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Journal

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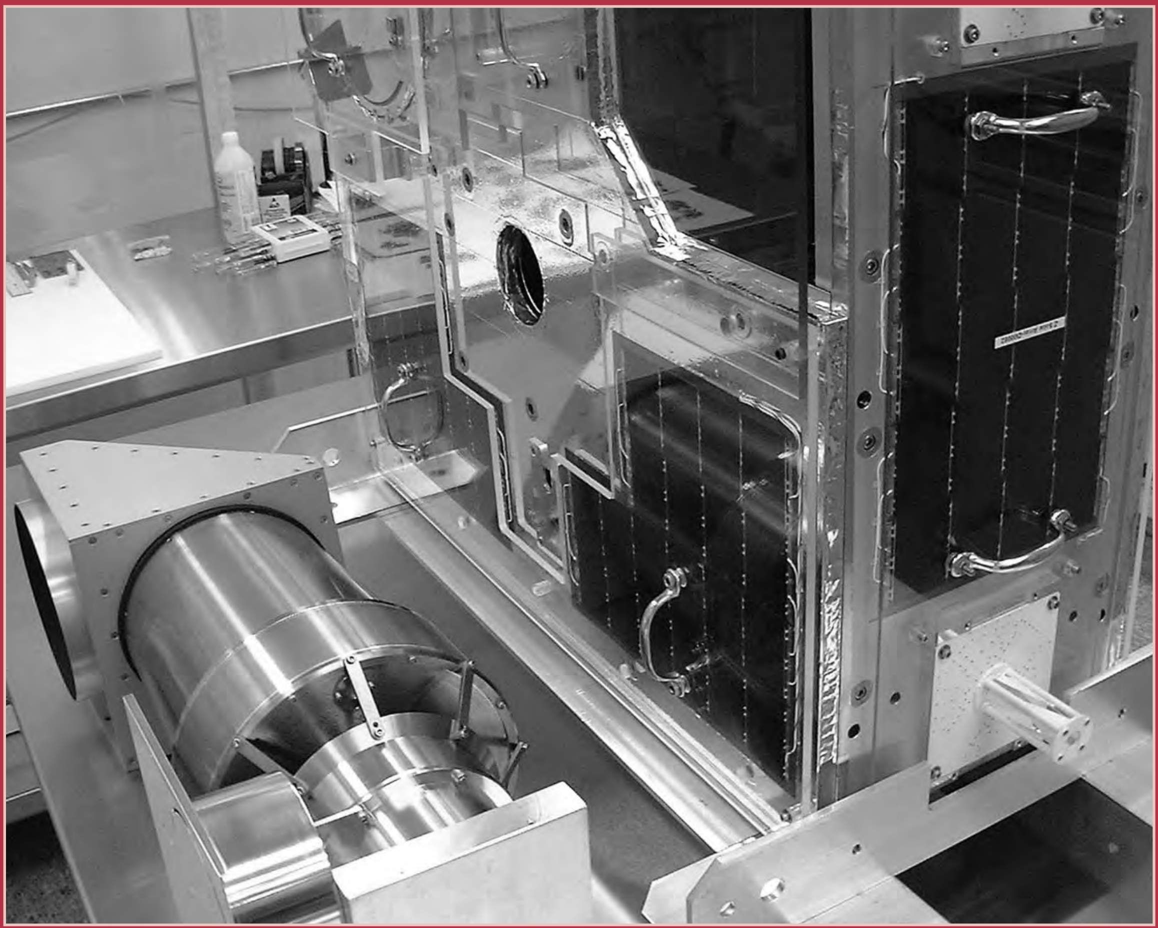

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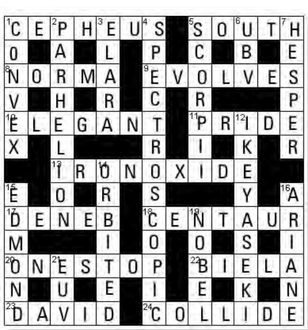

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President's Corner

by Rajiv Gupta (gupta@interchange.ubc.ca)

Yesterday, October 7, I had the honour of representing the RASC at a public event in Vancouver that was part of the Canadian Golden Jubilee Tour of Her Majesty Queen Elizabeth II. The Queen unveiled a bronze "book" that will be displayed in the Golden Jubilee Room in the main library of the University of British Columbia, and I was a member of the reserved seating party that witnessed the event.

The invitation to attend the event arose from an approach to the Royal Tour's organizers that the RASC made many months ago. A direct exchange of some form had originally been hoped for, but security and scheduling constraints meant that the official invitation from the Premier of British Columbia to attend the event of October 7 was the best the organizers could offer.

At this event, the Queen witnessed several groups of performers who represented Vancouver's wide ethnic mix. As I looked around, I noticed that most of the time more members of the audience were looking at the Queen instead of the colourful performers. I sat and watched Her Majesty myself, as she conducted herself with the grace and dignity that have defined her 50 years on the Throne, and I felt truly privileged to be able to represent the Society. As Her Majesty spoke about the unique, cross-cultural Canadian diversity and the fine example Canada sets for the world and expressed her deep pride in being our monarch, I'm sure she was thinking, just a little, about the diversity within the RASC and feeling the warm sentiments of RASC members everywhere. I brought with me the good wishes of 4500 RASC members, and tried my utmost as I sat and watched to telepathically transmit them to Her Majesty.

The RASC had a special reason to request a presence in the Golden Jubilee Tour: the "R" in RASC dates back almost exactly 100 years. In a petition to the Governor General of Canada dated January 7, 1903, the Toronto Astronomical Society, which had decided to change its name to the Astronomical Society of Canada, requested permission from the King to prefix "Royal" to its new name. The Society explained in the petition that "such gracious permission would strongly stimulate its efforts in the promotion and diffusion of Astronomical Science and that its influence in this direction would be greatly extended thereby throughout His Majesty's Dominions." The Society received a reply dated February 27, 1903 from the Canadian Under-Secretary of State, in which he reported that King Edward VII had graciously granted the requested permission. By an order of the Chief Justice of Ontario dated March 3, 1903, the Society's corporate name was changed to the Royal Astronomical Society of Canada.

Journal

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

The *Journal of The Royal Astronomical Society of Canada* is published at an annual subscription rate of $80.00 by The Royal Astronomical Society of Canada. Membership, which includes the publications (for personal use), is open to anyone interested in astronomy. Annual fees for 2002, $44.00; life membership is $880. Applications for subscriptions to the *Journal* or membership in the RASC, and information on how to acquire back issues of the *Journal* can be obtained from:

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(For more details on this and other aspects of the Society's history, see *Looking Up*, by Peter Broughton.) With the near-alignment of the Golden Jubilee of Edward VII's great-granddaughter and the Royal Centenary of the RASC, participation by the RASC, in the form of my presence at the October 7 event, was especially appropriate and meaningful.

As we enter our Royal centenary year, I encourage all members to pause and reflect on our Royal designation. This designation is an honour that very few astronomical organizations share. It is an indication of the official respect King Edward VII felt the precursor of the modern RASC had earned. Over the course of the reign of four monarchs, spanning the transition from the House of Saxe-Coburg-Gotha to the House of Windsor, the RASC has treasured its name, and its members — who have grown in number from 120 to 4500 — have striven to earn the respect bestowed upon them in 1903. The designation has also had practical implications in the fulfillment of the Society's mandate, as our astronomical forefathers had hoped for in 1903; whenever we interact with members of the general public or the media, the first word in our name immediately garners attention and respect. So, in our centenary year, say our name out loud, and say it often, placing a special emphasis on the word *Royal*.

Editorial

by Pierre J. Boulos, Assistant Editor, Windsor Centre (boulos@uwindsor.ca)

As I wrote this editorial, the August issue of the *Journal* arrived. "Wonderful!" I thought, "Let's see what guest editors have to say." I opened the issue and went straight for the *Editorial*. There it was, much to my horror: "When the *JRASC* Editor asked me to write a guest editorial, I agreed right away and immediately regretted it. What to say?" These are the words of David Chapman, one of our contributing editors. They should have been my words! I asked our Editor-in-Chief about the boundaries of my topic. Like a true physicist he informed me that there are no boundaries. I mulled over various topics since then. I tried some of these on colleagues during guest lectures at the University of Windsor. At one of these, a Sociology talk on "The Politics of Regret," I thought the talk could be about me. It is a curious thing: I sit down every day at my computer and write all sorts of things about my research, yet when I have to, nothing comes. I felt, and still feel, like the high-school student who just cannot get started on his or her essay.

What I've decided to do, in the end, is try to show that you, the astronomer, and I, the historian and philosopher of science, are really up to the same thing. That's my position and here's how I'll show you.

I spend some of my time working through historical texts looking for clues as to what science is about. More specifically I spend most of my time in Newton's *Philosophiae Naturalis Principia Mathematica (Mathematical Principles of Natural Philosophy)* and the works of various scientists who followed Newton. I've been intrigued with the beauty of the science, the genius of the authors, and the stories that surround their discoveries. Over the past couple of years, I've had the opportunity to present some of my findings to the RASC–Windsor Centre. Last year's talk covered Kepler's so-called attack on Mars. In short, the story goes something like this: Kepler was busy trying to find the orbit of the known planets. Through the work and detailed observations of Tycho Brahe, Kepler had a great number of positional observations of Mars. He tried various metaphysically- and religiously-inspired models. That planetary orbits are circles is one such model. At one point, he conjectured that planetary orbits stand in ratios to each other like the ratios that hold between the Platonic solids. As tools, these did not work quite well. Nonetheless, what struck me as interesting was that historical figures such as Kepler completed tasks that were unimaginable by today's standards. Kepler was able to deduce the laws that carry his name from data that do not readily "make plain" these laws. That is, Kepler deduced elliptical orbits of planets focused on the Sun. He did this, though, from a position on Earth, without a telescope, and definitely without computer modelling! The geometry he used to triangulate is beyond most of our grasps. Let's just say that this point was appreciated by my audience.

Among RASC types, we often hear the seasoned astronomer extolling the virtues of "naked eye astronomy," or the use of binoculars, to the uninitiated. So when we hear the story of Kepler, and Newton after him, making use of the wealth of observations made by Tycho Brahe without the use of a telescope, we cannot help but appreciate what these giants went through. The history of astronomy, if nothing else, reminds us of the benefits of simply looking up at the night's sky. Notice that I did not even have to mention the life-interpretive stories or, I daresay, myths we have inherited from our ancestors from long ago — stories that are still being told, thankfully, in each issue of magazines like *Sky News*.

Surely, you say, I still haven't shown you that what you do in astronomy is what I am doing in the history of astronomy, or vice versa. Consider the following: A number of members at the Windsor Centre, and I suspect other RASC Centres too, have embarked on active sunspot observations. Modern logbooks, just like Galileo's in the *Starry Messenger*, might have drawings of the sunspots, or even digital images. Let's remind ourselves, though, that these images, however accurate, will always be historical images. The recorded size, shape, and location of the sunspots will always be recordings of events that occurred some eight minutes prior to the observation. Eight minutes may not sound like a great deal. It is, nonetheless, the approximate amount of time the light from the sun takes to reach us. And as we revel in the crisp, clear, and long nights of a Canadian autumn and winter, remember that Polaris, a guidepost star, is some 431 light years distant. When we view Polaris in the night sky, we are viewing a heavenly body as it was 226,533,600 minutes ago!

I put forward then the following: Observational astronomy is the queen of historical studies. The difference between what we do as astronomers, amateur and professional, when we observe celestial phenomena, and what the historian records of events that happened some time ago, is one of precision. In my own reconstructions of Newton's arguments in the *Principia*, I often long for the precision and detail I gain through peering through my own telescope. Instead, I settle for the unpolished, poorly-ground glass of my historical musings. Another important difference is that the understanding of historical recording in astronomy also permits us to foretell the future positions of heavenly bodies. This is a good thing too; otherwise the editor of the *Observer's Handbook* would have an impossible task.

Let me end this short editorial by bidding all of you the best for your observing. Or should I say, the best for your history recording?

Correspondence
Correspondance

Erratum:

The image of the Sundial in *A New Sundial in Victoria* (JRASC, 96, 147) was mistakenly printed upside-down.

The Planetary Nebula images in *Planetary Nebulae in Lyra* (JRASC, 96, 144) are 15′ ×15′ in size.

News Notes
En Manchettes

BUT IT'S A DRY COLD...

Before you go to Mars, stop over in Winnipeg where the temperature can be as crisp as −100° C. The reason for the extreme Manitoba cold is not a sudden global cooling, but rather a characteristic of the world's first Mars Environment Simulator (MES), unveiled this past summer by Dr. E. Cloutis, Professor of Planetary Geology at the University of Winnipeg.

The MES is capable of replicating the frigid nighttime temperatures experienced on the Martian surface, as well as its carbon dioxide-rich atmosphere, at a pressure some 200 times lower than Earth's. The extreme UV radiation flux expected at the Martian surface can also be simulated. In addition, Dr. Cloutis commented "I want the Mars box to be dirty and disgusting. So we're going to have dust floating around in there all the time."

The MES is about the size of a two-drawer filing cabinet tipped on its side. This makes it large enough to hold any of the components that would likely fly on a robotic lander to Mars. "That to me is going to be the real bonus for Canadian industry, because we'll be able to certify that we've tested equipment under realistic Martian conditions" noted Cloutis, and the MES has already attracted attention from a Canadian robotics company and NASA.

In addition to its industrial testing capabilities, the MES will also be used to test fundamental Mars-related biological and geological questions under realistic conditions for the first time. The MES will be fully operational by late fall 2002, and Cloutis is now turning his sights towards the creation of a "Mars Room" — a room that would be capable of holding a full-size Mars robotic lander or rover.

The Mars Environment Simulator recently installed at the University of Winnipeg. (Image courtesy of Dr. E. Cloutis.)

MARS MISSION DEFINITION

Mr. Allan Rock, Minister of Industry and Minister responsible for the Canadian Space Agency (CSA), announced this past September the award of a $400,000 contract to MacDonald, Dettwiler and Associates (MDA) Ltd. of Richmond, B.C., to support the CSA in defining Canada's contribution to European missions to Mars, and the NASA-led Mars Science Laboratory mission.

Landing safely on the Red Planet is a critical element of any Mars mission, and the study to be undertaken by MDA will include an assessment of the design, development, and use of laser-based sensor technology to land spacecraft on the surface of Mars. As a world leader in robotic technologies, Canada will also be considering its role in the development of a robotic mining device that will extract samples of the planet's subsurface and prepare them for scientific study.

"The results of this study will help define Canada's potential role in upcoming missions to Mars, contribute to Canada's development of new knowledge and cutting-edge technologies, and firmly establish and enhance British Columbia's profile as a valuable partner in space exploration," said Minister Rock, who made the contract announcement during the opening ceremonies for a new exhibit on the International Space Station at the H.R. MacMillan Space Centre in Vancouver.

40 YEARS AND COUNTING

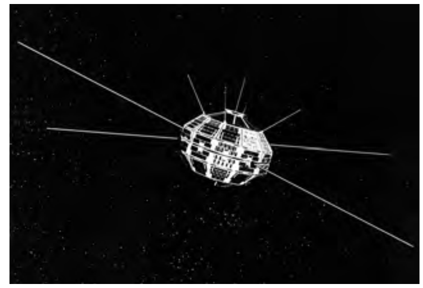
This past September 25 marked the fortieth anniversary of the launch of Alouette-1, Canada's first space experiment. Launched atop a Thor-Agena-B rocket from

Vandenberg Air Force Base, California, on September 29, 1962 at 6:05 UTC, Alouette-1 saw Canada become the third nation, following closely on the heels of the Soviet Union and the United States, to place a 'home-built' satellite in space.

"Just as the railroad linking the country from coast to coast has played a key role in Canada's history, the launch of Alouette-1 represents a major milestone in our space history", said Dr. Marc Garneau, President of the Canadian Space Agency. "It embodies Canadian leading expertise and excellence in space science and technology which continues today through critical space initiatives to deliver benefits to Canadians."

Alouette-1 was launched to study the Earth's ionosphere, a layer of ionized gas frequently used as a reflective layer for radio transmissions over long distances. Signals from Short Wave radio, the main mode of communications in the late 50s, propagate by bouncing against the ionosphere before returning to earth. Since the complexity of the ionosphere often produced confusing signals, a team of scientists from Canada's Defense and Research Telecommunications Establishment (DRTE), later renamed the Communications Research Centre, submitted a proposal to the newly formed National Aeronautics and Space Administration to study the ionosphere from above. Designed for a one-year lifetime, the satellite lasted ten years producing more than one million images of the ionosphere.

Besides the atmospheric studies performed by Alouette-1, the Canadian spacecraft also greatly contributed to space engineering and technology and helped Canadian scientists develop numerous satellites supporting telecommunications with the Anik series, Earth observation with RADARSAT-1, and science with SCISAT-1. More information on the Alouette-1 satellite can be found on the Internet at: www.space.gc.ca/csa_sectors/space_science/atmospheric_env/alouette.asp



Alouette-1 research satellite, Canada's first venture into space. (Image courtesy of the CSA.)

If you have any announcements, press release information, and/or news and research notes, please forward them to martin.beech@uregina.ca.

RASC INTERNET RESOURCES

Visit the RASC Web site
www.rasc.ca

Renew your Membership
www.store.rasc.ca

Contact the National Office
rasc@rasc.ca

Join the RASC's email Discussion List

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

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

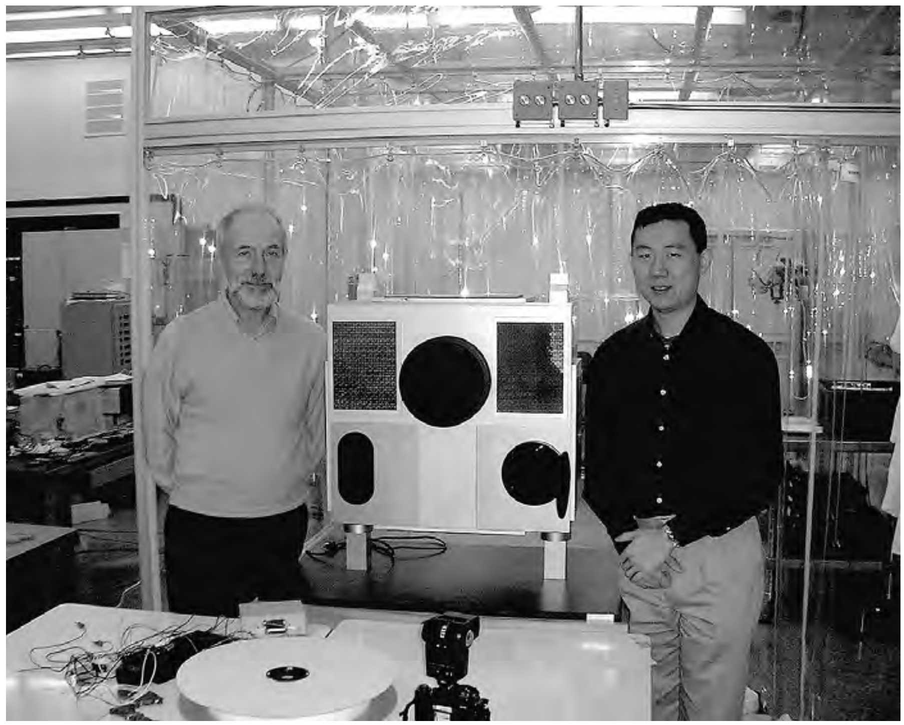
MOST:
Canada's First Space Telescope Part I

by Randy Attwood, Toronto Centre (randy.attwood@rogers.com)

Introduction

By spring 2003, Canada's first space telescope will be in Earth orbit. MOST, which stands for Microvariability and Oscillations of STars, will make precise measurements of the changing brightness of certain stars over a period of months. If successful, the data obtained by this small telescope may help answer some big questions in the field of astronomy.

In a small town in Poland in the 1950s, Slavek Rucinski's high-school teacher introduced him to astronomy. Slavek quickly became interested in observing variable stars, but he was frustrated by bad weather and day/night cycles, which limited the time he could make his observations. Around this time, the Space Age arrived with the launch of Sputnik, the first artificial satellite. Wouldn't it be great, thought Slavek, if we could place a telescope on one of those Earth-orbiting satellites, where it could observe variable stars all the time? Forty-five years later, Slavek's dream is about to come true.



Dr. Salvek Rucinski and Dr. Robert Zee stand beside a mockup of MOST at SFL/UTIAS.

Dr. Slavek Rucinski is now an astronomer at the University of Toronto and is on the science team for the upcoming MOST mission. In April 2003, the MOST spacecraft will be launched as Canada's first astronomy satellite. It carries a small telescope that will be used to observe the same star nonstop for a period of weeks, precisely measuring changes in its brightness. MOST may help answer some fundamental questions in astronomy: How old are the oldest stars? How old is the universe? The MOST telescope may also be the first to observe the light from planets orbiting nearby stars.

The funding of the project, engineering, design, and construction are all 100% Canadian. The principal investigator for the MOST project is Dr. Jaymie Matthews of the University of British Columbia. He calls MOST Canada's "humble" space telescope, since it is 1/10 the size and 0.001% the cost of the more famous Hubble Space Telescope. With a mirror diameter of just 15 cm, the MOST telescope is smaller than telescopes being used by thousands of amateur astronomers.

But this is Canada and funding is limited for projects such as MOST. With only $10,000,000 CDN available, costs had to be kept to a minimum. The spacecraft had to be small, the weight had to be kept down, and off-the-shelf materials had to be used. The limited size meant that new technologies would be developed and tried on MOST.

MOST is a microsatellite, which is a satellite that weighs less than 100 kg and measures approximately 60 cm on a side. About the size of a 27-inch television, MOST measures 65 cm by 65 cm by 30 cm and will weigh about 60 kg at launch. If you were travelling to the launch site to launch your microsatellite, you could just about check it with your other luggage. But don't expect it to arrive when you do.

MOST patch. Designed by Paul Fjeld.

Because microsatellites are limited in size and weight, they are usually simple in design and don't do much. They normally hitch a ride with a larger satellite on a rocket booster. Once the main payload is safely on its way, the secondary payload — the microsatellite — is unceremoniously tossed overboard into Earth orbit. Microsatellites are too small to have an attitude control system consisting of small rockets with a fuel supply onboard to keep them from spinning, so they are designed to tumble. They may transmit radio signals reporting on the local space environment, but that is about it.

Dr. Robert Zee and Dr. Jaymie Matthews at the August 1 unveiling of MOST for the media.

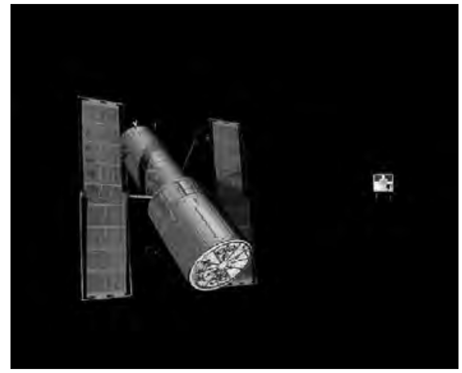
Clearly, a tumbling satellite is not a good platform for a telescope. The major achievement for the MOST team is the design and construction of a microsatellite with a stable platform from which to make telescopic observations. MOST will be able to point at a star and remain pointing at it with an error of less than 10 arcseconds. That is 400 times better than any other microsatellite to date. The spacecraft will spend between two and five years observing certain pre-selected stars for weeks at a time, measuring the changing brightness of each star to 1 part in 1,000,000. To put this sensitivity into perspective, consider this: to see the light from a street lamp 1 km away change by 1 part per million, you would have to move only 0.5 mm closer.

The MOST spacecraft consists of a rectangular "bus" that houses the electronics, communication equipment, power, and telescope. To fit the telescope into the bus, it has been placed on its side looking at a mirror positioned at a 45-degree angle, making it appear more like a periscope. Although the designers originally wanted to eliminate all moving parts on the spacecraft, for safety they have added a door over the telescope opening to prevent sunlight from entering and damaging the sensitive detectors in the case of an unexpected tumble. As a safeguard, power must be applied to open the door; a power failure will shut the door immediately.

MOST will be in a Sun-synchronous orbit, with the telescope side always pointing away from the Sun, to observe stars. The Sun-side of the microsatellite is covered with solar panels, to provide the 30 W of electricity necessary to power the electronics. There are five computers onboard: a housekeeping computer, two attitude control computers, and two instrument computers. When in orbit, MOST will pretty much be on its own most of the time. It is only when it passes over the three planned ground stations (two in Canada, one in Europe) that it will transmit data, receive instructions and, if necessary, send cries for help.

