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ORBIT
Hamilton Centre RASC
BOX 1223
Waterdown, ON
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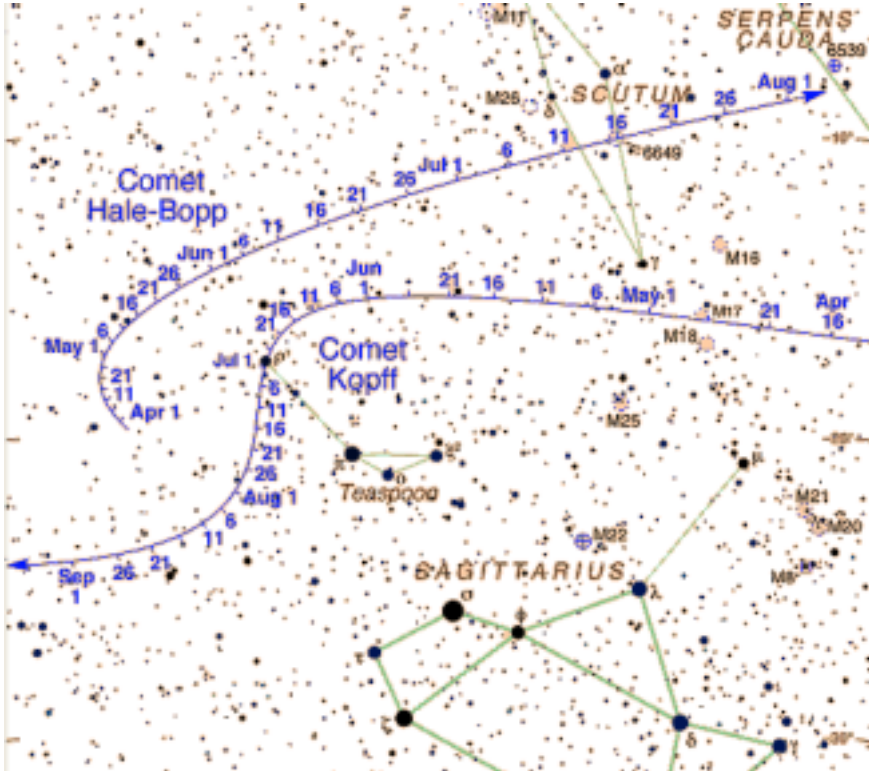
To:

ORBI

July / August 1996
Vol. 29, Issue 7



The Comets are Coming
Hale-Bopp & Kopff are on their way ! See them at Starfest!

The Official Publication of the Hamilton Centre of

Cover Image - Star map of Comets adapted from Sky & Telescope

ORIAL

Perfect Summer weather has come at last, provided you like hazy, hot, and humid. Fortunately for astronomers, there is StarFest, a breath of fresh air, held August 9-11 in Mount Forest, Ontario. I know many of you will be there. Back on the home front, we would like to remind you that there is always something happening at our Observatory, which is centrally located a few minutes from Burlington, Streetsville, Milton, and Guelph. Any clear evening is a great time to come out, and Sunday afternoons are usually busy. The public is always welcome, and we extend a hearty welcome to amateur astronomers everywhere. As we head toward the conclusion of this membership year, its time to start thinking about the role that our members have in setting next year's direction. In the coming months, fund raising is a priority, as well as developing increased membership. To that end, a number of fun events have been planned, and we will be doing a number of workshops throughout the year, ranging from a CCD workshop to Observing for Dummies. Our next official meeting is in September, but there are lots of opportunities to get involved now. In Orbit this month, some of the new projects are outlined, so enjoy the opportunities that present themselves. Like NASA did with the Martian meteorite, maybe you too can find life on another planet. Or just make your own impact craters. Clear Skies!

Colin A. Haig

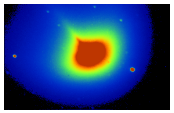
CONTENTS: THIS MONTH

MEMBERSHIP APPLICATION

Application for Membershipin the HAMILTON CENTRE of the ROYAL ASTRONOMICAL SOCIETY OF CANADA. Membership Year officially concludes September 30. We welcome people of all ages, skills, and interests in things Astronomical. Please make your cheque payable to: "RASC Hamilton Centre" and mail to the Treasurer c/o the address on the reverse. Associate membership is for those in other Astronomy Clubs. Please state the club. Full members receive The Observer's Handbook (approximately $20 value). Free 3 month Trial available - send no money!

