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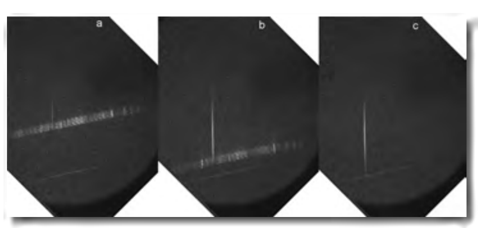

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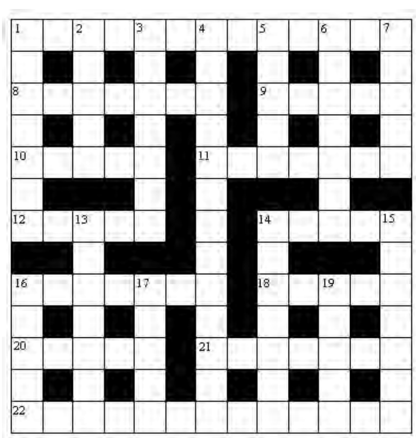

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DEPARTMENTS/DÉPARTEMENTS

ACROSS THE RASC
DU NOUVEAU DANS LES CENTRES

Cover: The photo of M27 (the Dumbbell Nebula, or NGC 6853), in the constellation Vulpecula, was obtained by Albert Saikaley in August 2004 using a Celestron C11 at f/6.3 with an SBIG ST10-XME camera on a G11 mount. The exposures, in HαRGB, were 60, 15, 15, and 15 minutes respectively.

COLUMNS/RUBRIQUES

Editorial

by Jay Anderson (jander@cc.umanitoba.ca)

We have travelled to the end of year one under this Editor's tutelage. Since last October the editors, proofreaders, authors, photographers, graphic artists, and scientists who form the backbone of the *JRASC* have helped make some fairly big changes — the *Journal* now reflects its amateur audience a little better and the content is more varied. Most of you seem to like it, judging by the letters and emails that arrive from time to time, though there are a few who are nostalgic for the *Journal* of Christmases Past.

Nevertheless, I feel that there is a part of the journey remaining to be made. We need material that reflects the broader range of RASC achievement — drawings, poems, insights, special moments, and also technical articles about mounts, observing aids (pass these ideas to Don Van Akker), observatories, digital processing (we all have digital cameras now, don't we?), star parties, and science.

So I'm challenging you to make the *Journal* even more RASC-like. We have a great collection of editors, many of whom focus on a particular topic. If you observe variable stars, send some of your insights and results to Rick Huziak. If you tackle asteroid occultations, let Guy Nason know what you're doing. Ask Warren Finlay or Doug Hube what they plan to feature in their next article and take a photo of the object for them - we'd prefer to use a member's images rather than those that come from *Hubble*. Argue with Geoff Gaherty, or provide him with your "through the eyepiece" story. If you know of a dynamite Web site, let Paul Langan know — he may have the byline, but we'll put your recommendation into print and give you the credit. Send us a sonnet, a *haiku*, or even a cartoon — we'll add them to the mix.

One of my bigger disappointments is the lack of content from our women astronomers. There is a women's perspective out there: these may be special insights into astronomy, personal "aha!" moments, or Leavitts and Cannons who need a little recognition. More than half of the new graduates in astronomy in the U.S. are women, but that achievement hasn't yet reached the pages of the *JRASC*.

Astronomy has the Universe as its sandbox. You've seen some of the new ideas in our pages already, and your Editor would like to see many more.

Journal

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

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News Notes
En Manchettes

Compiled by Martin Beech (beechm@uregina.ca) and Russ Sampson (sampsonR@easternct.edu)

CANADIAN CAMERA HELPS MEND *FUSE*

Launched in June 1999 and originally designed for a three-year mission, NASA's *Far Ultraviolet Spectroscopic Explorer* astronomy satellite is back in full operation. The *FUSE* satellite is working again thanks to a team of scientists and engineers at the operations centre in Johns Hopkins University who reprogrammed its onboard software control system during 2005 to continue the mission. *FUSE* had a near-death experience in December 2004 when the third of four onboard reaction wheels stopped spinning, depriving the satellite of stability and fine-pointing capacity.

"This return to operation is great news," declared Jean Dupuis, astronomer at the Canadian Space Agency. "With its high sensitivity and great powers of resolution, *FUSE* will keep providing Canadian and foreign astronomers with very interesting research opportunities."

FUSE now operates using onboard magnetometers for slewing, and uses its Canadian-built Fine Error Sensor cameras to measure drift rates after slews. Such functions were never intended for these components in the original design. In January 2006, *FUSE* operations were returned to efficiency levels seen early in the mission. Now the satellite will continue a broad range of science programs for hundreds of astronomers from around the world. To date, more than 350 publications based on *FUSE* observations have been published in the professional astronomy literature and many more are on the way. Canadian scientists have authored 74 of these publications.

FUSE is an orbiting telescope jointly run by NASA, the Canadian Space Agency, and the Centre national d'études spatiales, in Toulouse, France. Canada contributed the Fine Error Sensor camera system for tracking the telescope; it was built by COM DEV with technical advice and design work from the Herzberg Institute of Astrophysics in Victoria, B.C. *FUSE* partners also include Honeywell Technical Services Inc., the Johns Hopkins Applied Physics Laboratory, the University of Colorado at Boulder, the University of California, Berkeley, and the Orbital Sciences Corporation. France supplied the unique spectroscopic gratings.

Observations from the satellite have been used to discover an extended, tenuous halo of very hot gas surrounding our Milky Way galaxy; evidence of similar hot gas haloes around other galaxies has also been found. *FUSE* has detected molecular hydrogen in the atmosphere of the planet Mars for the first time. This has implications for the water history of our frozen neighbour. In addition, *FUSE* observations first detected molecular nitrogen in dense interstellar gas and dust clouds, but at levels well below those that astronomers had expected, requiring a return to the drawing board for theories of interstellar chemistry.

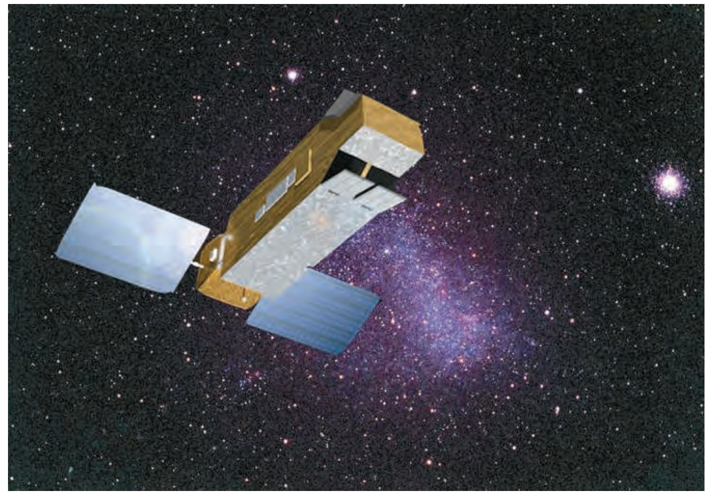

Figure 1 – The *FUSE* satellite is seen superimposed on an optical image of the Small Magellanic Cloud, a satellite galaxy of the Milky Way. At a distance of only 200,000 light years, the Small Magellanic Cloud is of intense interest to astronomers and well suited to *FUSE* observations. Over 100 individual stars in this galaxy have been observed to date. At far right is the globular cluster 47 Tuc, whose UV-bright stars have also been studied with *FUSE*. (Graphic courtesy NASA and Lauren Fowler, the JHU *FUSE* project.)

TAGISH LAKE METEORITE IN ROM COLLECTION

ROM, Toronto, Ont.: With the third-largest collection of meteorites in Canada, including over 500 specimens from 170 different meteorites, the Royal Ontario Museum (ROM) has now acquired a 200-gram fragment of the important Tagish Lake Meteorite. This meteorite is renowned as the only one in the world ever to be collected and preserved in pristine condition, frozen and uncontaminated. A 52-gram portion will be displayed in the ROM's upcoming Inco Limited Gallery of Minerals, Gems, and Jewels (opening in 2008).

The icy meteorite fell on the frozen surface of Tagish Lake, northern British Columbia, on January 18, 2000. Weighing about one kilogram, the specimen is rich in pre-solar grains and those from other stars that were present near our Solar System when it formed. It contains primitive molecules that are the building blocks necessary for life. The remarkable state of the meteorite makes it especially important for scientific study, presenting an unprecedented opportunity to look at extraterrestrial ices.

It may be one key in advancing our understanding of the formation of our Solar System.

In November 2005, the Minister of Canadian Heritage approved a Movable Cultural Property grant to assist the ROM and three partners in purchasing portions of the Tagish Lake Meteorite to ensure that all fragments could be retained in Canada for research purposes. Other recipients of portions of the meteorite are the University of Alberta (Figure 2), the Ministry of Canadian Heritage, Natural Resources Canada, and the Canadian Space Agency.

Meteorites are an invaluable and relatively inexpensive source of information about outer space, used by scientists to study the Universe. As most meteorites date from about 4.6 billion years ago, they provide clues about the nature and origin of our Solar System and the interior of planets. Acquisition of the Tagish Lake Meteorite gives Canadian scientists an opportunity to enhance their expertise in the handling and analysis of extraterrestrial material by working with international planetary scientists on this pristine material of unprecedented scientific value.

Further details on the ROM and what can be seen there can be found at www.rom.on.ca/index.php

Figure 2 — A 153-g piece of the Tagish Lake Meteorite now forming part of the University of Alberta's meteorite collection. Image credit: Michael Holly, University of Alberta. Further details at www.museums.ualberta.ca/dig/naturalhist/earth/meteorite/index.html

3-D MAP OF A MILLION GALAXIES

An international team of astronomers, lead by Dr. Chris Blake (Astronomy Department, University of British Columbia), has recently presented new results on the cosmos, based on the largest map of the heavens ever produced. (The findings are presented in "Cosmological parameters from a million photometric redshifts of SDSS Luminous Red Galaxies," a paper submitted to *Monthly Notices of the Royal Astronomical Society:* a preprint is available at http://xxx.arxiv.cornell.edu/abs/astro-ph/0605303).

This massive atlas emphatically confirmed recent findings that the Universe is full of dark energy, a mysterious substance that makes up three-quarters of our Universe, together with "dark matter," which accounts for most of the remaining quarter. Understanding this composition is now one of the most important problems facing the whole of science.

"We now have a precise view of what makes up our Universe, but little idea as to why," said Prof. Ofer Lahav, a member of the international team and the Head of the Astrophysics Group at University College London. "It is intriguing that the ordinary matter our bodies are made of and that we experience in everyday life only accounts for a few percent of the total cosmic budget."

Our Universe contains billions of galaxies of all shapes and sizes. In recent years, astronomers have used increasingly large surveys to map out the positions of these galaxies, gradually stepping their way out into the cosmos. The new map is the largest made to date and provides a 3-D atlas of over a million galaxies spread over a distance of more than five billion light years. The findings confirm that we live in a Universe filled with mysterious dark matter and dark energy.

"We have analyzed the patterns in this map and discovered waves of structure over a billion light years across," said Dr. Chris Blake of the University of British Columbia, principal author of the study. "These waves were generated billions of years ago and have been vastly stretched in size by the expanding Universe."

Construction of the cosmic atlas was led by co-author Dr. Adrian Collister of the University of Cambridge, as part of his Ph.D. work, using a novel artificial-intelligence technique he developed with his supervisor, Prof. Ofer Lahav.

"By using very accurate distances of just 10,000 galaxies to train the computer algorithm we have been able to estimate reasonably good distances for over a million galaxies," said Collister. "This novel technique is the way of the future."

The original 2-D positions of colours of the one million galaxies were from the Sloan Digital Sky Survey.

The precise observations of the 10,000 galaxy distances were made as part of an international collaboration between U.S., U.K., and Australian teams using data from the Sloan Digital Sky Survey and the Anglo-Australian Telescope.

By measuring the positions of galaxies, astronomers can unravel the balance of forces that govern our Universe: the force of gravity that pulls everything together and the competing effect of the expanding Universe that smoothes things out. These cosmic forces have arranged the galaxy distribution into a complex network of clusters, filaments, and voids.

"The galaxy map can tell us the amount of ordinary baryonic matter relative to the amount of mysterious dark matter," said co-author Dr. Sarah Bridle of University College London. "We have confirmed that over 80% of the material in the Universe consists of an invisible dark matter whose nature is not yet understood."

The cosmic atlas of a million galaxies will shortly be made freely available on the World Wide Web for the benefit of other researchers. This free exchange of data is an important feature of modern astronomy, since many discoveries are only possible when different observations are combined.

The key problem in mapping the cosmos is determining the distance to each galaxy. Researchers can measure these distances because, as the Universe expands, the colour of each galaxy changes as their emitted light waves are stretched or redshifted. Traditionally, astronomers have needed to take a spectrum of each galaxy to determine this distance, splitting its light into many components to reveal sharp features with which to measure the amount of redshifting. This requires a time-consuming, individual observation of each galaxy.

The new cosmic map has been constructed using a novel technique focusing on a special class of galaxy whose intrinsic colour is very well known. For these Luminous Red Galaxies researchers can measure the amount of colour distortion, and hence the approximate distance of the galaxy, just by looking at digital images of the sky, without the need to obtain a full spectrum.

All that is needed to exploit the technique is accurate observations of a small sample of the galaxies. In this case, precise measurements of just 10,000 galaxies were used to produce the atlas of over a million galaxies. These techniques will be very important for future large astronomical projects such as the Dark Energy Survey, scheduled to start in 2009, in which University College London and the universities of Portsmouth, Cambridge, and Edinburgh are key partners.

A large image map for the locations of the different classes of galaxies can be found at `www.star.ucl.ac.uk/~lahav/Galaxymap.JPG`

Correspondence
Correspondance

What is this object?

On the attached image of the stamp issued by the United States Post Office in 1973 to commemorate the 500th year of the birth of Nicholas Copernicus, there is an unusual object being held by Copernicus. What is and what is it called?

The portrait on this stamp is originally from a 1740's image that shows Copernicus holding a simplified "planetaria" of sorts, a symbol of his heliocentric universe. What is this object depicted in this image? Does an example of this object really exist or was it just a prop added by the artist to "symbolize" the new concept of the then known solar system? It is hoped that some of the readers may be able to assist in determining the above questions.

If you have any knowledge of the above, please contact Rick Stankiewicz at 10 Hazel Cresc, RR 8, Peterborough ON K9J 6X9 or stankiewiczr@nexicom.net

Your assistance would be greatly appreciated.

Rick Stankiewicz

WEB ACCESS TO THE 2006 ISSUES OF THE *JRASC*

The 2006 issues of the *Journal* can be accessed from the RASC Web site at `www.rasc.ca/currentjrasc` (userid="jrasc"; password="pelican"). Issues are posted immediately after the final production version is complete.

Meteor Trains -
Terminology and Physical Interpretation

by Jiří Borovička, Astronomical Institute of the Academy of Sciences, 251 65 Ondřejov, Czech Republic, email: borovic@asu.cas.cz

Abstract

This article presents a summary of various luminous phenomena that may follow after passage of a meteor. The terminology recommended by the International Astronomical Union in 1961 is used, which calls these phenomena trains. Nowadays, several types of trains can be clearly distinguished. The understanding of the underlying physical and chemical processes is, however, still not satisfactory and the nomenclature of different train phenomena has not yet been settled. In this paper I call them wake, green train, persistent train, and reflection train. Meteor wakes are formed by rarified non-equilibrium gas behind the meteoroid. The green train, produced by the radiation of the forbidden oxygen line at 557.7 nm, is created by reactions among atmospheric species. The persistent train is the most complex phenomenon with three phases of evolution. The afterglow phase is formed by cooling rarified gas. After that, atomic recombination phase follows. The third and most persistent continuum phase is probably fed by chemiluminescence. Finally, the reflection train occurs when sunlight is scattered by a dust cloud created by meteoroid disruption.

Résumé

Cet article présente un sommaire des différents phénomènes lumineux résultant du passage d'un météore. La terminologie recommandée par l'Union astronomique international en 1961, qui nomme ces phénomènes trainées, est employée ici. Actuellement plusieurs catégories de trainées se distinguent. Toutefois une compréhension des processus physiques et chimiques sous-jacents n'est toujours pas claire et la nomenclature des differents phénomènes de trainées n'a pas encore été établie. Dans cet article, je les nomme sillage, trainée verte, trainée persistante, et trainée réfléchissante. Les sillages météoriques sont formés par des gaz rarifiés non-équilibrés derrière le météore. La trainée verte, résultant de la radiation de la ligne interdite d'oxygène à 557.7 nm, est produite par les réactions parmi les molécules atmosphériques. La trainée persistante est la plus complexe affichant trois phases d'évolution. La phase de derniers reflects est produite par le refroidissement des gaz rarifiés. Après quoi suit la phase de la recombinaison atomique. La troisième et la plus persistante des phases est tout probablement le résultat de chimiluminescence. Enfin, la trainée réfléchissante se produit lorsque la lueur du soleil est éparpillée par le nuage de poussière provenant de la perturbation météorique.

1 Introduction

The radiation of a meteor is mainly produced by hot vapours and a heated atmosphere around the evaporating meteoroid. This radiation, which produces the familiar "shooting star," has a point-like or nearly circular form and disappears after the meteoroid evaporates. However, even observation by the naked eye can, in some cases, reveal different kinds of radiation following the meteoroid in space and time. These luminous phenomena can be found in literature under various names such as afterglow, wake, trail, or train. They may be separated by tens of metres up to many kilometres from the meteoroid and may last from a fraction of second up to more than an hour after the meteor disappearance.

The studies of these phenomena require the gathering of complex data on their temporal evolution, morphology, height in the atmosphere, and spectra. The amount of data has increased considerably in the recent years, mainly thanks to the observations of Leonid meteors. It is now clear that various physical and chemical processes are responsible for the formation of meteor-induced luminous objects but all the processes are still not well understood. This paper presents a summary of observational facts and their current interpretations.

2 Terminology

Many years ago, the International Astronomical Union (IAU) defined standard terms for meteoric astronomy in four languages — English, French, Russian, and German (Millman 1961). The purpose was to provide a fairly short list of very basic terms that would be clear to the nonspecialist and that would have a reasonable leeway in interpretation. The English list, which can be found on `www.amsmeteors.org/define.html`, contains three terms related to the topic of this paper. *Train* is defined as "anything (such as light or ionization) left along the trajectory of the meteor after the head of meteor has passed." The adjective *persistent* for use with *train* is defined as "indicating durations of some appreciable length." Finally, *wake* is defined as "train phenomena of very short duration, in general much less than a second." The frequently used term *trail* has been omitted from the list because there is only one Russian translation for the two English words *trail* and *train*.

In the following, I will use the IAU terminology. The fact that several types of trains exist will require the invention of more terms in the future. In the ideal case, detailed terminology should reflect the physical or chemical processes responsible for train formation. In the meantime, we have to use observational characteristics to distinguish individual types of trains.

3 Train types

In principle, the formation of a meteor train likely depends on the mass, velocity, and composition of the incoming meteoroid, on the properties of the atmosphere (which vary in diurnal cycle and according to the solar activity), and on the height of deposition of meteoric energy and mass. Under various conditions, several types of trains may or may not be formed. One meteor can produce more than one type of train.

3.1 Wakes

Morphologically, a meteor wake is a luminosity just behind the meteor head. It moves with the meteor and forms a kind of tail. The wake is often present in bright fireballs, which are then sometimes described as comet-like objects by witnesses. The length of the wake can exceed one kilometre. At a given position, the wake duration is usually less than 0.1 second.

The spectrum of the meteor wake is different from the spectrum of the meteor head. The wake spectrum consists chiefly from low excitation lines. The lines belong to Na I, Fe I, Mg I, Ca I, and other atoms released from the meteoroid. For a more detailed line list, see Halliday (1968). The presence of lines with low-transition probability, which are usually faint in meteor heads, is typical for wake radiation. The reason is that while the head is close to thermal equilibrium the wake is not. In the rarified conditions behind the meteoroid, collisions between atoms and electrons are infrequent and the collisions are unable to keep level populations in atoms in equilibrium.

The gas responsible for the wake radiation can come directly from the meteor head or may be produced by ablation of tiny dust particles released from the meteoroid. The wake is usually strongest at heights above 55 km, as was the case of the Benešov fireball (Borovička & Spurný 1996). In the denser atmosphere at lower heights, hydrodynamic conditions seem to be less favourable for the formation of this non-equilibrium wake. However, a wake of different kind may be formed after meteoroid fragmentation at lower heights. Macroscopic fragments behave as individual meteors that lag behind the main body. If individual fragments cannot be resolved, the whole formation resembles a wake. This kind of wake is sometimes called a particulate wake. Its spectrum is quite similar to the spectra of meteor heads.

The particulate wake can form wherever the meteoroid fragments. Fisher *et al.* (2000) searched for wake in faint sporadic meteors. Only a minority of the observed meteors showed a detectable wake.

3.2 Green trains

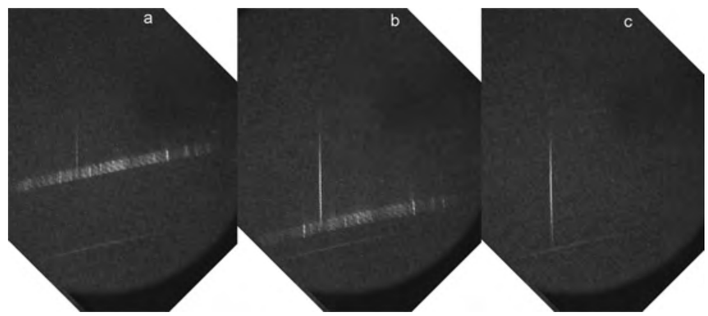

Figure 1 — Three frames from the video sequence of a Leonid meteor spectrum showing the formation of green oxygen train. The exposure time of each frame was 0.04 s. The frames are separated by 0.20 s. Frame a shows a relatively faint train. At frame b, the meteor moved down and the train intensified. At the time of frame c, the meteor has disappeared and the train is still glowing.

The short-duration train formed exclusively by the green oxygen line at 557.7 nm will be provisionally called green train in this paper. The presence of the green oxygen line in meteor spectra was discovered by Halliday (1958) and studied by Millman, Cook, & Hemenway (1971) using TV spectroscopy. No paper on this subject has been published in recent years. I will summarize the basic facts using my experience from Ondřejov TV spectroscopy.

The occurrence of green train is typical for high-velocity meteors of medium and low brightness. The train can be easily seen visually for one or two seconds after meteor disappearance when observing Leonids or Perseids (though the colour is hard to recognize). It occurs marginally in Geminids (36 km s^{-1}) but not in slower meteors. Figure 1 shows the evolution of the train in a Leonid meteor. At a given position, the green line appears with a short delay after the passage of the meteoroid and reaches maximum intensity after about 0.1 second. The intensity then starts to decay. Green trains are not visible for longer than about 3 seconds. The typical height where the green line is brightest and lasts longest is 105 km. This is often valid also when the meteor reaches maximum brightness at lower height. In very bright meteors, the green line can span a large height interval, *e.g.* from 80 km to 140 km. However, it decays quickly. Moreover, the green line intensity is not directly proportional to the meteor brightness and the green train is only a minor effect in bright fireballs. In faint meteors (+4 mag), the green line can be the strongest feature in the spectrum.

The fact that the green line intensity is not correlated with the meteor ablation rate supports the idea that the line is produced by atmospheric oxygen. The green line is a forbidden line; it is formed by a transition with very low transition probability. The upper level is a metastable level with radiative lifetime of 0.75 s. This can explain the train duration. The energy of the upper level is 4.2 eV. Baggaley (1976a) concluded that the most plausible excitation mechanism is charge transfer from O^+ to O_2^+ followed by dissociative recombination. The collisional deactivation of the metastable level at lower heights is responsible for the maximum line intensity at 105 km (Baggaley 1976b). The dependence of line brightness on meteor velocity was studied by Baggaley (1977a).

