

## Chair's Report (continued)

You will also see the exact wording of these changes in this Event Horizon. The membership will vote on these changes at the June meeting.

Our featured speaker at the May meeting will be Rory Woods. His talk "Welcoming Our Computer Overlords in Astronomy" I'm sure will be of interest to many of us, as it seems we are using computers more and more in this hobby of ours. Rory Woods is a PhD student at McMaster University, as well as a presenter at the McCallion Planetarium and the Origins Institute 3D Theater. His research is on computational methods in astrophysics and is applied to galaxy formation.

Astronomy Day this year falls on the 10th of May the day after our monthly meeting. We will be setting up telescopes at Bay Front Park from 12:00 noon till 4:00 pm. for solar* observing, and from 8:00 pm. till 11:00 pm for the moon, planets and stars. I hope you come out and join in the fun.

I apologise that there was no Astro photo group meeting this month due to the fact I was down with the Flu and I didn't want to infect others with it. Therefore, we will schedule the next Astro photo group meeting for May 17th at 7:30 in the recreation room at my place. Please feel free to come out, contact me at 905-627-4323 for details.

The Binbrook Conservation Area will be holding their spring fishing derby Sunday May 4th. We have been invited to setup our telescopes on Saturday night May 3rd, to entertain the fishermen that camp out to get an early start Sunday, with some observing, weather permitting. Also, if you're an early riser and would like to volunteer to help with parking in the morning, contact me at the above phone \#.

I hope to see you out there.

* Editor's Note:

When observing the sun, as we hope to be doing during the day on Astronomy Day, NEVER look at the Sun through a telescope that does not have a proper solar filter on its objective. Instant blindness would be the probable result.

## HAA Helps Hamilton



To support our community, we will be collecting nonperishable food items and cash for local food banks at our general meetings. Please bring a non-perishable food item to the meeting or a donation of cash and help us help others in these tough economic times.

If you would like to help or have any questions about this initiative, please contact Jim Wamsley at 905-627-4323.

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## April 11th HAA Meeting Summary by Bob Christmas

Since HAA Chair Jim Wamsley was feeling under the weather at the time, Second Chair John Gauvreau stood in as emcee for the April HAA meeting. John got things under way at 7:30 p.m. by welcoming everyone in the audience to our meeting. He had a few announcements, and talked about the Loaner Scope Program, food bank program, the upcoming Astronomy Day (May 10) at Bayfront Park, and the recent B.A.S.E.F science fair, at which the HAA helped with judging, and the fair's winner of the Jim Winger Award, Seth Stefanchuk. (See Seth's thank-you letter, next page.) John also mentioned the May HAA meeting's guest speaker will be Rory Woods (see Upcoming Events on Page 21 for more information).

John then passed the floor to Observing Director Matthew Mannering, who gave his presentation of the Sky this Month. Matthew talked about the 3 phases of Twilight, which are Civilian, Nautical and Astronomical twilight, in order of time and darkness. He mentioned the "Belt of Venus" effect that twilight produces at nightfall sets in, and he showed a couple of neat photos of Earth's shadows on landscapes.

Matthew showed some images of Jupiter, by Jeff Moore, and the Moon, by John Gauvreau, and the Moon over Niagara Falls, by his wife, Janice Mannering. Matthew also showed detailed sketches of Mars he himself drew while at the eyepiece of his telescope.

He talked about the recent discovery that the asteroid Chariklo has rings, and that they were discovered by the detection of multiple occultations of a background star directly behind Chariklo.

Matthew talked about the Crab Nebula (M1) and used charts to show its location in Taurus in the western sky. He mentioned the April 15th total lunar eclipse, the first of 2 this year and 2 next year, as well as the gathering of Mars, Spica and the asteroid belt objects Vesta and Ceres in the constellation Virgo this spring, which, in the early morning of April 15th was joined by the eclipsed moon.

He also mentioned the upcoming Astro Cats show on May 3 and 4.
Following Matthew's talk, Alex Tekatch and Membership Director Leslie Webb drew for the door prizes and the $50 / 50$. Then we took a 15 -minute break.

After the break, Leslie Webb gave the evening's main talk, entitled "Seeing".
Les mentioned that Mars was at opposition, and that one needs to be in space, or on the moon, or somewhere else outside of Earth's atmosphere to truly experience perfect seeing. He mentioned a couple of place on Earth where the seeing inside this atmosphere of ours is at its best, including the summit of Mauna Kea, elevation about 14,000 feet, where many large observatories are located.

He talked about other Earthly locations where "seeing" varies all over the map, including New York City, Mexico City and Binbrook Conservation Area. He used this discussion about these locations to segue into the topic of sky Transparency, which can be decreased by pollution from aerosols and relative humidity. He mentioned that Winter is the best time to observe for the simple reason that relative humidity is generally at its lowest during that time of year.

Les then talked about Steadiness, which can be adversely affected by atmospheric turbulance, especially when warm air passes over cold air. By the way, the twinkling effect of the stars as seen from Earth's surface, called Scintillation, is caused by atmospheric turbulance.

