OBSERVER'S HANDBOOK 1989

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THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

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OBSERVER'S HANDBOOK 1989

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IN PRAISE OF AMATEUR ASTRONOMERS

By
Helen Sawyer Hogg

And especially Canadian amateurs, in order to confine my words to the available space. Actually I could use almost all this space just discussing what is meant by the term "amateur astronomer" and various reactions to it. We could start with the definition of "amateur" from *Webster's Third New International Dictionary*, unabridged: "one that engages in a particular pursuit, study or science as a pastime rather than as a profession". And the definition of "profession" is: "a principal calling, vocation or employment." But precise meanings of words are often elusive. I was startled recently to hear one of our distinguished historians of science declare that Galileo was NOT an astronomer. Who deserves the title more than someone who discovered the craters on the Moon and the moons of Jupiter? In recent years, since I retired from the University payroll, I have wondered if, despite almost 50 years working as a professional astronomer, I am now best described as an amateur astronomer.

The term amateur astronomer certainly covers a wide range of activities. At the top of this category are those observers really dedicated to a study of the sky. They manage to spend many night hours, often well bundled up against harsh elements, scanning the skies with a particular field of interest in mind. Unlike many of us, they seem able to get along on very few hours sleep, and maintain their regular job by day.

In recent years the discoveries of Canadian amateurs have been really notable. The person who gives us the up-to-date information about them is Terence Dickinson. For almost 50 years the *Toronto Star* has had a weekly column on Saturdays on astronomy. Dickinson took over writing this when I gave up the task in 1981 after 30 years. His columns are full of the latest discoveries of both amateur and professional astronomers. The title of the column has expanded considerably from "With The Stars" to "The Universe". Dickinson's articles also appear in the beautiful periodical *Equinox* and other publications, and he has written some fine books.

Dickinson estimates that there are 30 000 amateur astronomers in Canada. Most of those making prominent discoveries are R.A.S.C. members. We can mention only a few. Warren Morrison of Peterborough, Ontario discovered Nova Cygni in 1978 and in January, 1985 caught the recurrent nova RS Ophiuchi on its first observed upswing in 18 years. Rolf Meier of Ottawa is the top Canadian observer for comets because he has discovered four from an observatory in Canada. His rival is Canadian David Levy who has also found four, but Levy works near Tucson, Arizona for better observing conditions. Recently Asteroid 3673 was named for Levy in recognition of his work. Jack Newton of Victoria, B.C. has taken and published many outstanding photographs, using telescopes and cameras of his own design, and now has a second book in press with Philip Teece (Cambridge University Press). Clifford Cunningham of Kitchener has had years of devotion to asteroids which have culminated this past year with invitations to use large professional telescopes and the publication of his attractive book, with human appeal, *Introduction to Asteroids*. Andrew Lowe of Calgary is one of the few observers who has had the good fortune to watch an asteroid blot out a star. An unusual branch of amateur astronomy is pursued by Réal Manseau of Drummondville, Quebec, who makes detailed replicas of historical astronomical instruments such as Isaac Newton's first reflecting telescope. Few amateurs are engaged in radio astronomy, but Frank Roy of Ottawa is, and hopes to make an all-sky radio survey.

A large proportion of amateurs are simply "armchair astronomers". They delight in reading astronomical items, they talk astronomy at social gatherings, and their monetary donations help maintain societies like this one. We are indebted to them for the fostering of public interest in astronomy. Then there are the "casual observers" whose interest in the sky has been sparked by a contemporary celestial event or even a chance remark. With binoculars or telescopes, especially on mild summer nights, they enjoy finding the beauties of the heavens, the moons of Jupiter, the rings of Saturn, the double cluster in Perseus, and the most distant object the human unaided eye can see, the Great Galaxy in Andromeda. Then there are the "telescope makers" who delight in building their own, often complex instruments. Some in this category become more interested in the instrument than in studying the sky itself. All sorts of astronomical undertakings except those requiring the most expensive and sophisticated instrumentation have amateurs in their midst.

Over the decades and the centuries, amateur astronomers of many nations have made a massive and a significant contribution to our understanding of the universe.

Now the dictionary gives another definition of amateur: "one that engages in an activity in an inexperienced or incompetent manner". This definition certainly does NOT apply to readers and users of the *Observer's Handbook* who are pursuing a most excellent course for astronomical experience and competence.

COVER PHOTOGRAPH

Unlike many photographs involving the Moon and other objects, this image of seven Canada Geese against the Harvest Moon is *not* a superposition of two separate photographs. This singular image was taken on October 2, 1982 (23:00 EDT) by Hein van Asperen of Brockville, Ontario, a member of the Kingston Centre of The Royal Astronomical Society of Canada. Mr. van Asperen was aware that migrating geese were occasionally passing in front of the Moon that evening, but was able to obtain only one negative with birds in view (1/1000 s exposure on Ilford FP4 film (ISO 125) at the prime focus of his home-made, 200 mm aperture, 1150 mm focal length, Newtonian telescope). The Moon was full two hours earlier. Assuming a wingspan of 1.6 m, from the dimensions on the photograph the geese were about 2 km from the telescope. From this, the time of the photograph, and the position of the Moon, the altitude of the birds must have been about 1.2 km. In contemplating this rare image of life against the backdrop of space, it is sobering to realize that geese know the night sky far better than most men in the darkness below. (RLB)

EDITOR'S COMMENTS

I am very pleased that once again this Handbook opens with a Foreword by Canada's most distinguished astronomer, Dr. Helen Sawyer Hogg. Also, it is worthy of note that, 60 years ago, the name "Mr. P. Millman" is cited in the Editor's comments for assisting with the preparation of *The Observer's Handbook for 1929*.

Among the many changes in this edition: with the assistance of David Levy, Dr. Brian Marsden, and Ian Shelton, the note **Reporting of Astronomical Discoveries** has been revised; Dr. Joseph Veverka has updated the table **Satellites of the Solar System**; several of the constants appearing on pages 16 and 17 have been revised in accordance with the 1986 adjustment of the fundamental physical constants (*Rev. Mod. Phys.*, *59*, 1121, 1987); the section **Solar Activity** has been revised by Dr. Gaizauskas and a new contributor, J. W. Dean of the Herzberg Institute of Astrophysics; a new section, **Observing Comets**, has been introduced by David Levy of Tucson, Arizona, USA; on the recommendation and with the assistance of Patrick Kelly of the Halifax Centre of the Society, pronunciations have been added for the genitive forms in the table **Constellations**; once again Dr. Robert Garrison has updated **The Brightest Stars** table; Dr. Janet Mattei has provided information concerning the variable star P Cygni in the section **Variable Stars**; Dr. Anthony Moffat has added information on the Hyades in the section **Star Clusters**; a new section consisting of a brief description and finder chart for the black hole candidate **Cygnus X-1** has been added, and thanks are due to Dr. Tom Bolton of the University of Toronto for reviewing this section; Alan Dyer has completely revised **The Messier Catalogue** and the table **The Finest N.G.C. Objects**, and he and a new contributor, Alister Ling of the Edmonton Centre of the Society, have prepared an expanded table entitled **Deep-Sky Challenge Objects**; a new contributor, James Himer of the Calgary Centre of the Society, has collaborated with Dr. Barry Madore to expand the table **Galaxies with Proper Names**. Revisions of a more routine nature (but, in many cases, no less time consuming) have been made to several other sections by the respective contributors (see the inside front cover), and I apologize for not mentioning them individually here.

In addition to the regular contributors, several individuals have provided information and/or made recommendations that have been incorporated into this edition: Brian Beattie, the Librarian of the Society; Randall Brooks, Douglas Pitcairn and Joe Yurchesyn, all of the Halifax Centre of the Society; and Max Radloff of the Minnesota Astronomical Society. Overall, significant additions and/or revisions have been made to more than three-quarters of the pages of this edition, the largest ever.

The Royal Astronomical Society of Canada is once again indebted to the Nautical Almanac Office of the U.S. Naval Observatory and its Director, Dr. P. K. Seidelmann, for essential pre-publication material from *The Astronomical Almanac*. The Astronomy Department of St. Mary's University provided the Vehrenberg chart used in preparing the diagram of Pluto's path. The Society's Executive-Secretary, Rosemary Freeman, deserves much credit for efficiently handling many details concerning the advertising and distribution of this publication throughout the year. Special acknowledgement is also due to Acadia University and its Department of Physics for providing an editor for the *Observer's Handbook*.

Suggestions for making this Handbook more useful to observers, both amateur and professional, are always welcome and should be sent directly to the Editor. Good observing *quo ducit Urania*!

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AN INVITATION FOR MEMBERSHIP IN THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

The history of The Royal Astronomical Society of Canada goes back to the middle of the nineteenth century. The Society was incorporated within the province of Ontario in 1890, received its Royal Charter in 1903, and was federally incorporated in 1968. The National Office of the Society is located at 136 Dupont Street, Toronto, Ontario M5R 1V2, telephone (416) 924 7973. The business office and library are housed there.

The Society is devoted to the advancement of astronomy and allied sciences, and has members in many countries and from all walks of life. Any serious user of this HANDBOOK would benefit from membership. An applicant may affiliate with one of the twenty Centres across Canada, or may join the Society directly as an unattached member. Centres are located in Newfoundland (St. John's), Nova Scotia (Halifax), Quebec (Montreal (2), and Quebec), Ontario (Ottawa, Kingston, Toronto, Hamilton, Niagara Falls, Kitchener-Waterloo, London, Windsor, and Sarnia), Manitoba (Winnipeg), Saskatchewan (Saskatoon), Alberta (Edmonton and Calgary), and British Columbia (Vancouver and Victoria). Contact the National Office for the address of any of the Centres.

Members receive the publications of the Society free of charge: the OBSERVER'S HANDBOOK (published annually in November), and the bimonthly JOURNAL and NATIONAL NEWSLETTER which contain articles on many aspects of astronomy. The membership year begins October 1, and members receive the publications of the Society for the following calendar year. Annual fees are currently $25, and $15 for persons under 18 years. Life membership is $500. (To cover higher mailing costs, these fees are to be read as U.S. dollars for members outside of Canada. Also, persons wishing to affiliate with one of the Centres are advised that some Centres levy a small surcharge.)

REPORTING OF ASTRONOMICAL DISCOVERIES

To report a possible significant discovery (e.g. a new comet, nova, or supernova) a message should be sent to the International Astronomical Union's Central Bureau for Astronomical Telegrams. Send a telex or telegram to (TWX) 710-320-6842 ASTROGRAM CAM and/or electronic mail to MARSDEN@CFA.BITNET or MARSDEN@CFAPS2.SPAN. Messages arriving by these methods are monitored at all times. If these preferred methods of communication are unavailable, a telephone call may be made to 617-495-7244 or -7440 or -7444, but telephone calls are discouraged, and these numbers will not be answered at all times. Also, a follow-up letter should be sent to the Central Bureau (60 Garden St., Cambridge, MA 02138, USA).

For any new object, specify the date and time of observation, RA and Dec (with epoch), magnitude, and some physical description. For photographic discoveries, confirmation with a second image is highly desirable. In the case of a new comet, the rate of motion in RA and Dec should also be indicated. Inexperienced observers should have their observation checked before contacting the Central Bureau. The Bureau has a computer service to which observers can subscribe, read circulars, and report observations. For an account of the history and operation of the Bureau, see *Sky and Telescope*, August 1980, p.92.

SUGGESTIONS FOR FURTHER READING

Astronomical Almanac for the Year 1989.[2] Nautical Almanac Office of the U.S. Naval Observatory, U.S. Government Printing Office, Washington, D.C. *The* standard reference for detailed tabular predictions of astronomical phenomena (primarily Solar System).

Burnham, Robert. *Burnham's Celestial Handbook, Volumes 1, 2 and 3.*[2] Dover Publications, Inc., New York, 1978. A comprehensive, well-presented, observer's guide to the universe beyond the Solar System.

Cunningham, Clifford. *Introduction To Asteroids.*[1] An attractive, informative account of the minor planets.

Dickinson, Terence. *Exploring The Night Sky*. Camden House Publishing Ltd., Camden East, Ontario, 1987. A brief, illustrated guide to stargazing, especially suitable for children.

Dickinson, Terence. *Nightwatch*. Camden House Publishing Ltd., Camden East, Ontario, 1983. An attractive, comprehensive, introductory guide to observing the sky.

Espenak, Fred. *Fifty Year Canon Of Solar Eclipses: 1986–2035.*[1] Predictions for all solar eclipses visible on Earth for half a century.

Harrison, Edward R. *Cosmology.*[1] Cambridge University Press, Cambridge, 1981. An elegant, stimulating introduction to the structure of the universe.

Hogg, Helen Sawyer. *The Stars Belong To Everyone*. Doubleday Canada Ltd., Toronto, 1976. Superb introduction to the sky (now, unfortunately, out-of-print).

Jones, K. G. (editor). *Webb Society Deep-Sky Observer's Handbook.*[2] Seven volumes: 1: *Double Stars*, 2: *Planetary and Gaseous Nebulae*, 3: *Open and Globular Clusters*, 4: *Galaxies*, 5: *Clusters of Glaxies*, 6: *Anonymous Galaxies*, 7: *The Southern Sky*. Enslow Publishers, Inc., Hillside, New Jersey, 1979–1987. An invaluable reference for the experienced observer.

Peltier, Leslie. *Starlight Nights.*[12] A charming autobiography that every person who loves the night should read.

Sky and Telescope.[1] A monthly magazine containing articles on all aspects of astronomy.

Texereau, Jean. *How To Make A Telescope.*[2] (2nd edition, 1984). The best guide to making a Newtonian telescope.

Whipple, Fred. *The Mystery of Comets.*[1] An authoritative, fascinating account of these visitors to the inner Solar System.

ATLASES

Moon, Mars and Venus, by A. Rukl. A compact, detailed, lunar atlas. Hamlyn Publishing Group Ltd., Toronto and New York, 1976 (now, unfortunately, out-of-print).

Norton's Star Atlas.[12] (Epoch 1950.0) A classic. Contains 8700 stars to magnitude 6.3 on 8 charts.

Sky Atlas 2000.0,[12] by Wil Tirion. Large format, modern and detailed. Contains 43 000 stars to magnitude 8.0 on 26 charts.

Uranometria 2000.0,[12] by W. Tirion, B. Rappaport, and G. Lovi. A comprehensive, general-purpose star atlas. Two volumes (Volume 1 covers the northern sky to declination −6°. Volume 2 will be available in 1989). Contains a third of a million stars to magnitude 9.5 and more than 10 000 clusters, nebulae, and galaxies on 473 charts.

[1] Available from: Sky Publishing Corp., P.O. Box 9111, Belmont, MA 02178-9111, U.S.A.

[2] Available from: Willmann-Bell, Inc., Box 35025, Richmond, VA 23235, U.S.A.

VISITING HOURS AT SOME CANADIAN OBSERVATORIES AND PLANETARIA

Compiled By Marie Fidler

OBSERVATORIES

Burke-Gaffney Observatory, Saint Mary's University, Halifax, Nova Scotia B3H 3C3.
October-March: Saturday evenings, 7:00 p.m.
April-September: Saturday evenings, 9:00 p.m.
Monday evening or daytime tours by arrangement. Phone 420-5633.

Canada-France-Hawaii Telescope, Mauna Kea, Hawaii, U.S.A. 96743.
R.A.S.C. members visiting the "Big Island" are welcome to day-time visits to the CFHT installations. Arrangements should be made in advance either by writing to Canada-France-Hawaii Telescope Corporation, P.O. Box 1597, Kamuela, HI 96743, U.S.A., or by telephone (808) 885-7944.

David Dunlap Observatory, Richmond Hill, Ontario L4C 4Y6.
Tuesday mornings throughout the year, 10:00 a.m.
Saturday evenings, April through October, by reservation. Telephone (416) 884-2112.

Dominion Astrophysical Observatory, 5071 West Saanich Road, Victoria, B.C. V8X 4M6.
May-August: Daily, 9:15 a.m.–4:30 p.m.
September-April: Monday to Friday, 9:15 a.m.–4:30 p.m.
Public observing, Saturday evenings, April-October inclusive. Phone (604) 388-0012.

Dominion Radio Astrophysical Observatory, Penticton, B.C. V2A 6K3.
Conducted Tours: Sundays, July and August only, 2:00–5:00 p.m.
Visitors' Centre: Open year round during daylight hours.
For information please phone (604) 497-5321.

Hume Cronyn Observatory, University of Western Ontario, London, ON, N6A 3K7.
For tour and program information please phone (519) 661-3183.

National Museum of Science and Technology, 1867 St. Laurent Blvd., Ottawa, Ontario. K1A 0M8.
Evening tours, by appointment only. Telephone (613) 991-3073.
October-June: Group tours: Mon. through Thurs. Public visits, Fri. (2nd Fri. French)
July-August: Public visits: Tues.(French), Wed. and Thurs. (English).

Observatoire astronomique du mont Mégantic, Notre-Dame-des-Bois, P.Q. J0B 2E0.
Telephone (514) 343-6718 for information on summer programs.

Science North Solar Observatory, 100 Ramsey Lake Road, Sudbury, ON, P3A 2K3.
Three heliostats provide viewing of the solar spectrum and the Sun in hydrogen-alpha and white light in a darkened theatre where a multi-media interpretation of the Sun is also presented. Open most days except for off-season Mondays. For information call (705) 522-3701.

Gordon MacMillan Southam Observatory, 1100 Chestnut St., Vancouver, BC, V6J 3J9.
Open Fri., Sat., Sun. and statutory holidays 12:00–5:00 p.m., 7:00 p.m.–11:00 p.m., weather and volunteer staff permitting. Extended hours during school holidays. For information call (604) 738-2855.

University of British Columbia Observatory, 2219 Main Mall, Vancouver, B.C. V6T 1W5.
Free public observing, clear Saturday evenings: telephone (604) 228-6186.
Tours: telephone (604) 228-2802.

PLANETARIA

Alberta Science Centre/Calgary Centennial Planetarium, 701–11 Street S.W., P.O. Box 2100, Stn. M, Calgary, Alberta T2P 2M5.
For program information, telephone (403) 264-4060 or 221-3700.

Doran Planetarium, Laurentian University, Ramsey Lake Road, Sudbury, Ontario P3E 2C6. Telephone (705) 675-1151, ext. 2222 for information.

Dow Planetarium, 1000 St. Jacques Street W., Montreal, P.Q. H3C 1G7.
Live shows in French and in English every open day. Closed three weeks in September after Labour Day. For general information telephone (514) 872-4530.

Edmonton Space Sciences Centre, Coronation Park, 11211-142 Street, Edmonton, Alberta T5M 4A1. Features planetarium Star Theatre, IMAX film theatre, and exhibit galleries. Public shows daily in both theatres. Telephone 451-7722 for program information. Also contains Science Magic telescope shop and bookstore: telephone 451-6516. Administration Office 452-9100.

The Halifax Planetarium, The Education Section of Nova Scotia Museum, Summer Street, Halifax, N.S. B3H 3A6.
Free public shows take place on some evenings at 8:00 p.m. and group shows can be arranged. The planetarium is located in the Sir James Dunn Building, Dalhousie University. For information, telephone (902) 429-4610.

The Lockhart Planetarium, 394 University College, 500 Dysart Road, The University of Manitoba, Winnipeg, Manitoba R3T 2M8.
For group reservations, telephone (204) 474-9785.

H.R. MacMillan Planetarium, 1100 Chestnut Street, Vancouver, B.C. V6J 3J9.
Public shows Tuesdays through Sundays and on most holidays; open daily during the summer.
For show information telephone (604) 736-3656.

Manitoba Planetarium, 190 Rupert Avenue at Main Street, Winnipeg, Manitoba R3B 0N2. Shows daily except some Mondays. New "Touch the Universe" science gallery features over 60 interactive exhibits. Museum Gift Shop has scientific books and equipment. Program information recording: 943-3142; switchboard (204) 956-2830.

McLaughlin Planetarium, 100 Queen's Park, Toronto, Ontario M5S 2C6.
Public shows Tues.–Fri. 3:00 and 7:30. Additional shows on weekends and during summer. School shows, Astrocentre with solar telescope, and evening courses. Sky information (416) 586-5751. For show times and information call (416) 586-5736.

Ontario Science Centre, 770 Don Mills Road, Don Mills, Ontario M3C 1T3.
Open daily except Christmas Day from 10:00 a.m. to 6:00 p.m. Telephone (416) 429-4100.

SYMBOLS

SUN, MOON, AND PLANETS

☉ The Sun	☾ The Moon generally	♃ Jupiter
🌑 New Moon	☿ Mercury	♄ Saturn
🌕 Full Moon	♀ Venus	♅ Uranus
☽ First Quarter	⊕ Earth	♆ Neptune
☾ Last Quarter	♂ Mars	♇ Pluto

SIGNS OF THE ZODIAC

♈ Aries .... 0°	♌ Leo .... 120°	♐ Sagittarius ... 240°
♉ Taurus ...... 30°	♍ Virgo ...... 150°	♑ Capricornus .. 270°
♊ Gemini ...... 60°	♎ Libra .... 180°	♒ Aquarius .... 300°
♋ Cancer ...... 90°	♏ Scorpius .... 210°	♓ Pisces .... 330°

THE GREEK ALPHABET

Α, α	Alpha	Ι, ι	Iota	Ρ, ρ	Rho
Β, β	Beta	Κ, κ	Kappa	Σ, σ	Sigma
Γ, γ	Gamma	Λ, λ	Lambda	Τ, τ	Tau
Δ, δ	Delta	Μ, μ	Mu	Υ, υ	Upsilon
Ε, ε	Epsilon	Ν, ν	Nu	Φ, φ	Phi
Ζ, ζ	Zeta	Ξ, ξ	Xi	Χ, χ	Chi
Η, η	Eta	Ο, ο	Omicron	Ψ, ψ	Psi
Θ, θ, ϑ	Theta	Π, π	Pi	Ω, ω	Omega

CO-ORDINATE SYSTEMS AND TERMINOLOGY

Astronomical positions are usually measured in a system based on the *celestial poles* and *celestial equator*, the intersections of Earth's rotation axis and equatorial plane, respectively, and the infinite sphere of the sky. *Right ascension* (R.A. or α) is measured in hours (h), minutes (m) and seconds (s) of time, eastward along the celestial equator from the *vernal equinox. Declination* (Dec. or δ) is measured in degrees (°), minutes (′) and seconds (″) of arc, northward (N or +) or southward (S or −) from the celestial equator toward the N or S celestial pole.

Positions can also be measured in a system based on the *ecliptic*, the intersection of Earth's orbit plane and the infinite sphere of the sky. The Sun appears to move eastward along the ecliptic during the year. *Longitude* is measured eastward along the ecliptic from the vernal equinox; *latitude* is measured at right angles to the ecliptic, northward or southward toward the N or S ecliptic pole. The *vernal equinox* is one of the two intersections of the ecliptic and the celestial equator; it is the one at which the Sun crosses the celestial equator moving from south to north.

Objects are *in conjunction* if they have the same longitude or R.A., and are *in opposition* if they have longitudes or R.A.'s which differ by 180°. If the second object is not specified, it is assumed to be the Sun. For instance, if a planet is "in conjunction", it has the same longitude as the Sun. At *superior conjunction*, the planet is more distant than the Sun; at *inferior conjunction*, it is nearer. (See the diagram on page 114.)

If an object crosses the ecliptic moving northward, it is at the *ascending node* of its orbit; if it crosses the ecliptic moving southward, it is at the *descending node*.

Elongation is the difference in longitude between an object and a second object (usually the Sun). At conjunction, the elongation of a planet is thus zero.

BASIC DATA

PRINCIPAL ELEMENTS OF THE SOLAR SYSTEM

MEAN ORBITAL ELEMENTS

Planet	Mean Distance from Sun: AU	Mean Distance from Sun: millions of km	Period of Revolution: Sidereal (P)	Period of Revolution: Synodic	Eccentricity (e)	Inclination (i)	Long. of Node (☊)	Long. of Perihelion (π)	Mean Long. at Epoch (L)
				days		°	°	°	°
Mercury	0.387	57.9	87.97d	116	0.206	7.0	47.9	76.8	222.6
Venus	0.723	108.2	224.70	584	0.007	3.4	76.3	131.0	174.3
Earth	1.000	149.6	365.26	...	0.017	0.0	0.0	102.3	100.2
Mars	1.524	227.9	686.98	780	0.093	1.8	49.2	335.3	258.8
Jupiter	5.203	778.3	11.86a	399	0.048	1.3	100.0	13.7	259.8
Saturn	9.539	1427.0	29.46	378	0.056	2.5	113.3	92.3	280.7
Uranus	19.182	2869.6	84.01	370	0.047	0.8	73.8	170.0	141.3
Neptune	30.058	4496.6	164.79	367	0.009	1.8	131.3	44.3	216.9
Pluto	39.439	5899.9	247.69	367	0.250	17.2	109.9	224.2	181.6

These elements, for epoch 1960 Jan. 1.5 E.T., are taken from the *Explanatory Supplement to the American Ephemeris and Nautical Almanac.*

PHYSICAL ELEMENTS

Object	Equat. Diam. km	Oblateness	Mass ⊕ = 1	Density g/cm³	Gravity ⊕ = 1	Esc. Speed km/s	Rotn. Period d	Incl. °	Albedo
☉ Sun	1 392 000	0	332 946.0	1.41	27.9	617.5	25–35*		—
☾ Moon	3 476	0	0.012300	3.34	0.17	2.4	27.3217	6.7	0.12
☿ Mercury	4 878	0	0.055274	5.43	0.38	4.3	58.646	0.0	0.11
♀ Venus	12 104	0	0.815005	5.24	0.91	10.4	243.017	177.3	0.65
⊕ Earth	12 756	1/298	1.000000	5.52	1.00	11.2	0.9973	23.4	0.37
♂ Mars	6 787	1/193	0.107447	3.94	0.38	5.0	1.0260	25.2	0.15
♃ Jupiter	142 800	1/15	317.833	1.33	2.54	59.6	0.4101†	3.1	0.52
♄ Saturn	120 000	1/9	95.159	0.70	1.08	35.6	0.4440	26.7	0.47
⛢ Uranus	51 200	1/45	14.500	1.30	0.91	21.3	0.718	97.9	0.51
♆ Neptune	48 600	1/40	17.204	1.76	1.19	23.8	0.768	29.6	0.41
♇ Pluto	2 300	0?	0.0026?	1.1?	0.05?	1.2?	6.3867	94	0.5?

The table gives the *mean* density, the gravity and escape speed *at the pole* and the inclination of equator *to orbit.*

*Depending on latitude

†For the most rapidly rotating part of Jupiter, the equatorial region.

D

SATELLITES OF THE SOLAR SYSTEM

BY JOSEPH VEVERKA

Name	Diam. (km)	Mass (10^{20} kg) / Density (t/m^3)	Mean Dist. from Planet (10^3 km/″) / Rev. Period (d)	Eccentricity / Orbit Incl (°)	Vis. Mag. / Vis. Albedo	Discovery
SATELLITE OF EARTH						
Moon	3476	734.9 ± 0.7 3.34	384.5/ — 27.322	0.0549 18–29	−12.7 0.11	
SATELLITES OF MARS						
I Phobos	21	(1.3 ± 0.2) × 10^{-4} ~2	9.4/ 25 0.319	0.015 1.1	11.6 0.07	A. Hall, 1877
II Deimos	12	(1.8 ± 0.2) × 10^{-5} ~2	23.5/ 63 1.263	0.0005 1.8v	12.7 0.07	A. Hall, 1877
SATELLITES OF JUPITER						
XVI Metis	(40)	— —	128/ 42 0.294	0 —	17.5 (0.05)	S. Synnott, 1979
XV Adrastea	(25)	— —	129/ 42 0.297	0 —	18.7 (0.05)	Jewitt, Danielson, Synnott, 1979
V Amalthea	170	— —	180/ 59 0.498	0.003 0.4	14.1 0.05	E. Barnard, 1892
XIV Thebe	(100)	— —	222/ 73 0.674	0.013 —	16.0 (0.05)	S. Synnott, 1979
I Io†	3630	892 ± 4 3.55	422/138 1.769	0.004 0	5.0 0.6	Galileo, 1610
II Europa†	3140	487 ± 5 3.04	671/220 3.551	0.010 0.5	5.3 0.6	Galileo, 1610
III Ganymede†	5260	1 490 ± 6 1.93	1 070/351 7.155	0.001 0.2	4.6 0.4	Galileo, 1610

Apparent magnitude and mean distance from planet are at mean opposition distance. The inclination of the orbit is referred to the planet's equator; a value greater than 90° indicates retrograde motion.

Values in parentheses are uncertain.

Note: Pronunciations of the names of the planetary satellites are given on p. 115.

†Laplace resonance. Longitudes satisfy $\lambda_I - 3\lambda_E + 2\lambda_G = 180°$.

Also, mean motions are such that $n_I \approx 2n_E$ and $n_E \approx 2n_G$.

Name	Diam. (km)	Mass (10^{20} kg) Density (t/m^3)	Mean Dist. from Planet (10^3 km/″) Rev. Period (d)	Eccen-tricity Orbit Incl (°)	Vis. Mag. Vis. Albedo	Discovery
IV Callisto	4800	1075 ± 4 1.83	1 885/ 618 16.689	0.007 0.2	5.6 0.2	Galileo, 1610
XIII Leda	(15)	— —	11 110/3640 240	0.147 27	20 —	C. Kowal, 1974
VI Himalia	185	— —	11 470/3760 251	0.158 28	14.8 0.03	C. Perrine, 1904
X Lysithea	(35)	— —	11 710/3840 260	0.107 29	18.4 —	S. Nicholson, 1938
VII Elara	75	— —	11 740/3850 260	0.207 28	16.8 0.03	C. Perrine, 1905
XII Ananke	(30)	— —	21 200/6954 631	0.17 147	18.9 —	S. Nicholson, 1951
XI Carme	(40)	— —	22 350/7330 692	0.21 164	18.0 —	S. Nicholson, 1938
VIII Pasiphae	(50)	— —	23 330/7650 735	0.38 148	17.1 —	P. Melotte, 1908
IX Sinope	(35)	— —	23 370/7660 758	0.28 153	18.3 —	S. Nicholson, 1914
SATELLITES OF SATURN						
XV Atlas	30	— —	137/ 23 0.601	0.002 0.3	(18) 0.4	R. Terrile, 1980
XVI Prometheus†	100	— —	139/ 23 0.613	0.002 0.0	(15) 0.6	S. Collins, D. Carlson, 1980
XVII Pandora†	90	— —	142/ 24 0.628	0.004 0.1	(16) 0.5	S. Collins, D. Carlson, 1980
X Janus*	190	— —	151/ 25 0.695	0.009 0.3	(14) 0.6	A. Dollfus, 1966
XI Epimetheus*	120	— —	151/ 25 0.695	0.007 0.1	(15) 0.5	J. Fountain, S. Larson, 1966
I Mimas	390	0.38 ± 0.01 1.2	187/ 30 0.942	0.020 1.5	12.5 0.8	W. Herschel, 1789
II Enceladus	500	0.8 ± 0.3 1.1	238/ 38 1.370	0.004 0.02	11.8 1.0	W. Herschel, 1789

†Shepherds of the F-ring.

*Co-orbital satellites. Horseshoe libration ($\lambda_J - \lambda_E$) about 180°.

D

Name	Diam. (km)	Mass (10^{20} kg)	Mean Dist. from Planet (10^3 km/″)	Eccen-tricity	Vis. Mag.	Discovery
		Density (t/m^3)	Rev. Period (d)	Orbit Incl (°)	Vis. Albedo	
III Tethys	1060	7.6 ± 0.9	295/ 48	0.000	10.3	G. Cassini, 1684
		1.2	1.888	1.1	0.8	
XIII Telesto	25	—	295/ 48	~0	(18)	Smith, Larson,
		—	1.888[a]	~0	0.7	Reitsema, 1980
XIV Calypso	25	—	295/ 48	~0	(18)	Pascu, Seidelmann,
		—	1.888[b]	~0	1.0	Baum, Currie, 1980
IV Dione	1120	10.5 ± 0.3	378/ 61	0.002	10.4	G. Cassini, 1684
		1.4	2.737	0.02	0.6	
XII Helene	30	—	378/ 61	0.005	(18)	P. Laques,
		—	2.737[c]	0.2	0.6	J. Lecacheux, 1980
V Rhea	1530	24.9 ± 1.5	526/ 85	0.001	9.7	G. Cassini, 1672
		1.3	4.517	0.4	0.6	
VI Titan	5550†	1345.7 ± 0.3	1 221/ 197	0.029	8.4	C. Huygens, 1655
		1.88	15.945	0.3	0.2	
VII Hyperion	255	—	1 481/ 239	0.104	14.2	W. Bond, G. Bond,
		—	21.276	0.4	0.3	W. Lassell, 1848
VIII Iapetus	1460	18.8 ± 1.2	3 561/ 575	0.028	11.0v	G. Cassini, 1671
		1.2	79.331	14.7	0.08	
					−0.4	
IX Phoebe	220	—	12 960/2096	0.163	16.5	W. Pickering, 1898
		—	550.46	150	0.05	
SATELLITES OF URANUS						
VI Cordelia[d]	25*	—	49.8/3.7	~0	22.4	Voyager 2, 1986
		—	0.333	~0	<0.1	
VII Ophelia[d]	30*	—	53.8/4.0	~0	22.2	Voyager 2, 1986
		—	0.375	~0	<0.1	
VIII Bianca	40*	—	59.2/4.4	~0	21.9	Voyager 2, 1986
		—	0.433	~0	<0.1	

[a]Librates about trailing (L_5) Lagrangian point of Tethys' orbit.
[b]Librates about leading (L_4) Lagrangian point of Tethys' orbit.
[c]Librates about leading (L_4) Lagrangian point of Dione's orbit with a period of ~790 d.
[d]Shepherds of the ϵ-ring.
†Cloud-top diameter. Solid-body diameter equals 5150 km.
*Diameter assuming same albedo (0.07) as Puck.

Name	Diam. (km)	Mass (10^{20} kg) Density (t/m^3)	Mean Dist. from Planet (10^3 km/″) Rev. Period (d)	Eccen-tricity Orbit Incl (°)	Vis. Mag. Vis. Albedo	Discovery
IX Cressida	60*	— —	61.8/ 4.6 0.463	~0 ~0	21.4 <0.1	Voyager 2, 1986
X Desdemona	55*	— —	62.6/ 4.7 0.475	~0 ~0	21.5 <0.1	Voyager 2, 1986
XI Juliet	85*	— —	64.4/ 4.9 0.492	~0 ~0	21.1 <0.1	Voyager 2, 1986
XII Portia	110*	— —	66.1/ 5.0 0.513	~0 ~0	20.8 <0.1	Voyager 2, 1986
XIII Rosalind	55*	— —	70.0/ 5.2 0.558	~0 ~0	21.5 <0.1	Voyager 2, 1986
XIV Belinda	65*	— —	75.3/ 5.6 0.621	~0 ~0	21.4 <0.1	Voyager 2, 1986
XV Puck	155*	— —	86.0/ 6.5 0.763	~0 ~0	20.3 0.07	Voyager 2, 1985
V Miranda†	485	0.75 ± 0.22 1.26 ± 0.39	129.9/ 9.7 1.413	0.017 3.4	16.5 0.34	G. Kuiper, 1948
I Ariel†	1160	13.4 ± 2.4 1.65 ± 0.30	190.9/14.3 2.521	0.0028 0	14.0 0.40	W. Lassell, 1851
II Umbriel†	1190	12.7 ± 2.4 1.44 ± 0.28	266.0/20.0 4.146	0.0035 0	14.9 0.19	W. Lassell, 1851
III Titania	1610	34.7 ± 1.8 1.59 ± 0.09	436.3/32.7 8.704	0.0024 0	13.9 0.28	W. Herschel, 1787
IV Oberon	1550	29.2 ± 1.6 1.50 ± 0.10	583.4/43.8 13.463	0.0007 0	14.1 0.24	W. Herschel, 1787
SATELLITES OF NEPTUNE						
I Triton	(3500)	1300? ?	354/17 5.877	<0.0005 160.0	13.6 (0.4)	W. Lassell, 1846
II Nereid	(300)	— —	5 600/264 365.21	0.75 27.6	18.7 —	G. Kuiper, 1949
SATELLITE OF PLUTO						
Charon	1300	— —	19.1/ 0.9 6.387	~0 ~0	17 —	J. Christy, 1978

†Near resonance(?). $\lambda_M - 3\lambda_A + 2\lambda_U$ drifts slowly (period ≈ 12.5 a).

D

SOME ASTRONOMICAL AND PHYSICAL DATA

Many of the numbers listed below are determined by measurement. Exceptions include defined quantities (indicated by three lines in the equal sign ≡), quantities calculated from defined quantities (e.g. m/ly, AU/pc), and numbers of mathematical origin such as π and conversion factors in angular measure. Of the measured quantities, some are known to only approximate precision. For these the equal sign is reduced to ≈. Many others are known to quite high precision. In these cases all digits shown are significant, with the uncertainties occurring after the last digit. The units, symbols, and nomenclature are based on recommendations of the *International Astronomical Union*, the *International Union of Pure and Applied Physics*, and the *Metric Commission Canada*. A concise review of physical measurement standards appears in *Physics in Canada 44*, p. 3, 1988. (RLB)

LENGTH

1 astronomical unit (AU)	= 1.495 978 70 × 10^{11} m = 499.004 782 light-seconds
1 light-year (ly)	= 9.460 536 × 10^{15} m (based on average Gregorian year)
	= 63 239.8 AU
1 parsec (pc)	= 3.085 678 × 10^{16} m
	= 206 264.8 AU = 3.261 631 light-years
1 mile*	≡ 1.609 344 km
1 micron*	≡ 1 μm
1 Angstrom*	≡ 0.1 nm

TIME

Day:	Mean sidereal (equinox to equinox)	= 86 164.092 s
	Mean rotation (fixed star to fixed star)	= 86 164.100 s
	Day (d)	≡ 86 400. s
	Mean solar	= 86 400.001 s
Month:	Draconic (node to node)	= 27.212 22 d
	Tropical (equinox to equinox)	= 27.321 58 d
	Sidereal (fixed star to fixed star)	= 27.321 66 d
	Anomalistic (perigee to perigee)	= 27.554 55 d
	Synodic (New Moon to New Moon)	= 29.530 59 d
Year:	Eclipse (lunar node to lunar node)	= 346.6201 d
	Tropical (equinox to equinox) (a)	= 365.2422 d
	Average Gregorian	≡ 365.2425 d
	Average Julian	≡ 365.2500 d
	Sidereal (fixed star to fixed star)	= 365.2564 d
	Anomalistic (perihelion to perihelion)	= 365.2596 d

EARTH

Mass = 5.974 × 10^{24} kg

Radius: Equatorial, a = 6378.140 km; Polar, b = 6356.755 km;
Mean, $\sqrt[3]{a^2b}$ = 6371.004 km

1° of latitude = 111.133 − 0.559 cos 2ϕ km (at latitude ϕ)

1° of longitude = 111.413 cos ϕ − 0.094 cos 3ϕ km

Distance of sea horizon for eye h metres above sea-level ≈3.9 $\sqrt{h}$ km (refraction inc.)

Standard atmospheric pressure ≡ 101.325 kPa (≈1 kg above 1 cm^2)

Speed of sound in standard atmosphere = 331 m s^{-1}

Magnetic field at surface ≈5 × 10^{-5} T

Magnetic poles: 76°N, 101°W; 66°S, 140°E

Standard acceleration of gravity ≡ 9.806 65 m s^{-2}

Age ≈4.6 Ga

Meteoric flux ≈1 × 10^{-15} kg m^{-2} s^{-1}

Escape speed from Earth = 11.2 km s^{-1}

Solar parallax = 8″.794 148 (Earth equatorial radius ÷ 1 AU)

Constant of aberration = 20″.495 52

*Deprecated unit. Unit on right is preferred.

Obliquity of ecliptic = 23°.4407 (1989.0)
Annual general precession = 50″.26; Precession period = 25 800 a
Orbital speed = 29.8 km s^{-1}
Escape speed at 1 AU from Sun = 42.1 km s^{-1}

SUN

Mass = 1.9891 × 10^{30} kg; Radius = 696 265 km; Eff. temperature = 5770 K
Output: Power = 3.85 × 10^{26} W; M_{bol} = 4.75
Luminous intensity = 2.84 × 10^{27} cd; M_V = 4.84
At 1 AU, outside Earth's atmosphere:
Energy flux = 1.37 kW m^{-2}; m_{bol} = −26.82
Illuminance = 1.27 × 10^5 lx; m_V = −26.73
Inclination of the solar equator on the ecliptic of date = 7°.25
Longitude of the ascending node of the solar equator on the ecliptic of date = 76°
Period of rotation at equator = 25.38 d (sidereal), 27.275 d (mean synodic)
Solar wind speed near Earth ≈ 450 km s^{-1} (travel time, Sun to Earth ≈ 5 d)
Solar velocity = 19.75 km s^{-1} toward α = 18.07 h, δ = +30° (solar apex)

MILKY WAY GALAXY

Mass ≈10^{12} solar masses
Centre: α = 17 h 42.5 min, δ = −28° 59′ (1950)
Distance to centre ≈9 kpc, diameter ≈100 kpc
North pole: α = 12 h 49 min, δ = 27° 24′ (1950)
Rotational speed (at Sun) ≈250 km s^{-1}
Rotational period (at Sun) ≈220 Ma
Velocity relative to the 3 K background ≈600 km s^{-1} toward α ≈ 10 h, δ ≈ −20°

SOME CONSTANTS

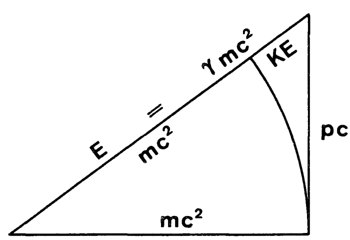
Speed of light, c ≡ 299 792 458. m s^{-1} (This, in effect, defines the metre.)
Planck's constant, h = 6.6261 × 10^{-34} J s = 4.135 67 × 10^{-15} eV s
Gravitational constant, G = 6.672 × 10^{-11} N m^2 kg^{-2}
Elementary charge, e = 1.602 18 × 10^{-19} C
Constant in Coulomb's law ≡ 10^{-7} c^2 (SI units) (This defines the coulomb.)
Avogadro constant, N_A = 6.022 1 × 10^{26} $kmol^{-1}$
Boltzmann constant, k = 1.381 × 10^{-23} J K^{-1} = 8.617 × 10^{-5} eV K^{-1} ≈1 eV/10^4 K
Stefan-Boltzmann constant, σ = 5.67 × 10^{-8} W m^{-2} K^{-4}
Wien's law, $\lambda_m T$ = 2.898 × 10^{-3} m K (per dλ)
Hubble constant, H ≈ 50 to 75 km s^{-1} Mpc^{-1} (depending on method of determination)
Volume of ideal gas at 0°C, 101.325 kPa = 22.41 m^3 $kmol^{-1}$

MASS AND ENERGY

Atomic mass unit (u) = 1.660 54 × 10^{-27} kg = N_A^{-1} = 931.494 MeV
Electron rest mass = 9.109 4 × 10^{-31} kg = 548.579 9 μu = 0.510 999 MeV
Proton rest mass = 1.007 276 5 u = 938.27 MeV = 1.672 62 × 10^{-27} kg
Neutron rest mass = 1.008 664 9 u = 939.57 MeV = 1.674 93 × 10^{-27} kg
Some atomic masses:

^1H = 1.007 825 u	^5Li = 5.012 5 u	^{16}O = 15.994 915 u
^2H = 2.014 102 u	^8Be = 8.005 305 u	^{56}Fe = 55.934 940 u
^4He = 4.002 603 u	^{12}C ≡ 12.000 000 u	^{235}U = 235.043 928 u

Electron-volt (eV) = 1.602 18 × 10^{-19} J
1 eV per event = 23 060 cal mol^{-1}
Thermochemical calorie (cal) ≡ 4.184 J
1 erg s^{-1} ≡ 10^{-7} W
$C + O_2 \rightarrow CO_2$ + 4.1 eV
$4\,^1H \rightarrow\, ^4He$ + 26.73 MeV
1 kg TNT releases 4.20 MJ (≈1 kWh)
Relation between rest mass (m), linear momentum (p), total energy (E), kinetic energy (KE), and $\gamma \equiv (1 - v^2/c^2)^{-0.5}$:



D

MAGNITUDE RELATIONS

Log of light intensity ratio ≡ 0.4 times magnitude difference

Distance Modulus (D) ≡ apparent magnitude (m) − absolute magnitude (M)

Log of distance in ly = 0.2 D + 1.513 435 (neglecting absorption)

Magnitude of sum of magnitudes $m_i = -2.5 \log \Sigma\, 10^{-0.4 m_i}$

OPTICAL WAVELENGTH DATA

Bright-adapted (photopic) visible range ≈ 400 − 750 nm

Dark-adapted (scotopic) visible range ≈ 400 − 620 nm

Wavelength of peak sensitivity of human eye ≈ 555 nm (photopic), ≈ 510 nm (scotopic)

Mechanical equivalent of light: 1 lm ≡ 1/683 W at 540 THz ($\lambda \approx 555$ nm)

Colours (representative wavelength, nm): violet (420), blue (470), green (530), yellow (580), orange (610), red (660).

Some useful wavelengths (element, spectral designation or colour and/or (Fraunhofer line):

H Lyman α	121.6 nm	N_2^+ blue**	465.2	Hg yellow	579.1
Ca (K solar)	393.4	Hβ (F solar)*	486.1	Na (D_2 solar)	589.0
Ca (H solar)	396.8	O^{++} green*	495.9	Na (D_1 solar)	589.6
Hg violet	404.7	O^{++} green*	500.7	O red**	630.0
Hδ (h solar)	410.2	Hg green	546.1	He-Ne laser	632.8
Hγ (g solar)	434.0	O yel.-green**	557.7	O red**	636.4
Hg deep blue	435.8	Hg yellow	577.0	Hα (C solar)	656.3

*Strong contributor to the visual light of gaseous nebulae.

**Strong auroral lines.

DOPPLER RELATIONS FOR LIGHT

α ≡ angle between velocity of source and line from source to observer.

$\beta \equiv v/c$

$\gamma \equiv (1 - \beta^2)^{-0.5}$

Frequency: $\nu = \nu_0 \gamma^{-1}(1 - \beta \operatorname{Cos} \alpha)^{-1}$

$z \equiv (\lambda - \lambda_0)/\lambda_0 = \gamma(1 - \beta \operatorname{Cos} \alpha) - 1$

$$\text{For } \alpha = \pi \begin{cases} z = (1+\beta)^{0.5}(1-\beta)^{-0.5} - 1 \quad (\approx \beta \text{ if } \beta \ll 1) \\ \beta = [(1+z)^2 - 1][(1+z)^2 + 1]^{-1} \end{cases}$$

ANGULAR RELATIONS

$\pi = 3.141\,592\,654 \approx (113 \div 355)^{-1}$

$1'' = 4.848\,14 \times 10^{-6}$ rad, 1 rad = 206 265″

Number of square degrees on a sphere = 41 253.

For 360° = 24 h, 15° = 1 h, 15′ = 1 min, 15″ = 1 s

Relations between sidereal time t, right ascension α, hour angle h, declination δ, azimuth A (measured east of north), altitude a, and latitude φ:

$$h = t - \alpha$$
$$\sin a = \sin \delta \sin \phi + \cos h \cos \delta \cos \phi$$
$$\cos \delta \sin h = -\cos a \sin A$$
$$\sin \delta = \sin a \sin \phi + \cos a \cos A \cos \phi$$

Annual precession in $\alpha \cong 3.0730 + 1.3362 \sin \alpha \tan \delta$ seconds

Annual precession in $\delta \cong 20''.043 \cos \alpha$

SOME SI SYMBOLS AND PREFIXES

m	metre	N	newton (kg m s^{-2})	f	femto	10^{-15}
kg	kilogram	J	joule (N m)	p	pico	10^{-12}
s	second	W	watt (J s^{-1})	n	nano	10^{-9}
min	minute	Pa	pascal (N m^{-2})	μ	micro	10^{-6}
h	hour	t	tonne (10^3 kg)	m	milli	10^{-3}
d	day	Hz	hertz (s^{-1})	c	centi	10^{-2}
a	year	C	coulomb (A s)	k	kilo	10^3
A	ampere	T	tesla (Wb m^{-2})	M	mega	10^6
rad	radian	cd	candela (lm sr^{-1})	G	giga	10^9
sr	steradian	lx	lux (lm m^{-2})	T	tera	10^{12}

TABLE OF PRECESSION FOR ADVANCING 50 YEARS

If declination is positive, use inner R.A. scale; if declination is *negative*, use *outer* R.A. scale, and *reverse the sign of the precession in declination*

R.A. for Dec.−	R.A. for Dec.+	Prec. in Dec.	Precession in right ascension											Prec. in Dec.	R.A. for Dec.+	R.A. for Dec.−
			δ = 85°	80°	75°	70°	60°	50°	40°	30°	20°	10°	0°			
h m	h m	′	m	m	m	m	m	m	m	m	m	m	m	′	h m	h m
12 00	0 00	+16.7	+ 2.56	+2.56	+2.56	+2.56	+2.56	+2.56	+2.56	+2.56	+2.56	+2.56	+2.56	−16.7	12 00	*24 00*
12 30	0 30	+16.6	4.22	3.39	3.10	2.96	2.81	2.73	2.68	2.64	2.61	2.59	2.56	−16.6	11 30	*23 30*
13 00	1 00	+16.1	5.85	4.20	3.64	3.35	3.06	2.90	2.80	2.73	2.67	2.61	2.56	−16.1	11 00	*23 00*
13 30	1 30	+15.4	7.43	4.98	4.15	3.73	3.30	3.07	2.92	2.81	2.72	2.64	2.56	−15.4	10 30	*22 30*
14 00	2 00	+14.5	8.92	5.72	4.64	4.09	3.53	3.22	3.03	2.88	2.76	2.66	2.56	−14.5	10 00	*22 00*
14 30	2 30	+13.3	10.31	6.41	5.09	4.42	3.73	3.37	3.13	2.95	2.81	2.68	2.56	−13.3	9 30	*21 30*
15 00	3 00	+11.8	11.56	7.03	5.50	4.72	3.92	3.50	3.22	3.02	2.85	2.70	2.56	−11.8	9 00	*21 00*
15 30	3 30	+10.2	12.66	7.57	5.86	4.99	4.09	3.61	3.30	3.07	2.88	2.72	2.56	−10.2	8 30	*20 30*
16 00	4 00	+ 8.4	13.58	8.03	6.16	5.21	4.23	3.71	3.37	3.12	2.91	2.73	2.56	− 8.4	8 00	*20 00*
16 30	4 30	+ 6.4	14.32	8.40	6.40	5.39	4.34	3.79	3.42	3.15	2.94	2.74	2.56	− 6.4	7 30	*19 30*
17 00	5 00	+ 4.3	14.85	8.66	6.57	5.52	4.42	3.84	3.46	3.18	2.95	2.75	2.56	− 4.3	7 00	*19 00*
17 30	5 30	+ 2.2	15.18	8.82	6.68	5.59	4.47	3.88	3.49	3.20	2.96	2.76	2.56	− 2.2	6 30	*18 30*
18 00	6 00	0.0	15.29	8.88	6.72	5.62	4.49	3.89	3.50	3.20	2.97	2.76	2.56	0.0	6 00	*18 00*
0 00	12 00	−16.7	2.56	2.56	2.56	2.56	2.56	2.56	2.56	2.56	2.56	2.56	2.56	+16.7	24 00	*12 00*
0 30	12 30	−16.6	+ 0.90	1.74	2.02	2.16	2.31	2.39	2.44	2.48	2.51	2.54	2.56	+16.6	23 30	*11 30*
1 00	13 00	−16.1	− 0.73	0.93	1.49	1.77	2.06	2.22	2.32	2.39	2.46	2.51	2.56	+16.1	23 00	*11 00*
1 30	13 30	−15.4	− 2.31	+0.14	0.97	1.39	1.82	2.05	2.20	2.31	2.41	2.49	2.56	+15.4	22 30	*10 30*
2 00	14 00	−14.5	− 3.80	−0.60	0.48	1.03	1.60	1.90	2.09	2.24	2.36	2.46	2.56	+14.5	22 00	*10 00*
2 30	14 30	−13.3	− 5.19	−1.28	+0.03	0.70	1.39	1.75	1.99	2.17	2.31	2.44	2.56	+13.3	21 30	*9 30*
3 00	15 00	−11.8	− 6.44	−1.90	−0.38	0.40	1.20	1.62	1.90	2.11	2.27	2.42	2.56	+11.8	21 00	*9 00*
3 30	15 30	−10.2	− 7.54	−2.45	−0.74	+0.13	1.03	1.51	1.82	2.05	2.24	2.41	2.56	+10.2	20 30	*8 30*
4 00	16 00	− 8.4	− 8.46	−2.91	−1.04	−0.09	0.89	1.41	1.75	2.00	2.21	2.39	2.56	+ 8.4	20 00	*8 00*
4 30	16 30	− 6.4	− 9.20	−3.27	−1.28	−0.27	0.78	1.33	1.70	1.97	2.19	2.38	2.56	+ 6.4	19 30	*7 30*
5 00	17 00	− 4.3	− 9.73	−3.54	−1.45	−0.39	0.70	1.28	1.66	1.94	2.17	2.37	2.56	+ 4.3	19 00	*7 00*
5 30	17 30	− 2.2	−10.06	−3.70	−1.56	−0.47	0.65	1.25	1.63	1.92	2.16	2.37	2.56	+ 2.2	18 30	*6 30*
6 00	18 00	0.0	−10.17	−3.75	−1.59	−0.50	0.63	1.23	1.63	1.92	2.16	2.36	2.56	0.0	18 00	*6 00*

To avoid interpolation in this table, which becomes increasingly inaccurate for large $|\delta|$, precession formulae may be used (see p. 18).

D

TELESCOPE PARAMETERS

I EQUATIONS

Objective: f_0 = focal length
D = diameter
FR = focal ratio

Eyepiece: f_e = focal length
d_f = diameter of field stop
θ_p = apparent angular field

Whole instrument: M = angular magnification
d_p = diameter of exit pupil
θ_c = actual angular field

$M = f_0/f_e = D/d_p = \theta_p/\theta_c$ $\quad FR = f_0/D \quad d_f{}^* = f_0\theta_c = f_e\theta_p$

*(θ_c and θ_p must be expressed in radians.)

II PERFORMANCE

(Here, D is assumed to be in millimetres)

Light Grasp (LG) is the ratio of the light flux intercepted by a telescope's objective lens or mirror to that intercepted by a human eye having a 7 mm diameter entrance pupil.

Limiting Visual Magnitude $m_l \simeq 2.7 + 5 \log D$, assuming transparent, dark-sky conditions and magnification $\geqslant$ 1D. (See article by R. Sinnott, *Sky and Telescope*, *45*, 401, 1973)

Smallest Resolvable Angle $\theta \simeq 120/D$ seconds of arc. However, atmospheric conditions seldom permit values less than 0″.5.

Useful Magnification Range $\simeq$ 0.2D to 2D. The lower limit may be a little less, but depends upon the maximum diameter of the entrance pupil of the individual observer's eye. (See the next section). The upper limit is determined by the wave nature of light and the optical limitations of the eye, although atmospheric turbulence usually limits the maximum magnification to 400× or less. For examination of double stars, magnifications up to 4D are sometimes useful. Note that the reciprocal of the coefficient to D is the diameter (in mm) of the telescope's exit pupil.

Values for some common apertures are:

D (mm)	60	75	100	125	150	200	350	440
LG	73	110	200	320	460	820	2500	4000
m_l	11.6	12.1	12.7	13.2	13.6	14.2	15.4	15.9
θ (″)	2.0	1.6	1.2	1.0	0.80	0.60	0.34	0.27
0.2D	12x	15x	20x	25x	30x	40x	70x	88x
2D	120x	150x	200x	250x	300x	400x	700x	880x

TELESCOPE EXIT PUPILS

The performance of a visual, optical telescope is constrained by Earth's atmosphere, by the laws of geometrical and wave optics, and by the properties of the human eye. The telescope and eye meet at the *exit pupil* of the telescope. When a telescope is pointed at a bright area, such as the daytime sky, its exit pupil appears as a small disk of light hovering in space just behind the eyepiece of the telescope (Insert a small piece of paper in this vicinity to demonstrate that this disk of light really is located behind the eyepiece). The exit pupil is the image of the telescope's objective lens or mirror formed by the eyepiece. Since the exit pupil is the narrowest point in the beam of light emerging from the telescope, it is here that the observer's eye must be located to make optimum use of the light passing through the telescope.

The graph two pages ahead may be used to display the relation between the **diameter of the exit pupil (d_p)** of a telescope and the **focal lengths (f_e) of various eyepieces.** Both d_p and f_e are expressed in millimetres. The numbered index marks around the upper right hand corner of the diagram indicate the **focal ratio (FR) of the objective lens or mirror** of a telescope. (The focal ratio is the focal length of the objective divided by its diameter.) The diagram is a graphical display of the standard relation: $d_p = f_e/FR$.

To prepare the diagram for a particular telescope, locate the focal ratio of the telescope's objective on the FR scale, and draw a straight diagonal line from there to the origin (the lower left-hand corner). To determine, for example, the eyepiece focal length required to give an exit pupil of 3 mm, locate $d_p = 3$ on the ordinate, run horizontally across to the diagonal line and at that point drop vertically downward to the abscissa to find f_e. This procedure may, of course, be reversed: for a given f_e, find the corresponding d_p.

The ranges H, M, L, and RFT (blocked off along the ordinate) break the d_p scale into four sections, starting at 0.5 mm and increasing by factors of two. Although this sectioning is somewhat arbitrary, it does correspond closely to what are usually considered to be the high (H), medium (M), low (L), and "richest-field telescope" (RFT) magnification ranges of any visual telescope (and the d_p values at the boundaries are easy to remember).

The highest useable magnification (which corresponds to $d_p = 0.5$ mm, assuming perfect optics and no atmospheric turbulence) is the point at which blurring due to diffraction (caused by the wave-nature of light) begins to become noticeable. Higher magnifications will not reveal any more detail in the image, and cause reductions in four desirable features: sharpness, brightness, field of view, and eye relief (the space between the eye and eyepiece).

Very low magnifications (the RFT range) are useful because they yield wide fields of view, the brightest images of extended objects, and for common telescope apertures, the most stars visible in one view (hence the term "richest field"). The lowest magnification that still makes use of the full aperture of a telescope is determined by the point at which the diameter of the telescope's exit pupil matches the diameter of the *entrance pupil* of the observer's eye. For the dark-adapted eye, the entrance pupil diameter seldom coincides with the often-quoted figure of 7 mm, but depends, among other things, upon the age of the observer as indicated by the scale in the upper left portion of the diagram (See: Kadlecová *et al.*, *Nature*, *182*, p. 1520, 1958). Note that this scale indicates *average* values; the maximum diameter of the entrance pupil of the eye of any *one* individual may differ by up to a millimetre from these values. A horizontal line should be drawn across the diagram corresponding to the maximum diameter of one's own entrance pupil. This line will be an upper bound on d_p in the same sense that the line at $d_p = 0.5$ mm is a lower bound. Note that in daylight, the entrance pupil of the eye has a diameter in the range of 2 to 4 mm. Thus for daylight use of telescopes, the upper bound on d_p will be correspondingly reduced.

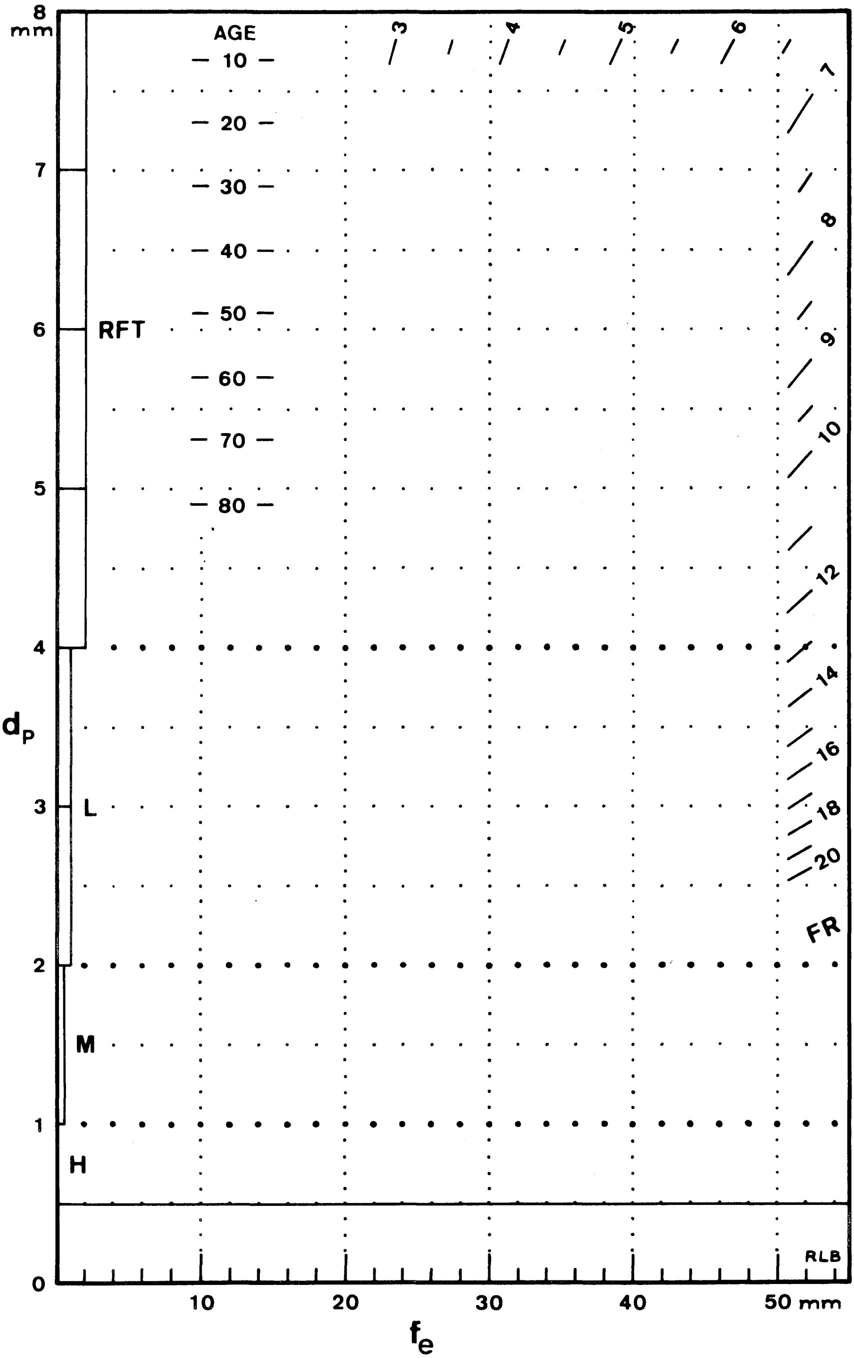
D

If d_p's larger than the entrance pupil of the eye are used, the iris of the observer's eye will cut off some of the light passing through the telescope to the retina. i.e. The iris will have become the light-limiting aperture of the system rather than the edge of the telescope's objective. In this case, the cornea of the eye together with the lenses of the telescope's eyepiece form an image of the observer's iris at the objective of the telescope: to the incoming starlight, a highly magnified image of the iris hovers as an annular skirt obscuring the outer region of the objective of the telescope. A telescope *can* be used at such "ultra low" magnifications, but obviously a telescope of smaller aperture would perform as well. The only advantages of ultra low magnifications are: (1) a wider true field of view (assuming the field stop of the longer f_e eyepiece will permit this); and (2) greater ease of alignment of the entrance pupil of the eye with the exit pupil of the telescope (important when using binoculars during activities involving rapid motion, such as sailing or bird-watching).

Even for RFT use, a value of d_p a millimetre or so smaller than the entrance pupil of the observer's eye has several advantages: (1) Viewing is more comfortable since the observer can move a bit without cutting into the light beam and dimming the image. (2) Light entering near the edge of the pupil of the dark-adapted eye is not as effective in stimulating the rod cells in the retina (This is known as the scotopic Stiles-Crawford effect. e.g. See VanLoo and Enoch, *Vision Research*, *15*, p. 1005, 1975). Thus the smaller d_p will make more efficient use of the light. (3) Aberrations in the cornea and lens of the eye are usually greatest in the peripheral regions and can distort star images. The smaller d_p will avoid the worst of these regions. (4) With the higher magnification and consequently larger image size, structure in dim, extended objects, such as gaseous nebulae and galaxies, will be more easily seen (The ability of the eye to see detail is greatly reduced in dim light as the retina organizes its cells into larger units, thereby sacrificing resolution in order to improve signal-to-noise in the sparse patter of photons). (5) The background sky glow will be a little darker producing views that some observers consider to be aesthetically more pleasing.

Having drawn the diagonal line corresponding to a telescope's focal ratio, and established the upper bound on d_p, the diagram on the next page gives a concise and convenient display of the eyepiece/exit pupil/magnification range relations for a particular telescope and observer. Note that one can see at a glance what range of eyepiece focal lengths is useable. Note also that the reciprocal of d_p equals the magnification per millimetre of objective diameter. *For example*: Consider the common "8-inch" Schmidt-Cassegrain telescope. These usually have FR = 10 and an aperture D = 200 mm. The graph indicates that eyepieces with focal lengths from 5 mm to more than 55 mm are useable (although older observers should be sure that their eye pupils can open sufficiently wide before purchasing a long focal length eyepiece. Also, the considerations in the preceding paragraph are relevant for any observer). With a 32 mm (f_e) eyepiece, the graph gives $d_p = 3.2$ mm, in the "L" magnification range, and the magnification $M = D/d_p = 200/3.2 = 62\times$.

It is readily apparent from the diagram that certain combinations are not reasonable. Some examples: (1) If an observer wishes to use the full aperture of an FR = 4 telescope, he should not use a 40 mm eyepiece. A 70-year-old observer should probably not use even a 24 mm eyepiece on such a system, and should not bother with "7 × 50" or "11 × 80" (=M × D) binoculars which have exit pupils near 7 mm (unless ease of eye/exit pupil alignment is important). (2) With ordinary eyepieces (55 mm or less in focal length), an FR = 15 telescope cannot be operated as an RFT (unless a "compressor" lens is added to reduce its FR). (3) There is no point in using extremely short focal length eyepieces on telescopes having large FR's (This is a common fault, among others, with camera-store refracting telescopes). (RLB).



8 mm
7
6
5
4
3
2
1
0
d_P
RFT
L
M
H
AGE
10
20
30
40
50
60
70
80
3
4
5
6
7
8
9
10
12
14
16
18
20
FR
RLB
10
20
30
40
50 mm
f_e

TIME

Time has been said to be nature's way of keeping everything from happening at once. For astronomical and physical purposes, time is defined by the means of measuring it (As Hermann Bondi has put it: "Time is that which is manufactured by clocks."). Thus, to deal with time, units and scales must be established and clocks devised.

There are three obvious, natural, periodic time intervals on Earth: the seasonal cycle (year); the cycle of lunar phases (month); and the day-night cycle (day). The problem of accurately subdividing these natural intervals to make time locally available at any moment was satisfactorily solved in 1657 by Christiaan Huygens who invented the first practical pendulum clock. Through successive refinements the pendulum clock reigned supreme for nearly three centuries, until it was surpassed in precision by the quartz oscillator in the 1940's. Within another 20 years the quartz clock was, in turn, superseded by the cesium atomic clock which today has a precision near one part in 10^{13} (one second in 300 000 years). The recent technique of "laser cooling" of atomic beams promises further improvements in the precision of atomic clocks.

The cycle of the seasons is called the *tropical year* and contains 365.2422 days. The cycle of lunar phases is known as the *synodic month* and equals 29.53059 days. The average day-night (diurnal) cycle is the *mean solar day* and contains approximately 86 400.001 s. Other types of year, month and day have been defined and are listed along with brief definitions and durations on p. 16.

Today the second is the basic unit of time. For many years a second meant 1/86400 of the mean solar day. However, Earth's rotation on its axis is not perfectly uniform: there are (i) long, (ii) medium, and (iii) short-term accelerations. (i) Over many centuries there is a *secular* slowing due to tidal friction of about 5 parts in 10^{13} per day (i.e. the day becomes one second longer about every 60 000 years). (ii) Over a few decades there are *random* accelerations (positive and negative), apparently due to core-mantle interactions. These are about ten times larger than the tidal acceleration and thus completely obscure the latter effect over time intervals of less than a century or so. (iii) The largest accelerations in Earth's rotation rate are short-term ones: they are *periodic* and are associated mainly with lunar-induced tides (over two-week and monthly intervals), and seasonal meteorological factors (over semiannual and annual intervals). They are typically one or two orders of magnitude larger again than the random, decade fluctuations on which they are superimposed. Also, although not actually a variation in Earth's rotation rate, shifts of Earth's crust relative to the axis of rotation (*polar wobble*) also affect astronomical time determinations through the resulting east-west shift in the meridian at latitudes away from the equator. Like the seasonal accelerations, these are short-term and periodic, but of smaller amplitude. (For more information, see the article by John Wahr in the June 1986 issue of *Sky and Telescope*, p. 545.)

Atoms display a permanence and stability that planets cannot, thus, since 1967, the second has had an atomic definition: 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium 133 atom. This is known as the SI (for Système International) second (abbreviation s).

Although Earth's axial rotation is not sufficiently predictable to serve as a precise clock, the orbital motions of the planets and of our Moon are predictable to high accuracy. Through the dynamical equations describing these motions, a uniform time scale can be derived. This scale, known as *Ephemeris Time* (ET), was for many years the basis of astronomical ephemerides. Also, the definition of the SI second, mentioned above, was chosen so that it was identical to the ephemeris second to within the precision of measurement. Because atomic clocks are readily available and because of their proven precision, at the beginning of 1984 Ephemeris Time was abandoned in favor of *Terrestrial Dynamical Time* (TDT). The unit of TDT is the SI second and its scale was chosen to agree with the 1984 ET scale.

Other time scales are in use. *International Atomic Time* (TAI), like TDT, runs at the SI rate but, for historical reasons, lags TDT by exactly 32.184 seconds. Another is *Universal Time* (UT1, or often simply UT) which is mean solar time at the Greenwich (England) meridian, corrected for polar wobble. In practice UT1 is defined in terms of *Greenwich Mean Sidereal Time* (GMST), the latter being defined in terms of Earth's rotation relative to the mean vernal equinox of date (see p. 10). The adjective *mean* is used here to denote that small, periodic variations due to the nutation of Earth's axis have been averaged out, the mean equinox being affected only by the precession of the axis. GMST is the hour angle of this equinox, i.e. GMST equals the right ascension of a star (corrected for nutation) at the Greenwich meridian. In short, UT1 follows Earth's rotation relative to the mean Sun, and includes the associated short-term (periodic), decade (random), and secular (tidal slowing) accelerations.

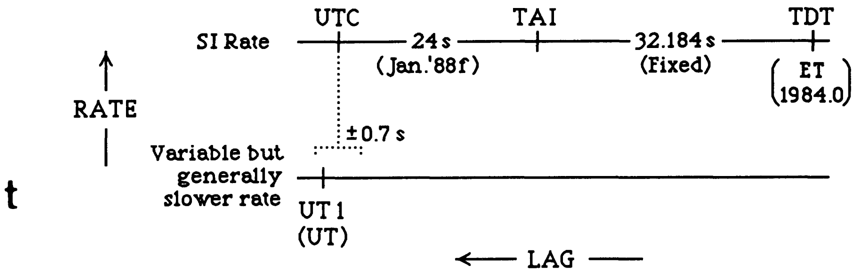
Early in the 20th century the UT1 and ET scales coincided, but since Earth's rotation rate has been generally slower than the SI (ET) rate, by 1970 UT1 was 40 seconds behind ET and was losing more than one second per year. During the next 15 years, Earth's rotation rate increased (part of the random decade fluctuations) so that UT1 now loses only about half a second per year relative to TDT.

Closely related to UT1 is *Coordinated Universal Time* (UTC). UTC runs at the SI rate and is offset an integral number of seconds from TAI so that it approximates UT1. When required (at the end of June 30 or December 31), "leap seconds" are inserted into (or, if necessary, deleted from) UTC so that the difference UT1 $-$ UTC $\equiv$ ΔUT1 does not exceed ± 0.7 s. UTC now lags TAI, and as of January 1, 1988 (when a leap second was last inserted) TAI $-$ UTC $\equiv \Delta$AT $= 24$ s. Thus as this edition of the *Observer's Handbook* goes to press (August, 1988), TDT $-$ UTC $= 24$ s $+ 32.184$ s $= 56.184$ s exactly). At the average rotational angular speed Earth has had over the past few years, an additional leap second will likely be needed at the end of 1989. (Note the diagram at the top of the next page).

The world system of civil time is based on UTC. To keep clocks at various longitudes reasonably in phase with the day-night cycle and yet to avoid the inconvenience to travellers of a local time that varies continuously with longitude, a century ago Earth was divided into about 24 *standard time* zones, adjacent zones generally differing by one hour and each ideally 15 degrees wide (see the maps on pages 26 and 27). The zero zone is centred on the Greenwich meridian. All clocks within the same time zone read the same time. Some countries observe "daylight saving time" during the summer months. In Canada and the United States, clocks are generally set one hour ahead of standard time on the first Sunday in April and return to standard time on the last Sunday in October ("spring ahead, fall back").

A sundial indicates *apparent solar time* at the observer's meridian. Not only is this, in general, different from standard time, but it is far from uniform because of Earth's elliptical orbit and the inclination of the ecliptic to the celestial equator. If the Sun is replaced by a fictitious mean sun moving uniformly along the equator, this defines *Local Mean (Solar) Time* (LMT). Apparent solar time can differ by up to 16 minutes from LMT depending upon the time of year (see p. 58). Also, depending upon the observer's location within his standard time zone, his standard time may differ by up to an hour or so from LMT (see p. 62).

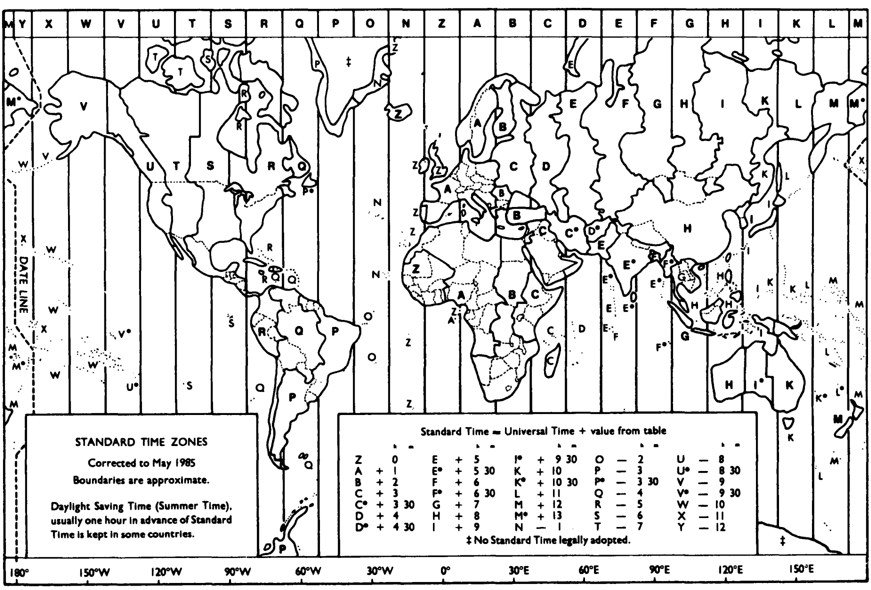
In the same manner that GMST is defined, a *Local Mean Sidereal Time* (LMST) is defined for each observer's meridian. Because Earth makes one more rotation with respect to the other stars than it does with respect to the Sun during a year, sidereal time gains relative to standard time, LMT, UT1, TAI or TDT by about 3^m56^s per day or 2^h per month. Also, because of precession, the mean sidereal day is about 8 ms shorter than Earth's period of rotation (see p. 16). LMST may be used to set a telescope on an object of known right ascension. The hour angle of the object equals the sidereal time less the right ascension. LMST may be available from a sidereal clock, or it can be calculated as explained on p. 28. (RLB)



This diagram displays the rate and scale relations between time scales which run at or near the SI rate and which are not longitude dependent.

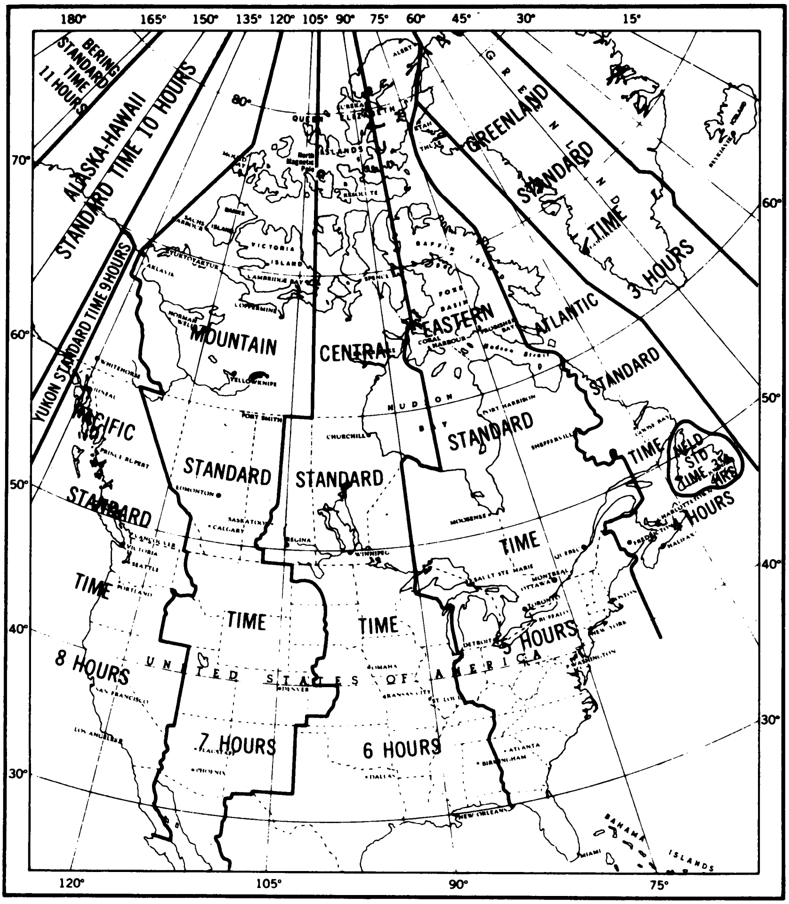
WORLD MAP OF TIME ZONES

Taken from *Astronomical Phenomena for the Year* 1989 (Washington: U.S. Government Printing Office, and London: Her Majesty's Stationery Office)



	h	m		h	m		h	m		h	m		h	m
Z	0		E	+ 5		I*	+ 9	30	O	— 2		U	— 8	
A	+ 1		E*	+ 5	30	K	+ 10		P	— 3		U*	— 8	30
B	+ 2		F	+ 6		K*	+ 10	30	P*	— 3	30	V	— 9	
C	+ 3		F*	+ 6	30	L	+ 11		Q	— 4		V*	— 9	30
C*	+ 3	30	G	+ 7		M	+ 12		R	— 5		W	— 10	
D	+ 4		H	+ 8		M*	+ 13		S	— 6		X	— 11	
D*	+ 4	30	I	+ 9		N	— 1		T	— 7		Y	— 12	

MAP OF STANDARD TIME ZONES



PRODUCED BY THE SURVEYS AND MAPPING BRANCH, DEPARTMENT OF ENERGY, MINES AND RESOURCES, OTTAWA, CANADA, 1973.

MAP OF STANDARD TIME ZONES

The map shows the number of hours by which each time zone is *slower* than Greenwich, that is, the number of hours which must be *added* to the zone's standard time to give Universal Time.

Note: Since the preparation of the above map, the standard time zones have been changed so that all parts of the Yukon Territory now observe Pacific Standard Time. The Yukon, Alaska-Hawaii, and Bering Standard Time Zones have disappeared, and all of Alaska is now on Alaska Standard Time, −9 hours. Also, the part of Texas west of longitude 105° is in the Mountain Time Zone.

TIME SIGNALS

National time services distribute Coordinated Universal Time (UTC). UTC is coordinated through the Bureau International de l'Heure in Paris so that most time services are synchronized to a tenth of a millisecond. Radio time signals available in North America include:

CHU Ottawa, Ontario	3.330, 7.335, 14.670 MHz
WWV Fort Collins, Colorado	2.5, 5, 10, 15, 20 MHz

The difference $\Delta UT1 = UT1 - UTC$ to the nearest tenth of a second is coded in the signals. If UT1 is ahead of UTC, second markers beginning at the 1 second mark of each minute are doubled, the number of doubled markers indicating the number of tenths of a second UT1 is ahead of UTC. If UT1 is behind UTC, the doubled markers begin at the 9 second point.

Time signals also are available by telephone from the National Research Council in Ottawa. Call 613-745-1576 (English) or 613-745-9426 (French).

MEAN SIDEREAL TIME 1989

The following is the Greenwich Mean Sidereal Time (GMST) on day 0 at 0^h UT of each month:

Jan. 0 06.6424^h	Apr. 0 12.5563^h	July 0 18.5359^h	Oct. 0 00.5812^h
Feb. 0 08.6794^h	May 0 14.5276^h	Aug. 0 20.5729^h	Nov. 0 02.6182^h
Mar. 0 10.5193^h	June 0 16.5646^h	Sep. 0 22.6099^h	Dec. 0 04.5895^h

GMST at hour t UT on day d of the month

$$= \text{GMST at } 0^h\text{UT on day } 0 + 0\overset{h}{.}065710d + 1.002738t$$

Local Mean Sidereal Time (LMST) = GMST − west longitude
(or + east longitude)

LMST calculated by this method will be accurate to ± 0.2s provided t is stated to ± 0.1s or better and the observer's longitude is known to $\pm 1''$. (Note that t must be expressed in decimal hours UT. Also, to achieve ± 0.1s accuracy in t, the correction ΔUT1 must be applied to UTC. See the above section on time signals.)

JULIAN DATE, 1989

The Julian date is commonly used by astronomers to refer to the time of astronomical events, because it avoids some of the annoying complexities of the civil calendar. The Julian day corresponding to a given date is the number of days which have elapsed since January 1, 4713 B.C. For an account of the origin of the Julian system see: "The Julian Period", by C. H. Cleminshaw in the *Griffith Observer*, April 1975; "The Origin of the Julian Day System", by G. Moyer in *Sky and Telescope*, April 1981.

The Julian day commences at noon (12^h) UT. To find the Julian date at any time during 1989, determine the day of the month and time at the Greenwich meridian, convert this to a decimal day, and add it to one of the following numbers according to the month. (These numbers are the Julian dates for 0^hUT on the "0th" day of each month.):

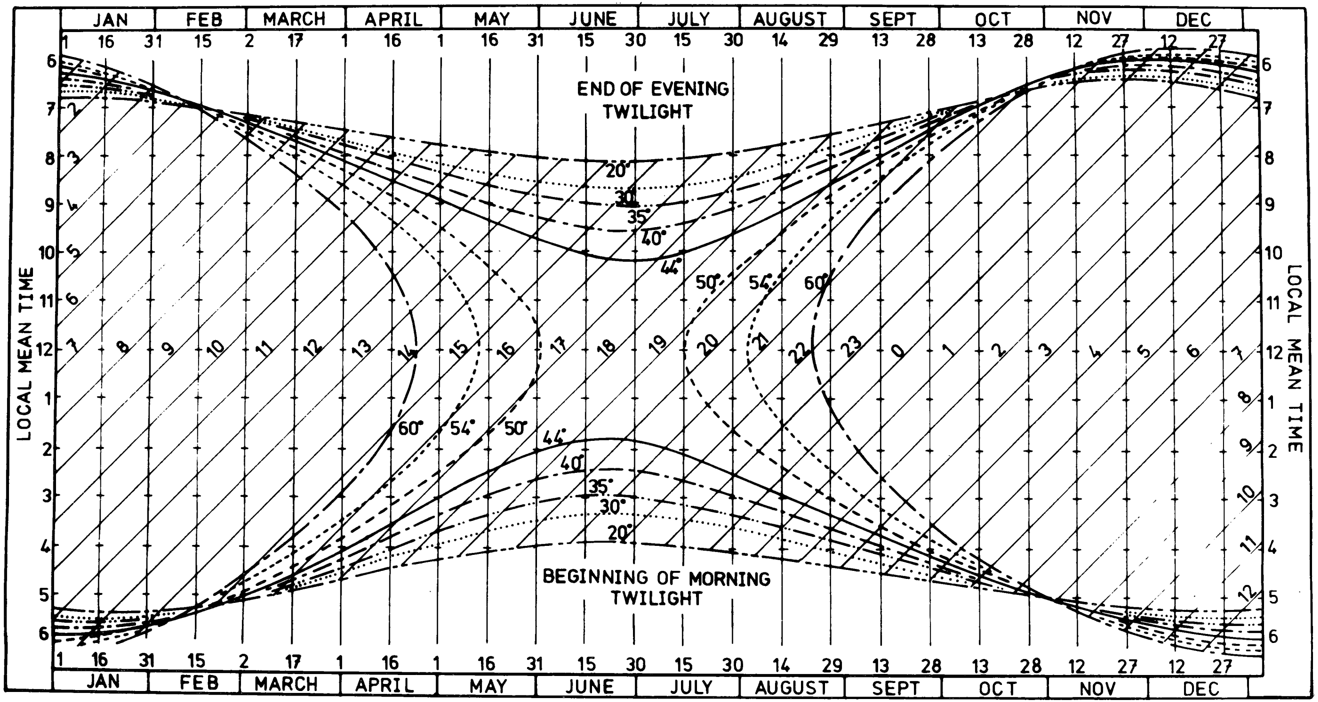
Jan. 244 7526.5	Apr. 244 7616.5	July 244 7707.5	Oct. 244 7799.5
Feb. 244 7557.5	May 244 7646.5	Aug. 244 7738.5	Nov. 244 7830.5
Mar. 244 7585.5	June 244 7677.5	Sep. 244 7769.5	Dec. 244 7860.5

e.g. 21:36 EDT on May 18 = 01:36 UT on May 19 = May 19.07 UT = 244 7646.5 + 19.07 = JD 244 7665.57

The Julian dates for 0 UT January 0 for several previous years are 244 0000.5 plus (for years indicated): 951(1971), 1316(1972), 1682(1973), 2047(1974), 2412(1975), 2777(1976), 3143(1977), 3508(1978), 3873(1979), 4238(1980), 4604(1981), 4969(1982), 5334(1983), 5699(1984), 6065(1985), 6430(1986), 6795 (1987), 7160 (1988).

ASTRONOMICAL TWILIGHT AND SIDEREAL TIME

The diagram gives (i) the local mean time (LMT) of the beginning and end of astronomical twilight (curved lines) at a given latitude on a given date and (ii) the local mean sidereal time (LMST, diagonal lines) at a given LMT on a given date. The LMST is also the right ascension of an object on the observer's celestial meridian. To use the diagram, draw a line downward from the given date; the line cuts the curved lines at the LMT of beginning and end of twilight, and cuts each diagonal line at the LMT corresponding to the LMST marked on the line. See pages 25 and 66 for definitions of LMT, LMST and astronomical twilight. (Diagram prepared by Randall Brooks.)



THE SKY MONTH BY MONTH

By John R. Percy

Introduction—In the monthly descriptions of the sky on the following pages, the right ascension (RA), declination (Dec) (both at 0^h UT), time of transit at the Greenwich meridian (Tran), and visual magnitude (Mag) have been tabulated for seven planets for the 1st, 11th, and 21st day of each month. Unless noted otherwise, the descriptive comments about the planets apply to the middle of the month, and dates are given in UT. Double dates (e.g. June 4–5), when used for planetary conjunctions, indicate that the event is visible at night in some part of North America. Estimates of altitude are for an observer in latitude 45°N.

M

The Sun—Data concerning the position, transit, orientation, rotation, activity, rise, and set of the Sun appear in the section beginning on page 56. For detailed information on solar eclipses during the year, see the section beginning on page 84.

The Moon—Its phases, perigee and apogee times and distances, and its conjunctions with the planets are given in the monthly tables. The perigee and apogee distances are taken from *Astronomical Tables of the Sun, Moon, and Planets* by Jean Meeus (Willmann-Bell, 1983). For times of moonrise and moonset, see p. 70.

Elongation, Age and Phase of the Moon—The *elongation* is the angular distance of the Moon from the Sun in degrees, counted eastward around the sky. Thus, elongations of 0°, 90°, 180°, and 270° correspond to new, first quarter, full, and last quarter moon. The *age* of the Moon is the time since the new moon phase. Because the Moon's orbital motion is not uniform, the age of the Moon does not accurately specify its phase. The Moon's elongation increases on the average by 12.2° per day, first quarter, full and last quarter phases corresponding approximately to 7.4, 14.8 and 22.1 days respectively.

The Sun's selenographic colongitude is essentially a convenient way of indicating the position of the sunrise terminator as it moves across the face of the Moon. It provides an accurate method of recording the exact conditions of illumination (angle of illumination), and makes it possible to observe the Moon under exactly the same lighting conditions at a later date. The Sun's selenographic colongitude is numerically equal to the selenographic longitude of the sunrise terminator reckoned eastward from the mean centre of the disk. Its value increases at the rate of nearly 12.2° per day or about $\frac{1}{2}$° per hour; it is approximately 270°, 0°, 90° and 180° at New Moon, First Quarter, Full Moon and Last Quarter respectively. Values of the Sun's selenographic colongitude are given on the following pages for the first day of each month.

Sunrise will occur at a given point *east* of the central meridian of the Moon when the Sun's selenographic colongitude is equal to the eastern selenographic longitude of the point; at a point *west* of the central meridian when the Sun's selenographic colongitude is equal to 360° minus the western selenographic longitude of the point. The longitude of the sunset terminator differs by 180° from that of the sunrise terminator.

Libration is the shifting, or rather apparent shifting, of the visible disk of the Moon (See *Sky and Telescope*, July 1987, p. 60). Sometimes the observer sees features farther around the eastern or the western limb (libration in longitude), or the northern or southern limb (libration in latitude). When the libration in longitude is positive, the mean central point of the disk of the Moon is displaced eastward on the celestial sphere, exposing to view a region on the celestial-west limb; i.e. the lunar-east limb (on the following pages east and west are used in the *celestial* sense). When the libration in latitude is positive, the mean central point of the disk of the Moon is displaced towards the south, and a region on the north limb is exposed to view.

The dates of the greatest positive and negative values of the libration in longitude and latitude are given in the following pages, as are the dates of greatest positive and negative declination.

The Moon's Orbit. In 1989, the ascending node of the Moon's orbit regresses from longitude 337.8° to 318.5° (Aquarius into Capricornus).

The Planets—Further information in regard to the planets, including Pluto, is found on pp. 113–132. For the configurations of Jupiter's four Galilean satellites, see the monthly tables. In these diagrams, the central vertical band represents the equatorial diameter of the disk of Jupiter. Time is shown by the vertical scale, each horizontal line denoting 0^h Universal Time. (Be sure to convert to U.T. before using these diagrams.) The relative positions of the satellites at any time with respect to the disk of Jupiter are given by the four labelled curves (I, II, III, IV) (see p. 12 for the key to these Roman numerals). In constructing these diagrams, the positions of the satellites in the direction perpendicular to the equator of Jupiter are necessarily neglected. Note that the orientation is for an inverting telescope. Similar diagrams for the four brightest satellites of Saturn appear on pages 146–149. For the various transits, occultations, and eclipses of Jupiter's satellites, see p. 133.

Minima of Algol—The times of mid-eclipse are given in the monthly tables and are calculated from the ephemeris: heliocentric minimum = 2440953.4657 + 2.8673075 E, and are expressed as geocentric times, for comparison with observations. (The first number in the equation is the Julian date corresponding to 1971 Jan. 1.9657, an Algol minimum. The second number is the period of Algol in days, and E is an integer.) We thank Roger W. Sinnott of *Sky and Telescope* for providing these times.

Occultations of Stars and Planets—For information about occultations of stars and planets visible in North America, see pp. 96–110 and 154.

ANNIVERSARIES AND FESTIVALS 1989

New Year's Day	Sun.	Jan. 1
M. L. King's Birthday (U.S.)	Mon.	Jan. 16
Valentine's Day	Tues.	Feb. 14
Good Friday		Mar. 24
Easter Sunday		Mar. 26
First Day of Ramadân	Fri.	Apr. 7
First Day of Passover	Thur.	Apr. 20
Astronomy Day	Sat.	May 13
Mother's Day	Sun.	May 14
Whit Sunday - Pentecost		May 14
Victoria Day (Canada)	Mon.	May 22
Memorial Day (U.S.)	Mon.	May 29
Feast of Weeks	Fri.	June 9
Father's Day	Sun.	June 18
Saint-Jean-Baptiste (P.Q.)	Sat.	June 24
C.A.S. AM (Univ. Montréal)		June 27 - 29
R.A.S.C. GA (Sydney, N.S.)		June 30 - July 2
Canada Day	Sat.	July 1
Independence Day (U.S.)	Tues.	July 4
Islamic New Year	Fri.	Aug. 4
Civic Holiday (Canada)	Mon.	Aug. 7
Labour Day	Mon.	Sept. 4
Jewish New Year	Sat.	Sept. 30
Day of Atonement	Mon.	Oct. 9
Thanksgiving Day (Canada)	Mon.	Oct. 9
Columbus Day (U.S.)	Mon.	Oct. 9
First Day of Tabernacles	Sat.	Oct. 14
Halloween	Tues.	Oct. 31
Remembrance Day (Canada)	Sat.	Nov. 11
Veterans' Day (U.S.)	Sat.	Nov. 11
Thanksgiving Day (U.S.)	Thur.	Nov. 23
Christmas Day	Mon.	Dec. 25

1989 and 1990 calendars are on the inside back cover.

		Mercury	Venus	Mars	Jupiter	Saturn	Uranus	Neptune
RA	1	19^h59^m	17^h07^m	1^h14^m	3^h39^m	18^h24^m	18^h08^m	18^h43^m
	11	20^h49^m	18^h01^m	1^h33^m	3^h37^m	18^h29^m	18^h10^m	18^h45^m
	21	20^h45^m	18^h56^m	1^h54^m	3^h36^m	18^h34^m	18^h13^m	18^h46^m
Dec	1	-22°34'	-22°04'	+8°24'	+18°33'	-22°36'	-23°39'	-22°10'
	11	-18°12'	-23°03'	+10°32'	+18°29'	-22°34'	-23°39'	-22°09'
	21	-15°27'	-22°52'	+12°38'	+18°29'	-22°30'	-23°38'	-22°07'
Tran	1	13^h18^m	10^h25^m	18^h30^m	20^h52^m	11^h40^m	11^h23^m	11^h58^m
	11	13^h26^m	10^h40^m	18^h10^m	20^h11^m	11^h06^m	10^h47^m	11^h21^m
	21	12^h40^m	10^h55^m	17^h51^m	19^h31^m	10^h31^m	10^h10^m	10^h43^m
Mag	1	-0.7	-3.9	0.0	-2.7	+0.5	+5.8	+8.0
	11	-0.4	-3.9	+0.1	-2.6	+0.5	+5.8	+8.0
	21	+2.6	-3.9	+0.4	-2.5	+0.5	+5.8	+8.0

The Moon – On Jan. 1.0 UT, the age of the Moon is 22.8 d. The Sun's selenographic colongitude is 191.43° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on Jan. 19 (5°) and minimum (east limb exposed) on Jan. 4 (6°). The libration in latitude is maximum (north limb exposed) on Jan. 4 (7°) and minimum (south limb exposed) on Jan. 17 (7°). The Moon reaches its greatest northern declination on Jan. 19 (+28°) and its greatest southern declination on Jan. 6 (−28°). This range in declination is close to the maximum possible. There is an occultation of Regulus by the Moon on Jan. 23–24, visible in parts of North America.

Mercury is visible early in the month, very low in the southwest, just after sunset. It is at greatest elongation east (19°) on Jan. 9, but by Jan. 25, it is in inferior conjunction.

Venus, in Sagittarius east of Antares, is visible very low in the southeast, just before sunrise. It passes 0.5° north of Uranus on Jan. 12, 0.6° south of Saturn on Jan. 16, and 0.9° south of Neptune on Jan. 18–19.

Mars moves from Pisces into Aries during the month. It is high in the southern sky at sunset, and sets at about midnight.

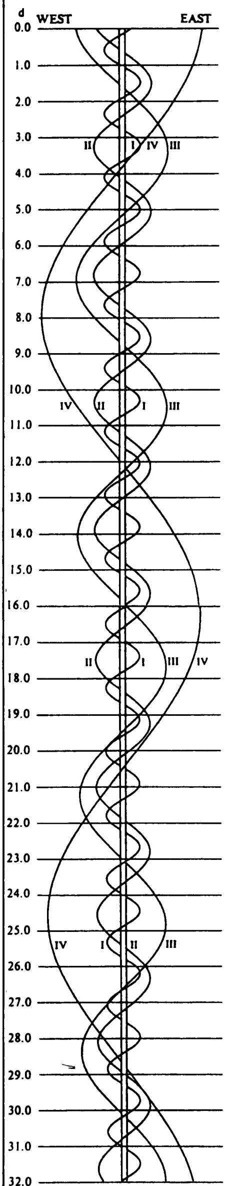
Jupiter, in Taurus, is about half-way up in the southeastern sky at sunset, and sets after midnight. It is stationary on Jan. 20, then resumes its direct or eastward motion relative to the stars. Jupiter is well-placed for viewing throughout most of the year, situated amid the prominent constellations of winter. For the next few months, it is situated below the Pleiades.

Saturn, in Sagittarius throughout the year, is too close to the Sun to be easily seen this month. You might want to use its proximity to Venus on Jan. 16 (see above) as a way of locating it at that time.

Uranus and *Neptune* are in Sagittarius, within 10° of Saturn all year; see also *Venus* above.

