http://www.raclub.org/

The StarGazer

Newsletter of the Rappahannock Astronomy Club No. 2 Vol. 10 August–October 2021

Virtual Stargazing Program Coming!

By Myron Wasiuta

NGC 7635 "Bubble Nebula" *Courtesy Myron Wasiuta*

As mentioned in an email and at the last RAC meeting, I will soon begin a live virtual stargazing program using the telescopes at the Mark Slade Remote Observatory (MSRO) and employing a Zoom session format.

Because the weather is somewhat unpredictable, I will send out a brief description of each of these programs in advance (see box at the end of this article for a description of the first program), but the actual date and time will be determined by the weather. I hope to be able to give 1–2 days advance notice. However, if you miss the live session, the programs will be recorded so you can view them after the fact. These programs are intended for all ages, and previous observing experience is definitely not needed.

NGC 7789 "Caroline's Rose" *Courtesy Myron Wasiuta*

Anyone in the club can participate. All that's needed is a computer or smartphone and an Internet connection. The format will be interactive, starting with an opening summary of the night's observing targets and orientation to the constellation containing the targets we will observe. I will incorporate live views not only of the target deep sky objects, but wide angle views of the sky itself as recorded by the MSRO SkyCam. These SkyCam views will allow participants to see the entire constellation and better appreciate the relative location of the deep-sky objects we will be observing.

To ensure these "virtual star parties" are an informative as well as entertaining experience, participants will be free to ask

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How to Join RAC

RAC, located in the Fredericksburg, Virginia, area, 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. Most RAC members are from the Fredericksburg area, including, but not limited to, the City of Fredericksburg and the counties of Stafford, Spotsylvania, King George, and Orange. We also have several members who live outside Virginia and have joined to have the opportunity to use the Mark Slade Remote Observatory (MSRO)—one of the benefits of membership.

RAC 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**. Our website, www.raclub.org is the best source of information on our events.

The StarGazer
August–October 2021
Published Quarterly by Rappahannock Astronomy Club
Editor: Linda Billard

Website: www.raclub.org
Groups.io: Members-only group. When you join RAC, you will receive an invitation to join from the RAC President.

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Options for Dues Payment

RAC annual membership is $20 per family. Student membership is $7.50. You can now pay your dues in two ways. (For reference, the RAC membership year is January–December.) If you join anytime in the last quarter, your membership covers the upcoming year. Astro League dues run July to June.

- **By Mail:** Make out a check to RAC Treasurer and send it to Matthew Scott, RAC Treasurer, PO Box 752, Fredericksburg, VA, 22404-0752. Both new and renewing members should also print out the membership application here, fill it out, and return it with their payment to keep our records up to date.
- ***By PayPal***: You can also pay your dues online. Simply go here, scroll down, and select the appropriate membership type from the dropdown box and click *Pay Now*. You do not need to complete an application because the notification the club receives of your payment will contain all the additional info needed. NOTE: If you pay using PayPal, your actual charge (including the PayPal usage fee) will be: Single/Family $21.23, Student $8.28, Single/Family & AL $29.00, Student & AL $16.05.

Upcoming Events*		Recent Events Completed	
Star Party, Caledon State Park	November 13	Star Party, Caledon State Park	August 14
Star Party, Caledon State Park	December 11	Star Party, Caledon State Park	September 4
		Star Party, Caledon State Park	October 2

*Our Caledon star parties are now public again! However, please check the website raclub.org for updates. To attend a RAC meeting via Zoom, email president@raclub.org for an invitation.

President's Corner

Dear Members,

RAC Star Parties are once again open to the public. Friends, guests, scouts, and school groups are welcome. Unfortunately, attendance has been very poor. If we want to continue to offer star parties to the public, member participation will have to improve. Non-members and large groups should contact a club officer before attending to make sure the Star Party hasn't been cancelled and that there will be members available to provide guidance and assistance.

