Journal

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President's Corner

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

Two years ago, when I became President, I set objectives for the RASC and reported them to you in this column. Now, in my final President's Message, I want to tell you how we did.

My first objective was to start running the Society like a small business. We designed a computer system that allows us to handle our customers more efficiently, both our members and those non-members who buy our products. The computer system is in place and running smoothly. Our annual revenues have increased from $250,000 to $325,000, roughly a 30% increase over two years. Our membership has also increased from 3,071 to over 4,200, a 36% increase. I expect further growth as we expand our customer database.

My second objective was to have the National Office operations running smoothly and efficiently. The computer system has helped with that, but Bonnie Bird and Isaac McGillis are the ones who made it happen. Today, members receive excellent service when they join the RASC or when they renew their membership. Product orders are filled quickly, and the sales of the *Observer's Handbook*, the *Observer's Calendar*, and *The Beginner's Observing Guide* are doing very well.

We are coming to the end of a six-year period of transition. During that period the *Journal* was redesigned, we began to advertise regularly, *SkyNews* became a benefit of membership, and we changed the way we did business in the National Office. As a result, we have experienced tremendous growth.

So where do we go from here? I think it is important for the Society to set some new goals. Here are some ideas for discussion.

With the National Office running smoothly, we can turn our attention to fulfilling our mandate: promoting astronomy in Canada. While it is good news that more and more provinces are now making astronomy a part of their education curriculum, the fact is that many teachers are worried about the impact of that in the classroom. To assist them, last year we created a National Public Education Committee. I hope the new working group will continue to help teachers across the country bring astronomy to their students.

Our mandate also extends to public education. That has never been more important than now. Astronomy misinformation often appears in the media, and studies show (see this issue) that the majority of university students tend to believe in the validity of astrology! It is my hope that we can co-operate with the Canadian Astronomical Society (Canada's society for professional astronomers) to create a strong and unified voice for astronomy from the Canadian astronomical community.

I would also like to see the RASC provide new members with the help they need in getting started in astronomy. My

wife recently joined an archery club. The first thing the club offered her was a six-week course on shooting techniques. New members join the RASC to learn astronomy, so it seems like a logical possibility for the Society to offer courses as well, possibly an introduction to astronomy or what to look for when buying a telescope. Such courses could also serve a social purpose: many new members are intimidated by the RASC, perhaps because of the cerebral aspects of astronomy, or the complexities of the science and technology of astronomy, or simply because of the "Royal" in the name.

Many members have told me that they like receiving *SkyNews* as a benefit of membership. *SkyNews* is especially useful for providing new members with information to help them learn astronomy. Up to now, the cost of providing *SkyNews* to Society members has been through sources other than membership fees. Although I believe we should keep *SkyNews* as a benefit of membership for all members, I would like to see the cost shifted to individual members. Membership in the RASC has been an incredible bargain for a long time, so the expense to individual members of a little more for *SkyNews* would not be asking too much.

I would also like to see the formation of a National Observing Committee. It has always struck me as peculiar that our national astronomy organization does not have a working group with a responsibility to oversee observing programs. Such a group could expand on the observing certificates we currently offer, and also help novice astronomers find their way around the night sky.

Several Centres run extensive programs for youth members. I hope other Centres will take advantage of their expertise and establish similar services in their regions. The average age of Society members seems to be increasing, and it is important that we involve more young people in the RASC and introduce them to the exciting hobby of astronomy.

Apart from being an excellent resource, the *Observer's Handbook* is a major source of revenue for the Society. A major drop in sales or a change in the value of the U.S. dollar (most of our sales are to the United States) would have an adverse effect on our finances. In the short term, the new product system at the National Office should help us to build our customer base and increase sales. Over the long term, the health of the Society's finances requires us to develop a plan to produce more publications to generate revenue. Within the Society we have many members with extensive astronomical expertise. If the Society could somehow take advantage of such expertise, say by employing professional writers and designers to assist members, it might be possible to produce more top-notch publications. Since it is unrealistic to ask members to volunteer the hundreds of hours required to make it happen, we would have to provide remuneration.

By the time you read this column, two new centres — Moncton and Charlottetown — will have joined the RASC. We now have Centre representation in all ten provinces. Moncton and Charlottetown, welcome to the RASC!

The next few years will be exciting for the Society. We are partners in a project to send the first Canadian astronomical telescope into Earth orbit — the MOST satellite — which will be launched in two years' time. Also, a new initiative by the Canadian Astronomical Society and the National Research Council will be seeking funding from the federal government to support Canadian astronomy for the next ten years, and the RASC may play a vital role in the public outreach arm of that initiative.

I cannot thank our Executive Secretary and Office Manager, Bonnie Bird, enough for her effort and dedication over the past four years. Her assistant, Isaac McGillis, has also become an important part of the RASC team and is a great promoter of the RASC and astronomy.

During my term, the Executive, consisting of Robert Garrison, Rajiv Gupta, Kim Hay, Raymond Auclair, and Michael Watson, has been very supportive during what were some challenging times. To all of them I express my sincere thanks. I wish the new Executive all the best.

Our Editors spend countless hours turning out quality publications — all on volunteer time. I thank Roy Bishop and David Turner for their generous contribution of time and skills to the Society, and wish their successors good luck.

To the members of the National Council, my thanks for participating in what, I think, were very productive meetings. The discussions at times were intense, but mostly they were civil and respectful.

Finally, I must thank my wife Betty for her love and support during my term on the Executive.

It has been an honour to be the President of the RASC. It was an experience I will always treasure.

Clear skies. ◉

From the Editor

by David Turner

Following my first year as editor of the *Journal of the Royal Astronomical Society of Canada*, I noted in an editorial (JRASC, 89, 1, 1995) that survival through one year on the job seemed to be only a minor accomplishment when compared with Clarence Augustus Chant's tenure of 50 years. The completion of a term of six and a half years as editor also seems to be of little note relative to the record of the JRASC's first editor, although, from personal experience, I can attest that, with the changeover of the *Journal* to its new format, the chore of one year's editing is probably comparable to five years of editing the *Journal* in its old format. It certainly has felt that way.

In the past year I have also been reminded of another unusual statistic regarding *Journal* editors, namely that its first two editors — Chant and Ruth Northcott — completed their terms of office through death rather than resignation, although in each case sub-editors carried out the editorial chores in their last days. The position of *Journal* editor has, fortunately, never been "officially" designated as one of "editor-for-life." It therefore seemed to me that the completion of my term of office in 1999 was a good time to step down in order to permit fresh blood and new ideas to take the reins of the Society's major bimonthly publication. More than one year later, this issue marks the completion of my term of office.

Six and a half years do not constitute a long period in one's lifetime, but that has been roughly the average length of the terms of office for the last five editors, all of whom, I am delighted to report, are still in reasonably good health! I have benefited greatly from having four of my predecessors available for advice when necessary, even if I have not always followed their suggestions. I have also had the pleasure of serving under four different Presidents of the Society, and have been assisted in the production of the *Journal* every two months (for some at least — for the rest of us there is never any let-up) by an extremely dedicated crew of editorial assistants, column writers, proofreaders, and publishers. I am also grateful to the many members who volunteered their services to assist with the *Journal* after our last plea. The only sore point has been the fact that the time available for editing on a volunteer basis has grown steadily smaller, my regular employment consisting of a relatively heavy mix of teaching and committee responsibilities at Saint Mary's University (for the first three and a half years I also chaired my department), in addition to the research that I enjoy so much.

For the moment I will continue to do a variety of chores related to the *Journal*. Many of the sub-editorial chores have devolved to me over the years as volunteer editors have come and gone, and I still find myself responsible for book reviews. Upon looking back over the past six and a half years, I realize that the job of editing the Society's *Journal* has been one rich in experiences of all types, most of them pleasant. I am grateful to everyone who, in their own way, has made the experience so delightful: paper reviewers, paper authors, concerned readers, and members of the production crew. Each has had a positive effect on the *Journal* in one way or another. ◉

GREAT ASTROPHOTOS WANTED

A new feature coming to the *Journal* is a regular gallery where we will feature members astrophotography. As well we always have a use for photos that can be used to illustrate articles in the *Journal*.

For many of our members astrophotography is a passion. The search for the perfect shot of some faint fuzzy can consume countless frigid nights and buggy evenings — as long as the sky is clear and dark some RASC member is out there shooting the stars and planets and other related phenomena such as aurorae and other atmospheric events.

We invite you to send us your best shots. We can handle prints, transparencies (from 35mm to 8×10 inches), and high resolution digital or scanned images in most popular formats. Your image will most likely be printed in black and white, but if you have a great color shot, send it along as we try to print at least one color section per year.

Contact Dave Lane (dlane@ap.stmarys.ca) or the editors (address can be found on the masthead at the beginning of this magazine).

Correspondence
Correspondance

EPICYCLES ON EPICYCLES

Dear Sir,

In a light-hearted column in the February issue of the *Journal* (JRASC, 94, 34, 2000), Gazer, hiding behind his anonymity, makes two remarkably common historical mistakes, and adds two brand new ones of his very own. First, he says, "Circles centred on the Earth would easily explain the motions of the Sun and Moon." Wrong! The most widely accepted solution from antiquity (Ptolemy's) used *eccentric* circles, that is, ones placed off-centre from the Earth. Second, he gives ear to the very popular "epicycle-on-epicycle" mythology,

and falls victim to the "80–34 syndrome," which falsely ascribes 80 circles to Ptolemy in contrast to 34 from Copernicus. Copernicus actually used more circles than Ptolemy, in spite of the fact that his heliocentric arrangement eliminates the large epicycles. For better or worse, medieval astronomers simply did not have the accurate observations to show that Ptolemy's relatively simple models of planetary motion were defective, nor did they have mathematics sophisticated enough to cope with epicycles on epicycles even if they had the necessary data. Those wishing further enlightenment on this question can check "epicycles on epicycles" via the index of my *The Eye of Heaven*

(1993, Springer).

Kepler started working on the orbit of Mars early in 1600, and found the elliptical form of its orbit by March 1605 — hardly 30 years! And he did not "get the math wrong" when, at an earlier stage, he used an ellipse as an approximating figure. The effect he was searching for was very subtle, and Tycho's observations had to be treated as "votes and ballots." Kepler finally hit upon the correct ellipse when he convinced himself that it fit into a theoretical physical model as well as with Tycho's observations.

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News Notes
En Manchettes

CANADIAN ASTRONOMER DISCOVERS COMET USING THE WEB

There are very few facets of astronomy that have not been profoundly affected by the Internet revolution. Astronomers can now access journals on-line, control telescopes on-line, and even discover comets on-line.

Today, one of the most prolific comet-finding tools has been the *Solar and Heliospheric Observatory* (SOHO), a project intended to study the internal structure of the Sun and the behaviour of the solar wind. To date, it has helped to discover just over 100 comets. The spacecraft is a joint European Space Agency (ESA) and NASA project that was launched on December 2, 1995. It was placed in a halo orbit 1.5 million kilometres towards the Sun in the L1 Lagrangian point — giving it an uninterrupted view of the Sun.

One of the experiments, the Large

One of the LASCO C3 images used by Michael Boschat to discover Comet C/2000 E1 (SOHO). North is at the top and east is to the left. (Image courtesy of SOHO/LASCO C3 consortium. SOHO is an ESA and NASA project.)

Angle and Spectrometric COronagraph (LASCO), continuously monitors the solar corona by creating an artificial solar eclipse with an occulting disk. LASCO has three separate telescopes of various fields of view. The widest-angle telescope is the C3 instrument that can observe the corona from 3.5 out to 30 solar radii. Since there is no atmosphere in space to scatter sunlight, the C3 images are filled

with faint stars and the occasional solar system object — a view not possible here on Earth. The spacecraft's spectacular images are downloaded onto the web continuously, making them accessible to all that are on-line (`http://sohowww.nascom.nasa.gov/`).

Amateur and professional astronomers from around the world have been using the SOHO web site to search for comets as they pass the Sun. Mike Boschat, a life-member of the Halifax Centre of the RASC, has been searching the images systematically since February 10. On March 4, after two near misses, Boschat bagged his first comet, sharing the honours with three other cyber-observers.

Comet C/2000 E1 (SOHO) was a Kreutz Sun-grazing comet. This family of objects is thought to have originated from a large parent comet that broke up as it passed close to the Sun some time in the distant past. Like many of its kind, the comet did not survive its encounter with the Sun.

At the time of discovery, Boschat described the comet as "a faint speck among the cosmic rays and stars in the

background…" Boschat goes on to describe his particular search technique. "I use the LASCO C3 512 × 512 pixel images… The images come on the site every 30 minutes, and I download them as soon as they do. After I have four images, I begin to loop them using GIF animation software that can be found on the Internet. I usually loop the images at four frames per second looking for an object that is moving towards the Sun in a steady manner and brightness. I also use a magnifying glass to watch the possible comet move. After I suspect it is a comet, I put my mouse arrow as close as possible to the object to get the *X* and *Y* co-ordinates. Then I send all the information via E-mail to Douglas Biesecker at Goddard." According to Boschat, the rules from ESA and NASA are straightforward: before observations are submitted, the object must appear in at least four images.

Asked how he felt when his first discovery was confirmed, Boschat replied, "I can say I was excited! I have been studying astronomy for 40 years now, and the comet was my gift. Even though it is named after the SOHO satellite and is a sungrazer, it still feels good to have made an astronomical discovery."

Editor's Note: As this issue goes to press, Michael has reached more than 10 confirmed SOHO comet discoveries!

SUPERNOVA DISCOVERED BY RASC PAST PRESIDENT

Among the rarest of celestial events are supernovae, titanic stellar explosions that occur, on average, about once every 300 years in our Galaxy. They are so luminous at maximum light, that for a few days supernovae can outshine an entire galaxy.
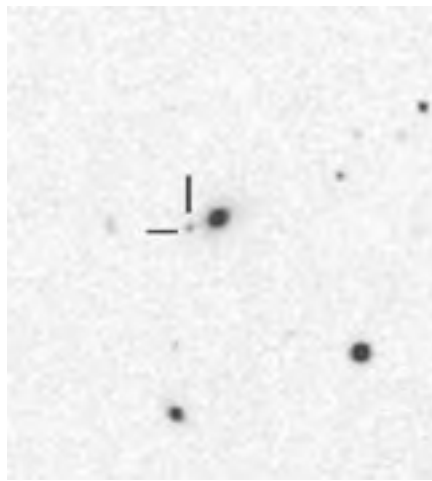
Discovery image of SN 2000K, from an unfiltered CCD image obtained with a 0.35-m Schmidt-Cassegrain telescope. Image provided by the Puckett Observatory.

Astronomers have been waiting expectantly for many centuries for the next supernova to occur in the Galaxy. Because of their scarcity, however, all supernovae discovered over the last few centuries have been events occurring among the countless galaxies beyond our own. The search for such extragalactic supernovae has also been carried out in recent decades by amateur astronomers, using either direct visual observation or CCD imaging of faint galaxies.

Recently, Doug George, past president of the RASC and an active member of the Ottawa Centre, joined Tim Puckett of Georgia to help him search for extragalactic supernovae. Puckett operates an automated supernova search programme using a 0.6-m f/8 Ritchey-Chrétien reflector and a 0.35-m Schmidt-Cassegrain, both automated and equipped with CCD cameras. Once the images of distant galaxies are obtained, Puckett and his group of amateur astronomers scan them for supernovae. The images are loaded on a computer screen, and team members

search for the telltale signs of a supernova by comparing the images to ones taken previously. According to Doug George, "[The Puckett observatory] produces 800–900 images per clear moonless night, which is why Puckett needs help scanning. Typically I scan between 150 and 300 images per night when we are busy."

On February 28, Doug George was scanning an image of the galaxy MCG+9–19–191 when he spotted a new stellar object in the field. Now designated SN 2000K (R.A. 11^h 47^m 50^s.08, Dec. +56°01′ 00″.1), the supernova was co-discovered by Paolo Sala of Munich. It was magnitude 18.1 at the time of discovery, and has since been found to be of Type Ia — the most useful supernovae for deriving distances to galaxies. Studies indicate that type I supernovae originate from the thermonuclear explosions of white dwarfs in close binary systems, when previously-existing white dwarfs with masses close to the Chandrasekhar limit acquire hydrogen-rich gas from larger normal stars in their systems. The sudden supply of "unprocessed" nuclear fuel to stars containing highly degenerate matter under enormously high pressures and temperatures is sufficient to initiate runaway thermonuclear reactions that destroy the white dwarfs in supernova explosions.

SN 2000K is Doug George's fourth supernova co-discovery using the Puckett images. In future the Puckett Observatory hopes to develop automated supernova searching software. As George says, however, "The human eye/brain system evolved over millions of years into an incredible image recognition system; it will take computers a while to catch up with that." The Puckett Observatory web site can be found at http://www.cometwatch.com/search.html. ◉

Getting Ready for
Solar Maximum

by Harry C. Pulley, Hamilton Centre (hpulley@home.com)

The Sun is an excellent observing subject. It is large and easy to find, and has plenty of detail visible with small telescopes. That detail exhibits changes from day to day.

With solar activity hitting its maximum level this year, or perhaps early next year, it is a good time to start recording the appearance of spots and faculae upon the photosphere. If you think the Sun's surface is more active than usual on a particular day, how can you be sure? Sketching or photographing the spots will allow you to directly compare past and present activity on the surface of our closest star. Next year, you can look back and see when solar activity was at its highest. If you keep on recording your observations after maximum, you will be able to compare this year's activity to normal and quiet years, and you will know if the next maximum is more or less active than the current one.

It is also fun to compare your drawings and photographs to those made by other amateurs, as well as with observations obtained at major observatories. On some days, all the large solar observatories are clouded out, but with your own personal observations you will be able to fill in the blanks. By recording solar activity, you will be able to compare your work with that done by experienced solar observers, helping you to improve both your observing and photographing techniques.

This article discusses sketching and film photography of our Sun in white light with a general-purpose telescope. Other techniques, including sunspot counts,

specialized solar telescopes, CCD cameras, and narrow-band solar filters, will not be covered.

TIPS ON SOLAR VIEWING

Whatever method you use to view the Sun, in addition to putting a solar filter on your telescope, always put a filter on your finder telescope. Either that, or cap it, or remove it entirely. Such a precaution is especially important when allowing others to look through your telescope to observe the Sun.

To find the Sun without a finder scope, simply look at the shadow cast by your telescope on the ground or wall. Move the telescope so that the shadow cast by the tube is the smallest circle possible. The Sun's image should now be in the telescope, if a medium power eyepiece is used.

PROJECTION

The most inexpensive way to view the Sun is by using projection. A book of sketches I made using just an old Tasco 50-mm f/12 refractor and 12.5-mm Huygens eyepiece demonstrates that the technique works well. The sketches show umbrae (the dark portion of sunspots), penumbrae (the lighter outer part of sunspots), and faculae (brighter areas, usually near the limb).

A white card was glued into a shoebox on which the image was projected. Some build a wire holder for the box so that the

The photos included with this article were taken with the author's Vixen 200mm f/9 catadioptric telescope and a Baader solar filter.

telescope and box may be moved as one, but I usually hold the box by hand. The shoebox helps to keep direct sunlight out of the image, greatly improving contrast.

The Huygens eyepiece design works well for this method, as the two elements are air spaced and thus less prone to cracking as a result of differential heating. Small telescopes are useful since there is less danger of heat build-up at the eyepiece, but I still managed to melt some of the plastic internal baffles of the Tasco telescope with such a setup. The lesson served as a warning not to use eyepiece-end filters, even in a small 50-mm telescope.

FILTER USE

Only use front aperture filters, which prevent any unfiltered light from entering your general-purpose telescope. Rear-mounted filters will heat up, and can crack or melt as their temperature rises.

The exception to the rule is when you are using photographic density filters
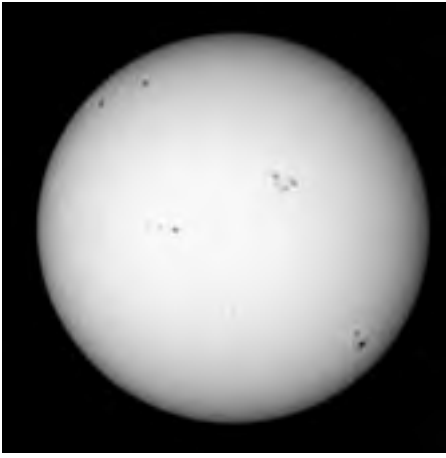
A full disk image taken on March 18, 2000 (17:30UT), taken at prime focus for 1/500th of a second on Kodak Elite Chrome 200 film.

for visual use; they require an additional rear-mounted filter. In that case you must always use both filters for visual use. Visual filters are identified as having a density of at least 5. Unless you have a lot of time, most of your solar work will probably be visual rather than photographic, so for the convenience and safety of not having to remember to use an additional rear filter, visual density 5 filters are recommended.

Always tape the front filter to your telescope's tube, so that a strong gust of wind or accidental nudge will not dislodge it. You can replace a tape-marked telescope tube, but you cannot replace your eyesight.

I recommend that you do not use a filter with coating damage, even as small as a pinhole. Do not fool around with black magic markers trying to patch them. Buy another one instead. Once again, your eyesight is not worth the cost of a filter.

For both cost and quality, I find Baader Solar Film to be the best filter material available today. The price has gone up recently, but $50 still gets you a 200 × 290 mm sheet (or $120 buys a large 0.5 × 1 m sheet). You will have to build a cell yourself, but that is easy to do. I have built a cardboard cell for both my 200-mm f/9 catadioptric and my 80-mm f/7 achromatic refractor, going by the included instructions. Each was completed in just a few hours, with most of that time spent waiting for glue to dry between steps. Telescopes with removable dew

caps make for safer construction since there is no chance that glue can make contact with the objective. The small sized sheet is satisfactory for one (nearly) full aperture filter for an 8-inch scope, or for a couple of smaller scopes plus a few finders or binocular objectives, which can be covered with the leftovers. The Baader film gives you a solar image that is light blue, masked much more easily than the darker blue provided by mylar. With an orange #21 filter, you can get approximately the same colour as a glass filter. It provides good views of high-resolution features like sunspots and granulation, as well as high contrast faculae.

Some prefer the orange colour of glass filters, and the convenience of a pre-made metal cell. A glass filter like the Thousand Oaks 2+ filter is more expensive than the Baader film, at over $100 for an 80 mm size.

I compared directly my Thousand Oaks 2+ filter to my Baader Solar film filter on my 80-mm f/7 refractor, swapping filters to view the Sun on the same day. The Baader film gives an image that is better in both resolution and contrast.

To enhance the contrast of some

A sketch of the Sun drawn by the author on February 15th, 1999 (13:44UT). He used solar projection with a 50-mm f/12 refractor and a 12.5-mm eyepiece, producing an image size of 10 centimetres.

features both by eye and by film, some colour filters are recommended. It is normally stated that blue increases the contrast of bright faculae, orange of spots and pores, and green improves the visibility

of granulation. I find those colour filters work well but differently from day to day, depending upon how much cloud and haze is in the atmosphere. Try Wratten #80A, #21, #56, and #58 filters to determine if you can see more or less detail with them. If they help you, use them to improve the view.

Telescope Selection

I have always read that a large scope will be severely limited by seeing during the day. While the seeing is generally unsteady during the day, I still find the image in my 200-mm telescope far superior to the view in my 80-mm scope. The resolution and contrast of the larger telescope are definitely better. I would have expected the seeing to be far worse in the larger scope. The small refractor is still much more convenient to set up for quick sessions before or after work, but when doing serious viewing, I always choose the larger instrument.

Photographing the Sun

For photographic use, the larger scope wins hands down. Its longer focal length — 1800 mm compared with 560 mm — means that I take full-disk photographs at prime focus instead of using eyepiece projection, so I am taking photos at f/9 instead of f/22. Taking pictures during the day at 1/1000th of a second makes for a much sharper image than another taken for 1/125th of a second. Along with the improvement in resolution and contrast, the shorter exposures with the larger scope give me a much better image. Perhaps with a lower-density photographic filter, the refractor would do better, but exposures with such a filter would still be shorter in the instrument with a longer focal length.

An equatorial mount makes it much easier to take photographs. While the exposure times are short enough to use a fixed tripod mount, focusing is difficult to attain with a magnifier when the image

slips out of the viewfinder. In addition, to bracket exposures, it is useful to be able to simply change the shutter speed and fire away, rather than framing after every shot.

Seeing is quite poor during the day, and changes from moment to moment. It can be useful to set up a second telescope to monitor seeing, taking photographs in the second telescope only when the seeing is steady. Alternatively, I suggest taking two sets of photographs with the same exposure times, to increase the probability of getting a good image for each desired shot.

Sketching Tips

It is difficult to draw a full size sketch of the Sun that includes all details and shows spot groups in their correct position and relative size. For correct recording of positional information, I need to have the entire disk visible easily without moving my eye around too much. I find 60× with a 50° apparent field, or 75× with a 60° apparent field gives me a good-sized disk to sketch spot groups with accurate size and position.

I use a 10-cm circle to record the full image. In my experience, the drawing turns out best if I start at the upper left of the disk and then do vertical swaths of the disk moving to the right. If I just draw spots in a random order, the positioning is less accurate. To get sizes and positions correct, I find it useful to look at the spot group and then relate its length to the distance it is from the edge of the disk along its major axis (longest dimension). Combining those two metrics gives me a good placement and orientation.

For details of individual groups, it is best to draw them on their own so you can draw them to the scale they deserve. Use as much power as you can to get the best image possible. I find magnifications of 150× only rarely useful during the day, but it is nice to have eyepieces that can go higher when the seeing will allow it.

Whether drawing the whole disk or a close-up of an interesting group, I find it best to draw the largest spots first,

A 1/30th of a second high-power image of the Sun taken on April 23rd, 2000. Eyepiece projection was utilized with a 9-mm orthographic eyepiece projected 75 mm onto Kodak E200 slide film.

especially at the outline of the group. Then I fill in smaller spots and penumbrae — the lighter region around most umbrae. I do that because I can record the relative size and orientation better by doing the outline rather than by sketching the spot group from one side to the other. If I start from one end, I usually end up making the group too long.

Even after following this advice, you will inevitably draw some spot groups too large, and some too small. When I compared drawings and discussed techniques with Bert Rhebergen (recent Chant Medal award winner for his solar work), he suggested that I should place size bars at the edge of the drawing to indicate the actual size. I find that works well, often better than erasing and sketching over and over again to get it right.

To compare spot groups, it is important to know which way is up on the Sun. Unlike many planets and the Moon, there are no convenient long-lasting features to use as a guide. With an equatorial mount it is easy to determine a consistent orientation for the Sun — simply keep the eyepiece straight with the tube. Bert Rhebergen suggests the following simple method to determine the correct orientation with an altitude-

azimuth mount. Move the Sun's image so it is just out of the eyepiece, and watch for the point on the Sun's limb that touches the field stop of the eyepiece as it comes into the field. Next watch the Sun drift across the field, and note the point on the opposite limb that first touches the field stop on the other side. Drawing a line through the two points should give you the same orientation as that provided by an equatorial mount. Note that the image will not have the true north and south poles positioned, but using it will allow you to compare drawings made at different times of the day. You can use solar ephemeris tables to find the alignment of the Sun's actual north and south poles, if desired.

Sketching Versus Photographing

Sketching will almost always show more detail than a photograph can capture, at least for most casual solar photographers, but the detail that is found in a photograph will be much more accurately sized and positioned. Use simultaneous sketching and photography to get the best of both worlds. Your photographs will teach you how to properly position spots on your sketches, and your sketches will expand upon detail objectively recorded on your film.

No matter what method of solar observing you use, get out there and observe the Sun! The show is just starting, and you do not want to miss the build-up. ◉

Harry Pulley lives in Guelph, Ontario. He is treasurer and past-editor of the newsletter for the Hamilton Centre of the RASC. He is acting co-ordinator of the Mercury Section of the Association of Lunar and Planetary Observers, and also contributes observations to several other sections. He loves to observe, sketch, and photograph all sorts of celestial objects, but solar system objects are his targets of more serious study.

The St. John's Centre and the Marine Institute Planetarium

by Garry Dymond, St. John's Centre (gdymond@mail.gov.nf.ca)
photographs by Brian Payton

I can still remember the first time I visited the only permanent planetarium in St. John's, Newfoundland. It was during an open house in 1969 at the College of Fisheries, Navigation, Marine Engineering and Electronics, affectionately known as the COD College. The College was located on Parade Street in the same building that originally housed Memorial College, which later became Memorial University of Newfoundland. After being led down a long corridor, through the secretary's office, and up three steps to a darkened room, I noticed a fourteen-foot dome hanging from the ceiling by chains linked to eyebolts. Under the glow of red lights, at the centre of the dome stood what looked like a giant squid monster. It turned out to be a Nova III Star Projector and planet cage. Around the star projector were sixteen metal, folding chairs, probably removed from the cafeteria! A ten-minute show was presented on celestial navigation. Afterwards, I spoke to the instructor, Captain Proven, who introduced me to the RASC St. John's Centre, of which he was the Secretary.

Soon after its formation in 1964, the College of Fisheries, Navigation, Marine Engineering and Electronics acquired the Nova III planetarium. Its original function was to assist in teaching astronomy within its diploma courses in Technology, those in Nautical Science and Celestial Navigation leading to the certificate of Master Mariner.

The college planetarium consists of a fourteen-foot diameter fibreglass dome, housing a Nova III pinpoint star projector with a planet cage projector. It also has motor drives for latitude and the diurnal motions of the stars, the Sun, the Moon,

and the planets. Other accessories include projectors for the celestial equator, the meridian, and the ecliptic. The unit also includes a hand-held arrow pointer as well as a constellation projector. The Nova III was developed in 1962 by Albert Faulkner for Harmonic Reed Company (U.S.A.), and the College obtained one of the prototypes that was selling for about US$2,000.

Initially, the planetarium was operated by Captain J. J. Strong, an instructor at the College and one of the founding members of a student Campus Astronomy Club that would later result in the establishment of the St. John's Centre of the RASC in 1966. In the early years, each meeting of the Astronomy Club would end with a short visit to the planetarium, where a presentation was given on what was in the sky for that month. The planetarium was available to the public only during the annual open house or through membership in the club. The Centre would hold open planetarium nights twice a year, with the Christmas show presented by J. J. Strong and Dora Russell.

Later, Captain Proven took over from Mr. Strong at the College, and added, as a special effect for the Christmas show, a silhouette of three wise men. He also made planetarium shows available for groups such as the Boy Scouts and Girl Guides. As his schedule became busier, he had a hard time making meetings, and offered to teach members how to use the planetarium to present shows. That was how I learned how to use the planetarium.

When Captain Proven left, there was no one at the college willing to keep the

The author, Garry Dymond, with the planetarium projector of the Marine Institute Planetarium.

student side of the club running, and the ties between the St. John's Centre and the College weakened. Access to the planetarium was now through Commodore Douglas, who had replaced Proven at the College. By then some of the working parts of the projector system were showing signs of wear, and there was no money to spend on needed repairs.

In 1985 the College moved to its new residence on Ridge Road, St. John's, and became the Marine Institute, which is now an integral part of Memorial University of Newfoundland. At that time the planetarium was upgraded. By 1985 the original planetarium suppliers, Space Education Laboratories, had been acquired by Spitz Space Systems. The new star projector at the Institute was therefore a combination of the Nova III instrument direct control console, with the main star projection system being replaced by a new star sphere enclosing an ILA/Xenon lamp E 20W (GES–1) in a LMP cup assembly. That produced brighter stars than the previous sphere, which only used a single GE 13 (3.7-volt) bulb. The planet cage projector for the Sun, the Moon, and

the planets remained similar to the earlier projection system, by utilising GE 13 miniature Edison screw bulbs. To house the new projector, an eighteen-foot dome was installed in a dedicated room in the new building, along with 26 comfortable reclining planetarium seats. Cove lighting to create sunrise and sunset effects was an added feature.

By 1987 the student Astronomy Club at the Marine Institute had disappeared, and the lack of faculty ties for those of us using the planetarium outside of the Marine Institute's direct activities resulted in the facility being closed for our use. Members of the St. John's Centre of the Royal Astronomical Society of Canada were by then meeting at Memorial University, and any use of the planetarium was done only through formal booking. The St. John's Centre continues to hold its meetings in Memorial University Science facilities, for which it is grateful. In the 1990s, the planetarium, now staffed by Marine Institute members or by students, was booked for school class visits, and for Scouts and Guide groups, but because of funding cutbacks the upkeep was taking its toll. By 1995 the equipment problems had resulted in fewer planetarium bookings, so the Marine Institute was simply not opening the planetarium to the public.

In 1996 the St. John's Centre of the RASC approached the Marine Institute to engage in open talks designed to foster a partnership that would permit greater access to the planetarium for our members, as well as increased use of the planetarium by the general public. Thanks to the interest of Captain Phillip Bulman and Mr. David Keeping of the Marine Institute, the negotiations were successful. By 1998 we concluded an agreement by which members of the St. John's Centre of the RASC would perform general maintenance on the projector and, in return, would be given use of the facility. All use of the planetarium by the Marine Institute was given precedence, but that is not an inconvenience to RASC members given that the St. John's Centre is not interested in daytime use of the facility, except perhaps on weekends. The agreement

also allowed the facility to be used not only by our own members, but also by our members giving presentations to the general public through arrangements with the Scouts and Guide movements, schools, and other interested groups.

By January 1998 the RASC had obtained a key to the planetarium. The first chore was to make a thorough examination of the projection system. It turned out that the planetarium was basically run down from lack of general maintenance. Although we were provided with two instruction books and manuals on the Nova III projector, it was not until we started repairing the wiring that we discovered that there had been changes to the projector system since the service books had been printed. From telephone calls to Ralph Menzo of Spitz, we learned that no manual had been made for the projector at the Marine Institute since it was constructed from two machines. Spitz was able to supply us with circuit diagrams of the power supply for the Xenon bulb, however, something that was not in the manuals. We had also noticed that the diurnal motion and latitude motors were not functioning. That must have been a recurring problem, since we found that over the ten previous years the Institute had purchased four new motors at US$450 apiece. We also learned that the problem did not originate with the motors themselves, but with a plastic gear in the train of gears within the motor casing, gears that could be purchased for US$25.00 apiece. We were fortunate to have Centre members with some mechanical skills, as well as members, such as Jack Cocker, with professional expertise in electrical circuits and electronics.

Close examination revealed that some of the light bulbs (3.7-volt miniatures) in the planet cage had burnt out. Replacement bulbs were also needed to indicate the positions of the cardinal points around the dome. Use of the sunrise and sunset effect also required the replacement of a number of fluorescent tubes in the cove lighting. From subsequent experience it appears that members of the St. John's Centre of the RASC are the

only people in the city, and perhaps the entire province that need 3.7-volt miniature Edison screw bulbs! Despite such obstacles, we had the planetarium in full operation again within two months. Brian Payton designed two slide projector mounts to allow images to be projected onto the dome. Placed on either side of the console are two projectors that are 180 degrees from each other. Front surface mirrors are used to deflect images from the horizontally mounted projectors onto the dome. The system requires duplicate slides to permit viewers, regardless of their seating, to see any projected image without it appearing upside down.

The modifications brought us up to level two on the L-H-S Level Specification of Planetarium capabilities. Following that I began to write and present planetarium shows for the general public, mostly catering to Guides, Scouts, and school classes.

The public demand for the planetarium has been greater than expected. At times Centre members have run four shows a week, with a particularly busy period from this past February on. We estimate that there have been over 1000 visitors to the planetarium over those past few months. The Centre is now searching for volunteer help among its members for assistance in operating the planetarium, since the present demand is greater than can be handled by Brian and me. Although the star projection system presents a realistic view of the night sky, proper operation of the instrument for public shows still requires someone who is familiar with the constellations as projected on a rather different-appearing and closer planetarium dome. Younger visitors to the planetarium are sharp enough to be able to spot any weaknesses in presentations as well as errors made by the presenter, so one must be very familiar with the overall view in the planetarium's smaller dome to be effective with such audiences. Despite that, sessions given so far have been a lot of fun, and have been greatly enjoyed by all.

