http://www.raclub.org/

The StarGazer

Newsletter of the Rappahannock Astronomy Club No. 1, Vol. 6 May 2017–July 2017

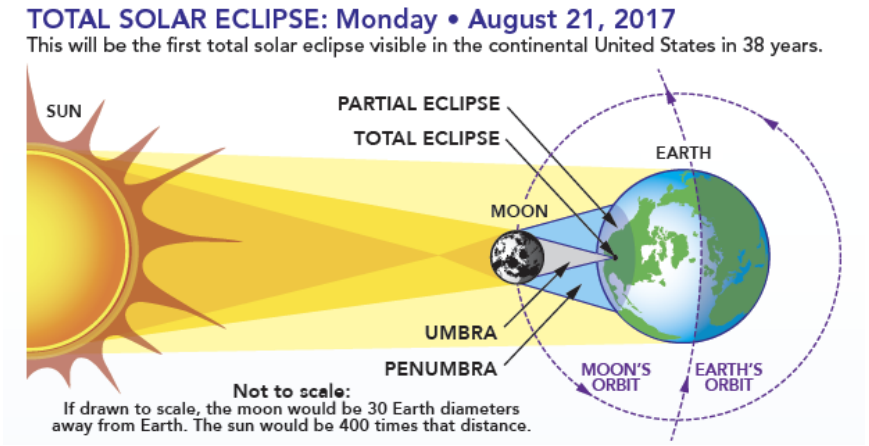
Total Eclipse of the Sun

By Linda Billard

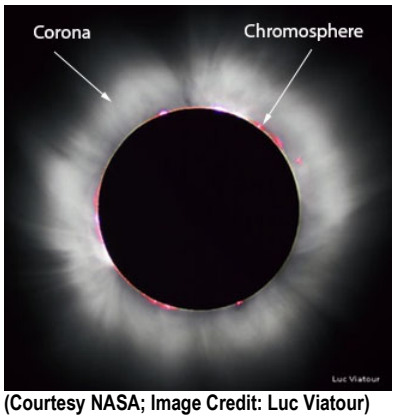
Unless you live off the grid and/or in a cave, you are aware that a total eclipse of the Sun will occur on August 21. This is the first total eclipse in the United States since 1991, the first on the mainland since 1979, and the first to cross the entire country since *1918*! Don't assume that going to a location "close to the path" is good enough. Paraphrasing the editor of eclipse2017.org, one of the best resources for understanding and viewing the eclipse: "*A partial eclipse is interesting but forgettable…a total eclipse is a memorable, life-changing event that burns itself into memory—and never fades….'Close' is not close enough…to see the eclipse in all its glory, you simply must…Get thee to the path!*"

What Is an Eclipse and Why Is This One Special?

Simply put, an eclipse of the Sun occurs when the Moon's shadow passes across the Earth's surface obscuring the Sun. Eclipses can be partial, i.e., when the shadow doesn't cover the entire face of the Sun, or total—when the shadow covers all of the Sun's disk, allowing a good look at the halo of gases that surround it. A total solar eclipse presents a rare opportunity to observe the corona and chromosphere, the two outermost layers of the Sun's atmosphere. Under normal circumstances, the bright yellow surface of the Sun—the photosphere—is the only feature you can observe. However, during an eclipse, the Moon blocks out that intense light, allowing you to observe the much dimmer solar atmosphere.



Earth-Sun-Moon geometry of a total solar eclipse. Not to scale: If drawn to scale, the Moon would be 30 Earth diameters away. The Sun would be 400 times that distance. (Courtesy NASA)



(Courtesy NASA; Image Credit: Luc Viatour)

In addition to giving us amateurs a great show, the 2017 total solar eclipse will allow U.S. scientists to pursue a range of unique science and engineering problems. According to the NASA website created for this event, the very dark color of the Moon can be used to calibrate X-ray imagers to properly record the "zero signal" state, while the eclipse will block out the disk of the Sun letting the light from the mysterious inner corona within 100 km of the solar photosphere shine into various experiments for detailed study. The Science page introduces you to some of the unique observations planned by NASA of the Sun and Moon during this eclipse, along with interviews with scientists about their work. *(continued on 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 closest to the new 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.

The StarGazer
May 2017–July 2017
Published Quarterly by Rappahannock Astronomy Club
Editor: Linda Billard

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

RAClub Officers
Scott Lansdale, President
Glenn Holliday, Vice President
Tim Plunkett Treasurer
Bart Billard Secretary
Points of Contact
Scott Lansdale, Public Outreach
Glenn Holliday, Scout Clinics
David Abbou School Programs
Glenn Holliday, Star Parties
Scott Busby Yahoo Group Admin
Web Editor & Image Gallery Editor/Don Clark
Don Clark Internet Administrator
Tim Plunkett Librarian
Glenn Holliday, Equipment Loan
Jerry Hubbell, Astrophotography
Myron Wasiuta Mark Slade Remote Observatory (MSRO)

Calendar of Upcoming Events

RAC Picnic, Belmont*	August 12
Eclipse Outreach, Porter Library, Stafford	August 21
Meet the Moon, Porter Library, Stafford	October 28

Recent Outreach Events Completed

Star Party, Stratford Hall	May 6–7
Star Party, Caledon State Park	May 27
Outreach, Mountain View High School	June 2
Outreach, Stafford Elementary School	June 7
Embrey Mill Star Party, Stafford County	July 2
Almost Heaven Star Party, Spruce Knob, WV	July 21–25
Star Party, Caledon State Park	July 22

*Members only

President's Corner

Welcome to New RAClub Members (May–July)

- Ross Csemez
- Barbara Deal
- Betsy & Mike Rodrigue
- Jean Benson & Matt Scott
- Mark Murway & Elaine Reardon
- Peter Orlowski
- Teresa Tindal

Hello fellow star-gazers. I want to begin by thanking Linda for putting the newsletter together. Without her, there would be no newsletter at all. There's a lot of great info in this installment of the *StarGazer*, including a few articles on the upcoming solar eclipse. We also have another great article by Ron Henke (our past president and only Arizona member) about the various observatories in Arizona.

I also want to thank Linda for enabling us to meet at the Heritage Center at the old Maury School in Fredericksburg. We've met there for the past several years but this past month was our last, as the room is being converted into further collection space. It has been a great meeting location, with plenty of space for meetings and setup of telescopes on occasion. August is our club picnic, followed by our first meeting in a new location in September. Please check the RAC.org website for updates on location.

