April /avril 1999 Volume/volume 93 Number/numero 2 [676]

Journal

The Journal of the Royal Astronomical Society of Canada Le Journal de la Société royale d'astronomie du Canada

INSIDE THIS ISSUE

Blue Moons · Telescope Limiting Magnitude · Mars
Nebular Filters · 150 Messier Certificates

April/avril 1999

Journal

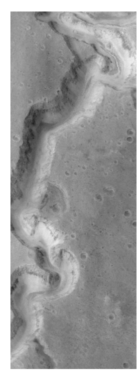
Vol. 93, No. 2 Whole Number 676

contents
table des matières

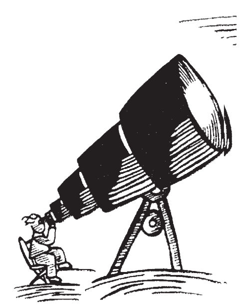
FEATURE ARTICLES/ARTICLES DE FOND

RESEARCH PAPERS/ARTICLES DE RECHERCHE

COLUMNS/RUBRIQUES



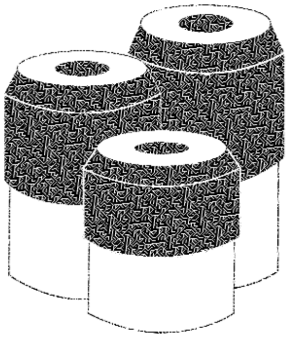
Mars, Up Close and Personal
p.78



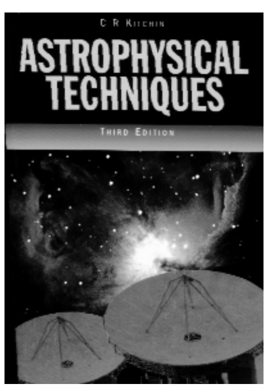
Ask Gazer
p.89

1999 General Assembly
p.85

Initial Impressions of Three New Eyepieces
p.97



Astrophysical Techniques
p.99



Cover Photo:

An image of the full Moon taken by Blair MacDonald (Halifax Centre) using Fuji HG400 film and his Meade 8-inch Schmidt-Newtonian telescope.

See page 68

From the Editor

by David Turner

By tradition, if two years' practice can be considered as "tradition," the April issue of the *Journal* has contained an April Fools' item. Each year my editorial has stated that this editorial is *not* the item. Upon examination of the material for the present issue, however, it occurred to me that perhaps this editorial *is* the item. There is plenty of variety to be found in the articles in the current issue, but nothing that seems to qualify as an April Fools' item. Perhaps you will be more discerning than I have been.

Under the category of day brighteners, Jay Ryan's *SkyWise* educational strips in *Sky & Telescope* impress me more and more with each one published. Always accurate, the strip is a wonderfully descriptive tool for depicting everyday — and decidedly non-everyday! — sights in the sky. The subject matter for the strip appearing in the April issue of *Sky & Telescope* is the appearance of the Earth and Moon, as well as the satellites Phobos and Deimos, as seen from the surface of Mars. It is not entirely a thought experiment, given ongoing satellite missions to the red planet and the possibility of future manned missions — preferably not ones carried out along the lines depicted in the movie *Capricorn One*.

Another day brightener was an E-mail message I received from Rod Clark commenting upon my discussion of perfect numbers in the December editorial. The relationship between the perfect number six and such things as the 360-degree circle and twenty-four hour day appear not to be well known. It occurred to me as an afterthought that there are probably other astronomical tie-ins. Why, for example, did Hipparchus choose to divide the stars visible to the unaided eye into six different magnitude bins, rather than say five or ten, unless it was because of the special significance of the number six? Is the entire sequence of stellar magnitudes therefore rooted in numerology? Of course, the number six also describes the number of sides on a cube (or die), the number of points on the Star of David, and probably a variety of other things that escape me at the moment. Perhaps the RASC should initiate a contest, akin to "The 1001 Uses for Duct Tape" or "A New Mnemonic for the Spectral Sequence," to identify examples of perfect numbers in everyday use. How many can you think of?

Let me finish with a few questions that come randomly to mind upon the occasion of completing five years of editing the *Journal*. Why does the Map of the Moon included in the *Observer's Handbook* have its directions oriented for observers on the Moon rather than for observers on Earth? Does the RASC have a lot of members on the Moon? Where has Gazer been for the last year? Has he/she been hiding from irate Questar owners? What version of *Spelling and Grammar Checker* is used by Joe O'Neil? Is there a version 0.0? What does being "profoundly sorry" (Bill Clinton) mean? How many levels of apology are there? Finally, how did April Fools' day originate, and why is it tied specifically to April? Do other months of the year not qualify for foolishness? :-)

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 one of the addresses given below.

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 1998, $36.00; life membership is $720. 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:

The Royal Astronomical Society of Canada
136 Dupont Street
Toronto, Ontario, M5R 1V2, Canada
Internet: rasc@rasc.ca
Website: www.rasc.ca
Telephone: (416) 924-7973
Fax: (416) 924-2911

Periodicals postage paid at Champlain, NY and additional mailing offices.

U.S. POSTMASTER: Send address changes to IMS of NY, P.O. Box 1518, Champlain, NY 12919.
U.S. Periodicals Registration Number 010-751.

Canada Post: Send address changes to University of Toronto Press Incorporated, 5201 Dufferin Street, North York, ON, M3H 5T8

ISSN 0035-872X

President's Corner

by J. Randy Attwood (attwood@istar.ca)

For amateur astronomers, it is quite an amazing time to be alive. For those interested in our solar system, there are space probes in orbit around the Moon, Mars, and Jupiter. Others are on their way to Mars, Saturn, an asteroid and a comet. There is another space probe that is constantly monitoring the Sun. For deep sky enthusiasts, every other week there is news about an amazing discovery by the *Hubble Space Telescope* or by ground-based instruments. Until recently, we would have to wait to hear about such results in magazines. Today the pictures and discoveries are available on your home computer via the Internet. At times it is hard to keep up with all of the data.

On the home front, telescope equipment and accessories have changed drastically over the last few years. To prove that yourself, flip through copies of *Sky & Telescope* from 1969, 1979, 1989, and 1999 — look at the ads. I can see how someone who has chosen astronomy as a hobby could easily be overwhelmed. Where do you start? Fortunately, a lot of Centres offer their new members advice on choosing their first telescope. The bright side to the technology explosion in amateur astronomy is that, for those who are buried in light pollution (like those in the Toronto area), deep sky photography is possible using CCD cameras. It is possible today to obtain professional results with affordable amateur equipment. That will be one of the central themes during the "Partners in Astronomy" conference at the General Assembly in Toronto this summer. Registration forms are now available on the Internet at the Astronomical Society of the Pacific (`www.aspsky.org`) site and at meetings of your centre. If you have any questions, please contact our Executive Secretary, Bonnie Bird, at the RASC National Office in Toronto.

After many months of planning, the responsibility of processing membership renewals has transferred from the University of Toronto Press to our National Office on Dupont Street in Toronto. If you have any questions about your membership, please contact Bonnie Bird (Telephone: 1–888–924–7973 or Email: `rasc@rasc.ca`).

Finally, you may remember that last year I challenged everyone working on their Messier Certificate to join me in observing all 110 objects by December 31, 1999. I hope you are all doing better than I am. On a recent visit to the Winnipeg Centre, I met one person who is — Tim Zacharias observed and drew all 110 objects in ten months. He told me that on average each drawing took one hour. Well done Tim! As for my progress, it is hovering at 61. Hopefully I can knock off the Virgo cluster this spring. I see in the Montreal Centre's newsletter *Skyward* that 13 members are working on their certificates. Good luck to all RASC Messier hunters.

Clear skies!

News Notes
En Manchettes

THE FATE OF THE SOLAR SYSTEM

Studying our solar system is like reading a good book. Sometimes we would like to know how the story ends. When the Sun dies, what happens to the planets? Recently, Martin Duncan of Queen's University and Jack Lissauer of NASA's Ames Research Center attempted to peak at the last chapter of the solar system's history (August 1998 issue of *Icarus*).

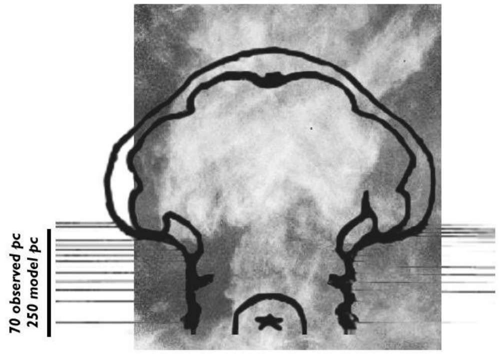
According to our current understanding of stellar evolution, we know reasonably well how the main character will die. Towards the end of the Sun's life, the hydrogen fuel at its centre will run out. With the subsequent loss in radiation pressure, the Sun's core will no longer be able to resist the relentless crush of gravity and will grow smaller. The overall size of the Sun will have increased during this interval. As the core region shrinks, however, the pressure and temperature will rise. That will raise the temperatures in regions adjacent to the Sun's centre, which will result in a shell of hydrogen surrounding the core to begin burning. The new heat source will expand the outer layers of the Sun further, producing a star with the dimensions, luminosity and surface temperature of a red giant. At the same time the Sun will probably expel a significant percentage of its mass. Eventually it will have consumed all of the available hydrogen fuel in its interior, and will shrink to the dimensions of a white dwarf. Depending upon the red giant stellar evolutionary model used, the final mass of the white dwarf will lie between 43% and 58% of the Sun's original mass.

But what about the planets, what happens to them? During the red giant stage the surface of the Sun may extend as far as the Earth. Increased friction with the tenuous gases in the Sun's outer layers will likely cause Mercury, and possibly Venus and the Earth, to spiral into the Sun. According to the Newtonian version of Kepler's third law of planetary motion, as the red-giant Sun sheds mass, the periods and orbital radii of the remaining planets will increase. But, are the new orbits stable, or will the planets eventually be ejected from the solar system or consumed by the Sun?

Using computer models to simulate the long-term behaviour of the planetary orbits, Duncan and Lissauer reduced the mass of the Sun to a white dwarf and watched what happened to the planets. Their results suggest that the surviving terrestrial planets (Venus, Earth, and Mars) will remain in their new orbits for a billion years or longer. The gas-giant planets (Jupiter, Saturn, Uranus, and Neptune) appear to be even more stable, lasting at least 10 billion more years after the Sun becomes a white dwarf. The fate of poor Pluto is much less rosy. There appears to be a very good chance that after the Sun dies the smallest member of the solar system will be lost forever.

DRAO IMAGES REVEAL GALACTIC MUSHROOM CLOUD

The more we probe our universe, the more violent it often appears. Recently released images from the Canadian Galactic Plane Survey/Relève Canadien du plan galactique (CGPS/RCPG), being carried out at the Dominion Radio Astrophysical Observatory (operated by the National Research Council of Canada), punctuate the explosive nature of our galactic home.



A comparison of the radio image of the mushroom cloud with a scaled schematic outline representing a blowout model generated by Tenorio-Tagle, Rozyczka and Bodenheimer.


A grayscale image of the mushroom cloud (catalogued as GW123.4–1.5) as seen in the integrated radio light of neutral hydrogen.

Jayanne English (Space Telescope Science Institute and Queen's University), Russ Taylor (University of Calgary), Judith Irwin (Queen's University), and Sergey Mashchenko (Université Laval) have uncovered what appears to be a huge hydrogen mushroom cloud rising away from the plane of the Milky Way. The feature is estimated to lie about 12,000 light years distant in the Perseus spiral arm of our Galaxy, and appears to extend at least 1,100 light years below the galactic disk. The power necessary to expel such a cloud is estimated to be equivalent to the total energy generated by a supernova explosion — roughly 10^{51} ergs — although the authors do not believe that it was necessarily created by such means. The angular scale of the base of the mushroom-shaped cloud (see accompanying images) corresponds to an extent of at least 70 pc (230 light years) at the estimated distance. In the models of galactic blowouts developed by Tenorio-Tagle and collaborators, similar features are expected to be about four times larger — 250 pc (815 light years) in extent (see illustration).

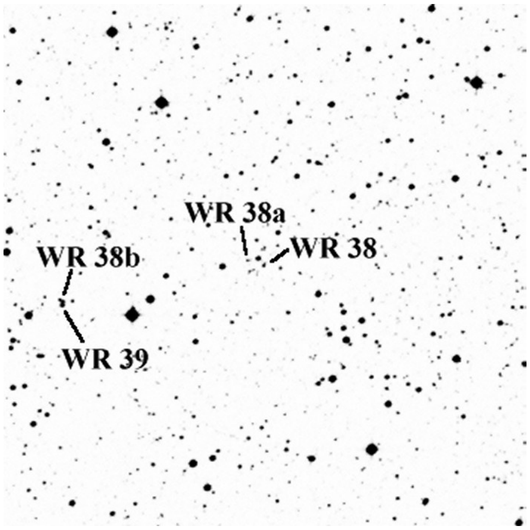
Various models have been proposed to explain the formation and appearance of monster mushroom clouds such as that found in the DRAO survey. Many require a series of supernova explosions to propel the gas away from the plane of the Galaxy in an expanding bubble. The DRAO images are detailed enough to place constraints upon whether or not such models are appropriate. In addition, detailed imaging of the interaction between the mushroom cloud and the surrounding high-latitude gases of the Milky Way may lead to a better understanding of such features.

Further information is given at `nemesis.stsci.edu/~jenglish/aas99/pressrelease.html` and at the DRAO home page `www.drao.nrc.ca`.

A DISTANT CALIBRATING CLUSTER IN CARINA

Wolf-Rayet stars are luminous blue objects that are believed to represent various stages in the evolution of hot stars, specifically those initially more massive than about 30 times the mass of the Sun. In the standard picture they originate from hot O-type stars whose outermost layers have been dredged away by the action of strong stellar winds, in the process revealing in their surrounding gaseous envelopes the products generated by the hydrogen and helium burning occurring in their convective cores. Three different varieties are recognized: (i) WN stars, in which the abundance of nitrogen and helium is enhanced at the expense of hydrogen, carbon and oxygen, (ii) WC stars, in which the abundance of helium, carbon and oxygen is enhanced, and (iii) WO stars, in which the abundance of oxygen and helium is enhanced. In standard models of massive star evolution, such abundance patterns occur naturally during the stages of hydrogen burning, helium burning, and advanced helium burning, respectively. The catch is that the elements appear in the stellar winds that dominate such stars.

Our Galaxy contains a few hundred such objects, many of which are still associated with the clusters and associations in which they were formed. The study of Wolf-Rayet stars belonging to stellar groups



The 10 arcminute diameter field in Carina centred on WR38 and WR38a. The Wolf-Rayet stars WR39 and WR38b lie on the east edge of the field.

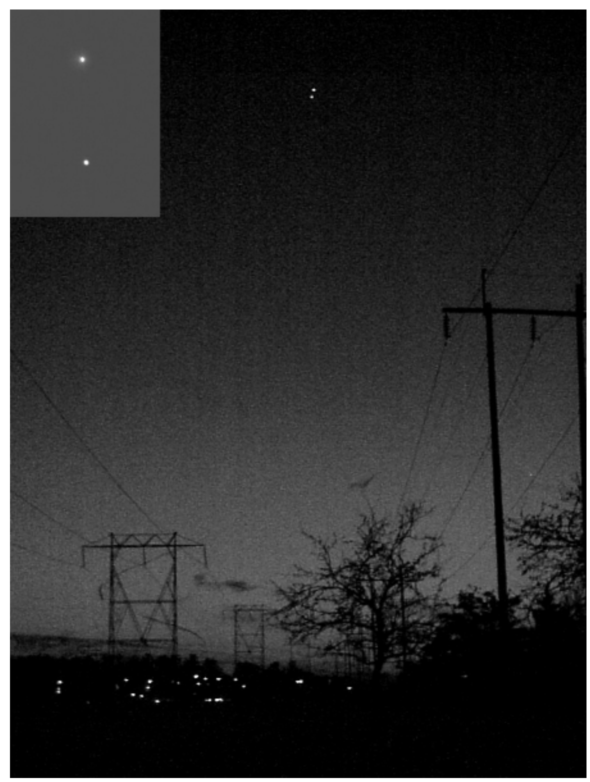
is important, since it allows one to establish the luminosities and temperatures of such stars by independent means — via cluster main-sequence fitting — and provides observational confirmation of models for massive star evolution. In a recent study completed as part of his M.Sc. thesis project at Saint Mary's University, Stephen Shorlin (University of Western Ontario) examined a field in Carina centred on two Wolf-Rayet stars: WR38, of type WC4, and WR38a, of type WN6. The work consisted of multi-colour CCD imaging of the field using the University of Toronto's Helen Sawyer Hogg Telescope, formerly on Cerro Las Campanas, Chile. The observations indicate that the two Wolf-Rayet stars are among the brightest members of a previously undetected cluster of young, luminous, OB stars, estimated to be roughly 41,000 light years distant.

An image of the 10-arcminute-diameter field in Carina centred on the two Wolf-Rayet stars is shown here. WR38 was recognized and catalogued many years ago, while WR38a was detected and identified in a survey completed by Michael Shara, Lindsey Smith, and Michael Potter (Space Telescope Science Institute), and Tony Moffat (Université de Montréal), published in 1991. Shara and his collaborators suspected that WR38 and WR38a might belong to an open cluster, owing to their close spatial proximity — they are separated by about 19 arcseconds. The detection of a half dozen or more fainter O-type companions to the stars was left to Steve Shorlin, in collaboration with *Journal* editor David Turner (Saint Mary's University). It is the first instance in which Wolf-Rayet stars of types WN6 and WC4 have been found together in the same cluster, and both appear to be of similar luminosity. Previous calibrations of the luminosities for such stars have implied differences in luminosity of a factor of six or more.

Coincidentally, the field immediately east of the newly discovered cluster contains two Wolf-Rayet stars of type WC7 — WR39 and WR38b, the latter discovered in the same survey completed by Shara and his collaborators. WR39 and WR38b lie within only three arcseconds of one another, and are of fairly similar brightness. Perhaps there are two distant young clusters in this part of Carina that may be used as calibrating groups for the parameters of Wolf-Rayet stars. Deep multi-colour imaging of both fields should reveal further details.

JUPITER-VENUS CONJUNCTION

The close approach of Venus and Jupiter on February 23 was a good demonstration of the platitude that not every astronomical spectacle needs to be tied to an eclipse, the passage of bright comets, or to collisions of comet fragments with a planet. At their closest, the two planets passed within eight arcminutes of one another in the sky, roughly one quarter of the angular diameter of the Full Moon. Although the time of closest approach occurred during daylight hours for observers in Canada, it was viewed during that time by a number of careful observers, including Larry Bogan and Sherman Williams in Nova Scotia. The event was witnessed and commented upon by many members of the general public, and the scene as viewed at twilight from the Ottawa area was later captured on digital camera by RASC Past President Doug George (see accompanying image).



The bright planet Venus in gibbous phase (upper) passed very close to the fainter planet Jupiter (lower) on the afternoon and evening of February 23, for observers in Canada.

Feature Articles
Articles de Fond

THE LAKE AT DAWN – *An Observer's Odyssey*

by Laura Gagné (rainbow@adan.kingston.net)

The world lay blanketed in thick darkness. Only the shadows of things could be perceived. Tall pines gathered around the meadow in solemn ceremony, their forms sharply silhouetted against the Moon-kissed sky. Blacks and grays competed for dominance in the shadows cast by the Moon, while the other colours slept in darkness. A crippled dirt road stumbled through the forest, tumbling up and down hills until it reached a lonely gate. It crawled under the barrier and limped across the meadow, disappearing into the trees once more. The meadow undulated like the sculpted waves of an ocean, frozen in time, which flowed from the edge of the forest to the shores of a small lake. The glassy surface of the water mirrored the beauty of a star-sprinkled sky, sparkling and glittering with a myriad of twinkling points of silver light. Jupiter shone unblinking from his seat in the heavens as a gibbous Moon watched over the land. The glory of the Milky Way hung reluctantly in the west, bidding adieu to the night sky until its vernal reawakening.