We are presently searching for equipment to enhance the planetarium

experience. We need slide projectors and a stereo system to increase each show's entertainment value. We would like to hear from any RASC members who have creative planetarium show-writing abilities, who know how to create special planetarium effects, or who have astronomy slides or images that can be used in the St. John's Planetarium. Persons interested in reserving the planetarium for a group presentation can do so by calling the Marine Institute at 709-778–0648.

At the request of the Marine Institute, it has been our policy to ask for a donation of $2 per person for group presentations. Half of the funds raised go to the Marine Institute's Scholarship Fund, and the remainder is used to support the RASC St. John's Centre in running and maintaining a functional system.

Our use of the planetarium has also allowed us to widen still further our public education programme. For some years now that has included two evening courses in Memorial University's continuing education programme, one basic introductory course in the fall, and another slightly more advanced course in the spring semester. The Centre's members also present occasional direct viewing opportunities at both Terra Nova National Park and, closer to St. John's, at Butter Pot Provincial Park. ◉

Garry Dymond became a member of the RASC St. John's Centre in 1971, and since then has been heavily involved with the Centre's astronomy education program. When not observing, Garry supervises an air photo and remote sensing lab, where it is said that every photo gets analyzed first for possible meteor crater impacts.

Fast Polar Alignment

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

About twelve years ago I built my first barn door tracker to take piggyback astrophotographs. With a small riflescope I would centre Polaris in the crosshairs and start shooting. Coarse-grained colour prints turned out okay, but my black and white fine-grained prints never contained sharp star images. I rebuilt my tracking mount with heavier hinges, learned better focusing techniques, stopped down the aperture on the lens, and used a heavier tripod, but could never achieve true pinpoint star images on B&W film. Then it was pointed out to me that Polaris is actually three-quarters of a degree from the true north celestial pole. So for the next few years I worked on different techniques for accurate polar alignment when one lacks a polar alignment scope, as was the case for my barn door tracker and later for my Vista and Byers camera-tracking platforms.

What I have developed is a technique that is surprisingly accurate without a computerized "*Goto*" system, but with a couple of caveats. First, the technique is good only for visual observing and piggyback photos made with, up to perhaps, a 100-mm camera lens. Second, the more you practice the technique, the easier it becomes. Finally, it takes longer to explain than it does to do.
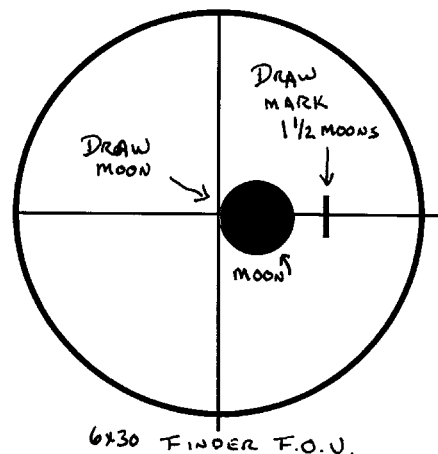
Figure 1

Before proceeding to the actual method, it can be noted that, for the sake of simplicity, Polaris is roughly 0.75 degrees from the north celestial pole. That distance is roughly the same as 1.5 Moon diameters. If you print a star map (which we will do) of Ursa Minor, and draw a line from Polaris to Kochab, the bright star on the end of the Little Dipper, the north celestial pole is almost exactly on that line. Therefore, if you follow a straight line 0.75 degrees from Polaris to Kochab, you are exactly on target. Here is one way to do it.

You need a finder scope (30-mm or 50-mm), a notebook and pencil, and a planetarium program (such as ECU) to print out two star maps, plus a couple of clear nights.

Step one. When the Moon is full, aim your finder scope at it. What kind of finder scope you use is not important, as long as you always use the same one — be consistent. I use an old 6 × 30 that was purchased for $10 at a Stellafane swap table ten years ago. Point the finder so that the crosshairs are directed at the edge of the Moon, and, using your notebook, draw an image as in figure 1 that indicates how wide the Moon is. You should then be able to guess the size of 1.5 "Moons," and write it down. An inexpensive plastic circle gauge will help you draw it.
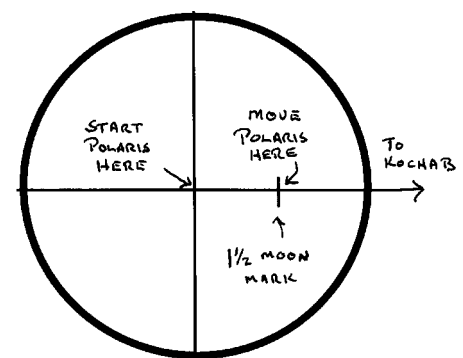
Figure 2
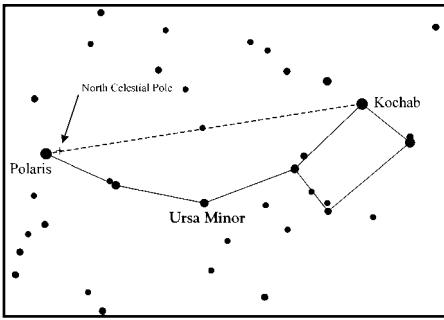
Figure 3 (ECU Chart prepared by Dave Lane)

Step Two. Mount the same finder exactly parallel to the right ascension axis of your mount or to the hinge of your barn door tracker. In my case, I used some crazy glue, some scrap metal shelving accessories, and a precision carpenter's square. However you do it, be it permanent or, like me, temporarily held in place with a quick-release wood clamp, take your time to make sure you have it aligned exactly.

    Step Three. For use as guides, print out two star maps (see figures 3 and 4). Map I should contain only Ursa Minor. You can draw a line yourself from Polaris to Kochab to see where the north celestial pole lies on that line. Map II should be an enlarged view around Polaris that is one to two degrees larger than the field of view (FOV) of your finder. You should be able to estimate the FOV from your Moon measurement. Most software programs allow you to custom define overlay circles on the star map. In figure four, my two circles are four degrees (the FOV of my finder), and 1.5 degrees, which nearly intersects the north celestial pole.

    Step Four. With a notebook and two maps, and with the finder attached to your mount or tracker, move the mount so that you centre your finder crosshairs on Polaris. Step back and draw an imaginary line in the sky from Polaris to Kochab. Still looking up, move and look through your finder, and slowly move your mount from Polaris towards Kochab three quarters of a degree in the finder, using your "Moon notes" as a reference (see figure 2).

This part will be difficult for the first few times you try it. The two printed star maps will help to guide and reassure you, and with enough practice you can get pretty close to the exact location of the north celestial pole. For high precision CCD and film shots, you will need to use the drift method of alignment, but the technique described here should help to

Figure 4 (ECU Chart prepared by Dave Lane)

provide an initial polar alignment. I find the hardest part to be visualizing, in the sky, an imaginary line from Polaris to Kochab, then following that line and estimating the width of "1.5 Moons" in the finder, but with practice or for seasoned star hoppers, it should become a familiar routine.

    Many of you will probably find ways of improving and refining the technique just described. If you do, please share it with the rest of us. ◉

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

Last Light

by Christine Kulyk, clkulyk@kos.net

A short poem commemorating the supernova discovery by Doug George.

Twinkle, twinkle, supernova —
Scientists will want to know ya,
Stargazers will want to spot you,
Atlases will want to plot you.

CCDs will magnify you,
IAU will certify you,
Headlines for a while will tout you,
Papers will be writ about you.

As for me, I wonder what
You were before you grabbed the spot:
Were you a loner, or binary?
Had you a family planetary?

The past's a fleeting do-si-do;
The future's never ours to know.
To be a supernova's not
Too lingering a parting shot.

Today you gleam, tomorrow — not.
You might become a big black hole
Or remnant, with an afterglow.
You might wink out, but here's a thought:

Your twinkle for a while has caught
The notice of a world below.
You picked a drastic way to go,
But while it lasted, what a show.
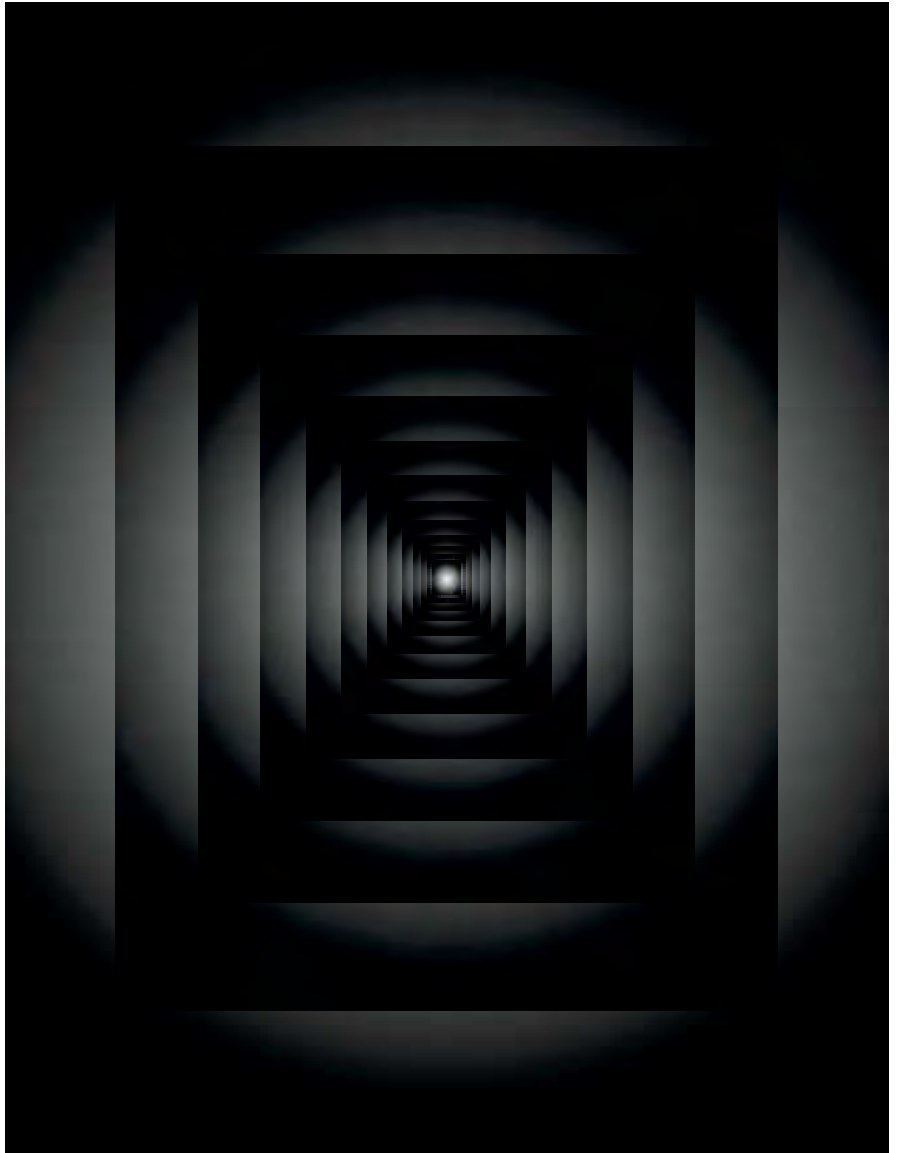
Christine Kulyk has been an RASC member off-and-on since the late 1960s, when she joined the Montreal Centre as a teenager. A native Montrealer, she attended McGill University, where she majored in Physics and Mathematics, then moved to Edmonton, where she graduated from the University of Alberta with a B.Ed. and a B.A. in English. She served as Treasurer of the Edmonton Centre for several years. After spending a few years in Toronto, she moved to Kingston nearly ten years ago and joined the Kingston Centre, where she served as President and Vice-President. She is a full-time freelance writer and editor, currently Assistant Editor of SkyNews *and a Researcher/Writer for* Equinox.

Reflections

Gian Domenico Cassini —
or is it Jean-Dominique?

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

Here is another astronomy word-association test. I say "Cassini," and you say "Division," referring of course to the 4550-kilometre gap in the rings of Saturn named after the astronomer who first observed it. Gian Domenico Cassini was born 375 years ago on June 8, 1625 in the Republic of Genoa (now part of Italy). Initially Cassini was attracted to writings on astrology, but he quickly rejected pseudo-science and embarked on a brilliant career in astronomy. Cassini had no formal university education, but was tutored by the Jesuits. In addition to his astronomical skills, he was adept at civil engineering and worked on a project to prevent the regular flooding of the Po River.

In 1669 he was enticed to Paris by the "Sun King," Louis XIV. He was appointed Director of the Paris Observatory in 1671, and became a French citizen, formally changing his first name to Jean-Dominique. He never returned to his country of birth. In Paris he earned the scientific reputation by which we know him today, chiefly as a keen observer and recorder. In the years 1671–1684 he discovered four moons of Saturn: Iapetus, Rhea, Tethys, and Dione. (Christian Huygens had already discovered Saturn's largest moon, Titan, in 1655.) Cassini discovered the gap in Saturn's rings in 1675. He championed the technique of measuring the rotation periods of the planets by observing the rotation of surface markings on Jupiter, Venus, and Mars. (Venus must have been tough!) He also studied the librations of the Moon, the zodiacal light, and cometary motion.

There is evidence that Cassini was not open to new ideas, despite all his discoveries. He was an opponent of Newtonian physics, and never accepted the principal of universal gravitation. He also took the view that the Earth was flattened at the equator, contrary to what we know today and what was confirmed by Maupertuis in 1735 (see the October 1998 *Reflections*).

On October 15, 1997, NASA launched the *Cassini-Huygens Mission*, an orbiter spacecraft bound for Saturn carrying a planetary probe. (Let's hope that it fares better than recent missions to Mars!) Mark December 30, 2000 on your *RASC Observer's Calendar*. That is when the *Cassini* spacecraft flies by Jupiter. *Cassini* will not enter Saturnian orbit until July 1, 2004. Apparently, the mission was somewhat controversial since there is a power source on board containing about 35 kilograms of plutonium dioxide. Last August the spacecraft swung by Earth, within several hundred kilometres, and there were protests against the mission. (I was on holiday at the time, and I do not recall hearing about the controversy… the gloom-and-doom web sites are beginning to look a little dated.)

* * *

To change gears a little, I now realize that this is my 19th *Reflections*, my first being three years ago in June 1997. From time to time I receive brief communications from readers (usually by E-mail), and I would like to thank everyone for their kind words. Our hard-working Editor came up with the idea of columnists including E-mail addresses after I had to respond to a critic through him; I have been fortunate that all subsequent E-mails have been much more positive! It appears that the historical astronomy topics please at least some folks out there,

Jean-Dominique Cassini (1625–1712)

and I have also received favourable comments regarding the calendar topics. I have a few snippets of things that did not make it into columns, for one reason or another, and I wish to offer up a couple now…

Comet Wilson 1987 VII. In my October 1999 *Reflections* entitled "Canadian Comet Catchers, I" was a small item on the contribution of Professor Christine Wilson, who managed to catch up with me after my deadline had passed. I find stories of comet discoveries most fascinating, and here is hers…

I discovered the comet while working on the second Palomar Sky Survey *in my first summer as a graduate student at Caltech. One part of the observing was to take a close look at each photographic plate after it was developed to assess the quality of the plate (focus, etc.) and to look for flaws, airplane trails, etc. I believe I discovered the comet in my second or third observing run at the telescope, so I had seen a lot of*
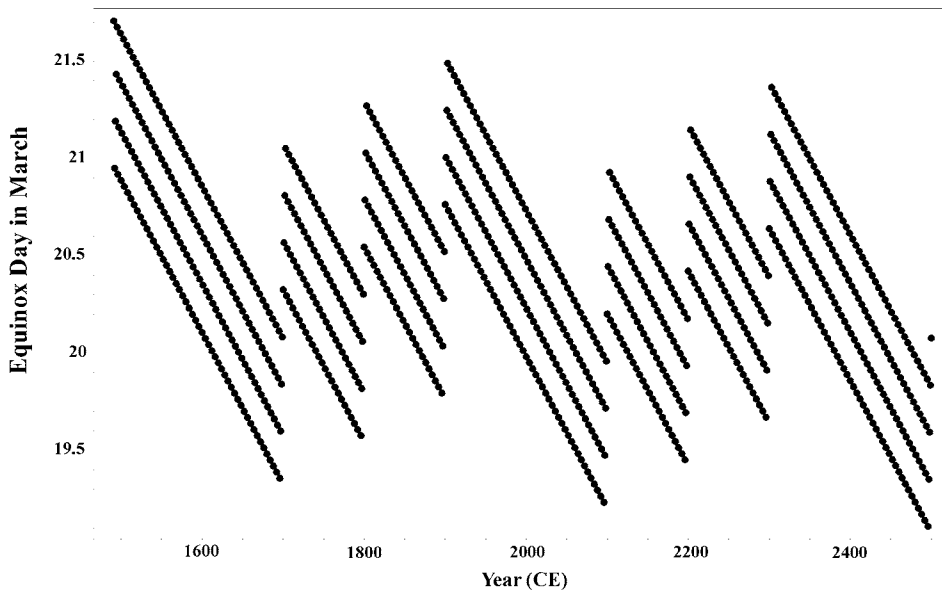
The date of the vernal equinox in the Pacific Standard Time zone, as determined by the Gregorian calendar (data from Jeremy Tatum).

normal plates by then, including many with asteroid trails. When I put the discovery plate on the light table, I noticed immediately a bright "smudge" towards the middle of the plate that did not look like anything I had seen previously. When I examined it with a magnifier, it looked like a trail of a moving object, but it was fuzzy, so I was pretty sure it was a comet. Then came the fun of trying to find out if a comet was expected to be in that part of the sky, in which I had help from a couple of other people at Palomar. When we could not find anything, one of them said we should report it to the IAU in Cambridge. The person on the other end did not believe us at first; in retrospect, that was because we had overestimated the comet's brightness by about five magnitudes (a factor of 100!). That occurred because we did not realize that we should have compared its size on the plate to galaxies (which are extended, like the comet) rather than to stars (which are point sources). We were impatient to have the comet confirmed, and so the survey photographer, who was from France, called a friend at a Schmidt telescope there and asked if he could try to recover the comet. The call came after dinner, when I was alone at the telescope getting ready to observe, and yes, they had recovered the comet. We recovered it ourselves as soon as it got dark, and even convinced the observer at the 60-inch telescope to take a quick CCD picture for us.

Visualizing the Gregorian Calendar. The February 2000 *Reflections* on the peculiarities of determining leap years prompted an E-mail from Jeremy Tatum, former Editor of the *JRASC*. He pointed out to me that in the year 2000 Spring arrives on March 19 for the first time on the west coast since 1896. Jeremy sent me some columns of figures to prove his point, and I was able to turn them into the graph reproduced here. The figure shows the effects of the leap years, dropping leap years in century years, and keeping them in "400" years. It also suggests that eventually an additional correction to the Gregorian calendar might be needed to prevent Spring from coming too early, but why anyone would want to do that is beyond me!

* * *

That is all for this issue. I have a few other tidbits that I will include in future columns. ◉

David Chapman is a Life Member of the RASC and a past President of the Halifax Centre. Visit his astronomy page at www3.ns.sympatico.ca/dave.chapman/ astronomy_page.

X-ray Background Explained

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

Richard Mushotzky, of NASA's Goddard Space Flight Center, along with his colleagues, now seem to have settled the mystery of the hard X-ray background (see the 30 March 2000 issue of *Nature*). Most readers of the *JRASC* are familiar with the cosmic microwave background radiation, the remnant of the cooling expanding aftermath of the Big Bang. The temperature of the radiation is 2.73 K. Some readers, however, may not know that there is background radiation at other wavelengths, and some of the sources for such radiation remain mysterious. Mushotzky and his colleagues have now demonstrated that the hard X-ray background is comprised of the contributions of many sources, of which about one third are bright normal galaxies. Most of the remainder are extremely faint optically, and may be more distant versions of the normal galaxies or perhaps some exotic population of extremely distant quasars.

The cosmic X-ray background was discovered in 1962 by Riccardo Giacconi, who subsequently became the first director of the Space Telescope Science Institute. For a long time after the discovery, it was unclear whether the radiation represented a true background, or represented the contributions of many "point" sources that could not be resolved by the technology of the day. Until the launch of the *Chandra Observatory* (the third of NASA's planned four "great observatories," of which the *Hubble Space Telescope* was the first), the spatial resolution of X-ray satellites was limited to that of a relatively small or primitive radio telescope. Because of the low resolution, it was impossible to tell if there were many faint point sources. The effect is comparable to looking at

> ## "Some readers may not know that there is background radiation at other wavelengths, and some of the sources for such radiation remain mysterious."

the Milky Way on a dark summer night. You see the summed contributions of the stars along the disk of our Galaxy as a continuous band of light. Increasing the spatial resolution by looking through a telescope, however, reveals that the band of light is composed of many individual stars. *Chandra* is the first X-ray telescope with the resolution and sensitivity to determine if the hard X-ray background contains many point sources like the visible stars in the Milky Way, or if it is a true diffuse background like the cosmic microwave background.

To further confuse the issue, observations of discrete bright X-ray sources in the sky, such as supernova remnants and nearby active galactic nuclei, indicated that if you distributed lots of them through the universe and added up their contributions, the total background would not look like what we see. Rather, it would produce a "soft" X-ray background — the energies of the observed photons would be too low. That was a serious problem — there was simply no way to take the observations of the X-ray galaxies we could study and extrapolate the data to make the "hard" X-ray background.

One possible resolution of the problem was to suppose that the space between galaxies was filled with hot plasma that radiated hard X-rays. Such

a "screen" would produce an observable distortion of the cosmic microwave background, but that distortion was not seen in 1994 when the results of the *COBE* satellite became available. That left astronomers with the conclusion that the hard X-rays must be coming from point sources. But what type of sources were they, and where were they located?

In 1989 the European astronomers Setti and Woltjer proposed that dust and gas obscuring the centres of many galaxies could resolve the puzzle. The key lies in the nature of galaxies and their relationship to quasars and other types of active galaxies. It is now broadly accepted, by all but a few old die-hards, that essentially all giant galaxies have massive black holes at their centres. As gas spirals into black holes, it radiates away gravitational potential energy that has been converted into increased kinetic energy of the gas atoms and molecules (such that survive). In some cases, large amounts of gas are fed into the black hole, making the region surrounding it appear very luminous from above or below the plane of the gas. Depending upon such factors as the angle of our line of sight to the centre of the galaxy, the mass of the black hole, and the amount of gas spiralling in, one might view the resulting radiation as an active galactic nucleus — such as a Seyfert galaxy and its variants — or a quasar. For those

> **"One possible resolution of the problem was to suppose that the space between galaxies was filled with hot plasma that radiated hard X-rays. Such a "screen" would produce an observable distortion of the cosmic microwave background …"**

cases where one views through the disk of the galaxy, Setti and Woltjer predicted that we would see a galaxy with a very bright infrared nucleus, since the ultraviolet and X-ray photons generated by the accretion process would be absorbed by dust in the swirling gas. The hot dust would re-radiate the energy in the infrared region of the spectrum. Hard X-rays would escape absorption by the dusty gas, to provide the hard X-ray photons we see as part of the background radiation.

Their hypothesis was convenient, because earlier in the 1980s the *Infrared Astronomical Satellite* had found many galaxies that are bright in the infrared region of the spectrum. Gas and dust are particularly good at absorbing soft X-rays while allowing hard X-rays to pass through.

(It means that when we look at such galaxies, we should see them as hard X-ray sources.) The German-American X-ray telescope *ROSAT* was able to resolve about 80% of the soft X-ray background, most of which originated from unobscured active galactic nuclei of some description. While it all sounds rather promising, in fact no model was ever able to produce the right mix to explain simultaneously the hard X-ray background along with the discrete sources of soft X-rays we could see.

Enter Mushotzky, with his long X-ray observation of a "deep field" previously studied at optical wavelengths by the Keck telescopes and in the submillimetre region with the James Clerk Maxwell Telescope. He has found many hard X-ray sources, which mainly appear to be bright "early-type" galaxies — elliptical (E), lenticular (S0), or those with large bulges (Sa) — and sources with extremely faint (or missing) optical counterparts. The faint sources are very interesting, because there is the possibility that they are a new population. Mushotzky speculates that they might be very distant quasars without a surrounding host galaxy to absorb the soft X-rays. The more conventional explanation is that they are simply more distant cousins to the bright early-type galaxies. Summing the contributions from all of the sources, Mushotzky notes, can explain anywhere from 75% to 100% of the hard X-ray background, where the uncertainty stems from a dispute between American and German groups regarding the calibration of the satellite's absolute flux readings.◉

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.*

Research Papers
Articles de recherche

THÉORIE SUR LE CADRAN SOLAIRE BIFILAIRE VERTICAL DÉCLINANT[1]

par Dominique Collin

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Résumé. On présente quelques aspects fondamentaux des cadrans solaires bifilaires verticaux déclinants. À partir d'une description géométrique simple et basée sur une astronomie locale, on déterminera dans un repère convenablement choisi, les coordonnées du point d'intersection des ombres de deux fils orthogonaux. De ce groupe de coordonnées, on établira les relations permettant d'obtenir un réseau de courbes relatif aux coordonnées locales, puis aux coordonnées horaires. Ce seront les courbes de hauteur, les droites d'azimut, les lignes horaires et les arcs diurnes ; données astronomiques essentielles fournies par de tels cadrans. L'étude de ces relations permettra de dégager les caractéristiques des cadrans bifilaires : courbes de hauteur indépendantes de la latitude et de l'orientation du plan vertical, équivalence entre un cadran vertical ordinaire et un cadran bifilaire, cadrans à lignes horaires homogènes, cadrans à lignes horaires parallèles.

Abstract. Presented here are some fundamental aspects of vertical declining double-threaded bifilar sundials, beginning with a simple geometric description and based upon the local astronomy. The co-ordinates for the intersection point of the shadows of two orthogonal threads are determined for various initial conditions. From the resulting group of parameters, relationships are established to create a network of curves pertaining to one's local co-ordinates, then to the hour lines. The network consists of altitude curves, right lines in azimuth, hour lines, and diurnal arcs — the essential astronomical data supplied by such sundials. The study of such relationships yields the characteristics of bifilar sundials: altitude curves independent of the orientation of the vertical plane, the equivalence between an ordinary vertical sundial and a bifilar sundial, sundials with homogeneous hour lines, or sundials with parallel hour lines.

1. Introduction

En 1922, un mathematicien allemand, Hugo Michnik, inventa un nouveau type de cadran solaire : le bifilaire (Michnik 1923). La nouveauté de ce cadran réside en ce que l'ombre n'est plus celle d'un style polaire, mais celle formée par l'intersection des ombres de deux fils distincts tendus au-dessus du plan du cadran. En l'occurrence, pour l'horizontal, le premier fil est placé dans la direction nord-sud, le second dans la direction est-ouest ; ils sont donc perpendiculaires. Depuis, de nombreuses variantes sont apparues, portant essentiellement sur la forme et la position des gnomons (on parlera de système bifilaire). Le cadran solaire bifilaire donne accès aux mêmes types d'information, de nature astronomique, que sont capables de fournir les cadrans solaires "ordinaires," avec cependant des propriétés particulières, surprenantes, et parfois fort utiles.

Pour commencer, proposons une définition générale de ces cadrans et qui servira de base au modèle théorique qui va suivre : *on appelle cadran solaire bifilaire (ou "bifilaire" tout court) tout cadran dont le point d'ombre est obtenu par l'intersection de la projection de deux fils orthogonaux placés dans des plans distincts, parallèles au plan de projection*. Dans ce qui suit, on présente une étude des *bifilaires verticaux* déclinants répondant à cette définition et ayant, comme système bifilaire orthogonal, un gnomon vertical, et un second horizontal, tous deux parallèles au plan du cadran. Les formulaires obtenus permettront leur construction et donneront un aperçu de quelques unes de leurs propriétés et peut-être susciteront de nouvelles pistes d'études[2] que ne manque pas de posséder cette nouvelle espèce de cadran solaire, élément de la gnomonique moderne.

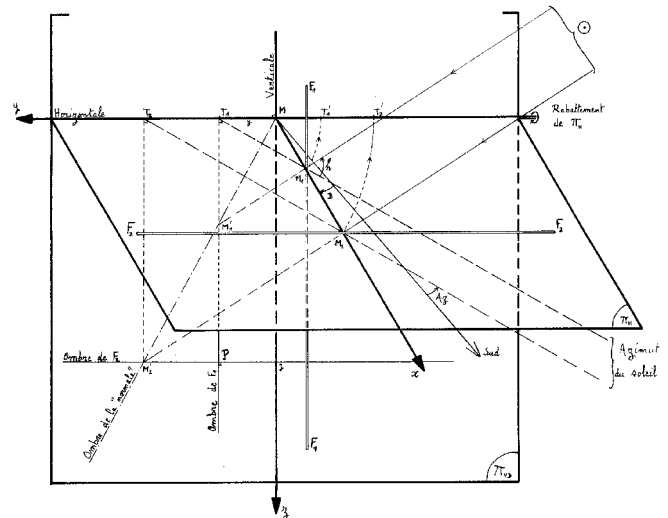### 2. Notations et définitions des termes utilisés

Fig. 1 — Vue en perspective et formation du point d'ombre dans un cadran solaire bifilaire vertical déclinant

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[1]An English version of this paper is available from the author or editor in electronic form.

[2]Comme cette variante qui consiste à courber un des gnomons afin d'obtenir des lignes horaires parallèles tout en ayant des courbes d'arcs diurnes.

La figure 1 donne une vue en perspective d'un cadran solaire bifilaire vertical déclinant et pose le problème général suivant : "quelles sont, dans un repère donné, les coordonnées du point d'intersection de la projection des ombres des deux gnomons?" Tout en permettant de trouver la solution, avec l'aide cependant, des figures 3 et 4 (voir §3), cette vue en perspective fait comprendre à la fois la géométrie de ce type de bifilaire et les configurations des gnomons. De cette figure, on en extrait les différentes notations utilisées dans cette étude. À la figure 2, on retrouve une photo d'un modèle de cadran solaire bifilaire vertical déclinant construit par l'auteur.

2.1 Les éléments du repère

L'Origine. Point M : c'est l'image de l'intersection des deux gnomons lorsque ceux-ci sont éclairés par des rayons normaux au plan du cadran ("soleil à l'horizon"). Ainsi, soit les gnomons sont déjà installés et le point M sera tel qu'il se trouve sur le croisement de l'image des deux gnomons, soit on place M et alors les gnomons doivent être installés avec cette particularité.

Les axes. Mx : axe perpendiculaire au plan du cadran. Il est parallèle au plan de l'horizon. My : intersection du plan de l'horizon avec le plan du cadran. C'est donc un axe horizontal. Mz : intersection du plan méridien avec le plan du cadran. C'est donc un axe vertical.

Leur orientation. Mx : dans le plan de l'horizon, et dirigé vers l'observateur. My : toujours orienté vers la gauche pour un observateur faisant face au cadran. Mz : orienté vers le nadir c'est-à-dire vers le bas pour un observateur de l'hémisphère nord.

Le repère de travail. Myz.

2.2 Le système bifilaire (les gnomons)

F_1 : segment (ou fil) vertical, parallèle à Mz et servant de premier gnomon. F_1 et Mz sont dans un plan vertical perpendiculaire au plan du cadran.

F_2 : segment (ou fil) horizontal, parallèle à My et servant de deuxième gnomon. F_2 et My sont dans un plan horizontal perpendiculaire au plan du cadran.

ℓ_{F_1}, ℓ_{F_2} : respectivement longueur utile des gnomons F_1 et F_2 (*cf.* figure 6).

a : distance (orthogonale) du fil F_1 au plan du cadran.

b : distance (orthogonale) du fil F_2 au plan du cadran ($b \neq a$).

M_1, M_2 : respectivement intersection des fils F_1 et F_2 avec l'axe Mx (*cf.* figure 1).

M'_1, M'_2 : respectivement projection des points M_1 et M_2 sur le plan du cadran en un instant donné[3].

Ce : centre du cadran. Point d'intersection des lignes horaires et point où l'axe du monde coupe le cadran vertical déclinant (dans le bifilaire et dans le cadran classique).

2.3 Les couples de coordonnées

Le point d'ombre dans Myz. P : point d'intersection des ombres des fils F_1 et F_2. y : ordonnée du point P. z : côte du point P.

Les coordonnées locales. Ce sont les coordonnées dans la sphère locale, de pôle Z, le zénith du lieu du cadran, et de centre le point M.
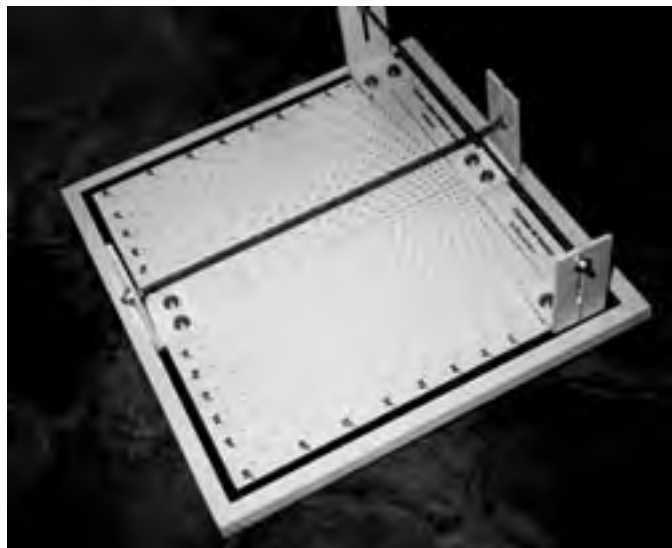
Az : azimut du soleil. Compté positivement depuis le sud vers l'ouest. h : hauteur du soleil.

Les coordonnées horaires. Ce sont les coordonnées dans la sphère céleste de pôle P_N, le pôle nord céleste (situé à moins d'un degré près de l'étoile polaire), et de centre M. $t_\odot$: temps solaire moyen (Danjon 1986, chapitre 3). C'est en fait un angle horaire dans l'hypothèse du soleil moyen. Pour obtenir $t_\odot$ en degrés on utilisera :

$$t_\odot = 15° \times n$$

n étant le nombre d'heures et fraction d'heures comptées depuis midi ; $n < 0$ le matin, $n > 0$ l'après-midi, et $n = 0$ lors du passage du soleil dans le plan du méridien, et bien sûr $|n| < 12^h$.

C'est cet argument qui est gravé sur la surface du cadran et qui fait donc l'objet du traitement mathématique qui suit. Le temps matérialisé par l'intersection des ombres des gnomons sera par contre un temps solaire vrai, mais lu par l'observateur, par l'intermédiaire des gravures, comme un temps solaire moyen. On ne parlera pas ici de la correction à apporter au temps solaire vrai pour obtenir l'heure légale en vigueur dans la zone où est placé le cadran (Savoie 1997; Grino 1989). δ : déclinaison du soleil. On la supposera constante pendant la durée d'éclairement du cadran. On admettra comme valeur journalière une valeur moyenne centrée à midi vrai local (c'est-à-dire lorsque $t_\odot = 0°$). δ_m est la valeur extrémale de la déclinaison ; $|\delta_m| = 23° 26'$.

Les coordonnées sur les gnomons (*cf.* figure 6). ξ : longueur comptée depuis M_1, vers le bas (sauf pour les septentrionaux), le long de F_1. ξ est de même signe que z. η : longueur comptée depuis M_2 le long de F_2, vers la droite ou vers la gauche. η est de signe opposé à y.

