Desert Skies Journal

Tucson Amateur Astronomy Association

Observing our Desert Skies since 1954

Winter 2017 Volume LXIII, Issue 1

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The Hand of God—Cometary Globule CG4 in Puppis

Cometary Globules are areas of star birth. Their characteristic cometary shape are the result of the intense stellar winds from young energetic nearby stars. This image, taken by TAAA member Russell Carpenter, is CG4, also known as the "Hand of God" Nebula. The object about to be grabbed by the hand is the edge-on galaxy PGC 21338. These objects are located in the constellation Puppis.

Russell used iTelescope.com to take this image. The instrument was a 27-inch Planewave telescope located in Siding Springs, Australia. Used by permission. © 2017 Russell Carpenter

Our mission is to provide opportunities for members and the public to share the joy and excitement of astronomy through observing, education and fun. We fulfill this by providing Astronomy Services to schools, church groups, scout troops, and convention organizers. We support many organizations in the Tucson area that are involved in Science, Technology, Engineering and Mathematics (STEM) programs. Our members enjoy observing the night sky under the dark skies that our observing sites offer. We are an all-volunteer, tax-exempt, non-profit, 501(c)(3) organization.

Frequency

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From Our President

Happy New Year to all TAAA Members! I hope that the New Year finds you all well and ready for 2017. We have a lot to look forward to. However, I would like to take a moment to recognize the contributions of our TAAA Board of Directors, Leaders, and Volunteers. We are very lucky to have such a dedicated and skilled set of folks to serve the club in many different ways. I salute each and every one of you and encourage all members to look for opportunities to help.

One of the biggest events for TAAA in 2017 will be the completion of the Reynolds-Mitchell Observatory at Chiricahua Astronomy Complex (CAC). The club was fortunate enough to secure some very substantial donations of equipment and funds which have put us on track to open a fine observatory featuring a forty inch Dobsonian telescope with some impressive capabilities, including Go-To, tracking, and the ability to be operated from a warm control room. Construction is on schedule and we look forward to completion in the first quarter of 2017. Current plans are to hold a ceremony to mark the event after initial shaking out and allowing the weather to warm up. Stay tuned!

In addition to the Reynolds-Mitchell Observatory, TAAA is moving forwards on an ambitious fund raising campaign for CAC. We have engaged the services of a consultant and plans are being finalized for the campaign that envisions raising very substantial funds towards completion of the CAC Master plan, including the Large Roll Off Roof Observatory, Multi-Purpose Building, and the Caretaker Cottage. Upon successful completion, CAC should rank among the finest club sites in the country.

Lastly, the newly constituted Nominations and Volunteer Resource Committee will be working to present a slate of candidates for the TAAA Board of Directors at the April General Meeting, to be elected at the May General Meeting. Please give the members of this committee your full attention and cooperation as they begin work. This is your very important opportunity to influence TAAA's direction. If you wish to run for a BOD position, be sure and let the committee members know.

I am looking forward to an exciting 2017 and encourage you all to get involved with TAAA.

Ben Bailey

Members' News

Chiricahua Astronomy Complex Update - Winter 2017

Text and Photos by John Kalas, CAC Site Director (mal3[at]tucsonastronomy.org)

Member Pads Area

In June, the ten concrete telescope pads were installed. Instead of installing individual parking spaces for each pad, the idea of graveling the entire area was considered. This alteration would yield flexibility in where vehicles could be parked around the pads and provide dust control for the entire area. A quotation was solicited and received. Before the graveling could be performed, some surface rocks needed to be removed from several areas. This task was completed on 11/30. The application of the gravel and the repair of the loop drive will be scheduled before Christmas. Several members have started using their pads.