Les talked about sky glow from light pollution, the physics of light dispersion (the splitting of white light into The Spectrum), the reflection of light by the atmosphere, the location in the sky of deep-sky objects based on latitude and the time of year, and about Adaptive Optics, the cool technology employed by some big observatory telescopes to correct for atmospheric turbulence and scintillation.

He mentioned that our human eyes can resolve down to 1.7 arc minutes.
In closing, Les gave everyone a piece of advice; to reduce the effect of atmospheric degradation during your observing session, let your equipment COOL DOWN.

John closed the meeting by reminding everyone of the next meeting on May 9, and Astronomy Day on May 10.

After the meeting, some of us reconvened at Kelsey's on Main Street for food, drinks, and further discussions.

## A Thank You Letter

08/04/14

Dear James Wamsley

My name is Seth Stefanchuk and I'm a Grade 7 at Saint Bernadette School in Dundas. I participated in the 2014 Bay Area Science and Engineering Fair (BASEF) held at Mohawk College from March 26 to April 12014.

I was the recipient of the James A. Winger Award sponsored by the Hamilton Association of Astronomers BASEF 2014 sponsored by your organization. I would like to thank you for your support in this year's Fair.

My project was about using principles of aeronautics, designing, and testing wings to find lift. From my effort I learned using Bernoulli's principle and changing the variables in the lift equation allows me to change the shape and amount of lift. I also learned that $20 \%$ camber on an airfoil produces the most lift.

I was able to share this knowledge with the judges who were very interested in this project and wanted to learn as much as they could. It was fun to tell someone else about something that I think is fun.

The Fair itself was a lot of fun. I got a ton of experience that will help me in my further years and I got to teach others about something I enjoy. This experience can help me in further science and technology areas because I hope to one day get my pilots licence and become able to fly a plane. I will need this experience because I would be completing a lot of paperwork to achieve this and have some background knowledge of the subject.

Again thank you very much. Your support helped make BASEF a success and I hope you continue supporting youth science in the future.

Sincerely,

## $\mathscr{S}_{\text {eth }}$ S' $_{\text {tefanchuk }}$

## The Sky This Month for May 2014 by Matthew Mannering

We have finally left winter behind and can enjoy milder evening weather. If you haven't had the chance to get out observing be sure to come out on Saturday May 10th for Astronomy Day. The club will be at Bayfront Park in Hamilton for a double public event. We will be doing solar observing during the afternoon and then setting up in the evening for our regular public viewing session. Everyone is welcome and there will be plenty of scopes of all sizes set up for the public and club members to look through. If you have a scope and need help setting it up, this is a good opportunity to try it out. My first public night occurred only a month after joining the club and coincidently was at Bayfront Park in May 2008. I was nervous showing up as a newbie but that quickly passed and it turned out to be a lot of fun.

The Lunar eclipse of April was the first of four that occur at six month intervals over the next two years. Unfortunately, as has happened all too often in the last year, the sky was completely covered by clouds and rain. Hopefully we will have better skies in October when the next one occurs.

## Easy Targets

For this month, my list of targets consists of the Planets, two Comets, two meteor showers and the Moon.

May seems to be a great time to view the planets. Jupiter is still high enough in the south west at dusk to give good views. Mars is starting to recede but is still large enough to get good views of surface detail. Mercury makes its' best appearance of the year in the evening. Saturn rises at darkness now and reaches a reasonable altitude for viewing by late evening. Neptune is high enough in the morning sky to allow a decent view for an hour before dawn. Uranus and Venus hang out near the morning Sun but still provide one good opportunity for astrophotography. Check out the monthly list of events below.

There are also a couple of Comets of note. The first is 209P/Linear which comes to within . 06 AU (astronomical units) or 8.90 million km of earth at months' end. I'll talk about the meteor shower associated with it in a minute. Linear may come close to the Earth but it looks like it will be quite dim. On the other hand Comet C/2012 K1 Panstarrs will max out at about magnitude 7 by months end. It's already being photographed by amateurs around the world. Here's the path K1 will take through the month.


There are two meteor showers this month. The first is the Eta Aquarid which will peak in the in the pre-dawn hours of May 6th. The radiant (where the meteors seem to originate from) is in the constellation of Aquarius and is best seen after 3am. It will have a maximum rate of 40 meteors per hour.

The second meteor shower is a brand new one named after comet 209P/Linear and may turn out to be the best of the year. It will peak in the early hours of May 24th at around 3am with a radiant in the constellation Camelopardalis. Computer models predict that the Earth will pass through a dense section of the debris which should result in a large number of meteors per hour.