RAC will continue to conduct its business meetings via Zoom Video Conferencing for the foreseeable future. I send Zoom meeting invitations to all RAC members via BCC eMail. Non-members may also participate by sending me a request at president@raclub.org.

The annual election of club officers will take place during the November 17 business meeting. Nominations for the four club officer positions opened in October, but you may still nominate someone before the elections are held. Please consider nominating someone or offering to serve as a club officer yourself. The more we contribute our time and talent, the better RAC will be able to serve its members and the community.

May God bless you with transparent skies and excellent seeing.

Glenn Faini
President

Did You Know? by Scott Busby

The Chaldeans learned to predict eclipses of the sun and moon as early as 2000 B.C., fifteen centuries before the Golden Age of Greece. They likewise discovered that eclipses went in a cycle of 18 years and 11 days. The first astronomers whose names are preserved in written history are the Chaldean astronomers, Naburiannu and Kidinnu.

These early studies of astronomy were important for themselves; but more important because they taught men the existence of the laws of nature, and so paved the way for the scientific method. Civilization literally was founded in the heavens.

Source: *The McDonald Telescope, Commemorating the Dedication and the Formal Opening of the McDonald Observatory of the University of Texas May Fifth, 1939*, The Caxton Company Cleveland, The Warner Swasey Company 1939.

Virtual Stargazing Program Coming! *(from page 1)*

questions and share observing experiences. Because the targets for the upcoming observing experience will be sent out in advance, members with telescopes can try locating the objects before the online session and will be invited to share their results online during the event. In addition, while we are observing the object, I will share information about each object we are observing taken from various field guides and reference sources. These sources will include *Burnham's Celestial Handbook* (Robert Burnham, Jr., Dover), *The Night Sky Observer's Guide* (George R. Kepple and Glen W. Sanner, Willmann-Bell), old issues of *Sky and Telescope* and *Astronomy* magazines, and other sources from my library.


NGC 457 “ET Cluster”

The sessions will be 60–90 minutes. There may be some glitches at first, but as we get more experience with this format, I think the sessions will run smoothly. Prior to each event, a Zoom link will be sent out via the RAC “groups.io” list. If you are not on the list, go here to become a RAC member, and you will receive an invitation to join the RAC groups.io group. This will keep you up to date on these RAC Virtual Stargaze programs as well as all RAC activities and special events.

And with that, here is the first session topic...

RAC Virtual Stargaze—The Clusters of Cassiopeia

Situated in a rich expanse of the northern Milky Way, Cassiopeia is a constellation replete with galactic star clusters, emission nebulae, and even a few galaxies. Our tour will feature examples of each of these objects, as well as an interloper known as Nova Cassiopeia 2021.

Targets we will try to observe include:

M52-galactic star cluster
NGC 7635 "Bubble Nebula"
N Cas 2021-a most unusual classical nova that erupted in March 2021 and is still visible in telescopes
NGC 7789 “Caroline’s Rose”
Iota Cassiopeia—beautiful triple star system
NGC 457 "ET Cluster"
NGC 147/185 (distant companions to the Great Andromeda Galaxy)
M103 “Christmas Tree Cluster"

Hope to see you at this event! (Editorial Note: See Picture of the Quarter at the end of this newsletter, for a photo of M103, the Christmas Tree Cluster.)

Astronomy Math—The Next Level (TNL)

By Scott Busby

As most readers of the *StarGazer* newsletter know, I have written a series of articles demonstrating math associated with astronomy. Most of these were simple math problems such as determining the focal ratio of a telescope/camera combination or perhaps the force of gravity on the Voyager spacecraft as it leaves Earth's influence. And of course, I re-familiarized readers with the use of scientific notation to make really big numbers easier to grasp by using exponents.


Courtesy Scott Busby

As I progressed in these articles, I quickly understood that astronomy math moves rapidly from simplistic problems to very complex equations that, in the end, help define our universe. In this new series—Astronomy Math TNL—I'll move gingerly up the ladder of complexity and try to maintain a reasonable level of understanding. To help me get started, I will use someone we all are familiar with: Mr. Isaac Asimov.

