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Journal

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INSIDE THIS ISSUE

Using the Medical Image-Processing Package, *ImageJ*, for Astronomy
DSLR Astrophotography, Part 1 • Near Earth Asteroid (2004 XP14)
night-flight • Investigating the Basic Properties of Black Holes Using
Newtonian Mechanics

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contents

table des matières

FEATURE ARTICLES/ARTICLES DE FOND

242 Using the Medical Image-Processing Package, *ImageJ*, for Astronomy

by Jennifer L. West and Ian D. Cameron

248 DSLR Astrophotography, Part 1

by Doug George

250 Near-Earth Asteroid (2004 XP14)

by Rick Stankiewicz

251 *night-flight*

by Sherrilyn Jahrig

279 Great Images: Celebrating 100 Years!

EDUCATION NOTES/RUBRIQUES PÉDAGOGIQUES

252 Investigating the Basic Properties of Black Holes Using Newtonian Mechanics

by William Dodd

Astrocryptic Answers
p. 275



DSLR Astrophotography
p. 248

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DEPARTMENTS/DÉPARTEMENTS

238 President's Corner

by Scott Young

239 News Notes/En manchettes

Planet-Planemo Twin Mystery/Looking deep into NGC 6397/The Baffling Champagne Supernova

274 Reviews/Critiques

Dying Planet: Mars in Science and the Imagination

276 Index to Volume 100

ACROSS THE RASC
DU NOUVEAU DANS LES CENTRES

265 New RASC Web Site Launched!

by Denis Grey

272 Beaver Hills Dark Sky Preserve

by Bruce McCurdy

273 Astronomy Roundup 2007 - Call for Papers

Astronomy Roundup Organizing Committee

275 Astrocryptic Solution

by Curt Nason

Cover:

The Rosette Nebula photographed by Jay Anderson on March 10, 2005 using a Starlight XPress SXV-M25 CCD camera and a 102-mm f/8 Takahashi FS102. Exposure time was 30 minutes. The Rosette Nebula is a vast cloud of dust and gas extending over an area more than twice the size of the Moon. The open star cluster NGC 2244 is embedded in the centre of the nebula.

COLUMNS/RUBRIQUES

257 Second Light: "A Collision in the Local Group of Galaxies"

by Leslie J. Sage

258 Deep-Sky Contemplations: The Crab Nebula

by Doug Hube and Warren Finlay

260 Through My Eyepiece: Finding Things

by Geoff Gaherty

262 Gizmos: A Finder Found

by Don Van Akker

264 A Moment With...Dr. Laura Ferrarese

by Philip Mozel

266 Carpe Umbram: Baby, it's cold outside!

by Guy Nason

269 Orbital Oddities: Planetary Perspectives

by Bruce McCurdy

270 Net Astronomy

by Paul Langan



President's Corner

by Scott Young (sdy@mts.net)

By the time you read this, the November meeting of National Council will have occurred. There are a few changes in the way we run things of which you should be aware.

First, the traditional style of National Council meetings has changed. If you've ever attended one of these, you know that they are about seven hours long and have a pre-set list of reports and events to go through before the meeting can get on to any "new" business. That has changed — the meetings now concentrate on making decisions. Email helps get people up to speed before the meeting, so we can spend our time moving forward.

We have also started to look at the bigger issues that the RASC is facing: publication revenue is falling as books become less popular; we continue to spend more money per member than we bring in with membership fees; and our governance model is large, unwieldy, and expensive. Yes, we could just crank up the fees to pay for this old model, but there is probably another way.

Council is going to find it over the next year or so. We have tried to do this before, with various task forces and committees, but this is really a job for Council, led by the Executive. It is what we are here for.

I'd love to hear feedback, good and bad, on these changes as they occur. Email me at sdy@mts.net with your suggestions, comments, criticisms, and feedback. It's your Society, so let me know what you think!

Some other changes have occurred in the Society: many of the publications, including the one you're holding in your hand or reading on your screen right now, have changed editors. It's great to see a new generation of folks step up and build on the successes of the previous volunteers who gave so much time to the Society.

(By the way, if you **are** reading this on your screen, I'd like to make a pitch to subscribe to the paper version instead. It's \$15 a year plus GST, which is incredibly inexpensive for such a high-quality publication. Jay and the Editorial Team are making our *Journal* something that appeals to a wide range of members. By subscribing, you help out the RASC as well as support one of its flagship publications.) ●

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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)

PLANET-PLANEMO TWIN MYSTERY

A team led by a University of Toronto astronomy professor is challenging an existing theoretical model and thrilling the astronomy community with its discovery of a seven-Jupiter-mass companion next to a planemo, or planetary mass object, only twice its mass. Both objects have masses similar to those of extra-solar giant planets, usually found in orbit around a star. Unexpectedly, these bodies appear to circle each other.

“This is a truly remarkable pair of twins — each weighing some hundred times less than our Sun,” says Ray Jayawardhana, an associate professor of astronomy and astrophysics at the University of Toronto. “Their mere existence is a surprise, and their origin and fate a bit of a mystery.”

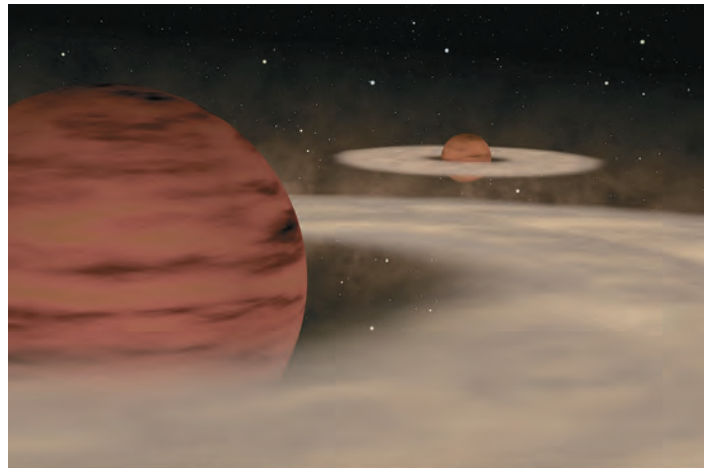
Jayawardhana and Valentin D. Ivanov of the European Southern Observatory (Chile) reported the discovery of the low-mass system in the August 3rd issue of *Science Express*, the rapid online publication service of *Science*.

The researchers discovered the companion candidate in an optical image taken with the European Southern Observatory’s 3.5-metre New Technology Telescope on La Silla, Chile, and investigated it further with optical spectra and infrared images obtained with ESO’s 8.2-metre Very Large Telescope on Paranal, Chile. These follow-up observations confirmed that both objects are young, at the same distance, and much too cool to be stars. By comparing the companion to widely used theoretical models, Jayawardhana and Ivanov estimate that it weighs about seven times as much as Jupiter, while the primary planemo is an estimated 14 times Jupiter’s mass. The newborn pair, barely a million years old, are separated by about 6 times the distance between the Sun and Pluto in our solar system, and is located in the Ophiuchus star-forming region approximately 400 light years away.

“Roughly half of all Sun-like stars, and about a sixth of brown dwarfs, come in pairs,” says Jayawardhana. Brown dwarfs are “failed stars” that weigh less than 75 Jupiter masses and are unable to sustain nuclear fusion. “Oph162225-240515, or Oph1622 for short, is the first planemo to be resolved into a double.”

The existence of this wide pair poses a challenge to a popular theory, which suggests that brown dwarfs and planemos are embryos ejected from multiple proto-star systems. Since the two objects in Oph1622 are so far apart and only weakly bound to each other by gravity, they would not have survived such a chaotic birth.

Planets are thought to form out of disks of gas and dust that surround stars, brown dwarfs, and even some planemos.



Double System of Planetary Mass Objects (Artist's View)

ESO Press Photo 29a/06 (3 August 2006)



Figure 1 — Artist's rendering of Oph1622. (Image courtesy of the ESO - www.eso.org/outreach/press-rel/pr-2006/pr-29-06.html)

The researchers think that these planemo twins formed together out of a contracting gas cloud that fragmented, like a miniature stellar binary.

“We are resisting the temptation to call it a “double planet” because this pair probably didn’t form the way that planets in our solar system did,” says Ivanov. “Now we’re curious to find out whether such pairs are common or rare. The answer could shed light on how free-floating planetary-mass objects form.”

LOOKING DEEP INTO NGC 6397

NASA’s *Hubble Space Telescope* has uncovered what astronomers are reporting as the dimmest stars ever seen in any globular star cluster. Globular clusters are spherical concentrations of hundreds of thousands of stars that formed early on in the 13.7-billion-year-old Universe. Globular cluster NGC 6397 is one of the closest globular star clusters to Earth, and seeing the whole range of stars it contains will yield insights into its age, origin, and evolution.

Although astronomers have conducted similar observations since *Hubble* was launched, a team led by Harvey Richer of the University of British Columbia is reporting that they have at last unequivocally reached the faintest stars. Richer’s team announced their findings at the 2006 International Astronomical Union General Assembly in Prague, Czech Republic, and published their results in the August 18 edition of *Science*.

“We have run out of hydrogen-burning stars in this cluster.



Figure 2 — The image at lower right shows the faintest red-dwarf star (the dot within the circle) spied by *Hubble*. The image at upper right pinpoints one of the dim white dwarfs. The white dwarf has been cooling for billions of years. It is so cool that instead of looking red, it has undergone a chemical change in its atmosphere that makes it appear blue. The images were taken with visual and red filters. NGC 6397, one of the closest globular clusters to Earth, is 8500 light-years away in the southern constellation Ara. Credit: NASA, ESA, and H. Richer (University of British Columbia)

There are no fainter such stars waiting to be discovered. We have discovered the lowest-mass stars capable of supporting stable nuclear reactions in this cluster. Any less-massive ones faded early in the cluster's history and by now are too faint to be observed," said Richer.

Hubble's Advanced Camera for Surveys completed a census of two distinct stellar populations in NGC 6397. *Hubble* surveyed the faintest red-dwarf stars, which fuse hydrogen in their cores like our Sun, and the dimmest white dwarfs, which are the burned-out relics of normal stars.

Remarkably, the light from these faint stars is as dim as the light produced by a birthday candle on the Moon seen from Earth. NGC 6397 is 8500 light-years away from Earth. Analyzing the burned-out remnants of stars that died long ago, *Hubble* showed that the dimmest white dwarfs have such low temperatures that they are undergoing a chemical change in their atmospheres that makes them appear bluer rather than redder as they cool.

These white dwarfs are the relics of stars that were initially up to eight times as massive as the Sun, and have exhausted the fuel capable of supporting nuclear reactions in their cores. Stars that were initially even more massive died as supernovae very early on in the cluster's history, leaving behind neutron stars, black holes, or no debris at all.

Astronomers have used white dwarfs in globular clusters as a measure of the Universe's age. The Universe must be at least as old as the oldest stars. White dwarfs cool down at a predictable rate — the older the dwarf, the cooler it is, making it a perfect

"clock" that has been ticking for almost as long as the Universe has existed. Richer and his team are using the same age-dating technique to calculate the cluster's age. NGC 6397 is currently estimated to be nearly 12 billion years old.

Richer's team used *Hubble's* Advanced Camera to probe deep within the NGC 6397 cluster for nearly five days to capture the faint stars. The camera's resolution is so sharp that it is capable of isolating cluster stars in the crowded cluster field, enabling cluster members to be distinguished from foreground and background stars. The cluster stars move together as the cluster orbits the Milky Way Galaxy, and *Hubble* was able to pinpoint which stars were moving with the cluster. The *Hubble* team used this technique together with archival *Hubble* images taken as much as a decade earlier to make sure they had a pure sample of cluster stars.

THE BAFFLING CHAMPAGNE SUPERNOVA

An international team of astronomers led by a group at the University of Toronto has discovered a supernova more massive than previously believed possible. This has experts rethinking our basic understanding of how stars explode as supernovae. The new research was recently reported in the journal *Nature*.

University of Toronto postdoctoral researcher Andy Howell, lead author of the study, identified a Type Ia supernova named SNLS-03D3bb in a distant galaxy 4 billion light years away that originated from a dense evolved star, termed a white dwarf, whose mass is far larger than any previous example. Type Ia supernovae are thermonuclear explosions that destroy carbon-oxygen white-dwarf stars that have accreted matter from a companion star.

Researchers say SNLS-03D3bb's "obesity" has opened up a Pandora's Box on the current understanding of Type Ia supernovae and how well they can be used for precision cosmology.

Current understanding is that Type Ia supernova explosions occur when the mass of a white dwarf approaches 1.4 solar masses, the Chandrasekhar limit. This important limit was calculated by Nobel laureate Subrahmanyan Chandrasekhar in 1930, and is founded upon well-established physical laws. As such, decades of astrophysical research have been based upon the theory. Yet, somehow the star that went supernova as SNLS-03D3bb reached about two solar masses before exploding.

"It should not be possible to break this limit," says Howell, "but nature has found a way. So now we have to figure out how nature did it."

In a separate *News & Views* article on the research in the same issue of *Nature*, University of Oklahoma professor David Branch has dubbed this the "Champagne Supernova," since extreme explosions that offer new insight into the inner workings of supernovae are an obvious cause for celebration.

The team speculates that there are at least two possible explanations for how this white dwarf got so fat before it

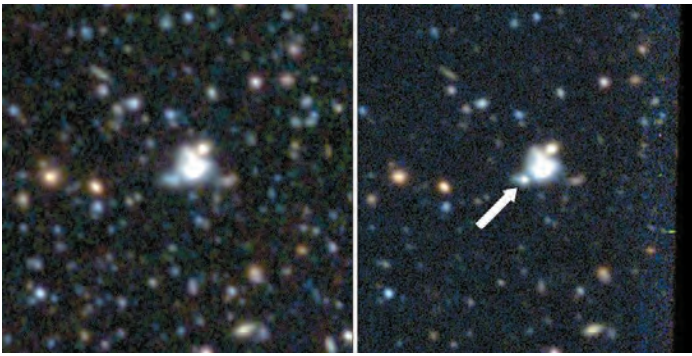


Figure 3 — Discovery images of SNLS-03D3bb taken with the 3.6-metre Canada-France-Hawaii Telescope. The supernova can be seen as the bright spot (arrowed) in the right-hand image. The image on the left shows the same field before the supernova occurred. Credit: University of Toronto, D. Andrew Howell, and the Supernova Legacy Survey.

exploded. One is that the original star was rotating so fast that centrifugal force kept gravity from crushing it at the

usual limit. Another is that the blast was in fact the result of two white dwarfs merging, such that the body was only briefly more massive than the Chandrasekhar limit before exploding. Observations of the supernova were obtained at the Canada-France-Hawaii telescope and the Keck telescope, both located on Mauna Kea in Hawaii.

Since all Type Ia supernovae usually have about the same brightness, they can be used to determine distances in the Universe. In 1998 they were used in the surprising discovery that the Universe is accelerating. While the authors are confident that the discovery of a supernova that doesn't follow the rules does not undermine this result, it will make them more cautious about using them in the future.

University of Toronto postdoctoral fellow Mark Sullivan, a coauthor on the research, says, "This supernova muddies the waters. We now know these rogue supernovae are out there which might throw off our cosmology results if we aren't careful about identifying them." ●

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Using the Medical Image-Processing Package, *ImageJ*, for Astronomy

by Jennifer L. West (jennifer_west@umanitoba.ca) and Ian D. Cameron (ian_cameron@umanitoba.ca), Winnipeg Centre

Abstract: At the most fundamental level, all digital images are just large arrays of numbers that can easily be manipulated by computer software. Specialized digital-imaging software packages often use routines common to many different applications and fields of study. The freely available, platform-independent, image-processing package *ImageJ* has many such functions. We highlight *ImageJ*'s capabilities by presenting methods of processing sequences of images to produce a star-trail image and a single high-quality planetary image.

Introduction

ImageJ is a particularly flexible image-processing package that is a free, open-source program developed by Wayne Rasband at the National Institutes for Health (NIH). The program will run on all computer platforms including *Windows*, *Mac*, *Linux*, *UNIX*, and even the *Sharp Zaurus PDA*. *ImageJ* claims to be the fastest pure *Java* image-processing program; it is capable of filtering a 2048×2048 image in 0.1 seconds (according to the *ImageJ* Web site).

ImageJ's intended purpose is medical image processing, but it works very well in an astronomical context. The software has a particular emphasis on analysis and incorporates a number of tools for measuring images. As a result, functions are often more mathematically "transparent" than in commercial packages such as *Adobe Photoshop*.

A well-developed "plugin" interface allows for customization. A very active user community has contributed dozens of freely available plugins, some of which are very useful for astronomy (see Appendix). There are even plugins available to interface with various CCD cameras and webcams. J. West has produced a plugin to interface with an SBIG CCD camera and many others are available on the *ImageJ* Web site; new ones are added frequently. A "macro" interface allows tasks to be recorded and automated.

This paper will highlight the functions in *ImageJ* that are useful for astronomy both in terms of measurement of astronomical data and for the creation of "pretty pictures." Two case studies of applications of *ImageJ*'s usefulness in an astronomical context are presented. Case study 1 is a straightforward application of *ImageJ*'s capabilities. We demonstrate how *ImageJ* can produce a time-lapse movie and a star-trail image from a set of digital photos. Case study 2 is a more complex application. Here we

undertake an experimental approach to process a Webcam movie of a planet to produce a single, high-quality image.

ImageJ Commands

Image Input and Output

ImageJ can read and write a wide variety of image file formats including TIFF (uncompressed), GIF, JPEG, BMP, PGM, and FITS (writing FITS files is accomplished through a plugin contributed by J. West). The program can also read and write raw data (the user must know the dimensions and image data type) and text images. There are currently no publicly available plugins to open raw files produced by commercial digital cameras. Of particular interest to astronomy is the ability to load sequences of images to create what *ImageJ* calls a "Stack." Stacks are discussed in further detail later in this paper.

In addition to single-frame images and image sequences, *ImageJ* can also load movies in AVI or *QuickTime* formats. User-contributed plugins are also available to read and write other formats such as animated GIFs, PNGs, and PICTs.

File Types

ImageJ is capable of handling both greyscale and colour images. Permissible file types include 8-bit, 16-bit, and 32-bit greyscale as well as 8-bit colour, RGB colour, and HSB colour. Other colour spaces such as LAB are supported through user-contributed plugins.

Working with Image Stacks

Similar in concept to "layers" in *Adobe Photoshop* or *Gimp*, *ImageJ* uses "stacks" to work with a group of images at one time. The individual images are called "slices." Available computer memory is the only limit to the number of slices that can be

included in the stack.

Stacks are very versatile and useful for several different applications. Movies in AVI, *QuickTime*, or animated GIF formats can be loaded as a stack. In addition, a directory of images can automatically be opened as a stack. Stacks can also be read and written as multi-image TIFF or RAW files. Thus, 3-D images such as multi-channel radio-telescope data can be visualized.

Standard image manipulation (such as level adjustments and filters) and measurements can be performed on the images individually or on the stack as a whole. This greatly simplifies the task of batch processing.

The images in a stack can be viewed in several ways. Animation controls allow the images to be displayed as a movie. The data can be projected or plotted along any axis, and the user is given the option of the “projection type,” which includes such options as “Average,” “Maximum,” and “Median.” The 3-D “cube” can be rotated and animated as well.

There is no built-in functionality for registering images in *ImageJ*. There is however, an excellent set of plugins called “TurboReg” and “StackReg,” contributed by Thévenaz, Ruttimann, & Unser (1998) to perform this task.

StackReg accepts a stack of images as input (such as a movie that has been loaded into the program) and automatically aligns each image to the selected slice. The user is given the option of five standard types of registration algorithms: Translation, Rigid Body, Scaled Rotation, Affine, and Bilinear.

Image Selections

The *ImageJ* toolbar (Figure 1) provides tools for selecting regular and irregular areas (called Regions Of Interest or ROIs) on an image. Several types of selections such as rectangles, circles, poly-line, and a “magic wand” are available. Selections can be measured, filtered, filled, or drawn.

A tool called the “ROI Manager...” (located under the “Analyze” -> “Tools” submenu) may be used to store, combine, and save multiple selections at one time. The ROI Manager may be used to measure the same region on multiple images or on all of the images in a stack.

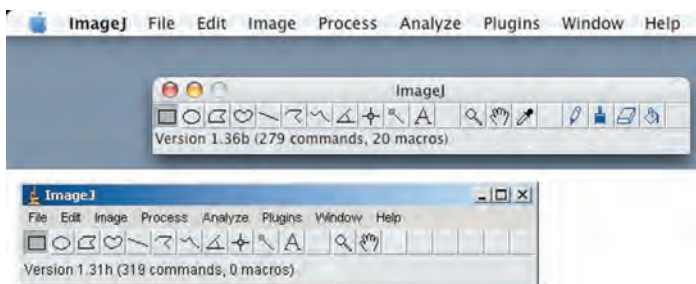


Figure 1 — *ImageJ* toolbar as it appears on both *Mac OS X* (top) and *Windows* (bottom) operating systems.

