REFLECTIONS / REFRACTIONS

University Lowbrow Astronomers Monthly Newsletter

February 2023, Vol 47, Issue 2

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University Lowbrow Astronomers
Ann Arbor, Michigan

COMET C/2022 E3 (ZTF)

BY GLENN W. KAATZ

Taken on the night of January 31 - February 1. "Boy, was it cold! I set the imaging rig up in the driveway and did all the calibration, then went into the garage with the door closed the rest of the time where I have a small space heater."

A few particulars:
William Optics Z61 refractor with a William Optics Field flattener. F/5.6. Celestron CGX mount. ASIAir Pro.
ASI294MC pro color camera. ZWO electronic filter wheel. ZWO off-axis guider with an ASI120MM mini guide camera.

152 X 30-sec exposures with no dithering so as to keep frame captures consistent. 25 darks, 25 dark flats, 25 flats. Processed in Pixinsight with final touch-up in Photoshop. ■

Additional photos of Comet C/2022 E3 (ZTF) and other "Frozen Observations" in this month's issue of the Objective Lens!

GRAB AND GO OBSERVING: YOU SHOULD BUILD A 3D-PRINTED NEWTONIAN

BY ALEX SWARTZINSKI

There is something to be said about a small grab-and-go telescope. When the night's only mission is to peer between the broken cloud layer at the Moon or Jupiter, even portable scopes such as 6-8" Dobsonians might not be practical to set up before the Great Lakes Nebula rolls back in.

A small 60-100mm refractor seems to be the perfect option. Many SCT and large refractor owners will go this route because they can simply attach little refractors to their existing mounts. Dob users do not have this capability. Many tripod-mounted scope owners also run into issues due to the size and complexity of their mounts which makes them unfavorable for quick deployments.

Then there's the scope itself. If you don't want to see chromatic aberration around bright objects like the moon, you must use a very long focal-length refractor or an apochromatic one. Long focal length instruments are less practical for grab-and-go due to size and mount requirements, and Apo glass costs a fortune per inch of aperture. The popular (and affordable for its class) Orion ED 80 costs $600 -- that's a lot of dough for a backup instrument! I simply couldn't afford to shell out $1000 for a Vicon Porta mount and 80mm telescope, especially since this instrument is a backup. Small Maksutov telescopes also suffer from this same cost and mount issue. Fortunately, there is another option.

Newtonians do not suffer from Chromatic Abberation since they use mirrors instead of lenses. Small Newtonians can also use spherical mirrors if a high focal ratio is used (f/8 or higher) which allows the cheapest possible optics that still provide a color-accurate and coma-free view. The only problem? Commercial small Newtonians are limited in this long focal ratio application. Most small Newtonians feature fast focal ratios and tabletop mounts. These are great if ou have a very steady table and don't mind coma, but requiring an axillary mount makes them less practical as quick grab-and-go instruments. Collimation tolerances are also more sensitive at fast focal ratios. A DIY project can create the perfect grab-and-go Newtonian.

Enter the 114mm Hadley design. For under $200, you can create a 3D-printed Newtonian telescope. This project can be completed without any power tools or woodworking. Aside from the plastic casts, a basic list of hardware is all you need to get observing. My Dad and I recently assembled a 114mm Hadley. It was a fairly straightforward process, but there are some notes to pass on.

It takes a long time to print these pieces. Luckily I had access to a nice printer over the holiday season that wasn't being used. This made it possible to get everything printed within a few days. The longest piece took 31 hours to print!

Once we were on the assembly stage, we found some issues with the hardware instructions. The website provides a great overview of the parts required, but there was some trial and error required to determine

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which screw sizes fit the various casts since units switch between imperial and metric depending on the particular webpage. We also found that a significant quantity of screws and locking nuts were required to assemble this scope, perhaps more than indicated on the website.

Setting up the $30 spherical optics was straightforward. The mirrors are glued onto their cells. We had some trouble finding the correct-sized compression springs to use for the collimation screws. Hardware stores sell springs in bulk packages and this made it necessary to buy springs that were obviously too large to fit.

The remaining assembly process went smoothly. You simply slide each component down the optical tube assembly (OTA) poles and when you find focus, everything is screwed into place. There is an optional base that uses the same pole material as the OTA which prevents any woodworking from being necessary.

It was time for first light. A few nights into the new year, the perfect grab-and-go window arose. A broken cloud layer gave me one of the most satisfying views of the moon yet. Through an instrument that was a plastic parts pile only days previously, I was gazing upon our satellite through a color-accurate and surprisingly sharp view. It's highly rewarding to look at celestial objects through a scope you assembled! The altitude bearings cause this scope to glide like my Obsession since they are similarly oversized. Plossil-sized eyepieces work best with this scope, but I tried some Delos widefield eyepieces and they were securely held by the little helical focuser without issue. Since this first light, I've rigged a Telrad on the scope for easier pointing. Rebalancing simply required a shift of the optics forward before tightening them back down.

The last challenge that I'm still sorting out is the azimuth bearing. A lazy susan bearing is suggested to provide azimuth motions, but mine creates a large shake when I move the scope. I haven't decided if I'm going to replace the bearing or use another solution (like Teflon pads) to control motions.

That's ultimately the joy with Hadley. You can tinker endlessly to create a perfect scope, or simply enjoy what the plans suggest. There are endless modifications possible for this design, and new cast pieces can be downloaded for free printing. Some of my favorite innovations are a 3D-printed rack and pinion focuser and a more secure secondary holder. This design has been scaled up to 8 inches successfully, and a beefed-up fast astrograph version looks impressive. The Hadley 114mm is a remarkable telescope. For hundreds less than commercial options, one can build their own telescope that's capable of quick deployments. This scope demonstrates that the dobsonian revolution is still progressing. Who knows how many people have been sucked into this incredible universe of astronomy because of a simple webpage? Here are some resources to build your own Hadley. I hope you do! ■

https://www.printables.com/model/224383-astronomical-telescope-hadley-an-easy-assembly-hig

https://www.printables.com/search/all?q=hadley%20114

GENERAL RELATIVITY, PART 4

BY DAVE SNYDER

This article is the fourth in a series discussing General Relativity. In part 3, I introduced the field equations. These equations are the heart of General Relativity. Einstein published the final version of these equations in a paper published in November 1915.

It was not enough to just present the equations. General Relativity is a theory of gravity, and there already was a perfectly acceptable theory of gravity, namely the one developed by Isaac Newton. Einstein had to answer a simple question: Why should someone use his theory instead of Newton's? With that in mind, Einstein presented three ways in which the field equations of General Relativity produce different results from those produced by Newton's equations. In this article, I will explore this as well as some related topics.