How MOST Came To Be

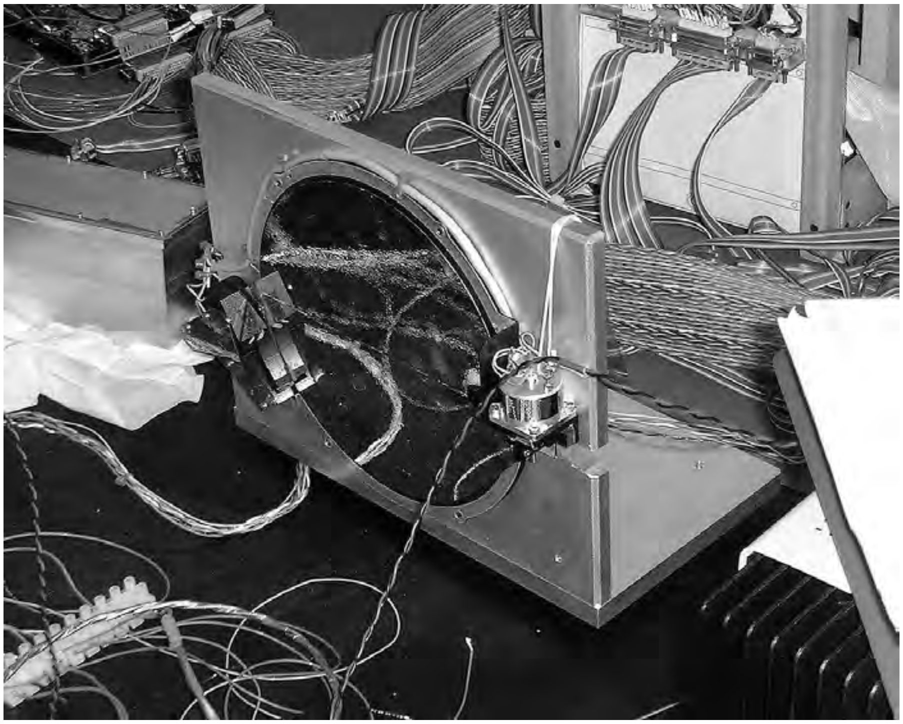
In 1996, the Canadian Space Agency announced the Small Payloads Programme, an initiative to support the launch of science microsatellites. A request for proposals was made. At a CSA meeting, Dr. Rucinski met Dr. Kieran Carroll, the Manager of Space Projects at Dynacon Enterprises Ltd. of Mississauga. The two started talking about potential satellite ideas. From these discussions arose the plans for MOST. In 1997, Dr. Rucinski left the MOST team to take a job in Hawaii, and Dr. Jaymie Matthews of the University of British Columbia became the principal investigator. In the spring of 1997, MOST, along with four other proposals, was chosen by the CSA for further study. A year later, MOST was chosen the winner and a contract with Dynacon as prime contractor was signed. Dynacon is responsible for systems engineering, the attitude control system, and power subsystems. It is the attitude control system, primarily designed by Dr. Carroll, that makes MOST possible. Small reaction wheels controlled by sophisticated software will control the attitude of the spacecraft and keep it pointed at the star of interest.



Comparison of the size of HST and MOST.

The University of British Columbia and the Centre for Research in Earth and Space Technology (CRESTech) of Toronto are responsible for the telescope.

The Space Flight Laboratory (SFL) at the University of Toronto Institute for Aerospace Studies (UTIAS) was made the prime subcontractor and is responsible for the bus, computers, thermal control, telemetry and command systems as well as assembling the spacecraft. It is also responsible for the ground stations, where data will be received from and transmitted to the spacecraft. Dr. Robert Zee is the Manager at SFL. In an effort to train engineers for the future, over 60 graduate students at the University of Toronto have had an opportunity to gain valuable experience working on some part of the MOST project.



An engineering version of the door is shown undergoing tests at SFL/UTIAS.

MOST – Quick Facts

Size: 65 cm × 65 cm × 30 cm
Weight: 60 kg
Telescope size: 15 cm
CCD size: two 1024 × 1024 pixel CCDs placed side by side
Launch date: April 2003 aboard a Russian "Rockot" from Plesetsk in northern Russia
Orbit: 950-km altitude, 100 minute period
Mission duration: between 2 and 5 years

The satellite is being funded by the Canadian Space Agency and the Ontario Research and Development Challenge Fund from the Province of Ontario.

Over the next two years from 1997 to 1999, critical design reviews were held and the construction of MOST began. During this time, Dr. Rucinski joined the MOST Science Team when he returned to Canada to work at the University of Toronto.

The Science

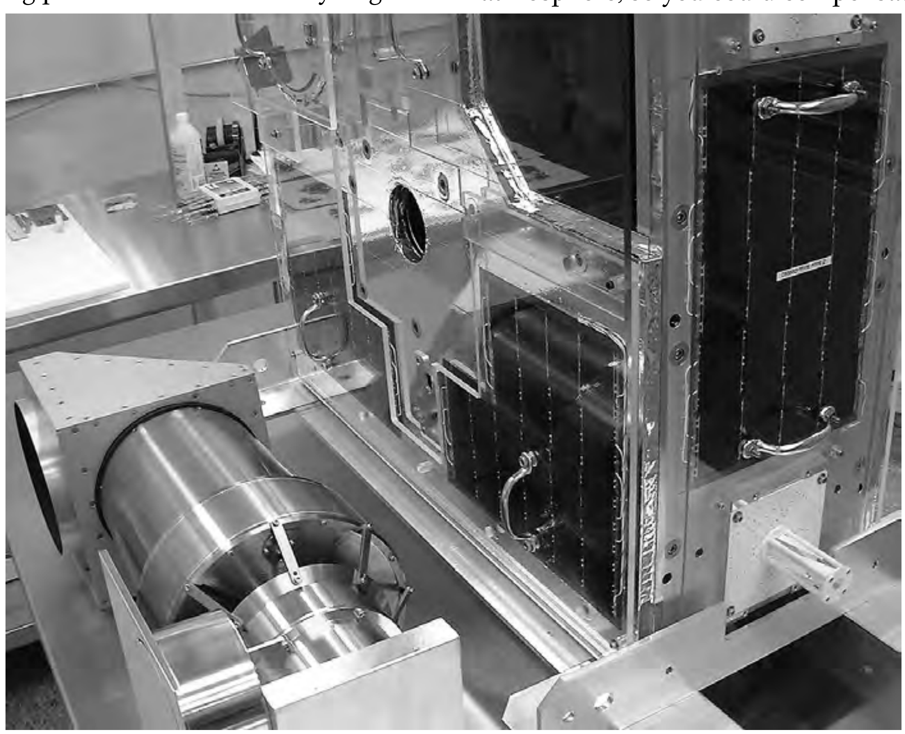
What is the Microvariability and Oscillations of Stars? What do we hope to learn with MOST? For a small satellite, Dr. Matthews is asking MOST to help answer some big questions.

Dr. Matthews is an astroseismologist, which means he studies the interiors of stars by observing the effects of sound waves under their surface. These sound waves are generated by turbulent motions in the star's surface (the photosphere), which then penetrate the star at different angles. As they travel down into the star, they encounter different temperatures and densities, which cause them to change speed and be deflected back to the star's surface. This creates oscillations at the surface of the star, which affects the star's brightness. This change, however, is very slight: a few parts per million.

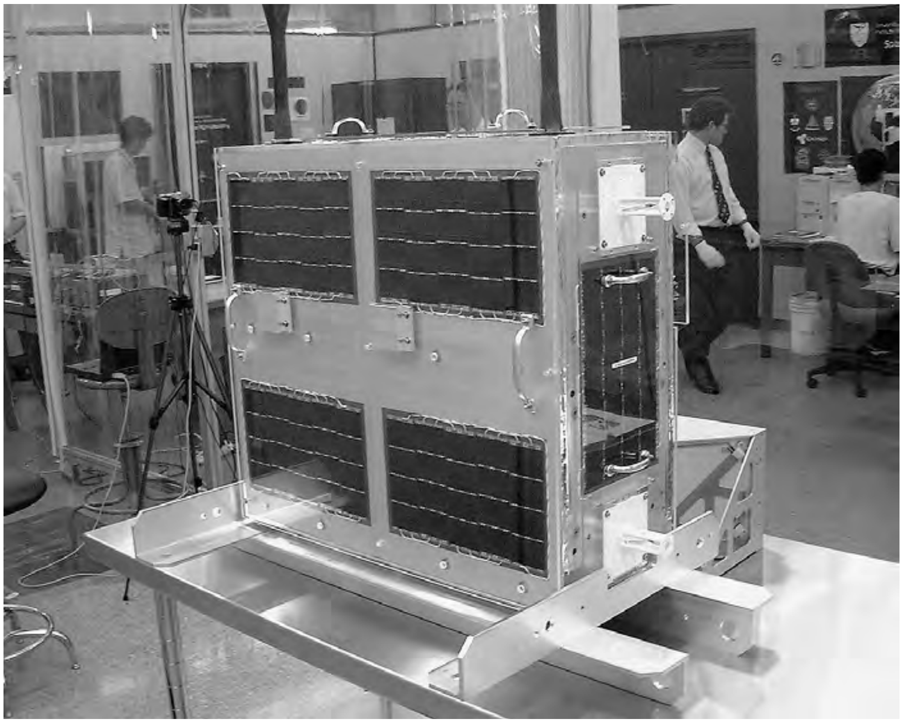
By measuring these changes over a long period of time and analyzing the data, an oscillation spectrum can be obtained. From this, much can be learned about the interior of the star.

Helioseismologists observe the oscillations of the nearest star, the Sun. The Sun is very dynamic and the gas at the surface is very turbulent. It oscillates every 5 minutes, causing it to ring like a bell.

Because all the other stars are much fainter than the Sun, to study their oscillations, you would have to link several 15-metre telescopes situated around the world to continuously make observations. The slight variability of the starlight would be wiped out by fluctuations in the atmosphere, so you could compensate



An engineering version of the telescope appears in front of MOST at SFL/UTIAS.



The Sun-side of MOST, covered in solar panels, is shown.

by using huge telescopes. Of course, bad weather at a site or a computer network problem could also ruin your observations. Plus, a project of this scale would cost millions — if not billions — of dollars. Alternatively, you could place a 15-cm telescope with a sophisticated data collection system into orbit around the Earth where it could make continuous observations of the stars. Sometimes bigger isn't better.

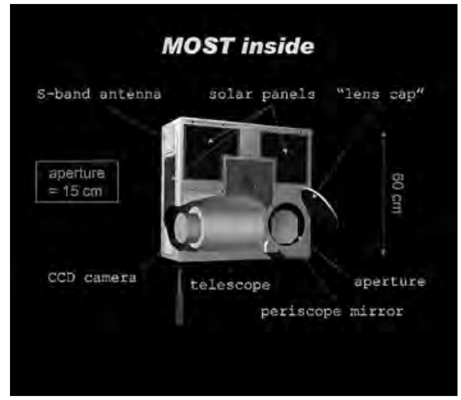
MOST will be looking at several different types of stars, which the science team has published on the Internet (see UBC Web site at end of article). Stars like the Sun — Procyon for example — will be observed to make comparisons of the models that are being used for these types of stars. Metal-poor subdwarfs will also be studied by MOST. These stars are thought to be very old. If the proportion of hydrogen to helium in these stars can be determined by obtaining oscillation spectra, the age of these stars may be determined and from that, the age of the universe.

Other targets for MOST are nearby stars that are known to have planets. The changing phases, and therefore the changing light levels, of a planet orbiting a nearby star are detectable with the MOST photometer. MOST may be the first instrument ever to make direct observations of a planet orbiting another star. From these data, the sizes and atmospheric compositions of these planets can be obtained.

Finally, Wolf-Rayet stars will be observed to try and learn how these massive, luminous stars add gas to the interstellar medium.

Public Outreach and the RASC

In 1996, when the original proposal for MOST was being drafted, Dr. Kieran Carroll approached the author about the possible affiliation of the RASC with the project. The RASC would organize and run a contest for Canadian students who would develop and propose observing projects



The MOST spacecraft (image courtesy of Slavek Rucinski).

for MOST. It is the plan that high-school students will work closely with university students or professors to develop these proposals. Two years after launch, the contest winner will be announced and the observing time allotted.

What an excellent opportunity for the Society to lend its support to this project, the first Canadian Space Telescope.

Next issue: How to point and shoot with MOST plus launch booster blues.

For more information on MOST visit these Web sites:

MOST: University of British Columbia (`www.astro.ubc.ca/MOST/2002/index.html`)

Dynacon (`www.dynacon.ca`)

Canadian Space Agency (`www.space.gc.ca/csa_sectors/space_science/space_astronomy/most/default.asp`)

Utias/SFL (`www.utias-sfl.net/`)

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An introduction to astronomical Events Recorded in THE RUSSIAN CHRONICLES

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In this year [1065], Vseslav began hostilities. At the time there was a portent in the west in the form of an exceedingly large star with bloody rays, which rose out of the west after sunset. It was visible for a week and appeared with no good presage…[1066] Vseslav came and took Novgorod, with the women and children; and he took down the bells from St. Sophia — Oh great was the distress at that time!

These excerpts from the Russian chronicles describe events that occurred in the eleventh century. Those interested in history may be pleasantly surprised to discover that such written accounts exist and can be explored. Astronomy enthusiasts will find the reference to the '*portent in the west*' of interest. What object was the chronicler describing? Can it be identified? Can the date be confirmed by other sources?

In this article, several astronomical events from the Russian chronicles will be examined including accounts of solar eclipses, lunar eclipses, comets, aurorae, sunspots, and meteor showers.

1. Introduction

In many early Christian monasteries it was a tradition to maintain an annual chronicle of local religious, political, and physical events. Many of these chronicles have been lost or destroyed, but a few have survived to provide valuable historical insights. In the western Christian church, the chronicle of the Venerable Bede (672–735) is an important document in British history. In the eastern Christian church, the chronicle of George Hamartolus (842–867) is an important document in the history of Constantinople.

In 988, Vladimir the Great, ruler of the Slav state of Rus, adopted Christianity as the state religion. In the following centuries, many churches and monasteries were established and the tradition of maintaining chronicles took root in medieval Russia. Unlike the Latin chronicles of the west, the Russian chronicles were written in the local language. It was also the custom for each new Russian chronicler to copy much of the previous writings of several monasteries before beginning to record the events of his own time. The result was a network of chronicles with overlapping content. These chronicles contain a treasure-trove of information on events in the Russian state from the years 911 to 1566. The overlapping feature of the Russian chronicles has made it difficult for historians to establish the identity of the original authors, but has made it possible for many descriptions of historical events to survive even when the original chronicles have not.

By the tenth century Kiev was the centre of the Rus state and an established trading centre on the banks of the Dnepr River. The Dnepr was part of an ancient route connecting northern Europe to the Byzantine Empire. The first Russian chronicle was created and compiled at Kiev from the early eleventh century to the mid-thirteenth century. At that time much of the city was destroyed by Mongol invaders. The chronicle of Kiev has become known as the *Primary Russian Chronicle*, because it also includes the earliest known history of the Rus state. Kiev is located at 50.4° north and 30.5° east.

Another important chronicle was created and maintained at Novgorod, from the tenth to the fifteenth centuries. Novgorod is located on the Volkhov River in northern Russia, at 58.5° north and 31.3° east. Novgorod was a principality of Kiev up to 1240. By 1478 Ivan III had completed his conquest of Novgorod and brought it under the control of Moscow. This effectively brought the *Chronicle of Novgorod* to an end.

During the period covered by the *Primary Russian Chronicle* and the *Chronicle of Novgorod*, Kiev and Novgorod were prosperous medieval cities. As in most medieval cities, everyday life was punctuated by local wars, plagues, fires, floods, and droughts. The Russians of this time were not known for their astronomy. Their cosmological view was Aristotelian, and unusual events in the sky were regarded as portents, or reflections of events on earth. Included among the chronicle entries are many descriptions of portents that correspond to astronomical events. The contents of these chronicles have survived over the centuries and contain one of the most complete sets of European astronomical observations for the medieval period.

The number and type of astronomical observations at any site are limited by local conditions. Novgorod, and to a lesser extent Kiev, are northern cities carved out of the Russian forests. At those sites, one can expect freezing temperatures and/or cloudy skies during the extended winter nights, and during short summer nights one can expect to encounter clouds of mosquitoes. In medieval times and under those conditions, one would expect relatively few observations of late-night astronomical events. It is no surprise then that the most common records dealing with astronomical events refer to solar eclipses.

In addition to reviewing the astronomical events in the *Primary Russian Chronicle* and the *Chronicle of Novgorod*, events and information from other sources are integrated into the discussion.

2. Dates and Time

The dates used in the Russian chronicles require some interpretation. Years were normally counted from the creation of the world in 5508 BCE, as determined by the Byzantine church. In the earliest chronicles, the new year began on the day of the first new Moon after the spring equinox. After some time, the Church New Year was introduced, which began on the first day of September. There was also frequent contact with western Europe and the use of the Julian calendar was not uncommon. Often, more than one mode of recording dates was used at the same time. The use of months and days of the week were usually connected with the celebration of a saint's day, and are much more consistent. Daylight hours were counted from 0^h at sunrise to 12^h at sunset. The hours of the night were similarly counted from 0^h at sunset to 12^h at sunrise.

Although the procedures for converting dates from various calendar systems to the Gregorian calendar are generally straightforward and accurate (Stephenson 1997), the Gregorian dates for historical events can still contain occasional errors. A description of an historical event may have been recorded many years after the actual event. Many ancient records reach us only after being transcribed, interpreted, and edited by different writers. Each transcription provides an opportunity for an accidental change in the content.

3. Historical Observations

In this section a variety of chronicle entries that describe astronomical events are presented with brief commentaries. This sampling includes descriptions of eclipses, comets, aurorae, and sunspots. In addition, the data for all solar and lunar eclipses described in the chronicles has been summarized in Tables 1 and 2. Abbreviations of the type (CS) or (AV) are used for frequently cited sources. The sources are discussed in Appendix A. Italics are used to denote excerpts from an historical document. The first number for each record corresponds to the year in the Gregorian calendar. The data for eclipse records have been generated for the location of Novgorod using the procedures described in Appendix B. The times given in the commentaries are local times.

908–911 *A great star appeared in the west in the form of a spear.* (CS)

A nova was recorded in June 911 near α Herculis, however this is unlikely to have been described as having the form of a spear. (DS) simply lists the year 912 as one of the Russian sightings of Halley's comet. (HY) notes that the Chinese and Japanese observed Halley's comet in 912.

1028 *A portent visible to the whole country appeared in the heavens. (CS)*

There appeared a sign in the sky like a serpent. (MF)

Judging by other descriptions in the chronicles, the term "serpent", "snake", or "dragon" was used to indicate an elongated object. For similar examples, see the entries for 1091 and 1214. The lack of an adjective such as 'flying' indicates that the object was slow moving, or perhaps stationary. This is probably a description of a comet.

1064 *Before this time even the sun changed and was not bright but became like the moon. Ignorant people said that the sun was being eaten up*. (AV)

There was a partial solar eclipse on April 19, 1064. It reached a maximum magnitude of 0.942 at 4:05 p.m., at an altitude of 25° in the west.

1065 *In this year, Vseslav began hostilities. At the time, there was a portent in the west in the form of an exceedingly large star with bloody rays, which rose out of the west after sunset. It was visible for a week and appeared with no good presage*. (CS)

This event is from the introductory excerpt. According to (DS), "It is the same appearance of Halley's comet which is associated with the Norman invasion of England" in 1066.

1091 *In this year while Vsevolod was hunting wild beasts behind Vyshgorod, and as the men were stretching snares and the beaters were shouting, a huge serpent fell from the sky, and all the people were terrified. At this time the earth uttered a groan audible to many*. (CS)

This report probably describes a single, bright bolide. There is only one serpent and the event was bright enough to be visible during the daytime. Audible sounds from the passage of a large meteor through the atmosphere are not uncommon.

1092 *An extraordinary event occurred at Polotsk. At night there was heard a clatter and groaning in the streets, and demons ran about like men. If any citizen went forth from his house to look upon them, he was wounded straightway by some invisible demon, and so many perished from such wounds that people dared no longer to leave their houses. The demons later began to appear on horseback during the day. They were not visible themselves but the hoofs of their horses could be seen. Thus they did injury to the people of Polotsk and the vicinity, so that it was commonly said that ghosts were killing the people of Polotsk. This portent had its beginning in Dryutesk. At this time, a sign appeared in the heavens like a huge circle in the midst of the sky.* (CS)

1092 *A panic came over the people of Polotsk, so that it was impossible to walk in the streets, because it was as if there was a quantity of soldiers and as if* *one could see horses' hoofs; and if anyone went out of his house, he would be suddenly and unaccountably killed.* (MF)

A possible interpretation is that the daytime demons were a broken meteor that scattered many fragments over Polotsk (55.5° north and 28.7° east, in Belorussiya), that injured a number of the citizens, and left indentations in the ground described as hoof prints. The sentence describing "a huge circle in the midst of the sky" may represent a separate event such as an atmospheric halo around the Sun. There was a comet reported in the east in Orion on January 8, 1092. (HY)

1102 *On January 29 of this year, there was a portent in the heavens visible for three days, resembling a fiery ray which proceeded from east, south, west, and north, and all night there was as much light as shines from the full moon.* (MF)

(DS) lists this event with other observations of the aurora. On September 29, 1102, another aurora was seen in Italy, indicating that the Sun was active during this year.

1102 *On February 5 of this year there was a portent in the moon.* (MF)

There was a full Moon on February 5, 1102, but there were no lunar eclipses at this time. Neither of the lunar eclipses that did occur in 1102 was visible from Novgorod, nor Kiev. Perhaps an aurora, or a meteor, appeared in front of the Moon.

1102 *On the seventh of the same month* (February) *there was a portent in the sun: it was surrounded by three rainbows, and there were other rainbows one above the other. (MF)*

There were no solar eclipses during February 1102. This was a time of high solar activity. Perhaps the portent refers to sunspots and the three rainbows may refer to aureole, a normal cloud phenomenon. In any event, the Russian chroniclers were keeping a close watch on the sky in early 1102.

1104 *In this year a portent appeared. The sun stood in a circle; in the middle of the circle, a cross appeared, and the sun stood in the middle of the cross. Within the circle, on both sides, were seen two other suns, and outside the circle, above the sun, there appeared a rainbow with its horns to the northward. There was likewise a portent of the same aspect in the moon on February 4, 5, and 6, so that this portent was visible three days in the sun and three nights in the moon by night.* (MF)

This could be the description of a halo complex. The circle with the Sun would be the usual 22° halo, while the two other suns would be normal sundogs (although these are on or just outside the 22° halo). Portions of an apparent cross could have been generated by a parhelic circle. The specific description "outside the circle, above the Sun, there appeared a rainbow with its horns to the northward" is a good and unique description of a circumzenithal arc. This is caused by cirrus clouds and is fairly common. Halo complexes can also be produced by moonlight, but the Moon was at first quarter on February 5, 1104, and probably would have been too faint to produce a prominent display. Meteorological conditions could well have produced a display that lasted for a few days.

1113 *On the 19th of March there was a terrifying darkening of the sun and very little of it was left… just like a crescent of the moon with its horns downwards.* (AV)

There was a partial solar eclipse on March 19, 1113. It reached its maximum magnitude of 0.61 at 7:47 a.m., at an altitude of 15° in the southeast. And according to a computer simulation, its horns were indeed pointing down at that time.

1122 *There was a sign in the sun in the month of March, on the tenth day, and in the moon during the same month on the 24th day.* (AV)

There was a partial solar eclipse, with a magnitude of just 0.27 on March 10, 1122. The maximum occurred at 7:21 a.m., at an altitude of 8° in the east. In the same month, on the 24th, there was a partial lunar eclipse. The magnitude of 0.24 was reached at 12:23 a.m. (actually March 25th local time), at an altitude of 26° in the south.

1141 *On April 1 there was a very marvelous sign in the sky; six circles, three close about the sun, and three other large ones outside the sun, and stood nearly all day.* (MF)

This is probably another large halo complex.

1145 *Vsevolod sent for his brothers Igor and Sviatoslav, and for Volodimir and Izyaslav Davidovichi, and they came to Kiev. And then a very great star appeared in the west letting forth rays.* (AV)

"In its 1145 appearance Halley's comet was a morning star until the middle of May, and only after May 14 did it appear in the west." (AV)

1149 *The same night there was a sign in the moon; the whole of it perished, during the morning service it filled out again, in February.* (MF)

This seems to be a clear description of a lunar eclipse. However, there was no lunar eclipse during February that year. There was a lunar eclipse on March 26, 1149, but that was partial and occurred about 2:30 a.m., local time. There was a total lunar eclipse on March 15, 1150. It reached a maximum at 5:07 a.m., just above the western horizon.