Cautious creatures moved carefully in the underbrush, knowing that a danger lurked in the shadows, stalking unwary prey. Tall trees bowed their heads, nodding wisely and whispering to one another in the breeze. The air was alive with unseen sounds. Crickets chirped their shrill encouragements to one another, singing "cheer up, cheer up!" as though in optimistic anticipation of the dawn. Overhead a majestic horned owl floated from treetop to treetop, mournfully calling "Who? Who?" in a low voice. In the distance, wolves howled lonely laments to each other across the still, black lake. The lake was surrounded by a chorus of frogs — small ones singing "creep, creeep, creeeep," while big bullfrogs groaned monotone chants in their deep, bass voices. Tenor frogs sang the endlessly repeating refrain of "wrunka, hrunka, wrunka." An accompanying troupe of fireflies danced and flickered above the tall grass at the edge of the tree line.

The late summer air was crisp and cool, and lightly scented with the sweet smell of damp grass. A thick, green scent of algae tinted the air near the lake, mingled with the pungent odour of nightcrawlers oozing from the moist earth. The final verdant smells of nature played out their final encore on the senses before being swept away by autumn's golden broom.

In the east, the horizon began to change slowly from black to azure and then to a deep, rich red. Robins began to stir and to sing praises to the morning, rejoicing in the new day. The frogs returned to their diurnal hiding places among the reeds. Small insects began to buzz and flit across the glassy, serene surface of the lake. Bass and trout could be heard breaking the surface to capture their hovering breakfast. Fireflies extinguished their lights and sought refuge in the thick grasses with the silent crickets as the birds awoke. The wolves ceased their lament as Nature's reveille began, and the owl returned to his nest, exhausted by his nightly vigil.

The sky began to lighten above the blazing horizon as light chased the darkness relentlessly westward. A few bands of cloud streaked the eastern sky, pointing wispy fingers towards the dramatic breaking of the new day. The Sun climbed sleepily over the distant landscape, paused thoughtfully for a few moments, then

> *"The sky began to lighten above the blazing horizon as light chased the darkness relentlessly westward."*

dragged itself up onto the hilltop. Fully awakened by the dutiful rooster crowing on a neighbouring farm, the Sun sprang into the sky, thrusting golden swords of light through the clouds that hugged the horizon. The fresh morning dew began to steam itself into a mist that crawled across the ground and tiptoed across the surface of the lake. A soft breeze played with tufts of ground fog, rolling them around bushes and across a gravel road. The dew-kissed road flavoured the air with a warm, earthy, morning fragrance as the Sun drank up the evening moisture laid down under the light of the Moon.

Rustling wings left treetop sanctuaries in pursuit of unsuspecting crawling things. The Sun's golden ascent into the heavens brought warmth and light to the meadow, where warm winds caressed the earth and playfully sculpted the tall yellowing grass into fleeting wave patterns. A breeze tickled the surface of the water into tiny ripples that laughed across the lake. Waterfowl paddled and dipped, seemingly oblivious to the hilarity of the wavelets. The warm moist air rising at the edge of the lake lifted the pungent aroma of decaying water plants and spilled it out as far as the roadway. Busy insects buzzed about the open meadow looking for scarce blooms amid the uncut grasses. A riotous cacophony of twittering birds filled the forest with their songs. Panic-stricken ants ravenously gathered winter provisions, skittering chaotically across the road, darting between immense blocks of gravel with enormous morsels grasped in their tiny mandibles. Morning had broken. It was time to head home.

Laura Gagné is Vice President of the Kingston Centre, as well as the chair of its education committee. She is a science tutor at École Madeleine de Roybon, the French public school in Kingston. Laura attends Queen's University during the day, and spends as many clear nights as possible observing the night sky.

STAR QUOTE

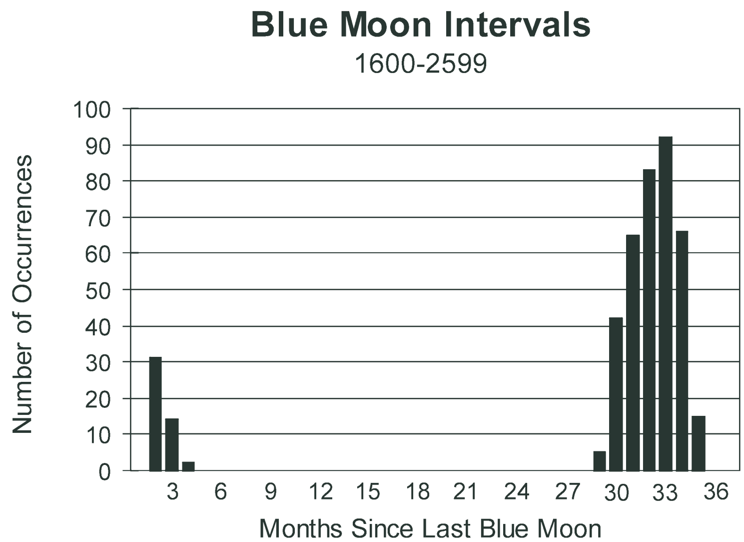
"Basic research is what I am doing when I don't know what I am doing."

Wernher von Braun
German/American rocket engineer (1912–1977)

Twice in a Blue Moon

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

The term "blue Moon" is nowadays commonly accepted to mean a second Full Moon in the same calendar month. Although the technical definition of the term seems to bear the authority of ancient folklore, it has apparently gained widespread popularity only recently through a question in the board game *Trivial Pursuit* (Genus II Edition). Nonetheless, our modern folklore provides a precise definition that can be applied across the centuries. A study of the distribution of blue Moons yields interesting insights about the relationship between the lunar phases and the western calendar.



Blue Moons are not as uncommon as the old saying suggests, but are periodic with a couple of interesting twists. Since the lunar synodic month (lunation) is on average 29.53 days in length compared to an average calendar month of 30.44 days, it follows that a given lunar phase should occur roughly one calendar day earlier each month. The same lunar phase should therefore occur twice in the same calendar month after a period of about 32 months. That can be illustrated by considering the Metonic cycle — well known to eclipse-chasers — in which lunar phases repeat themselves with a high degree of similarity every 19 years. In the associated 228 calendar months there are almost exactly 235 lunations. There are, therefore, seven "extra" lunar months, from which it follows that there should be seven blue Moons every 19 years. The same cycle is manifest in the Hebrew, Hindu, and Chinese calendars, which are strictly lunar but which insert seven "leap months" every 19 years to retain relevance to the seasons.

In the Gregorian calendar, however, we have the curious month of February, which in either of its states — 28 or 29 days in duration — is actually shorter than a synodic month. It is therefore possible for February to have *no* Full Moon. That happens four to six times per century in a given time zone, and when it does, there are always months with blue Moons both shortly before and after.

That has been the case in 1999, where the first three months of the year contained two, zero, and two Full Moons respectively. Such a case of a "double blue Moon" is relatively rare, having occurred previously this century in 1915, 1933-34 (see below), and 1961. There is an Internet site, David Harper's "Obliquity" page, with a list of calendrical double Blue Moons from 1600–9999. The 8,400-year period cited includes 331 cases of two blue Moons in the same calendar year, an average of about four per century. I had an extended E-mail correspondence with Mr. Harper — a professor of mathematics and astronomy, who recently worked at Her Majesty's Nautical Almanac Office at the Royal Greenwich Observatory until its relocation from Cambridge. Harper provided me with a mammoth database of blue Moons customized to requested specifications.

Some 75% of double blue Moons occur in January and March, as is the case in 1999. Roughly 8% of the time the doubles can occur in a January-April configuration (*e.g.* 1961), since in normal years February and March combined contain 59 days, slightly less than two lunations. Still more rare is a January-May pair. The complex lunar orbit yields synodic months ranging from 29 days 6 hours to 29 days 20 hours in length (the commonly accepted 29.53 days is simply an average), and since the longer months occur in clumps, it is possible for three successive lunations to exceed the 89 days that comprise February-April in a normal year. January-May doubles occur, on average, once in about 500 years, less than 5% of all instances.

Since the Web site confined itself to doubles within the period of a calendar year, it did not consider the other possibility of December-March doubles, which in theory should be about as likely as the January-April and January-May pairs combined. Harper's expanded list had 44 such occurrences, or some 12% of all doubles. The last such pair occurred in December 1933 and March 1934 (see above), and the next will not happen until 2066-67, 133 years (7×19) later.

Doubles also occur in leap years, but are predictably less common, since the "footprints" of the consecutive Full Moons must straddle February much more precisely. Some 8% of all doubles occur in bissextile (leap) years, and all must conform to a January-March distribution. The last leap year double in Universal Time occurred in 1608 — the year Hans Lippershey discovered the principle of the telescope — and there will not be another until 2572! Typically, leap years are missed in a given sequence, which resumes 38, 57, or even 76 years (a Callippic cycle) later. Consider the current sequence: 1695, 1714, 1771, 1790, 1809, 1847, 1866, 1885, 1961, 1999, 2018, 2037, 2094, 2113. The last corresponds to the extremely rare January-May pair, after which the cycle peters out. A given sequence can run for between 18 and 34 Metonic cycles (342–646 years). At any given time there can be two, but no more, Metonic cycles overlapping in that context, so in rare instances double blue Moons can occur at intervals of 8 or 11 years.

Harper's predictions of blue Moons in the distant future become more and more speculative, owing to an ever-growing ΔT — the difference between Universal Time and Dynamical Time — and a quadratic error in the latter (1.6 seconds per century squared) resulting from an uncertainty in the exact rate of the Moon's tidal deceleration. I therefore limited my most detailed analysis of the distribution of blue Moons to the 1000-year period from 1600–2599, when the deviations were minimal. As the accompanying graph attests, the large majority of the 415 blue Moons in that period occur within intervals of 29 to 35 months, distributed along a fairly standard bell-shaped curve. The instances of double blue Moons can be seen as a small clump on the extreme left edge of the graph.

My data base was confined to Universal Time, so blue Moons as defined for other time zones would differ as to specifics. For example, the 1980 *Observer's Handbook* indicates blue Moons in January and March for Eastern Standard Time, a rare leap-year double. The year 1980 was missing from the cycle shown above because the Full Moon of January 31, 1980, 21:21 EST, occurred simultaneously on February 1, 02:21 UT, so in Universal Time there was only one blue Moon that year, in March. When considered over long periods, the patterns for a given time zone would show a very high degree of similarity. The *Handbook* itself has since been standardized to UT.

My research yielded one more interesting fact: I was born in a "blue month" (October 1955). The apparent astrological implications: a lifelong fascination with the Moon, calendars, and trivial mathematical pursuits!

Bibliography

Meeus, Jean 1997, "Months with Five Lunar Phases," Mathematical Astronomy Morsels (Willmann-Bell, Inc.: Richmond, Virginia)

Meeus, Jean 1983, "Phases of the Moon 1951–2050," Astronomical Tables of the Sun, Moon and Planets (Willmann-Bell, Inc.: Richmond, Virginia)

Harper, David, & Stockman, Lynne Marie 1999, "Double Blue Moons," www.obliquity.com/astro/bluemoon.html

Hiscock, Philip 1999, "Folklore of the Blue Moon," Memorial University of Newfoundland Folklore & Language Archive, www.griffithobs.org/IPSBlueMoon.html

Hiscock, Philip 1999, "Once in a Blue Moon," Sky & Telescope, Vol. 97, No. 3, March, p. 52

Bruce McCurdy has just completed a two-year term as President of the Edmonton Centre RASC. He has an omnivorous appetite for both observational and theoretical astronomy, with a particular weakness for observing the Moon. He is an active astronomy educator and popularizer with a lifetime commitment as a volunteer at the Edmonton Space and Science Centre's Public Observatory. By nature a clock-watcher, Bruce has slowed sufficiently in recent years to become a calendar watcher instead.

STAR QUOTE

"Physics is becoming so unbelievably complex that it is taking longer and longer to train a physicist. It is taking so long, in fact, to train a physicist to the place where he understands the nature of physical problems that he is already too old to solve them."

Eugene Wigner
Hungarian/American educator

The Third Rainbow

by Alister Ling, Edmonton Centre (watcher@freenet.edmonton.ab.ca)

> Lucian Kemble, a Franciscan Friar, has long been teaching: "You can observe a lot just by watching."

You cannot argue the point. An intense rainbow captivates poets and scientists alike. Artists may emphasize that a rainbow should be experienced rather than dissected, but I prefer to believe that, as scientists, we can do both with full appreciation and inspiration. After a couple of decades of looking at rainbows, I finally saw something totally unexpected — a third bow, moderately bright, arcing between the bright primary and fainter secondary bows. The experience exemplifies a lesson that my friend Lucian Kemble, a Franciscan Friar, has long been teaching: "You can observe a lot just by watching." Keep your mind alert while you look.

The third bow I witnessed was brighter than the secondary bow, yet it defies explanation by classical ray-tracing optics — it's a small mystery solved with help from physiology.

Most readers are familiar with the basic concept of rainbow formation — white sunlight from behind the observer enters thousands of raindrops, reflects off the backsides of the droplets, and exits back through the front surfaces, in the process refracting into a spectrum of colours to greet the eyes. The second bow is formed from a percentage of the light that does not leave the drop, but reflects a second time before exiting the drops. It is the second reflection that reverses the order of the colours in the fainter secondary bow.

Those of you who have had the opportunity and desire to study rainbows in more depth know that a third bow is formed from a third light reflection inside the raindrop — its position was first announced by Sir Edmund Halley — but it has never been seen in the open air because it is simply too close to the Sun's direction. There are also special conditions where intersecting rainbows are visible, thanks to an appropriately positioned body of calm water that produces a reflected image of the Sun from the vantage of the raindrops. Other effects are the supernumary arcs, the alternating pale green and purple bands tucked along the inside edge of the primary bow — but they are not what we saw.

Some relatives of mine were the first to note, "Hey, there's a third bow too!" I quickly corrected them, stating that it was not possible. Captivated by the saturated colours of the primary, I finally saw the third bow after a few seconds. Startled, I shifted my gaze, and the third bow disappeared. When I stared back, it returned, but in a different place.

I quickly realized that I was a victim of trickery by my own eyes — colour reversal, more frequently referred to as negative afterimage. Most of us have performed the trick. You steadfastly stare at something, say red, shift your gaze to a white surface, and suddenly you see a green afterimage.

One of the most enjoyable aspects of the third, imaginary, bow is that it is not the order of the colours that is reversed, but the colours themselves are reversed — more properly called complementary. In particular, a bright purple band appears in the afterimage where the yellow was in the primary bow.

You do not even have to wait until a bright rainbow appears in your sky to witness the phenomenon. Simply find a nice picture in a book or magazine, stare at one spot in the arc for twenty seconds or so, then shift your gaze ever so slightly. The brighter the area in between the two bows, the easier it is to see the effect.

Sometimes there is more to observing than meets the eye.

Alister Ling has been watching the sky for over twenty-five years. His feelings about the experience are well expressed by the quotation: "The sky is the ultimate piece of artistry. Its variety of moods and depth of expression lie far beyond any painter's canvas." Alister is considering wall mounting his computer monitor. His negative spinal curvature makes it difficult to look below the horizontal.

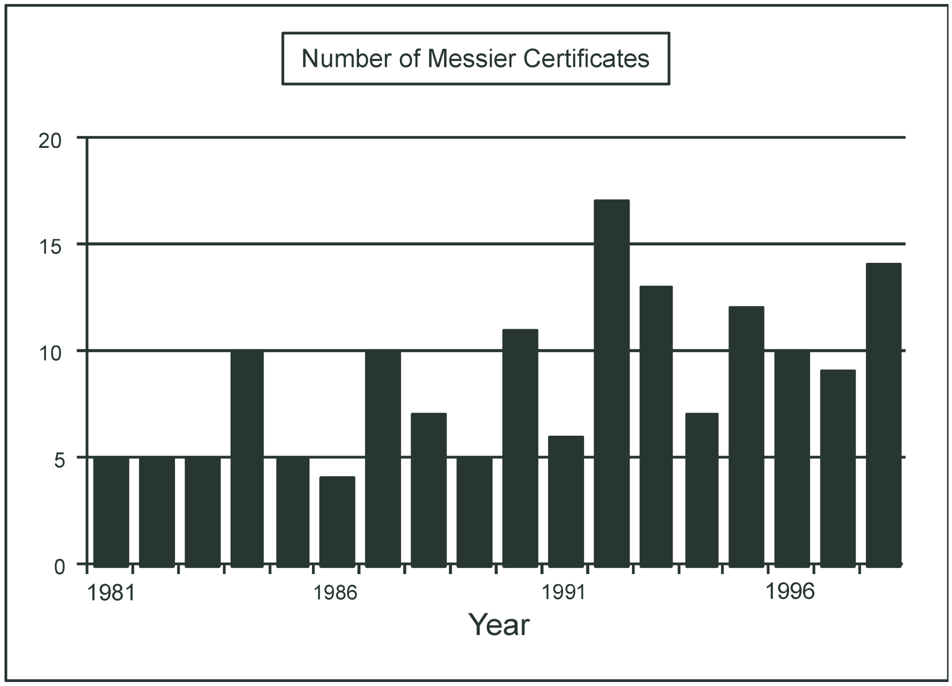
One Hundred and Fifty Messier Certificates

by Peter Broughton, Toronto Centre (peterb@torfree.net)

During 1998, the National Council of the Royal Astronomical Society of Canada approved the awarding of the 150th Messier Certificate. It seems an appropriate landmark to review some history and statistics.

The recognition of observers who located, identified and recorded the objects in Messier's catalogue had its start in the Montreal Centre in January 1943, thanks to a promotion by Isabel Williamson. Those participating in the popular centre activity belonged to "The Messier Club," and their records included comments on the appearance of each object, sketches and photographs. When Miss Williamson wrote for the Centre's fiftieth anniversary book in 1968, she noted that 149 persons had belonged to the Messier Club over the past twenty-five years, and ten members had observed all (103) objects. Her two-page article provides an interesting summary of the friendly co-operation and competition within the club. She believed that the Montreal Messier Club was the prototype for many subsequent groups across North America, a claim that I have never seen repudiated. The Astronomical League in the United States has a Messier Club, and offers a certificate to those who document seventy of the objects in the catalogue and honorary membership to those who complete the list.(See `www.astroleague.org/al/obsclubs/messier/mess.html`)

Nineteen sixty-eight marked the first year that the *Observer's Handbook* contained "Messier's Catalogue of Diffuse Objects," restricted at that time, for good reasons, to 103 items. It was not until 1980 that the *Handbook* expanded the list to 110 in response to an initiative from the members of the Edmonton Centre. Drawing their inspiration from Montreal, the Edmontonians had begun to systematically observe the Messier objects and intended to institute a local award for members who had seen them all. Alan Dyer, then Past-President and National Council Representative of the Edmonton Centre, suggested to the National Council in December 1979 that a national award suitably mark the achievement. By the following meeting in February, Dyer had prepared a certificate suitable for presentation, as well as a sample application form requiring the signatures of two other members who would vouch for the applicant's observing record and ability. He noted that the problem of which objects to include in the Messier list was resolved by a revision in the *Observer's Handbook* for 1980. National Council approved the certificates, and after some dithering about who was to print them and how they would be distributed, the decision was finalized in October 1980.



The first three to receive Messier Certificates were, appropriately, three Edmonton members: Alan Dyer, Gary Finley, and Mark Leenders. From there the idea proved its popularity by spreading across the country. A summary of the awards by Centre and by year is found in the accompanying table and graph, respectively. The total of 155 represents the number approved to the end of 1998.

Not surprisingly, Edmonton has more Messier Certificate winners than any other Centre, but in relation to size London and Kingston are surely champions. I hesitated to publish such statistics, since I am sure the award was never intended to foster competition or comparison between Centres. I would be the first to defend anyone or any Centre who feels that there are better things to do with one's time than to look for elusive blobs in the sky, but I also acknowledge the patience and skill of those 155 observers and salute their achievement. They undoubtedly have a much better general knowledge of the sky, and are much more perceptive observers, as a result of their experience.