Colour and Level Adjustment

Basic brightness/contrast and minimum/maximum level adjustments are available in *ImageJ*. This includes the allowance for colour adjustments by separately manipulating R, G, and B

(as well as C, M, and Y).

Several lookup tables (or “LUTs”) are also included in the software and allow for the customization of how the data are displayed without changing the actual pixel values in the image. Hundreds of additional LUTs may be downloaded from the Web site. A plugin, contributed by J. West, allows a LUT to be defined using standard mathematical functions such as Log and Square Root.

Other Image Adjustments

A range of standard image adjustments such as rotation, resizing (with or without interpolation), cropping, duplicating, zooming, and renaming are fully supported.

Image Filtering

Several standard image filters are included in *ImageJ*. These include “Gaussian Blur,” “Median,” “Mean,” and “Unsharp Mask,” among others. There is also the built-in capability of specifying a user-defined convolution mask. Dozens of user-contributed plugins provide access to many other filters, including Wavelet filters. Also part of the *ImageJ* package are Fourier transforms and frequency filtering.

A wide variety of mathematical functions may be performed on image pixels. For example, one may add, subtract, multiply, or divide by a constant, perform logarithms, square root, or reciprocal, or find the absolute value of a selection of pixels in an image.

Image Calculator

The “Image Calculator” allows images to be combined using one of several mathematical functions, including add, subtract, multiply, divide as well as AND, OR, XOR, min, max, and average. This is useful for performing calibrations such as dark subtraction and flat fielding on astronomical images. The image calculator accepts stacks as input, thus a stack of images can be batch reduced.

Measuring Images

A wide variety of measurements including Center of Mass, Min/Max Grey Value, Mean Grey Value, Standard Deviation, and Area can be performed on an image or a stack of images.

The measurements that should be performed are specified by the “Set Measurements...” command, located under the “Analyze” menu. The “Measure” command (also under the “Analyze” menu) can then be executed to measure a single image. In order to measure the entire stack at once, the “ROI Manager...” must be used (see section on *Image Selections*).

Measurements appear as a table in a separate results window. The measurements can be copied and pasted directly into a spreadsheet where they can be sorted.

Image Display Tools

Image scale, for example arcminutes per pixel, can easily be set using *ImageJ*’s “Set Scale...” command. A scale and/or greyscale

calibration bar can also be drawn on the image as shown in Figure 2.

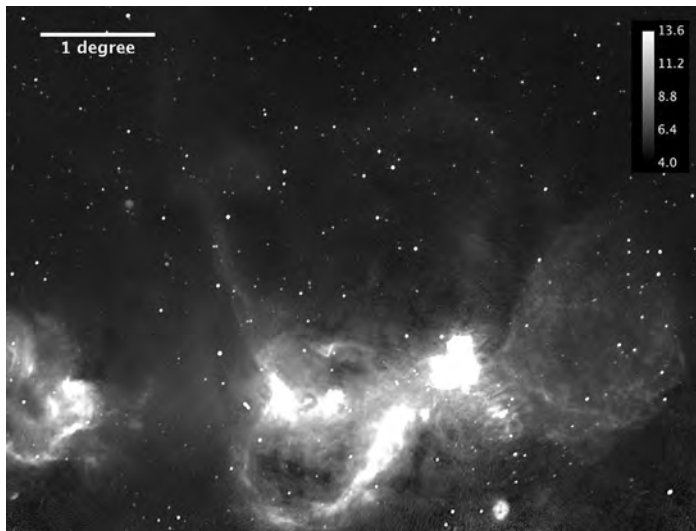


Figure 2 — Scale/grayscale calibration bar displayed on a 1420-Mhz radio image of the W4 star-forming region (also known as the “Heart Nebula” at optical wavelengths) from the Canadian Galactic Plane Survey (Taylor *et al.* 2003). The greyscale displayed is Brightness Temperature in units of kelvin.

Macros and Plugins

More than 300 plugins are freely available on the *ImageJ* Web site. Plugins are simple to install. All that is required is to download the file(s) to *ImageJ*'s “Plugins” directory and then restart the program. Plugins that are placed in a subfolder within the plugins folder will show up on a submenu when the program is launched. Plugins are usually written in the *Java* programming language, but other languages such as *JPython* are also supported. The interface is relatively straightforward for someone familiar with *Java* programming. A useful “Compile and Run” feature is included within the program, which greatly speeds up development, as there is no need to continually restart the application while debugging code. An online plugin-writing tutorial is also available.

For those not comfortable with programming, a macro-scripting language allows a series of commands to be automated. A “Record” function simplifies the task of writing a macro. More than 200 macro examples are available on the *ImageJ* Web site.

Case study 1 — Creating a Star-Trail Image from a Sequence of Short Exposures

With today's digital cameras, it is difficult to capture star trails since exposure times longer than a few minutes will cause the background to wash out the image. The solution is to take a sequence of short exposures and combine them. *ImageJ* allows this to be done very easily.

The sequence of images should first be opened as a stack.

Put all of the files in a single directory, and ensure that the sequential order of the files' names corresponds to the order in which you wish to open the images. Next, under the “File” menu, select “Import” -> “Image Sequence...” Select the first image in the directory and click “Open.” A dialogue box with several options will appear. This dialogue box allows the user to select the range of images that should be opened. There is also the option to increment the sequence, for example, to open every second image in the directory. The images may also be scaled and/or converted to grayscale or RGB. Click “OK” to import the sequence.

The next step is to adjust the brightness and contrast or apply any filters that may be required. The same settings can be applied to all of the images or just a single frame. Individual frames can be deleted from the stack by selecting “Delete Slice” under the “Image” -> “Stacks” submenu.

The final step is to combine all of the frames. We will use the “Z Project...” command, which is also located under the “Image” -> “Stacks” submenu. To create a star-trail image that keeps the background as dark as that in a single frame, we use the “Max Intensity” projection type. This projection method will create a new image by selecting the pixel with the maximum intensity for each x-y grid point in the stack.

The disadvantage of this method is that noise will be accentuated. If the original frames are excessively noisy, then steps should be taken to reduce noise before combining the frames. One possible method would be to average a few frames at a time and then combine the averaged frames. However, if the original images are well-exposed, then this method can produce a very striking star-trail image.

The sequence of images in the stack can also easily be saved as a time-lapse movie in either *AVI* or *QuickTime* formats. These formats are both available under the “Save As...” menu. In addition, a user-contributed plugin is available to save the stack as an animated *GIF*.

Figure 3 shows the final combined image produced by using this method on a sequence of 100 40-second exposures



Figure 3 — Final star-trail image produced from 100 40-second exposures with a 30-second gap between each exposure taken with a Canon 20Da DSLR having a 15-mm lens at f2.8 and an ISO speed of 1600.

with a 30-second gap between each exposure. The camera used was a Canon 20Da with a 15-mm lens at f2.8 and an ISO speed of 1600. The images were acquired over a period of approximately two hours, between 12:06 a.m. and 2:01 a.m. CDT, in the early morning of Saturday, September 2, 2006 by J. West. The location was Spruce Woods Provincial Park in southwestern Manitoba during the Spruce Woods Star Party.

Case Study 2 - Processing a Sequence of Planetary Images

Using a Webcam to produce high-quality planetary images is a well-known technique in the world of amateur astronomy. A popular freeware program called *Registax* allows the user to combine and process individual frames from a Webcam movie. Though this program does an excellent job, there are some disadvantages. Firstly, the program is only available for *Windows*, and secondly, the program's interface is somewhat restrictive. With *ImageJ* we can more easily customize and extend our processing procedure in response to the available data.

With a thoughtful selection of algorithms and parameters, we are able to use *ImageJ* to produce an image as good as, if not better than an image created with the same data using *Registax*. This case study discusses our method in detail, and we include rules-of-thumb to allow the reader to make intelligent parameter choices when creating their own images.

We processed a sequence of 451 images of Jupiter taken with a Philips *ToUcam* Webcam on the night of April 9, 2004 through a Celestron 11-inch telescope. The data were kindly provided by Jay Anderson.

The general stages of processing a sequence of planetary images include loading the raw data, registering (aligning) the individual frames, normalizing the stack, selecting the “best” frames, and enhancing and combining the images.

Loading Raw Data

Many Webcams output movies in AVI format, which can be directly loaded into *ImageJ* as a stack of single-frame images. The user can view all “slices” in the stack by using a scroll bar or by “animating” the stack.

Registering (Aligning) the Individual Frames

Using the plugin “StackReg,” the images can be automatically registered. The Rigid Body rotation option, which allows translations and rotations but maintains the size of the original image, works very well for a sequence of planetary images obtained with a Webcam.

Once the frames have been aligned, crop the stack to the desired size by selecting a square or rectangular region using the rectangle selection tool, and then choose “Crop” from the “Image” menu.

Normalizing the Stack

If there are any differences in the brightness values of the slices in the stack due to effects such as a changing sky condition,

the slices must be normalized before moving on to selecting the best frames. A plugin, called “Normalize Values,” was written by J. West to achieve this task. The plugin measures the mean value of each frame and finds the highest mean value in the stack. Each image in the stack is then multiplied by a value that is equal to the highest mean/mean of the slice. This raises the mean value of each image to a value equivalent to the highest mean.

Selecting the “Best” Frames

One of the more challenging aspects of processing a stack of planetary images is selecting the best frames. This is especially true when faced with hundreds of images.

Since the salient features of Jupiter are the cloud belts, we use an edge-detection algorithm to select the images that have the best-defined edges. This algorithm is built into *ImageJ* as the “Find Edges” filter, located under the “Process” menu. The command convolves the image with two standardized Sobel filters that calculate the derivatives of the image in both vertical and horizontal directions (see Gonzalez & Woods 2002 for further explanation). A single filtered image is produced that shows the edges as bright regions and the remainder of the image as dark regions, as shown in Figure 4. The mean value of the entire filtered image is then calculated. Planet images that have sharper, more-discontinuous edges will produce a filtered image with a higher mean value than images that have blurry or soft edges.

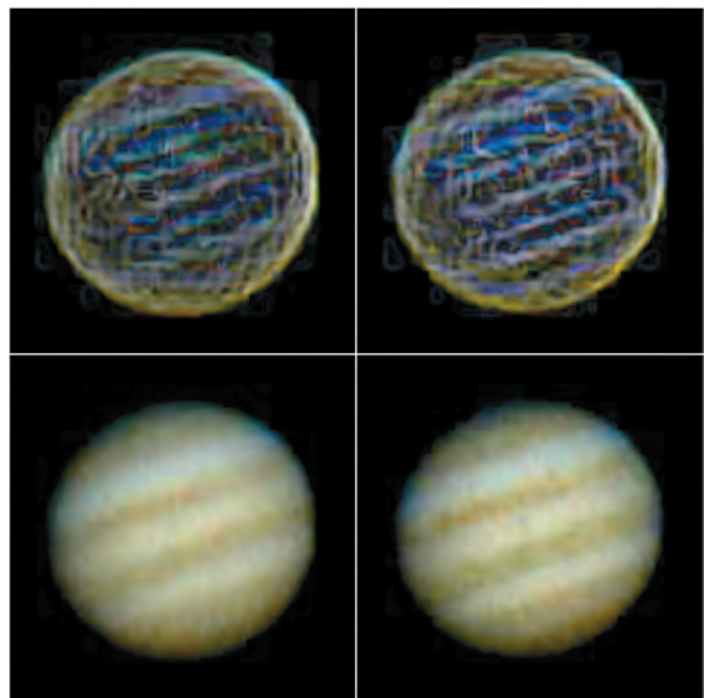


Figure 4 — Best (right) and worst (left) individual frames from the Jupiter Webcam sequence. The edge-detected images (top) are shown with the corresponding original images (bottom). The images on the right have more-clearly defined and brighter edges, especially along the cloud bands.

The “Find Edges” command may be executed on the stack as a whole, producing a stack of filtered images (the original images will be over-written, so it may be helpful to first execute the “Duplicate...” command located under the “Image” menu). The mean value of each image in the stack can then be measured.

In addition to measuring the stack of filtered images, one can also sort it by the mean value of the slices. This is accomplished by using a very useful plugin called the “Stack Sorter,” written by Bob Dougherty.

After the stack has been measured and/or sorted, the decision must be made of how many frames to use for the final image. Enough images must be used to ensure good signal-to-noise ratios. Using too many images will smooth out the final image, and fine detail may be lost. This is especially true if poor-quality images are included in the final selection. In general, use as few images as possible to retain a sufficient signal-to-noise ratio. This effect is illustrated in Figure 5. The image created by combining 8 images, although noisier, contains a significantly greater amount of detail than the image created by combining 451 images. A compromise between these two extremes would probably be the ideal solution. For the final image (Figure 6), we used the best 28 images and found this to be the most visually pleasing image.

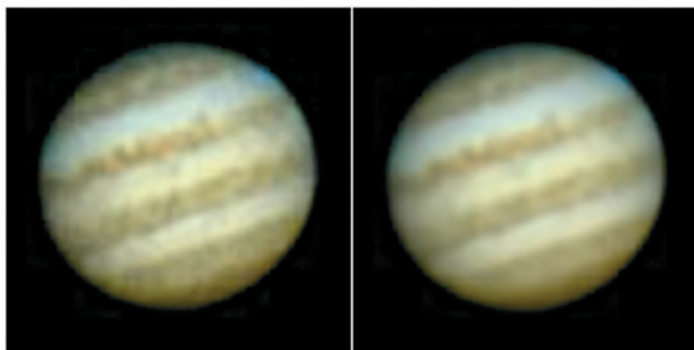


Figure 5 — Results of combining the top 8 frames (left) and 451 frames (right). The image on the left, while noisier, shows a greater amount of detail than the image on the right, which has been smoothed because of the large number of images in the combination.

A plugin called “Select Frames With Best Edges” was written by J. West to automate this whole procedure. This plugin requires that the user input a threshold value. It then creates a new stack of the best images by comparing each image to the best image and including those that are no worse than the threshold value.

Enhancing the Images

Although the photometry is not preserved, unsharp masking is a very effective technique for extracting detail in planetary images. The unsharp-masking algorithm involves subtracting a blurred version of the image from the original image. In this way, some of the larger-scale (lower frequency) components of the image are removed, thereby enhancing the smaller-scale (higher frequency) components. A severely unsharp-masked image will appear artificial and over-processed and may reveal



Figure 6: Final image of Jupiter produced by combining the top 28 frames from the Webcam movie.

“structure” that is in fact an artifact created by the processing.

We perform an unsharp-mask filter on the individual raw images before combining the frames into the final image. We find this technique allows a more severe unsharp-mask filter to be used at the start. By combining the images afterwards, the effects of the filtering are averaged, and the final result looks more natural.

ImageJ's built in “Unsharp Mask” filter blurs the image by convolving a Gaussian function with a user-specified radius. The blurred image is then scaled by a user-specified factor before it is subtracted from the original. Selecting the appropriate factors is a combination of science and art.

In an image of a planet, the detail in which we are usually most interested is in the high-spatial frequencies; that is, we are interested in the rapidly varying structure on the disk. Unfortunately, this is also the scale where we find noise. By using unsharp masking, we can enhance the high frequencies where the interesting structure is located but at the same time we enhance the noise. The trick is to combine multiple images by averaging, which will reduce the noise that varies from frame to frame, but retain the high-frequency detail that should be present in each frame. The rule of thumb that we use is to select the radius of the Gaussian filter such that it is a little larger than the scale of the features one is attempting to enhance. For example, for an image of Jupiter, we would choose a blurring radius that is approximately equal to the width of one of the cloud bands. By subtracting off an image blurred at this scale, we are reducing the contribution of all features larger than that radius and enhancing the contribution of all features that are smaller.

Combining the Images

Before the images are combined, it may be desirable to run StackReg once more and refine the image registration. The last step is to combine the images in the stack using the “Z Project...” command. The most useful projection type for the purposes of combining planetary images is “Average.”

Conclusions

ImageJ is a very versatile base for a wide range of image-processing applications. Our goal in this paper was to demonstrate the large range of its current capabilities and to make the reader aware of the great future potential that this software offers. It is our hope that it will be embraced by a growing number of professional and amateur astronomers as a viable alternative to other processing and visualization packages. ●

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Jennifer L. West received her M.Sc. in astronomy in 2003 at the University of Manitoba and has since been working in the field as an instructor, outreach coordinator, and observatory technician. She has been an active member of the RASC Winnipeg Centre for the past eight years serving as National Representative, 2nd Vice-President, and Councillor.

Ian D. Cameron has an M.Sc. in astronomy from the University of Victoria and is the Director of the Observatory and Planetarium at the University of Manitoba. He has been a long-time supporter of the RASC and is currently a member of the Winnipeg Centre.

Appendix

Useful Plugins

Following is a listing of some of the plugins that we find useful for analyzing or processing astronomical images. Links to each of the individual plugins as well as a downloadable zip archive of the complete set can be found at

www.umanitoba.ca/faculties/science/astronomy/jwest/ImageJ.html

TurboReg and StackReg, Philippe Thévenaz, Biomedical Imaging Group, Swiss Federal Institute of Technology Lausanne

TurboReg registers, or aligns, two or more images. The companion plugin, StackReg will register all of the image slices in a stack to the top image. Alignments can be performed automatically or manually by selecting landmarks in both the source and target images. The user is given the option of five alignment methods: translation, rigid body, scaled rotation, affine, and bilinear.

MosaicJ, Philippe Thévenaz, Biomedical Imaging Group, Swiss Federal Institute of Technology Lausanne

This plugin is used to create composite mosaic images, such as panoramic images, from any number of overlapping images. The input images do not have to be in a grid pattern; any regular or irregular arrangement of images may be used as long as there is sufficient overlap. The TurboReg engine (see above) is used for image registration and therefore it must also be installed.

Contour Plots, Walter O'Dell, University of Rochester

Draws contours at levels specified by the user. The contours are non-destructive but they may also be drawn on the image if desired. Contour lines can be converted to selections and the area within can be measured using *ImageJ*'s standard measurement tools.

Interactive 3-D Surface Plots, Kai Uwe Barthel, Internationale Medieninformatik

Creates 3-D (x, y, and intensity) surface plots that can be scaled and rotated. Plots can be drawn using dots, lines, mesh, or can be filled. The colours and lighting of the plots may also be dynamically adjusted.

Animated Gif Writer, Ryan Raz

Saves a stack as an animated GIF.

Animated Gif Reader, Kevin Weiner (FM Software), Wayne Rasband

Opens an animated GIF file as a stack.

Stack Combiner, Wayne Rasband

Creates a new stack by combining two arbitrarily sized input stacks.

Substack Maker, Anthony Padua, Daniel Barboriak, Duke University Medical Center

Extracts selected slices from a stack to create a new stack.

Stack Sorter, Bob Dougherty

This plugin allows the slices in a stack to be sorted by the mean value of the slices or by label name.

SaveAs FITS, Jennifer West

Saves an image in FITS format.

Plot FWHM, Jennifer West

Fits a Gaussian function to a horizontal and vertical cut that is centred on the brightest point in the image. Returns the FWHM (Full Width at Half Maximum) of the function both in numerical and graphical formats.

Background Extractor, Jennifer West

Extracts the background of a stack of images by normalizing each image in a stack and then combining the stack. Used to produce flat sky images from a sequence of exposures.

Moon Crater Calculator, Jennifer West

Calculates the height of a crater wall or lunar mountain using user input from measurements on lunar images.

Select Frames With Best Edges, Jennifer West

Selects the frames with the “best” edges from a stack of images. The edges are computed using the “Find Edges” routine in *ImageJ* (using a Sobel filter). The mean values of the edge frames are computed and the frames are ordered according to this value. A new stack is created that contains all the frames having

a mean value that is at least xx% as high as the highest mean value.

Normalize Values, Jennifer West

Measures the mean value of all images in a stack and finds the highest mean. Each image is then multiplied by a constant equal to the highest mean/mean of the image. This results in each image of the stack having the same mean value.

Remove Hot or Cool Pixels, Jennifer West

Replaces all pixels above and/or below a threshold value with either the nearest neighbour median, nearest neighbour mean, or zero.

Write LUT from Function, Jennifer West

Uses a user-defined transformation function to create a new non-linear LUT and apply it to the image. The image display is automatically updated; however, the data values remain unchanged. Included functions are $A \log(Bx)$, $A \sqrt{Bx}$, $A \exp(Bx)$, $A x^B$, and $A \sin(Bx)$, where A and B are user-defined constants.

DSLR Astrophotography, Part 1

by Doug George, Ottawa Centre (dgeorge@cyanogen.com)

When I started out in astrophotography in the 1970s, film photography was approaching its zenith. At the time, “High Speed Ektachrome” (160 ASA) was the best colour film available. Film emulsions improved dramatically in the ‘80s, and widening use of hypersensitization and cold cameras boosted performance. Yet film astrophotography was still very much a hit-and-miss affair. It was not unusual to get just a single satisfactory photo on a roll of film.

