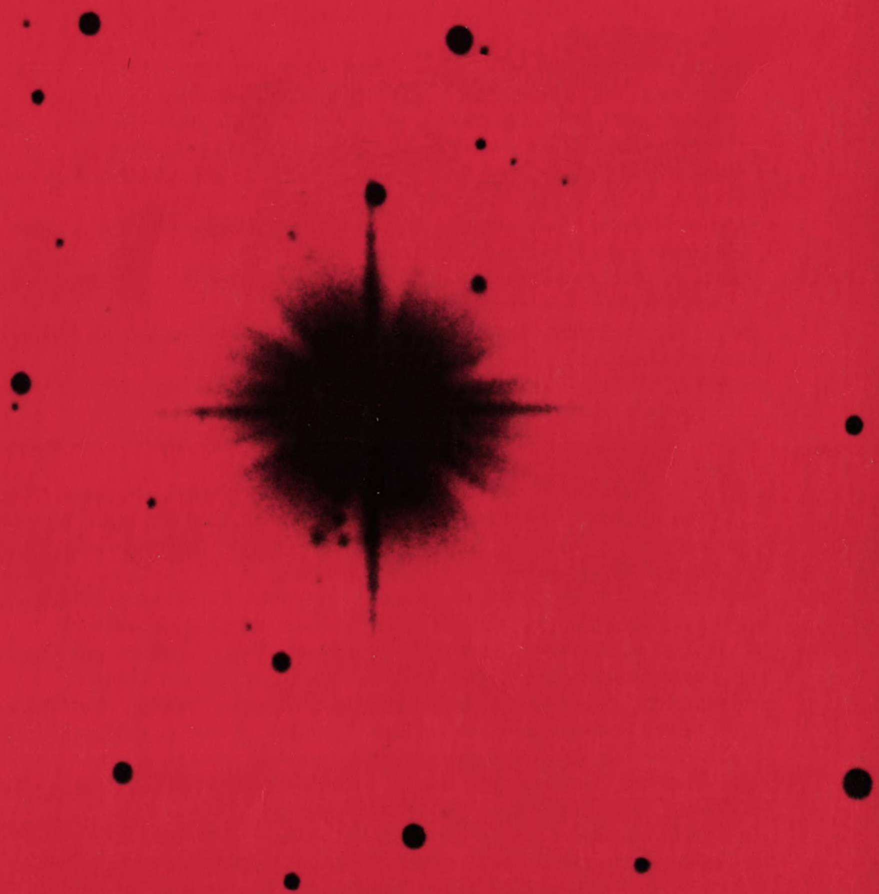
OBSERVER'S HANDBOOK 1988



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OBSERVER'S HANDBOOK 1988

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THE CENTENNIAL OF THE NGC

The initials "NGC" have appeared in many thousands of astronomical papers, including several pages of this edition of the *Observer's Handbook*, and will continue to do so for decades or centuries to come. Occasionally they even appear in newspapers when an important event such as a supernova bursts forth in a distant galaxy.

It is natural then that astronomers are frequently asked "What does NGC stand for?" The answer is easy. It is "New General Catalogue", compiled and published in 1888 by the remarkable astronomer J. L. E. Dreyer by invitation of the Royal Astronomical Society. The *New General Catalogue of Nebulae and Clusters of Stars* contains 7840 items, and its supplements, the first *Index Catalogue* (IC) in 1895, 1529, and the *Second Index Catalogue* in 1908, 3857, for a total of 13 226. These three catalogues were reprinted in 1953 by the Royal Astronomical Society in its Memoirs series, by the Replika Process by Lund Humphries, London. In 1973 the NGC was republished in revised and altered form by Jack W. Sulentic and William G. Tifft of the University of Arizona at its Press, as *The Revised New General Catalogue of Nonstellar Astronomical Objects* (RNGC) with corrections and updating of information. Whereas the editions of the NGC are now very scarce, copies of the RNGC may be found in many astronomical libraries around the world. It has been estimated that about 85% of the items listed in it are galaxies.

The cataloguing of the nebulous spots in the sky really began in a haphazard way in the 18th century. Charles Messier earned himself long-lasting fame by making a list of 103 nuisance spots that got in his way when he was trying to discover new comets. The last discoveries on his list were made with the help of Pierre Méchain. William Herschel was more thorough and his systematic survey published in three separate catalogues between 1786 and 1802 as a General Catalogue contained some 2500 objects. It was supplemented and expanded to the southern sky by his son John Herschel who published in 1864 the *General Catalogue of Nebulae and Clusters of Stars*, containing 5079 items. Then in 1888, at the invitation of the Royal Astronomical Society, John Louis Emil Dreyer published the *New General Catalogue of Nebulae and Clusters of Stars*. The reason for the name is obvious. Dreyer had spent the previous two years checking and systematizing the mass of data, including observations of his own, which had accumulated up to that time.

Besides giving accurate positions, Dreyer developed a neat, compact way of describing the nature of the objects in his Catalogues, with pages at the end of interpretation. In particular his use of exclamation marks seems to carry his own enthusiasm over into the reader. Here is part of his description of the Great Globular Cluster in Hercules, one of the distant starry objects most often viewed by amateur astronomers (The full description includes right ascension and north polar distance, both for epoch 1860.0, and the annual precession in these coordinates):

No.	G.C.	J.H.	W.H.	Other Observers	Summary Description
6205	4230	1968	. . .	Halley 1714, M 13	! ! ⊕ , eB, vRi, vgeCM, st 11. . .

∗ a star; ∗ 10, a star of 10th magnitude; ⁑ double star; ⁂ triple star
! remarkable, ! ! very much so, ! ! ! a magnificent or otherwise interesting object.
△ triangle, forms a triangle with;
⊕ globular cluster of stars; ○ planetary nebula; ◎ annular nebula
st 9 . . . stars from the 9th mag. downwards; st 9 . . . 13 stars from the 9th to 13th mag.

with a short section of his explanation. eB = extremely bright; vRi = very rich; vgeCM = very gradually extremely compressed in the middle. The RNGC has translated some of these symbols into modern computer print-out.

Dreyer was born in Copenhagen, Denmark on February 13, 1852. At age 14 he became keenly interested in astronomy when he read a book about the famous Danish astronomer Tycho Brahe. Dreyer began his studies at Copenhagen University in 1869 and by 1870 he had been given a key of access to its Observatory (a happy event which in various locations has befallen other budding astronomers). In 1874 he moved to Ireland where he remained until his retirement. First he worked at Birr Castle, Lord Rosse's Observatory, and then at Dunsink Observatory of the University of Dublin. In 1882 he became Director of the Armagh Observatory where he remained until his retirement in 1916 to Oxford and its University. There he maintained his publications until his death on September 14, 1926.

Not only did Dreyer complete these great catalogues which would be a creditable lifework for anyone, but he also did outstanding historical writing in astronomy. In fact, various astronomers appraising Dreyer's work differ in their opinions as to which were more important, his catalogues or his contributions to the history of astronomy. (The difference probably comes from the individual's own interests!) When Dreyer was awarded the Gold Medal of the Royal Astronomical Society (London) in 1916, it was on the basis of this double aspect of his scientific work. The President of the Society, Prof. R. A. Sampson, noted that the award was "for his Contributions to Astronomical History and for his Catalogues of Nebulae". Dreyer was a principal contributor to the "History of the Royal Astronomical Society" (1923), and he prepared an edition of the complete works of William Herschel. Only two years after he had finished the NGC he published an outstanding volume, *Tycho Brahe—A Picture of Scientific Life and Work in the Sixteenth Century*. (He says in his preface that for many years he had gathered books, pamphlets and excerpts on the subject). In later years (1913–1919) he went on to publish 15 volumes detailing all of Brahe's work.

As I perused the obituaries and biographical notes on Dreyer I wished that some of them had included personal details of his life, but the information was almost entirely about his scientific works. One thing I did learn—Dreyer never really recovered from the death in 1923 of his wife, Katherine Tuthill, whom he had married while at Birr Castle in 1875. He was survived by one daughter and three sons all of whom were military officers.

HELEN SAWYER HOGG

COVER PHOTOGRAPH—SUPERNOVA 1987A

(A description appears on page 95)

EDITOR'S COMMENTS

Although the casual user of this Handbook may have the impression that much of it remains the same from year to year, significant additions and/or revisions have been made to 162 of the 212 pages of this, the eightieth edition and the largest ever.

D. J. Jeffers of Cheadle, England provided valuable comments which have been incorporated into the section **Telescope Exit Pupils**; the section **Solar Activity** has been completely revised by Dr. Gaizauskas and two new contributors, C. L. Donaldson and E. J. Kennelly of the Herzberg Institute of Astrophysics; thanks to a recommendation by Leonard Larkin of Saint John, N.B., the key to the **Map Of The Moon** has been made more useful for observers by the addition of selenographic longitudes; on the suggestion of Dr. John A. Wheeler of the University of Texas at Austin, a new section, **Tides**, has been added; on the suggestion of Dr. Richard Herr of the University of Delaware, the two-year summary of full moon dates has been altered to give new moon dates and higher precision; Terence Dickinson has extensively revised **The Planets for 1988** section to give more of an observational emphasis; Dr. Larry Bogan has added data concerning Iapetus to the section of **Configurations of Saturn's Satellites**; Dr. Robert Millis has rewritten the text to the **Planetary Appulses and Occultations** section; a footnote concerning areas of the **Constellations** has been added to p.161 following a suggestion by James Himer of the Calgary Centre; once again Dr. Robert Garrison has updated **The Brightest Stars** table, maintaining its status as "the best in existence"; Dr. Alan Batten has made some revisions and additions to **The Nearest Stars** section; Dr. Janet Mattei has provided information concerning the star R Leonis in the section on **Variable Stars**. 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.

The Royal Astronomical Society of Canada is 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. As always, the Society is fortunate in having Rosemary Freeman, its Executive-Secretary, who looks after many details concerning this publication throughout the year. Special acknowledgement is again 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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REPORTING OF SIGNIFICANT ASTRONOMICAL DISCOVERIES

Professional and amateur astronomers who wish to report a possible discovery (e.g. a new comet, nova, or supernova) should send their report to Dr. Brian Marsden of the International Astronomical Union Central Bureau for Astronomical Telegrams, 60 Garden St., Cambridge, MA 02138, U.S.A. TWX/telex/telegraphic communication is preferred (TWX number: 710-320-6842 ASTROGRAM CAM). Inexperienced observers are advised to have their observation checked, if at all possible, before contacting the Central Bureau. For an account of the history of the Bureau and its work today, see "Life in the Hot Seat", *Sky and Telescope*, August 1980, p. 92.

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.)

SUGGESTIONS FOR FURTHER READING

Burnham, Robert. *Burnham's Celestial Handbook, Volumes 1, 2 and 3.* Dover Publications, Inc., New York, 1978. A detailed, well-presented, observer's guide to the universe beyond the solar system.

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

Hogg, Helen S. *The Stars Belong To Everyone.* Doubleday Canada Ltd., Toronto, 1976. Superb introduction to the sky.

Sky and Telescope. Sky Publishing Corp., 49 Bay State Road, Cambridge, MA 02238–9102. A monthly magazine containing articles on all aspects of astronomy.

Texereau, J. *How To Make A Telescope.* (2nd edition). Willmann-Bell, Box 35025, Richmond, VA 23235. 1984. The best guide to making a Newtonian telescope.

ATLASES

Moon, Mars and Venus, by A. Rükl. A compact, detailed lunar atlas. Available from Hamlyn Publishing Group Ltd., Toronto and New York, 1976.

Norton's Star Atlas, by A. Norton. A classic. Contains 8700 stars to magnitude 6.3 on 8 charts. Available from Sky Publishing Corp., 49 Bay State Road, Cambridge, MA 02238-9102, USA

Sky Atlas 2000.0, by W. Tirion. Large format, modern, and detailed. Contains 43 000 stars to magnitude 8.0 on 26 charts. Available from Sky Publishing Corp. (See above).

Uranometria 2000.0, by W. Tirion, B. Rappaport, and G. Lovi. The newest and most comprehensive, general-purpose star atlas. Two Volumes. (Volume 2, covering the Southern Hemisphere, will be available in mid-1988). Contains a third of a million stars to magnitude 9.5 and more than 10 000 clusters, nebulae, and galaxies on 473 charts. Available from Sky Publishing Corp. (See above).

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 (819) 888-2822 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 closed during much of January. For information call (705) 522-3701.

Gordon MacMillan Southam Observatory, 1100 Chestnut St., Vancouver, BC, V6J 3J9.

Open Tuesday through Sunday 12:00–5:00 p.m., 7:00 p.m.–11:00 p.m., weather and volunteer staff permitting. Closed non-holiday Mondays. Free admission. 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

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 264-2030.

Doran Planetarium, Laurentian University, Ramsey Lake Road, Sudbury, Ontario P3E 2C6. Telephone (705) 675-1151, ext. 2220 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.

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 daily except Monday.
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 astronomical equipment and science books. Show times (204) 943-3142 and weekdays (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.

Seneca College Planetarium, 1750 Finch Ave. E., North York, Ontario, M2J 2X5. School shows daily throughout the school year. Other shows on evenings and weekends. For reservations call (416) 491-5050, ext. 546.

D

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 110.)

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		Period of Revolution		Eccentricity (e)	Inclination (i)	Long. of Node (☊)	Long. of Perihelion (π)	Mean Long. at Epoch (L)
	AU	millions of km	Sidereal (P)	Synodic					
				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/cm^3	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)	Eccen-tricity 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	$(1.3 \pm 0.2) \times 10^{-4}$ ~2	9.4/ 25 0.319	0.015 1.1	11.6 0.07	A. Hall, 1877
II Deimos	12	$(1.8 \pm 0.2) \times 10^{-5}$ ~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. 111.

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

*Co-orbital satellites.

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
III Tethys	1060	7.6 ± 0.9 1.2	295/ 48 1.888	0.000 1.1	10.3 0.8	G. Cassini, 1684
XIII Telesto	25	— —	295/ 48 1.888[a]	~0 ~0	(18) 0.7	Smith, Larson, Reitsema, 1980
XIV Calypso	25	— —	295/ 48 1.888[b]	~0 ~0	(18) 1.0	Pascu, Seidelmann, Baum, Currie, 1980
IV Dione	1120	10.5 ± 0.3 1.4	378/ 61 2.737	0.002 0.02	10.4 0.6	G. Cassini, 1684
XII Helene	30	— —	378/ 61 2.737[c]	0.005 0.2	(18) 0.6	P. Laques, J. Lecacheux, 1980
V Rhea	1530	24.9 ± 1.5 1.3	526/ 85 4.517	0.001 0.4	9.7 0.6	G. Cassini, 1672
VI Titan	5550†	1345.7 ± 0.3 1.88	1 221/ 197 15.945	0.029 0.3	8.4 0.2	C. Huygens, 1655
VII Hyperion	255	— —	1 481/ 239 21.276	0.104 0.4	14.2 0.3	W. Bond, G. Bond, W. Lassell, 1848
VIII Iapetus	1460	18.8 ± 1.2 1.2	3 561/ 575 79.331	0.028 14.7	11.0v 0.08 −0.4	G. Cassini, 1671
IX Phoebe	220	— —	12 960/2096 550.46	0.163 150	16.5 0.05	W. Pickering, 1898
SATELLITES OF URANUS						
1986U7	(40)	— —	49.7/3.7 0.333	~0 ~0	>22.9 <0.1	Voyager 2, 1986
1986U8	(50)	— —	53.8/4.0 0.375	~0 ~0	>22.6 <0.1	Voyager 2, 1986
1986U9	(50)	— —	59.2/4.4 0.433	~0 ~0	>22.6 <0.1	Voyager 2, 1986

[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.
†Cloud-top diameter. Solid-body diameter equals 5150 km.

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
1986U3	(60)	— —	61.8/ 4.6 0.463	~0 ~0	>22.2 <0.1	Voyager 2, 1986
1986U6	(60)	— —	62.7/ 4.7 0.475	~0 ~0	>22.2 <0.1	Voyager 2, 1986
1986U2	(80)	— —	64.6/ 4.9 0.492	~0 ~0	>21.5 <0.1	Voyager 2, 1986
1986U1	(80)	— —	66.1/ 5.0 0.513	~0 ~0	>21.5 <0.1	Voyager 2, 1986
1986U4	(60)	— —	69.9/ 5.2 0.558	~0 ~0	>22.2 <0.1	Voyager 2, 1986
1986U5	(60)	— —	75.3/ 5.6 0.621	~0 ~0	>22.2 <0.1	Voyager 2, 1986
1985U1	170	— —	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

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*.

LENGTH

1 astronomical unit (AU)	$= 1.495\,978\,70 \times 10^{11}$ m = 499.004 782 light-seconds
1 light-year (ly)	$= 9.460\,536 \times 10^{15}$ m (based on average Gregorian year)
	= 63 239.8 AU
1 parsec (pc)	$= 3.085\,678 \times 10^{16}$ 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

Surface gravity at latitude 45°, g = 9.806 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°.4409 (1988.0)
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 ≡ 1S = 1.9891 × 10^{30} kg; Radius = 696 265 km; Eff. temperature = 5770 K
Output: Power = 3.83 × 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 = 1.36 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)

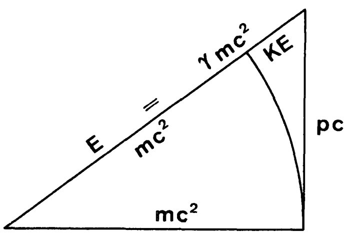
MILKY WAY GALAXY
Mass ≈10^{12} solar masses
Centre: α = 17 h 42.5 min, δ = −28° 59′ (1950)
Distance to centre ≈9 kpc, diameter ≈100 kpc
North pole: α = 12 h 49 min, δ = 27° 24′ (1950)
Rotational speed (at Sun) ≈250 km s^{-1}
Rotational period (at Sun) ≈220 Ma
Velocity relative to the 3 K background ≈600 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 = 6.6262 × 10^{-34} J s
Gravitational constant, G = 6.672 × 10^{-11} N m^2 kg^{-2}
Elementary charge, e = 1.6022 × 10^{-19} C
Constant in Coulomb's law ≡ 10^{-7} c^2 (SI units) (This defines the coulomb.)
Avogadro constant, N_A = 6.022 × 10^{26} $kmol^{-1}$
Boltzmann constant, k = 1.381 × 10^{-23} J K^{-1} = 8.62 × 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) = 1.6606 × 10^{-27} kg = $N_A{}^{-1}$ = 931.50 MeV
Electron rest mass = 9.1095 × 10^{-31} kg = 548.580 μu = 0.51100 MeV
Proton rest mass = 1.007 276 u = 938.28 MeV
Neutron rest mass = 1.008 665 u = 939.57 MeV
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) = 1.6022 × 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 $\gamma \equiv (1 - v^2/c^2)^{-0.5}$:



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)

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: $\nu = \nu_0 \gamma^{-1}(1 - \beta \text{ Cos } \alpha)^{-1}$
$z \equiv (\lambda - \lambda_0)/\lambda_0 = \gamma(1 - \beta \text{ Cos } \alpha) - 1$

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

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 |δ|, precession formulae may be used (see p. 16).

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

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

*(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 $\gtrsim$ 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.

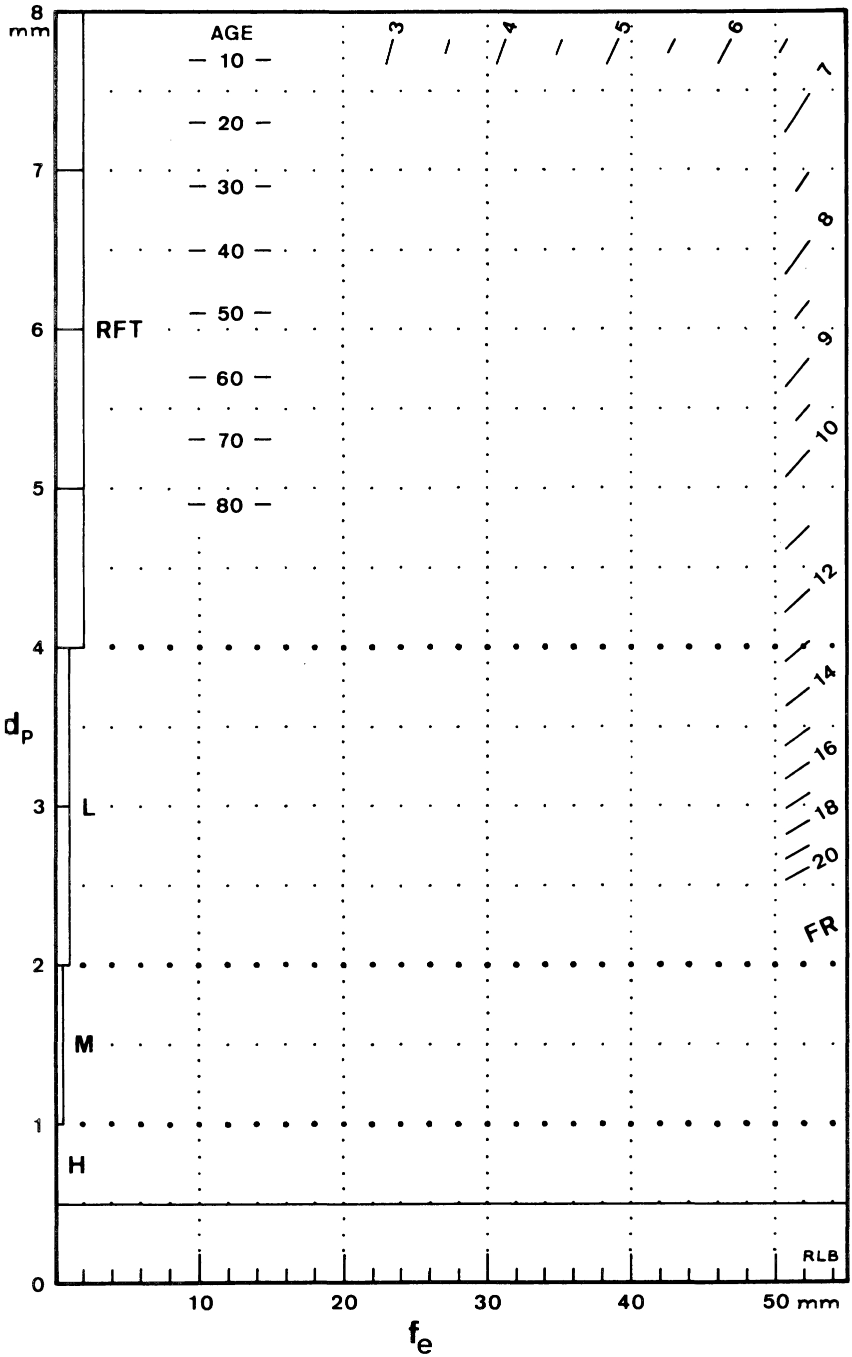
D

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
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12
14
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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. 14.

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. 8). 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.

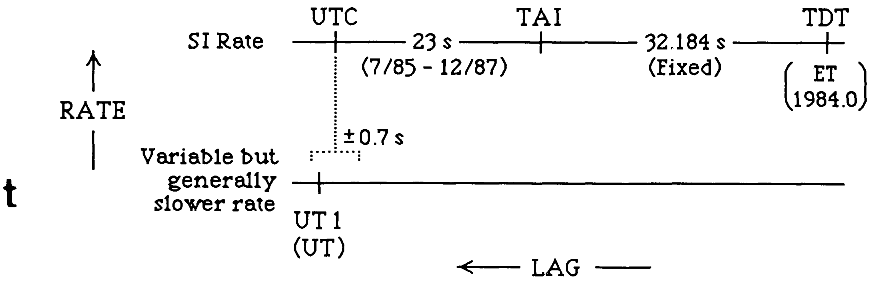
Early in the 20th century the UT1 and ET scales coincided, but since Earth's rotation rate has been generally slower than the SI (ET) rate, by 1970 UT1 was 40 seconds behind ET and was losing more than one second per year. During the next 15 years, Earth's rotation rate increased (part of the random 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 ≡ ΔUT1 does not exceed ±0.7 s. UTC now lags TAI, and as of July 1, 1985 (when a leap second was last inserted) TAI − UTC ≡ ΔAT = 23 s. Thus as this edition of the *Observer's Handbook* goes to press (August, 1987), TDT − UTC = 23 s + 32.184 s = 55.184 s exactly). However, it is likely that another leap second will be introduced into UTC at the end of 1987. (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 24 and 25). 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. 56). 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. 60).

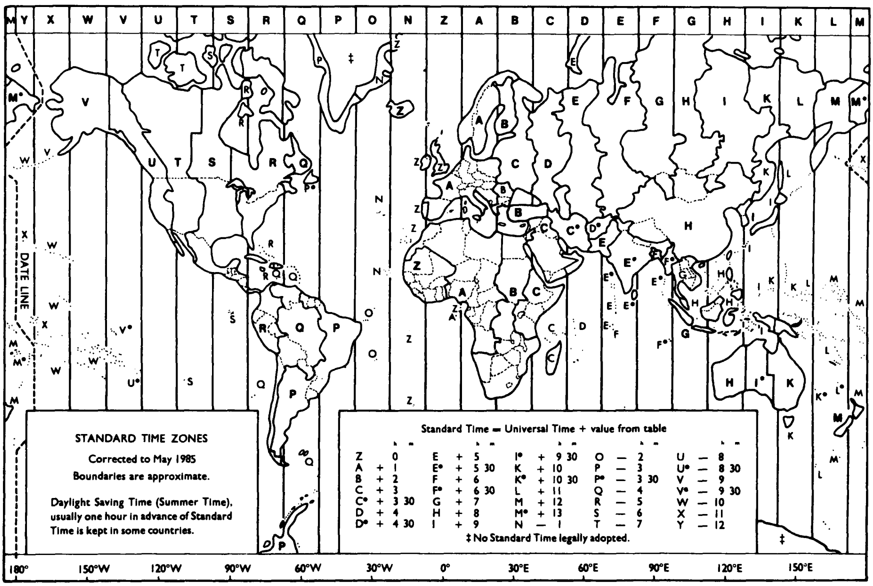
In the same manner that GMST is defined, a *Local Mean Sidereal Time* (LMST) is defined for each observer's meridian. Because Earth makes one more rotation with respect to the other stars than it does with respect to the Sun during a year, sidereal time gains relative to standard time, LMT, UT1, TAI 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. 14). 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. 26. (RLB)



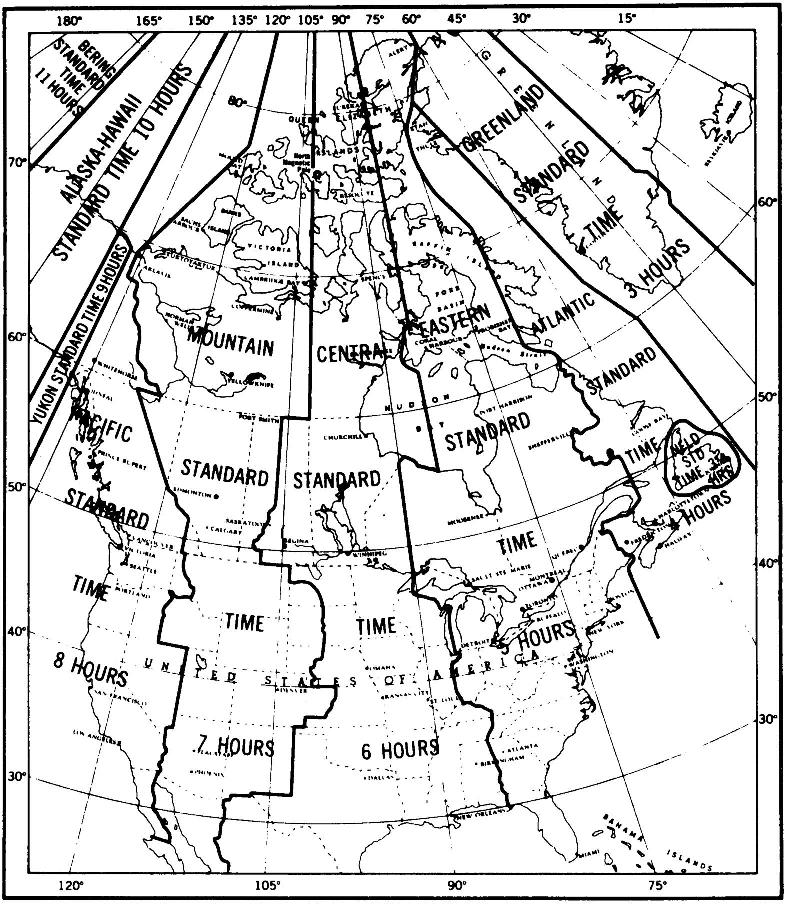
The rate and scale relations between time scales which run at or near the SI rate and which are not longitude dependent. It is likely that the difference TAI - UTC will equal 24 s as of January 1, 1988.

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)



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 1988

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

Jan. 0	06.5926^h	Apr. 0	12.5722^h	July 0	18.5518^h	Oct. 0	00.5971^h
Feb. 0	08.6297^h	May 0	14.5435^h	Aug. 0	20.5888^h	Nov. 0	02.6341^h
Mar. 0	10.5352^h	June 0	16.5805^h	Sep. 0	22.6258^h	Dec. 0	04.6054^h

GMST at hour t UT on day d of the month

$$= \text{GMST at } 0^h\text{UT on day } 0 + 0^{h}.065710d + 1^{h}.002738t$$

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 ± 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, 1988

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 1988, 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.):

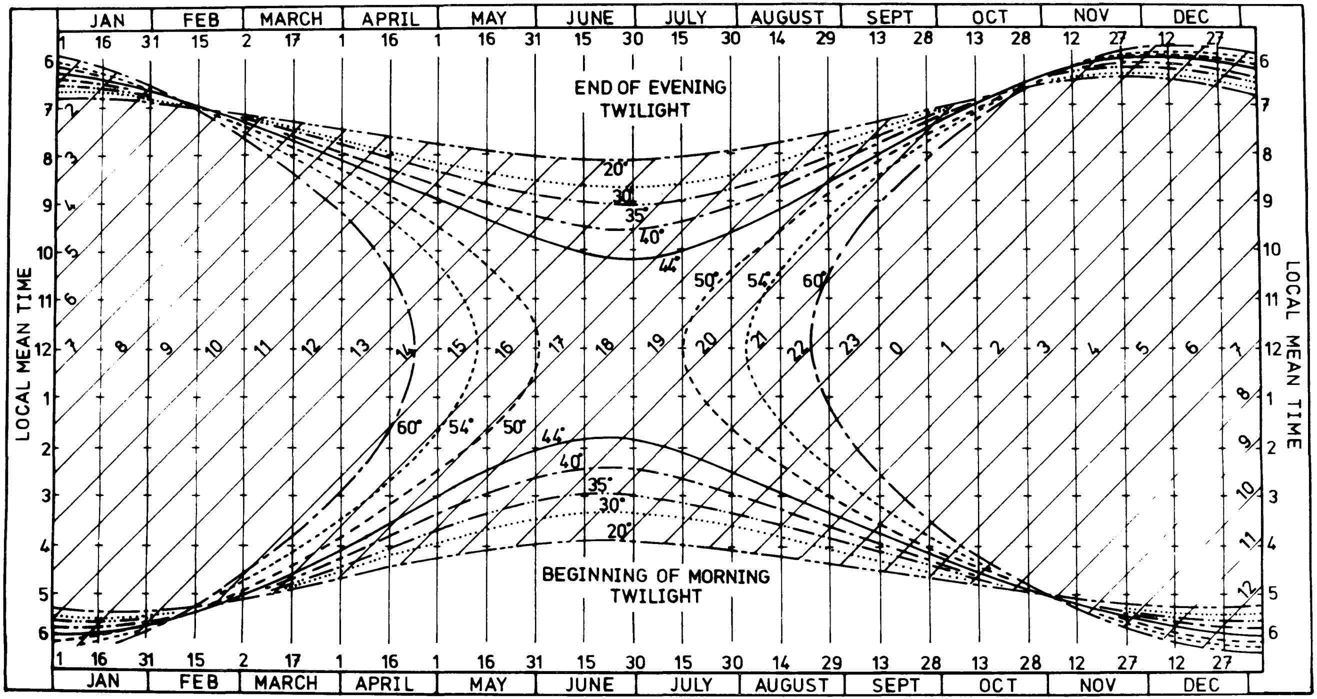
Jan.	244 7160.5	Apr.	244 7251.5	July	244 7342.5	Oct.	244 7434.5
Feb.	244 7191.5	May	244 7281.5	Aug.	244 7373.5	Nov.	244 7465.5
Mar.	244 7220.5	June	244 7312.5	Sep.	244 7404.5	Dec.	244 7495.5

e.g. 21:36 EDT on May 18 = 01:36 UT on May 19 = May 19.07 UT = 244 7281.5 + 19.07 = JD 244 7300.57

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).

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 23 and 64 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. Estimates of altitude are for an observer in latitude 45°N.

The Sun—Data concerning the position, transit, orientation, rotation, activity, rise, and set of the Sun appear in the section beginning on page 54. For detailed information on solar eclipses during the year, see the section beginning on page 82.

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. 68.

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 1988, the ascending node of the Moon's orbit regresses from longitude 357.2° to 337.8° (Pisces into Aquarius).

The Planets—Further information in regard to the planets, including Pluto, is found on pp. 109–132. 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. 10 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 144–147. 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. 92–106 and 151.

ANNIVERSARIES AND FESTIVALS 1988

New Year's Day	Fri.	Jan.	1
M. L. King's Birthday (U.S.)	Mon.	Jan.	18
Valentine's Day	Sun.	Feb.	14
Good Friday		Apr.	1
First Day of Passover	Sat.	Apr.	2
Easter Sunday		Apr.	3
First Day of Ramadân	Mon.	Apr.	18
Astronomy Day	Sat.	Apr.	23
Mother's Day	Sun.	May	8
Feast of Weeks	Sun.	May	22
Whit Sunday — Pentecost		May	22
Victoria Day (Canada)	Mon.	May	23
C.A.S. AM (Trent Univ.)	May 29 - June 1		
Memorial Day (U.S.)	Mon.	May	30
Father's Day	Sun.	June	19
Saint-Jean-Baptiste (P.Q.)	Fri.	June	24
R.A.S.C. GA (Victoria)	June 30 - July 2 (?)		
Canada Day	Fri.	July	1
Independence Day (U.S.)	Mon.	July	4
Civic Holiday (Canada)	Mon.	Aug.	1
Islamic New Year	Sun.	Aug.	14
Labour Day	Mon.	Sept.	5
Jewish New Year	Mon.	Sept.	12
Day of Atonement	Wed.	Sept.	21
First Day of Tabernacles	Mon.	Sept.	26
Thanksgiving Day (Canada)	Mon.	Oct.	10
Columbus Day (U.S.)	Mon.	Oct.	10
Halloween	Mon.	Oct.	31
Remembrance Day (Canada)	Fri.	Nov.	11
Veterans' Day (U.S.)	Fri.	Nov.	11
Thanksgiving Day (U.S.)	Thur.	Nov.	24
Christmas Day	Sun.	Dec.	25

1988 and 1989 calendars are on the inside back cover.

THE SKY FOR JANUARY 1988

		Mercury	Venus	Mars	Jupiter	Saturn	Uranus	Neptune
RA	1	19^h05^m	21^h00^m	15^h31^m	1^h17^m	17^h40^m	17^h50^m	18^h34^m
	11	20^h16^m	21^h49^m	15^h58^m	1^h19^m	17^h45^m	17^h52^m	18^h35^m
	21	21^h20^m	22^h35^m	16^h26^m	1^h23^m	17^h50^m	17^h55^m	18^h37^m
Dec	1	-24°38'	-18°56'	-18°32'	+6°43'	-22°15'	-23°35'	-22°16'
	11	-21°53'	-15°02'	-20°06'	+7°02'	-22°17'	-23°36'	-22°14'
	21	-16°45'	-10°29'	-21°25'	+7°27'	-22°19'	-23°37'	-22°13'
Tran	1	12^h28^m	14^h21^m	8^h51^m	18^h34^m	10^h59^m	11^h09^m	11^h52^m
	11	12^h59^m	14^h30^m	8^h39^m	17^h58^m	10^h25^m	10^h32^m	11^h15^m
	21	13^h23^m	14^h37^m	8^h27^m	17^h22^m	9^h50^m	9^h55^m	10^h37^m
Mag	1	-1.0	-4.0	+1.6	-2.5	+0.5	+5.8	+8.0
	11	-0.9	-4.0	+1.5	-2.5	+0.5	+5.8	+8.0
	21	-0.8	-4.0	+1.4	-2.4	+0.5	+5.8	+8.0

The Moon—On Jan. 1.0 UT, the age of the Moon is 11.2 days. The Sun's selenographic colongitude is 49.89° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on Jan. 26 (7°) and minimum (east limb exposed) on Jan. 13 (8°). The libration in latitude is maximum (north limb exposed) on Jan. 17 (7°) and minimum (south limb exposed) on Jan. 2 (7°) and Jan. 29 (7°). The Moon reaches its greatest northern declination on Jan. 2 (+29°) and Jan. 30 (+29°) and its greatest southern declination on Jan. 17 (−29°). This range in declination is close to the maximum possible.

Mercury is visible in the last half of the month, very low in the southwest, just after sunset. Greatest elongation east (19°) occurs on Jan. 26.

Venus is well placed for observing in 1988. This month, it stands about 25° above the southwestern horizon at sunset, and sets about 3 h later. It is joined by the waxing crescent Moon (and Mercury) around Jan. 20–21.

Mars is also well placed for observing in 1988. This month, it moves from Libra through Scorpius into Ophiuchus, passing 5° north of Antares on Jan. 21. It rises about 3 h before the Sun, and is approaching the meridian by sunrise. See also *Saturn* below.

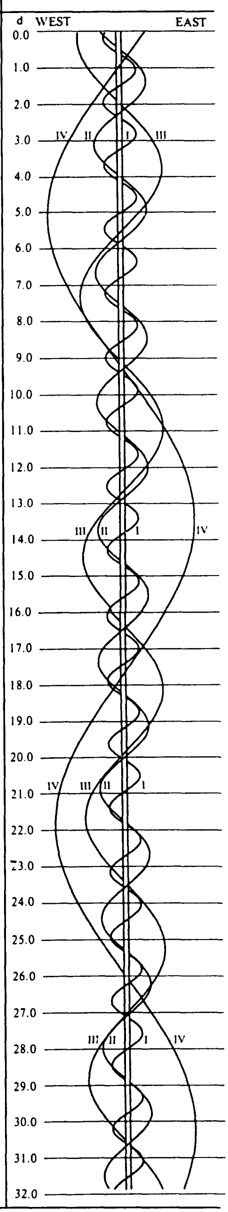
Jupiter is in Pisces, and dominates this rather barren area of the sky this winter. At sunset, it is approaching the meridian, high in the southern sky. It sets after midnight.

Saturn is in Sagittarius throughout 1988, between Antares and the Teapot. It was in conjunction with the Sun in December 1987, but by late January it is visible low in the southeast at sunrise. Around Jan. 15–17, the waning crescent Moon joins Saturn and Mars in the morning sky.

Uranus and *Neptune* are both buried in the Milky Way in Sagittarius in 1988. Uranus is within 5° of Saturn all year.

1988			JANUARY UNIVERSAL TIME	Min. of Algol
	d	h m		h m
Fri.	1			
Sat.	2			
Sun.	3			13 12
Mon.	4	00	Earth at perihelion (147 092 000 km)	
		01 40	☺ Full Moon	
		04	Quadrantid meteors	
Tue.	5			
Wed.	6			10 01
Thu.	7	06	Moon at apogee (405 981 km) Mercury at greatest hel. lat. S.	
Fri.	8			
Sat.	9			6 51
Sun.	10			
Mon.	11			
Tue.	12	07 04	☾ Last Quarter	3 40
		12	Spica 0.4° N. of Moon; occultation[1]	
Wed.	13			
Thu.	14			
Fri.	15	16	Mars 5° N. of Moon	0 29
		23	Antares 0.3° N. of Moon; occultation[2]	
Sat.	16			
Sun.	17	04	Saturn 6° N. of Moon	21 18
		06	Uranus 5° N. of Moon	
		21	Neptune 6° N. of Moon	
Mon.	18			
Tue.	19	05 26	● New Moon	
		21	Moon at perigee (357 509 km)	
Wed.	20	09	Mercury 2° N. of Moon	18 08
Thu.	21	19	Venus 0.07° N. of Moon; occultation[3]	
		22	Mars 5° N. of Antares	
Fri.	22	06	Vesta at opposition	
Sat.	23			14 57
Sun.	24			
Mon.	25	02	Jupiter 4° S. of Moon	
		21 53	☽ First Quarter	
Tue.	26	17	Mercury at greatest elong. E. (19°) Mercury at ascending node	11 46
Wed.	27			
Thu.	28			
Fri.	29			8 35
Sat.	30			
Sun.	31		Mercury at perihelion	

Config. of Jupiter's Satellites



[1]Visible in S. of S. America
[2]Visible in Indonesia, Australia except N., New Zealand
[3]Visible in S. America except N. and S., extreme W. of Africa

THE SKY FOR FEBRUARY 1988

		Mercury	Venus	Mars	Jupiter	Saturn	Uranus	Neptune
RA	1	21^h58^m	23^h24^m	16^h58^m	1^h28^m	17^h55^m	17^h57^m	18^h39^m
	11	21^h32^m	0^h07^m	17^h27^m	1^h34^m	17^h59^m	17^h59^m	18^h40^m
	21	20^h59^m	0^h49^m	17^h56^m	1^h41^m	18^h02^m	18^h01^m	18^h41^m
Dec	1	-10°50'	-4°59'	-22°32'	+8°02'	-22°20'	-23°37'	-22°11'
	11	-10°46'	+0°14'	-23°13'	+8°38'	-22°20'	-23°37'	-22°10'
	21	-14°18'	+5°27'	-23°35'	+9°18'	-22°20'	-23°37'	-22°09'
Tran	1	13^h15^m	14^h43^m	8^h15^m	16^h44^m	9^h12^m	9^h14^m	9^h55^m
	11	12^h07^m	14^h46^m	8^h05^m	16^h11^m	8^h36^m	8^h37^m	9^h17^m
	21	10^h56^m	14^h49^m	7^h55^m	15^h38^m	8^h01^m	7^h59^m	8^h39^m
Mag	1	+0.3	-4.1	+1.3	-2.3	+0.6	+5.7	+8.0
	11	+4.6	-4.1	+1.3	-2.2	+0.6	+5.7	+8.0
	21	+1.3	-4.1	+1.2	-2.2	+0.6	+5.7	+8.0

The Moon—On Feb. 1.0 UT, the age of the Moon is 12.8 days. The Sun's selenographic colongitude is 66.78° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on Feb. 23 (7°) and minimum (east limb exposed) on Feb. 11 (8°). The libration in latitude is maximum (north limb exposed) on Feb. 13 (7°) and minimum (south limb exposed) on Feb. 25 (7°). The Moon reaches its greatest northern declination on Feb. 26 (+29°) and its greatest southern declination on Feb. 13 (−29°).

Mercury is not visible this month. Inferior conjunction occurs on Feb. 11.

Venus is well up in the southwest at sunset, and sets about 3 h later.

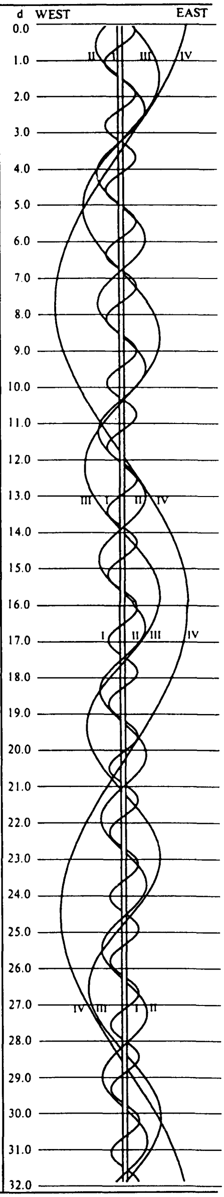
Mars moves from Ophiuchus into Sagittarius this month, passing 0.01° north of Uranus on Feb. 22 and 1.3° south of Saturn on Feb. 23. Saturn is slightly brighter than Mars, and Mars is the redder. Mars rises about 3 h before the Sun, and is approaching the meridian by sunrise. Around Feb. 13, the waning crescent Moon joins Mars and Saturn in the morning sky.

Jupiter is in Pisces. It is past the meridian at sunset, and sets about 5 h later.

Saturn is in Sagittarius. It rises about 3 h before the Sun, and is low in the southern sky at sunrise. Saturn is 1.3° north of Uranus on February 13. See also *Mars* above.

Uranus is only 0.01° south of Mars on Feb. 22, but the point of closest approach will not be visible from the Western Hemisphere.

1988			FEBRUARY UNIVERSAL TIME	Min. of Algol	Config. of Jupiter's Satellites
	d	h m		h m	
Mon.	1	10	Ceres in conjunction with Sun	5 25	
		15	Vesta 0.2° S. of Moon; occultation.		
		16	Mercury stationary		
Tue.	2	20 51	○ Full Moon		
Wed.	3	10	Moon at apogee (406 395 km)		
Thu.	4			2 14	
Fri.	5				
Sat.	6			23 03	
Sun.	7				
Mon.	8	19	Spica 0.7° N. of Moon; occultation[1]		
Tue.	9			19 53	
Wed.	10	23 01	☾ Last Quarter		
			Mercury at greatest hel. lat. N.		
Thu.	11	04	Mercury in inferior conjunction		
			Mars at descending node		
Fri.	12	08	Antares 0.5° N. of Moon; occultation[2]	16 42	
Sat.	13	01	Saturn 1.3° N. of Uranus		
		09	Mars 5° N. of Moon		
		19	Saturn 6° N. of Moon		
		19	Uranus 5° N. of Moon		
Sun.	14	09	Neptune 6° N. of Moon		
Mon.	15			13 31	
Tue.	16				
Wed.	17	10	Moon at perigee (356 914 km)		
		15 54	● New Moon		
Thu.	18	23	Pluto stationary	10 21	
			Venus at ascending node		
Fri.	19				
Sat.	20	17	Venus 1.9° S. of Moon		
Sun.	21	18	Jupiter 4° S. of Moon	7 10	
Mon.	22	21	Mars 0.01° N. of Uranus		
Tue.	23	04	Mercury stationary		
		13	Mars 1.3° S. of Saturn		
Wed.	24	12 15	☽ First Quarter	3 59	
Thu.	25				
Fri.	26				
Sat.	27			0 48	
Sun.	28	12	Vesta 0.2° N. of Moon; occultation.		
Mon.	29			21 38	



[1]Visible in Indonesia, W. and S. of Australia, Antarctica, extreme S. of New Zealand

[2]Visible in S. America except N., Antarctica

		Mercury	Venus	Mars	Jupiter	Saturn	Uranus	Neptune
RA	1	21^h08^m	1^h27^m	18^h22^m	1^h47^m	18^h05^m	18^h02^m	18^h42^m
	11	21^h44^m	2^h09^m	18^h52^m	1^h55^m	18^h08^m	18^h03^m	18^h43^m
	21	22^h35^m	2^h51^m	19^h21^m	2^h03^m	18^h09^m	18^h04^m	18^h43^m
Dec	1	-15°43'	+9°59'	-23°38'	+9°57'	-22°19'	-23°37'	-22°08'
	11	-14°38'	+14°40'	-23°22'	+10°42'	-22°18'	-23°38'	-22°06'
	21	-11°08'	+18°50'	-22°47'	+11°28'	-22°17'	-23°38'	-22°06'
Tran	1	10^h31^m	14^h51^m	7^h46^m	15^h09^m	7^h28^m	7^h25^m	8^h05^m
	11	10^h29^m	14^h54^m	7^h36^m	14^h38^m	6^h51^m	6^h47^m	7^h26^m
	21	10^h41^m	14^h56^m	7^h26^m	14^h06^m	6^h14^m	6^h08^m	6^h47^m
Mag	1	+0.3	-4.2	+1.0	-2.1	+0.5	+5.7	+8.0
	11	+0.1	-4.2	+0.9	-2.1	+0.5	+5.7	+8.0
	21	-0.1	-4.3	+0.8	-2.1	+0.5	+5.7	+7.9

The Moon—On Mar. 1.0 UT, the age of the Moon is 12.3 days. The Sun's selenographic colongitude is 59.64° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on Mar. 22 (7°) and minimum (east limb exposed) on Mar. 10 (7°). The libration in latitude is maximum (north limb exposed) on Mar. 11 (7°) and minimum (south limb exposed) on Mar. 24 (7°). The Moon reaches its greatest northern declination on Mar. 24 (+29°) and its greatest southern declination on Mar. 12 (−29°). There is a penumbral eclipse of the Moon on Mar. 3, not visible from North America.

Mercury is at greatest elongation west (27°) on Mar. 8, but this is a very unfavourable elongation from the point of view of northern observers. The planet is only 8° above the eastern horizon at sunrise.

Venus is approaching a very favourable greatest elongation east; it stands 40° above the southwestern horizon at sunset, and sets about 4 h later. It passes 2° north of Jupiter on Mar. 6, and these two bright planets (Venus the brighter) dominate this rather barren part of the sky. The waxing crescent Moon adds to the picture around Mar. 20–21.

Mars is in Sagittarius, moving across the top of the Teapot early in the month. It passes 1.4° south of Neptune on Mar. 7. It rises about 3 h before the Sun, and is approaching the meridian by sunrise. This situation will persist for the next several weeks, as its eastward motion keeps pace with that of the Sun.

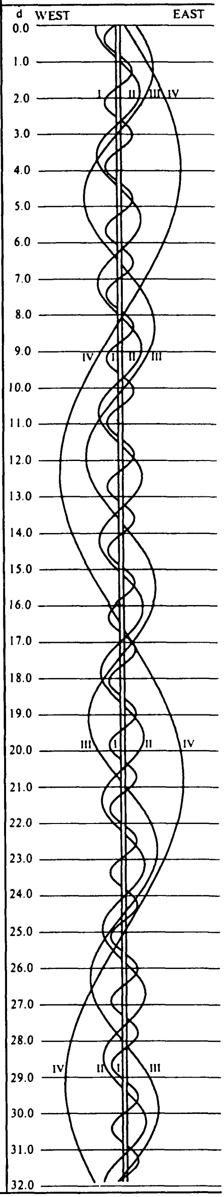
Jupiter moves from Pisces into Aries this month. It stands about 30° above the southwest horizon at sunset, and sets about 3 h later. See also *Venus* above.

Saturn, in Sagittarius, rises about 4 h before the Sun, and is approaching the meridian by sunrise.