1989			JANUARY UNIVERSAL TIME	Min. of Algol
	d	h m		h m
Sun.	1	22	Earth at perihelion (147 101 000 km)	16 45
Mon.	2			
Tue.	3	10	Quadrantid meteors	
Wed.	4	03	Juno stationary	13 34
Thu.	5	01	Antares 0.5° N. of Moon; occultation[1]	
Fri.	6	04	Venus 5° N. of Moon	
Sat.	7	19 22	● New Moon	10 24
Sun.	8			
Mon.	9	02	Mercury at greatest elong. E. (19°)	
		05	Mercury 1.7° N. of Moon	
Tue.	10	23	Moon at perigee (366 382 km)	7 13
Wed.	11			
Thu.	12	17	Venus 0.5° N. of Uranus	
			Mercury at ascending node	
Fri.	13			4 02
Sat.	14	13 58	☽ First Quarter	
		22	Mars 4° S. of Moon	
Sun.	15	15	Mercury stationary	
Mon.	16	16	Venus 0.6° S. of Saturn	0 51
Tue.	17	00	Jupiter 6° S. of Moon	
			Mercury at perihelion	
Wed.	18			21 41
Thu.	19	04	Venus 0.9° S. of Neptune	
Fri.	20	14	Jupiter stationary	
			Venus at descending node	
Sat.	21	21 33	○ Full Moon	18 30
Sun.	22			
Mon.	23			
Tue.	24	04	Regulus 0.03° S. of Moon; occultation[2]	15 19
Wed.	25	00	Mercury in inferior conjunction	
Thu.	26			
Fri.	27	00	Moon at apogee (405 100 km)	12 09
			Mercury at greatest hel. lat. N.	
Sat.	28			
Sun.	29			
Mon.	30	02 02	☾ Last Quarter	8 58
Tue.	31			

Config. of Jupiter's Satellites



[1]Visible in Madagascar, S. Indian Ocean, Antarctica, New Zealand
[2]Visible in the E. of North America, E. of Central America, West Indies, W. and S. of Africa

		Mercury	Venus	Mars	Jupiter	Saturn	Uranus	Neptune
RA	1	$19^{h}56^{m}$	$19^{h}55^{m}$	$2^{h}18^{m}$	$3^{h}37^{m}$	$18^{h}39^{m}$	$18^{h}15^{m}$	$18^{h}48^{m}$
	11	$19^{h}57^{m}$	$20^{h}47^{m}$	$2^{h}41^{m}$	$3^{h}39^{m}$	$18^{h}44^{m}$	$18^{h}17^{m}$	$18^{h}49^{m}$
	21	$20^{h}34^{m}$	$21^{h}37^{m}$	$3^{h}04^{m}$	$3^{h}43^{m}$	$18^{h}48^{m}$	$18^{h}19^{m}$	$18^{h}50^{m}$
Dec	1	$-17°21'$	$-21°19'$	$+14°53'$	$+18°35'$	$-22°26'$	$-23°37'$	$-22°05'$
	11	$-19°05'$	$-18°48'$	$+16°49'$	$+18°46'$	$-22°22'$	$-23°37'$	$-22°03'$
	21	$-18°57'$	$-15°23'$	$+18°37'$	$+19°00'$	$-22°18'$	$-23°36'$	$-22°02'$
Tran	1	$11^{h}08^{m}$	$11^{h}11^{m}$	$17^{h}32^{m}$	$18^{h}49^{m}$	$9^{h}53^{m}$	$9^{h}29^{m}$	$10^{h}01^{m}$
	11	$10^{h}32^{m}$	$11^{h}24^{m}$	$17^{h}15^{m}$	$18^{h}12^{m}$	$9^{h}18^{m}$	$8^{h}52^{m}$	$9^{h}24^{m}$
	21	$10^{h}31^{m}$	$11^{h}34^{m}$	$17^{h}00^{m}$	$17^{h}36^{m}$	$8^{h}43^{m}$	$8^{h}14^{m}$	$8^{h}45^{m}$
Mag	1	+1.7	-3.9	+0.6	-2.5	+0.6	+5.8	+8.0
	11	+0.3	-3.9	+0.7	-2.4	+0.6	+5.7	+8.0
	21	0.0	-3.9	+0.9	-2.3	+0.6	+5.7	+8.0

M

The Moon – On Feb. 1.0 UT, the age of the Moon is 24.2 d. The Sun's selenographic colongitude is 208.37° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on Feb. 14 (6°) and minimum (east limb exposed) on Feb. 1 (7°). The libration in latitude is maximum (north limb exposed) on Feb. 1 (7°) and Feb. 28 (7°) and minimum (south limb exposed) on Feb. 13 (7°). The Moon reaches its greatest northern declination on Feb. 15 (+28°) and its greatest southern declination on Feb. 2 (−28°). There is a total eclipse of the Moon on Feb. 20, visible in parts of North America.

Mercury is at greatest elongation west (26°) on Feb. 18, but this is a rather unfavourable elongation for observers in the Northern Hemisphere; the planet stands barely 12° above the southeastern horizon at sunrise on Feb. 18.

Venus may be seen with great difficulty early in the month, very low in the southeast at sunrise; by the end of the month, it is too close to the Sun to be seen.

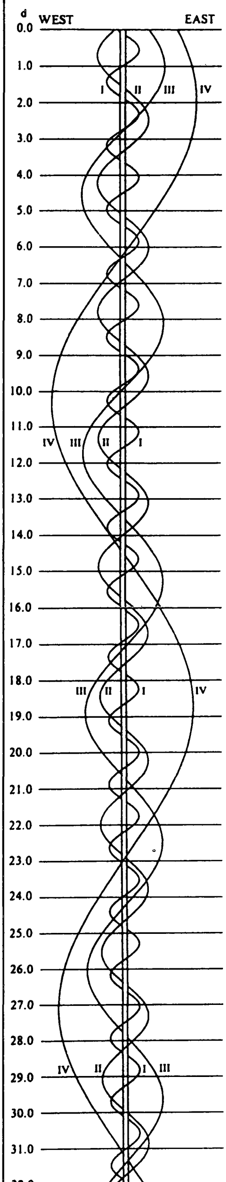
Mars, in Aries, is high in the southern sky at sunset, and sets at about midnight. It is west of Jupiter, and much fainter and redder.

Jupiter, in Taurus, is high in the southern sky at sunset, and sets at about midnight; see also *Mars* above.

Saturn, in Sagittarius, rises about 2 1/2 h before the Sun, and is very low in the southeast at sunrise.

1989			FEBRUARY UNIVERSAL TIME	Min. of Algol
	d	h m		h m
Wed.	1	03	Mercury 4° N. of Venus	
		11	Antares 0.7° N. of Moon; occultation[1]	
Thu.	2			5 47
Fri.	3	06	Uranus 4° N. of Moon	
		15	Saturn 5° N. of Moon	
		18	Neptune 5° N. of Moon	
Sat.	4	18	Mercury 6° N. of Moon	
Sun.	5	14	Mercury stationary	2 36
Mon.	6	07 37	● New Moon	
Tue.	7	22	Moon at perigee (360 935 km)	23 26
Wed.	8			
Thu.	9			
Fri.	10			20 15
Sat.	11			
Sun.	12	07	Mars 4° S. of Moon	
		23 15	☽ First Quarter	
Mon.	13	07	Jupiter 6° S. of Moon	17 04
Tue.	14			
Wed.	15			
Thu.	16			13 54
Fri.	17			
Sat.	18	16	Mercury at greatest elong. W. (26°)	
Sun.	19		Mercury at descending node	10 43
Mon.	20	11	Regulus 0.02° S. of Moon; occultation[2]	
		12	Pluto stationary	
		15 32	○ Full Moon; Eclipse of Moon, p. 84	
Tue.	21	02	Juno at opposition	
Wed.	22			7 32
Thu.	23	14	Moon at apogee (405 944 km)	
			Venus at aphelion	
Fri.	24			
Sat.	25	22	Pallas in conjunction with Sun	4 21
Sun.	26			
Mon.	27			
Tue.	28	19	Antares 0.7° N. of Moon; occultation[3]	1 11
		20 08	☾ Last Quarter	

Config. of Jupiter's Satellites



[1] Visible in the S. Pacific, extreme S. of South America, Antarctica
[2] Visible in Japan, N. Pacific, Hawaii, S.E. Pacific
[3] Visible in the S. Indian Ocean, Antarctica

		Mercury	Venus	Mars	Jupiter	Saturn	Uranus	Neptune
RA	1	21^h15^m	22^h16^m	3^h24^m	3^h46^m	18^h51^m	18^h20^m	18^h51^m
	11	22^h13^m	23^h04^m	3^h49^m	3^h52^m	18^h54^m	18^h22^m	18^h52^m
	21	23^h15^m	23^h50^m	4^h15^m	3^h58^m	18^h56^m	18^h23^m	18^h53^m
Dec	1	-17°18'	-12°07'	+19°55'	+19°13'	-22°15'	-23°36'	-22°01'
	11	-13°17'	-7°34'	+21°22'	+19°33'	-22°11'	-23°35'	-21°59'
	21	-7°12'	-2°41'	+22°36'	+19°54'	-22°08'	-23°35'	-21°58'
Tran	1	10^h40^m	11^h42^m	16^h48^m	17^h09^m	8^h14^m	7^h44^m	8^h15^m
	11	10^h59^m	11^h49^m	16^h34^m	16^h35^m	7^h38^m	7^h06^m	7^h36^m
	21	11^h23^m	11^h56^m	16^h20^m	16^h02^m	7^h01^m	6^h28^m	6^h58^m
Mag	1	0.0	-3.9	+1.0	-2.3	+0.6	+5.7	+8.0
	11	-0.2	-3.9	+1.1	-2.2	+0.6	+5.7	+8.0
	21	-0.7	-3.9	+1.3	-2.1	+0.5	+5.7	+7.9

M

The Moon – On Mar. 1.0 UT, the age of the Moon is 22.7 d. The Sun's selenographic colongitude is 189.05° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on Mar. 14 (7°) and minimum (east limb exposed) on Mar. 2 (8°) and Mar. 30 (8°). The libration in latitude is maximum (north limb exposed) on Mar. 27 (7°) and minimum (south limb exposed) on Mar. 13 (7°). The Moon reaches its greatest northern declination on Mar. 14 (+28°) and its greatest southern declination on Mar. 2 (−28°) and Mar. 29 (−28°).

Mercury is not visible this month.

Venus is not visible this month.

Mars moves from Aries into Taurus this month, passing 7° north of Aldebaran on Mar. 28. Mars passes 2° north of Jupiter on Mar. 11–12 (Mars is much fainter and redder than Jupiter); the Moon is only a few degrees away at the time. Mars and Jupiter are high in the southwestern sky at sunset, near the Pleiades, setting about 6 h later.

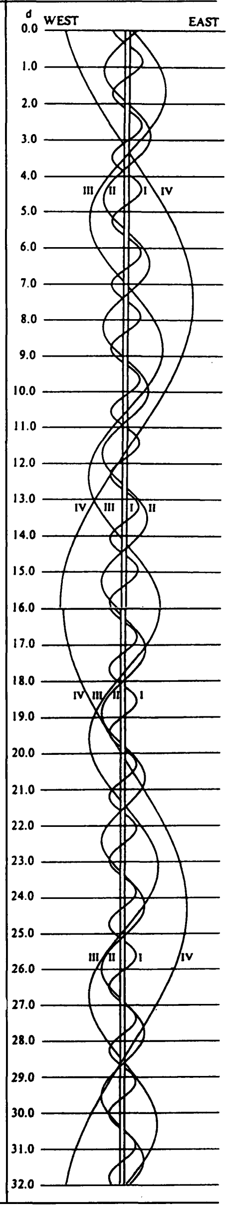
Jupiter, in Taurus, is high in the southwestern sky at sunset, and sets about 6 h later; see also *Mars* above.

Saturn, in Sagittarius, rises about 3 h before the Sun, and is low in the southeast at sunrise. It passes 0.2° south of Neptune on Mar. 2–3. This is the first of three conjunctions of these planets in 1989.

Neptune: see *Saturn* above.

1989			MARCH UNIVERSAL TIME	Min. of Algol
	d	h m		h m
Wed.	1			
Thu.	2	17	Uranus 4° N. of Moon	22 00
			Mercury at aphelion	
Fri.	3	02	Saturn 0.2° S. of Neptune	
		06	Neptune 5° N. of Moon	
		06	Saturn 5° N. of Moon	
Sat.	4			
Sun.	5			18 49
Mon.	6	04	Mercury 0.8° S. of Moon; occultation[1]	
Tue.	7	18 19	● New Moon; Eclipse of Sun, p. 85	
Wed.	8	08	Moon at perigee (357 540 km)	15 39
Thu.	9			
Fri.	10			
Sat.	11			12 28
Sun.	12	08	Mars 2° N. of Jupiter	
		19	Jupiter 6° S. of Moon	
		19	Mars 4° S. of Moon	
Mon.	13			
Tue.	14	10 11	☽ First Quarter	9 17
Wed.	15			
Thu.	16			
Fri.	17		Venus at greatest hel. lat. S.	6 06
Sat.	18			
Sun.	19	17	Regulus 0.01° S. of Moon; occultation[2]	
Mon.	20	15 28	Vernal equinox; spring begins	2 56
Tue.	21			
Wed.	22	09 58	○ Full Moon	23 45
		18	Moon at apogee (406 353 km)	
			Mercury at greatest hel. lat. S.	
Thu.	23			
Fri.	24			
Sat.	25			20 34
Sun.	26			
Mon.	27			
Tue.	28	02	Antares 0.6° N. of Moon; occultation[3]	17 23
		18	Mars 7° N. of Aldebaran	
Wed.	29			
Thu.	30	02	Uranus 4° N. of Moon	
		10 21	☾ Last Quarter	
		14	Neptune 5° N. of Moon	
		16	Saturn 5° N. of Moon	
Fri.	31			14 13

Config. of Jupiter's Satellites



[1]Visible in E. Africa, Asia
[2]Visible in S. Europe, N. Africa, S. Asia, East Indies, Australia except the eastern part
[3]Visible in the S. and S.E. of South America, Antarctica, extreme S.W. Australia

THE SKY FOR APRIL 1989

		Mercury	Venus	Mars	Jupiter	Saturn	Uranus	Neptune
RA	1	0^h30^m	0^h40^m	4^h44^m	4^h06^m	18^h59^m	18^h23^m	18^h53^m
	11	1^h44^m	1^h25^m	5^h11^m	4^h14^m	19^h00^m	18^h23^m	18^h53^m
	21	2^h58^m	2^h12^m	5^h38^m	4^h23^m	19^h00^m	18^h23^m	18^h53^m
Dec	1	+1°40'	+2°50'	+23°39'	+20°19'	-22°05'	-23°35'	-21°57'
	11	+10°54'	+7°46'	+24°20'	+20°41'	-22°03'	-23°35'	-21°57'
	21	+18°51'	+12°24'	+24°43'	+21°03'	-22°03'	-23°35'	-21°57'
Tran	1	11^h54^m	12^h03^m	16^h06^m	15^h27^m	6^h20^m	5^h45^m	6^h15^m
	11	12^h30^m	12^h09^m	15^h53^m	14^h56^m	5^h42^m	5^h06^m	5^h36^m
	21	13^h03^m	12^h16^m	15^h41^m	14^h25^m	5^h03^m	4^h26^m	4^h56^m
Mag	1	-1.7	-3.9	+1.4	-2.1	+0.5	+5.7	+7.9
	11	-1.6	-3.9	+1.4	-2.0	+0.5	+5.6	+7.9
	21	-0.8	-3.9	+1.5	-2.0	+0.4	+5.6	+7.9

M

The Moon – On. Apr. 1.0 UT, the age of the Moon is 24.2 d. The Sun's selenographic colongitude is 206.68° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on Apr. 11 (8°) and minimum (east limb exposed) on Apr. 27 (7°). The libration in latitude is maximum (north limb exposed) on Apr. 23 (7°) and minimum (south limb exposed) on Apr. 9 (7°). The Moon reaches its greatest northern declination on Apr. 10 (+28°) and its greatest southern declination on Apr. 25 (−28°). There is an occultation of Regulus by the Moon on Apr. 15, visible in parts of North America.

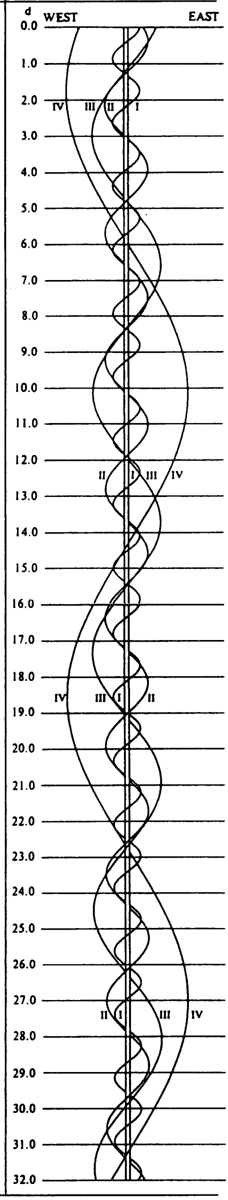
Mercury is in superior conjunction on Apr. 4, but by the end of the month, it is approaching a quite favourable greatest elongation east, and is visible low in the western sky, just after sunset.

Venus is not visible this month; it is in superior conjunction on Apr. 4.

Mars, in Taurus, is high in the southwestern sky at sunset, and sets about 5 h later; see also *Jupiter* below.

Jupiter is in Taurus, with Mars to the east and the constellations of winter nearby. It dominates the southwestern sky at sunset, and sets 4 h later. The crescent Moon passes north of the two planets on Apr. 9 and 10.

Saturn, in Sagittarius, rises about 4 1/2 h before the Sun, and is very low in the southeast at sunrise. It is stationary on Apr. 23, then begins retrograde or westward motion relative to the stars.

1989			APRIL UNIVERSAL TIME	Min. of Algol	Config. of Jupiter's Satellites
	d	h m		h m	
Sat.	1				
Sun.	2				
Mon.	3			11 02	
Tue.	4	14	Mercury in superior conjunction		
		23	Venus in superior conjunction		
Wed.	5	02	Juno stationary		
		20	Moon at perigee (357 191 km)		
Thu.	6	03 33	● New Moon	7 51	
Fri.	7				
Sat.	8				
Sun.	9	09	Uranus stationary	4 40	
		12	Jupiter 6° S. of Moon		
Mon.	10	09	Mars 4° S. of Moon		
			Mercury at ascending node		
Tue.	11				
Wed.	12	23 13	☽ First Quarter	1 29	
Thu.	13	22	Neptune stationary		
Fri.	14			22 18	
Sat.	15	23	Regulus 0.1° N. of Moon; occultation[1]		
			Mercury at perihelion		
Sun.	16				
Mon.	17			19 08	
Tue.	18	21	Moon at apogee (406 166 km)		
Wed.	19				
Thu.	20			15 57	
Fri.	21	03 13	○ Full Moon		
Sat.	22	09	Lyrid meteors		
Sun.	23	00	Saturn stationary	12 46	
Mon.	24	07	Antares 0.5° N. of Moon; occultation[2]		
Tue.	25		Mercury at greatest hel. lat. N.		
Wed.	26	08	Uranus 4° N. of Moon	9 35	
		20	Neptune 5° N. of Moon		
		23	Saturn 5° N. of Moon		
Thu.	27				
Fri.	28	06	Ceres in conjunction with Sun		
		20 46	☾ Last Quarter		
Sat.	29			6 24	
Sun.	30				

[1]Visible in the S. of North America, Central America, West Indies, N. of South America, S.W. Africa

[2]Visible in the S. Pacific, S. of South America, Antarctica, extreme S. of Africa

THE SKY FOR MAY 1989

		Mercury	Venus	Mars	Jupiter	Saturn	Uranus	Neptune
RA	1	3^h54^m	3^h00^m	6^h05^m	4^h32^m	19^h00^m	18^h22^m	18^h53^m
	11	4^h18^m	3^h50^m	6^h32^m	4^h41^m	18^h59^m	18^h22^m	18^h53^m
	21	4^h10^m	4^h42^m	6^h59^m	4^h51^m	18^h58^m	18^h20^m	18^h52^m
Dec	1	+23°02'	+16°33'	+24°48'	+21°25'	-22°03'	-23°36'	-21°57'
	11	+23°16'	+19°59'	+24°36'	+21°45'	-22°05'	-23°37'	-21°57'
	21	+20°23'	+22°32'	+24°06'	+22°03'	-22°07'	-23°37'	-21°58'
Tran	1	13^h18^m	12^h25^m	15^h29^m	13^h54^m	4^h24^m	3^h46^m	4^h17^m
	11	13^h01^m	12^h36^m	15^h16^m	13^h25^m	3^h43^m	3^h06^m	3^h37^m
	21	12^h12^m	12^h48^m	15^h04^m	12^h55^m	3^h03^m	2^h25^m	2^h57^m
Mag	1	+0.4	-3.9	+1.6	-2.0	+0.4	+5.6	+7.9
	11	+2.0	-3.9	+1.7	-2.0	+0.3	+5.6	+7.9
	21	+5.0	-3.9	+1.7	-2.0	+0.3	+5.6	+7.9

The Moon – On May 1.0 UT, the age of the Moon is 24.9 d. The Sun's selenographic colongitude is 212.62° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on May 10 (7°) and minimum (east limb exposed) on May 24 (6°). The libration in latitude is maximum (north limb exposed) on May 20 (7°) and minimum (south limb exposed) on May 6 (7°). The Moon reaches its greatest northern declination on May 8 (+28°) and its greatest southern declination on May 22 (−28°).

Mercury is visible early in the month, low in the western sky, just after sunset. It is at greatest elongation east (21°) on May 1, and this is a favourable elongation. It passes 0.6° north of Venus on May 15–16, but the planets are too close to the Sun to be easily seen; Mercury is in inferior conjunction on May 23. The crescent Moon passes Mercury, Jupiter and Mars between May 6 and May 9.

Venus is visible at the end of the month, very low in the western sky, just after sunset. In Taurus amid the setting constellations of winter, it passes 6° north of Aldebaran on May 19, and 0.8° north of Jupiter on May 22–23; see also *Mercury* above.

Mars moves from Taurus into Gemini this month. It is well up in the western sky at sunset, and sets about 3 h later. Watch the motion of Mars relative to Castor and Pollux in the next few weeks.

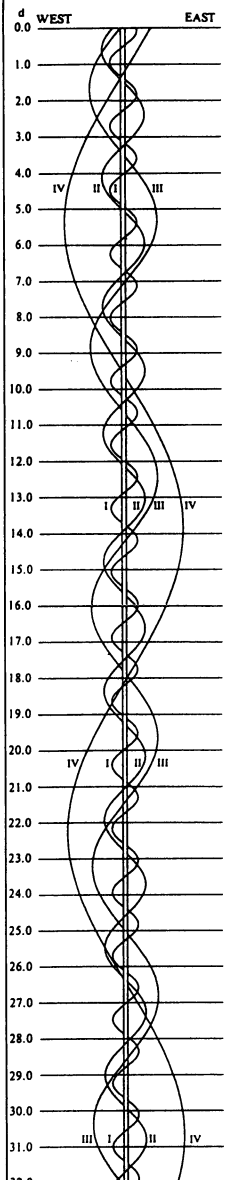
Jupiter is visible early in the month, low in the western sky, just after sunset. By the end of the month, however, it is too close to the Sun to be seen. In Taurus, it passes 5° north of Aldebaran on May 4. See also *Mercury* and *Venus* above.

Saturn, in Sagittarius, rises before midnight, and is low in the southern sky, past the meridian by sunrise.

Pluto is at opposition on May 4.

1989			MAY UNIVERSAL TIME	Min. of Algol
	d	h m		h m
Mon.	1	03	Mercury at greatest elong. E. (21°)	
Tue.	2			3 13
Wed.	3			
Thu.	4	05	Moon at perigee (359 785 km)	
		07	Pluto at opposition (28.688 AU, +13.6^{m})	
		12	Eta Aquarid meteors	
		17	Jupiter 5° N. of Aldebaran	
Fri.	5	11 46	● New Moon	0 02
Sat.	6	22	Mercury 3° S. of Moon	
Sun.	7	07	Jupiter 5° S. of Moon	20 51
Mon.	8			
Tue.	9	01	Mars 3° S. of Moon	
Wed.	10			17 40
Thu.	11			
Fri.	12	14 19	☽ First Quarter	
		23	Mercury stationary	
Sat.	13	03	Juno 0.4° S. of Moon; occultation	14 29
		06	Regulus 0.4° N. of Moon; occultation[1]	
			Venus at ascending node	
Sun.	14	17	Vesta stationary	
Mon.	15			
Tue.	16	07	Mercury 0.6° N. of Venus	11 18
		09	Moon at apogee (405 365 km)	
Wed.	17			
Thu.	18		Mercury at descending node	
Fri.	19	19	Venus 6° N. of Aldebaran	8 07
Sat.	20	18 16	○ Full Moon	
Sun.	21	13	Antares 0.4° N. of Moon; occultation[2]	
Mon.	22			4 56
Tue.	23	04	Venus 0.8° N. of Jupiter	
		12	Uranus 4° N. of Moon	
		22	Mercury in inferior conjunction	
Wed.	24	01	Neptune 5° N. of Moon	
		04	Saturn 4° N. of Moon	
Thu.	25			1 44
Fri.	26			
Sat.	27			22 33
Sun.	28	04 01	☾ Last Quarter	
Mon.	29		Mercury at aphelion	
Tue.	30	06	Pallas 0.7° S. of Moon; occultation	19 22
Wed.	31			

Config. of Jupiter's Satellites



[1]Visible in New Guinea, the S. Pacific
[2]Visible in Indonesia, Australia except the N., New Zealand, South Pacific

		Mercury	Venus	Mars	Jupiter	Saturn	Uranus	Neptune
RA	1	3^h49^m	5^h40^m	7^h29^m	5^h02^m	18^h55^m	18^h19^m	18^h51^m
	11	3^h52^m	6^h34^m	7^h55^m	5^h12^m	18^h53^m	18^h17^m	18^h50^m
	21	4^h23^m	7^h27^m	8^h21^m	5^h22^m	18^h50^m	18^h15^m	18^h49^m
Dec	1	+16°35'	+24°07'	+23°13'	+22°21'	-22°11'	-23°38'	-21°59'
	11	+16°02'	+24°19'	+22°08'	+22°35'	-22°15'	-23°39'	-22°00'
	21	+18°24'	+23°20'	+20°47'	+22°46'	-22°19'	-23°40'	-22°02'
Tran	1	11^h09^m	13^h03^m	14^h50^m	12^h22^m	2^h17^m	1^h41^m	2^h13^m
	11	10^h34^m	13^h17^m	14^h37^m	11^h53^m	1^h35^m	1^h00^m	1^h32^m
	21	10^h27^m	13^h31^m	14^h24^m	11^h24^m	0^h53^m	0^h19^m	0^h52^m
Mag	1	+3.3	-3.9	+1.8	-1.9	+0.2	+5.6	+7.9
	11	+1.4	-3.9	+1.8	-1.9	+0.1	+5.6	+7.9
	21	+0.3	-3.9	+1.8	-1.9	+0.1	+5.6	+7.9

The Moon – On June 1.0 UT, the age of the Moon is 26.5 d. The Sun's selenographic colongitude is 231.22° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on June 6 (6°) and minimum (east limb exposed) on June 20 (5°). The libration in latitude is maximum (north limb exposed) on June 16 (7°) and minimum (south limb exposed) on June 2 (7°) and June 30 (7°). The Moon reaches its greatest northern declination on June 4 (+28°) and its greatest southern declination on June 19 (−28°).

Mercury is at greatest elongation west (23°) on June 18, but it is also several degrees south of the ecliptic; at best, it stands barely 10° above the eastern horizon at sunrise. It passes 3° north of Aldebaran on June 22–23.

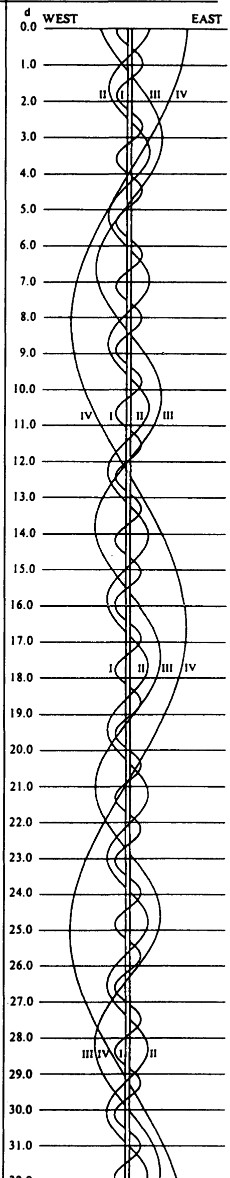
Venus moves from Taurus into Gemini during the month, passing 5° south of Pollux on June 23–24. It may be seen with difficulty, very low in the western sky below Castor and Pollux, just after sunset. The crescent Moon passes Venus and Mars on June 4–5 and 5–6.

Mars moves from Gemini into Cancer during the month, passing 5° south of Pollux on June 6–7, and through the Praesepe star cluster late in the month. It is low in the western sky at sunset, and sets about 3 h later. See also *Venus* above.

Jupiter is not visible this month; it is in conjunction on June 9.

Saturn, in Sagittarius, rises shortly after sunset, and is low in the southwestern sky at sunrise. It passes 0.3° south of Neptune on June 24, providing a good opportunity to look for the fainter planet.

Uranus is at opposition on June 24.

1989			JUNE UNIVERSAL TIME	Min. of Algol	Config. of Jupiter's Satellites
	d	h m		h m	
Thu.	1	05	Moon at perigee (364 388 km)		
Fri.	2			16 11	
Sat.	3	19 53	● New Moon		
Sun.	4				
Mon.	5	01	Venus 3° S. of Moon	13 00	
		02	Mercury stationary		
Tue.	6	18	Mars 1.6° S. of Moon		
Wed.	7	00	Mars 5° S. of Pollux		
Thu.	8			9 49	
Fri.	9	09	Jupiter in conjunction with Sun		
		14	Regulus 0.7° N. of Moon; occultation[1]		
Sat.	10				
Sun.	11	06 59	☽ First Quarter	6 37	
Mon.	12				
Tue.	13	02	Moon at apogee (404 461 km)		
Wed.	14		Mars at greatest hel. lat. N.	3 26	
Thu.	15				
Fri.	16		Venus at perihelion		
Sat.	17	21	Antares 0.4° N. of Moon; occultation[2]	0 15	
Sun.	18	12	Mercury at greatest elong. W. (23°)		
			Mercury at greatest hel. lat. S.		
Mon.	19	06 57	○ Full Moon	21 04	
		17	Uranus 4° N. of Moon		
Tue.	20	07	Neptune 5° N. of Moon		
		07	Saturn 4° N. of Moon		
Wed.	21	09 53	Summer solstice; summer begins		
Thu.	22			17 52	
Fri.	23	13	Mercury 3° N. of Aldebaran		
Sat.	24	09	Venus 5° S. of Pollux		
		16	Saturn 0.3° S. of Neptune		
		22	Uranus at opposition (18.330 AU, $+5.6^{m}$)		
Sun.	25			14 41	
Mon.	26	04	Vesta at opposition		
		09 09	☾ Last Quarter		
Tue.	27				
Wed.	28	04	Moon at perigee (368 959 km)	11 30	
Thu.	29				
Fri.	30				

[1]Visible in S. Africa, Madagascar, Antarctica

[2]Visible in the E. of South America, S. Atlantic, extreme S. Africa, Antarctica, extreme S.W. Australia

THE SKY FOR JULY 1989

		Mercury	Venus	Mars	Jupiter	Saturn	Uranus	Neptune
RA	1	5^h21^m	8^h19^m	8^h47^m	5^h32^m	18^h46^m	18^h14^m	18^h48^m
	11	6^h44^m	9^h09^m	9^h12^m	5^h41^m	18^h43^m	18^h12^m	18^h47^m
	21	8^h16^m	9^h56^m	9^h37^m	5^h51^m	18^h40^m	18^h10^m	18^h45^m
Dec	1	+21°50'	+21°13'	+19°13'	+22°54'	-22°23'	-23°41'	-22°03'
	11	+23°42'	+18°08'	+17°25'	+23°01'	-22°28'	-23°41'	-22°04'
	21	+21°32'	+14°15'	+15°27'	+23°05'	-22°32'	-23°42'	-22°06'
Tran	1	10^h46^m	13^h43^m	14^h10^m	10^h54^m	0^h10^m	23^h33^m	0^h12^m
	11	11^h31^m	13^h54^m	13^h56^m	10^h25^m	23^h24^m	22^h52^m	23^h27^m
	21	12^h23^m	14^h02^m	13^h41^m	9^h55^m	22^h41^m	22^h11^m	22^h47^m
Mag	1	-0.6	-3.9	+1.8	-1.9	0.0	+5.6	+7.9
	11	-1.5	-3.9	+1.8	-2.0	+0.1	+5.6	+7.9
	21	-1.8	-3.9	+1.8	-2.0	+0.1	+5.6	+7.9

M

The Moon – On July 1.0 UT, the age of the Moon is 27.2 d. The Sun's selenographic colongitude is 237.85° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on July 4 (5°) and July 31 (5°) and minimum (east limb exposed) on July 16 (5°). The libration in latitude is maximum (north limb exposed) on July 14 (7°) and minimum (south limb exposed) on July 27 (7°). The Moon reaches its greatest northern declination on July 2 (+28°) and July 29 (+28°) and its greatest southern declination on July 16 (−28°).

Mercury is not visible this month; it is in superior conjunction on July 18.

Venus may be seen with difficulty, very low in the western sky, just after sunset. It passes 0.5° north of Mars on July 11–12, and 1.2° north of Regulus on July 22–23.

Mars moves from Cancer into Leo, approaching Regulus, during the month. Early in the month, it may be seen with difficulty, very low in the west, just after sunset. Its eastern elongation is rapidly becoming smaller and less favourable, however, and by the end of the month, it is no longer visible.

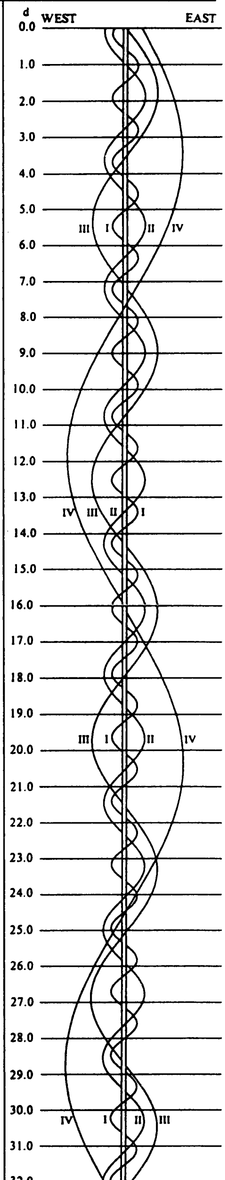
Jupiter moves from Taurus into Gemini during the month. Its visibility is rapidly improving. By the end of the month, it rises about 3 h before the Sun, and is low in the east at sunrise.

Saturn, in Sagittarius, rises at about sunset, and sets at about sunrise. It is at opposition on July 2

Neptune is at opposition on July 2.

1989			JULY UNIVERSAL TIME	Min. of Algol
	d	h m		h m
Sat.	1	21	Mercury 6° S. of Moon	8 18
		23	Jupiter 5°S. of Moon	
Sun.	2	13	Saturn at opposition (9.021 AU, 0.0^m)	
		17	Mercury 0.6° S. of Jupiter	
		23	Neptune at opposition (29.198 AU, $+7.9^m$)	
Mon.	3	04 59	● New Moon	
Tue.	4	12	Earth at aphelion (152 100 000 km)	5 07
Wed.	5	04	Venus 0.1° S. of Moon; occultation[1]	
		12	Mars 0.09° S. of Moon	
Thu.	6	23	Regulus 0.9° N. of Moon; occultation[2]	
Fri.	7		Mercury at ascending node	1 56
			Venus at greatest hel. lat. N.	
Sat.	8			
Sun.	9			22 44
Mon.	10	21	Moon at apogee (404 150 km)	
Tue.	11	00 19	☽ First Quarter	
Wed.	12	12	Venus 0.5° N. of Mars	19 33
			Mercury at perihelion	
Thu.	13			
Fri.	14			
Sat.	15	05	Antares 0.5° N. of Moon; occultation[3]	16 22
Sun.	16	23	Uranus 4° N. of Moon	
Mon.	17	12	Saturn 4° N. of Moon	
		14	Neptune 5° N. of Moon	
Tue.	18	08	Mercury in superior conjunction	13 10
		17 42	○ Full Moon	
Wed.	19			
Thu.	20			
Fri.	21			9 59
Sat.	22		Mercury at greatest hel. lat. N.	
			Mars at aphelion	
Sun.	23	07	Moon at perigee (368 431 km)	
		11	Venus 1.2° N. of Regulus	
Mon.	24			6 47
Tue.	25	13 31	☾ Last Quarter	
Wed.	26			
Thu.	27			3 36
Fri.	28	11	Pluto stationary	
		15	S. Delta Aquarid meteors	
Sat.	29	16	Jupiter 5° S. of Moon	
Sun.	30			0 24
Mon.	31			

Config. of Jupiter's Satellites



[1]Visible in E. Asia, Japan, W. and S. Pacific
[2]Visible in S. Pacific, extreme N. of New Zealand, Antarctica
[3]Visible in E. Australia, New Zealand, S. Pacific, Antarctica, S. of South America

		Mercury	Venus	Mars	Jupiter	Saturn	Uranus	Neptune
RA	1	9^h43^m	10^h47^m	10^h04^m	6^h01^m	18^h37^m	18^h09^m	18^h44^m
	11	10^h46^m	11^h31^m	10^h28^m	6^h09^m	18^h35^m	18^h07^m	18^h43^m
	21	11^h36^m	12^h14^m	10^h52^m	6^h17^m	18^h33^m	18^h07^m	18^h43^m
Dec	1	+15°20'	+9°16'	+13°05'	+23°06'	-22°36'	-23°42'	-22°07'
	11	+8°25'	+4°20'	+10°47'	+23°06'	-22°39'	-23°42'	-22°09'
	21	+1°36'	-0°48'	+8°22'	+23°04'	-22°41'	-23°42'	-22°10'
Tran	1	13^h06^m	14^h09^m	13^h25^m	9^h21^m	21^h55^m	21^h27^m	22^h02^m
	11	13^h29^m	14^h13^m	13^h09^m	8^h51^m	21^h14^m	20^h46^m	21^h22^m
	21	13^h39^m	14^h17^m	12^h54^m	8^h19^m	20^h33^m	20^h06^m	20^h42^m
Mag	1	-0.6	-3.9	+1.8	-2.0	+0.2	+5.6	+7.9
	11	-0.2	-3.9	+1.8	-2.0	+0.2	+5.6	+7.9
	21	+0.1	-4.0	+1.8	-2.1	+0.3	+5.6	+7.9

The Moon – On Aug. 1.0 UT, the age of the Moon is 28.8 d. The Sun's selenographic colongitude is 256.77° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on Aug. 26 (6°) and minimum (east limb exposed) on Aug. 13 (6°). The libration in latitude is maximum (north limb exposed) on Aug. 10 (7°) and minimum (south limb exposed) on Aug. 23 (7°). The Moon reaches its greatest northern declination on Aug. 25 (+28°) and its greatest southern declination on Aug. 12 (−28°). There is a total eclipse of the Moon on Aug. 17, visible in most parts of North America.

Mercury is at greatest elongation east (27°) on August 29 but, although the elongation is large, it is unfavourable for northern observers; the planet stands barely 13° above the western horizon at sunset. Mercury passes 0.8° north of Regulus on Aug. 4, and only 0.01° north of Mars on Aug. 5, but it is close to the Sun at the time, and the event occurs in daylight for observers in North America. The Moon passes just south of Mercury, Regulus and Mars on Aug. 2–3, and just south of Venus on the following night.

Venus may be seen with difficulty, very low in the western sky at sunset. See also *Mercury* above.

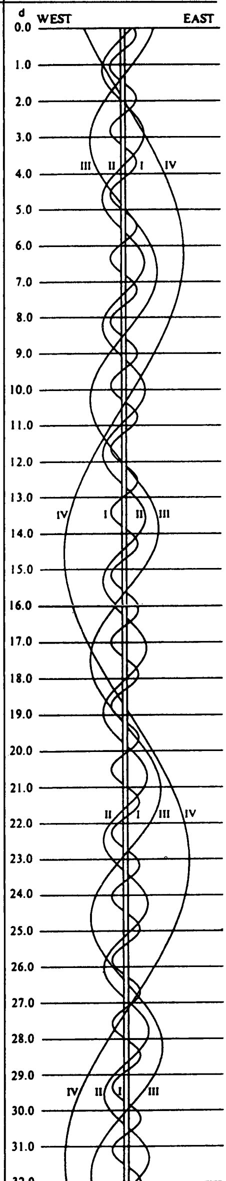
Mars, in Leo, is too faint, low and close to the Sun to be seen. It passes 0.7° north of Regulus on Aug. 2 and 0.01° south of Mercury on Aug. 5. See also *Mercury* above.

Jupiter, now in Gemini, is rapidly becoming prominent in the morning sky. By the end of the month, it rises shortly before midnight and is high in the southeastern sky at sunrise.

Saturn, in Sagittarius, is low in the southeastern sky at sunset, and sets after midnight.

1989			AUGUST UNIVERSAL TIME	Min. of Algol
	d	h m		h m
Tue.	1	16 06	● New Moon	21 13
Wed.	2	16	Mars 0.7° N. of Regulus	
Thu.	3	02	Mercury 1.6° N of Moon	
		07	Regulus 0.9° N. of Moon; occultation[1]	
		08	Mars 1.6° N. of Moon	
Fri.	4	13	Venus 3° N. of Moon	18 02
		16	Mercury 0.8° N. of Regulus	
Sat.	5	22	Mercury 0.01° N. of Mars	
Sun.	6			
Mon.	7	15	Moon at apogee (404 696 km)	14 50
		19	Vesta stationary	
Tue.	8			
Wed.	9	17 28	☽ First Quarter	
Thu.	10			11 39
Fri.	11	14	Antares 0.6° N. of Moon; occultation[2]	
Sat.	12	06	Perseid meteors	
Sun.	13	07	Uranus 4° N. of Moon	8 27
		18	Saturn 4° N. of Moon	
		22	Neptune 5° N. of Moon	
Mon.	14		Mercury at descending node	
Tue.	15			
Wed.	16			5 16
Thu.	17	03 07	○ Full Moon; Eclipse of Moon, p. 86	
Fri.	18	03	Pallas stationary	
Sat.	19	12	Moon at perigee (363 570 km)	2 04
Sun.	20			
Mon.	21			22 53
Tue.	22			
Wed.	23	18 40	☾ Last Quarter	
Thu.	24			19 41
Fri.	25		Mercury at aphelion	
Sat.	26	07	Jupiter 4° S. of Moon	
Sun.	27			16 30
Mon.	28			
Tue.	29	10	Mercury at greatest elong. E. (27°)	
Wed.	30			13 19
Thu.	31	05 44	● New Moon; Eclipse of Sun, p. 88	

Config. of Jupiter's Satellites



[1]Visible in S.E. Africa, Madagascar, S. Indian Ocean, Antarctica
[2]Visible in S. Africa, Antarctica, Tasmania, New Zealand, S.E. Australia

THE SKY FOR SEPTEMBER 1989

		Mercury	Venus	Mars	Jupiter	Saturn	Uranus	Neptune
RA	1	$12^{h}16^{m}$	$13^{h}01^{m}$	$11^{h}18^{m}$	$6^{h}26^{m}$	$18^{h}32^{m}$	$18^{h}06^{m}$	$18^{h}42^{m}$
	11	$12^{h}32^{m}$	$13^{h}44^{m}$	$11^{h}41^{m}$	$6^{h}32^{m}$	$18^{h}32^{m}$	$18^{h}06^{m}$	$18^{h}42^{m}$
	21	$12^{h}16^{m}$	$14^{h}28^{m}$	$12^{h}05^{m}$	$6^{h}37^{m}$	$18^{h}32^{m}$	$18^{h}06^{m}$	$18^{h}42^{m}$
Dec	1	-4°40'	-6°26'	+5°37'	+23°00'	-22°44'	-23°42'	-22°11'
	11	-7°47'	-11°22'	+3°02'	+22°57'	-22°45'	-23°42'	-22°11'
	21	-5°43'	-15°55'	+0°25'	+22°53'	-22°46'	-23°42'	-22°12'
Tran	1	$13^{h}35^{m}$	$14^{h}21^{m}$	$12^{h}36^{m}$	$7^{h}44^{m}$	$19^{h}48^{m}$	$19^{h}22^{m}$	$19^{h}58^{m}$
	11	$13^{h}10^{m}$	$14^{h}24^{m}$	$12^{h}20^{m}$	$7^{h}11^{m}$	$19^{h}09^{m}$	$18^{h}43^{m}$	$19^{h}18^{m}$
	21	$12^{h}13^{m}$	$14^{h}29^{m}$	$12^{h}04^{m}$	$6^{h}37^{m}$	$18^{h}30^{m}$	$18^{h}04^{m}$	$18^{h}39^{m}$
Mag	1	+0.3	-4.0	+1.8	-2.1	+0.3	+5.6	+7.9
	11	+0.9	-4.0	+1.7	-2.2	+0.4	+5.7	+7.9
	21	+3.4	-4.1	+1.7	-2.2	+0.4	+5.7	+7.9

M

The Moon – On Sept. 1.0 UT, the age of the Moon is 0.8 d. The Sun's selenographic colongitude is 275.47° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on Sept. 23 (7°) and minimum (east limb exposed) on Sept. 10 (7°). The libration in latitude is maximum (north limb exposed) on Sept. 6 (7°) and minimum (south limb exposed) on Sept. 19 (7°). The Moon reaches its greatest northern declination on Sept. 21 (+28°) and its greatest southern declination on Sept. 9 (−28°).

Mercury is not visible this month; it is in inferior conjunction on Sept. 24.

Venus may be seen with difficulty, very low in the southwestern sky, just after sunset. It passes 1.9° north of Spica on Sept. 6.

Mars is not visible this month; it is in conjunction on Sept. 29.

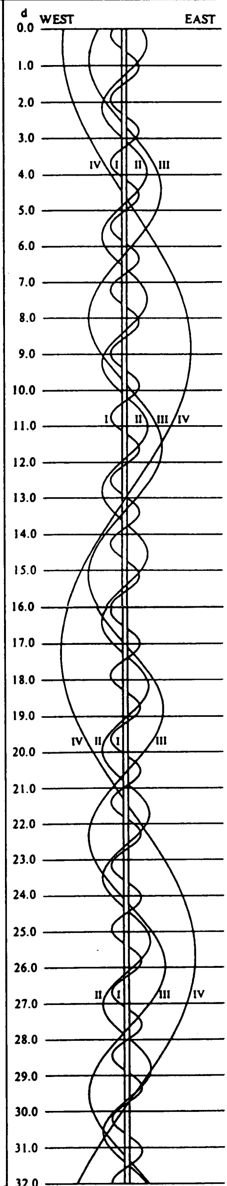
Jupiter, in Gemini, rises at about midnight, and is high in the southern sky at sunrise.

Saturn, in Sagittarius, is low in the southern sky at sunset, and sets about 5 h later. It is stationary on Sept. 11, after which it resumes direct or eastward motion relative to the stars.

Pluto is at perihelion on Sept. 5. This is the first perihelion since Pluto's discovery, and the next one will be in the year 2236.

1989			SEPTEMBER UNIVERSAL TIME	Min. of Algol
	d	h m		h m
Fri.	1		Venus at descending node	
			Uranus at extreme S. Dec. (since ~1905)	
Sat.	2	16	Mercury 0.6° N. of Moon; occultation[1]	10 07
Sun.	3	21	Venus 5° N. of Moon	
Mon.	4	08	Moon at apogee (405 733 km)	
Tue.	5		Pluto at perihelion (29.656 AU)	6 56
Wed.	6	13	Venus 1.9° N. of Spica	
Thur.	7	22	Antares 0.6° N. of Moon; occultation[2]	
Fri.	8	09 49	☽ First Quarter	3 44
Sat.	9	16	Uranus 4° N. of Moon	
Sun.	10	01	Uranus stationary	
		02	Saturn 4° N. of Moon	
		07	Neptune 5° N. of Moon	
Mon.	11	05	Saturn stationary	0 33
		14	Mercury stationary	
Tue.	12			
Wed.	13			21 21
Thu.	14		Mercury at greatest hel. lat. S.	
Fri.	15	11 51	○ Full Moon; Harvest Moon	
Sat.	16	15	Moon at perigee (359 045 km)	18 10
Sun.	17			
Mon.	18			
Tue.	19			14 59
Wed.	20			
Thu.	21	05	Neptune stationary	
Fri.	22	02 10	☾ Last Quarter	11 47
		19	Jupiter 4° S. of Moon	
Sat.	23	01 20	Autumnal equinox; autumn begins	
Sun.	24	22	Mercury in inferior conjunction	
Mon.	25			8 36
Tue.	26	21	Regulus 1.0° N. of Moon; occultation[3]	
Wed.	27			
Thu.	28			5 24
Fri.	29	19	Mars in conjunction with Sun	
		21 47	● New Moon	
Sat.	30	13	Pallas at opposition	

Config. of Jupiter's Satellites



[1]Visible in South America except the N., Antarctica
[2]Visible in S. Pacific, extreme S. of South America, Antarctica, S. Atlantic, extreme S. of Africa
[3]Visible from E. Australia, New Zealand, S. Pacific, Antarctica

THE SKY FOR OCTOBER 1989

		Mercury	Venus	Mars	Jupiter	Saturn	Uranus	Neptune
RA	1	11^h46^m	15^h14^m	12^h28^m	6^h42^m	18^h33^m	18^h07^m	18^h42^m
	11	12^h02^m	16^h00^m	12^h52^m	6^h45^m	18^h35^m	18^h08^m	18^h42^m
	21	12^h55^m	16^h48^m	13^h17^m	6^h47^m	18^h37^m	18^h09^m	18^h43^m
Dec	1	$+0°41'$	$-19°53'$	$-2°13'$	$+22°49'$	$-22°47'$	$-23°42'$	$-22°12'$
	11	$+1°36'$	$-23°06'$	$-4°51'$	$+22°47'$	$-22°47'$	$-23°42'$	$-22°12'$
	21	$-3°43'$	$-25°24'$	$-7°26'$	$+22°45'$	$-22°46'$	$-23°42'$	$-22°12'$
Tran	1	11^h05^m	14^h35^m	11^h49^m	6^h02^m	17^h51^m	17^h25^m	18^h00^m
	11	10^h43^m	14^h42^m	11^h33^m	5^h26^m	17^h14^m	16^h47^m	17^h21^m
	21	10^h58^m	14^h50^m	11^h18^m	4^h48^m	16^h37^m	16^h09^m	16^h42^m
Mag	1	+2.1	-4.1	+1.7	-2.3	+0.5	+5.7	+7.9
	11	-0.5	-4.2	+1.7	-2.3	+0.5	+5.7	+7.9
	21	-1.0	-4.3	+1.7	-2.4	+0.5	+5.7	+8.0

The Moon – On Oct. 1.0 UT, the age of the Moon is 1.1 d. The Sun's selenographic colongitude is 281.52° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on Oct. 21 (8°) and minimum (east limb exposed) on Oct. 9 (7°). The libration in latitude is maximum (north limb exposed) on Oct. 3 (7°) and Oct. 31 (7°) and minimum (south limb exposed) on Oct. 16 (7°). The Moon reaches its greatest northern declination on Oct. 19 (+28°) and its greatest southern declination on Oct. 6 (−28°).

Mercury is at greatest elongation west (18°) on Oct. 10 and, although the elongation is relatively small, it is favourable for northern observers. The planet rises shortly before the Sun, and stands about 16° above the southeastern horizon at sunrise.

Venus may be seen with difficulty, very low in the southwestern sky, just after sunset. It passes 1.8° north of Antares on Oct. 16–17.

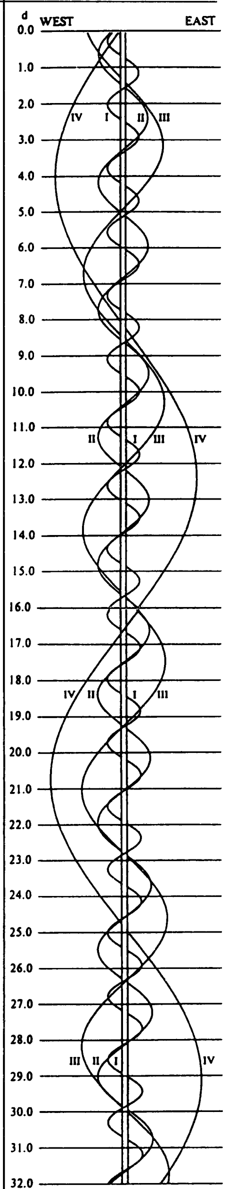
Mars is not visible this month.

Jupiter, in Gemini, rises before midnight, and is high in the southern sky by sunrise. On Oct. 29, it is stationary, and then begins retrograde or westward motion relative to the stars.

Saturn, in Sagittarius, is low in the southern sky at sunset, and sets about 4 h later.

1989			OCTOBER UNIVERSAL TIME	Min. of Algol
	d	h m		h m
Sun.	1	20	Moon at apogee (406 528 km)	2 13
Mon.	2		Saturn at extreme S. Dec. (since 1959)	
Tue.	3	06	Mercury stationary	23 02
			Mercury at ascending node	
Wed.	4	01	Venus 3° N. of Moon	
Thu.	5	05	Antares 0.4° N. of Moon; occultation[1]	
Fri.	6		Venus at aphelion	19 50
Sat.	7	00	Uranus 4° N. of Moon	
		11	Saturn 4° N. of Moon	
		15	Neptune 5° N. of Moon	
		16	Vesta 0.5° N. of Moon; occultation	
Sun.	8	00 52	☽ First Quarter	
			Mercury at perihelion	
Mon.	9	13	Juno in conjunction with Sun	16 39
Tue.	10	12	Mercury at greatest elong. W. (18°)	
Wed.	11			
Thu.	12			13 28
Fri.	13			
Sat.	14	20 32	○ Full Moon; Hunters' Moon	
Sun.	15	01	Moon at perigee (356 713 km)	10 16
Mon.	16			
Tue.	17	01	Venus 1.8° N. of Antares	
Wed.	18		Mercury at greatest hel. lat. N.	7 05
Thu.	19			
Fri.	20	05	Jupiter 4° S. of Moon	
Sat.	21	10	Orionid meteors	3 54
		13 19	☾ Last Quarter	
Sun.	22			
Mon.	23			
Tue.	24	02	Regulus 1.1° N. of Moon; occultation[2]	0 43
Wed.	25	23	Mercury 4° N. of Spica	
Thu.	26			21 32
Fri.	27			
Sat.	28	22	Moon at apogee (406 638 km)	
			Venus at greatest hel. lat. S.	
Sun.	29	01	Jupiter stationary	18 20
		15 27	● New Moon	
Mon.	30			
Tue.	31			

Config. of Jupiter's Satellites



[1]Visible in W. Java, W. and S. Australia, New Zealand, part of Antarctica
[2]Visible in S.E. Africa, Antarctica

THE SKY FOR NOVEMBER 1989

		Mercury	Venus	Mars	Jupiter	Saturn	Uranus	Neptune
RA	1	14^h02^m	17^h40^m	13^h44^m	6^h47^m	18^h40^m	18^h11^m	18^h43^m
	11	15^h05^m	18^h25^m	14^h10^m	6^h46^m	18^h44^m	18^h13^m	18^h45^m
	21	16^h09^m	19^h07^m	14^h36^m	6^h43^m	18^h48^m	18^h15^m	18^h46^m
Dec	1	-11°17'	-26°45'	-10°12'	+22°46'	-22°44'	-23°41'	-22°12'
	11	-17°25'	-26°52'	-12°36'	+22°48'	-22°41'	-23°41'	-22°11'
	21	-22°07'	-25°59'	-14°52'	+22°52'	-22°38'	-23°40'	-22°10'
Tran	1	11^h22^m	14^h59^m	11^h03^m	4^h05^m	15^h57^m	15^h27^m	16^h00^m
	11	11^h46^m	15^h05^m	10^h49^m	3^h25^m	15^h21^m	14^h50^m	15^h22^m
	21	12^h11^m	15^h07^m	10^h36^m	2^h43^m	14^h46^m	14^h13^m	14^h44^m
Mag	1	-1.1	-4.4	+1.7	-2.5	+0.5	+5.7	+8.0
	11	-1.3	-4.4	+1.7	-2.5	+0.6	+5.8	+8.0
	21	-0.9	-4.5	+1.7	-2.6	+0.6	+5.8	+8.0

The Moon – On Nov. 1.0 UT, the age of the Moon is 2.4 d. The Sun's selenographic colongitude is 299.28° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on Nov. 18 (8°) and minimum (east limb exposed) on Nov. 6 (7°). The libration in latitude is maximum (north limb exposed) on Nov. 27 (7°) and minimum (south limb exposed) on Nov. 13 (7°). The Moon reaches its greatest northern declination on Nov. 15 (+27°) and its greatest southern declination on Nov. 2 (−28°) and Nov. 29 (−27°).

Mercury is not visible this month; it is in superior conjunction on Nov. 10.

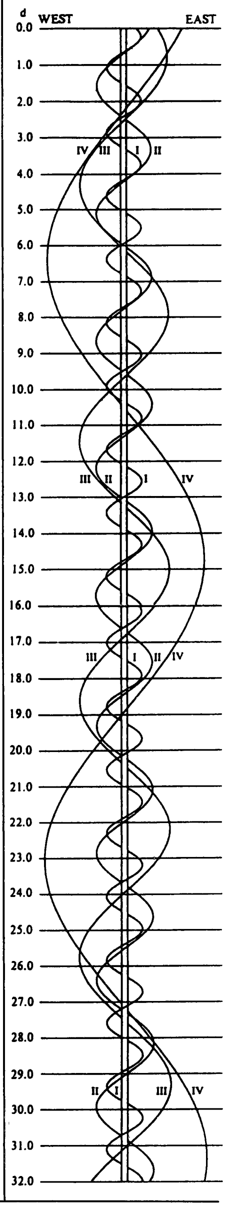
Venus is at greatest elongation east (47°) on Nov. 8, but this is not a very favourable elongation. The planet stands only about 15° above the southwestern horizon at sunset, and sets about 3 h later. It passes 3° south of Uranus on Nov. 7–8 and 4° south of Neptune and Saturn on Nov. 15, thus providing a motivation to look for both Uranus and Neptune this month. Note that the Moon passes Antares, Venus, Uranus, Saturn, Neptune and Vesta in the first four days of the month.

Mars moves from Virgo into Libra and, by the end of the month, is visible (faintly) in the morning sky, very low in southeastern sky, just before sunrise.

Jupiter, in Gemini below Castor and Pollux, rises in the early evening and is still well up in the western sky at sunrise.

Saturn, in Sagittarius, is very low in the southwestern sky at sunset, and sets about 3 h later. It passes 0.5° south of Neptune on Nov. 12 and is 4° north of Venus on Nov. 15.

Uranus and *Neptune*: see *Venus* and *Saturn* above. *Pluto* is in conjunction on Nov. 7.

1989			NOVEMBER UNIVERSAL TIME	Min. of Algol	Config. of Jupiter's Satellites
	d	h m		h m	
Wed.	1	11	Antares 0.2° N. of Moon; occultation[1]	15 09	
Thu.	2	11	S. Taurid meteors		
		22	Venus 0.7° N. of Moon; occultation[2]		
Fri.	3	00	Ceres stationary		
		08	Uranus 4° N. of Moon		
		21	Saturn 4° N. of Moon		
		22	Neptune 4° N. of Moon		
Sat.	4	20	Vesta 1.0° S. of Moon; occultation	11 58	
Sun.	5				
Mon.	6	14 11	☽ First Quarter		
Tue.	7	13	Pluto in conjunction with Sun	8 47	
Wed.	8	02	Venus 3° S. of Uranus		
		17	Venus at greatest elong. E. (47°)		
Thu.	9				
Fri.	10	19	Mercury in superior conjunction	5 36	
			Mercury at descending node		
Sat.	11				
Sun.	12	13	Moon at perigee (357 468 km)		
		21	Saturn 0.5° S. of Neptune		
Mon.	13	05 51	○ Full Moon	2 24	
Tue.	14				
Wed.	15	15	Venus 4° S. of Neptune	23 13	
		19	Venus 4° S. of Saturn		
Thu.	16	14	Jupiter 3° S. of Moon		
Fri.	17	16	Leonid meteors		
Sat.	18			20 02	
Sun.	19				
Mon.	20	04 44	☾ Last Quarter		
Tue.	21		Mercury at aphelion	16 51	
Wed.	22				
Thu.	23	23	Pallas stationary		
Fri.	24			13 40	
Sat.	25	04	Moon at apogee (406 135 km)		
Sun.	26	19	Mars 6° N. of Moon		
Mon.	27			10 29	
Tue.	28	09 41	● New Moon		
Wed.	29				
Thu.	30	16	Uranus 3° N. of Moon	7 18	

[1]Visible in S. Africa, S. Madagascar, S. Indian Ocean, E. Java, W. Australia
[2]Visible in New Zealand, Antarctica, extreme S. of South America

THE SKY FOR DECEMBER 1989

		Mercury	Venus	Mars	Jupiter	Saturn	Uranus	Neptune
RA	1	17^h16^m	19^h44^m	15^h03^m	6^h40^m	18^h52^m	18^h17^m	18^h47^m
	11	18^h23^m	20^h13^m	15^h31^m	6^h35^m	18^h57^m	18^h20^m	18^h49^m
	21	19^h23^m	20^h30^m	15^h59^m	6^h29^m	19^h02^m	18^h22^m	18^h50^m
Dec	1	-24°59'	-24°18'	-16°57'	+22°57'	-22°34'	-23°39'	-22°09'
	11	-25°39'	-22°02'	-18°50'	+23°02'	-22°28'	-23°38'	-22°07'
	21	-23°56'	-19°33'	-20°28'	+23°08'	-22°22'	-23°37'	-22°05'
Tran	1	12^h38^m	15^h04^m	10^h23^m	2^h00^m	14^h11^m	13^h36^m	14^h06^m
	11	13^h05^m	14^h53^m	10^h12^m	1^h16^m	13^h36^m	12^h59^m	13^h28^m
	21	13^h25^m	14^h30^m	10^h01^m	0^h31^m	13^h02^m	12^h22^m	12^h50^m
Mag	1	-0.6	-4.6	+1.6	-2.7	+0.5	+5.8	+8.0
	11	-0.6	-4.7	+1.6	-2.7	+0.5	+5.8	+8.0
	21	-0.5	-4.7	+1.6	-2.7	+0.5	+5.8	+8.0

The Moon – On Dec. 1.0 UT, the age of the Moon is 2.6 d. The Sun's selenographic colongitude is 304.36° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on Dec. 16 (7°) and minimum (east limb exposed) on Dec. 4 (6°) and Dec. 31 (5°). The libration in latitude is maximum (north limb exposed) on Dec. 24 (7°) and minimum (south limb exposed) on Dec. 10 (7°). The Moon reaches its greatest northern declination on Dec. 12 (+27°) and its greatest southern declination on Dec. 27 (−27°).

Mercury is at greatest elongation east (20°) on Dec. 23; it then stands about 14° above the southwestern horizon at sunset, and sets shortly afterward. It passes 2° south of Uranus on Dec. 10, 3° south of Neptune on Dec. 14–15, and 2° south of Saturn on Dec. 16–17. Mercury is the brighter of the two.

Venus is low in the southwestern sky at sunset, and sets about 3 h later. It is at greatest brilliancy (-4.7^m) on Dec. 14.

Mars moves from Libra through Scorpius (passing 5° north of Antares on Dec. 30–31) into Ophiuchus during the month. It rises about 2 h before the Sun, and is very low in the southeastern sky at sunrise.

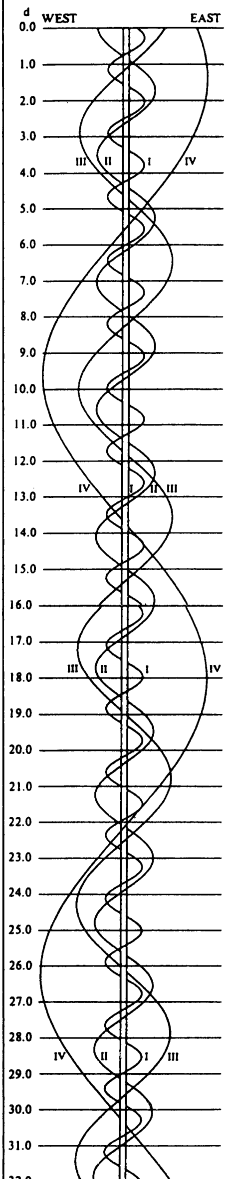
Jupiter, in Gemini, rises shortly after sunset, and is setting by sunrise; it is at opposition on Dec. 27.

Saturn, in Sagittarius, is rapidly approaching conjunction by the end of the month, and is no longer visible. See also *Mercury* above.

Uranus and *Neptune*: see *Mercury* above; *Uranus* is in conjunction on Dec. 27.

1989			DECEMBER UNIVERSAL TIME	Min. of Algol
	d	h m		h m
Fri.	1	05	Neptune 4° N. of Moon	
		07	Saturn 3° N. of Moon	
Sat.	2	08	Venus 0.8° S. of Moon; occultation[1]	
Sun.	3			4 07
Mon.	4			
Tue.	5			
Wed.	6	01 26	☽ First Quarter	0 56
Thu.	7			
Fri.	8			21 45
Sat.	9			
Sun.	10	13	Mercury 2° S. of Uranus	
		23	Moon at perigee (361 309 km)	
Mon.	11		Mercury at greatest hel. lat. S.	18 34
Tue.	12	16 30	○ Full Moon	
Wed.	13	20	Jupiter 3° S. of Moon	
Thu.	14	06	Geminid meteors	15 23
		09	Venus at greatest brilliancy (-4.7^m)	
Fri.	15	04	Mercury 3° S. of Neptune	
Sat.	16	22	Mercury 2° S. of Saturn	
Sun.	17			12 13
Mon.	18			
Tue.	19	23 54	☾ Last Quarter	
Wed.	20	07	Ceres at opposition	9 02
Thu.	21	21 22	Winter solstice; winter beings	
Fri.	22	12	Ursid meteors	
		19	Moon at apogee (405 219 km)	
Sat.	23	08	Mercury at greatest elong. E. (20°)	5 51
			Venus at ascending node	
Sun.	24			
Mon.	25	17	Mars 5° N. of Moon	
Tue.	26	00	Antares 0.2° N. of Moon; occultation[2]	2 40
Wed.	27	06	Uranus in conjunction with Sun	
		14	Jupiter at opposition (4.166 AU, -2.7^m)	
		23	Venus stationary	
Thu.	28	03 20	● New Moon	23 29
Fri.	29	15	Mercury 1.7° N. of Moon	
			Mars at descending node	
Sat.	30	10	Venus 2° N. of Moon	
		16	Mercury stationary	
		23	Mars 5° N. of Antares	
			Mercury at ascending node	
Sun.	31			20 18

Config. of Jupiter's Satellites



[1]Visible in Asia except extreme W., Japan
[2]Visible in East Indies, Australasia, S. Pacific

SUN
EPHEMERIS

Date 0^h UT	Apparent α (1989)	δ	UT Transit at Greenwich	Orientation P	B_0	L_0
Jan. 1	$18^h45.9^m$	$-23°01'$	$12^h03^m38^s$	+2.0°	-3.0°	107.6°
6	$19^h07.9^m$	$-22°32'$	$12^h05^m55^s$	+0.4°	-3.6°	41.8°
11	$19^h29.7^m$	$-21°51'$	$12^h08^m00^s$	-2.8°	-4.2°	335.9°
16	$19^h51.3^m$	$-20°59'$	$12^h09^m50^s$	-5.2°	-4.7°	270.1°
21	$20^h12.6^m$	$-19°57'$	$12^h11^m23^s$	-7.5°	-5.1°	204.2°
26	$20^h33.5^m$	$-18°46'$	$12^h12^m36^s$	-9.7°	-5.6°	138.4°
31	$20^h54.2^m$	$-17°27'$	$12^h13^m29^s$	-11.8°	-6.0°	72.6°
Feb. 5	$21^h14.5^m$	$-16°00'$	$12^h14^m03^s$	-13.8°	-6.3°	6.7°
10	$21^h34.5^m$	$-14°26'$	$12^h14^m16^s$	-15.7°	-6.6°	300.9°
15	$21^h54.1^m$	$-12°45'$	$12^h14^m10^s$	-17.4°	-6.8°	235.1°
20	$22^h13.4^m$	$-11°00'$	$12^h13^m45^s$	-19.0°	-7.0°	169.2°
25	$22^h32.5^m$	$-9°11'$	$12^h13^m04^s$	-20.5°	-7.1°	103.4°
Mar. 2	$22^h51.3^m$	$-7°18'$	$12^h12^m09^s$	-21.8°	-7.2°	37.5°
7	$23^h09.9^m$	$-5°22'$	$12^h11^m02^s$	-23.0°	-7.2°	331.6°
12	$23^h28.4^m$	$-3°25'$	$12^h09^m46^s$	-23.9°	-7.2°	265.8°
17	$23^h46.7^m$	$-1°26'$	$12^h08^m22^s$	-24.8°	-7.1°	199.9°
22	$0^h04.9^m$	$+0°32'$	$12^h06^m53^s$	-25.4°	-7.0°	133.9°
27	$0^h23.1^m$	$+2°30'$	$12^h05^m22^s$	-25.9°	-6.8°	68.0°
Apr. 1	$0^h41.3^m$	$+4°27'$	$12^h03^m51^s$	-26.2°	-6.5°	2.0°
6	$0^h59.6^m$	$+6°22'$	$12^h02^m24^s$	-26.3°	-6.2°	296.1°
11	$1^h17.9^m$	$+8°14'$	$12^h01^m02^s$	-26.2°	-5.9°	230.1°
16	$1^h36.4^m$	$+10°02'$	$11^h59^m47^s$	-26.0°	-5.5°	164.1°
21	$1^h55.0^m$	$+11°47'$	$11^h58^m40^s$	-25.6°	-5.1°	98.0°
26	$2^h13.7^m$	$+13°26'$	$11^h57^m45^s$	-25.0°	-4.6°	32.0°
May 1	$2^h32.7^m$	$+15°00'$	$11^h57^m03^s$	-24.2°	-4.2°	325.9°
6	$2^h51.9^m$	$+16°28'$	$11^h56^m34^s$	-23.2°	-3.6°	259.8°
11	$3^h11.4^m$	$+17°49'$	$11^h56^m19^s$	-22.0°	-3.1°	193.7°
16	$3^h31.0^m$	$+19°03'$	$11^h56^m19^s$	-20.7°	-2.5°	127.6°
21	$3^h51.0^m$	$+20°08'$	$11^h56^m32^s$	-19.2°	-2.0°	61.4°
26	$4^h11.1^m$	$+21°05'$	$11^h56^m58^s$	-17.6°	-1.4°	355.3°
31	$4^h31.4^m$	$+21°53'$	$11^h57^m37^s$	-15.8°	-0.8°	289.1°
June 5	$4^h51.9^m$	$+22°31'$	$11^h58^m26^s$	-13.9°	-0.2°	223.0°
10	$5^h12.6^m$	$+23°00'$	$11^h59^m23^s$	-11.9°	+0.4°	156.8°
15	$5^h33.3^m$	$+23°18'$	$12^h00^m25^s$	-9.8°	+1.0°	90.6°
20	$5^h54.1^m$	$+23°26'$	$12^h01^m30^s$	-7.6°	+1.6°	24.4°
25	$6^h14.9^m$	$+23°24'$	$12^h02^m34^s$	-5.4°	+2.2°	318.2°
30	$6^h35.7^m$	$+23°11'$	$12^h03^m36^s$	-3.2°	+2.8°	252.1°

Date 0^h UT	Apparent α (1989)	δ	UT Transit at Greenwich	Orientation P	B_0	L_0
July 5	6^{h}56.3^m	+22°49'	12^{h}04^{m}32^s	−0.9°	+3.3°	185.9°
10	7^{h}16.8^m	+22°16'	12^{h}05^{m}19^s	+1.4°	+3.8°	119.7°
15	7^{h}37.2^m	+21°34'	12^{h}05^{m}55^s	+3.6°	+4.3°	53.5°
20	7^{h}57.3^m	+20°43'	12^{h}06^{m}19^s	+5.8°	+4.8°	347.4°
25	8^{h}17.2^m	+19°43'	12^{h}06^{m}28^s	+8.0°	+5.2°	281.2°
30	8^{h}36.8^m	+18°34'	12^{h}06^{m}23^s	+10.0°	+5.6°	215.1°
Aug. 4	8^{h}56.3^m	+17°18'	12^{h}06^{m}03^s	+12.0°	+6.0°	149.0°
9	9^{h}15.4^m	+15°55'	12^{h}05^{m}28^s	+13.9°	+6.3°	82.8°
14	9^{h}34.3^m	+14°26'	12^{h}04^{m}38^s	+15.7°	+6.6°	16.8°
19	9^{h}53.0^m	+12°51'	12^{h}03^{m}34^s	+17.3°	+6.8°	310.7°
24	10^{h}11.5^m	+11°11'	12^{h}02^{m}19^s	+18.9°	+7.0°	244.6°
29	10^{h}29.8^m	+9°27'	12^{h}00^{m}54^s	+20.3°	+7.1°	178.5°
Sept. 3	10^{h}47.9^m	+7°38'	11^{h}59^{m}20^s	+21.6°	+7.2°	112.5°
8	11^{h}06.0^m	+5°47'	11^{h}57^{m}39^s	+22.7°	+7.2°	46.4°
13	11^{h}23.9^m	+3°53'	11^{h}55^{m}54^s	+23.7°	+7.2°	340.4°
18	11^{h}41.9^m	+1°58'	11^{h}54^{m}07^s	+24.6°	+7.1°	274.4°
23	11^{h}59.8^m	+0°01'	11^{h}52^{m}20^s	+25.2°	+7.0°	208.4°
28	12^{h}17.8^m	−1°56'	11^{h}50^{m}38^s	+25.8°	+6.8°	142.4°
Oct. 3	12^{h}35.9^m	−3°52'	11^{h}49^{m}01^s	+26.1°	+6.6°	76.4°
8	12^{h}54.1^m	−5°47'	11^{h}47^{m}33^s	+26.3°	+6.3°	10.5°
13	13^{h}12.5^m	−7°41'	11^{h}46^{m}14^s	+26.3°	+6.0°	304.5°
18	13^{h}31.1^m	−9°32'	11^{h}45^{m}09^s	+26.1°	+5.6°	238.6°
23	13^{h}50.0^m	−11°19'	11^{h}44^{m}20^s	+25.7°	+5.2°	172.6°
28	14^{h}09.1^m	−13°02'	11^{h}43^{m}48^s	+25.1°	+4.8°	106.7°
Nov. 2	14^{h}28.6^m	−14°40'	11^{h}43^{m}35^s	+24.3°	+4.3°	40.7°
7	14^{h}48.4^m	−16°12'	11^{h}43^{m}42^s	+23.4°	+3.7°	334.8°
12	15^{h}08.5^m	−17°38'	11^{h}44^{m}10^s	+22.2°	+3.2°	268.9°
17	15^{h}29.0^m	−18°56'	11^{h}44^{m}59^s	+20.8°	+2.6°	203.0°
22	15^{h}49.9^m	−20°05'	11^{h}46^{m}09^s	+19.3°	+2.0°	137.1°
27	16^{h}11.0^m	−21°05'	11^{h}47^{m}39^s	+17.6°	+1.4°	71.2°
Dec. 2	16^{h}32.5^m	−21°55'	11^{h}49^{m}27^s	+15.7°	+0.7°	5.3°
7	16^{h}54.3^m	−22°35'	11^{h}51^{m}30^s	+13.7°	+0.1°	299.4°
12	17^{h}16.2^m	−23°04'	11^{h}53^{m}45^s	+11.6°	−0.5°	233.5°
17	17^{h}38.3^m	−23°21'	11^{h}56^{m}08^s	+ 9.3°	−1.2°	167.6°
22	18^{h}00.5^m	−23°27'	11^{h}58^{m}37^s	+ 7.0°	−1.8°	101.8°
27	18^{h}22.7^m	−23°20'	12^{h}01^{m}06^s	+ 4.6°	−2.4°	35.9°
32	18^{h}44.8^m	−23°03'	12^{h}03^{m}32^s	+ 2.1°	−3.0°	330.0°

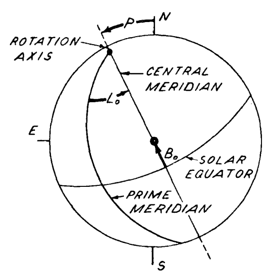
SUNDIAL CORRECTION

The "Transit at Greenwich" time on the previous two pages may be used to calculate the sundial correction at the observer's position. e.g. To find the correction at Winnipeg on August 16, 1989: At Greenwich the Sun transits at $12^h04^m38^s$ on August 14 and at $12^h03^m34^s$ on August 19. Thus, to the nearest minute, on August 16 at both Greenwich and Winnipeg the Sun will transit at 12^h04^m mean solar time, or 12^h33^m CST, since Winnipeg has a longitude correction of $+29^m$ (see page 62). Thus a 4^m correction must be added to the reading of a simple sundial to obtain mean solar time.

A figure accurate to a second or two can be obtained by interpolating for longitude. The interpolated transit time at Greenwich for August 16 is $12^h04^m12^s$, the daily change in the time being $-12\overset{s}{.}8$. Adjusting this for the longitude of Winnipeg: $12^h04^m12^s - (12\overset{s}{.}8 \times 6^h29^m \div 24^h) = 12^h04^m09^s$. Thus the sundial correction is 4^m09^s. To find the standard time of the Sun's transit to the nearest second or two, the observer's longitude must be known to 10″ or better. e.g. Suppose an observer in Winnipeg is at longitude 97°13′50″ W, or $6^h28^m55^s$ W of Greenwich. The time of transit will be $12^h04^m09^s + 28^m55^s = 12^h33^m04^s$ CST ($13^h33^m04^s$ CDT).

ORIENTATION OF THE SUN

The tables on the previous two pages give three angles which specify the orientation of the Sun. P is the position angle of the axis of rotation, measured eastward from the north point on the disk. B_0 is the heliographic latitude of the centre of the disk, and L_0 is the heliographic longitude of the centre of the disk, from Carrington's solar meridian, measured in the direction of rotation (see diagram, and also note the table below). The rotation period of the Sun depends on latitude. The *sidereal* period of rotation at the equator is 25.38d.



SOLAR ROTATION (SYNODIC)

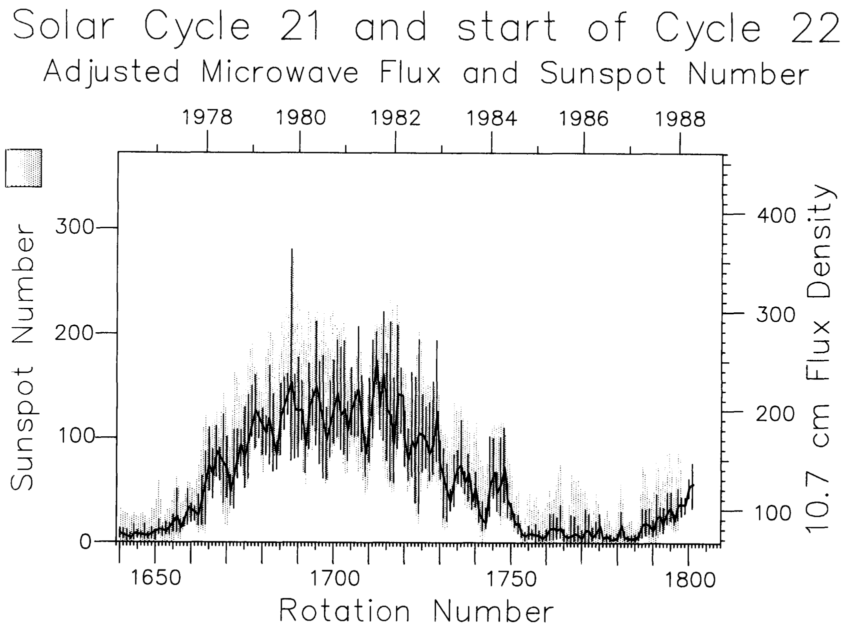
DATES OF COMMENCEMENT (UT, $L_0 = 0$)
OF NUMBERED SYNODIC ROTATIONS

No.	Commences	No.	Commences	No.	Commences
1810 ('88)	Dec. 12.84	1815	Apr. 28.42	1820	Sept. 11.52
1811 ('89)	Jan. 9.17	1816	May 25.64	1821	Oct. 8.79
1812	Feb. 5.51	1817	June 21.85	1822	Nov. 5.09
1813	Mar. 4.85	1818	July 19.05	1823	Dec. 2.40
1814	Apr. 1.16	1819	Aug. 15.27	1824	Dec. 29.73

SOLAR ACTIVITY

BY V. GAIZAUSKAS AND J. W. DEAN

The graph below depicts the pulse-beat of solar activity throughout cycle 21. At each rotation of the Sun, a vertical bar joins the maximum and minimum values of daily solar microwave flux measured for that rotation at a wavelength of 10.7 cm. This display emphasizes the sporadic nature of solar activity. The length of each bar and its height above the background ("quiet-Sun") level are both highly variable from one rotation to the next. The full curve through the vertical bars traces the mean microwave flux for each rotation. Microwave and sunspot variability are compared in the same display. The stippled overlay outlines the area between maximum and minimum values per rotation of the daily International Sunspot Number. The vertical scales of 10.7 cm flux (right) and of sunspot number (left) are adjusted so that zero sunspot number corresponds to the microwave flux density at sunspot minimum (66 solar flux units*).



The microwave flux and sunspot number follow the same trends but they do not correspond exactly because their physical origins, while related, are different. The microwave flux at times of very high sunspot activity can drop down to a low level which is almost the same for several rotations in succession (e.g. around rotation 1700 in mid-1980). The quasi-oscillatory behavior in the mean microwave emission results from the uneven distribution of active regions with solar longitude. Large active regions which are rich in microwave emission tend to be rejuvenated near one or just a few longitudes while intermediate zones tend to be free of activity for many rotations of the Sun.

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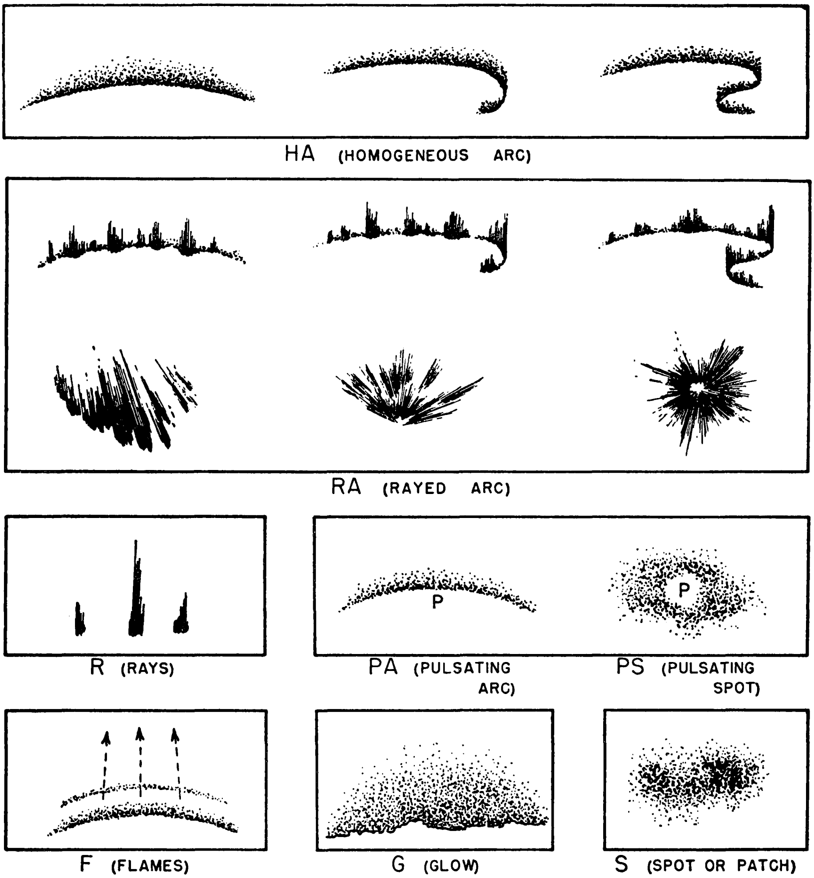
* 1 solar flux unit = 10^{-22} W m^{-2} Hz^{-1}

The minimum between cycles 21 and 22, determined from averages of microwave flux or sunspot number smoothed over many rotations of the Sun, occurred in September 1986 (rotation 1779). Activity has been rising substantially faster in Cycle 22 than in Cycle 21 and has led to speculation that the new cycle may compete with Cycle 19 (maximum at 1957.9) for reaching the highest peak of solar activity in this century.

High levels of solar activity in mid-March and mid-April 1988 were accompanied by strong auroral displays which will become increasingly frequent during 1988–89. Aurorae ("Northern Lights") are caused by the precipitation into the ionosphere of energetic charged particles from a vast reservoir enveloping Earth, the *magnetosphere*. Seen from above (e.g. from the Canadian ISIS satellites) aurorae are concentrated in elliptical bands called *auroral ovals* that ring Earth's magnetic poles. When the Sun is calm, the ovals shrink to nearly circular rings centred close to the geomagnetic poles. As the Sun grows more active, the ovals advance toward lower latitudes (e.g. in Canada to Churchill, Man. and to Yellowknife, N.W.T.) and become more eccentric with respect to the geomagnetic poles. During periods of very intense solar activity, the ovals shift closer still towards the Equator (e.g. down to the southern United States for the northern oval). For an observer at the ground, the shifting patterns of the aurora over the night sky reflect the changes in the magnetic and electric fields along the paths of electrons streaming toward Earth.

☉ The magnetospheric reservoir of particles is created by a complicated interaction between Earth's magnetic field and the *solar wind*, a magnetized plasma that flows continuously from the Sun even in the absence of solar activity. The solar wind has considerable structure; the highest speed streams originate in *coronal holes*, extended regions of low density and temperature in the solar corona. Near sunspot maximum, coronal holes are nearly absent except in small areas near the Sun's poles. But during the declining phase of the cycle, holes form rapidly and live longer (e.g. up to 10 solar rotations). They are firmly associated with recurrent 27-day geomagnetic disturbances. The normal balance between the solar wind and the magnetosphere can be suddenly upset (e.g. by changes in the magnitude and direction of the magnetic field 'blown' towards Earth by the solar wind, by changes in the wind's speed, or by a major solar flare) and can lead to an *auroral sub-storm*. But universal agreement is still lacking on the exact mechanism which triggers sub-storms.

The atoms and molecules, mostly those of oxygen and nitrogen, that radiate the shimmering light of the aurora are terrestrial in origin. They become luminous at heights between 100 and 400 km through collisions with energetic particles that have leaked out of the magnetosphere during a sub-storm. A faint auroral display may not exceed the brightness threshold of colour perception for vision; it will be sensed as white. Most aurorae appear green or blue-green with occasional faint patches of pink or red. The green colour is due to excited atoms of oxygen radiating at a wavelength of 558 nm; the blue is produced by ionized nitrogen molecules radiating in a group of spectral bands between 391 and 470 nm. The green and blue emissions are concentrated near an altitude of 110 km. Rare, all-red aurorae have been measured to occur between 200 and 400 km; the red colour is due to the 630 and 636 nm lines of atomic oxygen, and is normally faint (because of the low concentration of oxygen at that altitude) unless the influx of particles is very great. Red emission also occurs at lower altitudes, near 90 km, where the spectrum can be dominated by emission in a series of bands between 650 and 680 nm.



Editor's Note: *The above sketches illustrate standard auroral forms. This simplified classification was devised for visual observers during the International Geophysical Year (IGY) three decades ago (1957–58). Although there is great variety in auroral patterns, the sketches emphasize fundamental features and minimize variations which depend on the location of the observer. The light of the aurora is emitted by the upper fringes of Earth's atmosphere (heights of 100 to 400 km) as it is bombarded by electrons of the solar wind (solar wind protons contribute a smaller amount of energy). The modification of the trajectories of these particles by Earth's magnetic field restricts activity to high latitudes, producing the "aurora borealis" (in the Northern Hemisphere) and the "aurora australis" (in the Southern Hemisphere). The wavelengths of four, atmospheric, molecular and atomic emission lines which can contribute strongly to auroral light are included in the list on p. 18. Whether aurorae appear coloured depends on their luminance (light which is too faint will not activate colour vision and appears white). When the luminance is sufficiently great, the relative contributions of blue, green, and red emission lines can result in a variety of auroral hues. For a reference book on the aurora,* ***Majestic Lights****, by R. H. Eather (American Geophysical Union, Washington, 1980) is highly recommended. A beautiful, unique, half-hour video tape of the aurora is available from: The Aurora Color Television Project, Geophysical Institute, University of Alaska, Fairbanks, AK 99775-0800, USA, for $32.95 US (specify 1/2" VHS or 1/2" beta).*

TIMES OF SUNRISE AND SUNSET

The tables on the next three pages give the times of sunrise and sunset at four day intervals for places ranging from 20° to 60° north latitude. "Rise" and "set" correspond to the upper limb of the Sun appearing at the horizon for an observer at sea level. The times are local mean time (LMT) for the Greenwich meridian (i.e. UT at 0° longitude), although for North American observers the stated values may be read directly as LMT at the observer's position without significant error. The values may be interpolated linearly for both non-tabular latitudes and dates. Also, it is possible to extrapolate the table beyond the 20° and 60° latitude limits a few degrees without significant loss of accuracy.

The standard time of an event at a particular location must take account of the observer's longitude relative to his or her standard meridian. The table below lists the latitude and the longitude correction (in minutes of time) for a number of cities and towns. e.g. To find the time of sunrise at Toronto on February 17, 1989: The latitude is 44°, and from the table the time of sunrise at 0° longitude is 06:56 UT. Thus at Toronto the time of sunrise will be approximately 06:56 LMT. Toronto is in the Eastern time zone (E) and is 18 minutes of time west of the standard meridian for this zone (75°W). Thus the sunrise time of 06:56 LMT is equivalent to 07:14 EST. Corrections for places not listed below may be found by converting the difference between the longitude of the place and that of its standard meridian to time (15° = 1 h), the correction being positive if the place is west of its standard meridian, negative if east. Finally, *it should be emphasized* that the observed time will often differ up to several minutes from the predicted time because of a difference in height between the observer and the actual horizon.