I suggest you read the previous parts of this series if you haven't already (See Snyder 2021a, Snyder 2021b, and Snyder 2022).

Solving the Field Equations

Typically, the field equations are used to determine the trajectory of objects moving in a gravitational field. That requires that we solve the equations.

The field equations have an infinite number of solutions, and usually "solving the equations" means finding that one solution that applies in a specific situation. (1) Unfortunately finding exact solutions to these equations from scratch is notoriously difficult. Because of this, Einstein used approximation techniques and did not attempt to find exact solutions. Initially, he didn't believe anyone would be able to find exact solutions. (2)

In the early 1900s there were no computers (at least not in the sense we use the term today), so Einstein did his calculations by hand, which was time consuming and tedious. Nevertheless, he completed approximate solutions for three scenarios by November 1915: gravitational lensing, gravitational redshift, and precession of the perihelion.

Gravitational Lensing

The first effect predicted by Einstein involves the following question: what happens as light passes near a massive object? First consider a different question: What happens according to Newtonian physics? We can answer this provided we know two things:

1. Does light respond to gravity at all?
2. How fast does light travel?

If light doesn't respond to gravity, it will travel in a straight line no matter what massive objects might be nearby. Problem solved.

At the time of Newton, it was debatable if light traveled instantly or had a finite velocity. If the former was true, light travels in a straight line. Again, problem solved.

However, if neither of these are true, the solution requires a little more work. Newton himself argued that light was composed of small particles each of which of had mass (though he had no way to determine the value of that mass). If you assume light has a finite velocity and has mass, then when light passes near a massive body, it will bend toward that body (by Newton's time initial attempts at measuring the speed of light had been made, resulting in a value within 30% of the current value). Given the value of the speed of light, the angle of bending can be calculated. (You don't need to know the mass of a particle of light to do this calculation).

In general relativity, light responds to gravity and travels at a finite velocity. If we use general relativity to determine what happens to light passing near a massive object, we find it bends, but the angle of the bending is exactly twice the value we calculated using Newton's equations.

(In 1911, an early version of general relativity predicted a bending the same as predicted by Newton's equations).

Normally it is impossible to see both the sun and another star at the same time (which is necessary to measure the bending of light). However, it is possible during a solar eclipse and there was a solar eclipse in 1919. The locations of stars near the sun were recorded; these locations were shifted from the normal positions exactly as you'd expect if light bended as Einstein

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predicted. Better measurements have been done in the years since, always showing shifts in positions agreeing with Einstein's predictions.

One consequence of this bending: light from a distant object passing near a massive object will be "lensed" by that object. Just like a lens in a telescope, this will allow objects that otherwise are too dim to be seen to become visible.

Gravitational Redshift

There is another effect predicted by general relativity: If light travels away from a massive object, the wavelength of the light changes. The color of the light shifts toward red. It is redshifted. Conversely, if light travels toward a massive object, the color shifts toward blue. It is blueshifted. These shifts are tiny and could not be measured in the early 1900's but have been detected with modern equipment. No such effect is predicted by Newton's equations.

A related effect is as follows: A clock close to a massive object will run slower than a clock further away. Suppose there is a 100-story building. Alice is on the first floor and Bob on the 100th floor. A third observer watching both Alice and Bob, would see 24 hours go by for Alice when 24 hours plus 4 nanoseconds goes by for Bob.

Now suppose Bob is in orbit 12550 miles above the earth (the same distance as GPS satellites). A third observer would see 24 hours go by for Alice when 24 hours plus 39 microseconds goes by for Bob. (3)

While these are tiny effects and would have been impossible to measure in the early part of the 20th century, it is possible to measure them today with modern atomic clocks.

Bigger effects occur when observers are near massive objects such as stars and black holes.

This effect is known as gravitational time dilation and has recently been detected over distances of 1 millimeter. (4)

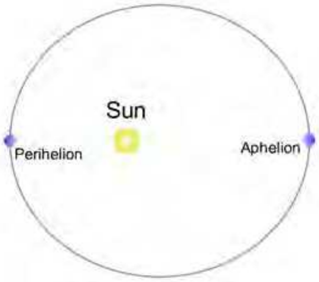
Precession of the Perihelion

The third effect predicted by general relativity involves the motion of the planet Mercury in its orbit. There was an irregularity in Mercury's orbit that couldn't be explained by Newtonian physics. Only after general relativity was used, was this irregularity explained.

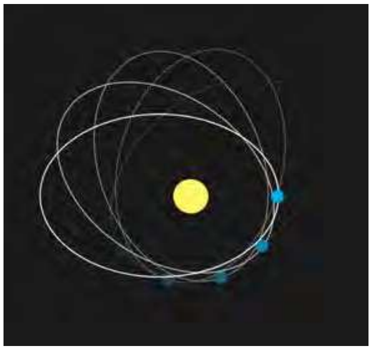
(This doesn't just affect Mercury, but the other planets as well. However, the effect is stronger as you get closer to the sun and thus is stronger for Mercury than the other planets).

To understand this, we need to explore what Newtonian physics says about the orbit of Mercury.

If we ignore the other planets and assume the sun is a perfect sphere, Newtonian physics predicts that Mercury should have an elliptical orbit. It will be closer to the sun sometimes and further away from the sun other times. The point where Mercury is closest to the sun is called the perihelion and the point where it is furthest from the sun is called the aphelion. In this situation, the perihelion and aphelion are fixed points in space.



However, it isn't that simple. The sun isn't a perfect sphere, it is an oblate spheroid. (5) A planet orbiting a star which is an oblate spheroid does not have an elliptical orbit, rather it "precesses." (6) This can be described as an ellipse where the perihelion slowly moves each orbit. This is shown below (the effect is greatly exaggerated, the difference between the actual orbit and a perfect ellipse is very tiny).