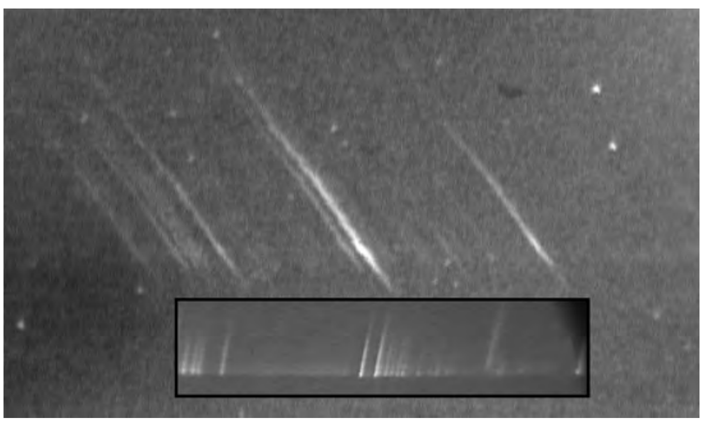

Figure 2 — The spectrum of a Leonid persistent train in the recombination phase, eight seconds after train formation. The three brightest lines, from the left to the right are Mg I (457 nm), Mg I (517 nm), and Na I (589 nm). The inset contains spectrum of another Leonid train in the afterglow phase, 0.05 s after meteor disappearance. The two dominant lines in the middle are Fe I (510 and 517 nm). The O I line at 558 nm is present and shifted up. The Na I line is at the edge of the field of view. From Borovička & Koten (2003).

3.3 Persistent trains

Self-luminous persistent trains, which can be visible for tens of minutes after meteor disappearance, have drawn the attention of observers since the 19th century (Trowbridge 1907). These are rare phenomena produced only by bright fireballs of high velocity. In the first approximation, brighter and faster meteors produce brighter and longer duration trains. Leonid meteors moving at 71 km s^{-1} are particularly favourable for producing persistent trains. A number of papers on Leonid trains have been published recently and whole catalogues have been compiled (Higa *et al.* 2005). Despite this effort, persistent trains are still far from being fully understood.

Persistent trains always form in the region of meteor maximum brightness, often at the position of a bright meteor flare. Their luminosity is therefore driven by the energy and material deposited in the atmosphere by the meteoroid. Persistent trains usually form somewhere between the heights of 75 and 100 km. Train properties and evolution may depend on the height but we will not go in such details in this paper. At the time of formation, the train may be very bright, exceeding magnitude -5 (*e.g.* Borovička & Jenniskenns 2000). The brightness then falls quickly within few seconds; this initial stage may be called the afterglow phase. Altogether, three distinct phases of train evolution have been identified (Borovička & Koten 2003).

3.3.1 Afterglow phase

The afterglow phase was studied in detail by Borovička & Jenniskens (2000). The afterglow spectrum has the same character as the spectra of meteor wakes. Atomic lines of low excitation dominate, including lines with low transition probability. The line decay rate was found to be proportional to the upper excitation potential. These facts were interpreted in terms of cooling of low density non-equilibrium gas. The excitation temperature dropped from 4500 K to 1200 K in two seconds. Other trains produced by fainter meteors and analyzed by other methods exhibited faster cooling (Jenniskens & Stenbaek-Nielsen 2004; Abe e*t al.* 2005). The cooling of the train analyzed by Borovička & Jenniskens (2000) was slower not only because of larger mass of the meteoroid but also because of secondary ablation of the dust in the train. Some parts of the train were still moving with a velocity of 2 km s^{-1} when the train formed.

3.3.2 Recombination phase

After the initial fading, the brightness of some lines stabilizes and a few even gain brightness. The train evolves into a second phase. This phase usually lasts several tens of seconds and is also characterized by atomic line emission. Although the spectrum is similar to the spectrum in the afterglow phase, the significant difference is that lines of higher excitation (up to 7 eV) are also present. The main difference in the visible region, as shown in Fig. 2, is the presence of Mg I line at 517 nm. In the afterglow, there are two lines of Fe I of the same brightness at 510 and 517 nm. By chance, the second line almost coincides with the Mg I line. However, the brightness ratio of the Fe I lines cannot change, so if the 517 nm line is much brighter it must be due to Mg I. There are, nevertheless, many more high excitation lines across the spectrum from the ultraviolet to infrared (Suzuki 2003, Borovička & Koten 2003, Abe *et al.* 2005), most notably Mg I at 383 nm. The two brightest lines in train spectra, Mg I

517 nm and Na I 589 nm, were identified by visual spectroscopy 130 years ago (von Konkoly 1874). The identification of forbidden nebular lines by Borovička *et al*. (1996) was incorrect.

The spectra of ~10-s-old trains also contain the band of molecular oxygen O_2 near 865 nm (Suzuki 2003, Abe *et al*. 2005). The oxygen molecule is excited by thermal processes. From the shape of the band, Abe *et al*. (2005) inferred a rotational temperature of 250 K. This temperature is insufficient to excite atomic lines. Borovička & Koten (2003) have shown that the observed line spectrum can be explained by recombination processes. Positive ions (*e.g.* Mg^+) gain electrons to excited levels and lines of neutral atoms are then produced during the downward cascade of the electrons. Recombination is more efficient at lower temperatures, so the intensity of the recombination lines such as Mg I 517 nm increases after the train has cooled (Spurný, Borovička, & Koten 2005). There are indications that the recombination does not proceed with free electrons but rather with negative ions as predicted theoretically by Baggaley (1977b).

The afterglow phase and recombination phase may not occur in all trains. Spurný, Borovička, & Koten (2005) observed two relatively faint and short trains (several seconds duration), one of them showed only the afterglow phase and the other only the recombination phase.

3.3.3 Continuum phase

When the recombination lines have faded, a minimum in train brightness occurs followed by a subsequent brightening. This brightening can be stronger in some parts of the train than in the others. Variations in the direction and strength of the atmospheric winds with the height cause train deformation (Drummond *et al.* 2001, Jenniskens & Rairden 2000). Persistent trains therefore often gain curious shapes after several minutes. Morphologically, two types of trains were distinguished (Drummond *et al.* 2002). A Type I train is wide, cloudy in appearance, bright, and has high diffusion rate. The fainter Type II train is narrow and has much lower diffusion rate. In fact, Type II trains were not observed separately: they form in sections of trains that are otherwise Type I. Both types appear often double under high resolution, *i.e.* they look like a pair of parallel trains. This appearance was previously explained by hollow tube nature of the trains (Trowbridge 1907) but this explanation has proved to be inadequate (Kruschwitz *et al.* 2001). Other explanations proposed recently include meteoroid fragmentation (Jenniskens 2003), train separation into gaseous phase and dust (Kelley *et al.* 2003), as well as buoyant rise and split into a pair of parallel line vortices (Zinn & Drummond 2005).

Not only the train morphology but also the fundamental question of train luminosity is incompletely understood. Low-resolution train spectra show a broad continuous emission with a maximum near 590 nm and possibly another maximum in the near infrared (Borovička & Koten 2003). Although a minor contribution of the Na I line (593 nm) is not excluded, most luminosity must be produced by molecules. The emitting molecules have not been identified with certainty. Jenniskens *et al.* (2000) claimed the identification of FeO, but FeO is not able to explain the whole spectrum. Other possible contributors are OH (Clemesha *et al.* 2001), NO_2, or CaO (Borovička & Koten 2003). These observations generally apply to Type I trains. Fainter Type II parts of trains may be produced by other sources. Note that train temperatures were directly measured by a Na lidar resulting in temperatures up to 270 K, which was 60 K above the ambient atmosphere (Chu *et al.* 2000). Mid-infrared spectroscopy of persistent trains showed the emissions of heated CH_4, CO, CO_2, and H_2O; species that pre-existed in the atmosphere (Russell *et al.* 2000).

There is a general agreement that the optical train luminosity in the continuum phase is driven by exothermic chemical reactions. The emission of FeO and other metal oxides is possible after reactions involving ozone (Baggaley 1976c) or FeS (Murad 2001). NO_2 emission is enabled by the reaction of O with NO, either in clusters (Rajchl 1975) or on the surface of dust (Murad 2001). OH radiation can be produced after reaction of hydrogen with ozone (*e.g.* Zinn *et al.* 1999). Various authors also discussed reactions leading to the radiation of Na and O_2. Recent observations have, nevertheless, shown that these species are not major contributors to the train luminosity in the continuum phase (Borovička & Koten 2003, Clemesha *et al.* 2001).

In summary, though chemiluminescence is likely responsible for train persistence, exact reactions and sources of radiation have not yet been identified.

3.4 Reflection train

Trains somewhat similar in appearance to persistent trains can be formed by the explosion of bright bolides in the atmosphere during the daytime or during twilight. The significant difference is that these trains are not self-luminous. They are visible thanks to the reflection or scattering of sunlight on the dust particles left in the train after the meteoroid disruption. Typical examples are the dust clouds formed during the Tagish Lake (Brown *et al.* 2000, see the title page of the issue) and Villalbeto de la Peña (Trigo-Rodríguez *et al.* 2006) meteorite falls. Under favourable circumstances, reflection trains can be visible for hours. They may be formed at any height, depending on the dust deposition by the fireball. Of course, more dust is produced by massive objects and they often explode at a height around 30 km. The observation of the Benešov fireball (Borovička & Spurný 1996) showed that the cloud formed after fireball explosion at the height of 24 km was self-luminous at the very beginning stage. The cloud spectrum showed bright continuum superimposed with bands of metal oxides (FeO, CaO, AlO, and MgO). The continuum may be done by dust thermal radiation and the oxide bands are possibly produced by the ozone reaction described by Baggaley (1976c).

Acknowledgements
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Determining the Orbit Height of a Low-Earth-Orbiting Artificial Satellite Observed near the Local Zenith

by Michael A. Earl, Ottawa Centre (mikeearl@castor2.ca)

Introduction

Do you ever wonder how far away satellites are when you spot them passing through your early evening (or early morning) sky? Intuitively, the slower-moving ones must be further away than the faster-moving ones. In fact, you can go beyond intuition to determine the orbit height of a low-Earth-orbiting (LEO) artificial satellite by using the satellite's apparent motion when it passes through or near your local zenith.

The method described below takes advantage of the fact that the satellite's true velocity can be determined when it is nearly overhead.

Preliminary

When you stand near (but not too near) a highway and look at cars approaching, passing, and receding, you must have noticed that a far-away car (approaching or receding) does not appear to move very fast. Instead the car appears to move most rapidly when it is just passing you.

What you are experiencing is a simple example of vectors. The far-away car has a velocity vector that is directed mostly toward (or away from) you, so you cannot see a lot of perpendicular motion. When a car is at its closest and just passing you, its velocity vector is exactly perpendicular to your line of sight and what you see is the true velocity of the car and its fastest apparent motion (Figure 1).

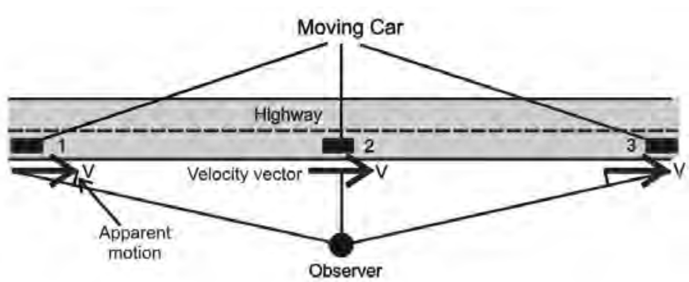

Figure 1 — Apparent motion of an automobile as seen by an observer at the side of the highway. When the car is far from the observer, its velocity v is mainly pointed along the observer's line of sight, and it therefore appears to move more slowly. When the car is closest to the observer, its velocity is perpendicular to the observer's line of sight, and it therefore is seen to move at its fastest rate.

Now let us extend our point of view into space, and imagine a set of satellites in increasingly distant orbits, as shown in Figure 2. Obviously the farthest satellites will appear to move slowest across the sky but we now have a more complicated situation than our simple highway example. In this case, the

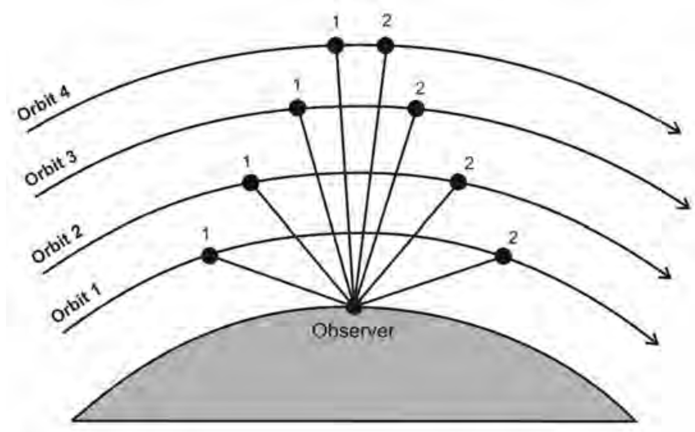

Figure 2 — Four satellites in four different orbits seen by an observer at the zenith. The observed angular velocities will depend on both the satellites' distances from the observer and the satellites' linear velocities, as stated in Equation 1.

satellites are also moving at different orbit speeds.

The only parameter that we are able to directly measure from our Earth-bound location is the apparent angular velocity of the satellite. Apparent angular velocity is the apparent angle traveled in a specific amount of time and is typically expressed in degrees per second or radians per second. A radian is simply another way of measuring angles. There are 2π radians (π ≈ 3.14156) in a circle of 360° so that one radian is about 57.3°. Equation 1 shows a well-known relationship between linear and angular velocity:

$$\omega = \frac{v}{r} \qquad \text{Eq. 1}$$

where ω = the apparent angular velocity (in radians/second);
v = the linear velocity; and
r = the distance from the observer to the moving object.

As the distance (r) increases, the apparent angular velocity (ω) decreases, for the same linear velocity (v).

Theory

A watcher at point P on the Earth observes a satellite S passing near his or her zenith, as illustrated in Figure 3. The observer notes the apparent position of the satellite in the sky at two specific times. By measuring the angle (θ_p) traced out by the satellite in an elapsed time (Δt), the apparent angular velocity (ω_p) can be determined using Equation 2.

$$\omega_p = \frac{\theta_p}{\Delta t} \qquad \text{Eq. 2}$$

where ω_p = the angular velocity of the satellite as seen from point P;
θ_p = the angle the satellite is observed to travel as seen from point P; and
Δt = the elapsed time the satellite is seen to travel the angle θ_p.

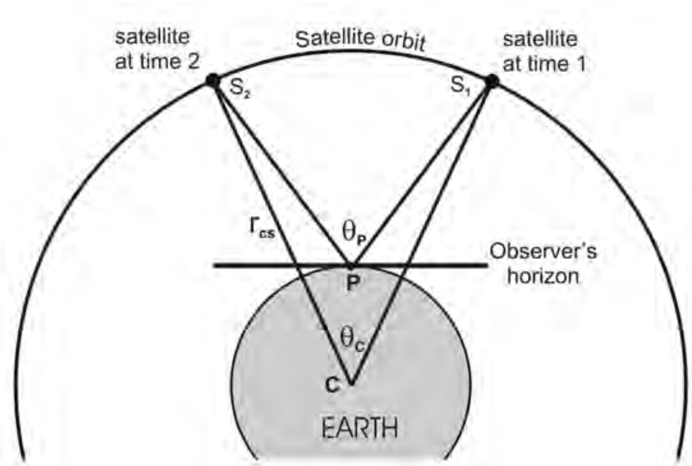

Figure 3 — An observer at point P sees a satellite S passing near his/her local zenith. He/she measures the apparent angle the satellite travels between S1 and S2, and divides it by the elapsed time to determine the apparent angular velocity.

Using ω_p for the angular velocity in Equation 1 and rearranging its terms, we get:

$$v = \omega_p h \qquad \text{Eq. 3}$$

where h = the height of the satellite above the Earth's surface (Figure 4).

The height of the satellite (h) is the variable that needs to be solved, but we require a value for v before the solution can be found.

An orbiting satellite feels a gravitational force attracting it to the centre of the Earth. Since that force is also centripetal we can equate these two forces as demonstrated in Equation 4 in which the left side represents the centripetal force, and the right, Newton's Law of Gravitation. This relationship is true for all perfectly circular orbits:

$$\frac{mv^2}{r_{cs}} = \frac{GMm}{r_{cs}^{\;2}} \qquad \text{Eq. 4}$$

where m = the satellite's mass;
G = the Gravitational Constant;
M = the Earth's mass; and
r_{cs} = the distance from the centre of the Earth to the satellite.

Simplifying Equation 4 leads to Equation 5.

$$v^2 = \frac{GM}{r_{cs}} \qquad \text{Eq. 5}$$

Substituting for v (from Equation 3) in Equation 5 gives us Equation 6:

$$\omega_p^{\,2} h^2 = \frac{GM}{r_{cs}} \qquad \text{Eq. 6}$$

The distance r_{cs} is not known. Since the satellite is near the observer's zenith, however, we can take advantage of the fact that a line drawn from the centre of the Earth (c) to the satellite (S) is co-located with the line drawn from the observer (P) to the satellite as shown in Figure 4. From these circumstances, we can write the simple relationship:

$$r_{cs} = r_{cp} + h \qquad \text{Eq. 7}$$

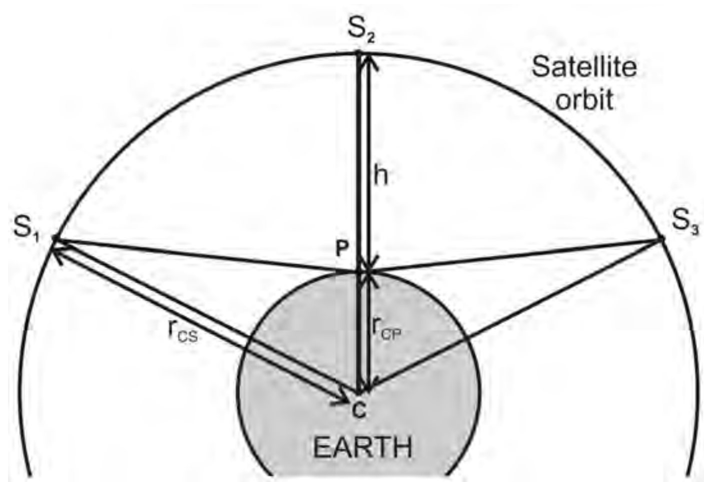

Figure 4 — When observed at zenith, a satellite's distance from an observer P and its height above the Earth's surface are identical. At zenith, the distance of the satellite from the Earth's centre C is the addition of the orbit height and the Earth's radius at the point P.

where r_{cp} = the distance from the centre of the Earth to the observer.

Now we can substitute for r_{cs} in Equation 6 to obtain Equation 8:

$$\omega_p^{\,2} h^2 = \frac{GM}{(r_{cp} + h)} \qquad \text{Eq. 8}$$

So that:

$$\omega_p^{\,2} h^2 r_{cp} + \omega_p^{\,2} h^3 - GM = 0 \qquad \text{Eq. 9}$$

Finally,

$$h^3 + r_{cp} h^2 - \frac{GM}{\omega_p^{\,2}} = 0 \qquad \text{Eq. 10}$$

Equation 10 is a cubic equation (of the form $Ax^3 + Bx^2 + Cx + D = 0$) and as a consequence there will be three unique solutions for the satellite orbit height (h). Two of the three solutions will be gibberish (which is slang for "not physically possible") and therefore can be ignored. The remaining solution will be the correct and physically realistic one.

Solving a cubic equation from scratch is not fun. If you thought the Quadratic Formula (that messy equation you learned, or at least tried to learn, in high school) was bad, the Cubic Formula is even worse. Fortunately, the Internet has cubic-equation solvers that automatically determine the solutions for you. See the References section to see the one that I used for this article. In this example, the four coefficients for Equation 10 are:

A = 1;
B = r_{cp};
C = 0; and
D = $-GM / \omega_p^2$

When plugging in these values, make sure that the units are correct. For r_{cp}, I used kilometres, for G, $km^3/kg.s^2$, and for M, kilograms, so that I got kilometres for the answer's units. Don't forget the negative sign for the D coefficient either, or all three solutions will be gibberish!

A Practical Example

This would be the end of the article, except we need to test out theories using actual data before they can be taken as correct. On the evening of February 11, 2006 I set up my CCD camera in Ottawa, fitted with a 50-mm lens to point directly at my local zenith.

From 7 p.m. to 9 p.m. E.S.T., the camera continuously captured five-second exposures of my local zenith (yes, the sky was clear). About 1500 images were collected in total. I sifted through these images, 20 at a time, using blink-comparator software to check for satellite streaks, finding 12 usable satellite streaks of differing lengths, and therefore differing heights. One of the 12 images is shown in Figure 5.

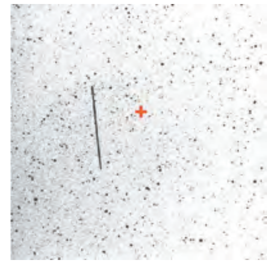

Figure 5 — An image of a Russian SL-3 rocket body (#13771) captured by my ST-9XE's CCD camera while pointed at my local zenith at 23:48:45 UTC on February 11, 2006. The location of my local zenith at that time is denoted by the large red cross. The image field of view is about 11.2 × 11.2 degrees. North is at top, east is at left. The exposure time was five seconds.

Example: SL-3 Rocket Body (#13771)

I used Figure 5 to determine the scale for all images obtained. I selected 15 stars scattered throughout the image and plotted actual angular separation (in arc-minutes) between the stars vs. the separation in pixels on the image for all combinations of two stars. I used a polynomial curve-fitting technique to find the most accurate equation from the resultant graph. To make a long story short, the resultant image-scale equation was determined to be:

$$\theta_p = (-3\times10^{-8})\lambda^3 + (3\times10^{-5})\lambda^2 + 1.3154\lambda + 0.2783 \qquad \text{Eq. 11}$$

where θ_p = the angular separation between two stars (in arc-minutes); and
λ= the pixel separation between the same two stars (in pixels).

The example's streak length was measured to be about 165 pixels. Using Equation 11, this streak length corresponded to an angle of 3.63 degrees, or 0.0634 radians. The exposure time was five seconds, which made the measured apparent angular velocity (ω_p) of the satellite 0.01267 radians per second.

For the same image in Figure 5, the coefficients of Equation 10 were determined to be:

A = 1;
B = 6367.313 km;
C = 0; and
D = -2.481602×10^9 km^3.

The value of r_{cp} (the B coefficient) was taken from my *JRASC* article (Earl 2005) concerning the determination of the range of a satellite using a trigonometric parallax technique. This value can also be calculated from the Web, where equations for the radius of the Earth as a function of latitude can be found. The D coefficient was found by determining the value for ω_p from the measured streak length and exposure time, as described in Equation 2 and Equation 11, and using a Gravitational Constant (G) of 6.6742x10^{-20} $km^3/kg.s^2$ and an Earth mass of 5.9742x10^{24} kg.

For this example, the three solutions to Equation 10 using the coefficients above were:

1) 597 km;
2) -6305 km; and
3) -659 km.

Solutions 2 and 3 are physically impossible, since they imply that the satellite orbited beneath the Earth's surface. Solution 1 indicates that the satellite orbits above the Earth's surface at a height of about 597 km, which is definitely possible for a LEO satellite.

Additional Measurements

Using this method on all the satellites I captured on that night, I tabulated the results (Table 1) in order of ascending orbit height to study the error behaviour with respect to decreasing streak length (increasing orbit height).

Conclusions

The technique I have outlined is indeed capable of determining the orbit altitude of the low-Earth-orbiting satellites. Nevertheless, there are several error characteristics that suggest a more in-depth investigation would prove fruitful. Examination of Table 1 shows the shorter streak lengths are correlated with larger errors in the calculated satellite altitude. The source of this behaviour may be partly due to the derivation of the image scale. Angular separations of 50 pixels and larger were used to solve the image scale and so Equation 11 might be biased against smaller angular separations and therefore smaller streak lengths. Re-determining the image-scale equation using smaller angular separations between calibration stars, using a larger number of stars, using a CCD with a higher resolution, and/or increasing the exposure time for the lower apparent-angular-velocity satellites might improve the results.