See the finder charts for both the Eta Aquarid and Camelopardalis meteor showers next page.
(Continued on page 6)

## The Sky This Month (continued)



## The Moon

Libration favours the North limb on the 5th. The East limb is favoured on the 26th and 29th. The South limb is at its best on the 19th while the West limb is favoured on the 12th. The north and south limbs are near maximum Libration this month, so get out your lunar atlas and see if you can identify any craters near the poles. At full moon, see how far you can trace the bright rays extending from the crater Tycho. You might be surprised at just how far they extend across the lunar face! These rays are the splatter from the enormous impact that created Tycho. It must have been an amazing sight at the time. Use a moon filter to cut down the glare and brightness.
(Continued on page 7)

## The Sky This Month (continued)

## The Planets:

- Mercury makes its best evening appearance of the year this month so be sure to take a look. All you need is a pair of binoculars to help you see it during twilight. You'll have to wait for the 6th of the month to get your first look at it. From the 1st to the 5th it will be too close to the Sun to view safely. On the 25th it will reach its greatest Eastern elongation from the Sun at 22.7 degrees. So how come it's called an Eastern elongation if Mercury is in the West in the evening? It turns out the compass direction is based on the point of view as seen from the Sun, not from the Earth. So if you were standing on the Sun facing the Earth, Mercury would appear to be in the East. As if all this terminology isn't confusing enough, they have to use a different frame of reference than most of us use in our daily lives! After the 25th, Mercury will appear to move back towards the Sun as it approaches inferior conjunction. Here's a sample list of dates, times and altitude above the horizon when you can see Mercury at its best for that particular evening. These times are when Mercury should brighten enough to stand out from the twilight. Mercury will be just south (left) of the point on the horizon where the Sun sets.

$$
\begin{array}{lll}
\text { 6th }-8: 45 \mathrm{pm}, 7.5 \mathrm{deg} & \text { 10th }-8: 55 \mathrm{pm}, 10 \mathrm{deg} & \text { 15th }-9: 00 \mathrm{pm}, 13 \mathrm{deg} \\
\text { 20th }-9: 10 \mathrm{pm}, 13 \mathrm{deg} & \text { 25th-9:20pm, 12 deg } & \text { 30th }-9: 25 \mathrm{pm}, 11 \mathrm{deg}
\end{array}
$$

Lastly, on the 30th/31st look for a Jupiter-Mercury-Moon grouping low in the west (see Page 8).

- Venus appears in the morning sky before dawn. It will be very low in the sky and the Sun will rise shortly after. There is one possible photographic event but it requires a clear view of the Eastern horizon and has a very short window of opportunity. Venus and Uranus will be about 1.5 deg apart, 10 deg above the horizon at 5:15am on the mornings of May 15th and 16th.
- Mars is still in Virgo and starts the month with a diameter of 14 arc seconds and ends the month at 11.8 arc seconds. Once Mars falls below a diameter of 10 arc seconds it's too small to see much surface detail. So this is probably the last good month for viewing in most backyard scopes. It spends the entire month near the star Porrima moving slowly westward against the background stars in retrograde motion. On the 21st, Mars ends retrograde motion and resumes its eastward motion. Mars sets at 5:10am at the beginning of May and sets at 3:10am by month's end. See a diagram showing the retrograde motion of Mars on Page 8.
- Jupiter is still high in the south west in Gemini and sets around 1:15am at the beginning of the month. By month's end it will only be 22 deg above the horizon at $9: 30 \mathrm{pm}$ and will set around 11:40pm. Spend your observing time on Jupiter earlier in the month rather than later as turbulence near the horizon will spoil the view towards month end. Jupiter's moons cross the face of the planet (transit) on a regular basis. Ganymede will transit Jupiter on May 5th starting around 10:08pm and will be mid-face around 11:40pm. On the same night Europa will follow Ganymede, beginning its transit at 12:37am. Our Moon will be three days old and 5 deg below Jupiter at 9:30pm on May 31st.
- Saturn rises at about 9pm on May 1st. By month's end, it will rise at 7pm. You will need to wait about 3 hours after Saturn rises to see it clearly. It never gets more than 32 degrees above the horizon on any evening during the month. Allow 5 hours after it rises to reach this point. The rings are almost at their maximum open angle this year at 22 degrees. In three years they will have opened to 25 degrees. They should be spectacular through your scope! On the night of the 13th/14th the Moon approaches Saturn. At 10pm they are separated by 5 deg and by 4 am less than 3 deg. On the 10th, Saturn will be at opposition, its' closest point to Earth for this year. See the moon and Saturn finder chart for May 14th on Page 8.
- Uranus won't be safely visible until mid-month in the morning twilight. Check out the pairing with Venus on the 15th as described in the 'Venus' section above.
- Neptune is in Aquarius and will be 20 degrees above the horizon at mid-month at 5am.
(Continued on page 8)


## The Sky This Month (continued)

## Other Events:

-May 5th: Ganymede transits Jupiter starting around 10:08pm.
-May 6th: 3am: Eta Aquarid meteors peak. First Quarter Moon.
-May 10th: Astronomy day. Saturn at opposition.
-May 14th: Full Moon.
-May 15th - 16th: Venus and Uranus 1.25 deg apart.
-May 21st: Mars' westward retrograde motion ends. Last Quarter Moon.
-May 24th: New meteor shower in Camelopardalis.
-May 28th: New Moon.