MEMBERSHIP INFORMATION	
NAME:	
ADDRESS (1/2):	
ADDRESS (2/2):	
CITY:	
POSTAL CODE:	
DAY PHONE:	( )
EVE PHONE:	( )
E-MAIL:	

PAYMENT OPTIONS		
ADULT	**@ $49.00**	
ASSOCIATE	**@ $30.00**	
YOUTH (under 21)	**@ $35.50**	
VOLUNTARY DONATION:		
TOTAL:		
Circle one:	**NEW Member**	**RENEWAL**



Hamilton Centre Info & Observatory

From Hamilton or Guelph:

- Hwy 6 north of Hamilton, take Concession 7 East.
- Proceed eastbound on 7E, cross Centre Rd.
- Continue on 7E, keep going past the rail tracks
- proceed nearly to the end.
- Our gate is on the south side on the last lot (south west).

From Mississauga or Milton:

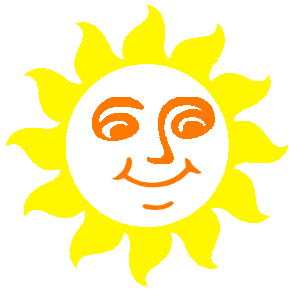
- Brittania Road past Hwy 25, Guelph Line, Cedar Springs to end
- South 1 block on Milborough TownLine to Concession 7 East.
- Our gate is on the south side on the last lot (south west).

NAME	Phone	Email Address
Observatory	689-0266	http://ad-here.com/RASC/
Astronomy emailing list	subscribe	bigbang@ad-here.com
President: Roger Hill	878-5185	roger@ad-here.com Fax: (905)878-3974
Secretary: Dave Coulson	634-4436	
Treasurer: John Kezys	648-5542	kezys@operatns.mohawkc.on.ca
Education: Carmen Martino	643-7283	
Observing: Rich Petrone	547-2589	petrone@ physun.physics.mcmaster.ca
Curator: Les Nagy	387-0690	lnagy@netaccess.on.ca
National:Mike Jefferson	648-8919	
General:Charles Baetsen	524-0148	charlesb@abelcomputers.com
Librarian/Recorder: Ray Badgerow	692-4184	s296489@ liberty.mohawkc.on.ca
Editor: Colin Haig	577-4074	chaig@vizbiz.com

From the Keyboard of the President

August, and an amateurs astronomers thoughts (in Southern Ontario, at least) turns to Starfest. The River Place, the site of Starfest, is not the dark sky Mecca that the Texas Star Party seems to be. Nor is it a venerable, long established, Ode to the Telescope Makers Art, like Stellafane, or Riverside. Yet its allure is unmistakable. Many come for some of the better skies to be found in the area, some come for the exceptional array of speakers, and still more come for other reasons. No matter what reason people come for, come they do. So, in this, the August, or Starfest issue of Orbit, let me just talk about what it means to me.

I am a relative latecomer to the Starfest scene, first showing up in 1991. Prior to that time, I was too busy to show up. 1991 was different, because 1991 was practically devoted to coverage of the 1991 total solar eclipse in Baja California in Mexico. Since I was fortunate enough to be able to travel on the RASC trip to the Shadow of the Moon (my third), I was really looking forward to seeing other peoples pictures and hearing the tales they had to tell. I also met with people I had met on the trip, and this made my first trip to Starfest very special. I resolved that I would endeavour to make Starfest as often as I could, and I have not missed one since. It has become the astronomical highlight of my summer.

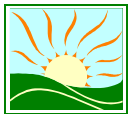


I have seen some glorious sights under the relatively dark skies north of Mount Forest, and a couple of them stand out. The biggest was seeing the scars on Jupiter left by Comet Shoemaker-Levy 9. I saw these black splotches through many telescopes, but the best view was through the Tekatches 'scope. The view I had through that wonderful instrument is a sight I will treasure for the rest of my life. Peter Ceravolos marvelous instruments were not slouches, either! In fact, even my old orange C-8 gave very pleasing views.