No satellite that orbits the Earth has a perfectly circular orbit, but LEO satellites have smaller orbit eccentricities than their high-altitude counterparts. In summary, higher orbit altitudes means a larger range of possible orbital eccentricities. The small five-second exposure time I used ensured that the height of the satellites would not change appreciably during the exposure time. While the height might be determined relatively accurately, the assumption of a circular orbit could result in a larger error in the determination of the orbit period.

The zenith angle of the satellite might also impose a noticeable effect. Those satellites that appear at the far edges of the image might have a noticeably larger height error than those nearer the centre (zenith). In the 11.2 × 11.2 degree field

ID	STREAK LENGTH (pixels)	STREAK LENGTH (radians)	D COEFFICIENT ($GM / \omega p^2$)	HEIGHT (km)	TRUE HEIGHT (km)	PERIOD (min)	TRUE PERIOD (min)
12465	177.912900	0.013677	-2.130869E+09	555	547	95.57	95.76
25527	169.434353	0.013024	-2.349776E+09	582	583	96.01	96.20
13771	164.878743	0.012673	-2.481590E+09	597	585	96.39	95.95
27840	123.328829	0.009477	-4.437512E+09	788	788	100.34	100.11
24968	120.503112	0.009260	-4.648144E+09	805	784	100.76	100.40
11111	113.216607	0.008700	-5.265847E+09	854	796	101.78	100.45
27433	105.304321	0.008092	-6.086907E+09	914	871	103.09	102.11
06154	94.810337	0.007286	-7.508461E+09	1009	953	105.07	104.53
25963	60.415230	0.004646	-1.846902E+10	1529	1418	116.40	114.08
25162	58.830264	0.004524	-1.947516E+10	1567	1471	117.21	115.23
09063	56.859948	0.004373	-2.084474E+10	1616	1499	118.30	115.17
25746	25.553865	0.001973	-1.024068E+11	3261	3013	156.71	148.48

Table 1: The calculated orbit heights of 12 LEO satellites imaged in Ottawa, Ontario on February 11, 2006, using an exposure time of 5 seconds. Satellites were identified and orbit heights extracted using the satellite orbit propagator from Software Bisque's *TheSky (level IV, version 5);* the true period was obtained by taking the reciprocal of the mean-motion value of the satellites' orbit elements.

of view of the images, satellites can be detected as far as six degrees from the zenith at the image corners.

Although increasing the exposure time to larger than five seconds might help to reduce the height-determination error, it might cause imaging difficulties. In order to determine the angular velocity of the satellite, both endpoints of the streak have to be present. If the exposure time is greater than five seconds, many of the lowest orbit satellites would be able to pass outside the FOV during the exposure time, thereby causing a streak with only one (or no) endpoints. Background noise increases with larger exposure times, such that the signal-to-noise ratio of the satellite streaks would be reduced, since the satellites are moving across the image with the same signal, while the background noise accumulates on every pixel of the image.

When all is said and done, this method is very accurate for the lower-orbiting LEO satellites (200-km to 800-km orbit heights), and this accuracy can be increased for the higher-orbiting LEO satellites (800-km to 4000-km orbit heights) when required, as long as the potential pitfalls are appreciated beforehand.

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Space Track: The Source for Space Surveillance Data `www.space-track.org/perl/login.pl` (Authorized Account Required)

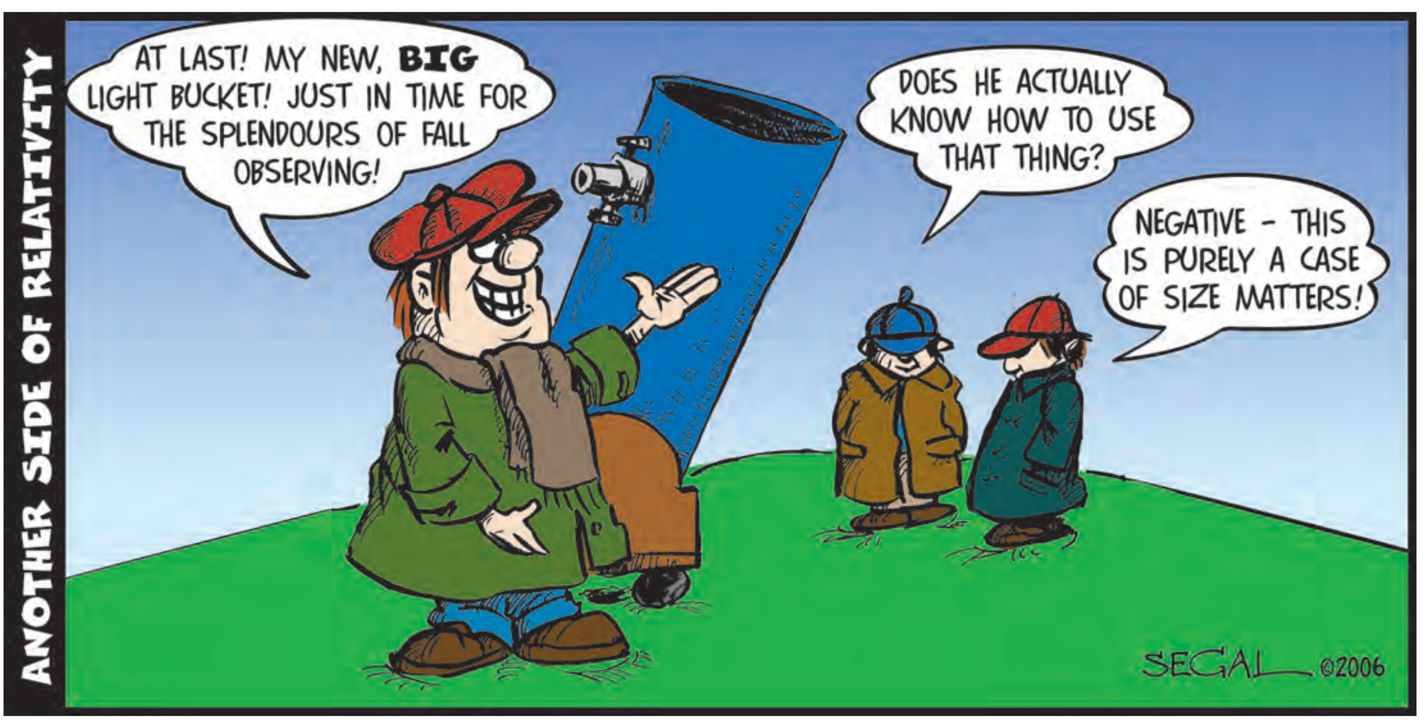
SOFTWARE

"SatSort" Version 2: Satellite TLE Sorting Software: Mike Earl

"TheSky" Level IV, Version 5: Astronomy Software: Software Bisque (`www.bisque.com`)

"CCDSof" Version 5: CCD Camera Control and Image Analysis Software: Software Bisque (`www.bisque.com`)

Michael A. Earl has been an avid amateur astronomer for over 30 years, and served the Ottawa RASC Centre as both its Meeting Chair and its Vice President. He is the "Artificial Satellites" Coordinator and the Webmaster for the Ottawa Centre's Web site (`http://ottawa.rasc.ca`). *He constructed the Canadian Automated Small Telescope for Orbital Research* (CASTOR): *the very first remotely controlled and automated optical satellite tracking facility in Canada. He is currently working on a second-generation* CASTOR *system geared toward the advanced amateur and professional astronomy communities. You are welcome to visit his new* CASTOR *optical satellite tracking Web site at* `www.castor2.ca`.



Astronomy and Astrology

by Roy Swanson, Mississauga Centre (swanee@direct.com)

1. Introduction

Over the last several centuries, there has been a lot of confusion about the relation between astronomy and astrology. In this article, I will describe some observations concerning this interesting juxtaposition of human knowledge and creativity.

Any article that has the temerity to discuss astronomy with astrology is going to encounter a lot of reader preconceptions, so I will go very carefully. These preconceptions arise because most people have strong feelings toward this meeting of worlds. Let me start by affirming that I have positive views for both sides.

I might begin with a legal case I ran into when I was a law student. In the British casebooks there was, some sixty years ago, a case where a young lady was suing a gentleman for seduction using dishonest means. Apparently, in Brighton, a young man was dating a young lady who incautiously mentioned that she firmly believed in astrology. He held back the fact that he wrote the local newspaper's astrology column. As one might expect, he inserted the admonition to "throw caution to the winds" at just the right time, with predictable consequences.

My point with this vignette is to underscore the most important aspect of astrology, that it is akin to religion for some people, and one does not pontificate in this area lightly without incurring the wrath of many readers.

To balance things, let me mention another vignette. I was walking along an ocean beach once with a person who was very skeptical of astrology, and he emphasized the impossibility, to his mind, of action at a distance. He seemed to be rather knowledgeable about tides, so I got him to agree about the influence of the Moon on the Earth's surface water. Then I mentioned the unusually high and low tides, and he had to agree that the Sun's position could be considered the cause of these extra large swings in the magnitude of the tides. I then ventured the opinion that perhaps humans, who are to a large proportion made of water, might somehow be affected as well. He said that a car driving near you has much more gravitational effect than distant bodies. I pointed out that more than gravity is implied by the believers in astrology — think of "the music of the spheres." We will return to another effect of the Sun, Moon, and planets shortly.

2. Precession and Ophiuchus

One of the strong tenets of astrology is that the exact positions of heavenly bodies of the Solar System with respect to the celestial background significantly influence your destiny and portentous inferences are made on that basis. Thus if you state in a horoscope that the position of a heavenly body at a given significant time, such as at birth, provides an indication of what lies ahead in your destiny, the mere divulgence of the position lends an authenticity to what is then surmised. In *The Mikado,* Poo-Bah calls this strategy the addition of "...corroborative detail, intended to give...verisimilitude to an otherwise...unconvincing narrative." (Gilbert & Sullivan 1885)

As an amateur astronomer, I find that there are two main points about these two disciplines that require discussion: the precession of the Earth's axis of rotation, and the existence of a thirteenth constellation in the zodiac.

2.1 Precession

First I want to begin with the Earth's dynamics in the Solar System. It is very much like a spinning top, with extra mass at the equator. The spin axis is tilted 23.5 degrees to the plane of the ecliptic. Now a spinning top will gyrate, or "precess," unless it is perfectly homogeneous and not affected by nearby objects. Since the Earth has an equatorial bulge, and has large gravitationally interacting bodies like the Moon and Sun relatively nearby, its axis wanders around in a circle. If there were a pencil sticking out of the top, it would point to different positions at different times, moving smoothly around, and repeating the cycle after a lot of spins.

The Earth precesses in a 25,800-year cycle. The northern extension of its axis is presently pointing very near Polaris, but the axis is always moving, and one day in the future, it will no longer be pointing near Polaris. The *Starry Night Pro* software package has a very interesting subroutine that shows the wandering of the celestial pole over this 25,800-year period. The Right Ascension (RA) of all the stars shifts due to precession, but the plane of the ecliptic does not change. Without applying a correction, key times in the seasons on Earth would change. Two thousand years ago, the spring equinox occurred when the celestial equator intersected the zodiac in the constellation Aries (first point of Aries). Our calendar is very deliberately altered with leap years, and earlier, even more drastic measures, to make sure that the spring equinox stays relatively put. At the present time, this important first seasonal point occurs with the celestial equator intersecting the zodiac near the Circlet in Pisces.

This process means that the positions of the Sun and planets as observed from the Earth are not time-invariant, as astrology assumes, but are really (slowly but continuously) timedependent. We call the current time interval an "epoch" in this long cycle of precession. An epoch is many hundreds of years in duration. It is actually very difficult to define an epoch, since it must refer, in the end, to time between inadmissible variances from a reference position, in a smoothly changing phenomenon. It is similar to replacing a smooth curve with a bar chart.

I suspect that astrologers came adrift with the problem of a suitable epoch before they finally gave up trying to relate properly to astronomy. They want timeless immutable positions for the solar bodies.

If we consider the zodiac as composed of twelve equal-sized constellations (as astrologers still do), then the vernal (March) equinox moves through the constellations at a rate of one every 2150 years. This shift amounts to about one hour of RA every millennium.

The problem is that in stating the positions of these heavenly bodies, most astrologers are at least one epoch back! As a result, the positions they use are nearly always very wrong. One can imagine a crusty farmer in the Middle Ages (in the northern hemisphere) saying to an astrologer, "you can believe what you want, but I am not planting crops until one week after spring equinox."

2.2 Ophiuchus

The zodiac refers to those constellations that lie along the plane of the ecliptic (*i.e.* the plane of the Solar System). The Sun appears to move smoothly to the east through the zodiac constellations as the year goes by. The modern boundaries of the constellations were set down in 1919. Since at least that time, it has been agreed that the constellation of the Snake Bearer, Ophiuchus, has part of his domain in the plane of the zodiac, taking away regions considered by the astrologers as part of the Scorpion (Figure 1). Stars very close to the ecliptic in this area, such as Theta Ophiuchi, have been considered part of Ophiuchus for many centuries, since Ptolemy at least. The problem is therefore that there are thirteen constellations in the zodiac, not twelve.

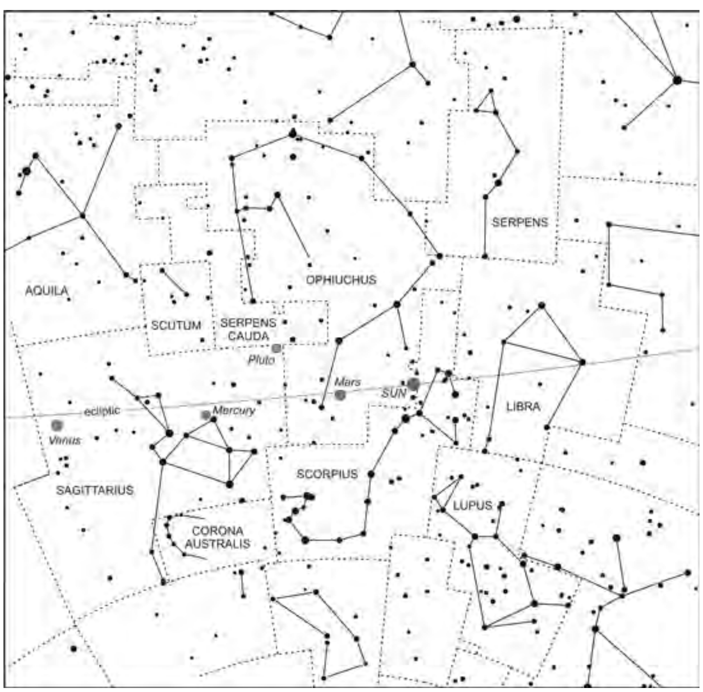


Figure 1— The sky for January 1, 2007, with the Sun and Mars in Ophiuchus. The other nearby planets have all recently passed through Ophiuchus.

An unlucky number indeed.

There is a great deal of beauty in the number twelve. It applies to a lot of things; a dozen, or the formal number of persons in a jury deciding your fate, for instance. It can be divided by 1, 2, 3, 4, 6, and 12, and it divides a circle of 360 degrees neatly by 30.

The problem is what to do about Ophiuchus? Astrologers simply ignore its existence, now and in the past. It does, however, emphasize the arbitrary nature of constellation boundaries, now and in the past.

3. The Sun in the Thirteen Constellations of the Zodiac

Pick up any newspaper article on horoscopes and the twelve constellations are, for all time, the "houses" as shown in the right hand side of Table 1.

The boundary days or "cusps" differ slightly in different listings of this table. Astronomically speaking, however, the correct positions of the Sun are as noted in the left-hand columns of the table. You may wish to check your own "sign" to see where you would fit in the modern scheme of things. A "Cancer," born on June 30, would actually find that the Sun was in Gemini on that date. Your chance of similarly being off by one sign is nearly 90 percent and growing.

The problem and the irony lie in the need in astrology to know the exact position of the Sun relative to a constellation at key times, such as at a person's birth. Since it is both fruitless (and dangerous) to look at where the Sun is with the naked eye or unprotected optics, the public accepts the word of the astrologers when they state where the Sun is located with respect to these background zodiac constellations (often referred to as "houses"). They also take the word of the astrologer for the positions of all the other major bodies of the Solar System, which suffer from a similar deficiency in reality.

However, with the recent advent of astronomical software such as *Starry Night Pro,* it is very easy to check the Sun's location, simply by removing the glare in the computer simulation. I have also found the programs helpful in planning what to look at, and where, before an evening of stargazing. I have been in email contact with the two local astrologers who write columns for the *Toronto Star* and the *Globe and Mail* newspapers. Aside from sniffing that I must be an Ophiuchan (which I am), they have never denied my numerous assertions as to where the (Solar System) heavenly bodies really are, compared to where they say they are.

It is instructive to take a program like *Starry Night Pro* and step the time back to noon on the same day one century

Table 1. The Sun in the Zodiac according to Astronomy and Astrology

Astronomical Position of the Sun		Astrological Position of the Sun	
Aries	April 18 - May 13	Aries	March 21 - April 20
Taurus	May 13 - June 21	Taurus	April 21 - May 20
Gemini	June 21 - July 20	Gemini	May 21 - June 21
Cancer	July 20 - August 10	Cancer	June 22 - July 22
Leo	August 10 - September 16	Leo	July 23 - August 22
Virgo	September 16 - October 30	Virgo	August 23 - September 22
Libra	October 30 - November 23	Libra	September 23 - October 23
Scorpius	November 23 - November 29	Scorpius	October 24 - November 22
Ophiuchus	November 29 - December 17		
Sagittarius	December 17 - January 20	Sagittarius	November 23 - December 17
Capricornus	January 20 - February 16	Capricornus	December 22 - January 20
Aquarius	February 16 - March 11	Aquarius	January 21 - February 19
Pisces	March 11 - April 18	Pisces	February 20 - March 20

earlier, then two centuries, and so on. Examples of this exercise are given in Appendix A. One then finds that the astrologers are often correct if the person was born, say, at that time about 2000 years ago. Yet, ironically, great significance is placed on these "exact" positions. Further, the temperament of the person of a given sign of the zodiac is also affected by the entry of a planet into that house. Many books and Internet sites describe the personalities assigned to these bodies. These are also badly out of position.

4. Final Remarks

Time is running out for astrology for two reasons:

1) the continuing effect of precession means that the gap between the fixed astrological table and the current astrometrical tables will continue to widen even more glaringly over the years. As Appendix A shows, the tables of antiquity became inaccurate shortly after the birth of Christ.
2) more and more members of the public are becoming computer literate, and excellent planetarium programs are becoming very popular.

Let me explain what I am getting at here. There are two aspects to the belief in astrology in my opinion. The first is the world of fantasy about heavenly bodies imbued with all sorts of human traits. To me this is an indulgence between consenting adults, and will be with us for a long time. You get nowhere using rhetoric to discredit that. The second is the stating of the position of these heavenly bodies. I think that astrologers should be liable for legal action — civil lawsuits — when they misrepresent the solar and planetary positions and take money for their statements. Sooner or later, a brave astrologer will break from the fold, and be the first of a new wave of 21st-century astrologers to make two major steps:

1) align all positions of the Solar System bodies with the actual positions as indicated by astronomy for the present epoch, and allow for future shifts, and
2) admit Ophiuchus into the houses of the zodiac.

These steps would not affect what is already written for the heavenly bodies in themselves. Unfortunately, in astrology, there is a tremendous amount of vested interest in preserving the past. If people who spend money on horoscopes wake up and sue the astrologers, there will be a very exciting time. I am nevertheless hopeful. I think it is fun to get up in the morning and read a heartening set of words to use for that day, regardless of their veracity. After all, having a doctorate in stochastic (random) processes, I know that every once in a while the comments will be "right on."

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Appendix A

The following examples underscore the assertion that the positions stated are certainly not right for the present year:

Example 1. Astronomy Table: January 20, 2004, Sun is on border between Sagittarius and Capricornus. Astrology Table: Sun is between Capricornus and Aquarius at that time. So how far back in time must we go to get the Sun on the border between Capricornus and Aquarius on January 20? The year 75 BC, according to *Starry Night Pro*.

Example 2. "Scorpio (Oct 24 - Nov 22): With Uranus now in Pisces, the tide will move you forward." (*Toronto Star,* Saturday, January 3, 2004, Page L7). *Starry Night Pro* has Uranus at noon, January 3, 2004 in Aquarius, 90% of the distance from the Piscean border to the Capricornian border. Stepping back in time, I find that at noon, January 3, 1935 Uranus was just inside the house of Pisces near the Aquarius border.

Example 3. "Aquarius (Jan 21 - Feb 19): Make the most of Venus in your sign." (*Toronto Star,* Sunday, January 4, 2004, Page B5). *Starry Night Pro* has Venus in the middle of Capricornus for that day. Venus was last in Aquarius on January 4, 2001, and will appear there again in 2009.

Example 4. "Leo (July 23 - Aug 22)...with Mars in Aries..." (*Toronto Star,* January 6, 2004, Page C4). On this day, Mars is half way along the west fish of Pisces, from the juncture to the Circlet. The last time Mars was in Aries on January 6 was 1974.

Creating a High-Dynamic-Range Solar Eclipse Composite Image

by Alson Wong, (alsonwong@charter.net)

Introduction

A total solar eclipse is perhaps the most spectacular of all regularly occurring astronomical events that can be viewed from Earth, and is relatively easy to photograph compared to most other astronomical objects. The solar corona and chromosphere are bright and large in apparent size, so they can be photographed with short exposures and modest focal lengths. On the other hand, while the human eye has sufficient dynamic range to appreciate the corona's great range of brightness, the limited dynamic range of photographic media makes it virtually impossible to record all of the corona's detail in a single exposure.

I used 31 exposures taken with a Nikon D70 digital SLR camera through a Borg 77-mm f/6.5 ED refractor (focal length 500 mm) on a Kenko SkyMemo equatorial mount to photograph the total eclipse from Egypt on March 29 of this year. The exposures were taken in one-stop increments ranging from 1/2000 second to 1 second using a pre-scripted sequence in *ImagesPlus 2.75,* a software package for DSLRs that allows unattended operation of the camera. This allowed me to visually observe the eclipse during the entire period of totality. *ImagesPlus* saves the image files to the computer's hard drive instead of to the camera's memory card, which requires download times of several seconds for each exposure. Although images saved in RAW format have a greater dynamic range than images saved in JPEG format, I decided to save the images in JPEG format because the smaller files and shorter download times allowed me to take more exposures at each exposure setting.

Processing in *Photoshop*

Photographers using radial-density gradient filters and darkroom techniques to combine multiple exposures were partially successful in increasing the amount of coronal detail that could be displayed in a single image, but it was the development of digital-image-processing techniques in the 1990s using image-editing software such as *Adobe Photoshop* that allowed the full range of coronal detail to be displayed in a single image. A successful and widely used technique was to combine multiple exposures with Layer Masks as described by Russell Brown [available by searching on the Web – ed.]. Although excellent results can be obtained this way, creating the masks for each layer involves a considerable amount of trial and error and is labor-intensive and time-consuming.

The latest version of *Adobe Photoshop, CS2,* contains a High Dynamic Range feature that creates a 32-bit image from multiple exposures. I was able to obtain a superior result using this technique compared to the result using Layer Masks, with much less time and work invested. This feature may be accessed in *Adobe Bridge* by selecting Tools > Photoshop > Merge to HDR, but the preferred method is to access it in *Photoshop* by selecting File > Automate > Merge to HDR, which brings up a dialogue box for selecting the images to be used, and includes an option for automatically aligning the images. The automatic alignment feature can be very useful, as the motion of the lunar disk between second and third contact can make it difficult to properly align the individual exposures in order to preserve coronal detail.

After the images have been selected for processing, select OK to create the HDR image.