Neptune is 1.4° north of Mars on Mar. 7

1988			MARCH UNIVERSAL TIME	Min. of Algol
	d	h m		h m
Tue.	1	12	Moon at apogee (406 250 km)	
Wed.	2			
Thu.	3	16 01	○ Full Moon; Eclipse of Moon, p. 82	18 27
Fri.	4		Mercury at descending node	
Sat.	5			
Sun.	6	20	Venus 2° N. of Jupiter	15 16
Mon.	7	01	Spica 0.7° N. of Moon; occultation[1]	
		22	Mars 1.4° S. of Neptune	
Tue.	8	06	Mercury at greatest elong. W. (27°)	
Wed.	9			12 06
Thu.	10	10	Vesta stationary	
		15	Antares 0.6° N. of Moon; occultation[2]	
Fri.	11	10 56	☾ Last Quarter	
Sat.	12	04	Uranus 5° N. of Moon	8 55
		06	Saturn 6° N. of Moon	
		19	Neptune 6° N. of Moon	
Sun.	13	00	Mars 5° N. of Moon	
Mon.	14			
Tue.	15		Mercury at aphelion	5 44
Wed.	16	05	Mercury 0.5° N. of Moon; occultation[3]	
		20	Moon at perigee (359 517 km)	
Thu.	17			
Fri.	18	02 02	● New Moon; Eclipse of Sun, p. 82	2 33
Sat.	19			
Sun.	20	09 39	Vernal equinox; spring begins	23 23
		14	Jupiter 5° S. of Moon	
Mon.	21	12	Venus 2° S. of Moon	
Tue.	22			
Wed.	23		Venus at perihelion	20 12
Thu.	24			
Fri.	25	04 41	☽ First Quarter	
Sat.	26	20	Vesta 0.5° N. of Moon; occultation.	17 01
Sun.	27			
Mon.	28			
Tue.	29	00	Moon at apogee (405 472 km)	13 50
Wed.	30			
Thu.	31			

Config. of Jupiter's Satellites



[1]Visible in extreme E. of S. America, extreme S. of Africa, Antarctica
[2]Visible in E. Australia, New Zealand, Antarctica, S. of S. America.
[3]Visible in Antarctica, S. of Indian Ocean, Indonesia, Australia except S.E.

THE SKY FOR APRIL 1988

		Mercury	Venus	Mars	Jupiter	Saturn	Uranus	Neptune
RA	1	23^h39^m	3^h37^m	19^h53^m	2^h13^m	18^h11^m	18^h05^m	18^h44^m
	11	0^h44^m	4^h18^m	20^h21^m	2^h22^m	18^h11^m	18^h05^m	18^h44^m
	21	1^h58^m	4^h55^m	20^h49^m	2^h31^m	18^h11^m	18^h04^m	18^h44^m
Dec	1	-4°51'	+22°35'	-21°48'	+12°20'	-22°17'	-23°38'	-22°05'
	11	+2°46'	+25°09'	-20°37'	+13°07'	-22°16'	-23°38'	-22°04'
	21	+11°35'	+26°50'	-19°11'	+13°53'	-22°16'	-23°38'	-22°04'
Tran	1	11^h02^m	14^h59^m	7^h14^m	13^h33^m	5^h32^m	5^h25^m	6^h05^m
	11	11^h28^m	15^h00^m	7^h03^m	13^h02^m	4^h53^m	4^h46^m	5^h25^m
	21	12^h03^m	14^h58^m	6^h52^m	12^h32^m	4^h13^m	4^h06^m	4^h46^m
Mag	1	-0.4	-4.3	+0.7	-2.1	+0.5	+5.6	+7.9
	11	-1.0	-4.4	+0.5	-2.0	+0.4	+5.6	+7.9
	21	-2.2	-4.5	+0.4	-2.0	+0.4	+5.6	+7.9

The Moon—On Apr. 1.0 UT, the age of the Moon is 13.9 days. The Sun's selenographic colongitude is 77.23° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on Apr. 19 (6°) and minimum (east limb exposed) on Apr. 6 (6°). The libration in latitude is maximum (north limb exposed) on Apr. 7 (7°) and minimum (south limb exposed) on Apr. 20 (7°). The Moon reaches its greatest northern declination on Apr. 21 (+29°) and its greatest southern declination on Apr. 8 (−29°).

Mercury is not visible this month. It is in superior conjunction on Apr. 20.

Venus is very well placed for viewing this month. It is at greatest elongation east (46°) on Apr. 3, at which time it stands about 40° above the western horizon at sunset. It moves eastward past the Pleiades early in the month, and is 10°N. of Aldebaran on Apr. 15.

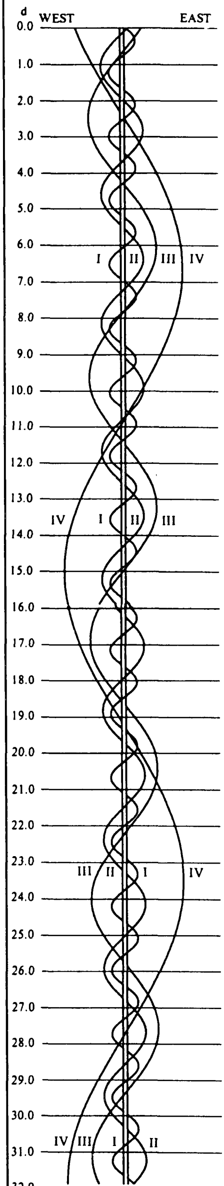
Mars moves from Sagittarius into Capricornus this month. It rises about 3 h before the Sun, and is approaching the meridian by sunrise.

Jupiter, in Aries, is rapidly closing in on the Sun, and is lost in the evening twilight by mid-month.

Saturn, in Sagittarius, rises about midnight and is past the meridian by sunrise. It is stationary on Apr. 11.

1988			APRIL UNIVERSAL TIME	Min. of Algol
	d	h m		h m
Fri.	1			10 40
Sat.	2	09 21	☺ Full Moon	
Sun.	3	07	Spica 0.7° N. of Moon; occultation[1]	
		08	Venus at greatest elong. E. (46°)	
Mon.	4	19	Uranus stationary	7 29
			Mercury at greatest hel. lat. S.	
Tue.	5			
Wed.	6	20	Antares 0.5° N. of Moon; occultation[2]	
Thu.	7			4 18
Fri.	8	10	Uranus 5° N. of Moon	
		13	Saturn 6° N. of Moon	
Sat.	9	01	Neptune 6° N. of Moon	
		19 21	☾ Last Quarter	
Sun.	10	15	Mars 3° N. of Moon	1 07
Mon.	11	02	Saturn stationary	
		12	Neptune stationary	
Tue.	12			21 56
Wed.	13	23	Moon at perigee (364 311 km)	
Thu.	14		Venus at greatest hel. lat. N.	
Fri.	15	14	Venus 10° N. of Aldebaran	18 45
Sat.	16	12 00	● New Moon	
Sun.	17			
Mon.	18		Martian autumnal equinox	15 34
Tue.	19			
Wed.	20	00	Venus 1.0° S. of Moon; occultation[3]	
		15	Mercury in superior conjunction	
Thu.	21			12 23
Fri.	22	03	Lyrid meteors	
Sat.	23	15	Vesta 0.9° N. of Moon; occultation.	
		22 32	☽ First Quarter	
			Mercury at ascending node	
Sun.	24			9 13
Mon.	25	19	Moon at apogee (404 509 km)	
Tue.	26			
Wed.	27			6 02
Thu.	28		Mercury at perihelion	
Fri.	29			
Sat.	30	14	Spica 0.7° N. of Moon; occultation[4]	2 51

Config. of Jupiter's Satellites



[1]Visible in Antarctica, extreme S. of S. America
[2]Visible in S.E. Africa, Madagascar, Antarctica, S. Tasmania, New Zealand
[3]Visible in Siberia, Arctic, Greenland, Iceland
[4]Visible in W. Australia, Antarctica

THE SKY FOR MAY 1988

		Mercury	Venus	Mars	Jupiter	Saturn	Uranus	Neptune
RA	1	3^h19^m	5^h28^m	21^h16^m	2^h40^m	18^h10^m	18^h03^m	18^h44^m
	11	4^h34^m	5^h51^m	21^h43^m	2^h50^m	18^h08^m	18^h02^m	18^h43^m
	21	5^h25^m	6^h02^m	22^h08^m	2^h59^m	18^h06^m	18^h01^m	18^h42^m
Dec	1	+19°40'	+27°38'	-17°33'	+14°38'	-22°16'	-23°38'	-22°04'
	11	+24°21'	+27°39'	-15°44'	+15°21'	-22°16'	-23°39'	-22°05'
	21	+25°17'	+26°56'	-13°48'	+16°02'	-22°16'	-23°39'	-22°05'
Tran	1	12^h45^m	14^h50^m	6^h39^m	12^h02^m	3^h32^m	3^h26^m	4^h06^m
	11	13^h19^m	14^h34^m	6^h26^m	11^h32^m	2^h52^m	2^h46^m	3^h26^m
	21	13^h30^m	14^h04^m	6^h12^m	11^h02^m	2^h10^m	2^h05^m	2^h46^m
Mag	1	-1.3	-4.5	+0.3	-2.0	+0.3	+5.6	+7.9
	11	-0.4	-4.5	+0.1	-2.0	+0.2	+5.6	+7.9
	21	+0.7	-4.4	0.0	-2.0	+0.2	+5.6	+7.9

The Moon—On May 1.0 UT, the age of the Moon is 14.5 days. The Sun's selenographic colongitude is 83.16° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on May 17 (5°) and minimum (east limb exposed) on May 2 (5°) and May 29 (6°). The libration in latitude is maximum (north limb exposed) on May 4 (7°) and minimum (south limb exposed) on May 17 (7°). The Moon reaches its greatest northern declination on May 18 (+28°) and its greatest southern declination on May 5 (−28°).

Mercury is visible most of the month, very low in the west at sunset. It is at greatest elongation east (22°) on May 19, and this is a favourable elongation. It is brighter before May 19 than after. On May 11, it passes 8° north of Aldebaran.

Venus is visible most of the month, progressively lower in the west at sunset. By the end of the month, it is rapidly closing in on the Sun. Greatest brilliancy (−4.5) occurs on May 6, and on the same date Venus reaches its greatest northern declination (27°44′) in several decades.

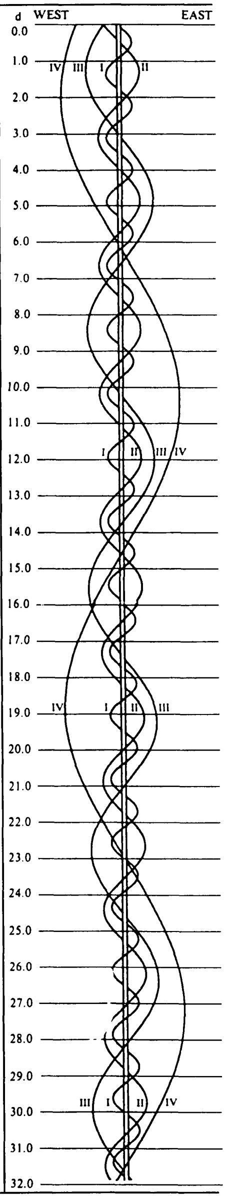
Mars moves from Capricornus into Aquarius this month. It rises about 4 h before the Sun, and is approaching the meridian by sunrise.

Jupiter is not visible this month. It is in conjunction on May 2.

Saturn, in Sagittarius, rises before midnight and is low in the southwest by sunrise.

1988			MAY UNIVERSAL TIME	Min. of Algol
	d	h m		h m
Sun.	1	09	Pluto at opposition	
		23 41	☺ Full Moon	
Mon.	2	21	Jupiter in conjunction	23 40
Tue.	3			
Wed.	4	02	Antares 0.4° N. of Moon; occultation[1]	
		06	Eta Aquarid meteors	
Thu.	5	15	Uranus 5° N. of Moon	20 29
		17	Saturn 6° N. of Moon	
Fri.	6	07	Neptune 6° N. of Moon	
		20	Venus at greatest brilliancy (−4.5)	
Sat.	7			
Sun.	8		Mercury at greatest hel. lat. N.	17 18
Mon.	9	01 23	☾ Last Quarter	
		06	Mars 0.8° N. of Moon; occultation[2]	
Tue.	10	22	Moon at perigee (369 065 km)	
Wed.	11	06	Mercury 8° N. of Aldebaran	14 07
Thu.	12			
Fri.	13			
Sat.	14			10 56
Sun.	15	22 11	● New Moon	
Mon.	16			
Tue.	17	17	Mercury 3° S. of Moon	7 45
Wed.	18	13	Venus 1.2° S. of Moon	
Thu.	19	02	Mercury at greatest elong. E. (22°)	
Fri.	20			4 33
Sat.	21			
Sun.	22	13	Venus stationary	
Mon.	23	12	Juno in conjunction with Sun	1 22
		14	Moon at apogee (404 096 km)	
		16 49	☽ First Quarter	
Tue.	24			
Wed.	25			22 11
Thu.	26			
Fri.	27	23	Spica 0.8° N. of Moon; occultation[3]	
Sat.	28			19 00
Sun.	29	12	Pallas stationary	
Mon.	30			
Tue.	31	10 53	☺ Full Moon	15 49
		10	Antares 0.4° N. of Moon; occultation[4]	
			Mercury at descending node	

Config. of Jupiter's Satellites



[1]Visible in S. America, Antarctica
[2]Visible in extreme S. of S. America, Antarctica, extreme S. of Africa, Madagascar
[3]Visible in S. of S. America, Antarctica
[4]Visible in New Guinea, Australia, New Zealand, S.W. of S. America

		Mercury	Venus	Mars	Jupiter	Saturn	Uranus	Neptune
RA	1	5^h46^m	5^h54^m	22^h35^m	3^h09^m	18^h03^m	17^h59^m	18^h41^m
	11	5^h33^m	5^h32^m	22^h59^m	3^h18^m	18^h00^m	17^h58^m	18^h40^m
	21	5^h13^m	5^h07^m	23^h21^m	3^h27^m	17^h57^m	17^h56^m	18^h39^m
Dec	1	+23°23'	+25°17'	-11°37'	+16°45'	-22°17'	-23°39'	-22°06'
	11	+20°29'	+22°55'	-9°36'	+17°21'	-22°18'	-23°39'	-22°07'
	21	+18°31'	+20°16'	-7°38'	+17°54'	-22°18'	-23°39'	-22°08'
Tran	1	13^h05^m	13^h12^m	5^h56^m	10^h29^m	1^h24^m	1^h20^m	2^h02^m
	11	12^h11^m	12^h10^m	5^h40^m	9^h59^m	0^h41^m	0^h39^m	1^h22^m
	21	11^h13^m	11^h06^m	5^h23^m	9^h28^m	23^h55^m	23^h54^m	0^h41^m
Mag	1	+2.4	-4.2	-0.2	-2.0	+0.1	+5.6	+7.9
	11	+5.0	-3.8	-0.4	-2.0	0.0	+5.5	+7.9
	21	+3.3	-4.0	-0.6	-2.1	0.0	+5.5	+7.9

M

The Moon—On June 1.0 UT, the age of the Moon is 16.1 days. The Sun's selenographic colongitude is 101.68° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on June 13 (5°) and minimum (east limb exposed) on June 26 (6°). The libration in latitude is maximum (north limb exposed) on June 1 (7°) and June 28 (7°) and minimum (south limb exposed) on June 13 (7°). The Moon reaches its greatest northern declination on June 14 (+28°) and its greatest southern declination on June 1 (−28°) and June 29 (−28°).

Mercury is not visible this month. It is in inferior conjunction on June 13.

Venus is in inferior conjunction on June 13, but it may be visible with difficulty by the end of the month, very low in the east at dawn.

Mars, in Aquarius, rises about 4 h before the Sun, and is well up in the southern sky by sunrise. In the next few weeks, its visibility rapidly improves as it moves northward and brightens.

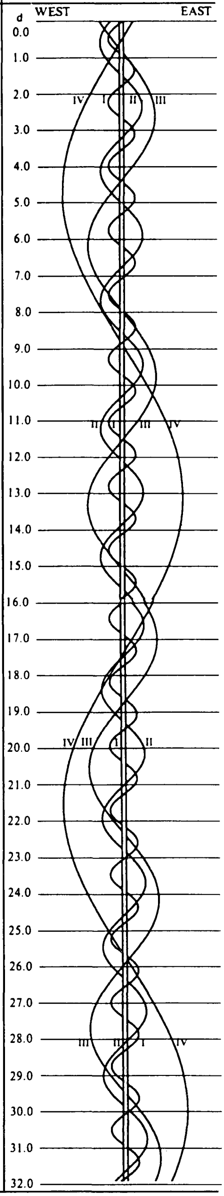
Jupiter moves from Aries into Taurus this month. At mid-month, it stands about 15° above the eastern horizon at sunrise, but its visibility rapidly improves as it moves away from the Sun.

Saturn, in Sagittarius, is at opposition on June 20. It rises at about sunset, and is visible all night. It passes 1.3° north of Uranus on June 27.

Uranus and *Neptune* are at opposition on June 20 and 30, respectively. See also *Saturn* above.

1988	d	h m	JUNE UNIVERSAL TIME	Min. of Algol h m
Wed.	1	01	Mercury stationary	
		21	Uranus 5° N. of Moon	
		22	Saturn 6° N. of Moon	
Thu.	2	12	Neptune 6° N. of Moon	
Fri.	3			12 38
Sat.	4			
Sun.	5	00	Moon at perigee (368 483 km)	
Mon.	6	20	Mars 2° S. of Moon	9 27
Tue.	7	06 21	☾ Last Quarter	
Wed.	8			
Thu.	9		Venus at descending node	6 15
Fri.	10			
Sat.	11		Mercury at aphelion	
Sun.	12	03	Jupiter 6° S. of Moon	3 04
Mon.	13	00	Venus in inferior conjunction	
		04	Mercury in inferior conjunction	
Tue.	14	09 14	🌑 New Moon	23 53
Wed.	15			
Thu.	16			
Fri.	17			20 42
Sat.	18			
Sun.	19	18	Regulus 1.2° S. of Moon; occultation[1]	
Mon.	20	04	Uranus at opposition	17 30
		08	Moon at apogee (404 541 km)	
		09	Saturn at opposition	
Tue.	21	03 57	Summer solstice; summer begins	
Wed.	22	10 23	☽ First Quarter	
Thu.	23			14 19
Fri.	24	08	Spica 1.1° N. of Moon; occultation[2]	
		23	Mercury stationary	
Sat.	25			
Sun.	26			11 08
Mon.	27	02	Saturn 1.3° N. of Uranus	
		19	Antares 0.4° N. of Moon; occultation[3]	
Tue.	28			
Wed.	29	04	Saturn 6° N. of Moon	7 56
		04	Uranus 5° N. of Moon	
		19 46	🌕 Full Moon	
		20	Neptune 6° N. of Moon	
Thu.	30	10	Neptune at opposition	

Config. of Jupiter's Satellites



[1]Visible in Arctic, W. of U.S.S.R.
[2]Visible in S. W. Australia, Antarctica
[3]Visible in extreme S. of Africa, Antarctica, W. Australia

THE SKY FOR JULY 1988

		Mercury	Venus	Mars	Jupiter	Saturn	Uranus	Neptune
RA	1	5^h16^m	4^h53^m	23^h42^m	3^h36^m	17^h53^m	17^h54^m	18^h38^m
	11	5^h53^m	4^h56^m	0^h01^m	3^h44^m	17^h50^m	17^h52^m	18^h37^m
	21	7^h01^m	5^h12^m	0^h18^m	3^h51^m	17^h48^m	17^h51^m	18^h36^m
Dec	1	+19°05'	+18°24'	-5°47'	+18°23'	-22°19'	-23°39'	-22°10'
	11	+21°21'	+17°46'	-4°06'	+18°50'	-22°19'	-23°39'	-22°11'
	21	+22°47'	+18°03'	-2°39'	+19°13'	-22°20'	-23°38'	-22°12'
Tran	1	10^h38^m	10^h14^m	5^h05^m	8^h58^m	23^h12^m	23^h13^m	0^h01^m
	11	10^h37^m	9^h38^m	4^h44^m	8^h26^m	22^h30^m	22^h32^m	23^h16^m
	21	11^h07^m	9^h15^m	4^h22^m	7^h54^m	21^h48^m	21^h51^m	22^h36^m
Mag	1	+1.2	-4.4	-0.8	-2.1	+0.1	+5.6	+7.9
	11	-0.1	-4.5	-1.0	-2.1	+0.1	+5.6	+7.9
	21	-1.0	-4.5	-1.3	-2.2	+0.2	+5.6	+7.9

The Moon—On July 1.0 UT, the age of the Moon is 16.6 days. The Sun's selenographic colongitude is 108.27° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on July 9 (6°) and minimum (east limb exposed) on July 24 (7°). The libration in latitude is maximum (north limb exposed) on July 25 (7°) and minimum (south limb exposed) on July 11 (7°). The Moon reaches its greatest northern declination on July 11 (+28°) and its greatest southern declination on July 26 (−28°). There is an occultation of Regulus by the Moon on July 17, visible from North America.

Mercury may be visible in early to mid-July, very low in the east at sunrise. Greatest elongation west (21°) occurs on July 6, but this is an unfavourable elongation, especially as Mercury is well south of the ecliptic this month.

Venus moves further from the Sun as the month progresses, and therefore becomes more easily visible. By the end of the month, it rises about 3 h before the Sun, and is well up in the east by sunrise. It moves eastward through Taurus, above Orion, late in the month. Greatest brilliancy (−4.5) occurs on July 19.

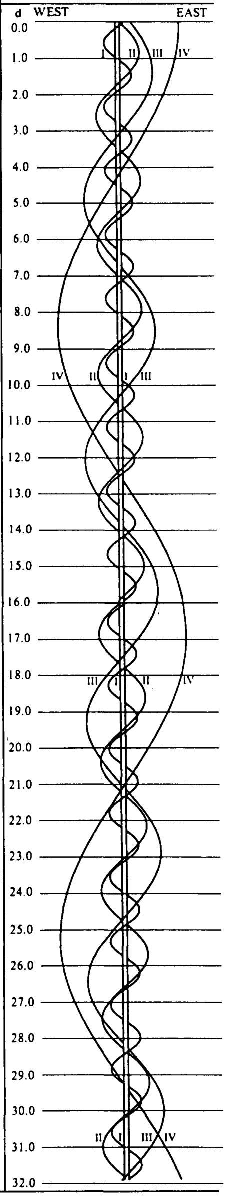
Mars moves from Aquarius through Pisces into Cetus during the month. It rises at about midnight, and is well up in the south at sunrise.

Jupiter, in Taurus, is well up in the southeast at sunrise, and becomes progressively more visible in the morning sky as it moves away from the Sun. Jupiter passes south of the Pleiades this month.

Saturn, in Sagittarius, is rising in the southeast at sunset, and is visible, low in the southern sky, for the rest of the night.

1988	d	h m	JULY UNIVERSAL TIME	Min. of Algol h m
Fri.	1		Mercury at greatest hel. lat. S.	
Sat.	2	06	Moon at perigee (363 667 km)	4 45
Sun.	3			
Mon.	4	08	Venus stationary	
Tue.	5	07	Mars 5° S. of Moon	1 34
Wed.	6	00	Earth at aphelion (152 099 000 km)	
		11 36	☾ Last Quarter	
		16	Mercury at greatest elong. W. (21°)	
Thu.	7			22 22
Fri.	8			
Sat.	9	19	Jupiter 6° S. of Moon	
Sun.	10			19 11
Mon.	11	01	Venus 10° S. of Moon	
Tue.	12	04	Mercury 7° S. of Moon	
Wed.	13	21 53	● New Moon	16 00
Thu.	14		Venus at aphelion	
Fri.	15			
Sat.	16			12 48
Sun.	17	01	Regulus 1.0° S. of Moon; occultation[1]	
			Mars at greatest hel. lat. S.	
Mon.	18	00	Moon at apogee (405 514 km)	
Tue.	19	18	Venus at greatest brilliancy (−4.5)	9 37
Wed.	20		Mercury at ascending node	
Thu.	21			
Fri.	22	02 14	☽ First Quarter	6 25
Sat.	23			
Sun.	24			
Mon.	25	05	Antares 0.6° N. of Moon; occultation[2]	3 14
		18	Pluto stationary	
			Mercury at perihelion	
Tue.	26	11	Saturn 6° N. of Moon	
		12	Uranus 5° N. of Moon	
Wed.	27	05	Neptune 6° N. of Moon	
Thu.	28	09	S. Delta Aquarid meteors	0 03
Fri.	29	03 25	○ Full Moon	
Sat.	30	08	Moon at perigee (359 331 km)	20 51
Sun.	31			

Config. of Jupiter's Satellites



[1]Visible in Arctic, N. America
[2]Visible in E. Australia, New Zealand, Antarctica, S. of S. America

THE SKY FOR AUGUST 1988

M

		Mercury	Venus	Mars	Jupiter	Saturn	Uranus	Neptune
RA	1	8^h37^m	5^h41^m	0^h34^m	3^h59^m	17^h45^m	17^h49^m	18^h35^m
	11	9^h58^m	6^h14^m	0^h44^m	4^h05^m	17^h44^m	17^h48^m	18^h34^m
	21	11^h05^m	6^h53^m	0^h49^m	4^h10^m	17^h43^m	17^h48^m	18^h33^m
Dec	1	+20°11'	+18°50'	-1°24'	+19°34'	-22°21'	-23°38'	-22°13'
	11	+14°10'	+19°28'	-0°39'	+19°50'	-22°22'	-23°38'	-22°14'
	21	+6°50'	+19°40'	-0°19'	+20°03'	-22°23'	-23°38'	-22°15'
Tran	1	12^h00^m	9^h01^m	3^h54^m	7^h19^m	21^h02^m	21^h06^m	21^h52^m
	11	12^h41^m	8^h55^m	3^h25^m	6^h45^m	20^h22^m	20^h26^m	21^h11^m
	21	13^h08^m	8^h55^m	2^h51^m	6^h11^m	19^h41^m	19^h46^m	20^h31^m
Mag	1	-1.9	-4.4	-1.6	-2.2	+0.2	+5.6	+7.9
	11	-1.2	-4.4	-1.8	-2.3	+0.3	+5.6	+7.9
	21	-0.5	-4.3	-2.1	-2.4	+0.4	+5.6	+7.9

The Moon—On Aug. 1.0 UT, the age of the Moon is 18.1 days. The Sun's selenographic colongitude is 127.08° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on Aug. 6 (7°) and minimum (east limb exposed) on Aug. 21 (8°). The libration in latitude is maximum (north limb exposed) on Aug. 21 (7°) and minimum (south limb exposed) on Aug. 7 (7°). The Moon reaches its greatest northern declination on Aug. 8 (+29°) and its greatest southern declination on Aug. 22 (−29°). There is a partial eclipse of the Moon on Aug. 27, visible from parts of North America.

Mercury is not visible this month. It is in superior conjunction on Aug. 3. See also *Mercury* for September 1988.

Venus, moving from Taurus into Gemini, rises about 4 h before the Sun, and stands about 40° above the eastern horizon at sunrise. Greatest elongation west (46°) occurs on Aug. 22.

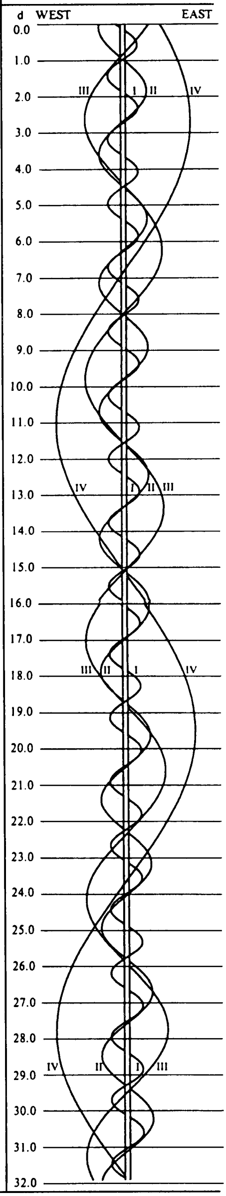
Mars, is Cetus, rises shortly after sunset, and is still visible low in the southwest at sunrise. It is stationary on Aug. 26, after which it begins retrograde or westward motion. Use the sides of the "Great Square of Pegasus" as markers to observe this motion.

Jupiter, in Taurus, rises at about midnight, and is high in the southern sky by sunrise. Together with Venus and the "winter" constellations, it dominates the morning sky.

Saturn, in Sagittarius, is low in the southern sky at sunset, and sets at about midnight. It is stationary on Aug. 30, after which it resumes direct or eastward motion.

1988			AUGUST UNIVERSAL TIME	Min. of Algol
	d	h m		h m
Mon.	1	12	Ceres stationary	
Tue.	2	11	Mars 8° S. of Moon	17 40
		16	Pallas at opposition	
Wed.	3	04	Mercury in superior conjunction	
Thu.	4	18 22	☾ Last Quarter	
			Mercury at greatest hel. lat. N.	
Fri.	5		Venus at greatest hel. lat. S.	14 28
Sat.	6	08	Jupiter 6° S. of Moon	
Sun.	7			
Mon.	8	12	Venus 9° S. of Moon	11 17
Tue.	9			
Wed.	10			
Thu.	11			8 05
Fri.	12	00	Perseid meteors	
		12 31	● New Moon	
			Mars at perihelion	
Sat.	13			
Sun.	14	12	Moon at apogee (406 319 km)	4 54
Mon.	15			
Tue.	16		Saturn at aphelion	
Wed.	17			1 42
Thu.	18			
Fri.	19			22 31
Sat.	20	15 51	☽ First Quarter	
Sun.	21	14	Antares 0.7° N. of Moon; occultation[1]	
Mon.	22	12	Venus at greatest elong. W. (46°)	19 20
		19	Saturn 6° N. of Moon	
		21	Uranus 5° N. of Moon	
Tue.	23	14	Neptune 6° N. of Moon	
Wed.	24			
Thu.	25			16 08
Fri.	26	23	Mars stationary	
Sat.	27	10 56	○ Full Moon; Eclipse of Moon, p. 82	
		17	Moon at perigee (357 101 km)	
			Mercury at descending node	
Sun.	28			12 57
Mon.	29			
Tue.	30	03	Mars 9° S. of Moon	
		11	Saturn stationary	
Wed.	31			9 45

Config. of Jupiter's Satellites



[1] Visible in extreme S. of Africa, Antarctica, Tasmania

THE SKY FOR SEPTEMBER 1988

		Mercury	Venus	Mars	Jupiter	Saturn	Uranus	Neptune
RA	1	12^h05^m	7^h39^m	0^h50^m	4^h14^m	17^h42^m	17^h47^m	18^h32^m
	11	12^h51^m	8^h23^m	0^h44^m	4^h16^m	17^h43^m	17^h47^m	18^h32^m
	21	13^h24^m	9^h08^m	0^h35^m	4^h18^m	17^h44^m	17^h48^m	18^h32^m
Dec	1	$-1°10'$	$+19°09'$	$-0°26'$	$+20°12'$	$-22°25'$	$-23°38'$	$-22°16'$
	11	$-7°35'$	$+17°52'$	$-0°55'$	$+20°18'$	$-22°27'$	$-23°38'$	$-22°17'$
	21	$-12°21'$	$+15°46'$	$-1°37'$	$+20°20'$	$-22°29'$	$-23°38'$	$-22°17'$
Tran	1	13^h24^m	8^h57^m	2^h08^m	5^h32^m	18^h58^m	19^h02^m	19^h48^m
	11	13^h30^m	9^h02^m	1^h23^m	4^h55^m	18^h19^m	18^h23^m	19^h08^m
	21	13^h23^m	9^h07^m	0^h34^m	4^h17^m	17^h41^m	17^h44^m	18^h29^m
Mag	1	-0.1	-4.3	-2.3	-2.4	+0.4	+5.6	+7.9
	11	+0.1	-4.3	-2.6	-2.5	+0.5	+5.6	+7.9
	21	+0.3	-4.2	-2.7	-2.6	+0.5	+5.7	+7.9

The Moon—On Sept. 1.0 UT, the age of the Moon is 19.5 days. The Sun's selenographic colongitude is 145.70° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on Sept. 3 (8°) and minimum (east limb exposed) on Sept. 18 (7°). The libration in latitude is maximum (north limb exposed) on Sept. 18 (7°) and minimum (south limb exposed) on Sept. 3 (7°) and Sept. 30 (7°). The Moon reaches its greatest northern declination on Sept. 4 (+29°) and its greatest southern declination on Sept. 19 (−29°).

Mercury is at greatest elongation east (27°) on Sept. 15, but this is a very unfavourable elongation (at least for Northern Hemisphere observers). The angle between the ecliptic and the western horizon is at its shallowest, and Mercury is also several degrees south of the ecliptic, so it is visible only with the greatest difficulty, just after sunset.

Venus rises about 4 h before the Sun, and stands about 40° above the eastern horizon at sunrise. In Gemini, it passes 9° south of Pollux on Sept. 2 and south of the Praesepe Cluster later in the month.

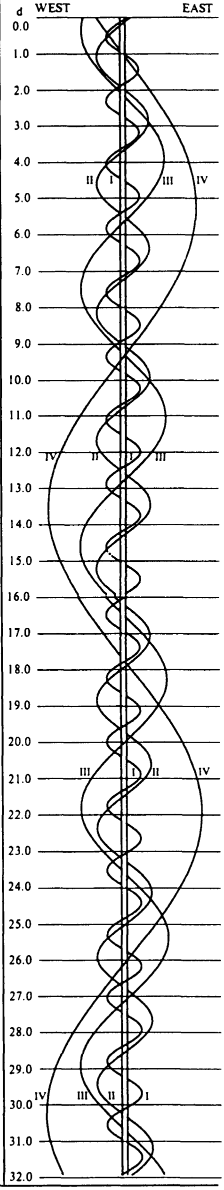
Mars rises at about sunset, and is visible all night. It is at opposition on Sept. 28, and is closest to Earth on Sept. 22 at a distance of 59 million km. At magnitude −2.8, it dominates the region in and around Cetus.

Jupiter, in Taurus, rises before midnight, and is past the meridian by sunrise. Watch as it approaches Aldebaran, becomes stationary on Sept. 24, then begins westward motion.

Saturn, in Sagittarius, is low in the southern sky at sunset, and sets at about midnight.

1988			SEPTEMBER UNIVERSAL TIME	Min. of Algol
	d	h m		h m
Thu.	1			
Fri.	2	08	Venus 9° of Pollux	
		20	Jupiter 6° S. of Moon	
Sat.	3	03 50	☾ Last Quarter	6 34
Sun.	4			
Mon.	5	10	Uranus stationary	
Tue.	6	23	Venus 6° S. of Moon	3 22
Wed.	7		Mercury at aphelion	
Thu.	8			
Fri.	9	13	Regulus 1.0° S. of Moon; occultation[1]	0 11
Sat.	10	15	Moon at apogee (406 475 km)	
Sun.	11	04 49	● New Moon; Eclipse of Sun, p. 82	21 00
			Martian winter solstice	
			Saturn at aphelion	
Mon.	12			
Tue.	13	16	Mercury 0.6° N. of Moon; occultation[2]	
Wed.	14			17 48
Thu.	15	22	Mercury at greatest elong. E. (27°)	
Fri	16			
Sat.	17	04	Ceres at opposition	14 37
		21	Antares 0.7° N. of Moon; occultation[3]	
Sun.	18	17	Neptune stationary	
Mon.	19	03 18	☽ First Quarter	
		03	Saturn 6° N. of Moon	
		05	Uranus 5° N. of Moon	
		22	Neptune 6° N. of Moon	
Tue.	20	16	Pallas stationary	11 25
Wed.	21	04	Mercury 1.3° S. of Spica	
Thu.	22	03	Mars closest approach (58 814 000 km)	
		19 29	Autumnal equinox; autumn begins	
Fri.	23			8 14
Sat.	24	16	Jupiter stationary	
Sun.	25	04	Moon at perigee (357 683 km)	
		19 07	○ Full Moon; Harvest Moon	
Mon.	26	04	Mars 7° S. of Moon	5 02
Tue.	27		Mercury at greatest hel. lat. S.	
Wed.	28	04	Mars at opposition	
		21	Mercury stationary	
Thu.	29			1 51
Fri.	30	05	Jupiter 6° S. of Moon	
			Venus at ascending node	

Config. of Jupiter's Satellites



[1]Visible in Arctic, Greenland, Iceland, Europe, N. Africa
[2]Visible in S. America except N., Antarctica
[3]Visible in Antarctica

		Mercury	Venus	Mars	Jupiter	Saturn	Uranus	Neptune
RA	1	13^h34^m	9^h53^m	0^h23^m	4^h17^m	17^h46^m	17^h48^m	18^h32^m
	11	13^h05^m	10^h38^m	0^h12^m	4^h16^m	17^h48^m	17^h49^m	18^h33^m
	21	12^h45^m	11^h22^m	0^h05^m	4^h13^m	17^h51^m	17^h51^m	18^h33^m
Dec	1	-13°46'	+12°54'	-2°17'	+20°18'	-22°31'	-23°38'	-22°17'
	11	-8°58'	+9°22'	-2°39'	+20°14'	-22°33'	-23°38'	-22°17'
	21	-3°30'	+5°19'	-2°34'	+20°06'	-22°35'	-23°38'	-22°17'
Tran	1	12^h52^m	9^h13^m	23^h38^m	3^h37^m	17^h03^m	17^h06^m	17^h50^m
	11	11^h42^m	9^h19^m	22^h49^m	2^h56^m	16^h27^m	16^h28^m	17^h11^m
	21	10^h45^m	9^h24^m	22^h03^m	2^h14^m	15^h50^m	15^h50^m	16^h32^m
Mag	1	+1.2	-4.1	-2.7	-2.6	+0.5	+5.7	+7.9
	11	+4.9	-4.1	-2.5	-2.7	+0.5	+5.7	+7.9
	21	+0.4	-4.1	-2.2	-2.8	+0.6	+5.7	+8.0

The Moon—On Oct. 1.0 UT, the age of the Moon is 19.8 days. The Sun's selenographic colongitude is 151.73° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on Oct. 1 (8°) and Oct. 29 (7°) and minimum (east limb exposed) on Oct. 16 (6°). The libration in latitude is maximum (north limb exposed) on Oct. 15 (7°) and minimum (south limb exposed) on Oct. 28 (7°). The Moon reaches its greatest northern declination on Oct. 1 (+29°) and Oct. 29 (+28°) and its greatest southern declination on Oct. 16 (−28°). There is an occultation of Regulus by the Moon on Oct. 6, visible from parts of North America.

Mercury is not visible early in the month; it is in inferior conjunction on Oct. 11. By the end of the month, it reaches a small but favourable greatest elongation west (18°), at which time it is visible low in the southeast, just before sunrise.

Venus rises about 3 h before the Sun, and stands about 35° above the southeastern horizon at sunrise. In Leo, it passes 0.2° south of Regulus on Oct. 4.

Mars, now in Pisces, rises shortly before sunset, and is visible most of the night. It is stationary on Oct. 30, after which it resumes direct or eastward motion.

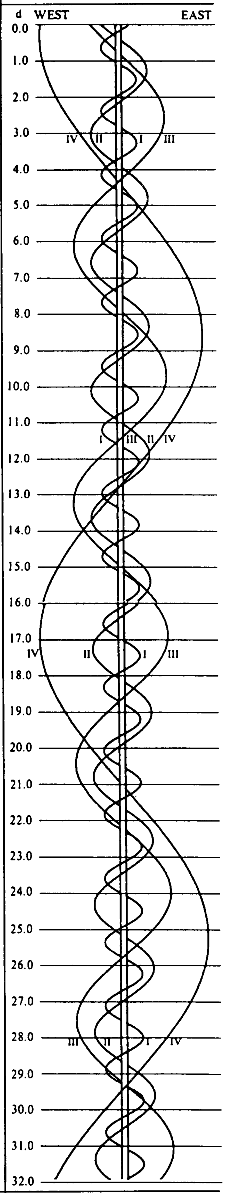
Jupiter, in Taurus, rises before midnight, and is high in the sky, to the west of south, by sunrise.

Saturn, in Sagittarius, is past the meridian at sunset, and sets about 3 h later. It passes 1.1° north of Uranus on Oct. 18.

Uranus: see *Saturn* above.

1988	d	h m	OCTOBER UNIVERSAL TIME	Min. of Algol h m
Sat.	1			22 40
Sun.	2	11	Vesta in conjunction with Sun	
		16 58	☾ Last Quarter	
Mon.	3			
Tue.	4	08	Venus 0.2° S. of Regulus	19 29
Wed.	5	18	Mercury 1.2° S. of Spica	
Thu.	6	20	Regulus 1.0° S. of Moon; occultation[1]	
Fri.	7	03	Venus 0.6° S. of Moon; occultation[2]	16 17
		20	Moon at apogee (405 977 km)	
Sat.	8			
Sun.	9			
Mon.	10	21 49	● New Moon	13 06
Tue.	11	07	Mercury in inferior conjunction	
Wed.	12			
Thu.	13			9 55
Fri.	14			
Sat.	15	02	Antares 0.6° N. of Moon; occultation[3]	
Sun.	16	12	Saturn 6° N. of Moon	6 43
		12	Uranus 5° N. of Moon	
			Mercury at ascending node	
Mon.	17	05	Neptune 6° N. of Moon	
Tue.	18	02	Saturn 1.1° N. of Uranus	
		13 01	☽ First Quarter	
Wed.	19	16	Mercury stationary	3 32
Thu.	20			
Fri.	21	04	Orionid meteors	
			Mercury at perihelion	
Sat.	22			0 21
Sun.	23	04	Mars 5° S. of Moon	
		12	Moon at perigee (361 111 km)	
Mon.	24			21 09
Tue.	25	04 35	○ Full Moon; Hunters' Moon	
Wed.	26	21	Mercury at greatest elong. W. (18°)	
Thu.	27	12	Jupiter 6° S. of Moon	17 58
Fri.	28			
Sat.	29			
Sun.	30	14	Mars stationary	14 47
Mon.	31		Mercury at greatest hel. lat. N.	

Config. of Jupiter's Satellites



[1]Visible in Arctic, N. America
[2]Visible in Scandinavia, E. Europe, Asia, Japan, Philippines
[3]Visible in Australia except N., S. of New Zealand, Antarctica, extreme S. of S. America

THE SKY FOR NOVEMBER 1988

		Mercury	Venus	Mars	Jupiter	Saturn	Uranus	Neptune
RA	1	13^h23^m	12^h11^m	0^h03^m	4^h08^m	17^h55^m	17^h53^m	18^h34^m
	11	14^h20^m	12^h56^m	0^h06^m	4^h03^m	17^h59^m	17^h55^m	18^h35^m
	21	15^h23^m	13^h42^m	0^h14^m	3^h58^m	18^h04^m	17^h57^m	18^h37^m
Dec	1	-6°27'	+0°28'	-1°55'	+19°54'	-22°38'	-23°39'	-22°17'
	11	-12°29'	-4°07'	-0°52'	+19°40'	-22°39'	-23°39'	-22°16'
	21	-18°12'	-8°39'	+0°32'	+19°25'	-22°40'	-23°39'	-22°16'
Tran	1	10^h42^m	9^h30^m	21^h18^m	1^h26^m	15^h11^m	15^h08^m	15^h50^m
	11	11^h00^m	9^h35^m	20^h42^m	0^h42^m	14^h36^m	14^h31^m	15^h12^m
	21	11^h23^m	9^h42^m	20^h10^m	23^h52^m	14^h01^m	13^h54^m	14^h33^m
Mag	1	-0.8	-4.0	-1.8	-2.8	+0.6	+5.7	+8.0
	11	-0.9	-4.0	-1.5	-2.8	+0.5	+5.7	+8.0
	21	-1.0	-4.0	-1.1	-2.9	+0.5	+5.8	+8.0

The Moon—On Nov. 1.0 UT, the age of the Moon is 21.1 days. The Sun's selenographic colongitude is 169.43° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on Nov. 26 (6°) and minimum (east limb exposed) on Nov. 12 (5°). The libration in latitude is maximum (north limb exposed) on Nov. 11 (7°) and minimum (south limb exposed) on Nov. 24 (7°). The Moon reaches its greatest northern declination on Nov. 25 (+28°) and its greatest southern declination on Nov. 12 (−28°). There is an occultation of Regulus by the Moon on Nov. 30, visible from parts of North America.

Mercury may be visible in the first half of the month, very low in the southeast, just before sunrise. It passes 4° north of Spica on Nov. 1. By the end of the month, it is approaching superior conjunction.

Venus rises about 3 h before the Sun, and stands about 30° above the southeast horizon at sunrise. It passes 4° north of Spica on Nov. 17. Around Nov. 6, the waning crescent Moon joins Venus and Mercury in the morning sky.

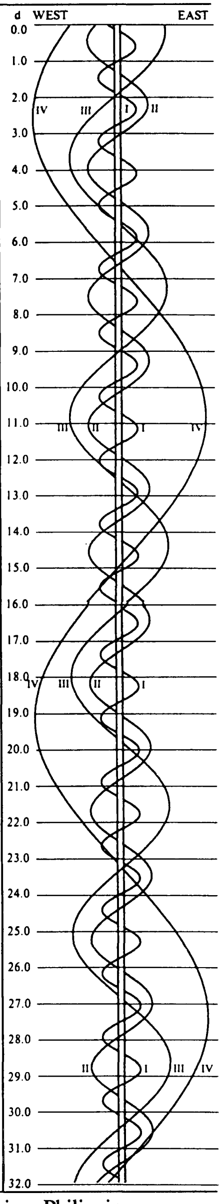
Mars, in Pisces, is visible low in the southeast at sunset, and sets after midnight.

Jupiter, in Taurus, rises at about sunset, and is visible for the rest of the night. It is at opposition on Nov. 23.

Saturn, in Sagittarius, is rapidly approaching the Sun, and is lost in the evening twilight by the end of the month.

1988	d	h m	NOVEMBER UNIVERSAL TIME	Min. of Algol h m
Tue.	1	07	Mercury 4° N. of Spica	
		10 11	☾ Last Quarter	
Wed.	2	05	S. Taurid meteors	11 36
Thu.	3	03	Regulus 0.8° S. of Moon; occultation[1]	
			Venus at perihelion	
Fri.	4	11	Moon at apogee (405 071 km)	
		17	Pluto in conjunction	
Sat.	5			8 25
Sun.	6	15	Venus 5° N. of Moon	
Mon.	7			
Tue.	8			5 14
Wed.	9	14 20	● New Moon	
Thu.	10			
Fri.	11	08	Antares 0.5° N. of Moon; occultation[2]	2 02
Sat.	12	18	Ceres stationary	
		19	Uranus 5° N. of Moon	
		21	Saturn 6° N. of Moon	
Sun.	13	11	Neptune 5° N. of Moon	22 51
Mon.	14			
Tue.	15			
Wed.	16	21 35	☽ First Quarter	19 40
Thu.	17	04	Venus 4° N. of Spica	
		10	Leonid meteors	
Fri.	18			
Sat.	19	16	Mars 3° S. of Moon	16 29
Sun.	20	10	Moon at perigee (366 482 km)	
Mon.	21			
Tue.	22			13 18
Wed.	23	03	Jupiter at opposition	
		15 53	○ Full Moon	
		17	Jupiter 6° S. of Moon	
			Mercury at descending node	
Thu.	24			
Fri.	25		Venus at greatest hel. lat. N.	10 07
Sat.	26			
Sun.	27			
Mon.	28			6 56
Tue.	29			
Wed.	30	11	Regulus 0.5° S. of Moon; occultation[3]	

Config. of Jupiter's Satellites



[1]Visible in Scotland, Scandinavia, Asia except for India, Japan, Indo-China, Philippines
[2]Visible in S. of Africa, Antarctica, S.E. Australia, New Zealand
[3]Visible in Alaska, Canada except extreme N.E., U.S.A. except S.W., West Indies, N. of S. America

THE SKY FOR DECEMBER 1988

		Mercury	Venus	Mars	Jupiter	Saturn	Uranus	Neptune
RA	1	16^h28^m	14^h29^m	0^h24^m	3^h52^m	18^h09^m	18^h00^m	18^h38^m
	11	17^h36^m	15^h18^m	0^h38^m	3^h47^m	18^h14^m	18^h02^m	18^h40^m
	21	18^h45^m	16^h09^m	0^h54^m	3^h42^m	18^h19^m	18^h05^m	18^h41^m
Dec	1	-22°32'	-12°54'	+2°12'	+19°10'	-22°40'	-23°39'	-22°15'
	11	-25°00'	-16°41'	+4°05'	+18°55'	-22°40'	-23°39'	-22°13'
	21	-25°13'	-19°45'	+6°06'	+18°43'	-22°39'	-23°39'	-22°12'
Tran	1	11^h49^m	9^h50^m	19^h42^m	23^h08^m	13^h26^m	13^h17^m	13^h56^m
	11	12^h18^m	9^h59^m	19^h17^m	22^h23^m	12^h52^m	12^h40^m	13^h18^m
	21	12^h48^m	10^h11^m	18^h53^m	21^h39^m	12^h18^m	12^h04^m	12^h40^m
Mag	1	-1.2	-4.0	-0.8	-2.9	+0.5	+5.8	+8.0
	11	-0.9	-4.0	-0.5	-2.8	+0.5	+5.8	+8.0
	21	-0.8	-4.0	-0.3	-2.8	+0.5	+5.8	+8.0

The Moon—On Dec. 1.0 UT, the age of the Moon is 21.4 days. The Sun's selenographic colongitude is 174.49° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on Dec. 23 (5°) and minimum (east limb exposed) on Dec. 8 (5°). The libration in latitude is maximum (north limb exposed) on Dec. 8 (7°) and minimum (south limb exposed) on Dec. 21 (7°). The Moon reaches its greatest northern declination on Dec. 22 (+28°) and its greatest southern declination on Dec. 9 (−28°).

Mercury is in superior conjunction on Dec. 1, and is not visible until late in the month. Then, it may be seen very low in the southwest, just after sunset. It passes 3° south of Neptune on Dec. 20.

Venus, in mid-December, rises about 2 h before the Sun, and stands about 20° above the southeast horizon at sunrise. By the end of the month, however, it is closing in on the Sun, and is lost in the morning twilight.

Mars, in Pisces, is well up in the southeast at sunset, and sets after midnight.

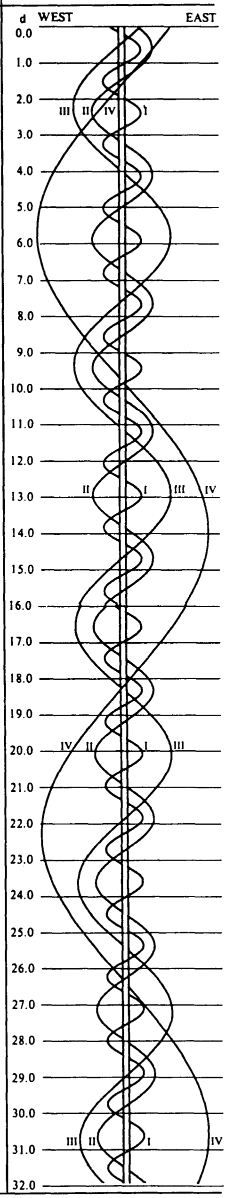
Jupiter, in Taurus, is rising in the east at sunset, and is visible for most of the night.

Saturn is not visible this month. It is in conjunction with the Sun on Dec. 26.

Uranus and *Neptune* are in conjunction with the Sun on Dec. 22 and 31, respectively.