CANADIAN CITIES AND TOWNS						AMERICAN CITIES		
	Lat.	Corr.		Lat.	Corr.		Lat.	Corr.
Baker Lake	64°	+24C	Peterborough	44°	+13E	Atlanta	34°	+37E
Brandon	50	+40C	Prince Albert	53	+63C	Baltimore	39	+06E
Calgary	51	+36M	Prince George	54	+11P	Birmingham	33	−13C
Charlottetown	46	+12A	Prince Rupert	54	+41P	Boston	42	−16E
Chicoutimi	48	−16E	Quebec	47	−15E	Buffalo	43	+15E
Churchill	59	+17C	Regina	50	+58C	Chicago	42	−10C
Corner Brook	49	+22N	Resolute	75	+20C	Cincinnati	39	+38E
Cornwall	45	−01E	Rimouski	48	−26E	Cleveland	42	+26E
Edmonton	54	+34M	St. Catharines	43	+17E	Dallas	33	+27C
Fredericton	46	+27A	St. Hyacinthe	46	−08E	Denver	40	00M
Gander	49	+08N	Saint John, N.B.	45	+24A	Fairbanks	65	−10A
Goose Bay	53	+02A	St. John's, Nfld.	48	+01N	Flagstaff	35	+27M
Granby	45	−09E	Sarnia	43	+29E	Indianapolis	40	−15C
Halifax	45	+14A	Saskatoon	52	+67C	Juneau	58	+58P
Hamilton	43	+20E	Sault Ste. Marie	47	+37E	Kansas City	39	+18C
Kapuskasing	49	+30E	Sept Iles	50	−35E	Los Angeles	34	−07P
Kenora	50	+18C	Sherbrooke	45	−12E	Louisville	38	−17C
Kingston	44	+06E	Sudbury	47	+24E	Memphis	35	00C
Kitchener	43	+22E	Sydney	46	+01A	Miami	26	+21E
Lethbridge	50	+31M	The Pas	54	+45C	Milwaukee	43	−09C
London	43	+25E	Thunder Bay	48	+57E	Minneapolis	45	+13C
Medicine Hat	50	+23M	Timmins	48	+26E	New Orleans	30	00C
Moncton	46	+19A	Toronto	44	+18E	New York	41	−04E
Montreal	46	−06E	Trail	49	−09P	Omaha	41	+24C
Moosonee	51	+23E	Trois Rivieres	46	−10E	Philadelphia	40	+01E
Moose Jaw	50	+62C	Vancouver	49	+12P	Phoenix	33	+28M
Niagara Falls	43	+16E	Victoria	48	+13P	Pittsburgh	40	+20E
North Bay	46	+18E	Whitehorse	61	00Y	St. Louis	39	+01C
Ottawa	45	+03E	Windsor, Ont.	42	+32E	San Francisco	38	+10P
Owen Sound	45	+24E	Winnipeg	50	+29C	Seattle	48	+09P
Pangnirtung	66	+23A	Yarmouth	44	+24A	Tucson	32	+24M
Penticton	49	−02P	Yellowknife	62	+38M	Washington	39	+08E

LAT.		+20°		+30°		+35°		+40°		+44°		+50°		+54°		+60°	
EVENT		RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET
		h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
Jan.	−2	6 34	17 30	6 55	17 09	7 07	16 57	7 21	16 43	7 34	16 30	7 59	16 06	8 19	15 45	9 03	15 01
	2	6 36	17 33	6 56	17 12	7 08	17 00	7 22	16 46	7 35	16 33	7 59	16 10	8 19	15 50	9 02	15 07
	6	6 37	17 35	6 57	17 15	7 09	17 03	7 22	16 50	7 35	16 37	7 58	16 14	8 17	15 55	8 59	15 13
	10	6 37	17 38	6 57	17 18	7 09	17 07	7 22	16 54	7 34	16 42	7 56	16 20	8 15	16 01	8 55	15 21
	14	6 38	17 41	6 57	17 22	7 08	17 11	7 21	16 58	7 32	16 46	7 54	16 25	8 12	16 07	8 49	15 29
	18	6 38	17 43	6 56	17 25	7 07	17 14	7 19	17 02	7 30	16 51	7 50	16 31	8 08	16 14	8 43	15 39
	22	6 38	17 46	6 55	17 29	7 05	17 18	7 17	17 07	7 27	16 57	7 46	16 37	8 03	16 21	8 36	15 48
	26	6 37	17 48	6 54	17 32	7 03	17 23	7 14	17 12	7 24	17 02	7 42	16 44	7 57	16 29	8 28	15 58
	30	6 36	17 51	6 52	17 35	7 00	17 27	7 11	17 17	7 20	17 07	7 37	16 51	7 51	16 37	8 19	16 09
Feb.	3	6 35	17 53	6 49	17 39	6 57	17 31	7 07	17 21	7 15	17 13	7 31	16 58	7 44	16 45	8 09	16 19
	7	6 33	17 55	6 46	17 42	6 54	17 35	7 03	17 26	7 10	17 18	7 25	17 04	7 36	16 53	7 59	16 30
	11	6 31	17 57	6 43	17 46	6 50	17 39	6 58	17 31	7 05	17 24	7 18	17 11	7 28	17 01	7 49	16 40
	15	6 29	17 59	6 40	17 49	6 46	17 43	6 53	17 36	6 59	17 29	7 11	17 18	7 20	17 09	7 38	16 51
	19	6 27	18 01	6 36	17 52	6 42	17 46	6 48	17 40	6 53	17 35	7 03	17 25	7 12	17 17	7 27	17 01
	23	6 24	18 03	6 32	17 55	6 37	17 50	6 42	17 45	6 47	17 40	6 56	17 32	7 03	17 25	7 16	17 12
	27	6 21	18 04	6 28	17 58	6 32	17 54	6 37	17 49	6 41	17 46	6 48	17 39	6 54	17 33	7 05	17 22
Mar.	3	6 18	18 06	6 24	18 00	6 27	17 57	6 31	17 54	6 34	17 51	6 40	17 45	6 44	17 41	6 53	17 32
	7	6 15	18 07	6 19	18 03	6 22	18 01	6 25	17 58	6 27	17 56	6 31	17 52	6 35	17 49	6 41	17 42
	11	6 12	18 08	6 15	18 06	6 16	18 04	6 18	18 03	6 20	18 01	6 23	17 58	6 25	17 56	6 29	17 52
	15	6 09	18 10	6 10	18 08	6 11	18 08	6 12	18 07	6 13	18 06	6 14	18 05	6 15	18 04	6 17	18 02
	19	6 05	18 11	6 05	18 11	6 05	18 11	6 05	18 11	6 05	18 11	6 05	18 11	6 05	18 11	6 05	18 12
	23	6 02	18 12	6 00	18 13	6 00	18 14	5 59	18 15	5 58	18 16	5 57	18 18	5 55	18 19	5 53	18 22
	27	5 58	18 13	5 56	18 16	5 54	18 17	5 52	18 19	5 51	18 21	5 48	18 24	5 46	18 26	5 41	18 31
	31	5 55	18 14	5 51	18 18	5 49	18 20	5 46	18 23	5 44	18 26	5 39	18 30	5 36	18 34	5 29	18 41
Apr.	4	5 51	18 15	5 46	18 20	5 43	18 24	5 40	18 27	5 36	18 30	5 31	18 36	5 26	18 41	5 17	18 51
	8	5 48	18 16	5 41	18 23	5 38	18 27	5 33	18 31	5 29	18 35	5 22	18 43	5 16	18 49	5 05	19 01
	12	5 45	18 17	5 37	18 25	5 32	18 30	5 27	18 35	5 22	18 40	5 14	18 49	5 07	18 56	4 53	19 11
	16	5 41	18 19	5 32	18 28	5 27	18 33	5 21	18 39	5 15	18 45	5 05	18 55	4 57	19 04	4 41	19 20
	20	5 38	18 20	5 28	18 30	5 22	18 36	5 15	18 43	5 09	18 50	4 57	19 01	4 48	19 11	4 29	19 30
	24	5 35	18 21	5 24	18 33	5 17	18 40	5 10	18 47	5 02	18 55	4 50	19 08	4 39	19 19	4 18	19 40
	28	5 33	18 22	5 20	18 35	5 13	18 43	5 04	18 51	4 56	18 59	4 42	19 14	4 30	19 26	4 07	19 50

☉

LAT.		+20°		+30°		+35°		+40°		+44°		+50°		+54°		+60°	
EVENT		RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET
		h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
May	2	5 30	18 24	5 16	18 38	5 08	18 46	4 59	18 56	4 50	19 04	4 35	19 20	4 22	19 33	3 56	20 00
	6	5 28	18 25	5 13	18 40	5 04	18 49	4 54	19 00	4 45	19 09	4 28	19 26	4 14	19 41	3 45	20 10
	10	5 26	18 27	5 10	18 43	5 01	18 53	4 50	19 03	4 40	19 14	4 22	19 32	4 06	19 48	3 35	20 20
	14	5 24	18 28	5 07	18 46	4 57	18 56	4 46	19 07	4 35	19 18	4 16	19 38	3 59	19 55	3 25	20 29
	18	5 23	18 30	5 05	18 48	4 54	18 59	4 42	19 11	4 31	19 22	4 10	19 43	3 53	20 01	3 16	20 39
	22	5 22	18 32	5 03	18 51	4 52	19 02	4 39	19 15	4 27	19 27	4 05	19 49	3 47	20 08	3 07	20 48
	26	5 21	18 33	5 01	18 53	4 50	19 05	4 36	19 18	4 24	19 30	4 01	19 54	3 41	20 14	2 59	20 56
	30	5 20	18 35	5 00	18 55	4 48	19 07	4 34	19 21	4 21	19 34	3 57	19 58	3 37	20 19	2 52	21 04
June	3	5 20	18 36	4 59	18 57	4 47	19 10	4 32	19 24	4 19	19 37	3 55	20 02	3 33	20 24	2 47	21 11
	7	5 20	18 38	4 58	18 59	4 46	19 12	4 31	19 27	4 18	19 40	3 52	20 06	3 30	20 28	2 42	21 17
	11	5 20	18 39	4 58	19 01	4 45	19 14	4 31	19 29	4 17	19 43	3 51	20 09	3 28	20 31	2 38	21 22
	15	5 20	18 41	4 58	19 02	4 45	19 15	4 30	19 30	4 16	19 45	3 50	20 11	3 27	20 34	2 36	21 25
	19	5 21	18 42	4 59	19 04	4 46	19 17	4 31	19 32	4 17	19 46	3 50	20 12	3 27	20 36	2 35	21 27
	23	5 22	18 42	5 00	19 04	4 47	19 18	4 32	19 33	4 18	19 47	3 51	20 13	3 28	20 36	2 36	21 28
	27	5 23	18 43	5 01	19 05	4 48	19 18	4 33	19 33	4 19	19 47	3 53	20 13	3 29	20 36	2 38	21 27
July	1	5 24	18 43	5 02	19 05	4 50	19 18	4 35	19 33	4 21	19 47	3 55	20 12	3 32	20 35	2 42	21 25
	5	5 25	18 44	5 04	19 05	4 51	19 17	4 37	19 32	4 23	19 46	3 58	20 11	3 35	20 33	2 47	21 21
	9	5 27	18 43	5 06	19 04	4 54	19 17	4 39	19 31	4 26	19 44	4 01	20 09	3 40	20 30	2 53	21 17
	13	5 28	18 43	5 08	19 03	4 56	19 15	4 42	19 29	4 29	19 42	4 05	20 06	3 44	20 26	2 59	21 11
	17	5 30	18 42	5 10	19 02	4 58	19 13	4 45	19 27	4 33	19 39	4 10	20 02	3 50	20 22	3 07	21 04
	21	5 31	18 41	5 12	19 00	5 01	19 11	4 48	19 24	4 36	19 36	4 14	19 58	3 55	20 16	3 15	20 56
	25	5 33	18 40	5 15	18 58	5 04	19 09	4 52	19 21	4 40	19 32	4 19	19 53	4 02	20 10	3 24	20 47
	29	5 34	18 38	5 17	18 55	5 07	19 05	4 55	19 17	4 45	19 28	4 25	19 47	4 08	20 04	3 33	20 38
Aug.	2	5 36	18 37	5 19	18 53	5 10	19 02	4 59	19 13	4 49	19 23	4 30	19 41	4 15	19 57	3 43	20 28
	6	5 37	18 34	5 22	18 49	5 13	18 58	5 03	19 08	4 53	19 18	4 36	19 35	4 22	19 49	3 52	20 18
	10	5 38	18 32	5 24	18 46	5 16	18 54	5 07	19 03	4 58	19 12	4 42	19 28	4 29	19 41	4 02	20 07
	14	5 40	18 29	5 27	18 42	5 19	18 50	5 10	18 58	5 02	19 06	4 48	19 20	4 36	19 32	4 11	19 56
	18	5 41	18 27	5 29	18 38	5 22	18 45	5 14	18 53	5 07	19 00	4 54	19 13	4 43	19 24	4 21	19 45
	22	5 42	18 24	5 31	18 34	5 25	18 40	5 18	18 47	5 12	18 53	5 00	19 05	4 50	19 15	4 31	19 33
	26	5 43	18 20	5 34	18 30	5 28	18 35	5 22	18 41	5 16	18 47	5 06	18 57	4 57	19 05	4 40	19 22
	30	5 44	18 17	5 36	18 25	5 31	18 30	5 26	18 35	5 21	18 40	5 12	18 48	5 04	18 56	4 50	19 10

LAT.	+20°		+30°		+35°		+40°		+44°		+50°		+54°		+60°	
EVENT	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET
	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
Sep. 3	5 45	18 14	5 38	18 20	5 34	18 24	5 29	18 29	5 25	18 33	5 18	18 40	5 11	18 46	4 59	18 58
7	5 46	18 10	5 40	18 15	5 37	18 19	5 33	18 22	5 30	18 25	5 24	18 31	5 19	18 36	5 09	18 46
11	5 46	18 06	5 42	18 11	5 40	18 13	5 37	18 16	5 34	18 18	5 30	18 23	5 26	18 26	5 18	18 34
15	5 47	18 03	5 44	18 06	5 43	18 07	5 41	18 09	5 39	18 11	5 36	18 14	5 33	18 16	5 27	18 22
19	5 48	17 59	5 47	18 01	5 46	18 01	5 44	18 02	5 43	18 03	5 42	18 05	5 40	18 07	5 37	18 09
23	5 49	17 55	5 49	17 56	5 49	17 56	5 48	17 56	5 48	17 56	5 48	17 56	5 47	17 57	5 46	17 57
27	5 50	17 52	5 51	17 51	5 52	17 50	5 52	17 49	5 53	17 49	5 54	17 47	5 54	17 47	5 56	17 45
Oct. 1	5 51	17 48	5 53	17 46	5 55	17 44	5 56	17 43	5 57	17 41	6 00	17 39	6 02	17 37	6 05	17 33
5	5 52	17 45	5 56	17 41	5 58	17 39	6 00	17 36	6 02	17 34	6 06	17 30	6 09	17 27	6 15	17 21
9	5 53	17 41	5 58	17 36	6 01	17 33	6 04	17 30	6 07	17 27	6 12	17 22	6 16	17 17	6 24	17 09
13	5 54	17 38	6 00	17 32	6 04	17 28	6 08	17 24	6 12	17 20	6 18	17 13	6 24	17 08	6 34	16 57
17	5 55	17 35	6 03	17 27	6 07	17 23	6 12	17 18	6 17	17 13	6 25	17 05	6 31	16 58	6 44	16 46
21	5 57	17 32	6 06	17 23	6 11	17 18	6 17	17 12	6 22	17 07	6 31	16 57	6 39	16 49	6 54	16 34
25	5 58	17 30	6 09	17 19	6 14	17 13	6 21	17 07	6 27	17 01	6 38	16 50	6 47	16 41	7 04	16 23
29	6 00	17 27	6 11	17 16	6 18	17 09	6 25	17 01	6 32	16 55	6 44	16 42	6 55	16 32	7 14	16 12
Nov. 2	6 02	17 25	6 15	17 12	6 22	17 05	6 30	16 57	6 38	16 49	6 51	16 35	7 02	16 24	7 24	16 02
6	6 04	17 23	6 18	17 09	6 26	17 01	6 35	16 52	6 43	16 44	6 58	16 29	7 10	16 16	7 35	15 52
10	6 06	17 22	6 21	17 07	6 29	16 58	6 39	16 48	6 48	16 39	7 04	16 23	7 18	16 09	7 45	15 42
14	6 08	17 21	6 24	17 04	6 33	16 55	6 44	16 45	6 53	16 35	7 11	16 17	7 26	16 03	7 55	15 33
18	6 11	17 20	6 27	17 03	6 37	16 53	6 48	16 42	6 59	16 31	7 17	16 12	7 33	15 57	8 05	15 24
22	6 13	17 19	6 31	17 01	6 41	16 51	6 53	16 39	7 04	16 28	7 24	16 08	7 40	15 51	8 15	15 17
26	6 15	17 19	6 34	17 00	6 45	16 49	6 57	16 37	7 09	16 26	7 30	16 05	7 47	15 47	8 24	15 10
30	6 18	17 19	6 37	17 00	6 49	16 49	7 01	16 36	7 13	16 24	7 35	16 02	7 54	15 43	8 33	15 04
Dec. 4	6 20	17 20	6 40	17 00	6 52	16 48	7 05	16 35	7 18	16 22	7 40	16 00	8 00	15 40	8 41	14 59
8	6 23	17 21	6 43	17 00	6 55	16 48	7 09	16 35	7 22	16 22	7 45	15 58	8 05	15 38	8 48	14 56
12	6 25	17 22	6 46	17 01	6 58	16 49	7 12	16 35	7 25	16 22	7 49	15 58	8 10	15 37	8 54	14 54
16	6 28	17 24	6 49	17 02	7 01	16 50	7 15	16 36	7 28	16 23	7 53	15 59	8 14	15 38	8 58	14 53
20	6 30	17 25	6 51	17 04	7 04	16 52	7 18	16 37	7 31	16 24	7 55	16 00	8 16	15 39	9 01	14 54
24	6 32	17 27	6 53	17 06	7 06	16 54	7 20	16 40	7 33	16 26	7 57	16 02	8 18	15 41	9 03	14 56
28	6 34	17 30	6 55	17 09	7 07	16 56	7 21	16 42	7 34	16 29	7 58	16 05	8 19	15 44	9 04	15 00
32	6 35	17 32	6 56	17 11	7 08	16 59	7 22	16 45	7 35	16 32	7 59	16 09	8 19	15 48	9 02	15 05

TWILIGHT

This table gives the beginning of morning and ending of evening astronomical twilight (Sun 18° below the horizon) in UT at the Greenwich meridian. For observers in North America, the times may be treated in the same way as those of sunrise and sunset (see p. 62).

LAT.	+20°		+30°		+35°		+40°		+44°		+50°		+54°		+60°	
M-E	MORN.	EVE.	MORN.	EVE.	MORN.	EVE.	MORN.	EVE.	MORN.	EVE.	MORN.	EVE.	MORN.	EVE.	MORN.	EVE.
	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
Jan. 0	5 16	18 50	5 30	18 36	5 38	18 29	5 44	18 22	5 50	18 16	6 00	18 07	6 06	18 00	6 18	17 48
10	5 20	18 56	5 33	18 43	5 39	18 37	5 45	18 30	5 51	18 25	5 59	18 17	6 05	18 11	6 15	18 01
20	5 21	19 01	5 32	18 50	5 38	18 45	5 43	18 40	5 47	18 36	5 54	18 29	5 58	18 24	6 06	18 18
30	5 20	19 07	5 29	18 58	5 34	18 54	5 37	18 50	5 40	18 47	5 45	18 43	5 47	18 40	5 51	18 37
Feb. 9	5 18	19 11	5 24	19 04	5 26	19 02	5 29	19 00	5 30	18 59	5 32	18 58	5 32	18 58	5 32	18 58
19	5 13	19 15	5 16	19 12	5 17	19 11	5 17	19 11	5 17	19 11	5 16	19 13	5 13	19 16	5 08	19 21
Mar. 1	5 06	19 18	5 07	19 18	5 06	19 20	5 04	19 22	5 02	19 24	4 56	19 30	4 52	19 35	4 40	19 46
11	4 59	19 22	4 56	19 25	4 53	19 28	4 48	19 33	4 44	19 37	4 35	19 46	4 27	19 55	4 09	20 13
21	4 50	19 24	4 44	19 32	4 38	19 37	4 32	19 44	4 25	19 51	4 11	20 04	4 00	20 17	3 33	20 44
31	4 41	19 28	4 30	19 39	4 23	19 46	4 14	19 56	4 04	20 05	3 46	20 24	3 29	20 41	2 52	21 19
Apr. 10	4 32	19 32	4 17	19 46	4 07	19 56	3 55	20 08	3 43	20 21	3 20	20 46	2 57	21 08	2 02	22 05
20	4 22	19 36	4 04	19 55	3 52	20 07	3 37	20 22	3 22	20 38	2 51	21 09	2 21	21 40	0 44	23 29
30	4 14	19 41	3 52	20 04	3 37	20 18	3 18	20 37	3 00	20 56	2 21	21 36	1 38	22 20	.. ..	.. ..
May 10	4 07	19 46	3 41	20 12	3 24	20 30	3 02	20 52	2 40	21 14	1 49	22 06	0 34	23 31	.. ..	.. ..
20	4 01	19 52	3 32	20 22	3 13	20 41	2 48	21 06	2 22	21 33	1 14	22 43	.. ..	.. ..	.. ..	.. ..
30	3 58	19 58	3 26	20 30	3 04	20 51	2 36	21 19	2 06	21 50	0 26	23 38	.. ..	.. ..	.. ..	.. ..
June 9	3 56	20 02	3 22	20 36	3 00	20 59	2 30	21 30	1 56	22 04	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..
19	3 57	20 06	3 22	20 40	2 59	21 04	2 27	21 35	1 51	22 11	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..
29	4 00	20 07	3 25	20 41	3 02	21 04	2 31	21 36	1 56	22 10	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..
July 9	4 04	20 06	3 31	20 39	3 09	21 01	2 39	21 30	2 07	22 02	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..
19	4 09	20 04	3 38	20 34	3 18	20 54	2 52	21 20	2 22	21 48	1 02	23 06	.. ..	.. ..	.. ..	.. ..
29	4 14	19 58	3 46	20 26	3 28	20 44	3 05	21 07	2 40	21 31	1 42	22 28	.. ..	.. ..	.. ..	.. ..
Aug. 8	4 19	19 52	3 55	20 16	3 39	20 31	3 19	20 50	2 58	21 11	2 14	21 54	1 20	22 46	.. ..	.. ..
18	4 24	19 43	4 04	20 03	3 50	20 17	3 33	20 33	3 17	20 50	2 42	21 24	2 06	21 59	.. ..	.. ..
28	4 28	19 34	4 12	19 50	4 00	20 01	3 46	20 15	3 33	20 28	3 06	20 54	2 40	21 20	1 28	22 27
Sep. 7	4 31	19 24	4 19	19 37	4 10	19 45	3 59	19 56	3 49	20 06	3 27	20 27	3 08	20 46	2 22	21 30
17	4 34	19 14	4 25	19 23	4 19	19 29	4 11	19 38	4 02	19 45	3 46	20 01	3 32	20 15	3 00	20 46
27	4 37	19 05	4 31	19 10	4 27	19 14	4 22	19 19	4 16	19 25	4 05	19 36	3 54	19 46	3 32	20 08
Oct. 7	4 40	18 56	4 37	18 58	4 36	19 00	4 32	19 03	4 28	19 06	4 21	19 14	4 14	19 20	4 00	19 34
17	4 42	18 49	4 43	18 47	4 43	18 47	4 42	18 48	4 41	18 49	4 37	18 53	4 33	18 56	4 25	19 05
27	4 45	18 43	4 50	18 38	4 51	18 36	4 52	18 35	4 52	18 34	4 52	18 34	4 52	18 36	4 48	18 38
Nov. 6	4 49	18 39	4 56	18 31	4 59	18 28	5 02	18 25	5 04	18 22	5 07	18 20	5 08	18 18	5 10	18 17
16	4 53	18 36	5 03	18 26	5 08	18 22	5 12	18 17	5 16	18 14	5 21	18 08	5 24	18 04	5 30	17 59
26	4 58	18 36	5 10	18 24	5 16	18 18	5 22	18 13	5 26	18 08	5 34	18 00	5 39	17 55	5 47	17 47
Dec. 6	5 04	18 38	5 17	18 25	5 24	18 18	5 30	18 12	5 36	18 06	5 45	17 57	5 51	17 50	6 02	17 40
16	5 09	18 42	5 23	18 28	5 30	18 21	5 38	18 14	5 44	18 08	5 53	17 58	6 00	17 51	6 12	17 39
26	5 14	18 47	5 28	18 33	5 36	18 26	5 43	18 18	5 49	18 12	5 58	18 03	6 06	17 56	6 18	17 44
Jan. 5	5 18	18 53	5 32	18 39	5 38	18 32	5 45	18 26	5 51	18 20	6 00	18 11	6 06	18 05	6 17	17 54

MOON

KEY TO THE MAP OF THE MOON

CRATERS

21—Albategnius (356°)
22—Alphonsus (3°)
23—Arago (338°)
24—Archimedes (4°)
25—Aristarchus (47°)
26—Aristillus (358°)
27—Aristoteles (342°)
28—Arzachel (2°)
29—Atlas (315°)
31—Autolycus (358°)
32—Bessel (342°)
33—Bullialdus (22°)
34—Cassini (355°)
35—Catharina (336°)
36—Clavius (15°)
37—Cleomedes (304°)
38—Cook (311°)
39—Copernicus (20°)
41—Cyrillus (336°)
42—Delambre (342°)
43—Endymion (305°)
44—Eratosthenes (11°)
45—Eudoxus (343°)
46—Fracastorius (326°)
47—Furnerius (299°)
48—Gassendi (40°)
49—Grimaldi (68°)
51—Halley (354°)
52—Hercules (321°)
53—Herschel (2°)
54—Hevelius (66°)
55—Hipparchus (354°)
56—Julius Caesar (345°)
57—Kepler (38°)
58—Langrenus (299°)
59—Lansberg (27°)
61—Longomontanus (21°)
62—Macrobius (314°)
63—Maginus (6°)
64—Manilius (351°)
65—Maskelyne (330°)
66—Maurolycus (345°)
67—Mersenius (49°)
68—Newcomb (316°)
69—Petavius (298°)
71—Piccolomini (327°)
72—Plato (10°)
73—Plinius (336°)
74—Posidonius (330°)
75—Ptolemaeus (2°)
76—Reinhold (23°)
77—Ross (338°)
78—Schickard (55°)
79—Schiller (40°)
81—Snellius (304°)
82—Stevinus (305°)
83—Taruntius (313°)
84—Theophilus (333°)
85—Timocharis (13°)
86—Tycho (11°)
87—Wilhelm (20°)

MARIA

LS —Lacus Somniorum (Lake of Dreams) (330°)
MC —Mare Crisium (Sea of Crises) (300°)
MFe —Mare Fecunditatis (Sea of Fertility) (310°)
MFr —Mare Frigoris (Sea of Cold) (0°)
MH —Mare Humorum (Sea of Moisture) (40°)
MI —Mare Imbrium (Sea of Rains) (20°)
MNe—Mare Nectaris (Sea of Nectar) (325°)
MNu—Mare Nubium (Sea of Clouds) (15°)
MS —Mare Serenitatis (Sea of Serenity) (340°)
MT —Mare Tranquillitatis (Sea of Tranquillity) (330°)
MV —Mare Vaporum (Sea of Vapors) (355°)
OP —Oceanus Procellarum (Ocean of Storms) (50°)
SA —Sinus Aestuum (Seething Bay) (8°)
SI —Sinus Iridum (Bay of Rainbows) (32°)
SM —Sinus Medii (Central Bay) (0°)
SR —Sinus Roris (Bay of Dew) (60°)

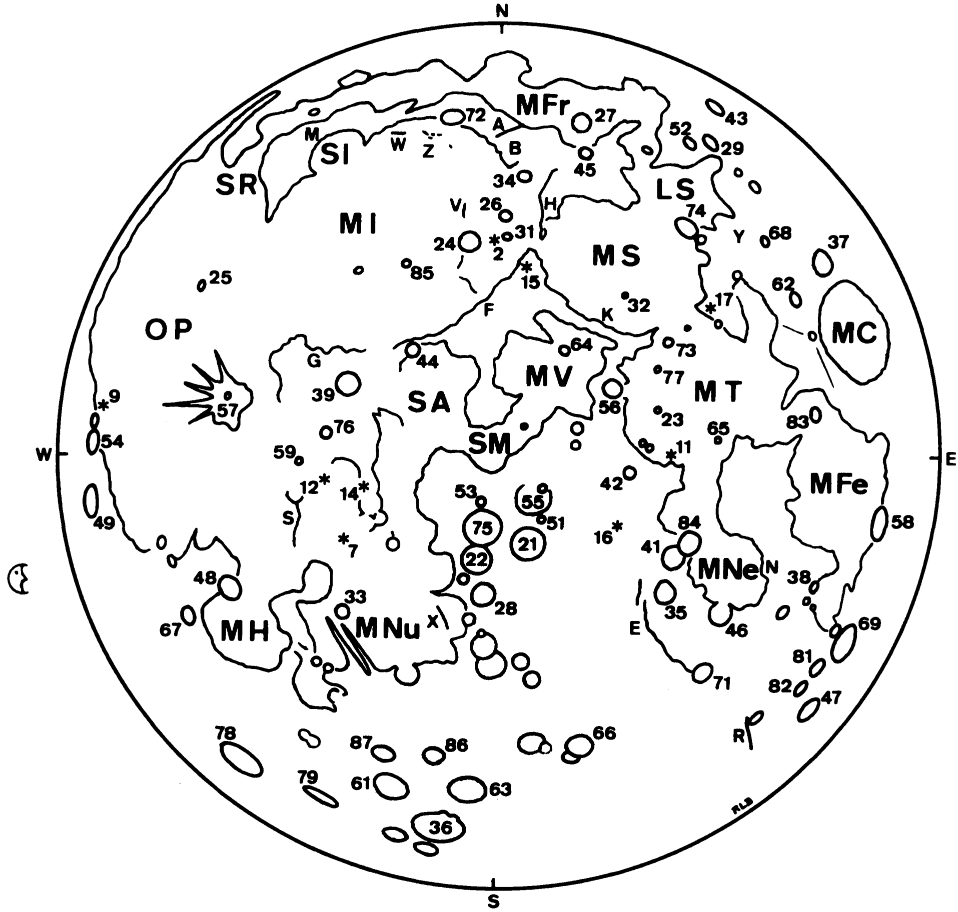
LUNAR PROBES

2—Luna 2, First to reach Moon (1959·9·13) (0°)
7—Ranger 7, First close pictures (1964·7·31) (21°)
9—Luna 9, First soft landing (1966·2·3) (64°)
11—Apollo 11, First men on Moon (1969·7·20) (337°)
12—Apollo 12 (1969·11·19) (23°)
14—Apollo 14 (1971·2·5) (17°)
15—Apollo 15 (1971·7·30) (356°)
16—Apollo 16 (1972·4·21) (344°)
17—Apollo 17 (1972·12·11) (329°)

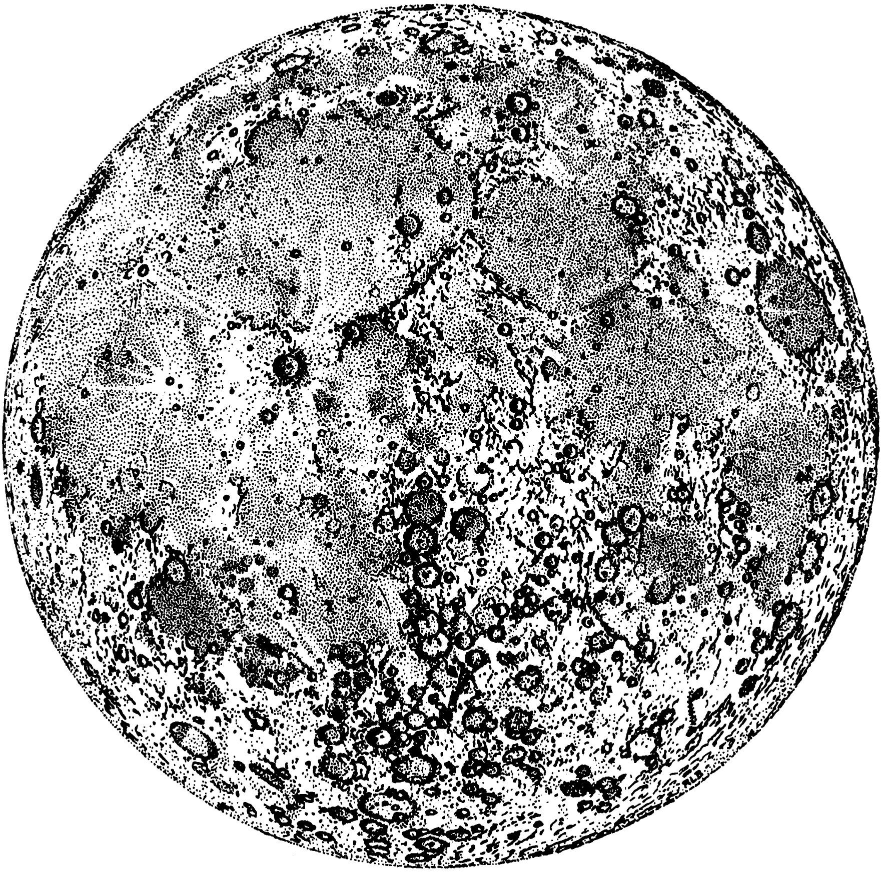
MOUNTAINS

A —Alpine Valley (356°)
B —Alps Mts. (359°)
E —Altai Mts. (336°)
F —Apennine Mts. (2°)
G —Carpathian Mts. (24°)
H —Caucasus Mts. (352°)
K —Haemus Mts. (349°)
M—Jura Mts. (34°)
N —Pyrenees Mts. (319°)
R —Rheita Valley (312°)
S —Riphaeus Mts. (27°)
V —Spitzbergen (5°)
W—Straight Range (20°)
X —Straight Wall (8°)
Y —Taurus Mts. (319°)
Z —Teneriffe Mts. (13°)

Angles in parentheses are the selenographic longitudes of the centre of each feature. 0° marks the mean centre of the lunar disk and the angles increase toward the observer's east (i.e. westward on the Moon). These angles will facilitate locating the feature on the accompanying map, and may be correlated with the Sun's selenographic colongitude (see The Sky Month By Month section) to determine the optimum times for viewing these areas on the Moon.



MAP OF



THE MOON

NEW MOON DATES

(UT)

1989				1990			
Jan.	7.8	July	3.2	Jan.	26.8	July	22.1
Feb.	6.3	Aug.	1.7	Feb.	25.4	Aug.	20.5
Mar.	7.8	Aug.	31.2	Mar.	26.8	Sept.	19.0
Apr.	6.1	Sept.	29.9	Apr.	25.2	Oct.	18.7
May	5.5	Oct.	29.6	May	24.5	Nov.	17.4
June	3.8	Nov.	28.4	June	22.8	Dec.	17.2
		Dec.	28.1				

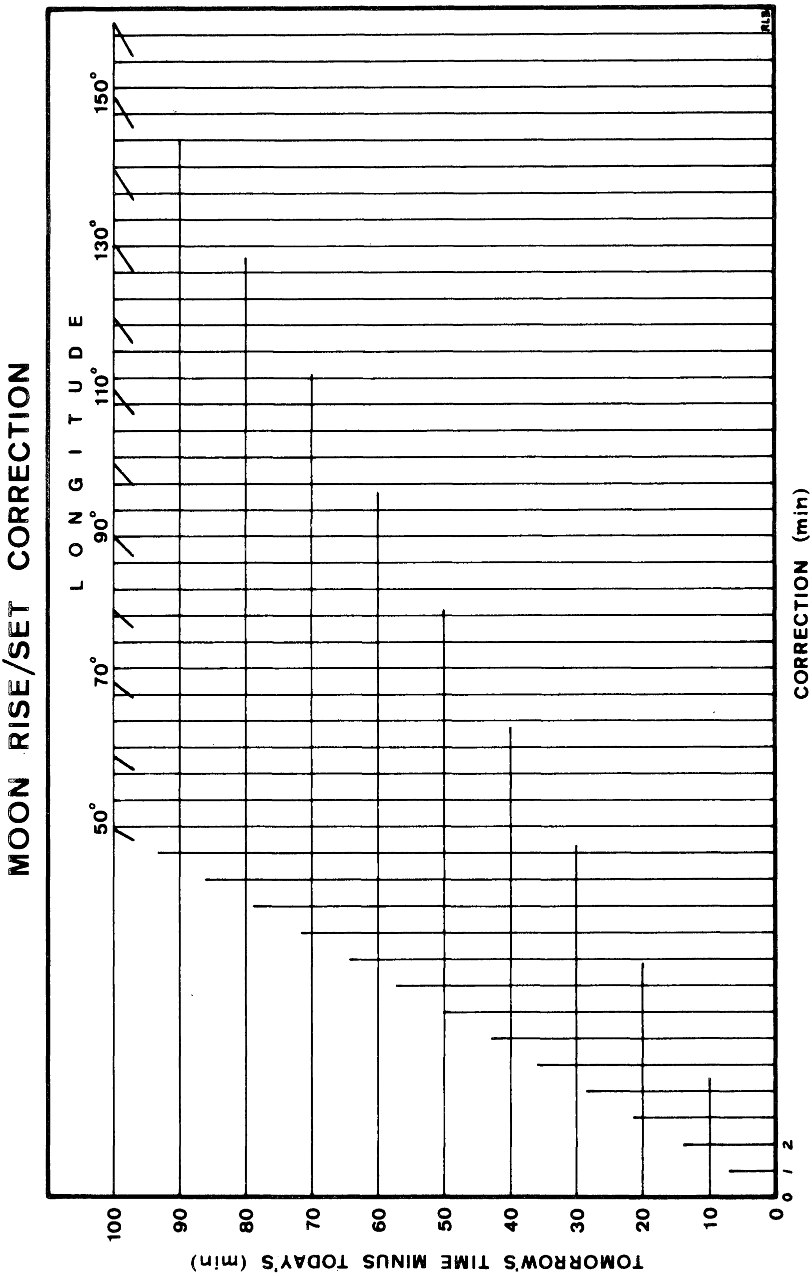
The new moon dates in the above table will be useful for planning future observing sessions (e.g. trips to southern latitudes), for determining favorable dates for observing very thin lunar crescents, and for setting moon dials on clocks.

TIMES OF MOONRISE AND MOONSET

The tables on pages 72 to 83 give the times of moonrise and moonset for each day of the year for places ranging from 20° to 60° north latitude. The tables may be interpolated linearly for non-tabular latitudes, and can be extrapolated beyond the 20° and 60° latitude limits a few degrees without significant loss of accuracy. "Rise" and "set" correspond to the upper limb of the Moon appearing at the horizon for an observer at sea level. The times are local mean time (LMT) for the Greenwich meridian (i.e. UT at 0° longitude). Because of the relatively rapid eastward motion of the Moon, unlike the sunrise and sunset tables, the times *cannot* be read directly as LMT for observers in North America. The table must be interpolated according to the observer's longitude. Also, to convert from the observer's LMT to standard time, the observer's longitude correction relative to his standard meridian must, of course, be applied (see p. 62). The graph on the opposite page enables the sum of these two corrections to be determined easily in one step. However, the graph must be set for your longitude.

To prepare the Moon Rise/Set Correction graph, first locate your longitude on the longitude scale. Using a straight-edge, draw a line from the origin (0,0 point) to your position on the longitude scale (a *red* pen is recommended to make this line stand out). Next, the CORRECTION axis must be labeled. As a guide, the first three divisions have been tentatively labeled 0, 1, 2; *but*, to these numbers must be added your longitude correction relative to your standard meridian (p. 62). e.g. For Toronto the correction is +18 minutes, thus an observer in Toronto would label this axis: 18, 19, 20, 21, ... 62, 63. An observer in Rimouski (longitude correction: −26) would label the axis: −26, −25, −24, ... 18, 19.

The graph is now ready for use on any day from your position. From the table obtain tomorrow's time and today's time for the event (moonrise, or moonset), enter the difference on the ordinate, and run horizontally across to meet the diagonal line. The correction, to the nearest minute, can then be read directly below off the abscissa. This correction is applied to "today's time" in the table and results in the standard time of the event for your position. (*Note* that, due to a difference in height between the observer and the actual horizon, the observed time may differ by up to several minutes from the predicted time.)


MOON RISE/SET CORRECTION
LONGITUDE
50°
70°
90°
110°
130°
150°
CORRECTION (min)
0
1
2
TOMORROW'S TIME MINUS TODAY'S (min)
0
10
20
30
40
50
60
70
80
90
100

LATITUDE:	+20°		+30°		+35°		+40°		+44°		+50°		+54°		+60°	
EVENT:	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET
	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
Jan. 1	0 41	12 23	0 50	12 11	0 56	12 05	1 03	11 57	1 09	11 50	1 19	11 37	1 28	11 26	1 46	11 05
2	1 31	12 59	1 46	12 42	1 55	12 32	2 05	12 21	2 14	12 11	2 31	11 52	2 45	11 37	3 14	11 06
3	2 25	13 39	2 45	13 18	2 56	13 05	3 10	12 51	3 22	12 38	3 45	12 13	4 05	11 52	4 47	11 08
4	3 22	14 25	3 46	14 00	4 00	13 45	4 17	13 28	4 32	13 12	5 01	12 41	5 27	12 15	6 27	11 14
5	4 22	15 18	4 49	14 50	5 05	14 34	5 24	14 15	5 41	13 57	6 15	13 22	6 47	12 51	8 06	11 31
6	5 22	16 18	5 51	15 49	6 07	15 33	6 27	15 13	6 46	14 55	7 21	14 19	7 54	13 46	9 22	12 19
● 7	6 21	17 22	6 48	16 55	7 04	16 40	7 23	16 22	7 41	16 05	8 14	15 32	8 44	15 03	9 57	13 51
8	7 16	18 27	7 40	18 05	7 54	17 52	8 10	17 37	8 25	17 23	8 52	16 57	9 17	16 34	10 09	15 43
9	8 06	19 32	8 24	19 16	8 35	19 06	8 48	18 55	8 59	18 44	9 20	18 25	9 38	18 09	10 14	17 36
10	8 50	20 35	9 03	20 24	9 11	20 18	9 19	20 11	9 27	20 05	9 41	19 53	9 53	19 44	10 15	19 24
11	9 31	21 35	9 38	21 31	9 42	21 29	9 46	21 26	9 51	21 23	9 58	21 19	10 04	21 15	10 16	21 08
12	10 09	22 34	10 10	22 36	10 11	22 38	10 11	22 39	10 12	22 40	10 13	22 43	10 14	22 45	10 15	22 48
13	10 47	23 33	10 42	23 41	10 39	23 46	10 36	23 52	10 33	23 57	10 27	:: ::	10 23	:: ::	10 15	:: ::
◗ 14	11 26	:: ::	11 15	:: ::	11 08	:: ::	11 01	:: ::	10 55	:: ::	10 43	0 06	10 33	0 14	10 15	0 29
15	12 07	0 33	11 50	0 47	11 40	0 55	11 30	1 05	11 19	1 14	11 01	1 30	10 46	1 43	10 16	2 11
16	12 52	1 34	12 30	1 53	12 17	2 05	12 03	2 18	11 50	2 31	11 25	2 54	11 04	3 14	10 19	3 57
17	13 42	2 36	13 16	3 00	13 01	3 14	12 43	3 31	12 27	3 47	11 56	4 16	11 29	4 43	10 27	5 44
18	14 36	3 38	14 08	4 05	13 52	4 21	13 32	4 40	13 14	4 58	12 40	5 32	12 08	6 03	10 49	7 22
19	15 34	4 37	15 06	5 05	14 49	5 22	14 30	5 41	14 12	6 00	13 37	6 35	13 05	7 07	11 41	8 31
20	16 33	5 32	16 07	5 59	15 52	6 15	15 34	6 33	15 17	6 50	14 45	7 23	14 16	7 52	13 07	9 02
☺ 21	17 31	6 21	17 09	6 45	16 56	6 59	16 40	7 15	16 26	7 30	16 00	7 57	15 37	8 21	14 46	9 14
22	18 26	7 05	18 09	7 24	17 58	7 35	17 47	7 48	17 36	8 00	17 15	8 22	16 58	8 40	16 22	9 18
23	19 19	7 43	19 06	7 58	18 59	8 06	18 51	8 16	18 43	8 25	18 29	8 40	18 17	8 54	17 54	9 20
24	20 09	8 17	20 02	8 27	19 57	8 33	19 52	8 39	19 48	8 45	19 40	8 55	19 33	9 04	19 20	9 20
25	20 57	8 49	20 55	8 54	20 54	8 57	20 52	9 00	20 51	9 03	20 48	9 07	20 46	9 12	20 42	9 19
26	21 45	9 20	21 48	9 20	21 49	9 19	21 51	9 19	21 53	9 19	21 56	9 19	21 59	9 19	22 04	9 18
27	22 33	9 50	22 41	9 45	22 45	9 42	22 51	9 39	22 55	9 36	23 04	9 30	23 11	9 26	23 25	9 17
28	23 22	10 22	23 35	10 11	23 43	10 06	23 51	9 59	23 59	9 53	:: ::	9 42	:: ::	9 33	:: ::	9 16
29	:: ::	10 55	:: ::	10 40	:: ::	10 32	:: ::	10 22	:: ::	10 13	0 14	9 56	0 26	9 43	0 50	9 16
☾ 30	0 14	11 33	0 31	11 13	0 42	11 01	0 54	10 48	1 05	10 36	1 26	10 14	1 43	9 55	2 20	9 17
31	1 08	12 15	1 30	11 51	1 43	11 37	1 59	11 21	2 13	11 06	2 40	10 38	3 03	10 14	3 55	9 20

LATITUDE:	+20°		+30°		+35°		+40°		+44°		+50°		+54°		+60°	
EVENT:	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET
	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
Feb. 1	2 05	13 04	2 31	12 37	2 47	12 21	3 05	12 02	3 22	11 45	3 54	11 12	4 23	10 42	5 34	9 30
2	3 05	13 59	3 33	13 31	3 49	13 14	4 09	12 54	4 28	12 35	5 03	12 00	5 36	11 27	7 04	9 58
3	4 04	15 00	4 32	14 33	4 49	14 17	5 08	13 57	5 26	13 39	6 02	13 05	6 34	12 33	7 57	11 10
4	5 01	16 06	5 26	15 41	5 42	15 27	5 59	15 10	6 16	14 54	6 47	14 24	7 14	13 58	8 17	12 56
5	5 53	17 12	6 15	16 53	6 27	16 41	6 41	16 28	6 55	16 16	7 19	15 53	7 40	15 33	8 24	14 52
● 6	6 41	18 17	6 57	18 04	7 06	17 56	7 16	17 47	7 26	17 39	7 43	17 24	7 58	17 11	8 27	16 45
7	7 24	19 21	7 34	19 14	7 40	19 10	7 46	19 05	7 52	19 01	8 02	18 53	8 11	18 47	8 27	18 35
8	8 05	20 22	8 08	20 22	8 10	20 22	8 13	20 22	8 15	20 21	8 18	20 21	8 21	20 21	8 27	20 20
9	8 44	21 23	8 41	21 30	8 40	21 33	8 38	21 37	8 36	21 41	8 33	21 48	8 31	21 53	8 26	22 04
10	9 24	22 25	9 15	22 37	9 10	22 44	9 04	22 53	8 58	23 00	8 49	23 14	8 41	23 26	8 26	23 49
11	10 05	23 27	9 50	23 45	9 42	23 56	9 32	:: ::	9 23	:: ::	9 07	:: ::	8 53	:: ::	8 27	:: ::
☽ 12	10 50	:: ::	10 29	:: ::	10 18	:: ::	10 04	0 08	9 51	0 20	9 29	0 41	9 09	0 59	8 29	1 37
13	11 38	0 29	11 14	0 53	10 59	1 07	10 42	1 22	10 27	1 37	9 58	2 05	9 32	2 30	8 35	3 26
14	12 31	1 32	12 04	1 59	11 48	2 15	11 29	2 33	11 11	2 50	10 37	3 24	10 06	3 54	8 50	5 09
15	13 28	2 32	13 00	3 00	12 43	3 17	12 23	3 36	12 05	3 55	11 29	4 31	10 57	5 03	9 31	6 29
16	14 26	3 28	13 59	3 55	13 43	4 12	13 25	4 30	13 07	4 48	12 34	5 22	12 04	5 53	10 48	7 09
17	15 24	4 18	15 00	4 43	14 46	4 58	14 30	5 15	14 15	5 30	13 46	6 00	13 21	6 26	12 24	7 24
18	16 19	5 03	16 00	5 24	15 49	5 36	15 36	5 50	15 24	6 03	15 01	6 27	14 42	6 47	14 01	7 30
19	17 13	5 42	16 58	5 59	16 50	6 08	16 40	6 19	16 31	6 29	16 15	6 47	16 01	7 02	15 34	7 32
⊛ 20	18 03	6 17	17 54	6 29	17 49	6 36	17 42	6 43	17 37	6 50	17 26	7 02	17 18	7 13	17 01	7 32
21	18 52	6 50	18 48	6 57	18 45	7 00	18 43	7 05	18 40	7 08	18 36	7 15	18 32	7 21	18 25	7 32
22	19 40	7 21	19 41	7 22	19 41	7 23	19 42	7 24	19 43	7 25	19 44	7 27	19 45	7 28	19 46	7 31
23	20 28	7 51	20 34	7 48	20 37	7 46	20 41	7 44	20 45	7 42	20 51	7 38	20 57	7 35	21 08	7 30
24	21 16	8 22	21 27	8 14	21 34	8 09	21 41	8 03	21 48	7 59	22 00	7 50	22 11	7 42	22 31	7 29
25	22 06	8 55	22 22	8 41	22 32	8 34	22 42	8 25	22 52	8 17	23 11	8 03	23 26	7 51	23 58	7 28
26	22 59	9 30	23 19	9 12	23 32	9 02	23 46	8 50	23 59	8 39	:: ::	8 19	:: ::	8 02	:: ::	7 28
27	23 54	10 10	:: ::	9 47	:: ::	9 34	:: ::	9 19	:: ::	9 05	0 23	8 40	0 44	8 18	1 30	7 30
☾ 28	:: ::	10 55	0 19	10 29	0 33	10 14	0 50	9 56	1 06	9 39	1 36	9 08	2 03	8 40	3 07	7 36

LATITUDE:	+20°		+30°		+35°		+40°		+44°		+50°		+54°		+60°	
EVENT:	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET
	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
Mar. 1	0 51	11 46	1 18	11 18	1 35	11 01	1 54	10 42	2 12	10 23	2 46	9 48	3 18	9 16	4 40	7 53
2	1 49	12 43	2 17	12 14	2 34	11 58	2 54	11 38	3 12	11 19	3 48	10 44	4 22	10 10	5 51	8 42
3	2 45	13 45	3 12	13 18	3 28	13 03	3 47	12 45	4 05	12 27	4 38	11 55	5 08	11 25	6 22	10 12
4	3 39	14 49	4 02	14 27	4 16	14 14	4 33	13 59	4 48	13 44	5 16	13 18	5 40	12 54	6 33	12 03
5	4 28	15 54	4 47	15 37	4 58	15 28	5 10	15 16	5 22	15 06	5 43	14 47	6 01	14 30	6 37	13 57
6	5 13	16 58	5 26	16 48	5 34	16 42	5 42	16 35	5 50	16 29	6 04	16 17	6 16	16 07	6 39	15 48
● 7	5 55	18 02	6 02	17 58	6 06	17 56	6 11	17 53	6 15	17 51	6 22	17 47	6 28	17 44	6 39	17 37
8	6 36	19 05	6 36	19 08	6 37	19 10	6 37	19 11	6 37	19 13	6 38	19 16	6 38	19 19	6 39	19 24
9	7 17	20 08	7 10	20 18	7 07	20 23	7 03	20 30	6 59	20 36	6 53	20 46	6 48	20 55	6 38	21 12
10	7 59	21 12	7 46	21 28	7 39	21 38	7 31	21 48	7 24	21 58	7 10	22 16	7 00	22 32	6 39	23 03
11	8 43	22 17	8 25	22 39	8 15	22 52	8 03	23 06	7 51	23 20	7 31	23 45	7 14	:: ::	6 40	:: ::
12	9 32	23 22	9 09	23 48	8 55	:: ::	8 40	:: ::	8 25	:: ::	7 58	:: ::	7 35	0 08	6 45	0 56
13	10 26	:: ::	9 59	:: ::	9 43	0 03	9 25	0 21	9 07	0 38	8 35	1 10	8 06	1 38	6 56	2 47
◑ 14	11 22	0 25	10 54	0 53	10 37	1 10	10 18	1 29	9 59	1 47	9 24	2 23	8 51	2 55	7 27	4 19
15	12 21	1 23	11 53	1 51	11 37	2 08	11 18	2 27	11 00	2 45	10 26	3 20	9 54	3 52	8 34	5 13
16	13 19	2 16	12 54	2 42	12 39	2 57	12 22	3 14	12 06	3 31	11 36	4 02	11 09	4 30	10 07	5 34
17	14 15	3 02	13 54	3 24	13 42	3 37	13 28	3 52	13 15	4 06	12 50	4 32	12 29	4 54	11 44	5 41
18	15 08	3 43	14 52	4 01	14 43	4 11	14 32	4 23	14 22	4 34	14 04	4 54	13 49	5 10	13 17	5 44
19	16 00	4 19	15 48	4 32	15 42	4 40	15 35	4 48	15 28	4 56	15 16	5 10	15 06	5 22	14 46	5 45
20	16 49	4 52	16 43	5 00	16 39	5 05	16 35	5 10	16 32	5 15	16 25	5 24	16 20	5 31	16 10	5 45
21	17 36	5 23	17 36	5 26	17 35	5 28	17 35	5 30	17 34	5 32	17 33	5 36	17 33	5 38	17 31	5 44
⊗ 22	18 24	5 54	18 28	5 52	18 31	5 51	18 34	5 50	18 36	5 49	18 41	5 47	18 45	5 45	18 52	5 43
23	19 12	6 24	19 22	6 17	19 27	6 14	19 33	6 09	19 39	6 05	19 49	5 58	19 58	5 53	20 15	5 42
24	20 02	6 56	20 16	6 45	20 25	6 38	20 34	6 30	20 43	6 23	20 59	6 11	21 13	6 01	21 41	5 41
25	20 53	7 31	21 13	7 14	21 24	7 05	21 37	6 54	21 49	6 44	22 11	6 26	22 30	6 11	23 11	5 41
26	21 47	8 09	22 11	7 48	22 25	7 36	22 40	7 22	22 55	7 09	23 24	6 45	23 49	6 25	:: ::	5 43
27	22 43	8 51	23 10	8 27	23 25	8 12	23 44	7 55	:: ::	7 40	:: ::	7 11	:: ::	6 45	0 45	5 47
28	23 40	9 39	:: ::	9 12	:: ::	8 56	:: ::	8 37	0 01	8 19	0 34	7 46	1 04	7 15	2 19	6 00
29	:: ::	10 33	0 08	10 05	0 25	9 48	0 44	9 28	1 03	9 10	1 38	8 34	2 11	8 01	3 39	6 34
☾ 30	0 35	11 31	1 03	11 04	1 19	10 48	1 39	10 29	1 57	10 11	2 31	9 37	3 03	9 06	4 23	7 47
31	1 28	12 33	1 53	12 09	2 08	11 54	2 26	11 38	2 42	11 22	3 12	10 53	3 39	10 27	4 40	9 27

LATITUDE:		+20°		+30°		+35°		+40°		+44°		+50°		+54°		+60°	
EVENT:		RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET
		h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
Apr.	1	2 17	13 35	2 39	13 16	2 51	13 05	3 05	12 51	3 18	12 39	3 43	12 17	4 03	11 57	4 47	11 16
	2	3 03	14 38	3 19	14 24	3 28	14 16	3 39	14 07	3 48	13 59	4 06	13 44	4 20	13 31	4 49	13 05
	3	3 45	15 40	3 55	15 33	4 01	15 29	4 08	15 24	4 14	15 19	4 24	15 11	4 33	15 05	4 50	14 52
	4	4 26	16 42	4 30	16 42	4 32	16 41	4 34	16 41	4 37	16 40	4 41	16 40	4 44	16 39	4 50	16 38
	5	5 06	17 45	5 04	17 51	5 02	17 55	5 00	17 59	4 59	18 03	4 56	18 09	4 54	18 15	4 50	18 25
●	6	5 48	18 50	5 39	19 03	5 33	19 10	5 28	19 19	5 22	19 26	5 13	19 40	5 05	19 52	4 50	20 16
	7	6 32	19 57	6 17	20 15	6 08	20 26	5 58	20 39	5 49	20 51	5 32	21 13	5 19	21 31	4 52	22 11
	8	7 20	21 04	6 59	21 28	6 47	21 42	6 33	21 58	6 20	22 14	5 57	22 43	5 37	23 08	4 55	:: ::
	9	8 14	22 10	7 48	22 38	7 33	22 54	7 16	23 12	7 00	23 30	6 30	:: ::	6 04	:: ::	5 04	0 07
	10	9 11	23 13	8 43	23 41	8 27	23 58	8 08	:: ::	7 50	:: ::	7 15	0 04	6 44	0 35	5 26	1 53
	11	10 11	:: ::	9 43	:: ::	9 27	:: ::	9 07	0 17	8 49	0 35	8 14	1 10	7 42	1 43	6 20	3 05
☽	12	11 11	0 09	10 45	0 36	10 30	0 52	10 12	1 10	9 56	1 27	9 24	1 59	8 56	2 28	7 48	3 38
	13	12 09	0 59	11 47	1 22	11 34	1 36	11 19	1 52	11 05	2 07	10 39	2 34	10 16	2 58	9 26	3 50
	14	13 04	1 42	12 46	2 01	12 36	2 12	12 24	2 25	12 13	2 37	11 53	2 59	11 36	3 17	11 01	3 54
	15	13 56	2 20	13 43	2 34	13 36	2 43	13 28	2 52	13 20	3 01	13 06	3 17	12 54	3 30	12 31	3 56
	16	14 45	2 54	14 38	3 04	14 33	3 09	14 28	3 15	14 24	3 21	14 16	3 32	14 09	3 40	13 56	3 56
	17	15 33	3 25	15 31	3 30	15 29	3 33	15 28	3 36	15 26	3 39	15 24	3 44	15 22	3 48	15 18	3 56
	18	16 21	3 56	16 23	3 56	16 25	3 56	16 27	3 56	16 28	3 56	16 31	3 55	16 34	3 55	16 38	3 55
	19	17 09	4 26	17 16	4 21	17 21	4 18	17 26	4 15	17 31	4 12	17 39	4 07	17 46	4 03	18 00	3 54
	20	17 58	4 58	18 11	4 48	18 18	4 42	18 26	4 36	18 34	4 30	18 49	4 19	19 01	4 11	19 24	3 54
☺	21	18 49	5 32	19 07	5 17	19 17	5 08	19 29	4 59	19 40	4 50	20 00	4 34	20 17	4 20	20 53	3 54
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ECLIPSES DURING 1989

BY FRED ESPENAK

Four eclipses occur during 1989. Two are partial solar eclipses and two are total lunar eclipses.

1. 20 February: Total Eclipse of the Moon

Penumbral Eclipse Begins:	12:31.2 UT
Partial Eclipse Begins:	13:43.5 UT
Total Eclipse Begins:	14:55.9 UT
Middle of Eclipse:	15:35.4 UT
Total Eclipse Ends:	16:15.2 UT
Partial Eclipse Ends:	17:27.4 UT
Penumbral Eclipse Ends:	18:39.7 UT

A little more than one hour after occulting the first magnitude star Regulus (α Leo), the Moon begins its passage through Earth's shadow during the first eclipse of 1989. Since apogee occurs on 23 February, the Moon's apparent semi-diameter of 14' 49.9" is rather small. Combined with the Moon's relatively slow orbital velocity and its deep penetration of the umbral shadow, this eclipse will last six hours and eight minutes. At middle eclipse, the umbral magnitude will reach 1.2791 as the Moon's southern limb passes within 1.1 arc-minutes of the shadow's central axis. At the same instant, the Moon's northern limb will be 8.3 arc-minutes from the shadow's edge. Observers may want to estimate the brightness and coloration of the Moon during totality (see: Danjon Scale of Lunar Eclipse Brightness).

First contact with the penumbra is at 12:31.2 UT, but casual observers won't notice anything unusual until half an hour or so before first contact with the umbra (13:43.5 UT). The partial umbral phases proceed smoothly over the next hour until the total eclipse begins at 14:55.9 UT. During mid-totality , the Moon will appear in the zenith from a point just east of the Philippines. The total phase ends at 16:15.2 UT, while the partial umbral phases last until 17:27.4 UT. The final penumbral phases of the eclipse end uneventfully at 18:39.7 UT. Three hours later, the Moon crosses the descending node of its orbit.

Table 1 lists predicted umbral immersion and emersion times for twenty well-defined lunar craters. The timing of craters is useful in determining the enlargement of Earth's shadow due to its atmosphere (see: Crater Timings During Lunar Eclipses).

Table 1

Crater Immersion/Emersion Times for the Total Lunar Eclipse of 20 Feb 1989

Crater Name	Immersion UT	Crater Name	Emersion UT
Grimaldi	13:48	Grimaldi	16:22
Billy	13:50	Aristarchus	16:23
Campanus	13:57	Billy	16:30
Kepler	14:01	Kepler	16:30
Tycho	14:03	Plato	16:35
Aristarchus	14:06	Pytheas	16:36
Copernicus	14:10	Copernicus	16:39
Pytheas	14:14	Timocharis	16:39
Timocharis	14:21	Campanus	16:42
Manilius	14:26	Aristoteles	16:46

Crater Name	Immersion UT	Crater Name	Emersion UT
Dionysius	14:26	Eudoxus	16:48
Menelaus	14:30	Tycho	16:51
Plinius	14:33	Manilius	16:54
Plato	14:34	Menelaus	16:58
Goclenius	14:35	Dionysius	17:02
Eudoxus	14:40	Plinius	17:02
Taruntius	14:40	Proclus	17:13
Langrenus	14:41	Taruntius	17:16
Aristoteles	14:42	Goclenius	17:17
Proclus	14:43	Langrenus	17:23

Note: Predictions include a 2% enlargement of the umbral shadow due to Earth's atmosphere.

Observers throughout Asia, Indonesia and Australia will witness the entire event. The total phase will also be visible around moonrise from Scandinavia, eastern Europe and Africa. In the Western Hemisphere, the total eclipse will occur shortly before or during moonset from Alaska, Yukon, British Columbia, Alberta, Washington, Oregon and northern California. The partial umbral phases will be visible near moonrise from central Europe and central Africa, and near moonset from Saskatchewan, Manitoba, western United States and northwestern Mexico. The early penumbral phases can be seen from Ontario and central U.S. and the late penumbral phases from western Europe and Africa. Unfortunately, none of the eclipse will be visible from eastern North America or South America.

2. <u>7 March: Partial Eclipse of the Sun</u>

Partial Eclipse Begins:	16:16.9 UT
Greatest Eclipse:	18:07.7 UT
Partial Eclipse Ends:	19:58.2 UT

Two weeks after the lunar eclipse, the first solar eclipse of 1989 occurs as the Moon's umbral shadow misses Earth and swings 596 kilometres above Alaska. The partial eclipse is visible from most of Canada west of Quebec, and the United States west of the Mississippi. Northwestern Mexico is also in the penumbral path as is Hawaii where the eclipse occurs during sunrise. The penumbral shadow first touches Earth in the Pacific Ocean about 600 kilometres east of the Hawaiian Islands at 16:16:52 UT. Greatest eclipse occurs at 18:07:44 UT, just off the western coast of Alaska. Observers there can witness a sunrise eclipse with a magnitude of 0.8253. The eclipse ends when the penumbra leaves Earth along the sunset terminator in central Greenland at 19:58:10 UT.

Eclipse times and local circumstances for a number of cities in North America are found in Table 2. The Sun's altitude and the eclipse magnitude are given at the instant of maximum eclipse. Eclipse magnitude is defined as the fraction of the Sun's diameter obscured by the Moon. Partial and annular eclipses are characterized by magnitudes less than 1.0 while total eclipses have a magnitude equal to or greater than 1.0.

Table 2

Local Circumstances for the Partial Solar Eclipse of 7 March 1989

Geographic Location	Eclipse Begins	Maximum Eclipse	Eclipse Ends	Sun's Altitude	Eclipse Magnitude
Albuquerque, NM	17:21	18:06	18:52	47°	0.200
Anchorage, Ak.	17:15	18:13	19:15	10°	0.797
Bismark, ND	17:42	18:33	19:23	38°	0.282
Boise, Idaho	17:10	18:09	19:11	36°	0.455
Billings, Mont.	17:26	18:22	19:19	37°	0.378
Casper, Wy.	17:27	18:20	19:14	40°	0.312
Denver, Co.	17:28	18:17	19:06	43°	0.244
Des Moines, Iowa	18:04	18:35	19:05	43°	0.086
Flagstaff, Az.	17:09	18:00	18:53	44°	0.285
Los Angeles, Ca.	16:55	17:50	18:47	40°	0.362
Portland, Or.	17:03	18:05	19:09	30°	0.561
San Diego, Ca.	16:56	17:49	18:45	41°	0.330
San Francisco, Ca.	16:53	17:52	18:54	35°	0.464
Seattle, Wa.	17:08	18:10	19:14	30°	0.565
Salt Lake City	17:14	18:10	19:07	40°	0.362
Rapid City, SD	17:35	18:26	19:17	40°	0.280
Calgary, Alta.	17:23	18:23	19:25	31°	0.505
Edmonton, Alta.	17:27	18:28	19:29	29°	0.521
Saskatoon, Sask.	17:35	18:33	19:31	32°	0.429
Vancouver, B.C.	17:10	18:12	19:16	29°	0.587
Victoria, B.C.	17:08	18:10	19:14	29°	0.583
Winnipeg, Man.	17:51	18:41	19:30	35°	0.277

Note : All times are in Universal Time.
Sun's altitude is for instant of Maximum Eclipse.

3. 17 August: Total Eclipse of the Moon

Penumbral Eclipse Begins:	0:23.9 UT
Partial Eclipse Begins:	1:20.6 UT
Total Eclipse Begins:	2:19.9 UT
Middle of Eclipse:	3:08.2 UT
Total Eclipse Ends:	3:56.6 UT
Partial Eclipse Ends:	4:55.8 UT
Penumbral Eclipse Ends:	5:52.4 UT

Two and a half days before its August perigee, the Moon once again swings through Earth's dark umbral shadow in eastern Capricornus. As a result of its orbital geometry, the Moon appears quite large (semi-diameter = 16' 15.3") and passes through the umbra at a relatively high angular velocity. Nevertheless, its very deep path through the centre of the umbra results in a total phase lasting one hour and thirty-six minutes. At maximum eclipse, the umbral magnitude peaks at 1.6039 as the Moon's centre passes 9 arc-minutes south of the shadow axis. This should produce a relatively dark eclipse and observers are encouraged to estimate the Danjon value at mid-totality.

The eclipse begins at 00:23.9 UT with first penumbral contact. An hour later, the partial eclipse commences with first umbral contact (01:20.6 UT). Totality begins at 02:19.9 UT and lasts until 03:56.6 UT. At mid-eclipse, the Moon appears in the zenith from eastern Brazil. After totality ends, the partial phases resume and continue until 04:55.8 UT. As the Moon crosses the ascending node of its orbit, the penumbral eclipse ends at 05:52.4 UT.

Table 3 lists predicted umbral immersion and emersion times for twenty lunar craters. Crater timings can be used to measure the enlargement of Earth's shadow due to its atmosphere (see: Crater Timings During Lunar Eclipses).

This eclipse will be widely seen from most of North and South America, Europe and Africa. In North America, eastern observers are favored since totality begins at moonrise along a line through western Saskatchewan, central Montana, western Utah and Arizona. Observers in Alberta, British Columbia and the west coast states will witness totality already in progress as the Moon rises. Only the partial phases after totality will be visible from northern British Columbia. In the Eastern Hemisphere, moonset occurs during mid-totality from Scandinavia, Russia, the Middle East and eastern Africa. Observers west of a line from the Netherlands through Greece and Tanzania will witness all of totality, while all the partial phases will be seen in Great Britain, central France and westward. None of the eclipse will be visible from the eastern half of Asia or Australia.

Table 3

Crater Immersion/Emersion Times for the Total Lunar Eclipse of 17 Aug 1989

Crater Name	Immersion UT	Crater Name	Emersion UT
Grimaldi	1:26	Grimaldi	4:00
Aristarchus	1:29	Billy	4:05
Kepler	1:33	Aristarchus	4:08
Billy	1:33	Kepler	4:11
Pytheas	1:39	Campanus	4:14
Copernicus	1:40	Copernicus	4:19
Timocharis	1:42	Pytheas	4:19
Plato	1:44	Tycho	4:20
Campanus	1:46	Timocharis	4:23
Aristoteles	1:52	Plato	4:24
Eudoxus	1:53	Aristoteles	4:32
Manilius	1:54	Eudoxus	4:33
Tycho	1:56	Manilius	4:33
Menelaus	1:57	Menelaus	4:37
Dionysius	1:59	Dionysius	4:38
Plinius	2:00	Plinius	4:40
Proclus	2:09	Goclenius	4:48
Taruntius	2:10	Proclus	4:49
Goclenius	2:12	Taruntius	4:49
Langrenus	2:16	Langrenus	4:53

Note: Predictions include a 2% enlargement of the umbral shadow due to Earth's atmosphere.

4. 31 August: Partial Eclipse of the Sun

Partial Eclipse Begins:	3:33.6 UT
Greatest Eclipse:	5:30.8 UT
Partial Eclipse Ends:	7:27.6 UT

The second and final solar eclipse of 1989 is another partial event as the axis of the lunar shadow passes 1311 kilometres above the southern Indian Ocean. The eclipse is visible from southern Africa, Madagascar, the Indian Ocean and eastern Antarctica. The eclipse begins at 03:33:38 UT when the penumbral shadow first touches Earth about 300 kilometres west of Madagascar. At greatest eclipse, an observer off the coast of Antarctica could then witness a sunrise eclipse with a magnitude of 0.6332. Finally, the penumbra leaves Earth along the sunset terminator in central Antarctica at 07:27:38 UT.

Eclipse times and local circumstances for cities in southern Africa are found in Table 4. The Sun's altitude and the eclipse magnitude are given at the instant of maximum eclipse.

Table 4

Local Circumstances for the Partial Solar Eclipse of 31 August 1989

Geographic Location	Eclipse Begins	Maximum Eclipse	Eclipse Ends	Sun's Altitude	Eclipse Magnitude
Kimberly, S. Afr.	4:37*	4:37	5:22	0°	0.330
Port Elizabeth, S. Afr.	4:37*	4:37	5:37	0°	0.429
Cape Town, S. Afr.	5:06*	5:06	5:32	0°	0.263
Johannesburg, S. Afr.	4:22*	4:24	5:16	0°	0.303
Durban, S. Afr.	4:12*	4:31	5:29	3°	0.374
Pretoria, S. Afr.	4:20*	4:24	5:15	0°	0.296
Tananarive, Mad.	3:36	4:19	5:05	18°	0.177
Salisbury, Rhodesia	4:04*	4:12	4:49	2°	0.142
Lusaka, N. Rhodesia	4:13*	4:13	4:36	0°	0.080
Mozambique, Moz.	3:39	4:10	4:43	10°	0.100

Note : All times are in Universal Time.
Sun's altitude is for instant of Maximum Eclipse.

* = Eclipse in progress at sunrise.

Solar Eclipse Figures

For each solar eclipse, an orthographic projection map of Earth shows the path of penumbral (partial) eclipse. North is to the top in all cases and the daylight terminator is plotted for the instant of greatest eclipse. The sub-solar point on Earth is indicated by a star shaped character. The partial solar eclipse maps are oriented with the origin at the sub-solar longitude at greatest eclipse and at a latitude equal to the Sun's declination plus or minus 45°.

The limits of the Moon's penumbral shadow delineate the region of visibility of the partial solar eclipse. This irregular or saddle shaped region often covers more than half of the daylight hemisphere of Earth and consists of several distinct zones or limits. At the northern and/or southern boundaries lie the limits of the penumbra's path. Partial eclipses have only one of these limits, as do central eclipses when the shadow axis falls no closer than about 0.45 radii of Earth's centre. Great loops at the western and eastern extremes of the penumbra's path identify the areas where the eclipse begins/ends at sunrise and sunset, respectively. The curves are connected in a distorted figure eight. Bisecting the 'eclipse begins/ends at sunrise and sunset' loops is the curve of maximum eclipse at sunrise (western loop) and sunset (eastern loop). The points 'P1' and 'P4' mark the coordinates where the penumbral shadow first contacts (partial eclipse begins) and last contacts (partial eclipse ends) Earth's surface.

A curve of maximum eclipse is the locus of all points where the eclipse is at maximum at a given time. Curves of maximum eclipse are plotted at each half hour Universal Time. They generally run from the northern to the southern penumbral limits, or from the maximum eclipse at sunrise and sunset curves to one of the limits. The curves of constant eclipse magnitude delineate the locus of all points where the magnitude at maximum eclipse is constant. These curves run exclusively between the curves of maximum eclipse at sunrise and sunset. Furthermore, they're parallel to the northern/southern penumbral limits and the umbral paths of central eclipses. In fact the northern and southern limits of the penumbra can be thought of as curves of constant magnitude of 0.0. The adjacent curves are for magnitudes of 0.2, 0.4, 0.6 and 0.8. The northern and southern limits of the umbra which define the path of totality are curves of constant magnitude of 1.0.

Greatest eclipse is defined as the instant when the axis of the Moon's shadow passes closest to Earth's centre. Although greatest eclipse differs slightly from the instants of greatest magnitude and greatest duration (for total eclipses), the differences are usually negligible. The point on Earth's surface which is at or is nearest to the axis at this time is marked by an ✳ . For partial eclipses, the shadow axis misses Earth entirely. Therefore, the point of greatest eclipse lies on the day/night terminator and the sun appears in the horizon.

Data pertinent to the eclipse appear with each map. In the upper left corner are the Universal Times of greatest eclipse and conjunction of the Moon and Sun in right ascension, the minimum distance of the Moon's shadow axis from Earth's centre in Earth radii (Gamma) and the magnitude at greatest eclipse. The magnitude is defined as the fraction of the Sun's diameter obscured by the Moon. To the upper right are exterior contact times of the Moon's shadow with Earth. P1 and P4 are the first and last contacts of the penumbra; they mark the start and end of the partial eclipse. Below each map are the geocentric coordinates of the Sun and Moon at the instant of greatest eclipse. They consist of the right ascension (RA), declination (DEC), apparent semi-diameter (SD) and horizontal parallax (HP). The Saros series for the eclipse is listed, followed by a pair of numbers in parentheses. The first number identifies the sequence order of the eclipse in the series, while the second number is the total number of eclipses in the series. The Julian Date (JD) at greatest eclipse is given, followed by the extrapolated value of ΔT used in the calculations (ΔT is the difference between Terrestrial Dynamical Time and Universal Time).

Lunar Eclipse Figures

Each lunar eclipse has two diagrams associated with it. The top figure shows the path of the Moon through Earth's penumbral and umbral shadows. Above and to the left is the time of middle eclipse, followed by the penumbral (PMAG) and umbral (UMAG) magnitudes of the eclipse. The penumbral and umbral magnitudes are the fraction of the Moon's diameter immersed in the penumbral and umbral shadows respectively at middle eclipse. To the upper right are the contact times of the eclipse. P1 and P4 are the first and last contacts of the Moon with the penumbra; they mark the start and end of the penumbral eclipse. U1 and U4 denote the first and last contacts of the Moon with the umbra; they are the instants when the partial umbral eclipse begins and ends. U2 and U3 are the instants of internal tangency between the Moon and the umbral shadow; they identify the start and end of total umbral eclipse. In the lower left corner is the angle subtended between the Moon's centre and the shadow axis at middle eclipse (AXIS), and the angular radii of the penumbral (F1) and umbral (F2) shadows. The Moon's geocentric coordinates at maximum eclipse are given in the lower right corner. They consist of the right ascension (RA), declination (DEC), apparent semi-diameter (SD) and horizontal parallax (HP). Below, the Saros series of the eclipse is given, followed by the Julian Date at middle eclipse and the extrapolated value of ΔT used in the calculations (ΔT is the difference between Terrestrial Dynamical Time and Universal Time).

The bottom map is a cylindrical equidistant projection of Earth which shows the regions of visibility for each stage of the eclipse. In particular, the moonrise/moonset terminator is plotted for each contact and is labeled accordingly. The point where the Moon is in the zenith at maximum eclipse is indicated by an ✳ . The region which is completely unshaded will observe the entire eclipse while the area marked by solid diagonal lines will witness none of the event. The remaining shaded areas will experience moonrise or moonset while the eclipse is in progress. The shaded zones east of ✳ will witness moonset before the eclipse ends while the shaded zones west of ✳ will witness moonrise after the eclipse has begun.

Danjon Scale of Lunar Eclipse Brightness

The Moon's appearance during a total lunar eclipse can vary enormously from one eclipse to the next. Obviously, the geometry of the Moon's path through the umbra plays an important role. Not as apparent is the effect that Earth's atmosphere has on total eclipses. Although the physical mass of Earth blocks off all direct sunlight from the umbra, the planet's atmosphere refracts some of the Sun's rays into the shadow. Earth's atmosphere contains varying amounts of water (clouds, mist, precipitation) and solid particles (meteoric dust, organic debris, volcanic ash). This material significantly filters and attenuates the sunlight before it's refracted into the umbra. For instance, large or frequent volcanic eruptions dumping huge quantities of ash into the atmosphere are often followed by very dark, red eclipses for several years. Extensive cloud cover along Earth's limb also tends to darken the eclipse by blocking sunlight.

The French astronomer A. Danjon proposed a useful five point scale for evaluating the visual appearance and brightness of the Moon during total lunar eclipses. 'L' values for various luminosties are as follows:

L = 0	Very dark eclipse. Moon almost invisible, especially at mid-totality.
L = 1	Dark Eclipse, gray or brownish in coloration. Details distinguishable only with difficulty.
L = 2	Deep red or rust-colored eclipse. Very dark central shadow, while outer edge of umbra is relatively bright.
L =3	Brick-red eclipse. Umbral shadow usually has a bright or yellow rim.
L=4	Very bright copper-red or orange eclipse. Umbral shadow has a bluish, very bright rim.

The assignment of an 'L' value to lunar eclipses is best done with the naked eye, binoculars or a small telescope near the time of mid-totality. It's also useful to examine the Moon's appearance just after the beginning and before the end of totality. The Moon is then near the edge of the shadow and provides an opportunity to assign an 'L' value to the outer umbra. In making any evaluations, you should record both the instrumentation and the time. Also note any variations in color and brightness in different parts of the umbra, as well as the apparent sharpness of the shadow's edge. Pay attention to the visibility of lunar features within the umbra. Notes and sketches made during the eclipse are often invaluable in recalling important details, events and impressions.

Crater Timings During Lunar Eclipses

In 1702, Pierre de La Hire made a curious observation about Earth's umbra. In order to accurately predict the duration of a lunar eclipse, he found it necessary to increase the radius of the shadow one arc-minute larger than warranted by geometric considerations. Although the effect is clearly related to Earth's atmosphere, it's not completely understood since the shadow enlargement seems to vary from one eclipse to the next. The enlargement can be measured through careful timings of lunar craters as they enter and exit the umbra.

Such observations are best made using a low-power telescope and a clock or watch synchronized with radio time signals. Timings should be made to a precision of 0.1 minute. The basic idea is to record the instant when the most abrupt gradient at the umbra's edge crosses the apparent centre of the crater. In the case of large craters like Tycho and Copernicus, it's recommended that you record the times when the shadow touches the two opposite edges of the crater. The average of these times is equal to the instant of crater bisection.

As a planning guide, Tables 1 and 3 list twenty well-defined craters with predicted umbral immersion and emersion times during the two lunar eclipses of 1989. The predictions assume a 2% enlargement of the umbra and include the effects of Earth's oblateness. Naturally, you should be thoroughly familiar with these features before an eclipse in order to prevent confusion and misidentifications. The four umbral contacts with the Moon's limb can also be used in determining the shadow's enlargement. However, these events are less distinct and difficult to time accurately. Observers are encouraged to make crater timings and to send their results to *Sky and Telescope* for analysis.

Eclipse Altitudes and Azimuths

The altitude (a) and azimuth (A) of the Sun or Moon during an eclipse depends on the time and the observer's geographic coordinates. They are calculated as follows.

$$h = 15\,(GST + UT - \alpha) - \lambda$$
$$a = \text{ArcSin}\,[\,\sin\delta \sin\phi + \cos\delta \cos h \cos\phi\,]$$
$$A = \text{ArcTan}\,[\,-(\cos\delta \sin h)\,/\,(\sin\delta \cos\phi - \cos\delta \cos h \sin\phi)\,]$$

where:
- h = Hour Angle of Sun or Moon
- a = Altitude
- A = Azimuth
- GST = Greenwich Sidereal Time at 0 UT
- UT = Universal Time
- α = Right Ascension of Sun or Moon
- δ = Declination of Sun or Moon
- λ = Observer's Longitude (West +, East -)
- ϕ = Observer's Latitude (North +, South -)

During the eclipses of 1989, the values for GST and the geocentric α and δ of the Sun or Moon (at greatest eclipse) are as follows:

Date	GST	α	δ
20 Feb	10.036	10.273	11.008
7 Mar	11.029	23.212	-5.076
17 Aug	21.699	21.772	-13.591
31 Aug	22.625	10.631	8.647

Acknowledgements

Predictions for "Eclipses During 1989" were generated on a DEC VAX 11/785 computer using algorithms developed primarily from the Explanatory Supplement [1974] with additional algorithms from Meeus, Grosjean and Vanderleen [1966]. The solar and lunar ephemerides were generated from the Jet Propulsion Laboratory Developmental Ephemeris DE-200. For lunar eclipses, the diameter of the umbral shadow was enlarged by 2% to compensate for Earth's atmosphere and the effects of oblateness were included.

The author would like to thank Goddard's Laboratory for Extraterrestrial Physics for several minutes of computer time. All calculations, diagrams, tables and opinions presented in this paper are those of the author and he assumes full responsibility for their accuracy.

References

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Explanatory Supplement to the Astronomical Ephemeris and the American Ephemeris and Nautical Almanac, 1974, Her Majesty's Nautical Almanac Office, London.

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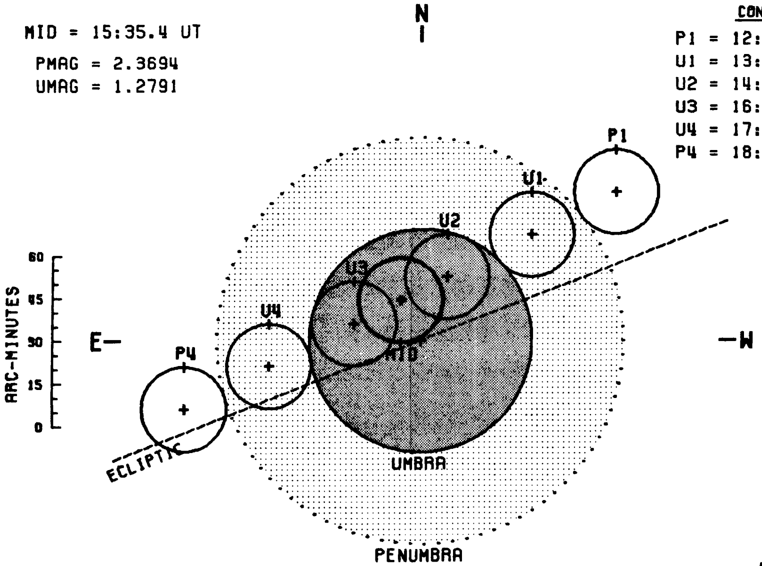
TOTAL LUNAR ECLIPSE - 20 FEB 1989

MID = 15:35.4 UT

PMAG = 2.3694
UMAG = 1.2791

CONTACTS

P1 = 12:31.2 UT
U1 = 13:43.5 UT
U2 = 14:55.9 UT
U3 = 16:15.2 UT
U4 = 17:27.4 UT
P4 = 18:39.7 UT

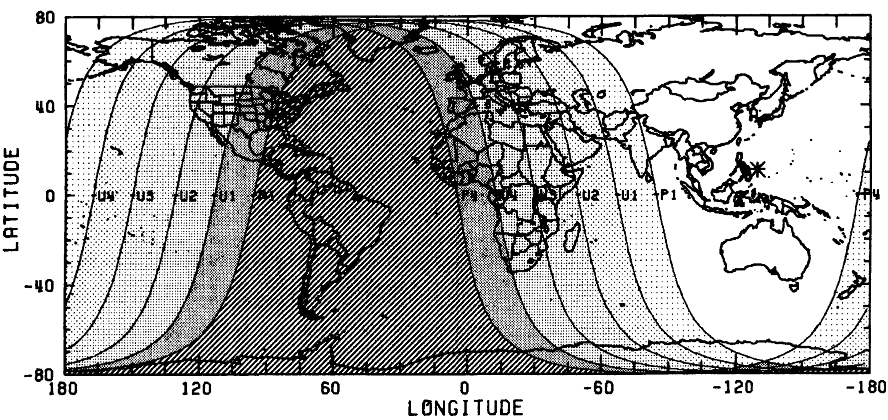


AXIS = 0°.2662
F1 = 1°.1905
F2 = 0°.6514

MOON

RA = 10h 16m 24.s6
DEC = 11° 0' 28."8
SD = 14' 49."9
HP = 0° 54' 25."9

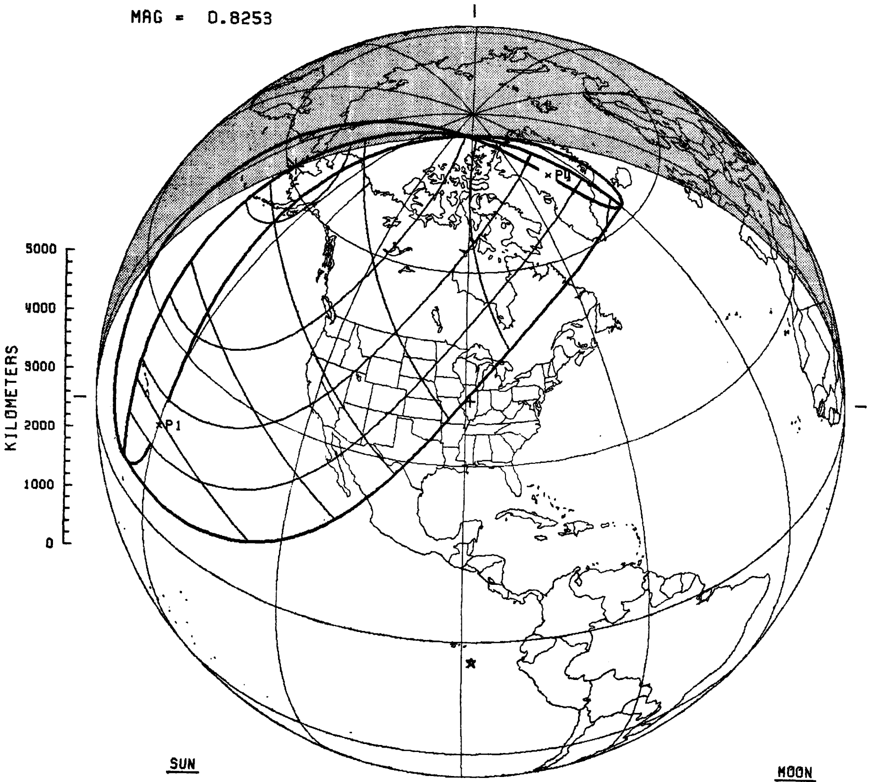
SAROS 123 JD = 2447578.150 ΔT = 56.6 S



PARTIAL SOLAR ECLIPSE - 7 MAR 1989

GREATEST = 18: 7:44.0 UT
CONJUNCTION = 19: 9: 3.2 UT
GAMMA = 1.09815
MAG = 0.8253

CONTACTS
P1 = 16:16:52.0 UT
P4 = 19:58: 9.8 UT



SUN
RA = 23h 12m 43s.3
DEC = -5° -4' -32".2
SD = 16' 6".8
HP = 0° 0' 8".9

MOON
RA = 23h 10m 35s.2
DEC = -4° -5' -29".5
SD = 16' 41".8
HP = 1° 1' 16".4

SAROS 149 (19/71)   JD = 2447593.256   ΔT = 56.6 S

TOTAL LUNAR ECLIPSE - 17 AUG 1989

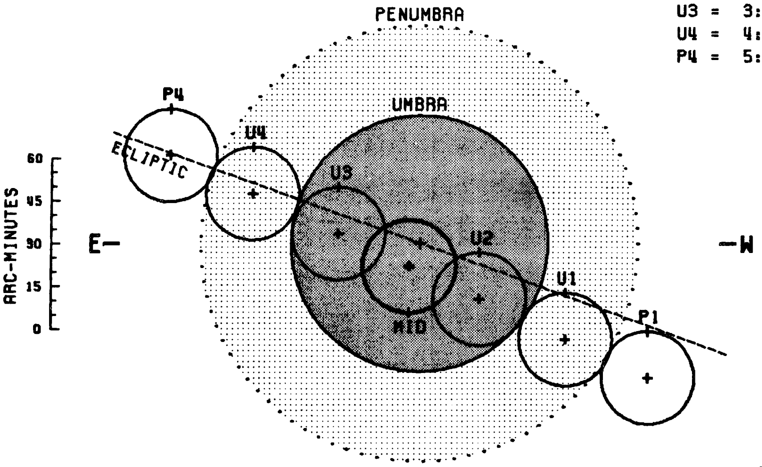
MID = 3: 8.2 UT

PMAG = 2.5758
UMAG = 1.6039

CONTACTS

P1 = 0:23.9 UT
U1 = 1:20.6 UT
U2 = 2:19.9 UT
U3 = 3:56.6 UT
U4 = 4:55.8 UT
P4 = 5:52.4 UT

N



S

AXIS = 0.°1482
F1 = 1.°2729
F2 = 0.°7463

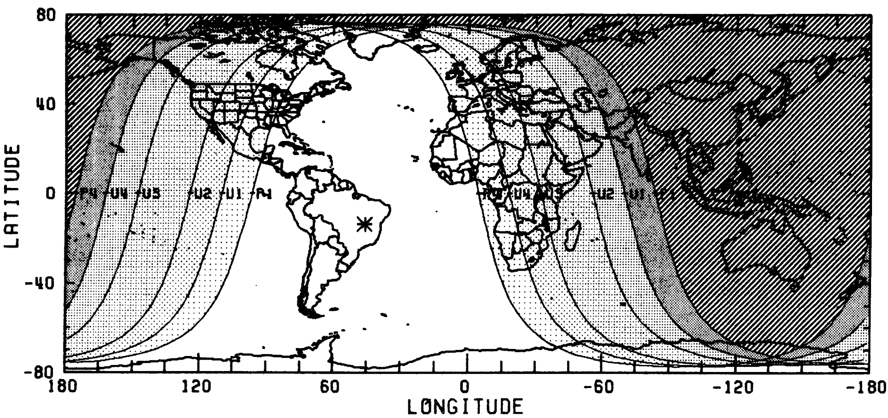
MOON

RA = 21h46m17.s4
DEC = -13°35'27."7
SD = 16'15."3
HP = 0°59'39."3

SAROS 128

JD = 2447755.631

ΔT = 56.9 S

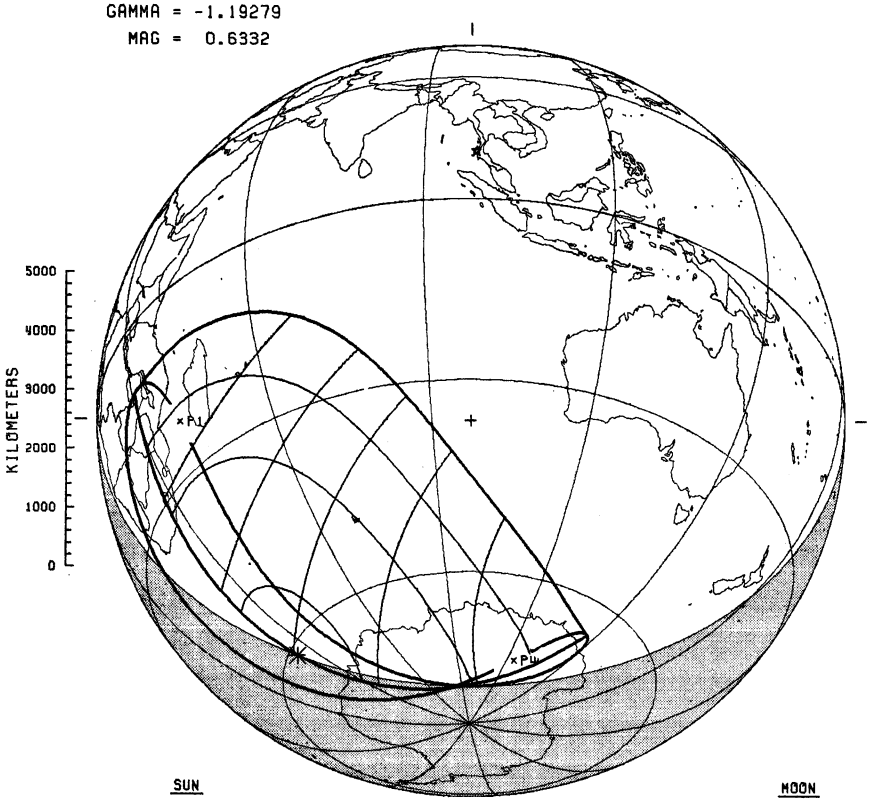


PARTIAL SOLAR ECLIPSE - 31 AUG 1989

GREATEST = 5:30:49.7 UT
CONJUNCTION = 6:43: 4.0 UT
GAMMA = -1.19279
MAG = 0.6332

CONTACTS

P1 = 3:33:37.5 UT
P4 = 7:27:37.7 UT



SUN

RA = $10^h 37^m 52^s.8$
DEC = $8^\circ 38' 48''.1$
SD = $15' 50''.7$
HP = $0^\circ\ 0'\ 8''.7$

MOON

RA = $10^h 35^m 50^s.9$
DEC = $7^\circ 40' 48''.1$
SD = $14' 58''.4$
HP = $0^\circ 54' 57''.0$

SAROS 154 (5/71) JD = 2447769.730 ΔT = 56.9 S

OCCULTATIONS BY THE MOON

PREDICTIONS BY THE
INTERNATIONAL LUNAR OCCULTATION CENTRE
TOKYO, JAPAN

The Moon often passes between Earth and a star, an event called an occultation. During an occultation a star suddenly disappears as the east limb of the Moon crosses the line between the star and observer. The star reappears from behind the west limb some time later. Because the Moon moves through an angle about equal to its own diameter every hour, the longest time for an occultation is about an hour. The time is shorter if the occultation is not central. Occultations are equivalent to total solar eclipses, except they are eclipses of stars other than the Sun.

Since observing occultations is rather easy, amateur astronomers are encouraged to try this activity. The slow, majestic drift of the Moon in its orbit is an interesting part of such observations, and the disappearance or reappearance of a star at the Moon's limb is a remarkable sight, particularly when it occurs as a *graze* near the Moon's northern or southern edge. In the latter case the star may disappear and reappear several times in succession as mountains and valleys in the Moon's polar regions pass by it. On rarer occasions the Moon occults a planet.

Lunar occultation and graze observations are used to refine our knowledge of the Moon's orbit, the shape of the lunar profile, and the fundamental star coordinate system. These observations complement those made by other techniques, such as laser-ranging and photographs. Improved knowledge of the lunar profile is useful in determinations of the Sun's diameter from solar eclipse records. Occultation observations are also useful for detecting double stars and measuring their separations. Binaries with separations as small as $0''.02$ have been discovered visually during grazes. Doubles with separations in this range are useful for filling the gap between doubles which can be directly resolved visually and those whose duplicity has been discovered spectroscopically.

Analysis of lunar occultation observations is currently being done at the U.S. Naval Observatory and the International Lunar Occultation Centre (ILOC). The latter organization is the world clearing house for such observations. Readers who are interested in pursuing a systematic program of lunar occultation observations should write to the ILOC (address on the inside front cover under "Senda") for their booklet: *Guide to Lunar Occultation Observations*.

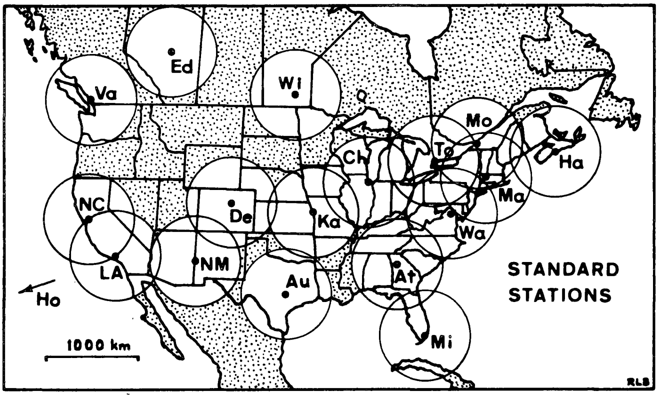
Observers in North America should also contact the International Occultation Timing Association (IOTA), 6 N 106 White Oak Lane, St. Charles, IL 60175, U.S.A. IOTA provides predictions and coordination services for occultation observers. Detailed predictions for any grazing occultation are available ($1.50 U.S. each); instructions concerning the use of predictions are also available ($2.50 U.S.). Annual membership in IOTA is $15.00 U.S. in North America, $20.00 U.S. overseas. Membership includes free graze predictions, descriptive materials, and a subscription to *Occultation Newsletter* (available separately for $10.00 U.S.).

The main information required in a lunar occultation observation is the time of the event and the observer's location. Supplementary information includes the seeing conditions, size of telescope used, timing method used, estimate of the observer's reaction time and the accuracy of the timing, and whether or not the reaction time correction has been applied. The timing should be as accurate as possible, preferably to 0.5 s or better. (A shortwave radio time signal and cassette tape recorder provide a simple, permanent time record). The observer's geodetic latitude, longitude, and altitude should be known to at least the nearest second of arc and 20 metres respectively. These can be determined from a suitable topographical map. For Canada these are available from the Canada Map Office, 615 Booth Street, Ottawa, ON, K1A 0E9. In the United States write to: U.S. Geological Survey, Denver Federal Centre, Bldg. 41, Denver, CO 80225, asking for an index to topographical maps in your state.

The following pages give tables of predictions, and a table and maps of northern or southern limits for many cases where grazing occultations may be seen.

1. TOTAL OCCULTATION PREDICTIONS

The total occultation predictions are for the 18 standard stations identified on the map below; the coordinates of these stations are given in the table headings.



The tables (see pages 100–105) are generally limited to stars of magnitude 5.0 or brighter. The first five columns give for each occultation the date, the Zodiacal Catalogue number of the star, its magnitude, the phenomenon (D.D. or D.B. = disappearance at dark limb or bright limb, respectively; R.D. or R.B. = reappearance at dark limb or bright limb, respectively), and the elongation of the Moon from the Sun in degrees (see page 30). Under each station are given the universal time of the event, factors A and B (see below), and the position angle (from the north point, eastward around the Moon's limb to the point of occurrence of the phenomenon). In several cases, predictions have been replaced by the cryptic notations: GBG (after moonset); GSM (before moonrise); NB2 (Sun's altitude greater than $-6°$); NSG (after sunrise); NBM (before sunset). If A and B give an unrealistic representation, as in the case of near grazes, they are omitted.

The terms A and B are for determining corrections to the times of the phenomena for stations within 500 km of the standard stations. Thus if λ_o, ϕ_o, be the longitude and latitude of the standard station and λ, ϕ, the longitude and latitude of the observer, then for the observer we have: UT of phenomenon = UT of phenomenon at the standard station + $A(\lambda - \lambda_o) + B(\phi - \phi_o)$ where $\lambda - \lambda_o$ and $\phi - \phi_o$ are expressed in degrees and A and B are in minutes of time per degree. Due regard must be paid to the algebraic signs of the terms. Also, to convert UT to the standard time of the observer, see page 25.

As an example, consider the occultation of ZC 890 on Jan. 19, 1989 as seen from Ottawa. For Ottawa, $\lambda = 75.72°$ and $\phi = 45.40°$. The nearest standard station is Montreal, for which $\lambda_o = 73.60°$ and $\phi_o = 45.50°$. Therefore, the UT of the disappearance at the dark limb ("D.D.") is $7^h41^m.5 - 0^m.2(75.72 - 73.60) - 1^m.7(45.40 - 45.50) = 7^h41^m.2$. Note that almost the same result is obtained by using Toronto as the standard station. The elongation of the Moon is 149° which means that the Moon is in the waxing gibbous phase (between first quarter and full). The position angle of disappearance is about 108°.

The total lunar occultation predictions on pages 100–105, being limited to stars of magnitude 5.0 or brighter, are only the more spectacular events and are presented in order to introduce observers to this type of work. The number of events observable at any location increases *rapidly* as predictions are extended to fainter and fainter stars. Observers who wish to pursue this work can obtain more extensive lists from Walter V. Morgan, 10961 Morgan Territory Rd., Livermore, CA 94550, U.S.A., by providing accurate geographical coordinates and a long, self-addressed envelope (with postage). Experienced observers who regularly measure 60 or more events per year may obtain even more detailed predictions computed for their location by contacting: Occultation Project, Nautical Almanac Office, U.S. Naval Observatory, 34th and Massachusetts Ave., NW, Washington, D.C. 20390, U.S.A.

2. GRAZE PREDICTIONS

The table on page 106 lists lunar graze predictions for much of North America for 1989. The events are limited to stars of magnitude 7.5 or brighter which will graze the limb of the Moon when it is at a favourable elongation from the Sun and at least 10° above the observer's horizon (5° in the case of stars brighter than $5\overset{m}{.}5$ and 2° for those brighter than $3\overset{m}{.}5$). For each is given: a chronological sequential number, the Zodiacal Catalogue number and magnitude of the star, the time of the beginning of each graze track (the west end of the track), the percent of the Moon sunlit (a minus sign indicates a waning Moon), and whether the track is the northern (N) or southern (S) limit of the occultation.

The maps on pages 107–110 show the predicted graze tracks. For any one observer, reference to a geographic map and using the scales on the margins of the graze maps plus a few minutes work with a straight edge and pencil will suffice to locate nearby political boundaries on the graze map (An alternative procedure is to use the same tools to transfer the graze tracks of interest to a geographic map of the observer's area). To obtain greater precision, write to the International Occultation Timing Association (see p. 96) for detailed predictions for any graze.

Each track is keyed to the sequential number in the table. For clarity, on the maps each track is numbered twice: once by computer, and a second time manually (the latter number is in an obvious location). Several tracks begin and/or end with a letter *A*, *B*, or *S* indicated. *A* denotes that the Moon is at a low altitude, *B* that the bright limb interferes, and *S* that daylight interferes. The tick marks along the tracks indicate multiples of 5 minutes of every hour. e.g. If the time for the west end of a track is $3^h16^m11^s$, the tick marks proceeding eastward correspond to $3^h20^m00^s$, $3^h25^m00^s$, *etc*. The locations of the North American *standard stations* for lunar total occultation predictions are indicated by small circles on the graze maps (as on the map on page 97, where the names are indicated by symbols).

NAMES OF OCCULTED STARS

The stars which are occulted by the Moon are stars which lie along the zodiac; hence they are known by their number in the *Zodiacal Catalogue* (ZC) compiled by James Robertson and published in the *Astronomical Papers Prepared for the Use of the American Ephemeris and Nautical Almanac*, vol. 10, pt. 2 (U.S. Government Printing Office, Washington, 1940). Robertson's *Zodiacal Catalogue* has been out of print for several years. In 1986 Isao Sato, a member of the Lunar Occultation Observers Group in Japan, republished the ZC. This new edition is based on the epoch J2000 and includes much new data, particularly on double stars. Since stars are not usually recognized by their ZC numbers, the equivalent Bayer designations or Flamsteed numbers of the stars of magnitude 5.0 or brighter occulted during the year are given in the following table:

ZC	Name	ZC	Name	ZC	Name
440	ε Ari	1599	58 Leo	2721	φ Sgr
539	19 Tau	1685	υ Leo	2784	τ Sgr
541	20 Tau	1815	χ Vir	2864	52 h2 Sgr
890	136 Tau	2263	1 Sco	3079	θ Cap
1170	κ Gem	2287	π Sco	3126	ι Cap
1486	31 Leo	2383	τ Sco	3494	λ Psc
1487	α Leo	2617	38B Sgr		

OCCULTED STARS KNOWN TO BE DOUBLE

In the table below is information on double stars for which occultation predictions are given on the next few pages. This information is from the Sato ZC catalogue. The successive columns give: the ZC number of the star, the number of the graze track (where applicable), the number of the star in the Aitken Double Star catalogue, the magnitudes of the brighter (A) and dimmer (B) components, the separation in seconds of arc, the position angle of B from A measured eastward from north, and the epoch for which the Sep. and P.A. are given.