Some other noteworthy sights were perhaps not as spectacular, or once in a lifetime, as this, but deserve note, anyway. Things like seeing the central star in the Ring nebula though a 14 inch telescope (optics by Ceravolo), and the sublime time I spent looking through Stewart Attleseyes 20 inch dobsonian at the Veil nebula. Even looking at comet Hale-Bopp last year, 18 months

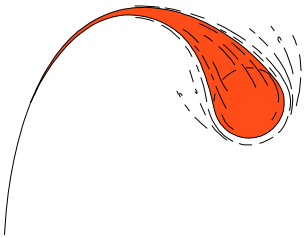
before perihelion, has to rank up there.

Not all the sights have been as spectacular. Some things come from seeing something relatively ordinary (for around here) through someone else's eyes. Like the two California amateurs who did not think our skies were particularly dark, but were totally blown away by the small display of Aurora, since they had never seen the Northern Lights before.



Similarly, several years ago, I drove Jason Post to Starfest, and his enthusiasm over such old favourites as the Double Cluster caused me to look again in wonder. Seeing the look on Jason's face when he looked though a telescope equipped with a hydrogen alpha filter and saw solar prominences was also worth the price of admission, that year.

In fact, many of the highlights of Starfest are inexplicably entwined up with the people who attend. Like listening to David Levy's talk about the death of SL-9. The poor guy was so dog tired after all he had been through, that he had not had the time to sort through his experiences. His talk that night was intensely personal, not at all what I had expected before entering the tent, that I must admit that my first reaction was disappointment. Yet further reflection changed my mind. If David had merely given us the latest and greatest findings and pictures, the talk would have been good, possibly even very good. It could not have been as riveting, as memorable, as inspiring as the talk David Levy did give. I feel privileged to have been a witness to it.



Some things have been humourous, like doing The Wave when Grant Dixon was introduced, or making up impromptu songs like If I Had a Ceravolo (to the tune of If I had a Million Dollars by The Barenaked Ladies). I think that was the year when half a dozen or so optical systems made by Peter found themselves congregated in one small area, prompting the area to be labeled Ceravolo Tololo. Last years light wars with the London Centre also come to mind.

Starfest has also brought me into contact with people that I would not have otherwise not met. This year, will be a little different, when I meet people to whom I have talked over the Internet, either on the RASC or the Bigbang listservers. In previous years I have met people like the fellow from Newfoundland who drove all the way to Starfest, and asked if he could pitch his tent in amongst the Hamilton Contingent. He told me, just before he left, that he had certainly picked the right group to join. He had never enjoyed himself quite as much during a star party as he had with us. In fact, that seems to be a recurring theme when it comes to people from Hamilton. Several people have noted that no other group seems to enjoy itself quite as

WHAT'S HAPPENING!

Monthly Meetings are held by the Hamilton Centre at McMaster University Medical Centre Ewart Angus 1A6 8pm. Next meeting is:

Thurs. Sept 5, 1996- 8pm: Hamilton Centre regular meeting. Summer Vacation fun! New members always welcome! Write this on your calendar! Bring your slides and stories!

Saturday, Sept. 14 - Car Wash at Canadian Tire, Mohawk and Upper James. 8:30am to 4:30pm. Special Fund Raising with Matching $$$. We need 8 people! Contact: John Kezys.

CCD Workshop - Date To Be Announced

PHENOMENA PAGE

The Phenomena Page is a place for tidbits of information that we just can't do without.

Trial Membership Program: The Hamilton Centre has started the Trial Membership program, effective immediately! New members will receive three (3) months of ORBIT, our leading newsletter, three months of attendance at all of our functions, and are welcome to come out to the observatory at any time, under the supervision and guidance of established club members. We encourage them to join at the end of their 3 month trial.

Ephemeris for Comet 22P/Kopff:

Date	RA(h,m)	Dec(D,M)	Elong.	Mag.
Aug. 9	19 30.4	-23 00'	154	7.4
Aug.19	19 37.5	-23 45'	146	7.6
Aug.29	19 47.3	-24 09'	138	7.9
Sep. 8	19 59.4	-24 11'	131	8.3
Sep.18	20 13.5	-23 54'	125	8.6
Sep.28	20 29.1	-23 19'	119	8.9

Razor, we accept that CO is responsible.