Though it is not apparent from the statistics published here, there are some conclusions that I was able to draw from the overall picture.

1. Awards to members of Centres often come in bunches, suggesting that Messier hunting is frequently encouraged by others in a group.

2. Centres that have observatories are *no* more likely to produce Messier Award winners than those that do not have one.

3. The absence of our two Francophone Centres and the very few unattached awardees suggest to me that the award should be publicized annually in the *Journal* in both official languages.

4. There are ten female recipients. That is a small number out of a total of 155, but it is in line with the proportion of women in the overall membership. Can we look to those ten as role models in the way that Isabel Williamson was for the Montreal Centre?

5. There are currently about 110 members who hold Messier Certificates. That is somewhat less than four percent of our membership. We will never know if it implies that most members have interests in other aspects of astronomy or that most members need to be encouraged to undertake the Messier search.

Since I recognize the hazards in collecting information from nearly twenty years of minutes, and the fact that I have not attempted to get a Messier certificate myself may colour my outlook, please let me know of any errors. I would be delighted if the summary engenders some discussion, as long as it is non-judgmental!

TABLE

Calgary	14
Edmonton	25
Halifax	14
Hamilton	4
Kingston	13
Kitchener-Waterloo	2
London	13
Montreal	16
Ottawa	6
Sarnia	1
Saskatoon	6
Thunder Bay	1
Toronto	19
Vancouver	2
Victoria	1
Windsor	9
Winnipeg	5
Unattached	4

Working With Magnitudes

by Glenn LeDrew, Ottawa Centre, reprinted from AstroNotes

If mathematics causes your eyes to glaze over and puts you into a stupor, you may want to skip to the next article. If, however, you want to understand the underpinnings of the magnitude scale and learn some interesting things that can be easily calculated, read on.

All scientists think in orders of magnitude when dealing with large numbers. One order of magnitude corresponds to a factor of ten, two orders correspond to a factor of 100, three orders correspond to a factor of 1000, and so on. We are dealing with a logarithmic scaling, where a particular order of magnitude is ten raised to the power of that number. For example, 10^3 (which equals 1000) corresponds to three orders of magnitude.

Astronomers use another logarithmic scale to define brightness, called, strangely enough, "magnitude." The brightness change for each step in the magnitude scale may seem equally illogical to beginners. It is not based on a factor of ten, or even a factor of two, which would seem to be the most logical choices. The actual base for the scale is the very strange number 2.5118862432…! Let us go back in time to see how such an odd situation came to be.

Over two thousand years ago, the Greek astronomer Hipparchus created a catalog of star brightnesses in which each star's brightness was graded such that the brightest were of the first magnitude and the faintest visible were sixth magnitude. After the invention of the telescope, the scale was extended to magnitudes seven, eight, and so on, to deal with fainter stars. William Herschel was the first to realize that the brightness ratio between stars that were one magnitude apart was a constant of approximately 2.5. Pogson later established the scale exactly by defining a difference of five magnitudes to be equal to a brightness ratio of 100. That definition kept the mathematical relationship from straying from the long-accepted magnitude scale. The fifth root of 100 is the source of the strange value, previously mentioned. Here we use an approximate value of 2.512.

While the magnitude scale follows a logical progression for fainter objects, there are, of course, stars and objects that appear brighter than first magnitude. It forces an extension of the magnitude scale into negative values. A few examples of negative magnitudes are: Sirius, which is at −1.46, Venus, typically at −4.4, the Full Moon at −12.6, and the Sun, which shines at −26.7.

The number that you should burn into your memory is 2.512. With that value and a calculator that handles logarithms, you can figure out a lot of things. The formulas that are given later were all derived from the following relationship (which you should also memorize).

$$a^b = c,$$
$$\text{therefore } b = \log(c) / \log(a).$$

Example: $2^3 = 8$,
$$\text{therefore } 3 = \log(8) / \log(2).$$

Definition of terms

m_1	=	magnitude of the brighter object
m_2	=	magnitude of the fainter object
Δm	=	$m_2 - m_1$ (difference in magnitude)
m_{comb}	=	combined magnitude of m_1 and m_2
B	=	Brightness ratio

Brightness Ratio from a Magnitude Difference

$$B = (2.512)^{\Delta m}$$

Example: How much brighter is Sirius (magnitude 1.46) than a star of magnitude 6.5?

$$B = (2.512)^{(6.5-(-1.46))}$$
$$B = (2.512)^{7.96}$$
$$B = 1{,}528$$

Therefore, it would take 1,528 stars of magnitude 6.5 added together to equal the brightness of Sirius.

Magnitude Difference from a Brightness Ratio

$$\Delta m = 2.5 \times \log(B)$$

Two stars are measured and one is 4,500 times brighter than the other. What is the difference in magnitude between the two stars?

$$\Delta m = 2.5 \times \log(B)$$
$$\Delta m = 2.5 \times \log(4{,}500)$$
$$\Delta m = 2.5 \times 3.64$$
$$\Delta m = 9.1$$

So, the two stars are 9.1 magnitudes apart.

Combined Magnitude of Two Objects

$$m_{comb} = m_1 - 2.5 \times \log(0.400^{\Delta m} + 1)$$
$$m_{comb} = m_2 - 2.5 \times \log(2.512^{\Delta m} + 1)$$

You can use either formula; they will both give the same result.

Consider a telescopic double star's components that have magnitudes 2.9 (m_1) and 3.4 (m_2). If, to the naked eye, they appear as one star, how bright would it appear? We use the second formula.

$$m_{comb} = 3.4 - 2.5 \times \log(2.512^{(3.4-2.9)} + 1)$$
$$m_{comb} = 3.4 - 2.5 \times \log(2.512^{(0.5)} + 1)$$
$$m_{comb} = 3.4 - 2.5 \times \log(1.58 + 1)$$
$$m_{comb} = 3.4 - 2.5 \times \log(2.58)$$
$$m_{comb} = 3.4 - 2.5 \times 0.41$$
$$m_{comb} = 2.37$$

The combined brightness of 2.37 is just

over half a magnitude brighter than the brighter component's magnitude of 2.9. If the brightness difference between the two components is greater than two magnitudes, the new combined value will be barely brighter (0.1 magnitude or less) than the brighter component itself.

Now, let us make things slightly more complicated. Suppose that we want to find the total brightness of all stars visible to the unaided eye, *i.e.* brighter than magnitude 6.5, over the entire sky. The following table gives star counts from *Sky Catalogue 2000 Vol. 1* and includes my calculated integrated brightness of all stars in each magnitude bin.

Magnitude Bin		Number of Stars	Integrated Magnitude
-1	(-1.5 to -0.51)	2	−1.8
0	(-0.5 to 0.49)	7	−2.1
+1	(0.5 to 1.49)	13	−1.8
+2	(1.5 to 2.49)	71	−2.6
+3	(2.5 to 3.49)	192	−2.7
+4	**3.5 to 4.49)**	**625**	**−3.0**
+5	(4.5 to 5.49)	1963	−3.2
+6	(5.5 to 6.49)	5606	−3.3

Ideally, one would integrate every individual star to get the highest accuracy, but the statistical approach certainly gets us in the proper range. We can work out one example. The table entry in boldface represents stars of fourth magnitude. There are 625 stars in that brightness range. Taking the mid-range value of +4.0 and making it 625 times brighter, we obtain:

$$\Delta m = 2.5 \times \log(B)$$
$$\Delta m = 2.5 \times \log(625)$$
$$\Delta m = 2.5 \times 2.8$$
$$\Delta m = 7.0$$

Since the integrated magnitude is seven magnitudes higher than the "average" value of +4.0, it must be +4.0 − 7.0 = −3.0. The same method was adopted in producing each of the values listed in the table. Finally, we can add the bins together one at a time to obtain the total combined magnitude of all of the stars. Specifically, from top to bottom (although you could select any order) you would combine the first two entries (−1.8 and −2.1) to get −3.0. You would next combine that result with the third entry (−1.8) to get −3.3, and if you continued the process to its conclusion, you would find that the 8,479 stars in the table would shine with the brightness of a single star of magnitude −5.0.

If the integrated magnitude of the nearly 8,500 stars visible to the unaided eye is −5.0, what, then, is the average magnitude of an individual star?

$$\Delta m = 2.5 \times \log(8479)$$
$$\Delta m = 2.5 \times 3.9$$
$$\Delta m = 9.8 \text{ magnitudes dimmer}$$

Since the total brightness is −5.0, a difference of 9.8 magnitudes means that the average star must have a magnitude of −5.0 + 9.8 = +4.8. It also implies that the total contribution of starlight in the night sky originates roughly equally from stars that are brighter than magnitude 4.8 and stars fainter than that amount.

At best, we can see roughly half of the stars at one time above the horizon. We actually see somewhat fewer stars because of atmospheric extinction near the horizon, but we can neglect that. Dividing brightness in half results in a magnitude reduction of 0.75 magnitude. Thus, the total light of all stars visible at any one time is roughly equivalent to a −4.2 magnitude star (−5.0 + 0.75 = −4.25), roughly equivalent to the brightness of Venus.

We can now consider another application of magnitude integration. This time we calculate just how bright the night sky actually is, *excluding* stars. Many sources cite the brightness of a dark country sky as about 22 magnitudes per square arcsecond. To visualize that, imagine a visually blank patch of sky divided into a grid with lines separated by one arcsecond (about the resolution limit of a 10-cm telescope). In each of the grid squares lies a 22nd magnitude star — a star at the limit of Palomar's 48-inch Schmidt telescope. That would replicate the sky's brightness at the darkest it can be at the zenith.

Like myself, I am sure you find the numbers difficult to imagine. In that case, let us picture it as follows. One degree, which is easy to visualize since it is equivalent to two Moon diameters, comprises 3,600 arcseconds. A square degree is $(3{,}600)^2$ or 12,960,000 square arcseconds. How bright would nearly thirteen million 22nd magnitude stars be?

$$\Delta m = 2.5 \times \log(12{,}960{,}000)$$
$$\Delta m = 2.5 \times 7.1$$
$$\Delta m = 17.8 \text{ magnitudes brighter}$$

Since the star has a magnitude of 22, one square degree would have a magnitude of 22 − 17.8 = 4.2. Conversely, a star of magnitude 4.2, if its light were spread out to cover one square degree, would become as dim as the night sky.

Now we can work out the night sky's total brightness. The visible hemisphere of the sky contains about 20,000 square degrees (a sphere is roughly 40,000 square degrees). What is the integrated magnitude of 20,000 stars of magnitude 4.2?

$$\Delta m = 2.5 \times \log(20{,}000)$$
$$\Delta m = 2.5 \times 4.3$$
$$\Delta m = 10.8 \text{ magnitudes brighter, or } -6.6\ (4.2 - 10.8)$$

At the very least, we can increase that value to magnitude −7 because the sky always brightens towards the horizon. The skyglow on the darkest of nights is about three magnitudes, or fifteen times, brighter than the combined starlight. As odd as it may seem, the stars contribute very little to the light that reaches the ground! The great majority of the background (actually foreground) skyglow on dark nights is from airglow. Only a little is from scattered starlight. Of course, moonlight and light pollution can add considerably more.

In order to help you get familiar with magnitude relationships, I have included three problems to give you some practice. The solutions can be found elsewhere in this issue. Practice with other cases that you can think up. Such handy, fundamental knowledge will serve you well, especially if you, too, like to dabble in back-of-the-envelope calculations.

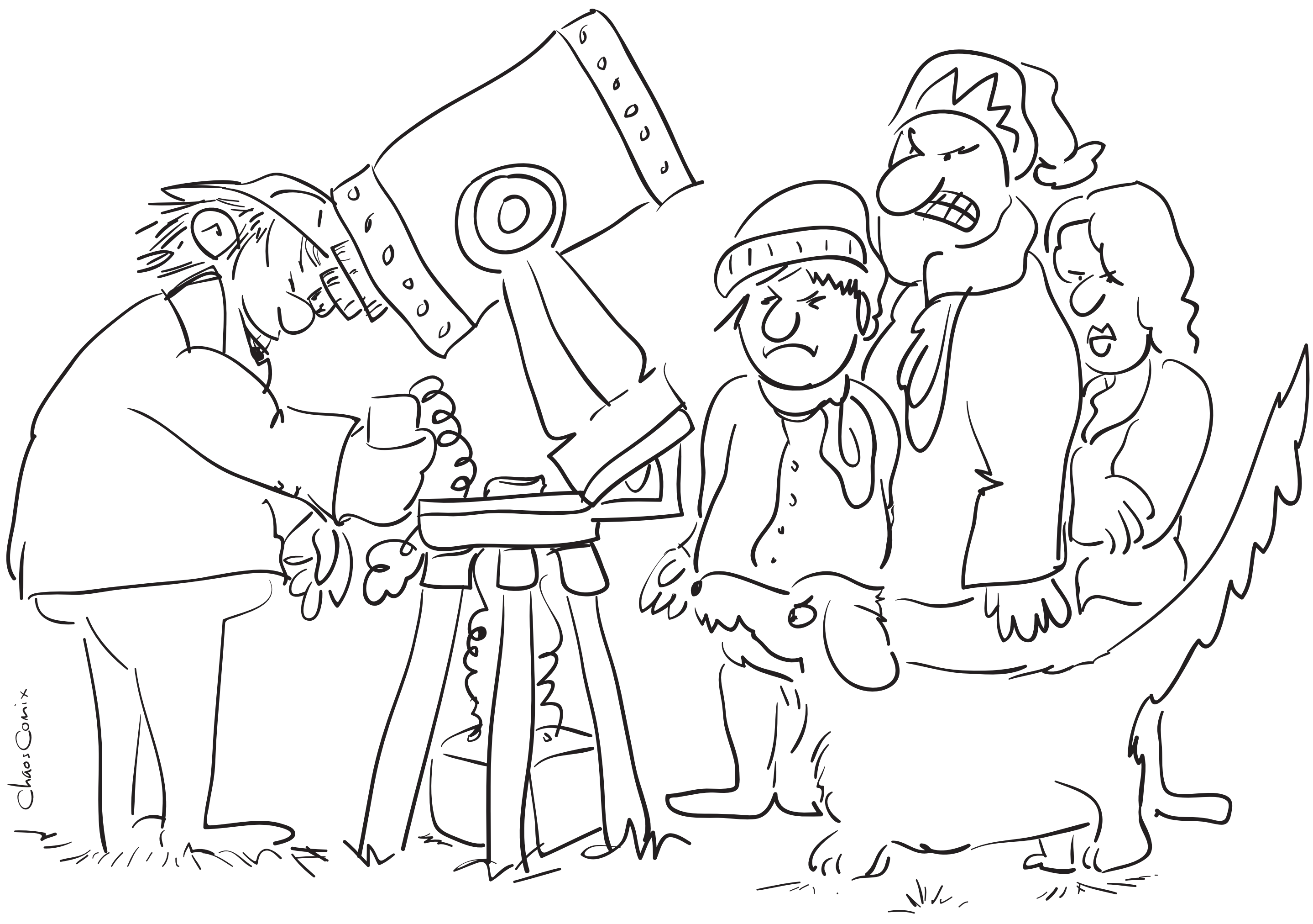
1. How many Full Moons (magnitude −12.6) are needed to equal the brightness of the Sun (magnitude −26.7)?

2. What is the difference in magnitude between the most massive supergiant (absolute magnitude −8.5) and a very dim red dwarf (absolute magnitude +17)?

3. A supergiant of absolute magnitude −8 explodes as a supernova. Its light is observed to increase by a factor of 400,000. What is its peak absolute magnitude?

Glenn LeDrew has been an avid amateur astronomer since the age of thirteen. He worked for Environment Canada as a weather observer, weather station manager and ice analyst for thirteen years (just over half of them in the high arctic). He has traveled to Australia four times to photograph the southern sky, and also went to Baja California in 1991 to videotape the total solar eclipse. He went to Arizona with Peter Ceravolo to image comet Hyakutake, and was involved in Cyanogen Productions' "Comet Odyssey" video and "Comet Explorer" CD-ROM. Since 1996 he has run his own business, The Starry Room, *which takes a portable Starlab planetarium around eastern Ontario. It features both an artificial star projector and photographic all-sky projector of his own design. So far, 20,000 people have gone through his dome in the last two-and-a-half years.*

Another Side of Relativity



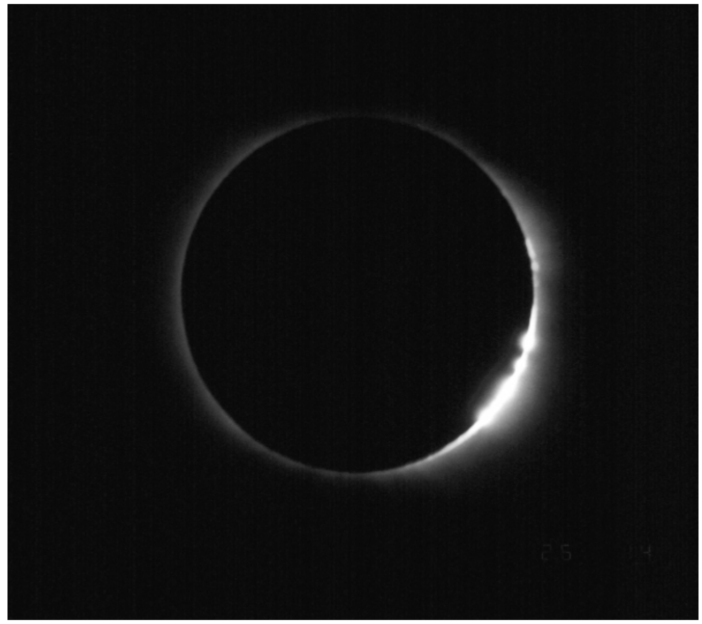
"C'mon, Uncle Ernie, let us look — we're FREEZIN'"

Francis Baily, *Father of all Eclipse Chasers*

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

I have been thinking about solar eclipses lately. As I write this, it is a little under one year since I stood in the shadow of the Moon in Curaçao, and a little over six months until the next total solar eclipse, which I will observe from Nova Scotia as a partial eclipse only. There are several stages to an eclipse, and one of the most unpredictable is the appearance of Baily's Beads — a fleeting apparition that takes place as the last sliver of the Sun disappears behind the Moon, and the corona is beginning to appear around the Sun, just before the start of totality. (Baily's Beads also appear at the end of totality, and can be observed during annular eclipses.) The effect is caused by the irregular perimeter of the Moon. The last sliver of Sun breaks up into small parcels of light, peeking through the valleys in between the mountains at the edge of the Moon's disk. These points of light appear as an irregular necklace or a string of beads. They are "Baily's" Beads because they were reported by the English astronomer Francis Baily following his observation of the annular eclipse of May 15th, 1836 ; he described the phenomenon as "a row of lucid points, like a string of bright beads." He also compared the beads to "the ignition of a fine train of gunpowder." Baily was not the first to see his beads. Halley had observed the effect in 1725, as did MacLaurin in 1737. [Baily quotations in this article are from *Totality: Eclipses of the Sun* by Mark Littman and Ken Willcox (University of Hawaii Press, Honolulu, 1991).]

Francis Baily was born 225 years ago on April 28th, 1774 in Newbury, Berkshire. His father was a well-to-do banker, and Baily received only a rudimentary education before apprenticing to a London firm of merchant bankers at the tender age of fourteen. After seven years at that profession, he sought adventure in the New World, exploring uncharted areas of North America. Having survived a shipwreck, he boated down the Ohio and Mississippi Rivers from Pittsburgh to New Orleans, then travelled on foot back to New York. It would have been a lifetime's worth of excitement for most grown men, but when Baily returned to London in 1798 (narrowly escaping marriage and settled-down life in America), he was only one-third of the way through his remarkable life.



Ralph Chou captured this photo of Baily's Beads during the February 26th, 1998 solar eclipse from Curaçao. He used a Celestron 5 telescope, Kodachrome 64 film and a 1/125 second exposure.

Budding astronomers should take note of the following: Baily returned to the world of finance, becoming a stockbroker and doing very well indeed. He became known for exposing and rooting out stock market fraud, and for writing explanatory treatises on various life insurance schemes. He did so well at finance, he retired a wealthy man at the age of 51 and devoted the rest of his years to astronomy, in which he had no formal training.