ZC	Graze No.	ADS	A	B	Sep.	P.A.	Epoch
440	-	2257	5.1	5.7	1.4"	203°	1966
539	7	-	4.4	9.	69."	330°	-
890	119	4474	4.8	6.3	0.0013"	-	-
1170	51	6321	4.	10.	7.0"	239°	1962
1486	146	7649	4.5	13.5	7.9"	44°	1934
1487	12, 57	7654	1.3	8.	177."	307°	1924
1599	147	-	5.8	5.8	0.1"	90°	1971
2617	116	-	5.1	5.9	0.26"	12°	1937
2721	-	-	4.1	4.1	0.13"	27°	1973
2864	-	12654	4.5	10.	2.5"	170°	1959

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DATE M D	ZC	MAG.	PH.	ELG. °	HALIFAX, N.S. W 63.6 , N 44.6 TIME H M	A	B	P °	MONTREAL, Q.P. W 73.6 , N 45.5 TIME H M	A	B	P °	TORONTO, ONT. W 79.4 , N 43.7 TIME H M	A	B	P °
JAN. 0	1815	4.8	R.D.	272	9 5.1	-1.3	-0.6	309	8 51.3	-1.4	0.2	295	8 42.1	-1.5	0.9	280
JAN. 19	890	4.5	D.D.	149	7 44.5	-0.1	-1.4	97	7 41.5	-0.2	-1.7	108	7 43.6	-0.2	-2.0	119
JAN. 24	1487	1.3	D.B.	205	2 17.6	...	...	46	2 15.4	...	...	37	2 2.6	...	...	53
JAN. 24	1487	1.3	R.D.	205	2 40.1	...	...	10	2 29.2	...	...	14	2 34.3	...	...	356
FEB. 1	2383	2.9	D.B.	298	13 24.5	-1.8	-0.7	97	13 5.4	-1.9	-0.3	97	12 54.6	-1.9	-0.1	101
FEB. 1	2383	2.9	R.D.	299	14 44.9	-1.4	-1.2	273	14 28.6	-1.7	-0.9	279	14 19.8	-1.9	-0.7	278
MAR. 3	2784	3.4	R.D.	302	NB2				NB2				10 59.7	-1.6	1.6	236
APR. 9	539	4.4	D.D.	41	1 30.7	0.3	-1.4	100	1 31.9	0.2	-1.7	109	1 36.6	0.3	-2.2	122
APR. 9	541	4.0	D.D.	41	1 49.1	0.7	-2.0	127	1 54.6	0.8	-2.9	141	.. ..			
APR. 11	890	4.5	D.D.	68	2 52.4	-0.3	-0.8	65	2 48.2	-0.4	-1.1	77	2 48.0	-0.4	-1.3	89
APR. 13	1170	3.7	D.D.	90	0 8.5	-2.3	0.2	69	NBM				NBM			
MAY 23	2617	4.7	R.D.	210	7 58.6	-1.9	-1.0	285	7 37.8	-2.1	-0.7	294	7 26.8	-2.1	-0.5	295
JULY 20	3126	4.3	R.D.	201	NB2				8 20.4	-1.4	-0.5	256	8 12.5	-1.7	-0.5	262
SEP. 8	2383	2.9	D.D.	86	.. ..				.. ..				1 40.9	...	...	164
SEP. 13	3126	4.3	D.D.	147	2 31.5	-1.0	0.9	33	2 24.3	-0.7	1.5	15	2 17.5	-0.6	2.0	8
OCT. 7	2617	4.7	D.D.	78	GBG				0 11.7	-2.0	-1.6	116	0 2.5	-2.1	-1.3	112
OCT. 17	539	4.4	R.D.	217	9 46.4	-1.4	1.4	211	9 33.0	-1.5	2.0	208	9 18.4	...	...	194
NOV. 3	2721	3.3	D.D.	59	22 49.2	-0.7	-0.2	48	22 42.5	-0.6	0.4	31	22 37.5	-0.7	0.8	25
NOV. 20	1486	4.6	R.D.	272	9 0.4	-2.9	2.6	248	8 34.9	...	...	230	.. ..			
NOV. 22	1685	4.5	R.D.	294	9 10.9	-0.4	-1.8	346	9 5.0	-0.5	-1.1	336	9 3.4	-0.6	-0.6	324
DEC. 11	539	4.4	D.D.	160	7 8.7	-0.5	-1.4	93	7 1.0	-0.8	-1.5	99	6 59.2	-0.9	-1.9	109
DEC. 11	541	4.0	D.D.	160	7 27.8	-0.1	-2.2	119	7 23.3	-0.3	-2.7	126	7 27.4	-0.2	-4.1	143

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					WINNIPEG,MAN				EDMONTON,ALTA.				VANCOUVER,B.C.			
					W 97.2 , N 49.9				W113.4 , N 53.6				W123.1 , N 49.2			
DATE	ZC	MAG.	PH.	ELG.	TIME	A	B	P	TIME	A	B	P	TIME	A	B	P
M D				°	H M			°	H M			°	H M			°
JAN. 0	1815	4.8	R.D.	272	8 29.3	-0.8	1.4	278	GSM				GSM			
JAN. 16	440	4.6	D.D.	113	8 40.2	...	...	143	8 43.4	...	...	158	.. ..			
JAN. 17	539	4.4	D.D.	122	3 6.1	...	...	148	2 23.6	-1.6	0.0	105	2 6.4	-1.7	0.4	105
JAN. 19	890	4.5	D.D.	149	7 22.3	-0.7	-2.3	125	6 59.7	-1.1	-2.2	128	7 2.7	...	...	156
FEB. 1	2383	2.9	D.B.	298	12 28.2	-1.2	0.6	110	GSM				GSM			
FEB. 1	2383	2.9	R.D.	299	13 46.2	-1.6	0.2	278	GSM				GSM			
FEB. 13	539	4.4	D.D.	95	GBG				9 8.6	0.4	-1.4	99	9 20.3	0.6	-1.9	119
FEB. 13	541	4.0	D.D.	95	GBG				9 27.6	0.8	-1.9	128	.. ..			
APR. 11	890	4.5	D.D.	67	2 28.2	-0.8	-1.5	96	NSG				NSG			
APR. 24	2383	2.9	D.B.	217	10 34.9	...	...	156	10 6.2	-1.2	-0.6	154	10 0.9	...	...	170
APR. 24	2383	2.9	R.D.	218	11 13.3	...	...	214	10 52.9	-1.6	-0.1	225	10 31.7	...	...	214
MAY 15	1685	4.5	D.D.	120	GBG				8 43.1	-0.2	-2.1	150	8 50.5	-0.3	-2.3	156
MAY 23	2617	4.7	R.D.	210	6 56.3	-1.3	0.5	299	GSM				GSM			
JUN. 29	440	4.6	R.D.	310	NB2				NB2				10 18.0	0.2	1.5	250
JULY 27	539	4.4	R.D.	295	NB2				NB2				10 54.9	-0.3	1.7	254
JULY 27	541	4.0	R.D.	295	NB2				NB2				11 2.4	0.1	2.1	223
SEP. 8	2383	2.9	D.D.	86	0 51.0	-1.7	-1.0	138	0 25.8	-1.1	-0.1	141	0 17.9	-0.6	-0.5	157
SEP. 8	2383	2.9	R.B.	86	1 52.4	-1.2	-0.5	233	1 27.0	-1.7	-0.0	238	1 6.0	-2.3	1.0	228
SEP. 19	440	4.6	R.D.	232	4 40.6	0.3	2.2	207	4 51.3	0.2	1.8	228	4 46.8	0.4	1.6	232
OCT. 17	539	4.4	R.D.	216	9 6.8	-1.3	1.2	230	8 50.1	-1.2	0.9	253	8 33.5	-1.2	1.3	250
OCT. 17	541	4.0	R.D.	216	9 4.2	...	...	191	8 58.8	-1.0	1.8	223	8 41.1	-0.8	2.2	220
NOV. 20	1486	4.6	R.D.	272	8 19.3	-0.7	3.7	240	8 22.9	-0.2	2.2	259	8 12.0	0.2	2.8	244
NOV. 22	1685	4.5	R.D.	294	8 53.9	-0.1	-0.7	336	GSM				GSM			
DEC. 11	539	4.4	D.D.	160	6 29.0	-1.4	-0.8	91	6 6.1	-1.3	0.5	74	5 50.1	-1.4	0.7	80
DEC. 11	541	4.0	D.D.	160	6 52.5	-1.3	-2.3	121	6 23.8	-1.5	-0.7	102	6 11.0	-1.8	-0.7	111

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DATE	ZC	MAG.	PH.	ELG.	MASSACHUSETTS W 72.5 , N 42.5 TIME	A	B	P	WASHINGTON,D.C. W 77.0 , N 38.9 TIME	A	B	P	CHICAGO,ILLINOIS W 87.7 , N 41.9 TIME	A	B	P
M D				°	H M			°	H M			°	H M			°
JAN. 0	1815	4.8	R.D.	272	8 52.2	-1.6	0.3	289	8 41.3	-2.1	1.3	268	8 26.4	-1.7	2.2	259
JAN. 4	2287	3.0	D.B.	318	.. ..				10 50.7	...	...	38	GSM			
JAN. 4	2287	3.0	R.B.	318	.. ..				11 8.5	...	...	9	GSM			
JAN. 19	890	4.5	D.D.	149	7 47.0	-0.1	-1.8	113	7 53.8	0.0	-2.1	128	7 46.3	-0.1	-2.6	137
JAN. 24	1487	1.3	D.B.	205	2 0.6	-0.5	3.3	63	1 49.8	-0.3	1.9	79	1 56.2	0.2	3.2	59
JAN. 24	1487	1.3	R.D.	205	2 42.7	-0.8	-2.5	349	2 45.4	-0.8	-1.2	331	2 33.2	-0.6	-2.1	347
FEB. 1	2383	2.9	D.B.	298	13 8.6	-2.0	-0.4	100	13 0.5	-2.1	-0.3	106	12 39.2	-1.7	0.1	111
FEB. 1	2383	2.9	R.D.	299	14 33.3	-1.7	-0.9	275	14 27.9	-2.0	-0.7	272	14 4.3	-2.1	-0.3	275
MAR. 3	2784	3.4	R.D.	302	NB2				10 55.7	-1.9	1.8	230	GSM			
APR. 9	539	4.4	D.D.	41	1 36.9	0.3	-1.8	116	1 46.9	0.7	-2.7	137	1 44.5	0.6	-3.6	143
APR. 9	541	4.0	D.D.	41	2 3.5	...	...	155	.. ..				.. ..			
APR. 11	890	4.5	D.D.	68	2 51.9	-0.3	-1.1	82	2 55.0	-0.2	-1.3	97	2 46.9	-0.5	-1.6	104
APR. 12	1170	3.7	D.D.	90	23 49.0	-2.1	-0.3	90	NBM				NBM			
MAY 23	2617	4.7	R.D.	210	7 42.4	-2.2	-0.7	289	7 34.5	-2.3	-0.5	287	7 10.2	-2.0	-0.0	293
JULY 20	3126	4.3	R.D.	201	8 23.1	-1.2	-0.3	247	8 17.5	-1.5	-0.0	247	7 56.8	-2.3	-0.4	274
SEP. 8	2383	2.9	D.D.	86	.. ..				.. ..				1 24.2	...	...	155
SEP. 8	2383	2.9	R.B.	86	.. ..				.. ..				2 2.1	...	...	209
SEP. 13	3126	4.3	D.D.	147	2 20.6	-0.9	1.5	22	2 10.3	-1.0	1.8	21	2 9.9	...	...	355
SEP. 19	440	4.6	R.D.	232	.. ..				.. ..				4 10.3	...	...	163
OCT. 6	2617	4.7	D.D.	78	24 19.4	-2.3	-2.0	124	24 15.7	-2.6	-2.0	125	23 46.2	-2.2	-0.7	106
OCT. 17	539	4.4	R.D.	216	9 24.2	...	...	186	.. ..				8 55.6	...	...	179
OCT. 19	890	4.5	R.D.	243	8 20.5	...	...	343	8 25.6	-2.2	-2.6	319	.. ..			
OCT. 31	2287	3.0	D.B.	25	.. ..				21 41.0	...	...	16	.. ..			
OCT. 31	2287	3.0	R.B.	25	.. ..				21 56.6	...	...	353	.. ..			
NOV. 3	2721	3.3	D.D.	59	22 42.3	-0.8	0.3	39	22 36.4	-1.1	0.5	40	NBM			
NOV. 22	1685	4.5	R.D.	294	9 8.5	-0.7	-0.8	326	9 7.0	-0.8	-0.2	309	8 59.5	-0.5	-0.1	311
DEC. 11	539	4.4	D.D.	160	7 6.8	-0.7	-1.8	108	7 11.9	-0.6	-2.7	127	6 54.5	-1.2	-2.5	121
DEC. 11	541	4.0	D.D.	160	7 32.6	-0.0	-3.5	139	.. ..				.. ..			

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					MIAMI, FLORIDA W 80.3, N 25.8				ATLANTA, GEORGIA W 84.3, N 33.8				AUSTIN, TEXAS W 97.8, N 30.2			
DATE M D	ZC	MAG.	PH.	ELG. °	TIME H M	A	B	P °	TIME H M	A	B	P °	TIME H M	A	B	P °
JAN. 4	2287	3.0	D.B.	317	10 19.4	-0.8	0.5	100	GSM				GSM			
JAN. 4	2287	3.0	R.D.	318	11 27.7	-0.8	-0.5	311	11 21.1	-0.2	-0.7	326	11 16.4	-0.5	0.4	291
JAN. 19	890	4.5	D.D.	149	.. ..				8 9.9	0.9	-3.7	160	.. ..			
JAN. 24	1487	1.3	D.B.	205	1 39.8	-0.4	-0.4	127	1 41.2	-0.1	1.0	96	GSM			
JAN. 24	1487	1.3	R.D.	205	2 45.8	-0.9	0.5	281	2 43.4	-0.7	-0.3	310	2 37.5	-0.3	-0.1	302
FEB. 1	2383	2.9	D.B.	298	13 2.6	-2.3	-1.4	133	12 46.9	-2.0	-0.5	120	12 28.9	-0.8	-1.2	148
FEB. 1	2383	2.9	R.D.	299	14 24.4	-2.6	0.3	248	14 14.2	-2.4	-0.2	264	13 36.2	-3.1	1.1	247
MAR. 3	2784	3.4	R.D.	301	.. ..				10 28.8	...	...	207	.. ..			
APR. 11	890	4.5	D.D.	68	3 16.1	0.4	-2.0	135	3 1.6	-0.1	-1.8	120	3 12.3	0.7	-3.7	158
APR. 13	1170	3.7	D.D.	90	0 4.3	-1.2	-3.9	159	NBM				NBM			
APR. 15	1487	1.3	D.D.	123	20 47.3	-0.5	0.6	100	20 57.6	-0.3	2.8	64	GSM			
APR. 15	1487	1.3	R.B.	123	21 57.6	-1.2	-0.8	311	21 42.2	-0.8	-2.4	344	21 38.6	-0.6	-1.3	330
MAY 23	2617	4.7	R.D.	210	7 29.2	-2.8	0.2	264	7 18.6	-2.5	-0.1	280	6 45.8	-2.2	0.7	268
JUN. 17	2263	4.8	D.D.	154	.. ..				.. ..				2 45.3	...	...	54
JUN. 29	440	4.6	R.D.	310	.. ..				.. ..				9 34.3	0.9	2.7	189
JULY 20	3126	4.3	R.D.	201	8 5.8	-1.3	1.2	222	8 4.8	-1.9	0.2	249	7 32.3	-2.7	0.2	269
SEP. 11	2864	4.7	D.D.	124	GBG				GBG				6 16.4	-0.3	0.6	40
SEP. 13	3126	4.3	D.D.	147	1 41.2	-1.7	1.9	42	1 52.0	-1.2	2.3	20	1 26.6	-1.2	3.0	14
OCT. 7	2617	4.7	D.D.	78	.. ..				0 4.9	-3.1	-1.9	127	NBM			
OCT. 19	890	4.5	R.D.	243	8 28.6	-2.5	0.5	267	8 17.3	-2.3	-0.9	299	7 49.2	-2.1	-0.5	299
OCT. 31	2287	3.0	D.D.	25	21 23.7	-1.6	0.2	61	21 25.3	...	...	30	EL25			
OCT. 31	2287	3.0	R.B.	26	22 34.3	-1.7	-2.2	306	22 1.0	...	...	341	21 38.2	-2.6	-3.9	341
NOV. 22	1685	4.5	R.D.	294	8 54.5	-1.6	2.2	255	8 59.6	-0.9	0.6	285	8 46.3	-0.4	1.6	261

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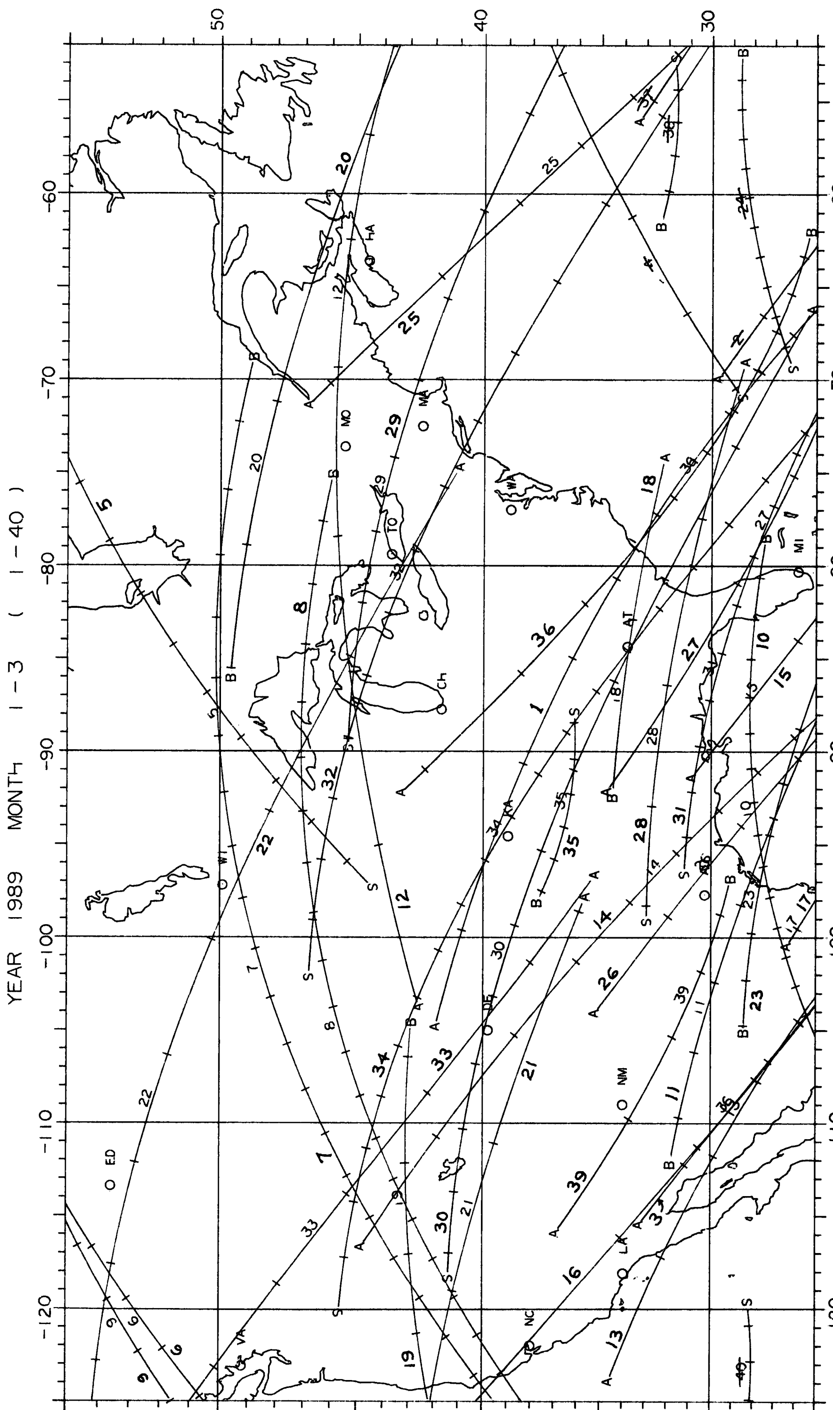
DATE	ZC	MAG.	PH.	ELG.	KANSAS CITY, MO. W 94.5 , N 39.0 TIME				DENVER,COLORADO W105.0 , N 39.8 TIME				NEW MEX.-ARIZONA W109.0 , N 34.0 TIME			
M D				°	H M	A	B	P °	H M	A	B	P °	H M	A	B	P °
JAN. 19	890	4.5	D.D.	149	7 57.0	...	...	162	.. ..				.. ..			
JAN. 24	1487	1.3	R.D.	205	2 34.0	-0.5	-1.2	336	GSM				GSM			
FEB. 1	2383	2.9	D.B.	298	12 28.3	-1.4	-0.0	123	12 17.2	-0.7	-0.2	138	12 20.3	0.2	-1.6	163
FEB. 1	2383	2.9	R.D.	299	13 49.7	-2.3	0.2	268	13 26.5	-2.2	0.9	258	13 8.0	-3.1	2.2	236
MAR. 27	2263	4.8	R.D.	234	.. ..				.. ..				7 33.2	...	...	359
APR. 11	890	4.5	D.D.	68	2 49.1	-0.4	-2.0	121	2 42.2	-0.5	-2.7	135	3 4.4	...	...	172
MAY 23	2617	4.7	R.D.	210	6 56.7	-1.9	0.3	286	6 39.4	-1.5	0.8	280	6 27.9	-1.6	1.1	265
JUN. 29	440	4.6	R.D.	310	9 53.9	0.3	2.3	206	9 58.5	0.3	1.9	222	9 49.2	0.5	1.8	216
JULY 20	3126	4.3	R.D.	200	7 40.8	-2.8	-0.4	282	7 5.7	...	...	314	6 58.7	...	...	302
JULY 27	539	4.4	R.D.	295	10 33.1	...	...	181	10 39.7	0.0	2.6	210	10 25.2	0.4	2.7	202
SEP. 8	2383	2.9	D.D.	86	1 15.1	...	...	157	0 50.1	-1.9	-1.9	155	1 7.4	...	...	187
SEP. 8	2383	2.9	R.B.	86	1 54.7	...	...	210	1 39.7	-2.0	0.9	220	1 11.7	...	...	192
SEP. 11	2864	4.7	D.D.	124	6 23.4	0.4	1.2	17	.. ..				6 24.7	...	...	356
SEP. 13	3126	4.3	D.D.	147	1 59.2	...	...	349	.. ..				NSG			
SEP. 19	440	4.6	R.D.	232	4 11.4	...	...	177	4 22.1	0.6	2.2	200	4 11.7	0.8	2.4	192
OCT. 17	539	4.4	R.D.	216	.. ..				8 32.1	-0.6	4.3	193	.. ..			
NOV. 22	1685	4.5	R.D.	294	8 55.8	-0.4	0.4	297	GSM				GSM			
DEC. 11	539	4.4	D.D.	160	6 55.4	...	...	141	6 33.1	-2.2	-3.7	134	.. ..			
DEC. 31	3079	4.2	D.D.	35	GBG				1 50.4	-0.2	-0.1	52	1 49.9	-0.5	-0.3	65

LUNAR OCCULTATION 1989 UT

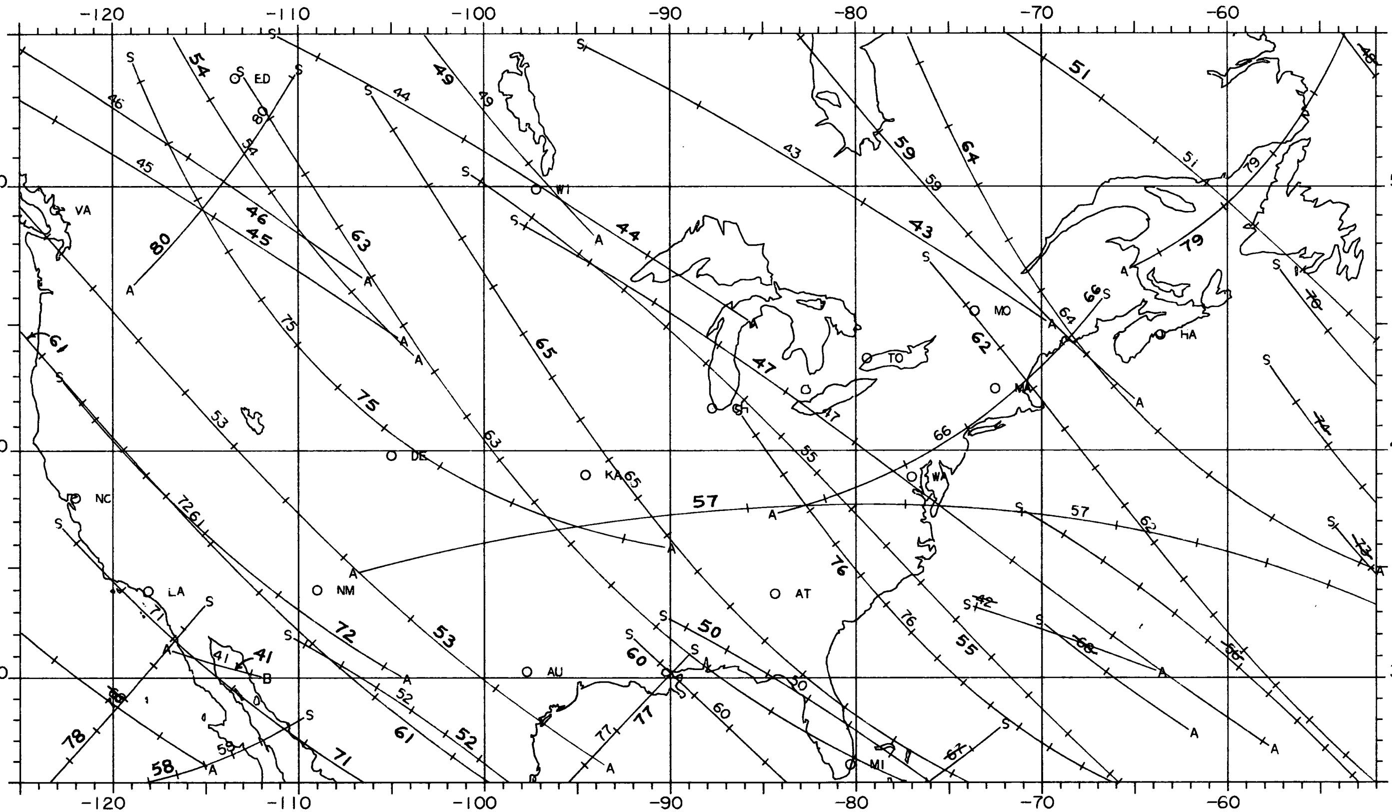
					LOS ANGELES,CAL. W118.3 , N 34.1				N. CALIFORNIA W122.0 , N 38.0				HONOLULU,HAWAII W157.9 , N 21.3			
DATE M D	ZC	MAG.	PH.	ELG. °	TIME H M	A	B	P °	TIME H M	A	B	P °	TIME H M	A	B	P °
FEB. 17	1170	3.7	D.D.	145	.. ..				.. ..				13 4.0	-0.3	-1.4	116
FEB. 20	1487	1.3	D.D.	177	.. ..				.. ..				10 9.8	-3.3	-0.4	99
FEB. 20	1487	1.3	R.B.	178	.. ..				.. ..				11 26.2	-0.5	-3.4	348
MAR. 27	2263	4.8	R.D.	234	7 38.3	0.2	-1.0	333	GSM				.. ..			
MAR. 27	2287	3.0	D.B.	235	.. ..				.. ..				10 18.1	-1.3	0.9	87
MAR. 27	2287	3.0	R.D.	236	.. ..				.. ..				11 23.7	-0.5	-1.4	326
MAY 15	1685	4.5	D.D.	121	GBG				9 19.1	-0.1	-2.9	172	.. ..			
MAY 23	2617	4.7	R.D.	209	6 14.1	-1.4	1.6	252	GSM				.. ..			
JUN. 17	2287	3.0	D.D.	155	.. ..				.. ..				5 42.5	-1.4	0.2	103
JUN. 17	2287	3.0	R.B.	156	.. ..				.. ..				7 3.1	-1.6	-0.9	309
JUN. 29	440	4.6	R.D.	310	9 53.7	0.5	1.6	226	10 1.3	0.4	1.5	236	GSM			
JULY 20	3126	4.3	R.D.	200	6 30.5	...	...	322	.. ..				GSM			
JULY 27	539	4.4	R.D.	294	10 27.9	0.2	2.1	220	10 35.8	0.0	1.8	234	GSM			
JULY 27	541	4.0	R.D.	295	.. ..				10 35.6	0.7	2.8	196	GSM			
AUG. 13	2617	4.7	D.D.	131	8 0.2	-1.6	-1.6	106	7 49.8	-1.4	-1.1	90	6 35.1	-2.9	0.2	90
OCT. 17	539	4.4	R.D.	216	8 3.9	-0.1	3.8	195	8 13.8	-0.8	2.5	217	7 27.6	0.0	1.4	237
OCT. 17	541	4.0	R.D.	215	.. ..				.. ..				7 28.9	0.7	2.4	202
DEC. 11	539	4.4	D.D.	159	.. ..				5 53.9	-2.8	-1.7	122	4 40.2	-1.2	0.2	104
DEC. 31	3079	4.2	D.D.	35	1 44.5	-0.6	0.2	50	1 44.6	-0.3	0.7	32	NSG			
DEC. 34	3494	4.6	D.D.	75	6 10.8	-0.1	2.2	10	.. ..				5 26.0	-0.9	2.3	21

No.	ZC	m_v	UT at Start of Track in West			%	L
1	1815	4.8	Jan.	0	$7^h53^m18^s$	-48	S
3	2297	6.9		4	$13^h03^m12^s$	-12	S
5	399	5.7		15	$23^h47^m05^s$	66	S
6	536	5.4		17	$2^h14^m28^s$	77	S
7	539	4.4		17	$2^h16^m37^s$	77	S
8	542	5.8		17	$2^h41^m01^s$	77	S
9	541	4.0		17	$2^h49^m59^s$	77	S
10	538	5.6		17	$2^h56^m21^s$	77	S
11	569	5.4		17	$6^h21^m40^s$	78	N
12	1487	1.3		24	$2^h14^m14^s$	-95	N
13	1885	7.4		28	$8^h16^m05^s$	-66	S
14	1993	6.8		29	$9^h21^m34^s$	-56	S
15	2370	6.8	Feb.	1	$9^h59^m34^s$	-27	S
16	2383	2.9		1	$12^h30^m02^s$	-26	S
17	2702	6.8		3	$12^h19^m39^s$	-10	S
18	233	6.2		11	$2^h50^m10^s$	29	N
19	244	6.9		11	$3^h30^m13^s$	29	S
20	370	6.1		12	$2^h24^m50^s$	40	N
21	387	6.9		12	$5^h35^m24^s$	41	N
22	518	5.9		13	$4^h57^m49^s$	52	N
23	673	6.6		14	$3^h14^m52^s$	62	N
25	2164	6.8		27	$6^h39^m24^s$	-65	S
26	2174	6.4		27	$7^h51^m36^s$	-64	S
27	2784	3.4	Mar.	3	$10^h05^m54^s$	-24	S
28	311	6.5		11	$1^h04^m25^s$	15	N
29	603	7.5		13	$0^h29^m42^s$	35	N
30	616	5.6		13	$2^h23^m21^s$	35	N
31	768	7.0		14	$0^h56^m23^s$	46	N
32	771	6.1		14	$1^h20^m42^s$	46	N
33	797	6.3		14	$6^h27^m56^s$	48	N
34	1089	6.8		16	$2^h35^m35^s$	67	N
35	2276	5.6		27	$10^h54^m02^s$	-78	N
36	2406	6.0		28	$7^h54^m14^s$	-70	S
39	2727	7.2		30	$10^h40^m23^s$	-49	S
41	3031	5.9	Apr.	1	$11^h42^m23^s$	-28	S
43	538	5.6		9	$1^h46^m00^s$	12	N
44	555	6.8		9	$2^h53^m30^s$	12	N
45	571	6.9		9	$4^h13^m46^s$	13	N
46	574	6.8		9	$4^h29^m53^s$	13	N
47	885	5.6		11	$1^h49^m32^s$	30	N
49	909	6.1		11	$6^h00^m24^s$	32	N
50	1042	6.6		12	$0^h52^m51^s$	40	N
51	1170	3.7		13	$0^h11^m53^s$	50	N
52	1180	7.1		13	$2^h13^m23^s$	51	N
53	1195	6.7		13	$5^h57^m02^s$	53	N
54	1200	6.9		13	$7^h46^m23^s$	53	N
55	1304	6.6		14	$2^h09^m01^s$	61	N
57	1487	1.3		15	$21^h15^m01^s$	78	N
58	2852	7.4		27	$11^h49^m38^s$	-64	N
59	994	6.5	May	9	$2^h09^m46^s$	16	N
60	1253	7.4		11	$1^h21^m07^s$	34	N
61	1269	7.0		11	$4^h32^m16^s$	36	N
62	1466	5.2		13	$0^h45^m03^s$	54	N
63	1476	7.0		13	$4^h06^m25^s$	56	N
64	1567	6.3		14	$3^h22^m46^s$	65	N
65	1573	7.0		14	$3^h37^m07^s$	65	N
66	3474	6.0		29	$7^h37^m46^s$	-37	N
71	1340	6.6	June	8	$3^h58^m20^s$	21	N
72	1343	6.6		8	$4^h21^m34^s$	21	N
75	1635	5.4		11	$4^h48^m31^s$	49	N
76	1809	6.9		13	$1^h52^m35^s$	67	N
77	3177	6.0		23	$10^h07^m22^s$	-81	N
78	3322	6.4		24	$11^h36^m16^s$	-71	N
79	3416	5.6		25	$4^h38^m05^s$	-63	N
80	438	6.7		29	$9^h50^m30^s$	-17	N
81	1685	4.5	July	9	$0^h34^m40^s$	31	N
83	538	5.6		27	$10^h16^m00^s$	-29	N

No.	ZC	m_v	UT at Start of Track in West			%	L
84	555	6.8	July	27	$11^h50^m43^s$	-28	N
86	2174	6.4	Aug.	10	$3^h46^m46^s$	54	N
88	2297	6.9		11	$2^h40^m44^s$	63	N
89	2586	6.0		13	$4^h12^m45^s$	81	S
90	336	7.4		22	$4^h04^m33^s$	-68	N
91	370	6.1		22	$9^h56^m33^s$	-65	N
92	470	7.0		23	$3^h19^m49^s$	-57	N
94	518	5.9		23	$12^h26^m08^s$	-53	N
95	994	6.5		26	$8^h21^m55^s$	-23	N
96	1013	6.9		26	$11^h12^m17^s$	-21	N
97	1117	5.1		27	$6^h49^m48^s$	-15	N
98	1269	7.0		28	$11^h10^m36^s$	-7	N
99	2383	2.9	Sept.	8	$1^h16^m32^s$	46	S
100	2540	7.0		9	$5^h33^m33^s$	58	S
101	603	7.5		20	$6^h52^m11^s$	-69	N
102	616	5.6		20	$8^h58^m22^s$	-68	N
105	773	6.9		21	$6^h46^m36^s$	-58	N
107	797	6.3		21	$11^h49^m06^s$	-56	N
108	906	6.8		22	$2^h37^m55^s$	-49	N
109	958	6.7		22	$9^h48^m40^s$	-46	N
110	958	6.7		22	$10^h20^m00^s$	-46	S
111	1085	7.0		23	$6^h19^m31^s$	-37	N
112	1094	6.9		23	$7^h31^m50^s$	-36	N
113	1221	6.2		24	$6^h52^m14^s$	-27	N
114	1222	7.2		24	$7^h11^m28^s$	-27	N
115	1340	6.6		25	$7^h22^m53^s$	-18	N
116	2617	4.7	Oct.	7	$0^h27^m36^s$	39	S
117	3069	6.2		10	$2^h50^m22^s$	71	S
118	3206	5.2		11	$2^h37^m24^s$	81	S
119	890	4.5		19	$6^h56^m27^s$	-73	N
120	1046	6.9		20	$6^h02^m26^s$	-63	S
121	1049	6.6		20	$6^h26^m31^s$	-63	S
122	1061	6.1		20	$8^h38^m20^s$	-62	N
123	1062	6.3		20	$9^h10^m38^s$	-62	N
124	1068	6.9		20	$10^h27^m59^s$	-61	S
127	1215	6.8		21	$13^h19^m53^s$	-50	S
129	1298	6.5		22	$4^h47^m49^s$	-43	N
130	1302	6.7		22	$4^h51^m13^s$	-43	N
132	1303	6.8		22	$5^h07^m32^s$	-42	N
133	1312	6.8		22	$7^h24^m38^s$	-42	S
136	2879	6.6	Nov.	4	$23^h21^m50^s$	33	S
137	3014	7.3		6	$0^h14^m25^s$	44	S
139	3167	7.1		7	$4^h51^m33^s$	56	S
140	3416	5.6		9	$1^h15^m18^s$	76	S
141	1261	7.2		18	$5^h45^m53^s$	-69	S
142	1282	6.6		18	$11^h01^m03^s$	-67	S
143	1287	6.7		18	$12^h53^m51^s$	-67	S
144	1385	6.5		19	$7^h49^m05^s$	-58	S
145	1396	7.1		19	$12^h14^m01^s$	-57	S
146	1486	4.6		20	$7^h49^m35^s$	-48	S
147	1599	5.0		21	$12^h51^m51^s$	-36	S
148	1778	7.1		23	$11^h17^m53^s$	-20	S
149	1872	7.3		24	$9^h16^m57^s$	-14	S
150	2988	6.8	Dec.	3	$3^h08^m08^s$	20	S
151	3105	6.2		3	$23^h21^m57^s$	28	S
152	3252	7.0		5	$2^h32^m17^s$	39	S
153	3357	6.8		5	$22^h35^m44^s$	49	S
155	3380	6.2		6	$3^h12^m44^s$	50	S
157	1331	5.9		16	$5^h21^m03^s$	-84	S
158	1539	7.4		18	$4^h09^m26^s$	-67	S
159	1649	6.3		19	$9^h12^m57^s$	-55	S
160	1852	6.0		21	$13^h05^m08^s$	-35	S
161	1944	5.6		22	$8^h35^m00^s$	-28	S
162	1960	6.9		22	$13^h01^m09^s$	-26	S
163	2164	6.8		24	$10^h30^m43^s$	-12	S
164	2174	6.4		24	$11^h43^m48^s$	-12	S
165	3334	6.3		32	$23^h43^m01^s$	24	S
166	3460	7.1		33	$22^h14^m55^s$	33	S


YEAR 1989 MONTH 1 - 3 (1 - 40)
50
40
30
-60
-70
-80
-90
-100
-110
-120

YEAR 1989 MONTH 4 - 6 (41 - 80)



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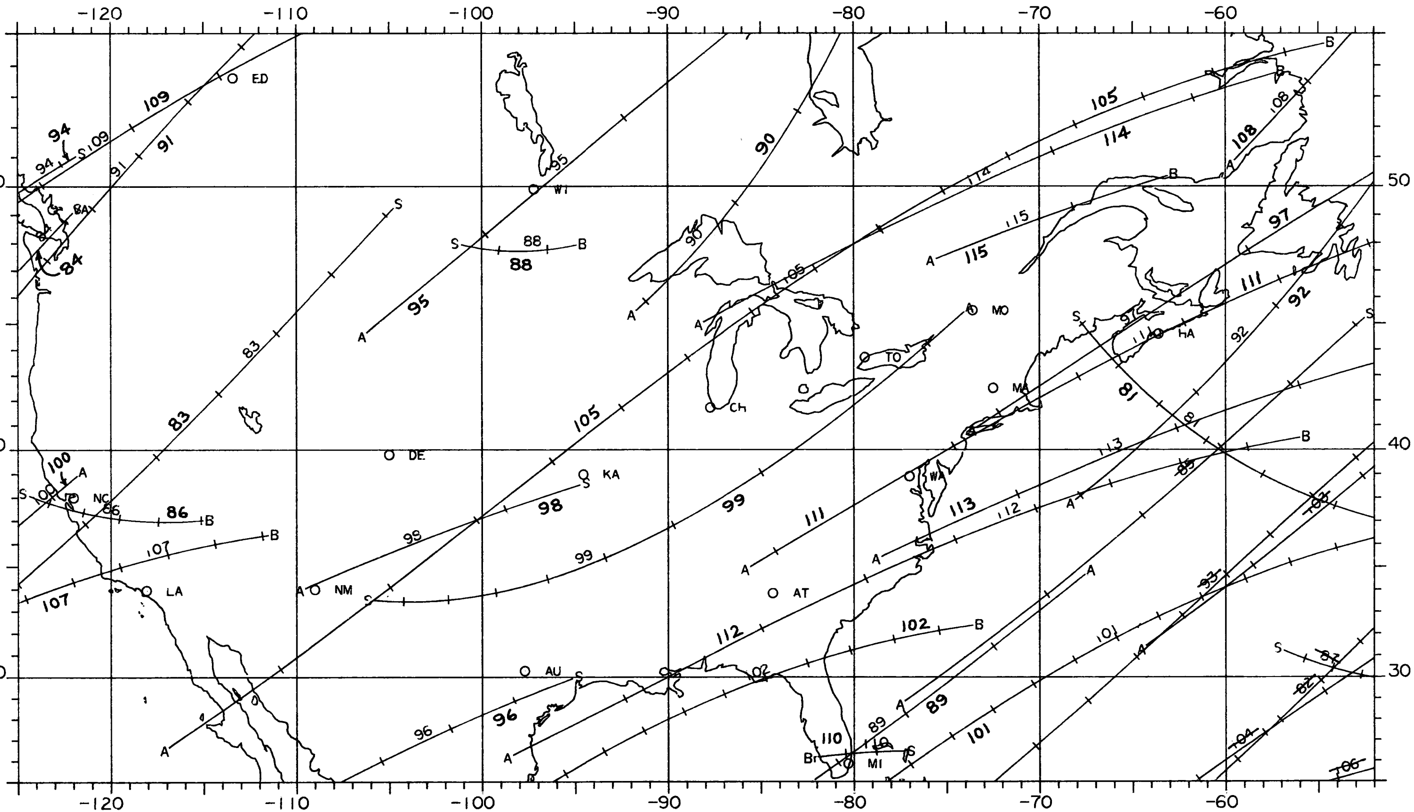

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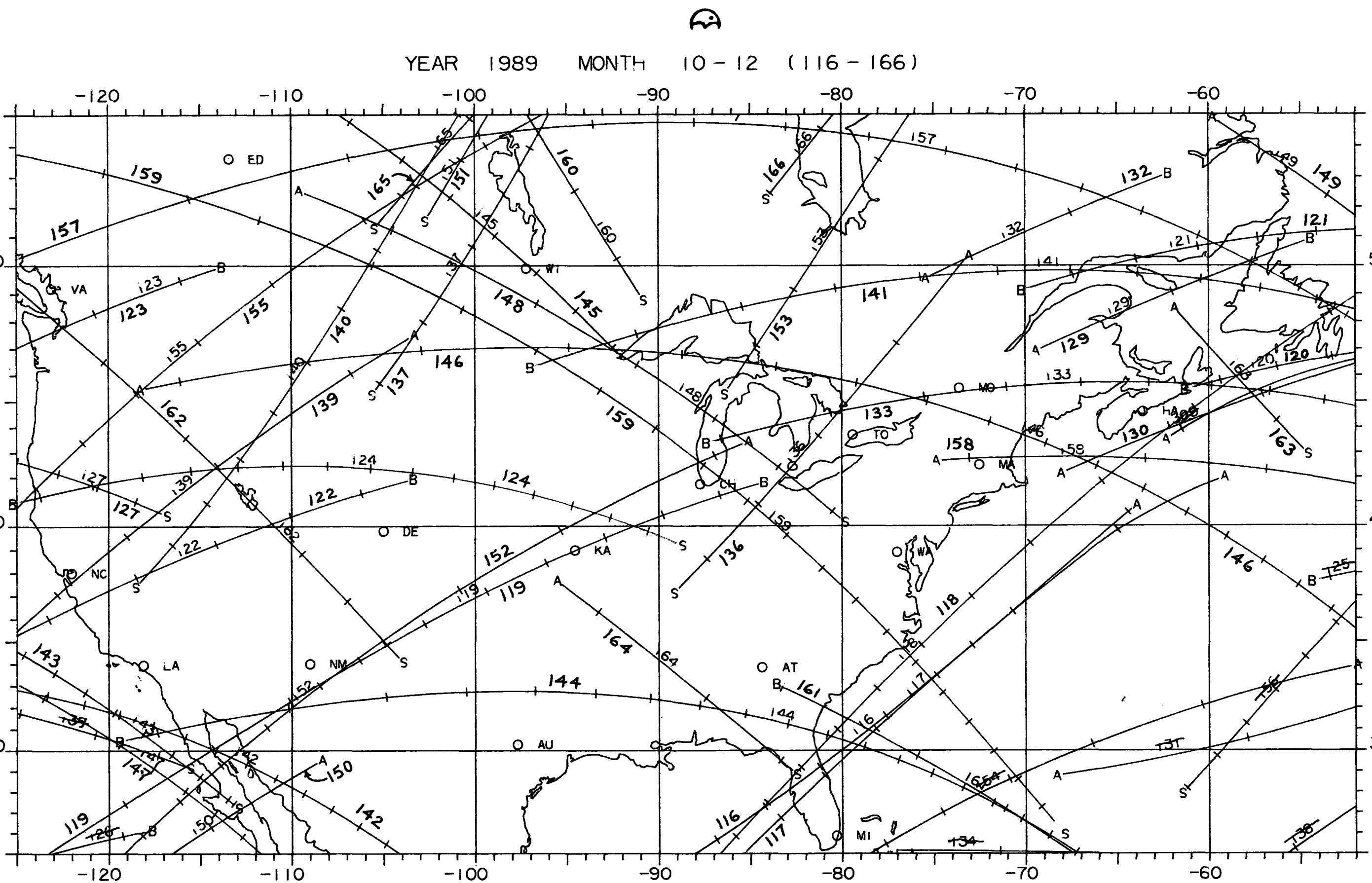


TIDES

The tidal aspect of gravitation produces some of the most interesting phenomena in the universe, from the structure of interacting galaxies, such as M51, to the volcanoes of Io, the synchronous rotation of our Moon, and the pulse of the seas on our planet. Perhaps because they occur at our feet, the tides of the oceans often are overlooked when considering the heavens. These tides were known to the ancients, but an understanding of their origin came only three centuries ago with the publication of Newton's *Principia*.

In the Newtonian context, tides originate in the fact that the force of gravity decreases with distance from a massive body. The Moon exerts a force on Earth, and Earth responds by accelerating toward the Moon; however, the waters on the side facing the Moon, being closer to the Moon, accelerate more and fall ahead of Earth. Similarly, Earth itself accelerates more than the waters on the far side and falls ahead of these waters. Thus two aqueous bulges are produced, one on the side of Earth facing the Moon, and one on the side facing away from the Moon. As Earth rotates on its axis beneath these two bulges, the rise and fall of the oceans results. If Earth had no rigidity, the entire planet would flex freely in the same fashion, the ocean bottoms would rise and fall too, and there would be virtually no water tides. The very existence of the tides indicates that on a time scale of several hours, our planet displays considerable rigidity.

Because of the Moon's orbital motion, it transits on the average 50.47 minutes later each day. Thus on successive days, high tides recur about 50 minutes later (or for the many regions experiencing two high tides daily, these tides recur at intervals of 12^h25^m).

Although the Sun exerts a gravitational force 180 times as strong as does the Moon on Earth, because the Moon is so much closer, the *variation* in the Moon's force across Earth's diameter is about 2.2 times larger than the variation in the Sun's force. As noted above, it is this variation that produces tides, thus the pair of bulges raised by the Moon are considerably larger than the pair raised by the Sun. As the Moon goes through its monthly cycle of phases, these two pairs of tidal bulges get in and out of step, combining in step to produce "spring" tides (no connection with the season) when the Moon is new or full, and out of step to produce "neap" tides when the Moon is at first or last quarter.

Another factor having a substantial influence on tidal ranges is the elliptical shape of the Moon's orbit. Although the Moon is only 9 to 14% closer at perigee than at apogee, because the *variation* in its gravitational force varies inversely as the cube of its distance (the force itself varies inversely as the square of the distance), the Moon's tidal influence is 30 to 48% greater at perigee than at apogee. In some areas, such as the Bay of Fundy in eastern Canada, the perigee-apogee influence is greater than the spring-neap influence. Although the variation in the Moon's distance is not readily apparent to observers viewing the Moon directly, to observers near the shores of the Bay of Fundy, the three to six metre *increase* in the vertical tidal range makes it obvious when the Moon is near perigee, clear skies or cloudy!

There are many astronomical factors influencing the tides. These can be sorted out according to the periods they produce. The periods of the more important factors are: (1) Semidiurnal, 12^h00^m (two solar-induced tidal bulges, as described above); (2) Semidiurnal, 12^h25^m (two lunar-induced tidal bulges, as described above); (3) Diurnal, 24^h50^m (the changing declinations of the Moon and Sun shift the pairs of tidal budges out of Earth's equatorial plane resulting in a tidal component with a one day period. In some areas, such as parts of the southern coast of Canada's Gulf of St. Lawrence, this is the dominant tide); (4) Bimonthly, 13.66 days (variation in the Moon's declination); (5) Bimonthly, 14.77 days (spring-neap cycle, described above); (6) Monthly, 27.55 days (perigee-apogee cycle, described above); (7) Biyearly, 182.6 days (variation in the Sun's declination); (8) Yearly, 365.26 days (perihelion-aphelion variation in the Sun's tidal influence); (9) 8.8 years (rotation period of the Moon's perigee); and (10) 18.6 years (rotation period of the nodes of the Moon's orbit).

In addition to astronomical factors, the tides on Earth are strongly influenced by the sizes, boundaries, and depths of ocean basins and inlets, and by Earth's rotation, winds, and barometric pressure fluctuations. Tides typically have ranges (vertical high-to-low) of a metre or two, but there are regions in the oceans where the various influences conspire to produce virtually no tides at all, and others where the tides are greatly amplified. Among the latter regions are the Sea of Okhotsk, the northern coast of Australia, the English Channel, Ungava Bay in northern Quebec, and the Bay of Fundy between New Brunswick and Nova Scotia. The tidal ranges in these regions are of the order of 10 metres. The highest tides on Earth occur in Minas Basin, the eastern extremity of the Bay of Fundy, where the mean tide range is 12 metres and can reach 16 metres when the various factors affecting the tides are in phase (although the highest tides occur typically a day or two after the astronomical influences reach their peak).

The primary cause of the immense tides of Fundy is a resonance of the Bay of Fundy-Gulf of Maine system. The system is effectively bounded at its outer end by the edge of the continental shelf with its approximately 40:1 increase in depth. The system has a natural period of approximately 13 hours, a Q-value of about 5, and is driven near resonance by the dominant semidiurnal tides of the Atlantic Ocean (but not to any extent directly by the Moon and Sun).

Through friction, the tides convert Earth's rotational energy into heat at a rate of about 3 TW. Approximately 1% of this occurs in the Bay of Fundy and, since 1984, a tiny portion of this (20 MW peak) is being turned into commercial electric power at the Annapolis Basin tidal power plant in Nova Scotia. The only other large-scale tidal power installation is in France on the Rance estuary (240 MW peak). Due to tidal friction, the day is lengthening by about 1 second every 60 000 years—imperceptible on a human time scale, but of profound significance to Earth's rotation over a few billion years. If the Sun does not first incinerate our planet, there will come a day that is as long as the lunar month and the Moon will stand stationary in the sky, as does Earth now in the lunar sky. But this situation will not endure, for solar tides will still be present and cause further changes.

P

The tidal influence of the Moon and Sun is generally obvious at the shores of the oceans. Perhaps the most awesome place to observe the tides on our planet is at Cape Split, Nova Scotia, on the southern side of the entrance to Minas Basin (Cape Split may be reached by a pleasant, two-hour walk along a well-marked trail from the village of Scots Bay). Here, at the time of the mid-point of an incoming tide, for a considerable distance the forest is filled with a hollow roar produced by the turbulence of the waters surging past the rugged cliffs below. The currents exceed 8 knots (4 m/s) and the flow in the deep, 5 km-wide channel on the north side of Cape Split is equal to about 80 times that of Canada's largest river, the St. Lawrence. Three hours later the spectacle pauses, and then begins flowing in the opposite direction.

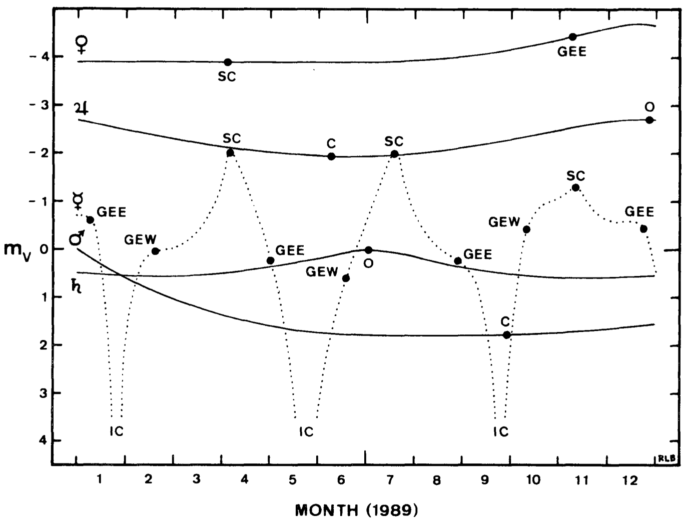
For more information, an excellent introduction is: *The Tides* by E. P. Clancy, Anchor Books, Doubleday and Co., 1969 (now unfortunately out of print); *Exploration of the Universe* (4th edition) by G. O. Abell, Saunders College Publishing, 1982, is another good introductory reference; the pamphlet *Tides in Canadian Waters* by G. Dohler of the Canadian Hydrographic Service gives a brief summary of the topic of its title and is available from Canadian Government bookstores. The major astronomical factors influencing the tides (the phases, perigees and apogees of the Moon) are tabulated in The Sky Month By Month section of this Handbook. These may be scanned to determine days favorable for large tides. Detailed predictions for tides in Canadian waters are published in *Canadian Tide and Current Tables*, the six volumes of which are individually available from Canadian Government bookstores, or by mail from the Canadian Government Publishing Centre, Supply and Services Canada, Ottawa, ON, K1A 0S9. (RLB)

PLANETS, SATELLITES, AND ASTEROIDS

PLANETARY HELIOCENTRIC LONGITUDES 1989

The heliocentric longitude of a planet is the angle between the vernal equinox and the planet, as seen from the Sun. It is measured in the ecliptic plane, in the direction of the orbital motion of the planet (counterclockwise as viewed from the north side of the ecliptic plane). Knowing the heliocentric longitudes, and the approximate distances of the planets from the Sun (see page 11), one can construct a diagram or model showing the orientation of the Sun and planets on any date.

UT	☿	♀	⊕	♂	♃	♄	♅	♆	♇
Jan. 1.0	348°	226°	101°	61°	64°	275°	271°	280°	223°
Feb. 1.0	161	275	132	77	67	276	272	280	223
Mar. 1.0	254	320	160	91	70	277	272	280	223
Apr. 1.0	357	9	191	106	72	278	272	280	224
May 1.0	166	57	221	120	75	279	273	281	224
June 1.0	265	107	250	133	78	280	273	281	224
July 1.0	12	156	279	147	80	281	273	281	224
Aug. 1.0	182	206	309	160	83	282	274	281	224
Sept. 1.0	276	255	339	174	86	282	274	281	225
Oct. 1.0	34	303	8	187	88	283	274	282	225
Nov. 1.0	197	352	39	201	91	284	275	282	225
Dec. 1.0	285	40	69	215	94	285	275	282	225
Jan. 1.0	58	90	100	231	96	286	276	282	226

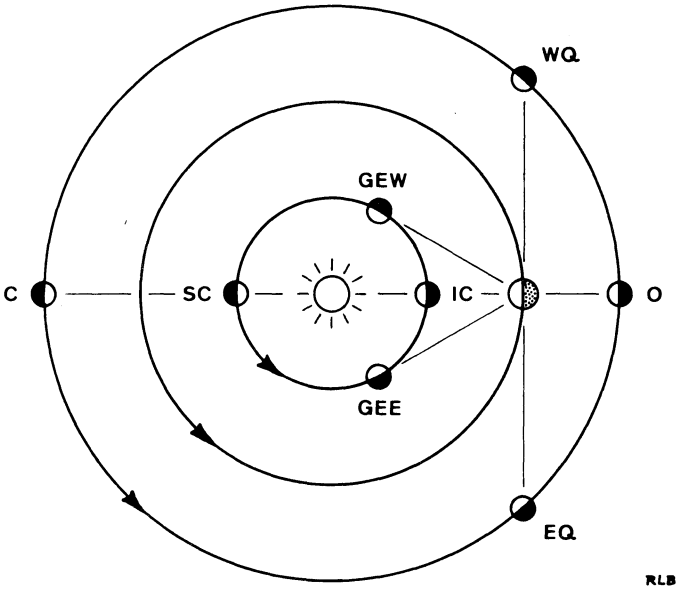


The magnitudes of the five, classical (naked eye) planets in 1989. Oppositions (O), conjunctions (C), inferior and superior conjunctions (IC, SC), and greatest elongations east and west (GEE, GEW) are indicated. (Note the diagram explaining these terms on page 114. For planetary symbols see page 10.)

PRONUNCIATION OF PLANET NAMES

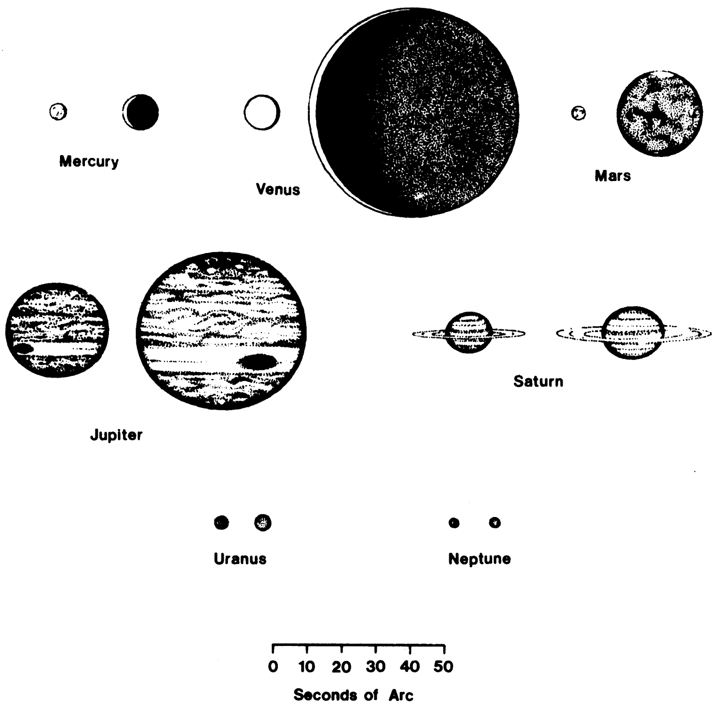
Mercury	mûr'kū-rē
Venus	vē'nŭs
Earth	ûrth
Mars	mȧrs
Jupiter	jo͞o'pĭ-tẽr
Saturn	sȧt'ûrn
Uranus	yoor'ȧ-nŭs
Neptune	nĕp'tyo͞on
Pluto	plo͞o'tō

ā dāte; ă tăp; â câre; ȧ ȧsk; ē wē; ĕ mĕt; ẽ makẽr; ī īce; ĭ bĭt; ō gō; ŏ hŏt; ô ôrb; oo book; o͞o mo͞on; ū ūnite; ŭ ŭp; û ûrn.



This diagram is a simplified view of the Solar System, from the north side. Earth is shown (middle orbit) together with an "inferior" planet (e.g. Venus) and a "superior" planet (e.g. Mars). Four special configurations of the inferior planet relative to Earth are shown (in counterclockwise chronological sequence): inferior conjunction (IC), greatest elongation west (GEW), superior conjunction (SC), greatest elongation east (GEE). Four special configurations of the superior planet relative to Earth are also shown (in clockwise chronological sequence): opposition (O), eastern quadrature (EQ), conjunction (C), western quadrature (WQ).

PLANETS: APPARENT SIZES

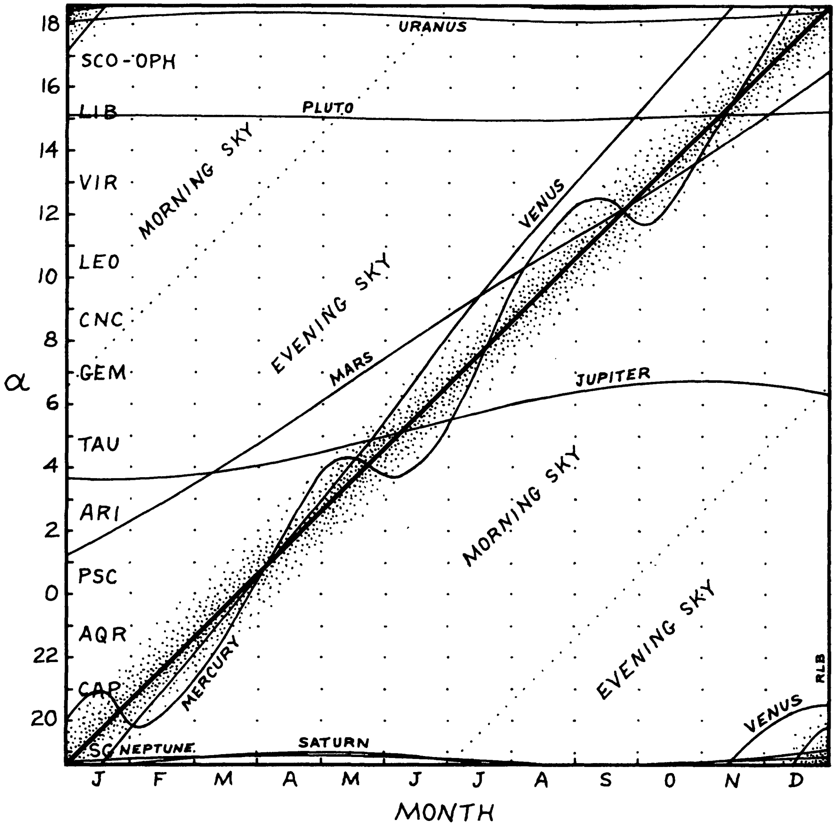


The apparent maximum and minimum observable size of seven planets is illustrated along with characteristic telescopic appearance. The large satellites of Jupiter (not shown) appear smaller than Neptune.

PRONUNCIATION OF SATELLITE NAMES

Adrastea	ȧ-drăs'tē-ȧ	Europa	yoo-rō'pȧ	Oberon	ō'bȧ-rŏn'
Amalthea	ăm''l-thē'ȧ	Ganymede	găn'ĕ-mēd'	Pandora	păn-dôr'ȧ
Ananke	ȧ'năn-kē	Himalia	hĭm'ȧ-lĭ-ȧ	Pasiphae	pȧ-sĭf'ȧ ē'
Ariel	âr'ē-ĕl	Hyperion	hī-pēr'ĭ-ĕn	Phobos	fō'bŏs
Atlas	ăt'lăs	Iapetus	ī-ăp'ĕ-tŭs	Phoebe	fē'bē
Callisto	kȧ-lĭs'tō	Io	ī'ō	Prometheus	prŏ-mē'thē-ŭs
Calypso	kȧ-lĭp'sō	Janus	jā'nŭs	Rhea	rē'ȧ
Carme	kȧr'mē	Leda	lē'dȧ	Sinope	sĭ-nō'pē
Charon	kâr'ĕn	Lysithea	lĭs'ĭ-thē'-ȧ	Telesto	tȧ-lĕs'tō
Deimos	dī'mŏs	Metis	mē'tĭs	Tethys	tē'thĭs
Dione	dī-ŏ'nē	Mimas	mī'măs	Thebe	thē'bē
Elara	ē'lȧr-ȧ	Miranda	mĭ-răn'dȧ	Titan	tī't'n
Enceladus	ĕn-sĕl'ȧ-dŭs	Moon	mo͞on	Titania	tī-tā'nē-ȧ
Epimetheus	ĕp'ȧ-mē'thē-ŭs	Nereid	nēr'ē-ĭd	Triton	trī't'n
				Umbriel	ŭm'brē-ĕl'

ā dāte; ă tăp; â câre; ȧ ȧsk; ē wē; ĕ mĕt; ē makēr; ī īce; ĭ bĭt; ō gō; ŏ hŏt; ô ôrb; oo book; o͞o mo͞on; ū ūnite; ŭ ŭp; û ûrn.



This diagram shows the variation during the year in the right ascension (α) of the Sun and the planets. The diagram is simplified in that the heavy diagonal line for the Sun (which should be slightly curved) is straight, and the months are assumed to be of equal duration. The stippling in the vicinity of the line for the Sun indicates the region of the night sky affected by twilight. The rectangular grid of dots is an aid to reading the two axes. The two dotted diagonal lines represent the boundary between the evening sky and the morning sky.

The diagram may be used as a quick reference to determine: in what part of the sky a planet may be found (including in which constellation – note the names along the vertical axis); when a superior planet is in conjunction with the Sun or at opposition (opposition is approximately where its curve intersects the dotted diagonal line, and note that, due to retrograde motion, this point is also where the planet's curve has its maximum negative slope); when Mercury and Venus have their various greatest elongations and conjunctions; and when there are conjunctions of planets. e.g. Note that as Mars recedes toward conjunction with the Sun, it has conjunctions with Jupiter in Taurus early in March, with Venus west of Leo in mid-July, and with Mercury in Leo as Mars sinks into the evening twilight early in August. Saturn has a triple conjunction with Neptune, the one in late June being most conveniently placed for observations. For more information on these and other events, see the following pages and "The Sky Month By Month" section. (RLB)

THE PLANETS FOR 1989

BY TERENCE DICKINSON

INTRODUCTION

Planetary observing is perhaps the most widely accessible and diversified category of amateur astronomical pursuits. Planets can be seen almost any clear night of the year. Indeed, in heavily light-polluted cities they are sometimes the *only* celestial objects visible. With dark sky sites ever more remote from population centres, planetary observing is returning—partly by default—to take its place as an important part of the amateur astronomers' repertoire. But a more important factor than sky conditions is the recent resurgence of the refractor which has, in effect, been reborn in modern moderately-priced apochromatic and semi-apochromatic designs in 90mm to 180mm apertures. These telescopes provide by far the cleanest planetary images of any telescope design (for a reprint of a 1986 *Handbook* article on this subject contact the author at the address on the inside front cover).

Planetary observing divides into three distinct categories, each with its opportunities and limitations. *Unaided-eye* observing consists of detecting, identifying and monitoring the night-to-night and week-to-week motion and visibility of the five brighter planets. *Binoculars* add Uranus and Neptune along with the Galilean satellites of Jupiter. Binoculars are ideal for tracking planetary motion against the backdrop of stars, many of which are too faint for naked-eye detection. But it is only through *telescopic* observing that the planets reveal their uniqueness, and this section concentrates on that aspect.

Urban and suburban locales unsuited for many aspects of astronomy can be perfectly acceptable for telescopic planetary observing. Atmospheric turbulence—seeing—is often no worse, and sometimes better, in urban areas. However, observers should avoid using telescopes on pavement, balconies or immediately beside a house or substantial building due to the heat radiated to the surrounding atmosphere from these structures. Also, avoid looking over these objects if possible. A typical grassed backyard is fine in most instances. For optimum performance, all telescopes (except small refractors) require from 10 minutes to an hour to cool to outside temperature when taken outdoors. Hazy but otherwise cloudless nights are usually just as good as, and sometimes better than, clear skies for steady telescopic images of planets.

More than any other class of telescopic observing, planetary observing is most affected by seeing. Many nights are rendered useless for planet watching by ever-present ripples and undulations in Earth's atmosphere. Planets within 15° of the horizon are virtually always afflicted. Minimum altitude for expectations of reasonable seeing is 25°. A further problem with lower-altitude planetary targets is dispersion associated with atmospheric refraction. Refraction causes celestial objects to appear displaced to higher altitudes. Since the effect is wavelength-dependent (being less for longer wavelengths), for planets at low altitudes, this produces a red fringe on the lower side of the planet and a green (or blue) fringe on the upper, as well as introducing chromatic smearing to the whole image.

Regardless of the type of telescope used for planetary observing, optical quality is far more critical than aperture. In no other type of observing are the effects of less-than-perfect optics more apparent. Other factors that significantly degrade a telescope's planetary performance include: a large *central obstruction* in the optical system (all Schmidt-Cassegrains, Maksutov-Cassegrains and Newtonians faster than f/6); *secondary mirror supports* (most Newtonians); *chromatic aberration* (most doublet refractors over 90mm); *internal currents* (all types, refractors least); optical component *cool-down time* (mostly aperture-dependent, telescopes over 200mm can take hours); *dirty optics*.

In the remarks below, when a planetary phenomenon is stated as being visible in a certain minimum aperture, good seeing is assumed. When a specific minimum aperture is cited, an unobstructed optical system (i.e. a refractor) is assumed. Somewhat larger apertures are often required if centrally obstructed systems are used.

MERCURY

Of the five planets visible to the unaided eye, Mercury is by far the most difficult to observe and is seldom conveniently located for either unaided eye or telescopic observation. The problem for observers is Mercury's tight orbit which constrains the planet to a small zone on either side of the Sun as viewed from Earth. When Mercury is east of the Sun we may see it as an evening "star" low in the west just after sunset. When it is west of the Sun we might view Mercury as a morning "star" in the east before sunrise. But due to celestial geometry involving the tilt of Earth's axis and Mercury's orbit we get much better views of Mercury at certain times of the year.

The best time to see the planet in the evening is in the spring, and in the morning in the fall (from the Northern Hemisphere). Binoculars are of great assistance in searching for the planet about 40 minutes to an hour after sunset or before sunrise during the periods when it is visible. The planet's brightness, which varies by more than two magnitudes, is a more important factor influencing its visibility than its distance from the Sun during any particular elongation. Mercury's true colour is almost pure white but absorption from Earth's atmosphere within 15° of the horizon, where Mercury is usually best seen, usually imparts a yellow or ochre hue to the planet.

Telescopic observers will find the rapidly changing phases of Mercury of interest. The planet appears to zip from gibbous to crescent phase in about three weeks during each of its evening elongations. The phases are accessible to users of 75mm or larger telescopes; the 30% phase can be detected at 50×. Large apertures (over 200mm) rarely offer an advantage due to the crippling effects of poor seeing at lower altitudes, especially following sunset when the planet is most frequently observed. Experienced planetary observers often report their most satisfying telescopic observations

MERCURY
TELESCOPIC OBSERVING DATA FOR FAVOURABLE EASTERN (EVENING) ELONGATIONS 1989

Date 0^h UT	Mag.	Angular Diameter	% of Disk Illuminated	Distance From Sun	α (1989)	δ
Jan. 4	-0.7	6.1"	75%	18°	20^h17^m	-21°22'
9	-0.6	6.8"	59%	19°	20^h42^m	-19°06'
14	0.0	7.9"	37%	18°	20^h55^m	-16°57'
Apr. 19	-1.0	5.9"	77%	15°	02^h44^m	+17°31'
24	-0.5	6.6"	60%	19°	03^h18^m	+20°33'
29	+0.1	7.5"	44%	21°	03^h45^m	+22°32'
May 4	+0.7	8.5"	30%	20°	04^h05^m	+23°29'

of Mercury in the morning sky. Near favourable western elongations, the planet may be easily located at least an hour before sunrise, then followed to higher altitudes into the daytime sky. Seeing often remains steady more than an hour after sunrise by which time the planet may be 30° above the horizon. Under such conditions the phase is sharply defined and the small disc takes on a unique appearance, paler than Venus, with a vaguely textured surface. Surface details, though suspected in moments of fine seeing, are always elusive. There is only a fair correlation between the Mariner 10 spacecraft images of Mercury and the few dusky features seen by the most acute visual observers prior to that interplanetary mission. Contrasts among the planet's surface features are lower than on the lunar surface, though in other respects the two bodies are similar.

VENUS

Venus is the only world in the solar system that closely resembles Earth in size and mass. It also comes nearer to Earth than any other planet, at times approaching as close as 0.27 AU. Despite the fundamental similarity, surface conditions on Earth and Venus differ greatly. The chief disparity is that Venus' surface temperature varies only a few degrees from a mean of 455°C on both day and night sides of the planet. The high temperature is due to the dense carbon dioxide atmosphere of Venus which, when combined with small quantities of water vapour and other gases known to be present, has the special property of allowing sunlight to penetrate to the planet's surface but does not permit the resulting heat to escape. This process is commonly known as the greenhouse effect.

Clouds and haze that cloak the planet, consisting chiefly of droplets of sulphuric acid, are highly reflective, making Venus the brightest natural celestial object in the nighttime sky apart from the Moon. Whenever it is visible, it is readily recognized. Because its orbit is within that of Earth's, Venus is never separated from the Sun by an angle greater than 47 degrees. However, this is more than sufficient for the dazzling object to dominate the morning or evening sky.

Like Mercury, Venus exhibits phases, although they are much more easily detected in small telescopes because of Venus' greater size. When it is far from us (near the other side of its orbit), we see the planet nearly fully illuminated, but because of its distance, it appears small—about 10 seconds of arc in diameter. As Venus moves closer to Earth, the phase decreases (we see less of the illuminated portion of the planet), but the diameter increases until it is a thin slice nearly a minute of arc in diameter. It takes Venus several months to move from one of these extremes to the other, compared to just a few weeks for Mercury.

When Venus is about a 20% crescent even rigidly-held, good quality binoculars can be used to distinguish that the planet is not spherical or a point source. A 60 mm refractor should be capable of revealing all but the gibbous and full phases of Venus. Experienced observers prefer to observe Venus during the daytime, and indeed the planet is bright enough to be seen with the unaided eye if one knows where to look.

As 1989 opens, Venus is a brilliant beacon low in the southeast before sunrise. It becomes less prominent during January as it nears the Sun and is lost in the twilight glow by early February. Superior conjunction is April 4. Venus enters the evening sky in mid-May, low in the west at dusk, and remains an evening object for the rest of the year. This is not a favorable year for mid-northern latitude observers of Venus since the planet is never well away from twilight glow as it was during much of 1988.

Telescopically on January 1 Venus is gibbous, 93% illuminated and 11.0″ in diameter. On July 1 the values will be 92% and 10.9″ respectively; on October 1, 66% and 17.4″. The interval leading up to inferior conjunction, when the phase is less than 50% and the planet has a large apparent size, is the prime telescopic observing period (see accompanying table).

Venus appears to most observers to be featureless no matter what type of telescope is used or what the planet's phase. However, over the past century some observers using medium or large size telescopes have reported dusky, patchy markings usually described as slightly less brilliant than the dazzling white of the rest of the planet. We now know that there are many subtle variations in the intensity of the clouds of Venus as photographed in ultraviolet by spacecraft and Earth-based telescopes. But when the ultraviolet photos are compared to drawings of the patchy markings seen by visual observers the correlation is fair at best.

Because of Venus' high surface brightness (about 40 times greater than Jupiter's), Venus can accommodate the highest magnifications a telescope can deliver. The author has used magnifications over 4× per millimetre of aperture on occasion and regularly employs 1.5× to 3× per millimetre on the planet, particularly in twilight when the sky is moderately dark but Venus is still high enough to avoid low-altitude seeing degradation.

When Venus is less than 10% illuminated the cusps (the points at the ends of the crescent) can sometimes be seen to extend into the night side of the planet. This is an actual observation of solar illumination being scattered by the atmosphere of Venus. When Venus is a thin sliver of a crescent the extended cusps may be seen to ring the entire planet, but this is a very difficult observation. A similar, though unrelated Venus phenomenon called the ashen light, has been reported by visual observers since the seventeenth century. It is an alleged illumination of the night side of Venus (analogous to Earthshine on the Moon), seen when the planet is in crescent phase. Since nothing like Earthshine can be operating at Venus, electrical phenomena in the planet's atmosphere offer a plausible explanation. However most authorities attribute the sightings to visual contrast effects caused by the brilliant crescent set in a dark sky. Diffraction effects caused by secondary mirror supports in reflector telescopes have also been suggested (*Sky and Telescope*, June 1988, p.574).

VENUS NEAR INFERIOR CONJUNCTION 1989

Date 0^h UT	Mag.	Apparent Diameter	% of Disk Illuminated	Distance From Sun	α (1989)	δ
Nov. 2	-4.4	23.3"	53	47°E	17^h44^m	-26°49'
18	-4.5	28.0"	45	47°	18^h55^m	-26°21'
30	-4.6	32.9"	37	45°	19^h41^m	-24°30'
Dec. 8	-4.6	37.1"	31	43°	20^h05^m	-22°46'
16	-4.7	42.1"	25	40°	20^h23^m	-20°48'
20	-4.7	44.9"	21	37°	20^h29^m	-19°48'
24	-4.7	48.0"	17	34°	20^h33^m	-18°49'
28	-4.6	51.1"	14	30°	20^h34^m	-17°52'
Jan. 1	-4.6	54.2"	10	26°	20^h33^m	-16°59'

MARS

Mars is the planet that has long captivated the imagination of mankind as a possible abode of life. Although the biology experiments in the two Viking spacecraft that landed on the planet in 1976 detected no known life processes in the Martian soil samples, there are many facets of Mars that make it the most Earthlike planet in the solar system. Volcanoes, polar caps at least partially composed of water ice, and ancient channels where water once flowed are among the most intriguing features. Observations from Earth as well as Mars-orbiting spacecraft have disclosed winds in the Martian atmosphere that reach speeds exceeding 300 km/h and raise vast amounts of dust that can envelop the planet for weeks at a time. The dust storms were thought to occur with seasonal regularity shortly after Mars passed the perihelion point of its elliptical orbit, but the Viking observations revealed more complex weather patterns.

In many ways Mars is the most interesting planet to observe with the unaided eye. It moves rapidly among the stars—its motion can usually be detected after an interval of less than a week—and it varies in brightness over a far greater range than any other planet. Mars may be distinguished by its orange-red colour, a hue that originates with rust-coloured dust that covers much of the planet.

Telescopically Mars is usually a disappointingly small featureless ochre disk except within a few months of opposition when its distance from Earth is then near minimum. If Mars is at perihelion at these times the separation can be as little as 56 million km. Such close approaches occur at intervals of 15 to 17 years; the most recent was in 1988. At a perihelion opposition the telescopic disk of Mars is 25 seconds of arc in diameter and much detail on the planet can be distinguished with telescopes of 100 mm aperture or greater. At oppositions other than when Mars is at perihelion, the disk is correspondingly smaller.

This year marks a lull between the 1988 perihelion opposition and the moderately favourable intermediate opposition in late 1990. Consequently, Mars will be of little interest telescopically, but the planet will offer a fine target for unaided eye viewing as it traces a path through five constellations in seven months.

As 1989 opens the final glimmer of the 1988 apparition remains as Mars is still high in the south in Pisces in early evening, prominent at magnitude zero. But the planet quickly fades as Earth leaves it behind. By March Mars will have passed through Aries, becoming a first-magnitude evening object in Taurus. When Mars passes into Gemini in May it will be dimmer than Pollux. By July Mars will be less than conspicuous in Cancer, low in the west at dusk.

Except for the first three weeks of the year when Mars is still more than 8″ in diameter (the threshold for detecting more than fleeting surface detail) the planet is of no telescopic interest in 1989. Expect to see nothing more than an orange blip. Looking ahead to 1990, opposition is on November 27 when the planet will be 18.1″ in diameter. This will be by far the best opposition of Mars for the remainder of the century. A detailed observing guide will be published in next year's Handbook.

JUPITER

Jupiter, the solar system's largest planet, is a colossal ball of hydrogen and helium without any solid surface comparable to land masses on Earth. Jupiter likely has a small rocky core encased in a thick mantle of metallic hydrogen which is enveloped by a massive atmospheric cloak topped by a quilt of multi-coloured clouds. These clouds are the visible surface of Jupiter—a realm of constant change characterized by alternating dark belts and brighter zones. The zones are ammonia ice-crystal clouds, the belts mainly ammonium hydrosulphide clouds. Frequently the belts intrude on the zones with dark rifts or loops called festoons.

The equatorial region of Jupiter's clouds rotates five minutes faster than the rest of the planet: 9 hours 50 minutes compared to 9 hours 55 minutes. This means constant interaction as one region slips by the other at about 400 km/h. It also means that there are basically two rotational systems from the viewpoint of week-to-week telescopic observation.

In the table on the next page, the two quantities L(1) and Δ can be used to calculate the longitude L of the central meridian of the illuminated disk of Jupiter. System I is the most rapidly rotating region between the middle of the North Equatorial Belt and the middle of the South Equatorial Belt. System II applies to the rest of the planet. For a given date and time (UT) of observation, L is equal to L(1) for the month in question *plus* Δ times the number of complete days elapsed since 0 h UT on the first of the month *plus* either 36.58° (for system I) or 36.26° (for system II) times the number of hours elapsed since 0 h UT. The result will usually exceed 360°; if so, divide the result by 360 and then multiply the decimal portion of the quotient by 360°. This procedure, which is accurate to 1°, is readily computed using a modest calculator.

Jupiter's rapid rotation also makes the great globe markedly oval so that it appears about 7% "squashed" at the poles. Jupiter's apparent equatorial diameter ranges from a minimum of 32″ at conjunction on June 9 to 47″ at opposition on December 27.

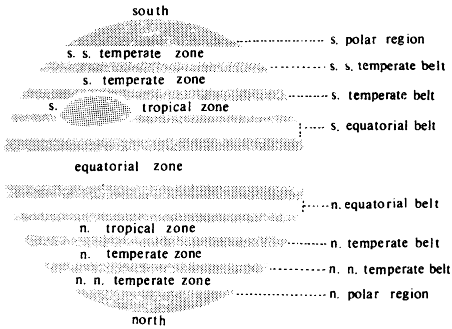
The Great Red Spot, a salmon-coloured oval vortex whose hue may possibly be due to organic-like compounds that are constantly spewed from some heated atmospheric source below, is the longest-lived structure on the visible surface of Jupiter. The spot and the changing cloud structures that stripe the planet can be easily observed in small telescopes because the apparent size of the visible surface of Jupiter is far greater than that of any other planet. Occasionally (1981–88 for example) the Red Spot loses its prominence, becoming difficult to detect in smaller telescopes, only to return to its normal state a few years later. In recent years the Red Spot Hollow, a bay in Jupiter's South Equatorial Belt that largely encloses the Red Spot, has been far more prominent than the Spot itself. But a darkening and apparent agitation in the southern part of the Hollow suggests that the Spot may be ready to emerge once again.

The smallest of telescopes will reveal Jupiter's four large moons, each of which is equal to or larger than Earth's satellite. The moons provide a never-ending fascination for amateur astronomers. Sometimes the satellites are paired on either side of the belted planet; frequently one is missing—either behind Jupiter or in the planet's shadow. Even more interesting are the occasions when one of the moons casts its shadow on the disk of the planet. The tiny black shadow of one of the moons can be particularly evident if it is cast on one of the bright zones of Jupiter. According to some observers this phenomenon is evident in a good 60 mm refractor.

The satellite umbral shadows vary significantly in size from one moon to another. Mean opposition angular diameters in seconds of arc are: Io 0.9, Europa 0.6, Ganymede 1.1, and Callisto 0.5. Theoretically such tiny markings should not be visible in telescopes smaller than 120mm, but the enormous contrast between the dark shadow and the bright Jovian clouds enhances the phenomenon in a way that the human eye is very sensitive to. Furthermore, the satellites' penumbral shadows are quite large, especially Callisto's, which adds a few tenths of an arc second to their effective visual diameters. The satellites themselves have the following mean opposition apparent diameters: Io 1.2, Europa 1.0, Ganymede 1.7, Callisto 1.6. A 150mm telescope reveals the size differences as well as colour variations among the moons. When the Galilean satellites transit the disc of Jupiter they are seldom visible in telescopes under 100mm and are best seen near the planet's limb when entering or leaving the disc. Tracking a satellite transit completely across Jupiter is a challenging observation. Each satellite has a characteristic appearance when superimposed on the Jovian cloudscape. Europa is bright white, similar to the brightest Jovian clouds. When traversing a white cloud zone in the central sector of Jupiter, Europa is usually

JUPITER'S BELTS AND ZONES

Viewed through a telescope of 100 mm aperture or greater, Jupiter exhibits a variety of changing detail and colour in its cloudy atmosphere. Some features are of long duration, others are short-lived. The standard nomenclature of the belts and zones is given in the figure.



JUPITER — EPHEMERIS FOR PHYSICAL OBSERVATIONS — 1989

Date UT	Mag.	App. Equat. Diam.	System I L(1)	System I Δ	System II L(1)	System II Δ
Jan. 1.0	-2.7	46.0"	124.1°	157.84°	154.0°	150.21°
Feb. 1.0	-2.5	41.8"	337.2°	157.74°	130.7°	150.11°
Mar. 1.0	-2.3	38.2"	73.8°	157.67°	13.6°	150.04°
Apr. 1.0	-2.1	35.1"	281.6°	157.64°	344.9°	150.01°
May 1.0	-2.0	33.2"	330.9°	157.65°	165.3°	150.02°
June 1.0	-1.9	32.4"	178.0°	157.67°	135.9°	150.04°
July 1.0	-1.9	32.5"	228.2°	157.72°	317.2°	150.09°
Aug. 1.0	-2.0	33.6"	77.4°	157.78°	289.9°	150.15°
Sept. 1.0	-2.1	35.9"	288.5°	157.85°	264.4°	150.22°
Oct. 1.0	-2.3	39.0"	344.0°	157.94°	90.9°	150.30°
Nov. 1.0	-2.5	42.9"	199.9°	158.01°	70.4°	150.38°
Dec. 1.0	-2.7	46.2"	260.4°	158.04°	261.9°	150.41°
Jan. 1.0	-2.7	47.2"				

RLB

invisible. However, it stands out well when near the limb or against a dark belt. Callisto, the darkest moon, is best seen in the reverse circumstances. When seen against a pale zone this grayish moon can be mistaken for a satellite shadow, but it is often lost against a dark belt. Ganymede is intermediate in surface brightness, but because of its great size, it is the easiest of the four to track completely across Jupiter's face. Io, innermost of the Galilean moons, is also the most frequently seen in transit. It is close to Europa in brightness but is generally easier to follow over typical cloud features, probably due to its slightly greater diameter. Near opposition, a transiting satellite often appears adjacent to its own shadow. These events are especially worth a look.

Both the satellite positions and the times of their interaction with the Jovian disk are given elsewhere in the HANDBOOK. Jupiter's other satellites are photographic objects for large instruments.

As 1989 opens, Jupiter is in Taurus high in the southern evening sky. By mid-May it is too close to the Sun for observation. Jupiter enters the morning sky in July and late in that month it advances into Gemini, where it remains for the rest of the year. In October it rises not long after midnight, beginning a six month period when the giant planet is well placed for telescopic viewing. At opposition on December 27, Jupiter's distance is 4.166 AU (623 million km) from Earth. (*Editor's Note*: Because of its brightness, near magnitude −2.5, Jupiter is unmistakable as it moves through Taurus and Gemini this year. Hence a finding chart is not provided).

Although Jupiter will be well placed for telescopic scrutiny (from mid-northern latitudes) both early and late in the year, this coincides with the season of least favourable weather prospects in many parts of Canada and the USA. Nevertheless, the planet is near its maximum possible altitude, high on the ecliptic, so that there is the potential for outstanding viewing with a minimum of atmospheric turbulence. In any case, Jupiter is still the most rewarding target for planetary observers in 1989.

SATURN

Saturn is the telescopic showpiece of the night sky. The chilling beauty of the small pale orb floating in a field of velvet is something no photographs or descriptions can adequately duplicate. Any telescope magnifying more than 30 times will show the rings. The view is exquisite in 100 to 200mm instruments. The rings consist of billions of particles—largely water ice—that range in size from microscopic specks to flying mountains kilometres across. The reason "rings" is plural and not singular is that gaps and brightness differences define hundreds of distinct rings. However, from Earth only the three most prominent components—known simply as rings A, B, and C—can be distinguished visually. (See the diagram on p. 125.)

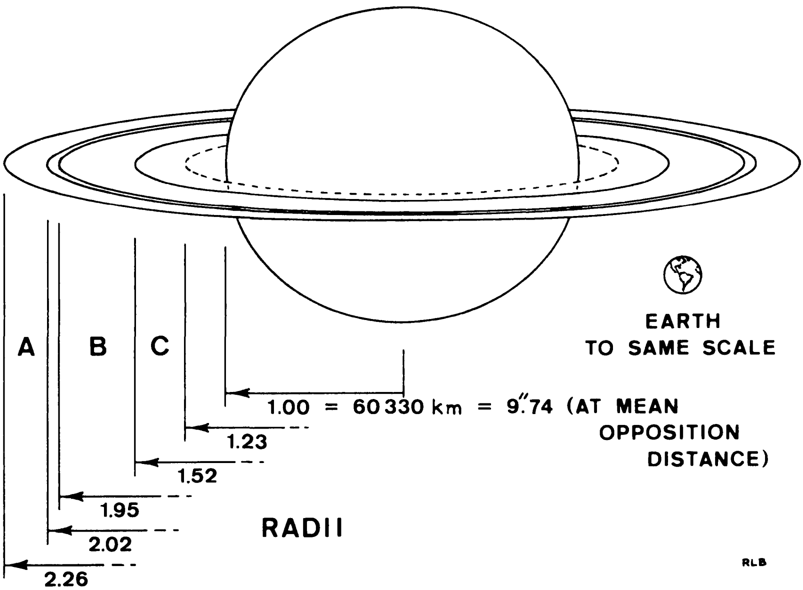
Cassini's Division, a gap between rings A and B discovered in 1675, is visible in small telescopes when the ring system is well inclined to our view. Cassini's Division is a region less densely populated with ring particles than adjacent rings. Ring B, the brightest, overpowers ring C to such an extent that ring C, also known as the crepe ring, is seen only with difficulty in small telescopes. A Saturn phenomenon easily seen with backyard telescopes is the shadow of the planet on the rings. At times this is the most easily observed feature apart from the rings themselves. At opposition it is barely seen, but from one to four months before or after opposition the shadow falling on the rings is very apparent, often giving the scene a powerful three-dimensional aura.

In addition to the rings, Saturn has a family of at least seventeen satellites. Titan, the largest, is easily seen in any telescope as an eighth-magnitude object orbiting Saturn in about 16 days. At east and west elongation Titan appears about five ring diameters from the planet. Titan is the only satellite in the solar system with a substantial atmosphere, now known to be primarily nitrogen and 4.6 times as massive as Earth's, with a surface pressure of 1.6 Earth atmospheres.

Telescopes over 60 mm aperture should reveal Rhea at 10th magnitude less than two ring-diameters from Saturn. The satellite Iapetus has the peculiar property of being five times brighter at western elongation ($10^{\mathrm{m}}.1$) than at eastern elongation ($11^{\mathrm{m}}.9$). One side of the moon has the reflectivity of snow while the other resembles dark rock. The reason for this is unknown. When brightest, Iapetus is located about 12 ring-diameters west of its parent planet, but it is often difficult to distinguish from a star. Several nights' observation is usually needed to confirm a sighting of Iapetus. Of the remaining moons Tethys and Dione may be glimpsed in a 150 mm telescope but the others require larger apertures or photographic techniques. (See pages 146–149 for the configurations of Saturn's brightest satellites during 1989.)

SATURN

MAIN RING FEATURES VISIBLE FROM EARTH



SATURN'S RING SYSTEM
MAIN STRUCTURAL REGIONS

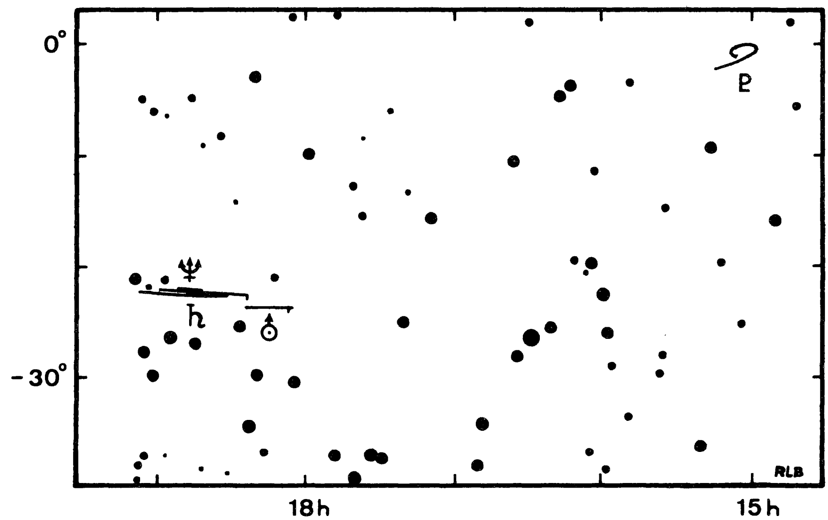
Ring	Radius**	Discoverer
D	1.11 - 1.23	Voyager 1 (1980)
C*	1.23 - 1.52	W. C. & G. P. Bond, W. R. Dawes (1850)
B*	1.52 - 1.95	Galileo (1610), C. Huygens (1659),
A*	2.02 - 2.26	G. D. Cassini (1675)
F	2.33	Pioneer 11 (1979)
G	2.8	Voyager 1 (1980)
E	3. - 8.	W. A. Feibelman (1966)

* Visible from Earth. Also, the "E" ring can be detected when Saturn's ring system appears edge-on.

** In units of Saturn's equatorial radius (60330 km).

The disk of Saturn appears about 1/6 the area Jupiter appears through the same telescope with the same magnification. In telescopes less than 75 mm aperture probably no features will ever be seen on the surface of the planet other than the shadow cast by the rings. As the size of the telescope is increased the pale equatorial region, a dusky equatorial band, and the darker polar regions become evident. Basically, Saturn has a belt system like Jupiter's but it is much less active and the contrast is reduced. Seldom in telescopes less than 100 mm aperture do more than one or two belts come into view. Very rarely a spot among the Saturnian clouds will appear unexpectedly, but less than a dozen notable spots have been recorded since telescopic observation of Saturn commenced in the 17th century.

From year to year the rings of Saturn take on different appearances. The planet's orbit is an immense 29.5 year circuit about the Sun, so in the course of an observing season the planet moves relatively little in its orbit (and thus appears to remain in



The paths of **Saturn, Uranus, Neptune,** *and* **Pluto** *during 1989. The coordinates are for 1989.5, and for planetary symbols see page 10. (Note that larger scale charts for Uranus, Neptune and Pluto appear a few pages ahead. Also, there is a chart showing the mid-year sections of the paths of Saturn, Uranus, Neptune, and the asteroid Vesta on page 151). On the scale of this chart, Neptune's path is touching that of Saturn: Neptune's path is the short, thick "bump" on the north side of the central portion of Saturn's path. Saturn has a close, triple conjunction with Neptune this year, passing 14'S on March 3, 18'S on June 24, and 30'S on November 12. This is a relatively rare encounter, occurring only every 36 years. Moreover, a grouping of Saturn, Uranus and Neptune less than 10° apart is even rarer, occurring at intervals of several centuries. For Saturn and Uranus, the single tick mark on each path indicates the position of the planet at the beginning of the year. With the exception of Neptune, each planet is at the east (left) end of its path at year's end. Saturn begins its retrograde loop on April 23, is at opposition on July 2, and ends retrograde motion on September 11. For observers in the Northern Hemisphere, 1989 is the worst year since 1959 for viewing Saturn, and the worst since 1905 for viewing Uranus. Both planets reach their extreme southern declinations this year. (RLB)* about the same general area of the sky) and maintains an essentially static orientation toward Earth. 1987 marked the maximum inclination (26.75°) of the north side of the rings towards the Sun. A maximum inclination of the north side of the rings last occurred in 1958, with the south side being in a similar position in 1944 and 1973. The rings were edge-on in 1950, 1966, 1980, and will be again in 1996. In apparent width the rings are equal to the equatorial diameter of Jupiter.

Saturn is in Sagittarius during 1989. As the year opens, the sixth planet is too close to the Sun for observation, but from February to May it is prominent in the morning sky. At opposition on July 2 the planet is 9.021 AU (1.35 billion km) from Earth. At that time Saturn's equatorial diameter is 18.3″, and the rings are 41.6″ in width. Throughout the prime telescopic observing window, from May to September, the rings are tilted between 24.7° and 26.1° with respect to Earth, with the north face being visible. Saturn becomes lost in the evening twilight in early December.

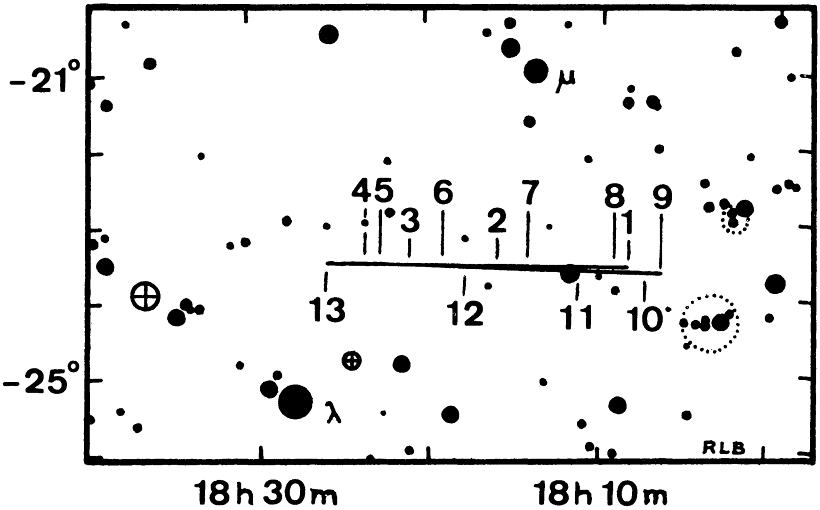
URANUS

Although Uranus can be seen with the unaided eye under a clear, dark sky, it was apparently unknown until 1781 when it was accidentally discovered by William Herschel with a 160 mm reflecting telescope. It can be easily seen with binoculars, and a 75mm telescope will reveal its small, greenish, featureless disk.

Jupiter, Saturn, Uranus and Neptune are rather similar in the sense that their interiors consist mainly of hydrogen and helium and their atmospheres consist of these same elements and simple compounds of hydrogen. Unlike the three other giant planets, the axis of Uranus is tipped almost parallel to the plane of the solar system. This means that we can view Uranus nearly pole-on at certain points in its 84-year orbit of the Sun. The southern (and counter-clockwise turning) hemisphere of Uranus is now facing Earth. Its south pole appeared nearest to (and slightly south of) the centre of its disk in 1985, although the geometry is nearly the same this year. Uranus has at least fifteen satellites, all smaller than Earth's moon, none of which can be detected in small or moderate sized telescopes.

The first spacecraft encounter with Uranus was by the U.S. Voyager 2 probe in late-January 1986 and resulted in a huge increase in our meagre knowledge of the seventh planet. A rotation period of 17.24 hours for the planet's interior was determined together with a latitude-dependent rotation period for its atmosphere (average of 16.7 hours); a substantial magnetic field tilted at a remarkably large angle of some 60° to the rotation axis was found; detailed images of the surfaces of the five large satellites revealed them as individually-unique worlds; ten previously unknown satellites were detected; Uranus' nine, main, slender, dark rings were confirmed, and numerous diffuse bands of dust within the ring system were discovered.

Uranus is in Sagittarius in 1989, near the Lagoon Nebula and easy to find with binoculars. When at opposition on June 24, the planet is 18.33 AU (2.74 billion km) from Earth. Its magnitude is then +5.6 and its apparent diameter is 3.82 seconds of arc.