The presence of near-surface CO in vast supply tells us immediately that the comets formed and have been stored in a cold place. It would be difficult to account for the CO if the comets formed at a temperature much in excess of 50K, and lower formation temperatures are possible. These temperatures are characteristic of heliocentric distances of order 30 to 50 AU, and place the origin of the nuclei in the Neptune region or the Kuiper Belt beyond.

Many interesting molecules have transitions in the submillimeter and millimeter wavelength regimes. Sensitive observations at these wavelengths have become possible only in the last few years. Currently, we are using JCMT [James Clerk Maxwell Telescope, Mauna Kea, Hawaii] to study the bright near-Earth comet Hyakutake (1996 B2), and the promising incoming Hale-Bopp (1995 O1).

In the coming months, as Hale-Bopp approaches earth more closely, we should plan on doing some simple spectroscopy again, and perhaps be more diligent in recording findings.

OBSERVATORY WISH LIST OR DO YOU HAVE WHAT WE

As always, we are trying to scavenge to keep the observatory in good repair. We are in need of donations of equipment, time, and money. Can you help? Tax receipts are available for many types of donations. Here is a brief list of things we need:

tree removal	lawnmower repairs
paint for buildings	new door and frame for Marsh
eyepieces	filter wheel for CCD
picnic tables (1 more)	UPS for computer
spectroscope	replacement of VCR
shelving for Butler	driven mount for scopes

Repairs are needed to all buildings. Please donate your time or finances.

much as the gang from the Steel City (we were the ones who held BIC lighters high, like a rock concert, after one speaker gave a talk). I suspect that this will always be the case. There are also those who no doubt are annoyed that we don't assume a 'proper professorial' decorum, but as a group we never have done, and I suspect that we never will. It seems that the Hamilton people also want the Party in Star Party.

What will happen this year? Hopefully, we won't get drenched like we did when hit with the tail end of Hurricane Andrew, a few years ago. With luck, we will see some nice perseid meteors, (although the chances are very slim indeed that we will see the bright bolide many people witnessed last year), and some superb deep sky views through telescopes I can only dream about. Will something happen this year that will spark someone to do something special, like when Charles Baetsen, Richard Petrone and I decided to build a CCD camera? Will this year another memorable Starfest? No doubt.

A couple of things before I completely remove my fingerprints on my keyboard, I would like to remind you that the Hamilton Centre needs you. This year, as almost never before, the Centre needs you. We have some big plans, and we need people to accomplish them. How do you get on the Board? Simplicity itself: all you do is fill in the form included in the September Orbit, or write a letter stating that you want to serve on the Board, and have another member of the Centre sign it (if you want, I'll sign it!). Then, when the next Board convenes for the first time at the October meeting, the people on the Board decide amongst themselves who will do what. They will typically decide on who will be President, Vice President, etc. That is all there is to it. Nothing mysterious, or sinister. Quite the opposite, really. In fact, being on the Board is a great way to make good friends in the Centre, and all it takes is a few hours scattered through the month. Please, don't assume that others will step forward. It is you that the Centre needs, regardless of how you perceive your ability or talent. Please, see me if you have any questions.

The last thing? The September meeting is usually a Members night, and this year is no exception. Bring your slides from your summer vacation: particularly those star trails you took. Show up with pictures of Starfest, bring in your moonshots, show us your new 'scope, and tell us about your new infatuation with globular clusters.

Clear skies to all, and see you at the Observatory!

Roger Hill
email: roger@ad-here.com
voice: (905)878-5185
fax: (905)878-3974

Roger Hill

WHY WE ARE STARGAZERS

BY MIKE RICKS

Together, Ellen, my good wife and I recently joined the Hamilton Centre of The Royal Astronomical Society. We purchased a pair of bird-watching binoculars with triple zoom. Right away it was found that Jupiter danced like a firefly because we were hand holding the glasses. However, adapting them to our camcorder tripod was a cinch and the stars settled down quite nicely.