2.4 Les plans

Π_H : plan horizontal et contenant le fil F_2. (Tout ce qui est contenu dans ce plan sera rabattu dans le plan du cadran, avec pour charnière l'axe My (voir figures 3 et 4). Π_M : plan du méridien du lieu. Il contient l'axe Nord-Sud, le pôle nord céleste P_N, le zénith Z ainsi que le fil F_1. Π_N : plan normal au plan Π_{VD} et contenant le fil F_1. Π_{VD} : plan vertical

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[3] Remarque: le segment $[M'_1 M'_2]$ est l'ombre projetée sur le plan Myz du segment $[M_1 M_2]$, si celui-ci était matérialisé. Notons ici que les segments $[M M_1]$ et $[M M_2]$ sont respectivement les styles droits associés aux fils F_1 et F_2 et de pied commun le point M.

déclinant. C'est le plan de travail dans lequel est installé le repère *Myz*.

2.5 Quelques angles utiles

L'angle φ : latitude du lieu du cadran. L'angle $(\Pi_M, \Pi_N) = D$: déclinaison gnomonique. L'angle $T_1\,T'_1\,M_1$ = l'angle $T_2\,T'_2\,M_2 = h$: hauteur du soleil. L'angle $M'_1\,T_1\,M_1$ = l'angle $M'_2\,T_2\,M_2 = Az - D$. α, α' : respectivement angle entre la ligne de midi et une ligne horaire $L_\odot$ d'un cadran bifilaire vertical et d'un cadran vertical ordinaire.

3. Coordonnées du point d'intersection
des ombres des deux gnomons

Le principe du bifilaire étant posé, on passe maintenant à la résolution du problème général qui est de trouver les coordonnées cartésiennes du point d'ombre *P* dans le repère que l'on s'est choisi. À chaque fil (donc à chaque ombre) étant associé une coordonnée, on examinera donc séparément chacune d'elle, ce que permettent les figures de rabattement 3 et 4. Ces figures sont obtenues en rabattant dans le plan Π_{VD}, avec *My* pour charnière, le plan horizontal Π_H, ainsi que le plan azimutal du soleil qui lui, est rabattu autour de la trace qu'il laisse en un instant donné dans Π_{VD} (ce sera l'ombre de F_1 pour la figure 3).

3.1 Ordonnée du point d'ombre *P* dans *Myz* (figure 3)

Dans la figure de rabattement (figure 3), $M\,M_1$ est la distance du fil F_1 au plan du cadran. $(M\,M'_1)$ est la projection de la normale *Mx* au plan du cadran si celle-ci était matérialisée. T'_1 est le centre diviseur de la ligne $(\overrightarrow{T'_1\,M'_1})$. T'_1 est obtenu en rabattant autour de T_1 le point M_1 sur l'horizontale *My*.

Fig. 3 — Rabattement du plan horizontal sur le plan du cadran — ordonnée du point d'ombre *P*

Après examen de la figure 3, il ressort que :

$$
\begin{aligned}
M\,M_1 &= a & \overrightarrow{M\,Sud}\,,\overrightarrow{Mz} &= D \\
M\,T_1 &= y & \text{L'angle } T_1\,T'_1\,M'_1 &= h \\
T_1\,M_1 &= T_1\,T'_1 \quad \text{et} & \text{L'angle } M'_1\,T_1\,M_1 &= Az - D
\end{aligned}
$$

Dans le triangle rectangle $T_1\,M\,M_1$ il vient immédiatement en tenant compte des signes entre *y* et $t_\odot$ (Az et $t_\odot$ sont de même signe) :

$$ y = -a\tan\,(Az - D) $$

On peut écrire en quelque sorte :

$$ y = -a \times f(D;Az) \quad \text{avec} \quad a = c^{te} $$

L'ordonnée de *P* ne dépendra que de *a*, de la déclinaison gnomonique, et de l'azimut du soleil.

3.2 Côte du point d'ombre *P* dans *Myz* (figure 4)

Pour obtenir la côte du point *P* dans *Myz*, on se place dans la figure de rabattement (figure 4) qui est semblable à la figure 3 mais en considérant le fil F_2. Dans la figure 4, $M\,M_2$ est la distance du fil F_2 au plan du cadran. $(M\,M'_2)$ est la projection de la normale au plan du cadran si celle-ci était matérialisée. T'_2 est le centre diviseur de la ligne $\overrightarrow{T_2\,M'_2}$. T'_2 est obtenu en rabattant autour de T_2 le point M_2 sur l'horizontale *My*.
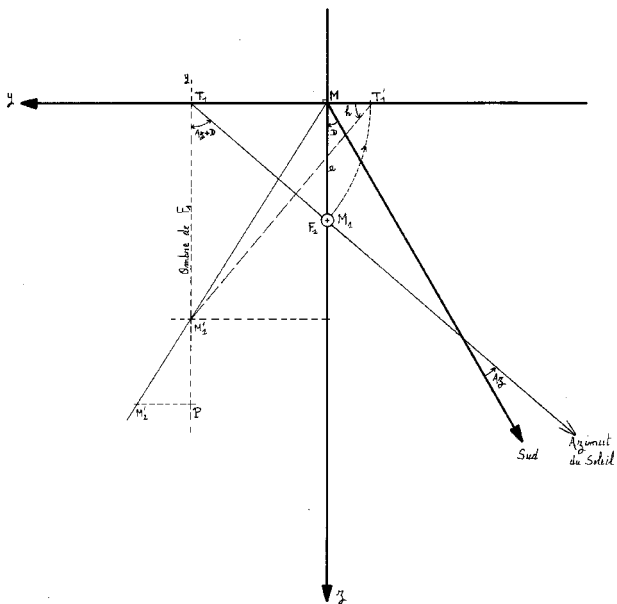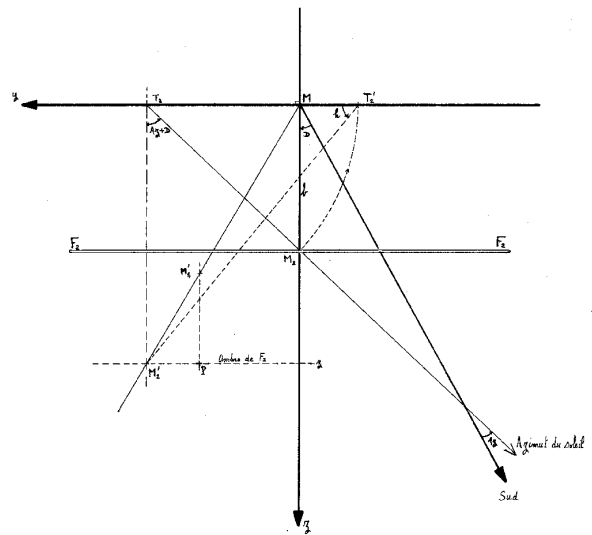

Fig. 4 — Rabattement du plan horizontal sur le plan du cadran — côte du point d'ombre *P*

Après examen de cette figure on peut poser :

$$
\begin{aligned}
M\,M_2 &= b & \overrightarrow{M\,Sud}\,,\overrightarrow{Mz} &= D \\
T_2\,M'_2 &= z & \text{L'angle } T_2\,T'_2\,M'_2 &= h \\
T_2\,M_2 &= T_2\,T'_2 \quad \text{et} & \text{L'angle } M'_2\,T_2\,M_2 &= Az - D
\end{aligned}
$$

Dans le triangle rectangle : $M'_2 T_2 T'_2$:

$$\tan h \;=\; \frac{z}{T_2 T'_2} \qquad \text{d'où} \qquad z \;=\; T_2 T'_2 \times \tan h$$

Pour calculer $T_2 T'_2$, dans le triangle rectangle $T_2 M M_2$:

$$\sin[90° - (Az - D)] \;=\; \frac{b}{T_2 M_2} \;=\; \frac{b}{T_2 T'_2}$$

Soit donc :

$$T_2 T'_2 \;=\; \frac{b}{\cos (Az - D)}$$

Et ainsi :

$$z \;=\; \frac{b \tan h}{\cos (Az - D)}$$

On peut écrire aussi :

$$z \;=\; b \times g\,(D; Az; h) \quad \text{avec} \qquad b = c^{te}$$

La côte du point P dans le repère Myz dépendra de b, de la déclinaison gnomonique, et des coordonnées horizontales du soleil $(Az ; h)$.

3.3 Coordonnées horizontales de P

Les coordonnées cartésiennes dans Myz du point d'ombre P sont en coordonnées horizontales :

$$\begin{aligned} y &= -a \tan (Az - D) \\ z &= b\,\frac{\tan h}{\cos (Az - D)} \end{aligned} \qquad\qquad (1)$$

3.4 Coordonnées horaires de P

Le passage des coordonnées horizontales aux coordonnées horaires du point d'ombre P est fourni par le groupe de Gauss établi dans le triangle de position de sommets P_N, Z, S (figure 5) [elles sont aussi appelées relations fondamentales de la trigonométrie sphérique ; voir Danjon (1986), chapitre I, §7] :

$$\begin{aligned} \sin h &= \sin \varphi \sin \delta + \cos \varphi \cos \delta \cos t_\odot \\ \cos h \sin Az &= \cos \delta \sin t_\odot \\ \cos h \cos Az &= \sin \varphi \cos \delta \cos t_\odot - \cos \varphi \sin \delta \end{aligned} \qquad (2)$$

La substitution de ces relations (2) dans les équations (1) donne directement les coordonnées horaires de P dans Myz. Ainsi pour un cadran bifilaire vertical déclinant :
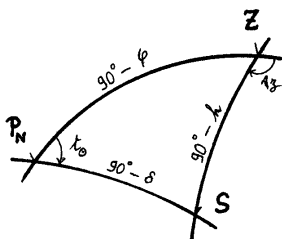
Fig. 5 — Triangle sphérique $P_N Z S$

$$y \;=\; -a\,\frac{\cos D \sin t_\odot - \sin D\,(\sin \varphi \cos t_\odot - \cos \varphi \tan \delta)}{\cos D\,(\sin \varphi \cos t_\odot - \cos \varphi \tan \delta) + \sin D \sin t_\odot}$$

$$\qquad\qquad (3)$$

$$z \;=\; b\,\frac{\cos \varphi \cos t_\odot + \sin \varphi \tan \delta}{\cos D\,(\sin \varphi \cos t_\odot - \cos \varphi \tan \delta) + \sin D \sin t_\odot}$$

4. Réseau de courbes relatif aux coordonnées horizontales

Maintenant que les coordonnées de P sont complètement déterminées, on peut s'intéresser aux lieux géométriques décrits par ce point d'ombre dans le plan du cadran. On détermine ci-après les équations cartésiennes de ces lieux, ce qui constituera les réseaux de courbes recherchés.

4.1 Les courbes de hauteur

On appelle courbe de hauteur le lieu géométrique des points des intersections des ombres des deux gnomons pour lesquels la hauteur du soleil est constante.

4.1.1 Équation générale des courbes de hauteur

Par cette définition, les courbes de hauteur sont indépendantes de l'azimut. Reprenons alors les coordonnées locales [équations (1)] du point P et à partir de celles-ci, prenons les carrés de y et z.

$$\frac{z^2}{(b \tan h)^2} \;=\; \frac{1}{\cos^2 (Az - D)}$$

$$\frac{y^2}{a^2} \;=\; \tan^2 (Az - D)$$

Puis en soustrayant ces deux équations :

$$\frac{z^2}{(b \tan h)^2} - \frac{y^2}{a^2} = \frac{1}{\cos^2 (Az - D)} - \tan^2 (Az - D) = \frac{1 - \sin^2 (Az - D)}{\cos^2 (Az - D)} = 1$$

Ce qui n'est pas autre chose que l'équation réduite des courbes de hauteur dans le plan de travail Myz.

L'équation générale des courbes de hauteur a donc pour expression :

$$\frac{z^2}{(b \tan h)^2} - \frac{y^2}{a^2} \;=\; 1 \quad \text{avec} \qquad a \neq b \ \text{ et } \ h \neq 0 \qquad (4)$$

4.1.2 Nature des courbes de hauteur — Propriétés

La latitude φ et la déclinaison gnomonique D n'apparaissent pas explicitement dans la relation (4). Par conséquent, les courbes de hauteur sont indépendantes du lieu de l'observateur et de l'orientation donnée au plan vertical. D'où cette étonnante propriété : *Dans un cadran solaire bifilaire vertical, les courbes de hauteur sont invariantes par changement de latitude et par changement d'orientation du plan du cadran.*

Pour un cadran bifilaire construit sur un mur vertical cette propriété n'offre rien de bien particulier puisqu'un cadran mural est réputé intransportable. Par contre si l'on imagine un cadran bifilaire portatif alors cette propriété le rend universel en ce qui concerne les

courbes de hauteur. C'est un avantage que les cadrans verticaux à style polaire (cas dit "classique") ne possèdent pas. Seuls les verticaux à style droit ont cette particularité. Il en est maintenant de même des bifilaires.

Le lecteur veillera à ne pas confondre cadran avec courbes de hauteur et cadran de hauteur. S'il est vrai que les cadrans de hauteur mesurent la hauteur du soleil, c'est avant tout pour déterminer l'heure, ce qui les assujetti au lieu d'observation et à la date (ceci à cause de la relation fondamentale de la trigonométrie sphérique qui fait le lien entre sphère locale et sphère céleste :

$$\sin h \;=\; \sin \varphi \sin \delta + \cos \varphi \cos \delta \cos t_\odot$$

En tout lieu de la terre, les courbes de hauteur sont des hyperboles de paramètre $\tan h$ et toutes situées en-dessous de la ligne d'horizon My. Les caractéristiques pour le tracé de ces hyperboles sont résumées dans la table I. On posera :

$$c(h) \;=\; \sqrt{(b \tan h)^2 + a^2}$$

TABLE I
Caractéristiques des courbes de hauteurs

CARACTÉRISTIQUES DES HYPERBOLES	
Excentricité	$\dfrac{c(h)}{b \tan h}$
Axe focal	axe Mz
Foyers F	F $[0 ; c(h)]$
Directrice associée	$z \;=\; \dfrac{(b \tan h)^2}{c(h)}$
Asymptotes	$y \;=\; \pm \dfrac{a}{b \tan h} z$

Puisque les variables $(\delta ; t_\odot)$ n'apparaissent pas non plus explicitement, les courbes de hauteur ne seront pas uniquement utilisables avec le soleil ; elles peuvent l'être aussi avec la lune. En effet lors d'une pleine lune on peut lire l'intersection des ombres des gnomons sur une courbe de hauteur, laquelle donnera la hauteur de notre compagne nocturne.

4.2 Les droites d'azimut

C'est le gnomon vertical F_1 seul qui va engendrer le réseau des courbes d'azimut. En effet, les plans azimutaux du soleil vont tourner autour de F_1 et les traces des intersections de ces plans avec le plan Π_{VD} constitueront le réseau de courbes recherché. On a fait remarquer en §3.1 que l'ordonnée du point d'ombre ne dépend que de l'azimut du soleil. De là, il vient que l'équation générale des courbes d'azimut n'est pas autre chose que l'équation (1) c'est-à-dire :

$$y \;=\; -a \tan (Az - D)$$

Propriétés.
i. Quelle que soit l'orientation donnée au plan du cadran, les courbes d'azimut sont des droites parallèles entre elles et à la verticale du lieu (axe Mz).
ii. Le réseau des droites d'azimut est symétrique par rapport à la droite d'azimut $Az = 0$, distante de l'axe Mz de $y_0 = a \tan D$. Pour une déclinaison nulle, les droites d'azimut sont symétriques par rapport à la ligne de midi (qui sera dans ce cas particulier l'axe Mz).
iii. Cas des plans orientaux ou occidentaux. Pour une déclinaison de ±90° le réseau des droites d'azimut s'établit à partir de la relation :

$$y \;=\; a \cot Az$$

5. Réseau de courbes relatif aux coordonnées horaires

5.1 Les lignes horaires de temps moyen

5.1.1 Équation générale des lignes horaires

Par définition, les lignes horaires sont indépendantes de la déclinaison du soleil. Aussi pour trouver la trace des intersections des cercles horaires avec le plan du cadran en relation avec les gnomons F_1 et F_2, on élimine la déclinaison δ des équations (3). Mais vu que l'établissement de l'équation générale des lignes horaires est un peu plus longue par rapport à ce qui a été fait en §3.1 et §3.2, je propose au lecteur intéressé de se reporter à l'annexe 1.

L'équation cartésienne des lignes horaires sous leur forme la plus générale s'écrit :

$$yb (\cos D \cos t_\odot + \sin \varphi \sin D \sin t_\odot) + za (\cos \varphi \sin t_\odot) + ab (\sin \varphi \cos D \sin t_\odot - \sin D \cos t_\odot) \;=\; 0 \quad (5)$$

5.1.2 Étude des lignes horaires

L'habitude veut que l'on est plus à l'aise avec l'équation réduite d'une équation cartésienne qu'avec l'équation cartésienne elle-même L'équation réduite de l'équation (5) est alors dans Myz :

$$y = mz + p \text{ avec } \begin{cases} m \;=\; -\dfrac{a}{b} \; \dfrac{\cos \varphi \sin t_\odot}{\cos D \cos t_\odot + \sin \varphi \sin D \sin t_\odot} \\[2mm] p \;=\; -a \tan (\psi_\odot - D) \\[2mm] \text{et} \quad \tan \psi_\odot \;=\; \sin \varphi \tan t_\odot \end{cases} \quad (6)$$

Celle-ci étant plus "parlante" et permet d'obtenir les résultats fondamentaux suivants :
i. L'angle α entre l'axe Mz et une ligne horaire $L_\odot$ est donné par :

$$\tan \alpha = -\frac{a}{b} \; \frac{\cos \varphi \sin t_\odot}{\cos D \cos t_\odot + \sin \varphi \sin D \sin t_\odot} \quad (7)$$

ii. L'intersection de la ligne horaire $L_\odot$ avec l'axe My est donné par :

$$y|_{z=0} \;=\; -a \tan (\psi_\odot - D) \quad \text{avec} \quad \tan \psi_\odot \;=\; \sin \varphi \tan t_\odot \quad (8)$$

iii. Étant donné que les pentes des lignes horaires sont différentes et dépendantes de $t_\odot$ on peut déterminer leur point de concours.

Ordonnée du point de concours. Lorsque $t_\odot = 0$, (midi vrai local) :

$$y\big|_{t_\odot=0} \;=\; y_{Ce} \;=\; a \tan D$$

Remarquons que la ligne de midi est verticale et distante de $|a \tan D|$ de Mz, et sa position par rapport à cet axe dépendra du signe de D.

Côte du point de concours lorsqu'à partir de l'équation générale des lignes horaires d'équation (5), on remplace y par y_{Ce} on obtient :

$$z_{Ce} \;=\; -b\,\frac{\tan \varphi}{\cos D}$$

Les lignes horaires se coupent toutes en un point Ce de coordonnées :

$$y_{Ce} \;=\; a \tan D$$
$$z_{Ce} \;=\; -b\,\frac{\tan \varphi}{\cos D} \qquad\qquad (9)$$

5.1.3 Propriétés générales des cadrans bifilaires

i. Propriété fondamentale commune à tous les bifilaires. Pour interpréter le résultat d'équation (9), on sait que dans un cadran solaire vertical déclinant ordinaire, les lignes horaires sont concourantes en un point qui est celui où l'axe du monde (matérialisé par le style) coupe le plan du cadran. Par analogie, on admet que pour le bifilaire vertical déclinant : c'est en Ce que l'axe du monde coupe le plan Π_{VD}, et c'est en Ce que se coupent toutes les lignes horaires d'un cadran vertical déclinant ordinaire dont le style droit a pour longueur b, et est distant de M de $(a - b) \times \tan D$. Cette particularité est valable quel que soit le cadran bifilaire déclinant. On énonce cette propriété fondamentale de la façon suivante : *Le réseau de lignes horaires généré par un système bifilaire orthogonal est équivalent à celui créé par un style polaire passant par* Ce *et de longueur:*

$$\frac{b}{\cos \varphi \cos D}$$

L'utilisation de cette propriété fondamentale va conduire à deux autres propriétés pratiques fort remarquables, découvertes par Hugo Michnik pour le bifilaire horizontal (Michnik 1923). On démontre ci-dessous qu'elles se prolongent naturellement pour le cadran bifilaire *plein sud* $(D = 0°)$ (resp. plein nord ; $D = 180°$), et *qu'elles n'existent pas pour les autres verticaux déclinants*!

ii. Propriétés relatives aux seuls bifilaires méridionaux (et septentrionaux). Reprenons les relations (3) et faisons $D = 0°$. On obtient :

$$y \;=\; -a\,\frac{\sin t_\odot}{\sin\varphi \cos t_\odot - \cos \varphi \tan \delta}$$

$$z \;=\; b\,\frac{\cos \varphi \cos t_\odot + \sin \varphi \tan \delta}{\sin\varphi \cos t_\odot - \cos \varphi \tan \delta} \qquad (10)$$

L'équation réduite des lignes horaires est alors d'après équations (6) :

$$y \;=\; mz + p \quad \text{avec} \quad \begin{aligned} m &= \tan \alpha = -\frac{a}{b}\cos \varphi \tan t_\odot \\ p &= -a \sin \varphi \tan t_\odot \end{aligned} \;(11)$$

a. $1^{\text{ière}}$ propriété : cadran fonctionnant sous toutes les latitudes. Sachant que le réseau de lignes horaires est équivalent à celui d'un vertical à style polaire on peut rapprocher (donc comparer) le formulaire du cas classique, donnant l'angle entre une ligne horaire et la ligne de midi, de celui du bifilaire plein sud. Dans le cas classique, Savoie (1997), Garino (1989), ou Rohr (1986) donnent pour l'angle α' d'un vertical plein sud placé à une latitude φ' (en prenant la précaution de se placer dans le même repère que Myz, ce qui se traduit par un changement de signe) :

$$\tan \alpha' \;=\; -\cos \varphi' \tan t_\odot$$

Si l'on veut l'équivalence avec notre bifilaire plein sud placé à une latitude φ on posera :

$$(\tan \alpha)_{\text{bifilaire}} \;=\; (\tan \alpha')_{\text{classiquee}}$$

C'est-à-dire que les deux fils doivent être tels que leur distance au plan du cadran est réglée par :

$$\frac{a}{b} \;=\; \frac{\cos \varphi'}{\cos \varphi} \qquad\qquad (12)$$

Ainsi, une fois le bifilaire tracé, il peut servir sous toutes les latitudes (sauf aux pôles) en ajustant convenablement le rapport a/b des gnomons donné par (12).

b. $2^{\text{ième}}$ propriété : lignes horaires homogènes. On utilise encore la tangente de l'angle entre la ligne horaire et la ligne de midi. D'après les relations (10) remarquons que lorsque :

$$\frac{a}{b}\cos \varphi \;=\; 1 \qquad \text{alors} \qquad \tan \alpha \;=\; -\tan t_\odot$$

donc $\alpha = -t_\odot$ et $t_\odot = 15° \times n$. Les longueurs des gnomons seront telles que :

$$b \;=\; a \cos \varphi \qquad\qquad (13)$$

Lorsque l'angle entre la ligne horaire $L_\odot$ et la ligne de midi est égal à l'angle horaire du soleil, on parle de *cadran à lignes horaires homogènes.* Alors que pour le cadran ordinaire cela se produit seulement à l'équateur de la Terre, pour le bifilaire plein sud, cela se produira en tout lieu (hormis aux pôles) pourvu que les gnomons soient dans le rapport donné par (13). Remarque : d'après l'équation (12), on fait $\varphi' = 0$ pour obtenir l'équation (13). Ainsi le bifilaire à lignes horaires homogènes construit pour une latitude φ est un bifilaire satisfaisant la relation (12) à l'équateur de la Terre.

Lorsque la propriété (13) est satisfaite, le tracé des lignes horaires du cadran bifilaire s'en trouve considérablement simplifié puisque cela revient à construire les lignes horaires d'un équatorial (voir Toussaint 1982) : les lignes horaires d'heures pleines d'un bifilaire plein sud seront espacées chacune de 15°.

c. Qu'en est-il du bifilaire déclinant? On soulignera qu'un bifilaire vertical plein sud possède un axe de symétrie: la ligne de midi, ce que traduit la relation :

$$\tan \alpha \;=\; k \times \tan t_\odot$$

(et réciproquement). Or pour le bifilaire vertical déclinant (comme pour le cadran classique) la symétrie par rapport à la ligne de midi des lignes horaires disparait complètement. La forme fonctionnelle réglant la distribution angulaire des lignes horaires n'est plus simple :

$$\cot \beta \,=\, k \times \cot t_\odot + k'$$

(k, k' constantes ne dépendant que de φ et D) ce qui ôte la symétrie et donc les deux précédentes propriétés. La propriété fondamentale (§5.1.3i), elle, en revanche, reste valable.

5.1.4 Cadrans à lignes horaires parallèles : les unifilaires

Dans l'expression (6) le rapport a/b est constant puisque l'on assure que la distance des fils au plan du cadran est constante. Il paraît légitime de se demander ce que devient le réseau des lignes horaires dans le cas où le rapport a/b est indéterminé. On peut déjà faire remarquer que lorsque a/b tend vers l'infini, $\alpha = 90°$, les lignes horaires seront toutes parallèles entre elles. On donne ci-dessous les résultats obtenus lorsque l'on éloigne indéfiniment un des deux gnomons du plan du cadran. Il ne restera qu'un seul fil générateur d'un réseau de lignes horaires parallèles à l'un des axes de référence. Les relations fournies dans la table II suffisent à leur construction dans *Myz*.

TABLE II
Formulaire pour le cadran "unifilaire"

	$b \longrightarrow \infty$	$a \longrightarrow \infty$
Gnomon	vertical (F_1)	horizontal (F_2)
Équation horaire	$y = -\tan(\varphi_\odot - D)$	$z = -b\dfrac{\cos D}{\cos \varphi}(\sin \varphi - \tan D \cos t_\odot)$
Condition sur $t_\odot$	$\tan t_\odot \neq \dfrac{-1}{\tan D \sin \varphi}$	$t_\odot \neq 0°$
Parallélisme	$L_\odot \parallel (Mz)$	$L_\odot \parallel (My)$

Les relations constitutives ainsi obtenues conduisent à un type particulier et peu répandu de cadran vertical : celui dont le gnomon est parallèle au plan de projection[4]. Dans le cas des cadrans verticaux à style polaire on ne rencontre cette situation que pour ceux qui sont plein est et plein ouest — les lignes horaires sont effectivement parallèles entres elles et le style est parallèle au cadran et dirigé vers l'étoile polaire. Ainsi, et ceci est remarquable : *les bifilaires, à partir desquels on éloigne indéfiniment un des deux fils, permettent d'obtenir, pour toute orientation désirée, des cadrans à lignes horaires parallèles, verticales ou horizontales*, au choix.

De nombreuses situations pratiques peuvent être exploitées pour le cadran dit "unifilaire." En effet, le gnomon peut-être : l'arête d'un mur, le bord d'une fenêtre, d'une toiture, *etc.*, un pilier, une colonne placée devant mur (comme on peut souvent le voir dans les édifices modernes), ou tout objet rectiligne placé parallèlement et verticalement ou horizontalement devant le mur de projection. Les exemples ne manquent pas! Tout dépend des configurations rencontrées et de l'imagination du gnomoniste. Faisons remarquer que pour ce type de cadran on ne peut tracer que des lignes horaires et des lignes d'azimut.

5.2 Les courbes d'arcs diurnes

5.2.1 L'équation générale des arcs diurnes

On se propose de déterminer l'équation de la courbe décrite au cours d'une journée par le point d'intersection des ombres des gnomons. Par les mêmes raisons évoquées au §5.1.1, j'invite le lecteur à se reporter à l'annexe 2 pour l'établissement de l'équation générale des arcs diurnes (c'est simple mais plutôt long!). La démonstration développée dans cette annexe conduit à un polynôme de degré 2 de la forme :

$$f(y,z) = A\,y^2 + B\,z^2 + 2\,C\,yz + 2\,E\,y + 2\,F\,z + G = 0 \qquad (14)$$

une expression très classique et pour laquelle les six coefficients sont :

$$
\begin{aligned}
A &= b^2(\sin^2 \delta - \cos^2 \varphi \sin^2 D)\\
B &= -a^2 \sin(\varphi + \delta)\sin(\varphi - \delta)\\
C &= a\,b \cos \varphi \sin \varphi \sin D \qquad\qquad (15)\\
E &= -a\,b^2 \cos^2 \varphi \cos D \sin D\\
F &= a^2\,b \cos \varphi \sin \varphi \sin D\\
G &= a^2\,b^2(\sin^2 \delta - \cos^2 \varphi \cos^2 D)
\end{aligned}
$$

Les arcs diurnes sont donc dans le plan du cadran bifilaire vertical déclinant (et sans surprise !) des *sections coniques*.

5.2.2 Nature des arcs diurnes

L'étude du polynôme du second degré (équation 14) par la détermination des signatures de ses matrices représentatives M et Q donne directement une classification des coniques (voir Fresnel 1997). On se servira de l'algorithme de Gauss pour déterminer les signatures des matrices

$$
M = \begin{bmatrix} A & C & E \\ C & B & F \\ E & F & G \end{bmatrix}
\qquad \text{et} \qquad
Q = \begin{bmatrix} A & C \\ C & B \end{bmatrix}
$$

Exposer ici tout le détail de ces étapes pour chaque situation du plan du cadran en déclinaison et en latitude ne serait qu'ennuyeux et complètement inutile. On trouvera ici une table (table III) récapitulative des résultats attendus, à savoir : *quelle est la nature des arcs diurnes dans un cadran solaire bifilaire vertical déclinant* ?

6. Construction du réseau de courbes relatif aux coordonnées locales

6.1 Le formulaire

Formulaire pour le réseau de courbes en coordonnées locales:

Courbes de hauteur: $z = b \tan h \sqrt{1 + (y/a)^2}$, prendre des valeurs entières pour y et h.
Droites d'azimut: $y = -a \tan(Az - D)$, prendre des valeurs entières pour Az.

6.2 Construction des courbes de hauteur

i.   Dans un plan vertical placer le repère *Myz* tel qu'il a été défini au §2.1.

---

[4] L'auteur propose de l'appeler "cadran unifilaire." Même si l'expression n'est pas très heureuse, elle est en tout cas assez parlante, suggérant fortement le lien avec le bifilaire.

Natures des arcs diurnes

Latitude	Zone	Déclinaison	Date	Nature des arcs diurnes
$\varphi = 0°$	Équateur	$D = 0°$	$\delta \neq 0°$	Ellipses
...		$D \neq 0°$	$|\delta| < |D|$	Hyperboles
...		...	$|\delta| > |D|$	Ellipses
...		...	Si $\frac{a}{b} = \sqrt{1 - \left(\frac{\sin D}{\sin \delta}\right)^2}$	Cercle
...		...	$|\delta| = |D|$	Parabole
...		D qcq	$\delta = 0°$	Pas de fonctionnement
$|\varphi| \leq |\delta_m|$	Zone inter tropicale	$D = 0°$	$|\delta| > |\varphi|$	Ellipses
...		...	Si $\frac{b}{a} = \sqrt{1 - \left(\frac{\sin \varphi}{\sin \delta}\right)^2}$	Cercle
...		...	$|\delta| < |\varphi|$	Hyperboles
...		...	$|\delta| = |\varphi|$	Parabole
...		$|D| = |\delta|$	$\delta \neq 0°$	Hyperbole
...		$|D| = |\varphi|$	$|\varphi| < \arccos \sqrt{\cos|\delta|}$	Ellipses
...		...	Si $\frac{b}{a} = g(\varphi, \delta)$	Cercle
...		...	$|\varphi| = \arccos \sqrt{\cos|\delta|}$	Parabole
...		...	$|\varphi| > \arccos \sqrt{\cos|\delta|}$	Hyperboles
...	Autres valeurs		$\delta \neq 0°$	Hyperboles
...	...		$\delta = 0°$	Droite
$|\delta_m| < |\varphi| < |90° - \delta_m|$	Tempérée	D qcq	$\delta \neq 0°$	Hyperboles
...	...		$\delta = 0°$	Droite
$|90° - \delta_m| < |\varphi| < |90°|$	Polaire	D qcq	$\delta \neq 0°$	Hyperboles
...	...		$\delta = 0°$	Droite

Dans le rapport $\dfrac{a}{b}$, g a pour expression : $g(\varphi, \delta) = \sqrt{\dfrac{\sin^2\delta - \cos^2\varphi \ \sin^2\varphi}{\sin^2\delta - \sin^2\varphi}}$, $|\delta| \neq 0°$

ii.   Se fixer une valeur de h en partant de $h = 0°$, jusqu'à une valeur maximale. A chaque valeur de h correspondra une hyperbole. On prendra de préférence des valeurs entières pour h.

iii.   Se donner des valeurs entières pour y. Afin de faciliter les calculs et surtout le tracé on pourra prendre l'ensemble des valeurs : $y = \{-n, ..., -3, -2, -1, 0, 1, 2, 3, ..., n\}$ (en cm). La quantité $2n$ représentant soit la largeur que vous souhaitez donner au cadran bifilaire, soit la largeur qui vous est imposée (cette valeur maximale de y pourra être aussi utilisée pour déterminer la longueur utile du gnomon F_2 — voir pour cela §8.2).

iv.   Calculer les valeurs de z correspondant à chaque valeur entière de y. On utilisera la formule :

$$z = \pm b \tan h \ \sqrt{1 + (y/a)^2}$$

On prendra $z > 0$ puisque le point d'intersection des ombres des deux gnomons est toujours situé en-dessous de la ligne d'horizon My.

v.   Puis on recommence avec une autre valeur de h. À titre d'exemple on pourra incrémenter h de 10°, en 10°, jusqu'à la valeur maximale $(90° - \varphi + |\delta_m|)$, ou davantage si l'on souhaite réaliser un abaque des

courbes de hauteur qui soit utilisable n'importe où.

vi.   À la fin du tracé point par point, il ne reste plus qu'à installer le système des deux fils. Le premier fil F_1 sera placé au-dessus de l'axe Mz à la distance a. Le second fil F_2 sera placé au-dessus de l'axe My à la distance b. Il vous appartient de choisir des valeurs numériques pour a et b sachant que celles-ci jouent sur l'aspect des hyperboles. À ce stade tout est permis !

6.3 Construction des droites d'azimut

On procédera de la même façon que pour le réseau de courbes de hauteur, mais on considérera Az plutôt que h et on supprimera les étapes iii et iv. Quand aux valeurs extrémales de l'azimut, elles seront liées au passage du soleil dans le plan du cadran, puis, suivant la position de celui-ci avec le méridien, liées aux azimuts de lever et/ou de coucher du soleil. Pour plus de détails voir Savoie (1997).

7. Formules pour tracer les lignes horaires et les arcs diurnes

On regroupe ci-dessous les principaux résultats concernant les coordonnées du point d'ombre P, du centre Ce du cadran, ainsi que l'équation paramétrique des lignes horaires.