1185 *On the 1st day of May, at the 10th hour of the day, at evening bell, the sun grew dark, for an hour or more, and there were the stars; then it shone out again and we were glad.* (MF)

There was a total solar eclipse visible in the late afternoon at Novgorod on that day. The comment that stars are visible during a total solar eclipse is common in old chronicles. However, it is unlikely that any actual stars were observed during historical eclipses, with the possible exception of Sirius. Observing a star with magnitude 0.0, or fainter, during a solar eclipse is very difficult unless the observer is deliberately searching for it and knows exactly where to look. Reports of seeing stars during a solar eclipse are probably references to the planets Venus and/or

Jupiter, and occasionally Mercury. During the total eclipse on May 1, 1185, Venus had a magnitude of –3.9 and would have been easily sighted about 24° above the Sun. Other objects that also might have been observed include Jupiter with a magnitude of –1.6, high in the east; Sirius with a magnitude of –1.4, low in the south; and Mercury with a magnitude of –0.6, near Venus and 17° from the Sun.

1187 *The same year, in September, on the ninth day, there was a sign in the sun, about noon, when it became dark, and the sun appeared as a crescent. But after a short while it filled in again and became brilliant.* (AV)

There was a partial solar eclipse visible in the early afternoon at Novgorod on September 4, 1187.

1201 *During the same winter there was a sign in the moon in the month of December on the 24th day, the day of Saint Eugenia. The princess of the House of Yaroslov … died the next morning.* (AV).

Saint Eugenia's Day does occur just before Christmas. Although the chronicle date is for the year 1201, the eclipse that seems to match this record was a total lunar eclipse that occurred on December 22, 1200. It reached its maximum at 7:42 a.m., just above the horizon in the northwest. The partial lunar eclipse of December 11, 1201 was below the horizon at Novgorod.

1202 *During the same winter there were many signs in the sky, but we shall describe only the following. It occurred in the fifth hour of the night that the whole sky began to run and became red, and to the men who saw it, it seemed as if blood was spilled over the snow that covered the ground and the house roofs. And some people saw the streaming of the stars in the sky; the stars tore themselves off and fell toward the earth. The witnesses thought it was the end of everything. All these signs, either in the sky, or in the stars, or in the sun, or in the moon, or anywhere else, are not for good. They foretell evil, either wars or famine or somebody's death.* (AV)

A display of the aurora borealis was observed along with a Leonid meteor shower on October 18, 1202.

1206 *During the same winter there was a sign in the sky, in the sun on the 28th of February, on Wednesday of butter-week, and it lasted from noon till the evening service. What was left of the sun was like the crescent of the first-day moon.* (AV)

There was a partial solar eclipse, with a magnitude of 0.89, on February 28, 1207. Its maximum occurred at 2:07 p.m., at an altitude of 22° in the southwest. 'Butter-week' is the week before Lent.

1214 *On February 1, on Quinquagesima Sunday, there was thunder after morning service, and all heard it; then at the same time they saw a flying snake (or dragon).* (MF)

This was likely a bright bolide with a tail. (AV) notes that this event probably occurred in 1215 since Quinquagesima (butter-week) Sunday occurred on February 1 in 1215, while in 1214 it occurred on 1 March.

1222 *During the same year there appeared a star in the west; rays were coming from it not toward people but toward the south; two rays appeared from it as it was rising in the west after sunset, and it was more magnificent than any other stars. And it was like this for seven days; and after that the rays went from it towards the east. This lasted for four days and then it became invisible.* (AV)

Halley's comet was visible during September in 1222. Halley's comet was also noted in Chinese records for September 1222. (HY)

1230 *During the same month, on the fourteenth day, on Tuesday of the sixth week after Easter, the sun, as the people were watching it, began to disappear and little of it was left, and it became like a three-day old moon. And then it began to fill in again, and many people thought it was the moon traveling across the sky, because it was then the time between the moons. But other people thought that it was the sun who had begun to move backwards because many frequent and small clouds were moving rapidly across the sun from north to south. On the same day and at the same hour the same apparition was seen in Kiev, where it was even more terrifying. Everybody there saw the sun become like the moon, and on both sides of it appeared two moving columns of scarlet, green and blue. Then a fire came down from the sky which looked like a huge cloud and stood above the creek Lebed. All the people despairing of their lives and thinking death was close at hand began to embrace each other and ask one another's forgiveness and the wept bitterly and prayed. … All this was told to us by witnesses who were there personally.* (AV)

There was a partial solar eclipse on May 14, 1230. In Novgorod, it reached a maximum magnitude of 0.92 at 5:54 a.m., at an altitude of 18° in the east. In Kiev, it reached a maximum magnitude of 0.83 at 5:46 a.m., at an altitude of 15° in the east. The scarlet, green, and blue colours noted at Kiev may refer to an aureole or to iridescent clouds.

1259 *There was a sign in the moon; such as no sign had ever been. (MF)*

There was a sign in the moon, but it was really not a sign. (AV)

These two interpretations highlight the importance of a translator's skill. In the first translation, the phrase *such as no sign had ever been* seems to imply that a major event had occurred. In the second translation, the phrase *but it was really not a sign* seems to imply that the event was relatively minor and did not qualify as a portent of things to come.

The lunar eclipse of November 1, 1259 was partial, with a magnitude of 0.7. The maximum occurred at 10:24 p.m., with the Moon in the south-southeast at an altitude of 46°.

1264 *A star with a tail appeared in the east and it was horrible even to look at. It let out long rays, and it was called a 'hairy star'.* (AV)

There appeared a terrifying star. It was shining for more than three months, *and let out rays which reached the noon part of the sky.* (AV)

In July 1264 a comet was observed in many European localities and in the east (HY).

1266 *During the same winter a star appeared in the west and it had a long ray like a tail which was directed toward noon. It remained there for thirteen nights and after this became invisible.* (AV)

In January of 1266 a comet was recorded by the Japanese. (HY)

1269 *Great wonders. People saw an army fully equipped in the sky; it was divided into two parts which fought one another. During the same year in the night of December 6, a light appeared in the sky in the shape of a cross and illuminated not only the town but all the surrounding country as well.* (AV)

(AV) lists this event as a display of the aurora borealis and comments, "It requires little imagination to see in certain auroras the flashing spears and waving banners of a medieval army."

1271 *The sun darkened on the fifth Sunday of Lent in the middle of the morning; it filled up again and we were glad.* (AV)

There was partial solar eclipse on March 23, 1270. The maximum magnitude of 0.90 was reached at 8:13 a.m. at an altitude of 20° in the southwest. There were no solar eclipses visible at Novgorod during 1271.

1284 *There was a sign in the moon, on December 24th, on Sunday. Two weeks later, in January, on the twelfth, a calamity happened; the Germans massacred the people of Pskov … such signs are not for good but always foretell evil.* (AV)

There was a partial lunar eclipse on December 24, 1284. It reached its maximum magnitude of 0.8 at 5:45 a.m., at an altitude of 20° in the west.

Notice in the chronicle record, that in the first date a 'th' abbreviation is used while in the second date, the number is written in full. This difference in style for two dates in the same record serves to remind us that every number, and date, in these chronicles is only available to us after a series of copying, editing, and translating efforts.

1301 *During the same year, in autumn, there appeared a star in the west, with rays which looked like a tail turned upwards, while its face was turned toward the south.* (AV)

This passage of Halley's comet in October 1301 was also observed by the Chinese. (HY)

1316 *During the same year the moon lost its light before the early dawn and went down still not filled up.* (AV)

There was a total lunar eclipse on October 2, 1316. It reached its maximum at 4:18 a.m., at an altitude of 15° in the west. The Moon was just exiting the penumbra as it set at 4:30 a.m.

1331 *…and they confirmed him on the Day of the Apostle St. Titus. A sign then appeared in the heavens: a bright star over the church.*

In the Eastern Orthodox Church, the feast day for St. Titus of Crete is August 25. On this date, Venus was near its greatest western elongation, about 50° ahead of the Sun, and could have been seen in a clear daytime sky. (DS) lists this event as a daytime sighting of Venus.

1365 *During forest fires the Sun appeared bloody and on its surface were seen some 'black spots like nails'.* (DS)

Sunspots were also recorded in China that year. The juxtaposition of sunspots with forest fires is not accidental. The smoke from forest fires has the potential to dim the Sun sufficiently for people to look at the Sun in detail. In general, old sunspot reports must have been associated with some circumstance (forest fires, dust storms, volcanic ash in the stratosphere; all perhaps combined with a low solar altitude) that substantially dimmed the Sun.

1382 *There was a portent or a sign which appeared in the sky for several nights. In the east, before dawn, a certain star appeared with a tail in the shape of a spear. Then it was visible in the evening dusk, and then again in the morning dawn. This happened several times. This sign foretold the invasion of the Russian land by the Khan Tokhtamysh and the vicious attack on the Christians by the infidels.* [The destruction of Moscow by the Tartars occurred in 1382.] (AV)

(DS) lists this event as a description of Halley's comet, which would have risen in the east just before sunrise in early October 1378 at Novgorod. An observation of Halley's comet recorded on September 26, 1378 in the Chinese records (HY). There were also other bright comets sighted in Europe (BH) and the far east (YP) during 1380 and 1381.

1385 *In the winter of the same year, on January 1, there was a sign in the sun, on the day of the Holy Father Vasili.* (MF)

There was no solar eclipse on January 1, 1385. However, there was a partial solar eclipse visible at Novgorod on January 1, 1386. A different chronicle record gives the date as 1386 and (AV) lists this event as the eclipse of January 1, 1386.

1399 *In the month of September the moon darkened in the fourth hour of the night. And for a long time there was none of it left and therefore it was very dark.* (AV)

There was no eclipse visible at Novgorod in September 1399. However, the lunar eclipse of April 20, 1399 provides a reasonable match. Its maximum was at 9:45 p.m., roughly the fourth hour of the night, with the Moon at an altitude of 11° in the south-southeast. "The error in the name of the month may probably be traced to the confusion created by the custom of counting the 'Church Year' from September 1, while still retaining the earlier 'Spring Year' which began in March." (AV)

1402 *There was a sign in the sky, a tailed star, having a bright ray in the west, which lasted all of the month of March.* (MF)

There were many sightings of this comet, in Asia, as well as in Europe. (BH)

1406 *In the same year, on Tuesday before Saint Peter's Lent, the moon lost its light before early dawn and it set before it brightened up*. (AV)

There was a partial lunar eclipse on June 2, 1406. It reached a magnitude of 0.7 about 3 a.m., just above the western horizon. The Moon set about 3:00 a.m. while still mostly in the umbra.

1415 *The Tartars ravaged the country round Elets, and Moscow and Smolensk were burnt; and there was a sign in the sun on June 7*. (MF)

There was a partial solar eclipse, with a magnitude of 0.94, on June 7, 1415 at Novgorod. The maximum occurred at 8:32 a.m., at an altitude of 40°. Observations of this eclipse were recorded in over ten different Russian chronicles. The eclipse was total a few hundred kilometres to the southeast of Novgorod.

1421 *The same year on May 19, during Peter's Fast, there was a great storm by night in the skies; clouds came up from the south, and in the north thunder and fiery lightning came from the skies with frightful noise, and purple rain fell with stones and hail.* (MF)

This is probably a description of a terrestrial weather event; however, falling stones might refer to a meteor shower.

1476 *In the month of March, on the tenth day, but of the celestial February on the fifteenth, during the night from Sunday to Monday, in the third hour, the moon began to lose its light and lost all of it. Up to midnight nothing was seen of it, and later it appeared again.* (AV)

There was a total lunar eclipse on March 10, 1476. It reached maximum at 6:46 p.m. 'The full Moon was referred to as the "Celestial February" because fifteen days passed from the "birth of the Moon in February".' (AV)

1485 *During the same year on the day of the Saint Elija, the sun lost its light.* (AV)

According to (AV), Saint Elija's day was July 20, 1487. There was a partial solar eclipse, with a magnitude of 0.88 on that day. The maximum occurred at 3:28 p.m.

1533 *At that time, on August the twentieth, on Wednesday, there was a sign in the sky. As the sun was rising at the second hour, its top appeared sliced off… at the fifth hour it was full again* (AV).

There was a partial solar eclipse, with a magnitude of 0.43 on August 20, 1533, at an altitude of 6° in the east. The maximum occurred at 5:45 a.m., as the Moon moved across the upper left of the Sun's disk.

1563 *On the twentieth of June, before the evening, there occurred a diminishing of the sun, as if the moon came under the sun. It was dark for only a short time, and it happened at the beginning of the birth of the moon.* (AV)

There was a partial solar eclipse, with a magnitude of 0.86 on June 20, 1563. The maximum occurred at 6:15 p.m. In this record, there appears to be an understanding of the real cause of the eclipse. This was hinted at previously: see entry dated 1230 for a similar hint without mention of a possible understanding of the cause of the eclipse.

4. Discussion of Observations

The Russian chronicles contain forty-two entries describing solar eclipses. The chronicle dates (based on Vyssotsky) and the dates of corresponding solar eclipses in the NASA/Goddard lists (as described in Appendix B) are summarized in Table 1. Twenty-four of the solar eclipse entries (58%) have dates that are accurate to the day, including twelve entries that also describe the time of day. Only eight entries (19%) for the solar eclipses had errors in the dates.

Scanning through the magnitudes and altitudes listed in column 4 of Table 1, it can be seen that most of the observed eclipses had relatively large magnitudes and/or low altitudes. From a scatter plot of the magnitudes and corresponding altitudes, it can be shown that 40 out of the 42 observed eclipses satisfy the relation: $M > 0.15(1 + 0.1a)$, where M = observed magnitude, and a = altitude ($0° < a < 56°$). Such a relationship is reasonable. During a partial eclipse there may not be a significant change in the overall brightness of the sky, yet the exposed part of the solar disk is still bright enough to damage the naked eye. At lower altitudes, atmospheric extinction dims the solar disk making it easier to view, and a person's eyes naturally look toward the horizon rather than upwards, so lower altitudes are scanned more often. A dramatic eclipse near the horizon is more likely to be observed than a partial eclipse near the zenith.

Chronicle entries describing thirty-seven lunar eclipses are summarized in Table 2. Twenty-eight of these eclipses were total, eight were partial (including two penumbral eclipses). The lunar eclipse of November 1, 1259 was unusual in that it was observed and recorded even though it was only a partial penumbral eclipse and it occurred at the relatively high altitude of 46°. Only twenty (54%) of the chronicle records for lunar eclipses correspond directly to eclipses in the NASA/Goddard lists. Seventeen (46%) of the lunar eclipse observations have errors in their dates, and 13 of these are in error by a year, or more. Apparently, there were systematic difficulties in recording the correct dates of lunar eclipses in medieval Russia.

A total of seventy-nine eclipses are described in Tables 1 and 2. Only thirty-five of these observations (44%) are accurate to the day. Another 19 observations (24%) are accurate to the year and/or month. The remaining twenty-five eclipse observations (32%) have recorded dates that are in error by at least a day. Similar error rates have been found in medieval chronicles from western Europe (Newton).

Errors in dates could have arisen from faults in the original observations, from copying errors, from confusion in the use of various calendars, or from editorial changes. Some of the errors, particularly the year dates for lunar eclipses, seem to have systematic components. One should not rush to characterize ancient chroniclers as careless record keepers. See Appendix C for examples of modern errors that could also lead to the erroneous dating of historical astronomical events.

On occasion, different chronicles reported different years for the same description of an event. For example, according to Vyssotsky the '*portent in the west*' of 1065 is reported as occurring in 1064 in the chronicles of Lavrentievsky and Avrahamka, but in 1065 in the chronicles of Novgorodsky I and Gustinsky. Similarly, the eclipse identified with May 21, 1091 is listed as occurring in 1091, 1078, 1088, and 1088 in four different chronicles. A total of thirty-four year dates were reported in various chronicles for the ten eclipses recorded between 1113 and 1185. Eight of these thirty-four year dates (24%) were in error by one year. These numbers provide some indication of the error rates for copying and/or ancient calendar conversions by scribes.

5. Summary

When you read the Russian chronicles, you are communing with a series of ancient authors who recorded significant events occurring around them. The original entries and interpretations help to bring that period of history back to life.

The Russian chronicles contain a rich collection of observations of eclipses, comets, aurorae, and other celestial phenomena. These chronicles span a period from 911 to 1566, and reflect the determined will of the Russian people to survive a variety of historical challenges. A majority of astronomical events described in the chronicles can be confirmed by independent sources. This fact adds significant credibility to other historical events described in the chronicles.

Observations of eclipses are of particular interest to historians because these records can be compared with the features of computed eclipses. When a match can be found between a computed eclipse and an historical record, the veracity of the historical record is enhanced, and by examining the details of the computed eclipse it is possible to gain a greater appreciation of the historical event.

The eclipse data also provide evidence that errors exist in approximately one third of the dates ascribed to events in the Russian chronicles.

Appendix A: Notes on the Historical Sources

In 1837 the Russian Archeographic Commission began the task of collecting, editing and publishing the *Medieval Russian Chronicles*. To minimize the impact of modern editorial interpretations the original archaic Russian language was retained. By 1921 more than two hundred manuscripts had been published in twenty-four volumes.

In 1916 descriptions of the astronomical items in the chronicles published by that date were summarized, in the original archaic Russian, by Daniel Sviatsky. A two page summary of his work was published in the *Journal of the British Astronomical Association* in 1923. A more extensive summary of Sviatsky's work was published by Alexander Vyssotsky in the *Historical Notes and Papers of the Lund Observatory* in 1949. In the works of Sviatsky and Vyssotsky, the astronomical events have been extracted from their historical context, and have been classified and matched with historical astronomical events.

An English translation of *The Chronicle of Novgorod* (based on the chronicle Novgorodsky I) was prepared by Robert Mitchel and Nevill Forbes in 1914. A translation of the *Russian Primary Chronicle* by S.H. Cross and O.P. Sherwood-Wetzor was published in 1953. If you are interested in history as well as astronomy, then these works let you discover astronomical events mixed in with the descriptions of daily events in medieval Russia. The *Primary Russian Chronicle* spans the years from 852 to 1114 and focuses on the events at and around the city of Kiev. *The Chronicle of Novgorod* spans the years from 1016 to 1471 and focuses on the events at and around the city of Novgorod. Limited versions of these chronicles can also be found in *The Russian Chronicles*, edited by Joseph Ryan in 1990.

Many of the astronomical events described in the Russian chronicles can be matched with astronomical events recorded in other historical documents. Ho Peng Yoke, in his paper "Ancient and Medieval Observations of Comets and Novae in Chinese Sources", presents a detailed summary of astronomical events recorded in historical documents of the far east. Barry Hetherington, in A Chronicle of Pre-Telescopic Astronomy, provides a listing of astronomical events in historical records from around the world.

The following abbreviations are used in Section 3 for frequently cited sources:

- (CS) – Cross and Sherwood-Wetzor, *The Russian Primary Chronicle* (1953)
- (MF) – Mitchel and Forbes, *The Chronicle of Novgorod* (1914)
- (AV) – A. Vyssotsky, *Astronomical Records in the Russian Chronicles from 1000 to 1600 A.D.* (1949)
- (DS) – D. Sviatsky, "Astronomy in the Russian Chronicles" (1923)
- (HY) –Ho Peng Yoke,"Ancient and Medieval Observations of Comets and Novae in Chinese Sources" (1962)

Appendix B: Simulating Ancient Eclipses

The following procedure was very helpful in simulating the visual appearance of, and in determining the properties of, historical eclipses.

i) Note the date, location, and description of an eclipse in an historical record.

ii) The NASA/Goddard Space Flight Centre Web sites: `sunearth.gsfc.nasa.gov/eclipse/SEcat` (solar eclipses) and `sunearth.gsfc.nasa.gov/eclipse/LEcat` (lunar eclipses), provide basic data for all eclipses from −1999 to +3000.
Find the eclipse of the required type that comes closest to the date of the historical record. Finding the best fit may require some trial-and-error runs through steps iii) and iv).

iii) Run a computerized star-catalogue program such as *Starry Night Pro* by Sienna Software Inc., 2000 or *Voyager III* by Carina Software. With either of these programs, you can enter the longitude and latitude of a site on Earth, enter the date, and set the time to Universal Time or local time. The positions of stars, planets, the Sun, and Moon are calculated for that time and that location, and then the local sky is displayed. Time can be advanced in regular intervals and the computed eclipse can be observed, as it would have appeared at the given time and location. Utilizing the **FIND** function to locate the Sun or Moon simplifies searching the virtual sky. If a simulated eclipse occurs above the horizon, then it could have been visible at the selected site at the given time.

iv) The details of the computed eclipse can be viewed using the **ZOOM** function, and can then be compared with any details in the historical record.

For an overview of eclipse characteristics, see Eclipse Patterns in the *Observer's Handbook 2002* of the RASC.

Appendix C: Examples of Erroneously Dating Astronomical Events in History

In *The Russian Chronicles* (ed. Ryan, 1990), an account is given of the events surrounding the death of Yaroslav in the year 1054. Then the entries from 1055 to 1065 are omitted without comment, and in the very next paragraph an undated account is given "*At the time, there was a portent in the west in the form of an exceedingly large star with bloody rays...*" The juxtaposition of the entry from 1054 with a partial entry from 1065 makes it appear to the reader that the "*portent in the west...*" actually occurred in 1054. The eruption of a supernova in the Crab Nebula in 1054 is a famous astronomical event. A reader of Ryan's book might erroneously identify the "*portent in the west...*" as an historical account of the Crab Nebula supernova. Vyssotsky has more accurately classified this account as a description of Halley's comet in 1066.

In a second example, a date has simply been miscopied. In Sviatsky's brief article in 1923, he lists observations of the aurorae that occurred in 1102, 1202, 1272, 1269, and 1292. The sighting in 1272 appears to be out of sequence. In a more extensive review of Sviatsky's work, Vyssotsky (1949) includes accounts of aurorae in 1102, 1202, 1242, 1269, and 1292. In this version, there is no mention of a sighting in 1272, but there is a detailed account of a sighting in 1242. Apparently, the '4' in 1242 was accidentally changed to a '7' in Sviatsky's earlier article.

In a third example, Vyssotsky's paper contains a number of dating errors in the month given for eclipses. The actual partial lunar eclipse of '1 November 1259' is identified as occurring on '1 December 1259.' The actual total lunar eclipse of '27 December 1395' is identified as occurring on '27 October 1395.' In the commentary for the lunar eclipse in 1399, Vyssotsky refers to other possible eclipses that occurred in 'September 1398' and 'September 1399.' According to the NASA/Goddard lists these references should have been 'October 1398' and 'October 1399.' The discrepancy of one month, in the dating of several eclipses, suggests that a systematic computational error may have occurred. Vyssotsky states that he has used the eclipse calculations of Sviatsky, and those calculations were done long before the advent of computers.

Editorial deletions, copying errors, and computational errors still occurred occasionally in the twentieth century. It is not surprising that similar errors sometimes occurred in the previous nine centuries.