*The path of **Uranus** in Sagittarius during 1989 (note also the wide-field charts on pages 126 and 151). The position of Uranus is indicated for the beginning of each month where 1 = January, 2 = February, etc. The faintest stars shown are of magnitude 8. The coordinates are for 2000.0. The magnitude of Uranus is about 5.6 (just visible to the unaided eye under dark sky conditions) and its pale-green disk is about 3.8" in diameter when it is on the retrograde portion of its path. Opposition is on June 24 when Uranus is 2.54 light-hours (18.33 AU) from Earth. The Lagoon (M8) and Trifid (M20) nebulae are indicated by the larger and smaller dotted circles, respectively. The circles with crosses indicate globular clusters, the smaller one being M28 and the larger one M22. The bright star λ marks the top of the Sagittarian "teapot". M22, λ Sgr, and M8 appear on the July all-sky chart at the back of the Handbook and are located immediately west of the January 1 position of the Sun. (RLB)*

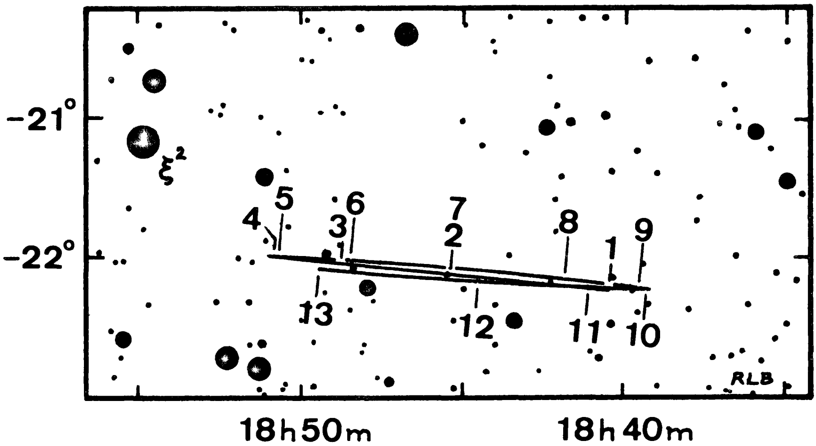
NEPTUNE

The discovery of Neptune in 1846, after its existence in the sky had been predicted from independent calculations by Leverrier in France and Adams in England, was regarded as the crowning achievement of Newton's theory of universal gravitation. Actually Neptune had been seen—but mistaken for a star—several times before its "discovery".

Since the discovery of Uranus' rings in 1977, numerous searches for a Neptunian ring system have yielded evidence that a horseshoe-shaped "ring" may exist. The exact nature of the feature may be uncovered when Voyager 2 arrives at the planet in August.

Neptune is an 8th-magnitude binocular object—an easy target in 7×50 or larger glasses—but seeing the planet as a disc rather than a point of light is a different matter. Powers over 200× are usually necessary, and even then Neptune is just a tiny bluish dot with no hard edge due to limb darkening. At 800× Neptune appears about the same size as the naked-eye full moon, but much dimmer. No distinct surface features have ever been recorded visually. Neptune's large moon Triton can be seen by an experienced observer using a 300 mm telescope. Triton varies from 8 to 17 seconds of arc from Neptune during its 5.9-day orbit.

In 1989 Neptune is buried in the Milky Way in western Sagittarius a couple of degrees from the globular cluster M22 (see the chart). At opposition on July 2 Neptune is magnitude +7.9, 29.20 AU (4.37 billion km) distant from Earth, and 2.″3 in diameter.



The path of ***Neptune*** *in Sagittarius, 1989 (note also the wide-field charts on pages 126 and 151). Neptune's position is indicated for the beginning of each month, where 1 = January, 2 = February, etc. The faintest stars shown are of magnitude 9. The coordinates are for 1950.0. The magnitude of Neptune is about 7.9 and its diameter 2.3" when it is on the retrograde portion of its path. Opposition is on July 2 when Neptune is 4.05 light-hours (29.20 AU) from Earth, the most distant planet at the present time. The bright (magnitude 3.5) star at the east side of the chart, Xi*^{2} *Sgr, serves as a convenient starting point for locating Neptune (Xi*^{2} *Sgr appears on the July map of the night sky at the end of this handbook as the star directly east of the "J" marking the Sun's position on January 1). Neptune has a close, triple conjunction with Saturn this year, with Saturn passing 14'S of Neptune on March 3, 18'S on June 24, and 30'S on November 12. (RLB)*

PLUTO

Pluto, the most distant known planet, was discovered at the Lowell Observatory in 1930 as a result of an extensive search started two decades earlier by Percival Lowell. The faint star-like image was first detected by Clyde Tombaugh by comparing photographs taken on different dates. Routine examinations of photographs of the planet taken in 1978 revealed an elongation of Pluto's image on some of the photos which has been confirmed as a large satellite revolving once every 6.3867 days—identical to the planet's rotation period. This means that the moon is visible only from one hemisphere of Pluto. Calculations made some years ago suggest that this is the only stable orbit a satellite could have with Pluto's slow rotation rate. The moon too would likely have one side constantly turned to Pluto forming a unique double-planet system.

Pluto and its satellite Charon are almost certainly balls of ice, most likely water, methane, and ammonia. This conclusion is supported by recent observations of a tenuous methane atmosphere on Pluto. However, since Pluto's surface gravity is too feeble to retain a primordial methane atmosphere it is probable that as the planet nears perihelion, the Sun is evaporating its frosty surface.

Besides being the solar system's smallest planet, Pluto is different from the other eight in almost every respect. Its unique characteristics include its orbit which is relatively higher inclined and so elliptical that the planet will be closer to the Sun than Neptune from 1980 to 1999. Just where such a freak fits into the solar system's origin and evolution is unknown. Perhaps Pluto is the largest member of a group of small, icy, comet-like structures beyond Neptune.

Pluto is at perihelion, 0.6 AU inside Neptune's orbit, in early September this year. A more accurate statement is not possible because the planet's orbit is not known with sufficient precision to predict the exact time of perihelion. Nevertheless, in September the planet will be closer to the Sun than it has been since well before its discovery.

Opposition is on May 4 when the planet will be 28.688 AU (4.3 billion km) from Earth, its closest approach until early in the 23rd century. Visually the planet appears as a 13.6 magnitude star on the Virgo-Libra border. It can be identified using the accompanying chart and a 200mm or larger telescope. (Pluto has been seen by experienced observers using telescopes as small as 150mm aperture.) Positive identification requires observation on at least two nights to ensure the object has moved. Since Pluto will never be brighter, seeking the smallest planet should be a high priority this spring.

BIBLIOGRAPHY

There are hundreds of published sources of information on the physical nature of the planets and their satellites. Two outstanding volumes are mentioned below (Hartmann and Hunt). In contrast, there are relatively few references on planetary *observing* that are not either novice-level guides or manuals for establishing a program of systematic scientific investigation of planetary phenomena. Observers might find the following of some interest, especially the two recently published works by Dobbins *et al.* and Sheehan.

Alexander, A. F. O'D., 1962, *The Planet Saturn*, Dover, New York. [The definitive 450-page record of Saturn observations made prior to the space age. If only Alexander had done the same with every planet ...]

Antoniadi, E. M., 1975, *The Planet Mars* (translated by P. Moore), Keith Reid, Devon, England. [Antoniadi was among the top two or three planetary observers of all time.]

Baker, James G., 1963, "Planetary Telescopes," *Applied Optics*, *2*, 2. [A landmark paper that details the importance of unobstructed apochromatic telescopes for planetary observing.]

Ceravolo, Peter, and Dickinson, Terence, "Telescope Performance: Trends, Myths and Principles in Amateur Astronomy," to be published in 1989 in the *Journal of The Royal Astronomical Society of Canada*. [Contains practical information of special interest to the planetary observer.]

Dobbins, T.A., Parker D.C., and Capen, C.F., 1988, *Introduction to Observing and Photographing the Solar System*, Willmann-Bell, Richmond, Virginia, 1988. [The most comprehensive and up-to-date reference available. Highly recommended. A two-part condensed version by Dobbins and Parker appeared in the October and December 1987 issues of *Sky & Telescope*.]

Doherty, Paul, 1980, *Atlas of the Planets*, McGraw-Hill, New York. [Despite the title this is not an atlas but a descriptive work with observing material and fine planetary drawings by an accomplished amateur astronomer.]

Dollfus, Audouin, 1961, "Visual and Photographic Studies of the Planets at the Pic du Midi," in *Planets and Satellites*, Kuiper and Middlehurst (Eds.), U. of Chicago Press. [One of the very few review articles in English written during the last 40 years by a professional astronomer who studied the planets visually.]

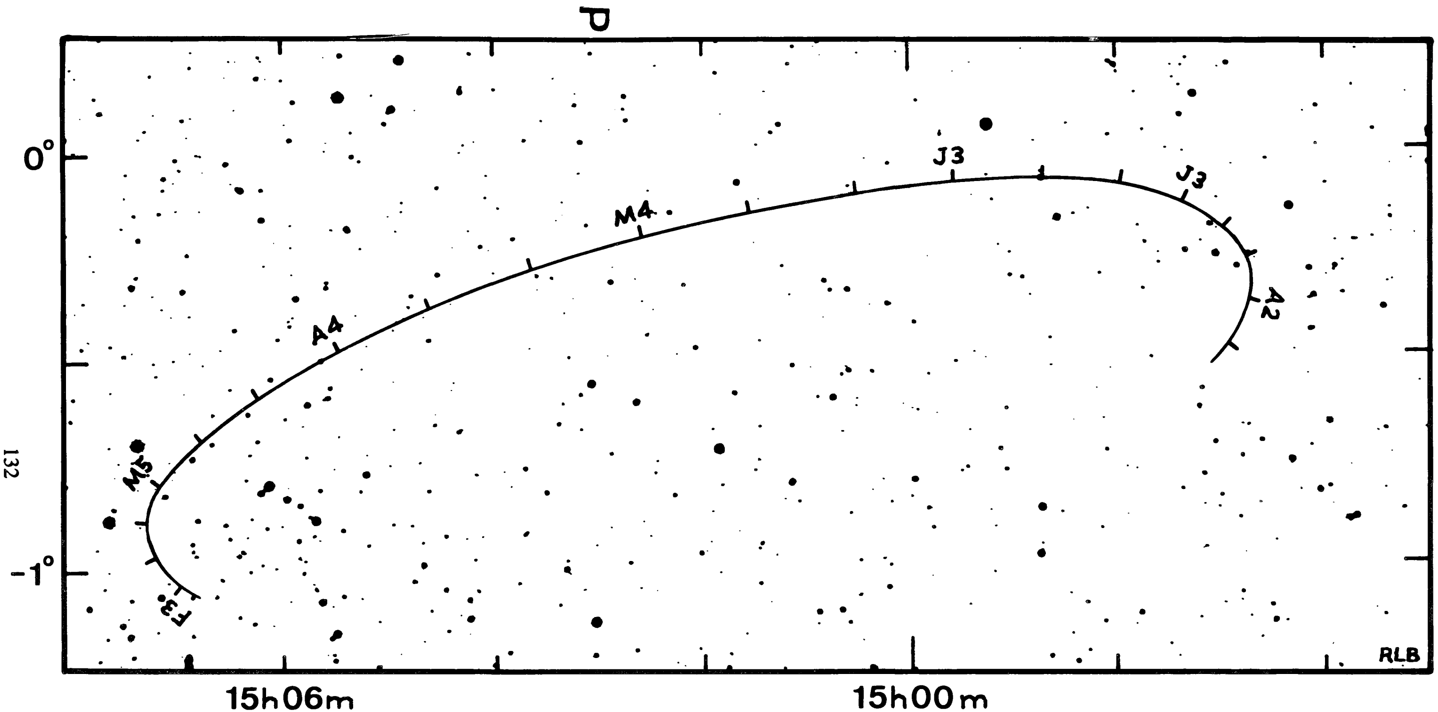
Hartmann, William K., 1983, *Moons and Planets*, second edition, Wadsworth, Belmont, Calif. [A comprehensive descriptive text devoted to the surfaces, interiors and atmospheres of the planets and their satellites.]

Hunt, G. and Moore, P., 1983, *Atlas of the Solar System*, Rand McNally, New York. [Includes many spacecraft images of planets and moons out to Saturn. Very limited observing information.]

Roth, Gunter D., 1970, *Handbook for Planet Observers*, Faber, London. [Though outdated and out of print, this is a fairly extensive reference on planetary observing.]

Rudaux, L., and de Vaucouleurs, G., 1959, *Larousse Encyclopedia of Astronomy*, Hamlyn, London. [The illustrations in Chapter 7 of this out-of-print masterpiece offer a wonderful look at visual planetary astronomy from a time when that activity was at its zenith among amateurs.]

Sheehan, William, 1988, *Planets and Perceptions*, U. of Arizona Press, Tucson. [Superbly researched investigation into why the great planetary observers (Schiaparelli, Lowell and others) so frequently misinterpreted what they saw or thought they saw.]



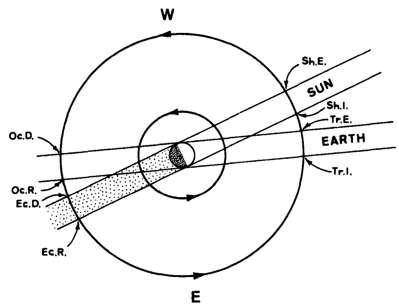
The path of **Pluto** *at the northern Libra-Virgo border during the six months centred on opposition, 1989. Its position is marked at 10-day intervals, beginning at February 3 (F3). The bright (magnitude 6) star just northwest of the June 3 position may be used to locate the star field shown here. This star is 2 Serpentis and is located 2.2°S of the star 110 Virginis (110 Virginis appears at α = 15h just above the celestial equator on the "May" map of the night sky at the end of this Handbook). Note also the wide-field chart on page 126. Pluto reaches opposition on May 4 at magnitude 13.6 and 3.98 light-hours from Earth. With perihelion occuring in September, Pluto is closer to us this year than it will be again until the 23rd century. Also, Pluto comes 0.5 AU closer to Earth than does Neptune this year. The faintest stars shown on the chart are about magnitude 13. Note that an aperture of at least 200 mm will be needed to see Pluto, and that two observations a day or more apart probably will be needed to confirm a sighting of this faint planet. The chart is based on Vehrenberg's* **Atlas Stellarum** *1950.0, and the coordinates are for that epoch. (RLB)*

JUPITER

PHENOMENA OF THE GALILEAN SATELLITES

The following tables give the various transits, occultations, and eclipses of the four great satellites of Jupiter. Since the phenomena are not instantaneous but require up to several minutes, the predicted times are for the middle of each event. The abbreviations are: I = Io, II = Europa, III = Ganymede, IV = Callisto; Ec = eclipse, Oc = occultation, Tr = transit of the satellite, Sh = transit of the shadow, I = ingress, E = egress, D = disappearance, R = reappearance.

The general motions of the satellites, and the successive phenomena are shown in the diagram at right. Satellites move from east to west across the face of the planet, and from west to east behind it. Before opposition, shadows fall to the west, and after opposition, to the east (as in the diagram). The sequence of phenomena in the diagram, beginning at the lower right, is: transit ingress (Tr.I.), transit egress (Tr.E.), shadow ingress (Sh.I.), shadow egress (Sh.E.), occultation disappearance (Oc.D.), occultation reappearance (Oc.R.), eclipse disappearance (Ec.D.) and eclipse reappearance (Ec.R.), but this sequence will depend on the actual Sun-Jupiter-Earth angle.



Over half the phenomena listed will not be visible from any one locality because they occur when Jupiter is below the horizon or when daylight interferes. To determine which phenomena are visible from a given locality (latitude ϕ) on a certain date, note the local time that Jupiter transits and its declination δ (see The Sky Month By Month section). Jupiter will be above the horizon for a time of $(1/15)\cos^{-1}(-\tan\phi\tan\delta)$ hours on either side of the time of transit. A second time interval corresponding to nighttime can be determined from the Twilight table. The region of overlap of these two time intervals will correspond to Jupiter being both above the horizon and in a dark sky. Those phenomena in the table which fall within this time "window" will be visible.

In practice, the observer usually knows when Jupiter will be conveniently placed in the night sky, and the table can simply be scanned to select those events which occur near these times. For example, an active observer in Victoria, British Columbia, on December 19 would know that Jupiter is well placed in the late evening sky. If he planned to observe from 9 pm to 1 am PST (8 h behind UT), he could scan the table for events in the interval December 20, 5 h to 9 h UT. He would find two events, at 2235 and 2258 PST, both involving the satellite Europa.

SATELLITES OF JUPITER, 1989

UNIVERSAL TIME OF GEOCENTRIC PHENOMENA

JANUARY

d	h m	
0	1 43	I.Tr.I.
	2 37	I.Sh.I.
	3 53	I.Tr.E.
	4 46	I.Sh.E.
	13 02	II.Oc.D.
	17 11	II.Ec.R.
	23 03	I.Oc.D.
1	2 08	I.Ec.R.
	12 47	III.Oc.D.
	14 56	III.Oc.R.
	16 30	III.Ec.D.
	18 45	III.Ec.R.
	20 10	I.Tr.I.
	21 05	I.Sh.I.
	22 20	I.Tr.E.
	23 15	I.Sh.E.
2	8 08	II.Tr.I.
	10 00	II.Sh.I.
	10 25	II.Tr.E.
	12 18	II.Sh.E.
	17 30	I.Oc.D.
	20 37	I.Ec.R.
3	14 37	I.Tr.I.
	15 34	I.Sh.I.
	16 46	I.Tr.E.
	17 44	I.Sh.E.
4	2 12	II.Oc.D.
	6 29	II.Ec.R.
	11 57	I.Oc.D.
	15 06	I.Ec.R.
5	2 33	III.Tr.I.
	4 41	III.Tr.E.
	6 30	III.Sh.I.
	8 43	III.Sh.E.
	9 04	I.Tr.I.
	10 03	I.Sh.I.
	11 14	I.Tr.E.
	12 13	I.Sh.E.
	21 19	II.Tr.I.
	23 18	II.Sh.I.
	23 36	II.Tr.E.
6	1 37	II.Sh.E.
	6 24	I.Oc.D.
	9 34	I.Ec.R.
7	3 31	I.Tr.I.
	4 32	I.Sh.I.
	5 41	I.Tr.E.
	6 42	I.Sh.E.
	15 24	II.Oc.D.
	19 49	II.Ec.R.
8	0 51	I.Oc.D.
	4 03	I.Ec.R.
8	16 19	III.Oc.D.
	18 30	III.Oc.R.
	20 32	III.Ec.D.
	21 59	I.Tr.I.
	22 47	III.Ec.R.
	23 01	I.Sh.I.
9	0 08	I.Tr.E.
	1 11	I.Sh.E.
	10 31	II.Tr.I.
	12 36	II.Sh.I.
	12 48	II.Tr.E.
	14 55	II.Sh.E.
	19 18	I.Oc.D.
	22 32	I.Ec.R.
10	16 26	I.Tr.I.
	17 30	I.Sh.I.
	18 35	I.Tr.E.
	19 40	I.Sh.E.
11	4 36	II.Oc.D.
	9 07	II.Ec.R.
	13 45	I.Oc.D.
	17 01	I.Ec.R.
12	6 07	III.Tr.I.
	8 18	III.Tr.E.
	10 31	III.Sh.I.
	10 53	I.Tr.I.
	11 59	I.Sh.I.
	12 44	III.Sh.E.
	13 03	I.Tr.E.
	14 09	I.Sh.E.
	23 43	II.Tr.I.
13	1 54	II.Sh.I.
	2 00	II.Tr.E.
	4 13	II.Sh.E.
	8 13	I.Oc.D.
	11 30	I.Ec.R.
14	5 21	I.Tr.I.
	6 28	I.Sh.I.
	7 30	I.Tr.E.
	8 37	I.Sh.E.
	17 49	II.Oc.D.
	22 27	II.Ec.R.
15	2 40	I.Oc.D.
	5 59	I.Ec.R.
	19 55	III.Oc.D.
	22 09	III.Oc.R.
	23 49	I.Tr.I.
16	0 33	III.Ec.D.
	0 57	I.Sh.I.
	1 58	I.Tr.E.
	2 49	III.Ec.R.
	3 06	I.Sh.E.
16	12 56	II.Tr.I.
	15 12	II.Sh.I.
	15 14	II.Tr.E.
	17 31	II.Sh.E.
	21 08	I.Oc.D.
17	0 27	I.Ec.R.
	18 16	I.Tr.I.
	19 25	I.Sh.I.
	20 26	I.Tr.E.
	21 35	I.Sh.E.
18	7 02	II.Oc.D.
	9 22	II.Oc.R.
	9 24	II.Ec.D.
	11 45	II.Ec.R.
	15 35	I.Oc.D.
	18 56	I.Ec.R.
19	9 45	III.Tr.I.
	11 59	III.Tr.E.
	12 44	I.Tr.I.
	13 54	I.Sh.I.
	14 32	III.Sh.I.
	14 53	I.Tr.E.
	16 04	I.Sh.E.
	16 46	III.Sh.E.
20	2 10	II.Tr.I.
	4 27	II.Tr.E.
	4 31	II.Sh.I.
	6 50	II.Sh.E.
	10 03	I.Oc.D.
	13 25	I.Ec.R.
21	7 12	I.Tr.I.
	8 23	I.Sh.I.
	9 21	I.Tr.E.
	10 33	I.Sh.E.
	20 17	II.Oc.D.
	22 37	II.Oc.R.
	22 44	II.Ec.D.
22	1 05	II.Ec.R.
	4 31	I.Oc.D.
	7 54	I.Ec.R.
	23 37	III.Oc.D.
23	1 40	I.Tr.I.
	1 54	III.Oc.R.
	2 52	I.Sh.I.
	3 49	I.Tr.E.
	4 35	III.Ec.D.
	5 02	I.Sh.E.
	6 52	III.Ec.R.
	15 24	II.Tr.I.
	17 42	II.Tr.E.
	17 49	II.Sh.I.
	20 08	II.Sh.E.
	22 59	I.Oc.D.
24	2 23	I.Ec.R.
	20 08	I.Tr.I.
	21 21	I.Sh.I.
	22 17	I.Tr.E.
	23 31	I.Sh.E.
25	9 31	II.Oc.D.
	11 52	II.Oc.R.
	12 02	II.Ec.D.
	14 24	II.Ec.R.
	17 27	I.Oc.D.
	20 52	I.Ec.R.
26	13 30	III.Tr.I.
	14 36	I.Tr.I.
	15 45	III.Tr.E.
	15 50	I.Sh.I.
	16 45	I.Tr.E.
	18 00	I.Sh.E.
	18 33	III.Sh.I.
	20 48	III.Sh.E.
27	4 38	II.Tr.I.
	6 57	II.Tr.E.
	7 07	II.Sh.I.
	9 26	II.Sh.E.
	11 55	I.Oc.D.
	15 20	I.Ec.R.
28	9 04	I.Tr.I.
	10 19	I.Sh.I.
	11 13	I.Tr.E.
	12 29	I.Sh.E.
	22 47	II.Oc.D.
29	1 08	II.Oc.R.
	1 22	II.Ec.D.
	3 43	II.Ec.R.
	6 23	I.Oc.D.
	9 49	I.Ec.R.
30	3 24	III.Oc.D.
	3 32	I.Tr.I.
	4 48	I.Sh.I.
	5 42	I.Tr.E.
	5 43	III.Oc.R.
	6 58	I.Sh.E.
	8 36	III.Ec.D.
	10 53	III.Ec.R.
	17 54	II.Tr.I.
	20 12	II.Tr.E.
	20 25	II.Sh.I.
	22 44	II.Sh.E.
31	0 51	I.Oc.D.
	4 18	I.Ec.R.
	22 00	I.Tr.I.
	23 17	I.Sh.I.

SATELLITES OF JUPITER, 1989

UNIVERSAL TIME OF GEOCENTRIC PHENOMENA

FEBRUARY

d	h m		d	h m		d	h m		d	h m	
1	0 10	I.Tr.E.	8	2 04	I.Tr.E.	15	3 59	I.Tr.E.	22	5 55	I.Tr.E.
	1 27	I.Sh.E.		3 22	I.Sh.E.		5 18	I.Sh.E.		7 14	I.Sh.E.
	12 03	II.Oc.D.		14 37	II.Oc.D.		17 14	II.Oc.D.		19 53	II.Oc.D.
	14 24	II.Oc.R.		16 59	II.Oc.R.		19 36	II.Oc.R.		22 16	II.Oc.R.
	14 40	II.Ec.D.		17 19	II.Ec.D.		19 57	II.Ec.D.		22 35	II.Ec.D.
	17 02	II.Ec.R.		19 41	II.Ec.R.		22 20	II.Ec.R.			
	19 19	I.Oc.D.		21 13	I.Oc.D.		23 07	I.Oc.D.	23	0 58	II.Ec.R.
	22 47	I.Ec.R.								1 03	I.Oc.D.
			9	0 42	I.Ec.R.	16	2 38	I.Ec.R.		4 33	I.Ec.R.
2	16 29	I.Tr.I.		18 23	I.Tr.I.		20 18	I.Tr.I.		22 14	I.Tr.I.
	17 19	III.Tr.I.		19 42	I.Sh.I.		21 37	I.Sh.I.		23 33	I.Sh.I.
	17 46	I.Sh.I.		20 33	I.Tr.E.		22 28	I.Tr.E.			
	18 38	I.Tr.E.		21 14	III.Tr.I.		23 47	I.Sh.E.	24	0 25	I.Tr.E.
	19 37	III.Tr.E.		21 51	I.Sh.E.					1 43	I.Sh.E.
	19 56	I.Sh.E.		23 34	III.Tr.E.	17	1 14	III.Tr.I.		5 17	III.Tr.I.
	22 35	III.Sh.I.					3 35	III.Tr.E.		7 40	III.Tr.E.
			10	2 36	III.Sh.I.		6 38	III.Sh.I.		10 39	III.Sh.I.
3	0 50	III.Sh.E.		4 52	III.Sh.E.		8 55	III.Sh.E.		12 57	III.Sh.E.
	7 09	II.Tr.I.		9 43	II.Tr.I.		12 18	II.Tr.I.		14 55	II.Tr.I.
	9 28	II.Tr.E.		12 02	II.Tr.E.		14 38	II.Tr.E.		17 15	II.Tr.E.
	9 43	II.Sh.I.		12 19	II.Sh.I.		14 55	II.Sh.I.		17 31	II.Sh.I.
	12 02	II.Sh.E.		14 39	II.Sh.E.		17 15	II.Sh.E.		19 32	I.Oc.D.
	13 47	I.Oc.D.		15 41	I.Oc.D.		17 36	I.Oc.D.		19 51	II.Sh.E.
	17 16	I.Ec.R.		19 11	I.Ec.R.		21 06	I.Ec.R.		23 02	I.Ec.R.
4	10 57	I.Tr.I.	11	12 51	I.Tr.I.	18	14 47	I.Tr.I.	25	16 44	I.Tr.I.
	12 15	I.Sh.I.		14 10	I.Sh.I.		16 06	I.Sh.I.		18 02	I.Sh.I.
	13 07	I.Tr.E.		15 01	I.Tr.E.		16 57	I.Tr.E.		18 54	I.Tr.E.
	14 24	I.Sh.E.		16 20	I.Sh.E.		18 16	I.Sh.E.		20 12	I.Sh.E.
5	1 20	II.Oc.D.	12	3 56	II.Oc.D.	19	6 33	II.Oc.D.	26	9 14	II.Oc.D.
	3 42	II.Oc.R.		6 18	II.Oc.R.		8 56	II.Oc.R.		11 37	II.Oc.R.
	4 00	II.Ec.D.		6 38	II.Ec.D.		9 17	II.Ec.D.		11 55	II.Ec.D.
	6 22	II.Ec.R.		9 01	II.Ec.R.		11 39	II.Ec.R.		14 01	I.Oc.D.
	8 16	I.Oc.D.		10 10	I.Oc.D.		12 05	I.Oc.D.		14 18	II.Ec.R.
	11 45	I.Ec.R.		13 40	I.Ec.R.		15 35	I.Ec.R.		17 31	I.Ec.R.
6	5 26	I.Tr.I.	13	7 20	I.Tr.I.	20	9 16	I.Tr.I.	27	11 13	I.Tr.I.
	6 44	I.Sh.I.		8 40	I.Sh.I.		10 35	I.Sh.I.		12 31	I.Sh.I.
	7 15	III.Oc.D.		9 30	I.Tr.E.		11 26	I.Tr.E.		13 23	I.Tr.E.
	7 35	I.Tr.E.		10 49	I.Sh.E.		12 45	I.Sh.E.		14 41	I.Sh.E.
	8 53	I.Sh.E.		11 11	III.Oc.D.		15 12	III.Oc.D.		19 18	III.Oc.D.
	9 36	III.Oc.R.		13 34	III.Oc.R.		17 37	III.Oc.R.		21 44	III.Oc.R.
	12 37	III.Ec.D.		16 38	III.Ec.D.		20 38	III.Ec.D.			
	14 55	III.Ec.R.		18 56	III.Ec.R.		22 58	III.Ec.R.	28	0 40	III.Ec.D.
	20 26	II.Tr.I.		23 00	II.Tr.I.					3 01	III.Ec.R.
	22 45	II.Tr.E.				21	1 36	II.Tr.I.		4 14	II.Tr.I.
	23 01	II.Sh.I.	14	1 20	II.Tr.E.		3 56	II.Tr.E.		6 35	II.Tr.E.
				1 37	II.Sh.I.		4 13	II.Sh.I.		6 49	II.Sh.I.
7	1 20	II.Sh.E.		3 57	II.Sh.E.		6 33	II.Sh.E.		8 31	I.Oc.D.
	2 44	I.Oc.D.		4 39	I.Oc.D.		6 34	I.Oc.D.		9 09	II.Sh.E.
	6 13	I.Ec.R.		8 09	I.Ec.R.		10 04	I.Ec.R.		11 59	I.Ec.R.
	23 54	I.Tr.I.									
			15	1 49	I.Tr.I.	22	3 45	I.Tr.I.			
8	1 13	I.Sh.I.		3 08	I.Sh.I.		5 04	I.Sh.I.			

UNIVERSAL TIME OF GEOCENTRIC PHENOMENA

MARCH

d	h m	
1	5 42	I.Tr.I.
	7 00	I.Sh.I.
	7 52	I.Tr.E.
	9 10	I.Sh.E.
	22 34	II.Oc.D.
2	0 57	II.Oc.R.
	1 14	II.Ec.D.
	3 00	I.Oc.D.
	3 37	II.Ec.R.
	6 28	I.Ec.R.
3	0 12	I.Tr.I.
	1 29	I.Sh.I.
	2 22	I.Tr.E.
	3 39	I.Sh.E.
	9 24	III.Tr.I.
	11 48	III.Tr.E.
	14 40	III.Sh.I.
	16 59	III.Sh.E.
	17 34	II.Tr.I.
	19 55	II.Tr.E.
	20 07	II.Sh.I.
	21 29	I.Oc.D.
	22 27	II.Sh.E.
4	0 57	I.Ec.R.
	18 41	I.Tr.I.
	19 58	I.Sh.I.
	20 51	I.Tr.E.
	22 08	I.Sh.E.
5	11 56	II.Oc.D.
	14 19	II.Oc.R.
	14 34	II.Ec.D.
	15 59	I.Oc.D.
	16 57	II.Ec.R.
	19 26	I.Ec.R.
6	13 11	I.Tr.I.
	14 27	I.Sh.I.
	15 21	I.Tr.E.
	16 37	I.Sh.E.
	23 27	III.Oc.D.
7	1 54	III.Oc.R.
	4 41	III.Ec.D.
	6 54	II.Tr.I.
	7 02	III.Ec.R.
	9 15	II.Tr.E.
	9 24	II.Sh.I.
	10 28	I.Oc.D.
	11 45	II.Sh.E.
	13 55	I.Ec.R.
8	7 40	I.Tr.I.
	8 56	I.Sh.I.
	9 51	I.Tr.E.
8	11 06	I.Sh.E.
9	1 17	II.Oc.D.
	3 41	II.Oc.R.
	3 52	II.Ec.D.
	4 57	I.Oc.D.
	6 16	II.Ec.R.
	8 24	I.Ec.R.
10	2 10	I.Tr.I.
	3 25	I.Sh.I.
	4 20	I.Tr.E.
	5 35	I.Sh.E.
	13 34	III.Tr.I.
	16 00	III.Tr.E.
	18 41	III.Sh.I.
	20 15	II.Tr.I.
	21 01	III.Sh.E.
	22 36	II.Tr.E.
	22 42	II.Sh.I.
	23 27	I.Oc.D.
11	1 03	II.Sh.E.
	2 52	I.Ec.R.
	20 39	I.Tr.I.
	21 54	I.Sh.I.
	22 50	I.Tr.E.
12	0 04	I.Sh.E.
	14 39	II.Oc.D.
	17 04	II.Oc.R.
	17 12	II.Ec.D.
	17 56	I.Oc.D.
	19 36	II.Ec.R.
	21 21	I.Ec.R.
13	15 09	I.Tr.I.
	16 23	I.Sh.I.
	17 20	I.Tr.E.
	18 33	I.Sh.E.
14	3 40	III.Oc.D.
	6 08	III.Oc.R.
	8 43	III.Ec.D.
	9 35	II.Tr.I.
	11 05	III.Ec.R.
	11 57	II.Tr.E.
	12 00	II.Sh.I.
	12 26	I.Oc.D.
	14 21	II.Sh.E.
	15 50	I.Ec.R.
15	9 39	I.Tr.I.
	10 52	I.Sh.I.
	11 49	I.Tr.E.
	13 02	I.Sh.E.
16	4 02	II.Oc.D.
16	6 26	II.Oc.R.
	6 31	II.Ec.D.
	6 56	I.Oc.D.
	8 55	II.Ec.R.
	10 19	I.Ec.R.
17	4 09	I.Tr.I.
	5 21	I.Sh.I.
	6 19	I.Tr.E.
	7 31	I.Sh.E.
	17 48	III.Tr.I.
	20 15	III.Tr.E.
	22 42	III.Sh.I.
	22 56	II.Tr.I.
18	1 03	III.Sh.E.
	1 18	II.Sh.I.
	1 18	II.Tr.E.
	1 25	I.Oc.D.
	3 39	II.Sh.E.
	4 48	I.Ec.R.
	22 38	I.Tr.I.
	23 50	I.Sh.I.
19	0 49	I.Tr.E.
	2 00	I.Sh.E.
	17 25	II.Oc.D.
	19 50	II.Oc.R.
	19 51	II.Ec.D.
	19 55	I.Oc.D.
	22 15	II.Ec.R.
	23 16	I.Ec.R.
20	17 08	I.Tr.I.
	18 19	I.Sh.I.
	19 19	I.Tr.E.
	20 29	I.Sh.E.
21	7 55	III.Oc.D.
	10 24	III.Oc.R.
	12 18	II.Tr.I.
	12 43	III.Ec.D.
	14 25	I.Oc.D.
	14 36	II.Sh.I.
	14 40	II.Tr.E.
	15 06	III.Ec.R.
	16 57	II.Sh.E.
	17 45	I.Ec.R.
22	11 38	I.Tr.I.
	12 48	I.Sh.I.
	13 49	I.Tr.E.
	14 58	I.Sh.E.
23	6 48	II.Oc.D.
	8 54	I.Oc.D.
	11 34	II.Ec.R.
	12 14	I.Ec.R.
24	6 08	I.Tr.I.
	7 17	I.Sh.I.
	8 19	I.Tr.E.
	9 27	I.Sh.E.
	22 06	III.Tr.I.
25	0 34	III.Tr.E.
	1 40	II.Tr.I.
	2 44	III.Sh.I.
	3 24	I.Oc.D.
	3 53	II.Sh.I.
	4 02	II.Tr.E.
	5 05	III.Sh.E.
	6 15	II.Sh.E.
	6 43	I.Ec.R.
26	0 38	I.Tr.I.
	1 45	I.Sh.I.
	2 49	I.Tr.E.
	3 56	I.Sh.E.
	20 12	II.Oc.D.
	21 54	I.Oc.D.
27	0 54	II.Ec.R.
	1 12	I.Ec.R.
	19 08	I.Tr.I.
	20 14	I.Sh.I.
	21 19	I.Tr.E.
	22 25	I.Sh.E.
28	12 13	III.Oc.D.
	14 43	III.Oc.R.
	15 02	II.Tr.I.
	16 24	I.Oc.D.
	16 44	III.Ec.D.
	17 11	II.Sh.I.
	17 24	II.Tr.E.
	19 07	III.Ec.R.
	19 33	II.Sh.E.
	19 40	I.Ec.R.
29	13 38	I.Tr.I.
	14 43	I.Sh.I.
	15 49	I.Tr.E.
	16 54	I.Sh.E.
30	9 35	II.Oc.D.
	10 54	I.Oc.D.
	14 09	I.Ec.R.
	14 13	II.Ec.R.
31	8 08	I.Tr.I.
	9 12	I.Sh.I.
	10 19	I.Tr.E.
	11 23	I.Sh.E.

SATELLITES OF JUPITER, 1989

UNIVERSAL TIME OF GEOCENTRIC PHENOMENA

APRIL

d	h m	
1	2 26	III.Tr.I.
	4 24	II.Tr.I.
	4 54	III.Tr.E.
	5 24	I.Oc.D.
	6 29	II.Sh.I.
	6 45	III.Sh.I.
	6 47	II.Tr.E.
	8 38	I.Ec.R.
	8 51	II.Sh.E.
	9 07	III.Sh.E.
2	2 38	I.Tr.I.
	3 41	I.Sh.I.
	4 50	I.Tr.E.
	5 52	I.Sh.E.
	23 00	II.Oc.D.
	23 54	I.Oc.D.
3	3 07	I.Ec.R.
	3 33	II.Ec.R.
	21 09	I.Tr.I.
	22 10	I.Sh.I.
	23 20	I.Tr.E.
4	0 21	I.Sh.E.
	16 33	III.Oc.D.
	17 47	II.Tr.I.
	18 24	I.Oc.D.
	19 04	III.Oc.R.
	19 46	II.Sh.I.
	20 10	II.Tr.E.
	20 44	III.Ec.D.
	21 35	I.Ec.R.
	22 09	II.Sh.E.
	23 09	III.Ec.R.
5	15 39	I.Tr.I.
	16 39	I.Sh.I.
	17 50	I.Tr.E.
	18 50	I.Sh.E.
6	12 24	II.Oc.D.
	12 54	I.Oc.D.
	16 04	I.Ec.R.
	16 52	II.Ec.R.
7	10 09	I.Tr.I.
	11 08	I.Sh.I.
	12 20	I.Tr.E.
	13 19	I.Sh.E.
8	6 48	III.Tr.I.
	7 09	II.Tr.I.
	7 24	I.Oc.D.
	9 04	II.Sh.I.

d	h m	
8	9 18	III.Tr.E.
	9 33	II.Tr.E.
	10 33	I.Ec.R.
	10 47	III.Sh.I.
	11 27	II.Sh.E.
	13 10	III.Sh.E.
9	4 39	I.Tr.I.
	5 37	I.Sh.I.
	6 50	I.Tr.E.
	7 48	I.Sh.E.
10	1 49	II.Oc.D.
	1 54	I.Oc.D.
	5 02	I.Ec.R.
	6 12	II.Ec.R.
	23 09	I.Tr.I.
11	0 06	I.Sh.I.
	1 21	I.Tr.E.
	2 17	I.Sh.E.
	20 24	I.Oc.D.
	20 32	II.Tr.I.
	20 56	III.Oc.D.
	22 22	II.Sh.I.
	22 56	II.Tr.E.
	23 28	III.Oc.R.
	23 30	I.Ec.R.
12	0 44	III.Ec.D.
	0 45	II.Sh.E.
	3 10	III.Ec.R.
	17 40	I.Tr.I.
	18 35	I.Sh.I.
	19 51	I.Tr.E.
	20 46	I.Sh.E.
13	14 54	I.Oc.D.
	15 14	II.Oc.D.
	17 59	I.Ec.R.
	19 31	II.Ec.R.
14	12 10	I.Tr.I.
	13 04	I.Sh.I.
	14 22	I.Tr.E.
	15 15	I.Sh.E.
15	9 24	I.Oc.D.
	9 56	II.Tr.I.
	11 12	III.Tr.I.
	11 39	II.Sh.I.
	12 20	II.Tr.E.
	12 28	I.Ec.R.
	13 42	III.Tr.E.
	14 03	II.Sh.E.

d	h m	
15	14 47	III.Sh.I.
	17 12	III.Sh.E.
16	6 40	I.Tr.I.
	7 32	I.Sh.I.
	8 52	I.Tr.E.
	9 44	I.Sh.E.
17	3 55	I.Oc.D.
	4 39	II.Oc.D.
	6 57	I.Ec.R.
	8 50	II.Ec.R.
18	1 11	I.Tr.I.
	2 01	I.Sh.I.
	3 22	I.Tr.E.
	4 13	I.Sh.E.
	22 25	I.Oc.D.
	23 19	II.Tr.I.
19	0 57	II.Sh.I.
	1 21	III.Oc.D.
	1 25	I.Ec.R.
	1 43	II.Tr.E.
	3 20	II.Sh.E.
	3 53	III.Oc.R.
	4 46	III.Ec.D.
	7 12	III.Ec.R.
	19 41	I.Tr.I.
	20 30	I.Sh.I.
	21 53	I.Tr.E.
	22 41	I.Sh.E.
20	16 55	I.Oc.D.
	18 04	II.Oc.D.
	19 54	I.Ec.R.
	22 09	II.Ec.R.
21	14 11	I.Tr.I.
	14 59	I.Sh.I.
	16 23	I.Tr.E.
	17 10	I.Sh.E.
22	11 25	I.Oc.D.
	12 42	II.Tr.I.
	14 15	II.Sh.I.
	14 23	I.Ec.R.
	15 07	II.Tr.E.
	15 37	III.Tr.I.
	16 38	II.Sh.E.
	18 08	III.Tr.E.
	18 48	III.Sh.I.
	21 13	III.Sh.E.
23	8 42	I.Tr.I.

d	h m	
23	9 28	I.Sh.I.
	10 53	I.Tr.E.
	11 39	I.Sh.E.
24	5 55	I.Oc.D.
	7 30	II.Oc.D.
	8 52	I.Ec.R.
	11 29	II.Ec.R.
25	3 12	I.Tr.I.
	3 57	I.Sh.I.
	5 24	I.Tr.E.
	6 08	I.Sh.E.
26	0 26	I.Oc.D.
	2 06	II.Tr.I.
	3 20	I.Ec.R.
	3 32	II.Sh.I.
	4 31	II.Tr.E.
	5 47	III.Oc.D.
	5 56	II.Sh.E.
	8 20	III.Oc.R.
	8 46	III.Ec.D.
	11 14	III.Ec.R.
	21 43	I.Tr.I.
	22 26	I.Sh.I.
	23 54	I.Tr.E.
27	0 37	I.Sh.E.
	18 56	I.Oc.D.
	20 55	II.Oc.D.
	21 49	I.Ec.R.
28	0 48	II.Ec.R.
	16 13	I.Tr.I.
	16 55	I.Sh.I.
	18 25	I.Tr.E.
	19 06	I.Sh.E.
29	13 26	I.Oc.D.
	15 30	II.Tr.I.
	16 18	I.Ec.R.
	16 50	II.Sh.I.
	17 55	II.Tr.E.
	19 14	II.Sh.E.
	20 03	III.Tr.I.
	22 35	III.Tr.E.
	22 48	III.Sh.I.
30	1 15	III.Sh.E.
	10 43	I.Tr.I.
	11 23	I.Sh.I.
	12 55	I.Tr.E.
	13 35	I.Sh.E.

SATELLITES OF JUPITER, 1989

UNIVERSAL TIME OF GEOCENTRIC PHENOMENA

MAY

d	h m		d	h m		d	h m		d	h m	
1	7 57	I.Oc.D.	9	7 16	I.Tr.I.	17	6 30	I.Oc.D.	24	15 48	II.Tr.E.
	10 21	II.Oc.D.		7 48	I.Sh.I.		9 05	I.Ec.R.		16 19	II.Sh.E.
	10 46	I.Ec.R.		9 28	I.Tr.E.		10 31	II.Tr.I.		23 40	III.Oc.D.
	14 07	II.Ec.R.		9 59	I.Sh.E.		11 18	II.Sh.I.			
							12 58	II.Tr.E.	25	3 18	III.Ec.R.
2	5 14	I.Tr.I.	10	4 28	I.Oc.D.		13 43	II.Sh.E.		5 51	I.Tr.I.
	5 52	I.Sh.I.		7 10	I.Ec.R.		19 11	III.Oc.D.		6 07	I.Sh.I.
	7 26	I.Tr.E.		7 42	II.Tr.I.		23 17	III.Ec.R.		8 03	I.Tr.E.
	8 04	I.Sh.E.		8 43	II.Sh.I.					8 19	I.Sh.E.
				10 08	II.Tr.E.	18	3 49	I.Tr.I.			
3	2 27	I.Oc.D.		11 08	II.Sh.E.		4 11	I.Sh.I.	26	3 02	I.Oc.D.
	4 54	II.Tr.I.		14 43	III.Oc.D.		6 01	I.Tr.E.		5 28	I.Ec.R.
	5 15	I.Ec.R.		19 16	III.Ec.R.		6 23	I.Sh.E.		8 23	II.Oc.D.
	6 07	II.Sh.I.								11 20	II.Ec.R.
	7 20	II.Tr.E.	11	1 46	I.Tr.I.	19	1 00	I.Oc.D.			
	8 32	II.Sh.E.		2 16	I.Sh.I.		3 33	I.Ec.R.	27	0 21	I.Tr.I.
	10 15	III.Oc.D.		3 59	I.Tr.E.		5 31	II.Oc.D.		0 35	I.Sh.I.
	15 15	III.Ec.R.		4 28	I.Sh.E.		8 42	II.Ec.R.		2 34	I.Tr.E.
	23 44	I.Tr.I.		22 59	I.Oc.D.		22 19	I.Tr.I.		2 47	I.Sh.E.
							22 40	I.Sh.I.		21 32	I.Oc.D.
4	0 21	I.Sh.I.	12	1 39	I.Ec.R.					23 57	I.Ec.R.
	1 56	I.Tr.E.		2 39	II.Oc.D.	20	0 32	I.Tr.E.			
	2 33	I.Sh.E.		6 04	II.Ec.R.		0 52	I.Sh.E.	28	2 45	II.Tr.I.
	20 57	I.Oc.D.		20 17	I.Tr.I.		19 31	I.Oc.D.		3 10	II.Sh.I.
	23 44	I.Ec.R.		20 45	I.Sh.I.		22 02	I.Ec.R.		5 13	II.Tr.E.
	23 47	II.Oc.D.		22 29	I.Tr.E.		23 56	II.Tr.I.		5 37	II.Sh.E.
				22 57	I.Sh.E.					14 00	III.Tr.I.
5	3 26	II.Ec.R.				21	0 35	II.Sh.I.		14 51	III.Sh.I.
	18 15	I.Tr.I.	13	17 29	I.Oc.D.		2 23	II.Tr.E.		16 35	III.Tr.E.
	18 50	I.Sh.I.		20 07	I.Ec.R.		3 01	II.Sh.E.		17 21	III.Sh.E.
	20 27	I.Tr.E.		21 07	II.Tr.I.		9 29	III.Tr.I.		18 52	I.Tr.I.
	21 02	I.Sh.E.		22 00	II.Sh.I.		10 50	III.Sh.I.		19 04	I.Sh.I.
				23 33	II.Tr.E.		12 04	III.Tr.E.		21 04	I.Tr.E.
6	15 28	I.Oc.D.					13 20	III.Sh.E.		21 16	I.Sh.E.
	18 12	I.Ec.R.	14	0 25	II.Sh.E.		16 50	I.Tr.I.			
	18 18	II.Tr.I.		5 00	III.Tr.I.		17 09	I.Sh.I.	29	16 03	I.Oc.D.
	19 25	II.Sh.I.		6 50	III.Sh.I.		19 02	I.Tr.E.		18 25	I.Ec.R.
	20 44	II.Tr.E.		7 34	III.Tr.E.		19 21	I.Sh.E.		21 49	II.Oc.D.
	21 50	II.Sh.E.		9 18	III.Sh.E.						
				14 48	I.Tr.I.	22	14 01	I.Oc.D.	30	0 39	II.Ec.R.
7	0 31	III.Tr.I.		15 14	I.Sh.I.		16 31	I.Ec.R.		13 23	I.Tr.I.
	2 49	III.Sh.I.		17 00	I.Tr.E.		18 57	II.Oc.D.		13 33	I.Sh.I.
	3 04	III.Tr.E.		17 26	I.Sh.E.		22 02	II.Ec.R.		15 35	I.Tr.E.
	5 16	III.Sh.E.								15 45	I.Sh.E.
	12 45	I.Tr.I.	15	11 59	I.Oc.D.	23	11 20	I.Tr.I.			
	13 19	I.Sh.I.		14 36	I.Ec.R.		11 38	I.Sh.I.	31	10 33	I.Oc.D.
	14 58	I.Tr.E.		16 05	II.Oc.D.		13 33	I.Tr.E.		12 54	I.Ec.R.
	15 30	I.Sh.E.		19 24	II.Ec.R.		13 50	I.Sh.E.		16 10	II.Tr.I.
										16 28	II.Sh.I.
8	9 58	I.Oc.D.	16	9 18	I.Tr.I.	24	8 31	I.Oc.D.		18 38	II.Tr.E.
	12 41	I.Ec.R.		9 43	I.Sh.I.		10 59	I.Ec.R.		18 55	II.Sh.E.
	13 13	II.Oc.D.		11 30	I.Tr.E.		13 20	II.Tr.I.			
	16 46	II.Ec.R.		11 55	I.Sh.E.		13 53	II.Sh.I.			

UNIVERSAL TIME OF GEOCENTRIC PHENOMENA

JUNE

d	h m	
1	4 10	III.Oc.D.
	7 18	III.Ec.R.
	7 53	I.Tr.I.
	8 02	I.Sh.I.
	10 05	I.Tr.E.
	10 14	I.Sh.E.
2	5 03	I.Oc.D.
	7 22	I.Ec.R.
	11 15	II.Oc.D.
	13 58	II.Ec.R.
3	2 24	I.Tr.I.
	2 30	I.Sh.I.
	4 36	I.Tr.E.
	4 42	I.Sh.E.
	23 34	I.Oc.D.
4	1 51	I.Ec.R.
	5 34	II.Tr.I.
	5 46	II.Sh.I.
	8 03	II.Tr.E.
	8 12	II.Sh.E.
	18 29	III.Tr.I.
	18 51	III.Sh.I.
	20 54	I.Tr.I.
	20 59	I.Sh.I.
	21 06	III.Tr.E.
	21 22	III.Sh.E.
	23 07	I.Tr.E.
	23 11	I.Sh.E.
5	18 04	I.Oc.D.
	20 20	I.Ec.R.
6	0 41	II.Oc.D.
	3 17	II.Ec.R.
	15 25	I.Tr.I.
	15 28	I.Sh.I.
	17 37	I.Tr.E.
	17 40	I.Sh.E.
7	12 35	I.Oc.D.
	14 48	I.Ec.R.
	18 59	II.Tr.I.
	19 03	II.Sh.I.
	21 28	II.Tr.E.
	21 30	II.Sh.E.
8	8 40	III.Oc.D.
	9 55	I.Tr.I.
	9 56	I.Sh.I.

d	h m	
8	11 20	III.Ec.R.
	12 08	I.Tr.E.
	12 08	I.Sh.E.
9	7 05	I.Oc.D.
	9 17	I.Oc.R.
	14 06	II.Oc.D.
	16 37	II.Oc.R.
10	4 25	I.Sh.I.
	4 26	I.Tr.I.
	6 37	I.Sh.E.
	6 38	I.Tr.E.
11	1 34	I.Ec.D.
	3 48	I.Oc.R.
	8 21	II.Sh.I.
	8 24	II.Tr.I.
	10 48	II.Sh.E.
	10 53	II.Tr.E.
	22 50	III.Sh.I.
	22 54	I.Sh.I.
	22 56	I.Tr.I.
	22 58	III.Tr.I.
12	1 06	I.Sh.E.
	1 09	I.Tr.E.
	1 23	III.Sh.E.
	1 36	III.Tr.E.
	20 02	I.Ec.D.
	22 18	I.Oc.R.
13	3 26	II.Ec.D.
	6 03	II.Oc.R.
	17 22	I.Sh.I.
	17 27	I.Tr.I.
	19 35	I.Sh.E.
	19 39	I.Tr.E.
14	14 31	I.Ec.D.
	16 48	I.Oc.R.
	21 38	II.Sh.I.
	21 49	II.Tr.I.
15	0 06	II.Sh.E.
	0 18	II.Tr.E.
	11 51	I.Sh.I.
	11 57	I.Tr.I.
	12 47	III.Ec.D.
	14 03	I.Sh.E.
	14 10	I.Tr.E.
	15 49	III.Oc.R.

d	h m	
16	9 00	I.Ec.D.
	11 19	I.Oc.R.
	16 44	II.Ec.D.
	19 29	II.Oc.R.
17	6 20	I.Sh.I.
	6 28	I.Tr.I.
	8 32	I.Sh.E.
	8 40	I.Tr.E.
18	3 28	I.Ec.D.
	5 49	I.Oc.R.
	10 56	II.Sh.I.
	11 14	II.Tr.I.
	13 24	II.Sh.E.
	13 43	II.Tr.E.
19	0 48	I.Sh.I.
	0 58	I.Tr.I.
	2 50	III.Sh.I.
	3 01	I.Sh.E.
	3 11	I.Tr.E.
	3 28	III.Tr.I.
	5 23	III.Sh.E.
	6 06	III.Tr.E.
	21 57	I.Ec.D.
20	0 20	I.Oc.R.
	6 02	II.Ec.D.
	8 55	II.Oc.R.
	19 17	I.Sh.I.
	19 29	I.Tr.I.
	21 29	I.Sh.E.
	21 41	I.Tr.E.
21	16 25	I.Ec.D.
	18 50	I.Oc.R.
22	0 14	II.Sh.I.
	0 38	II.Tr.I.
	2 42	II.Sh.E.
	3 08	II.Tr.E.
	13 46	I.Sh.I.
	13 59	I.Tr.I.
	15 58	I.Sh.E.
	16 12	I.Tr.E.
	16 47	III.Ec.D.
	20 20	III.Oc.R.
23	10 54	I.Ec.D.
	13 21	I.Oc.R.
	19 20	II.Ec.D.

d	h m	
23	22 20	II.Oc.R.
24	8 15	I.Sh.I.
	8 30	I.Tr.I.
	10 27	I.Sh.E.
	10 42	I.Tr.E.
25	5 22	I.Ec.D.
	7 51	I.Oc.R.
	13 31	II.Sh.I.
	14 03	II.Tr.I.
	16 00	II.Sh.E.
	16 34	II.Tr.E.
26	2 43	I.Sh.I.
	3 00	I.Tr.I.
	4 55	I.Sh.E.
	5 12	I.Tr.E.
	6 50	III.Sh.I.
	7 57	III.Tr.I.
	9 24	III.Sh.E.
	10 36	III.Tr.E.
	23 51	I.Ec.D.
27	2 21	I.Oc.R.
	8 39	II.Ec.D.
	11 46	II.Oc.R.
	21 12	I.Sh.I.
	21 30	I.Tr.I.
	23 24	I.Sh.E.
	23 43	I.Tr.E.
28	18 20	I.Ec.D.
	20 52	I.Oc.R.
29	2 49	II.Sh.I.
	3 28	II.Tr.I.
	5 17	II.Sh.E.
	5 59	II.Tr.E.
	15 40	I.Sh.I.
	16 01	I.Tr.I.
	17 52	I.Sh.E.
	18 13	I.Tr.E.
	20 47	III.Ec.D.
30	0 50	III.Oc.R.
	12 48	I.Ec.D.
	15 22	I.Oc.R.
	21 57	II.Ec.D.

SATELLITES OF JUPITER, 1989

UNIVERSAL TIME OF GEOCENTRIC PHENOMENA

JULY

d	h m	
1	1 11	II.Oc.R.
	10 09	I.Sh.I.
	10 31	I.Tr.I.
	12 21	I.Sh.E.
	12 44	I.Tr.E.
2	7 17	I.Ec.D.
	9 52	I.Oc.R.
	16 07	II.Sh.I.
	16 53	II.Tr.I.
	18 36	II.Sh.E.
	19 24	II.Tr.E.
3	4 38	I.Sh.I.
	5 01	I.Tr.I.
	6 50	I.Sh.E.
	7 14	I.Tr.E.
	10 50	III.Sh.I.
	12 26	III.Tr.I.
	13 25	III.Sh.E.
	15 07	III.Tr.E.
4	1 45	I.Ec.D.
	4 23	I.Oc.R.
	11 15	II.Ec.D.
	14 37	II.Oc.R.
	23 06	I.Sh.I.
	23 32	I.Tr.I.
5	1 18	I.Sh.E.
	1 44	I.Tr.E.
	20 14	I.Ec.D.
	22 53	I.Oc.R.
6	5 25	II.Sh.I.
	6 17	II.Tr.I.
	7 53	II.Sh.E.
	8 49	II.Tr.E.
	17 35	I.Sh.I.
	18 02	I.Tr.I.
	19 47	I.Sh.E.
	20 15	I.Tr.E.
7	0 46	III.Ec.D.
	5 19	III.Oc.R.
	14 42	I.Ec.D.
	17 23	I.Oc.R.
8	0 33	II.Ec.D.
	4 02	II.Oc.R.
	12 03	I.Sh.I.
	12 32	I.Tr.I.
	14 16	I.Sh.E.
	14 45	I.Tr.E.
9	9 11	I.Ec.D.
	11 54	I.Oc.R.
	18 42	II.Sh.I.
	19 42	II.Tr.I.
	21 11	II.Sh.E.
	22 14	II.Tr.E.
10	6 32	I.Sh.I.
	7 03	I.Tr.I.
	8 44	I.Sh.E.
	9 15	I.Tr.E.
	14 50	III.Sh.I.
	16 53	III.Tr.I.
	17 26	III.Sh.E.
	19 35	III.Tr.E.
11	3 39	I.Ec.D.
	6 24	I.Oc.R.
	13 51	II.Ec.D.
	17 27	II.Oc.R.
12	1 01	I.Sh.I.
	1 33	I.Tr.I.
	3 13	I.Sh.E.
	3 45	I.Tr.E.
	22 08	I.Ec.D.
13	0 54	I.Oc.R.
	8 00	II.Sh.I.
	9 06	II.Tr.I.
	10 29	II.Sh.E.
	11 38	II.Tr.E.
	19 29	I.Sh.I.
	20 03	I.Tr.I.
	21 41	I.Sh.E.
	22 16	I.Tr.E.
14	4 45	III.Ec.D.
	9 47	III.Oc.R.
	16 37	I.Ec.D.
	19 24	I.Oc.R.
15	3 08	II.Ec.D.
	6 51	II.Oc.R.
	13 58	I.Sh.I.
	14 33	I.Tr.I.
	16 10	I.Sh.E.
	16 46	I.Tr.E.
16	11 05	I.Ec.D.
	13 55	I.Oc.R.
	21 18	II.Sh.I.
	22 31	II.Tr.I.
	23 47	II.Sh.E.
17	1 03	II.Tr.E.
	8 26	I.Sh.I.
	9 03	I.Tr.I.
	10 38	I.Sh.E.
	11 16	I.Tr.E.
	18 50	III.Sh.I.
	21 20	III.Tr.I.
	21 27	III.Sh.E.
18	0 03	III.Tr.E.
	5 34	I.Ec.D.
	8 25	I.Oc.R.
	16 26	II.Ec.D.
	20 16	II.Oc.R.
19	2 55	I.Sh.I.
	3 34	I.Tr.I.
	5 07	I.Sh.E.
	5 46	I.Tr.E.
20	0 02	I.Ec.D.
	2 55	I.Oc.R.
	10 36	II.Sh.I.
	11 55	II.Tr.I.
	13 05	II.Sh.E.
	14 28	II.Tr.E.
	21 23	I.Sh.I.
	22 04	I.Tr.I.
	23 35	I.Sh.E.
21	0 16	I.Tr.E.
	8 45	III.Ec.D.
	11 23	III.Ec.R.
	11 30	III.Oc.D.
	14 14	III.Oc.R.
	18 31	I.Ec.D.
	21 25	I.Oc.R.
22	5 44	II.Ec.D.
	9 40	II.Oc.R.
	15 52	I.Sh.I.
	16 34	I.Tr.I.
	18 04	I.Sh.E.
	18 46	I.Tr.E.
23	12 59	I.Ec.D.
	15 55	I.Oc.R.
	23 54	II.Sh.I.
24	1 20	II.Tr.I.
	2 23	II.Sh.E.
	3 52	II.Tr.E.
	10 21	I.Sh.I.
	11 04	I.Tr.I.
24	13 16	I.Tr.E.
	22 49	III.Sh.I.
25	1 27	III.Sh.E.
	1 45	III.Tr.I.
	4 29	III.Tr.E.
	7 28	I.Ec.D.
	10 25	I.Oc.R.
	19 02	II.Ec.D.
	23 04	II.Oc.R.
26	4 49	I.Sh.I.
	5 34	I.Tr.I.
	7 01	I.Sh.E.
	7 46	I.Tr.E.
27	1 56	I.Ec.D.
	4 56	I.Oc.R.
	13 11	II.Sh.I.
	14 43	II.Tr.I.
	15 41	II.Sh.E.
	17 17	II.Tr.E.
	23 18	I.Sh.I.
28	0 04	I.Tr.I.
	1 29	I.Sh.E.
	2 16	I.Tr.E.
	12 45	III.Ec.D.
	15 24	III.Ec.R.
	15 55	III.Oc.D.
	18 41	III.Oc.R.
	20 25	I.Ec.D.
	23 26	I.Oc.R.
29	8 19	II.Ec.D.
	12 28	II.Oc.R.
	17 46	I.Sh.I.
	18 34	I.Tr.I.
	19 58	I.Sh.E.
	20 46	I.Tr.E.
30	14 53	I.Ec.D.
	17 56	I.Oc.R.
31	2 29	II.Sh.I.
	4 08	II.Tr.I.
	5 00	II.Sh.E.
	6 41	II.Tr.E.
	12 15	I.Sh.I.
	13 04	I.Tr.I.
	14 26	I.Sh.E.
	15 16	I.Tr.E.

SATELLITES OF JUPITER, 1989

UNIVERSAL TIME OF GEOCENTRIC PHENOMENA

AUGUST

d	h m		d	h m		d	h m		d	h m	
1	2 48	III.Sh.I.	8	13 17	III.Tr.E.	16	7 23	II.Oc.R.	23	15 42	I.Tr.E.
	5 26	III.Sh.E.		14 26	I.Oc.R.		10 31	I.Sh.I.			
	6 09	III.Tr.I.					11 32	I.Tr.I.	24	9 32	I.Ec.D.
	8 54	III.Tr.E.	9	0 12	II.Ec.D.		12 43	I.Sh.E.		12 53	I.Oc.R.
	9 22	I.Ec.D.		4 38	II.Oc.R.		13 44	I.Tr.E.		23 35	II.Sh.I.
	12 26	I.Oc.R.		8 37	I.Sh.I.						
	21 37	II.Ec.D.		9 33	I.Tr.I.	17	7 38	I.Ec.D.	25	1 49	II.Tr.I.
				10 49	I.Sh.E.		10 55	I.Oc.R.		2 06	II.Sh.E.
2	1 52	II.Oc.R.		11 45	I.Tr.E.		20 59	II.Sh.I.		4 25	II.Tr.E.
	6 43	I.Sh.I.					23 04	II.Tr.I.		6 53	I.Sh.I.
	7 34	I.Tr.I.	10	5 44	I.Ec.D.		23 30	II.Sh.E.		8 00	I.Tr.I.
	8 55	I.Sh.E.		8 55	I.Oc.R.					9 05	I.Sh.E.
	9 46	I.Tr.E.		18 23	II.Sh.I.	18	1 39	II.Tr.E.		10 12	I.Tr.E.
				20 18	II.Tr.I.		5 00	I.Sh.I.			
3	3 50	I.Ec.D.		20 54	II.Sh.E.		6 02	I.Tr.I.	26	4 01	I.Ec.D.
	6 56	I.Oc.R.		22 52	II.Tr.E.		7 11	I.Sh.E.		4 41	III.Ec.D.
	15 47	II.Sh.I.					8 14	I.Tr.E.		7 23	I.Oc.R.
	17 31	II.Tr.I.	11	3 06	I.Sh.I.					7 25	III.Ec.R.
	18 17	II.Sh.E.		4 03	I.Tr.I.	19	0 42	III.Ec.D.		9 16	III.Oc.D.
	20 05	II.Tr.E.		5 17	I.Sh.E.		2 07	I.Ec.D.		12 07	III.Oc.R.
				6 15	I.Tr.E.		3 25	III.Ec.R.		18 38	II.Ec.D.
4	1 12	I.Sh.I.		20 44	III.Ec.D.		4 59	III.Oc.D.		23 29	II.Oc.R.
	2 04	I.Tr.I.		23 25	III.Ec.R.		5 24	I.Oc.R.			
	3 23	I.Sh.E.					7 49	III.Oc.R.	27	1 22	I.Sh.I.
	4 16	I.Tr.E.	12	0 13	I.Ec.D.		16 04	II.Ec.D.		2 29	I.Tr.I.
	16 44	III.Ec.D.		0 40	III.Oc.D.		20 46	II.Oc.R.		3 33	I.Sh.E.
	19 25	III.Ec.R.		3 25	I.Oc.R.		23 28	I.Sh.I.		4 41	I.Tr.E.
	20 19	III.Oc.D.		3 29	III.Oc.R.					22 29	I.Ec.D.
	22 19	I.Ec.D.		13 29	II.Ec.D.	20	0 31	I.Tr.I.			
	23 06	III.Oc.R.		18 01	II.Oc.R.		1 40	I.Sh.E.	28	1 52	I.Oc.R.
				21 34	I.Sh.I.		2 43	I.Tr.E.		12 53	II.Sh.I.
5	1 26	I.Oc.R.		22 33	I.Tr.I.		20 35	I.Ec.D.		15 12	II.Tr.I.
	10 54	II.Ec.D.		23 46	I.Sh.E.		23 54	I.Oc.R.		15 25	II.Sh.E.
	15 15	II.Oc.R.								17 47	II.Tr.E.
	19 40	I.Sh.I.	13	0 45	I.Tr.E.	21	10 17	II.Sh.I.		19 50	I.Sh.I.
	20 34	I.Tr.I.		18 41	I.Ec.D.		12 27	II.Tr.I.		20 58	I.Tr.I.
	21 52	I.Sh.E.		21 55	I.Oc.R.		12 48	II.Sh.E.		22 02	I.Sh.E.
	22 46	I.Tr.E.					15 02	II.Tr.E.		23 11	I.Tr.E.
			14	7 41	II.Sh.I.		17 56	I.Sh.I.			
6	16 47	I.Ec.D.		9 41	II.Tr.I.		19 01	I.Tr.I.	29	16 58	I.Ec.D.
	19 56	I.Oc.R.		10 12	II.Sh.E.		20 08	I.Sh.E.		18 45	III.Sh.I.
				12 16	II.Tr.E.		21 13	I.Tr.E.		20 22	I.Oc.R.
7	5 05	II.Sh.I.		16 03	I.Sh.I.					21 27	III.Sh.E.
	6 55	II.Tr.I.		17 02	I.Tr.I.	22	14 46	III.Sh.I.		23 25	III.Tr.I.
	7 36	II.Sh.E.		18 14	I.Sh.E.		15 04	I.Ec.D.			
	9 29	II.Tr.E.		19 15	I.Tr.E.		17 27	III.Sh.E.	30	2 14	III.Tr.E.
	14 09	I.Sh.I.					18 24	I.Oc.R.		7 55	II.Ec.D.
	15 03	I.Tr.I.	15	10 46	III.Sh.I.		19 09	III.Tr.I.		12 50	II.Oc.R.
	16 20	I.Sh.E.		13 10	I.Ec.D.		21 57	III.Tr.E.		14 19	I.Sh.I.
	17 16	I.Tr.E.		13 26	III.Sh.E.					15 28	I.Tr.I.
				14 51	III.Tr.I.	23	5 21	II.Ec.D.		16 30	I.Sh.E.
8	6 47	III.Sh.I.		16 25	I.Oc.R.		10 07	II.Oc.R.		17 40	I.Tr.E.
	9 26	III.Sh.E.		17 38	III.Tr.E.		12 25	I.Sh.I.			
	10 30	III.Tr.I.					13 30	I.Tr.I.	31	11 26	I.Ec.D.
	11 16	I.Ec.D.	16	2 47	II.Ec.D.		14 36	I.Sh.E.		14 51	I.Oc.R.

UNIVERSAL TIME OF GEOCENTRIC PHENOMENA

SEPTEMBER

d	h m	
1	2 11	II.Sh.I.
	4 33	II.Tr.I.
	4 43	II.Sh.E.
	7 09	II.Tr.E.
	8 47	I.Sh.I.
	9 57	I.Tr.I.
	10 58	I.Sh.E.
	12 09	I.Tr.E.
2	5 55	I.Ec.D.
	8 40	III.Ec.D.
	9 21	I.Oc.R.
	11 25	III.Ec.R.
	13 31	III.Oc.D.
	16 22	III.Oc.R.
	21 12	II.Ec.D.
3	2 11	II.Oc.R.
	3 15	I.Sh.I.
	4 26	I.Tr.I.
	5 27	I.Sh.E.
	6 38	I.Tr.E.
4	0 23	I.Ec.D.
	3 50	I.Oc.R.
	15 29	II.Sh.I.
	17 55	II.Tr.I.
	18 01	II.Sh.E.
	20 31	II.Tr.E.
	21 44	I.Sh.I.
	22 55	I.Tr.I.
	23 55	I.Sh.E.
5	1 07	I.Tr.E.
	18 51	I.Ec.D.
	22 20	I.Oc.R.
	22 44	III.Sh.I.
6	1 27	III.Sh.E.
	3 38	III.Tr.I.
	6 28	III.Tr.E.
	10 30	II.Ec.D.
	15 31	II.Oc.R.
	16 12	I.Sh.I.
	17 25	I.Tr.I.
	18 24	I.Sh.E.
	19 37	I.Tr.E.
7	13 20	I.Ec.D.
	16 49	I.Oc.R.
8	4 47	II.Sh.I.
	7 16	II.Tr.I.
	7 19	II.Sh.E.
	9 52	II.Tr.E.
	10 41	I.Sh.I.

d	h m	
8	11 54	I.Tr.I.
	12 52	I.Sh.E.
	14 06	I.Tr.E.
9	7 48	I.Ec.D.
	11 18	I.Oc.R.
	12 39	III.Ec.D.
	15 24	III.Ec.R.
	17 42	III.Oc.D.
	20 35	III.Oc.R.
	23 47	II.Ec.D.
10	4 51	II.Oc.R.
	5 09	I.Sh.I.
	6 23	I.Tr.I.
	7 20	I.Sh.E.
	8 35	I.Tr.E.
11	2 17	I.Ec.D.
	5 47	I.Oc.R.
	18 05	II.Sh.I.
	20 37	II.Tr.I.
	20 38	II.Sh.E.
	23 14	II.Tr.E.
	23 37	I.Sh.I.
12	0 52	I.Tr.I.
	1 49	I.Sh.E.
	3 04	I.Tr.E.
	20 45	I.Ec.D.
13	0 16	I.Oc.R.
	2 42	III.Sh.I.
	5 26	III.Sh.E.
	7 47	III.Tr.I.
	10 38	III.Tr.E.
	13 03	II.Ec.D.
	18 06	I.Sh.I.
	18 10	II.Oc.R.
	19 21	I.Tr.I.
	20 17	I.Sh.E.
	21 33	I.Tr.E.
14	15 14	I.Ec.D.
	18 45	I.Oc.R.
15	7 23	II.Sh.I.
	9 56	II.Sh.E.
	9 57	II.Tr.I.
	12 34	I.Sh.I.
	12 34	II.Tr.E.
	13 49	I.Tr.I.
	14 45	I.Sh.E.
	16 01	I.Tr.E.
16	9 42	I.Ec.D.

d	h m	
16	13 15	I.Oc.R.
	16 39	III.Ec.D.
	19 25	III.Ec.R.
	21 52	III.Oc.D.
17	0 45	III.Oc.R.
	2 20	II.Ec.D.
	7 02	I.Sh.I.
	7 29	II.Oc.R.
	8 18	I.Tr.I.
	9 14	I.Sh.E.
	10 30	I.Tr.E.
18	4 11	I.Ec.D.
	7 43	I.Oc.R.
	20 41	II.Sh.I.
	23 14	II.Sh.E.
	23 18	II.Tr.I.
19	1 31	I.Sh.I.
	1 55	II.Tr.E.
	2 47	I.Tr.I.
	3 42	I.Sh.E.
	4 59	I.Tr.E.
	22 39	I.Ec.D.
20	2 12	I.Oc.R.
	6 41	III.Sh.I.
	9 25	III.Sh.E.
	11 53	III.Tr.I.
	14 45	III.Tr.E.
	15 37	II.Ec.D.
	18 10	II.Ec.R.
	18 11	II.Oc.D.
	19 59	I.Sh.I.
	20 48	II.Oc.R.
	21 16	I.Tr.I.
	22 10	I.Sh.E.
	23 28	I.Tr.E.
21	17 08	I.Ec.D.
	20 41	I.Oc.R.
22	9 59	II.Sh.I.
	12 32	II.Sh.E.
	12 37	II.Tr.I.
	14 27	I.Sh.I.
	15 14	II.Tr.E.
	15 44	I.Tr.I.
	16 39	I.Sh.E.
	17 56	I.Tr.E.
23	11 36	I.Ec.D.
	15 10	I.Oc.R.
	20 38	III.Ec.D.
	23 25	III.Ec.R.

d	h m	
24	1 57	III.Oc.D.
	4 51	III.Oc.R.
	4 54	II.Ec.D.
	7 28	II.Ec.R.
	7 29	II.Oc.D.
	8 56	I.Sh.I.
	10 06	II.Oc.R.
	10 13	I.Tr.I.
	11 07	I.Sh.E.
	12 25	I.Tr.E.
25	6 05	I.Ec.D.
	9 39	I.Oc.R.
	23 18	II.Sh.I.
26	1 51	II.Sh.E.
	1 57	II.Tr.I.
	3 24	I.Sh.I.
	4 34	II.Tr.E.
	4 42	I.Tr.I.
	5 36	I.Sh.E.
	6 54	I.Tr.E.
27	0 33	I.Ec.D.
	4 08	I.Oc.R.
	10 39	III.Sh.I.
	13 25	III.Sh.E.
	15 56	III.Tr.I.
	18 11	II.Ec.D.
	18 48	III.Tr.E.
	20 44	II.Ec.R.
	20 47	II.Oc.D.
	21 52	I.Sh.I.
	23 10	I.Tr.I.
	23 24	II.Oc.R.
28	0 04	I.Sh.E.
	1 22	I.Tr.E.
	19 02	I.Ec.D.
	22 36	I.Oc.R.
29	12 35	II.Sh.I.
	15 09	II.Sh.E.
	15 15	II.Tr.I.
	16 21	I.Sh.I.
	17 38	I.Tr.I.
	17 52	II.Tr.E.
	18 32	I.Sh.E.
	19 50	I.Tr.E.
30	13 30	I.Ec.D.
	17 05	I.Oc.R.

SATELLITES OF JUPITER, 1989

UNIVERSAL TIME OF GEOCENTRIC PHENOMENA

OCTOBER

d	h m	Phenomenon
1	0 37	III.Ec.D.
	3 26	III.Ec.R.
	5 58	III.Oc.D.
	7 28	II.Ec.D.
	8 54	III.Oc.R.
	10 01	II.Ec.R.
	10 04	II.Oc.D.
	10 49	I.Sh.I.
	12 07	I.Tr.I.
	12 41	II.Oc.R.
	13 01	I.Sh.E.
	14 19	I.Tr.E.
2	7 58	I.Ec.D.
	11 33	I.Oc.R.
3	1 54	II.Sh.I.
	4 28	II.Sh.E.
	4 33	II.Tr.I.
	5 17	I.Sh.I.
	6 35	I.Tr.I.
	7 11	II.Tr.E.
	7 29	I.Sh.E.
	8 47	I.Tr.E.
4	2 27	I.Ec.D.
	6 02	I.Oc.R.
	14 37	III.Sh.I.
	17 24	III.Sh.E.
	19 54	III.Tr.I.
	20 44	II.Ec.D.
	22 48	III.Tr.E.
	23 18	II.Ec.R.
	23 20	II.Oc.D.
	23 46	I.Sh.I.
5	1 03	I.Tr.I.
	1 57	I.Sh.E.
	1 58	II.Oc.R.
	3 15	I.Tr.E.
	20 55	I.Ec.D.
6	0 30	I.Oc.R.
	15 12	II.Sh.I.
	17 46	II.Sh.E.
	17 51	II.Tr.I.
	18 14	I.Sh.I.
	19 31	I.Tr.I.
	20 26	I.Sh.E.
	20 29	II.Tr.E.
	21 44	I.Tr.E.
7	15 24	I.Ec.D.
	18 58	I.Oc.R.
8	2 49	IV.Oc.D.
	3 36	IV.Oc.R.
	4 36	III.Ec.D.
	7 25	III.Ec.R.
	9 55	III.Oc.D.
8	10 01	II.Ec.D.
	12 35	II.Ec.R.
	12 36	II.Oc.D.
	12 42	I.Sh.I.
	12 51	III.Oc.R.
	14 00	I.Tr.I.
	14 54	I.Sh.E.
	15 14	II.Oc.R.
	16 12	I.Tr.E.
9	9 52	I.Ec.D.
	13 27	I.Oc.R.
10	4 30	II.Sh.I.
	7 05	II.Sh.E.
	7 08	II.Tr.I.
	7 11	I.Sh.I.
	8 28	I.Tr.I.
	9 22	I.Sh.E.
	9 47	II.Tr.E.
	10 40	I.Tr.E.
11	4 21	I.Ec.D.
	7 55	I.Oc.R.
	18 37	III.Sh.I.
	21 24	III.Sh.E.
	23 18	II.Ec.D.
	23 50	III.Tr.I.
12	1 39	I.Sh.I.
	2 44	III.Tr.E.
	2 56	I.Tr.I.
	3 51	I.Sh.E.
	4 29	II.Oc.R.
	5 08	I.Tr.E.
	22 49	I.Ec.D.
13	2 23	I.Oc.R.
	17 48	II.Sh.I.
	20 07	I.Sh.I.
	20 22	II.Sh.E.
	20 25	II.Tr.I.
	21 23	I.Tr.I.
	22 19	I.Sh.E.
	23 03	II.Tr.E.
	23 36	I.Tr.E.
14	17 18	I.Ec.D.
	20 51	I.Oc.R.
15	8 34	III.Ec.D.
	11 25	III.Ec.R.
	12 35	II.Ec.D.
	13 47	III.Oc.D.
	14 36	I.Sh.I.
	15 51	I.Tr.I.
	16 44	III.Oc.R.
	16 47	I.Sh.E.
	17 44	II.Oc.R.
	18 04	I.Tr.E.
16	11 46	I.Ec.D.
	13 09	IV.Tr.I.
	14 11	IV.Tr.E.
	15 19	I.Oc.R.
17	7 06	II.Sh.I.
	9 04	I.Sh.I.
	9 41	II.Tr.I.
	9 41	II.Sh.E.
	10 19	I.Tr.I.
	11 16	I.Sh.E.
	12 20	II.Tr.E.
	12 31	I.Tr.E.
18	6 15	I.Ec.D.
	9 47	I.Oc.R.
	22 35	III.Sh.I.
19	1 24	III.Sh.E.
	1 51	II.Ec.D.
	3 32	I.Sh.I.
	3 40	III.Tr.I.
	4 47	I.Tr.I.
	5 44	I.Sh.E.
	6 34	III.Tr.E.
	6 59	II.Oc.R.
	6 59	I.Tr.E.
20	0 43	I.Ec.D.
	4 15	I.Oc.R.
	20 24	II.Sh.I.
	22 01	I.Sh.I.
	22 56	II.Tr.I.
	22 59	II.Sh.E.
	23 14	I.Tr.I.
21	0 12	I.Sh.E.
	1 27	I.Tr.E.
	1 35	II.Tr.E.
	19 12	I.Ec.D.
	22 42	I.Oc.R.
22	12 33	III.Ec.D.
	15 08	II.Ec.D.
	15 25	III.Ec.R.
	16 29	I.Sh.I.
	17 35	III.Oc.D.
	17 42	I.Tr.I.
	18 41	I.Sh.E.
	19 54	I.Tr.E.
	20 13	II.Oc.R.
	20 33	III.Oc.R.
23	13 40	I.Ec.D.
	17 10	I.Oc.R.
24	9 43	II.Sh.I.
	10 57	I.Sh.I.
	12 09	I.Tr.I.
	12 12	II.Tr.I.
24	12 18	II.Sh.E.
	13 09	I.Sh.E.
	14 22	I.Tr.E.
	14 50	II.Tr.E.
	19 53	IV.Oc.D.
	21 04	IV.Oc.R.
25	8 09	I.Ec.D.
	11 38	I.Oc.R.
26	2 34	III.Sh.I.
	4 25	II.Ec.D.
	5 24	III.Sh.E.
	5 25	I.Sh.I.
	6 37	I.Tr.I.
	7 26	III.Tr.I.
	7 37	I.Sh.E.
	8 49	I.Tr.E.
	9 26	II.Oc.R.
	10 21	III.Tr.E.
27	2 37	I.Ec.D.
	6 05	I.Oc.R.
	23 00	II.Sh.I.
	23 54	I.Sh.I.
28	1 04	I.Tr.I.
	1 26	II.Tr.I.
	1 36	II.Sh.E.
	2 06	I.Sh.E.
	3 17	I.Tr.E.
	4 04	II.Tr.E.
	21 06	I.Ec.D.
29	0 33	I.Oc.R.
	16 32	III.Ec.D.
	17 42	II.Ec.D.
	18 22	I.Sh.I.
	19 24	III.Ec.R.
	19 31	I.Tr.I.
	20 34	I.Sh.E.
	21 19	III.Oc.D.
	21 44	I.Tr.E.
	22 39	II.Oc.R.
30	0 17	III.Oc.R.
	15 34	I.Ec.D.
	19 00	I.Oc.R.
31	12 19	II.Sh.I.
	12 50	I.Sh.I.
	13 59	I.Tr.I.
	14 40	II.Tr.I.
	14 55	II.Sh.E.
	15 02	I.Sh.E.
	16 11	I.Tr.E.
	17 19	II.Tr.E.

SATELLITES OF JUPITER, 1989

UNIVERSAL TIME OF GEOCENTRIC PHENOMENA

NOVEMBER

d	h m	
1	10 03	I.Ec.D.
	13 27	I.Oc.R.
2	5 47	IV.Tr.I.
	6 32	III.Sh.I.
	6 58	II.Ec.D.
	7 03	IV.Tr.E.
	7 19	I.Sh.I.
	8 26	I.Tr.I.
	9 23	III.Sh.E.
	9 31	I.Sh.E.
	10 38	I.Tr.E.
	11 06	III.Tr.I.
	11 51	II.Oc.R.
	14 02	III.Tr.E.
3	4 31	I.Ec.D.
	7 55	I.Oc.R.
4	1 37	II.Sh.I.
	1 47	I.Sh.I.
	2 53	I.Tr.I.
	3 53	II.Tr.I.
	3 59	I.Sh.E.
	4 13	II.Sh.E.
	5 05	I.Tr.E.
	6 32	II.Tr.E.
	23 00	I.Ec.D.
5	2 22	I.Oc.R.
	20 15	II.Ec.D.
	20 15	I.Sh.I.
	20 32	III.Ec.D.
	21 20	I.Tr.I.
	22 27	I.Sh.E.
	23 25	III.Ec.R.
	23 33	I.Tr.E.
6	0 58	III.Oc.D.
	1 03	II.Oc.R.
	3 57	III.Oc.R.
	17 28	I.Ec.D.
	20 49	I.Oc.R.
7	14 44	I.Sh.I.
	14 55	II.Sh.I.
	15 47	I.Tr.I.
	16 56	I.Sh.E.
	17 06	II.Tr.I.
	17 32	II.Sh.E.
	17 59	I.Tr.E.
	19 45	II.Tr.E.
8	11 57	I.Ec.D.
	15 16	I.Oc.R.

d	h m	
9	9 12	I.Sh.I.
	9 32	II.Ec.D.
	10 14	I.Tr.I.
	10 30	III.Sh.I.
	11 24	I.Sh.E.
	12 26	I.Tr.E.
	13 22	III.Sh.E.
	14 14	II.Oc.R.
	14 42	III.Tr.I.
	17 37	III.Tr.E.
10	6 25	I.Ec.D.
	9 43	I.Oc.R.
	12 02	IV.Oc.D.
	13 24	IV.Oc.R.
11	3 40	I.Sh.I.
	4 13	II.Sh.I.
	4 40	I.Tr.I.
	5 53	I.Sh.E.
	6 17	II.Tr.I.
	6 50	II.Sh.E.
	6 53	I.Tr.E.
	8 56	II.Tr.E.
12	0 54	I.Ec.D.
	4 10	I.Oc.R.
	22 09	I.Sh.I.
	22 49	II.Ec.D.
	23 07	I.Tr.I.
13	0 21	I.Sh.E.
	0 31	III.Ec.D.
	1 20	I.Tr.E.
	3 24	II.Oc.R.
	3 25	III.Ec.R.
	4 32	III.Oc.D.
	7 31	III.Oc.R.
	19 22	I.Ec.D.
	22 37	I.Oc.R.
14	16 37	I.Sh.I.
	17 32	II.Sh.I.
	17 34	I.Tr.I.
	18 49	I.Sh.E.
	19 29	II.Tr.I.
	19 47	I.Tr.E.
	20 09	II.Sh.E.
	22 08	II.Tr.E.
15	13 51	I.Ec.D.
	17 03	I.Oc.R.
16	11 05	I.Sh.I.
	12 00	I.Tr.I.
	12 05	II.Ec.D.

d	h m	
16	13 18	I.Sh.E.
	14 13	I.Tr.E.
	14 28	III.Sh.I.
	16 34	II.Oc.R.
	17 21	III.Sh.E.
	18 13	III.Tr.I.
	21 09	III.Tr.E.
17	8 19	I.Ec.D.
	11 30	I.Oc.R.
18	5 33	I.Sh.I.
	6 27	I.Tr.I.
	6 50	II.Sh.I.
	7 46	I.Sh.E.
	8 39	II.Tr.I.
	8 40	I.Tr.E.
	9 27	II.Sh.E.
	11 19	II.Tr.E.
	21 28	IV.Tr.I.
	22 51	IV.Tr.E.
19	2 48	I.Ec.D.
	5 57	I.Oc.R.
20	0 02	I.Sh.I.
	0 53	I.Tr.I.
	1 22	II.Ec.D.
	2 15	I.Sh.E.
	3 06	I.Tr.E.
	4 30	III.Ec.D.
	5 43	II.Oc.R.
	7 26	III.Ec.R.
	8 02	III.Oc.D.
	11 00	III.Oc.R.
	21 17	I.Ec.D.
21	0 23	I.Oc.R.
	18 30	I.Sh.I.
	19 20	I.Tr.I.
	20 08	II.Sh.I.
	20 43	I.Sh.E.
	21 33	I.Tr.E.
	21 50	II.Tr.I.
	22 46	II.Sh.E.
22	0 30	II.Tr.E.
	15 45	I.Ec.D.
	18 50	I.Oc.R.
23	12 59	I.Sh.I.
	13 46	I.Tr.I.
	14 39	II.Ec.D.
	15 11	I.Sh.E.
	15 59	I.Tr.E.
	18 27	III.Sh.I.

d	h m	
23	18 52	II.Oc.R.
	21 21	III.Sh.E.
	21 40	III.Tr.I.
24	0 36	III.Tr.E.
	10 14	I.Ec.D.
	13 16	I.Oc.R.
25	7 27	I.Sh.I.
	8 13	I.Tr.I.
	9 26	II.Sh.I.
	9 40	I.Sh.E.
	10 26	I.Tr.E.
	11 00	II.Tr.I.
	12 04	II.Sh.E.
	13 39	II.Tr.E.
26	4 42	I.Ec.D.
	7 43	I.Oc.R.
	20 38	IV.Ec.D.
	21 13	IV.Ec.R.
27	1 55	I.Sh.I.
	2 39	I.Tr.I.
	3 16	IV.Oc.D.
	3 56	II.Ec.D.
	4 08	I.Sh.E.
	4 40	IV.Oc.R.
	4 52	I.Tr.E.
	8 01	II.Oc.R.
	8 29	III.Ec.D.
	11 26	III.Ec.R.
	11 27	III.Oc.D.
	14 25	III.Oc.R.
	23 11	I.Ec.D.
28	2 09	I.Oc.R.
	20 24	I.Sh.I.
	21 05	I.Tr.I.
	22 37	I.Sh.E.
	22 45	II.Sh.I.
	23 18	I.Tr.E.
29	0 09	II.Tr.I.
	1 23	II.Sh.E.
	2 49	II.Tr.E.
	17 39	I.Ec.D.
	20 35	I.Oc.R.
30	14 52	I.Sh.I.
	15 31	I.Tr.I.
	17 05	I.Sh.E.
	17 13	II.Ec.D.
	17 44	I.Tr.E.
	21 09	II.Oc.R.
	22 26	III.Sh.I.

SATELLITES OF JUPITER, 1989

UNIVERSAL TIME OF GEOCENTRIC PHENOMENA

DECEMBER

d	h m	
1	1 03	III.Tr.I.
	1 21	III.Sh.E.
	4 00	III.Tr.E.
	12 08	I.Ec.D.
	15 02	I.Oc.R.
2	9 20	I.Sh.I.
	9 57	I.Tr.I.
	11 34	I.Sh.E.
	12 03	II.Sh.I.
	12 10	I.Tr.E.
	13 18	II.Tr.I.
	14 41	II.Sh.E.
	15 57	II.Tr.E.
3	6 37	I.Ec.D.
	9 28	I.Oc.R.
4	3 49	I.Sh.I.
	4 23	I.Tr.I.
	6 02	I.Sh.E.
	6 30	II.Ec.D.
	6 37	I.Tr.E.
	10 16	II.Oc.R.
	12 28	III.Ec.D.
	17 46	III.Oc.R.
5	1 05	I.Ec.D.
	3 54	I.Oc.R.
	7 18	IV.Sh.I.
	8 16	IV.Sh.E.
	12 18	IV.Tr.I.
	13 42	IV.Tr.E.
	22 17	I.Sh.I.
	22 49	I.Tr.I.
6	0 30	I.Sh.E.
	1 03	I.Tr.E.
	1 21	II.Sh.I.
	2 27	II.Tr.I.
	4 00	II.Sh.E.
	5 06	II.Tr.E.
	19 34	I.Ec.D.
	22 20	I.Oc.R.
7	16 46	I.Sh.I.
	17 15	I.Tr.I.
	18 59	I.Sh.E.
	19 29	I.Tr.E.
	19 47	II.Ec.D.
	23 24	II.Oc.R.
8	2 25	III.Sh.I.
	4 23	III.Tr.I.
	5 21	III.Sh.E.
	7 20	III.Tr.E.
	14 02	I.Ec.D.
	16 46	I.Oc.R.
9	11 14	I.Sh.I.
	11 41	I.Tr.I.
	13 27	I.Sh.E.
	13 55	I.Tr.E.
	14 39	II.Sh.I.
	15 35	II.Tr.I.
	17 18	II.Sh.E.
	18 14	II.Tr.E.
10	8 31	I.Ec.D.
	11 12	I.Oc.R.
11	5 42	I.Sh.I.
	6 07	I.Tr.I.
	7 56	I.Sh.E.
	8 21	I.Tr.E.
	9 04	II.Ec.D.
	12 31	II.Oc.R.
	16 27	III.Ec.D.
	21 04	III.Oc.R.
12	3 00	I.Ec.D.
	5 38	I.Oc.R.
13	0 11	I.Sh.I.
	0 33	I.Tr.I.
	2 24	I.Sh.E.
	2 47	I.Tr.E.
	3 58	II.Sh.I.
	4 43	II.Tr.I.
	6 37	II.Sh.E.
	7 22	II.Tr.E.
	14 25	IV.Ec.D.
	15 40	IV.Ec.R.
	17 43	IV.Oc.D.
	19 09	IV.Oc.R.
	21 28	I.Ec.D.
14	0 04	I.Oc.R.
	18 39	I.Sh.I.
	18 59	I.Tr.I.
	20 53	I.Sh.E.
	21 12	I.Tr.E.
	22 21	II.Ec.D.
15	1 37	II.Oc.R.
	6 24	III.Sh.I.
	7 40	III.Tr.I.
	9 22	III.Sh.E.
	10 38	III.Tr.E.
	15 57	I.Ec.D.
	18 30	I.Oc.R.
16	13 08	I.Sh.I.
	13 25	I.Tr.I.
	15 21	I.Sh.E.
	15 38	I.Tr.E.
	17 16	II.Sh.I.
	17 50	II.Tr.I.
16	19 56	II.Sh.E.
	20 30	II.Tr.E.
17	10 26	I.Ec.D.
	12 56	I.Oc.R.
18	7 36	I.Sh.I.
	7 51	I.Tr.I.
	9 50	I.Sh.E.
	10 04	I.Tr.E.
	11 38	II.Ec.D.
	14 44	II.Oc.R.
	20 27	III.Ec.D.
19	0 21	III.Oc.R.
	4 54	I.Ec.D.
	7 22	I.Oc.R.
20	2 05	I.Sh.I.
	2 16	I.Tr.I.
	4 19	I.Sh.E.
	4 30	I.Tr.E.
	6 35	II.Sh.I.
	6 58	II.Tr.I.
	9 14	II.Sh.E.
	9 37	II.Tr.E.
	23 23	I.Ec.D.
21	1 48	I.Oc.R.
	20 33	I.Sh.I.
	20 42	I.Tr.I.
	22 47	I.Sh.E.
	22 56	I.Tr.E.
22	0 55	II.Ec.D.
	1 09	IV.Sh.I.
	2 31	IV.Tr.I.
	2 37	IV.Sh.E.
	3 50	II.Oc.R.
	3 55	IV.Tr.E.
	10 23	III.Sh.I.
	10 55	III.Tr.I.
	13 21	III.Sh.E.
	13 53	III.Tr.E.
	17 51	I.Ec.D.
	20 14	I.Oc.R.
23	15 02	I.Sh.I.
	15 08	I.Tr.I.
	17 16	I.Sh.E.
	17 22	I.Tr.E.
	19 53	II.Sh.I.
	20 05	II.Tr.I.
	22 33	II.Sh.E.
	22 44	II.Tr.E.
24	12 20	I.Ec.D.
	14 40	I.Oc.R.
25	9 30	I.Sh.I.
	9 34	I.Tr.I.
	11 44	I.Sh.E.
	11 47	I.Tr.E.
	14 12	II.Ec.D.
	16 57	II.Oc.R.
26	0 27	III.Ec.D.
	3 36	III.Oc.R.
	6 49	I.Ec.D.
	9 05	I.Oc.R.
27	3 59	I.Sh.I.
	4 00	I.Tr.I.
	6 13	I.Sh.E.
	6 13	I.Tr.E.
	9 11	II.Sh.I.
	9 12	II.Tr.I.
	11 52	II.Sh.E.
	11 52	II.Tr.E.
28	1 17	I.Oc.D.
	3 32	I.Ec.R.
	22 25	I.Tr.I.
	22 27	I.Sh.I.
29	0 39	I.Tr.E.
	0 41	I.Sh.E.
	3 25	II.Oc.D.
	6 08	II.Ec.R.
	14 10	III.Tr.I.
	14 21	III.Sh.I.
	17 07	III.Tr.E.
	17 21	III.Sh.E.
	19 43	I.Oc.D.
	22 01	I.Ec.R.
30	7 46	IV.Oc.D.
	10 00	IV.Ec.R.
	16 51	I.Tr.I.
	16 56	I.Sh.I.
	19 05	I.Tr.E.
	19 10	I.Sh.E.
	22 19	II.Tr.I.
	22 30	II.Sh.I.
31	0 59	II.Tr.E.
	1 10	II.Sh.E.
	14 09	I.Oc.D.
	16 30	I.Ec.R.
32	11 17	I.Tr.I.
	11 25	I.Sh.I.
	13 31	I.Tr.E.
	13 38	I.Sh.E.
	16 32	II.Oc.D.
	19 26	II.Ec.R.

CONFIGURATIONS OF SATURN'S BRIGHTEST SATELLITES

BY LARRY D. BOGAN

The curves on the following pages enable one to determine the appearance of Saturn and its brightest satellites during the period January 31 to November 1, 1989. The names and magnitudes of these satellites, in order outward from Saturn, are: *Tethys*, 10.3, *Dione*, 10.4, *Rhea*, 9.7, and *Titan*, 8.4.

The diagrams show the elongations of the satellites from Saturn as they change with time. The horizontal lines mark 0^h UT on the days indicated. The narrower, central, vertical band represents the disk of Saturn, while the wider vertical band represents the outer edge of the "A" ring of Saturn. All four orbits have essentially zero inclination and thus lie nearly in the plane of Saturn's rings. During 1989 there are no eclipses or occultations due to the tilt of Saturn's axis; hence the curves are not shown occulted by the bands representing Saturn's disk and rings. The curve for Dione, the second out from Saturn, is drawn heavier so that it is easier to distinguish from those for Tethys and Rhea. Titan's orbit is not as circular as the others and is the only satellite of the four that has been treated as having an elliptical orbit.

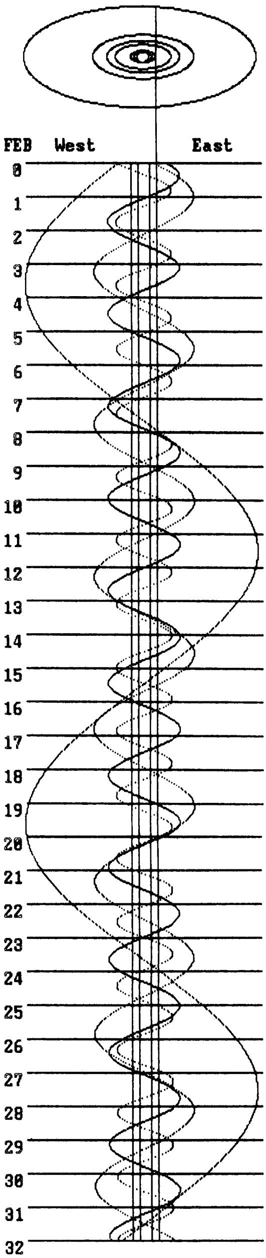
At the beginning of each month is a scale drawing of Saturn with the orbits of the four satellites tilted as seen through an inverting telescope (in the Northern Hemisphere). South is up. The axis of Saturn is now tipped toward Earth so that we see the northern side of the rings and satellite orbits. The directions of motion of the satellites are counterclockwise.

