The Journal of The Royal Astronomical Society of Canada

Journal

Le Journal de la Société royale d'astronomie du Canada

PROMOTING ASTRONOMY IN CANADA

October/octobre 2011
Volume/volume 105
Number/numéro 5 [750]

Inside this issue:

The stunning Orion Nebula

Journal

October/octobre 2011 | Vol. 105, No. 5 | Whole Number 750

Royal Astronomical Society of Canada

Société Royale d'Astronomie du Canada

contents / table des matières

Feature Articles / Articles de fond

Departments / Départements

Columns / Rubriques

Front cover *– This stunning image of the Orion Nebula was provided by Kevin Black of the Winnipeg Centre, who won the "Khan Scope Prize for Deep-Sky Imaging" at the 2011 General Assembly of the RASC in Winnipeg. Kevin used a Canon 20Da on a 5.1-inch f/6 Apo refractor. Exposure was a combination of many sub-frames at ISOs ranging from 1600 to 400 and exposure times from 342 seconds to 10 seconds.*

Journal

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

The *Journal* of The Royal Astronomical Society of Canada is published at an annual subscription rate of $93.45 (including tax) by The Royal Astronomical Society of Canada. Membership, which includes the publications (for personal use), is open to anyone interested in astronomy. Applications for subscriptions to the *Journal* or membership in the RASC, and information on how to acquire back issues of the *Journal* can be obtained from:

The Royal Astronomical Society of Canada
203 – 4920 Dundas St W
Toronto ON M9A 1B7, Canada
Internet: nationaloffice@rasc.ca
Web site: www.rasc.ca
Telephone: (416) 924-7973
Fax: (416) 924-2911

Canadian Publications Mail Registration No. 09818
Canada Post: Send address changes to 203 - 4920 Dundas St W, Toronto ON M9A 1B7

Canada Post Publication Agreement No. 40069313
We acknowledge the financial support of the Government of Canada through the Canada Periodical Fund (CPF) for our publishing activities.

Canada

President's Corner

Mary Lou Whitehorne
President, RASC

As fall approaches, the observers among us look forward to earlier sunsets and the darkness that provides good observing at a convenient time of the evening. For many in Canada, fall also brings the best observing weather, with crisp, clear, and dry skies. I hope everyone has good observing, and does not miss too much the warm sunny days of summer at the beach, pool, golf course, on the boat, in the garden, around the BBQ, on the trail, or out camping under the stars.

For many, summer is the time to relax and take it easy. In the RASC annual cycle of events, it is also the less-busy time of year. Now we are moving into the traditionally busiest time of our year, with the new 2012 publications being printed and distributed. This is the time of year when most memberships are renewed, and everything in the office is in high gear. RASC Centres are also getting back into the swing of things with a new cycle of meetings and events after the summer star-party season. I trust everyone's summer events were enjoyable and successful, and the upcoming year will be a successful one for our 29 Centres.

One of the big tasks we will soon face as an organization is the incoming new Canada Not-for-Profit Corporations Act (CNCA). When this is declared law by the federal government (expected later this year), every charitable organization in Canada will have three years to make the switch from the old Canada Corporations Act to the new CNCA.

As part of the legislative process, the federal government is also redefining what constitutes charitable activity. The new legislation will require some changes to the charitable, governance, and membership structures of tens of thousands of Canadian not-for-profits, including the RASC and its Centres.

The precise terms of the new legislation will not be released until the legislation comes into force. This makes the process difficult because it leaves everyone guessing about the details. In general terms, this is what we have learned so far about the changes required by the new legislation:

1. New Articles of Incorporation must be drafted. These must include the RASC's charitable objects, which are currently found in our Letters Patent.

2. The definitions and descriptions of classes of membership must be written in the Articles of Incorporation. These are currently part of our existing By-Laws.

3. The definitions and descriptions of member rights and privileges, currently found in our By-Laws, must be written into the new Articles of Incorporation.

As you can see, for the RASC, these three items are currently contained in our two governance documents: the Letters Patent and By-Law Number One. Certain sections of both of these governing documents will have to be restructured into the new Articles of Incorporation. This then will become our new overarching governance document. The existing By-Laws will necessarily be extensively revised, or even completely replaced. The new By-Laws will further describe and explain the material in the new Articles of Incorporation. Other material will be included in a policy or operational manual.

Such changes are time consuming and detail oriented. The newly constituted Constitution Committee will be working closely with the Executive Committee and our staff to draft new documents for approval by the membership and submission to government well before the deadline. With external legal assistance, we plan to develop and provide template documents to assist RASC Centres with the required changes when the time comes. We will focus on making the process as smooth and painless as possible for everyone.

For anyone who wants more information, please see these reports to National Council on the Members' Only section of the RASC Web site:

Executive Committee
www.rasc.ca/private/reports/ExecComm_Report_NC112.pdf
www.rasc.ca/private/reports/ExecComm_NC111_Report.pdf

Executive Director
www.rasc.ca/private/reports/ED_Report_NC112.pdf

Constitution Committee
www.rasc.ca/private/reports/ConstitutionReport-NC112.pdf

While some of us are stuck dealing with the necessary evils of administration, I encourage everyone else to get out there and enjoy your astronomical activities, be they solitary moments under the stars or shared events with your fellow RASCals.

Clear skies and great observing! ✶

News Notes / En Manchettes

Compiled by Andrew I. Oakes
(copernicus1543@gmail.com)

Orbiter captures possible salt-water flows on Mars

After repeated observations, the *Mars Reconnaissance Orbiter*'s High-Resolution Imaging Science Experiment (HiRISE) suggests the possibility of flowing water on Mars during that planet's warmest months. The NASA *Orbiter* has tracked seasonal changes on several steep Martian slopes in the middle latitudes of Mars' southern hemisphere. Scientists describe the recurring features as being dark and finger-like, forming and extending down some Martian slopes during late spring through the Martian summer. The features fade in winter and return during the following spring season.

Only some 0.5 to 5 metres wide, the distinct features appear on warmer, equator-facing slopes and show lengths of up to hundreds of metres. Researchers assess the best explanation for this phenomenon to date is "the flow of briny water." According to the scientists, the locations of the flows are too warm for carbon-dioxide frost, while at some of the sites it is too cold for pure water, making salt-laden water a viable alternative explanation. It is known that salt deposits exist on Mars, which indicate to scientists that brines were abundant in Mars' distant past, and that these still form near the surface today in select locations and periods.

Figure 1 — This image is an oblique view of warm-season flows in Mars' Newton Crater made on 2011 May 30 by the Mars Reconnaissance Orbiter. *The image has been superimposed on a 3-D model of the Martian surface and reprojected to give a "helicopter view" of the site. The flow features are the dark linear features on the slope surface. Image: NASA/JPL-Caltech/KSC.*

However, the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM), another scientific instrument package, shows no sign of water on the flow-marked slopes. The failure to detect water at the flow sites can be explained if the flow-like features are drying quickly on the surface, or if they result from shallow subsurface flows.

The report of salt-water flows, representing the closest scientists have come to finding evidence of liquid water on the planet's surface to date, appeared in the 2011 August 4, issue of *Science*.

Juno to meet up with Jupiter in mid-2016

NASA's *Juno* spacecraft is currently on a five-year, 640-million-kilometre voyage to Jupiter, arriving at the giant gaseous planet in July 2016. The spacecraft will orbit Jupiter for about one year (33 orbits), and the mission will end when the spacecraft de-orbits into Jupiter in October 2017. *Juno* will investigate Jupiter's origins and evolution, employing eight instruments to probe the planet's internal structure and gravity field, measure water and ammonia in its atmosphere, map its powerful magnetic field, and observe its intense aurorae.

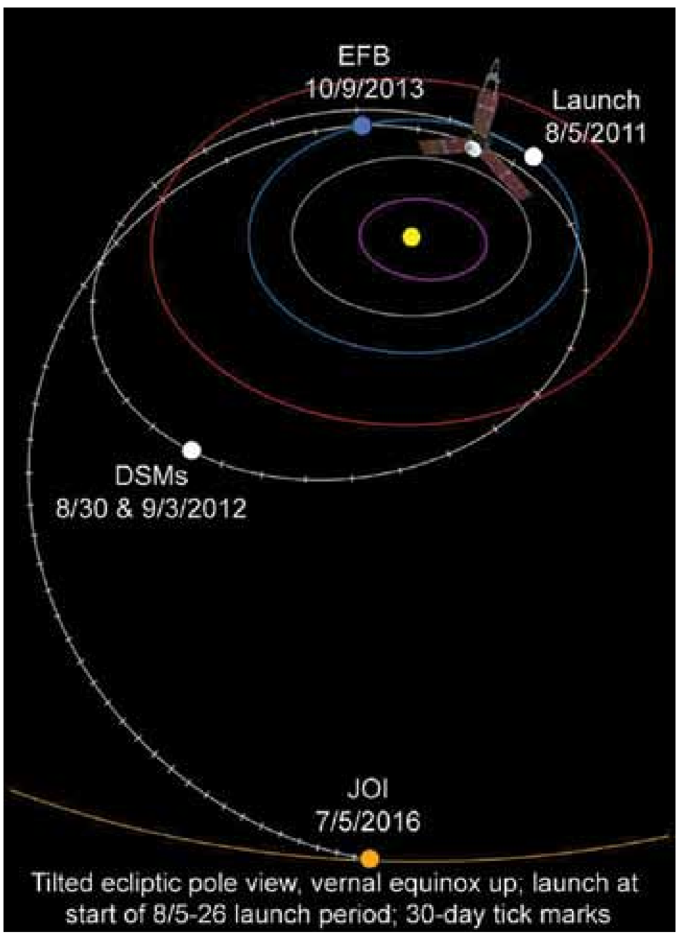


Figure 2 — The Juno *Jupiter-bound interplanetary spacecraft's trajectory. Image: NASA/JPL-Mission Timeline.*

More specifically, the probe will:

- Determine how much water is in Jupiter's atmosphere, which helps determine which planet formation theory is correct (or if new theories are needed);
- Look deep into Jupiter's atmosphere to measure composition, temperature, cloud motions, and other properties;
- Map Jupiter's magnetic and gravity fields to reveal the planet's deep structure; and
- Explore and study Jupiter's magnetosphere near the planet's poles, especially the aurorae, providing new insights about how the planet's magnetic force-field affects its atmosphere.

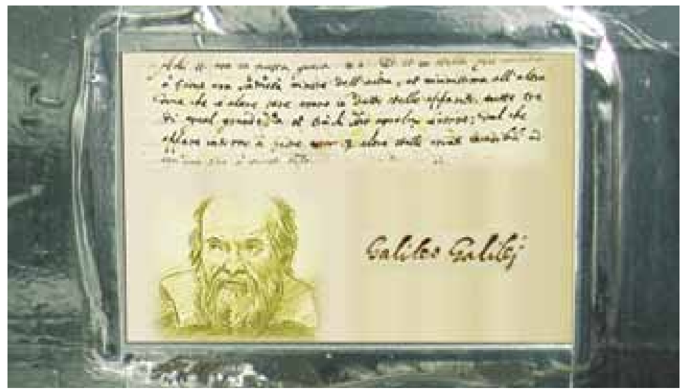


Figure 3 — Juno *Jupiter Mission carries tiny plaque dedicated to Galileo. Image: NASA/JPL-Caltech/KSC.*

Launched on 2011 August 5 aboard an Atlas V rocket from Cape Canaveral Air Force Station in Florida, the spacecraft is carrying a plaque dedicated to Galileo Galilei, the 17th-century astronomer who in 1610 discovered that moons orbited Jupiter—Io, Europa, Ganymede and Callisto (also known as the Galilean moons). The Italian Space Agency provided the plaque, which measures 71 by 51 millimetres. Made of flight-grade aluminum and weighing only six grams, the plaque is bonded to *Juno*'s propulsion bay. A self-portrait of Galileo appears on the plaque along with a passage in Galileo's own hand that he made in 1610 of observations of Jupiter.

The text, from the archives in the *Biblioteca Nazionale Centrale* in Florence, reads:

> *On the 11th it was in this formation—and the star closest to Jupiter was half the size than the other and very close to the other so that during the previous nights all of the three observed stars looked of the same dimension and among them equally afar; so that it is evident that around Jupiter there are three moving stars invisible till this time to everyone.*

NASA scientists are confident the *Juno* mission will take them "a giant step forward" in their search to understand how giant planets form and the role such titans played in the rest of the Solar System. The targeted planetary space mission is the second spacecraft designed under NASA's New Frontiers Program, which provides opportunities to carry out several high-priority medium-class missions.

Silicate volcanoes confirmed on "dark side" of Moon

Data and high-resolution images from NASA's *Lunar Reconnaissance Orbiter (LRO)* have revealed the presence of a rare set of dormant silicate volcanoes on the far side of Moon. The *LRO* photographed a number of domelike features with steeply sloping sides—telltale signs of lunar volcanoes. The nearby presence of thorium and other silicate deposits prompted the identification of silicate volcanoes. According to lunar scientists, the silicate volcanoes show the geologic complexity and range of processes that operated on the Moon, and how the Moon's volcanism changed with time. Basaltic volcanoes are ubiquitous on the Moon's surface, so the identification of non-basaltic eruptions on the far side reflects the compositionally diverse nature of Earth's close companion.

The volcanic domes, located in the so-called "Compton-Belkovich region," are said to have formed by lava—likely from deep within the Moon—that flowed upward through cracks to pool just beneath the surface, where it pressed out to form the large domes. Lunar scientists estimate that the Moon's rare far-side silicate volcanoes are some 800 million years old. The estimate extends volcanic activity of the Moon by 200 million years.

Details of the most recent lunar research into the Moon's volcanism appeared the 2011 July 24 edition of *Nature Geoscience*.

Fourth satellite discovered around Pluto

The *Hubble Space Telescope* has found a fourth moon orbiting our Solar System's dwarf planet Pluto. The tiny moon—the smallest seen so far orbiting Pluto—was discovered in a *Hubble* survey searching for rings around the distant, icy, dwarf planet. The new satellite has an estimated diameter of 13 to 34 km; Pluto's largest moon, Charon, is 1043 km across. The dwarf planet's other two moons, Nix and Hydra, have sizes in the range of 32 to 113 km. The new moon is located between the orbits of Nix and Hydra, which *Hubble* discovered in 2005.

The new moon, temporarily designated as P4, was first seen in a photo taken with *Hubble*'s Wide Field Camera 3 on June 28, and confirmed in subsequent Hubble pictures taken on July 3 and July 18. It was not seen in earlier *Hubble* images because the exposure times were too short.

This most recent discovery is due to the ongoing work to support NASA's *New Horizons* mission, scheduled to fly through the Pluto system in 2015.

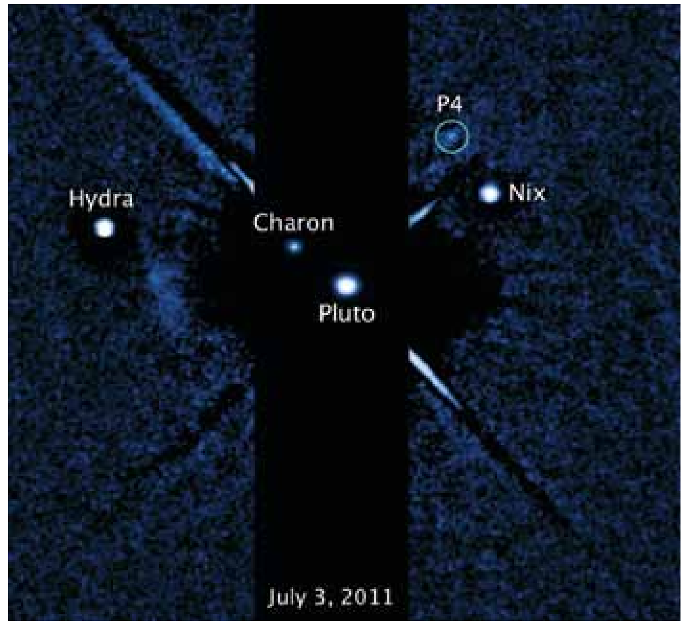


Figure 4 — The Hubble Space Telescope*'s Wide Field Camera 3 image of the newly discovered fourth moon P4 (circled). Image: NASA, ESA, and M. Showalter (SETI institute)*

Pioneer anomaly solved?

The *Pioneer* Anomaly was defined as "anomalous acceleration in the direction of the Sun"—from Earth, the spacecraft appeared to be slowing down. It was first detected in 1980 by John D. Anderson of the Jet Propulsion Laboratory through his analysis of the Doppler shift in the radio signal from *Pioneers 10* and *11*. The *Pioneer* spacecraft are currently in the distant reaches of our Solar System, headed for interstellar space.

Using funds provided by members of the Planetary Society, a team of researchers led by Slava Turyshev has recovered telemetry data from the early days of the *Pioneer* saga; subsequent analysis showed that the anomaly was gradually decreasing over time. This behaviour is consistent with an on-board phenomenon and not an external force, leading the research team to suspect that a gradually decaying leak of heat from the thermo-isotope generating system was the culprit. Modelling of the spacecraft environment indicated that internal heat reflecting off of the large antenna on the spacecraft was gradually slowing them down and causing the anomaly. The research paper describing their results is available online at http://arxiv.org/abs/1107.2886.

Canada partners on Japanese X-ray space observatory

An ambitious next-generation X-ray space telescope, *ASTRO-H*, currently under development by the Japan Aerospace Exploration Agency (JAXA), has taken on several Canadian partners. Scheduled for launch in February 2014, *ASTRO-H* will include five specialized X-ray telescopes and detectors. The instruments will look at cosmic sources of X-rays with unprecedented resolution.

Canada is involved in one of the spacecraft's key instruments, the Hard X-ray Telescope. It will be deployed at the end of a six-metre mast that is expected to twist and bend; this is due to on-orbit vibrations and the extreme day-night transitions the spacecraft will experience as it orbits the Earth at 550 km, where temperatures swing from -30 °C to +40 °C. JAXA approached the Canadian Space Agency in 2009 to explore the possibility of Canada providing an innovative measurement system for the mission's Hard X-ray Telescope, now called the Canadian *ASTRO-H* Metrology System, or CAMS. CAMS will be able to measure the mast's distortions to a level of accuracy equivalent to the width of a human hair, allowing mission operators to calibrate the data of the Hard X-ray Telescope and significantly enhance the telescope's performance.

In return for this critical piece of hardware, Canada secures positions for Canadian institutions on the mission's Science Working Group. The CSA has selected three university astronomers to represent Canada on the Science Working Group and support Canada's CAMS Project:

- Dr. Luigi Gallo, Principal Investigator for CAMS, of Saint Mary's University;
- Dr. Brian McNamara of the University of Waterloo; and
- Dr. Samar Safi-Harb of the University of Manitoba.

Canadian researchers will use their time on *ASTRO-H* to study the flow of hot gases in and out of supermassive black holes and the high-energy phenomena associated with supernova explosions and their neutron-star remnants. ✶

Andrew I. Oakes is a long-time unattached member of RASC who lives in Courtice, Ontario.

The Royal Astronomical Society of Canada

Vision To inspire curiosity in all people about the Universe, to share scientific knowledge, and to foster collaboration in astronomical pursuits.

Mission The Royal Astronomical Society of Canada (RASC) encourages improved understanding of astronomy for all people, through education, outreach, research, publication, enjoyment, partnership, and community.

Values The RASC has a proud heritage of excellence and integrity in its programmes and partnerships. As a vital part of Canada's science community, we support discovery through the scientific method. We inspire and encourage people of all ages to learn about and enjoy astronomy.

Feature Articles
Articles de Fond

Decans, Djed Pillars, and Seasonal Hours in Ancient Egypt

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

Abstract

A desktop planetarium program was used to simulate the night sky over ancient Egypt every tenth night during the year 2500 BC. From these simulations, a list of stars (pseudo-decans) was generated that parallels the decans used in ancient Egypt. An observational technique is suggested that makes use of an object known as a djed pillar. A djed pillar mounted on an official staff is known as a "Ptah-sceptre" (named after a creation god of ancient Memphis who is often depicted holding such a staff). Such a device could have served as an effective instrument for monitoring the hourly motions of stars near the western and eastern horizons. The available archaeological evidence is consistent with the observation of six decans, in succession, near the western horizon for the first half of each night, and six more near the eastern horizon for the final half of each night.

Introduction

The use of seasonal hours was a common practice in ancient times. While the day and night were each divided into twelve equal time intervals, the length of these intervals varied with the seasons. The nighttime hours were shorter in summer and longer in winter.

The ancient Egyptians observed a specific set of stars, now called the *decans*, to mark the passage of the nighttime hours. The exact identity of these stars has never been established and there are only a few incomplete references to the observational techniques used by the Egyptians. Dodd (2005a, b) conducted some simulations with a desktop planetarium program[1] to reproduce some of the astronomical results known to have been obtained by the ancient Egyptians.

In this article, four strands related to ancient Egypt are explored and six components of simulated observational techniques are developed. The results are then combined to produce a working model of observational techniques that matches the available data on astronomical practices in ancient Egypt.

The four strands are:

I. Astronomical culture and theology of ancient Egypt
II. The use of decans to measure the passage of time
III. The djed pillar as an observational instrument
IV. Simulated observations in 2500 BC.

The six model components involve the following concepts:

1. The ancient Egyptians marked the passage of the nighttime hours so that they could aid *Ra* and the *ba* of a deceased pharaoh through the underworld each night.
2. A table of 37 selected stars (now called decans) was developed to mark the passage of nighttime hours over an entire year.
3. A modern list of pseudo-decans can be constructed to parallel the content and sequence of the ancient Egyptian list of decans.
4. The djed pillar symbol represents a physical device that was one cubit tall. The top third of the device consisted of four evenly stacked disks. The stack had a total height of seven fingers and a diameter of seven fingers.
5. The djed pillar was an astronomical instrument used to observe the vertical motions of decans near the western and eastern horizons so that the nighttime could be divided into twelve equal parts.
6. The ancient Egyptians were able to adjust the length of their hours to match one twelfth of the night, during all seasons of the year. They did this by varying the distance of the djed pillar from the eye of the observer.

