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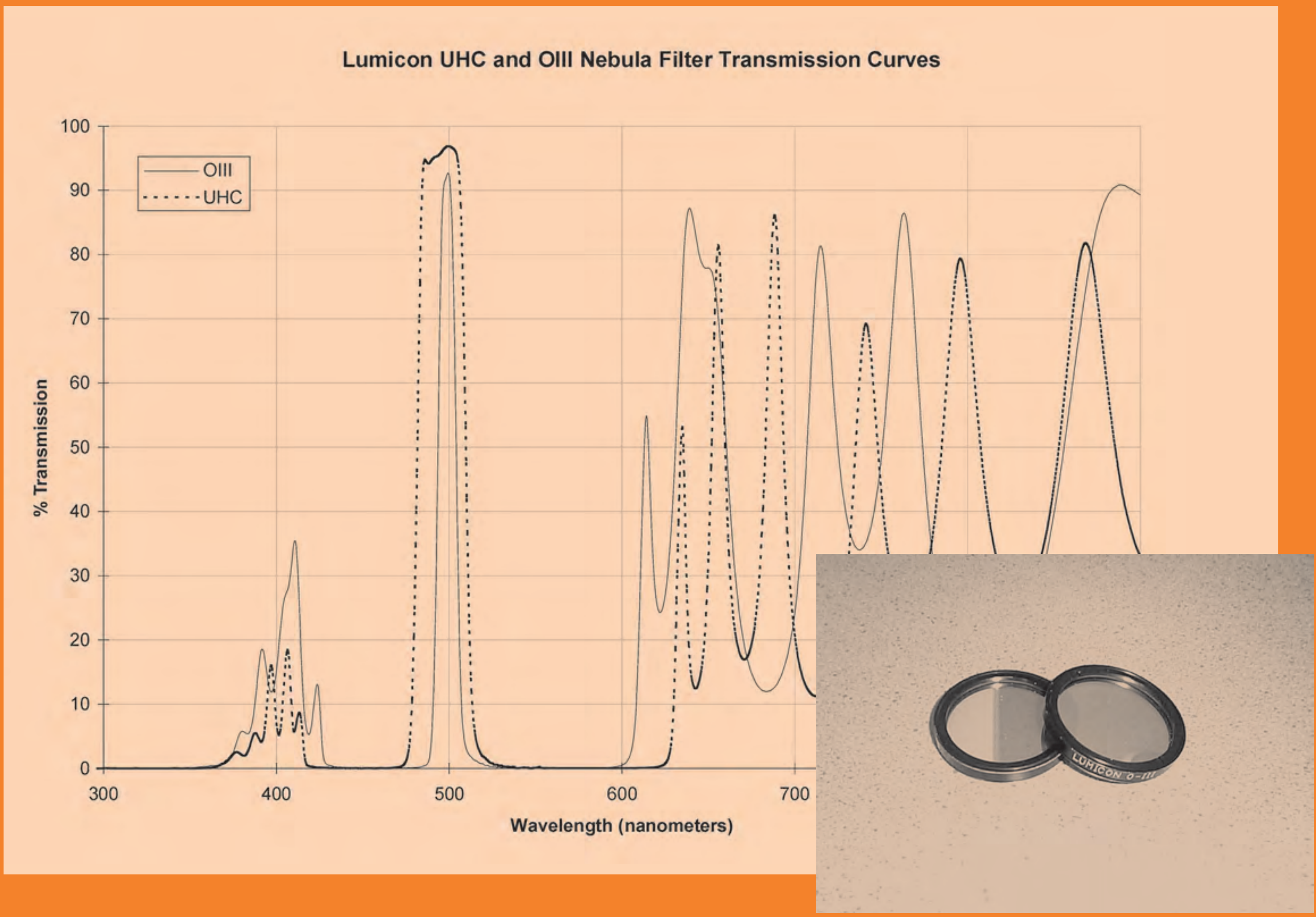


INSIDE THIS ISSUE

Deep Sky Filters · Observing Omega Centauri · Grinding Up Comets

Shooting Lunar Rays · Mini-Messier List

April/avril / 2001

Journal

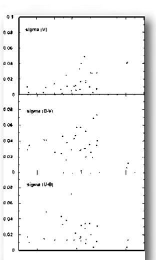
Vol. 95, No. 2 Whole Number 687

contents
table des matières

FEATURE ARTICLES/ARTICLES DE FOND

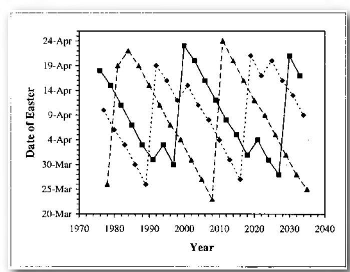
RESEARCH PAPERS/ARTICLES DE RECHERCHE

Shooting Lunar Rays
p. 79



Broadband Photometry of Northern-Hemisphere Luminous Stars. VI. UBV Photometry for 62 Case-Hamburg Stars
p. 64

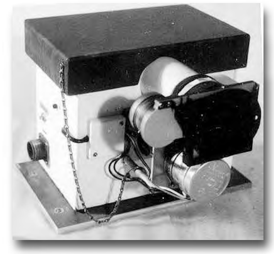
COLUMNS/RUBRIQUES



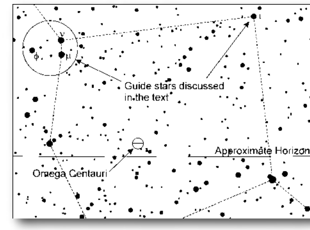
Orbital Oddities
p. 72

Reflections
p. 60

Reviews
p. 85



Correspondence
p.49



Observing Omega Centauri from Canada
p.70

DEPARTMENTS/DÉPARTEMENTS

AstroCryptic Answers p. 87

ACROSS THE RASC
DU NOUVEAU DANS LES CENTRES

Amateur Eyepieces Compared
p. 58

Cover:
The transmission curves of Lumicon UHC and O III filters were traced using a spectrophotometer in the Department of Chemistry at Saint Mary's University. See *Deep Sky Filters*
p. 55

President's Corner

by Robert F. Garrison (garrison@astro.utoronto.ca)

Teachers are important in our lives. It seems strange to me that some provincial governments are attacking them instead of supporting them. Good teachers often appear at pivotal points in life and can inspire major changes in personal and academic directions. The key challenge for students, of course, is to recognize exceptional teachers and to use every opportunity to experience their wisdom.

When I give a public talk, a question frequently asked is: "How did you decide to become a professional astronomer?" For me, the answer is simple: "I had teachers whose passion for the subject was so strong that it spilled over and infected their students." That infection was especially contagious to those who were already primed with good backgrounds in mathematics and science.

In second grade, there was Miss Hunger, who talked about stars with affection, and in sixth grade, Miss Grandy, a highly respected educator who taught geometry as a subject that was worth learning. Mr. Hoffenrichter was a secondary-school teacher whose charming humility combined with a deep passion for mathematics and chemistry was contagious, so much so that when I finished high school, I planned to be a chemist. Those plans ended abruptly when I took the first-year chemistry course in college from a teacher so boring that I decided chemistry was not something I wanted to do for a lifetime. The physics teachers were competent but uninspired, so I turned to mathematics because, at least, the subject itself was beautiful. It was hierarchical and would provide a good platform for branching into any of the sciences. At that point, I was only vaguely aware of astronomy as a field of study.

It was in my second year at Earlham, a small Quaker college in east-central Indiana, that I started on a passionate path to astronomy, guided by a sequence of truly great and inspired teachers. Clifford C. Crump was a retired astronomer, who had worked at Yerkes Observatory and whose career highlight had been as Director of Perkins Observatory (a 69-inch telescope at Ohio State University). He came to the college every day but only taught one or two courses. The real inspiration was at lunch. He would sit at the back table of the cafeteria and tell anecdotal stories about astronomy and astronomers to a group of a half dozen or so students. He knew Hubble as a friend and most of the other famous astronomers of the first half of the twentieth century well enough to tell stories about them. He was a good storyteller and gave astronomy a human face. He invited Harlow Shapley, an old man by the late 1950s, to spend several days at the college and to give a few lectures. Shapley joined us at the lunch table and took over the storytelling, at which he was a master. By this time, I began to suspect that astronomy would play an important role in my life. In my third

Journal

The *Journal* is a bi-monthly publication of the Royal Astronomical Society of Canada and is devoted to the advancement of astronomy and allied sciences. It contains articles on Canadian astronomers and current activities of the RASC and its centres, research and review papers by professional and amateur astronomers, and articles of a historical, biographical, or educational nature of general interest to the astronomical community. All contributions are welcome, but the editors reserve the right to edit material prior to publication. Research papers are reviewed prior to publication, and professional astronomers with institutional affiliations are asked to pay publication charges of $100 per page. Such charges are waived for RASC members who do not have access to professional funds as well as for solicited articles. Manuscripts and other submitted material may be in English or French, and should be sent to the Editor-in-Chief.

The *Journal of The Royal Astronomical Society of Canada* is published at an annual subscription rate of $80.00 by The Royal Astronomical Society of Canada. Membership, which includes the publications (for personal use), is open to anyone interested in astronomy. Annual fees for 2001, $40.00; life membership is $800. Applications for subscriptions to the *Journal* or membership in the RASC, and information on how to acquire back issues of the *Journal* can be obtained from:

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year, I did a special research course, which involved observing every clear night using the college's six-inch refractor, an ancient instrument made by Alvin Clarke. It was cold and the telescope was old and cranky, but it was exciting. That clinched it. I had found my passionate path, illuminated by a couple of old, retired astronomers with good stories to tell. About ten Ph.D. astronomers, still active today, started from that lunch table. The list includes Ed Churchwell, Nat White, and Susan Simkin, all from a small school and comprising about half of all the physics graduates of those few years.

The rest is history, so to speak, to be told in another time and place. There were more good, influential teachers in my time in graduate school, including W.W. Morgan, Margaret Burbidge, Don Osterbrock, Subramanyan Chandrasekhar, and others. The point of all this is that good teachers can make a difference, and the RASC's mandate to promote astronomy fits right in. John Percy (a former President of the RASC) has a grant for education and public outreach, and the RASC is identified specifically as one of the groups most active and most successful in public education and outreach. I will say more about that next issue. In the meantime, keep up the good work; it does make a difference.

Editorial

by Wayne A. Barkhouse, Editor-in-Chief (barkhous@astro.utoronto.ca)

Today we stand at a crossroads regarding the future of Canadian astronomy. The Long Range Planning Panel (LRPP), a coalition of academia whose purpose was to map out the course of astronomy in Canada, has completed its job (see `www.casca.ca` for more details). After many months of hard work, including the active solicitation of input from astronomers from coast-to-coast, the LRPP's recommendations are now in the hands of the federal government. With the return to a budget surplus, despite the fact that this country has a large debt, the time is now right for the government to make an investment in the future of science and technology in Canada.

The future of astronomy will move forward regardless of what the government decides — it is just a question of whether we as a nation will be at the forefront of its development. Many new, exciting projects are now being built or in the planning stage and Canada is in a great position to become involved at the grass roots level. Instruments, such as the Atacama Large Millimeter Array (ALMA), Square Kilometer Array (SKA), Next Generation Space Telescope, and large optical/infrared telescopes, will lead the way to the new "high ground" in astronomical research for decades to come. Making sure that we are part of this new initiative should be given the highest priority. I would encourage all of you to make an effort to contact your member of Parliament and let them know how important it is for Canada to be part of this new undertaking.

One of my favorite possibilities is the construction of a large (20 to 30 metre) optical/infrared telescope. Gone are the days when the 5-metre Palomar telescope was considered to be at the limit of our engineering abilities. With advances made in mirror fabrication and active computer controlled optics, we are now able to seriously contemplate the construction of very large telescopes. The European Southern Observatory is studying the possibility of constructing a 100-metre diameter telescope, appropriately named the Overwhelmingly Large Telescope (OWL). This telescope will stretch our engineering skills to the limit, as well as requiring a very deep pocketbook (`www.eso.org/projects/owl`).

At the present time, Canada has a nearly 50% share of the 3.6-metre Canada-France-Hawaii Telescope (CFHT) on Mauna Kea, Hawaii. This telescope will be optimized for wide-field imaging in the era of 8-metre telescopes (Canada has a share of the twin Gemini 8-metre telescopes). Eventually the CFHT will be superseded by larger aperture telescopes. Now is the time to think about a replacement for the CFHT (whether that involves replacing the CFHT with a much larger telescope at the same location or moving to an entirely different area is up for debate). A recent amendment to the LRPP report has addressed the need for Canada to become involved in a large optical telescope project of 20 to 30 metres in diameter.

If the funding becomes available for the highest priority targets recommended by the LRPP, Canada will have a secure footing in the advancement of astronomy and astrophysics in the foreseeable future. The alternative will be to watch things progress from the outside as our young scientists leave the country for greener pastures elsewhere.

With this issue of the *Journal* we are introducing a new addition. We will be publishing the abstracts of successfully defended astronomy-related MSc. and Ph.d theses from Canadian institutions. This free service is being offered as a way of helping to inform the astronomical community of the research being conducted in Canada. I encourage all of you to submit your abstracts to the contact person listed in the "Canadian Thesis Abstracts" section. I hope readers will enjoy this new addition to the *Journal*.

Correspondence
Correspondance

LIFE MEMBER HONOURED

News follows about one of our Life Members, Dr. William Tutte, from the University of Waterloo website, February 15. Now 80 years old, he is a Professor Emeritus at the University.

The government announced the appointments yesterday among 98 new Companions, Officers and Members of the Order of Canada. The appointments are retroactive to November 15, 2000. William T. Tutte was honoured not just for his work as a teacher and theoretical mathematician, but for his contributions to breaking German codes for the British armed forces during World War II. That work led to a lifelong interest in cryptography, and Tutte is now honorary director of the UW Centre for Cryptographic Research. In a citation for the CRM-Fields Institute Prize in mathematics a few weeks ago, colleagues said of Tutte that "In graph theory he established fundamental results for matching, connectivity, symmetry in graphs, reconstruction, colouring, Hamiltonian circuits, graphs on higher surfaces, graph enumeration and graph polynomials. In matroid theory, he is the single most important pioneer." He becomes an Officer of the Order of Canada.

INVITATION TO THE 2001 GENERAL ASSEMBLY

Canada's Forest City, London, Ontario, will be the location of the Society's 42nd General Assembly (GA) over the Canada Day weekend, and you are all most cordially invited to attend.

The GA is a traditional highlight of the astronomical calendar, an opportunity to meet and to manifest our enthusiasm with members from across the country and even around the world. The social aspect of the event is also not to be overlooked; Peter Broughton wrote in *Looking Up* that participants end up "exhilarated but exhausted."

The avant-GA begins with observing nights Monday, June 25, to Wednesday, June 27, weather permitting, at the dark site near Fingal. There will be an open house at the Hume Cronyn Observatory on campus at the University of Western Ontario on Thursday evening, June 28. Accommodation for the duration of the GA will be offered at the new residence of Fanshawe College.

All GA weekend events will be held at Fanshawe College. Friday, the National Council will meet. Meanwhile, a workshop on teaching astronomy to young persons will take place. In the evening, there will be a barbecue and a movie. Saturday's events include workshops, the Ruth J. Northcott Lecture, the group photo and the annual banquet. The Society's formal Annual Meeting and the follow-up National Council meeting will be held on Sunday, along with vendors' displays and a swap meet. A "search-and-answer" contest is being organized which will conclude on Sunday evening. The GA concludes with a winery tour on Monday, July 2. As much as possible, situations will be arranged so that families can participate.

The Guests of Honour for Saturday's workshops include William K. Hartmann, J. A. "Triple" Nickle, David H. Levy, Pete Ceravolo, Robert Jedicke and Steven James O'Meara. All will be introduced at a plenary session prior to the assembly moving into a workshop format. Each of the Guests of Honour will discuss their work, expertise and experience with the participants at length. Bill Hartmann, astronomer, author and artist, will deliver the Northcott Lecture, "Mars and Monet: Artists on the Space Frontier."

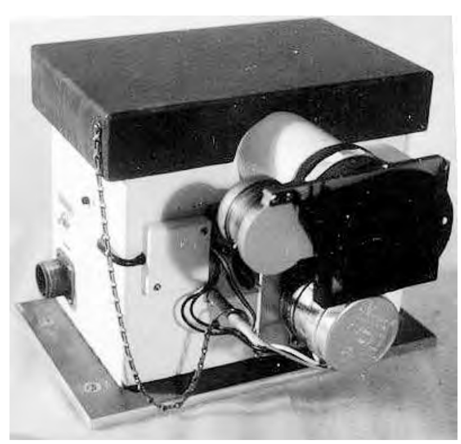
The price of full registration is $110 (all fees are in Canadian dollars), and residence prices are based on $70 per room per night. Companion registration is $40. (A spouse or life partner or child is considered a companion.) Registration for a single day is $50. Registration and accommodation prices rise after May 14. The banquet price is $35 per person or $65 per couple, the barbecue is $15, lunches are $10 each, the winery tour price is $30. There is a price of $10 for the observing sessions and $5 for the Cronyn open house.

All registration information and confirmation will be handled over the Internet, through our website, `www.rasc.ca/ga2001`, or our email address, `ga2001@rasc.ca`. A member who cannot access the Internet can write to the RASC London Centre, P.O. Box 842, Station B, London, ON, N6A 4Z3, or call the Society's toll-free number, 1-888-924-7272. The appropriate web page will be printed out and mailed to them. Payment should be sent by cheque or money order via postal mail to the London Centre postal address.

Every effort will be made to ensure that participants find the London GA a congenial and enlightened event. We're looking forward to seeing you!

WANTED: SURPLUS MORP METEOR PATROL CAMERA

I am looking for a surplus Meteorite Observation and Recovery Project camera for a special project. These cameras were used by the MORP meteor patrol from 1971 to March 31, 1985. Sixty cameras were deployed across the Prairie provinces



to provide meteor flux rates and fireball tracking. One camera is located at the Canadian Science and Technology Museum in Ottawa, Ontario. The others, I am told, were probably turned over to Crown Assets for disposal after this program was sadly shut down (See the attached photograph).

There were two versions of this camera; the earlier model was built by SPAR Aerospace, and the later version by Hulcher in Virginia, U.S.A. They used an f/3.5–50 mm focal length Super Komora wide-angle lens using 70 mm roll film.

There was a sectored chopping shutter near the focal plane, which chopped up the meteor trail for velocity measurements. This rotating shutter had three equal sectors, clear, ND-3 and ND-5 parts. The neutral density sections were used to reduce the intensity of a very bright fireball so the shutter breaks could more readily be measured.

I am interested in obtaining one of these sectored chopping shutters in good condition so I can incorporate it into a fireball patrol camera that a friend of mine, John Purdy, and I have made.

My observatory is part of the Sandia Bolide Detection Network deployed along Vancouver Island and northern Washington State. See; www.amsmeteors.org/spectro.html for a photo of my observatory and a Sandia video patrol camera mounted on the roof. Follow the link to the fireball patrol network.

A similar looking camera has been built using film instead of a video camera. The video system is not sensitive enough to record background stars, which are required for accurate elevation measurements of a fireball. The film camera will record star trails for this purpose.

If you have or know where I can get or find a MORP camera please drop me an email at epmajden@home.com.

As an amateur meteor spectroscopist I am also looking for used but good condition blazed replica transmission gratings, 200 g/mm to 600 g/mm blazed for the visual region of the spectrum. If you have one to spare I would be most happy to take it off your hands.

Ed Majden, Victoria Centre,
Courtenay, B.C.

INTERNATIONAL ASTRONOMICAL YOUTH CAMP 2001

The International Astronomical Youth Camp (IAYC) 2001 will take place in Tolmin, a small Slovene village close to the Italian border. It is situated in the picturesque valley of the Soca River, at the edge of the Triglav National Park, and surrounded by the Julian Alps.

The IAYC is an international youth camp (ages 16 to 24) with participants from 20 different countries. As a participant, you work for three weeks in one of the 7 working groups — together with other young people — on astronomical projects. In IAYC 2001, we offer working groups which study the following topics: Matter, Astrophysics, Celestial Mechanics, Sky Imaging, Physics of Astronomy, Astrochemistry, and Deep Sky Observations.

For further information, see www.iayc.org.

News Notes
En Manchettes

MAJOR BOOST FOR CANADIAN SOLAR SYSTEM RESEARCH

Canadian Research Chairs and a Canadian Foundation for Innovation (CFI) infrastructure grant have recently been awarded to Dr. Peter Brown (University of Western Ontario) and Dr. Alan Hilderbrand (University of Calgary). The awards will enable the recipients to continue and hopefully expand upon their research efforts with respect to some of the smaller objects within our Solar System. One of the major goals of the research to be carried out is to characterize and better understand the origin and nature of the metre-sized asteroids that occasionally plow into the Earth's upper atmosphere.

As the holder of a Canada Research Chair, Dr. Brown in particular intends to continue investigating the physical structure and orbital characteristics of large meteoroids — especially the ones large enough to produce meteorites. He plans to develop computer models to determine how they might be distributed throughout the Solar System. And he'll use radar, sound, and satellite data to document actual examples of large objects arriving on earth.

The research to be conducted by Brown will provide more reliable estimates of the number of large meteoroids travelling near to the Earth's orbit, and consequently to constrain the probabilities of ground impacts. Brown also expects to measure the energy released in the form of sound and light as those meteors enter the atmosphere and strike the Earth. In this context, he plans to consider the question that asks, "just how large should meteoroids actually be in order to cause significant damage upon striking the ground?"

The infrastructure grant awarded by the Canadian Foundation for Innovations to Brown and Hilderbrand amounts to some one-half million dollars and will be used to fund several Solar System research projects. A Canada-based telescopic survey of Near Earth Asteroids will be funded and monies will also be directed towards the development of a fireball detection camera network. Some of the CFI funds will also be used to establish a permanent storage facility for the highly important and very rare Tagish Lake meteorite that fell in Northern B.C. last year.