7.1 Cadran bifilaire plein sud ($D = 0°$)

Coordonnées dans Myz, du point d'ombre P :

$$y = -a\, \frac{\sin t_\odot}{\sin \varphi \cos t_\odot - \cos \varphi \tan \delta}$$

$$z = b\, \frac{\cos \varphi \cos t_\odot + \sin \varphi \tan \delta}{\sin \varphi \cos t_\odot - \cos \varphi \tan \delta}$$

du centre du cadran:

$$y_{Ce} = 0$$

$$z_{Ce} = -b \tan \varphi$$

et l'équation réduite des lignes horaires, $y = m\,z + p$:

$$m = \frac{a}{b} \times \cos \varphi \tan t_\odot$$

$$p = -a \sin \varphi \tan t_\odot$$

7.2 Cadran bifilaire plein Est ou plein Ouest ($D = \pm90°$)

Coordonnées dans Myz, du point d'ombre P :

$$y = -a\, \frac{\sin \varphi \cos t_\odot - \cos \varphi \tan \delta}{\sin t_\odot}$$

$$z = \pm b\, \frac{\cos \varphi \cos t_\odot + \sin \varphi \tan \delta}{\sin t_\odot}$$

du centre du cadran:

rejeté à l'infini,

et l'équation réduite des lignes horaires, $y = m\,z + p$:

$$m = \pm \frac{a}{b} \times \frac{1}{\tan \varphi}$$

$$p = a \frac{\cot t_\odot}{\sin \varphi}$$

7.3 Cadran bifilaire plein nord ($D = 180°$)

Coordonnées dans Myz, du point d'ombre P :

$$y = -a\, \frac{\sin t_\odot}{\sin \varphi \cos t_\odot - \cos \varphi \tan \delta}$$

$$z = -b\, \frac{\cos \varphi \cos t_\odot + \sin \varphi \tan \delta}{\sin \varphi \cos t_\odot - \cos \varphi \tan \delta}$$

du centre du cadran:

$$y_{Ce} = 0$$

$$z_{Ce} = b \tan \varphi$$

et l'équation réduite des lignes horaires, $y = m\,z + p$:

$$m = \frac{a}{b} \times \cos \varphi \tan t_\odot$$

$$p = -a \sin \varphi \tan t_\odot$$

7.4 Cadran bifilaire vertical déclinant — Cas général

Coordonnées dans Myz, du point d'ombre P :

$$y = -a\, \frac{\cos D \sin t_\odot - \sin D\,(\sin \varphi \cos t_\odot - \cos \varphi \tan \delta)}{\cos D\,(\sin \varphi \cos t_\odot - \cos \varphi \tan \delta) + \sin D \sin t_\odot}$$

$$z = b\, \frac{\cos \varphi \cos t_\odot + \sin \varphi \tan \delta}{\cos D\,(\sin \varphi \cos t_\odot - \cos \varphi \tan \delta) + \sin D \sin t_\odot}$$

du centre du cadran:

$$y_{Ce} = a \tan D$$

$$z_{Ce} = -b \frac{\tan \varphi}{\cos D}$$

et l'équation réduite des lignes horaires, $y = m\,z + p$:

$$m = -\frac{a}{b}\, \frac{\cos \varphi \sin t_\odot}{\cos D \cos t_\odot + \sin \varphi \sin D \sin t_\odot}$$

$$p = -a \tan (\psi_\odot - D) \qquad \text{avec} \qquad \tan \psi_\odot = \sin \varphi \tan t_\odot$$

8. Longueur utile des gnomons

8.1 Les relations de base

Lorsque l'on veut construire un cadran solaire on se pose en premier la question de savoir où et sur quelle surface. Puis vient ensuite le problème de la longueur utile du style qu'il faut se donner pour que le réseau de courbes en coordonnées locales ou horaires occupe au maximum la surface choisie. On peut en effet rappeler que l'étendue des arcs diurnes, par exemple, dépend de la longueur de l'ombre du style polaire et donc du style lui-même.

Pour les cadrans solaires bifilaires, la nature du problème ne change pas, et on doit donc se demander : *quelle longueur faut-il donner aux fils F_1 et F_2 pour que le réseau de courbes occupe au maximum la surface plane choisie* ? (et donc que le point d'ombre reste toujours sur la surface du cadran !). On écartera la solution élémentaire qui consiste à placer les gnomons sur toute leur longueur au-dessus de la surface du cadran.

Rappelons ce que l'on sait du système bifilaire que l'on s'est imposé ici (voir la table IV).

La figure 1 montre déjà (pour $D \in]-\tfrac{1}{2}\pi, +\tfrac{1}{2}\pi[$) que la partie du fil F_1 située au-dessus du plan horizontal Π_H ne sera jamais utilisée

TABLE IV
Caractéristiques des gnomons

	Π_{VD}	Π_N	Π_M	Π_H
F_1	$\parallel$	$\in$	$\in$	$\perp$ en M_1
F_2	$\parallel$	$\perp$ en M_2	—	$\in$

dans la formation du point P puisque : P est toujours situé en-dessous de My, et le soleil se trouve toujours au-dessus de Π_H. Plaçons-nous sur F_1 et, à partir de M_1 pris pour origine, considérons la portion du fil caractérisé par $\xi = M_1 \Sigma_1$ où Σ_1 est le point où le rayon lumineux servant à former P coupe F_1 (figure 6). De la même manière, considérons la portion du fil F_2 caractérisé par $\eta = M_2 \Sigma_2$ où Σ_2 est le point où le rayon lumineux servant à former P coupe F_2 (M_2 sera l'origine prise sur F_2). Le chemin $\Sigma_2\Sigma_1 P$ représente donc le trajet du rayon lumineux s'il n'était pas arrêté par le fil F_2 en Σ_2.

La figure 6 permet de déduire d'une part que la longueur η de la portion de fil F_2 va dépendre de y et d'autre part que la longueur ξ de la portion de fil F_1 va dépendre de z. Il y aura donc proportionnalité et on sait déjà quel outil utiliser pour trouver ces relations de proportionnalité. Les coordonnées (ξ; η) caractérisent donc le glissement sur chacun des fils du rayon lumineux en un instant $t_\odot$ et par-là même la position de P dans le plan Π_{VD}.

On peut considérer de la même façon le rayon $M_2\Sigma_1 z$ obtenu
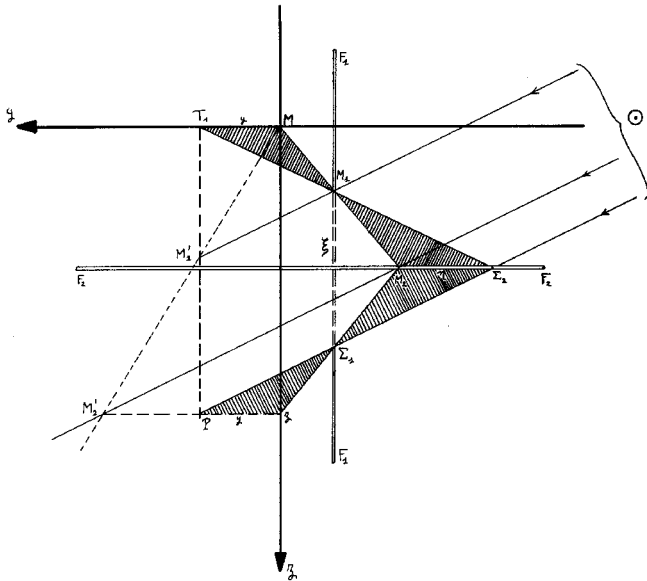
FIG. 6 — Longueur utile des gnomons

lorsque le soleil passe dans le plan Π_N. Les segments $T\Sigma_2$ et MM_2 représentent les traces des plans azimutaux du soleil sur Π_H. On extrait alors à partir de la figure 6 les figures de travail 7 à 10, qui permettent d'obtenir immédiatement, par application du théorème de Thalès, la proportionnalité recherchée entre (ξ; η) et (y; z).
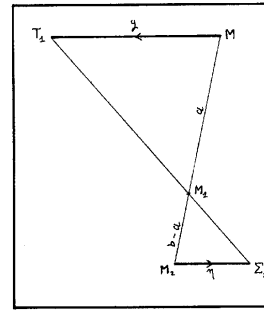
FIG. 7 — Dans le plan horizontal
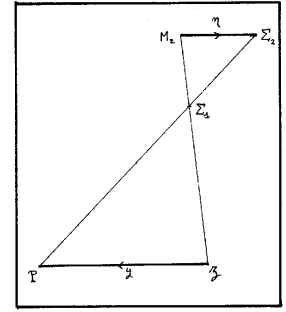
FIG. 8 — Dans le plan de projection
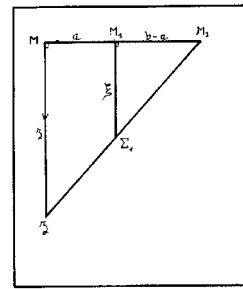
FIG. 9 — Dans le plan normal au cadran
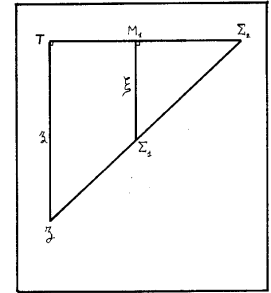
FIG. 10 — Dans le plan azimutal du soleil

À partir de cette configuration bifilaire :

$$\eta = -q \times y \qquad q = 1 - \frac{a}{b}$$
$$\text{avec} \tag{16}$$
$$\xi = q \times z \qquad a \neq b \quad et \quad q > 0$$

Le signe moins dans η indique que le déplacement de η sur F_2 se fait dans le sens contraire au déplacement de y sur My (le sens du glissement est indiqué par des flèches placées sur les segments parallèles dans les figures 7 à 10).

8.2 Discussion des cas pratiques

En pratique, les longueurs utiles des gnomons sont intimement liées aux conditions d'éclairement du plan vertical, conditions qui dépendront essentiellement des azimuts et de la déclinaison du soleil, et qui se traduiront sous la forme de coordonnées y_m et z_m — voir équations (1) — ce qui donnera ensuite accès, grâce aux équations (16), aux longueurs recherchées ξ_m et η_m. On n'oubliera pas de prévoir les fixations des gnomons qui, bien entendu, ne devront pas empiéter sur la partie servant à la formation de l'ombre !

Dans le cas d'un cadran bifilaire plein sud, il y a symétrie des réseaux de courbes par rapport à la ligne de midi. Donc pour les longueurs des gnomons contribuant à la formation du point d'ombre P on aura :

$$\ell_{F_1} = |\xi_m|$$
$$\tag{17}$$
$$\ell_{F_2} = 2 \times |\eta_m|$$

Relations dans lesquelles ξ_m et η_m sont calculées à partir des équations (16), si l'on se donne y_m et z_m.

Dans le cas d'un cadran bifilaire d'orientation quelconque, il

FIG. 11 — Exemples de lignes horaires et courbes d'arcs diurnes de cadrans solaires bifilaires verticaux déclinants pour *D* = 0°, 15°, 45°, 75°, 90°, 120°, 150°, 180°, −150°, −120°, −90°, −75°, −45°, et −15°. Pour *D* = ± 90°, on remarquera que les lignes horaires, toutes parallèles entre elles, ne sont pas perpendiculaires à l'équinoxiale comme pour les cadrans occidentaux ou orientaux classiques
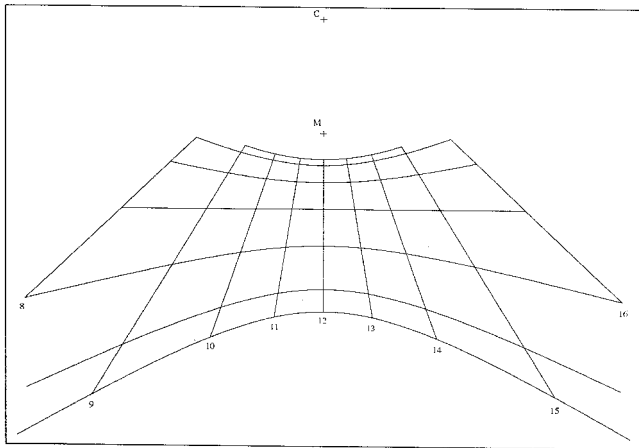
FIG. 11-1   D = 0°
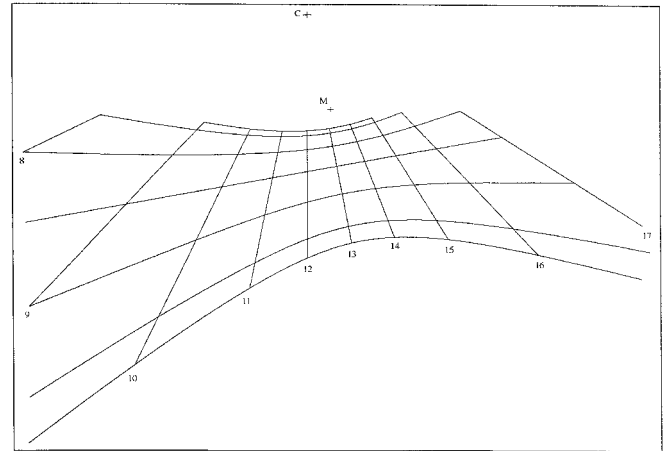
FIG. 11-2   D = +15°
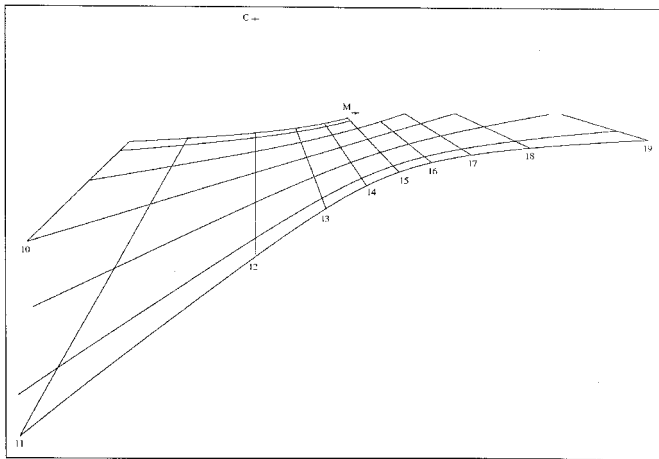
FIG. 11-3   D =+45°
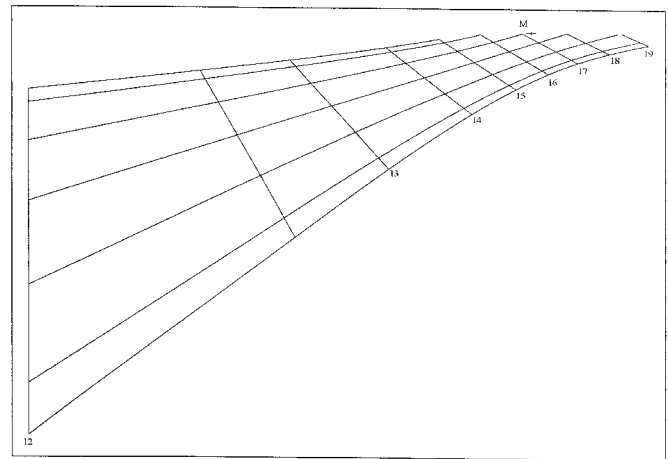
FIG. 11-4   D = +75°
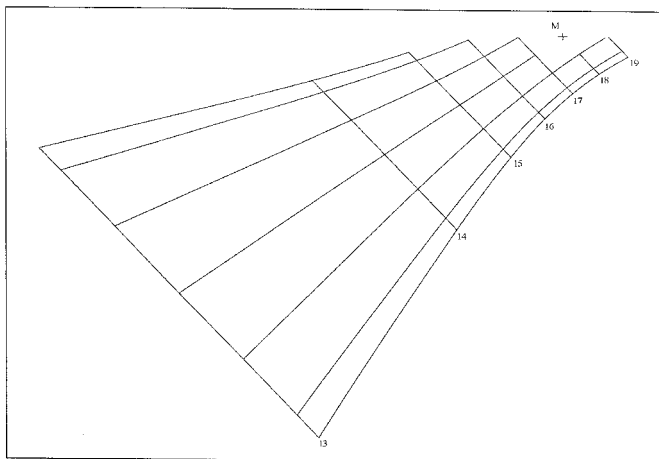
FIG. 11-5   D = +90°
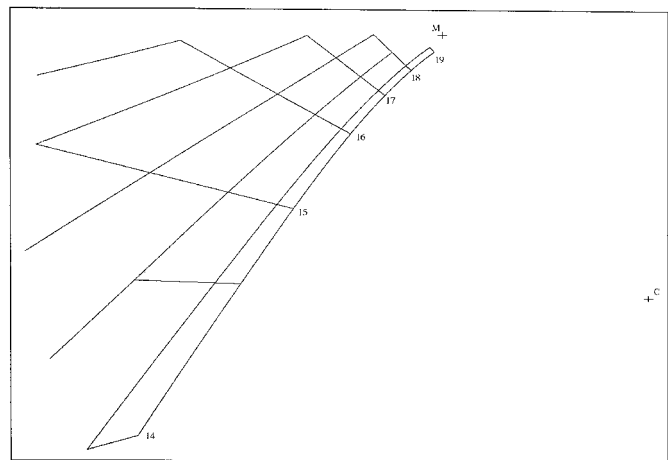
FIG. 11-6   D = +120°
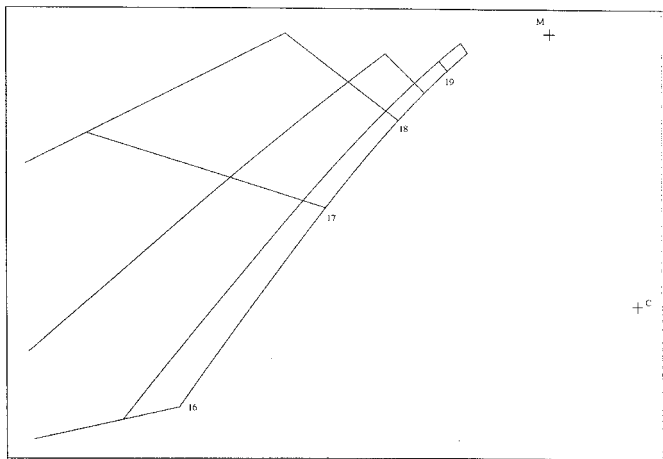
FIG. 11-7   D = +150°
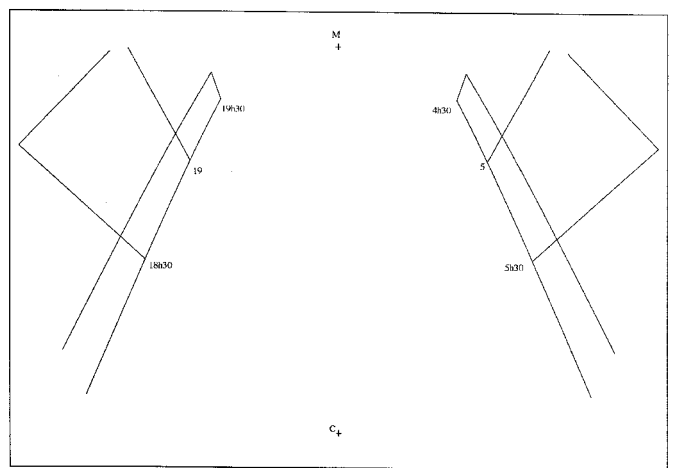
FIG. 11-8   D = +180°
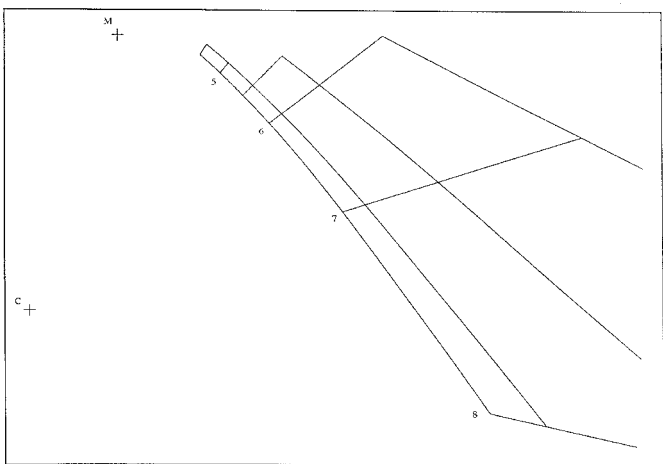
FIG. 11-9   D =−150°
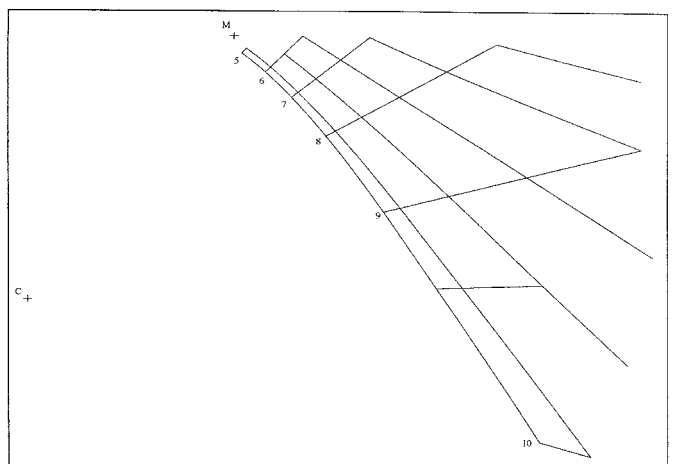
FIG. 11-10   D = −120°
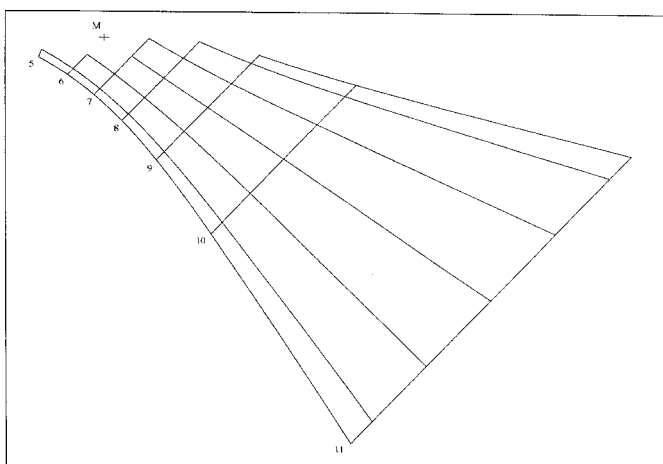
FIG. 11-11   D = −90°
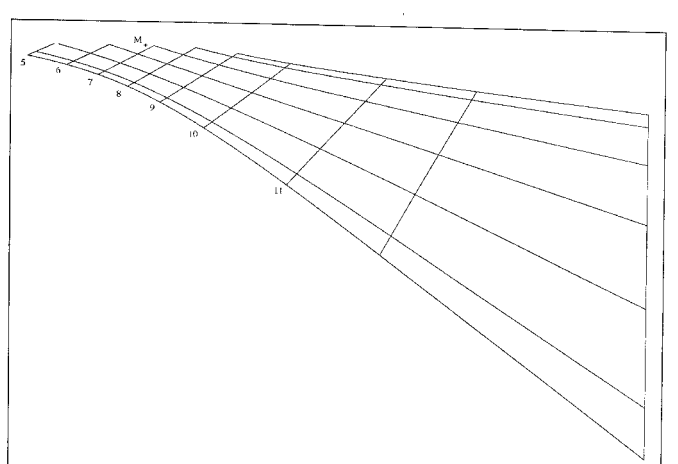
FIG. 11-12   D = −75°
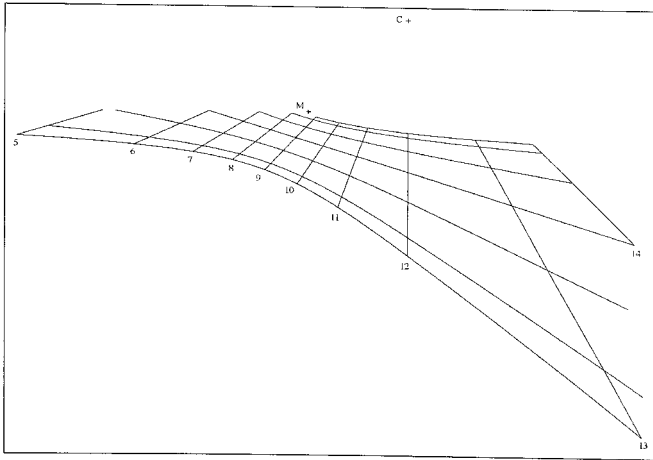
FIG. 11-13 D = −45°
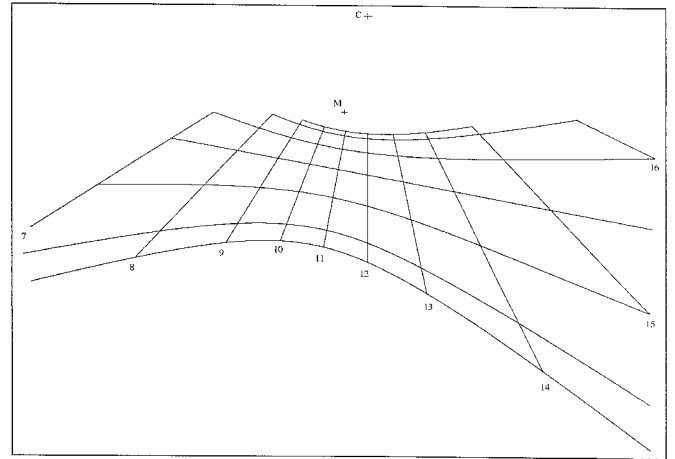
FIG. 11-14 D = −15°
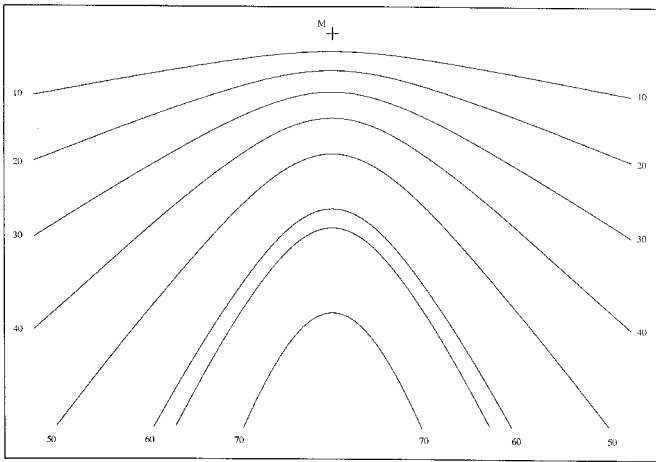
FIG. 12 — Courbes de hauteur de cadrans solaires bifilaires verticaux déclinants pour $(a;b) = (3;5)$ cm, φ, D quelconques, $h_{max - \text{Calais}} = 62°\ 26´$
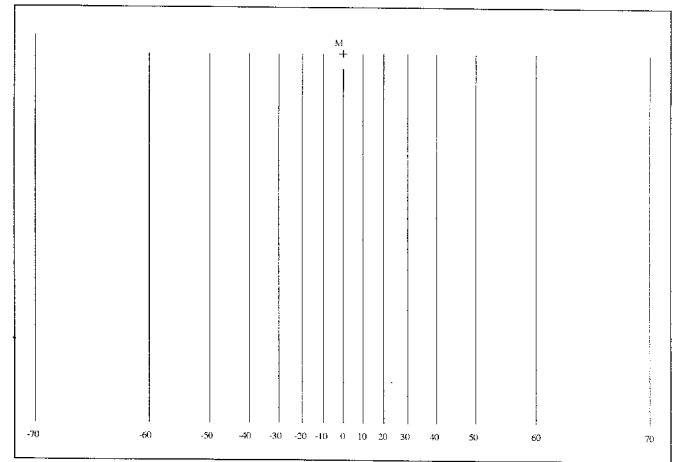
D = 0°

FIG. 13 — Droites d'azimut de cadrans solaires bifilaires verticaux déclinants pour $D = 0°$, $+45°$, et $−45°$
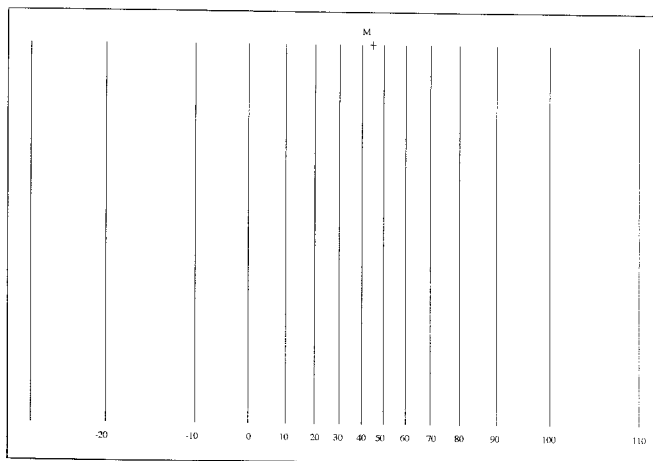
FIG. 13-2 D = +45°
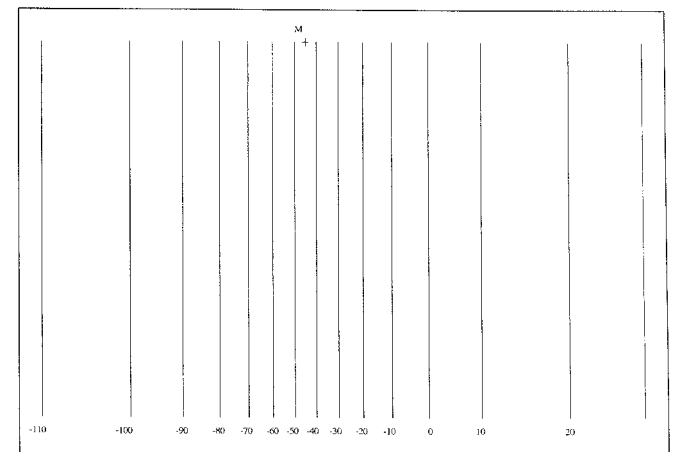
FIG. 13-3 D = −45°

n'y a plus symétrie du réseau de courbes. Les longueurs utiles des gnomons sous leur forme la plus générale s'écriront :

$$\ell_{F_1} = |\xi_m|$$

$$\ell_{F_2} = |\eta_{\text{avant}\Pi_N}| + |\eta_{\text{après}\Pi_N}|$$

(18)
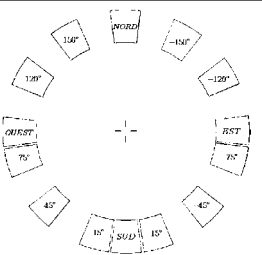
et dans lesquelles $|\eta_{\text{avant}\Pi_N}|$ et $|\eta_{\text{après}\Pi_N}|$ seront à déterminer d'après la déclinaison du plan, la date et la latitude où est prévu le bifilaire.

Le problème de la longueur utile des gnomons d'un bifilaire vertical déclinant n'est pas simple à résoudre. Il faut en effet d'abord déterminer, selon la déclinaison gnomonique D, les heures de passage du soleil dans le plan du cadran. On devra donc calculer l'angle horaire de la sous-stylaire du cadran *ordinaire* associé ce qui permettra de déterminer les heures de début et de fin d'éclairement du bifilaire. À partir de ces angles horaires extrêmes, à déclinaison δ donnée (qui sera aussi à déterminer ; en pratique ce sera le solstice d'été), on peut alors calculer y_m et z_m. D'où finalement ξ_m et les η — voir plus en détail Savoie (1997).

9. Exemples de tracés de cadrans solaires bifilaires verticaux déclinants

9.1 Lignes horaires et courbes d'arcs diurnes

Afin d'avoir un aperçu complet du réseau de courbes en coordonnées horaires du cadran bifilaire vertical, on se propose de parcourir en déclinaison la rose des vents. Le diagramme ci-dessous donne les valeurs des déclinaisons qui ont été retenues pour un tour complet de l'horizon sud à l'horizon nord. Conjointement à ce diagramme, on donne la latitude, les dimensions du système bifilaire, et les dates correspondant aux sept arcs diurnes habituellement tracées sur les cadrans solaires.

Diagramme des déclinaisons gnomoniques utilisées	Caractéristiques pour des tracés des cadrans bifilaires verticaux	Arcs diurnes Déclinaison du soleil	
		Dates	δ
	Latitude : φ = 51° Nord (Calais). Gnomons : $(a;b)$ = (8;10) cm	Solstice d'hiver 20/01 – 22/11 19/02 – 23/10 Équinoxes 20/04 – 23/08 21/05 – 22/07 Solstice d'été	-23°26´ -20°08′ -11°17´ 0° 11°17´ 20°08´ 23°26´

Les dessins ont été obtenus grâce au traceur de courbes Gnuplot[5]. Chaque graphique (figure 11) comporte : le point M, centre du repère Myz, le centre C du cadran solaire vertical déclinant *équivalent* (cadran à style polaire), et les indications des heures pleines. Lorsque l'écartement angulaire entre deux lignes horaires pleines consécutives est important, la ligne de la demi-heure correspondante est alors tracée en traits interrompus. Les traces des fils F_1 et F_2 sur le plan du cadran n'ont pas été représentées afin de ne pas surcharger les figures.
9.2 Courbes de hauteur et droites d'azimut

9.2.1 Courbes de hauteur :

Les courbes de hauteur sont des hyperboles dont les caractéristiques sont indépendantes de φ et D. Seules les distances a et b des fils au plan vertical affecteront la forme des hyperboles. Pour le tracé de la figure 12, on a pris : $(a;b)$ = (3;5) cm. Les courbes sont tracées de 10° en 10°. La courbe de hauteur maximale pour la latitude de Calais est tracée en traits interrompus ; la courbe de hauteur de 70° est quand même tracée afin de montrer "l'universalité" de ces courbes (c'est-à-dire que le tracé est utilisable n'importe où, sauf aux pôles).

9.2.2 Droites d'azimut :

Seul le gnomon vertical est à l'origine du réseau de courbes d'azimut. Ce réseau est constitué par des droites parallèles entre elles et symétriques par rapport à la normale au plan du cadran passant par M. Pour le tracé des figures 13, le système bifilaire choisi est : $(a;b)$=(8;10) cm. La latitude n'intervient pas : le tracé est valable en tout lieu sauf aux pôles.

9.3 Cadran à *lignes horaires homogènes*

Lorsque le système bifilaire est tel que $(a;b)$ = $(a;a \cos \varphi)$, alors l'angle entre deux lignes d'heures pleines consécutives est de 15°. On a démontré que cette propriété n'est vérifiée que par le bifilaire plein sud. Le tracé ci-dessous (figure 14) est un bifilaire à lignes horaires homogènes avec $(a;b) \approx$ (8;5) cm. Les arcs diurnes correspondent aux déclinaisons du soleil données dans le tableau du §9.1.
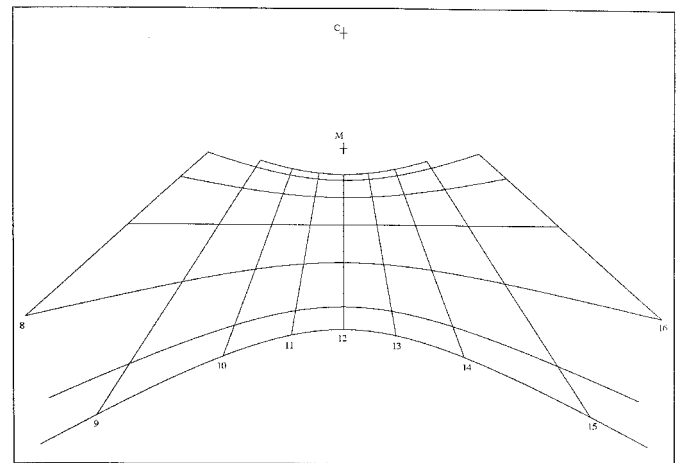
Fig. 14 — Cadran à lignes horaires homogènes pour $(a;b)$ = (8;5) cm, φ= 51° N, et D = 0°. Remarque : On ne trouvera pas directement sur le graphique un angle de 15° entre deux lignes horaires consécutives puisque les unités sur les axes sont différentes

9.4 Cadran *unifilaire*

Les situations conduisant à l'utilisation d'un cadran unifilaire sont nombreuses. On se contentera de présenter, à titre d'exemples et pour un gnomon vertical, les tracés pour D = 0°, D = +45° et D = −30°. Le réseau obtenu est un ensemble de lignes horaires parallèles (figure

15). Le système bifilaire utilisé est : $(a;b \rightarrow \infty) = (8; \infty)$, pour une latitude de 51° N.