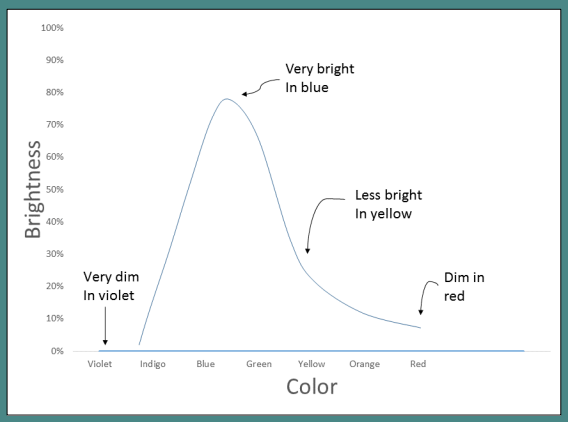
A few club members have traveled recently to events, including the Almost Heaven Star Party, which is reported on later in this issue. I personally attended another conference for the Society of Amateur Radio Astronomers (SARA). Both of these events were in WV in late July. The SARA Conference, which I reported on in July 2015, includes various presentations about radio astronomy projects, tours of the Green Bank Observatory, and hands-on experiments with a 40-ft antenna. One of the talks this year was given by a group from Eclipse Mob (see also the article in this issue), a group focused on the effect of the upcoming eclipse on the ionosphere through the study of radio wave propagation. Trust me, it is very interesting to see how the same event has so many effects on the things around us, even from the light we cannot see.

Everyone—please observe the eclipse carefully, and wherever you are observing it from, travel safely. Clear Skies, Scott Lansdale

Astronomy Math: Light and Spectrum Fundamentals by Scott Busby

In astronomy, almost everything we learn about the universe comes from various forms of light. The word *light* is often used to refer to any type of electromagnetic radiation—radio waves, microwaves, infrared radiation, visible light, ultraviolet radiation, X-rays, and gamma rays. A lot of the information in the light from astronomical objects can be derived from the *spectrum* of that light. First, I need to talk a bit about astronomical spectra, and in coming newsletters, I'll discuss some of the techniques astronomers use to interpret spectra.

The most fundamental property that distinguishes one type of light from another is its color. All forms of light are referred to as the electromagnetic spectrum. The word *spectrum* (plural *spectra*) refers to the entire range of light found in nature. In science, the term spectrum is used in a slightly different way and has a special meaning. The spectrum of an object is a graphical representation of the amount of each color of light present in an object's radiation. The horizontal axis of a spectrum represents the color of light (or one of its proxies, such as wavelength, frequency, or energy). The vertical axis is the amount of light (which may be called brightness, intensity, or energy flux). An example is shown at right. As you can see from the graphic, the height of the line in the vertical direction indicates the brightness of each color of the light.



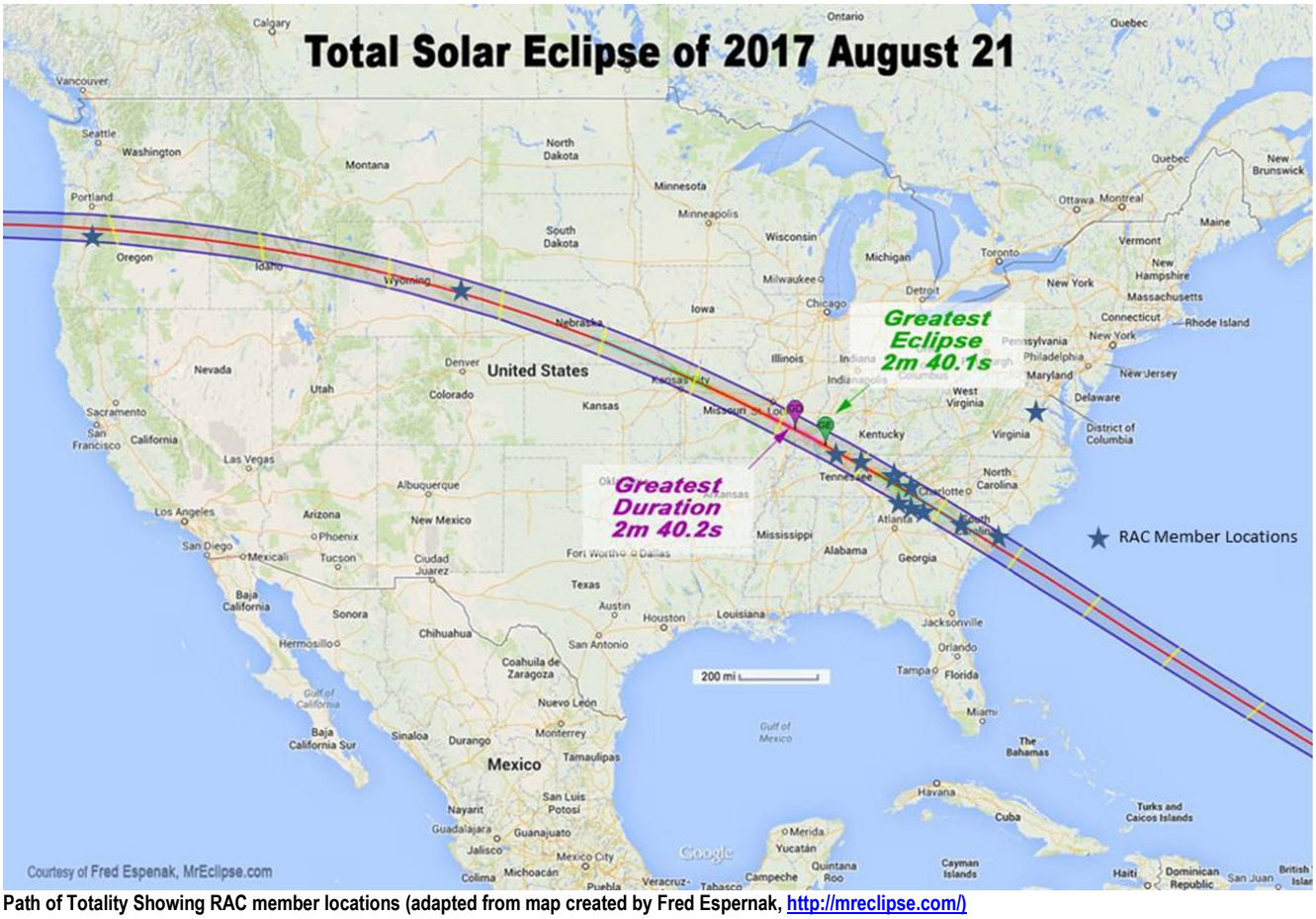
A spectrum of visible light

When we detect light with our eyes (or a telescope), all the colors of the light are mixed together. To produce a spectrum, the colors need to be separated using a prism, diffraction grating, or interferometer technique. This allows us to determine how much of each color is present. The brightness of each color can then be represented visually on a graph like the one above. In the next newsletter, I'll discuss the relationship among wavelength, frequency, and energy.