Most science fiction readers have, at one time or another, read Isaac Asimov's stories. For science fiction or science writers to succeed in their work, they must possess—beyond their writing talent—a basis of understanding steeped in the fundamentals of how the Universe works. Mr. Asimov certainly understood the fundamentals, and I intend to enlist his talents in this new Astronomy Math series.

Asimov regretted never having taken an astronomy class. However, occasionally, he would come across an interesting astronomy article or book. It would amaze him learning about astronomy just as you or I might be amazed reading any one of our personal library books on the same subject. He pointed out that if he had had formal training in the field, then these items would have been old news and he would have not had these moments of delight.

In one case, Asimov came across a text in astronomy, *Introduction to Astronomy* by Dean B. McLaughlin (Houghton Mifflin, 1961). Professor McLaughlin intrigued him so much with his comments on Kepler's harmonic law that he devoted much time to thinking about it. He began by answering the question: What is Kepler's harmonic law? I'll share that with you here as the first lesson in "Next Level."

In 1619, the German astronomer Johannes Kepler discovered a neat relationship between the relative distances of the planets from the Sun and their periods of revolution about the Sun.

For two thousand years, philosophers had felt that planets were spaced at such distances that their movements gave rise to sounds that united in heavenly harmony ("music of the Spheres"). This was analogous to musical instruments' strings of different lengths producing a sound beautifully united in harmony when simultaneously struck.

For that reason, Kepler's relationship of distances and periods, usually called, with scientific dullness, "Kepler's third law" (since he had earlier discovered two other important generalizations about planetary orbits) is also called, much more romantically, "Kepler's harmonic law."

The law may be stated thus: "The squares of the periods of the planets are proportional to the cubes of their mean (average) distances from the Sun."

To get at the consequences of this law, we must get slightly mathematical. (You knew it was coming.) Let's consider two planets of the solar systems, planet-1 and planet-2. Planet-1 is at a mean distance D_1 from the Sun and planet-2 is at a mean distance D_2. Their periods of revolution are, respectively, P_1 and P_2. Then, by Kepler's harmonic law, we can say that:

$$P_1^2 / P_2^2 = D_1^3 / D_2^3 \quad \text{Eq–1}$$

This is not a very complicated equation, but any equation that *can* be simplified *should* be simplified, and that's what we do next. Let's pretend that planet-2 is Earth, and we are going to measure all periods of revolution in years and all distances in astronomical units (A.U.).

The period of revolution of the Earth, by definition, is 1 year; therefore, P_2 and P_2^2 both equal 1. Then, too, the astronomical unit is defined as the mean distance of the Earth from the Sun. Consequently, the Earth is 1 A.U. from the Sun, which means that D_2 and D_2^3 both equal 1.

The denominators of both fractions in this equation (Equation 1) become unity and disappear. With only one set of P's and D's to worry about, we can eliminate subscripts and write Equation 1 simply as follows:

$$P^2 = D^3 \quad \text{Eq–2}$$

Remember to express P in years and D in astronomical units.

To show how this works, let's consider the nine major planets of the solar system (yes, Pluto in this article is a major planet), and list for each the period of revolution in years and the distance from the Sun in astronomical units (*see* table at right). If, for each planet, you take the square of the value under P and the cube of the value under D, you will find, indeed, that the two results are virtually identical.

Planet	P (Period of Revolution in Years)	D (Mean Distance in A.U.)
Mercury	0.241	0.387
Venus	0.615	0.723
Earth	1.000	1.000
Mars	1.881	1.524
Jupiter	11.86	5.203
Saturn	29.46	9.54
Uranus	84.01	19.18
Neptune	164.8	30.06
Pluto	248.4	38.52

Of course, the period and distance of any given planet can be determined separately and independently by actual observation. The connection between the two, therefore, is interesting but not vital. However, what if we can't determine both quantities independently. Suppose, for instance, you imagined Planet Q between Mars and Jupiter at just 4 A.U. from the Sun. What would its period of revolution be? From Equation 2, we see that:

$$P = \sqrt{D^3} \quad \text{EQ-3}$$

and therefore, we can answer the questions easily. In the case of Planet Q, the period of revolution would be the square root of the cube of four, or just 8 years.