Reynolds-Mitchell Observatory (RMO)

The approved building permit was received in early October. Randy Maddox was selected as the contractor. Construction began on 10/3 with the clearing of the site. The warm room footer was trenched / poured and the concrete block stem wall was erected by the end of October. The stem wall was backfilled / compacted and the concrete floor slab was poured in November. Recently, the telescope observing deck construction was started with the digging of half of the holes for the concrete deck piers. Completion of the RMO is scheduled for the end of January with delivery / installation of the telescope scheduled for mid-February.

Community Involvement & Outreach

TAA's Impact on Astronomy Awareness in Tucson—2016

Text and Photo by Jim Knoll, Volunteer Coordinator (school-star-party[at]tucsonastronomy.org)

Another successful outreach program was accomplished in 2016. Members shared the enjoyment of astronomy with others in our community at schools, churches, and community events. We are off to a great start in 2017 with thirteen scheduled events in January. We couldn't be successful without the extraordinary help of our members.

TAAA Community Outreach Summary –Audience (Jan-Dec 2016)

Month	Events	Audience		Estimated Attendance
		Schools	Other	
Jan	13	7	6	1,795
Feb	14	11	3	3,375
Mar	12	5	7	2,520
Apr	11	5	6	1,206
May	5	1	4	390
Jun	2	1	1	210
Jul	5	2	3	830
Aug	3	2	1	540
Sep	7	1	6	990
Oct	11	3	8	850
Nov	10	6	4	805
Dec	3	1	2	175
Totals	96	45	51	13,686

Jim Knoll in silhouette. Note the "Snoopy" astronaut mounted at the top of the tube.

TAAA Community Outreach Summary –Volunteers (Jan-Dec 2016)

Month	Outreach Hours	Astronomers		Telescopes	Astronomy Guides	NSN Toolkits
		Number	Hours			
Jan	37.5	52	155.5	50	2	2
Feb	41.0	59	200.0	59	0	0
Mar	40.5	50	180.5	39	11	9
Apr	32.0	47	130.0	42	4	2
May	14.5	34	109.0	34	6	3
Jun	5.0	6	15.0	6	0	0
Jul	14.0	14	41.0	14	0	0
Aug	8.5	14	40.0	14	0	0
Sep	18.5	29	84.0	14	0	0
Oct	30.0	35	107.0	35	1	1
Nov	23.5	31	80.5	31	0	0
Dec	7.0	10	23.0	10	0	0
Totals	272	381	1,166	348	24	17

Quarterly Community Outreach Reports

See Summer 2016 Desert Skies for January to June 2016 reports.

July - September

TAAA supported two large events (July & August) at the AZ Sonora Desert Museum with 10 telescopes at several locations throughout the museum. We estimated 250 participants at each location for each event (the Museum estimated 1,000 overall for each event). Total potential contacts for just these two events was 1,000 participants. The August event was cut short some due to Monsoon weather. In September, we supported two of our large recurring TAAA Public events, Oracle State Park and Catalina State Park.

October - December

We had a good mix of school and public/non-profit star parties. We supported two Boy Scout events and several Pima County Natural Resources Parks & Recreation (NRPR) public events. Several of our volunteers supported the Rattlesnake Ridge Elementary school Astronomy Club with monthly star parties and training. We only cancelled two events due to weather, but did have several events that were degraded because of clouds.

Observing and Imaging

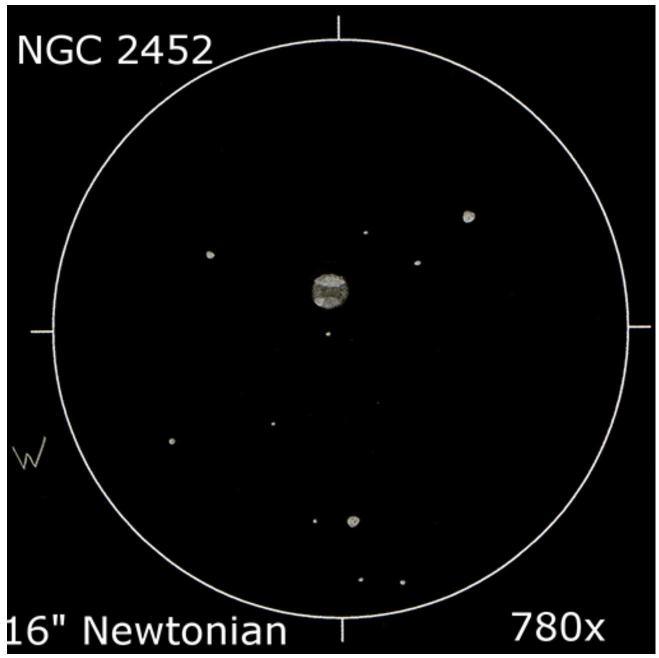
Planetary Nebulae of the Quarter – Winter 2017