## Notice of Motion to Amend HAA Bylaws

Over the rich 20 year history of the Hamilton Amateur Astronomers, the club has grown in varied and interesting ways. This growth is undoubtedly due to the enthusiasm and passion of the many club members who have contributed to the club's wellbeing over the years. However, the nature and direction of this growth has been in unexpected directions. Some of this could never have been anticipated, like the growth of the Internet and electronic communications which has meant that a person working as the club's webmaster does a lot of work even though no such position was created at the time the bylaws were written. The other change being suggested is the creation of a position to handle the club's publicity. Although the work is currently being done, it is being covered by the education director. There is more than enough work to fill a full time position in publicity and another in education. Because of this, the council feels the operation of the club will be enhanced by some changes to the bylaws that reflect the current state of the club.

At the June general meeting, to be held on Friday June 13th, 2014, the general membership of the club will be asked to vote on a motion to amend the bylaws so that two new positions will be created, that of Webmaster and Publicity Director. As such, the bylaws will read, in part, in the following manner;

## "Council

1. Composition

Council shall be composed of the three officers defined in the Constitution, Second Chair, Recorder, and the following directors: Observing Director, Public Education Director, Publicity Director, Editor, Membership Director and Webmaster. In addition, council may appoint up to five councillors."

If you have any questions or would like to know more, contact John Gauvreau by emailing:
secondchair 'at' amateurastronomy.org

Treasurer's Report by Steve Germann

Treasurer's report for April 2014 (unaudited)
Opening balance: $\quad \$ 8052.35$
Revenue: $\quad \$ 91.00$

Expenses: $\quad \$ 0.00$
Closing Balance: $\quad \$ 8143.35$
Revenue items were $50 / 50 \$ 41$ and Memberships $\$ 50$.
This time of year the club has no major expenses until we pay the rent for the hall in August and our insurance probably in October.
At our last meeting we also received a cash donation of $\$ 2.30$ which we forwarded to the Food Bank.

## Through the Looking Glass by Greg Emery

It has been a few months since I have submitted an article for the Event Horizon. It seems life got slightly ahead of me, although I am not entirely sure how. It was such a long, cold winter you would think that I would have a year's worth of articles written and waiting for submission. But I never seem to get ahead of the curve no matter what I am doing or how hard I try. A prime example of this is my telescope. I knew I needed to have it recoated. The Aluminum coating was showing both its age and less than ideal care and storage in my previous basement. I contacted someone I had met at a star party Normand Fullum - about doing my mirror. I saw the exquisite work he has done in producing some of his scopes and knew I could trust him with my mirror. My first email to him about doing my mirror was in August 2011 - I shipped the mirror last week, so that would qualify as being behind the curve for sure. Back in February I mentioned about some of the things that come to earth - electromagnetic radiation, rocks, dust, ice, life-and I was reminded again last week of the rocks and dust that come to earth on a continual basis by a friend. He wanted to know the best place to look to see the meteors when he was in his hot tub. The earth is continually impacted by material ranging from grains of dust/sand to hunks of rock the size of a small house. It is so very similar to the windshield of your car driving behind a truck this time of year - all the sand and debris on the road beats a steady rhythm.
Estimates for the amount of material that falls to Earth each year varies greatly, but a number like 45,000 tonnes would be a good average of the estimates - that is like dropping 9 African Elephants from outer space on to the Earth. OK, you are right not only would it make a huge mess if you did that, but it would definitely anger some people in PETA. When we look up and see a meteor, remember it has a brother, sister and a whole extended family coming with it that we can't see. The smaller rocks coming into our atmosphere burn up at a high elevation due to frictional heating. Larger pieces of rock do not completely burn up and make it to the ground. A meteor can also experience a third fate upon entering our atmosphere - the heating process can lead to the meteor exploding which in turn can lead to many smaller fragments.
In general as a meteor, or any object, approaches the earth at cosmic speeds, it will encounter the atmosphere. The Earth orbits at about $30 \mathrm{~km} / \mathrm{s}$ around the Sun. The object can be travelling at faster speeds, in the same directions or opposed to the Earth's motion. Therefore the meteors are travelling at anywhere from 30 to $70 \mathrm{~km} / \mathrm{s}$ as an approximation ( $108,000 \mathrm{~km} / \mathrm{h}$ to $252,000 \mathrm{~km} / \mathrm{h}$ - which would make the morning commute to work a little more bearable!). Moving through the atmosphere - even the barely perceptible atmosphere that they first encounter - causes the meteors to slow down greatly due to the friction encountered with passing through the wisp of air at those altitudes. This frictional heating is very beneficial to us.
Firstly the frictional heating slows the smaller objects down to normal terrestrial velocities, the terminal velocity of free fall. The kinetic energy of the object is dissipated as heat or thermal energy to the atmosphere - this is much better than having all the energy dissipated by the roof of your house or the top of your head! The other benefit that I perceive from this mechanism is the light show that it provides. As the object passes through the atmosphere the atoms burned off of or ablated from the meteor can absorb energy. The energy that is absorbed can be utilized to raise electrons to a higher state or orbit in the atom. As the electron returns to a lower state it will emit a photon of light. The energy of the photon is governed by the starting and ending orbital of the electron. A photon of given energy will always be the same wavelength or colour. Both the image below and the one at the top of Page 11 show the same information - one with the colours and the next with the associated wavelengths (note the difference in the two images around 7500 Angstroms is due to the complexity of the emission spectra of N and O in that region).
(Continued on page 11)