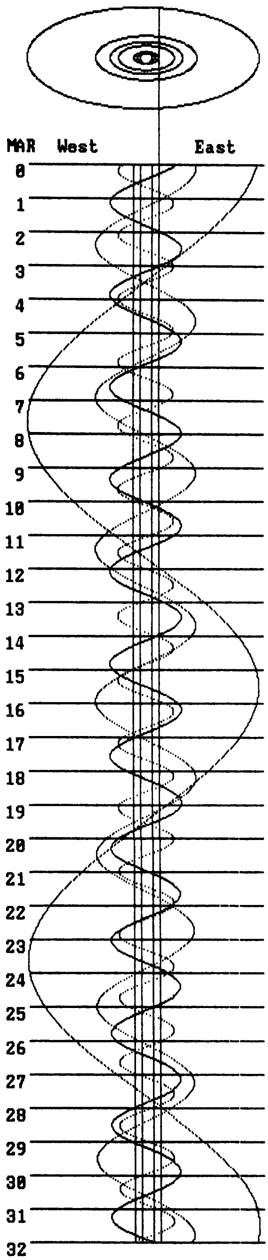
Constructing the configuration from the diagrams is very similar to that for Jupiter's satellites. The main difference is that the orbits of the satellites are not seen edge-on, and the satellites move above and below Saturn. By projecting the elongations for the date and time of interest onto the drawing at the beginning of each month, and locating the satellites on the proper side (north or south) of the orbits, the complete configuration can be developed. A millimetre scale, or better, a pair of dividers, enables one to do this both quickly and accurately. For this purpose, the vertical line representing the east edge of Saturn's "A" ring has been extended upward across the scale drawing. Use this as a fiducial line to transfer the various satellite positions at a given moment in time to the scale drawing (It is convenient first to draw a horizontal line across the lower diagram at the time (UT!) of interest). Since the satellites revolve around Saturn counterclockwise, a satellite moving toward the *right* (east) will be *below* (north of) Saturn in the diagram, and a satellite moving toward the *left* (west) will be *above* (south of) Saturn in the diagram. Hence the mnemonic statement: *right-below, left-above*.

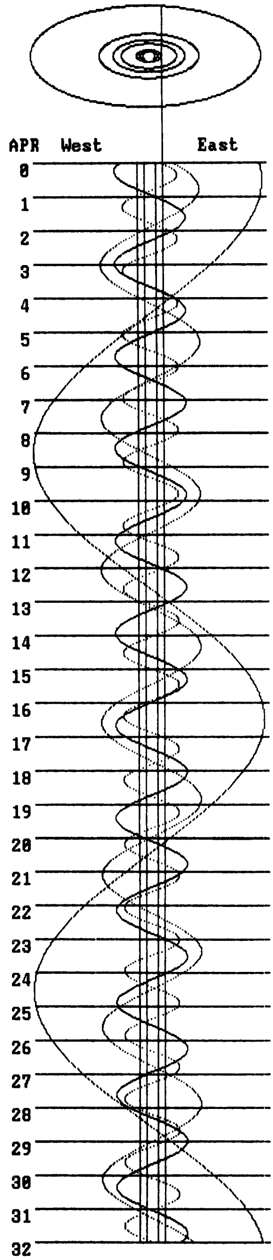
Iapetus is also considered a bright satellite of Saturn. Its magnitude varies between 10.1 (western elongation) and 11.9 (eastern elongation). Below is a table of times for four configurations of Iapetus and Saturn throughout the year. Iapetus-Saturn distances for conjunctions and maximum elongations will be nearly 2.9 times those for Titan distance for the same configuration. This is only an approximation since Iapetus' orbit has a moderate eccentricity (0.028) and is tilted 15 degrees to the plane of the Saturn's rings and the other bright satellite orbits. Iapetus' orbital period is 79.33 days so there is about 20 days between elongations and conjunctions. This can be used to estimate its position at times other than those listed below.

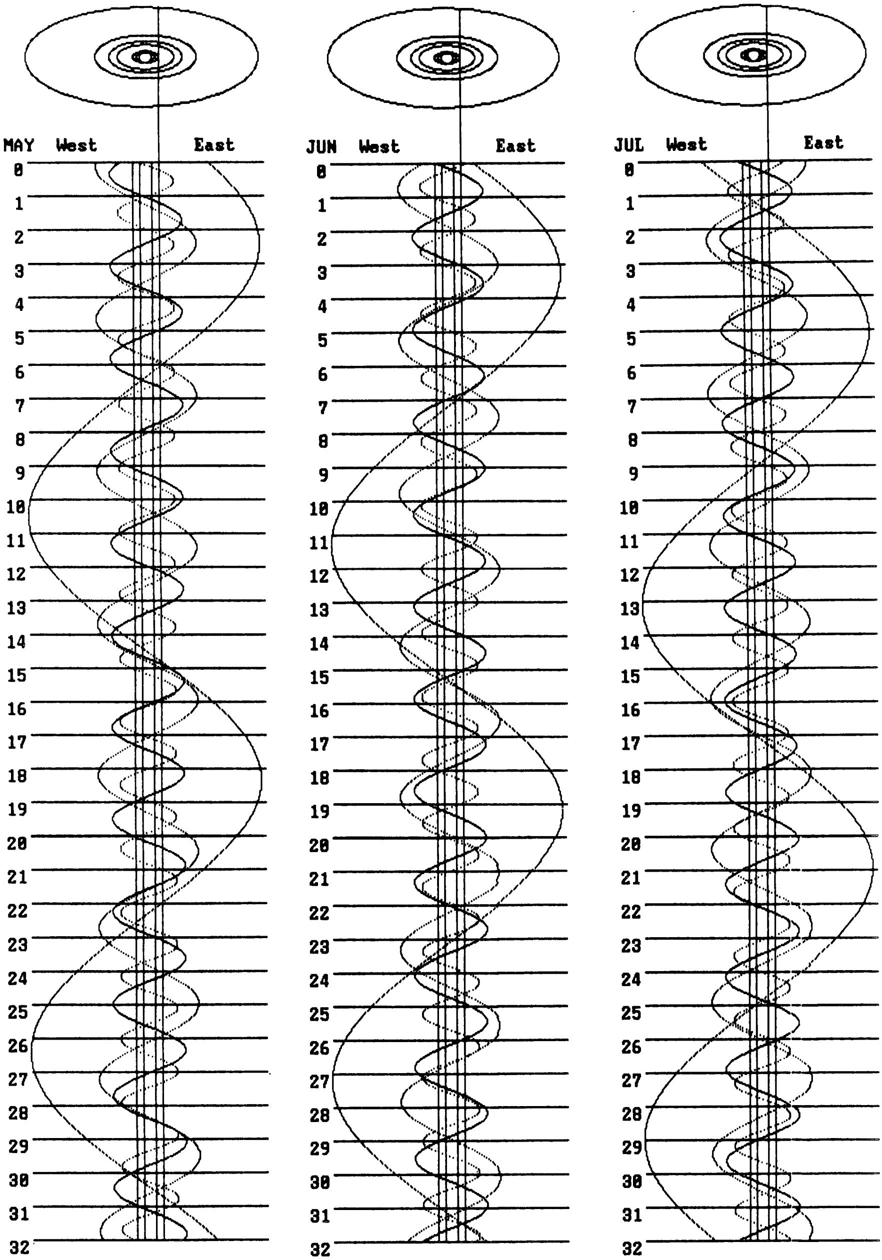
SATURN-IAPETUS CONFIGURATIONS 1989 (UT)

Eastern Elong.	Inferior Conj.	Western Elong.	Superior Conj.
Jan. 5 17.7h	Jan. 25 8.0h	Feb. 15 9.4h	Mar. 8 6.4h
Mar. 27 13.2h	Apr. 15 20.6h	May 6 11.0h	May 26 18.1h
June 14 13.9h	July 3 11.0h	July 23 17.2h	Aug. 12 23.9h
Aug. 31 23.7h	Sept.20 2.5h	Oct. 10 19.4h	Oct. 31 15.1h
Nov. 20 1.8h	Dec. 9 16.5h	Dec. 30 20.7h	–


FEB
West
East
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32


MAR
West
East
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32


APR
West
East
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32


MAY West East
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
JUN West East
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
JUL West East
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
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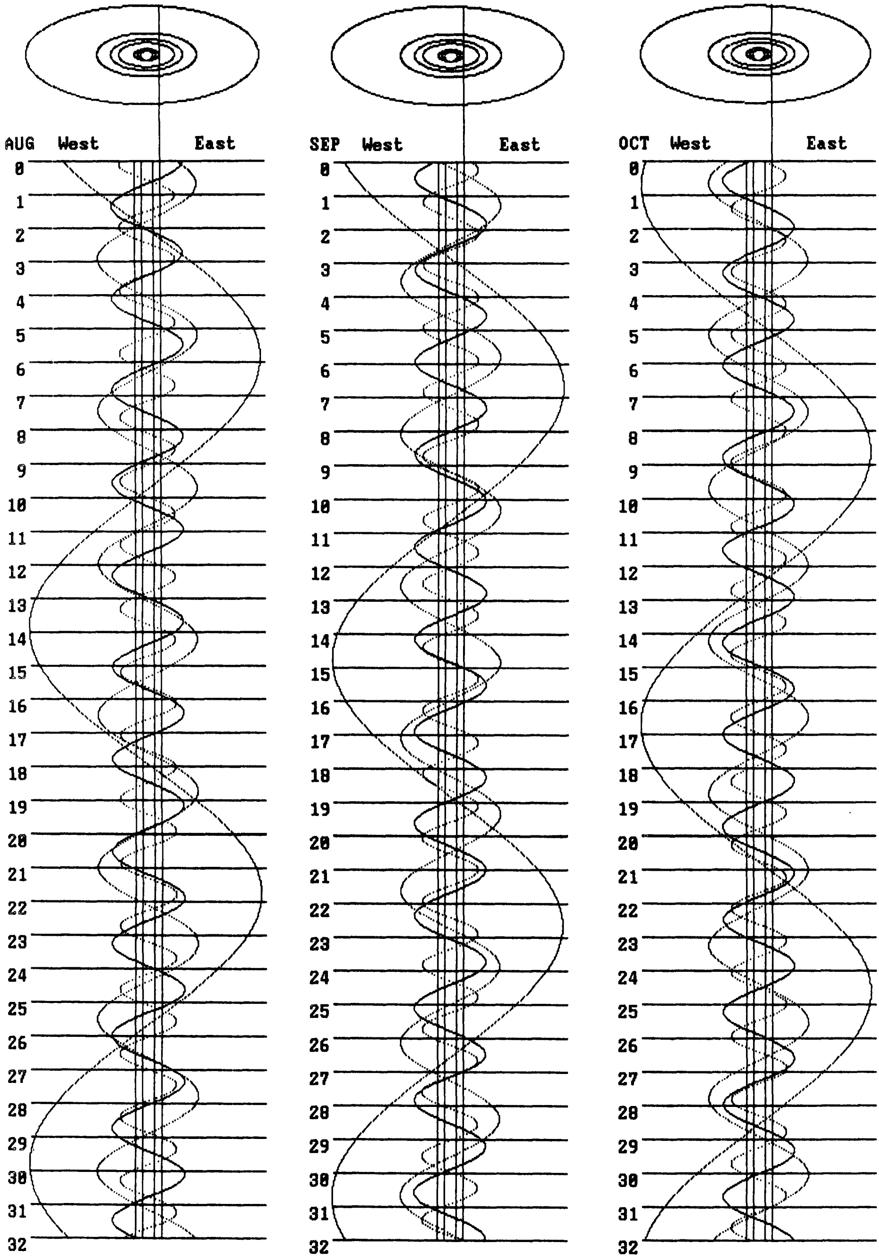
32

P


AUG West East
SEP West East
OCT West East
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
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EPHEMERIDES FOR THE BRIGHTEST ASTEROIDS 1989

PROVIDED BY BRIAN G. MARSDEN

The following are the ephemerides for the brightest asteroids in 1989: those asteroids which will be brighter than visual magnitude 10.0 and more than 90° from the Sun. The tables give the number and name of the asteroid, the date at 0^h ET (which differs only slightly from UT), the right ascension and declination for the epoch 1950 and the visual magnitude (which is normally about $0^m.7$ *brighter* than the photographic magnitude). These data were derived from current osculating elements, and were generously calculated and provided by Dr. Brian G. Marsden of the Smithsonian Astrophysical Observatory.

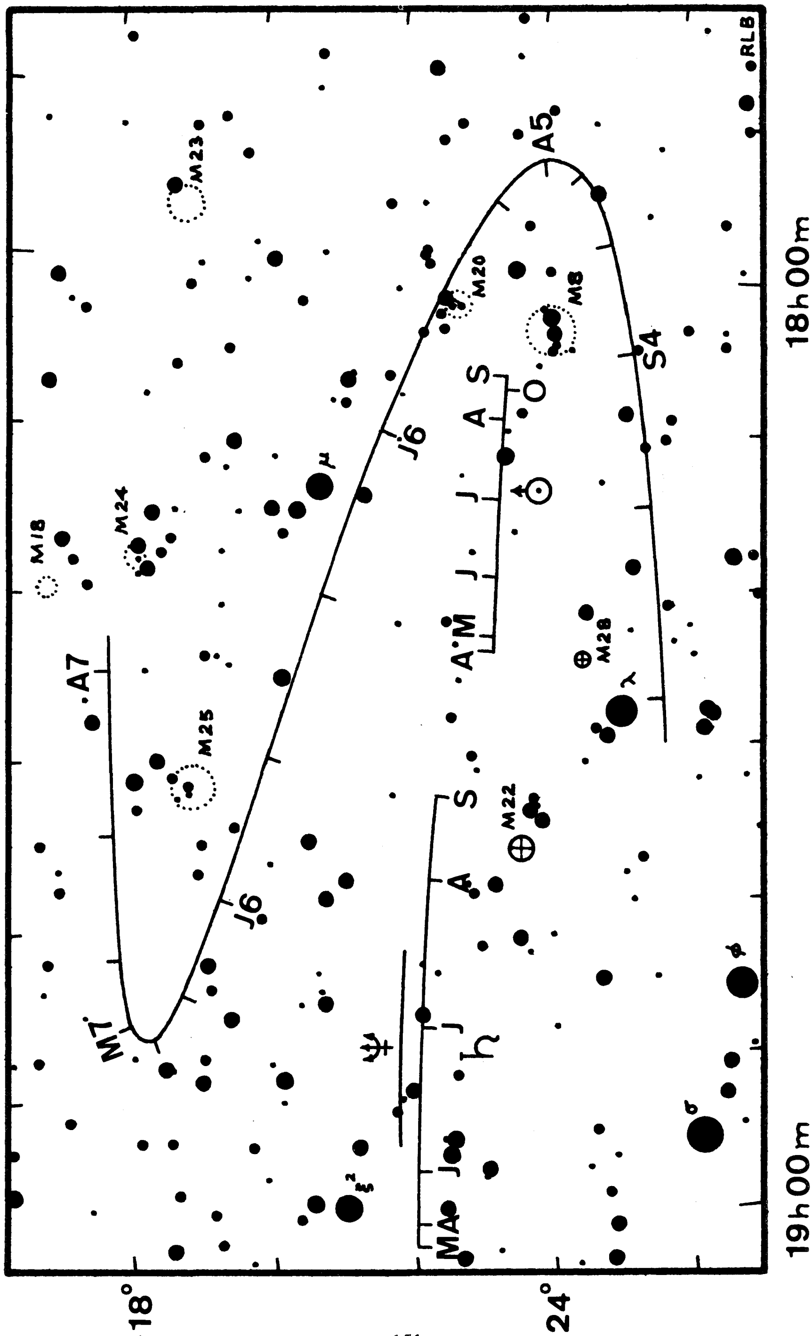
Readers can make charts for the asteroids listed on pages 152 and 153 by using the ephemerides provided and an appropriate star atlas. Remember to allow for precession if your atlas does not use the same epoch as the tables: 1950.0 (See page 19).

The chart on the next page shows the path of **Vesta** as it moves through its retrograde loop against the star clouds of northern Sagittarius. This will be a fascinating section of sky to watch during the spring and summer of 1989 for, as shown on the chart, during this period Saturn, Uranus and Neptune are also retrograding in this region. Charts showing the paths of these three planets during the *entire* year appear earlier in this Handbook and, for Neptune, the other chart must be used to identify this faint planet.

Tick marks along Vesta's path locate its position at 10-day intervals, beginning with April 7 (A7). Tick marks along the paths of Saturn and Uranus locate their positions at the beginnings of the months April through September (A, M, J, ...). For planetary symbols see page 10. The chart magnitude limit is 8.0 and the coordinates are for 2000.0.

In early April, Vesta is near magnitude 7.0. It brightens to magnitude 6.0 by late May, and to 5.3 when at opposition on June 26, 1.14 AU from Earth. By late July Vesta has faded to 6.0, and reaches 7.0 by mid-September.

During June and much of July, Uranus (magnitude 5.6) and Vesta will be of nearly equal brightness and should both be visible to the unaided eye. However, the low declination (for observers at mid-northern latitudes) and the Milky Way backdrop will hamper attempts to see these bodies without optical aid. It is only at intervals of several years that Vesta is at opposition when it is also near perihelion. June oppositions, as in 1989, are of this type, and at such times Vesta becomes the only asteroid that can ever be seen with the unaided eye. Although Vesta is third in order of diameter amongst the asteroids (538 km for Vesta, versus 1003 km for Ceres and 608 km for Pallas), it has an unusually high albedo ($\sim$23%) and a smaller orbit than the other large asteroids. Thus when at a perihelic opposition Vesta is the brightest asteroid. (RLB)


-18°
-24°
19h00m
18h00m
M23
M24
M18
M25
M20
M8
M28
M22
A7
M7
J6
J6
A5
S4
RLB
μ
λ
σ
φ
ξ²

(1) Ceres

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Oct. 1	$6^h06^m.1$	$+21^\circ 20'$	8.5
11	6 13.1	+21 40	
21	6 17.9	+22 02	8.2
31	6 20.1	+22 29	
Nov. 10	6 19.5	+23 02	7.8
20	6 15.9	+23 39	
30	6 09.5	+24 20	7.3
Dec. 10	6 00.7	+25 02	
20	5 50.4	+25 43	6.7
30	5 40.0	+26 18	

(2) Pallas

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Dec. 25	$21^h00^m.6$	$-3^\circ 15'$	10.5
July 13	0 54.8	+ 4 03	9.7
23	1 00.5	+ 3 19	
Aug. 2	1 04.5	+ 2 15	9.4
12	1 06.8	+ 0 49	
22	1 07.0	- 1 00	9.0
Sept. 1	1 05.1	- 3 10	
11	1 01.1	- 5 37	8.6
21	0 55.2	- 8 16	
Oct. 1	0 48.1	-10 56	8.2
11	0 40.3	-13 25	
21	0 32.9	-15 34	8.5
31	0 26.7	-17 15	
Nov. 10	0 22.3	-18 26	8.8
20	0 20.2	-19 08	
30	0 20.4	-19 24	9.1
Dec. 10	0 23.1	-19 17	
20	0 27.9	-18 52	9.3
30	0 34.8	-18 11	

(3) Juno

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Jan. 4	$10^h32^m.5$	$-0^\circ 41'$	
14	10 31.1	- 0 17	9.1
24	10 27.0	+ 0 31	
Feb. 3	10 20.7	+ 1 43	8.8
13	10 12.8	+ 3 14	
23	10 04.4	+ 4 55	8.6
Mar. 5	9 56.6	+ 6 37	
15	9 50.3	+ 8 13	9.1
25	9 46.3	+ 9 34	
Apr. 4	9 44.7	+10 38	9.5
14	9 45.7	+11 24	
24	9 49.0	+11 52	10.0
May 4	9 54.3	+12 04	

(4) Vesta

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Apr. 4	$18^h18^m.5$	$-18^\circ 09'$	7.0
14	18 29.0	-18 08	
24	18 36.9	-18 09	6.7
May 4	18 42.0	-18 15	
14	18 43.9	-18 29	6.2
24	18 42.4	-18 52	
June 3	18 37.6	-19 25	5.8
13	18 29.9	-20 08	
23	18 20.3	-20 55	5.3
July 3	18 10.1	-21 44	
13	18 00.9	-22 32	5.7
23	17 54.0	-23 16	
Aug. 2	17 50.2	-23 55	6.2
12	17 49.9	-24 30	
22	17 53.1	-25 01	6.6
Sept. 1	17 59.4	-25 27	
11	18 08.5	-25 47	7.0
21	18 19.9	-26 01	
Oct. 1	18 33.4	-26 07	7.3
11	18 48.5	-26 05	

(6) Hebe

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Jan. 4	$8^h42^m.1$	$+10^\circ 09'$	
14	8 33.4	+11 33	8.9
24	8 23.5	+13 08	
Feb. 3	8 13.7	+14 48	9.0
13	8 05.2	+16 22	
23	7 59.0	+17 46	9.5
Mar. 5	7 55.6	+18 57	
15	7 55.2	+19 53	10.0
25	7 57.7	+20 34	

(7) Iris

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Jan. 4	$9^h51^m.6$	$+5^\circ 53'$	
14	9 45.8	+ 5 44	8.7
24	9 37.4	+ 5 54	
Feb. 3	9 27.2	+ 6 21	8.4
13	9 16.7	+ 7 00	
23	9 07.2	+ 7 44	8.6
Mar. 5	8 59.8	+ 8 27	
15	8 55.3	+ 9 04	9.2
25	8 53.8	+ 9 32	
Apr. 4	8 55.2	+ 9 49	9.7
14	8 59.3	+ 9 56	

(8) Flora

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Feb. 3	$11^h33^m.9$	$+10^\circ 03'$	9.8
13	11 27.8	+11 21	
23	11 19.3	+12 46	9.4
Mar. 5	11 09.4	+14 09	
15	10 59.5	+15 20	9.5
25	10 50.7	+16 11	
Apr. 4	10 44.1	+16 40	10.0
14	10 40.3	+16 46	

(9) Metis

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
July 13	$21^h55^m.2$	$-20^\circ 54'$	10.0
23	21 49.4	-21 54	
Aug. 2	21 41.3	-22 58	9.6
12	21 31.7	-23 58	
22	21 21.7	-24 47	9.5
Sept. 1	21 12.6	-25 19	
11	21 05.5	-25 33	9.9
21	21 01.2	-25 29	

(10) Hygiea

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Apr. 24	$17^h18^m.4$	$-26^\circ 24'$	9.9
May 4	17 15.9	-26 21	
14	17 10.9	-26 11	9.5
24	17 03.8	-25 56	
June 3	16 55.6	-25 34	9.0
13	16 47.1	-25 07	
23	16 39.4	-24 38	9.4
July 3	16 33.3	-24 09	
13	16 29.5	-23 44	9.8
23	16 28.2	-23 24	

(11) Parthenope

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Aug. 2	$23^h50^m.4$	$-5°12'$	9.9
12	23 49.1	- 5 58	
22	23 45.0	- 7 00	9.5
Sept. 1	23 38.6	- 8 14	
11	23 30.6	- 9 30	9.1
21	23 22.3	-10 39	
Oct. 1	23 14.9	-11 32	9.5
11	23 09.5	-12 04	
21	23 06.7	-12 14	10.0
31	23 06.8	-12 02	

(12) Victoria

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
July 13	$22^h31^m.0$	$+6°37'$	9.7
23	22 31.5	+ 7 52	
Aug. 2	22 28.8	+ 8 37	9.3
12	22 23.3	+ 8 45	
22	22 16.0	+ 8 17	8.9
Sept. 1	22 08.3	+ 7 14	
11	22 01.7	+ 5 49	9.0
21	21 57.5	+ 4 15	
Oct. 1	21 56.5	+ 2 44	9.6
11	21 58.7	+ 1 26	

(15) Eunomia

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
June 3	$22^h18^m.3$	$-6°09'$	9.9
13	22 25.0	- 4 33	
23	22 29.7	- 3 02	9.5
July 3	22 32.2	- 1 37	
13	22 32.1	- 0 21	9.1
23	22 29.3	+ 0 43	
Aug. 2	22 23.9	+ 1 34	8.6
12	22 16.1	+ 2 07	
22	22 06.9	+ 2 23	8.1
Sept. 1	21 57.1	+ 2 22	
11	21 48.2	+ 2 07	8.2
21	21 41.2	+ 1 45	
Oct. 1	21 37.0	+ 1 22	8.6
11	21 35.9	+ 1 02	
21	21 38.0	+ 0 51	9.0
31	21 43.0	+ 0 50	
Nov. 10	21 50.7	+ 1 02	9.3
20	22 00.7	+ 1 27	

(16) Psyche

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
July 13	$21^h09^m.5$	$-14°24'$	10.0
23	21 03.0	-15 00	
Aug. 2	20 55.1	-15 43	9.5
12	20 47.0	-16 27	
22	20 39.5	-17 10	9.8
Sept. 1	20 33.5	-17 45	

(20) Massalia

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
May 14	$15^h05^m.0$	$-16°55'$	9.8
24	14 55.7	-16 13	

(29) Amphitrite

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Apr. 4	$14^h57^m.1$	$-22°58'$	10.0
14	14 49.9	-22 57	
24	14 40.9	-22 44	9.6
May 4	14 31.0	-22 18	
14	14 21.4	-21 45	9.6
24	14 13.1	-21 08	
June 3	14 06.9	-20 33	10.0
13	14 03.2	-20 05	

(30) Urania

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Oct. 1	$1^h05^m.2$	$+10°53'$	9.8
11	0 56.1	+10 06	
21	0 47.2	+ 9 12	9.8
31	0 39.9	+ 8 22	

(40) Harmonia

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Mar. 15	$12^h02^m.0$	$+7°41'$	10.0
25	11 52.4	+ 8 45	

(51) Nemausa

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Mar. 15	$11^h38^m.6$	$+1°49'$	9.6
25	11 30.8	+ 3 43	

(79) Eurynome

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Sept.11	$23^h16^m.8$	$+1°07'$	10.0
21	23 08.6	- 0 13	

(89) Julia

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Nov. 30	$5^h24^m.5$	$+45°08'$	10.0
Dec. 10	5 10.9	+44 24	
20	4 57.9	+43 10	10.0
30	4 47.1	+41 35	

(115) Thyra

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Nov. 10	$4^h20^m.6$	$+42°53'$	9.8
20	4 10.0	+42 29	
30	3 58.4	+41 25	9.6
Dec. 10	3 48.1	+39 49	
20	3 41.2	+37 53	9.9
30	3 38.5	+35 54	

(192) Nausikaa

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Nov. 10	$5^h09^m.8$	$+35°31'$	9.7
20	5 00.7	+35 53	
30	4 48.8	+35 50	9.3
Dec. 10	4 36.6	+35 22	
20	4 26.0	+34 34	9.6
30	4 18.8	+33 35	

PLANETARY APPULSES AND OCCULTATIONS

By Robert L. Millis

Planets, satellites, asteroids, and comets, as they move across the sky, will on occasion pass near an observer's line of sight to a distant star. Such close passes are called appulses. More rarely, the moving object's trajectory will carry it directly between the observer and a star, thereby producing an occultation. Astronomers have learned much about various solar system bodies by carefully monitoring the changing apparent brightness of stars during the immersion and emersion phases of occultations. If the occulting body has an atmosphere, the star's disappearance and reappearance will occur more gradually than otherwise would be the case. If a planet has rings or other debris in its environs, the extent and degree of transparency of this material can be precisely mapped. Indeed, the rings of Uranus were discovered in this way. Additionally, if an occultation can be observed at several appropriately distributed sites, it is often possible to determine the size and shape of the occulting body far more accurately than by other Earth-based techniques.

Amateur astronomers can sometimes contribute importantly to occultation observing campaigns. This is particularly true for asteroid occultations where the strip across Earth from which an event is observable is often very narrow and uncertain in location. By recording the times of the star's disappearance and reappearance as seen from several sites, the asteroid's profile can be directly determined. Often timings of adequate accuracy can be made by visual observers using modest telescopes. The table two pages ahead gives the circumstances for seven asteroid occultations predicted to be observable from North America or Hawaii in 1989. The predictions were taken from a paper by L. H. Wasserman, E. Bowell, and R. L. Millis at Lowell Observatory (*Astronomical Journal 94*, 1364, 1987).

In addition to the asteroid occultation predictions, data are given in the table for an occultation of 28 Sgr by Saturn. According to predictions by Doug Mink at the Center for Astrophysics, the star will be covered by the outer edge of the A Ring at 6:01 UT, disappear behind the ball of the planet at 6:50, re-emerge at 8:29, and be clear of the A Ring by 9:31. The occultation of a star as bright as 28 Sgr by Saturn and the Rings is quite unusual and offers an opportunity to study the astonishingly complex structure of the Rings first revealed by Voyagers 1 and 2. However, because of the high surface brightness of the Rings, the occultation will be observationally very challenging at visual wavelengths. The best results are likely to be obtained in the infrared, where water ice absorption bands reduce the brightness of the Rings.

The occultations by Bamberga, Kleopatra, and Brixia are attractive opportunities for individuals wishing to observe an asteroid occultation. In all three events, the star to be occulted is bright relative to the asteroid and, as a consequence, the disappearance and reappearance of the star will be easily detectable visually. Moreover, the occultation by Kleopatra is likely to be the target of intensive observational effort by professional astronomers. Radar observations suggest that this asteroid has an unusual shape, being either extremely elongated or, perhaps, a near-contact binary. If sufficient observational coverage of the occultation can be arranged, the shape of Kleopatra can be determined. The shape of Bamberga is also of interest, because observations of a recent occultation gave evidence of a large limb irregularity. Those observations, however, were not conclusive, so observations of the upcoming Bamberga occultation are desired. An occultation by Brixia has not yet been well observed.

The successive columns in the table list (1) the date; (2) the name of the occulting body; (3) the apparent magnitude of the planet or asteroid; (4) the catalog number of the star; (5) the apparent magnitude of the star; (6) the right ascension and (7) declination of the star; (8) the expected fractional drop in the combined brightness of the star and occulting body at immersion; (9) the predicted maximum duration of the occultation; and (10) the approximate region from which the occultation is predicted to be observable. Be advised that the exact region of visibility of an occultation often cannot be determined until a few days prior to the event.

When observing an occultation, it is important that an observer know his location to within a fraction of a kilometre. Geographic longitude and latitude as well as the altitude of the site can then be determined from a high-quality topographic map. If observations are to be of maximum value, the times of immersion and emersion must be determined as accurately as possible—certainly to better than 0.5 second. Photoelectric equipment with high-speed digital data recording systems are best suited for this work, but visual observers equipped with tape recorders and shortwave time signal receivers can contribute usefully. Even simple measurements of the duration of an occultation made with an ordinary stopwatch can be of value.

Occultation observations are coordinated in North America by the International Occultation Timing Association (IOTA). This organization publishes a useful newsletter and maintains "hot-lines" for disseminating last-minute prediction updates. (Within a few days of each event, improved predictions may be obtained from recorded telephone messages at 312-259-2376 (Chicago, Ill.), 713-488-6871 (Houston, Tex.), or 301-495-9062 (Silver Spring, Md.)). Individuals interested in joining IOTA should see p. 96 of this Handbook. Other sources of occultation information include the *Solar System Photometry Handbook* (published by Willmann-Bell, Inc. 1983), *Sky and Telescope* (particularly the January issue), and occasional papers in the *Astronomical Journal*, *Icarus*, and other scientific journals.

Editor's Note: Observations of planetary occultations, *including* negative observations, should be sent to: James Stamm, 11781 N. Joi Drive, Tucson, AZ 85737, U.S.A., for publication by the IOTA. When reporting timings describe your geographic longitude, latitude, and altitude (to the nearest second of arc and 20 m, respectively), the telescope used, and the timing method (including reaction time corrections, if applicable).

U.T. Date 1989	Occulting Body	m_a (mag)	Star	m_s (mag)	α (1950)	δ (1950)	ΔI	Max Dur. (sec)	Approximate Area of Visibility
6.10 Feb	3 Juno	9.5	AG+02°1370	10.2	$10^h18^m21.1$	+02°09′31″	0.35*	23	Mexico, Caribbean
18.17 Mar	324 Bamberga	12.5	AG−02°0652	9.2	11 15 16.2	−02 16 58	0.96*	15	SE to NW U.S.
3.32 Jul	Saturn	...	28 Sgr	5.8	18 43 19.8	−22 26 47	...	...	Western Hemisphere
14.32 Aug	216 Kleopatra	11.9	AG+00°2438	9.8	19 56 32.0	+00 32 00	0.88*	24	NW U.S., Central Canada
16.45 Sep	34 Circe	13.6	AG+07°0162	7.2	01 25 45.7	+07 42 11	1.00*	13	NW Canada
23.10 Oct	521 Brixia	10.9	SAO 147658	7.2	01 09 03.0	−13 06 30	0.97	22	Eastern Canada
11.46 Nov	1 Ceres	7.8	LJ 00631	10.5	06 19 13.9	+23 07 08	0.07	196	W U.S., W Mexico
2.29 Dec	895 Helio	12.6	LJ 01028	10.9	06 28 35.6	+21 06 05	0.83	8	Central U.S., E Canada

*Magnitudes pertain to blue spectral region.

METEORS, COMETS, AND DUST

METEORS, FIREBALLS, AND METEORITES

BY PETER M. MILLMAN

Meteoroids are small solid particles moving in orbits about the Sun. On entering Earth's atmosphere they become luminous and appear as meteors or fireballs, and in rare cases, if large enough to avoid complete fragmentation and vaporization, they may fall to Earth as meteorites.

Meteors are visible on any night of the year. At certain times of the year Earth encounters larger numbers of meteoroids all moving together along the same orbit. Such a group is known as a meteor stream and the visible phenomenon is called a meteor shower. The orbits followed by these meteor streams are very similar to those of short-period comets, and in many cases can be identified with the orbits of specific comets.

The radiant is the position among the stars from which the meteors of a given shower seem to radiate. This is an effect of perspective commonly observed for any group of parallel lines. Some showers, notably the Quadrantids, Perseids, and Geminids, are very regular in their return each year and do not vary greatly in the numbers of meteors seen at the time of maximum. Other showers, like the Leonids, are very unpredictable and may arrive in great numbers or fail to appear at all in any given year. The δ Aquarids and the Taurids are spread out over a fairly extended period of time without a sharp maximum.

For more information concerning meteor showers, see the paper by A. F. Cook in "Evolutionary and Physical Properties of Meteoroids", NASA SP-319, pp. 183–191, 1973.

The light of meteors is produced by a mixture of atoms and molecules, originating from both the meteoroid and Earth's atmosphere. i.e. The light of a meteor is primarily from a glowing gas, and not from the solid meteoroid itself. The collision, at a very high speed, of the material from the meteoroid with Earth's atmosphere

MAJOR VISUAL METEOR SHOWERS FOR 1989

Shower	Shower Maximum			Radiant				Single Observer Hourly Rate	Speed of Encounter with Earth	Normal Duration to ¼ Strength of Max.
	Date	U.T.	Moon	Position at Max. R.A.	Position at Max. Dec.	Daily Motion R.A.	Daily Motion Dec.			
	(1989)	h		h m	°	m	°		km/s	days
Quadrantids	Jan. 3	10	NM	15 28	+50	—	—	40	41	1.1
Lyrids	Apr. 22	09	FM	18 16	+34	+4.4	0.0	15	48	2
η Aquarids	May 4	12	NM	22 24	00	+3.6	+0.4	20	65	3
S. δ Aquarids	July 28	15	LQ	22 36	−17	+3.4	+0.17	20	41	7
Perseids	Aug. 12	06	FQ	03 04	+58	+5.4	+0.12	50	60	4.6
Orionids	Oct. 21	10	LQ	06 20	+15	+4.9	+0.13	25	66	2
S. Taurids	Nov. 2	11	NM	03 32	+14	+2.7	+0.13	15	28	—
Leonids	Nov. 17	16	LQ	10 08	+22	+2.8	−0.42	15	71	—
Geminids	Dec. 14	06	FM	07 32	+32	+4.2	−0.07	50	35	2.6
Ursids	Dec. 22	12	LQ	14 28	+76	—	—	15	34	2
	(1990)									
Quadrantids	Jan. 3	16	FQ	15 28	+50	—	—	40	41	1.1

excites the involved atoms and molecules to shine, each with its own characteristic wavelength (colour). In addition to the light of oxygen and nitrogen, prominent in the luminosity of meteors, we find the orange-yellow of sodium, the brilliant green of magnesium, and various other wavelengths of light produced by iron, calcium, and some dozen, less-common elements. For a general survey of the light of meteors see *Smithsonian Contributions to Astrophysics*, *7*, pp. 119–127, 1963.

An observer located away from city lights, and with perfect sky conditions on a moonless night, will see an overall average of seven sporadic meteors per hour apart from the shower meteors. These sporadic meteors have been included in the hourly rates listed in the table. Slight haze or nearby lighting will greatly reduce the number of meteors seen. More meteors appear in the early morning hours than in the evening, and more during the last half of the year than during the first half.

When a meteor has a luminosity greater than the brightest stars and planets it is generally termed a fireball. The visible trails of most meteors occur high in the atmosphere from 60 to 110 kilometres altitude. Only the rare, very bright fireballs survive down to the lower levels of Earth's atmosphere, and, in general, these are not associated with meteor showers. The occurrence of such an object should be reported immediately to the nearest astronomical group or other organization concerned with the collection of such information. Where no local organization exists, in Canada reports should be sent to Meteor Centre, Herzberg Institute of Astrophysics, National Research Council of Canada, Ottawa, Ontario, K1A 0R6. In the United States, fireball reports should be mailed to the Scientific Event Alert Network (SEAN), Mail Stop 129, Natural History Building, Smithsonian Institution, Washington, DC 20560. Special "Fireball Report" forms and related instructions are available from the Meteor Centre without charge. If sounds are heard accompanying a bright fireball there is a possibility that a meteorite may have fallen. Astronomers must rely on observations made by the general public to track down such an object.

Editor's Note: For more information on meteors and their observation, an excellent reference is *Observe Meteors* by David Levy and Stephen Edberg, a guidebook of the Association of Lunar and Planetary Observers. It was published in 1986 by the Astronomical League, Science Service Building, 1719 N. Street, NW, Washington, DC, 20036, U.S.A.

A SELECTION OF MINOR VISUAL METEOR SHOWERS

Shower	Dates	Date of Max.	Speed
			km/s
δ Leonids	Feb. 5–Mar. 19	Feb. 26	23
σ Leonids	Mar. 21–May 13	Apr. 17	20
τ Herculids	May 19–June 14	June 3	15
N. δ Aquarids	July 14–Aug. 25	Aug. 12	42
α Capricornids	July 15–Aug. 10	July 30	23
S. ι Aquarids	July 15–Aug. 25	Aug. 5	34
N. ι Aquarids	July 15–Sept. 20	Aug. 20	31
κ Cygnids	Aug. 9–Oct. 6	Aug. 18	25
S. Piscids	Aug. 31–Nov. 2	Sept. 20	26
N. Piscids	Sept. 25–Oct. 19	Oct. 12	29
N. Taurids	Sept. 19–Dec. 1	Nov. 13	29
Annual Andromedids	Sept. 25–Nov. 12	Oct. 3	18–23
Coma Berenicids	Dec. 12–Jan. 23	—	65

NORTH AMERICAN METEORITE IMPACT SITES

BY P. BLYTH ROBERTSON

The realization that our Earth is truly part of the solar system, and not a planet in isolation, has been dramatically demonstrated by the past two decades of space exploration. Bodies such as Phobos, Callisto, Mimas, which were once solely part of the astronomer's realm, are now familiar terrain to planetary geologists, and an insight into the age and history of their surfaces can be derived from a knowledge of, and comparison with geological processes on Earth. In particular, as the only common feature apparent on all bodies from Mercury outward to the moons of Uranus is the abundance of meteorite craters, studies of the terrestrial equivalents may lead to better understanding of the evolution of planetary crusts.

Although all the terrestrial planets are heavily cratered, the source of the impacting bodies is not the same throughout the solar system, nor has the rate been constant with time. The densely-cratered lunar highlands reveal a period of intense bombardment between 4.6 and 3.9 billion years ago, whereas the crater populations on the younger mare surfaces indicate a subsequent, considerably reduced rate that may have fluctuated somewhat over the past 3 billion years. It is believed that the cratering history of Earth is like that of the Moon, but all vestiges of the early bombardment, and a large percentage of the craters from the later period have been obliterated by various geologic processes on the 'active' Earth. A significant number of the larger, younger craters have been preserved, however, and their ages determined through radiometric age-dating techniques, to permit a calculation of the recent cratering rate. This rate, for the past 120 million years, is 5.4×10^{-15} per square kilometre of Earth per year, for craters 20 kilometres or larger in diameter. In other words, an event of this magnitude may occur every 7.6 million years in North America.

An impact crater results from a combination of excavation of the shattered target rocks and further expansion of the cavity by outward and downward movements of highly fractured material. Craters larger than 4 or 5 km undergo further modification through rebound and uplift of the crater floor, and downward faulting and displacement of large blocks in a broad annulus surrounding the crater. These movements result in a comparatively shallow impact structure whose outer dimension is approximately 40% larger than that of the initial crater.

The magnitude of the impact event is proportional to the kinetic energy of the meteorite, and therefore depends on its size, composition and speed. A 20 km impact structure on Earth would result from an impact yielding the equivalent of approximately 64 000 megatons of TNT, and could be produced by a stony meteorite (density 3.4 g/cm^3), 900 m in diameter, travelling at a typical speed of 20 km/s. Thus the diameter of the impact structure is many times that of the impacting body. (The kinetic energy of a typical meteor is about 100 times the explosive energy of the same mass of TNT.—Ed.)

In impacts, where craters greater than approximately 1.5 km are created, extreme shock pressures and temperatures vaporize and melt the meteorite. It subsequently becomes thoroughly mixed with the melted target rocks and is no longer recognizable in its original form, although chemical traces have been discovered. Of the 39 North American impact structures listed, which account for roughly 40% of the world's recognized total, meteorite fragments are preserved at only 3. The remainder are identified by the presence of characteristic deformation features in the target rocks; features that are uniquely produced by extreme shock pressures generated in nature only by hypervelocity, meteorite impact. In addition to these sites there are twenty or more structures in Canada and the United States whose impact origin seems highly probable, but where distinctive shock deformation has not been found.

In the table, sites accessible by road or boat are marked "A" or "B" respectively and those sites where data have been obtained through diamond-drilling or geophysical surveys are signified by "D" and "G", respectively.

Name	Lat. °	'	Long. °	'	Diam. (km)	Age ($\times 10^6$ a)	Surface Expression	Visible Geologic Features			
Barringer, Meteor Crater, Ariz.	35	02	111	01	1.2	.05	rimmed polygonal crater	fragments of meteorite, highly shocked sandstone	A	D	G
Bee Bluff, Texas	29	02	099	51	2.4	40±10	shallow circ. depress'n.; rim remnants	breccia	A		
Brent, Ont.	46	05	078	29	3.8	450±30	sediment-filled shallow depression	fracturing	A	D	G
Carswell, Sask.	58	27	109	30	37	485±50	discontinuous circular ridge	shatter cones, breccia			G
Charlevoix, Que.	47	32	070	18	46	360±25	semi-circular trough, central elevation	breccia, shatter cones, impact melt	A		G
Clearwater Lake East, Que.	56	05	074	07	22	290±20	circular lake	sedimentary float		D	G
Clearwater Lake West, Que.	56	13	074	30	32	290±20	island ring in circular lake	impact melt		D	G
Crooked Creek, Missouri	37	50	091	23	5.6	320±80	oval area of disturbed rocks, shallow marginal depression	breccia, shatter cones	A		
Decaturville, Missouri	37	54	092	43	6	<300	slight oval depression	breccia, shatter cones	A	D	
Deep Bay, Sask.	56	24	102	59	12	100±50	circular bay	sedimentary float		D	G
Flynn Creek, Tenn.	36	16	085	37	3.8	360±20	sediment-filled shallow depression with slight central elevation	breccia, shatter cones, disturbed rocks	A	D	G
Glover Bluff, Wis.	43	58	089	32	0.4	?	disturbed dolomite exposed in 3 quarries	shatter cones	A		G
Gow Lake, Sask.	56	27	104	29	5	<250	lake and central island	breccia			G
Haviland, Kansas	37	35	099	10	0.0011	<0.001	excavated depression	fragments of meteorite	A		
Haughton, NWT	75	22	089	40	20	<20	shallow circular depression	shatter cones, breccia			G
Holleford, Ont.	44	28	076	38	2	550±100	sediment-filled shallow depression	sedimentary fill	A	D	G
Ile Rouleau, Que.	50	41	073	53	4	<300	island is central uplift of submerged structure	shatter cones, breccia dikes			
Kentland, Ind.	40	45	087	24	13	300	central uplift exposed in quarries, rest buried	breccia, shatter cones, disturbed rocks	A		
Lac Couture, Que.	60	08	075	18	8	430	circular lake	breccia float			
Lac la Moinerie, Que.	57	26	066	36	8	400	lake-filled, partly circular	breccia float			G
Lake St. Martin, Man.	51	47	098	33	23	225±40	none, buried and eroded	impact melt	A	D	G
Lake Wanapitei, Ont.	46	44	080	44	8.5	37±2	lake-filled, partly circular	breccia float	A		G
Manicouagan, Que.	51	23	068	42	100	210±4	circumferal lake, central elevation	impact melt, breccia	B		G
Manson, Iowa	42	35	094	31	32	<100	none, central elevation buried to 30 m	none	A	D	G
Middlesboro, Ky.	36	37	083	44	6	300	circular depression	disturbed rocks	A		
Mistastin Lake, Labr.	55	53	063	18	28	38±4	elliptical lake and central island	breccia, impact melt			
Montagnais Crater, N.S.	42	53	064	13	45?	52±5	none (under water (115 m) and sediments)	none		D	G
New Quebec Crater, Que.	61	17	073	40	3.2	<5	rimmed, circular lake	raised rim			G
Nicholson Lake, NWT	62	40	102	41	12.5	<400	irregular lake with islands	breccia			G
Odessa, Tex.	31	48	102	30	0.17	0.03	sediment-filled depression with very slight rim, 4 others buried and smaller	fragments of meteorite	A	D	G
Pilot Lake, NWT	60	17	111	01	6	<440	circular lake	fracturing, breccia float			
Redwing Creek, N. Dak.	47	40	102	30	9	200	none, buried	none	A	D	G
Serpent Mound, Ohio	39	02	083	24	6.4	300	circular area of disturbed rock, slight central elevation	breccia, shatter cones	A		G
Sierra Madera, Tex.	30	36	102	55	13	100	central hills, annular depression, outer ring of hills	breccia, shatter cones	A	D	G
Slate Islands, Ont.	48	40	087	00	30	350	islands are central uplift of submerged structure	shatter cones, breccia dikes	B		G
Steen River, Alta.	59	31	117	38	25	95±7	none, buried to 200 metres	none		D	G
Sudbury, Ont.	46	36	081	11	140	1840±150	elliptical basin	breccia, impact melt, shatter cones	A	D	G
Wells Creek, Tenn.	36	23	087	40	14	200±100	basin with cenral hill, inner and outer annular, valleys and ridges	breccia, shatter cones	A	D	G
West Hawk Lake, Man.	49	46	095	11	2.7	100±50	circular lake	none	A	D	G

COMETS IN 1989

BY BRIAN G. MARSDEN

The following periodic comets are expected at perihelion during 1989:

Comet	Perihelion Date	Perihelion Dist.	Period
		AU	a
Tempel 1	Jan. 4	1.50	5.5
d'Arrest	Feb. 4	1.29	6.4
Churyumov-Gerasimenko	June 18	1.30	6.6
Pons-Winncecke	Aug. 19	1.26	6.4
Gunn	Sept. 24	2.47	6.8
Brorsen-Metcalf	Sept. 27	0.48	70.6
Lovas 1	Oct. 10	1.68	9.1
du Toit-Neujmin-Delporte	Oct. 18	1.72	6.4
Schwassmann-Wachmann 1	Oct. 26	5.77	14.9
Gehrels 2	Nov. 3	2.35	7.9
Clark	Nov. 28	1.56	5.5

By far the brightest periodic comet to appear during 1989 should be P/Brorsen-Metcalf, although the positions in the ephemeris below are somewhat uncertain. The returns of P/Lovas 1 and P/Gehrels 2 are also rather favourable, and the former is making its first predicted appearance. P/Pons-Winnecke is moderately well placed for observation in 1989, but the returns of P/Tempel 1, P/Churyumov-Gerasimenko and P/du Toit-Neujmin-Delporte are not particularly good. P/d'Arrest and P/Clark are rather unfavourably placed for observation, but observations should still be possible. P/Schwassmann-Wachmann 1 and P/Gunn are observable every year but both happen to be at perihelion in 1989; the former comet is known for its erratic outbursts in brightness.

COMET BRORSEN-METCALF

0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Aug. 2	$0^h56^m.8$	+25° 01′	10.4
7	1 28.5	+32 11	
12	2 16.0	+40 31	9.0
17	3 29.7	+48 31	
22	5 12.2	+52 50	7.7
27	6 55.9	+51 12	
Sept. 1	8 11.8	+45 41	6.8
6	9 01.3	+39 13	
11	9 34.9	+33 01	5.9
16	10 00.1	+27 18	
21	10 21.2	+21 56	5.2
26	10 40.8	+16 45	
Oct. 1	10 59.8	+11 45	5.5
6	11 18.5	+ 7 02	
11	11 36.5	+ 2 42	7.1
16	11 53.6	- 1 13	
21	12 09.7	- 4 43	8.9
26	12 24.7	- 7 51	
31	12 38.7	-10 40	10.4

OBSERVING COMETS

By David H. Levy

Comets are interesting and fun to observe because they are so individual. Every comet is different from every other comet, and each comet differs from itself as the nights of its apparition pass. Recent comets like P/Halley, Bradfield 1987s, and Liller 1988a, changed almost nightly with the flaring of dust jets.

When a comet is announced, it is assigned a letter designation based on the order of discovery, or "recovery" in the case of a predicted returning comet, in a particular year. If the comet is known to be periodic and with a period of less than 200 years, the prefix P/ precedes the name; thus P/Machholz 1986e was the 5th comet to be found in the year 1986 and it is known to be a "short-period" comet. The letter designation is provisional, but important since it is used when most of the observations of a comet are being made. A few years later when the data on a given year appear to be complete, the comets are assigned permanent designations using Roman numerals based on the order in which they passed closest to the Sun. Thus Comet Bennett 1969i, the 9th comet to be found in 1969, has a permanent designation 1970 II since it was the 2nd comet known to pass perihelion in the following year.

Observationally, comets are very much like deep sky objects. Even in large telescopes an observer can confuse a comet with a galaxy or a diffuse planetary nebula. Comets near a telescope's limit are virtually impossible to spot without an accurate position extracted from a detailed atlas like *Uranometria* or *Stellarum*. It is difficult to define a telescope's limiting magnitude for comets, because the more diffuse a comet is, the more difficult it is to find. Typically, under a dark sky a 15 cm telescope will catch a 9th magnitude comet, a 20 cm telescope will see 10th, and a 40 cm should have no trouble with a 13th magnitude comet.

Magnitude Estimates

The brightness of the coma can be estimated using a variety of methods, the most common of which is the "In-Out" method designed by Sidgwick:

1. Study the coma until you become familiar with its "average" brightness, an easy process if the coma is of uniform brightness but rather difficult if there is a strong nuclear condensation.

2. Using a variable star chart or some source on which star magnitudes are listed, find a comparison star at approximately the same altitude as the comet.

3. Defocus this star to the size of the in-focus coma.

4. Compare the star's out-of-focus brightness with that of the coma.

5. Repeat the last three steps with a second star, or more if needed, until an interpolation can be made.

Coma Size

A comet magnitude estimate becomes more useful if an estimate of the coma diameter is made at the same time. An observer seeing a 3 minute of arc coma, for example, will estimate much brighter than another observer who sees only a 1 arc-minute coma at the same time. The simplest way of estimating coma size is to draw the coma with the embedded and surrounding field stars and then compare the drawing to an atlas, using its scale to determine the size.

Degree of Condensation

A nightly measurement of a comet's degree of condensation is a good way of studying its changing behavior. A comet undergoing an outburst of dust from its nucleus might begin its display by showing almost overnight the development of an increased condensation. Use an integer scale from 0 to 9, where 0 means a diffuse coma with absolutely uniform brightness, 3 means a diffuse coma with gradually increasing brightness toward the centre, 6 involves a definite central condensation, and 9 refers to an almost stellar image.

Tail

Because of the changing Earth-Sun-comet geometry, as well as because of changing activity in a comet, the length and position angle of a tail should be measured. A rough way to measure the length of tail is to sketch it and compare with a detailed atlas, as with the coma. Observers can also measure the position angle using an atlas and a protractor.

Comet Hunting

To ensure a continuing supply of new comets, an ambitious observer really needs to keep only three things in mind:

1. Keep the covers off the telescope and the eye affixed to the eyepiece. The more time spent hunting for comets, the greater the chance for a discovery.

2. Know what a comet looks like. This means observing every known comet you can find, following the returning periodic comets, and keeping in touch with new discoveries.

3. Know what a comet doesn't look like. Observe all the Messiers and as many other deep sky objects as the telescope can locate. Know the territory and what to avoid; M78 and the Cone Nebula exemplify what Leslie Peltier called "comet masqueraders".

Search Procedure

Although comets may appear at any time, they are usually found within 90 degrees of the Sun. A good area to search is in the evening western sky during the week after full moon, and in the morning eastern sky before dawn around new moon. Although comet hunters differ in their approaches to searching, one way is to use an altazimuth mount and make horizontal sweeps. In the western sky, begin near the end of twilight at the horizon, sweep across, then return to the point of origin, move upward about half a field of view and sweep again, etc. In the morning reverse the process.

If you are sure you have discovered a comet, follow the procedure on page 6. For more information on comet observing and hunting, read *Observe Comets* by Stephen J. Edberg and David H. Levy (Astronomical League, Washington, D.C., 1985).

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Editor's Note: In 1980 David Levy was awarded the Chant Medal of The Royal Astronomical Society of Canada in recognition of his many contributions to observations and education in astronomy. More recently he was the co-discoverer of Comet Levy-Rudenko 1984t, and the discoverer of Comet Levy 1987a, Comet Levy 1987y, and Comet Levy 1988e. In 1988, asteroid #3673 was named Levy in his honour, making him the first Canadian amateur astronomer to be so recognized.

INTERPLANETARY DUST

Outside of the astronomical community it is not generally realized that the inner solar system contains a vast cloud of dust. The particles in this cloud are concentrated near the plane of the ecliptic and toward the Sun, their spatial particle density in the ecliptic falling off somewhat more rapidly than the reciprocal of their distance from the Sun. Measurements from spacecraft indicate that the cloud extends well beyond the orbit of Mars, but that it is negligible in the vicinity of Jupiter's orbit and beyond. In 1983, *IRAS*, the pioneering Infrared Astronomical Satellite, discovered that there is an extra concentration of dust in the asteroid region, in the form of a ring or torus centred on the Sun. Aside from this overall structure, the cloud is quite uniform both spatially and temporally.

The particles composing the cloud have a continuum of sizes, from pebble-sized clumps down to specks with diameters comparable to the wavelength of visible light and smaller. The smaller particles are the more numerous, although the mass distribution appears to peak near 10^{-8} kg, corresponding to a particle diameter of a few tenths of a millimetre. The total mass of the cloud is small, amounting to perhaps 10^{-14} of the mass of the solar system. It is as if the moons of Mars had been pulverized and spread throughout the inner solar system.

Like the planetary system, the interplanetary dust cloud is not static. Its particles generally move in orbits about the Sun. In addition, the particles undergo continual fragmentation due to collisions, sputtering associated with bombardment by the solar wind, electrostatic bursting, and sublimation. This progression toward smaller and smaller sizes is of crucial significance for the cloud, since particles with diameters appreciably less than a tenth of a millimetre have a sufficiently large surface-to-volume ratio that the pressure of the Sun's radiation has a significant effect upon their motion. Their orbits become non-Keplerian and many particles are lost as they spiral inward toward the Sun (the Poynting–Robertson effect). During a total solar eclipse in 1983, instruments carried by a balloon detected a ring-like concentration of dust only a couple of solar diameters from the Sun. Its inner edge apparently marks the point at which the Sun's heat vaporizes the infalling particles. The resulting tiny gas molecules, like the smallest particles of dust, are blown out of the solar system by the dominant radiation pressure and interactions with the solar wind.

Because of the above-mentioned influences on the sizes and motions of the dust particles, the estimated mean life of a cloud particle is about 10^5 years. Since this is much less than the age of the solar system, it is obvious that the cloud must be in a dynamic equilibrium. Part of the tail of a bright comet is due to significant quantities of dust ejected from its nucleus, and it is generally assumed that comets provide the main supply of new dust to the cloud. Since comet nuclei are believed to consist of the undifferentiated matter from which the solar system formed, the dust of the interplanetary cloud is most likely composed of this same low-density, fragile, primitive material. Collisions of asteroids may also provide dust, but the extent of this possible contribution is unknown.

To an observer on Earth the most noticeable aspect of the dust cloud is meteors – larger particles of the cloud which encounter Earth and vaporize in its upper atmosphere. In addition, sunlight scattered by the dust cloud appears as a faint glow in the vicinity of the ecliptic. This glow is brightest toward the Sun, is due primarily to particles having diameters between a few micrometres and a millimetre, and is referred to as the *zodiacal light*. A slight brightening in the sky opposite the Sun, called the *Gegenschein* (German for "counter-glow"), is due to a phase effect (analogous to the full moon), and also possibly to a concentration of dust at the L3 Lagrangian point of the Earth-Sun system. As astronomical objects, the zodiacal light and Gegenschein are unusual in that they can be seen only with the unaided eye. Both are invisible in binoculars or a telescope.

The Zodiacal Light

Nearly a millenium ago the Persian astronomer-poet Omar Khayyam referred to the zodiacal light in the second quatrain of his *Rubaiyat*. As translated by the poet Edward FitzGerald, we have the haunting lines: "Dreaming when Dawn's Left Hand was in the Sky", and "Before the phantom of False morning died".

When conditions are favorable, the zodiacal light is indeed a mysterious and beautiful sight. It is best seen after the end of evening twilight and before the beginning of morning twilight (see page 66). Because the zodiacal light is brightest nearest the Sun, it is best seen when the ecliptic is at a steep angle relative to the horizon. In the tropics this is always the case and the short duration of twilight is an added advantage. At mid-northern latitudes the optimum geometry occurs in the evening western sky in February and March, and in the morning eastern sky in October. The zodiacal light appears as a huge, softly radiant pyramid of white light with its base near the horizon and its axis centered on the zodiac. In its brightest parts it exceeds the luminance of the central Milky Way.

Despite its brightness, many people have not seen the zodiacal light. As mentioned above, certain times of night and times of year are more favorable than others. In addition, moonlight, haze, or light pollution rule out any chance of seeing this phenomenon. Even with a dark, transparent sky the inexperienced observer may confuse the zodiacal light with twilight and thus ignore it, or he may not notice it because he is expecting a much smaller object.

The Gegenschein

Photometric measurements indicate that the zodiacal light extends all around the zodiac with a shallow minimum in brightness some 120° to 150° from the Sun; nevertheless, this "zodiacal band" or "light bridge" is exceedingly faint and hence rarely visible. However, the slight brightening in the vicinity of the anti-solar point can be seen under the right conditions.

The Gegenschein is very faint. The slightest haze, moonlight, bright nearby stars, planets, or light pollution will hide it completely. Most observers, including experienced ones, have not seen it. It is a ghostly apparition best seen near midnight and, in mid-northern latitudes, in the fall or winter when the anti-solar point is nearest the zenith. To avoid interference from bright stars or the Milky Way, observations should be restricted to the periods late September to early November, and late January to early February when the Gegenschein is in Pisces and Cancer respectively. It appears as a faint yet distinct, somewhat elliptical glow perhaps 10° in diameter. The luminance of the Gegenschein is about 10^{-4} cd/m^2, some ten orders of magnitude dimmer than the brightest light the human eye can tolerate. (RLB)

STARS

CONSTELLATIONS

Nominative & Pronunciation	Genitive & Pronunciation	Abbr.	Meaning
Andromeda, ăn-drŏm'ē-dȧ	Andromedae, ăn-drŏm'ē-dē'	And	Daughter of Cassiopeia
Antlia, ănt'lĭ-ȧ	Antliae, ănt'lē-ē'	Ant	The Air Pump
Apus, ā'pŭs	Apodis, ăp'ă-dĭs	Aps	Bird of Paradise
Aquarius, ȧ-kwâr'ē-ŭs	Aquarii, ȧ-kwâr'ē-ī'	Aqr	The Water-bearer
Aquila, ȧ-kwĭl'ȧ	Aquilae, ȧ-kwĭl'ē	Aql	The Eagle
Ara, ā'rȧ	Arae, ā'rē	Ara	The Altar
Aries, âr'ēz	Arietis, ȧ-rī'ĕ-tĭs	Ari	The Ram
Auriga, ô-rī'gȧ	Aurigae, ô-rī'jē	Aur	The Charioteer
Bootes, bō-ō'tēz	Bootis, bō-ō'tĭs	Boo	The Herdsman
Caelum, sē'lŭm	Caeli, sē'lī	Cae	The Chisel
Camelopardalis kȧ-mĕl'ō-pȧr'dȧ-lĭs	Camelopardalis kȧ-mĕl'ō-pȧr'dȧ-lĭs	Cam	The Giraffe
Cancer, kăn'sēr	Cancri, kăn'krē	Cnc	The Crab
Canes Venatici kā'nēz vē-năt'ĭ-sī	Canum Venaticorum kā'nŭm vē-năt'ĭkôr'ŭm	CVn	The Hunting Dogs
Canis Major, kā'nĭs mā'jēr	Canis Majoris, kā'nĭs mȧ-jôr'ĭs	CMa	The Big Dog
Canis Minor, kā'nĭs mī'nēr	Canis Minoris, kȧ'nĭs mī-nôr'ĭs	CMi	The Little Dog
Capricornus, kăp'rĭ-kôr'nŭs	Capricorni, kăp'rĭ-kôr'nī	Cap	The Horned Goat
Carina, kȧ-rī'nȧ	Carinae, kȧ-rī'nē	Car	The Keel
Cassiopeia, kăs'ĭ-ō-pē'yȧ	Cassiopeiae, kăs'ĭ-ō-pē'yē	Cas	The Queen
Centaurus, sĕn-tôr'ŭs	Centauri, sĕn-tôr'ī	Cen	The Centaur
Cepheus, sē'fē-ŭs	Cephei, sē'fē-ī'	Cep	The King
Cetus, sē'tŭs	Ceti, sē'tī	Cet	The Whale
Chamaeleon, kȧ-mē'lē-ŭn	Chamaeleontis, kȧ-mē'lē-ŏn'tĭs	Cha	The Chameleon
Circinus, sûr'sĭ-nŭs	Circini, sûr'sĭ-nī'	Cir	The Compasses
Columba, kō-lŭm'bȧ	Columbae, kō-lŭm'bē	Col	The Dove
Coma Berenices kō'mȧ bĕr'ĕ-nī'sēz	Comae Berenices kō'mē bĕr'ĕ-nī'sēz	Com	Berenice's Hair
Corona Australis kō-rō'nȧ ôs-trā'lĭs	Coronae Australis kō-rō'nē ôs-trā'lĭs	CrA	The Southern Crown
Corona Borealis kō-rō'nȧ bôr'ē-ăl'ĭs	Coronae Borealis kō-rō'nē bôr'ē-ăl'ĭs	CrB	The Northern Crown
Corvus, kôr'vŭs	Corvi, kôr'vī	Crv	The Crow
Crater, krā'tēr	Crateris, krā-têr'ĭs	Crt	The Cup
Crux, krŭks	Crucis, kro͞o'sĭs	Cru	The Cross
Cygnus, sĭg'nŭs	Cygni, sĭg'nī	Cyg	The Swan
Delphinus, dĕl-fī'nŭs	Delphini, dĕl-fī'nī	Del	The Dolphin
Dorado, dō-rȧ'dō	Doradus, dō-rȧ'dŭs	Dor	The Goldfish
Draco, drā'kō	Draconis, drā-kō'nĭs	Dra	The Dragon
Equuleus, ē-kwo͞o'lē-ŭs	Equulei, ē-kwo͞o'lē-ī'	Equ	The Little Horse
Eridanus, ē-rĭd'ȧ-nŭs	Eridani, ē-rĭd'ȧ-nī'	Eri	A River
Fornax, fôr'năks	Fornacis, fôr-nās'ĭs	For	The Furnace
Gemini, jĕm'ĭ-nī	Geminorum, jĕm'ĭ-nôr'ŭm	Gem	The Twins
Grus, grŭs	Gruis, gro͞o'ĭs	Gru	The Crane (bird)
Hercules, hûr'kū-lēz	Herculis, hûr'kū-lĭs	Her	The Son of Zeus
Horologium, hŏr'ō-lō'jĭ-ŭm	Horologii, hŏr'ō-lō'jĭ-ī	Hor	The Clock
Hydra, hī'drȧ	Hydrae, hī'drē	Hya	The Water Snake (♀)
Hydrus, hī'drŭs	Hydri, hī'drī	Hyi	The Water Snake (♂)
Indus, ĭn'dŭs	Indi, ĭn'dī	Ind	The Indian
Lacerta, lȧ-sûr'tȧ	Lacertae, lȧ-sûr'tē	Lac	The Lizard

Nominative & Pronunciation	Genitive & Pronunciation	Abbr.	Meaning
Leo, lē'ō	Leonis, lē-ō'nĭs	Leo	The Lion
Leo Minor, lē'ō mī'nẽr	Leonis Minoris, lē-ō'nĭs mī-nôr'ĭs	LMi	The Little Lion
Lepus, lē'pŭs	Leporis, lĕp'ôr-ĭs	Lep	The Hare
Libra, lē'brȧ	Librae, lē'brē	Lib	The Balance
Lupus, lo͞o'pŭs	Lupi, lo͞o'pī	Lup	The Wolf
Lynx, lĭnks	Lyncis, lĭn'sĭs	Lyn	The Lynx
Lyra, lī'rȧ	Lyrae, lī'rē	Lyr	The Lyre
Mensa, mĕn'sȧ	Mensae, mĕn'sē	Men	Table Mountain
Microscopium mī'krō-skō'pē-ŭm	Microscopii mī'krō-skō'pē-ī'	Mic	The Microscope
Monoceros, mō-nŏs'ẽr-ŏs	Monocerotis, mō-nŏs'ẽr-ō'tĭs	Mon	The Unicorn
Musca, mŭs'kȧ	Muscae, mŭs'ē	Mus	The Fly
Norma, nôr'mȧ	Normae, nôr'mē	Nor	The Square
Octans, ŏk'tănz	Octantis, ŏk-tăn'tĭs	Oct	The Octant
Ophiuchus, ō'fē-ū'kŭs	Ophiuchi, ō'fē-ū'kī	Oph	The Serpent-bearer
Orion, ō-rī'ŏn	Orionis, ôr'ē-ō'nĭs	Ori	The Hunter
Pavo, pā'vō	Pavonis, pȧ-vō'nĭs	Pav	The Peacock
Pegasus, pĕg'ȧ-sŭs	Pegasi, pĕg'ȧ-sī	Peg	The Winged Horse
Perseus, pûr'sē-ŭs	Persei, pûr'sē-ī'	Per	Rescuer of Andromeda
Phoenix, fē'nĭks	Phoenicis, fē-nī'cĭs	Phe	The Phoenix
Pictor, pĭk'tẽr	Pictoris, pĭk-tôr'ĭs	Pic	The Painter
Pisces, pī'sēz	Piscium, pĭsh'ē-ŭm	Psc	The Fishes
Piscis Austrinus pī'sĭs ôs-trī'nŭs	Piscis Austrini pī'sĭs ôs-trī'nī	PsA	The Southern Fish
Puppis, pŭp'ĭs	Puppis, pŭp'ĭs	Pup	The Stern
Pyxis, pĭk'sĭs	Pyxidis, pĭk'sĭ-dĭs	Pyx	The Compass
Reticulum, rē-tĭk'ū-lŭm	Reticuli, rē-tĭk'ū-lī	Ret	The Reticle
Sagitta, sȧ-jĭt'ȧ	Sagittae, sȧ-jĭt'ē	Sge	The Arrow
Sagittarius, săj'ĭ-târ'ē-ŭs	Sagittarii, săj'ĭ-târ'ē-ī'	Sgr	The Archer
Scorpius, skôr'pē-ŭs	Scorpii, skôr'pē-ī	Sco	The Scorpion
Sculptor, skŭlp'tẽr	Sculptoris, skŭlp-tôr'ĭs	Scl	The Sculptor
Scutum, skū'tŭm	Scuti, sko͞o'tī	Sct	The Shield
Serpens, sûr'pĕnz	Serpentis, sûr-pĕn'tĭs	Ser	The Serpent
Sextans, sĕks'tănz	Sextantis, sĕks-tăn'tĭs	Sex	The Sextant
Taurus, tôr'ŭs	Tauri, tôr'ī	Tau	The Bull
Telescopium tĕl'ȧ-skō'pē-ŭm	Telescopii, tĕl'ȧ-skō'pē-ī	Tel	The Telescope
Triangulum, trī-ăng'gū-lŭm	Trianguli, trī-ăng'gū-lī'	Tri	The Triangle
Triangulum Australe trī-ăng'gū-lŭm ôs-trā'lē	Trianguli Australis trī-ăng'gū-lī' ôs-trā'lĭs	TrA	The Southern Triangle
Tucana, to͞o-kăn'ȧ	Tucanae, to͞o-kăn'ē	Tuc	The Toucan
Ursa Major, ûr'sȧ mā'jẽr	Ursae Majoris, ûr'sē mȧ-jôr'ĭs	UMa	The Great Bear
Ursa Minor, ûr'sȧ mī'nẽr	Ursae Minoris, ûr'sē mī-nôr'ĭs	UMi	The Little Bear
Vela, vē'lȧ	Velorum, vē-lôr'ŭm	Vel	The Sails
Virgo, vûr'gō	Virginis, vûr'jĭn-ĭs	Vir	The Maiden
Volans, vō'lănz	Volantis, vō-lăn'tĭs	Vol	The Flying Fish
Vulpecula, vŭl-pĕk'ū-lȧ	Vulpeculae, vŭl-pĕk'ū-lē'	Vul	The Fox

ā dāte; ă tăp; â câre; ȧ ȧsk; ē wē; ĕ mĕt; ẽ makẽr; ī īce; ĭ bĭt; ō gō; ŏ hŏt; ô ôrb; o͞o mo͞on; ū ūnite; ŭ ŭp; û ûrn.

In terms of area (based on the official IAU boundaries), of the 88 constellations the three largest are Hydra (1303 square degrees), Virgo (1294), and Ursa Major (1280); the three smallest: Sagitta (80), Equuleus (72), and Crux (68). A complete list of the areas of the constellations appears in the 1972 edition of *The Handbook of the British Astronomical Association*, and was reproduced in the June 1976 issue of *Sky and Telescope* (p. 408).

FINDING LIST OF SOME NAMED STARS

Name	Con.	R.A.	Name	Con.	R.A.
Acamar, ā'kȧ-mȧr	θ Eri	02	Gienah, jē'nȧ	γ Crv	12
Achernar, ā'kēr-nȧr	α Eri	01	Hadar, hăd'ȧr	β Cen	14
Acrux, ā'krŭks	α Cru	12	Hamal, hăm'ăl	α Ari	02
Adara, ȧ-dā'rȧ	ε CMa	06	Kaus Australis,	ε Sgr	18
Al Na'ir, ăl-nâr'	α Gru	22	kôs ôs-trā'lĭs		
Albireo, ăl-bĭr'ē-ō	β Cyg	19	Kochab, kō'kăb	β UMi	14
Alcor, ăl-kôr'	80 UMa	13	Markab, mȧr'kăb	α Peg	23
Alcyone, ăl-sī'ō-nē	η Tau	03	Megrez, mē'grĕz	δ UMa	12
Aldebaran,	α Tau	04	Menkar, mĕn'kȧr	α Cet	03
ăl-dĕb'ȧ-rȧn			Menkent, mĕn'kĕnt	θ Cen	14
Alderamin,	α Cep	21	Merak, mē'răk	β UMa	11
ăl-dĕr'ȧ-mĭn			Merope, mĕr'ō-pē	23 Tau	03
Algeiba, ăl-jē'bȧ	γ Leo	10	Miaplacidus,	β Car	09
Algenib, ăl-jē'nĭb	γ Peg	00	mī'ȧ-plăs'ĭ-dŭs		
Algol, ăl'gŏl	β Per	03	Mintaka, mĭn-tȧ'kȧ	δ Ori	05
Alioth, ăl'ĭ-ŏth	ε UMa	12	Mira, mī'rȧ	o Cet	02
Alkaid, ăl-kād'	η UMa	13	Mirach, mī'răk	β And	01
Almach, ăl'măk	γ And	02	Mirfak, mĭr'făk	α Per	03
Alnilam, ăl-nī'lăm	ε Ori	05	Mizar, mī'zȧr	ζ UMa	13
Alphard, ăl'fȧrd	α Hya	09	Nunki, nŭn'kē	σ Sgr	18
Alphecca, ăl-fĕk'ȧ	α CrB	15	Peacock, pē'kŏk'	α Pav	20
Alpheratz, ăl-fē'răts	α And	00	Phecda, fĕk'dȧ	γ UMa	11
Altair, ăl-târ'	α Aql	19	Polaris, pō-lâr'ĭs	α UMi	02
Ankaa, ăn'kȧ	α Phe	00	Pollux, pŏl'ŭks	β Gem	07
Antares, ăn-tā'rēs	α Sco	16	Procyon, prō'sĭ-ŏn	α CMi	07
Arcturus, ȧrk-tū'rŭs	α Boo	14	Pulcherrima,	ε Boo	14
Atria, ā'trĭ-ȧ	α TrA	16	pŭl-kĕr'ĭmȧ		
Avior, ă-vĭ-ôr'	ε Car	08	Ras-Algethi,	α Her	17
Bellatrix, bĕ-lā'trĭks	γ Ori	05	rȧs'ăl-jē'thē		
Betelgeuse, bĕt'ĕl-jūz	α Ori	05	Rasalhague,	α Oph	17
			rȧs'ăl-hā'gwē		
Canopus, kȧ-nō'pŭs	αCar	06	Regulus, rĕg'ū-lŭs	α Leo	10
Capella, kȧ-pĕl'ȧ	α Aur	05	Rigel, rī'jĕl	β Ori	05
Caph, kăf	β Cas	00	Rigil Kentaurus,	α Cen	14
Castor, kȧs'tēr	α Gem	07	rī'jĭl kĕn-tô'rŭs		
Cor Caroli, kôr kăr'ō-lī	α CVn	12	Sabik, sā'bĭk	η Oph	17
Deneb, dĕn'ĕb	α Cyg	20	Scheat, shē'ăt	β Peg	23
Denebola, dĕ-nĕb'ō-lȧ	β Leo	11	Schedar, shĕd'ȧr	α Cas	00
Diphda, dĭf'dȧ	β Cet	00	Shaula, shô'lȧ	λ Sco	17
Dubhe, dŭb'ē	α UMa	11	Sirius, sĭr'ĭ-ŭs	α CMa	06
Elnath, ĕl'năth	β Tau	05	Spica, spī'kȧ	α Vir	13
Eltanin, ĕl-tā'nĭn	γ Dra	17	Suhail, sŭ-hāl'	λ Vel	09
Enif, ĕn'ĭf	ε Peg	21	Thuban, tho͞o'bȧn	α Dra	14
Fomalhaut, fō'măl-ôt	α PsA	22	Vega, vē'gȧ	α Lyr	18
Gacrux, gȧ'krŭks	γ Cru	12	Zubenelgenubi,	α Lib	14
Gemma, jĕm'ȧ	α CrB	15	zo͞o-bĕn'ĕl-jĕ-nū'bē		

Key to pronunciation on p. 167.

THE BRIGHTEST STARS

By Robert F. Garrison

The 314 stars brighter than apparent magnitude 3.55 in both hemispheres are listed with 1989.5 positions. A few errors have been corrected this year and several types have been changed because of better available data. The spectral classification column, especially, is therefore a valuable resource for both professionals and amateurs.

Star. If the star is a visual double, the letter A indicates that the data are for the brighter component. The brightness and separation of the second component (B) are given in the last column. Sometimes the double is too close to be conveniently resolved and the data refer to the combined light,(AB); in interpreting such data the magnitudes of the two components must be considered.

Visual Magnitude (V). These magnitudes are based on photoelectric observations. The V filter is yellow and corresponds roughly to the response of the eye. The photometric system is that of Johnson and Morgan in *Ap. J.*, vol. 117, p. 313, 1953. It is as likely as not that the true magnitude is within 0.03 mag. of the quoted figure, on the average. Variable stars are indicated with a "v". The type of variability, range and period are given in the remarks.

Colour index (B–V). The blue magnitude, B, is the brightness of a star as observed photoelectrically through a blue filter. The difference B–V is therefore a measure of the colour of a star. There is a close relation between B–V and the spectral type, but some of the stars are reddened by interstellar dust. The probable error of a value of B–V is about 0.02 mag. at most.

Spectral Classification. A "temperature" type (O, B, A, F, G, K, M) is given first, followed by a finer subtype (0–9) and a "luminosity" class (Roman numerals I–V, with an "a" or "b" added occasionally to indicate slightly brighter or fainter). The sequences are in the sense that the O stars are hottest, M stars are coolest, Ia stars are the most luminous supergiants, III stars are giants and V stars are the most numerous; the V's are known as dwarfs or main-sequence stars. Other symbols used in this column are: "p" for peculiar; "e" for hydrogen emission; "m" for strong metallic lines; "f" for broad, non-hydrogen emission in hot stars; and "n" or "nn" for unusually broad lines (= rotation). The table now contains the best types available, either from the literature or from my own plates.

Parallax and Proper Motion. From "The Bright Star Catalogue" by Dorrit Hoffleit and Carlos Jaschek, *Yale University Press*, 1982. Parallaxes in which the decimal point is preceded by the letter "D" are "dynamical parallaxes" (i.e. determined through Kepler's laws rather than by trigonometric measurement). Proper motions given are the absolute value of the vector resultant from the individual-coordinate proper motions given in "The Bright Star Catalogue".

Absolute Visual Magnitude and Distance in Light-Years. If the parallax is greater than 0.″05 the distance and absolute magnitude correspond to this trigonometric parallax. Otherwise a generally more accurate absolute magnitude and distance were obtained from a new (by the author, unpublished) calibration of the spectral classification; distances determined in this way are called "spectroscopic parallaxes." In a few cases (the Hyades, Orion, and Scorpius clusters), the cluster distances are given; these are indicated by parentheses. The effect of the absorption of light was corrected by comparing the spectral classification and the B–V, using an intrinsic-colour calibration by the author (unpublished).

Radial Velocity. From "The Bright Star Catalogue" referenced above. The symbol "V" indicates variable velocity and an orbit is usually not known. On the other hand, "SB" indicates a spectroscopic binary, which is an unresolved system whose duplicity is revealed by periodic oscillations of the lines in its spectrum and an orbit is generally known. If the lines of both stars are detectable, the symbol "SB2" is used. "+" indicates motion away from, "–" towards, the observer.

Remarks. These contain data on companions and variability as well as notes on the spectra. Traditional names have been selected from "The Bright Star Catalogue". The Navigation stars are in bold type.

In preparing the table, the aid of Brian Beattie is gratefully acknowledged.

	Right Ascension (Hours, Minutes)	Declination (Degrees, Minutes)	Visual Magnitude	Colour Index	Spectral Classification	Parallax	Absolute Magnitude	Distance (Light Years)	Proper Motion	Radial Velocity		
Star Name	R.A. 1989.5	Dec	V	B−V	MK Type	$\pi('')$	M(V)	D(ly)	$\mu('')$	RV(km/s)	Remarks	
Sun	— —	— —	−26.73	0.63	G2 V	— —	+4.7	8 lm	— —	varies		**Sun**
α And	00 07.8	+29 02	2.1v	−0.11	B9p IV:(HgMn)	0.032	−0.4	100	0.209	−12 SB		Alpheratz
β Cas	00 08.6	+59 06	2.3v	0.34	F2 III	0.072	2.0	45	0.555	+11 SB	var: 2.25–2.31, 0.10d	Caph
γ Peg	00 12.7	+15 08	2.8v	−0.23	B2 IV	0.000	−3.1	490	0.008	+4 SB	var: 2.80–2.87, 0.15d	Algenib
β Hyi	00 25.2	−77 19	2.80	0.62	G1 IV	0.159	3.8	20	2.255	+23		
α Phe	00 25.8	−42 22	2.39	1.09	K0 IIIb	0.039	0.7	62	0.442	+75 SB		Ankaa
δ And A	00 38.8	+30 48	3.27	1.28	K3 III	0.028	−0.3	170	0.161	−7 SB		
α Cas	00 39.9	+56 29	2.23	1.17	K0 IIIa	0.016	−0.8	110	0.058	−4 V?		Shedir
β Cet	00 43.1	−18 03	2.04	1.02	K0 III	0.061	0.3	53	0.234	+13		Diphda
η Cas A	00 48.5	+57 46	3.44	0.57	G0 V	0.176	4.7	18	1.218	+9 SB	B: 7.51, K4 Ve, 12″	
γ Cas	00 56.1	+60 40	2.5v	−0.15	B0 IVnpe(shell)	0.016	−4.7	730	0.026	−7 SB	var: 1.6–3.0; B: 8.8, 2″	
β Phe AB	01 05.6	−46 46	3.31	0.89	G8 III	0.021	0.3	130	0.030	−1	AB similar in light, spectrum, 1″	
η Cet	01 08.1	−10 14	3.45	1.16	K1.5 III CN1	0.041	0.1	140	0.250	+12		
β And	01 09.1	+35 34	2.06	1.58	M0 IIIa	0.049	−1.6	170	0.210	+3 V		Mirach
δ Cas	01 25.1	+60 11	2.7v	0.13	A5 IV	0.037	1.4	59	0.303	+7 SB	ecl.? 2.68–2.76, 759d	Ruchbah

Star Name	R.A. 1989.5	Dec	V	B−V	MK Type	$\pi('')$	M(V)	D(ly)	$\mu('')$	RV(km/s)	Remarks
γ Phe	01 27.9	−43 22	3.4v	1.57	K7 IIIa	0.000	−1.4	280	0.204	+26 SB	var: 3.39−3.49
α Eri	01 37.3	−57 17	0.46	−0.16	B3 Vnp (shell)	0.026	−1.3	69	0.108	+16 V	**Achernar**
τ Cet	01 43.6	−16 00	3.50	0.72	G8 V	0.287	5.8	11	1.921	−16	
α Tri	01 52.5	+29 32	3.41	0.49	F6 IV	0.057	2.6	53	0.230	−13 SB	Metallah
ϵ Cas	01 53.6	+63 37	3.38	−0.15	B3 IV:p(shell)	0.010	−2.4	440	0.036	−8 V	Segin
β Ari	01 54.1	+20 45	2.64	0.13	A4 V	0.074	1.8	44	0.145	−2 SB	Sharatan
α Hyi	01 58.5	−61 37	2.86	0.28	F0 III−IVn	0.048	1.7	55	0.271	+1 V	
γ And A	02 03.3	+42 17	2.26	1.37	K3 IIb	0.013	1.8	42	0.066	−12 SB	B: 5.4,B9V,10″;C: 6.2,A0V;BC: 1″ Almaak
α Ari	02 06.6	+23 25	2.00	1.15	K2 IIIab	0.049	0.1	78	0.238	−14 SB	Calcium weak? Hamal
β Tri	02 08.9	+34 56	3.00	0.14	A5 IV	0.022	1.3	71	0.153	+10 SB2	
o Cet A	02 18.8	− 3 02	2−10v	1.42	M5.5−9 IIIe	0.024	−0.5	200	0.232	+64 V	LPV, 2−10; B: VZ Cet,9.5v,Bpe,1″ Mira
α UMi A	02 20.7	+89 13	2.0v	0.60	F5−8 Ib	0.007	−5.1	820	0.046	−17 SB	Cep 1.9−2.1,4d; B: 8.2,F3 V,18″ Polaris
γ Cet AB	02 42.8	+ 3 12	3.47	0.09	A2 Va	0.052	1.4	63	0.203	−5 V	A: 3.57; B: 6.23, 3″ Kaffaljidhma
θ Eri A	02 57.9	−40 21	3.42	0.14	A5 IV	0.035	1.3	93	0.065	+12 SB2	B: 4.35, A1 Va, 8″ Acamar
α Cet	03 01.7	+ 4 03	2.53	1.64	M1.5 IIIa	0.009	−1.5	200	0.075	−26	Menkar
γ Per	03 04.0	+53 28	2.93	0.70	G8 III + A2 V	0.016	0.3	100	0.002	+3 SB	composite spectrum
ρ Per	03 04.5	+38 48	3.4v	1.65	M4 II	0.011	−2.6	500	0.165	+28	semi−regular var: 3.3−4.0
β Per	03 07.5	+40 55	2.1v	−0.05	B8 V + F:	0.045	0.1	75	0.004	+4 SB	ecl: 2.12−3.4,2.87d; composite Algol
α Per	03 23.6	+49 49	1.79	0.48	F5 Ib	0.016	−5.1	630	0.033	−2 V	in cluster Mirphak
δ Per	03 42.2	+47 45	3.01	−0.13	B5 IIIn	0.016	−2.2	340	0.042	+4 SB	
δ Eri	03 42.7	− 9 48	3.54	0.92	K0 IV	0.113	3.8	29	0.752	−6	
η Tau	03 46.9	+24 04	2.87	−0.09	B7 IIIn	0.008	−1.5	450	0.048	+10 V?	in Pleiades Alcyone
γ Hyi	03 47.4	−74 16	3.24	1.62	M2 III	0.005	−1.1	230	0.128	+16	
ζ Per A	03 53.5	+31 51	2.85	0.12	B1 Ib	0.010	−5.8	1100	0.011	+20 SB	B: 9.16, B8 V, 13″
ϵ Per A	03 57.1	+39 59	2.89	−0.18	B0.5 IV	0.009	−4.2	740	0.029	+1 SB2	B: 7.39, B9.5 V, 9″
γ Eri	03 57.5	−13 32	2.95	1.59	M1 IIIb	0.010	−0.7	170	0.124	+62	Calcium, Chromium weak Zaurak
λ Tau A	04 00.1	+12 28	3.5v	−0.12	B3 V	0.002	−1.3	270	0.011	+18 SB2	ecl: 3.3−3.8, 3.95d; B: A4 IV
α Ret A	04 14.3	−62 30	3.35	0.91	G8 II−III	0.013	−0.9	230	0.068	+36 SB?	
ϵ Tau	04 28.1	+19 09	3.53	1.01	K1 III	0.020	0.2	(150)	0.114	+39	in Hyades Ain
θ^2 Tau	04 28.0	+15 51	3.40	0.18	A 7 III	0.029	1.1	(150)	0.105	+40 SB	in Hyades

Star Name	R.A. 1989.5 Dec		V	B−V	MK Type	$\pi('')$	M(V)	D(ly)	$\mu('')$	RV(km/s)	Remarks	
α Dor AB	04 33.8	−55 04	3.27	−0.10	A0p V:(Si)	0.018	0.0	190	0.051	+26	A: 3.8; B: 4.3, B9 IV, 0.2″	
α Tau A	04 35.3	+16 29	0.85	1.54	K5 III	0.054	−0.3	60	0.200	+54 SB	var: 0.75–0.95	**Aldebaran**
π^3 Ori	04 49.3	+ 6 57	3.19	0.45	F6 V	0.137	3.9	24	0.463	+24 SB2		Hassaleh
ι Aur	04 56.3	+33 09	2.69	1.53	K3 II	0.021	−2.0	240	0.018	+18	var?	
ϵ Aur A	05 01.2	+43 49	3.04	0.54	A9 Iae + B	0.007	−7.8	2800	0.004	−3 SB	ecl: 2.94–3.83, 9892d	Al Anz
ϵ Lep	05 05.0	−22 23	3.19	1.46	K4 III	0.011	−0.3	160	0.073	+1		
η Aur	05 05.8	+41 13	3.17	−0.18	B3 V	0.022	−1.3	250	0.073	+7 V?		Hoedus II
β Eri	05 07.3	− 5 06	2.79	0.13	A3 IVn	0.050	0.5	65	0.128	−9		Kursa
μ Lep	05 12.5	−16 13	3.3v	−0.11	B9p IV:(HgMn)	0.023	−0.2	150	0.043	+28	var: 2.97–3.36, 2d	
β Ori A	05 14.0	− 8 13	0.12	−0.03	B8 Iae	0.013	−8.1	(1400)	0.004	+21 SB	B: 7.6,B5 V,9″; C: 7.6; BC: 0.1″	**Rigel**
α Aur AB	05 15.9	+45 59	0.08	0.80	G6:III + G2:III	0.080	0.4	41	0.430	+30 SB	composite; A: 0.6; B: 1.1, 0.04″	**Capella**
η Ori AB	05 23.9	− 2 24	3.4v	−0.17	B1 IV + B	0.007	−3.8	(1400)	0.003	+20 SB2	ecl: 3.14–3.35,8d; A: 3.6; B: 5.0, 1.6″	
γ Ori	05 24.6	+ 6 20	1.64	−0.22	B2 III	0.029	−3.9	(1400)	0.018	+18 SB?		Bellatrix
β Tau	05 25.7	+28 36	1.65	−0.13	B7 III	0.028	−1.5	140	0.178	+9 V		Alnath
β Lep A	05 27.8	−20 46	2.84	0.82	G5 II	0.020	−2.1	320	0.090	−14	B: 7.4, 2.6″	
δ Ori A	05 31.5	− 0 18	2.23	−0.22	O9.5 II	0.014	−5.8	(1400)	0.002	+16 SB	ecl: 1.94–2.13,5.7d	Mintaka
α Lep	05 32.3	−17 50	2.58	0.21	F0 Ib	0.007	−5.1	1090	0.006	+24		Arneb
β Dor	05 33.5	−62 30	3.8v	0.82	F7–G2 Ib	0.012	−5.1	820	0.007	+7 V	Cepheid: 3.46–4.08, 9.8d	
λ Ori A	05 34.6	+ 9 56	3.54	−0.18	O8 III	0.007	−5.8	2200	0.006	+34	B: 5.61, B0 V, 4″	Meissa
ι Ori A	05 34.9	− 5 55	2.77	−0.24	O9 III	0.025	−5.6	(1400)	0.005	+22 SB2	B: 7.3, B7 IIIp(He wk), 11″	Nair al Saif
ϵ Ori	05 35.7	− 1 12	1.70	−0.19	B0 Ia	0.000	−7.0	(1400)	0.004	+26 SB		Alnilam
ζ Tau	05 37.0	+21 08	3.0v	−0.19	B2 IIIpe(shell)	0.008	−4.0	830	0.023	+20 SB	var: 2.90–3.03; B: 5.0, 0.007″	
α Col A	05 39.3	−34 05	2.64	−0.12	B7 IV	0.001	−1.1	180	0.026	+35 V?		Phaet
ζ Ori A	05 40.2	− 1 57	2.05	−0.21	O9.5 Ib	0.024	−6.2	(1400)	0.002	+18 SB	B: 4.2, B0 III, 2.4″	Alnitak
ζ Lep	05 46.5	−14 50	3.55	0.10	A2 Vann	0.049	1.0	97	0.023	+20 SB?		
κ Ori	05 47.3	− 9 40	2.06	−0.17	B0.5 Ia	0.015	−7.0	(1400)	0.006	+21 V?		Saiph
β Col	05 50.6	−35 46	3.12	1.16	K1.5 III	0.028	0.1	120	0.405	+89 V		Wezn
α Ori	05 54.6	+ 7 24	0.5v	1.85	M2 Iab	0.005	−7.2	(1400)	0.028	+21 SB	var: 0.4–1.3	**Betelgeuse**
β Aur	05 58.8	+44 57	1.90	0.03	A1 IV	0.041	0.7	55	0.055	−18 SB2	ecl: 1.93–2.02, 4d(=mags)	Menkalinan
θ Aur AB	05 59.0	+37 13	2.62	−0.08	A0p II:(Si)	0.022	0.0	110	0.097	+30 SB	B: 7.2, G2 V, 4″	

Star Name	R.A. 1989.5	Dec	V	B−V	MK Type	$\pi('')$	M(V)	D(ly)	$\mu('')$	RV(km/s)	Remarks	
η Gem	06 14.2	+22 31	3.3v	1.60	M3 III	0.014	−0.7	210	0.068	+19 SB	var: 3.3−3.9; B: 8.8, 1.6″	Propus
ζ CMa	06 19.9	−30 03	3.02	−0.19	B2.5 V	0.004	−1.6	260	0.006	+32 SB		Phurud
μ Gem	06 22.3	+22 31	2.9v	1.64	M3 IIIab	0.020	−1.1	190	0.125	+55	var: 2.76−3.02	Tejat Posterior
β CMa	06 22.2	−17 57	2.0v	−0.23	B1 II−III	0.019	−4.9	750	0.014	+34 SB	var: 1.93−2.00, 0.25d	Murzim
α Car	06 23.7	−52 41	−0.72	0.15	A9 II	0.028	−2.5	74	0.034	+21		**Canopus**
γ Gem	06 37.1	+16 25	1.93	0.00	A1 IVs	0.037	0.7	57	0.061	−13 SB		Alhena
ν Pup	06 37.4	−43 11	3.17	−0.11	B8 IIIn	— —	−1.2	240	0.010	+28 SB		
ϵ Gem	06 43.3	+25 09	2.98	1.40	G8 Ib	0.017	−1.2	940	0.016	+10 SB		Mebsuta
ξ Gem	06 44.7	+12 54	3.36	0.43	F5 IV	0.055	−4.0	59	0.224	+25 V?		Alzirr
α CMa A	06 44.7	−16 42	−1.46	0.00	A0mA1 Va	0.378	1.4	9	1.324	−8 SB	B: 8.5, WDA, 50y, 10″(1980)	**Sirius**
α Pic	06 48.1	−61 56	3.27	0.21	A6 Vn	0.052	2.1	63	0.275	+21		
τ Pup	06 49.7	−50 36	2.93	1.20	K1 III	— —	0.1	100	0.079	+36 SB		
ϵ CMa A	06 58.2	−28 57	1.50	−0.21	B2 II	D.001	−4.8	570	0.002	+27		**Adara**
σ CMa	07 01.3	−27 55	3.5v	1.73	K7 Ib	0.024	−4.0	830	0.008	+22	var: 3.43−3.49	
o^2 CMa	07 02.6	−23 49	3.02	−0.08	B3 Ia	— —	−6.3	2200	0.007	+48 SB		
δ CMa	07 08.0	−26 23	1.84	0.68	F8 Ia	0.000	−8.0	2600	0.008	+34 SB		Wezen
L_2 Pup	07 13.2	−44 37	2.6v	1.56	M5 IIIe	0.022	−1.3	200	0.346	+53 V?	Long Period Var: 2.6−6.2	HR2748
π Pup	07 16.8	−37 05	2.70	1.62	K3 Ib	0.032	−4.0	570	0.012	+16		
δ Gem AB	07 19.5	+22 00	3.53	0.34	F0 IV	0.061	2.2	53	0.029	+4 SB	B: 8.2, K3 V, 0.2″	Wasat
η CMa	07 23.7	−29 17	2.45	−0.08	B5 Ia	— —	−7.0	2500	0.008	+41 V		Aludra
β CMi	07 26.6	+ 8 19	2.90	−0.09	B8 V	0.019	0.1	110	0.065	+22 SB		Gomeisa
σ Pup A	07 28.9	−43 17	3.25	1.51	K5 III	0.020	−0.3	160	0.195	+88 SB	B: 8.6, G5: V, 22″	
α Gem A	07 33.9	+31 55	1.94	0.03	A1mA2 Va	0.067	1.2	49	0.199	+6 SB	AB: 2″ separation	Castor
α Gem B	07 34.0	+31 55	2.92	0.04	A2mA5 V:	0.067	1.4	49	0.199	−1 SB	BA: 2″ separation	Castor
α CMi A	07 38.8	+ 5 15	0.38	0.42	F5 IV−V	0.292	2.7	11	1.248	−3 SB	B: 10.3, 4″	**Procyon**
β Gem	07 44.7	+28 03	1.14	1.00	K0 IIIb	0.094	0.7	35	0.629	+3 V		**Pollux**
ξ Pup	07 48.9	−24 50	3.34	1.24	G6 Ia	0.003	−4.2	800	0.033	+3 SB		
χ Car	07 56.5	−52 57	3.47	−0.18	B3 IVp(note)	0.004	−2.4	470	0.042	+19 V	Si II strong	
ζ Pup	08 03.2	−39 58	2.25	−0.26	O5 Iafn	— —	−6.8	2000	0.033	−24 V?		Naos
ρ Pup	08 07.1	−24 16	2.8v	0.43	F2mF5 II:(var)	0.035	−2.0	280	0.100	+46 SB	delta Del spec; var: 2.68−2.78, 0.14d	