Text and Drawings by Christian Weis (weis[at]astroweis.de)

Planetary nebulae (PN) are fascinating objects which come in numerous forms or appearances. Besides the well-known grand four Messiers (M27, M57, M76 and M97), there are hundreds more to explore. This article suggests two PNs, a pretty bright and easy-to-observe one, and a harder one for the more ambitious observer who is equipped with a bigger scope.

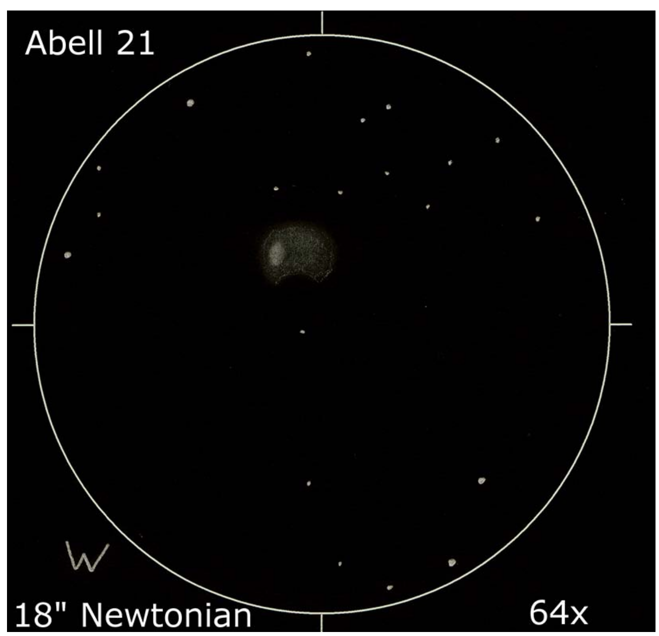
Despite its catalog brightness which ranges from 11m9 to 12m6, NGC 2452 in Puppis is quite an easy object to observe. It was discovered by William Herschel's son John in 1837. It is rather small, so you want to make sure to magnify as much as possible in order to see any structures in this PN. This also means you will need dark skies and very good seeing conditions. If both is true for your observing location, you will be amazed by NGC 2452's beauty. Even though NGC 2452 is gorgeous on its own, there is more to see. The open cluster NGC 2453 is in close proximity to the PN and you should be able to see both in one field of view when power is below some 200x. I observed this object in November 2010 with a 16" Dobsonian from a remote spot up at Mt. Lemmon at an altitude of some 7'000 feet and noted: no central star, small, bipolar, SE and NW brighter with slight differences in brightness, UHC helps, [OIII] does not, needs higher magnifications, until 200x an open cluster is situated in the same field of view; 780x, fst 6m4 (Gem)

NGC 2452
RA: 7h 47.4min
Dec: -27° 12´
Constellation: Puppis
Brightness: 11m9
Central star: 17m5
Size: 0.5 arcmin
Distance: 8800 ly