1988			DECEMBER UNIVERSAL TIME	Min. of Algol
	d	h m		h m
Thu.	1	06 49	☾ Last Quarter	3 45
		09	Mercury in superior conjunction	
Fri.	2	06	Moon at apogee (404 355 km)	
Sat.	3			
Sun.	4		Mercury at aphelion	0 34
Mon.	5			
Tue.	6			21 23
Wed.	7	00	Venus 7° N. of Moon	
Thu.	8			
Fri.	9	05 36	● New Moon	18 12
Sat.	10	20	Neptune 5° N. of Moon	
Sun.	11		Mars at ascending node	
Mon.	12			15 01
Tue.	13			
Wed.	14	00	Geminid meteors	
Thu.	15			11 50
Fri.	16	04	Moon at perigee (370 354 km)	
		05 40	☽ First Quarter	
Sat.	17	16	Mars 3° S. of Moon	
Sun.	18			8 40
Mon.	19			
Tue.	20	09	Mercury 3° S. of Neptune	
		20	Jupiter 6° S. of Moon	
Wed.	21	15 28	Winter solstice; winter beings	5 29
Thu.	22	06	Ursid meteors	
		20	Uranus in conjunction	
Fri.	23	05 29	○ Full Moon	
Sat.	24	18	Venus 6° N. of Antares	2 18
			Mercury at greatest hel. lat. S.	
Sun.	25			
Mon.	26	12	Saturn in conjunction	23 07
Tue.	27	20	Regulus 0.2° S. of Moon; occultation[1]	
Wed.	28			
Thu.	29			19 56
Fri.	30	04	Moon at apogee (404 375 km)	
Sat.	31	04 57	☾ Last Quarter	
		09	Neptune in conjunction	

Config. of Jupiter's Satellites



[1] Visible in Asia except N. and extreme S., Indo-China, Philippines, East Indies, New Guinea, N.E. Australia

SUN

EPHEMERIS

Date 0^h UT	Apparent α (1988)	δ	UT Transit at Greenwich	Orientation P	B_0	L_0
Jan. 1	$18^h42.5^m$	-23°05'	$12^h03^m16^s$	+2.4°	-3.0°	258.3°
6	$19^h04.6^m$	-22°37'	$12^h05^m34^s$	0.0°	-3.5°	192.5°
11	$19^h26.4^m$	-21°58'	$12^h07^m41^s$	-2.4°	-4.1°	126.6°
16	$19^h48.0^m$	-21°07'	$12^h09^m33^s$	-4.8°	-4.6°	60.8°
21	$20^h09.4^m$	-20°07'	$12^h11^m09^s$	-7.1°	-5.1°	355.0°
26	$20^h30.4^m$	-18°58'	$12^h12^m26^s$	-9.4°	-5.5°	289.1°
31	$20^h51.1^m$	-17°39'	$12^h13^m22^s$	-11.5°	-5.9°	223.3°
Feb. 5	$21^h11.4^m$	-16°13'	$12^h13^m58^s$	-13.5°	-6.2°	157.5°
10	$21^h31.4^m$	-14°40'	$12^h14^m14^s$	-15.4°	-6.5°	91.6°
15	$21^h51.1^m$	-13°01'	$12^h14^m11^s$	-17.2°	-6.8°	25.8°
20	$22^h10.5^m$	-11°17'	$12^h13^m50^s$	-18.8°	-7.0°	320.0°
25	$22^h29.6^m$	-9°28'	$12^h13^m12^s$	-20.3°	-7.1°	254.1°
Mar. 1	$22^h48.5^m$	-7°35'	$12^h12^m19^s$	-21.6°	-7.2°	188.3°
6	$23^h07.1^m$	-5°40'	$12^h11^m13^s$	-22.8°	-7.2°	122.4°
11	$23^h25.6^m$	-3°43'	$12^h09^m57^s$	-23.8°	-7.2°	56.5°
16	$23^h43.9^m$	-1°44'	$12^h08^m35^s$	-24.6°	-7.1°	350.6°
21	$0^h02.2^m$	+0°14'	$12^h07^m07^s$	-25.3°	-7.0°	284.7°
26	$0^h20.4^m$	+2°12'	$12^h05^m37^s$	-25.8°	-6.8°	218.8°
31	$0^h38.6^m$	+4°09'	$12^h04^m06^s$	-26.1°	-6.6°	152.8°
Apr. 5	$0^h56.8^m$	+6°04'	$12^h02^m37^s$	-26.3°	-6.3°	86.8°
10	$1^h15.1^m$	+7°57'	$12^h01^m14^s$	-26.3°	-5.9°	20.8°
15	$1^h33.6^m$	+9°46'	$11^h59^m58^s$	-26.0°	-5.6°	314.8°
20	$1^h52.1^m$	+11°31'	$11^h58^m51^s$	-25.6°	-5.1°	248.8°
25	$2^h10.9^m$	+13°12'	$11^h57^m55^s$	-25.1°	-4.7°	182.8°
30	$2^h29.8^m$	+14°46'	$11^h57^m10^s$	-24.3°	-4.2°	116.7°
May 5	$2^h49.0^m$	+16°15'	$11^h56^m38^s$	-23.3°	-3.7°	50.6°
10	$3^h08.4^m$	+17°37'	$11^h56^m21^s$	-22.2°	-3.2°	344.5°
15	$3^h28.1^m$	+18°52'	$11^h56^m19^s$	-20.9°	-2.6°	278.3°
20	$3^h47.9^m$	+19°59'	$11^h56^m30^s$	-19.5°	-2.0°	212.2°
25	$4^h08.0^m$	+20°57'	$11^h56^m55^s$	-17.8°	-1.4°	146.1°
30	$4^h28.3^m$	+21°46'	$11^h57^m32^s$	-16.1°	-0.9°	79.9°
June 4	$4^h48.8^m$	+22°26'	$11^h58^m18^s$	-14.2°	-0.3°	13.8°
9	$5^h09.5^m$	+22°56'	$11^h59^m14^s$	-12.2°	+0.4°	307.6°
14	$5^h30.2^m$	+23°16'	$12^h00^m16^s$	-10.1°	+1.0°	241.4°
19	$5^h51.0^m$	+23°26'	$12^h01^m21^s$	-8.0°	+1.5°	175.2°
24	$6^h11.8^m$	+23°25'	$12^h02^m26^s$	-5.7°	+2.1°	109.0°
29	$6^h32.5^m$	+23°14'	$12^h03^m28^s$	-3.5°	+2.7°	42.8°

Date	Apparent		UT Transit at	Orientation		
0^h UT	α (1988)	δ	Greenwich	P	B_0	L_0
July 4	$6^h53.2^m$	+22°53'	$12^h04^m24^s$	-1.2°	+3.2°	336.7°
9	$7^h13.7^m$	+22°22'	$12^h05^m13^s$	+1.0°	+3.8°	270.5°
14	$7^h34.1^m$	+21°41'	$12^h05^m51^s$	+3.3°	+4.3°	204.3°
19	$7^h54.3^m$	+20°51'	$12^h06^m17^s$	+5.5°	+4.7°	138.2°
24	$8^h14.2^m$	+19°52'	$12^h06^m29^s$	+7.6°	+5.2°	72.0°
29	$8^h33.9^m$	+18°45'	$12^h06^m25^s$	+9.7°	+5.6°	5.9°
Aug. 3	$8^h53.3^m$	+17°30'	$12^h06^m07^s$	+11.7°	+5.9°	299.7°
8	$9^h12.5^m$	+16°09'	$12^h05^m34^s$	+13.6°	+6.3°	233.6°
13	$9^h31.5^m$	+14°40'	$12^h04^m47^s$	+15.4°	+6.5°	167.5°
18	$9^h50.2^m$	+13°06'	$12^h03^m46^s$	+17.1°	+6.8°	101.4°
23	$10^h08.7^m$	+11°27'	$12^h02^m32^s$	+18.6°	+7.0°	35.4°
28	$10^h27.0^m$	+9°43'	$12^h01^m07^s$	+20.1°	+7.1°	329.3°
Sept. 2	$10^h45.2^m$	+7°55'	$11^h59^m34^s$	+21.4°	+7.2°	263.2°
7	$11^h03.2^m$	+6°04'	$11^h57^m54^s$	+22.6°	+7.2°	197.2°
12	$11^h21.2^m$	+4°11'	$11^h56^m10^s$	+23.6°	+7.2°	131.2°
17	$11^h39.1^m$	+2°15'	$11^h54^m23^s$	+24.4°	+7.2°	65.2°
22	$11^h57.1^m$	+0°19'	$11^h52^m37^s$	+25.1°	+7.0°	359.2°
27	$12^h15.1^m$	-1°38'	$11^h50^m53^s$	+25.7°	+6.9°	293.2°
Oct. 2	$12^h33.1^m$	-3°34'	$11^h49^m15^s$	+26.1°	+6.6°	227.2°
7	$12^h51.3^m$	-5°30'	$11^h47^m45^s$	+26.3°	+6.4°	161.2°
12	$13^h09.7^m$	-7°24'	$11^h46^m25^s$	+26.3°	+6.0°	95.3°
17	$13^h28.3^m$	-9°15'	$11^h45^m19^s$	+26.1°	+5.7°	29.3°
22	$13^h47.1^m$	-11°03'	$11^h44^m27^s$	+25.8°	+5.3°	323.4°
27	$14^h06.2^m$	-12°47'	$11^h43^m52^s$	+25.2°	+4.8°	257.4°
Nov. 1	$14^h25.6^m$	-14°26'	$11^h43^m35^s$	+24.5°	+4.3°	191.5°
6	$14^h45.3^m$	-15°59'	$11^h43^m39^s$	+23.5°	+3.8°	125.6°
11	$15^h05.4^m$	-17°25'	$11^h44^m05^s$	+22.4°	+3.3°	59.6°
16	$15^h25.9^m$	-18°44'	$11^h44^m51^s$	+21.1°	+2.7°	353.7°
21	$15^h46.7^m$	-19°55'	$11^h45^m58^s$	+19.6°	+2.1°	287.8°
26	$16^h07.8^m$	-20°57'	$11^h47^m24^s$	+17.9°	+1.5°	221.9°
Dec. 1	$16^h29.2^m$	-21°48'	$11^h49^m09^s$	+16.0°	+0.8°	156.0°
6	$16^h50.9^m$	-22°30'	$11^h51^m10^s$	+14.0°	+0.2°	90.1°
11	$17^h12.9^m$	-23°00'	$11^h53^m24^s$	+11.9°	-0.4°	24.2°
16	$17^h35.0^m$	-23°19'	$11^h55^m48^s$	+ 9.6°	-1.1°	318.4°
21	$17^h57.1^m$	-23°26'	$11^h58^m15^s$	+ 7.3°	-1.7°	252.5°
26	$18^h19.3^m$	-23°22'	$12^h00^m44^s$	+ 4.9°	-2.3°	186.6°
31	$18^h41.5^m$	-23°06'	$12^h03^m10^s$	+ 2.5°	-2.9°	120.8°

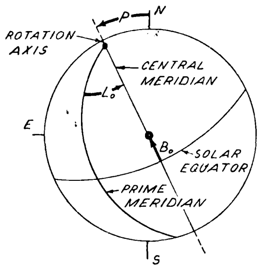
SUNDIAL CORRECTION

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, 1988: At Greenwich the Sun transits at $12^h04^m47^s$ on August 13 and at $12^h03^m46^s$ on August 18. 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 60). 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 $12^h04^m10^s$, the daily change in the time being $-12\overset{s}{.}2$. Adjusting this for the longitude of Winnipeg: $12^h04^m10^s - (12\overset{s}{.}2 \times 6^h29^m \div 24^h) = 12^h04^m07^s$. Thus the sundial correction is 4^m07^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 $12^h04^m07^s + 28^m55^s = 12^h33^m02^s$ CST ($13^h33^m02^s$ 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)

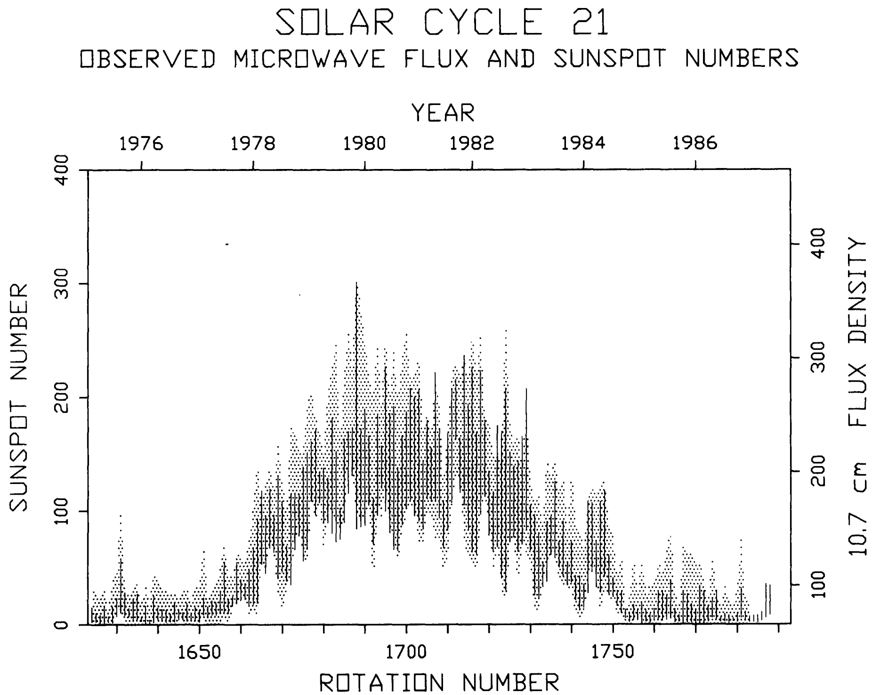
DATES OF COMMENCEMENT (UT, $L_0 = 0°$)
OF NUMBERED SYNODIC ROTATIONS

No.	Commences	No.	Commences	No.	Commences
1797 ('87)	Dec. 24.28	1802	May 8.83	1807	Sept. 21.94
1798 ('88)	Jan. 20.62	1803	June 5.04	1808	Oct. 19.22
1799	Feb. 16.96	1804	July 2.24	1809	Nov. 15.52
1800	Mar. 15.29	1805	July 29.44	1810	Dec. 12.84
1801	Apr. 11.58	1806	Aug. 25.68	1811 ('89)	Jan. 9.17

SOLAR ACTIVITY

By C. L. Donaldson, V. Gaizauskas, and E. J. Kennelly

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. 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*).



There is a close correspondence in shape between the outlines of extreme values of microwave flux and sunspot number. The shapes do not match exactly because the physical origins for sunspots and for microwave emission, 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 1690 at the end of 1979). This behaviour results from the uneven distribution of active regions with solar longitude. Large active regions tend to be rejuvenated

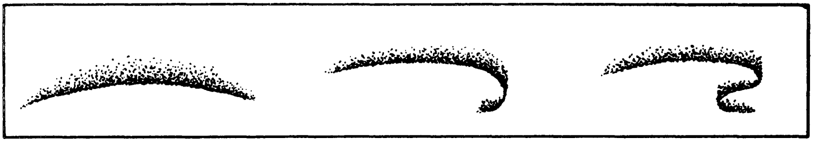
* 1 solar flux unit = 10^{-22} W m^{-2} Hz^{-1}

near one or just a few longitudes while intermediate sectors tend to be free of activity for many rotations of the Sun.

Solar microwave emission has been monitored daily since February 1947 at a wavelength of 10.7 cm (2800 MHz) by the National Research Council's Laboratories based in Ottawa. The monitoring program, begun by Arthur Covington, grew out of NRC's development of radar systems during World War II to become Canada's first venture into radio astronomy. It now constitutes the longest unbroken record of solar microwave emission anywhere. The solar microwave flux has many practical advantages as a proxy indicator of ultraviolet and X-ray flux from the Sun. These highly ionizing radiations, which have a powerful impact on our terrestrial environment, are inaccessible to direct observation from ground level, but the solar microwave flux can be measured even through cloud.

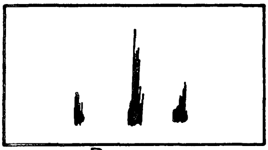
The International Sunspot Numbers are compiled by the Sunspot Index Data Centre, Brussels, Belgium from a network of more than 25 observing stations. The observations are combined into a single daily number by following a method introduced by Wolf in 1848. An observer adds ten times the number of sunspot groups to a total count of individual spots. Because each measurement is subject to an observer's interpretation, the final number is a carefully weighted average of measurements made by a large network of experienced observers.

The minimum phase of the cycle is found from averages smoothed over many rotations of either sunspot numbers or microwave flux. The minimum between cycles 21 and 22 is now placed in September 1986 (rotation 1779). The activity indicated in the last bars at the right of the graph (April and May 1987) confirm that Solar Cycle 22 is underway. We can expect to observe many sunspots in 1988 and to have a return of auroral activity.



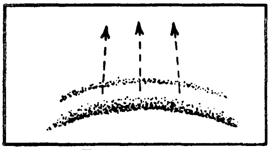
HA (HOMOGENEOUS ARC)

RA (RAYED ARC)

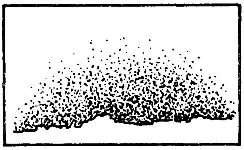


R (RAYS)

PA (PULSATING ARC) PS (PULSATING SPOT)



F (FLAMES)



G (GLOW)

S (SPOT OR PATCH)

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. 16. 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.*

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 values are in UT and are for the Greenwich meridian, although for North American observers the stated values may be read as standard time at the standard meridians (60°, 75°, *etc.*) 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 18, 1988: The latitude is 44°, and from the table the time of sunrise at 0° longitude is 06:56 UT. Thus at the Eastern time zone (E) meridian (75° west), the time of sunrise will be approximately 06:56 EST. The correction for Toronto is + 18 minutes, so sunrise will occur at 07:14 EST on that date. 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. −1	6 34	17 30	6 55	17 10	7 07	16 57	7 21	16 43	7 35	16 30	7 59	16 06	8 19	15 46	9 03	15 01
3	6 36	17 33	6 56	17 12	7 08	17 00	7 22	16 47	7 35	16 34	7 59	16 10	8 19	15 50	9 02	15 07
7	6 37	17 35	6 57	17 15	7 09	17 04	7 22	16 50	7 35	16 38	7 58	16 15	8 17	15 55	8 59	15 14
11	6 37	17 38	6 57	17 19	7 09	17 07	7 22	16 54	7 34	16 42	7 56	16 20	8 15	16 01	8 54	15 21
15	6 38	17 41	6 57	17 22	7 08	17 11	7 20	16 58	7 32	16 47	7 53	16 25	8 11	16 07	8 49	15 30
19	6 38	17 43	6 56	17 25	7 07	17 15	7 19	17 03	7 30	16 52	7 50	16 32	8 07	16 14	8 43	15 39
23	6 38	17 46	6 55	17 29	7 05	17 19	7 16	17 07	7 27	16 57	7 46	16 38	8 02	16 22	8 35	15 49
27	6 37	17 48	6 53	17 32	7 03	17 23	7 14	17 12	7 24	17 02	7 41	16 44	7 57	16 29	8 27	15 59
31	6 36	17 51	6 51	17 36	7 00	17 27	7 10	17 17	7 20	17 08	7 36	16 51	7 50	16 37	8 18	16 09
Feb. 4	6 35	17 53	6 49	17 39	6 57	17 31	7 07	17 22	7 15	17 13	7 30	16 58	7 43	16 45	8 09	16 20
8	6 33	17 55	6 46	17 42	6 54	17 35	7 02	17 27	7 10	17 19	7 24	17 05	7 36	16 53	7 59	16 31
12	6 31	17 57	6 43	17 46	6 50	17 39	6 58	17 31	7 05	17 24	7 17	17 12	7 28	17 01	7 48	16 41
16	6 29	17 59	6 40	17 49	6 46	17 43	6 53	17 36	6 59	17 30	7 10	17 19	7 20	17 10	7 38	16 52
20	6 27	18 01	6 36	17 52	6 42	17 47	6 48	17 41	6 53	17 35	7 03	17 26	7 11	17 18	7 27	17 02
24	6 24	18 03	6 32	17 55	6 37	17 50	6 42	17 45	6 47	17 41	6 55	17 32	7 02	17 26	7 15	17 12
28	6 21	18 04	6 28	17 58	6 32	17 54	6 36	17 50	6 40	17 46	6 47	17 39	6 53	17 33	7 04	17 23
Mar. 3	6 18	18 06	6 24	18 01	6 27	17 58	6 30	17 54	6 33	17 51	6 39	17 46	6 44	17 41	6 52	17 33
7	6 15	18 07	6 19	18 03	6 22	18 01	6 24	17 59	6 27	17 56	6 31	17 52	6 34	17 49	6 40	17 43
11	6 12	18 09	6 15	18 06	6 16	18 04	6 18	18 03	6 19	18 01	6 22	17 59	6 24	17 57	6 29	17 53
15	6 08	18 10	6 10	18 08	6 11	18 08	6 11	18 07	6 12	18 06	6 14	18 05	6 15	18 04	6 16	18 03
19	6 05	18 11	6 05	18 11	6 05	18 11	6 05	18 11	6 05	18 11	6 05	18 12	6 05	18 12	6 04	18 12
23	6 01	18 12	6 00	18 13	5 59	18 14	5 59	18 15	5 58	18 16	5 56	18 18	5 55	18 19	5 52	18 22
27	5 58	18 13	5 55	18 16	5 54	18 17	5 52	18 19	5 50	18 21	5 47	18 24	5 45	18 27	5 40	18 32
31	5 54	18 14	5 51	18 18	5 48	18 21	5 46	18 23	5 43	18 26	5 39	18 31	5 35	18 34	5 28	18 42
Apr. 4	5 51	18 15	5 46	18 21	5 43	18 24	5 39	18 27	5 36	18 31	5 30	18 37	5 25	18 42	5 16	18 52
8	5 48	18 16	5 41	18 23	5 37	18 27	5 33	18 31	5 29	18 36	5 22	18 43	5 16	18 49	5 04	19 01
12	5 44	18 17	5 36	18 25	5 32	18 30	5 27	18 36	5 22	18 40	5 13	18 49	5 06	18 57	4 52	19 11
16	5 41	18 19	5 32	18 28	5 27	18 33	5 21	18 40	5 15	18 45	5 05	18 56	4 57	19 04	4 40	19 21
20	5 38	18 20	5 28	18 30	5 22	18 37	5 15	18 44	5 08	18 50	4 57	19 02	4 47	19 12	4 29	19 31
24	5 35	18 21	5 24	18 33	5 17	18 40	5 09	18 48	5 02	18 55	4 49	19 08	4 38	19 19	4 17	19 41
28	5 33	18 23	5 20	18 35	5 12	18 43	5 04	18 52	4 56	19 00	4 42	19 14	4 30	19 26	4 06	19 51

☉

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

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

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

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°)

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°)

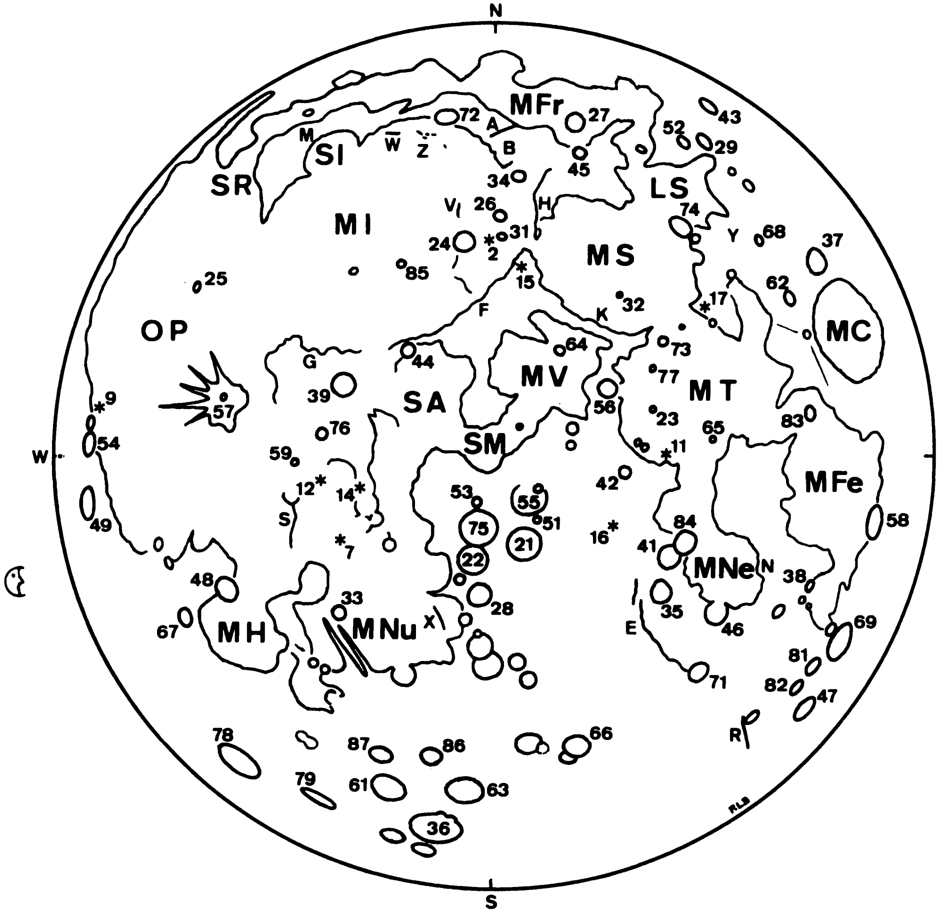
MARIA

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°)

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.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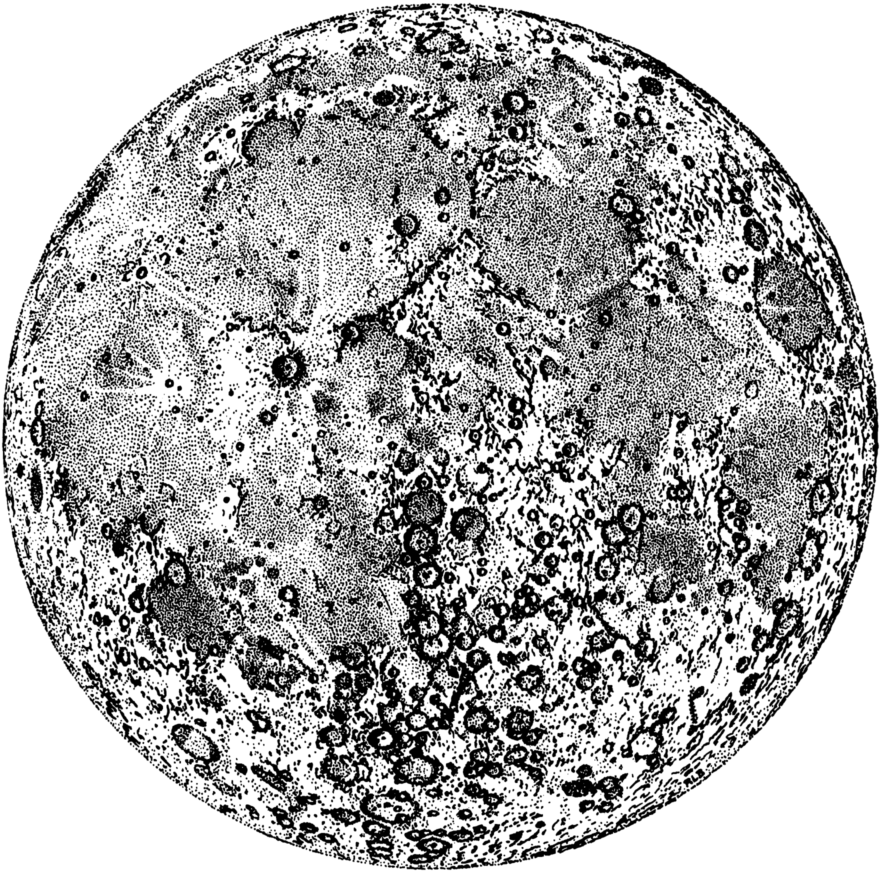
MAP OF



THE MOON

NEW MOON DATES

(UT)

1988				1989			
Jan.	19.2	July	13.9	Jan.	7.8	July	3.2
Feb.	17.7	Aug.	12.5	Feb.	6.3	Aug.	1.7
Mar.	18.1	Sept.	11.2	Mar.	7.8	Aug.	31.2
Apr.	16.5	Oct.	10.9	Apr.	6.1	Sept.	29.9
May	15.9	Nov.	9.6	May	5.5	Oct.	29.6
June	14.4	Dec.	9.2	June	3.8	Nov.	28.4
						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.

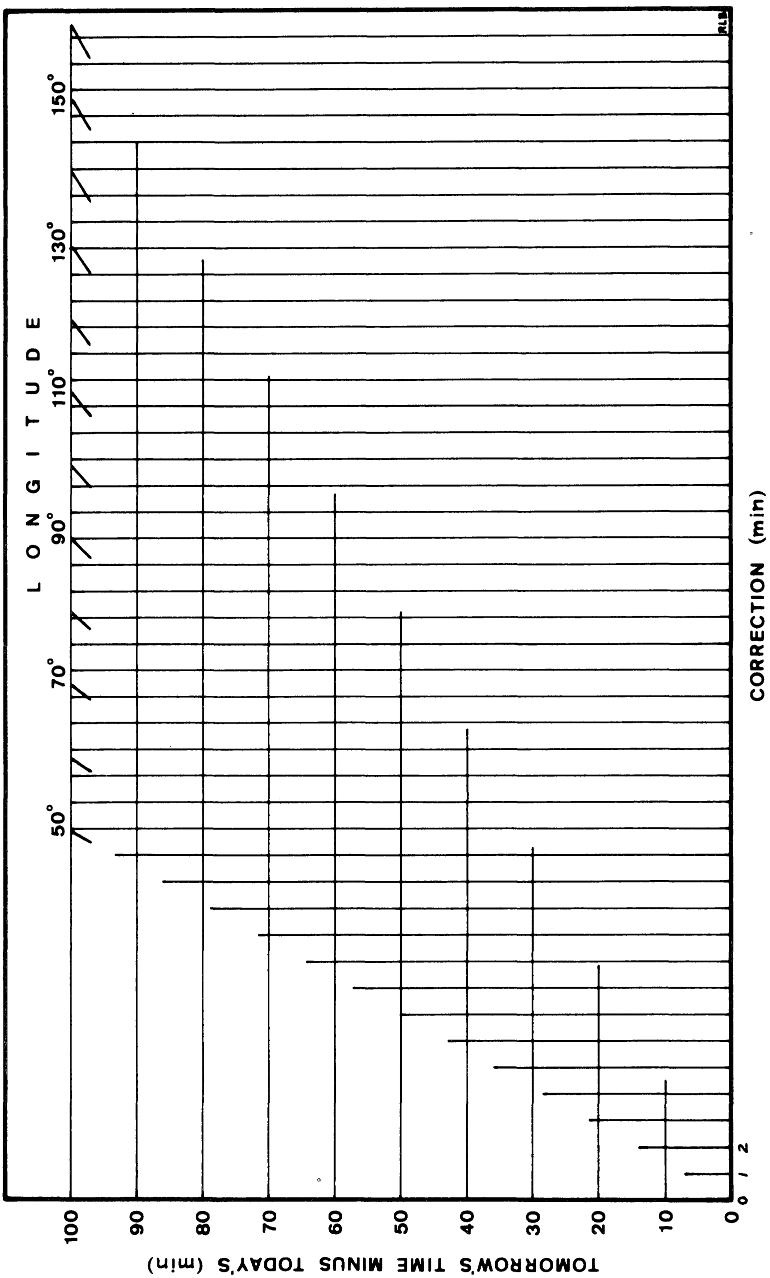
TIMES OF MOONRISE AND MOONSET

The tables on pages 70 to 81 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 in UT and are for the Greenwich meridian. Because of the relatively rapid eastward motion of the Moon, unlike the sunrise and sunset tables, the times *cannot* be read directly as standard times at the various standard meridians in North America. The table must be interpolated according to the observer's longitude. Also, the observer's longitude correction relative to his standard meridian must, of course, be applied (see p. 60). 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. 60). 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. (*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



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
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2	16 10	5 16	15 42	5 44	15 25	6 00	15 06	6 20	14 47	6 38	14 12	7 13	13 39	7 45	12 14	9 11
3	17 04	6 10	16 36	6 38	16 20	6 55	16 00	7 15	15 42	7 33	15 07	8 09	14 35	8 41	13 10	10 06
⊕ 4	17 59	7 00	17 33	7 27	17 18	7 43	17 00	8 01	16 44	8 18	16 12	8 51	15 43	9 20	14 34	10 30
5	18 53	7 46	18 31	8 09	18 18	8 23	18 03	8 39	17 49	8 54	17 22	9 22	16 59	9 46	16 08	10 39
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LATITUDE:	+20°		+30°		+35°		+40°		+44°		+50°		+54°		+60°	
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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
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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
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3	19 22	6 19	19 35	6 08	19 43	6 02	19 52	5 56	20 00	5 49	20 16	5 38	20 28	5 29	20 54	5 12
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8	:: ::	10 11	:: ::	9 42	0 03	9 25	0 23	9 05	0 43	8 46	1 19	8 09	1 54	7 34	3 29	5 59
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MOON

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

ECLIPSES DURING 1988

By Fred Espenak

Four eclipses will occur during 1988. Two of these are solar eclipses (one total and one annular) and two are lunar eclipses (both partial umbral).

1. March 3: Partial Umbral Eclipse of the Moon

   Two days after reaching apogee, the Moon will swing through Earth's outer penumbral shadow and will barely graze the inner umbral shadow. At maximum eclipse (16:12.7 UT), the umbral magnitude will peak at 0.0030 as the Moon's southern limb passes a scant 5 arc-seconds within the umbral shadow. The umbra is not defined by a sharp edge and its appearance is strongly dependent on the transparency of Earth's atmosphere. To the naked eye, the southern half of the Moon will appear somewhat darker than several hours earlier.

   The eclipse begins at 13:43.6 UT and ends five hours later at 18:41.8 UT. At mid-eclipse, the Moon will appear in the zenith from the southern Philippines and northern Kalimantan (Borneo). Observers throughout Asia, Indonesia and Australia will witness the entire event. The central umbral phase will be visible from Eastern Europe and Africa, eastward through Alaska, Hawaii and the Pacific Ocean. The early penumbral phases can be seen from western North America and the late penumbral phases from western Europe/Africa. Unfortunately, none of the eclipse will be visible from eastern North America or South America.

2. March 18: Total Eclipse of the Sun

   The first solar eclipse of 1988 is a total one of moderate duration which offers the best opportunity of its kind since June 1983. Crossing the ascending node of its orbit, the Moon will obscure the Sun's disk for up to 3 and 3/4 minutes along a narrow corridor on Earth. The Moon's cone-shaped shadow delineates a path from the Indian Ocean, across the islands of Sumatra, Kalimantan (Borneo) and Mindanao (Philippines), and north through the Pacific Ocean. From within the much broader path of the Moon's penumbral shadow, a partial eclipse will be seen from the eastern half of Asia, Japan, Indonesia, the northwestern half of Australia, and Alaska [Espenak, 1987; Fiala,Bangert and Harris, 1987].

   The total eclipse commences at sunrise (00:23 UT) in the Indian Ocean about 1500 kilometers west of Sumatra. Five minutes later, the Moon's shadow reaches the western shores of Sumatra. At 00:29 UT, the umbra engulfs Palembang, the first large city in its path. Early morning risers there will witness 2 minutes and 13 seconds of totality while the Sun stands 20° above the horizon. Swinging north of the Java Sea, the shadow transits the Selat Karimata and reaches western Kalimantan (Borneo) at 00:35 UT. Lying on the Equator, the tropical rain forests of the island's interior are relatively inaccessible and offer little hope of a suitable site for observing the eclipse. Leaving Kalimantan and sweeping across the Celebes Sea, the umbra arrives at the southwestern coast of Mindanao (Philippines) at 01:02 UT. The center line passes 9 kilometers north of General Santos where totality lasts 3 minutes and 18 seconds as the Sun stands 49° above the horizon. Moving with an average velocity of 0.85 kilometers per second, the shadow quickly carves out a 172 kilometer wide path through southern Mindanao and the Davao Gulf. The City of Davao lies 55 kilometers north of the center line but still experiences a total eclipse lasting 2 minutes and 30 seconds.

   The remainder of the path lies over the open waters of the northern Pacific Ocean. The instant of greatest eclipse occurs at 01:58:00 UT when the umbra lies approximately 1900 kilometers east of Formosa and 1400 kilometers south of Japan (lat. = 20° 42' North, long. = 139° 58' East). At that time, totality achieves its maximum duration of 3 minutes and 46 seconds. The path is then 169 kilometers wide and the Sun has an altitude of 65°. From the standpoint of duration and altitude, this is the most desirable point along the entire path of totality (i.e. - for ships and aircraft). Continuing on a northeastern course, the shadow passes 200 kilometers south of the Alaskan Aleutians and leaves Earth's surface at 3:33 UT.

Eclipse times and local circumstances for a number of cities is found in Table 1. The Sun's altitude and the eclipse magnitude are for the instant of maximum eclipse. Eclipse magnitude is the fraction of the Sun's diameter obscured; when the magnitude exceeds 1.00, the eclipse is total.

Long range weather prospects for the 1988 total eclipse are not particularly encouraging. Nevertheless, many expeditions will be mounted in the hopes of beating the odds. During March along the Sumatra-Kalimantan-Mindanao eclipse path, clouds tend to form less over water than over land [Anderson ,1987]. The daytime heating of land triggers the convection of warm moist air which cools as it rises and creates the cumulus clouds which are so characteristic of the tropics. Inland sites are more prone to cloudiness than is the coast, although morning fog may pose a problem there. The mean monthly cloudiness (in tenths) for regions along the East Indies eclipse path are as follows: Sumatra - 0.8, Bangka - 0.8, Selat Karimata - 0.7, Kalimantan (west coast and interior) - 0.8, Kalimantan (east coast) - 0.7, Celebes Sea - 0.6, Mindanao - 0.7. The figure drops to 0.5 in the Pacific Ocean east of the Philippines and gradually rises to 0.7 East of Japan. The mean monthly cloudiness climbs above 0.8 south of the Aleutians which are often plagued by storms and fog.

One outstanding anomaly in the weather prospects is General Santos in Mindanao. It's one of the driest, sunniest sites in the Philippines. The mean number of days in March with less than 0.3 cloud cover and no fog is 16.4. In contrast, the same figure for Davao is only 8.8. Unfortunately, Mindanao is not currently safe for tourists [O'Meara, 1987] and eclipse chasers there are taking chances whose consequences far exceed those of being clouded out.

Table 1

Local Circumstances for the Total Solar Eclipse of 18 March 1988

Geographic Location	Eclipse Begins	Maximum Eclipse	Eclipse Ends	Sun's Altitude	Eclipse Magnitude
New Delhi, India	0:57*	1:02	1:38	1°	0.212
Rangoon, Burma	23:59	0:51	1:48	16°	0.483
Bangkok, Thailand	23:53	0:50	1:52	20°	0.571
Singapore	23:34	0:35	1:43	21°	0.901
Palembang, Sumatra	23:29	0:30	1:39	20°	1.036
Djakarta, Indononesia	23:27	0:28	1:37	22°	0.905
Balikpapan, Kalimantan	23:35	0:43	1:58	36°	0.956
Manila, Philippines	0:04	1:15	2:33	45°	0.773
Davao, Philippines	23:53	1:07	2:29	50°	1.044
Saigon, Viet Nam	23:49	0:50	1:59	26°	0.684
Hong Kong	0:16	1:20	2:29	39°	0.550
Peking, China	1:04	1:56	2:50	37°	0.303
Shanghai, China	0:44	1:48	2:55	45°	0.489
Soul, S. Korea	1:03	2:07	3:14	46°	0.486
Tokyo, Japan	1:08	2:24	3:40	53°	0.739
Vladivostok, USSR	1:18	2:22	3:27	44°	0.484
Perth, Australia	23:59	0:19	0:38	25°	0.047
Darwin, Austalia	23:43	0:44	1:49	49°	0.456
Guam	0:30	1:50	3:13	71°	0.813
Fairbanks, Alaska	2:27	3:22	3:59^	3°	0.703

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

*/^ = Eclipse in progress at sunrise/sunset.

3. August 27: Partial Umbral Eclipse of the Moon

The second lunar eclipse of the year occurs with the Moon in Aquarius near its ascending node. The umbral magnitude reaches a maximum value of 0.2976 at 11:04.5 UT, when the Moon's northern limb will extend 10 arc-minutes into the dark inner shadow.

The eclipse begins at 08:51.5 UT and ends four and a half hours later at 13:17.5 UT. At mid-eclipse, the Moon will appear in the zenith from the south Pacific near Western Samoa. This eclipse will be widely seen from most of North and South America excluding Newfoundland, Greenland and eastern Brazil where moonset occurs before first contact. Observers west of Montreal will see part of the umbral phase. However, only those west of a line from Winnipeg to Houston will witness the entire umbral eclipse. The Pacific and eastern Asia will also enjoy the event. None of the eclipse will be visible from Europe, Africa and the western half of Asia.

4. September 11: Annular Eclipse of the Sun

The second solar eclipse of 1988 begins just thirteen hours after the Moon reaches its September apogee. As a result, the Moon's umbral shadow falls short of Earth, producing an annular eclipse of the Sun. The central eclipse begins at 2:56 UT as the anti-umbra crosses the sunrise terminator along the east coast of equatorial Africa. Observers in Mogadishu, Somalia will witness a 3 minute 21 second annular phase beginning four minutes after sunrise. During the next three and one half hours, the shadow sweeps across the Indian Ocean with no major landfall. At 3:22 UT, the anti-umbra passes between the Maldive Islands and the Chagos Archipelago. The instant of greatest eclipse occurs at 4:43:28 UT; the Sun will have an altitude of 62° and while 87.9% of its disk is obscured for the 6 minute 57 second annular phase. Continuing on its course, the anti-umbra passes south of Australia and New Zealand where it leaves Earth at 6:31 UT.

The partial phases of the eclipse will be visible from eastern Africa (at sunrise), southern Asia, Indonesia, Australia and New Zealand (at sunset). Eclipse times and local circumstances for a number of cities is found in Table 2. The Sun's altitude and the eclipse magnitude are for the instant of maximum eclipse.

Table 2

Local Circumstances for the Annular Solar Eclipse of 11 September 1988

Geographic Location	Eclipse Begins	Maximum Eclipse	Eclipse Ends	Sun's Altitude	Eclipse Magnitude
Nairobi, Kenya	3:26*	3:26	4:10	0°	0.590
Mogadishu, Somalia	2:51*	2:57	4:12	1°	0.933
Karachi, Pakistan	1:58	2:50	3:47	22°	0.269
New Delhi, India	2:15	2:54	3:34	30°	0.118
Colombo, Ceylon	1:54	3:16	4:51	40°	0.684
Bangkok, Thailand	2:32	3:34	4:39	63°	0.214
Rangoon, Burma	2:22	3:23	4:27	56°	0.223
Djakarta, Indonesia	2:60	4:32	6:05	78°	0.464
Singapore	2:42	4:06	5:35	76°	0.396
Adelaide, Australia	5:05	6:23	7:33	25°	0.501
Brisbane, Australia	5:45	6:33	7:17	14°	0.185
Melbourne, Australia	5:14	6:29	7:37	18°	0.534
Perth, Australia	4:09	5:48	7:20	47°	0.744
Sidney, Australia	5:29	6:33	7:32	14°	0.380
Wellington, N. Z.	5:38	6:06	6:06^	0°	0.323

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

*/^ = Eclipse in progress at sunrise/sunset.

SOLAR ECLIPSE MAPS

For each solar eclipse, an orthographic projection map of Earth shows the path of penumbral (partial) and umbral (total or annular) 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 maps are oriented with the point of greatest eclipse at the origin.

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 center. 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. If the penumbra has both a northern and southern limit, the rising and setting curves form two separate, closed loops. Otherwise, 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. If the penumbral path has both a northern and southern limit, then points 'P2' and 'P3' are also plotted. These correspond to the coordinates where the penumbral shadow cone becomes internally tangent to Earth's disk.

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. If the eclipse is central (i.e. - total or annular), the curves of maximum eclipse run through the half-hourly outlines of the umbral shadow, from which the Universal Time of each curve can be identified. 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 center. 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. For central eclipses, the umbral path begins and ends along the curves of maximum eclipse at sunrise and sunset. The outline of the Moon's umbral shadow is plotted at every half hour Universal Time along the central path. In addition, the umbra's position is labeled at each integral hour Universal Time.

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 center in Earth radii (Gamma) and the geocentric ratio of diameters of the Moon and the Sun. For partial eclipses, the geocentric ratio is replaced by 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. U1 and U4 are the first and last contacts of the umbra; they denote the start and end of the total or annular 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). Finally, the geodetic coordinates of the point of greatest eclipse are given, as well as the local circumstances there. In particular, the Sun's altitude (ALT) and azimuth (AZ) are listed along with the duration of totality or annularity (minutes:seconds) and the width of the path (kilometers).

LUNAR ECLIPSE MAPS

Each lunar eclipse has two diagrams associated with it. The top one shows the path of the Moon with respect to Earth's penumbral and umbral shadows. Above it and to the left is the time of maximum eclipse, the angle subtended between the Moon and the shadow axis at that instant, followed by the penumbral (PMAG) and umbral (UMAG) magnitudes of the eclipse. The penumbral (or umbral) magnitude is the fraction of the Moon's diameter immersed in the penumbral (or umbral) shadow at maximum 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. In the lower left corner are the Julian Date at maximum eclipse and the extrapolated value of ΔT used in the calculations (ΔT is the difference between Terrestrial Dynamical Time and Universal Time). 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).

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.

ACCURACY OF EPHEMERIDES

These predictions were generated using a solar ephemeris based on the classic work of Newcomb [1895]. The lunar ephemeris was developed primarily from Brown [1919] and the Improved Lunar Ephemeris 1952-1959 [Eckert, Jones and Clark, 1954]. In order to determine the accuracy of these ephemerides, they have been compared against the JPL DE-200 for 260 new moon dates over the interval 1980 through 2000. The solar ephemeris agrees with the DE-200 with a standard deviation of 0.04 seconds in right ascension and 0.03 arc-seconds in declination; the lunar ephemeris agrees with a standard deviation of 0.03 seconds in right ascension and 0.39 arc-seconds in declination. This accuracy far exceeds that necessary for the prediction of lunar eclipses. For solar eclipses, the combined deviations correspond to an uncertainty in the terrestrial position of the Moon's shadow of 1044 meters along the north/south axis and 2102 meters in the east/west axis. On the scale of the eclipse maps presented here, such shifts are invisible. Thus, the solar eclipse predictions should be adequate for most applications. However, observations made near the path limits of a total or annular eclipse will require ephemerides of higher accuracy.

In August 1982, the IAU General Assembly passed a resolution to adopt a value for the mean lunar radius of k=0.2725076, in units of Earth's equatorial radius. This is the value currently used for solar eclipse predictions by the Nautical Almanac Office and is believed to be the best mean radius, averaging mountain peaks and low valleys along the Moon's rugged limb. As has been pointed out by Meeus, et. al [1966], an eclipse of the Sun cannot be regarded as total as long as any photospheric rays reach the observer through deep valleys along the Moon's limb. Using a smaller value of k = 0.272281 results in a better approximation of the Moon's minimum diameter and a slightly shorter total eclipse (or longer annular eclipse). The author has chosen to use the latter value of k for calculating the circumstances for total and annular eclipses. The larger IAU value for k is retained for partial phases and partial eclipses.

These predictions were generated on a DEC VAX 11/785 computer using eclipse algorithms developed primarily from the Explanatory Supplement [1974]. The author would like to thank Goddard's Laboratory for Extraterrestrial Physics for several minutes of computer time. Additional information about eclipses is published annually in the Astronomical Almanac. Special circulars on up-coming central solar eclipses are usually published twelve months in advance of an event. They contain many pages of detailed predictions and can be obtained by writing to: Almanac Office, U. S. Naval Observatory, Washington, D. C. 20392-5100, U.S.A.. All calculations, diagrams and opinions presented in this paper are those of the author and he assumes full responsibility for their accuracy.

REFERENCES

Anderson, J., 1987, "Eclipse Weather: The March 1988 Total Solar Eclipse", Roy. Astron. Soc. Can., 81, 2 (Nat. Newsletter).

Brown, E. W., 1919, Tables of the Motion of the Moon, Yale University Press, New Haven.

Eckert, W. J., Jones, R., and Clark, H. K., 1954, Improved Lunar Ephemeris 1952-1959, Nautical Almanac Office, Washington, D.C..

Espenak, F., 1987, "Predictions for the Total Solar Eclipse of 1988", J. Roy. Astron. Soc. Can., 81, 2.

Espenak, F., 1987, Fifty Year Canon of Solar Eclipses: 1986 - 2035, NASA RP 1178, Goddard Space Flight Center, Greenbelt, MD.

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

Fiala, A. D., Bangert, J. A. and Harris, W. T., 1987, Total Solar Eclipse of 17-18 March 1988, USNO Circular No. 172, Nautical Almanac Office, Washington, D.C..

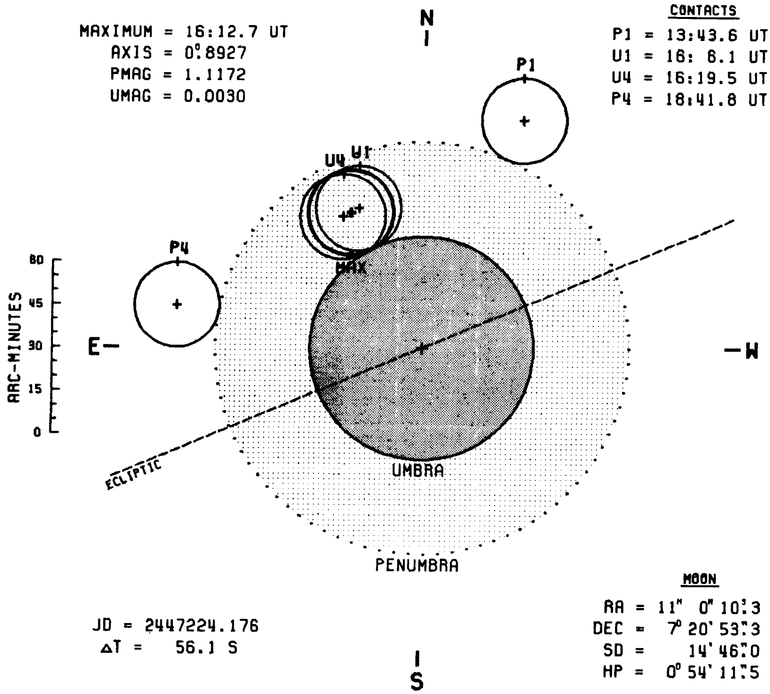
Meeus, J., Grosjean, C. C., and Vanderleen, W., 1966, Canon of Solar Eclipses, Pergamon Press, New York.

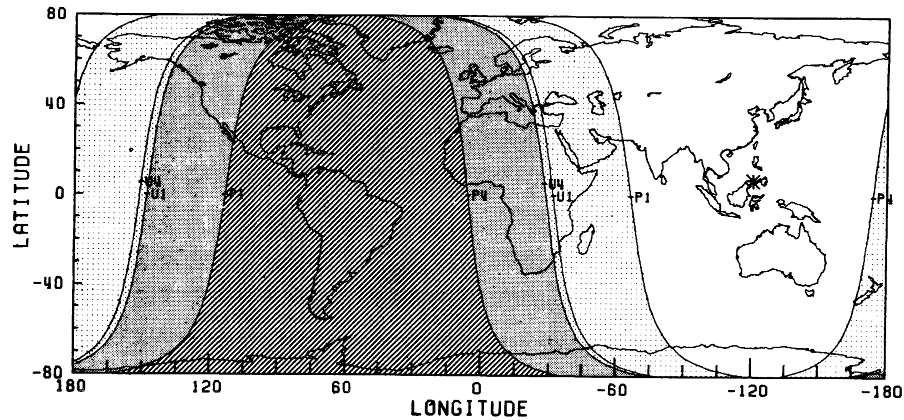
Mucke, H. and Meeus, J., 1983, Canon of Solar Eclipses: -2003 to +2526, Astronomisches Buro, Wien.