One might ask “why bother, just to see a tiny disk that is Jupiter along with some faint dots which we are told may be moons?” The big observatories and various space craft have produced astounding pictures showing the greatest of detail. Our answer is simply that there is a special thrill seeing first hand what Galileo saw hundreds of years ago. We now have taken up a second challenge: determine which of those faint dots are moons and which may be background stars. We could ask one of the more seasoned members but it is going to be fun observing the motion of those dots over time in relation to Jupiter itself to see whether they are moons or stars.

The most exciting thrill is observing a total solar eclipse. We have chased eclipses before joining the R.A.C.S.. Again, magazine pictures, slides and professional videos show eclipses in all their splendor and with more detail than can be seen with the naked eye. Those pictures don’t quite convey the atmosphere or excitement as the darkness approaches and the temperature noticeably drops just minutes before totality. And then there is the total

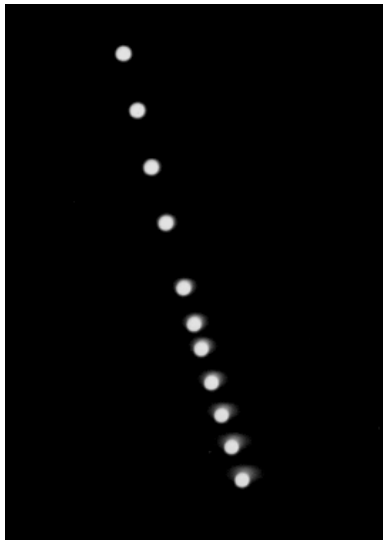
effectively frozen as ice, leading to the expectation that distant comets should be inactive. This indeed appears to be the case for a great many distant comets.

However, a subset of the comets support actively regenerated comae even at heliocentric distances larger than 5 or 6 AU. Over the past 4 decades, a number of hypotheses have been proposed to account for the presence of activity in distant comets. For example, some researchers supposed that the solid state phase change from amorphous (disordered) water ice to crystalline water ice could drive the observed activity, since this phase change is known to be exothermic. Others argued that slow internal propagation of conducted heat in periodic comets might account for sporadic activity observed in a number of distant comets. And still others noted that, while water ice is solid at large heliocentric distances, other so-called "super-volatiles" would not be. Candidate super-volatiles include carbon dioxide, carbon monoxide and diatomic nitrogen. Even hydrogen and helium have, at times, been suggested as potential sources of activity in distant, cold comets.”

The colouration that we had noticed during our Centre observations of Hyakutake suggested that carbon monozide (CO) was almost certainly responsible.

The advent of sensitive, ground-based telescopes operating in the submillimeter and millimeter wavelength regimes allows us to directly search for the source of activity in distant comets. Starting with the archetypal distant, active comet P/Schwassmann-Wachmann 1 we detected strong rotational transitions unambiguously associated with carbon monoxide. The strengths of the CO lines indicate outgassing at rates in the range 1000 kg/s to 2000 kg/s (1 tonne/s to 2 tonne/s). Following our discovery of CO in P/Schwassmann-Wachmann 1 (Senay and Jewitt 1994), we detected comparably prodigious CO outgassing in distant comet C/ Hale-Bopp (Jewitt, Senay and Matthews 1996). Recently, we have identified CO in comet C/Hyakutake (1996 B2), where the outgassing rate is again close to 1 tonne/s.

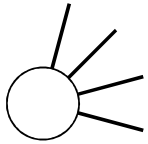
As a result of these measurements, we feel that the source of the activity observed in distant comets has been identified. The observed CO outgassing is so strong that it is easily capable of supporting the diverse phenomena (dust coma, jets) long associated with activity in distant comets. Other suggested processes (amorphous-crystalline phase change, propagating thermal waves) may also operate, but we do not need to invoke them to explain what we see. By Occam's



Mike Jefferson made this multiple time-exposure shot of the full moon on 120 format black and white film.

Mike uses a large format camera, and does his own film processing.

If you would like to learn more about astrophotography or film processing, Mike is a great resource.



BOB'S COMET UPDATE

Here is some more comet stuff, in part from Sky&Tel's comet home page. This is particularly relevant due to the talks we were having with NASA on the night of the comet back in March, when Hyakutake was at closest approach.

At that time we noticed strong green / blue colouration, and found it very prominent with the use of a home-made spectroscope. A simple diffraction grating showed this colouration clearly. Our comments to NASA's Ames Research Centre scientists resulted in a confirmed of the presence of CO molecules in the comet's outgassing.

