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Journal

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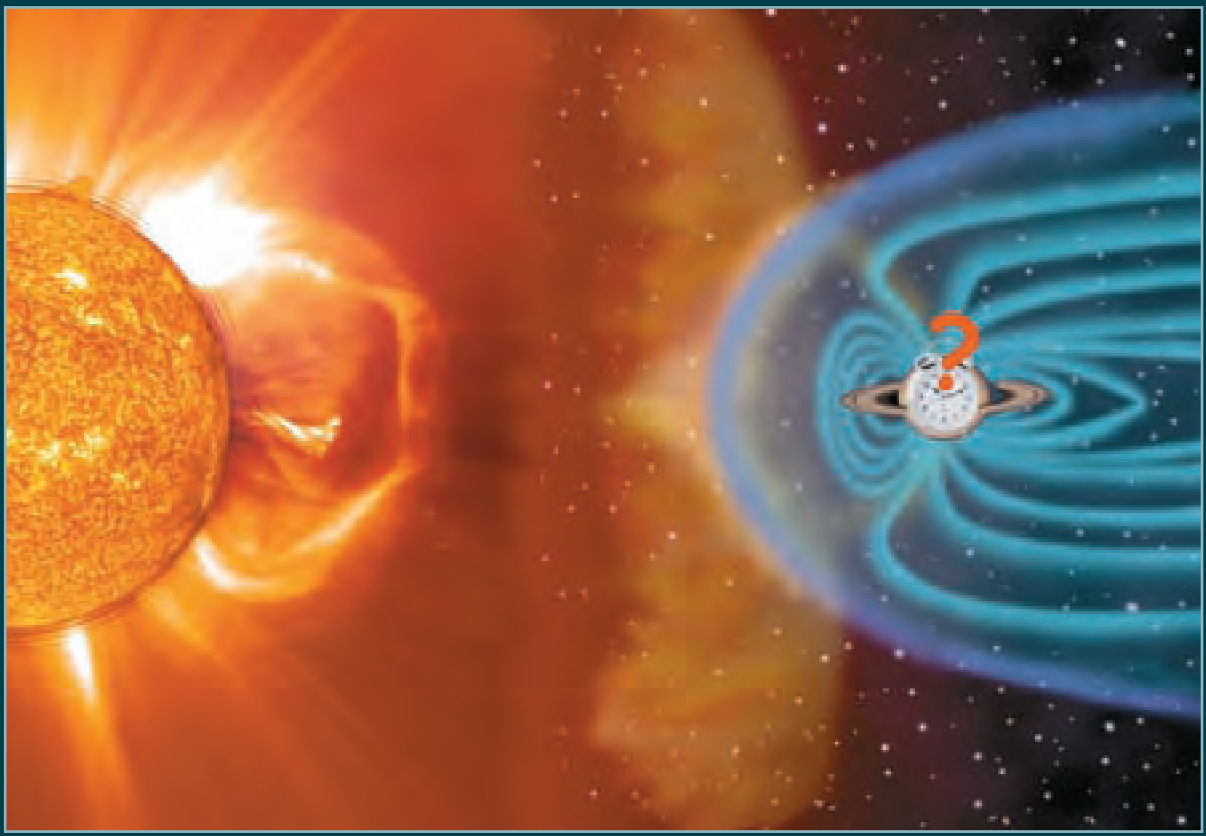

Le Journal de la Société royale d'astronomie du Canada

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CELEBRATING 100 YEARS OF PUBLICATION

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Journal

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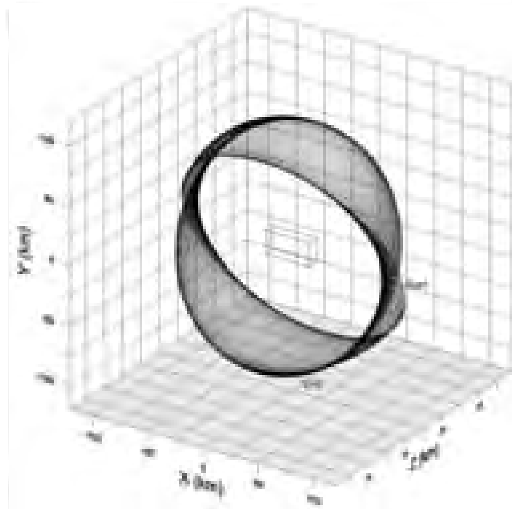

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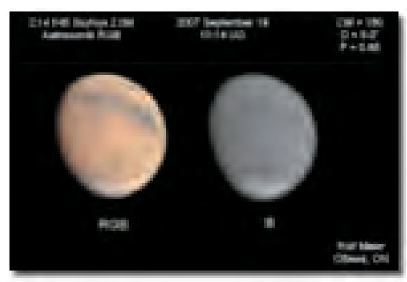

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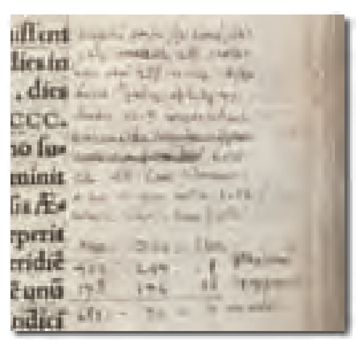

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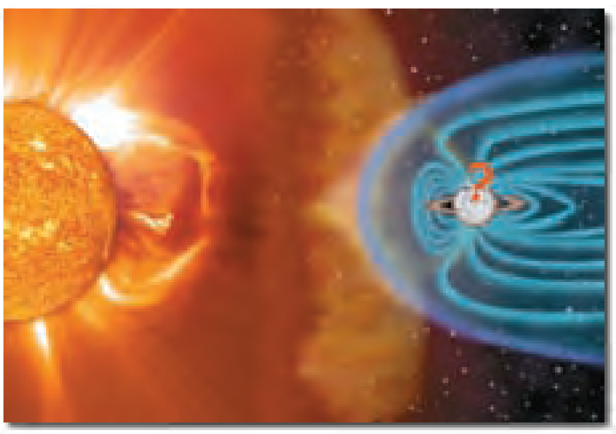

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An artist's illustration of the solar wind hitting Saturn's magnetosphere, and affecting its "clock rate" as measured by its radio period. Courtesy of Philippe Zarka and the Observatoire de Paris.

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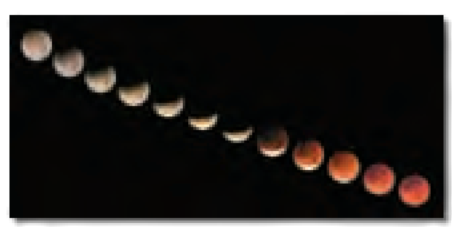

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Editorial

by Jay Anderson, Winnipeg Centre (jander@cc.umanitoba.ca)

The Universe Doesn't Care

We live in troubled times. They would be much less-troubled without the likes of CNN, CSIS, and David Suzuki to remind us how desperate is our existence but, still, species are disappearing, the Earth is warming, the Moon is moving farther away, asteroids might hit at any time, "fundamentalists" want to guide our thoughts, and crops are being genetically altered into cancer-causing mind-destroying chimeras. Most of all, there are too many of us — 'way too many. The Earth is wrecked, to put it succinctly.

Fortunately, we can take comfort from our astronomy passions in a way that no other belief system can offer. We don't have to worry about the distant future, about the opportunities for our remote descendants, for the upkeep of our burial plots. Worlds come and go, suns come and go, and planets come and go. The Universe doesn't care.

Why should we? All we can affect is the schedule for a few events.

The disappearance of humanity is inevitable in the universal scheme of things. The Sun will blow up, for one thing. Or that Armageddon Asteroid might even now be turning sunward somewhere in the Kuiper belt, aiming for a Pacific Ocean splashdown. Species have always appeared and disappeared — if the polar bear goes, just wait for the next one to evolve. There's time. Or better still: imagine another one on some distant planet around a distant star — hopefully a star without intelligent life (or perhaps with). If the Earth is too hot, just wait and see what hot really means. Hot, as in boiling continents, as in the past. Been there, done that.

The Universe doesn't care about the Earth. Science supplies the ultimate impartial judgement. To the True Astronomer, the laws of science will dictate the fate of worlds and souls. Sure, there may be a little temporary regret at the pace of things, or the loss of a favourite ecosystem element, but that's the Universe for you. We are chemicals obeying a bigger set of rules dictated by the physics of that Universe.

As Astronomers, we see this bigger picture. There are other worlds, other galaxies, other atmospheres to give comfort to thoughts of our inevitable demise. We can see things in time-frames that dwarf the political and social machinations of the present era: the light

Journal

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

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from Andromeda that started when humans were fur-covered and ambling through the Savannah dwarfs the ten-year-reign of a Prime Minister. There is comfort in knowing that somewhere out there is more life, more polar bears, another Earth. There is comfort in knowing that some day your carbon and oxygen and calcium will be incorporated into another star, planet, or organism, courtesy of an expanding Sun, a planetary nebula, and the inevitable evolution of the Universe. Parts of you may even become Somebody Else.

Go out and buy the SUV. It won't change the Universe in any measurable way. It might make life for your kids a little tougher, so leave them something under the inheritance tree. In the end, we're all stardust. Astronomy gives us the Valium to say it really doesn't matter at the end. Except, perhaps, to the polar bear.

Astrophotography Contest

Your photo — in full colour — could grace the back cover of the *Journal* in February, April, or June next year. We are pleased to announce the first ever *JRASC* photo contest, in recognition of the growing capability of the RASC membership and the establishment of the new RASC Astroimaging Group.

Photos must be submitted on or before 2007 December 31, conform to the normal requirements (300 dpi in final size) of the *Journal's* graphical standards (www.rasc.ca/journal), and be accompanied by a description of the object, the photographic details, and non-exclusive permission to reproduce in the *Journal*. Images must be in digital form, but may include sketches, paintings, film photographs, and drawings, provided they are converted to a digital format before submission.

The competition will award "the back page" to submissions in three categories: deep-sky images; wide-angle photographs that include at least a part of the landscape; and scenes of Centre outreach activities. Winners will be expected to provide a short bio prior to publication. Images submitted may be published at other times and places in the *Journal*, with credit to the owner. Please send submissions to editor@rasc.ca.

The Royal Astronomical Society of Canada is dedicated to the advancement of astronomy and its related sciences; the Journal *espouses the scientific method, and supports dissemination of information, discoveries, and theories based on that well-tested method.*

ORBITS OF SMALL SATELLITES IN THE FIELD OF A RECTANGULAR SLAB

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Abstract: We give exact expressions for the components of the acceleration due to gravity in the vicinity of a rectangular, homogeneous slab. These are used to compute trajectories of a satellite of infinitesimal mass for a range of initial conditions, and for both non-rotating and rotating slabs. Although a body closely resembling this "brick" is not likely to be realized in nature, the slab is a fair approximation to the shapes of certain asteroids, and the exercise illustrates the key features of orbital motion in a non-inverse-square force field.

Résumé: Nous présentons des expressions mathématiques exactes pour les composantes de l'accélération causée par la gravité à proximité d'une dalle rectangulaire et homogène. Celles-ci servent à calculer les trajectoires d'un satellite de masse infinitésimale pour une gamme de conditions initiales, et pour des dalles au repos ou en rotation. Bien qu'un tel corps soit improbable à l'état naturel, la dalle est une approximation adéquate de la forme de certains astéroïdes, et l'exercice illustre les éléments principaux du mouvement orbital dans un champ de force n'obéissant pas à la loi de l'inverse du carré.

1. Introduction

All introductory mechanics texts include a discussion of the gravitational two-body problem, but those discussions are often confined to the simplest case of point-like masses. While this restriction is understandable, the methods that result are of very limited applicability. In fact, there are very few cases in which exact expressions have been obtained for the potential, so what Grossman (1996) describes as "tedious calculations" are needed in order to follow satellite motion, even when a high degree of symmetry is present. The slab geometry considered here is one of the rare cases for which exact expressions can be found for both the gravitational potential and the gravitational force; particle trajectories are readily computed. Although the results are instructive in themselves, the exercise is of more than purely hypothetical interest; many asteroids, such as 243 Ida (which is accompanied by a tiny satellite), are at least roughly slab-like in appearance. We consider briefly the Ida-Dactyl system as an application of our results to a "real-world" situation.

2. Gravitational Acceleration due to a Uniform Slab

An exact expression for the gravitational potential of a homogeneous, rectangular slab has been given by MacMillan (1958), who stopped just short of setting down explicitly the corresponding components of the force. Since the latter are required for the purpose at hand, we derive them directly here. We could differentiate MacMillan's expression for the potential, but it is equally straightforward to proceed as follows: the acceleration due to gravity at a point r in the field of a mass distributed over a volume V' with mass density $\rho(\mathbf{r}')$ is

$$\mathbf{g} = -G\iiint_{V'} \frac{\rho(\mathbf{r}')(\mathbf{r}-\mathbf{r}')}{|\mathbf{r}-\mathbf{r}'|^3} d^3\mathbf{r}', \tag{1}$$

where G = 6.673×10^{-11} m^3 kg^{-1} s^{-2} is the gravitational constant, and the primes denote source points. Consider a slab of uniform density ρ whose dimensions are $2\alpha \times 2\beta \times 2\gamma$, $\alpha > \beta > \gamma$, occupying the volume $-\alpha \leq x \leq \alpha$, $-\beta \leq y \leq \beta$, $-\gamma \leq z \leq \gamma$. Then equation (1) becomes

$$\mathbf{g}(x,y,z) = -G\rho \int_{-\gamma}^{+\gamma} \int_{-\beta}^{+\beta} \int_{-\alpha}^{+\alpha} \frac{(x-x')\mathbf{i} + (y-y')\mathbf{j} + (z-z')\mathbf{k}}{[(x-x')^2 + (y-y')^2 + (z-z')^2]^{3/2}} dx'\,dy'\,dz'. \tag{2}$$

The x-component of **g** is therefore

$$g_x(x,y,z) = -G\rho \int_{-\gamma}^{+\gamma} \int_{-\beta}^{+\beta} \int_{-\alpha}^{+\alpha} \frac{(x-x')}{[(x-x')^2 + (y-y')^2 + (z-z')^2]^{3/2}} dx'\,dy'\,dz'. \tag{3}$$

The components g_y and g_z are given by similar expressions in which the numerator of the integrand is replaced by $(y - y')$ and $(z - z')$, respectively, Integrate over x' from $-\alpha$ to α to find

$$\begin{aligned} g_x &= -G\rho \int_{-\gamma}^{+\gamma} \int_{-\beta}^{+\beta} \frac{dy'\,dz'}{[(x-\alpha)^2 + (y-y')^2 + (z-z')^2]^{1/2}} \\ &\quad + G\rho \int_{-\gamma}^{+\gamma} \int_{-\beta}^{+\beta} \frac{dx'\,dy'}{[(x+\alpha)^2 + (y-y')^2 + (z-z')^2]^{1/2}}. \end{aligned} \tag{4}$$

Next, integrate (4) over y' from $-\beta$ to β to obtain

$$\begin{aligned} g_x &= +G\rho \int_{-\gamma}^{+\gamma} ln\left[-y+\beta+\sqrt{(x+\alpha)^2 + (y-\beta)^2 + (z-z')^2}\right] dz' \\ &\quad - G\rho \int_{-\gamma}^{+\gamma} ln\left[-y+\beta+\sqrt{(x-\alpha)^2 + (y-\beta)^2 + (z-z')^2}\right] dz' \\ &\quad - G\rho \int_{-\gamma}^{+\gamma} ln\left[-y-\beta+\sqrt{(x+\alpha)^2 + (y+\beta)^2 + (z-z')^2}\right] dz' \\ &\quad + G\rho \int_{-\gamma}^{+\gamma} ln\left[-y-\beta+\sqrt{(x-\alpha)^2 + (y+\beta)^2 + (z-z')^2}\right] dz' \end{aligned} \tag{5}$$

Evaluation of these integrals is accomplished using

$$\begin{aligned} \int \ln\left[\eta + \sqrt{\xi^2 + \eta^2 + \zeta^2}\right] d\zeta &= \zeta \ln\left[\eta + \sqrt{\xi^2 + \eta^2 + \zeta^2}\right] + \eta \ln\left[\zeta + \sqrt{\xi^2 + \eta^2 + \zeta^2}\right] \\ &\quad - \zeta + \xi \arctan\left(\frac{\zeta}{\xi}\right) - \xi \arctan\left(\frac{\eta\zeta}{\xi\sqrt{\xi^2 + \eta^2 + \zeta^2}}\right). \end{aligned} \tag{6}$$

The result is

$$
\begin{aligned}
-\frac{g_x(x,y,z)}{G\rho} &= (y+\beta)\{ln[\rho_{211}+(z+\gamma)]-ln[\rho_{111}+(z+\gamma)] \\
&\quad +ln[\rho_{112}+(z-\gamma)]-ln[\rho_{212}+(z-\gamma)]\} \\
&\quad +(y-\beta)\{ln[\rho_{121}+(z+\gamma)]-ln[\rho_{221}+(z+\gamma)] \\
&\quad +ln[\rho_{222}+(z-\gamma)]-ln[\rho_{122}+(z-\gamma)]\} \\
&\quad +(z+\gamma)\{ln[\rho_{111}-(y+\beta)]-ln[\rho_{211}-(y+\beta)] \\
&\quad +ln[\rho_{221}-(y-\beta)]-ln[\rho_{121}-(y-\beta)]\} \\
&\quad +(z-\gamma)\{ln[\rho_{212}-(y+\beta)]-ln[\rho_{112}-(y+\beta)] \\
&\quad +ln[\rho_{122}-(y-\beta)]-ln[\rho_{222}-(y-\beta)]\} \\
&\quad +(x+\alpha)\Big\{arctan\left[\frac{-(y-\beta)(z+\gamma)}{(x+\alpha)\rho_{121}}\right]-arctan\left[\frac{-(y-\beta)(z-\gamma)}{(x+\alpha)\rho_{122}}\right] \\
&\quad +arctan\left[\frac{-(y+\beta)(z-\gamma)}{(x+\alpha)\rho_{112}}\right]-arctan\left[\frac{-(y+\beta)(z+\gamma)}{(x+\alpha)\rho_{111}}\right]\Big\} \\
&\quad +(x-\alpha)\Big\{arctan\left[\frac{-(y-\beta)(z-\gamma)}{(x-\alpha)\rho_{222}}\right]-arctan\left[\frac{-(y-\beta)(z+\gamma)}{(x-\alpha)\rho_{221}}\right] \\
&\quad +arctan\left[\frac{-(y+\beta)(z+\gamma)}{(x-\alpha)\rho_{211}}\right]-arctan\left[\frac{-(y+\beta)(z-\gamma)}{(x-\alpha)\rho_{212}}\right]\Big\}
\end{aligned}
\tag{7}
$$

The terms ρ_{ijk} have the form $\sqrt{(x\pm\alpha)^2+(y\pm\beta)^2+(z\pm\gamma)^2}$. The sign in $(x \pm \alpha)$ is indicated by the first subscript: 1 for $(x + \alpha)$, 2 for $(x - \alpha)$. The other subscripts indicate the signs in $(y \pm \beta)$ and $(z \pm \gamma)$, in accordance with MacMillan's notation. The corresponding expressions for g_y and g_z are given in the Appendix.

3. Orbits in the Field of a Non-Rotating Slab

With initial position and velocity vectors and the components of **g**, the orbits of small (*i.e.* of negligible mass) satellites are readily followed. We begin with a non-rotating, uniform slab of dimensions 40×20×10 km along the *x*–, *y*–, and *z*– axes, respectively, with density $\rho = 2500$ kg m^{-3}, and total mass $M_{slab} = 2 \times 10^{16}$ kg. After some experimentation, a Bulirsch-Stoer (B-S) integration routine (Press *et al.* 1992) was adopted. Although it executes rather slowly when compared to a simple Euler integrator, it returns accurate results in all circumstances, even when the satellite is close to a rapidly spinning slab. Under less trying conditions, the two methods agree rather well. For example, one experiment involved starting the satellite at $z = 20$ km, $x = y = 0$, with velocity components $v_y = -\sqrt{GM_{slab}/r} = -8.16859229$ m s^{-1}, $v_x = v_z = 0$. The orbit was followed for 10^5 seconds using both integration schemes; the final positions agreed to within 2.5 metres. As a further check, the slab was modelled as a 40×20×10 array of point masses, each with mass $M = 2.5\times10^{12}$ kg. The acceleration component $g_x(x,y,z)$ due to each mass is just

$$
g_x(x,y,z) = -GM\frac{(x-x')}{[(x-x')^2+(y-y')^2+(z-z')^2]^{3/2}}
\tag{8}
$$

where x', y', and z' are its coordinates; g_y and g_z are found by replacing the numerator above by $y - y'$, and $z - z'$, respectively. The contributions of the point masses are summed to obtain the resultant g_x, g_y, and g_z at each field point, and the orbit was integrated using Euler's method, starting from the same initial conditions, and using a 10-second time step. The integration was also carried out using the B-S scheme; the final positions agreed within 15.2 metres. (With the exact expressions for g_x, g_y, and g_z in the B-S routine, final positions agreed within 30 metres.) A further test of numerical accuracy will be described in the next section.