You can work it the other way round, too, by converting Equation 2 into:

$$D = \sqrt[3]{P^2} \quad \text{EQ-4}$$

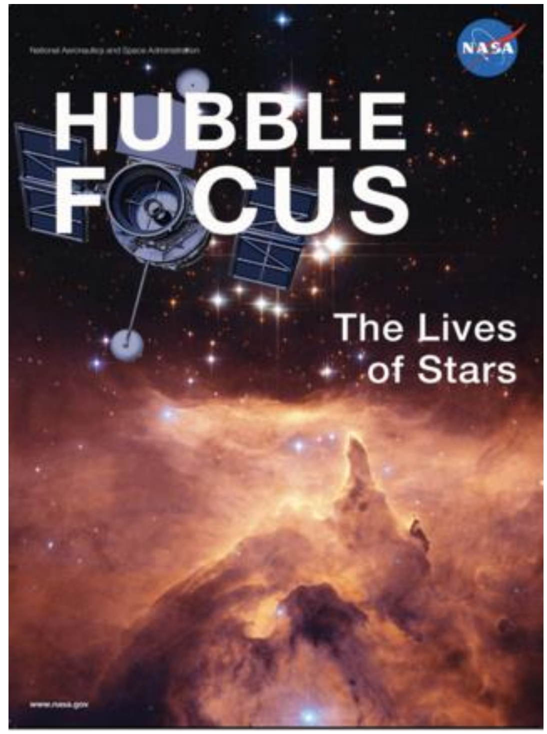
You can then find out how distant from the Sun a planet must be to have a period of revolution of 20 years or of one million years. This gives you an answer of 7.35 A.U. for the first case and about 10,000 A.U. for the second.

In the next newsletter we'll have some fun by seeking some extremes. For instance, how far out can a planet be and still be a member of the solar system?

Source: *Asimov on Astronomy*, Isaac Asimov, Bonanza Books, New York, 1979—Paraphrased except where the Asimov quotes other works or examples. In this case, the mathematical problems are described verbatim.

Hubble Focus: The Lives of Stars—A Review

By Linda Billard



I recently stumbled across a NASA publication easily available as a free download. This beautiful and informative e-book is part of a series called Hubble Focus. The current volume, *Hubble Focus: The Lives of Stars,* highlights some of the Hubble Telescope's more recent discoveries about the birth, evolution, and death of stars. It includes stories discussing the science associated with those discoveries, illustrated, of course, by the relevant Hubble photos. An example is the piece called "Observing Star Birth Fueled by a Supermassive Black Hole," which is illustrated with the composite of Hubble, Chandra, and VLA data showing visible light, x-ray, and radio emissions. The book also includes active links to videos. An example is "Zooming in on Shrapnel from an Exploded Star," which focuses on a part of the Veil Nebula where the remnants of a star that exploded thousands of years ago are visible.

This book brings together, at a high level, some of the recent breakthroughs that Hubble's photography has helped facilitate and offers links and references for addition information. Download it and see!

Staunton River Star Party

By Troy Major

Staunton River State Park is certainly a beautiful park, but it's definitely "out in the sticks." Good for astronomy but a long way to drive. The park has some very dark skies, which would have been awesome to do some observing. However, Mother Nature decided not to cooperate and brought in some heavy cloud cover. Most of the people who had been there all week had already left Thursday afternoon because forecasters were calling for rain all weekend. I went to the park on Friday all day and met Jim Browder from the Richmond Astronomical Society. The park has a nice restaurant with some pretty good food. I also saw some very nice equipment setups. The home-built 6-inch refractor was huge. Sadly, I left Saturday morning because the rain set in Friday night. This site is certainly worth the trip if the weather is firmly predicted to be good. I took a few pictures when I got there to give you a feel for the place.