Any proposed observational model has to be consistent with both astronomical data and existing archaeological information. The model should be relatively simple and depend on a minimum set of reasonable assumptions. While the Egyptians were systematic observers and sophisticated thinkers, their technology was limited to that of the early Bronze Age. Monitoring the nighttime hours was probably an important priestly activity as early as 2500 BC, so the proposed model also has to be consistent with religious practices and observational data from that period.

Any model of Egyptian observational methods has three components:

- it provides a reasonable summary of the available data;
- it provides a reasonable framework for testing alternate theories;
- it can be used to help interpret any new archaeological finds.

Strand I: Astronomical culture and theology of ancient Egypt

Ancient Egypt consisted of over 30 cantons (regions along the Nile with 1 or 2 principal cities) and each canton had its own pantheon of deities. After the cantons were united (*ca*. 3000 BC), a new mythology was created that contained an amalgam of these founding deities. Different gods were emphasized as different parts of the country or different invading cultures dominated the political scene. Many temples were oriented towards the rising or setting of specific stars such as *Capella*, *Canopus*, or *Sirius*. During the pyramid-building era of the Fourth Dynasty (*ca*. 2600 to 2400 BC), there was a greater emphasis on the Sun god, *Ra*, and by the Fifth Dynasty it was doctrine that all pharaohs were defined as sons of *Ra*. Most of the pyramids at Saqqara and Giza were oriented along a north-south axis and each pyramid complex included a mortuary temple.

Each day after the Sun set in the west, *Ra* and a deceased pharaoh's *ba* (part of his eternal spirit) had to struggle though the perils of the underworld. If all went well, they were reborn the following morning on the eastern horizon. Passage through the underworld included many dangers and challenges separated by 12 gates. There were many magic spells that the *ba* could invoke to help meet these challenges, but they were intricate and difficult to remember. In the pyramid of Unas (*ca*. 2350 BC), many of these spells were inscribed on the walls of the burial chamber as reminders for the *ba*; collectively they are known as the *Pyramid Texts*. In tombs of later dynasties, similar collections of spells were often reproduced on tomb walls or written on a papyrus scroll and wrapped with the mummy of the deceased. These later versions of collected spells are commonly known as *The Book of the Dead*.

For the ancient Egyptians, the stars were "the shining ones"—the eternal spirits of lesser gods (after the Sun and Moon). Thus, it is not an unreasonable assumption that following the motion of the stars was a religious devotion rather than a scientific procedure.

Model Component #1: The priests would have been anxious to help *Ra* and the pharaoh's *ba* through the underworld each night. One way they could have done this was by chanting the appropriate spells at the appropriate times. Since there were 12 gates that had to be opened and 12 sets of challenges that had to be met, the spells were divided into 12 groups. That is likely why the time of darkness was divided into 12 equal units. If the chants of the priests were too early, or too late, then the *ba* of the pharaoh might be trapped in the underworld forever, the Sun might not rise, and the Universe would come to an end. This was serious business.

Since the length of the night varies from winter to summer and back, the Egyptians had to devise some means for varying their measure of nighttime hours during the year. At the latitude of ancient Memphis (near modern Cairo), the night-hours in December can be as long as 69 minutes, while the night-hours in June can be as short as 49 minutes.

Strand II: The use of decans to measure the passage of time

The ancient Egyptians used a civil calendar with 36 10-day weeks, plus 5 extra feast days, for a year of 365 days. From charts drawn on coffin lids and decorations on the ceilings of tombs[2], it is apparent that a specific list of 12 stars was observed each night of each 10-day week (hence the name *decans*). At the end of a typical ten-day week (*decand*), the list of active decans was adjusted so that the western-most star was dropped and a newly visible one was added in the east[3].

In the Carlsberg Papyrus Ia (Parker, 1962), instructions for observing the star Sirius, (*Sothis* to the Greeks, *Sopdet* [the bright one] to the Egyptians) are given as a model for observing all the other decans:

Over the course of a year Sirius is: first, then 90 days later it is Shen Duat, then 70 days after that it is born, then it works or serves for 80 days, then 120 days later it is back to first.

This wording is somewhat ambiguous. However, a reasonable interpretation can be devised by referring to a graph of the angular separation between Sirius and the Sun as shown in Figure 1. As the Earth orbits the Sun, all morning stars appear to advance about a degree per day ahead of the Sun. After a year, the stars have returned to their original positions relative to the Sun and the cycle begins again. Sirius appears closest to the Sun in late May, and farthest from the Sun in late November.

The regions of the graph can be interpreted as follows:

- Region A: Sirius would have shifted to a position high over the western horizon (*first*) at midnight and could be *worked* again for another 90 days above the western horizon to monitor the passage of hours between sunset and midnight.

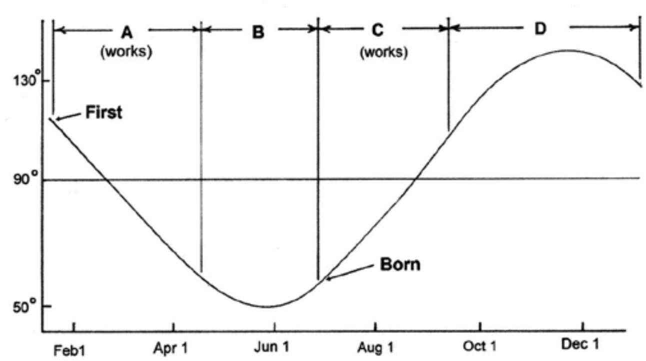


Figure 1 — The angular separation between the Sun and Sirius through the year during 2500 BC.

- Region B: *Shen Duat* and the following 70 days correspond to the days when Sirius is closest to the Sun and not visible in the night-time sky.

- Region C: The *birth* of Sirius corresponds to its rising in the east just before sunrise (helical rising). For the next 80 days Sirius could be *worked* above the eastern horizon to mark the passage of hours between midnight and sunrise.

- Region D: For the next 120 days, although Sirius would still be visible in the nighttime sky, it would not be conveniently located for observations above either the eastern or western horizons.

Although the instructions in the Carlsberg Papyrus for observing a decan add up to just 360 days, the system was flexible enough to accommodate an extra 5 days, and then be re-initialized upon the helical rising of *Sirius*. A similar pattern of angular separation can be used to describe any star within approximately 30 degrees of the ecliptic.

The tomb of Rameses VII (KV1)[4] contains one of the best surviving examples of a decan chart, engraved on the ceiling of the burial chamber. The tomb also contains a subtle indication that observations of the decans were broken into two sets, consistent with observations in the west and in the east. Parker (1974) notes that on an end wall of the burial chamber there is a picture of a seated individual with directions for a second person to observe stars near the horizon: "opposite the heart," "on the right eye," *etc*. Parker mentioned only one such figure, but there are actually two similar figures side-by-side, each with a table of data above them. The two figures and two tables suggest that there were two sets of observations. A similar diagram with two seated figures and two tables is also depicted in the tomb of Rameses IX (KV6)[5].

Model Component #2: If the ancient Egyptians did indeed use the strategies outlined in the Carlsberg Papyrus to observe the decans, then there are some specific implications:

- Observations were made near the horizon, not along the meridian as suggested by Parker.

- Observations were not based on the continuous flow of stars past some marker, but were broken into at least two sequences, one for the first six hours of darkness in the west (following *Ra* into the underworld) and one for the final six hours of darkness in the east (anticipating of the re-birth of *Ra*).

- The decans for each 10-day week (decand) consisted not of one list, but of two: six stars that would set successively in the west to mark the first six hours after sunset, followed by six stars that would rise successively in the east to mark the six hours before sunrise. At the start of a typical decand, one star would be dropped from the bottom of the west-list with another added at the top. The reverse would happen with the east-list.

A decan would cycle through the western sunset list in 60 days, and then later in the year would cycle through the eastern sunrise list in another 60 days. However, the Carlsberg Papyrus I implies that Sirius was worked for 80 + 90 = 170 days a year. This number can still make sense if it is assumed that working could mean either direct use as a marker for an hour, or indirect use as a guide star to identify other decans.

Another impressive set of decans is depicted on the ceiling of the Temple of Hathor at Denderah[6]. The 37th decan is identified as *Septet* (or *Sepdet*), the only decan that has been clearly identified with a specific star (Sirius). Thirty-seven decans are depicted as gods travelling in boats, often with groups of stars near their heads.

Observers commonly use a pattern of nearby stars to identify a star of particular interest. The stars about the heads of the decan gods depicted at the Temple of Hathor may in fact be field stars used to help locate each of these celestial gods. If it is assumed that the star groups accompanying each decan-god are not random drawings, but maps of finder-stars, then it may be possible to identify more of the decans with their modern names. For example, the 32nd decan is labelled *Remen-heru-an-Sah* and is accompanied by 14 stars. Apparently *Remen-heru-an-Sah* is related to a star cluster, and the most famous star cluster is the *Pleiades*. Perhaps *Remen-heru-an-Sah* refers to a star in the *Pleiades*, or to the whole cluster.

Model Component #3: The decans were probably among the brightest and most easily recognized stars. Decans were also located in the sky so that at some time during the year they appeared near the eastern horizon before dawn, and later in the year near the western horizon after sunset. Although approximately 6000 stars can be seen from Earth with the naked eye, the fact that decans were among the brightest stars and had to appear near the western and eastern horizons allows a list of potential pseudo-decan stars to be created with fewer than 100 candidates.

The planetarium program, *Starry Night*, was used to reduce the list of potential pseudo-decans to 37 of the most likely candidates. *Starry Night* was set to simulate the night sky over Giza and Saqqara (latitude 30° north) during the year 2500 BC. Stars were limited to those with visual magnitudes brighter than three. The brightest of these stars were noted, hour by hour, as they passed through one of two celestial viewing windows[7]. To be considered as a pseudo-decan for a given hour, a star had to remain within one of these windows for that entire hour despite its motion down towards the western horizon, or up away from the eastern horizon.

Each evening's simulation consisted of the following steps:

- A date was chosen, then the times of sunrise and sunset were used to determine the total time of darkness. This time was then divided by 12 to determine the length of a seasonal hour for that date.
- Just after sunset and facing the western viewing window, the brightest star that remained in the window for the next seasonal hour was selected as a pseudo-decan. This selection process was repeated for the next five seasonal hours.
- The viewing direction was then shifted to the eastern observation window and the process was repeated for another six seasonal hours. Sunrise marked the end of the 12th seasonal hour.

Simulations were carried out for the 36 decands during 2500 BC. For each nighttime seasonal hour, the name and altitude of the most likely pseudo-decan was recorded. The resulting lists of pseudo-decans were then integrated to produce the list summarized in Table 1. Thirty-seven pseudo-decans were chosen to match the number of decans depicted at the temple of Hathor.

Only a few hundred of the brightest stars have individual names, so the fact that all the stars in Table 1 are named indicates that they are among the brightest stars in the sky. Most of these star names have Arabic or Greek roots. The ancient Egyptians also named several of the brightest stars, but it is largely unknown which Egyptian name corresponds with which star.

For most hours, on most nights, there was a clear choice for the star to select as the most suitable pseudo-decan. However, bright stars are not evenly distributed along the ecliptic. On occasion, there was a gap between successive bright stars above the eastern or western horizons. Then a fainter star would have to serve as a pseudo-decan, or one of the boundaries of the viewing window (other than the lower boundary) was stretched a few degrees to find a suitable pseudo-decan.

The order of the pseudo-decans in Table 1 presents some challenges. The relative orientation of the equatorial plane and the ecliptic plane varies during different seasons, and from evening sessions to morning sessions. In one instance, star "A" may appear several degrees closer to the horizon than star "B" and thus be a good choice as the next pseudo-decan, but the reverse might occur on another date and time. For example, in the early morning on 2500 BC September 9 the preferred order of pseudo-decans was *Pollux* followed by *Procyon*, but in the early evening on March 28, *Procyon* preceded *Pollux*. On other occasions, the positions of stars relative to the observing window could alter the selection of pseudo-decans. For example, just after sunset on August 10, *Dschubba* was followed by *Antares*, but just before dawn on December 8, *Dschubba* was followed by *Sabik*. Even the standard shifting of stars from one decand to the next did not always seem appropriate. For example, for the 14th decand, beginning November 18, the first 6 pseudo-decans were: *Altair, Vega*, *Enif*, *Deneb*, *Alpheratz*, and *Mirach*; and for the next decand starting November 28, the first 6 pseudo-decans were *Altair*, *Vega*, *Deneb*, *Scheat*, *Alpheratz*, and *Mirach*. *Enif* was dropped, *Deneb* moved up, and *Scheat* was added, while the other four pseudo-decans remained in the same positions. Despite these variations, the general flow in the sequence of pseudo-decans should approach the sequence of decans observed by the ancient Egyptians.

Strand III: The djed pillar as an observational instrument

As early as 3000 BC, the ancient Egyptians were using a hieroglyphic symbol for an object called a djed pillar. A djed pillar as a work of art is shown in Figure 2. The djed symbol is often associated with royal burials, and in the Old Kingdom, was linked with Ptah, the chief god of Memphis, as shown in Figure 3. Although a number of theories have been proposed, the precise significance of the djed symbol is still unknown. It has been described variously as a symbol of stability, a symbol of fertility, a symbolic tree, and as a symbol for the backbone of Osiris (reigning deity of the underworld).

Symbols for djed pillars appear in many tomb illustrations and in versions of the *Book of the Dead*. Many amulets in the shape of djed pillars have been excavated. Some amulets are small enough to be items of jewellery. Some depictions show djed columns almost as tall as a man. Despite these variations

1. Sirius (-1.47)	7. Regulus (1.34)	13. Spica (0.96)	19. Nunki (2.03)	25. Deneb (1.25)	31. Almach (2.09)
2. Alhena (1.90)	8. Algieba (2.00)	14. Arcturus (-0.07)	20. Cebalrai (2.75)	26. Gienah Cygnus (2.46)	32. Algol (2.06)
3. Procyon (0.37)	9. Zosma (2.50)	15. Dschubba (2.28)	21. Rasalhague (2.06)	27. Markab (2.46)	33. Pleiades (1.37)
4. Pollux (1.15)	10. Denebola (2.12)	16. Shaula (1.59)	22. Altair (0.75)	28. Scheat (2.43)	34. Aldebaran (0.84)
5. Castor (1.56)	11. Gienah Corvus (2.56)	17. Antares (1.03)	23. Vega (0.00)	29. Alpheratz (2.06)	35. Rigel (0.15)
6. Alphard (1.96)	12. Menkent (2.03)	18. Sabik (2.40)	24. Enif (*2.37)	30. Mirach (2.06)	36. Betelgeuse (0.43)
37. Capella (0.06)					

Table 1 — A list of 37 pseudo-decans (The numbers in brackets indicate the visual magnitude of each star)

Figure 2 — A green glazed pendant in the form of a djed pillar. © Trustees of the British Museum / www.britishmuseum.org. Used with permission.

in size, every depiction of a djed pillar shows a vertical column intersected by four equally-spaced horizontal disks. The combination of disks and spaces is about one third of the column height.Note that in Figure 3, the god Ptah is shown with a djed pillar mounted on the end of a staff. This image is found in many royal tombs[8] and the djed pillar-staff combination is called a Ptah-sceptre. In Figure 4, djed pillars are being fashioned in a royal workshop. Comparing the sizes of the heads of the persons in each part of Figure 4 with the djed pillars they are holding, it appears that the combined height of the four disks and three spaces is about the distance between the bottom of the nose and the top of the head, or approximately 14 cm.

Figure 3 — A sketch of Ptah with a Ptah-sceptre, a djed pillar mounted on a staff. (Lockyer, 1894, p. 38)

Model Component #4: In Figure 5, a design for a working djed pillar is proposed. This design utilizes the system of linear measurement used by the ancient Egyptians in which one standard cubit was equal to six palms, and one palm was equal to four fingers (1 cubit = 45 cm, 1 palm = 7.5 cm, 1 finger = 1.875 cm).

According to this design, the total height of the djed pillar, including its supporting column, would be 1 cubit, or 24 fingers. The top-to-bottom height of the disks would be seven fingers, including four thin disks with three equal spaces between them. The bottom of the supporting column is hollow so that the djed pillar could be mounted on a staff. When such a djed pillar is mounted on a staff and held at a distance of 32 fingers (60 cm), the 4 disks subtend an angle of 12.3° relative to the eye of an observer. If the djed pillar is held four fingers

Figure 4 — Craftsmen working on djed pillars. From the tomb of Nebaman and Ipuky, ca. 1460 BC © Thierry Benderitter / www.osirisnet.net. Used with permission.

closer to the eye, the angle increases to 14°, and when held six fingers further away the angle decreases to 11°. The potential to easily vary these angles from 11° to 14° is a key feature of the proposed djed pillar design.

The same simulations used to identify the pseudo-decans in Table 1 were also used to determine that stars rising in the eastern window, or setting in the western window, shift in altitude by about 13° per 60 minutes during all seasons[9].

Model Component #5: The ancient Egyptians used the djed pillar as an astronomical instrument to monitor the motion of decans near the western and/or eastern horizons. When a djed pillar was mounted on a staff and held at arm's length, a bright star near the eastern horizon would appear to rise towards the bottom disk, pass behind the four disks in succession, and after an hour appear above the top disk. Similarly, a star near the western horizon would appear to sink from above the top disc and appear below the bottom disk after the passage of an hour[10]. By monitoring the motion of 12 decans with a Ptah-sceptre, the ancient Egyptians would have been able to divide the night into 12 equal hours.

All the procedures for observing decans can be easily adapted to monitor stars rising above the eastern horizon or sinking towards the western horizon. For simplicity, the following section considers only stars sinking towards the western horizon.

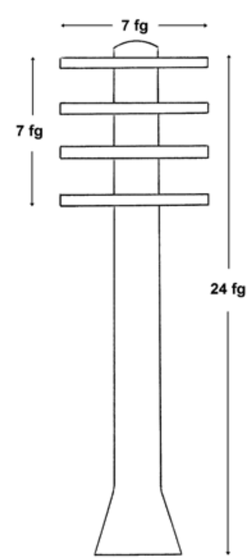


Figure 5 — A proposed design for a djed pillar (fg is used here as an abbreviation for "finger").

Preparing for an observation would simply involve holding a Ptah-sceptre at arm's length and then adjusting the djed pillar height so that the star could be seen just above the top disk. The height could easily be adjusted by moving the staff along a ramp.

Assuming that the Ptah-sceptre was at eye level to start with, a simple ramp varying from 5 fingers to 24 fingers in height would supply the needed adjustments in height. When placed at the low end of the ramp and held at arm's length, the bottom disk would appear to be 10° above the horizon. When placed at the high end of the ramp, the top disk would appear to be to 45° above the horizon.

To divide the night into 12 equal parts, the djed pillar would first be set on a suitable decan in the west. After the passage of an hour, the decan would have moved from above the top disk to below the bottom disk. (An observer could even note fractions of an hour as the decan passed through the stack of four disks.) The djed pillar would then be reset on the next decan, and the process would be repeated[11]. After six hours, observations would shift to stars rising above the eastern horizon. At the end of the 12th hour, dawn would be breaking in the east.

Model Component #6: The ancient Egyptians measured hours that varied in length with the seasons. They achieved this result by varying the observer-to-djed pillar distance.

- At the spring equinox, the observer-to-djed pillar distance was set to 32 fingers, so that relative to an observer's eye, the djed pillar subtended an angle of about 12.7°. With this setting, it took 60 minutes for a decan to shift from above the top disk to below the bottom disk.

- The observer-to-djed pillar distance was then increased for successive decands until it reached a maximum of 36 fingers at the summer solstice. On that date, the djed pillar subtended an angle of 11° and it took just 49 minutes for a decan to shift from above the top disk to below the bottom disk.

- In the following decands, the distance was shortened until it reached 32 fingers at the autumnal solstice and the seasonal hour was again 60 minutes.

- As the winter solstice approached, the observer-to-djed pillar distance was gradually shortened to 26 fingers. At the winter solstice, the djed pillar subtended an angle of about 14° and it then took 69 minutes for a decan to shift from above the top disk to below the bottom disk.

Setting the appropriate observer-to-djed pillar distance could have easily been managed by using a string tied to the djed pillar with knots spaced one finger apart. The essential data from the simulation are summarized in Table 2.

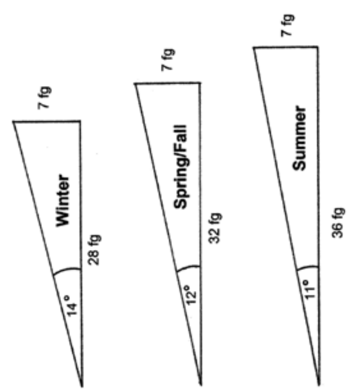


Figure 6 — Setting djed pillar distances for different seasons.

The ancient Egyptians need not have made any precise measurements or complex computations to design djed-pillar observations. They could easily have developed their observational procedures after watching setting stars as they sank by a tree (or building) near the horizon. With a bit of trial-and-error, observers could have designed the first djed pillar as a symbolic tree to be held at arm's length, so that a western star would sink from the top to the bottom in 1/12th of the night. They would also have noted that as you move away from a tree, the tree appears smaller and the stars sink by it in less time. The opposite occurs when you move towards the tree. As a result, they would know that you could shorten a djed-pillar hour by holding the djed pillar farther away, and lengthen the hour by bringing it closer. Systematic trial and error over a few years would calibrate the djed pillar to a distance of 28 fingers during winter nights, and 36 fingers during summer nights, as in Figure 6.