We now consider more carefully the motion of a satellite in the field of a non-rotating slab. The centre of the slab is at the origin, and its axes are oriented along the coordinate axes as described above. The satellite starts at $x = r_0$, $y = z = 0$, with velocity components $v_z = 0$, $v_y = \varepsilon\sqrt{\mu/r_0}$ $(0<\varepsilon<1)$, and $v_x = \sqrt{(1-\varepsilon^2)\,\mu/r_0}$; that is, so that $v_x^2 + v_y^2 = \mu/r_0$, where $\mu = GM$ with $M = M_{slab}$. The speed of a satellite in a circular orbit of radius r about a point mass equal to M_{slab} is $\sqrt{\mu/r_0}$; the otherwise arbitrary assignment of components ensures that the orbit has eccentricity $e \neq 0$ and lies in the x-y plane. Because the orbits are not closed, the eccentricity does not have its usual meaning; here,

$$e = \frac{r_a - r_p}{r_a + r_p}, \tag{9}$$

where r_a and r_p are, respectively, the apoapsis and periapsis distances of the satellite. Figure 1 illustrates the motion for a distance r_0 = 125 km with ε = 0.9. The satellite was followed for 2.5 $\times 10^7$ s (to avoid clutter, only the first 10^7 seconds of the motion are shown). Looking down the z-axis toward the slab (outlined), the satellite orbits in a counterclockwise sense. Its first complete orbit has r_p = 68.44191 km, and r_a = 176.86607 km, so that the semimajor axis $a = (r_a + r_p)/2$ = 122.654 km, and e =0.44199. The sidereal period P =2.32163 $\times 10^5$ s, close to the Keplerian period of 2.33629 $\times 10^5$ s.

The line of apsides precesses in a counterclockwise direction, at a mean rate of 3.17×10^{-7} s^{-1} . Periapsis distances vary

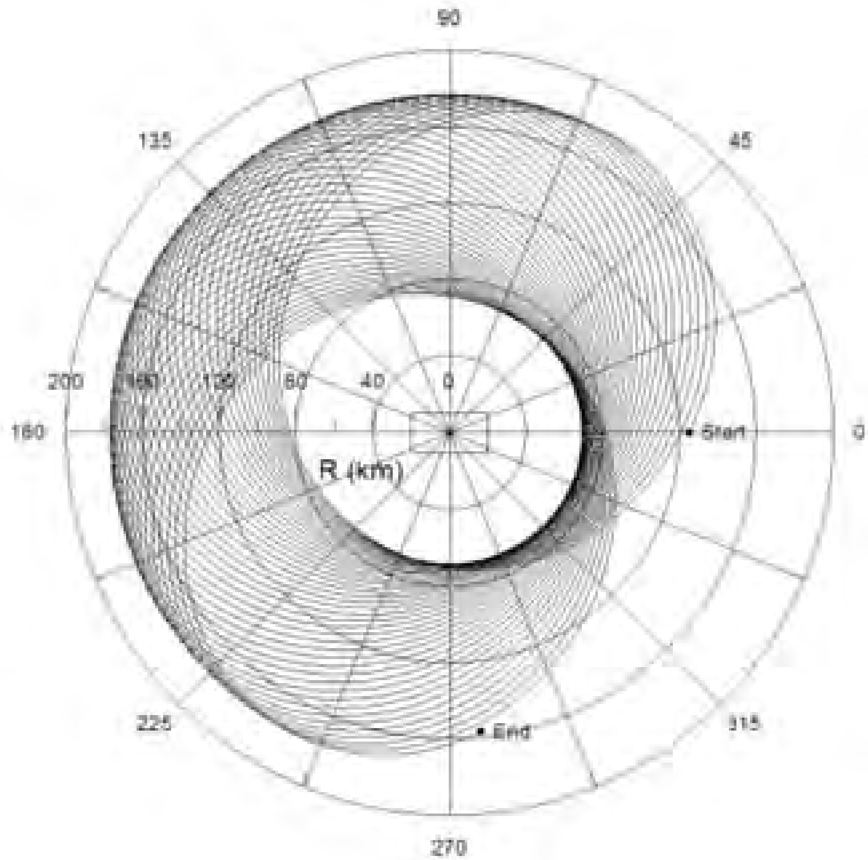

Figure 1 — An orbit about the long axis of a non-rotating slab, whose outline is shown. The motion is confined to the x-y plane. The rapid advance of the line of apsides is apparent.

periodically with an amplitude of about 923 m, about a mean value $\langle r_p \rangle$ = 68.741 km. The period is 9.8803×10^6 s, half the apsidal precession period. Apoapsis distances vary with the same period about $\langle r_a \rangle$ = 176.894 km with amplitude just over 98 m.

We can compare the observed rate of precession of the longitude of periapsis with that predicted from a multipole expansion of the slab's potential. Scheeres and Hu (2001) have expressed in convenient form the gravitational potential of a non-rotating body (of any shape) to second degree and second order. Assuming a principal axis coordinate system with the principal moments of inertia satisfying the relation $I_{xx} \leq I_{yy} \leq I_{zz}$, they show that

$$\frac{di}{dt} = \frac{1}{2} B\sigma \sin i \sin 2\Omega, \tag{10}$$

$$\frac{d\Omega}{dt} = -B\cos i(1-\sigma\cos^2\Omega), \tag{11}$$

$$\frac{d\omega}{dt} = -\frac{B}{2}(5C-4+\sigma+2\sigma\cos^2\Omega), \tag{12}$$

where

$$B = \frac{3n(I_{zz}-I_{xx})}{2a^2(1-e^2)^2}, \tag{13}$$

$$C = \sin^2 i(1-\sigma\cos^2\Omega), \tag{14}$$

and

$$n = \sqrt{\frac{\mu}{a^3}}. \tag{15}$$

Here,

$$\sigma = \frac{I_{yy}-I_{xx}}{I_{zz}-I_{xx}}, \tag{16}$$

where I_{xx}, I_{yy}, and I_{zz} are the slab's principal moments of inertia *per unit mass, i* is the inclination of the orbit, Ω is the longitude of the ascending node, and ω is the argument of periapsis (the angular distance in the plane of the orbit and in the direction of motion from the ascending node to the periapsis point). It is easy to show that here,

$$I_{xx} = \frac{\beta^2+\gamma^2}{3}, \tag{17}$$

$$I_{yy} = \frac{\alpha^2+\gamma^2}{3}, \tag{18}$$

and

$$I_{zz} = \frac{\alpha^2+\beta^2}{3}; \tag{19}$$

with α, β, and γ as given above, $I_{xx} < I_{yy} < I_{zz}$.

In the present case, $i = 0$. In this case (or when $i = 180°$), Ω is undefined, and the relevant quantity is the longitude of periapsis, denoted by ϖ. Its equation of motion is

$$\frac{d\varpi}{dt} = B\left(1-\frac{\sigma}{2}\right). \tag{20}$$

As indicated above, both *a* and *e* vary periodically; this variation is not seen in the approximate theory. To evaluate *B* we therefore use the mean values of *a* and *e* from the first complete orbit to find

$$\frac{d\varpi}{dt} = 3.11\times10^{-7}\,\mathrm{s}^{-1}, \tag{21}$$

in good agreement with the observed value. Clearly, $di/dt = 0$, as expected.

Now consider an orbit inclined to the x-y plane. The initial conditions are $r_0 = x_0 = 100$ km, with $v_x = 0$, $v_y = \varepsilon\sqrt{\mu/r_0}$; and $v_z = \sqrt{(1-\varepsilon^2)\mu/r_0}$; $\varepsilon = 0.9$ as before. The motion over the first 10^7 s is illustrated in Figure 2. The initial inclination of the orbit

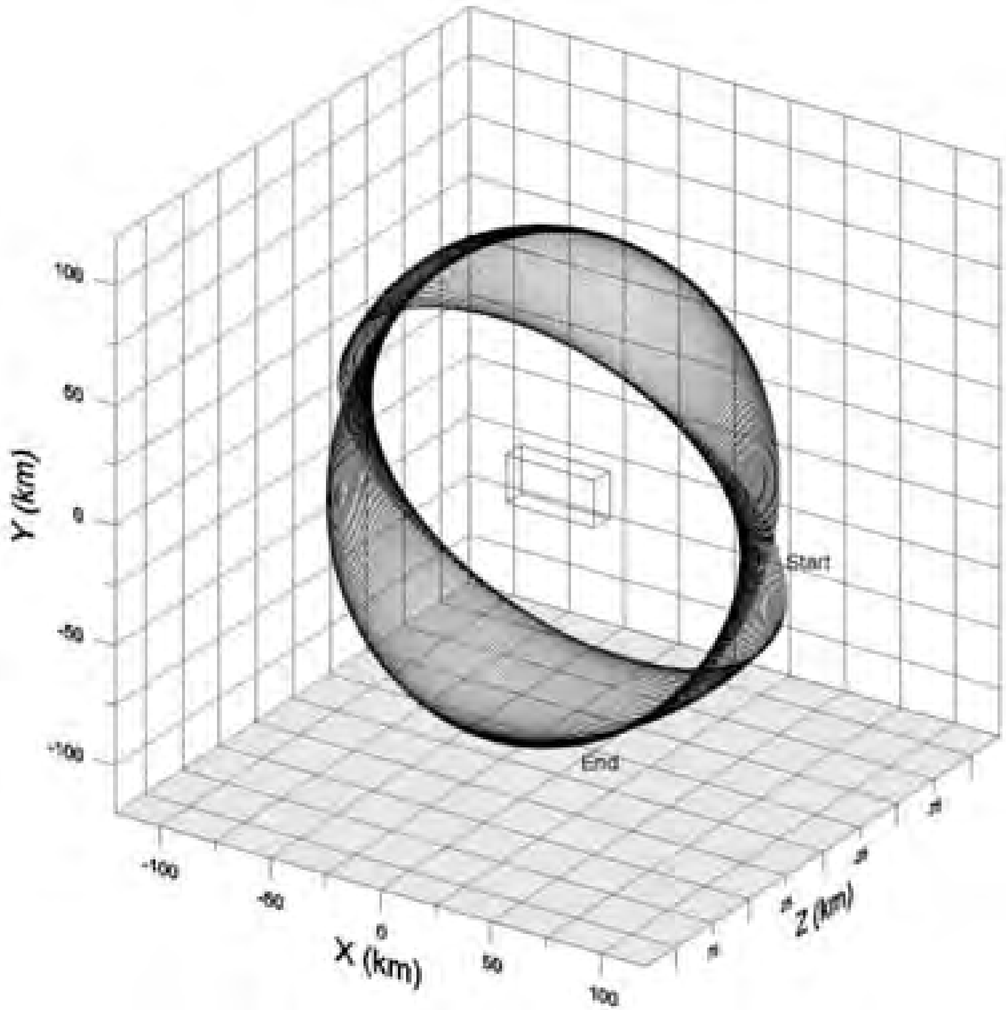

Figure 2 — A three-dimensional orbit about a non-rotating slab, whose outline is shown. Both the orbital plane and the line of apsides undergo precession.

is 25.8419 degrees, and the longitude Ω of the first ascending node is zero. The descending node is reached at $t = 82{,}024 \pm 5$ s, periapsis passage is at $r_p = 95.3651$ km and $t = 84{,}070 \pm 90$ s. (It is difficult to pinpoint the instants of periapsis and apoapsis passage because of the low eccentricity ($e = 0.023715$) of the orbit). The next periapsis passage occurs at 95.3538 km and $t = 252{,}040 \pm 50$ s; as usual, both e and a are variable. Between these events, the particle passes the ascending and descending nodes at $t = 163{,}825 \pm 5$ s, and $t = 246{,}072 \pm 5$ s, respectively. At the ascending node, i has decreased slightly, to 25.8134 degrees. We evaluate B using the initial values of e and $a = 97.6826$ km. The coupled pair of equations (10) and (11) is then solved numerically. The solutions are plotted in Figure 3 and Figure 4, along with the observed values of $i(t)$ and $\Omega(t)$. Evidently, equations (10) and (11), derived from the approximate averaged potential, account qualitatively for the behaviour of $i(t)$ and $\Omega(t)$, but (as expected, given the proximity of the satellite to the slab) the quantitative comparison is less satisfactory. Finally, $d\omega/dt$ is evaluated from equation (12), using for B and C their average values between the first two periapsis passages. The result is 5.25×10^{-7} s^{-1}. The actual $d\omega/dt \approx 6.35 \pm 0.05 \times 10^{-7}$ s^{-1}.

4. A Spinning Slab

Asteroids rotate; a typical period is several hours. We allow our slab asteroid to spin in a state of *principal-axis rotation* in which its spin axis coincides with one of its symmetry axes, specifically, the one about which the moment of inertia takes on its maximum value. Burns and Safronov (1973) have argued that this is, in fact, a likely state of affairs because of internal energy dissipation. They estimated that the timescale τ over which the evolution of the spin state takes place lies in the range 4×10^4 P^3_{spin}/r^2 yr

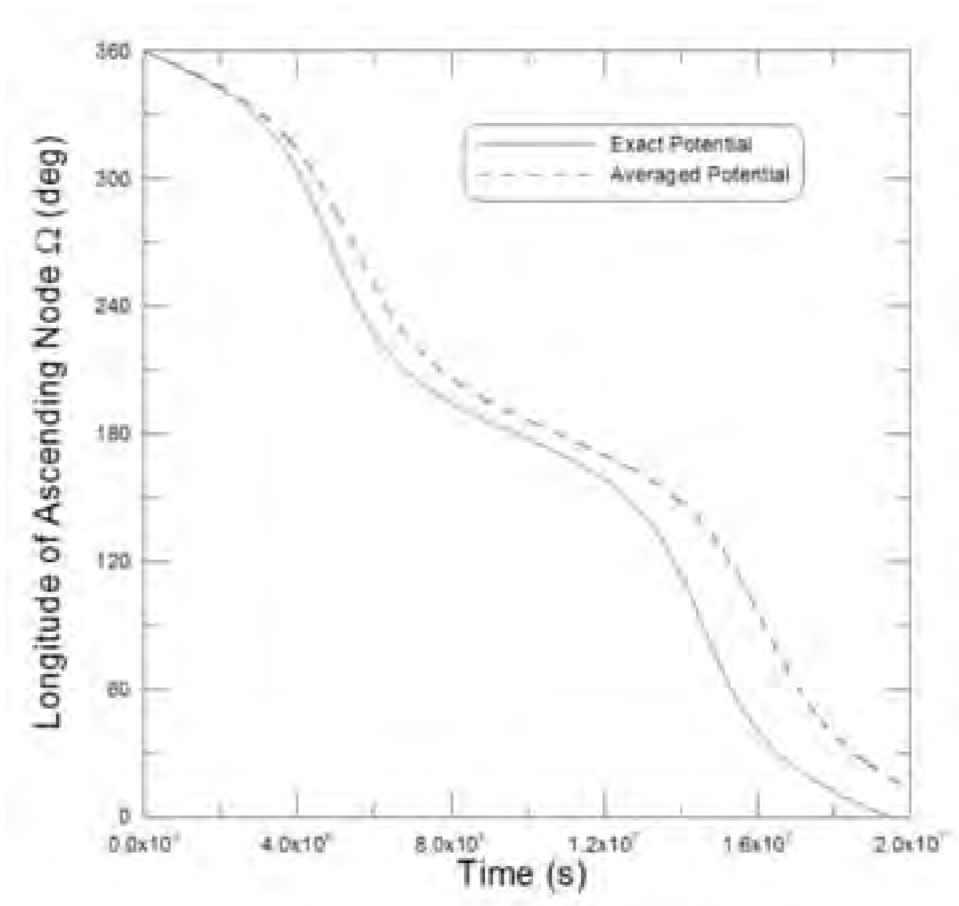

FIGURE 3 — The "observed" (solid line) time dependence of the longitude of the ascending node (Ω) of the orbit illustrated in Figure 2. The dashed line is a prediction based on a multipole expansion of the slab potential to degree and order 2.

to $6 \times 10^7\ P^3_{spin}/r^2$ yr, where P_{spin} is the asteroid spin period (in hours, here), and r is its mean radius in kilometres. Although these limits are probably underestimates because asteroids in general seem not to be as dense as the authors assumed, the key point is that we may reasonably expect damping times much less than the age of the Solar System for many asteroids, and the assumption of principal axis rotation greatly simplifies the analysis.

From our assumed values of α, β, and γ, it is clear that the slab's maximum moment of inertia is $I_{zz} = M_{slab}\,(\alpha^2 + \beta^2)/3$, so that its rotation will be about the z-axis.

5. Orbital Dynamics near a Spinning Slab

It is convenient to carry out our calculations in the rest frame of the slab (the " body-fixed" frame) and then transform to the inertial frame in which it is spinning about an axis through the centres of its largest faces. The equation of motion in the body-fixed system is

$$\ddot{\mathbf{r}} = \mathbf{g} - 2\mathbf{L} \times \dot{\mathbf{r}} + \mathbf{L}(\mathbf{L} \times \mathbf{r}) \tag{22}$$

(*e.g.* Kibble 1985), where **r** is the vector from the asteroid centre of mass to the satellite, and **L** is the angular momentum, with components $L_x = L_y = 0$, $L_z = \omega$, as deduced above. Taking components of equation (22), we obtain the equations of motion in scalar form:

$$\ddot{x} = g_x + 2\omega\dot{y} + \omega^2 x, \tag{23}$$

$$\ddot{y} = g_y + 2\omega\dot{x} + \omega^2 y, \tag{24}$$

and

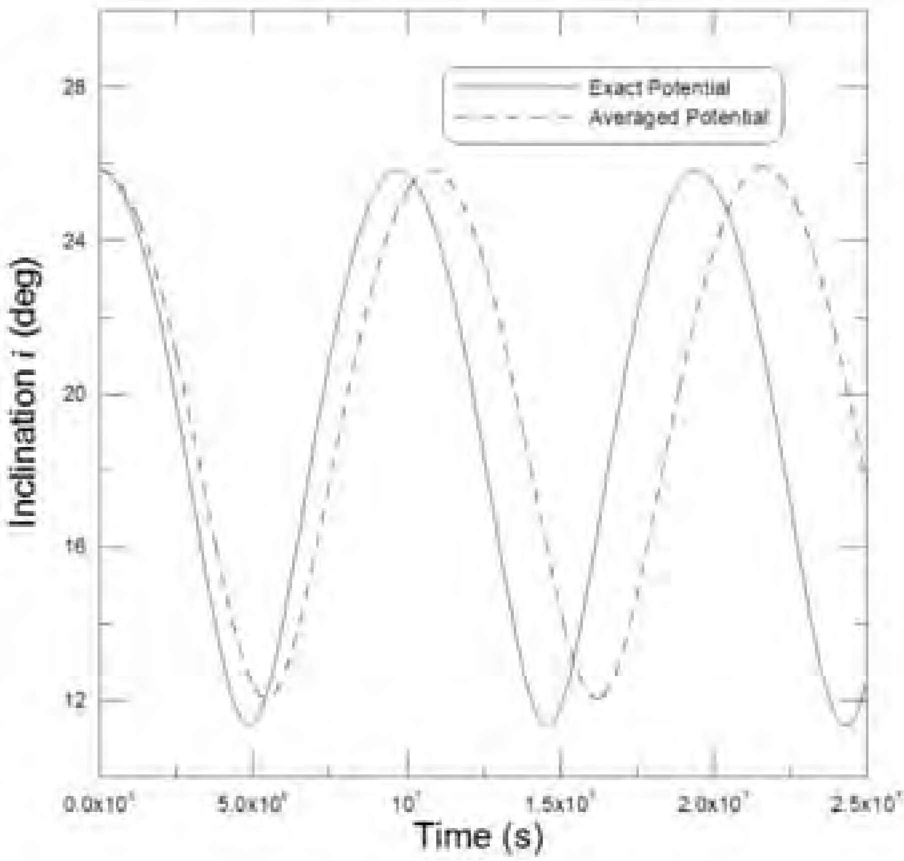

FIGURE 4 — The "observed" (solid line) time dependence of the inclination i of the plane of the orbit illustrated in Figure 2. The dashed line is a prediction based on a multipole expansion of the slab potential to degree and order 2.

$$\ddot{z} = g_z . \tag{25}$$

With these, it is straightforward to investigate orbital stability in the field of the spinning slab. An orbit is unstable if (a) the satellite crashes into the slab, or (b) the satellite moves off toward infinity. The latter condition is checked by calculating the total energy of the satellite at each point in its orbit. To do this, we use MacMillan's (1958) exact expression for the potential; the satellite's kinetic energy at any point is easily found, so its total energy can be checked whenever its excursions indicate that it may have become unbound. Clearly, a stable orbit must not intersect the slab. The relevant criterion, namely

$$|x| > \alpha \text{ or } |y| > \beta \text{ or } |z| > \gamma ,$$

is simple in the body-fixed coordinate system, but more complicated in the inertial frame. The latter is the natural one from which to visualize the satellite orbit, and it is connected to the body-fixed frame by a simple coordinate transformation. If the slab is spinning in a counterclockwise sense as seen by an inertial observer located on the positive z-axis, then after a time t, it will have spun through an angle ωt, where $\omega = \Omega_z$ is the angular speed. If x, y, and z are the rectangular coordinates of the satellite at time t in the body-fixed reference frame, then its coordinates in the inertial frame are

$$\begin{pmatrix} x' \\ y' \\ z' \end{pmatrix} = \begin{pmatrix} \cos\omega t & -\sin\omega t & 0 \\ \sin\omega t & \cos\omega t & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} x \\ y \\ z \end{pmatrix} . \tag{26}$$