Total Eclipse of the Sun (continued from page 1)

The Path

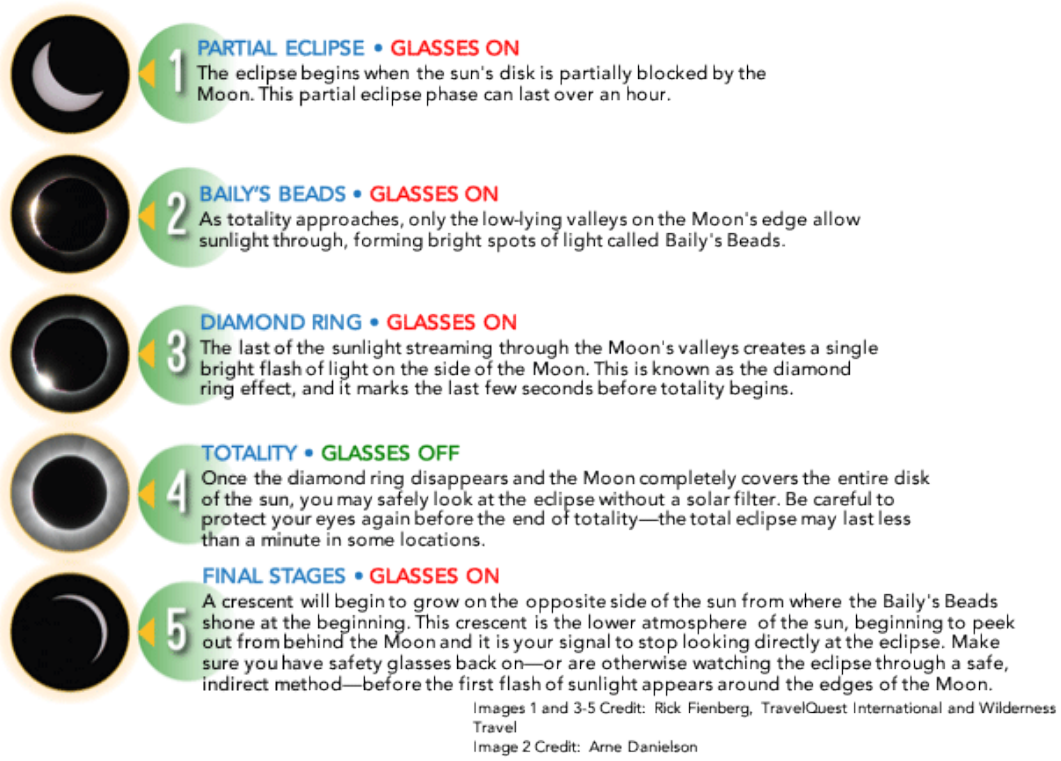
As you can see in the map below, the *path of totality* enters the U.S. mainland in Oregon, sweeps across the United States through Idaho, Wyoming, Nebraska, a corner of Kansas, Missouri, the toe of Illinois, Kentucky, Tennessee, the southwest corner of North Carolina, the northeast corner of Georgia, and finally marches straight through the middle of South Carolina to the Atlantic Ocean. (Royal Caribbean is even offering a cruise that passes through the path of totality while at sea.) However, given the wide range of land-based locations to choose from, you certainly don't need to go to sea! On the map below, the stars indicate the wide variety of locations where RAC members will be waiting patiently (or perhaps, not so patiently) for the appointed time at their chosen site.



Path of Totality Showing RAC member locations (adapted from map created by Fred Espernak, http://mreclipse.com/)

How to Safely Observe the Solar Eclipse

Never look directly at the Sun without appropriate protection except during totality. That could severely damage your eyes. However, there are many ways to safely view an eclipse of the Sun, including direct viewing (which requires some type of filtering device) and indirect viewing (where you project an image of the Sun onto a screen). Both methods should produce clear images of the partial phase of an eclipse. The following list (provided by NASA) describes when to wear your glasses and when you can safely look at the eclipse (only during totality)!



Images 1 and 3-5 Credit: Rick Fienberg, TravelQuest International and Wilderness Travel
Image 2 Credit: Arne Danielson

When Will the Eclipse Occur and How Long Will It Last at My Location?

The best way to find out is to use the wonderful interactive Google® map developed by Xavier Jubier. Type your location (town/city, state) into the search window and hit return. The map will show your location, along with a popup window with lots of information about viewing at the location. Don't forget that all times are in Universal Time (UT), so you need to convert that time to your local time.

Get thee to the path!

Postal Service Issues Solar Eclipse Forever® Stamp

The stamp image is a photograph taken by astrophysicist Fred Espernak, aka Mr. Eclipse, of Portal, AZ, that shows a total solar eclipse seen from Jalu, Libya, on March 29, 2006. The stamp is the first U.S. stamp that uses thermochromic ink. If you rub your thumb or finger over the eclipse image, you will reveal an underlying image of the Moon. (Espernak also took the photograph of the full Moon.) The image reverts to the eclipse once it cools. On the back of the stamp is Espernak's map of the eclipse path of totality.

Embrey Mill Star Party Outreach

By Linda Billard

Mark Burns (left) and David Abbou (right) at Embrey Mills (Courtesy Don Clark)

On July 2, David Abbou, assisted by Mark Burns, held a star party for the Embrey Mills community in Stafford County. Don Clark also dropped by to provide some eclipse outreach materials and took a few pictures. David and Mark had many Embrey Mill residents and their children come by to view the Moon through both telescopes, as well as Jupiter through Mark's telescope. They battled the persistent clouds but did have a few breaks that afforded decent views. The Embrey Mill community manager provided a microphone and speaker, so David was able to mention RAC and our monthly meetings and star parties as well as answer lunar trivia questions. This is the second year is a row that David, supported by other RAC members, has provided this star party for the Embrey Mills community. Thanks David…for all you do!

Club News Briefs

- **NEW MEETING LOCATION:** Starting with the September 20 meeting, RAC will no longer meet in the Heritage Center meeting room. The Heritage Center collection has grown so much that the meeting room is being taken over to accommodate newly acquired materials. Please be sure to watch the website for info on our new meeting location.
- **MEETUP:** Payel Patel has established a page for RAC at Meetup.com. You are encouraged to join and use it as an additional source of info on club activities, etc.
- **UPDATED MSRO PAGE:** Jerry Hubbell, Linda Billard, and Don Clark have updated the Mark Slade Remote Observatory (MSRO) page on the RAC website to reflect new equipment.
- **NEW MSRO VIDEO:** Jerry has created a 30-min YouTube video explaining startup procedures for MSRO. This is the first in a series on how to start up, operate, and shutdown MSRO. It walks through how to start up MSRO, including discussion of the GPS program and Weather Ninja weather application.
- **NEWSLETTER INDEX:** On the 5th anniversary of the new *StarGazer* newsletter, Jerry HAS developed an index of all the articles that have appeared in the newsletter over the 5-year period.