Time of Year	Time between sunset and sunrise (minutes)	Average length of a seasonal night-time hour (minutes)	Average observed altitude change* (degrees)	Corresponding djed pillar distance** (fingers)
Winter solstice	831	69	14.3 ± 1.0	28
Vernal equinox	711	59	12.5 ± 0.5	32
Summer solstice	592	49	11.1 ± 0.4	36
Fall equinox	714	60	12.8 ± 0.7	32

Table #2 — Seasonal hours and corresponding djed pillar settings at the latitude of Memphis (+30°, 2500 BC)
** The average change in altitude, during a seasonal hour, for pseudo-decans as observed using the planetarium program,* Starry Night.
*** The eye-to-djed pillar distance that sets the length of the seasonal hour.*

Strand IV: Simulated observations in 2500 BC

Imagine that you are an Egyptian priest standing on the roof of a mortuary temple, *ca*. 2500 BC. *Ra* is setting in the west and it is your duty to observe the stars so that you can call out the passage of every quarter hour. How would you do it? Which stars would you observe? What instruments would you use?

Suppose that it is the time of the winter solstice, 2500 BC January 11. The Sun has just set and you are facing the western horizon. Earlier you reviewed the list of decans to be observed during the night. Now, right on schedule, you are able to identify the star *Deneb* with an altitude of 24°. You set your Ptah-sceptre on a ramp so that *Deneb* is just visible above the top disk. A string with knots marking lengths from 26 to 36 fingers hangs from the top of the staff. You hold the knot for 26 fingers close to your cheek and stand back till the string is taut. As time passes, *Deneb* appears to sink behind the top disk and then reappear between the first and second disks. At that moment you would call out "star 1, disk 1" or some such signal to indicate that the first quarter of the first hour of the night had passed. Fellow priests in the temple sanctuary would hear your call and chant the first set of spells to assist *Ra* and the *ba* of a deceased pharaoh to meet the first challenge in the underworld that night.

After another quarter hour, *Deneb* would sink to a position between the second and third disks and you would call out "star 1, disk 2," and so on. At the end of 69 minutes, *Deneb* would appear below the bottom disk and you would call out "end of hour 1." Then the Ptah-sceptre is moved and set so that *Alpheratz* (the next decan on the list for the night) appears just above the top disk (its altitude would be approximately 31°). *Alpheratz* would then be monitored until it appeared below the bottom disk. And so on for four more decans. After the first six hours of the night had elapsed, *Ra* and the *ba* of the pharaoh would have passed the low point in their nightly journey and would begin rising towards the eastern horizon. Accordingly, attention would shift to the east. Facing towards the eastern horizon, decans would appear to rise from below the bottom disk to above the top disk. *Spica* would be the seventh decan observed, with a beginning altitude of 23°; then *Menkent* with an altitude of 16°. If all went well, just as the 12th star on the decan list appeared over the top disk of the djed pillar, dawn would be breaking in the eastern sky.

In this manner, the Egyptian priests could have measured the passage of the hours during any night of the year.

A Summary of the Model Components

Taken together, the 6 model components provide an explanation for why the ancient Egyptians divided the night into 12 equal hours, and how they could have accomplished that task even as the length of the night varied during the year. The model also provides a reasonable explanation for the purpose, design, and use of the djed pillar and Ptah-sceptre.

For clarification, the concepts that have been proposed in this paper are in italics.

1. The ancient Egyptian priests marked the passage of the night-time hours *so that they could chant the appropriate spells and thus aid Ra and the ba of a deceased pharaoh through the underworld each night*.
2. A table of 37 select stars (decans) was developed to mark the passage of nighttime hours over an entire year. Twelve stars were observed each night, *six in the west after sunset, six more in the east before sunrise. Usually*, after each decand (10 days) one star was dropped from each list and the next decans were added.
3. Using simulations of the Egyptian sky in 2500 BC, *a list of pseudo-decans can be constructed that should be similar to the content and sequence of the ancient Egyptian list of decans*.
4. *The djed pillar symbol represents a physical device that was one cubit tall. The top third of the device consisted of four evenly stacked disks. The stack had a total height of seven fingers, and a diameter of seven fingers.*
5. The djed pillar, mounted as a Ptah-sceptre, *was an astronomical instrument used to observe the vertical motions of decans near the western and eastern horizon so that the nighttime could be divided into 12 equal parts*.
6. The ancient Egyptians were able to adjust the length of their hours to match 1/12th of the night during all seasons of the year. *They did this by varying the distance of the djed pillar from the eye of the observer*.

Concluding Comments

The ancient Egyptians were not astronomers, but priests who observed and worshipped the Sun, Moon, planets, and stars as gods moving through ethereal realms. By studying celestial cycles, they were seeking ways to appease, gain favour, and assist the gods.

There is scant direct historical evidence describing the astronomical techniques that were used in ancient Egypt (Wells, 1996). Many tomb decorations provide some clues and there is one section in the Carlsberg Papyri Ia with a short description of the use of decans. From the available evidence, it is apparent that the Egyptians did measure the seasonal hours of the night, and they did make use of a set of 37 specific stars now called decans.

Interpreting the djed pillar as an astronomical instrument is a key feature of this paper. A djed pillar, with a design similar to that shown in Figure 5, could have been used to observe the motion of a sequence of decans near the western and/or eastern horizons. Such a conjecture meshes with the available archaeological and astronomical data. The use of a djed pillar as an astronomical instrument provides a reasonable explanation for the association of djed pillars with Egyptian royalty; with Osiris, the god of the underworld; and with ceremonies related to the annual calendar. The use of a djed pillar to observe the motion of stars is a sophisticated idea, but the djed pillar is not a sophisticated instrument, and does not require sophisticated observational techniques. The strategies for observing decans with a Ptah-sceptre could have easily evolved from trial-and-error observations of stars sinking towards the western horizon and rising above the eastern horizon. Ptah-sceptre observations would have been robust. It would have been a simple procedure to "set" on a decan, and if a particular decan could not be found, then another star in the vicinity could serve for monitoring the next hour. It was not necessary for every seasonal hour to be exactly 1/12th of the night. The required goal was to measure 12 seasonal hours that were approximately the same length and that added up to the length of the night.

It has only been in the past two decades that planetarium programs with high precision and detailed graphics have been readily available for use with desktop computers. Although earlier researchers have explored the same source material, they had to deal with tedious computations and limited graphics. With a program such as Starry Night, it is a simple matter to set the date, time, and location of an observer and then view a detailed image of the corresponding sky. The image can be set in a static mode, can be advanced in time steps specified by the user, or can be viewed as a movie. Precise information for any selected star can be displayed on a sidebar. It would have been very challenging for pre-1990 investigators to have reproduced the simulations at the core of this paper.

It is a reasonable proposition that ancient Egyptian priests (*ca.* 2500 BC) used a Ptah-sceptre to monitor the hourly motion of the decans. With this technique, they would have been able to time the chant of appropriate spells to keep them in sequence with the passage of Ra and the ba of a departed pharaoh through the 12 gates of the underworld each night. This was not a trivial exercise. By this method, the priests would have been able to assist in the daily rebirth of Ra and prevent the end of the Universe. ✶

William Dodd is a member of the Toronto Centre and has authored a number of articles for the JRASC. *His current interest is in the use of desktop planetarium programs to simulate features of ancient astronomy.*

References

Dodd, William (2005a), Exploring the astronomy of ancient Egypt with simulations I: the Sun, Moon, and Milky Way, *JRASC*, *99*, 24-29, February

Dodd, William (2005b), Exploring the astronomy of ancient Egypt with simulations II: Sirius and the decans, *JRASC*, *99*, 65-69, April

Lockyer, J. Norman (1894), *The Dawn of Astronomy – A Study of the Temple Worship and Mythology of the Ancient Egyptians*, reprinted MIT Press 1964

Parker, Richard A. (1962), Two demotic astronomical papyri in the Carlsberg Collection, *American Center of Oriental Research*, 143-147.

Parker, R.A. (1974), Ancient Egyptian Astronomy, *Phi. Trans. R.Soc. Lon. A276*, 51-65

Wells, Ronald. A. (1996), *Astronomy in Egypt, in Astronomy before the telescope*, ed. Walker, C., British Museum Press

(Endnotes)

1 *Starry Night*, Version 2.1, Sienna Software Inc., 1998. This program contains a database with over 30,000 stars, and calculates accurate star positions for any date in the range: present ± 99,000 years.

2 The ceiling of the tomb of Seti I, Dynasty 19, provides a good example. (See www.thebanmappingproject.com, image ref. # 15456.)

3 This adjustment compensates for the movement of the Earth in its orbit about the Sun of about one degree per day.

4 www.thebanmappingproject.com, image ref # 15570

5 www.thebanmappingproject.com, image ref # 15603

6 A detailed drawing of a sculpture featuring the goddess Nut and including a complete set of decan images, can be found in *The Monuments of Ancient Egypt, The Napoleonic Edition* (the complete archaeological plates from La Description De L'Egypte), Vol. IV, Pl. 20, edited by Charles C. Gillispie and Michel Dewachter, 1987, Princeton Architectural Press. You can also find copies of the individual decans from this same sculpture online at http://ib205.tripod.com/decans.html.

7 The concept of a viewing window for ancient Egyptian observations is essential for the model under consideration. The windows were chosen to be 70° wide and 30° high: the western one was centered at azimuth 270° and altitude 25°, the eastern one at azimuth 90° and altitude 25°. A lower altitude limit of 10° was set to avoid irregularities and obstructions on the horizon in ancient Egypt. The upper altitude limit of 40° is a practical value that would have allowed for comfortable observations. The ranges in azimuth allow a variety of stars to be observed while still focussing attention on the region where *Ra* has already set, or is about to rise.

8 For example, images of Ptah with a Ptah-sceptre can be found in the tombs of Set I, Rameses II, Rameses III, Nefertari, Amenherkhepshef, and Sethnakhte.

9 The actual rate varies continuously from 13.5° per 60 minutes for stars due east or west, to 11° per 60 minutes at the southern and northern borders of an observation window. There was no need for the ancient Egyptians to worry about these details. As their observations ranged across an observation window, some hours may have been a little longer or shorter, but, by morning, the sum of the 12 hours would closely match the time of darkness.

10 An ancient camper may have observed stars, near the western horizon, as they slowly sunk down through the branches of a tree, and was then inspired to design the djed pillar to make the process more systematic and portable. Thus, a djed pillar may indeed be symbolic of a tree.

11 The process would be analogous to keeping time with a set of 12 hourglasses. As the last sand grains left the top of the first hourglass, you would turn over the second, and so on, until all 12 had been turned and emptied.

Astronomy Outreach in Cuba

Trip Two

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

Last year, my wife and I delivered 12 donated Galileoscopes[1] to Cuba and took part in workshops with young people at the National Museum of Natural History, hosted by our new Cuban friend, Alejandro Jiminez (*JRASC* 104 (6), 232–236, December, 2010). This year we returned to continue the collaboration, carrying more astronomy materials generously donated by fellow RASCals. Most in demand were tripods for the Galileoscopes, star atlases, sky charts, and astronomy books. I also delivered a donated used laptop PC, which will be a tremendous asset for the amateur astronomers of Cuba. The gifts were received gratefully, and were followed by serious discussions on how the Cuban amateurs must organize themselves and build their network.

Figure 1 — The 160-mm Perkin Elmer refractor.

We visited the observatory at the University of Havana, where Mónica de la Guardia Durán (a science outreach officer) is leading a refurbishment project. The observatory is in a sad state of repair, but there are some wonderful vintage instruments there, including a 150-mm Perkin Elmer refractor from the 1940s. To assist in this project, we hope to recruit some advisors from observatory technologists associated with the RASC.

One day, we visited a potential dark-sky site, Las Terrazas, about a 90-minute drive from Havana. It was not possible for our group to visit at night, but we were able to explore the layout and assess the lighting situation during the day. Most rural areas in Cuba are naturally dark, owing to the country's less-advanced stage of economic development. Accordingly, the lighting situation in Las Terrazas is very good. The site already contains a camp for the Pioneers (a Cuban youth organization) and is a UNESCO Biosphere Reserve. Thanks to the generosity of the RASC, Alejandro now has a Sky-Quality Meter to quantitatively document the sky glow at that site and other locations in Cuba. On this trip, we also hiked up a 400-m hill in sweltering heat, observed some Cuban bird life, and discussed the ins and outs of the Cuban revolution while we sat under a monument to Che Guevara. It was a magnificent vista, looking onto the Caribbean Sea on one side and the Gulf of Mexico on the other.

Figure 2 — Alejandro and Dave discuss Che and revolutionary ideals.

At the Museum on another day, Alejandro and I jointly presented "Responsible Night-time Lighting for Protected Areas." Alejandro had specifically requested this presentation for the audience along with a discussion of the Halifax Centre's experience assisting Kejimkujik National Park and National Historic Site to become an RASC Dark-sky Preserve (www.pc.gc.ca/eng/pn-np/ns/kejimkujik/natcul/nat/nat6.aspx). For the presentation, we used material provided by Robert Dick, Chair of the RASC Light-Pollution Abatement Committee (LPAC), and by Parks Canada staff at Keji, who had put together an all-ages show "Blinded by the Light." Alejandro provided the Spanish translation of the slide captions and my spoken commentary. We also played the video "Our Vanishing Night" (www.youtube.com/watch?v=JJ9aLiy9ucQ) by RASC Winnipeg Centre members Jennifer West and Ian Cameron (with Spanish subtitles supplied by Alejandro!). Thirty people attended the event, including Dr. Oscar Alvarez[2], museum staff, some Cuban amateur astronomers, some Pioneers, and representatives from CNAP (essentially Cuba's equivalent to Parks Canada). The presentation was received very well and there was a vigorous discussion afterwards, not all of which I followed! It became clear that it is especially important to establish responsible lighting principles before Cuba becomes more developed, which may eventually come to pass if U.S.–Cuba relations improve in the future, as is expected.

Returning to the Museum on Sunday morning (!), Alejandro and I presented "Explore the Universe–Cuba" to a crowd of

Figure 3 — Havana sky glow, as only the Cubans can enjoy it.

40, including amateur astronomers, Pioneers, teachers, and parents. There was considerable interest in the EU Observing Program with many detailed questions. I made a "motivational" speech about the value of amateur astronomy and the benefits of following a structured observing program with specific goals. We showed the EU pins, the certificate template, and the observing logs. (The RASC recently granted Alejandro authority equivalent to the RASC Observing Chair (within Cuba) to assess applications for the EU program and to award certificates and pins.) Prior to the talk, there had been some discussion about the Cubans setting up their own observing program modelled after the RASC EU program, but in the end, the amateurs present agreed that they want the RASC to be the organization recognizing the achievement. There was at least one member of the audience who is seriously interested in following this program, judging by the particular questions he asked! In thanks for our efforts, the Museum presented us with a beautiful inscribed photographic book on the Cuban landscape, which is now in the RASC Halifax Centre library.

On Sunday night, we participated in a public observing session on the roof of the museum. It was a very social evening. I helped with the Galileoscopes and tripods, demonstrated the Sky Quality Meter in the light-polluted skies (18.4 magnitudes/arcsecond^2, worse than Halifax!), demonstrated my MusicBox EQ mount to the astrophotographers, and took sky-glow photos.

The events on this trip extended and deepened our collaboration with Cuban amateurs and broadened the involvement of the RASC. (Thanks to John Jarvo, John Liddard, Alex Lecreux, Roy Bishop, Dave Lane, Mike Boschat, Chris Young, Wes Howie, and the LPAC for their donations!). The manner in which we were welcomed back by the Cuban amateurs was heartwarming, and I feel that an unbreakable bond has been formed with these proud and courageous people. Astronomy without borders! The experience has motivated my wife, Chris Hanham, to look into forming a charitable organization to extend the work even further. Stay tuned for developments! ✶

David Chapman (M.Sc., Physics, University of British Columbia, 1977) is a retired Defence Scientist and has been an amateur astronomer for about 50 years. He has earned the Messier and Isabel Williamson Lunar Observing certificates. He is a Life Member of the RASC attached to the Halifax Centre, an Assistant Editor of JRASC, *and the Editor of the RASC* Observer's Handbook. *This article was previously published with minor alterations in* Nova Notes, *the newsletter of the RASC Halifax Centre.*

(Endnotes)

1 The Galileoscope is an inexpensive telescope kit useful for astronomy education (www.astronomy2009.org/globalprojects/cornerstones/galileoscope/).

2 Dr. Oscar Alvarez is a member of the International Astronomical Union and the National Academy of Sciences (Cuba), and is now an Honorary Member of the RASC.

Discovery of the Expansion of the Universe

Sidney van den Bergh
Dominion Astrophysical Observatory
Herzberg Institute of Astrophysics
National Research Council of Canada
5071 West Saanich Road
Victoria BC V9E 2E7
(sidney.vandenbergh@nrc.ca)

The myth that the expansion of the Universe was discovered by Hubble was first propagated by Humason (1931). The true nature of this discovery turns out to have been both more complex and more interesting.

On the last observing night before his retirement, Milton Humason was tasked with teaching me how to use the Palomar 48-inch Schmidt telescope. By midnight, Milt went to bed, apparently believing that his pupil was doing well enough to be left alone to use "The Big S." During the preceding three decades, Humason had spent many very long nights collecting the spectra of faint galaxies that would enable Hubble & Humason (1931), using the new radial-velocity observations by Humason (1931), to establish the linear expansion of the Universe beyond reasonable doubt. This work strengthened and confirmed the first hints of this expansion collected by Wirtz (1924), Lundmark (1925), Lemaître (1927), Hubble (1929), and de Sitter (1930).

In his memoirs, collected during an oral history project (www.aip.org/history/ohilist/4686.html) undertaken by the American Institute of Physics (Shapiro 1965), Milt Humason is quoted as follows:

> *The velocity-distance relationship started after one of the IAU meetings, I think it was in Holland.* [The Third IAU meeting took place in Leiden in the Netherlands, 1928 September 5 – 13.] *And Dr. Hubble came home rather excited about the fact that two or three scientists over there, astronomers, had suggested that the fainter the nebulae were, the more distant they were and the larger the red shifts would be. And he talked to me and asked me if I would try and check that out.*

Among the astronomers present at the IAU meeting, who might have been interested in a possible velocity-distance relationship for galaxies, were de Sitter, Hubble, Lemaître, Lundmark, Shapley, and Smart.

The first tentative steps toward the discovery of the velocity-distance relationship were made by Wirtz (1922, 1924) and Lundmark (1925). In his 1922 paper, Wirtz concludes that either the nearest or the most massive galaxies have the lowest redshifts. From the more extensive observational material available in 1924, Wirtz found that the radial velocities of spiral nebulae grow quite significantly with increasing distance. He was aware of the fact that the general theory of relativity predicted that redshifts should increase with increasing distance. Wirtz published his results in the *Astronomische Nachrichten*, the leading German astronomy journal.

[Hubble received an A in his high-school German course (Christianson 1995, p. 31) and he also read German text books on corporate law (Christianson 1995, p. 79), so he would have had no trouble reading Wirtz's papers.] In 1925, Lundmark wrote, "A rather definite correlation is shown between apparent dimensions and radial velocity, in the sense that the smaller and presumably more distant spirals have the higher space-velocity." In interpreting this result, Lundmark opines that the observed Doppler shifts might be "... effects consequent to the general theory of relativity." Lundmark's 1925 paper was published in the prestigious *Monthly Notices of the Royal Astronomical Society*, and was cited in Hubble (1929). However, Hubble dismisses this important paper with the comment that Lundmark's favoured solution "offered little advantage."

Lemaître (1927) published a crucial paper that both established the expansion of the Universe and interpreted it as a consequence of the general theory of relativity. However, it is possible that Hubble (1929) was unaware of Lemaître's 1927 paper on the expansion of the Universe, because it had been published in French in a rather obscure publication. Nevertheless, it is puzzling that Hubble and Lemaître would not have discussed this problem when they were both attending the 1928 IAU meeting in Holland. That Hubble dismissed Lundmark's paper might well be related to a bitter personal feud that resulted from the fact that Hubble (1926) had accused Lundmark of plagiarizing his system of galaxy classification. Hubble's failure to take Lundmark's 1925 paper seriously may have been largely responsible for the fact that this work has been ignored by many recent reviews of the discovery of the expansion of the Universe (Block 2011, Kragh 1987, Luminet 1997, Shaviv 2011)—but not by Nussbaumer & Bieri (2009). In this connection, it is of interest to note that Christianson (1995, p.230), in her biography of Hubble, writes about "[A] bitter, if little known, flare-up with Willem de Sitter, whom Grace [Hubble] had credited with spurring him to pursue the velocity-distance relationship with the great telescopes at his command." She also writes that "Hubble became enraged at de Sitter's casual statement that several astronomers had commented on the [velocity-distance] relation." For a more detailed account of this matter [based on a letter from Hubble to de Sitter (dated 1930 August 21) which is preserved in the Huntington Library] see Nussbaumer & Bieri (2009, p. 130).

In their 1931 paper, Hubble and Humason berate the previous work by de Sitter (1930) because "[H]e arrived at the same numerical result" [see Table 1]. This was to be expected, since he used essentially the same data. Exactly the same criticism may be applied to the paper by Hubble (1929), which used essentially the same input data that had previously been used by Lemaître (1927).

The history of the discovery of the expansion of the Universe may be summarized as follows:

1922: From radial velocities of only 29 spirals, Wirtz concludes that either the nearest or the most massive galaxies have the smallest redshifts.

1924: Using observations of 42 galaxies, Wirtz (1924) concludes (my translation) "that there remains no doubt that the positive radial velocities of spiral nebulae grow quite significantly with increasing distance."

1925: Lundmark notes that the redshifts of small (presumably distant) spiral galaxies are larger than those of larger nearby ones.

1927: Lemaître derives the expansion rate of the Universe and explains its expansion in terms of the general theory of relativity.

1929: Hubble repeats Lemaître's work with essentially the same data and obtains similar results.

1930: de Sitter discusses mostly the same data more thoroughly and again finds the same result.

1931: Hubble & Humason obtain 40 new radial velocities, which extend the determination of redshifts to the Leo cluster at a redshift of 19,600 km/s. This places the reality of a linear velocity-distance relationship for galaxies beyond reasonable doubt.