Figure 5 illustrates an example of the general case. The slab (again, of dimensions 40 × 20 × 10 km) has $P_{spin} = 8.91961 \times 10^4$ s, and the satellite starts at $x_0 = r_0 = 40.66378$ km with velocity components (in the rotating frame) $\upsilon_x = 0$, $\upsilon_y = 0.8 \cdot (\upsilon_{circ} - \omega x_0)$,

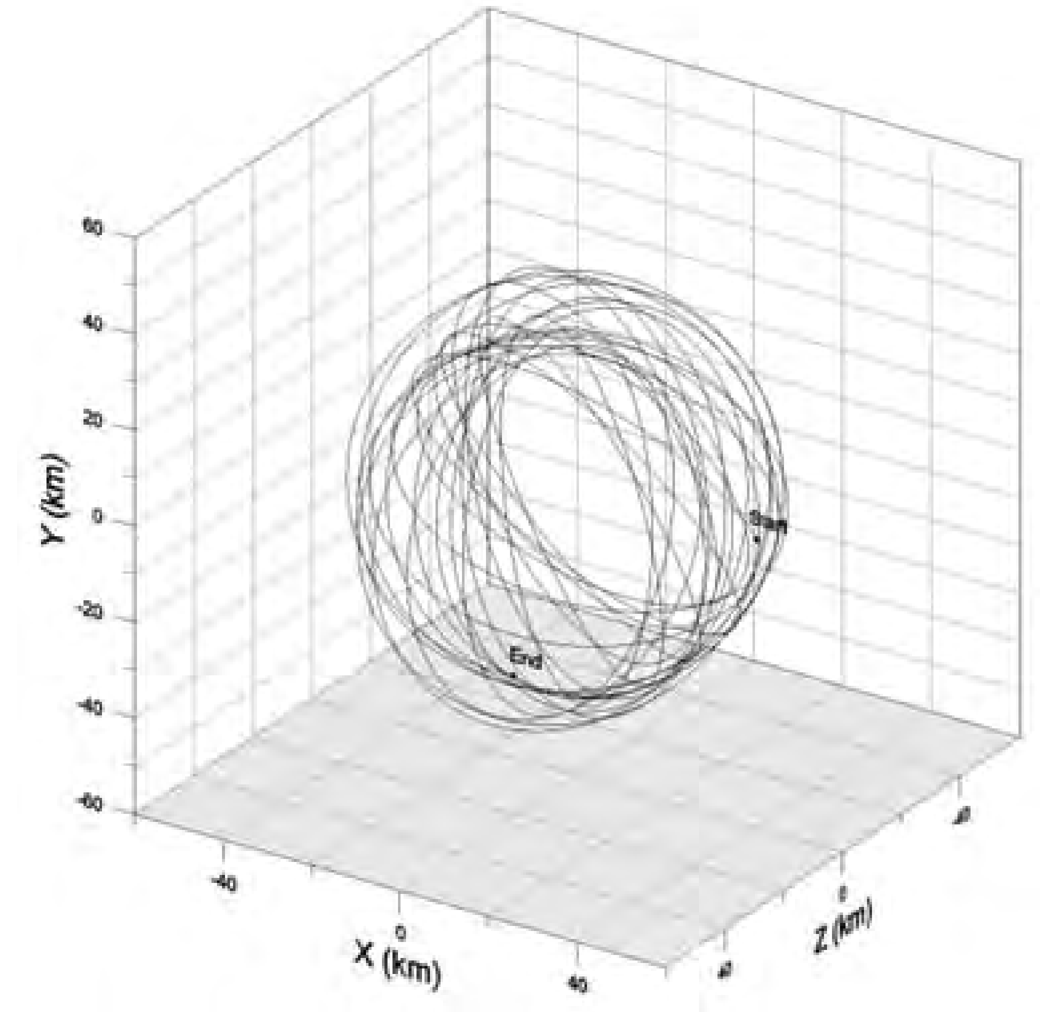

Figure 5 — A segment of a three-dimensional orbit about a rotating slab whose center is located at $x = y = z = 0$. The view is from the inertial frame; the slab's spin period is a little less than 25 hours.

and $v_z = 0.6v_{circ}$. The orbit was followed for 100 P_{spin}, of which the first 8.91961×10^5 s is shown. To check the accuracy of the integration scheme, we ran it backwards from the final state to see how closely the satellite approaches its initial position. That is, we took the coordinates and velocity components of the satellite at $t = 8.91961 \times 10^6$ seconds, changed the signs of the velocity components, reversed the slab's spin direction, and integrated the trajectory over a further 8.91961×10^6 seconds. The satellite returned to within 26 m of its starting point, after a round trip of 104,587.8 km, and the initial and final velocity components agreed to within 1 part in 10^5. The orbit sampled in Figure 5 persists for at least 100 P_{spin}, and perhaps indefinitely. However, many, if not most, asteroids have substantially shorter spin periods, and it is generally difficult to find stable orbits close to a rapid rotator.

Hu and Scheeres (2004) carried out a numerical study of the stability of orbits in uniformly rotating gravity fields of second degree and second order; in particular, they explored the regions of stability for initially circular, equatorial (confined to the x-y plane if the central body is spinning about the z-axis) orbits. They began by introducing a length scale $r_s = (\mu/\omega^2)^{1/3}$ — the distance at which the gravitational acceleration due to a point mass equal to that of the central body is equal to the acceleration arising from that body's spin — to normalize the equations of motion that correspond in their approximation to our equations (23), (24), and (25). In this way, they reduced the number of independent parameters in their system of equations to two: $(I_{zz} - I_{xx})/r_s^2$ and σ (see Equation (16)). If the dimensions, shape, and mass of the asteroid are fixed, then the only adjustable parameter is P_{spin}. In the present case, σ = 0.8. We vary the other independent parameter so that its value lies in the range

$$0 < (I_{zz} - I_{xx})(\omega^2 / \mu)^{2/3} \leq 1. \quad (27)$$

Given the slab's properties, this corresponds to a range of values of ω such that 2.1449881×10^4 s $\leq P_{spin} < \infty$. Now consider an infinitesimal mass in orbit about a point mass equal to M_{slab}. If its orbital period is P_{orb}, then the corresponding angular frequency is $\omega_{orb} = 2\pi/P_{orb}$, and, if the semimajor axis of the orbit is a_0, then, from Kepler's Third Law, $a_0^{3/2} = \mu^{1/2}/\omega_{orb}$. It follows that the quantity

$$(a_o / r_s)^{3/2} = a_0^{3/2}(\omega^2 / \mu)^{1/2} = P_{\text{orb}} / P_{\text{spin}} . \tag{28}$$

Following Hu and Scheeres, we integrated Equations (23) - (25) from the initial conditions $x' = a_0$; $y' = z' = 0$; $\dot{x}' = \dot{z}' = 0$; $\dot{y}' = (\mu/a_0)^{1/2}$ in the (unscaled) inertial frame, where a_0 is the initial orbital radius. An orbit is classified as stable if it endures for 100 P_{spin} or 1.5779×10^7 s (6 months) — whichever is less. Each outcome — stable or unstable — is represented by a point in the $(a_0/r_s)^{3/2}$ – $(I_{zz} - I_{xx})/r_s^2$ plane. The result, which is presented in Figure 6 (and which can be compared with Figures 3 and 4 in the paper just referred to) is a map showing regions of stable and unstable initially circular orbits. Stable orbits are denoted by X. It is not our intention here to analyze in detail the structure seen in Figure 6; the reader may refer to the paper by Hu and Scheeres for a fuller discussion.

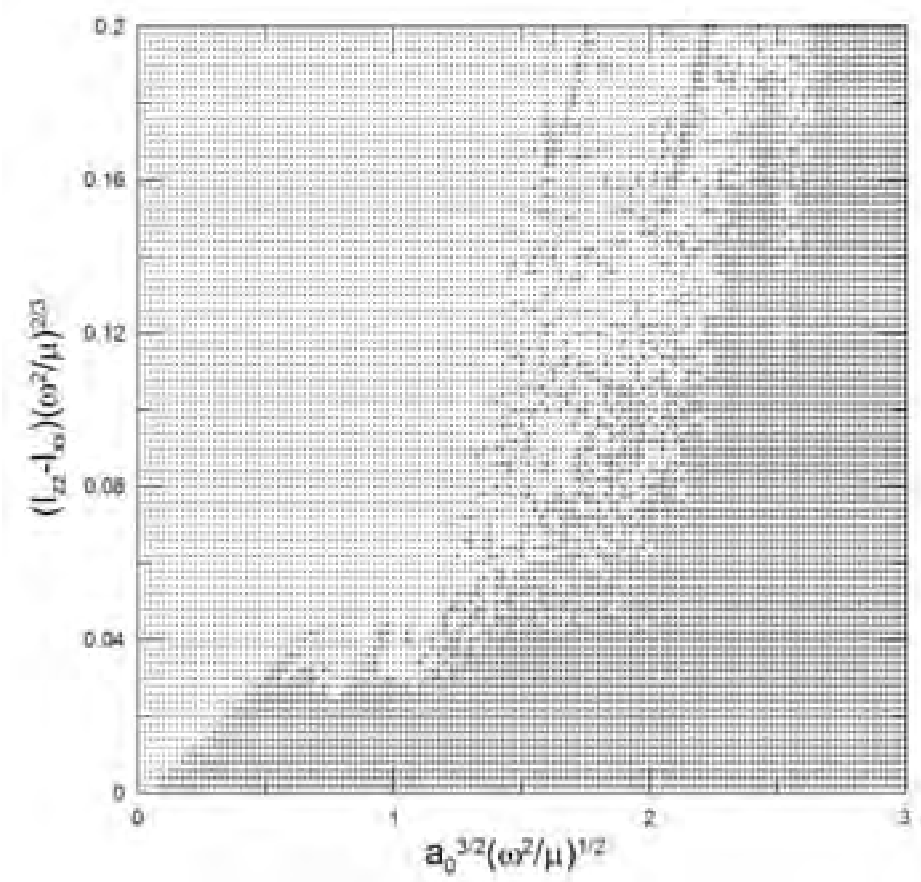

Figure 6 — A map showing regions of stable (denoted by X) and unstable initially circular equatorial orbits. The details are given in the text; the abscissa is the ratio of the period of the initial circular orbit to that of the slab's rotation.

Regions towards the bottom of the plot are characterized by small values of ω (*i.e.* long spin periods), and initially circular equatorial orbits are stable over long periods of time. In the case of the stable orbit corresponding to the point near the extreme lower left of the plot, $a_0 \approx 44.46$ km, and the slab has $P_{spin} \approx 7.9$ days. As we progress towards the top of Figure 6, P_{spin} decreases, and the limiting distance within which long-lived orbital motion is impossible moves to the right, *i.e.* to large values of a_0. Resonances between the spin period of the slab and the orbital period of the satellite occur when $(a_0/r_s)^{3/2} = k/2$, k =1, 2, 3,...; near these, the boundary of the region of stability generally lies at a lower value of $(I_{zz} - I_{xx})/r_s^2$ (effectively, of ω), than elsewhere in the immediate neighbourhood.

We emphasize that the map displayed in Figure 6 may not be definitive because the stability criterion employed to generate it is not really very stringent. Ideally, orbits would be tracked for much longer times. However, even the exercise outlined here runs for over 1.25×10^5 s on a 3.3 GHz PC, so a really thorough investigation would probably require a dedicated machine.

We conclude with a brief look at a real case: that of the asteroid 243 Ida and its moon Dactyl. Ida is a highly elongated object that resides in the outer reaches of the main asteroid belt. It is a rapid rotator: $P_{spin} = 4.633632 \pm 0.000007$ hr, and it is in a state of principal-axis rotation (Belton *et al.* 1996). The best-fitting ellipsoid has axes 59.8 × 25.4 × 18.6 km, the volume is estimated to be 16,100 ± 1900 km^3, and the bulk density is estimated at 2600 ± 500 kg m^{-3}, through constraints on Dactyl's orbit. We model Ida as a slab of dimensions 53.6 × 21.8 × 13.8 km, with the above density. The long axis matches the longest dimension of Ida itself, and the other axes are in the same proportion as are the asteroid's minor axes. Such a slab has σ = 0.893744, r_s = 27.0325 km, and $(I_{zz} - I_{xx})/r_s^2$ = 0.305858. A reasonable extrapolation from Figure 6 suggests that initially circular equatorial orbits having $(a_0/r_s)^{3/2} \lessapprox 5$ (corresponding to $a_0 \approx 80$ km) are not likely to be stable. We therefore try an initially circular equatorial orbit with a_0 = 90 km. It turns out that such an orbit is stable for at least 5.7×10^6 P_{spin} (about 3013 yr), and probably indefinitely. The orbital period and eccentricity are slightly variable, but, averaged over the first 10 complete orbits, $\langle e \rangle$ = 0.016441 with sidereal period $\langle p \rangle$ = 97,654 s. There is considerable scope for varying not only the initial conditions of Dactyl's motion, but also the density of the slab itself; Ida's density is not, after all, tightly constrained.

6. Summary

We have given exact expressions for the components of the acceleration due to gravity in the neighbourhood of an homogeneous, rectangular slab. This is one of a very few situations in which exact solutions for both the potential and the forces can be found, and it provides an opportunity to explore particle motion in a non-inverse-square gravitational field. Using the exact expressions for the acceleration due to gravity and the potential, we have integrated orbits of a satellite of infinitesimal mass near both non-rotating and rotating slabs, for a range of initial conditions. We have noted several of the interesting features of these orbits, and have compared exact and approximate results for the rate of periapsis advance in the field of a non-rotating slab. Several questions suitable for further exploration suggest themselves. Are the apparent "islands of stability" in Figure 6 really stable on very great timescales? Are retrograde equatorial orbits generally stable or unstable? Under what conditions are polar orbits stable? How does satellite motion appear to an observer on the asteroid; *i.e.* from the rotating frame of reference? How does orbit stability depend on eccentricity for any particular semimajor axis? Questions such as these are well suited to exploration by upper-year undergraduate students.

7. Appendix

g_y and g_z

The components g_y and g_z of the acceleration due to gravity in the field of the slab are given here. The ρ_{ijk} have been defined immediately after equation 7.

$$
\begin{aligned}
-\frac{g_y(x,y,z)}{G\rho} = {} & (x+\alpha)\{\ln[\rho_{112}+(z-\gamma)]-\ln[\rho_{122}+(z-\gamma)] \\
& +\ln[\rho_{121}+(z+\gamma)]-\ln[\rho_{111}+(z+\gamma)]\} \\
& +(x-\alpha)\{\ln[\rho_{222}+(z-\gamma)]-\ln[\rho_{212}+(z-\gamma)] \\
& +\ln[\rho_{211}+(z+\gamma)]-\ln[\rho_{221}+(z+\gamma)]\} \\
& +(z+\gamma)\{\ln[\rho_{111}-(x+\alpha)]-\ln[\rho_{121}-(x+\alpha)] \\
& +\ln[\rho_{221}-(x-\alpha)]-\ln[\rho_{211}-(x-\alpha)]\} \\
& +(z-\gamma)\{\ln[\rho_{212}-(x-\alpha)]-\ln[\rho_{222}-(x-\alpha)] \\
& +\ln[\rho_{122}-(x+\alpha)]-\ln[\rho_{112}-(x+\alpha)]\} \\
& +(y+\beta)\left\{\arctan\left[\frac{-(x-\alpha)(z+\gamma)}{(y+\beta)\rho_{211}}\right]-\arctan\left[\frac{-(x-\alpha)(z-\gamma)}{(y+\beta)\rho_{212}}\right]\right. \\
& \left.+\arctan\left[\frac{-(x+\alpha)(z-\gamma)}{(y+\beta)\rho_{112}}\right]-\arctan\left[\frac{-(x+\alpha)(z+\gamma)}{(y+\beta)\rho_{111}}\right]\right\} \\
& +(y-\beta)\left\{\arctan\left[\frac{-(x-\alpha)(z-\gamma)}{(y-\beta)\rho_{222}}\right]-\arctan\left[\frac{-(x-\alpha)(z+\gamma)}{(y-\beta)\rho_{221}}\right]\right. \\
& \left.+\arctan\left[\frac{-(x+\alpha)(z+\gamma)}{(y-\beta)\rho_{121}}\right]-\arctan\left[\frac{-(x+\alpha)(z-\gamma)}{(y-\beta)\rho_{122}}\right]\right\}
\end{aligned}
\tag{29}
$$

$$-\frac{g_z(x,y,z)}{G\rho} = (x+\alpha)\{\ln[\rho_{112}+(y+\beta)] - \ln[\rho_{111}+(y+\beta)]$$
$$+\ln[\rho_{121}+(y-\beta)] - \ln[\rho_{122}+(y-\beta)]\}$$
$$+(x-\alpha)\{\ln[\rho_{211}+(y+\beta)] - \ln[\rho_{212}+(y+\beta)]$$
$$+\ln[\rho_{222}+(y-\beta)] - \ln[\rho_{221}+(y-\beta)]\}$$
$$+(y+\beta)\{\ln[\rho_{111}-(x+\alpha)] - \ln[\rho_{112}-(x+\alpha)]$$
$$+\ln[\rho_{212}-(x-\alpha)] - \ln[\rho_{211}-(x-\alpha)]\}$$
$$+(y-\beta)\{\ln[\rho_{122}-(x+\alpha)] - \ln[\rho_{121}-(x+\alpha)]$$
$$+\ln[\rho_{221}-(x-\alpha)] - \ln[\rho_{222}-(x-\alpha)]\}$$
$$+(z+\gamma)\left\{\arctan\left[\frac{-(x-\alpha)(y+\beta)}{(z+\gamma)\rho_{211}}\right] - \arctan\left[\frac{-(x-\alpha)(y-\beta)}{(z+\gamma)\rho_{221}}\right]\right.$$
$$\left.+\arctan\left[\frac{-(x+\alpha)(y-\beta)}{(z+\gamma)\rho_{121}}\right] - \arctan\left[\frac{-(x+\alpha)(y+\beta)}{(z+\gamma)\rho_{111}}\right]\right\}$$
$$+(z-\gamma)\left\{\arctan\left[\frac{-(x-\alpha)(y-\beta)}{(z-\gamma)\rho_{222}}\right] - \arctan\left[\frac{-(x-\alpha)(y+\beta)}{(z-\gamma)\rho_{212}}\right]\right.$$
$$\left.+\arctan\left[\frac{-(x+\alpha)(y+\beta)}{(z-\gamma)\rho_{112}}\right] - \arctan\left[\frac{-(x+\alpha)(y-\beta)}{(z-\gamma)\rho_{122}}\right]\right\} \quad (30)$$

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DID PHILIPS LANSBERGEN OWN THE UNIVERSITY OF TORONTO'S *DE REVOLUTIONIBUS* BY NICOLAUS COPERNICUS?

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Abstract: This article investigates the possibility that the copy of Copernicus' *De revolutionibus* (1566) held at the University of Toronto was once owned by the Flemish astronomer Philips Lansbergen (1561-1632). Based on a comparison between a newly discovered sample of Lansbergen's handwriting and the annotations in the Toronto *De revolutionibus,* it proposes a revision to the hitherto accepted history of this book and offers a few suggestions as to the implications of this revised provenance.

Résumé: Cet article étudie la possibilité que l'exemplaire du livre *De Revolutionibus* (1566) de Copernic, détenu par l'université de Toronto, ait appartenu à l'astronome flamand Philips Lansbergen (1561-1632). À partir d'une comparaison d'un échantillon nouvellement découvert de l'écriture de Lansbergen et des annotations que contient l'exemplaire de l'université de Toronto, nous proposons une nouvelle version de l'historique de cet exemplaire et offrons quelques suggestions quant aux implications qui en découlent.

Nicolaus Copernicus and Philips Lansbergen

Among the more than 14 million items in the University of Toronto library system is a copy of the second edition of *De revolutionibus orbium coelestium (On the Revolutions of the Heavenly Spheres)* by Nicolaus Copernicus, published in Basel in the year 1566. It is housed at the Thomas Fisher Rare Book Library as part of the Stillman Drake Galileo Collection, and is described in the university's catalogue as having annotations and diagrams attributed to Philips Lansbergen, a Flemish astronomer of the late sixteenth and early seventeenth centuries.

The astronomical historian Owen Gingerich (Professor Emeritus of Astronomy and History of Science at Harvard University and Senior Astronomer Emeritus at the Smithsonian Astrophysical Observatory) has written a fascinating account of his decades-long search to locate and describe all existing copies of *De revolutionibus.* In *The Book Nobody Read* (2004), Gingerich describes his adventures in traveling the world, first to unearth his quarry and then to publish his findings as *An Annotated Census of Copernicus' De revolutionibus (Nuremburg, 1543 and Basel, 1566)* (Gingerich 2002). Both books indicate that a copy of *De revolutionibus* is held at the Fisher Library and that previous owners of this copy include a James Erskine, the Society of Writers to Her Majesty's Signet (an Edinburgh legal library), and the noted Galileo scholar Stillman Drake. In his *Census,* Gingerich goes on to say that this copy may also once have belonged to Philips Lansbergen, though he stops short of asserting that Lansbergen was definitely a previous owner. "In the absence of independent manuscript material from Lansbergen," Gingerich explains, "it is impossible to know with certainty if this is actually Lansbergen's own copy," though "it must at least reflect his annotations" (Gingerich 2002).