Even the best film emulsions are not very sensitive. As a result, very long, single exposures were required. The fastest films not only had worse grain, but also had worse reciprocity failure — the tendency to lose sensitivity with lower illumination levels. In many cases the “slow” films were far better than the “fast” ones.

The film was also a moving target. Kodak and Fuji were continuously “improving” their emulsions — improving for daylight photography, that is. They would suddenly change the chemistry without notice of any kind; some of these changes greatly improved astrophotography, and some made it much, much worse. So after seeing very good results from a particular roll of film, the enterprising astrophotographer would immediately return to the store and buy two-dozen rolls from the same batch, which would then be safely stored in the freezer for future use. The long-exposure times on film led to the need for guiding.



Figure 1 — M8, captured by a Canon EOS 20Da and a Takahashi FSQ-106, shot and processed with MaxIm DL/CCD software. The image is a stack of individual 4-minute exposures at ISO 800 — 7 exposures lasting a total of 28 minutes — obtained on August 31, 2006.

Back then, only manual guiding was possible, and even with (apparently) careful guiding, trailed photos were an ongoing curse. Focus was tricky; the devices built into film cameras for focusing simply didn’t work on astronomical targets. Even framing the target could be difficult, because you usually could

not see faint targets in the viewfinder.

Film was also expensive to purchase and to develop, especially considering the rate of successful shots per roll. It was difficult to learn from your (expensive) mistakes when the film took a week to get developed. Even with the advent of one-hour processing there was still an enormous need for “instant feedback,” so you could detect focus and guiding problems before wasting hours of dark-sky time.

The Digital Revolution

Something amazing happened in the early 1990s: Charge-Coupled Device (CCD) cameras became available for the amateur astronomer. With solid-state cooling and low-noise electronics, these devices had sensitivity levels that simply blew away film emulsions. Sure, the early models had pathetically small arrays and weren't very sensitive by modern standards, but the early results were incredibly exciting — and everyone knew the technology would improve and drop in cost.

The cost reductions took a while: for many reasons the improvement in technology was much slower than the “Moore's Law” that applies to computers. Nevertheless, by the end of the decade, some amateur astronomers were using very large arrays to take stunning astrophotos, targeting far fainter objects than would be possible with any film camera. Today, these CCD cameras are far less expensive — but still well out of the range of many amateur pocketbooks. Custom cameras for astrophotography are made in small volume, and the sensors themselves are expensive to manufacture.

CCD sensors are built using a specially-tuned process in an obsolete wafer fabrication. Yes, obsolete. They use N-channel Metal Oxide Semiconductor (NMOS) semiconductor technology;

today, almost everyone else uses Complimentary Metal Oxide Semiconductor (CMOS) technology. So despite the great success of CCD sensors, there has been an enormous push to develop CMOS sensors. It was easy enough to make a sensor; it turned out to be much harder to make a good one.

Until a couple of years ago, CMOS sensors were simply terrible for low-light imaging. Progress was very slow. Then, seemingly out of nowhere, consumer digital cameras appeared with a quantum leap in performance. The consumer camera companies had invested huge sums of cash to build special manufacturing facilities, and were now pumping these devices out in large quantities. Suddenly, high-performance digital imaging was a mass-consumer product — and astrophotographers benefited enormously as a side-effect.

How do these new cameras compare? They are perhaps two or three time *less* sensitive than a high-performance CCD camera. But they are also *ten times* less expensive. They are more than good enough for astrophotography; in fact, their sensitivity simply blows away film emulsion. The best cameras are known as Digital Single Lens Reflex or DSLR cameras. These DSLRs are not perfect, and they are not optimized for astronomy, but they are now within reach of most amateurs.

Next issue — choosing a camera. ●

Doug George is President of Diffraction Limited, an Ottawa-based company that produces astronomical imaging products including MaxIm DL and MaxDSLR. In addition to engaging in astrophotography and observing occultations, he enjoys participating in patrol programs. He has co-discovered one comet visually and co-discovered 12 supernovae as a member of the Puckett Observatory Supernova Search team. Doug is also a Past President of the RASC.

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.

Near-Earth Asteroid (2004 XP14)

by Rick Stankiewicz, Peterborough Astronomical Association (stankiewiczr@nexicom.net)

Near-Earth Asteroids (NEAs) are objects we tend not to think about very much, but they can be quite fascinating, as some Peterborough Astronomical Association (PAA) club members found out this past July 3. Astronomer/astrophotographer John Chumack from Dayton, Ohio was vacationing in the Rice Lake area and hooked up with myself and Brett Hardy to spend the night at Brett's "Cedar Knoll Observatory" in an attempt to observe and image one of the largest and closest asteroids to happen near Earth in recent years (one of 796 potentially hazardous objects being tracked on the NASA SpaceWeather Web site). Neither Brett nor I had ever been involved in tracking an asteroid, let alone recording one. On the other hand, John was an expert in this field, having done this sort of thing from his observatories throughout the United States many times over the years. The challenges were many on this night, however. John was not using his usual equipment, other than having brought his own CCD camera and laptop computer. Brett had no experience with CCD cameras or tracking asteroids, but he had the facilities required to pull it off and he knew his equipment well. I had never observed an asteroid before, but was anxious to try to get a visual on this reportedly 11.1-magnitude piece of space rock, as it tumbled on an orbit that was only 1.1 lunar distances ($LD = 384,401 \text{ km}$) from Earth, using Brett's 7-inch (178-mm) refractor.

It was midnight before our trio gathered at the observatory and started to set-up. The weather was next to perfect, but the mosquitoes were out in good numbers, too. The set-up included running a copy of the latest ephemeris from the JPL Web site, to track accurately the route of the asteroid. The CCD camera was mounted on the 4-inch (102-mm) TeleVue Genesis refractor piggybacked on the 7-inch. After much trial and error and the eventual addition of an extension tube, we managed to focus the camera. Then the proper coordinates were punched into the computer and the GoTo mount whirred to a point in the northeast sky below Cassiopeia. We waited to see if we would intercept the asteroid. It was traveling so fast that it would move the diameter of a Full Moon in just four minutes. The screen of the computer displayed the approximately one degree of sky that the camera was imaging every ten seconds.

We did not have to wait long for results. By about 01:48 EDT we registered a streak on the screen. We had nailed it! The asteroid, travelling at 62,400 km/h, was well-centred on the screen but moving quickly: after about 35 separate images it left our field of view and then we were off to the

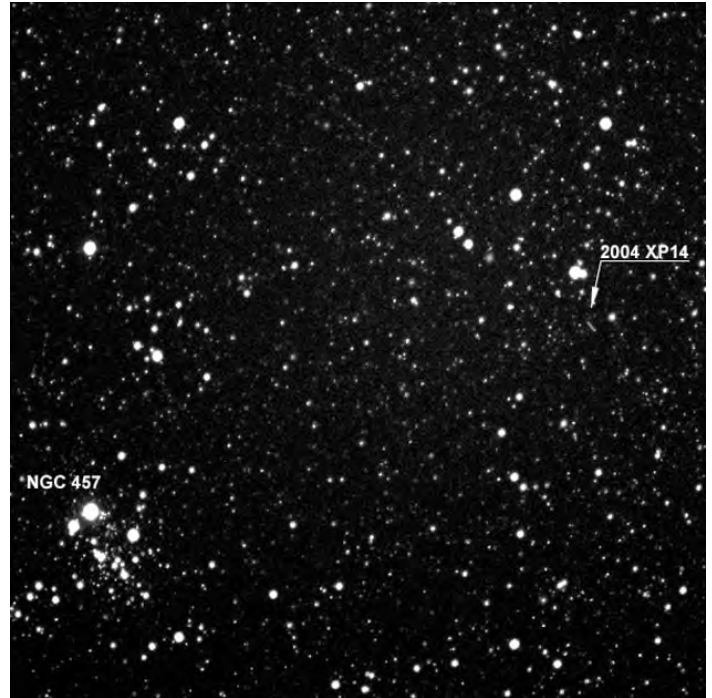


Figure 1 — NEA 2004 XP14 passing NGC 457.



Figure 2 — The NEA trio at the dome of the Cedar Knoll Observatory (L to R - Rick Stankiewicz, Brett Hardy, John Chumack).

next set of coordinates to intercept it as it climbed in the night sky. Would we be able to leapfrog like this all night?

You bet we did! We captured screen after screen of data and ended up with enough images to create movies of the 600-metre-wide asteroid traversing the star-filled background only 430,197 km from Earth. All the time I was trying to get a visual observation of this event in the eyepiece of the 7-inch, but there was no way that I was able to see the faint object that was being recorded so easily by the CCD camera. I suspect that this asteroid was actually closer to a 12-magnitude object, as some were predicting, rather than the 11.1 magnitude being advertised for this event. I suppose I never got truly “night adapted,” because I was always looking at the computer monitor. I did not want to miss anything.

Throughout the night, we recorded hundreds of images of the asteroid, plus our frames captured NGC items, passing satellites, and even a possible micro-meteor burst. The nicest framing included NGC 457 (The E.T. or Owl Cluster) and 2004 XP14. An animation generated from the many ten-second exposures is located at www.galacticimages.com/astronomical_events.html

This was a great example of a group effort that paid off handsomely. For Brett and me, it has been the highlight of our astronomical year to date. I think you will agree from our results that the blurry eyes and mosquito bites were worth the effort. ●

night-flight

by Sherrilyn Jahrig

*stars keep me awake at night
above the ceiling of the world
far from the turning face of earth
diamond sapphire and topaz
tonight I cannot sleep for stars*

*from here the day's a shallow thing
behind us shrinking out to sea
its narrow wake to toss and tow
the children of one lonely sun
we cannot sleep tonight for stars*

*dream's fingertip soothes settling brow
wipes web of knowledge from our eyes
draws into fold of jealous robe
last sigh we live beyond the grasp
of stars tonight and cannot sleep*

*diamond sapphire and topaz
inlaid across black desert skies
past fusion burns with clarity
toward the empty deep
tonight my heart it cannot sleep*

*it hears the voice below the sea
believes in gentle tug of Sun
the Star that never sleeps it hums
that where I go has just begun
tonight I cannot sleep*

The award winning poem “*night-flight*” (Cranberry Tree Press 2001) reflects Sherrilyn’s lifelong fascination with nature, astronomy, creative thought, and expression. She dedicates this poem to her father, Richard Alcock, who had a great sense of humour and inspired her curiosity about the Universe. Richard Alcock passed away September 9, 2006. “*night-flight*” was one of his favourite poems.

Sherrilyn Jahrig is Public Education Director for the Edmonton Centre and coordinator for the recent declaration of the Beaver Hills Dark Sky Preserve. In September 2006, Sherrilyn produced “Many Cultures, One Sky” at Elk Island National Park as well as the first-ever Edmonton Poetry Festival - www.edmontonpoetryfestival.com.

INVESTIGATING THE BASIC PROPERTIES OF BLACK HOLES USING NEWTONIAN MECHANICS

by William Dodd, Toronto Centre (wwdodd@sympatico.ca)

INTRODUCTION

There are at least two approaches that can be taken to examine the interactions between light and gravity. The first approach uses Newton's description of gravity as a force between masses, and light as a stream of corpuscles. The second approach involves Einstein's description of gravity as a warping of the space-time continuum, and light as an electromagnetic field. Einstein's general theory of relativity supplies the standard approach for dealing with massive objects such as black holes. However, Newtonian gravity is much simpler to work with; for the purposes of this article, the results of Newtonian mechanics will be regarded as reasonable first approximations to the results of general relativity.

A black hole is an object that is so massive that nothing, not even light, can escape from the force of gravity at its surface. Anything that falls into a black hole is lost to the rest of the Universe forever. A black hole cannot eject any particles (though there may be a slow evaporation from the singularity as a result of virtual particle creation) and it cannot give off any radiation. No one can be certain of what happens inside a black hole, although it is usually assumed that its mass collapses to an infinitesimally small, infinitely dense region.

Using the Newtonian approach, and assuming that Newton's corpuscles are equivalent to photons, many features of black holes can be investigated using just a few equations from high-school physics. Basic results are described in the body of the article; corresponding derivations are provided in the Appendices.

GRAVITATIONAL RED SHIFTS

Consider a photon emitted from the photosphere of a star. As the photon moves away from the star, it loses "light energy" and gains an equal amount of gravitational potential energy. When a photon loses energy, it does not slow down — instead it shifts to a lower frequency and a longer wavelength. Photons that gain energy are blue-shifted.

A simple formula expresses the Gravitational Red Shift (*GRS*) of a photon after it has left the gravity well of a massive object such as a star. The *GRS* is just the ratio of the gravitational potential energy (E_g) of the photon, after it has left a star's surface, to the initial light energy (E_p) of the photon (see Appendix A for details)

$$GRS = \frac{E_g}{E_p} = \left(\frac{2G}{c^2} \right) \frac{M}{R}. \quad (1)$$

In this formula, M is the mass of the star and R is the radius of the star. The factor M/R provides a measure of the strength of the gravitational force at the surface of the star.

Consider a photon emitted by the Sun. Using formula (1) and data from the Basic Data section of the *Observer's Handbook*, the calculated *GRS* for the Sun is about 4.2×10^{-6} . This means that a photon leaving the surface of the Sun loses about 4 parts per million of its original energy to the gravitational field of the Sun. This "Newtonian result" compares with an observed *GRS* of about 2 parts per million. Formula (1) provides *GRS* values that are too large, but at least have the correct order of magnitude.

White dwarfs are much more compact than the Sun and have a much stronger surface gravity, so one would expect their *GRS* effects to be more pronounced. The white dwarf 40 Eridani is a companion of Sirius, and based on its calculated orbital velocity about Sirius, the expected Doppler¹ red shift for 40 Eridani is 17 km/s.² However, the total observed red shift is 38 km/s. If the extra 21 km/s is due to a gravitational red shift, then this observed shift is

$$\frac{21}{3 \times 10^5} = 7 \times 10^{-5},$$

or about 70 parts per million.³ By comparison, when the values for 40 Eridani ($R = 0.014 R_{\text{Sun}}$ and $M = 0.43 M_{\text{Sun}}$) are substituted into the Newtonian *GRS* formula (1), one obtains an estimated shift of 130 parts per million; about twice the observed value. As in our first example, the simple Newtonian *GRS* formula and the observed *GRS* have at least the same order of magnitude.

A neutron star with a radius of 20 km and mass of $2.5 M_{\text{Sun}}$ has a very strong surface gravity compared to the Sun. Using formula (1) again, the calculated *GRS* of such a star is 370,000 parts per million. One would expect all the photons of this neutron star to be shifted towards the red with their energies reduced by about 37%. The Milky Way has an estimated radius of $2 \times 10^{12} R_{\text{Sun}}$ and an estimated mass of $10^{12} M_{\text{Sun}}$. These values lead to a ratio of M/R for the Milky Way that is just half that of the Sun, or 2 parts per million.

¹ Photons are Doppler shifted towards the red when their source is moving away from us at a high velocity.

² George Abell, *Exploration of the Universe*, 1975, p. 461.

³ 3×10^5 km/s is the speed of light

On a cosmic scale, a photon moving out of the gravity well of a distant galaxy also loses energy. The same photon falling back into the gravity well of the Milky Way would gain light energy. Any observed cosmic *GRS* for photons traveling from one galaxy to another would be due to the difference in these two effects. Since the expected *GRS* for the Milky Way is only two parts per million, one would expect any net cosmic *GRS* to be very small. However, there are two factors that might alter this expectation. First, photons emitted in the compact early Universe would have come from a region with an *M/R* ratio much larger than that of the Milky Way, producing significantly larger *GRS* effects. Second, the latest cosmological theories claim that most of the Universe consists of “dark energy” (74%) and “dark matter” (22%). The light-emitting material that we normally observe and measure constitutes only about 4% of the total mass. If dark energy and/or dark matter are clumped in any way, then there is the potential for much larger *GRS* effects on any photons traveling through, or emitted from, these regions.

A SHORT HISTORY OF BLACK HOLES

The ultimate gravitational red shift occurs when the *GRS* = 1.00, or 100%. Then the *M/R* ratio is so high that photons cannot escape and a black hole is formed. Black holes cannot be detected directly, and the possibility of their existence was hotly debated from the 1930s to the 1960s. It has taken over 200 years of sporadic theoretical developments and systematic improvements in observational techniques for black holes to be accepted as members of the heavenly host.

In a report to the Royal Society of London in 1783, John Michell predicted that a “dark star” would result if the surface gravity of a star was strong enough to prevent light from escaping. His argument was based on the assumption that Newton’s corpuscles of light would be affected by gravity, just like any other object. Michell reasoned that at the point of no escape from a star’s gravity, the kinetic energy of a light corpuscle would just equal its gravitational potential energy

$$\frac{1}{2}mV_e^2 = \frac{GmM}{R}, \quad (2)$$

where *m* is the mass of the corpuscle, and *V_e* is the escape velocity from a star with mass *M* and radius *R*. Equation (2) can be simplified to obtain

$$V_e^2 = 2G\frac{M}{R}. \quad (3)$$

Then setting the escape velocity equal to the speed of light, *c*, and rearranging the equation he obtained

$$R_c = \frac{2G}{c^2}M, \quad (4)$$

where *R_c* is the critical radius⁴ for a star of mass *M*. Michell proposed that if a star had a radius less than *R_c*, then no light could escape its

gravity and it would be a “dark star.” He further speculated that the Universe might contain large numbers of such dark stars.

A decade later the French mathematician and scientist Pierre Simon Laplace included a similar description of dark stars (without reference to Michell) in the first two editions of his popular book *Le Systeme du Monde*. Then, in 1801, Thomas Young conducted his famous double-slit experiment that convincingly demonstrated that light consisted of waves rather than corpuscles. Newton’s corpuscular theory of light was largely abandoned and there was no known mechanism for any interaction between gravity and waves of light. In the third edition of *Le Systeme du Monde* in 1808, the concept of dark stars was omitted.⁵

Dark stars were forgotten for over 100 years. Then, in 1915, Einstein published his general theory of relativity in which the path of photons could be affected by the curvature of space around massive objects. In 1916, Karl Schwarzschild published a solution to Einstein’s equations and showed that a “dark star” could exist when the radius of a star fell below a critical value — now known as the Schwarzschild radius.⁶ Despite the difference in theoretical approaches, the Schwarzschild radius has the same value as Michell’s critical radius

$$R_c = R_s = \frac{2G}{c^2}M. \quad (5)$$

The dark stars of Schwarzschild were considered to be mathematical novelties rather than descriptions of actual celestial objects. However, a series of theoretical developments over the next several decades made the existence of super-dense stars more plausible. In 1930, Subrahmanyan Chandrasekhar used quantum mechanics to explain the dense structure of white dwarfs, and by 1934 he had predicted that all stars with *M* < 1.4 *M_{Sun}* would end up as white dwarfs. Also in 1934, Fritz Zwicky and Walter Baade published the first theoretical work describing the formation of neutron stars — stars 500 times more dense than white dwarfs — in the aftermath of supernovae explosions. In 1938, George Volkoff, Richard Tolman, and Robert Oppenheimer predicted that neutron stars had maximum sizes of a few solar masses. The question remained “What is the evolutionary fate of more massive stars?” Oppenheimer concluded that massive stars eventually imploded to form dark stars.

Detailed computer simulations by Sterling Colgate, Richard White, and Michael May in 1960 showed that stars with *M* > 2 *M_{Sun}* eventually used up all their nuclear fuel and then imploded without limit. In 1967, John Wheeler coined the term “black holes” to describe these imploded stars. In the late 1960s and early 1970s, theoretical work by Roger Penrose, Stephen Hawking, and others, explored the expected properties of black holes.

In 1971, evidence from combined X-ray, radio, and optical observations of Cygnus X-1 led to the conclusion that the first known black hole had been discovered. In 1979, evidence was found that there is a 3-million-solar-mass black hole at the center of the Milky Way. It is now generally accepted that there is a massive black hole at the core of every quasar, and of many galaxies.

⁴ Actually, Michell referred to a “critical circumference,” equivalent to a “critical radius.”

⁵ Kip S. Thorn 1994, *Black Holes and Time Warps*, 122-123.

⁶ Schwarzschild’s solution of Einstein’s field equations also showed that time would be dilated in the vicinity of a large mass. At the surface of the Sun the time dilation is about two parts per million, so the gravitational time shift of light arriving at the Earth from the Sun is also two parts per million. This shift was too small to be detected until the 1960s.