D = 0°

FIG. 15 — Lignes horaires parallèles d'un cadran unifilaire vertical pour $D = 0°$, 45°, et −30°

FIG. — 15-2   D = 45°

FIG. — 15-3   D = −30°

10. CONCLUSION

Cet aperçu a pour vocation de faire connaître les cadrans solaires bifilaires au travers de l'étude des verticaux, et suggérer des voies expérimentales : influences des facteurs a et b, puis du rapport a/b sur les coordonnées y et z, et par conséquent sur les différents nomogrammes du bifilaire.

Mais il reste encore à étudier la construction de lignes encore mal connues du public que sont les lignes de temps sidéral, les heures babyloniques et italiques, les heures temporaires, et la courbe de temps moyen. Quoique peu utilisées de nos jours (hormis la courbe de temps moyen), elles n'en restent pas moins le signe de la richesse et de la capacité qu'ont les cadrans solaires, et maintenant les bifilaires à exploiter le mouvement diurne.

D'autres voies plus riches encore s'ouvrent, si l'on imagine que la distance d'un des gnomons au plan du cadran n'est plus constante, mais varie dans des limites fixées par l'expérimentateur, ou encore si l'on imagine que l'angle entre les deux fils est quelconque… Le champ d'étude est ouvert ![6]

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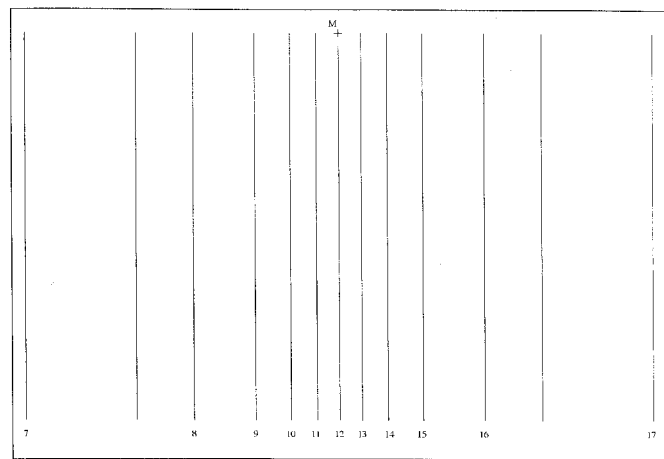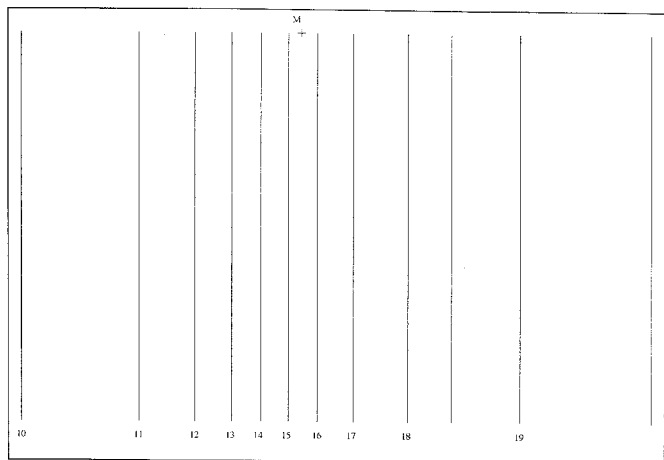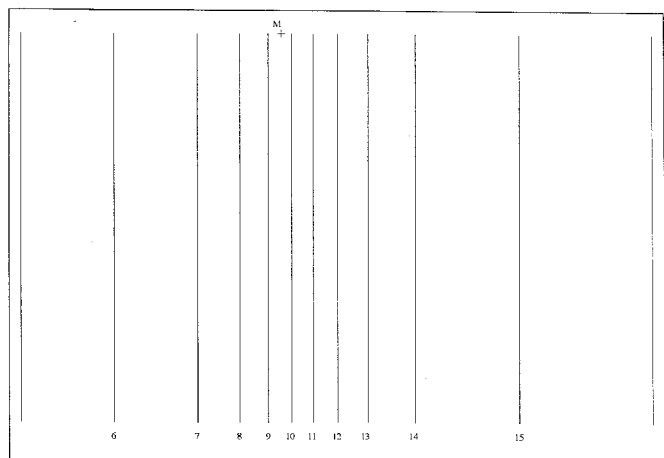
DOMINIQUE COLLIN is a professor of mathematics and physical sciences at the Lycée Pierre de Coubertin in Calais, France. His academic degrees include a Diplôme d'Études Approfondies (D.E.A.) in fundamental astronomy, celestial mechanics, and geodesy from l'Observatoire de Paris. His interest in sundial design has included gaining access to rare articles on the subject of bifilar sundials written by Hugo Michnik.

[6] Ces études sont en cours par l'auteur. Pour les curieux, je les invite à consulter l'article de Th. de Vries paru en 1979 dans la revue *De Zonnewijzerkring* (n°3): "De Tweedraads-Zonnewijzer met rechte en gekromde draden." (Traduction française disponible par voie électronique et sur demande à dcollin@hotmail.com − fichier en format pdf.)

ANNEXE 1. Équation cartésienne des lignes horaires

On se propose ici de déterminer l'équation générale des lignes horaires dans le repère *Myz*. Afin de manipuler plus aisément les coordonnées du point d'ombre on effectue un petit changement de notation, quitte ensuite à revenir aux notations initiales. On pose à cet effet :

$$\bar{y} = y/a \quad \text{et} \quad \begin{aligned} p &= \cos D \sin t_\odot - \sin\varphi \sin D \cos t_\odot \\ q &= \cos\varphi \sin D \\ r &= \cos\varphi \cos t_\odot \\ s &= \sin\varphi \\ t &= \sin\varphi \cos D \cos t_\odot + \sin D \sin t_\odot \\ u &= \cos\varphi \cos D \end{aligned} \tag{19}$$

Pour écrire finalement :

$$\bar{y} = -\frac{p + q\tan\delta}{t - u\tan\delta}$$
$$\bar{z} = +\frac{r + s\tan\delta}{t - u\tan\delta} \tag{20}$$

Tout d'abord isolons $\tan\delta$ des equations (20) :

$$\tan\delta = \frac{\bar{y}\,t + p}{\bar{y}\,u - q} \quad \text{et} \quad \tan\delta = \frac{\bar{z}\,t - r}{\bar{z}\,u + s}$$

Et ainsi l'égalité entre les deux expressions de $\tan\delta$ donne directement l'équation cartésienne des lignes horaires.

$$\frac{\bar{y}\,t + p}{\bar{y}\,u - q} = \frac{\bar{z}\,t - r}{\bar{z}\,u + s} \tag{21}$$

C'est-à-dire :

$$\bar{y}(ru + st) + \bar{z}(pu + qt) + (ps - qr) = 0 \tag{22}$$

Ou encore, en revenant au couple (y, z) :

$$yb(ru + st) + za(pu + qt) + ab(ps - qr) = 0 \tag{23}$$

Il ne reste plus qu'à revenir aux notations initiales en utilisant (19) :

$$-ru + st = \cos D \cos t_\odot + \sin\varphi \sin D \sin t_\odot$$
$$-pu + qt = \cos\varphi \sin t_\odot$$
$$-ps - qr = \sin\varphi \cos D \sin t_\odot - \sin D \cos t_\odot$$

La substitution de ces relations dans (23) donne (24) qui est l'équation générale des lignes horaires dans *Myz* :

$$yb(\cos D \cos t_\odot + \sin\varphi \cos D \sin t_\odot) + za(\cos\varphi \sin t_\odot) +$$
$$ab(\sin\varphi \cos D \sin t_\odot - \sin D \cos t_\odot) = 0 \tag{24}$$

ANNEXE 2. Équation générale des arcs diurnes

Pour déterminer l'équation des lignes horaires de paramètre $t_\odot$, on a éliminé δ des équations du groupe (3). De la même façon, pour déterminer l'équation cartésienne des arcs diurnes de paramètre δ,

on élimine $t_\odot$ des équations de (3).

On adoptera la même démarche en commençant par changer de notation en ne faisant apparaître que ce que l'on souhaite enlever.

a. Préliminaires.

Changeons l'écriture dans les équations de (3) :

$$\bar{y} = \frac{c\cos t_\odot - d\sin t_\odot - e}{f\cos t_\odot + g\sin t_\odot - h}$$
$$\bar{z} = \frac{i\cos t_\odot + j}{f\cos t_\odot + g\sin t_\odot + h} \tag{25}$$

En ayant posé :

$$\bar{y} = y/a \quad \text{et} \quad \begin{aligned} c &= \sin\varphi \sin D \\ d &= \cos D \\ e &= \cos\varphi \sin D \tan\delta \\ f &= \sin\varphi \cos D \\ g &= \sin D \\ h &= \cos\varphi \cos D \tan\delta \\ i &= \cos\varphi \\ j &= \sin\varphi \tan\delta \end{aligned} \tag{26}$$

b. L'observation de (25) fait suggérer que la seule façon d'éliminer la variable rapide $t_\odot$ est d'utiliser la relation bien connue $\cos^2 t_\odot + \sin^2 t_\odot = 1$, ce qui conduira à une forme quadratique en y et z, indépendante de $t_\odot$. D'où ce qui suit :

i. Isolons $\sin t_\odot$ indépendamment de $\cos t_\odot$. Partons de $\bar{y}$, on en extrait :

$$\sin t_\odot = \left(\frac{c - \bar{y}f}{\bar{y}g + d}\right)\cos t_\odot + \left(\frac{\bar{y}h - e}{\bar{y}g + d}\right) \tag{27}$$

De $\bar{z}$, isolons $\cos t_\odot$:

$$\cos t_\odot = \left(\frac{\bar{z}h + j}{\bar{z}f - i}\right) - \left(\frac{\bar{z}g}{\bar{z}f - i}\right)\sin t_\odot \tag{28}$$

On substitue maintenant (28) dans (27), ce qui donne (29) :

$$\sin t_\odot = -\frac{\bar{y}(hi + fj) - \bar{z}(ch - ef) - (cj + ei)}{\bar{z}(fd + gc) - \bar{y}gi - id} \tag{29}$$

ii. Isolons $\cos t_\odot$ indépendamment de $\sin t_\odot$. De la même façon, on substitue (27) dans (28), ce qui donne (30) :

$$\cos t_\odot = \frac{\bar{y}gj + \bar{z}(dh + eg) + jd}{\bar{z}(fd + gc) - \bar{y}gi - id} \tag{30}$$

c. On forme maintenant $\cos^2 t_\odot + \sin^2 t_\odot = 1$. Puis après une réduction au même dénominateur suivi d'une simplification, on obtient (31) :

$$[-\bar{y}(hi + fj) + \bar{z}(ch - ef) + (cj + ei)]^2 + [\bar{y}gj + \bar{z}(dh + eg) + jd]^2$$
$$= [-\bar{y}gi + \bar{z}(fd + gc) - id]^2 \tag{31}$$

d. Après développement des carrés et réduction des constantes, des termes du premier et du second degré, on obtient un polynôme de degré 2 :

$$f(\bar{y}, \bar{z}) = A\bar{y}^2 + B\bar{z}^2 + 2C\bar{y}\bar{z} + 2E\bar{y} + 2F\bar{z} + F = 0 \quad (32)$$

Les coefficients étant donnés par :

$$
\begin{aligned}
A &= (hi + fj)^2 + g^2(j^2 - i^2) \\
B &= (ch - ef)^2 + (dh + eg)^2 - (fd + gc)^2 \\
C &= gj(dh + eg) + gi(af + gc) - (hi + fj)(ch - ef) \quad (33) \\
E &= gd(j^2 - i^2) - (hi + fj)(cj + ei) \\
F &= (ch - ef)(cj + ei) + jd(dh + eg) + id(af + gc) \\
G &= (cj + ei)^2 + d^2(j^2 - i^2)
\end{aligned}
$$

L'équation (32) est l'équation générale d'une section conique décrite par le point d'intersection des ombres des gnomons au cours d'une journée ($\delta = cte$).

e. Exprimons maintenant les coefficients A, B, C, E, F et G en fonction de δ et des paramètres du cadran.

i. Préliminaires.

$$
\begin{aligned}
hi + fj &= \cos D \tan \delta \\
j^2 - i^2 &= (\sin^2 \varphi - \cos^2 \delta)/\cos^2 \delta \\
ch - ef &= 0 \\
dh + eg &= \cos \varphi \tan \delta \\
fd + gc &= \sin \varphi \\
cj + ei &= \sin D \tan \delta
\end{aligned}
$$

ii. Calcul des coefficients.

On présente ci-dessous, sous forme d'une table (table V), les résultats conduisant à l'expression des six coefficients du polynôme (32). [Le lecteur intéressé peut toujours faire les calculs intermédiaires en utilisant (26) et (33).]

f. Réduction des coefficients du polynôme. En utilisant l'identité remarquable :

$$\sin^2 a - \sin^2 b = \sin(a + b)\sin(a - b)$$

on transforme le coefficient B, puis une simplification par $\cos^2 \delta$, appliquée à tous les coefficients, permet d'écrire

$$
\begin{aligned}
A &= \sin^2 \delta - \cos^2 \varphi \sin^2 D \\
B &= -\sin(\varphi + \delta)\sin(\varphi - \delta) \\
C &= \cos \varphi \sin \varphi \sin D \quad (34) \\
E &= -\cos^2 \varphi \cos D \sin D \\
F &= \cos \varphi \sin \varphi \cos D \\
G &= \sin^2 \delta - \cos^2 \varphi \cos^2 D
\end{aligned}
$$

TABLE V
Coefficients du polynôme

Coefficient	en variables réduites	en fonction de D, ξ et δ
A	$(hi + fj)^2 + g^2(j^2 - i^2)$	$\dfrac{(\sin^2 \delta - \cos^2 \varphi \sin^2 D)}{\cos^2 \delta}$
B	$(ch - ef)^2 + (dh + eg)^2 - (fd + gc)^2$	$\dfrac{(\sin^2 \delta - \sin^2 \varphi)}{\cos^2 \delta}$
C	$gj(dh + eg) + gi(fd + gc) - (hi + fj)(ch - ef)$	$\dfrac{\sin \varphi \cos \varphi \sin D}{\cos^2 \delta}$
E	$+ gd(j^2 - i^2) - (hi + fj)(cj + ei)$	$\dfrac{-\cos^2 \varphi \sin D \cos D}{\cos^2 \delta}$
F	$(ch - ef)(cj + ei) + jd(dh + eg) + id(fd + gc)$	$\dfrac{\sin \varphi \cos \varphi \sin D}{\cos^2 \delta}$
G	$(cj + ei)^2 + d^2(j^2 - i^2)$	$\dfrac{(\sin^2 \delta - \cos^2 \varphi \cos^2 D)}{\cos^2 \delta}$

Sachant que $f(y, z) = a^2 b^2 f(\bar{y}, \bar{z})$ [c.a.d. équation (14) $= a^2 b^2$ équation (32)], la forme la plus réduite des six coefficients de l'équation des sections coniques des arcs diurnes d'un bifilaire vertical déclinant sera, dans Myz :

$$
\begin{aligned}
A &= b^2(\sin^2 \delta - \cos^2 \varphi \sin^2 D) \\
B &= -a^2 \sin(\varphi + \delta)\sin(\varphi - \delta) \\
C &= ab \cos \varphi \sin \varphi \sin D \quad (35) \\
E &= -ab^2 \cos^2 \varphi \cos D \sin D \\
F &= a^2b \sin \varphi \cos \varphi \cos D \\
G &= a^2b^2(\sin^2 \delta - \cos^2 \varphi \cos^2 D)
\end{aligned}
$$

L'étude de ces six coefficients permettra de déterminer la nature des sections coniques. La discussion portera sur les paramètres du cadran φ, D et sur la variable "lente" δ — voir les résultats en §5.2.2.

A SECOND SURVEY OF THE ATTITUDES OF UNIVERSITY STUDENTS TO ASTROLOGY AND ASTRONOMY

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Abstract. A survey of over 1600 first-year university students, effectively identical in content to one taken in 1991, has been carried out to determine students' attitudes towards astrology and to establish whether they are able to distinguish between astronomy and astrology. Current survey results indicate that over 53% of both Arts and Science students subscribe at least somewhat to the principles of astrology, 60% of Arts students and 50% of Science students are unable to distinguish between astronomy as the science and astrology as the pseudoscience, and females are much more likely to subscribe strongly to pseudoscience than males from the same Faculty and with the same mathematics background. While the same trends were evident in the first survey, subscription to astrological principles and the inability to distinguish between astrology and astronomy are several percent higher in the current study. Unlike the first survey, in which the responses of Science students were somewhat more sceptical than those of Arts students, no statistically significant differences were found for most responses in the current survey. Such findings are likely to be of concern to educators, particularly at the primary and secondary school levels. It would appear that the level of science literacy, and critical-thinking skills among students, are seriously deficient, especially among science students. A strategy that is often recommended in the same context is to enhance mathematics and science instruction in primary and secondary schools, as well as to emphasize the application of critical thinking skills. In particular, it is suggested that "hands-on" investigation of pseudosciences such as astrology at the secondary level may be a useful tool to promote critical thinking.

Résumé. Un sondage de plus de 1600 étudiants de première année universitaire, plus ou moins identique à celui de 1991, a été entrepris afin de déterminer l'attitude des étudiants envers l'astrologie. Il cherche aussi à établir s'ils peuvent distinguer l'astrologie d'avec l'astronomie. Les résultats actuels indiquent que plus de 53% des étudiants en lettres et en sciences sont quelque peu partisans des principes d'astrologie. De plus, 60% des étudiants en lettres et 50% des étudiants en sciences ne peuvent pas distinguer l'astronomie en tant que science d'avec l'astrologie en tant que pseudoscience, et les étudiantes ont beaucoup plus tendance a être partisanes de la pseudoscience que les étudiants dans la même faculté et qui ont les mêmes connaissances en mathématiques. Quoique les mêmes tendances paraîssent dans le premier sondage, être partisan des principes de l'astrologie et ne pouvoir pas distinguer l'astrologie d'avec l'astronomie ont augmenté de plusieurs pour cents dans le sondage actuel. Contrairement aux résultats du premier sondage dans lequel les opinions des étudiants en sciences étaient un peu plus sceptiques que celles des étudiants en lettres, il ne paraît y avoir aucune différence d'importance statistique dans les réponses du sondage actuel. Ces résultats devraient inquiéter les instituteurs, spécialement ceux aux primaire et secondaire. Ils laissent à croire que le niveau de connaissance en sciences et la faculté de juger d'un oeil critique des étudiants font preuve d'une grande lacune, spécialement parmi les étudiants en sciences. La stratégie recommendée pour combler cette lacune est celle d'améliorer l'enseignement des mathématiques et des sciences dans les écoles primaires et secondaires, aussi bien que de mettre l'accentuation sur le développement des facultés critiques. En particulier, on suggère que l'étude "sur le tas" des pseudosciences telles que l'astrologie pourrait, au secondaire, fournir un outil utile pour améliorer le jugement avec un oeil critique. SEM

1. Introduction

Motivated by the apparent popularity of astrology in the general population as reported in Paulos (1988) and Fraknoi (1989), De Robertis & Delaney (1993) sampled the attitudes of first-year university students to astronomy and astrology. The first survey, hereafter DD, was designed to establish whether students entering a major university in Canada were able to distinguish between astronomy and astrology. Such data for university students were meagre at the time, though important to obtain. Were more highly educated university students more sceptical than the general population *vis-à-vis* pseudoscience and the paranormal? Given that so many of our nation's leaders are university educated, the answer to that question has wide-ranging implications.

While it was not possible to address the issues directly, based solely on a short survey as in DD, the results proved surprising: the attitudes of first-year university students in our area did not appear dramatically different from those in the general population. Even more surprising was the observation that Science students were only slightly more sceptical than were Arts students.

The purpose of this paper is to report the results of an almost identical survey administered to first-year university students six years after the first survey. In §2 the survey is described in some detail, including its findings, as well as the differences between the results of the first and second surveys. The broader implications of the findings in relation to the practice of pseudosciences and the paranormal are discussed in §3, along with some suggestions to grapple with the problem.

2. The Survey

As noted in §1, the survey was designed to sample the attitudes that first-year university students have towards astrology, as well as to test whether they are aware of the distinction(s) between astrology and astronomy. The reader is referred to DD for a more thorough discussion

Survey on Astrology & Astronomy — September 1997

This is a voluntary survey initiated by the Department of Physics and Astronomy at York University. We would appreciate it if you would take 5 minutes to fill it out. No names or student numbers please.

Place an 'X' in the ONE space which <u>best</u> describes your opinion/situation:

Faculty: Arts ___(1) Fine Arts ___(2) Science ___(3) Other ___(4)

Gender: Female ___(1) Male ___(2) **Year of Birth:** 19 __ __

Highest level/year of Math <u>completed</u>:

Less than grade 10 ___(1) Grade 10-11 ___(2) Grade 12-13 ___(3) Post-Secondary ___(4)

Birthdate: Jan 20-Feb 19 ___(1) Feb 20-Mar 20___(2) Mar 21-Apr 19___(3)
Apr 20-May 20 ___(4) May 21-Jun 20___(5) Jun 21-Jul 22 ___(6)
Jul 23-Aug 22 ___(7) Aug 23-Sep 22___(8) Sep 23-Oct 23___(9)
Oct 24-Nov 22 ___(10) Nov 23-Dec 21___(11) Dec 21-Jan 19___(12)

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1. **My astrological sign (Sun sign, sign of the zodiac) is:**
   Don't know ___(1) Aries ___(2) Taurus ___(3) Gemini ___(4) Cancer ___(5)
   Leo ___(6) Virgo ___(7) Libra ___(8) Scorpio ___(9)
   Sagittarius ___(10) Capricorn ___(11) Aquarius ___(12) Pisces ___(13)

2. **In the past year I have paid attention to my horoscope:**
   Never ___(1) A few (1-9) times ___(2) Many (10-99) times ___(3) Almost daily ___(4)

3. **I would say my horoscope is usually:**
   Inaccurate ___(1) Somewhat accurate ___(2) Very accurate ___(3) Doesn't apply ___(4)

4. **In the past year I have made** *conscious decisions* **based on my horoscope:**
   Never ___(1) Once or twice ___(2) A few (3-10) times ___(3) More than 10 times ___(4)

5. **Astrology holds that one's character and destiny can be understood from the positions of the Sun, planets and stars. I subscribe to these principles of astrology:**
   Not at all ___(1) Somewhat ___(2) Completely ___(3)

6. **I would classify the following as a science:**
   Only astrology ___(1) Only astronomy ___(2) Both astrology and astronomy ___(3)
   Neither astronomy nor astrology ___(4)

7. **Astronomers can predict one's character and future by studying the heavens:**
   No ___(1) Don't know ___(2) Yes ___(3)

8. **I believe in:**

	Strongly	Moderately	Weakly	Not at all	Don't know
a) Fortune Telling	___(1)	___(2)	___(3)	___(4)	___(5)
b) Reincarnation (past lives)	___(1)	___(2)	___(3)	___(4)	___(5)
c) ESP (parapsychology)	___(1)	___(2)	___(3)	___(4)	___(5)
d) Alien Abductions	___(1)	___(2)	___(3)	___(4)	___(5)

Fig. 1 — The second survey.

of the details underlying the survey, though the more significant items will now be described.

The survey was designed to be brief, easy to administer and reduce, and simple to interpret. Curriculum requirements in place within the Faculties of Arts, Fine Arts, and Pure and Applied Science at York University, Canada's third largest university, give us access to a large, homogeneous sample of representative university students. All Faculty of Arts and Fine Arts students are required to take one science course from the Division of Natural Science (NATS) at York. Enrolments in such courses tend to be very large, making them ideal for survey purposes. (Four Natural Science classes containing about 25% of the total number of students in the program are included in the survey. There is no *a priori* reason to believe that those classes are not representative of the general population of Arts and Fine Arts students.) We were also able to obtain a large sample of Science students, since a significant fraction of them take the same first-year Chemistry course.

Designations and titles for courses included in the survey, as well as the number of respondents from each class, are provided in Table Ia. Table Ib gives a break-down of the survey by Faculty and gender. The total sample consists of 1224 students taking a science course for non-science majors (hereafter referred to as "Arts students" — with mean university entrance average between 79–80%) and 438 students taking courses from the Faculty of Pure and Applied Science (hereafter referred to as "Science students" — with mean university entrance average of over 81%). The survey was carried out in the first week of the fall 1997 term, six years after the first survey. No mention was made of astrology in any of the courses, at least up until the time of the survey. The authors were permitted to use a maximum of ten minutes of class time to carry out the survey, which explains the brevity requirement.

A copy of the survey administered to the students is reproduced in figure 1. The first section requests relevant biographical information (while preserving anonymity), and the second section is concerned with attitudes and opinions. Little will be said of the biographical information, apart from the fact that 90% of those sampled knew their own Sun Sign, a clear indication of the popularity of astrology in contemporary western society. (That is to be compared with 92% in the first survey.) Why the data were taken is discussed in DD.

The "attitudes" questions were designed to be simple, to admit mutually exclusive and preferably quantitative answers where possible, to be symmetric with respect to the treatment of astrology and astronomy, and to be capable of a relatively straightforward interpretation.

Questions 2 through 5 are meant to sample the respondent's opinions and attitudes towards astrology. Results from question 2, *the frequency of attention paid to one's horoscope*, and 3, *the accuracy of horoscopes*, need not paint an unambiguous picture; after all, some people regularly read their horoscope simply for amusement or entertainment. Moreover, one could be sceptical of astrology and still rate the accuracy of horoscopes fairly highly, because they are so general in nature. Data must be combined from questions 2 through 5 to get a true indication of a student's interest in astrology[1].

Question 4, *the frequency of conscious decisions based upon horoscopes*, is a quantitative indicator of the significance of the influence of astrology in a person's life. Question 5, *subscription to the principles of astrology*, is perhaps the best measure of whether a person "believes" in astrology. (The term "believe in astrology" was not used in the survey because the symmetric construction is not normally associated with astronomy.)

Questions 6 and 7 distinguish whether respondents not only think they know the difference(s) between astrology and astronomy, but also whether or not they really comprehend the difference in their nature. Such a distinction is important, given the inherent uncertainties associated with surveys of this kind. Finally, to test how sympathetic a respondent is to other pseudosciences or paranormal phenomena, we included question 8. It should be noted that the only difference between the new version of the survey and the version reported in DD is that we eliminated Numerology and added Reincarnation and Alien Abductions to this question.

The integrated results of the survey are provided in Table II. As noted earlier, the total number of Arts students in the survey was 1224, while the total number of Science students was 438. The designation "N/A" indicates the number of students who either did not answer the question or whose answers were invalid. The number of "No Answer" responses is proportionally very small, between 0.3% and 2.3% per question. In question 8, the total number of responses in all three categories have been summed, making the totals up to three times larger than the other questions. It served no actual purpose to report the pseudoscience/paranormal results individually. As in the first survey, parapsychology had considerably more "strong" and "moderate" adherents than the other options, about at the same level as a "belief" in astrology.

In the first survey, Science students were less likely than Arts students to pay attention to their horoscopes, to have made conscious decisions based on their horoscopes, to subscribe to astrology, to confuse astronomy and astrology, and to believe in other pseudosciences, though the differences were not large. In the current survey, within statistical uncertainties of less than 2%, there are few differences between the two groups. Furthermore, the overall level of scepticism is significantly weaker in 1997 than it was in 1991. Fully 53% of Arts students and Science students subscribe at least somewhat to the principles of astrology; in more common parlance, "believe in astrology." Moreover, over 60% of Arts students and about 50% of Science students confuse astronomy and astrology. Those figures can be compared with the first survey, in which 45% of Arts students and 37% of Science students subscribed at least somewhat to the principles of astrology, while 56% of Arts students and 44% of Science students confused astronomy and astrology.

Tables III–VIII summarize the survey results based on specific criteria — the answers to individual questions. In each table, the total number of respondents to each question does not necessarily sum to the total number of students participating in the survey because the "N/A" responses have been ignored. That is, the corresponding percentages are based only on valid responses. Because the number of questions with invalid answers is so small, we feel that is a reasonable simplification. Note also that the percentages have been rounded to one decimal place, and therefore the sum may differ from 100% by ±0.1%.

For clarity of presentation, some of the options have been grouped together. In question 2, a distinction was made between

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[1] Even though astrology is more than just horoscopes, we believe that for the vast majority of the population, attitudes towards astrology may be uncovered through questions about horoscopes.

<table>
TABLE Ia
Courses Participating in the Survey
</table>

Course Designation	Course Title	Number of Respondents
NATS 1710.06	The Nature and Growth of Scientific Thought	141
NATS 1720.06	Light and Sound	280
NATS 1740.06	Astronomy	406
NATS 1770.06	Technology and the Environment	397
	Total Number Arts:	1224
SC 1000.06	Chemistry	438
	Total Number Science:	438

TABLE Ib
Biographical Information

Category		Non-science Courses	Science Course
Faculty:	Arts	1063	30
	Fine Arts	82	0
	Science	18	403
	Other	57	5
	No Answer	4	0
Gender:	Female	654	252
	Male	549	174
	No Answer	21	12

TABLE II
Summary of Results

Question		Arts Responses	%	Science Responses	%
2. Attention to Horoscope	Never	173	14.1	79	18.0
	Few	548	44.8	202	46.1
	Many	388	31.7	116	26.5
	Daily	111	9.1	39	8.9
	N/A	4	0.3	2	0.5
3. Horoscope accuracy	Inaccurate	222	18.1	93	21.2
	Somewhat	756	61.8	249	56.9
	Very	39	3.2	14	3.2
	Doesn't Apply	187	15.3	72	16.4
	N/A	20	1.6	10	2.3
4. Conscious decisions made	Never	837	68.4	318	72.6
	Once/twice	287	23.4	89	20.3
	Few times	76	6.2	27	6.2
	Often	15	1.2	2	0.5
	N/A	9	0.7	2	0.5
5. Subscribe to Astrology	Not at all	550	44.9	198	45.2
	Somewhat	617	50.4	216	49.3
	Completely	42	3.4	17	3.9
	N/A	15	1.2	7	1.6
6. Classify as Science	Only Astrology	47	3.8	13	3.0
	Only Astronomy	488	39.9	219	50.0
	Both	620	50.7	193	44.1
	Neither	46	3.8	8	1.8
	N/A	23	1.9	5	1.1
7. Astronomers predict future	No	516	42.2	190	43.8
	Don't Know	603	49.3	215	49.1
	Yes	93	7.6	31	7.1
	N/A	12	0.8	2	0.5
8. Belief in other paranormal areas	Strongly	503	10.3	196	11.2
	Moderately	1169	23.9	344	19.6
	Weakly	1256	25.7	412	23.5
	Not at all	1412	28.9	569	32.5
	Don't know	482	9.8	191	10.9
	N/A	72	1.5	40	2.3

Table IIIa
Results by Gender

	Arts		Science	
	Female	Male	Female	Male
Responses	654	549	252	174

Table IIIb

Question/Options	Arts				Science			
	Female		Male		Female		Male	
	No.	%	No.	%	No.	%	No.	%
2. No/little attention	331	50.8	378	68.8	137	54.6	135	78.0
Much attention	320	49.2	171	31.2	114	45.4	38	22.0
3. Inaccurate	115	17.9	107	19.8	45	18.2	47	27.5
Somewhat accurate	450	70.0	291	53.8	163	66.0	80	46.8
Very accurate	22	3.4	16	3.0	7	2.8	7	4.1
Doesn't apply	56	8.7	127	23.5	32	13.0	37	21.6
4. Few decisions	596	92.0	509	93.2	233	92.8	163	94.2
Many decisions	52	8.0	37	6.8	18	7.2	10	5.8
5. Astrology not at all	228	35.3	313	57.7	89	35.9	103	59.9
Astrology somewhat	392	60.7	214	39.5	146	58.9	65	37.8
Astrology completely	26	4.0	15	2.8	13	5.2	4	2.3
6. Astronomy as science	216	33.6	267	49.5	112	44.8	101	59.1
All other responses	427	66.4	272	50.5	138	55.2	70	40.9
7. Astronomers cannot predict future	223	34.5	286	52.6	92	36.7	93	53.8
All other responses	424	65.5	258	47.4	159	63.3	80	46.2
8. Pseudoscience belief: Moderate/Strong	948	40.9	691	35.5	355	40.7	170	28.0
Pseudoscience belief: Weak/None	1371	59.1	1255	64.5	517	59.3	437	72.0

Table IVa
Results by Attention to Horoscope — Question 2

	Arts		Science	
	Little	Much	Little	Much
Responses	721	499	281	155

Question/Options	Arts				Science			
	Little		Much		Little		Much	
	No.	%	No.	%	No.	%	No.	%
3. Inaccurate	157	22.3	65	13.1	72	26.5	21	13.5
Somewhat accurate	372	52.8	383	76.9	128	47.1	120	77.4
Very accurate	6	0.9	33	6.6	7	2.6	7	4.5
Doesn't apply	170	24.1	17	3.4	65	23.9	7	4.5
4. Few decisions	704	98.6	418	83.8	276	98.6	131	84.5
Many decisions	10	1.4	81	16.2	4	1.4	24	15.5
5. Astrology not at all	411	57.7	138	27.9	160	57.8	38	24.8
Astrology somewhat	292	41.0	324	65.5	109	39.4	106	69.3
Astrology completely	9	1.3	33	6.7	8	2.9	9	5.9
6. Astronomy as science	327	46.2	161	32.7	152	54.9	66	42.6
All other responses	381	54.8	331	67.3	125	45.1	89	57.4
7. Astronomers cannot predict future	341	47.7	175	35.3	143	51.3	87	56.1
All other responses	374	52.3	321	64.7	136	48.7	68	43.9
8. Pseudoscience belief: Moderate/Strong	800	31.7	867	47.8	258	26.7	278	50.7
Pseudoscience belief: Weak/None	1721	68.3	945	52.2	710	73.3	270	49.3

TABLE Va

Results by Conscious Decisions — Question 4

	Arts		Science	
	Never	Sometimes	Never	Sometimes
Responses	837	378	318	118

TABLE Vb

Question/Options	Arts				Science			
	Never		Sometimes		Never		Sometimes	
	No.	%	No.	%	No.	%	No.	%
2. No/little attention	589	70.5	125	33.1	236	74.2	44	37.6
Much attention	246	29.5	253	66.9	82	25.8	73	62.4
3. Inaccurate	190	23.1	31	8.2	83	26.9	10	8.5
Somewhat accurate	447	54.4	306	81.2	155	50.2	93	78.8
Very accurate	7	0.9	32	8.5	6	1.9	8	6.8
Doesn't apply	178	21.7	8	2.1	65	21.0	7	5.9
5. Astrology not at all	475	57.6	73	19.3	179	56.8	19	16.4
Astrology somewhat	335	40.6	278	73.5	130	41.3	86	74.1
Astrology completely	15	1.8	27	7.1	6	1.9	11	9.5
6. Astronomy as science	378	45.9	108	29.0	179	56.8	40	33.9
All other responses	446	54.1	264	71.0	136	43.2	78	66.1
7. Astronomers cannot predict future	415	50.0	99	26.3	166	52.4	24	20.3
All other responses	415	50.0	278	73.7	151	47.6	94	79.7
8. Pseudoscience belief: Moderate/Strong	965	32.7	696	51.0	339	30.7	201	48.6
Pseudoscience belief: Weak/None	1984	67.3	668	49.0	767	69.3	213	51.4

	Arts		Science	
	Never	Sometimes	Never	Sometimes
Responses	550	659	198	233

TABLE VIb

Question/Options	Arts				Science			
	Never		Sometimes		Never		Sometimes	
	No.	%	No.	%	No.	%	No.	%
2. No/little attention	411	74.9	301	45.7	160	80.8	117	50.4
Much attention	138	25.1	357	54.3	38	19.2	115	49.6
3. Inaccurate	136	25.1	84	12.9	60	30.9	33	14.4
Somewhat accurate	264	48.8	484	74.2	74	38.1	170	74.2
Very accurate	4	0.7	34	5.2	4	2.1	10	4.4
Doesn't apply	137	25.3	50	7.7	56	28.9	16	7.0
4. Few decisions	538	98.2	574	87.6	196	99.0	207	88.8
Many decisions	10	1.8	81	12.4	2	1.0	26	11.2
6. Astronomy as science	302	55.5	181	27.9	138	70.1	81	34.9
All other responses	242	44.5	467	72.1	59	29.9	151	65.1
7. Astronomers cannot predict future	319	58.3	194	29.6	130	65.7	59	25.3
All other responses	228	41.7	461	70.4	68	34.3	174	74.7
8. Pseudoscience belief: Moderate/Strong	476	24.2	1185	50.6	155	22.5	381	46.7
Pseudoscience belief: Weak/None	1490	75.8	1156	49.4	533	77.5	434	53.5

TABLE VIIa
Results by Which is a Science — Question 6

	Arts		Science	
	Astronomy Only	Other	Astronomy Only	Other
Responses	488	713	219	214

Question/Options	Arts				Science			
	Never		Sometimes		Never		Sometimes	
	No.	%	No.	%	No.	%	No.	%
2. No/little attention	327	67.0	381	53.5	152	69.7	125	58.4
Much attention	161	33.0	331	46.5	66	30.3	89	41.6
3. Inaccurate	102	21.3	116	16.5	55	25.6	38	18.1
Somewhat accurate	263	54.8	480	68.2	108	50.2	139	66.2
Very accurate	9	1.9	30	4.3	4	1.9	10	4.8
Doesn't apply	106	22.1	78	11.1	48	22.3	23	11.0
4. Few decisions	463	95.3	645	90.8	213	97.3	191	89.3
Many decisions	23	4.7	65	9.2	6	2.7	23	10.7
5. Astrology not at all	302	62.5	242	34.1	138	63.0	59	28.1
Astrology somewhat	176	36.4	431	60.8	80	36.5	135	64.3
Astrology completely	5	1.0	36	5.1	1	0.5	16	7.6
7. Astronomers cannot predict future	309	63.7	205	28.9	138	63.0	52	24.3
All other responses	176	36.3	504	71.1	81	37.0	162	75.7
8. Pseudoscience belief: Moderate/Strong	559	31.7	1091	43.7	220	28.0	318	43.7
Pseudoscience belief: Weak/None	1203	68.3	1404	56.3	565	72.0	409	56.3

Table VIIIa
Results by Predicting the Future — Question 7

	Arts			Science	
	No	Other		No	Other
Responses	516	696		190	246

Question/Options	Arts				Science			
	No		Other		No		Other	
	No.	%	No.	%	No.	%	No.	%
2. No/little attention	341	66.1	374	53.8	143	75.3	195	80.6
Much attention	175	33.9	321	46.2	47	24.7	47	19.4
3. Inaccurate	115	22.6	106	15.4	45	24.3	146	59.6
Somewhat accurate	266	52.4	485	70.4	83	44.9	79	32.2
Very accurate	12	2.4	26	3.8	5	2.7	18	7.3
Doesn't apply	115	22.6	72	10.4	52	28.1	2	0.8
4. Few decisions	497	96.7	620	89.5	186	97.9	220	89.8
Many decisions	17	3.3	73	10.5	4	2.1	25	10.2
5. Astrology not at all	319	62.2	228	33.1	130	68.8	68	28.1
Astrology somewhat	182	35.5	431	62.6	57	30.2	159	65.7
Astrology completely	12	2.3	30	4.4	2	1.1	15	6.2
6. Astronomy as science	309	60.1	176	25.9	138	72.6	81	33.3
All other responses	205	39.9	504	74.1	52	27.4	162	66.7
8. Pseudoscience belief: Moderate/Strong	585	31.2	1077	44.2	183	27.4	365	42.5
Pseudoscience belief: Weak/None	1292	68.8	1362	55.8	485	72.6	494	57.5

"little or no attention" (selections 1 and 2) and "much attention" to horoscopes (selections 3 and 4). In question 4, the first two answers ("never" and "once or twice") became "few decisions," while the last two answers ("a few" or "more than 10") became "many decisions." In questions 6 and 7, the correct answer is distinguished from "all other answers." Once again, in the final question, the other paranormal options are presented together. The total numbers reflect up to three times the number of respondents as a result. (The factor will be actually less than three because there was a "don't know" option in the question that is not recorded in the tables.)