It is certainly reasonable to suppose that Philips Lansbergen would have owned a copy of Copernicus' *De revolutionibus.* Nicolaus Copernicus (1473-1543) is justly celebrated as a founder of modern astronomy and one of the great minds in the history of science. He is best remembered today for his heliocentric theory, proposed in or before 1514 in his *Commentariolus,* a work that was circulated discreetly among a small number of friends, and more fully developed in his *De revolutionibus orbium coelestium,* published shortly before his death. While the inspiration behind Copernicus' heliocentric insight is not fully understood, it was possibly connected with the revival of ancient Greek learning in Italian universities and the Pythagorean idea of planets moving around a central fire, identified as the sun by Renaissance Europeans. Therefore, although he was challenging the geocentric system that had dominated Western thought since Aristotle and Ptolemy, Copernicus probably would not have felt that he was introducing a new, previously unknown idea; rather, like other scholars of the time, Copernicus likely would have felt that he was drawing on the best of what the ancients offered (Campbell 2005, Howell 2002, Rosen 1971). To put it another way, while we are inclined to think of a Copernican "revolution," Copernicus himself would probably have thought of his contribution to cosmology more as a "reformation."

Philips Lansbergen (also sometimes known as Phillips Lansbergen, Philipp Lansbergen, Philip van Lansberge, Philippe van Lansberge, or Philippus Lansbergius) was born in Ghent (Flanders, modern-day Belgium) on 1561 August 25. The 1560s were a turbulent time in that city as different religious factions battled for control. Lansbergen's Protestant parents fled with him as a young boy to France and later to England, where the young Philips studied theology. In the 1570s, the Calvinists regained power in Ghent, and Lansbergen returned to the city of his birth by 1579. From here he set out to preach in several places around Flanders. In 1580 he took up the post of Minister to the Calvinist community in Antwerp, where he remained until the Spanish invaded in 1585. At that time he went to Leiden, where he continued his theological studies. He served as a minister at Goes in Zealand from 1586 to 1613, and then moved to Middleburg, where he remained until his death in 1632 (Bergmans 1890-91, Busard 1973, Decavele and Hakkenberg 2005, Vermij 2003).

Although he also published works on theology and mathematics, Lansbergen's main intellectual interest lay with astronomy. His publications in this field included a book on cyclometrics, a tripartite work consisting of a series of tables describing celestial motion using a heliocentric theory closely following Copernicus, theories on the motions of celestial bodies, and various astronomical observations. He further published two works in which he defended the Copernican doctrine on the motion of the Earth. In these, Lansbergen sought not just to defend Copernicus in an academic discourse, but also to champion the Copernican system in a more popular arena. To that end, he wrote in Dutch (rather than Latin), and aimed the text at an audience not expert in mathematics (Vermij 2003). Lansbergen obtained a standing of considerable fame and respect among his contemporary astronomers. His most significant contribution was thought to be his tables, which in the 1630s and 1640s rivaled the Rudolphine Tables of Kepler and were often preferred because they were easier to use (even if it did emerge much later that Kepler's tables were the more accurate) (Gingerich 2007, personal communication).

Like Copernicus and other humanists, Lansbergen was convinced that the best knowledge was not new knowledge, but rather knowledge recovered from the ancients. He believed that ancient men had had a perfect knowledge of the motions of Sun and Moon, but that such knowledge had since sunk into oblivion. Lansbergen and others of like mind thought that the proper object of scholarship was to recover this lost ancient knowledge, and to do so through observation. Lansbergen therefore set about obtaining suitable astronomical instruments and observing the motions of the Sun and the planets. However, when he compared his findings with the records of observations made by classical and medieval astronomers, Lansbergen found wide divergence. While this was troubling to his initial full acceptance of the observations reported by the ancients, Lansbergen continued to respect ancient and some more recent authorities, referring to Ptolemy as "Astronomiae Princeps et Pater" or "the prince and father of astronomy," and to Copernicus as "Ptolemaeo suppar" or "almost equal to Ptolemy" (Vermij 2003).

Lansbergen was a Christian astronomer, and his theological training affected both his interest in and his interpretation of the heavens. That a Calvinist minister and theologian should also have been a scientist may come as a surprise to modern readers, but religion and science were not so opposed in early modern Europe as many people today are inclined to believe (or, indeed, are inclined to make them now). The greatest natural philosophers and scientists of the medieval West may have been in the employ of the Catholic Church, but they inherited much of their learning about the natural world from ancient pagan Greek and more recent Islamic sources. Astronomy, greatly indebted both to pagans and to Muslims, was one of the seven Liberal Arts that all university graduates would have studied, and it was put to many uses in the Middle Ages. One of its most important applications was in the complicated calculation of Easter, Christendom's most important festival, which depended on a solid understanding of the solar calendar, the lunar calendar, and where the days of the week would fall in any given year.

The connection between religion and science continued through the Renaissance and into the Scientific Revolution, and it cut across boundaries separating the different sects of Christianity that appeared during the Reformation. From among the Roman Catholics, Giordano Bruno (1548-1600) was both an early vocal supporter of Copernicus and a Dominican friar. Natural philosophy and mathematics were particularly important areas of study at Jesuit schools, of which there were about 370 by 1615. The Jesuit Christoph Clavius (1537-1612) was a professor of mathematics at the Roman College who, among other things, helped design the Gregorian calendar. From among the Protestants, the early Lutheran systematizer Philipp Melanchthon reorganized the Faculty of Arts at the University of Wittenberg in 1545 to place greater emphasis on mathematics and botany, two disciplines he believed to be essential to the proper reading of nature's signs (Findlen 2005). Calvinists, too, took part in scientific discovery without anxiety over whether such investigation was undermining their faith. John Calvin himself had a strongly humanist background that led him to think of all true knowledge as a gift from God. This included knowledge gained from a study of natural philosophy, a discipline upon which he sometimes drew in order to explain a difficult or perplexing biblical word or phrase (Howell 2002).

While leaders of the various Christian Churches could and sometimes did show hostility toward individual scientific ideas and scientists (Galileo Galilei being only the most famous of targets), they were not necessarily hostile to scientific investigation itself. Many intellectuals, Lansbergen among them, were convinced that a better understanding of nature on Earth and in the cosmos more widely would lead to a better understanding of God. To take one example, Lansbergen believed that a discovery of order in the Universe was also a discovery of divine order: one of his favourite biblical phrases seems to have been "God is a God of order, not of confusion" (1 Cor. 14:33) (Howell 2002). He was not perturbed if a literalist reading of the Bible contradicted mathematical calculation or astronomical observation. As he wrote in his *Commentationes:*

> *It is absurd to judge the motion of the earth from Holy Scripture. Of course when the foundations of these questions are raised in astronomy and geometry, they are not to be answered from Holy Scripture. I agree with the Apostle that all Scripture is divinely inspired and*

> *useful for doctrine, rebuke, correction, and teaching in righteousness (2 Tim. 3:16). But I deny that it is useful for instruction in geometry and astronomy. The Spirit, as author of the Holy Scriptures, did not desire to hand down the foundations in either of these sciences. Those things that support the principles [of geometry and astronomy] are not properly learned from Holy Scripture but from those who are engaged in it. Thus, we read that Moses had learned them not from Scripture but from the Egyptians (Acts 7:12) and Daniel with his associates had received them from the instruction of the Babylonians (Dan. 1:4, 10). So they miss the purpose of Scripture who see geometrical and astronomical questions as its norm (Howell 2002).*

In short, when the Bible appears to contradict scientific observation, the Bible is not wrong; it is instead simply communicating in the manner of common speech (Howell 2002).

Philips Lansbergen was clearly a person with sophisticated scientific interests who would have found much to engage him in the writings of Copernicus. Based on the findings of his *Census,* Professor Gingerich concluded not only that most of the leading astronomers of later 16th-century Europe owned a copy of *De revolutionibus,* but also that there was a silent network connecting astronomers of this time, as demonstrated by annotations hand-written by the early owners (Gingerich 2002). It would be surprising, therefore, if an astronomer of Lansbergen's calibre did not possess a copy of Copernicus' most famous work. But the question remains: is the University of Toronto's copy of *De revolutionibus* in fact the same copy once owned by Philips Lansbergen?

The Provenance of the University of Toronto's Copy of *De revolutionibus* and the Lansbergen Letter

The University of Toronto's copy of *De revolutionibus* contains many annotations in a rather faded brown ink. The most heavily annotated section is Book III, though annotations can be found elsewhere too. In addition to the marginal and interlinear annotations, are full pages of writing at the beginning and end of the book and two separate pages inserted (using glue) between 124v and 125r, and on 125v . All these notes appear at first glance to have been written by the same person, including those on a page at the end with Lansbergen's name on it. (This page has the titles and outlines of six chapters of another work and is marked "Philipp Lansberg", but Dr. Gingerich says the chapter headings do not agree with any of Lansbergen's printed works (Gingerich 2006, personal communication).) Stillman Drake, who donated the book to the University of Toronto, was of the opinion that it was once owned by Lansbergen, and the University has followed the donor's lead in listing Lansbergen as an early owner in its catalogue entry for *De revolutionibus.* However, as Gingerich remarks in his *Census,* with no known independent handwriting sample of Lansbergen to measure against the handwriting in the Toronto Copernicus, no certain connection could be made between Lansbergen and the copy of *De revolutionibus* in the Fisher Library.

We have recently found the "missing link" between Lansbergen and Copernicus, in the form of a hand-written letter in the university library at Leiden. It was written at Goes on 1595 March 15, addressed to the writer's "Reverende in Chr[ist]o frater" ("reverend brother in Christ"), and signed by "Tuus Philippus Lansbergius" ("your Philips Lansbergen"). The main theme of the letter, other than enquiring after the health of the recipient's family, deals with Joseph Justus Scaliger (1540-1609). Born in France, Scaliger was a poet, linguist, classical scholar, and mathematician. By 1593 he had obtained a honorary professorship at the University of Leiden where he spent the rest of his life. Scaliger determined that 4713 January 1 BC was the date on which three cycles coincided: the 28-year solar cycle, the 19-year lunar cycle, and the 15-year cycle of tax assessment called the "Roman Indiction." This, then, is day "zero" of the Julian Day System often used in astronomy today (AAVSO 2005).

The letter provides a good sample of Lansbergen's own hand, and can be compared with the annotations in the University of Toronto's copy of *De revolutionibus* to determine whether this book now in Toronto once belonged to Philips Lansbergen. Based on an analysis of the forms of the letters "r," "x," "d," the "st" ligature, and the Arabic numeral "7," it seems clear that:

1. Although all the notes may appear to have been written by one person, there are in reality two different hands in the Toronto Copernicus — Hand A and Hand B. The "r" in Hand A has a final stroke that returns to the line before connecting to the next letter, whereas the "r" in Hand B has a raised stroke connecting it to the next letter; the "x" in Hand A is written using two separate strokes (where the pen would be lifted from the paper in between the two strokes), whereas the "x" in Hand B is made from a single stroke; the "d" in Hand A has an ascender that is (almost always) straight up, whereas the "d" in Hand B has an ascender that curves back; the "st" ligature in Hand A has quite a low connecting stroke, whereas the "st" ligature in Hand B has a high connecting stroke; the "7" in Hand A has a bit of a dip in the top, whereas the "7" in Hand B has a very flat top.

2. Hand A wrote all the marginal and interlinear annotations in Books I-III, the "Schema triplicis motus Terrae" and "Chronographia Christum praecedens" at the beginning of the volume, and the "De motibus qui circa terram considerantur, ac primum de motibus Terrae" as well as the "Schema triplicis motus Terrae" at the end of the volume. (Figures 1 and 2.)

3. Hand B wrote the inserts glued in (a) between 124v and 125r and (b) on 125v, as well as the marginal and interlinear annotations in the "De motibus" at the end of the volume. Hand B may also have written the annotations at the bottom of 122r, as well as those on 125r and 125v (under the insert),

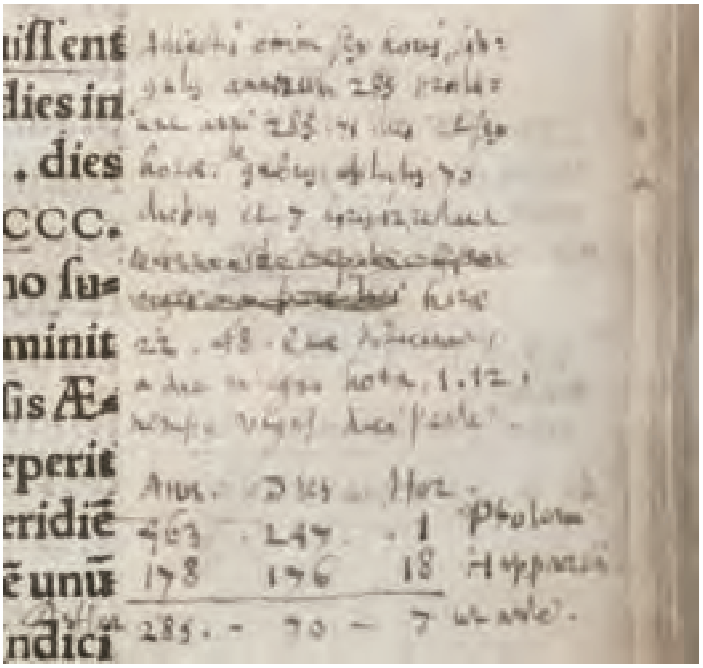

Figure 1— Hand A in Copernicus' *De revolutionibus,* p. 79 r, The Thomas Fisher Rare Book Library, University of Toronto. [file name: 79r lower]

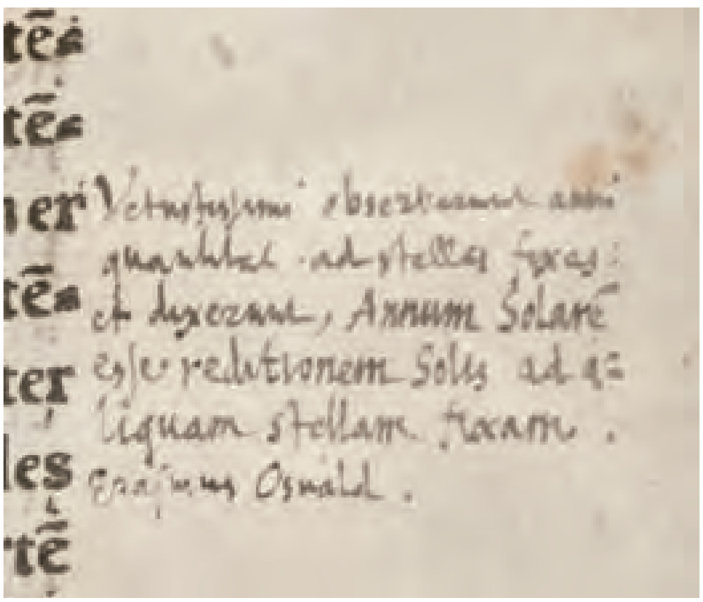

Figure 2 — Hand A in Copernicus' *De revolutionibus,* p. 79 r, The Thomas Fisher Rare Book Library, University of Toronto [file name: 79r upper]

though the visible text is insufficient to allow any certain conclusions. (Figure 3.)

4. Since Hand B corrects Hand A in the Toronto *De revolutionibus* and in one case is glued on top of earlier annotations, Hand B wrote in the book later than Hand A. (Figure 3.)

5. Hand B is the same Hand that wrote the letter signed "Philippus Lansbergius." Presuming that this letter was, in fact, written in Lansbergen's own hand, then Hand B in the Toronto Copernicus is probably also Lansbergen's own hand. (Figure 4.)

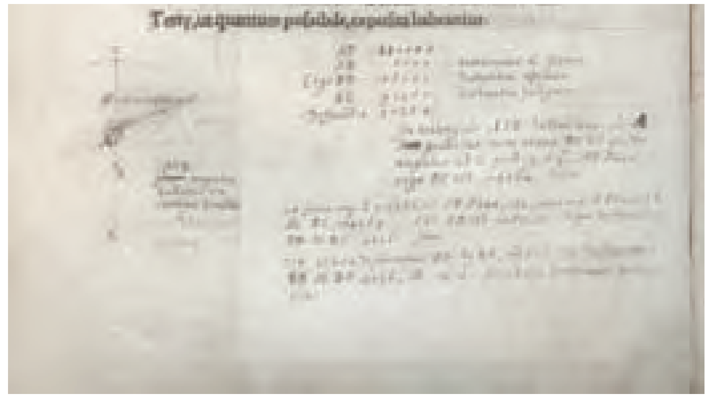

Figure 3: Hand B in Copernicus' *De revolutionibus,* p. 125 v, The Thomas Fisher Rare Book Library, University of Toronto [file name: 125v]

Figure 4: A letter written by Philips Lansbergen, 1595 [file name: letter]

6. If Hand B is Lansbergen, then Philips Lansbergen did have the Toronto *De revolutionibus,* but only after someone else had already written in it.

That Philips Lansbergen was likely not the first to possess the Toronto *De revolutionibus* is not surprising, since he was only five years old when it was published, leaving plenty of time for previous ownership. The identity of the person who owned and annotated the book before Lansbergen remains a mystery and the University of Toronto's copy of *De revolutionibus* awaits further study. Its annotations, both those by Lansbergen and those by its earlier owner, have the potential to shed further light on the reception of Copernicus by succeeding generations of astronomers, the extent to which these thinkers agreed and disagreed with Copernicus and with each other, and, more generally, how scientific knowledge was transmitted in early modern Europe.

Acknowledgements

For their help in the preparation of this paper the authors wish to thank John Cramer, Special Collections Reading Room, University of Leiden; Dr. Owen Gingerich, Harvard Smithsonian Center for Astrophysics; Professor Paul Hoftijzer, University of Leiden; Milton Kooistra, Ph.D. candidate, Centre for Medieval Studies, University of Toronto; Chris Meyer, image preparation; Dr. Adriaan van der Weel, University of Leiden; Dr. Kimberley Yates, Centre for Reformation and Renaissance Studies, University of Toronto; the staff of the Thomas Fisher Rare Book Library, University of Toronto; the staff of the Bibliotheek Rijksuniversiteit Groningen.

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Mairi Cowan specializes in the religious and social history of medieval and early modern Europe. She has been teaching history and writing at the University of Toronto, and is currently on maternity leave.

Nominations

2008 Award Nominations

The deadline for nominations for recipients of awards in 2008 is 2007 January 31. Awards include the Chant Medal, the Service Award, the Chilton Prize, and the Simon Newcomb Award. For more details about each, please see the Society's Web site. Nominations can be submitted by any member or group of members, but in the case of a Service Award, approval of the nomination by the Council of the nominee's Centre is encouraged, if the nominee is attached to a Centre. Please help the Society recognize outstanding achievement by its members by sending your nominations to Past President Peter Jedicke by email.

2008 Executive Nominations: President, 1st Vice-President, 2nd Vice-President, and Secretary

The three presidential positions and the position of Secretary will be filled by election or acclamation at the Society's Annual Meeting, scheduled for 2008 June 30 during the General Assembly. Names of candidates must be presented to the Secretary at least 60 days prior to the Annual Meeting by the Society's Nominating Committee, or by a private nomination supported by the signatures of five members of the Society. The duties associated with these positions are specified in the Society's bylaws, which are available in the password-protected portion of the Society's Web site. As chair of the Nominating Committee, I invite you to send suggestions for these positions for the Nominating Committee's consideration. Please send any suggestions by email, no later than 2007 January 31.

Peter Jedicke
Chair, Awards Committee
Chair, Nominating Committee
pjedicke@yahoo.com

A NEW BRUDERHEIM FRAGMENT

Jeremy B. Tatum
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Abstract: A new fragment of the Bruderheim meteorite has come to light. Its mass is 0.720 kg, bringing the known total mass recovered to at least 307 kg.

Résumé: Un nouveau fragment du météore Bruderheim a fait surface. Sa masse de 0.720 kg amène la masse totale récupérée à au moins 307 kg.

On 1960 March 4, a large meteorite, broken into many fragments, fell near the community of Bruderheim, Alberta. The circumstances of the fall and recovery of most of the fragments are described by Folinsbee and Bayrock (1961). In terms of the mass of recovered material, this is the largest meteorite fall recorded in modern times in Canada. It is a stony meteorite, technically classified as an L6 hypersthene chondrite. According to the *Catalog of Meteorites* (Graham *et al.* 2000), about 303 kg of material was recovered. The *Catalog* gives the present locations of many of the larger fragments.

It would not be surprising if new, unrecorded fragments turned up from time to time. Some were doubtless found and kept by individuals at the time; others may yet turn up in fields and in rock piles. Indeed, in 1989 Mr. Norman Nemirsky brought in to the University of Victoria a 3.65 kg specimen, which his father had found in 1960. A photograph of this specimen adorned the 1990 cover of the *Journal,* and the circumstances were described inside (Tatum 1990). Mr. Nemirsky at least initially decided to keep the specimen, which had been in his family for so many years, though its present whereabouts are unknown.

In somewhat similar circumstances, Mr. Leonard Franko recently brought in several putative meteorite specimens, one of which he felt was probably a Bruderheim fragment. Most were not meteorites, but David Balam and I confirmed that one of them was indeed a new Bruderheim fragment. It was found in 1960 by his father Steve Franko on his farm, which is between Two Hills and Myrnam, 75 km east of Bruderheim. The purpose of this article is merely to record the existence of the new specimen in the scientific literature. A photograph of the new specimen is included with this article as Figure 1. Its dimensions are 12.5 × 9 × 5 cm, and its mass is 0.720 kg. Together with the Nemirsky fragment, this brings the total known recovered mass to about 307 kg. The Franko fragment is now in the private collection of Mr. Don Hurkot in Alberta. I am much indebted to Mr. Franko for showing this meteorite to me, and to David Balam, and for telling us its history (besides treating us to an excellent lunch!).