Newcomb, S., 1895, "Tables of the Motion of the Earth on its Axis Around the Sun", Astron. Papers Amer. Eph., Vol. 6, Part I.

O'Meara, S. J., 1987, "The Philippines: A Land in Shadow", Sky and Telescope, 73,4.

PARTIAL LUNAR ECLIPSE - 3 MAR 1988



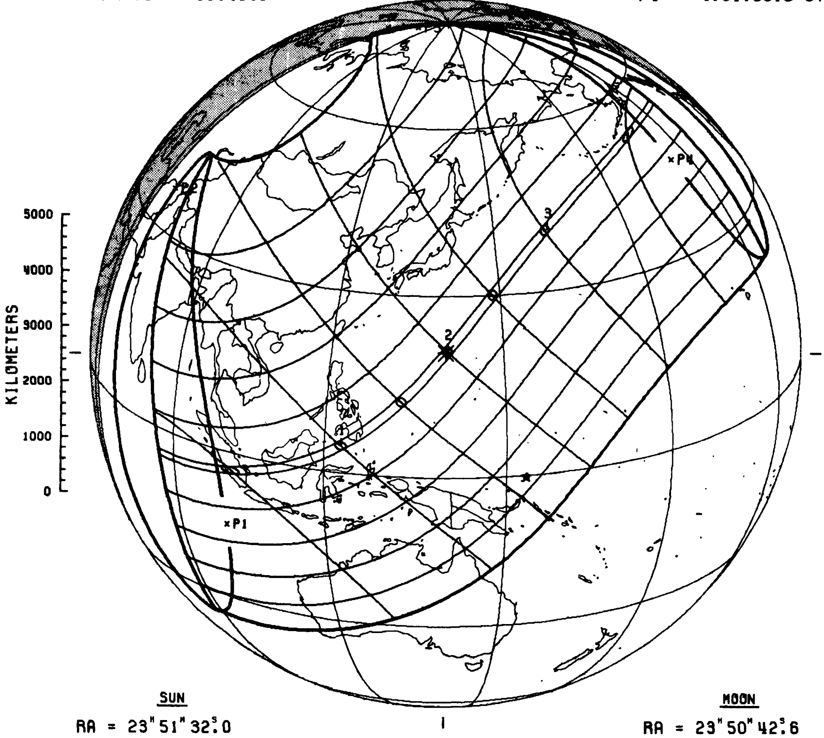


TOTAL SOLAR ECLIPSE - 18 MAR 1988

GREATEST = 1:57:59.6 UT
CONJUNCTION = 2:22:13.5 UT
GAMMA = 0.41865
RATIO = 1.04641

CONTACTS

P1 = 23:24: 1.6 UT
U1 = 0:22:35.5 UT
U4 = 3:33: 7.9 UT
P4 = 4:31:50.9 UT



SUN

RA = $23^{h}51^{m}32^{s}.0$
DEC = 0°55' -3".2
SD = 16' 4".0
HP = 0° 0' 8".8

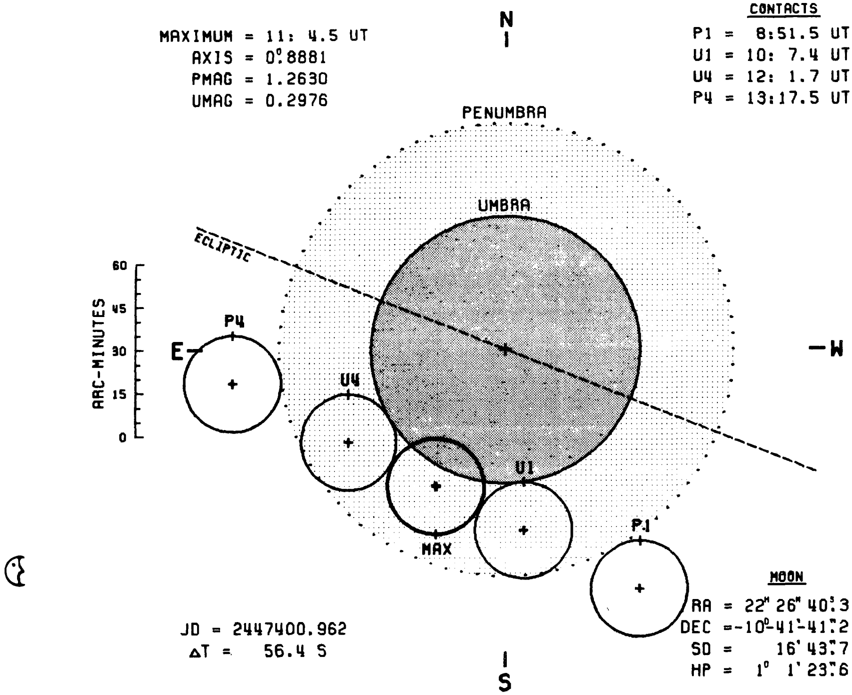
MOON

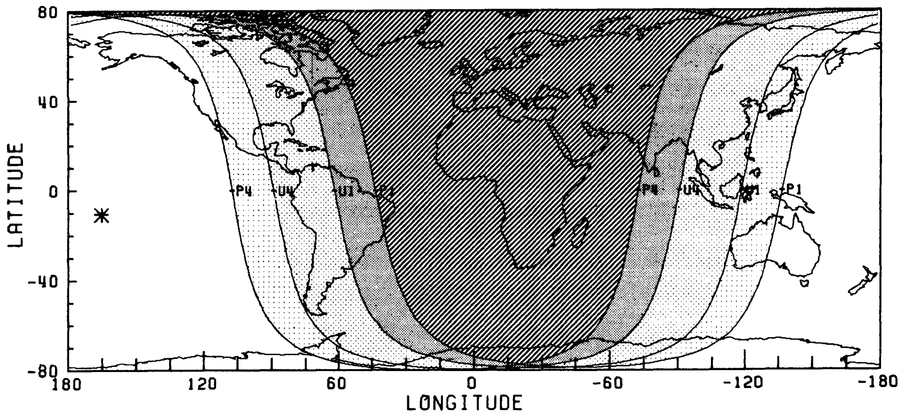
RA = $23^{h}50^{m}42^{s}.6$
DEC = 0°32'-52".5
SD = 16' 33".4
HP = 1° 0' 45".8

SAROS 139 (28/71) JD = 2447238.583 ΔT = 56.1 S

GREATEST	LAT = 20° 42'.0N	ALT = 65°.2	DURATION = 3:46.5
ECLIPSE :	LONG = 139° 58'.4E	AZ = 149°.4	WIDTH = 168.6 KM

PARTIAL LUNAR ECLIPSE - 27 AUG 1988



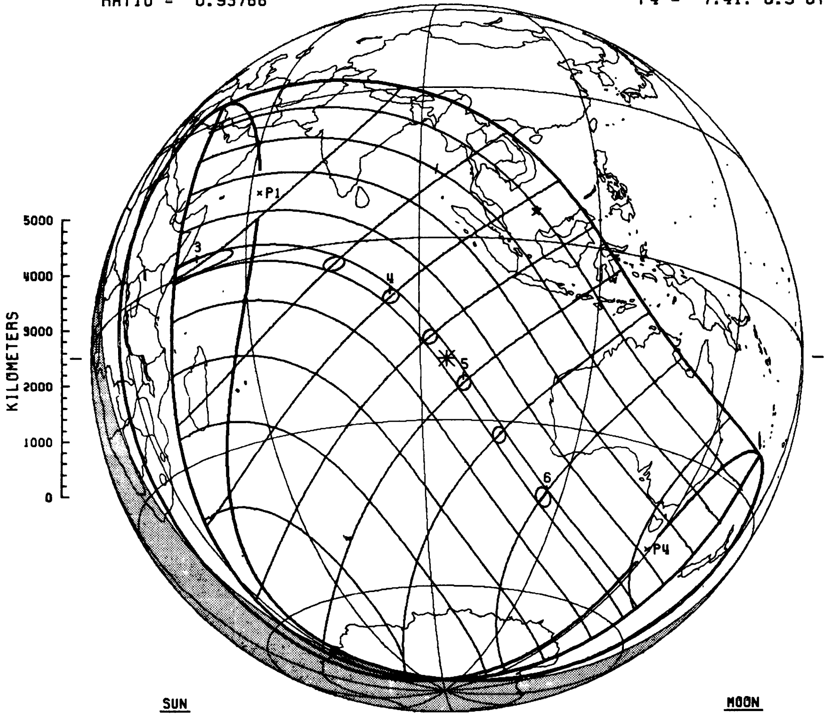


ANNULAR SOLAR ECLIPSE - 11 SEP 1988

GREATEST = 4:43:28.3 UT
CONJUNCTION = 5:14: 2.6 UT
GAMMA = -0.46841
RATIO = 0.93766

CONTACTS

P1 = 1:45:37.2 UT
U1 = 2:55:30.8 UT
U4 = 6:31: 7.1 UT
P4 = 7:41: 6.9 UT



SUN

RA = $11^h 18^m 19^s.3$
DEC = $4° 29' 3''.0$
SD = $15' 53''.3$
HP = $0° 0' 8''.7$

MOON

RA = $11^h 17^m 30^s.6$
DEC = $4° 6' 58''.2$
SD = $14' 42''.2$
HP = $0° 53' 57''.5$

SAROS 144 (15/70) JD = 2447415.698 ΔT = 56.4 S

GREATEST	LAT = $20° 1'.4$S	ALT = $62°.0$	DURATION = 6:56.9
ECLIPSE :	LONG = $94° 24'.5$E	AZ = $30°.1$	WIDTH = 257.8 KM

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*.

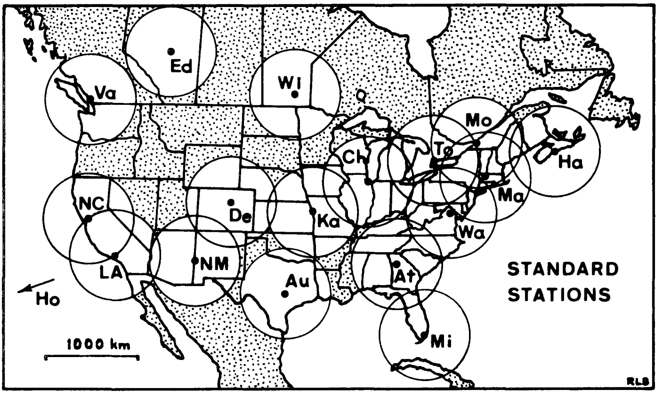
Observers in North America should also contact the International Occultation Timing Association (IOTA), 6 N 106 White Oak Lane, St. Charles, IL 60174, U.S.A. IOTA provides predictions and coordination services for occultation observers. Detailed predictions for any grazing occultation are available ($1.50 U.S. each); instructions concerning the use of predictions are also available ($2.50 U.S.). Annual membership in IOTA is $12.00 U.S. in North America, $17.00 U.S. overseas. Membership includes free graze predictions, descriptive materials, and a subscription to *Occultation Newsletter* (available separately for $8.00 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.

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 96–101) 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 28). 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 23.

As an example, consider the occultation of ZC 552 on Jan. 27, 1988 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 $18^h19^m.8 + 0^m.4(75.72 - 73.60) + 1^m.8(45.40 - 45.50) = 18^h20^m.5$. Note that almost the same result is obtained by using Toronto as the standard station. The elongation of the Moon is 112° which means that the Moon is in the waxing gibbous phase (between first quarter and full). The position angle of disappearance is about 46°.

The total lunar occultation predictions on pages 96–101, 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 102 lists lunar graze predictions for much of North America for 1988. 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 $5^{m}.5$ and 2° for those brighter than $3^{m}.5$). 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 103–106 show the predicted graze tracks. This year the graze maps have been reproduced directly from the computer-generated maps. This ensures accuracy by eliminating the additional step of manual drafting. In past editions provincial and state boundaries were inserted by hand, but the precision was insufficient to locate graze tracks to within the few kilometres that observers require. The omission of these boundaries makes it more difficult to see at a glance what graze tracks pass near the observer, but it also reduces clutter. 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. 92) 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 dots on the graze maps (as on the map on page 93, 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). 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
105	δ Psc	1170	κ Gem	2609	W Sgr
440	ε Ari	1308	γ Cnc	2784	τ Sgr
537	17 Tau	1487	α Leo	3078	η Cap
539	19 Tau	1547	ρ Leo	3171	γ Cap
541	20 Tau	1815	χ Vir	3190	δ Cap
545	23 Tau	1853	ψ Vir	3237	ι Aqr
552	η Tau	2263	1 Sco	3353	λ Aqr
560	27 Tau	2268	2A Sco	3412	φ Aqr
810	β Tau	2287	π Sco		
890	136 Tau	2383	τ Sco		

COVER PHOTOGRAPH—SUPERNOVA 1987A

At 07:35 UT on February 23, 1987 Earth was riddled by an intense burst of neutrinos, a few of these elusive particles being detected simultaneously at two underground detectors, one in Japan and the other in the United States. Twenty-two hours later, at the University of Toronto Southern Observatory on Las Campanas Mountain in Chile, the brightest supernova since the invention of the telescope was discovered by Ian Shelton. SN 1987A is located in the Large Magellanic Cloud, at $\alpha = 5^h35^m50^s$, $\delta = -69°17'58''$ (epoch 1950.0). Shelton, the University of Toronto's resident astronomer at Las Campanas, is a native of Winnipeg, a former member of the Winnipeg Centre of The Royal Astronomical Society of Canada, and presently a life member of the Society. The original photograph from which the negative image on the cover was adapted was a 3-hour exposure on Ektachrome film taken by Shelton on March 26 using the 0.60 metre telescope at Las Campanas. At that time the supernova was near visual apparent magnitude +4. The scale of the cover photograph is approximately 15″/cm. At this scale the geometric image of the distant (160 000 ly?) supernova would be a tiny speck. The splash of light making up its overexposed image is due primarily to scattering of light in the optics of the telescope and the photographic film, plus diffraction of light by the boundaries of the telescope optics. The four orthogonal rays are due to diffraction around the four-arm "spider" support of the secondary mirror of the telescope. The six, symmetrically-arranged gaps are caused by retaining clips near the edge of a mirror in the telescope. Photograph courtesy of the University of Toronto. (RLB)

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. 6	1308	4.7	R.D.	202	.. ..				1 17.9	...	...	213	1 13.7	...	...	212
JAN. 15	2287	3.0	R.D.	308	10 14.3	-1.3	0.8	277	10 2.7	-1.2	1.4	263	GSM			
JAN. 27	552	3.0	D.D.	112	18 15.9	0.1	1.8	59	18 19.8	0.4	1.8	46	18 19.0	0.5	1.8	43
JAN. 27	552	3.0	R.B.	112	19 16.5	-0.4	1.7	253	19 14.0	-0.3	1.5	268	19 9.8	-0.2	1.3	273
FEB. 12	2383	2.9	D.B.	288	9 30.6	-0.7	-0.3	146	9 27.2	0.1	-0.8	163	.. ..			
FEB. 12	2383	2.9	R.D.	288	10 31.2	-2.2	0.8	249	10 9.9	-2.4	1.9	235	.. ..			
FEB. 24	539	4.4	D.D.	85	2 28.4	-0.7	-0.8	69	2 19.4	-1.0	-0.8	74	2 15.0	-1.1	-1.1	84
FEB. 24	541	4.0	D.D.	85	2 44.5	-0.3	-1.6	96	2 38.2	-0.6	-1.9	102	2 38.0	-0.7	-2.4	113
APR. 6	2287	3.0	D.B.	226	.. ..				.. ..				6 18.4	-2.8	2.3	56
APR. 6	2287	3.0	R.D.	226	.. ..				.. ..				6 59.8	-0.0	-1.5	351
JUN. 7	3412	4.4	R.D.	270	6 51.5	-0.9	1.7	247	6 45.3	-0.6	1.7	253	6 39.1	-0.5	1.7	253
JULY 17	1487	1.3	D.D.	35	GBG				GBG				1 56.6	0.2	-1.8	130
JULY 30	3190	3.0	D.B.	196	7 22.1	-1.5	-0.6	83	7 7.9	-1.3	0.1	64	6 59.6	-1.4	0.4	58
JULY 30	3190	3.0	R.D.	197	8 20.1	-0.3	0.6	208	8 15.1	-0.8	0.2	227	8 9.5	-1.0	0.2	232
AUG. 8	890	4.5	R.D.	312	5 46.7	1.1	2.2	209	GSM				GSM			
AUG. 24	2784	3.4	D.D.	134	3 35.8	...	...	3	.. ..				.. ..			
SEP. 2	539	4.4	R.D.	259	7 0.1	-0.7	2.4	220	6 55.0	-0.7	2.0	237	6 47.8	-0.6	1.9	242
SEP. 2	541	4.0	R.D.	259	R.B.				6 56.8	0.0	3.0	201	6 51.6	-0.0	2.7	208
SEP. 17	2383	2.9	D.D.	76	23 46.2	-1.3	-1.2	91	23 30.5	-1.6	-0.8	85	23 21.6	-1.9	-0.6	86
SEP. 18	2383	2.9	R.B.	77	GBG				GBG				0 42.1	-1.5	-1.4	286
SEP. 23	3171	3.8	D.D.	142	1 47.3	...	...	349	.. ..				.. ..			
SEP. 23	3190	3.0	D.D.	144	5 10.9	...	...	119	4 52.3	-1.5	-1.1	92	4 44.8	-1.6	-0.7	86
SEP. 23	3190	3.0	R.B.	144	5 39.6	...	...	175	5 44.0	-0.0	0.8	200	5 41.8	-0.2	0.8	204
OCT. 26	440	4.6	R.D.	197	8 58.4	-1.1	1.2	208	8 48.1	-1.2	1.4	208	8 37.3	-1.3	2.6	198
OCT. 27	539	4.4	R.D.	206	1 26.8	-1.2	0.7	295	1 10.1	...	...	330	.. ..			
OCT. 27	537	3.8	R.D.	206	1 12.0	-0.1	2.0	227	1 13.1	-0.0	1.7	241	1 10.2	0.1	1.6	245
OCT. 27	552	3.0	D.B.	206	.. ..				1 36.1	...	...	145	1 26.5	...	...	132
OCT. 27	541	4.0	R.D.	206	1 46.8	-0.7	1.5	259	1 41.8	-0.6	1.3	274	1 36.5	-0.5	1.1	280
OCT. 27	552	3.0	R.D.	206	.. ..				1 49.2	...	...	170	1 51.3	...	...	184
OCT. 29	890	4.5	R.D.	232	.. ..				3 30.9	...	...	198	3 29.7	0.8	3.3	204
NOV. 16	3078	4.9	D.D.	79	1 29.0	-0.8	-1.2	86	1 19.9	-0.8	-0.6	68	1 15.6	-1.0	-0.4	64
NOV. 16	3190	3.0	D.D.	88	18 15.0	-0.8	1.4	94	GSM				GSM			
NOV. 16	3190	3.0	R.B.	89	19 15.4	-1.0	1.9	216	19 7.4	-0.9	2.0	219	18 58.8	-0.8	2.1	216
NOV. 18	3353	3.8	D.D.	106	2 54.4	-0.8	-0.6	69	2 46.1	-0.8	-0.0	54	2 40.9	-0.9	0.2	51
NOV. 30	1487	1.3	D.B.	261	10 55.2	-2.5	-0.5	84	10 32.3	-2.0	-0.6	102	10 22.5	-1.8	-0.9	116
NOV. 30	1487	1.3	R.D.	261	11 52.6	-0.0	-3.0	351	11 46.2	-0.7	-2.4	334	11 44.9	-1.1	-2.0	320
DEC. 4	1853	4.9	R.D.	303	8 10.3	-0.8	1.2	279	GSM				GSM			
DEC. 20	440	4.6	D.D.	140	1 43.6	...	...	138	1 12.2	-2.3	-0.6	109	0 59.4	-2.2	0.0	104
DEC. 20	552	3.0	D.D.	150	20 10.3	-0.5	0.7	122	20 9.1	0.0	1.0	107	20 8.0	0.2	1.0	104
DEC. 20	552	3.0	R.B.	150	20 43.3	0.7	2.6	196	20 51.0	0.5	2.0	213	20 50.5	0.5	1.8	217
DEC. 31	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

DATE	ZC	MAG.	PH.	ELG.	WINNIPEG,MAN W 97.2 , N 49.9 TIME	A	B	P	EDMONTON,ALTA. W113.4 , N 53.6 TIME	A	B	P	VANCOUVER,B.C. W123.1 , N 49.2 TIME	A	B	P
M D				°	H M			°	H M			°	H M			°
JAN. 6	1308	4.7	R.D.	202	1 37.7	0.3	1.7	261	GSM				GSM			
JAN. 27	552	3.0	D.D.	112	18 42.5	0.8	1.9	16	.. ..				.. ..			
JAN. 27	552	3.0	R.B.	112	19 13.6	-0.2	1.0	304	.. ..				.. ..			
FEB. 23	440	4.6	D.D.	75	.. ..				.. ..				6 37.9	...	...	353
FEB. 24	539	4.4	D.D.	85	1 47.4	-1.5	0.1	66	1 27.9	-1.2	1.5	46	NSG			
FEB. 24	541	4.0	D.D.	85	2 5.9	-1.4	-1.3	96	1 39.5	-1.5	0.2	77	NSG			
APR. 6	2287	3.0	R.D.	226	6 51.7	-0.3	-0.1	331	GSM				GSM			
APR. 8	2609	4.3	R.D.	252	10 3.5	-1.5	0.7	263	GSM				GSM			
APR. 18	552	3.0	D.D.	31	.. ..				20 33.7	...	...	138	20 16.4	...	...	138
APR. 18	552	3.0	R.B.	31	.. ..				21 0.2	...	...	180	20 39.7	...	...	175
APR. 24	1308	4.7	D.D.	93	.. ..				5 34.1	-1.7	-0.7	59	5 23.8	-1.4	-1.2	87
MAY 3	2263	4.8	R.D.	199	GBG				GBG				10 59.4	-1.4	-1.7	340
JUN. 5	3190	3.0	D.B.	249	GBG				15 44.2	-0.1	0.3	24	15 40.7	-0.2	0.6	23
JUN. 5	3190	3.0	R.D.	249	GBG				GBG				16 33.4	-0.9	-1.5	271
JUN. 27	2263	4.8	D.D.	145	3 14.9	...	...	40	GSM				GSM			
JULY 17	1487	1.3	D.D.	35	1 45.7	-0.1	-2.1	136	1 34.7	-0.2	-2.2	148	1 43.5	-0.0	-2.6	166
JULY 17	1487	1.3	R.B.	35	2 44.3	0.0	-1.7	285	2 34.1	-0.5	-1.8	276	2 34.8	-1.0	-1.5	262
JULY 30	3190	3.0	D.B.	196	6 45.8	-0.8	1.2	24	6 41.3	...	...	1	6 27.9	...	...	356
JULY 30	3190	3.0	R.D.	197	7 44.2	-1.7	-0.0	271	7 14.3	...	...	302	6 53.9	...	...	310
AUG. 23	2609	4.3	D.D.	121	3 18.8	-1.7	-0.8	121	NSG				NSG			
SEP. 1	440	4.6	R.D.	249	NB2				NB2				12 8.5	-1.0	2.0	216
SEP. 2	537	3.8	R.D.	259	6 21.4	0.4	2.3	208	6 33.6	0.3	1.8	231	6 29.5	0.4	1.6	235
SEP. 2	539	4.4	R.D.	259	6 47.0	-0.6	1.4	278	6 42.9	-0.5	1.0	306	6 34.4	...	...	315
SEP. 2	541	4.0	R.D.	259	7 1.5	-0.3	1.8	245	7 4.6	-0.1	1.6	267	6 57.7	0.1	1.4	271
SEP. 17	2383	2.9	D.D.	76	22 47.6	-1.7	0.3	87	GSM				GSM			
SEP. 17	2383	2.9	R.B.	76	24 6.1	-1.6	-0.7	297	23 41.2	-1.3	0.2	292	23 26.1	-1.4	0.6	280
SEP. 23	3190	3.0	D.D.	143	4 21.7	-1.0	0.6	46	4 10.8	-0.7	1.1	22	3 57.7	-0.7	1.7	15
SEP. 23	3190	3.0	R.B.	144	5 29.6	-1.2	-0.2	246	5 5.8	-1.6	-0.0	276	4 47.6	-2.0	0.3	284
OCT. 6	1487	1.3	D.B.	316	20 27.6	-0.2	-1.9	118	20 14.7	-0.5	-2.1	129	20 19.6	-0.4	-2.3	145
OCT. 6	1487	1.3	R.D.	316	21 28.1	0.1	-1.8	303	21 19.9	-0.3	-2.0	295	21 24.1	-0.6	-1.8	283
OCT. 26	440	4.6	R.D.	196	8 23.9	-1.3	0.8	232	8 5.0	-1.3	0.5	257	7 48.3	-1.4	1.0	256
OCT. 27	537	3.8	R.D.	206	1 20.8	0.1	1.3	270	1 28.7	0.3	1.1	286	GSM			
OCT. 27	552	3.0	D.B.	206	1 26.6	0.1	1.3	96	1 35.5	0.4	1.3	81	GSM			
OCT. 27	541	4.0	R.D.	206	1 31.3	...	...	324	.. ..				.. ..			
OCT. 27	545	4.3	R.D.	206	1 40.8	0.5	1.9	210	1 55.0	0.5	1.5	228	GSM			
OCT. 27	552	3.0	R.D.	206	2 14.1	0.3	1.9	224	2 25.0	0.3	1.6	243	2 22.3	0.5	1.4	246
OCT. 27	560	3.8	R.D.	206	.. ..				2 48.5	0.6	2.1	199	2 46.4	0.7	1.8	204
OCT. 29	890	4.5	R.D.	232	3 50.4	0.2	1.7	247	3 59.8	0.3	1.3	269	3 57.7	0.4	1.1	272
NOV. 13	2784	3.4	D.D.	53	23 42.2	-1.4	-0.7	86	NBM				NBM			
NOV. 16	3078	4.9	D.D.	79	1 3.1	-0.5	0.7	22	.. ..				.. ..			
NOV. 18	3353	3.8	D.D.	106	2 35.8	-0.1	1.8	4	.. ..				.. ..			
NOV. 20	105	4.6	D.D.	136	GBG				9 29.4	-0.3	-1.9	96	9 35.8	-0.6	-3.1	116
NOV. 23	552	3.0	D.D.	175	GBG				14 1.6	...	...	150	.. ..			
NOV. 23	552	3.0	R.D.	175	GBG				14 21.5	...	...	195	.. ..			
NOV. 27	1170	3.7	R.D.	229	NB2				13 30.4	-0.9	-1.7	288	13 24.6	-1.6	-0.8	266
NOV. 30	1487	1.3	D.B.	261	9 51.7	-1.3	-0.1	119	9 35.1	-0.9	0.6	117	9 26.2	-0.7	0.0	133
NOV. 30	1487	1.3	R.D.	261	11 12.2	-1.4	-0.9	307	10 49.9	-1.1	-0.0	302	10 36.5	-1.2	1.0	282
DEC. 20	440	4.6	D.D.	139	0 42.4	-0.7	1.8	62	0 43.6	-0.1	2.2	36	NSG			
DEC. 20	552	3.0	R.B.	150	21 9.0	0.5	1.4	240	GSM				GSM			
DEC. 31	1815	4.8	R.D.	272	8 29.4	-0.8	1.4	278	GSM				GSM			

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. 6	1308	4.7	R.D.	202	.. ..				.. ..				1 14.5	...	...	219
JAN. 15	2287	3.0	R.D.	308	9 59.6	-1.5	1.6	257	9 43.4	...	...	231	.. ..			
JAN. 27	552	3.0	D.D.	112	18 14.0	0.3	1.8	52	18 9.7	0.4	1.6	52	18 20.7	0.7	1.7	37
JAN. 27	552	3.0	R.B.	112	19 9.9	-0.3	1.5	262	19 3.7	-0.1	1.4	262	19 6.4	-0.1	1.1	280
FEB. 12	2383	2.9	D.B.	288	9 30.2	...	...	170	.. ..				.. ..			
FEB. 12	2383	2.9	R.D.	288	10 6.5	...	...	229	.. ..				.. ..			
FEB. 24	539	4.4	D.D.	85	2 23.4	-0.9	-1.1	83	2 24.0	-1.0	-1.6	99	2 6.5	-1.5	-1.3	94
FEB. 24	541	4.0	D.D.	85	2 44.8	-0.5	-2.2	112	2 53.0	-0.2	-3.5	132	2 36.2	-0.9	-3.4	127
APR. 6	2287	3.0	D.B.	226	6 40.9	...	...	35	6 15.3	-2.7	1.8	65	5 57.6	-1.6	1.5	80
APR. 6	2287	3.0	R.D.	226	6 58.2	...	...	10	7 7.8	-0.5	-1.5	344	6 58.4	-0.6	-0.6	329
APR. 8	2609	4.3	R.D.	252	NB2				NB2				10 15.8	-2.0	0.4	259
JUN. 7	3412	4.4	R.D.	270	6 41.0	-0.7	1.7	250	6 32.3	-0.5	1.7	246	GSM			
JUN. 27	2263	4.8	D.D.	145	.. ..				4 0.1	...	...	33	3 31.6	...	...	41
JULY 17	1487	1.3	D.D.	35	GBG				GBG				2 1.6	0.1	-2.0	136
JULY 30	3190	3.0	D.B.	196	7 9.3	-1.5	-0.0	72	7 1.6	-1.7	0.2	71	6 47.1	-1.3	0.9	48
JULY 30	3190	3.0	R.D.	197	8 14.9	-0.6	0.5	217	8 9.6	-0.8	0.7	217	7 59.0	-1.4	0.3	242
AUG. 23	2609	4.3	D.D.	121	.. ..				.. ..				3 51.6	...	...	147
SEP. 2	541	4.0	R.D.	259	6 46.5	0.6	3.7	189	6 36.2	0.7	3.6	188	6 46.9	-0.0	2.3	218
SEP. 2	539	4.4	R.D.	259	6 49.6	-0.6	2.1	229	6 39.5	-0.4	2.1	229	6 40.0	-0.5	1.7	251
SEP. 17	2383	2.9	D.D.	76	23 34.8	-1.7	-0.9	89	23 29.4	-2.0	-0.7	92	23 5.7	-2.1	-0.2	89
SEP. 18	2383	2.9	R.B.	77	0 53.4	-1.2	-1.4	279	0 52.0	-1.5	-1.2	277	0 30.3	-1.8	-1.1	288
SEP. 23	3190	3.0	D.D.	143	4 58.4	-1.9	-1.8	105	4 55.0	-2.4	-1.8	107	4 31.9	-1.7	-0.1	75
SEP. 23	3190	3.0	R.B.	144	5 40.3	0.3	1.6	186	5 35.3	0.5	2.1	181	5 37.1	-0.6	0.6	214
OCT. 6	1487	1.3	D.B.	316	GBG				GBG				20 43.2	0.1	-1.8	119
OCT. 26	440	4.6	R.D.	197	8 42.8	...	...	191	.. ..				8 21.5	-1.1	3.7	191
OCT. 27	537	3.8	R.D.	206	1 7.9	0.0	1.8	235	1 2.1	0.2	1.7	235	1 8.5	0.2	1.4	252
OCT. 27	539	4.4	R.D.	206	1 14.7	...	...	310	1 8.9	...	...	310	.. ..			
OCT. 27	545	4.3	R.D.	206	.. ..				.. ..				1 13.7	...	...	175
OCT. 27	552	3.0	D.B.	206	.. ..				.. ..				1 19.3	-0.4	0.7	119
OCT. 27	541	4.0	R.D.	206	1 38.5	-0.5	1.3	268	1 31.8	-0.4	1.2	267	1 31.3	-0.3	0.9	288
OCT. 27	552	3.0	R.D.	206	.. ..				.. ..				1 53.3	0.7	2.5	197
OCT. 29	890	4.5	R.D.	232	.. ..				.. ..				3 30.6	0.7	2.5	215
NOV. 14	2784	3.4	D.D.	53	.. ..				.. ..				0 7.0	-2.0	-1.9	115
NOV. 16	3078	4.9	D.D.	79	1 23.1	-1.0	-0.8	78	1 20.9	-1.3	-0.8	80	1 7.4	-1.1	0.1	54
NOV. 16	3190	3.0	R.B.	89	19 2.3	-0.9	2.1	215	18 50.3	-0.9	2.3	209	GSM			
NOV. 18	3353	3.8	D.D.	106	2 47.6	-1.0	-0.3	64	2 43.5	-1.3	-0.2	69	2 32.0	-1.0	0.7	43
NOV. 30	1487	1.3	D.B.	261	10 36.8	-2.0	-0.9	108	10 32.3	-1.8	-1.4	125	10 10.5	-1.5	-1.2	134
NOV. 30	1487	1.3	R.D.	261	11 54.3	-0.8	-2.4	330	11 57.7	-1.3	-2.1	314	11 36.0	-1.7	-1.3	301
DEC. 4	1853	4.9	R.D.	303	8 0.5	-0.7	2.1	260	GSM				GSM			
DEC. 20	440	4.6	D.D.	140	1 19.4	...	...	126	1 13.6	...	...	136	0 42.2	-1.7	0.8	93
DEC. 20	440	4.6	R.D.	140	R.B.				1 34.0	...	...	166	R.B.			
DEC. 20	552	3.0	D.D.	150	20 6.4	-0.1	0.8	114	GSM				GSM			
DEC. 20	552	3.0	R.B.	150	20 44.2	0.6	2.1	206	20 39.7	0.7	2.1	205	20 51.9	0.6	1.6	223
DEC. 31	1815	4.8	R.D.	272	8 52.3	-1.6	0.3	289	8 41.3	-2.1	1.3	268	8 26.4	-1.7	2.2	259

DATE	ZC	MAG.	PH.	ELG.	MIAMI, FLORIDA W 80.3 , N 25.8 TIME	A	B	P	ATLANTA, GEORGIA W 84.3 , N 33.8 TIME	A	B	P	AUSTIN, TEXAS W 97.8 , N 30.2 TIME	A	B	P
M D				°	H M			°	H M			°	H M			°
JAN. 27	552	3.0	R.B.	112	18 46.1	0.3	1.4	242	18 57.0	0.1	1.2	262	GSM			
FEB. 24	539	4.4	D.D.	85	.. ..				2 28.1	-1.0	-3.2	126	.. ..			
MAR. 15	3190	3.0	D.B.	329	20 17.4	0.0	0.8	36	20 32.7	...	...	349	.. ..			
APR. 6	2268	4.8	R.D.	224	3 43.9	0.9	-2.0	347	.. ..				GSM			
APR. 6	2287	3.0	D.B.	225	5 56.3	-1.6	0.1	108	5 53.7	-1.6	0.8	95	5 40.2	-0.3	-0.2	130
APR. 6	2287	3.0	R.D.	226	7 18.6	-1.8	-0.8	307	7 6.6	-1.2	-0.7	318	6 49.3	-1.4	0.4	284
APR. 8	2609	4.3	R.D.	252	10 21.8	-2.6	1.4	230	10 19.2	-2.4	0.6	247	9 40.3	-2.8	2.0	230
APR. 24	1308	4.7	D.D.	94	GBG				6 21.3	...	...	44	6 13.5	-0.6	-0.9	82
JUN. 7	3412	4.4	R.D.	270	6 8.0	-0.3	1.9	223	GSM				GSM			
JUN. 27	2263	4.8	D.D.	145	3 38.6	-3.0	0.3	74	3 31.3	-3.1	0.9	59	2 49.8	-2.4	0.4	91
JUN. 27	2287	3.0	D.D.	147	GBG				GBG				7 53.3	-0.7	0.0	56
JULY 3	3237	4.4	R.D.	227	5 47.6	...	...	310	.. ..				.. ..			
JULY 17	1487	1.3	D.D.	35	GBG				GBG				2 29.0	0.4	-2.5	164
JULY 30	3190	3.0	D.B.	196	6 53.5	-3.1	-0.3	95	6 45.9	-1.9	0.7	67	6 17.3	-1.7	1.4	52
JULY 30	3190	3.0	R.D.	197	7 48.7	-0.1	2.4	187	7 58.6	-1.1	1.0	219	7 35.3	-1.8	1.0	238
AUG. 24	2784	3.4	D.D.	133	2 58.2	-1.3	1.9	27	.. ..				.. ..			
SEP. 2	539	4.4	R.D.	259	6 8.6	0.4	2.7	202	6 26.7	-0.2	2.0	230	6 18.8	-0.0	1.5	244
SEP. 2	541	4.0	R.D.	259	.. ..				6 24.4	0.8	3.3	190	6 22.7	0.5	2.2	209
SEP. 17	2383	2.9	D.D.	76	23 33.9	-2.6	-1.3	115	23 16.6	-2.4	-0.6	100	22 45.7	-2.3	-0.5	115
SEP. 18	2383	2.9	R.B.	77	0 57.9	-1.6	-0.3	253	0 45.5	-1.9	-1.0	274	0 18.1	-2.5	-0.4	271
SEP. 23	3171	3.8	D.D.	141	0 48.7	-0.9	3.3	5	.. ..				.. ..			
SEP. 23	3190	3.0	D.D.	143	.. ..				4 43.7	-2.9	-1.4	105	4 9.8	-2.4	0.3	80
SEP. 23	3190	3.0	R.B.	144	.. ..				5 27.1	0.4	2.4	180	5 17.8	-0.7	1.5	204
SEP. 24	3353	3.8	D.D.	161	GBG				GBG				10 12.9	-0.3	-0.5	76
OCT. 1	810	1.8	D.B.	254	7 34.2	...	...	8	.. ..				.. ..			
OCT. 1	810	1.8	R.D.	254	8 5.6	...	...	325	.. ..				.. ..			
OCT. 6	1487	1.3	D.B.	316	GBG				GBG				21 5.9	0.2	-2.0	143
OCT. 27	537	3.8	R.D.	205	0 40.6	0.6	1.9	212	0 55.8	0.4	1.5	235	GSM			
OCT. 27	539	4.4	R.D.	206	1 1.7	-0.3	0.6	279	1 2.2	...	...	310	.. ..			
OCT. 27	541	4.0	R.D.	206	1 14.8	0.1	1.3	246	1 24.0	-0.1	1.1	268	GSM			
OCT. 27	552	3.0	R.D.	206	.. ..				.. ..				1 32.0	...	...	180
OCT. 29	890	4.5	R.D.	232	.. ..				.. ..				3 18.5	1.1	2.4	209
NOV. 14	2784	3.4	D.D.	53	.. ..				.. ..				0 5.8	...	...	130
NOV. 16	3078	4.9	D.D.	79	1 34.8	...	...	124	1 13.3	-1.7	-0.5	80	0 49.4	-1.8	0.5	61
NOV. 18	3353	3.8	D.D.	106	2 49.9	...	...	113	2 33.4	-1.7	0.0	70	2 8.3	-1.7	1.1	51
NOV. 30	1487	1.3	D.B.	261	10 58.3	-0.7	-3.5	168	10 30.4	-1.3	-2.5	153	.. ..			
NOV. 30	1487	1.3	R.D.	262	12 12.6	-2.8	-1.0	278	11 53.4	-2.3	-1.2	288	.. ..			
DEC. 20	440	4.6	D.D.	139	.. ..				0 58.0	...	...	141	0 16.0	-1.8	0.5	104
DEC. 20	440	4.6	R.D.	139	.. ..				1 8.3	...	...	157	R.B.			
DEC. 28	1547	3.9	R.D.	239	R.B.				.. ..				8 1.3	-0.6	-3.6	354

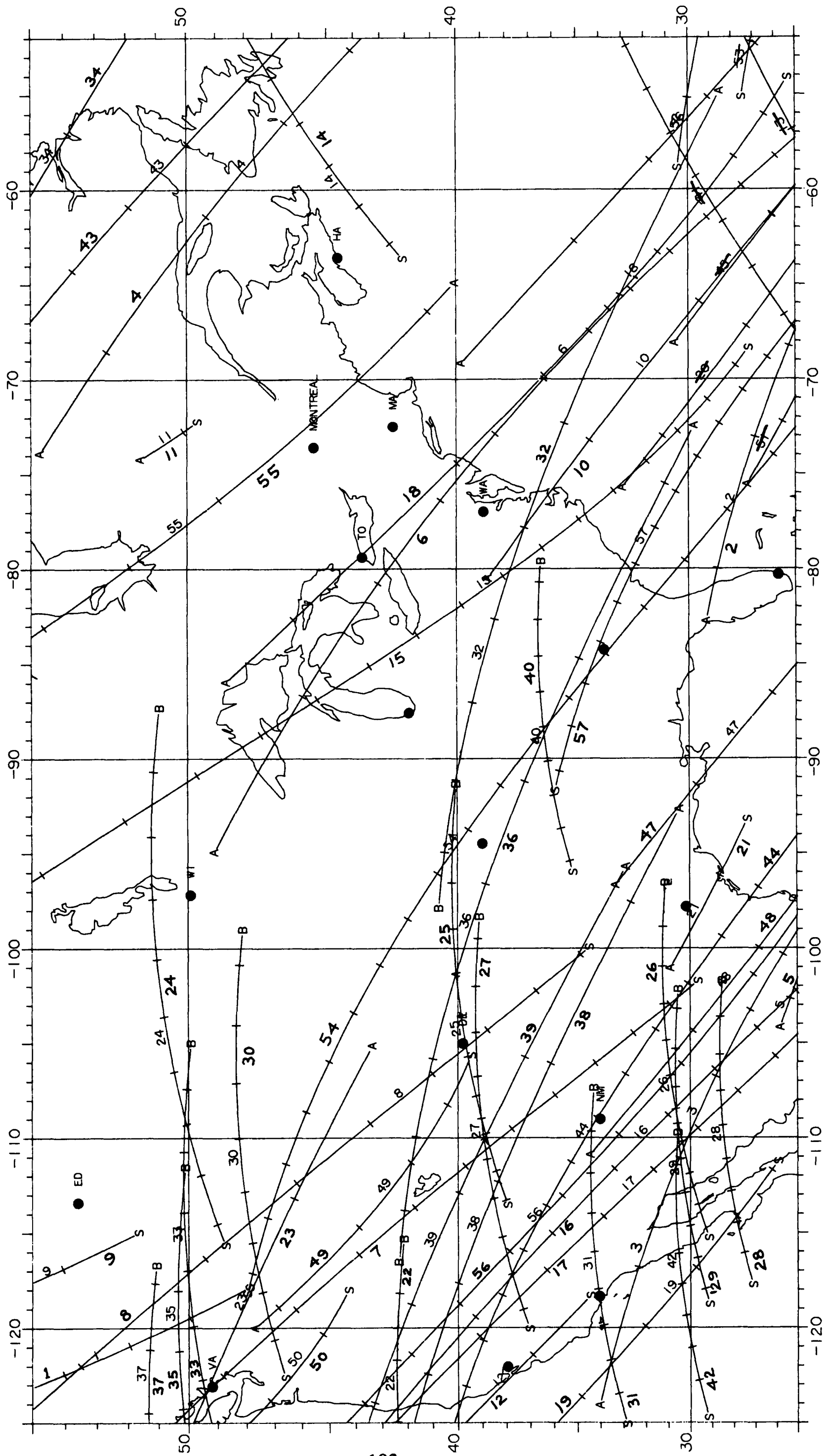
					KANSAS CITY, MO. W 94.5 , N 39.0				DENVER, COLORADO W105.0 , N 39.8				NEW MEX.-ARIZONA W109.0 , N 34.0			
DATE M D	ZC	MAG.	PH.	ELG. °	TIME H M	A	B	P °	TIME H M	A	B	P °	TIME H M	A	B	P °
JAN. 27	552	3.0	R.B.	112	19 3.5	0.1	0.9	283	GSM				GSM			
FEB. 23	440	4.6	D.D.	75	.. ..				GBG				6 29.9	-0.2	0.1	52
FEB. 24	539	4.4	D.D.	85	1 59.9	-1.8	-1.8	106	1 37.0	-2.3	-1.0	99	1 36.9	-3.1	-3.0	122
FEB. 24	541	4.0	D.D.	85	2 47.5	...	...	158	2 23.0	...	...	150	.. ..			
APR. 6	2287	3.0	D.B.	225	5 45.6	-0.9	0.9	100	GSM				GSM			
APR. 6	2287	3.0	R.D.	226	6 54.2	-0.9	-0.1	311	6 45.7	-0.8	0.5	295	6 37.8	-1.1	1.0	273
APR. 8	2609	4.3	R.D.	252	9 59.9	-2.1	0.9	252	9 39.4	-2.0	1.5	243	9 18.8	-2.7	2.9	221
APR. 24	1308	4.7	D.D.	93	6 11.1	...	...	51	5 58.4	-1.1	-1.0	73	6 1.2	-0.9	-1.3	93
MAY 3	2263	4.8	R.D.	199	GBG				NB2				11 53.3	-1.5	-2.0	308
JUN. 5	3190	3.0	D.B.	249	GBG				15 50.7	-0.7	-0.8	76	15 52.7	-1.1	-1.2	90
JUN. 5	3190	3.0	R.D.	249	GBG				GBG				16 43.0	0.2	1.1	203
JUN. 27	2263	4.8	D.D.	144	3 5.8	-2.9	1.2	64	NSG				NSG			
JUN. 27	2287	3.0	D.D.	147	GBG				.. ..				7 50.0	...	...	26
JUN. 27	2287	3.0	R.B.	147	GBG				.. ..				8 13.0	...	...	351
JULY 17	1487	1.3	D.D.	35	2 8.4	0.1	-2.1	145	2 7.4	0.0	-2.4	154	2 22.8	0.3	-2.8	170
JULY 17	1487	1.3	R.B.	36	GBG				2 59.9	-0.2	-1.4	269	3 5.5	-0.5	-0.9	255
JULY 30	3190	3.0	D.B.	196	6 34.6	-1.4	1.3	42	6 22.9	-1.1	1.8	28	6 7.2	-1.3	2.0	33
JULY 30	3190	3.0	R.D.	197	7 47.3	-1.7	0.4	248	7 27.1	-2.1	0.4	268	7 15.3	-2.2	0.7	264
AUG. 23	2609	4.3	D.D.	121	3 38.9	...	...	142	3 11.3	-2.2	-1.0	131	3 9.3	-2.5	-1.7	143
SEP. 2	537	3.8	R.D.	259	5 49.5	...	...	174	6 3.0	0.7	2.3	201	5 52.9	1.0	2.5	193
SEP. 2	539	4.4	R.D.	259	6 32.6	-0.3	1.5	256	6 30.7	-0.2	1.2	272	6 23.4	-0.0	1.1	266
SEP. 2	541	4.0	D.D.	259	6 40.7	0.1	2.1	223	6 42.7	0.1	1.7	239	6 33.7	0.3	1.6	234
SEP. 17	2383	2.9	D.D.	76	22 51.3	-2.2	-0.0	97	22 30.3	-1.8	0.2	107	22 23.3	-1.5	-0.2	123
SEP. 17	2383	2.9	R.B.	76	24 19.8	-2.1	-0.9	286	23 56.9	-2.1	-0.3	284	23 48.7	-2.5	0.0	272
SEP. 23	3190	3.0	D.D.	143	4 19.9	-1.7	0.4	68	4 3.8	-1.5	1.1	50	3 50.8	-1.7	1.3	53
SEP. 23	3190	3.0	R.B.	144	5 30.2	-0.9	0.7	219	5 18.0	-1.5	0.4	240	5 8.1	-1.7	0.8	236
SEP. 24	3353	3.8	D.D.	161	GBG				10 10.8	-0.2	0.5	36	10 7.8	-0.4	0.2	52
OCT. 6	1487	1.3	D.B.	316	20 48.7	0.0	-1.9	126	20 46.2	-0.2	-2.1	134	20 58.3	-0.1	-2.3	147
OCT. 6	1487	1.3	R.D.	317	GBG				21 46.4	-0.0	-1.6	289	21 54.9	-0.1	-1.4	278
OCT. 26	440	4.6	R.D.	196	8 2.0	...	...	180	7 56.4	-1.0	2.8	203	7 32.7	-0.1	4.6	184
OCT. 27	537	3.8	R.D.	206	1 6.3	0.3	1.3	254	GSM				GSM			
OCT. 27	545	4.3	R.D.	206	1 14.5	...	...	182	GSM				GSM			
OCT. 27	552	3.0	D.B.	206	1 15.6	-0.1	0.6	116	GSM				GSM			
OCT. 27	541	4.0	R.D.	206	1 27.1	-0.2	0.7	292	GSM				GSM			
OCT. 27	552	3.0	R.D.	206	1 51.2	0.7	2.2	202	1 59.2	0.6	1.8	218	GSM			
OCT. 29	890	4.5	R.D.	232	3 28.5	0.7	2.2	219	3 36.7	0.6	1.6	237	GSM			
NOV. 13	2784	3.4	D.D.	53	23 57.7	-2.2	-1.4	109	NBM				NBM			
NOV. 16	3078	4.9	D.D.	79	0 58.9	-1.2	0.5	49	0 47.9	-1.0	1.2	28	0 35.6	-1.3	1.5	32
NOV. 18	3353	3.8	D.D.	106	2 22.4	-1.1	1.1	37	2 14.8	-0.5	1.9	14	2 0.5	-0.8	2.1	19
NOV. 30	1487	1.3	D.B.	261	10 5.9	-1.2	-2.0	153	9 52.9	-0.9	-2.4	163	.. ..			
NOV. 30	1487	1.3	R.D.	261	11 24.6	-2.4	-0.3	281	10 58.3	-2.6	1.2	264	.. ..			
DEC. 20	440	4.6	D.D.	139	0 28.7	-1.4	1.1	88	0 19.5	-0.6	1.6	69	NSG			
DEC. 28	1547	3.9	R.D.	239	.. ..				.. ..				7 40.4	...	...	0