UNIVERSITY OF VICTORIA ASTRONOMERS RECEIVE FUNDS FOR COMPUTATIONAL COSMOLOGY

University of Victoria astronomers must be counting their lucky stars as well as their hard-earned dollars. UVic cosmologists have recently received a grant of $480,000 from Natural Sciences and Engineering Research Council (NSERC). To top it off, the group also received at total of $272,000 in cash and stock options from the largest-ever, private donation to a Canadian research group.

The NSERC grant was intended to jump-start Canadian-based research into the burgeoning field of computational cosmology. This branch of astronomy attempts to produce computer simulations of the large-scale evolution of galaxies and the Universe itself. This particular research effort is lead by UVic astronomers Dr. Arif Babul and Dr. Julio Navarro, plus Dr. Hugh Couchman of McMaster University in Hamilton. The project has been dubbed the Canadian Computational Cosmology Collaboration or C4. The group will be using UVic's new "Minerva" supercomputer — currently the most powerful computer in Canadian academic research. As well, additional parallel computing power is provided by an ingenious system of 40 standard desktop computers nicknamed "Beowulf". In such a parallel computing architecture each individual desktop computer works on separate problems at the same time, dramatically increasing the overall computing speed. Together the researchers and their computers hope to simulate different galaxies and clusters of galaxies seen through such instruments as the Hubble Space Telescope.

The private donation arrived as an early Christmas present on December 22, 2000. John Criswick, a software developer raised in Victoria and now working in Ottawa, made the record donation. Criswick made his fortune designing "Impact" one of the first Java-based Web browsers for cell phones and other wireless devices. He sold his company, and his idea, to Sun Microsystems in 1998. Like many in the high tech industry, Criswick is a scientific polymath. He developed a love for astronomy during his studies at the University of Victoria. He then studied space physics at York University, and eventually found work applying the electrical engineering degree he received from UBC.

Nearly 30 per cent of the donation ($80,000) will go towards astronomy student bursaries and student travel subsidies. According to Babul, "With possible matching funds from government granting agencies, John's gift can be leveraged to secure nearly $1 million for our planned national Institute for Cosmological Science."

ASTRONOMY ON THE WEB — PART 1

by Les Dickson (lcdickson@sk.sympatico.ca)

Introduction

The Internet and the World Wide Web (WWW) interface have made available to the professional and amateur astronomer alike a wealth of resources easily available from just about any personal computer. However, finding the most useful and relevant information is very difficult, even with the help of sophisticated search engines. In the course of using the Web to conduct research into topics on which to base presentations given at Centre meetings and star parties, I have compiled my own highly personal and idiosyncratic list of useful Web sites that I would like to share with you. This article is in two parts. Part 1 presents an overview of astronomical resources available on the Web, organized into three main areas: Web Portals, Web Directories, and Webrings; General Astronomy Sites for Young and Old; and Image Galleries. Part 2 will focus on doing astronomy over the Internet by using robotic telescopes and remote access observatories that are available to both amateur and professional astronomers.

Web Portals, Web Directories, and Webrings

The *Yahoo* site is a Web portal and Web indexing service that combines a search engine with an extensive subject index of pages on the Web. You can search for "astronomy" using *Yahoo's* search engine, or just go directly to `dir.yahoo.com/Science/Astronomy/`, which has over 30 different subject areas, including software, telescopes, and news and media sites, related to astronomy. The *Alta Vista* Web portal indexes the Web much as *Yahoo* does. The site URL is `www.altavista.com`. Follow the links through "Library & Resources," "Sciences," to "Astronomy & Space."

Some of the general-purpose web directories provide more value to the user by ranking sites by relevance and identifying and reviewing a few "best" sites out of thousands on the Web. Two that I find useful are *About.com* and *Links2Go*. *About.com* uses human guides who organize the Web resources by subject and write original articles and reviews. They also host forums and chat rooms and maintain a calendar of events related to the subject. The astronomy-related entries can be found at `space.about.com/education/space/index.htm`. *Links2Go* combines a well-organized index of sites by subject with the identification of "key resources," sites that meet its criterion of being most representative of a given topic, based on the number of links to that site by other Web pages. The best start page for astronomy here is `www.links2go.com/topic/Astronomy`.

There are also specialized Web directories dedicated just to astronomy. Among the best of the lot are the related *Astroweb* and *Starpages* sites located at the University of Strasbourg. *Astroweb* maintains a database of over 2970 sites related to professional and amateur astronomy. It can be found at `www.stsci.edu/astroweb/astronomy.html`. *Starpages* lists over 6200 links to organizations, institutions, associations and companies, and over 5500 personal Web pages maintained by professional and amateur astronomers. Its location is `cdsweb.u-strasbg.fr/~heck/spages.htm`.

Webrings are Web sites related by common interests that are connected to each other by circles of links. Within each Webring, you can easily go to the next link, visit a site at random, or see a directory of all the sites within the ring. The master site for all Webrings is *Webrings.com* at `www.webring.com`. If you search for astronomy-related sites, you will be presented with a list of over 48 different rings. One interesting ring is "The RASC Member Home Page's Webring," which links many of the home sites of members of the *Royal Astronomical Society of Canada* and affiliated centres across Canada.

General Astronomy Sites For Young and Old

One of the best general astronomy sites on the Web is the *Astronomy Café*, to be found at `itss.raytheon.com/cafe/cafe.html`. This site is run by Dr. Sten Odenwald, an astrophysicist and Chief

Scientist with Raytheon Corp. at the NASA Goddard Space Flight Centre, and the Public Outreach Manager for the NASA *IMAGE* satellite program. Odenwald describes his site as "the Web site for the astronomically disadvantaged." Two main sections of his site are "Ask the Astronomer" and "Ask the Space Scientist." He claims to answer over 40 questions posted to his site each day, and has posted answers for over 3000 questions so far. Many of his answers, each of which are mini-essays or FAQs, are accompanied by links to other sites that provide background information and interesting sidebars on the topic in question.

"There are also specialized Web directories dedicated just to astronomy. Among the best of the lot are the related Astroweb and Starpages sites located at the University of Strasbourg."

A similar site is run by *Dr. Sky* (`www.drsky.com`), aka Steven R. Kates, a columnist and speaker on astronomy, and an on-air host of a radio program on astronomy. The site has an image gallery, stories archives, media clips, and a selection of astronomical links in its Reference Lab. As I write this, I am listening to Dr. Sky, on a RealAudio feed from his site, talking about the most recent Shuttle launch to repair and boost the space station to a higher orbit. This site warrants a visit.

There are sites that bill themselves as sites for beginning astronomers. Two of these sites are *Getting Started in Astronomy* (`members.home.net/astrokeith/index.htm`) and *The Complete Newbie's Guide to Getting Started in Astronomy* (`pw1.netcom.com/~dauphinb/newbie.htm`). Some other sites are aimed at children and young adults. *StarChild* (`starchild.gsfc.nasa.gov/docs/StarChild/StarChild.html`) is a NASA site geared to delivering accessible astronomy information to children under the age of 14. An associated site, *Imagine the Universe* (`imagine.gsfc.nasa.gov/index.html`, is aimed at young adults. The *Cyberspace* site (`library.thinkquest.org/12659/main.html`) is less aimed at astronomy and more geared to the solar system and space exploration. It has an interactive section with News and Events, Questions and Answers, and a Space Puzzle Game.

Another source of basic astronomical information on the Web is on-line university courses. One example is *Astronomy 1* (`online.bc.cc.ca.us/sea/astronomy/index.htm`), offered by Bakersfield College, California. This site is a good place to start if you want to learn astronomy at your own pace and at a basic level.

Lastly, I want to close this section by introducing you to a rather different, and fun, site. Called *Bad Astronomy* (`www.badastronomy.com`), it is run by Phil Plait, who has taken it upon himself to shed some much needed light on that darkness that is misinformation and down-right sloppiness regarding astronomy. He takes on "bad astronomy" as it appears on TV and in the movies and news reporting. He has a section called "Bitesize Astronomy," a collection of short articles on astronomy, and another called "Mad Science," where, as a member of the "Mad Scientist Network," he answers questions on astronomy and related subjects sent in by students and the general public. Phil has a great time poking fun at all the mistakes he and others come across.

Image Galleries

One of the many reasons that astronomers, both amateur and professional, get into this field is to marvel at the sights available to us; among them are colourful nebulae, dancing aurorae, and bright globular clusters. The Internet provides access to a wealth of sites that cater to those of us who cannot get enough of the night sky. These "image galleries" have something for everyone.

One of the most popular sites on the Web for astronomical images is that of the *Hubble Heritage Project* (`heritage.stsci.edu`). The Heritage team at the *Space Telescope Science Institute* (STScI) (`www.stsci.edu`) sees the *Hubble Space Telescope* (HST) "...as a tool for extending human vision, one that is capable of building a bridge between the endeavours of scientists and the public. By emphasizing compelling HST images distilled from scientific data, we hope to pique curiosity about our astrophysical understanding of the universe we all inhabit." The team goes through the images that the HST has taken and posts a new image on the first Thursday of each month. The Heritage Project also hosts an on-line voting event to let the public vote on the image to be posted the next month. While the team primarily uses the Internet to distribute these images, many are available as prints, slides and posters through outside agencies, such as the *Astronomical Society of the Pacific* (`www.aspsky.org`) or *Sky Publishing* (`www.skypub.com`).

The Goddard Space Flight Centre hosts a site (`nssdc.gsfc.nasa.gov/photo_gallery/photogallery.html`) that provides public access to some of the more popular NASA images. The pictures are part of the *National Space Science Data Centre* located at GSFC. The pictures were taken primarily during NASA missions and are organized by object and/or phenomenon. The major groupings are: "Planetary," including Solar System objects; "Astronomical Objects," including nebulae, galaxies and globular clusters, and stars and exotic objects; and "Others," including the Sun and spacecraft." There is a special index of images taken by NASA probes, such as Galileo, the HST, and Voyager. While you are there, visit the home page of the NSSDC (`nssdc.gsfc.nasa.gov`) and select the links to "General Public" and "Space Science Education Page." These pages are lift-off points to many other NASA and related sites geared to public outreach and providing education resources. They are worth browsing if you are interested in space sciences in general, not just astronomy. NASA also has a central repository of images held in the *Johnson Space Centre Digital Image Collection* (images.jsc.nasa.gov). While most are of the Earth from orbit, they are also worth looking at.

There are several sites on the Internet that cater more to the professionals and serious amateurs. The mission of the *Digitized Sky Survey* (stdatu.stsci.edu/dss) is to digitize photoplates taken by the Schmidt Camera telescope. These images are used by the HST team to plan observation runs and select guide stars. The pictures are available for download from the main site or from mirror sites, including a Canadian site at the *Canadian Astronomy Data Centre*, Dominion Astrophysical Observatory, Victoria (cadcwww.dao.nrc.ca/dss). Another professional site is run by the *2-Micron All Sky Survey* (2MASS) out of Caltech (www.ipac.caltech.edu/2mass/gallery). The survey takes images of the sky at several near-IR (infra-red) wavelengths, notably 2.17 microns, enabling astronomers to see through most of the obscuring dust in the galaxy and observe the dimmer, cooler stars of the universe that emit primarily at IR wavelengths. The images in this gallery use false colours to code the IR wavelengths: J-band (1.25 μm) in blue, H-band (1.65 μm) in green, and K-band (2.17 μm) in red. The IR pictures show many interesting details that are not apparent at visible wavelengths.

"Given the wealth of sky survey images and data available on the Internet, it is now possible to do astronomy by mining the data taken by others and made available over the Internet. This practice has been called 'Virtual Astronomy.'"

Given the wealth of sky survey images and data available on the Internet, it is now possible to do astronomy by mining the data taken by others and made available over the Internet. This practice has been called "Virtual Astronomy." One very nice site dedicated to it is *Virtual Sky* (virtualsky.org). The data and images on this site include the Digital Palomar Optical Sky Survey; IR, radio and X-ray images from groups such as 2MASS; a multi-resolution star map produced by John Walker; and many historical and cultural representations of the sky, including Johann Bayer's "Uranometria," first published in 1603. The site offers an image of a user-selected part of the sky and provides buttons that allow you to tilt, pan, and zoom in up to 12 levels of resolution. The interface is based on *Terraserver* (www.terraserver.com), a Web site with over a terabyte of Earth imagery and mapping data, much of it taken from orbit.

In part 1 of this article, I presented an overview of Internet Web sites that provide good information on astronomy and space sciences. In part 2, I will demonstrate that the Internet is not only a useful tool for researching and teaching astronomy, but that it can be used to do astronomy using robotic telescopes and remotely accessible observatories.

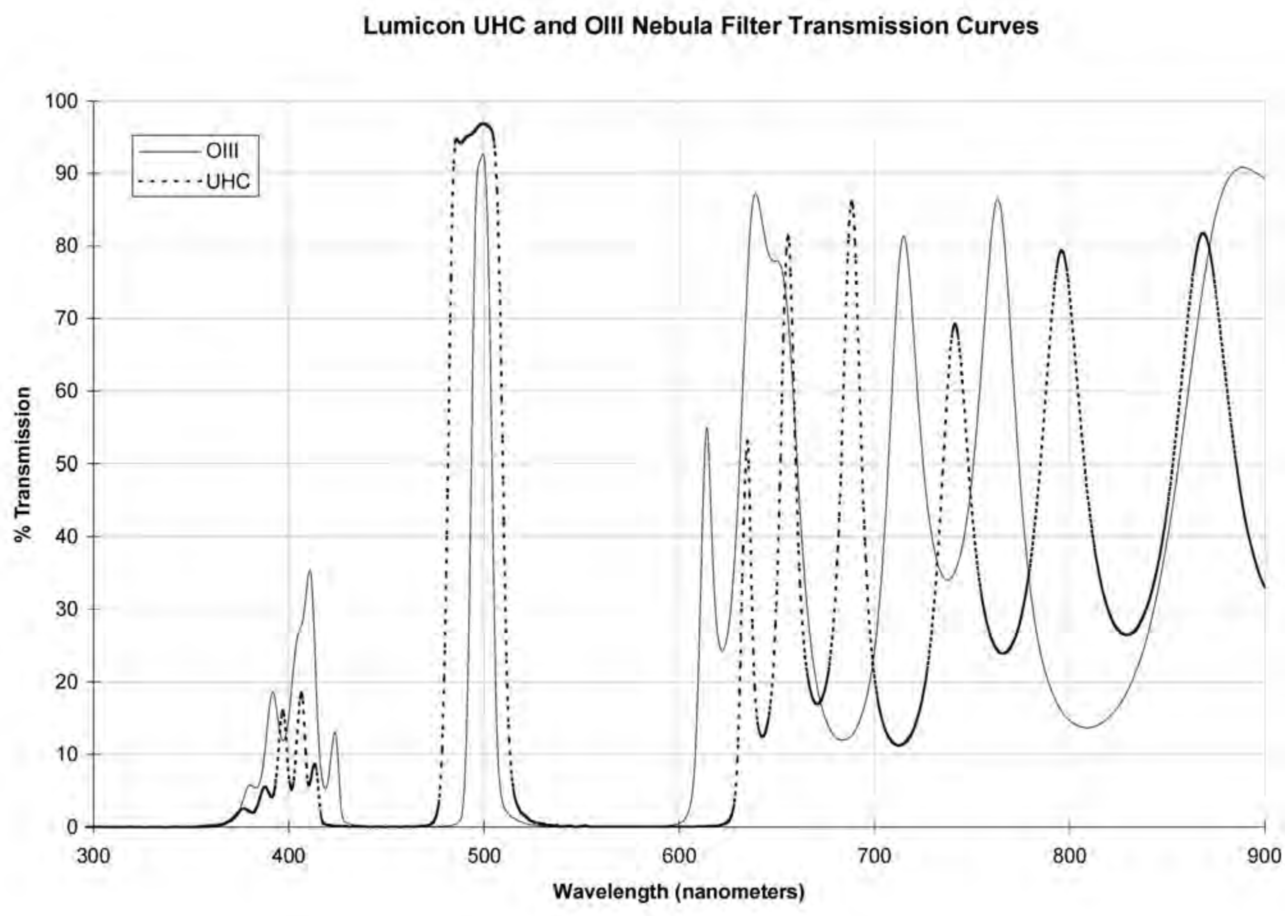
Les Dickson is the president of the Saskatoon Centre of the RASC and is co-chair of the Saskatchewan Summer Star Party. He holds a Doctorate in Chemistry, and is a Research Scientist working for a Federal Government agency.

Deep Sky Filters[1]

by Paul Markov (pmarkov@ica.net)

Despite having been an avid deep sky observer for the past 18 years, I had never owned a deep sky filter until October of last year (1999). The misconception I had about deep sky filters is that they are very expensive and that they are not very useful under relatively dark skies. It was one of my observing friends at one of our usual observing sessions who got me seriously thinking about deep sky filters. In this article I will describe what kind of deep sky filters are available on the market and what you can expect from each, as well as tell you about some observations I made with an O III filter from a fairly dark sky and from within the city.

There are three categories of deep sky filters available: broad-band "light pollution" filters, narrow-band "nebula" filters, and the specialized "line" filters. Broad-band filters let the majority of light through, only filtering out a few wavelengths; narrow-band filters block a good portion of incident light, letting through only a few selected wavelengths; while "line" filters only let through one or two specific wavelengths. I want to point out something that is very important before getting into the details — a filter that substantially improves views of star clusters, galaxies, or reflection nebulae does not exist. This is because deep sky



The transmission curves of Lumicon UHC and O III filters were traced using a spectrophotometer in the Department of Chemistry at Saint Mary's University. The region centred at about 500 nanometers is of interest to visual astronomers. Due to the nature of their construction, these filters "leak" rather erratically in the deep red and near-infrared part of the spectrum. However these wavelengths are essentially invisible to the eye (Prepared by Dave Lane).

[1] This article was first published in *Scope*, the newsletter of the Toronto Centre, in December 2000.

The 48-mm versions of the Lumicon Deep Sky and O III filters (Photo by Dave Lane).

objects comprised of stars (or objects which reflect starlight, such as *reflection* nebulae) shine with a continuous spectrum, meaning that if a filter tried to completely remove any particular wavelength (such as man-made light pollution or natural sky glow) it would also remove light from the actual deep sky object, dimming it considerably, or making it disappear altogether. Filters are most useful for *emission* and *planetary* nebulae because they glow at very specific wavelengths. For more details on the physics behind filters, please reference the 2001 *Observer's Handbook*, page 49. These filters come in various sizes, with the most common being 1.25-inch, 2-inch, and Schmidt-Cassegrain rear-cell size. The prices noted below are for the 1.25-inch size at local telescope shops. If you are looking for the other two sizes, the cost is about double that of the 1.25-inch size.

Broad-Band Filters

Examples of broad-band filters available on the market are the Lumicon Deep Sky, the Meade Broadband, the Celestron LPR, the Orion SkyGlow, and the Thousand Oaks LP-1, and sell for between $90 and $160. These filters are designed to block the most common sources of man-made light pollution such as mercury vapour and sodium lights and are intended to be used on all types of deep sky objects. Although it sounds like this type of filter would really help, in practice it yields just a marginal improvement over unfiltered views. Some gain in contrast can be expected for nearly all deep sky objects, still, I would not recommend broad-band filters unless you are restricted to urban skies at all times. You will enjoy much nicer views under darker skies.

Narrow-Band Filters

Examples of narrow-band filters on the market are the Lumicon UHC, the Meade Narrowband, the Orion Ultrablock, and the Thousand Oaks LP-2. These filters only pass the two Oxygen III emission lines, the Hydrogen Beta emission line, and the wavelengths between these two, making them most useful for observing emission or planetary nebulae. Because this type of filter blocks all other wavelengths, the background field of view becomes rather dim, but target objects still stand out well and actually *appear* brighter because of the added contrast. Brighter nebulae, which are visible without a filter, still benefit from the increased contrast, while nebulae which are altogether invisible without a filter may become visible. A narrow-band filter will help considerably whether you are observing from the city or from a dark sky, therefore it should be seriously considered. Narrow-band filters cost between $130 and $160.

Line Filters

There are three types of "line" filters — Hydrogen beta (H-beta), Swan band (C_2), and Oxygen III (O III). Each of these can be purchased for between $130 and $160.

The H-beta filter transmits only the H-beta emission line and is only useful on a handful of objects, with the most popular being the Horsehead nebula, the California nebula, and the Cocoon nebula. Because of its limited application, this filter is probably the last one you should consider buying. However, if you are determined to view the above mentioned objects and lack aperture or very dark skies, the H-beta filter is a must. This filter is manufactured by Lumicon and Thousand Oaks.

The Swan band filter is used for enhancing the diatomic carbon (C_2) emission lines found in comets, so it has a very limited application, especially because not all comets respond well to a Swan band filter. I believe this filter is only manufactured by Lumicon.

The O III filter transmits only the two O III emission lines but due to the abundance of objects that glow in the O III region of the spectrum, there are hundreds of objects that benefit from this type of filter. Many emission nebulae and most planetary nebulae will look remarkably better through an O III filter, which is manufactured by Lumicon, Thousand Oaks, and Meade, to name a few. Because the O III filter discriminates against all other wavelengths, the background image is considerably dimmer, even more than a narrow-band filter, thus it is more suitable for telescopes 6-inches and larger. The O III filter is the preferred choice for planetary nebulae.