The myth that Hubble discovered the velocity-distance relation seems to have originated with Humason (1931) [who was at that time acting as Hubble's observing assistant]. Humason started his 1931 paper with the words "In 1929 Hubble found a relation connecting the velocities and the distances of the extragalactic nebulae for which spectra were then available." This point of view is supported by Hubble's statement (Christianson 1995, p. 230) that "I consider the velocity-distance relation, its formulation, testing and confirmation, as a Mount Wilson contribution and I am deeply concerned in its recognition as such." By contrast, Lemaître (1950) also wished to leave no doubt about who really discovered the expansion of the Universe. He writes about his 1927 paper: "[J']'y calcule le coefficient d'expansion (575 km par mégaparsecs, 625 avec une correction statistique contestable)…. Le titre de ma note ne laise aucun doubte sur mes intentions: <<Un Univers de masse constant et de rayon croissant rendant compte de la vitesse radiale des nébuleuses extra-galactiques.>>" The story told above shows that the actual history of the discovery of the expansion of the Universe was more complex and interesting than Humason suggested in 1931.

I thank Vivien Reuter for providing me with a listing of the "delegates" who attended the 1928 IAU meeting in Leiden. Also, I am deeply indebted to numerous colleagues who have sent me e-mail messages related to various aspects of my recent article on Lemaître in this *Journal*. I am particularly indebted to Harry Nussbaumer, Jean-Pierre Luminet, and David Block for their comments and encouragement. Thanks are also due to our librarian Bonnie Bullock for providing me with many ancient books and journal articles. ✶

Reference	H_o(km/s/Mpc)
Lemaître (1927)	625 (weighted)
Lemaître (1927)	575 (unweighted)
Hubble (1929)	530
de Sitter (1930)	460
Hubble & Humason (1931)	558

Table 1 — Early determinations of the Hubble parameter

References

Block, D. (2011). A Hubble Eclipse: Lemaitre and Censorship, *arXiv: 1106*, 3071.

Christianson, G.E. (1997). *Edwin Hubble Mariner of the Nebulae*. Toronto: HarperCollins Canada.

de Sitter, W. (1930). On the magnitudes, diameters and distances of the extragalactic nebulae, and their apparent radial velocities. *Bull. Astr. Inst. Netherlands 5*, 157.

Hubble, E. (1926). Extra-galactic nebulae. *ApJ, 64*, 321.

Hubble, E. (1929). A relation between distance and radial velocity among extra-galactic nebulae. *Proc. National Acad. Sci. 15, Issue 3*, 168; *Pub. US Nat Acad Sci, 15,* 168.

Hubble, E. & Humason, M.L. (1931). The velocity-distance relation among extra-galactic nebulae. *ApJ 74*, 43.

Humason, M.L. (1931). Apparent velocity-shifts in the spectra of faint nebulae. *ApJ 74*, 35.

Humason, M.L. (ca.1965). Center for the History of Physics, oral history project, interview by S. Shapiro.

Kragh, H. (1987). The beginning of the world: Georges Lemaître and the expanding universe. *Centaurus, 32*, 114.

Lemaître, G. (1927). L'univers en expansion. *Ann. Soc. Sci. de Bruxelles, 47*, 49. Translated in (1931) *MNRAS, 91*, 483.

Luminet, J-P. (1997). L'invention du Big Bang. Paris: Editions du Seuil.

Lundmark, K. (1925). The motions and distances of spiral nebulae. *MNRAS, 85*, 865

Nussbaumer, H. & Bieri, L. (2009). *Discovery of the expanding universe*. Cambridge: Cambridge University Press.

Shapiro, S. (ca. 1965). Oral history project of the Center for History of Physics of the American Institute of Physics.

van den Bergh, S. (2011). The Curious case of Lemaître's Equation No. 24. *JRASC*, 105, 151. (also arXiv:1106.1195).

Wirtz, C. (1922). Einiges zur Statistik der Radialbewegungen von Spiralnebeln und Kugelhaufen. Astr. Nachr., 215, 349.

Wirtz, C. (1924). De Sitters Kosmologie und der Radialbewgung der Spiralnebel, Astr. Nachr., 222, 21.

Palomar Oranges

by Ken Backer, Mississauga Centre
(kbacker@iprimus.ca)

Recently my wife, Lin, and I engaged in one of our favourite Sunday-morning activities—cruisin' the Aberfoyle Flea Market near Guelph, Ontario. Several acres of stuff, from antiques to junk, await one's discovery, and if you can't find what you're looking for, it probably hasn't been made. High on the shelf in back of one stall I noticed a small sign with the word "Palomar" in white letters, and below it was an illustration of an observatory. Closer examination revealed this was the end board of a crate, an orange crate to be exact, for the paper sign attached to it read "Palomar Brand" and below the illustration of the Observatory were the words "Grown and Packed by Escondido Orange Ass'n., Escondido, Calif." After handing over the appropriate coinage, I was the proud owner and added it to the other treasures we had purchased that morning.

A check on the Internet produced no information on Palomar Oranges. The Escondido Orange Association came into being in 1928 when it split from the Escondido Fruit Growers, but appears to be in business no longer. Escondido is an area north of San Diego, and San Diego is the closest major centre to the Palomar Observatory. Construction of the Palomar Observatory began in 1928, but completion and scientific research didn't take place until 1948. It housed the Hale telescope, and with its 14.5-ton 200-inch mirror, remained the largest reflecting telescope in the world until 1976.

I'm sure the construction of this observatory was a major event, and its completion made it a prominent attraction for the area (Disneyland had not been built yet). It appears some savvy enterpriser decided to capitalize on this and name his orange growing business after the observatory.

Next, I will keep an eye out for a crate end board for Kitt Peak Cabbage (big crop in Arizona). Or, Mount Wilson Peaches.... ✶

Ken Backer is a member of the Mississauga Centre who displays acquired flea-market treasures at his home in Milton, Ontario.

To See the Stars Anew

by Martin Beech, Campion College,
The University of Regina, Regina SK S4S 0A2

> *It has always irked me as improper that there are still so many people for whom the sky is no more than a mass of random dots.*
>
> – M.C. Escher

I am a child of Earth's Northern Hemisphere, and from Auckland, New Zealand, the night sky is a blend of the familiar and the new. Some of the heavenly patterns I can recognize, but other regions are unfamiliar, novel, and exhilarating. Whole new vistas of the Universe have opened out to my silent gaze—the scene is star studded and unsettling in the way that only the unfamiliar can jolt one from the deep rut of routine. I am a child of the Northern Hemisphere and the night sky has changed.

Age has an annoying way of creeping up on you—the great sea-swell of time carrying one ever forward on a shifting tide of distraction and work. Younger dreams and aspirations become lost and re-directed, perhaps inevitably, by the insidious flux of the every day. To climb Mt. Everest, to become a train driver, an explorer, or an astronomer, to see Machu Picchu, the Ross ice shelf, to experience Pamplona and the running of the bulls, to gaze upon Southern Hemisphere skies—all such plans were laid in the enthusiasm and moneyless state of high-school youth. Well, my inspiration wish list is still growing and certainly it is nowhere near completed, but recently at least one item was successfully removed from its time-ridden lines.

To witness, for the first time, the stars of the Southern Hemisphere was, to my great delight, an experience that both transformed and rejuvenated my mid-life mind. The vista wrenched my brain from the standard routine; nothing was immediately recognizable, and I saw the heavens afresh and new. There was novelty in the celestial vault. The experience re-kindled my seemingly, and without clear realization, long-lost wonder in simply looking at the stars—no telescopic optics, no computers, no Internet, no star maps.

My first view of strange star fields was caught through scuttling clouds on a damp and blustery Auckland night towards the end of July, the southern winter. Moving windows of clarity, edged by dark cumulus, revealed The Pointers of alpha and beta Centauri. Toliman was riding high in the sky, shining with a brilliant unashamed light—like quicksilver, strong and defiant. Slightly below The Pointers, its longer axis horizontal, rested Crux, the Southern Cross. From beyond the dry and lifeless star maps, this smallest of constellations burst into sight; definitive, vibrant, and distinct. The view was all too brief, however, and my viewing window of the sky, all too soon morphed and reformed, moved-on, and closed. It was a fleeting vista, but to my northern eyes, it was a sight never before held; novel and unworldly it floated briefly like a pointillist ghost, a hitherto abstract form made real before my very eyes.

My second view of the Southern Cross, just a few days later, was altogether different and much more powerful than my Auckland city teaser. It had been a perfect day in Whangamata, on the eastern coast of the Coromandel Peninsula: warm and sunny and full of colour and life. As the day closed, however, and the Sun dipped below the western edge of the world, a cool, blue-black, bruised-black celestial vault unfolded, star-encrusted, magnificent and thrilling. My northern-star-adapted eyes were overpowered, confused, and delighted. The constellations, otherwise familiar to my gaze, were twisted beyond immediate recognition—their familiar shapes were turned, obscured to my eye by a near 180-degree rotation. The view was familiar and yet new and strange and joyful—it was like seeing a loved-one all anew and in a different way: in a way that only the heart can feel and that words cannot describe. I was lost to the heavens. The celestial sphere was at its most primordial; clear, alive, pulsing, and defiant, revealing a stellar display that in long-centuries past brought forth magnificent gods, terrifying beasts, and mythical heroes and heroines.

A cool breeze developed as the night grew older, blowing along the winding path of the Otahu river estuary. Sounds from the gentle surf and creaking trees serenaded the darkness. Goosebumps peppered my skin and I could taste the salt air. The grass was cool and damp beneath my bare feet. Saturn, orange and distinct, hung above the western horizon; it was as if celestial time had stopped. I held my breath. Most magnificent of all these numinous sensations, however, was the sheer sight of the Milky Way. It was a great swath of crepuscular stars that cleaved the heavens in two. Indeed, I have never seen the Milky Way so bright and dominant. It was a broad, green blush across the otherwise obsidian-black celestial vault. Almost directly overhead stalked Scorpius, its body and tail oddly orientated to my northern eyes. Antares was magnificent, red and dominant, and Sagittarius was encased within a billowing mist of Milky Way light and dust-cloud darkness. It seemed to my eyes as if I could see to the very core of the galaxy—physical laws and reality be damned.

To my south, low in the sky, something strange caught my eye. Something new. Two faint clouds of dappled light, glow-worm green in colour. There, not-there, and there again to my gaze; my first view of the Magellanic Clouds. To the southwest, the Southern Cross lay, once again, upon its side, Mimosa pointing uppermost. The view was sublime and the stars down to the very faintest observable were sharp, distinct, and magnificent. Indeed, the stars were so palpable that the Coal Sack Nebula, nestled in the lower left quadrant of the Southern Cross, looked like a diluted ink-stain spread upon the surface of a piece of coarse-grained paper.

The sky from Whangamata was timeless, primordial, and awesome. And, while the indomitable spin of the celestial sphere seemed halted to my perception, all was far from stationary. With heartbeat-stopping fastness, the sky was intermittently illuminated by the flash of numerous falling stars—transient scratches of light animating the stillness of the heavens. Purely by chance, and entirely to my surprise, I had rediscovered the delta Aquarid meteor shower. From the Northern Hemisphere, this shower is never very prominent, the radiant barely peeking above the horizon for nighttime-bound Canadian observers; from Whangamata, however, the meteors poured down from high overhead. The meteors added a time dislocation to the celestial vault, their brief burst of light contrasting against the timelessness of the background stars and the imposing majesty of the Milky Way.

To my northern eye, the southern sky was a synergy of contrasts: fast and slow, nebulous and acute, bedazzling and crepuscular. The stars above Whangamata reminded me of the reasons why I became, now long ago, an astronomer in the first place, and they afforded me the rare gift of seeing the heavens anew. ✶

For my part I know nothing with any certainty but that the sight of the stars makes me dream.

– V. van Gogh

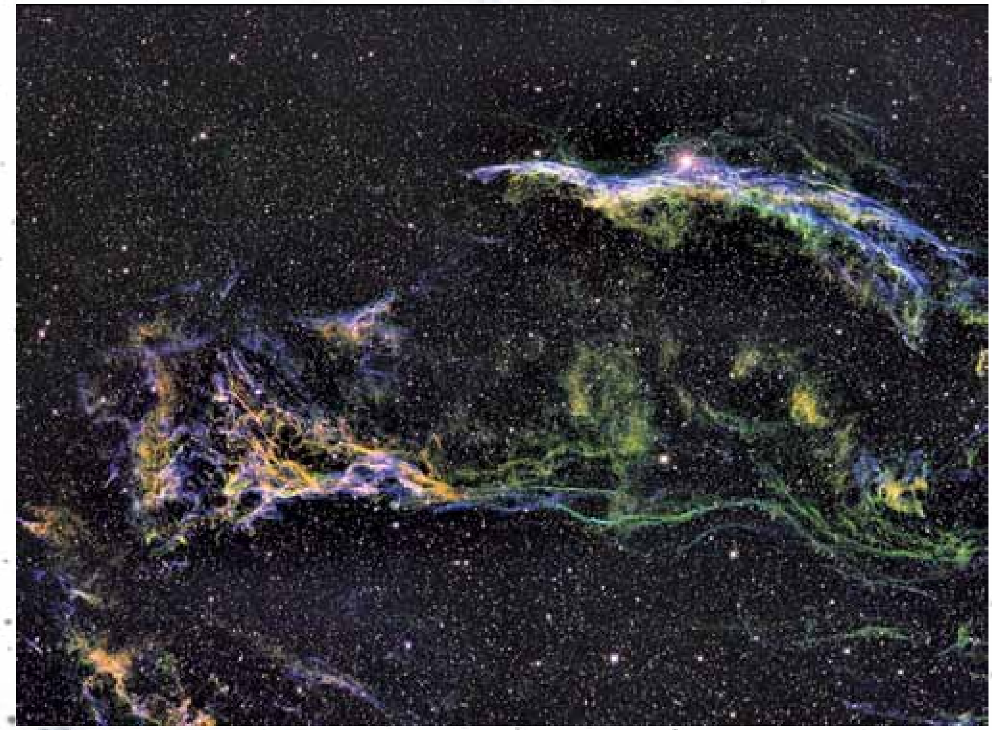


Figure 1 — Pierre Tremblay of the FAAQ captured the Cygnus Loop in psychedelic colours using three narrow-band wavelengths on six nights in June 2009. For this two-frame mosaic, Pierre used a Takahashi CN-212 Newtonian telescope and Hα, OIII, and SII filters. Exposures for each image were 12 x 900 s in Hα, 16 x 900 s in OIII, and 16 x 900 s in SII using a QSI QS-583 camera.

Figure 2 — The Toronto Centre's Joel Parks captured this view of the Seagull Nebula in Monoceros using a 130-mm Takahashi TOA at f/6.2 and an SBIG ST-L 11000 CCD camera. Exposure was 4 x 20 min in Hα, 6 x 20 min in OIII, and 4 x 5 min in RGB. The "head" of the Seagull is an emission nebula; the blue wings are reflections of starlight. Just above and to the right of the head is the planetary nebula PLN 223-2.1.

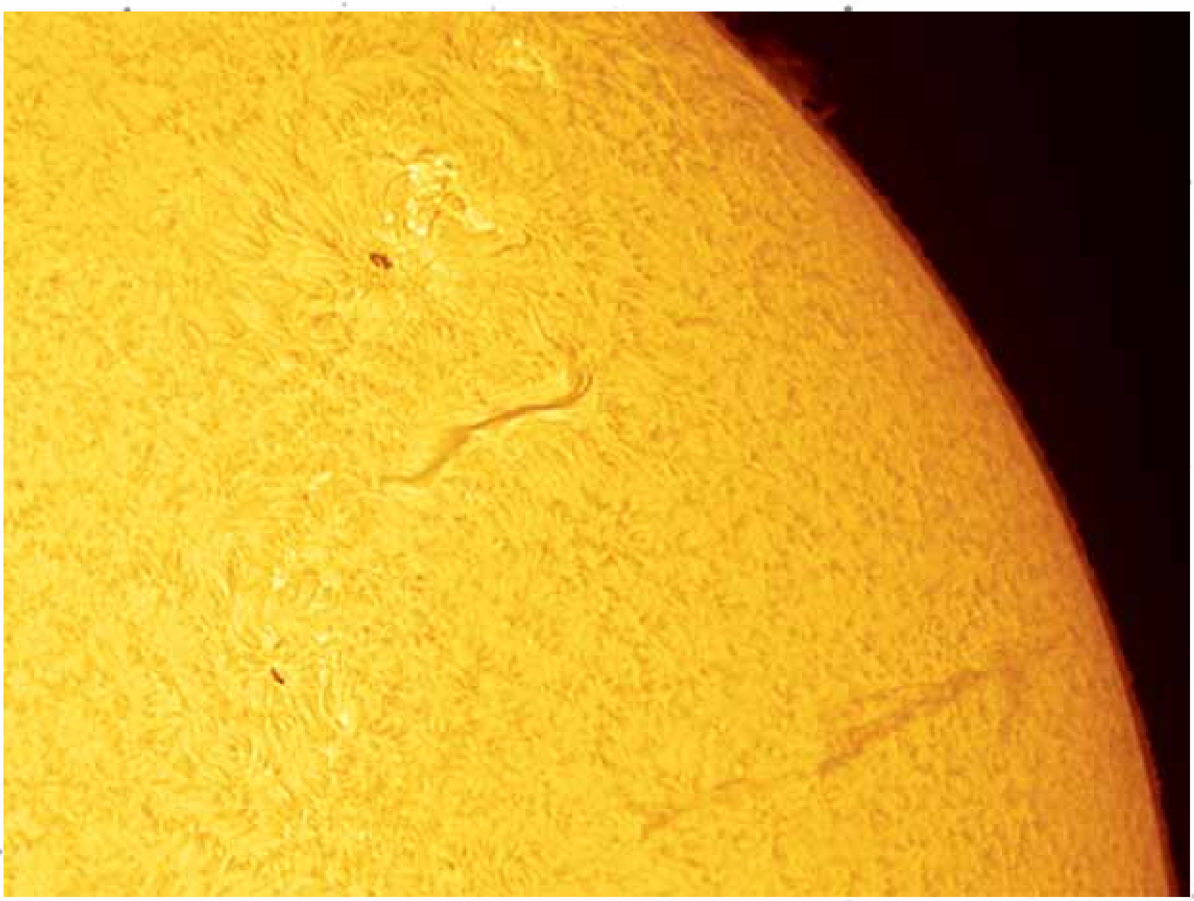


Figure 3 — Les Marczi of the Niagara Centre won the "Canadian Telescopes Prize for Solar Photography" at the 2011 General Assembly in Winnipeg with this image of the solar surface taken on May 31. Les used a Takahashi Sky 90 telescope with a DMK USB monochrome camera. The image is composed of the best of 2000 images.

Figure 4 — "Springtime in Manitoba." Winnipeg Centre member Ron Berard captured the mood of spring and the stars in this image of two RASC members warming by the fire at Patricia Beach Provincial Park, while Orion sinks toward the horizon. This image won the "McKittrick's Prize for Best Piggy-back or Tripod-mounted Camera" in the 2011 General Assembly photo contest. Image details: two 30-second exposures on a tripod-mounted Camtrak, Nikon D90 with Nikkor DX 18-105 lens at 18 mm, f/3.5, ISO 800.

Figure 5 — Toronto Centre member Denis Grey won the "Best Cell-Phone Astrophoto" with this image of anti-crepuscular rays converging over the mountains of Guatemala. Denis used a Blackberry 8520. He noted that the exposure process consisted of two steps: point; shoot.

Figure 6 — Lynn Hilborn combined 6¼ hours of exposure in LLRGB to build this stunning image of the Leo Triplet in the spring. Lynn used an FLI ML8300 camera on his TEC 140 f/7 telescope. The image won the "Vixen Optics Prize for High-Magnification Deep-Sky Imaging" at the recent RASC General Assembly in Winnipeg.

Figure 7 — Charles Banville from the Victoria Centre bagged two consecutive passes of the International Space Station *on June 14 from the Dominion Astrophysical Observatory. The first pass (the brighter trace) was at midnight, the second, 90 minutes later. Charles used a set of 11 30-second exposures with an 8-mm fisheye lens on a Canon 7D at f/3.5 and ISO 400.*

Figure 8 —The Elephant Trunk Nebula captured Dr. Howard Trottier's fancy in August last year, and he captured enough photons to produce this lovely high-contrast image. Howard used a PlaneWave CDK17 telescope at f/4.5 and an SBIG STL-4020M camera for this 15-hour exposure taken from his Cabin in the Sky observatory in the South Okanagan. Exposure was 10 hours in LGRB, and 100 minutes each in R, G, and B.

Cosmic Contemplations

Widefield Astro Imaging with the new Micro 4/3rds Digital Cameras

by Jim Chung, Toronto Centre
(jim_chung@sunshine.net)

Canon's EOS DSLR cameras have dominated the amateur astro-imaging market for the past decade and for good reason. They offer good high-ISO signal-to-noise ratio (SNR), and used 10/20/30/40D camera bodies are so common that they're an ideal economical alternative to dedicated thermo-electrically cooled CCDs. Second-hand bodies also have no warranties to void should you decide to remove the original IR blocking filter, which will greatly enhance Hydrogen-alpha (Hα) sensitivity and finally allow nebula imaging. The digital camera also requires no computer to store images and confirm focus and exposure. Although subexposure times are probably limited to less than five minutes due to noise accumulation in warmer climates, I often shoot unguided, so that a five-minute exposure coincides nicely with the unguided accuracy of my mount at a short focal length of 200 mm.

Figure 1 — Canon 20D, Olympus EP1, and Casio Exlim Point & Shoot

I'm an imaging addict, so when I go on vacation I like to be prepared. However, it's inconvenient to lug around an equatorial (EQ) mount, my AP Traveler, 12 VDC car battery, and my Canon 20D. A few years ago, I pared this down to a minimum that would fit into a knapsack by building a miniature GOTO EQ mount, but the clunky 20D and its lenses took up most of the space. There's an old astro maxim, the best telescope to own is…the one that you use! And sadly, even that fully kitted knapsack sat unused. What's needed is a complete camera redesign to reflect the digital nature of the recording media and not some continued adaptation of a film camera. That is just what Olympus and Panasonic (Lumix) have done with the introduction of their new compact digital cameras using the micro 4/3-inch sensor format.