DATE	ZC	MAG.	PH.	ELG.	LOS ANGELES,CAL. W118.3 , N 34.1 TIME				N. CALIFORNIA W122.0 , N 38.0 TIME				HONOLULU,HAWAII W157.9 , N 21.3 TIME			
M D				°	H M	A	B	P °	H M	A	B	P °	H M	A	B	P °
FEB. 11	2263	4.8	R.D.	279	NB2				NB2				16 12.3	-2.8	-0.0	277
FEB. 11	2287	3.0	D.B.	281	GBG				GBG				20 2.5	-1.6	-0.0	72
FEB. 11	2287	3.0	R.D.	281	GBG				GBG				21 12.8	-1.5	-1.7	302
FEB. 23	440	4.6	D.D.	75	6 27.1	-0.4	-0.3	62	6 24.7	-0.6	-0.0	53	.. ..			
MAR. 10	2383	2.9	D.B.	261	.. ..				GBG				17 47.6	-2.9	-3.2	149
MAR. 10	2383	2.9	R.D.	262	.. ..				GBG				18 38.4	-1.0	1.7	220
MAR. 24	810	1.8	D.D.	79	.. ..				.. ..				4 49.9	-2.9	-0.4	91
MAR. 24	810	1.8	R.B.	79	.. ..				.. ..				6 24.6	-2.0	-0.9	275
APR. 24	1308	4.7	D.D.	93	5 52.3	-1.0	-1.7	109	5 41.8	-1.2	-1.7	108	.. ..			
MAY 3	2263	4.8	R.D.	199	11 37.0	-1.9	-2.0	314	11 22.3	-1.9	-2.0	323	10 10.9	-3.6	1.5	250
MAY 3	2287	3.0	D.B.	200	GBG				GBG				14 6.6	-2.1	-0.4	85
MAY 3	2287	3.0	R.D.	201	GBG				GBG				15 25.9	-1.5	-1.4	292
JUN. 5	3190	3.0	D.B.	249	15 42.0	-1.2	-0.4	73	15 37.6	-0.9	0.1	55	14 35.4	-1.2	2.4	21
JUN. 5	3190	3.0	R.D.	249	16 43.2	-0.2	0.6	217	16 42.8	-0.5	-0.1	235	15 48.0	-2.8	0.2	262
JUN. 20	1547	3.9	D.D.	67	GBG				GBG				8 44.1	0.3	-2.4	160
JUN. 27	2287	3.0	D.D.	146	.. ..				.. ..				5 37.8	-1.2	-0.5	124
JUN. 27	2287	3.0	R.B.	146	.. ..				.. ..				6 59.4	-2.3	-0.4	290
JULY 17	1487	1.3	D.D.	35	2 27.7	...	...	188	2 16.7	...	...	187	.. ..			
JULY 17	1487	1.3	R.B.	36	2 56.9	...	...	240	2 49.5	...	...	243	.. ..			
JULY 25	2383	2.9	D.D.	129	GBG				GBG				7 50.9	-2.5	-3.3	155
JULY 25	2383	2.9	R.B.	129	GBG				GBG				8 41.5	-2.0	2.0	221
JULY 30	3190	3.0	D.B.	196	5 56.3	-1.1	2.2	27	6 1.4	-1.0	2.4	18	GSM			
JULY 30	3190	3.0	R.D.	196	6 55.6	-2.0	0.7	276	6 50.9	-1.8	0.6	288	GSM			
AUG. 7	810	1.8	D.B.	307	.. ..				.. ..				19 2.0	-3.0	1.4	66
AUG. 7	810	1.8	R.D.	307	.. ..				.. ..				20 32.5	-2.2	-1.8	295
AUG. 20	2287	3.0	R.B.	94	.. ..				.. ..				23 52.8	-0.7	0.7	271
AUG. 23	2609	4.3	D.D.	120	2 49.7	-1.7	-1.3	145	NSG				.. ..			
SEP. 1	440	4.6	R.D.	249	.. ..				R.B.				10 42.8	0.1	2.3	207
SEP. 2	539	4.4	R.D.	259	6 23.8	0.1	0.9	278	6 27.2	0.0	0.7	290	GSM			
SEP. 2	541	4.0	R.D.	259	6 36.5	0.3	1.4	245	6 42.8	0.3	1.3	256	GSM			
SEP. 17	2383	2.9	D.D.	75	22 12.6	-0.8	-0.5	138	22 8.9	-0.6	-0.1	135	.. ..			
SEP. 17	2383	2.9	R.B.	76	23 25.5	-2.5	0.8	261	23 20.1	-2.2	0.9	264	.. ..			
SEP. 22	3078	4.9	D.D.	134	GBG				GBG				11 43.0	-0.9	-0.6	86
SEP. 23	3190	3.0	R.B.	143	4 50.6	-2.1	0.7	253	4 45.3	-2.1	0.6	265	3 32.7	-0.8	1.2	254
SEP. 23	3190	3.0	D.D.	143	3 36.5	-1.4	1.7	41	3 38.7	-1.2	1.9	31	GSM			
SEP. 24	3353	3.8	D.D.	160	10 3.2	-0.5	0.6	40	10 5.2	-0.3	1.2	21	9 22.6	1.1	4.2	347
OCT. 6	1487	1.3	D.B.	316	20 57.6	-0.0	-2.6	160	20 47.2	-0.1	-2.6	159	.. ..			
OCT. 6	1487	1.3	R.D.	317	21 51.5	-0.6	-1.3	269	21 43.7	-0.7	-1.4	271	.. ..			
OCT. 26	440	4.6	R.D.	196	7 27.9	-0.8	2.8	206	7 33.3	-1.2	2.0	225	6 35.2	-0.4	1.2	251
NOV. 18	3353	3.8	D.D.	105	1 57.3	0.3	3.3	354	.. ..				.. ..			
NOV. 27	1170	3.7	R.D.	229	.. ..				13 24.1	...	...	225	.. ..			
NOV. 30	1487	1.3	D.B.	261	.. ..				9 49.1	...	...	194	.. ..			
NOV. 30	1487	1.3	R.D.	261	.. ..				10 8.1	...	...	222	.. ..			
DEC. 28	1547	3.9	R.D.	239	7 34.4	-0.6	-3.3	355	.. ..				GSM			

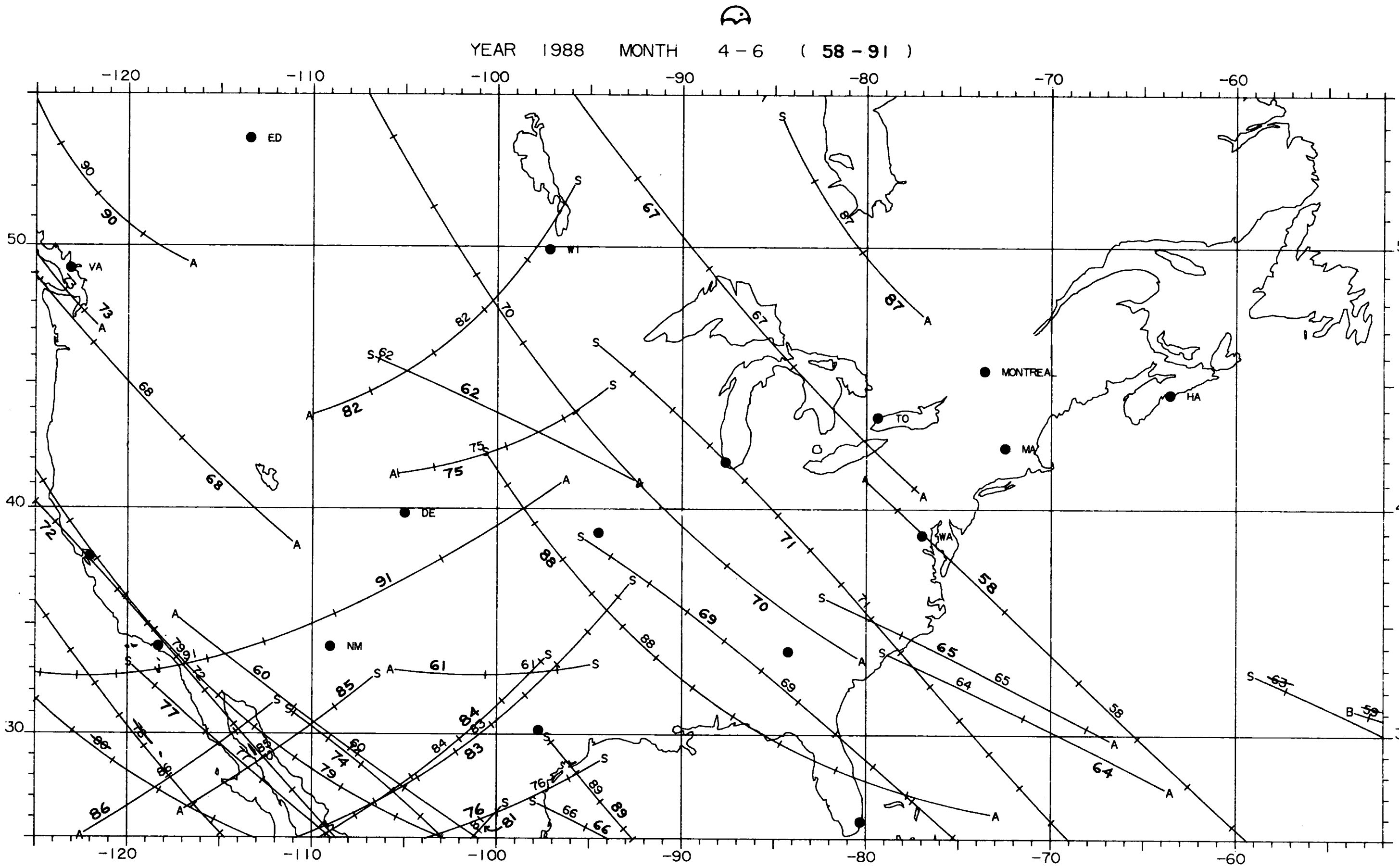
No.	ZC	m_v	UT at Start of Track in West			%	L
1	1735	6.4	Jan.	10	$14^h47^m46^s$	-66	S
2	1798	6.3		11	$5^h38^m45^s$	-60	S
3	1807	5.9		11	$8^h35^m58^s$	-58	S
4	1907	6.7		12	$7^h12^m31^s$	-49	S
5	1914	6.8		12	$7^h59^m21^s$	-49	S
6	1913	7.1		12	$8^h15^m40^s$	-49	S
7	1930	5.6		12	$12^h27^m06^s$	-47	S
8	2039	5.6		13	$12^h43^m34^s$	-37	S
9	2051	5.7		13	$14^h58^m37^s$	-36	S
10	2287	3.0		15	$9^h27^m47^s$	-19	S
11	2297	6.9		15	$12^h03^m44^s$	-18	S
12	2318	6.7		15	$14^h26^m22^s$	-17	S
14	313	7.5		25	$21^h48^m30^s$	50	S
15	1884	5.3	Feb.	8	$9^h49^m29^s$	-74	S
16	2108	6.4		10	$10^h35^m39^s$	-55	S
17	2109	6.1		10	$11^h15^m02^s$	-54	S
18	2383	2.9		12	$9^h39^m05^s$	-34	S
19	2406	6.0		12	$13^h18^m28^s$	-33	S
21	2914	5.0		15	$12^h38^m31^s$	-7	S
22	425	7.0		23	$3^h54^m58^s$	36	S
23	440	4.6		23	$6^h40^m29^s$	37	N
24	537	3.8		24	$1^h28^m16^s$	45	S
25	536	5.4		24	$1^h31^m00^s$	45	S
26	539	4.4		24	$1^h45^m17^s$	45	S
27	541	4.0		24	$1^h57^m58^s$	45	S
28	542	5.8		24	$2^h10^m26^s$	46	S
29	543	6.5		24	$2^h13^m16^s$	46	S
30	546	7.0		24	$2^h16^m25^s$	46	S
31	548	6.7		24	$2^h36^m06^s$	46	S
32	538	5.6		24	$2^h41^m22^s$	46	N
33	553	6.8		24	$2^h50^m54^s$	46	S
34	542	5.8		24	$3^h08^m09^s$	46	N
35	557	6.6		24	$3^h28^m47^s$	46	S
36	555	6.8		24	$3^h56^m43^s$	46	N
37	562	6.6		24	$3^h59^m15^s$	46	S
38	571	6.9		24	$5^h37^m09^s$	47	N
39	574	6.8		24	$5^h58^m57^s$	47	N
40	701	6.5		25	$0^h39^m01^s$	55	S
42	1008	5.0		27	$2^h25^m11^s$	75	S
43	1008	5.0		27	$3^h56^m12^s$	75	N
44	1022	5.8		27	$5^h21^m10^s$	75	N
47	2334	7.5	Mar.	10	$7^h46^m31^s$	-61	S
48	2496	6.8		11	$10^h00^m13^s$	-50	S
49	2511	6.7		11	$12^h34^m06^s$	-49	S
50	2517	5.9		11	$13^h33^m33^s$	-49	S
54	1093	6.4		26	$2^h43^m40^s$	59	N
55	1105	6.5		26	$5^h39^m18^s$	60	N
56	1108	6.9		26	$6^h43^m03^s$	60	N
57	1211	6.2		27	$0^h48^m27^s$	68	N
58	2276	5.6	Apr.	6	$5^h09^m04^s$	-85	S
60	2609	4.3		8	$8^h52^m12^s$	-65	S
61	3240	6.6		12	$11^h15^m25^s$	-21	N
62	440	4.6		18	$2^h09^m54^s$	3	N
64	571	6.9		19	$0^h15^m04^s$	8	N
65	574	6.8		19	$0^h32^m08^s$	8	N
66	731	5.9		20	$1^h21^m32^s$	15	N
67	1056	7.0		22	$4^h25^m11^s$	33	N
68	1067	7.2		22	$6^h46^m07^s$	34	N
69	1169	5.4		23	$1^h16^m43^s$	41	N
70	1308	4.7		24	$5^h52^m04^s$	53	N
71	1392	7.1		25	$1^h51^m04^s$	61	N
72	1402	7.5		25	$4^h47^m00^s$	62	N
73	1418	5.9		25	$9^h36^m41^s$	63	N
74	1493	6.4		26	$2^h24^m50^s$	70	N
75	3332	7.2	May	10	$10^h03^m00^s$	-34	N
76	53	6.9		12	$10^h51^m14^s$	-14	N
77	1131	7.2		20	$3^h22^m37^s$	18	N
79	1660	6.2		25	$5^h58^m37^s$	64	N
81	3310	6.4	June	6	$11^h13^m32^s$	-59	N
82	3430	5.7		7	$8^h51^m30^s$	-48	N
83	3437	6.7		7	$9^h36^m59^s$	-48	N
84	143	6.8		9	$10^h27^m09^s$	-26	N

No.	ZC	m_v	UT at Start of Track in West			%	L
85	536	5.4	June	12	$11^h40^m34^s$	-4	N
86	541	4.0		12	$12^h05^m35^s$	-4	N
87	1522	6.8		20	$3^h10^m54^s$	29	N
88	1708	6.2		22	$2^h56^m25^s$	47	N
89	1901	6.9		24	$1^h59^m47^s$	66	N
90	1919	7.1		24	$6^h31^m16^s$	67	N
91	2287	3.0		27	$7^h29^m14^s$	92	N
92	3237	4.4	July	3	$5^h08^m57^s$	-84	N
93	103	6.1		6	$9^h16^m42^s$	-51	N
94	105	4.6		6	$10^h13^m24^s$	-50	N
95	797	6.3		11	$10^h10^m00^s$	-6	N
96	1487	1.3		17	$2^h36^m25^s$	9	S
97	2084	6.5		23	$3^h28^m16^s$	60	N
100	196	6.9	Aug.	3	$7^h13^m56^s$	-66	N
102	470	7.0		5	$10^h35^m57^s$	-42	N
104	756	6.5		7	$9^h03^m34^s$	-23	N
106	771	6.1		7	$11^h03^m54^s$	-22	N
108	1067	7.2		9	$10^h16^m42^s$	-8	N
109	2152	7.3		20	$1^h38^m06^s$	44	N
111	2609	4.3		23	$3^h29^m54^s$	75	S
112	2784	3.4		24	$2^h02^m02^s$	84	N
113	399	5.7	Sept.	1	$3^h30^m15^s$	-71	N
114	538	5.6		2	$5^h58^m46^s$	-59	N
115	542	5.8		2	$6^h38^m33^s$	-59	N
116	555	6.8		2	$7^h11^m34^s$	-58	N
117	571	6.9		2	$8^h47^m59^s$	-58	N
118	569	5.4		2	$9^h16^m56^s$	-58	N
119	574	6.8		2	$9^h20^m03^s$	-58	N
120	579	7.2		2	$10^h19^m19^s$	-57	N
121	701	6.5		3	$4^h27^m12^s$	-49	N
122	731	5.9		3	$10^h11^m31^s$	-47	N
123	1035	6.8		5	$9^h15^m30^s$	-27	N
125	2538	6.8		19	$1^h58^m44^s$	49	S
127	3190	3.0		23	$4^h52^m28^s$	90	S
128	518	5.9		29	$11^h56^m08^s$	-82	N
129	797	6.3	Oct.	1	$5^h15^m57^s$	-65	N
130	810	1.8		1	$7^h42^m02^s$	-64	N
131	996	6.8		2	$9^h33^m40^s$	-52	N
132	1008	5.0		2	$12^h26^m14^s$	-52	N
135	1131	7.2		3	$10^h35^m57^s$	-42	N
137	1547	3.8		7	$8^h04^m57^s$	-11	S
138	2496	6.8		16	$0^h08^m59^s$	24	S
139	2848	5.6		18	$4^h07^m14^s$	45	S
140	3268	5.6		21	$1^h55^m51^s$	77	S
141	885	5.6		29	$2^h25^m24^s$	-81	N
142	1056	7.0		30	$4^h34^m01^s$	-71	N
143	1067	7.2		30	$6^h40^m42^s$	-70	N
145	1208	6.4		31	$9^h49^m25^s$	-59	S
148	1329	6.8	Nov.	1	$10^h45^m15^s$	-49	S
149	1531	5.9		3	$12^h45^m14^s$	-30	S
150	1792	7.1		6	$9^h43^m17^s$	-9	S
151	2784	3.4		14	$0^h19^m52^s$	20	S
152	3081	6.7		16	$1^h33^m50^s$	40	S
153	3078	4.9		16	$1^h47^m31^s$	40	S
154	3210	7.0		16	$22^h53^m07^s$	51	S
157	3383	6.5		18	$7^h49^m39^s$	65	S
158	1170	3.7		27	$13^h04^m51^s$	-83	S
160	1387	6.8		29	$10^h49^m58^s$	-67	S
161	1395	6.3		29	$12^h20^m03^s$	-66	S
162	1487	1.3		30	$9^h54^m36^s$	-58	S
163	1487	1.3		30	$11^h08^m13^s$	-58	N
166	1970	6.2	Dec.	5	$11^h24^m05^s$	-14	S
167	2084	6.5		6	$11^h43^m03^s$	-8	S
168	3031	5.9		12	$23^h04^m39^s$	16	S
169	3307	4.9		14	$21^h06^m51^s$	35	S
171	3325	6.7		15	$1^h48^m11^s$	37	S
172	145	6.7		17	$21^h00^m56^s$	68	S
173	166	6.9		17	$23^h37^m43^s$	70	S
174	173	6.6		18	$1^h04^m06^s$	70	S
175	1652	5.5		29	$14^h53^m17^s$	-65	S
176	1815	4.8		31	$7^h53^m31^s$	-48	S

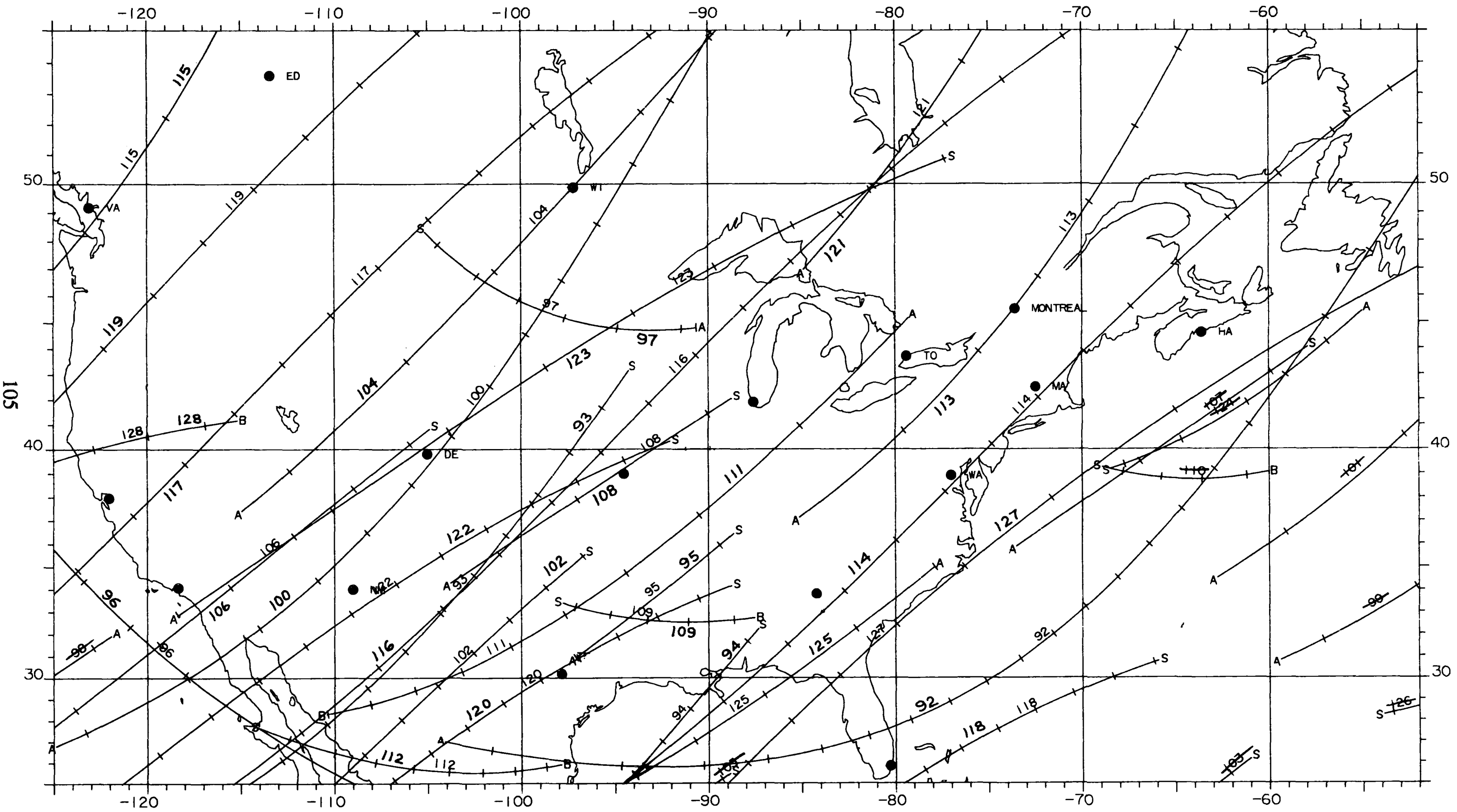
YEAR 1988 MONTH 1 - 3 (1 - 57)



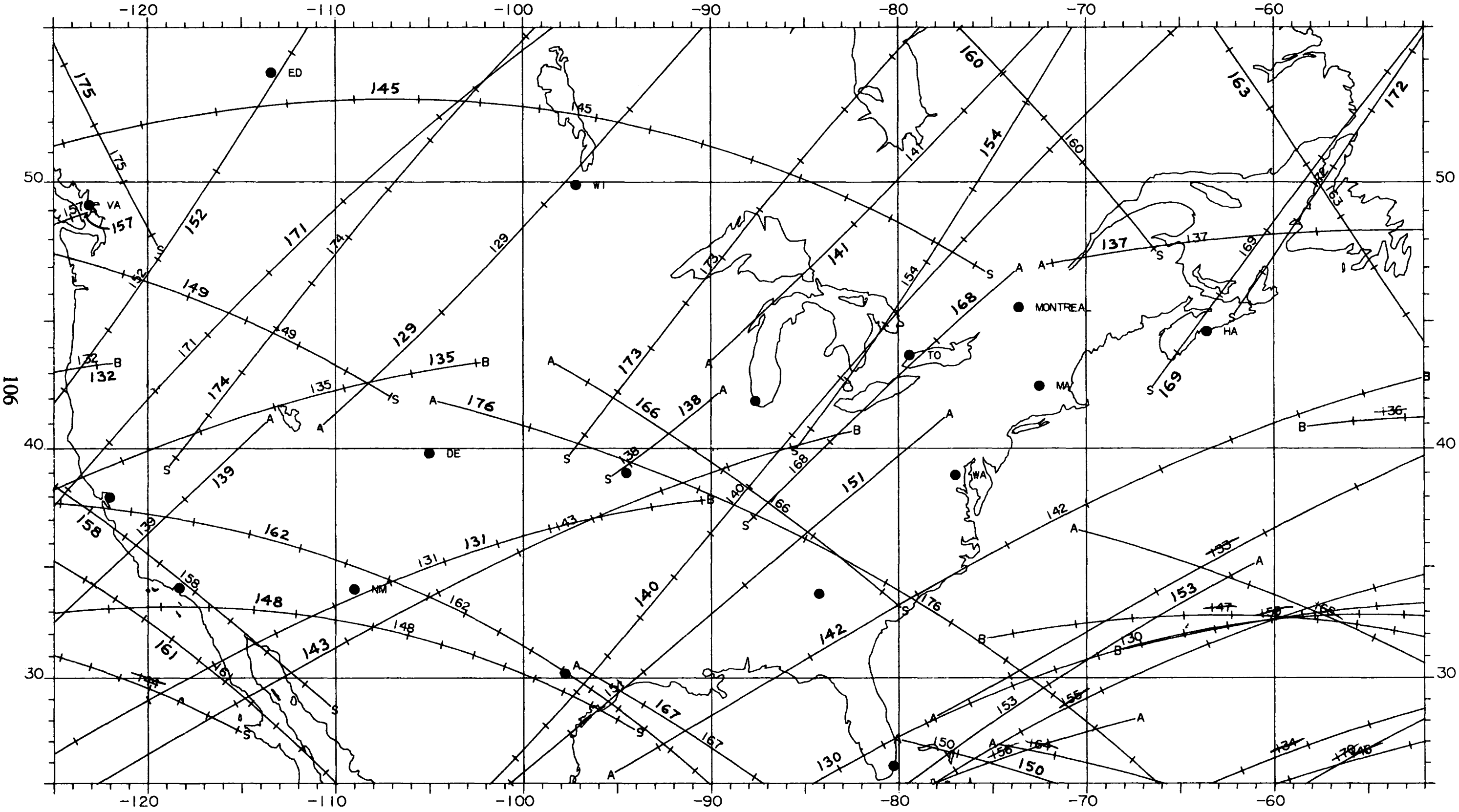
YEAR 1988 MONTH 4 - 6 (**58 - 91**)



YEAR 1988 MONTH 7 - 9 (**92 - 128**)



YEAR 1988 MONTH 10 - 12 (129 - 176)



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^h25^m (two tidal bulges, as described above); (2) 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); (3) Bimonthly, 13.66 days (variation in the Moon's declination); (4) Bimonthly, 14.77 days (spring-neap cycle, described above); (5) Monthly, 27.55 days (perigee-apogee cycle, described above); (6) Biyearly, 182.6 days (variation in the Sun's declination); (7) Yearly, 365.26 days (perihelion-aphelion variation in the Sun's tidal influence); (8) 8.8 years (rotation period of the Moon's perigee); and (9) 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.

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.

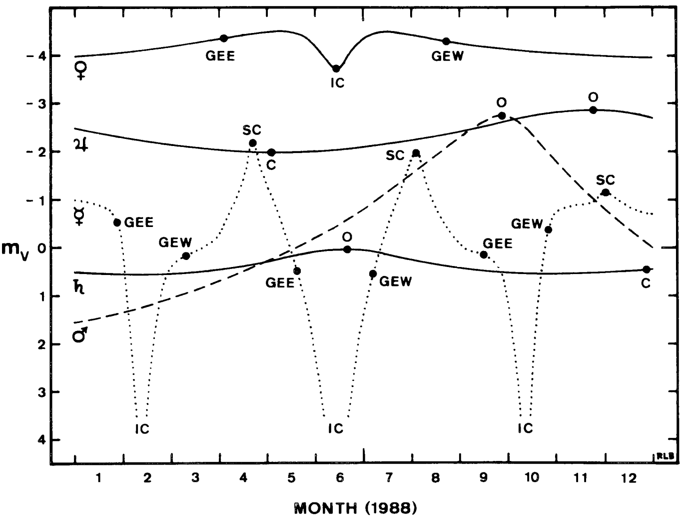
For more information, an excellent introduction is: *The Tides* by E. P. Clancy, Anchor Books, Doubleday and Co., 1969 (now unfortunately out of print); *Exploration of the Universe* (4th edition) by G. O. Abell, Saunders College Publishing, 1982, is another good introductory reference; the pamphlet *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 1988

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 9), one can construct a diagram or model showing the orientation of the Sun and planets on any date.

UT	☿	♀	⊕	♂	♃	♄	♅	♆	♇
Jan. 1.0	296°	358°	100°	209°	31°	264°	267°	278°	220°
Feb. 1.0	82	48	131	224	34	265	267	278	221
Mar. 1.0	216	95	161	239	37	266	268	278	221
Apr. 1.0	306	145	191	255	40	267	268	278	221
May 1.0	94	193	221	272	42	268	268	278	221
June 1.0	228	243	251	291	45	269	269	279	221
July 1.0	316	291	279	309	48	270	269	279	222
Aug. 1.0	119	340	309	329	51	271	270	279	222
Sept. 1.0	240	29	339	348	54	271	270	279	222
Oct. 1.0	331	77	8	7	56	272	270	279	222
Nov. 1.0	141	127	39	26	59	273	271	280	222
Dec. 1.0	248	176	69	43	62	274	271	280	223
Jan. 1.0	348	226	101	61	64	275	271	280	223



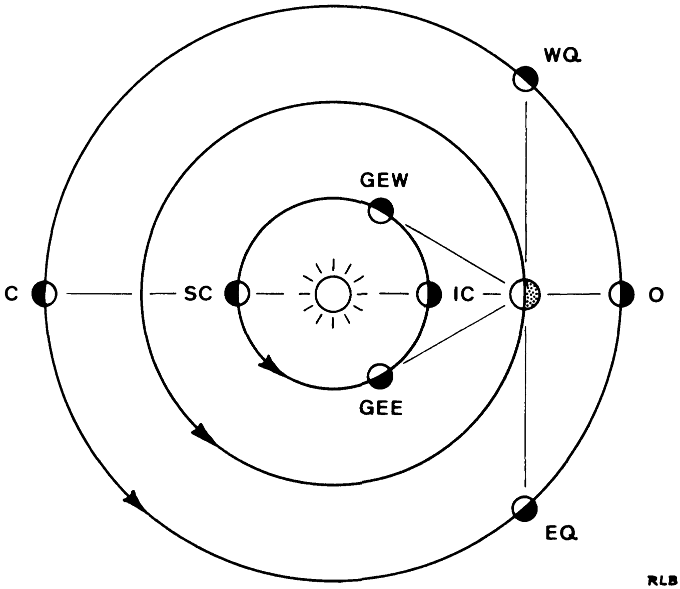
The magnitudes of the five, classical (naked eye) planets in 1988. Oppositions (O), conjunctions (C), inferior and superior conjunctions (IC, SC), and greatest elongations east and west (GEE, GEW) are indicated. (Note the diagram explaining these terms on page 110. For planetary symbols see page 8.)

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

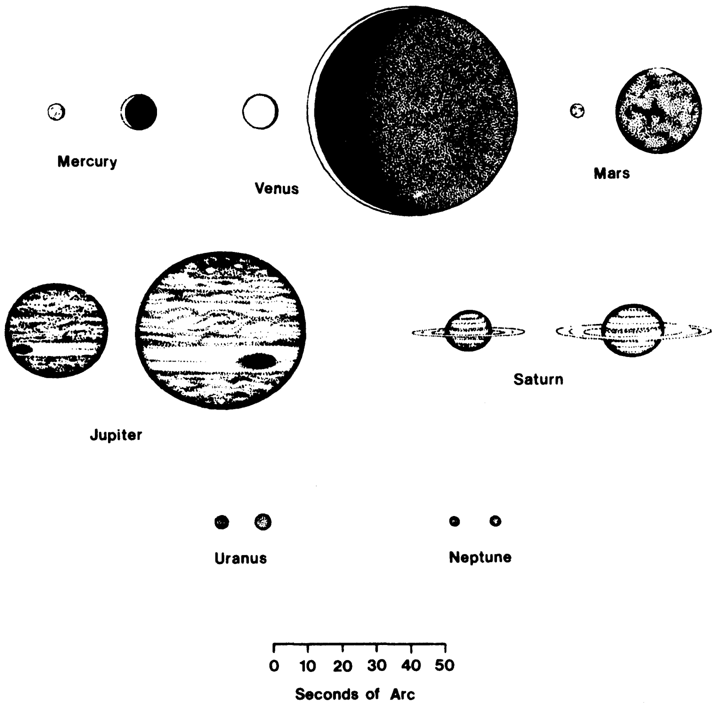
ā dāte; ă tăp; â câre; ȧ ȧsk; ē wē; ĕ mĕt; ẽ makẽr; ī īce; ĭ bĭt; ō gō; ŏ hŏt; ô ôrb; oo book; o͞o mo͞on; ū ūnite; ŭ ŭp; û ûrn.

P



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

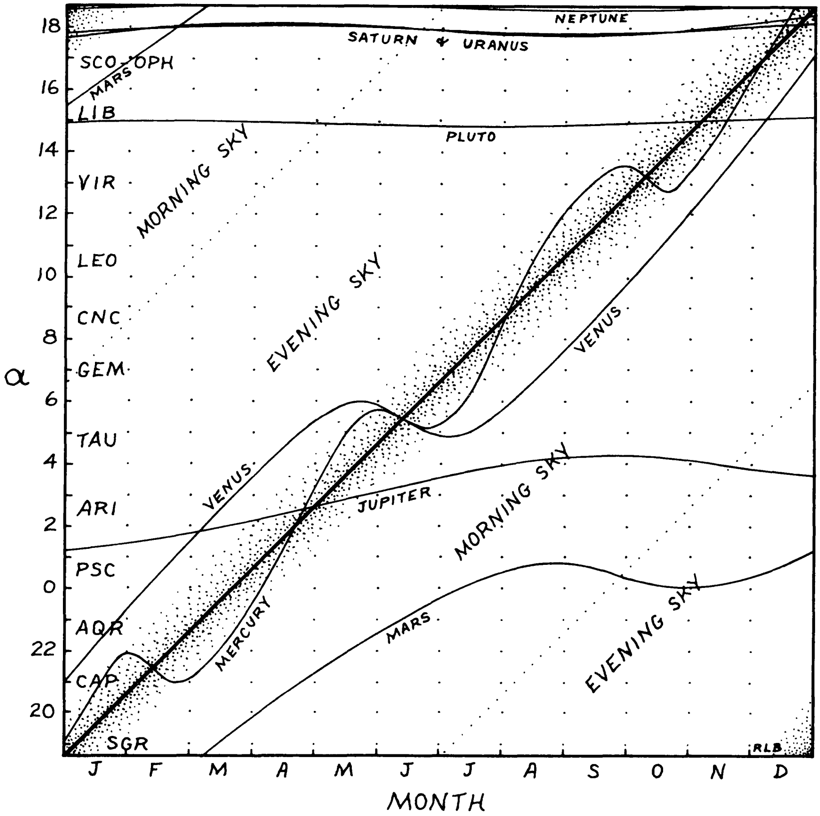


The apparent maximum and minimum observable size of seven planets is illustrated along with characteristic telescopic appearance. The large satellites of Jupiter (not shown) appear smaller than Neptune.

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'ī-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; ẽ makẽr; ī īce; ĭ bĭt; ō gō; ŏ hŏt; ô ôrb; oo book; o͞o mo͞on; ū ūnite; ŭ ŭp; û ûrn.



P

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 Venus and Mercury undergo inferior conjunction together near the middle of June; a striking conjunction of Venus and Jupiter in the evening sky early in March; and the three conjunctions of Saturn and Uranus (in February, June, and October). For more information on these and other events, see the following pages and "The Sky Month By Month" section. (RLB)

THE PLANETS FOR 1988

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).

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 1988

Date 0^h UT	Mag.	Angular Diameter	% of Disk Illuminated	Distance From Sun	α (1988)	δ
Jan. 18	-0.9	5.7"	83%	16°	21^h02^m	-18°29'
24	-0.7	6.5"	66%	18°	21^h36^m	-14°57'
30	-0.1	7.7"	40%	18°	21^h56^m	-11°39'
May 3	-1.1	5.7"	82%	14°	03^h35^m	+20°56'
9	-0.5	6.4"	64%	19°	04^h20^m	+23°45'
15	0.0	7.3"	47%	21°	04^h58^m	+25°07'
21	+0.7	8.5"	32%	22°	05^h25^m	+25°17'
27	+1.5	9.8"	20%	20°	05^h42^m	+24°31'

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.

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.

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.

As 1988 opens, Venus is a brilliant beacon in the west after sunset. It continues to dominate the evening sky until early June when it descends into the twilight glow and to inferior conjunction on June 13. By late June Venus is a prominent morning-sky object in the east, and remains so for the rest of the year. Since Venus is away from bright twilight interference for all but a two week period in mid-June, this is an excellent year for observation of the nearest planet. The interval around 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 NEAR INFERIOR CONJUNCTION 1988

Date 0^h UT	Mag.	Apparent Diameter	% of Disk Illuminated	Distance From Sun	α (1988)	δ
Jan. 1	-4.0	12.5"	85	32°E	21^h00^m	-18°56'
Mar. 1	-4.2	17.4"	67	43°	1^h27^m	+09°59'
Apr. 1	-4.3	22.9"	52	46°	3^h37^m	+22°35'
17	-4.4	27.6"	43	45°	4^h41^m	+26°16'
May 3	-4.5	34.6"	31	41°	5^h33^m	+27°42'
11	-4.5	39.3"	24	38°	5^h51^m	+27°39'
19	-4.5	44.7"	17	32°	6^h01^m	+27°08'
23	-4.4	47.6"	13	29°	6^h02^m	+26°43'
27	-4.3	50.4"	9.1	24°	6^h00^m	+26°09'
31	-4.2	53.1"	5.7	19°	5^h56^m	+25°28'
June 4	-4.1	55.4"	2.9	14°	5^h48^m	+24°39'
8	-3.9	57.0"	0.9	8°	5^h39^m	+23°42'
12	-3.7	57.7"	0.0	2°	5^h29^m	+22°39'
16	-3.8	57.4"	0.4	4°W	5^h18^m	+21°34'
20	-4.0	56.2"	1.8	11°	5^h09^m	+20°31'
24	-4.2	54.2"	4.3	16°	5^h01^m	+19°35'
28	-4.3	51.7"	7.4	22°	4^h56^m	+18°50'
July 2	-4.4	48.9"	11	27°	4^h53^m	+18°17'
6	-4.4	46.1"	15	30°	4^h53^m	+17°56'
14	-4.5	40.5"	22	37°	4^h59^m	+17°47'
22	-4.5	35.7"	29	41°	5^h14^m	+18°07'
Sept. 1	-4.3	21.4"	55	46°	7^h39^m	+19°09'
Nov. 1	-4.0	13.8"	79	37°	12^h11^m	+00°28'
Dec. 32	-3.9	11.0"	93	23°	17^h07^m	-22°04'

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 1986. 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 Mars will pass through its best perihelion opposition since 1956 for observers in mid-northern latitudes. During most perihelion opposition cycles Mars is well south of the celestial equator. The opposition of 1986 was one of the worst examples. Mars was large (23.2″ at closest approach to Earth), but the planet remained between declination −23° and −28° throughout the principal observing window. Seeing at such low elevations ranged from fair to rotten according to most observers who kept watch from Canada and many parts of the United States. The situation this year will be much improved. During the prime observing window, from mid-July to late November, the planet's declination averages −2° and it is never farther south than −5°. This means an observer at +45° latitude will be peering through half the air mass to see Mars compared to 1986. Furthermore, Mars is 0.01 AU closer to Earth at opposition on September 28 than it was in 1986. Overall this is an *extremely favourable* Mars apparition for mid-northern latitudes—certainly the best since 1956 and probably the best until 2020. The planet's large apparent size (23.8″ at opposition) and relatively high elevation are in rare harmony this year.

Any good-quality telescope over 70mm aperture should reveal surface features on the planet near opposition. The author has detected considerable detail using a 75mm apochromatic refractor, including changes in the Martian dark zones from one opposition to the next. These alterations are due to shifting climate regimes on Mars that regionally transport vast quantities of dust, both dark and light. The clarity of the surface features—white polar caps and dark, irregular patches on a peach-coloured sphere—depends to a great extent on the transparency of the Martian atmosphere. Major dust storms can lower contrast across large sectors of the disc within a week of a storm's onset. The planet can remain partly or completely shrouded for many weeks thereafter. The desert region Hellas is especially storm-prone.

Experienced observers can detect emerging storms when familiar desert areas of the planet brighten and encroach on nearby dark features. The worst dust storms are usually (but not always) seen after Martian perihelion, which this year occurs on August 12, seven weeks *before* opposition. This means there is a chance that some

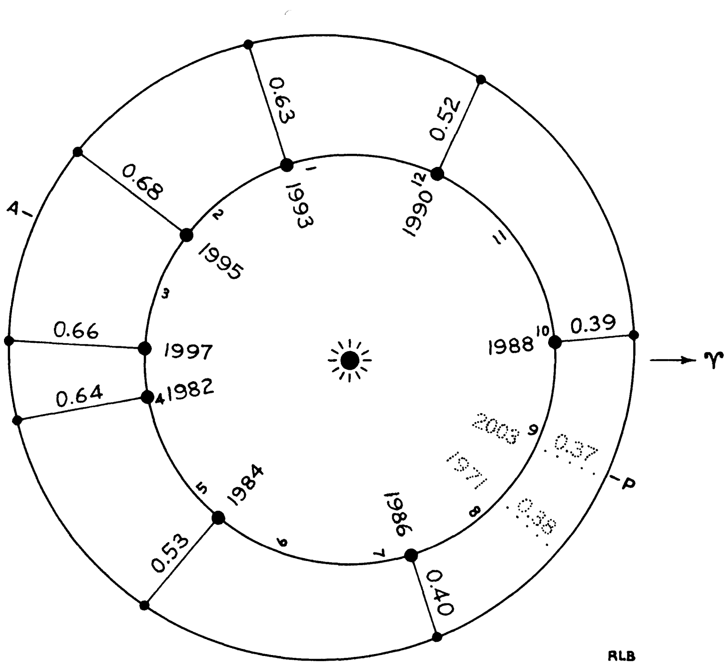
Martian features will be below ideal contrast levels during the choicest observing period. As a hedge against this risk, observers should begin examining the planet in early July when dust storms are less likely. Dust storms vary from perihelion to perihelion. In 1971 the planet was totally blanketed; 1956 partly obscured; 1958 local squalls only.

The polar caps are often the most prominent of all the planet's features and this will certainly be the case during most of the current apparition as the Martian south pole is tipped strongly Earthward from May 1988 to January 1989. The brilliant white polar cap will shrink noticeably throughout this period since summer begins in the Martian southern hemisphere on September 11.

Coloured eyepiece filters can improve the visibility of Martian surface features and reduce the effects of irradiation as explained in the next paragraph. Deep yellow, orange or light red filters enhance the contrast of the dark areas. Larger telescopes also benefit from the filter's reduction of the Martian disc's brilliance. However, in smaller instruments this is a liability that negates most of the advantages of filtration. Generally, telescopes over 150mm are more likely to respond well to colour filters than smaller instruments.

Optimum magnification varies with telescope type and seeing conditions, however, powers about 1.3 times those typically used for observing Jupiter are often ideal. (Actually, powers 1.8 times greater yield images of Mars equal in brightness to Jupiter per unit surface area, but in practice this is too much magnification.) The objective is to strike a balance by providing an aesthetically appealing image while avoiding the effects of *irradiation*. Irradiation is a contrast effect that originates in the eye. It causes brighter areas to encroach on darker adjacent areas. In the case of Mars it produces the apparent enlargement of the polar caps and reduction in—or apparent loss of—fine darker details next to desert areas. Irradiation is most troublesome at powers below $1\times$ per mm aperture on a bright object like Mars. It is therefore a serious problem in large, unfiltered telescopes. Regardless of the instrumentation, experience is the key to detecting the wealth of detail Mars can present to backyard observers. A 100mm telescope should reveal many of the features on the accompanying Mars map during the July-November window.

To the unaided eye, Mars will be an exceptionally rewarding subject to follow during the last half of 1988. In January it is an inconspicuous morning-sky object in Libra. However, the planet's rapid sky motion carries it nearly halfway around the zodiac to Pisces by July when it surges in brightness to become the dominant late-evening celestial object. Mars remains in Pisces for the rest of the year, reaching magnitude -2.8 in late September. The planet's striking orange hue is so distinctive when it is this bright that it becomes instantly recognizable from this characteristic alone. Binocular observers can track Mars's relatively speedy motion against the stellar backdrop from night to night except near the ends of its retrograde loop (see chart).



The above diagram represents the orbits of Earth and Mars as viewed from the north ecliptic pole. Conjugate positions of Earth and Mars (linked by straight lines) are shown for eight successive oppositions of Mars, beginning with that of the year 1982. In addition to this sequence, the 1971 and 2003 perihelic oppositions are indicated with dotted lines. The various years are marked just inside of Earth's orbit, together with small numbers which indicate the approximate position of Earth at the beginning of each month of any year, where 1 = January, 2 = February, etc. Thus from the diagram the approximate date of each opposition can be inferred. The separation of the two planets (in astronomical units) at the various oppositions is marked beside each of the connecting lines. The two tick marks labeled A and P indicate the aphelion point and the perihelion point, respectively, of the orbit of Mars. The direction of the vernal equinox ♈ is shown.

Although Mars is closest to Earth on September 22 in 1988, it is not at opposition until six days later (see p. 47). The reason for this is apparent from the diagram if one keeps the orbital velocities of the two planets in mind: On September 28 (the position shown in the diagram) the Sun, Earth, and Mars lie in a single plane perpendicular to the ecliptic (the latter being the plane of the diagram). Because Mars is a few weeks past perihelion, when at opposition on September 28 its velocity relative to Earth has a component directed away from Earth. It was 6 days earlier that this velocity component was zero, marking the point of closest approach.

Because the 1988 opposition occurs about the time of Earth's Northern Hemisphere autumnal equinox, Mars appears near the celestial equator and is thus quite favorably placed for observers in Canada and the United States. Indeed, for these observers, this is the best opposition of Mars since 1956, and, because of the declination of Mars, it is better than the slightly closer opposition of the year 2003. i.e. During the six decade interval following 1956, 1988 provides the best opposition of Mars for Northern Hemisphere observers. (RLB)

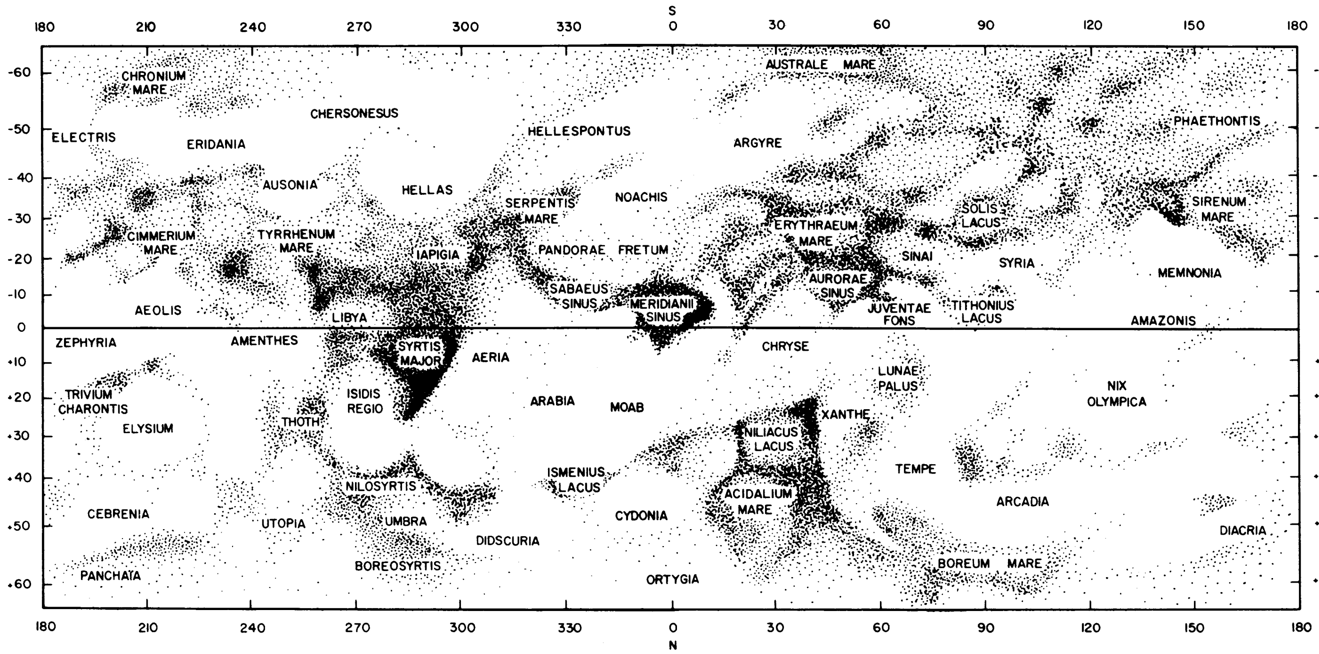
MARS — EPHEMERIS FOR PHYSICAL OBSERVATIONS 1988

Date 0ʰ UT	Dist. AU	Mag.	Equat. Diam.	Illum. %	Pos. Angle	Incl.	L(1)	Δ
Jan. 20	1.989	+1.4	4.7"	94	35°	7°	117.68°	9.70°
Feb. 17	1.755	+1.2	5.3"	91	28°	-2°	206.13°	9.71°
Mar. 16	1.515	+0.9	6.2"	89	18°	-9°	294.33°	9.74°
Apr. 13	1.282	+0.5	7.3"	87	7°	-16°	21.71°	9.77°
May 11	1.063	+0.1	8.8"	86	355°	-21°	108.18°	9.77°
June 8	0.864	-0.4	10.8"	**85**	344°	-24°	194.53°	9.71°
July 6	0.688	-0.9	13.6"	86	335°	-23°	282.70°	9.54°
Aug. 3	0.537	-1.6	17.4"	89	330°	-21°	15.64°	9.36°
11	0.500	-1.8	18.7"	91	329°	-21°	300.74°	9.26°
19	0.467	-2.0	20.0"	93	328°	-20°	226.66°	9.15°
27	0.439	-2.2	21.3"	95	328°	-20°	153.45°	9.04°
Sept. 4	0.416	-2.4	22.5"	97	328°	-20°	81.16°	8.93°
12	0.401	-2.6	23.4"	98	329°	-21°	9.73°	8.84°
20	**0.393**	-2.7	**23.8**"	99	330°	-21°	298.98°	8.81°
28	0.396	**-2.8**	23.6"	**100**	331°	-22°	228.53°	8.82°
Oct. 6	0.408	-2.6	23.0"	100	332°	-22°	158.00°	8.88°
14	0.429	-2.4	21.8"	99	332°	-23°	86.99°	8.98°
22	0.460	-2.1	20.4"	97	333°	-24°	15.18°	9.09°
30	0.498	-1.9	18.8"	95	333°	-25°	302.46°	9.21°
Nov. 7	0.544	-1.6	17.2"	94	333°	-25°	228.81°	9.31°
15	0.595	-1.3	15.7"	92	332°	-25°	154.30°	9.41°
23	0.651	-1.1	14.4"	91	331°	-26°	79.04°	9.49°
Dec. 1	0.712	-0.8	13.1"	90	330°	-26°	3.15°	9.61°
29	0.949	-0.1	9.9"	88	325°	-25°		

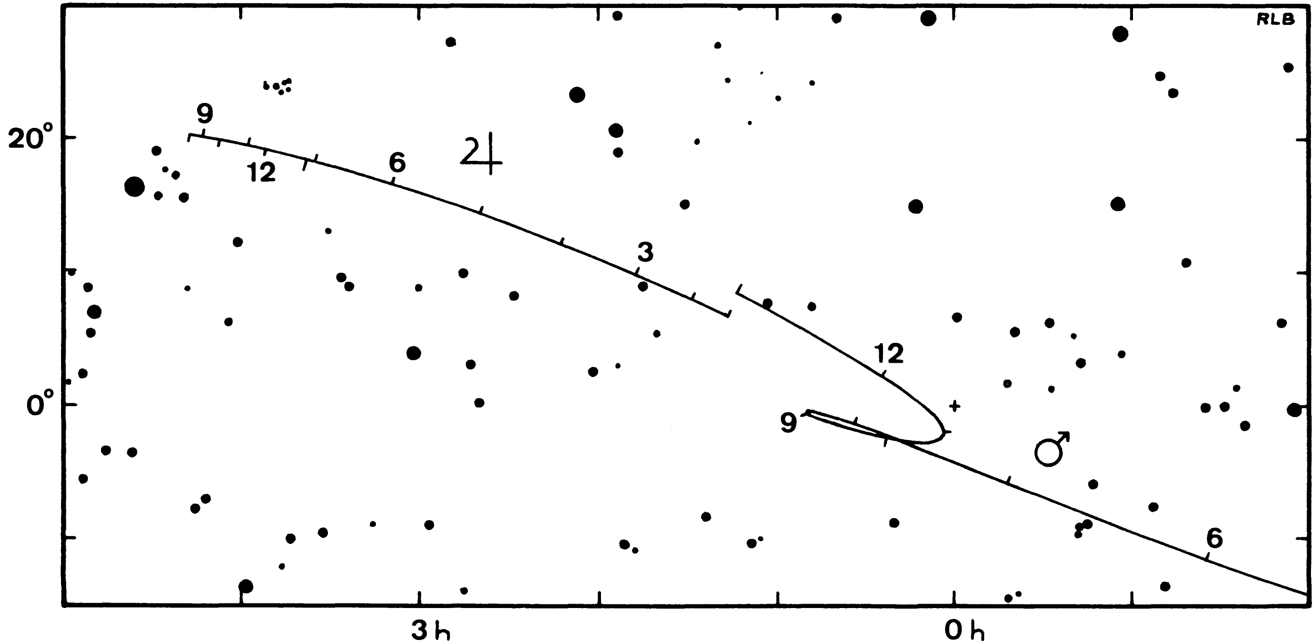
RLB

The above table gives information concerning observations of Mars during 1988. The data are given at 28-day intervals, except around opposition (September 28) when the intervals are 8-day. The columns give (1) the date; (2) the distance of Mars from Earth in astronomical units; (3) the visual magnitude of Mars; (4) its apparent equatorial angular diameter; (5) the percent of its disk illuminated; (6) the position angle of its rotation axis, measured counterclockwise from north (clockwise in telescopes having an odd number of reflections); (7) the inclination of its rotation axis to the plane of the sky, positive if its north pole is tipped toward Earth; and two quantities, (8) L(1) and (9) Δ, which can be used to calculate the longitude L of the central meridian of Mars at any moment during 1988. For a given date and time (UT) of observation, L is equal to L(1) for the nearest preceding date in the table less Δ multiplied by the number of complete days elapsed since that date. To the result, add 14.6° multiplied by the time in hours elapsed since 0ʰ UT. If the result is less than 0°, add 360°; if the result is greater than 360°, subtract 360°. The answer is accurate to better than 1°, provided the time of observation is accurate to ± 2 or 3 minutes. This value of L can then be used to orient the map on page 121 to the view of Mars seen in a telescope. (RLB)

MAP OF MARS



Latitude is plotted on the vertical axis (south at the top); longitude is plotted on the horizontal axis



The path of ***Jupiter*** *during 1988 and the path of* ***Mars*** *during the last half of the year (For planetary symbols see page 8). The tick marks indicate the positions of the planets at the beginning of the various months, with 3, 6, 9, and 12 representing March 1, June 1, September 1, and December 1, respectively. The long tick on each path marks the position at year's end.* ***Mars*** *is on its retrograde loop during September and October in the vicinity of the vernal equinox (marked with a small cross), and blazes at magnitude −2.8 when at opposition on September 28. It is then 24″ in diameter. Mars is stationary on August 26 and October 30.* ***Jupiter*** *retrogrades between the Hyades and the Pleiades during the autumn and is unmistakable at magnitude −2.9 when at opposition on November 23. It is then 49″ in equatorial diameter. It is in conjunction with the Sun on May 2, is stationary on September 24 and again on January 20, 1989. The coordinates are for 1988.5. (RLB)*

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 (U.T.) 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 U.T. 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 U.T. 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 33″ at conjunction on May 2 to 49″ at opposition on November 23.