My Experience WIth an O III Filter

As mentioned above, it was one of my observing friends who introduced me to an O III filter last October at our dark sky observing site, about one hour away from Toronto. Our first target using his 16-inch was the Veil Nebula in Cygnus. The O III filtered view was absolutely stunning and appeared very much like a long exposure photograph; I had no idea a filter could improve an object to that degree! Next he showed me M27, the Dumbbell nebula, and a little later M42, the Orion nebula. Both were spectacular and also resembled long exposure photos with the exception of the missing colour. Again, I was quite taken by views that can typically only be had in books and magazines. Removing the filter made these objects appear less prominent and washed out due to the loss in contrast. After only three objects I was already sold on the O III filter! Much later we looked at the Rosette nebula in Monoceros which was almost invisible, but the filter revealed the entire nebula with ease. I then borrowed the filter for use on my own telescope to see what it could do on NGC 2359, an emission nebula in Canis Major. Without the filter this nebula was just barely visible in my 10-inch, but with the filter it "stuck out like a sore thumb!" Coincidentally, by observing this nebula I completed my Finest NGC Objects list. My observing log entry for this object reads "the O III filter does wonders!" and all this was from a dark country sky, which I thought would not benefit from the use of filters. The next day I found out that this little "magic" piece of glass was quite affordable, and the following weekend I bought my own Lumicon O III filter.

I was fortunate to have two clear nights right after my purchase to evaluate the O III filter. I observed from my Toronto backyard and targeted some of the better known objects. My 10-inch equipped with the O III filter showed a much brighter M57, which was also more clearly defined. M27 was considerably brighter, with a little extra nebulosity visible. M76 was much brighter and showed a more clearly defined shape. M1 was barely visible from the city without a filter, and the O III only improved the view marginally. The filtered view of planetary nebula NGC 7662 in Andromeda was only slightly better than the unfiltered view. M42 was considerably brighter with some additional nebulosity visible. M78 and the Merope nebula in M45 (both reflection nebulae) did not improve at all with the O III filter as expected, and finally the Rosette nebula was invisible from the city, even with the filter, probably due to the overwhelming light pollution.

Which Filter is Best?

My recommendation, which is based on extensive research as I only recently acquired a filter myself, is to buy either a narrow-band filter or an O III filter. If you want the best "all-purpose nebular filter" most experts will recommend a narrow-band filter. Keep in mind that regardless of whether you buy a narrow-band or an O III filter, you will be very pleased with the results. Each has its benefits and drawbacks; a narrow-band filter shows more nebulosity than an O III filter, but the O III filter shows more contrast and fine detail, and a narrow-band filter performs slightly better on emission nebulae, whereas an O III filter performs slightly better on planetary nebulae. In terms of which brand name to choose, it appears that there is not much difference between manufacturers, with the exception of the Meade narrow-band filter, which seems to noticeably outperform other brands when used with refractors (*Sky & Telescope*, July 1995, 41).

Paul Markov has been observing deep sky objects since 1982 and has been writing a column on deep sky observing for the Toronto Centre newsletter since June 1999. You can read Paul's other articles at `home.ica.net/~pmarkov/articles.htm`.

An Amateur Comparison of Eyepieces

by Christopher Mulders (mirkak@cadvision.com)

When I look around our club, especially on star nights, it's very obvious that the most popular telescope is the Dobsonian. These telescopes are inexpensive to build and easy to use. Many beginners start with such a telescope and a few inexpensive eyepieces. But not long after they start using them, they realize they want more. This was the situation I found myself in last summer at Mt. Kobau with my 8-inch f/6 Dobsonian.

I already had a nice eyepiece for wider-field viewing and a couple for medium power. However, with the aurora associated with solar maximum, I quickly found out that faint and fuzzy deep-sky objects weren't great targets, even when viewed from the mountain. Well, Saturn and Jupiter were on the rise! I realized that I needed a higher-power eyepiece for viewing objects like planets. For seeing details in Jupiter's belts and Saturn's rings and resolving globular clusters, good contrast, sharpness and higher magnification are important, which means using shorter focal length eyepieces.

What to buy? From most of the seniors in the clubs, the response is almost automatic: buy TeleVue. At Mt. Kobau I tried a 7-mm "Tack Sharp" Nagler. With my glasses, I found it uncomfortable and awkward to use. TeleVue now offers their Radian line of eyepieces that combine long eye relief, wide apparent field, and some very short focal lengths. The problem is that they cost well over $300 each. University Optics advertises their Abbe Orthoscopics as being well-made eyepieces with high contrast and high sharpness. This sounds like just what we're looking for, and you can buy three University Optics Orthoscopics for the price of a single TeleVue Radian. The down side is that they don't have the long eye relief and wide apparent field of the Radians. The next question I asked was, "Do you really need to buy TeleVue or can you get by with a cheaper option?" The answers I received to that question were less clear. In fact, I never really got a satisfactory answer or even a consensus of opinion.

The obvious step then was to figure it all out for myself. Since I don't have the money to buy one of each eyepiece, I had another problem. To my rescue came Sky Vue Telescopes here in Calgary. Sky Vue Telescopes kindly loaned me 5 different eyepieces of the same 10-mm focal length to compare with my own 10-mm eyepiece. So for this comparison I had:

Front Row: Orthoscopic. Middle Row left to right: No-name Plossl, Antares Ultima Plossl, No-name Kellner. Back Row left to right: TeleVue Radian, Vixen Lanthanum.

Model	Make and Origin	Approx. Price CDN	Number of Lens Elements	Apparent Field of View (Degrees)
Kellner	No-name (China)	$30	3	50
Orthoscopic	No-name (Japan)	$85	4	45
Plossl	No-name (China)	$40	4	50
Ultima Plossl	Antares (Japan)	$100	5	52
Lanthanum	Vixen (Japan)	$175	6	50
Radian	Tele Vue (Taiwan)	$350	6	60

Each eyepiece was either new or freshly cleaned. The test telescope was my own 8-inch f/6 Dobsonian. It represents a good platform for this test, as it is a very common size and format for serious beginners. I have some extra features in my telescope, such as a smaller diagonal, light baffling, fan cooling, and a set of nice Barry Arnold optics to improve seeing and contrast. Collimation was checked and tuned before observing.

The actual testing was spread over two weeks at the end of September when we had some nice nights here in Calgary. My observing sites were either at the Wilson Coulee Observatory, within easy reach of Calgary, or at Carsland Provincial Park when I wanted a darker location.

The eyepieces were compared by observing 6 different objects: the Double-Double in Cygnus, the M13 globular cluster, M31 (the Andromeda Galaxy), the Ring Nebula (M57), and the planets Saturn and Jupiter. Transparency ranged from medium to good. Seeing, or steadiness of the air, was only "okay" with occasional moments when it was rock steady.

Results

An important factor is that I have slight astigmatism in my observing eye and am short-sighted. This means that if I don't use my glasses, I cannot get stars to focus as sharp points. Instead, they appear as short lines. I have contact lenses, but I don't like observing with them as they tend to float around and I am constantly shifting the fine focus while looking at globular clusters. Thus, I need an eyepiece with enough eye relief (the distance from the top of the eyepiece to the point where the image is focused) to observe comfortably with my glasses on.

The first thing I found out is I *can* use every one of the eyepieces with eyeglasses. Varying the eye relief affects how much of the eyepiece's field of view I can actually see. I can focus and observe with glasses, even with short eye relief eyepieces — I just lose field of view. To see the whole image from edge to edge with a short eye relief eyepiece and no glasses, I have to almost mash my eye up against it. With glasses on, I see a small "hole" for a view. If I move my head around, I can see to the edges but never edge to edge at the same time. The funny thing is, this is what it was like looking through a 7-mm Nagler (with its extremely wide apparent field of view) with my eyeglasses off! The new, long eye relief eyepieces such as the Lanthanums and Radians let me see the whole view, from edge to edge, with my glasses on. This is one of the advantages of their additional cost.

I found all the eyepieces gave clear, clean images with the exception of the Kellner. I can't put my finger on why, but I did not like the Kellner. On M13, I felt I couldn't find a happy focus for the whole image. It was fine on the Double-Double, but I found it poor on the Ring and on the planets.

Everyone warned me that the Orthoscopic would have horribly short eye relief and a small field of view. It did, but I didn't find it annoying. Yes, especially with glasses, I had a miserably small view, but it did give very nice, clean images on M13, on the Double-Double, and on the planets. I found it better than the Radian and my Lanthanum on the Ring Nebula. It was a waste on M31, but that's a big object. If I didn't have to wear eyeglasses, this would be a fine eyepiece.

The two Plossls gave fine images, with the Antares Plossl giving a slightly (but not much) sharper view on the Double-Double and the Ring than the No-name unit. I think the Orthoscopic gave an even sharper view than the Antares Plossl on the Double-Double and on Jupiter and Saturn, but again not by much and at the expense of field of view. They both rated okay on M31.

The Lanthanum performed very similarly to the Antares Plossl, maybe not quite as sharp as the Orthoscopic but still with nice, reasonably clean images and a better field of view. The big strength of the Lanthanum over the Ultima Plossl was the long eye relief. I could see the whole field, edge to edge, with my glasses on.

Testing the Radian was tougher than I thought. In a less rigorous test at the Mt. Kobau star party, I thought I could detect increased sharpness on clusters, and more contrast, with the Radian over my Lanthanum. I had a hard time seeing the same differences when observing from the Wilson Coulee Observatory and Carsland Provincial Park. I think it was slightly better on M13, but I found no difference on the Ring Nebula or on the planets. The big difference was that Radian had a noticeably wider field of view than the other eyepieces, especially when I wore glasses. It gave a nicer view of M31 because of this.

Note that field of view can be important for another reason. When observing with a Dobsonian at higher powers, the telescope must be moved frequently to compensate for sky rotation. A wider field of view for the same magnification gives more time to look before the object drifts out and the telescope needs re-aiming. Of course, telescopes with a motorized equatorial mount don't have this problem, so with them an eyepiece's apparent field of view is not as big an issue.

Conclusions

If you don't need glasses to observe, then almost any reasonably made Plossl or Orthoscopic eyepiece will do. I would avoid the Kellners. If you have to wear glasses to observe, then you should seriously consider investing in long eye relief eyepieces: the Lanthanums or the Radians. You can get by with Plossls or others, but you'll find observing with the long eye relief eyepieces more comfortable, and less damaging to your eyeglasses because of their rubber eyecups. If you have an Alt Azimuth mount, such as a Dobsonian, then a wider apparent field of view is a big asset, but not absolutely necessary. You can get by nicely with the narrower field of view, but you have to move the telescope more often.

Special thanks are due to Sky Vue Telescopes for the loan of the eyepieces and to Gary Billings, editor of *The Starseeker*, the Calgary Centre's newsletter.

Christopher Mulders is the Biomedical Technologist for the Calgary Centre of the Canadian Blood Services by day, and putters with his computer and telescopes by nights. Having first joined the Ottawa Centre in his early teens, he finally built his first telescope in 1999 with the help of many friends at the Calgary Centre. He's still working on sketching objects from the Messier list.

Le Verrier: The Celestial Mechanic

by David M. F. Chapman (dave.chapman@ns.sympatico.ca)

Urbain Jean Joseph Le Verrier, who was born 190 years ago, is best known for his role in the discovery of the planet Neptune. By applying the principles of Newtonian mechanics to the unusual motion of Uranus, he deduced the presence of a previously unknown planet whose gravitational pull accounted for the discrepancy. Using the same scientific methods, Le Verrier also analyzed peculiarities of Mercury's orbit, and postulated the existence of another planet that was never found.

Le Verrier was born on March 11, 1811, in St-Lô, Normandy, France. His father, a minor government official, sold the family home to finance Le Verrier's education at the École Polytechnique in Paris. Although Le Verrier started his career as a chemist in the laboratory of Gay-Lussac (1778–1850), in 1836 he was recruited to be an astronomy teacher at the École. He took up the study of celestial mechanics that had become a specialty of his countrymen, Lagrange (1736–1813) and Laplace (1749–1827). In the years 1845–46, Le Verrier concentrated on the irregularities of the motions of the planets Mercury and Uranus, with the encouragement of the Director of the Paris Observatory, François Arago (1786–1853).

Isaac Newton (1642–1727) had paved the way for the precise mathematical description of planetary motion with his development of the Laws of Motion and the Universal Law of Gravitation. However, the initial triumphs of these theories were restricted to the simple case of two-body motion; for example, a single planet travelling around the Sun, ignoring the effects of all other bodies. For a body bound to the Sun, the orbital motion is a perfect ellipse, with specified major axis and eccentricity (out-of-roundness), the ellipse occupying a fixed orientation in space. The planet moves on this unchanging orbit almost like a bead on a wire, endlessly revolving on the same course. As soon as a third body is introduced to the system, the additional mutual attractions destroy this perfect picture; the orbit of the planet is no longer a perfect ellipse. (There do exist some mathematically simple solutions to the "three-body problem" but the conditions for their existence are so peculiar that they are never realized in Nature.) In general, the motion of three or more bodies moving under the influence of mutual gravitational attraction is mathematically predictable, but without apparent pattern — a classic example of chaos.

In cases where there is a single large attracting body, such as the Sun in the Solar system, we are rescued from this seemingly hopeless state of confusion by perturbation theory. If the masses of the minor bodies in the system are sufficiently small, over a short interval of time (which is still many, many revolutions of the planets around the Sun), it appears as though each planet is following its own, unchanging, elliptical orbit, regardless of the motions of the others. The influence of the Sun dominates the effects of the other bodies on each other; however, over time it will be seen that the size, shape, and orientation of the orbital ellipses slowly shift in response to the gentle tugs of the secondary bodies. Instead of a planet endlessly drawing out the same

A French postage stamp bearing the likeness of Urbain Le Verrier. (Issued 1958 February 15, Scott catalogue # 870)

ellipse repeatedly, the path of the planet traces out a complex curve that almost (but not quite) joins up after one revolution. (I am reminded of the multi-lobed curves produced by the child's toy known as the Spirograph. Do they still make those?)

Le Verrier's analysis of the orbit of Mercury discovered the planet's orbital precession; that is, the planet is a little further ahead after one revolution than the position predicted by simple Newtonian analysis. Even when the perturbative effects of all the other planets were accounted for, still there was a discrepancy of 40 seconds of arc per century (about one hundredth of a degree). Le Verrier's study of Mercury lasted much of his life. Flushed by his success in predicting the existence and location of Neptune (described below), he deduced that there was another undiscovered planet causing the discrepancy in Mercury's motion. He became so confident of the existence of this planet he gave it the name Vulcan, after the blacksmith of the gods. This prediction fueled the search for an intra-Mercurian planet, which had already begun. There were several false alarms, and Le Verrier himself was convinced that the planet had been seen, but we now know that there is no such planet.

This part of Le Verrier's story does not end here, however, as the mystery of the precession of Mercury's orbit was eventually solved by Albert Einstein (1879–1955). Einstein's General Theory of Relativity is a radical departure from the Newtonian view of gravity and dynamics, but the differences are almost undetectable when applied to the motion of the solar system. Only in the case of Mercury, the planet subjected to the strongest gravitational field, are the relativistic effects significant (although still small). The precession noticed by Le Verrier is explained exactly by Einstein's theory. Today, Einstein's relativistic corrections are absolutely necessary to correctly interpret time and positional data of Earth satellites used in the Global Positioning System.

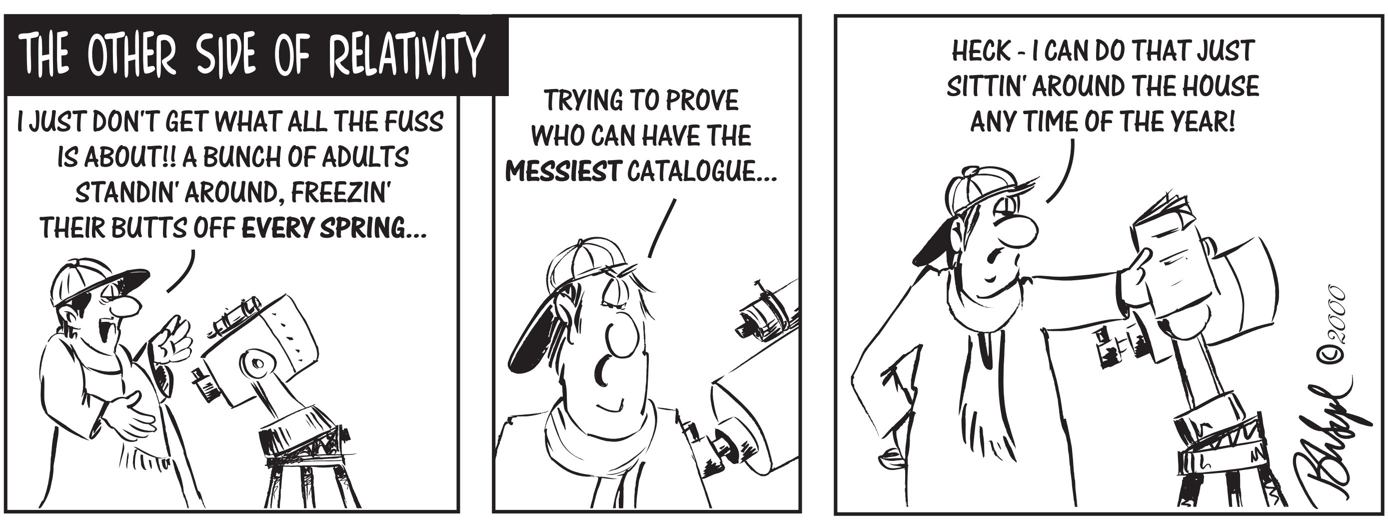
Le Verrier's work on the precession of Mercury gained him admission to the prestigious Paris Academy of Sciences in 1846. Arago urged him to study the motion of Uranus, which had only been followed for a half-century or so. This planet was not quite in the position predicted by Newtonian analysis of its motion. This time, Le Verrier's calculations paid off: he estimated the size and position of a planet needed to explain the motion of Uranus, and he wrote to Johann Galle (1812–1910) at the Berlin Observatory. Galle was the younger man, and had sent his doctoral dissertation to Le Verrier for comment; the Neptune prediction was only a passing comment in Le Verrier's reply. With the reluctant permission of the observatory director, Johann Encke (1791–1865), Galle began to search for the new planet on September 23, 1846, and found it at once, with the help of some newly printed star charts compiled by Carl Bremiker (1804–1877) and suggested by his doctoral student assistant Heinrich d'Arrest (1822–1875).

Unknown to Le Verrier, the Englishman John Couch Adams (1819–1892) had followed the same line of reasoning, but had difficulty having his prediction followed up by the British scientific establishment. Once the Le Verrier-Galle discovery was announced, supporters of Adams unsuccessfully attempted to have the priority of prediction ascribed to Adams. There followed an acrimonious debate between English and French scientific camps that spilled into the popular press. John Herschel (1792–1871), whose father William had discovered Uranus, was instrumental in casting oil on the troubled scientific waters, and he eventually introduced Le Verrier and Adams at a scientific meeting in 1847, after which they became friends. Today, both Le Verrier and Adams are given equal credit for the achievement. Le Verrier received the Copley Medal of the Royal Society of London and became an officer of the Legion of Honour in France.

Le Verrier's subsequent career was somewhat chequered. He supported the 1848 Republican revolution, but quickly switched sides when Louis Napoleon restored the Empire. Le Verrier succeeded Arago as the Director of the Paris Observatory, but proved to be a demanding and unpopular boss, and was eventually removed from the position. He died in Paris on September 23, 1877, on the 31st anniversary (to the day) of the discovery of Neptune.

David Chapman is a Life Member of the RASC and a past President of the Halifax Centre. Visit his astronomy page at: `www3.ns.sympatico.ca/dave.chapman/astronomy_page`.

'Tis the season to be Messier...



Grinding Up Comets

by Leslie J. Sage (l.sage@naturedc.com)

> **"Comets are sent to the inner Solar System after being perturbed by stars or clouds of molecular gas that the Sun happens to pass on its orbit around the centre of the Milky Way Galaxy, or by tides within the Galaxy."**

We all enjoy seeing the spectacular comets, such as Hyakutake and Hale-Bopp, that occasionally are visible in the night sky. The dust and gases they give off as they approach the Sun produce beautiful tails. After a few hundred close passes by the Sun, though, comets generally are reduced to burnt-out cinders. In order to continue seeing bright ones in the sky, we need a source of "fresh" comets. This source is called the "Oort cloud" — it's a swarm of comets in a shell surrounding the Sun. The shell extends from about 10,000 AU to about 100,000 AU. Just to provide a comparison, remember that Pluto is about 40 AU from the Sun, and the nearest star is about 300,000 AU away. Computer models of the very early Solar System have shown that comets were flung out to the Oort cloud by gravitational interactions with the giant planets soon after the comets were formed, thereby keeping the icy material on the comets in a cosmic deep freeze.

Comets are sent to the inner Solar System after being perturbed by stars or clouds of molecular gas that the Sun happens to pass on its orbit around the centre of the Milky Way Galaxy, or by tides within the Galaxy. At least that's the conventional wisdom. Now, Alan Stern of the Space Studies Department of the Southwest Research Institute and Paul Weissman of the Jet Propulsion Laboratory have shown that this simple and elegant picture may not work. It now appears that comets were ground up in collisions before they can be ejected to the Oort cloud (see the February 1, 2001 issue of *Nature*).

This startling revelation came about because for the first time ever, Stern and Weissman put comet-comet collisions into a computer model of the ejection process. All previous models had considered gravitational influences from the planets in the Solar System, and even Galactic tides, but had always assumed that the comets were point sources that didn't physically collide with each other. It turns out that this is a very misleading assumption. Stern and Weissman used a standard model of the early Solar System, which specifies the distribution of material with distance from the Sun. They found that the perturbations of the comets' orbits that are necessary to bring the icy bodies close to the giant planets (from before they could be ejected to the Oort cloud) would, with any reasonable number of comets, lead them to pulverize each other much more rapidly than they could be ejected. That process would continue until the density of comets and other proto-planetary material at a particular location decreased sufficiently so that the time between collisions was longer than the average time to eject the comet to the Oort cloud. An everyday analogy is trying to get quickly through a crowded airport to catch a plane: it's hard to make significant progress until the crowd is thin enough so that you're not continuously bumping into people or changing directions to go around them.