The following notes provide a more detailed explanation, from the Submillimeter Comet home page.

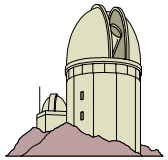
"General Introduction

In Whipple's standard model of the cometary nucleus, the basic features of cometary activity are controlled by the thermodynamics of water ice. Water ice sublimates appreciably at heliocentric distances less than 5 or 6 AU. At larger distances, water is

eclipse itself, an emotional experience which cannot be described. As they say "You just have to be there.?" Listening to the "ohs" and "ahs" of your fellow observers does the best job of explaining the magic of the moment.

Hopefully this tells a little of why we suffer frost bite or mosquito bites at the Hamilton observatory. The genuine help and friendly attitude of all the senior members also goes a long way to assure that rookies like us keep coming back.

Mike Ricks



JUNE MEETING NOTES - *OR - OUR SECRET CONNECTION WITH THE*

The June 6th meeting got underway a little bit after 8pm, as our guest speaker, Ivan Semeniuk, was slightly delayed. Our illustrious editor, Colin Haig, jumped right in with some fabulous slides from his trip up to the Lick Observatory, located about 20km outside of San Jose, California. Colin told tales of his death-defying drive up the mountain side in the dark, and had many of us laughing in the isles at his pilgrimage.
One of the *weird coincidences* is that the Lick Observatory sits atop Mount Hamilton and some might argue that our observatory is not far from Hamilton Mountain. Another weird coincidence: Lick Observatory was founded in the late 1890's, a handful of years before the time that our predecessors founded the Hamilton Astronomical Society. The folks at Lick were kind enough to give our humble ambassador a tour of the facility, and Colin showed us some slides of the famous 36-inch Clark Refractor, which is to date the second largest refractor in the world. The slides also included the giant 120-inch Shane Reflector, which has been used to make some of the discoveries recently announced concerning planets around other stars.

Ivan Semeniuk then took over, and gave us a whirlwind tour of (strangely enough) planetary

discoveries that have made the news lately, in part by the team of Geoff Marcy and Paul Butler. Even more coincidently, it was *the same Shane Reflector* at Lick on Mount Hamilton that they used to make their discoveries. Ivan then went on to show us many informative and intersting slides, charts, diagrams, and so on. And of course, a picture of the Lick Observatory on Mount *Hamilton.* Needless to say, it was just a little too weird... Of course, the icing on the cake was that McMaster's own Denise Kaisler, who is rapidly becoming known for her work in the same stellar neighbourhood as 51-Pegasi, was there in the audience to spur us all on.

So, we had an exciting night of strange happenings and coincidences. Stranger still, Doug Welch asked Colin about what was so special about the pier that the Clark Refractor is mounted on ? "Well," Colin answered, "could it be that it's where James Lick demanded to be buried?" And this led many of us to start thinking ... "Who is buried at our Observatory ?"

A great time was had by all. Roger, our fearless leader assured that all was well in the world, no one is buried under our pier, reminded us to volunteer for observatory maintenance, and closed the meeting by thanking Ivan shortly after 10:15pm.