Baily's first astronomical paper, written at the age of 37, was an investigation of a solar eclipse recorded in ancient times. In 1820 he observed his first solar eclipse — an annular eclipse — in southeast England, and caught the eclipse-chasing bug. The same year, he and some notable scientists (such as John Herschel and Charles Babbage) co-founded what became the Royal Astronomical Society (RAS). When he was not observing eclipses, Baily worked on the mind-numbing task of revising star catalogues. For his efforts, the RAS awarded him their Gold Medal on two occasions. Baily was elected President of the RAS four times, and served in several other capacities. In 1838 Baily, Herschel, and the Astronomer Royal, George Airy, worked on a plan to reform the constellations. The proliferation of star atlases at that time had led to a state of total confusion regarding the names and boundaries of the constellations. The plan was published in 1841, but it was not accepted by the astronomical community, although its features strongly anticipated the system internationally accepted today.

Baily was not regarded as a prolific observer, but his keen attention to detail and his ability to convey his impressions kindled a fascination for eclipses in the astronomical community. He travelled to Scotland to see the annular eclipse of 1836. The next eclipse — his first total eclipse — found him in good company, as astronomers from all over travelled to southern France to catch a glimpse of "Baily's Beads" on July 8th, 1842 That was the start of a sequence of far-flung solar eclipse expeditions for astronomers and curiosity-seekers that continues to this day. (I personally admit to having travelled considerable distances to observe the total eclipses of 1972 and 1998, and two blocks — from my house to the school — to see the annular eclipse of 1994.) Baily is indeed the "Father of all Eclipse Chasers."

Having inadvertently convened the crowds of eclipse-watchers, Baily avoided them. In his words, "All I wanted was to be left alone during the whole time of the eclipse, being fully persuaded that nothing is so injurious to the making of accurate observations as the intrusion of unnecessary company." At sixty-eight years of age, he perhaps realized that the eclipse of 1842 would be his last eclipse, and believed that he had earned the right to be a curmudgeon. I leave the closing words to Baily:

"Splendid and astonishing, however, as this remarkable phenomenon really was, and although it could not fail to call forth the admiration and applause of every beholder, yet I must confess that there was at the same time something in its singular and wonderful appearance that was appalling; and I can readily imagine that uncivilized nations may occasionally have become alarmed and terrified at such an object, more especially in times when the true cause of the occurrence may have been but faintly understood and the phenomenon itself wholly unexpected."

David Chapman is a Life Member of the RASC and a past President of the Halifax Centre. In addition to writing "Reflections," he has written for SkyNews *and the U.S. National Public Radio program* StarDate, *mostly on historical and calendrical aspects of astronomy. In his other life, he is Head of the Naval Sonar Section of the Defence Research Establishment Atlantic.*

Working with Magnitudes

Problem Solutions

1.
$$B = (2.512)^{\Delta m}$$
$$B = (2.512)^{(-12.6 - (-26.7))}$$
$$B = (2.512)^{(14.1)}$$
$$B = 437{,}000$$

The numbers representing their magnitudes do not sound very different, yet it would take almost half a million Full Moons to bathe us with the same amount of light as that provided by the Sun.

2.
$$B = (2.512)^{\Delta m}$$
$$B = (2.512)^{(-17 - (-8.5))}$$
$$B = (2.512)^{(25.5)}$$
$$B = 16{,}000{,}000{,}000$$

It would take sixteen billion red dwarfs to put out as much visible light as a very bright supergiant.

3.
$$\Delta m = 2.5 \times \log(B)$$
$$\Delta m = 2.5 \times \log(400{,}000)$$
$$\Delta m = 2.5 \times 5.6$$
$$\Delta m = 14$$

Peak visual brightness is therefore −8, −14 or −22; about the total light output of a galaxy!

Second Light

Mars, Up Close and Personal

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

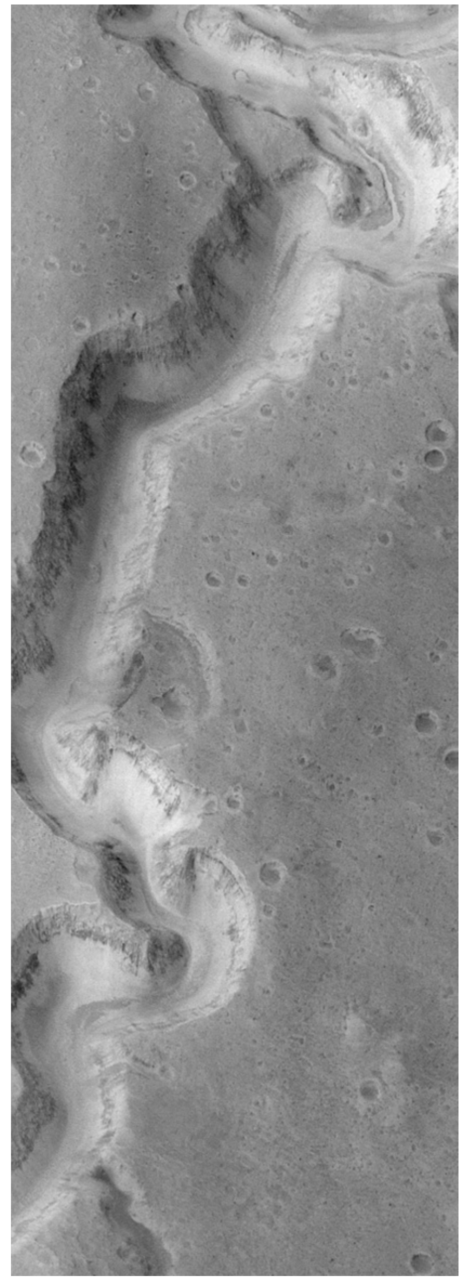
It is difficult enough to determine what happened during the early history of the Earth, even though we live here, but trying to investigate Mars is more complicated because of its distance. On the bright side, its surface evolves much less quickly than the Earth's. Planetary scientists are trying to determine what the surface of Mars might have looked like when it was young, and how it has evolved with time. For example, did it once look like the Earth, with liquid water and a substantial atmosphere? Up until recently we had only a few small samples of its surface (in the form of Martian meteorites), high-resolution images of tiny regions around three vehicles that have landed there, and rather low-resolution maps of the surface. Now, scientists using the *Mars Orbiter* Camera on the *Mars Global Surveyor* spacecraft have photographs in which features as small as 10 metres can be seen. That is more than a factor of twenty better than previous maps (see 17 February issue of *Nature*).

The inner (terrestrial) planets of the solar system went through a period of "heavy bombardment" for roughly the first 400 million years after they formed. During that period the debris left over from the formation process was gravitationally scattered until it either accreted onto a planet through collisions or was placed into more stable orbits, where it was safe from collisions with the planets. The main asteroid belt between Mars and Jupiter represents a range of such relatively stable orbits. Many of the large craters on the Moon and Mercury date from late in the period. Impacts have been less frequent for the last four billion years, and craters formed by such impacts allow us to estimate the ages of the surfaces. On Earth, craters generally are erased fairly quickly (on geological and astronomical time scales), since they are eroded by weather, covered by vegetation, and shifted or obliterated by moving continental plates and volcanism.

Mars has an atmosphere (mostly carbon dioxide), though at the present time the pressure is less than 1% that of the Earth. Mars is also known to have had active volcanoes in the past; Olympus Mons, at a height of 25 km above the surrounding plains, is the largest volcano in the solar system. The presence of liquid water, now or in the past, is a subject of hot debate. On the other hand, we know that some fraction of the north polar cap is made of water ice that can only sublimate (go from solid to gas phase) under present conditions and therefore cannot produce running surface water. Yet, it has been apparent for at least twenty years that some of the large surface features on Mars are best explained through the actions of flowing water.

All of the above processes can erase craters. By determining how many craters there are in a particular area, and comparing the numbers to the crater density on the Moon (where craters are erased only by new craters), relative ages of areas can be determined. William Hartmann and his colleagues find that portions of the volcano Arsia Mons may be as young as 40-100 million years, which is very young relative to the 4½-billion year age of Mars. Other areas, which have not seen recent volcanism, have had smaller craters partially or mostly filled by dust that blows around during Martian dust storms. Recent volcanism might also account for some water runoff channels, because the heat could melt underground ice, thereby producing local floods.

Blowing dust on Mars also makes dunes, which have been studied by Peter Thomas and his collaborators. The dunes come in two different varieties: dark and light. The light-coloured dunes are restricted



A portion of the meandering canyons of the Nanedi Valles system — one of several valleys that cut through the smooth and cratered plains of the Xanthe Terra region of Mars. The valley is about 2.5 km wide. The floor of the valley in the upper right corner exhibits a small, 200 m wide channel that is covered by dunes and debris elsewhere on the valley floor (Credit: Malin Space Science Systems/NASA).

to locations near outcroppings of bright rocks, while the dark dunes can be found in extensive fields. Thomas speculates that the bright dunes are composed of gypsum or another type of sulphate, as such materials would be easily eroded by dust in the Martian wind. Most of the light dunes are aligned with the current wind direction — as indicated by wind streaks on the surface — which means that they formed quite recently.

Alfred McEwen and his coworkers have looked at the layering of the rock, where it has been exposed along the Valles Marineris. Valles Marineris is much larger than the Grand Canyon on Earth, extending over 4,000 km of the Martian surface. The researchers interpret the band structure as lava flows, which would imply that volcanoes were very active in the first billion years of Mars's existence. That period extends beyond the time of heavy bombardment, which indicates that the volcanoes were not simply triggered by asteroid impacts, but perhaps resulted from the same kind of processes that produce shield volcanoes on the Earth.

If Mars once had oceans, lakes and rivers under atmospheric conditions like those on the early Earth, then life may have had a brief chance to evolve there. The large outflow channels seen on the surface are widely regarded as having been created by giant floods, but the origin of the smaller valley networks has been more controversial. Such networks could indicate flowing water relatively recently in Mars's history, perhaps as a result of volcanic activity (as mentioned above). If so, the episodes were almost certainly too brief to allow for life to develop. They may have also been caused by groundwater, or perhaps ground-ice processes. Mike Malin, the principal scientist for the *Mars Orbiter* camera, has obtained close-up images of some of the valley networks, which seem to show that they were created by groundwater. Unfortunately, he is unable, as yet, to determine when the networks were formed.

Taken together, the new images reveal a Mars that was more active, for longer than previously suspected. It is certainly a fitting target for the numerous space probes that have recently been launched towards it, or will be sent over the next few years.

Dr. Leslie J. Sage is Senior Editor, Physical Sciences, for Nature *Magazine and a Research Associate in the Astronomy Department at the University of Maryland. He grew up in Burlington, Ontario, where even the bright lights of Toronto did not dim his enthusiasm for astronomy. Currently he studies molecular gas and star formation in galaxies, particularly interacting ones.*

Astrocryptic

by Curt Nason, Halifax Centre

HERE ARE THE ANSWERS TO
LAST ISSUE'S ASTROCRYPTIC PUZZLE

[1]W	O	[2]L	F	[3]R	A	[4]Y	E	[5]T	■	[6]R	A	[7]M
O	■	A	■	H	■	E	■	E	■	I	■	O
[8]M	A	C	H	O	■	[9]R	A	M	S	D	E	N
B	■	E	■	■	■	K	■	P	■	E	■	T
[10]A	U	R	O	[11]R	A	E	■	[12]E	A	R	T	H
T	■	T	■	A	■	S	■	R	■	■	■	S
■	[13]C	A	N	I	S	■	[14]M	A	J	[15]O	R	■
[16]L	■	■	■	N	■	[17]B	■	T	■	U	■	[18]L
[19]O	R	[20]T	H	O	■	[21]I	N	E	R	T	I	A
W	■	R	■	F	■	O	■	■	■	W	■	S
[22]E	D	I	T	I	O	N	■	[23]S	P	A	C	E
L	■	N	■	C	■	I	■	O	■	R	■	R
[24]L	O	G	■	[25]E	N	C	E	L	A	D	U	S

NEW FORMULAE FOR OPTIMUM MAGNIFICATION AND TELESCOPIC LIMITING MAGNITUDE

by R. H. Garstang
JILA, University of Colorado
Electronic Mail: garstang@earthlink.net

(Received June 19, 1998; revised December 21, 1998)

Abstract. New approximate formulae are presented for the optimum magnification and limiting magnitude of a telescope. The formulae are based on a new mathematical representation of the threshold illuminance of the eye as a function of source size and background brightness. The new results are compared with formulae derived from an alternative representation by Schaefer.

Résumé. De nouvelles formules approximatives pour le calcul du grossissement optimal et de la magnitude limite d'un télescope sont présentées. Ces formules sont basées sur une nouvelle représentation du seuil d'illumination de l'oeil, en fonction de la dimension de la source et de la brillance du ciel. Les nouvelles formules sont comparés à celles dérivées de la représentation alternative par Schaefer.

SEM

1. Introduction

The faintest magnitude star that can be seen through a telescope depends on the response of the eyes to incident radiation and on the properties of the telescope. Many authors have studied the response of the eyes. If i is the illuminance (light received per unit area) at the observer produced by a source and b is the surface brightness (light reflected, emitted, or transmitted per unit area per unit solid angle) of the background against which the source is observed, then there is a relation of the form $i = f(b)$ for the minimum illuminance that can be perceived by the observer. Some early workers used dependences of the type $f(b) = kb^{1/2}$ and $f(b) = i_0(1 + kb)^{1/2}$. An important advance was made by Hecht (1934), who suggested the relation:

$$i = f(b) = i_0(1+kb^{1/2})^2 , \tag{1}$$

which has proven to be an excellent approximation in spite of having been proposed on the basis of a now discredited chemical theory of vision.

Hecht (1947) also proposed the use of two formulae of the same form: one for faint illuminances when the rods of the retina are dominant (the scotopic region), and one for bright illuminances when the cones of the retina are dominant (the photopic region). He based his values of i_0 and k on laboratory observations by Knoll *et al.* (1946) of sources one arcminute in diameter in fields whose brightness ranged from complete darkness to daylight. The eye has a resolving power of about one arcminute, so the sources were effectively point sources. Hecht's formulae were used by Weaver (1947) and Garstang (1986), and, with great success, by Schaefer (1990) in his exhaustive treatment of telescopic limiting visual magnitudes.

In visual photometry light emission is measured in candelas (abbreviated cd), where 1.0 cd is 1/60th the luminous intensity of 1.0 projected cm^2 of a black body at the temperature of melting platinum (2044 K). Luminous flux is measured in lumens, where 1.0 lumen is the flux from 1.0 cd into unit solid angle. In metric units, illuminances are measured in lux, where 1.0 lux is equivalent to 1.0 lumen falling on 1.0 square metre; lighting engineers and photographers often use foot-candles, with 1.0 foot-candle = 1.0 lumen falling on an area of 1.0 square foot. The units are related by the relation: 1.0 foot-candle = 10.76 lux. There are many possible units of surface brightness (also known as luminance). The SI unit is the nit, which is 1.0 lumen per square metre per unit solid angle, or 1.0 cd/m^2. Another metric unit is the stilb, where 1.0 stilb = 10^4 nit. A unit that is frequently used is the lambert, where 1.0 lambert = $1/\pi$ stilb = 1.0 lumen per square centimetre for a uniformly diffusing surface. Engineers often use 1.0 foot-lambert = 1.0 lumen per square foot for a perfectly diffusing surface = 1.076×10^{-3} lambert.

For the night sky, astronomers often use magnitudes per square second or per square degree, or the number of 10th magnitude stars per square degree. Nanolamberts (1.0 nanolambert = 10^{-9} lambert) are also convenient. Most physicists would use photons per second per square metre (or centimetre) per unit solid angle. Relationships between the various units may be found in Allen (1973, p. 26) and Garstang (1986, 1989). The present paper uses illuminances in lux and surface brightnesses in nanolamberts, abbreviated nL.

2. Modifications

Some modification is needed if a source being observed is of finite size. That occurs when looking at stars through a telescope with a high power eyepiece or when the seeing is very bad. Schaefer proposed one modification, which will be discussed below. This paper suggests an alternative modification.

Threshold contrast is the ratio of the minimum increment of brightness of a source that can be detected to the value of the brightness. As a result of a major World War II project, Blackwell (1946) reported a large set of laboratory naked-eye binocular observations of threshold contrast as a function of *b* (about 2 million observations were made, and 450,000 analyzed). The present paper uses the final results in his Table VIII, which were based on about 90,000 observations by seven observers with an average age of about 23 years and of normal eyesight. Seven small, circular, illuminated disks of various diameters were used as stimuli against a large background whose brightness could be varied from 10^9 nL down to 10 nL. The experiments determined the threshold contrast for seeing a disk against the background. Tousey & Hulburt (1948) modified Blackwell's data by changing from threshold contrasts to absolute thresholds and by doubling the values of *i* to change the threshold criterion from a 50% probability of detection to a 98% probability of detection. The units of illuminance *i* in Tousey & Hulburt's data were changed to lux. Knoll *et al.* used nanolamberts, as did Hecht (1947). Blackwell used foot-lamberts, but Tousey & Hulburt changed his data to nanolamberts. Nanolamberts were adopted in this work because the unit has been used extensively in studies of light pollution, and it is a convenient size. All the photometry was expressed in terms of the photopic response curve. A correction was applied to the observations of Blackwell in the scotopic region to allow for the difference of colour temperatures between his sources and those of Knoll *et al.* Finally small systematic corrections were applied to Blackwell's data for each background brightness separately, so that for effectively point sources Blackwell's data would agree with the results of Knoll *et al.* The effect of such corrections is to ensure that the Knoll *et al.* data were used for point sources and the contrast ratios measured by Blackwell were used for larger sources.

It seemed desirable to continue to use equations of Hecht's form, but generalized to include the effect of source size θ as described by Blackwell's data. In astronomical applications θ is the seeing disk diameter, which Blackwell expressed in arcminutes. When the data were examined, it became apparent that the values of illuminance *i* increased from the values for point sources as θ increased. The increments were very nearly proportional to θ^2 for a given value of surface brightness *b*. It seemed appropriate to multiply Hecht's formula [equation (1) above] by a correction factor of the form $(1 + a\theta^2)$, with a different value of *a* for each value of *b*. It turned out that the values of *a* increased as *b* increased. A relationship of the type $a = \alpha + yb^z$ proved to be a good approximation.

The complete formula for the threshold illuminance is therefore:

$$i = i_o(1+kb^{1/2})^2(1+[\alpha + yb^z]\theta^2) \;, \tag{2}$$

which is used for the scotopic region. A similar formula can be used in the photopic region, with different numerical values for the constants, but it will not be needed here. There does not seem to be a simple explanation for the presence of the term in θ^2 in the formula. However, θ^2 is proportional to the area of the image on the retina. One might guess that its occurrence is probably connected with the areal density of the rods on the retina, which falls off on either side of the position of maximum sensitivity to averted vision (Cornsweet 1970, p. 11). The observed rate of fall-off is much faster than the rate of rod density fall-off, however, so that other factors, perhaps the angular sensitivity of the rods, must be involved.

3. Results

The values of the constants in equation (2) were determined by fitting the formula by least squares to the data for $b = 10$ and 100 nL, and $\theta = 0.595$, 3.6, 9.68, 18.2, 55.2, and 121 arcminutes. Data for $b = 1000$ nL were omitted because the cones of the eye begin to contribute to the eye sensitivity at that brightness. Our results should be quite good up to at least $b = 300$ nL, which for the unaided eye corresponds to a moderately light polluted sky. Data for $\theta = 360$ arcminutes were also omitted; including them would have reduced the goodness of fit significantly, and one is not usually interested in observing fields as large as 6° in apparent diameter.