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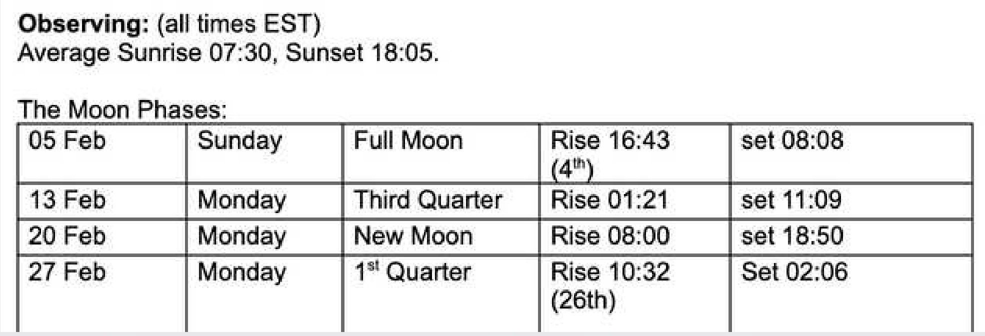
OVER THE HORIZON

BY JACK SPRAGUE



Observing: (all times EST)
Average Sunrise 07:30, Sunset 18:05.

The Moon Phases:

05 Feb	Sunday	Full Moon	Rise 16:43 (4th)	set 08:08
13 Feb	Monday	Third Quarter	Rise 01:21	set 11:09
20 Feb	Monday	New Moon	Rise 08:00	set 18:50
27 Feb	Monday	1st Quarter	Rise 10:32 (26th)	Set 02:06

The clouds continue….

We are entering our third month without any great windows of observation due to the weather. Hopefully, the clear, cold skies of February will change this appalling bad fortune.

I have included a number of stars as featured objects as these are rewarding “quick sight” topics suitable for the coldest of evenings.

I “graduated” from a quick set-up lightweight imaging rig last winter to a heavyweight bit of kit. In the cold now with windows only for peeking between clouds, I wish I had upgraded my lightweight gear instead of moving to heavyweight gear. But every choice has a cost.

Stay well. Stay warm. Stay encouraged. The clouds will eventually part.

The summers are beautiful in Michigan.

Meridian Constellations as of 10 February – 20:00 hours.

Normally, the OTH list is based on a date of the 15th of the month; but, I’m hoping that by shifting to the 10th I’ll encourage good skies. Consider it a Lowbrow version of the “rally cap.”

(-), (--) represent a positional modifier to constellations and objects east of the meridian by less than an hour and more than an hour. (+), (++) represent a positional modifier to objects west of the meridian by less than an hour and more than an hour, respectively.

I mention here a few objects contained in the constellations which I find meaningful. The list is in no way comprehensive!

-- Southern Horizon --

Caelum

Eridanus

Struve 571- double. Mag 6.3/11.0 separation 17.5”. Located at the “top eastern” end of Eridanus: the river. A white and blue pair. (4hr 36’ x -03° 37’).

NGC 1337 Galaxy. 5’ x 1.4’. Highly elongated. Does best at 125x magnification. Mag 11.9. A mottled core appears at 150x but admittedly, this effect for me requires good clear, cold seeing. EAA – 90 second exposures with solid tracking with 10 – 15 exposures stacked proves rewarding. Really, this is more of an AP target for the mottling to stand out. Perhaps a better filter set-up than I’ve employed would help: more OIII and IR and less H-alpha? Needs pretty solid post-processing in my hands. (3hr 28.1’ x -08° 23’).

IC 2118 – Witch Head Nebula – reflection nebula. 180’ x 60’. A large diffuse object which does best with steady hands and binoculars in dark skies, or EAA. Fifteen 30 second exposures stacked shows nice emerging detail. It is of course an AP showpiece which will reveal nice ribbons of color with two or three hours of stacked images. (5hr 6.9’ x -07° 13’).

NGC 1232 Spiral Galaxy. 6.8’x 5.6’. Mag 10. A lovely face-on galaxy with a bright core. Likes high magnification but works well with EAA. Knots and condensed clumps in the arms are the attractive bits. (3rh 9.8’ x -20° 35’).

NGC 1400 Galaxy. 2.8’ x 2.5’. (3hr 39.5’ x -18° 41’).

NGC 1407 Galaxy. 6.0’ x 5.8’. (3hr 40.2’ x -18° 35’).

A pair of elliptical galaxies represented as bright halos around their brighter cores. These are early-type galaxies of the Eridanus-A group. The pair are approximately 12 arc minutes apart.

Taurus

Struve 495 double star. Mag 6.0/8.8. Separation 3.8”! This pair is composed of yellow stars just resolvable in a small scope. (4hr 7.7 x 15°10’).

M45 - the Pleiades. Open Cluster. (3hr 47’ x 24° 31’).

OVER THE HORIZON continues**,** p. 7

Struve 559. Double stars. Mag 6.9/7.0. Separation 3.1"! This is an attractive bluish pair in the Hyades. (4hr 33.5' x 16˚ 31').

NGC 1807/1817 open clusters. Similar to the double clusters in Perseus but still an interesting pair. 1807 is sparse with a few bright stars. 1817 is denser but with fewer brights. Together in low power, the pair are quite nice. (5hr 21.1' x 16˚ 42').

M1/NGC 1952 The Crab Nebula. (5hr 34.5' x 22˚ 49').

NGC 1996 – open cluster. An odd duck. In the revised NGC it is classified as non-existent or so says my copy of **The Night Sky Observer's Guide** (Kepple & Sanner). SW of 125 Tauri (mag 5.2) it represents 100+ 10th – 14th magnitude stars in a 15' area. It feels good to me to look for something that doesn't exist and find it. William Herschel discovered the cluster on December 7, 1785. Try to find the 4 bright central stars. (5hr 38.2' x 25˚ 49').

Auriga

Home of Capella – my favorite star for celestial navigation.

Struve 845. Doubles. "41 Auriga" representing a nice blue-white pair. The attendant star is lilac pale. Well-adjusted eyes and a 125x magnification make a great deal of this 7.7" separated pair (or so say my 30+ year old notes!). (6hr 11.6' x 48˚ 43').

IC 405. Reflection and emission nebula. About 30' x 20'. Try a UHC filter at 75x to pick-up a large fan-shaped glow N of AE Aurigae. (5hr 16.2' x 34˚ 16').

NGC 1893 open cluster within the emission nebula IC 410. This is a rich cluster within the Milky Way. Try to count the fifteen 9th and 10th magnitude stars central to the cluster. (5hr 22.7'x 33˚ 24')..

M38 – open cluster. (5hr 28.7' x 35˚ 50').

M36 - open cluster. (5hr 36.1' x 34˚ 08').

M37 – open cluster. (5hr 52.4' x 32˚ 33').

Perseus (+) – an early in the evening set of targets.

Struve 392 – double star. Mag 7.4/9.6. Separation 25.8". An easy split for small wide-field scopes but a pleasing one: yellow and pale blue. It is an excellent choice to try eyepiece EAA. Careful of the lens! (3hr 30.3' x 52˚ 54').