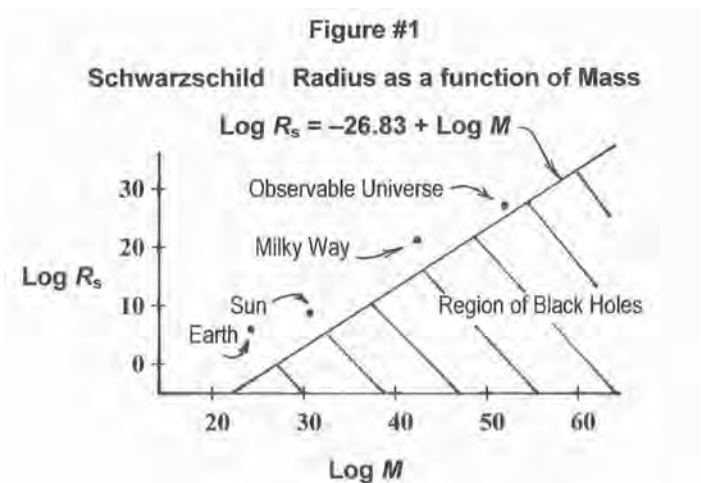
BLACK HOLES AND THE SCHWARZSCHILD RADIUS

The diagonal line in Figure 1 is a graph of the relationship for Schwarzschild's radius versus mass as indicated in equation (5). This equation is just a straight line with the slope,

$$\frac{2G}{c^2},$$

which is approximately 1.485×10^{-27} m/kg. For astronomical objects, the range of the numbers is so large that a logarithmic version has been used to compress the graph. Objects that fall above the line can radiate light. Objects that fall below the line are black holes. A black hole with a mass of 1 kg would have a radius of 1.485×10^{-27} m, smaller than an electron. A black hole with the mass of the Sun would have a radius of about 3 km. Since the actual radius of the Sun is about 700,000 km, it is clearly above the line.

On the graph, objects such as stars and galaxies that contract as they evolve, move vertically downwards over time. Early investigations of black holes concentrated on the question: "Under what conditions will a star contract until it becomes a black hole?" Once an object does become a black hole, no one knows what goes on inside its Schwarzschild radius.



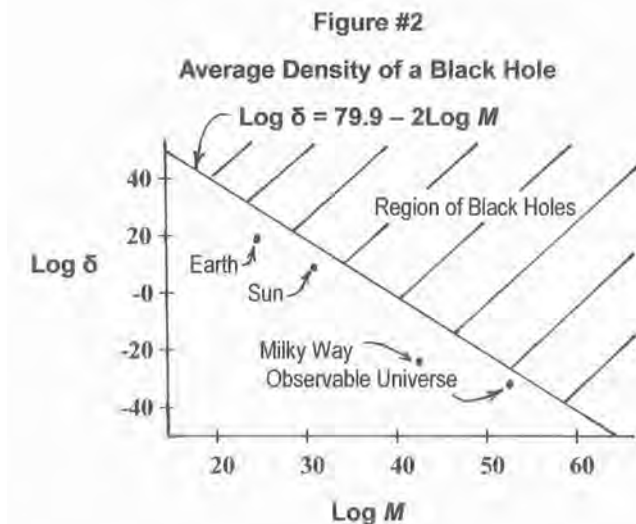
THE AVERAGE DENSITY OF BLACK HOLES

The average density of a spherical black hole can be deduced from its mass and its Schwarzschild radius. A simplified expression for the average density of a black hole can be written

$$\delta = \frac{k}{M^2}, \quad (6)$$

where k is a constant (7.289×10^{79} kg³/m³), M is the mass of the black hole, and δ is its average density (see Appendix B for details). Surprisingly, the average density of a black hole decreases rapidly as its mass increases (Figure 2).

A black hole with a mass equal to the Sun has an average density of 1.8×10^{20} kg/m³. This is so dense that any protons, neutrons, or electrons would be jammed so close together that none of the known rules of physics could apply. In contrast, a black hole with the mass of the Milky Way ($10^{12} M_{\text{Sun}}$) would have a radius of 3×10^{12} km (about one third of a light year) and an average density of just 1.8×10^{-5} kg/m³. This is 100,000 times less than the density of air. If the substance of



such a black hole were evenly distributed inside its Schwarzschild radius, there would be lots of room for the usual laws of physics to apply.

A black hole with the mass of 100 billion galaxies would have a Schwarzschild radius of about 3×10^{26} m (31 billion light years) and an average density of about 1.8×10^{-27} kg/m³. That's about one proton per cubic metre. If such a black hole could ever exist and its substance was evenly distributed, then the particles of matter would also have lots of space in which to operate. Even if the distribution of particles in such a massive black hole was destined to collapse under the force of gravity, the collapse process might take billions of years.

Using known physical forces, is it possible for the substance of a low-density black hole to have a stable configuration that would prevent its total internal collapse? Current mathematical models suggest that once a mass is contained within its Schwarzschild radius, the material will continue to collapse under gravity to an infinitesimal region, eventually placing it beyond any known laws of physics. This conclusion relies on two fundamental assumptions.

The first assumption is that the "inverse square law" for gravity continues to operate over very small distances; that is, every time you halve the distance between two objects, you increase the force of gravity by a factor of four. This assumption is difficult to test on the scale of sub-atomic particles, and, as yet, there is no complete theory of quantum gravity to lead us to the answer. The two other fundamental forces of nature, the nuclear force and the weak nuclear force, do change dramatically as distances approach the scale of sub-atomic particles.

The second assumption is that there is no possible stable configuration for mass once it falls within its Schwarzschild radius. There is a hint that this assumption may not always apply. In 1955, Wheeler explored the theoretical concept of a ball of photons, so big and so massive that none of the photons could escape their combined gravity. He coined the name "geon" to describe these entities. His calculations showed that a geon could exist if all the photons circulated in a torus (doughnut shape), but that the configuration was unstable: any little nudge would cause the system to disintegrate. Although Wheeler was not dealing with black holes, he did demonstrate that there may be configurations of matter/energy that could prevent the escape of photons without collapsing to an infinitely dense point.

SUMMARY

Simple equations and Newtonian mechanics provide a means for exploring gravitational red shifts, and the mass, radius, and density of black holes. Graphs of Schwarzschild radii versus mass, and average densities of black holes versus mass, provide visual displays of the simple relationships among these properties. With this basic knowledge, other questions about black holes can be examined.

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APPENDIX A

A Derivation of Gravitational Red Shift (GRS) using Newtonian Mechanics

The kinetic energy of an object with mass, m , and velocity, V , is defined as

$$E_k = \frac{mV^2}{2}. \quad (\text{A1})$$

If it is assumed that a photon travelling at the speed of light, c , has an “effective mass” (m) then equation (A1) becomes

$$E_p = \frac{mc^2}{2}. \quad (\text{A2})$$

To describe the effect of gravity on a photon leaving the surface of a star, let m correspond to the effective mass of the photon, let M represent the mass of the star, and let R be the radius of the star. Then the gravitational energy of the photon would be

$$E_g = \frac{GmM}{R}, \quad (\text{A3})$$

where G is Newton’s universal gravitational constant.

An expression for the GRS of a photon can be obtained by taking the ratio of the gravitational energy (A3) and the photon energy (A2)

$$GRS = \frac{E_g}{E_p} = \left(\frac{2G}{c^2} \right) \frac{M}{R}. \quad (\text{A4})$$

In this expression, the effective mass of the photon cancels out. The first factor ($2G/c^2$) is a constant, approximately equal to 1.485×10^{-27} m/kg. The second factor (M/R) provides a measure of the surface gravity of a star.

Notes:

1. If we had used Einstein’s equation, $E = mc^2$, rather than $E =$

$mc^2/2$, to represent the energy of a photon, the formula for GRS would have been twice as accurate. However, in this paper, the use of $E = mc^2/2$ has two advantages. First it allows us to be consistent in using only Newtonian mechanics. Second, in the resulting GRS formula, when the GRS is set equal to “1” the expression leads directly to the critical radius, R_c , found by Michell for “dark stars.”

2. In this paper, the units *metre*, *kilogram*, and *second* have been used in most numerical computations. When necessary, masses and distances have been converted to these units using information found in the *Basic Data* section of the *Observer’s Handbook*.

APPENDIX B

A Derivation of an Expression for the Average Density of a Black Hole

Density is defined as the amount of a substance per unit volume, and is calculated by dividing the mass of an object by its volume. Density provides a means for comparing the relative amount of mass in equal volumes of different materials. For example, air has a density of 1.23 kg/m³ while methane has a lower density of 0.72 kg/m³. In a mixture of air and methane, methane is less dense and would rise to the top.

For spherical black holes, the Schwarzschild radius provides a connection between radius and mass

$$R_s = \left(\frac{2G}{c^2} \right) M \quad \text{or} \quad M = \left(\frac{c^2}{2G} \right) R_s. \quad (\text{B1})$$

The volume of any sphere is given by

$$V = \left(\frac{4\pi}{3} \right) R^3. \quad (\text{B2})$$

An expression for the average density, δ , of a black hole can be found by dividing equation (B1) by equation (B2):

$$\delta = \left(\frac{V}{M} \right) = \left(\frac{3c^2}{8G\pi} \right) \frac{1}{R_s^2} \quad (\text{B3}), \text{ or}$$

$$\delta = \left(\frac{3c^6}{32G^3\pi} \right) \frac{1}{M^2}. \quad (\text{B4})$$

Equation (B3) provides the average density in terms of the radius, R_s , while equation (B4) provides the average density in terms of the mass, M . Equation (B4) is known as the Schwarzschild-Oppenheimer density solution for a spherically symmetric, non-rotating black hole. The term “average density” is important because this calculation assumes that the mass of a black hole is distributed evenly through the volume enclosed by its Schwarzschild sphere. In contrast, most discussions of black holes assume that the mass will collapse to infinite density at the centre of its “Schwarzschild sphere.”

Substituting the values of the constants in equation (B4), the average density of a black hole is given by

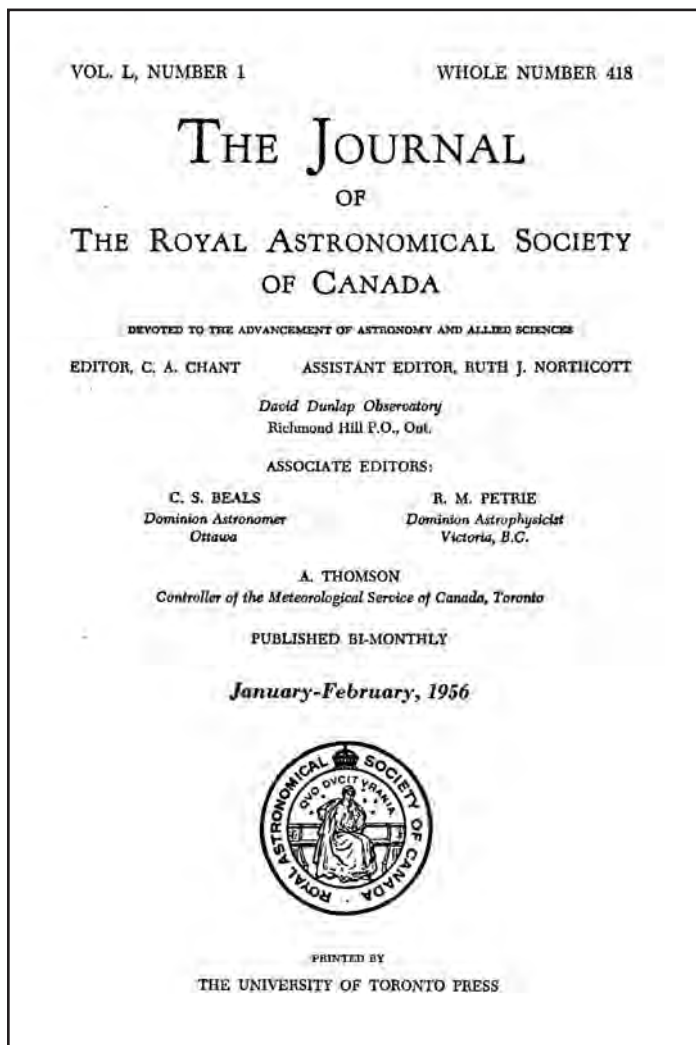
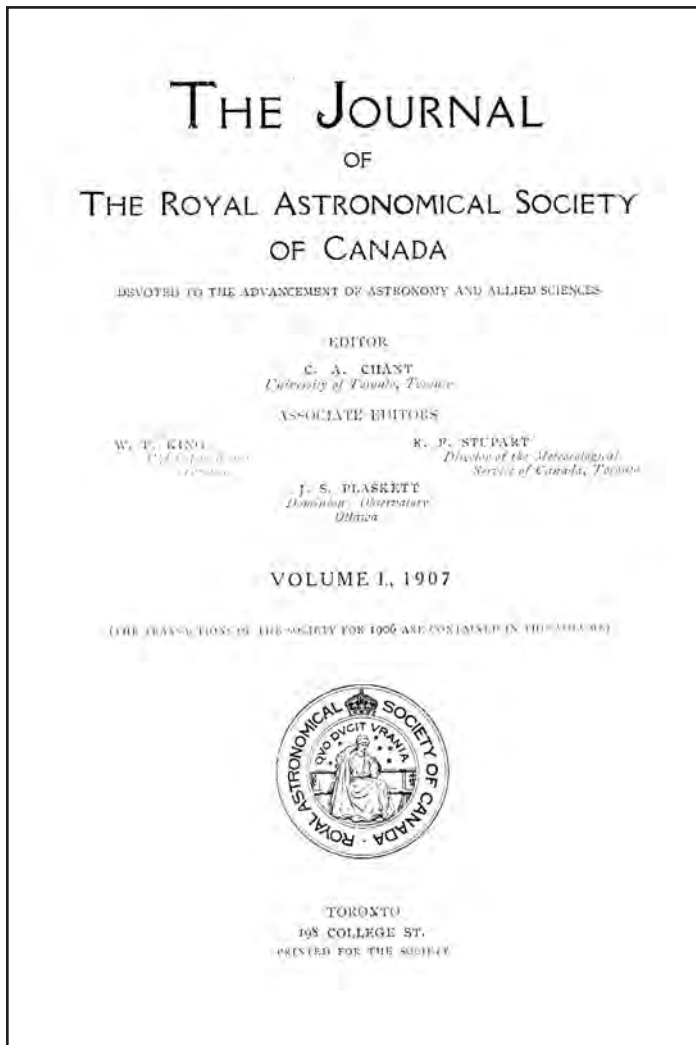
$$\delta = (7.29 \times 10^{79}) \frac{1}{M^2} \text{ kg} / \text{m}^3 \quad (\text{B5}),$$

or, in logarithmic form,

$$\text{Log} \delta = 7.29 - 2 \text{Log} M. \quad (\text{B6})$$

William Dodd has a M.Sc. in astronomy and a D.Ed. in computer applications. He is a retired mathematics teacher with a particular interest in the fundamental and historical aspects of astronomy.

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Two milestone *Journals*: Left: Volume 1, Number 1 (1907); Right: Volume 50, Number 1 (1956)

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“A collision in the local group of galaxies”

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

In late 1984, when I defended the proposal for my thesis (to be on the effect of interactions on the gas content of galaxies), one of the committee members (a cosmologist) said “But galaxies don’t interact — take the number of galaxies, divide by the volume of the Universe and it’s obvious they don’t interact.” Of course, that conventional wisdom of the time was turned on its head within a couple of years, and we now know that galaxy-galaxy interactions drive many of the most interesting phenomena, like bursts of star formation, and the assembly of galaxies in the early Universe. Now David Block, of the University of the Witwatersrand in South Africa, and his colleagues have found that the nearby Andromeda Galaxy (M31) was struck almost head on by its companion M32 about 200 million years ago (see the October 19 issue of *Nature*).

M31 has been known for a long time to be rather different from the Milky Way. Our galaxy has lots of gas, mainly molecular hydrogen, inside the Sun’s orbit around the centre, but M31 has almost none. Stars form inside the clouds of molecular gas, and those stars, along with the dust associated with the gas, combine to give the appearance of the Milky Way in the night sky. The famous Orion nebula is a relatively nearby example of a cloud actively forming stars. M31 does have molecular hydrogen in a ring with a radius of about 10 kpc (something like the distance of the Sun from the centre of the Milky Way), whose centre is offset somewhat from the centre of the galaxy. Star formation in M31 is restricted to that ring. Why are the two galaxies, whose overall shape is otherwise similar, so different? That has been a long-standing puzzle.

Block and his colleagues recently discovered that M31 has an inner ring that shows up in emission from warm dust and gas, with dimensions of about 1.5×1 kpc, and offset about 0.5 kpc from the centre. They used data from the Spitzer Space Telescope (SST), the last of the four “great observatories” launched by NASA, which collects data in the infrared range of the spectrum. It was the IRAS mission of the 1980s that led to the revolution in our understanding of galaxy interactions, so it seems appropriate that its successor, the SST, is the one to show that M31 recently had an interaction itself.

The inner ring appears in an image taken at a wavelength of 8 microns, which traces dust and large molecules (known as polycyclic aromatic hydrocarbons, or PAHs) at temperatures of ~ 100 °K. Once the ring was found, Block and his team proposed that it — and the outer ring — were caused by a collision. As such collisions typically cause bursts of star formation, that would also nicely explain the general absence of gas from both M31 and M110 (another companion of M31 which, though essentially identical to M32, does have gas): the gas was depleted by the starburst.

In order to demonstrate that a collision really is the best explanation, Block and his colleagues ran computer simulations of collisions to determine which galaxy collided and when, and to predict the velocity of the gas in the rings. The simulations included the mass of stars, gas, and dark matter, but they differed from previous simulations in that they had M32 approaching M31 almost along its polar axis, and M32 was more massive than it is now, allowing for considerable stripping of gas (and perhaps dark matter) during its passage through M31. The simulations reproduce very nicely the observed rings, and the gas velocities predicted by the model for the outer ring are in good agreement with the velocities previously observed. So it would appear that a mystery is solved: M31 and M32 underwent an interaction, leading to their current states after 200 million years.

It’s fascinating to watch science evolve with time. In 20 years, we’ve gone from a conventional wisdom of no interactions, to an understanding that they happen all the time and largely drive how galaxies appear. In just the same way, we know now that Pluto isn’t really a planet, but just the first Kuiper belt object to be discovered. But that’s a story for another day. ●

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.

The Crab Nebula

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

While it has become trite through repetition, it remains true that “we are children of the stars.” The most abundant substance within our bodies is water, H_2O , two hydrogen atoms bound to one oxygen atom. The constituents of this simple molecule are comfortable in one-another’s arms, but their mutual attraction and quantized dance are the result of the crossing of two very different paths in life. The hydrogen nuclei were created during the first few seconds following the Big Bang approximately 13.7 billion years ago. The oxygen nucleus could not have existed until the Universe had an age of at least a few million — perhaps a few billion — years. Hydrogen nuclei are *primordial*; they were the first nuclei formed. In contrast, the oxygen nuclei are the product of nuclear reactions within stars and their subsequent dispersal through space via supernovae explosions.

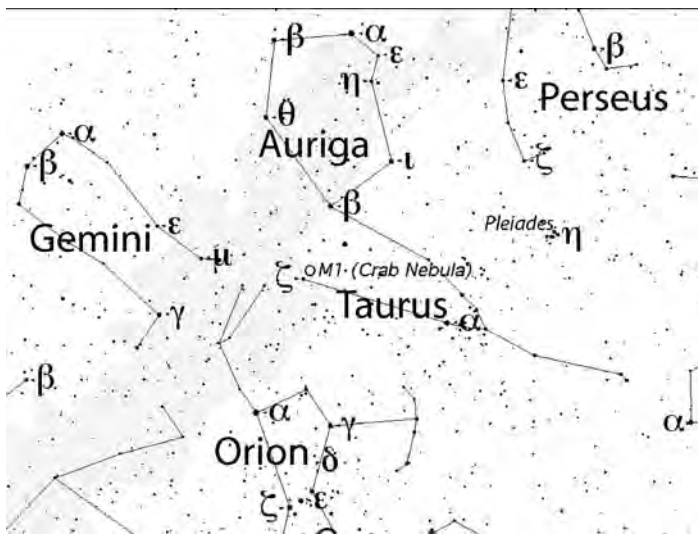


Figure 1 — Field within Taurus containing M1 (NGC 1952).