Almost Heaven? Star Party…Not Even Close!

By Jerry Hubbell and Myron Wasiuta (with Linda Billard)

Jerry's booth before Saturday's storms (Courtesy Jerry Hubbell)

From Jerry: We left home on Friday, July 21, for Spruce Knob, WV, to attend the Almost Heaven Star Party sponsored by NOVAC and held at the Spruce Knob Mountain Center on the mountain. Starting out, the weather was good, but as we approached the mountain and started up the hill, it started to rain. Initially, we drove to where Michelle and the kids were staying—Yokum's Vacationland in Seneca Rock, WV. We then went to the star party location amidst a thunderstorm (raining cats and dogs) at about 3 in the afternoon. We sat in the rental Suburban (we didn't have our own

Suburban…but that's another story) for about an hour before we could get out and talk to someone about where to set up.

We set up the 10 ft x 10 ft tent I had bought and started unpacking the equipment, including the new Explore Scientific FCD100 102mm f/7.0 carbon fiber refractor and the Explore Scientific EXOS 2 mount with the PMC-Eight® mount control system. The Explore Scientific banner went up on the tent, and all was well.

Over the next few hours, I talked with several attendees and showed the scope—everyone was impressed with our equipment. I enjoyed the dinner provided by the organizers and then waited for the sky to clear for the evening activities. The sky finally cleared after about 11 p.m. on Friday, and I spent a couple of hours showing attendees Jupiter and Saturn. We also looked at a couple of deep sky objects.

The next day, we woke to cloudy skies, but the temperature was very pleasant…in the 70s. A couple of storms were forecasted for that afternoon. I spent the morning talking with attendees and sold a couple of items. But sure enough, after lunch, the sky got darker and a thunderstorm started to roll in (click here for Myron's video of the approaching storm). During that time, I was working with Dr. Mike Reynolds and his new EXOS 2 PMC-Eight mount. We managed to get things running under the tent and finished up in time for the storms to come.


One dead tent. (Courtesy Jerry Hubbell)

Two storms came through quickly over the next couple of hours. Myron has posted two YouTube videos (part 1 and part 2) showing the carnage. A monster third storm was forecast to hit us at around 6 p.m. I battened down the hatches and made sure everything was covered and protected. We had weathered the previous storms so I didn't think it would be a problem. I was wrong. The monster storm came in. starting with a 60–70 mph microburst that ripped the tent out of the ground, knocking the telescope on the EXOS 2 mount over so it nose-dived into the ground, ARRRGHHH! When the tent got ripped out, I grabbed it thinking I could save it from being totally destroyed but it was not to be. At that point, Myron and I grabbed the telescope and mount off the ground and attempted to ram it into his car's backseat…you had to be there! We concluded it was best to set it on the ground, close to the car so it wouldn't be knocked over again. At this point, we were as soaked as if we had been thrown into a swimming pool, and we hightailed it to the dorm room that I was staying in. Myron had slept in his tent the night before, but I invited him to stay with me in my "luxurious" dorm room. My son Jed was also going to sleep in the dorm with us. We stayed in the dorm until the next day.

Sunday dawned clear and a little breezy; I thought it might be a good day. First thing, I went to where we set the booth up, uncovered everything, and started to assess the damage. The scope and mount had survived the storm with nary a scratch. The mount worked like a charm when tested later that afternoon. The tent was a balled-up mess across the road from where we had set up. That and the box for the mount were the only casualties. Overall things weren't too bad.

From Myron: I gave my talk at 10:30 a.m. about how the human eye can be used most effectively for visual astronomy. I began with a basic lesson on ocular anatomy and how the most important refracting surface in the eye is *not* the cornea or lens, but the pre-corneal tear film. Maintaining its integrity is of the utmost importance in making sure you have the best possible contrast sensitivity and visual acuity so that all other techniques discussed work best. I then discussed the ocular diseases that most commonly occur as we age and how they can affect night vision and astronomical viewing. I then discussed human dark adaptation, emphasizing the mechanisms by which

the eye increases it sensitivity almost 100 million times. The differences between cone and rod adaptation were presented, with graphs showing the increase in sensitivity as the eye dark adapts and how a distinct biphasic process results from rapid cone adaptation followed by slower rod adaptation (rod/cone break). Finally, I talked about the eye's ability to see color under varying lighting conditions and showed a few example slides to demonstrate color vision differences and processes by which our brain interprets color, which lead to the wide variation among individuals in their color perception ability and perception of color at the eyepiece.

I then shifted gears and discussed how to maximize dark adaptation and contrast sensitivity for astronomical viewing. I presented visual charts and graphs from Roger Clark's book *Visual Astronomy of the Deep Sky* and discussed the importance of using the proper magnification when observing, as well as other telescopic techniques to enhance detection of faint or subtle detail in deep sky objects.

Back to Jerry: My talk was scheduled for later in the day at 3:30 p.m. Before that, I worked with a couple of customers and attended Myron's talk. I also had a terrific lunch and then prepared for my talk. My talk about the Mark Slade Remote Observatory, which was similar to a number I have given for RAC, went well. I got several questions during and after the talk.

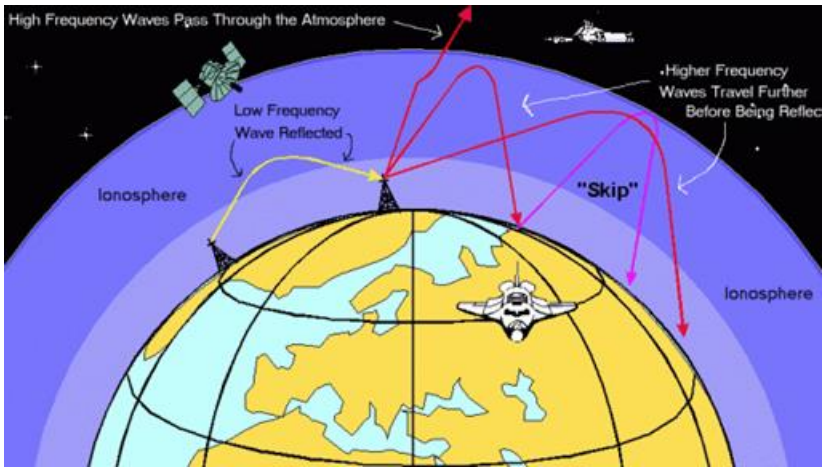
Later Sunday night, right after sunset, the sky played hide-and-seek with us, showing us selected parts of the sky. We observed Jupiter and Saturn with the scope that evening. I was not able to do an all-sky alignment of the mount because the clouds kept hiding all the alignment stars, ugh! After midnight, the sky cleared up so we had a magnificent view of the Milky Way. An awesome end to an otherwise extremely challenging weekend.