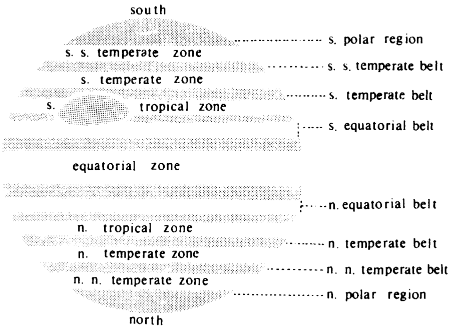
The Great Red Spot, a salmon-coloured oval vortex whose hue may possibly be due to organic-like compounds that are constantly spewed from some heated atmospheric source below, is the longest-lived structure on the visible surface of Jupiter. The spot and the changing cloud structures that stripe the 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 (1981–87 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.

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

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 — 1988

Date UT	Mag.	App. Equat. Diam.	System I		System II	
			L(1)	Δ	L(1)	Δ
Jan. 1.0	-2.5	42.0"	327.1°	157.72°	269.7°	150.09°
Feb. 1.0	-2.3	38.0"	176.4°	157.66°	242.4°	150.03°
Mar. 1.0	-2.1	35.3"	68.4°	157.64°	273.2°	150.01°
Apr. 1.0	-2.1	33.5"	275.1°	157.65°	243.4°	150.02°
May 1.0	-2.0	32.9"	324.5°	157.68°	63.8°	150.05°
June 1.0	-2.0	33.3"	172.4°	157.72°	35.2°	150.09°
P July 1.0	-2.1	34.7"	224.0°	157.78°	218.0°	150.15°
Aug. 1.0	-2.2	37.2"	75.3°	157.86°	192.7°	150.23°
Sept. 1.0	-2.4	40.7"	288.9°	157.94°	169.8°	150.31°
Oct. 1.0	-2.6	44.7"	347.3°	158.02°	359.2°	150.39°
Nov. 1.0	-2.8	48.0"	205.9°	158.04°	341.3°	150.41°
Dec. 1.0	-2.9	48.6"	267.1°	157.97°	173.6°	150.34°
Jan. 1.0	-2.7	46.0"				RLB

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 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 1988 opens, Jupiter is near the Pisces-Aries border in the western evening sky. By early April it is too close to the Sun for observation. Jupiter enters the morning sky in May and by mid-June it is a prominent dawn object in Taurus, where it remains for the rest of the year. In September it rises not long after midnight, beginning a five month period when the giant planet is well placed for telescopic viewing. Opposition occurs on November 23.

This is an excellent year for telescopic observation of the giant planet. Jupiter passed perihelion in 1987, so its opposition diameter is close to the maximum possible. Opposition declination is +19° which means that for much of the night the planet is well above seeing degradation near the horizon. Near opposition this year a telescope magnifying only 36 times will yield an image of Jupiter equal in size to the full moon seen with the naked eye. A telescope at 190× will make the Great Red Spot's major axis the same apparent diameter as the Moon to the unaided eye. At opposition Jupiter's distance is 4.034 AU (603 million km) from Earth.

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. 126.)

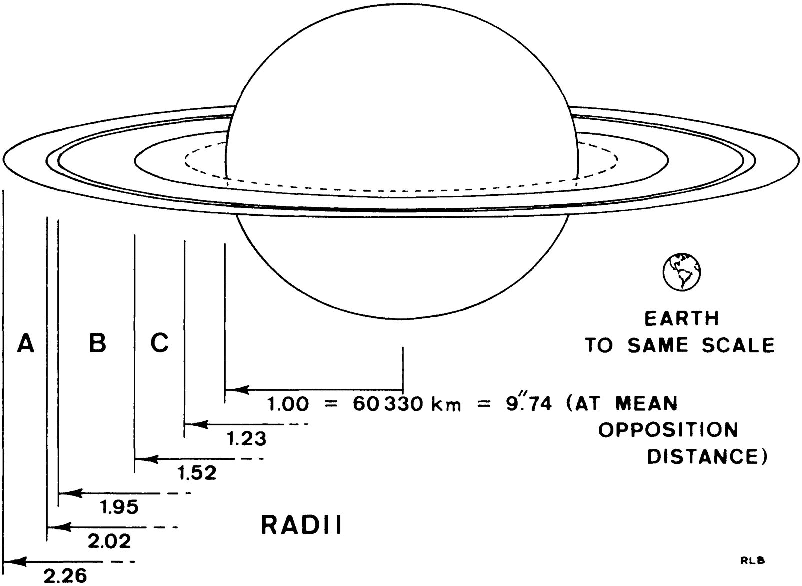
Cassini's Division, a gap between rings A and B discovered in 1675, is visible in small telescopes when the ring system is well inclined to our view. Cassini's Division is a region less densely populated with ring particles than adjacent rings. Ring B, the brightest, overpowers ring C to such an extent 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 ($10^{m}.1$) than at eastern elongation ($11^{m}.9$). One side of the moon has the reflectivity of snow while the other resembles

SATURN

MAIN RING FEATURES VISIBLE FROM EARTH



P

SATURN'S RING SYSTEM
MAIN STRUCTURAL REGIONS

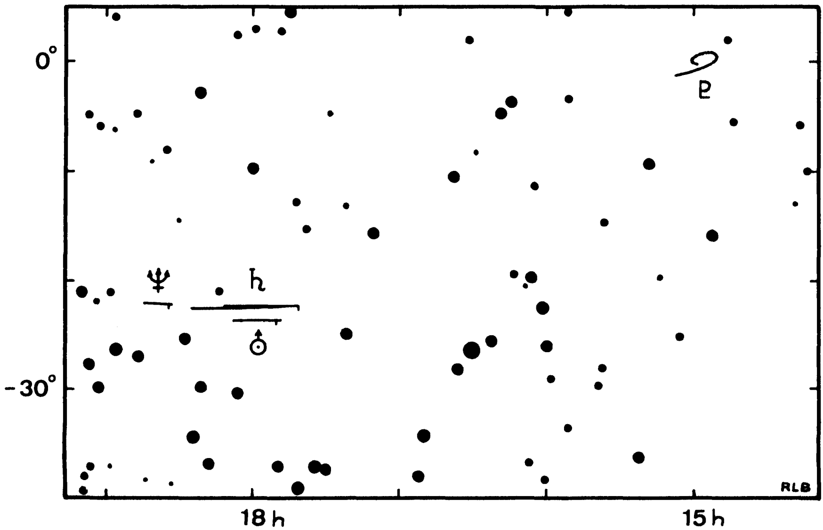
Ring	Radius**	Discoverer
D	1.11 - 1.23	Voyager 1 (1980)
C*	1.23 - 1.52	W. C. & G. P. Bond, W. R. Dawes (1850)
B*	1.52 - 1.95	Galileo (1610), C. Huygens (1659),
A*	2.02 - 2.26	G. D. Cassini (1675)
F	2.33	Pioneer 11 (1979)
G	2.8	Voyager 1 (1980)
E	3. - 8.	W. A. Feibelman (1966)

* 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).

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 144–147 for the configurations of Saturn's brightest satellites during 1988.)

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



*The paths of **Saturn, Uranus, Neptune,** and **Pluto** during 1988 (For planetary symbols see page 8, and note that larger scale charts for Uranus, Neptune and Pluto appear a few pages ahead). The coordinates are for 1988.5. For Saturn, Uranus, and Neptune, 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. The winter solstice lies between the paths of Saturn and Uranus. **Saturn** begins its retrograde loop on April 11, is at opposition on June 20, and ends retrograde motion on August 30. Saturn has a triple conjunction with Uranus this year, passing 1.3°N on February 13, 1.3°N on June 27, and 1.1°N on October 18. **Mars** moves rapidly through this part of the sky during the winter, but because it is difficult to observe and to avoid cluttering the chart, its path is not shown (the path of Mars during the last half of the year is shown on p. 122). At the New Year Mars is west of Scorpius. It passes between Saturn and Uranus in late February, being only 40″N of Uranus on the 22nd (at 20^h47^m UT) and 1.3°S of Saturn 16^h later—an unusual close grouping of three planets. Moreover, the conjunction with Uranus is the closest of any planetary conjunction for several years (unfortunately, the point of closest approach will not be visible from the Western Hemisphere). Mars passes 1.4°S of Neptune on March 7. (RLB)* 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 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. However, the tilt of Saturn's orbit to the ecliptic results in a greater inclination of the rings toward Earth this year (26.94° in late September) than in 1987 (26.90° in late November). 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 1988. 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 June 20 the planet is 9.028 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 26.2° and 26.9° with respect to Earth, with the north face being visible. Saturn becomes lost in the evening twilight in late-November, and is in conjunction with the Sun on December 26.

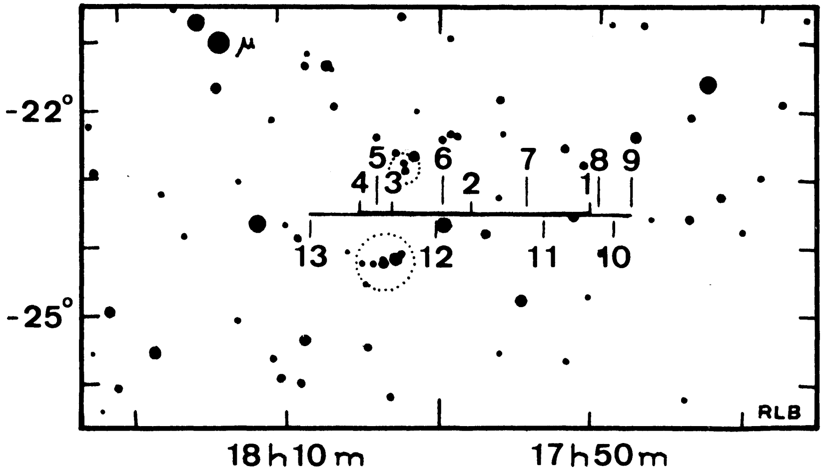
URANUS

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 (see p.12); Uranus' nine, main, slender, dark rings were confirmed, and numerous diffuse bands of dust within the ring system were discovered. For detailed popular accounts of the Uranian findings, see *National Geographic,* August 1986; *Scientific American*, January, April, and July 1987.

Uranus is in Sagittarius in 1988. When at opposition on June 20, the planet is 18.26 AU (2.73 billion km) from Earth. Its magnitude is then +5.5 and its apparent diameter is 3.84 seconds of arc.



*The path of **Uranus** in Sagittarius during 1988 (note also the wide-field chart on page 127). 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 20 when Uranus is 2.53 light-hours (18.26 AU) from Earth. This is a particularly interesting year to observe Uranus in large binoculars and rich-field telescopes since it passes between the Lagoon (M8) and Trifid (M20) nebulae (indicated by the lower and upper dotted circles, respectively, on the chart). In addition, Saturn makes three passes about 1.3° north of Uranus (on February 13, June 27, and October 18). Also, at 20^h47^m UT on February 22, Mars passes only 40" north, an unusually close planetary conjunction. Unfortunately the point of closest approach will not be visible from the Western Hemisphere. (RLB)*

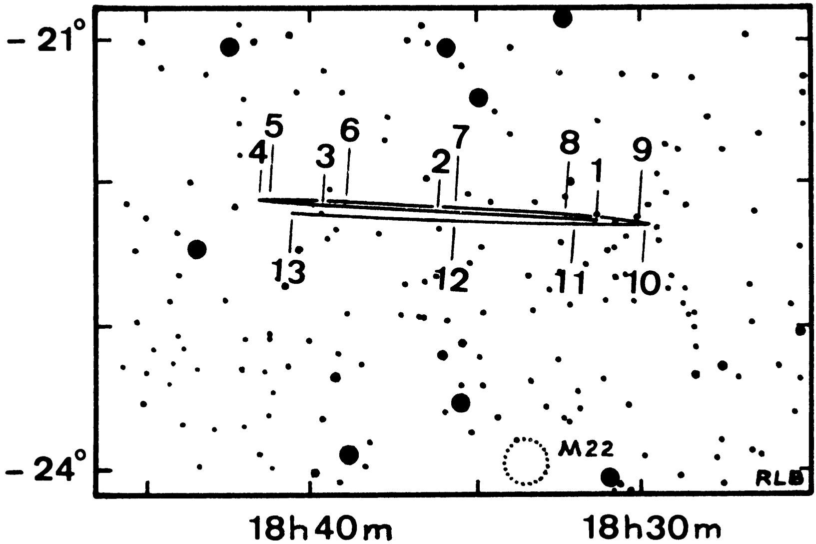
NEPTUNE

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".

In telescopes 100mm aperture and larger, the planet appears as a very small, featureless, bluish-green disk. 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.

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 1989.

In 1988 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 June 30 Neptune is magnitude +7.9, 29.21 AU (4.37 billion km) distant from Earth, and 2".3 in diameter.



*The path of **Neptune** in Sagittarius, 1988 (note also the wide-field chart on page 127). 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 June 30 when Neptune is 4.05 light-hours (29.21 AU) from Earth, the most distant planet at the present time. The dotted circle is the spectacular globular cluster M22 which serves as a convenient starting point for locating Neptune (M22 appears on the July map of the night sky at the end of this handbook as the small cluster of dots next to the Sun's position on January 1). On March 7, Mars passes 1.4°S of Neptune. (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.

At opposition on May 1, Pluto is located in eastern Virgo (see chart) and its distance from Earth will be 28.70 AU (4.29 billion km). With an apparent magnitude of +13.7, Pluto is a difficult target in telescopes below 250 mm aperture.

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. Although popular among amateur astronomers until the early 1960s, so-called scientific observation of the planets is virtually an extinct branch of modern amateur astronomy. However, aesthetic planetary observing has continued to gain adherents in recent years. A reference with that focus has yet to appear, but observers might find the following of some interest.

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.

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

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 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.]

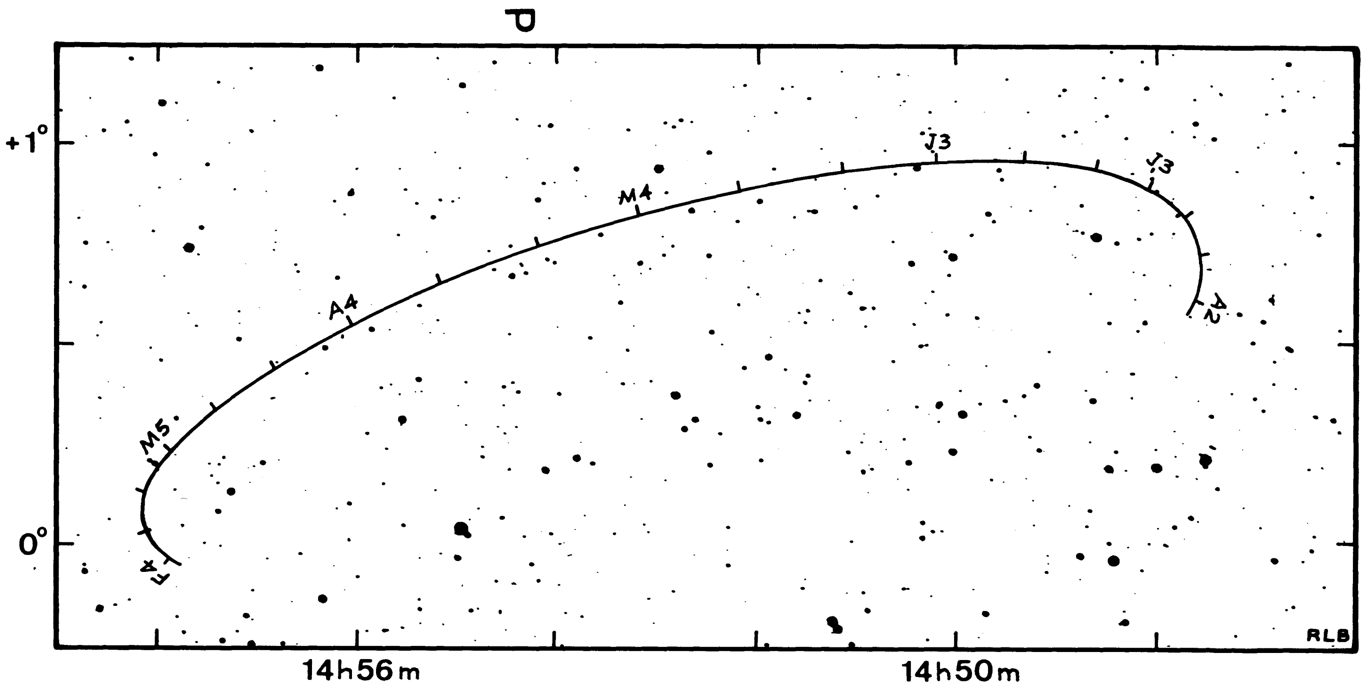
Hartmann, William K., 1983, *Moons and Planets*, second edition, Wadsworth, Belmont, Calif. [A comprehensive descriptive text devoted to the surfaces, interiors and atmospheres of the planets and their satellites.]

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.]

Muirden, Paul, 1983, *The Amateur Astronomer's Handbook*, Third Edition, Harper & Row, New York. [Several chapters on the planets and observing them.]

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.]



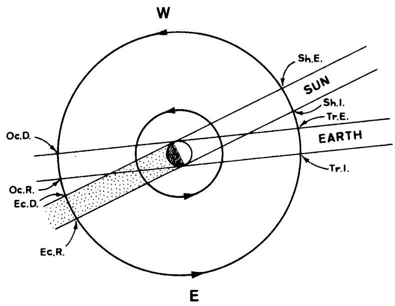
The path of ***Pluto*** *in eastern Virgo during the six months centred on opposition, 1988. Its position is marked at 10-day intervals, beginning at February 4 (F4). The bright (magnitude 8) star just northwest of "M4" may be used to locate the star field shown here. This star is 2.6° at a position angle of 117° from the star 109 Vir (109 Vir appears at α = 14h 44m and 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 127 where 109 Vir is shown immediately northwest of Pluto's path). Pluto reaches opposition on May 1 at magnitude 13.7 and 3.98 light-hours from Earth. It is then closer to Earth than it has ever been since its discovery, and is 0.5 AU closer than 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. All such phenomena are given except when Jupiter is within a few weeks of conjunction (May 2, 1988). 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 November 28 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 November 29, 5 h to 9 h UT. He would find four events, at 2150, 2159, 2358 and 0009 PST, all involving the satellite Io.

SATELLITES OF JUPITER, 1988

UNIVERSAL TIME OF GEOCENTRIC PHENOMENA

JANUARY

d	h	m	Phenomenon
0	9	58	II. Oc.D.
	12	24	II. Oc.R.
	12	43	II. Ec.D.
	13	40	I. Oc.D.
	15	04	II. Ec.R.
	17	10	I. Ec.R.
1	10	52	I. Tr.I.
	12	12	I. Sh.I
	13	03	I. Tr.E.
	14	22	I. Sh.E.
	22	03	III. Oc.D.
2	0	37	III. Oc.R.
	3	34	III. Ec.D.
	4	54	II. Tr.I.
	5	53	III. Ec.R.
	7	17	II. Tr.E.
	7	33	II. Sh.I.
	8	09	I. Oc.D.
	9	51	II. Sh.E.
	11	39	I. Ec.R.
3	5	21	I. Tr.I.
	6	41	I. Sh.I.
	7	32	I. Tr.E.
	8	51	I. Sh.E
	23	15	II. Oc.D.
4	1	42	II. Oc.R.
	2	03	II. Ec.D.
	2	37	I. Oc.D.
	4	23	II. Ec.R.
	6	08	I. Ec.R.
	23	50	I. Tr.I
5	1	10	I. Sh.I.
	2	01	I. Tr.E.
	3	20	I. Sh.E.
	12	06	III. Tr.I.
	14	39	III. Tr.E.
	17	39	III. Sh.I.
	18	11	II. Tr.I.
	19	55	III. Sh.E.
	20	34	II. Tr.E.
	20	51	II. Sh.I.
	21	06	I. Oc.D.
	23	09	II. Sh.E.
6	0	37	I. Ec.R.
	18	19	I. Tr.I.
	19	39	I. Sh.I.
	20	29	I. Tr.E.
	21	49	I. Sh.E.
7	12	34	II. Oc.D.
	15	01	II. Oc.R.
	15	23	II. Ec.D.
	15	35	I. Oc.D.
	17	43	II. Ec.R.
	19	06	I. Ec.R.

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

d	h	m	Phenomenon
16	10	04	II. Tr.I.
	11	38	III. Ec.D.
	11	59	I. Oc.D.
	12	28	II. Tr.E.
	12	45	II. Sh.I.
	13	55	III. Ec.R.
	15	03	II. Sh.E.
	15	30	I. Ec.R.
17	9	13	I. Tr.I.
	10	33	I. Sh.I.
	11	23	I. Tr.E.
	12	43	I. Sh.E
18	4	33	II. Oc.D.
	6	28	I. Oc.D.
	7	00	II. Oc.R.
	7	21	II. Ec.D.
	9	41	II. Ec.R.
	9	59	I. Ec.R.
19	3	42	I. Tr.I.
	5	02	I. Sh.I.
	5	53	I. Tr.E.
	7	12	I. Sh.E.
	20	12	III. Tr.I.
	22	46	III. Tr.E.
	23	23	II. Tr.I
20	0	57	I. Oc.D.
	1	46	III. Sh.I
	1	47	II. Tr.E.
	2	04	II. Sh.I.
	4	00	III. Sh.E.
	4	21	II. Sh.E.
	4	27	I. Ec.R.
	22	11	I. Tr.I.
	23	31	I. Sh.I
21	0	22	I. Tr.E.
	1	41	I. Sh.E.
	17	54	II. Oc.D.
	19	26	I. Oc.D.
	20	21	II. Oc.R.
	20	41	II. Ec.D.
	22	56	I. Ec.R.
	23	01	II. Ec.R.
22	16	40	I. Tr.I.
	18	00	I. Sh.I
	18	51	I. Tr.E.
	20	10	I. Sh.E.
23	10	07	III. Oc.D.
	12	43	II. Tr.I.
	12	45	III. Oc.R.
	13	55	I. Oc.D.
	15	06	II. Tr.E.
	15	22	II. Sh.I.
	15	41	III. Ec.D.
	17	25	I. Ec.R.
	17	39	II. Sh.E.

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

SATELLITES OF JUPITER, 1988

UNIVERSAL TIME OF GEOCENTRIC PHENOMENA

FEBRUARY

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

SATELLITES OF JUPITER, 1988

UNIVERSAL TIME OF GEOCENTRIC PHENOMENA

MARCH

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

SATELLITES OF JUPITER, 1988

UNIVERSAL TIME OF GEOCENTRIC PHENOMENA

JUNE

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

SATELLITES OF JUPITER, 1988

UNIVERSAL TIME OF GEOCENTRIC PHENOMENA

JULY

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

SATELLITES OF JUPITER, 1988

UNIVERSAL TIME OF GEOCENTRIC PHENOMENA

AUGUST

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

SATELLITES OF JUPITER, 1988

UNIVERSAL TIME OF GEOCENTRIC PHENOMENA

SEPTEMBER

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

SATELLITES OF JUPITER, 1988

UNIVERSAL TIME OF GEOCENTRIC PHENOMENA

OCTOBER

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

SATELLITES OF JUPITER, 1988

UNIVERSAL TIME OF GEOCENTRIC PHENOMENA

NOVEMBER

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

SATELLITES OF JUPITER, 1988

UNIVERSAL TIME OF GEOCENTRIC PHENOMENA

DECEMBER

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

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, 1988. 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 1988 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 of Dione, the second out from Saturn, is dashed so that it is easy to distinguish from those of 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.

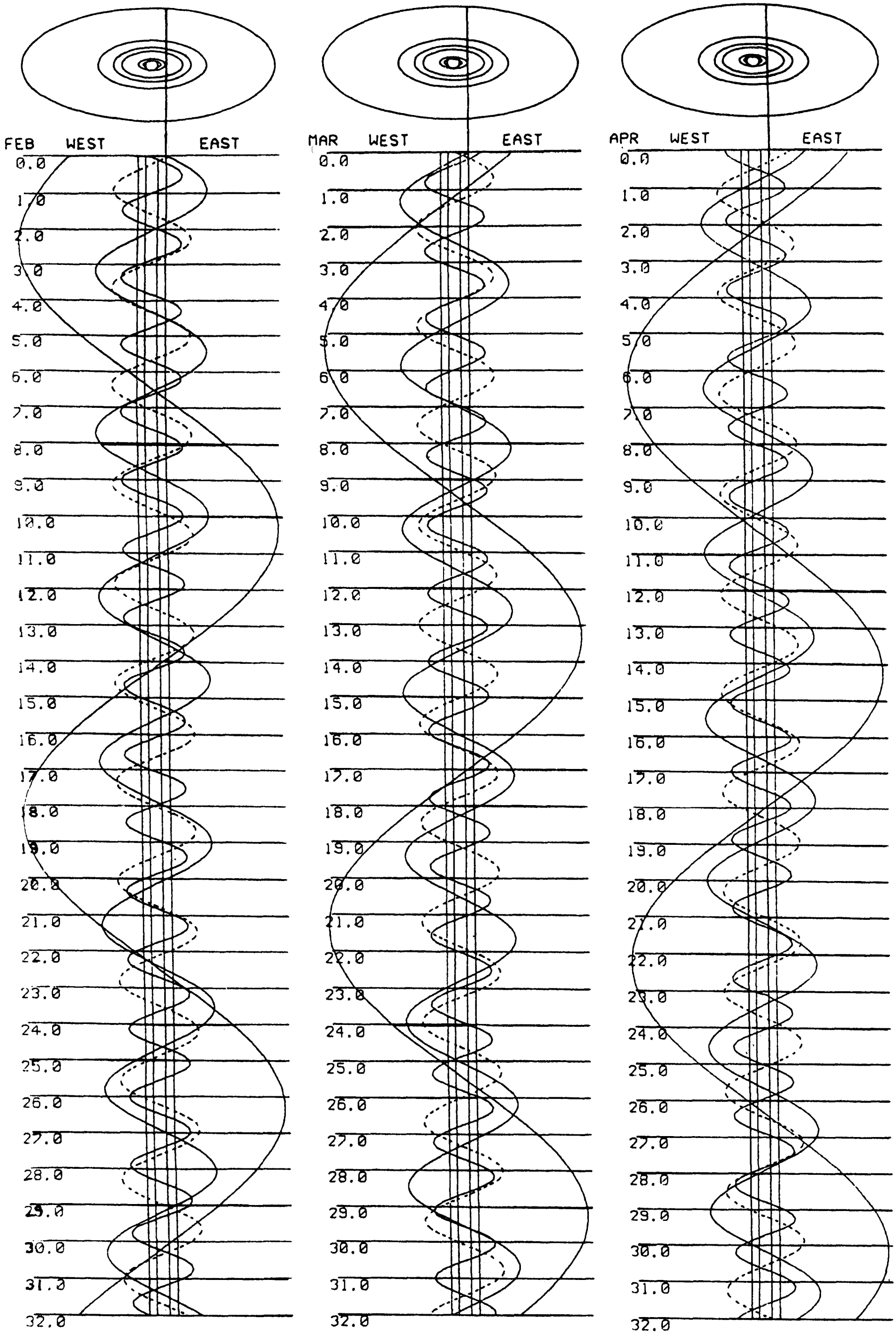
At the beginning of each month is a scale drawing of Saturn with the orbits of the four satellites tilted as seen through an inverting telescope (in the Northern Hemisphere). South is up. The axis of Saturn is now tipped toward Earth so that we see the northern side of the rings and satellite orbits. 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 1988 (UT)

Eastern Elong.	Inferior Conj.	Western Elong.	Superior Conj.
		Jan. 12 12.5h	Feb. 02 16.4h
Feb. 22 06.1h	Mar. 12 13.4h	Apr. 2 4.3h	Apr. 22 18.5h
May 11 19.6h	May 30 15.3h	June 19 18.3h	July 10 1.9h
July 29 2.2h	Aug. 16 22.9h	Sept. 6 7.7h	Sept.27 3.2h
Oct. 16 15.2h	Nov. 5 0.1h	Nov. 25 22.7h	Dec. 17 2.3h


FEB WEST EAST
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
13.0
14.0
15.0
16.0
17.0
18.0
19.0
20.0
21.0
22.0
23.0
24.0
25.0
26.0
27.0
28.0
29.0
30.0
31.0
32.0
MAR WEST EAST
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
13.0
14.0
15.0
16.0
17.0
18.0
19.0
20.0
21.0
22.0
23.0
24.0
25.0
26.0
27.0
28.0
29.0
30.0
31.0
32.0
APR WEST EAST
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
13.0
14.0
15.0
16.0
17.0
18.0
19.0
20.0
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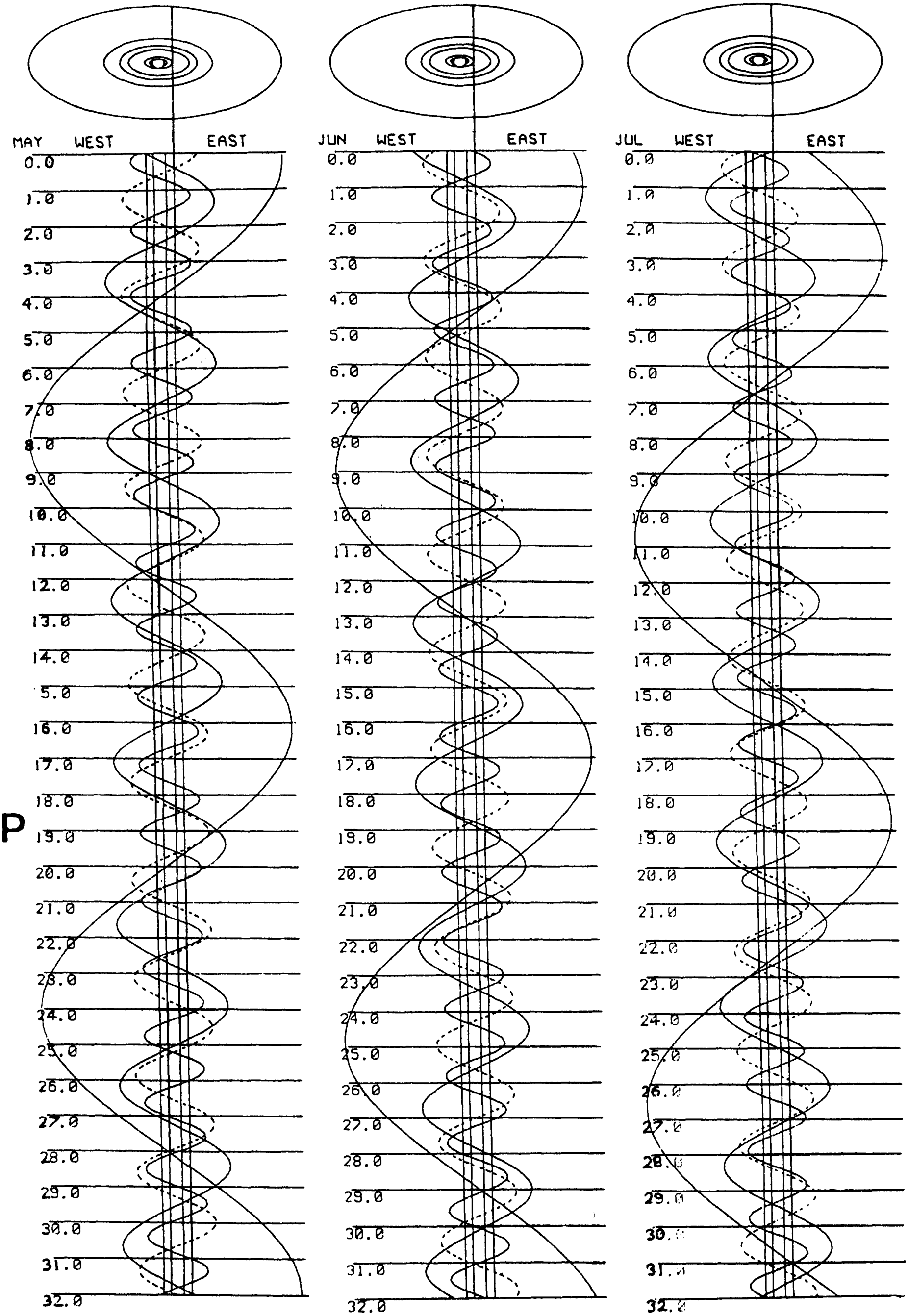
30.0
31.0
32.0


MAY
WEST
EAST
JUN
WEST
EAST
JUL
WEST
EAST
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1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
13.0
14.0
15.0
16.0
17.0
18.0
19.0
20.0
21.0
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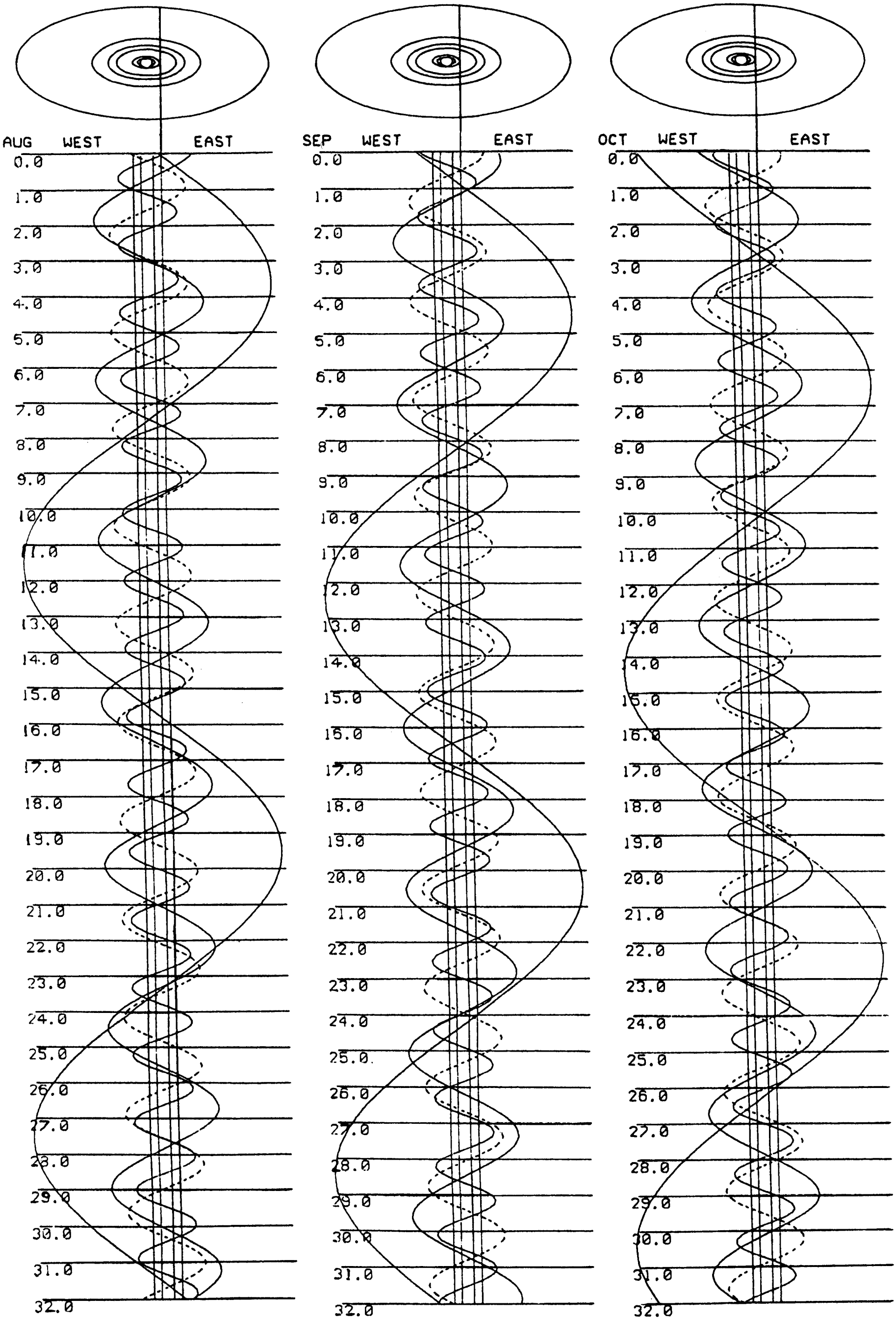
29.0
30.0
31.0
32.0

P

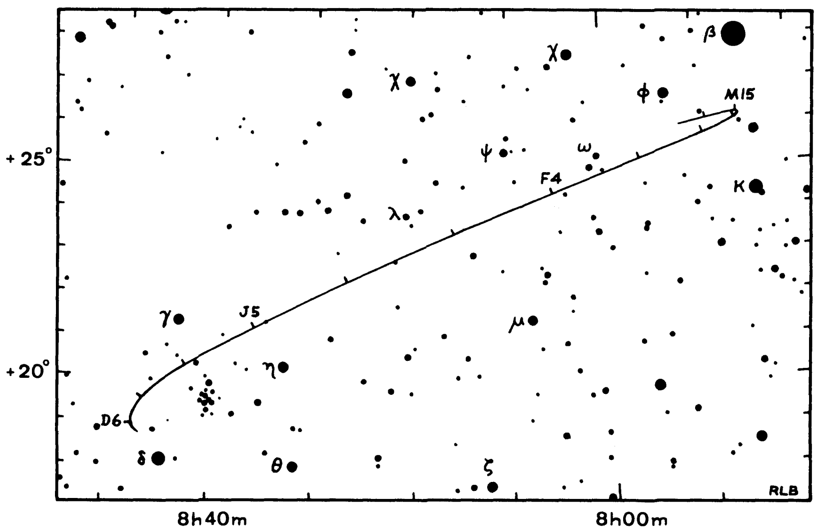

AUG WEST EAST
SEP WEST EAST
OCT WEST EAST
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
13.0
14.0
15.0
16.0
17.0
18.0
19.0
20.0
21.0
22.0
23.0
24.0
25.0
26.0
27.0
28.0
29.0
30.0
31.0
32.0

EPHEMERIDES FOR THE BRIGHTEST ASTEROIDS 1988

PROVIDED BY BRIAN G. MARSDEN

The following are the ephemerides for the brightest asteroids in 1988: 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 E.T. (which differs only slightly from U.T.), the right ascension and declination for the epoch 1950 (for convenience in plotting on commonly-used star charts) 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.

A map is provided for Vesta. Readers can make maps for other asteroids by using the ephemerides on the next two pages 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 17.)



*The path of **Vesta** in Cancer and Gemini during December of 1987 and the first three months of 1988. Vesta's position is marked at 10-day intervals, beginning with December 6, 1987 (D6). The chart magnitude limit is 8.0 and the coordinates are for 2000.0 Vesta passes through the northern edge of "the Beehive" open star cluster in late December, and is stationary about 2° south of Pollux on March 10. Vesta brightens from visual magnitude 7.6 to 6.9 during December, and to 6.2 when at opposition on January 22, 1.51 AU from Earth. It may then just be visible to the unaided eye, assuming good vision and dark, transparent skies. By late March it has faded to magnitude 7.5. With a diameter of 540 km, Vesta is the third largest asteroid after Ceres and Pallas. However, it has an unusually high albedo (~23%) and a smaller orbit than the two larger asteroids; thus when near opposition, Vesta is the brightest asteroid. (RLB)*

(1) Ceres

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
June 28	$0^h14^m.3$	$-11°05'$	8.9
July 8	0 20.1	-11 12	
18	0 24.2	-11 31	8.6
28	0 26.2	-12 05	
Aug. 7	0 26.1	-12 51	8.3
17	0 23.7	-13 48	
27	0 19.1	-14 51	7.9
Sept. 6	0 12.6	-15 55	
16	0 04.8	-16 53	7.6
26	23 56.4	-17 38	
Oct. 6	23 48.3	-18 06	7.8
16	23 41.4	-18 13	
26	23 36.3	-18 00	8.2
Nov. 5	23 33.4	-17 29	
15	23 32.8	-16 42	8.5
25	23 34.4	-15 41	
Dec. 5	23 38.1	-14 30	8.8
15	23 43.6	-13 09	

(2) Pallas

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
June 8	$20^h46^m.1$	$+17°16'$	10.0
18	20 43.3	+17 52	
28	20 38.7	+18 10	9.7
July 8	20 32.6	+18 07	
18	20 25.3	+17 39	9.5
28	20 17.4	+16 45	
Aug. 7	20 09.6	+15 27	9.5
17	20 02.6	+13 50	
27	19 56.8	+11 57	9.6
Sept. 6	19 52.8	+ 9 57	
16	19 50.8	+ 7 54	9.8
26	19 50.9	+ 5 56	
Oct. 6	19 52.9	+ 4 06	10.0
16	19 56.8	+ 2 26	

(3) Juno

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Dec. 5	$10^h20^m.8$	$+ 0°15'$	9.6
15	10 27.3	- 0 23	
25	10 31.5	- 0 43	9.4

(4) Vesta

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Jan. 10	$8^h28^m.3$	$+22°06'$	
20	8 18.2	+23 12	6.2
30	8 07.4	+24 14	
Feb. 9	7 57.4	+25 05	6.5
19	7 49.4	+25 43	
29	7 44.3	+26 07	6.9
Mar. 10	7 42.5	+26 19	
20	7 44.0	+26 19	7.3
30	7 48.5	+26 10	
Apr. 9	7 55.7	+25 52	7.6
19	8 05.1	+25 25	

(6) Hebe

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Nov. 15	$8^h45^m.3$	$+ 8°05'$	10.0
25	8 50.5	+ 7 53	
Dec. 5	8 52.9	+ 7 56	9.7
15	8 52.4	+ 8 19	
25	8 48.8	+ 9 03	9.3

(7) Iris

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Nov. 15	$9^h33^m.2$	$+10°47'$	9.6
25	9 42.6	+ 9 24	
Dec. 5	9 49.5	+ 8 10	9.4
15	9 53.5	+ 7 08	
25	9 54.3	+ 6 21	9.1

(9) Metis

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Apr. 9	$14^h29^m.3$	$- 8°57'$	9.9
19	14 20.0	- 8 22	
29	14 10.1	- 7 48	9.7
May 9	14 00.7	- 7 21	

(10) Hygiea

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Feb. 9	$10^h32^m.7$	$+ 4°39'$	9.9
19	10 25.3	+ 5 10	
29	10 17.4	+ 5 48	9.6
Mar. 10	10 09.8	+ 6 27	
20	10 03.3	+ 7 03	10.0
30	9 58.6	+ 7 33	

(11) Parthenope

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Apr. 9	$13^h25^m.2$	$- 1°04'$	9.9
19	13 16.2	- 0 05	

(14) Irene

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Feb. 9	$12^h17^m.4$	$+13°53'$	9.6
19	12 15.7	+15 08	
29	12 10.9	+16 30	9.1
Mar. 10	12 03.8	+17 45	
20	11 55.3	+18 44	8.9
30	11 46.9	+19 17	
Apr. 9	11 40.0	+19 19	9.3
19	11 35.4	+18 51	
29	11 33.8	+17 56	9.8
May 9	11 35.1	+16 40	

(15) Eunomia

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Apr. 29	$15^h 23^m.7$	−34° 12′	9.8
May 9	15 14.1	−33 40	
19	15 04.2	−32 51	9.7
29	14 55.0	−31 50	
June 8	14 47.5	−30 42	9.9
18	14 42.2	−29 33	

(18) Melpomene

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
June 28	$22^h 45^m.8$	− 3° 19′	9.8
July 8	22 53.8	− 3 13	
18	22 59.6	− 3 33	9.2
28	23 02.6	− 4 22	
Aug. 7	23 02.8	− 5 43	8.6
17	23 00.0	− 7 35	
27	22 54.9	− 9 50	7.9
Sept. 6	22 48.5	−12 14	
16	22 42.1	−14 29	8.0
26	22 37.3	−16 20	
Oct. 6	22 35.3	−17 37	8.5
16	22 36.7	−18 17	
26	22 41.6	−18 22	9.0
Nov. 5	22 49.7	−17 55	
15	23 00.6	−17 02	9.5
25	23 13.8	−15 46	
Dec. 5	23 28.8	−14 12	9.8
15	23 45.3	−12 22	

(20) Massalia

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Jan. 10	$4^h 03^m.0$	+19° 45′	
20	4 04.1	+19 49	9.7
30	4 08.7	+20 04	

(21) Lutetia

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
June 8	$16^h 27^m.7$	−20° 58′	10.0
18	16 18.0	−20 52	

(28) Bellona

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Feb. 9	$9^h 08^m.7$	+14° 18′	9.9
19	9 00.9	+15 43	

(29) Amphitrite

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Jan. 10	$7^h 45^m.7$	+30° 38′	
20	7 34.4	+30 48	9.0
30	7 24.0	+30 43	
Feb. 9	7 15.9	+30 24	9.5
19	7 10.8	+29 55	
29	7 09.3	+29 18	9.9
Mar. 10	7 11.0	+28 38	

(43) Ariadne

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
May 19	$16^h 25^m.6$	−24° 27′	9.5
29	16 16.0	−23 37	
June 8	16 06.5	−22 40	9.5
18	15 58.9	−21 44	
28	15 54.4	−20 57	10.0
July 8	15 53.8	−20 23	

(44) Nysa

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Jan. 10	$4^h 14^m.0$	+16° 39′	
20	4 13.7	+17 09	10.0
30	4 17.0	+17 49	

(63) Ausonia

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Aug. 7	$21^h 58^m.2$	−15° 45′	10.0
17	21 48.0	−16 02	
27	21 38.0	−16 13	10.0
Sept. 6	21 29.5	−16 16	

(89) Julia

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
June 28	$17^h 44^m.4$	−41° 18′	9.9
July 8	17 32.9	−40 01	

(532) Herculina

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
July 18	$21^h 00^m.9$	−25° 01′	10.0
28	20 52.5	−26 24	
Aug. 7	20 43.5	−27 38	10.0
17	20 35.1	−28 39	

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 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 the 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 on the next page gives the circumstances for six asteroid occultations predicted to be observable from North America or Hawaii in 1988. The predictions were taken from a paper by L. H. Wasserman, E. Bowell, and R. L. Millis at Lowell Observatory that has been submitted for publication in the *Astronomical Journal*. In addition to the asteroid occultation predictions, data for an important occultation of a star by Pluto are given in the table. This occultation was discovered by D. J. Mink and A. R. Klemola. It is described more completely in their original paper (*Astronomical Journal* **90**, 1894, 1985) and in a subsequent paper by Bosh *et al.* (*Icarus* **66**, 556, 1986) from which the Pluto data listed in the table were taken.

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 be 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 301-585-0989 (Silver Spring, Md.)). Individuals interested in joining IOTA should see p. 92 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, Route 13, Box 109, London, KY 40741, 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).