Understanding the formation of the elements in stellar interiors has been, perhaps, the principal goal of astrophysics and has, necessarily, led to a consideration of the nature of supernovae. One object more than any other has been at the core of such research, namely, the Crab Nebula, the first object on Messier’s list, also identified as NGC 1952 [RA(2000) = $05^h 34.5^m$, DEC(2000) = $+22^\circ 01'$] There are historical reasons as to why the “Crab” is M1 and not further down the list. Certainly, it is not the easiest to observe nor the most spectacular of the

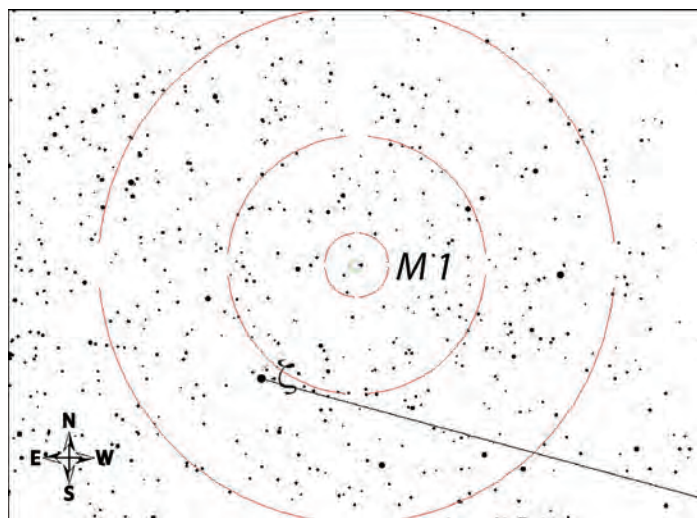


Figure 2 — Finder chart shown with 0.5°, 2°, and 4° Telrad circles.

Messier objects. (It is, however, the most conspicuous supernova remnant.) It was detected by Bevis in 1731, and independently by Messier in 1758 while searching for Comet Halley. Under very dark, clear-sky conditions, a few people with very good eyesight claim to be able to see M1 while using 10×50 binoculars. In a small telescope the Crab’s resemblance to an elongated tail-less comet is apparent, a fact that accounts for Messier’s interest in it. A hint of the filaments that are so prominent in, for example, HST images appears only under excellent observing conditions and with apertures of 40 cm (16 inches), or more. Lord Rosse detected filaments using a 36-inch diameter telescope, an observation that led to the description “crab-like.”

One of us (DPH) had the good fortune to be present at the early morning seminar at the University of Arizona on January 16, 1969, when the detection (at the Steward Observatory the evening before) of *optical* pulses with a period of 33 *milliseconds* was announced. That is still a remarkably short period for a “normal” rotating neutron star, and the Crab pulsar is still but one of only five or six that have been detected optically. [As an aside, sitting in the front row during that exciting and historical seminar was George Van Biesbroeck, age 89 years, a man whose career as a professional astronomer began in 1904! One wonders what thoughts passed through GVB’s mind during that presentation on a member of a class of objects and a physical

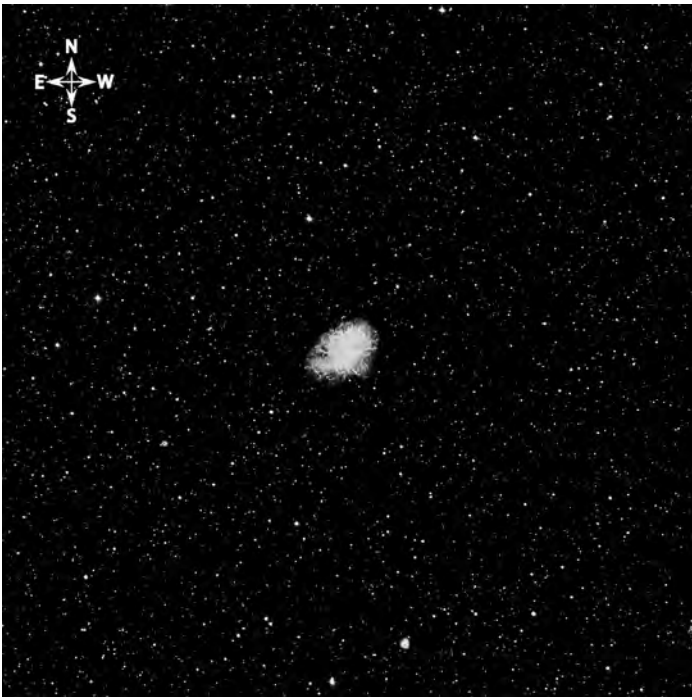


Figure 3 — $50' \times 50'$ field that includes NGC 1952 taken from POSS images.

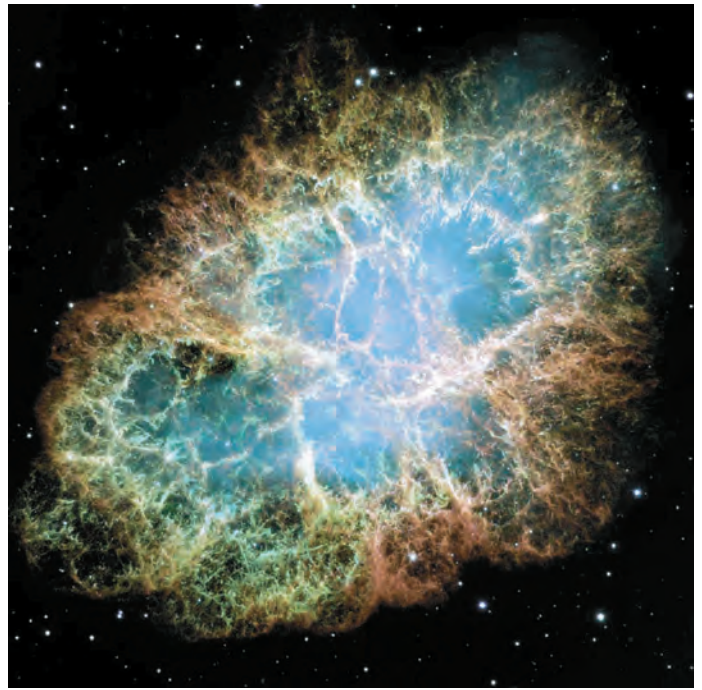


Figure 4 — Hubble Space Telescope image of NGC 1952 courtesy of NASA and STScI.

phenomenon that could not have even been *imagined* during most of his long career.]

The Crab pulsar/neutron star is an object of superlatives. It is a star that spins on its axis more than 30 times per second, has an equatorial rotational speed that is several percent the speed of light, and has a density comparable to that of nuclear matter.

As well as serving as a natural laboratory for testing many aspects of modern astrophysics, M1/NGC 1952 offers challenges for the observer and opportunities for testing one's visual acuity and the advantages (or not) of various combinations of aperture, eyepiece, and filter. Does a deep-sky/ultrablock filter help? Some

say "yes," and some say "no." What aperture do you require in order to detect filaments? Can you detect it using binoculars? Have a look at this famous object next time you are observing, and take a moment to consider that your atoms came from supernovae like this one. ●

Doug Hube is a professional astronomer retired from the University of Alberta. Warren Finlay is the author of "Concise Catalog of Deep-sky Objects: Astrophysical Information for 500 Galaxies, Clusters and Nebulae" (Springer, 2003), and is a professor of engineering at the University of Alberta.

Finding Things

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

I'm a starhopper. When I got started in astronomy back in 1957, there were two ways of finding things in the sky: setting circles or the other way. It didn't have a name back then.

Setting circles appealed to my 16-year-old geek brain, but I couldn't afford a telescope with setting circles and, besides, I wasn't sure I could ever figure out what the current sidereal time was. Back then, astronomy books assumed you had an observatory with a sidereal clock, and that's how they explained how to use setting circles.

Luckily, two months elapsed between the time I first got interested in astronomy and the arrival of my first telescope on July 4, an Edmund *Palomar Jr.* 4.25-inch reflector. By the time it arrived, I had been studying the sky for two months with my naked eyes and my trusty 6 × 30 monocular (half of my father's World War I binocular that my brother had disassembled and, as usual, only half reassembled). I already had a backlog of objects to look at with my new telescope, and, thanks to my monocular, I knew exactly where to look that first night: the Moon, Saturn ("Oh wow! It *really* has *rings!*"), Epsilon Lyrae, and Mizar and Alcor. Over the next few weeks I observed various double stars, which was what you did in those days, identified Saturn's moon Titan, and observed Jupiter and its retinue of moons. On July 17, I observed my first deep-sky object, M22 in Sagittarius. I don't remember now how I found it, but it was probably by the technique we now call "starhopping": start from a known bright object and then navigate by star patterns to the target.

A few months later, I made the trek up behind Molson Stadium and joined the Montreal Centre. My two most vivid memories of that first night were of the Centre's library — shelves full of books and magazines — and their beautiful brass 6.5-inch f/15 refractor, mounted in a dome atop a gigantic pier and mount, with *setting circles!* Soon I hoped to be initiated into the secret order of serious astronomers who used setting circles.

As the weeks went by and I spent every Wednesday and Saturday night at the observatory, I noticed that nobody actually *used* the setting circles. Instead, everyone seemed to find things exactly the same way I did with my little scope. In fact, one of the rules in the Messier Club was that setting circles were strictly prohibited, as they would make things too easy. I gradually began to suspect that the problem was that no one had figured out how. The only time those beautiful engraved brass setting circles were ever used were when George Wedge (seen at the



Figure 1 — The Montreal Centre's 6.5-inch f/15 Topham refractor with its setting circles.

eyepiece in Figure 1) and I, on a Saturday morning, would look up the coordinates of the Sun and Venus, and then offset the scope by the difference in coordinates to find Venus in the blue daytime sky. We once even found Mercury that way.

Myself, I continued starhopping. First the Messiers, then the Finest NGCs, then the Herschel 400. When I took up variable-star observing a few years ago, I starhopped to all of "my" stars. I defended starhopping stoutly as an educational and aesthetic tool against the hordes of GoTo scope users who invaded the hobby. I prided myself on being able to locate dozens of objects by heart. I tested a couple of GoTo scopes for a local dealer, and found them frustratingly slow and noisy, and I had to install a fresh set of batteries each night.

Then last year, I was given for testing purposes an Orion 6-inch Dobsonian equipped with IntelliScope digital-setting circles. This took only a couple of minutes to align on two bright stars, and I had fun looking at various deep-sky objects, including a few I hadn't looked at in years because I'd forgotten the starhop to them. Unlike a GoTo scope, finding things was fast, because I moved the scope myself until the hand controller read "0.0 0.0". It was totally silent: no motors. The batteries seemed to last forever because they weren't powering those noisy motors.

I wrote my review and moved on, but a little idea started teasing the back of my brain. Observing variable stars involves



Figure 2 — The Argo Navis controller.

a lot more time in locating and identifying the variable's field than in actually estimating its brightness. The IntelliScope controller has a user database where you can enter the coordinates of up to 99 objects. Why not enter the coordinates of my variable stars? I entered a couple dozen, which proved to be quite easy. The next clear night I timed myself, and found that I could observe three variables using the digital setting circles in the time it took me to observe two stars by starhopping. Since quantity of estimates is important in variable-star observing,

this meant a major increase in productivity.

I quickly found myself using the little 6-inch far more often for my variable-star sessions than my 11-inch Starmaster. So I recently made the decision to install digital setting circles on my Starmaster. Friends locally in the Toronto Centre and online all strongly recommended the Argo Navis system, made by Aussie Gary Kopff. Though more expensive than the competition, it offered advanced electronics, a simple and elegant user interface, and, best of all from my point of view, a large user object database (up to 1100 objects), easily updateable from a computer using software provided. Gary recommended an installation kit from Sky Engineering for my scope.

Installation took under an hour, even for a technoklutz like me. The 228-page manual looks daunting, but in fact only about 30 pages are required reading, which took about an hour with the Argo Navis computer in hand. Then all I had to do was wait until a clear night (few and far between at this time of year) and I was up and running.

In practice, the Argo Navis has proved extremely accurate and easy to use. Alignment (set horizontal and then two stars) takes a minute or two. Moving from one object to the next takes under a minute. My ratio of observing time to finding time is going up really fast. The user interface consists of two buttons and a dial, perfect for operation in Canadian temperatures with heavy gloves on. The red LCD screen is easily readable, even with my astigmatic eyes without glasses.

The main problem with Argo Navis for me has been what I call "the peanut factor." At the end of the observing session, when I'm beginning to feel a bit tired and cold, I'll say, "Oh well, I'll just observe *one* more object..." Half an hour later, I'm still playing. So, even for this crusty old starhopper, the Argo Navis has proven a double benefit: it increases my productivity, but it also increases my fun. When I'm done my variable-star "work," I'm still out there looking at deep-sky objects that I haven't viewed in ages, because the starhops are too obscure. Or double stars in out-of-the-way places. Or having a peek at Uranus and Neptune because the nearer planets are all on the far side of the Sun. But mostly, having fun! ●

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A Finder Found

by Don van Akker (don@knappett.com)

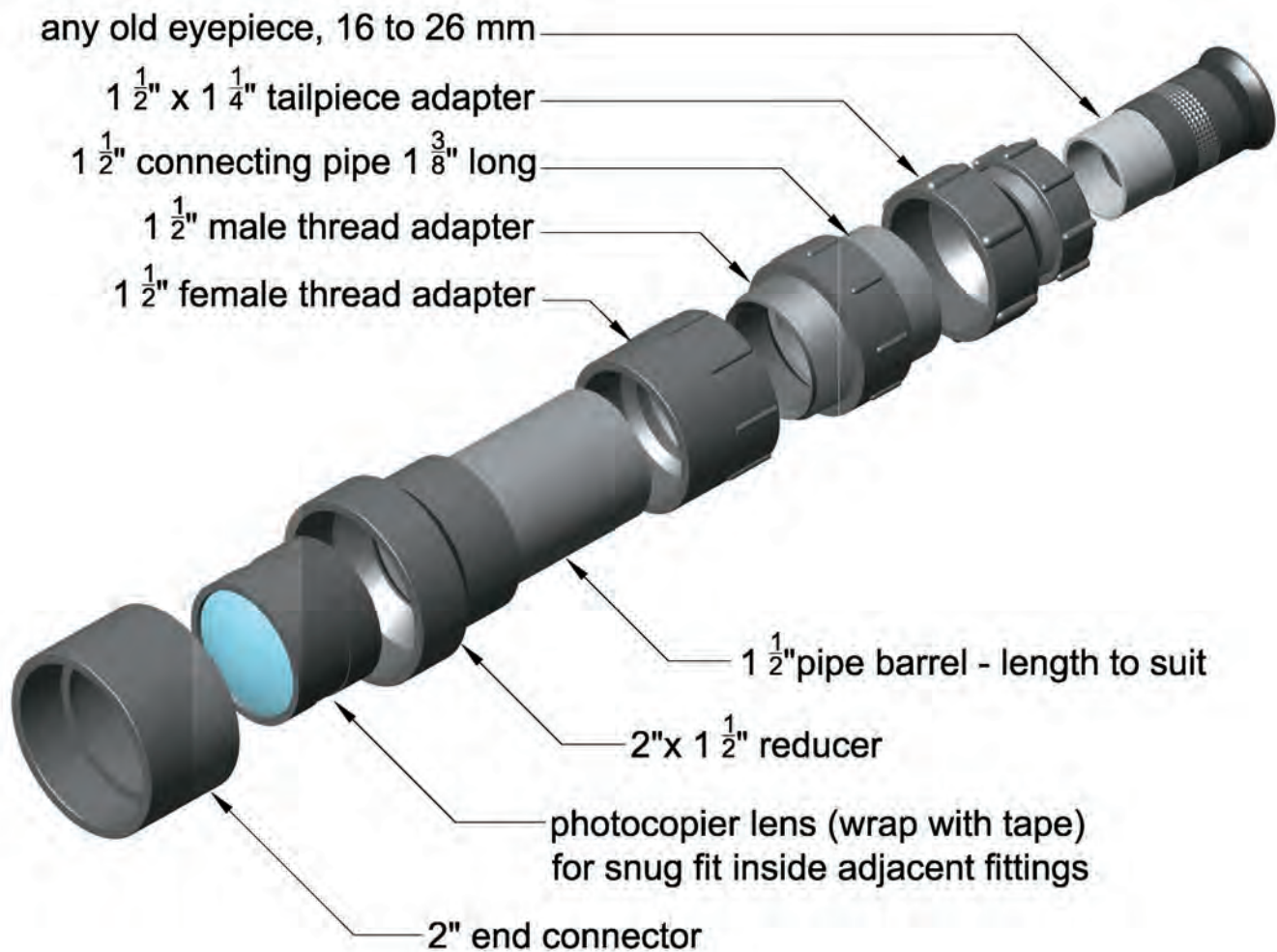
The idea for this project comes from Norm Willey of the Cowichan Valley Star Finders, who did a workshop on it at their July 2006 star party. It is gratifying because it is a strike back at the appalling stream of techno trash that pours into our landfills and even more rewarding because the result is an impressive little finder scope that is the equal of most consumer models.

The first thing you need is the lens out of an old photocopier. Almost everyone has seen one of these headed for the dumpster at one time or another. The next time you do, intercept it —

inside is the heart of this great little scope. If you can't wait that long, try visiting a few repair shops or talk to the copier geek that comes to your office. Be warned that these lenses come in different sizes; if you get one of the smaller ones, be prepared to scale everything down to fit.

Revisit the plumbing department of your local hardware store for everything else needed. All the parts are ABS plastic, as listed in the illustration.

Two items deserve special interest — first are the adapters that fit together to make the focuser. Because plumbing threads



are tapered to fit tightly only when seated, there will be some slop when the focuser is extended. Off-shore binocular makers get past this problem with a special gluey grease they use to make cheap mechanisms operate smoothly. Plumbers use Teflon tape, easier to get and not so sticky. This thin white tape is wrapped clockwise onto the male thread three or four times. Try it, adjusting the number of turns to fit.

Our second special item is the 1 1/4" tailpiece adapter. This was so obviously designed to be an eyepiece holder that the plumbing industry must have appropriated it afterwards. It is strange that there is no 2" equivalent. Evidently, the designer had no 2" eyepieces.

The photocopier lens has several elements mounted in a cylindrical cell. Mine was just over two inches in diameter, which didn't fit anything from the plumbing shelves. The solution was to wrap it with masking tape until it was the correct diameter for a snug fit between the end connector and the reducer. Assemble these into a unit simply by pushing them together. Next, assemble the focuser, the eyepiece holder, and the connecting pipe into a unit the same way. Put in any midrange eyepiece and hold it to your eye. Now hold up the lens assembly in front of it, moving it back and forth until you get focus. Have someone measure the distance between the lens elements, and that distance, plus the combined depth of two fittings, is the length of the barrel. Plan on doing this a few times before you get it

just right.

Pipe fittings such as these are made with an "interference fit," which means that, when fully seated, they are so tight as to be very difficult to disassemble. This makes gluing optional and I still haven't glued mine. I like to be able to take them apart later and tinker.

Alas, when fully assembled, you may find that your little scope is a disaster. Except for a narrow tunnel down the centre, you might not see anything but the glare of stray light bouncing around inside the tube. The solution is a coat of matte-black paint inside all the fittings. When dry, put everything back together and look at the Moon. That's not too bad is it? In fact it's really quite good and it focuses sharp as a knife! Plus you have just joined the hallowed ranks of ATMs (amateur telescope makers) — the people who build their own.

Next issue...mounting rings, a simple mount, crosshairs for your eyepiece, and John McDonald's prism diagonal. Stay tuned. ●

Don van Akker and his wife Elizabeth are members of the Victoria RASC and think their new finder is like found money. Don will answer questions about any Gizmos project and would love to hear your ideas for future columns at don@knappett.com.



Left: The finder exploded view. Above: The assembled finder

Dr. Laura Ferrarese

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

Black holes — even the most disinterested person has heard of them and has some notion of their strangeness. Nevertheless, their properties remain, in large measure, an enigma, and the influence they wield on their surroundings is largely unknown. Ramp up the weirdness factor a thousand...a million...a billion-fold and you are dealing with SBHs — supermassive black holes that lie in the centres of many galaxies. As part of a team whose research involves what has been described as “...one of the most important discoveries to come out of the Hubble Space Telescope,” Dr. Laura Ferrarese has immersed herself in these strange objects.

Growing up in Italy, Dr. Ferrarese had a general interest in science and physics but not particularly for astronomy, although she viewed the subject as an opportunity to learn. One opportunity of which she took early advantage was connecting with local amateurs — she joined a club and found herself spending a fair amount of time at an observatory in the Alps, something most of us can only dream of! (However, she points out that there is little opportunity to see stars, as Italy is quite urban). Her teaching career got its start at the club since she presented classes for fellow members on topics such as star finding.

The amateur connection is an important one. Dr. Ferrarese maintains that one can become detached if one studies only from books. Amateur activity keeps a person in touch and demonstrates that “the stuff on your computer screen is actually out there.” Acknowledging that amateurs, given their numbers and locations, can be sometimes be more successful than the pros at securing data, she hopes to strengthen her amateur ties as her busy schedule permits.

When it comes time to “turn pro,” Italian universities provide some good astronomy departments with which to study. Since there are few astronomy students in the country but a reasonable number of professors, the student/teacher ratio is a favourable one. Dr. Ferrarese wound up studying at the University of Padua where the Department of Astronomy is housed in the same building in which Galileo worked! Interestingly, this historical connection is taken in stride by students and faculty, who don’t give it a second thought. In fact, Dr. Ferrarese has found that North Americans are more sensitive to the past than Europeans, despite (or because of?) our relatively short history.