Figure 1 — The Franko fragment of the Bruderheim meteorite. Note the thumbprint-like depressions on the surface. These are called "regmaglypts" and are characteristic of many meteorites. They are produced as molten fragments of the meteoroid are calved away during its flight through the atmosphere. *Photo: Neil Honkanen*

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Dr. Jeremy Tatum is a retired Professor of Physics and Astronomy at the University of Victoria, where for 31 years he taught and conducted research on atomic and molecular spectroscopy, the composition of comets, and the orbits of asteroids — particularly near-Earth asteroids. An asteroid bears the name "Tatum" in honour of his work.

Mars: The 2007 Opposition

by Murray D. Paulson, Edmonton Centre (murrpaul@telus.net)

At the beginning of December, Mars glows brightly in the evening sky. At magnitude 1.3, it outshines Betelgeuse and Aldebaran, the other reddish embers in the evening sky, and will remain brighter than this magnitude until the end of the first week of January. Mars will also be larger than 15 arc-seconds, if that can be considered large! This apparition is not "the" aphelic opposition, but it isn't far off. The next two oppositions will both be smaller, though that in 2012 will be diminished by only 2″ compared to this year. For northern observers, however, this apparition is "the one." Mars will sit as high as it can sit in our sky, and at opposition, it will actually be 3.5 degrees above the ecliptic, at nearly +27 degrees declination. During opposition at my latitude in Edmonton, Mars will rise at 3:34 p.m. local time and set at 9:32 a.m. the next morning for a grand total of 17 hours above the horizon. At Toronto's southerly latitude, Mars is above the horizon for 16 hours. This is the "Harvest Moon" phenomenon, and for a bonus, we have the benefit (?) of the long winter nights.

In early December, Mars rises just before 6 p.m. local time and by 8:30 will be higher than 20 degrees altitude, well placed for observing. When it crosses the meridian after 2 a.m., it will crest at 62 degrees at latitude 53° N, and 65 degrees at latitude 49° N. It has been winter in Mars's northern hemisphere, but on December 9, Mars will pass through its vernal equinox. At our latitude on Mars, we could go out and scrape the CO_2 frost off the car windows in the morning. It is cold! In Mars's polar regions, the temperature will drop to −150 °C during the night. At 53° N, temperatures will range between overnight lows below −100 °C and daytime maximums in the −40s. Opposition is on Christmas Eve, when Mars will shine at magnitude −1.6. In the eyepiece that evening, you will see Syrtis Major on the planet's 15.7″ disk. This opposition is very similar to that of 1993, which occurred on January 7 when Mars was 14.9″ in size and shone at magnitude −1.4. At that time, the Red Planet was so high in the sky that occasionally you could use ridiculously large magnifications.

Figure 1 — Images by Rolf Meier using a Celestron 14, SkyNyx 2.0 camera; processed with Registax. Used with permission.

Equipment

What constitutes the best telescope for observing the planets? Arguably, it is the one that you own, or can borrow! I do like the clean, high-contrast image that APO refractors can give. The first time that I clearly saw white clouds against the pink background of the desert regions north of Mare Cimmerium was during the 1999 apparition, using an 8-inch refractor at the Calgary Science Centre. Wow, that was nice! (Thanks, Alan!) The problem with refractors is that an 8-inch (or larger) instrument is rare, big, and very expensive. The next option is a reflecting telescope with a small central obstruction, but even that last qualification is not a truism. Maksutov-Newtonians, Maksutov-Cassegrains, and planetary-optimized Newtonians fit the bill. The only critical items are that the optics be very good, the telescope well collimated, and time allowed to thermally equilibrate with the outside temperature. It's not a hard-and-fast rule — Damian Peach takes some of the best images of the planets that I have seen using a Celestron 14. That telescope has a large central obstruction (32%), but the optics are excellent. Check out his images on the Web! I observe through a Takahashi 250 Mewlon — the contrast and resolution are quite good, though it has a 29% obstruction.

When it comes to telescopes and planets, one word is king: contrast. Scattered light destroys contrast, and one major culprit here is dust on the optics. The closer that dust lies to the eyepiece, the more scattering becomes an issue. For refractors and catadioptrics, the mirror diagonal is usually the guilty party.

Telescopes must cool down if you are to use them to their limits. My 5-inch refractor takes 45 minutes to reach ambient temperature and my old 12.5-inch Dobsonian takes 90 minutes before the optics are cool and the tube currents flushed out.

Eyepieces make a difference. Features on Mars are low in contrast and every glass surface in the eyepiece scatters a bit of light. The fewer elements, the better. Many planetary observers prefer quality orthoscopic, monocentric, or Plössl eyepieces. I have a few orthoscopics in my collection along with the usual Plössls, but I also use my Naglers and Panoptics. Use as much magnification as you can. Mars takes power well: I have used 300× with the 5-inch and even more with larger apertures. I find that the major consideration is that the eyepiece be clean and free of scratches. For those without some sort of clock drive, a wide-field eyepiece under high-power magnification is a big advantage. The Naglers and Ultrawides do very well here. In the 1990s, when I observed with the 12.5-inch Dobsonian, I used a 4.7-mm Ultrawide eyepiece and the image of Mars was sharp as a razor as it drifted across the field. A wide-field eyepiece is the poor man's clock drive.

I would be remiss if I didn't mention binoviewers. The best view of Mars that I have had in recent years was through a friend's binoviewer in a 5-inch APO refractor. Like many of us, I have more than a few floaters, and if you can use both eyes, your eye/brain ignores what is not common in both eyes, leaving you with a very good view indeed.

Observing

The first thing that strikes you in the eyepiece is the ruddy pink colour of Mars and the bright white of the polar region. The North Polar Cap has tipped into view from our perspective and may be enhanced by a polar hood of cloud. It wasn't visible earlier this fall due to the geometry between Earth and Mars. Careful observers may note morning hazes on the following limb of the planet, along with the occasional brightening that indicates a small dust storm. In late summer, there was a lot of dust in the Martian atmosphere that made it difficult to see surface details, but the atmosphere appears to be clearing up in time for the opposition.

On a solar eclipse trip in Zimbabwe, I noted that the soil on the dirt roads of Hwange National Park looked just like Mars! It was a startling revelation that the soil below my feet was Mars-red. Some of the processes and geology of our two planets are not too dissimilar.

Planets, and especially this one, can be frustrating to observers due to their low-contrast features. Typically, at the beginning of a "Mars" season, I look in the eyepiece and see only the major high-contrast features on the disk. The polar caps just jump out at you of course, and the major maria like Syrtis Major are obvious, but other dark albedo features take some patience to notice. My eye's reluctance to see the subtle details is due to the fact that it has been two years since the last opposition and I have to re-train my eye/brain to see the subtle features. You can train your eye by giving yourself time to look. Let the image play over your retina until you notice soft features that pop in and out. It is similar to using averted vision. You have to give the image time to build up on the retina and brain and you have to learn to trust what you see. The more you observe, the *more* you see.

Colour filters also help. They increase the contrast between planetary and atmospheric features, and the background of the planet. There are two major principles here. One is that the longer the wavelength of light, the farther it can travel in a haze of atmosphere. Blue light does not penetrate too far down into Mars's atmosphere, and so it shows cloud features best. Green and yellow light gets farther down, helping to emphasize dust storms. The orange and red filters can see through the haze and emphasize the contrast with the maria. The orange or red filter does not darken the blue-green maria, because they are mostly gray to gray-brown in colour. The blue-greenish cast is a contrast effect in the eye caused by the pinkish colour of the bright regions. The filter lightens up the pinkish regions and this emphasizes the contrast with the gray terrain.

Mars occasionally, though rarely, has a "blue clearing," where you can see the surface of the planet distinctly through a blue filter. In the spring season on Mars, you may occasionally see a bluish cloud over Syrtis Major.

Filter colour	Feature
Red (Wratten 25)	Emphasizes darker features and dust clouds. A very dark filter. Good in larger apertures
Orange (Wratten 21)	Emphasizes darker features and dust clouds. Lighter filter than red, good for smaller apertures. If you have only one filter, this is it.
Yellow (Wratten 12)	Dust clouds; improves contrast with the darker regions
Green (Wratten 57)	Improves contrast with atmospheric features but you can still see the surface
Blue (Wratten 38)	Brings out atmospheric features: clouds, limb hazes

Drawing

Drawing Mars enhances your skills as an observer. The process gives your eye lots of time to integrate subtle details that flicker in and out. To get started, you need only a pad of paper, an HB and an H pencil, a red flashlight, and an eraser.

The Association of Lunar and Planetary Observers (ALPO) recommends a standard 42-mm diameter circle to draw Mars. Why 42? Go ask Douglas Adams.[1] Start off with a circle template

[1] Mars is ~ 4200 miles in diameter

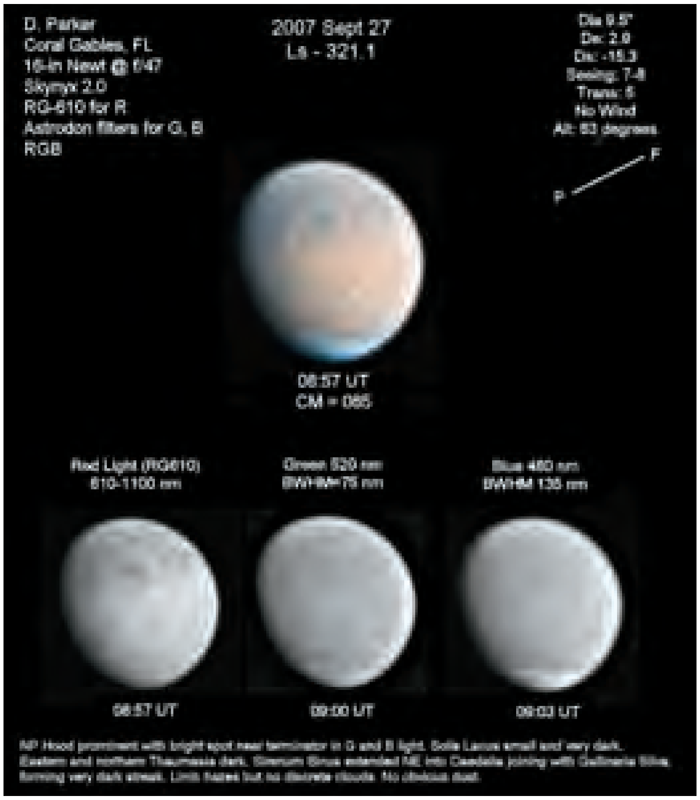

Figure 2 — Images by Donald Parker, Coral Gables, Fla., using a 16-inch Newtonian @ f4.7 Skynyx 2-0 camera Astrodon filters. Used with permission.

drawn on your page, or download the ALPO "Blank Mars Observing Form" from ALPO's Web site under the link to the Mars section. At the eyepiece, find the north (or south) polar cap and orient your drawing to the sheet with south up (north for those using a diagonal). Next, draw the terminator line. Put in the major features like the polar cap and larger maria. Try to get the features in their proper proportions and in relation with each other. Work quickly, and when you have the major features down, note the time on your drawing. If you see cloud or limb hazes, put them in with a dotted line. As you spend more time on the drawing, you will see more and more details. This is the good thing about making drawings of Mars — you spend time making critical assessments of what you are seeing and in those moments, you see the subtle details come and go. On your drawing, put the Universal Time and date, the instrument you observed with, including eyepieces and filters used, and an estimate of the seeing conditions and transparency. Add a small arrow on the drawing showing the direction in which the planet moves with the drive off, [←P] (P for Preceding), and a note if you are using a star diagonal. I put down my location, the temperature, and any particular notes on the observation.

The ALPO is interested in observations of Mars, and you can submit images or drawings to them. Just go to `http://tech.groups.yahoo.com/group/marsobservers/` and join the group. The welcome message will explain things to you.

Special events

In western Canada we get an early Christmas present: a lunar occultation and graze of Mars on December 23 (December 24 UT). The graze line runs through Portland, Oregon to Churchill, Manitoba. If you are north of that line, you will see a complete occultation, and if you are south of it, you will observe a miss. Exactly on the graze line, you will see Mars partially covered by the Moon. Cool! This will be quite a spectacle, though Mars and the Moon will be low in the eastern sky, only 22 degrees above the horizon at mid-event from Calgary. Things improve as you go east. At Churchill, Mars and the Moon will be at 37 degrees altitude. The event takes place on December 24 at 1:54 UT; at Calgary, this is 18:54 MST (local time), but on the night of the 23rd! Good luck to you all!

Figure 3 — The December 23 grazing occultation path for Mars. Regions north of the line will see an occultation. Those along the line will see Mars move along the Moon's limb. Graphics generated with *Guide,* post-processed by the author.

Mars Occultation / Graze

Place	Ingress	Mid-event	Egress
Vancouver, B.C.	1:40:59	1:53:44	2:06:41
Castlegar, B.C.	1:46:25	1:53:12	2:00:06
Calgary, Alta.	1:49:13	1:55:43	2:02:18
Graze 70 km south of Calgary, Alta,		1:54:51	
Graze 90 km east of Calgary, Alta,		1:55:47	
Graze 50 km NW of Battleford, Sask.		1:59:02	
Edmonton, Alta.	1:47:28	1:59:22	2:11:28
Graze 30 km NW of Churchill, Man.		2:12:50	

Note: All times are for December 24 UT

A Stroll about Mars

Lastly, let's take a stroll around Mars. Here is a week-by-week description of what can be seen on the planet, at 10 p.m. CST as seen from Winnipeg. The view will be south up, as seen in a Newtonian telescope. The surface of Mars rotates in the direction that the planet moves with the drive off, thus the morning side is the trailing side.

Week 1: In the first week of December, Solus Lacus, a prominent round region, is on the meridian in the south. There is a dark region that arches over it. Another thin dark region is just below it (toward the equator). The lighter region in between is Valles Marineris. You won't see these canyons, but they run just under Solus Lacus, coming across from the preceding side. As we head south we cross a large pink desert region, where the great volcanoes of Mars reside. Amateurs image them all the time, but visually you may note them by the orographic[2] clouds that form over them.

Week 2: Erythraeum Planum [now called Bosporos Planum] and Aurorae Sinus are on the meridian in the south and Niliacus Lacus and Mare Acidalium are in the north. *Pathfinder* and *Viking* are located in the light area, Chryese-Xanthe, in between these regions.

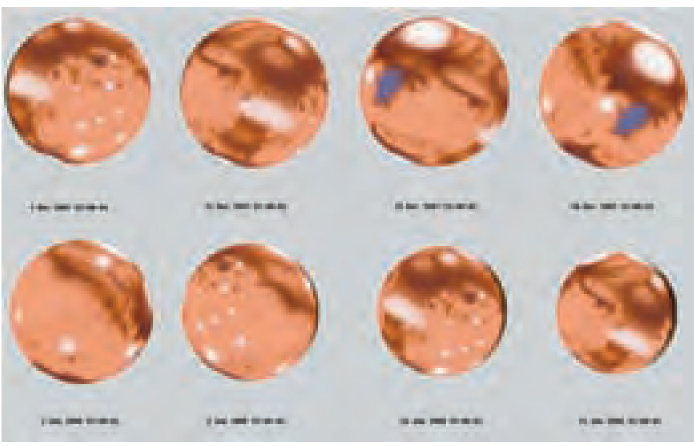

Figure 4 — A view of the face of Mars at weekly intervals in December and January.

Week 3: Syrtis Major is on the preceding side of the disk and the arm of Sinus Meridiani stretches across the disk to the other side. Sinus Meridiani is a fist-like lump on the end of this arm, and is where the central meridian of Mars is located. The rover *Opportunity* is located just off the western tip of Sinus Meridiani. South of Syrtis Major is the vast crater basin of Hellas, 1700 km in diameter. It is a low region, 8 km below the surrounding highlands. The floor of Hellas is bright and may have frosts, making it easy to mistake for a polar cap.

Week 4: Syrtis Major is now on the following side of the planet, and you may get a chance to see a significant part of a rotation of this prominent feature over the night. To the north of Syrtis Major, bordering the north polar region, is Utopia. There is a small dark projection that pokes up toward Syrtis Major, Nodus Alcyonius. (Hey, any Naglers under the tree?)

Week 5: We are now looking at the least-detailed side of Mars. Mare Cimmerium arches gracefully across the southern region of the disk. There is a lighter region, Hesperia, between Mare Cimmerium and Mare Tyrrhenum that flows out of Syrtis Major. It is now early January, and the cycle repeats again as Mars starts to shrink and recede.

This will be a great apparition and I wish you clear skies! I'm looking forward to seeing images and drawings from those of you who would like to submit them. We may try to put a summary of some of the amateur images and drawings in a future issue of the *Journal*. You may contact me at mars.paulson@gmail.com

Interesting Web sites

www.gaherty.ca/rogers/marstoolkit.htm

ALPO's discussion group on Mars:
http://tech.groups.yahoo.com/group/marsobservers/messages

Damian Peach's Views of the Solar System
www.damianpeach.com/index2.htm

Rolf Meier
www.cyberus.ca/~ec088060/pages/mars07.html

A Glossary of Terms

Lac: Latin for lake. *e.g.* Solus Lacus (Lake of the Sun)

Mare: Latin for sea. The dark areas on Mars were interpreted to be seas; a contrast effect with the pinkish hue of Mars makes them look blue greenish. *e.g.* Mare Acidalium

Mons: Latin for mountain. *e.g.* Mons Olympus

Sinus: Latin for bay. *e.g.* Sinus Meridiani

[2] Orographic: Clouds that form in the air mass passing over a mountain.

The Ultimate Travel Scope for Visual Observing

By Warren Finlay, Edmonton Centre (warren.finlay@interbaun.com)

For many amateur astronomers, one of life's more frustrating scenarios is finding oneself under incredibly dark skies without a telescope. Although I make the best of naked-eye or binocular observing in such circumstances, I will sometimes catch myself on a business trip, looking up at the night sky, thinking "Wow, I wish I had a good-sized scope with me." Camping on family vacations often leads to a similar experience, with me wishing that my large telescope fitted into the back of a minivan that is already too full of other gear. Sometimes I manage to squeeze in a travel scope, typically something with a few inches of aperture. Cruising the night sky with my small scope, revelling in the beauty that a dark sky brings to the eyepiece, I sometimes find myself thinking: "This would be truly amazing in a 10-inch scope." Of course, the thought is dismissed quickly as impossible. Who would ever market a 10-inch telescope that could go on the plane with me? The thought wouldn't even cross my mind on a backpacking trip, since nobody sells a 10-inch telescope that is that portable.

Figure 1 — The Genstar telescope as it appears when set up for observing.

Until now, that is.

Believe it or not, right here in Canada, Dwight Hansen of Hansen Optical makes and sells the Genstar, a 10-inch f/5 Dobsonian truss-tube scope that meets the carry-on weight and size limits of North American airlines. Indeed, I have taken

Figure 2 — The Genstar with its shroud removed in order to show the carbon-fibre truss tubes and secondary holder.

this telescope with me on all of the above seemingly impossible travels. To say that the Genstar has opened entirely new possibilities for my observing is an understatement. For example, during the close approach of asteroid 2004 XP 14, I was scheduled to be backpacking with my daughter. Fortunately, I was able to fit the Genstar snugly in the bottom compartment of my Arcteryx Bora 80-litre pack with the entire main compartment free to carry the rest of my gear, allowing me to search for this asteroid with a 10-inch telescope during the middle of my backpacking trip!

For airline travel, removing three thumbscrews allows the focuser to come off so that the secondary ring can be firmly clamped onto the aluminum primary rocker box and slid into the optional carry-on case. The focuser, eyepieces, and red-dot finder all tuck into a second carry-on bag with my other carry-on items. The carbon-fibre truss tubes go as checked baggage in a supplied 3-inch-diameter tube or, if you're good at sweet-talking the gate agent, they could go as carry-on, since although their length is over the allowed limit, the tube is unobtrusive enough that I am guessing they would often be allowed as carry-on (although I have not tried this). On a trip from Edmonton to Florida, I had to change planes, walk interminable distances, and ride buses through Toronto's Pearson Airport construction. That was in addition to hauling my checked bags through customs. I had no troubles with my Genstar and second carry-on bag tucked over my shoulder. After I arrived in Florida, the telescope was back together and ready to go in about ten minutes. A quick collimation of the primary mirror at my observing site deep in the Everglades soon had me observing with fireflies flitting nearby, whip-poor-wills calling hauntingly, and alligators in a nearby ditch staring up at the weird Canadian whose home was still snowbound.

The telescope had no trouble fitting in the cramped overhead bin of a Canadair Regional Jet (CRJ) 700 on a flight from Edmonton to San Francisco, the smallest plane I have boarded with this telescope as carry-on. The instrument performed admirably upon arrival, after being hauled in my backpack a mile or so into a state park south of San Francisco. Over three days hiking in the backcountry, I observed about 130 objects from the Herschel II list. Occasional tweaking of the tension in the altitude bearings as the night temperature dropped and one additional mid-session collimation were the only adjustments needed during that awesome California spring observing run.

