http://www.raclub.org/

The StarGazer

Newsletter of the Rappahannock Astronomy Club No. 1, Vol. 5 May 2016–July 2016

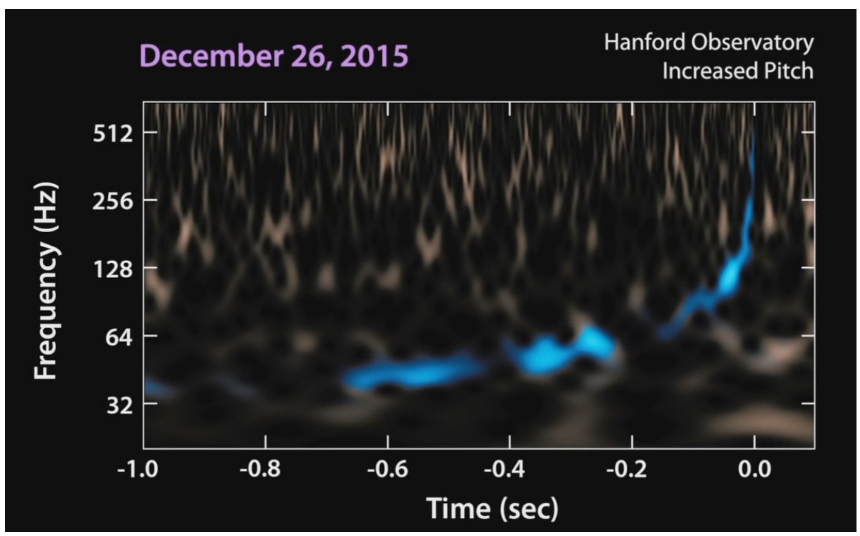
A Novel Mode of Astronomical Observing Detects Gravitational Waves

By Bart Billard

Following press releases about the confirmed detection of gravitational wave signals by the Laser Interferometer Gravitational Observatory (LIGO) Scientific Collaboration, I was looking for more to read about a favorite astronomy story line of mine: the surprising things we learn when someone finds a new way of looking at the sky. For 7 years, I've been following the Kepler story, in which the "new way" still involves collecting light from stars with a telescope. Kepler simply improved and expanded existing forms of observation. LIGO, on the other hand, has now directly detected the waves produced by two distant binary black hole systems in the process of spiraling together and merging with each other. A third signal recorded during the 4-month operation of this phase of Advanced LIGO is suggestive of a binary black hole merger but is not strong enough to confirm with sufficient confidence. It has an estimated 1-in-8 chance (not good odds) of being produced by "noise" sources such as seismic activity and local environmental vibrations getting past the isolation systems to affect the interferometers.

Gravity Waves and Their Detection

One problem Einstein recognized with Newton's theory of gravity was its implication of instantaneous effects, which violated the speed-of-light limit established by his special theory of relativity. When he worked out his general theory of relativity, he found it indeed implied moving masses could create disturbances that traveled as waves, obeying the speed limit. These gravitational waves manifest as alternating distortions of space. If you face a wave traveling toward you, space stretches in one direction, say, left to right, while contracting in the other (up and down). Then, half a cycle later, the direction that stretched contracts while the other direction stretches. This effect, called strain, is measured as the fractional increase in length: if space stretches by a millimeter for every million kilometers, the strain would be a trillionth (10^{-12}).



Hanford LIGO detector frequency content versus time during the arrival of GW151226, with the signal highlighted. A video animation with sound effects appeared as the Astronomy Picture of the Day on June 15, 2016, credited to the LIGO Scientific Collaboration and the National Science Foundation. You can download the sound effects for either gravitational wave detection from LIGO Scientific Collaboration webpage.

The first binary pulsar, discovered in 1974 by Joseph Taylor Jr. and Russell Hulse, provided indirect evidence of these gravitational waves. The two neutron stars orbiting each other were found to lose energy in accordance with the general relativity prediction of the energy they would radiate as gravitational waves. (*continued page 4)*

How to Join RAClub

RAClub is a non-profit organization located in the Fredericksburg, Virginia, area. The club is dedicated to the advancement of public interest in, and knowledge of, the science of astronomy. Members share a common interest in astronomy and related fields as well as a love of observing the night sky.

Membership is open to anyone interested in astronomy, regardless of his/her level of knowledge. Owning a telescope is not a requirement. All you need is a desire to expand your knowledge of astronomy. RAClub members are primarily from the Fredericksburg area, including, but not limited to, the City of Fredericksburg and the counties of Stafford, Spotsylvania, King George, and Orange.

RAClub annual membership is $20 per family. Student membership is $7.50. Click here for a printable PDF application form.

The RAClub offers you a great opportunity to learn more about the stars, get advice on equipment purchases, and participate in community events. We meet once a month and hold regular star parties each month on the Saturday close to the dark of the Moon. Our website, www.raclub.org is the best source of information on our events.

We also have an active Yahoo group that you can join to communicate with the group as a whole. Just click the link, then the blue Join this Group! button, and follow the instructions to sign up.

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Website: www.raclub.org
Yahoo Group:
http://tech.groups.yahoo.com/group/rac_group/

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Jerry Hubbell, Astrophotography
Myron Wasiuta Mark Slade Remote Observatory (MSRO)

Calendar of Upcoming Events		Recent Outreach Events Completed	
RAC Picnic, Belmont	6 August	Star Party, Caledon State Park	May 7
Star Party, Pratt Park, Stafford County	September 10	Star Party, Park Ridge Elem. School	May 13
Star Party, Caledon State Park	September 24	Star Party, Caledon State Park	June 11
Star Party Stratford Hall, Westmoreland Cty	October 6	Star Party, Caledon State Park	July 9
Star Party, Caledon State Park	October 22	Embrey Mill, Stafford County	July 15

*For RAC members and their families only

President's Corner

Welcome to New RAClub Members (May–July)

- M.L. Buchanan, III
- Augustus Cotera
- Mark Burns

This is my first entry for the newsletter as the president. I was honored to take Ron's place in June so he could travel westward to his new home in Arizona. It's been a challenge so far keeping up with all the events and correspondence but I look forward to supporting the club through the end of the year.

It has been a hot and busy summer so far, and we have held several events since the last newsletter in April. David Abbou and Ron Henke conducted a successful event at Park Ridge Elementary School back in May. David, Mark Burns, and I hosted an event at Embry Mill Subdivision in Stafford in July. The clouds thickened but then cleared late, allowing us to show the Moon, Saturn, and Jupiter to more than 100 visitors. In addition, the Caledon Star Parties have been a great success, with a number of new visitors in the past 2 months.

Following in Ron's footsteps, I believe the public outreach events are the most beneficial and enjoyable club activities. It's always amazing to hear how many people have never looked through a telescope; I'm so glad we can provide that experience because it literally provides a whole new dimension for those who've only seen photos in a book or online. Not only do the kids get excited about seeing the planets or the Moon, the adults do too. I admit that after viewing on a particularly clear night—that feeling never goes away.

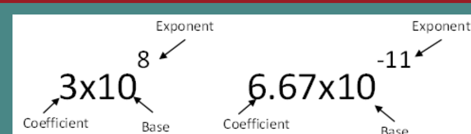
We have a number of events still to come for the year, including several Caledon Star Parties. A couple of the others are a Star Party at Stratford Hall in October and another at Ferry Farm in November. Take a look at the website for additional info and updates.