Struve 425 – a tough double. Mag 7.6/7.6. Separation 1.8". A pair of equal yellow stars. This is a good bit of practice for focus adjustments before looking for DSOs. (3hr 40.1' x 34˚ 7').

M76, Planetary nebula. Little dumbbell nebula. Needs solid magnification. (1hr 42.4' x 51˚ 34').

NGC 869 / NGC 884 – the double cluster! (2hr 19' x 57˚ 09' ; 2hr 22.4' x 57˚ 07'). A famous and entertaining pair.

M34 – open cluster, (2hr 42' x 42˚ 47').

Camelopardalis

Struve 1694/ HD112028, HD112014 – whitish doubles. The pair consists of "A", a white-type A giant star of apparent magnitude 5.3 and "B", a magnitude 5.8 type A star which is itself a spectroscopic binary of 2 type A white stars. The separation between HD112028 and HD112014 is 21.6". Spectroscopic binaries are by definition stars (in this case two A sequence stars) whose separation is too small compared to luminosity to allow a split with conventional telescopes. Modern AP techniques can counter these conditions though the means to do so are beyond the scope of a survey article such as this. SO, here we have a binary Struve 1694 which is actually 3 stars in close visual association! Observe two, get one free! ~~ Note, some observers differ in color description suggesting yellowish and blue-white. They both look white to me. Please share your own color observation! ~~ (12hr 49.2' x 83˚ 25').

C7/NGC 2403 – spiral galaxy. Part of the M81/M82 group – an outlying member – was the first galaxy outside our Milky Way local group to be identified as containing Cephid variable stars. A size of 22'x12' makes this an especially photogenic object. It can be observed with binoculars or a wide-field low-power telescope, either. (7hr 37' x 65˚ 36').

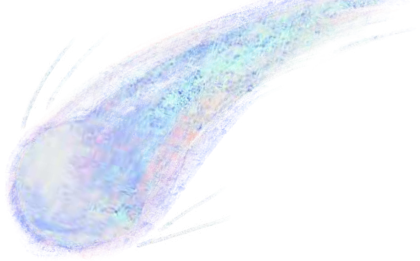
Draco

C6/NGC 6543 Cat's Eye Nebula – a planetary nebula. Discovered in 1786 by William Herschel, the Cat's Eye is approximately 16" in size but bright at a magnitude 9. It benefits from good seeing conditions, a magnification of 75x (at least) and a dark-adjusted eye. At 100x magnification, one sees a greenish ring surrounding an 11th magnitude central star.

William Huggins made the Cat's Eye the first planetary nebula to be spectroscopically examined. (17hr 58.6' x 66˚ 38'). ■

HALLEY'S COMET ASTROMETRY

BY JIM ABSHIER



I have lately been digitizing some astro-photograph slides that were taken back in the 1980s. Among the slides was one of Halley’s Comet taken during its appearance in 1986. I also did some astrometry to determine the celestial position of the comet. Back then plate reduction involved measuring positions of the object as well as reference stars in the film image using a precision measuring device. A computer was then used to calculate the plate parameters and the object's location. For measuring the comet and reference star positions in the slide, I used a measuring microscope that was available where I was working. With this instrument, positions in the film image could be measured with an accuracy of 2 microns. Equations for plate solving had been published in the September 1982 edition of Sky And Telescope by Brian Marsden. Based on these equations, I coded a program in Pascal on an Apple II computer. With the measurements and computer program, I was able to determine a position for Halley’s comet at the time of exposure.

I have now become aware of online capabilities for plate reduction. There are several tools called plate solvers that determine the celestial position and other parameters of an image from measurements of star positions in the image. The most popular use for plate solving today is to determine the position of astro-images in order to calibrate go-to telescopes. One of the online plate-solving tools is available at the astrometry.net website. This plate solver can come up with a solution using only an image. It is really remarkable. It detects and measures several reference stars in the image and searches a star catalog index database to find the stars as well as their positions in the sky. It then does the plate reduction to determine the celestial position of the image center, the image scale as arcseconds per pixel, and rotation of the image with respect to North. Details of how this is done can be learned from the astrometry.net website.

This readily available tool for plate solving prompted me to consider comparing my 1986 plate reduction result with what could be determined from the astrometry.net plate solver. Since I had digitized the Halley's Comet slide, I only needed to upload the digital image for analysis using the website tool. This time, measurement of the comet's position in the image was easy. The GIMP image editor has a measurement function that reports the pixel position of a cursor that can be placed on the comet image. With the celestial coordinates of the image center and the pixel scale, I was able to determine a celestial position for the comet.

The coordinates I got from my analysis back in 1986 were:

10h 48m 29s -16d 36m 43s

The position solution obtained from the astrometry.net parameters was:

10h 50m 54s -16deg 52m 57s

This difference was rather discouraging until I realized that the 1986 solution was probably in J1950 coordinates. Using the simplified equations for proper motion correction, the 1986 solution was updated to J2000 coordinates to obtain:

10h 50m 56s -16deg 52m 35s

This was more encouraging. The errors were only 60 arc seconds in right ascension and 22 arc seconds in declination. Although errors this large would make the solution useless for precision orbit determination, they are reasonable for the tools and equipment used in this project. The pixel spacing reported by astrometry.net was 17.4 arc seconds, so the errors were just a few pixels. The size of the reference stars in the digitized image was typically 6 pixels across with the brightest one being 12 pixels across. In arc-seconds, these would be 104 and 209 arc-seconds respectively. Measurement error for these star images could easily be one or two pixels. Other things that could have contributed to the difference in results include the camera lens, differential film shrinkage, the scanner,

HALLEY'S COMET ASTROMETRY continues**,** p. 9

HALLEY'S COMET ASTROMETRY continues ...

and my ability to accurately point to the correct location. The plate solution in 1986 required knowledge of focal length. The camera lens that I used then was a telephoto zoom lens that covered 100 to 400 mm focal length. For the Halley's comet image, it was set for 200 mm. This was a much shorter focal length than is typically recommended for astrometry.

An image of the 1986 Halley's Comet slide is shown in Figure 1. The faint fuzzy object near the center of the image is Halley's Comet. Figure 2 shows a screenshot of the graphic produced by the astrometry.net plate solver. I assume that the stars that have been circled were the ones used as reference stars in the analysis. These same stars and one additional star were used in the 1986 solution.