Monday, I started early, spending a few hours before lunch sitting and enjoying the view where the booth was set up, and talking to a couple of attendees. Lunch was very good, and then Michelle and the kids arrived and we packed up and headed down the mountain.

Overall, it was not a good star party in terms of observing, but I met some new friends, and I plan to attend next year. I will definitely be better prepared!

EclipseMob—Citizen Radio Astronomy on a Grand Scale

By Linda Billard



The Ionosphere (courtesy http://www.swpc.noaa.gov/phenomena/ionosphere

The ionosphere provides a "boost" for some forms of long-distance communications by bouncing radio waves so they travel farther around the globe. However, because signals passing through the ionosphere don't always behave as expected, many questions remain about its properties and behavior.

EclipseMob is a crowdsourced[1] experiment to investigate low-frequency radio wave propagation during the 2017 solar eclipse. Citizen scientists will collect

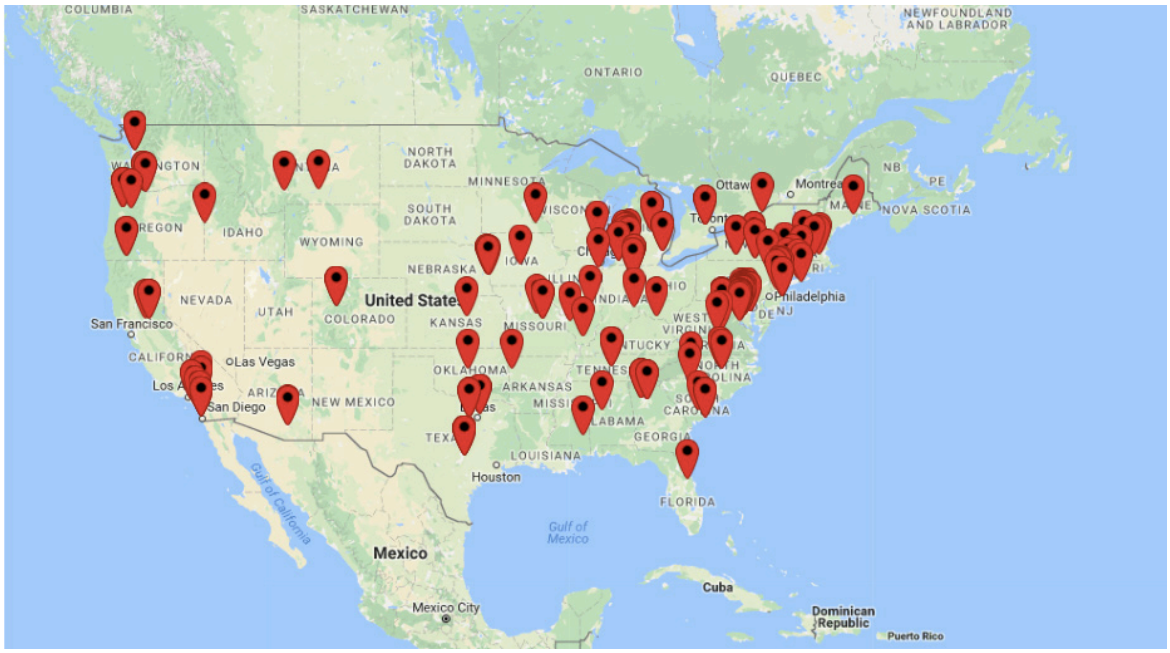
[1] Crowdsourcing: the practice of obtaining needed services, ideas, or content by soliciting contributions from a large group of people and especially from the online community rather than from traditional employees or suppliers (Merriam-Webster Dictionary).

data on the ionosphere by recording changes in radio signals.

EclipseMob is the idea of Extra Class Radio Amateur Bill Liles and professors Laura Lukes, Jill Nelson, and K.C. Kerby-Patel. **Liles** has had a life-long interest in understanding radio-wave propagation and antennas. **Lukes** is Assistant Director of the Center for Teaching and Faculty Excellence and an Affiliate Assistant Professor in Atmospheric, Oceanic, & Earth Sciences at George Mason University. **Nelson** is an Associate Professor in the Department of Electrical and Computer Engineering at George Mason. Her research focus is statistical signal processing, specifically detection and estimation and machine learning for applications in surveillance and in physical layer communications. **Kerby-Patel** is an Assistant Professor in the Engineering Department at the University of Massachusetts Boston, where her research focuses on applied electromagnetics. Her current research includes high impedance surfaces, low-profile antennas, crowdsourced measurement of low-frequency skywave propagation, and link signature keying.

The Experiment

On April 17, 1912, William Henry Eccles was the first to collect data on the effect of a solar eclipse. He used a transmitter with a frequency of approximately 54.545 kHz and a wavelength of 5,500 meters. Data for the same eclipse were collected in France and Denmark using the transmitter at the Eiffel Tower in Paris with a frequency of 115 kHz. EclipseMob has a number of advantages over this initial study and other subsequent studies. These include the large number of people involved, consistency of the radio signals, and, by hooking receivers to smartphones, accurate data on location and time. Also, because the eclipse passes over populous regions in the continental United States, the August totality will be particularly useful. EclipseMob participants are scattered, with some close to the path of the eclipse and others located in far corners of the country.



Locations of EclipseMob Radio Receivers. Courtesy EclipseMob.org

EclipseMob participants have built their own radio receivers to collect data. Although all 150 receiver kits created with a National Science Foundation grant have been distributed, it's not too late to join the EclipseMob if you build your own receiver. The project's website includes instructions for ordering parts and constructing your own radio receiver.

EclipseMob will collect two radio wave signals before, during, and after the 2017 solar eclipse. One signal will be transmitted from the WWVB radio station in Colorado and one from the Navy transmitter in central California. The purpose of the study is collect data on the effect of sunlight on the ionosphere. Disturbances in the ionosphere can cause problems with communications around the globe, which in turn can disrupt GPS signals and emergency communications that use the ionosphere when cell towers are down during instances such as hurricanes or other natural disasters. Why was crowdsourcing used? Crowdsourcing means the participants will collect radio wave signals at locations all over the United States. This will allow the researchers to study how the signals were affected as they traveled along different paths.