Eventually, Dr. Ferrarese left Italy to pursue her Ph.D. in



Dr. Laura Ferrarese

the United States. The reason was simple — resources. The United States and Canada are rich in astronomers, astronomy programs, telescopes, data, jobs, and the ever-important funding. Her Ph.D. was obtained at Johns Hopkins University and was followed with a Hubble Fellowship at the California Institute of Technology. She became a Research Associate at UCLA and then an Assistant Professor at Rutgers University. Shortly thereafter, she became a Senior Research Officer at the Herzberg Institute of Astrophysics (HIA). She is also an Adjunct Professor at the University of Victoria.

Why Canada? Canada is in a unique position in astronomy because of several new initiatives. A good example is the proposed Thirty-Metre Telescope, which Dr. Ferrarese finds “very, very exciting.” Canada is also involved in programs to replace the Hubble Space Telescope. “Things are actually happening here.” And the HIA, according to Dr. Ferrarese, is *the* centre, and she likes “being in the middle of the action.”

When asked what she enjoys most about her research, Dr. Ferrarese admits to finding almost everything engaging...but does single out her work on early-type galaxies. This galaxy type includes elliptical and lenticular-shaped galaxies that

usually contain little gas or dust and, in the case of ellipticals, have no spiral arms or disks. They contain few hot, bright stars. However early-type galaxies do sometimes contain quasars and strong radio sources — and supermassive black holes.

Dr. Ferrarese was in on the ground floor of SBH detection. While a grad student in Baltimore, her advisor and his team announced the first detection of a SBH (in M87). A year later, the team, now including Dr. Ferrarese, announced a second detection, this time in NGC 4261. It is now believed that SBHs are to be found in most galaxies.

Looking for a dark heart in the bright core of a distant galaxy is not the easiest job in the world. “But, using SBH masses painstakingly measured, mostly using the Hubble Space Telescope, in two-dozen galaxies,” Dr. Ferrarese and her colleagues have found a correlation between the mass of these central black holes and the host galaxy’s velocity dispersion (a measure of the random velocity of stars in the outskirts of the galaxy). This is the important discovery alluded to earlier. “It is extremely useful because the velocity dispersion is a very easy quantity to measure: the relation therefore allows us to estimate black-hole masses in any galaxy from a very simple measurement! This has allowed astronomers to perform a complete census of supermassive black holes in the local universe.”

Are there galaxies that do not have a supermassive black hole in their centres? Remarkably, Dr. Ferrarese says, “it’s easier to prove that a galaxy has a black hole rather than that it doesn’t! If I were a betting person, I would bet that M33 (the Pinwheel Galaxy) and NGC 205 (a companion of the Andromeda Galaxy) do not have a black hole.” Using the Hubble Space Telescope, Dr. Ferrarese and her colleagues “have been able to place upper limits on the mass of the putative black holes in M33 and NGC

205 that are smaller than predicted by the relation mentioned earlier.”

When not peering into the core of galaxies, Dr. Ferrarese tries figuring out just how far away the galaxies lie. To do this, she uses the HST and the classic distance indicator, Cepheid variable stars. It turns out that what the Cepheids are trying to tell us about their distance depends on their metal content, that is, the relative amount of elements heavier than hydrogen. Dr. Ferrarese is trying to determine this relationship, which ultimately also has a bearing on the Hubble constant.

It turns out that Cepheids are not found in early-type galaxies, which is definitely a problem if you want to know how far away this kind of galaxy lies! Dr. Ferrarese and her team are using the HST to observe Cepheids in spiral galaxies that are interacting with, and therefore at the same distance as, early galaxies for which direct measurements are more problematic.

Being a research scientist means, of course, learning new things. This is certainly true of Dr. Ferrarese, but she points out that most of the things she learned during the course of her work were not in any way mentioned in her initial funding proposals. This makes going to work each day a bit of an adventure in discovery.

What lies in the future? The Thirty-Metre Telescope for one thing. It should be capable of finding ten-thousand-solar-mass black holes in distant galaxies. And while looking for those, who knows what other interesting things Dr. Ferrarese will turn up? ●

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.

New RASC Web Site Launched!

by Denis Grey, Toronto Centre (denis.grey@sympatico.ca)

The Information Technology Committee is pleased to announce the availability of a new RASC Web site at www.rasc.ca. The new site features more-advanced navigation and style techniques, and has been thoroughly reviewed and revised to bring most content up to date.

As part of this upgrade, the RASC Web Team has implemented a basic content management system that allows any authorized user from across the country to update the Web site without any familiarity with HTML. Members who have access to the Internet and a few hours to spare each month are asked to consider “adopting” a section of the Web site to help keep it timely and fresh. For more information, please contact the RASC Web team at webmaster@rasc.ca.

More information on the new Web site and its updated content will be available in the next issue of the Journal.

Baby, it's cold outside!

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

She: I really can't stay
He: Baby, it's cold outside
She: I've got to go away
He: Baby, it's cold outside
 ...
She: I really can't stay
He: Baby don't hold out
Both: Ahh, but it's cold outside

—From *Baby, It's Cold Outside*
 (c) FRANK LOESSER, 1949

I like to think that the woman in the song really can't stay because she has an occultation to time. But it *is* cold outside this time of year, so she'd be wise to take suitable precautions. She should remember that Mother Nature does not suffer the unprepared kindly. (If you doubt this, read Jack London's short story *To Build a Fire*.)

DATE	ASTEROID			STAR Δ-MAG	Maximum Duration Seconds	Path
	Number	Name	Magnitude			
2006						
Dec 02	407	Arachne	9.7	2.8	9.3	QC - ON
Dec 05	3615	Safronov	7.4	9.2	1.7	NL - SK
Dec 11	164	Eva	9.3	5.6	6.0	MB - ON
Dec 12	5976	Kalatajean	6.4	9.9	1.0	ON
Dec 20	2951	Perepadin	7.8	7.0	8.6	BC - AB
Dec 22	5824	Inigaki	8.6	7.0	1.3	QC - BC
Dec 24	5416	Estremadoyro	9.3	6.5	1.5	NL - MB
Dec 27	1730	Marceline	9.5	5.1	1.7	NS - ON
Dec 28	5651	Traversa	9.5	6.6	2.2	ON - AB
2007						
Jan 01	801	Helwerthia	9.9	5.1	3.0	NL - BC
Jan 05	1000	Piazzia	9.5	5.3	7.1	AB - BC
Jan 14	161	Athor	10.0	3.1	4.4	NL - ON
Jan 15	2650	Elinor	9.8	6.0	1.9	BC - AB
Jan 18	4523	MIT	7.0	8.6	1.2	NL - BC
Jan 25	313	Chaldaeaa	7.2	6.1	4.2	NL - QC
Jan 30	2486	Metsahovi	9.2	6.0	1.6	MB - SK
Feb 01	510	Mabella	9.3	5.3	4.7	AB - BC
Feb 04	6794	Masuisakura	8.9	6.9	2.2	NS
Feb 08	1540	Kevola	9.2	5.5	4.3	SK - BC

Chart 1

If you decide to time an asteroidal occultation away from home one of these fine winter nights — or undertake any other activities in the wild for that matter — please prepare both yourself and your equipment appropriately. To many of you experienced winter-time observers, this will be “old hat,” but I hope that those new to remote-winter observing will take to heart the following advice and act accordingly. The rest of you might treat this as a review.

Personal Comfort and Safety

If possible, always use the buddy system. Two people are better than one and can assist each other if necessary. In the case of an occultation event, I suggest that observers team up and either observe together, or nearby each other, perhaps a kilometre or two apart to avoid duplicating each other's efforts. Take at least one vehicle per station. It's your shelter and means of escape — your lifeboat, if you like. Take cell phones along if service is available. CB radios and FRS radios are also useful. Before you head out, give your phone number to someone at home and tell them where you are going and when you will return.

Dress warmly. The rule of thumb is to dress for 10 degrees colder than the forecast wind-chill factor (see chart). You will not be physically active once your equipment is set up, so you won't be generating as much body heat as you would if skiing or snowshoeing, for instance. Cold is the enemy and wind and moisture are its agents. Dress in layers and pay close attention to your feet, hands, and head. The layer closest to your skin should be a “wickable” material such as wool, polypropylene, polyester, or even silk. “Polypro” long underwear should be worn whenever the temperature is below freezing, and even if it's a few degrees above. It will pull moisture away from your skin and into the next layer where it can do no damage. Your outermost layer should be wind- and water-proof, but “breathable.” GORE-TEX® is good. For all layers, avoid moisture-retaining cotton. When it gets wet, it stays wet and will bleed moisture into all it contacts.

During the travel phase, shed some of those layers so you don't overheat in the car. Then don them

as necessary when on-site. This will minimize sweating. I find it best to be just slightly cool, but not cold. If you begin shivering, stop what you're doing and seek heat immediately. Shivering is the first sign of hypothermia — the lowering of the core body temperature — and is not to be taken lightly. If you begin to shiver, abandon the enterprise, stow your gear, and go somewhere warm. A couple of other hints to keep you comfortable: take along a small piece of carpet to stand on (or, if sitting, to rest your feet on). A Thermos® flask containing a warm drink (no alcohol!) is also a good idea. In very cold weather I wear light gloves inside heavy mittens. I pull off a mitt to make fine adjustments to my equipment, and then promptly reinsert my gloved hand back into the mitt. Never touch freezing metal with bare skin! If you do this you will become instantly stuck if there is any moisture on your hand. Do not try to pull away or you will leave skin behind. Instead, warm the metal until you are released.

Your vehicle

Be sure you have a full tank of fuel before you arrive on-site. Late-night service stations are rare in rural areas and running out of gas could be fatal. In very cold weather you might want to keep your engine running. If so, be sure the tailpipe is clear of all obstructions, open a window slightly, and keep the exhaust well away from your telescope and line of sight to the target star.

Of course, your car, van, or truck must be equipped for winter and in very good condition: winter tires (tire chains for those of you in the Rockies and perhaps elsewhere); strong battery; properly inflated spare tire; jack, and tire iron on board; *etc.* A winter-survival kit is always essential, not just for occultations. It should contain: a shovel; a bag of traction aid such as sand or “kitty litter”; booster cables; a flashlight with fresh batteries; first-aid kit; safety triangles or flares; a tow rope; a heat source (Sterno™ or candles); matches; duct tape; basic tools; and a fire extinguisher.

Your Astronomical Equipment

In general, telescope optics are not adversely affected by extreme cold once they reach ambient temperature. However, moving parts and electronics are affected. For moving parts such as focusers, gear trains, and axle bearings, the major problem is the lubricant supplied by the manufacturers. Only Russian manufacturers such as Intes pay any attention to designing their equipment to operate in the cold. If you use your telescope at temperatures near or below freezing, it is a good idea to replace the stock lubricant with grease designed to perform well at sub-freezing temperatures. One such lubricant is Dow Corning's *Molykote® 33 Extreme Low Temp. Bearing Grease, Light*. It's a phenyl/methyl silicone grease with a lithium thickener that is rated for use from -73°C to +208°C. It's available in small 180-gram tubes and larger containers. For more information, visit www.dowcorning.com/applications/Product_Finder.

LCD displays do not like the cold at all. If your telescope is so equipped, you'll have trouble reading any message that crawls across the screen because of the prolonged decay times of the on-screen characters. The only way to beat this is to keep the controller warm. A chemical hand warmer rubber-banded to the back of the hand controller should help.

Batteries can cause serious grief in cold weather. Make sure that *all* your batteries are fresh and/or fully charged and keep them as warm as you can. Use new alkaline batteries in flashlights, radios, and tape recorders. Use heavy-duty deep-cycle batteries for more demanding equipment such as motor drives, TV/VCR combo units, and dew-remover systems. I suggest activated glass-mat lead-acid batteries for these more demanding tasks. They are heavy but robust and spill-proof. Lead-acid and gel-cell batteries lose considerable capacity as the temperature drops. Typically, at 0 °C such batteries are working at only 80% of their nominal capacity. At -20 °C, power is reduced to 60%. Therefore, use the highest amp-hour-rated

air temperature	5	0	-5	-10	-15	-20	-25	-30	-35	-40
wind velocity										
5	4	-2	-7	-13	-19	-24	-30	-36	-41	-47
10	3	-3	-9	-15	-21	-27	-33	-39	-45	-51
15	2	-4	-11	-17	-23	-29	-35	-41	-48	-54
20	1	-5	-12	-18	-24	-31	-37	-43	-49	-56
25	1	-6	-12	-19	-25	-32	-38	-45	-51	-57
30	0	-7	-13	-20	-26	-33	-39	-46	-52	-59
35	0	-7	-14	-20	-27	-33	-40	-47	-53	-60
40	-1	-7	-14	-21	-27	-34	-41	-48	-54	-61
45	-1	-8	-15	-21	-28	-35	-42	-48	-55	-62
50	-1	-8	-15	-22	-29	-35	-42	-49	-56	-63
55	-2	-9	-15	-22	-29	-36	-43	-50	-57	-63
60	-2	-9	-16	-23	-30	-37	-43	-50	-57	-64
65	-2	-9	-16	-23	-30	-37	-44	-51	-58	-65

This chart, adapted from that used by Environment Canada, shows the temperature-equivalent wind chill for a selection of wind speeds and temperatures. Light-shaded regions highlight values in which frostbite can occur in 10 to 15 minutes. Dark-shaded areas are those in which frostbite can occur in less than two minutes. Note that equipment will cool at a rate related to the wind-chill value, but will not cool below the ambient temperature. Note: air temperature is in degrees Celsius; wind velocity is in km/h.

batteries you can lift. A word of caution: avoid using your vehicle battery. No matter how successful your observations, you will not be very happy if your car won't start afterwards. Another tip: put batteries in a picnic cooler, activate a couple of chemical-type hand-warmers, toss them into the cooler and close the lid. **Warning: Never use lighter-fluid warmers or other devices that use an open flame anywhere near batteries!** Batteries emit hydrogen and could explode if brought near a flame! Flying shrapnel and acid aren't things you want to experience.

Cables are the most common cause of electrical failure in the cold. Bring extra cables for every task and be sure that they are in good condition. Wires get very stiff in sub-freezing conditions, so try not to move them once they are in place and operating properly.

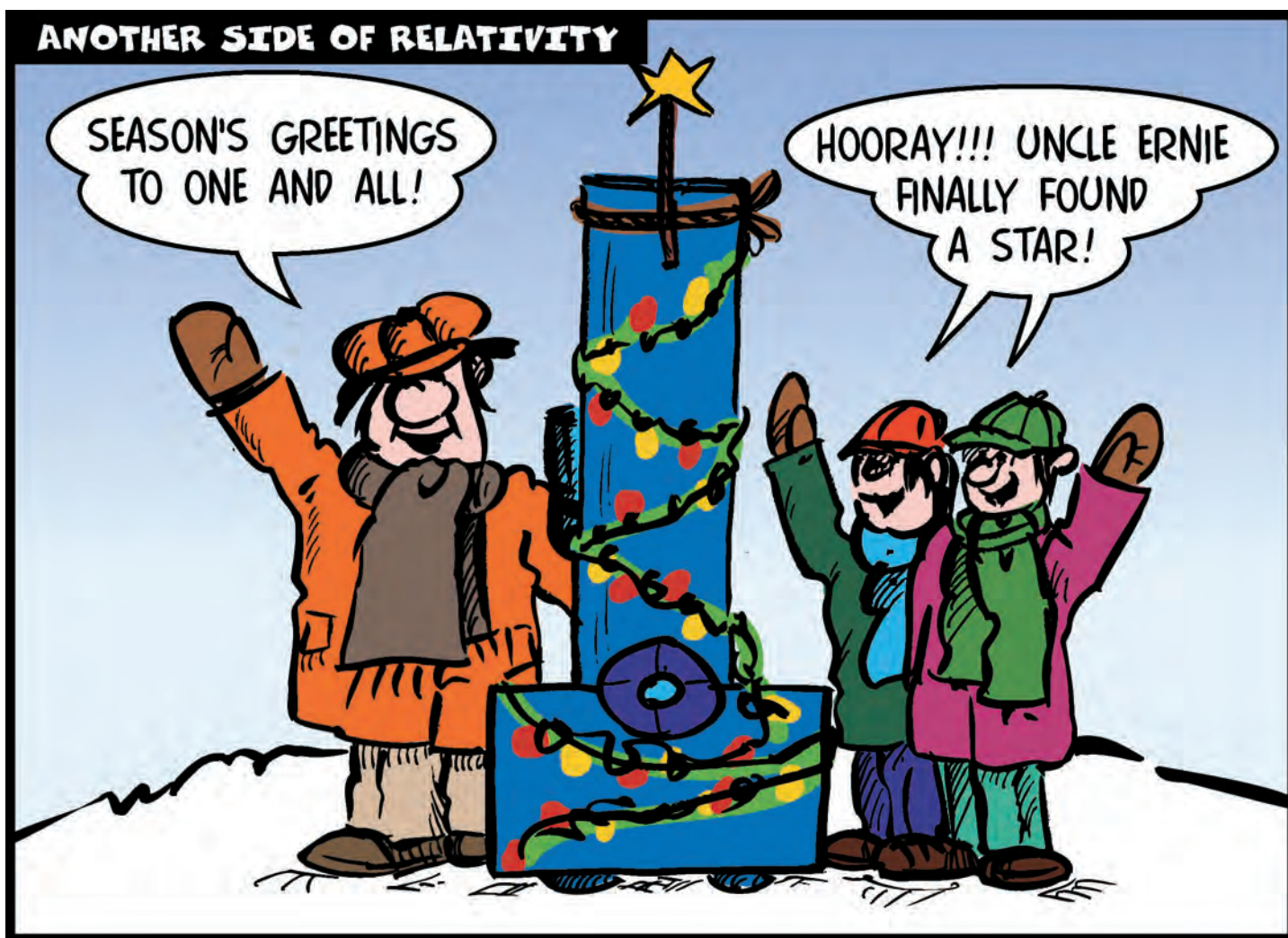
Allow Extra Time

Aside from personal safety, allowing extra time is perhaps the most important piece of advice for cold-weather observing. Everything takes longer in the cold. There is extra gear to prepare and load. You need time to get into cold-weather clothing on-

site. Equipment setup is slower and connections require more rigorous testing. Things will go wrong much more frequently, requiring extra time to rectify.

I hope this helps all you occultationists and other hearty observers to have safe and successful observing sessions. Remember above all to take care of yourselves and your fellow observers. No data are worth personal injury - or worse. Nevertheless, with that in mind, don't let Old Man Winter scare you away from clear dark skies. Just prepare properly when, *Baby, it's cold outside!*

The longer winter nights bring more occultation opportunities — so much so that it's impossible to list them all here for the next couple of months. Here are those I know of that involve stars of magnitude 10.0 or brighter. For finder charts and other details for these and other opportunities in your area, please visit Steve Preston's Web site at www.asteroidoccultation.com and Derek Breit's site for Google maps and station sorts at www.poyntsource.com/New/index.htm. As always, please drop me a line if you plan to observe and time any asteroidal occultations or if you would like to know more about how to observe and time asteroidal occultations. Good luck and clear skies! ●



Planetary Perspectives

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

“Frank, what I keep imagining is if I am some lonely traveller from another planet what I would think about the Earth at this altitude, whether I think it would be inhabited or not...I was just curious if I would land on the blue or the brown part of the Earth.”

— JIM LOVELL, *Apollo 8* astronaut, speaking to fellow astronaut Frank Borman and a global television audience

“You better hope that we land on the blue part.”

— BILL ANDERS, *Apollo 8* astronaut

December, 1968: The Perspective of Space

After a decade of dipping a toe in the cosmic ocean, humankind takes its first baby steps and wades ankle-deep into the void. Three men undertake a daring 6-day journey to the Moon and back, pausing to orbit their destination for 20 hours on Christmas Day and give the first close-up eyewitness accounts of our mysterious neighbour. The spirit of adventure has never been higher, for unlike previous explorers, these are able to instantly communicate thoughts, words, and pictures to the denizens of the home planet. Even as the mind reels, the imagination soars: surely, the sky really is the limit.

But perhaps the watershed moment of the thrilling *Apollo 8* mission has nothing to do with the Moon at all. For during this unprecedented journey, human eyes finally gain sufficient perspective to really see that “home planet” in its glorious entirety. The astronauts’ hand-held cameras serve as mirrors that allow us to see our full reflection for the first time. The image is not just a pretty picture, but a concept. Earth is *not* flat as it appears from ground level, nor even a gentle curve as seen from near space. It is indeed a globe, a finite, self-contained, spherical island that appears to the outward-bound astronauts to be ever-shrinking into the hostile blackness of space. In December 1968, our blue-and-white oasis makes the most exquisite Christmas ornament, suspended by the invisible hook of solar gravity. In this newly revealed bigger picture, “the heavens and the Earth” are no longer two solitudes, but a continuum.