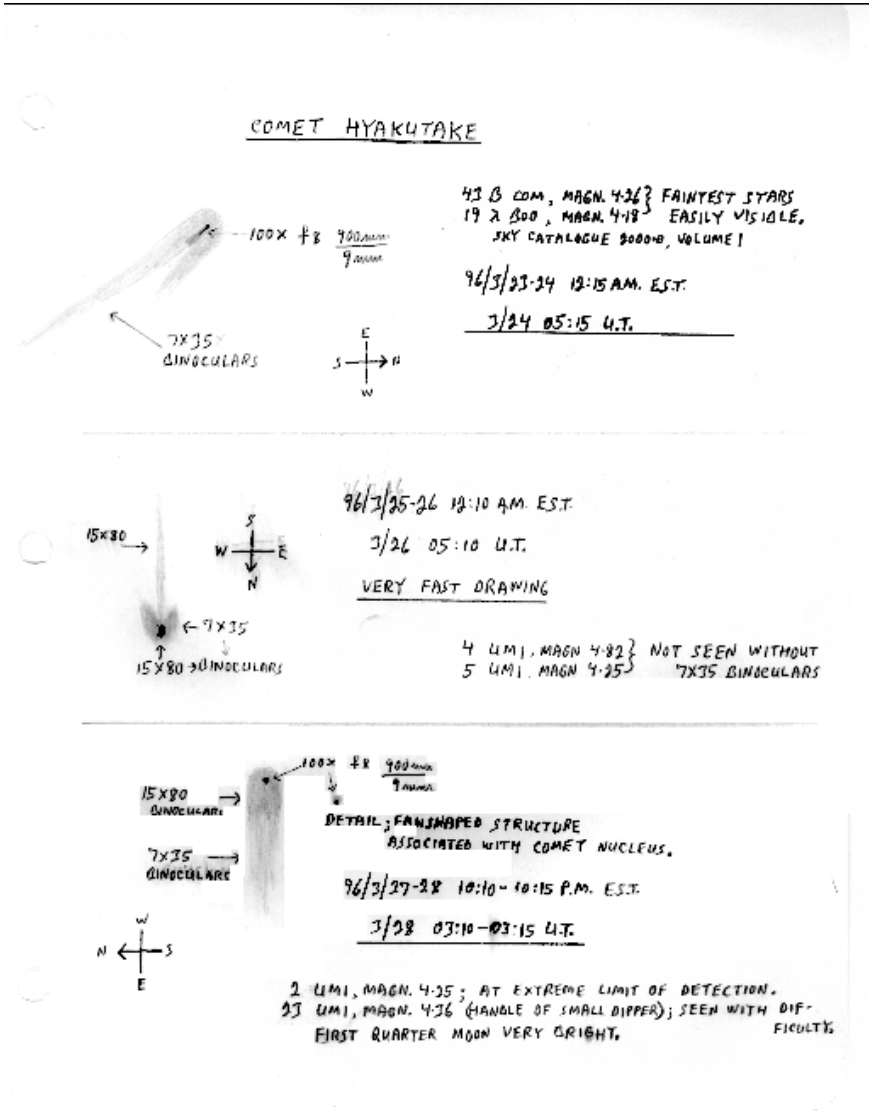
RASC HAMILTON CENTRE JUNE BOARD MEETING

Our final board meeting of the year was scheduled at President Roger's home on July 18. Board members Roger Hill, John Kezys, Colin Haig, and regular member Bob Botts were in attendance. Unfortunately, not enough board members to make a quorum. Some matters were discussed informally, including the need to raise additional funds to keep operating the observatory. Additionally, our request for a Special Grant to the National Council General Assembly was discussed. At this point, we had not heard anything as to a response to our request for monies to upgrade and maintain the facilities. We expect that we will have to do additional work on this proposal once we hear from National Council.

John indicated that the car wash would be moved to a September date. The Great BBQ Building bash was a success, even though we had foggy weather. About 8 to 10 people came out at various times during the day, and a lot of work got done. Hot dogs, burgers, chicken breasts, pasta salads, all kinds of great food were there. Things are now in better shape! We even have a sundial! And thanks also to the Baetsen's for subsequent cleanup work!

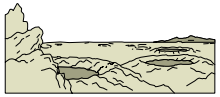
IMAGE GALLERY

Bert Rhebergen submitted this fine set of sketches of Comet Hyakutake. Note how complete his observing records are, and how detailed the sketches. [The editor apologizes for the reproduction quality].



the existence of significant mass (dark matter) outside the galactic nucleus.

M. John Kezys



CRATER RESEARCH PROJECT

I have initiated a project on CRATER STUDY at the the observatory.

The goal is to create models to help demonstrate crater formation. These models will be compared to the surface feautures of planetary bodies within the solar system. The models will then be subjected to erosional forces which will be compared to features which have been distorted on surfaces such as the Earth or Mars.

We may find it necessary to procure an undetermined amount of pyrotechnics (useful in the formation of such models), as well as bits and pieces of machinery to construct a rudimentary wind tunnel and sand table.

This is a fun project that anyone can participate in. Check with Bob for the next meeting. 522-9644

FUN(D) RAISING CHALLENGE

To raise operating funds for the Hamilton Centre without raising dues there are plans hold several fund raising events. In the past a car wash has proven to be profitable and fun. I have reserved the Canadian Tire Gas Station (Mohawk & Upper James) for a car wash on Saturday, September 14.