This format uses a sensor that is only slightly smaller than the popular APS size. It has a conservative 12-megapixel array that promises decent-sized pixels that translate into good low-noise performance under poor light conditions and high ISO. The bulky and wear-prone mirror box with pentaprism, viewfinder, and swinging mirror have been eliminated, allowing a very short CCD sensor-to-lens-flange distance. In effect, we have a camera body that approaches the pocketable slimness of a point-and-shoot but with the interchangeable lenses and low light/high ISO capability of a DSLR. Much like a DSLR, the TFT screen on the back of the micro 4/3rds allows you to compose and confirm the focus by magnifying a live view. The slightly smaller sensor results in a crop size of 2× as compared to 1.6× for a DSLR, so equivalent telephoto prime lenses can be made smaller and lighter. The very short lens-flange-to-sensor distance also allows the use of almost any existing lens with a suitable simple and inexpensive adaptor.

Figure 2 — Relative sizes of the sensors discussed in the text.

Even more interesting is the ability of the micro 4/3rds to use C-mount lenses found in night-vision CCTV security cameras or from 16-mm cinematic-film cameras that have astounding f/ratios of around 1.0 or even less. Such fast lens would have wonderful astro-imaging applications, surpassing by several-fold the f/2 speed of the legendary Hyperstar. An equivalent lens of this speed for a DSLR would cost several thousands of dollars; only a year ago these forgotten lenses languished on eBay at giveaway prices. No longer!

The perfect camera would be the size of the Casio, something we could take anywhere at anytime. However its lens is neither removable nor interchangeable, and it has a CCD sensor so small that it simply cannot be used for low-light imaging. The 12 million pixels crowded onto the small Casio sensor means each pixel is about 1 μm in size—too small for a decent signal-to-noise ratio (SNR) in astronomical applications. A Canon 20D has 6.4 μm pixels occupying a much larger chip; the EP1 has 4.3 μm pixels.

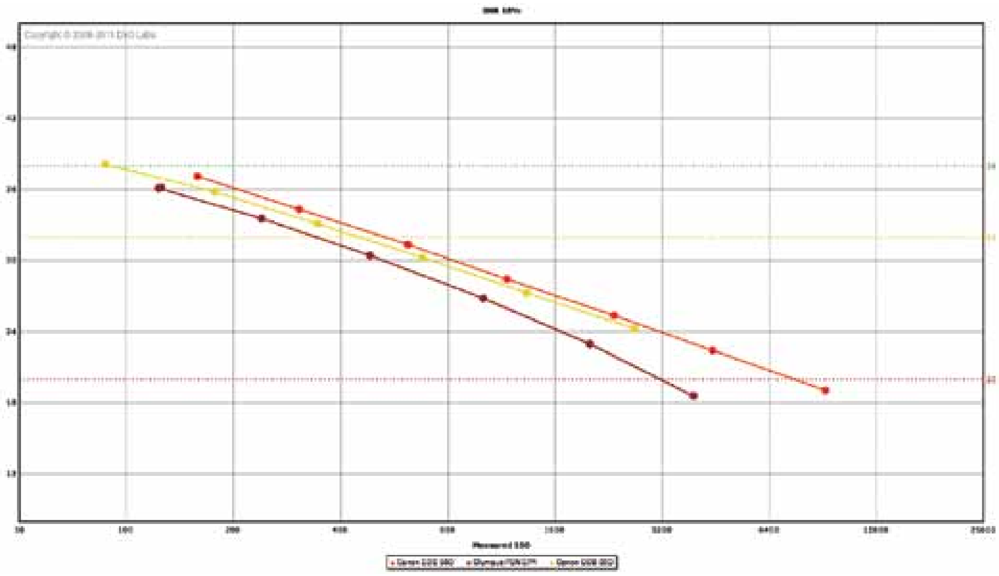


Figure 3 — This graph is courtesy of DxO Labs, a web-based independent host of scientifically executed digital camera image-quality measurements. It demonstrates that SNR is highest with the largest pixel Canon 20D and lowest with the smaller EP1. As predicted, the median pixel-sized Canon 50D performs between these two curves. To achieve the SNR of a 20D at ISO 1600, the EP1 should be operated at about ISO 800.

In matters of pixel size, bigger is better. A bigger pixel is able to capture more photons, increasing the SNR. Noise is present in all cameras and comes in many forms. Read noise is the noise added from the camera circuitry during sensor readout, digitization, and amplification. Increasing the ISO increases both light sensitivity and read noise, with further assaults on the SNR. In cameras with small pixels, the reduced SNR becomes intolerable, resulting in very grainy or noisy images. Large pixels start out with a better SNR and can tolerate a higher ISO gain without showing noise. Based on pixel size alone, the EP1 promises noise performance on par with the current Canon 50D, which has a 15-megapixel sensor and 4.7 μm pixels.

It would seem that the lowest ISO setting would result in the best SNR because noise would be the lowest. However, higher-ISO noise does not necessarily reduce the SNR as faint signals become amplified and detected. Faint signals with single-digit values become amplified to double digits and hence are not lost through quantization error. For the Canon cameras, ISO 800 represents the optimal setting, although I have often shot at ISO 1600.

There are two other important areas of noise to consider when evaluating the EP1 as a viable camera for astroimaging. Thermal noise is the result of electrons released by thermal agitation that add to the electron count generated by photon capture. Because thermal noise increases with time, it becomes a very important factor in long-exposure astroimaging. Given enough time, thermal noise will saturate every pixel, even if the camera is being exposed in a lightproof box.

It is not unusual that, with higher ISO settings and increasing exposure time, the EP1 generates a large dark current or thermal noise. What's surprising is how much better the old Canon 20D is at suppressing thermal noise. It has been suspected that Canon is performing some sort of on-board preprocessing of the image to keep thermal noise so low. New is not necessarily better.

The compact dimensions of the EP1 also make heat dissipation more difficult (that and shooting inside a foam-lined Pelican case during my tests). Most (but not all) thermal noise can be subtracted with an appropriate dark frame during image processing, but it's better to start with a cleaner initial image. Imaging at ISO 400 may be a better guideline for the EP1 than ISO 800, but performance will be better in the field, as most nights will be significantly cooler than 22° C. In fact, the image of M27 (Figure 5) was taken on a night that was a few degrees Celsius above freezing, and the noise at ISO 800 was substantially less than ISO 400 at room temperature (ADU of 1800).

The bias frames taken to determine thermal noise can be used to demonstrate the fixed-pattern noise in a camera. This type of noise pattern is often an indication of circuit design compromises that leave a signature noise pattern. Pattern noise can also be removed with dark-frame subtraction, since the bias-frame pattern is a part of the dark frame. More troublesome is fixed-frequency noise, which is a noise artefact that is present in each frame but in a different location each time. The EP1 does appear to show a fixed pattern of horizontal banding, along with vertical bands that appear in variable positions, as shown in the stretched-bias frames in Figure 4.

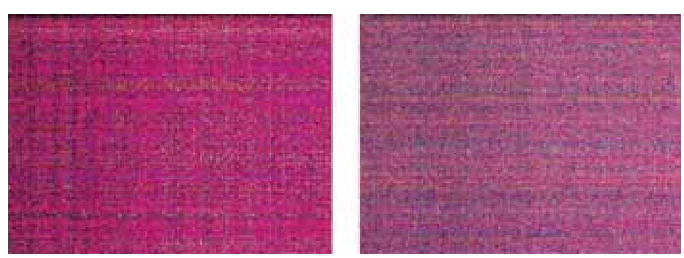


Figure 4 — Horizontal and vertical banding in the EP1 sensor.

Stacking multiple frames or subexposures will tend to reduce the fixed-frequency vertical banding noise. In actual practice, the vertical bands do not appear as a problem, but several thick horizontal bands persist in the final stacked image, and require choosing an aggressively high black point to hide them.

Figure 5 — Dumbbell M27 Nebula, 70×1 minute unguided subexposures at 400 mm using an f/5.6 Sigma FD Mirror lens and Olympus EP1 @ ISO 800.

Figure 6 — North America & Pelican Nebula from 30×120s subexposures at ISO 800, taken using an Olympus EP1 with noise-reduction function, a Canon FL 55-mm lens @ f2, and a Baader 7-nm Hα filter.

Imaging in the summer may require a complex approach to imaging. Temperatures at night tend to remain fairly high with an attendant thermal noise, but also tend to fall throughout the night, making dark-frame subtraction inaccurate. Like many DSLRs, the EP1 has an on-board noise-reduction function that performs a dark-frame subtraction with every exposure. This noise-reduction process is perfect, as each dark frame is thermally matched and the process is performed using the RAW format. The downside is that each exposure will take twice as long, making the short summer nights appears even shorter.

As with all digital cameras designed for terrestrial use, there is very poor response in the Hα region of the spectrum, resulting in poor nebula-imaging performance. The image of M27 shows very little red and the nebula is only visible because of its strong OIII emission. There are many companies willing to remove the IR blocking filter from Canon DSLRs and restore Hα sensitivity for astro imaging. However, I could find nobody who was willing to operate on the EP1. I turned to Renaud Landry in Quebec who had performed this modification on my Canon 20D. I was willing to sacrifice the EPL1 and he was willing to attempt it.

Figure 7 — A new area in imaging.

My assessment of the 4/3 sensor

Pros:

- Compact, light-weight camera with acceptable thermal noise levels at ISO 800
- Short flange-to-sensor distance means universal acceptance of all camera lenses
- Excellent battery life, full charge can last at least six hours of shooting
- Live-view focusing

Cons:

- Difficulty in removing IR filter
- Still noisier than Canon DSLRs and troublesome horizontal banding patterns require extra effort to tame
- No remote shutter release capability for less-expensive EPL1 model

Removing the IR blocking filter was difficult because the Olympus camera is so much smaller than the Canon DSLRs and Renaud faced several obstacles and delays in the initial disassembly before he was successful, especially as this was completely new territory for him. He had the capability to custom cut and replace the IR filter with optically clear glass, which is sometimes necessary to restore the infinity focus function of some lenses. He was able to preserve electronic autofocus and the ultrasonic dust-removal system; sadly he was unable to neither reestablish the USB line that provides remote shutter release nor provide an external parallel circuit to the shutter-release switch mechanism, components that were inaccessible inside the camera body.

Vintage lenses are typically inexpensive and often very well made and designed, only suffering from the lack of the modern coatings. 35-mm film camera lenses tend to perform especially well on the micro 4/3rds format, because the sensor is so much smaller than film—most of the image lies in the sharp central region of the lens where it was designed to perform best. TV-camera lenses and 16-mm cinematic movie camera lenses probably should be avoided because they were designed for film that was significantly smaller than the 4/3-inch sensor, resulting in severe vignetting in the corners.

In the end, modifying the EPL1 has also opened up another fascinating area of photography to explore: that of street photography in infrared! ✶

Jim Chung has degrees in biochemistry and dentistry and has developed a particular interest for astroimaging over the past four years. He is also an avid rider and restorer of vintage motorcycles, which conveniently parlayed into ATM projects, such as giving his Sky-Watcher collapsible Dobsonian a full Meade Autostar GOTO capability. His dream is to spend a month imaging in New Mexico away from the demands of work and family.

On Another Wavelength

M56 – A Globular Cluster in Lyra

by David Garner, Kitchener-Waterloo Centre
(jusloe1@wightman.ca)

Lyra is a favourite constellation to be hunting around at this time of the year. Not only does it have several variable stars, including the well-known RR Lyr, it has: Vega (α Lyr), the fifth-brightest star in the sky and one corner of the Summer Triangle; M57, the Ring Nebula; and the "Double Double" (ε Lyr)—a pair of bright double stars. Most of us have seen these before, so something a little different might be in order: try looking about 8 degrees south of α Lyr for a small globular cluster known as M56 (see Figure 1).

Globular clusters are a spherical collection of stars bound together by gravity (Figure 2), and are frequently found in the halo of our galaxy orbiting the galactic core. In 1917, Harlow Shapley studied RR Lyrae variable stars contained within these clusters, as they are often used as standard candles to measure galactic distances. He noticed that these clusters centred on Sagittarius and outlined the shape and size of the Milky Way.

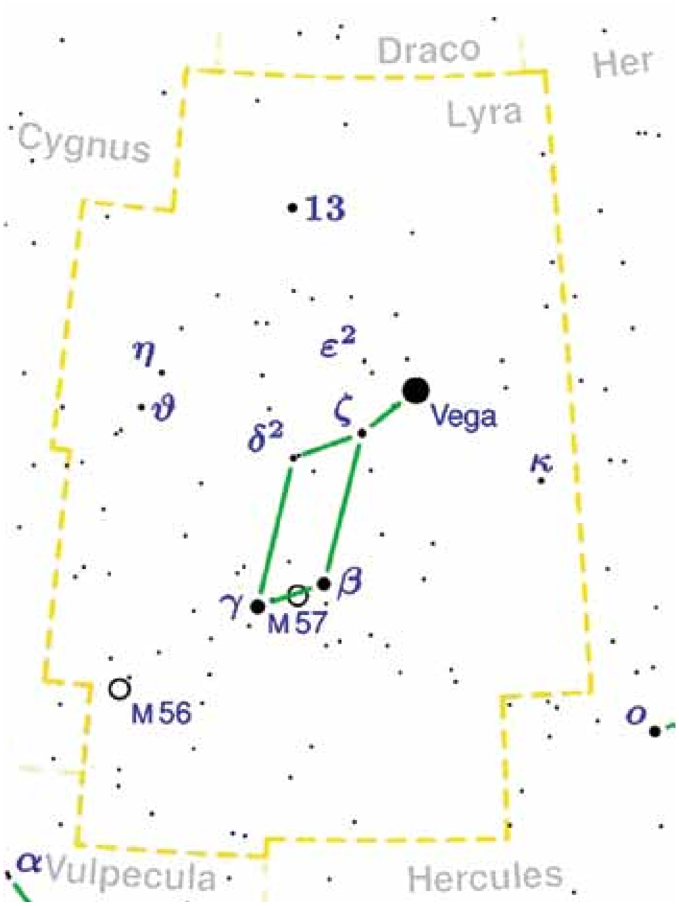


Figure 1 — A map of the constellation Lyra.

Figure 2 — M56, the Globular Cluster in Lyra, courtesy of Ron Brecher, Kitchener-Waterloo Centre. Ron acquired this image using a QSI583wsg camera, Astrodon RGB Gen-2 filters, and an 8-inch f/8 RC on a MI-250 mount, from my SkyShed in Guelph, Ontario.

M56 (NGC 6779) is a ball of a few hundred thousand stars that is approximately 85 light-years across (which corresponds to a linear dimension of 8.8 arcmin) and 32,900 light-years distant. Lacking a bright core, it is somewhat dim, with an apparent brightness of magnitude 8.3. It was first discovered by Charles Messier in 1779 and described as a "nebula without stars, having little light." Later, in 1784, it was resolved into stars by Sir William Herschel. The NGC lists the stars between 11th and 14th magnitude.

M56 was described by Harlow Shapley as an elongated cluster, and he found only one variable star there. Today, approximately a dozen variables have been identified in M56. In 2008, the CURiuos Variables Experiment (CURVE) detected several new variables in the cluster, one of which is an RR Lyrae star, the third star of that type found in M56.

M56 does not have nearly as many variables as the globular cluster M15 (as described in a previous article) and it is somewhat difficult to see with a small telescope, but is certainly worth a try. You can find it at RA $19^h\ 16^m\ 35^s$ and Dec +30° 11′ 4″. ✶

Dave Garner teaches astronomy at Conestoga College in Kitchener, Ontario, and is a Past President of the K-W Centre of the RASC. He enjoys observing both deep-sky and Solar System objects, and especially trying to understand their inner workings.

Astronomical Art & Artifact

The Affair of the Sir Adam Wilson Telescope, Societal Negligence, and the Damning Miller Report

by R.A. Rosenfeld, RASC Archivist (randall.rosenfeld@utoronto.ca)

In the course of their existence, cultural institutions amass worldly goods as they captivate patrons, pursue mandates, and attract fellows. The Royal Society has an outstanding collection of science, written and drawn; the Adler Planetarium & Astronomy Museum curates a collection of historical astronomical hardware second to none; the Specola Vaticana possesses a significant meteorite collection. From near the start of their corporate existence, the British Astronomical Association (BAA) and the American Association of Variable Star Observers (AAVSO) both accumulated valuable and usable telescopes through gifts. The AAVSO's telescope loan programme wrapped up in the early 1980s, but its spirit continues with the loan of photometric equipment, while the BAA's instrument collection currently numbers several hundred, and some of its telescopes are of considerable historical significance (Scovil 1981; AAVSO: M. Templeton, Infrared Photoelectric Photometry Program; BAA: R.A. Marriott, Instrument Collection). Both organizations have suffered accidental (and not so accidental) losses of equipment over time, but on the whole they have responsibly curated the gifts they have received. As a beneficiary of optical largesse, the RASC has never been able to vie with the BAA or the AAVSO, nor has it been in the same league as those organizations when it comes to caring for generous donations (Broughton 1994, 160). The Society has quietly excelled at a thoroughgoing dereliction of responsibility borne of nescient indolence, efficiently conveying thoughtless disrespect of its thoughtful donors. An impressive achievement in its way, and one as regrettable as it is venerable.

In 1903, the RASC had five telescopes in its possession, all but one the result of gifts: the Larratt Smith and Andrew Elvins refractors with 75-80-mm O.G. (apparently quality instruments, but the makers are unknown); the Todhunter refractor with a 63.5-mm O.G. (maker also unidentified); a 100-mm O.G. refractor by Thomas Cooke & Sons of York (the OTA was purchased by the Society); and the Sir Adam Wilson Telescope, a 150-mm speculum primary mirror reflector (Harvey 1904, 60). The number was brought up to six when in 1904 the Society was given a pier-mounted John Brashear reflector with a 200-mm primary mirror (Chant 1905, opposite xxvi). The Brashear reflector is a very impressive looking telescope. The RASC also owned several spectroscopes, and two Rowland gratings by Brashear, one a gift from Uncle John himself (the great optician was an Honorary Member, observed from Urania Island on Lake Muskoka when he could, and wrote for the *Journal*). Of the telescopes and associated equipment owned by the RASC before 1905, only the Cooke refractor is present and accounted for in the Society's possession. The conservation state of the others, their location, and even their survival are unknown. We do have fragments of the narrative of the Todhunter, Brashear, and Wilson instruments while they were in the Society's hands. As far as can be ascertained, none of these instruments was ever permanently alienated from the Society by a motion in Council. What were once solid glass, brass, and steel and now exist solely as literary vestiges in our archival documents—mere ghosts of instruments—still remain the legal property of the RASC.

Some trace of the Todhunter Telescope can be found in the *Journal* amidst the turmoil of the Great War (the instrument was given by James Todhunter †1907, onetime Treasurer; A. 1907, 197). In the fall of 1916, the commanding officer of the 4th Canadian Mounted Rifles Battalion, Colonel H.D. Lockhart Gordon (1873-1966), sought assistance from the RASC in securing usable small telescopes for intelligence work on the Front (Collins 1917). The Todhunter Telescope was chosen for this distinction, as well as several other instruments secured through the agency of RASC General Secretary J.R. Collins (1865-1957; Broughton 1994, 71). Patriotically supplied on loan, the Society did not realistically expect to see the instrument ever again (Collins 1919, 251; Hunter 1919). The Todhunter saw active service at Vimy Ridge, Passchendaele, Amiens, Arras, and possibly at Cambrai and Mons. Two of the instruments were returned by the Battalion, and came back with a telescope's version of decorations, namely an inscription listing the battles at which they were employed. A third telescope took a direct hit at Arras, and didn't survive (Collins 1919, 254). It is not stated if one of the decorated veterans was indeed the Todhunter Telescope, or if it was the hero that tragically perished at Arras. The subsequent history of these instruments after their return to the Society is unknown. The Society cannot be faulted for the use to which the Todhunter refractor was put during the war; the Society can be greatly faulted for losing track of it after its return—if it did indeed return.[1]

The Brashear reflector, a generous gift of RASC Fellow Winston Wetherbee of New York (the Fellowship was a form of honorary membership that once existed), surfaces in print in 1936, over three decades after it was donated to the Society (Chant 1936). The Society loaned the instrument to T.H. Mason for his private observatory on Lightwood Island, in Lake Muskoka. The *Journal* article by Chant is written so as to give the strong impression that the telescope was being lent to a "community observatory" for education and public outreach. Perhaps that was the intent; however there is no evidence in the RASC Archives that Mason's observatory was used for anything other than his own gratification and that of close friends. This impression is reinforced when one reads that the property "with observatory" was advertised for private sale in 1945. Mason was very well-connected in Toronto circles, and served as Toronto Centre Treasurer and Recorder from the late 1930s to the early 1950s. By the time Mason was loaned the telescope, C.A. Chant was arguably the politically dominant figure in the RASC and had been so for decades. His word was writ when it came to the disposition of things such as telescopes or historically valuable books. It is not known what became of the Brashear when Mason sold his island property and observatory. Perhaps the telescope was included to sweeten the deal. Its present location is not known.

The best-documented case of RASC neglect of an instrument acquired through gift concerns the Sir Adam Wilson Telescope. The telescope was part of a larger gift, the Sir Adam Wilson Memorial, which also included his 18-inch celestial globe (Anon. 1893, 35-36; the globe is discussed in Rosenfeld 2009). It is clear from the minutes that the Society's leadership esteemed the donor and valued the gift.