For overseas travel, one needs to be careful with carry-on baggage since some European airlines have more stringent limits than do our North American airlines. However, I had no trouble taking the scope as carry-on luggage on Air Canada flights to France, where noisy bullfrogs serenaded me among chateaux during two nights of peaceful deep-sky observing at a rural site near the Loire Valley.

For car travel, there is no need to remove the focuser, making setup even simpler. On a 6000-km family road trip through the southwest U.S., I used the telescope every clear night from our campsites, with an average set-up time, including

Figure 3 — The Genstar rocker box with primary and secondary mirrors secured for storage or car travel.

collimation of the primary mirror, of less than 10 minutes. Indeed, one of the most attractive aspects of the scope's design, other than its portability, is its ease of collimation. The three collimating bolts on the primary mirror are readily turned by hand without any need to unlock or lock any bolts or use any wrenches. On the trip, the telescope sat underneath camping gear on the floor of our minivan and was subjected to extensive road vibration due to travel over several hours of badly washboarded gravel roads, as well as several hundred kilometres of heavily damaged paved roads, in addition to thousands of kilometres of highway. Despite such travel, only the primary mirror needed adjusting at each setup; collimation took only a short time: a simple matter of lining up the primary mirror's white centre ring with the dark central perforation in my Cheshire eyepiece.

Given the affordable pricing of this telescope, I wouldn't change a thing about it. Those observers who do not like red-dot finders may take issue with the one normally supplied with the telescope, but putting a telescopic finder on a travel scope would increase its weight and reduce its portability. When I'm using a travel scope, I'm typically under very dark skies where I find a red-dot finder works admirably well, unlike in light-polluted skies where a telescopic finder is more helpful.

Given the compact size and light weight of this telescope, you may be surprised to learn that its components are CNC-machined aluminum, making this an exceptionally sturdy instrument. The aluminum rocker box has ingenious milled slots within which the altitude bearings slide in a manner that actually places the horizontal axis of rotation at a virtual location above the physical rocker box. While this feature allows the scope to have a magically light weight, it also results in a minor limitation: the scope cannot travel lower than about 20° altitude unless the rocker box is tilted. Since sky transparency is typically poor at such low altitudes, this is not much of a concern. Besides, this is a travel scope, and if you really need to see a horizon-hugging object, you would be better off buying a plane ticket and flying with the scope to a more southerly location where your target is higher in the sky!

The diffraction-limited 1/6-wavelength mirrors that are standard with this scope are supplied by Glen Speers of Sky Instruments, who imports them from Wan Chen in China. The optics in the telescope I tested gave views that were superb during many nights of observing both deep-sky and planetary objects, and I never wanted for anything better.

For those who wish that they had a good-sized visual observing telescope to take with them while travelling, this is the scope of your dreams. There is no other commercially available scope with a mirror of this size that can go as carry-on luggage on a plane. Winter holidays to the tropics never looked so good! Its extreme portability, ease of setup, high quality manufacturing, and reasonable cost for its features make this instrument a delightful new addition to the telescope marketplace. If you have even the slightest interest in purchasing a portable telescope, you need to give this one a very serious look.

Telescope Specifications

Focal length	1270 mm
Primary mirror diameter	254 mm (10″)
Secondary mirror diameter	50.8 mm (2″)
Total weight when setup for observing	24.6 lbs.
Weight when compacted for carry-on	20.8 lbs.
Focuser (JMI)	1.25″
	(2″ focuser not available)
Height when setup and pointed at zenith	48″
Height when compacted for carry-on	7.5″
Width	12″
Depth	12.5″
Price	$2195

Available from

Hansen Optical (`www.genstartelescopes.com`)
118 Great Oaks
Sherwood Park AB T8A 0V8
(780) 464-1268

The Science Shop (`www.thescienceshop.com`)
316 Southgate Centre
Edmonton AB T6H 4M6
(888) 435-0519

Warren Finlay is the author of Concise Catalog of Deep-Sky Objects: Astrophysical Information for 500 Galaxies, Clusters and Nebulae *and is the 2006 RASC Simon Newcomb award recipient. He co-authors* JRASC's *"Deep-Sky Contemplations" column. By day, he is a Professor of Mechanical Engineering at the University of Alberta, but at night, he observes the deep sky from the darkest sites to which he can manage to travel.*

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Pen & Pixel

Night Work: Ron Berard is well-known around the Winnipeg Centre for his images of "astronomers at work." Here he's captured Ray Andrejowich at the eyepiece of his 25 inch Dob, scanning for faint planetaries and Hickson galaxies. The photo was taken using a Nikon D70, 2 minutes @ ISO 800, and a Sigma 14-mm @ f/2.8 lens.

Mantario Trails by Jennifer West of the Winnipeg Centre.
Using a Canon 20Da camera at f2.8, ISO 1600, and a 15-mm lens. A combination of 92 60-s exposures with a 1-s gap between each exposure. The images were taken in the early morning of 2007 August 16, at Lake Mantario in Whiteshell Provincial Park, Manitoba between 12:00 a.m. and 1:33 a.m. Images combined using *ImageJ*.

A Moment With…

Dr. Ralf Gellert

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

For more than three years, the *Mars Exploration Rovers* (MER) *Spirit* and *Opportunity* have been rumbling about Mars looking, sniffing, and generally checking out anything of interest. A major on-board instrument allowing the rovers to do this is the Alpha Particle X-Ray Spectrometer (APXS). Located on the robot arm at the front of the rovers, this device is used to sniff out the composition of rocks and soil that come within reach. The APXS consists of a source of alpha particles (helium nuclei) and X-rays (^{244}Cm) and appropriate detectors. When the instrument is placed on a target, the specimen is irradiated and the energy spectra of backscattered alpha particles and X-rays are measured. In this way, the elemental composition of the rock and soil can be determined. The information then comes streaming back to Earth. But what does it actually say? Does it scream "Water!" or "Sulphur!" or "Iron!"? Not quite. Interpreting what it actually does say is determined in the labs of Dr. Ralf Gellert of the University of Guelph.

Dr. Ralf Gellert

Like many scientists profiled in these columns, Dr. Gellert was influenced by a certain science-fiction television show that involved trekking to the stars — along with his own urge to explore. Unlike those fictional futuristic times, our sensors do not give instant results. Dr. Gellert works on designing and building scientific instruments, and then devising the methods of analyzing the results that they provide.

For example, Dr. Gellert is currently a member of the team working with the Mossbauer spectrometer on MER that identifies iron-bearing minerals. He is also the lead scientist for the APXS. As such, he wrote most of the software used to talk to the instruments and, during the four months subsequent to the landings, he (then at the Max Planck Institute for Chemistry in Germany) and his group communicated with the rovers every day. However, getting the information is only half the battle. What it actually means must be teased out using theoretical models and analytical tools. And time is of the essence. With rovers having the ability to go somewhere new every day, decisions, based on the latest results, about where to go and what to do next must be made quickly.

Here is where the Guelph connection comes in. Dr. Iain Campbell of U of G's physics department does analytical work with a scanning proton microprobe and a technique called proton-induced X-ray emission. This method is based on the same principles used by the APXS. Using this technology, and a special computer package that he developed, Dr. Campbell is able to analyze everything from rocks, to air pollutants, to paintings by the Masters, and to Martian soil. In fact, Dr. Campbell conducted simulations to predict what the rovers' instruments should see. The connection to Dr. Gellert's work was a natural one and he made the move to Canada.

The rewards of this type of work come in seeing the data and coaxing the hidden information from it. Dr. Gellert's exhilaration comes with each new spectrum, when a fresh data point, perhaps indicating something new, is added to our bank of knowledge. Such was the case, for example, when the APXS detected the presence of salts in certain rocks, indicating that liquid water existed in the Martian past. It's all about collecting one piece of the puzzle at a time.

Helping with the puzzle are students. Fourth-year specialist students have approached Dr. Gellert with requests to work on Mars-related material. He has provided them with archived data in which the students looked for the spectral signature of argon from the atmosphere. They checked to see if the spectral peak remains constant (it doesn't) and looked for correlations between the variability and other parameters in Mars's environment. This may provide clues to circulation patterns in the atmosphere. Dr. Gellert explains that while this work is not "rocket science," the students are nonetheless on the cutting edge of science. This is a wonderful opportunity since sometimes there is something obvious in the data that no one (other than, perhaps, students) may examine.

In 2004, NASA made an Announcement of Opportunity for potential instruments to be attached to the upcoming *Mars Science Laboratory* (MSL) mission, a large and very capable rover. Dr. Gellert suggested a design for an improved version of MER's APXS and his proposal was accepted. The device is being designed at Guelph with Dr. Gellert providing direction on the scientific specifications; it will be built by the Canadian firm MDA (MacDonald, Dettwiler and Associates) and is scheduled for launch with MSL in 2009.

Given the high failure rate of Mars-bound spacecraft, I wondered what would prompt someone to spend years of their career working on an instrument that might simply disappear into space. Dr. Gellert explains that it is a combination of curiosity, the desire for discovery, and the urge to perform good science. While there is an element of luck involved, mitigating the risk is good planning and good engineering. Besides, in the several years he worked to prepare the rovers, he was so focused on making the instruments as good as possible that he didn't spend much time worrying about the risk.

Given that the APXS has found evidence for water in Mars's distant past, what is Dr. Gellert's view of the ancient Martian environment? He feels that the planet must have had a great deal of water two or three billion years ago and there may even be local sources of water, such as hot springs or pools, existing today. However, despite the hundreds of thousands of photographs and other measurement transmitted to Earth from the red planet, Dr. Gellert reminds us that we have still only successfully landed at five locations, all fairly similar, and been reasonably mobile at only two of them. Even with the orbiters, the situation regarding water is far from clear.

Other than Mars, Dr. Gellert is fascinated with the possibilities offered by Phobos. He suggests that this Martian moon is a good bet for the first human landing in the Mars system. To get the ball rolling, he is part of a group studying the possibilities offered by a Canadian robotic mission to Phobos called PRIME (**P**hobos **R**econnaissance and **I**nternational **M**ars **E**xploration). Two options are being considered. One, an orbiter, would co-orbit Mars with Phobos, and study the moon for up to ninety days. The other, a fixed lander, would examine its surroundings for up to a Martian year. Either way, Dr. Gellert will have plenty of fascinating data to pore over and analyze for years to come.

Philip Mozel is a past librarian of the Society and was the Producer/Educator at the former McLaughlin Planetarium. He is currently an educator at the Ontario Science Centre.

Second Light

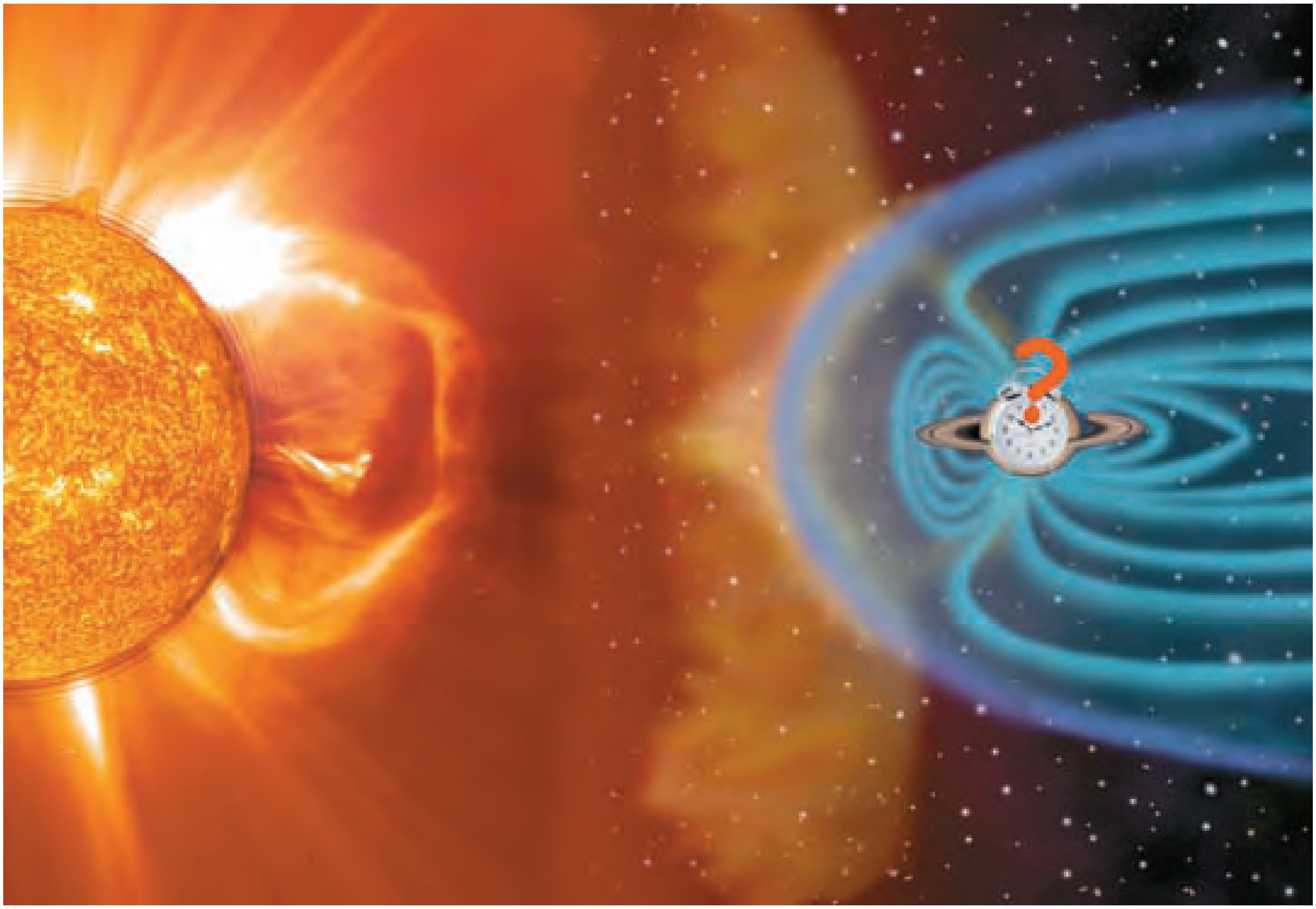
Saturn's Irregular Clock

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

Measuring the rotation rate of a planet where the surface is invisible can be quite a challenge. For a long time, the rotation rates of the giant planets in the Solar System were determined by following features in the clouds. This was known to be somewhat risky — the clouds were probably moving at speeds different from the true rotation rate, just as clouds in Earth's atmosphere move relative to the surface over a day. Until the accidental discovery of radio emission from Jupiter, there was no other choice. After that, Jupiter's rotation period could be measured quite precisely because the emission is quite anisotropic and therefore acts like a searchlight. However, Saturn's magnetic field is apparently aligned more or less exactly with its rotation axis, unlike Jupiter, and therefore the magnetic pole does not sweep around with each rotation. Saturn does, however, have radio emission arising from auroral spots in its magnetosphere, and these have been used to establish a rotation period of 10 hours 39 minutes 24 seconds (which is close to the rotation rate of cloud features). However, this period varies by plus or minus about six minutes on a timescale of months to several years. Just why it did that, and the physical significance of the drift, was not known. Now Philippe Zarka of the Observatoire de Paris and his colleagues have found that the drift in apparent rotation period is correlated with the speed of the solar wind at Saturn (see the November 8 issue of *Nature*). Why it should be is unclear, but it seems very odd indeed that Saturn's clock could be controlled — at least partially — by something external to Saturn.

The variation of Saturn's apparent rotation rate by ±6 minutes was a peculiar result from the start, though it was obvious that the planet itself was not speeding up and slowing down. Conservation of angular momentum precludes such large and rapid changes because there's nowhere to dump, or pick up, the vast amount of angular momentum needed to slow down or speed up an entire planet's rotation. Given that, and the general worry that the auroral spots might be subject to the same kind of motion relative to the solid body of the planet as cloud features are, it is important to see if the variations in the period are correlated with anything at all. One could imagine that infalling material from a moon, or the ring system, might affect the auroral spots, just as sodium atoms spewed out of volcanoes on Io affect Jupiter's magnetosphere. In fact, Enceladus had recently been proposed as a source of such material, given its venting from the "tiger stripes" near its south pole.

The alternative explanation for the variation, proposed by Cecconi and Zarka a couple of years ago, was that fluctuations in



An artist's illustration of the solar wind hitting Saturn's magnetosphere, and affecting its "clock rate" as measured by its radio period. Courtesy of Philippe Zarka and the Observatoire de Paris.

the speed of the solar wind caused displacements in the auroral spots that emit the radio photons. He and his colleagues used the almost-continuous coverage of Saturn's radio emission by the *Cassini* spacecraft to see if they could find a correlation with the solar wind. The analysis was fairly complicated, but revealed quasi-periodic fluctuations of the phase of the radio emission (and hence the rotation period) with a timescale of 20 to 30 days. While the solar wind is known to fluctuate on such timescales, *Cassini*'s orbit around Saturn also varies between 18 and 30 days, so Zarka first had to determine that he was not simply seeing *Cassini* go around Saturn. (A similar thing happened about 15 years ago, when a pulsar astronomer apparently found a planet orbiting a pulsar with a period of exactly one Earth year. It turned out, of course, to be a glitch in the software and he really had found that the Earth goes around the Sun in one year.) Curiously, the density, dynamic pressure, and magnetic field of the solar wind are completely uncorrelated with variations in the radio period, indicating that there is something special about the speed. While Zarka cannot exclude an additional component of variation that is internal to the planet, because the correlation isn't completely one-to-one, the wind speed is definitely a prominent effect.

In the course of studying the variations of the period, Zarka found that the long-term variations noticed by others are simply the averages of the short-term ones, meaning that the solar wind speed probably influences the long-term ones as well. These long-term variations affect a component of Saturn's magnetic field, and possibly the density of electrons in the magnetosphere, but it is hard to study short-term variations in those quantities because *Cassini* can measure them for only a short time in each orbit.

The physical cause of the correlation between solar wind speed and the fluctuations remains unknown. But the next time you have Saturn in your telescope eyepiece, spare a thought for the solar wind blowing by it, and affecting its apparent rotation rate.

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

Dust and Asymmetry

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

Every astronomical object is in motion in one way or another. The most common forms of motion are rotation and revolution. It is difficult to imagine an object of significant size that is not spinning around an axis or in mutual orbital motion with another object. Indeed, serious research has been conducted on the possibility that the Universe as a whole is rotating!

One consequence of rotation is symmetry. Planets and dwarf planets have, by definition, a high degree of radial symmetry. They are spherical in shape, or nearly so. Many galaxies — but certainly not all — are rotating or, more accurately, their major constituents revolve around their centres in such a way that they have evolved into a form with radial symmetry. Galaxies that have such symmetry range in shape from spherical to highly flattened discs and are routinely described as "normal."

In astronomical objects, as in people, it is often the deviations from normality that attract the greatest attention — and reveal the most interesting science. Deviations from normal galactic forms occur for many reasons, some understood, and some not. Some abnormal features of galaxies are revealed only when advanced techniques such as spectroscopy are applied, but other abnormal features are revealed to the discerning eye.

NGC 4826 (M64) [RA = 12^h 56.7^m, DEC = +21° 41´] is the "Black Eye Galaxy," so-named because of the prominent dust cloud superposed on, and offset from, the centre of an otherwise normal-looking galaxy. With an apparent magnitude of 8.5 and angular size approximately 10´ × 5´, this galaxy is within the range of most amateur telescopes. However, observing the black eye itself may be a challenge. William Herschel applied the descriptive "black eye" to this object in 1787, when he detected a "dark arch" under (north of) a star-like "lucid spot." His son, John, recorded his own observations of the galaxy on several occasions, sometimes seeing the dust cloud as a "vacuity," and at other times being left with the impression that the galaxy

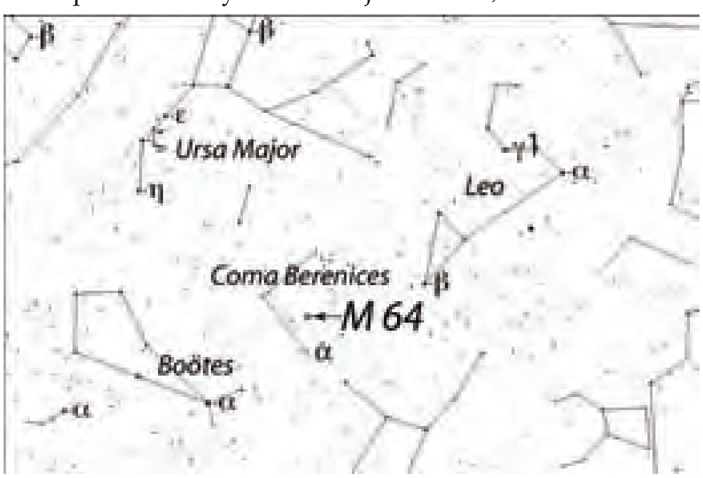


Figure 1 — Position of NGC 4826 in the night sky.

Figure 2 — Finder chart for NGC 4826.