New Exoplanet Section at ALPO

By Jerry Hubbell and Linda Billard

Jerry Hubbell is currently working to stand up a new section of the Association of Lunar & Planetary Observers specifically intended to support exoplanet observation, analysis, and reporting. This article describes the intent of the new organization and how its goals will be achieved. Whether you are a beginner interested in learning about exoplanets or an experienced exoplanet chaser, contact Jerry at [jerry.hubbell@alpo-astronomy.org\\](mailto:jerry.hubbell@alpo-astronomy.org).

Starting a new observing section for a well-respected organization such as the Association of Lunar & Planetary Observers (ALPO) can be a challenge but also an opportunity. It relies on existing members who are very experienced in doing related observations of minor planets, variable stars, and other celestial objects to obtain the best data possible using small telescopes with advanced instrumentation.

Logo courtesy of Rachel Good

Why does ALPO need a new exoplanet section? What makes this program different from any of the other groups that already have exoplanet sections or programs, such as the American Association of Variable Star Observers (AAVSO), and the British Astronomical Association (BAA)? The answer forms the design basis for the ALPO exoplanet section.

The challenge of getting into exoplanet observation is that it requires potential observers to reexamine their instruments and equipment, the procedures currently used, and their analysis processes. All these need to be updated to be successful in doing transit photometry. For this reason, the structure of the exoplanet section focuses on these fundamental differences and needed improvements. The logo for the new exoplanet section incorporates this notion.

The exoplanet section is currently in a 2-year probation period during which the ALPO leadership is monitoring the progress of the section. The initial goals are related to three fundamental areas: Instrumentation, Observation, and Analysis. The plan includes creating the following groups within the section, with assistant coordinators assigned to each:

- Instrumentation Group
- Observing Program Group
- Analysis & Modeling Group
- Exoplanet Data Reporting Group
- Exoplanet Observation Training Group

Instrumentation Group

The instrumentation group is listed first because instrument performance is fundamental in obtaining the high-precision data to successfully observe, measure, and model exoplanet transits. The primary goal of the group is to define and demonstrate valid instrument configurations and components, including selecting off-the-shelf instruments, determining configuration settings and parameters, and researching the use and application of new instrument systems, subsystems, and components. The group members also need to understand and measure the different sources of error caused by the instruments used for observing exoplanet transits. The group will help further define and assist other members of the exoplanet section in learning what a successful instrument system configuration looks like and what is needed to get the best results.

Observing Program Group

The observing program group is concerned with developing and refining the observing plans, processes, and procedures used by members to obtain the best exoplanet transit data. Its primary goal is to provide the needed resources for members to easily identify exoplanets to observe, develop the information needed to acquire the observations, and do the analysis of the observations for specific exoplanets. Members of the observing program group will also have a way to submit their data to members of the analysis and modeling group to perform the analysis and develop results based on their data. This creates a collaborative structure across the groups within the exoplanet section.

Analysis and Modeling Group

The analysis and modeling group members want to learn how to process the data acquired during their own observation runs or, perhaps, how to process and analyze other members' data. This group will provide resources and services to other members of the exoplanet section for their use. These resources will include currently freely available analysis tool configuration files, data analysis examples, and training materials.

Exoplanet Data Reporting Group

The primary role of the exoplanet data reporting group members is to coordinate the transfer of data and analysis results to those external professional and other organizations that want and need the data our section members create. The reporting group will facilitate all section members in creating datasets and narrative reports for publication in the section newsletter *The Exoplanet Observer* aka TEO, and in the quarterly *JALPO* publication. The group will also be responsible for publication of the section newsletter every month and management of the ALPO webpage for the exoplanet section. *The Exoplanet Observer* will cover the following items every month:

- Latest exoplanet developments and discoveries
- Online and in-person meetings schedule
- Member observation reports
- Instrumentation and Equipment
- Observing and analysis procedures and techniques
- Education corner: discussion of exoplanet transit observing terminology, methods, and resources
- Member presentations and paper submissions.