Star Name	R.A. 1989.5	Dec	V	B−V	MK Type	π(″)	M(V)	D(ly)	μ(″)	RV(km/s)	Remarks	
γ^2 Vel	08 09.2	−47 18	1.8v	−0.22	WC8 + O9 I:	0.017	−6.7	1500	0.007	+35 SB2	var: 1.6−1.8, 154s	Suhail al Muhlif
β Cnc	08 15.9	+ 9 13	3.52	1.48	K4 III	0.012	−0.2	160	0.068	+22		Altarf
ϵ Car	08 22.3	−59 29	1.86	1.28	K3:III + B2:V	— —	−0.1	79	0.030	+2	ecl? 3.1−3.4, 785d	Avior
o UMa A	08 29.4	+60 45	3.4v	0.84	G5 III	0.009	0.5	120	0.171	+20	var: 3.3−3.8, 358d	
δ Vel AB	08 44.4	−54 40	1.96	0.04	A1 Va	0.051	0.7	64	0.082	+ 2 V?	B: 5.0, 2″	
ϵ Hya ABC	08 46.2	+ 6 27	3.38	0.68	G5:III + A:	0.027	0.5	150	0.198	+36 SB	composite A: 3.8; B: 4.7, 0.2 ″; C: 7.8,3″	
ζ Hya	08 54.8	+ 5 59	3.11	1.00	G9 II−III	0.035	−1.0	220	0.101	+23		
ι UMa A	08 58.5	+48 05	3.14	0.19	A7 IVn	0.075	1.7	43	0.501	+9 SB	BC: 10.8, M1 V, 4″	Talitha
λ Vel	09 07.6	−43 23	2.21	1.66	K4 Ib−IIa	0.022	−3.3	330	0.026	+18	var: 2.14−2.22	Suhail
a Car	09 10.7	−58 55	3.44	−0.19	B2 IV−V	— —	−2.6	500	0.028	+23 SB2	ecl: 3.2−3.6, 6.7d	HR3659
β Car	09 13.1	−69 40	1.68	0.00	A1 III	0.021	0.2	64	0.183	−5 V?		Miaplacidus
ι Car	09 16.8	−59 14	2.2v	0.18	A7 Ib	0.017	−2.6	300	0.019	+13	var: 2.2−2.5	Turais
α Lyn	09 20.4	+34 26	3.13	1.55	K7 IIIab	0.025	−0.5	170	0.223	+38		
κ Vel	09 21.8	−54 58	2.50	−0.18	B2 IV−V	0.013	−3.3	430	0.012	+22 SB		
α Hya	09 27.1	− 8 37	1.98	1.44	K3 II−III	0.022	−1.0	110	0.034	−4 V?		Alphard
N Vel	09 30.9	−56 59	3.13	1.55	K5 III	0.022	−0.3	150	0.034	−14		HR3803
θ UMa	09 32.2	+51 44	3.17	0.46	F6 IV	0.068	2.6	48	1.094	+15 SB		
o Leo AB	09 40.6	+ 9 56	3.52	0.49	F5 II + A5?	0.034	−2.3	590	0.149	+27 SB	A: occ.bin.(=mags)	Subra
1 Car	09 45.0	−62 28	3.4v	1.22	F9−G5 Ib	0.027	−5.1	750	0.016	+3 V	Cepheid var: 3.38−4.10, 35d	HR3884
ϵ Leo	09 45.3	+23 49	2.98	0.80	G1 II	0.010	−2.3	350	0.048	+4 V?		Ras Elased Australis
υ Car AB	09 46.8	−65 01	3.01	0.28	A6 II	0.027	−5.1	1100	0.012	+14	B: 6.26, B7 III, 5″	
ϕ Vel	09 56.5	−54 31	3.54	−0.08	B5 Ib	— —	−5.4	1900	0.013	+14		
η Leo	10 06.8	+16 49	3.52	−0.03	A0 Ib	0.003	−5.2	1800	0.006	+3 V	B: 4.5, 0.1″	
α Leo A	10 07.8	+12 01	1.35	−0.11	B7 Vn	0.045	−0.3	69	0.248	+6 SB		**Regulus**
ω Car	10 13.5	−69 59	3.32	−0.08	B8 IIIn	— —	−1.2	250	0.032	+7 V		
ζ Leo	10 16.1	+23 28	3.44	0.31	F0 IIIa	0.017	1.5	77	0.023	−16 SB		Adhafera
λ UMa	10 16.5	+42 58	3.45	0.03	A1 IV	0.030	1.0	100	0.170	+18 V		Tania Borealis
q Car	10 16.7	−61 17	3.4v	1.54	K3 IIa	0.027	3.0	35	0.027	+8	var: 3.36−3.42	HR4050
γ Leo A	10 19.4	+19 54	2.61	1.15	K1 IIIb Fe−0.5	0.022	0.7	76	0.342	−37 SB	AB: 5″ separation	Algieba
γ Leo B	10 19.4	+19 54	3.47	1.10	G7 III Fe−1	0.022	0.8	76	0.358	−36 V	BA: 5″ separation	

Star Name	R.A. 1989.5	Dec	V	B−V	MK Type	π(″)	M(V)	D(ly)	μ(″)	RV(km/s)	Remarks	
μ UMa	10 21.7	+41 33	3.05	1.59	M0 IIIp	0.035	−0.7	170	0.088	−21 SB	Ca II emission	Tania Australis
p Car	10 31.6	−61 38	3.3v	−0.09	B4 Vne	— —	−1.1	220	0.021	+26	var: 3.27−3.37	HR4140
θ Car	10 42.6	−64 20	2.76	−0.22	B0.5 Vp	— —	−3.5	540	0.022	+24 SB	Nitrogen enhanced	
μ Vel AB	10 46.3	−49 22	2.69	0.90	G5 III + F8:V	D.022	0.8	75	0.085	+6 SB	B: 6.4, 2″	
ν Hya	10 49.1	−16 08	3.11	1.25	K2 III	0.028	0.1	110	0.215	−1		
β UMa	11 01.2	+56 26	2.37	−0.02	A0mA1 IV−V	0.053	0.7	62	0.087	−12 SB		Merak
α UMa AB	11 03.1	+61 48	1.79	1.07	K0 IIIa	0.038	−0.8	100	0.138	−9 SB	A: 1.86, B: 4.8, A8 V, <1″	Dubhe
ψ UMa	11 09.1	+44 33	3.01	1.14	K1 III	— —	0.2	110	0.075	−4		
δ Leo	11 13.6	+20 35	2.56	0.12	A4 IV	0.048	1.6	51	0.197	−20 V		Zosma
θ Leo	11 13.7	+15 29	3.34	−0.01	A2 IV(K var)	0.026	1.4	80	0.104	+8 V		Chort
ν UMa	11 17.9	+33 09	3.48	1.40	K3 III Ba0.3	0.020	0.0	130	0.036	−9 SB	B: 9.5, 7″	Alula Borealis
ξ Hya	11 32.5	−31 48	3.54	0.94	G7 III	0.027	0.4	130	0.211	−5 V		
λ Cen	11 35.3	−62 58	3.13	−0.04	B9.5 IIn	— —	−0.6	170	0.039	−1 V		
β Leo	11 48.5	+14 38	2.14	0.09	A3 Va	0.082	1.5	40	0.511	0 V		Denebola
γ UMa	11 53.3	+53 45	2.44	0.00	A0 Van	0.028	0.5	80	0.094	−13 SB		Phad
δ Cen	12 07.8	−50 40	2.6v	−0.12	B2 IVne	0.026	−3.1	370	0.034	+11 V	var: 2.51−2.65	
ε Crv	12 09.6	−22 34	3.00	1.33	K2 III	0.027	−0.8	180	0.073	+5		Minkar
δ Cru	12 14.6	−58 41	2.80	−0.23	B2 IV	0.003	−3.1	490	0.039	+22 V?	var: 2.25−2.31, 3.7h	
δ UMa	12 14.9	+57 05	3.31	0.08	A2 Van	0.061	1.2	53	0.102	−13 V		Megrez
γ Crv	12 15.3	−17 29	2.59	−0.11	B8 III	— —	−1.2	190	0.163	−4 SB	sp. var?	Gienah Ghurab
α Cru A	12 26.0	−63 02	1.33	−0.24	B0.5 IV	D.008	−4.2	510	0.030	−11 SB	AB: 5″	**Acrux**
α Cru B	12 26.0	−63 02	1.73	−0.26	B1 Vn	D.008	−3.2	510	0.031	−1	BA: 5″	
δ Crv A	12 29.3	−16 27	2.95	−0.05	B9.5 IVn	0.024	−0.3	150	0.255	+9 V	B: 8.26, K2 V, 24″	Algorab
γ Cru	12 30.6	−57 03	1.63	1.59	M3.5 III	— —	−1.2	120	0.269	+21	var: 1.6−1.9	Gacrux
β Crv	12 33.8	−23 20	2.65	0.89	G5 II	0.034	−2.3	310	0.059	−8		Kraz
α Mus	12 36.5	−69 05	2.69	−0.20	B2 IV−V	— —	−2.5	340	0.043	+13 V	var: 2.17−2.24, 2h	
γ Cen A	12 40.9	−48 54	2.87	−0.03	A1 IV	0.016	−0.3	190	0.190	−6 SB	AB: 5″	
γ Cen B	12 40.9	−48 54	2.96	0.01	A0 IV	0.016	0.0	190	0.190	−6 SB	BA: 5″	
γ Vir AB	12 41.1	− 1 24	2.76	0.36	F1 V + F0mF2 V	0.099	2.6	31	0.567	−20 SB	A: 3.48, B: 3.50, 4″	Porrima
β Mus AB	12 45.6	−68 03	3.05	−0.18	B2 V + B2.5 V	D.015	−1.9	520	0.041	+42 V	A: 3.58, B: 4.10, 1″	

Star Name	R.A. 1989.5	Dec	V	B−V	MK Type	$\pi('')$	M(V)	D(ly)	$\mu('')$	RV(km/s)	Remarks
β Cru	12 47.1	−59 38	1.2v	−0.23	B0.5 III	— —	−4.7	460	0.042	+16 SB	var: 1.23−1.31, 0.7d? **Becrux**
ϵ UMa	12 53.6	+56 01	1.8v	−0.02	A0p IV:(CrEu)	0.009	0.3	65	0.109	−9 SB?	var: 1.76−1.79, 5.1d Alioth
δ Vir	12 55.1	+ 3 27	3.38	1.58	M3 III	0.022	−1.2	270	0.474	−18 V?	Auva
α^2 CVn A	12 55.5	+38 22	2.9v	−0.12	A0p II:(SiEu)	0.027	0.0	130	0.242	−3 V	B: 5.6, F0 V, 20″ Cor Caroli
ϵ Vir	13 01.7	+11 01	2.83	0.94	G9 IIIab	0.043	0.3	100	0.274	−14	Vindamiatrix
γ Hya	13 18.3	−23 07	3.00	0.92	G8 IIIa	0.027	−0.8	190	0.081	−5 V?	
ι Cen	13 20.0	−36 39	2.75	0.04	A2 Va	0.062	1.4	53	0.351	0	
ζ UMa A	13 23.5	+55 00	2.27	0.02	A1 Va	0.047	0.7	74	0.122	−6 SB2	B: 3.94, A1mA7 IV−V, 14″ Mizar
α Vir	13 24.6	−11 06	1.0v	−0.23	B1 V	0.023	−3.2	220	0.054	+1 SB2	var: 0.97−1.04; mult. 3.1,4.5,7.5 **Spica**
ζ Vir	13 34.2	− 0 33	3.37	0.11	A2 IV	0.044	1.4	79	0.287	−13	Heze
ϵ Cen	13 39.2	−53 25	2.3v	−0.22	B1 III	— —	−4.4	670	0.028	+3	
η UMa	13 47.1	+49 22	1.86	−0.19	B3 V	0.035	−1.3	140	0.127	−11 SB?	Alkaid
ν Cen	13 48.9	−41 38	3.41	−0.22	B2 IV	— —	−3.1	640	0.035	+9 SB	
μ Cen	13 49.0	−42 25	3.0v	−0.17	B2 IV−V pne	— —	−2.5	380	0.034	+9 SB	variable shell: 2.92−3.43
η Boo	13 54.2	+18 27	2.68	0.58	G0 IV	0.108	2.8	31	0.370	0 SB	Mufrid
ζ Cen	13 54.9	−47 14	2.55	−0.22	B2.5 IV	— —	−2.7	370	0.072	+7 SB2	
β Cen AB	14 03.1	−60 19	0.6v	−0.23	B1 III	0.009	−4.4	320	0.030	+6 SB	var: 0.61−0.68; B: 3.9, 1″ **Hadar**
π Hya	14 05.8	−26 38	3.27	1.12	K2 IIIb	0.049	0.7	67	0.049	+27	
θ Cen	14 06.1	−36 19	2.06	1.01	K0 IIIb	0.065	0.7	50	0.738	+1	Menkent
α Boo	14 15.2	+19 14	−0.04	1.23	K1.5 III Fe−0.5	0.097	0.2	34	2.281	−5 V?	high space velocity **Arcturus**
ι Lup	14 18.7	−46 01	3.55	−0.18	B2.5 IVn	— —	−2.7	550	0.014	+22	
γ Boo	14 31.7	+38 21	3.03	0.19	A7 IV+	0.025	1.9	53	0.189	−37 V	Seginus
η Cen	14 34.8	−42 07	2.3v	−0.19	B1.5 IV pne	— —	−3.5	450	0.049	0 SB	variable shell
α Cen B	14 38.9	−60 48	1.33	0.88	K1 V	0.750	5.7	4	3.678	−21 V?	BA: 21″; C: Proxima, 12.4, M5e, 2deg
α Cen A	14 38.9	−60 47	−0.01	0.71	G2 V	0.750	4.4	4	3.678	−25 SB	AB: 21″ **Rigil Kentaurus**
α Lup	14 41.2	−47 21	2.3v	−0.20	B1.5 III	— —	−4.1	580	0.026	+5 SB	var: 2.28−2.31, 0.26d
α Cir	14 41.6	−64 56	3.19	0.24	A7p (Sr)	0.056	2.0	58	0.302	+7 SB?	B: 8.6, K5 V, 16″
ϵ Boo AB	14 44.5	+27 07	2.37	0.97	K0 II−III+A0 V	0.016	−1.0	160	0.054	−17 V	A: 2.70; B: 5.12, 3″ Izar
α Lib A	14 50.3	−16 00	2.75	0.15	A3 III−IV	0.050	1.2	65	0.130	−23 SB	Zuben Elgenubi
β UMi	14 50.7	+74 12	2.08	1.47	K4 III	0.039	−0.2	83	0.036	+17 V	Kocab

Star Name	R.A. 1989.5	Dec	V	B−V	MK Type	$\pi('')$	M(V)	D(ly)	$\mu('')$	RV(km/s)	Remarks
β Lup	14 57.8	−43 06	2.68	−0.22	B2 IV	— —	−3.1	460	0.057	0 SB	
κ Cen	14 58.5	−42 04	3.13	−0.20	B2 V	— —	−1.9	320	0.033	+8 SB	
β Boo	15 01.5	+40 26	3.50	0.97	G8 IIIa(note)	0.037	−0.8	230	0.056	−20	Ba 0.4, Fe −0.5. Nekkar
σ Lib	15 03.5	−25 14	3.3v	1.70	M2.5 III	0.064	−1.0	51	0.087	−4	var: 3.20−3.36 Brachium
ζ Lup	15 11.5	−52 04	3.41	0.92	G8 III	0.043	0.3	130	0.128	−10	
δ Boo	15 15.1	+33 21	3.47	0.95	G8 III Fe−1	0.030	0.3	140	0.143	−12 SB	
β Lib	15 16.4	− 9 21	2.61	−0.11	B8 IIIn	0.000	0.1	100	0.101	−35 SB	Zuben Elschemali
γ TrA	15 17.9	−68 38	2.89	0.00	A1 IIIn	0.010	0.2	110	0.067	−3 V	
δ Lup	15 20.7	−40 37	3.2v	−0.22	B1.5 IVn	— —	−3.4	650	0.036	0 V?	
γ UMi	15 20.7	+71 52	3.05	0.05	A3 III	0.003	0.4	110	0.031	−4 V	Pherkad
ϵ Lup AB	15 22.0	−44 39	3.37	−0.18	B2 IV−V	D.009	−2.5	510	0.024	+8 SB2	A: 3.5; B: 5.0, <1″
ι Dra	15 24.7	+59 00	3.29	1.16	K2 III	0.040	0.1	140	0.020	−11	Ed Asich
α CrB	15 34.2	+26 45	2.2v	−0.02	A0 IV(composite)	0.045	0.3	78	0.151	+2 SB	ecl: 2.21−2.32, 17.4d Alphekka
γ Lup AB	15 34.4	−41 08	2.78	−0.20	B2 IVn	D.008	−3.1	650	0.035	+2 V	A: 3.5; B: 3.6, <1″; similar spectra
α Ser	15 43.7	+ 6 27	2.65	1.17	K2 IIIb CN1	0.053	0.7	62	0.143	+3 V?	var? Unukalhai
μ Ser	15 49.1	−3 24	3.53	−0.04	A0 III	0.007	0.0	170	0.094	−9 SB	
β TrA	15 54.2	−63 24	2.85	0.29	F0 IV	0.083	2.2	39	0.438	0	
π Sco A	15 58.3	−26 05	2.89	−0.19	B1 V + B2 V	0.010	−3.2	(522)	0.028	−3 SB2	A: occ.bin: 3.4 + 4.5, 0.0003″ sep.
T CrB	15 59.0	+25 57	2.0v	0.10	gM3: + Bep	— —	−1.0	8200	0.013	−29 SB	recurrent nova 1866, 1946; now V=11
η Lup A	15 59.4	−38 22	3.41	−0.22	B2.5 IVn	D.008	−2.7	550	0.040	+8 V	A: 3.47, B: 7.70, 15″
δ Sco AB	15 59.7	−22 36	2.32	−0.12	B0.3 IV	— —	−4.4	(522)	0.027	−7 SB	AB:mult<1″;C:4.9,B2IV−V,8″ Dschubba
β Sco AB	16 04.8	−19 47	2.62	−0.07	B0.5 V	0.009	−3.5	(522)	0.022	−1 SB	A: 2.78; B: 5.04, 1″; C: 4.93, 14″ Graffias
δ Oph	16 13.8	− 3 40	2.74	1.58	M0.5 III	0.034	−0.8	160	0.153	−20 V	Yed Prior
ϵ Oph	16 17.8	− 4 40	3.24	0.96	G9.5 IIIbFe−0.5	0.043	0.2	130	0.089	−10 V	Yed Posterior
σ Sco A	16 20.5	−25 34	2.9v	0.13	B1 III	— —	−4.4	(522)	0.025	+3 SB	var: 2.94−3.06,0.25d; B: 8.3, B9 V, 20″
η Dra A	16 23.8	+61 32	2.74	0.91	G8 IIIab	0.051	0.3	64	0.064	−14 SB?	B: 8.7, 6″
α Sco A	16 28.8	−26 25	0.9v	1.83	M1.5 Iab	0.024	−5.2	(522)	0.024	−3 SB	B: 5.37, B2.5 V, 3″ **Antares**
β Her	16 29.8	+21 31	2.77	0.94	G7 IIIa	0.024	−0.8	170	0.100	−26 SB	Kornephoros
τ Sco	16 35.2	−28 12	2.82	−0.25	B0 V	0.020	−4.0	(522)	0.026	+2 V	
ζ Oph	16 36.6	−10 33	2.56	0.02	O9.5 Vn	0.003	−4.2	(522)	0.026	−15 V	

Star Name	R.A. 1989.5	Dec	V	B−V	MK Type	$\pi('')$	M(V)	D(ly)	$\mu('')$	RV(km/s)	Remarks
ζ Her AB	16 40.9	+31 37	2.81	0.65	G1 IV	0.102	3.0	31	0.614	−70 SB	A: 2.90; B: 5.53, G7 V, 1.1″
η Her	16 42.5	+38 57	3.53	0.92	G7.5 IIIb Fe−1	0.034	0.7	120	0.089	+8 V?	
α TrA	16 47.5	−69 01	1.92	1.44	K2 IIb−IIIa	0.031	−1.0	110	0.044	−3	Atria
ϵ Sco	16 49.5	−34 16	2.29	1.15	K2 III	0.022	0.1	89	0.661	−3	
μ^1 Sco	16 51.2	−38 02	3.1v	−0.20	B1.5 IVn	— —	−3.5	610	0.031	−25 SB2	ecl: 2.80−3.08, 1.4d
κ Oph	16 57.2	+ 9 23	3.20	1.15	K2 III	0.031	0.1	140	0.293	−56	
ζ Ara	16 57.7	−55 58	3.13	1.60	K4 III	0.044	−0.2	110	0.037	−6	
ζ Dra	17 08.8	+65 44	3.17	−0.12	B6 III	0.023	−1.8	310	0.033	−17 V	Aldhibah
η Oph AB	17 09.8	−15 43	2.43	0.06	A2.5 Va	0.052	1.4	63	0.102	−1 SB	A: 3.0; B: 3.5, A3 V, 1″ Sabik
η Sco	17 11.4	−43 14	3.33	0.41	F2p V:(Cr)	0.062	2.7	53	0.286	−27	
α Her AB	17 14.2	+14 24	3.1v	1.44	M5 Ib−II	0.000	−3.2	630	0.035	−33 V	var: 3.0−4.0; B: 5.4, 5″ Ras Algethi
δ Her	17 14.6	+24 51	3.14	0.08	A1 Vann	0.044	0.7	94	0.159	−40 SB	B: 8.8, 9″ Sarin
π Her	17 14.7	+36 49	3.16	1.44	K3 IIab	0.025	−2.0	330	0.029	−26	
θ Oph	17 21.4	−24 59	3.3v	−0.22	B2 IV	— —	−3.1	610	0.021	−2 SB	occ.bin: 3.4, 5.4; var: 3.25−3.29, 0.14d
β Ara	17 24.4	−55 31	2.85	1.46	K3 Ib−IIa	0.034	−3.5	580	0.024	0	
γ Ara A	17 24.5	−56 22	3.34	−0.13	B1 Ib	— —	−5.8	2000	0.011	−3 V	broad lines for Ib; B: 10.0, 18″
υ Sco	17 30.1	−37 17	2.69	−0.22	B2 IV	0.000	−3.1	460	0.032	8 SB	
β Dra A	17 30.2	+52 19	2.79	0.98	G2 Ib−IIa	0.013	−3.5	490	0.026	−20 V	B: 11.5, 4″ Restaban
α Ara	17 31.0	−49 52	2.95	−0.17	B2 Vne	0.007	−1.9	280	0.075	0 SB	
λ Sco	17 32.9	−37 06	1.6v	−0.22	B1.5 IV	— —	−3.5	330	0.029	−3 SB2	var: 1.59−1.65, 0.21d Shaula
α Oph	17 34.5	+12 34	2.08	0.15	A5 Vnn	0.067	0.7	49	0.255	+13 SB?	Rasalhague
θ Sco	17 36.6	−43 00	1.87	0.40	F1 III	0.027	−2.4	200	0.016	+1	Sargas
ξ Ser	17 37.0	−15 24	3.54	0.26	F0 IIIb	0.030	1.8	73	0.076	−43 SB	
κ Sco	17 41.8	−39 02	2.4v	−0.22	B1.5 III	— —	−4.2	650	0.030	−14 SB	var: 2.39−2.42, 0.2d
β Oph	17 42.9	+ 4 34	2.77	1.16	K2 III	0.033	0.1	110	0.164	−12 V	Cebalrai
μ Her A	17 46.0	+27 44	3.42	0.75	G5 IV	0.133	4.0	25	0.808	−16 V	BC: 9.78, 33″
ι^1 Sco	17 46.9	−40 07	3.03	0.51	F2 Ia	0.019	−8.0	3500	0.006	−28 SB	
G Sco	17 49.1	−37 02	3.21	1.17	K2 III	0.040	0.1	130	0.064	+25	HR6630
γ Dra	17 56.4	+51 29	2.23	1.52	K5 III	0.025	−0.3	100	0.025	−28	Etamin
ν Oph	17 58.4	− 9 46	3.34	0.99	K0 III	0.021	0.2	140	0.118	+13	

Star Name	R.A. 1989.5 Dec		V	B−V	MK Type	$\pi('')$	M(V)	D(ly)	$\mu('')$	RV(km/s)	Remarks
γ^2 Sgr	18 05.1	−30 25	2.99	1.00	K0 III	0.025	0.2	120	0.192	+22 SB	Nash
η Sgr A	18 16.9	−36 46	3.11	1.56	M3.5 IIIab	0.045	−1.0	210	0.210	+1 V?	var: 3.08, 3.12; B: 8.33, G8: IV:, 4″
δ Sgr	18 20.3	−29 50	2.70	1.38	K2.5 IIIa	0.047	−0.8	140	0.050	−20	Kaus Meridionalis
η Ser	18 20.8	− 2 54	3.26	0.94	K0 III–IV	0.058	1.8	56	0.890	+9 V?	
ϵ Sgr	18 23.5	−34 23	1.85	−0.03	A0 II:n(shell?)	0.023	0.0	76	0.129	−15	Kaus Australis
α Tel	18 26.2	−45 58	3.51	−0.17	B3 IV	— —	−2.4	480	0.048	0 V?	
λ Sgr	18 27.3	−25 26	2.81	1.04	K1 IIIb	0.053	0.7	62	0.190	−43	Kaus Borealis
α Lyr	18 36.6	+38 46	0.03	0.00	A0 Va	0.133	0.6	25	0.348	−14 V	**Vega**
ϕ Sgr	18 45.0	−27 00	3.17	−0.11	B8 III	— —	−1.0	220	0.052	+22 SB	similar companion, 0.1″
β Lyr	18 49.7	+33 21	3.4v	0.00	B7 Vpe (shell)	0.000	−0.3	150	0.002	−19 SB	ecl: 3.34–4.34, 12.9d Sheliak
σ Sgr	18 54.6	−26 19	2.02	−0.22	B3 IV	— —	−1.6	170	0.056	−11 V	Nunki
ξ^2 Sgr	18 57.1	−21 07	3.51	1.18	K1 III	0.011	0.1	130	0.035	−20	
γ Lyr	18 58.5	+32 40	3.24	−0.05	B9 II	0.021	−0.6	190	0.007	−21 V	Sulaphat
ζ Sgr AB	19 01.9	−29 54	2.60	0.08	A2 IV–V + A4:V:	0.025	1.4	74	0.014	+22 SB	A: 3.2; B: 3.5, <1″ Ascella
ζ Aql A	19 04.9	+13 51	2.99	0.01	A0 Vann	0.045	0.3	110	0.095	−25 SB	
λ Aql	19 05.7	− 4 54	3.44	−0.09	A0 IVp (weak 4481)	0.032	0.6	120	0.090	−12 V	
τ Sgr	19 06.3	−27 41	3.32	1.19	K1.5 IIIb	0.044	0.7	92	0.255	+45 SB	
π Sgr ABC	19 09.1	−21 02	2.89	0.35	F2 II–III	0.026	−2.4	480	0.035	−10	A: 3.7; B: 3.8; C: 6.0, <1″ Albaldah
δ Dra	19 12.6	+67 39	3.07	1.00	G9 III	0.032	0.3	110	0.130	+25	Nodus Secundus
δ Aql	19 25.0	+ 3 06	3.36	0.32	F2 IV–V	0.072	2.2	45	0.267	−30 SB	
β Cyg A	19 30.3	+27 56	3.08	1.13	K3 II + B9.5 V	0.017	−2.2	380	0.002	−24 V	B: 5.11, 35″ Albireo
δ Cyg AB	19 44.6	+45 06	2.87	−0.03	B9.5 III	0.030	−0.3	140	0.069	−20 SB	B: 6.4, F1 V, 2″
γ Aql	19 45.8	+10 35	2.72	1.52	K3 II	0.016	−2.2	270	0.016	−2 V	Tarazed
α Aql	19 50.3	+ 8 50	0.77	0.22	A7 Vnn	0.202	2.3	16	0.662	−26	**Altair**
η Aql	19 51.9	+ 0 59	3.5v	0.90	F6–G1 Ib	0.010	−5.1	860	0.009	−15 SB	Cepheid var: 3.50–4.30, 7.2d
γ Sge	19 58.3	+19 28	3.47	1.57	M0 III	0.013	−0.7	220	0.070	−33	
θ Aql	20 10.8	− 0 51	3.23	−0.07	B9.5 III	0.012	−0.3	170	0.037	−27 SB2	
β Cap A	20 20.4	−14 49	3.08	0.79	K0: II: + A5: V:n	0.010	−2.2	560	0.039	−19 SB	A: mult: 4.0+4.3+4.8+6.7, <1″ Dabih
γ Cyg	20 21.8	+40 13	2.20	0.68	F8 Ib	0.003	−5.1	800	0.001	−8	Sadr
α Pav	20 24.8	−56 46	1.94	−0.20	B2.5 V	— —	−1.6	150	0.087	+2 SB	Peacock

Star Name	R.A. 1989.5	Dec	V	B–V	MK Type	$\pi('')$	M(V)	D(ly)	$\mu('')$	RV(km/s)	Remarks
α Ind	20 36.8	−47 20	3.11	1.00	K0 III CN−1	0.046	0.2	120	0.090	−1	
α Cyg	20 41.1	+45 15	1.25	0.09	A2 Ia	0.000	−7.2	1500	0.005	−5 V	**Deneb**
β Pav	20 44.0	−66 14	3.42	0.16	A6 IV	0.035	1.5	79	0.041	+10	
η Cep	20 45.1	+61 48	3.43	0.92	K0 IV	0.076	3.1	43	0.827	−87	
ϵ Cyg	20 45.8	+33 56	2.46	1.03	K0 III	0.057	0.2	57	0.484	−11 SB	
ζ Cyg	21 12.5	+30 11	3.20	0.99	G8 IIIa Ba 0.6	0.027	−0.8	200	0.052	+17 SB	
α Cep	21 18.3	+62 32	2.44	0.22	A7 Van	0.068	2.0	48	0.159	−10 V	Alderamin
β Cep	21 28.5	+70 31	3.2v	−0.22	B1 III	0.014	−4.4	1000	0.016	−8 SB	var: 3.16–3.27, 0.2d; B: 7.8, 13″ Alphirk
β Aqr	21 31.0	− 5 37	2.91	0.83	G0 Ib	0.006	−4.0	710	0.020	+7	Sadalsuud
ϵ Peg	21 43.7	+ 9 49	2.4v	1.53	K2 Ib	0.006	−4.0	470	0.030	+5 V	var: 0.7–3.5 (flare in 1972) Enif
δ Cap	21 46.5	−16 11	2.9v	0.29	A3mF2 IV:	0.087	1.5	37	0.394	−6 SB	var: 2.83–3.05, 1d; occ.bin: 3.2 + 5.2
γ Gru	21 53.3	−37 25	3.01	−0.12	B8 IV–Vs	0.013	−1.2	230	0.104	−2 V?	
α Aqr	22 05.2	− 0 22	2.96	0.98	G2 Ib	0.012	−4.0	680	0.016	+8 V?	Sadalmelik
α Gru	22 07.6	−47 01	1.74	−0.13	B7 Vn	0.057	−1.1	57	0.198	+12	Al Nair
θ Peg	22 09.7	+ 6 09	3.53	0.08	A2mA1 IV–V	0.049	1.4	82	0.277	−6 SB2	Baham
ζ Cep	22 10.5	+58 09	3.35	1.57	K1.5 Ib	0.017	−4.0	750	0.015	−18 SB	
α Tuc	22 17.8	−60 19	2.86	1.39	K3 III	0.026	0.0	100	0.071	+42 SB	
δ Cep A	22 28.8	+58 22	3.5v	0.60	F5–G2 Ib	0.011	−5.1	1200	0.012	−15 SB	Cepheid variable: 3.48–4.34, 5.4d
ζ Peg	22 40.9	+10 47	3.40	−0.09	B8.5 III	0.023	0.1	140	0.080	+7 V?	Homam
β Gru	22 42.0	−46 56	2.1v	1.60	M5 III	0.008	−1.0	140	0.138	+2	var: 2.0–2.3
η Peg	22 42.5	+30 10	2.94	0.86	G8 II + F0 V	0.017	−2.1	330	0.025	+4 SB	Matar
ϵ Gru	22 47.9	−51 22	3.49	0.08	A2 Va	0.044	1.0	97	0.126	0 V	
ι Cep	22 49.3	+66 09	3.52	1.05	K0 III	0.041	0.2	140	0.137	−12	
μ Peg	22 49.5	+24 33	3.48	0.93	G8 III	0.040	0.3	140	0.152	+14	
δ Aqr	22 54.1	−15 53	3.27	0.05	A3 V: (weak 4481)	0.038	1.2	85	0.047	+18 V	Skat
α PsA	22 57.1	−29 41	1.16	0.09	A3 Va	0.149	2.0	22	0.373	+7	**Fomalhaut**
β Peg	23 03.3	+28 02	2.4v	1.67	M2 II–III	0.022	−2.0	220	0.236	+9 V	var: 2.31–2.74 Scheat
α Peg	23 04.2	+15 09	2.49	−0.04	A0 III–IV	0.038	0.7	74	0.073	−4 SB	Markab
γ Cep	23 38.9	+77 34	3.21	1.03	K1 III–IV	0.068	1.5	48	0.168	−42	Alrai

THE NEAREST STARS

BY ALAN H. BATTEN

Measuring the distances of stars is one of the most difficult and important jobs of the observational astronomer. As Earth travels round the Sun each year, the apparent positions of nearby stars—against the background of more distant ones—change very slightly. This change is the *annual parallax*. Even for the closest star to our Sun, Proxima Centauri, it is only about three-quarters of an arc-second: that is, the apparent size of a penny viewed from rather more than 5 km distance. A graphic way of conveying the distances to stars is to speak of a *light-year*, the distance (about ten million million km) that light travels in a year. The first astronomers to measure parallax spoke in this way, but modern astronomers prefer to speak of a *parsec*—the distance at which a star would have a parallax of exactly one arc-second. One parsec is equal to about 3.26 light-years. The distance of a star in parsecs is simply the reciprocal of its parallax expressed (as in the table) in arc-seconds.

Attempts to determine annual parallax have played an important role in the history of astronomy. One convincing determination of the parallax of a star would have provided Galileo with the proof of the heliocentric theory he so desperately needed, but it was beyond the capabilities of his telescopes. Two unsuccessful attempts led to important discoveries of other things. James Bradley (1693–1762), who showed that parallaxes must certainly be less than 2″ and probably less than 1″, discovered the aberration of light. William Herschel (1738–1822) believed the best chance of measuring parallax was offered by double stars – which he at first believed to be only optical pairs – and so made the measurements that proved the existence of *binary stars* (his own term) in which the components revolve around their mutual centre of mass.

It is well known that three men, F. W. Bessel (1785–1846), F. G. W. Struve (1793–1864) and Thomas Henderson (1798–1844), succeeded almost simultaneously (in the 1830s) in measuring convincing parallaxes for 61 Cygni, α Lyrae and α Centauri respectively. For different reasons, each man delayed publication of his result and some arguments about priority are still heard. Undoubtedly, Bessel's paper was published first (1838): contemporaries credited him with being the first to measure a parallax successfully, and posterity has – for the most part – confirmed that judgment. Bessel received the Royal Astronomical Society's Gold Medal in 1841, specifically for his achievement. Sir John Herschel's address on this occasion is often quoted, but it bears repetition:

> I congratulate you and myself that we have lived to see the great and hitherto impassable barrier to our excursions into the sidereal universe; that barrier against which we have chafed so long and so vainly ... almost simultaneously overleaped at three different points. It is the greatest and most glorious triumph that practical astronomy has ever witnessed. Perhaps I ought not to speak so strongly – perhaps I should hold some reserve in favour of the bare possibility that it may all be an illusion – and that further researches, as they have repeatedly before, so may now fail to substantiate this noble result. But I confess myself unequal to such prudence under such excitement. Let us rather accept the joyful omens of the time and trust that, as the barrier has begun to yield, it will speedily be effectually prostrated. Such results are among the fairest flowers of civilization.

Herschel's hope for the speedy prostration of the barrier was not fulfilled. Only a few stars have parallaxes large enough to be detected by even the most skilful visual observers. Until photography reached the stage at which it could be used for accurate positional measurements, the number of known parallaxes grew very slowly. Even today, the direct measurement of stellar parallax is impossible beyond about 50 to 100 parsecs (150 to 300 light-years), except for a few visual binaries whose radial velocities have also been observed. All our knowledge of greater distances depends on inference and indirect estimates. We may soon overleap another barrier, however. Astrometric measurements from space promise greater accuracy and should enable us to extend the radius within which we can determine distances directly. Yet it is ironical that the results that so excited Herschel are now obtained by routine observations, to which only very few astronomers are prepared to dedicate their lives.

The accompanying table lists all the stars known to be within a distance of just over 5 parsecs (17 light-years) from the Sun. The table is based on one published in Volume 8 of the *Landolt-Bornstein* tabulations by Professor W. Gliese. It contains, however, two additional objects, one of which was drawn to my attention by Professor Gliese and the other (L143-23) whose parallax was first published in 1986 by Ianna and Bessell (no relation to Bessel!) in a paper brought to my attention by Dr. R. S. Harrington.

All the parallaxes given here are uncertain by several units in the last decimal; some are uncertain in the second decimal. It is thus inevitable that the order of stars of nearly equal parallaxes will change, either because of new results or because different compilers evaluate differently the quality of individual determinations of parallax that make up the means recorded here.

The table gives the name of each star, its coordinates for 2000, its parallax π, its distance in light-years, its spectral type, proper motion (seconds of arc per year), position angle of the proper motion (measured from north through east), total space velocity relative to the Sun (km s^{-1}, where known, with the sign of the radial velocity), apparent (V) and absolute (M_V) visual magnitudes. A colon (:) after a tabular entry indicates that the value is uncertain. The 1985 revision of the table provided an opportunity to improve the presentation of the spectral types. Dr. R. F. Wing classified all the stars in the old table on the MK system, except the white dwarfs, the stars of type K3 or earlier (whose spectral types are given in the *Bright Star Catalogue*), the Sun, and those whose parallaxes are less than 0.″2. He kindly provided his data in advance of publication and I adopted his classifications, except that I retained the e, indicating the presence of emission lines in the spectrum. Classifications given for the white dwarfs (indicated by D) are taken from Gliese's table. I know of no spectral types for the newcomers LP 731-58 and L143-23, but their colours correspond to early and late M-type, respectively. In general, I have used the same names for stars as in earlier versions of the table. I have, however, given the two components of Σ2398 their B.D. number, and changed the designation of α Centauri C to Proxima. This latter change emphasizes that Proxima is indeed somewhat closer to us than α Centauri itself. Some readers may enjoy working out the true spatial separation between Proxima and its brighter companions.

The table contains 65 stars. Of these, 35 are single (including the Sun, whose planets are not counted), 24 are found in 12 double systems, and six in the two triple systems o^2 Eridani and α Centauri (with Proxima). There is some evidence for unseen companions of low mass associated with nine of the stars. The list gives an idea of the frequencies of different kinds of stars in our part of the Galaxy. Only four of the stars are brighter than the Sun; most are very much fainter and cooler. No giants or very hot massive stars are found in the solar neighbourhood.

Not all astronomers agree about all the suspected unseen companions. The existence of some is well established while that of others is inferred from perturbations not much larger than the errors of observation. Does the Sun have a stellar companion? Such a companion must be faint—or we would already have detected it—and would have very small proper motion and radial velocity since it would be travelling through space with the Sun. Faint stars with small proper motions are unlikely to be selected for parallax measurement. Thus we may never know for sure whether we have a companion or not.

Name	α (2000)	δ (2000)	π	D	Sp.	μ	θ	W	V	M_v
	h m	° ′	″	l.y.		″/a	°	km/s		
Sun					G2V				−26.72	4.85
Proxima	14 30	−62 41	0.772	4.2	M5.5Ve	3.85	282	−29	11.05	15.49
α Cen A	14 40	−60 50	.750	4.3	G2V	3.68	281	−32	−0.01	4.37
B					K1V				1.33	5.71
Barnard's*	17 58	+04 34	.545	6.0	M3.8V	10.31	356	−140	9.54	13.22
Wolf 359	10 56	+07 01	.421	7.7	M5.8Ve	4.70	235	+54	13.53	16.65
BD+36°2147*	11 03	+35 58	.397	8.2	M2.1Ve	4.78	187	−102	7.50	10.50
L-726-8A	01 39	−17 57	.387	8.4	M5.6Ve	3.36	80	+50	12.52	15.46
B								+52	13.02	15.96
Sirius A	06 45	−16 43	.377	8.6	A1Vm	1.33	204	−19	−1.46	1.42
B					DA				8.3:	11.2:
Ross 154	18 50	−23 50	.345	9.4	M3.6Ve	0.72	104	−11	10.45	13.14
Ross 248	23 42	+44 10	.314	10.4	M4.9Ve	1.60	176	−85	12.29	14.78
ε Eri	03 33	−09 28	.303	10.8	K2Ve	0.98	271	+22	3.73	6.14
Ross 128	11 48	+00 48	.298	10.9	M4.1V	1.38	152	−26	11.10	13.47
61 Cyg A	21 07	+38 45	.294	11.1	K3.5Ve	5.22	52	−106	5.22	7.56
B*					K4.7Ve				6.03	8.37
ε Ind	22 03	−56 47	.291	11.2	K3Ve	4.70	123	−86	4.68	7.00
BD+43°44A	00 18	+44 01	.290	11.2	M1.3Ve	2.90	82	+49	8.08	10.39
B					M3.8Ve			+51	11.06	13.37
L789-6	22 39	−15 19	.290	11.2		3.26	46	−80	12.18	14.49
Procyon A	07 39	+05 13	.285	11.4	F5IV-V	1.25	214	−21	0.37	2.64
B					DF				10.7	13.0
BD+59°1915A	18 43	+59 38	.282	11.6	M3.0V	2.29	325	38†	8.90	11.15
B					M3.5V	2.27	323	+39	9.69	11.94
CD−36°15693	23 06	−35 52	.279	11.7	M1.3Ve	6.90	79	+117	7.35	9.58
G51-15	08 30	+26 47	.278	11.7	M6.6V	1.27	242		14.81	17.03
τCet	01 44	−15 56	.277	11.8	G8V	1.92	297	−37	3.50	5.72
BD5°1668*	07 26	05 14	.266	12.3	M3.7V	3.77	171	+72	9.82	11.94
L725−32	01 12	−17 00	.261	12.5	M4.5Ve	1.32	62	+37	12.04	14.12
CD−39°14192	21 17	−38 52	.260	12.5	K5.5Ve	3.46	251	+66	6.66	8.74
Kapteyn's	05 12	−45 01	.256	12.7	M0.0V	8.72	131	+293	8.84	10.88
Krüger 60A	22 28	+57 42	.253	12.9	M3.3Ve	0.86	246	−31	9.85	11.87
B									11.3	13.3
BD−12°4253	16 30	−12 39	.247	13.2	M3.5V	1.18	183	−26	10.11	12.07
Ross 614A	06 29	−02 49	.246	13.3	M4.5Ve	1.00	133	+31	11.10	13.12
B									14.	16.
van Maanen's	00 49	+05 23	.232	14.1	DG	2.99	155	+82	12.37	14.20
Wolf 424A	12 33	+09 01	.230	14.2	M5.3Ve	1.76	279	−37	13.16	14.97
B									13.4	15.2
CD−37°15492	00 06	−37 21	.225	14.5	M2.0V	6.11	112	+131	8.56	10.32
L1159-16	02 00	+13 03	.224	14.6	M4.5Ve	2.09	149		12.26	14.01
BD+50°1725	10 11	+49 27	.222	14.7	K5.0Ve	1.45	250	−40	6.59	8.32
L143-23	10 44	−62 13	.221	14.8		1.65	282		13.92	15.64
LP731-58	10 48	−11 20	.219	14.9		1.64	160		15.60	17.30
CD−46°11540	17 29	−46 54	.216	15.1	M2.7V	1.06	147		9.37	11.04
G158−27	00 07	−07 33	.214	15.2	M5.5:	2.04	204		13.74	15.39
CD−49°13515	21 34	−49 00	.214	15.2	M1.8V	0.81	184	+20	8.67	10.32
CD−44°11909*	17 37	−44 20	.213	15.3	M3.9V	1.16	217		10.96	12.60
BD+68°946*	17 36	+68 21	.213	15.3	M3.3V	1.31	196	−37	9.15	10.79
G208−44 A*	19 54	+44 25	.211	15.5		0.74	143		13.41	15.03
B					M5:				13.99	15.61
BD−15°6290	22 53	−14 16	.209	15.6	M3.9V	1.14	124	+27	10.17	11.77
o² Eri A	04 15	−07 39	.207	15.7	K1V	4.08	213	−102	4.43	6.01
B					DA	4.07	212	−96	9.52	11.10
C					M4.3Ve			(−45)‡	11.17	12.75
BD+20°2465*	10 20	+19 52	.206	15.8	M3.3Ve	0.49	264	+16	9.43	11.00
L145−141	11 46	−64 50	.206	15.8	DC	2.68	97		11.50	13.07
70 Oph A	18 05	+02 30	.203	16.1	K0Ve	1.12	167	−27	4.22	5.76
B					K4Ve				6.00	7.54
BD+43°4305*	22 47	+44 20	.200	16.3	M5e:	0.83	236	−20	10.2	11.7
Altair	19 51	+08 52	.198	16.5	A7V	0.66	54	−30	0.76	2.24
AC+79°3888	11 48	+78 42	.193	16.9	M4:	0.89	57	−121	10.80	12.23
G9−38A	08 58	+19 45	.192	17.0		0.89	267		14.06	15.48
B									14.92	16.34
BD+15°2620	13 46	+14 54	.192	17.0	M1.7Ve	2.30	129	+59	8.49	9.91

*Suspected unseen companion.
†Radial velocity is zero.
‡Radial velocity only.

DOUBLE AND MULTIPLE STARS

By Charles E. Worley

Many stars can be separated into two or more components by use of a telescope. The larger the aperture of the telescope, the closer the stars which can be separated under good seeing conditions. With telescopes of moderate size and good optical quality, and for stars which are not unduly faint or of large magnitude difference, the minimum angular separation in seconds of arc is given by 120/D, where D is the diameter of the telescope's objective in millimetres.

The following lists contain some interesting examples of double stars. The first list presents pairs whose orbital motions are very slow. Consequently, their angular separations remain relatively fixed and these pairs are suitable for testing the performance of small telescopes. In the second list are pairs of more general interest, including a number of binaries of short period for which the position angles and separations are changing rapidly.

In both lists the columns give, successively: the star designation in two forms; its right ascension and declination for 1980; the combined visual magnitude of the pair and the individual magnitudes; the apparent separation and position angle for 1989.0; and the period, if known. (The position angle is the angular direction of the fainter star from the brighter, measured counterclockwise from north.)

Many of the components are themselves very close visual or spectroscopic binaries. (Other double stars appear in the tables of Nearest Stars and Brightest Stars. For more information about observing these stars, see the articles by: J. Ashbrook in *Sky and Telescope*, **60**, 379 (1980); J. Meeus in *Sky and Telescope*, **41**, 21 and 89 (1971); and by C. E. Worley in *Sky and Telescope*, **22**, 73, 140 and 261 (1961). The latter two articles have been reprinted by Sky Publishing Corp., 49 Bay State Road, Cambridge, Mass. 02238 under the titles *Some Bright Visual Binary Stars* and *Visual Observing of Double Stars*, each $1.95 U.S.—Ed.)

Star		A.D.S.	R.A. 1980.0 h	m	Dec. 1980.0 °	′	Magnitudes comb.	A	B	P.A. 1989.0 °	Sep. 1989.0 ″	P (app.) years
λ	Cas	434	00	30.7	+54	26	4.9	5.5	5.8	186	0.6	640
α	Psc	1615	02	01.0	+02	40	4.0	4.3	5.3	279	1.9	930
33	Ori	4123	05	30.2	+03	16	5.7	6.0	7.3	28	1.9	—
ΟΣ	156	5447	06	46.3	+18	13	6.1	6.8	7.0	234	0.5	1100
Σ	1338	7307	09	19.7	+38	17	5.8	6.5	6.7	269	1.1	400
35	Com	8695	12	52.3	+21	21	5.1*	5.2	7.4	172	1.1	500
Σ	2054	10052	16	23.6	+61	44	5.6	6.0	7.2	353	1.1	—
ϵ^1	Lyr†	11635	18	43.7	+39	38	5.1	5.4	6.5	353	2.6	1200
ϵ^2	Lyr†	11635	18	43.7	+39	38	4.4	5.1	5.3	87	2.3	600
π	Aql	12962	19	47.7	+11	45	5.6	6.0	6.8	108	1.4	—
61	Cyg	14636	21	05.5	+38	34	4.8	5.2	6.0	148	29.9	722
ΟΣ	500	16877	23	36.5	+44	20	5.9	6.4	7.1	0	0.5	—
η	Cas	671	00	47.7	+57	44	3.5*	3.5	7.2	312	12.4	480
Σ	186	1538	01	54.8	+01	45	6.0	6.8	6.8	57	1.3	170
γ	And AB	1630	02	02.4	+42	16	2.1*	2.1	5.1	63	9.7	—
γ	And BC	1630	02	02.4	+42	16	5.1	5.5	6.3	106	0.6	61
ΟΣ	65	2799	03	49.2	+25	32	5.2	5.8	6.2	211	0.4	62
α	CMa	5423	06	44.3	−16	40	−1.4	−1.4	8.5	14	5.4	50
α	Gem	6175	07	33.3	+31	55	1.6	2.0	2.8	80	3.0	500
ζ	Cnc AB	6650	08	11.1	+17	43	5.0	5.6	5.9	194	0.6	60
ζ	Cnc AC	6650	08	11.1	+17	43	5.2	5.4	7.3	77	5.9	1150
σ^2	UMa	7203	09	08.6	+67	13	4.8*	4.8	8.2	358	3.5	1100
γ	Leo	7724	10	18.9	+19	57	1.8	2.1	3.4	124	4.4	620
ξ	UMa	8119	11	17.1	+31	39	3.8	4.3	4.8	70	1.5	60
γ	Vir	8630	12	40.7	−01	21	2.8	3.5	3.5	288	3.1	170
ζ	Boo	9343	14	40.1	+13	49	3.8	4.5	4.5	303	1.0	125
ξ	Boo	9413	14	50.4	+19	12	4.5	4.7	6.8	326	7.1	150
ζ	Her	10157	16	40.6	+31	38	2.8	2.9	5.5	90	1.6	35
τ	Oph	11005	18	01.9	−08	11	4.7	5.2	5.9	280	1.8	280
70	Oph	11046	18	04.5	+02	32	4.0	4.2	6.0	240	1.6	88
δ	Cyg	12880	19	44.4	+45	04	2.9*	2.9	6.3	228	2.4	830
4	Aqr	14360	20	50.4	−05	53	6.0	6.4	7.2	15	0.9	190
τ	Cyg	14787	21	13.9	+37	57	3.7	3.8	6.4	39	0.5	50
μ	Cyg	15270	21	43.2	+28	39	4.5	4.8	6.1	306	1.6	500
ζ	Aqr	15971	22	27.8	−00	08	3.6	4.3	4.5	209	1.9	850
Σ	3050	17149	23	58.5	+33	37	5.8	6.5	6.7	321	1.6	350

*There is a marked colour difference between the components.
†The separation of the two pairs of ε Lyr is 208″.

VARIABLE STARS

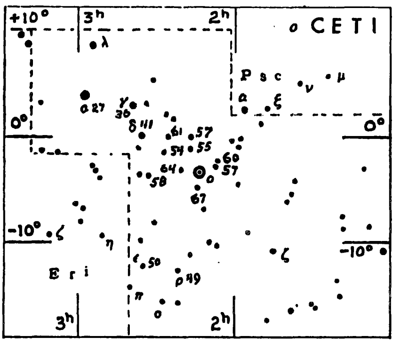
By Janet A. Mattei

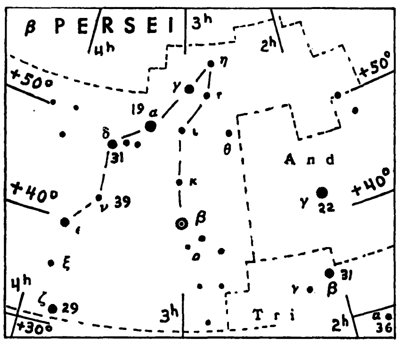
Variable stars provide information about many stellar properties. Depending upon their type, variables can tell the mass, radius, temperature, luminosity, internal and external structure, composition, and evolution of stars. The systematic observation of variable stars is an area in which an amateur astronomer can make a valuable contribution to astronomy.

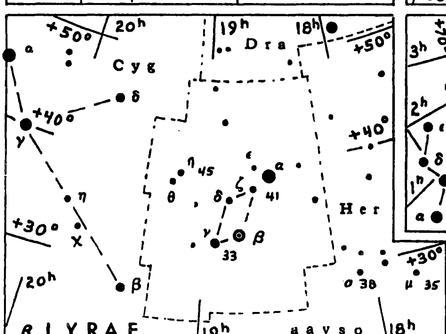
For beginning observers, charts of the fields of four different types of bright variable stars are printed below. On each chart, the magnitudes (with decimal point omitted) of several suitable comparison stars are shown. A brightness estimate of the variable is made using two comparison stars, one brighter, one fainter than the variable. The magnitude, date, and time of each observation are recorded. When a number of observations have been made, a graph of magnitude versus date may be plotted. The shape of this "light curve" depends on the type of variable. Further information about variable star observing may be obtained from the American Association of Variable Star Observers, 25 Birch St., Cambridge, Massachusetts 02138-1205, U.S.A.

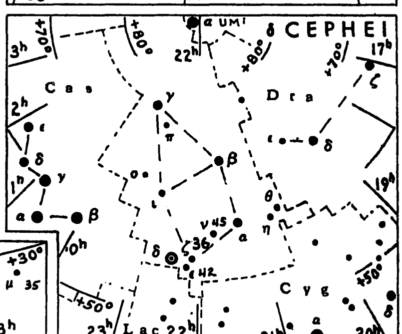
The first table on the next page is a list of long-period variables, brighter than magnitude 8.0 at maximum, and north of −20°. The first column (the Harvard designation of the star) gives the position for the year 1900: the first four figures give the hours and minutes of right ascension, the last two figures the declination in degrees (italicised for southern declinations). The column headed "Max." gives the mean maximum magnitude. The "Period" is in days. The "Epoch" gives the predicted date of the earliest maximum occurring this year; by adding multiples of the period to this epoch the dates of subsequent maxima may be found. These variables may reach maximum two or three weeks before or after the epoch and may remain at maximum for several weeks. This table is prepared using the observations of the American Association of Variable Star Observers.

The second table contains stars which are representative of some other types of variables. The data for the preparation of the predicted epoch of maximum or minimum are taken from the *General Catalog of Variable Stars*, Vols. I and II, 4th ed., for eclipsing binaries and RR Lyrae variables from *Rocznik Astronomiczny Obserwatorium Krakowskiego 1988, International Supplement*.









LONG-PERIOD VARIABLE STARS

Variable	Max. m_v	Per d	Epoch 1989	Variable	Max. m_v	Per d	Epoch 1989
001755 T Cas	7.8	445	July 2	142539 V Boo	7.9	258	Apr. 17
001838 R And	7.0	409	June 10	143227 R Boo	7.2	223	Apr. 20
021143 W And	7.4	397	Nov. 20	151731 S CrB	7.3	361	Nov. 30
0214*03* o Cet	3.4	332	Nov. 14	154639 V CrB	7.5	358	June 23
0228*13* U Cet	7.5	235	Jan. 15	154615 R Ser	6.9	357	May 1
023133 R Tri	6.2	266	Apr. 15	160625 RU Her	8.0	484	Sept. 27
043065 T Cam	8.0	374	Jan. 20	162119 U Her	7.5	406	Nov. 13
0455*14* R Lep	6.8	432	July 14	1621*12* V Oph	7.5	298	Sept. 8
050953 R Aur	7.7	459	June 12	163266 R Dra	7.6	245	Aug. 3
054920 U Ori	6.3	372	Dec. 9	164715 S Her	7.6	307	Oct. 22
0617*02* V Mon	7.0	335	May 10	1702*15* R Oph	7.9	302	Apr. 18
065355 R Lyn	7.9	379	Oct. 23	171723 RS Her	7.9	219	Mar. 13
070122 R Gem	7.1	370	Sept. 25	180531 T Her	8.0	165	Mar. 25
070310 R CMi	8.0	338	Aug. 4	181136 W Lyr	7.9	196	May 12
072708 S CMi	7.5	332	Jan. 27	183308 X Oph	6.8	334	July 19
081112 R Cnc	6.8	362	Nov. 22	190108 R Aql	6.1	300	June 2
081617 V Cnc	7.9	272	Feb. 1	1910*17* T Sgr	8.0	392	Mar. 29
084803 S Hya	7.8	257	Apr. 28	1910*19* R Sgr	7.3	269	May 19
0850*08* T Hya	7.8	288	Sept. 9	193449 R Cyg	7.5	426	Apr. 5
093934 R LMi	7.1	372	July 7	194048 RT Cyg	7.3	190	Apr. 14
094211 R Leo	5.8	313	Apr. 7	194632 χ Cyg	5.2	407	Dec. 22
103769 R UMa	7.5	302	June 14	201647 U Cyg	7.2	465	Sept. 20
1214*18* R Crv	7.5	317	Jan. 7	2044*05* T Aqr	7.7	202	Feb. 22
122001 SS Vir	6.8	355	Jan. 2	210868 T Cep	6.0	390	July 8
123160 T UMa	7.7	257	May 16	213753 RU Cyg	8.0	234	Aug. 13
123307 R Vir	6.9	146	Apr. 1	230110 R Peg	7.8	378	June 4
123961 S UMa	7.8	226	Feb. 21	230759 V Cas	7.9	228	Feb. 23
131546 V CVn	6.8	192	Mar. 30	231508 S Peg	8.0	319	Jan. 26
1327*06* S Vir	7.0	378	July 2	2338*15* R Aqr	6.5	387	Oct. 24
134440 R CVn	7.7	328	Nov. 1	235350 R Cas	7.0	431	—
142584 R Cam	7.9	270	July 24	2357*15* W Cet	7.6	351	July 26

OTHER TYPES OF VARIABLE STARS

Variable		Max. m_v	Min. m_v	Type	Sp. Cl.	Period d	Epoch 1989 U.T.
005381	U Cep	6.7	9.8	Ecl.	B8+gG2	2.49307	Jan. 1.80*
025838	ρ Per	3.3	4.0	Semi R	M4	33–55, 1100	—
030140	β Per	2.1	3.3	Ecl.	B8+G	2.86731	—
035512	λ Tau	3.5	4.0	Ecl.	B3	3.952952	Jan. 2.63*
060822	η Gem	3.1	3.9	Semi R	M3	233.4	—
061907	T Mon	5.6	6.6	δ Cep	F7–K1	27.024649	Jan. 14.54
065820	ζ Gem	3.6	4.2	δ Cep	F7–G3	10.15073	Jan. 4.74
154428	R Cr B	5.8	14.8	R Cr B	cFpep		—
171014	α Her	3.0	4.0	Semi R	M5	50–130, 6 yrs.	—
1842*05*	R Sct	5.0	7.0	RVTau	G0e-K0p	144	—
184633	β Lyr	3.4	4.3	Ecl.	B8	12.93681†	Jan. 2.12*
192242	RR Lyr	6.9	8.0	RR Lyr	A2–F1	0.566839	Jan. 1.39
194700	η Aql	3.5	4.3	δ Cep	F6–G4	7.176641	Jan. 4.90
222557	δ Cep	3.5	4.4	δ Cep	F5–G2	5.366341	Jan. 6.08

*Minimum.

†Changing period.

BRIEF DESCRIPTION OF VARIABLE TYPES

Variable stars are divided into four main classes: Pulsating and eruptive variables where variability is intrinsic due to physical changes in the star or stellar system; eclipsing binary and rotating stars where variability is extrinsic due to an eclipse of one star by another or the effect of stellar rotation. A brief and general description about the major types in each class is given below.

I. *Pulsating Variables*

Cepheids: Variables that pulsate with periods from 1 to 70 days. They have high luminosity and the amplitude of light variation ranges from 0.1 to 2 magnitudes. The prototypes of the group are located in open clusters and obey the well known period-luminosity relation. They are of F spectral class at maximum and G to K at minimum. The later the spectral class of a Cepheid the longer is its period. Typical representative: δ Cephei.

RR Lyrae Type: Pulsating, giant variables with periods ranging from 0.05 to 1.2 days with amplitude of light variation between 1 and 2 magnitudes. They are usually of A spectral class. Typical representative: RR Lyrae.

RV Tauri Type: Supergiant variables with characteristic light curve of alternating deep and shallow minima. The periods, defined as the interval between two deep minima, range from 30 to 150 days. The amplitude of light variation may be as much as 3 magnitudes. Many show long term cyclic variation of 500 to 9000 days. Generally the spectral classes range from G to K. Typical representative: R Scuti.

Long period—Mira Ceti variables: Giant variables that vary with amplitudes from 2.5 to 5 magnitudes or more. They have well defined periodicity, ranging from 80 to 1000 days. They show characteristic emission spectra of late spectral classes of M, C, and S. Typical representative: o Ceti (Mira).

Semiregular Variables: Giants and supergiants showing appreciable periodicity accompanied by intervals of irregularities of light variation.The periods range from 30 to 1000 days with amplitudes not more than 1 to 2 magnitudes in general. Typical representative: R Ursae Minoris.

Irregular Variables: Stars that at times show only a trace of periodicity or none at all. Typical representative: RX Leporis.

II. *Eruptive Variables*

Novae: Close binary systems consisting of a normal star and a white dwarf that increase 7 to 16 magnitudes in brightness in a matter of 1 to several hundreds of days. After the outburst, the star fades slowly until the initial brightness is reached in several years or decades. Near maximum brightness, the spectrum is generally similar to A or F giants. Typical representative: CP Puppis (Nova 1942).

Supernovae: Brightness increases 20 or more magnitudes due to a gigantic stellar explosion. The general appearance of the light curve is similar to novae. Typical representative: CM Tauri (Supernova of A.D. 1054 and the central star of the Crab Nebula).

R Coronae Borealis Type: Highly luminous variables that have non-periodic drops in brightness from 1 to 9 magnitudes, due to the formation of "carbon soot" in the stars' atmosphere. The duration of minima varies from a few months to years. Members of this group have F to K and R spectral class. Typical representative: R Coronae Borealis.

U Geminorum Type: Dwarf novae that have long intervals of quiescence at minimum with sudden rises to maximum. Depending upon the star, the amplitude of eruptions range from 2 to 6 magnitudes, and the duration between outbursts ten to thousands of days. Most of these stars are spectroscopic binaries with periods of few hours. Typical representative: SS Cygni.

Z Camelopardalis Type: Variables similar to U Gem stars in their physical and spectroscopic properties. They show cyclic variations interrupted by intervals of constant brightness (stillstands) lasting for several cycles, approximately one third of the way from maximum to minimum. Typical representative: Z Camelopardalis.

III. *Eclipsing Binaries*

Binary system of stars with the orbital plane lying near the line of sight of the observer. The components periodically eclipse each other, causing decrease in light in the apparent brightness of the system, as is seen and recorded by the observer. The period of the eclipses coincides with the period of the orbital motion of the components. Typical representative: β Persei (Algol).

IV. *Rotating Variables*

Rapidly rotating stars, usually close binary systems, which undergo small amplitude changes in light that may be due to dark or bright spots on their stellar surface. Eclipses may also be present in such systems. Typical representative: R Canum Venaticorum.

THE STAR OF THE YEAR—P CYGNI

P Cygni, the remarkable, especially luminous blue supergiant, is our Star of the Year. When it was discovered in August 1600 by the Dutch astronomer and mathematician Willem Blaeuw of Amsterdam, this now 5th magnitude naked-eye star was in outburst and appeared as a 3rd magnitude star. From its discovery until 1715 its brightness fluctuated drastically between 3rd and 6th magnitudes. Since then it has remained around 5th magnitude, with small amplitudes of variation as long as 18 years and as short as 0.5 days (M. De Groot, 1986, *JAAVSO, 15*, 12).

Because of its sudden brightening in the 17th century, P Cygni is sometimes included in the list of novae and referred to as "Nova Cygni #1." However, it is not an ordinary nova. C.P. Gaposchkin in her book, *The Galactic Novae*, refers to P Cygni as "a bright star which underwent something akin to a shell activity when it brightened to 3rd magnitude in 1600." The evidence for the expanding shell appears in its interesting spectra where strong emission lines are bordered by blue-shifted sharp absorption components (the so-called P Cygni profile) and implies mass loss and more rapid expansion of the outer regions of the shell than the inner.

P Cygni has been in the visual observing program of the AAVSO for decades to look for reoccurences of long-term, large amplitude variations. One observation per week by observers with small telescopes or binoculars is sufficient to monitor its behavior.

P Cygni is an excellent object for photometrists with small-aperture telescopes to monitor. In fact, it is only through continuous photoelectric observations made every clear night that we are able to study its short-term, small-amplitude variations.

Figure 2 is a finder chart both for visual observers and for photometrists. P Cygni is located near 20^h15^m, + 38°. 22 Cygni and 36 Cygni, the comparison and check stars to be used by photometrists, are shown with four-digit magnitudes. The V/(B-V)/(U-B) values for 22 Cygni and 36 Cygni are 4.949/-0.092/-0.523 and 5.594/0.048/0.028, respectively.

The compilation of photoelectric observations in 1985 and 1986 from amateur and professional astronomers (J. Percy *et al.*, 1988, *Astron. Astrophys., 191*, 248) shows that P Cygni varies irregularly by about 0.2 magnitude in the V on time scales ranging from a few days to a few months, with a characteristic time scale of 35 to 40 days. The analysis of the AAVSO visual observations by the same authors suggests that although there is no strict periodicity or regularity, there is some evidence for a long-term variation with a range of 0.2 magnitude.

Figure 1 shows the UBV photoelectric light curve for 1985 (*AAVSO Photoelectric Photometry Newsletter, 7*, No. 2) used in the Percy *et al.* study. As may be seen from this figure, the largest amplitude of variation occurs in V, whereas the (B-V) and

(U-B) color variations are much smaller in amplitude. The cause(s) of variation is not yet very clear — complex pulsation or rotation of the system or even the existence of a companion has been suggested. Visual monitoring will alert the astronomical community to increased activity in P Cygni. Long-term photoelectric monitoring will not only help to find the cause of variation, but correlations between photometric and spectroscopic observations may also help to find the connection between episodes of shell ejection and mass loss in this fascinating variable.

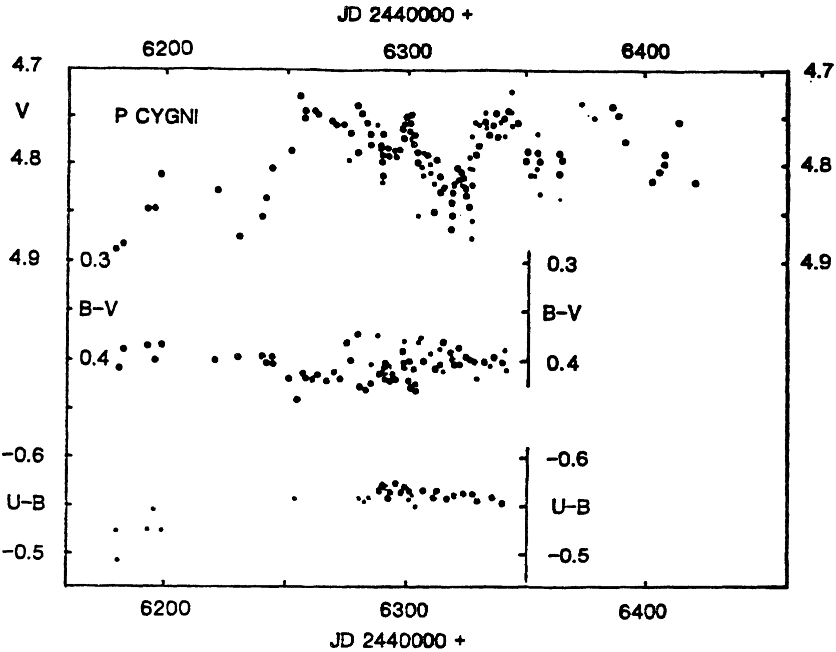


Figure 1. Photoelectric light curve of ***P Cygni*** *for 1985 by AAVSO photometrists (W. E. Clark, H. J. Landis, R. Milton, and R. C. Reisenweber) and astronomers at the University of Toronto, the Hvar Observatory in Yugoslavia, the Ondrejov Observatory in Czechoslovakia, and the Konkoly Observatory in Hungary (*AAVSO Photoelectric Photometry Newsletter, *7, No. 2, 1987).*

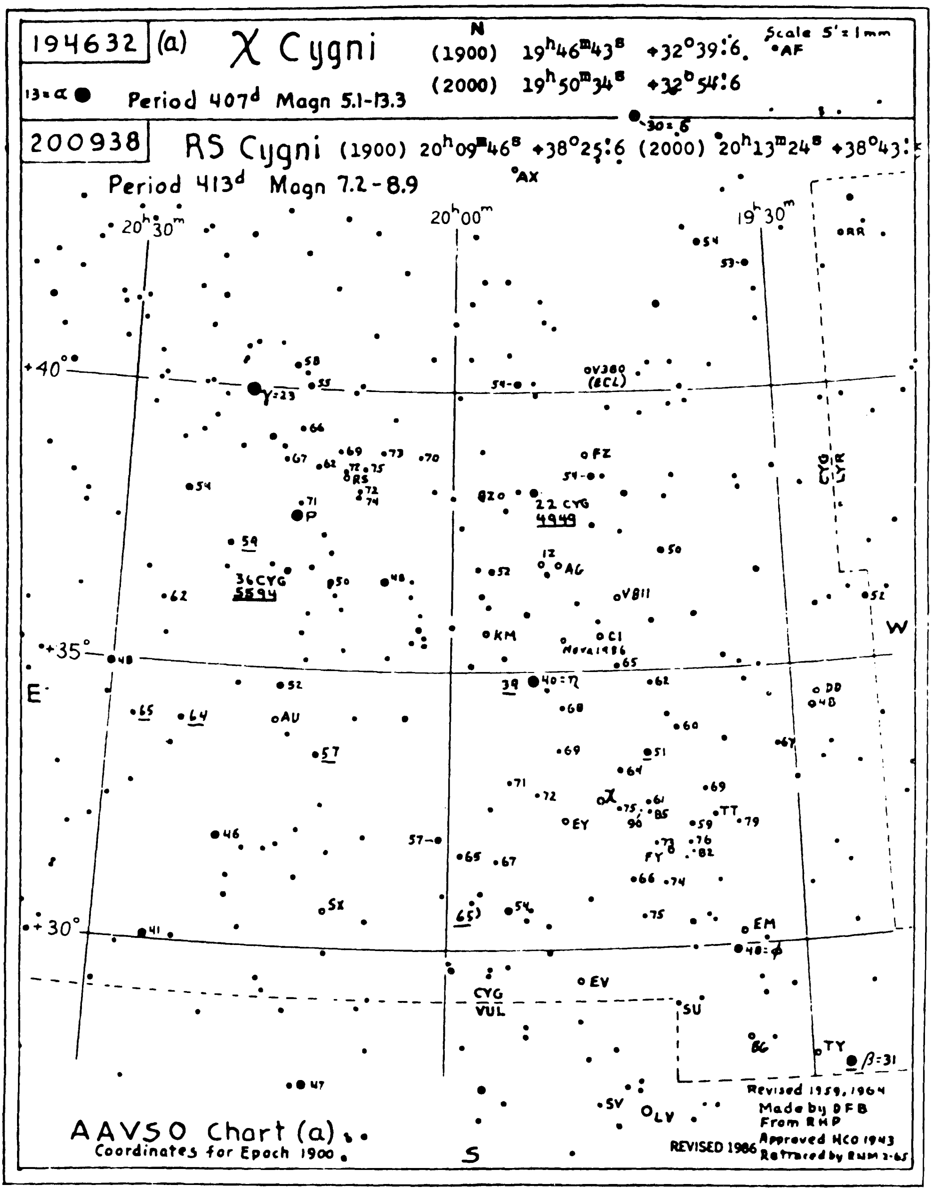


Figure 2. Finding chart for ***P Cygni****, with comparison stars suitable for visual and photoelectric observation. 22 Cygni and 36 Cygni, shown with 4-digit magnitudes, are the comparison and check stars, respectively, for photoelectric observations.*

STAR CLUSTERS

BY ANTHONY MOFFAT

The study of star clusters is crucial for the understanding of stellar structure and evolution. For most purposes, it can be assumed that the stars seen in a given cluster formed nearly simultaneously from the same parent cloud of gas and dust; thus, the basic factor which distinguishes one star from another is the quantity of matter each contains. Comparing one cluster with another, it is essentially only the age and the chemical composition of their stars that differ. But what makes one cluster *appear* different from another in the sky is mainly the degree of concentration and regularity, the spread in magnitude and colour of the member stars, all of which vary mainly with age, and the total number of stars. Extremely young clusters are often irregular in shape with clumps of newly formed stars, pervaded by lanes of obscuring dust and bright nebulosity (e.g. the Orion Nebula around the Trapezium Cluster), while the oldest clusters, if they were fortunate enough not to have already dissipated or been torn apart by external forces, tend to be symmetric in shape, with only the slower-burning, low-mass stars remaining visible; the massive stars will have spent their nuclear fuel and passed to the degenerate graveyard of white dwarfs, neutron stars, or black holes depending on their original mass.

The star clusters in the lists below were selected as the most conspicuous. Two types can be recognized: *open* and *globular*. Open clusters often appear as irregular aggregates of tens to thousands of stars, sometimes barely distinguishable from random fluctuations of the general field; they are concentrated toward the Galactic disk and generally contain stars of chemical abundance like the Sun. They range in age from very young to very old.

Sometimes we observe loose, extended groups of very young stars. When precise methods of photometry, spectroscopy and kinematics are applied, we see that these stars often have a common, but not necessarily strictly coeval, origin. Such loose concentrations of stars are referred to as *associations*. Dynamically, they are generally unbound over time scales of the order of ten million years, being subject to the strong tidal forces of passing clouds and the background Galaxy. Often, they contain sub-concentrations of young open clusters (e.g. the double cluster h and χ Persei of slightly different ages despite their proximity, in the association Per OB1, which stretches over some 6° on the sky), with a strong gradient in age as the star formation process rips through them from one edge to another. In view of their sparse nature, we do not consider it appropriate here to list any of the over 100-odd catalogued associations in the Galaxy.

Globular clusters on the other hand are highly symmetric, extremely old and rich agglomerations of up to several million stars, distributed throughout the Galactic halo but concentrated toward the centre of the Galaxy. Compared to the Sun and other disk stars, they tend to be much less abundant in elements heavier than hydrogen and helium.

The first table includes all well-defined Galactic open clusters with diameters greater than 40′ and/or integrated magnitudes brighter than 5.0, as well as the richest clusters and some of special interest. The apparent integrated photographic magnitude is from Collinder, the angular diameter is generally from Trumpler, and the photographic magnitude of the fifth-brightest star, m_5, is from Shapley, except where in italics, which are new data. The distance is mainly from Becker and Fenkart (*Astr. Astrophys. Suppl.* **4**, 241 (1971)). The earliest spectral type of cluster stars, Sp, is a measure of the age as follows: expressed in millions of years, 05 = 2, B0 = 8, B5 = 70, A0 = 400, A5 = 1000, F0 = 3000 and F5 = 10000.

Open Clusters

NGC or other†	R.A. 1980 h m	Dec. 1980 ° ′	Int. m_{pg}	Diam. ′	m_5	Dist. 1000 l.y.	Sp	Remarks
188	00 42.0	+85 14	9.3	14	14.6	5.0	F2	Oldest known
752	01 56.6	+37 35	6.6	45	9.6	1.2	A5	
869	02 17.6	+57 04	4.3	30	9.5	7.0	B1	h Per
884	02 21.0	+57 02	4.4	30	9.5	8.1	B0	χ Per, M supergiants
Perseus	03 21	+48 32	2.3	240	5	0.6	B1	Moving cl.; α Per
Pleiades	03 45.9	+24 04	1.6	120	4.2	0.41	B6	M45, best known
Hyades	04 19	+15 35	0.8	400	*3.9*	0.15	A2	Moving cl.**, in Taurus
1912	05 27.3	+35 49	7.0	18	9.7	4.6	B5	M38
1976/80	05 34.4	−05 24	2.5	50	*5.5*	1.3	O5	Trapezium, very young
2099	05 51.1	+32 32	6.2	24	9.7	4.2	B8	M37
2168	06 07.6	+24 21	5.6	29	9.0	2.8	B5	M35
2232	06 25.5	−04 44	4.1	*20*	*7*	1.6	B1	
2244	06 31.3	+04 53	5.2	27	*8.0*	5.3	O5	Rosette, very young
2264	06 39.9	+09 54	4.1	30	*8.0*	2.4	O8	S Mon
2287	06 46.2	−20 43	5.0	32	*8.8*	2.2	B4	M41
2362	07 18.0	−24 54	3.8	7	9.4	5.4	O9	τ CMa
2422	07 34.7	−14 27	4.3	30	9.8	1.6	B3	
2437	07 40.9	−14 46	6.6	27	10.8	5.4	B8	M46
2451	07 44.7	−37 55	3.7	37	6	1.0	B5	
2516	07 58.0	−60 51	3.3	50	10.1	1.2	B8	
2546	08 11.8	−37 35	5.0	45	7	2.7	B0	
2632	08 39.0	+20 04	3.9	90	7.5	0.59	A0	Praesepe, M44
IC2391	08 39.7	−52 59	2.6	45	3.5	0.5	B4	
IC2395	08 40.4	−48 07	4.6	20	10.1	2.9	B2	
2682	08 49.3	+11 54	7.4	18	10.8	2.7	F2	M67, very old
3114	10 02.0	−60 01	4.5	37	7	2.8	B5	
IC2602	10 42.6	−64 17	1.6	65	6	0.5	B1	θ Car
Tr 16	10 44.4	−59 36	6.7	10	10	9.6	O3	η Car and Nebula
3532	11 05.5	−58 33	3.4	55	8.1	1.4	B8	
3766	11 35.2	−61 30	4.4	12	8.1	5.8	B1	
Coma	12 24.1	+26 13	2.9	300	5.5	0.3	A1	Very sparse
4755	12 52.4	−60 13	5.2	12	7	6.8	B3	κ Cru, "jewel box"
6067	16 11.7	−54 10	6.5	16	10.9	4.7	B3	G, K supergiants
6231	16 52.6	−41 46	*3.5*	16	7.5	5.8	O9	O supergiants, WR stars
Tr 24	16 55.6	−40 38	*3.5*	60	*7.3*	5.2	O5	
6405	17 38.8	−32 12	4.6	26	8.3	1.5	B4	M6
IC4665	17 45.7	+05 44	5.4	50	7	1.1	B8	
6475	17 52.6	−34 48	3.3	50	7.4	0.8	B5	M7
6494	17 55.7	−19 01	5.9	27	10.2	1.4	B8	M23
6523	18 01.9	−24 23	5.2	45	7	5.1	O5	M8, Lagoon Neb.
6611	18 17.8	−13 48	6.6	8	10.6	5.5	O7	M16, nebula
IC4725	18 30.5	−19 16	6.2	35	9.3	2.0	B3	M25, Cepheid U Sgr
IC4756	18 38.3	+05 26	5.4	50	8.5	1.4	A3	
6705	18 50.0	−06 18	6.8	12.5	12	5.6	B8	M11, very rich
Mel 227	20 08.2	−79 23	5.2	60	9	0.8	B9	
IC1396	21 38.3	+57 25	5.1	60	*8.5*	2.3	O6	Tr 37
7790	23 57.4	+61 06	7.1	4.5	11.7	10.3	B1	Cepheids CEa, CEb and CF Cas

†IC = Index Catalogue; Tr = Trumpler; Mel = Melotte.
**Basic for distance determination.

The table below includes all globular clusters with a total apparent photographic magnitude brighter than about 7.5. The data are taken from a compilation by Arp (*Galactic Structure*, ed. Blaauw and Schmidt, U. Chicago 1965), supplemented by H. S. Hogg's Bibliography (*Publ. David Dunlap Obs.* **2**, No. 12, 1963). The apparent diameter given contains 90% of the stars, except values in italics which are from miscellaneous sources. The concentration class is such that I is the most compact, XII is least. The integrated spectral type varies mainly with the abundances, and m(25) refers to the mean blue magnitude of the 25 brightest stars excluding the 5 brightest, which are liable to fluctuate more. The number of variables known in the cluster is also given. A more detailed, recent catalogue of fundamental data for galactic globular clusters can be found in reviews by Harris and Racine (*Annual Review of Astronomy and Astrophysics, 17,* 241, 1979) and by Webbink (*IAU Symposium No. 113,* p. 541, 1985).

GLOBULAR CLUSTERS

NGC	M or other	R.A. 1980 h m	Dec. 1980 ° ′	Int. m_{pg}	Diam. ′	Conc.	Int. Sp. T.	m(25)	No. Var.	Dist. 1000 l.y.
104 †	47 Tuc	00 23.1	−72 11	4.35	*44*	III	G3	13.54	11	16
1851*		05 13.3	−40 02	7.72	*11.5*	II	F7		3	46
2808		09 11.5	−64 42	7.4	*18.8*	I	F8	15.09	4	30
5139†	ω Cen	13 25.6	−47 12	4.5	*65.4*	VIII	F7	13.01	165	17
5272†	3	13 41.3	+28 29	6.86	9.3	VI	F7	14.35	189	35
5904	5	15 17.5	+02 10	6.69	10.7	V	F6	14.07	97	26
6121	4	16 22.4	−26 28	7.05	22.6	IX	*G0*	13.21	43	14
6205	13	16 41.0	+36 30	6.43	12.9	V	F6	13.85	10	21
6218	12	16 46.1	−01 55	7.58	21.5	IX	F8	14.07	1	24
6254	10	16 56.0	−04 05	7.26	16.2	VII	G1	14.17	3	20
6341	92	17 16.5	+43 10	6.94	12.3	IV	F1	13.96	16	26
6397		17 39.2	−53 40	6.9	*19*	IX	F5	12.71	3	9
6541†		18 06.5	−43 45	7.5	*23.2*	III	F6	13.45	1	13
6656†	22	18 35.1	−23 56	6.15	26.2	VII	F7	13.73	24	10
6723		18 58.3	−36 39	7.37	11.7	VII	G4	14.32	19	24
6752		19 09.1	−60 01	6.8	*41.9*	VI	F6	13.36	1	17
6809	55	19 38.8	−30 59	6.72	21.1	XI	F5	13.68	6	20
7078*	15	21 29.1	+12 05	6.96	9.4	IV	F2	14.44	103	34
7089	2	21 32.4	−00 55	6.94	6.8	II	F4	14.77	22	40

*Bright, compact X-ray sources were discovered in these clusters in 1975.
†These clusters contain dim X-ray sources.

AN EXAMPLE: THE HYADES — A FAMILIAR STAR CLUSTER

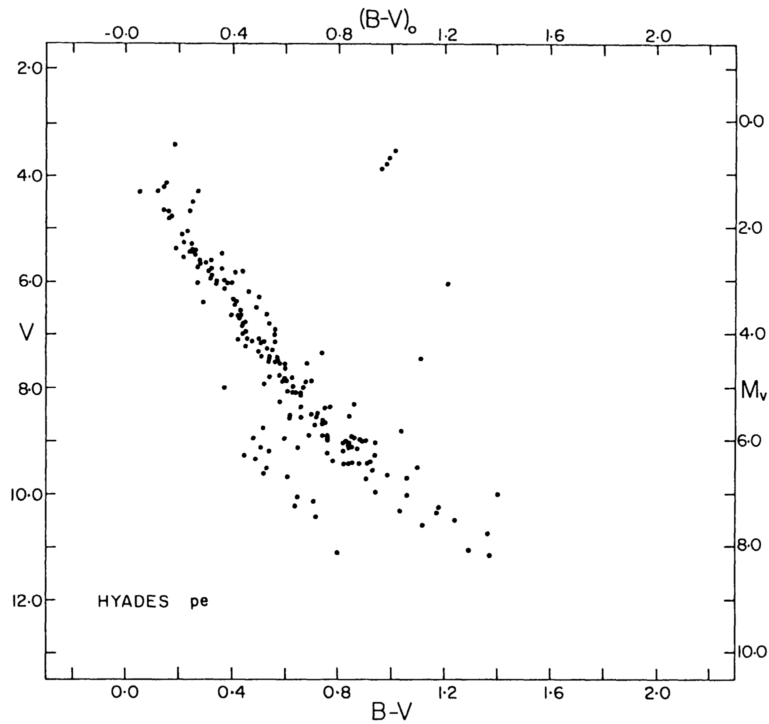
The closest sizeable star cluster to us is the famous Hyades cluster, best visible in the winter evening sky as forming the head of Taurus the bull. The brightest star in the direction of the Hyades is the flaming eye of the bull, the bright orange giant, Aldebaran. However, this association is an artifact of our location in space, for Aldebaran is only 40% as far away and is not a member of the cluster (cf., The Brightest Stars section).

Although the number of stars in the Hyades visible to the naked eye is a couple of dozen, more than three hundred stars ranging down to apparent magnitude 18 have been identified. These stars are more numerous in the vicinity of the face of the bull, but they are spread across the entire constellation of Taurus. The cluster is moderately old, probably several hundred million years. There are no hot, young stars nor any visible nebulosity.

The distance to the Hyades is fundamental in providing the connecting link between the geometric methods for determining distances of nearby stars and the photometric methods used for more distant objects. The distance to the Hyades, about 150 light-years, has been determined by several methods: trigonometric parallaxes of its individual members, the streaming parallax method, dynamical parallaxes of binary stars, and fitting the Hyades' main sequence to the theoretical Zero Age Main Sequence (ZAMS) from stellar models. The stars of the Hyades are moving as a group relative to the Sun. They were closest to the Solar System perhaps a million years ago. Now, as they recede into the galactic void, the directions of their proper motions converge to a point in the sky east of Betelgeuse. (For more information, see *Sky and Telescope*, February 1988, p.138).

The Hyades are interesting for other reasons too. Recently, for example, Einstein satellite data have revealed that more than half of its stars are detectable X-ray sources. Studies like this help greatly in our basic understanding of stars, something best done in star clusters.

Below is a colour-magnitude diagram for the Hyades cluster (G. L. Hagen, *Publ. D. Dunlap Obs.*, *4*, 31, 1970). Apparent visual magnitude is plotted vertically (brighter stars toward the top), and the colours are redder (temperatures cooler) as one moves from left to right. The main diagonal distribution lies close to the ZAMS. At the distance of the Hyades, our Sun would be located at V = 8.0, B-V = 0.63, right in the centre of this distribution (Can you use the information at the top of pages 18 and 170 to confirm these coordinates?). Note that the stars visible to the naked eye are only those near the top of the distribution.



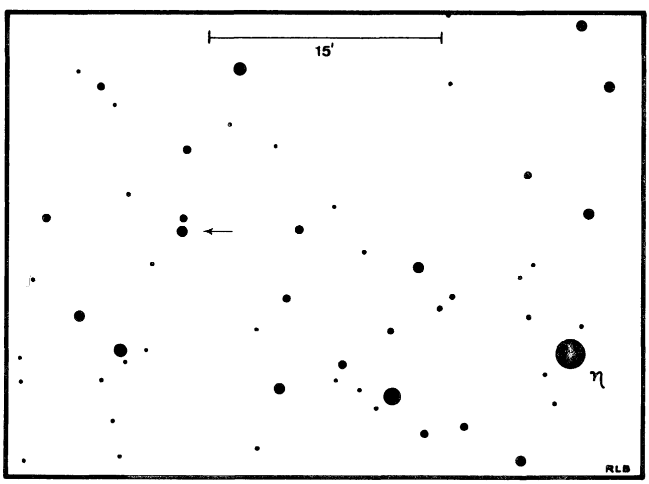
A BLACK HOLE CANDIDATE: CYGNUS X-1

Located near Eta Cygni is a very ordinary-looking star of 9th magnitude. In a catalogue along with thousands of other stars, it is listed as HDE 226868. Spectroscopic studies indicate that it is a *O9.7*Iab star, a very luminous, hot supergiant located several thousand light-years from the Sun. Furthermore, it is a single-line spectroscopic binary, having a 5.6 day period as it orbits around its nearby, unseen companion. In addition, astronomers have known since the early 1970's that this star coincides with one of the strongest galactic X-ray sources in the sky: Cygnus X-1 (C. T. Bolton, *Nature, 235*, 271, 1972). The X-rays extend to quantum energies of 100 keV and higher, corresponding to temperatures exceeding a billion degrees, and vary on time scales as short as tens of milliseconds. The X-rays appear to be generated as material from the supergiant falls onto its nearby, invisible companion.

The data indicate that the unseen companion has a mass in the range of 10 to 16 times that of our Sun. The fact that it is not visible and is associated with intense, rapidly-varying X-rays indicates that it is not an ordinary star and must be very compact. The General Theory of Relativity predicts that an object of this mass and size cannot be supported by any known mechanism: not by thermal pressure (as in its visible companion), not by electron degeneracy pressure (as in a white dwarf), and not by nucleon degeneracy pressure (as in a neutron star). The object can only be a black hole: a totally-collapsed entity around which the fabric of spacetime has closed upon itself.

The arguments are compelling, but indirect. The most one can say is that the companion to HDE 226868 is probably the best candidate for a stellar black hole in our galaxy. (For additional information, see *Sky and Telescope, 75*, 28, 1988).

At 9th magnitude, the supergiant HDE 226868 is visible in any small telescope. Since it is less than half a degree from the 4th magnitude, yellow star Eta Cygni, it is easy to locate (Eta Cygni is the star in the neck of the swan, next to the "C" in CYGNUS on the September all-sky star chart at the back of this Handbook). Any low magnification will more than encompass the entire field shown in the finder chart below. North is upward, Eta Cygni is at the lower right, and HDE 226868 is indicated by the small arrow. The chart magnitude limit is about 13. Although HDE 226868 is a blue supergiant, in telescopes with sufficient aperture to cause colour to appear, this star appears orange because of heavy reddening by intervening dust. Don't mistake the blue star immediately north of HDE 226868 for the latter! (RLB)



NEBULAE

GALACTIC NEBULAE

By William Herbst

The following objects were selected from the brightest and largest of the various classes to illustrate the different types of interactions between stars and interstellar matter in our galaxy. *Emission regions* (HII) are excited by the strong ultraviolet flux of young, hot stars and are characterized by the lines of hydrogen in their spectra. *Reflection nebulae* (Ref) result from the diffusion of starlight by clouds of interstellar dust. At certain stages of their evolution stars become unstable and explode, shedding their outer layers into what becomes a *planetary nebula* (Pl) or a *supernova remnant* (SN). Protostellar nebulae (PrS) are objects still poorly understood; they are somewhat similar to the reflection nebulae, but their associated stars, often variable, are very luminous infrared stars which may be in the earliest stages of stellar evolution. Also included in the selection are three *extended complexes* (Comp) of special interest for their rich population of dark and bright nebulosities of various types. In the table S is the optical surface brightness in magnitude per square second of arc of representative regions of the nebula, and m* is the magnitude of the associated star.

NGC	M	Con	α 1980 δ h m	° ′	Type	Size ′	S mag. sq″	m *	Dist. 10^3 l.y.	Remarks
1435		Tau	03 46.3	+24 01	Ref	15	20	4	0.4	Merope nebula
1535		Eri	04 13.3	−12 48	Pl	0.5	17	12		
1952	1	Tau	05 33.3	+22 05	SN	5	19	16v	4	"Crab" + pulsar
1976	42	Ori	05 34.3	−05 25	HII	30	18	4	1.5	Orion nebula
2070		Dor	05 38.7	−69 06	HII	20	—	13	200	Tarantula Neb.
ζOri		Ori	05 39.8	−01 57	Comp	2°			1.5	Incl. "Horsehead"
2068	78	Ori	05 45.8	+00 02	Ref	5	20		1.5	
IC443		Gem	06 16.4	+22 36	SN	40			2	
2244		Mon	06 31.3	+04 53	HII	50	21	7	3	Rosette neb.
2261		Mon	06 38.0	+08 44	PrS	2		12v	4	Hubble's var. neb.
2392		Gem	07 28.0	+20 57	Pl	0.3	18	10	10	Clown face neb.
2626		Vel	08 34.9	−40 34	Ref	2	—	10	3	
3132		Vel	10 06.2	−40 19	Pl	1	17	10	—	Eight-Burst
3324		Car	10 36.7	−58 32	HII	15	—	8	9	
3372		Car	10 44.3	−59 35	HII	80	—	6v	9	Carina Neb.
3503		Car	11 00.5	−60 37	Ref	3	—	11	9	
3587	97	UMa	11 13.6	+55 08	Pl	3	21	13	12	Owl nebula
—		Cru	12 50	−63	Dark	6°	—	—	0.5	Coal Sack
5189		Mus	13 32.4	−65 54	HII	150	—	10	—	
ρOph		Oph	16 24.4	−23 24	Comp	4°			0.5	Bright + dark neb.
6514	20	Sgr	18 01.2	−23 02	HII	15	19		3.5	Trifid nebula
6523	8	Sgr	18 02.4	−24 23	HII	40	18		4.5	Lagoon nebula
6543		Dra	17 58.6	+66 37	Pl	0.4	15	11	3.5	
6618	17	Sgr	18 19.7	−16 12	HII	20	19		3	Horseshoe neb.
6720	57	Lyr	18 52.9	+33 01	Pl	1.2	18	15	5	Ring nebula
6726		CrA	19 00.4	−36 56	PrS	5	—	7	0.5	
6853	27	Vul	19 58.6	+22 40	Pl	7	20	13	3.5	Dumb-bell neb.
6888		Cyg	20 11.6	+38 21	HII	15				
γCyg		Cyg	20 21.5	+40 12	Comp	6°				HII + dark neb.
6960/95		Cyg	20 44.8	+30 38	SN	150			2.5	Cygnus loop
7000		Cyg	20 58.2	+44 14	HII	100	22		3.5	N. America neb.
7009		Aqr	21 03.0	−11 28	Pl	0.5	16	12	3	Saturn nebula
7027		Cyg	21 06.4	+42 09	Pl	0.2	15	13		
7129		Cep	21 42.5	+65 00	Ref	3	21	10	2.5	Small cluster
7293		Aqr	22 28.5	−20 54	Pl	13	22	13		Helix nebula

THE MESSIER CATALOGUE

BY ALAN DYER

In the late 1700's Charles Messier compiled a list of deep-sky objects to aid prospective comet-hunters. Some of these objects he discovered himself; some were first seen by other astronomers of the day. Messier's Catalogue provides a selection of the brightest and best deep-sky wonders north of declination 35° S. The Messier numbers do not follow a neat sequence across the sky. Rather, they are numbered in the order he "discovered" them. Messier never did produce a list with entries re-numbered in order of right ascension, though that was his intention.

In our version of Messier's Catalogue, we've listed the objects by season *for the evening observer*, grouping the objects within their respective constellations. The constellations are then listed roughly in order of increasing right ascension, i.e. constellations further to the east and which rise later in the night are further down the list. This is to help plan the sequence of an evening's observing and to help novice observers learn which Messiers belong to the various constellations.

The identity of some Messier objects is controversial. Some believe that M91 and M102 are mistaken observations of M58 and M101 respectively. M104 to M109 were found by a colleague, Pierre Mechain, and reported to Messier for inclusion in his Catalogue. NGC 205, one of the companion galaxies to M31, was apparently found by Messier but never included in the Catalogue. Modern day observers have dubbed this object M110. In our list, we have included 110 entries, including two objects that some have suggested as alternative candidates for M91 and M102.

Modern-day Messier hunters often wonder what telescopes Messier himself used. The largest were 20-cm and 19-cm reflectors. However, their speculum metal mirrors had the equivalent light-gathering power of a modern 8 to 10-cm telescope. He also used a number of 90-mm refractors.

The columns contain: Messier's number (M); the constellation; the object's New General Catalogue (NGC) number; the type of object; its epoch 2000 co-ordinates (compatible with *Sky Atlas 2000.0* and *Uranometria*); and the visual magnitude. (Data taken from *Sky Catalogue 2000.0*)

OC = open cluster, GC = globular cluster, PN = planetary nebula, EN = emission nebula, RN = reflection nebula, SNR = supernova remnant, G = galaxy, with the type of galaxy listed. Objects marked '!!' are spectacular showpieces. The 'Seen' column is for checking off the Messiers. The most difficult for northern observers are M83 and the objects in southern Sagittarius and Scorpius.

R.A.S.C. members who have seen all 110 objects on this list are eligible for a Messier Certificate. Contact your local Centre or R.A.S.C. National Office for details.