Please keep reading…there are a number of great articles this month. Thanks to the contributors and Linda Billard for another great newsletter.

See you under the stars, Scott Lansdale

Astronomy Math by Scott Busby

Coefficient, Base, and Exponent



In scientific notation, the very large number 300,000,000 (the number of meters light travel in 1 sec) is written as 3×10^8, and the very small number 0.0000000000667 (the Universal Gravitational Constant in standard units) is written as 6.67×10^{-11}. As shown in the example, each of these expressions consists of three numbers called the *coefficient*, the *base*, and the *exponent*.

The standard base for scientific notation is 10. Exponents are usually integers and can be positive or negative. The coefficient can be any number at all. If you see a number in scientific notation with the coefficient missing, such as 10^6, it is important to remember that a coefficient of 1.0 is implicit. That is, $10^6 = 1 \times 10^6$.

Many astronomy texts use "normalized" scientific notation in which the decimal point in the coefficient always appears immediately to the right of the leftmost non-zero digit. So although 3.5×10^4 and 35×10^3 represent exactly the same number, the former version would be used. In normalized scientific notation, the coefficient is always between 1 and 10, and the exponent is called the "order of magnitude" of the number.

One thing to remember regarding numbers written in scientific notation is that a negative sign in front of the coefficient (such as -6×10^3) means that the number is negative, but a negative sign in the exponent (such as 6×10^{-3}) has no effect on whether the number is positive or negative. So what does a negative exponent mean? Simply this: the more negative the exponent, the closer the value of the number is to zero. So 6×10^{-3} is a small number, and 6.3×10^{-11} is a very, very small number. In astronomy, you are unlikely to encounter many negative coefficients, but you are very likely to see negative exponents. For example, the values of some of the physical constants, wavelengths of light, and masses of atoms are all very small and are often written using scientific notation with negative exponents.

(continued from page 1)…A Novel Mode of Astronomical Observing Detects Gravitational Waves

The pulsar's regular radio signals allow accurate measurement of the stars' orbit via Doppler shifts, and as the stars lose energy by radiating gravitational waves, they spiral closer, decreasing their orbital period.

To directly detect gravitational waves, Advanced LIGO uses laser light in the world's largest, most advanced, Michelson interferometer. A beam of light enters the interferometer through a diagonal mirror made to reflect half the light out at right angles into one 4-km leg, while letting the other half pass straight through into the other 4-km leg. In a simplified version, the light is reflected back from the ends of the legs. By tuning the distance to the ends of the two legs, one can make the light go back out the way it came in or go out at a right angle, in the direction opposite from the first leg. A change of only one quarter of a wavelength of the laser light in the relative lengths of the legs is sufficient to completely switch the way the light comes out. If the interferometer is tuned so most of the light is going back the way it came in, the small amount going the other way can be measured. A small fraction of a quarter wavelength change would noticeably increase or decrease the small amount of light remaining. The basic principle is that a gravitational wave disturbance can change the balance of an interferometer tuned that way by compressing space along one leg and stretching it along the other. A photodetector can measure the strain by monitoring the increase and decrease in the light intensity from the alternating strain as the wave passes.

This simplified example glosses over a lot of the technology needed to make Advanced LIGO much more sensitive. More information is available in an article by Sung Chang in *Physics Today*. A few examples are a four-stage suspension system for the mirrors in the interferometer, operation of the interferometer in a vacuum chamber (a big one with 4-km tubes for each leg), and recycling of light in each leg to make their effective length more than 1,000 km. In addition, there are two interferometers, located in Hanford, Washington, and Livingston Parish, Louisiana, far enough apart that simultaneous signals are extremely unlikely to arise from nearby environmental vibrations (e.g., traffic and ocean waves). The added complexity of these and more enhancements is needed because the observed strain of the first signal was 10^{-21} (the length change in the interferometer arms was 1/1,000 the radius of an atomic nucleus). Very tiny.

The original LIGO detectors were built in the 1990s and operated at their designed sensitivity from November 2005 to September 2007. After an upgrade to Enhanced LIGO, it operated from July 2009 to October 2010. Advanced LIGO operated in a low-power mode from September 12, 2015, to January 19, 2016. When fully commissioned and operating at full power by 2019, it will have the ability to detect signals from 1,000 times the volume of space compared with the original LIGO. A third interferometer was originally planned as a second detector at Hanford but is now consigned for installation later at a site to be determined, in India.

Significance of the Advanced LIGO Results

The two confirmed detections of gravitational waves are designated GW150914 and GW151226 for the dates they arrived (September 14, 2015, and December 26, 2015). GW150914 produced a waveform steadily increasing in amplitude and in frequency from 35 Hz to 250 Hz. Then, reaching its peak amplitude as it reached 250 Hz, it decayed in amplitude at that frequency. It reached the Livingston detector 7 milliseconds before it reached Hanford and lasted 0.2 seconds in both cases. The GW151226 signal was similar (see figure), but lasted about a second.

These signals matched the waveforms generated by computer simulations of various binary black hole mergers using the equations of general relativity. GW150914 best matches for black holes of 29.1 and 36.2 solar mass in the final stages of "inspiral" (as the pair of black holes orbit closer and closer because of the loss of energy radiated away by the gravitational waves—the increasing amplitude and frequency phase), merger, and "ring down" (the decaying amplitude at constant frequency). The strength of the signal corresponds to a distance of 1.3 billion light years. The computer simulation match for GW151226 corresponds to the merger of a 1.4-billion light year distant pair of black holes with 7.5 and 14.2 solar mass. According to the numerical simulations, the merger process radiated the equivalent of 3 and 1 solar mass of energy as gravitational waves, leaving the final merged black holes that much less massive than the original binaries.

Physics Today quotes David Leitze, the executive director of the LIGO Laboratory who announced the first confirmed detection (GW150914) to reporters February 11, saying that observing a binary black hole merger "may be as important as the fact that we were finally able to detect gravitational waves." Two confirmed and one likely merger in 4 months of observation time is a promising indication of the number of observations to come, especially because the volume of the universe observed will increase some 30-fold when LIGO reaches full power. This benchmark is expected to be achieved by 2018. The Advanced Virgo Interferometer in Italy, expected to begin taking data this year, will soon add a third detector with 3-km legs. Another interferometer is under construction in Japan, and Germany has a smaller interferometer that serves as a testbed for new ideas. A memorandum of understanding is now in place for establishing the third LIGO detector in India. A network of interferometers increases the opportunity of comparing arrival times at three or more detectors. This greatly narrows the amount of sky to be searched for light or other signals associated with the source of a gravitational wave signal when one is detected.

What is striking to me is the amount of information obtained by finding the best match between the detected signal and numerical computations. For binary mergers, matching the detected signal constrains the masses of the two objects and their total mass as well as their distance. When the smaller mass is constrained to be significantly larger than the limit on neutron star masses, it implies the two objects are both black holes. There are indications that if one or both components are neutron stars, details of the signal could pick up tidal distortions of the neutron star(s). Stiffness properties of the nuclear material could show up in measurements of the perturbations of the orbital period caused by these distortions. The large masses of the GW150914 black hole pair represent another first for gravitational wave astronomy.