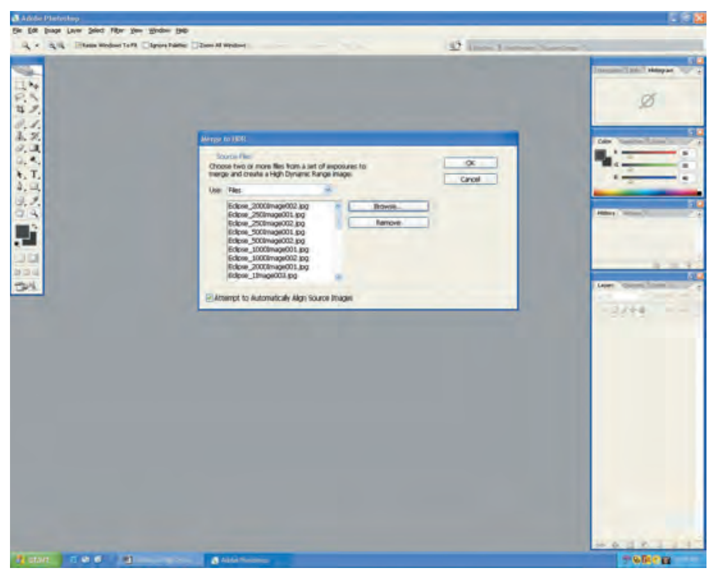

Figure 1 — Selecting files to be merged into an HDR image

If scanned film images are being used, exposure information must be manually entered for each image. If the exposures were all taken at the same ISO and f-stop, then set the Exposure Value (EV) to 0 for the exposure(s) in the middle of the exposure range, with EV in increasing order for long exposures and decreasing order for shorter exposures. The EV values should correspond to f-stops, so if the exposures are in one-stop increments use one-stop increments when setting the EV. If the exposures are in two-stop increments use two-stop increments for the EV. Exposures taken with a digital camera already contain this information, so the images will have an EV assigned automatically.

The HDR preview image is displayed in a window along with thumbnails of the individual exposures on the left side with their corresponding EV and check boxes that allow selection and deselection of individual exposures. The right side of the window displays a histogram with a slider for a white point adjustment that allows previewing of different parts of the brightness range of the HDR image, as computer monitors are incapable of displaying the entire range at once. Adjusting the White Point Preview will not alter the final HDR image. With the bit depth set at 32 bits, select "OK" to create the HDR image file and then save it as a Portable Bit Map file before proceeding further. Creating the HDR image is very computer-intensive and may consume a lot of computer time, depending on the number and size of the image files used. About one hour of computer time was required for my 1.8-GHz, 1-GB RAM desktop to create the HDR image using the 31 JPEG images.

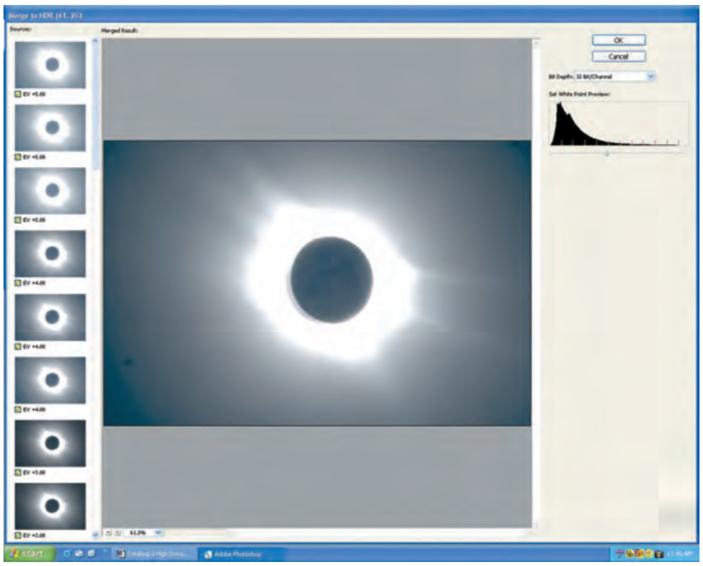

Figure 2 — The HDR preview image

Most of *Photoshop's* features are disabled in 32-bit mode, so to process the image further, select Image > Mode > 16 Bits/Channel to convert the image to a 16-bit image. This will bring up the HDR Conversion dialog box, with four methods available. Local Adaptation offers the most control. The Threshold and Radius sliders sharpen the image; it may take several attempts with different settings to determine the best combination of values to create a sharp image without artifacts. The Toning Curve and Histogram adjust the contrast of the image. The tick marks on the bottom represent f-stops. Start by moving the left lower portion of the curve to a point one or two tick marks to the left of the histogram — this sets the black point. If necessary, adjust the right upper portion of the curve so that it is one or two ticks to the right of the histogram. Other points in the middle of the curve can be added to adjust the contrast of the midtones. After completing adjustments, click "OK" to convert the image to 16 bits.

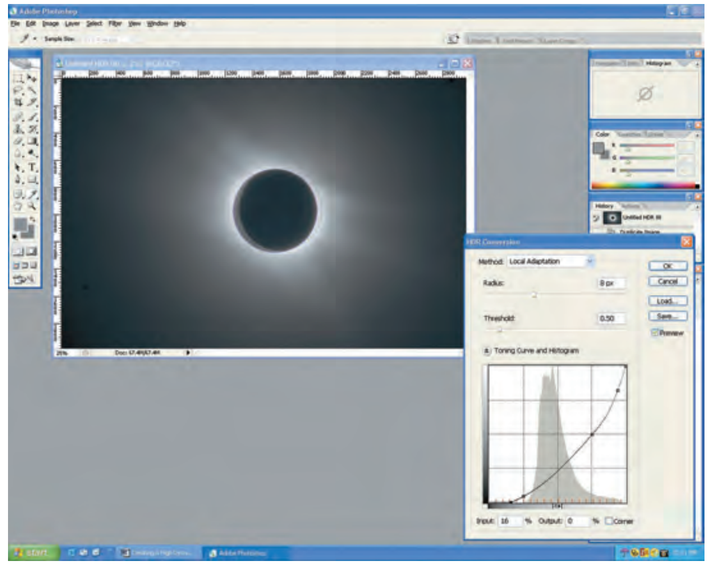

Figure 3 — Using Local Adaptation to convert from 32-bit to 16-bit mode

The 16-bit image can now be processed with the full range of tools in *Photoshop CS2*. If the image is not perfectly centred in the frame, crop the image so that it is centred. Having the image centred in the frame is important when creating a sharpening layer, since an off-centre image will create more artifacts. Select Layer > Duplicate Image to duplicate the image. With the duplicate layer selected, apply a Radial Blur to the image using Filter > Blur > Radial Blur. This brings up a dialog box. Set Blur Method to Spin, and Quality to Best: values of 10 to 20 usually give the best results. Click "OK" to blur the duplicate layer.

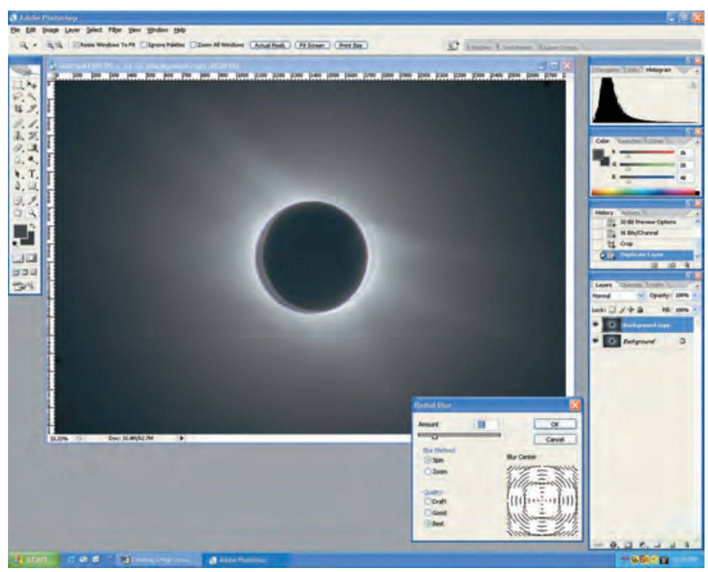

Figure 4 — Applying a Radial Blur to a copy of the background image

Next, select Image > Calculations, which brings up a dialog box. For Source 1, set Layer to Background copy and Channel to Gray. For Source 2, set Layer to Background and Channel to Gray. Set Blending to Subtract with an Opacity of 100%, Offset of 128, and Scale of 1. Set Result to New Document and click "OK." This creates the sharpening image.

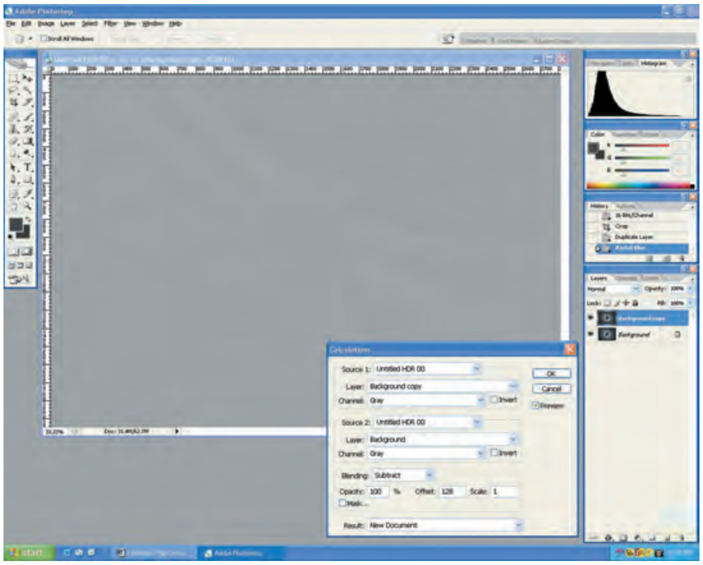

Figure 5 — Creating the sharpening image

To apply the sharpening image, select the image using Select > Select All, then select Edit > Copy and then click on the original image and select Edit > Paste to add the sharpening image as a new layer (Layer 1). Click on the eye icon next to the Background copy layer to hide it. Next, click on the sharpening layer (Layer 1) and change the blend mode by opening the drop-down menu at the top of the Layers palette. Set the blend mode to Overlay for a mild sharpening effect or Linear Light for a stronger sharpening effect. The sharpening layer can also be duplicated to strengthen the sharpening effect even further.

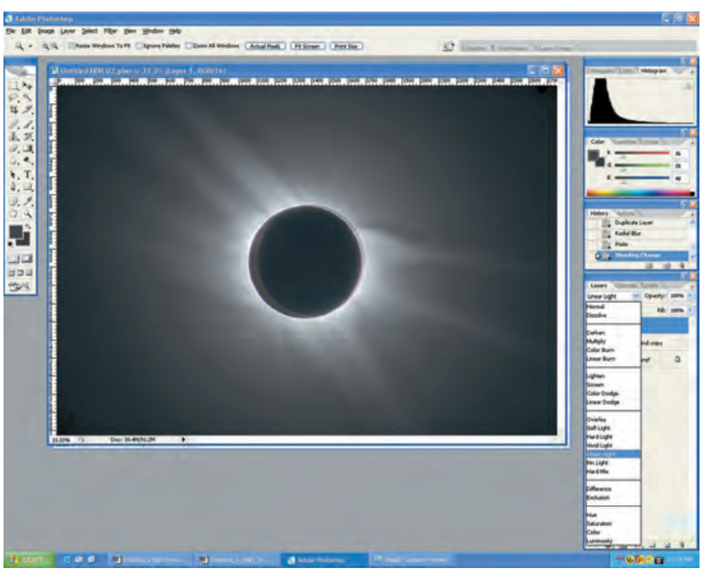

Figure 6 — Applying the sharpening layer

Motion of the lunar disk between exposures usually results in some limb artifacts, as the individual exposures are aligned on the corona. A slightly enlarged lunar disk image can be pasted in as a layer to cover most of these artifacts. I chose to combine my second-contact exposure (1/1000 second) and third-contact exposure (1/2000 second) to feature prominences and chromosphere on both sides. One image is pasted on top of the other. Using the Move tool, the top layer is aligned with the background layer. Zooming into 100% and setting the blend mode to Difference can be useful when aligning the two layers. When the layers are aligned, the blend mode is set to Lighten. In this example, since the two layers are of different exposure length, the brightness curve of the 1/1000-second exposure is adjusted to match the extent of corona displayed in the 1/2000-second exposure, so that the corona appears symmetrical on either side of the lunar disk. After this has been done, the image is flattened using Layer > Flatten Image.

In order for this image to cover the lunar disk and limb artifacts in the composite image, it will need to be enlarged slightly. To do this, select Image > Image Size and enter in a new value in one of the dimensions that is 5-10% greater. Be sure that the Constrain Proportions box is checked so that the image is enlarged in both dimensions and click "OK." To select only the lunar disk, prominences, and chromosphere, click on these portions of the image with the Magic Wand tool until you are satisfied with the portion being selected.

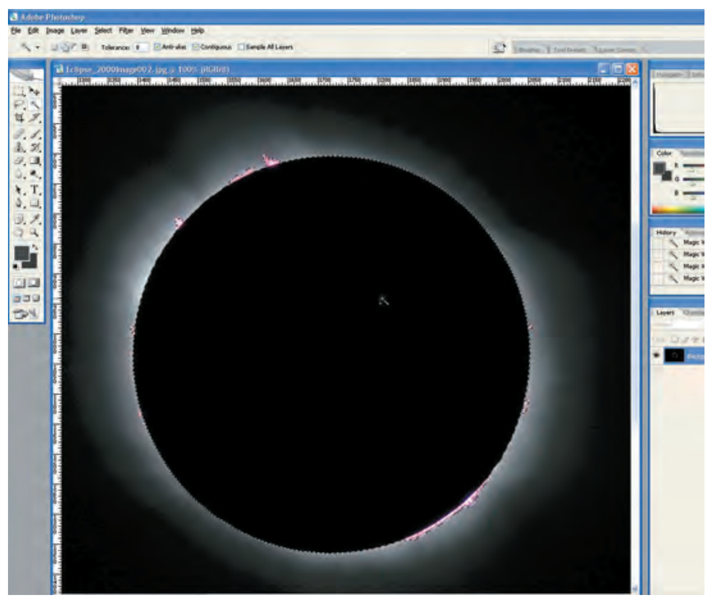

Figure 7 — Selecting the lunar disk and prominences with the Magic Wand tool

Choose Edit > Copy and then paste this selection into the composite image. Use the Move tool to align the lunar-disk image layer with the rest of the composite image. It may take a few attempts to find the optimum size for the lunar-disk image that just barely covers the disk and limb artifacts in the composite image while minimizing the amount of inner corona that is covered. If you need to try again, delete the lunar-disk layer and resize the lunar-disk image that you created in the previous step and repeat the selection process using the Magic Wand tool.

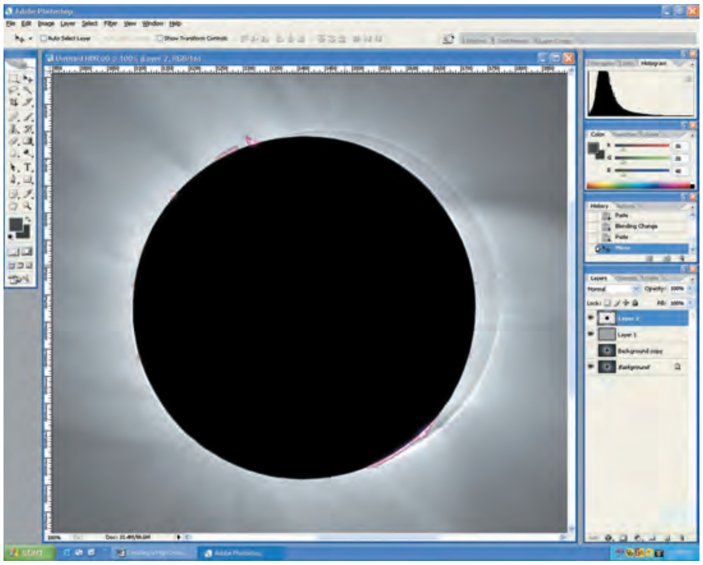

Figure 8 — Lunar limb artifact extending into the corona

In the example illustrated in Figure 8, there is an artifact that extends an appreciable distance from the right side of the lunar limb into the inner corona. I did not want to cover up this portion so I left this to be removed later using the Healing Brush tool.

Further adjustments to the background layer can be made, such as contrast adjustments with Image > Adjustments > Curves. Sharpening the image may have increased the noise, so this can be reduced using Filter > Noise > Reduce Noise.

When the contrast and sharpness of the image have been optimized, save the image in Photoshop (.PSD) format with the layers intact so that additional processing can be performed later if desired. Artifacts in the image such as the one in the inner corona and defects such as dust spots are most easily removed after flattening the layers. Before flattening the layers, be sure that the Background copy layer is hidden (indicated by an absent eye icon next to the layer), so that it is discarded when the image is flattened. The defects may then be removed with the Healing Brush tool and the final version saved.

When done properly, this process results in an image that captures the full range of the corona's brightness, resembling its spectacular visual appearance.

Figure 9 — the final image.

Alson Wong is an amateur astronomer based in Southern California and is a member of the Riverside Astronomical Society. He has observed and imaged six total solar eclipses (1995, 1999, 2001, 2002, 2003, & 2006). By day, and often at night, he is a pediatrician with the Southern California Permanente Medical Group.

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Is Artificial Light at Night Too Much of a Good Thing?

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The increasing availability and use of electric light at night to improve visibility has brought about a profound transformation of human existence in a little over a century. Activities such as work, recreation, and travel are far less limited than when candles and gaslights were the main ways of overcoming natural darkness. The benefits are considerable. Copious artificial light certainly decreases the fear of crime[1], which leads people to think that light also discourages actual crime. Retailers know that bright lighting attracts customers. Politicians encourage the proliferation of lighting to give an impression of prosperity and security. Road-safety authorities believe that increased road lighting reduces the rate of accidents at night. Fossil-fuelled power stations are more efficient and hence more profitable when the base (night) load is kept high, so lighting is encouraged by lower prices for the electricity used. Commercial and decorative illumination tends to be competitive in quantity. Religions tend to associate darkness with evil and light with goodness, thereby reinforcing the notion that more light is a good thing.

It is not surprising that satellite imagery of Earth at night indicates worldwide trends for more and brighter artificial lighting. Generally, city lighting is becoming brighter and extending further into the surrounding countryside in the UK[2] and other countries. It seems that there is a great deal of scope for this to continue, insofar as many inhabited areas are still unlit at night and most of the areas that are lit are not yet illuminated to daylight levels.

Ophthalmic practitioners doubtless see more lights and brighter illumination as beneficial for visual performance at night. Can we have too much of this good thing? Is artificial light an almost boundless boon, or are there adverse factors that need to be taken into account?

It would help to know something about the amounts of light in question. The total artificial-light flux emitted by a city is proportional to the product of two quantities: the number of light sources and their mean output of light. Both of these quantities are typically increasing over time in cities. This suggests exponential growth in the total flux. The same result can be reached by considering the increasing amount of light used per person and the growth in population. Exponential growth cannot be sustained indefinitely. There are practical limits set by costs and finite resources and ultimately by visual intolerance to excessively bright ambient illumination.

In outdoor situations, such as key areas in retail precincts and sports arenas lit for television broadcasting, illuminances of over 1000 lux are routinely achieved at night. Although this is well into the daylight range, it is still a log unit or more short of allowing optimal visual performance. On the other hand, it is also about four log units brighter than strong moonlight and seven log units brighter than natural dark conditions in the open. This capability in lighting practice is sufficient to allow a useful degree of supplementary lighting to be provided outdoors, as desired during daylight hours when natural illumination is reduced by low solar altitude, weather, and shadowing/shielding effects of the built environment and terrain.

The growth in ambient artificial light at night over the past century represents a massive environmental change. In general, outdoor luminaires emit some or even most of their light above the horizontal and some of the downwardly directed light is reflected upwards by the terrain. Typically, about one third of all outdoor artificial light ends up travelling above the horizontal, heading for outer space. This mixture of unused and waste light is one form of light pollution. A tiny fraction of it is backscattered towards the ground by air molecules and suspended matter. This is seen as artificial sky glow, which adds to the faint natural sky light emitted mainly by oxygen in the upper atmosphere.

Major astronomical observatories were built originally in or close to large cities — for example, Paris, Greenwich, Melbourne, and Mount Wilson — but, within a few decades of the introduction of electric light in the 1880s, the accompanying artificial sky glow was seriously diminishing the visibility of faint celestial objects. This made city locations unsuitable for professional astronomical research. Newer observatories were built further away. Ironically, the presence of these observatories and the roads to them has tended to foster the establishment and growth of local towns along with their light pollution.

Increasing concern about light pollution as an astronomical problem led to the formation of the International Dark Sky Association in 1987[3]. Currently, it has more than 10,000 members.

Most are professional or amateur astronomers, and the others include environmentalists, ecologists, lighting people, and bushwalkers. The IDA has tried hard to get the lighting industry on side and has succeeded to the extent that the industry funds IDA activities such as seminars, while increasing use is being made of luminaires of the full-cutoff type, which have reduced intensity near the horizontal and no light emission above it.

A genuine solution of the light-pollution problem requires more than better luminaires: substantial reductions are necessary in the total emitted light flux. Billboard, decorative, commercial, domestic, roadway, and landscape lighting are burgeoning regardless, so it is hardly surprising that public debate on the issues has become increasingly polemic in recent years.

The growth in artificial sky glow is an approximate but nonetheless valuable indication of the growth of energy use for outdoor lighting. Accurate direct measurement of night-sky luminance generally requires costly equipment but sky luminance can be estimated from observation of faint stars[4] or by counts of stars in the visible hemisphere or in a part of it marked by bright stars. In natural dark-sky conditions, about 2700 stars are detectable in the sky hemisphere without optical aid. In the middle suburbs of Melbourne, for example, in which the total population is 3.5 million, only two to three per cent of the 2700 stars are now visible and the sky is often bright enough to show a dark blue colour, that is, within the range of sensitivity of retinal cones. As in other large cities in the Southern Hemisphere, the fifth star of the Southern Cross is often invisible and the fourth star is becoming harder to see.

In Melbourne the observed rate of increase of sky luminance is doubling every decade[5], which is more than 20 times the relatively generous growth rate for greenhouse gases requested by Australia and agreed to in the Kyoto Protocol but not yet ratified. Artificial sky glow causes great aesthetic losses in our natural heritage and affects the education of schoolchildren[6]. There has been little community concern about this, possibly because the loss has been so gradual. It brings to mind the proverbial frog in hot water being unaware of danger when the rise in temperature is imperceptibly slow. Light pollution is increasingly hampering astronomical research. This is of great practical concern as astronomy is one of the main wellsprings of intellectual, scientific, and technological progress.

Exposure to artificial light at night appears to have a large range of generally adverse effects on animals and plants[7] and has led to coining of the term "ecological light pollution" as something akin to but generally different from astronomical light pollution. Mammals tend to exhibit circannual periodicity in aspects such as amount of body fat and reproductive behaviour. These variations are known to be responses to seasonal changes in the length of daylight[8].

Some endocrine functions in humans are susceptible to interference by excessive exposure to artificial light at night, for example, from night shifts, long hours of watching television, brighter indoor lighting, and possibly stray light leaking into bedrooms. The consequences apparently include increased incidence of breast and colorectal cancer[9], overeating, and obesity-related medical conditions. Light leakage into bedrooms can also cause sleep disruption and sleep loss. Inadequate sleep can result in daytime fatigue and sleepiness. Drowsiness contributes to causation in up to 20 percent of traffic and industrial accidents[10-12].

Reasons for reducing light pollution include the above and many others. Practical ways of minimizing lighting excesses and obtrusiveness without compromising mobility safety do exist. In fact, reduced glare is often a most useful outcome. Many governments have already introduced legislation to control light pollution and light trespass; however, achieving the overall improvement required has been greatly impeded by the belief that outdoor lighting prevents crime.