The fit was made using the logarithmic form of the data. The experimental data used and all the formulae in the present paper use logarithms to the base 10. The constants obtained were $i_0 = 2.908 \times 10^{-9}$ lux, $k = 0.115$, $\alpha = 0.000154$, $y = 0.000062$, and $z = 0.276$. The root mean square (r.m.s.) uncertainty for the fit to the log *i* data was about ±0.033 in log *i*. Omission of the $y\,b^z\,\theta^2$ term in equation (2) and a subsequent least squares determination for *i*, *k*, and *n* produced an r.m.s. uncertainty for the fit to the same log *i* data of about ±0.046 in log *i*. The fits made use of the mean values of Knoll, Tousey and Hulburt. A comparison of the Hecht formula with the original individual experimental points of Knoll, Tousey and Hulburt gave an r.m.s. uncertainty of ±0.20 in log *i*. The fit obtained above is applicable to the whole range of θ. With *i* in lux, the visual magnitude is given by:

$$m = -13.98 - 2.5\log i \;. \tag{3}$$

The constant in the formula is quoted from Allen (1973, p. 197); it is based on very extensive detailed spectrophotometry of stars of many spectral types and on comparisons with laboratory standard lamps seen through a telescope.

Such considerations apply to the unaided eyes. Application to the visual use of a telescope requires appropriate changes in equation (2). One may follow Schaefer's detailed treatment, or one may make a few approximations and derive the results from first principles. The following substitutions are made in equation (2):

$$i_o \rightarrow \frac{\sqrt{2}\,p^2}{tD^2}\,i_o, \qquad b \rightarrow \frac{tD^2 b}{\sqrt{2}\,p^2 M^2}\;, \qquad \theta \rightarrow M\,\theta\,. \tag{4}$$

The factor of $\sqrt{2}$ converts from binocular vision with unaided eyes to telescopic observations with a single eye. The factor *t* is the transmission of the telescope, to allow for losses in reflections at mirrors, obstruction by the secondary mirror, and losses in the lenses by absorption and at the air-glass interfaces. *D* is the diameter of the objective, and *p* is the average diameter of the eye pupils of the observers who determined the data on which equation (2) is based. The factor p^2/D^2 compensates for the increased light gathering power of the telescope relative to the eye, and results in a decrease in the threshold illuminance and an increase in the number of background photons received. The factor M^2 accounts for the magnification M of the telescope, which reduces the surface brightness of the observed background; the factor M also makes the apparent image size larger. If we define:

$$\beta = \frac{kD\sqrt{tb}}{2^{1/4}p} \qquad \text{and} \qquad \gamma = \left(\frac{\beta}{k}\right)^{2z}, \tag{5}$$

then the illuminance received is given by:

$$i = \frac{\sqrt{2}\,p^2}{tD^2}\, i_o \left(1+\frac{\beta}{M}\right)^2 (1 + \alpha M^2\theta^2 + y\gamma M^{2-2z}\theta^2) \ . \tag{6}$$

There is a value for the magnification M for which the illuminance i is a minimum. Calculus shows that it is the value of M that satisfies the equation:

$$\alpha M^3\theta^z = \beta - y\gamma(1-z)M^{3-2z}\,\theta^2 + \beta\, y\gamma z M^{2-2z}\theta^2. \tag{7}$$

This equation does not admit of a simple algebraic solution for M. In any given case, the equation can easily be solved by iteration on a personal computer, starting with the value of M given by equation (8) below. When the value of M has been found, equation (6) gives the minimum value of i and equation (3) gives the limiting magnitude. A correction for atmospheric extinction should also be applied.

Examination of many cases has shown that the term with co-efficient $\beta y \gamma z$ is very small and usually negligible, but the term with co-efficient $y\gamma$ is appreciable, typically being between roughly 0.1 β and 0.3 β for telescopes ranging in size from 15 cm up to 152 cm (the 60-inch reflector at Mount Wilson) and with sky brightnesses up to ten times the natural brightness at sunspot minimum. It is a reasonable first approximation to neglect the $y\gamma$ term, in which case:

$$M = \left(\frac{\beta}{\alpha\theta^2}\right)^{1/3} = \left(\frac{kD\sqrt{tb}}{2^{1/4}p\alpha\theta^2}\right)^{1/3} \tag{8}$$

This is the simple general formula. The value obtained for M can then be used to calculate the minimum value of i, which is [with the $y\gamma$-term in equation (6) neglected]:

$$i = \frac{\sqrt{2}\ p^2}{tD^2}\, i_o\left[1+(\alpha\beta^2\theta^2)^{1/3}\right]^3. \tag{9}$$

The limiting magnitude is then calculated using equation (3). It works out to be:

$$m = 7.76 + 5\log D + 2.5\log t - 7.5\ \log\left(1 + 0.000935\, D^{2/3}t^{1/3}b^{1/3}\theta^{2/3}\right) \ . \tag{10}$$

An extinction correction must be applied to the derived value of m. A more accurate value can be obtained using Schaefer's theory, which includes several factors that have been neglected in the above derivation, such as Stiles-Crawford corrections, star colour corrections, and an acuity correction to take into account any exceptional sensitivity of the observer's eyes. The simple formula above gives a result of acceptable accuracy for most purposes.

A useful approximation can be obtained by substituting $p = 0.7$ cm for the eye pupil, a reasonable average for the young observers who obtained the laboratory data. To convert θ to arcseconds, it is replaced by the ratio $\theta/60$. The dependence of magnification M on telescope transmission t varies as $t^{1/6}$, which lies between 0.91 and 0.99 for most telescopes. It is adequate to assume that $t^{1/6} = 0.95$, in which case:

$$M = 140\ \frac{D^{1/3}\,b^{1/6}}{\theta^{2/3}}\ . \tag{11}$$

The above formula is useful for making estimates as well as for perceiving the importance of various factors. Note that the background brightness is not very critical, the most important factor being the seeing.

Schaefer replaced equation (2) by:

$$i = i_o\,(1+kb^{1/2})^2\ g \ . \tag{12}$$

For a telescope, the variables i_0 and b are replaced by the expressions given by relation (4), and the function g is taken to be $g(M) = 1$ for $(M\,\theta/900) < 1$ and $g(M) = (M\,\theta/900)^{1/2}$ for $(M\,\theta/900) \geq 1$; θ is in arcseconds. There is a value of the magnification M for which the illuminance i is a minimum. Define $M = 3\beta$, in which case the assumption that $k = 0.115$ and $p = 0.7$ cm leads to:

$$M_o = 0.414Dt^{1/2}b^{1/2}. \tag{13}$$

A careful calculus derivation indicates that if $M_0 < 900/\theta$ then $M = 900/\theta$ is the optimum magnification, while if $M_0 \geq 900/\theta$ then $M = M_0$ is the optimum magnification. The threshold illuminance and the limiting visual magnitude can be calculated. The results are:

$M_0 < 900/\theta$,

$$m = 7.76 + 5\log D + 2.5\ \log t - 5\ \log\left(1+0.000153D\sqrt{tb}\,\theta\right), \tag{14a}$$

$M_0 \geq 900/\theta$,

$$m = 11.31 + 3.75\log D + 1.875\log t - 0.625\ \log b - 1.25\log\theta. \tag{14b}$$

Although the formulae look very different from equation (10), they give results that are nearly the same.

There is another interesting formula that can be compared with the above formulae. Lewis (1913) made a study of the magnifications that were in use by 36 observers of double stars, and he showed that their practice was well represented (with D now measured in cm) by the equation:

$$M = 88D^{1/2}. \tag{15}$$

Although it is not a formula for limiting magnitude, it does represent an optimum magnification.

4. Discussion

Table I gives a few examples of results calculated using the various formulae discussed here, together with the values given by the traditional rule of magnification equals 30× per inch of aperture. The limiting magnitudes in columns (6), (7), and (8) are in close agreement except for the largest telescope under adverse sky brightness conditions.

Figure 1 illustrates the behavior of the limiting magnitude for the case $D = 15$ cm, $t = 0.9$, $b = 60$ nL, and $\theta = 1.5$ arcsecond. Curve 1 illustrates the relation between limiting magnitude and magnification for equations (6) and (3) combined. Curve 2 shows the relation given by Schaefer's formula [equations (12), (4) and (3) combined], and curve 3 plots the relation for Hecht's formula [equations (1), (4) and

(3) combined]. The optimum magnification is for a minimum in the illuminance *i*, and hence for maximum numerical value for the limiting magnitude *m*. (Note that in figure 1 the magnitude scale is inverted so that the brightest magnitude is at the top.) The curve for the maximum value of *m* and the curve for the minimum value of *i* (which is not shown in the figure) are very broad functions of *M*, so moderate changes in magnification hardly change the values of *i* and *m*. Hecht's formula has no minimum illuminance as a function of magnification. Schaefer's results only differ slightly from results based on equation (2), but the discontinuity in his curves probably does not give a proper representation of the behavior of the human eye. The Yerkes Observatory 40-inch (102 cm) refractor was included for comparison with observations by Barnard, who obtained a limiting magnitude of about 17.1 — which, after an extinction correction, is somewhat fainter than our formula predicts, probably in part because of Barnard's well-known very good eyesight. A more elaborate treatment of the same case (Garstang 1999) leads to the conclusion that Barnard must have had an eyesight capable of detecting a star with 69 per cent of the normal threshold illuminance.

I am indebted to an anonymous referee for a number of helpful suggestions that have been incorporated in the paper.

R. H. Garstang
JILA
University of Colorado
Boulder, Colorado, 80309-0440
U.S.A.

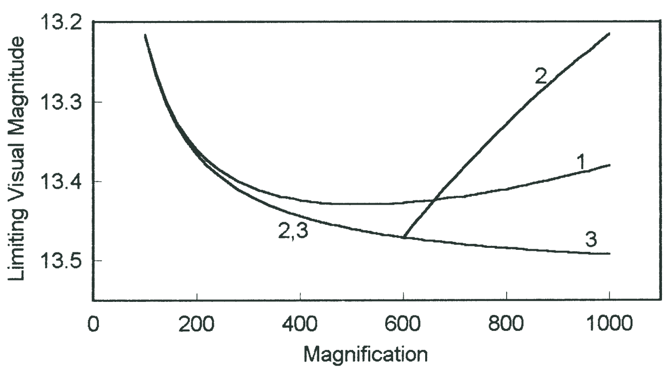


Fig. 1 — Limiting visual magnitude as a function of the magnification of the telescope, for $D = 15$ cm, $t = 0.9$, $b = 60$ nL, and $\theta = 1.5$ arcsecond. The magnitude axis is plotted with the brightest at the top and faintest at the bottom, so that a minimum of a curve corresponds to the least detectable illuminance. Curve 1 is calculated from equations (6) and (3), curve 2 is from Schaefer's modification [equations (12), (4) and (3)], and curve 3 is from Hecht's formula [equations (1), (4) and (3)]. Note the very broad minimum for curve 1, the sudden change of slope for curve 2, and the absence of a minimum for curve 3.

Table I

Optimum Magnifications and Limiting Magnitudes

D (cm)	*b* (nL)	*M* (1)	*M* (2)	*M* (3)	*M* (4)	*M* (5)	*m* (6)	*m* (7)	*m* (8)
15	60	540	520	600	340	180	13.46	13.45	13.49
15	180	650	620	600	340	180	13.42	13.41	13.46
15	600	800	750	600	340	180	13.36	13.34	13.38
40	60	750	710	600	560	470	15.51	15.49	15.54
40	180	900	840	600	560	470	15.43	15.41	15.44
40	600	1100	1010	600	560	470	15.32	15.27	15.25
102	60	960	890	600	890	1200	16.99	16.96	16.98
152	60	1090	1000	600	1080	1800	17.73	17.68	17.67
152	180	1310	1180	640	1080	1800	17.58	17.51	17.41
152	600	1600	1420	1180	1080	1800	17.36	17.25	17.09

Notes: All the above were calculated using $\theta = 1.5$ arcseconds. For typical 15 cm and 40 cm telescopes, a value of $t = 0.92$ was adopted. For $D = 102$ cm (the Yerkes refractor), the value of *t* was taken to be 0.61, and for $D = 152$ cm (the Mount Wilson 60-inch reflector), the value of *t* was taken to be 0.58. No extinction corrections have been applied.
(1) Optimum magnification, Garstang's formula, simple approximation, equation (8).
(2) Optimum magnification, Garstang's formula, accurate solution, equation (7).
(3) Optimum magnification, Schaefer's formulae, see text following equation (13).
(4) Optimum magnification, Lewis's formula for double star observers, equation (15).
(5) Optimum magnification, traditional rule, $M = 30\times$ per inch of aperture.
(6) Limiting magnitude, Garstang's formula, simple approximation, equation (10).
(7) Limiting magnitude, Garstang's formula, accurate solution, equations (6) and (3).
(8) Limiting magnitude, Schaefer's formulae, equations (14a) and (14b).

References

Allen, C. W. 1973, Astrophysical Quantities, 3rd Edition (Athlone Press: London)
Blackwell, H. R. 1946, J. Opt. Soc. Am., 36, 624
Cornsweet, T. N. 1970, Visual Perception (Academic Press: New York)
Garstang, R. H. 1986, PASP, 98, 364
Garstang, R. H. 1989, PASP, 101, 306
Garstang, R. H. 1999, Mem. Soc. Astron. Italia, 70, in press
Hecht, S. 1934, Proc Nat. Acad. Sci., 20, 644
Hecht, S. 1947, J. Opt. Soc. Am., 37, 59
Knoll, H. A., Tousey, R. & Hulburt, E. O. 1946, J. Opt. Soc. Am., 36, 480
Lewis, T. 1913, Observatory, 36, 423
Schaefer, B. E. 1990, PASP, 102, 212
Tousey, R. & Hulburt, E. O. 1947, J. Opt. Soc. Am., 38, 886
Weaver, H. F. 1947, PASP, 59, 232

ROY H. GARSTANG is a Professor Emeritus of Physics and of Astrophysical and Planetary Sciences at the University of Colorado at Boulder. He received B.A., M.A., and Ph.D. degrees in mathematics from the University of Cambridge. He was a Lecturer in Astronomy at University College, London, and subsequently Reader in Astronomy at the University of London. He became a professor at the University of Colorado in 1964, and officially retired in 1994. His early work was concerned with laboratory astrophysics, for which he received the Sc.D. degree from Cambridge in 1983. More recently he has been devoting much of his time to the modelling of light pollution. He now has time to do astronomical work for pure enjoyment. He has been a life member of the RASC since 1947.

Society News/Nouvelles de la Société

PROPOSED CHANGES TO THE SOCIETY'S BY-LAWS — USE YOUR PROXIES!

The past year has been a very busy and exciting one around National Office and National Council. Mainly as a result of difficulties with the handling of our membership data base and membership renewals by the University of Toronto Press ("UTP"), your National Council decided at an important meeting held in Montreal last November to enact several significant administrative changes. The changes require significant amendments to the Society's By-laws. The proposed By-law amendments will be brought before the general membership for approval at the Annual Meeting, which will be held in conjunction with the General Assembly in Toronto during the first weekend of July.

The most significant of the proposed changes are summarized here. As chair of the Constitution Committee, I ask all members of the Society to support the By-law amendments by filling in and submitting the Proxy forms that will be sent in May when the Agenda for the Annual Meeting and the full text of the By-law amendments are mailed.

First, last November the Council approved the termination of our relationship with UTP for membership handling purposes, and voted to implement in-house membership handling, through the upgrading of the National office's computer system and the development of specialized software to accommodate that function. *Second*, Council voted to abolish the long-standing, but very inflexible, fixed membership year of the Society. Under the existing By-laws, the Society's membership year runs from the 1st of October to the 30th of September, and the memberships of all Society members therefore expire at the same time, regardless of when during the year they actually joined the Society. In its place will be a more flexible floating membership year, in which memberships will expire, and be renewed, throughout the year. *Third*, Council voted to remove the current inflexible system whereby a new applicant for membership in the Society has to be elected to membership by special resolution of the Centre that the applicant wishes to join. The amended By-laws will permit Centres themselves to determine how applicants will become members. There are several other less significant, but necessary, By-law changes for which National Council is seeking approval of the membership as well.

After National Council approved the initiatives, the Constitution Committee went to work over the next three months, and produced a detailed report and a set of very wide-ranging By-law amendments in order to implement the changes. The report, and all of the draft By-law amendments, were adopted by National Council, after lengthy discussion, with the required two-thirds vote at its meeting in Toronto on March 6th. In addition, the Computer Use Committee purchased additional computer hardware, and established a computer network within National Office to facilitate the new membership handling functions. The Executive Committee searched out and retained a software consultant to develop and implement membership-handling software. Development of the new system is well underway, and by the time you read this note, membership handling will probably have been transferred from UTP to the Society's National Office. We hope and believe that the new system will provide timely and accurate membership service to Centres and members.

The Society executive is excited by the advances implemented, but needs the help of you, the membership, to vote in favour of the proposed amendments to the Society's By-laws, which are required to implement them properly. When you receive the Agenda for the Annual Meeting in May, please read the By-law amendments and the explanatory statement carefully, and consult with your Centre's National Council Representative for any additional information that you require. Most important, please take the time to complete and submit your Proxy form. You may name any proxyholder whom you wish, or leave the name of your proxyholder blank, in which case the Executive Committee will designate a proxyholder on your behalf.

We are looking forward to an era of enhanced service for all Society members, and we ask for your help in achieving that goal!

Michael Watson
National Treasurer and
Chair, Constitution Committee

Be a "Partner in Astronomy" at the **1999 General Assembly**

by John R. Percy, University of Toronto (jpercy@credit.erin.utoronto.ca)

We are delighted to invite everyone to attend the 1999 General Assembly, in Toronto. But there is more! It will be a first-ever, joint meeting with the Astronomical Society of the Pacific (ASP), and the American Association of Variable Star Observers (AAVSO). The meeting theme is "Partners in Astronomy" to signify the three partner organizations, the two neighbouring countries Canada and the U.S., the partnerships between amateurs and professionals, and between scientists and educators, and the many facets of astronomy that are on the program. We have carefully arranged the schedule so that, in addition to the RASC National Council Meeting, Business Meeting, and Papers Session, you can enjoy an outstanding assortment of other astronomical, educational and social events — tours of the David Dunlap Observatory, the University of Toronto Campus Observatory and the famous Ontario Science Centre.

There will be two days of exhibits and non-technical lectures on Frontiers of Astronomy, two days of invited and contributed papers on the History of Astronomy, a day of AAVSO meetings and papers, a three-day workshop for teachers (something that the ASP is especially experienced in organizing), a Family Fair for children, a Project ASTRO workshop on creating partnerships between astronomers and teachers, the Ruth Northcott Memorial Lecture given by Professor Geoff Marcy (San Francisco State University), an outstanding public speaker whose research group has discovered most of the score of new planets around other Sun-like stars, and a gala AAVSO + ASP + RASC Awards Banquet. For those who are deeply engaged in astronomy research or education, there is a special three-day symposium on "Amateur Professional Partnership in Astronomical Research and Education." The RASC, of course, is known for the wide assortment of important activities that it carries out in education, research, history, and heritage. The symposium, and its proceedings, will play a major role in the future evolution of amateur-professional partnership.

The Medical Sciences Building of the University of Toronto, the site for displays, the annual meeting, the meeting of National Council, and the paper sessions.

Our host for the meeting is the University of Toronto, which has been a leader in astronomy research and education for almost a century. The meeting will be held on the main campus of the University, in the heart of the city, close to restaurants, shops, museums, and galleries. Accommodation ranges from about $45 a night (including breakfast), in air-conditioned university residences, to $85 a night at the Quality Inn or more if you want a more upscale hotel. Toronto is arguably the most multicultural city in the world. You can get around easily and safely on foot, or on the excellent public transit system. You can relax in Toronto's island parks, or watch the July 1 weekend fireworks. Niagara Falls is just over an hour away.

Convocation Hall at the University of Toronto, where the Ruth Northcott lecture will be presented by Geoff Marcy.

So do not miss Toronto in 1999, for the most varied, interesting, and affordable meeting of the decade! You will be able

The Ontario Science Centre and OMNIMAX Theatre, the location for the Friday night reception.