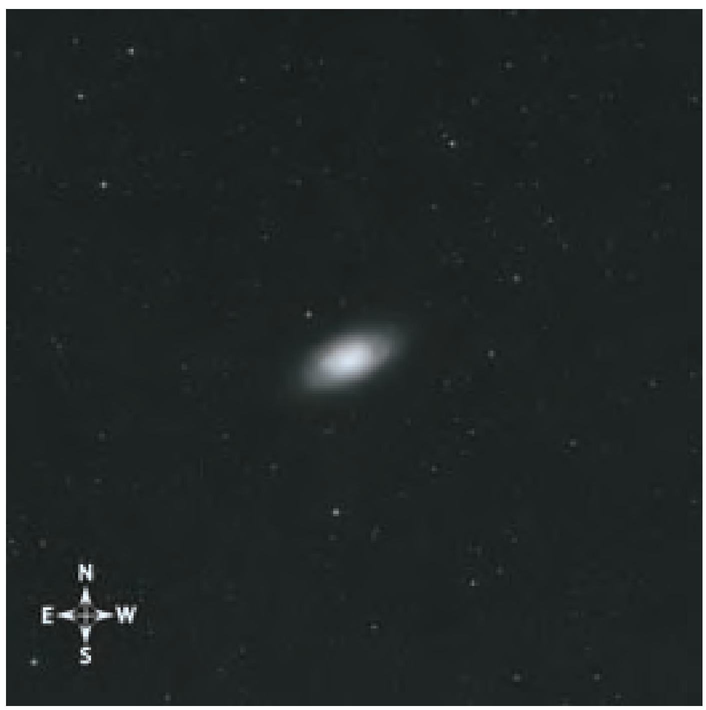


Figure 3 — 50´ × 50´ image centred on NGC 4826, from the Space Telescope Science Institute where it was produced under U.S. Government Grant NAG W-2166.

had a double nucleus — or was a double star — and at still other times not noting the presence of the dark feature at all. In many published images, such as that from the Palomar Observatory Sky Survey included here (Figure 1), Herschel's "dark arch" is a rather subtle feature. Published images that have been digitally processed may exaggerate the contribution of the dust cloud to the appearance of the galaxy and mislead the observer into expecting more than the eye can deliver.

A person who sports a black eye does so, most probably, as the result of a collision with another object. NGC 4826's black eye has been ascribed by some to a recent collision with what had been a companion galaxy. Such a violent collision may explain another peculiarity: material in the inner and outer regions of the galaxy travels in opposite directions. Where the two counter-rotating streams meet, there is enhanced star formation. Not surprisingly, this galaxy is also a radio source.

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

Figure 4 — Image of NGC 4826 courtesy of Mike Noble, obtained from a stack of two 5-minute exposures taken 2007 April 9 from near Edmonton, Alberta. Equipment used was a CGE-mounted C8 at f/6.3 and a Canon 20Da.

Astrocryptic

by Curt Nason, New Brunswick Centre

The solution to last issue's puzzle…

1 P	H	2 O	E	3 N	I	4 X	■	5 M	A	6 G	M	7 A
L	■	R	■	A	■	R	■	E	■	R	■	T
8 A	B	B	E	S	■	9 A	S	T	R	A	E	A
N	■	I	■	O	■	Y	■	O	■	I	■	X
10 A	N	T	E	N	N	A	■	11 N	U	N	K	I
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12 V	E	L	O	13 C	I	T	Y	C	U	14 R	V	E
O	■	■	■	A	■	R	■	■	■	E	■	■
15 Y	E	16 A	R	S	■	17 O	H	18 M	'S	L	A	19 W
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20 G	A	L	I	L	E	O	■	21 S	I	G	H	T
E	■	A	■	E	■	M	■	I	■	H	■	A
22 R	U	S	T	S	■	23 Y	U	C	A	T	A	N

August's Lunar Eclipse from Southern Ontario

Les Marczi of the Niagara Centre captured these marvelous images of the August 28 lunar eclipse from the shores of Lake Ontario, in St. Catharines. Figure 1 was taken using a Canon Rebel XT 350D with a 200-mm lens. For Figure 2, he used a Rebel 300D and a Takahashi Sky 90 II on a Super Polaris mount. The mosaic was compiled from images taken through the Sky 90. "The sky stayed clear for the whole thing...well, until it set at full eclipse. It couldn't have been much better...." he mused.

Figure 1

Figure 2

Figure 3

Starting Out: What am I Going to Look at Tonight?

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

When I started this series of articles for beginners back in February, I promised I was going to make suggestions about what to look at, but I got distracted, and am only getting back to it this month. I find that many new telescope owners, after they've looked at the Moon and a planet or two, begin to lose their enthusiasm, and do not know what to do next. They know there are supposed to be lots of interesting things in the sky, but don't know where to start, or how to go about finding these things. Even if they have a computerized telescope, they may *look* at a bunch of things but hardly *see* anything through their eyepieces.

I actually find I have the opposite problem. Given the awful weather we experience so much of the year here in Canada, when I do get a clear night, I panic over trying to make up my mind about what to look at! The solution to both problems is to have a plan, a program.

When I set up my new Edmund 108-mm "Palomar Junior" reflector for the first time on 1957 July 4, I knew exactly what I was going to look at. I'd been hooked on astronomy for two whole months, and had been reading everything I could get my hands on — I had a list of targets as long as my arm. First and foremost was the Moon, 8 days old, just past First Quarter. I examined it carefully with the two eyepieces (a 28-mm Kellner and a 12.5-mm Ramsden) and the Barlow lens that came with the scope. I'd been following Saturn with my naked eye for nearly two months, so it was my second target: I was totally amazed. It *really* had *rings!* I'd been reading up on double stars and had been looking at them with my 6 × 30 monocular, so Epsilon Lyrae, and Mizar and Alcor were also on my agenda; I was now able to see the smaller components. Then, inevitably, the clouds rolled in. A couple of nights later, I set the scope up at our cottage near Weir, Québec, and again studied the Moon (I spotted the crater Copernicus for the first time), Saturn (was that Titan to its south? — 50 years later, *Starry Night* tells me it was!), and Jupiter and its moons, rapidly sinking in the west. Double stars dominated my "program" in those early weeks, as did my lucky independent discovery of Comet Mrkos on August 16.

When I joined the Montréal Centre on October 5, I found a whole palette of observational programs available to me. Like

Figure 1 — Geoff's fascination with the Horsehead Nebula is explained with this image taken by Toronto's Stef Cancelli. The luminance signal in Hα was acquired from Toronto; the RGB colours were obtained several days later from New Mexico. Total exposure is 200 minutes in Hα and 15 minutes each in R, G, and B. Stef used a Vixen VC200LDG for the hydrogen image and a Takahashi Epsilon for the other colours.

David Levy a few years later, I was immediately attracted to the Centre's lunar training program, which entailed identifying the 300 named craters on *Sky & Telescope*'s lunar map and plotting them on an outline map of my own. Views through Centre's 6.5-

inch refractor got me interested in looking for deep-sky objects with my own telescope. I was soon observing aurorae and meteors for the International Geophysical Year programs directed by Dr. Peter Millman at the National Research Council in Ottawa.

Beginners starting out in 2007 have an even richer cornucopia of observational opportunities arrayed before them. Given the Canadian weather: freezing cold in the winter, mosquito-ridden in the summer, and cloudy 90% of the time [actually only 65% -Ed.], where do you start? My recommended entry point is the RASC's excellent Explore the Universe certificate program (`www.rasc.ca/eu`). This provides a balanced set of targets that will expose you to a very wide range of observing: constellations, stars, the Moon, the Solar System, deep-sky objects, and double stars. This will get you familiar with many aspects of the night sky and may give you some ideas that you want to pursue further.

Back in 1957, one of my first observing projects was trying to observe all of the objects in Charles Messier's catalog of deep-sky objects. This is something I encourage most people to try. Messier spotted the best and brightest of the "faint fuzzies," and hunting them down introduces an observer to the joys of starhopping in many of the most interesting areas of the sky. One list leads to another, as I discussed in an article last year on "cosmic bird watching."

As mentioned in that article, after working my way through Messier's list, Alan Dyer's Finest NGC list, and the Herschel 400 list, I'd begun to tire of faint fuzzies. Rather than sink into boredom, I've found new ways to occupy my observing time. In fact, I'm always on the lookout for new and different observing projects, as that's what keeps my interest in astronomy alive and growing. Here are some of the projects I currently work on.

Variable-star observing remains the central pillar of my observing program. Variable-star observing is fun and provides constant challenges. I've been observing the same list of variables for a number of years, mostly from the AAVSO's so-called "Stars Easy to Observe" list (`www.aavso.org/observing/aids/easystars.shtml`). "Oh, easy for Leonardo!" to quote Dylan Thomas. To these mostly long-period variables, I've added a few cataclysmic variables over the years, as they're such fun. This year I'm trying something new: adding a dozen new stars all from the same constellation, Andromeda, to give a bit of focus to my observations.

Some projects are pretty simple. The other day, someone on the Toronto Centre Yahoo Group posted a link to the Great World Wide Star Count Web page at `www.windows.ucar.edu/starcount`. This is a project designed to measure the actual limiting magnitude of the night sky around the world during a two-week period (now past, but I think the plan is to do this annually). Everything you need is included on the site, and anybody can do it. Neat!

Some projects are long overdue. Back in 1957, when I was first getting hooked on astronomy, one of the books I tried to read was Fred Hoyle's *Frontiers of Astronomy* (Harper 1955). I'm not sure I got much out of the text, but the first plate in the book immediately burned an image into my brain: "The Horse-head Nebula: The 'horse's-head' is a cold cloud of gas and opaque dust that is being squeezed by hot surrounding gas, The hot gas is being illuminated by radiation from the near-by stars.... Nebulae like this have dimensions that are measured in tens of millions of millions of miles." That early Palomar black-and-white image has always been one of my favourites, yet I have never observed the Horsehead Nebula with my own eyes. Well, I just ordered a Hydrogen-Beta filter, and the Horsehead is one of my targets for this winter.

So, whenever you're at a loss for something to look at with your telescope, remember Robert Louis Stevenson's words:

The world is so full of a number of things,
I'm sure we should all be as happy as kings.

Clear skies!

Nightlight

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

Elizabeth never comes away from a star party without trophies, usually records of ever-fainter objects carefully noted in her observer's log. One year however, she wore her trophies on her knees, hands, and forehead — scrapes and bruises from tripping over a tent rope invisible in the dark. That's why, now, when you see all those discreetly blinking red lights at a star party, it's probably our place.

We put a light on everything we want to protect, like tripod legs under a mount that took a whole night to drift align, and on anything we want to be protected from, like that tent rope, or the protruding trailer hitch lying in wait for a kneecap.

We tried a few different lights, starting with the small purpose-made ones with the big button cells. They were expensive, the big button cells didn't seem to last long, and, oddly enough, they were brighter than seemed necessary.

We finally settled on the bicycle light you see in the picture (Figure 1). They are cheap, they have a handy clip, and the two AAA batteries seem to last the whole season. They are also bright enough to be seen a kilometre away, but we can fix that.

When you open the cover, you will see five super-bright LED lights neatly lined up in a row. That's at least two more than you need. If you are a techno-type, they can be removed easily with a fine-tip soldering iron and a solder removal tool. If you aren't adept with the soldering iron, use a pair of pliers to grab the LED, and without exerting a lot of force, rotate it slightly. Rotate back, then back and forth again until the prongs break. Don't force it and don't rush it — they'll break off when they're ready.

If you take out two of the five, you have increased your battery life by 40% and cut the light output somewhat, but what's left is still far too bright. The solution is electrical tape. Put a strip up the inside of the cover and all the direct light is blocked. You are left with only the indirect light diffused through the faceted sides, easy to see and easy to look at.

Elizabeth's cuts have healed, but we are both left with an abiding aversion to tent ropes in the dark. We really like these little lights.

Don and Elizabeth Van Akker observe together from Salt Spring Island. They don't see well in the dark. Don will answer questions on this or any other Gizmos project if you email don@knappett.com.

Figue 1 — This little bicycle light is inexpensive and easy to get. Try your favourite hardware store or even the notions rack at your grocery store. Ours came from Mountain Equipment Co-op.

Figure 2 — Remove two of the LEDs gently with brute force. Put electrical tape up the inside of the lens and you're done.

Holiday Season Wish List

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

Oh Lord, won't you buy me a Mercedes-Benz?
My friends all drive Porsches, I must make amends.
Worked hard all my lifetime, no help from my friends.
So oh Lord, won't you buy me a Mercedes-Benz?

— (c) 1971 Janis Joplin, Pearl

Well, a Mercedes-Benz might be a little over the top on anyone's wish list, so I'll set that idea aside for now. Instead, I have here a few more modest proposals that budding occultationists and experienced shadow-chasers alike might like to drop as hints for this holiday (read: gift-receiving) season. Whether you're the gift-er or the gift-ee, I hope you'll find this useful. But first, a note or two about prices: those quoted here are approximate; your experiences may vary. At the time of writing, the Canadian dollar is on par with, or a bit above, the U.S. buck. Therefore, a dollar is a dollar. In theory, the prices on both sides of the border are — or should be — interchangeable. Scream if they're not. With that in mind, here we go.

Membership in IOTA: The International Occultation Timing Association is the leading promoter, collector, and clearing-house for all things occultational. You do not need to be a member to participate in their programmes, but I suggest you ask for — or give — a membership, anyway. Members receive the quarterly *Occultation Newsletter* and predictions, and have the satisfaction of knowing that their modest fee helps IOTA in its day-to-day operations and outreach. $30.00 in North America; $35.00 overseas. Visit `www.occultations.org/guests/membrsub.htm#join` for membership information and `www.lunar-occultations.com/iota/iotandx.htm` for general stuff, including their mission statement, administration details, predictions, contact info, how-to advice, and much more.

Short-wave receiver: An example is the Eton G4000a, which recently replaced the dearly departed Grundig YB400PE AM-FM-SW receiver. It is a compact and reliable "digital-tuner-equipped" receiver at about $150.00 retail (less on-line at *Amazon, etc.*). Shop around for similar receivers for less cash. Whatever s/w radio you choose, be sure that it has a "digital tuner" with station pre-sets; and that it can receive frequencies from 3 MHz to 20 MHz. Avoid the hand-crank "emergency" s/w receivers: they're much cheaper, but are less sensitive, lack the mandatory preset-able tuner, and require constant cranking in the field.

Voice recorder: Either a solid-state voice recorder or an old-fashioned portable cassette recorder will do. If you choose the former, be sure that it can record continuously (some are strictly voice-activated, which won't do at all.) Prices: $50.00 - $500.00 for digital; $40.00 - $60.00 for cassette-type.

Low-light-sensitive video cameras: The Supercircuits PC164C and the Watec 902H2 Supreme are the experienced occultationist's cameras of choice. The PC164C is an all-auto b&w "surveillance-type" camera about the size of a Plossl eyepiece that, in a "fast" telescope, can detect stellar magnitudes comparable to the capacity of the human eye. It's auto-gain feature is always on, but that's not an issue with asteroid occultations. However, it can be a problem when the Moon or a bright planet enters the picture. $115.00 at `www.supercircuits.com` (search on "PC164C"). The Watec 902H2 Supreme uses a similar but larger chip (0.5-in versus 0.33-in) for improved field of view, and it does have manual gain control for $322.50 at `www.psicompany.com/cctv-cameras` (search on "902H2"). The Stellacam II, by Adirondack Video is also popular, but it's pricey at $800.00. However, it does permit one to adjust the frame rate (integrate) to detect faint stars that would otherwise be out of reach. Whichever you choose, don't forget the Astrovid C-mount-to-1.25-in. adapter ($35.00 from Adirondack Video).

F3.3 focal reducer: If you have a slow scope such as an f/10 SCT, you need (yes, need) a focal reducer if you plan to do video astronomy. The field of view of these cameras is extremely narrow to begin with. Focal ratios in excess of six or so need to be reduced. Focal reducers are available for SCTs in f6.3 and f3.3 sizes. Go with f3.3. You need all the help you can get. $150.00, plus or minus, at your favourite astro-retailer.

KIWI-OSD on-screen time display: There's not much point in doing video without one of these incredible machines. Designed specifically for occultation-work, it uses a one-pulse/second GPS device to accurately determine the time at your location and marries it to your video recording, thereby time-stamping every single video field to give 1/60-second accuracy. Everything you need to know about it is at `www.pfdsystems.com/kiwiosd.html`, ($250.00, including the required Garmin 18 GPS unit, plus S&H).

Camcorder: Whether it records on digital tape, DVD, or built-in hard-drive doesn't matter, but inputs for external video and audio do. Make sure it can accept the feed from your PC164C or Watec 902H2.

DVD player: The trouble with the LCD screen on the above camcorder is that it's really small and difficult to see faint stars in it. So you need a larger video screen and these 7-inch and larger DVD players are just the ticket. Like the camcorder, be sure they will accept external inputs. $120.00 and up.

Cables and batteries: Great stocking-fillers! Be sure to specify to your would-be gift giver the exact sizes and specifications you need for your personal set-up. Other odds-and-ends include video tapes, audio cassette tapes, mini-DV discs — whatever fits your equipment.

Gasoline gift cards: These will be especially welcomed by mobile occultation chasers, especially with the cost of fuel these days. Other gift cards or certificates will also be appreciated: Canadian Tire and Tim Hortons are popular. Perhaps your local astronomy retailer has a similar arrangement. Ask.

So there you have it: just a few gift ideas to hint about, or to give to the asteroidal occultationist in your family. And for the Occultationist Who Has Everything? Well, a Mercedes-Benz might be nice — especially one big enough to lug around a good-sized telescope and all the gear listed above. How about an R550 at $78,000 and up? Or, choose the more modest B-Class in the $35,000 range. Either way, all-wheel-drive is a useful option on these cold, snowy, winter nights.

Oh yes, one more thing: the disclaimer. I have no personal connection with any of the manufacturers, suppliers, retailers, or others mentioned above who might be interested in separating you from your money. Nor do I stand to gain financially by any arrangement you or your friends and relatives might enter into as a result of ideas and suggestions described above. But if you should become involved — or more involved — in the sport and science of asteroidal occultation chasing; and if you collect better and more reliable data as a result of the acquisition of any of the described products or services, well then, we'll all profit from that, won't we?

Here is a list of possible occultations over populated parts of Canada for the next two months. For more information on events in your area, visit the IOTA Web site, `www.asteroidoccultation.com`. It is very important that you advise me or another IOTA member if you plan to observe and time an event so we can avoid duplicating chords.

DATE (UT) 2007	ASTEROID #	Name	STAR MAG	Δ-MAG	MAX DUR	PATH
Dec 5	1200	Imperatrix	10.8	4.5	2.7	swON
Dec 6	1086	Nata	12.0	1.9	5.4	QC
Dec 6	1633	Chimay	9.4	6.6	1.4	cBC-swSK
Dec 9	380	Fiducia	11.5	2.7	11.4	ON
Dec 9	105	Artemis	11.5	2.1	16.0	eQC-NL
Dec 12	658	Asteria	9.8	6.1	1.1	MB
Dec 12	5331	Erimomisaki	9.0	4.6	1.8	ON
Dec 13	6823	1988 ED1	10.9	3.0	1.9	sON
Dec 13	25	Phocaea	10.7	2.2	5.8	nQC-cON
Dec 14	4061	Martelli	9.8	7.1	1.3	nMB-cBC
Dec 14	227	Philosophia	11.8	2.3	6.2	nwON-nSK
Dec 16	474	Prudentia	11.0	3.9	3.4	swON, swBC
Dec 18	602	Marianna	11.3	1.4	21.5	wSK
Dec 18	1031	Arctica	11.5	3.4	5.3	swSK-nAB
Dec 18	849	Ara	11.2	3.2	4.2	AB
Dec 23	1649	Fabra	10.1	6.3	2.2	sNL-sMB
Dec 24	1665	Gaby	8.0	8.0	0.8	swBC-nAB
Dec 24	2450	Ioannisiani	11.5	4.4	2.2	NS-BC
Dec 24	3475	Fichte	10.5	4.2	2.5	nON-sBC
Dec 25	6823	1988 ED1	10.9	2.7	1.8	wQC-eON
Dec 25	380	Fiducia	11.6	2.2	6.5	BC
Dec 26	2111	Tselina	8.9	6.2	8.8	nwON-neMB
Dec 29	7588	1992 FJ1	10.9	5.5	2.3	swNS
Dec 29	191	Kolga	11.6	1.7	8.3	eNS-nBC
Dec 30	1846	Bengt	9.7	5.3	1.4	swNL-eQC
Dec 31	717	Wisibada	11.1	4.4	2.3	swNL-eQC
Dec 31	284	Amalia	9.6	5.3	11.9	seQC-swNS
2008						
Jan 1	801	Helwerthia	10.0	5.1	3.0	sNL-cBC
Jan 2	459	Signe	11.5	3.0	1.7	Atl Provs
Jan 5	1000	Piazzia	9.5	5.3	7.1	nAB-cBC
Jan 7	1362	Griqua	11.4	3.3	2.1	seAB-nwBC
Jan 8	697	Galilea	11.2	3.1	9.8	nwON-sMB
Jan 9	697	Galilea	11.2	2.8	10.1	sQC-sBC
Jan 9	407	Arachne	11.8	1.3	11.0	sQC-cBC
Jan 10	2651	Karen	10.3	4.5	1.2	nwON
Jan 13	2621	Goto	12.0	3.3	4.6	NS-SK
Jan 13	4421	Kayor	10.5	4.6	1.0	NS-NL
Jan 14	161	Athor	10.0	3.2	4.4	cQC-cON
Jan 15	2650	Elinor	9.8	6.0	1.9	AB
Jan 16	1159	Granada	11.5	5.0	0.9	sMB-nwON
Jan 18	265	Anna	10.6	5.1	1.7	QC
Jan 19	1266	Tone	11.8	3.1	5.3	NL-cON
Jan 20	1438	Wendeline	11.1	4.8	3.0	sSK-nBC
Jan 21	929	Algunde	10.5	4.9	1.6	NS-BC
Jan 23	2194	Arpola	10.1	5.3	1.0	nwON-seMB
Jan 28	2649	Oongaq	10.7	4.6	4.3	NL-BC
Jan 28	393	Lampetia	11.0	3.1	6.6	sON-cBC
Jan 30	2486	Metsahovi	9.2	6.0	1.6	nMB-sAB
Jan 30	411	Xanthe	11.1	2.5	4.9	eBC, wAB
Jan 31	247	Eukrate	11.5	0.8	10.9	cQC-sON
Feb 1	72	Feronia	12.0	1.2	10.1	sNL-nBC
Feb 2	510	Mabella	9.3	5.3	4.7	sAB-sBC
Feb 2	1502	Arenda	11.5	3.9	5.2	sON
Feb 5	37	Fides	10.6	0.7	14.9	nNL-nON
Feb 7	1902	Shaposhnikov	11.2	4.9	5.4	sON, sNS

How Deep? The Limits of Binoviewing

by Gerry Smerchanski, Winnipeg Centre (smirch@mts.net)

The merits of using two eyes to observe astronomical objects are difficult to define but relatively easy to demonstrate. A look at Saturn or the Moon through a well-collimated binoviewer will do far more to get the message across than talk about increased contrast and resolution, solutions to "eye floaters" at high magnification, or pseudo-3-D effects.