Despite the efforts of a few criminologists who claim to have evidence for a beneficial effect of increased light[13], there is much stronger evidence for an adverse effect. Crime is typically reduced during lighting blackouts. For example, crime dropped dramatically across the whole area of the blackout that affected 50 million people in North America in August 2003. Earlier, an official report described how crime increased by 21 percent when Chicago's alleyways were given a four-fold increase in light as a supposed crime-prevention strategy[14].

This editorial is a somewhat unexpected outcome of the writer's concern that high-intensity, low-mounted, upwardly aimed decorative floodlamps could be an ocular hazard to children and others attracted to stare into the lamps at close range. Complaints to one authority about children observed to be doing this at the former Melbourne Observatory were dismissed with a statement that it was purely an issue of parental control. A municipal council referred a complaint about similar incidents in a public park to Professor Barry Cole. Our respective assessments of the degree of hazard differed, so Professor Cole invited acknowledged expert Dr. J.J. (Hans) Vos to review the subject. Dr. Vos graciously agreed and his review appears in this issue of *Clinical and Experimental Optometry*.

To date, lighting standards have largely been developed by lighting professionals and others from the lighting industry. Accordingly, the standards hardly skimp on the minimum light levels recommended and tend to favour continuation of established practices in the face of research results about obtrusiveness, unsustainability, and adverse ecological effects. There is a pressing need for vision scientists and ophthalmic practitioners to pursue a much more active role in researching the issues and ensuring that lighting standards take due account of the results. A balanced assessment of the benefits and disadvantages of light at night should go well beyond the degree to which it assists the ability to see. The many compromises that set outdoor-lighting practices will need to be rethought accordingly. Increased participation of vision experts in the setting and evolution of lighting standards would help optimize the practical benefits of night lighting within the severe environmental constraints that appear inevitable. Not the least difficulty in bringing this about will be the known reluctance of existing lighting-standards committees in several countries to provide places for experts from outside the lighting industry.

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Small Kuiper Belt Bodies Seen by X-ray Occultation

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

The Kuiper (pronounced "kwiper") Belt is a collection of rocky-icy bodies beyond the orbit of Neptune. Pluto and its moon Charon are part of the Kuiper Belt, and there are several other bodies whose sizes are comparable to, or even larger than, Pluto. About a thousand such bodies are known, but there must be many more that are too small to see directly, because in any population of bodies that collide with each other the number in each size range rises approximately as the inverse cube of the diameter. For example, 100-km bodies are about a thousand times more numerous than 1000-km bodies. Extrapolating that to 100-m-sized bodies predicts about 10^{14} of them. But the only practical way to "see" such small bodies is through stellar occultations. Several projects are underway using optical telescopes, but a very interesting approach by Hsiang-Kuang Chang of the National Tsing Hua University in Taiwan uses X-ray occultation and recently reported 58 events (see the August 10, 2006 issue of *Nature*).

Chang used data from the orbiting *Rossi X-ray Timing Explorer,* with Scorpius X-1 as the background source. It is the brightest X-ray source outside the Solar System and conveniently lies just six degrees away from the ecliptic. Even so, there were numerous technical difficulties that Chang had to overcome, including the lack of photons and deciding whether the observed dips arose from something at the source or an instrumental effect. He took all of the observations of Sco X-1 by *RXTE* over the period from 1996 to 2002, with a total exposure time of 322,000 seconds, and found that there was an excess of "dips" in the X-ray flux, with most events lasting two to three milliseconds (the longest is seven milliseconds). The occurrence times of the dips in X-rays are random. While Sco X-1 is known to flare on millisecond timescales, dips were hitherto unknown. When Chang looked at the Crab Nebula he saw no dips. Because the Crab is an extended source, there should be no small fluctuations: their absence implies that the dips for Sco X-1 are not an instrumental effect. This leaves occultation by Solar System objects as the most plausible explanation.

One problem with this result is that Chang's estimate of the number of bodies in the 10 to 100-metre-size range is $\sim10^{15}$, far more than the $\sim10^{12}$ suggested by computer models of the collisional evolution of the Kuiper Belt. This could be due to a lower average collision rate between the bodies than assumed by the models, or (Chang suggests) it might indicate the presence of another component of smaller KBOs at distances greater than the generally assumed 50-AU cut-off for the Kuiper Belt.

Two other groups are looking for Kuiper Belt occultations in the optical range. One, led by Françoise Roques of the Observatoire de Paris, has a paper in press with the *Astronomical Journal* reporting the detection of three objects with sizes ranging from 220 to 600 m. They used a clever technique at the William Herschel telescope on La Palma, in the Canary Islands. The smallest of the three appears to be in an orbit between Saturn and Uranus, while the other two are much further away from the Sun than usual for the Kuiper Belt (140 and 210 AU). They comment that finding these two objects suggests a large population of small bodies in the "outer solar disk," and first suggested this at the annual meeting of the Division of Planetary Sciences (of the American Astronomical Society) in Louisville two years ago.

The third group is the Taiwanese American Occultation Survey (TAOS), which uses four telescopes to weed out "false positives" arising from variations in the star's brightness. The four telescopes are installed in the mountains of a national park in central Taiwan.

They have not yet reported any detections of unexpected occultations, but they have seen occultations coming from known asteroids. The project is a multi-year automated survey of ~3000 stars.

It is worth emphasizing again that occultations are the only way to find objects this small in the Kuiper Belt. Even the largest telescopes struggle to find KBOs much larger (in the 1000-km-size range), though the hope is that, after finding some through occultations, follow-up observations with a 10-m-class telescope will be able to locate the ones that are larger than about 25 km. The field of view of the Keck telescopes is just 37 arcseconds, however, so the follow-up observations must be done quickly. No telescope currently under consideration could ever detect objects as small as those found by Chang and Roques.

With all the work being done on high-redshift galaxies and investigations of the Big Bang, it is a little disconcerting to realize that we have not yet completed the inventory of our own Solar System!

Leslie J. Sage is Senior Editor, Physical Science (Astronomy), 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, but is not above looking at a humble planetary object.*

Deep-Sky Contemplations

by Warren Finlay (warren.finlay@interbaun.com) and Doug Hube (jdhube@telus.net), Edmonton Centre

In this ever-changing world, where governments, countries, and regimes hyperactively flit across the world stage, you can normally turn to the deep sky if you want constancy. Ignoring notable transient exceptions that include novae, supernovae, and variable stars, the galaxies and clusters we gaze at today through our telescopes will look no different to future generations of RASC *Journal* readers for the foreseeable future. However, if you were Methuselah and wanted to see changes in a deep-sky object, your best bet would be to look at the more dynamic ones, *i.e.* open clusters and nebulae, where changes readily occur on a scale of a few million years or less. In contrast, the average globular cluster has a disruption time of about 30-billion years. Of course, there are exceptions to the rule of longevity for globular clusters. One such exception is NGC 288, an easily seen globular cluster in Sculptor (RA(2000) = 00^h 52.8^m, DEC(2000) = -26° 35´). At a distance of about 30,000 light years, it has a diameter of 13´ and a magnitude of 8.1, containing about 100,000 stars. It is visible in binoculars from southern latitudes, but benefits from aperture here in the northern latitudes where its low altitude results in dimming due to atmospheric extinction.

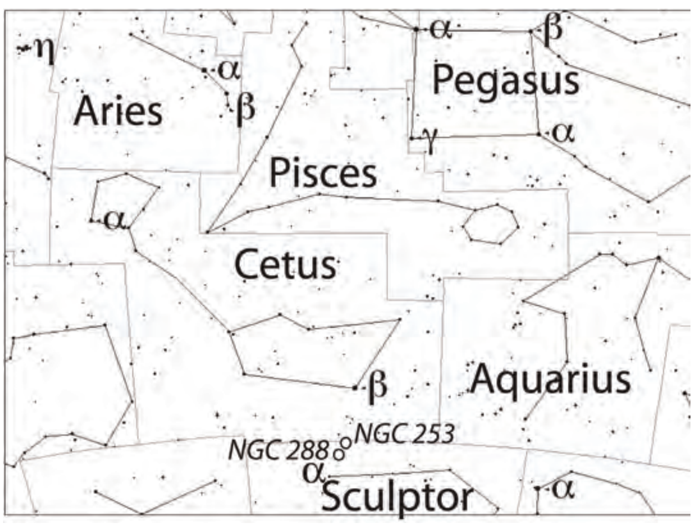


Figure 1 – Position of NGC 288 and NGC 253 in the night sky.

Compared to most other globular clusters, NGC 288 has a terminal sentence, being expected to dissolve within the next billion years or so. Its early demise will be the logical consequence of its frequent flirtations with the galactic centre. Indeed, every 200 million years or so, its orbit takes it within 5000 light years of the centre of our Galaxy on a path inclined at 47° from the Galactic plane. At the moment it is being coy, lying at its apogalactic point about 35,000 light years from the galactic

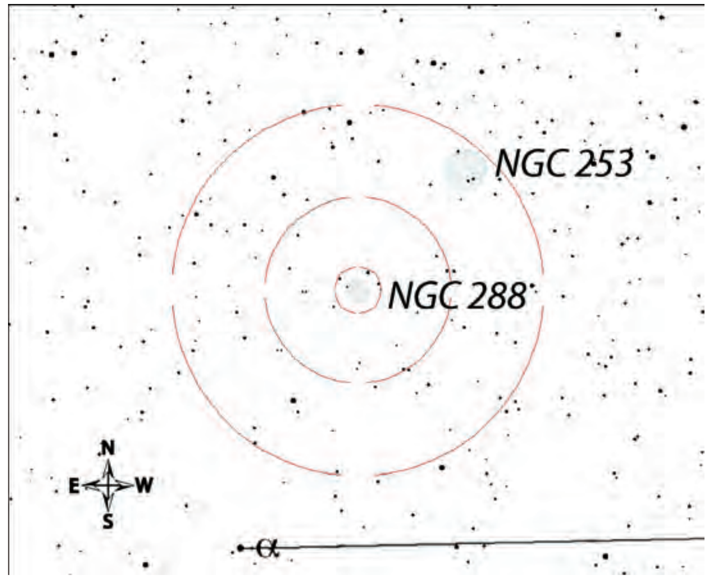


Figure 2 – Finder chart for NGC 288 and NGC 253 shown with 0.5°, 2°, and 4° Telrad circles.

centre and nearly directly below us from the galactic plane. However, it will soon return on a kamikaze brush with tidal forces deep within the bulge of our galaxy, flinging off stars in a process where pairs of stars duel each other in a slingshot manner that ejects one from the pair and sends the other closer to the core of the cluster. As it navigates the crowded interior of our galaxy, each such flirtation speeds NGC 288 on its way to tenuous oblivion. Don't feel sorry for this cluster, though, since it has already had been in existence for more than twice as long as the Earth.

Despite its somewhat short life expectancy on cosmic time scales, NGC 288 is of course unchanging when viewed by us mortals. Indeed, if you observe this cluster you will see exactly what William Herschel saw on that autumn night 221 years ago (October 27, 1785) when he was the first-ever human to view this object.

If you decide to observe NGC 288, you absolutely must swing your scope 1° 45´ NW and have a peek at the Sculptor Galaxy, NCG 253 (RA(2000) = 00^h 47.6^m, DEC(2000) = -25° 17´), aptly called the Silver Coin by some. At latitudes where this galaxy rises well above the murky horizon, it is one of the highlights of the night sky, shining nearly edge-on, big and beautiful just as its colloquial name suggests. With a magnitude of 7.2, and apparent size of 26.4´ × 6.0´, the beauty of this galaxy hides a violent side — it is thought to have swallowed a one-million-solar-mass satellite body some ten million years ago, setting off a burst of star formation in its centre that has yielded

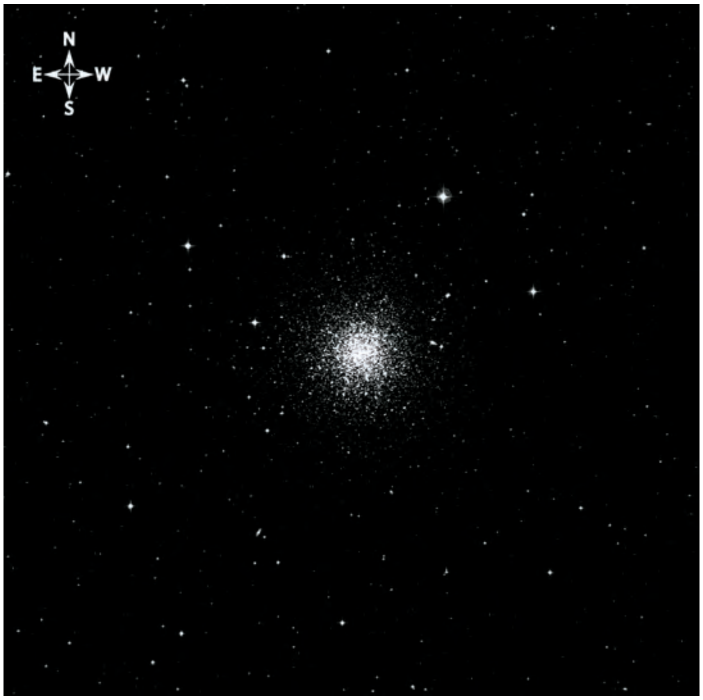


Figure 3 – 50′x50′ POSS image of the field that includes NGC 288.

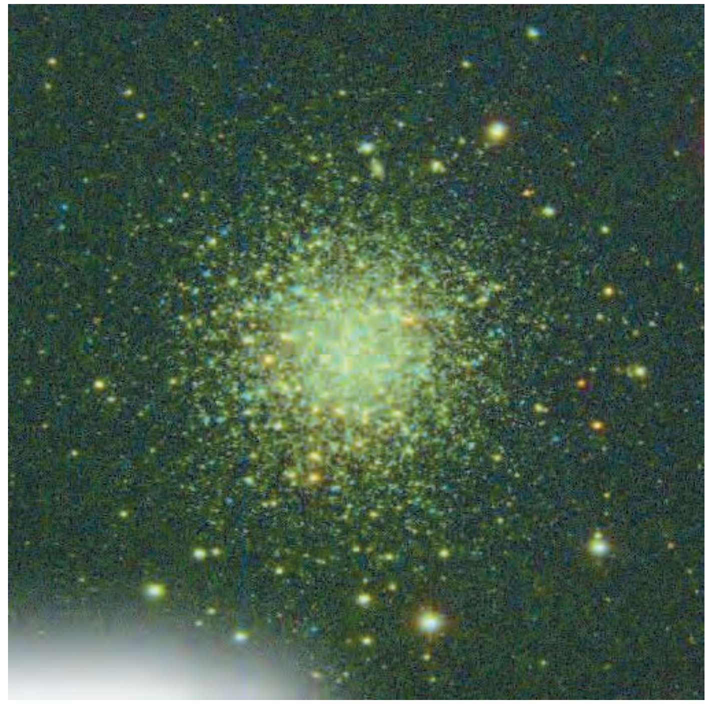


Figure 5 – Image of NGC 288 from the Sloan Digital Sky Survey.

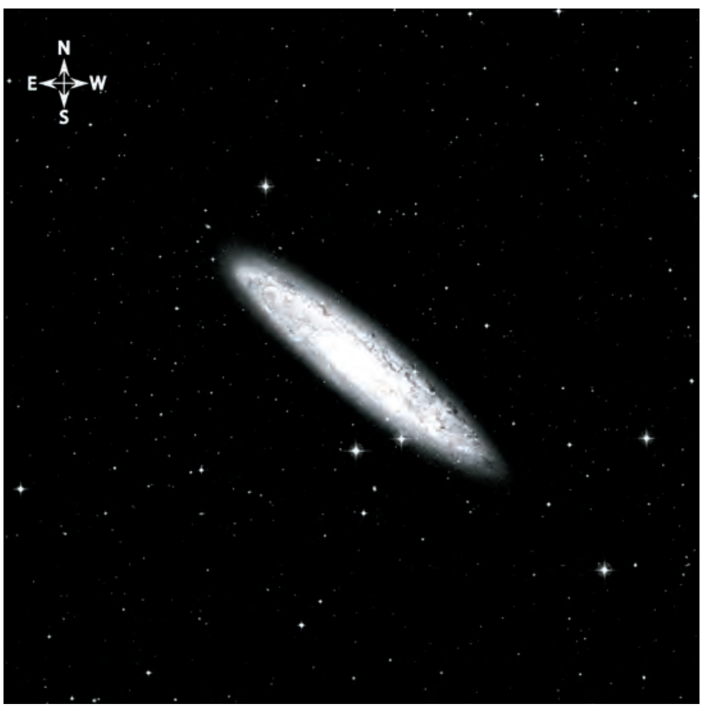


Figure 4 – 50′x50′ POSS image of the field that includes NGC 253.

a new cluster of 1.5-million solar masses whose birth is in counterpoint to the fading reign of NGC 288.

Next time you have a night of good transparency, have a look at these two horizon-hugging beauties. Better hurry though — you only have a billion years before NGC 288 exits the cosmic stage.

Warren Finlay is the author of "Concise Catalog of Deep-sky Objects: Astrophysical Information for 500 Galaxies, Clusters, and Nebulae" (Springer, 2003) and is this year's RASC Simon Newcomb Award recipient. Doug Hube is a professional astronomer retired from the University of Alberta.

City Mouse and Country Mouse

by Geoff Gaherty, Toronto Centre (geoff@foxmead.ca)

Now you must know that a City Mouse once upon a time went on a visit to his cousin in the country. He was rough and ready, this cousin, but he loved his city friend and made him heartily welcome. Beans and bacon, cheese and bread, were all he had to offer, but he offered them freely. The City Mouse rather turned up his long nose at this country fare, and said: "I cannot understand, Cousin, how you can put up with such poor food as this, but of course you cannot expect anything better in the country; come you with me and I will show you how to live. When you have been in the city a week you will wonder how you could ever have stood a country life." No sooner said than done: the two mice set off for the city and arrived at the City Mouse's residence late at night. "You will want some refreshment after our long journey," said the polite City Mouse, and took his friend into the grand dining-room. There they found the remains of a fine feast, and soon the two mice were eating up jellies and cakes and all that was nice. Suddenly they heard growling and barking. "What is that?" said the Country Mouse. "It is only the dogs of the house," answered the other. "Only!" said the Country Mouse. "I do not like that music at my dinner." Just at that moment the door flew open, in came two huge mastiffs, and the two mice had to scamper down and run off. "Good-bye, Cousin," said the Country Mouse, "What! going so soon?" said the other. "Yes," he replied; "Better beans and bacon in peace than cakes and ale in fear."

— Æsop's Fables

Once upon a time there was a city mouse who was an amateur astronomer. He lived almost all his life in one city or another. When he was a young mouse, there was not much light pollution, and he was able to spend many nights on his back porch gazing at the stars. When he returned to astronomy as an older mouse he found that the city lights had become much brighter and that he was hard pressed to see all but the brightest stars. So he tried to visit his country mouse cousins as often as he could, but that was not often enough to satisfy his craving to observe.

Our city mouse studied many books on observing, and got much advice, some good and some bad. Some said "The perfect telescope for urban observing is a small refractor," but he found that he could see even less with this than with his larger telescopes. Thus he learned that, as in other locations, in the city, aperture rules. In fact it takes a significantly larger telescope in the city to equal the views of a quite small telescope in the country.

He learned to modify his observing targets in order to have satisfying observing experiences in the city. He concentrated on the Solar System, observing the Sun, Moon, and planets. When there were no planets around, he consulted his *Observer's Handbook* and tracked down a number of bright asteroids, and watched them move through the sky from night to night. He once spent a wonderful night watching Pallas pass through the outer edges of the star cluster Messier 47 (February 28/29, 2000). He discovered that the beauties of double and multiple stars were undimmed by light pollution, and observed all of the stars on the Astronomical League's Double Star Club list (`www.astroleague.org/al/obsclubs/dblstar/dblstar1.html`). One of his mouse friends named Richard encouraged him to observe variable stars, and this proved to be the most rewarding observing of all: no matter what the state of light pollution, moonlight, or seeing, there were hundreds of variable stars visible! He spent less time looking for deep-sky objects, as these were hard to find in his city skies and, once found, rather disappointing to look at, if they could be seen at all. He saved his deep-sky observing for those rare times he visited his country cousins, when the views were much more satisfying.

A little over a year ago, this city mouse decided to move permanently to the country. At first he spent a great deal of time observing those deep sky objects he had been deprived of for so long. But, by and by, he found that one faint, fuzzy galaxy looked much like every other faint, fuzzy galaxy. Then he heard that Jupiter's Great Red Spot had been joined by a smaller friend of similar hue, Red Jr. Soon our newly minted country mouse was back observing Jupiter with fresh enthusiasm. And as Jupiter disappeared into the twilight, he found himself returning to another of his city favourites, variable stars.

Just around the time the city mouse made his move, he acquired a 150-mm Dobsonian with digital setting circles (DSCs). With this, he discovered he could see variable stars as faint in the country as the faintest stars he could ever see in the city with his 280-mm reflector. He also discovered that he could move from variable to variable much more quickly with the help of the digital setting circles. He's now purchased DSCs for his larger scope. Some of his more conservative mouse friends say he's gone over to the Dark Side, but he doesn't seem to mind.

One of the things that surprised the city mouse on moving to the country is that he was much less bothered by wildlife. In the city he'd shared his backyard with neighbourhood skunks and raccoons. In fact he almost lost an eyepiece to a marauding raccoon one night. The eyepiece had been deftly removed from its case and carried half way across the yard before it was retrieved! In the country, although our mouse hears rumours of bears and moose in the area, his most dangerous foe has been the lowly mosquito, which seems to exist in astonishing numbers.

But the transposed mouse's greatest pleasure is, no matter what he may be observing in his telescope, the opportunity to sit back from the eyepiece now and then, and just take in the beauty and richness of the dome of stars overhead. That's like having the cakes and ale *without* the fear!

Gizmos

Sun Screen

by Don Van Akker, Victoria Centre (don@knappett.com)

In our rush to see stars light-years away we tend to ignore the star next door — the Sun. True, it's hard to look at. You need special filters or even special telescopes, and the more you want to see the more you need to spend. But for simple sunspot viewing, this eyepiece projector is easy, safe, and inexpensive. We use ours in a Meade ETX 90 but it will work in almost any reflector. The components are from the plumbing department and from your eyepiece box.