Seen	M	Con	NGC	Type	R.A. (2000) h m	Dec ° ′	m_V	Remarks
The Winter Sky								
....	1	Tau	1952	SNR	05 34.5	+22 01	8.4	!! famous Crab Nebula supernova remnant
....	45	Tau	—	OC	03 47.0	+24 07	1.2	!! Pleiades; use low power; look for nebulosity
....	36	Aur	1960	OC	05 36.1	+34 08	6.0	best at low power; bright but scattered group
....	37	Aur	2099	OC	05 52.4	+32 33	5.6	!! finest of 3 Auriga clusters; very rich
....	38	Aur	1912	OC	05 28.7	+35 50	6.4	look for the small cluster NGC 1907 1/2° S
....	42	Ori	1976	EN	05 35.4	−05 27	≈ 4	!! Orion Nebula ! ; a magnificent object
....	43	Ori	1982	EN	05 35.6	−05 16	≈ 9	detached part of Orion Nebula; in same field
....	78	Ori	2068	RN	05 46.7	+00 03	≈ 8	featureless reflection nebula
....	79	Lep	1904	GC	05 24.5	−24 33	8.0	20-cm telescope needed to resolve
....	35	Gem	2168	OC	06 08.9	+24 20	5.1	!! look for small cluster NGC 2158 1/4° SW
....	41	CMa	2287	OC	06 47.0	−20 44	4.5	4° S of Sirius; bright but coarse cluster
....	50	Mon	2323	OC	07 03.2	−08 20	5.9	between Sirius and Procyon; use low power
....	46	Pup	2437	OC	07 41.8	−14 49	6.1	!! contains planetary nebula NGC 2438
....	47	Pup	2422	OC	07 36.6	−14 30	4.4	coarse cluster; 1.5° W of M46
....	93	Pup	2447	OC	07 44.6	−23 52	6.2	compact, bright cluster; fairly rich
....	48	Hya	2548	OC	08 13.8	−05 48	5.8	former 'lost' Messier object; sparse group

Seen	M	Con	NGC	Type	R.A. (2000) h m	Dec ° ′	m_V	Remarks
The Spring Sky								
....	44	Cnc	2632	OC	08 40.1	+19 59	3.1	!! Beehive Cluster; use low power & wide field
....	67	Cnc	2682	OC	08 50.4	+11 49	6.9	one of the oldest star clusters
....	40	UMa	—	—	12 22.4	+58 05	8.0	double star Winnecke 4; separation of 50"
....	81	UMa	3031	G-Sb	09 55.6	+69 04	6.8	!! bright spiral; M82 $^1/_2$° N
....	82	UMa	3034	G-Irr	09 55.8	+69 41	8.4	!! the 'exploding' galaxy; look for structure
....	97	UMa	3587	PN	11 14.8	+55 01	11.2	!! Owl Nebula; appears brighter than 11^{m}2
....	101	UMa	5457	G-Sc	14 03.2	+54 21	7.7	!! Pinwheel Galaxy; face-on spiral; diffuse
....	108	UMa	3556	G-Sc	11 11.5	+55 40	10.0	nearly edge-on; very close to M97
....	109	UMa	3992	G-Sb	11 57.6	+53 23	9.8	barred spiral near γ UMa
....	65	Leo	3623	G-Sb	11 18.9	+13 05	9.3	!! bright elongated spiral
....	66	Leo	3627	G-Sb	11 20.2	+12 59	9.0	!! M65 & NGC 3628 in same field
....	95	Leo	3351	G-SBb	10 44.0	+11 42	9.7	bright barred spiral
....	96	Leo	3368	G-Sbp	10 46.8	+11 49	9.2	M95 in same field
....	105	Leo	3379	G-E1	10 47.8	+12 35	9.3	very near M95 and M96
....	53	Com	5024	GC	13 12.9	+18 10	7.7	15-cm telescope needed to resolve
....	64	Com	4826	G-Sb	12 56.7	+21 41	8.5	!! Black Eye Galaxy; 'eye' needs large aperture
....	85	Com	4382	G-Ep	12 25.4	+18 11	9.3	bright elliptical shape
....	88	Com	4501	G-Sb	12 32.0	+14 25	9.5	bright multiple-arm spiral
....	91	Com	4548	G-SBb	12 35.4	+14 30	10.2	some lists say M91 is M58, not NGC 4548
....	98	Com	4192	G-Sb	12 13.8	+14 54	10.1	nearly edge-on spiral near the star 6 Comae B.
....	99	Com	4254	G-Sc	12 18.8	+14 25	9.8	nearly face-on spiral near M98
....	100	Com	4321	G-Sc	12 22.9	+15 49	9.4	face-on spiral with starlike nucleus
....	49	Vir	4472	G-E4	12 29.8	+08 00	8.4	very bright elliptical
....	58	Vir	4579	G-SB	12 37.7	+11 49	9.8	bright barred spiral; M59 and M60 1° East
....	59	Vir	4621	G-E3	12 42.0	+11 39	9.8	bright elliptical paired with M60
....	60	Vir	4649	G-E1	12 43.7	+11 33	8.8	bright elliptical with M59 and NGC 4647
....	61	Vir	4303	G-Sc	12 21.9	+04 28	9.7	face-on two-armed spiral
....	84	Vir	4374	G-E1	12 25.1	+12 53	9.3	M86 and many NGC's nearby; lots to explore!
....	86	Vir	4406	G-E3	12 26.2	+12 57	9.2	in richest part of Coma-Virgo galaxy cluster
....	87	Vir	4486	G-E1	12 30.8	+12 24	8.6	the one with the famous jet and black hole
....	89	Vir	4552	G-E0	12 35.7	+12 33	9.8	resembles M87 but smaller
....	90	Vir	4569	G-Sb	12 36.8	+13 10	9.5	bright spiral; near M89
....	104	Vir	4594	G-Sb	12 40.0	−11 37	8.3	!! Sombrero Galaxy; look for dust lane
....	3	CVn	5272	GC	13 42.2	+28 23	6.4	!! contains many variable stars
....	51	CVn	5194/5	G-Sc	13 29.9	+47 12	8.1	!! Whirlpool Galaxy; superb in big telescope
....	63	CVn	5055	G-Sb	13 15.8	+42 02	8.6	!! Sunflower Galaxy; bright, elongated
....	94	CVn	4736	G-Sbp	12 50.9	+41 07	8.1	very bright and very comet-like
....	106	CVn	4258	G-Sbp	12 19.0	+47 18	8.3	!! large bright spiral
....	68	Hya	4590	GC	12 39.5	−26 45	8.2	15-cm telescope needed to resolve
....	83	Hya	5236	G-Sc	13 37.0	−29 52	10.1	large and diffuse; tough from northern latitude
....	102	Dra	5866	G-E6p	15 06.5	+55 46	10.0	or is M102 = M101? (look for 5907 nearby)
....	5	Ser	5904	GC	15 18.6	+02 05	5.8	!! one of the finest globulars
The Summer Sky								
....	13	Her	6205	GC	16 41.7	+36 28	5.9	!! Hercules Cluster ! ; NGC 6207 $^1/_2$° NE
....	92	Her	6341	GC	17 17.1	+43 08	6.5	9° NE of M13; fine object but often overlooked
....	9	Oph	6333	GC	17 19.2	−18 31	7.9	smallest of Ophiuchus globulars
....	10	Oph	6254	GC	16 57.1	−04 06	6.6	rich cluster; M12 3° NW
....	12	Oph	6218	GC	16 47.2	−01 57	6.6	loose globular cluster
....	14	Oph	6402	GC	17 37.6	−03 15	7.6	20-cm telescope needed to resolve
....	19	Oph	6273	GC	17 02.6	−26 16	7.2	oblate globular; M62 4° South
....	62	Oph	6266	GC	17 01.2	−30 07	6.6	unsymmetrical; in rich field
....	107	Oph	6171	GC	16 32.5	−13 03	8.1	small, faint globular

Seen	M	Con	NGC	Type	R.A. (2000) Dec		m$_V$	Remarks
Summer Sky continued								
					h m	° ′		
....	4	Sco	6121	GC	16 23.6	–26 32	5.9	bright globular near Antares
....	6	Sco	6405	OC	17 40.1	–32 13	4.2	!! Butterfly Cluster; best at low power
....	7	Sco	6475	OC	17 53.9	–34 49	3.3	!! excellent in binoculars or rich-field telescope
....	80	Sco	6093	GC	16 17.0	–22 59	7.2	very compressed globular
....	16	Ser	6611	EN+OC	18 18.8	–13 47	6.0	Eagle Nebula with open cl.; use nebula filter
....	8	Sgr	6523	EN	18 03.8	–24 23	5.8	!! Lagoon Nebula with open cl. NGC 6530
....	17	Sgr	6618	EN	18 20.8	–16 11	≈ 7	!! Swan or Omega Nebula ! ; use nebula filter
....	18	Sgr	6613	OC	18 19.9	–17 08	6.9	sparse cluster; 1° S of M17
....	20	Sgr	6514	E/RN	18 02.6	–23 02	≈ 8.5	!! Trifid Nebula; emission & reflection nebula
....	21	Sgr	6531	OC	18 04.6	–22 30	5.9	0.7° NE of M20; sparse cluster
....	22	Sgr	6656	GC	18 36.4	–23 54	5.1	spectacular from southern latitude
....	23	Sgr	6494	OC	17 56.8	–19 01	5.5	bright, loose cluster
....	24	Sgr	—	—	18 16.9	–18 29	4.5	rich star cloud; contains open cl. NGC 6603
....	25	Sgr	I 4725	OC	18 31.6	–19 15	4.6	bright but sparse cluster
....	28	Sgr	6626	GC	18 24.5	–24 52	6.9	compact globular near M22
....	54	Sgr	6715	GC	18 55.1	–30 29	7.7	not easily resolved
....	55	Sgr	6809	GC	19 40.0	–30 58	7.0	bright, loose globular
....	69	Sgr	6637	GC	18 31.4	–32 21	7.7	small, poor globular
....	70	Sgr	6681	GC	18 43.2	–32 18	8.1	small globular 2° E of M69
....	75	Sgr	6864	GC	20 06.1	–21 55	8.6	small and distant globular; 59 000 L.Y. away
....	11	Sct	6705	OC	18 51.1	–06 16	5.8	!! Wild Duck Cluster; perhaps the best open cl.
....	26	Sct	6694	OC	18 45.2	–09 24	8.0	bright, coarse cluster
....	56	Lyr	6779	GC	19 16.6	+30 11	8.2	within a rich starfield
....	57	Lyr	6720	PN	18 53.6	+33 02	9.0	!! Ring Nebula ! ; 15^m central star very tough
....	71	Sge	6838	GC	19 53.8	+18 47	8.3	loose globular; looks like an open cluster
....	27	Vul	6853	PN	19 59.6	+22 43	8.1	!! Dumbbell Nebula ! ; superb object
....	29	Cyg	6913	OC	20 23.9	+38 32	6.6	small, poor open cluster 2° S of γ Cygni
....	39	Cyg	7092	OC	21 32.2	+48 26	4.6	very sparse cluster; use low power
The Autumn Sky								
....	2	Aqr	7089	GC	21 33.5	–00 49	6.5	20-cm telescope needed to resolve
....	72	Aqr	6981	GC	20 53.5	–12 32	9.4	near NGC 7009, the Saturn Nebula
....	73	Aqr	6994	OC	20 58.9	–12 38	—	group of 4 stars only; an 'asterism'
....	15	Peg	7078	GC	21 30.0	+12 10	6.4	rich, compact globular
....	30	Cap	7099	GC	21 40.4	–23 11	7.5	toughest object in one-night Messier marathon
....	52	Cas	7654	OC	23 24.2	+61 35	6.9	young, rich cluster; faint Bubble Neb. nearby
....	103	Cas	581	OC	01 33.2	+60 42	7.4	3 NGC clusters nearby
....	31	And	224	G-Sb	00 42.7	+41 16	3.4	!! Andromeda Gal.; 4° wide; look for dust lanes
....	32	And	221	G-E2	00 42.7	+40 52	8.2	closest companion to M31
....	110	And	205	G-E6	00 40.4	+41 41	8.0	more distant companion to M31
....	33	Tri	598	G-Sc	01 33.9	+30 39	5.7	large, diffuse spiral; requires dark sky
....	74	Psc	628	G-Sc	01 36.7	+15 47	9.2	faint, elusive spiral; difficult in small telescopes
....	77	Cet	1068	G-Sbp	02 42.7	–00 01	8.8	a Seyfert galaxy; starlike nucleus
....	34	Per	1039	OC	02 42.0	+42 47	5.2	best at very low power
....	76	Per	650-1	PN	01 42.4	+51 34	11.5	Little Dumbbell; faintest Messier object

NUMERICAL LISTING OF MESSIER OBJECTS

M	SKY	Con	M	SKY	Con	M	SKY	Con	M	SKY	Con	M	SKY	Con
1	WIN	Tau	**23**	SUM	Sgr	**45**	WIN	Tau	**67**	SPR	Cnc	**89**	SPR	Vir
2	AUT	Aqr	**24**	SUM	Sgr	**46**	WIN	Pup	**68**	SPR	Hya	**90**	SPR	Vir
3	SPR	CVn	**25**	SUM	Sgr	**47**	WIN	Pup	**69**	SUM	Sgr	**91**	SPR	Com
4	SUM	Sco	**26**	SUM	Sct	**48**	WIN	Hya	**70**	SUM	Sgr	**92**	SUM	Her
5	SPR	Ser	**27**	SUM	Vul	**49**	SPR	Vir	**71**	SUM	Sge	**93**	WIN	Pup
6	SUM	Sco	**28**	SUM	Sgr	**50**	WIN	Mon	**72**	AUT	Aqr	**94**	SPR	CVn
7	SUM	Sco	**29**	SUM	Cyg	**51**	SPR	CVn	**73**	AUT	Aqr	**95**	SPR	Leo
8	SUM	Sgr	**30**	AUT	Cap	**52**	AUT	Cas	**74**	AUT	Psc	**96**	SPR	Leo
9	SUM	Oph	**31**	AUT	And	**53**	SPR	Com	**75**	SUM	Sgr	**97**	SPR	UMa
10	SUM	Oph	**32**	AUT	And	**54**	SUM	Sgr	**76**	AUT	Per	**98**	SPR	Com
11	SUM	Sct	**33**	AUT	Tri	**55**	SUM	Sgr	**77**	AUT	Cet	**99**	SPR	Com
12	SUM	Oph	**34**	AUT	Per	**56**	SUM	Lyr	**78**	WIN	Ori	**100**	SPR	Com
13	SUM	Her	**35**	WIN	Gem	**57**	SUM	Lyr	**79**	WIN	Lep	**101**	SPR	UMa
14	SUM	Oph	**36**	WIN	Aur	**58**	SPR	Vir	**80**	SUM	Sco	**102**	SPR	Dra
15	AUT	Peg	**37**	WIN	Aur	**59**	SPR	Vir	**81**	SPR	UMa	**103**	AUT	Cas
16	SUM	Ser	**38**	WIN	Aur	**60**	SPR	Vir	**82**	SPR	UMa	**104**	SPR	Vir
17	SUM	Sgr	**39**	SUM	Cyg	**61**	SPR	Vir	**83**	SPR	Hya	**105**	SPR	Leo
18	SUM	Sgr	**40**	SPR	UMa	**62**	SUM	Oph	**84**	SPR	Vir	**106**	SPR	CVn
19	SUM	Oph	**41**	WIN	CMa	**63**	SPR	CVn	**85**	SPR	Com	**107**	SUM	Oph
20	SUM	Sgr	**42**	WIN	Ori	**64**	SPR	Com	**86**	SPR	Vir	**108**	SPR	UMa
21	SUM	Sgr	**43**	WIN	Ori	**65**	SPR	Leo	**87**	SPR	Vir	**109**	SPR	UMa
22	SUM	Sgr	**44**	SPR	Cnc	**66**	SPR	Leo	**88**	SPR	Com	**110**	AUT	And

DEEP-SKY OBSERVING HINTS

In the 1960's and 70's, telescopes over 20-cm aperture were owned by only a handful of advanced observers. Today, 25-cm to 45-cm Dobson-mounted reflectors are common-place, and deep-sky observing has become the main pastime of many amateur astronomers.

However, owners of small aperture instruments shouldn't think they are shut out of deep-sky viewing. In a dark sky, an 8 to 10-cm telescope will show all the Messiers, and reveal hundreds of the brighter NGC objects. In fact, many large objects are best seen in fast (f/4–f/6) small aperture telescopes or in big binoculars. Contrary to popular belief, even slow f/ratio instruments (f/11–f/16) are useful; their only disadvantage is the difficulty of achieving a low-power wide-field. No matter what telescope you use, here are a few techniques for getting the most out of deep-sky exploring:

- Always plan each night's observing. Prepare a list of a dozen or so objects for that night. Hunt them down on star charts first during the day to become familiar with their location.
- Seek out dark skies. A black sky improves contrast and makes up for a lack of aperture.
- To preserve night vision, always use a dim flashlight for reading charts, preferably a red light.
- Avoid prolonged exposure to bright sunlight earlier in the day (such as a day at the beach). It will reduce your ability to dark adapt and make for very tired eyes at night.
- Don't depend on setting circles. Learn to find your way around the sky by star-hopping through the constellations. Besides, in a portable telescope setting circles will rarely be accurate.
- Use averted vision. Look to one side of an object to place it on a more sensitive part of the retina.
- Another technique for picking out faint objects is to jiggle the telescope (and the image) slightly.
- Don't be afraid to use high power. It often brings out small faint objects like planetary nebulas and galaxies, plus resolves detail in globulars, in small rich open clusters, and in bright galaxies.
- Try a nebula filter on emission and planetary nebulas. Even in a dark sky, they can dramatically enhance the view of these kinds of objects, though the degree of effect varies from object to object.
- Be comfortable. Sit down while at the eyepiece and be sure to dress very warmly.
- Take time to examine each object. Don't be in a rush to check off as many objects as possible each night. Make notes. Try drawing each object. It will help train your eye to see subtle detail.
- Collimate and clean your optics. A poorly maintained telescope will produce distorted star images, reduce the image contrast, and make it more difficult to see faint stars and other threshold objects.

THE FINEST N.G.C. OBJECTS

BY ALAN DYER

The "New General Catalogue" of deep-sky objects was originally published by J.L.E. Dreyer in 1888, a work that expanded upon the earlier "General Catalogue" published by John Herschel in 1864. Supplementary "Index Catalogues" were published in 1895 and 1908. Together, the NGC and two IC's contain descriptions and positions of 13 226 galaxies, clusters and nebulas. (The NGC alone contains 7 840 entries. As a matter of interest NGC 1 is a 13th mag. galaxy in Pegasus.) In 1973, Jack Sulentic and William Tifft published *The Revised New General Catalogue* (RNGC) with updated data (printed by the University of Arizona Press). For more details about the NGC, see Helen Sawyer Hogg's article in the 1988 edition of the *R.A.S.C. Observer's Handbook.*

Most NGC objects are within reach of amateur telescopes. Indeed, the brightness and size of the best NGC's rivals those of the better known deep-sky targets of the Messier Catalogue (almost all of which are also in the NGC). To match the Messier Catalogue, this list contains 110 of the finest NGC objects visible from mid-northern latitudes. The arrangement is similar to that used in the Messier list. At least a 15-cm telescope will be required to complete the list.

The *Wil Tirion Sky Atlas 2000.0*, the sets of index card charts called *AstroCards*, or the *Uranometria 2000.0* star atlas are recommended finder aids. For more information about these and many other deep-sky objects, see the 3-volume *Burnham's Celestial Handbook* and the series of *Webb Society Deep-Sky Observer's Handbooks.*

OC = open cluster, GC = globular cluster, PN = planetary nebula, EN = emission nebula, RN = reflection nebula, E/RN = combination emission and reflection nebula, DN = dark nebula, SNR = supernova remnant, G = galaxy (with the Hubble classification also listed). Sizes of objects are in minutes of arc, with the exception of planetary nebulas which are given in seconds of arc. (Most galaxies will appear smaller than size listed.) For open clusters, the number of stars (*) is also given. All magnitudes are visual. Entries marked with a '!!' are showpiece objects.

(Most data taken from *Sky Catalogue 2000.0 Vol. 2*. Where unavailable in *Sky Catalogue*, some visual magnitudes taken from *Webb Society Handbooks*, from *Burnham's Celestial Handbook*, or from *Atlas Coeli Catalogue 1950.0.*)

No.	NGC	Con	Type	R.A. (2000)	Dec	m_V	Size	Remarks
The Autumn Sky								
				h m	° ′			
1	7009	Aqr	PN	21 04.2	−11 22	8.3	25"	!! Saturn Nebula; small bright oval
2	7293	Aqr	PN	22 29.6	−20 48	6.5	770"	!! Helix Nebula; large, diffuse; use filter
3	7331	Peg	G-Sb	22 37.1	+34 25	9.5	10.7 x 4.0	!! large, bright spiral galaxy
4	7635	Cas	EN	23 20.7	+61 12	—	15 x 8	Bubble Neb.; very faint; 1/2° SW of M52
5	7789	Cas	OC	23 57.0	+56 44	6.7	16	!! 300*; faint but very rich cluster
6	185	Cas	G-E0	00 39.0	+48 20	11.7	≈ 2 x 2	companion to M31; paired with NGC 147
7	281	Cas	EN	00 52.8	+56 36	—	35 x 30	!! large, faint nebulosity near η Cas.
8	457	Cas	OC	01 19.1	+58 20	6.4	13	80*; rich; one of the best Cas. clusters
9	663	Cas	OC	01 46.0	+61 15	7.1	16	80*; look for NGC's 654 and 659 nearby
10	IC 289	Cas	PN	03 10.3	+61 19	12.3	34"	dim oval smudge; use nebula filter
11	7662	And	PN	23 25.9	+42 33	9.2	20"	!! Blue Snowball; annular at high power
12	891	And	G-Sb	02 22.6	+42 21	10	13.5 x 2.8	!! faint, classic edge-on with dust lane
13	253	Scl	G-Scp	00 47.6	−25 17	7.1	25.1 x 7.4	!! very large and bright but at low altitude
14	772	Ari	G-Sb	01 59.3	+19 01	10.3	7.1 x 4.5	diffuse spiral galaxy
15	246	Cet	PN	00 47.0	−11 53	8.0	225"	faint (closer to 11th); dark mottling
16	936	Cet	G-SBa	02 27.6	−01 09	10.1	5.2 x 4.4	near M77; NGC 941 in same field
17	869/84	Per	OC	02 20.0	+57 08	≈ 4.4	30 / 30	!! Double Cluster; 350*; use low mag.
18	1023	Per	G-E7p	02 40.4	+39 04	9.5	8.7 x 4.3	bright lens-shaped galaxy near M34
19	1491	Per	EN	04 03.4	+51 19	—	3.0 x 3.0	small, fairly bright emission nebula
20	1501	Cam	PN	04 07.0	+60 55	12.0	52"	faint; dark centre; look for NGC 1502
21	1232	Eri	G-Sc	03 09.8	−20 35	9.9	7.8 x 6.9	face-on spiral; look for NGC 1300 nearby
22	1535	Eri	PN	04 14.2	−12 44	10.4	18"	bright planetary with blue-grey disk

No.	NGC	Con	Type	R.A. (2000) Dec	m_V	Size	Remarks
The Winter Sky							
23	1514	Tau	PN	$04^{h}\,09^{m}.2$ +30° 47'	10.8	114"	faint glow around $9^{m}.4$ central star
24	1931	Aur	E/RN	05 31.4 +34 15	—	3.0 x 3.0	haze surrounding 4 close stars
25	1788	Ori	RN	05 06.9 –03 21	—	8.0 x 5.0	fairly bright but diffuse reflection nebula
26	1973+	Ori	E/RN	05 35.1 –04 44	—	40 x 25	near M42 and M43; often neglected
27	2022	Ori	PN	05 42.1 +09 05	12.4	18"	small, faint & distinct with annular form
28	2024	Ori	EN	05 40.7 –02 27	—	30 x 30	bright but masked by glow from ζ Ori.
29	2194	Ori	OC	06 13.8 +12 48	8.5	10	80*; faint, rich; look for 2169 nearby
30	2371/2	Gem	PN	07 25.6 +29 29	13.0	55"	faint double-lobed planetary; use filter
31	2392	Gem	PN	07 29.2 +20 55	8.3	13"	!! Clown-Face or Eskimo Nebula
32	2237+	Mon	EN	06 32.3 +05 03	—	80 x 60	!! Rosette Neb.; very large; use neb. filter
33	2261	Mon	E/RN	06 39.2 +08 44	var.	2 x 1	Hubble's Variable Nebula; comet-shaped
34	2359	CMa	EN	07 18.6 –13 12	—	8.0 x 6.0	bright; look for NGC 2360 & 2362 nearby
35	2440	Pup	PN	07 41.9 –18 13	10.3	14"	almost starlike; irregular at high power
36	2539	Pup	OC	08 10.7 –12 50	6.5	22	50*; rich cluster near M46 & M47
37	2403	Cam	G-Sc	07 36.9 +65 36	8.4	17.8 x 11.0	!! very large & bright; visible in binocs.
38	2655	Cam	G-Sa	08 55.6 +78 13	10.1	5.1 x 4.4	bright ellipse with starlike nucleus
The Spring Sky							
39	2683	Lyn	G-Sb	08 52.7 +33 25	9.7	9.3 x 2.5	nearly edge-on spiral; very bright
40	2841	UMa	G-Sb	09 22.0 +50 58	9.3	8.1 x 3.8	!! classic elongated spiral; very bright
41	3079	UMa	G-Sb	10 02.2 +55 41	10.6	7.6 x 1.7	edge-on spiral; NGC 2950 nearby
42	3184	UMa	G-Sc	10 18.3 +41 25	9.7	6.9 x 6.8	large, diffuse face-on spiral
43	3877	UMa	G-Sb	11 46.1 +47 30	10.9	5.4 x 1.5	edge-on; same field as χ UMa
44	3941	UMa	G-E3	11 52.9 +36 59	9.8	3.8 x 2.5	small bright elliptical
45	4026	UMa	G-S0	11 59.4 +50 58	10.7	5.1 x 1.4	lens-shaped edge-on near γ UMa
46	4088	UMa	G-Sc	12 05.6 +50 33	10.5	5.8 x 2.5	nearly edge-on; NGC 4085 in same field
47	4157	UMa	G-Sb	12 11.1 +50 29	11.9	6.9 x 1.7	a thin sliver; NGC's 4026 & 4088 nearby
48	4605	UMa	G-SBcp	12 40.0 +61 37	9.6	5.5 x 2.3	bright, distinct edge-on spiral
49	3115	Sex	G-E6	10 05.2 –07 43	9.2	8.3 x 3.2	Spindle Galaxy; bright, elongated
50	3242	Hya	PN	10 24.8 –18 38	8.6	16"	!! Ghost of Jupiter; small and bright
51	3003	LMi	G-Sc	09 48.6 +33 25	11.7	5.9 x 1.7	faint elongated streak
52	3344	LMi	G-Sc	10 43.5 +24 55	9.9	6.9 x 6.5	diffuse face-on spiral
53	3432	LMi	G-SBm	10 52.5 +36 37	11.3	6.2 x 1.5	nearly edge-on; faint flat streak
54	2903	Leo	G-Sb	09 32.2 +21 30	8.9	12.6 x 6.6	!! very large, bright elongated spiral
55	3384	Leo	G-E7	10 48.3 +12 38	9.9	5.9 x 2.6	same field as M105 and NGC 3389
56	3521	Leo	G-Sb	11 05.8 –00 02	8.7	9.5 x 5.0	very large, bright spiral
57	3607	Leo	G-E1	11 16.9 +18 03	10.0	3.7 x 3.2	NGC's 3605 & 3608 in same field
58	3628	Leo	G-Sb	11 20.3 +13 36	9.5	14.8 x 3.6	large edge-on; same field as M65 & M66
59	4111	CVn	G-S0	12 07.1 +43 04	10.8	4.8 x 1.1	bright lens-shaped edge-on spiral
60	4214	CVn	G-Irr	12 15.6 +36 20	9.7	7.9 x 6.3	large irregular galaxy
61	4244	CVn	G-S	12 17.5 +37 49	10.2	16.2 x 2.5	!! large distinct edge-on spiral
62	4449	CVn	G-Irr	12 28.2 +44 06	9.4	5.1 x 3.7	bright rectangular shape
63	4490	CVn	G-Sc	12 30.6 +41 38	9.8	5.9 x 3.1	bright spiral; 4485 (Cocoon Gal.) in field
64	4631	CVn	G-Sc	12 42.1 +32 32	9.3	15.1 x 3.3	!! very large, bright edge-on; no dust lane
65	4656/7	CVn	G-Sc	12 44.0 +32 10	10.4	13.8 x 3.3	in field with 4631; 4657 is the companion
66	5005	CVn	G-Sb	13 10.9 +37 03	9.8	5.4 x 2.7	bright elongated spiral near α CVn
67	5033	CVn	G-Sb	13 13.4 +36 36	10.1	10.5 x 5.6	large bright spiral near NGC 5005

Spring Sky continued on next page

No.	NGC	Con	Type	R.A. (2000)	Dec	m_V	Size	Remarks
Spring Sky continued								
68	4274	Com	G-Sb	12^h19^m8	+29° 37'	10.4	6.9 x 2.8	NGC's 4278 / 83 / 86 in same field
69	4414	Com	G-Sc	12 26.4	+31 13	10.2	3.6 x 2.2	bright spiral with starlike nucleus
70	4494	Com	G-E1	12 31.4	+25 47	9.8	4.8 x 3.8	small bright elliptical
71	4559	Com	G-Sc	12 36.0	+27 58	9.8	10.5 x 4.9	large spiral with coarse structure
72	4565	Com	G-Sb	12 36.3	+25 59	9.6	16.2 x 2.8	!! superb edge-on spiral with dust lane
73	4725	Com	G-Sb	12 50.4	+25 30	9.2	11.0 x 7.9	very bright, large spiral
74	4038/9	Crv	G-Sc	12 01.9	−18 52	10.7	≈ 3 x 2	'Antennae' or 'Rattail' interacting galaxies
75	4361	Crv	PN	12 24.5	−18 48	10.3	45"	small and bright; with 13^m central star
76	4216	Vir	G-Sb	12 15.9	+13 09	9.9	8.3 x 2.2	nearly edge-on; with NGC's 4206 & 4222
77	4388	Vir	G-Sb	12 25.8	+12 40	11.0	5.1 x 1.4	with M84 & 86 in Markarian's chain
78	4438	Vir	G-Sap	12 27.8	+13 01	10.1	9.3 x 3.9	paired with NGC 4435 to form 'The Eyes'
79	4517	Vir	G-Sc	12 32.8	+00 07	10.5	10.2 x 1.9	faint edge-on spiral
80	4526	Vir	G-E7	12 34.0	+07 42	9.6	7.6 x 2.3	between two 7^m stars; the 'Lost' Galaxy
81	4535	Vir	G-Sc	12 34.3	+08 12	9.8	6.8 x 5.0	near M49 and 3/4° N of NGC 4526
82	4567/8	Vir	G-Sc	12 36.5	+11 15	≈ 11	4.6 x 2.1	'Siamese Twins' interacting galaxies
83	4699	Vir	G-Sa	12 49.0	−08 40	9.6	3.5 x 2.7	small & bright; look for NGC 4697 3° N
84	4762	Vir	G-SB0	12 52.9	+11 14	10.2	8.7 x 1.6	flattest galaxy known; 4754 in same field
85	5746	Vir	G-Sb	14 44.9	+01 57	10.6	7.9 x 1.7	fine edge-on spiral near 109 Virginis
86	5466	Boo	GC	14 05.5	+28 32	9.1	11.0	loose Class XII; like rich open cl.; faint
87	5907	Dra	G-Sb	15 15.9	+56 19	10.4	12.3 x 1.8	!! fine edge-on with dust lane; near 5866
88	6503	Dra	G-Sb	17 49.4	+70 09	10.2	6.2 x 2.3	bright elongated spiral
89	6543	Dra	PN	17 58.6	+66 38	8.8	18"	Cat's Eye Nebula; with 11^m central star
The Summer Sky								
90	6210	Her	PN	16 44.5	+23 49	9.3	14"	very starlike blue planetary
91	6369	Oph	PN	17 29.3	−23 46	10.4	30"	Little Ghost; look for NGC 6309 nearby
92	6572	Oph	PN	18 12.1	+06 51	9.0	8"	tiny bright blue oval
93	6633	Oph	OC	18 27.7	+06 34	4.6	27	sparse wide field cluster; IC 4756 nearby
94	6712	Sct	GC	18 53.1	−08 42	8.2	7.2	small globular; look for IC 1295 in field
95	6781	Aql	PN	19 18.4	+06 33	11.8	109"	pale version of M97; fairly bright
96	6819	Cyg	OC	19 41.3	+40 11	7.3	5	150*; faint but rich cluster in Milky Way
97	6826	Cyg	PN	19 44.8	+50 31	9.8	30"	!! Blinking Planetary; $10^m.4$ central star
98	6888	Cyg	SNR ?	20 12.0	+38 21	—	20 x 10	Crescent Nebula; faint; use nebula filter
99 a	6960	Cyg	SNR	20 45.7	+30 43	—	70 x 6	!! Veil Nebula: west half; use filter !
99 b	6992/5	Cyg	SNR	20 56.4	+31 43	—	78 x 8	!! Veil Nebula: east half; use filter !
100	7000	Cyg	EN	20 58.8	+44 20	—	120 x 100	!! North American; use filter & low mag.
101	7027	Cyg	PN ?	21 07.1	+42 14	10.4	15"	unusual proto-planetary nebula
102	6445	Sgr	PN	17 49.2	−20 01	11.8	34"	small, bright and annular; near M23
103	6520	Sgr	OC	18 03.4	−27 54	8.1	6	60*; small; dark neb. B86 in same field
104	6818	Sgr	PN	19 44.0	−14 09	9.9	17"	Little Gem; annular; NGC 6822 3/4° S
105	6802	Vul	OC	19 30.6	+20 16	8.8	3.2	at east end of Brocchi's cluster Cr 399
106	6940	Vul	OC	20 34.6	+28 18	6.3	31	60*; fairly rich cluster in Milky Way
107	6939	Cep	OC	20 31.4	+60 38	7.8	8	80*; very rich; NGC 6946 in same field
108	6946	Cep	G-Sc	20 34.8	+60 09	8.9	11.0 x 9.8	faint, diffuse face-on spiral near 6939
109	7129	Cep	RN	21 44.4	+66 10	—	8 x 7	faint reflect. neb. around several stars
110	40	Cep	PN	00 13.0	+72 32	10.2	37"	unusual red planetary; $11^m.6$ central star

- For an excellent observing project, try tackling both the Messier and NGC lists. It may take up to 2 or 3 years to complete them both, but it provides a satisfying goal to work toward in your observing, along with an answer to that persistent question, "What do I look at tonight ?"

DEEP-SKY CHALLENGE OBJECTS

By Alan Dyer and Alister Ling

For those who wish to venture beyond the NGC, here is a selection of 45 "challenge" targets. Most will require a 25 to 45-cm telescope. However, for detecting challenge objects, the quality of the sky, quality of the optics, use of an appropriate filter, and the observer's experience is often more important than sheer aperture. Don't be afraid to tackle some of these with a smaller telescope.

Objects are listed in order of right ascension. Abbreviations are the same as in the Messier and NGC lists. Two columns have been added: one lists the Chart where you'll find that object in the *Uranometria 2000.0* ; the last column suggests the minimum aperture needed to see that object.

(Most data taken from *Sky Catalogue 2000.0 Vol. 2*. Some visual magnitudes from other sources.)

No	Object	Con	Type	R.A. (2000) Dec	m_V	Size	Chart #	Min. Aperture
1	**NGC 7822**	Cep	E/RN	$00^h 03^m6$ +68° 37'	—	60 x 30	# 15	30 cm
	large, faint emission neb.; rated 'eeF'; also look for E/R nebula Ced 214 (assoc'd with cluster Berkley 59) 1° S							
2	**IC 59**	Cas	E/RN	00 56.7 +61 04	—	10 x 5	# 36	20–25 cm
	faint emission/reflection nebulosity paired with IC 63 very close to γ Cas.; requires clean optics; rated as 'pF'							
3	**NGC 609**	Cas	OC	01 37.2 +64 33	11.0	3.0	# 16	25–30 cm
	faint patch at low power; high power needed to resolve this rich cluster (also look for Trumpler 1 cluster 3° S)							
4	**IC 1795**	Cas	EN	02 24.7 +61 54	—	27 x 13	# 17	20 cm
	brightest part of a complex of nebulosity that includes IC 1805 and IC 1848; use a nebula filter							
5	**Maffei I**	Cas	G-E3	02 36.3 +59 39	≈ 14	5 x 3	# 38	30 cm
	heavily reddened galaxy; very faint; requires large aperture and black skies; nearby Maffei II probably invisible							
6	**NGC 1049**	For	GC	02 39.7 –34 29	11.0	0.6	# 354	25–30 cm
	Class V globular in dwarf 'Fornax System' Local Group galaxy 630 000 L.Y. away; galaxy itself invisible ?							
7	**NGC 1275**	Per	G-Pec	03 19.8 +41 31	11.6	2.6 x 1.9	# 63	20–25 cm
	Perseus A exploding galaxy; brightest member of Abell 426 gal. cl. 300 million L.Y. away; see Webb Vol. 5							
8	**1432/35**	Tau	RN	03 46.1 +23 47	—	30 x 30	# 132	10–15 cm
	Pleiades nebulosity (also includes IC 349); brightest around Merope; requires transparent skies and clean optics							
9	**IC 342**	Cam	G-SBc	03 46.8 +68 06	≈ 12	17 x 17	# 18	20–30 cm
	large and diffuse face-on spiral; member of UMa–Cam cloud (Kemble's Cascade of stars also on this chart)							
10	**NGC 1499**	Per	EN	04 00.7 +36 37	—	145 x 40	# 95	8–12.5 cm RFT
	California Nebula; very large and faint; use a wide-field telescope or big binoculars plus H-Beta filter							
11	NGC 1554/5	Tau	RN	04 21.8 +19 32	—	var.	# 133	20 cm ?
	Hind's Variable Neb.; small reflect. neb. around 9^m–13^m var. star T Tau; use high power; difficulty varies							
12	**IC 405**	Aur	E/RN	05 16.2 +34 16	—	30 x 19	# 97	20 cm
	Flaming Star Neb. assoc'd with runaway star AE Aurigae; see Burnham's Handbk p. 285 (also look for IC 410)							
13	**IC434/B33**	Ori	E/DN	05 40.9 –02 28	—	60 x 10	# 226	15–20 cm in dark sky!
	B33 is the Horsehead Nebula, a dark neb. superimposed on a very faint emission neb. IC 434; use H-Beta filter							
14	**Sh 2–276**	Ori	EN	05 48 +01 --	—	600 x 30 !	# 226	10–15cm RFT
	Barnard's Loop; SNR or interstellar bubble?; difficult to detect due to size; use filter and sweep with wide field							
15	**Abell 12**	Ori	PN	06 02.4 +09 39	≈ 13	37"	# 181	25–30 cm
	also called PK 198 –6.1; faint; not plotted on Uranometria but is on NW edge of μ Orionis; OIII filter required							
16	**IC 443**	Gem	SNR	06 16.9 +22 47	—	50 x 40	# 137	25–30 cm
	faint supernova remnant very close to η Gem.; use filter (also look for NGC 2174 and Sh 2–247 on this chart)							
17	**J 900**	Gem	PN	06 25.9 +17 47	12.2	8"	# 137	20 cm
	Jonckheere 900; bright starlike planetary; plotted as PK 194 +2.1 in Uranometria; use OIII filter & high power							
18	**IC 2177**	Mon	E/RN	07 05.1 –10 42	—	120 x 40	# 273	20–30 cm
	Eagle Nebula; large, faint; contains bright patches Gum 1 (–10°28'), NGC 2327 (–11°18') & Ced 90 (–12°20')							
19	**PK205 +14.1**	Gem	PN	07 29.0 +13 15	≈ 13	≈ 700"	# 184	20–25 cm
	Medusa Nebula or Abell 21; much larger than plotted in Uranometria; impressive in large aperture w/ OIII filter							
20	**NGC 2419**	Lyn	GC	07 38.1 +38 53	10.4	4.1	# 100	15–20 cm
	at 200 000 L.Y. away the most distant Milky Way globular for amateur telescopes; v. small & faint; Class II							

No	Object	Con	Type	R.A. (2000) Dec	m_V	Size	Chart #	Min. Aperture
21	PK164 +31.1	Lyn	PN	$07^{h}\,57^{m}8$ +53° 25'	≈ 14	400"	# 43	25 cm
	extremely faint with two small components; use OIII filter; sometimes confused with nearby NGC 2474–75							
22	**Leo I**	Leo	G-E3	10 08.4 +12 18	9.8	10.7 x 8.3	# 189	30 cm
	dwarf elliptical; satellite of Milky Way; very low surface brightness; 0.3° N of Regulus !; requires clean optics							
23	**Abell 1367**	Leo	G's	11 44.0 +19 57	13–16	≈ 60	# 147	30–40 cm
	cluster of some 30 or more galaxies within a 1 degree field near 93 Leonis; see Webb Handbook Vol. 5, p. 139							
24	NGC 3172	UMi	G–?	11 50.2 +89 07	13.6	0.7 x 0.7	# 2	25 cm
	'Polarissima Borealis' — closest galaxy to the North Celestial Pole; small, faint and otherwise unremarkable							
25	NGC 4236	Dra	G-SBb	12 16.7 +69 28	9.6	18.6 x 6.9	# 25	20–25 cm
	very large, dim barred spiral; a diffuse glow (NGC 4395 on Chart #108 a similar large diffuse face-on)							
26	**Mrk 205**	Dra	Quasar	12 21.6 +75 18	14.5	stellar	# 9	30 cm
	Markarian 205; a faint star on SW edge of NGC 4319; plotted as a radio source; centre of red-shift controversy							
27	**3C 273**	Vir	Quasar	12 29.1 +02 03	12~13	stellar	# 238	25–30 cm
	at 2 to 3 billion L.Y. away one of the most distant objects visible in amateur telescopes; magnitude variable							
28	**NGC 4676**	Com	G's	12 46.2 +30 44	14.1p	≈ 2 x 1	# 108	25 cm
	'The Mice' or VV 224— two classic interacting galaxies; very faint; double nature detectable at high power							
29	**Abell 1656**	Com	G's	13 00.1 +27 58	12–16	≈ 60	# 149	25–30 cm
	Coma Berenices gal. cl.; very rich; 400 million L.Y. away; brightest member NGC 4889; see Webb Vol. 5							
30	**NGC 5053**	Com	GC	13 16.4 +17 42	9.8	10.5	# 150	10–20 cm
	faint and very loose globular 1° SE of M53; requires large aperture to resolve; difficult in hazy skies; Class XI							
31	**NGC 5897**	Lib	GC	15 17.4 –21 01	8.6	12.6	# 334	15–20 cm
	large, faint and loose globular; mag. 10.9 in Atlas Coeli Catalogue; requires large aperture to resolve; Class XI							
32	**Abell 2065**	CrB	G's	15 22.7 +27 43	≈ 16	≈ 30	# 154	50 cm in superb sky!
	Corona Borealis gal. cluster; perhaps the most difficult object for amateur telescopes; 1.5 billion L.Y. away							
33	**NGC 6027**	Ser	G's	15 59.2 +20 45	≈ 15	≈ 2 x 1	# 155	40 cm
	Seyfert's Sextet (6027 A–F); compact group of 6 small and very faint galaxies; see Burnham's Handbk p. 1793							
34	**B 72**	Oph	DN	17 23.5 –23 38	—	30	# 338	8–12.5 cm RFT
	Barnard's dark S-Nebula or 'The Snake'; opacity of 6/6; 1.5° NNE of θ Ophiuchi; area rich in dark nebulas							
35	**NGC 6791**	Lyr	OC	19 20.7 +37 51	9.5	16	# 118	20–25 cm
	large, faint but very rich open cluster with 300 stars; a faint smear in smaller instruments; Type II 3 r							
36	**PK 64 +5.1**	Cyg	PN	19 34.8 +30 31	9.6	8"	# 118	20 cm
	Campbell's Hydrogen Star; very bright but very starlike; also catalogued as star BD +30°3639							
37	**M 1-92**	Cyg	RN	19 36.3 +29 33	11.0	12" x 6"	# 118	25–30 cm
	Minkowski 92 or Footprint Nebula; bright, starlike reflection neb.; double at high mag.; assoc'd star invisible							
38	**NGC 6822**	Sgr	G-Irr	19 44.9 –14 48	≈ 11	10.2 x 9.5	# 297	10–15 cm
	Barnard's Galaxy; member of the Local Group; large but very low surface brightness; requires transparent skies							
39	**IC 4997**	Sge	PN	20 20.2 +16 45	10.9	2"	# 163	20 cm
	bright but starlike planetary; the challenge is to see the disk !; blink the field with and without a nebula filter							
40	**IC 1318**	Cyg	EN	20 26.2 +40 30	—	large	# 84	8–15 cm RFT
	complex of nebulosity around γ Cygni; multitude of patches in rich starfield; use a very wide field plus filter							
41	**PK 80 –6.1**	Cyg	PN ?	21 02.3 +36 42	13.5	16"	# 121	25 cm
	the 'Egg Nebula'; a very small proto-planetary nebula; can owners of large telescopes detect polarization ?							
42	**IC 1396**	Cep	EN	21 39.1 +57 30	—	170 x 140	# 57	10–12.5 cm RFT
	extremely large and diffuse area of emission nebulosity; use nebula filter and very wide field optics in dark sky							
43	**IC 5146**	Cyg	E/RN	21 53.5 +47 16	—	12 x 12	# 86	20–25 cm
	Cocoon Nebula; faint and diffuse; use H-Beta filter; at the end of the long filamentary dark nebula Barnard 168							
44	NGC 7317–20	Peg	G's	22 36.1 +33 57	13–14	each ≈ 1'	# 123	25–30 cm
	Stephan's Quintet; 0.5° SSW of NGC 7331; easy to pick out 3 or 4 (also look for 'companions' to 7331)							
45	**Jones 1**	Peg	PN	23 35.9 +30 28	12.1	332"	# 124	25–30 cm
	plotted as PK 104 –29.1 (from Perek & Kohoutek catalogue) in Uranometria; large dim glow; OIII filter required							

GALAXIES: BRIGHTEST AND NEAREST

BY BARRY F. MADORE

External galaxies are generally of such low surface brightness that they often prove disappointing objects for the amateur observer. However it must be remembered that many of these galaxies were discovered with very small telescopes and that the enjoyment of their discovery can be recaptured. In addition the central concentration of light varies from galaxy to galaxy making a visual classification of the types possible at the telescope. Indeed the type of galaxy as listed in the first table is in part based on the fraction of light coming from the central bulge of the galaxy as compared to the contribution from a disk component. Disk galaxies with dominant bulges are classified as Sa; as the nuclear contribution declines, types of Sb, Sc, and Sd are assigned until the nucleus is absent at type Sm. Often the disks of these galaxies show spiral symmetry, the coherence and strength of which is denoted by Roman numerals I through V, smaller numbers indicating well-formed global spiral patterns. Those spirals with central bars are designated SB while those with only a hint of a disk embedded in the bulge are called S0. A separate class of galaxies which possess no disk component are called ellipticals and can only be further classified numerically by their apparent flattening: E0 being apparently round, E7 being the most flattened.

Environment appears to play an important role in the determining of the types of galaxies we see at the present epoch. Rich clusters of galaxies such as the system in Coma are dominated by ellipticals and gas-free S0 galaxies. The less dense clusters and groups tend to be dominated by the spiral, disk galaxies. Remarkably, in pairs of galaxies the two types are much more frequently of the same Hubble type than random selection would predict. Encounters between disk galaxies may in some cases result in the instabilities necessary to form the spiral structure we often see. M51, the Whirlpool and its companion NGC 519S are an often-cited example of this type of interaction. In the past when the Universe was much more densely packed, interactions and collisions may have been sufficiently frequent that entire galaxies merged to form a single large new system; it has been suggested that some elliptical galaxies formed in this way.

The following table presents the 40 brightest galaxies taken from the Revised Shapley-Ames Catalog. As well as their designations, positions, and types, the table lists the total blue magnitudes, major and minor axis lengths (to the nearest minute of arc), one modern estimate of their distances in thousands of parsecs, and finally their radial velocities corrected for the motion of our Sun about the galactic centre.

THE 40 OPTICALLY BRIGHTEST SHAPLEY-AMES GALAXIES

NGC/IC (Other)	α/δ (1983)	Type	B_T ma × mi	Distance Corrected Radial Vel.
55	$00^h14^m04^s$ −39°17.1′	Sc	8.22 mag 25 × 3 arc min	3 100 kpc +115 km/s
205 M110	00 39 27 +41 35.7	Sϕ/E5pec	8.83 8 × 3	730 +49
221 M32	00 41 49 +40 46.3	E2	9.01 3 × 3	730 +86
224 M31	00 41 49 +41 10.5	Sb I–II	4.38 160 × 40	730 −10
247	00 46 19 −20 51.2	Sc III–IV	9.51 18 × 5	3 100 +604
253	00 46 46 −25 23.0	Sc	8.13 22 × 6	4 200 +504
SMC	00 52 10 −72 55.3	Im IV–V	2.79 216 × 216	60 +359
300	00 54.05 −37 46.7	Sc III	8.70 20 × 10	2 400 +625
598 M33	01 32 55 +30 34.0	Sc II–III	6.26 60 × 40	670 +506
628 M74	01 35 49 +15 41.6	Sc I	9.77 8 × 8	17 000 +507
1068 M77	02 41 49 −00 05.2	Sb II	9.55 3 × 2	25 000 +510
1291	03 16 42 −41 11.3	SBa	9.42 5 × 2	15 000 +512
1313	03 18 04 −66 33.6	SBc III–IV	9.37 5 × 3	5 200 +261
1316 Fornax A	03 22 03 −37 16.1	Sa (pec)	9.60 4 × 3	30 000 +1713
LMC	05 23 45 −69 46.3	SBm III	0.63 432 × 432	50 +34
2403	07 35 13 +65 38.2	Sc III	8.89 16 × 10	3 600 +299
2903	09 31 02 +21 34.4	Sc I–III	9.50 11 × 5	9 400 +472
3031 M81	09 54 11 +69 08.9	Sb I–II	7.86 16 × 10	3 600 +124
3034 M82	09 54 24 +69 45.5	Amor-phous	9.28 7 × 2	3 600 +409
3521	11 04 57 +00 03.5	Sb II–III	9.64 7 × 2	13 000 +627

NGC/IC (Other)	α/δ (1983)	Type	B_T ma × mi	Distance Corrected Radial Vel.
3627 M66	11 19 22 +13 05.0	Sb II	9.74 8 × 3	12 000 +593
4258 M106	12 18 07 +47 24.1	Sb II	8.95 20 × 6	10 000 +520
4449	12 27 24 +44 11.4	Sm IV	9.85 5 × 3	5 000 +250
4472 M49	12 28 55 +08 05.8	E1/Sϕ	9.32 5 × 4	22 000 +822
4486 M87	12 29 58 +12 29.2	Eϕ	9.62 3 × 3	22 000 +1136
4594 M104	12 39 07 −11 31.8	Sa/b	9.28 7 × 2	17 000 +873
4631	12 41 18 +32 38.0	Sc	9.84 12 × 1	12 000 +606
4649 M60	12 42 49 +11 38.7	Sϕ	9.83 4 × 3	22 000 +1142
4736 M94	12 50 06 +41 12.9	Sab	8.92 5 × 4	6 900 +345
4826 M64	12 55 55 +21 46.5	Sab II	9.37 8 × 4	7 000 +350
4945	13 04 28 −49 22.5	Sc	9.60 12 × 2	7 000 +275
5055 M63	13 15 04 +42 07.4	Sbc II–III	9.33 8 × 3	11 000 +550
5128 Cen A	13 24 29 −42 35.7	Sϕ (pec)	7.89 10 × 3	6 900 +251
5194 M51	13 29 10 +47 17.2	Sbc I–II	8.57 12 × 6	11 000 +541
5236 M83	13 36 02 −29 46.8	SBc II	8.51 10 × 8	6 900 +275
5457 M101	14 02 39 +54 26.4	Sc I	8.18 22 × 22	7 600 +372
6744	19 08 09 −63 53.0	Sbc II	9.24 9 × 9	13 000 +663
6822	19 43 59 −14 50.8	Im IV–V	9.35 20 × 10	680 +15
6946	20 34 30 +60 05.9	Sc II	9.68 13 × 9	6 700 +336
7793	23 56 57 −32 41.1	Sd IV	9.65 6 × 4	4 200 +241

The nearest galaxies, listed below, form what is known as our Local Group of Galaxies. Many of the distances are still quite uncertain.

THE NEAR-BY GALAXIES: OUR LOCAL GROUP

Name	α (1983.0)	δ	B_T	Type	Distance (kpc)
M31 = NGC 224	$00^h41^m.8$	$+41°11'$	4.38	Sb I–II	730
Galaxy	—	—	—	Sb/c	—
M33 = NGC 598	01 32.9	+30 34	6.26	Sc II–III	670
LMC	05 23.8	−69 46	0.63	SBm III	50
SMC	00 52.2	−72 55	2.79	Im IV–V	60
NGC 6822	19 44.0	−14 51	9.35	Im IV–V	520
IC 1613	01 03.9	+02 02	10.00	Im V	740
M110 = NGC 205	00 39.5	+41 36	8.83	S0/E5 pec	730
M32 = NGC 221	00 41.8	+40 46	9.01	E2	730
NGC 185	00 38.0	+48 15	10.13	dE3 pec	730
NGC 147	00 32.3	+48 25	10.36	dE5	730
Fornax	02 39.2	−34 36	9.1	dE	130
Sculptor	00 59.0	−33 47	10.5	dE	85
Leo I	10 07.6	+12 24	11.27	dE	230
Leo II	11 12.6	+22 15	12.85	dE	230
Draco	17 19.8	+57 56	—	dE	80
Ursa Minor	15 08.6	+67 16	—	dE	75
Carina	06 47.2	−50 59	—	dE	170
And I	00 44.6	+37 57	13.5	dE	730
And II	01 15.5	+33 21	13.5	dE	730
And III	00 34.5	+36 25	13.5	dE	730
LGS 3	01 02.9	+21 48	—	?	730

GALAXIES WITH PROPER NAMES

By James T. Himer and Barry F. Madore

The following table contains the catalogue designations and positions of galaxies known to have proper names which usually honour the discoverer (e.g. McLeish's Object), identify the constellation in which the galaxy is found (e.g. Andromeda Galaxy), or describe the galaxy in some easily remembered way (e.g. Whirlpool Galaxy).

Galaxy Name	Other Designations	B1950.0		J2000.0		Notes
Ambartsumian's Knot	NGC 3561, UGC 06224, ARP 105	11 08.5	+28 58	11 11.2	+28 42	Nilson (1973)
Andromeda Galaxy	M31, NGC 224, UGC 00454	00 40.0	+41 00	00 42.7	+41 16	
Andromeda I		00 43.0	+37 44	00 45.7	+38 00	
Andromeda II		01 13.5	+33 09	01 16.3	+33 25	
Andromeda III		00 32.6	+36 14	00 35.3	+36 31	
Andromeda IV		00 39.8	+40 18	00 42.5	+40 34	
Antennae Galaxy	Ring Tail, NGC 4038/39, ARP 244	11 59.3	-18 35	12 01.9	-18 52	
Aquarius Dwarf	DDO 210	20 44.1	-13 02	20 46.9	-12 51	Van Den Bergh (1981)
Arp's Galaxy		11 16.8	+51 46	11 19.6	+51 30	Arp (1965)
Atoms For Peace	NGC 7252, ARP 226	22 18.0	-24 56	22 20.8	-24 41	
Baade's Galaxies A & B	MCG+07-02-018/19	00 47.1	+42 19	00 49.9	+42 35	
Barbon's Galaxy	Markarian 328, ZWG 497.042	23 35.2	+29 51	23 37.7	+30 08	
Barnard's Galaxy	NGC 6822, IC 4895, DDO 209	19 42.1	-14 56	19 44.9	-14 48	
Bears Paw (Claw)	NGC 2537, UGC 04274, ARP 6	08 09.7	+46 09	08 13.2	+46 00	
BL Lacertae		22 00.7	+42 02	22 02.7	+42 17	
Black Eye Galaxy	M64, NGC 4826, UGC 08062	12 54.2.	+21 57	12 56.7	+21 41	Burnham (1978) 1
Bode's Galaxies	M81/82, NGC 3031/4, UGC 05318/22	09 51.6	+69 37	09 55.7	+69 23	
Burbidge Chain	MCG-04-03-010 to 13	00 45.0	-20 42	00 47.5	-20 26	
BW Tauri	UGC 03087, MCG+01-12-009	04 30.5	+05 15	04 33.2	+05 21	Nilson (1973)
Capricorn Dwarf	MCG-04-51-013, Palomar 12	21 43.7	-21 28	21 46.5	-21 14	Dixon (1980); 2
						Hanes & Madore (1980)
Carafe Galaxy	Near NGC 1598 + 1595	04 26.6	-48 01	04 28.0	-47 54	Hawarden et al (1979)
Carina Dwarf		06 40.4	-50 55	06 41.6	-50 58	Van Den Bergh (1981)
Cartwheel Galaxy	MCG-06-02-022a	00 35.0	-34 01	00 37.4	-33 44	Davies et al (1981)
Centaurus A	NGC 5128, ARP 153	13 22.5	-42 45	13 25.5	-43 01	Sandage & Tammann (1981)
Circinus Galaxy		14 09.3	-65 06	14 13.2	-65 20	
Coddington's Nebula	IC 2574, UGC 05666, DDO 81	10 24.7	+68 40	10 28.4	+68 25	
Copeland Septet	MCG+04-28-004/05/07-11, ARP 320, NGC 3745/46/48/50/51/53/54	11 35.2	+22 16	11 37.8	+21 59	Dixon (1980); 2
Cygnus A	MCG+07-41-003	19 57.7	+40 35	19 59.4	+40 43	
Draco Dwarf	UGC 10822, DDO 208	17 19.4	+57 58	17 20.2	+57 55	Nilson (1973)
Exclamation Mark Galaxy		00 36.9	-43 22	00 39.3	-43 06	
The Eyes	NGC 4435/8, UGC 07574/5, ARP 120a,b	12 25.2	+13 19	12 27.7	+13 03	
Fath 703	NGC 5892	15 10.9	-15 18	15 13.7	-15 29	Dixon (1980); 3
Fornax A	NGC 1316, ARP 154	03 20.8	-37 23	03 22.7	-37 12	Sandage & Tammann (1981)
Fornax Dwarf	MCG-06-07-001	02 37.8	-34 45	02 39.9	-34 32	Dixon (1980)
Fourcade-Figueroa	MCG-07-28-004	13 31.8	-45 18	13 34.8	-45 33	Graham(1978)
The Garland	S. of NGC 3077 = UGC 05398	10 00.2	+68 55	10 04.2	+68 40	
Grus Quartet	NGC 7552/82/90/99	23 15.0	-42 42	23 17.8	-42 26	Maccacaro (1981); 4
GR 8 (Gibson Reaves)	UGC 08091, DDO 155	12 56.2	+14 29	12 58.7	+14 13	Nilson (1973)
Hardcastle's Galaxy	MCG-05-31-039	13 10.2	-32 25	13 13.0	-32 41	Dixon (1980)
Helix Galaxy	NGC 2685, UGC 04666, ARP 336	08 51.7	+58 55	08 55.6	+58 44	
Hercules A	MCG+01-43-006	16 48.7	+05 04	16 51.2	+04 59	Dixon (1980)
Hoag's Object		15 15.0	+21 46	15 17.2	+21 35	Sky & Tel (1986)

Holmberg I	UGC 05139, DDO 63	09 36.0	+71 25	09 40.5	+71 11	Nilson (1973)
Holmberg II	UGC 04305, DDO 50, ARP 268	08 14.1	+70 52	08 19.3	+70 43	Nilson (1973)
Holmberg III	UGC 04841	09 09.4	+74 26	09 14.6	+74 14	Nilson (1973)
Holmberg IV	UGC 08837, DDO 185	13 52.9	+54 09	13 54.7	+53 54	Nilson (1973)
Holmberg V	UGC 08658	13 38.7	+54 35	13 40.6	+54 20	Nilson (1973)
Holmberg VI	NGC 1325a	03 22.7	-21 31	03 24.9	-21 20	
Holmberg VII	UGC 07739, DDO 137	12 32.2	+06 34	12 34.7	+06 17	Nilson (1973)
Holmberg VIII	UGC 08303, DDO 166	13 11.0	+36 28	13 13.3	+36 12	Nilson (1973)
Holmberg IX	UGC 05336, DDO 66	09 53.5	+69 17	09 57.6	+69 03	Nilson (1973)
Horologium Dwarf	Schuster's Spiral	03 57.0	-46 00	03 58.6	-45 25	Sky & Tel. (1977)
Hydra A	MCG-02-24-007	09 15.7	-11 53	09 18.1	-12 06	Dixon (1980
Integral Sign	UGC 03697, MCG+12-07-028	07 05.6	+71 55	07 11.4	+71 50	
Keenan's System	NGC 5216/16a/18, UGC 08528/9, ARP 104	13 30.5	+62 59	13 32.2	+62 43	Dixon (1980); 5
Kowal's Object		19 27.0	-17 47	19 29.9	-17 41	Sky & Tel.(1979) IAU Circular 3385
Large Megallanic Cloud	Nubecula Major	05 24.0	-69 48	05 23.6	-69 45	
Leo I	Regulus Dwarf, UGC 05470, DDO 74, Harrington-Wilson #1	10 05.8	+12 33	10 08.5	+12 18	Nilson (1973)
Leo II	Leo B, UGC 06253, DDO 93, Harrington-Wilson #2	11 10.8	+22 26	11 13.4	+22 10	Nilson (1973)
Leo III	Leo A, UGC 05364, DDO 69	09 56.4	+30 59	09 59.3	+30 45	Nilson (1973)
Lindsay-Shapley Ring	Graham A	06 44.2	-74 12	06 42.8	-74 15	Dixon (1980)
Lost Galaxy	NGC 4535, UGC 06834	12 31.8	08 28	12 34.3	+08 11	Burnham (1978)
McLeish's Object		20 05.0	-66 22	20 09.7	-66 13	
Maffei I	UGCA 34	02 32.6	+59 26	02 36.3	+59 39	Dixon (1980)
Maffei II	UGCA 39	02 38.2	+59 24	02 42.0	+59 37	Dixon (1980)
Malin 1		12 34.5	+14 36	12 37.0	+14 20	Bothun (1987)
Mayall's Object	MCG+07-23-019, ARP 148	11 01.1	+41 06	11 03.9	+40 50	Burbidge (1964)
Mice	NGC 4676a/b, UGC 07938/9, IC 819/20, ARP 242	12 43.7	+31 00	12 46.1	+30 44	Dixon (1980)
Minature Spiral	NGC 3928	11 49.2	+48 58	11 51.8	+48 41	van den Bergh (1980)
Minkowsi's Object	ARP 133 (N.E. of NGC 541)	01 23.2	-01 36	01 25.8	-01 21	
Pancake	NGC 2685, UGC 04666, ARP 336	08 51.7	+58 55	08 55.6	+58 44	
Papillon	IC 708, UGC 06549	11 31.2	+49 20	11 33.9	+49 03	Valee et al. (1979)
Pegasus Dwarf	UGC 12613, DDO 216	23 26.0	+14 27	23 28.5	+14 44	Nilson (1973)
Perseus A	NGC 1275/6, UGC 02669	03 16.5	+41 20	03 19.8	+41 31	Dixon (1980)
Pinwheel Galaxy	M33, NGC 598, Triangulum Galaxy	01 31.1	+30 24	01 33.9	+30 39	Burnham (1978)
- " -	M99, NGC 4254, UGC 07345	12 16.2	+14 42	12 18.8	+14 25	Burnham (1978)
- " -	M101, NGC 5457, UGC 08981, ARP 26	14 01.5	+54 36	14 03.3	+54 22	Astr. Almanac (1987)
Pisces Cloud	NGC 379/80/82-85, UGC 00682/3/6-9, ARP 331	01 04.7	+32 09	01 07.5	+32 25	Nilson (1973)
Pisces Dwarf	LGS 3	00 01.2	+21 37	00 03.8	+21 54	Van Den Bergh (1981)
Polarissima Australis	NGC 2573	02 38.2	-89 35	01 37	-89 21	
Polarissima Borealis	NGC 3172, ZWG 370.002	11 42.6	+89 24	11 50.3	+89 07	Sky & Tel. (1982), (1978)
Reinmuth 80	NGC 4517a, UGC 07685	12 29.9	+00 40	12 32.5	+00 23	Nilson (1973); 8
Reticulum Dwarf	Sersic 040.03	04 35.4	-58 56	04 36.2	-58 50	Dixon (1980); 7
Sagittarius Dwarf		19 27.1	-17 47	19 30.0	-17 41	Van Den Bergh (1981)
Sculptor Dwarf	MCG-06-03-015	00 57.8	-33 58	01 00.2	-33 42	Dixon (1980); 9
Sculptor Dwarf Irr.		00 05.6	-34 51	00 08.1	-34 34	

Seashell Galaxy	Companion to NGC 5291	13 44.5	-30 08	13 47.4	-30 23	Lausten et al (1977)
Serpens Dwarf	UGC 09792, Palomar 5	15 13.5	+00 03	15 16.1	-00 08	Nilson (1973)
Sextans A	UGCA 205, MCG-01-26-030, DDO 75	10 08.5	-04 26	10 11.0	-04 41	Dixon (1980)
Sextans B	UGC 05373, DDO 70	09 57.4	+05 34	10 00.0	+05 19	Nilson (1973)
Sextans C	UGC 05439	10 03.0	+00 19	10 05.6	+00 04	Nilson (1973)
Seyfert's Sextet	Serpens Sextet, NGC 6027 + a-e, UGC 10116	15 57.0	+20 54	15 59.2	+20 46	Nilson (1973)
Shapley-Ames 1		01 02.6	-06 29	01 05.1	-06 13	
Shapley-Ames 2	NGC 4507	12 32.9	-39 38	12 35.1	-39 55	
Shapley-Ames 3	MCG-02-33-015	12 46.8	-09 51	12 49.4	-10 07	
Shapley-Ames 4	UGC 08041	12 52.7	+00 23	12 55.2	+00 07	
Shapley-Ames 5	MCG-07-42-001	20 20.6	-44 09	20 24.0	-44 00	
Shapley-Ames 6		21 20.0	-45 59	21 23.2	+45 46	
Siamese Twins	NGC 4567/4568	12 34.0	+11 32	12 36.5	+11 15	
Silver Coin	Sculptor Galaxy, NGC 253, UGCA 13	00 45.1	-25 34	00 47.6	-25 18	
Small Megallanic Cloud	Nubecula Minor	00 51.0	-73 06	00 52.7	-72 50	
Snickers		06 25	+15	06 28	+15	Simonson (1975)
Sombrero Galaxy	M104, NGC 4594	12 37.3	-11 21	12 39.9	-11 37	
Spider	UGC 05829, DDO 84	10 39.8	+34 43	10 42.6	+34 27	
Spindle Galaxy	NGC 3115	10 02.8	-07 28	10 05.2	-07 42	
Stephan's Quintet	NGC 7317-20, UGC 12099-102, ARP 319	22 33.7	+33 42	22 36.0	+33 58	
Sunflower Galaxy	M63, NGC 5055, UGC 08334	13 13.5	+42 17	13 15.8	+42 02	Burnham (1978) 4
Triangulum Galaxy	Pinwheel, M33, NGC 598, UGC 01117	01 31.1	+30 24	01 33.9	+30 39	
Ursa Minor Dwarf	UGC 09749, DDO 199	15 08.2	+67 23	15 08.8	+67 12	Nilson (1973)
Virgo A	M87, NGC 4486, UGC 07654, ARP 152	12 28.3	+12 40	12 30.8	+12 23	
Whirlpool Galaxy	Rosse's Galaxy, Question Mark Gal. M51, NGC 5194/5, UGC 08493/4, ARP 85	13 27.8	+47 27	13 29.9	+47 12	
Wild's Triplet	MCG-01-30-032/34, ARP 248	11 44.2	-03 31	11 46.8	-03 49	Dixon (1980)
Wolf-Lundmark-Melotte	MCG-03-01-015, DDO 221	23 59.4	-15 44	00 02.0	-15 28	Dixon (1980)
Zwicky #2	UGC 06955, DDO 105	11 55.8	+38 20	11 58.4	+38 03	Nilson (1973)
Zwicky's Triplet	UGC 10586, ARP 103	16 48.0	+45 33	16 49.5	+45 30	Nilson (1973)

ARP = *Atlas of Peculiar Galaxies, Ap. J. Suppl.*, **14**, 1.
DDO = *David Dunlap Obs. Publ.*, van den Bergh, S., 1959, II, No. 5, 147.
MCG = *Morphological Catalogue of Galaxies*, Vorontsov-Velyaminov, B.A. *et al.*, 1961-74, Moscow: Moscow State University.
UGC = *Uppsala General Catalogue of Galaxies*, Nilson, P. 1973, Nova Acta Regiae Societatis Scientiarum Upsaliensis, Ser. V:A, Vol. 1, Uppsala, Sweden.

RADIO SOURCES

By Ken Tapping

This list gives examples of the various classes of radio sources to be found among the several thousand objects that have been catalogued. In addition, sources lying within the reach of small (amateur-built) radio telescopes are included. Where possible, the flux densities (S) at the frequencies 100, 500, and 1000 MHz are given. The flux unit is the "jansky" (Jy), where 1 Jy equals 10^{-26} W m^{-2} Hz^{-1}.

For information on radio astronomy, see *Radio Astronomy*, by J. D. Kraus, (McGraw Hill, 1966). Radio maps of the sky can be found in *Sky and Telescope, 63*, 230 (1982). Amateur radio astronomy is discussed in *Astronomy, 5*, no. 12, 50 (1977), in a series of articles in *J. Roy. Ast. Soc. Canada, 72*, L5, L22, L38, ... (1978), and in *Sky and Telescope, 55*, 385 and 475, and *56*, 28 and 114 (1978).

Source	α(2000)δ		S (at 100, 500, 1000 MHz) Remarks
3C10	$00^h25^m.3$	+64°08′	180, 85, 56 Remnant of Tycho's Supernova of 1572
W3	02 25.4	+62 06	—, 80, 150 IC1795; Multiple HII region; OH source
Algol	03 07.9	+40 56	* Eclipsing binary star
3C84	03 19.8	+41 32	70, 25, 17 NGC 1275; Seyfert galaxy; m = 12.7, z = 0.018
Fornax-A	03 20.4	−37 22	900, 160, 110 NGC 1316; Galaxy; m = 10.1, z = 0.006
Pictor-A	05 19.9	−45 47	440, 140, 100 Galaxy; m = 15.8, z = 0.034
V371 Orionis	05 33.7	+01 55	* Red dwarf, flare star
Taurus-A	05 34.5	+22 01	1450, 1250, 1000 Crab Nebula; Remnant of 1054 Supernova
NP0532	05 34.4	+22 01	15, 0.5, 1 Crab Pulsar; Period = 0.0331 s
Orion-A	05 35.3	−05 25	90, 200, 360 Orion Neb.; HII region; OH, IR source
3C157	06 17.6	+22 42	360, 195, 180 IC443; Supernova remnant
VY CMa	07 23.1	−20 44	* Optical var.; IR, OH, H_2O source
Puppis-A	08 20.3	−42 48	650, 300, 100
Hydra-A	09 18.1	−12 05	390, 110, 65 Galaxy; m = 14.8, z = 0.052
3C273	12 29.1	+02 03	150, 57, 49 Strongest quasar; m = 13.0, z = 0.158

*Important but weak or sporadic radio source. Mean flux density ≲1 flux unit.

Source	α(2000)δ		S (at 100, 500, 1000 MHz) Remarks
Virgo-A	$12^h30^m.8$	$+12°23'$	1950, 450, 300 M 87; Elliptical galaxy with jet
Centaurus-A	13 25.4	−43 02	8500, 2500, 1400 NGC 5128; Galaxy; m = 7.5, z = 0.002
3C295	14 11.4	+52 12	95, 60, 28 Galaxy; m = 20.5, z = 0.461
OQ172	14 45.3	+09 59	10, 4, 2 Quasar; m = 18.4, z = 3.53
Scorpius X1	16 19.9	−15 38	* X-ray, radio, and optical variable
Hercules-A	16 51.2	+05 01	800, 120, 65 Galaxy; m = 18.5, z = 0.154
Gal. Cen. Region	17 42.0	−28 50	4400, 2900, 1800 Strong, diffuse emission
Sagittarius-A	17 42.5	−28 55	100, 250, 200 Associated with Galactic Centre
Sagittarius-B2	17 47.3	−28 24	—, 10, 70 Contains many molecules
SS433	19 11.9	+04 58	* Compact object with high velocity jets
CP1919	19 21.6	+21 52	0.08, 0.03, 0.005(?) First pulsar discovered; P = 1.3375 s
PSR 1937+21	19 39.6	+21 35	5, 0.2(?), 0.04(?) millisecond pulsar; P = 0.001558 s
Cygnus-A	19 59.5	+40 44	15 500, 4000, 2100 Strong radio galaxy
Cygnus-X	20 22.6	+40 23	400, 150, 30 Complex region
BL-Lacertae	22 02.7	+42 17	—, 5, 4 Radio galaxy; m = 14.0, z = 0.07
Cassiopeia-A	23 23.4	+58 49	25 000, 4500, 2800 Supernova remnant
Jupiter			Bursts at metre wavelengths
Moon			Thermal source (~220K)
Sun			20 000, 300 000, 900 000 Also intense bursts and strong, varying emissions.

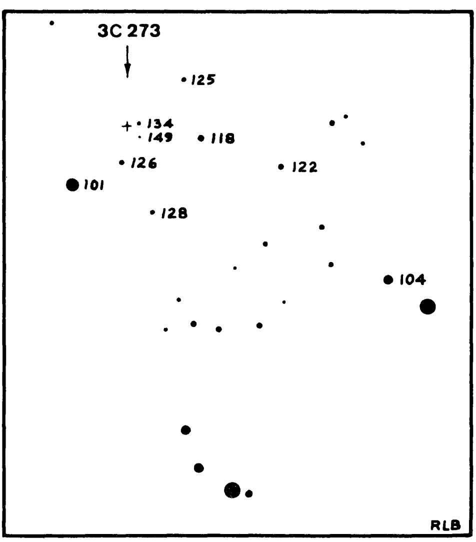
*Important but weak or sporadic radio source. Mean flux density ≲1 flux unit.

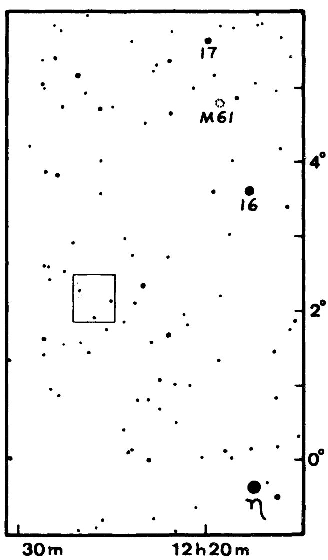
VARIABLE GALAXIES

Some peculiar galaxies (Seyfert galaxies, BL Lacertae objects, and quasars) have bright, star-like nuclei which vary in brightness by up to several magnitudes on a time scale of months to years. These variations can be studied by amateurs and students, especially using photographic techniques. The following table lists the brightest variable galaxies. For more information, see *Sky and Telescope* **55**, 372 (1978), which gives finder charts and comparison stars for the four brightest Seyfert galaxies (indicated with asterisks in the table).

Charts for finding the brightest quasar, 3C 273, are at the bottom of the page. Start with the right-hand chart which shows a "binocular size" field of view down to nearly 10th magnitude. The stars η Vir (Mag 3.9), 16 Vir (mag 5.0), and 17 Vir (mag 6.5) are labelled (η Vir is the star immediately east of the autumnal equinox on the MARCH or MAY star chart in the back of this Handbook). The two "bright" stars about 0.5° west of the small rectangle are of 7.6 magnitude (the small rectangle shows the area covered by the left-hand chart). On the left-hand chart, nine stars have their visual magnitudes indicated (on their west sides) to the nearest tenth of a magnitude, with the decimal point omitted. The position of 3C 273 is indicated by a small cross. With a red shift z = 0.158, 3C 273 is receding from us at 47 000 km/s, and is probably 2 or 3 billion light years from Earth, making it, by far, the intrinsically-brightest (output $\approx 10^{39}$ W), most-distant object that can be seen in a small telescope. (RLB)

Name	Type	R.A. 1950 h m	Dec. ° ′	Mag.
NGC 1275*	Seyfert?	3 16.5	+41 20	11–13
3C 120	Seyfert	4 30.5	+05 15	14–16
OJ 287	BL Lac	8 52.0	+20 18	12–16
NGC 4151*	Seyfert	12 08.0	+39 41	10–12
3C 273	Quasar	12 26.6	+02 20	12–13
3C 345	Quasar	16 41.3	+39 54	14–17
Mkn. 509*	Seyfert	20 41.5	−10 54	12–13
BL Lac	BL Lac	22 00.7	+42 02	14–17
NGC 7469*	Seyfert	23 00.7	+08 36	12–13





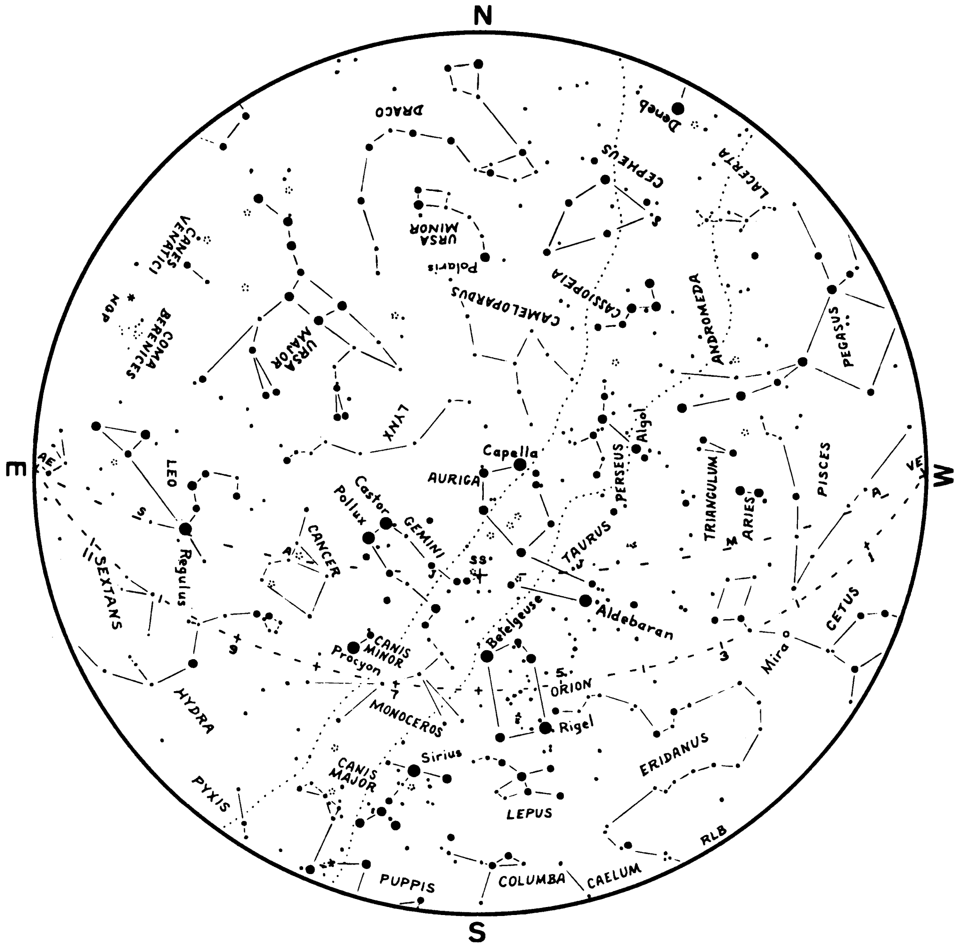
MAPS OF THE NIGHT SKY

The maps on the next seven pages cover the entire sky. Stars are shown down to a magnitude of 4.5 or 5, i.e. those which are readily apparent to the unaided eye on a reasonably dark night.

The first six maps are drawn for 45° N latitude, but are useful for latitudes several degrees north or south of this. They show the hemisphere of sky visible to an observer at various times of year. Because the aspect of the night sky changes continuously with both longitude and time, while time zones change discontinuously with both longitude and time of year, it is not possible to state simply when, in general, a particular observer will find that his or her sky fits exactly one of the six maps. The month indicated below each map is the time of year when the map will match the "late evening" sky. On any particular night, successive maps will represent the sky as it appears every four hours later. For example, at 2 or 3 am on a March night, the May map should be used. Just after dinner on a January night, the November map will be appropriate. The center of each map is the zenith, the point directly overhead; the circumference is the horizon. To identify the stars, hold the map in front of you so that the part of the horizon which you are facing (west, for instance) is downward. (The four letters around the periphery of each map indicate compass directions.)

The southern sky map is centred on the south celestial pole, and extends to 20° S declination at its periphery. There is thus considerable overlap with the southern areas of the other maps. Note that the orientation of the various names is generally inverted compared to that on the first six maps. This was done in recognition that most users of this Handbook will be residents of the Northern Hemisphere, and will make use of the southern sky map when they go on infrequent trips to the tropics. Thus in "normal" use this map will be read in an area above its centre, unlike the first six maps which are normally read below their centres. The months indicated around the edge of the map may be used to orient it to each of the preceding six maps, and have the same "late evening" significance as explained above. Tick marks around the edge of the map indicate hours of right ascension, with hours 0, 3, 6, etc. labelled. Starting at the centre of the map, the series of small crosses along 0 h right ascension indicates southern declinations 90°, 80°, 70°, ... , 20°. With the aid of a drawing compass, an observer in the Northern Hemisphere can quickly locate a circle, centred on the south celestial pole, which represents the southern limit of his or her sky.

On all seven maps, stars forming the usual constellation patterns are linked by straight lines, constellation names being given in upper case letters. Three constellations (Horologium, Mensa, and Microscopium) consist of faint stars; hence no patterns are indicated and the names are placed in parentheses. The names in lower case are those of first magnitude stars, except Algol and Mira which are famous variable stars, and Polaris which is near the north celestial pole. Small clusters of dots indicate the positions of bright star clusters, nebulae, or galaxies. Although a few of these are just visible to the naked eye, and most can be located in binoculars, a telescope is needed for good views of these objects. The pair of wavy, dotted lines indicates roughly the borders of the Milky Way. Small asterisks locate the directions of the galactic centre (GC), the north galactic pole (NGP), and the south galactic pole (SGP). LMC, SMC, and CS signify, respectively, the Large Magellanic Cloud, the Small Magellanic Cloud, and the Coal Sack. Two dashed lines appear on each of the first six maps. The one with more dashes is the celestial equator. Tick marks along this indicate hours of right ascension, the odd hours being labelled. The line with fewer dashes is the ecliptic, the apparent annual path of the Sun across the heavens. Letters along this line indicate the approximate position of the Sun at the beginning of each month. Also located along the ecliptic are the vernal equinox (VE), summer solstice (SS), autumnal equinox (AE), and winter solstice (WS). The Moon and the other eight planets are found near the ecliptic, but since their motions are not related in a simple way to our year, it is not feasible to show them on a general set of star maps. (RLB)


N
S
E
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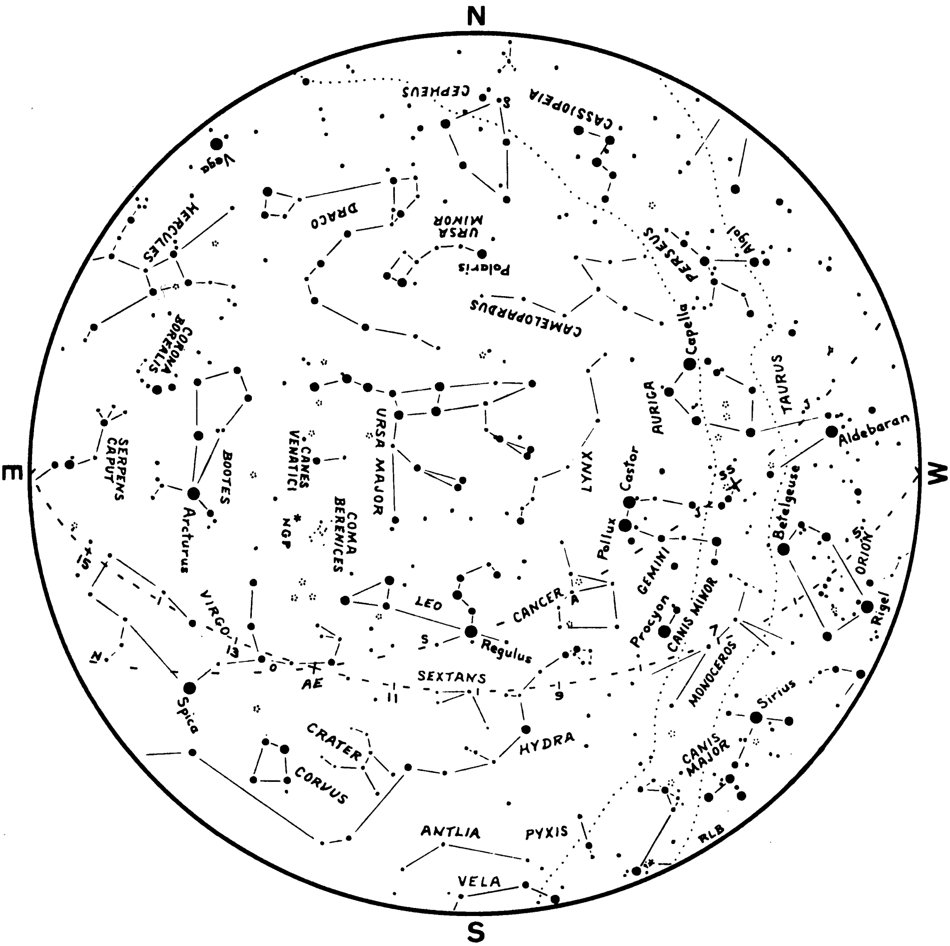
DRACO
Deneb
CEPHEUS
LACERTA
URSA MINOR
Polaris
CAMELOPARDUS
CASSIOPEIA
ANDROMEDA
PEGASUS
CANES VENATICI
COMA BERENICES
URSA MAJOR
LYNX
Capella
AURIGA
PERSEUS
Algol
TRIANGULUM
ARIES
PISCES
LEO
Regulus
SEXTANS
CANCER
Castor
Pollux
GEMINI
TAURUS
Aldebaran
CETUS
Mira
Betelgeuse
CANIS MINOR
Procyon
ORION
Rigel
MONOCEROS
HYDRA
ERIDANUS
Sirius
CANIS MAJOR
LEPUS
PYXIS
PUPPIS
COLUMBA
CAELUM
RLB

JANUARY


N
S
E
W
CEPHEUS
CASSIOPEIA
Vega
HERCULES
DRACO
URSA MINOR
Polaris
PERSEUS
Algol
CAMELOPARDUS
CORONA BOREALIS
Capella
TAURUS
AURIGA
Aldebaran
URSA MAJOR
SERPENS CAPUT
BOOTES
CANES VENATICI
LYNX
Castor
Arcturus
NGP
COMA BERENICES
Pollux
GEMINI
Betelgeuse
ORION
Rigel
VIRGO
LEO
CANCER
Procyon
CANIS MINOR
Regulus
MONOCEROS
AE
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Sirius
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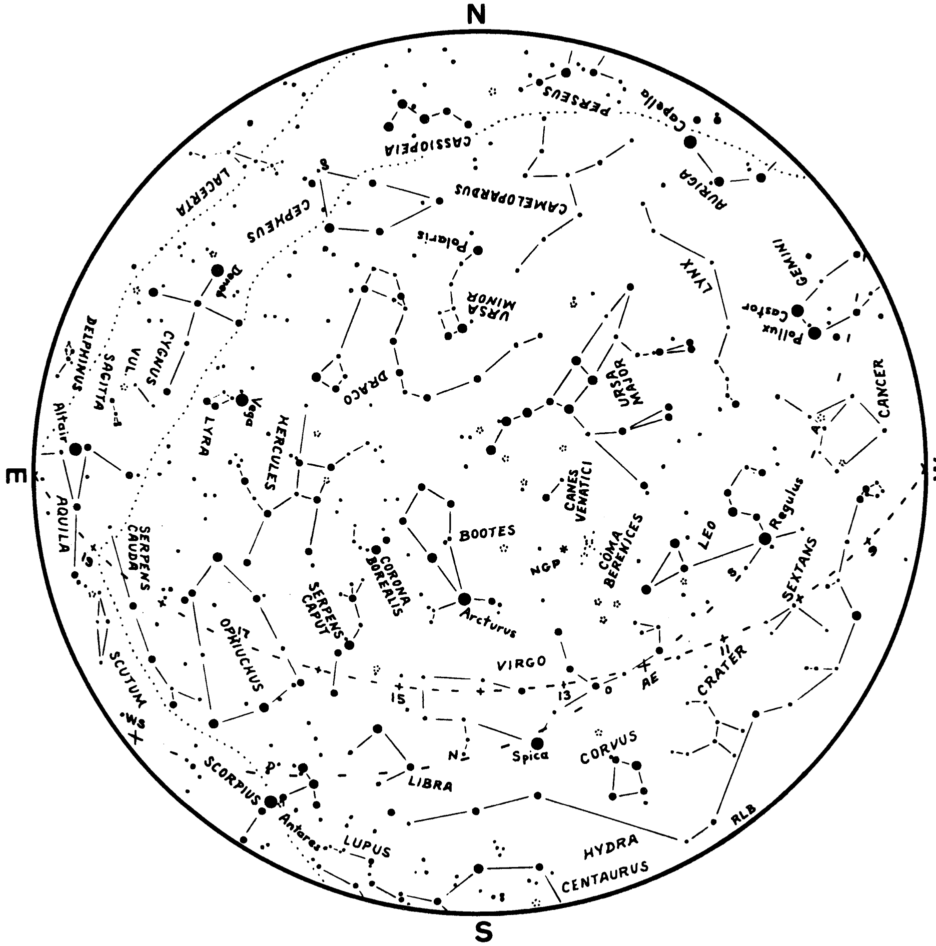
VELA

MARCH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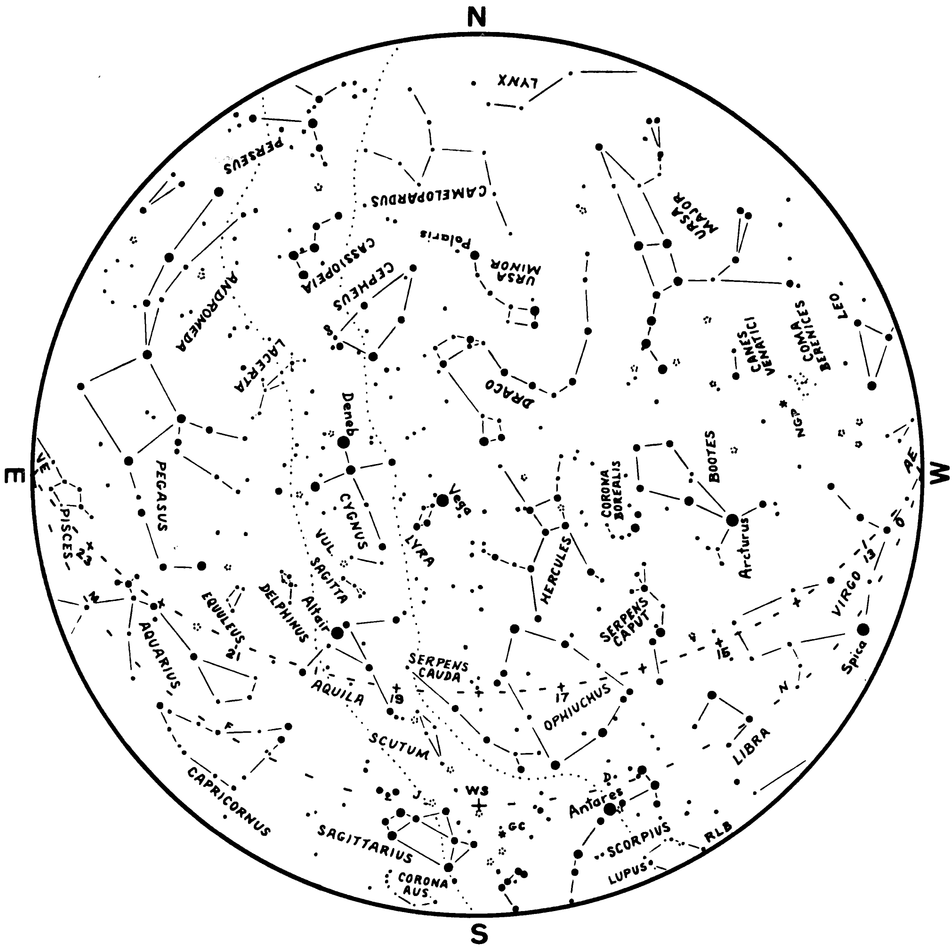
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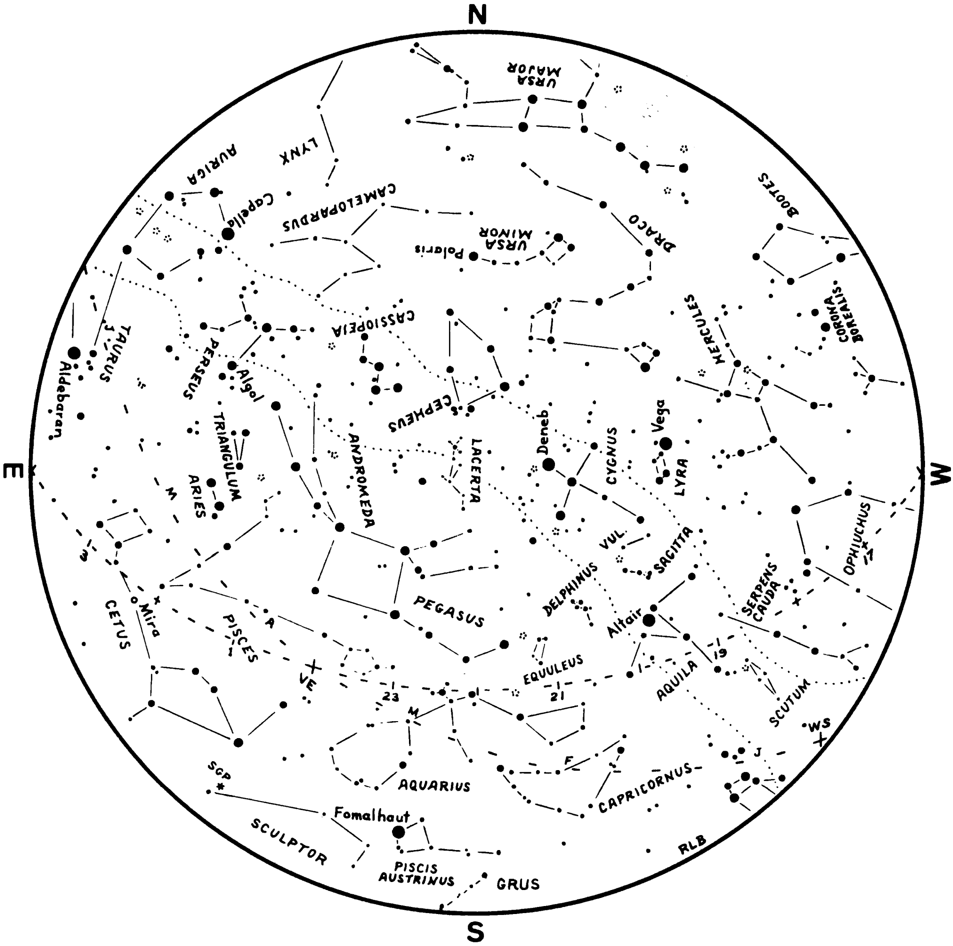
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PISCIS AUSTRINUS
GRUS
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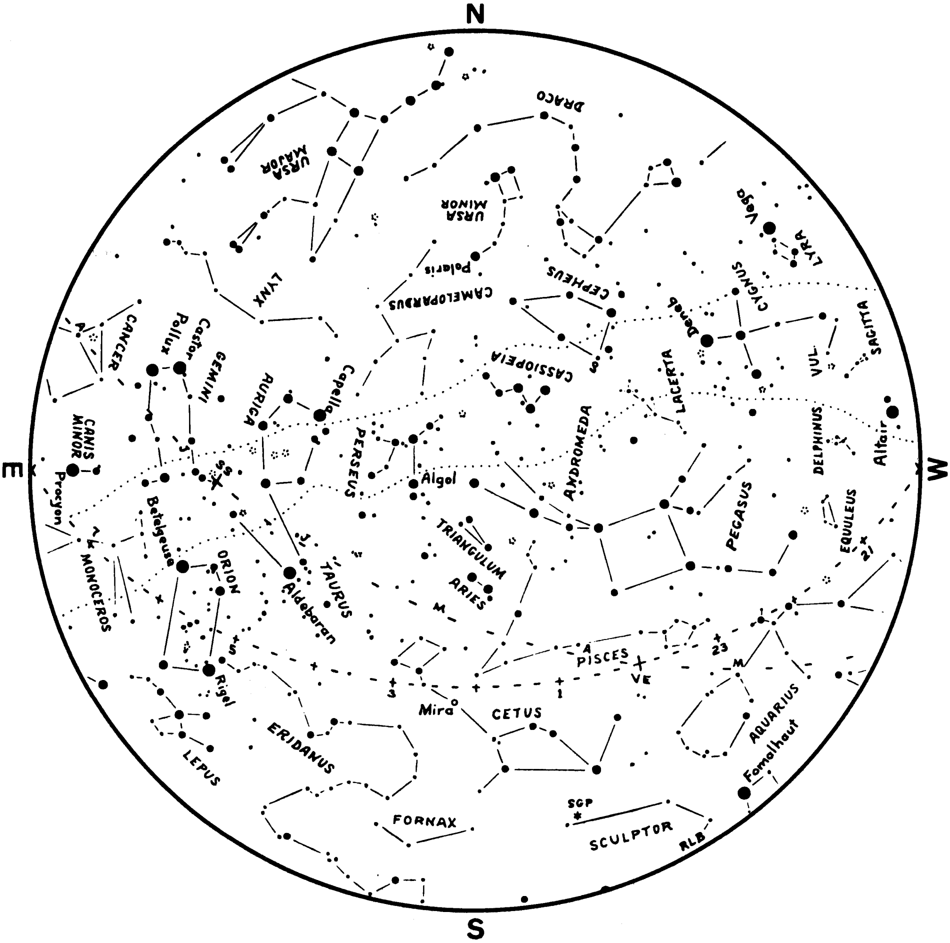
SEPTEMBER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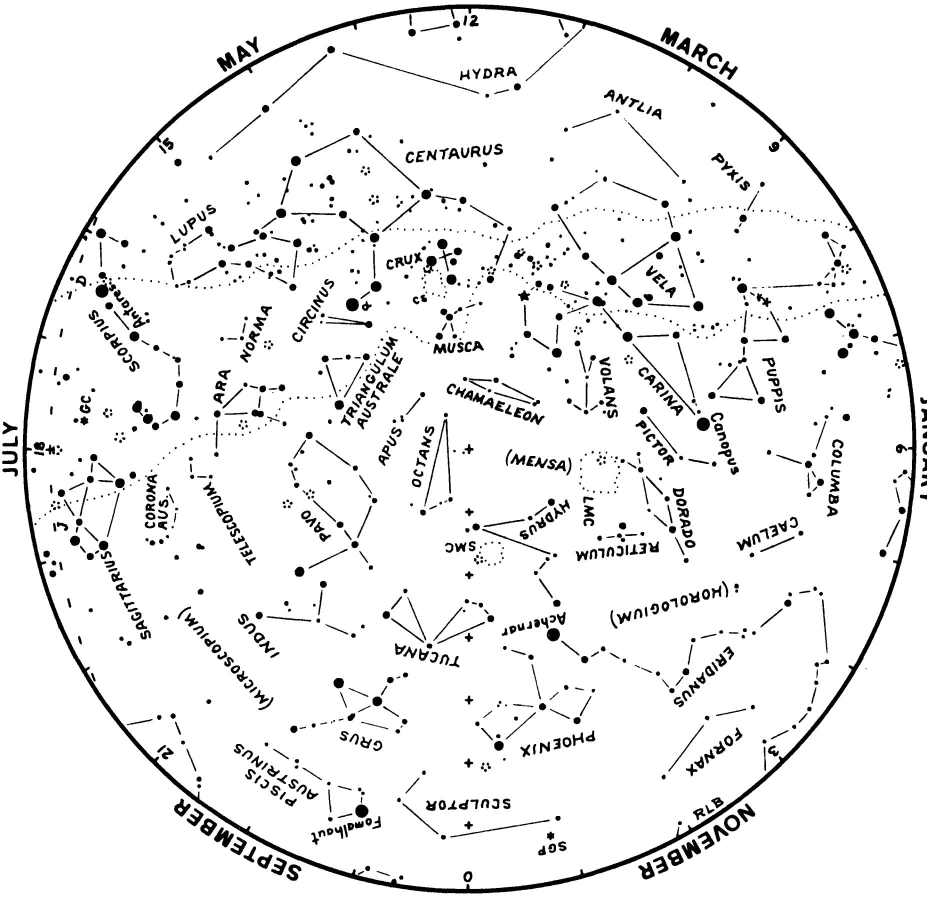
NOVEMBER



THE SOUTHERN SKY

KEY TO LEFT-HAND MARGIN SYMBOLS

D BASIC DATA

t TIME

M THE SKY MONTH BY MONTH

☉ SUN

☾ MOON

P PLANETS, SATELLITES, AND ASTEROIDS

╲. METEORS, COMETS, AND DUST

✸ STARS

⁘ NEBULAE

INDEX

CALENDAR 1989

January

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

February

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19	20	21	22	23	24	25
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March

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May

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June

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July

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August

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September

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October

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November

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December

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24	25	26	27	28	29	30
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