Stern and Weissman's result leads to the rather strange conclusion that the total mass of comets in the Oort cloud may be much less than currently believed. At a simplistic level, we know that there must be a good number of comets out in the Oort cloud because we keep seeing new ones coming in, even four and half billion years after the formation of the Solar System. In addition, the mass of comets in the Oort cloud has been estimated based on the observed flux of comets through the inner Solar System — that's an observation, and if it's in conflict with the theoretical predictions of Stern and Weissman, one might naturally conclude that there is something wrong with their calculation. However, the mass estimate for the Oort cloud does in fact depend on a lot of assumptions and is rather poorly constrained, so there might not be a true conflict.

There are several other possible ways to reconcile Stern and Weissman's predicted mass with that estimated from the data. If the radii — which are particularly difficult to determine — or densities of comets have been systematically overestimated, then the total mass of the cloud could be reduced. In addition, there may have been substantial amounts of material rapidly ejected into the Oort cloud from the region around Neptune's orbit or even further out in the Kuiper belt. (Pluto is the largest example of a Kuiper belt object.)

Whatever the outcome of the conflict, it is clear that collisions among comets play a much larger role in the formation of the Oort cloud than previously suspected. More detailed follow-up calculations will be needed to explore this hypothesis further. In particular, "migrating planets" — those that move from their birthplace either through interactions with the proto-solar nebula or gravitational scattering by other planets — may clear out the disk more quickly than presently assumed, thereby reducing the role of collisions.

"Our view of our Solar System has undergone a revolution over the last fifteen years, as computers have enabled astronomers to predict and explore structures — such as the Oort cloud and Kuiper belt — with ever increasing precision."

Our view of our Solar System has undergone a revolution over the last fifteen years, as computers have enabled astronomers to predict and explore structures — such as the Oort cloud and Kuiper belt — with ever increasing precision. I wonder what cherished belief will next be turned on its ear?

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Research Papers
Articles de recherche

BROADBAND PHOTOMETRY OF NORTHERN-HEMISPHERE LUMINOUS STARS. VI. UBV PHOTOMETRY FOR 62 CASE-HAMBURG STARS[1]

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Abstract. CCD-based UBV photometry for 62 intrinsically luminous stars (fifty-nine previously unobserved photometrically) drawn from volumes I, III, and V of the *Luminous Stars in the Northern Milky Way* catalog is reported. These 62 stars include a number of bright giants and supergiants of spectral types B, A, and F.

Résumé. Nous présentons les mesures photométriques UBV pour soixante deux étoiles intrinsèquement brillantes, dont cinquante neuf d'entre elles n'ayant pas auparavant été observées à l'aide de photométrie. Toutes ces étoiles sont tirées des volumes I, III et V du catalogue Luminous Stars in the Northern Milky Way. Parmi ces soixante deux étoiles, on compte un certain nombre d'étoiles brillantes géantes et supergéantes de types spectrales B, A et F.

1. Introduction

The most luminous stars — those of spectral types O and B and supergiants of all types — have long been of interest in view of their significance as tracers of galactic structure and dynamics and their value as testbeds for theories of the formation and evolution of massive, short lived stars. For such objects within our own galaxy, the Case-Hamburg luminous-stars surveys (Hardorp *et al.* 1959, 1964, 1965; Nassau *et al.* 1963, 1965; Stephenson & Sanduleak 1971; Stock *et al.* 1960; hereafter referred to as the "LS" catalogs) have long served as starting points for such investigations. Collectively, these seven volumes list 12235 objects within 10 degrees of the galactic plane to a limiting photographic magnitude of approximately 13. The vast majority of LS objects are ordinary O–B2 stars, but a number of Wolf-Rayet stars and B, A, and F-type giants and supergiants are also present. The LS catalogs also give a rough objective-prism spectral classification for each star, with most objects classified as one of OB^+, OB, or OB^- according to the strength of their hydrogen lines in the sense that luminosity decreases from OB^+ through OB^-, a scheme introduced by Nassau & Stephenson (1960).

Despite their significance, it is surprising to learn that some 40% of the LS stars still lack fundamental broadband photometry and nearly 60% lack MK-system spectral classifications. To address this situation, this author has been engaged for some years both in observing campaigns to secure photometry for previously unobserved LS and in maintaining a database (accessible via anonymous ftp from directory `/pub at sirius.mcs.alma.edu`) of published photometry and classifications for these objects. This paper is thus the sixth in a series reporting CCD-based photometry for LS stars accessible from the northern hemisphere. Papers I through V in this series (see paper V, Reed & Reed 2000, and references therein) reported BVR (or BV only) photometry for a total of 333 LS stars obtained with the Lowell Observatory/National Undergraduate Research Observatory (NURO) 31-inch reflector. The present work adds 62 stars (all but three of which are apparently previously unobserved photometrically) from LS volumes I, III, and V to this count. With the recent donation of a copper-sulfate U filter to the 31-inch facility by a generous anonymous benefactor, it is now possible to undertake traditional UBV photometry for these intrinsically blue objects.

2. Observations and Reduction

Four nights, October 15/16 through 18/19, 2000, were assigned for this project on the Lowell/NURO 31-inch. The middle two nights were clear, but work had to be suspended somewhat more than halfway through the latter of these before the CCD temperature could change in response to incipient exhaustion of liquid nitrogen coolant. In view of the observing run beginning shortly after full moon, attention was restricted for the most part to brighter (V < 10) program stars. CCD-based UBV photometry was carried out with the same TEK 512×512 chip of scale 0.49 arcsec/pixel used for the data reported in Papers I–V. Integration times varied from 3 seconds through the V filter for bright standard and program stars to 4 minutes through the U filter for occasional faint standard-star observations; the longest program-star exposures were 150 seconds through the U filter. The NURO CCD shutter has opening and closing times of 8 and 10 ms, respectively; any nonuniform illumination of the chip due to shutter motion should be negligible (maximum effect ~ 0.004 mag for a 3-second exposure). As in previous observing runs in this series, no dark images were taken (the dark count from this chip is extremely low); however, twenty bias frames were acquired nightly, as were five 1-second flats in each filter.

[1]This research was performed at the Lowell Observatory 31-inch telescope, which, under an agreement with Northern Arizona University, is shared with the national Undergraduate Research Observatory.

Some 55 observations of standard stars from Landolt (1983) were acquired over the two clear nights of observing; these spanned V = 7.7 to 10.0 and B–V = –0.1 to 1.6. As reported in Papers I–V, I carried out synthetic aperture photometry via the "qphot" quick-photometry program within the IRAF software package, utilizing an aperture of radius 18 pixels with sky sampling taken in an annulus of from 18 to 25 pixels radius. Extinction and transformation coefficients were computed according to the multi-night method of Harris *et al.* (1981). Observations of standards were weighted as $(\text{airmass})^{-2}$, and the final weighted RMS residuals in V, B–V, and U–B were 0.0151, 0.0108, and 0.0161 magnitudes, respectively. These V and B–V residuals are similar to those reported in previous papers in this series. No non-random trends in residuals as functions of magnitude, colour, time or airmass were evident.

Results for the program stars (in order of increasing LS-North volume number — declination zone — running number) are given in Table I. The columns give (1) LS-North identifier, (2) HD or BD identification, (3) – (5) V, B–V, and U–B, (6) the number of times each star was observed, (7) – (9) the standard deviations of V, B–V, and U–B for stars measured on both nights, (10) the LS-catalog objective-prism spectral classification, and (11) notes pointing out variable or double stars. In column (10), "ce" designates Balmer continuum emission, "l" that at least one emission line, nearly always a Balmer line, was visible on a blue-region plate, and "h" that Hα was noted in emission on an independently-scanned Hα plate; an exclamation point indicates that a feature is particularly pronounced. Many of the program stars are A and F bright giants and supergiants. The Hipparcos catalog lists LS III +47 58 (V409 Lac) as a variable of unsolved type with V = 8.41 to 8.62; LS III +49 37 (V2175 Cyg) is a high-mass X-ray binary with V = 9.26 to 9.38.

Table I
UBV Photometry of LS Stars

LS (1)			HD/BD (2)	V (3)	B-V (4)	U-B (5)	n (6)	σ((V) (7)	σ(B-V) (8)	σ(U-B) (9)	Prism (10)	Notes (11)
I	+54	5	+54 448	8.635	0.076	-0.706	1	—	—	—	OB(h)	
I	+55	12	7694	7.361	-0.083	-0.874	1	—	—	—		
I	+56	41	+55 557	10.063	0.092	-0.709	1	—	—	—	OB-	
I	+60	1	220819	6.472	0.435	0.382	2	0.010	0.029	0.017	A6II	
I	+60	11	+60 2582	8.645	0.714	-0.036	2	0.025	0.016	0.038	B7Ia	
I	+60	128		10.346	0.189	-0.678	1	—	—	—	OB	
I	+60	136	236612	9.358	0.278	-0.472	1	—	—	—	OB-	
I	+60	164	236790	9.620	0.277	-0.542	1	—	—	—	OB-	
I	+61	17	222275	6.569	0.567	0.482	2	0.003	0.034	0.010	A3II(h)	
III	+42	25	204132	7.517	0.498	0.373	2	0.009	0.041	0.049	A6II	
III	+45	73	+35 3652	10.165	-0.012	-0.653	2	0.003	0.069	0.004	OB-	
III	+45	75	+45 3808	10.056	0.261	0.230	1	—	—	—	A2II	
III	+46	62	+46 3337	9.706	0.079	-0.380	2	0.000	0.031	0.034	OBl	
III	+47	46	+46 3348	9.950	0.322	0.068	2	0.010	0.035	0.034	A0II	
III	+47	58	213129	8.435	0.099	-0.639	2	0.002	0.046	0.033	OB-ce	V409 Lac
III	+48	40	+47 3506	10.034	0.147	-0.567	2	0.028	0.026	0.020	OB	
III	+49	35	+48 3536	9.438	0.045	-0.591	2	0.007	0.057	0.017	OB-	
III	+49	37	+49 3718	9.180	0.200	-0.429	2	0.012	0.047	0.022	OBlh!	V2175 Cyg
III	+49	39	+48 3598	9.413	0.322	0.223	2	0.033	0.028	0.015	A2Ib	
III	+49	43	+48 3667	8.931	0.003	-0.589	2	0.005	0.029	0.072	OB-	
III	+50	39	212511	7.397	0.189	0.201	2	0.003	0.041	0.015	A5II	
III	+53	49	235754	9.492	0.082	-0.579	2	0.040	0.002	0.032	OBl	
III	+54	29		10.379	0.118	-0.639	2	0.008	0.040	0.031	OB-	
III	+54	46	211868	8.001	0.398	0.371	2	0.014	0.026	0.013	A8II	
III	+55	33	211820	8.368	0.790	0.583	2	0.007	0.024	0.043	F3II	
III	+55	48		12.109	0.147	-0.546	2	0.042	0.012	0.013	OBl	
III	+55	106	240159	9.083	0.089	-0.408	2	0.011	0.043	0.013	OB-	
III	+55	112	240249	9.735	0.129	-0.309	2	0.016	0.052	0.009	OB-	
III	+56	67		9.690	0.562	-0.442	2	0.049	0.031	0.028	OB-	
III	+56	82	215177	8.692	0.208	-0.030	2	0.011	0.038	0.013	B8II	
III	+59	18	239840	9.209	0.413	0.300	2	0.006	0.057	0.002	A2II-III	
III	+60	65	240261	9.455	0.873	0.429	2	0.017	0.029	0.012	F1Iab	
III	+60	69	+60 2523	9.751	0.369	-0.413	2	0.018	0.020	0.014	OB-	
V	+26	1	32018	7.386	0.511	-0.214	1	—	—	—	OB-	ADS 3602AB
V	+33	37	35953	7.159	0.543	0.382	1	—	—	—	F1II	
V	+38	2	27381	7.452	1.057	0.699	1	—	—	—	A4Ib,h	
V	+38	3	29723	7.889	0.507	-0.195	1	—	—	—	OBl	
V	+39	8	277164	9.923	0.233	-0.368	1	—	—	—	OBl	
V	+39	26	34832	8.560	0.010	-0.702	1	—	—	—	OBl	
V	+40	24	32189	7.611	0.433	0.401	1	—	—	—	A7II	
V	+41	4	26782	8.680	0.641	0.483	1	—	—	—	A0II	

V	+42	1	22509	8.590	0.192	-0.581	1	—	—	—	OB-	ADS 2651AB
V	+43	10	28502	8.690	0.257	-0.094	1	—	—	—	B9II	
V	+43	13	30004	8.672	0.299	-0.388	1	—	—	—	OB-	
V	+45	22	36467	8.552	0.087	-0.087	1	—	—	—	B9II	
V	+46	25	+46 979	6.827	0.183	-0.789	1	—	—	—	A0II	ADS 3781A
V	+48	21	29093	7.970	0.327	-0.121	1	—	—	—	OBl	ADS 3325AB
V	+50	1	11968	9.154	0.027	-0.731	1	—	—	—	OB-	
V	+50	2	19419	8.783	0.343	0.108	1	—	—	—	B9II-III	
V	+55	5	+55 613	10.371	0.094	-0.671	2	0.028	0.073	0.011	OB-	
V	+55	6		10.340	0.079	-0.619	2	0.007	0.034	0.011	OB-	
V	+56	5	+56 472	9.941	0.196	-0.651	1	—	—	—	OBl	
V	+56	31	14357	8.507	0.362	-0.621	1	—	—	—	OB-	
V	+56	32	+56 556	9.427	0.297	-0.661	1	—	—	—	OB-	
V	+56	35	+55 594	10.046	0.167	-0.616	1	—	—	—	OB-	
V	+57	10	+56 506	10.368	0.418	-0.481	1	—	—	—	OB-h	
V	+57	13	+56 560	10.123	0.242	-0.576	1	—	—	—	OB-	
V	+57	27	14661	9.134	0.551	-0.374	1	—	—	—	OB-	
V	+57	32	+56 617	10.110	0.287	-0.548	2	0.028	0.019	—	OB-	
V	+57	50		12.050	0.502	-0.279	2	0.041	0.006	0.004	OB	
V	+58	21	29130	8.266	0.154	-0.657	1	—	—	—	OB-	
V	+60	04		11.606	0.869	0.130	1	—	—	—	(OB-)	

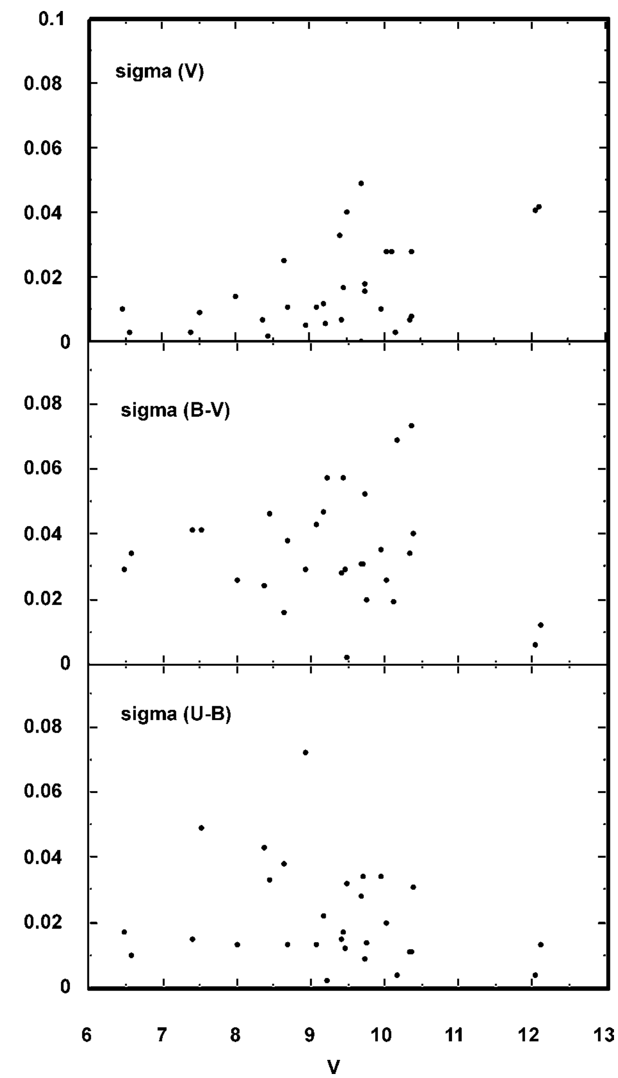

Fig. 1 — Distribution of program-star standard deviations as a function of V magnitude.

The distribution of standard deviations for program stars measured twice is shown in Figure 1, and a colour–colour diagram appears in Figure 2. The distribution of standard deviations is similar to those found in earlier papers in this series. The solid curve in Figure 2 represents the locus of intrinsic colours for main-sequence stars, and the dashed one for type Iab supergiants; the solid straight line indicates the reddening line for O5 stars. The distribution of points in the two-colour diagram is consistent with the many less-luminous OB^- classifications appearing in Table I; the points scattered along the supergiant intrinsic-colour locus are all of luminosity class II–III or brighter. As has been noted previously with LS stars (Reed 1996), a minimum reddening of E(B–V) ~ 0.2 is present; maximum reddenings can exceed E(B–V) ~ 1, not surprising in view of the placement of these objects in the galactic plane.

Three stars in Table I have measurements in common with

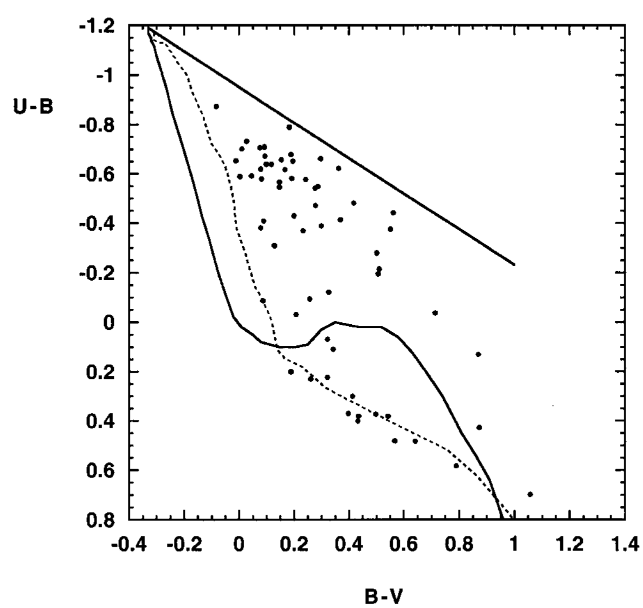

Fig. 2 — Colour-colour diagram for LS stars. The solid and dashed curves are loci of intrinsic colours for main sequence and type Iab supergiant stars, respectively; the solid line is the reddening line for O5 stars.

results published by other observers. These are summarized in Table II. In one case, (LS V +56 31) the present results appear slightly brighter and somewhat redder than those published otherwise, whereas in another (LS I + 60 11) they appear again slightly brighter but somewhat bluer, while in the third (LS I +61 17) they are essentially identical. No meaningful trends can be inferred from such a limited number of comparisons.

Table II
Comparison of Results with Other Sources

LS		V	B-V	U-B	Reference
I	+6 11	8.645	0.714	−0.036	Present work
		8.67	0.77	0.02	Haug (1970)
		8.68	0.77	0.01	Hiltner (1956)
I	+61 17	6.569	0.567	0.482	Present work
		6.58	0.57	0.49	Haug (1970)
		6.59	0.53	—	Ljunggren & Oja (1964)
V	+56 31	8.507	0.362	−0.621	Present work
		8.52	0.31	−0.52	Hiltner (1956)
		8.53	0.32	−0.53	Johnson & Morgan (1955)
		8.53	0.32	−0.53	Wildey (1964)

Given the quality and efficiency of modern guiding and imaging systems, many of the yet-unobserved LS objects are sufficiently bright (V ~ 11–12) as to be measurable with modest-aperture telescopes at good sites; amateur astronomers could make a real contribution in this regard. A listing of epoch-2000 coordinates for unobserved LS objects can be found at the anonymous ftp site given in the Introduction above.

Acknowledgements

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References

Hardorp, J., Rohlfs, K., Slettebak, A., & Stock, J. 1959, Luminous Stars in the Northern Milky Way I. (Hamburg-Bergedorf: Hamburger Sternwarte and Warner and Swasey Obs.)
Hardorp, J., Theile, I., & Voigt, H. H. 1964, Luminous Stars in the Northern Milky Way III. (Hamburg-Bergedorf: Hamburger Sternwarte and Warner and Swasey Obs.)
Hardorp, J., Theile, I., & Voigt, H. H. 1965, Luminous Stars in the Northern Milky Way V. (Hamburg-Bergedorf: Hamburger Sternwarte and Warner and Swasey Obs.)
Harris, W. E., FitzGerald, M. P., & Reed, B. C. 1981, PASP, 93, 507
Haug, U. 1970, AAS, 1, 35
Hiltner, W. A. 1956, ApJS, 2, 389
Johnson, H. L., & Morgan, W. W. 1955, ApJ, 122, 429
Landolt, A. U. 1983, AJ, 88, 439
Ljunggren, B., & Oja, T. 1964, Ark. Ast., 3, 439
Nassau, J. J., & Stephenson, C. B. 1960, ApJ, 132, 130
Nassau, J. J., & Stephenson, C. B. 1963, Luminous Stars in the Northern Milky Way IV. (Hamburg-Bergedorf: Hamburger Sternwarte and Warner and Swasey Observatory)
Nassau, J. J., Stephenson, C. B., & MacConnell, D. J. 1965, Luminous Stars in the Northern Milky Way VI. (Hamburg-Bergedorf: Hamburger Sternwarte and Warner and Swasey Observatory)
Reed, B. C. 1996, Vistas in Astron., 40, 317
Reed, B. C., & Reed, L. G. 2000, PASP, 112, 409
Stephenson, C. B., & Sanduleak, N. 1971, Luminous Stars in the Southern Milky Way. Publ. Warner & Swasey Obs., 1, 1
Stock, J., Nassau, J. J. & Stephenson, C. B. 1960, Luminous Stars in the Northern Milky Way II. (Hamburg-Bergedorf: Hamburger Sternwarte and Warner and Swasey Observatory).
Wildey, R. L. 1964, ApJS, 8, 439

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THE STARS

The grandest problem in astronomy is the structure of the universe. Year by year our knowledge of the stars increases and we hope that at some time in the future our successors will be able to formulate a comprehensive view of the distribution of the worlds through space.