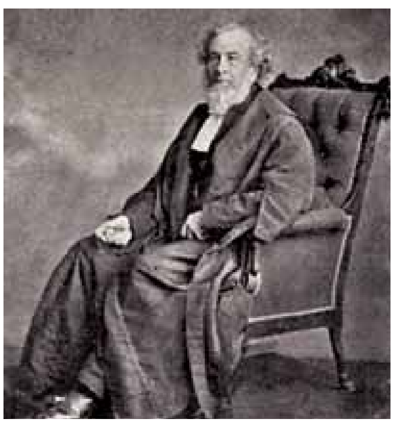


Figure 1 — Sir Adam Wilson

Sir Adam (1814-1891) may have owed his interest in astronomy to the spirit of the late Scottish Enlightenment. (Figure 1) If so, he was certainly not alone among his fellow countrymen. A lawyer by training and profession, he was a successful municipal politician, served for a brief period as Solicitor General of Upper Canada, and for several decades presided as a judge, switching paths between the Court of Common Pleas and the Court of Queen's Bench, until he rose to become Chief Justice of one, and then the other. Politically he was in the camp of the "mild" reformers, clashing with both George Brown and John A. MacDonald. He was a substantial public figure (DCBO: G. Parker, Sir Adam Wilson).

There are some curious gaps in our record of Sir Adam's telescope; no document I have been able to find specifies the maker, and there is no reliably certain image of the instrument, either photographic, or drawn. The primary mirror is said to have been fashioned out of speculum metal, and if the instrument was manufactured in the late 1860s or afterwards, it is highly unlikely that it was produced by the leading British makers catering to the amateur market. Craftsmen such as John Browning (using George With's mirrors), George Calver, and Horne & Thornthwaite, all produced instruments with silver-on-glass mirrors. The mirror of Wilson's telescope could have been produced in the United Kingdom before the late 1860s, or, a much more exciting prospect, it could have been made in North America. I am unaware of any professional makers of speculum-mirror reflectors in 19th-century British North America. If the Sir Adam Wilson Telescope or its speculum were produced in British North America and had indeed survived, it would be a very significant natural-philosophic artifact, and one of considerable rarity.

By 1901, a decade after the gift of the Sir Adam Wilson Memorial to the Society by Lady Wilson (Anon. 1893, 35-36), it was obvious even to the RASC that something was amiss with its oversight of the gift. Council commissioned A.F. Miller to write a "Report on the Condition of the 'Sir Adam Willson [*sic*] Telescope'." Miller was to assess the optical and mechanical quality of the instrument, and whether it was worth the effort of reconditioning, what measures were needed to do so, and whether the Society should do so. The Society couldn't have chosen a better person for the task. Miller (1851-1947), a senior hospital administrator by profession, was a recognized figure in Canadian astronomy for his stellar spectroscopic work (he may have been the first person in Canada to investigate solar prominences) and planetary observations, he was a correspondent of G.E. Hale, an early member of the IAU, and served as RASC President from 1918-1919 (Figure 2; Mozel 1984, 75-77; Broughton 1994, 137).

Miller's report, never before published, is a remarkable document, and a scathing indictment of the RASC's negligence towards its gift, and by extension, towards the memory of the donor. The report is published in its entirety below. It is worth reading for its trenchant style alone. It has also lost none of its force. How well do we, the RASC of the 21st century, curate what our predecessors have bequeathed to us? The RASC has fought some notable battles over the years on the side of preservation; one thinks of the efforts to save the McLaughlin Planetarium and more recently, to save a major research telescope. In both cases, the RASC was on the side of the angels, yet it is a good thing for us that our opponents were unfamiliar with our tarnished record when it came to the care of our own historical equipment. Our record could have been used against us. A.F. Miller has an important lesson to impart.

Few readers will be surprised at the immediate outcome of the report. The meeting of the Council at which Miller's opinion was presented briskly authorized him "to do whatever is required to put the Sir Adam Wilson Telescope in working order" (Council Minutes 1901 June 11). Two years later the Society had still not done anything. At times, it seems Rudolf Clausius could have metaphorically modelled entropy from observing us.

Principles of the edition

The text below is a diplomatic transcription of the report. Original orthography and other internal features of the text are retained. Editorial additions are enclosed in square brackets, and interlineal authorial additions in pen and ink are enclosed in angled brackets. The original document is typewritten, apart from the pen and ink additions. The original is unpaginated.

/p. 1 **Report on the condition of the "Sir Adam Willson [*sic*] Telescope."**

To The President and Council, Toronto Astronomical Society.

Some time ago I was asked by you to make an examination of this instrument, which had been lying unused at the Toronto Observatory since last summer, and regarding which some very unfavourable statements had been made by various members of the Society. On May 23 I went with Mr. Howell to the Observatory and was shown the telescope, which had been left by the Society in a shed, but which Mr. Stupart afterwards had taken into the Observatory Building. As it was impossible to do anything with it there I arranged with Mr. Howell to have it sent to my house: This was done on May 31st. I examined the instrument that evening and found it in a very unsatisfactory condition, being not only quite out of adjustment but evidently much worse for the careless usage which it had received at the hands of <some of > those members to whom it was formerly intrusted [*sic*]. Anyone who can remember the telescope as shown to the Society just before its delivery to Sir. [*sic*] Adam Willson [*sic*] by the maker must now feel shocked to find evidences of careless neglect visible on both tube and stand. The telescope has evidently been left out in all weathers, so that the neat appearance which it once had is quite destroyed. As we are aware, the eyepieces originally belonging to it were lost during one of its transfers from house to house, and when put into my hands there was but one apology for an ocular, quite undeserving of the name however. The tube has several great dinges [*sic*], evidence of falls which it has suffered in time past.: [*sic*]. The finder eye-piece [*sic*] has disappeared, probably gone in search of the oculars belonging to the telescope proper.

/p. 2 I brought the instrument into my workshop and took out the mir<r>ors, so as to judge of their condition, on which, of course now depemds [*sic*] the whole question of what had better be done. I was glad to find the large speculum has preserved its polish in spite of the careless way it has been treated: It only shows some scratches due to wiping with a rough duster, which seems to have been the method followed by some former user. There are a few small spots due to dust and damp, but these are unimportant. The cell [of the primary mirror] is a very imperfect affair, and seems to have been fixed up in a temporary way with a thin wooden bottom. These defects, however, only affect the adjusting and collimating: Otherwise the cell is very excellent, for above all things it does not seem to strain the mirror. I found the diagonal very much stained through being fingered on the surface by careless hands thrust in to move it. Being speculum-metal it would have been impossible to polish it without destroying the figure; I therefore washed it with pure alcohol on a swab of surgical cotton, and had the satisfaction of finding by this means I had removed the tarnish, without in the least affecting the surface, which was thus restored to a fine polish without any rubbing. I then put the mirrors in place and adjusted them; this work in the case of the large speculum is very difficult, on account of the way its cell has been patched up with a wooden bottom; however after many trials I got the line of collimation to coincide with the axis of the tube, and proceeded to test the telescope on stars. The focusing arrangement is not well contrived, and the diagonal is inserted so near the apex of the cone of rays that a huyghenian [*sic*] eyepiece has to be pushed almost into the body-tube to come to focus. If the instrument ever had a sliding eye-tube that is gone now, and its place is taken by an ill-turned wooden ring with a brass bushing fixed tight in the eye end. The wretched ocular sent with the telescope fits this bush, but has a scratch on the eye lens which makes it useless for viewing stars.

Figure 2 — A.F. Miller

/p. 3 Fortunately I have a small positive ocular belonging to my own telescope, and this I employed in testing the Society's instrument. I had expected that the mirrors would turn out fairly decent; I was not prepared to find them so good as they are: Both mirrors appear to be of high excellence, and give fine definition even on bright stars; I divided several <close> ~~cllose~~ doubles and found the definition most excellent. The light-gathering power is less than I expected, not being accustomed to speculum metal mirrors, which evidently absorb much light.

The stand, which gives a parallactic motion, is not very convenient, as only stars some degrees south of the zenith can be reached; for objects east or west the eyetube assumes most inconvenient directions: Like the telescope, the stand has suffered by exposure to all weathers; the motions are stiff with rust; the wooden parts are split.

What I have written ~~affords~~ supplies an object-lesson—painful, but instructive, as to the inadvisability of passing any article or instrument owned by the Society from hand to hand as has been done in the case of the Sir Adam Wilson telescope. Here is an instrument with mirrors of high quality and with a full set of oculars, the whole get up neat and even handsome. It is presented to the Society, passes through the hands of those who upset the adjustments and then because they cannot see with it, condemn the telescope they have themselves deranged.

The oculars and appliances [*i.e.* "accessories"] vanish, no one knows how. Finally the instrument, after living in an open shed for months is condemned as worthless at the Council table. I myself would certainly <have> accepted that verdict but for the fact that while Sir: Adam was still with us he once asked me to his house and showed me some objects with his telescope; I therefore felt that what the instrument had done before it might be made to do again (provided it had not been ruined meanwhile). The Sir Adam Willson [*sic*] telescope is well worth a couple of new oculars and such other fittings as will put it into shape for use. These things given it will be a very valuable instrument in the Society's observatory.

A.F. Miller ✶

References, Manuscripts, Books and Articles

A., D.E. (1907). Meetings of the Society at Toronto. *JRASC 1, 3*, 195-198

Anon., (1893). Tenth Meeting. *Transactions of the Astronomical and Physical Society of Toronto for the Year 1892*, 35-38

Broughton, R.P. (1994). *Looking Up: A History of the Royal Astronomical Society of Canada*. Toronto – Oxford: Dundurn Press

Chant, C.A. (1905). President's Address: Astronomical and Astrophysical Progress During 1904. *The Royal Astronomical Society of Canada: Selected Papers and Proceedings1904*, xiii-xxvi

Chant, C.A. (1936). A Summer Community Observatory. *JRASC 30, 7*, 300.

Collins, J.R. (1917). Telescopes at the Battle Front. *JRASC 11, 3*, 119-121.

Collins, J.R. (1919). Telescopes Which "Did Their Bit." *JRASC 13, 5*, 252-254.

Harvey, A. (1904). The Astronomical Equipment of Canada. *The Royal Astronomical Society of Canada: Selected Papers and Proceedings 1902 and 1903*, 52-60.

Mozel, P. (1984). A Telescope's First Century. *JRASC 78*, 2, 75-81

RASC Archives, A.F. Miller, Report on the condition of the "Sir Adam Willson [sic] Telescope." File of Minutes for 1901.

RASC Archives, Council Minutes 1901 June 11. File of Minutes for 1901.

Rosenfeld. R.A. (2009). A Tale of Two Globes. *JRASC 103, 1*, 28-31.

Scovil, C.E. (1981). Telescope Loan Committee Report. *JAVSO 10, 2*, 115.

Web sites

AAVSO, M. Templeton, Infrared Photoelectric Photometry Program
www.aavso.org/infrared-photoelectric-photometry-program
(accessed 2011 July 31)

BAA, R.A. Marriott, Instrument Collection
www.britastro.org/baa/index.php?option=com_content&view
=article&id=25:instrument-collection&catid=17&Itemid=42
(accessed 2011 July 31)

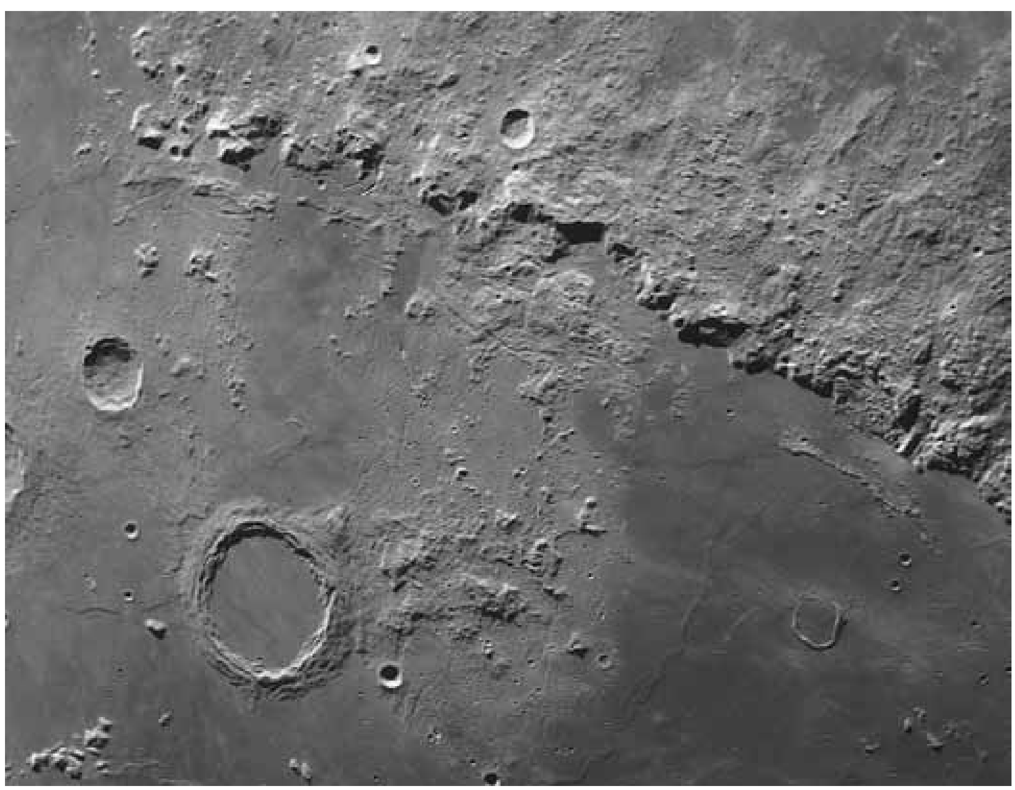
DCBO, G. Parker, Sir Adam Wilson
www.biographi.ca/009004-119.01-e.php?&id_nbr=6502&inte
rval=15&&PHPSESSID=5q9f75398dievhf11gjalheng6
(accessed 2011 August 3)

(Endnotes)

1 The Archivist wishes to thank Eric Briggs (Toronto Centre) for alerting him to the story of these instruments.

Great Images

Michael Wirths of the Ottawa Centre captured this high-resolution image of the Apennine Mountains to win the "Canadian Telescopes Prize for Lunar Imaging" at the RASC's General Assembly in Winnipeg in July. Mike used a Lumenera Infinity 2-2 camera on an 18-inch Starmaster Dob. The image is composed of the best 115 frames from a total of 1145.



Second Light

A Conference to Remember

by Leslie J. Sage
(l.sage@us.nature.com)

Magical. Amazing. The experience of a lifetime.

It isn't often that one hears a scientific conference described in terms like that, but that was what one heard in the corridors of the Hotel Abama on the island of Tenerife, June 20-24, where about 400 people gathered for the Starmus Festival—the brainchild of Garik Israelian of the Astrophysics Institute of the Canaries. The speakers included Nobel laureates, astronauts, cosmonauts, and luminaries from every branch of astronomy. I do not have the space to mention them all, but interested readers can see the programme at www.starmus.com/pages/en/programme.php.

Two amazing "rock" stars attended: Dr. Brian May, astronomer and chancellor of Liverpool John Moores University in the UK, and founder of the rock band *Queen*; and Neil Armstrong, the first man to walk on the surface of the Moon. It is a close contest which of them is the more shy and reserved, though Brian is more comfortable in his rock-star persona than Neil as a moon walker. Both of them are men of great intelligence who care passionately about the future of our fragile planet.

Figure 1 — Katherine Gray opening Starmus. Photo by Max Alexander Photography. ©Max Alexander/Starmus.

If there was a unifying theme that brought together astronauts, cosmonauts, Nobel laureates, and scientists of great note from around the world, it was the worry about the future of our planet. Our over-populated, warming world, increasingly dominated by faceless corporations that give not a thought for anything beyond the next quarterly report, was the main worry expressed by almost all speakers, who were tasked to reach out not just to their peers, but to a captivated audience drawn from across the globe.

Figure 2 — Brian May rocking Starmus to a close. Photo courtesy of Paul Gray.

Jack Szostack, another Canadian, and winner of the 2009 Nobel Prize in biology, told us about his quest for the origin of life on Earth, while Jill Tarter, director of the SETI Institute in California, explained how the search for intelligent life elsewhere is going (nothing yet!). Jim Lovell entranced the audience with stories of Apollo 13. And, yes, the movie is very accurate about what happened—even down to Jim's wife losing her ring down the shower drain (it was recovered).

I had the honour of moderating a 108-minute panel (www.starmus.com/pages/en/round-table.php) from the dome of the Grand Telescope of the Canaries, which was held to commemorate Yuri Gagarin's feat of being the first person to orbit the Earth. Several interesting nuggets emerged from the discussion. Neil Armstrong said that with the technology we had in the early 1970s, a permanent lunar base—along the lines of the Antarctic bases—could have been established. There just was not the political will to do it at that time. Reflecting on Russia's short-lived space-shuttle programme, Alexey Leonov (the first person to do a space walk) said that they had always assumed NASA knew what it was doing, and if they had to have a space shuttle, then Russia should have one too. He said they flew it once, realized that it was a stupid idea, and abandoned it. Charlie Dukes (Apollo 16) made a similar point the day before, when he said that NASA had originally wanted a flexible launch vehicle for Apollo, but discovered that a specially designed one would be cheaper and faster.

Brian May gave a courageous talk about "What are we doing in space?" in which he made several important points. One is that the manned space programme in the U.S. has been driven largely by corporate interests, not science, or even in the spirit of exploration. And, he worries about the fate of the creatures who share our planet. While humanity can adapt to climate change, on an evolutionary timescale, it is being driven too rapidly for most plants and animals to do the same.

All of the astronauts, Russian and American, commented on how they entered the space programme as gung-ho nationalists, almost all from the military, but they left it changed. They no longer think of countries, but instead think of the whole Earth.

The conference was opened by a wonderfully poised 10-year-old girl—Katherine Aurora Gray, from New Brunswick—who earlier this year became the youngest person to discover a supernova. As I write this on a plane heading back to Washington, D.C., I am listening to Queen's "We will rock you," that ended the conference with a performance by Brian May and Tangerine Dream. It was a fitting ending to a conference that truly did rock all the attendees. ✶

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

Through My Eyepiece

Logs and Blogs

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

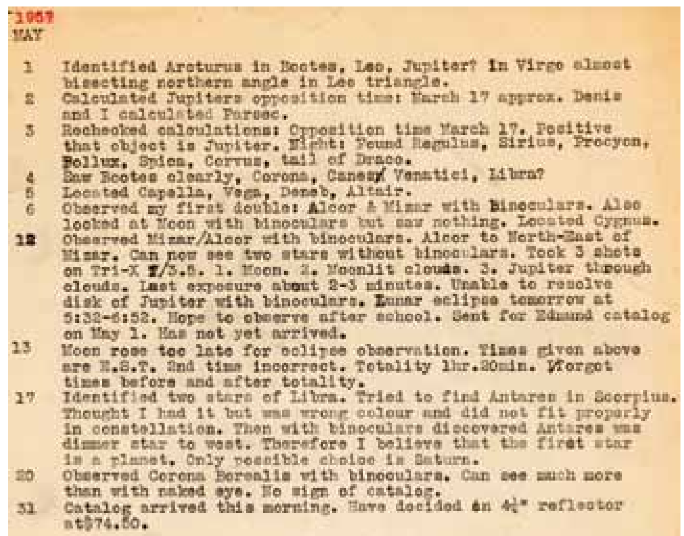
When I got back into astronomy in 1997, one of my greatest discoveries was my old log books. I kept a log of my observations when I got started in 1957. In retrospect, the comments seem pretty terse, but reading between the lines, I am able to recapture much of the joy of my first encounters with astronomy.

Over the years, my log-keeping deteriorated. By December 1957, I stopped typing up my log and reverted to a hand-written one. In April 1958, I ceased keeping a daily log and recorded my observations on the various forms used by the Montreal Centre, mostly designed by the indefatigable Isabel Williamson. I resumed daily logs in March 1959 and kept at it through November. My log-keeping came and went sporadically through September 1963, when it lapsed for an amazing 34 *years*, resuming only in July 1997, when I got serious about astronomy again.

Because I derived so much pleasure from my early logs, I resolved to be more systematic about my log-keeping, and I've pretty much kept to that resolution.

Fast forward to summer of 2011. After filling many volumes with paper logs, I finally decided to go electronic, and on July 1 started an electronic observing blog on Google's Blogspot.com. You can now follow my observing logs at http://geoffsobservingblog.blogspot.com.

At first, I just wrote my electronic log the same way I wrote my paper log: terse, with lots of cryptic abbreviations. Now that some of you will be looking over my shoulder, I've become a bit more verbose. I hope you will enjoy sharing my nights



1957
MAY

1 Identified Arcturus in Bootes, Leo, Jupiter? In Virgo almost bisecting northern angle in Leo triangle.
2 Calculated Jupiters opposition time: March 17 approx. Denis and I calculated Parsec.
3 Rechecked calculations: Opposition time March 17. Positive that object is Jupiter. Night: Found Regulus, Sirius, Procyon, Pollux, Spica, Corvus, tail of Draco.
4 Saw Bootes clearly, Corona, Canes Venatici, Libra?
5 Located Capella, Vega, Deneb, Altair.
6 Observed my first double: Alcor & Mizar with binoculars. Also looked at Moon with binoculars but saw nothing. Located Cygnus.
12 Observed Mizar/Alcor with binoculars. Alcor to North-East of Mizar. Can now see two stars without binoculars. Took 3 shots on Tri-X f/3.5. 1. Moon. 2. Moonlit clouds. 3. Jupiter through clouds. Last exposure about 2-3 minutes. Unable to resolve disk of Jupiter with binoculars. Lunar eclipse tomorrow at 5:32-6:52. Hope to observe after school. Sent for Edmund catalog on May 1. Has not yet arrived.
13 Moon rose too late for eclipse observation. Times given above are E.S.T. 2nd time incorrect. Totality 1hr.20min. Forgot times before and after totality.
17 Identified two stars of Libra. Tried to find Antares in Scorpius. Thought I had it but was wrong colour and did not fit properly in constellation. Then with binoculars discovered Antares was dimmer star to west. Therefore I believe that the first star is a planet. Only possible choice is Saturn.
20 Observed Corona Borealis with binoculars. Can see much more than with naked eye. No sign of catalog.
31 Catalog arrived this morning. Have decided on 4¼" reflector at $74.50.

under the stars, and get as much pleasure from reading my logs as I do.

For those of you who don't keep an observing log, I strongly urge you to do so. To get started, I highly recommend Paul Markov's excellent article on page 96 of your *Observer's Handbook*.