PK 205+14.1 – better known as Abell 21 – is a huge PN in Gemini. Interestingly, the apparent brightness is a magnitude brighter than NGC 2452. But due to its extent the surface brightness is really low. This means, you will need extremely dark skies in order to have the chance of spotting Abell 21. Seeing might be a less important factor as you will need a maximum exit pupil at the eyepiece which is equivalent to rather small magnifications. Without a filter you will see nothing at all. Try different magnifications around the power that gives you an exit pupil of, say, some 6 to 7 mm and sweep a little. Averted vision and a black cloth over your head would also help. If everything comes together, you might even be prone to call Abell 21 an easy object for an Abell-PN. I observed this PN in September 2012 with an 18" Dobsonian from my home in southern Germany and noted: Quite easy, directly visible at 64x and using an [OIII]-filter, big, circular, well-defined, only visible with filter and [OIII] being more helpful than UHC, at 94x there is a clearly visible indentation in the northwest, not all faint stars are sketched; 64x, fst 7m0 (And)

PK 205+14.1 (=Abell 21)
RA: 7h 29.0min
Dec: 13°15´
Constellation: Gemini
Brightness: 11m3
Central star: 16m0
Size: 10 x 6 arcmin
Distance: no data



Observing and Imaging

Lunartic's Corner

Text by Rik Hill (rhill[at]lpl.arizona.edu)

Why the Moon?

At the recent TAAA Holiday Party, several people who had seen my FaceBook posts of lunar images and my articles here, asked "Why the moon?" That's a good question for which I have a well thought out answer. The U.S. government decided some years back, that we would not go back to the moon. That may change, but for now that's the operating paradigm. However, there are five other space programs in the world that have plans on going to the moon and have taken strides in that direction: Japan, China, Russia, ESA and India. All but the ESA have announced plans to put manned colonies on the Moon in the 2020s though the ESA has expressed a preference for manned lunar exploration over Martian exploration. When these countries get there they will begin to dig holes, big holes, as they mine materials for base construction. If we want to image these structures from Earth, we have to hone our skills now for doing kilometer resolutions or better. Currently there are about a dozen people around the world working on this goal.

So how big would your telescope have to be to image at this scale? You might be surprised. To figure that out we need to do a little simple trigonometry to determine the size of crater (C) for say, the average ubiquitous 8" telescope of good quality and alignment. The formula we need is:

$$C = (D)(\sin 0.000156)$$

where 0.000156 is the theoretical resolution of the 8" telescope (0.56") in degrees. D is the Moon's distance which goes from just under 357,000km (perigee) to just over 406,000km (apogee).

Plugging these numbers in we find that an 8" can resolve a 0.98km crater on the moon at perigee and at apogee 1.1 km in the best conditions. I have actually done this in the best seeing (along with 0.5" double stars). Thus an 8" telescope is theoretically and demonstrably the smallest aperture that will do kilometer imaging on the moon.

Next, you need each pixel of the chip in your camera to be at least half the size of a resolution element (Dawes Limit) of your telescope (or smaller) to be sure that when the seeing is good all the available resolution will actually be captured by the camera. This is called "plate scale" (PS) left over from the old photographic days of astronomy. Here again we go to some minimal math:

$$PS = \frac{206265}{Dia + f/ratio}$$

where "Dia" is the diameter of the aperture of your telescope.

For example, with my 8" f/20 Mak-Cass a resolution element (Dawes Limit) is 0.56" and with this formula the plate scale works out to be:

$$PS = \frac{206265}{200mm * 20} = 51.6"/mm$$

This would be 51.6" per mm or 0.0516" per micron (1 mm = 1000 microns). So I would need a camera that had 5 micron pixels or smaller to assure I could catch all the available resolution during the best moments of seeing. It just so happens that Celestron had the solution at the time I was looking for a camera, with the Skyris cameras that have a 3.74 micron pixel size. A number of other companies now use this pixel size in their cameras. If you cannot achieve this requirement at prime focus, you may need to use a barlow lens to increase the focal length and thus the f/ratio. With all the variety of these on the market today this should not be a serious problem.