It has been gratifying to have obtained some verification of the 1986 solution with an independent plate solver. The present availability of digital cameras and online plate solvers makes determining celestial positions from astro-images very easy today compared with what was required back in 1986.

In addition to the use of the astrometry.net plate solver for checking the 1986 result, I found a plate reduction tool online that implements the same equations that my program uses. In the July 1990 issue of Sky And Telescope, an article by Jordon Marche II described his plate reduction work and supplied a BASIC program for doing the plate reduction calculations. The program that he gave implemented the same equations from Bryan Marsden's 1982 article that my program implemented. I also discovered that this BASIC program has been implemented in an online tool at:

http://www1.phys.vt.edu/~jhs/SIP/astrometrycalc.html

Figure 1. Halley's Comet Slide Image

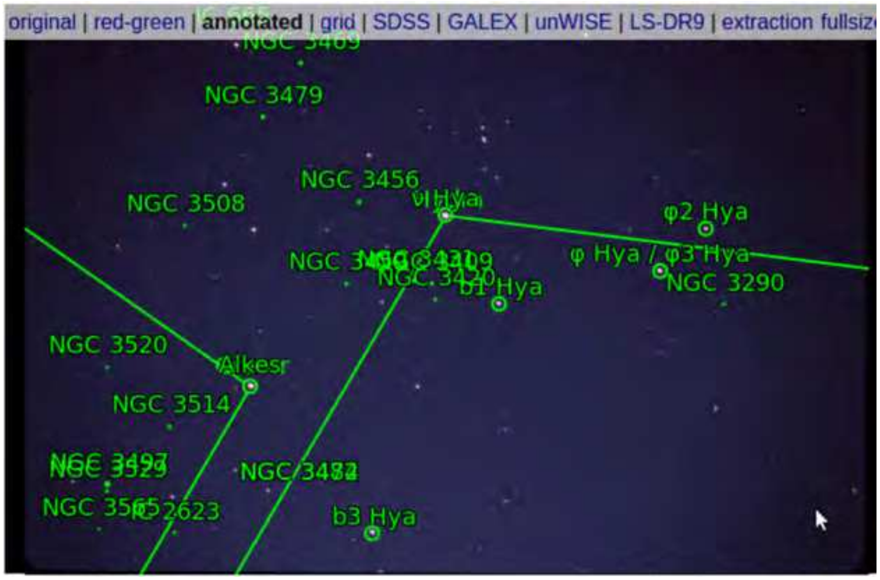


Figure 2. Astrometry.net Screen Shot

This provided the opportunity for me to check my program results with the BASIC program results. I entered the same data into the online tool that I had used in my plate reduction program back in 1986 and got essentially the same result.

10h 48m 28.9847s -16d 36m 43.377s

This provided additional verification that my program was working properly. I did not compute an overall rms residual error in my program, but the online program did. The online program reported an overall rms residual error of 23.13 arc seconds. This error represents the rms difference in reference star positions entered from the catalog and those computed by the fitted model using measured image positions. It is an indication of the overall accuracy of the whole plate reduction process. ■

MILKY WAY "SEASON" (?)

BY ADRIAN BRADLEY

In our latitude of 42 degrees North, "Milky Way Season" is mentioned by a lot of night sky photography enthusiasts. They refer to the roughly nine months a year that the galactic core -- the brightest part of our home galaxy -- rises above the horizon in the night sky.

If you look for examples of Milky Way photography, and you aren't talking about the Southern Hemisphere, you will see something like this: ⤵

The author re-enacting the day it all started.

In this photo at left, the plane of our galaxy is slanted where the core is low to the right and angles up through the Cygnus region. You see the core to the right and follow the plane up to near the Zenith where Cygnus has also risen, then on through the Cassiopeia region towards the Northeast horizon. Most images focus on this region because it is the brightest part of our galaxy. It is easiest to capture with shorter exposure times and is great for using photographic composition techniques such as the leading line.

The other popular image style using the Milky Way is later in the summer when the plane of the galaxy rotates and becomes fully vertical from north and the south. ⤵

In this image at right, from the Okie Tex Star Party (~37degrees North), the Core lies close to the horizon and the plane goes straight up with Cygnus at the Zenith.

There are six total 'regions' of the Milky Way that we see from all parts of the Earth (including the Southern Hemisphere). I'll do some research to see if there are any other official designations for these regions, but this is how I see it:

- **Core Region**: The area including the Galactic Center, Baade's Window, and the Galactic 'Bar' Bulge which contains DSOs for Sagittarius, Scorpius, Scutum, bordered by Aquilla, Ophiuchus, and below our horizons, Lupus and Centaurus.

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MILKY WAY SEASON continues ...

- **Cygnus/Summer Triangle Region**: Bordered by Cygnus, Aquilla, and Lyra.

- **Cassiopeia/Perseus Region**: Connected to the Summer Triangle Region by Lacerta, runs through Cassiopeia and then Perseus. Bordered by Andromeda and Cepheus.

- **Orion/Winter Hexagon Region**: Orion is the central figure to the right of where the galactic plane runs. Auriga connects this region to the Cassiopeia/Perseus region and the plane runs through the feet of Gemini, from head to tail of Canis Major, and through Eridanus. From there it goes below the horizon. Canis Minor, Taurus, and Lepus all border this region.

- **The Magellanic Clouds**: If we were to see below the horizon to the south when Orion stands vertically, we would see the Magellanic Clouds and the star Canopus sitting directly below him. The galactic plane runs through the constellation Vela.

- **Centaurus and Crux**: If we were to see below the horizon to the south when the Galactic Center stands on end, we would get to Centaurus and Crux, the Southern Cross. A little further down, Eta Carinae and the nebulous region around it would show up about the same distance from the core as the Summer Triangle region sits on the side we can see. The second largest globular cluster (or largest, if you agree that Omega Centauri is actually a dwarf galaxy stripped of everything but the core) is known as 47 Tucanae.

In future articles, I will go through the other regions of the Milky Way that we see in the Northern Hemisphere and suggest methods for framing these parts of the sky. You will see that our home galaxy has seasons rather than sections and that all of them can be imaged. This makes Milky Way Photography a year-round pursuit.