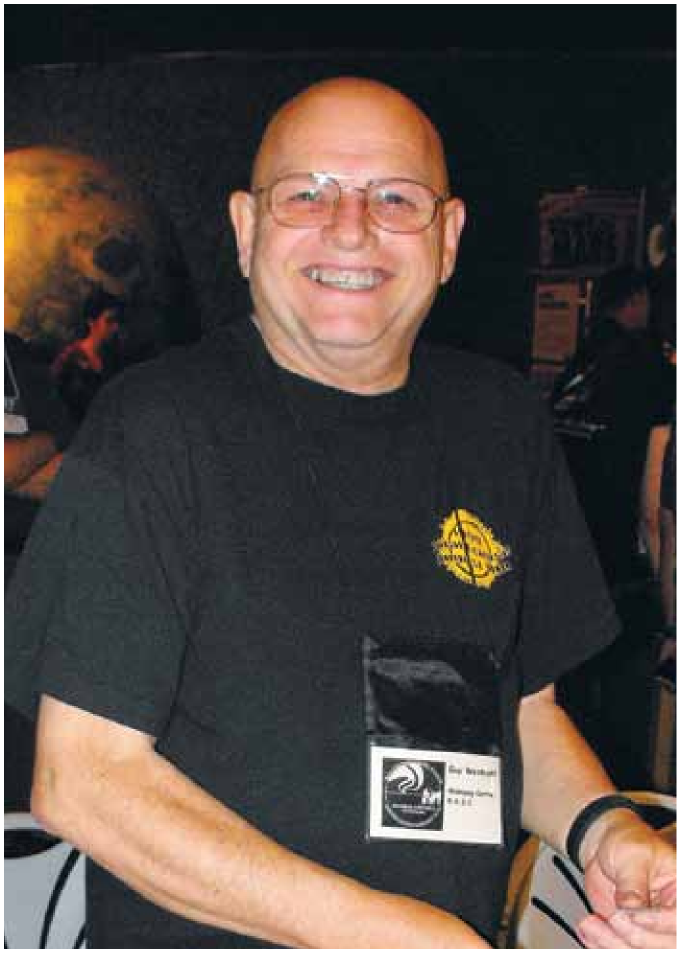
Besides my logbooks, I keep several databases in *FileMaker* to track my observations. My deep-sky observations are recorded in a database based on the Saguaro Astronomy Club's extensive database, and my variable-star observations in a database of my own design. These databases serve as an index to my logbooks: from the dates in the databases, I can easily look up the original observing sessions. ✶

Geoff Gaherty received the Toronto Centre's Ostrander-Ramsay Award for excellence in writing, specifically for his JRASC *column, Through My Eyepiece. Despite cold in the winter and mosquitoes in the summer, he still manages to pursue a variety of observations, particularly of Jupiter and variable stars. Besides this column, he contributes regularly to the* Starry Night Times *and writes a weekly article on the Space.com web site.*

Obituary

Guy Westcott (1946–2011)

by Jay Anderson, Winnipeg Centre



Guy Westcott, 1946-2011

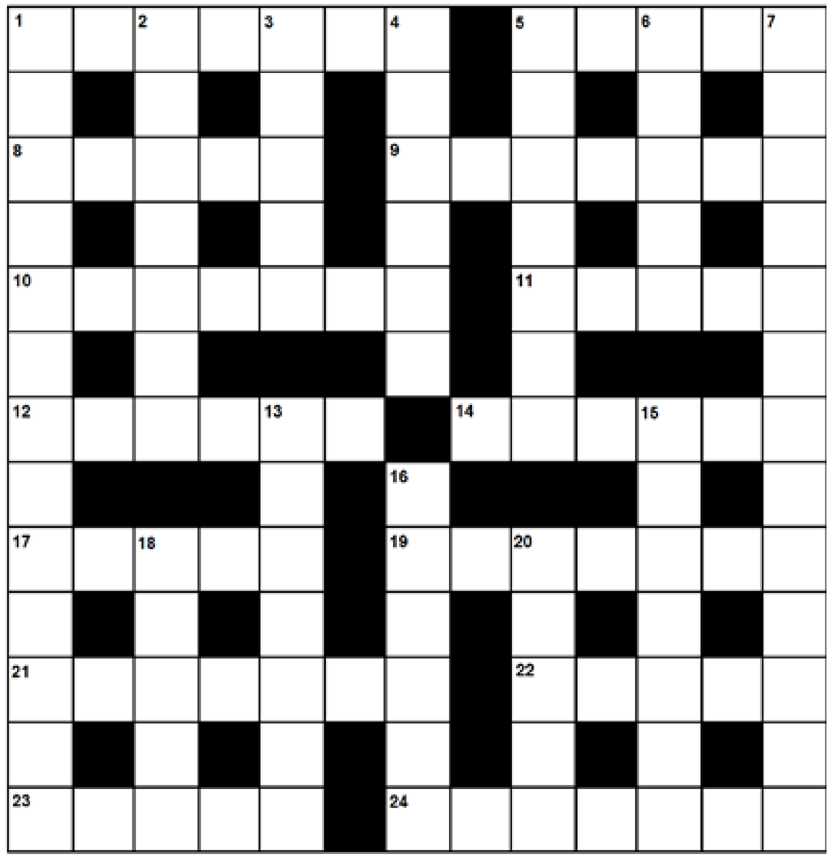
The Winnipeg Centre is mourning one of its stalwarts, Guy Westcott, who passed away in August. Guy had an eclectic and infectious personality, spreading good cheer to those about him, always ready to talk. In the lean days of the 1970s, Guy led the Centre out of the doldrums, helping to rebuild the membership, planting the seeds of growth that have continued to this day. His life was a pot-pourri of adventures and achievement: champion bowler; master angler; award-winning photographer; musician; eclipse chaser; painter; race-car driver; RAF veteran—a list that invited suspicion (did he really go diving with Jacques Cousteau?) until you heard the story in person, which he was delighted to recount.

Born in England in 1946, Guy was transported to Canada at the age of 3. He attended Miles MacDonell Collegiate, where, in the early '60s, his interest in music and his guitar-playing skills lead him briefly to a stint as a "doo-wop guy" in a garage band called the Silvertones, which later morphed into the Guess Who. His father died while he was in his early teens, and so he returned to the home country to finish his schooling. While away, he completed a stint with the Royal Air Force in Cyprus, became a DJ on a pirate radio station, and immersed himself in the English music scene. Coming home to Canada, he worked first for the CBC and then joined Bristol Aerospace for the rest of his career. The Canadian Space Agency acknowledged Guy's work at Bristol by recognizing him for contributions to the development of *SCISAT-1/ACE*, launched in 2003.

Guy's legacy in the Winnipeg Centre is in the friends he left behind. Present at nearly every meeting, always ready to help or offer advice, Guy gave a substance and history to the Centre. His signature is scratched into the floor of the Glenlea observatory that he helped construct in the 1970s, and reconstruct after the flood in 1997. He brought the day and night skies to the public, particularly at the MASCON (Manitoba Astronomy Conference), a star party that he organized and that brought 4000 people to Riding Mountain National Park. Even in sickness, he threw his effort into the organization of this year's General Assembly. In a sense, Guy was a "translator" who took his own love of the skies out to the public. He left behind several telescopes for the use of the Winnipeg Centre in its outreach programs, but his legacy will be in his organizational skills and his endearing personality. We will miss him. ✶

Astrocryptic

by Curt Nason



ACROSS

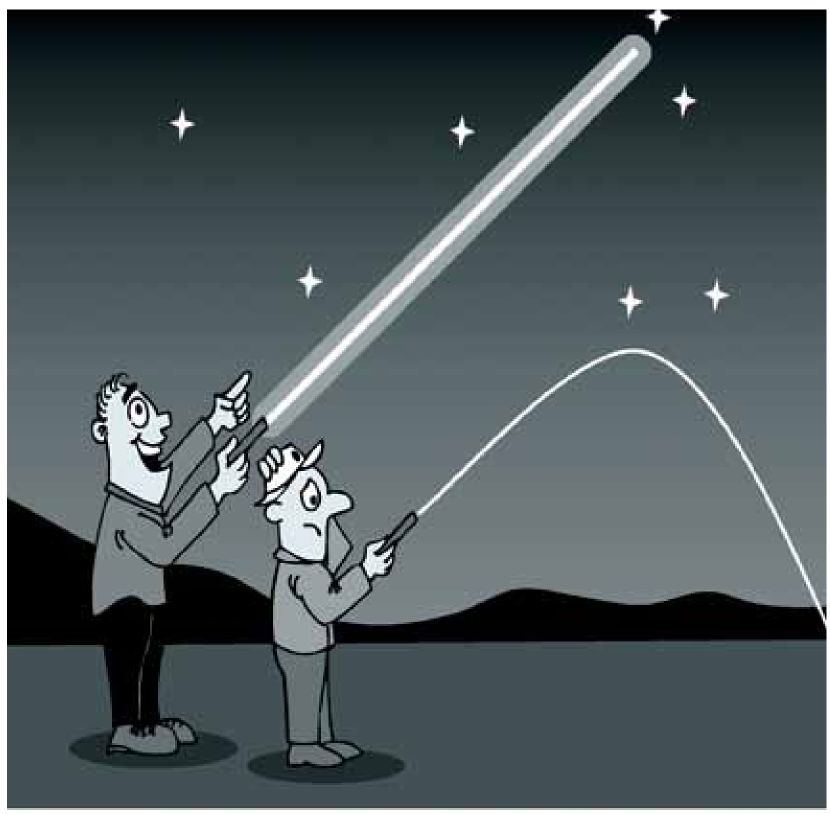
1. Bum around to Rhode Island with the Spanish moon of Uranus (7)
5. Piece of information about universal time reversal in Hoover, for example (5)
8. Plants and animals adapted to volcanic world between Britain's capital and Maine (5)
9. Solar wind craft scattered Seuss around a light year (7)
10. Good eyepieces range around fifty to seventy at first (7)
11. Comet hunter stocked potassium iodide behind the altar (5)
12. Will star mapper change in riot gear? (6)
14. Addition columns or calculus for relativity problems (6)
17. Super-cracked scarp (5)
19. Seeing a subgiant in Pegasus sent Nagler on a binge drunk (7)
21. Spinning a star northeast of the heart of Scorpius (7)
22. Planets spanning a third of the ecliptic are oddly inert (5)
23. Tiger slugger lost a prominent part of the solar spectrum (1-4)
24. Fish head round the head of Taurus (7)

DOWN

1. Stargazing area at ancient city bans cover for old boat (5,4,4)
2. Could modern writer perhaps ogle RGB filters? (7)
3. Infrared source detected east-northeast of a double-digit asteroid (5)
4. Use oil around a crater in Mare Imbrium (6)
5. Race around after sunrise to drop the kids off here (7)
6. Magnetic flux density measured in a satellite's Lagrangian point (5)
7. Mir ejects Bose orbiting the Pleiades or Crab Nebula (7,6)
13. What we do at night when strangely verbose (7)
15. Greek letters reversed on a laid back timepiece (7)
16. A very long distance around eastern scarp (6)
18. Lab dish collects a couple from Perseus with a few from Triangulum (5)
20. Gilbert-Sullivan sailor is like the Sun (5)

It's not all Sirius

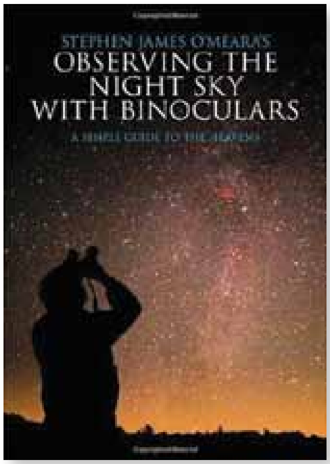
by Ted Dunphy



WOODY'S NEW POWERFUL LASER MADE DOBBY'S LOOK IMPOTENT

Reviews / Critiques

Observing the Night Sky with Binoculars: A Simple Guide to the Heavens, by Stephen James O'Meara, pages 168, 30 cm × 21 cm, Cambridge University Press, 2008. Price $29.99 US, softcover (ISBN: 978-0-521721-70-7).



It was exciting for me to review O'Meara's *Observing the Night Sky with Binoculars*, given that O'Meara's keen eyesight guided my Messier nights while I made use of his *Deep-Sky Companions: The Messier Objects* (Cambridge University Press 1998), the source for many years of everything I needed to know about faint fuzzy objects. In O'Meara's Deep-Sky Companion series, he has championed the *Caldwell Objects* (2002) and *Hidden Treasures* (2007), and has completed the set with the *Herschel 400 Observing Guide* (2007). O'Meara is a talented observer and passionate educator, who provided many helpful hints about drawing at the eyepiece when I met him at the 2009 George Moore workshop.

Observing the Night Sky with Binoculars contains an incredible variety of visual and written information, and uses the full cultural range of myths and storytelling to connect the reader to the sky in a meaningful way. I greatly enjoyed O'Meara's vivid picture-words and colourful palette of star-colour descriptors. The book makes for a lengthy read, mainly because of the density of information that is designed to be used immediately during observing sessions. It is not always clear to the reader that *Observing the Night Sky with Binoculars* is truly a beginner's book or "simple guide."

O'Meara tends to go further than most. He is a master of astronomical information and knowledge that is extraordinary in every way, accumulated from an astonishing number of observing hours and years of experience. He appeals to both the "mystical mind and the logical mind" (p. 113) with language, style, and visual information. He includes a stimulating range of information: star charts; astrophotographs; including time-lapse imagery and aerial shots; images of Egyptian art; poems; and other sources of mythology to round out his story telling. Some of the more advanced material, such as obscure objects requiring dark skies or challenging mathematical concepts, are red flagged, denoting them as difficult for the beginner. I had some concerns about the blend of beginning and advanced information, given that information can often help to either open or close doors for readers, becoming either a discouragement or a seed for future reference.

O'Meara's book can be compared with the RASC's *Observer's Handbook*, an excellent source of year-specific information if one knows how to use it. In that respect, both publications can be difficult to use because of their combination of advanced and beginner information. While both are excellent resources, at times it is necessary to divine the needed information through careful reading and rereading of the text. It would be interesting to see how useful O'Meara's book is in the hands of a novice or to test the book under the stars while hunting for less familiar objects.

Wisely and skillfully, O'Meara begins with the Big Dipper and ends with Gemini, all the time walking us around the sky from spring constellations to those of late winter, including a closing appendix on observing novae. In the Great Bear classroom, he introduces us to a valuable array of astronomical ideas and vocabulary: demonstrating constellation sizes with hand measurements; stretching our 3-D imagination with light-year star distances; using Greek symbols and star names; and including the Hertzsprung-Russell diagram to relate star colour to brightness. While such inclusions are nice, I had some issues with the organization of information. For example, O'Meara's "Dipper full of wonder" is easy to follow, but becomes more challenging with the introduction of arcminutes and fractions. Would a novice reader skip the advanced information and move on, or lose interest? According to the media release, the book is "the best way to begin observing as an absolute novice with little investment."

O'Meara also organizes the book into seasons, an excellent strategy, but season transition months are grouped awkwardly. In my Canadian experience, June is not spring, September is not summer, December is definitely not fall, nor is March a part of winter. Perhaps that is how the seasons are organized in Hawaii? O'Meara also fails to label or number his graphics, figures, or maps, and refers to them embedded within the text. A list of steps on how to get to the visual treasures in the sky would have been beneficial in the field. For example, using a combination of detailed steps embedded in the text in conjunction with fragmented maps to observe a few obscure objects in Aquarius became a challenge for me, and I quickly lost interest. In addition, a little hunting reveals that the constellations are grouped together under the heading "constellations," and not where expected, separately by individual name in the body of the index.

As a personal aid to sort the information, I tried different strategies: highlighting information steps embedded in paragraphs, writing star names that I wanted to remember directly on charts, and starring or sticky-noting pages to return to on the next opportunity for observing. Using the information with objects in the night sky is the key, for O'Meara motivates the reader to put the book aside and to go and explore under the stars to put directions into practice.

O'Meara prepares the observer with a knowledge-based kit prior to an observing period. Of particular value is information on measuring angles with an outstretched hand, observing with averted vision, and paying close attention to star colours and the science they represent, along with the names of stars. Such features are easy to learn and make observing more interesting, especially with company. Some examples from O'Meara's star-colour palette include: yellow tulip, large halo of mottled light, butterscotch flavour, aquamarine, crisp blue light, sapphire gem, lemon yellow, blue-white spark, snapdragon yellow, pumpkin orange Aldebaran, brilliant lilac and ashy Mirtak in Perseus, smouldering fire-orange, and Antares, the scorpion's red pulsing heart. He describes Sirius the Dog Star as a "molten white gem, like liquid star light," and relates the ancient Egyptian prediction of the annual flooding of the Nile coinciding with the heliacal rising of Sirius in the east. O'Meara includes a variety of other ancient star knowledge references from cultures around the globe.

O'Meara also introduces the reader to variable-star observing as an easy activity, in the process explaining star life cycles and introducing the reader to extrasolar planets and deep-sky objects, consistently using hand measurements to contextualize the size of major constellations. *Observing the Night Sky with Binoculars* also includes information from O'Meara's personal experience, such as the shake-the-telescope strategy to make objects pop into view, and stargazing at his home volcano (!) during an earth tremor. A number of volcano references permeate the text, and link the reader to O'Meara's other passion. He compares and contrasts astronomical time scales to those of terrestrial geology in order to illustrate concepts of time. Of M81 he relates, "You are glimpsing starlight that has traversed a distance of 12 million light years to reach your eye. The light we see from that distant object left its host during the Miocene epoch…" (p. 16).

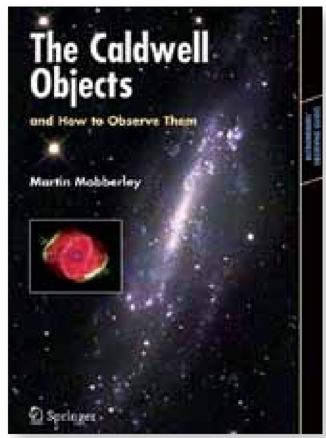
The book contains several entertaining highlights, as well, such as his image of the 1998 Leonid meteor shower, with a nice time lapse of himself next to his telescope in Hawaii. His descriptions are insightful, such as his interpretation that Scorpius was de-clawed when Libra became its own constellation, the Scales of Justice. His multicultural Pleiades legends are a delight, including Inuit, Russian, Ancient Egyptian, Hawaiian, and Japanese sources. The famous Perseus double-star clusters are described as "Stunning swirls and streams of starlight that, with imagination, are reminiscent of an explosion in a spaghetti factory" (p. 116).

The star charts and observing tips are for use under the stars, and I hope to learn from the book for years to come, to return to it, and to extract more information as needed. *Observing the Night Sky with Binoculars* is a spectacular and complex resource designed to enable observers to grow in their craft. It will introduce unfamiliar objects or new ways at looking at familiar objects, and encourage observers to weave their own stories about the night sky.

Kathleen Houston

Kathleen Houston is a member of RASC Saskatoon Centre, a teacher (B.Ed.), an accomplished artist (BAC and M.A. in Fine Art), and is passionate about stargazing. At the recent Edmonton Winterlight Festival Event she developed and hosted some highly successful children's EPO activities using participatory art to teach astronomy. She can be reached at e.b.a@sasktel.net.

The Caldwell Objects and How to Observe Them, by Martin Mobberley, pages 288 + xiv, 23 cm × 18 cm, Springer, 2009. Price $34.95 US, softcover (ISBN: 978-1-4419-0325-9).



For those unfamiliar with the term, the Caldwell List was devised by well-known British astronomer Sir Patrick Moore, middle name Caldwell, his mother's maiden name. Unlike the RASC's Finest NGC list, the Caldwell list is neither the best nor the brightest of the non-Messier objects, but a series of 109 deep-sky targets listed according to declination, from farthest north to farthest south. To make it onto the list, objects require some type of claim to fame, and the range is from bright and obvious targets, such as NGC 188, the most northerly cluster, to the faint and obscure, like IC 405, an object illuminated by a runaway star from Orion. Many objects are shared with RASC lists, so if you have completed them, you are well on your way. Unlike other lists, Caldwell objects include those far enough north and south that virtually everyone attempting to complete the list will end up packing their bags at some point. That you cannot observe all objects from one location, and the fact that many are faint and obscure, has led to criticism since its publication in the December 1995 issue of *Sky & Telescope*. Even the author mentions several as being dim and unremarkable.

The Caldwell Objects and How to Observe Them is a recent addition to the Springer Astronomers' Observing Guide Series. I already have several of the titles, and find the planet guides particularly useful. The author, Martin Mobberley, was president of the British Astronomical Association from 1997 to 1999, has written articles for *Astronomy Now* magazine, and has appeared as a guest on Patrick Moore's *Sky at Night* television series. Mobberley is the author of seven other astronomy books, four by Springer Publishing, the most notable being the *Lunar and Planetary Webcam User's Guide* (2006). In addition, Mobberley is a longtime associate and fellow countryman of

Sir Patrick Caldwell Moore, and his close affiliation with the list's originator has provided him with extensive background on the objects, as well as on the interesting character of Sir Patrick (who is also an Honorary Member of the RASC). The goals of the text are clearly stated within the introduction: to provide a lighter-weight field-friendly text with updated object information and to include lightly detailed observations as well as images and finder charts. He praises Stephen James O'Meara's *Caldwell Objects* (Cambridge University Press), but claims that his new work is designed to update the amateur on astrophysical research published since O'Meara's 2003 publication. Mobberly also notes a downside of O'Meara's book: that it is big, cumbersome, and not robust enough for field use. He goes on at length to describe how his own edition of O'Meara's book fell apart after light field use.

Chapter 1 introduces Mobberley, the Caldwell list, and Patrick Moore, and is followed by the main portion of the book, Chapter 2, which begins with Caldwell 1 and proceeds via declination through the list. The book presents a different structure than other observing texts: the author not only describes an object's visual appearance, but also aims to provide advice to the budding astro-imager. Each object is presented with details such as magnitude, location, size, age, and other pertinent information, and images by the author and others. There are also finder charts for each object. Chapter 3 includes visual guides for making your observations, while Chapter 4 includes information on photographically recording and digitally observing the objects.