It is interesting to note that when operating, a network of these interferometers observes all of the sky at once, day or night and above or below the horizon. Gravitational waves travel right through the Earth. LIGO scientists anticipate observing one event per month and hope to reach one a day eventually.

First Impressions of Tucson

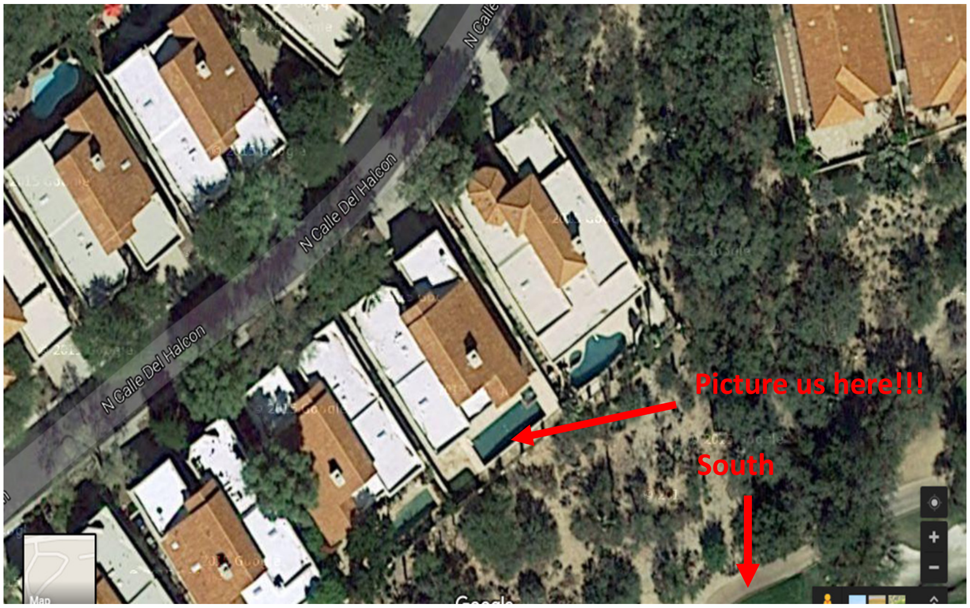
By Ron Henke

Jane and I have been in Tucson for about 5 weeks, and we have been busy the entire time. There are more problems with the house than can be described here. I gave Linda an earful the other day. She can give you the details, if you are interested. The good news is that the house in Stafford finally closed, so we have money to start tackling the problems here.

Our first impression is the same one that everybody else has…it's hot. Three weeks ago, Tucson had a record temperature for the day, 118 °F. I just returned from one of the astronomy stores, and it was 110 °F out. More about the stores in a minute. While 110 °F is certainly hot, 100 °F is not oppressive. Jane and I routinely have breakfast outside when it is 90 °F, and it is pleasant.

Another thing we noticed from the start is the lack of traffic, at least compared with northern Virginia. I have to say, after 15 years of navigating DC area traffic, the traffic here seems almost non-existent. I was coming home from a Tucson Amateur Astronomy Association (TAAA) the other night about 8:45 p.m., and on one of the main roads near the house, there were NO cars visible. More about the club later.

The house faces southeast and the view is almost completely unobstructed (see Google Earth image). We even have some interesting visitors (see unidentified raptor). It's really neat to look up at the night sky and not see any trees or other houses. Jane and I will be in the pool at night and look south, and we can see the entire ecliptic. Right now, we can see Saturn, the Moon, Mars, and Jupiter all in an arc. If we turn around, the Big Dipper and the Polaris are clearly visible. There are a lot of stars mixed in, and this is even with the light dome of Tucson to the south. The sky doesn't really get dark until you get above 40 degrees, but the sky here is considerably darker than it was at our house in Stafford, even this close to Tucson.



There are two astronomy stores in Tucson. The most well-known is Starizona, and it's less than 4 miles away. I can't tell you how neat it is to have a really good astronomy store this close…but I digress. The showroom isn't very big and it's really cluttered—just like most astronomy stores. I have talked with the owner, Dean, and his staff several times about many topics, and they all seem quite knowledgeable. Dean is trying to talk me into buying a Celestron Advanced VX, which is a small equatorial mount. It comes with many options for OTAs. If I buy one, I will get the basic 8-inch SCT. It's the same optics as the 8SE that I had. I was talking with one of the staff members who said that they stay in business not from selling astronomy equipment but from the manufacturing they do. Besides the Hyperstar lens, they also make a power supply and a microfocuser. I also get the impression that they manufacture other things. On Friday and Saturday nights, they are open until 10 p.m. and have their own mini star parties. I have been several times, and they are as informative as they are fun. All types of scopes brought their owners so I have seen and discussed many different types of mounts and telescopes.

The other astronomy store is Stellar Vision. It's on the industrial side of town in a building that's the size of a small house. I have never seen so many telescopes in one place in my life. There are least 100 scopes of all sizes. The day I was there, there were four 14-inch scopes and their mounts and tripods. They were huge. Stellar Vision is the Meade dealer in town, so there were a lot of Meades around. This store has so much "stuff," I don't know how it stays in business. Some of the items on display are so old and out of date as to be useless. The owner, Frank Lopez, is a nice guy and willing to share his knowledge.

The TAAA is a very large club, at least compared with the RAC. I am told there are 400 dues-paying members. I attended the last meeting, which was held in a lecture hall at the University of Arizona. There were about 100 in attendance. There would have been more, but a lot of people were out of town to escape the heat. The general meeting is in two parts. The first part of the meeting is a how-to given by a club member. The second part is a lecture given by a guest speaker. In this case it was a PhD candidate talking about the polar shift on the Moon.

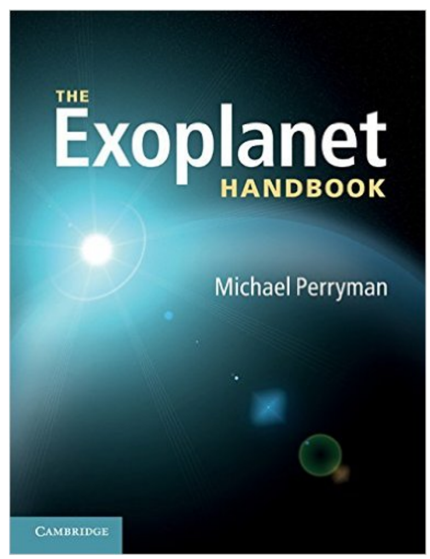
Because the club is so large, there are Special Interest Groups (SIGs). The one I attended was about fundamentals. This SIG looks and feels a lot like the RAC. There were about 20 people there the night I attended. They always have three parts—club business, constellation of the month, and a demonstration of some sort. These are all done by club members.

The club has two dark sites. The nearest is about 45 minutes from the house and is shared with the Tucson International Model Plane Association (TIMPA). I have not been there yet, but I understand that it's pretty dark. The club has a 14-inch SCT housed there that the membership can use once they have been trained. The next star party there is July 29, and I will try to attend. The other dark site, which is about 90 miles away, is called the Chiricahua Astronomy Complex (CAC). While the property has been deeded to the club, there are a number of restrictions that go along with it. This is known as the Very Dark Site and is supposed to have some of the darkest skies in southern Arizona. This site has 10 pads with electricity to them, a shower room, and space for three RVs (without any hook ups). There is also a 14-inch SCT housed there.