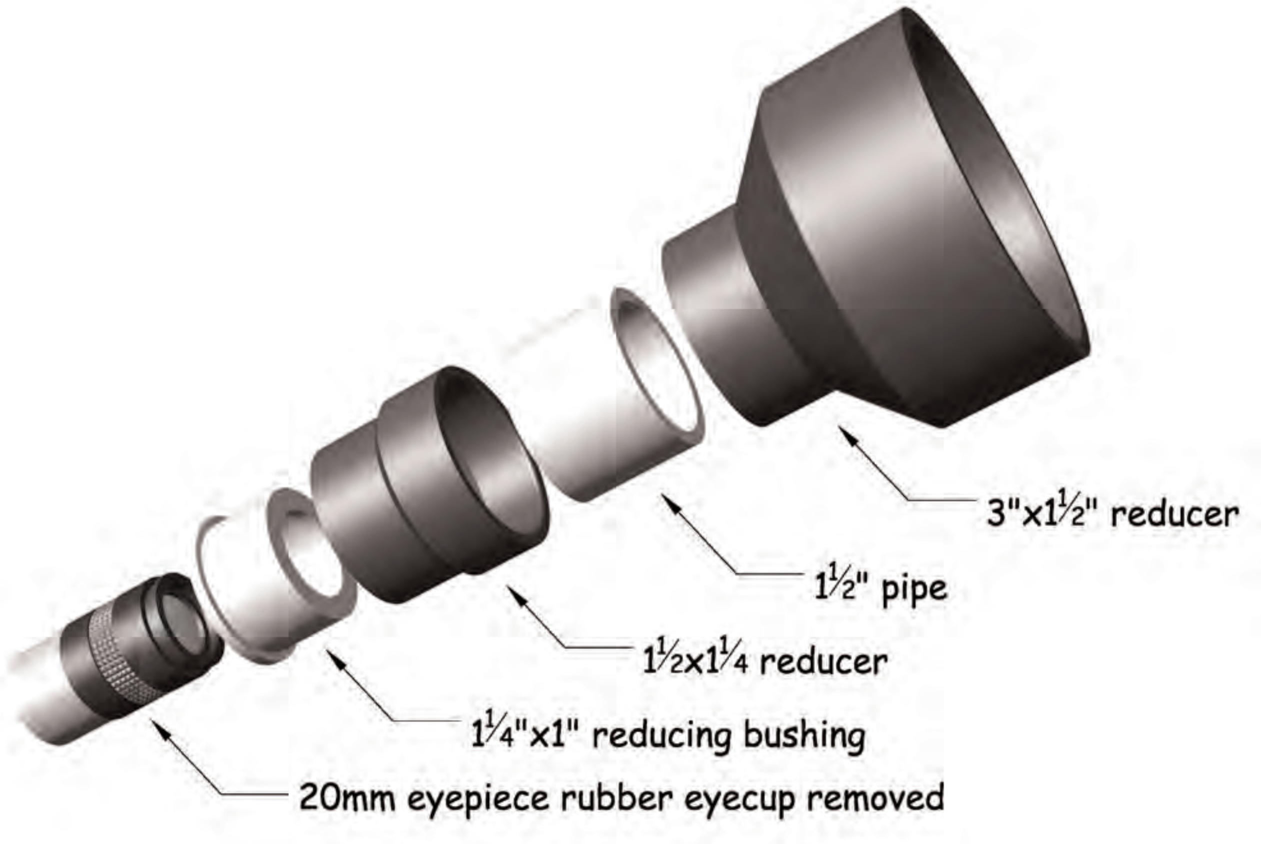
Plastic pipe comes in two main flavours. ABS, the black stuff, is used for waste pipes, and PVC, the white stuff, is used for water. We used some of each in this project because not all the fittings are available in either type alone. You need a $3\times1^1/_2''$ ABS reducer, a $1^1/_2''$ length of $1^1/_2''$ ABS or PVC pipe (you can buy this by the foot and you can use either), a $1^1/_2''\times1^1/_4''$ ABS reducer, a $1^1/_4''\times1''$ PVC reducing bushing and an eyepiece. Put it all together like the picture. You don't need to use glue because the "interference fit" of these parts is snug enough to hold things together without it. The Meade 20-mm eyepiece we used is a friction fit in the $1^1/_4''$ reducing bushing. If yours isn't, wrap it with tape or try a different fitting.

The screen is made of ordinary copy paper. Treat it with vegetable oil applied with a paper towel. Wipe off all excess and let it dry for a few days. Wrap the paper over the open end of the big reducer and stretch an elastic band around it. Pull the paper as tight as possible and trim with scissors. That's all there is to it.

In use, remember that the Sun is the engine that powers our world. Sunlight can be dangerous. Focused into your retinas by even the smallest telescope it has so much raw energy that your eyesight can be destroyed almost instantly. Sunlight reflected from an 8-inch, 10-inch, or 12-inch mirror is more useful for boiling tea than for viewing. The image projected on the screen is far too bright to look at and there may even be a heat build up that could damage the eyepiece. The easy solution is just to cover most of your mirror with a mask. Make it out of a file folder or similar paper, cut a hole in it off-centre (2 inches or 3 inches in diameter is plenty), and tape it over the end of the tube. Aim your scope by watching its shadow. When the tube casts no shadow on any side the Sun will appear on the screen.

A 20-mm eyepiece is a good match for the 1250-mm focal length of the ETX. It projects a solar image about 50 mm in diameter on the screen. With a 1500-mm Dob it projects an image that almost completely fills the 3″ screen. A scope with a longer focal length will need a different eyepiece. Experiment, but don't use your Naglers for this, and don't use a refractor because there may be damaging heat issues.

Focus until you see a nice crisp edge and sunspots will appear as shadowy blobs. Check them out daily to watch their progress across the face of the Sun and go to SOHO (`http://soho.nascom.nasa.gov`) to compare with what the big money sees.



The sunscreen exploded

The Sun is a fascinating study. When you see sunspots follow them day by day and watch their progress. Get the kids involved but teach them the precautions. Protect your eyes and don't forget the sunscreen.

Don Van Akker observes with his wife Elizabeth from Victoria and Salt Spring Island. He can be contacted at don@knappett.com to answer questions about any Gizmos project and would love to hear about some of your ideas for future articles.

Erratum: An Amazing RR Lyrae Star - XZ Cygni

Due to overly-aggressive editing in the XZ Cygni article (Ramblings..., *JRASC,* June 2006, p. 130) the method of variation of this star as stated in the second & third paragraphs is not an accurate representation of the pulsation method for RR Lyrae stars. The paragraph should read

RR Lyrae stars are pulsating stars. The class of stars is named after the brightest example, RR Lyrae (of course). RR Lyrae stars are low-mass stars of about 0.7 solar mass that are very old and evolved enough to have begun burning helium in their cores. Burning helium causes the star to expand and leave the Main Sequence. As it expands the temperature drops, stopping the helium burning and the star shrinks again. This pulsation is seen as a cyclical brightening and dimming of the star. This mechanism is basically similar to classical Cepheid stars, but RR Lyrae stars have shorter periods, generally one-half to one day. Another difference is that RR Lyrae star are Population I stars - or stars found in the halo of the Milky Way, whereas Population II Cepheids are found mostly confined to the galaxy's disk. Differences in these stars' mass and composition cause them to be classified in separate pulsating categories. RRLyrae stars were first found in abundance in globular star clusters, so they are often referred to as *cluster variables.* (See the amazing animation at the *Astronomy Picture of the Day* Web site given in the *Internet Resources* section). However, it is now known that these variable stars are distributed over the whole sky.

I would like to thank Walter Zukauskas for pointing out this error *(and we apologize for the error - ed.)*

Introducing CCD Variable-Star Photometry

by Richard Huziak, Saskatoon Centre (huziak@sedsystems.ca)

After several articles dedicated to getting amateur astronomers to expand their observing programs to include visual estimating of variable stars, I figure I should do the same with those who have chosen CCD cameras as their major method of viewing the skies. CCD astrophotography has taken off like the wind, replacing cooled film as the medium of choice. With a good quality CCD camera and a colour-filter wheel, imaging that formerly took days and weeks of exposing at the scope and hours in the darkroom now takes much less time and produces results much more quickly.

Soon after the invention of CCDs in 1969 at AT&T Bell Labs, they were found to be ideal for astronomical imaging due to their sensitivity over a very wide spectral range from ultraviolet to infrared. Demand for better astronomical images and denser arrays helped accelerate the devices' development. About a dozen years ago commercial CCD cameras became available to amateurs. This put amateurs into the league of professionals for imaging and data gathering. Amateurs have never looked back!

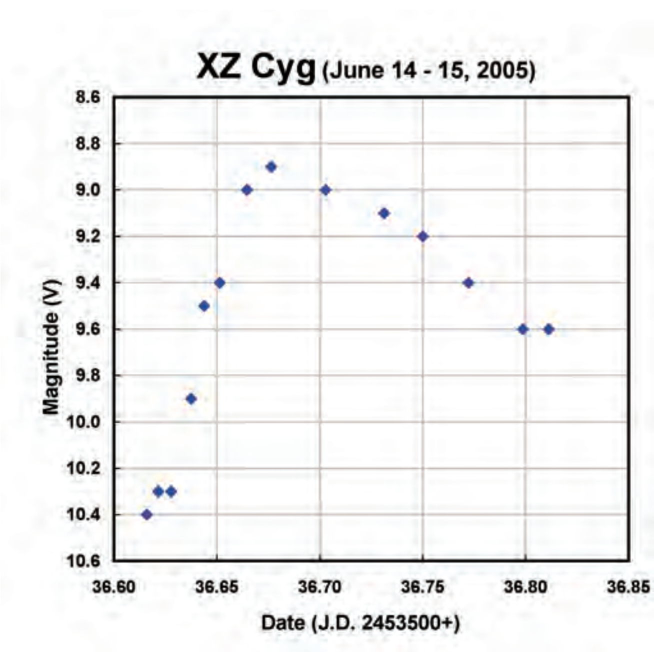


Figure 1 — A visual light curve of the rise of an RR Lyrae star XZ Cygni. This is a pretty good light curve, and useful timings will come from it. Individual points are somewhat scattered, though, and none of these measurements can be made again to improve this exact light curve. Compare this to a similar star shown in Figure 2.

CCDs are valuable detectors because their images, or more correctly, the data collected by the CCD and used to create the images, can be electronically and mathematically manipulated. Each CCD pixel contains a specific number of charges that can be stored, counted, mapped, and interpreted. Counting gives quantitative measurement of intensity, and mapping allows images to be created and interpreted. The data can be manipulated by stretching and compressing using mathematical algorithms. Images can also be stacked together, which reduces electronic noise and allows fainter objects to be seen. This ease of manipulation makes CCDs wonderfully versatile tools whose image quality now rivals that of film. Exposure times that used to be hours on film now take mere minutes with the CCD. Furthermore, the images can be kept for the future as files stored on CDs or DVDs, and can be recalled and reprocessed at any time.

There are several applications for CCD cameras: most common are imaging, measuring, and data gathering, or in

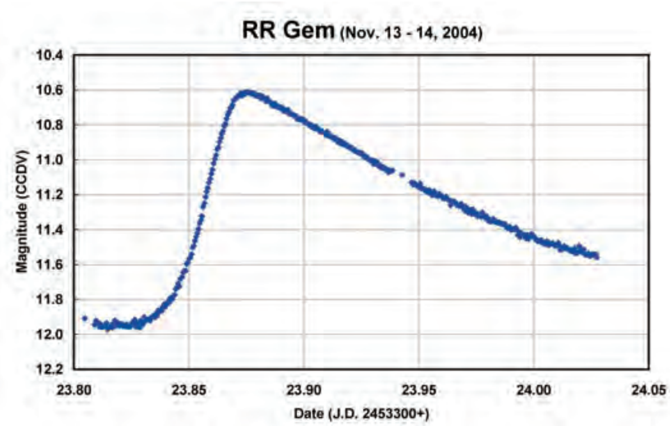


Figure 2: The CCD light curve of the RR Lyrae star RR Geminorum. With the precision of CCDs, a very nice continuous light curve can be generated. Data points from over 300 images were used for this curve. The quality difference from XZ Cygni (Figure 1) is obvious.

other words, astrophotography, astrometry, and photometry. Most astronomical CCD cameras "see" in black-and-white, producing monochromic images; if colour images are desired, it is accomplished by taking exposures through red, green, and blue (RGB) filters, then computer stacking these exposures to produce the colour images. Full-colour cameras do this in one step, but their use in photometry is more complicated; I will discuss only monochrome CCDs in this article.

Photometry begins by imaging a target star with one monochromatic filter, then using measurement software to count the number of photon charges that have been captured to make up the image of the star. A single CCD image may contain hundreds or thousands of star images and every star in the image can be measured. Carefully done, CCD cameras allow you to image a field, and then measure the brightness of the variable stars in the field to great precision. Combining astrophotography with photometry can provide both interesting pictures and a lot of scientific data. However, there is a catch.

CCD astrophotographers traditionally adopted RGB filters from the film industry in order to reproduce accurate colour renditions with electronic images. However, RGB filters are too broadband for most scientific data collection, and professional astronomers have adopted a different set of filters that are narrowband and are tuned to parts of the spectrum that will provide astrophysical clues to the goings-on of the objects they are studying. The most common science filters are called U, B, V, R, and I, which translate roughly to near-ultraviolet, blue, green-yellow, red, and infrared. These five filters sample most of the visible or near-visible spectrum, and most measurements intended to be done for scientific purposes need to be done through one of these filters so that data can be interpreted and compared within a *standard system*. If you want to make measurements in the same way that professionals do, it is important to use the same baseline. Unfortunately, RGB filters do not fit this bill.

However, the science of simple repetitive measurement as is done with variable-star photometry can be done with any one of these narrowband filters, with the default standard being the V-band filter. Conveniently, the V-filter is centred very near the yellow part of the spectrum where our eyes are most sensitive, so images taken through a V-filter tend to represent the sky much the same as our eyes do.

So as it turns out, CCD astrophotographers are only one step away from being able to do useful scientific photometry of variable stars. They already have most of the required paraphernalia: a tracking telescope, a computer, a filter wheel, a CCD camera, and CCD control and data-gathering software. By writing this article it is highly unlikely that I will instantly convert hard and tested astrophotographers to enthusiastic photometrists, but I do have a compromise to suggest. Most filter wheels have five or six spaces for filters and most filter wheels used for astrophotography have R, G, B, and maybe IR-blocking and clear filters in them. This provides an opportunity for the empty or clear position be populated with a V-filter, and

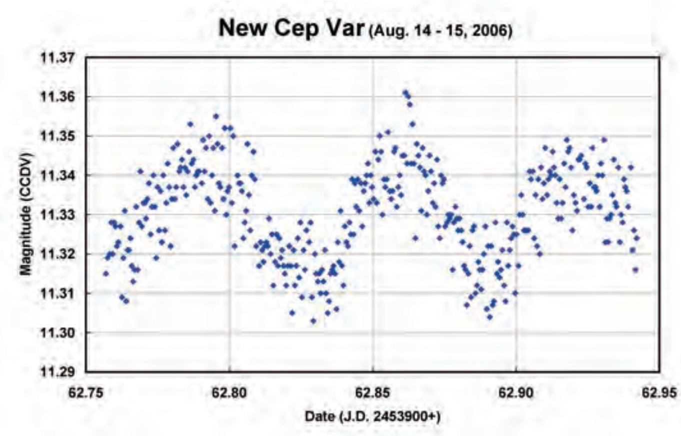


Figure 3: The light curve of a new δ Scuti variable in Cepheus discovered by the author in July 2006. Note that the range is only 0.06 magnitudes, but this is easy with modern CCD equipment. The decreasing amplitude for the variation indicates that the star is vibrating in more than one period at a time. The light curve is six hours long and includes about 350 measurements.

that allows for the capture of images suitable for photometry when the need arises.

Adding a single V-filter to your filter wheel allows you to expand your observing horizons and now and then contribute to science by making measurements of *targets of opportunity*, such as newly discovered novae, supernovae, interesting variable stars, or even asteroids and exo-planet transits! When doing colour imaging of these objects, or any objects in the sky, swing the V-filter into place and record an additional image that can later be measured. One handy fact is that CCD photometry is generally done slightly out-of-focus, so on nights where image size is not small enough for astrophotography, very good photometry can be done, providing an opportunity to use otherwise ideal telescopes.

Should you decide to do a wholesale changeover to UBVRI filters, you can continue to do colour astrophotography. As a matter of fact, virtually all the amazing *Hubble* images you may have seen in astronomy magazines are made through these filters (plus some extras). Everyone *oohs* and *aahs* at these images, but few of us think about the filters that were used. The difference is that every *Hubble* image contains electronic information that can be interpreted or measured because a standard set of filters was used, and information can be read off each image layer. By switching to BVR filters and substituting these for RGB filters, a creative astrophotographer can accomplish both colour imaging and photometry in each of these three bands. The downside is that exposure times must increase because the narrowband filters allow less light to pass through them.

So what are the advantages of CCD photometry over visual estimates? CCD photometry involves basically the same steps: measurements are made of a variable target using a set of standard comparison stars. However, a visual observer makes a real-time estimate of the brightness by interpolation — a best guess between two or more comparison star values. The estimate made by a reasonably experienced observer generally gives a value good to 0.1 or 0.2 magnitudes, with an error generally estimated to be ± 0.1 mag. But the estimate is a fleeting measurement, and the observer can't go back a few days later and recheck that exact observation. Visual observers are also doomed to follow variable stars with amplitudes of 0.5 magnitude or greater or the light curves become lost in their errors.

A CCD measurement is done from the image data. With experience and decent sky conditions, an observer can electronically measure the magnitude of a star to ±0.01 magnitude with an error generally <0.01 magnitudes — ten times finer than the visual observer. Furthermore, the measurement can be repeated or checked later if the image files are retained. With some practice, amateur photometrists are reliably following the light curves of stars with amplitudes as small as 0.01 magnitude. This opens up the whole new world of microvariability to amateur research, and allows amateurs to participate in the search for, and follow-up of exo-planet transits. Just a few months ago, a campaign involving several amateurs resulted in the detection of the first planet transit around the star XO-1 in Corona Borealis. The passage of this hot Jupiter-type planet (XO-1b) across the star caused a drop of a mere 0.025 magnitude. Even so, it was easily detected.

With the obvious accuracy of CCD photometry, what happens to the future of visual variable-star observers? Well, nothing! Visual observers fill a very important niche. There are a lot of visual observers, so they can follow hundreds of stars nightly, estimating longer-period Mira or semi-regular stars at which photometrists rarely look, or cataclysmic variables and other unusual stars looking for signs of activity that would trigger researchers into action. So if you are satisfied with doing visual observing, we all still cherish your hard-earned observations! Visual observers in the AAVSO have been following some stars for almost 100 years, providing valuable long-term light curves. This work needs to continue.

There are some pitfalls to CCD imaging of the sky. One problem is that unfiltered CCD cameras are very infrared-sensitive. Some astrophotographers use IR-blocking filters to reduce imaging issues but every month I receive an email from an astrophotographer imaging with no filter stating that they have discovered a new star where one should not be. My first course of action is to search the coordinates for a Mira star or other red giant at that position in the sky, no matter how faint. These stars emit most of their energy in the infrared part of the spectrum so it is not unusual for these stars to look six or seven magnitudes brighter than on a visible-light image. Unfiltered CCD cameras are responsible for many false discoveries. Using the narrowband science filters completely cures this. On the other hand, those wishing a great challenge can invest in an I-band filter and do photometry in the infrared. The infrared sky is an unfamiliar area and many new discoveries await I-band amateurs.

One other drawback is that astronomical CCD cameras are still quite expensive and out of the reach of some amateurs. A few years ago, Meade introduced the monochrome Deep Sky Imager. Arne Henden, Director of the AAVSO, reviewed this camera in *Sky & Telescope* magazine and found it worthy as a beginning CCD camera for photometry; all for only a few hundred dollars. Digital cameras are now very popular and are producing amazing images of the sky. Although CCD-based, useful photometry cannot yet be done with these, it may just be a matter of time.

So much awaits the dedicated amateur who invests in a CCD camera and a V-filter!

Resources

AAVSO Photometry Handbook
`www.aavso.org/observing/programs/ccd/manual`
Discovery of a New Exo-planet
`http://hubblesite.org/newscenter/newsdesk/archive/releases/2006/22/full`
Dr. Arne Henden Review of Meade DSI
And Science, Too!, Sky & Telescope, October, 2005
History of CCDs
`www.ctio.noao.edu/CCD-world/Janesick.html`

Richard Huziak converted from a visual observer to a CCD observer two years ago, though he still gets to his Dob occasionally. He enjoys the precision of the measurements and the possibility for amateurs to do research and publish scientific papers. To keep him busy for the next few decades he has adopted a program to sort out whether or not 1400 suspected variable stars in the AAVSO catalogue are or are not variable. The sense of imminent discovery keeps him going — he currently is making brand new variable-star discoveries about every third night of imaging, proof of the power of CCDs!

Dr. David Guenther

by Phil Mozel, Toronto and Mississauga Centres (phil.mozel@sympatico.ca)

Not long before conducting the interview for this issue's column, an earthquake struck fairly close to my home. Well, *struck* may be too dramatic a term since the tremor was just barely detectable. Yet it was, I thought, well timed, since the subject of this column, Dr. David Guenther of St. Mary's University, Halifax has a keen interest in quakes...albeit none that occur on this, or any other, planet.

While doing initial research on Dr. Guenther's Web site, it wasn't anything astronomical that first caught my attention. Rather, it was the venue for some of his physics classes — The Gambia. For the past decade, St. Mary's has assisted in the development of higher education in this West African nation. Working with the government of The Gambia and other sponsors, faculty from Canadian universities and Gambian colleges taught university courses in a country that, at the time, had no university of its own. The core of the faculty came from St. Mary's. After the first 5 years, some 200 Bachelor's degrees had been conferred. Dr. Guenther's course was the first university-level physics taught there. By volunteering to participate he not only seized an opportunity to visit Africa but to do something both challenging and eminently worthwhile. It wasn't easy.

A nominal 13-week course had to be taught in 6 weeks. There was no equipment, no resources, and no real data with which to work. The climate was hot and humid and required a long acclimation period. Fortunately, the students were "*very* eager and talented." Some ultimately went on to study in Britain, France, or St. Mary's itself. However, for many, it was not possible to go abroad and most waited for the eventual opening of Gambia's first university (which, according to its Web site, offers a course in cosmology). In any case, the government asks that the students stay (or return) to apply their expertise at home.

Another attention-getter on Dr. Guenther's Web site was a link entitled "The Meaning of Life." This takes one to a painting, by Eugène Delacroix, of an orphan girl in a cemetery. I did not get a clear-cut answer as to why she was here. Instead, I was invited by Dr. Guenther to ask questions.

"Why is she there?"

"What do you think she is thinking?"

"What is important in life?"

It was up to me to decide. Dr. Guenther enjoys mixing disparate elements together thereby fostering inquisitiveness. (It turns out that this Web page gets a large number of hits and Dr. Guenther is rather distressed that so many people find it necessary to seek the meaning of life online.)

Dr. David Guenther

As for Dr. Guenther, he is seeking the meaning of quakes — star quakes, that is. Just as geologists can listen to different earthquake-generated sound waves and deduce the inner structure of our planet at different depths, helioseismologists can do the same with the Sun and other stars.

It was in the early 1960s that astronomers detected solar absorption lines moving back and forth, a Doppler effect due to gas rising and falling through a distance of several metres in the solar atmosphere every few minutes. This turned out to be the surface manifestation of sound waves trapped more deeply in the Sun. These standing waves, like the wind-generated waves that cause a telephone wire to hum, churn the Sun's surface into a boiling porridge of millions of separate oscillations that combine to make different surface patterns. Is the Sun humming, then? Might we be able to listen to its symphony? Alas, no. The range of frequencies tops out around twenty cycles per second, below the human threshold of hearing. And the cause? Turbulent motion in the outermost layers of the Sun's convective envelope.

With the changing distances of the rising and falling gas being miniscule, special equipment is needed to detect the effect when studying distant stars. This is where the Canadian Microvariability and Oscillations of STars (*MOST*) satellite comes in. Its 15-cm telescope is designed to stare at a target star for weeks on end and is capable of noting ridiculously small changes in brightness (comparable to detecting the "brightness variations caused by moving your eye just one-half millimetre closer to, or farther away from, a streetlight located one kilometre away"). No other device is capable of doing this. Making detections like these provides the data upon which theories of how stars operate will be built. The numbers provided by *MOST* will be crunched at St. Mary's Institute for Computational Astrophysics using software developed by Dr. Guenther, who is a member of the *MOST* science team. This allows astronomers, for the first time, to essentially get a detailed look inside far-distant suns.

The numbers indicate that *MOST* is seeing oscillations in other stars although they may be caused by mechanisms other than those operating in the Sun. And, during our conversation, Dr. Guenther expressed his excitement at the prospects of a meeting a few days later where *MOST* data for Alpha Centauri would be presented. These results will have an accuracy of one part in ten thousand. Solar results are accurate to one part in one hundred thousand! Not bad, considering that some astronomical results, particularly in years gone by, had double-digit percentage errors!

Asked if working with *MOST* has been exciting, the answer comes back strongly in the affirmative! Aside from the issue of national pride, there is also the matter of being one of the first explorers to face these new problems and to work on them using a new tool. Team members have turned up much that is unexpected, which "is what a scientist wants." After all, scientists "would rather have questions than answers."