Mobberley includes some interesting anecdotes and observing comments, such as a friend's reference to NGC 891 as two fried eggs on top of one another. The author also includes interesting and up-to-date information on AE Aurigae, the star that illuminates NGC 405 and which is thought to have escaped the Orion trapezium. Mobberley is an experienced observer and author, and I could not locate any errors in the text, spelling, or grammar.

How does *The Caldwell Objects and How to Observe Them* fare in field use? I was able to include the book on several observing sessions, although I was concerned about the low-contrast charts, plotting stars only to magnitude 5 and occupying just a third of a page. Despite that, I found the charts adequate, although in a few instances the *Sky & Telescope Pocket Atlas* would have made hunting easier. I wish Mobberley had included only one finder chart per object, as that would have saved the frustration of flipping pages in the dark, not to mention the difficulty of objects being jammed into chart corners, forcing the observer to star hop from odd directions. Although Mobberley set the production of a more field-friendly alternative to O'Meara's book as one of his goals, I found that the pages of *The Caldwell Objects and How to Observe Them* began curling even after a single use, and I did not take it into the field after that. I feel that Mobberley's criticism of O'Meara's text as a poor field edition is unjustified, since O'Meara's book is mostly descriptive and is intended for home use to prepare one's observing sessions. In fact, Mobberley's book fared far worse under actual field conditions. My Springer edition of *Jupiter And How to Observe It* seems much more robust, with a thicker cover and tougher pages. I wish the publisher had used the same quality of paper on the other volumes of the How To Observe series.

Missing from *The Caldwell Objects and How to Observe Them* is adequate format editing: there is too much blank space for objects that do not have a finder chart. Additional or larger images would have been preferable. Apparently, the layout was originally intended to include a finder chart for each object within the individual object section, whereas only every fourth or sixth object has such a chart. The Digital Sky Survey (DSS) gets heavy usage, especially for the most southerly objects. That is disappointing, since, in my experience, it is relatively straightforward to obtain superior astro-images from amateurs in southern climates, and Mobberley states that one of his goals is to assist the astro-imager.

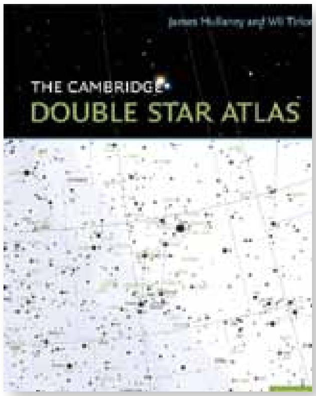
The strengths of the book lie in the simple but useful finder charts, the background information on Patrick Moore and his list, and the great tidbits of information on observing and gear selection in the third chapter. In particular, the author steers away from ultra-wide eyepieces in favour of smaller, more comfortable oculars – great advice that is seldom dispensed in the midst of 100-degree mania. Such strengths make *The Caldwell Objects and How to Observe Them* a worthwhile addition to your library if you are working on the list. I am unqualified to critique the imaging advice in the text, but those attempting that type of project with their CCD cameras will likely have other resources at hand. The publisher's description of the book implies that both visual and imaging descriptions are combined successfully, and Mobberley manages it smoothly.

The Caldwell objects comprise a list that I perused a few years ago after purchasing the O'Meara book, but had to exchange it for badly needed telescope maintenance, which put the project on hold. The O'Meara Deep Sky Companions series contain in-depth analyses of each object with drawings and descriptions. Since I enjoyed his book on the Caldwell Objects as much as his other works, I was intrigued by Mobberley's mention of using the O'Meara text as a jumping-off point. After having read both, I feel they complement each other nicely. Although the O'Meara book contains greater detail and useful drawings, at $25, the Mobberley text is about half the cost. If I had to choose only one for my library, the O'Meara edition would win. For me, the final evaluation of the worth of any astro text is whether it made me want to go out to observe and did I learn anything useful from it? In the case of Mobberley's *The Caldwell Objects and How to Observe Them*, my answer is a firm "yes."

Chris Beckett

Chris Beckett is originally from Nova Scotia, although he is currently on loan to the Regina Centre, where he is content creator for astronomyregina.ca. Access that site to find his podcasts and obscure deep-sky articles.

The Cambridge Double Star Atlas, by James Mullaney and Wil Tirion, pages 154, 30 cm × 23 cm, Cambridge University Press, 2009. Price $35 US, spiral bound (ISBN: 978-0-521-49343-7).



The Cambridge Double Star Atlas is a lush, beautiful, and very nice book that is worth being added to the list of observing resources for regular double-star observers. It will provide new ideas for observing targets, and because of the high quality of the charts, which include a variety of other plotted objects, can serve as a general-purpose star atlas, not merely a supplementary document.

The telescope I normally use has an excellent 8-inch refractor as its finder scope, which is used for object identification and centring. It provides an excellent instrument for general stargazing and to try out the charts in *The Cambridge Double Star Atlas*. The "showpieces" are indeed wonderful, and any minor quibble with inclusion or exclusion is reflective of individual tastes and preferences. The star charts are beautiful, easy to read, and allow easy navigation for "star hopping." The biggest issue here is personal: when you turn to a page to look at a specific system, those other green double-star names seem to beckon (or taunt) the observer. I found that when examining a pair, I would usually bounce around and make incidental observations of many others.

The stellar duplicity rate, given as approximately 80 percent, can be a contentious number. At the same astronomy meeting, I have seen different posters claiming that all stars (within uncertainties) are double and that no stars (within uncertainties) are double. Charles Worley used to say that "three out of every two stars are double," which is accurate if you look at it the right way. A useful relationship is to consider a sample of N stars. The number of binaries is M (= $N/2$). The number of tertiaries (triples) is L (= $M/3$). The number of quadruples = $L/4$, etc. It is not a rule, but approximately right, especially for the sample we know best: stars that are nearby.

The table of designations and WDS (Washington Double Star) codes in the book appear to come from an antiquated version of the WDS. It was certainly updated for our most recent major release of the catalogue in 2006.5. One of the more difficult issues in dealing with the WDS as a database is the presence of duplicate discovery designations—in other words, different systems assigned the same 3-character + 4-digit code. They generally fall into one of two categories: systems given the same numbers but published in different lists, and those given an additional designation appended to the original one.

Examples of the first are the binaries first resolved by W. Herschel and both F.G.W. Struve and O. Struve. Sir William Herschel published seven lists (I to VI, plus "new," or N), with stars of each list starting at number 1. In addition to their original discovery lists, each of the Struves published an appendix. Such multiple lists were completely spelled out in the Aitken Double Star Catalogue (e.g. H IV 48), but when the Index Catalogue (IDS) was compiled at Lick Observatory, all of the other double-star designators were dropped for lack of space. As a result there were, for example, five components with the designation H 48! The source Herschel list was given in the notes file to the IDS. Also changed at that time were Greek letters as designators, which did not work in the electronic card catalogue format of the IDS.

In the second (and fortunately rare) case, systems found quite near to known ones were given the same designation plus trailing character(s), e.g. ES 1293a or BU 885½. Sometimes both components were assigned the additional characters, sometimes only one. Occasionally two pairs in an entirely different section of the sky were given the same designation by the author (probably by mistake).

Each case was handled in a different manner. For the William Herschel discoveries, a list identifier is added to column three of each designation. For example: H 19 (at 16 hours) was originally H II 19 and is now known as H 2 19, H 7 (at 18 hours) was originally H V 7 and is now known as H 5 7, and H 111 (at 06 hours) was originally H N 111 and is now known as H N 111. In the case of the Otto Struve appendix, an A is added following STT in the name. For Friedrich Struve (STF), he provided two appendices: those from the shorter list (Appendix II) are designated STFB. For example: STF 11 (appendix I) is now STFA 11, STF 11 (Appendix II) is now STFB 11, and STT 252 (Appendix) is now STTA252.

Stars of the second type are given the same 3-letter discovery designation but a new number, starting with 9001, to indicate that they originally had a different designation. For example: BAL2356b is now BAL9001, and BU 885½ is now BU 9001. The case of missing discovery numbers was changed in the earlier edition, WDS 2001.0. The electronic version of the WDS listed in the list of references provides corrections and notes to many of them.

The idea of "training the eye" as described in the text sounds quite interesting. As described, it would seem that pre-knowledge of the marks, especially if repeated, could influence the sketching. A more thorough description of how to avoid biases would be handy. Another tool I have found handy is an eye patch over the dark-adapted eye. With an eye patch and a red head lamp, your appearance can be quite comical, but if the goal is optimizing observing, that would seem a small price to pay.

The WDS and the Journal of Double Star Observations (JDSO) are both excellent sources of information. Groups that may interest the reader include The Webb Society, which has a double-star section (www.webbdeepsky.com), the double-star section of the SAF (http://saf.etoilesdoubles.free.fr), and the double-star section of the Liga Iberoamericana de Astronomia (http://sites.google.com/site/doblesliada and http://elobservadordeestrellasdobles.wordpress.com).

Any shortcomings of the work, such as the items just discussed, are only in the area of "other things I would want." They are provided simply as things I would like to see in the next edition.

CCDs are the predominant method used for measuring of double stars, even by amateurs. Those not interested in measuring double stars often use a laptop-enabled Webcam for imaging. Indeed, by taking short images and de-selecting those made under poor seeing conditions, and then stacking the images, the observer is doing organic lucky imaging, sort of a poor man's speckle interferometry, to co-add those frames made under the best conditions. That is a handy procedure, since seeing can be quite variable. As so many observers work with a laptop at the telescope, if the tables of "showpieces" and those in the appendix were also available as spreadsheets for sorting in columns by map number or right ascension, they could be used more easily.

The very nature of double stars is the ephemeral quantity of their morphology. While they may indeed move about one another only slightly, we know with certainty that, whether by differential proper or orbital motion, the pair we observe tonight is different, if ever so slightly, from the same pair observed last night. A useful and not overly complicated program or phone "app" could easily extract the most current data for all of the pairs from the WDS. They could then be updated as frequently as the user wanted. In fact, for the pairs with predicted positions either from orbits or linear motion, a linear interpolation of the predicted position for that observing night is also easy to achieve.

I could also imagine lists tailored to particular interests, for example, colour-contrast systems could be enumerated that would include those highlighted in the "showpieces," but also including others from Appendix C. Another interesting list, again including those highlighted in the "showpieces," as well as others from Appendix C, would be those with relatively short (< 100yr?) periods. Such pairs, like ξ Ursae Majoris, would show significant motion from year to year and could easily be seen in a sketch highlighting the system orientation.

Double stars can also be used to test the imaging of telescopes, the quality of observers, or the current observing conditions, thanks to their simple arrangement. Groups of magnitude-difference classes sorted by separation would give you a numerical assessment of your capabilities or the sky conditions.

While the numerical scale of seeing appears objective, it is actually subjective, with different people rarely normalizing their scales with each other, if at all. However, when your minimum-resolution capability is assessed each night, you have a truly numerical way to assess the seeing conditions.

While the simplicity of a double, or even multiple, system cannot match the "wow" factor of nebulosities or planetary imaging, some can be seen in most conditions, and the variety of magnitude, colour, and separation are delights that vividly demonstrate the variety of even simple objects in space. *The Cambridge Double Star Atlas* is an excellent book to explore the great variety of such "simple" objects.

Brian D. Mason

Brian Mason is a professional astronomer in the Astrometry department of the United States Naval Observatory, and lead author on the present incarnation of The Washington Double Star Catalog *(http://ad.usno.navy.mil/wds). His doctoral thesis was an in-depth treatment of the techniques and results of speckle interferometry in the observation of lunar occultations of binary systems, and he has worked on and published widely on the techniques of modern double-star observation, has added greatly to our observational data, and has published on the historical instrumentation, techniques, and results of his predecessors. And, he still has time to enjoy the art of visual observation of double stars with refractors.* ✶

Presentation Abstracts

2011 General Assembly of the RASC Winnipeg

Is This Guy's Music Any Good? Herschel's Music and his Astronomy

Randall Rosenfeld, Unattached member

It is common knowledge among astronomers that William Herschel went from being a provincially fashionable musician to being a world-renowned natural philosopher. The legacy of his astronomical achievements is widely dispersed and easily accessible, from the Solar System objects he discovered to late-Georgian images of his great 40-foot telescope, from his papers on the "construction of the heavens" to his substantial double-star and DSO catalogues. These objects of his discovery and industry can readily be found in the sky, in public and private collections, and most accessible of all, on the Internet. His musical work is much less well-known, and vastly more inaccessible.

Even during IYA2009, the cumulative exposure to his music did not appreciably increase, despite that year's emphasis on drawing broader connections between astronomical culture and culture at large. The first part of this talk looks at the connection between Herschel's intellectual commitment to music as a "philosophical" pursuit together with his attention to the craft of music in performance, and his engagement with cosmological speculation, and the development of his design and production skills as a renowned and innovative maker of scientific instruments. It is argued that not only did music equip him with conceptual tools and practical skills that were useful to his astronomical work, but that in going from music to astronomy he was going no great distance, penetrating no impermeable disciplinary boundary. He was in fact walking a path broadly laid down in antiquity. The second part of the talk is a concrete attempt to increase exposure to Herschel's music, at least for GA delegates. It consists of a live performance of one of his pieces as it could have been performed during his lifetime. The instrument used is an accurate copy of an instrument by one of the outstanding musical instrument makers of late-18th century England. GA delegates will be able to answer the question posed in the title for themselves.

Cookbook Protection of your Observing Site

Robert Dick, Ottawa Centre

Canada leads the world in the number and size of its Dark-Sky Preserves. The three main reasons are its rational lighting protocol, a clear list of necessary documentation, and a national organization that accepts and vets the nominations. This presentation will outline how to nominate a park as a RASC-DSP by using examples from existing preserves. Although Parks Canada is encouraging its facilities to seek a DSP designation, they may require assistance from local astronomers as they develop their astronomy outreach programmes. Therefore, the catalyst for a DSP is the local astronomy membership. If you rely on a park for observing, then a DSP can institutionalize its protection.

The Star Trek Observing List

Patrice Scattolin, Centre Francophone de Montréal

The Star Trek observing list is a combination of science fiction and astronomy. It is a typical observing list like other more ambitious observing projects proposed to amateur astronomers. All the objects it contains appeared in a Star Trek episode or movie. Derived from secondary sources, the list unites both universes and entices the reader to relive the Star Trek universe at the eyepiece. Mostly made of bright northern-sky stars, it is an ideal list for the beginner observer and has served to hone the observing skills of co-author Clara. We will present the genesis of the project, the document itself, and how the list was tested and promoted. As a conclusion, we will compare the fictional universe against what is currently known of some of these objects, in an attempt to determine if the pervasive picture of our surroundings painted by this popular science fiction is close to the real Universe.

Wide-Field Astrophotography with a Compact Mechanical Equatorial Mount

Dave Chapman (Dave XVII), Halifax Centre

Many consumer digital cameras allow amateur astronomers to create high quality night-sky photographs like never before; however, time exposures longer than a few seconds demand a polar-aligned and driven mount to minimize star trails. The MusicBox EQ mount is a solid mechanical mount that allows exposures of up to 5 minutes using a standard camera. It is sturdy but small enough to pack for a trip. Its operation is explained—yes, it involves a music box!—and some astrophoto examples are shown. A trip to the southern hemisphere posed some challenging complications.

At Last! Our Own Eclipse of the Sun

Jay Anderson, Winnipeg Centre

A central solar eclipse hasn't been spotted over the populated parts of North America since 1994, but next year that drought is about to come to an end. The event that brings the 17-year hiatus to a close is an annular eclipse that crosses into the U.S. in northern California and ends at sunset in Texas. Weather prospects are important, but annulars also present a very different observing experience than total eclipses. Where do you position your observing site – on the edge of the track, at sunset, or in the middle of the shadow? This presentation will discuss those questions and provide a weather outlook.

Digital Archiving of Canadian Astronomical Records

Eric Briggs, Toronto Centre

Current technology now allows for rapid archiving of old records. Private and public records can be used to build a more-or-less accurate visualization of the history of the study of astronomy in Toronto, and the rest of Canada. Examples of this archiving are demonstrated, and reasons why this procedure may or may not be a good idea are questioned.

Graphite and Starlight: Recording the Universe

Scott Young, Winnipeg Centre

Telescopic observation is a uniquely human experience, one that cannot be replicated by digital imagery. The appearance of an object through the eyepiece is most faithfully reproduced by drawing what is seen, complete with all the bias and subjectivity inherent in the process. This talk covers the process of sketching through the telescope and provides tools and techniques for the budding astroartist.

Are the Symptoms of Future Supernovae Amenable to Early Diagnosis?

Dr. David Turner, Halifax Centre

The possibility that a bright, "nearby," red supergiant like Betelgeuse or Mu Cephei might soon explode as a Type II supernova is a genuine, if highly uncertain, prospect. The variability observed in many M supergiant type C semiregular (SRC) variables like Betelgeuse and Mu Cephei may contain a signature of their future fate, but has not yet been examined in sufficient detail to establish notable trends. Our present understanding of such stars is presented from knowledge of their brightness and spectroscopic changes, as tied to archival material and AAVSO magnitude estimates. M supergiant variables are more regular than sometimes believed, although the nature of the regular pulsation in some is still unclear. Amateur astronomers could provide valuable assistance to such research through regular observations of the dozens of variable M supergiants readily accessible to observation, as do many members of the AAVSO. Precision monitoring of the variability in M supergiants is a challenging yet attainable goal, one that could improve the quality of all types of observations made by regular sky observers. Such observations seem essential for learning more about massive stars as they approach the terminal stages of their evolution.

Nightscapes: Creative Use of Composition and Lighting in Wide-Angle Astrophotography

Ron Berard, Winnipeg Centre

Combining the techniques of landscape and portrait photography with astrophotography can yield compelling images that appeal to a broad variety of viewers.

Starmus! An Astronomical Adventure!

By Paul and Kathryn Gray, New Brunswick Centre

Following the hype around Kathryn's discovery of SN2010lt, she was invited to participate in a number of events. The most exciting of all was invitation by Garik Isrealian to perform the official opening of Starmus! In this presentation, I will highlight some of Kathryn's amazing adventures in the Canary Islands where she (we) had a chance to meet many interesting people from astronomy, space flight, music, and art backgrounds that made Starmus the amazing event it was. As a representative for the RASC, Kathryn, Susan, and I owe many thanks to the RASC family for its support of this adventure. ✶

THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

Executive committee and appointed officers for 2011/Comité exécutif et membres attitrés pour 2011

Honorary President	Jim Hesser, Ph.D., Victoria
President	Mary Lou Whitehorne, Halifax
1st Vice-President	Glenn Hawley, B.Sc., B.Ed., Calgary
2nd Vice-President	Colin Haig, B.Sc., M.Sc., Hamilton
Secretary/Recorder	James Edgar, Regina
Treasurer	Mayer Tchelebon, MBA, CMA, Toronto
Past Presidents	Dave Lane, Halifax and Scott Young, B.Sc., Winnipeg
Editor of Journal	Jay Anderson, B.Sc., MNRM, Winnipeg
Editor of Observer's Handbook	David M.F. Chapman, M.Sc., Halifax
Editor of The Beginner's Observing Guide	Mary Lou Whitehorne, Halifax
Editor of Observer's Calendar	Dave Lane, Halifax
Executive Director	Deborah Thompson, CAE, Toronto

Centre addresses/Adresses des centres

The most current contact information and Web site addresses for all Centres are available at the Society's Web site: www.rasc.ca

Belleville Centre
c/o Greg Lisk, 11 Robert Dr
Trenton ON K8V 6P2

Calgary Centre
c/o Telus World of Science, PO Box 2100
Stn M Location 73
Calgary AB T2P 2M5

Charlottetown Centre
c/o Brian Gorveatt,
316 N Queen Elizabeth Dr
Charlottetown PE C1A 3B5

Edmonton Centre
c/o Telus World of Science
11211 142 St
Edmonton AB T5M 4A1

Halifax Centre
PO Box 31011, Halifax NS B3K 5T9

Hamilton Centre
c/o Mr. A. Blanchard, 2266 Lakeshore Rd W
Oakville ON L6L 1G8

Kingston Centre
PO Box 1793, Kingston ON K7L 5J6

Kitchener-Waterloo Centre
305 - 20 St George St, Kitchener ON N2G 2S7

London Centre
c/o Peter Jedicke, 82 Barrydale Cres
London ON N6G 2X4

Mississauga Centre
PO Box 98011, 2126 Burnhamthorpe Rd W
Mississauga ON L5L 5V4

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

Montréal Centre
18455 Meloche St
Pierrefonds QC H9K 1N6

New Brunswick Centre
c/o Paul Gray, 1068 Kingsley Rd
Birdton NB E3A 6G4

Niagara Centre
c/o Dr. Brian Pihack
4245 Portage Rd
Niagara Falls ON L2E 6A2

Okanagan Centre
PO Box 20119 TCM
Kelowna BC V1Y 9H2

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

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

Québec Centre
2000 Boul Montmorency
Québec QC G1J 5E7

Regina Centre
PO Box 20014
Regina SK S4P 4J7

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

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

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

Sunshine Coast Centre
5711 Nickerson Road
Sechelt BC V0N3A7

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

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

Vancouver Centre
1100 Chestnut St
Vancouver BC V6J 3J9

Victoria Centre
3046 Jackson St
Victoria BC V8T 3Z8

Windsor Centre
c/o Greg Mockler
1508 Greenwood Rd
Kingsville ON N9V 2V7

Winnipeg Centre
PO Box 2694
Winnipeg MB R3C 4B3

Great Images

Farewell Discovery. *This montage shows the launch of the space shuttle* Discovery *on February 24 at the start of its 39th and final mission.* Discovery *is probably best known for its deployment of the* Hubble Space Telescope *in 1990 and subsequent repair and maintenance missions in the years following. Photo: Jay Anderson, Winnipeg Centre.*