UPDATE: I ordered a Celestron Advanced VX this afternoon (Monday, July 18); it should be here by Friday. I was hoping to be able to unbox it and learn how to set it up before the weekend. Oh well. I should have the setup and alignment down by the time July 29 gets here for the TIMPA star party, weather permitting. We are starting the monsoon season, and it will rain heavily off and on for the next 6 weeks. That's it for now. I'll send another update later. Clear skies!

Book Review: *The Exoplanet Handbook* by Michael Perryman

By Jerry Hubbell



Over the past few years, exoplanets have become a popular topic for professional and amateur astronomers alike. Currently, principally owing to the success of the Kepler and K2 missions, 5,154 candidates and 2,453 confirmed exoplanets have been discovered by the space probe alone. According to exoplanets.org, a total of 2,951 exoplanets have been confirmed. Early on in the discovery process, amateurs have been there to do follow-up work and helped to nail down the specifics on orbits and masses on dozens of bright star exoplanets. Multiple techniques exist to discover and monitor these exoplanets and are spelled out in exquisite detail in The Exoplanet Handbook by Michael Perryman, published by Cambridge University Press in 2011 (hardcover).

For almost 3 decades, Michael Perryman has been working on the technology and techniques used in performing astrometric measurements and has applied these and other techniques in the discovery of exoplanets. In some respects, he can be considered the expert in exoplanet discovery methodology. His book outlines and discusses in great detail the different ways used to discover and monitor the movement of exoplanets around a wide variety of stars. He also goes into great depth about the host stars and their characteristics to help the reader understand how such systems may have evolved. Finally, he discusses the characteristics of the exoplanets themselves, including their atmospheres and internal structures.

Of particular interest to me and to other amateur astronomers are the techniques Perryman discusses on how to measure exoplanets that transit their host stars. This is the primary method available to the amateur astronomer who wants to get into observing exoplanets. Perryman goes into great detail to help the reader understand all the factors that go into the specific measurement technique. For those who are into technology and the mathematics behind it, there is a treasure trove of information available. The book is strewn with detailed charts and plots, sidebars discussing the mathematics, and other delightful tidbits for the citizen scientist wanting to get his feet wet in this exciting field of astronomy. Some may consider the text a bit tedious, but again it is very comprehensive and thorough in its coverage.

Overall, the book is a scholarly book that will have broad appeal to those citizen scientists that want to dig into the details on how to discover and observe exoplanets. Other books exist for the amateur astronomer about exoplanets, most notably the fine, practical guidebook, Exoplanet Observing for Amateurs Second Edition by Bruce L. Gary, published by Reductionist Publications in 2007. It is available for free download at: http://brucegary.net/book_EOA/x.htm. These two books together provide the bulk of the knowledge needed by the amateur astronomer to at least get started and successfully observe a large number of exoplanets.

On a personal note, I hope to soon start an exoplanet observing program at the Mark Slade Remote Observatory (MSRO). If you are interested in participating in this program, please contact Myron Wasiuta or Jerry Hubbell.

Make Magazine

By Terry Barker

Make Magazine is hard to describe—it's a combination of content that might come from other magazines like Popular Mechanics, Popular Science, Nuts and Volts, and Woodworking. And because there's an overlap with all kinds of science, there's almost always something about space science or astronomy.

For instance, the issue pictured at right had several articles about Mars and space:

- Reach for the stars—Lessons learned from building a backyard Dobsonian telescope
- Near-space balloon photography—Track a hacked Canon camera to the stratosphere and bring it back safely
- DIY ion thruster—Build a real ion engine that flings out charged atoms for thrust
- Satellite communications—Build your own Yagi radio antenna for listening to satellites
- Breathable atmosphere—Practice making breathable air by using electricity to split water into hydrogen and oxygen
- 10 minute cosmic ray detector—Build a cloud chamber at home and detect cosmic ray particles.

And from some other issues:

- Build a twilight photometer to detect stratospheric particles—Tease out the secrets of twilight and find the altitude of dust, smoke, and air pollution that influence the colors of twilight
- Raspberry Pi telescope—Assemble a 120x astrocam using 3D printed bits and the Pi Camera Module.

You can find the magazine at Barnes and Noble and Books a Million. But be careful. This magazine is addictive, and you may find yourself without enough time to build all these cool things—astronomical or not

Focus On: Palus Epidemiarum and Capuanus

by Jerry Hubbell
(Note from the author: A version of this article was published in the July 2016 ALPO The Lunar Observer *as the Focus On bi-monthly article. Part of my role as the Assistant Coordinator (Lunar Topographical Studies) is to write articles periodically on research done by ALPO contributors. To see full-size versions of the photos, go to* *http://moon.scopesandscapes.com/tlo.pdf* *)*

Palus Epidemiarum (Figure 1), aka "Marsh of Epidemics," is a lunar mare located in the southwest at selenographic coordinates 32.0° S, 28.2° W. The "Marsh" encompasses an area of about 175 square miles (280 square km) with several distinguishing features of note, not the least of which is the large crater Capuanus.

Figure 1. Palus Epidemiarum—G. Grassmann—SP, Brazil, May 17, 2016, 2146 UT. Seeing 5/10 Transparency 3/6, North/Up, East/Right, 10" SCT, ZWO 127 CCD Video Camera.

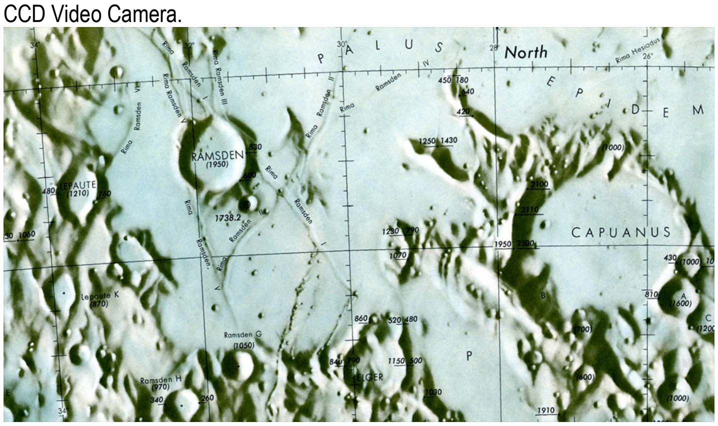


Figure 2. Excerpt from LAC-111-NASA, Air Force, Aeronautical Chart and Information Center, November 1967.

The area's smooth mare floor, most likely formed during the Imbrium period about 3.5 billion years ago, slopes down 0.62 miles (2 km). To the west of Capuanus across the mare is the crater Ramsden 15 miles (25 km) away where a number of rilles to the southeast cross. These rilles—Rima Ramsden I, II, III, IV, and V—are very prominent and have a wealth of detail worthy of extended study. Rima Ramsden VI, which is to the west of the rest of the rille complex, extends northeast of crater Lapaute, a small crater 10 miles (17 km) in diameter. Lunar Aeronautical Chart LAC-111 Capuanus shows the rilles in exquisite detail and is a good resource for comparative studies (Figure 2).