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TABLE 1. SUMMARY OF SOLAR ECLIPSES AS DESCRIBED IN THE RUSSIAN CHRONICLES

Chronicle Date	Summary of the Historical Entry	Date of Best Match	Computed Description at Novgorod
1064	The Sun eclipsed and became like the moon (DS).	April 19, 1064	Partial, mag = 0.94 14:05 UT, alt = 25°, az = 253°
May 21, 1091	Kiev, 2nd hour of the day, there was a portent in the Sun (CS).	May 21, 1091	Partial, mag = 0.66 05:25 UT, alt = 31°, az = 100°
Aug. 1106	A darkening of the Sun occurred in August (AV).	Aug. 1, 1106	Partial, mag = 0.81 05:47 UT, alt = 9°, az = 72°
March 19, 1113	A sign in the Sun in 1st hour of the day. Looked like a crescent moon (AV).	March 19, 1113	Partial, mag = 0.61 05:47 UT, alt = 15°, az = 112°
1115	There was a sign in the Sun as though it had perished (MF).	July 23, 1115	Partial, mag = 0.75 03:06 UT, alt = 10°, az = 69°
March 10, 1122	There was a sign in the Sun (AV).	March 10, 1122	Partial, mag = 0.27 05:21 UT, alt = 8°, az = 107°
Aug. 11, 1124	The Sun began to decrease and it totally perished — there were stars (MF).	Aug. 11, 1124	Total[4] 12:18 UT, alt = 37°, az = 225°
March 30, 1131	There was a sign on the Sun during evening service (AV).	March 30, 1131	Partial, mag = 0.60 15:13 UT, alt = 11°, az = 264°
1133	There was a sign in the Sun before evening service (MF).	Aug. 2, 1133	Partial, mag = 0.64 12:01 UT, alt = 42°, az = 221°
March 20, 1140	There was a sign in the Sun — it was like a four-day moon (AV).	March 20, 1140	Partial, mag = 0.96 15:04 UT, alt = 9°, az = 259°
1146	The rays of the Sun perished (AV).	June 11, 1146	Partial, mag = 0.55 02:05 UT, alt = 7°, az = 55°
1147	There was a sign in the Sun (AV).	Oct. 26, 1147	Partial, mag = 0.65 10:20 UT, alt = 16°, az = 190°
Aug. 17, 1162	There was a sign in the Sun (AV).	Jan. 17, 1162	Partial, mag = 0.55 14:30 UT, alt = 1°, az = 132°
May 1, 1185	10th hour, the Sun grew dark and there were stars (MF).	May 1, 1185	Total[4] 14:30 UT, alt = 25°, az = 262°
Sept. 9, 1187	There was a sign in the Sun at mid-day — dim like the moon (MF).	Sept. 4, 1187	Partial, mag = 0.87 11:08 UT, alt = 43°, az = 203°
Feb. 28, 1207	There was a sign in the sky, in the Sun from noon to evening service (AV).	Feb. 28, 1207	Partial, mag = 0.89 12:07 UT, alt = 22°, az = 213°

Chronicle Date	Summary of the Historical Entry	Date of Best Match	Computed Description at Novgorod
May 14, 1230	The Sun grew dark and became like a moon of the 5th night (MF).	May 14, 1230	Partial, mag = 0.92f 03:54 UT, alt = 18°, az = 80°
Aug. 3, 1236	The Sun became like a four-day moon, on Sunday in the afternoon (AV).	Aug 3, 1236	Partial, mag = 0.90 11:23 UT, alt = 44°, az = 209°
March 1271	Wed., 5th week of lent, the Sun grew dark then filled out (MF).	March 23, 1270	Partial, mag = 0.90 06:13 UT, alt = 20°, az = 118°
1283	There was a terrifying sign in the sky (AV).	Jan. 30, 1283	Partial, mag = 0.58 09:25 UT, alt = 15°, az = 169°
June 26, 1321	There was a sign in the Sun before morning service (MF).	June 26, 1321	Partial, mag = 0.93 05:38 UT, alt = 33°, az = 99°
Nov. 30, 1331	There was a darkening of the Sun lasting from one to three (MF).	Nov. 30, 1331	Partial, mag = 0.93 06:49 UT, alt = 0°, az = 139°
1361	There was a sign in the sky. The Sun lost its light (AV).	May 5, 1361	Partial, mag = 0.47 08:43 UT, alt = 48°, az = 156°
Aug. 7, 1366	There was a darkening of the Sun. It looked like a moon of 3 days (AV).	Aug. 7, 1366	Partial, mag = 0.87 04:25 UT, alt = 16°, az = 88°
July 29, 1375	There was a sign in the Sun (MF).	July 29, 1375	Partial, mag = 0.70 02:15 UT, alt = 1°, az = 59°
Jan. 1, 1386	At noon, the Sun lost its light until it looked like a four-day moon (AV).	Jan. 1, 1386	Partial, mag = 0.85 10:32 UT, alt = 9°, az = 186°
Oct. 28, 1399	The Sun darkened — the form of a scythe appeared in the sky (MF).	Oct. 29, 1399	Partial, mag = 0.89 12:26 UT, alt = 8°, az = 220°
June 16, 1406	The Sun perished and looked like a Moon three days old (DS).	June 16, 1406	Partial, mag = 0.97 06:27 UT, alt = 39°, az = 111°
June 7, 1415	There was a sign in the Sun (MF).	June 7, 1415	Partial, mag = 0.94 06:32 UT, alt = 40°, az = 112°
1423	There was a sign in the Sun (MF).	June 26, 1424	Partial, mag = 0.81 15:18 UT, alt = 24°, az = 274°
June 17, 1433	There was a sign in the Sun at the ninth hour of the day (AV).	June 17, 1433	Partial, mag = 0.73 15:23 UT, alt = 25°, az = 275°
July 18, 1460	The Sun lost its light (AV).	July 18, 1460	Partial, mag = 0.61 04:21 UT, alt = 19°, az = 84°
Feb. 25, 1476	As the Sun was rising ... it suddenly began to grow darker (AV).	Feb. 25, 1476	Total 05:18 UT, alt = 4°, az = 108°

Chronicle Date	Summary of the Historical Entry	Date of Best Match	Computed Description at Novgorod
Sept. 30, 1476	A third of the Sun lost its light and it became as a crescent with horns (AV).	Sept. 30, 1475	Partial, mag = 0.25 04:55 UT, alt = 4°, az = 109°
July 20, 1485	The Sun lost its light (AV).	July 20, 1487	Partial, mag = 0.88 13:28 UT, alt = 35°, az = 260°
1486	The Sun lost its light for a short time only (AV).	March 6, 1486	Partial, mag = 0.83 05:25 UT, alt = 9°, az = 109°
1491	There was a sign in the Sun (AV).	May 8, 1491	Partial, mag = 0.89 14:12 UT, alt = 29°, az = 260°
Aug. 20, 1533	At the 2nd hour, the Sun's top appeared sliced off (AV).	Aug. 20, 1533	Partial, mag = 0.43 03:45 UT, alt = 6°, az = 83°
April 7, 1540	The Sun lost its light until the 2nd hour (AV).	April 7, 1540	Partial, mag = 0.99 04:51 UT, alt = 16°, az = 97°
Jan. 24, 1544	Great darkness spread over … and the Sun became like a crescent (AV).	Jan. 24, 1544	Partial, mag = 0.95 09:23 UT, alt = 14°, az = 168°
June 20, 1563	The Sun was diminished as if the moon came under the Sun (AV).	June 20, 1563	Partial, mag = 0.86 16:15 UT, alt = 17°, az = 286°
April 4, 1567	All of the Sun was darkened (AV).	April 9, 1567	Partial, mag = 0.69 11:52 UT, alt = 37°, az = 217°

TABLE 2. SUMMARY OF LUNAR ECLIPSES DESCRIBED IN THE RUSSIAN CHRONICLES

Chronicle Date	Summary of the Historical Entry	Date of Best Match	Computed Description at Novgorod
Feb. 5, 1102	There was a portent in the Moon (CS).	Nil	There was a full Moon on this date, but there was no lunar eclipse.
May 17, 1117	And in the evening there was a sign in the Moon (MF).	June 16, 1117	Total 00:04 UT, alt = 2°, az = 209°
March 24, 1122	There was a sign in the Moon (AV).	Mar. 24, 1122	Partial, mag = 0.2 22:23 UT, alt = 26°, az = 189°
1146	The Moon was red like blood or copper (DS).	Nov. 20, 1146	Total 05:03 UT, alt = 7°, az = 297°
Feb. 1149	The Moon perished completely, then became full near dawn (AV).	Mar. 15, 1150	Total 03:07 UT, alt = 5°, az = 260°
Feb. 12, 1161	The Moon diminished until it perished (AV).	Feb. 12, 1161	Total 02:58 UT, alt = 18°, az = 260°
Aug. 20, 1161	The Moon perished completely (AV).	Aug. 7, 1161	Total 19:24 UT, alt = 9°, az = 142°
Dec. 24, 1201	There was a sign in the Moon (AV).	Dec. 22, 1200	Total 05:42 UT, alt = 6°, az = 304°
Feb. 3, 1207	It was all darkened, a crescent like a one day Moon was left (AV).	Feb. 3, 1208	Total 17:55 UT, alt = 25°, az = 105°
1248	The Moon was all bloody and lost its light (AV).	June 7, 1248	Total 21:11 UT, alt = 7°, az = 170°
1259	There was a unique sign in the Moon (MF).	Nov. 1, 1259	Partial, mag = 0.7 20:24 UT, alt = 46°, az = 154°
Nov. 1276	The Moon lost its light completely and little by little returned (AV).	Nov. 23, 1276	Total 02:21 UT, alt = 27°, az = 266°
Feb. 24, 1279	The Moon lost its light completely. It returned at daylight (AV).	Mar. 18, 1280	Total 00:36 UT, alt = 21°, az = 222°
Dec. 24, 1284	There was a sign in the Moon (AV).	Dec. 24, 1284	Partial, mag = 0.8 03:45 UT, alt = 20°, az = 279°
1291	The Moon was like blood then changed into darkness (AV).	Feb. 14, 1291	Total 22:23 UT, alt = 41°, az = 185°
1316	The Moon lost its light and set still not filled up (AV).	Oct. 2, 1316	Total 02:18 UT, alt = 15°, az = 255°

Chronicle Date	Summary of the Historical Entry	Date of Best Match	Computed Description at Novgorod
Nov. 1360	The Moon appeared as if covered with a dark covering (MF).	Nov. 23, 1360	Total 14:53 UT, alt = 11 °, az = 68°
1361	The Moon turned into blood (AV).	Nov. 20, 1361	Penumbral 04:41 UT, alt = 8°, az = 292°
Dec. 5, 1379	The Moon darkened and turned into blood (AV)	Dec. 4, 1378	Total 23:31 UT, alt = 49°, az = 218°
May 10, 1389	The Moon lost its light and it appeared again before dawn (AV).	May 10, 1389	Total 18:41 UT, alt = 2°, az = 136°
Sept. 1, 1393	The Moon lost its light (AV)	Sept. 2, 1392	Total 02:42 UT, alt = 4°, az = 252°
Dec. 27, 1396	At the 7th hour, the Moon lost its light and was like blood (AV).	Dec. 26, 1395	Total 23:53 UT, alt = 49°, az = 221°
Sept. 1398	At the 4th hour the Moon darkened, then vanished completely (AV).	April 20, 1399	Total 19:45 UT, alt = 11°, az = 149°
Aug. 2, 1404	There was a sign in the Moon at the 6th hour of the night (AV).	Aug. 2, 1403	Total 22:33 UT, alt = 15°, az = 188°
May/Jun. 1406 St.Peter's Lent	The Moon lost its light before dawn and looked blood red (AV).	June 2, 1406	Partial, mag = 0.7 00:43 UT, alt = 1°, az = 219°
May 25, 1407	The Moon lost its light, and thus it set (AV)	May 22, 1407	Total 00:58 UT, alt = 0°, az = 223°
July 24, 1431	There was a sign in the Moon about midnight (AV).	July 24, 1431	Partial, mag = 0.3 23:10 UT, alt = 11°, az = 197°
Jan. 17, 1432	There was a sign in the Moon (AV).	Jan. 17, 1432	Total 16:26 UT, alt = 18°, az = 83°
Jan. 6, 1433	There was sign in the Moon at the 7th hour (AV).	Jan. 6, 1433	Total 01:34 UT, alt = 36°, az = 248°
July 3, 1460	There was a diminishing of the Moon (AV).	July 3, 1460	Partial, mag = 0.3 19:59 UT, alt = 6°, az = 154°
Dec. 17, 1462	The Moon changed into darkness, from the 5th to the 12th hour (AV).	Dec. 17, 1461	Total 14:54 UT, alt = 11°, az = 64°
Oct. 5, 1466	Starting at the 1st hour of the night, the Moon lost all its light (AV).	Oct. 4, 1465	Total 16:19 UT, alt = 11°, az = 94°
Nov. 27, 1471	The Moon lost its light and looked as if covered with blood (AV).	Nov. 27, 1471	Total 20:37 UT, alt = 55°, az = 154°

Chronicle Date	Summary of the Historical Entry	Date of Best Match	Computed Description at Novgorod
Mar. 10, 1476	Starting in the 3rd hour, the Moon lost all its light (AV).	Mar. 10, 1476	Total 16:46 UT, alt = 17°, az = 120°
Sept. 3, 1477	The Moon lost its light (AV).	Sept. 3, 1476	Total 22:30 UT, alt = 26°, az = 191°
Nov. 27, 1537	Starting in the 1st hour, little by little the Moon got darker (AV).	Nov. 27, 1536	Partial, mag = 0.8 17:10 UT, alt = 29°, az = 95°
Oct. 28, 1566	The Moon became as blood and thus remained for 3 hours (AV).	Oct. 28, 1566	Total 15:31 UT, alt = 12°, az = 80°

Notes for Tables 1 & 2

1. Computed descriptions are derived from simulations using the *Starry Night Deluxe* software.
2. The summaries are derived from the sources indicated.
3. The time for each eclipse maximum is given in UT. To switch to local time, add 2 hours and convert to a.m./p.m.
4. The reports of the solar eclipses in the Russian chronicles for 1124 and 1185 were included in the database used by Stephenson to investigate accelerations in the Earth/Moon system since 700 BC.

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The Real **Supermassive Black Hole** at the Centre of the Milky Way

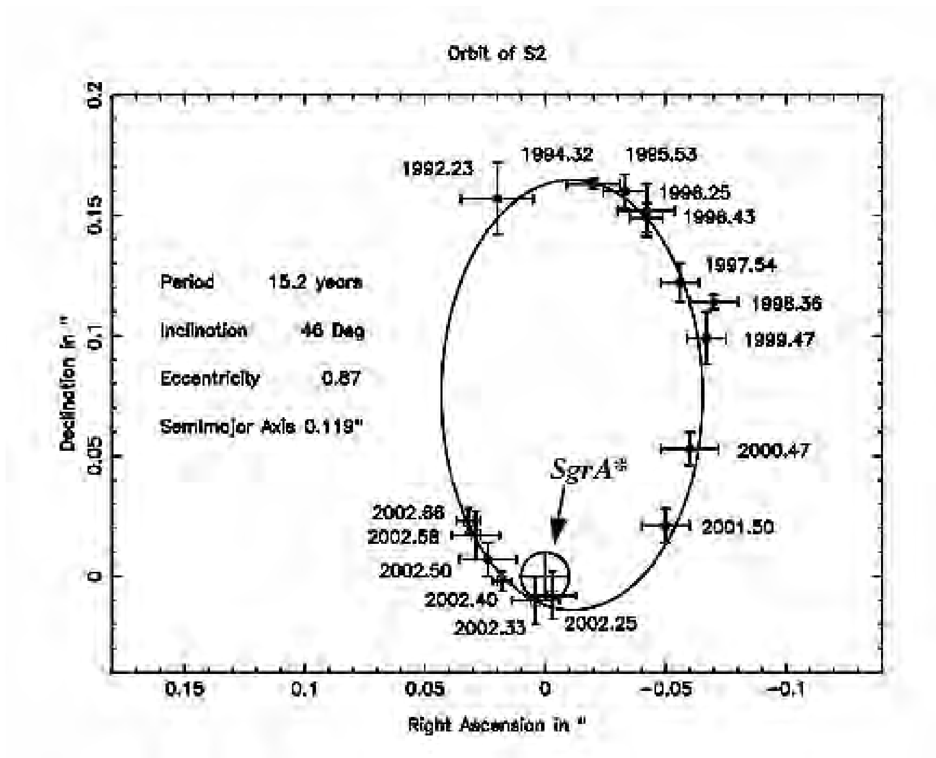
by Leslie J Sage (l.sage@naturedc.com)

I am sure that many of you thought to yourselves upon reading the title above that I'm losing my grip on reality because everyone knows there's a black hole at the centre of the Milky Way. Well, yes and no. But the amazing proof provided by Rainer Schödel of the Max-Planck-Institut für Extraterrestrische Physik in Germany, and his many collaborators around the world, settles the issue (see October 17, 2002 issue of *Nature*). They have tracked a star through two thirds of its orbit around the centre of the Milky Way, including its closest approach — only 17 light hours away from the black hole.

The story starts almost forty years ago, with the discovery of the first quasar by Maarten Schmidt (see March 16, 1963 issue of *Nature*). The realization that massive amounts of energy are being radiated by star-like sources at immense distances forced astronomers to come up with novel ways of getting so much light out of so small an object. The problem at the time seemed rather daunting because these "quasi-stellar objects" (QSOs), as they then were called, were a hundred times as luminous as the entire Milky Way galaxy, but they showed no galaxy-like structure at all. Nuclear fusion, which powers individual stars, did not appear able to provide that huge luminosity.

Gravity ultimately is a more efficient way than fusion of converting mass into energy, so the suggestion arose that perhaps QSOs — and the radio quasars — were powered by gas falling into a massive black hole. This was still being debated 20 years ago, but after a lot of observational and theoretical work, it came largely to be accepted amongst astronomers that the various forms of active galactic nuclei (AGN), which included QSOs, quasars, Seyfert galaxies, blazars, *etc*., could be explained through what became known as the "unified model." In this picture, the various forms of AGN simply resulted from a combination of effects, including the amount of gas being fed into the black hole, its mass, and the angle at which we are viewing it. Largely because of conservation of angular momentum, the gas swirls into a black hole through an accretion disk. This disk also contains lots of dust, so it is necessarily difficult to see through it. On the other hand, if we happen to be looking down the polar axis of the black hole, then we can see much closer to the hole itself, so it will look quite different.

While the research into AGN was underway, astronomers were also investigating whether massive black holes — and here we're talking about a million or more times the mass of the Sun —



The orbit of the star S2 around the Galactic Centre (Sgr A*). The observed positions are marked with the date of the observation, and the crosses indicate the positional uncertainties. The solid ellipse is the best-fitting orbit, which has the parameters indicated to the left. Image courtesy of Rainer Schödel and Reinhard Genzel of the MPE.

lived at the centres of galaxies that showed no evidence of AGN activity. As the centre of the Milky Way is the closest galactic centre to us, it has received particular attention: astronomers have been looking at it at all wavelengths with ever higher resolution for years. Gradually many people have been persuaded that indeed there is a black hole located at the position of the radio source Sagittarius A* — and at the centres of most galaxies — but this has not been universally accepted.

The reasons for the lack of universal acceptance provide some insights into the way science really works. First of all, the black hole itself cannot be seen — all we can see is the hot gas outside it. In general, astronomers have been reluctant to accept the presence of something they cannot see ("dark matter" faced the same problem). In addition to our not being able by definition to see a black hole, it turns out that at many wavelengths the gas and dust near the centres of galaxies make a murky haze that is difficult to see through. Moreover, clever theorists keep inventing alternative explanations for the observations that do not require a black hole. Remember, at the centre of the Milky Way there is no quasar-like activity to require the presence of a very compact and energetic source. Finally, physicists want to see the event horizon itself — the boundary between what we can see in our Universe and what is inside the black hole. When you combine this with the relatively coarse observational resolution we have had, the total gives you a level of skepticism about the presence of massive black holes that I have always found somewhat surprising. I think most members of the general public who care about such things concluded long ago that massive black holes do exist.

Now it's really over. Schödel and his colleagues have tracked the motion of the star S2 — the nearest to Sgr A* — for the last ten years, following its orbit through the most distant and closest points to the black hole (see diagram above). At its closest, the star was moving at over 5000 km s^{-1}! As far as Schödel can determine, the orbit is a stable Keplerian one, like a planet in the Solar System, with a period of 15.2 years. (For comparison, the Earth orbits the Sun with an average velocity of about 30 km s^{-1}, and we are eight light minutes from the Sun. The Sun is about 8 kpc from the centre of the Milky Way.) This orbital motion completely rules out a dense cluster of stars and some other "exotic" explanations. The only possible remaining alternative to a massive black hole is a dense ball of bosons, but this is so unlikely that it would be hard to understand any further opposition to a black hole.

The observational breakthrough that allowed Schödel to accomplish this confirmation was the combination of adaptive optics on one of the telescopes of the Very Large Telescope in Chile, which provided resolution higher than the Hubble Space Telescope, and very accurate alignment of the radio image of the centre, using Sgr A* and some stars that give off maser light (the microwave equivalent of laser) from silicon monoxide (SiO) molecules. The figure tells the story very clearly — over the space of just five months, Schödel watched the star zoom around Sgr A*, covering something like fifteen percent of its total orbital path in that time.

The next step is to use several telescopes together as an interferometer to achieve another factor of five or so increase in resolution, which means being able to track stars when they are within a few light hours of the black hole. At that point, astronomers will be able to look for the peculiar general relativistic effects arising from the extreme curvature of space in that region. In the meantime, I think it's safe to say we can cast away any remaining doubts about the existence of black holes!

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

Sir Arthur Stanley Eddington

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

Arthur S. Eddington (1882–1944). Pioneer of stellar dynamics.

December 28 this year is the 120th anniversary of the birth of Arthur Stanley Eddington, a giant among 20th century astronomers. Not only did Eddington make significant scientific contributions of his own, he was an effective popularizer of science, writing 13 books on astronomy and astrophysics, most of them for the lay public. He incorporated emerging ideas in both relativity theory and quantum mechanics into theories of stellar dynamics, and by doing so aided the scientific acceptance of these difficult concepts. Just before his death, the Royal Astronomical Society of Canada had nominated him to be one of the first two honorary members of the Society. A. Vibert Douglas, the RASC President at the time, wrote a moving and lucid obituary that appeared in the *Journal of the Royal Astronomical Society of Canada*, Vol. 39, No. 1, (Whole No. 340), January, 1945.

Arthur Eddington was born in Kendal, Westmoreland, in the northwest of England, on December 28, 1882. He was a brilliant student, studying at Manchester and Cambridge. One of his Cambridge professors was Alfred North Whitehead (1861–1947) and in 1904 he was head of the class in mathematics (Senior Wrangler). For seven years, he was the Chief Assistant at The Royal Observatory, Greenwich. In 1913, before he attained the age of 32, he became the Director of Cambridge Observatory. He resided in Cambridge until his death on November 21, 1944. A life-long member of The Society of Friends (The Quakers), Eddington's religious convictions were deep, to the extent that he was a conscientious objector during World War I.

One of Eddington's chief contributions to science is the mass-luminosity diagram. Eddington carefully combined observations of stars over a wide range of sizes, between 1/5 solar mass and 25 solar masses. The determination of mass was a tricky business, and most of the data derived from careful observation of the orbits of binary stars. (As students of orbital motion know, the relation between the size and the period of two objects orbiting around each other is determined by their combined gravitational mass.) Eddington's investigation concluded that the energy output (luminosity) of a star was tightly correlated with its mass. He showed that stellar luminosity scaled roughly as the mass raised to the power 3.5 for smaller stars, with the exponent decreasing to 2.7 for larger stars.

In the 1920s, Eddington's consideration of the physics that allowed stars to be stable entities reached several conclusions: (1) radiation and gas pressure from a star's heated interior is the force that balances gravitational attraction, (2) it is most likely that the Solar System formed through condensation from a gas cloud, and (3) there is an upper limit to the mass of a stable star, around fifty solar masses. At the boundary between stability and instability, there is a class of stars that pulsate with a period associated with their mass (and absolute magnitude): the Cepheid variables. Eddington was the first to explain the dynamics of these stars, which proved to be critical to measuring the distances to extragalactic spiral nebulae.

The huge amount of radiation pressure required to stabilize a star suggests that the interior temperature is in the millions of degrees, high enough to sustain nuclear fusion. Eddington proposed that the radiation pressure came from subatomic interactions fuelled by the conversion of mass into energy, a consequence of the theories of Albert Einstein (1879–1955). Eddington argued that the mere existence of the element helium (as the product of hydrogen fusion) proved the point, and he challenged his critics to find a *hotter* place than the interior of stars in which helium could have originated. However, this was mostly a conjecture on Eddington's part, and the complete analysis of this astrophysical problem was worked out later by Hans Bethe (1906–).

Speaking of relativity, Eddington was a primary interpreter of these abstract theories. Einstein himself complimented Eddington's writings on the subject. Eddington was the leader of one of two expeditions in 1919 that observed star positions during a solar eclipse, proving Einstein's prediction of gravitational deflection of starlight. Eddington was so busy changing and exposing photographic plates on Principe Island, West Africa, he did not actually observe the eclipse himself! The scientific results of this expedition catapulted Einstein into international scientific stardom. Although a promoter of relativity, Eddington disparaged the conclusion of Subrahmanyan Chandrasekhar (1910–1995) that stars of greater than 1.4 solar masses would not simply contract to become white dwarfs, but would collapse further to become neutron stars or black holes.

Eddington's name is carved in the history of science, but he also lives on in other ways: he has a lunar crater named for him, and also minor planet 2761. The Royal Astronomical Society (that awarded him its Gold Medal in 1924) awards the Eddington Medal for specific achievements in science (not for a life's work), typically to younger scientists in mid-career. The (US) National Academy of Sciences awarded Eddington the Henry Draper Medal in 1924, and the Royal Society awarded him the Royal Medal in 1928. He was knighted in 1930.

One of Eddington's lectures, "Stars and Atoms," presented in 1927, was reproduced in book form. The text and figures are available on the World Wide Web at `www.bibliomania.com`. Perhaps his most famous book is *The Expanding Universe*, which was published in 1933 but still can be found in quality used bookstores.

David Chapman is a Life Member of the RASC and a past President of the Halifax Centre. At the RASC General Assembly in Montreal, he was inducted into the RASD: the Royal Astronomical Society of Daves, which (among other things) entitles him to sign his postings to RASCals Listserver as "Dave XVII." By day, he is Acting Chief Scientist at Defence R&D Canada–Atlantic. Visit his astronomy page at `www3.ns.sympatico.ca/dave.chapman/astronomy_page`.

FROM THE PAST — AU FIL DES ANS

SUMMER EVENINGS WITH THE STARS—VICTORIA, 1941

During the summer of 1932 a small group of amateur astronomers, members of the Victoria Centre of the R.A.S.C., met weekly at Mr. H. Boyd Brydon's Oak Bay Observatory to discuss the most interesting features of astronomy and to discover for themselves the wonders of the heavens which were to be seen through his four-inch refractor. Their aim has been stated: "to stimulate interest and knowledge of practical astronomy, to afford an opportunity for constellation study and for experience in observational work." Ten meetings were held and the celestial sphere, the constellations, the solar system and the naked-eye stars were studied.