Table III gives the results sorted by gender. (Note that, unlike the case for subsequent tables, the percentages here refer not to the total number of either Arts or Science responses per question, but rather to the number of responses per question by gender of the Arts or Science students. That makes it easier to see the corresponding trends.) There appear to be very significant differences between the responses of females and males. Females are more likely to pay much attention to their horoscopes, to make decisions based upon them, to subscribe to astrology, and to believe strongly in other paranormal phenomena. They are also aware of the distinctions between astrology and astronomy significantly less often than males. That is true for both Arts and Science students. It should be noted that the average mathematics (and presumably science) background of females for both the Arts and Science samples is the same.

Table IV gives the results based on the response to question 2,

attention paid to horoscopes — "little" or "much." Table V summarizes question 4, *conscious decisions based on horoscopes* — "never" or "sometimes." Table VI lists the results from question 5, subscription to the principles to astrology — "never" or "sometimes." Finally, Table VII gives the results from question 6, *classification of astronomy and/or astrology as science(s)* — "only [astronomy]" and "other [responses]." In each case there are good correlations among the answers given by "sceptical students" and among the answers of "believing students." That is, "sceptical students" tend to pay little or no attention to their horoscopes, make few or no decisions based upon their horoscopes, do not subscribe to astrological principles or other pseudosciences, and acknowledge astronomy as the science. "Believing students" have a higher probability of paying attention to their horoscopes, making decisions based upon their horoscopes, subscribing somewhat or completely to astrological principles, believing in other pseudosciences, and confusing astronomy and astrology.

3. Discussion

It seems indisputable from the results of our survey that a majority of both Arts and Science students display a level of credulity that one would not expect of "well educated" students at the close of the twentieth century[2]. The fact that responses from Arts and Science students are nearly indistinguishable is a clear indication to us that

[2] We emphasize here that the survey was conducted of entering first-year students and not upper-year students. Are graduates more sceptical? Probably, but that is sheer speculation on our part. In the first place, only about half of students entering first year eventually graduate. Science students are exposed to scientific reasoning throughout their university career and would likely be able to identify pseudoscientific thinking upon graduation more easily. It is not clear that Arts students are comparably challenged at any point and, therefore, whether graduating Arts students are significantly more sceptical. It is considerably more difficult to survey a large number of graduating students, since upper-year classes are substantially smaller than first-year classes, which is the major reason we have not done so. We believe, however, that it would be very useful if all colleges and universities devoted some resources to assessing the magnitude of the problem and to making appropriate changes to their curricula to ensure that all graduating students possess a modicum of critical thinking skills in such areas.

there is a serious deficiency in secondary school education, particularly science education. Although the overall results of our survey are even more disquieting than the first, there is some comfort that very few students continue to make frequent conscious decisions based on horoscopes or to subscribe completely to astrological principles. An optimist might even take some comfort from the fact that about half the students are critically discerning on the subject. But is that good enough?

Astrology is the archetypal pseudoscience (*e.g.* Thagard 1980; Kelly 1997; Kelly 1998), with roots that lie in a magical rather than the scientific world-view, from a time when demons and spirits were called upon to explain the workings of the world (Harrison 1981). It has only been since the fifteenth century in the west that reason and the scientific method have been employed systematically to understand the universe.

As Sagan (1995) and Vyse (1997) have noted, however, human beings seem predisposed to seek magical explanations in order to make sense of the world, largely because magical thinking comes rather easily. The application of the scientific method, on the other hand, often requires the expenditure of considerable effort. But, as Sagan (1995) and Wilson (1998) argue persuasively, the payoffs have been, and continue to be, well worth the effort: so many of the benefits taken for granted in western society have resulted from the adoption of the scientific world-view.

Sagan (1995) among others has soberly reflected upon the adverse consequences to contemporary society of the scientific world-view being seriously challenged by a rapidly increasing fascination with pseudoscience and the paranormal. He linked the onset of such "darkness" with a low level of science literacy in the general population. Some of the dangers most frequently associated with widespread science illiteracy were described in DD. For example, there are very real economic consequences — in an era of globalization, countries that can supply a more scientifically literate workforce will be more attractive to businesses — as well as political consequences — a democracy in which a significant fraction of the electorate cannot perceive issues that have any kind of technical component faces serious problems.

Such concerns are more than academic. Perhaps the best illustration of the dangers posed by widespread science illiteracy can be found in the context of alternative medicine. North Americans spend over $30 billion each year on alternative therapies (Eisenberg *et al.* 1998), a figure that is growing rapidly, despite the fact that such therapies have not been demonstrated to be efficacious, with many plainly antithetical to biomedical science. Why people seek alternative therapies is a complex issue, as Astin (1998) remarks, but one contributing factor is that many people simply do not appreciate how evidence is assessed in science, often relying upon anecdotal claims to make health-related decisions. There is little appreciation of the need for a control sample (*e.g.* randomized clinical trials) in order to assess a drug's or therapy's efficacy, and hence why anecdotal evidence has a limited role in biomedicine. Such concepts are not difficult to understand or to teach at an elementary level. [Indeed, a nine-year old Emily Rosa gained some notoriety for being involved in a simple scientific experiment whose results call into question the efficacy for "therapeutic touch" — a widespread alternative therapy in North America (Rosa *et al.* 1998.)] It could be argued that such information and techniques for assessing evidence are essential for an informed citizenry, and as such should be taught at the secondary school level.

How might that be achieved in practice? With regard to astrology, students could explore the nature of pseudoscience by first learning a few basic astrological/astronomical concepts with the accompanying jargon, and then carrying out some simple, practical experiments of their own design. For example, they could follow horoscopes over a few weeks — not just their Sun Sign, but all the Signs, and from a variety of astrologers — in order to evaluate the accuracy of random Signs with their own. Students will soon come to appreciate the most obvious differences between astronomy and astrology, in the manner of Fraknoi (1987), while gaining valuable skills they can apply to other pseudoscience and paranormal contexts, including elementary statistical skills.

The other significant survey result which emerges is that females, whether Arts or Science students, appear to be considerably less sceptical than males. That trend was also evident in the first survey, and is often noted in science literacy surveys (*e.g.* Einsiedel 1990). It is normally attributed to the fact that males often have more mathematics and science courses for a given level of education. That is not the case here; males and females in each Faculty have the same level of mathematics (and presumably) science education.

Although we will not speculate on the reason(s) for the phenomenon, differences in gender socialization undoubtedly play some role. That observation also underscores the importance that "belief" plays in forming and maintaining such attitudes, making it unlikely that changes to mathematics and science curricula alone will entirely solve the problem at hand.

Finally, we speculate on the reason for the decrease in the level of scepticism by a few percent in the past several years, well in excess of statistical uncertainties. There has certainly been an increase in the proliferation of the paranormal within the popular culture in the past decade, from children's television programs and feature movies to the Internet. That could serve to make first-year students from 1997 more accepting of paranormal phenomena than their 1991 counterparts.

It is easy to blame the media for the current state of affairs. Although the media must share some of the responsibility, a significant fraction of the population appears unable to distinguish science from pseudoscience, or fact from fiction, largely because of a lack of critical skills and because the important distinction is not widely discussed in the school system. To achieve a more rationally discerning society, the education system at all levels must face the problem head-on by introducing rigorous programs in critical thinking and by improving students' science literacy.

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WHAT OF THE FUTURE?

Some amusement was provided by the appearance in American papers of a despatch from London dated October 27 which stated that the *British Journal of Astrology* had suspended publication because of the "uncertainty of the immediate future." The natural thought was that the astrologer, who claims that by reading the sky he can forecast one's future, should make special efforts to enlighten the people during these serious times!

It is remarkable that such superstition still persists. The Copernican theory of the universe is universally accepted. The Earth is simply one of a group of planets revolving about the Sun, and the fixed stars, other suns, are millions of millions of miles away. How can the positions of these bodies at the time a person is born determine what will happen to him all through his life? Still further, Newton demonstrated that these bodies move in accordance with the principle of universal gravitation, and he supplied the method by which the astronomer is able to compute the precise direction and distance and the force of attraction of each planet at any moment in the past or the future. The Sun and the planets and their satellites comprise a system operating according to definite mathematical laws. Ours is an orderly system. It is simply incredible that the conduct of a person's life is controlled by the configuration of a number of comparatively small material bodies millions of miles out in space. Certainly we should not believe anything of the sort without observational and statistical proof, but such is entirely wanting.

Some persons believe that the figures 1, 3 in that order are "unlucky." In the reverse order 3, 1 they must be favourable. Happily the writer's birthday was on the 31st of the month! "Rubbish!" you say? The same word applies to the following fair sample from a well-known book on astrology. Referring to the planet Mars, it says: "In the vegetable world he rules all such herbs as are *hot* and *dry*, or have sharp-pointed leaves, or that are red, and usually in barren high stony places, as the thistle, brambles, briers, nettles, onions, lingwort, radish, mustard seed, ginger, pepper, garlic, hemlock, horehound, tamarinds, etc."

Years ago the writer made a serious attempt to learn the principles or rules by which the astrologer works, and tried to read some of the books on the subject. The first difficulty in the way was the indefiniteness throughout the books. The term "house" is referred to continually but nowhere was a clear definition of it given. Similarly with other terms. Was it intentional or did the writers themselves have a clear notion of what they were talking about? An admirable paper on Astrology by Professor Alfred Baker was printed in this *Journal* for November 1921.

It is gratifying to note that we do not hear the voice of the astrologer over the radio or see his (or her) contributions in the press so frequently as five years ago.

From a recently published book entitled "You and Heredity" a friend sends the following quotation:

There are many myths and superstitions, and not a few pseudoscientific theories, regarding the influence of the Sun, planets, atmospheric conditions, and various cosmic factors, on the behaviour and achievements of individuals, all implying that the person born at certain times, under certain conditions, will have such and such a personality. Regarding these, we can only say that Science offers no corroborative evidence whatever. To discuss these "influences" at greater length would be like setting up stuffed dummies for the sole purpose of promptly knocking them down again.

by C. A. Chant,
from *Journal*, Vol. 33, pp. 396–397, November, 1939.

PERIOD CHANGES IN THE SX PHOENICIS STARS. I.
BL CAMELOPARDALIS AND DY PEGASI

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Abstract. We present observed–calculated (O–C) diagrams for two SX Phoenicis stars, BL Cam and DY Peg. We have obtained three new estimates for the times of light maximum for DY Peg, and eight new values for BL Cam. The data were combined with times of light maxima from the literature to calculate O–C diagrams for both stars. The O–C diagram for BL Cam confirms the results of Hintz *et al.* (1997) that the star has an increasing period. Our observations for BL Cam also corroborate the observation by those authors that the amplitude of the star's light curve is modulated, the physical cause of which may be tied to the fact that the star is known to exhibit the features of double-mode pulsation. Our observations of DY Peg do not support previous suggestions that the star exhibits sudden changes in its pulsational period. Rather we find that the star appears to exhibit a continuously decreasing period.

Résumé. Nous présentons des schémas O–C (observé moins calculé) pour deux étoiles de type SX Phoenicis, BL Cam et DY Peg. Nous avons obtenu trois nouvelles évaluations pour les courbes de lumière maximale de DY Peg, et huit nouvelles valeurs pour BL Cam. Ces données ont été jointes avec les périodes de lumière maximale puisées dans la littérature afin de calculer les schémas O–C pour chaque étoile. Le schéma O–C pour BL Cam sert à confirmer les résultats d'Hintz *et al.* (1997) en indiquant que cette étoile possède d'une période accroissante. Nos observations de BL Cam corroborent aussi celles de ces auteurs, en indiquant que l'amplitude de la courbe de lumière maximale est modulée. La cause physique de ce processus résulte peut-être du fait que l'étoile présente des caractéristiques de pulsation bimode. Nos observations de DY Peg n'appuient pas les suggestions antérieures selon lesquelles l'étoile présentait des changements soudains de la période de ses pulsations. Nous trouvons plutôt que l'étoile paraît présenter une période de pulsation toujours décroissante.   SEM

1. INTRODUCTION

The SX Phoenicis variables are metal-poor stars of Population II that are in the process of evolving off the main sequence but within the instability strip for pulsating variables in the Hertzsprung-Russell (H-R) diagram (Høg & Petersen 1997). They are characterized by pulsational periods of several hours and amplitudes of less than 0.7 magnitude (Becker 1998), and some exhibit multiple modes of pulsation and possibly non-radial modes. In an evolutionary sense, they are similar to other high amplitude δ Scuti variables, except for their metal-poor composition. They appear to be blue stragglers, that is stars which are much less evolved than other members of the same age group. That would account for their somewhat unusual location in the H-R diagram, blueward of the main-sequence turnoff point for most other old members of the Population II age group. A possible origin from mergers of pre-existing close binaries is the scheme that most readily explains the origin of such stars. While most are found in globular clusters, a few are members of the Galaxy's halo in the Sun's vicinity and are bright enough to be oberved with small telescopes.

According to our understanding of stellar evolution for low-mass, metal-poor Population II stars, such objects, which appear to lie just above the subdwarf main sequence, are expected to evolve in the H-R diagram primarily towards higher luminosities and lower temperatures, with their mean radii slowly increasing as a consequence. That should result in slowly increasing pulsational periods for the stars, as evolution slowly increases their radii and in turn decreases the frequencies of their pulsations. Recent reviews of their period changes (Breger & Pamyatnykh 1998; Rodriguez *et al.* 1995), however, reveal a confusing picture. The measured period changes are found to be both increasing *and* decreasing. Moreover, even when the periods appear to be increasing in the expected sense, the rates of period change seem to be too large relative to predictions from stellar evolutionary calculations (Breger & Pamyatnykh 1998). Added to the sense of confusion is the fact that some of the O–C diagrams for SX Phoenicis stars (diagrams that compare the Observed and Computed times of light maximum) have been reported to exhibit discontinuities, followed by cycles where the period seems to be unchanging — as reported for DY Pegasi (Mahdy & Szeidl 1980) and XX Cygni (Szeidl & Mahdy 1981), for example.

The relatively short pulsational period for one such variable, BL Camelopardalis (56 minutes), suggests that we can expect to observe evolutionary period changes in its pulsation over a short time scale. The rate of period change for BL Cam was studied recently by Hintz *et al.* (1997). They found that, over an observational baseline of 30 years, BL Cam has exhibited a steady period change, with no sudden jumps occurring. The light curve of BL Cam was also found to exhibit periodic amplitude variations of up to 0.2 magnitude. Such behaviour was unexpected and not previously reported.

DY Pegasi is another well-studied SX Phoenicis star. Its times of light maximum given in the literature cover an interval of more than 50 years. The nature of its period change is controversial, with both continuous and discontinuous interpretations being proposed (Mahdy 1987). If they are continuous, then the direction of period change is not in the expected sense. Stellar evolutionary considerations

would indicate that the period should be increasing, while an interpretation of its O–C diagram leads to the opposite conclusion.

York University Observatory is located in a large metropolitan area. That restricts the types of research projects that can be conducted to those not requiring absolute photometry, as well as to studies of bright objects. Given the occasional large gaps in observational coverage of SX Phoenicis stars that hinder the study of their period changes, we decided to establish a long-term monitoring program for such variables. We report here on our observations of BL Cam and DY Peg, obtained as part of a monitoring program conducted by staff and volunteers at the observatory. Our observations and data reductions for these stars are described in §2, our results are presented in §3, and §4 presents our conclusions with regard to these two variables.

2. OBSERVATIONS AND DATA REDUCTIONS

New observations of the two stars that are the subject of this paper were made using the York University Observatory's 0.6-m f/13 Cassegrain telescope, equipped with an HPC-1 CCD camera manufactured by Spectra Source Instruments. When mounted on the telescope, the CCD camera has a 4.8 by 4.8 arcminute field of view. In order to minimize exposure times and provide better phase coverage, all observations were taken in the red *I*-band of the Johnson system. Use of this band takes advantage of the red sensitivity of the CCD. Typical exposures were 150 seconds in duration, and the fields of view for each star were chosen in such a manner as to provide as many comparison stars as possible for differential photometry. On all nights, bias, dark, and dome flat fields were obtained for use in pre-processing.

Images were corrected for DC-offset, two dimensional bias pattern, dark current, and sensitivity variations using standard techniques (Gilliland 1992). Images at the telescope were acquired in such a manner that from three to seven comparison stars were present on all images obtained on any given night. Significant drift of the field over the night caused by tracking error meant not all stars found using DAOPHOT's automatic star finding routines would be on every image. That would have led to a time-consuming extra step of matching the stars afterwards. Since we had only a few stars of interest, we decided to use manual star identification, thereby identifying only the brightest stars that were present on every image taken on a given night. Manual identification proved faster because only the desired stars were identified and measured.

We obtained co-ordinates for the variable and comparison stars by first using the image cursor to obtain initial guesses for the positions of each star. For more precise centring, the region identified in each initial guess was then fitted by a two-dimensional Gaussian curve using the DAOPHOT routine as implemented in the IRAF software package, following which aperture magnitudes were determined. Tests showed that our procedure produced identical aperture magnitudes to those obtained using the automatic star finding procedure. Figures 1 and 2 present finder charts for DY Peg and BL Cam, showing the comparison stars used for each variable. Three comparison stars were used for DY Peg, while five to six stars were used for BL Cam.

We calculated the differences in instrumental magnitudes between each star and every other selected star on each image, as well as the averages of such magnitude differences. For the non-variable field stars the differences in magnitude between them and

Fig. 1 — A finder chart for the field of BL Cam, made from a 150-second *I*-band exposure. BL Cam is identified, as well as the comparison stars used for the differential photometry. The field shown is 4.8 arcminutes on a side.

the variable star were not included when calculating the average. The average magnitude difference was next plotted versus universal time to produce the light curve of the variable star. We checked similar plots obtained for the comparison stars in each field to ensure that none of them were variable. From the data for them, we found that there was a scatter of about ±0.02 magnitude present in our photometry.
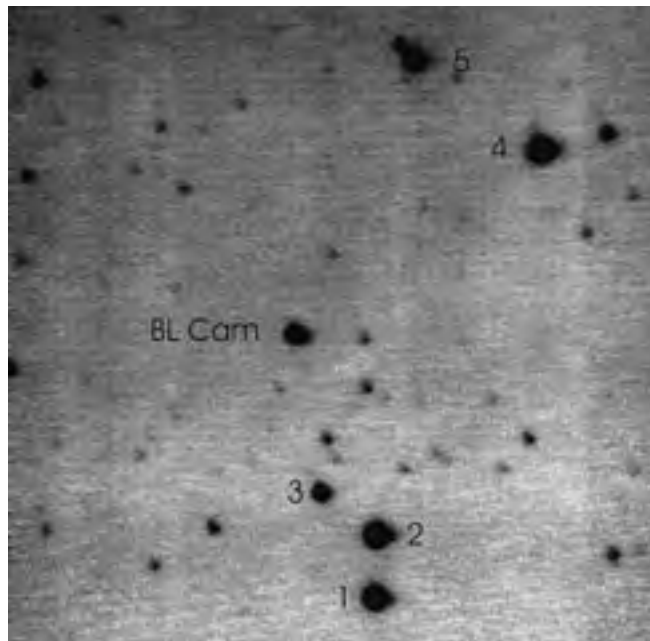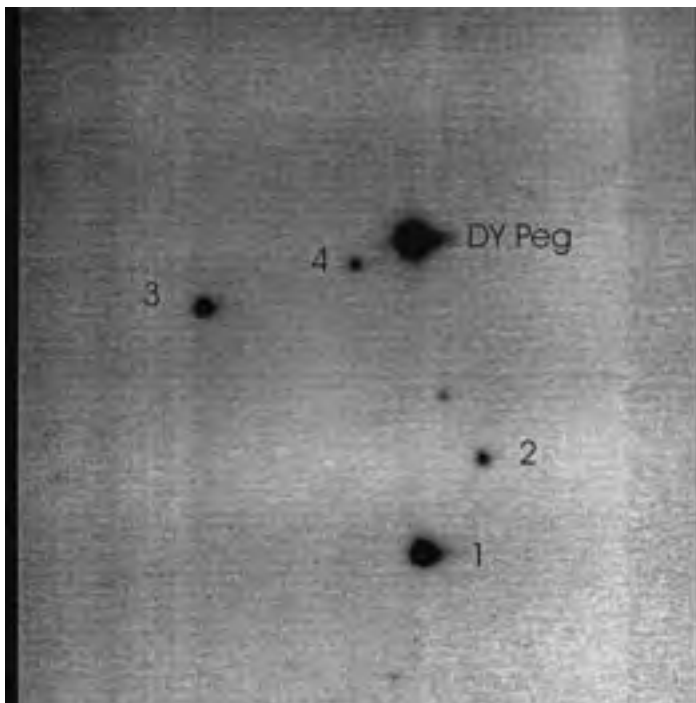

Fig. 2 — A finder chart for the field of DY Peg, made from a 150-second *I*-band exposure. DY Peg is identified, as well as the comparison stars used to for the differential photometry. The field is the same size as in figure 1.

In the case of BL Cam, three of the selected stars were in common with those used by Hintz *et al.* (1997), which they chose as being the most stable in brightness in the field.

In order to measure the time of maximum light, each cycle of the individual light curves was fitted using a 13th order polynomial. The derivative for each fitted polynomial was computed, and the points of inflection corresponding to epochs of light maximum were determined from the corresponding null points. That procedure provided the Universal Time (UT) of light maximum. This time was then converted to heliocentric Julian date (HJD) using the IRAF software. For BL Cam the ephemeris of Hintz *et al.* (1997) was used to calculate the expected times of light maxima, while for DY Peg the ephemeris of Mahdy (1987) was employed.

3. RESULTS FOR BL CAMELOPARDALIS

Figure 3 illustrates the four cycles observed for BL Cam on February 7, 1998 (UT). We noticed immediately that the depths of minimum light were varying, with alternating cycles showing shallower minima by about 0.05 magnitude. Possible indications of such fluctuations were observed on the previous night, but had been attributed to changes in transparency. The clear reproducibility seen in the data of figure 3, however, indicates that the variations represent true brightness changes in BL Cam. Hintz *et al.* (1997) previously reported a similar phenomenon in their data, and the data of figure 3 represent a verification of their discovery. Without further study, it is not clear to us what the physical cause for such amplitude changes may be. BL Cam is known to exhibit the features of double-mode pulsation, however, so the amplitude variations may arise from the modulation of the primary pulsation by pulsation at the beat frequency.

It should be noted that other SX Phoenicis and dwarf Cepheid

variables also exhibit amplitude modulation, in particular AE UMa, which shows noticeable Blashko behaviour. It can be furthur noted that the amplitude modulation seems to be more pronounced in our *I*-band observations than in the *V*-band observations of Hintz *et al.* (1997). That may indicate that a red passband is preferable when searching for such effects in other stars of the type.

Table I presents the new times of light maximum that we have obtained for BL Cam. The heliocentric Julian date (HJD) of the observed times of maxima are given in column 1, the computed times are listed in column 2, the cycle number obtained using the linear ephemeris of Hintz *et al.* (1997) is given in column 3, and the differences between observed (O) and computed (C) times of light maximum, O−C, are given in column 4. For reference purposes, the ephemeris of Hintz *et al.* (1997) for BL Cam is:

$$HJD_{max} = 2443125.8026 + 0^d.03909783\,E, \qquad (1)$$

where *E* is the number of elapsed cycles.

Figure 4 is a plot of the O−C differences as a function of cycle

TABLE I
New O−C Data for BL Camelopardalis

HJD$_{Observed}$ 2450000+	HJD$_{Calculated}$ 2450000+	Cycle *E*	O−C (days)
850.6786	850.6737	197578	+0.00494
850.7180	850.7128	197579	+0.00528
850.7568	850.7519	197580	+0.00495
851.6584	851.6511	197603	+0.00731
851.6951	851.6902	197604	+0.00483
851.7358	851.7293	197605	+0.00649
851.7741	851.7684	197606	+0.00572
852.7152	852.7067	197630	+0.00842

Fig. 3 — The light curve for BL Cam for UT date February 12, 1998. Note the significant cycle-to-cycle amplitude changes in the light curve of about 0.1 magnitude, also noted by Hintz *et al.* (1997).

Fig. 4 — The O−C diagram for BL Cam derived from our new measurements and the data compiled by Hintz *et al.* (1997). The upwards trend of the data indicates a significant increase in pulsational period for the star over the 30-year interval of photometric observation.

number for BL Cam, where we used the data of Hintz *et al.* (1997) to augment our own data. The new data seem to fit the trend found by Hintz *et al.* (1997) quite well, and the upward trend of the points confirms that the star is undergoing a slow increase in its period. The rate of period change can be estimated by fitting the data to a polynomial. We have used a simple quadratic relation to fit the data, and have obtained the following updated ephemeris for the variable:

$$\mathrm{HJD_{max}} = 2443126.0293 + 0^\mathrm{d}.03909748\,E + 2.14 \times 10^{-12}\,E^2 .\quad(2)$$

The quadratic term, $2.14\,(\pm0.34) \times 10^{-12}$, agrees reasonably well with a value of 0.6153×10^{-12} (with no uncertainty given) obtained by Hintz *et al.* (1997), and confirms their results.

4. RESULTS FOR DY PEGASI

A literature search was conducted for DY Peg in order to locate other times of light maxima for the variable. Table II presents the data for DY Peg in the same format as used in Table I, but with the source of information for the observed times of maximum given in column 5. As a service to future observers, we include all literature times of light maximum that were available to us. We do not have access to all published work for the star, some o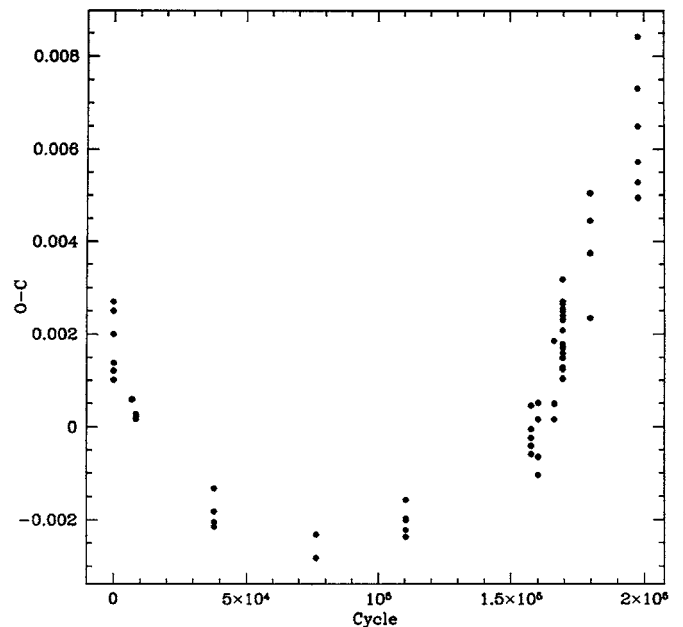f which is located in now-defunct journals. The data for DY Peg represent 193 times of light maximum over a baseline of about 50 years. We point out, however, that the times we quote for the results of Quigley & Africano (1979) do not include the correction of $0^\mathrm{d}.0005$ suggested by Mahdy & Szeidl (1980). Instead, we chose to report the original times of light maximum as originally published.