UT Date 1988	Occulting body	m_p (mag)	Star	m_s (mag)	α (1950)	δ (1950)	ΔI	Max. Dur. (s)	Approximate Area of Visibility
13.02 Feb	654 Zelinda	11.9*	AG+15°0511	8.2*	$5^h38^m42^s.5$	+15°11′ 25″	0.97	11	N.E. Canada
27.12 Feb	209 Dido	13.3*	AG+11°1262	10.3*	10 49 9.1	+11 43 47	0.94	10	Canada, N. USA
9.42 Jun	Pluto	13.9	P8	12.3	14 49 36.9	+0 57 19	0.81	168	W. USA (?)
27.52 Jun	804 Hispania	11.5	SAO 229997	9.5	19 58 17.3	−43 4 50	0.87	21	Hawaii
12.12 Aug	63 Ausonia	9.8	SAO 164745	9.0	21 53 0.4	−15 54 7	0.68	11	S. USA
13.34 Oct	626 Notburga	12.9*	AG+58°0402	8.6*	4 13 27.1	+58 59 10	0.98	8	Central USA, Canada
11.26 Dec	690 Wratislavia	12.8*	AG+16°0692	9.7*	6 49 28.5	+16 48 21	0.95	15	Mexico (?)

*Asterisks indicate blue magnitudes; others are visual.

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 1988

Shower	Shower Maximum			Radiant				Single Observer Hourly Rate	Speed of Encounter with Earth	Normal Duration to ¼ Strength of Max.
				Position at Max.		Daily Motion				
	Date	U.T.	Moon	R.A.	Dec.	R.A.	Dec.			
	(1988)	h		h m	°	m	°		km/s	days
Quadrantids	Jan. 4	04	FM	15 28	+50	—	—	40	41	1.1
Lyrids	Apr. 22	03	FQ	18 16	+34	+4.4	0.0	15	48	2
η Aquarids	May 4	06	FM	22 24	00	+3.6	+0.4	20	65	3
S. δ Aquarids	July 28	09	FM	22 36	−17	+3.4	+0.17	20	41	7
Perseids	Aug. 12	00	NM	03 04	+58	+5.4	+0.12	50	60	4.6
Orionids	Oct. 21	04	FQ	06 20	+15	+4.9	+0.13	25	66	2
S. Taurids	Nov. 2	05	LQ	03 32	+14	+2.7	+0.13	15	28	—
Leonids	Nov. 17	10	FQ	10 08	+22	+2.8	−0.42	15	71	—
Geminids	Dec. 14	00	FQ	07 32	+32	+4.2	−0.07	50	35	2.6
Ursids	Dec. 22	06	FM	14 28	+76	—	—	15	34	2
	(1989)									
Quadrantids	Jan. 3	10	NM	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 1988

By Brian G. Marsden

The following periodic comets are expected at perihelion during 1988:

Comet	Perihelion Date	Perihelion Dist.	Period
		AU	a
Reinmuth 1	May 9	1.87	7.3
Finlay	June 6	1.09	7.0
Tempel 2	Sept. 16	1.38	5.3
Longmore	Oct. 12	2.41	7.0
du Toit	Dec. 25	1.27	14.7

After 1987's record crop, the number of comets due at perihelion is small. P/Tempel 2, recovered early in 1987, is making a particularly favourable return in 1988, and an ephemeris is given below, together with a short continuation of the ephemeris of P/Borrelly, the brightest periodic comet of 1987. None of the other four 1988 returns is very favourable, particularly that of P/Finlay. These comets will be faint, although they should all be detectable at some time in the year with large telescopes.

COMET BORRELLY

0h E.T.	R.A. (1950)	Dec. (1950)	Mag.
Jan. 10	$2^h 31^m.5$	+27°46′	
20	2 45.0	+35 06	10.5

COMET TEMPEL 2

0h E.T.	R.A. (1950)	Dec. (1950)	Mag.
June 28	$15^h 24^m.6$	+ 0°07′	10.6
July 8	15 23.6	- 2 33	
18	15 27.4	- 5 44	10.2
28	15 35.9	- 9 14	
Aug. 7	15 49.3	-12 56	10.0
17	16 07.3	-16 40	
27	16 29.8	-20 18	9.9
Sept. 6	16 56.7	-23 38	
16	17 27.4	-26 30	10.0
26	18 01.6	-28 45	
Oct. 6	18 38.2	-30 14	10.3
16	19 16.3	-30 52	
26	19 54.5	-30 40	10.8

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

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

Key to pronunciation on p. 161.

THE BRIGHTEST STARS

By Robert F. Garrison

The 314 stars brighter than apparent magnitude 3.55

The table has been printed camera-ready on an Imagen Laser Printer, so updates can be made yearly. 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.

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. 1988.5	Dec	V	B−V	MK Type	π(")	M(V)	D(ly)	μ(")	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	Manganese star Alpheratz
β Cas	00 08.6	+59 05	2.3v	0.34	F2 III	0.072	2.0	37	0.555	+11 SB	var:2.25−2.31,0.10d Caph
γ Peg	00 12.6	+15 07	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 25.7	−42 22	2.39	1.09	K0 IIIb	0.039	0.7	62	0.442	+75 SB	Ankaa
δ And A	00 38.7	+30 48	3.27	1.28	K3 III	0.028	−0.3	170	0.161	−7 SB	
α Cas	00 39.8	+56 28	2.23	1.17	K0 IIIa	0.016	−0.8	110	0.058	−4 V?	Shedir
β Cet	00 43.0	−18 03	2.04	1.02	K0 III	0.061	0.3	53	0.234	+13	Diphda
η Cas A	00 48.4	+57 45	3.44	0.57	G0 V	0.176	4.7	18	1.218	+9 SB	B: 7.51, K4 Ve, 12"
γ Cas	00 56.0	+60 39	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 47	3.31	0.89	G8 III	0.021	0.3	130	0.030	−1	AB similar in light, spectrum, 1"
η Cet	01 08.0	−10 15	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. 1988.5 Dec		V	B−V	MK Type	π(")	M(V)	D(ly)	μ(")	RV(km/s)	Remarks
γ Phe	01 27.9	−43 23	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 18	0.46	−0.16	B3 Vnp (shell)	0.026	−1.3	69	0.108	+16 V	**Achernar**
τ Cet	01 43.5	−16 00	3.50	0.72	G8 V	0.287	5.8	11	1.921	−16	
α Tri	01 52.4	+29 31	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 54.0	+20 45	2.64	0.13	A5 V	0.074	1.8	44	0.145	−2 SB	Sharatan
α Hyi	01 58.4	−61 38	2.86	0.28	F0 III−IVn	0.048	1.7	55	0.271	+1 V	
γ And A	02 03.2	+42 16	2.26	1.37	K3 IIb	0.013	1.8	42	0.066	−12 SB	B:5.4,B9V,10";C:6.2,A0V;BC1" Almaak
α Ari	02 06.5	+23 24	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 19.8	+89 13	2.0v	0.60	F5−8 Ib	0.007	−5.1	820	0.046	−17 SB	Cep1.9−2.1,4d;B:8.2,F3V,18" Polaris
γ Cet AB	02 42.7	+ 3 11	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 57.8	−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 04.4	+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 07.4	+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 23.5	+49 49	1.79	0.48	F5 Ib	0.016	−5.1	630	0.033	−2 V	in cluster Mirphak
δ Per	03 42.1	+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 46.8	+24 04	2.87	−0.09	B7 IIIn	0.008	−1.5	230	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 53.4	+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 33	2.95	1.59	M1 IIIb	0.010	−0.7	170	0.124	+62	Calcium, Chromium weak Zaurak
λ Tau A	04 00.0	+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 14.4	−62 30	3.35	0.91	G8 II−III	0.013	−0.9	230	0.068	+36 SB?	
ϵ Tau	04 27.9	+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. 1988.5	Dec	V	B−V	MK Type	$\pi('')$	M(V)	D(ly)	$\mu('')$	RV(km/s)	Remarks
α Dor AB	04 33.7	−55 04	3.27	−0.10	A0p III:(Si)	0.018	0.0	190	0.051	+26	A: 3.8; B: 4.3, B9 IV, 0.2"
α Tau A	04 35.4	+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 49.2	+ 6 57	3.19	0.45	F6 V	0.137	3.9	24	0.463	+24 SB2	Hassaleh
ι Aur	04 56.2	+33 09	2.69	1.53	K3 II	0.021	−2.0	240	0.018	+18	var?
ϵ Aur A	05 01.1	+43 48	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 05.7	+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 12.4	−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 24.5	+ 6 20	1.64	−0.22	B2 III	0.029	−3.9	(1400)	0.018	+18 SB?	Bellatrix
β Tau	05 25.6	+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 31.4	− 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 32.2	−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 34.5	+ 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,B7IIIp(He wk),11" Nair al Saif
ϵ Ori	05 35.6	− 1 13	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 39.2	−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 46.4	−14 50	3.55	0.10	A2 IVn	0.049	1.0	97	0.023	+20 SB?	
κ Ori	05 47.2	− 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 54.5	+ 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 58.7	+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 58.9	+37 13	2.62	−0.08	A0p III:(Si)	0.022	0.0	110	0.097	+30 SB	B: 7.2, G2 V, 4"

Star Name	R.A. 1988.5 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 37.0	+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 43.2	+25 09	2.98	1.40	G8 Ib	0.017	−1.2	940	0.016	+10 SB		Mebsuta
ξ Gem	06 44.6	+12 55	3.36	0.43	F5 IV	0.055	−4.0	59	0.224	+25 V?		Alzirr
α CMa A	06 44.6	−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 49.6	−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 02.5	−23 49	3.02	−0.08	B3 Ia	— —	−6.3	2200	0.007	+48 SB		
δ CMa	07 07.9	−26 22	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 16.7	−37 05	2.70	1.62	K3 Ib	0.032	−4.0	570	0.012	+16		
δ Gem AB	07 19.4	+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 23.6	−29 17	2.45	−0.08	B5 Ia	— —	−7.0	2500	0.008	+41 V		Aludra
β CMi	07 26.5	+ 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 33.9	+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 38.7	+ 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 44.6	+28 03	1.14	1.00	K0 IIIb	0.094	0.7	40	0.629	+3 V		**Pollux**
ξ Pup	07 48.8	−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. 1988.5 Dec		V	B−V	MK Type	$\pi('')$	M(V)	D(ly)	$\mu('')$	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 28	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 29.3	+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 28	3.38	0.68	G5:III + A:	0.027	0.5	150	0.198	+36 SB	compositeA: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 58.4	+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 27	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 27.0	− 8 36	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 32.1	+51 44	3.17	0.46	F6 IV	0.068	2.6	48	1.094	+15 SB		
o Leo AB	09 40.5	+ 9 57	3.52	0.49	F5 II + A5?	0.034	−2.3	590	0.149	+27 SB	A:occ.bin.(=mags)	Subra
l Car	09 44.9	−62 27	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 45.2	+23 50	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 06.7	+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 29	3.44	0.31	F0 IIIa	0.017	1.5	77	0.023	−16 SB		Adhafera
λ UMa	10 16.4	+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 16	3.4v	1.54	K3 IIa	0.027	3.0	35	0.027	+8	var: 3.36−3.42	HR4050
γ Leo A	10 19.3	+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 19.3	+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. 1988.5	Dec	V	B−V	MK Type	$\pi('')$	M(V)	D(ly)	$\mu('')$	RV(km/s)	Remarks	
μ UMa	10 21.6	+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 42.5	−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 27	2.37	−0.02	A0mA1 IV−V	0.053	0.7	62	0.087	−12 SB		Merak
α UMa AB	11 03.0	+61 49	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 09.0	+44 34	3.01	1.14	K1 III	— —	0.2	110	0.075	−4		
δ Leo	11 13.5	+20 35	2.56	0.12	A4 IV	0.048	1.6	51	0.197	−20 V		Zosma
θ Leo	11 13.6	+15 30	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 32.4	−31 48	3.54	0.94	G7 III	0.027	0.4	130	0.211	−5 V		
λ Cen	11 35.2	−62 57	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 53.2	+53 46	2.44	0.00	A0 Van	0.028	0.5	80	0.094	−13 SB		Phad
δ Cen	12 07.8	−50 39	2.6v	−0.12	B2 IVne	0.026	−3.1	370	0.034	+11 V	var: 2.51−2.65	
ϵ Crv	12 09.5	−22 33	3.00	1.33	K2 III	0.027	−0.8	180	0.073	+5		Minkar
δ Cru	12 14.5	−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 14.8	+57 06	3.31	0.08	A2 Van	0.061	1.2	53	0.102	−13 V		Megrez
γ Crv	12 15.2	−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 25.9	−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 V	0.024	−0.3	150	0.255	+9 V	B: 8.26, K2 V, 24"	Algorab
γ Cru	12 30.5	−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 04	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 23	2.76	0.36	F1 V + F0mF2 V	0.099	2.6	33	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. 1988.5	Dec	V	B−V	MK Type	$\pi('')$	M(V)	D(ly)	$\mu('')$	RV(km/s)	Remarks
β Cru	12 47.0	−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 53.5	+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 55.0	+ 3 28	3.38	1.58	M3 III	0.022	−1.2	270	0.474	−18 V?	Auva
α^2 CVn A	12 55.5	+38 23	2.9v	−0.12	A0p III:(SiEu)	0.027	0.0	130	0.242	−3 V	B: 5.6, F0 V, 20" Cor Caroli
ϵ Vir	13 01.6	+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 19.9	−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	var0.97−1.04;mult3.1,4.5,7.5 **Spica**
ζ Vir	13 34.1	− 0 32	3.37	0.11	A2 IV	0.044	1.4	79	0.287	−13	Heze
ϵ Cen	13 39.2	−53 24	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 48.8	−41 38	3.41	−0.22	B2 IV	— —	−3.1	640	0.035	+9 SB	
μ Cen	13 48.9	−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 54.1	+18 27	2.68	0.58	G0 IV	0.108	2.8	31	0.370	0 SB	Mufrid
ζ Cen	13 54.8	−47 14	2.55	−0.22	B2.5 IV	— —	−2.7	370	0.072	+7 SB2	
β Cen AB	14 03.0	−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 05.7	−26 38	3.27	1.12	K2 IIIb	0.049	0.7	67	0.049	+27	
θ Cen	14 06.0	−36 19	2.06	1.01	K0 IIIb	0.065	0.7	50	0.738	+1	Menkent
α Boo	14 15.1	+19 15	−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 00	3.55	−0.18	B2.5 IVn	— —	−2.7	550	0.014	+22	
γ Boo	14 31.6	+38 22	3.03	0.19	A7 IV+	0.025	1.9	53	0.189	−37 V	Seginus
η Cen	14 34.8	−42 06	2.3v	−0.19	B1.5 IV pne	— —	−3.5	450	0.049	0 SB	variable shell
α Cen B	14 38.8	−60 47	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 38.8	−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 20	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 50.0	−15 57	2.75	0.15	A3 III−IV	0.050	1.2	56	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. 1988.5	Dec	V	B−V	MK Type	π(")	M(V)	D(ly)	μ(")	RV(km/s)	Remarks
β Lup	14 57.8	−43 05	2.68	−0.22	B2 IV	— —	−3.1	460	0.057	0 SB	
κ Cen	14 58.4	−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 03.4	−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 03	3.41	0.92	G8 III	0.043	0.3	130	0.128	−10	
δ Boo	15 15.0	+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 20	2.61	−0.11	B8 IVn	0.000	0.1	100	0.101	−35 SB	Zuben Elschemali
γ TrA	15 17.8	−68 38	2.89	0.00	A1 IIIn	0.010	0.2	110	0.067	−3 V	
δ Lup	15 20.6	−40 36	3.2v	−0.22	B1.5 IVn	— —	−3.4	650	0.036	0 V?	
γ UMi	15 20.7	+71 53	3.05	0.05	A3 III	0.003	0.4	110	0.031	−4 V	Pherkad
ε Lup AB	15 21.9	−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 28	2.65	1.17	K2 IIIb CN1	0.053	0.7	62	0.143	+3 V?	var? Unukalhai
μ Ser	15 49.0	−3 24	3.53	−0.04	A0 III	0.007	0.0	170	0.094	−9 SB	
β TrA	15 54.1	−63 24	2.85	0.29	F 0 IV	0.083	2.2	39	0.438	0	
π Sco A	15 58.2	−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 35	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 46	2.62	−0.07	B0.5 V	0.009	−3.5	(522)	0.022	−1 SB	A:2.78;B:5.04,1";C4.93,14" Graffias
δ Oph	16 13.7	− 3 40	2.74	1.58	M0.5 III	0.034	−0.8	160	0.153	−20 V	Yed Prior
ε Oph	16 17.7	− 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 28.7	−26 24	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 29.7	+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 36.5	−10 33	2.56	0.02	O9.5 Vn	0.003	−4.2	(522)	0.026	−15 V	

Star Name	R.A. 1988.5	Dec	V	B−V	MK Type	π(″)	M(V)	D(ly)	μ(″)	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 47.4	−69 00	1.92	1.44	K2 IIb−IIIa	0.031	−1.0	110	0.044	−3		Atria
ε Sco	16 49.4	−34 16	2.29	1.15	K2 III	0.022	0.1	89	0.661	−3		
μ¹ Sco	16 51.1	−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 57.1	+ 9 24	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 09.7	−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 11.3	−43 13	3.33	0.41	F2p V:(Cr)	0.062	2.7	53	0.286	−27		
α Her AB	17 14.1	+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 14.6	+36 49	3.16	1.44	K3 IIab	0.025	−2.0	330	0.029	−26		
θ Oph	17 21.3	−24 59	3.3v	−0.22	B2 IV	— —	−3.1	610	0.021	−2 SB	occbin: 3.4,5.4; var: 3.25−3.29, 0.14d	
β Ara	17 24.3	−55 31	2.85	1.46	K3 Ib−IIa	0.034	−3.5	580	0.024	0		
γ Ara A	17 24.4	−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 30.0	−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 32.8	−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 34.4	+12 34	2.08	0.15	A5 Vnn	0.067	0.7	49	0.255	+13 SB?		Rasalhague
θ Sco	17 36.5	−42 59	1.87	0.40	F1 III	0.027	−2.4	200	0.016	+1		Sargas
ξ Ser	17 36.9	−15 24	3.54	0.26	F0 IIIb	0.030	1.8	73	0.076	−43 SB		
κ Sco	17 41.7	−39 01	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″	
ι¹ Sco	17 46.8	−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 56.3	+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. 1988.5	Dec	V	B−V	MK Type	π(")	M(V)	D(ly)	μ(")	RV(km/s)	Remarks
γ^2 Sgr	18 05.1	−30 26	2.99	1.00	K0 III	0.025	0.2	120	0.192	+22 SB	Nash
η Sgr A	18 16.8	−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 20.7	− 2 54	3.26	0.94	K0 III−IV	0.058	1.8	56	0.890	+9 V?	
ϵ Sgr	18 23.4	−34 23	1.85	−0.03	A0 II:n(shell?)	0.023	0.0	76	0.129	−15	Kaus Australis
α Tel	18 26.1	−45 59	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 36.5	+38 46	0.03	0.00	A0 Va	0.133	0.6	25	0.348	−14 V	**Vega**
ϕ Sgr	18 44.9	−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 57.0	−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 01.8	−29 54	2.60	0.08	A2.5 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 05.6	− 4 54	3.44	−0.09	B9 V	0.032	0.6	120	0.090	−12 V	
τ Sgr	19 06.2	−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 03	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 38	3.07	1.00	G9 III	0.032	0.3	110	0.130	+25	Nodus Secundus
δ Aql	19 24.9	+ 3 05	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 45.7	+10 35	2.72	1.52	K3 II	0.016	−2.2	270	0.016	−2 V	Tarazed
α Aql	19 50.2	+ 8 50	0.77	0.22	A7 Vn	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 58.2	+19 28	3.47	1.57	M0 III	0.013	−0.7	220	0.070	−33	
θ Aql	20 10.7	− 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 24.7	−56 46	1.94	−0.20	B2.5 V	— —	−1.6	150	0.087	+2 SB	Peacock

Star Name	R.A. 1988.5	Dec	V	B−V	MK Type	π(")	M(V)	D(ly)	μ(")	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 41.0	+45 14	1.25	0.09	A2 Ia	0.000	−7.2	1500	0.005	−5 V	**Deneb**
β Pav	20 43.9	−66 15	3.42	0.16	A6 IV	0.035	1.5	79	0.041	+10	
η Cep	20 45.1	+61 47	3.43	0.92	K0 IV	0.076	3.1	43	0.827	−87	
ε Cyg	20 45.7	+33 56	2.46	1.03	K0 III	0.057	0.2	57	0.484	−11 SB	
ζ Cyg	21 12.4	+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	var3.16−3.27,0.2d;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 43.6	+ 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 46.4	−16 11	2.9v	0.29	A5mF2 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 53.2	−37 25	3.01	−0.12	B8 IV−Vs	0.013	−1.2	230	0.104	−2 V?	
α Aqr	22 05.2	− 0 23	2.96	0.98	G2 Ib	0.012	−4.0	680	0.016	+8 V?	Sadalmelik
α Gru	22 07.5	−47 01	1.74	−0.13	B7 Vn	0.057	−1.1	57	0.198	+12	Al Nair
θ Peg	22 09.6	+ 6 08	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 17.7	−60 19	2.86	1.39	K3 III	0.026	0.0	100	0.071	+42 SB	
δ Cep A	22 28.7	+58 21	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 46	3.40	−0.09	B8.5 III−IV	0.023	0.1	140	0.080	+7 V?	Homam
β Gru	22 42.0	−46 57	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 23	3.49	0.08	A2 Va	0.044	1.0	97	0.126	0 V	
ι Cep	22 49.3	+66 08	3.52	1.05	K0 III	0.041	0.2	140	0.137	−12	
μ Peg	22 49.5	+24 32	3.48	0.93	G8 III	0.040	0.3	140	0.152	+14	
δ Aqr	22 54.0	−15 53	3.27	0.05	A3 V	0.038	1.2	85	0.047	+18 V	Skat
α PsA	22 57.0	−29 41	1.16	0.09	A3 Va	0.149	2.0	22	0.373	+7	**Fomalhaut**
β Peg	23 03.2	+28 01	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	2000 α	2000 δ	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
o^2 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 1988.0; 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. 1988.0 °	Sep. 1988.0 ″	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	280	1.9	930
33	Ori	4123	05	30.2	+03	16	5.7	6.0	7.3	28	1.9	—
OΣ	156	5447	06	46.3	+18	13	6.1	6.8	7.0	235	0.5	1100
Σ	1338	7307	09	19.7	+38	17	5.8	6.5	6.7	268	1.1	400
35	Com	8695	12	52.3	+21	21	5.1*	5.2	7.4	171	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	147	29.8	722
OΣ	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	311	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
OΣ	65	2799	03	49.2	+25	32	5.2	5.8	6.2	210	0.4	62
α	CMa	5423	06	44.3	−16	40	−1.4	−1.4	8.5	21	6.2	50
α	Gem	6175	07	33.3	+31	55	1.6	2.0	2.8	82	2.9	500
ζ	Cnc AB	6650	08	11.1	+17	43	5.0	5.6	5.9	206	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	77	1.7	60
γ	Vir	8630	12	40.7	−01	21	2.8	3.5	3.5	290	3.2	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	327	7.1	150
ζ	Her	10157	16	40.6	+31	38	2.8	2.9	5.5	95	1.5	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	255	1.7	88
δ	Cyg	12880	19	44.4	+45	04	2.9*	2.9	6.3	229	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	55	0.5	50
μ	Cyg	15270	21	43.2	+28	39	4.5	4.8	6.1	305	1.6	500
ζ	Aqr	15971	22	27.8	−00	08	3.6	4.3	4.5	211	1.8	850
Σ	3050	17149	23	58.5	+33	37	5.8	6.5	6.7	320	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

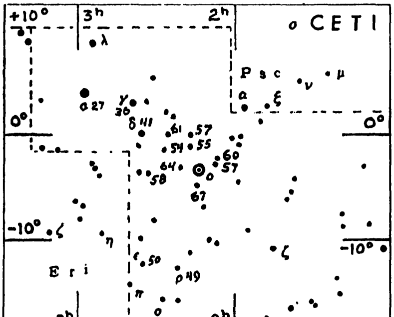
By Janet A. Mattei

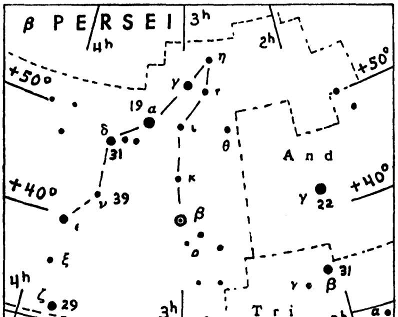
Variable stars provide information about many stellar properties. Depending upon their type, variables can tell the mass, radius, temperature, luminosity, internal and external structure, composition, and evolution of stars. The systematic observation of variable stars is an area in which an amateur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

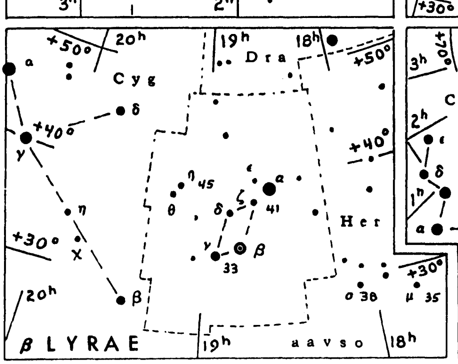
For beginning observers, charts of the fields of four different types of bright variable stars are printed below. On each chart, the magnitudes (with decimal point omitted) of several suitable comparison stars are shown. A brightness estimate of the variable is made using two comparison stars, one brighter, 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.

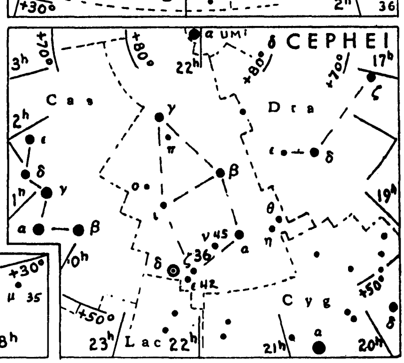
The first table on the next page is a list of long-period variables, brighter than magnitude 8.0 at maximum, and north of $-20°$. The first column (the Harvard designation of the star) gives the position for the year 1900: the first four figures give the hours and minutes of right ascension, the last 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 1987, International Supplement*.









LONG-PERIOD VARIABLE STARS

Variable	Max. m_v	Per d	Epoch 1988	Variable	Max. m_v	Per d	Epoch 1988
001755 T Cas	7.8	445	Apr. 3	142539 V Boo	7.9	258	Sept. 9?
001838 R And	7.0	409	Apr. 25	143227 R Boo	7.2	223	Feb. 5
021143 W And	7.4	397	Nov. 1	151731 S CrB	7.3	361	Dec. 5
0214*03* o Cet	3.4	332	Jan. 7	154639 V CrB	7.5	358	July 13
0228*13* U Cet	7.5	235	May 28	154615 R Ser	6.9	357	May 11
023133 R Tri	6.2	266	July 12	160625 RU Her	8.0	484	June 7
043065 T Cam	8.0	374	—	162119 U Her	7.5	406	Oct. 6
0455*14* R Lep	6.8	432	May 5	1621*12* V Oph	7.5	298	Jan. 23
050953 R Aur	7.7	459	Mar. 13	163266 R Dra	7.6	245	Mar. 29
054920 U Ori	6.3	372	Dec. 5	164715 S Her	7.6	307	Feb. 22
0617*02* V Mon	7.0	335	June 4	1702*15* R Oph	7.9	302	July 2
065355 R Lyn	7.9	379	Oct. 10	171723 RS Her	7.9	219	Jan. 3
070122aR Gem	7.1	370	Aug. 26	180531 T Her	8.0	165	May 2
070310 R CMi	8.0	338	Sept. 1	181136 W Lyr	7.9	196	Apr. 11
072708 S CMi	7.5	332	Mar. 9	183308 X Oph	6.8	334	Sept. 2
081112 R Cnc	6.8	362	Nov. 26	190108 R Aql	6.1	300	Jan. 1
081617 V Cnc	7.9	272	May 5	1910*17* T Sgr	8.0	392	Feb. 28
084803 S Hya	7.8	257	Aug. 10	1910*19* R Sgr	7.3	269	Aug. 24
0850*08* T Hya	7.8	288	Feb. 16	193449 R Cyg	7.5	426	Feb. 9
093934 R LMi	7.1	372	June 30	194048 RT Cyg	7.3	190	Mar. 31
094211 R Leo	5.8	313	May 30	194632 χ Cyg	5.2	407	Nov. 2
103769 R UMa	7.5	302	Aug. 20	201647 U Cyg	7.2	465	June 13
1214*18* R Crv	7.5	317	Feb. 27	2044*05* T Aqr	7.7	202	Jan. 21
122001 SS Vir	6.8	355	Dec. 3	210868 T Cep	6.0	390	June 8
123160 T UMa	7.7	257	Sept. 7	213753 RU Cyg	8.0	234	Apr. 11
123307 R Vir	6.9	146	Jan. 20	230110 R Peg	7.8	378	May 19
123961 S UMa	7.8	226	July 10	230759 V Cas	7.9	228	July 4
131546 V CVn	6.8	192	Feb. 23	231508 S Peg	8.0	319	Mar. 7
1327*06* S Vir	7.0	378	June 20	2338*15* R Aqr	6.5	387	Sept. 24
134440 R CVn	7.7	328	Jan. 20	235350 R Cas	7.0	431	Dec. 2
142584 R Cam	7.9	270	Feb. 2	2357*15* W Cet	7.6	351	Aug. 9

OTHER TYPES OF VARIABLE STARS

Variable		Max. m_v	Min. m_v	Type	Sp. Cl.	Period d	Epoch 1988 U.T.
005381	U Cep	6.7	9.8	Ecl.	B8+gG2	2.49307	Jan. 1.32*
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. 1.01*
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. 2.20
065820	ζ Gem	3.6	4.2	δ Cep	F7–G3	10.15073	Jan. 5.32
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	12.93661†	Jan. 5.90*
192242	RR Lyr	6.9	8.0	RR Lyr	A2–F1	0.566839	Jan. 1.22
194700	η Aql	3.5	4.3	δ Cep	F6–G4	7.176641	Jan. 4.89
222557	δ Cep	3.5	4.4	δ Cep	F5–G2	5.366341	Jan. 1.81

*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—R LEONIS

How do you locate a variable star? This is the most frequently asked question among new variable star observers. For many, the first observing experience is a discouraging one when after several hours of search the variable still cannot be found. If you have had this experience, don't be dismayed, for you are not alone. Fortunately, with perseverance success is guaranteed! It also helps to begin variable star observing with a star that is easy to locate. It is for this reason that the bright variable R Leonis has been selected from among 30 000 variable stars as "our" star of the year, for it is one of the easiest variable stars in the sky to find.

R Leonis was the fifth star discovered to be a variable, and was identified by J. A. Koch of Germany in 1780. Since then it has become one of the best observed variable stars. R Leonis owes this popularity to its brightness, significant range of variation, and its location in the sky. It is about 5 degrees west of alpha Leonis (Regulus) in the direction of xi Leonis. Several 6th and 7th magnitude stars nearby provide good comparisons for estimating its brightness, particularly at maximum.

The deep red color of R Leo also helps in its identification. The English astronomer J. R. Hind (1823–1895) wrote of R Leonis, "It is one of the most fiery-looking variables on our list—fiery in every stage, from maximum to minimum, and is really a fine telescopic object in a dark sky, when its color forms a striking contrast with the steady white light of the 6th magnitude star (19 Leo) a little to the north."

R Leo varies between magnitudes 5.8 and 10.0 in a little over 10 months, with a 313-day cycle. This red giant star is 50 times as bright at maximum as it is at minimum because it pulsates. Although R Leo pulsates periodically, there is considerable variation in the brightness levels of the maxima and minima of different cycles, as well as in the shape of the light curve of each cycle. The accompanying AAVSO light curve from 1974 to mid-1977 gives a good example of its periodic behavior with varying brightnesses of maxima and minima.

Often new AAVSO observers are introduced to variable star observing by receiving the finder chart of R Leo in their New Member Observing Kit. This was the case with Leslie Peltier (1900–1980) when he started his remarkable observing career in 1918. In his autobiography, *Starlight Nights*, Leslie gave an account of his introduction to variable star observing. He wrote:

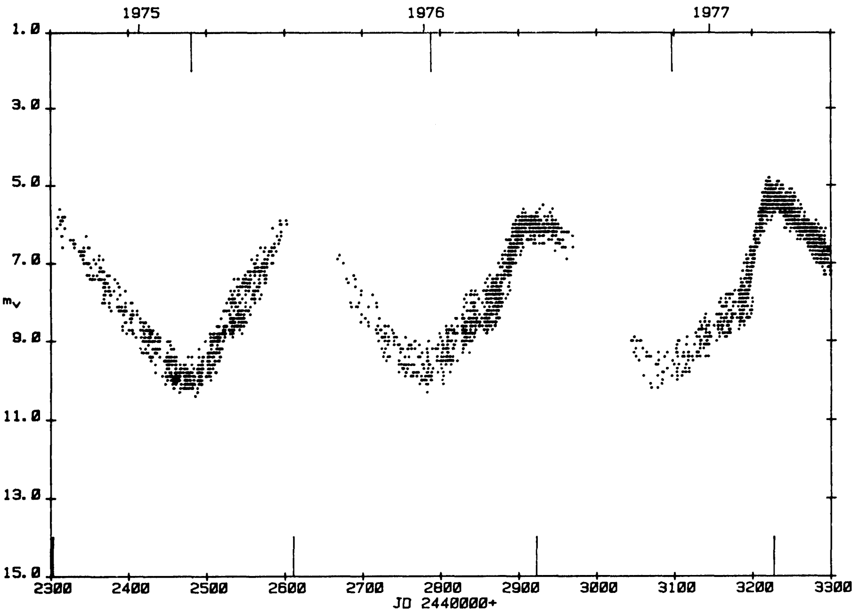
> "As soon as darkness fell I bundled up and, with telescope, atlas, and charts in my mittened hands, I went out to find my variables. Two hours later when I returned, half frozen, to the fire I had not found a single one.
>
> "Nor was I any more successful on several succeeding nights and I was becoming more and more discouraged. Finally, however, on the night of

March 1, 1918, I set the telescope up near the northeast corner of the house to keep out of the wind and got out my chart of the variable, R Leonis. I pointed the telescope at the fourth-magnitude star Omicron Leonis and, using it as a base of operations I started exploring the adjacent territory. To my great delight, about a minute later and just a little more than one field to the northeast of Omicron I found the tiny triangle of stars with R, my first variable, forming one angle precisely as shown on the chart.

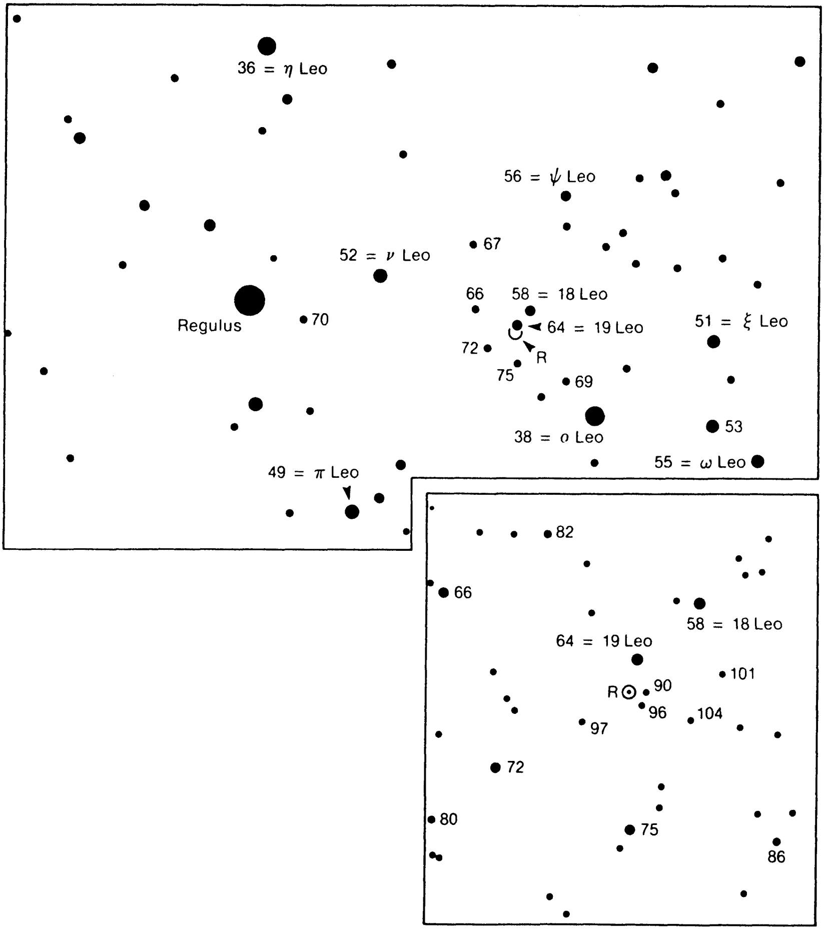
"Why had success been so long coming? Simply because I had no mental image of what to look for. I had not bothered to figure out just how much of the chart area was covered by the instrument's field of view. After this experience I soon made a wire ring which could be moved about over my charts to show me just what my telescope was seeing."

During his 62 years of observing, Leslie contributed a total of 132 123 observations to the AAVSO, and on every March 1, he celebrated his observing anniversary with a brightness estimate of R Leo.

We invite new observers of variable stars to give R Leo a try using the accompanying finder charts. In the beginning of the year R Leo will be at minimum, but, by the end of May, it should be near maximum brightness and easy to locate.



The AAVSO light curve (apparent visual magnitude as a function of time) of ***R Leonis*** *from 1974 to mid-1977. Each dot represents one observation. Note the different shapes of the cycles and the varying brightness of the maxima and minima. A gap appears in each cycle around late summer and early fall, when R Leonis is too close to the Sun to observe.*



Two finder charts for ***R Leonis****. North is at the top in each case. The upper chart is suited for binocular observation. The angular distance from Regulus to R Leonis (marked with "R") is 5°. The lower chart is on a scale more than 4 times larger, shows fainter stars, and is suited for telescopic observation. The apparent visual magnitudes of several comparison stars are indicated (with decimal points omitted). Note the distinctive pair of 9th magnitude stars that form an isosceles triangle with R Leonis and help to locate it. These charts are reproduced from* Sky and Telescope, *March 1983, p. 252, by permission from A. M. MacRobert of Sky Publishing Corporation. The comparison star magnitudes are from AAVSO charts.*

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	*1.5*	0.13	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	8.5	16	7.5	5.8	O9	O supergiants, WR stars
Tr 24	16 55.6	−40 38	8.5	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.

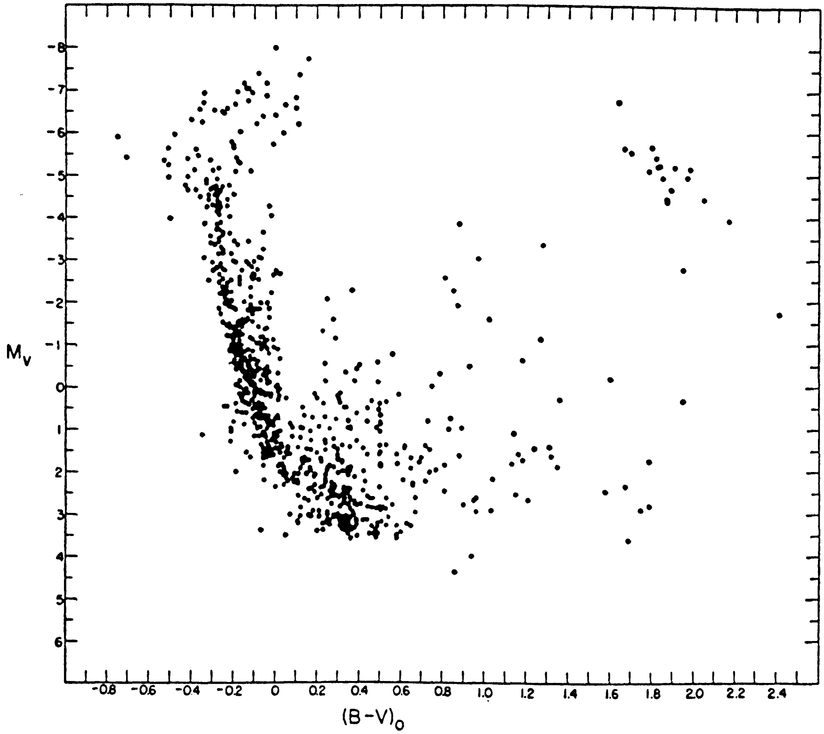
AN EXAMPLE OF A YOUNG (DOUBLE) STAR CLUSTER

The 1985 and 1986 editions of the Handbook featured the young clusters NGC 457 in the north and NGC 4755, the "jewel box", in the south. We present here the famous Double Cluster in Perseus, listed as NGC 869 (h Per) and NGC 884 (χ Per) in the table. Both of these clusters are among the richest young clusters known in the Galaxy, each containing over a thousand stars.

At a distance of 7 to 8 thousand light-years, the double cluster is visible to the naked eye about half way between α Per and γ Cas (the central star of the "W"). They appear as very fine objects even in small telescopes. Their centres are separated by an angle corresponding to the size of the Moon, which is also the rough angular size of each cluster.

The colour-magnitude diagram (see below) implies that the mean age of both clusters is about 10 million years, but with significant variations from star to star. The fact that χ Per contains red supergiants (like the star α Ori, one of these is a fine ruby coloured star near the centre of χ Per) while h Per does not, suggests that χ Per may be slightly older than h Per, although this point has never been definitively settled.

Surrounding both clusters out to a diameter of about 6° is the young association Per OB1, which contains a total of some three dozen blue supergiants and two dozen red supergiants among its brightest members.



A colour-magnitude diagram of all stars in and around h and χ Per observed in the monumental Ph.D. thesis study of Wildey (1964, Ap. J. Sup., 8, 439), corrected for the effects of interstellar extinction. Absolute visual magnitude M_V = 0 corresponds to V_0 = 12.0 or approximate visual apparent magnitude V = 13.5. Hence, the brightest stars at M_V = −7 have V = 6.5. Note that these brightest stars are each some 50 000 times more luminous than our Sun. A star like our Sun at the distance of the Double Cluster would have V = 18.3, far beyond the reach of small telescopes. The large spread in intrinsic colour index, $(B\text{-}V)_0$, for the brightest stars (extreme upper left) occurs mainly among the outlying association stars and may be due to a combination of age spread and an excess of ultraviolet emission from the stars. Note the clump of red supergiants centred at M_V = −5 and $(B\text{-}V)_0$ = 1.9. Most of the stars scattered between the densely occupied main sequence at the left and the clump of red supergiants are probably non-member field stars.

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		Type	Size	S	m	Dist.	Remarks
			h m	° ′		′	mag. sq″	*	10^3 l.y.	
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

The Messier Catalogue, with its modern additions, represents a listing of many of the brightest and best deep-sky wonders. The following table lists the Messier objects by season for the *evening observer*, grouping the objects within their respective constellations, with the constellations themselves 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.

The columns contain: Messier's number (M); the constellation; the object's New General Catalogue (NGC) number; the type of object (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 also listed); the 1980 co-ordinates; the visual magnitude (unless marked with a "p" which indicates a photographic magnitude). The "Remarks" column contains comments on the object's appearance and observability. The final column, marked "Seen", is for the observer to use in checking off those objects which he or she has located. An asterisk in the "Type" column indicates that additional information about the object may be found elsewhere in the HANDBOOK, in the appropriate table. Most data are from the Skalnate Pleso *Atlas of the Heavens* catalogue; occasionally from other sources.

All these objects can be seen in a small telescope (60 mm refractor, for instance), with M74 and M83 generally considered to be the most difficult. The most southerly M-objects are M6 and M7 in Scorpius, with M54, M55, M69, and M70 in Sagittarius almost as far south. Notice how different classes of objects dominate the skies of the various seasons: open clusters dominate the winter sky; galaxies by the hundreds abound in the spring sky; the summer sky contains many globular clusters and nebulae; while the autumn sky is a mixture of clusters and galaxies. This effect is due to the presence (or absence) of the Milky Way in any particular season, and whether or not we are looking toward the centre of the Galaxy (as in summer) or away from the centre (as in winter).

M	Con	NGC	Type	R.A. (1980) Dec.	m_v	Remarks	Seen
The Winter Sky				h m ° ′			
1	Tau	1952	SNR*	5 33.3 +22 01	8.4	Crab Neb.; supernova remnant	
45	Tau	—	OC*	3 46.3 +24 03	1.4	Pleiades; RFT object	
36	Aur	1960	OC	5 35.0 +34 05	6.3	best at low magnification	
37	Aur	2099	OC*	5 51.5 +32 33	6.2	finest of 3 Aur. clusters	
38	Aur	1912	OC	5 27.3 +35 48	7.4	large, scattered group	
42	Ori	1976	EN*	5 34.4 −05 24	—	Orion Nebula	
43	Ori	1982	EN	5 34.6 −05 18	—	detached part of Orion Neb.	
78	Ori	2068	RN	5 45.8 +00 02	—	featureless reflection neb.	
79	Lep	1904	GC	5 23.3 −24 32	8.4	20 cm scope needed to resolve	
35	Gem	2168	OC*	6 07.6 +24 21	5.3	superb open cluster	
41	CMa	2287	OC*	6 46.2 −20 43	5.0	4°S. of Sirius; use low mag.	
50	Mon	2323	OC	7 02.0 −08 19	6.9	between Sirius and Procyon	
46	Pup	2437	OC*	7 40.9 −14 46	6.0	rich cl.; contains PN NGC 2438	
47	Pup	2422	OC	7 35.6 −14 27	4.5	coarse cl.; 1.5°W. of M46	
93	Pup	2447	OC	7 43.6 −23 49	6.0	smaller, brighter than M46	
48	Hya	2548	OC	8 12.5 −05 43	5.3	former "lost" Messier object	
The Spring Sky							
44	Cnc	2632	OC*	8 38.8 +20 04	3.7	Beehive Cl.; RFT object	
67	Cnc	2682	OC*	8 50.0 +11 54	6.1	"ancient" star cluster	
40	UMa	—	—	12 34.4 +58 20	9.0	two stars; sep. 50″	

M	Con	NGC	Type	R.A. (1980) Dec.	m_v	Remarks	Seen
81	UMa	3031	G-Sb*	9 54.2 +69 09	7.9	very bright spiral	
82	UMa	3034	G-Pec*	9 54.4 +69 47	8.8	the "exploding" galaxy	
97	UMa	3587	PN*	11 13.7 +55 08	12.0	Owl Nebula	
101	UMa	5457	G-Sc*	14 02.5 +54 27	9.6	large, faint, face-on spiral	
108	UMa	3556	G-Sc	11 10.5 +55 47	10.7	nearly edge-on; near M97	
109	UMa	3992	G-Sb	11 56.6 +53 29	10.8	barred spiral; near γ UMa	
65	Leo	3623	G-Sb	11 17.8 +13 13	9.3	bright elongated spiral	
66	Leo	3627	G-Sb	11 19.1 +13 07	8.4	M65 in same field	
95	Leo	3351	G-SBb	10 42.8 +11 49	10.4	bright barred spiral	
96	Leo	3368	G-Sbp	10 45.6 +11 56	9.1	M95 in same field	
105	Leo	3379	G-E1	10 46.8 +12 42	9.2	very near M95 and M96	
53	Com	5024	GC	13 12.0 +18 17	7.6	15 cm scope needed to resolve	
64	Com	4826	G-Sb*	12 55.7 +21 48	8.8	Black Eye Galaxy	
85	Com	4382	G-SO	12 24.3 +18 18	9.3	bright elliptical shape	
88	Com	4501	G-Sb	12 30.9 +14 32	10.2	bright multiple-arm spiral	
91	Com	4548	G-SBb	12 34.4 +14 36	10.8	not the same as M58	
98	Com	4192	G-Sb	12 12.7 +15 01	10.7	nearly edge-on spiral	
99	Com	4254	G-Sc	12 17.8 +14 32	10.1	nearly face-on spiral	
100	Com	4321	G-Sc	12 21.9 +15 56	10.6	face-on spiral; star-like nuc.	
49	Vir	4472	G-E4*	12 28.8 +08 07	8.6	very bright elliptical	
58	Vir	4579	G-SB	12 36.7 +11 56	9.2	bright barred spiral	
59	Vir	4621	G-E3	12 41.0 +11 47	9.6	bright elliptical near M58	
60	Vir	4649	G-E1	12 42.6 +11 41	8.9	bright elliptical near M59	
61	Vir	4303	G-Sc	12 20.8 +04 36	10.1	face-on barred spiral	
84	Vir	4374	G-E1	12 24.1 +13 00	9.3	bright elliptical	
86	Vir	4406	G-E3	12 25.1 +13 03	9.7	M84 in same field	
87	Vir	4486	G-E1	12 29.7 +12 30	9.2	nearly spherical galaxy	
89	Vir	4552	G-E0	12 34.6 +12 40	9.5	resembles M87; smaller	
90	Vir	4569	G-Sb	12 35.8 +13 16	10.0	bright spiral; near M89	
104	Vir	4594	G-Sb*	12 38.8 −11 31	8.7	Sombrero Galaxy	
3	CVn	5272	GC*	13 41.3 +28 29	6.4	contains many variables	
51	CVn	5194	G-Sc*	13 29.0 +47 18	8.1	Whirlpool Galaxy	
63	CVn	5055	G-Sb*	13 14.8 +42 08	9.5	Sunflower Galaxy	
94	CVn	4736	G-Sbp*	12 50.1 +41 14	7.9	very bright and comet-like	
106	CVn	4258	G-Sbp*	12 18.0 +47 25	8.6	large, bright spiral	
68	Hya	4590	GC	12 38.3 −26 38	8.2	15 cm scope needed to resolve	
83	Hya	5236	G-Sc*	13 35.9 −29 46	10.1	very faint and diffuse	
102	Dra	5866	G-E6p	15 05.9 +55 50	10.8	small, edge-on galaxy	
5	Ser	5904	GC*	15 17.5 +02 11	6.2	one of the finest globulars	
The Summer Sky							
13	Her	6205	GC*	16 41.0 +36 30	5.7	spectacular globular cl.	
92	Her	6341	GC*	17 16.5 +43 10	6.1	9°NE. of M13; bright	
9	Oph	6333	GC	17 18.1 −18 30	7.3	smallest of Oph. globulars	
10	Oph	6254	GC*	16 56.0 −04 05	6.7	rich cl.; M12 3.4° away	
12	Oph	6218	GC*	16 46.1 −01 55	6.6	loose globular	
14	Oph	6402	GC	17 36.5 −03 14	7.7	20 cm scope needed to resolve	
19	Oph	6273	GC	17 01.3 −26 14	6.6	oblate globular	
62	Oph	6266	GC	16 59.9 −30 05	6.6	unsymmetrical; in rich field	
107	Oph	6171	GC	16 31.3 −13 02	9.2	small, faint globular	
4	Sco	6121	GC*	16 22.4 −26 27	6.4	bright globular near Antares	
6	Sco	6405	OC*	17 38.9 −32 11	5.3	best at low magnification	
7	Sco	6475	OC*	17 52.6 −34 48	3.2	excellent in binoculars	
80	Sco	6093	GC	16 15.8 −22 56	7.7	very compressed globular	
16	Ser	6611	EN*	18 17.8 −13 48	—	Star-Queen Neb. w/ open cl.	
8	Sgr	6523	EN*	18 02.4 −24 23	—	Lagoon Neb. w/cl. NGC 6530	
17	Sgr	6618	EN*	18 19.7 −16 12	—	Swan or Omega Nebula	
18	Sgr	6613	OC	18 18.8 −17 09	7.5	sparse cluster; 1°S. of M17	
20	Sgr	6514	EN*	18 01.2 −23 02	—	Trifid Nebula	
21	Sgr	6531	OC	18 03.4 −22 30	6.5	0.7°NE. of M20	
22	Sgr	6656	GC*	18 35.2 −23 55	5.9	low altitude dims beauty	
23	Sgr	6494	OC*	17 55.7 −19 00	6.9	bright, loose cluster	
24	Sgr	—	—	18 17 −18 27	4.6	Milky Way patch; binoc. obj.	