Image 1: Spectrum of typical Leonid Meteor (Image from NASA)

## Through The Looking Glass (continued)



Image 2: Spectrum of typical Leonid Meteor (Image from ASU Center of Astronomical Science)

The only question left is why meteors exhibit different colours? Composition is the deciding factor on that one. There are different types or classes of meteors. Each type or class has a varied chemical composition. Every element has numerous spectral lines or emissions - a great web page to see this is http://chemistry.bd.psu.edu/jircitano/periodic4.html. Many of these overlap or are very near to one another. The prominent lines for the prominent colours tend to be what we see.
Of the non-metallic types of meteors the basic composition is pretty much $\mathrm{FeO}, \mathrm{SiO}_{2}$ and MgO (which typically accounts for about 65 to $70 \%$ of the mass). Metallic meteors are basically Fe and Ni. I have included the line spectra for the $\mathrm{Fe}, \mathrm{Si}, \mathrm{Mg}, \mathrm{O}$ and Ni below.

Fe


Si


O


Ni


## Niceness and two nice Nice models of the Solar System by Doug Black

We live on a very nice planet! A bit fragile of course. And it's nice only if the solar system stays stable, more or less as-is. Will it stay stable? The history of this question is interesting, because over hundreds of years observations have improved so much, and because over the same time improvements in mathematics led to today's extremely difficult and complex analyses. I don't understand the really difficult math, and rely a lot on Wikipedia, but maybe I can make some sense of it here.

Before people could wonder whether the solar system was stable or not, they first had to realize that the planets revolved around the Sun. In Europe this came in the 16th and 17th centuries. There were careful measurements by Tycho Brahe and inspired guesses by Copernicus and Galileo.

The next step got underway with Kepler's three Laws for planets in the early $17^{\text {th }}$ century: First, each planet orbits the Sun on an elliptical path, with the Sun at one focus of the ellipse. And the line from the Sun to the planet sweeps out equal areas in equal time intervals. Finally, the square of the period of the orbit is proportional to the cube of half the long axis of its orbit (called the semi-major axis).

Kepler's Laws worked pretty well, because they were all based on good observations. But they weren't yet connected to any other ideas, such as a universal Theory of Gravity.

Isaac Newton (1643-1727), was one of the most important mathematicians / physicists the world has seen. At about the same time as Gottfried Liebniz, he invented calculus. He invented Newtonian telescopes and more, and he set out his three Laws of Motion, plus a first-ever Theory of Gravitation: "The force ( $\mathbf{F}$ ) of gravity of a body with mass $m_{1}$ on a body with mass $m_{2}$ equals the gravitational constant $G$, times $m_{1}$ times $m_{2}$, divided by the square of the distance ( $\mathbf{r}$ ) between the two objects." The short form is $F=G m_{1} m_{2} / r^{2}$.

And using his new calculus, Newton showed that his Gravitation law actually led back to all three of Kepler's measurement-based laws!

Especially in older English, two meanings of the word "nice" are precise or neat. So calculating future orbits of planets seemed to fall into place nicely! Newton and others felt that if we did lots of calculation, with careful measurements, all future orbits were computable. Even today, nice shiny brass orreries embody the basically 18th century vision of a clock universe. This idea reappeared, smushed as usual, in the 2001 movie "Lara Croft: Tomb Raider".

Newton did understand the Moon's librations, yet one thing bothered him seriously, to the end of his life: the Moon had other odd motions. Maybe he had some inkling of future ideas?

Celestial Mechanics as part of mathematical Astronomy really began around this time! Often it was about the " $n$-body" problem - that is, what orbits happened if more than two bodies were in orbit how did their masses influence each other? And for a hundred years improvements in the analyses went ahead. For example, Pierre-Simon de Laplace (18-19th centuries) held forth with a group of friends in Arceuil, just south of Paris. Laplace was even starting to think about the possibility of black holes, and galaxies outside the Milky Way!

Resonances turn out to be important in Celestial Mechanics. It's just like pushing swings - if you push at the right time, again and again, the swing will go higher and higher; that is, the planets (say) will change orbit more and more if the ratio of their orbits' periods is, say, 2 to 1,3 to 2 , or other small whole numbers.

Jupiter and Saturn's periods are nearly in the ratio 2 to 5 . And Laplace showed that the JupiterSaturn system acts oddly because the periods are nearly ratios of small whole numbers. But he had the bottom line wrong! He thought that the solar system is really self-correcting - and it's not.

Joseph Louis Lagrange, at around the same time, did much more work on making orbit calculations easier. He too, tried to solve the n-body problem, and made lots of discoveries, such as the five Lagrange Points. Any pair of bodies orbiting about each other in space have these five "balance points".