As a high traffic site, this is a popular location for car washes. I am seeking volunteers for this event. I suspect that at a minimum we need seven people. We need 2 people with signs directing traffic, 1 "go for", and 4 washing cars. We would start a t 8:30 am and finish at 4:30 pm. If people cannot stay for the whole day we can have an 8:30 to noon shift and then a noon to 4:30 shift. Maybe we can have 1 or 2 telescopes out for solar viewing and we can distribute membership brochures.

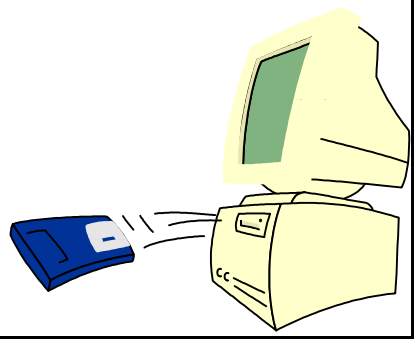
A challenge has been offered to match each dollar earned during the car wash by $1.30 up to $330. So if you can participate please contact me.

John Kezys, 648-5542, kezysj@operatns.mohawkc.on.ca

Hamilton Centre Car Wash:
Mohawk & Upper James on Saturday, September 14.

Join South-Western Ontario's Astronomy List! Discuss with friends and peers from all over! Astronomy not Club Meetings! Send an email to:
bigbang@ad-here.com
Put the words:
subscribe bigbang
in the subject and the first line.

The RASC has a list, that you can reach by sending an email to:
rasclist@astrotech.stmarys.ca
Put the words:
subscribe rasclist
in the subject and first line.



How Much Does the Sun Weigh ?

No, you do not have to use large bathroom scales but you do need some basic Newtonian mechanics formulas learned in high school. The mass of any star can be estimated from the orbiting characteristics of a planet.

A) Law of Universal Gravitation

It is said that Newton was inspired by a falling apple and this allowed him to formalize the concept that all bodies within the universe are attracted to one another by the same force of gravity. The size of this gravitational force (Fg) depends directly on the masses (sun's mass ms and earth's mass me) of the two separating bodies and it depends inversely as to the square of the separating distance (d^2).

$$Fg = \frac{G * ms * me}{d^2}$$

G is a universal constant having the same value for all pairs of bodies
* multiplication symbol

Just imagine, this force acts instantaneously and constantly through empty space of infinite extent. This force cannot be blocked nor suspended. Light can be blocked or shunted by lenses. Electric and magnetic forces can be controlled. But gravity is immutable.

B) Centrifugal Force

An orbiting body about the sun is acted upon by two forces. One force is the gravitational pull of the sun. The other is the apparent centrifugal force (Fc) which acts in the opposite direction to the sun's gravitational pull.

$$Fc = \frac{me * v^2}{d}.$$

v is the speed of the earth around the sun

C) Solar Mass Determination

Since the earth has maintained a stable orbit about the sun then the two forces can be equated:

$$\frac{G * ms * me}{d^2} = \frac{me * v^2}{d}$$

By algebraically rearranging this equation to solve for the sun's mass ms

$$ms = \frac{v^2 * d}{G}$$

Given (d) the distance from the earth to the sun = 1.496 * 10^11 m
(v) the velocity of the earth about the sun = 2.98 * 10^4 m/s
(G) gravitational constant = 6.672 * 10 ^-11 N m^2 / kg^2

$$ms = \frac{(2.98 * 10^4)^2 * 1.496 * 10^{11}}{6.672 * 10^{-11}} = 1.99 * 10^{30} \text{ kg}$$

You should try this exercise with the other planets and the moon-earth system.

D) Search for Dark Matter

The ms equation can be generalized for any orbiting system and rearranged for velocity (v) with a central mass of m.

$$v = \sqrt{\frac{G * m}{d}}$$

Given that most of the mass of a galaxy is located within the nucleus then it should be observed that the velocity of orbiting bodies about the nucleus should decrease with distance from the center. However high velocities are observed at large distances from the center. This can only be explained by