Perhaps the most striking advance is the demonstration that the proper motions of the stars, instead of being wayward and lawless, are distinctly systematic. This view was put forward by Kapteyn, of Groningen, but it has been worked out in a very elegant manner by A. S. Eddington, who for his work received the gold medal of the Royal Astronomical Society. He found that the motions of the stars, instead of being haphazard, could be classified into two "drifts" in relative motion one to the other. The stars of drift i. have a common motion, relative to the Sun, away from a point near R. A. 18 h., declination +18°, while those of drift ii. move from R. A. 7 h. 30 m., declination +58°. The velocity of those in the first drift relative to the Sun is much greater than that of the second, the ratio being about 17 to 5. We thus appear to have two great groups of starry worlds moving through space in almost exactly opposite directions but with very different velocities with respect to us.

This highly interesting and important result has been urged as an argument against Dr. A. R. Wallace's view as to the unique position of our earth in the universe, it being claimed that the new discovery shows that we have in reality two universes of stars. This would render Dr. Wallace's position untenable unless it be assumed that the Solar System is the centre about which both universes oscillate. Dr. Wallace discusses Eddington's paper. Assuming with Kelvin a single vast stellar universe, slowly condensing towards its centre of gravity, the component stars would move in ellipses or spirals of varying degrees of eccentricity and inclination to the mean orbit. If, further, the Sun is placed near the centre, Wallace contends that the stars would have forward or retrograde motions which he thinks would exhibit the motions observed. It is hard to see, as Eddington points out, how this can fulfil the required conditions, as the motions which the stars would then have would be essentially haphazard.

by C. A. Chant,
from *Journal*, Vol. 2, pp. 9–10, January, 1908.

CANADIAN THESIS ABSTRACTS

Compiled by Melvin Blake (blake@aries.phys.yorku.ca)

Evolutionary and Pulsation Models of Metal-Poor Subdwarfs
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University of British Columbia, MSc.

Metal-poor subdwarfs (MPSDs) are probably the Sun's oldest neighbours and are almost certainly low-amplitude *p*-mode pulsators, like the Sun. One of the goals of the Microvariability and Oscillations of Stars (*MOST*) Space Telescope project (due for launch in 2002–2003) is to detect MPSD oscillations and apply asteroseismology to refine the calibration of globular cluster isochrone fitting and possibly set a lower limit to the age of the Universe.

To be able to interpret the eigenfrequency data, a comprehensive grid of nonadiabatic, nonradial pulsation models for MPSDs was generated for the first time using a code developed by Guenther (1994). Each pulsation model was calculated from a structural evolutionary model using the Yale Stellar Evolution Code with Rotation (YREC) which included up-to-date physics such as both He and heavy element diffusion and the latest EOS and opacity tables. The grid spanned the following ranges: helium abundance Y = 0.235 to 0.255 (consistent with estimates of primordial Y); heavy element abundance Z = 0.0002 to 0.01 (consistent with MPSD spectra); mass M = 0.7 to 1.0 solar mass; and age A = 5 to 16 Gyr. From the calculated eigenfrequencies of each model, the large and small frequency spacings ($\Delta\nu$, $\delta\nu_{02}$) were derived as defined by asymptotic pulsation theory (Tassoul 1980). These spacings are sensitive diagnostics of the mass and main-sequence age of the star. Combining *MOST*'s resolution with the uncertainties in the input parameters, *MOST* data could refine MPSD masses to better than ± 0.005 solar mass and ages to ± 0.05 Gyr (average errors assuming the input physics are correct).

Variability of Radio Sources in the Canadian Galactic Plane Survey
by Stephanie Wilder (steph@ras.ucalgary.ca)
University of Calgary, MSc.

The Canadian Galactic Plane Survey (CGPS) is a large-scale survey of a section of the Milky Way. It is more sensitive than past surveys by at least a factor of ten, thereby sampling a new population of faint radio sources in the galactic plane.

Measurements of the positions and intensities of compact sources in an 81 square degree sub-region of the survey produced about 5000 sources with flux densities down to about 1 mJy. A sensitive search for variability in the source was performed by combined analysis of the CGPS data in this sub-region and the NRAO VLA Sky Survey. This search produced twenty-two variables, ten of which had flux density below 18 mJy — a previous lower limit.

Spectral indices from the Cambridge 151 MHz survey and the Westerbork WENSS 325 MHz survey give an indication of the variable source's spectral nature. As well, a comparison between the Palomar Sky Survey and the CGPS variables was used to search for optical counterparts.

Molecular Gas in Interacting Galaxies
by Ming Zhu (zhu@astro.utoronto.ca)
University of Toronto, Ph.D

A systematic study of the molecular gas properties in strongly interacting galaxies (SIGs) has been undertaken, which includes two parts: (1) a statistical study of a large, optically-selected, complete sample of SIGs; (2) a case study of the nearest colliding pair NGC4038/9 (the "Antennae") with multi-transition data of both ^{12}CO and ^{13}CO.

Consisting of 126 galaxies in 92 systems, our complete sample of SIGs includes all the SIGs in the northern sky with optical magnitude B_T < 14.5. CO data have been collected for 95 SIGs (59 of which were observed by us) as well as for comparison samples of 59 weakly interacting and 69 isolated spiral galaxies. The statistical analysis of the samples shows that the SIGs, especially the colliding and merging systems, have a higher CO luminosity than isolated spiral galaxies. However, there is no significant difference in the atomic gas contents between the samples. This indicates that the excess CO emission is not due to the conversion of atomic gas to molecular gas, but may more plausibly be accounted for by a lower CO-to-H_2 conversion factor X.

For the Antennae galaxies, we have obtained high quality, fully sampled, single dish maps at ^{12}CO J=1–0 and 3–2 transitions with an angular resolution of 15″ (1.5 kpc). These are so far the highest resolution single dish data at both the J=1–0 and 3–2 transitions. ^{12}CO J=2–1 data at the positions of the two nuclei, as well as in part of the overlap region with 20″ angular resolution, have also been obtained. We find twice as much ^{12}CO J=1–0 flux in the Nobeyama 45m single dish map, as was reported by Wilson *et al.* (2000) using the OVRO interferometer. The ^{12}CO J=1–0, 2–1, 3–2 emissions all peak in an off-nucleus region adjacent to where the two disks overlap. Using the conventional X factor yields ~ 4×10^9 solar mass of molecular gas in the overlap region. Such large amounts of molecular gas are almost impossible for this particular region to accumulate, given the relatively short lifetime of molecular clouds and the limited period of time for this region to overlap.

The ^{13}CO J=2–1 and 3–2 line emissions are detected at selected points in the two nuclei and the overlap region. Both the ^{12}CO/^{13}CO J=2–1 and 3–2 integrated intensity ratios are remarkably high in the overlap region. This is the first published case in which such high ^{12}CO/^{13}CO J=2–1 and 3–2 ratios are found outside a galactic nucleus. Detailed LVG modeling indicates that the ^{12}CO and ^{13}CO emissions come from different spatial components. The ^{12}CO emission originates from a non-virialized low density gas component with a large velocity gradient. Such a large velocity gradient can produce "over-luminous" CO emission and the model derived X factor is an order of magnitude lower than the conventional value. We suggest that the apparently strong CO emission in the overlap region of the Antennae galaxies is due to increased radiative efficiency, possibly because of the large velocity dispersion.

A comparison of the CO J=3–2 emission with the Submillimetre Common-User Bolometer Array of the James Clerk Maxwell Telescope (*SCUBA*) 850 μm continuum in the Antennae galaxies shows that CO line emission on average contributes 46% of the 850 μm continuum flux and the ratio of ^{12}CO J=3–2 to *SCUBA* 850 μm flux varies by a factor of two across the system. After correcting for the ^{12}CO J=3–2 contamination, the dust emission at 850 μm detected by *SCUBA* is consistent with the thermal emission from a single warm dust component with a mass of 1.7×10^7 solar mass. This value is more than six times lower than that estimated by Haas *et al.* (2000) using the uncorrected 850 μm data.

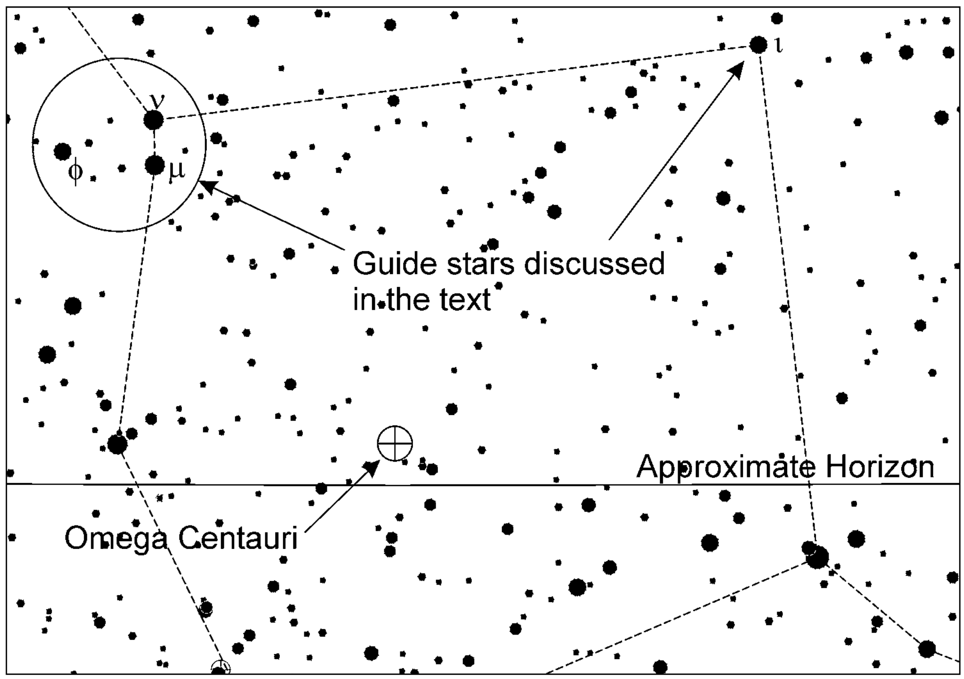
On Observing Omega Centauri *From Canada*

by Dan Taylor, Windsor Centre

The wind, blowing from the southwest, bore a damp chill. We were just a few metres from the waters of Lake Erie, where waves lapped lazily, matched by the wind's gauge. Our steps were measured in the yielding sand as we ported our equipment across the beach to a clear southern vista. This location affords a unique advantage, for from here, observers can ferret out more southern sky than from anywhere else in the nation.

Thus began our odyssey last March 31, at Point Pelee National Park, where we hoped to glimpse the sublime globular cluster Omega Centauri in its diurnal passage just above the waters of Lake Erie. Just what is so special about Omega Centauri, you may ask? It is the largest globular cluster visible from Earth and indeed most likely in our entire galaxy. It is estimated to hold about a million stars. It is one of the celestial crown jewels for observers at such places as the famed Texas Star Party.

On the preceding day I secured permission from Dan Reeves, Park Warden, for our small group of Windsor Centre members to enter the park after hours and set up on the northwest beach. As a geographical note, Point Pelee, on the north shore of western Lake Erie, straddles the 42nd parallel. In addition, our location had the distinction of lying midway between the light domes of Cleveland and Sandusky, Ohio. Our arrival and set-up unfolded problem-free. Tim Bennett brought the Windsor centre's 10-inch f/8 Dobsonian, while Larry Burgess set up his finely crafted 10-inch f/6 Dob, and Robin Smallwood brought a 6-inch f/8 refractor. I toted a couple of eyepieces and star charts.



A finder chart for Omega Centauri showing stars to about magnitude 8 (ECU Chart prepared by Dave Lane).

The exceptional clarity of the air was quickly noted. All present saw the 4th magnitude horn-shaped asterism of nu, mu, chi, and phi Centauri with the unaided eye. Since this was just 5 degrees above our horizon we were hopeful, as this has proven to be a good omen on prior excursions. In addition the temperature was about 0° C, winds were light out of the SSW, and the humidity was a dry 35%.

Set-up was completed by 12:45 am EST. I dropped the 17-mm Nagler into the 10-inch f/8 (120×) yielding a 2/3-degree field of view. The Telrad was centered on iota Centauri, and then the scope was plumbed to the horizon. Peering into the eyepiece, I was instantly rewarded with a tightly grouped smattering of about three to four dozen stars. This grouping appeared circular and covered about one quarter of the eyepiece field. Omega Centauri once again was found!

The horizon was visible and razor-sharp at the edge of the same field. The stars were pulsing rapidly, at about one-second intervals. Bennett stepped up to the eyepiece and noted even more, excitedly describing fleeting glimpses of an unresolved halo. Burgess found the stars obvious in his 10-inch f/6 with similar moments of seeing too. Smallwood was able to locate the cluster in the refractor, although no halo was discerned. Newcomers to the Omega Centauri pursuit, Burgess and Smallwood were most enthusiastic about the sighting.

Our window of opportunity was startlingly short. Twenty minutes later, although perched on the meridian, the cluster and its component stars were seen poorly and only in rare moments. A remarkable thought occurred to me — had we waited those twenty minutes to start in on Omega Centauri, we most probably would have gone away disappointed with a negative observation.

The difficulty in observing low elevation objects is well known to amateur astronomers. Over water, seeing and transparency are affected by the weather conditions encountered as the cluster traverses the sky. Winter and spring conditions, although vastly different, often yield the same results, *i.e.*, a negative observation. In all, there have been more than a dozen trips to the lake for the purpose of sighting the grand cluster. The March 30, 2000 weather system that arrived had, as we have come to learn, the critical components necessary to successfully observe Omega Centauri: cool dry air, with light breezes, and air temperatures that closely match the water temperature. Unfortunately, these conditions are rarely encountered together, as my own experiences show.

My first attempt for Omega Centauri took place in late May of 1986. Meridian crossing was around 11 p.m. Well-known Windsor Centre member Joady Ulrich accompanied me as we set up on private property near the hamlet of Colchester, Ontario. Expectations were high as twilight yielded to nightfall. Our first lesson in understanding the nuances of espying Omega Centauri was displayed before us. A shroud-like veil of mist formed over the lake, totally obscuring the horizon. Overhead and to within a disgustingly close proximity to the horizon, the stars shone splendidly. Those hazy conditions typically begin in mid-April and continue into the summer, thus putting an end to the viable observing season for all intents and purposes.

Omega Centauri reaches the meridian just before morning twilight early in the year, heralding its passage over our sky. These crisp, snappy mornings are the sort that are stirring and speak deeply to the eager amateur. However, puffy lake-effect clouds form over open water ranges in January and February, and to date, have thwarted excursions at that time of the year. Open water in mid-winter is increasingly more common on Lake Erie, as a direct result of the recent mild winters. If ever a climatically traditional winter should arrive and freeze the lake over, we may be treated to a truly outstanding observation of the cluster. This, of course, is owing to the colder, drier, and therefore, more transparent winter air.

Finally on April 9, 1989, Randy Groundwater and I overcame these obstacles and succeeded in bagging Omega Centauri. We set up on a small spit of land adjacent to the merging place of the Detroit River and Lake Erie. Using my 13-inch f/4.5 Newtonian and a 9-mm Nagler, we both noted a steady, very faint halo with scads of stars pulsing in and out of visibility. Moreover, we had serendipitously discovered a brief period of seasonal weather stasis.

From these observations, it is apparent that a window of opportunity exists in late March and early April, when favorable conditions occasionally develop. This was underscored by the fact that every success thus far has taken place during the March/April period. Further successes took place on April 6, 1992 and March 27, 1994. Al DesRosiers, Frank Shepley and Tim Bennett were co-observers those times. Our site was just outside Kingsville, Ontario. Although convenient, it was compromised somewhat by the glow of Sandusky, Ohio, due south of our site. Urban developments were also encroaching on three sides (as they are all along the shores of Essex County).

These are accounts of the very first confirmed sightings of Omega Centauri from Canada. They are not, however, the farthest north. In 1999 two groups, one in Boston, the other from London, Ontario, made that claim. The London group accomplished this remarkable feat from the bluffs of Lake Erie, southeast of London. Not only were they battling the light dome of Cleveland, but also the cluster's core just cleared the horizon.

Should you decide to pursue Omega Centauri take note — time is limited. The Earth's axial precession is carrying the cluster south. During this century it will sink below the southerly horizon for a long, long time. Such observations, as unique as they are, will, as time passes and precession marches on, be beyond our reach and be exclusive to more southerly climes.

Dan Taylor has served the Windsor Centre in a number of offices, including president. After having been an active urban observer since the early seventies, he has resided with his family in rural southern Essex County since 1994. Conveniently, this is very close to Point Pelee National Park.

FAQs, Facts and Epacts

by Bruce McCurdy (bmccurdy@freenet.edmonton.ab.ca)

"I wonder why Easter falls when it does?"

This is a Frequently Asked Question by people of the "normal" persuasion. The implied corollary is that only a severely *abnormal* person would actually try to answer what is clearly a convoluted problem. Fortunately or otherwise, the straitjacket of presumed normalcy has long since been gathering dust at the back of my closet (right behind my suits!), and the real me has emerged unencumbered from said enclosure to fearlessly tackle life's great mysteries.

In 2000 the Easter question surfaced more frequently than usual, due to its unusually late date of April 23. As he prepared for a CBC Radio interview on the subject, my good friend Russ Sampson innocently raised a question that sent us both careening down this particular slippery slope amidst an avalanche of emails, Web sites, graphs, and raw data.

My own fascination with calendars predates even that with astronomy, but the two are inextricably intertwined. In *The Timetables of History* (Grun 1982), the first entry in the category Science, Technology, Growth reads, "[5000 to 4001 B.C.E.] The Egyptian calendar, regulated by sun and moon: 360 days, 12 months of 30 days each." This suggests that not only is astronomy the oldest of the sciences (some would argue for physics), but that its first application was to measure the passage of time. Or, as Eisenberg (1958) states simply, "All calendars that have ever been in use are based on a study of the skies."

The calculation of Easter is the subject of fascinating chapters in histories of science and religion. Steel (2000) declares, "The single factor which has caused most controversy and division in the Christian religions, and which is pivotal in calendar definitions, is the calculation of the date of Easter." Duncan (1998) makes the extraordinary claim that at the start of the Middle Ages, "the calculation of the date of Easter became the slender thread that science would hang by over the coming centuries," in effect becoming the primary justification for continuing astronomy and mathematics. According to Gould (1997), "In Christian history, the need to reconcile solar and lunar cycles has centered on one of the most complex and persistently vexatious problems in the history of calendrics: the calculation of Easter. Books, indeed libraries, have been written on the subject, and great scholars have devoted their lives to devising rules and procedures for getting this cardinal day right... Easter became more problematic than any other calendrical day, or any other movable feast, because its definition includes both solar and lunar elements, and its date cannot be determined until we know how to reconcile all the great, and distressingly fractional, cosmic cycles. For Easter falls on the Sunday following the first full moon (the lunar component) after the vernal equinox (the solar contribution)."

Fortunately, the relatively small integers 235 and 19 comprise a good working ratio of lunar to solar cycles. Although he was likely beaten to the punch by Chinese and Babylonian astronomers, Meton of Athens is generally credited with the discovery of this relationship in the 5th century B.C.E. The relationship is therefore known as the Metonic cycle. Its implications are that lunar phases occur on the same date at 19-year intervals. In the Gregorian calendar, which is strictly solar, the dates of lunar phases gradually creep forward through the months, resulting in a given phase occurring twice in a month, such as the so-called "blue moon," 7 times in 19 years (McCurdy 1999). By comparison, the luni-solar Hebrew calendar deals with this by having 12 "common" years of 12 lunar months and 7 "embolismic" years of 13 months in a 19-year cycle. An intercalary month, We-Adar or 2nd Adar, is added to Years 3, 6, 8, 11, 14, 17, and 19 of the lunar cycle (Parise 1982).

The Council of Nicæa in 325 C.E. adopted the convention that Easter must occur on a Sunday. This introduced a third factor, namely that the artificial construct of the seven-day week be superimposed on the already complex interrelationship between the solar year and the lunar month. Other conventions introduced by Dionysius Exiguus in the 6th century and Aloysius Lilius and Christopher Clavius in the 16th century replaced astronomical observations with a more rigid structure. The vernal equinox was assumed to occur always on March 21, while the date of the Paschal Full Moon was limited to 29 possibilities, called epacts, derived from ecclesiastical tables. Easter was thus confined to the 35-day period from March 22 to April 25. Their methods may seem crude today, but given the mathematical and observational tools at their disposal, they were in fact remarkably sophisticated, even elegant.