Alignment of the optics must be exactly right, no room for misalignment! Procedures for obtaining that will not be detailed here but a bright star at zenith must show a symmetrical pattern of diffraction rings or you will not get the most from your optical system. Don't hesitate to spend a whole night on this task alone to get it right. There are hundreds of websites that can help you with this depending on your type and focal length of telescope.

So far seeing has blithely been ignored. All the above discussion assumed perfect skies. If you are not fortunate enough to fly to a remote island where the seeing is often 9/10 or better, you will have to make do with what you have. You have to be able to catch those fleeting moments during the best of the best seeing at your observatory. To do this you need a telescope and camera combination that is sensitive and fast enough to get better than 1/100 sec exposure regardless of the frames per second (f.p.s.) your camera will be using. With an 8" at f/20 (or a typical Schmidt-Cassegrain and a 2x barlow) this will likely mean increasing your gain to the max. But keep in mind that your maximum f.p.s. will be dictated by your exposure. For example, if your exposure is 1/100 sec. you cannot take more than 100 f.p.s. and should probably go a bit slower like 90 f.p.s. to allow for liberal transfer and overhead time.

This has all been borne out in the images. On any night of 8/10 seeing or better, 1-2km craters can be routinely captured in images like the one at right of the great craters Ptolemaeus (158 km diameter) on the left and

(Continued on page 8 - Lunartics Corner)

Observing and Imaging

Constellation of the Season

Text and artwork provided by Chris Lancaster

Monoceros - The Unicorn

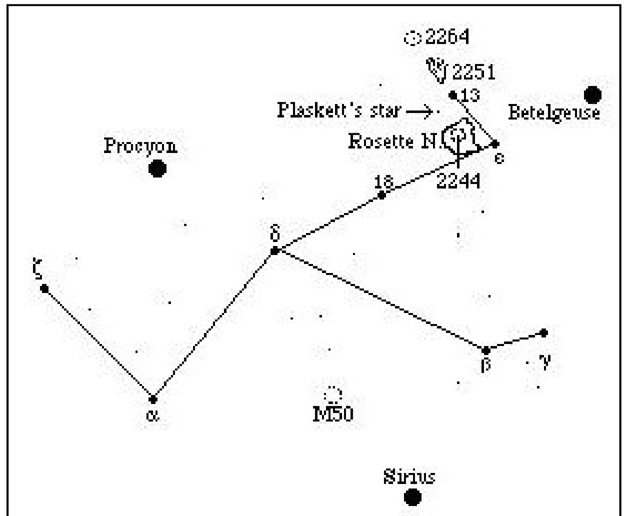
If you browse through the winter skies with the naked eye you will enjoy some of the best sights available of the heaven's brightest stars and most recognizable constellations. But then you will come to a rather lackluster region alongside Orion. At first glance this area may look uninteresting, but it compensates for its lack of bright stars with some excellent deep sky objects. The winter Milky Way cuts right through this area occupied by the constellation of Monoceros, so it is rich in nebulae and star clusters.

It was in the early 1600's that the German astronomer Jakob Bartsch established the constellation of Monoceros out of some dim stars stretching between Orion and his two hunting dogs, Canis Major and Canis Minor. The Latin name Monoceros is derived from the Greek word "monokeras," or "one horned," so this constellation represents the mythical creature called a unicorn, although it might require a fantastic imagination to see a unicorn in this pattern of stars.

One of the brightest stars of this constellation is Beta Monocerotis, among the finest multiple stars visible through small telescopes. When Sir William Herschel discovered this system in 1781, he described it as a "beautiful sight." Having a combined magnitude of 3.8, it is a triple system of stars which are uniquely very similar in both brightness and spectral type. Beta Mon A, magnitude 4.7, and Beta Mon B, magnitude 5.2, are separated by 7.4", while Beta Mon C is of magnitude 5.6 and between the two about 2.8" from the B component. All three are of spectral type B2 to B3 and appear as a trio of pure white stars forming a very flat triangle. Another notable binary star is Epsilon Monoceros. Its components are of magnitudes 4.3 (spectral type A5) and 6.7 (spectral type F4) and are separated by 13".