Capuanus is a partially flooded, ringed plain 34 miles (55 km) in diameter (Figure 3). On its western edge, the crater wall rises some 8,000 feet (2.44 km) above the surrounding terrain and is marked by a small silhouette of a crater, Capuanus B. This 6-mile (11-km) crater is deep in shadow late in the lunar day. When observing the Moon during its last quarter, you can see a small rille, Rimae Hesiodus running NE/SW to the north of Capuanus all the way to Hesiodus. The rille's namesake crater Hesiodus is located nearly 180 miles (290 km) to the east. This is a very interesting feature to observe, and it's possible to view with a 4-inch (102 mm) telescope or larger. Of note, the small satellite crater Capuanus L, 6 miles

(11 km) in diameter, is on the ALPO list of banded craters and is worthy of observation during the lunation.

To the east of Capuanus is the relatively smooth mare all the way to the crater Chicus, 25 miles (41 km) in diameter and located 100 miles (160 km) from the eastern wall of Capuanus to the western wall of Chicus. (Figure 4) This area is interesting to observe because there is the hint of a flooded crater half in and half out of the frozen lava lake that looks more like a half ring mountain range that is not even worthy of a name on the LAC-111 Capuanus chart. Chicus C is also an interesting little crater 7 miles (12 km) in diameter. This diminutive crater is bisected by its larger brother's western rim.

To the northern edge of Palus Epidemiarum lie the twin craters Campanus, 29 miles (48 km), and Mercator 29 miles (48 km) in diameter (Figure 5). This pair of craters is a sight to see and beg to be observed closely and compared and contrasted. The rille, Rima Campanus I runs NE/SW bisecting the two craters to the southwest of where they come together. Of note is the fact that Campanus has several small craters in its floor, but Mercator is very smooth, except for the small craters that intersect Mercator's rim on the eastern and western sides. Mercator also appears to be "filled" to a higher level with lava compared with Campanus, which is probably the reason Mercator's floor is devoid of any distinguishing features. The crater Marth 4 miles (7 km) in diameter stands out in the vast wasteland between Ramsden and Campanus/Mercator, a distance of nearly 180 miles (290 km). This small concentric crater is a fascinating object to observe with larger telescopes.

Figure 3. Capuanus—David Teske, Starkville, MS, June 16, 2016, 0144 UT, Seeing 7/10, North/Up, East/Right, iOptron 150, Mallincam GMTm Video Camera. *Author's Note: This is a crop of the original image provided by David.*

Figure 4. Capuanus and Chicus—Francisco Alsina Cardinalli, Oro Verde, Argentina, June 19, 2016, 0248 UT, Colongitude 78.2 degrees, Northwest/Up, Northeast/Right, 10" SCT, QHY5-II CCD, Astronomik ProPlanet 742 IR-pass.

Figure 4. CAMPANUS and MERCATOR—Alberto Martos, et al., September 4, 2014, 0014 UT, North/UP, East/Right, *Author's Note: The craters Campanus and Mercator are located in the lower left of the image.*

ADDITIONAL READING:

Bussey, B. & P. Spudis. 2004. *The Clementine Atlas of the Moon*. Cambridge University Press, New York.

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Chong, S.M., A.C.H. Lim, & P.S. Ang. 2002. *Photographic Atlas of the Moon*. Cambridge University Press, New York.

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Detecting Solar X-Rays

By Tom Watson

The Sun is a vast ball of highly energetic plasma, constantly in a superheated state and undergoing nuclear fusion in its core. With a mass of about 1.989×10^{30} kg[1] and a maximum temperature of about 15 million °C at its core,[2] there is a lot of energy in motion. Over the billions of years that our Sun has existed, the Earth has been bathed in a constant shower of energetic protons, alpha particles, and a very large supply of photons. However, our Sun does not just produce a constant wind of particles; it can also produce great bursts of energy on a much more impressive scale.

Given the right set of circumstances, large masses of plasma (ionized gases) and particles can be ejected in various amounts and energies. These ejections give rise to many different phenomena, from coronal mass ejections (CMEs), to their smaller cousins, solar flares. In each case, large amounts of energy are released in many different directions, sometimes even toward Earth. This energy can easily reach 10^{20} joules of energy, and on rare occasions, thousands of times greater magnitudes.[3]

[1] *Solar Mass. Accessed online at https://en.wikipedia.org/wiki/Solar_mass*
[2] *Sharp, T. (August 15, 2012). How Hot is the Sun? Accessed online at http://www.space.com/17137-how-hot-is-the-sun.html*
[3] *Solar Flare. Accessed online at https://en.wikipedia.org/wiki/Solar_flare*

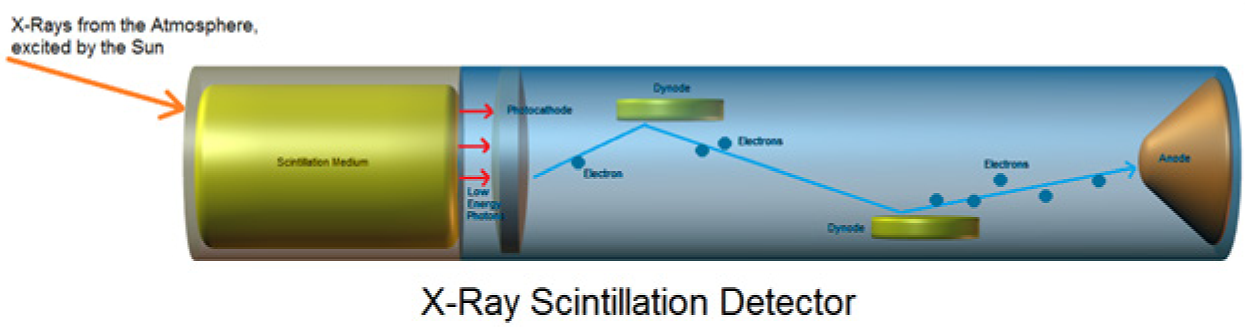
Sol, our closest star and bringer of life. Tom Watson 2016

Luckily for us, as well as all life on Earth, terrestrial organisms evolved in a sea of radiation. Over billions of years, life has evolved techniques for coping with radiation. More important, our atmosphere and the Van Allen radiation belt, a powerful magnetic shield surrounding the Earth and generated by our spinning metallic core, work together to keep us safe from such phenomena as solar flares and CMEs, among other sources of cosmic radiation.

With all of these safeguards in place to lessen or even wholly block radiation from the Sun, how can such phenomena be detected and measured by amateur terrestrial astronomy equipment? The key to detecting radiation from the Sun is the measurement of x-rays from the atmosphere, which are produced as a result of solar phenomena. When high-energy particles from the Sun, such as an x-ray flare or a significant CME, impact the atmosphere, they rip electrons free from their orbits or energize the electrons into higher atomic orbits around the atoms in the atmosphere. The results of these disruptions of electrons are emissions of low-energy x-rays.

Methods Used

X-rays are measured using a device known as a scintillator. A scintillator, as shown below, detects x-rays by means of a crystalline medium that emits tiny flashes of light when struck by x-rays. These flashes always have the same energy for a given scintillation medium, but the number of photons released increases as the energy of the x-ray that impacted that medium increases. The crystal medium photons strike a photo cathode, a device that produces electrons when struck by photons. The number of electrons produced is proportional to the number of photons that struck the photo cathode. These free electrons flow down a vacuum tube containing a series of small electrical field generators, known as dynodes. As electrons are pulled into one dynode, more electrons from the dynode are released, and electrons are pulled toward the next dynode, thus increasing the number of electrons produced as an amplification effect. Because the amplified output is proportional to the energy of the x-ray that struck, it is possible for the analysis equipment attached to the scintillator to determine the energy of the pulse based on how many electrons were produced per x-ray strike, as well as create a gross count of detections.