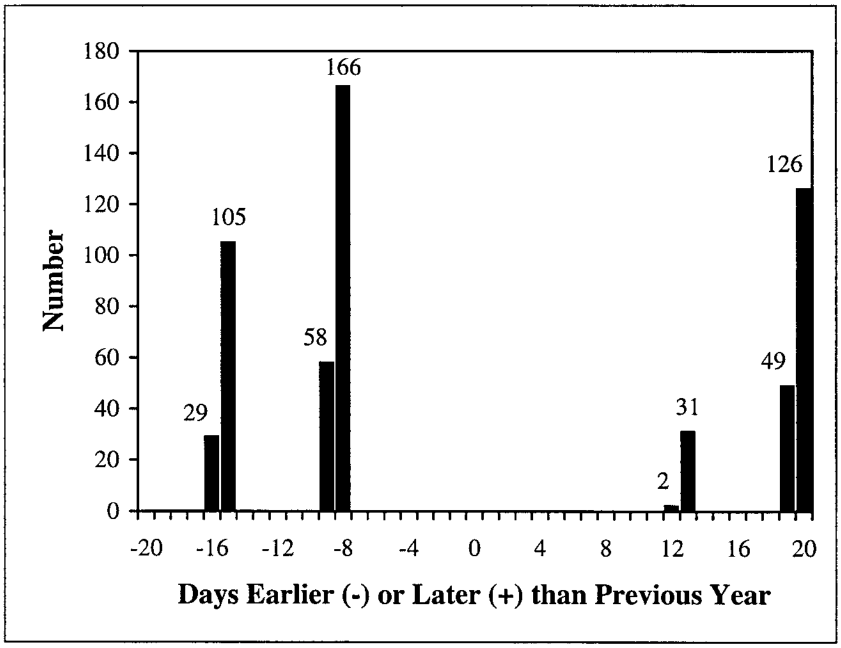


Figure 1: The intervals from each Easter to the next for the period 1583 to 2150 show the range of eight possibilities. In 12/19 (63%) of all cases, Easter moves earlier in the calendar. Note that leap-year Easters, as displayed by the shorter bars on the left of each pair, are disproportionate because leap years are smoothed out of the ecclesiastical tables but not, of course, on the calendar. One result is that the occurrence of Easter twelve days later than the previous year is exceptionally rare, occurring only in 1748 and 2076 in the period under review. (All diagrams courtesy of Russell D. Sampson.)

Since I didn't wish to write my own book, much less an entire library, on the subject, the primary subject of my research was to seek patterns in the date of Easter in the short and medium term. First, how does the date of Easter change from one year to the next? There is a range of eight possibilities, four of which apply to leap years only (`www.tondering.dk/claus/calendar.html`), as shown in Figure 1. Given that neither the common lunar year of 354 days nor the embolismic year of 384 days is close to the solar year of 365.24 days, one result is that Easter always differs by more than a week from one year to the next, seemingly jumping all over the chart. One night while under voluntary house arrest (I was volunteering at a Bingo), I spent an enjoyable six hours poring over about 5,000 digits of Easter dates, from calendar reform in 1583 through to 2150. (Did I mention that I'm not normal?) I tried to remove some of the inherent noise by reorganizing the data.

One fact that was immediately apparent was the extremely regular application of the Metonic cycle. Easter moves later in the calendar exactly 7 times every 19 years, in a cycle of 3 / 3 / 2 / 3 / 3 / 3 / 2, precisely the same frequency as the intercalary insertion of We-Adar. The pattern resembles a rhythm cycle, or *tala*, used in East Indian music, where a long complex bar is subdivided into regular, smaller intervals. As the most common subdivision is three years long, I took a set of 60 Easters from 1976 to 2035 and sorted them into three columns, as follows:

1976/04/18	1977/04/10	1978/03/26
1979/04/15	1980/04/06	1981/04/19**
1982/04/11	1983/04/03	1984/04/22*
1985/04/07	1986/03/30	1987/04/19
1988/04/03	1989/03/26	1990/04/15
1991/03/31	1992/04/19**	1993/04/11
1994/04/03*	1995/04/16	1996/04/07
1997/03/30	1998/04/12	1999/04/04
2000/04/23**	2001/04/15*	2002/03/31
2003/04/20	2004/04/11	2005/03/27
2006/04/16	2007/04/08	2008/03/23
2009/04/12	2010/04/04	2011/04/24***
2012/04/08	2013/03/31	2014/04/20
2015/04/05	2016/03/27	2017/04/16
2018/04/01	2019/04/21**	2020/04/12
2021/04/04*	2022/04/17	2023/04/09
2024/03/31	2025/04/20*	2026/04/05
2027/03/28	2028/04/16	2029/04/01
2030/04/21**	2031/04/13	2032/03/28
2033/04/17	2034/04/09	2035/03/25

Each vertical column therefore displays 20 Easters at three-year intervals. Each column is not a Metonic cycle *per se*, but simulates one. Note how the bottom row compares to the top; after 57 years the calendar shift is one day, and the moon phase is identical.

At three-year intervals, a regular pattern starts to emerge. The Paschal Full Moon moves ahead at extremely regular intervals of three days (occasionally two or four), as seen in Figure 2. Easter Sunday itself is shown in Figure 3; it typically moves earlier by four days every three years (three if there is no leap day in that time). About 10% of the time, however, Easter moves later by a similar shift of three or four days. This occurs when the Paschal Full Moon falls in the first instance on a Saturday, and the second on a Sunday, forcing Easter back by an entire week. These are indicated with an asterisk.

Two dates of each set of 19 contain a major shift backwards (double asterisk). These shifts occur when there is what I call a "double correction," or two embolismic years out of three. In such cases there are 38 lunations between Easters three years apart, rather than the usual 37, resulting in a major leap back in the calendar to cancel out the otherwise forward creep in the dates. All of the extreme early Easters occur just prior to a double correction, and all the extreme late ones just after, as can be seen in the following table:

1902/03/30	1905/04/23	1913/03/23	1916/04/23
1921/03/27	1924/04/20	1932/03/27	1935/04/21
1940/03/24	1943/04/25	1951/03/25	1954/04/18
1959/03/29	1962/04/22	1970/03/29	1973/04/22
1978/03/26	1981/04/19	1989/03/26	1992/04/19
1997/03/30	2000/04/23	2008/03/23	2011/04/24***
2016/03/27	2019/04/21	2027/03/28	2030/04/21
2035/03/25	2038/04/25	2046/03/25	*etc.*

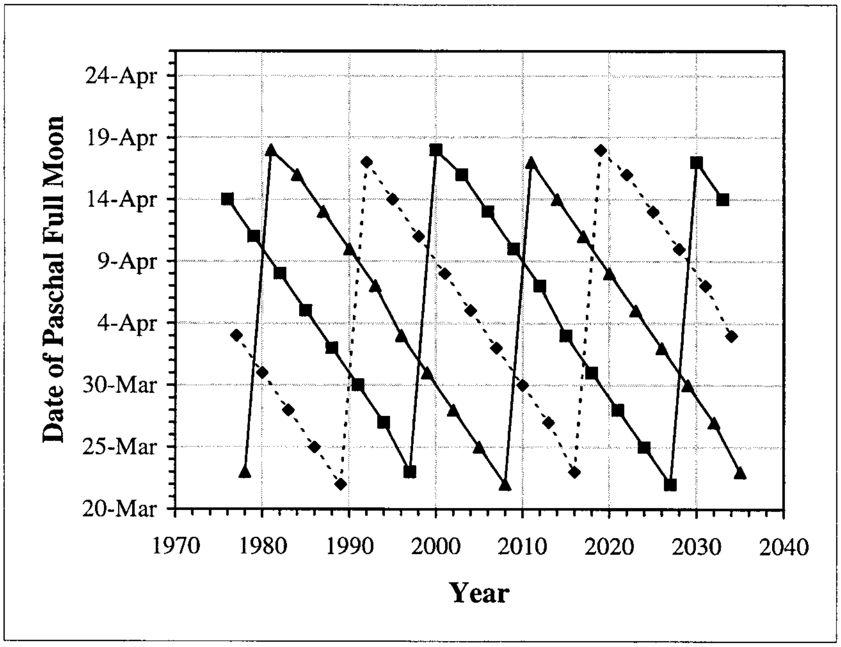


Figure 2: The Paschal Full Moon is derived from preordained ecclesiastical tables causing exceptionally regular intervals. The period 1976 to 2035 is represented here, sorted into three-year intervals to approximate three overlapping Metonic cycles of identical shape. In a given series, each successive Paschal Full Moon occurs two epacts earlier than its predecessor, which typically translates into three-day intervals. Two-day intervals occur at the very top of the graph due to the exceptional case of Epacts 24 and 25, which cause periodic bunching of three epacts. This problem was caused by the fact that the epacts are determined at New Year's during a "full" month of 30 days, but are applied for the purposes of Easter to a "hollow" month of 29 days.

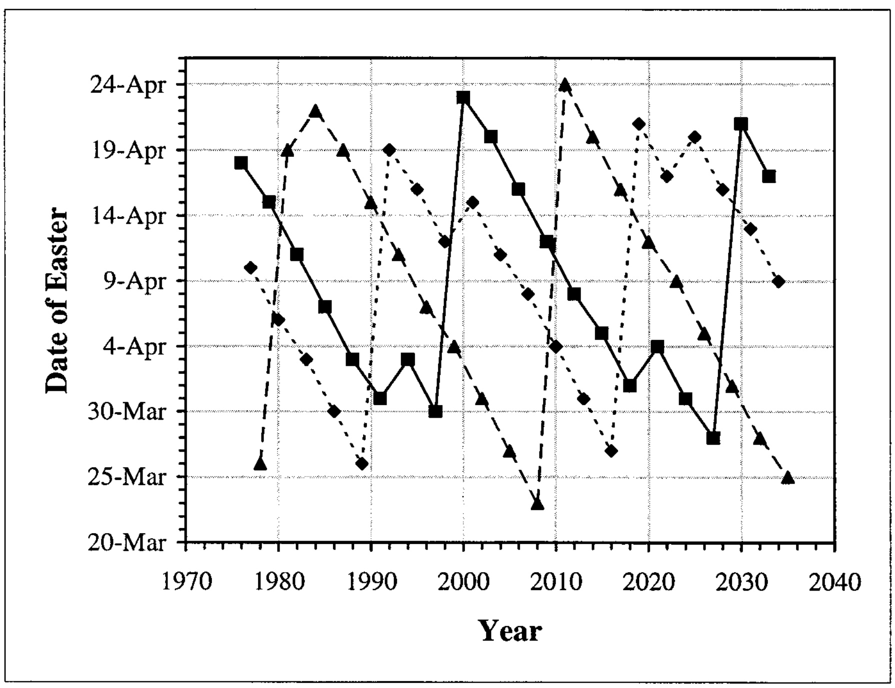


Figure 3: Dates of Easter for the same period, also sorted into three-year intervals. Generally the forward progression within a series is three to four days, depending on the fall of leap years. Occasional corrections "backwards" are due to the fact that 37 lunations are slightly longer than 156 weeks.

While a few of these dates have moderated towards the other end of the week, these four Metonic cycles carry *all* of the extreme dates of Easter in our lifetimes. Note that all the late Easters occur exactly three years after the early ones. Of particular note is the pair in 2008 and 2011, when both corrections occur simultaneously (triple asterisk). The two dates involved are separated by the maximum possible 161 weeks. Remarkably, the two most extreme dates in over 60 years will occur only three years apart.

Let's look at the medium term patterns by returning to our database of the 568 Easters beginning in 1583. In the complex Gregorian system, every few centuries the table of epacts is rotated by a day, due to a change in the "Clavian Differential" caused by the inexactitude of any of the measured periods (`www.friesian.com/easter.htm`). A "solar adjustment" automatically occurs in non-leap century years, while a "lunar adjustment" in the opposite direction is inserted eight times in 2,500 years to correct for the Metonic cycle. Occasionally the two cancel each other out, as in 1800 and 2100 (Richards 1998). The rotation of the epacts is graphically displayed in Figure 4 as quantum jumps from otherwise absolute linearity.

This linearity is much less in evidence in Figure 5, a nifty graph Russ produced that shows all the dates of Easters rather than their related Paschal moons. The most striking pattern is a series of diagonals, indicating groups of Easters slowly moving later in the calendar by roughly one day per twenty years. What's going on?

Let's start by looking at any narrow vertical segment of the graph representing, say, a quarter century. At a given time there are roughly eight clusters of possible dates, each separated by half-week intervals. This jives nicely with our previous finding that Easters at three-year intervals have almost invariably moved ahead or back by three or four days. There is a natural resonance reminiscent of Kirkwood gaps.

Meanwhile, examine any given (non-extreme) date horizontally across the chart. Typically, Easter will recur on that date two, three, or even four times at intervals of 11 years, followed by gaps of a half century or so before another cluster. Eleven-year recurrences are common due to two near resonances. Eleven years is the most natural fraction — along with its complement, 8 — of a Metonic cycle; in 11 years the lunar phase moves earlier in the calendar by only one or two days. Eleven years is also the most natural fraction — along with its complement, 17 — of a solar cycle of 28 years, in which a full rotation of possible calendars is completed. A given date occurs on the same weekday as 11 years previously 75% of the time; *e.g.*, April 15, 1979, April 15, 1990, and April 15, 2001 all happened to be Sundays. As the Paschal Full Moon occurred during the previous week in all three cases (April 11, 10, and 8, respectively), in all three of those years Easter fell on April 15. Next year's Easter is part of a foursome (1991, 2002, 2013, 2024) that occur on March 31. Such foursomes always end with a leap year (Meeus 1997a). However, a leap year falling earlier in a cycle results in the next Easter being pushed back by a day, for example:

1998/04/12	1988/04/03
2009/04/12	1999/04/04
2020/04/12	2010/04/04
2031/04/13	2021/04/04

Thus it appears that the fall of leap years — specifically, the one-in-four *absence* of a leap day in an 11-year cycle — is the primary cause of the gradual upward slopes of the diagonals in Figure 5. It is instructive to note that foursomes disappear and an unusual number of "singletons" occur around non-leap century years, where a leap day is removed from *all* cycles, which are thus shifted to one calendar day later. For example, Easters at 11-year intervals occur on:

1689/04/10	1700/04/11
1690/03/26	1701/03/27
1691/04/15	1702/04/16
1692/04/06	1703/04/08
1693/03/22	1704/03/23
	etc.

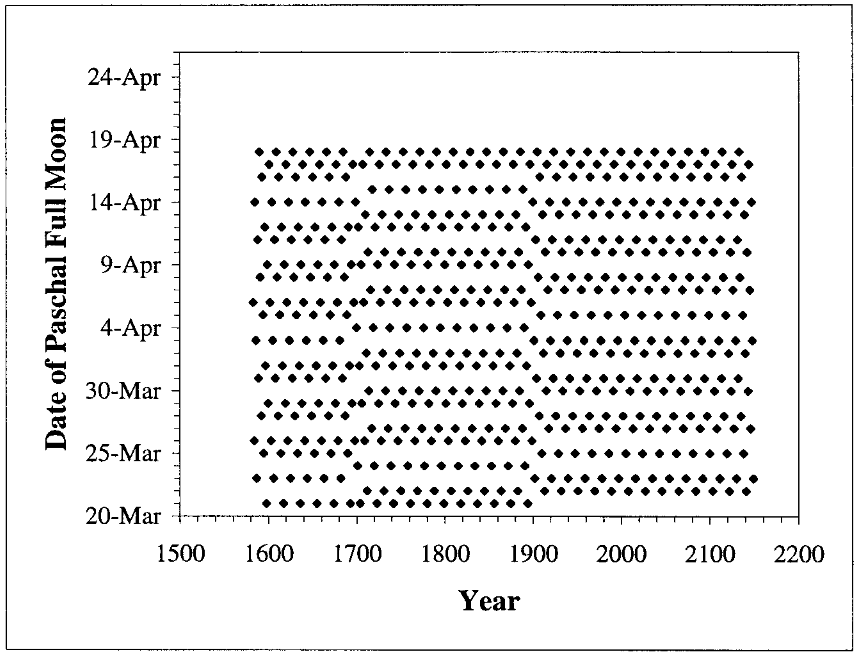


Figure 4: The distribution of Paschal Full Moons for the period 1583 to 2150 shows an extremely regular pattern. The data points on a given horizontal line are separated by intervals of 19 years. In the period shown, there are four solar corrections of one day that occur in the non-leap century years 1700, 1800, 1900, and 2100; however, lunar corrections of one day in the opposite direction in 1800 and 2100 effectively cancel out two of them. As a result, the cycle of epacts shifted, or rotated, only in 1700 and 1900, as can be readily seen. Note that in the current era, ecclesiastical full moons cannot occur on March 21; as a result, there are no March 22 Easters between 1818 and 2285.

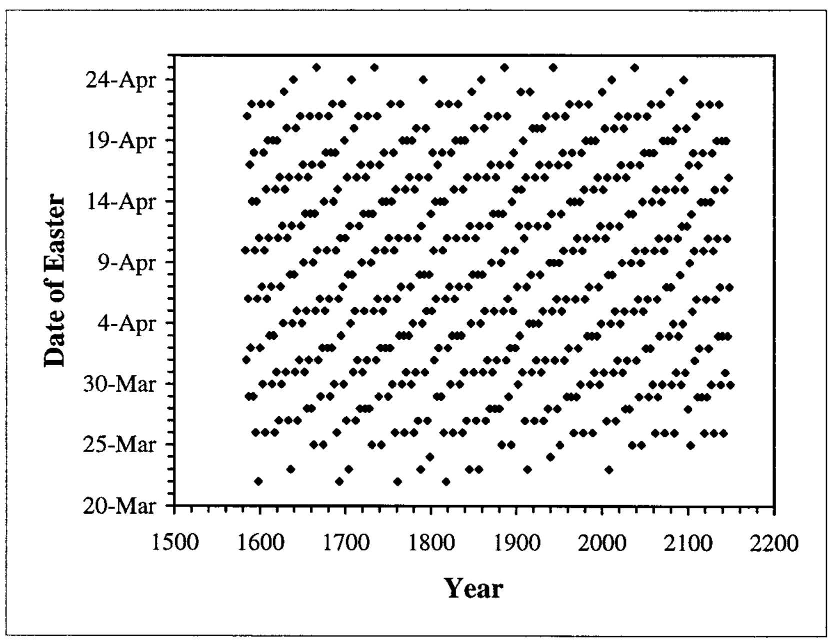


Figure 5: Dates of Easter from 1583 to 2150 graphically show the effect of the superimposition of the seven-day week. The horizontal rows of Figure 4 have largely disappeared, to be replaced by a pattern of diagonal lines. These show an apparent advance in the date of Easter by one day every ~19 years (a coincidence unrelated to the Metonic cycle). Easters on a given date frequently show a repetition of three or even four occurrences at 11-year intervals, followed by gaps of half a century or so.

Note the rare two-day lag between 1692 and 1703, because there is only *one* leap day in the 11-year interval. Similar two-day jumps account for the largest intervals in the entire period between Easters for a common (non-extreme) date. Because Easter jumps from April 8, 1792 to April 10, 1803, Easter does not occur on April 9 from 1730 until 1871; likewise a jump from March 27, 1796 to March 29, 1807 results in no March 28 Easters between 1728 and 1875. These two exceptions show up as gaps in the diagonal lines on Figure 5, which are otherwise remarkably inclusive.

On Figure 5 there are also some 30 "triplets" where three Easters occur on the same date within 11 years. The middle one is always the result of one of the corrections described in Figure 3. Curiously, all of the triplets are completely isolated in that there are no further Easters either 11 years before or after the triplet. Doublets of two Easters in five or six years are less common, but similarly isolated.

No doubt there are other patterns in the graphs that might emerge to the interested reader. I would be happy to correspond with anybody who has questions or discoveries.

There are still longer periods that can be examined. Meeus (1997b) refers to a periodicity of some 6,000 years and to the cyclical recurrence of all Easter dates over 5,700,000 years! Such immense time spans are beyond the scope of this study, so I have to conclude that they are of even less practical value.

References

Duncan, D. E. 1998, Calendar: Humanity's Epic Struggle to Determine a True and Accurate Year (Avon Books Inc.), 59

Eisenberg, A. 1958, The Story of the Jewish Calendar (Abelard-Schuman Ltd.), 25

Gould, S. J. 1997, Questioning the Millennium: A Rationalist's Guide to a Precisely Arbitrary Countdown (Harmony Books), 154

Grun, B. 1982, The Timetables of History (Simon & Schuster Inc.), 3

McCurdy, B. 1999, JRASC, 93, 68

Meeus, J. 1997a, Mathematical Astronomy Morsels (Willmann-Bell Inc.), 361

Meeus, J. 1997b, Mathematical Astronomy Morsels (Willmann-Bell Inc.), 354

Parise, F. 1982, The Book of Calendars (Facts on File Inc.), 12

Richards, E. G. 1998, Mapping Time: The Calendar and its History (Oxford University Press Inc.), 367

Ross, K. E., www.friesian.com/easter.htm

Steel, D. 2000, Marking Time: The Epic Quest to Invent the Perfect Calendar (John Wiley & Sons Inc.), 93

Tondering, C., www.tondering.dk/claus/calendar.html

Bruce McCurdy is a Past President of the Edmonton Centre and a 15-year volunteer at the Edmonton Space & Science Centre's Public Observatory. He also enjoys playing with numbers. A clock-watcher by nature, Bruce has slowed sufficiently in recent years to become a calendar-watcher instead.