The McLennan Physical Laboratories at the University of Toronto, the location of the reception on Thursday evening.

to meet old friends and new ones too. The bulk of the meeting events are on the holiday weekend of Thursday, July 1, to Monday, July 5. The symposium is July 5–7. Stay an extra week, and enjoy one of the great cities of the world! For advance information, contact John R. Percy, Erindale Campus, University of Toronto, Mississauga ON, Canada L5L 1C6; E-mail: jpercy@erin.utoronto.ca. Information on registration, accommodation, and submission of papers will be provided later. As the arrangements for the meeting become finalized, you can find them on the ASP web site (`www.aspsky.org`), as well as on the AAVSO (`www.aavso.org`) and RASC (`www.rasc.ca`) sites. Those interested in participating in the symposium should contact John Percy directly.

"ELEMENTARY, MY DEAR WATSON…"

Sherlock Holmes and Dr. Watson went to a star party. As they lay down for the night, Holmes said to his colleague, "Watson, look up into the sky and tell me what you see."

Watson said, "I see hundreds and hundreds of stars."

Holmes: "And what does that tell you?"

Watson: "Astronomically, it tells me that there are hundreds of stars in our Galaxy and potentially thousands of planets. Theologically, it tells me that God is great and that we are small and insignificant. Meteorologically, it tells me that we will have a beautiful day tomorrow. What does it tell you?"

Holmes: "Elementary, my dear Watson. Someone has stolen our tent."

Nebular Filter Performance

by Alan Whitman, Okanagan Centre (awhitman@vip.net)

In the days before nebular filters, my 8-inch Newtonian revealed the "eyes" in the Owl Nebula (M97) only with great difficulty at 116× and 174×. The 13th magnitude central star could be seen, also with great difficulty and using averted vision, at 166× in a 13-inch telescope. Not having recorded any observations of the Owl using an [O III] or ultra high contrast (UHC) filter, I asked experienced observers how much difference nebular filters make in observing M97, especially with regard to the visibility of the "eyes."

Toronto native Mark Turner reported observing the eyes with his 5.6-inch apochromatic refractor, using an [O III] filter. Mark's report certainly impressed me, given the difficulty that I had seeing them with my 8-inch.

Southern Alberta observer Richard Keppler, using a 16-inch f/3.75 reflector, found the eyes to be "…fairly obvious using low to moderate power (80–200×) with the [O III] filter." At powers of 500× and higher they disappeared, probably because the eyes filled so much of the field that there was not enough contrast relative to surrounding regions. Without a filter, Richard found that the eyes "…are not visible at very low power, are best at moderate power, but not nearly as obvious as with the [O III], and are almost totally invisible at high power." With the 16-inch, M97's central star was fairly easy at any power, whether or not a filter was used.

Vancouver observer Lee Johnson provided a detailed discussion of the proper choice and use of filters, illustrated first by the case of the Owl Nebula. "One of the 'eyes' is more prominent than the other, and the filtered views simply corroborate one's sense of the difference relative to an unfiltered view. On good nights, the UHC filter works very well on the Owl, if one uses it properly at a decent magnification: an exit pupil of 2 mm. For my 17.5-inch f/4.5, an exit pupil of 2 mm occurs with a 9-mm Nagler at 222×. At that power, the Owl is nicely magnified, so that one can see details in its swirls of nebulosity, both eyes, and lots of mottling. The [O III] filter works best with exit pupils around 4-6 mm. The contrast is greater than with the UHC filter, but the view is smaller; details are more difficult to ferret out, even with the 17.5-inch (2000 mm focal length) telescope at 82× (using my 24-mm Wide-Field eyepiece and [O III] filter). In my 10.1-inch f/4.5 (focal length of 1150 mm) telescope, the results are similar: a 9-mm Nagler gives 128×, with an exit pupil of 2 mm, and provides a good view with a UHC filter. The [O III] filter brings the view down to 48×, at which point the Owl looks almost 'solid' with glowing nebulosity, although rather tiny (and therefore often uncertain) in its details."

Lee elaborated further, using other emission nebulae as examples.

"I know that many people routinely prefer the [O III] filter to the UHC filter... but a UHC filter used at low power (exit pupils of 4-7 mm) is simply not being employed properly, and at low magnifications cannot compete with a [O III] filter. Use of the UHC filter at a proper magnification will often reveal details that the [O III] filter's lower power will not disclose. The Owl is one of those objects for which that is the case. For the more delicate NGC 6888 (Van Gogh's Ear or The Crescent), by comparison, the [O III] filter always works better than the UHC filter. For the Veil, the [O III] filter gives better, low-power, wide-field views. On the other hand, the UHC filter, used properly at higher magnifications, reveals details in the braiding that are not given proper justice through the [O III] filter. Jones 1 (the faint planetary off the top of the Great Square) responds better to the [O III] filter. It is similar in size to the Owl, but being much fainter, seems to respond better to the great contrast (9–11 nanometre bandpass) of the [O III] filter, which is twice as severe as the 24 nm bandpass of the UHC filter. The preceding comments presume reasonably dark skies, such as those typical of Mount Kobau. From the suburbs, an [O III] filter will work much better on the Owl than does the UHC filter, even if the latter is being used properly at higher powers. When the skies are dark enough, straight unfiltered magnification of the Owl at exit pupils of 1-2 mm may provide the most satisfying views."

A 15 arcminute field of M97, the Owl Nebula, taken from the Digitized Sky Survey.[1]

Edmonton observer Larry Wood echoed Lee's last point, saying: "I find using an [O III] filter (under dark conditions) kills most of the fine detail in brighter planetary nebulae. I have seen the 'eyes' of the Owl on several occasions, but my notes say nothing about using an [O III] filter."

I know that an [O III] filter is not always the best — a UHC filter far outperforms an [O III] filter on a few nebulae such as the Rosette Nebula. Presumably that is because such nebulae produce a significant fraction of their visible light at the wavelength of Hβ, which a UHC filter passes in addition to the light in the wavelength band of an [O III] filter. Yet I had no idea that the situation was as complex as Lee Johnson has described. Lee recommends trying different combinations of powers and filters (including no filter), since seeing and transparency vary from hour to hour or night to night.

Retired weatherman Alan Whitman is now a full time amateur astronomer. His other interests include windsurfing on the Okanagan Valley's lakes, hiking and skiing on its mountains, and travel. He invites observing reports for use in this column from experienced amateurs who have largely completed their Messier list.

[1]Based on photographic data of the National Geographic Society — Palomar Observatory Sky Survey (NGS-POSS) obtained using the Oschin Telescope on Palomar Mountain. The NGS-POSS was funded by a grant from the National Geographic Society to the California Institute of Technology. The plates were processed into the present compressed digital form with their permission. The Digitized Sky Survey was produced at the Space Telescope Science Institute under US Government grant NAG W-2166.

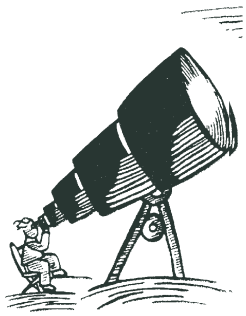
FROM THE PAST — AU FIL DES ANS

NIGHT VISION

For every visual observer, it is very important to have the eyes as sensitive as possible to faint light. This is particularly important for a variable star observer who has to estimate the magnitudes of stars near the limit of visibility, especially if he, like me, prefers to observe U Geminorum and Z Camelopardalis stars, which are almost always faint. It has been suggested that wearing red goggles thirty minutes before needing the eyes for night vision is satisfactory, that remaining in complete darkness for thirty minutes is even better. To remain in a dark room for half an hour every clear night is a nuisance, one that no observer will do regularly. I tie a black bandage over my right eye half an hour before observing. Then I use only that eye for observing, and between every look in the eyepiece I tie the bandage over the eye again. Then it is possible to use a flashlight to make notes concerning the observation, to glance at the star charts for comparison stars, magnitudes, etc., without the light influencing the eye used for observing. My experience is that with great care it is possible to gain half a magnitude if the sky is not bright with Moonlight.

by Gunnar Darsexius,
from *Journal*, Vol. 52, p. 44, February, 1958.

Ask Gazer



Dear Gazer:

Whatever happened to my favourite advice columnist? Surely the Quackstar owners are not still after your scalp after all this time. Come February, how about sticking your head up out of your foxhole, groundhog style, and offering more of your comments on the Canadian astronomy scene from your unique perspective.

Alan Whitman

Dear Alan:

A question! Since before your Sun burned brightly in the Galaxy, I have awaited a question. Actually, it was not quite that long ago, it just seemed like it. No, my friend, I am not still running and ducking from the Quackstar crew, although I must admit that for astronomers they seem to be a very touchy lot — possibly from some deeply-rooted insecurity about their instruments. Still, I must admit that the last time I lost that much ablative armour was when I tried to steer a neutral path through a discussion of whether Jim Kirk or Jean-Luc Picard was the better captain of the *Enterprise*.

No, my lack of recent activity is entirely the result of a lack of questions. I have already seen the February issue of this publication (first week of March — who says that rank does not have its privileges), and I noticed that one of the editors has a similar lack of feedback from the general membership. One could speculate on the reasons for the lack of participation. Do all RASC members spend so much time outside observing that they do not have any free time to write? That seems unlikely given our Canadian weather. Is it a case of most members not reading the newly formatted *Journal*? That also seems unlikely given the feedback that has filtered back to me. Could it be the quality of my advice? Hmmm… that must be a new record, twelve milliseconds to dismiss that as a possibility. Time to sip on my beer and ruminate further… blood flowing to brain… synapses firing at lightning speed…

Eureka! The RASC's list server is to blame! Think about it, why submit a question to me, and have to wait at least two months for a reply, when you can submit it to the list server and get an answer almost instantly. Even if you do not belong to the list, I would bet that just about every member knows someone who is on it. All it takes is to have them submit the question, and then sit around drinking mango juice until the answers start to flow back.

So, what can I do to compete with a service like that? I guess that if I cannot compete based on speed, I shall have to do it based on the quality of the replies to the questions. There are certain people on the list server (they know who they are, so I do not have to name names) whose command of grammar and spelling might be advanced enough for graduating from elementary school, but hardly appropriate for such an august location as our list server. At the other extreme, if one asks a question that is at all close to the thesis topic of anyone on the list, you can be assured of a comprehensive, though incomprehensible, reply. I shall now answer a question that was recently on the list server, and see if my middle-of-the-road approach to answering causes a few more questions to come my way.

Dear Gazer:

I was just looking over the minutes of the last National Council meeting that were posted here by Peter the Great, our over-sized, but under-appreciated, national recorder. I see that a lot of motions were tabled. Can you tell me what that means?

Muddled by Minutes

Dear Muddled:

I can understand your confusion. Unless one has been involved in a large, formal, decision-making body, the rules can be a bit confusing, especially as a large number of them have been handed down, essentially unchanged, over long periods of time. To get back to your question, one such procedure is that in the meeting room for such bodies, there is a table, off to one side, on which was placed a large pile of blank sheets of paper and a pen. If something was brought up for discussion and it needed more consideration, there would be a vote to put the proposal on that table. People at the meeting would then try to think of every possible repercussion of adopting the new proposal. Once they had thought it through, they would wait for a part of the meeting that they found boring, sit down at the table, write their concerns on the blank sheets of paper that were provided, and attach them to the back of the proposal. In some rare instances, when it appeared that there would be no tiresome lulls in the business at hand, people had been known to take the proposal and some blank paper with them to the "water closet" as a way of saving time. At some later point in the meeting, one or more committees would then be charged with taking the pile of paperwork, reviewing it, and reporting back on the implications of the proposal.

Now, as one can imagine, in a parliamentary setting (*i.e.* one in which politicians make up the body), each person would try to think of as many things as they could to add to the pile. As a result, the size of the proposal would grow very quickly. The result of that growth caused one of the clerks in the English Parliament to call such tables (including the one in the House of Lords) *multiplication tables*, a term I am sure that you have heard before.

Now, as one might expect, after the Renaissance and the birth of modern science, scientists formed their own bodies, such as the Royal Society in England, and they also based their procedures on the traditional methods. Thus, their meetings also had a multiplication table, to which proposals were tabled. Now scientists, as any of them will tell you, would prefer to spend their time doing science rather than paperwork. Consequently, it did not take long before the first scientist, whose name is lost to antiquity, decided to save time by making a short list of his objections and then reading the papers that the people before him had already added to the pile. He would then only have to write up those items that someone else had not already covered. As a result, the pile of additional material grew quickly, but then tapered off. This trend was noticed by one of the members of the Royal Society, and having a mathematical background, he started referring to the table as the *logarithmic table*, again, a term that has since come into common use, but with a different meaning.

Well folks, I am sure that should have convinced you to start sending in your questions. If I still do not get any queries, I can always follow the lead of humourist Dave Barry, who, in the persona of Mr. Grammar Man, writes his own questions and then answers them. It is now up to you, the readership: do you want Gazer, or Mr. Astronomy Man?

Gazer is a member of the Halifax Centre who wishes to remain anonymous. Gazer's true identity is known only to the current and past editors of Nova Notes, *the Halifax Centre's newsletter. Questions to Gazer should be sent to gazer@rasc.ca.*

How Distant is that Star?

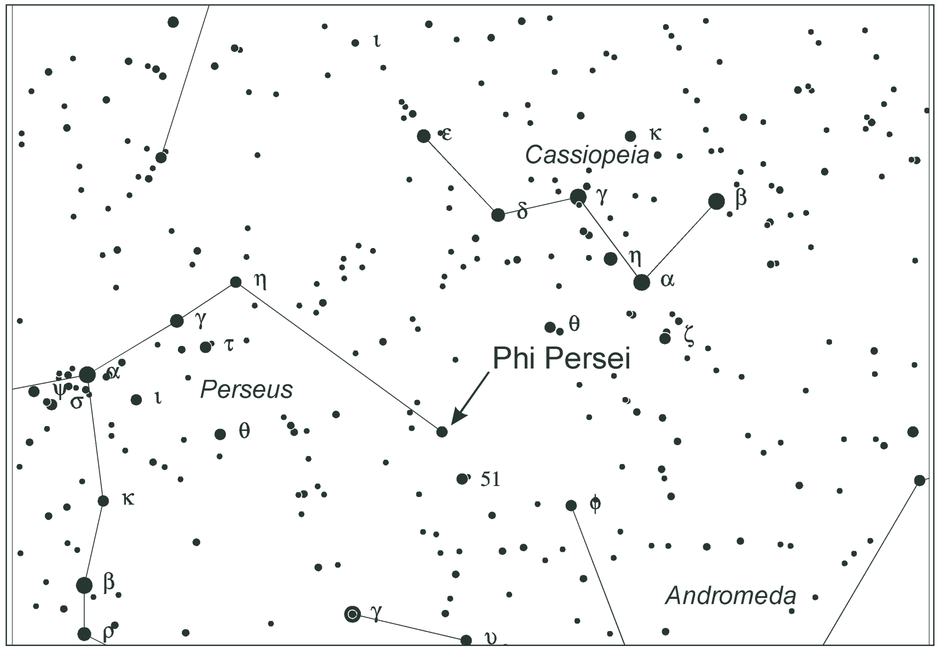
by Mary Lou Whitehorne, Halifax Centre (whitehorne@husky1.stmarys.ca)

As amateur astronomers, we often find ourselves in front of a group of people giving a talk and answering questions about our favourite subject — astronomy. We spiel off lots of information, often including distances to certain objects. People like to hear about the enormous distances to astronomical objects, and they often ask, "How do you measure such distances?" It is, of course, a fundamental question, and it is a question that I asked of myself recently.

I know the principles of how it is done, more or less, but I had some fun trying to resolve for myself the widely varying distances assigned by different sources to one particular star. The star is one of my personal friends — ϕ Persei, which is a Be star.

I will not discuss ϕ Persei's emission-line peculiarities, but its distance. I was enjoying the January/February issue of *SkyNews*, in particular an article by Glenn LeDrew about the Cassiopeia-Taurus association, which happens to be one of my favourite regions of the sky. Ten stars were mentioned and had their distances quoted (three of them are Be stars!). The distance of 1140 light years given for ϕ Persei struck me as being peculiar because, having observed the star very carefully for a couple of years, I thought I had a pretty good idea of its distance.

Intrigued, I started to look for more information. My first stop was my computer and the *Starry Night Deluxe* software, where I found the distance cited for ϕ Persei to be 1142 light years, a rather large distance for a star visible to the unaided eye. It was probably from the same source that the author for the *SkyNews* article obtained the distance he quoted for the star. The software seems to be correct with regard to facts and figures, so there is no reason to question the author of the article or the software!



A finder chart for ϕ Persei (ECU Chart prepared by Dave Lane).

"Okay, I'm confused," I mumbled to myself, being certain in my mind that ϕ Persei was closer than 1142 light years. My next stop was the *Voyager II* software, which cited a distance of 40 parsecs, or 130 light years[1]. That was quite a difference! I searched a bit further, and found that the book *StarList 2000* produced even more interesting results. It cites a parallax of 0.025 arcsecond and a distance of 1300 light years! Quickly doing the math, I determined that a parallax of 0.025 arcsecond corresponds to a distance of 40 parsecs, or 130 light years — a perfect match to the results quoted by *Voyager II*. The quoted values for the parallax and distance of ϕ Persei in *StarList 2000* differ in distance by a factor of 10, so I assume that a typographical error occurred somehow.

The difference between 130 and 1142 light years seemed a bit extreme to me, even for astronomical numbers where frequently it is joked that 1 = 10. I scoured my bookshelves and came up empty. It was time to call in the big guns — meaning *Hipparcos*. Where else can one find the latest, greatest and most accurate numbers in positional astronomy? I went back to the computer and onto the Internet, where I went to the European Space Agency and the data base for the *Hipparcos Catalogue*.

It is fun. Everyone should try it. You can search the *Hipparcos* data base on-line at:

`astro.estec.esa.nl/hipparcos_scripts/HIPcatalogueSearch`.

Cool! I scrolled through a few pages to figure out where to begin my search, clicked a likely looking button, and the search facility appeared. It asked me for

[1] The number probably comes from *The Bright Star Catalogue*, which cites a parallax of 0.025 arcsecond for ϕ Persei. That value has since been superceded by the fourth edition of *The General Catalogue of Trigonometric Stellar Parallaxes* (Van Altena, Lee & Hoffleit 1995), which gives a parallax of 0.0241 ±0.0185 arcsecond for ϕ Persei, corresponding to a distance of 135 ±104 light years.

the star's right ascension and declination in degrees. Huh? Right ascension in degrees? Not hours and minutes, but degrees? I was stumped for a minute, but only for a minute before I had the hours and minutes converted to degrees and typed into the search window. I then specified the magnitude limit and width of field for the search, clicked "enter," and waited for something to happen. To be quite truthful, I went through the procedure more than once before I got it right. Soon my poor beleaguered computer began clicking and moaning, and — voila! — a star field with three big red dots appeared. "Which one is ϕ Persei?" I wondered. I took a stab at the one in the middle, and clicked on it. Immediately data began to flow onto my computer screen. In the end I had 77 fields of data, and, by golly, they were for the right star — ϕ Persei!

Next I had to try and make sense of those long strings of numbers and meaningless identifier codes. I found an entry, field number H11, that gave a trigonometric parallax of 4.55 mas — "mas"? That is where it helps to download the 36-page document explaining the identifier codes. It is a PDF file that requires *Adobe Acrobat Reader* to open. "Mas" turns out to be the abbreviation for milliarcseconds. Oh, 4.55 milliarcseconds! That means that the parallax is 0.00455 arcsecond, which corresponds to a distance of 220 parsecs or 716 light years[2], a number right between the two values of 130 and 1142 light years cited above. What an interesting turn of events!

There is yet another method that can be used, namely spectroscopic parallax. From a knowledge of ϕ Persei's spectral type of B2 Vpe (it is an early B-type main sequence star with peculiar emission lines), we can place it on an H–R diagram and obtain its absolute magnitude. I just happen to have an H–R diagram that I constructed myself. You can make one too. All you need to do is to get out the *Observer's Handbook* and plot absolute magnitude versus spectral class for the brightest stars (that gives the top half of the H–R diagram) as well as for the nearest stars (that yields the lower portion of the H–R diagram, for stars less luminous than the Sun). It is simple! There are only a few hundred stars, and it does not take long. Draw in the main sequence and — presto! — you have your very own H–R diagram. Line up ϕ Persei's spectral class, B2 V, with the main sequence and read off its absolute magnitude, M. I obtained $M = -3$ from my home-made main sequence.