Increasingly, observations kept coming in. Thousands of asteroids exist, but essentially none have orbits with ratios of periods (Jupiter-to-asteroid) like 3:1, 5:2, 7:3 or 2:1, as you can see in the first picture (from Wikipedia; next page). By 1867 Daniel Kirkwood showed how (Continued on page 13)

## Niceness and two nice Nice models of the Solar System (continued)

Jupiter has ejected asteroids from resonance orbits. (Today we know that meteorites are ejected from the asteroid belt after straying into one of the resonant gaps. And in the outer solar system, the giant planets gradually remove icy worlds from the Kuiper belt, sending us the short-period comets)

# Asteroid Main-Belt Distribution Kirkwood Gaps 



Time to digress! A 1952 short story by Ray Bradbury has become part of popular culture, and it's relevant here. A vacationing time traveller goes way back in time, to shoot a T-rex, and by mistake steps on a butterfly. Because of this, when he returns to his own remote future time, everything is subtly worse, and an extremely nasty government has taken over. People call this sensitivity of a chaotic system (that's our world, in case you hadn't noticed) the Butterfly Effect. Chaotic systems are (a) Very sensitive to initial conditions, (b) Deterministic - to describe them no probabilities, quantum or otherwise, are needed, and (c) Nonlinear - responses of the system don't depend linearly on whatever impulse you give it.

For instance, the way a large ordinary pendulum behaves is not generally chaotic. And why not? Because it's essentially linear unless you swing it really hard: To push it 3 inches from its rest position takes just 3 times the force needed to push it one inch.
But just as a counter example, a very simple triangle with sides of length 3, 4 and 5 floating about in space, with point masses of 3,4 and 5 at its three corners, is definitely a chaotic system. If, in a computer simulation, we "release" the masses, the masses move toward each other, although they don't actually collide. After some very messy orbiting, the little mass (the 3) even gets ejected from the system - forever!

In 1889 King Oscar II of Sweden and Norway decided to have a contest to celebrate his birthday! The winner would solve the $n$-body problem, and among other results, decide whether the Solar System was going to remain stable or not.
(Continued on page 14)

## Niceness and two nice Nice models of the Solar System (continued)

No one came up with a complete answer, but Henri Poincaré came closest and won. And he showed that Laplace had been wrong - the Solar system appears to be chaotic and does not correct itself.

He also invented Poincaré maps. Imagine that you held a huge flat sheet of paper in space, at 90 degrees to the orbit, so that the orbiting rock or whatever hit it each time it came around. The pattern left on the paper after many revolutions would be the Poincaré map. A perfectly regular orbit's map would be just a dot on the paper. This is actually a general technique of taking sections, in phase space (position - momentum space), in many dimensions. You study the pattern made by the orbits as they repeat (or not). It is applied to systems other than orbits too.

Alexandre Lyapunov (1857-1918) is definitely worth mentioning here. The "Lyapunov time" indicates how fast the simplest of chaotic systems go wild. It's exponential. For example, for Solar System objects, any imprecision in knowing orbits today is multiplied by about ten every 10 million years.

Paul Painlevé needs a mention too. He expanded Poincaré's work, acted as Prime Minister of France twice, (in all his spare time!), and did a lot of early work on black holes and General Relativity.

The Modern Era : An important problem is whether or not a small perturbation of a system results in lasting quasi-periodic orbits, or whether chaos sets in. Quasi-periodic orbits are orbits of a dynamical system more complex than periodic orbits: they correspond to oscillations with multiple frequencies that have no common period - so the dynamics is said to be "quasiperiodic." Work by Andrey Kolmogorov, Vladimir Arnol'd and Jurgen Moser, first published in 1954, addresses this. It's called KAM theory, and it's used to generate corrections of astronomical models, and to prove long-term stability and the avoidance of orbital resonances in the solar system. Arnol'd later used the KAM methods to prove the stability of
 elliptical orbits in the planar three-body problem. KAM theory is not easy! The second picture here shows a result, not just a dot or line or small region for the Poincaré section of a regular orbit, but instead the messy "2-D cloud" Poincaré section of an orbit where general chaos is setting in.

Many astronomers and mathematicians have been involved in all this. Just a few I'm aware of are Jack Wisdom (MIT), Jacques Laskar (CNRS), Jeff Xia (Northwestern U.), Renu Malhotra (U. of Arizona), Alessandro Morbidelli (OCA, Nice), and our "local guy" Scott Tremaine (McMaster first, Princeton now).

Nice, and astronomers making nice Nice models
In 2005 Alessandro Morbidelli (France), Rodney Gomes (Brazil), Kleomenis Tsiganis (Greece), and Hal Levison (USA) published a model, hammered out over six months in Nice, France, of the Solar System's past, present and future, using observations, and mathematics similar to that mentioned above. It's called the Nice Model.