Another binary star worth mentioning is Plaskett's star. It is noteworthy because it is one of the most massive pairs known. Located at RA 06h 37.6' Dec +06d 11', or about 1.5 degrees to the southeast of 13 Monocerotis, this binary, which was first studied by J. S. Plaskett in 1922, is made up of two stars of spectral type O separated by only about 50 million miles. It is estimated that the two stars have masses of 40 and 60 suns and shine with an apparent magnitude of 6.06.

Among the deep sky objects that Monoceros presents to us is M50, a medium sized open cluster that is easily within the grasp of binoculars. Located approximately a third of the distance along a line connecting Sirius and Procyon and shining at magnitude 7.2, its coordinates are RA 7h 03' Dec -8d 21'. The main group in this cluster is roughly 10' in size. Long exposure photographs bring out about 200 stars within this cluster.



Monoceros

In the northern regions of the constellation are two more splendid star clusters and associated nebulosity. Starting with NGC2244, this is a bright cluster in the shape of a bent rectangle which lies in the center of a vast, doughnut shaped nebulosity known as the Rosette Nebula. The brightest sections of the nebula, which as a whole occupy an incredible 80' of the sky, actually are given separate NGC designations of 2237, 2238, 2239, and 2246. With dark skies, a 6" telescope will begin to show the soft glow of this dim nebula, and you may not be able to view the entire structure at once depending on your magnification. This complex of stars and nebulosity is centered at RA 6h 30.3' Dec +5d 03'.

Farther north is NGC2264. The nickname of this cluster is the "Christmas Tree" cluster because of the way it resembles the outline of Christmas tree. It is a large cluster of very young stars about the same size as the lunar diameter, so low power is required to fully see it. Studies suggest that some of the members of the cluster are still undergoing gravitational collapse on their way to main sequence status. The brightest star of the cluster, 4.6 magnitude S Monocerotis, forms the trunk of the tree and shines with the light of 8500 suns. Long exposure images show strong nebulosity near S Monocerotis, but the most recognizable feature is found just off the point of the tree, which points south, and is known as the Cone (or Conus) Nebula. This is a dark nebula about six light years in length, or spanning about 10 arc minutes in the sky, contrasted by brighter clouds surrounding it. You can find NGC2264 at RA 6h 41' Dec +9d 48'.

(Continued on page 8 - Constellation of the Month)

The Constellation of the Season, written by Chris Lancaster, is the basis of his book, "Under Dark Skies - A Guide to the Constellations, Trafford Publishing (http://bookstore.trafford.com/Products/SKU-000158114/Under-Dark-Skies.aspx). While the information was accurate at the time of the original writing, the reader should be aware that the sky does change over time. In particular, separation and position angles of double stars may have increased or decreased. This article is presented as originally written. Consult current observing resources for correct separations and position angles.

(Continued from page 6) *Lunartic's Corner*

Albategnius (139 km) on the right. The floors of these two are littered with 1-2 km craterlets. You can identify these tiny features using the LROC QuickMap at:

http://target.lroc.asu.edu/q3/

Lastly, you should give some further thought to archiving. My images are slowly being added to a database at:

http://www.lpl.arizona.edu/~rhill/moonobs.html

This page is designed after the Lunar Orbiter archive at Lunar and Planetary Institute in Houston. With this arrangement images can be quickly and easily located. With such an arrangement you will be prepared to explore the new landing sites as lunar exploration and colonization moves forward.

Craters Ptolemaeus (left) Abategnius with diameters of 158km and 139km, respectively.

(Continued from page 7- Constellation of the Month)

A much easier nebula to spot is Hubble's variable nebula, or NGC2261. This is located to the southwest of NGC2264 at RA 6h 39.2' Dec 8d 44'. It appears as a fan shaped nebula about 2 to 3 arc minutes in size and of fairly high surface brightness which Edwin Hubble found to vary in overall magnitude, size, and structure, sometimes over the short span of a few months. The nebula shrouds the variable star R Monocerotis, but the variability of this star does not seem to coincide with the behavior of the nebula.