The experiment relies on National Institute of Standards and Technology (NIST) radio station WWVB in Fort Collins, CO, which constantly transmits time synchronization information on a 60 kHz carrier frequency. NIST operates several radio stations that provide precise time and frequency reference signals. The WWVB signal is primarily used to synchronize radio-controlled clocks and watches all over the United States to a very precise atomic clock. In the EclipseMob experiment, participants will observe how the signal strength changes in response to the ionospheric changes caused by the eclipse.

Observatories in Arizona

By Ron Henke

While Chile is the world leader in terms of large telescopes, Arizona is still the leader in the number of research-grade telescopes/observatories. Many of these observatories are consortiums owned and operated by universities. While there are observatories all over the state, most are in three locations: Kitt Peak, Mount Hopkins, and Mount Graham. This article describes some of the observatories at these three locations.

Kitt Peak

Courtesy Ron Henke

Probably the best known of these three areas is Kitt Peak. According to its Visitors Center, Kitt Peak is home to the largest array of optical and radio telescopes in the world. At left is a picture of the plaque listing the universities that are part of the various consortiums on Kitt Peak. There are 22 optical and 2 radio research-grade observatories on Kitt Peak. Three observatories are open to the public, and guided tours are provided.


NSO. Courtesy Ron Henke

The ***National Solar Observatory*** (NSO) is also known as the McMath-Pierce Solar Telescope (shown at right). What you do not see is the other 300 ft of the telescope that is underground. The NSO was dedicated in March 1960 and has operated ever since. Its days may be numbered, however. Another NSO, called the Sunspot Solar Observatory, was built in the mountains near Alamogordo, NM, and has been operating since 1998. In October, the Sunspot Solar Observatory Consortium will take over its operations, with New Mexico State University as the operating entity. In addition, the Daniel K. Inouye Solar Telescope, located on Mt. Haleakalā on Maui will soon be operational. Both of these facilities are more modern and have more advanced instrumentation than the McMath-Pierce Solar Telescope.


2.1 Meter Telescope. Courtesy Ron Henke

The second telescope that is part of the Kitt Peak tour is the **2.1-m telescope**, pictured at left. When it saw first light in 1964, it became the largest on Kitt Peak for almost a decade. It had an unusually short focal length and a mirror made of a brand-new material called "Pyrex" whose weight was lessened by empty cavities inside the glass. In many ways, this telescope design was ahead of its time.

Numerous important discoveries were made using the 2.1-meter. It was the first to detect very distant clouds of hydrogen gas between galaxies, known as the Lyman-alpha forest. It observed the first example of gravitational lensing (as predicted by Einstein) and the first pulsating white dwarf star. According to the National Optical Astronomy Observatory (NOAO) website, research on the rotation rate of spiral galaxies that began at the 2.1-meter eventually led to our current understanding of the existence of dark matter in the Universe.


Mayall Telescope. Courtesy Ron Henke

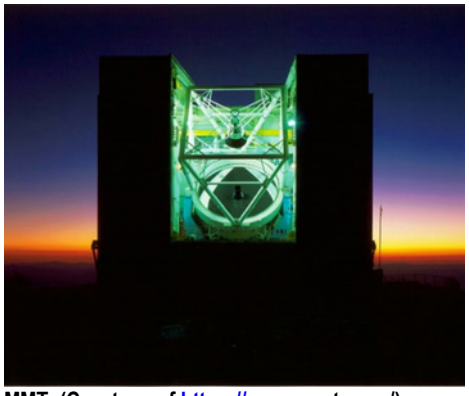
The last of the three telescopes open to the public on Kitt Peak is the 4-m Mayall Telescope. At the time of its first light in 1973, the Mayall 4-Meter Telescope was the second largest in the world. Today, it remains the largest telescope on Kitt Peak. The 180-foot dome is easily visible from Tucson, 55 miles to the northeast. For more than 40 years, the Mayall has been used in cutting-edge astronomical research, most notably understanding the size and large-scale structure of the visible universe. Currently, much of its time is spent in research on exoplanets (planets that orbit stars other than the Sun). According to the NOAO.edu website, future plans for the telescope involve a multiyear dedicated research project that hopes to unlock some of the secrets of dark energy.

Mount Hopkins

Like Kitt Peak, Mount Hopkins hosts a number of observatories. The following discussion focuses on the Multi-Mirror Telescope (MMT), the largest on the mountain. According to the MMT website, the 6.5-m (21-ft) diameter MMT is operated by the MMT Observatory (MMTO), a joint venture of The Smithsonian Institution and the University of Arizona. The MMT is located on the summit of Mount Hopkins approximately 47 miles south of Tucson on the grounds of the Smithsonian's Fred Lawrence Whipple Observatory, along with a number of Smithsonian-operated telescopes.


MMT. Courtesy of https://www.mmto.org/

At an elevation of 2,616 m (8,585 ft), Mount Hopkins is the second highest peak in the Santa Rita range of the Coronado National Forest. At this elevation, the MMT is positioned above the Earth's lower atmosphere, which helps reduce the impact of atmospheric effects (i.e. "seeing") on the image quality at the telescope.



MMT. (Courtesy of https://www.mmto.org/)

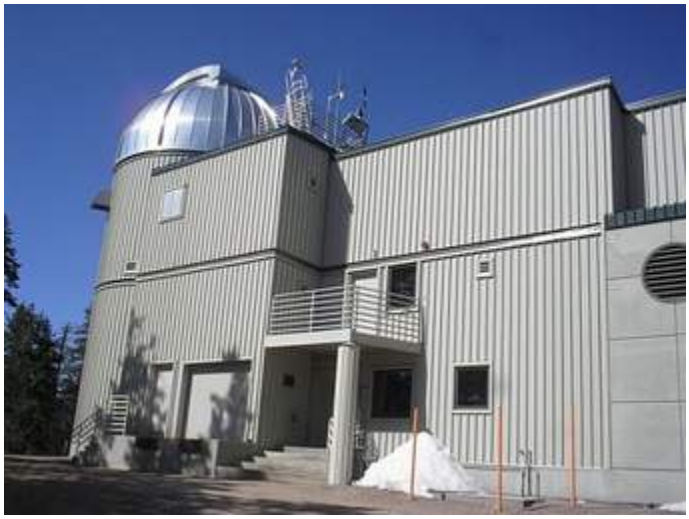
While the telescope today is a 6.5-m single-lens instrument, it didn't start out that way. The MMT Observatory came into existence using six 1.8-m mirrors to provide an effective aperture of a 4.5-m telescope, which, at the time, was the third largest telescope in the world. However, the innovation didn't stop at telescope design; it was the first telescope to be housed in a rotating building and to be supported on ball bearings rather than hydrostatic bearings.