Typical Crystal-Based X-Ray Scintillation Probe. (Tom Watson 2016)

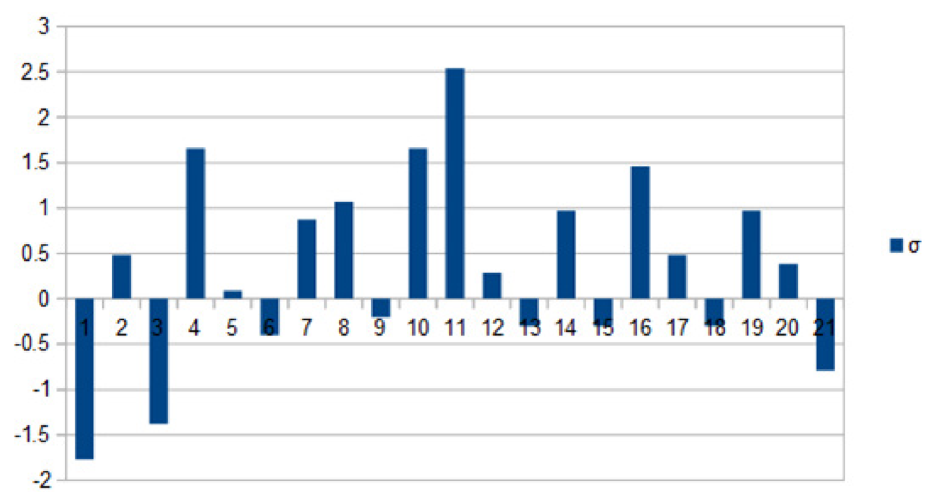
Placing a scintillation detector in the highest point in my home allows the best unimpeded view of the sky. Some of the materials that make up the house could reduce the x-rays coming from the atmosphere. Further, applying several millimeters of lead and copper shielding beneath the detector will prevent the majority of naturally occurring radioactive material from affecting the detector. Once the detector is in place, it can run continuously for multiple days until a flare is detected.

The detector counts all detections from any source for a given period of time and collects the gross count into a single memory storage location, called a channel or a bin. When more than normal numbers of detections occur, a channel/bin will register a count above what is expected. The three techniques that can be used by the amateur astronomer to determine these “peaks” are the following:

- **Standard Deviation**—Taking the standard deviation of each channel with respect to the entire list of channels allows quick detection of significant peaks. When a peak surpasses two or three standard deviations from the norm, the likelihood that that peak is merely background radiation and not from some other source, such as the Sun, falls significantly. This technique is quick and useful, but it fails to detect very low count detections, where the variance is small compared with the mean of the data.
- **Rigorous Mathematical Peak Detection**—A more complicated method involving a confidence interval and a running window of comparison against the dataset can be performed, although the math involved exceeds the scope of this article. In a way, it performs the same basic operation as the standard deviation check, but uses statistics to ensure a confidence threshold is at least met, if not surpassed.
- **NASA Correlation**—The most convenient method involves accessing NASA solar data and observing confirmed flares and CMEs from NASA's fleet of amazing satellites. Returning to your data, the coincidence of a peak using one of the aforementioned methods and a correlating detection by NASA is a very good indicator of a positive identification. This method may appear to be cheating, but it is a great way to ensure that your equipment is actually making valid detections.

To capture higher and lower energy x-rays, I used two detectors, one sensitive to lower energies and another sensitive to higher energy photons. The lower-energy probe used a cesium iodide crystal, doped with thallium, known as a CsI(Tl). In this configuration, the crystal was sensitive between 8 and 500 keV (kiloelectron volt) photons. The significance of this configuration is important because higher energy particle interactions often result in photons emitted at an energy of 511 keV, the rest mass of an electron. Using two detectors that do not fully overlap allows you to differentiate lower and higher energy detections. The second detector uses a different crystal, more suited to higher energies. A sodium iodide crystal, doped with thallium, known as an NaI(Tl) was configured to detect between 30 keV and 3.5 MeV (megaelectron-volt) photons.

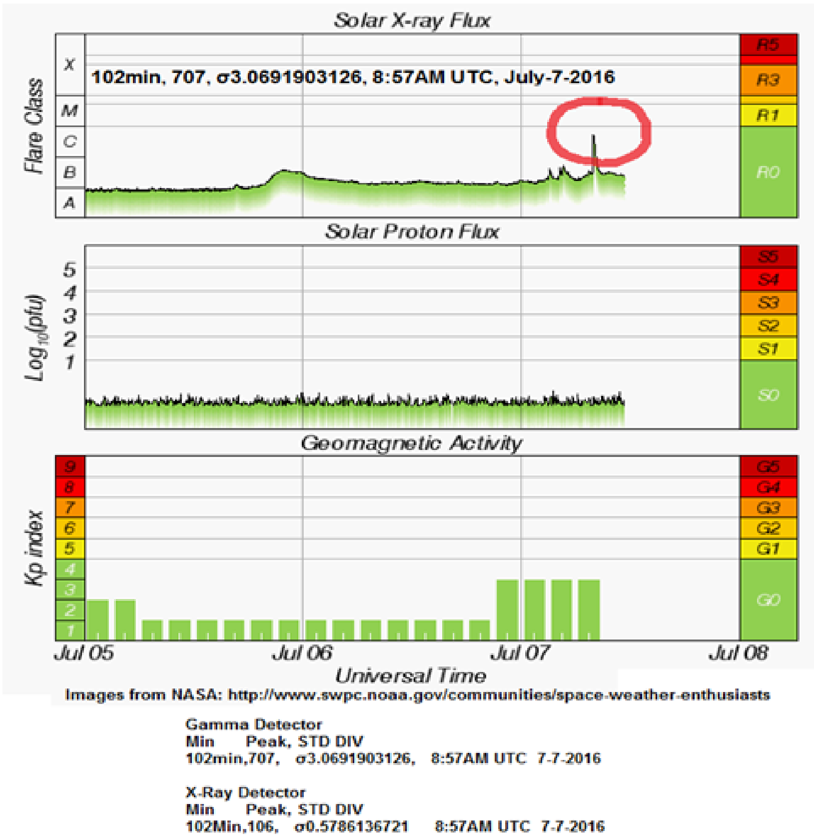
Event 1



Event 1—7:55:00 AM UTC July 7, 2016 – Class C5.1 Flare. Tom Watson 2016

At 7:49:00 am UTC, Thursday, July 7, 2016, a solar flare was detected by NASA's GEOS spacecraft. Seven minutes later, the flare peaked, having reached a class of C5.1. During the same time, the CsI(Tl) probe in my house detected an increase in x-ray background, culminating in a single spike, which occurred at exactly the same minute as NASA's GEOS detection, and achieved an intensity 2.53 standard deviations from the norm. It is impossible for me to be absolutely sure beyond any reasonable doubt that the data collected was indeed from the flare that NASA detected, but the likelihood that the data is indeed a valid flare detection is extremely high. The peak can be visualized on the standard deviation chart above.