Like countless millions around the globe, a starstruck 13-year-old boy in St. John’s, Newfoundland, is truly inspired by this image and its implications. My first exposure to it borders on the surreal: my family is out doing some last-minute Christmas shopping when I happen upon a large display of the latest electronic “fad” — colour televisions. Suddenly I am confronted



Earthrise as seen by human eyes for the first time, by the *Apollo 8* astronauts Borman, Lovell, and Anders in circumlunar orbit. The author’s choice of the *Photo of the Century* appropriately marks the occasion of JRASC’s centennial issue.

(Source: NASA)

by a wall full of Earths, all in living colour. Our own black-and-white at home, which will be perfectly adequate for next summer’s moonwalk, could never have done justice to this first glimpse of the living Earth. Oblivious to the calls of my siblings, I find the biggest screen with the best picture and remain transfixed for the duration of the broadcast. Pictures of the Moon follow, and I am hooked.

I can never look at my grade-school atlas the same way again, for the real Earth has no edges. The real Earth has no pink and green and yellow polygons as determined by politicians and their armies and duly sketched by cartographers. The real Earth has no barriers to contain the storms visible in its atmosphere, or to suppress the more insidious intrusion of a spiralling human population and the by-products of its nascent technology. Indeed, the only apparent boundaries are between land and sea, and space.

December, 2006: The Perspective of Time

That single television image provided a spiritual awakening of sorts during that boyhood holiday season. It gave me a fledgling

awareness of Earth's place in a much larger universe, and provided the impetus to find out what I could about both. Nearly four decades later, my first-remembered astronomical observation remains my most significant, and most stunningly beautiful. A poster of *Earthrise* hangs near my desk, a constant reminder that I am, first and foremost, a global citizen.

As an astronomer, one can “escape” occasionally into a vastly wider realm. The visible Universe is expanding at the speed of light, but our understanding of it is increasing even faster, sporadically surging forward at the true cosmic speed limit, the superluminal “speed of thought.”

In our quest for knowledge of the infinite, our reach *must* exceed our grasp. In the years since the remarkable *Apollo 8*, human-made robots have visited the planets of our Solar System in turn, finding fabulously interesting but ultimately hostile vistas. Scientists using sensitive ground-based telescopes have found unambiguous evidence of large but decidedly unearthy planets orbiting distant stars. We have kept an ear to the Universe with large radio telescopes, seeking evidence of an intelligent life force to match, let alone exceed, our own, and to date have found none. Orbiting spacecraft have looked out into the previously uncharted depths, bringing the big picture into ever-clearer focus.

The cosmos is in general an inhospitable environment, full of exotic objects and particles and radiations and forces

that continue to challenge and regularly defeat our keenest intellects. Yet that same cosmos is parent to the unlikely series of knife-edge balances that gave rise to our Earth with its indigenous life forms and its inquiring minds.

We may not all be astronauts, but those of us among the earthbound who look out and wonder, also have the perspective — at least in our minds' eyes — to look back and see our beautiful Earth for the marvel that it is. Through the eyes of a still-starstruck 51-year-old man in Edmonton, Alberta, another four decades of submission to the human imperative toward growth — be it biological, military, or economic — have not made the picture any prettier. Unlike the Universe in which it resides, Earth is *not* expanding, and we who depend on its increasingly cramped quarters and limited resources must come to terms with that inescapable fact. Down here, we are in danger of *overreaching*, of grasping until our hands come up empty.

It is time for the human race to step out and collectively take another look at the good Earth for all that it is. We dare not lose our perspective.

There is truly no place like home. ●

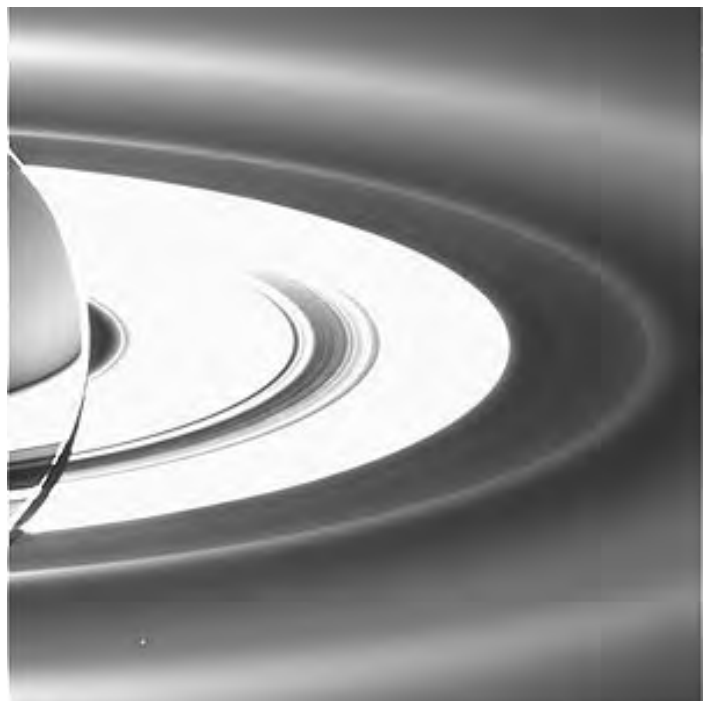
Bruce McCurdy has long been fascinated by Earth's small but significant place within the space-time continuum.

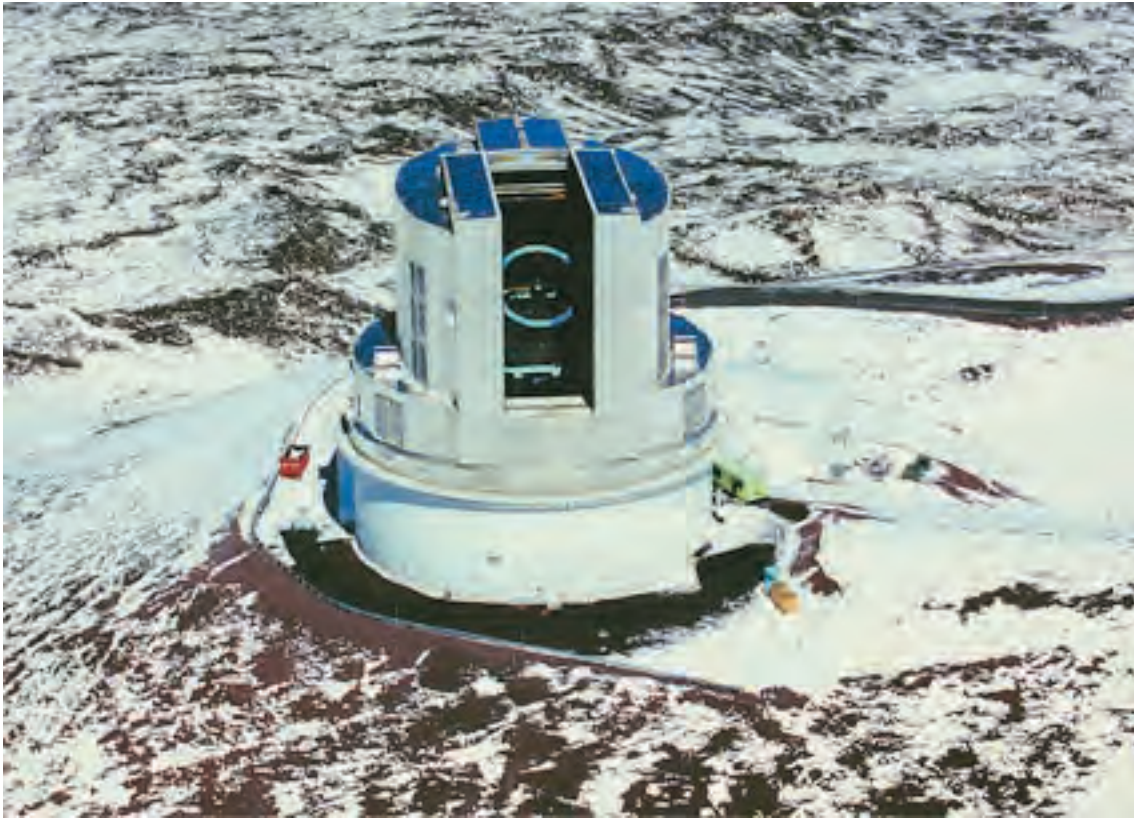
Net Astronomy

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

Cassini at Saturn

Ever since the *Cassini* spacecraft entered orbit around Saturn in 2004, a wealth of stunning images and fascinating new discoveries have been served up to the world. The CICLOPS (Cassini Imaging Central Laboratory for OPERations) Web site is one portal to these images; another is the NASA/JPL Web site called *Cassini-Huygens*. Together the two offer an impressive access to the ISS (Imaging Science Subsystem) camera and its spectacular images. CICLOPS is geared to the scientist, while *Cassini-Huygens* appeals to the public and media, but the boundaries are not strictly defined and exploration of both addresses is heartily recommended. Both Web sites are very well laid out — the CICLOPS site has a simple approach while the *Cassini-Huygens* site follows the standard image-rich format found on most NASA Web pages. At CICLOPS, the home page has a “Captain’s Log” written by the project leader, Carolyn Porco. Her most recent filing talks of the discoveries in the backlit, long-exposure images, including two new rings, a possible comet collision, and a view of Earth from the ringed planet.





The images are largely in JPEG format, while the animations are in GIF and QuickTime — the movie files are large and downloading may take a while! If at least one of these sites isn't in your Favourites list, it should be.

<http://ciclops.org>

<http://saturn.jpl.nasa.gov/home/index.cfm>

The Subaru Telescope

Imagine — a world-class observatory that actually wants to share its images and science with the public. (CFHT, where are you?) First impressions might suggest that this site is mainly for professionals — a notion caused by the placement of science articles at the top of the page — but a little scrolling reveals that Subaru also has links for casual visitors and kids. It has everything you might want from an observational site: all the latest news, information on the observatory, a complete section devoted to children, Flash animations of summit panoramas

and the telescope, instructions and schedules for visitors, and a huge image gallery. There is even a section entitled “Goodies” where you can currently get desktop images and screen savers. While the English is occasionally a little arcane, the site is a great showpiece of Japanese science and achievement. The material on the site is continually being updated, leaving some links in the construction zone, but there is still much to explore. My favourite part of this site is the children's sections — kids should love it and they'll learn something along the way. This site also gives a great overview of the operation of the telescope — imagine this 8.2-m behemoth as your own!

<http://subarutelescope.org> ●

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.

RASC INTERNET RESOURCES



Visit the RASC Web site

www.rasc.ca

Renew your Membership

www.store.rasc.ca

Contact the National Office

nationaloffice@rasc.ca



Join the RASC's email Discussion List

The RASCals list is a forum for discussion among members of the RASC. The forum encourages communication among members across the country and beyond. It began in November 1995 and currently has about 300 members.

To join the list, send an email to listserv@ap.stmarys.ca with the words “subscribe rascals Your Name (Your Centre)” as the first line of the message. For further information see: www.rasc.ca/computer/rasclist.htm

Across the RASC du nouveau dans les Centres

Beaver Hills Dark Sky Preserve

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

“THE STARS BELONG TO EVERYONE!”
Helen Sawyer Hogg famously declared in the title of her popular astronomy book. The long-standing matriarch of the Royal Astronomical Society of Canada would have been well-pleased with events that occurred in Elk Island National Park on September 3, 2006.

The occasion was the declaration of Beaver Hills Dark Sky Preserve, a partnership between Parks Canada Agency, Alberta Parks and Protected Areas, and the RASC. Canada's latest DSP incorporates almost 300 km², including Elk Island Park and the adjacent Cooking-Lake Blackfoot Provincial Recreation Area, where Edmonton Centre RASCals have been conducting their dark-sky observing sessions for over two decades. Two years of negotiation and preparation preceded the formal declaration.

Under near-perfect conditions, over 2000 day visitors and overnight campers flocked to Elk Island Park, which celebrated a century of conservation in style by extending its protective legacy to the skies above its lands and lakes. The official theme of the day's events was “Many Cultures, One Sky,” highlighting humanity's multifarious connections with the dark night sky, be they scientific, cultural, artistic, or simply experiential.



Figure 1 — The official declaration, signed by (L-R) Roger Reilander (Area Manager of Alberta Parks and Protected Areas), Marilyn Peckett (Superintendent of Elk Island Park), and Scott Young (National President of the RASC).



Figure 2 — The proverbial “icing on the cake” displays the official BHDSP logo.

The day's activities featured music, dance, poetry, and painting, each inspired in its own way by the night sky; cultural events including vintage games and storytelling of Aboriginal sky legends; and astronomy galore, from a series of outstanding lectures to solar observing, constellation tours, and a late-night telescope field containing over thirty scopes! The field was abuzz with excited voices punctuated by cries of delight from visitors receiving their first telescopic views of the Moon, Jupiter, or M13. Those who stayed into the wee hours were treated to a fabulous display of aurora that painted the sky red, green, and violet and danced the night away.

It is impossible to adequately recognize and thank the many RASC volunteers who made this event an enormous success; however, acknowledgement must be given to a few key people. John Cliff, Warren Finlay, and Sherrilyn Jahrig spearheaded the initial outreach, lobbying, and negotiations with the various levels of government. Doug Hube was a superb MC of the declaration ceremony, Bob Jahrig was performance director (and headliner) of the evening concert, and Harris Christian organized the heritage games. Orla Aaquist, Shelly Sodergren, Dave Robinson, Tom Casey, and Frank Florian provided invaluable support on a number of fronts down the homestretch of preparations. Cornelia Blunck did a fantastic job coordinating

the 63 (!) Edmonton Centre volunteers, and kept us extremely well fed in the process. On the national front, the assistance of Scott Young, Rob Dick, Rick Huziak, and Alan Dyer is gratefully appreciated.

We also acknowledge the hard work of our partners, namely Marilyn Peckett, Robert Sheldon, and Matt Davis of Parks Canada, and Jeanette Brooks, Cheryl Robb, Roger Reilander, and John Leslie of Alberta Parks & Protected Areas, who were instrumental in the signing of the declaration and the success of the day's events. Both agencies were formally recognized by RASC with national LPA awards presented by Scott Young.

The multi-cultural, multi-disciplinary outreach of DSP Day was the vision of Sherrilyn Jahrig, who put in countless hours and immeasurable effort as the event's producer to make it all happen.

It is through building broad alliances with natural partners like the conservation and artistic communities that astronomers can reach the broadest audience with the commonsense message about responsible lighting. Conserving the precious birthright that is our natural night sky is but one beneficial outcome of improved artificial lighting; others include positive effects for human health and safety, a more natural environment for wildlife, reduced greenhouse-gas emissions, and significant economic benefits. The declaration of Beaver Hills Dark-Sky Preserve and attendant publicity - through radio, television, and print media, and a popular foyer display in the local Mountain Equipment Co-op -- greatly increased public and political awareness of this astronomically important issue. ●

Bruce McCurdy is a National Representative of Edmonton Centre and a proud member of the Beaver Hills Dark Sky Preserve team.

"Astronomy in Our Backyards"



Astronomy Roundup 2007

Astronomy Roundup 2007 — Call for Papers

Too much frost on your corrector plate? Hands frostbitten from adjusting your focuser at -30 °C? Now is the time to retreat to a place of warmth and pick up your pen, or fire up your computer. Astronomy Roundup 2007, a joint meeting of the RASC (2007 General Assembly), the AAVSO (96th Spring Meeting), and the ALPO (60th Annual Meeting), invites you to submit a proposal for a poster or a paper to be presented in Calgary, June 29 to July 1.

The theme of the conference is "Astronomy in Our Backyards," so papers and posters describing your observing programs and results are particularly apt. Of course, we invite papers and posters from the wide spectrum that is amateur astronomy.

Being a joint conference, it is difficult to estimate how

many papers might be submitted, so we have arranged extra "optional" meeting space besides the three half-day oral paper sessions (plus poster space) that we have booked. To allow time for confirming those bookings, and to give you time to prepare either your paper or poster, **we ask that you submit your abstracts by March 31**. You will be notified by April 30 of whether your paper has been accepted as an oral paper or as a poster.

Our Web site <http://calgary.rasc.ca/ar2007> will have up-to-date information regarding paper and poster sessions and how to submit your abstract.

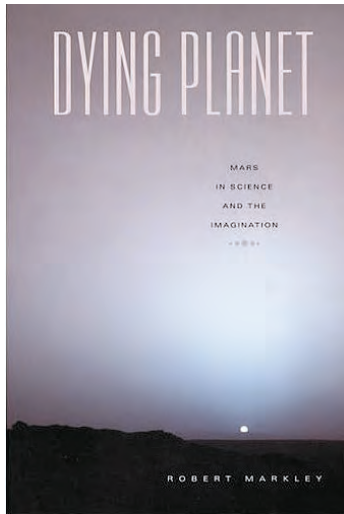
Please consider presenting a paper to share your work and inspire your fellow amateur astronomers to follow your lead! ●

— Astronomy Roundup Organizing Committee

Reviews of Publications

Critiques d'ouvrages

Dying Planet: Mars in Science and the Imagination, by Robert Markley, pages 444 +x, 15.5 cm × 23.5 cm, Duke University Press, 2005. Price \$24.95 US softcover (ISBN 0-8223-3638-3).



Reviewing this book from the point of view of an astronomer, I asked myself if I would have picked up a copy if I had seen it in a bookstore. I have the paperback version and perhaps the hardcover edition is different, but if I had seen the book in a bookstore it is unlikely to have attracted my attention. The cover is not unattractive, but the spine, which is nondescript, has no reference to Mars. The title “Dying Planet” gives it the flavour of yet another book about how we are destroying the planet we live on. That, indeed, is one of the threads throughout the book. The front cover has “Dying Planet” in large print but in smaller font “Mars in Science and the Imagination.” If that gets your attention enough to turn to the back cover, then suddenly you know you have a book that is filled with both fact and fiction about the red planet. The minute you start reading you discover that it is a scholarly text; perhaps I should say “textbook.”

In the acknowledgments Robert Markley says, “Writing any book is a long and involved process, and writing a book that encompasses more than one discipline extends and complicates that process.” That is an understatement. If I had to categorize the text, I do not know if I would consider it as astronomy, planetary science, literature, history, science fiction, criticism, history of science, history of science fiction, astrobiology, or philosophy of science. It is all of them and more.

It is at once a book about how science works and about how science fiction works, and, in the case of Mars at least, about how science has influenced fiction but also how fiction has, in many cases, guided science.

The author’s three stated goals are “to describe and contextualize” the scientific debates about Mars, to explore the reasons why Mars has held such an important place in scientific and popular imagination, and to explain why there has been, since the 1800s, such an interaction among planetary science, science fiction, ecology, and other disciplines centred around

Mars. He suggests that our intense fascination with Mars reflects our sociocultural view that Mars’s history reflects the future ecological fate of Earth.

The high interest in Mars, more than other planets since the invention of the telescope, is driven by Mars’ similarity to Earth. We can observe changes in the polar ice caps, changes in surface albedo, and image a surface that suggests similarities to Earth. Current debates about Mars originate in controversies that go back to the 18th century, “and the historical, epistemological and cultural implications of such debates are...” an important subject of the present study.

Dying Planet starts out with an introduction in which the author gives summaries, chapter by chapter, of what he will be covering. I found that particularly valuable when I had to put the book down for periods of time because of other commitments. But the summaries are worth revisiting after reading each chapter to put each chapter in perspective. The approach is quite interesting. In the author’s words, “...the chapters on science and those on science fiction alternate and interweave. My purpose is not to divide ‘science’ from ‘fiction’ but to pursue the internal logic of developments in each genre as well as to explore the ways in which their concerns overlap and interpenetrate.”

Those who have been interested in the scientific history of Mars will find a detailed history of how our knowledge developed from the invention of the telescope to the present-day visits by spacecraft that are exploring the planet. Percival Lowell’s “observation” of canals on Mars and the subsequent debate influenced science fiction, and the science fiction influenced how the debate developed, and both influenced and were influenced by theological debate. What would Martians be like and how did they dig the canals? The non-existence of canals was clarified in the 20th century, since we now have a close-up view of the planet’s surface. We are still searching for the Martians, but now they look different. Science and science fiction developed along parallel lines. As our scientific knowledge evolved, science fiction evolved along with it. The detailed photographs of Mars’ surface we see on the Internet are still influencing Mars’ science fiction. However, I found it interesting to discover how much fiction influenced the direction of science and how we are reluctant to give up our preconceived views even when science shows the fiction to be faulty.

I found the sections on Mars’ science easy to read, and they provide a great review. However, some of the science fiction sections are more difficult to absorb because of the author’s great breadth of knowledge. They remind me of doing literature courses at university when the professor described every section

of the novel under study in terms of other novels I had not read. The author's knowledge of science fiction is very extensive, as would be expected of a professor of English specializing in the area, but, thankfully, he also understands the science. The book is very readable, but does have sections that appear to use the Rex Murphy dictionary of English.