Thus was inaugurated that feature of the Victoria Centre which has grown into the annual series of "Summer Evenings with the Stars." As the course developed from year to year many changes were made. The lectures were designed for pre-members as well as members of the Society; a number of telescopes, most of them made by members of the Society, replaced the single refractor; the meeting-place was changed from Oak Bay to the heights of Victoria College; and, more important, the gatherings grew in number and in interest until the large lecture room in the college became filled and the telescopes were often in use long after the meeting broke up. But the primary object of the series remained the same: to offer the interested beginner an opportunity to learn about the solar system and the starry heavens in talks specially designed to interest him and give first-hand telescopic views of the grand celestial objects.

by K.O. Wright,
from *Journal,* Vol. 35, pp. 438, December, 1941

Research Papers
Articles de recherche

CANADIAN THESIS ABSTRACTS

Compiled By Melvin Blake (blake@ddo.astro.utoronto.ca)

A Submillimetre Survey of Dust Enshrouded Galaxies In The Hubble Deep Field Region By Colin Borys (borys@submm.caltech.edu), University of British Columbia, Ph.D.

This thesis investigates the emission of submillimetre-wave radiation from galaxies in the Hubble Deep Field North region. The data were obtained from dedicated observing runs from our group and others using the SCUBA camera on the James Clerk Maxwell Telescope. The data were combined using techniques specifically developed here for low signal-to-noise source recovery. The sources found represent over 10% of all cosmological sources SCUBA has detected since it was commissioned. The number of submillimetre galaxies we detect account for a significant fraction of the submillimetre background, and we show that mild extrapolations can reproduce it entirely. We comment on their clustering properties, both with themselves and other high-redshift galaxy types. A multi-wavelength analysis of these galaxies shows that SCUBA sources do not all have similar properties, and are made of a collection including: star-forming radio galaxies; optically invisible objects; active galactic nuclei; and extremely red objects. Reasonable attempts to determine the redshift distribution of the sample show that SCUBA galaxies have a median redshift of around 2, and suggest that the global star formation rate may be dominated by such objects at redshifts beyond about 1. The thesis summarizes the current state of extra-galactic submillimetre astronomy, and comments on how new surveys and detectors will allow us to place stronger constraints on the evolution properties of the high-redshift Universe.

The Formation and Evolution of Galaxies: A Deep Submillimetre Survey By Tracy Webb (webb@astro.utoronto.ca), University of Toronto, Ph.D.

Galaxies are the basic units of the universe and yet we know relatively little about the processes involved in their formation and evolution. Until recently, most advancements in this area of research were due to optical and ultraviolet observations of the high-redshift universe. However, the existence of a far-infrared background of substantial magnitude has highlighted the importance of studying the universe at these longer wavelengths. The commissioning of the Submillimetre Common-User Bolometric Array (SCUBA) on the James Clerk Maxwell Telescope has made this possible and has revolutionized the field of submillimetre cosmology.

This thesis addresses the formation and evolution of galaxies through a large-scale survey for the bright objects responsible for the submillimetre background. A substantial catalogue of 50 sources, selected at 850 microns, is presented. Extensive follow-up observations (new and archival) have been assembled, including radio maps from the Very Large Array, optical data from the Canada-France-Redshift Survey, near-infrared imaging from the Canada-France-Hawaii Telescope, Hubble Space Telescope data, and mid-infrared data from the Infrared Space Observatory.

The 850-micron source counts are determined and the contribution of these objects to the far-infrared background is measured allowing us to draw conclusions regarding their cosmic importance. In addition, the strength of the angular clustering of the SCUBA population is investigated.

Determining the counterparts of these objects at other wavelengths is difficult, as the SCUBA position is uncertain. Using positional coincidence arguments, identifications at radio, mid- and near-infrared and optical wavelengths are made. From these data redshifts are estimated and general conclusions about the redshift distribution and the nature of the SCUBA population are drawn.

The relationship between the submillimetre-bright and optically-selected Lyman-break galaxy (LBG) population is explored. The average submillimetre flux of the LBGs is measured and possible submillimetre-bright LBGs are discussed. The strength of the cross-clustering between these two populations is also measured.

A PHOTOGRAPH OF NINE YOUNG WOMEN ASTRONOMERS AT HARVARD COLLEGE OBSERVATORY IN 1928

BY PETER BROUGHTON
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ABSTRACT. A photograph and some contextual and biographical information is presented on Adelaide Ames, Helen Howarth, Margaret Mayall, Cecilia Payne, Helen Roper, Helen Sawyer, Henrietta Swope, Emma Williams, and Doris Wills. A letter from Harlow Shapley appointing Helen Sawyer as a Pickering Fellow is quoted. The suggestion is made that photographs could be used to provide a stimulating project for motivating and introducing students to historical research in astronomy.

RÉSUMÉ. Une photographie et des notes biographiques en contexte sont présentées au sujet d'Adelaide Ames, Helen Howarth, Margaret Mayall, Cecilia Payne, Helen Roper, Helen Sawyer, Henrietta Swope, Emma Williams et Doris Wills. Une lettre d'Harlow Shapley nommant Helen Sawyer boursière Pickering est citée. Nous suggérons que ces photographies pourraient servir à établir un projet stimulant pour motiver et introduire les étudiants à la recherche historique en astronomie.

The women are (from left to right): Helen Roper, Margaret Mayall, Helen Sawyer, Helen Howarth, Cecilia Payne (behind), Doris Wills, Henrietta Swope (behind), Emma Williams, Adelaide Ames.

1. INTRODUCTION

The accompanying photograph was sent to the author about a year ago by Victor Vyssotsky, the son of now-deceased University of Virginia astronomers, Alexander and Emma (Williams) Vyssotsky. The location (Harvard College Observatory at Cambridge, Massachusetts), the approximate date (1928 or 1929), and the names of the nine women were given, but nothing more. My challenge was to learn more about these people and what they did at the Observatory. It turned out that another print of this photograph, faded and not labelled with any names, is among the Helen Sawyer Hogg records at the University of Toronto Archives.

2. CONTEXT

The purpose of this article is to provide a brief introduction to careers of these nine women, to direct the reader to more extensive biographical information where it exists, and to highlight the circumstances that brought these women together at the Harvard College Observatory (HCO). Harvard did not accept female students until 1943, so women who wanted a Harvard education in the 1920s enrolled at nearby Radcliffe College. Harvard professors would repeat their lectures for Radcliffe students, thus earning an extra stipend, known as the Radcliffe mark-up.

Harlow Shapley had been the Director of the HCO since1921. He followed the custom of his predecessor, Edward Pickering, in hiring women to do a lot of the routine measurements, classification, and calculations at the observatory. Shapley also included women graduate students who combined their academic studies in astronomy at Radcliffe College with research at the HCO as part of their degree requirements. In this way Helen Sawyer began her astronomical research. The details are given in a letter written February 17, 1926, by Shapley to Helen Sawyer as she was finishing her undergraduate degree at Mount Holyoke College in South Hadley, Massachusetts:

> My dear Miss Sawyer:
> We have decided to offer you for the academic year 1926–27 the Edward C. Pickering Fellowship. It will be held under the following arrangement:

All of the work is to be done at the Harvard Observatory in Cambridge, at least one-half of it on individual research problems, under my direction or that of some other member of the staff. The remainder of the time is to be devoted to assistance in some of the more general Observatory problems, such as photographic magnitude work, proper motions, measurement of spectrograms, assistance in the Henry Draper Extension [catalogue].

By enrolling in Radcliffe and paying the appropriate tuition, the work at the Observatory is allowed to count as fulfilling one-half of the requirements for the degree of master of arts. There will be no formal courses or lectures connected with this arrangement, which is, in fact, the plan decided upon some time ago for the use of the Pickering Fellowship.

You will be expected to come to Cambridge during the latter part of September. The total time required for the fulfillment of the fellowship has usually been about 1500 hours.

If this arrangement is not suitable, it might be possible later in the year to arrange for a regular assistantship, independent of Radcliffe and of the Pickering Fellowship. Will you please let me have your decision as soon as convenient. We should be glad to have you join our group, as there is a large amount of interesting researches ahead — interesting for those who are attracted to astronomical problems.

Very truly yours,
Harlow Shapley.

P.S. The stipend for next year will be $600 or $650, depending on the available income.

Lankford (1997), in his book *American Astronomy*, devotes a chapter to Science and Gender where he quotes Shapley (1969) as saying, "Luckily Harvard College was swarming with cheap assistants; that was how we got things done." Indeed, in the 1920s, the HCO did operate like a factory with lots of raw material accumulated from decades of photographic patrols. The 150-cm telescope at Harvard's Boyden Station in South Africa came into service in 1927, producing many new spectra and photographs of variable stars yet to be discovered and classified. The 1920s were an exciting era in astronomy with many new ideas afloat involving the role of interstellar absorption, the structure of the Milky Way, and extra-galactic distances. *The Internal Constitution of the Stars* by Eddington was beginning to influence the understanding of the physical nature of stars, including variables and the period-luminosity law.

3. THE WOMEN IN THE PHOTOGRAPH

Of course, this 1928 photograph does not include all of the women (let alone the men) connected with the HCO. According to Hoffleit (1994), there were 32 women and 18 men employed at the HCO in 1927. Historical information on people associated with the HCO is available in Hoffleit (1993), in the *Bulletins* [HB] and *Circulars* [HC] of the HCO (no *Annals* were published between 1924 and 1936), and in the Annual Reports of the HCO and of Radcliffe College. Additional biographical information can be found in the reference work *American Men of Science* (AMS).

The following material focuses on the nine women shown in the photograph. Five of these received their Master of Arts degrees from Radcliffe College: Adelaide Ames in 1924; and Helen Roper, Margaret Mayall, Helen Sawyer, and Henrietta Swope in 1928. Perhaps the graduation of the last four was the reason for this photograph being taken.

Helen Roper

Helen Jessie Roper began her HCO research in 1926, assisting Shapley with the study of stars in M5, and revising the periods of 73 Cepheid variables. Helen Roper was mentioned in Helen Sawyer's diary. Apparently Helen Roper became engaged to "Donald" on January 21, 1926 and her new address was in Chicago. Since there is no further mention of Helen Roper in HCO reports or publications, she may have left for Chicago after receiving her Master's degree in 1928, or perhaps continued her career under her unknown married name.

Margaret Walton Mayall (1902–1995)

Margaret Walton married landscape architect and AAVSO member, Newton Mayall, in 1927. While working on her Master's degree, she determined the median photographic magnitudes of 50 Cepheid variables, a study that formed the basis of estimates of their distances. In 1929–1930, with the help of several assistants, and under the supervision of Annie Jump Cannon, she identified and measured the positions and magnitudes of several thousand stars. She and Helen Sawyer Hogg were close friends. Margaret Mayall's long and dedicated career, including her directorship of the AAVSO, has been described by Hogg (1975) and Hoffleit (1996).

Additional Specific References: HB 845, 848, 859 with Shapley, HB 862 with Gerasimovic, HB 874 with Cannon, HC 288, 313, 316 with Shapley.

Helen Sawyer Hogg (1905-1993)

Helen Hogg's study of variable stars in globular clusters, which became a life-long project, began at HCO under Shapley's supervision. Her early career, and that of her husband, Frank Hogg, have recently been included in a RASC Journal paper entitled, "Canadian Astronomers who earned the Ph.D. at Harvard in the Shapley Era" (Hoffleit 1999). Their obituaries also appeared in the RASC *Journal*: Frank Hogg (Chant 1951), and Helen Hogg (Clement & Broughton 1993).

Additional Specific Reference: AMS

Helen Howarth (1894–?)

Born in Philadelphia, Helen Ethel Howarth earned her Bachelor's degree at Swarthmore in 1920 and her Master's degree at Smith College in 1926 while serving there as an instructor in astronomy. She was an assistant professor at Hood College in 1926 before moving to the HCO as a research assistant in 1927, and research associate in 1929. As early as 1922, Howarth was working with Adelaide Ames and Shapley on statistical parallaxes of stars of Classes B, A, and F. She co-edited *A Source Book of Astronomy* with Shapley. This book, containing excerpts of classical and fundamental papers from Copernicus to G. H. Darwin, was published in 1929. In the Smith College Alumnae Directory, she is cross-referenced as Mrs. Elisha S. Lewis.

Additional Specific References: HC 285 with Shapley, AMS (1933)

Cecilia Payne (1900–1979)

Unlike the others in the photo, Cecilia Payne already had her doctorate and was an astronomer on the staff of the HCO. Earlier, as an undergraduate at Cambridge University in England, Cecilia Payne was inspired to study astronomy by Sir Arthur Eddington. She crossed the Atlantic and under Shapley's direction at the HCO became, in 1925, the first person to earn a Ph.D. in astronomy there. Her thesis, *Stellar atmospheres — a contribution to the observational study of high temperature in the reversing layer of stars*, was published as a Harvard monograph, and was lauded by Otto Struve (1962) as "undoubtedly the most brilliant Ph.D. thesis ever written in astronomy." Her first graduate student was a young Canadian, Frank Hogg, who earned his doctorate in 1929 and who married Helen Sawyer in 1930. Cecilia Payne married astronomer Sergei Gaposhkin in 1934. She authored, or co-authored, hundreds of papers and nine books.

Additional Specific References: Haramundanis (1996), AMS.

Doris Wills

Helen Sawyer, in her correspondence with Frank Hogg, did mention Doris Wills occasionally, but it is not clear what Doris' role was at the observatory. No HCO publications credit Doris Wills, and her name does not appear in any of the reports of Radcliffe College or of the Observatory.

Henrietta Swope (1902–1980)

Like Shapley, Henrietta Hill Swope was born in Missouri. She obtained her undergraduate degree at Barnard College, Columbia University. In 1927, while working towards her Master's degree at the HCO, she specialized in the variables of M22. She became a research assistant at the Observatory in 1928 and determined the approximate elements for hundreds of variable stars across the Milky Way, including the periods of 57 long-period variables and 35 cluster-type variables. Using cluster-type variables in Scorpio and Ophiuchus, she and Shapley presented evidence that the centre of the Galaxy is at a distance of 14,400 parsecs in accordance with the position found earlier from globular clusters. In the *Observatory Report* for the year 1929–30, Shapley wrote:

The study of special fields both in and outside the Milky Way has been carried on during the year by seven workers under the general guidance of Miss Swope. Over seventeen hundred new variable stars have been found in eleven fields. The periods of more than a hundred have been determined. The data are not yet complete enough for significant discussion, but they promise results of great importance. Two of the fields in high galactic latitude … were found to be unexpectedly rich, containing twenty-one and ten variable stars.

She used variable stars to find distances within and outside our own Galaxy. The 1-metre telescope at Las Campanas was named after her.

Additional Specific References: Welther (1992), Ogilvie & Harvey (2000), Laird & Hoffleit (1997), Anon (1981), AMS (1933), HB 857, 862-3, 867-8, 870.

Emma Williams Vyssotsky (1894–1975)

Emma T. R. Williams was born in Pennsylvania in 1894 and earned her undergraduate degree from Swarthmore College in 1916. The following year, she worked as a demonstrator in astronomy at Smith College, but then went into actuarial work for a few years. In 1927, she was awarded a Whitney Fellowship and a Bartol Scholarship, and began working towards her graduate degree in astronomy at Radcliffe College. She worked with Cecilia Payne on the spectral line contours of hydrogen and ionized calcium throughout the spectral sequence. She wrote her dissertation "A Spectrophotometric Study of A Stars" and obtained her Ph.D. in February, 1930. Shapley summarized her results as follows:

The total energy absorption of the K line is a close correlate of the effective temperature — an observation readily interpreted theoretically; the Henry Draper classification is a close index of temperature from A0 to F0; the line contour is related within any one spectral class to the luminosity of the stars; and, incidentally, there is considerable variation of color index with season.

She married Alexander Vyssotsky the same year and they both pursued astronomical careers at the Leander McCormick Observatory, University of Virginia .

Additional Specific References: Roberts (1997), HC 348, AMS.

Adelaide Ames (1900–1932)

Adelaide Ames was born June 3, 1900, and according to a brief biography by Welther (1990) she graduated from Vassar College in 1922. She began work at the HCO while studying at Radcliffe. After earning her Master's degree in 1924, she worked with Shapley on a photometric survey of the brighter spiral nebulae. The condensations in the spiral arms led them to conclude that the nebulae were likely at great distances. She and Shapley went on to make a catalogue of the positions, angular dimensions, classification, and integrated magnitudes of more than two thousand nebulae, mostly in the Coma-Virgo "cloud." They concluded that the system "apparently lies at a distance of more than ten million light years, is two million light years in diameter, and is composed of nearly three hundred individual systems" and that there were five or six super-systems of various sizes and at different distances. After her accidental drowning in 1932, Shapley wrote:

In the field of external galaxies she had at the age of thirty one attained an international reputation which was recognized by appointment to the International Committee on Clusters and Nebulae. Miss Ames was an active participant in the administrative problems of the Observatory and at the time of her death was in general charge of arrangements for the entertainment of the International Astronomical Union at its Cambridge meeting.

Her name is perpetuated in the Adelaide Ames Memorial fund and in the Shapley-Ames catalogue of Bright Galaxies, revised in 1981.

Additional Specific References: HB 864-6, 868-9, 873 with Shapley, HC 243, 295.

4. AN EDUCATIONAL ACTIVITY

The preparation of this article was enjoyable and educational, and required only a few days for research and writing. It involved investigation of Web sites, data bases, reference works, books and journals, and archives.

Although not originally planned as an *Education Note*, the thought occurred that any photograph of two or more identified figures who played a documented role in astronomy, or any other discipline for that matter, could serve as a delightful springboard for a student investigation. Students could explore who the people were, why they came together, what went on at the place where the photograph was taken, and what the intellectual or other conditions were like at the time. For high school students, a teacher would likely choose an image of prominent figures from a book or journal (known only to the teacher). For more advanced students with access to a good university library, more obscure people in archival photographs would probably provide a more interesting challenge. Individual students, or pairs, within a class could all work on a single photograph, and could then compare their findings in a seminar. Alternatively each individual, or small group, could be provided with a different photograph and could make a series of presentations to the class, outlining their research techniques and findings. Any new findings and/or collections of material could then be offered to the archives of the organization that provided the original photograph. This approach could also be extended to photographs of astronomical objects, observatories, telescopes, and other instruments.

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The Helen Sawyer Hogg records are at the University of Toronto Archives [B94/0002] and are easily accessed with a helpful finding aid. For the letter from Shapley of February 17, 1926, see B94-0002/055, File 10.

The annual Reports of Radcliffe College (*Report of the Dean*) and Reports of the President and the Treasurer of Harvard College (*The Observatory*) are available online at `hul.harvard.edu/huarc` and are searchable.

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Peter Broughton taught mathematics in Toronto high schools for 33 years. He served as President of the RASC, and is the author of Looking Up — A History of the RASC. *He currently is Chairman of the Society's Historical Committee.*

Society News/Nouvelles de la société

by Kim Hay, National Secretary (kimhay@kingston.net)

National Events

It is almost the end of the year, yet again. Even though the threat of snow is around the corner for most of us, except those members who live in Calgary, who have already tasted mother nature's winter weather, we can all reflect on our summer and early fall, where there have been many great star parties.

To get us through the rest of the year, many observing challenges were set forth on the National RASC email list, RASCals. There has been the call for Variable Star Observations from Saskatoon Member, Richard Huziak. His goal is to have 100 Canadian Amateur Astronomers submit variable star observations to the AAVSO by September 2003. Richard promises that he will find and observe a particular object that you have already seen. At last count, Rick had 52 people left to join up. If you would like to join this observing challenge, contact Richard at (`huziak@sedsystems.ca`). To join in the fun, observing reports, and camaraderie of the National RAScals email list, send the appropriate command to the email address below.

Function	Email to: listserv@ap.stmarys.ca
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digest — one message per day	set rascals digest
no digest — mail as it happens	set rascals nodigest

Michael Spicer of the Hamilton Centre is re-creating the Saturn Study, which was first presented over 30 years ago and published in the 1970 *Journal*, Vol 64, pp. 53, by K.E. Chilton. If anyone wishes to be in this year's study, which will run to the end of December 2002 (more than one observation per person will be accepted), please go to `homepages.interscape.net/homeroom/rascsite/rascfiles/orbit/orbit-march-02web.pdf`. The Saturn Study is on pages 9–10. Print out the pages and send your observations to Michael Spicer by email to `lawfirm@lara.on.ca`, by fax to (905) 388-0602, or to the Hamilton Centre mailing address, which is:
Les Powis Observatory, PO Box 1223, Waterdown ON L0R 2H0

The intent is to gather the data, and submit another article to the *Journal* with comparisons to the 1970 study. Good Observing.

On another note, many amateur astronomers and weather buffs have been using the Clear Sky Clock program, which was created by Attilla Danko (Ottawa Centre) and Allan Rahill of the Canadian Meteorological Centre. There was some discussion at the CMC that the information used for the Clear Sky Clock program was going to have the plug pulled. However, following a massive email campaign by many people from around the world, the USA, and by members of the RASC, who sent in their thoughts and views, and after discussions with the CMC managers and others in the weather field, Allan Rahill announced the good news on October 4, 2002 that "It was decided that my Web site will remain open as it is right now in the short term which sounds like a year (could be longer)." This is great news to us all, as many of us use the sky clock as a great predictor of weather for our observing sessions. If you would like to visit Allan Rahill's site please go to Astro-Metro Weather (`www.cmc.ec.gc.ca/cmc/htmls/mainpage.html`). To visit Attila Danko's site of the Clear Sky Clock page (`cleardarksky.com/csk/`).

Example of the Clear Sky Clock — Camden Lake Area

Congratulations

Well, a new stargazer, Marc Antonio Reginald Scattolin, has been born to Patrice Scattolin and Laurie Williams on October 3, 2002 at 2:40 a.m. EDT, (6:40

UT). Sisters Clara and Sophie are very excited to have a new brother. Marc, was born at home and mother and baby are doing fine. Dad (a member of the Centre Francophone de Montréal and a National Representative), who had to overcome some obstacles with the city's road construction before all could get to the hospital, is relieved and in great shape. Congratulations, Patrice and Laurie.

(Picture supplied by Proud Papa — Patrice Scattolin)

Upcoming Events

At the time of this writing, our next National Council meeting has not yet happened. It will be held on October 26, 2002 at 9:00 a.m. at the at Gowling Lafleur Henderson LLP, Suite 4900, Commerce Court West (southeast corner, King and Bay Streets), Toronto ON M5L 1J3. The Toronto Centre has invited all members of Council and guests to their observatory (E.C. Carr Observatory) in Collingwood following the meeting, for an evening of observing and conversation (see `www.rasc.ca/toronto/`). In the next "Across the RASC" there will be a small report on the National Council meeting and the trip to the Toronto Centre Observatory.

The General Assembly for 2003 will be held in Vancouver, hosted by the Vancouver Centre. Bookmark your browser to `www.rasc.ca/vancouver/ga2003` to keep up-to-date on the coming events for the GA.

Remember that the Royal Astronomical Society will be celebrating its 100th year next year in 2003. It's a great Society; let's make it last another 100 years. It is our members and volunteers who keep the Society going. Thank you everyone for such a Great Society.

If your Centre has any upcoming events, or if you know of any in your area, please let me know at (`kimhay@kingston.net`), so we can include them in the *Journal* and let all the RASCals know.

Lastly, on behalf of the National Executive, for Bonnie Bird and Issac McGillis, I wish everyone a Merry Christmas and a Wonderful, Clear Skies New Year.

Mount Wilson Days Mount Wilson Nights

by Eric Briggs (ebriggs@sympatico.ca)

On June 11, 2002, I read a message from Bonnie Bird on the RASCals email list passing on information about an opportunity to live and study at an observatory in California for two weeks. It looked like an interesting prospect, so I sent in an application without telling my family. I figured that my chances of being admitted were low, and should my application be accepted, I would worry about trying to explain it to them at that point. I was busy with work, and helping to plan astronomy panels at an upcoming Star Trek convention, so it sort of slipped out of my mind.

July 9, the day after I got back from the convention, I received an email from Dr Michael Faison, the director of the program. I had been accepted. I was boggled. Conveniently, my temporary job contract was not being renewed for August, so I had a window in my schedule. I also found I could somehow afford the extra expense. On August 11, after leaving the Starfest star party late at night, I got on a plane to Los Angeles for two weeks at Mount Wilson Observatory.