Event 2



Event 2—8:57 AM UTC July 7, 2016—Class C5 Flare. Tom Watson 2016

With a valid detection confirmed, I configured the detectors again and left them to run. At 8:57 am UTC, July 7, 2016, NASA detected a second and more powerful flare. During this time, my higher energy NaI(Tl) detector registered a peak about 3.1 standard deviations from the norm. Interestingly, the x-ray detector merely logged a calm about 0.58 standard deviations from the norm. This suggests that much of the energy detected by the higher energy sodium iodide detector was above 500 keV, which in turn suggests that the majority of the particles detected were the result of high-energy collisions in the upper atmosphere, although this analysis is speculative. A visual representation of the peak can be seen at left from NASA x-ray data.

Our Sun is a beautiful and mysterious nuclear fire that brings us life in the most energetic and dangerous way imaginable. In much the same way a moth is attracted to a candle flame, many amateur astronomers are attracted to the fiery plasma and scintillating x-rays of our closest star.

Highlights of Recent RAClub Presentations

Abstracted from Bart Billard's Meeting Minutes

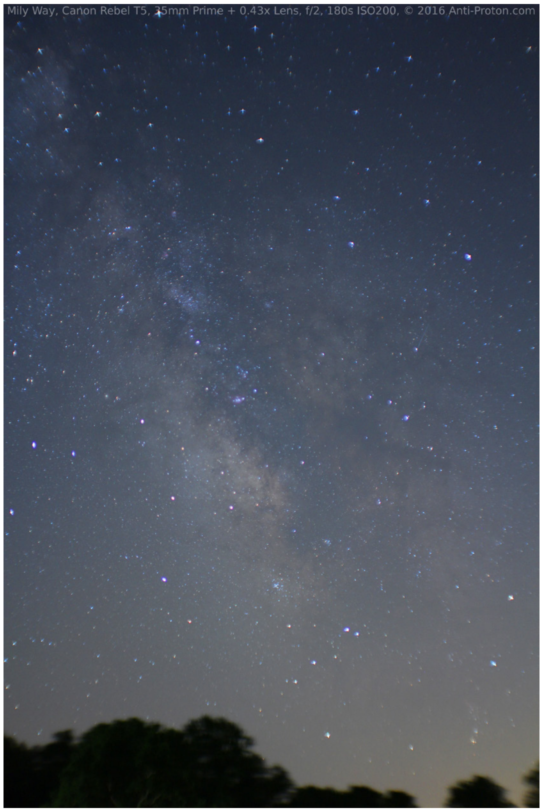
May 2016

[Note: no highlights are presented because Bart was unable to attend this meeting.]

June 2016—Astrophotography Without the Telescope: A Look at Photography Using Camera and Lens

Tom Watson began his presentation by saying he had been a professional photographer for a time in the past, but he did not claim to be an expert or very experienced with astrophotography. He continued with some basics on cameras and lenses, including shutter speed and aperture, wide-angle and telephoto lenses, along with the difference between full frame and cropped formats like APS-C.

Tom showed the dial on his camera with various settings from fully automatic to manual and said all except the latter were not relevant for night sky photos. He said the lens was the most important element, with wide angle usually being the best choice for night sky scenes. He explained that a 50-mm lens (with a full frame format camera) captured about what the eye sees, and shorter focal lengths were called “wide angle,” while longer focal lengths were called telephoto. Tom pointed out that the cropped formats would make a normal lens act like a telephoto, and it paid to look carefully at how a lens designed for a cropped format was described. He had an $89 lens that he said worked well, and it was hard to see a difference between it and an expensive lens. He did find the focusing seemed sloppier. The tripods Tom showed the group illustrated a range of quality. He suggested a cheap one that had a hook for hanging heavy weights can work.



Milky Way at Caledon ©Tom Watson

After this introduction, Tom used a number of his night sky photos to illustrate some tips. One was a nice image from Caledon showing the Sagittarius region of the Milky Way. His tip was to try to find a site without sky glow in the direction you want to shoot. Tom also suggested the white balance setting can enhance night sky images. He suggested the “tungsten” setting, which also would help reduce chromatic aberration. He showed images you could get with round fisheye lenses, which can show the entire sky with the horizon around it, and fisheye rectangular lenses, which would give a panorama of 150 to 180 degrees. (He did not like the $150 Amazon one.)

Continuing on the subject of lenses, Tom said it helped to get a good fast aperture, like f/1.4, to reduce the time needed for exposure and hence blurring. For that reason, using the lowest f number possible was usually best. Sometimes there were exceptions. For example, with telephoto images, especially single stars, higher f numbers could reduce aberrations. Tom said older lenses could be very good, but some were made using thorium to improve performance. Thorium can cause yellowing of the glass over time, and he said you could find procedures online for reversing the yellowing.

Tom also discussed ISO setting and noise effects. In the past, the sharpest films were ones with low ISO ratings (100, 200, or 400). With digital cameras, it was still best to use the lowest ISO setting you could get away with. He also said some DSLRs took better pictures after cooling for a while—it paid to take a break after using the camera a while, although it generally was not necessary in winter.

Tom closed with several more tips and topics. He said you could buy filters to create diffraction spikes if you liked them (some do, some hate them). He had an image of the Moon and Jupiter with spikes, made with a 35-mm lens, as an illustration. He said he enjoyed catching satellites: the best times were near sunset or sunrise. Tom also said he liked to keep his camera set for whatever he was most likely to see at that time of day. He showed bird images he got that way before dark at Caledon. He also suggested looking for something interesting to have in the foreground (or have someone cooperative pose to add foreground interest). Alternatively, Tom said you could just be lucky. He showed a galaxy image “photobombed” by a firefly.

Tom described his way of focusing for night sky shots. First he focuses on a bright star (through the viewfinder, if necessary). Then he puts the camera on the tripod and finds a bright star roughly in the direction he plans to image and uses the display to refine the focus, taking advantage of the zoom capability to see the star better. Finally, he composes the image.

For exposure times, Tom said he started with the rule of thumb to divide 500 or 600 by the focal length in millimeters to get the number of seconds you could expose without blur from Earth’s rotation. He recommended using the bulb setting, preferably with a remote release or cable to trip the shutter. For the Moon and planets, fast shutter speeds like 1/100 second, along with higher f number and lower ISO worked well. The final recommendation was to use an air blower, which Tom said could make the difference between a good and bad picture.

July 2016—Astronomy in the News


Noctilucent clouds over Stockholm (Source:Wikipedia

The program for the evening was a discussion of astronomy in the news by the members present. Scott Lansdale led off with four items. The first was about a minor G1-class geomagnetic storm that occurred the day of the meeting, which he said was interesting for him because of his radio astronomy interests. Spaceweather.com recommended watching out for auroras, especially in the southern hemisphere winter skies. Myron Wasiuta suspected the active region he had been watching during the last week could be the source. Another topic was increasing frequency of noctilucent clouds seen at lower latitudes. Scott said the earliest sightings date back to about 1885. He said they now are being studied by the NASA Aeronomy of Ice in the Mesosphere (AIM) program. Measurements by AIM indicate that at noctilucent cloud altitudes, temperature is decreasing about 0.5 K per decade, and water vapor is increasing about 1 percent per decade. Myron wondered why the temperature decreased when increasing carbon dioxide in the atmosphere tends to cause warming. Bart Billard and some others suggested the warming was caused lower down in the atmosphere, and the carbon dioxide below the noctilucent clouds absorbing the radiated heat acted like insulation and allowed the air at those levels to cool.