Should I ever get an opportunity to go to the Southern Hemisphere, then I will be able to complete the puzzle by imaging the other two regions we cannot see. Otherwise, I'll get permission from one of the Southern Hemisphere imagers that I know. ■

UPCOMING MEETING SPEAKER SCHEDULE

FEBRUARY 17: Ken Bertin, Warren Astronomical Society.
Topic: ***The Birth, Life, and Death of Stars***

MARCH 17: Dr. Mojtaba Akhavan-Tafti, U-M Astronomy.
Topic: ***Parker Solar Probe: Mission Design and Scientific Discoveries***

April 21: Jeff Morgenthaler, Ph.D, Planetary Science Institute.
Topic: ***Studying Volcanic Activity on Jupiter's Moon Io Using Equipment You Can Buy at a Camera Shop***

May 19: Buddy Stark, Planetarium Manager, U-M Museum of Natural History. ***(Visit to the U-M Museum of Natural History Museum Planetarium)***

June 16: Jim Shedlowski.
Topic: ***Orbital Light Pollution***

July 21: Norbert Vance, Director of Sherzer Observatory @ EMU.
Topic: ***Updated Planetarium***

Another issue: Mercury and the Sun are not the only objects in the solar system. There are planets and other objects, each of which exerts a gravitational force on Mercury. It is possible to calculate the effect caused by each of these objects one by one. For each object the result is an additional precession.

The total precession is calculated by adding the precession caused by the sun's shape and the precession caused by other objects in the solar system. This calculated value is 5557 arc seconds per century. However, Mercury is observed to have a precession of 5600 arc seconds per century. The difference of 43 arc seconds required an explanation. (7, 8)

When people tried to produce such an explanation, one idea was frequently mentioned: a previously unseen planet that exerts a gravitational force on Mercury and causes the additional 43 arc seconds. However, this unseen planet was never found, and until General Relativity no other explanation was successful.

General relativity predicts the Newtonian effects described above plus a precession caused by the distortion of space-time near massive objects, an effect not predicted by Newton. Einstein calculated this extra precession as 43 arc seconds per century, the exact amount needed to produce the observed 5600 arc seconds per century.

Schwarzschild Metric

A number of exact solutions have been found in the years after the November 1915 paper. Many of these are generic solutions, they apply to a group of situations. If you need to use the field equations and the situation you are studying falls under the conditions of a generic solution already published, then the task is dramatically simplified. And if that doesn't work, there are approximation techniques. Properly used these techniques can produce results close to the results an exact solution would give.

Karl Schwarzschild was the first person to find an exact solution (this was a generic solution).

Schwarzschild was a German astronomer and physicist. He enlisted in the German army in 1914 and served on both the western and eastern fronts where his primary job was calculating ballistic tables. In spite of this, he was able to keep up to date on Albert Einstein's progress with the new theory of gravity. And he had a good understanding of the underlying mathematics (at the time few people had such an understanding).

When Einstein published his November 1915 paper, Schwarzschild obtained a copy. In a few weeks Schwarzschild constructed an exact solution to the field equations. Einstein was impressed and corresponded with Schwarzschild. Unfortunately, Schwarzschild suffered from an autoimmune disease (probably unrelated to his military service) and died of that disease in early 1916.

This solution is now known as the "Schwarzschild solution" and applies for the case of a single spherical non-rotating mass. (It is presumed there will be a much less massive test mass that responds to the resulting gravitational field). In the most common cases, this produces results very similar to those that appeared in Einstein's 1915 paper. But the Schwarzschild solution produces more accurate results and was easier to use than the approximation techniques Einstein used.

In addition, this solution also predicts that if the mass density is high enough, strange things will happen. In other words, when we are close to what is now called a black hole (I'll discuss black holes in more depth later).

There are a few things to note:

1. This only applies to the motion of a single test mass in the gravitational field of a single massive object. When there are additional objects, this becomes a 3-body problem. 3-body problems can sometimes be difficult to deal with. But there are techniques that work in certain situations. Specifically, under the right conditions the techniques described under "precession of the perihelion" work well.
2. This only applies to spherical masses. When dealing with oblate spheroids (commonly caused by the rotation that distorts otherwise spherical objects), the techniques used to determine precession of the perihelion explained above can be used.
3. While this solution only applies to non-rotating masses, the rotation of objects with reasonable density (i.e., anything that isn't a black hole) doesn't change the results that much. So even though many astronomical objects rotate, it is reasonable in most cases to pretend they are not rotating, and this allows the Schwarzschild solution to be used.

4) The Schwarzschild solution only applies outside a massive object. For example, suppose you build a tunnel that goes from the surface of Earth to the center of Earth. The Schwarzschild solution would suggest that the gravitational field will increase as you

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GENERAL RELATIVITY, PART 4 continues**,** p. 13

move from the surface to the center. In fact, the opposite happens, the gravitational field decreases as you get closer to the center. In short, don't expect the Schwarzschild solution to work inside any massive object, Earth, or anything else.

Weak Field Approximation

In Newtonian physics, the gravitational field of a massive object extends to infinity, but rapidly gets weaker as you get farther from that object.

You might think that in General Relativity, if we are far from any massive object, that we could approximate the gravitational field as zero.

Yes and no.

That approximation works in many situations, but there are two situations where such an approximation is not appropriate.

1. Weak gravitational lensing. Even if the gravitational field is weak, it can still cause light to bend and it still can cause gravitational lensing. We cannot approximate the field as zero and still get lensing.
2. Gravitational waves. Imagine an extreme event billions of light years away creating gravitational waves. The gravitational waves must be able to propagate through empty space, space that might be far from any massive objects. If the gravitational field far from massive objects was precisely zero, no gravitational waves could exist. But they have been observed, so approximating the field as zero is not appropriate (I'll go into gravitational waves later).

Inside of approximating the field as zero, we can use what is called the "weak field approximation." This assumes that gravitational field is not zero but is small enough that using simple approximation techniques will produce reasonable results. The same techniques do not work if you are close to a massive object.

The weak field approximation is also known as "linearized gravity."

Computers

Today most people working with the field equations use computers, either to obtain an exact solution or to use an approximation technique to solve the equations.