According to this detailed model, in the early solar system, all the large planets "populated" the Oort cloud. Saturn, Uranus and Neptune tossed more small bodies inward, and so migrated outward. Jupiter ejected most small bodies, so migrated inward. The September 2007 issue of Sky and Telescope describes these results.
(Continued on page 15)

## Niceness and two nice Nice models of the Solar System (continued)

Well, simulations of an inwardly migrating Jupiter nicely reproduce the observed orbits of the Hilda asteroids, which are trapped in a 3:2 resonance with Jupiter. So it seems that Jupiter did indeed migrate inward. About 3.9 billion years ago the periods of Saturn and Jupiter reached a $2: 1$ resonance, which wildly disrupted the solar system. This is known as the Late Heavy Bombardment, and there's lots of evidence for this, and its timing, from the Earth and from Moon samples. Asteroid belt measurements provide more evidence for the Nice model: Renu Malhotra's more recent analyses assumed that Jupiter moved inward by 0.2 a.u., and Saturn, Uranus, and Neptune outward by $0.8,3.0$, and 7.0 a.u. The distribution of the 690 largest asteroids matches what results from migrating planets and is a poor match if the giant planets didn't move.

So Jupiter/Saturn reached 2:1 resonance, Neptune's orbit shifted, the Kuiper Belt was scattered, Jupiter ejected most inner Kuiper Belt bodies. And it all came out of the 2005 Nice model.

Then in 2009 Jacques Laskar and Mikael Gastineau ran 2500 simulations of the Solar System for the next five billion years. Under Newton's laws, there would be about a 60 percent chance that Mercury would head toward the Sun or Venus during the Sun's lifetime. But General Relativity lowers these chances to about 1 percent. Yes, we've been saved by General Relativity! Even that 1\% doesn't hurt us, unless Venus tidally disrupts Mercury, sending fragments our way. But in just one of the 2500 simulations, all the terrestrial planets destabilize at about 3.3 billion years from now. Mercury, Mars or Venus could hit the Earth! Even without a direct hit, Earth's orbit can be enormously modified. Renu Malhotra even commented that Mercury might even owe its current eccentricity, inclination and high density to some previous collision.

We're now into 2014, and the Nice model is still a hot topic. Since its initial publication, the model's initial conditions have changed significantly, because of investigations of the behavior of planets orbiting in a gas disk. Now an early quadruple resonant configuration with each large planet in resonance with its nearest neighbors seems likely: it's probably Jupiter and Saturn in a 3:2 resonance, Saturn and Uranus in a 3:2 resonance, and Uranus and Neptune in a 4:3 resonance.

Then the gravitational stirring of the outer planetesimal disk by Pluto-sized objects results in breaking of the quadruple resonance via a mechanism that is not sensitive to the distance between the outer planet and the planetesimal disk. That is, the planets migrate inward while remaining in resonance. During this migration the eccentricity of the inner ice giants increases, leading to secular resonance crossings. (Secular resonances occur when the precession of two orbits is synchronised; over time, secular resonance will change the eccentricity and inclination of the smaller body.) After several hundred million years the resonant configuration is destabilized during one of these secular resonance crossings.

This mechanism for triggering the late instability of resonant planets has been called the Nice 2 model. The former smooth migration of Jupiter and Saturn has been shown to excite the eccentricities of the terrestrial planets beyond their current values and to leave an asteroid belt with an excessive ratio of high to low inclination objects after the migration. That's a problem. In the original Nice model the slow approach of Jupiter and Saturn to their mutual 2:1 resonance, necessary to match the timing of the Late Heavy Bombardment, can result in the ejection of Mars and the destabilization of the inner Solar System. A step-wise separation of Jupiter's and Saturn's orbits due to gravitational encounters with one of the ice giants, called the Jumping-Jupiter Scenario has been shown to be necessary to avoid these issues. The frequent ejection of the "ice giant" (that's a large planet such as Uranus or Neptune, made of materials less volatile than hydrogen or helium) encountering Jupiter has even led some to propose an early Solar System with five giant planets, one of which was ejected during the instability!

Well, what is really stable then? The big outer planets' orbits are very stable. The Trojans of Jupiter, Neptune and Mars too. The plutinos in a 2:3 resonance with Neptune, and some objects locked into $3: 4$ and $1: 2$ resonances. The Kuiper belt is generally stable, because there seem to be no more planets beyond Neptune.

All the chaotic behavior described above happens in star clusters and galaxies too. It's kind of amazing that we're here!

## NASA's Space Place



# The Power of the Sun's Engines 

By Dr. Ethan Siegel

Here on Earth, the sun provides us with the vast majority of our energy, striking the top of the atmosphere with up to 1,000 Watts of power per square meter, albeit highly dependent on the sunlight's angle-ofincidence. But remember that the sun is a whopping 150 million kilometers away, and sends an equal amount of radiation in all directions; the Earth-facing direction is nothing special. Even considering sunspots, solar flares, and long-and-short term variations in solar irradiance, the sun's energy output is always constant to about one-part-in- 1,000 . All told, our parent star consistently outputs an estimated $4 \times$ $10^{26}$ Watts of power; one second of the sun's emissions could power all the world's energy needs for over 700,000 years.