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Featured Article

Skyward—December 2016

Text and Photos by David H. Levy, TAAA Past President

A canal, a telescope, and a star

This Skyward article is provided by David H Levy. The Skyward series is featured in the community publication, The Vail Voice. Other editions of Skyward can be found at http://jarnac.jarnac.org/

What does a canal have to do with the night sky? For me, plenty. I remember visiting the Lachine Canal many times as a child growing up in Montreal. I even have a dim memory of watching the water raise our boat once. But actually standing aboard the Norwegian Dream, a gigantic cruise ship to experience the Panama Canal, had to wait until the fall of 2016. As the water surged quietly into and out of the locks on the Pacific and Caribbean sides of the canal, the ship rose and lowered as gently and as quietly as a toy boat in a bathtub. Being part of it was an amazing experience.

Miraflores Canal, above, one of three locks that make up the Panama Canal. At right is Alouette, the telescope David Levy has used for 46 years.

Being in Panama, on both the Pacific and Caribbean sides, led me to recall another childhood memory. When I was in high school I would occasionally bring a tiny telescope I called Alouette. During recess or lunch I'd bring the telescope out of the school and get a reading on how many sunspots there were on the Sun. The telescope was so small it didn't capture many sunspots.

I no longer have the original Alouette, but in 1970 I bought a new finderscope. I have now used that telescope, also named Alouette, for 46 years. Made mostly of war surplus materials, the revised Alouette served as a finderscope, but recently it has evolved into a travel telescope. When I first got it, Acadia University physics professor Roy Bishop helped me get it installed and aligned, so I thought it proper that it be given a long-overdue first light ceremony. At his Nova Scotia home on the morning of November 7, we used Alouette to enjoy a traditional view of Jupiter, the object I like to use to begin the careers of most of my telescopes.

What does all this have to do with the Panama Canal? I brought Alouette down there and used it to observe stars not normally visible from my Arizona home. In particular, the "star" of the Panama Canal was Achernar. I've seen it from Arizona but only as it lay sleeping at the horizon, opening its eyes and winking at me briefly before setting again. But in Panama Achernar shone high and prominently in the southern sky.

Because of an effect of the Earth's wobble called precession, Archernar appears to be moving northward. In a few thousand years it will become more easily visible from most of the United States and even southern Canada.

Achernar is a big star, 6.7 times more massive and 3150 times more luminous than our Sun. Even though it is about 139 light years away, it shines as one of the brightest stars in the sky. It rotates about its axis so quickly that it isn't even spherical, but instead it is flattened into an oblate spheroid so dramatically that its equator is half again as fat as its poles. Moreover, Achernar is surrounded by a very large gaseous envelope that grows outward from the star, collapses inward and then regrows.

It is this final fact of Achernar's envelope that brings me back to the Panama Canal. As I looked through Alouette at Achernar, I could imagine that envelope quietly growing and shrinking, just as the waters in the locks we passed through a few hours earlier rise and fall, lifting and lowering the ships that pass through. The canal helps define two continents. Achernar, even as seen through Alouette, helps define a universe.

Featured Article

Comet Campaign: Amateurs Wanted

Text by Marcus Woo

This article is used by permission granted by NASA's Space Place. With articles, activities, crafts, games, and lesson plans, NASA Space Place encourages everyone to get excited about science and technology. Visit spaceplace.nasa.gov to explore space and Earth science!

In a cosmic coincidence, three comets will soon be approaching Earth—and astronomers want you to help study them. This global campaign, which will begin at the end of January when the first comet is bright enough, will enlist amateur astronomers to help researchers continuously monitor how the comets change over time and, ultimately, learn what these ancient ice chunks reveal about the origins of the solar system.