The Mackie 1 Asterism

by Guy Mackie, Okanagan Centre (guy.m@home.com)

> **"For future reference, I would suggest a name for this group of something like Mackie 1 or Mackie J1841.9-2003."**
> **– Brent Archinal, US Naval Observatory**

This past summer I was fortunate enough to find a lonely little fuzzy that had been drifting nameless for eons and now carries the proud name of MACKIE 1. In all honesty, most of the credit for this nomenclature-nomination belongs to Alan Whitman. Alan had me looking in the right part of the sky, he had the maps necessary to confirm the absence of prior plotting, and he had the mettle to make further inquiries, which led to the cluster christening. The discovery took place on the night of August 3/4, 2000, on the windy peak of Mount Kobau, during the yearly Mount Kobau Star Party. Alan had as part of his observing plan the goal of spotting some of the very challenging Palomar globular clusters. Discovered in the 1950s on the survey plates of the first Palomar Observatory Sky Survey (POSS), these objects are difficult to see because of intervening dust or in some cases due to their extreme distance. When Alan shouted, "Pal 8!" I was instantly on my way to his 16-inch scope to bum a look. Not long after, Alan was patiently teaching me the star-hop sequence so I could give it a try in my 12.5-inch scope, and also, I'm sure, so he could get back to his own eyepiece. Within a couple of minutes I was proudly on target and enjoying Palomar 8 with my own scope. After Pal 8 had made about five or six drifts across the field of view, I noticed a little fuzzy that would appear at the edge just before Pal 8 slipped from view. Closer study revealed six to eight stars in a close cluster. I noticed that four of the stars would hold well in direct vision while the rest twinkled in averted vision. This was when I spoke the immortal words, "Alan, what is the little fuzzy in the upper right of the field?" and the rest is history.

Alan's maps did not show any objects plotted in the critical area, so he (thankfully) volunteered to see what he could find out after the star party through his other sources. The big day came on August 14, when Alan forwarded to me an e-mail from professional astronomer Brent Archinal of the US Naval Observatory in Washington DC. In his message to Alan, Mr. Archinal says that he cannot find any listing of this group of stars in any catalogue of which he is aware. The real kicker is at the end of the message where Mr. Archinal states, "For future reference, I would suggest a name for this group of something like Mackie 1 or Mackie J1841.9-2003." WOW, this news hits me like a ton of bricks! I don't know much about these things, but I figure if someone from the USNO "suggests" something, it is as if my wife "suggests" that she needs dinner and a movie — it's official enough for me! Using a DSS image, Mr. Archinal describes Mackie 1 as "an irregular group of 7 stars of about equal brightness, and something like 9-15 fainter background stars, in an area about 2´ in diameter." This has been a very exciting experience for me, and I would like to extend a big thank you to Alan Whitman for making it happen.

This is a very sparse, very faint and very unspectacular open cluster (or asterism), but if ever you should want to see it, just observe with me any time Sagittarius is above the horizon — I won't be able to help myself from showing the cluster off. Mackie 1 can also be seen on a DSS image by retrieving the image at the co-ordinates of $18^h\,41^m\,52^s$ and $-20°\ 03.4´$. The group of stars is best appreciated on the image by squinting your eyes while standing on the other side of the room from the monitor and tapping your head slightly to improve contrast.

The Mini-Messier Hunt: A Great Introduction to the Sky

by Mary Lou Whitehorne (ml.whitehorne@stmarys.ca)

> The Mini-Messier Hunt was indeed a hunt. Yet with the skills I have learned completing the Mini List, I am ready and eager to press on and complete the MESSIER LIST. … For those of you that have been thinking of starting your own Messier Hunt, I recommend going ahead. Look for those faint smudges on the window pane. Finding them can be very rewarding. — Paul Heath, Halifax Centre (who recently completed the Mini-Messier List)

There are many challenges that face would-be stargazers. Some of these include light pollution, poor weather (certainly not here in the Maritimes!), no telescope, an overabundance of other commitments, and a lack of familiarity with the night sky. Learning the sky and all that happens in it is challenging, but also very enjoyable. Since it takes a year for Earth to complete one orbital trip around our primary star, it stands to reason that it will also take a year to observe the entire cycle of seasonally changing constellations. If you are really keen, you can get a full season's jump on things by observing both in the evening and in the morning (pre-dawn) skies.

A telescope is not required to begin to learn, and enjoy, the night sky. Start by learning the patterns of the constellations, and you will eventually notice the advancing rising times of the stars. This slow change is the result of the Earth's orbital motion, which also causes the seasonal drift through the constellations. As you observe, you might as well look a little deeper with a pair of binoculars and discover for yourself some of the celestial gems that lurk out there. This is a wonderful way to become acquainted with the stars — recognizing the first few constellations, noting their progressively earlier rising times, and watching for new and less familiar star patterns to clear the eastern horizon. Later on you will see these then-familiar groupings sinking in the west. At the same time as you are watching the annual cycle of the stars, you can add another dimension to your observing by hunting for celestial treasure with your binoculars.

The Mini-Messier Hunt (see table) is an excellent way to start exploring the depths of the sky. This list of celestial objects has been compiled and tested by some of Halifax Centre's most experienced observers. In fact, the primary author of the Mini-Messier list is long-time Halifax Centre member and past Centre President, Dave Chapman. The list offers a wide range of types of objects, spanning the entire year, so there is something to look for no matter when you start this observing program. Once finished, you will have gained considerable familiarity with the sky and its motions. You will also have gained in skill and confidence, and you will be well on your way towards observing the entire Messier list, should you choose to continue. What are you waiting for? Sunset? OK, wait for sunset, but then get out there and start gazing! Happy hunting!

The Mini-Messier List

Object	Con.	Type*	Name	Date	Time	Instrument
WINTER						
M45	Tau	OC	Pleiades			
M37	Aur	OC	—			
M42	Ori	EN	Orion Nebula			
M35	Gem	OC	—			
M41	CMa	OC	—			
SPRING						
M44	Cnc	OC	Beehive Cluster			
M3	CVn	GC	—			
M5	Ser	GC	—			
SUMMER						
M13	Her	GC	Hercules Cluster			
M6	Sco	OC	—			
M7	Sco	OC	—			
M8	Sgr	EN	Lagoon Nebula			
M20	Sgr	EN	Trifid Nebula			
M17	Sgr	EN	Omega Nebula			
M11	Sct	OC	Wild Duck Cluster			
M27	Vul	PN	Dumbell Nebula			
AUTUMN						
M15	Peg	GC	—			
M31	And	G	Andromeda Galaxy			
M34	Per	OC	—			
NGC 869/884	Per	OC	Double Cluster			

*OC = open cluster GC = globular cluster PN = planetary nebula EN = emission nebula G = galaxy

Mary Lou Whitehorne has been an active member of the Halifax Centre for more than a decade. During the past several years, she has been kept busy training maritime Canadian teachers in basic astronomy and how to effectively use a Starlab in the classroom.

Shooting Lunar Rays

by Harry Pulley (hpulley@home.com)

I often hear fellow astronomers say there is no reason to observe with the bright Moon in the night sky. Even experienced lunar observers complain of the lack of interesting features on the Moon when it is near full. I counter that the Moon itself is a worthwhile target, especially near full. Though it is lacking in visible relief features such as partially shadowed craters, it is bountiful in albedo features, including the lunar rays.

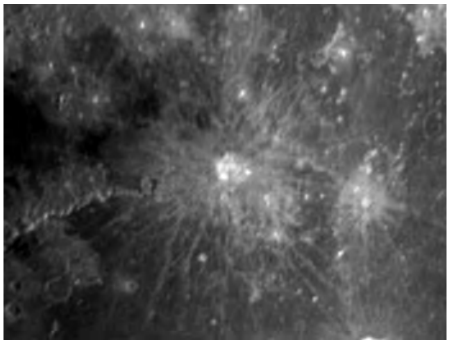
Once you've become interested in ray craters, you'll want to examine them on consecutive nights. Like all features on the Moon, ray systems change in appearance during the month. When a ray system is illuminated by sunlight from a low angle, it is often invisible, while at high illumination angles the parent crater itself often disappears. At what sunrise lighting angles do they appear and at what sunset angles do they disappear? Is the angle different for each ray system or similar for all of them? By observing and imaging lunar ray systems on successive nights, we may be able to answer these questions.

The origin of craters on the Moon was in dispute for a long time. Astronomers debated whether volcanic or impact processes could have created them. The impact argument can easily explain the ray systems but the volcanic mechanism does not provide a close fit. Impact debris placement tends to be symmetrical, as seen on the Moon, while volcanic eruptions on Earth tend to have some directional bias. When I think about the two possibilities, I wonder how anyone could ever have thought volcanic processes created the craters. It appears obvious to me that impacts were the cause.

Viewed near full, the Moon is often too bright for comfortable observing, especially when seen through a large telescope. Neutral density or polarizing filters can reduce the brightness for more relaxed viewing. I find red and green filters also provide a nice contrast enhancement, especially between the bright rays and darker albedo features. The two filters can also be combined for a dim brown view when a neutral density filter is not available.

This image was taken in November, 1998, using a Vixen 200-mm, f/9, at prime focus using Kodak E200 slide film. The exposure was scanned at 1800 dpi, unsharp masked, and gamma stretched.

You can record ray systems by sketching, or else by taking photographs or CCD images. Sketching has the least setup time but is the most time-consuming activity. Sketching also has the lowest required investment: just pencil and paper, in addition to a telescope. Photography is fairly quick to set up and has a large field to capture most if not the entire Moon at once. The dynamic range of film may limit the results, however, especially when taking images near the full phase.



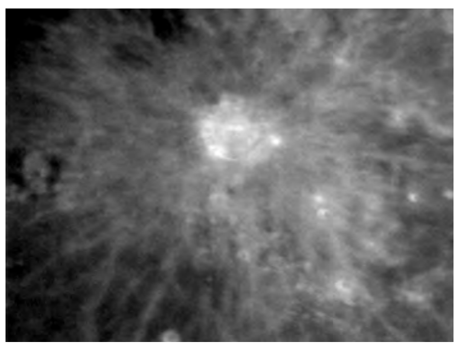
This image was taken on August 19, 2000, with a Vixen 200-mm f/9 catadioptric telescope and ST-5C CCD camera. It was taken at f/3.9 (780-mm focal length) of the craters Copernicus and Kepler using a blue filter.

CCD cameras offer a wider dynamic range but a smaller field of view, unless a very large sum of money is spent on the device. CCD imagers take longer to focus than film cameras, but since disk space is cheap, it is more affordable to take many images than many rolls of film. Instant results are another bonus of CCD work over film, which must be developed and possibly printed. As each recording method has advantages over the others, you can use different methods on different nights to study the rays. Different methods are good to use on the same night too, for example to capture a wide overview on film and then some close-ups using a CCD.

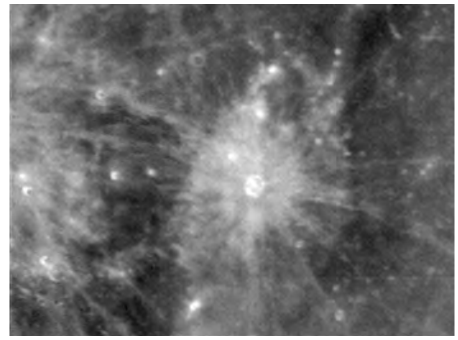
When sketching the rays, use the two-sketch system. Do a line-outline drawing while under the Moonlight, and do a final drawing with shading later, from the comfort of your desk. For the final drawing of light areas such as ray systems, I often find it easiest to shade an area evenly with pencil and blending stump, and then use an eraser to mark out the bright features. I find this easier than trying to sketch the darker area around a blank region. The two-sketch system lets you maximize your available time at the eyepiece while yielding a good finished drawing in the end.

When taking photographs of ray systems, it is usually best to try exposure times shorter than normally called for. If you take the usual exposure suggested by your light meter, the ray systems may be overexposed and washed out. Experiment with one, two and four-stop underexposure. Write down what you do so you can repeat the results next month without using so much film.

Most astronomy CCD cameras have larger dynamic ranges than most films. This means you can often capture both the bright rays and dark shaded areas in the same image. Experiment with images that are completely linear and those that have some non-linearity. I prefer fully linear lunar images but in some cases it is nice to expose shadowed areas deeper by allowing the bright areas to be overexposed.



This image was also taken on August 19, 2000, with a Vixen 200-mm f/9 catadioptric telescope and ST-5C CCD camera. It was taken at f/3.9 (780-mm focal length) of the crater Copernicus and surrounding area using a red filter.



This image was also taken on August 19, 2000, with a Vixen 200-mm f/9 catadioptric telescope and ST-5C CCD camera. It was taken at f/3.9 (780-mm focal length) of the crater Kepler using a red filter.

Go ahead and shoot some lunar rays!

Harry Pulley lives in Guelph, Ontario. He is the past treasurer of the Hamilton Centre. He loves to observe, sketch, photograph, and take CCD images of all sorts of celestial objects, but solar system objects are his targets of long-term study.

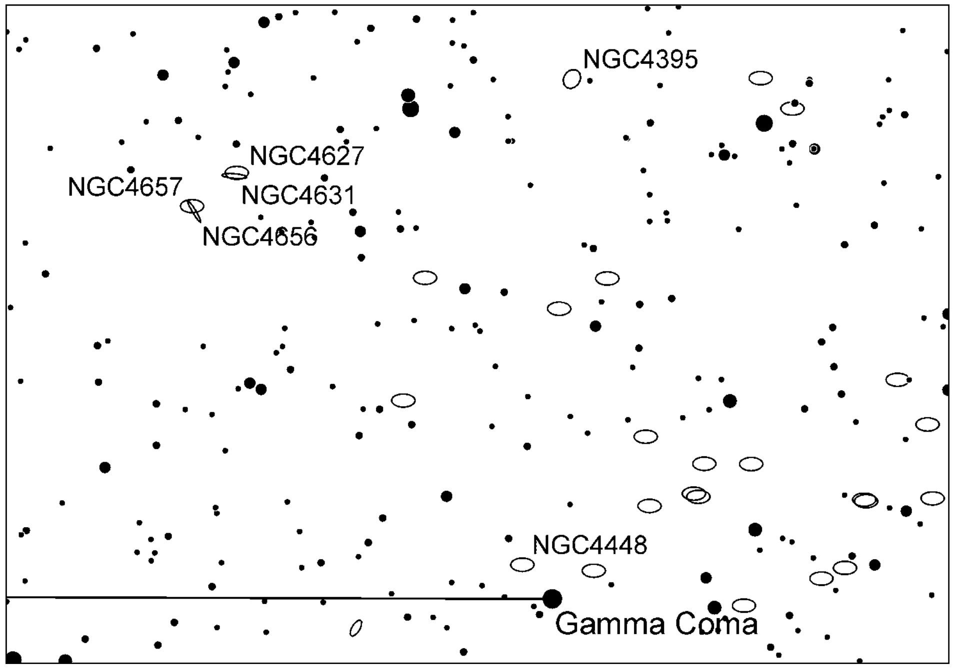
The Observing Run

by Mark Bratton, Montreal Centre (mbratton@generation.net)

We who live in humid, temperate climates can only look on in envy at our brethren who reside in more astronomy-friendly climates. Consider life in Arizona, where chances are, if you want to go out observing this coming Friday, you can be almost certain that the weather will cooperate and you will be blessed with dry, clear skies. True, the desert air may be a bit nippy on occasion and it is important that your observing site is rattlesnake-free, but compare this to our own weather — damp, chilly and seemingly perpetually cloudy (except on nights when the Moon is full!) Which would you choose?

Despite our obvious disadvantage, there is little reason to become depressed. Instead, a little attitude-adjustment is in order. Treat every one of those rare clear nights as a special occasion when the universe reveals its secrets. Well-prepared amateurs who do their homework on a cloudy night are ready to take advantage of a little good weather. With a small cottage in Sutton, I know all about poor weather. Because of the local geographic conditions (a mountain range running north-south from the Eastern Townships well into Vermont) my locality is frequently cloudy and even clear evenings in late spring, summer, and fall are often plagued by local ground fog in low-lying areas. The result is that even good nights are often interrupted by fog or sudden banks of clouds.

The evening of May 20/21, 1995 was my first observing session in six weeks. Poor weather or other commitments had conspired to restrict my access to clear, dark skies. Now a clear night waited with steady skies. After assembling my reflector, I swung the scope up into the region of Canes Venatici to observe a galaxy that I had seen only once before, and that view was with a smaller telescope from light-polluted Dorval.



A few of the mentioned galaxies are shown in this chart of northern Coma/southern Canes Venatici. The chart is about 7 degrees tall and shows stars to about 9th magnitude (ECU Chart by Dave Lane).

My target was NGC4631, a spectacular galaxy when seen in a large telescope under dark skies. The galaxy appeared extremely bright and much elongated due east-west. The western half tapers to a point, while the eastern portion appears blunt. There is much mottling along the major axis. A tenth-magnitude field star is located immediately north of its centre. Two arcminutes southeast of the star, a bright condensation is visible in the envelope. A similar, but fainter one can be seen three arcminutes southwest from the star. NGC 4627, a companion galaxy, appears faint and small, oriented northeast-southwest with a smooth envelope and moderately well-defined edges. A faint stellar nucleus is visible.

It was a short hop to the next object of the evening, the peculiar galaxy NGC4656/57. It appears delicate, though fairly bright, and is oriented south-southwest/north-northeast. A bright concentration appears in the south-southwest with a stubby arm curving to the west. At the tip of this branch is a magnitude 13 star. A faint bridge of light curves away to the north where a second, fainter concentration is seen. That concentration is NGC 4657, which was thought to be a separate nebulosity when it was first discovered by Sir William Herschel.

Sweeping back towards the east brought me to the next target of the night. NGC 4395 is a galaxy I had noticed on chart 108 of *Uranometria 2000.0* while doing some research earlier that spring. I saw a plump oval on the chart and thought: “What’s this?” The size of the oval indicated that this galaxy was fairly large, probably nearby, and yet I had never heard of it. I had resolved to observe it at the earliest opportunity. One look through the reflector that evening told me why it was so obscure. I needed to use my lowest magnification to see anything at all. In my notes I wrote: "This is a large, diffuse and very faint galaxy, best seen at low magnification. It pretty much disappears at 146×. There is a faint concentration of light toward the centre, with averted vision this appears as a bar oriented northwest/southeast. The envelope is extremely tenuous and fades very gradually into sky background."

South of NGC 4395, just over the border in Coma Berenices, were several galaxies that would occupy me for the next hour. The first was fairly bright. NGC 4448 was a well-concentrated galaxy. The central region was very bright and condensed, brightening to the middle though no stellar core was visible. A faint secondary envelope was best seen at 146× and elongated due east-west. The edges of the envelope were defined moderately well and very mottled.

At this point I looked up. What had been a good night had become a very good night indeed. I decided to swing the scope 3.5° to the east-northeast to pick up the tight little galaxy group Hickson 61. The group is made up of four galaxies arranged in a rectangular form, which in some circles, has earned it the nickname "The Box". Four NGC galaxies are involved. The most interesting is NGC 4173, a faint, flat streak of light, the largest in the group and displaying an even surface brightness. NGC 4169, the brightest of the group, is well-condensed and, like 4173, oriented southeast-northwest. The other two galaxies, NGC 4174 and NGC 4175 were very small though well-condensed. NGC 4174 in particular was virtually stellar at all magnifications. The group is interesting because, like Stephan's Quintet, one member, NGC 4173, has a redshift significantly lower than the other galaxies in the group, implying that it is not at the same distance as they are.

A little farther to the east, I came upon another small group, this time consisting of three galaxies. NGC 4134 was the largest and brightest of the three. Oval and moderately well-defined, it was oriented northwest-southeast and a little brighter to the middle. The other two galaxies, NGC 4131 and NGC 4132 were quite small, though well-defined. By this time it was midnight and the Coma/Canes region was sinking towards the trees that border the western part of my property. It was time to take in a few sights in the constellation Draco.

First stop was a group of galaxies that long ago had made it onto my "gotta see it one day" list. NGC 4386 is the brightest of the three, a well-condensed oval of light oriented northwest-southeast. The central region is quite bright but non-stellar and the envelope is well-defined. NGC 4291 is next brightest, a round well-condensed object with some mottling visible in its well-defined envelope. A bright central core was prominent. The galaxy is located due west of a triangle of tenth-magnitude field stars. NGC 4319 is a little smaller and fainter, though it is the most interesting of the three. Oval in shape and oriented north-south, the galaxy appeared a little brighter to the middle. The galaxies themselves are not particularly special, though they appear fairly bright in my 15-inch reflector. What made this grouping interesting was a small stellar object located immediately south of the core of this last galaxy. This was the quasar Markarian 205, stellar in appearance and usually visible with direct vision in my 15-inch. These two objects were at the center of the "Red Shift Controversy" when deep-field images taken by Halton Arp seemed to indicate that a luminous bridge of matter connected the two objects. Since quasars are thought to be at great distances, the problem became how to explain a distant quasar that was physically connected to a bright, relatively nearby galaxy.

Looking up, I thought the transparency was not quite what it had been just a few moments earlier. Time for one last quick one. Just six degrees due south from NGC 4319 is an ethereal, though large, galaxy designated NGC 4236. In my notes I wrote: "NGC 4236 is a very faint galaxy, diffuse and very poorly defined, much elongated almost due north-south. Difficult to detect at 146× although a faint star or stellar nucleus is visible at this magnification. The galaxy is best at 48×, a little brighter along its major axis but texture appears fairly smooth." I was, in fact, looking at a galaxy quite similar in morphology to NGC 4395, though this time almost edge-on. As I moved back from the eyepiece, a quick glance towards the west told me that my run was at an end — a typical late night Sutton cloudbank was moving in.

Still, I had to be pleased with the night's work. Ghostly nearby spirals, a bright, detailed edge-on spiral, a galaxy group with a discordant redshift and my first quasar. A night like this can sustain an amateur astronomer for along time. Let it rain! Let it pour!

Mark Bratton, who is a member of the Webb Society, has never met a deep sky object he did not like. He is one of the authors of Night Sky: An Explore Your World Handbook.