That's a literally astronomical amount of energy, and it comes about thanks to the hugeness of the sun. With a radius of 700,000 kilometers, it would take 109 Earths, lined up from end-to-end, just to go across the diameter of the sun once. Unlike our Earth, however, the sun is made up of around $70 \%$ hydrogen by mass, and it's the individual protons - or the nuclei of hydrogen atoms - that fuse together, eventually becoming helium- 4 and releasing a tremendous amount of energy. All told, for every four protons that wind up becoming helium- 4 , a tiny bit of mass - just $0.7 \%$ of the original amount - gets converted into energy by $\mathrm{E}=\mathrm{mc}^{2}$, and that's where the sun's power originates.

You'd be correct in thinking that fusing $\sim 4 \times 10^{38}$ protons-per-second gives off a tremendous amount of energy, but remember that nuclear fusion occurs in a huge region of the sun: about the innermost quarter (in radius) is where $99 \%$ of it is actively taking place. So there might be $4 \times 10^{26}$ Watts of power put out, but that's spread out over $2.2 \times 10^{25}$ cubic meters, meaning the sun's energy output per-unit-volume is just 18 W $/ \mathrm{m}^{3}$. Compare this to the average human being, whose basal metabolic rate is equivalent to around 100 Watts, yet takes up just 0.06 cubic meters of space. In other words, you emit 100 times as much energy-per-unit-volume as the sun! It's only because the sun is so large and massive that its power is so great.

It's this slow process, releasing huge amounts of energy per reaction over an incredibly large volume, that has powered life on our world throughout its entire history. It may not appear so impressive if you look at just a tiny region, but - at least for our sun - that huge size really adds up!


Image credit: composite of 25 images of the sun, showing solar outburst/activity over a 365 day period; NASA / Solar Dynamics Observatory / Atmospheric Imaging Assembly / S. Wiessinger; post-processing by E. Siegel.

Check out these "10 Need-to-Know Things About the Sun":
http://solarsystem.nasa.gov/planets/profile.cfm?Object=Sun.
Kids can learn more about an intriguing solar mystery at NASA's Space Place:
http://spaceplace.nasa.gov/sun-corona.

## First Impressions From a New HAA Member

My name is Tom Kelly and I just joined the HAA at the last meeting in April. I was impressed at the large turn out, the friendly and inviting atmosphere of the group. I was also impressed with the ad hoc viewing in the parking lot! You asked for any sort of thoughts or ideas to contribute to the newsletter so I thought I would like to share with you and the members my first view through my new Celestron Skymaster $9 \times 63$ binoculars. My children all chipped in and bought me my first ever telescope about 12 years ago for my 50th birthday. It was an entry level Celestron 3 inch, 700 mm Firstscope reflector, with a Newtonian mount. It's limitations were expected but it gave me my first views of the planets, although not too large. My wife knew I was interested in trying out astro binoculars so she went to Camtech and consulted with the owner about which one to buy and she presented it to me last June for my 62nd Birthday. Due to the poor viewing (seeing) last June I didn't really get a real chance to try them out until we were up North at our friends cottage on MacGregor Bay (part of Georgian bay near Espanola). I went out on a clear dark night armed with my old pair of binoculars for a true comparison, a rather good pair of $7 \times 25$ 's, with great optics, and I viewed the milky way. I then picked up my new Celestrons and looked at the same location and the first words that came into my mouth was BAM!!!! Look at all the Stars!!! I couldn't believe what a difference there was. I went nuts looking for any and all of the stars and things I knew about. The most amazing thing for me that night was actually seeing the Andromeda Galaxy for the first time, not ever being able to see it in my Telescope before. Looking forward to the next meeting and much more. I have a ton of things to learn.

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## Cartoon Corner by Alexandra Tekatch

## Bad Astronomy Joke \#42



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## UPCOMING EVENTS

May 9, 2014-7:30 pm - General Meeting at the Hamilton Spectator Auditorium. Our main speaker will be Rory Woods, whose talk will be "Welcoming Our Computer Overlords in Astronomy". This talk will give an overview of computers in astronomy. Rory Woods is a PhD student at McMaster University as well as a presenter at the McCallion Planetarium and the Origins Institute 3D Theater. His research is on computational methods in astrophysics and is applied to galaxy formation.
May 10, 2014 - Astronomy Day observing at Hamilton's Bayfront Park; 12:00 noon to 4:00 pm; 8:00 pm to 11:00 pm.

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| Observing site for the HAA provided with the generous support of the <br> Binbrook Conservation Area <br> Come observing with the HAA and see what a great location this is for stargazing, a family day or an outdoor function. <br> Please consider purchasing a season's pass for $\$ 79$ to help support the park. <br> http://www.npca.ca/conservation-areas/binbrook/ 905-692-3228 |  | Newsletter: <br> editor@amateurastronomy.org |
|  |  | Webmaster: David Tym Webmaster@amateurastronomy.org |
|  |  | $\mathrm{H} / \underset{\wedge}{\mathrm{MILTON}}$ |


[^0]:    Masthead Photo: Sunset over Lake Niapenco at Binbrook Conservation Area, near Hamilton, ON, by John Gauvreau.