Many observers are attracted by the prospects of better views using binoviewers but are daunted by the thought of having to double their eyepiece collection, only to find, in the end, that the value of binoviewers is limited. Some even dismiss binoviewers as a novelty that is the equivalent of a party trick for public-observing sessions; or they are made wary by stories of how certain observers just cannot get binoviewers to work.

Figure 1 — A modern no-compromise binoviewing set-up of Astro-Physics 130 refractor, TeleVue diagonal, and 24-mm Panoptic eyepieces set in a Denkmeier II binoviewer with power switch.

I have been using binoviewers for almost a decade now and I am convinced of their usefulness for certain types of viewing. I find that I forsake the cyclopic view for the more natural binoviewer image when observing planets, even when the binoviewer eyepieces are modest optics and the single-eyed view uses some of the finest eyepieces available. I would argue that binoviewers are one of the best improvements to be made in planetary observing. At one time, the major drawbacks were cost and some demanding alignment issues, especially with early units that were converted from other uses. With the introduction of affordable and reliable binoviewers in the past few years, I have become something of a proselytizer for binoviewing and take every chance available to extol the virtues of two-eyed observing. Yes, it is true that a few people have a difficult time using binoviewers, but I have found that a well collimated pair, with enough time to get them set up, will allow most people to use binoviewers successfully.

Nevertheless, there is one issue that remains rather vague and poorly addressed. Binoviewers do produce a dimmer image because the entire light cone is split into two parts, one for each eye. Therefore, In the pursuit of fainter objects, we would want to abandon two-eyed viewing at some point, in order to get maximum image brightness. But exactly at what point does this occur?

For many people, that limit is reached at the edge of the Solar System. Binoviewers can be used to great effect when viewing the bright planets and the Sun, where the higher powers associated with most binoviewers is an advantage. However, they are returned to the shelf when the telescope turns to deep-space objects (DSOs). One of the early advocates of binoviewing, Todd Gross, discounted concerns about this boundary:

> *I want to dispel the myth about not being able to use binoviewers for deep sky objects right off the top here...[C]ertain units are designed to be able to be used at low power, with a wide clear aperture and large prisms that enable you to use 1.25″ eyepieces down to 35, 40mm without any vignetting. The most commonly quoted disadvantage of binoviewers (other than price!) is that they split the same beam of light into two beams, thus decreasing the amount of light you are seeing by at least 50%. While this is true on paper, just as you have an additive advantage when using binoculars over a monocular, you take away very little light gathering with a binoviewer, especially in larger*

aperture, as your brain seems to account somehow for this split. In fact, since you perceive the image better with two eyes anyway, you end up almost where you started from, after splitting the beam, and then viewing with two eyes. True, I have measured between a 1/4 and 1/2 magnitude starlight loss in an 8″ scope, and at first glance globulars are significantly less resolved, indicating less light gathering, but the amount of the loss seems far less than 50% in practice; perhaps closer to 25% effectively, or thereabouts.

— Todd Gross: *Binoviewers — Enjoying the Sky with Two Eyes*

Todd's entire paper can be found at `www.weatherman.com`, where he tries to explore the limits of various binoviewers by giving some general impressions of views through various telescopes. Here is one of his examples:

Thus on my 10″ scope for instance, I noticed that deep sky objects are not quite as bright as without the binoviewer, but certainly brighter than my old 8″ scope without the binoviewer. I have effectively lost about an inch or so of aperture light wise, although this is purely subjective. I have noticed the same thing with a 4″ refractor; I am seeing more than a 3″ scope, but not as much deep sky brightness as with the 4″ scope without the viewer attached.

While this was done over a considerable period of time, with all the problems that such comparisons entail, he manages to give an idea of the expectations we should have when using binoviewers. Gross goes on to say that there seems to be a threshold to these limitations, and when the telescope aperture is 15 inches and larger, *"...views are equal to, if not better than single eyepiece views in just about every way, on every object."* This provocative statement, while not addressed here, can serve to define an upper limit for an investigation into the magnitude limits and faint-object utility of binoviewers. Gross's initial report was made in 1996 and updates were added as new equipment was introduced, but the statement on brightness limits was left in its original form. Much has transpired since the first report, and the central issue of just how deep can one expect to go with binoviewers is still a vague notion. For those of us extolling the virtues of two-eyed viewing, it behooves us to know where such limits lie.

The following test is modest in its goals and simple in its application. Various deep-sky objects were viewed through binoviewers with telescopes between 5 and 12.5 inches to determine when the binoviewers yielded a better, or at least a worthwhile view. Since Gross wrote his report, we have seen some very good and economical binoviewers, made in China and sold under various names, arrive on the market. We also have seen an evolution of the high-end binoviewers, giving them incredible versatility and compatibility with all sorts of telescopes. Both of these aspects are represented in this test: a set of Stellarvue binoviewers (typical of the economical units), and one of Denkmeier IIs, equipped with a power switch and optical correction system (OCS) that allows quick changes in magnification.

Figure 2 — The two units used in this investigation represent two trends current in binoviewing. The Denkmeier no-compromise units (left) have large prisms yielding a ~25-mm clear aperture, they are set up for use in 2-inch format at the field lens end while maintaining 1.25 eyepieces, and can use the optical correction system (OCS) — a telenegative lens (a.k.a. Barlow) that allows the unit to reach focus on telescopes with limited focal travel. The Denkmeier binoviewers are best considered as part of a surprisingly versatile and encompassing system of lenses and adaptors to optimize the binoviewing experience; these are used with TeleVue 24-mm Panoptic eyepieces to maximize their strengths. On the right is the Stellarview system.

The two units used in this investigation represent two trends current in binoviewing. The Denkmeier no-compromise units have large prisms yielding a ~25-mm clear aperture, they are set up for use in 2-inch format (at the "field lens" end, while maintaining 1.25-inch eyepieces), and can use the optical correction system (OCS) — a telenegative lens (a.k.a. Barlow) that allows the unit to reach focus on telescopes with limited focal travel. The Denkmeier binoviewers are best considered as a versatile and encompassing system of lenses and adaptors to optimize the binoviewing experience. In these tests, they are used with a pair of TeleVue 24-mm Panoptic eyepieces to maximize their strengths.

The Stellarvue (SV) binoviewers represent a new wave in binoviewing in that they are affordably priced, and can even come complete with a set of eyepieces and a Barlow-type corrector to increase focus range. Similar units are sold under many names and various packages by several telescope companies, and represent a tremendous value for cost as the entire package costs less than one high-end eyepiece. The SVs have a clear aperture of 19.5 mm (latest units now have 22-mm clear aperture). The included eyepieces for my testing are 23-mm Plössls.

Three main aspects determine the limits to binoviewing:

* light-gathering ability is the most obvious limiting factor — the larger the telescope, the deeper into space one can go;

* a second issue is related to the quality of the binoviewers themselves, as some are better suited than others to display certain deep-sky objects (DSOs). Most of this has to do with the low-magnification limits of the system and how large an apparent field of view can be rendered by the binoviewers. Light transmission and the ability to work at lower powers contribute to flexibility;
* the third factor to consider in any test is the type of object being viewed (somewhat dependant on the second issue). Large, faint, or diffuse nebulae are not captured as well by binoviewers as other DSOs, such as globular clusters and planetary nebulae. Galaxies give mixed results when viewed through binoviewers.

Figure 3 — This comparison shows the clear aperture, relative sizes, and the dimensions of the two prism housings. The bars on either side of the Denkmeiers are the levers that push correcting lenses into the optical path to change magnification. Note that the SVs are 1.25-inch format, while the Denkmeiers are 2-inch.

The results of this investigation can perhaps best be presented by concentrating on the third factor or "object type" as a way of breaking down the various combinations. There are countless combinations of telescope, eyepieces, and binoviewer quality, and I can only sample a few. As they say in the advertisements, "Your mileage may vary." This investigation gives general rules of thumb that should prove valuable for those contemplating the purchase of a binoviewer.

Globular Clusters (and tight open clusters)

Even in telescopes with objectives of five inches or less, binoviewers can render interesting views of globular clusters. Many globulars, such as M13 (the Great Cluster in Hercules), are bright enough to take on a new dimension of depth. The penalty of course is that the view is dim and many fainter stars are lost — even in a 5-inch Astro-Physics refractor. For both binoviewers, a Barlow (or in this case, the Denkmeier OCS) attached ahead of the diagonal is required to reach focus. Still it's worthwhile to use binoviewers on these relatively bright DSOs, in that part of what you want to do with these objects is to make out the structures or patterns, and using two eyes is best for this.

The Denkmeiers, with their larger field of view and slightly better light transmission, gave an impressive view, even in the 5-inch scope. The smaller field of view of the SV binoviewers was large enough to frame M13, and so it will also frame other large globulars.

When this test was repeated with an 8-inch SCT (Schmidt-Cassegrain Telescope), the binoviewer view (binoview) was preferable to the single-eyepiece view. SCTs have enough focusing range that no Barlow adaptor is required, allowing lower magnifications to be used. The image was still dimmer with slightly fewer stars but the acuity and contrast were such that it was the more involving view. The penalty of light loss was so slight that most globulars would probably benefit from such a two-eyed view. Since globulars are concentrated targets, the absence of low-power/wide-field views is not as relevant as when viewing other targets.

The same conclusions hold for a 12.5-inch Dobsonian. Even with the light loss, the binoview showed stars more distinctly and gave a more revealing view. It is hard to imagine a globular that wouldn't look more impressive with a binoviewer at this light-gathering level. The only caveat here is that in order to reach focus, a Barlow or OCS adaptor is usually needed and so the lowest power is not available.

Planetary Nebulae

The quintessential planetary nebula and the target for my testing is M57, the Ring Nebula in Lyra. The view of the Ring through binoviewers on 5-inch and smaller scopes is dim — so dim that the better vision provided by binoviewers is not enough to compensate for the brighter view through a single eyepiece. Interestingly however, the subtle shape variances of the Ring were as easily determined in the binoview as the single-eyed view, so there was at least a comparable, if not equal, view. At this aperture, the mono view was preferable for sheer aesthetic impact.

In an 8-inch SCT, the view shifted in favour of the binoviewer. Not only was the ring shape more discernable, but the contrast increase more than compensated for the slightly dimmer view. The benefits of the binoview increased when the 12.5-inch Dobsonian was brought to bear. Since there still was some light loss in the binoviewer/Dob combination, it would be incorrect to say that all planetary nebulae would be improved by using binoviewers, as planetaries are much tougher targets than globulars. However, all but the dimmest targets visible in a 12.5-inch scope deserve a two-eyed look. With the increased visual acuity that binoviewers provide, the ability to distinguish tiny planetary nebulae from stars should be improved.

Diffuse Nebulae

There is great variation among nebular objects and the limits to binoviewing are unclear. Binoviewers limit the observation in two ways: the very faintest and lowest-contrast objects might

Figure 4 — Using binoviewers means adding as much as five inches to the light path (yellow line shows the altered and extended path) causing focusing and magnification problems.

be beyond the detectability of the dimmer binoview; or the object might be too large to fit into the narrower field of view of the binoviewer. The most attractive diffuse nebula, M42 in Orion, is bright enough and can be framed so that it yields a breathtaking view through binoviewers. The sense of three dimensions with foreground stars and a background bowl shape leaves a lasting impression. The Lagoon Nebula, M8, is also a good target.

The smaller 5-inch scopes do well with a binoviewer on these brighter objects, but their performance falls off as the objects get dimmer. Eight-inch SCTs gather enough light to show many more nebulae in binoviewers, but they bring relatively high power and narrow fields of view, limiting their visual impact. It is when you get to larger and faster scopes, such as my 12.5-inch Dobsonian, that diffuse nebulae stand out when two eyes are used — especially if a Barlow can be avoided. Many of the brighter and smaller diffuse nebulae are rendered as well or better by binoviewers in larger scopes — the view can only improve as the objective diameter increases. Large and very faint objects are best tried without binoviewers.

Galaxies

The pattern noted above continues when we turn to the observation of galaxies. Bright galaxies such as the Andromeda Galaxy, M31, take on new dimensions in binoviewers, but its large size usually means that you will not be taking in the entire object. Narrow-field binoviewers do not do justice to this object, and optical limits that require Barlows or other telenegative adaptors will provide too much magnification to be beneficial. In less than totally dark skies, large but faint extended galaxies such as M33 and M101 are practically undetectable in the dim, high-power, narrow-field binoviewers. There are reports that some observers have successfully used optimized binoviewers to see structure within M33, and even glimpsed its H-II regions in 11-inch SCTs. Such performance was obtained under very dark skies and nothing even close to that could be duplicated under test skies with a Sky Quality Meter reading of 20.50 magnitude/square arcsecond at my site.

On the other hand, small, relatively bright galaxies, such as Mirach's ghost (NGC 404), were easily visible, and the glare from Mirach itself was not an issue in the binoview. The dark lane in M82 was easy to ascertain when using two eyes. This was done with the 12.5-inch Dob; the 8-inch SCT also worked on this object, but it wasn't as impressive as the larger telescope. The views of these small and dimmer objects through the smaller 5-inch scope were less than rewarding in binoviewers. M82 was bright enough to be visually interesting but the smaller scope binoviews soon ran out of light-gathering ability. Even the quality of the test scope, a 130 EDF Astro-Physics apochromatic refractor, could only take me a small distance beyond less-costly small scopes.

The Two Binoviewers

As might be expected, the Denkmeier II binoviewers coupled with the Televue 24-mm Panoptic eyepieces produced images that were marginally better than the Stellarvue setup in most of my tests. The difference was not proportional to the price of these respective units and the "Law of Diminishing Returns" seems to hold here as in so many other situations. In fact, when it comes to using binoviewers on their "home turf" of planetary observing, the units were almost indistinguishable in performance (except for the size of the field of view). The true strength of the Denkmeier's large clear-aperture system is the versatility that comes with accommodating lower magnification and wider fields of view for a given telescope. This factor should not be underestimated, as the results above show that the biggest problem in using binoviewers on DSOs seems to be the restriction on low magnification that give the brightest view. When binoviewers are forced into using correctors or Barlows to reach focus, they suffer from the dimmer and narrower fields of view that are inherent in the increased magnification of the focal extenders. The accessory Denkmeier Powerswitch was thoughtfully constructed so that one of its options works as a focal reducer, lowering the magnification and increasing the field of view — but at the expense of introducing another element into the optical train. Many telescope owners have gone to great lengths to modify their optical train (usually by shortening the tube, struts, or mirror placement) so that they could use binoviewers without increasing magnification and adding extra lens elements. Some manufacturers are now providing such modified optical tube assemblies for binoviewing.

In evaluating these two binoviewer units there was more than one variable; to many, the most glaring inequality would be the use of the high-quality Televue Panoptics in the Denkmeiers and the less expensive "included" eyepieces with the Stellarvues. Just how much difference was due to the eyepieces rather than the binoviewers? To get a feeling for this factor, I swapped eyepieces from one unit to the other throughout the testing. I estimate that half of the better view of the Denkmeier/Panoptic combination could be attributed to the eyepieces. When the Panoptic eyepieces were moved to the SV binoviewers, a small target would be similar in appearance in either pair, with only the slightest advantage remaining with the Denkmeiers. However, the Panoptics in the Stellarvue binoviewers vignetted terribly and presented a much smaller clear area than the original eyepieces - despite having a much larger apparent field of view. The advantage of Panoptics was lost when coupled to the Stellarvue unit.

Summary

Binoviewers can be put to good use in observing DSOs and should not just be reserved for planetary viewing, but there still are limits to keep in mind. The major obstacle is not so much the loss of light, it is being able to achieve low enough power and wide enough fields of view to properly frame the target. A careful choice of equipment, tailored for the desired object, will reward the observer with a more precious viewing experience and alleviate concerns about the limitations of two-eyed observing. Even inexpensive binoviewers can be successfully used without any significant compromise — especially when the concern over magnification and true field of view is addressed. When it comes to observing planets, binoviewers provide a very noticeable improvement. We live in good times for pushing the frontier of visual astronomy.

Acknowledgements

I thank Jay Anderson, Ray Andrejowich, and Terry Bailley for graciously loaning some of the items used in the test.

Gerry Smerchanski's interest in astronomy extends at least as far back as his second spoken word, which was "moon," but it took a leap forward when he obtained his first department store telescope in 1969. Gerry is a scope-aholic and suffers from "ocularosis," which is defined as the inability to ignore eyepieces and other optical equipment.

Society News/ Nouvelles de la société

by James Edgar, Secretary

One of the things we do as a Society is remember our friends in their passing. One such long-time member is Sydney Sundell, pictured here. Senior members of the Montréal Centre may recall Sydney — he was active in the Centre in the 1960s and 1970s. Heinz Berrys of Montréal recalls at the 1964 Ottawa General Assembly having to give Sydney's car a boost because his battery was discharged. Heinz also recalls with pleasure many Star Nights at Sydney's home in Montgomery, Vermont. Sydney Mortimer Sundell died, aged 101 years, in Enosburgh, Vermont, on 2007 September 24. Condolences were sent on behalf of the RASC members.

Condolences also were sent to the family of the late Rev. Norman Green. He was an active member of the Hamilton Centre for many years, Society Secretary, plus a winner of the RASC Service Award. Norman passed way on 2007 September 11.

New Administration System Goes Live

In June 2007, after an extensive search, the Society's National Council approved an investment in a new integrated membership, subscription, and customer service system. The **iMIS** system from *Advanced Solutions International* replaces the proprietary MPA system used since 1996, and promises to bring the Society's information processing into the 21st century.

On October 1, the new system was brought live with the conversion of membership, customer, and subscription records. This Phase I implementation will replicate the functions of our existing system. Phase II, expected in January or February 2008, will dramatically improve member services by offering each member a customized login account that will provide access to their RASC member benefits and their personal information record. Members will be able to maintain their own personal data in the Society database over the Web, including updating their address, telephone number, or email address. Membership renewals will also be made much easier with instant access to current renewal information and the option to pay on-line in real time, as well as to subscribe to Centre benefits and programs.

Looking ahead, the new system will reduce volunteer workload by providing a simple interface for maintaining mailing lists and on-line access to membership information for Centre Executives. In addition, staff will enjoy benefits from the system's more robust credit-card processing options and other features designed especially for associations like the RASC.

Announcements about the progress of the iMIS system rollout will be made in the *eBulletin* as they are scheduled and a complete summary will be published in a future issue of the *Journal*.

BPC events

The new Board Pilot Committee (BPC) met in Collingwood, Ontario, on the weekend of September 28 to 30, for an intense "brainstorming" workshop. The 13-member group discussed various topics, and mainly outlined tasks for each of the members as the RASC heads toward the International Year of Astronomy in 2009 (IYA 2009). The project will be an exciting time for our Society, as we are expected to be the primary link between amateur astronomers and the public, giving as many people as possible their own "Galileo moment." Watch for more on this in the coming months.

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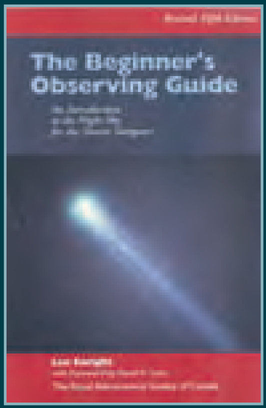

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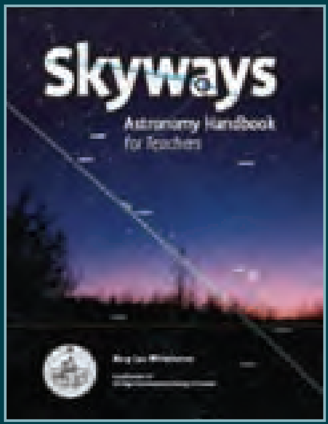

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