Despite its closeness to the light pollution of Los Angeles, Mount Wilson has been involved in important astronomical research for almost a hundred years. The man responsible for Mount Wilson's success was George E. Hale, probably the most ambitious astronomer of the last hundred years. He built the world's largest telescope, four times. When he was 24 he invented the spectrohelioscope, to observe the disc of the Sun in any visible wavelength of light. In 1896, his father gave him a 1.5-metre mirror blank, which later became the 1.5-metre reflector primary at Mount Wilson. The observatory site was chosen for its unparalleled seeing. Air coming off the Pacific Ocean is very steady and undisturbed until it passes over the coastal range of the Rockies, downwind of Mount Wilson. Hale lobbied the newly-endowed Carnegie Foundation for the money to lease the Mount Wilson property and build telescopes on it. Hale signed a 99-year lease with the Mount Wilson Toll Road Company in 1904, so I am very glad I had this chance to use the observatory before the landlords evict it next year!

I was a participant in the thirteenth annual Consortium for Undergraduate Research in Education and Astronomy (CUREA) program. Dr Joe Snider of Oberlin College, who returned as an instructor this year, started the program in 1990. The other instructors this year were Dr Michael Faison (Reed College), Mike

Figure 1 – Tom Hakewill observes solar spectra at the Snow Solar Telescope as Helen Kirk looks on.

Simmons (UCLA), Dr Paula Turner (Kenyon College), and Matt Wenger (Adler Planetarium). The seven participants came from England, Canada, and the United States, and there was a wide spread of ages.

The facilities at Mount Wilson are very diverse, and we were allowed access to different areas. We were the exclusive users of the Snow Solar Telescope, which was built in 1904. Most nights we also had access to a Meade 0.4-metre LX-200 telescope, in a dome that has, in the past, housed a 150-mm Brashear refractor and a 0.3-metre Schmidt camera. We also had two nights of observing and imaging at the Cassegrain focus of the historic 1.5-metre reflector.

The 1.5-metre instrument was completed in 1908. Parts of it were brought up the mountainside in a motorized truck — up to that point the telescope parts had to travel the 15 km (and 1700 metres of altitude) behind horses and mules, on a switchback trail less than 3 metres wide. The 1.5-metre was the first telescope to resolve stars in other galaxies, proving that the 'spiral nebulae' were not part of our galaxy. Harlow Shapley used the telescope to map the distribution of globular clusters and find our place in the Milky Way. The 1.5-metre incorporated a number of technical innovations that worked so well that they were replicated in the nearby 2-metre telescope. (The 2-metre telescope is also known as the 100-inch Hooker Telescope, named for the man who helped fund its construction.)

The Hooker Telescope was completed in 1918. Edwin Hubble and Walter Baade used the Hooker to photograph variable stars in other galaxies, work they continued at the 5-metre Hale Telescope at nearby Palomar Mountain. While the 1.5-metre is now available for private groups at a fee of about $1,000 US per night, the Hooker has two major ongoing projects. One is the HK Project, a thirty-year program to observe calcium absorption lines in the spectra of about 300 cool stars. The Hooker was shut down for eight years after 1986, while the Carnegie Foundation reallocated funds to build other astronomy projects in South America. There is also an adaptive-optics package being developed at the Hooker Telescope, which tested the use of an ultraviolet laser while we were on the mountain. For safety reasons, even the visitor's gallery at the 2-metre was off limits some of the time.

The Snow Solar Telescope has a 0.6-metre primary mirror and operates at f/30. The entire length of the telescope is indoors, with a retractable shed at one end covering two mirrors: the coelostat, a flat mirror that tracks the Sun across the sky, and a mirror that bounces the sunlight from the coelostat along the length of the building to the primary. The Sun is brought to focus as an image about 15 cm across, and is uncomfortable to look at without stopping down the primary's aperture. The full aperture is only used for spectroscopy: at the telescope's focus is the slit of a spectrograph that sits in a 4-metre-deep pit underneath the building. We used this Babcock-Littrow spectrograph to measure the Doppler shift in spectral lines between the west and east limbs of the Sun, to calculate its rotation period.

$$V = (c/2\,\lambda_o)\,(\lambda_w - \lambda_e)$$

Where V = the rotational velocity of the Sun
c = the speed of light (299,792,458 m s^{-1})
λ= the wavelength of the Sodium D spectral lines (589.0 nm and 589. 6 nm)
λ_o = the actual wavelength
λ_w = the wavelength at the Sun's west limb
λ_e = the wavelength at the Sun's east limb

Figure 2 – Mike Simmons holds one of the eyepieces for use at the 1.5-metre reflector.

Figure 3 – Looking along the polar axis of the Hooker Telescope.

The spectrograph produced a spectrum that advances 0.033 nm per millimeter in the 5th Order. A Doppler shift of 0.19 mm, or 0.006 nm, was measured between the west and east limbs. The rotational velocity was measured to be 1602 m s^{-1}. The Sun's rotation period must be $2\pi \times$ (Radius/Velocity) where Radius is 696,000,000 metres, as given in the RASC *Observer's Handbook*. The period was found to be 31 days, which agreed well with the period given in the *Observer's Handbook*. As a non-solid body the Sun has slightly different rotation periods at different points on the photosphere. I took it as a personal crusade to finish the experiment, as I was stumped on this question of differential rotation in a quiz at Starfest last year!

Besides measuring the solar spectrum, we were also able to photograph it at the Snow Telescope. Using sheets of film that we cut and developed ourselves, one-second exposures were sufficient when photographing the 1st Order of the spectrum. By racking the reflection grating out to the 5th Order, where the spectrum repeats itself in an elongated and dimmed fashion, we also tried to observe and photograph the elusive Zeeman effect.

The Zeeman effect is the splitting of spectral lines into multiple, polarized components in the presence of a magnetic field such as a sunspot. Observing the Zeeman effect was George E. Hale's prime motivation for building the Snow Telescope in the first place, and he could not confirm its existence there. There was instability in the image due to the telescope laying flat along the ground, and so in 1908 Hale built a similar solar telescope in an 18-metre tower next door. Less than a month after its first light he had confirmed the presence of the Zeeman effect on the Sun, proving that sunspots have very powerful magnetic fields. We think we observed the effect at the Snow Telescope, but to photograph it in the 5th Order would have taken a ten second exposure that would be blurred by the air currents. The 18-metre solar tower is still there: in the 1950s the five-minute oscillation of the Sun's surface was discovered there, and it is currently being used for solar seismology by the University of Southern California as a complement to the GONG group of helioseismographs. Using helioseismology it is now possible to observe the Doppler shift of solar surface vibrations and extrapolate what is going on inside the Sun, and even out on its far side.

We toured the third, 38-metre tall solar tower at Mount Wilson and were given the chance to ride up to the coelostat at the top in a rickety bucket elevator. Larry Webster, who is usually the observer at the 38-metre Solar Tower, daily draws details of sunspot groups and their polarities for publication on the Internet. The 38-metre tower also has a Littrow spectrograph, but it sits at the bottom of a 21-metre pit — much deeper than the spectrographs in the 18-metre and Snow telescopes. Zeeman splitting is much more pronounced in the longer spectrograph, and Larry showed us an interesting phenomenon: a variable polarizing filter moved across the eyepiece can show one side of the Zeeman split, and then the other. There is a guest book at the 38-metre Tower that has been signed by Stephen Hawking, among others. We signed it as well.

Mount Wilson used to have a fourth solar telescope down the mountain in Pasadena itself. The Hale Solar Laboratory has a 12-metre solar telescope with its own spectrograph pit. Don Nicholson, the president of the Mount Wilson Observatory Association, gave us a tour of the laboratory. His father, Seth, discovered four outer moons of Jupiter using the Mount Wilson telescopes. Nowadays, the instruments at the laboratory have been mothballed, but the building is still the head office of the Mount Wilson Institute, which administers the observatory.

Just as Mount Wilson is historically the most important solar observatory in the world, it has always been on the cutting edge of the science of interferometry. By recombining beams of light from different telescopes at a distance from each other, an interferometer simulates the resolution of a telescope with an aperture as wide as the baseline between the two telescopes. Interferometers have very small fields of view and most of their data comes from examining diffraction patterns. Interferometers do not make pretty pictures. Mount Wilson was picked out as the ideal setting for interferometric research because of its excellent seeing conditions. When the 2-metre telescope was built, a special secondary mirror assembly was built with pick-off mirrors on a baseline that could be extended up to 6 metres. The 6-metre interferometer was used to determine the sizes of seven red-giant stars in 1920. Then it was mothballed for decades before being put back together as an exhibit in the lobby of the great new interferometer at Mount Wilson: the Center for High Angular Resolution Astronomy (CHARA) Array.

The CHARA array consists of six 1-metre telescopes arranged like spokes in a wheel with a radius of 400 metres. CHARA is the longest baseline optical interferometer in the world, and is operated by Georgia State University. The different baselines are still being tested, and while we were at Mount Wilson a team of French scientists successfully tested a fiber optic instrument on the array. One of the CHARA operators, Lars Turner, gave us an extensive tour of the array, which included climbing up inside one of the robotic domes.

There is a second large interferometer on Mount Wilson. The Infrared Spatial Interferometer (ISI) consists of three 1.65-metre telescopes mounted on three flatbed trucks with retractable roofs. ISI is run by the University of California at Berkeley. The three trucks can be moved around a large parking lot for baselines of up to 85 metres. ISI is optimized for infrared imaging at wavelengths of about 11 microns, but operator Dave Hale explained to us how lasers are used to record the signals in the microwave range. I wish I could remember how it is done, but the microwave signals have longer wavelengths and are easier to recombine than near-optical wavelengths. ISI's main research is done on dusty giant and supergiant stars. Dave was one of the first CUREA participants twelve years ago.

As our two weeks wore on, we were faced with the choice of what each of us would observe for the projects we were to present at the end of the program. Aside from our tuition fees, CUREA is also funded by the Mount Wilson Observatory Association (MWOA). MWOA is a group of amateur astronomers not unlike a typical RASC Centre (except for the several massive and historic telescopes in their backyard!). At the end of our two weeks we were expected to show them what we had accomplished.

Figure 4 – One of the optical benches in the Chara Array's Beam Synthesis Facility.

We had access to three great telescopes — the Snow, the 1.5-metre, and the LX-200. Imaging was possible with an FLI-1024 CCD camera from Finger Lakes Instruments and an ST-8E CCD camera from SBIG. We decided the FLI camera, with its large pixels, would best fit the image scale on the 1.5-metre. We were using the Cassegrain focus of a 1.5-metre telescope, which operates at f/16. Even with a 50-mm eyepiece the effective magnification was about 480×, and that eyepiece was 4 inches wide, not the more common 2 inches. The FLI CCD chip was 2.4 cm on a side. We decided that when we put the eyepieces down and imaged with the 1.5-metre we would only image small, bright planetary nebulae: M57, NGC 7009, NGC 6543 and NGC 7662. Four of us took the images: Anne Forbes (Wells Cathedral School, England), Tom Hakewill (Cardiff University, Wales), Helen Kirk (University of Toronto, Canada), and myself. Anne did the colour recombination and presented the images, along with some taken with the LX-200, as the core of her project. I like to think our instructors were impressed that we chose to spend only half our allotted time on the 1.5-metre observing visually, and sacrificed the rest to take images.

The ST-8E has smaller pixels than the FLI. Its autoguider would have been useless on the 94-year old instrument but it was perfectly suited to the LX-200. The ST-8E could also take spectra, using a large spectrograph box from SBIG fitted between the imager and the telescope. John Pearson (University of Western Sydney, Australia — and a resident of Los Angeles) chose for his observing project to complement our 1.5-metre images with spectra of planetary nebulae showing the prominent emission lines. The combined weight of the camera and the spectrograph made the images hard to capture, even with the telescope re-balanced. There was almost too much flexure to get any data. Matthew Firth (University of Cambridge, England) chose to use the spectrograph combination to image the differential Doppler shift of an edge-on spiral galaxy, NGC 7331, showing its rotation. Matthew and John both got their data eventually.

Helen pushed the envelope with her project by using the Snow Telescope to photograph the Moon and its spectrum. There are three different gear ratios available on the Snow: one for tracking the Sun, one for tracking the Moon and a third for tracking the stars (although at f/30, low image brightness makes this difficult without very long exposures.) Helen made several negatives of the Moon at different phases on photographic paper.

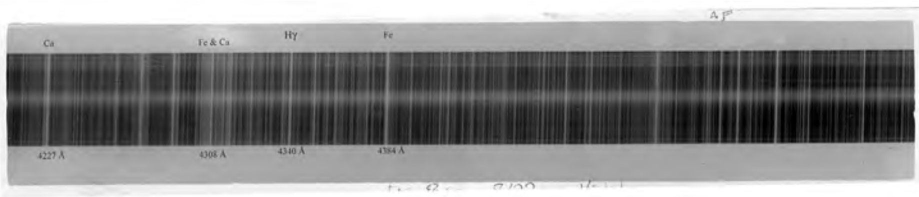

Figure 5 – Part of the violet end of the spectrum photographed at the Snow Solar Telescope on August 22, 2002. The smudge running through the middle of the image is the huge sunspot group 0069, which was aligned with the spectrograph slit.

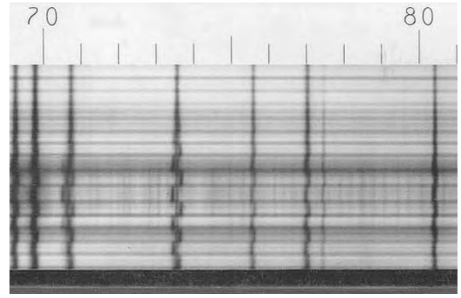

Figure 6 – Zeeman splitting is observed in the Fe absorption line at 617.3 nm, in a scan from the archives of the 38-metre Solar Tower. (Image courtesy of Pam Gillman, Mount Wilson Observatory)

She also took a one-hour exposure of the spectrum of moonlight, showing its similarities to sunlight.

Yury Turetsky (Los Angeles Valley College, USA), Tom, and I were also interested in photometry. We learned a great deal about photometry from John Hoot, a dedicated amateur astronomer who visited us several times. For his project, Tom wanted to try to observe the dip in brightness of a star as its planet transited its disk. A combination of factors made that impossible, and so Tom chose to calculate the light curve of an eclipsing variable star, V1321 Cygni. Yury chose to calibrate magnitudes between several variable stars. I was interested in photometry of asteroids.

During the program, I had taken notice of the flyby of the asteroid 2002 NY40, which missed the Earth by less than 1-million kilometers during the CUREA program. I took animations of the asteroid with the ST-8E on the nights leading up to the flyby, but on the big night the asteroid was crossing more than 6 arcminutes of sky every minute. We were pleased enough to find it in the eyepiece, and left the CCD alone. Photometry of NY40 was out of the question for more than practical reasons. I wanted an asteroid that was in opposition to the Sun and would show as few shadows as possible. With a simple Internet search, John Hoot showed that there are plenty of asteroids out there whose rotation period and size are unpublished. I had a night of observing time on one of our alternate telescopes: a 0.35-metre Celestron SCT on a Paramount, usually used for remote imaging by high-school students. There was an almost-full Moon that night, as well as scattered high clouds. It was the worst weather we had at Mount Wilson. While making a time-lapse movie of asteroid 25 Phocaea against background stars, I imaged targets of opportunity: M13, the Bubble Nebula, and Perseus A were beautiful when they were not obscured by cloud. In the end, I did not get the data I wanted, but I took all that the equipment and the weather conditions provided.

Besides all the work and observations we did at Mount Wilson, we visited several great astronomy institutions. We visited the 5-metre Hale telescope at Palomar Mountain. We toured the Jet Propulsion Laboratory in Pasadena guided by Charles Morris, JPL's comet-observation guru. We looked around the astrophysics department at CalTech and found the lecture hall Richard Feynman used for his popular science lectures.

The chance to participate in the CUREA program is not one to be missed. Plans are underway for the program to continue next summer, and RASC members are welcome to apply. Studying at Mount Wilson was a chance of a lifetime. I must thank Bonnie Bird, Geoff Gaherty, and Guy Nason for their help. I also have to acknowledge the efforts of the MWOA to keep the program running, and the CUREA instructors for their time and patience.

For more information about the CUREA Program, visit `www.curea.org`. For more information about Mount Wilson Observatory, visit `www.mtwilson.edu` and `www.mwoa.org`.

Eric Briggs is a full-time employee of Khan Scope Centre in Toronto. He observes with the RASC and privately with his 8-inch f/6 reflector. A product of the Trudeau years, he is fluent in both languages — metric and Imperial.

Copernicus and the Index: Data versus Explanation

by William Lonc (william.lonc@stmarys.ca)

In the context of the Galileo Affair, the Congregation of the Index's "condemnation until corrected" on March 5, 1616 of Copernicus' *De Revolutionibus*, and the subsequent report on May 15, 1620, are presented. It is found that virtually all ten or so "corrections" pertain to philosophy rather than theology or religion, or any other category. The only exception is an objection to calling the Earth a "star."

One of the significant events in the chain of events that could be called the Galileo Affair is surely the "condemnation" on March 5, 1616 of Copernicus' *De Revolutionibus Orbium Coelestium* by the Congregation of the Index "until it be corrected." A reader might wonder what corrections the Congregation had in mind: would it be something pertaining to Mathematics? Theology? Philosophy? And, at the end of the day, what significance would these corrections have?

This short paper is based on the translations of the two relevant documents in Finocchiaro's *The Galileo Affair: A Documentary History*. I also make use of Finocchiaro's notes because they contain translations of the relevant passages from *De Revolutionibus* (Copernicus 1976).

On the basis of the two relevant documents: the "condemnation" of March 5, 1616, and the "corrections" of May 15, 1620, it is seen that all the "corrections" — except for one[1] — pertain to a lapse on the part of Copernicus' text in keeping the reader aware of the hypothetical nature of the theory in his book. Specifically, the Corrector(s) pointed out a few places in the text — about ten — in which Copernicus' wording was such that it could give a reader the impression that — for Copernicus — the heliocentric model was the final answer to questions about the motion of the objects in what we today call the Solar System. These ten or so lapses in wording could have had, for the unwary reader perhaps, the effect of diluting the hypothetical stance expressed by Copernicus at the outset of the book: namely, that the book contained a hypothetical explanation of observations, NOT the final explanation.

For the reader's convenience, I now cite the Decree issued by the Congregation of the Index in 1616:[2]

Decree of March 5, 1616
[p. 148–150 in Finocchiaro]
"Decree of the Holy Congregation of the Most Illustrious Lord Cardinals especially charged by His Holiness Pope Paul V and by the Holy Apostolic See with the Index of books and their licensing, prohibition, correction, and printing in all of Christendom. To be published everywhere."
[There follow several paragraphs referring to books to be prohibited absolutely.]

"...This Holy Congregation has also learned about the spreading and acceptance by many of the false Pythagorean doctrine, altogether contrary to the Holy Scripture, that the earth moves and the sun is motionless, which is also taught by Nicolaus Copernicus' On the Revolutions of the Heavenly Spheres *and by Diego de Zuñiga's* On Job. *This may be seen from a certain letter published by a certain Carmelite Father, whose title is* Letter of the Reverend Father Paolo Antonio Foscarini, on the Pythagorean and Copernican Opinion of the Earth's Motion and Sun's Rest and on the New Pythagorean World System *(Naples: Lazzaro Scoriggio, 1615), in which the said Father tries to show that the above-mentioned doctrine of the sun's rest at the centre of the world and the earth's motion is consonant with the truth and does not contradict Holy Scripture. Therefore, in order that this opinion may not creep any further to the prejudice of Catholic truth, the Congregation has decided that the books by Nicolaus Copernicus (*On the Revolutions of Spheres*) and Diego de Zuñiga (*On Job[3]*) be suspended until corrected; but that the book of the Carmelite Father Paolo Antonio Foscarini be completely prohibited and condemned; and that all other books which teach the same be likewise prohibited, according to whether with the present decree it prohibits, condemns, and suspends them respectively. In witness thereof, this decree has been signed by the hand and stamped with the seal of the Most Illustrious and Reverend Lord Cardinal of St. Cecilia, Bishop of Albano[4], on March 5 1616.*
P. Bishop of Albano, Cardinal of St. Cecilia.
Fra Franciscus Magdalenus Capiferreus, O.P., Secretary.
Rome, Apostolic Palace Press, 1616."

For the purposes of this paper, the only significant passages in this Decree are those in the last paragraph because

[1] The one in which the Earth is being called a "star."
[2] Translation by Finocchiaro in *The Galileo Affair*.
[3] The Book of Job in the Christian Old Testament.
[4] Albano is some 20 miles south of Rome.

they refer to Copernicus.

A committee was formed and reported on May 15, 1620 as follows [for convenience, I number the paragraphs]:

Corrections of May 15, 1620

[p. 200–202 in Finocchiaro]

1. *The Fathers of the Holy Congregation of the Index decreed that the writings of the distinguished astronomer Nicolaus Copernicus, On the Revolutions of the World, were to be absolutely prohibited*[5] ***because he does not treat as hypotheses, but advances as completely true****, [emphasis mine] principles about the location and the motion of the terrestrial globe that are repugnant to the true and Catholic interpretation of Holy Scripture; this is hardly to be tolerated in a Christian. Nevertheless, since Copernicus's work contains many things that are very useful generally, in that decision they were pleased by unanimous consent to allow it to be printed with certain corrections according to the emendations below,* ***in places where he discusses the location and motion of the earth not as a hypothesis but as an assertion*** *[emphasis mine]. In fact, copies to be subsequently printed are permitted only with the above-mentioned places emended as follows and with this correction added to Copernicus's preface.*

   Emendations of the passages in Copernicus's book which are deemed suitable for correction:
2. *In the preface, toward the end, delete everything from the beginning of the last paragraph up to the words "this work of mine," and substitute: "For the rest, this work of mine . . .*[6]
3. *In book 1, chapter 1, page 6*[7] *where it says "However, if we consider the matter more closely," substitute: "However, if we consider the question more closely, we think it is immaterial whether the earth is placed at the center of the world or away from the center, so long as one* ***saves the appearances***[8] *[emphasis mine] of celestial motions."*[9]
4. *In chapter 8 of the same book, this whole chapter could be expunged since it explicitly treats of the earth's motion while it refutes the ancient arguments proving its rest; however, since it is preferable to speak problematically, so as to satisfy scholars and to keep integral the book's sequential order, it may be emended as follows.*
5. *First, on page 6, delete the sentence from "Why therefore" to the words "We sail out," and correct the passage in this manner: "Why therefore can we not grant it the motion suitable to its shape, rather than rendering unstable the whole universe, whose limits are unknown and cannot be known, and why not grant that the things which appear in heaven happen in the same manner as expressed by Virgil's Aeneas?"*[10]
6. *Second, on page 7, the sentence beginning with "I also add" should be corrected this way: "I also add that it is no more difficult to attribute motion to that which is in a place in a container, namely to the earth, than to the container".*[11]
7. *Third, on the same page, at the end of the chapter, the passage from the words "You see" till the end of the chapter is to be deleted.*[12]
8. *In chapter 9, page 7, correct the beginning of this chapter up to the sentence "For the fact that . . ." thus: "If, then, I assume that the earth moves, I think that we now have to see also whether several motions can belong to it. For the fact that . . .*[13]
9. *In chapter 10, page 9, correct the*

[5] "Actually the decree by the Index of March 5, 1616 (see above) stated less severely that Copernicus's work was to be 'suspended until corrected'" [Finocchiaro's note #3].

[6] "This amounts to deleting the first several sentences of the last paragraph of that preface, namely the following passage: "There may be triflers who though wholly ignorant of mathematics nevertheless abrogate the right to make judgements about it because of some passage in Scripture wrongly twisted to their purpose, and will dare to criticize and censure this undertaking of mine. I waste no time on them, and indeed I despise their judgement as thoughtless. For it is well known that Lactantius, a distinguished writer in other ways but no mathematician, speaks very childishly about the shape of the Earth when he makes fun of those who reported that it has the shape of a globe. Mathematics is written for mathematicians, to whom this work of mine . . ." (Copernicus 1976, pp. 26–27). The paragraph would then begin with the following sentence: "For the rest, this work of mine, if my judgement does not deceive me, will be seen to be of value to the ecclesiastical Commonwealth over which your Holiness now holds dominion" (Copernicus 1976, p. 27). Note that this deleted passage is also the one Galileo quoted approvingly at the beginning of his "Letter to the Grand Duchess Christina" (see above, paragraph #4)." [Finocchiaro's note #4]. The relevant passage in paragraph #4 from Galileo's Letter is: "Mathematics is written for the mathematician, to whom this work of mine, if my judgement does not deceive me, will seem to be of value to the ecclesiastical Commonwealth over which your Holiness now holds domain" [Finocchiaro, p. 91].

[7] "This and subsequent references are to the original edition of Copernicus's book (Nuremberg, 1543). However, as Favaro (19: 400, n. 2) points out, this first reference is erroneous and should read 'book 1, chapter 5, page 3'" [Finocchiaro's note #5].