ϕ Persei is also a variable star, and its visual magnitude, m, ranges from 4.06 to 3.95. The average value is $m = 4.0$, which corresponds to a difference of seven magnitudes — the distance modulus, $m - M$ — relative to the absolute magnitude. Next we apply the distance modulus relation to derive the distance to the star. The distance modulus equation is:

$$d = 10^{1 + 0.2(m - M)} \text{ parsecs.}$$

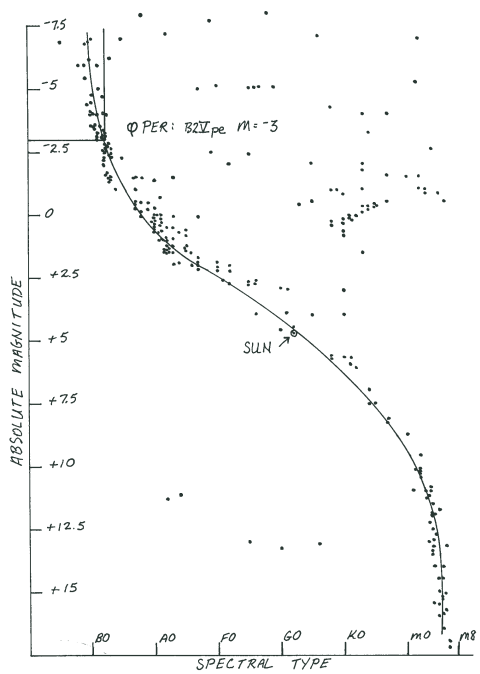
When the numbers are substituted into the equation, we obtain:

$$d = 10^{1+ 0.2(4.0 + 3)} \text{ parsecs}$$
$$d = 10^{1 + 0.2(7)} \text{ parsecs}$$
$$d = 10^{2.4} \text{ parsecs}$$
$$d = 251 \text{ parsecs, or 819 light years.}$$

That is not a bad match to the *Hipparcos* result, especially when one takes into consideration the inaccuracies of my hand-drawn H–R diagram. To summarize, ϕ Persei is found to lie at different distances from the Sun, depending upon the reference source:

130 light years — *Voyager II*
1142 light years — *Starry Night Deluxe*
1300 light years — *Star List 2000* (but the quoted parallax corresponds to 130 light years)
819 light years — spectroscopic parallax
716 light years — *Hipparcos* (my personal preference!)

By the way, none of the values correspond to the distance of approximately 400 light years that I thought was ϕ Persei's distance. I have no idea where that number came from! Regardless, it was fun playing around with the question. Perhaps you have a favourite star or two, and would like to get to know it better. Go ahead, use all of the resources available and explore the stars for yourself. It brings the universe a little closer to home!



Whitehorne's hand-drawn Hertzprung-Russell diagram constructed from plotting absolute magnitude versus spectral class for the brightest stars (the top half) and the nearest stars (the lower portion) given in the *Observer's Handbook*.

Mary Lou Whitehorne has been an active member of the RASC Halifax Centre since 1986, serving twelve years on the Centre Executive, two of those years as Centre President. Currently she is the Starlab Operations Manager for The Atlantic Space Sciences Foundation. In addition to astronomy, Mary Lou enjoys swimming, hiking, aviation and travel.

[2] The parallax also has a quoted uncertainty of ±0.75 mas, which means that the *Hipparcos* distance to ϕ Persei is 716 ±118 light years.

Scenic Vistas: Little Jewels

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

You do not have to be involved with observational astronomy very long before you realize that showpiece deep sky objects — bright nebulae, rich star clusters, large detailed spiral galaxies — are few and far between in our neck of the universe. Many such objects are already conveniently organized into the Messier List, and the enthusiastic beginning observer often hotly pursues that project for a year or two until each and every one of the Messier objects has a neat check mark beside its catalogue entry. If the observer continues to pursue deep sky observing, he is faced with the daunting task of tackling the NGC, the *New General Catalogue* of Clusters and Nebulae. Unlike the Messier Catalogue, which consists of 110 objects (as defined by the RASC), there are 7,840 entries in the NGC, far more than a lifetime of observing for any amateur who has a life outside of astronomy. The observer is faced, therefore, with the challenge of separating the wheat from the chaff — the interesting from the merely visible. It is time to do a little homework.

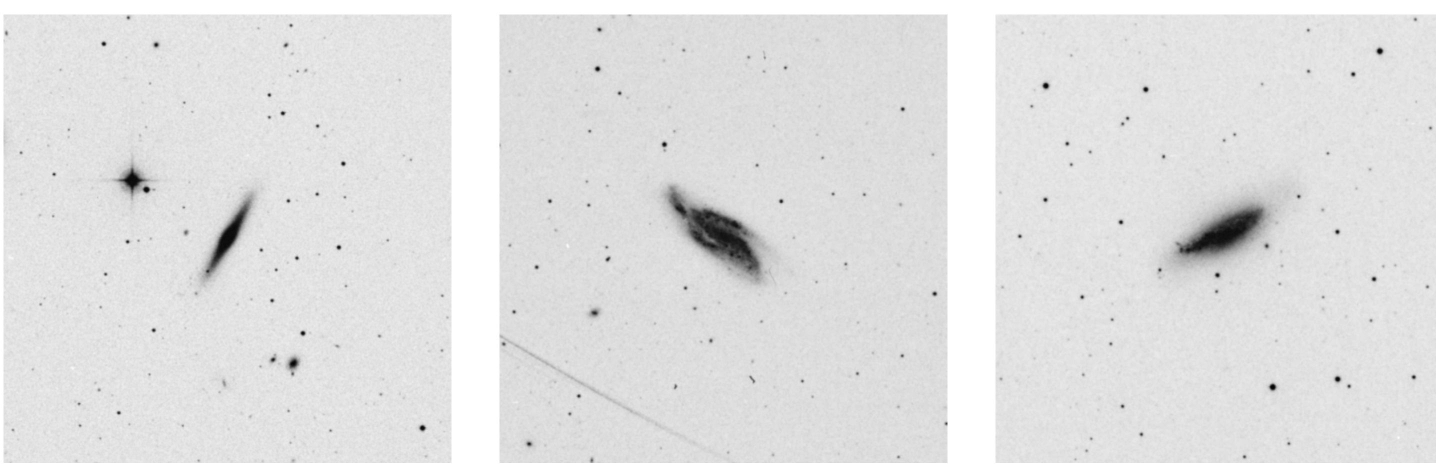
One interesting project is to search out galaxies of high surface brightness. Generally speaking, such galaxies are typically ellipticals or S0 galaxies, the latter, lenticular galaxies, being flattened galaxies like spirals only without spiral arms or dust, a feature that can be noted even when they are seen almost edge-on. The important point is that a high surface brightness galaxy contains little or no dust, which blocks starlight from the host galaxy. Despite being fairly bright, most elliptical galaxies are often dull objects to observe. That is not so for the S0 class, or for highly tilted spiral galaxies. I have often thought of such galaxies as "little jewels," for although they are sometimes small, they are very often sharply defined, elongated objects that easily cut through moderate suburban light pollution, even when using a 20-cm telescope.

The region directly overhead during spring evenings is a great place to start. An easy target to locate is the Sb spiral NGC 3877, situated about 15´ due south of Chi Ursae Majoris. This spiral is seen almost edgewise, and in my 15-inch reflector appears as a flat, well-defined streak of light with a slightly brighter central region. The galaxy appeared slightly thicker at the centre, but no core was visible. It is a good idea to use high magnification on NGC 3877 because of the proximity of magnitude 3.7 Chi Ursae Majoris, the brightness of which will hinder the view of the galaxy, especially in smaller aperture telescopes.

One of my favourite "little jewels" is located just over the border from NGC 3877 in Canes Venatici. NGC 4111, an S0 galaxy, is pretty much the prototype of the S0 class. The galaxy is easy picking, even with an 8-inch telescope under light-polluted conditions. At low magnification one night in 1992, the bright stellar core seemed surrounded by a faint, nearly circular envelope. When I boosted the magnification to 161×, the galaxy's extensions became easy to see, and NGC 4111 became a most attractive object. The visible surface is extremely well defined, with sharply defined borders. The bright star in the image of NGC 4111 is about ninth magnitude, and contrasts nicely with its stellar core.

A virtual twin of the preceding galaxy is NGC 4026, located not far from Gamma Ursae Majoris. I observed this S0 galaxy during an extremely busy and successful observing session conducted in my back yard in Dorval in April 1989. The core of the galaxy was very prominent upon initial examination, and nebulous extensions oriented due north/south became evident with averted vision. I found the view best at 123×. A magnitude nine star was visible north following the galaxy.

On that same April night I made an observation of NGC 4088, a highly tilted



From left to right are 15 arcminute wide negative images of NGC 4111, NGC 4088 and NGC 4605 taken from the Digitized Sky Survey.[1]

Sc spiral galaxy located south/southeast of NGC 4026. As can be seen in the accompanying image, the galaxy is a little out of the ordinary, since its thick, clumpy, star-rich spiral arms are laced with dust. It was actually a fairly difficult observation with my old Schmidt-Cassegrain telescope. I described the galaxy as an oval haze with an even surface brightness and with no nucleus visible. The galaxy should be a very interesting sight through my 15-inch reflector at a dark sky site.

While we are on the subject of the unusual, you can always take a peek at NGC 4605, a SBc spiral that is classified as peculiar. The accompanying image shows a highly inclined galaxy that is definitely asymmetrical in appearance. My only observation of the galaxy came in May 1987, when I was still living in Cote St.-Luc, a nice place to live but one of the worst places in the world to do observational amateur astronomy! With my old Schmidt-Cassegrain, NGC 4605 was a challenging object, difficult to distinguish from the sky background. Distinctly oblong, the galaxy had an even surface brightness and no evidence of brightening to the centre. That observation is a classic example of the experiences of a rookie observer. At the time, I had little observational experience, and observing any object in the *New General Catalogue* was a great challenge for me from a light polluted location. Today, even using the same telescope under the same conditions, I doubt that I would describe a magnitude 9.6 galaxy as a challenge!

Bright, edge-on galaxies are not exclusively located in Ursa Major, of course. Their equals can be found in Leo, Sextans, Virgo, and other galaxy-rich regions of the spring sky. I invite you to try your hand at finding jewels that no amount of money can buy.

Mark Bratton has had a life-long interest in astronomy, and first became acquainted with the RASC in November 1966 at the age of eleven. He did not become a member until twenty-five years later. He is currently the editor of the Montreal Centre's newsletter Skyward *and in his second term as president of the Centre. He is the single parent of a twelve year old boy, Kristopher, and his greatest joy, besides his son, is slowly exploring the skies with a 375-mm reflector from the deck of his small country cottage near Sutton, Québec.*

[1]Based on photographic data of the National Geographic Society — Palomar Observatory Sky Survey (NGS-POSS) obtained using the Oschin Telescope on Palomar Mountain. The NGS-POSS was funded by a grant from the National Geographic Society to the California Institute of Technology. The plates were processed into the present compressed digital form with their permission. The Digitized Sky Survey was produced at the Space Telescope Science Institute under US Government grant NAG W-2166.

The Messier Tour, *First Leg of a Greater Journey*

by Randy Klassen, Coquitlam, B.C. (randy@omnexcontrols.com)

Childhood experiences beneath the vast canopy of Saskatchewan's heavens fueled my lifelong desire to know the night sky. I smile when I remember huddling in a tangle of kids piled up like prairie dogs inside big old tractor tire tubes that bobbed and swayed like the ocean when one of us squirmed. We would all be nestled together trying to keep warm, faces pointed up to the stars, our parents' voices murmuring and laughing in the distance while we contemplated the *eeriness* of space, the subtle twisting trail of the Milky Way, the rhythm of the Northern Lights. Such memories return as feelings. I was awestruck, almost scared by it all. Through the years I never truly understood what was up there.

> **My desire to know the night sky deepens with each new observing experience, and after following the Messier objects through the sky, I am perhaps more awestruck and overwhelmed by the heavens than before.**

Being older and more methodical now (less bobbing around on inner tubes), I have been enjoying the exploration of the night sky I loved as a youngster. A "text book approach" is what you would probably call my journey as an amateur stargazer. I did my reading, bought the simple charts, and learned the constellations. I dug up an old pair of binoculars to probe deeper, and eventually purchased a four-inch reflector to pursue the unreachable things I longed to see — not buying big in case I might lose interest, just as the books suggested. I remember happily bringing my first scope home one warm, clear day at the beginning of March 1996. With my targets picked out for the evening and the scope waiting patiently in the living room for darkness, the first blank pages of "Randy's SkyLog" rolled out, hot off the printer. I was ready to observe and record.

I still like to go back to my very first entry, March 3rd, 1996. "First time out with the new telescope. Purchased this afternoon. Moon phase is three days before full, and it is already high in the east. Orion Nebula — disappointing first look. Very faint. Pleiades — more stars than I imagined. Cannot make out where I am in the cluster. Will need to get used to the mirror image twists. Moon — very bright." I laugh just reading it. Those few words alone are a study in innocence at the eyepiece. Later, with more reading and better charts, I would learn that I had observed my first two Messier objects.

Let us jump ahead in time. On August 4th, 1997, I was bumping my way down the winding gravel washboard road that four days earlier had led me to the Mount Kobau Star Party. Leaving Kobau I had forty Messier objects left to observe on the list of 110 assorted objects I had chosen to help me learn the sky. My goal was to complete the Messier List with my four-inch, and then to graduate to a larger scope I planned to build that winter. I had spotted thirty-three new Messier objects that weekend with my own little scope, and was further inspired by other observers on the mountaintop who shared many spectacular sights with me.

By September 23rd I had logged all the Messier objects I could for the fall season. The remainder awaited discovery in the winter and spring constellations, but as most amateurs discover very quickly, time in the sky can be cheated by getting up early. With that in mind, I laid out a schedule to capture my targets as they rose over the eastern horizon.

October was scrubbed because of West Coast rains, but on November 9th the clouds broke and, while my scope cooled in the morning chill, I wrote, "Stars of Cancer visible to naked eye. Thin high cloud coming in. Temperature is about four degrees Celsius, though it seems warmer. Moon already set." Between 04:03 and 04:57 I managed to observe eight Messier objects, previously missed, between Lepus and Hydra's head. I recorded an added bonus at the end of my notes. "At the beginning of the session I was aligning the scope to Canis Major, when a slow-moving meteor went through Lepus. About as bright as Venus, perhaps a little less. The interesting part was I listened, and sure enough a few seconds later I heard the rumbling sounds of its explosion as it crackled through the quiet of the morning."

Two days later my charts were ready for the long awaited star hop through the target-rich Leo/Coma Berenices/Virgo region. I spied M65 at 04:15, and moved on from there. At 05:47 I recorded, "M84, M86 — a nice pair at 50×. Perhaps the nicest grouping of the tour." I had tagged eighteen Messier objects in one exciting swoop. My lengthy notes concluded, "Sun came up too soon! I had five targets left in the area. Almost got them all! The keys to the tour were the marker stars in Coma and Virgo. They were essential to return to repeatedly. Star hops were crucial. The time flew by. What fun!" I had seven Messier objects left to go when the November clouds rolled back in.

A wonderful fall high pressure system off the coast brought clear skies at the beginning of December, and on the fifth I E-mailed the following report to fellow observers on an Internet list:

On Tuesday of this week, between 03:00 and 05:00, I struggled through high wispy clouds to grab M49 and M61 in Virgo, stolen from me the previous month by a rising Sun. Patience paid off, leaving me with five to go. It should have been four, but M53 would not pop out of the haze no matter how long I stared.

Up this morning again at 03:30. I spied my targets over the neighbour's house. Caught rising, not three degrees from their chimney, M53 was bagged at low power. It certainly is easy when the clouds are not around. Nice object, by the way. A short star hop had me at M64. Low power nabbed it easily, too. Higher power showed it off. My scope swung up toward the eaves. Time was working against me as Boötes' dogs snuck between the houses. M94 fell prey to my eyepiece with room to spare, before being lost to the gutters.

Two left to go. Corvus was up in full, though masked by city glow to the south. Ahhgg! Hydra would be slithering through enough light pollution to kill a bear. I know from experience that I have little hope of getting M68 and M83 from my house. A trip is in the works.

Wave after wave of rain, churning in from the Pacific, would keep me from my goal throughout the remainder of December. Finally, on January 9th, 1998, high winds tore open the clouds and gave me the window to the south I needed. Groggy, yet pleased, I wrote to the observers' list:

Patience is a virtue, but hauling your butt out of bed at 03:00, loading the car, and driving southeast of the city on the first clear morning in a month gets the result.

At 04:30 I parked in a driveway to someone's orchard about thirty metres north of the Canada–U.S. border. With incredibly transparent skies, hand-numbing minus nine degree Celsius temperatures, and my scope howling like a Coke bottle in the wind, I viewed my last two Messier objects!

M68 stuck out like a sore thumb at low power (could not see it for the life of me from the city), and at 50× and 100× it showed itself off nicely. M83 revealed a dim core at low power, and at 50× its extended fuzziness and size were apparent. I did not get a chance to view it at powers greater than that as the wind got very nasty and messed with my setup. I chose a humble victory over having my scope blow into a big icy mud puddle, and packed up.

The Messier Tour was complete, and as I look back along its winding path I see the many valuable observing skills it taught me along the way — skills necessary for the greater journey that lies ahead. "Lots of observing awaits," I wrote. "Today, though, I'll savour this little step."

My desire to know the night sky deepens with each new observing experience, and after following the Messier objects through the sky, I am perhaps more awestruck and overwhelmed by the heavens than before. My pursuit of astronomy has become a quiet, welcome part of my busy life — a chance to dream and wonder. I do not think I will ever truly understand what is up there, which makes it all the more intriguing.

On those rare occasions when the B.C. coast is blessed with clear skies, Randy Klassen can be found busying himself with charts and lists, as well as with long looks through the eyepieces of his homemade 10-inch f/6 Dobsonian. A sales and marketing manager for a high-tech company, Randy is decidedly low-tech when it comes to his hunter/gatherer approach to combing the night sky, believing "go to" to be a four-letter word.

Initial Impressions of Three New Eyepieces

by Joseph O'Neil, London Centre (joneil@multiboard.com)

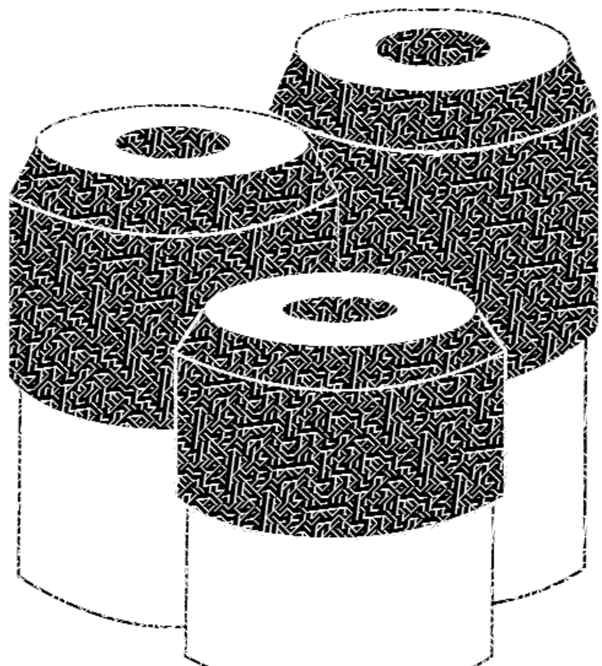
As baby boomers grow older, they have created a demand in the astronomical community for eyepieces with longer eye relief to suit the needs of older eyes. The new eyepieces from Vixen and TeleVue fit the bill very well. The Antares line is intended to compete with the TeleVue Naglers, but it is worthy enough for comparison with both types. The present review is based upon my personal impressions from using all three eyepieces side by side.