Table II
New O–C Data for DY Pegasi

HJD_Observed 2430000+	HJD_Calculated 2430000+	Cycle E	O–C (days)	Reference
976.4250	976.42405	−24347	+0.00095	1
976.4967	976.49697	−24347	−0.0027	1
987.3619	987.3630	−24197	−0.0011	1
1086.3238	1086.3241	−22840	−0.0030	1
1104.2638	1104.26398	−22594	−0.00018	1
1288.5472	1288.54893	−20067	−0.00173	1
1290.5170	1290.51794	−20040	−0.00094	1
1306.4861	1306.48882	−19821	−0.00272	1
1314.4391	1314.4378	−19712	+0.00130	1
1317.4288	1317.42778	−19671	+0.00102	1
1318.4481	1318.44875	−19657	−0.00065	1
1318.5228	1318.52167	−19656	+0.00113	1
1320.4892	1320.49069	−19629	−0.00149	1
1328.5124	1328.51259	−19519	−0.00019	1
1330.4801	1330.4816	−19492	−0.00150	1
1671.4834	1671.48533	−14816	−0.00193	1
1797.3563	1797.35625	−13090	+0.00005	1
1824.2672	1824.26608	−12721	+0.00112	2
2011.5414	2011.54101	−10153	+0.00039	2
2093.3646	2093.36441	−9031	+0.00019	2
2172.2697	2172.27075	−7949	−0.00105	2
2379.5271	2379.52750	−5107	−0.00040	2
2380.5477	2380.54847	−5093	−0.00077	2
2381.4948	2381.49561	−5080	−0.00171	2
2382.5174	2382.51748	−5066	−0.00008	2
2385.5809	2385.58039	−5024	+0.00051	2
2386.5267	2386.52843	−5011	−0.00173	2
2387.5496	2387.54940	−4997	+0.00020	2
2394.5505	2394.55034	−4901	+0.00016	2
2398.5607	2398.56129	−4846	−0.00059	2
2406.5103	2406.51026	−4737	+0.00004	2
2409.4989	2409.50024	−4696	−0.00134	2
2410.5200	2410.52121	−4682	−0.00121	2
2411.4686	2411.46926	−4669	−0.00066	2
2413.4370	2413.43827	−4642	−0.00127	2
2414.6057	2414.60509	−4626	+0.00061	2
2415.4786	2415.48021	−4614	−0.00161	2
2421.4592	2421.46017	−4532	−0.00097	2
2425.3979	2425.39819	−4478	−0.00029	2
2427.4403	2427.44013	−4450	+0.00017	2
2428.3876	2428.38817	−4437	−0.00057	2
2432.3978	2432.39912	−4382	−0.00132	2
2433.4201	2433.42009	−4368	+0.00001	2
2434.3681	2434.36814	−4355	−0.00004	2
2751.8890	2751.88957	−1	−0.00057	3
2751.9608	2751.96250	0	−0.00170	3
2752.9092	2752.91054	13	−0.00134	3
4661.3915	4661.39378	26183	−0.00228	4
4661.4644	4661.4670	26184	−0.00230	4
4662.3402	4662.34182	26196	−0.00162	4
4662.4150	4662.41475	26197	+0.00025	4
4662.4857	4662.48767	26198	−0.00197	4
4662.5589	4662.5606	26199	−0.00170	4
4689.3228	4689.32458	26566	−0.00178	4
4689.3968	4689.3975	26567	−0.00070	4
4690.3437	4690.34555	26580	−0.00185	4
4690.4165	4690.41847	26581	−0.00197	4
4690.4897	4690.4914	26582	−0.00170	4
4691.2919	4691.29359	26593	−0.00169	4
4691.3646	4691.36652	26594	−0.00192	4
4691.4376	4691.43944	26595	−0.00184	4
4692.2400	4692.24163	26606	−0.00163	4
4692.3138	4692.31456	26607	−0.00076	4
4692.3858	4692.38749	26608	−0.00169	4
4692.4585	4692.46041	26609	−0.00191	4
4693.2614	4693.2626	26620	−0.00120	4
4693.3338	4693.33553	26621	−0.00173	4
4693.4058	4693.40846	26622	−0.00266	4
4693.4788	4693.48138	26623	−0.00258	4
4695.3021	4695.30454	26648	−0.00244	4
4695.3756	4695.37747	26649	−0.00187	4
4695.4487	4695.45039	26650	−0.00169	4
4696.2515	4696.25258	26661	−0.00108	4
4696.3242	4696.32551	26662	−0.00131	4
3696.3966	3696.39844	26663	−0.00184	4
5745.5891	5745.59019	41050	−0.00109	5
5745.6625	5745.66312	41051	−0.00062	5
5745.7345	5745.73605	41052	−0.00155	5
5745.8076	5745.80897	41053	−0.00137	5
5760.6851	5760.68595	41257	−0.00085	5
5760.7580	5760.75888	41258	−0.00088	5

5761.7794	5761.77985	41272	−0.00045	5
5762.5811	5762.58204	41283	−0.00094	5
5762.6540	5762.65497	41284	−0.00097	5
5762.7271	5762.72789	41285	−0.00079	5
5762.8006	5762.80082	41286	−0.00022	5
5770.6035	5770.60394	41393	−0.00044	5
5770.6759	5770.67687	41394	−0.00097	5
5770.7496	5770.74979	41395	−0.00019	5
5771.5523	5771.55198	41406	+0.00032	5
5771.6235	5771.62491	41407	−0.00141	5
5771.6963	5771.69784	41408	−0.00154	5
5773.6657	5773.66685	41435	−0.00115	5
5773.7387	5773.73977	41436	−0.00107	5
5780.5941	5780.59485	41530	−0.00075	5
5780.6666	5780.66778	41531	−0.00118	5
10897.6134	10897.61981	111697	−0.00641	6
11937.4701	11937.47699	125956	−0.00689	7
11937.5444	11937.54992	125957	−0.00552	7
11957.3785	11957.38589	126229	−0.00739	7
11957.4535	11957.45882	126230	−0.00532	7
11957.5998	11957.60467	126232	−0.00487	7
14501.19445	14501.2037	161111	−0.00925	8
14501.26798	14501.27663	161112	−0.00865	8
14502.07044	14502.07882	161123	−0.00838	8
14502.14335	14502.15175	161124	−0.00840	8
14502.21642	14502.22467	161125	−0.00825	8
14502.28891	14502.2976	161126	−0.00869	8
14559.02439	14559.03432	161904	−0.00993	8
16653.4688	16653.47981	190624	−0.01101	9
16653.5419	16653.55273	190625	−0.01083	9
16653.6150	16653.62566	190626	−0.01066	9
16654.4168	16654.42785	190637	−0.01105	9
16654.4901	16654.50078	190638	−0.01068	9
16654.5619	16654.5737	190639	−0.01180	9
16654.6352	16654.64663	190640	−0.01143	9
16655.6571	16655.6676	190654	−0.01050	9
16656.4581	16656.46979	190665	−0.01169	9
16656.5313	16656.54272	190666	−0.01142	9
16656.6052	16656.61564	190667	−0.01044	9
16645.4466	16645.45791	190514	−0.01131	10
16645.5195	16645.53083	190515	−0.01133	10
16646.4675	16646.47888	190528	−0.01138	10
16646.5408	16646.5518	190529	−0.01100	10
16647.4155	16647.42692	190541	−0.01100	10
16649.3849	16649.39593	190568	−0.01142	10
16649.4578	16649.46886	190569	−0.01103	10
16649.5307	16649.54178	190570	−0.01108	10
16007.7784	16007.78968	181770	−0.01128	11
16018.7999	16018.80157	181921	−0.00167	11
16019.5916	16019.60376	181932	−0.01216	11
16019.6634	16019.67668	181933	−0.01328	11
16021.6357	16021.64569	181960	−0.00999	11
16022.5835	16022.59374	181973	−0.01024	11
16052.6290	16052.6394	182385	−0.01040	11
16054.6000	16054.60842	182412	−0.00842	11
16055.6180	16055.62939	182426	−0.01139	11
16056.6393	16056.65036	182440	−0.01106	11
13085.69513	13085.70276	141701	−0.00763	12
13085.76839	13085.77569	141702	−0.00730	12
13085.84032	13085.84862	141703	−0.00830	12
13088.68603	13088.69275	141742	−0.00672	12
13088.75817	13088.76567	141743	−0.00750	12
13089.70642	13089.71371	141756	−0.00729	12
13305.93293	13305.94042	144721	−0.00749	12
13307.83079	13307.83650	144747	−0.00571	12
13307.90232	13307.90943	144748	−0.00711	12
13348.81430	13348.82112	145309	−0.00682	12
13348.88671	13348.89405	145310	−0.00734	12
13348.95979	13348.96698	145311	−0.00719	12
13350.78333	13350.79014	145336	−0.00681	12
13350.85544	13350.86306	145337	−0.00762	12
13350.92876	13350.93599	145338	−0.00723	12
13351.80424	13351.81111	145350	−0.00687	12
13351.87655	13351.88403	145351	−0.00748	12
13353.77280	13353.78012	145377	−0.00732	12
13353.84589	13353.85304	145378	−0.00715	12
20742.66431	20742.68043	246697	−0.01612	13
20765.70529	20765.72517	247013	−0.01988	13
20785.69301	20785.70699	247287	−0.01398	13

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Figure 5 is a plot of the O–C data for DY Peg as a function of the cycle number, from the data of Table II. The cycles were computed using the ephemeris of Mahdy (1987), namely:

$$\mathrm{HJD_{max}} = 2432751.96555 + 0^{\mathrm{d}}.072926302\, E. \qquad (3)$$
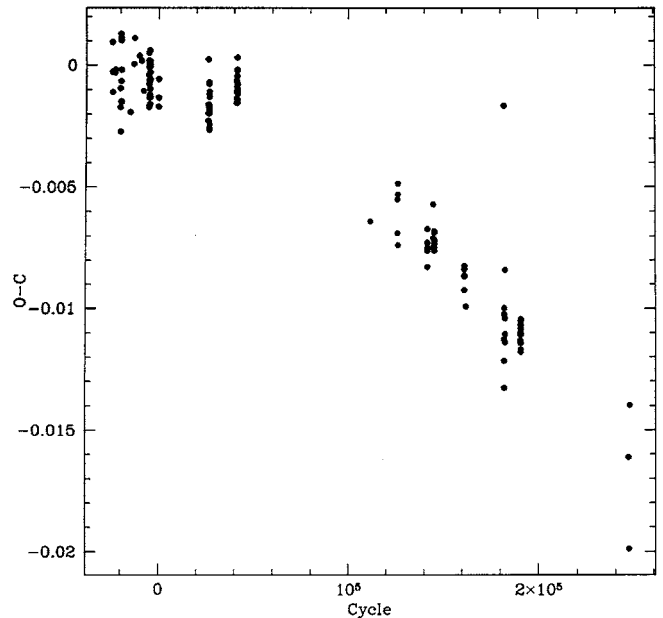
FIG. 5 — The O–C diagram for DY Peg derived from our new measurements and the data compiled in Table II. The downward trend of the data indicates a significant decrease in pulsational period for the star over the 50-year interval of photometric observation. Previous arguments for sudden changes in pulsational period may be the result of gaps in the data, underscoring the need for continuous monitoring of the stars.

The data points exhibit a tendency towards a decreasing slope, which represents a slowly decreasing period for the star. There is a noticeable

gap in the data between HJD 2436000 and HJD 2440000, however. Mahdy & Szeidl (1980) suggested that the O–C data for DY Peg are well matched by two straight line segments, an interpretation that infers a constant period for the star marked by a sudden change in the pulsational period — in this case to a smaller rate of pulsation. We do not interpret the O–C data in such a manner, but instead favour a parabolic trend such as that obtained by Jian & Zhao (1982). That is a bias on our part, simply because sudden period changes are not expected from an evolutionary standpoint. The fact that the apparent abrupt change in period found by Mahdy & Szeidl (1980) occurs where there is a paucity of data also suggests to us that the inferred discontinuity may be misleading. It merely emphasises the necessity of continuous data sets for the study of period changes in pulsating variables.

A fit was made of the values in Table II for HJD_{max} as a function of cycle number, and produced the following updated quadratic ephemeris for DY Peg:

$$HJD_{max} = 2432752.0106 + 0^{d}.072926\,E - 1.36 \times 10^{-12}\,E^{2}. \quad (4)$$

The quadratic term here, $-1.36\,(\pm 0.20) \times 10^{-12}$, is larger in an absolute sense than the value of $-0.231\,(\pm 0.20) \times 10^{-12}$ (with no uncertainty given) obtained by Mahdy (1987), but is in the same sense, which is opposite to that expected from evolutionary expectations.

5. CONCLUSIONS

The current results indicate that both BL Cam and DY Peg exhibit significant changes in their periods of pulsation, at rates that are greater than those expected on the basis of their inferred evolution through the instability strip. The rate of period change for BL Cam translates into a value of $(1/P)(dP/dt)$ of $1.02 \times 10^{-6}\,\mathrm{year}^{-1}$, while that for DY Peg corresponds to a value of $(1/P)(dP/dt)$ of $-1.86 \times 10^{-7}\,\mathrm{year}^{-1}$. According to predictions from post-main sequence evolutionary models given by Breger & Pamyatnykh (1998) and Rodriguez et al. (1995), the expected rates of period change $(1/P)(dP/dt)$ should be about $1.0 \times 10^{-8}\,\mathrm{year}^{-1}$ and $1.7 \times 10^{-10}\,\mathrm{year}^{-1}$, respectively. In the case of DY Peg the period change is in the wrong sense relative to what is expected for a star evolving upwards and to the right in the H-R diagram. Such a discrepancy, which is at odds with what is expected from stellar evolutionary models, indicates either that there is some missing factor in the models for late stages of evolution for metal-poor Population II stars or that the observed period changes result from something other than evolution. The large vertical scatter in the O–C data at closely spaced epochs may indicate that short timescale effects are occurring. Slight cycle-to-cycle changes in pulsational period would account for much of the observed scatter. They could in turn introduce spuriously large calculated rates of period change for such stars when thousands of cycles are referred to a single epoch for the calculation of O–C values. We intend to examine such effects in a future paper. In the interim, we plan to continue our photometric monitoring efforts for both stars.

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R. MELVIN BLAKE hails from the beautiful island of Newfoundland, and is currently a graduate student at York University in Toronto, Ontario. His interests in astronomy are varied, and include research in cD galaxies, old open clusters, globular clusters, and binary and variable stars. He also has a keen interest in the public teaching of astronomy. He is happiest when in a telescope dome under a clear sky. Melvin plans to return to Newfoundland upon graduation to establish its first professional astronomy program.

HOUMAN KHOSRAVANI is an undergraduate student at York University presently enrolled in a combined major program in astronomy and biology. His interests and research experience are diverse between the two fields and include non-linear dynamics, stellar astrophysics, and neuroscience. The study of global system properties in the context of physical "laws" and oscillatory behaviour are some of the approaches Houman is keen to apply. Upon completion of his undergraduate degree, he plans on continuing studies at the graduate level.

PAUL DELANEY is a senior lecturer in the Department of Physics and Astronomy at York University. He is also the co-ordinator for the York University Astronomical Observatory. His interests in astronomy lie in teaching and variable stars.

Education Notes
Rubriques pédagogiques

NOVA SCOTIA TEACHERS MEET AN
ASTRONOMICAL CHALLENGE

by Mary Lou Whitehorne
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Abstract. The new Pan-Canadian Science Curriculum includes large sections on astronomy and space science at both the grade six and grade nine levels. Its introduction presents a challenge for teachers who have no familiarity with the subject, and a golden opportunity for RASC members to assist such teachers through their expertise and enthusiasm.

Résumé. Le nouveau curriculum scientifique pancanadien aux niveaux des sixième et neuvième années scolaires comprend des parties importantes sur l'astronomie et les sciences de l'espace. Leur présentation offre un défi aux enseignants qui ne connaissent pas ces sujets, et une parfaite occasion pour les membres de la SRAC de fournir de l'aide aux instituteurs, en y apportant leur expertise et leur enthousiasme.

SEM

Astronomy education in Canada is about to turn a new corner with the introduction, adoption, and implementation of the new Pan-Canadian Curriculum in Science. More properly titled the "Common Framework of Science Learning Outcomes," the document is produced by the Council of Ministers of Education, Canada (CMEC). Most Canadian provinces are now in the process of implementing the new science curriculum, which has large astronomy sections in both grade six and grade nine.

Astronomy has been a part of the elementary school program for some time, and it has been taught mostly in either grade five, grade six, or both. It is a very popular topic among elementary school students, and the wise teacher recognizes its appeal and uses it to teach a variety of mathematics, science, and technology concepts. Astronomy has also been used extensively in the teaching of social studies, language arts, and fine arts. As we all know, it is a subject with many links to all areas of the school curriculum, and it also has wide public appeal. There is something about the stars and galaxies that is, to use a very bad pun, universally attractive.

What is exciting about the new science curriculum is the appearance of astronomy in the higher grades, *i.e.* grade nine. In some parts of the country, grade nine is the first year of high school; in other places, grade nine is the final year of the junior high school program. Either way, by grade nine, school science courses are usually becoming fairly specialized, as opposed to the cross-subject linking approach used in elementary schools. That necessitates taking a much more focused approach to the teaching of astronomy in grade nine. Remarkably, the astronomy section of the new grade nine science course is fully one quarter of the entire year's program! It means that students and teachers will be spending as much as ten to twelve weeks studying our favourite science.

As always, there are pros and cons with the situation. As Laura Gagné pointed out in her Education Notes article in the February 2000 issue (Gagné 2000), there is great potential for students to be "turned off" of astronomy. One major reason for that is the fact that most teachers have never had any exposure to the subject at all. Many teachers have no science background, and even if they do have an extensive science background, astronomy is usually not part of it. They are entering foreign territory, and therein lie risks of great harm; for if teachers do not receive adequate in-servicing so that they are comfortable in this new territory, they and their students will be ill served by the new curriculum.

The February 2000 issue reported on a very successful astronomy teacher workshop organized and presented by members of the Kingston Centre. The Kingston folks are to be commended for taking such an initiative, for they have, without a doubt, started those teachers on the royal road to the stars by giving them some background information to draw upon, by demonstrating and modeling astronomical concepts, by clearing up common misconceptions, and by transferring their enthusiasm for the subject to the teachers. Let us hope that other, similar workshops will happen across the country!

I too, have had the opportunity to work with teachers who have been confronted with the new and foreign curriculum, although not as an RASC member. For the last five years I had a lot of involvement with astronomy in the schools through The Atlantic Space Sciences Foundation (TASSF) and its Starlab program, as well as through my work with the Canadian Space Resource Centre – Atlantic. (In a somewhat poorly-timed move, the Canadian Space Agency has chosen to close down its network of regional Space Resource Centres just as the new curriculum is being implemented.) I left the Space Resource Centre a year ago, and now work almost exclusively with *Starlab*, both through TASSF, and commercially as *Starlab* Manager for Design Group Displays, who represent *Starlab* in eight provinces. Design Group Displays not only sells *Starlab*, but also offers five different levels of astronomy workshops for teachers as part of their teacher support program.

Presently in Nova Scotia, teachers are evaluating two different books that are vying for selection as the grade nine text for Nova Scotia schools. The curricula of both books are wonderful but daunting in their scope — perhaps it is too much of the good thing all at once. The feedback that I have received from some teachers is distressing

from the point of view of literacy. I am told that a large percentage of their students will have difficulty simply reading the textbook, let alone understanding the contents! Both textbooks are nothing if not ambitious. They cover everything from constellation recognition, angular measurement, size and scale, and stellar evolution to the fate of the universe, as well as a chapter devoted to space exploration. Happily, they contain many good illustrations, examples, and hands-on activities that encourage students to explore the subject and discover the universe for themselves.

We in the RASC know and value the relevance of astronomy in our lives. To have astronomy as a major component of grade nine science offers the chance for thousands of students to embark on their own voyage of discovery. In order for the journey to be a rewarding one, however, their teachers will need some help! I hope that the various educational powers-that-be will recognize that and take steps to ensure that teachers have the necessary tools in hand to carry out their responsibilities.

In my case, I was approached by a keen Vice-Principal who took the initiative to secure the funding, substitute teachers, and a venue to offer an astronomy in-service to grade nine teachers in her area. I spent two full days with eight teachers, and we went on a light-speed tour of the universe. My chief concern was that I address the specific learning outcomes as outlined in the Framework of Common Learning Outcomes, and to make it fun at the same time. We all know that astronomy is fun, and it has to be fun for teachers or it will not be fun for students.

One entire day was devoted to astronomy in the *Starlab* portable planetarium. We examined some of the basic framework for observational astronomy. In *Starlab* the teachers got to explore, using *Starlab* and manipulated models, day and night, seasons, the phases of the Moon, and eclipses. They saw and understood the changing patterns of the motion of the Sun across the sky from different latitudes and at different times of the year. They were introduced to the constellations, their origins, and how to use known star patterns to locate unknown star patterns. We used the Celestial Co-ordinates and Solar System projection cylinders to introduce, explain, and understand the motions of the planets, the Moon, and the Sun across the sky. The teachers must have been from Starfleet — they were fearless in going where no teacher had gone before!

Day two was spent in the classroom, where, once again, hands-on models were built and manipulated to reinforce what was discussed the previous day. Scale models are very effective learning tools, and trying to build a scale model of the Sun-Earth-Moon system is always a true eye-opener. It was a very successful introduction to the rest of the workshop, which went from the Sun to the observable edges of the universe — albeit in an overly rapid fashion. In addition to an introduction to the planets, there was discussion of how stars form, live, and die, of star clusters, spectral classes, and the H-R diagram, and of the structure of galaxies, galaxy clusters, and large scale structure in the universe.

In spite of the time constraints and the amount of information to cover, the reaction from the teachers was overwhelmingly positive. The one negative comment was that the workshops were not long enough. They wished for a third day so they could do even more. In spite of their enthusiasm, one must still consider this fundamental truth: the brain can only absorb what the behind can endure…

Following those two days, a small group of teachers went away with a reasonable foundation with which to begin teaching a totally new subject. They are now armed with a number of hands-on activities to assist in teaching the most basic and important astronomical concepts. They took with them over one hundred fifty pages of background materials, references, and resource lists. The materials came from a wide variety of places: many I have developed myself from several years of experience in working with teachers and students, some are adapted from the *Observer's Handbook*, and some are adapted from the *Starlab* User's Manual. The Astronomical Society of the Pacific's wonderful teaching resource "The Universe At Your Fingertips" is invaluable, and I always include activities from it in my teacher workshops and recommend it to teachers. Most importantly, the teachers left at the end of the day with the self-assurance to teach a new and strange subject confidently and competently, and to have fun doing it. Their students will be the lucky ones.

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Reference

Gagné, L. 2000, JRASC, 94, 30

MARY LOU WHITEHORNE is a relative newcomer to the RASC, having been a member for only sixteen years. Some years ago she committed the sin of becoming a Life Member, and so feels a degree of compulsion to carry out the RASC's motto of promoting astronomy and allied sciences. To that end she does a lot of work with Starlab *portable planetariums and with teacher workshops. She sometimes also sticks her paddle unbidden into RASC business at both the Centre and National levels.*

Society News/Nouvelles de la société

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

On Saturday March 18, 2000, the spring meeting of National Council was held in the boardroom of Smith-Lyons in the Scotia Plaza, Toronto. The meeting began at 10:00 a.m., and was over by 4:52 p.m. There was a large turnout, with many Centres being represented, and a number of motions were made and passed. Though all motions have an impact on the operation of the Society, the one with the greatest impact on members and the Society itself was motion 2000107 to increase regular membership fees by $4. That would increase the cost of regular membership to $40 from $36, youth membership $25 from $22.50, and life membership to $800 from $720. The formal motion will have been voted upon at the Annual General Assembly Meeting July 2, 2000, in Winnipeg, Manitoba. A proxy form allowed members who could not attend the annual meeting to vote individually on the motion. For those with questions or concerns, please contact the Finance Committee Chair, Michael Watson, at MSFWatson@SmithLyons.ca.

After 19 years of editing the *Observer's Handbook* (1982–2000), Roy Bishop is stepping down to take a long-deserved break. Expressions of thanks were expressed to Roy for providing The Royal Astronomical Society of Canada with an outstanding manual for the observing and research needs of the members, and for making the *Observer's Handbook* a great success. Rajiv Gupta was nominated to replace Roy as editor, and has accepted the appointment. Best wishes go to Rajiv in his preparation of the 2001 edition of the *Observer's Handbook*, and for many future issues.

As a result of unforeseen circumstances, National Librarian Andrew Oakes (Unattached) has stepped down from his position. He has been replaced by Colin Haig (Hamilton), a Library Committee member who was appointed to the position of National Librarian by a special resolution, for the remainder of the present term of the National Librarian. The position of National Librarian will be open for formal renewal at the General Assembly. Colin is looking for volunteers to help with much-needed cataloguing at the National Library, which is located at 136 Dupont Street, Toronto. Those willing to volunteer their time should contact Colin at chaig@compuserve.com.

ASTRONOMY DAY

April 8, 2000 was International Astronomy Day, though some Centres may have celebrated the event in April and May. Many Centres and RASC members contributed their time and efforts to make Astronomy Day a success in their area, and reports of the event should be sent to Kim Hay so that we can all share in the experience.

Astronomy Day co-ordinator, Peter Williams, did a wonderful job on the information that he provided on the Society's Web site for organizing a public event. Though the site was set up specifically for Astronomy Day, the information can be used for any event. Point your browser to www.rasc.ca to view the Astronomy Day information.

HONORARY MEMBER

At the March 18, 2000 meeting of National Council, Leif J. Robinson, Editor of *Sky & Telescope*, was elected as our Society's newest honorary member. For more information on *Sky & Telescope*, visit their Web site at www.skypub.com.

UPCOMING EVENTS

There are many forthcoming events of interest to members that they may wish to incorporate into summer vacations or observing sessions. Some of those events are listed below.

If you know of an event that is not on the list, please send a note to Kim Hay at kimhay@kingston.net for inclusion

Date	Event	Place	Contact Information
July 29–30	Stellefane Star Party	Springfield, VT	www.stellafane.com
July 27–Aug. 2	Great Manitou Star Party	Manitoulin Island, ON	www.manitoulin-link.com/starparty
July 28–31	Island Star Party 2000	Victoria, BC	starfinders.cvnet.net
July 29–Aug 6	Mt. Kobau Star Party	Kelowna, BC	www.bcinternet.com/~mksp
Aug. 4–7	Nova East 2000	Smiley's Provincial Park, NS	halifax.rasc.ca/ne
Aug. 24–27	Starfest	Mt. Forest, ON	www.interlog.com/~nyaa

in future items on Upcoming Events.

MESSIER MARATHONS

In the April 2000 edition of the Journal, I made reference to the March Marathon of searching for 110 Messier Objects to achieve the Messier certificate that is offered by the RASC. The article was not intended to project the hunt as a one-night affair in order to achieve a certificate. It was mainly to introduce to new observers and seasoned observers that if you have not finished your Messier hunt for the 110 objects then March is a good time to do so, as all objects are in the sky over the March period.

I apologize if the article suggested that the feat should only take one night to accomplish, and did not intend to show any disrespect for those who have already achieved the goal of obtaining a search for the Messier Objects, or for those who are still observing. I know that it can take months or even years, and that each observer takes what time is needed to complete their study of each object to obtain the goal of observing all 110 Messier objects. The universe has been around for millions of years, and one night alone should not be used to take in all of its grandeur.

CONGRATULATIONS TO…

… Mike Boschat, Halifax Centre (www.mscs.dal.ca/~andromed), who co-discovered several comets using images from the *SOHO* satellite (sohowww.nascom.nasa.gov). See *News Notes* for details.

… Doug George, Past President and Ottawa Centre member (www.cyanogen.com), who is credited with the co-discovery of supernova SN2000K. See *News Notes* for details.

… Bob Hawkes, *Observer's Handbook* contributor on Meteors, who was awarded the Canadian Association of Physics (www.cpa.ca) Medal for Excellence in Teaching. Dr. Hawkes teaches physics and astronomy at Mount Allison University.

… all those who were awarded Messier and NGC Certificates at the March 18 meeting of National Council. The newest Messier Certificate holders are: Dunstan Pasterfield (Regina), Michael Pataky (Windsor), and Gail Lorraine Wise (Winnipeg). The newest NGC Certificate holders are: Dale Jeffrey (Saskatoon), Gordon E. Sarty (Saskatoon), and Garry Dymond (St. John's). Congratulations to everyone on their hard work and accomplishments. ◉

At the Eyepiece

Cygnus Delights

Guest column by Guy Mackie, Okanagan Centre (guy.m@home.com)

At a star party last summer I helped a few observers with their first-time Messier list identifications of M29 and M39 in Cygnus the "Swan." I felt a great deal of empathy for them as they made many frustrating attempts to match their telescopic views of the stars in those less-than-spectacular open clusters to pictures and star maps that they had prepared. While I enjoyed locating, observing, and sketching M29 and M39, the objects are described justifiably by Robert Burnham, Jr. in *Burnham's Celestial Handbook* as being "indistinguished" and "sparse," respectively. The *Finest NGC Objects* in Cygnus are a different story altogether. The Cygnus portion of the *Observer's Handbook* list contains more "‼"s — indicating showpiece objects — than any other constellation. Huge sweeping clouds of nebulosity, a small but distinct open cluster, and a couple of challenging planetary nebulae make this portion of the *Finest NGC Objects* list one of the finest. All of the objects are easily accessible through my 8-inch f/6 Dobsonian, and, while a nebular filter does enhance the view of some, it is not necessary.

We begin with one of the most beautiful sights in the night sky. At low power the clouds of the Veil Nebula twist and curve through the field of view like fluorescent rivers. The nebula constitutes part of the remains of a supernova explosion some 30 to 40 thousand years ago. It lies immediately south of the outstretched wing of Cygnus the Swan, between Zeta and Epsilon Cygni. Its brightest section, visible through binoculars, is crescent-shaped NGC 6992. Some areas are bright and well defined, while others fade and dissolve into the background like a sleepy ox-bow. While observing through my 8-inch on July 5th 1999, Daniel Martin, a member of the local RASC centre, described NGC 6992 as similar to a Crescent Moon. My best view of the fainter Veil component NGC 6960, about $2\frac{1}{2}$ degrees west-southwest of NGC 6992, was from the "Clam Shell," a friend's observatory south of Penticton, British Columbia. As viewed through his 16-inch f/4.5 Newtonian at 75× with an [O III] filter, the smoky

tendrils led me on a tangled trek. I followed one laced curve to its scattered end, and in trying to return to my starting point I mistakenly journeyed down another part of the maze, which turned out to be the unnumbered Nile-like section adjacent to NGC 6960. I have played over those five minutes of observing in my mind enough times to make a James Cameron epic.

NGC 7000, commonly called the North America Nebula, can be detected with the unaided eye in a dark sky three degrees east of Deneb. Use binoculars or very low power to bring out the distinctive continental shape of North America, with the Gulf of Mexico and Central America standing out very clearly. The apparently substantial cloud of mixed dust and gas composing the nebula is actually very rarefied, with a density of only a dozen or so hydrogen atoms per cubic centimetre. Spread over a 45 light-year diameter, the cloud is estimated to contain enough hydrogen to make a hundred suns. A narrow-band ultra high contrast (UHC) nebular filter makes a tremendous difference when viewing less well-defined areas of the object. Long dark lanes and bays are engulfed in a pale blue haze, while long wisps and streamers flow throughout, like cosmic contrails.

NGC 6888, the Crescent Nebula, is found southwest of Sadr (Gamma Cygni) in the body of the Swan. Through my 8-inch, three bright stars clustered closely together catch the eye at 67×, while a fourth star is revealed at 97× along with a slight hint of nebulosity. Again, the use of a UHC nebular filter is a great benefit here, as it enhances the distinctive crescent shape. The best view I had was at 163× using the filter to highlight the brighter region while sweeping in an arc around the three stars.

Unlike the sparse Messier clusters, the open cluster NGC 6819, located five degrees south of Delta Cygni, is unmistakable. When it floats into the field of view, you know you are looking at a cluster. Appearing at first to be smaller than its already diminutive 9´.5 diameter, this very rich cluster is actually made up of over 150 stars. Through my reflector,

the eye-grabbing compact central region shows a distinct U-shape consisting of a dozen or so brighter stars set within a fuzzy cloud of faint stars. Higher power (163×) will resolve the fainter stars to provide a very rewarding view.

If you are looking for a challenging planetary nebula (PN), the Cygnus *Finest NGC Objects* list offers two good candidates. Some PNs are rather difficult to find for planetary nebula-challenged types such as myself, but star hops to the two in Cygnus are fairly straightforward, so finding them does not take long. The Blinking Planetary, NGC 6826, is located due north of Delta Cygni at an almost mirror position of NGC 6819. The planetary acquired its name from the curious antics of its 10.6-magnitude O-type central star. With direct vision the star is bright and visible, but when using averted vision the bright nebula causes the star to blink out! Searching through broken cloud and first quarter moonlight, I located it using 97×, noticing a small, round and slightly creamy nebulosity with even surface brightness. At 163× the central star was resolved. The object is fun to share with others. Both serious observers and flat earth types alike will enjoy the novelty of this interactive planetary.

Usually when I am looking for planetaries, I hear the Yoda-like voice of Okanagan Centre president Ron Scherer whispering in my head, "use the colour Guy, use the colour." Sadly however, it is only after I find the object that I notice the colour. For those more in tune with the "force," NGC 7027 has a blue tint that stood out for Scherer, who found it July 7, 1999 with his 10-inch f/6 Dobsonian at only 60×. At that low power he described a "distinctive blue colour" and "even surface brightness," while at 121× he
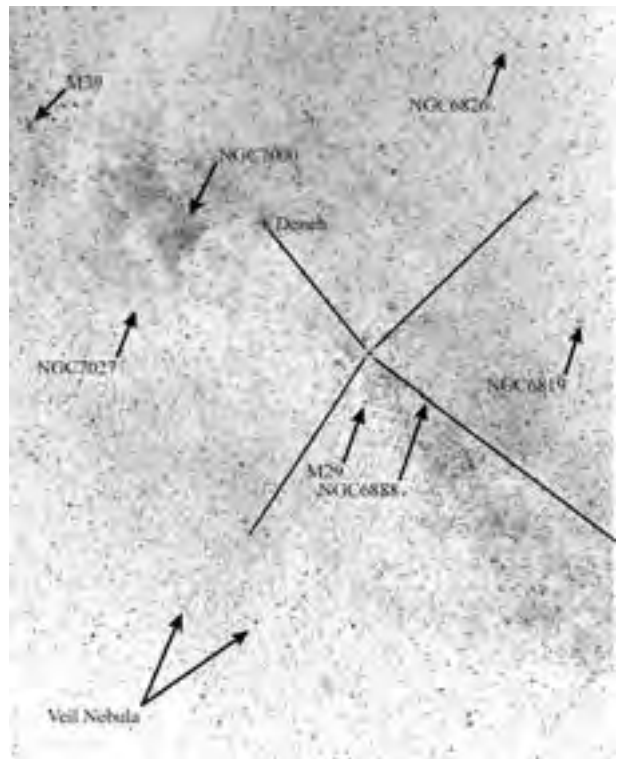
The locations for all objects discussed are identified in this negative image photograph of Cygnus. A ten minute exposure was used with hypered Kodak Technical Pan film and a 50-mm f/2.8 lens (photo by Dave Lane).

reported that "averted vision improved visibility, revealing a fading towards the edges" and even "hinted at the central star." I reached the planetary positioning pinnacle when locating NGC 7027. Travelling southeast from Deneb, I put the Telrad slightly offset from the mid-point of Xi and Nu Cygni, looked through the eyepiece, and there it was dead centre! At 97× it was stellar in my scope, but even I could not miss that hint of blue. At 163× it was round in shape.

The *Finest NGC Objects* list offers a varied and rewarding selection of targets in the constellation of Cygnus. Your search for all listed objects is certain to reveal many other astronomical delights in this rich area of the Milky Way encompassed by the Swan's eternal flight. ◉

Guy Mackie enjoys observing from the clear and dark hillsides near Kelowna, British Columbia. He recently completed the RASC Messier list, and over half of the Finest NGC Objects *with his 8-inch Dobsonian. He enjoys skiing, hiking, and camping with his family.*

Scenic Vistas:
Some Southern Globulars

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

As the nights grow shorter, though thankfully warmer in mid-northern latitudes, variety in observing returns once again. As many of you have no doubt discovered, spring observing is devoted almost exclusively to galaxies far beyond our own. With the Milky Way's return, open clusters, nebulae both bright and dark, as well as planetary nebulae, are numerous once again. So too are globular clusters, a fairly rare class of deep-sky object, which are nevertheless numerous enough and bright enough to be good targets for amateurs with small or moderate sized telescopes. Over 140 globular clusters associated with our home Galaxy have now been identified. The overwhelming majority of them are located below the celestial equator, seeming to hover around the centre of our Galaxy.

When considering globular clusters, I like to divide them into three orders of visibility. The first order consists of the large, often easily resolved, and for the most part nearby globulars, the majority of which can be found in the Messier catalogue. A number of these objects, such as Omega Centauri, 47 Tucanæ, and NGC 6397 are, unfortunately, too far south to be seen from Canada. The second order consists of clusters that were beyond Messier's grasp, though they were all discovered visually in the 18th or 19th century. These objects, though fairly bright, usually resist resolution in the typical amateur telescope, for reasons that will be discussed a little later. The third order consists of objects that are, generally speaking, beyond the easy grasp of amateurs. These objects were primarily discovered photographically, and exist in obscure catalogues with names such as Terzan or Palomar.

This article considers some representatives of the second order, which are interesting challenges for observers who want to go beyond the Messier catalogue
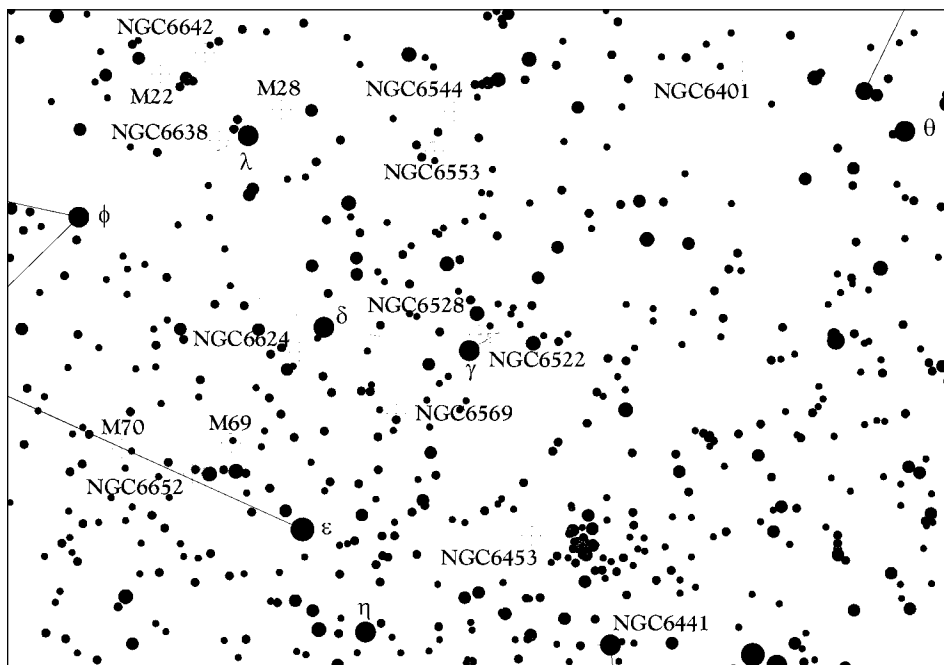
A 15° high finder chart in Sagittarius showing the location of many of the globulars discussed in the text. Stars to about 8th magnitude are shown (ECU chart prepared by Dave Lane).

this summer. While the objects are usually easy to locate, they are not easy objects to resolve into individual stars, even partially. There are a number of factors that conspire to create such a situation.