Elementary *Perceptions*

by Guy Mackie (guy.m@home.com)

> **"I was fascinated by the concept that all elements heavier than iron can only be produced in a star with enough mass that it will eventually explode in a supernova, thus explaining the rarity of these heavy elements."**

My imagination has been captured by a single sentence from the book *The Universe Revealed* by Chris Impey and William K. Hartmann. Describing the elements produced in a supernova, the text reads, "Supernovae are the source of most of the rare elements and precious metals in the world — the silver in the coins in our pockets and the gold in the jewelry on our bodies." I was fascinated by the concept that all elements heavier than iron can only be produced in a star with enough mass that it will eventually explode in a supernova, thus explaining the rarity of these heavy elements. Our sun does not contain enough mass to go through the funeral march of supernova nucleosynthesis, but the presence of elements heavier than iron in our solar system speak to the distant past. These precious elements tell us that everything in Sol's domain (including ourselves) has been recycled from a cloud made partly of supernova stardust that was likely compressed in the increased density of a galactic spiral arm, approximately 5 billion years ago.

A supernova remnant (SNR) is the element-rich clouds of gas and dust left after a supernova explosion, and there are many examples of them to be seen with small to moderately sized amateur telescopes. Some have been given names referring to their discovery dates (*e.g.*, SN1987A, the brightest and nearest supernova of the last three centuries, discovered by Canadian Ian Shelton). Many SNRs have made it onto lists of radio sources, so they have catalogue numbers beginning with 3C.

The only example of a SNR on the Messier list is M1 or the Crab Nebula. This remnant is the result of a supernova on July 4, 1054 (current era) that was well documented by Chinese observers of the Sung dynasty. With an estimated brightest magnitude of -4 it is surprising that there is only one European record of this event, by a Christian physician from Bagdad, Ibn Butlan. As a novice to the hobby, I found M1 a difficult object to locate using my 4.5-inch reflector, from a light polluted backyard, but find it I did. One of the biggest obstacles I had was a frustrating habit of always starting my search beside Beta Tau instead of Zeta Tau. As I gained experience I still carried this habit, along with a new 8-inch reflector, onto the hillsides around Kelowna for a much more rewarding view of M1. My sparse notes of the time describe it as a large but diffuse nebula, slightly flattened and extended northwest to southeast. Using my 12.5-inch reflector I re-observed with hopes of seeing some of the detail mentioned by Stephen James O'Meara in his book *Deep-Sky Companions: The Messier Objects*. The best I could do was to notice the two mis-aligned halves, which were described to me by Alan Whitman as forming a "fat S-shape."

The constellation Cygnus contains, in my opinion, the most dramatic example of a SNR. This is the Veil Nebula or Cygnus Loop. Here the lacy filaments of the scattered shell still glow from the tremendous energy released when a star blew up many thousands of years ago. (For Mackie's description of the Veil see "Cygnus Delights" in the June 2000 issue of the *Journal*.)

Wanting to push the limits of my 12.5-inch Dobsonian, I went in search of fainter targets. My research indicated that there might be visual evidence of the remnants 3C58 (SN1181), 3C10 (SN1572), and Cassiopeia A (SN1671). It was perhaps unrealistic to have these objects as targets for a 12.5-inch scope and I found no observational evidence of these objects, but I did enjoy the hunt. On August 7, 1181, the supernova 3C58 was reported by Fujiwara Kenezane, a courtier of the Japanese imperial court, as a guest star in the constellation Wang-liang, our constellation Cassiopeia. It was observed for 6 months and probably never rose in brightness above magnitude 0. Many may be familiar with the story of Tycho's star, 3C10, which was noticed by Tycho on an evening stroll home from a day in the alchemical laboratory on November 11, 1572. This supernova brightened to about -4 magnitude and was visible for close to a year. A slightly more recent event was Cassiopeia A (SN1671) which has been seen in visible light by the 200-inch reflector at Palomar, but not by a 12.5-inch Dobsonian — big surprise. It probably rose to magnitude 5, but if any visual reports were made at the time, they have not survived.

I had better luck tracking down IC 443, an SNR in Gemini. The subject of numerous observing sessions, IC 443 stubbornly refused to yield a truly positive identification, until an exceptionally clear night in December of 2000. As with past observations, on this night I was drawn to a glow around a faint Y-shaped asterism east of Eta Geminorum. The glow within the Y is not likely part of the SNR, but

"A supernova remnant (SNR) is the element-rich clouds of gas and dust left after a supernova explosion, and there are many examples of them to be seen with small to moderately sized amateur telescopes."

using 63× and alternately a UHC and O III filter, I detected a gauzy fan extending from the leg of the Y to a catcher's mitt of three stars (SAO 78203 and SAO 78194 are the brightest) 20´ to the north. I concentrated on this area for some time without a satisfying identification. I increased the power to 88× using an O III filter, which gave a darker background and made the area stand out better, but I was still not sure. I found that tube movement with my hands cupped around the eyepiece (no small feat) improved the view. On one of my sweeps I drifted off about 20´ to the north-northwest of SAO 78194 and there was a distinct glowing patch! Careful observation revealed a flattened S-shaped arc lying east to west, approximately 12´ to 15´ in length and 4´ in width. It broadened to 6´ to 7´ at the brighter west end. Switching to a UHC filter I could still detect a dim blush but it was very much muted. A photograph of IC 443 on page 944 of *Burnham's Celestial Handbook* shows many of the details that I have mentioned. About one third of the way up the page on the left hand (east) side is the Y-shaped asterism. The brightest star above (north) and almost off the left side is SAO 78203, the easternmost of three stars in the catcher's mitt. A flattened S-shape delineates the northernmost boundary of the nebulosity, which is most likely the area I observed.

If shown on your star maps, the huge rippled shell of Simeis 147 makes a tempting target; however this titan of Taurus is very faint and presents one of the most challenging objects for the amateur. I have made S147 a whimsical stop on many observing sessions with absolutely no luck at all. That is, until a beautiful night in November of 2000. I drove to my 3600-foot-high dark site with windows down and a cold (garage stored) mirror. Simeis 147 was my only target on this night, and I believe I was successful! During this observing session I spent more than two and a half hours studying the small area near SAO 77350 using a low power of 63× and an O III filter. Two brief periods of superb seeing lasting less than 30 seconds in total are the basis for my positive identification of S147. On these two occasions the seeing improved to reveal dark striations, reminiscent of the intertwined tendrils of the Veil, in the portion near to SAO 77350. These striations were the most exciting part of the observation. Both times they appeared in averted vision and I could hold them there for a few seconds, before they melted in direct vision. The first time I saw them I was optimistic (read "thrilled") but still not sure. When they repeated about 15 or 20 minutes later, I was ready, and I held them in averted vision till I was sure of the observation. On subsequent observations the seeing has never been as good as on that night, and I have not seen the striations again. There are however some areas that have repeatedly shown a subtle texture or stain, which agrees with other observing reports and photographic evidence of S147. Using a 20-mm Meade Erfle eypiece to yield 80× and an O III filter, I can detect a dim stain extending from 5´ south of SAO 77350 in an arc to finish in a point-shape near a faint double star at $05^h\ 37^m\ 20^s$ +26° 34.8´. This stain breaks apart to the east of 77350 but there is a slight strengthening approaching SAO 77398. Traveling north to the area of SAO 77478, there is a definite texture to the sky between SAO 77478 and SAO 77466. Tube movement of 1 field or more highlights this area. The dim milky band starts northeast of 77478 and streams directly towards 77466. I would have overlooked a nebulous patch 30´southeast of SAO 77397, at $5^h\ 43^m\ 37^s$ +28° 15.1´, were it not for an observing report by Jay McNiel. Here a sparse "clump" of 10^{th} magnitude stars does seem to show an area of nebulosity extending further from the sparse cluster than the unfiltered view would lead you to expect. When attempting to observe S147 I wear a towel over my head as a light shield, I occasionally remove the filter to study the unfiltered star patterns and I refrain from making frequent checks of star charts to preserve my night vision. While I strongly believe that I have observed sections of S147 with my 12.5-inch scope, visual observations are a subjective experience and I accept contrary opinions as being legitimate and constructive.

When observing these diffuse, element-rich clouds I sometimes cast my thoughts into the distant future, to a time when these remnant clouds may again coalesce into a new solar system. Will they hold the genesis of yet another Klondike Gold Rush or galleons sailing an alien Spanish Main, as subsequent intelligent (?) life forms come to recognize the rarity of supernova elements?

I wonder.

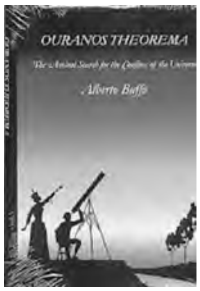
I gaze upon the beauty of the stars
That cover the face of the sky,
And think of them as a garden of blossoms.
— Moses Ibn Ezra (1070-1138)

References

Burnham, Jr., R. 1978, Burnham's Celestial Handbook (General Publishing Company: Toronto)
Gribbin, J. 2000, Stardust (Penguin Books)
Impey, C. 2000, The Universe Revealed (Brooks/Cole)
Marschall, L. A. 1988, The Super-Nova Story (Plenum Press)

Guy Mackie enjoys observing from the dark hillsides near Kelowna, British Columbia. He has completed the Messier and Finest NGC Objects lists and eagerly pushes the limits of his 12.5-inch Dobsonian on the Challenge Objects list and other deep sky targets.

Reviews
Critiques



Ouranos Theorema: The Ancient Search for the Confines of the Universe, by Alberto Buffo, pages 346, 18.5 cm × 26 cm, Bovolo Press, 2000. Price US$32.95, hardcover (ISBN 0-9675538-0-6).

Galileo's Dialogue on the *Two Great World Systems* of 1632 is the most famous book in the history of science to be written in the form of a dialogue. Galileo's own points of view are presented through his mouthpiece, Salviati, who engages in discussions with two friends: Sagredo, a person of good sense who, not surprisingly, usually ends up agreeing with Salviati, and Simplicio, who defends the Aristotelian line and whose arguments Salviati seeks to undermine. The result is a scintillating account of, among other things, the then novel Copernican cosmology and the new evidence in its favour secured by the telescope.

Alberto Buffo's *Ouranos Theorema* is also written in the form of a dialogue, this time between a mathematician Albertus, who we can reasonably presume speaks for the author, and Plebeius. The main subjects of their dialogues are how distances have been measured to the most distant parts of the universe (or at least what were reckoned to be the most distant at different times) and the related attempts to understand the structure of the physical universe. The book starts with the consideration of theories from the ancient world, and carries the analysis forward to ideas current in the early twentieth century. It ends with Plebeius and Albertus pondering very broad questions such as, for example, the limits of scientific thinking and the relationship of science and religion.

Ouranos Theorema, then, covers a lot of ground and is nothing if not ambitious. How well, however, does the author meet his goal of making the subjects intelligible to a general reader?

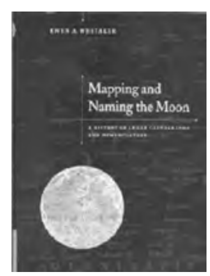
First, the writing does not match the lively pace or energy of Galileo's *Dialogue*. The author's odd decision not to use paragraph breaks too often makes for tough going. For instance, Albertus embarks on page 186 on a discussion of a range of topics that continues until page 211 when Plebeius finally gets a word in, but to read 25 pages of text with no paragraph breaks is hard indeed. The above example also underscores another problem in that the dialogue — again, unlike the case in Galileo's *Dialogue* where a reader feels an engagement with the characters — is often not much of a dialogue at all. For a lot of the time Albertus, in effect, lectures, usually at very considerable length. No doubt because it is aimed at a general audience, the book is without footnotes or bibliography, and the index is rather skimpy.

For a work that deals essentially with the history of astronomy and cosmology, the text also contains a fair number of historical errors. Let me give a couple to do with Edwin Hubble. On page 266, Albertus suggests that in his pioneering studies of the spectral shifts of spiral nebulae, V. M. Slipher measured the redshifts of only a few of them. In fact, when Hubble came in 1929 to write his now famous paper on "A Relation between Distance and Radial Velocity among Extra-galactic Nebulae," he exploited over forty such measurements by Slipher. In the second example, Albertus contends that Hubble's famous discovery of Cepheids in the Andromeda Nebula — very widely taken as clear evidence that the spirals are indeed distant galaxies of stars — was the result of a tedious and time consuming search for Cepheids. In fact, Hubble was hunting for novae in the spirals, not Cepheids, and the Cepheids were found by chance.

The result, then, is a book that is interesting in parts, but has problems. For those readers interested in the topics discussed in the *Ouranos Theorema*, I would suggest they might first turn to, for example, Michael Hoskin's *The Cambridge Illustrated History of Astronomy* for more reliable and accessible accounts. In addition, for serious students of the early history of the search for the confines of the universe, Albert Van Helden's *Measuring the Universe: Cosmic Dimensions from Aristarchus to Halley* is indispensable.

Robert W. Smith

*Robert W. Smith is chair of the Department of History and Classics at the University of Alberta. He is the author, among other works, of T*he Expanding Universe: Astronomy's "Great Debate" 1900–1931 *and* The Space Telescope: A Study of NASA, Science, Technology and Politics. *Most recently he has co-edited* Sputnik Reconsidered: Forty Years after the Soviet Satellite.



Mapping and Naming the Moon: A History of Lunar Cartography and Nomenclature, by Ewan A. Whitaker, pages xix + 242, 20 cm × 25 cm, Cambridge University Press, 1999. Price US$59.95, hardcover (ISBN 0-521-62248-4).

Ewan Whitaker was in the right place at the right time, a lunar astronomer when the Moon was unfashionable, who found himself in demand when the Moon became a destination. He helped map the Moon and organize its chaotic system of crater names at the dawn of the Space Age, and worked with photography of the lunar surface from the early NASA missions. By painstaking comparison of features seen in surface and orbital images, he identified the *Surveyor 3* landing site, which became the target of the *Apollo 12* astronauts. He has long been one of the world's leading authorities on the history of lunar cartography. Now his decades of experience are condensed into this slim, rich, and beautifully produced volume.

The title states the book's two interwoven themes: how people mapped the Moon and named its features. In four-fifths of the book, Whitaker presents such subjects chronologically. The remaining fifty pages contain detailed lists of names assigned by lunar cartographers over the centuries. The history of lunar mapping has been described elsewhere, including other works by Whitaker, but this is by far the most complete and best illustrated description of the subject yet published, except (unfortunately) for its coverage of the last few decades. Many maps described and illustrated here have not been portrayed in any other presentation of the subject. An excellent example is a map by Johann Lambert using an innovative map projection (p. 86), a map I have never seen elsewhere. A map by Sirsalis (p. 59) was thought lost until recently rediscovered, so it is not shown in any previous sources.

A unique feature of the book is its first chapter on pre-telescopic observations, which, I confess, mentions my own work. Alas, such thoroughness fades towards the end, where the thousands of *Apollo*-era maps are mentioned only in passing, the emphasis falling primarily on the names. Readers who need a detailed discussion of recent lunar mapping must revert to *Mapping of the Moon* by Z. Kopal and R. W. Carder (D. Reidel, 1974). An opportunity to update that reference was lost here. As just one example of what might have been covered, geological mapping in both the U.S. and U.S.S.R. has never been described in a historical context.

Whitaker could also have brought

things properly up to date by mentioning recent digital mapping from *Clementine* data, though admittedly that mission was flown after he retired. On the other hand, lunar nomenclature (the assigning of place names) has never been described in as much detail as it is in this book. From Plutarch's few ancient names to the competing seventeenth-century systems and recent efforts to standardize nomenclature for scientific users, two millennia of evolution and argument are laid out in detail. That may be of limited interest to some readers compared with the visually striking maps, but for historians of astronomy and others it is a fascinating and valuable reference.

Naturally there are a few points about which one could quibble. The most grievous omission is the lack of proper bibliographic citation throughout the book, making it very difficult to step back into the literature to follow up points of interest. I am convinced that Whitaker's statements concerning the Caspian Sea, or Caspia, as a name for a lunar feature (p. 6) are based on a misunderstanding of Plutarch. When Plutarch mentioned the Caspian he was referring quite explicitly to the terrestrial feature and never likened it to any lunar marking.

The author's involvement with official mapping and nomenclature causes him to pay scant attention to more popular or non-scientific works, a fault by no means unique to him. For instance, the early eighteenth-century map by Hohmann comparing the naming schemes of Hevelius and Riccioli is widely known but never mentioned here. An inset of the Moon in a celestial map by Allard (p. 92) is mentioned because of its idiosyncratic names, but not illustrated. How I would have liked to see it! Whitaker might argue that such maps are of no significance to the course of science, but consider the following example of the significance of unofficial maps and names. In the 1960s, Herbert Ross of Massachusetts published several hand-drawn maps of the Moon with which space enthusiasts could follow the progress of the *Apollo* missions. Ross applied the name "Lacus Titicaca" to a dark spot near the crater Copernicus, an unofficial name that I have not seen elsewhere. His maps and the associated name are not mentioned by Whitaker. In 1966, however, the Ginn educational publishing company reprinted Ross's map for classroom use. Ironically, that "unofficial" cartography may have been seen by far more people, may have become more a part of the public perception of the Moon, than any official map. So, all in all it is a superb book, but it is far from being the last possible word on the subject.

Is the book worth buying? Yes, certainly, for anyone with a fascination for the history of astronomy, and certainly for any reference library. Most of what the book gives us is either unique or more complete than can be found elsewhere. Many of the illustrations are not to be found in any similar compilation. I wholeheartedly recommend it, and I am very pleased with my copy.

PHIL STOOKE

Philip Stooke is an associate professor in the Department of Geography at the University of Western Ontario. His research includes both the history of planetary cartography and the mapping of asteroids and other non-spherical worlds.

Astrocryptic

by Curt Nason, Moncton Centre

The answers to last issue's puzzle.

1P	U	2R	K	I	N	3J	E	■	4S	5C	A	6R
R	■	Y	■	■	■	U	■	7P	■	R	■	O
8I	N	D	U	9S	■	10P	H	O	T	O	N	S
S	■	B	■	Y	■	I	■	L	■	S	■	E
11M	E	E	U	S	■	12T	R	A	N	S	I	T
■	■	R	■	T	■	E	■	R	■	■	■	T
13D	A	G	U	E	R	R	E	O	T	14Y	P	E
I	■	■	■	M	■	E	■	R	■	U	■	■
15O	N	16E	H	A	L	F	■	17B	A	C	O	18N
P	■	N	■	T	■	F	■	I	■	A	■	A
19T	A	C	T	I	L	E	■	20T	I	T	A	N
E	■	K	■	C	■	C	■	■	■	A	■	N
21R	H	E	A	■	22S	T	I	C	K	N	E	Y

Former Gold Medallist, Dr. Shirley Jones, dies at 87

A member of the Toronto Centre for 66 years and a life member for 40 years, F. Shirley Jones passed away on December 18, 2000, in the USA. Though she had little direct involvement with professional astronomy or the Society for the last 30 years, she was an outstanding astronomy student and teacher. At the University of Toronto Shirley Patterson earned the RASC Gold Medal in 1935 and her Master's degree the following year. Proceeding to Harvard, she studied under Cecilia Payne and completed her Ph.D on surface photometry of galaxies in 1941. This, and solar prominence work which she later carried out with Donald Menzel, were her chief astronomical interests.

Shirley Jones (left) with Ruth Northcott

In her student days at Toronto, Shirley became a good friend of her contemporary, Ruth Northcott, and they both played an active part in the Toronto Centre, especially in encouraging and supervising amateur participation in nova searches and observations of meteors and variable stars. During the war, Dr. Patterson returned to Toronto, where she was hired by her future husband, Donald Jones, at the government-owned Research Enterprises. They moved to Chalk River and then to Buffalo, NY, where Dr. Shirley Jones began a teaching career that included a spell at that city's Museum of Science and at several universities and colleges in the US. Shirley was also accomplished in arts and crafts. She loved to return each summer to a cabin in Haliburton, Ontario where she would delight in painting, bird watching and stargazing. As a "master weaver," she combined creativity and talent to achieve an artistic result, using a computer as an aid in later years. In retirement, she continued to bring astronomy to her friends and associates, helping them view eclipses and comets.

Her last contribution to the *Journal* was a 1985 book review of Cecilia Payne-Gaposchkin's autobiography. Anyone reading this book would get a good feeling for the plight of young women trying to enter the male-dominated field of astronomy in the 1930s.

Peter Broughton

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Observer's Calendar — 2001

This calendar was created by members of the RASC. All photographs were taken by amateur astronomers using ordinary camera lenses and small telescopes and represent a wide spectrum of objects. An informative caption accompanies every photograph.

It is designed with the observer in mind and contains comprehensive astronomical data such as daily Moon rise and set times, significant lunar and planetary conjunctions, eclipses, and meteor showers. The 1998, 1999, and 2000 editions each won the Best Calendar Award from the Ontario Printing and Imaging Association (designed and produced by Rajiv Gupta).

Price: $14.95 (members); $16.95 (non-members)
(includes taxes, postage and handling)

The Beginner's Observing Guide

This guide is for anyone with little or no experience in observing the night sky. Large, easy to read star maps are provided to acquaint the reader with the constellations and bright stars. Basic information on observing the Moon, planets and eclipses through the year 2005 is provided. There is also a special section to help Scouts, Cubs, Guides and Brownies achieve their respective astronomy badges.

Written by Leo Enright (160 pages of information in a soft-cover book with otabinding which allows the book to lie flat).

Price: $15 (includes taxes, postage and handling)

Promotional Items

The RASC has many fine promotional items that sport the National Seal. Prices include postage and taxes. Included are a *Cloth Crest* (size 11cm with the background white and the stitching in royal blue - $11), *Lapel pins* (blue, white, and silver - $5), *Golf shirts* (white, available in small and medium - $24), *Stickers* (size 7.5cm, blue with white overlay - $1 each or 2 for $1.50), *Thermal mugs* (in blue and white - $5.50), *Toques* (Black with Yellow lettering - $17), *Key chains* (Clear arcylic and Blue/white - $2.50).

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