After 19 years of productive operations, progress in the production of large mirrors (pioneered at the University of Arizona's Mirror Lab) and new instrument technologies drove the desire to upgrade the telescope to use a single 6.5-m mirror in place of the smaller six-mirror array. The conversion would more than double the light-gathering power of the telescope and increase the area of sky the telescope could observe at one time by a factor of more than 300. The original telescope was decommissioned in March 1998. The telescope enclosure was modified, the optics support structure was replaced, and a single 6.5-m primary mirror was installed. The new telescope was renamed simply the "MMT," which is no longer an acronym. The telescope, with its new lens, went into operation in 2000.

Mount Graham

The third important area in southern Arizona for observatories is Mount Graham, which houses three observatories—the Large Binocular Telescope (LBT); the Heinrich Hertz Submillimeter Telescope (SMT), and the Vatican Advanced Technology Telescope (VATT).

Linda Billard wrote an excellent article on the LBT in January 2016 edition of the *StarGazer*. Please refer to that article for more information about this unique telescope.



The VATT. (Courtesy http://www.stimmen-der-zeit.de/zeitschrift/online_exklusiv/details_html?k_beitrag=3692531)

The VATT is also a one-of-a-kind instrument. It is a 1.8-m, f/1.0 telescope. The primary mirror is so deeply dished that the focus of the telescope is only as far above the mirror as the mirror is wide, thus allowing a structure that is about three times as compact as the previous generation of telescope designs. The VATT conducts research in many areas, including planetary sciences, exoplanets, stellar astronomy, galaxies, and cosmology. I recently attended a talk by the director of the VATT, Bro. Guy J. Consolmagno, S.J. I found the Catholic approach to science and religion to be enlightened and modern.

For fans of radio astronomy, the Submillimeter Telescope (SMT), formerly known as the Heinrich Hertz Submillimeter Telescope, is a submillimeter wavelength radio telescope located on Mount Graham. It is a 10-m-wide parabolic dish inside a building to protect it from bad weather. The building's front doors and roof are opened when the telescope is in use. The telescope was completed in 1993. Along with the 12-Meter Telescope on Kitt Peak, this telescope is maintained by the Arizona Radio Observatory, a division of Steward Observatory at the University of Arizona.

The SMT. (http://aro.as.arizona.edu/ Photo courtesy of Dave Harvey)

The dryness of the air around and above Mount Graham is particularly vital for EHF (extremely short wavelength radio) and far-infrared observations—a region of the spectrum where electromagnetic waves are strongly attenuated by any water vapor or clouds in the air.

This telescope is used 9 to 10 months of the year, and it is stowed only when there is too much water vapor in the atmosphere, primarily during the summertime. This telescope is one of the telescopes that make up Mount Graham International Observatory.

Conclusion

This is just a sample of the observatories in Arizona. All the observatories mentioned here are in southern Arizona. Most are open to the public, but the times of the year vary, so please check the appropriate websites. If you are coming, let us know. We would love to show you around!

Highlights of Recent RAClub Presentations

Abstracted from Bart Billard's Meeting Minutes

May 2017—Photography of Satellites

Tom Watson's presentation dealt with photographing manmade Earth satellites. His reasons for imaging satellites included that they were interesting and fun to see, and they were good for introducing beginners to astronomy. He also said it was rewarding to see what he could learn. He gave an example of photographing a North Korean satellite after seeing statements indicating it was tumbling that were then contradicted by North Korea. He was able to see for himself that it was tumbling.

Tom then addressed what things affected being able to see and photograph a satellite. First, he mentioned the darkness of the sky and other things affecting astronomy, such as clear skies and transparency. He said conditions were better when the Sun was near, but below, the horizon, for example after sunset or before sunrise. He said getting an image of a satellite could be as easy as pointing the camera up (west after sunset or east before sunrise) and taking a 10-second exposure while the sky was just dark enough for it.

Low Earth orbit satellites are easier to see, but not late at night, while higher satellites can be seen later, but are not as bright. They include lots of scientific and communication satellites with orbital periods of about 4 hours. Tom said geosynchronous satellites, with 24-hour orbits, could be seen any time of night, and there were some satellites with higher orbits taking more than 24 hours. He said these satellites, some the size of a minivan, were very hard to see, and he had had numerous comments online claiming it was impossible when he posted images of them. He explained how a minivan-sized satellite could be visible at 25,000 or more miles, pointing out the overheating effects of sunlight in a vacuum without filtering by Earth's atmosphere that made it necessary for the satellites to be shiny. Tom said a lot of satellites were about third to fifth magnitude, which one could see by eye in dark conditions, and definitely with a telescope, assuming the Moon was not up. He noted that satellites did not light themselves, and we would not see that light if they did. Instead they reflected light, usually from the Sun. He said reflections could be an effect of scattering or sometimes a "flare" in which a flat surface of the satellite aligned to reflect sunlight right at the viewer. A very high satellite could sometimes do this in the middle of the night. Tom said you could also see a satellite by silhouette, usually against the Moon but also against the Sun if you had filters to safely

view it. He warned it should only be tried with proper equipment and mentioned that the dedicated, narrow-band hydrogen alpha telescopes, one of which the club had available for loan, would work best.

For photographs, Tom recommended a DSLR camera, along with a tripod, and added that some cell phone cameras would work at night. He recommended using the camera timer even with a tripod because pressing the release on the camera could still cause blur even on a tripod. Certain tripods, Tom said, could be made to track satellites. He recommended adjusting the white balance, and a color temperature setting of about 5,500K would be a good setting. Tom said you could use the "kit" zoom lens that came with your camera and try about a 3-second exposure with wide-open aperture and relatively high ISO. You could then focus on a star while zooming in using the display on the back, and then set the timer release to take the picture. He showed some fancier, but still inexpensive, lenses. They included a very wide angle 8-mm lens, a fast f/2 lens, or a wide-angle converter you could screw onto your own lens, if you didn't mind distortions around the edges. Filters were also useful, Tom said. He had a $20 red filter that could get rid of the yellow sodium line of a lot of light-pollution sources.

Tom concluded with a selection of images on his laptop. First he showed some "not-satellites:" airplanes that showed dashed lines instead of a continuous streak and a firefly that looked somewhat like a meteor. As he showed satellite images, he told us how you could use the free planetarium program, Stellarium, to identify satellites you found. It could simulate the location, time, and the area of the sky in the image and would show the satellite passing by. You could then click on it to get identification. One of his satellite images was the North Korean satellite he mentioned earlier. Don Clark asked Tom what he thought about the news that some companies wanted to put thousands of satellites in orbit. Tom agreed it would be really bad for astrophotography as well as astronomy to have satellites going through images all the time.