For northern observers, the first problem is a factor known as atmospheric extinction. The higher in the sky a deep sky object is located, the clearer the view we have of that object. When we are looking directly overhead, we are observing through a shorter column of air and consequently through less water vapour and dust. The closer we get to the horizon, the longer and thicker the air column becomes and the more water vapour and dust we have to contend with. An object located at a declination of twenty-five degrees south can easily appear two to three times fainter to a northern observer than it does to an observer in the southern hemisphere. All objects considered in the present article

are located at declinations between −7°.5 and −37°.

The second factor is the globular cluster's concentration class. Some globulars appear as tightly compacted balls of light, others are much more loosely structured with little concentration towards the centre. A scale running from I (most compressed) to XII (least compressed) exists to describe a globular's apparent visual concentration. Generally, the looser a globular cluster is, the easier it is to resolve, given a sufficiently large aperture. Globulars with concentration classes of I or II are usually easy to observe, but almost impossible to resolve. Globulars with concentration classes in the XI or XII range are often so loosely structured that they become very difficult to see in small telescopes.

The third major determinant is interstellar absorption. As our own atmosphere is a rather dusty place, so too

is our Galaxy. When a globular star cluster is located near the plane of our Galaxy (as the majority are), its brightness is diminished depending on its distance and how much intervening gas and dust exist to absorb the cluster's light. A globular cluster such as M3, which is located high above the galactic plane, is subject to very little interstellar absorption, whereas some globulars located in the heart of Sagittarius can easily have their brightness diminished by three magnitudes!

The fourth factor affecting resolution is the intrinsic faintness of the stars populating globular clusters themselves. Most globular clusters lie anywhere from 7,000 to 80,000 light-years from Earth. Even bright, easily resolved globulars such as M5 and M13 are so far away that they rarely have component stars brighter than magnitude +12 to +14, pretty much the limit for small amateur telescopes. Clusters where the brightest stars are magnitude +15 and fainter remain stubbornly irresolvable, no matter how big or bright the globular cluster itself appears.

The following clusters have all been chosen primarily because they are easy to find. In almost all cases they are located a very short distance from a bright, easily-identified field star. Two of the clusters are located close to the Lagoon Nebula, a popular summertime target of many observers. Information on distance or interstellar absorption appearing here have been taken from *Hartung's Astronomical Objects for Southern Telescopes*, an indispensable, modern resource for the dedicated observer.

Our first two targets are located immediately northeast of Nu Ophiuchi. NGC 6517 is a difficult object which I observed on the night of July 24/25, 1992 from northern New Brunswick. Through a Celestron C-8 on a night of poor seeing and even poorer transparency, the globular appeared as little more than a weakly concentrated glow, difficult to hold with direct vision and with poorly defined edges. Though small, under ideal conditions a brighter core should be visible. The cluster is viewed through 3.5 magnitudes of interstellar absorption, and its distance is about 23,000 light-years. About two degrees to the northeast, one comes to NGC 6539, a cluster cursed with the same problem of

absorption. On that same July night I described the cluster as: "Very, very weak nebulous glow, visible with certainty only with averted vision. With direct vision a faint, star-like core shines through. Field located with certainty. Observation very difficult." Your best bet is to wait for an evening of good transparency to tackle these two objects.

Most observers are familiar with M4, since it is easily located west of the brilliant star Antares, but a smaller globular cluster is located even closer to Antares, immediately to its northwest. NGC 6144 will be a challenge because the region is bathed in faint nebulosity, and light scatter in your telescope from nearby Antares could pose a problem as well. Use high magnification and try to keep Antares out of the field of view. In my 15-inch (37-cm) reflector, I found the cluster faint and diffuse, located due east of a magnitude 10 field star. A little brighter to the middle, the globular was elongated north-south. Although resolution did not seem possible, one or two faint stars were visible embedded in the nebulous envelope, and the glow appeared grainy, a sure sign of stars just below the threshold of resolution. *Hartung's* rates the absorption as 1.3 magnitudes and the distance at about 26,000 light-years.

Just east of the Stinger of Scorpius, observers will come upon the third magnitude star G Scorpii. The field of this bright orange star is shared by the globular cluster NGC 6441. It is a remarkably bright object that never rises more than 7°.5 above the southern horizon when viewed from Montreal. Despite that, its light is able to cut through heavy atmospheric extinction even in a light-polluted environment, as I discovered in 1989 when I observed the cluster from the backyard of my Dorval home.

Southeast of the brilliant Lagoon Nebula in Sagittarius, the observer will find two globulars well worth seeking out. NGC 6544 is a fairly bright, irregularly round globular that is also visible under less than ideal conditions. Its brightest stars shine at magnitude +12.8, but from my Dorval backyard the nebulous haze appeared granular in my C-8. The cluster may be partially resolvable from a dark-sky site.

NGC 6553 is a bright, loosely structured globular cluster, elongated northwest-southeast. From my Robertville, New Brunswick observing site in July 1991 it appeared as a fairly smooth, well-defined object with a centre that brightened very gradually, with a 10th magnitude foreground star visible on the northwestern edge. The brightest members shine at +14.7 magnitude, too faint to be resolved with a 20-cm aperture.

Immediately northwest of Gamma Sagittarii is a sight that I believe is unique in the sky: two globular clusters visible together in a medium or high power field. NGC 6522 and NGC 6528 are bright enough to cut through suburban light pollution, and I made an observation of the two clusters from my Dorval backyard in June 1989 with a Celestron C-8. I was able to observe both clusters in the same field using a 12.4-mm eyepiece magnifying at 161×. NGC 6522 is the larger and more conspicuous of the two, being round with a fairly even surface brightness, and not exhibiting a brighter core. NGC 6528 is close to the threshold of vision under such conditions, about half the size of NGC 6522 and quite irregular in shape.

My ninth and final selection is NGC 6638, a cluster located immediately east of Lambda Sagittarii. This rather loosely-structured, class VI globular is small and rather faint, especially in suburban skies. In my old C-8, the cluster appeared round with just a hint of a brighter core. The brightest stars of the cluster shine feebly at magnitude +15, and NGC 6638 lies a little more than 29,000 light-years away.

The preceding sampling is fairly typical of the quarry available to the amateur astronomer in this extraordinary region of the sky. There are many NGC globulars in the region that are brighter, and others that are fainter that will test the patience and determination of even the most seasoned observer. I invite all of you to get out under the stars this summer to embark on your own personal voyages of discovery. ◉

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.

Observing Programs

by Douglas Stuart, Thunder Bay Centre (doug@lakehead.net)

A New Observing Certificate

There has been some discussion recently in the Society about the creation of a certificate for beginning observers. The Thunder Bay Centre has a newly minted certificate of that type, unofficially called the Bronson Observing Certificate after the person who designed it. I have attempted the required observations myself, and have found that they provide an excellent foundation for the required observing skills needed to pursue more advanced projects, like the Messier certificate program.

It is a well-rounded observing program that teaches good note-taking skills. Observers need to record the direction, elevation, colour, magnitude, and size of observed objects, in addition to time and date. I have been a serious observer for the last six years, but had never bothered to estimate stellar magnitudes or to observe double stars. I found the experience to be both entertaining and interesting.

The necessary observing instrument ranges from the unaided eye to binoculars, with a telescope required for most of the double stars. What is particularly interesting about the program is that it consists of individual segments. Observers do not have to complete all of the requirements before they receive the certificate, just one of its segments. Additional signatures are added to the certificate as more of its segments are completed, until the last segment is added. The observer then receives a gold seal to complete the certificate.

The segments themselves cover the full spectrum of targets, from major constellations and stars to a sampling of brighter Messier objects. Other segments are dedicated to the planets, double stars, and all-encompassing astronomical events, such as solar and lunar eclipses, auroral displays, planetary conjunctions, meteor showers, and satellite observations.

My Early Observing Efforts

Even when one owns a telescope, the best place to start is with binoculars. Long before I joined the RASC, I used to sweep the band of the Milky Way with binoculars from my backyard. Although I did not know any of the constellations, it did not matter. It was still fun to do. At the time I used an inexpensive pair of 16×50 binoculars, and light loss and poor eye relief made them difficult to use.

When I began more serious observing, the *Observer's Handbook* indicated that the minimum requirement to view all 110 objects on the Messier list was a 4-inch telescope. That did not appear to be a problem, since I owned a 4-inch Schmidt-Cassegrain telescope. Many members of the Society do not, however, and even as a dedicated observer it still took me a year and a half to complete the Messier observing project.

Good Binoculars on Messier 110

I recently purchased a pair of good-quality binoculars. The sharpness and brightness of objects viewed through my new Nikon 10×50 binoculars is breathtaking in comparison with what I could see through the older pair of $50 binoculars I had been using previously. It was possible to see M33, the galaxy in Triangulum, just from

The author with his new 10-inch Dobsonian and his 4-inch Schmidt-Cassegrain.

the backyard. From the countryside I can see the Veil Nebula as a broken ring shape. The experience inspired me to attempt something that is considered to be impossible — observe all 110 Messier objects through 10×50 binoculars. Recall that the *Observer's Handbook* recommends a 4-inch telescope as a minimum requirement to observe all of them.

As it turned out, I was able to observe over 30 Messier objects a night for the first couple of sessions. I was delighted. I quickly concluded that binoculars are great for Messier observing. One finds instant gratification in hopping from one deep-sky object to another in a matter of seconds. With that type of enthusiasm, it was not long before I completed the

The author shows off his trophies: the Messier Certificate (lower right), the Finest NGC 110 Certificate (upper right), and the Bronson Observing Certificate (at left). The details of the latter observing program are on the Thunder Bay Centre's web site.

All Binocular Messier Project. As a caveat, however, it was necessary to do most of the observing from the countryside. For those interested in trying it for themselves, I found M99 to be the most difficult object on the list.

NGC 110 with a 4-inch Telescope

There are limits to what can be accomplished with binoculars. The *Observer's Handbook* contains another observing list that is referred to as the Finest NGC 110. A warning indicates that a 6-inch aperture is required to find all of the objects on the list. When I read that statement four years ago, I assumed it to be valid and put off attempting observations of the list. I considered it to be a waste of time to initiate a project I felt I would be unable to finish.

I eventually decided to try to observe as many of the objects as possible with my 4-inch telescope. One of the first on the list is NGC 6888 in Cygnus. There was nothing there! (NGC 6888 is generally regarded as the most difficult object on the list, but I did not know that at the time.) That negative detection only reinforced my concerns about the 6-inch aperture requirement. I searched for a few additional objects — mostly planetary nebulae. They were not very impressive. Since I was using the telescope from my backyard and since I live in a city, light pollution was making my observations very difficult. I felt, however, that the Lumicon Deep Sky filter I was using would eliminate the effects of light pollution.

Persistence does pay off, however, and eventually I was able to go back and make that observation of NGC 6888 with my 4-inch telescope from the city. It was just marginally detectable on the second occasion. The amount of humidity in the air magnifies the effect of light pollution, and I have found that the best deep sky views are those when the humidity is at 50% or less. That does not happen very often where I live, for which I blame Lake Superior.

I found galaxies much easier to detect than planetary nebulae or emission nebulae. Since the NGC 110 list is comprised mostly of galaxies, it was not long before I was able to complete observations for the list. In retrospect I would not have taken the stipulation of 6-inch telescope requirement so seriously. I could have completed the NGC 110 list a year earlier otherwise.

The Future

Last year when I felt that I had reached the full potential of my 4-inch telescope and my new binoculars, I had two choices: be content or get a bigger scope. I decided upon a bigger telescope. I purchased a 10-inch f/4.5 Dobsonian, and I am now anxious to go back and observe all of the Messier objects and the Finest NGC 110 list with the 10-inch to see what I was missing using smaller aperture instruments.

Conclusions

Six years of experience in observing have led me to the following conclusions.

1. Never believe someone who says that an object in question cannot be seen with the equipment you have, until you attempt it yourself.

2. A "small" aperture telescope is capable of ambitious observing projects.

3. A pair of binoculars can be a legitimate observing instrument, provided they are of good quality.

4. The extra effort it takes to observe from the countryside is worth it, since it becomes much easier to find objects and they are more spectacular when viewed.

5. A Lumicon Deep Sky filter does help, but not nearly as much as leaving the light pollution behind. ◉

Doug Stuart joined the RASC in his last year of university, and was recruited into the local executive of the Thunder Bay Centre almost immediately. Following four years of promoting club activities, giving presentations, writing articles for the local newsletter, and attempting eyepiece projection astrophotography, he took the next two years off to concentrate on deep sky observing programs. He is now back as Vice-President of the Thunder Bay Centre, collecting more photons than ever before with his new 10-inch Dobsonian.

Reviews of Publications
Critiques d'ouvrages

Magnificent Universe, by Ken Croswell, pages 192 + xviii, 27 cm × 36 cm, Simon & Schuster, 1999. Price US$60, hardcover (ISBN 0–684 –84594–6).

My first impression of this book was that it was yet another, pretty, coffee table book with the usual collection of repeated astronomy prints. The dust cover praise for the book, however, hinted at a difference. Most of the comments on the back and in the fold edges praise the book's text, as well as its pictures. I found that somewhat unusual, and yet, as I was to discover, well deserved.

The book uses the normal "here to there" approach of introductory astronomy textbooks, first exploring the planets of our solar system, then moving on to the components of our Galaxy, then outward to extragalactic matters and the rest of the universe. That is common enough. After the first few pages, however, I began to see a difference. I was turning the pages, and concentrating on the text! In some cases I found myself looking back to see what the previous page's photograph had been, which is most unusual for me. I had expected the rather bland and predictable descriptive comments about each image, but as I read, I found myself immersed in a concise, colourful examination of the cosmos. Not only were the important facts well laid out, but the text was also nicely sprinkled with interesting tidbits — you know, those odd little facts that lecturers crave for holding students' interest. For example, did you know that a pebble, dropped from waist height onto the surface of a white dwarf, will impact at 4000 miles per hour, or that the same

pebble dropped from the same height onto a neutron star would impact at 5 million miles per hour?

Such attention to quality, with such well thought out and complete text, sets Croswell's book apart from many of the other books of the same format I have browsed through. Indeed, the text of the book would be able to stand on its own as a layperson's guide to the current science of astronomy. Well done!

The images are also impressive. After all, this is a coffee table book with lots of pretty pictures, right? You bet it is. There is a good selection of the best *Hubble Space Telescope* images of the last few years, impressive images from many of the major observatories, as well as the best space probe images of the worlds of our solar system. Each image has its own page, and is scaled to deliver maximum impact in this large format book. The paper is of high quality, with a semi-satin finish, framing the glossy photographs. It is a beautiful combination.

I suppose I should find something to criticize. For example, I can point out that some of the images, such as the image of the Trifid Nebula on page 60, have the common problem of over-saturated colour. It is not as bad as in some images I have seen, but I would have turned down the saturation a bit nevertheless. I suppose it is a very subjective thing.

One other item is somewhat annoying. Since I do a lot of reading in bed, I found it to be almost impossible to get comfortable with the book in that location because of its large format. It is simply too large to lie back and read! Nevertheless, Croswell is to be congratulated for an excellent book that I highly recommend to anybody looking for a pleasant and informative read, as well as a beautiful showpiece for the coffee table.

DOUG PITCAIRN

Doug Pitcairn is a technician in the Faculty of Architecture at Daltech, the technical component of Dalhousie University in Halifax. An avid astronomy enthusiast, he also teaches astronomy part-time at Saint Mary's University.

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Sky Atlas 2000.0, by Wil Tirion and Roger Sinnott, pages 31, 42.5 cm × 31 cm, Sky Publishing, 1998, Second Edition (deluxe version). Price $77.95, wirebound in leatherette cover (ISBN 0–933346–87–5).

It must be in the genes. My father was a collector of maps as well as a stargazer. In stargazing his interests were casual, and a little paperback by Newton Mayall suited his purposes. The feature of that book (*The Sky Observer's Guide*, now out of print) which stood out so much for me was the star map on its last eight pages. The black stars with their Greek letters and the network of constellation boundaries were particularly fascinating. It was the only star map in my life until the eve of my first serious star party, when it became clear that I would have to acquire something more wide-ranging. That was Wil Tirion's *Sky Atlas 2000.0.*

Sky Atlas 2000.0 (first edition, 1980) took its inspiration from *Atlas Coeli 1950.0* (Atlas of the Heavens), produced in 1948 under the direction of Antonin Becvar. *Atlas Coeli* was one of those enviable successes in publishing, where an empty niche was filled by the right work at the right time. Good timing favoured *Sky Atlas 2000.0* as well, appearing as it did when *Atlas Coeli* had grown long in the tooth, but I think *Sky Atlas 2000.0* would have done well anyway. According to Tirion's remarks in *Sky & Telescope* at the time of publication, I suspect that ambitions of the highest order were at work. Work

on the atlas brightened a period in Tirion's life when he, like many, people tend to judge themselves too harshly.

Such an exacting task as hand-plotting a star atlas grinds away any tendencies towards the radical. Indeed, the symbols, format, style, and even the title of *Sky Atlas 2000.0* were virtually copied from *Atlas Coeli*. It contained almost the same number of deep-sky objects, about 2,500, and a modest increase in identified stars, about 43,000. Much was made of Tirion's method of displaying the spherical surface of the celestial sphere in flat projection, but I think a greater impact resulted from two layout changes. First, three separate sheets replaced the usual polar sky chart centred on Polaris. Second, the amount of sky depicted on each sheet was reduced by thirty percent. Distortion was therefore brought completely under control, without compromising the illusion of panoramic coverage. In the Becvar atlas the Big Dipper is stretched; in Tirion's it is realistic. One should not think of *Sky Atlas 2000.0* as the Nagler of star maps, though. Quite the contrary, each of Tirion's sheets enclosed less sky than did Becvar's, so there had to be more of them.

Although Tirion's charts were made available in a number of formats, they were all issued on 15-inch by 20-inch sheets of heavy cream-coloured paper, and all were printed single-sided. Leaving the backs white not only made the charts more readable, but the starfields could also be reversed by the expedient of turning the sheets over and illuminating them by backlighting. The basic format was a stack of loose sheets, with a choice of white stars (the field version) or black stars (desk version). For more money there was the "deluxe" version, a coloured version with the charts folded over and bound with wire, and if you were willing to pay extra you could obtain the laminated version. Most users seemed to prefer the loose sheets. The observatory where I work had many sets of the black-on-white charts, and over the years a number of memorable comets and novae were pencilled on them. By swapping sheets, I could probably make about two complete

sets today.

Like all classics, *Sky Atlas 2000.0* had its weaknesses. The charts were ordered by right ascension instead of the more natural east-to-west order, and in the deluxe version there was the additional bother of unfolding the pages. The charts were not numbered on their backs, and there were no guide numbers along the edges to help the user locate the adjoining ones more easily. The perpetuation of such irritations in the revised edition is a shame.

Nevertheless, Tirion and Sinnott have brought us a second edition materially superior to the first. Superficially the atlas looks the same with its 26 single-sided sheets, but in fact it has been redesigned. The detailed maps have been enlarged and moved into an appendix along with new close-ups of the Virgo cluster of galaxies and the celestial poles. The magnitude limit has been taken half a step deeper to 8.5, allowing 40,000 more stars to be included. Even the transparent overlay has received attention. It is made of better material, and its co-ordinate grids match the charts more precisely. Even better, a magnitude scale and Telrad rings have been added.

Although it is not obvious at first glance, the star fields have been rendered with greater delicacy. About ten years ago *Sky & Telescope* printed some letters criticizing the practice of "binning," or rounding star magnitudes to whole numbers. For example, a magnitude 4.44 star would be assigned a larger dot than a magnitude 4.45 star of nearly the same brightness. Moreover, the magnitude 4.44 star would get the same dot size as a much brighter magnitude 3.45 star. The point was taken. Smoothly scaled dots are now being used, and differences of a tenth of a magnitude can be distinguished with calipers. In an attempt to approximate the eye's response to starlight, the magnitude-scaling law has also been doctored so that the brightest stars are larger than before and the faintest ones smaller. Without those changes the infusion of forty thousand stars would certainly have ruined the atlas. Indeed, the star fields appear even more realistic now, a

quality best appreciated on those exceptionally fine nights when a thousand stars are shining in your finder scope.

Alan Whitman points out additional enhancements: dark nebulae like the Pipe and the Snake have appeared, and the Milky Way has been rendered with more shades of blue. Oddly, the Milky Way contours have been deleted from the untinted field versions, and only the galactic equator is plotted. I have not yet examined the untinted desk version to see if it also lacks the contours.

The new *Sky Atlas 2000.0* appears to have a satisfactory selection of deep-sky objects for visual work, with 1,540 galaxies plotted. Deep-sky observers will be pleased to know that all of the galaxies have been redrawn to their true sizes and orientations. I know many readers who use *Sky Atlas 2000.0* with *Burnham's Celestial Handbook*, so I checked the Virgo galaxies in that popular guide against the atlas. Every galaxy brighter than magnitude 12.9 was plotted, with some of the fainter ones appearing in the Virgo cluster enlargement in the back of the atlas. In Fornax and Tucana, however, the correspondence is less consistent. *Burnham's Celestial Handbook* lists some faint field galaxies that failed to make the cut in the atlas, and the atlas has NGC, IC, PK, ESO, and Morphological Catalogue objects that are not in *Burnham's*. Another coverage gauge is the "Challenge Object" list in the *Observer's Handbook*. Of its 45 entries, 33 are in the atlas.

If you still believe that a magnitude 8.5 atlas is not a useful tool for deep-sky work, perhaps you are too comfortable. Once I needed a short observing project for a night that had grown unexpectedly cold, so I decided to go galaxy hopping inside the bowl of the Big Dipper. That was the night I finally came to appreciate the selection of objects in my *Sky Atlas 2000.0*. A tome like *Uranometria*, with 50 galaxies in the Dipper's bowl alone, would keep the observer squinting until he or she froze solid and tipped over with a loud thud. *Sky Atlas 2000.0* has twenty, which is just right.

Sadly, the authors have continued to exclude the constellation figures. One

night a colleague and I went looking for NGC 6888, a nebula in Cygnus shaped like a disembodied ear. The colleague knew that the nebula lies on a line between two of the stars in the Northern Cross but could not remember which two. When I opened his copy of *Sky Atlas 2000.0* to look for it, I noticed that he had boldly drawn in the Cross and all the other constellations!

Is a laminated atlas a good investment? Perhaps it is. Those of us who work inside drippy domes could benefit from the extra protection. You can also write on one with a grease pencil, something some people like to do when planning their observing projects. A colleague thought that was a good idea, and took his unbound field sheets to a service bureau to have them laminated. That proved to be a mistake. Sky Publishing's product is less expensive and nicer. Personally I do not know why anyone would pay the huge premium. Laminated copies of *Sky Atlas 2000.0* tend to be heavy, unwieldy, and extremely difficult to read by flashlight.

Are the colours worth the extra expense of the deluxe version? Yes, they look great, and the blue Milky Way tints work particularly well under a red flashlight. But are they essential? In my view, no.

Should I get black stars or white stars? I agree with Paul Markov's preference for the former (JRASC, December, 1999), and would add that a field of shiny black ink tends to pick up an annoying bloom when a light is held over it. On the other hand, some observers dislike the temporary loss of night vision that follows an examination of a mostly white chart. (In fact the paper is too white! The publisher should tone it down.) If you cannot decide, be assured that both types have been used successfully under the stars.

Despite the improvements, I am obliged to note that the finest computer-aided design tools cannot recapture the human touch. Such a negative opinion is likely to be challenged, so I showed copies of both editions to my wife and persuaded her to take a Tirion taste test. She is not particularly interested in astronomy, but she is a more reliable arbiter of aesthetic issues than I am. She is also more farsighted — in the ophthalmological sense. It was "no contest." The older edition received her nod for its clearer typefaces, bolder star dots, sparser use of tint, and more mellow paper.

Similar design tools were applied with similarly unfortunate results to the mighty *Millennium Star Atlas*, Tirion's stable mate at Sky Publishing. The *Millennium Star Atlas* is ruthlessly accurate — after the *Hipparcos* mission, there can be no excuses — but it is also dull. The *Millennium Star Atlas* approaches that stylistic nadir. It is accurate and useful, even attractive, but desiccated.

On the other hand, the use of *Hipparcos* data should remove all doubt about the faithfulness of the star fields. A clumsy merging of star catalogues can seriously mar an atlas, for example, see the unmistakable break along the −23° line in *Uranometria*. Although *Hipparcos* brings thousands of new stars to *Millennium Star Atlas,* the temptation to carpet the charts with deep-sky objects has thankfully been avoided. Only a few hundred have been added.

Amateur astronomers looking for a good first atlas will find the revised edition of *Sky Atlas 2000.0* a useful and rewarding companion for the telescope.

Dan Collier

Dan Collier is a councillor for the Vancouver Centre. He claims to have a photographic memory for terrestrial maps, but is hopeless with star fields, being unable to find the Double Cluster or M101 by memory alone.

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From White Dwarfs to Black Holes: The Legacy of S. Chandrasekhar, edited by G. Srinivasan, pages xiv + 240, 16 cm × 23.5 cm, The University of Chicago Press, 1999. Price $US40. Hard cover (ISBN 0-226-76996-8).
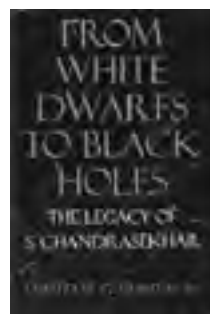
Warning! This is a frightening book. It begins innocently enough. "Subrahmanyan Chandrasekhar was a legend in his own times," we are told in the Preface. "He was one of the colossal figures of 20th century science." Practically everybody who is anybody in 20th century astronomy or physics is mentioned in the book, because Chandrasekhar's remarkable, wide-ranging career touched them all — from Eddington and Struve to Hawking and Sagan. But to amateur astronomers with a bent for theory and to undergraduate students who dream of one day publishing research papers, Chandrasekhar is best known for work done early in his scientific life, in which he established the "Chandrasekhar limit" for the mass of a white dwarf star. Srinivasan, the editor, explains in the Preface that Chandrasekhar followed a pattern of focussing on a specific topic for a few years and then writing a major book that summed up the state of modern knowledge on the topic. Chandrasekhar did that eight times from 1929 to 1995, moving from stellar structure to stellar dynamics and eventually to relativity, black holes, and gravitational waves. As if that were not enough, Chandrasekhar was managing editor of the *Astrophysical Journal* from 1952 to 1971, and he even won a Nobel Prize in 1983.

But by page 3, the terror of advanced theory will have most readers cowering in their armchairs. The easiest sentence among five daunting equations informs us that "Chandrasekhar became aware of Fowler's seminal paper in 1929, and immediately applied the theory of polytropic gas spheres to the new equation of state and derived the mass-radius relation for completely degenerate white dwarf configurations." If panic has not set in by that point, do not relax, because the equations become even more intimidating: there are double integrals on page 56, a vector curl on page 110, and the "tensor virial equations" on page 134, a blood-curdling family of nine equations, written as one, that has four different uppercase symbols, two lowercase symbols, two more summation subscripts, six Greek letters, two integrals, and a double derivative

with respect to time!

And yet, the book is not merely a recapitulation of Chandrasekhar's research papers. In fact, Chandrasekhar did publish *Selected Papers* in no less than six monstrous volumes prior to his death in 1995. It is unlikely that anyone would read *Selected Papers* in order to gain a thorough overview of Chandrasekhar's scientific work, so this book serves that purpose. The eleven chapters in the book were, in fact, presented as papers in a special issue of the *Journal of Astrophysics and Astronomy* in 1996. Each chapter is by a different author, each an expert in one of the fields to which Chandrasekhar contributed. Each author summarizes the state of their field before Chandrasekhar joined the fray, then describes in some detail what Chandrasekhar contributed, and also explains what progress has been made by more recent researchers. And the authors did not restrict themselves to menacing the reader with theory. Excellent anecdotes, both personal and technical, abound in this volume. Donald Osterbrock's paper on Chandrasekhar's years as a teacher at Yerkes Observatory is the easiest chapter to read and very enjoyable; so much so that I recommend it — independent of the rest of the book — to anyone who has an interest in this aspect of 20th century astronomy.

I cannot imagine that there is much of an audience for this book outside of professional astronomers. Most casual readers would be intimidated by the theoretical content. Almost anyone who is capable of understanding Chandrasekhar's work already has access

to the issue of the *Journal of Astrophysics and Astronomy* that contains the same papers. And almost anyone who wants to avoid hiding under the covers but is interested in Chandrasekhar as a historical figure will read *Chandra: A Biography of S. Chandrasekhar* by Kameshwar C. Wali (University of Chicago Press, 1991) instead. However, in some ways this book is better than Wali's. For instance, there is a famous story that Chandrasekhar taught an entire course to just two students — who each ended up winning a Nobel Prize — but Osterbrock tells the legend more accurately (on page 205) than it is told by Wali (on page 17). And Chandrasekhar's personality does come through. He was a quiet, elegant, stern, profound man, whose students and colleagues lived in awe (or fear!) of his talent. I wish there had been more quotes from Chandrasekhar himself. Chandrasekhar's own words on a wide range of topics, even including Shakespeare and Beethoven, can be found in the excellent book *Truth and Beauty: Aesthetics and Motivations in Science* by S. Chandrasekhar (University of Chicago Press, 1987). And thank goodness Chandrasekhar had a warm sense of humour to temper his amazing mathematical genius. Another important resource for understanding Chandrasekhar is the delightful spoof paper "On the imperturbability of elevator operators: LVII," which is mentioned by both Osterbrock and Wali but which is only reprinted in *A Random Walk in Science* by R. L. Weber (Institute of Physics, 1973). (Sadly I could not find the parody posted on the World Wide Web.)

I confess that the theory presented in the volume paralyzed me with horror, but I relished the book nonetheless. I used to dream that I would wake up one magic morning and suddenly find that I could understand that kind of mathematics, but until that day, I will have to read a book like this in a very special way, skipping over the equations the way I might avert my eyes when a snarling velociraptor lunges toward me on the movie screen. Try to read this book — if you dare.

Peter Jedicke

Peter Jedicke is Honorary President of the London Centre and the Society's National Recorder. He failed 3rd year applied mathematics twice.

Erratum: Observing Variable Stars: A Guide for the Beginner, by David H. Levy.

The review for this book published in the last issue (JRASC, 94, 74, 2000) contained one typographical error and one unexplained statement. The typographical error occurs on page 76, where reference is made to "BB Herculis variables." The correct designation for luminous Cepheid-like supergiants of the type indicated is UU Herculis variables. On page 75 reference is made to P Cygni being a challenge even for photoelectric observers. The reason for that derives from the fact that much of the time the amplitude of the star's variations is much too small to be detected by visual observers. ◉

Astrocryptic #7

by Curt Nason, Halifax Centre

ACROSS

1. Users are confused after a bit of peering at the galactic arm (7)
5. He was in the community chosen for Uraniborg (5)
8. A bad thing to see or to lose when observing (5,6)
10. Lord of astronomy finds Eros around south (5)
11. The first name in quantum electrodynamics is wealthy and mostly hard (7)
12. Proser rewrote the law on sunspot migration (6)
14. Around short months I am somehow viewing a variable in the Cross (6)
17. Copper found in odd piles of a gas jet (7)
18. Hare star appears in an irregular nebula (5)
20. Argon viability is unlikely cause of stellar inconstancy (11)
21. Aspen is poorly situated for viewing tides (5)
22. Not quite noon when Mostel obtains a positive result, perhaps (7)
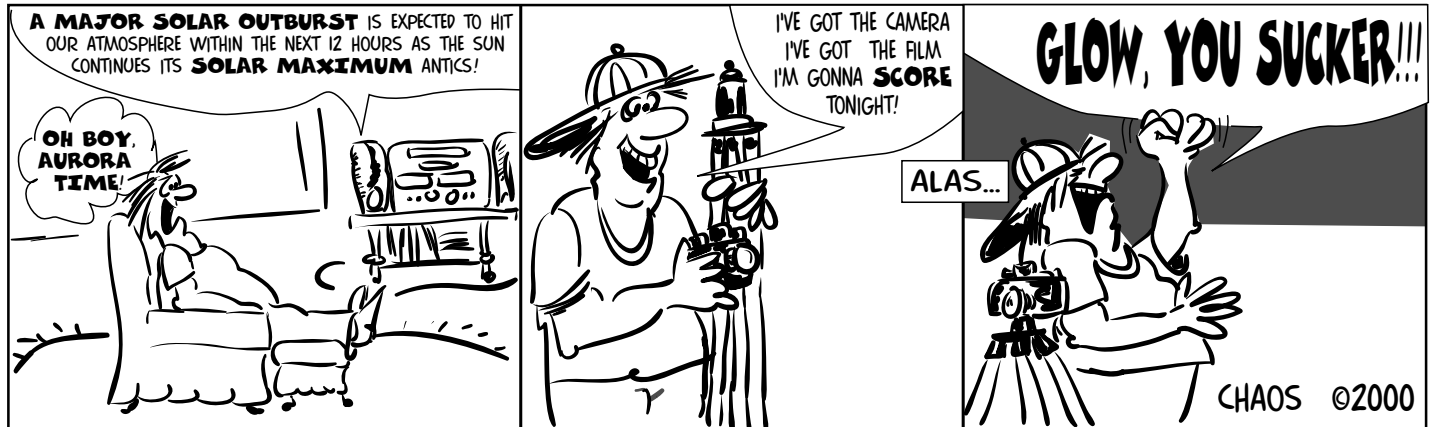
DOWN

1. Unusual solar pi mesons detected from a star (7)
2. Phones for gas giant phenomena (5)
3. HST resolves a blue angel east of Serpens (5,6)
4. Uranus soundly dropped you for tea and somehow begat a son (6)
6. Yerkes' university was stylish in the past (7)
7. Bought a telescope in downtown Edinburgh (5)
9. Bent off the ecliptic (11)
13. Sicilian misrepresented Io and Re in his ephemerides (7)
15. Endless borealis obscures the colourful double star (7)
16. Area stretching from the start of Regulus to the end of Orion (6)
17. First woman in bipolar situation with stellar sisters (5)
19. Bright galactic classification recorded in county periodicals (1,4)

Cartoon Corner

ANOTHER SIDE OF RELATIVITY

Once again an enthusiast gets seduced by the solar windbags...

Cartoons contributed by Dan Collier, Vancouver Centre
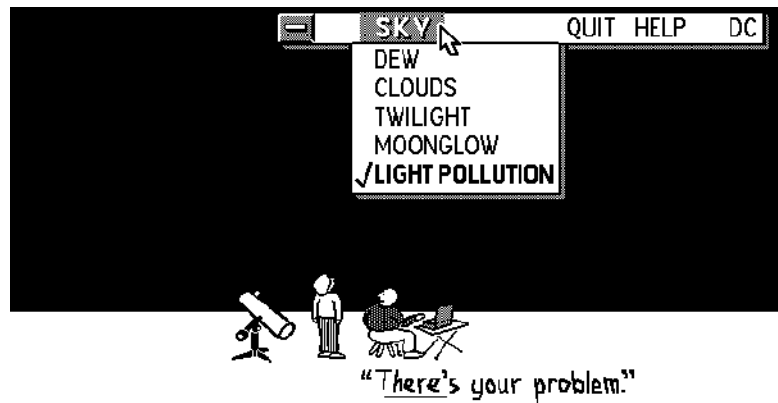
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Observer's Calendar — 2000

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: $14.95 (members); $16.95 (non-members)
(includes taxes, postage and handling)

The Beginner's Observing Guide

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

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

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

Promotional Items

The RASC has many fine promotional items that sport the National Seal. Prices include postage and taxes. Included are a *Cloth Crest* (size 11cm with the background white and the stitching in royal blue - $11), *Lapel pins* (blue, white, and silver - $5), *Golf shirts* (white, available in small and medium - $24), *Stickers* (size 7.5cm, blue with white overlay - $1 each or 2 for $1.50), *Thermal mugs* (in blue and white - $5.50), *Toques* (Black with Yellow lettering - $17), *Key chains* (Clear arcylic and Blue/white - $2.50).

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