[8] The Latin has *salva apparentia*. I think that a literal translation, such as Finocchiaro's, is not quite intelligible in English. Rather, the phrase should be rendered — in my opinion — along the lines of *respect the data*. The "data" in the context of our paper is the "perception of the Sun setting or rising". Then, on the basis of the data, one or more hypotheses can be constructed to account for the data — but the data is not to be thrown away! I have more to say on this further on.

[9] "The original sentence reads: "However, if we consider it more closely, the question will be seen to be still unsettled, and so decidedly not to be despised" (Copernicus 1976, p. 40). The sentence immediately preceding introduces the "question" by asserting: "Among the authorities it is generally agreed that the Earth is at rest in the middle of the universe, and they regard it as inconceivable and even ridiculous to hold the opposite opinion" (Copernicus 1976, p. 40)" [Finocchiaro's note #6].

[10] "The original passage says: "Why therefore do we still hesitate to concede movement to that which has a shape naturally fitted for it, rather than believe that the whole universe is shifting, although its limit is unknown and cannot be known? And why should we not admit that the daily revolution itself is apparent in the heaven, but real in the Earth; and the case is just as if Virgil's *Aeneas* were saying 'We sail out from the harbor, and the land and cities recede'?" (Copernicus 1976, p. 44)" [Finocchiaro's note #7]

[11] "The original sentence says: "I also add that it would seem rather absurd to ascribe motion to that which contains and locates, and not rather to that which is contained and located, that is the Earth" (Copernicus 1976, p. 46)" [Finocchiaro's note #8].

[12] "The deleted passage says: "You see then that from all these arguments the mobility of the Earth is more probable than its immobility, especially in the daily revolution, as that is particularly fitting for the Earth" (Copernicus 1976, p. 46)" [Finocchiaro's note #9].

[13] "The original initial sentence says: "Since, then, there is no objection to the mobility of the Earth, I think it must now be considered whether several motions are appropriate for it, so that it can be regarded as one of the wandering stars" (Copernicus 1976, p. 46)" [Finocchiaro's note #10]

sentence beginning with "Consequently" thus: "Consequently we should not be ashamed to assume . . .,[14] *And a little below that, where it says "is correctly attributed to the motion of the Earth," substitute: "is consequently attributed to the motion of the Earth".* [15]

10. *Page 10, at the end of the chapter, delete the very last words: "Such truly is the size of this structure of the Almighty's".*[16]

11. *In chapter 11, the title of the chapter is to be changed in this manner: "On the Hypothesis of the Triple Motion of the Earth, and Its Demonstration".*[17]

12. *In book 4, chapter 20, page 122, in the title of the chapter, delete the words "these three stars," since the earth is not a star, as Copernicus would have it.*[18]

Fra Franciscus Magdalenus Capiferreus, O.P.,
Secretary of the Holy Congregation of the Index.
Rome, Apostolic Palace Press, 1620."

On the basis of the published corrections given above, it could be quite plausible to infer from the document that the Index people were not against the Heliocentric theory or model as such or absolutely, but only if it were being proposed as the unique and final explanation of the data in question — the experience of seeing the sun rise and seeing the sun set.[19]

Hence, there are two significant concerns on the part of the Congregation of the Index. First, the Congregation does not like seeing a hypothetical model or theory being presented in an absolute manner —this concern is apparent in the kind of corrections that are being suggested. Second, the Congregation, in paragraph #3, does not like seeing experience — data — being swept aside by a theory when it says "so long as one saves the appearances."

Regarding this second point, the phrase "saving appearances" is not normal English usage. We say "saving face", or "saving a photo", but we do not say "saving appearances." Unfortunately, the phrase in English is an excessively literal translation of the Latin *salva apparentia*, which was used frequently at that time in epistemological discussions, denoting "sense experience" or "data." For example, we see the Sun set and we see it rise, and we can report the experience without necessarily explaining it. Spontaneously, however, we do ask *why*? We do go on to ask why the Sun is seen to rise or we do ask why the Sun is seen to set, and the answers to these questions imply a theory, and a theory may or may not be correct. In any event, generating acceptable answers to the "why" questions does not logically justify us to then eliminate the experience — the data — that gave rise to the question.

In sum, we may be somewhat surprised to read, as in paragraph #3 of the list of Corrections, that the Index people — presumed to be professional theologians — have no quarrel with the placement of the Earth relative to the "centre of the world" when they say "*...we think it is immaterial whether the earth is placed at the center of the world or away from the center...*", but, when they go on to say "*... so long as one saves the appearances of celestial motions*" they definitely do have a quarrel about the fate of data. Hence, for the purposes of understanding the Galileo Event more accurately, it could be significant to learn that the Congregation of the Index was concerned more about the Epistemology than about the Theology in *De Revolutionibus*.

Note: The Latin texts are available from the author.

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William Lonc is Professor Emeritus in Physics in the Astronomy and Physics Department at Saint Mary's University since 1995. Among other things, he is working on the second edition of his book Radio Astronomy Projects*, expanding the contents by almost a factor of 2. His interest in things pertaining to the Galileo Event is ongoing, and he thinks he has "cracked" the case by appealing to a model in terms of a speeding ticket being issued to a VIP, who agrees to settle for a lesser charge, but at the last minute stoutly denies having been speeding. A few more features of the model remain to be worked out, at which point the story might appear in the pages of this* Journal.

[14] "The original sentence is: "Consequently we should not be ashamed to admit that everything that the Moon encircles, including the centre of the Earth, passes through that great sphere between the other wandering stars in an annual revolution round the Sun, and the centre of the universe is in the region of the Sun" (Copernicus 1976, p. 49)" [Finocchiaro's note #11].

[15] "The original sentence reads: "That the Sun remains motionless and whatever apparent motion the Sun has is correctly attributed to the motion of the earth" (Copernicus, 1976, p. 49)" [Finocchiaro's note #12].

[16] "Copernicus (1976, p. 51)" [Finocchiaro's note #13].

[17] "The original title is "Derivation of the triple motion of the Earth" (Copernicus 1976, p. 51)" [Finocchiaro's note #14].

[18] "The original title is "The size of these three stars, the Sun, the Moon, and the Earth, and a comparison of them with each other" (Copernicus 1976, p. 217)." [Finocchiaro's note #15].

[19] Astronomical handbooks, such as the *Observer's Handbook* published by the RASC, quite legitimately include Tables of times for Sun Rise/Sun Set rather than Tables of Earth's motion relative to the Sun — in other words, the Tables contain data, not theory.

Planet Promenade

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

Something flashed in a corner of the sky
I just saw an eternity go by
A thread of light through the middle of my eye
In Jumbo Sky
— Bob Jahrig, "*Jumbo Sky*"

An enduring memory from my days as a neophyte stargazer is of a remarkable sight during a regular, usually brief walk to see stars of a different type. I'm a lifelong fan of the performance art known as ice hockey, and was a full season ticket holder when the supernova known as Wayne Gretzky and several other hockey stars of the first magnitude plied their trade right here in River City. It was a crisp evening in the winter of 1985 as I emerged from my car for another appointment with the reigning Stanley Cup champions, and my recently acquired habit of looking up immediately upon emerging from any enclosure revealed an unpromisingly dismal, whitish sky. As I turned south, my attention was grabbed by the spectacular apparition of the crescent Moon and Venus, separated by maybe five degrees, burning right through the ice fog. Each was surrounded by a fabulous halo. The apparent low ceiling of the sky that swallowed whole all other astronomical objects was shown to be a mirage as the Universe beyond revealed itself to me. Time stood still as I stopped to admire this unforgettable show, forgetting entirely my ultimate destination. For once, the game started without me.

Ever since then I've had a soft spot for conjunctions, and have taken every opportunity to observe them over the intervening years. As the memory of a moment in 1985 has endured, so too will those of a remarkable sequence of alignments over the past year.

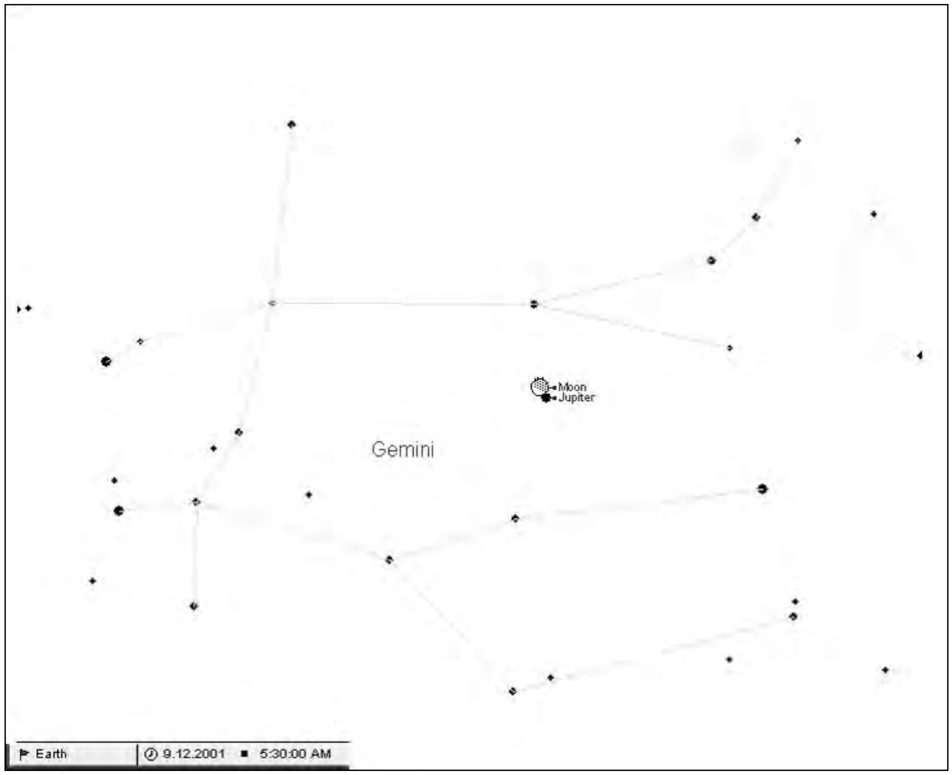


Figure 1 – The constellation of Gemini, September 12, 2001, 5:30 a.m.

The Year of Conjunctions began at the summer solstice of 2001, with Mars at its closest approach to Earth in over a decade. The other planets were massing in the pre-dawn sky and rewarded the early riser with a series of remarkable sights. All four of Saturn, Venus, Jupiter, and Mercury were occulted by the Moon within a two-day span in mid-July; I was fortunate to observe two of these events. A similar series, minus Mercury, occurred in mid-August.

On the awful, sleep-deprived morning of September 12, 2001, I observed a spectacularly close appulse of the crescent Moon and Jupiter, shining through occasional holes in the roiling clouds. To my tired eyes and the exhausted mind beyond came a chilling thought: in this tight celestial pair I suddenly recognized the symbol of Islam, which — rightly or wrongly — was indelibly associated with the previous day's mayhem. The billowing clouds were reminiscent of the smoke and dust I had watched for endless hours on television. Out of sight beyond the clouds was the backdrop of Gemini, envisioned in my mind's horrified eye as twin towers lying horizontal in the eastern sky. The celestial symbolism was powerful; while I refused to accept it as such even in my shattered emotional state, I knew that others might. I wondered if somewhere in the world, somebody's astrologer had foreseen in this upcoming appulse a "sign" for action. Astrologers have certainly counselled invasions in the past, based on fast and loose interpretations of celestial portents. For the only time in two decades of skywatching, on that morning my skies brought me no solace.

(Please do not interpret the foregoing paragraph as misgivings against any particular religious faith, but against the more general threats of astrology and superstition. Indeed, given that this apparition occurred 24 hours after the attacks it was most likely a complete coincidence, but an appallingly timed one which made a visceral impact in the pit of my stomach. It triggered powerful emotions that may be dismissed in retrospect, but couldn't be denied at the time.)

Happier times were ahead, especially on the morning of November 18 when the pair of Jupiter and Saturn proved to be handy comparison objects for a spectacular storm of bright Leonid meteors. Throughout the winter, mighty Jupiter ruled the celestial roost, gleaming brilliantly high in the southern sky in the constellation of Gemini. It was accompanied by the ringed wonder, Saturn, in the neighbouring constellation of Taurus. The two had been passing acquaintances the past three winters, as Jupiter in its smaller orbit had appeared to cruise by stately Saturn. Such conjunctions of the giant planets occur at intervals of 20 years.

But as the winter of 2002 progressed, the pair of giants was gradually joined from the west by the terrestrial planets, leading to the opportunity of a lifetime to see all of the naked-eye planets massing in the evening sky. To call it an "alignment," as the popular press did, was somewhat misleading; at their closest, Jupiter and Mercury were separated by some 33°. But considering the five are normally scattered all around the Great Circle known as the ecliptic, each stepping to its own drummer, to see all five squeezing into the same narrow slice of the pie was extraordinary.

By April 13, elusive Mercury was the last to put in an appearance, joined on that evening by a thin crescent Moon. For the next calendar month Mercury put on its best evening apparition of the year, as indeed it always does around the time of the vernal equinox, ensuring that the planetary massing would be of the longest possible duration.

Not surprisingly, clouds intervened for several evenings for observers in northern Alberta. Finally, on the evening of April 17, the sky was clear right down to the horizon. I was committed to attend a concert involving a fellow Edmonton Centre RASC member, Bob Jahrig. Bob is a talented singer-songwriter who draws considerable inspiration for his compositions from the natural Universe. Indeed, the premiere live performance of "Jumbo Sky" occurred at one of the Edmonton Centre's occasional Stars of the Arts meetings. On this occasion, such a musical prelude seemed appropriate, and at the intermission we stepped outside for an overview of the solar system.

On that particular evening, the crescent Moon nicely filled a gap between Jupiter and Saturn so that each of the objects was roughly equidistant, stepping up the ecliptic. Starting at the bottom was the one object that can be observed even when below the horizon, namely the Sun, followed at regular intervals by Mercury, Venus, Mars, Saturn, the Moon, and Jupiter. Each highlighted a station that would be occupied by the Sun at roughly two-week intervals as it rose towards the summer solstice. The favourable angle of the spring ecliptic was never more apparent.

Collectively, these seven bodies are associated with the ancient tradition of the seven-day week. Use your hard-won bilingual skills and the relationship becomes obvious: the French *mardi, mercredi, jeudi, vendredi* and the English Saturday, Sunday, Monday can be clearly associated with the objects named above. And here they all were, lined up for a single sweep of the unaided eye. Indeed, our own home planet could even be observed indirectly, in the form of Earthshine on the Moon.

One would expect the music of the spheres to be *classical* music, precise and majestic. But while the rhythms of the nearby spheres, our planetary neighbours, are individually tight and predictable (with an occasional retrograde flourish), as an ensemble they resemble free-form jazz. Each seems to do its own thing without much regard for the others, one playing 4 beats to the bar, another 5, another 7, or something. Suddenly they come together on the downbeat and the music briefly makes sense before each goes its separate way again. The planetary polyrhythms achieved such a confluence in April, 2002.

The outer giant planets set the pulse as they slowly circle the sky, the inner terrestrial ones the melody as they flit back and forth. Frequently two of them will come together in a conjunction, more occasionally three in a planetary massing; all five at once is exceptional. This was the best such opportunity in my lifetime.

Mars, Venus, and Mercury, with their smaller orbits, faster speeds, and foreshortened viewing angles, were particularly interesting to follow. And of course Viewing Platform Earth was moving, too. While we couldn't see Earth's orbital motion directly, it was reflected in the observed position of the Sun as Earth revolved around it. Conveniently, all five planets were situated on the far side of the Sun, therefore all six objects appeared to be going in the same direction — east — against the background stars.

It was fascinating over the following nights to observe the relative speeds of the planets, which could be directly associated with their position in the solar system. As it whipped out from behind the Sun, elusive Mercury was clearly the fastest, Venus second, then the Sun in its imagined role as a surrogate Earth. In the last weeks of April the two inner planets, Mercury and Venus, appeared to pull away from the Sun as the slower outer planets seemed to fall towards it. It was fascinating to watch them group

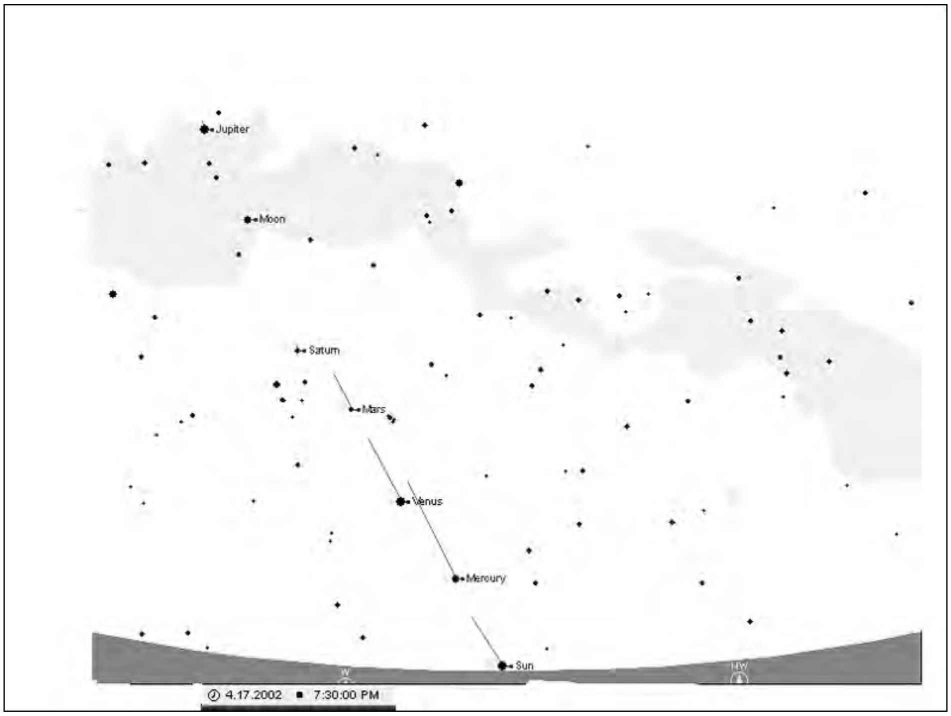


Figure 2 – Sunset, April 17, 2002. With their different orbital periods, the planets are normally about as synchronized as those damn traffic lights on the road to the airport; to see the major bodies of the solar system so regularly spaced was extraordinary. The line extending upward from the Sun and each planet points to their positions in seven days, revealing, to a much greater degree than is normally possible, the relative speed of each. Note how the Sun has the third greatest *apparent* velocity, as the change in its position as seen from Earth is caused by our planet's own motion.

together and overtake one another.

With Jupiter continuing to supervise from the east, the other four conducted an elaborate square dance. As luck had it, Mercury, Venus, Mars, and Saturn were initially aligned in that order, fastest to slowest, so they gradually bunched up on each other. Mercury, the elusive winged messenger, faded from night to night, reflecting less sunlight in our direction even as it approached Earth. Seen through a telescope, it resembled a tiny waning Moon.

By April 26, Mercury had joined Venus, Mars, and Saturn in the constellation of Taurus the Bull. The Hyades, a V-shaped grouping of stars representing the horns of the bull, appeared to gradually prod the planets away. The brightest star in this group, the orange giant Aldebaran, could be used as an observational anchor to confirm the gradual eastern motion of all four planets. Indeed, the path of the planets passed between Aldebaran on the left and the famous star cluster the Pleiades to the right. This richly studded star field provided a beautiful backdrop to the planetary dance, especially as seen through binoculars.

Aldebaran provides a nice example of the immense distances between the stars. It's bright because it's relatively nearby, at "only" 68 light years. But consider this: the spacecraft Pioneer 10 is currently headed in its general direction. One of the fastest craft ever built by humankind, Pioneer 10 was launched in March, 1972, and became the first robot probe to reach Jupiter in late 1973. While it took less than two years to reach Jupiter, three-quarters of a billion klicks away, it will take over two *million* years to approach Aldebaran. It's these vast distances that make the stars appear stationary from our remote vantage point.

On a single occasion in late April, I was able to observe all five planets simultaneously, paradoxically by not looking directly at any of them. Way off in my averted vision, Jupiter was easily held as a thread of light through the corner of my eye, but the smaller planets were more difficult. I found that by fixing my gaze on a spot between Mercury and Mars, slightly closer to the dimmer Red Planet, I could discern all five without scanning.

Because we see their orbits from the outside, the so-called "inferior planets" Mercury and Venus seem to do a pendulum swing back and forth against the Sun, visible for a few hours at a time but never all night. By May 3 Mercury reached its furthest apparent point from the Sun, slowing to a halt as it appeared to be reined in by a tight gravitational leash.

Also in that first week of May, first Mars, then Venus, appeared to overtake Saturn. The three formed a near-perfect equilateral triangle on the evening of May 5. This grouping closely resembled an apparition of the same three planets, also in Taurus, in April of 2 BCE. Some scholars consider this earlier grouping to be one of several candidates for the Star of Bethlehem, a significant astrological event that may have been interpreted by the Magi as a sign from above.

The famous pair of Venus and Mars continued to close in on an exceptionally close encounter on the evenings of the May 9 and 10. I noted how the goddess of love outshone her counterpart in the war ministry by a factor of 200! By this time all four planets, plus Aldebaran, occupied a circle of sky less than 10° around, roughly the size of a fist held at arm's length.

Alas, the Sun awaited its turn on the dance floor, promising to dazzle all others with its brilliance. The planetary foursome became progressively difficult to see in the sunset glare as the fainter members dropped below brilliant Venus. The evening of May 13 offered a group finale of sorts when the slender crescent Moon again joined the show, once again near tiny Mercury, as it had been exactly one month previous. By this point I found binoculars a requirement to pick out faint Mars and faded Mercury; as they dropped away from Venus, the lesser lights of the planetary troupe literally faded into the sunset. Exit, Stage West.

A couple of highlights remained to close the show. On June 3 the two brightest planets, Venus and Jupiter, conducted a seemingly private waltz on the suddenly vacant celestial stage. Finally, on the evening of Monday, June 10, came a *pas de deux* between the Sun and Moon. This show-stopper was the last partial eclipse of the Sun to be seen from Alberta for a decade. To see these two most famous of celestial objects invade each other's space for a brief time somehow seemed an appropriate grand finale to the Year of Conjunctions.

ACKNOWLEDGEMENT

Lyrics of "Jumbo Sky" provided courtesy of Bob Jahrig. For details on his CD *Tree Tops*, visit his Web site at www.bobjahrig.com. Figures 1 and 2 were created with Starry Night Deluxe.

Bruce McCurdy has been active in astronomy and its public education outreach since the mid-1980s. He is past president of the RASC Edmonton Centre and currently serves the National Council as Astronomy Day Coordinator. Bruce is the Education Development Coordinator of the SkyScan Science Awareness Project, an initiative of the Edmonton Area Radio Astronomy Group, which offers Grade 9 students a science curriculum-related project observing meteors using FM radios.

Scenic Vistas

The Environs of Delta Ceti

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

Last year, two other Montreal Centre members spent a rather enjoyable evening with me observing the deep sky at David Ross' farm in the Eastern Townships. All was not sweetness and light however. My two partners spent a good part of the evening trying to track down NGC 6543, the Cat's Eye nebula. They never succeeded and in frustration, towards the end of the evening, asked if I might show it to them in the 15-inch reflector. I cursed them, and not silently, either! It was late and I was tired, and I didn't particularly relish the five-degree star hop down from Psi Draconis. We managed, however, and in a few minutes the Cat's Eye was neatly framed in the field of view.

My companions and I spoke briefly of their difficulties, and of course I sympathized. As inexperienced users of their telescope, they'd set themselves up for disappointment. I didn't envy them a long starhop near the north celestial pole with a fork-mounted Schmidt-Cassegrain and a finderscope that provided an upright, mirror reversed image of the night sky: nearly impossible to match with a star chart!

But they wanted to see the Cat's Eye, no doubt inspired by the multi-coloured Hubble images appearing on the cover of *Sky and Telescope* and elsewhere. The fact that it was bright but relatively featureless, even in my reflector, was probably a little disappointing. But my friends were, and are, enthusiastic observers who won't let a little setback sour them on astronomy or observing.

Still, there are better ways to spend those rare cloudless nights than fruitlessly scanning the heavens, getting lost and starting all over. Fortunately there's often great observing possible in the neighbourhood of bright field stars and I recommend this frustration-free observing to rookies and more-experienced observers alike. It does require some preparation however — cloudy evenings spent with a star atlas and a good field guide like *Burnham's Celestial Handbook*. The rewards offered are well worth it. This month, the sky surrounding Delta Ceti is a great example of how much fun this kind of observing can be.