First some background on the eyepieces. The Antares Speers-Waler eyepiece is designed by Canadian Glen Speers, partly in response to a demand for a homegrown product, but also because the low Canadian dollar has increased the price of many imported accessories. Glen saw an opening and, I think, filled it nicely.

The Speers-Waler line is made in Canada using optics cut in Japan. Except for the 30-mm eyepiece, they all have 1.25-inch barrels and either eight or nine elements. There are eight sizes ranging from a 30-mm eyepiece to the 5/8-mm zoom lens. The apparent field of view (FOV) for the 10-mm eyepiece is 71°, and eye relief is around 14 mm. The street price for the 10-mm eyepiece is about US$159.

The Vixen Super Wide Lanthanum eyepieces are made in Japan by Vixen, and bear little resemblance to the earlier Lanthanum series. They are very large in size — the 8-mm eyepiece is almost the same size as a 9-mm Nagler. There are four sizes, ranging from 22-mm to 8-mm, and all have dual 1.25/2-inch barrels, being composed of eight elements. Eye relief is 20-mm on all sizes, and the apparent field of view is 65°. The street price for the 8-mm eyepiece is about US$205.

The TeleVue Radian eyepiece will eventually be available in sizes ranging from 3-mm to 14-mm, but at the time of writing only the 14-mm and 10-mm sizes were available. The apparent field of view is listed as 60°, although it looks like it could be only 57° to 58°. Eye relief on all models is 22 mm and all have 1.25-inch barrels. I am not certain how many elements they have (probably at least six), and they apparently contain some lanthanum glass. TeleVue has been tight-lipped about the specifics of their new eyepieces, possibly because they do not want a competitor to make a "Super-Radian" by adding one more element and an extra two degrees of apparent field of view. The barrel is stamped "Taiwan," but I do not know if the entire eyepiece is made in Taiwan or if the optics are Japanese and only the barrels are made in Taiwan. In size it is close to the height of a 32-mm TeleVue Plössl, but about 50% larger in diameter. The street price is about US$230 for all sizes.



All three models have rubber eyecups and extensive multi-coatings on all lens surfaces, so ghosting is at a minimum and image contrast is at a maximum. The ultimate test comes from looking through the eyepieces rather than just inspecting them.

First the Speers-Waler. I love and hate this eyepiece. The image it produces is sharp to the edge, provides good contrast for the planets and handles telescopes down to f/5 quite well. It does, however, suffer from the "kidney bean" effect seen in the older 13-mm Naglers, although not as seriously. My main complaint is that the eyepiece requires the focus to be adjusted almost all of the way in. That is not usually a problem on Schmidt-Cassegrain telescopes or refractors, but on some Newtonians you simply cannot rack the focuser in close enough to focus the image. Still, it is impressive to use and it is a lot less expensive than the other two eyepieces. I should note that the Speers-Waler line is not as impressive once you get above the 14-mm size. Larger sizes work fine, but they lack the "Oh-Wow" effect that the 14-mm and smaller sizes seem to provide.

I found the Vixen 8-mm eyepiece to be the easiest on the eye of the three, as it has very little, if any, "blackout" when you move your head about. The image contrast it provides for the planets is superb — better by a notch than the Speers-Waler eyepiece. Stars are tack-sharp to the edge of the field, even on the fastest Dobsonians, but the eyepiece also suffers from the all-the-way-in focus problem. On some Newtonians you may have to use a 2-inch focuser in order to drop the eyepiece low enough to obtain a focus.

The TeleVue Radian eyepiece is the most interesting of them all. First of all, I have only been able to test it through hazy city skies, but the view it provides is sharp enough to shave with! The image contrast appears to be excellent, on a par with the Vixen eyepiece, but its most unique feature is its "click stop" barrel. Literally the outside barrel and rubber eyecup moves up and down to adjust for your eye. The Radian is the most "touchy" eyepiece I have ever used for having to centre your eye exactly, but the adjustable barrel, once set, keeps your head in exactly the right place.

Another unique feature of the Radian eyepiece is its focus. Most TeleVue eyepieces are parfocal. Simply put, a 32-mm TeleVue Plössl and a 4.8-mm TeleVue Nagler in almost any telescope will require very little refocusing when they are replaced, and in a TeleVue telescope — such as a Ranger — the focal adjustments match exactly. The Radian eyepiece is the exact opposite — you have to adjust the focus *out* to regain a sharp image. Most eyepieces, any type or brand, usually require moving the focus *in* the smaller they are in focal length. For example, between a 4-mm eyepiece and a 25-mm University Optics ortho eyepiece, one normally adjusts the 4-mm eyepiece in by almost an inch. The 10-mm Radian eyepiece on my Maksutov-Newtonian, however, had to be focused outwards almost a quarter of an inch compared with the focus of a 32-mm TeleVue Plössl eyepiece. For people experiencing problems with low-profile Newtonian focusers, the Radian eyepieces will be a dream come true. They are probably not terribly superior to Panoptic eyepieces in image sharpness, although perhaps a bit in contrast. But they definitely are in eye relief.

How do they stack up to each other? For people who need long eye relief, either the Vixen or the Radian eyepieces are great, the drawback to the Radian eyepieces being that they only come in focal lengths up to 14-mm, while the Vixen line goes up to 22-mm. Perhaps the greatest "problem" for both eyepieces is the poor exchange rate for the Canadian dollar, which places them in the price range of "when I win the lottery." While the Speers-Waler eyepiece is not, in my opinion, in the same class as the TeleVue or the Vixen eyepieces, there is nothing out there on the market that can touch it for its lower price range. My personal choice will eventually be a Radian eyepiece, for it is the only one of the three that will work in the 1.25-inch focuser on my Maksutov-Newtonian telescope.

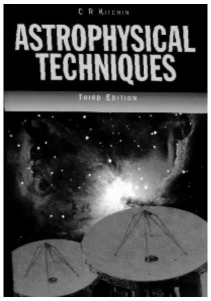
The other point to consider is whether or not any of the three is better than a good 32-mm Plössl eyepiece with a good 3× Barlow lens. If you have the money, I would suggest getting just one. If not, do what you can with what you can afford. The wider apparent field of view of the more expensive eyepieces is very nice to have, especially in a Dobsonian. And the lanthanum glass used in both the Vixen and the Radian eyepieces does give them an edge for image contrast, especially for the planets. The usual rule of thumb is that the more elements there are in an eyepiece, the less contrast there is for bright objects. Despite all of the elements in the Radian and Vixen eyepieces, however, they give the impression of looking through an eyepiece with only four elements.

Also, from an unscientific point of view, both the Vixen and the Radian eyepieces produce very little, if any, eyestrain in any telescope on which I have tested them. The Speers-Waler eyepiece is similar in that area, but perhaps with advancing years I am growing to appreciate the greater eye relief of the other two eyepieces.

Finally, I feel that at low powers one does not always see much difference between eyepieces, but for focal lengths of 10-mm or less the differences in quality jump right out. If I won the lottery, I might be inclined to buy a 35-mm Panoptic eyepiece, or I might not. But I would not hesitate to spend the money on one good high-power eyepiece.

A member of the London Centre of the RASC, Joe O'Neil has been interested in astronomy since grade school. In his spare time he enjoys planetary and lunar observing from the light polluted skies of London, and black and white astrophotography from the family farm near Granton, Ontario, about five kilometres due north of Western's Elginfield Observatory.

Reviews of Publications
Critiques d'ouvrages



Astrophysical Techniques, 3rd Edition, by C. R. Kitchin, pages xiv + 474, 15.5 cm × 23 cm, Institute of Physics Publishing, 1998. Price US$39.50, soft cover. (ISBN 0-7503-0497-9)

Science is becoming increasingly specialized, and astronomy is no exception. Gone are the days of Sir Edmund Halley, who was able to make key contributions to stellar and cometary astronomy, geomagnetism and diving-bell technology, while still finding spare time to develop the basic precepts of life insurance. The growing variety of objects, phenomena, and techniques has forced modern astronomers to focus on their own sub-disciplines.

The same degree of specialization has played itself out across the electromagnetic spectrum, with astronomers staking out their respective turfs in the optical, infrared, microwave, radio, ultraviolet, gamma ray and X-ray bands. In recent years, however, there has been movement away from such wavelength chauvinism to a "synoptic" approach (literally, "taking the broad view of the whole"). Astronomers have joined forces in global campaigns to tackle problems with all of the observational tools at our disposal. As a result, the mystery of the gamma-ray bursters is yielding to the combined efforts of high-energy measurements from satellites and optical spectroscopy from the ground. Similarly, an expert on the Sun must understand the nuances of neutrino detection as well as radio flux monitoring.

C. R. Kitchin is clearly an advocate of the synoptic approach, explaining that one aim of his book is to "reduce the recent trend towards fragmentation of astronomical studies." This single volume attempts to familiarize the reader with observational methods from photography to gravitational wave detection, with a few forays into the principles of data analysis, such as the section on Fourier transforms. The book has an encyclopedic scope coupled with attention to practical details that set it apart from other similar works. Where else would you find a table of radio astronomy reserved frequencies and the spectral response curve of 3–ethyl–5[4–(3–methyl–2–benzothiazolinylidene)–1,3–neopentylene–2–butenylidene] rhodamine (a dye used in photographic emulsions) in a single volume?!

Such broad scope comes with its own challenges. Rather than dividing the book by wavelength regions or technology, Kitchin takes a conceptual approach, progressing from detection to imaging to instrumentation. That is a good choice for a textbook clearly aimed at astronomy students, but occasionally makes for strange bedfellows, such as when lunar occultations and synthetic aperture radar find themselves side by side in the same chapter. (Fortunately, the table of contents and index are sufficiently detailed to track down specific topics.) The level of detail is also somewhat uneven. Kitchin devotes five pages to derive the diffraction pattern of light passing through a circular hole (known as an Airy disk), but less than four pages on the techniques of modern electronic image processing.

For a new edition, surprisingly little space is set aside to describe exciting observational advances since the previous edition was published in 1991. Precise Doppler techniques used to detect extra-solar planets and to probe the Sun's structure through helioseismology, and the *Hipparcos* satellite astrometry that has challenged fundamental tenets in the cosmic distance scale, together merit a total of only three paragraphs, with no illustrations. Despite a section on radio and microwave detection, I could find only a single passing reference to the cosmic microwave background — and that in the section on cosmic ray detectors. Nothing on the principles of the *Cosmic Background Explorer* (COBE) satellite or multi-pole analyses of the resulting microwave maps, which are our best probes of large-scale structure in the early universe. Those seem to be serious oversights in a text aimed at undergraduates, whose motivation and interest in astronomy might be stimulated by a better understanding of headline-making science.

One part of the book that desperately needs updating is the appendix on catalogues. The most recent references date back to 1980, and there is no mention of the vast electronic data bases that have revolutionized astronomy catalogues and data archiving. Web-based tools such as SIMBAD and VizieR — maintained by the Centre de données astronomiques de Strasbourg and available through the Canadian Astronomy Data Centre (`cadcwww.dao.nrc.ca`) — have largely replaced tedious searches through musty library shelves.

In spite of such omissions, I would recommend *Astrophysical Techniques* to any research astronomer or graduate student. It is a good primer on techniques outside your area of expertise, and a great reference source for preparing courses on astronomical instrumentation. You will find nuggets of information here that might otherwise require hours of searching through other more specialized volumes. To the amateur astronomer, on the other hand, I cannot truly recommend that you buy *Astrophysical Techniques*, despite the dust jacket's claim that amateurs "of any level will find this book to be of immense value." Sections of the book could be very instructive, but it is not likely to become a well-thumbed volume on the shelf beside your copy of the *Observer's Handbook*. That is, unless you have been dying to learn things like how to derive the emergent spectrum of a birefringent monochromator.

Jaymie Matthews

Jaymie Matthews is a professor of astronomy at the University of British Columbia, and Mission Scientist for the MOST *microsatellite project — slated to be Canada's first space telescope. Despite extensive research in stellar pulsation and asteroseismology, this is the first time he has ever been able to use "3–ethyl–5[4–(3–methyl–2–benzothiazolinylidene)–1,3–neopentylene–2–butenylidene] rhodamine" in a sentence.*

An Introduction to Active Galactic Nuclei, by Bradley M. Peterson, pages xvi + 238, 17 cm × 24.5 cm, Cambridge University Press, 1997. Price US$27.95 soft cover. (ISBN 0-521-47911-8)

Activity in galactic nuclei occupies the attention of a significant fraction of contemporary research astronomers — twenty percent according to the cover notes of this book. Yet despite the breadth and diversity of the field, there are surprisingly few texts available at the advanced undergraduate and graduate levels. In my opinion, *An Introduction to Active Galactic Nuclei* is among the best.

For starters, it is a comprehensive work. The author treats virtually every major aspect of research in the field, from gas physics and accretion-disk theory to the large-scale environment of active galactic nuclei (AGN) and the implications of absorption-line statistics in high redshift quasi-stellar objects, the most luminous members of the AGN family.

What makes it a particularly useful text for advanced students are the good introductions Peterson provides for each topic. He also takes care to articulate some of the intermediate steps when deriving important mathematical or physical results, and states explicitly the assumptions and limitations underlying particular arguments or conclusions — something of great value to young scientists. The author also pays sufficient attention to the seminal papers in this relatively young field (even though they may have been written prior to the 1980s!) For example, the serious biases and selection effects inherent in the discovery and classification of AGN and the subsequent calculation of AGN luminosity functions are dealt with in some detail, and give the reader an appreciation for why progress on some fronts has been slow and often not conclusive.

Even AGN researchers will find this text a valuable resource, given the clear exposition of its material and the diversity of the field. Inevitably, there are a few typographical errors in the text and the equations, and some areas are treated more completely than are others. For example, some readers may wish for a more complete discussion on the starburst-AGN connection, as well as the torus that is essential to account for spectroscopic differences between broad- and narrow-line objects according to Unified Models of AGN. But, by and large, all the major research areas are well represented.

In summary, this well-written text provides an excellent introduction to a stimulating field, and conclusively answers the question: Why study AGN? I would highly recommend it to students and researchers alike.

Michael De Robertis

Michael De Robertis is a professor in the Department of Physics & Astronomy at York University. His chief scientific interests lie in the area of activity in galactic nuclei.

THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

NATIONAL OFFICERS AND COUNCIL FOR 1998-99/CONSEIL ET ADMINISTRATEURS NATIONAUX

Honorary President	Jack Locke, Ph.D., Ottawa
President	Randy Attwood, Toronto
1st Vice-President	Robert Garrison, Ph.D., Toronto
2nd Vice-President	Rajiv Gupta, Ph.D., Vancouver
Secretary	Raymond Auclair, Unattached Member
Treasurer	Michael S. F. Watson, Unattached member
Recorder	Peter Jedicke, London
Librarian	Andrew Oakes, B.A., M.A., Unattached Member
Past Presidents	Douglas P. George, M. Eng. B.A.Sc., Ottawa and Douglas P. Hube, Ph.D., Edmonton
Editor of *Journal*	David G. Turner, Ph.D., Halifax
Associate Editor of *Journal*	Pat Kelly, M.Sc., Halifax
Editor of *Observer's Handbook*	Roy L. Bishop, Ph.D., Halifax
Editor of *Beginner's Observing Guide*	Leo Enright, Kingston
Executive Secretary	Bonnie Bird, M.L.Sc., 136 Dupont Street, Toronto, ON, M5R 1V2 (Telephone: 416-924-7973)

CENTRE ADDRESSES/ADRESSES DES CENTRES

Calgary
c/o Calgary Science Centre, P. O. Box 2100, Station "M", Loc #73, Calgary, AB, T2P 2M5

Edmonton
c/o Edmonton Space & Sciences Centre, 11211 - 142 St., Edmonton, AB, T5M 4A1

Halifax
P. O. Box 31011, Halifax, NS, B3K 5T9

Hamilton
P. O. Box 1223, Waterdown, ON, LOR 2HO

Kingston
P. O. Box 1793, Kingston, ON, K7L 5J6

Kitchener-Waterloo
c/o J. Brunton, 123 Grand River Street N., Paris, ON, N3L 2M4

London
P. O. Box 842, Station B, London, ON, N6A 4Z3

Montréal
P. O. Box 1752, Station B, Montréal, QC, H3B 3L3

Centre Francophone de Montréal
C. P. 206, Station St-Michel, Montréal, QC, H2A 3L9

Niagara
P. O. Box 4040, St. Catharines, ON, L2R 7S3

Okanagan
P. O. Box 20119 TCM, Kelowna, BC, V1Y 9H2

Ottawa
P. O. Box 33012, 1974 Baseline Road, Nepean, ON, K2C OEO

Québec
2000, boul. Montmorency, Québec, QC, G1J 5E7

Regina
P. O. Box 20014, Cornwall Centre, Regina, SK, S4P 4J7

St. John's
c/o 206 Frecker Drive, St. John's, NF, A1E 5H9

Sarnia
c/o Alice Lester, P.O. Box 394, Wyoming, ON, NON 1T0

Saskatoon
P. O. Box 317, RPO University, Saskatoon, SK, S7N 4J8

Thunder Bay
c/o 135 Hogarth Street, Thunder Bay, ON, P7A 7H1

Toronto
c/o Ontario Science Centre, 770 Don Mills Road, Don Mills, ON, M3C 1T3

Vancouver
c/o Gordon Southam Observatory, 1100 Chesnut Street, Vancouver, BC, V6J 3J9

Victoria
c/o Bill Almond, 354 Benhomer Drive, Victoria, BC, V9C 2C6

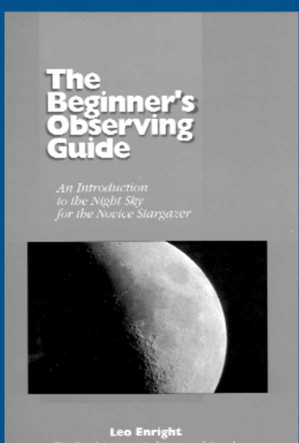
Windsor
c/o Frank J. Shepley, 344 South Middle Road, R.R. # 2, Maidstone, ON, NOR 1K0

Winnipeg
P.O. Box 2694, Winnipeg, MB R3C 4B3

Publications and Products of
The Royal Astronomical Society of Canada

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).



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.

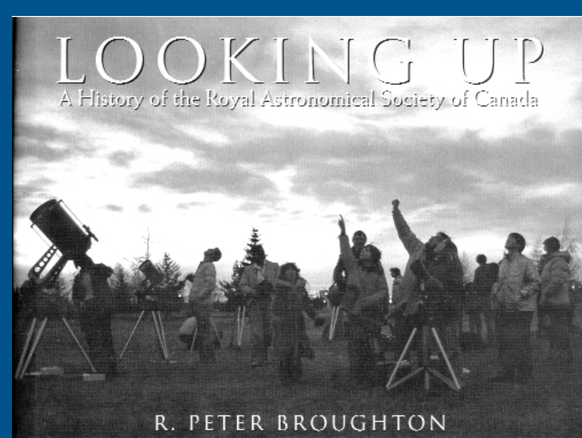
Written by Leo Enright (160 pages of information in a soft-cover book with otabinding which allows the book to lie flat).

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

Looking Up:
A History of the Royal Astronomical Society of Canada

Published to commemorate the 125th anniversary of the first meeting of the Toronto Astronomical Club, "Looking Up — A History of the RASC" is an excellent overall history of Canada's national astronomy organization. The book was written by R. Peter Broughton, a Past President and expert on the history of astronomy in Canada. Histories on each of the centres across the country are included as well as dozens of biographical sketches of the many people who have volunteered their time and skills to the Society. (hard cover with cloth binding, 300 pages with 150 b&w illustrations)

Price: $43 (includes taxes, postage and handling)



*** Special Discount — Looking Up and the BOG — $50 ***

Send cheque or money order to: RASC, 136 Dupont St., Toronto, ON, M5R 1V2 Canada
Please allow 6-8 weeks for delivery. Orders outside Canada please remit in U.S. Funds.
Major credit cards accepted. Call the National Office toll-free at 1-888-924-7272 to place your order.
(copies of these publications may also be available directly from your local Centre)