Next Time

Next time I will explore other predictions of general relativity, including the expansion of the universe, black holes, and gravitational waves. ■

NOTES

1, 2. If you know calculus: The field equations are effectively a system of 16 differential equations. When expressed in tensor form, they don't look like differential equations. They become differential equations when the tensors are replaced with the appropriate 16 expressions. Almost all differential equations that are encountered in the sciences have an infinite number of solutions. Once sufficient conditions are applied (either initial or boundary conditions) they can usually be reduced to a single solution.
The field equations are non-linear. There are simple techniques for solving linear differential equations, usually taught in college level mathematics courses. There are no techniques that reliably produce solutions to an arbitrary non-linear differential equation. Most attempts to solve non-linear equations involve the following procedure: make a guess and see if it works. If it doesn't, make additional guesses until it works, or you give up.
3. To calculate this, first calculate the gravitational time dilation at the Earth's surface relative to frame of reference far from any gravitational fields (see the Hyperphysics article referenced in the bibliography below). Then calculate it again at the specific height. Dividing these two numbers gives the time dilation from the surface relative to the specified height. I then multiplied by 24 hours to get the values given in the text. Note, these operations are likely to cause a significance fault since the two time dilations are very close to the same value. In this case a significance fault results in the value 1, whereas it should be a value that isn't 1, but is very close to 1. To avoid the significance fault, I used variable precision arithmetic. The Hyperphysics article used a binomial series to avoid the fault. I found using variable precision easier.
4. See Bothwell 2021 and Conover 2021.
5. Technically Newton's equations only apply if all relevant objects are point masses. Early on, Newton realized that a spherically symmetric mass would have the same gravitational effect as a point mass. And all of the large objects in the solar system can be approximated as spheres.
6. Calculating gravitational force when objects are oblate spheroids requires calculus, basically breaking the oblate spheroid into "chunks" and adding (or integrating over) the forces created by each chunk.
7. This is an average over 100's of orbits of Mercury. In some orbits the precession is larger, in other orbits, the precession is smaller. Assume we need to calculate the effect of Venus on Mercury's orbit (the technique for other planets is similar). Over 100's of orbits, Venus will be in various positions relative to Mercury. So, the position of Venus can be considered random, and you can pretend that Venus's mass is evenly spread out over its orbit. Given that, calculus allows the precession to be calculated.
8. While this applies to Mercury, it doesn't necessarily apply to other objects.

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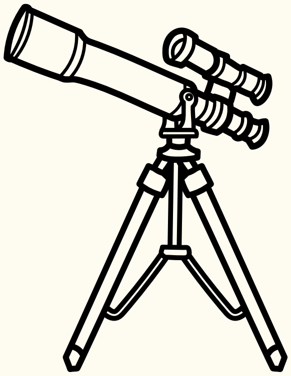
MEDIA CREDITS

1. Diagram of a body's direct orbit around the Sun with its nearest (perihelion) and farthest (aphelion) points. Shows the definition of Perihelion and Aphelion with the sun. The ellipse is exaggerated for effect, but the focus is in the correct position for the eccentricity. By Chris55 - Own work, CC BY-SA 4.0, Created 26 September 2015. https://commons.wikimedia.org/w/index.php?curid=43688106 This file is licensed under the Creative Commons Attribution-Share Alike 4.0 Unported license (https://creativecommons.org/licenses/by-sa/4.0/deed.en).
2. Precession of the Perihelion. By Benutzer:Rainer Zenz - Own work, Public Domain. https://commons.wikimedia.org/w/index.php?curid=23994538

UPCOMING TOPICS FOR THE OBJECTIVE LENS

BY JACK SPRAGUE



All images are welcome and while we have a monthly theme, we love any submission.

Images submitted will be included in ‘The Objective Lens” and in the annual Backfocus compilation without any rights transfer beyond your permission to allow The University Lowbrow Astronomers use of your image for inclusion in these two documents.

March - Mobile Observations: Observations and observers observing outside of the home environment. Make sure and take snaps from Joshua Tree, the west side of Florida, Costa, the Namibian Safari, and your sojourn to Kuai. [Peach Mountain counts ... barely].

April – Moons: Ours, Jupiter’s, Saturn’s.... We spend so much time in AP work dodging this great glowing orb and planning ways to defeat its influence. Let’s do some lunar captures! (Apollo landing sites especially desired!).

May – Observing partners. Mine have tails. Yours may have s’mores-smeared faces. Observing, whether visual or in image capture, brings late nights and solitude. Breaking that solitude are our partners. Let’s see them! I’ve included mine for whom the Beagle Meadows Observatory is named. ■

University Lowbrow Astronomers Monthly Meeting Minutes January 20, 2023

President Charlie Nielsen called the meeting to order and introduced our guest speaker, the Vatican Astronomer Brother Guy Consolmagno. His talk, “What’s Surfacing on Bennu,” presented what has so far been learned from the OSIRIS-REx mission, which is due to return to Earth with material from the asteroid this coming September, was well received and generated numerous questions from the membership.

Business Meeting

President Charlie Nielsen:

Appealed for members to recruit speakers. Vice President Adrian Bradley volunteered to make the March featured presentation.

Talks are progressing to move the site of our monthly meeting to the new classroom building adjacent to the Detroit Observatory. Not quite a done deal, but very close.

Proposed a $200 donation to the Vatican Observatory Foundation. Passed by the membership unanimously.

Vice President Dave Snyder:

Met with the COO of the Hands-On-Museum/Leslie Science Center Sue Westhoff about Lowbrow participation in public outreach events at the Museum and Leslie Science Center. This led to a discussion of reviving Lowbrow “Sidewalk Observing” events in downtown Ann Arbor, possibly in late May or June.

On-Line Coordinator Jeff Kopmanis:

49 people attended the meeting—21 in person and 28 via Zoom.

Emerson School has approached the club about conducting an on campus observing session for students and their families, possibly April 25.

The work on the new Lowbrow website using the Wordpress application is proceeding and something preliminary should be ready to view in March or April.

Vice President Jim Forrester:

The 2023 schedule of Peach Mountain Open Houses, beginning in April and ending in November was adopted by the membership. The March dates were set aside for a club Messier Marathon at Lake Hudson State Recreation Area March 18 (back up 3/25)

Requests for member observing nights on Peach Mt. requires adequate notice, especially in

winter, to the key holders. It was noted weather forecast accuracy improves greatly beginning 72 hours prior to any particular date and that requests should be placed at least the day before. The membership was reminded Peach Mt. was open to the members 20 nights, May September, in 2022.
A suggestion from the floor to set up a "What's App" chat group to announce member nights on Peach Mt. was referred to the On-Line Coordinator for investigation and implementation.

The Amateur Telescope Making sub-Group maintaining the 17.5-inch telescope requested authorization to spend up to $550 improving the dew removal capabilities of the scope. This expenditure was approved by the membership. Member and Director of the Sherzer Observatory on the EMU campus, Norbert Vance generously offered surplus dew removal hardware to the club. This offer will be evaluated before any expenditure.

Director Vance also announced the Sherzer Observatory would be open the evenings of January 30 and February 6 in hopes of catching views of c/2022 E3 (ZTF), possibly the year's brightest comet.