As for getting into this business in the first place, it seemed like a stupid thing to do, at least according to some people with whom Dr. Guenther conferred. He had always wanted to be a scientist but was advised to become a physicist because, after all, how can you make a living as an astronomer? Ultimately, he did what he had always wanted, and turned to the stars. His influences? The term *Star Trek* came up at this point, with Dr. Guenther suggesting that many people became scientists because of its influence, which may have been even stronger than that of the *Apollo* missions. There were other influences not elaborated on. I was once again asked to explore on my own by following the *Acknowledgements* link on his Web site, as the reader is also invited to do.

And that's the way it went: the interviewer being challenged to ask more questions and explore the unexpected. This is also what Dr. Guenther hopes of all amateur astronomers. For example, he suggests that amateurs will be first to see certain types of stellar variability. He is emphatic that we *do* observe and submit our results. Then there is the question of Dr. Guenther's story of the stars and sheep...but that is an answer you will have to find for yourself.

(Dr. Guenther may be found at `apwww.stmarys.ca/~guenther/guenther.html`).

Philip Mozel is a past Librarian of the Society and was the Producer/Educator at the former McLaughlin Planetarium. He is currently an Educator at the Ontario Science Centre and a member of the new Mississauga Centre of the RASC.

Memories Wanted

Our December issue will celebrate the 100th volume of the *Journa*l and we'd like to paste your verbal memories into that issue. Do you have a special moment in astronomy that occupies a small corner of your long-term memory? It might be a person who helped you along, an open cluster that struck just the right visual note one night, an event — meteor shower, occultation, or aurora perhaps — that brings a warm feeling in a quiet moment. We'd like you to share it with us and with the generations of RASCals to come.

It can be poetic, photographic, sketched, or literary. A small paragraph (no more than 3 sentences and 50 words) will do just fine. A credit-card sized photo (300 dpi please), a sonnet or *haiku,* a small drawing — even a clean limerick (no one said it would be easy). We'll pick the best, or the most nostalgic, or the one with the correct punctuation of a compound adjective. Those selected will be published in Volume 100 in December. Contributions should be sent to *editor@rasc.ca* by mid-October.

Carpe Umbram

by Guy Nason, Toronto Centre (asteroids@toronto.rasc.ca)

"There was so much to say, but she's already gone, so
Thank you Carmen, don't be afraid; this is not the end,
So rest your head, I hope someday we will meet again.
Goodbye, Carmen"

— From the song *Good-bye Carmen,*
by Wilson Phillips, © 1992, Wilson Phillips

Carmen and I had a date last July 26. She promised to rise up above the eastern horizon and then, at 02:54 UT, do a neat little magic act, making her colleague, a real HIP star performer, 100244 disappear. Excited, I went to our agreed rendezvous spot at a place called Nirvana by local astronomers — actually an abandoned airstrip ninety minutes north of Kingston, Ontario. Wanting to preserve the magic moment for posterity, I set up my telescope, a low-light "surveillance" video camera and a TV/recorder combo unit. Carmen and HIP 100244 ("244" to her fans) appeared on schedule, but failed to perform their promised trick. 244 just glowed more or less steadily in a clear, but turbulent sky while I watched her on the monitor and did my best to feed Nirvana's mosquito population. (Question: Why do they call it Nirvana when it has all these hellish insects in abundance?)

Actually, I was not Carmen's only admirer on this occasion. Unfortunately, though, the infamous Cloud Curtain failed to rise sufficiently, so most were prevented from viewing the stage. They were "clouded out." The rest of us watched, but nothing special happened. Carmen (aka Asteroid 558) and her stellar companion wandered onstage together and just hung around. After awhile we all got bored, packed up and left.

The audience on the north side of the stage might have seen the effect, but unfortunately, everyone on that side was foiled by that balky Cloud Curtain. Even Geoff Gaherty, near Coldwater, Ont., who staked out front row centre, was done in by the Curtain. But a few of us on the south side of the house, including Eric Briggs near Barrie, Ont.; Leo Enright in Sharbot Lake, Ont.; Phil Mozel in Mississauga, Ont.; Kim Hay and Kevin Kell in Yarker, Ont.; and me in Nirvana, managed to dodge the Curtain. But none of us saw anything unusual. Well, almost none of us. Eric Briggs recorded a 23-second disappearance of HIP 100244. Expert critics contend that he must be in error, since Carmen is not equipped to hold the effect for more than about 4.6 seconds. We have no indication that Carmen was on steroids or otherwise "pumped up," so we think that a tattered end of the Cloud Curtain must have blown up and over at just the wrong time.

Although Carmen disappointed us, we didn't give up on her. She promised to try again with a different partner — a much less prominent starlet — on August 6. That gig would be even farther from home, so, given the act's record, I decided it was just too risky to invest in the extra gas and time. Instead, I chose to watch from my Gneiss Hill Observatory in eastern Ontario in case the Carmen entourage got a little off track — an all-too-common occurrence for these asteroidal magicians.

I took my seat in good time, but, again, Carmen let me down. This time I even got a good look at Carmen all by herself before she approached her new partner, TYC 6315-01445-1 ("Little Tyke"). But still the star failed to disappear. Most of the audience from the previous show did not return for this reprise. But those who did, including Frank Dempsey and Geoff Gaherty, were again foiled by that pesky Cloud Curtain.

Note to asteroid (558) Carmen: You eluded us twice in a dozen nights, my Pretty! But one of these nights we'll catch your act. For now all we can do is move on to other performers when they come to town. "I hope someday we will meet again." Make that some night.

Here's a list of upcoming potential asteroidal occultations over populated Canada. For more information on these and other events, including target star coordinates, finder charts, *etc.*, please visit Steve Preston's Web site: `www.asteroidoccultation.com`. Interactive Google maps for many of these occultations will be posted by Derek Breit at `http://www.poyntsource.com/New/index.htm` at least one week prior to the events. I'm sure you'll find at least one occultation coming to a sky near you. Please advise me of your plans.

Notes to the table:

Particularly favoured occulations are marked by an asterisk (*)
Oct 18 Quintilla: The asteroid will occult both components of the double star, HIP4716. Pick one and let me know your choice, please.
Oct 30 SAF: A binocular occultation! The star is 70 Aquilae (mag 4.9).
Nov 20 Tyson: The star is SAO 77744, 6.6° due east from ß Aurigae. The shadow path is only 11 km wide and the confidence of the predictions (at the time of writing) is extremely low. But other circumstances are good (star magnitude, altitude, absence of moonlight, *etc.*). Observers within 100 km of the path are encouraged to watch anyway. We know very little about "5-digit asteroids." All observations, even without good timing, would be useful.

Nov 26 Clarissa: Observers in every province except Newfoundland and Labrador have a good chance of seeing this event. It could be a truly national effort.

Dec 12 Kalatajean: Another small asteroid with a very uncertain path. (See Nov 20 Tyson above.) The star is SAO 40512, 5° southwest from ß Aurigae.

DATE 2006	TIME (UT)	ASTEROID NUMBER	NAME	STAR MAG	CHANGE IN MAGNITUDE	MAX DUR (s)	PATH
Oct 01	10:10	1724	Vladimir	10	6	3.5	nBC-sSK
Oct 03	0:51	25	Phocaea	8.8	1.6	6.3	eON
Oct 04	7:45	74	Galatea	10.1	2.2	48.4	eQC-wNL
Oct 06	12:38	144	Vibilia	11.6	1.2	8.9	sBC
Oct 07	2:21	341	California	7.1	6.1	1.8	nON
Oct 07	2:29	1605	Milankovitch	10.1	4.4	2.8	eNL
Oct 07	5:47	119	Althaea	11.3	1.1	9.6	cON
Oct 09	1:09	200	Dynamene	11.3	1.3	37.9	swON
Oct 11	9:33	46	Hestia	11.7	0.6	21.9	nON-seMB
Oct 15	4:40	208	Lacrimosa	11.9	2.5	4.5	seSK-swMB
Oct 18	4:52	1116	Catriona	9.8	5	5.2	SK only
Oct 18	6:20	755	Quintilla	7.6	7.4	2.5	NL-cQC-cON*
Oct 18	6:20	755	Quintilla	8.8	6.2	2.5	NL-cQC-cON
Oct 22	9:56	88	Thisbe	12.6	1	10.3	sBC-cON
Oct 27	1:52	1187	Afra	10.1	3.6	4.6	NL-QC-ON
Oct 28	8:37	275	Sapientia	12.4	1.4	12	swNS
Oct 29	12:06	101	Helena	12.3	1.3	6.1	sBC-wcSK
Oct 30	3:28	4162	SAF	4.9	12.1	1.5	nBC-nON*
Nov 03	6:08	132	Aethra	11.9	1.8	2.8	cQC-cON
Nov 03	7:35	24	Themis	11	1.2	9.5	nMB-sBC
Nov 06	10:32	258	Tyche	11.7	1	8.2	AB-seBC
Nov 07	3:35	1980	Tezcatlipoca	10.4	3.3	1	NL
Nov 09	5:08	695	Bella	11.7	1	4.7	nwON
Nov 10	1:48	1040	Klumpkea	9.5	4.6	3.9	NL
Nov 12	2:28	3667	Anne-Marie	6.3	10	3.6	AB
Nov 12	5:12	637	Chrysothemis	11.8	3.8	3.1	nAB-cBC
Nov 16	7:55	414	Liriope	11.6	3.1	8.4	swON
Nov 17	6:41	1031	Arctica	11.5	2.7	5.5	swSK-MB
Nov 20	3:36	13123	Tyson	6.4	9.7	0.8	swNS-sON*
Nov 22	3:44	1988	Delores	11.3	5	2.8	nwON-seMB
Nov 23	6:49	1283	Komsomolia	10.9	3	2.8	NL-ON
Nov 24	9:50	18	Melpomene	11.2	0.4	27.5	seON-nBC
Nov 25	11:47	1980	Tezcatlipoca	8.6	4.5	1	nSK-cBC
Nov 26	3:51	422	Berolina	10.7	2.6	4.1	swNS
Nov 26	9:24	302	Clarissa	11.9	1.4	4.4	NS-BC*
Nov 27	7:14	2152	Hannibal	12.3	1.8	4.6	nMB-sAB
Nov 30	8:53	2806	Graz	9.8	6.4	2.3	sQC-sBC
Dec 01	9:37	242	Kriemhild	11.6	2.3	3.8	BC
Dec 01	12:25	407	Arachne	11.7	1.2	9.4	sSK-nBC
Dec 02	1:50	407	Arachne	9.7	2.8	9.3	cQC-cON
Dec 02	8:36	242	Kriemhild	11.7	2.2	3.9	swSK-cBC
Dec 02	9:42	1988	Delores	11.3	4.7	2.3	NS-nBC
Dec 05	6:10	3615	Safronov	7.4	9.2	1.7	NL-swSK
Dec 09	2:53	371	Bohemia	11.7	2.4	3	sBC-nQC
Dec 11	2:32	13832	1999 XR13	11.5	4.3	3.1	NL-ON
Dec 11	12:01	164	Eva	9.3	5.6	6	cMB-nwON
Dec 12	6:24	5976	Kalatajean	6.4	9.9	1	sON*
Dec 12	8:22	242	Kriemhild	11.1	2.6	6	eQC-NS
Dec 13	1:23	2961	Katsurahama	11.8	3.1	4.1	nNL-nON

Pen & Pixel

Figure 1 — NGC 4565 in Coma Berenices by Albert Saikaley. This image was taken with a Celestron 11 at f/7 using an SBIG ST10-XME camera and an AO-7 guider. The exposures, in LRGB, were 60, 15, 15, and 20 minutes in duration. One of the best edge-on galaxies, NGC 4565 is a gem both visually and photographically. At magnitude 9.7, its stellar core and dark dust lane can be seen easily through even modest telescopes.

Figure 2 —This image of M74 was provided by Stef Cancelli, but was acquired using a telescope located at Kitt Peak. According to Stef "A bunch of us from the RASC contributed to renting some time on the Kitt Peak 20-inch RC so we could share the data." The image was acquired between October 5 and 7, 2005 by Paul Mortfield and Dietmar Kupke using the 20-inch Ritchey-Chrétien telescope at f/8.3. The exposure consists of 13 luminance images at 10 minutes each (binned 1×1), and four 10-minute images (binned 2×2) in each of the R, G, and B filters.

Transit Tandems and Tetrads

by Bruce McCurdy, Edmonton Centre (bmccurdy@telusplanet.net)

I know that I am mortal by nature, and ephemeral, but when I trace at my pleasure the windings to and fro of the heavenly bodies I no longer touch earth with my feet: I stand in the presence of Zeus himself and take my fill of ambrosia, food of the gods.

— Claudius Ptolemy

Ptolemy got a bad rap as far as I'm concerned. Certainly he was anchored to a faulty premise — the geocentric Universe — but his system of epicycles and deferents was an ingenious attempt to solve a complex problem. The basic idea of circles within circles was the right sort of geometry that simply required Earth to be set free to trace its own loop around the true centre of the Solar System.

Surely Ptolemy's pleasure was peppered with puzzle when it came to Mercury. Bound by the Sun's tight gravitational leash, the elusive innermost planet winds to and fro rapidly and erratically. Its bi-monthly apparitions to either side of the Sun last a few weeks at best, and are next to unobservable at worst. How best to get a fix on the nature of the Winged Messenger's windings?

The keys to the puzzle were discovered 1500 years after Ptolemy's time by Johannes Kepler, who combined the theory of Copernicus and the observations of Tycho with his own elliptical insights and considerable mathematical skills to develop his famous Three Laws of Planetary Motion (Sobel 2005). A man after my own heart, Kepler frequently strayed into such interesting diversions as the perfect solids, the golden ratio, and "the Music of the Spheres" in his quest to make cosmic sense of it all (Gingras 2003).

Among Kepler's many accomplishments were the successful predictions of the transits of Mercury and Venus in 1631, in November and December respectively. At such moments the brilliant Sun, normally an implacable adversary that regularly thwarts our view of Mercury, becomes an invaluable aid. The prepared observer can briefly capture the Winged Messenger in stark silhouette and measure, in the manner of a bird-bander, its exact position and size.

As with all things planetary, such encounters are periodic. Because they can only occur under exacting circumstances, transits are particularly precise measuring sticks that will yield true periodicities of the planet in question with respect to Earth.

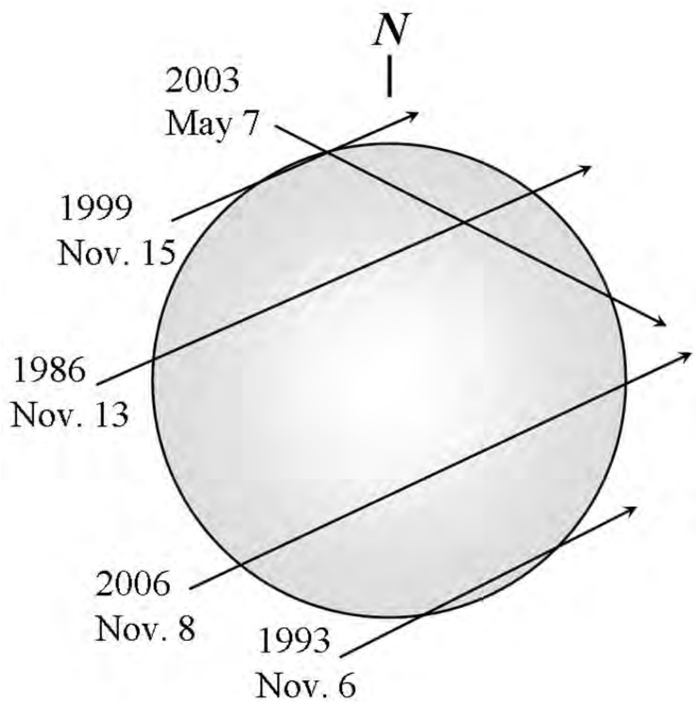


Figure 1 — The paths of the five transits 1986-2006 are shown. As might be expected from such a proliferation of events, none of them is particularly central. This is analogous to similar clusters of solar and lunar eclipses such as duos, double duos, and tetrads, all of which involve relatively grazing events. Note particularly the exceptional six-year pair of 1993-99, two marginal events just barely falling within the opposite extremes of the ten-day November transit window. Note also the sequential calendar dates from bottom to top of the diagram; a central transit would occur around November 10. The May transit at the descending node is clearly the black sheep of this family. (Diagram courtesy Russ Sampson, RASC Edmonton Centre and JRASC Contributing Editor.)

Such periodicities can nowadays be calculated by other means. Meeus (1997) discusses one such method using modern values:

> "The sidereal revolution periods of Earth and Mercury are 365.256363 and 87.969256 days, respectively. If we divide the first value by the second, we obtain 4.152091. If we

now search for successive fractions with integer numerator and denominator, and which converge ever more closely to the given value 4.152091, we obtain:

4/1 25/6 29/7 54/13 137/33 191/46 901/217

"In the denominators of these fractions we find the periods [for Mercury]. For instance, the fraction 54/13 means that 13 sidereal periods of the Earth correspond to approximately 54 revolutions of Mercury."

Meeus goes on to state that the first fraction corresponds to 1 year, but it is too inaccurate to be very useful. Experienced observers will know that each year apparitions of Mercury occur some $2^1/_2$ weeks earlier than the previous year. However, the subsequent periods are increasingly accurate, and all can be found in transits of Mercury (see Table 1). And if one looks hard enough, even the one-year "period" can be found to play a role.

Using the best periods, Meeus (1989, 2002) developed a panorama for each node with rows of 46 years and columns of 217, covering all transits of Mercury in an unbroken latticework of dates. This spreadsheet is efficient in that every transit is represented and every cell is full, but the intervals between transits are not apparent, and the sequence of events can only be followed by jumping around in a barely discernable pattern: for example, the transit of 2006 appears 3 columns to the right and 14 rows above its predecessor in 1999.

I have developed a different method I call a "window panorama" (see Table 2). The columns are separated by six to seven years, the time it takes Mercury to complete one extra revolution over and above the base 4:1 ratio and effectively "lap" Earth. Each such occurrence represents a window of opportunity. Sometimes the window is open, sometimes it's closed. But the gaps in the data still contain information, as they accurately display the interval between transits. Better yet, the transits are laid out in chronological order.

The rows are at the excellent intermediate period of 46 years, containing exactly seven windows, which at the ascending node typically result in four, exceptionally five November transits. The "full" windows form lengthy series of some 19 events at the 46-year interval, with Mercury's path across the Sun gradually shifting northward from one event to the next, followed by a lengthy hibernation at that window. For example, the grazing transit of 1999 was the last one of a series that began in 1171. In 2045 Mercury will achieve inferior conjunction a few hours too late for a transit. One year later it will be a number of days too early. But many centuries after that, a new series starts in that window, offset by one year to the sequence of the old series. Note that Series B will resume in 2644, after a hibernation of 645 [(14*46) + 1] years. Thus does the "imperfect" period of one year manifest itself, by allowing the intervals between columns to vary between seven and six years.

The still better period of 217 years can be seen in the gradual diagonal shift, typically two columns to the left every fifth row. Note the start dates of the series: 1776-1993-2210-2427....

Space does not permit a similar panorama at the descending node, which would be much sparser, with typically two transits per seven windows of opportunity. To my astonishment I discovered that in the present era, all May transits are *invariably* followed by a November transit $3^1/_2$ years later, an inseparable pair I call a "transit tandem." Therefore the second panorama can effectively be superimposed on the first! In Table 2 the second event of these transit tandems is shown in **bold** (**blue** in the on-line *JRASC*), and represents a **pair** of transits. The pattern of May transits can be seen by simply considering those boldfaced entries, and dates can be derived by subtracting three years.

The stability of this May-November romance can also be readily seen. The columns show that the 10-event May series currently occur just about dead centre in the 19-event November series. In other words, every May transit is followed $3^1/_2$ years later by a fairly *central* one in November, never a marginal event. I am certain that one could search many millennia into the past or future before finding a single example of a May transit without a counterpart ~1282 days later. At present it's an infallible predictor.

On the other hand, since the "halves" of Mercury's orbit are asymmetric, May transits are immediately *preceded* by November transits only rarely, with the invariable result a seven-year transit trio such as has happened in 1999-2003-2006. (McCurdy 2006)

The 2006 transit is the finale to quite an interesting sequence. Not only is it the last member of a transit twin, tandem, and trio, it is the final instalment of a rare transit tetrad. This is a group of 4 November transits in just 20 years, the sequence 1986-1993-1999-2006. The rarity here is the 6-year interval 1993-99, which is only possible with a pair of nearly grazing events at opposite poles (see Figure 1). The next such tetrad will occur in the 29th Century.

Counting the May 2003 event, there have been five transits in the past two decades. It follows that there will be a lull after the 2006 event. But circumstances favour us. After $9^1/_2$ years there will be another May event in 2016, which is inevitably followed by a November counterpart in 2019. Fortunately, North America is again favoured for *both,* meaning it will have been possible for an observer in a universally central location (say, Toronto) to have observed 5 consecutive transits in just 20 years, plus 2 of Venus! Only then will the expected lull kick in, with no more Mercury transits to be seen from this continent until 2049. For now, however, the transit gods are with us, so let's follow Ptolemy's lead and take our fill.

Dedication

This column is dedicated to Dr. Doug Hube, Honorary President of Edmonton Centre, astronomer, academic, marathoner, bird-bander, and a pillar of every community fortunate enough to have him.

Bruce McCurdy has long been fascinated with the natural rhythms of the solar system. He does some of his deepest thinking on the subject while attending concerts of the Edmonton Raga Mala Music Society, of which he is a patron member of long standing.

Table 1.

Periodicities of Mercury

Revs	Years	Days	R.	May displ.	# in series	Nov. displ.	# in series
4	**1**	**-17**	0	> S.D.	-	> S.D.	-
25	**6**	**+10**	1	> S.D.	-	+1890″	2
29	**7**	**-7**	1	> S.D.	-	-1390″	2
54	**13**	**+3**	2	-1030″	2	+500″	4
137	**33**	**-2**	5	+830″	2	-390″	4
191	**46**	**+1**	7	-200″	10	+100″	19
901	**217**	**+3**	33	<+25″	??	<+20″	??

Table 1

The number of revolutions of Mercury in the first column results in roughly an integer number of Earth years, plus or minus a few days. The R. column is the remainder when dividing the first column by the second, and represents the number of times Mercury "laps" Earth near the node during the period in question. The periods of six and seven years are not possible for May transits, as Mercury is displaced by more than the solar diameter of >1900"; however both are possible in the November window. The displacement during longer periods is roughly half as much in November as May, so the number of repetitions in a series is about double.

The period of 217 years and 3 days is especially accurate, generating very long series at both nodes. The apparent "error" of 3 days is almost commensurate with the precession of Mercury's nodes, which is about 1.3 days per century. It is interesting that the 217-year period does not follow the normal rule of displacements of opposite signs at opposite nodes, in a similar manner as the 243-year period of transits of Venus (McCurdy 2004). Both periods are so good that the small remaining variations are due to oscillating secondary factors.

Table 2

The Music of the Spheres, from the time of Kepler to a thousand years hence. In this device I call a "window panorama," the rhythm of transit cycles can be seen. The columns separated by six *or* seven years represent each window of opportunity for a transit. To this aficionado of Indian classical music, the pattern resembles a seven beat tal (rhythm cycle) subdivided into three groups, each ending in an "empty" beat. In fact, such a rhythm is known as Rupak tal, seven beats divided 3-2-2 (Russell 1997).

As described in the text, the bolded events represent a transit tandem where two transits occur in the window, descending (May) node first, then ascending. The implied May transits can be considered to fall a "half beat" ahead of their November counterparts. May transits *never* occur in an empty beat.

The letters labeling the columns were defined by Meeus (1989), derived from the sequence of 46-year series (starting in 1600, Series A ends first, then Series B...). That the columns are labeled A through G evokes another musical analogy, that of pitch. The lowercase letters are defined by the writer in simple chronological sequence of the transit windows; each row could be played as a simple note progression or chord, which would allow one to "hear" the gradually changing sequence of the 46-year pattern. Kepler would have loved it!