By happy accident, Delta Ceti sits right in the middle of a moderately bright cluster of galaxies, many of which are visible in amateur telescopes. If you're involved in hunting down Messiers, you will be coming by here sooner or later. M77 lies less than a degree southeast from Delta Ceti. It is the brightest galaxy in the region and an unusual one as well. I've observed it many times but one of the best views ever occurred in the late summer of 1992 from the deck at Mount Sutton. It was a strange night, the transparency not particularly great, but at high power M77 was an amazing sight. Its blazing core was surrounded by a bright envelope with tapered, slightly curved ends elongated north-east/southwest. This central area was surrounded by a large round, but faint, outer region. It is rare to see this kind of structure in a galaxy, particularly one as far away as M77, which is probably more than 50-million light years distant.

But what is unusual about this galaxy? It is one of the brightest of a class known as Seyfert galaxies. These systems feature intensely bright core regions, often starlike in appearance, which when studied spectrographically reveal strong emission lines. Large, dense clouds of gas are being ejected from the core, quite possibly by a large black hole. Seyfert galaxies are believed to resemble quasars, though on a smaller, less energetic scale.

A half degree northwest from M77 we find NGC 1055, a bright galaxy that is surprisingly difficult in a small aperture telescope. The reason is that it is bordered to the north by two magnitude 7.5 field stars whose brilliance swamps its delicate light. Try to observe at high magnification and keep the bright stars out of the field of view. In an 8-inch Schmidt-Cassegrain at 80×, I found NGC 1055 to be a wispy, threshold object. I've never had the chance to observe it with my 15-inch Newtonian. Forty-five arcminutes due north of Delta Ceti you will come upon NGC 1032, a difficult object for a small telescope. In my old Schmidt-Cassegrain I found it a challenging object, impossible with direct vision and gradually elongated east/west. Sky conditions might have played a role here and on an excellent night this magnitude 11.6 galaxy might reveal a little more.

Two degrees southeast of Delta Ceti the observer will come across the magnitude 5 field star 75 Ceti. There are three galaxies located less than one degree due west from this star. The easiest of the bunch is NGC 936. This galaxy has a bright core and an east/west oriented outer envelope. In my notes in 1992, I noted that the galaxy was part of an asterism that resembled the Sickle of Leo in the upright, mirror-reversed field. The galaxy took the place of Regulus.

NGC 955, the galaxy nearest 75 Ceti, was a faint object, though visible with direct vision. Little more than the tiny core of the elongated galaxy was visible at 80×. NGC 941, at magnitude 12.4, was not visible in my Schmidt-Cassegrain on this occasion, though under good conditions it should be detectable.

Returning to Delta Ceti and sweeping a degree and a half towards the southeast, passing M77 along the way, the observer will come upon a quartet of galaxies.

The brightest are NGC 1087 and NGC 1090, a large bright pair that can be easily observed together in the field of a low to moderate power eyepiece.

Here is a good study in contrasts, especially since the galaxies initially appear fairly equal in brightness. NGC 1087, the more southerly of the two, is the brighter, oriented north/south with a broadly concentrated central region. The envelope of this galaxy appeared fairly smooth and well defined in my 15-inch reflector. NGC 1090, on the other hand, is a little fainter, strongly elongated east/ west and gradually brighter towards the middle. Again I found the outer envelope fairly smooth and well defined. All in all, two good targets for a six- or 8-inch telescope.

Immediately west of these galaxies are two more difficult targets. Of the two, NGC 1094 is probably the easier to observe. This is a faint galaxy, located due south of a wide, uneven pair of field stars. An oval, diffuse haze oriented almost due east/west, it is slightly brighter to the centre. At magnitude 13.6, NGC 1104 is probably beyond most smaller telescopes. I found it faint and diffuse, poorly defined and slightly elongated north/south in my 15-inch reflector.

To finish off, we can return to Delta Ceti and sweep 1.5 degrees northeast to NGC 1073, a barred spiral galaxy that had been on my must-see list for a long time. In my 15-inch, I was surprised at how faint and diffuse it appeared. It was very slightly brighter to the middle and the whole galaxy appeared very diffuse and poorly defined with no trace of any spiral structure.

NGC 1073 is of interest because of a study done by Jack Sulentic and Halton Arp in 1979, in which they imaged three quasars apparently associated with the spiral arms of this galaxy. Arp proposed that quasars are not necessarily high-energy, extremely luminous and distant objects, but rather relatively nearby and associated with many bright galaxies. Although his theories are largely viewed with skepticism by the astronomical community at large, it is interesting to note that conventional wisdom once held that the earth was flat and at the centre of the universe!

So there you have eleven potential targets, all located within two degrees of a star that's easily visible to the naked eye.

There are many areas of the sky that offer similar experiences. I offer you the challenge to settle down some night with a star atlas and seek them out!

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

New Meadows Campground Sign

by James Edgar (jamesedgar@sasktel.net)

There's a new sign at "The Meadows" campsite in Cypress Hills Interprovincial Park at the southern convergence of the Saskatchewan and Alberta borders. The sign marks the recent discovery of comet P/2001 Q2 (Comet Petriew) by Vance Petriew during the Saskatchewan Summer Star Party (SSSP) in August 2001 at the park (see Petriew's write-up in the *JRASC* February 2002, page 9, and the accompanying article by Richard Huziak, page 15).

It all came about because of hard work by Lorne Harasen of the Regina Centre. He contacted the Provincial Minister of Northern Affairs, the Honourable Buckley Belanger — who also holds the Saskatchewan Environment portfolio, including Parks and Recreation — to find a way to honour Petriew's discovery. As a result, Belanger arranged to have Petriew present in early June 2002 to receive recognition from the dignitaries and Honourable Members of the Saskatchewan Provincial Legislature as the first person in Saskatchewan and only the 8th Canadian in history to discover a comet (see: `www3.ns.sympatico.ca/dave.chapman/CanCom.html`).

An earlier bit of work behind the scenes saw the creation of the new sign for the Meadows campground. Belanger made the announcement of its unveiling during his speech at the Legislature.

Later, on August 10, during the 2002 SSSP gathering at Cypress Hills, Belanger was on hand with many other well-wishers to unveil the new sign and plaque. The sign is the creation of park manager Brad Mason and includes a colour plaque commemorating Petriew's discovery (see photos).

The management and staff of Cypress Hills Park enthusiastically welcome the annual gathering of stargazers and literally roll out the red carpet for them. As part of the plaque wording reflects, the location is a favourable one for looking at the heavens: "The elevation of Cypress Hill and the lack of urban light pollution make this an ideal site for astronomical viewing."

The plaque, which reads:

Comet Petriew Discovery

From this site in Cypress Hills Interprovincial Park at 3:48 am on August 18, 2001 amateur astronomer Vance Petriew of Regina, Saskatchewan sighted the first comet discovered from Saskatchewan skies. It was the only comet discovered by an amateur astronomer in the world during 2001 and he was only the 8th Canadian in history to discover a comet.

Confirmed by the International Astronomical Union, the comet was named P/2001 Q2 Petriew or unofficially "Comet Petriew".

Composed of rock and ice, Comet Petriew's size is estimated to be one kilometre in diameter. It was discovered 128 million kilometres from earth and has an orbital period of 5.5 years, which could change over time by the gravitational influences of Jupiter. Its life expectancy is unknown.

Mr. Petriew's discovery was made during the Saskatchewan Summer Star Party, sponsored by the Regina and Saskatoon centres of the Royal Astronomical Society of Canada. This annual event draws amateur astronomers from Saskatchewan, Alberta and British Columbia as well as American States as far away as Texas and Alabama. The elevation of Cypress Hill and the lack of urban light pollution make this an ideal site for astronomical viewing.

This marker placed by Saskatchewan Environment, August, 2002.

The Petriew family at the unveiling ceremony: Jennifer, Vance, Emily, Vance's father and mother, Paul and Karen (All photos taken by the Author).

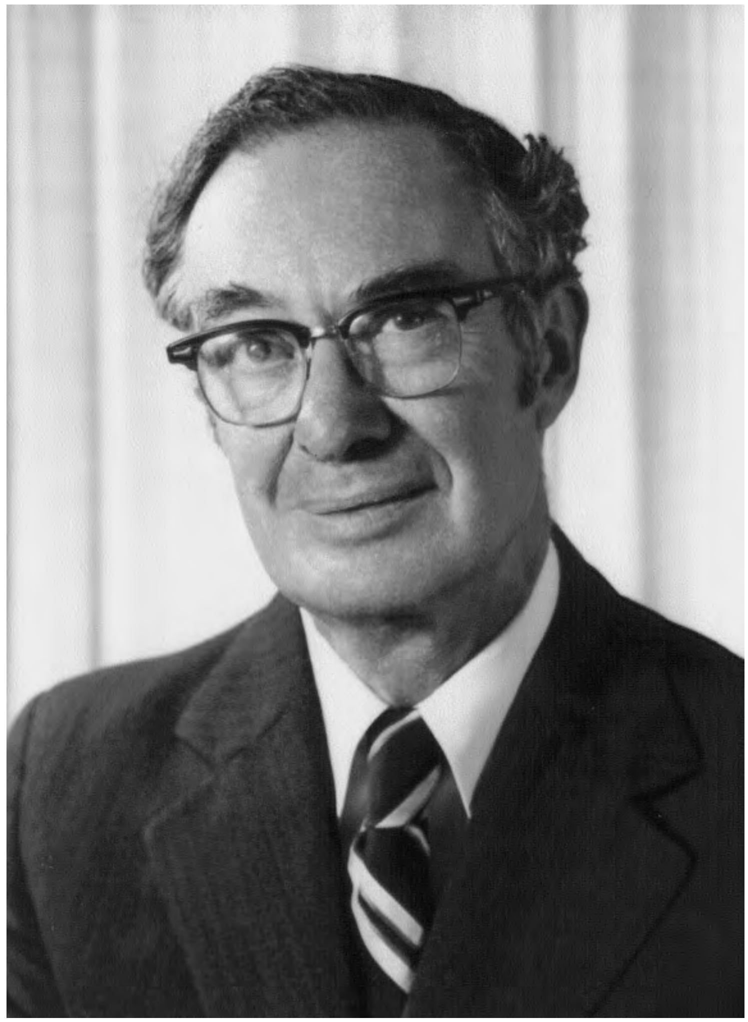
James Edgar is an RASC Life Member, attached to the Regina Centre. His serious love affair with astronomy began in Vancouver, B.C. in the early 1970s, when he volunteered as a docent at the MacMillan Planetarium. He enjoys many dark sky nights from his home in Melville, Saskatchewan.

Obituary
Nécrologie

Kenneth Osborne Wright (1911–2002)

On July 25, 2002, Canada lost one of her most senior astronomers and our Society the most senior of its former National Presidents, when Kenneth Osborne Wright died in his ninety-first year. Born on November 1, 1911 in Fort George, B.C., he was to spend most of his life in his native province. Education in astronomy was not available, however, in British Columbia in his student days and he spent his undergraduate years at the University of Toronto, graduating B.A. (and winning the Society's Gold Medal) in 1933 and M.A. in 1934. During the following academic year, he was an Astronomical Assistant at the University and, in 1935–36, he held a similar appointment at the University of Michigan, from which he received his Ph.D. in 1940. Already in 1936, however, he had returned to Canada and British Columbia, to take up an appointment at the Dominion Astrophysical Observatory in Victoria. He was one of three appointed to the D.A.O. staff shortly after the retirement of the founding Director, J.S. Plaskett (the other two were R.M. Petrie and A. McKellar) and was the last person associated with the D.A.O. to have known Plaskett personally. Apart from short periods of absence for visiting appointments elsewhere, Ken Wright was to remain at the D.A.O. for his entire professional career and was the Observatory Director for the last ten years of his working life. He retired at the end of October 1976 just before reaching the then mandatory retirement age of 65. During his last few weeks as Director, he was heard to complain that, since his birthday that year fell on a Monday, he would be unable to work on the last two days of his sixty-fifth year!

Ken Wright's primary interest was in stellar atmospheres, in both their structure and their chemical composition. Since most of his work was done before computers were readily available and while the photographic plate was the only detector astronomers could use, he had to work by methods now considered old-fashioned. The preparation for observing, the making of observations (sometimes involving several consecutive nights on one star), and the reduction and analysis of the observations all called for both skill and patience. Although Ken could sometimes be impatient with colleagues, for stars and spectrograms he seemed to have limitless patience. He set himself very high standards and was meticulous in all his work. One of his major contributions to the study of stellar atmospheres was the observational determination of standard values of line intensities in the spectra of stars across the whole range of spectral types. This work, carried out with the assistance of E.K. Lee and T.V. Jacobson and the collaboration of J.L. Greenstein, was published in the *D.A.O. Publications* in 1963. That paper was the fruit of Ken's twelve-year incumbency as President of Sub-Commission 29b of the International Astronomical Union. He also studied the atmospheres of the supergiant components of long-period binary systems, using the light of the companion (usually B-type) star as a probe as that star passed behind



Kenneth Osborne Wright

the atmosphere of the supergiant. He made several contributions to the study of that class of system; the orbital elements that he derived for VV Cephei (period just over 20 years) are still the best available.

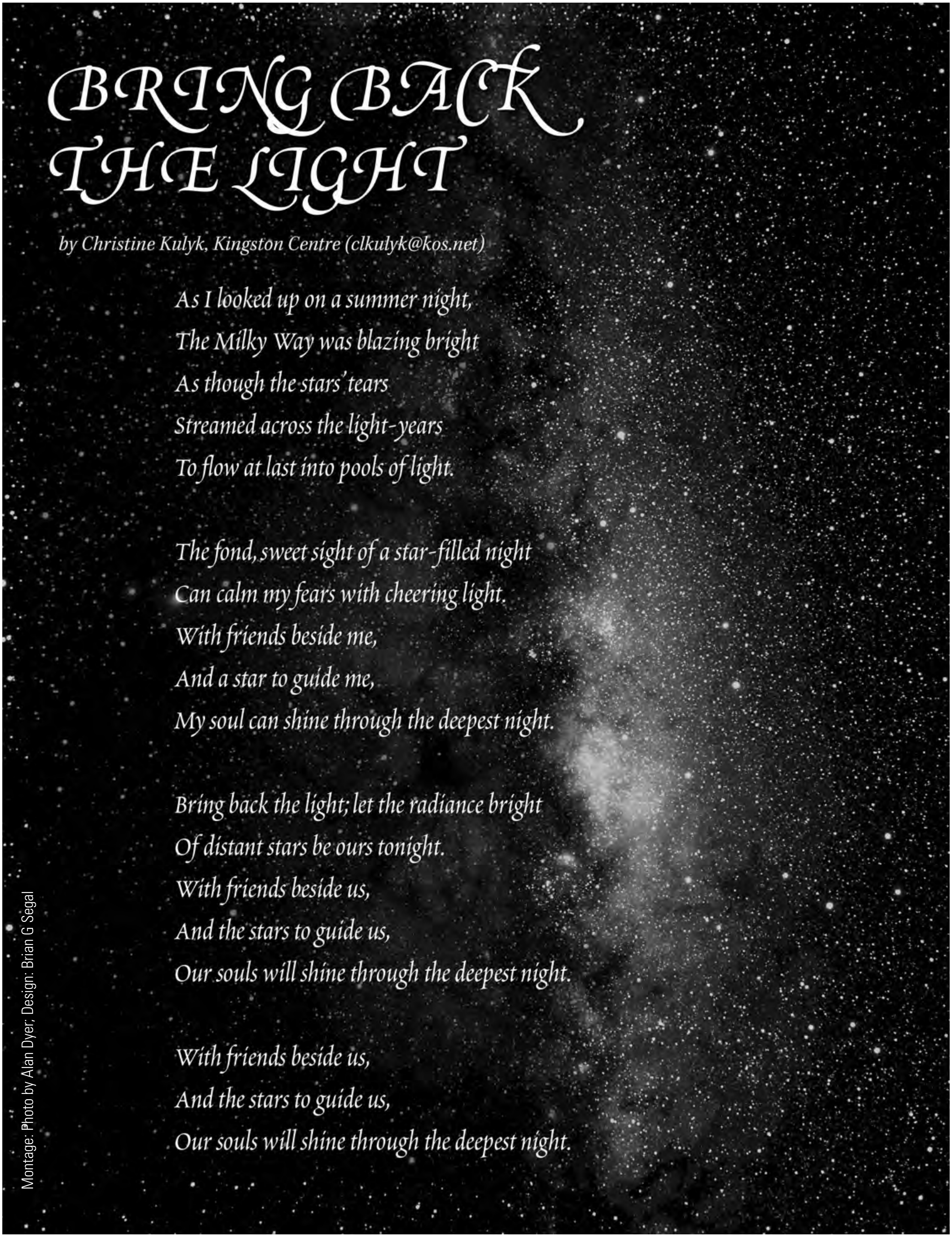
Ken was also interested in the Sun as a typical star. In spite of the Sun being so close, some solar phenomena are difficult to observe. In particular, emission lines in the spectrum of the chromosphere are swamped by the continuous light of the photosphere. At that time, even the brightest of these lines could be observed only for a few seconds during a total eclipse, as the so-called flash spectrum, seen after the Moon has covered the photosphere, but before it covers the chromosphere. Records of the flash spectrum on calibrated photographic plates were rare in the 1950s and Ken wanted to use the opportunity of a total solar eclipse, visible from northern Ontario on June 30, 1954, to capture the flash spectrum on carefully calibrated plates and to apply to them the techniques of photographic spectrophotometry that he and his colleagues had developed in Victoria. A large grating spectrograph was specially built and shipped to the eclipse site. A party of four, including Ken and one of us (J.A.G.), spent a month at the site, clearing the ground, mixing concrete, and setting up the spectrograph, the plate-calibration apparatus, a heliostat, and a darkroom. A detailed account appears in Vol. 48 of this *Journal* (p. 231, 1954). Unfortunately the sky was totally overcast at the time of the eclipse!

A more successful observing campaign was one in which Ken organized both the D.A.O. staff and the Victoria amateur astronomers in cooperative observation of the transit of Mercury of November 11, 1940. This time results were obtained and they were also published in this *Journal* (Vol. 35, p. 1, 1941). This was just one part of Ken's service to the Victoria Centre and the National Society, which culminated in his term as National President (1964–66).

Ken became Director of the D.A.O. after the sudden death of R.M. Petrie in the spring of 1966. This was a time of sharp disagreement within the Canadian astronomical community about the location of a proposed major instrument. However disappointed he may have been by the consequent cancellation of the project, Ken continued, with G.J. Odgers, to look for alternative ways to gain access to large telescopes for Canadian astronomers. His persistence in this quest was a major factor in securing Canada's eventual participation in the CFHT, and therefore indirectly in our participation in Gemini and other projects. The period of Ken's Directorship was also a period of transition for the D.A.O. in that the Observatory ceased to belong to a Department of the Federal Government and became a part of the National Research Council, later of the Herzberg Institute of Astrophysics.

Ken was elected a Fellow of the Royal Society of Canada in 1954 and received an honorary degree of D.Sc. from the Nicolas Copernicus University of Torun, Poland in 1973 during an Extraordinary General Assembly of the International Astronomical Union, held to mark the 500th anniversary of the birth of Copernicus. He was active in the University of Victoria, where he was an honourary professor of physics and served on the Senate, and in the wider community; for many years he was an Elder of First United Church. He was twice married, to Margaret Sharp in 1937, who died in 1969, and subsequently to Jean Ellis, who also predeceased him by about a year. He is survived by a daughter from the first marriage, Nora, to whom we extend our sympathy.

A.H. Batten and J.A. Galt.



Bring Back the Light

by Christine Kulyk, Kingston Centre (clkulyk@kos.net)

As I looked up on a summer night,
The Milky Way was blazing bright
As though the stars' tears
Streamed across the light-years
To flow at last into pools of light.

The fond, sweet sight of a star-filled night
Can calm my fears with cheering light.
With friends beside me,
And a star to guide me,
My soul can shine through the deepest night.

Bring back the light; let the radiance bright
Of distant stars be ours tonight.
With friends beside us,
And the stars to guide us,
Our souls will shine through the deepest night.

With friends beside us,
And the stars to guide us,
Our souls will shine through the deepest night.

Montage: Photo by Alan Dyer; Design: Brian G Segal

Astrocryptic

by Curt Nason, Moncton Centre

We present the answers to last issue's puzzle:

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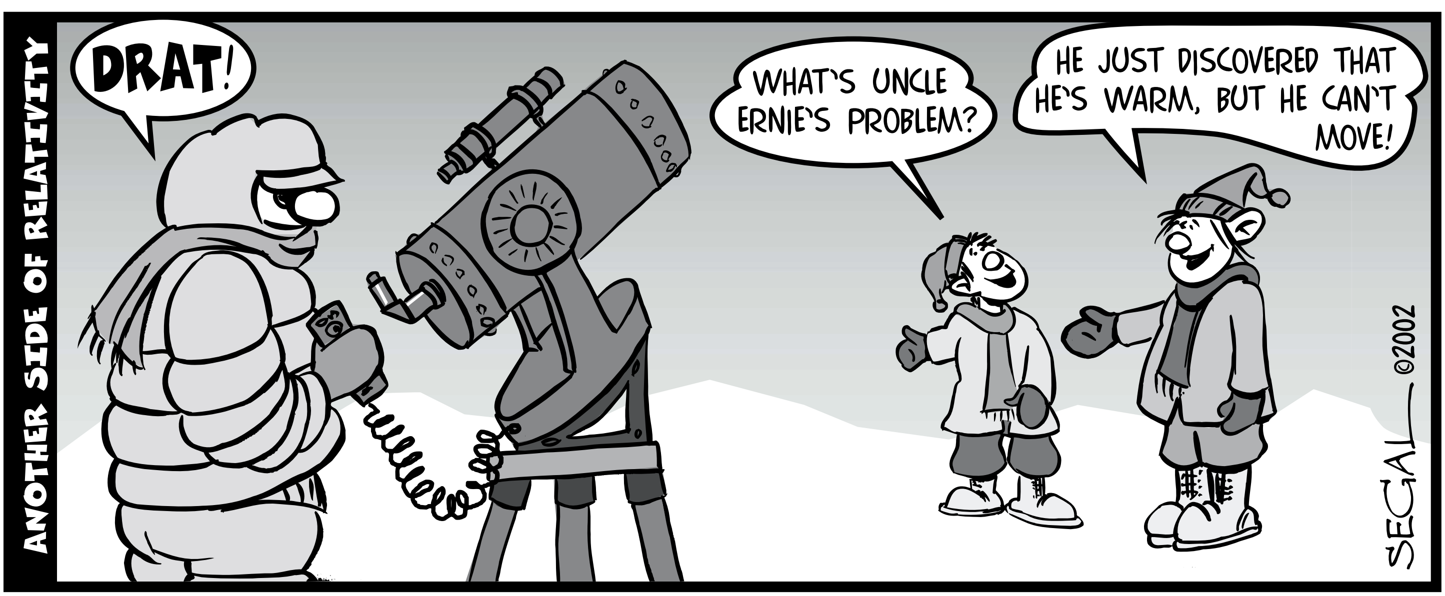
		13 I	R	14 O	N	O	X	I	D	E		
15 E		O		R		S				Y		16 A
17 D	E	N	E	B		18 C	E	19 N	T	A	U	R
M				I		O		O		S		I
20 O	N	21 E	S	T	O	P		22 B	I	E	L	A
N		U		E		I		E		K		N
23 D	A	V	I	D		24 C	O	L	L	I	D	E



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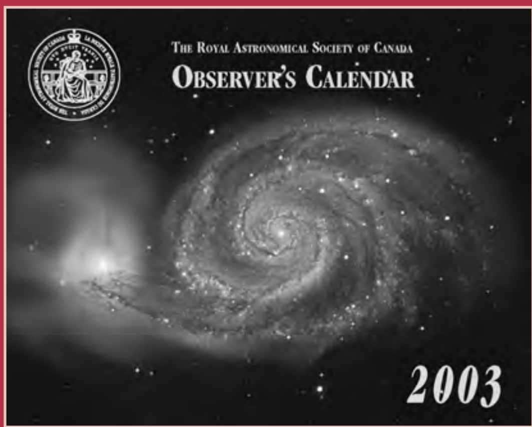


Observer's Calendar — 2003

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

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

Price: $15.95 (members); $17.95 (non-members)
(includes postage and handling; add GST for Canadian orders)

The Beginner's Observing Guide

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

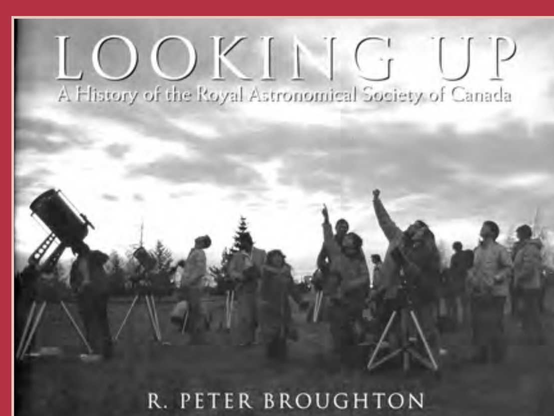
Written by Leo Enright (160 pages of information in a soft-cover book with otabinding that allows the book to lie flat).

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

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

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

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



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