Over the last few years, spacecraft like NASA's Deep Impact/EPOXI or ESA's Rosetta (of which NASA played a part) discovered that comets are more dynamic than anyone realized. The missions found that dust and gas burst from a comet's nucleus every few days or weeks—fleeting phenomena that would have gone unnoticed if it weren't for the constant and nearby observations. But space missions are expensive, so for three upcoming cometary visits, researchers are instead recruiting the combined efforts of telescopes from around the world.

"This is a way that we hope can get the same sorts of observations: by harnessing the power of the masses from various amateurs," says Matthew Knight, an astronomer at the University of Maryland.

By observing the gas and dust in the coma (the comet's atmosphere of gas and dust), and tracking outbursts, amateurs will help professional researchers measure the properties of the comet's nucleus, such as its composition, rotation speed, and how well it holds together.

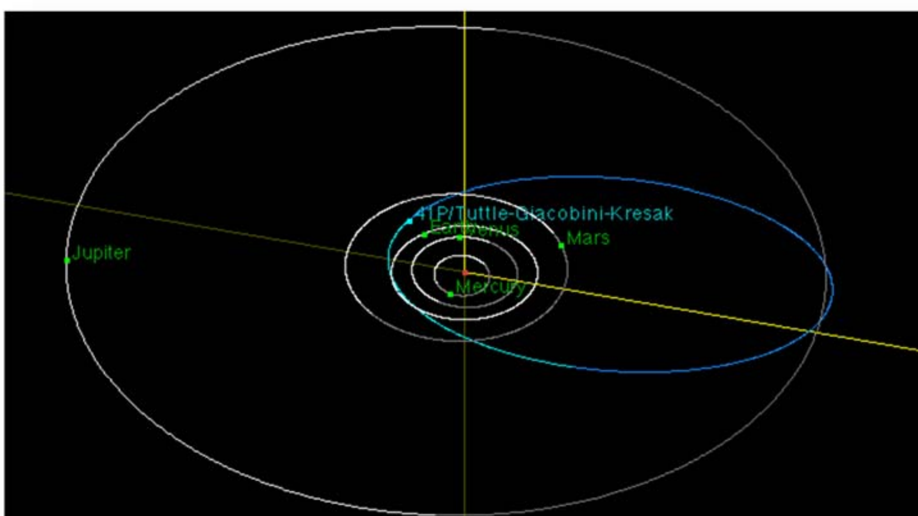
The observations may also help NASA scout out future destinations. The three targets are so-called Jupiter family comets, with relatively short periods just over five years—and orbits that are accessible to spacecraft. "The better understood a comet is," Knight says, "the better NASA can plan for a mission and figure out what the environment is going to be like, and what specifications the spacecraft will need to ensure that it will be successful."

The first comet to arrive is 41P/Tuttle-Giacobini-Kresak, whose prime window runs from the end of January to the end of July. Comet 45P/Honda-Mrkos-Pajdusakova will be most visible between mid-February and mid-March. The third target, comet 46P/Wirtanen won't arrive until 2018.

Still, the opportunity to observe three relatively bright comets within roughly 18 months is rare. "We're talking 20 or more years since we've had anything remotely resembling this," Knight says. "Telescope technology and our knowledge of comets are just totally different now than the last time any of these were good for observing."

For more information about how to participate in the campaign, visit http://www.psi.edu/41P45P46P.

Want to teach kids about the anatomy of a comet? Go to the NASA Space Place and use Comet on a Stick activity! http://spaceplace.nasa.gov/comet-stick/



An orbit diagram of comet 41P/Tuttle-Giacobini-Kresak on February 8, 2017—a day that falls during the comet's prime visibility window. This image was created with the Orbit Viewer applet, provided by the Osamu Ajiki (AstroArts) and modified by Ron Baalke (Solar System Dynamics group, JPL).

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Membership Assistant	Forrest Holly	-	
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