June 2017—The Sun

Scott Lansdale began his program with some statistics. The Sun's diameter is 109 times that of Earth, and it rotates once every 25 to 35 days, depending on the proximity to its equator. (Sunspot motion takes longer in the equatorial zone.) The composition is 74.8 percent hydrogen, 25 percent helium, and 0.1 percent everything else. The temperature at the surface is 10,000° Fahrenheit and ranges down to 6,300° Fahrenheit in sunspots.

Scott said the internal structure of the Sun includes the core, the inner 20 to 25 percent of the radius where nuclear fusion supplies the energy to keep the Sun shining, followed by a radiative zone, then a convective zone. Outside the surface layers, the corona is very hot—higher than the temperature of the core. Scott showed a Hertzsprung-Russell diagram of stars plotted against their color (representing temperature) and luminosity, or brightness as they would appear at the same distance from us. Stars on the "main sequence" (leaving out the red giants and white dwarfs) of his diagram ranged from dim red stars near the lower right to bright blue stars near the upper left. Glenn Holliday brought up the question, "Why are there no green stars?" We could see red, orange, yellow, white, and blue, but not really any green on the diagram. Glenn Holliday explained that although green was where the eye was most sensitive, it was a narrow range of the spectrum, especially compared with red, yellow, or blue.

Glenn said he had done a daytime outreach observing the Sun for about 10 hours, and he was able to see changes in the appearance of sunspots. He also described two historical magnetic storm events, one in the 1860s and one in the 1970s. The first caused damage to telegraph stations, and the second caused power outages in Canada.

Scott next talked about observing the Sun. He started with the warning never to look directly at the Sun. Always use solar filters, protective eyewear, equipment designed for solar observing, or a pinhole camera. Scott mentioned some of the satellites that were monitoring the Sun. He said the Parker Solar Probe, named for Eugene Parker, was scheduled for launch in 2018 and would go through the Sun's atmosphere at 4 million miles from the surface. Scott said it had a 4-1/2 inch thick carbon composite shield. It would try to find more about how energy moves through the corona and what drives the solar wind.

Scott's final topic was solar observing via amateur radio astronomy. He mentioned his radio astronomy group, the Society of Amateur Radio Astronomers (SARA). It meets in West Virginia each year in June or July. Scott said SARA offered an inexpensive kit for monitoring sudden ionospheric disturbances (SIDs) caused by solar activity. X-rays from a coronal mass emission event affect the ionosphere, causing changes in very low frequency (VLF) signal reception. Scott showed recordings from his antenna and amplifier made on his computer and pointed out some features showing variations from day to night and disturbances from solar activity. He said VLF signals were used because they could go even farther than AM band signals.

July 2017—Astronomy in the News

The program started with discussion of the solar eclipse coming to the United States in August. Scott Lansdale said apart from one eclipse that crossed a corner of the United States in 1991, the last eclipse crossing a significant part of the country was in 1979. Linda Billard passed around a set of stamps issued by the Postal Service for the eclipse. They feature a photograph of a total eclipse and are the first use of thermochromic ink for stamps. When warmed by a thumb, an image of the Moon appears where its silhouette blocks the solar disk. One member said he was going to Greenville, SC, for the eclipse. He said he had considered a hike on the Appalachian Trail into the path of totality but decided on something less strenuous out of consideration for his wife. A visitor recommended an overlook near Huckleberry Knob in Nantahala National Forest as a high location from which to see the approaching shadow. Tom Watson said he would be at home to do spectroscopy of secondary x-rays and gamma rays produced as protons from the Sun strike the upper atmosphere. He was interested in what effects he might find from the Moon possibly intercepting protons headed for the atmosphere around him, and he said he did not have enough portable power to operate his instruments.

Scott mentioned learning about Eclipse Mob from Linda. It is a citizen science project to monitor ionospheric effects on radio propagation and what changes might occur because of the eclipse. Scott said it was a similar approach to his Sudden Ionospheric Disturbance (SID) radio astronomy project but was using different frequencies. He said he was interested in running his SID recorder, and Tom proposed comparing their data afterward.

Don Clark emphasized the advice to be aware of what is going on around you during totality (and not be glued to an instrument). A visitor said he had found a discussion comparing sunlight at various stages before totality with what the sunlight is like on Mars, saying there should be a certain time before totality when the sunlight intensity is like that on Mars. At other times closer to totality, it would be like sunlight on more distant planets. Don passed around glasses provided by the Night Sky Network for viewing the eclipse. He also passed around some cards with a pinhole that could be used to project an image during the partial phase. Some people present were interested in how to get pictures. One was thinking of using one camera with a filter during the partial phase, then during totality taking the lens cap off the other to get pictures. Bart Billard wondered whether he might be able to mount the camera to the same tripod so the one with the lens cap would be reasonably well aimed when he was ready to use it. The visitor who spoke earlier about Huckleberry Knob also asked whether the club had arrangements for a regular observing location members could use. He said he belonged to NOVAC, which has a number of such sites where members have permission to go after hours for observing and suggested it would be worthwhile for the club to approach one of the counties to look into getting such an arrangement. Glenn Holliday asked whether some members would consider going to Caledon for the partial eclipse. Two members expressed interest in going. As we turned to other astronomy news, Scott ran a simulation on the projector screen showing the Moon's shadow following the path of the eclipse across the United States.

Arecibo Observatory (Source: http://outreach.naic.edu/ao/about-0

Glenn offered a news item on the red dwarf star Ross 128. He said astronomers at Arecibo Observatory in Puerto Rico detected a signal they had never seen before and could not immediately explain. The report indicated more data had been obtained from further observing, and it suggested a press release would come out on Friday and might have an explanation of the signal. Glenn also said he saw news indicating the Mars Orbiters are both getting up in age and may not be able to support communication with Mars rovers much longer. (If the Mars 2020 mission arrives in 2020, Mars Odyssey will be 19 years old. The Mars Reconnaissance Orbiter will be 14, and NASA does not currently have plans for the next communications orbiter.)

Image of the Quarter

Lagoon Nebula (M8) by Jerry Hubbell

On 27 May 2017 0455 UT, Jerry took this beautiful image remotely using the Mark Slade Remote Observatory. Equipment: Explore Scientific 6-inch refractor 152 ED APO CF, 851 mm FL f/5.6, with a 0.7x focal reducer and the QHY163C CCD camera. The image is 18 x 5-min sub-frames stacked. Total exposure was 1 hr 30 min.