Table 2:

Transits of Mercury 1601-3000

Bold/blue - transit tandems: follow May transit by $3\frac{1}{2}$ years
Underline - transit duos (twins) at interval 2550 days
Italic plus underline - double duos (transit tetrads) 4 in 20 years

D	G	C	F	B	E	A
a	b	c	d	e	f	g
1605		**1618**		**1631**		1644
1651		**1664**		**1677**		1690
1697		**1710**		1723		1736
1743		**1756**		*1769*	*1776*	*1782*
1789		**1802**		1815	1822	
1835		**1848**		1861	1868	
1881		**1894**		1907	1914	
1927		**1940**		1953	**1960**	
1973		*1986*	*1993*	*1999*	***2006***	
2019		2032	2039		**2052**	
2065		2078	2085		**2098**	
2111		2124	2131		**2144**	
2157		2170	**2177**		**2190**	
2203	2210		**2223**		**2236**	
2249	2256		**2269**		**2282**	
2295	2302		**2315**		**2328**	
2341	2348		**2361**		**2374**	
2387	**2394**		**2407**		2420	2427
	2440		**2453**		2466	2473
	2486		**2499**		2512	2519
	2532		**2545**		2558	2565
	2578		**2591**		2604	**2611**
	2624		2637	2644		**2657**
	2670		2683	2690		**2703**
	2716		2729	2736		**2749**
	2762		2775	2782		**2795**
	2808	*2815*	*2821*	*2828*		**2841**
	2854	2861		**2874**		**2887**
	2900	2907		**2920**		**2933**
	2946	2953		**2966**		**2979**
	2992	2999				

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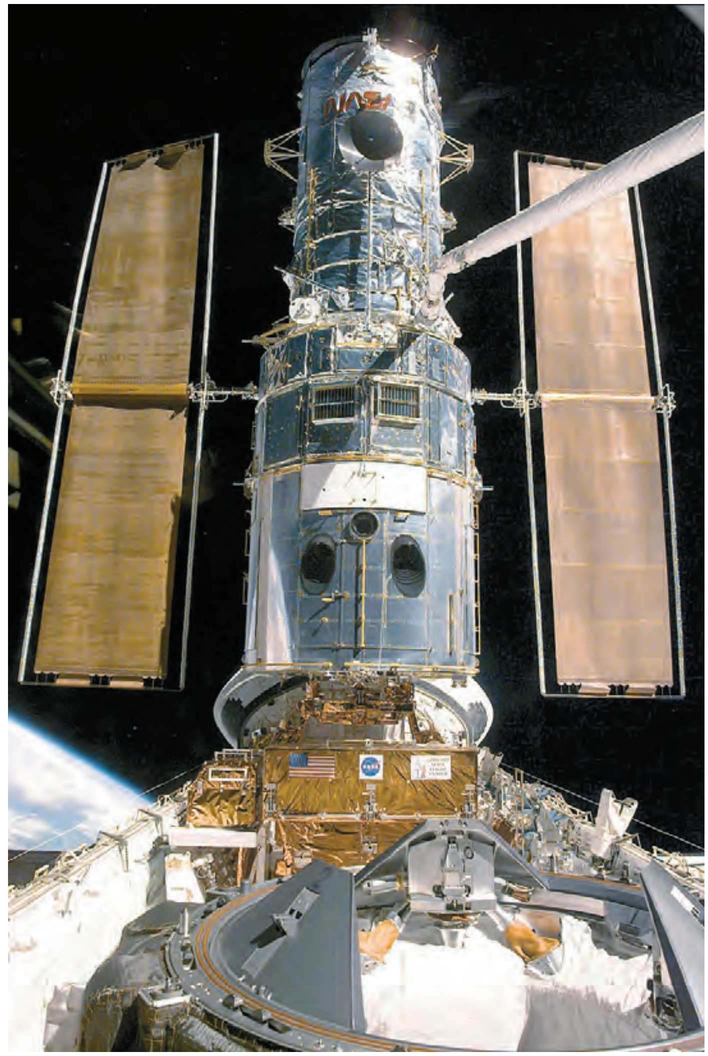
Net Astronomy

by Paul J. Langan (Paul@Langan.ca)

Exciting Images

When people think of images of far-off galaxies and all manner of other exciting objects, it is the *Hubble Space Telescope* that most often springs to mind. Yes, it has had a few problems but it has still managed to gain us tremendous knowledge and capture the minds of people in a way not seen since *Apollo*. This site not only has a spiffy collection of *Hubble's* high-quality images of galaxies, stars, the Solar System, and nebulae, but the site's authors are eager to hand out photos for you to print out — providing not only step-by-step instructions (geared to kids), but also a variety of resolutions, all the way up to 16 × 20-inch wall hangings, if you are lucky enough to own a printer that large (and an ink factory). The other notable thing about this site is that it gives an insight to the *Hubble*'s launch, repair, and ongoing operations through its images. For readers who prefer movies, it is a veritable video store, with intriguing explorations of astronomical objects, and *Hubble* launch, maintenance, and repair missions. Highly recommended is a video of the Helix Nebula that will reveal its surprising 3-dimensional shape. Movies are in QuickTime, but the photos come in a variety of formats. Be prepared for a big download and if the collection entrances you, there is a wallpaper selection to keep on your desktop. This site is especially easy to navigate, and kids and adults can while away the afternoon in this electronic attic.
`http://hubblesite.org/gallery`



HST spacecraft.

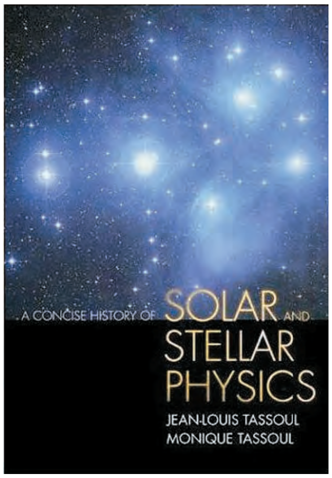
Origins

How did galaxies form? Are there life-sustaining planets around other stars? Is somebody out there?

These questions and others form the basis of the *Origins* site, though they may be a tad optimistic in promising that "some of the answers are within our grasp." The site is a kind of omnibus gallery of NASA missions that are related to the questions — missions with ominous names such as *WIRE, FUSE, SIM*, and *PI*. It is not a stand-alone site in its own right, but more a set of links to "origin"-related explorations, some of them very advanced and loaded with resources and educational materials. The site is designed well but a few of the links to missions do not work (in particular, to Keck and Palomar) and I have to put in a caveat that the site is a little out of date — not old, but too new. Some of the deeper part is still under construction. Still, the titles are intriguing, and worth revisiting on occasion to see what's happening once some content is installed. As it is, the site is worth a visit and the links will keep you busy for a considerable time. In the not-too-distant future, the question of origins will be uppermost on our astronomical minds and we will all be looking here.
`http://origins.stsci.edu/under/understanding.shtml`

Paul Langan is President and CEO of a multinational company and a Fellow of the Royal Commonwealth Society, but his heart is more directed to the stars. If you have recommendations for future site visits, please email him at the address above.

Reviews of Publications
Critiques d'ouvrages



A Concise History of Solar and Stellar Physics, by Jean-Louis Tassoul and Monique Tassoul, pages 282 + xiii, 16 cm × 24 cm, Princeton University Press, 2004. Price $39.95 US hardcover (ISBN 0-691-11711-X).

You know you are getting old when you encounter the names of colleagues, friends, and co-authors of your research papers in a history book on your field of study. That was my sobering experience as I thumbed through Jean-Louis and Monique Tassoul's *A Concise History of Solar and Stellar Physics*. Normally I do not get terribly excited at the prospect of reading through a dry history of the early years of astronomy, particularly when many of the more notable characters are better known for rather absurd ideas and some of the more colourful characters led lives far outside the standard fare of the present era. But *Concise History* manages to present a fresh outlook on the history of stellar astronomy, a field of study that I sometimes worry may soon become extinct. The outcome is a delightfully readable and comprehensive study of the major developments in stellar astronomy over the past few millennia.

Concise History is an extremely well-written book, and I say that with great respect given that I daily put up with the illiterate writing that is commonplace in recent journal papers, not to mention in an upper-year course textbook that has a dangling participle in every other sentence! By comparison *Concise History* was a breath of fresh air for me, and I eagerly lapped up each chapter. In the process I found myself learning a lot about my field of which I was previously unaware. An example is Kelvin-Helmholtz contraction, or more properly Helmholtz-Kelvin contraction, which, as an energy source for the Sun and stars, originated with the Scottish physicist John James Waterston. Like many concepts in astronomy, it is the popularizer, not the originator, who is eventually associated with it.

The book also presents astrophysical concepts through the development of equations, so in that respect it is also very much like a course textbook. But one with a difference — *Concise History* contains some very elegant developments of fundamental equations that presents them in a fashion that makes it far easier for students of the discipline to grasp than is the case in every other textbook in my experience. I found myself mentally placing tabs here and there throughout the book to assist me later in preparing course notes for my stellar-astronomy course. It is to the credit of the authors that they have managed to transform the often dry plodding of equation development into a revelation of how simple concepts are used to develop more complex results. At times the book is quite brilliant in how ideas are presented.

That having been said, I was a bit dismayed to find that the writing style of the book tended to degenerate towards the end, as the authors traced historical developments contemporaneous with their own research careers. Here, sadly, the writing style tends more towards the North American jargonese that promulgates the current literature in the field.

There are a number of recurring themes throughout the book: the Sun, development of ideas in stellar evolution, end stages of evolution, and pulsation theory of variable stars, to name the most prominent. All are infinitely readable and educational. It is instructive to follow how concepts developed and changed with time, the early incorrect ideas about stars evolving towards cooler surface temperatures and lower luminosities being but one of them. It is also interesting to see how the authors fit some of the lesser-known ideas into the grand picture. Here, for example, I mention the work of Olin Wilson in helping to develop the study of ionized calcium flux variability in stars as analogous to the solar sunspot cycle, that of Bill Herbst in studying rotation in T Tauri stars through their periodic brightness fluctuations, and the work by the authors themselves (not to mention that by my Université de Montréal colleagues) on white dwarf asteroseismology. Nothing seems to have been omitted, and it is nice to see how current research extends and clarifies the work of our earliest ancestors doing stellar astronomy.

Overall *Concise History* is probably not a book for everyone. Mathematical developments are introduced fairly early in order to describe first-year concepts such as distance from parallax and the Doppler effect in stellar spectral line displacement, and reach a pinnacle with the Lane-Emden equations describing polytropic models of stars. Instructors will find the book to be a valuable resource in that regard, particularly for developing the history of how important ideas evolved. More casual readers could easily skip the numbered equations and still find a lot to interest them. It is, quite simply, an excellent summary of the important developments in stellar astronomy over the ages. There are still some of us out there who are interested in stars, right?

David Turner

David Turner is book review editor for the JRASC *as well as a professor in the Department of Astronomy and Physics at Saint Mary's University. His research is centred on stellar astronomy, which he believes is still one of the most exciting fields in astronomy.*

Mauna Kea: A Guide to Hawai'i's Sacred Mountain, by Leslie Lang and David A. Byrne, pages 146 + vi, 14 cm × 21.5 cm, Watermark Publishing, 2005. Price $17.95 US softcover (ISBN 0-975-37405-2).

Mauna Kea is a special place — sacred to Hawaiians because of its significance to their culture, and sacred to astronomers because of the exceptional seeing conditions. A trip to the Hawaiian Islands by anyone with an interest in astronomy should include a visit to Hawaii (the Big Island) in order to see the observatories and to experience the observing conditions at the summit of Mauna Kea.

Such a visit is truly an adventure that must be planned carefully. The summit is about two hours away from the two most popular tourist destinations on the Big Island, Kona and Hilo. The summit of Mauna Kea is at an altitude of 4 km, which places it above almost half of the Earth's atmosphere and thus half of its oxygen. Typical daily temperatures range from -5 C to +5 C. The access road is rough and, without due care, can be treacherous. Such conditions make for a rigorous journey.

In spite of the challenges, the trip is well worth the effort. The general observing conditions at the summit of Mauna Kea are, arguably, the best in the world. The seeing at times rivals that available to the *Hubble Space Telescope*. The view of both land and sky is magnificent! Anyone with a strong interest in astronomy, the requisite physical condition, and the resources to get to the summit, should pay a visit. It is an unforgettable experience.

*Mauna Kea: A Guide to Hawai'i's Sacred Mountai*n is an excellent resource for planning such an adventure and for understanding the mountain. The authors of the *Guide* are locals to the Big Island. David A. Byrne is the manager of the Mauna Kea Visitor Information Station that is located about 1.4 km below the summit at Hale Pohaku. Leslie Lang is a writer who lives on a slope of Mauna Kea.

The *Guide* is divided into nine chapters: Visit Mauna Kea, The Sacred Mountain, Natural History, Recreation, Visitor Information Station, Astronomy on Mauna Kea, Maunakea Discovery Center, The Future, and Resources.

The first chapter carefully outlines all that a traveller needs to know about conditions at the summit and how to get there.

It lists and describes natural and historical sites that one can see and/or explore along the road leading to the summit. The importance of the mountain in Hawaiian culture is sensitively treated in the second chapter. It is important to appreciate that the Hawaiians are truly generous in permitting the astronomical community to use the summit for research.

Of most interest to astronomers, chapter 6, "Astronomy on Mauna Kea," lists the properties of the mountain that make it ideal for astronomy, and provides a detailed "Self-guided Drive to the Summit," which guarantees that you will see everything. It is followed by a detailed description of each of the observatories at the summit. The descriptions include a brief history, details of the instrumentation, and research areas. The *Guide* also provides Web site URLs for each of the observatories. Good preparation for a trip to Mauna Kea would include viewing the Web sites in order to become familiar with those observatories. Since there is so much to see and do at the summit and the time actually spent at the summit is inevitably brief, advance familiarization by reading the *Guide* and viewing the Web sites would greatly enhance the experience. Visitors from Canada would be especially interested in visiting the observatories that Canada supports: the Canada-France-Hawaii Telescope, the James Clerk Maxwell Telescope, and the Gemini North Telescope.

The *Guide* is filled with many photographs, of which some are magnificent examples of what awaits. There are four maps: Island of Hawai'i, Summit Area, Cultural and Religious Sites, and Observatories and Facilities. The maps are useful in finding many of the locations mentioned in the text. Unfortunately, the Cultural and Religious Sites map is very sketchy and extremely difficult to relate to the other maps and to the text. Perhaps a future edition of the *Guide* will improve the map since much of the discussion in Chapter 2 relates to it.

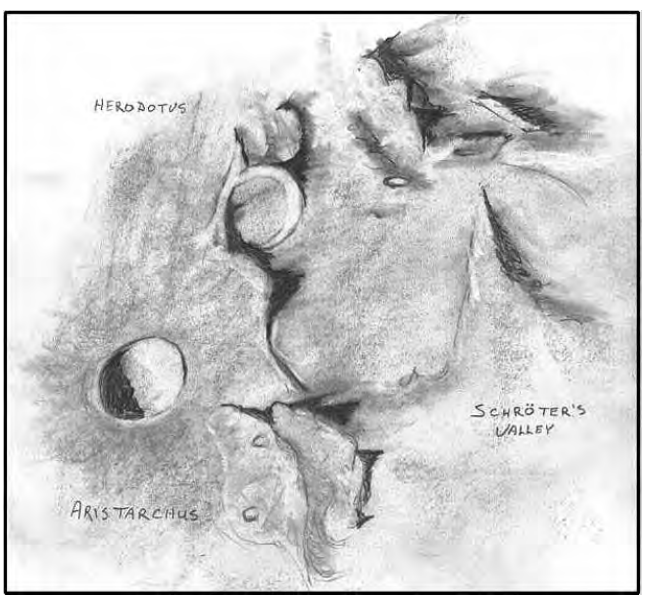
Overall, the *Guide* will be very useful for visiting Mauna Kea. I wish that it had been available during the year that I spent living on the Big Island. It would have enriched my understanding and appreciation of Mauna Kea. I plan to use it during my next visit to locate the Adze Quarry near the summit that I did not even know existed.

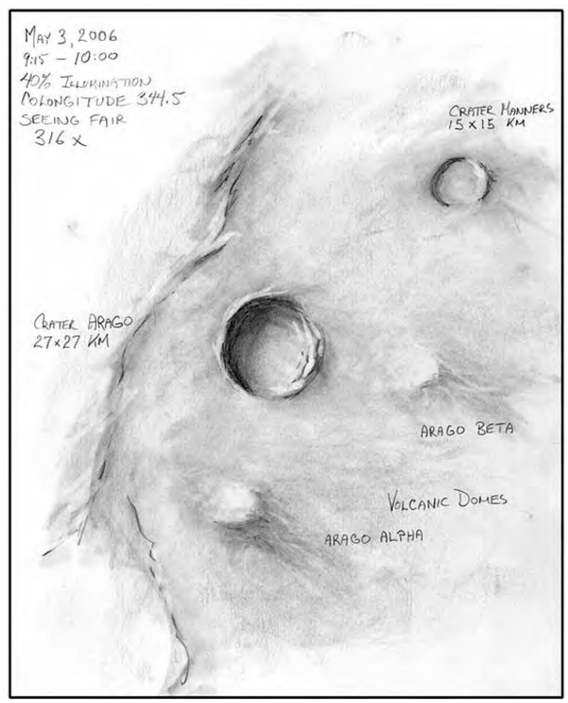
Richard Bochonko

Richard Bochonko, a Senior Scholar in the Department of Physics and Astronomy at the University of Manitoba, is enjoying his retirement in Victoria. He spent his sabbatical leave in 1983-4 working at CFHT on the Big Island.

Two lunar sketches

by Guy Mackie, Okanagan Centre.



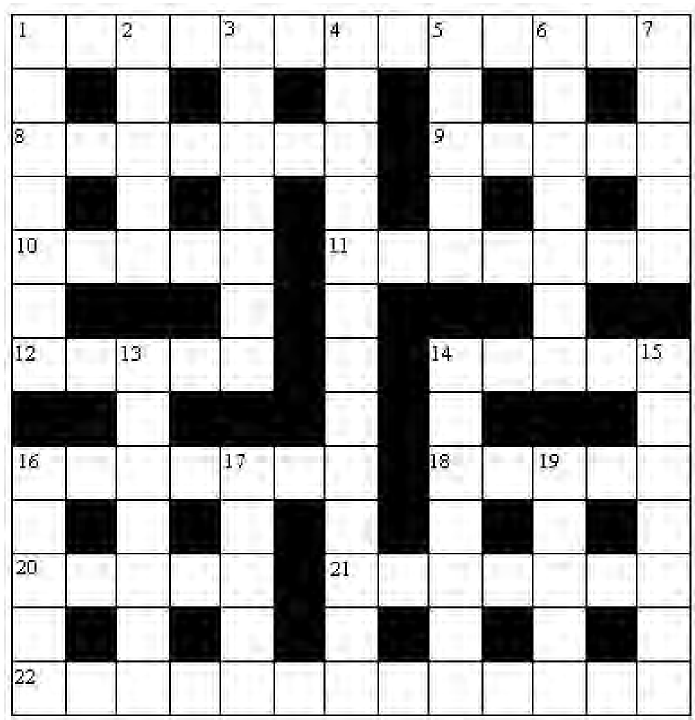


These lunar sketches by Guy Mackie of the Okanagan Centre show two of the thousands of attractions available to lunar observers. The left image, of Aristarchus, Herodotus, and Schröter's Valley, shows an area that has long fascinated amateur astronomers. The crater Aristarchus, toward the lower left, has a diameter of 46 km and is the brightest feature on the Moon. It has been reported as a source of Transient Lunar Phenomena (TLPs). According to the Lunar Section of the Association of Lunar and Planetary Observers (ALPO), transient lunar phenomena can consist of red glows, flashes, obscuration, and abnormal albedo and shadow effects. Curving around the centre of the drawing and ending just under the crater Herodotus is Schröter's Valley. The terminus of the Valley, where it widens, is known as the Cobra's Head.

The right hand drawing shows the crater Arago and two volcanic domes, Arago Alpha and Arago Beta. The two domes are subtle features, 20-26 km in size, best seen under oblique lighting conditions. Volcanic domes on the Moon are akin to shield volcanoes on the Earth and tend to be wide, rounded, circular features formed by highly viscous lava erupting from vents. Arago Alpha and Beta are among the largest and most-distinct domes on the Moon.

Astrocryptic

by Curt Nason, Moncton Centre



ACROSS

1. A jumbo nuclear explosion from the old LMC (8,5)
8. Theoretical time standard from an average star (4,3)
9. Southern sky figure across or within dust lanes (5)
10. Southern star followers rearranged Greek character (5)
11. Electric motors around with no end to ocular wire (7)
12. Health club opens near the Church of England in the final frontier (5)
14. Mislabel a catalogue of galaxy clusters (5)
16. Greek cross half rusted by a radio source in M1 (6,1)
18. Put us in gas chamber to measure magnetic field (5)
20. Rigel begins in clenched hand at this magnitude (5)
21. One on time will be sick antisunward of a comet (3,4)
22. Blue rain leaps out of old galaxies (6,7)

DOWN

1. Men turn to eastern sibling when faced with solar system disruptor (7)
2. Boast about gravitational acceleration x-tal X-ray spectrometer (5)
3. Professional astronomers from French line of Kembles (7)
4. Earth wobbles to turn a lunation around (5,8)
5. Wet one in our space telescope (5)
6. Past President Star Wars knight touches Dickens midsection (7)
7. Earl tossed roses in the whirlpool (5)
13. Somehow Iraqi gold symbolically belongs to a bearer of water (7)
14. Big lane swirling near Gamma Pegasi (7)
15. The room in Québec where *Les Observateurs de la Magnitude Absolue* meet
16. Spats arising from image file formats (5)
17. Return in smart lunar probe to beyond beginning (5)
19. You soundly hula around a way to cart your big scope (1-4)

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576 - Concession 7 E, PO Box 1223, Waterdown ON L0R 2H0

Kingston Centre
PO Box 1793, Kingston ON K7L 5J6

Kitchener-Waterloo Centre
460 Sandbanks Cres, Waterloo ON N2V 2J2

London Centre
PO Box 842 Stn B, London ON N6A 4Z3

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

Mississauga Centre
c/o Randy Attwood, 4348 Dallas Ct, Mississauga ON L4W 4G7

Moncton Centre
c/o Dr. Francis LeBlanc, Département de Physique et Astronomie,
Université de Moncton, Moncton NB EIA 3E9

Montreal Centre
PO Box 1752 Stn B, Montreal QC H3B 3L3

Niagara Centre
PO Box 4040, St. Catharines ON L2R 7S3

Okanagan Centre
PO Box 20119 TCM, Kelowna BC V1Y 9H2

Ottawa Centre
1363 Woodroffe Ave, PO Box 33012, Ottawa ON K2C 3Y9

Prince George Centre
7365 Tedford Rd, Prince George BC V2N 6S2

Québec Centre
2000 Boul Montmorency, Québec QC G1J 5E7

Regina Centre
PO Box 20014, Regina SK S4P 4J7

St. John's Centre
c/o Randy Dodge, 206 Frecker Dr, St. John's NL A1E 5H9

Sarnia Centre
c/o Marty Cogswell, 6723 Pheasant Lane RR 1, Camlachie ON N0N 1E0

Saskatoon Centre
PO Box 317 RPO University, Saskatoon SK S7N 4J8

Thunder Bay Centre
286 Trinity Cres, Thunder Bay ON P7C 5V6

Toronto Centre
c/o Ontario Science Centre, 770 Don Mills Rd, North York ON M3C 1T3

Vancouver Centre
1100 Chestnut St, Vancouver BC V6J 3J9

Victoria Centre
333 - 1900 Mayfair Dr, Victoria BC V8P 1P9

Windsor Centre
2831 Alexandra Ave, Windsor ON N9E 2J8

Winnipeg Centre
PO Box 2694, Winnipeg MB R3C 4B3