Treasurer Doug Scobel:

- We have 197 memberships and $13,952.43 in the treasury.
- All our RASC 2023 calendars and handbooks have been purchased and distributed. Big thanks to Jim Forrester for handing the distribution!
- Besides our usual monthly costs for the Open House "hotline" and printed newsletter printing and mailing costs, our only recent expenditure was $128.21 to replace the on board batteries in the club's 17.5" Dobsonian TeleKit.

Observatory Director Jack Brisbin:

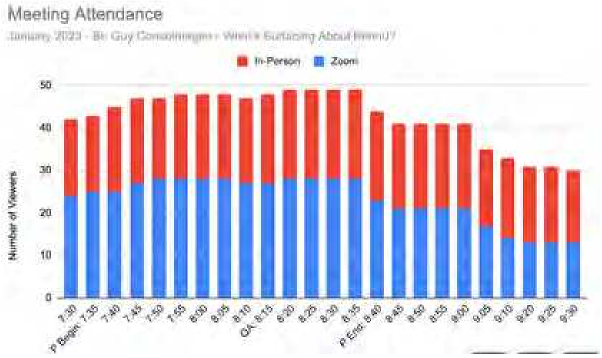
As of his most recent trip to Peach Mt., the Observatory is in good shape. In March or early April we will be moving the 17.5-inch telescope from Dave Jorgensen's wood shop in Chelsea to the Observatory for the 2023 observing season.

Vice President Adrian Bradley:

Responding to requests several new members will be trained on the operation of the McMath telescope.

Adrian also plans to recruit speakers through his contacts in Explore Scientific's World Star Party including Scott Roberts, David Eicher, and David Levy, as well as contributors from Argentina and Brazil.

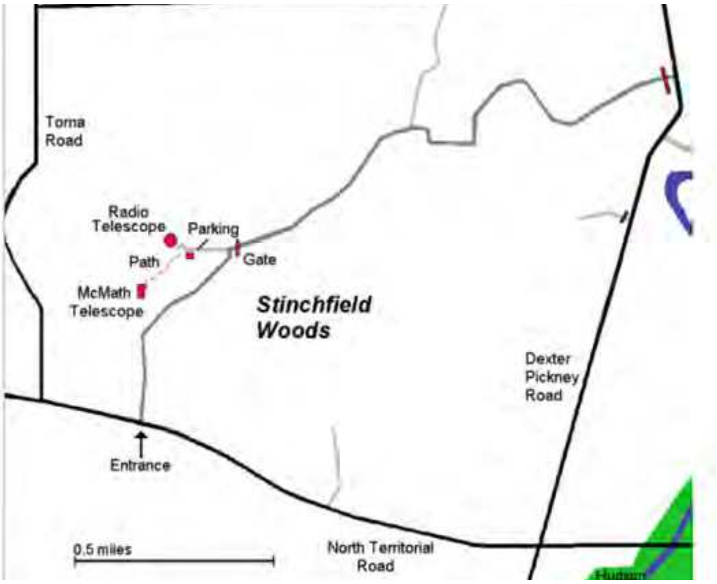
Member John Wallbank, one of several Lowbrows on the board of the Great Lakes Association of Astronomy Clubs announced new GLAAC officers had been elected and that the 2023 Astronomy At The Beach would be at Kent Lake Beach in the Island Lake State Recreation Area September 22 and 23.



PLACES & TIMES

Monthly meetings of the University Lowbrow Astronomers are held the third Friday of each month at 7:30 p.m. The location is usually Angell Hall, ground floor, Room G115. Angell Hall is located on State Street on the University of Michigan Central Campus between North University and South University Streets. The building entrance nearest Room G115 is the east-facing door at the south end of Angell Hall.

Peach Mountain Observatory is the home of the University of Michigan's 25-meter radio telescope and McMath 24" telescope, which is maintained and operated by the Lowbrows. The entrance is addressed at 10280 North Territorial Road, Dexter MI, which is 1.1 miles west of Dexter-Pinckney Rd. A maize and blue sign marks the gate. Follow the gravel road to the top of the hill to a parking area south of the radiotelescope, then walk about 100 yards along the path west of the fence to reach the McMath Observatory.



PUBLIC OPEN HOUSE / STAR PARTIES

Public Open Houses / Star Parties are generally held on the Saturdays before and after the New Moon at the Peach Mt. Observatory but are usually canceled if the forecast is for clouds or temperatures below 10 degrees F. For the most up-to-date info on the Open House / Star Party status call: (734) 975-3248 after 4 pm. Many members bring their telescope to share with the public and visitors are welcome to do the same. Mosquitoes can be numerous, so be prepared with bug repellent. Evenings can be cold so dress accordingly.

MEMBERSHIP

Annual dues are $30 for individuals and families, or $20 for full time tudents and seniors age 55+. If you live outside of Michigan's Lower Peninsula then dues are just $5.00. Membership lets you access our monthly newsletter online and use the 24" McMath telescope (after some training). Dues can be paid by PayPal or by mailing a check. For details about joining the Lowbrows, contact the club treasurer at: lowbrowdoug@gmail.com

Lowbrow members can obtain a discount on these magazine subscriptions:

Sky & Telescope - $43.95/year

Astronomy - $34.00/year, $60.00/2 years or $83.00/3 years

Newsletter Contributions:
Members and non-members are encouraged to write about any astronomy-related topic. Contact the Newsletter Editor: Amy Cantu cantu.amy@gmail.com to discuss format. Announcements, article, and images are due by the 1st day of the month as publication is the 7th.

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Observatory Director:	Jack Brisbin
Newsletter Editor:	Amy Cantu
Key-holders:	Jim Forrester
	Jack Brisbin
	Charlie Nielsen
Webmaster:	Krishna Rao
Online Coordinator	Jeff Kopmanis

A NOTE ON KEYS: The Club currently has three keys to the Observatory and the North Territorial Road gate to Peach Mountain. University policy limits possession of keys to those whom they are issued. If you desire access to the property at an unscheduled time, contact one of the key-holders. Lowbrow policy is to provide as much member access as possible.

Lowbrow's Home Page
http://www.umich.edu/~lowbrows/

Email to all members
Lowbrow-members@umich.edu

University Lowbrow Astronomers

University Lowbrow Astronomers
Ann Arbor, Michigan

www.youngastronomer.org

Astronomical League

Astronomical League 50th Anniversary est. 1967 Observing Programs

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