Overall, Markley has accomplished his aim and has produced a book that would be an excellent text in an English course or a reading in how science works for both science and non-science students. Science-fiction readers and historians of science will also find it a valuable addition to their libraries, and I would bet that there are references to fiction that even the most ardent

science-fiction fan will have missed. The hardcover edition is a bit expensive, but the softcover version is well worth the money.

Robert Markley is Professor of English at the University of Illinois, Urbana-Champaign. He is a coauthor of the DVD-ROM *Red Planet: Scientific and Cultural Encounters with Mars*, and editor of the book *Virtual Realities and Their Discontents*.

Frederick R. Smith is an Associate Professor in the Faculty of Science at Memorial University of Newfoundland. He teaches introductory astronomy and astrophysics. ●

Astrocryptic

by Curt Nason, Moncton Centre

Here are the answers to last issue's puzzle:

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TITLES

- Combined Morphometric and Spectrophotometric Study of the Complex Lunar Volcanic Region in the South of Petavius, A, *Rafaello Lena, Christian Wöhler, Maria Teresa Bregante, and Cristian Fattinanzi*, Feb., 14
- From Antarctica to Manitoba – the 14th Annual MIAC meeting, *Martin Beech*, Feb., 26
- Meteor Trains - Terminology and Physical Interpretation, *Jiří Borovička*, Oct., 194
- Sun's Displacement from the Galactic Plane from Spectroscopic Parallaxes of 2500 OB Stars, The, *B. Cameron Reed*, Aug., 146

AUTHORS

- Anderson, Jay*, Editorial, Feb., 2, Oct., 190
- Attas, Michael*, The Big Zit, Jun., 122
- Attwood, Randy, Alson Wong, and Bill Weir*, Pen and Pixel: Two Views of the March 29, 2006 Solar Eclipse/A Comet to Remember, Aug., 176
- Barrett, Anthony*, Johann Bayer and the Relative Magnitudes of α and β Geminorum, Aug., 156
- Bartlett, Hank and Kim Hay*, International Astronomy Day 2006 at the RASC-Kingston Centre, Aug., 181
- Beech, Martin*, From Antarctica to Manitoba – the 14th Annual MIAC meeting, Feb., 26
- Beech, Martin*, On Seeing D2, Jun., 118
- Borovička, Jiří*, Meteor Trains – Terminology and Physical Interpretation, Oct., 194
- Clark, Barry A.J.*, Is Artificial Light at Night Too Much of a Good Thing? Oct., 212
- Clark, David*, A Special Bequest – Walter A. Feibelman, Apr., 96
- Crawford, Tim R.*, My First Variable-Star Observation – A Series of Misadventures, Jun., 120
- Dodd, William*, Investigating the Basic Properties of Black Holes Using Newtonian Mechanics, Dec., 252
- Earl, Michael*, Determining the Orbit Height of a Low-Earth-Orbiting Artificial Satellite Observed near the Local Zenith, Oct., 199
- Edgar, James*, Editorial, Jun., 102
- Edgar, James*, Pioneering Observatories of the British Isles, Aug., 157
- Edgar, James*, Strengthening the Society Through Planned Giving, Apr., 97
- Egler, Robert*, Measuring the Heavens: Astronomical Instruments before the Telescope, Feb., 37
- Enright, Leo*, *New Horizons*: Mission to Pluto, Charon, and Beyond: Launch of Long-Awaited Project to Study the Outer Solar System, Apr., 73
- Finlay, Warren and Doug Hube*, Deep-Sky Contemplations, Feb., 12, Apr., 82, Jun., 127, Aug., 166, Oct., 216
- Fleming, Christopher*, The Skies Over Canada: Observing Committee News, Feb., 35, Apr., 80
- Gaherty, Geoff*, Through My Eyepiece, Feb., 32, Apr., 78
- Through My Eyepiece: A Tale of Two Eclipses, Jun., 126
- Through My Eyepiece: City Mouse and Country Mouse, Oct., 218

- Through My Eyepiece: Cosmic Bird Watching, Aug., 164
- Through My Eyepiece: Finding Things, Dec., 260
- George, Doug*, DSLR Astrophotography, Part I, Dec., 248
- Grey, Denis*, New RASC Web Site Launched!, Dec., 268
- Grey, Denis*, Society Donations Report, Apr., 94
- Hladiuk, Don and Steve Donaldson*, An Interview with Dr. Steven Squyres, Mars Exploration Rover Principal Investigator, Feb., 6
- Hube, Doug and Warren Finlay*, Deep Sky Contemplations: The Crab Nebula, Dec., 258
- Huziak, Richard*, An Invitation: the 2006 Saskatchewan Star Party, Jun., 138
- Huziak, Richard*, Editorial: Who Will Protect Your Night Sky if You Won't?, Apr., 58
- Huziak, Richard*, Ramblings of a Variable-Star Addict: An Amazing RR Lyrae Star - XZ Cygni, Jun., 130
- Ramblings of a Variable-Star Addict: Introducing CCD Variable-Star Photometry, Oct., 221
- Ramblings of a Variable-Star Addict: Just the Bare Basics, Feb., 44
- Ramblings of a Variable-Star Addict: Marvelous Miras!, Aug., 169
- Ramblings of a Variable-Star Addict: The Wonderful World of Easy Eclipsers, Apr., 84
- Jahrig, Sherrilyn*, *night-flight*, Dec., 251
- Jedicke, Peter*, 2006 Society Awards, Aug., 184
- Kelly-McArthur, Brian*, The Haloed Moon/And Leo's Capture, Aug., 163
- King, Bob*, An Invitation to the RASC 2007 General Assembly, Jun., 137
- Langan, Paul J.*, Net Astronomy, Feb., 53, Aug., 180, Oct., 232, Dec., 270
- Lena, Rafaello, Christian Wöhler, Maria Teresa Bregante, and Cristian Fattinanzi*, A Combined Morphometric and Spectrophotometric Study of the Complex Lunar Volcanic Region in the South of Petavius, Feb., 14
- Mazzucato, Michele T.*, Giovanni Virginio Schiaparelli, Jun., 114
- McCausland, Phil J. A., Peter Brown, and Graham C. Wilson*, The Dresden (Ontario) H6 Chondrite, Part II: Classification, Estimated Fireball Trajectory, and Possible Origin, Jun., 104
- McCullough, Brian*, Seven Easy Steps to Sketching the Lunar Surface in Real Time, Aug., 159
- McCurdy, Bruce*, Beaver Hills Dark Sky Preserve, Dec., 272
- McCurdy, Bruce*, Orbital Oddities: Mercurial Meanderings, Apr., 88
- Orbital Oddities: Planetary Perspectives, Dec., 269
- Orbital Oddities: Shadow Shows, Feb., 50
- Orbital Oddities: Transit Tandems and Tetrads, Oct., 229
- Orbital Oddities: Transit Twins and Trios, Aug., 178
- McMahon, Peter*, Wilderness Stargazing, Apr., 75
- Mozel, Philip*, A Moment With . . . Dr. Alan Hildebrand, Apr., 92
- A Moment With . . . Dr. David Guenther, Oct., 224
- A Moment With . . . Dr. Laura Ferrarese, Dec., 264
- A Moment With . . . Dr. Ray Jayawardhana, Aug., 169
- A Moment With . . . Dr. Victoria Kaspi, Jun., 134
- A Moment With . . . Janet Chodas, Feb., 55

Mozel, Philip, The Woodstock College Observatory - II, Jun., 123
Mozel, Philip and Meg Morden, The Cult Statue of Aphrodite at Palaepaphos: A Meteorite?, Aug., 149
Nason, Curt, Astrocryptic, Feb., 49, Apr., 63, Jun., 133, Aug., 165, Oct., 236, Dec., 275
Nason, Guy, Carpe Umbram, Apr., 91, Jun., 132, Aug., 171, Oct., 226
Nason, Guy, Carpe Umbram: Baby, it's cold outside!, Dec., 266
Plotkin, Howard, The Dresden (Ontario) H6 Chondrite, Part I: Fireball Observations, Recovery and Sale, Field Searches, and Tribute, Apr., 64
Rainault, Gil, Pumpkin Creek Observatory, Feb., 47
Reed, B. Cameron, The Sun's Displacement from the Galactic Plane from Spectroscopic Parallaxes of 2500 OB Stars, Aug., 146
Sage, Leslie J., Second Light: A collision in the local group of galaxies, Dec., 257
 Second Light: A New View of Vega, Jun., 125
 Second Light: A Quick and Cheap Way to Find Earth-like Planets around Other Stars, Aug., 162
 Second Light: Exciting Times with Cosmic Rays, Apr., 76
 Second Light: Small Kuiper Belt Bodies Seen by X-ray Occultation, Oct., 215
 Second Light: The Huygens Probe Lands on Titan, Feb., 13
Saikaley, Albert, John Mirtle, and Rolf Mier, Film and Pixel, Feb., 43
Saikaley, Albert, Paul Mortfield, and Dietmar Kupke, Pen and Pixel: NGC 4565 and M74, Oct., 228
Stankiewicz, Rick, Near-Earth Asteroid (2004 XP14), Dec., 250
Swanson, Roy, Astronomy and Astrology, Oct., 204
Theberge, Serge and Albert Saikaley, Film and Pixel: The Cocoon Nebula and NGC 3953, Jun., 136
Van Akker, Don, Gizmos: A Finder Found, Dec., 262
 Gizmos: A Finger for your Dob, Feb., 34
 Gizmos: A Paean to Plumbing, Aug., 168
 Gizmos: Finding Up, Apr., 83
 Gizmos: Painting the Sky, Jun., 129
 Gizmos: Sun Screen, Oct., 219
West, Jennifer L. and Ian D. Cameron, Using the Medical Image-Processing Package, *ImageJ*, for Astronomy, Dec., 242
Whitehorne, Mary Lou and Don Kelly, Education and Outreach is Worth the Effort!, Aug., 182
Wong, Alson, Creating a High-Dynamic-Range Solar Eclipse Composite Image, Oct., 208
Young, Scott, President's Corner, Aug., 142, Dec., 238

DEPARTMENTS

Across The RASC

2006 Society Awards, Aug., 184
 Astrocryptic, Feb., 49, Apr., 63, Jun., 133, Aug., 165, Oct., 236, Dec., 275
 Astronomy Roundup 2007 – Call For Papers, Dec., 273
 Beaver Hills Dark Sky Preserve, Dec., 272
 Education and Outreach is Worth the Effort!, Aug., 182
 Instructions to Authors, Aug., 186
 International Astronomy Day 2006 at the RASC-Kingston Centre, Aug., 181
 Invitation: The 2006 Saskatchewan Summer Star Party, An, Jun., 138
 Invitation to the RASC 2007 General Assembly, An, Jun., 137

Memories Wanted, Oct., 225
 New RASC Web Site Launched!, Dec., 268
 Ottawa GA2006 Invitation to all RASC Members, Feb., 41
 Skies Over Canada: Observing Committee News, The, Feb., 35, Apr., 80
 Society Donations Report, Apr., 94
 Special Bequest - Walter A. Feibelman, A, Apr., 96
 Strengthening the Society Through Planned Giving, Apr., 97

Columns

A Moment With ... Dr. Alan Hildebrand, Apr., 92
 A Moment With ... Dr. David Guenther, Oct., 224
 A Moment With ... Dr. Laura Farrarese, Dec., 264
 A Moment With ... Dr. Ray Jayawardhana, Aug., 169
 A Moment With ... Dr. Victoria Kaspi, Jun., 134
 A Moment With ... Janet Chodas, Feb., 55
 Deep-Sky Contemplations, Feb., 12, Apr., 82, Jun., 127, Aug., 166, Oct., 216,
 Deep-Sky Contemplations: The Crab Nebula, Dec., 258
 Film and Pixel, Feb., 43
 Film and Pixel: The Cocoon Nebula and NGC 3953, Jun., 136
 Gizmos: A Finder Found, Dec., 262
 Gizmos: A Finger for your Dob, Feb., 34
 Gizmos: A Paean to Plumbing, Aug., 168
 Gizmos: Finding Up, Apr., 83
 Gizmos: Painting the Sky, Jun., 129
 Gizmos: Sun Screen, Oct., 204
 Net Astronomy, Feb., 53, Aug., 180, Oct., 232, Dec., 270
 Orbital Oddities: Mercurial Meanderings, Apr., 88
 Orbital Oddities: Planetary Perspectives, Dec., 269
 Orbital Oddities: Shadow Shows, Feb., 50
 Orbital Oddities: Transit Tandems and Tetrads, Oct., 229
 Orbital Oddities: Transit Twins and Trios, Aug., 178
 Pen and Pixel: NGC 4565 and M74, Oct., 228
 Pen and Pixel: Two Views of the March 29, 2006 Solar Eclipse/A Comet to Remember, Aug., 176
 Ramblings of a Variable-Star Addict: An Amazing RR Lyrae Star – XZ Cygni, Jun., 130
 Ramblings of a Variable-Star Addict: Introducing CCD Variable-Star Photometry, Oct., 221
 Ramblings of a Variable-Star Addict: Just the Bare Basics, Feb., 44
 Ramblings of a Variable-Star Addict: Marvelous Miras!, Aug., 169
 Ramblings of a Variable-Star Addict: The Wonderful World of Easy Eclipsers, Apr., 84
 Second Light: A Collision in the Local Group of Galaxies, Dec., 257
 Second Light: A New View of Vega, Jun., 125
 Second Light: A Quick and Cheap Way to Find Earth-like Planets around Other Stars, Aug., 162
 Second Light: Exciting Times with Cosmic Rays, Apr., 76
 Second Light: Small Kuiper Belt Bodies Seen by X-ray Occultation, Oct., 215
 Second Light: The Huygens Probe Lands on Titan, Feb., 13
 Through My Eyepiece: Feb., 32, Apr., 78
 Through My Eyepiece: A Tale of Two Eclipses, Jun., 126
 Through My Eyepiece: City Mouse and Country Mouse, Oct., 218
 Through My Eyepiece: Cosmic Bird Watching, Aug., 164
 Through My Eyepiece: Finding Things, Dec., 260

Correspondence

Feb., 3, Oct., 193

Education Notes

Investigating the Basic Properties of Black Holes Using Newtonian Mechanics, Dec., 252

Editorial

Feb., 2, Apr., 58, Jun., 102, Oct., 190

Feature Articles

Astronomy and Astrology, Oct., 204
Big Zit, The, Jun., 122
Creating a High-Dynamic-Range Solar Eclipse Composite Image, Oct., 208
Cult Statue of Aphrodite at Palaepaphos: A Meteorite?, The, Aug., 149
Determining the Orbit Height of a Low-Earth Orbiting Artificial Satellite Observed near the Local Zenith, Oct., 199
Dresden (Ontario) H6 Chondrite, Part I: Fireball Observations, Recovery and Sale, Field Searches and Tribute, The, Apr., 64
Dresden (Ontario) H6 Chondrite, Part II: Classification, Estimated Fireball Trajectory, and Possible Origin, The, Jun., 104
DSLR Astrophotography, Part I, Dec., 248
Giovanni Virginio Schiaparelli, Jun., 114
Haloed Moon/And Leo's Capture, The, Aug., 163
Interview with Dr. Steven Squyres, Mars Exploration Rover Principal Investigator, An, Feb., 6
Is Artificial Light at Night Too Much of a Good Thing?, Oct., 212
Johann Bayer and the Relative Magnitude of α and β Geminorum, Aug., 156
Measuring the Heavens: Astronomical Instruments before the Telescope, Feb., 37
My First Variable-Star Observation – A Series of Misadventures, Jun., 120
Near-Earth Asteroid (2004 XP14), Dec., 250
New Horizons: Mission to Pluto, Charon and Beyond; Launch of Long-Awaited Project to Study the Outer Solar System, Apr., 73
night-flight, Dec., 251
On Seeing D2, Jun., 118
Pioneering Observatories of the British Isles, Aug., 157
Pumpkin Creek Observatory, Feb., 47

Seven Easy Steps to Sketching the Lunar Surface in Real Time, Aug., 159

Using the Medical Image-Processing Package, *ImageJ*, for Astronomy, Dec., 242

Wilderness Stargazing, Apr., 75

Woodstock College Observatory - II, The, Jun., 123

News Notes

Feb., 4, Apr., 60, Aug., 143, Oct., 191, Dec., 239

President's Corner

Aug., 142, Dec., 238

Research Papers — see TITLES -

Review of Publications

Albert Einstein's Vision: Remarkable Discoveries that Shaped Modern Science, by *Barry Parker*, 2004, 286 pages, reviewed by David M. F. Chapman, Apr., 99
Cold Dark Matter, by *Alex Brett*, 2004, 348 pages, reviewed by Michael Attas, Feb., 54
Concise History of Solar and Stellar Physics, A, by *Jean-Louis Tassoul* and *Monique Tassoul*, 2004, 282 pages, reviewed by David Turner, Oct., 233
Dying Planet: Mars in Science and the Imagination, by *Robert Markley*, 2005, 444 pages, reviewed by Frederick R. Smith, Dec., 274
England's Leonardo: Robert Hooke and the Seventeenth-Century Scientific Revolution, by *Allan Chapman*, 2005, 330 pages, reviewed by Randall Brooks, Jun., 138
Mauna Kea: A Guide to Hawai'i's Sacred Mountain, by *Leslie Lang* and *David A. Byrne*, 2005, 146 pages, reviewed by Richard Bochonko, Oct., 234
Sky Phenomena: A Guide to Naked-eye Observation of the Stars, by *Norman Davidson*, 2004, 207 pages, reviewed by Leo Enright, Apr., 98
Sun Observer's Guide, by *Pam Spence*, 2004, 159 pages, reviewed by Roy Bishop, Jun., 139
Violent Universe: Joyrides through the X-ray Cosmos, The, by *Kimberley Weaver*, 2005, 195 pages, reviewed by Joe Carr, Apr., 100

Celebrating 100 Years!



Comet SWAN: Kevin Black of Winnipeg Centre obtained this image of comet SWAN using a Canon 20Da; a 5-minute exposure at ISO 800 with an 8-inch f/5 Newtonian on October 24, 2006, obtained near Vivian, Manitoba.



SWSP Cabin: The summer Milky Way sprawls across the dark skies of Spruce Woods Provincial Park during Winnipeg Centre's Spruce Woods Star Party, September September 3, 2006. Winnipeg Centre President Ron Berard took this image with his Nikon D70 with an 18-70 Nikon DX zoom lens set at 18 mm, f/3.6, ISO 400, and a 5-minute exposure.



Left: Ursa Major Aurora: James Edgar took this from his backyard on August 19, 2006 with his new Canon 20D DSLR, almost before he got it out of the box. He thought he might do some star gazing, but the sky showed a bit of haze. Ten minutes later, that haze had turned into a full-blown aurora. Camera details: ISO 1600, f/5, 18 to 125-mm Sigma zoom lens set at 18-mm, 5 second exposure, at 4.5 shutter speed.



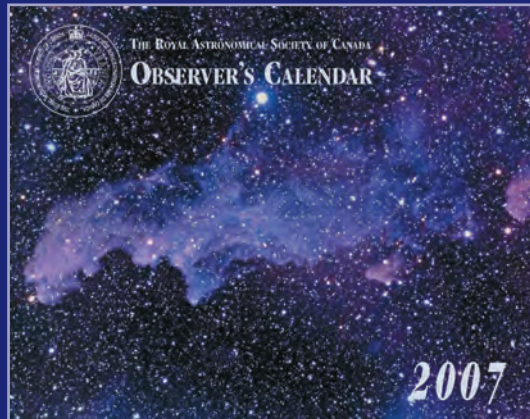
Below Left: Orion Reflection: Orion reflects off flooded farmland on March 31, 2006 near Vivian, Manitoba. The skyglow from Winnipeg paints a golden hue on the western horizon. Ron Berard used his Nikon D70, set at ISO 400, f/3.6, 18 mm, for a 93-second exposure.

Below Right: NGC 253: Kevin Black used his Canon 20Da, with an 8-minute exposure at ISO 800 through an 8-inch f/5 Newtonian taken from Chiracahua Mountains, Arizona on September 05, 2006.



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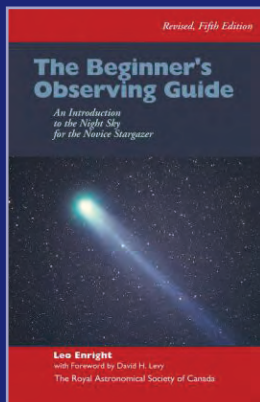
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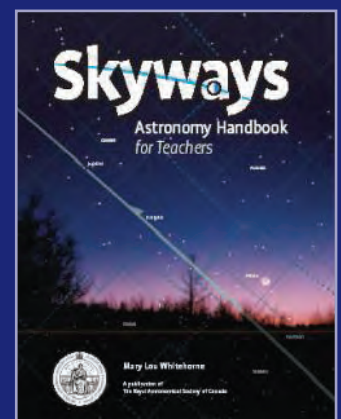
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