Scott's next topic was evidence of water clouds found outside the solar system. The brown dwarf, or failed star, WISE 0855, has a similar water absorption spectrum to Jupiter. It is about five times the mass of Jupiter and has a temperature of about -10° F compared with -224° F for Jupiter. The final topic was NASA's Juno mission, which entered an eccentric orbit around Jupiter earlier this month. Goals include trying to confirm ideas about Jupiter's structure. Does it rotate as a solid body? Is there a solid core, and if so, how large? Myron noted that if we could see Jupiter's magnetosphere, it would stretch 5 degrees on the sky. Tom asked about observing Jupiter's radio emissions, and Scott confirmed amateur radio astronomy equipment could. One of Juno's instruments is the Jupiter Energetic Particle Detector Instrument (JEDI). Scott mentioned that the JunoCam is not one of the science instruments. It will produce close-up images of Jupiter's poles, and the public will be able to select other points of interest for images. Scott showed two short Bill Nye videos about Juno topics, including how Juno is powered and what questions the mission is designed to try to answer. One technique for investigating Jupiter's structure involves precise measurements of Juno's orbit using the Doppler effect.

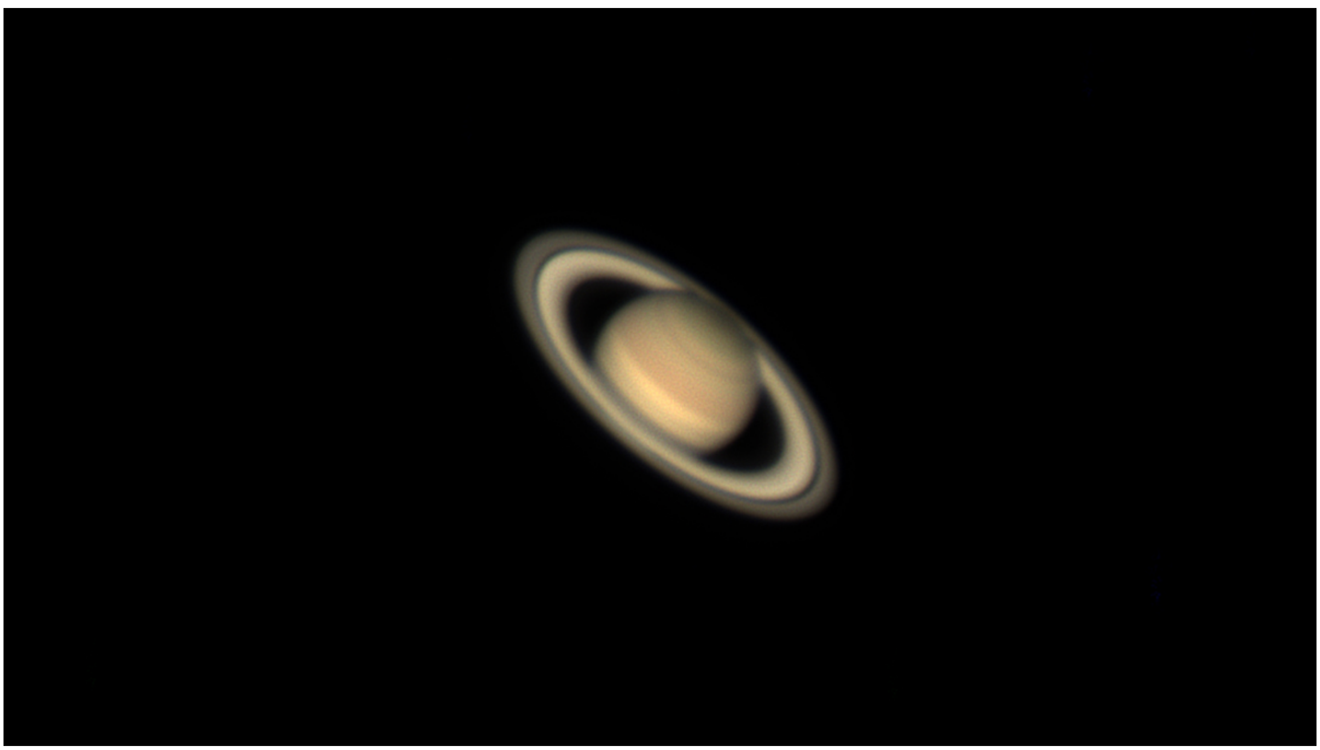
Bart followed Scott with a discussion of the Laser Interferometer Gravitational Wave Observatory (LIGO) accomplishments during the 4-month operation in the Advanced LIGO configuration at low power. Two confirmed detections were announced in February and June, and one reasonably likely one was also observed. All represented binary black holes in their "death spiral," in which orbital energy lost to emission of gravitational waves results in their separation decaying and their orbital periods decreasing until they merge. The LIGO signals show increasing frequency and amplitude until a peak in both is reached, followed by decreasing amplitude at a constant frequency as the black holes merge and "ring down." The February 12 Astronomy Picture of the Day (APOD) featured a simulation of a binary black hole merger. For the June announcement, APOD featured an animated graph of the LIGO detector frequency content versus time during the event. For sound, the video used what the waveform of the merger sounds like when played as an audio recording.

Bart said information about such mergers is found by matching the waveforms of the signals with computer simulations of merging binary black holes with various masses and spins. The details of the waveforms measured by LIGO provide data on their total mass and individual masses and even some information about their spin. The masses found also indicate how strong the wave emission is, telling us how far away they are. A network of gravitational wave detectors has the ability to monitor all of the sky (up or down) both day and night. Three or more detections (for this run, LIGO had two, one in Washington State and one in Louisiana) provide the possibility of localizing the source enough for follow-up observations in visible light or other wavelengths.

Jerry Hubbell showed us YouTube videos available on the SpaceX Falcon 9 reusable booster. He said they are launching about once a month, so you should be able to see a new video every month. We saw one video of a successful vertical landing on a barge; Myron wondered how to tell it was not a takeoff video run backward, Another showed an unsuccessful landing in which the booster fell over after setting down (not a video run backward).

Myron talked about "Tabitha's Star," a star with an unusual dimming pattern found in Kepler data via a citizen science project run by Yale astronomers that allows people to analyze Kepler light curves via the Internet. Tabitha Boyajian is one of the astronomers investigating this find. This star is the one that was in the news recently with the media speculating about alien civilizations and Dyson spheres. Other proposed explanations are a huge swarm of comets or debris from a planet broken up by a collision. A Kickstart program was established to fund controlled observations of the star with a network of amateur telescopes. It is now getting about 15–20 observations a day from around the world. AAVSO is also involved. Bart mentioned the PANOPTES project, which is attempting to design a small robotic telescope that could be built by amateurs and schools to create an observatory network for transit searches and other applications. They could be used to observe this star, although they have a wide field of view for covering many stars at once. Myron said Tabby's star is an easy star to observe. He showed a Ted Talk she gave about the star.

Image of the Quarter



Saturn by Scott Busby—This amazing image of Saturn was taken June 18 by Scott with his ASI120MC camera on the Takahashi Mewlon 250S/EM400 scope at Belmont. He took 2,000 frames at 120 fps and created the final image shown here by stacking.