M	Con	NGC	Type	R.A. (1980) Dec.	m_v	Remarks	Seen
25	Sgr	I4725	OC*	18 30.5 −19 16	6.5	bright but sparse cluster	
28	Sgr	6626	GC	18 23.2 −24 52	7.3	compact globular near M22	
54	Sgr	6715	GC	18 53.8 −30 30	8.7p	not easily resolved	
55	Sgr	6809	GC*	19 38.7 −31 00	7.1p	bright, loose globular	
69	Sgr	6637	GC	18 30.1 −32 23	8.9	small, poor globular	
70	Sgr	6681	GC	18 42.0 −32 18	9.6	small globular; 2°E. of M69	
75	Sgr	6864	GC	20 04.9 −21 59	8.0	small, remote globular	
11	Sct	6705	OC*	18 50.0 −06 18	6.3	superb open cluster	
26	Sct	6694	OC	18 44.1 −09 25	9.3	bright, coarse cluster	
56	Lyr	6779	GC	19 15.8 +30 08	8.2	within rich field	
57	Lyr	6720	PN*	18 52.9 +33 01	9.3	Ring Nebula	
71	Sge	6838	GC	19 52.8 +18 44	9.0	loose globular cl.	
27	Vul	6853	PN*	19 58.8 +22 40	7.6	Dumbbell Nebula	
29	Cyg	6913	OC	20 23.3 +38 27	7.1	small, poor open cl.	
39	Cyg	7092	OC	21 31.5 +48 21	5.2	very sparse cluster	
The Autumn Sky							
2	Aqr	7089	GC*	21 32.4 −00 54	6.3	20 cm scope needed to resolve	
72	Aqr	6981	GC	20 52.3 −12 39	9.8	near NGC 7009 (Saturn Neb.)	
73	Aqr	6994	OC	20 57.8 −12 44	11.0	group of 4 stars only	
15	Peg	7078	GC*	21 29.1 +12 05	6.0	rich, compact globular	
30	Cap	7099	GC	21 39.2 −23 15	8.4	noticeable elliptical shape	
52	Cas	7654	OC	23 23.3 +61 29	7.3	young, rich cluster	
103	Cas	581	OC	01 31.9 +60 35	7.4	3 NGC clusters nearby	
31	And	224	G-Sb*	00 41.6 +41 09	4.8	Andromeda Gal.; large	
32	And	221	G-E2*	00 41.6 +40 45	8.7	companion gal. to M31	
110	And	205	G-E6*	00 39.1 +41 35	9.4	companion gal. to M31	
33	Tri	598	G-Sc*	01 32.8 +30 33	6.7	large, diffuse spiral	
74	Psc	628	G-Sc	01 35.6 +15 41	10.2	faint, elusive spiral	
77	Cet	1068	G-Sbp	02 41.6 +00 04	8.9	Seyfert gal.; star-like nuc.	
34	Per	1039	OC	02 40.7 +42 43	5.5	best at very low mag.	
76	Per	650	PN*	01 40.9 +51 28	12.2	Little Dumbbell Neb.	

NUMERICAL LISTING OF MESSIER OBJECTS

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

The abbreviations are: Wi, winter; Sp, spring; Su, summer; Au, autumn.

Footnote to Messier Catalogue: The identifications of M91 and M102 are controversial; some believe that these two objects are duplicate observations of M58 and M101 respectively. Also, objects M104 to M110 are not always included in the standard version of the Messier Catalogue. Like many other objects in the catalogue, they were discovered by Mechain and reported to Messier for verification and inclusion in the catalogue.

THE FINEST N.G.C. OBJECTS + 20

BY ALAN DYER

The New General Catalogue of deep-sky objects was originally published by J. L. E. Dreyer in 1888. Supplementary Index Catalogues were published in 1895 and 1908. Together, they contain descriptions and positions of 13,226 galaxies, clusters and nebulae. Many of these are well within reach of amateur telescopes. Indeed, the brightness and size of many NGC objects rival those of the better known deep-sky targets of the Messier Catalogue (almost all of which are also in the NGC catalogue). However, most NGC objects are more challenging to locate and observe than the Messiers.

The first four sections of the following list contain 110 of the finest NGC objects that are visible from mid-northern latitudes. The arrangement is similar to that used in the preceding Messier Catalogue. A telescope of at least 15 cm aperture will likely be required to locate all these objects. The last section is for those wishing to begin to extend their deep-sky observing program beyond the basic catalogue of Charles Messier or the brightest objects of the New General Catalogue. It is a selected list of 20 "challenging" objects, and is arranged in order of right ascension.

The *Wil Tirion Sky Atlas 2000.0*, the sets of index card finder charts called *AstroCards*, or the *AAVSO Variable Star Atlas* will be indispensible in locating the objects on this list. For more information about them, and many other deep-sky objects, see *Burnham's Celestial Handbook* (Vol. 1, 2, 3), and the *Webb Society Deep-Sky Observer's Handbooks*.

Abbreviations used: 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 (the Hubble classification is also listed with each galaxy). Magnitudes are visual; exceptions are marked with a "p" indicating a photographic magnitude. Sizes of each object are in minutes of arc, with the exception of planetary nebulae which are given in seconds of arc. The number of stars (*) and, where space permits, the Shapley classification is also given for star clusters in the Remarks column.

No.	NGC	Con	Type	R.A. (1950)	Dec.	m_v	Size	Remarks
The Autumn Sky								
				h m	° ′			
1	7009	Aqr	PN	21 01.4	−11 34	9.1	44″ × 26″	Saturn Nebula; bright oval planetary
2	7293	Aqr	PN	22 27.0	−21 06	6.5	900″ × 720″	Helix Nebula; very large and diffuse
3	7331	Peg	G-Sb	22 34.8	+34 10	9.7	10.0 × 2.3	large, very bright spiral galaxy
4	7789	Cas	OC	23 54.5	+56 26	9.6	30	200*; faint but very rich cluster
5	185	Cas	G-EO	00 36.1	+48 04	11.7	2.2 × 2.2	companion to M31; quite bright
6	281	Cas	EN	00 50.4	+56 19	—	22 × 27	large, faint nebulosity near γ Cas.
7	457	Cas	OC	01 15.9	+58 04	7.5	10	100*; Type e—intermediate rich
8	663	Cas	OC	01 42.6	+61 01	7.1	11	80*; NGC 654 and 659 nearby
9	7662	And	PN	23 23.5	+42 14	9.2	32″ × 28″	star-like at low mag.; annular, bluish
10	891	And	G-Sb	02 19.3	+42 07	10.9p	11.8 × 1.1	faint, classic edge-on with dust lane
11	253	Scl	G-Scp	00 45.1	−25 34	8.9	24.6 × 4.5	very large and bright but at low alt.
12	772	Ari	G-Sb	01 56.6	+18 46	10.9	5.0 × 3.0	diffuse spiral galaxy
13	936	Cet	G-SBa	02 25.1	−01 22	10.7	3.3 × 2.5	near M77; NGC 941 in same field
14a	869	Per	OC	02 15.5	+56 55	4.4	36	Double Cluster; superb!
14b	884	Per	OC	02 18.9	+56 53	4.7	36	Double Cluster; superb!
15	1023	Per	G-E7p	02 37.2	+38 52	10.5p	4.0 × 1.2	bright, lens-shaped galaxy; near M34
16	1491	Per	EN	03 59.5	+51 10	—	3 × 3	small, fairly bright emission nebula
17	1501	Cam	PN	04 02.6	+60 47	12.0	56″ × 58″	faint, distinctive oval; darker centre
18	1232	Eri	G-Sc	03 07.5	−20 46	10.7	7.0 × 5.5	fairly bright, large face-on spiral
19	1300	Eri	G-SBb	03 17.5	−19 35	11.3	5.7 × 3.5	large barred spiral near NGC 1232
20	1535	Eri	PN	04 12.1	−12 52	10.4	20″ × 17″	blue-grey disk

No.	NGC	Con	Type	R.A. (1950) h m	Dec. ° ′	m_v	Size	Remarks
The Winter Sky								
21	1907	Aur	OC	05 24.7	+35 17	9.9	5	40*; nice contrast with nearby M38
22	1931	Aur	EN	05 28.1	+34 13	—	3 × 3	haze surrounding 4 stars
23	1788	Ori	E/RN	05 04.5	−03 24	—	8 × 5	fairly bright but diffuse E/R neb.
24	1973+	Ori	E/RN	05 32.9	−04 48	—	40 × 25	near M42 and M43; often neglected
25	2022	Ori	PN	05 39.3	+09 03	12.4	28″ × 27″	small, faint but distinct; annular
26	2194	Ori	OC	06 11.0	+12 50	9.2	8	100*; Type e; faint but rich
27	2158	Gem	OC	06 04.3	+24 06	12.5	4	40*; same field as M35; nice contrast
28	2392	Gem	PN	07 26.2	+21 01	8.3	47″ × 43″	Clown-Face Nebula; very bright
29	2244	Mon	OC	06 29.7	+04 54	6.2	40	16*; in centre of Rosette Nebula
30	2261	Mon	E/RN	06 36.4	+08 46	var.	5 × 3	Hubble's Variable Nebula
31	2359	CMa	EN	07 15.4	−13 07	—	8 × 6	fairly bright; NGC's 2360 & 2362 nearby
32	2438	Pup	PN	07 39.6	−14 36	11.8	68″	within M46 open cluster
33	2440	Pup	PN	07 39.9	−18 05	10.3	54″ × 20″	almost starlike; irregular at high mag.
34	2539	Pup	OC	08 08.4	−12 41	8.2	21	150*; Type f—fairly rich
35	2403	Cam	G-Sc	07 32.0	+65 43	8.9	17 × 10	bright, very large; visible in binocs.
36	2655	Cam	G-S	08 49.4	+78 25	10.7	5.0 × 2.4	bright ellipse w/ star-like nucleus
The Spring Sky								
37	2683	Lyn	G-Sb	08 49.6	+33 38	9.6	8.0 × 1.3	nearly edge-on spiral; very bright
38	2841	UMa	G-Sb	09 18.6	+51 12	9.3	6.4 × 2.4	classic elongated spiral; very bright
39	2985	UMa	G-Sb	09 46.0	+72 31	10.6	5.5 × 5.0	near M81 and M82
40	3077	UMa	G-E2p	09 59.4	+68 58	10.9	2.3 × 1.9	small elliptical; companion to M81/82
41	3079	UMa	G-Sb	09 58.6	+55 57	11.2	8.0 × 1.0	edge-on spiral, NGC 2950 nearby
42	3184	UMa	G-Sc	10 15.2	+41 40	9.6	5.6 × 5.6	large, diffuse face-on spiral
43	3675	UMa	G-Sb	11 23.5	+43 52	10.6	4.0 × 1.7	elongated spiral; same field as 56 UMa
44	3877	UMa	G-Sb	11 43.5	+47 46	10.9	4.4 × 0.8	edge-on; same field as Chi UMa
45	3941	UMa	G-Sa	11 50.3	+37 16	9.8	1.8 × 1.2	small, bright, elliptical shape
46	4026	UMa	G-E8	11 56.9	+51 12	10.7	3.6 × 0.7	lens-shaped edge-on; near γ UMa
47	4088	UMa	G-Sc	12 03.0	+50 49	10.9	4.5 × 1.4	nearly edge-on; 4085 in same field
48	4111	UMa	G-S0	12 04.5	+43 21	9.7	3.3 × 0.6	bright, lens-shaped, edge-on spiral
49	4157	UMa	G-Sb	12 08.6	+50 46	11.9	6.5 × 0.8	edge-on, a thin sliver; 4026+4088 nearby
50	4605	UMa	G-Scp	12 37.8	+61 53	9.6	5.0 × 1.2	bright, distinct, edge-on spiral
51	3115	Sex	G-E6	10 02.8	−07 28	9.3	4.0 × 1.2	"Spindle Galaxy"; bright, elongated
52	3242	Hya	PN	10 22.4	−18 23	9.1	40″ × 35″	"Ghost of Jupiter" planetary
53	3344	LMi	G-Sc	10 40.7	+25 11	10.4	7.6 × 6.2	diffuse, face-on spiral
54	3432	LMi	G-Sc	10 49.7	+36 54	11.4	5.8 × 0.8	nearly edge-on; faint flat streak
55	2903	Leo	G-Sb	09 29.3	+21 44	9.1	11.0 × 4.6	very bright, large elongated spiral
56	3384	Leo	G-E7	10 45.7	+12 54	10.2	4.4 × 1.4	same field as M105 and NGC 3389
57	3521	Leo	G-Sc	11 03.2	+00 14	9.5	7.0 × 4.0	very bright, large spiral
58	3607	Leo	G-E1	11 14.3	+18 20	9.6	1.7 × 1.5	NGC 3605 and 3608 in same field
59	3628	Leo	G-Sb	11 17.7	+13 53	10.9	12.0 × 1.5	large, edge-on; same field as M65/M66
60	4214	CVn	G-irr	12 13.1	+36 36	10.3	6.6 × 5.8	large irregular galaxy
61	4244	CVn	G-S	12 15.0	+38 05	11.9	14.5 × 1.0	large, distinct, edge-on spiral
62	4449	CVn	G-irr	12 25.8	+44 22	9.2	4.1 × 3.4	bright rectangular shape
63	4490	CVn	G-Sc	12 28.3	+41 55	9.7	5.6 × 2.1	bright spiral; 4485 in same field
64	4631	CVn	G-Sc	12 39.8	+32 49	9.3	12.6 × 1.4	very large, bright, edge-on; no dust lane
65	4656	CVn	G-Sc	12 41.6	+32 26	11.2	19.5 × 2.0	same field as 4631; fainter, smaller
66	5005	CVn	G-Sb	13 08.5	+37 19	9.8	4.4 × 1.7	bright elongated spiral; near α CVn
67	5033	CVn	G-Sb	13 11.2	+36 51	10.3	9.9 × 4.8	large, bright spiral near NGC 5005
68	4274	Com	G-Sb	12 17.4	+29 53	10.8	6.7 × 1.3	NGC 4278 in same field
69	4494	Com	G-E1	12 28.9	+26 03	9.6	1.3 × 1.2	small, bright elliptical
70	4414	Com	G-Sc	12 24.0	+31 30	9.7	3.2 × 1.5	bright spiral; star-like nucleus
71	4559	Com	G-Sc	12 33.5	+28 14	10.6	11.0 × 4.5	large spiral; coarse structure
72	4565	Com	G-Sb	12 33.9	+26 16	10.2	14.4 × 1.2	superb edge-on spiral with dust lane
73	4725	Com	G-Sb	12 48.1	+25 46	8.9	10.0 × 5.5	very bright, large spiral
74	4361	Crv	PN	12 21.9	−18 29	11.4	18″	$12^{m}.8$ central star

No.	NGC	Con	Type	R.A. (1950)	Dec.	m_v	Size	Remarks
75	4216	Vir	G-Sb	12 13.4	+13 25	10.4	7.4 × 0.9	nearly edge-on; two others in field
76	4388	Vir	G-Sb	12 23.3	+12 56	11.7p	5.0 × 0.9	edge-on; near M84 and M86
77	4438	Vir	G-S	12 25.3	+13 17	10.8	8.0 × 3.0	paired with NGC 4435
78	4473	Vir	G-E4	12 27.3	+13 42	10.1	1.6 × 0.9	NGC 4477 in same field
79	4517	Vir	G-Sc	12 29.0	+00 21	12.0	8.9 × 0.8	faint edge-on spiral
80	4526	Vir	G-E7	12 31.6	+07 58	10.9	3.3 × 1.0	between two $7^{m}0$ stars
81	4535	Vir	G-Sc	12 31.8	+08 28	10.4p	6.0 × 4.0	near M49
82	4697	Vir	G-E4	12 46.0	−05 32	9.6	2.2 × 1.4	small, bright elliptical
83	4699	Vir	G-Sa	12 46.5	−08 24	9.3	3.0 × 2.0	small, bright elliptical shape
84	4762	Vir	G-Sa	12 50.4	+11 31	11.0	3.7 × 0.4	flattest galaxy; 4754 in same field
85	5746	Vir	G-Sb	14 42.3	+02 10	10.1	6.3 × 0.8	fine, edge-on spiral near 109 Virginis
86	5907	Dra	G-Sb	15 14.6	+56 31	11.3	11.1 × 0.7	fine, edge-on spiral with dust lane
87	6503	Dra	G-Sb	17 49.9	+70 10	9.6	4.5 × 1.0	bright spiral
88	6543	Dra	PN	17 58.8	+66 38	8.7	22″	luminous blue-green disk
The Summer Sky								
89	6207	Her	G-Sc	16 41.3	+36 56	11.3	2.0 × 1.1	same field as M13 cluster
90	6210	Her	PN	16 42.5	+23 53	9.2	20″ × 13″	very star-like blue planetary
91	6369	Oph	PN	17 26.3	−23 44	9.9	28″	greenish, annular, and circular
92	6572	Oph	PN	18 09.7	+06 50	8.9	16″ × 13″	tiny oval; bright blue
93	6633	Oph	OC	18 25.1	+06 32	4.9	20	wide-field cluster; IC4756 nearby
94	6712	Sct	GC	18 50.3	−08 47	8.9	2.1	small globular near M26
95	6819	Cyg	OC	19 39.6	+40 06	10.1	6	150*; faint but rich cluster
96	6826	Cyg	PN	19 43.4	+50 24	9.4	27″ × 24″	Blinking Planetary Nebula
97	6960	Cyg	SNR	20 43.6	+30 32	—	70 × 6	Veil Nebula (west component)
98	6992–5	Cyg	SNR	20 54.3	+31 30	—	78 × 8	Veil Nebula (east component)
99	7000	Cyg	EN	20 57.0	+44 08	—	120 × 100	North America Neb.; binoc. obj.
100	7027	Cyg	EN	21 05.1	+42 02	10.4	18″ × 11″	very star-like H II region
101	6445	Sgr	PN	17 47.8	−20 00	11.8	38″ × 29″	small, bright and annular; near M23
102	6818	Sgr	PN	19 41.1	−14 17	9.9	22″ × 15″	"Little Gem"; annular; 6822 nearby
103	6802	Vul	OC	19 28.4	+20 10	11.0	3.5	60*; small, faint but rich
104	6940	Vul	OC	20 32.5	+28 08	8.2	20	100*; Type e; rich cluster
105	6939	Cep	OC	20 30.4	+60 28	10.0	5	80*; very rich; 6946 in same field
106	6946	Cep	G-Sc	20 33.9	+59 58	9.7p	9.0 × 7.5	faint, diffuse, face-on spiral
107	7129	Cep	RN	21 42.0	+65 52	—	7 × 7	small faint RN; several stars inv.
108	40	Cep	PN	00 10.2	+72 15	10.5	60″ × 38″	small circular glow; $11^{m}.5$ central star
109	7209	Lac	OC	22 03.2	+46 15	7.6	20	50*; Type d; within Milky Way
110	7243	Lac	OC	22 13.2	+49 38	7.4	20	40*; Type d; within Milky Way
Challenge Objects								
1	246	Cet	PN	00 44.6	−12 09	8.5	240″ × 210″	large and diffuse; deceptively difficult
2	1275	Per	G	03 16.4	+41 20	12.7	0.7 × 0.6	small and faint; exploding gal.; Perseus A
3	1432/35	Tau	RN	03 43.3	+23 42	—	30 × 30	Pleiades nebl'y; brightest around Merope
4	1499	Per	EN	04 00.1	+36 17	—	145 × 40	California Neb.; very large and faint
5	IC434/35/ B33/2023	Ori	E/R/DN	05 38.6	−02 26	—	60/3/10	complex of nebl'y S. of zeta Ori., B33 is famous dark Horsehead Neb.; difficult
6	IC431/32/ NGC 2024	Ori	E/RN	05 39.4	−01 52	—	4/6/30	complex of nebl'y N. of zeta Ori., NGC2024 is easy but masked by glow from zeta.
7	IC 443	Gem	SNR	06 13.9	+22 48	—	27 × 5	v. faint supernova remnant NE. of η Gem.
8	J 900	Gem	PN	06 23.0	+17 49	12.2	12″ × 10″	bright but starlike; oval at high mag.
9	2237/46	Mon	EN	06 29.6	+04 40	—	60	Rosette Neb.; very large; incl. NGC2244
10	2419	Lyn	GC	07 34.8	+39 00	11.5	1.7	most distant known Milky Way GC (2×10^5 l.y.)
11	5897	Lib	GC	15 14.5	−20 50	10.9	7.3	large, but faint and loose globular cl.
12	B 72	Oph	DN	17 21.0	−23 35	—	30	Barnard's dark S-Nebula; RFT needed
13	6781	Aql	PN	19 16.0	+06 26	11.8	106″	pale version of M97; large, fairly bright
14	6791	Lyr	OC	19 19.0	+37 40	11	13	large, faint but very rich cl.; 100+*
15	M1-92	Cyg	RN	19 34.3	+29 27	11	0.2 × 0.1	Footprint Neb.; bright but starlike; double
16	6822	Sgr	G-irr	19 42.1	−14 53	11.0	16.2 × 11.2	Barnard's Gal.; member Local Grp.; faint
17	6888	Cyg	SNR?	20 10.7	+38 16	—	18 × 12	Crescent Neb.; small faint arc near γ Cyg.
18	IC 5146	Cyg	RN	21 51.3	+47 02	—	12 × 12	Cocoon Neb.; faint; at end of long dark neb.
19	7317–20	Peg	G's	22 33.7	+33 42	14–15	—	Stephan's Quintet; ½°SSW. of NGC 7331
20	7635	Cas	EN	23 18.5	+60 54	—	4 × 3	Bubble Neb.; v. faint; ½°SW. of M52

GALAXIES

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 following table contains the positions and catalogue designations of all those galaxies known to have proper names which usually honour the discoverer (Object McLeish), identify the constellation in which the galaxy is found (Fornax A) or describe the galaxy in some easily remembered way (Whirlpool galaxy).

GALAXIES WITH PROPER NAMES

Name/Other	α/δ (1950)
Andromeda Galaxy = M31 = NGC 224	$00^{h}40^{m}.0$ $+41°00'$
Andromeda I	00 43.0 +37 44
Andromeda II	01 13.5 +33 09
Andromeda III	00 32.6 +36 14
Andromeda IV	00 39.8 +40 18
Antennae = NGC 4038/39	11 59.3 −18 35
Barnard's Galaxy = NGC 6822	19 42.1 −14 53
BL Lac	22 01.9 +42 11
Capricorn Dwarf = Pal 13	21 44.0 −21 29
Caraffe Galaxy	04 26.6 −48 01
Carina Dwarf	06 45.1 −51 00
Cartwheel Galaxy	00 35.0 −34 01
Centaurus A = NGC 5128 = Arp 153	13 22.5 −42 46
Circinus Galaxy	14 09.3 −65 06
Copeland Septet = NGC 3745/54 = Arp 370	11 35.1 +22 18
Cygnus A	19 57.7 +40 36
Draco Dwarf = DDO 208	17 19.2 +57 58
Fath 703	15 11.0 −15 17
Fornax A = NGC 1316	03 20.8 −37 23
Fornax Dwarf	02 37.8 −34 44
Fourçade-Figueroa Object	13 32.4 −33 38
GR8 (Gibson Reaves) = DDO 155	12 56.2 +14 29
Hardcastle Nebula	13 10.2 −32 26
Hercules A	16 48.7 +05 06
Holmberg I = DDO 63	09 36.0 +71 25
Holmberg II = DDO 50 = Arp 268	08 13.7 +70 52
Holmberg III	$09^{h}09^{m}.6$ $+74°26'$
Holmberg IV = DDO 185	13 52.8 +54 09
Holmberg V	13 38.8 +54 35
Holmberg VI = NGC 1325 A	03 22.6 −21 31
Holmberg VII = DDO 137	12 33.2 +06 35
Holmberg VIII = DDO 166	13 11.0 +36 29
Holmberg IX = DDO 66	09 53.5 +69 17
Hydra A	09 15.7 −11 53
Keenan's System = NGC 5216/18 = Arp 104	13 31.1 +62 52
Large Magellanic Cloud	05 24.0 −69 48
Leo I = Harrington-Wilson #1 = Regulus Dwarf = DDO 74	10 05.8 +12 33
Leo II = Harrington-Wilson #2 = Leo B = DDO 93	11 10.8 +22 26
Leo A = Leo III = DDO 69	09 56.5 +30 59
Lindsay-Shapley Ring	06 44.4 −74 11
McLeish's Object	20 05.0 −66 22
Maffei I	02 32.6 +59 26
Maffei II	02 38.1 +59 23
Mayall's Object = Arp 148 = VV32	11 01.1 +41 07
Mice = NGC 4676 = Arp 242	12 44.7 +30 54
Pegasus Dwarf = DDO 216	23 26.0 +14 28
Perseus A = NGC 1275	03 16.5 +41 20
Pinwheel Galaxy = M101 = NGC 5457	14 01.5 +54 36
Regulus Dwarf = Leo I = DDO 74	10 05.8 +12 33
Reticulum Dwarf	04 35.4 −58 56
Reinmuth 80 = NGC 4517 A	00 57.6 −33 58
Seashell Galaxy	13 44.5 −30 10

Name/Other	α/δ (1950)	Name/Other	α/δ (1950)
Serpens Dwarf	$15^h13^m.5$ +00°03′	Triangulum Galaxy = M33 = NGC 598	$01^h31^m.0$ +30°24′
Seyfert's Sextet = NGC 6027 A–D	15 57.0 +20 54	Ursa Minor Dwarf = DDO 199	15 08.2 +67 23
Sextans A = DDO 75	10 08.6 −04 28	Virgo A = M87 = NGC 4486 = Arp 152	12 28.3 +12 40
Sextans B = DDO 70	09 57.4 +05 34	Whirlpool Galaxy = M51 = NGC 5194	13 27.8 +47 27
Sextans C	10 03.0 +00 19	Wild's Triplet = Arp 248	11 44.2 −03 33
Small Magellanic Cloud	00 51.0 −73 06	Wolf-Lundmark-Melotte = DDO 221	23 59.4 −15 44
Sombrero Galaxy = M104 = NGC 4594	12 37.6 −11 21	Zwicky No. 2 = DDO 105	11 55.9 +38 21
Spindle Galaxy = NGC 3115	10 02.8 −07 28	Zwicky's Triplet = Arp 103	16 48.0 +45 33
Stephans Quintet = NGC 7317-20 = Arp 319	22 33.7 +33 42		

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	Sϕ/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

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 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.

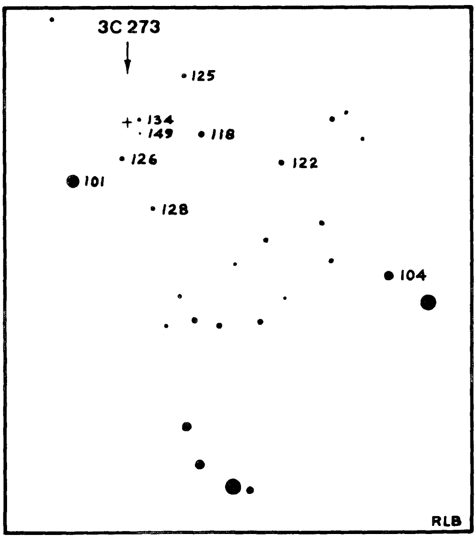
*Important but weak or sporadic radio source. Mean flux density ≲1 flux unit.

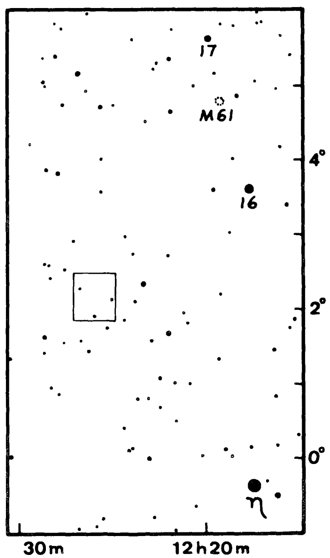
VARIABLE GALAXIES

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		Dec.		Mag.
		h	m	°	′	
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





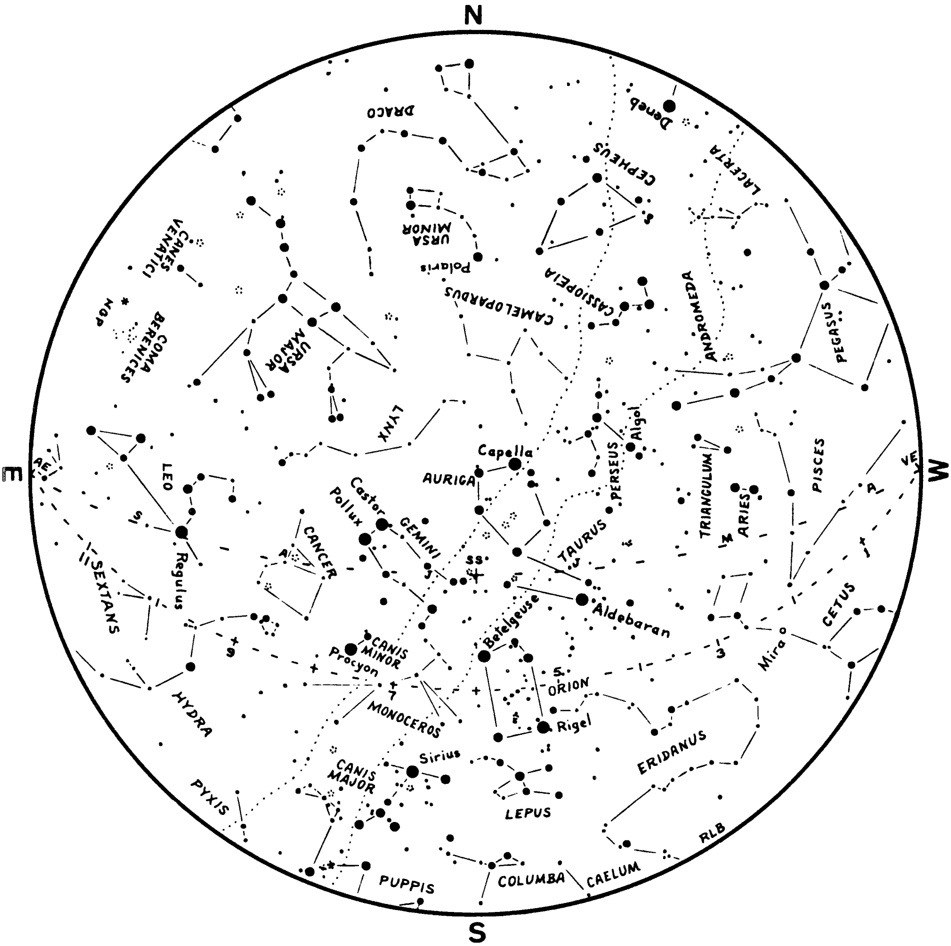
MAPS OF THE NIGHT SKY

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.

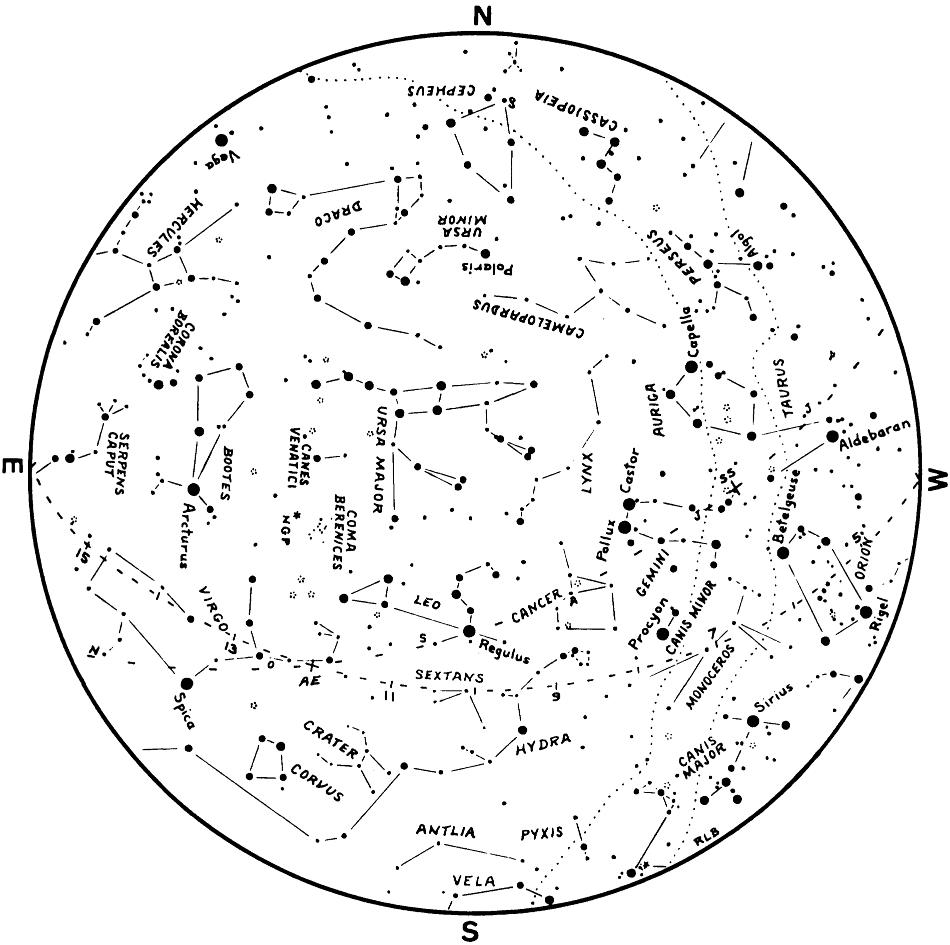
The first six maps are drawn for 45° N latitude, but are useful for latitudes several degrees north or south of this. They show the hemisphere of sky visible to an observer at various times of year. Because the aspect of the night sky changes continuously with both longitude and time, while time zones 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.

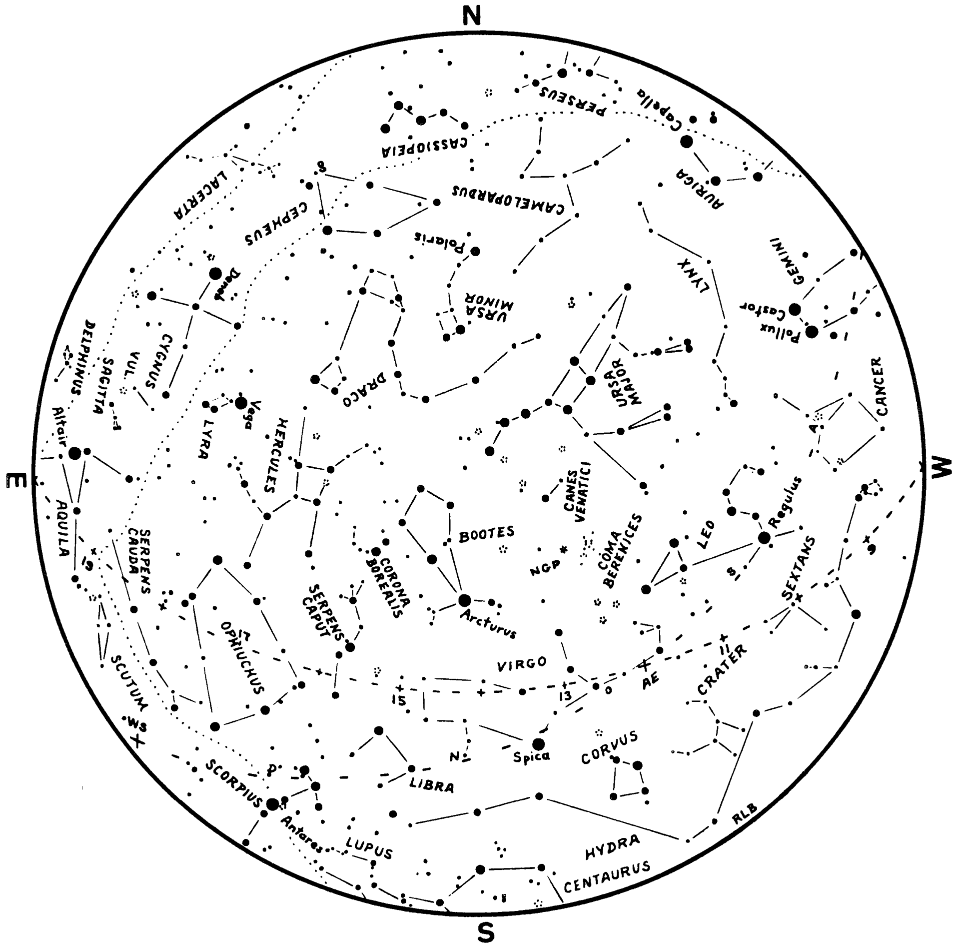
On all seven maps, stars forming the usual constellation patterns are linked by straight lines, constellation names being given in upper case letters. Three constellations (Horologium, Mensa, and Microscopium) consist of faint stars; hence no patterns are indicated and the names are placed in parentheses. 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
W
DRACO
Deneb
CEPHEUS
LACERTA
URSA MINOR
Polaris
CANES VENATICI
COMA BERENICES
URSA MAJOR
CAMELOPARDUS
CASSIOPEIA
ANDROMEDA
PEGASUS
LYNX
Algol
PERSEUS
TRIANGULUM
PISCES
ARIES
Capella
AURIGA
LEO
Castor
Pollux
GEMINI
CANCER
TAURUS
SEXTANS
Regulus
Aldebaran
CETUS
Betelgeuse
Mira
CANIS MINOR
Procyon
ORION
HYDRA
MONOCEROS
Rigel
ERIDANUS
Sirius
CANIS MAJOR
LEPUS
PYXIS
PUPPIS
COLUMBA
CAELUM
RLB

JANUARY


N
S
E
W
CEPHEUS
CASSIOPEIA
Vega
DRACO
URSA MINOR
Polaris
HERCULES
PERSEUS
Algol
CAMELOPARDUS
CORONA BOREALIS
Capella
TAURUS
AURIGA
URSA MAJOR
CANES VENATICI
SERPENS CAPUT
BOOTES
Aldebaran
LYNX
Castor
Arcturus
NGP
COMA BERENICES
Pollux
GEMINI
Betelgeuse
ORION
VIRGO
LEO
CANCER
Procyon
CANIS MINOR
Rigel
Regulus
MONOCEROS
SEXTANS
AE
Spica
Sirius
CRATER
HYDRA
CORVUS
CANIS MAJOR
ANTLIA
PYXIS
RLB
VELA

MARCH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Capella
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LACERTA
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GEMINI
Castor
Pollux
URSA MINOR
Deneb
CYGNUS
DELPHINUS
SAGITTA
VUL.
DRACO
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CANCER
Vega
LYRA
HERCULES
Altair
AQUILA
CANES VENATICI
BOOTES
LEO
Regulus
SERPENS CAUDA
CORONA BOREALIS
NGP
COMA BERENICES
SEXTANS
OPHIUCHUS
SERPENS CAPUT
Arcturus
VIRGO
AE
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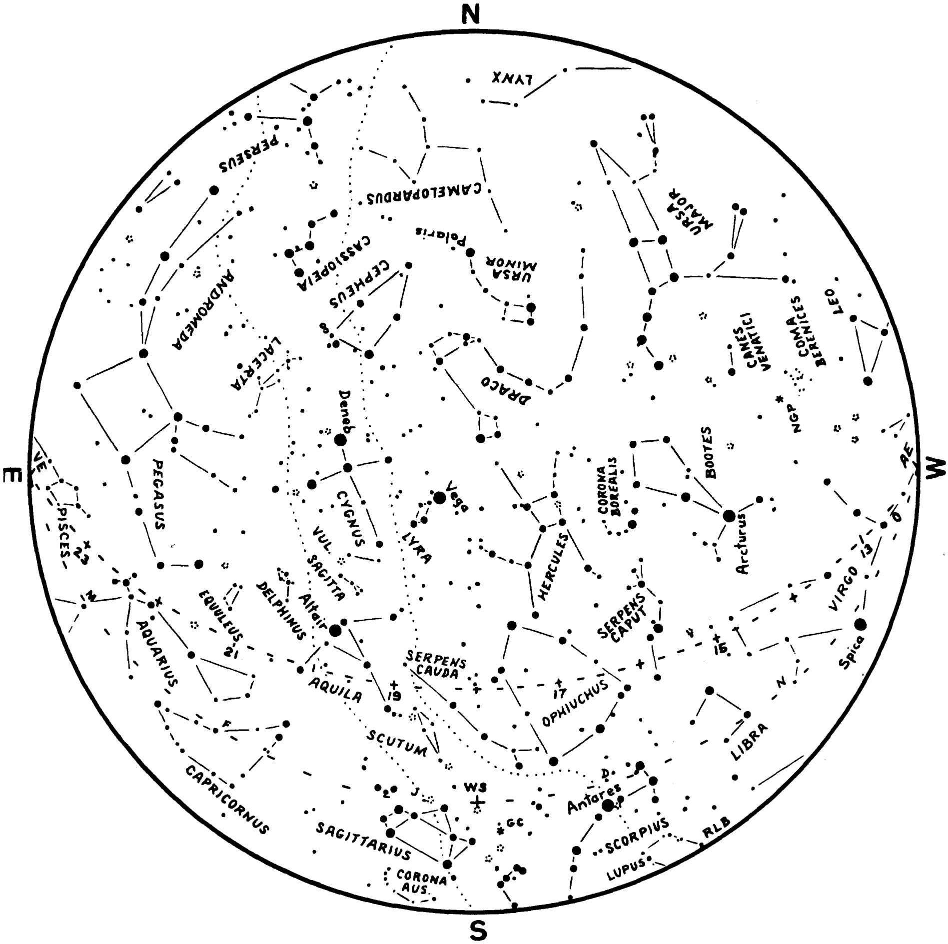
CENTAURUS

MAY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Spica
AQUARIUS
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AQUILA
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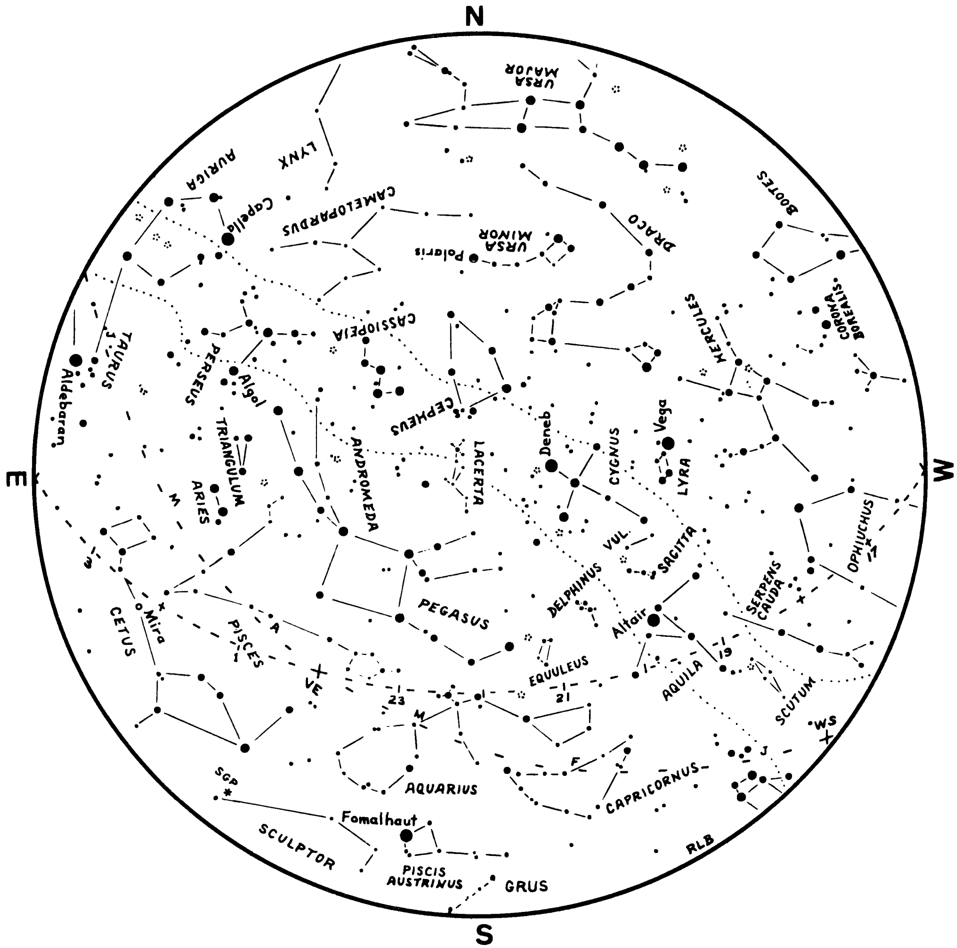
JULY



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Aldebaran
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PEGASUS
SERPENS CAUDA
Altair
CETUS
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SGP
Fomalhaut
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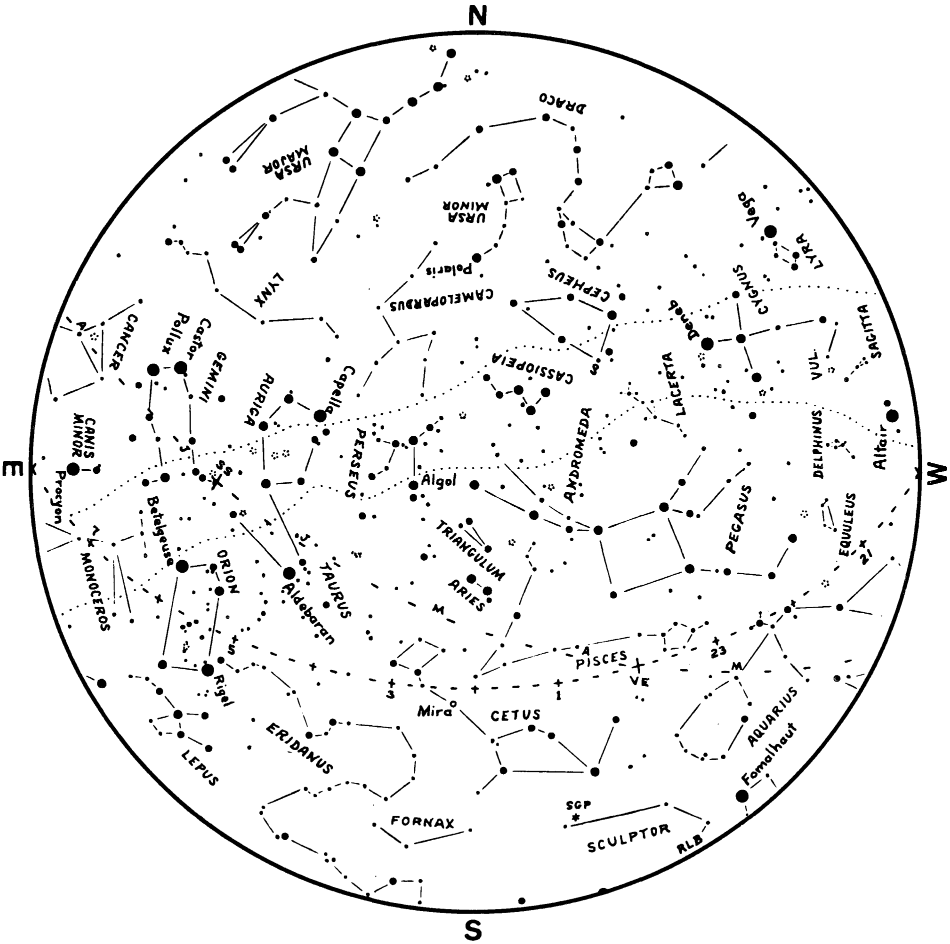
PISCIS AUSTRINUS
GRUS
RLB

SEPTEMBER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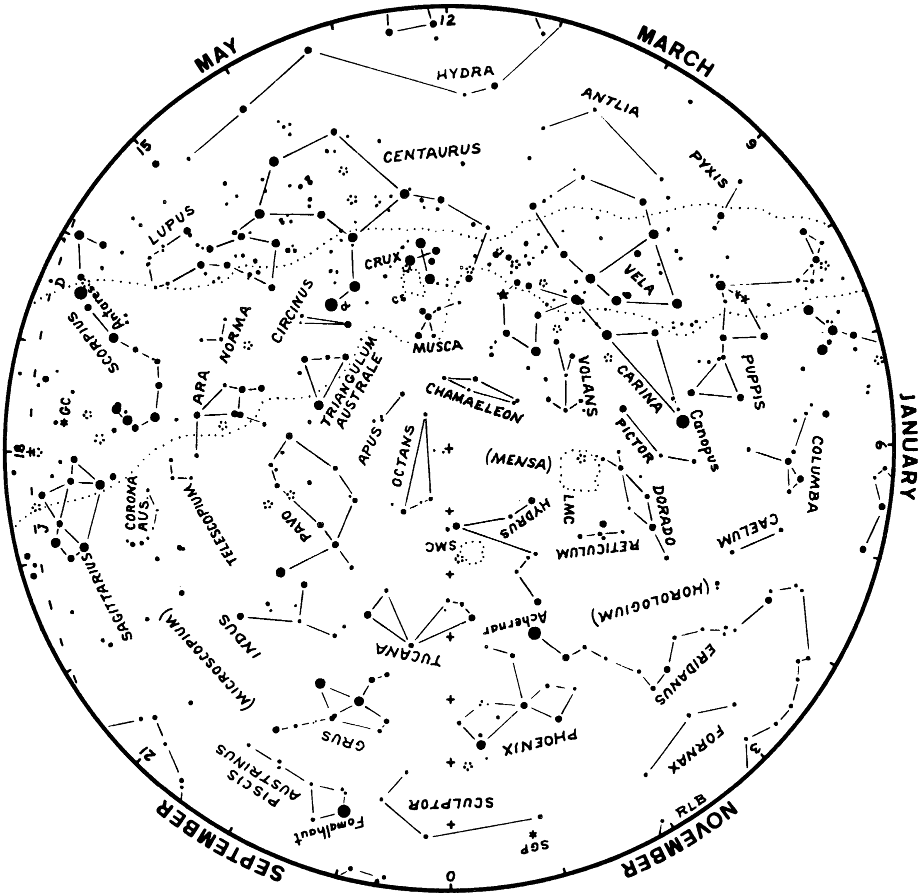
NOVEMBER



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 1988

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

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					

March

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13	14	15	16	17	18	19
20	21	22	23	24	25	26
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April

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May

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June

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July

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24	25	26	27	28	29	30
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August

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September

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October

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30	31					

November

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December

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18	19	20	21	22	23	24
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CALENDAR 1989

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29	30	31				

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March

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