Additional reporting areas will be developed, and changes to this basic outline may occur over time based on suggestions submitted by the members.

Exoplanet Observation Training Group

The exoplanet observation training group will provide documents, procedures, presentations, and other training material developed by the section needed to learn how to observe and analyze transit data and report exoplanet transit observations. The training group members will also maintain contact with the larger exoplanet observing community to share results with the industry and to bring best practices and relevant information back to the exoplanet section for implementation as desired.

The group will also develop multimedia training materials, including videos and presentations, and may hold live training sessions to foster a more collaborative and active training environment. The training group members will be directly involved with and contribute to the other groups on an as-needed basis.

In Summary

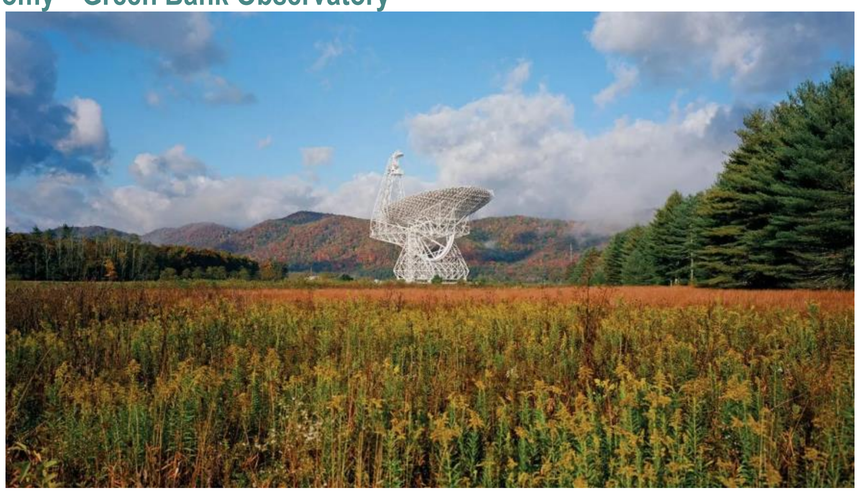
Becoming an active member of the new ALPO exoplanet section offers not only a challenge and an excellent learning opportunity but the chance to contribute to cutting-edge astronomical observing techniques for small telescope systems. If you want to join the exoplanet section, contact me at jerry.hubbell@alpo-astronomy.org and also let me know if you would like to be considered for an assistant coordinator position.

Highlights of Recent RAClub Presentations

Abstracted from Bart Billard's Meeting Minutes
NOTE: There was no presentation in August. Synopses of the September and October presentations are below.

September 2021—Tour of Radio Astronomy—Green Bank Observatory

Sue Ann Heatherly, Green Bank Observatory senior education officer, gave a presentation on the radio telescopes at Green Bank as a "Tour of Radio Astronomy." She began with the Robert C. Byrd Green Bank Telescope (GBT), which is in a valley surrounded by mountains. The mountains help shield the GBT from interference from nearby radio sources. That is why radio telescopes are not on top of mountains. The Green Bank Observatory's mission is "to develop and operate state-of-the-art instruments for use by scientists at universities and institutions in the U.S. and around the world."



Green Bank. Courtesy: *Highland Outdoors Magazine https://highland-outdoors.com/green-bank-observatory-wild-wonderful-radio-quiet/*

As she showed time-lapse video of the GBT in operation, Sue Ann said that sometimes it moves steadily to track an object, and sometimes it wiggles. She explained that it is like a single-pixel camera, wiggling back and forth to build an image of an area of sky. It does not use pixel arrays like an optical telescope camera does. The GBT covers a large frequency range (100 MHz to 100 GHz) by rotating different receivers into place at the focus. The telescope operates 24/7, apart from maintenance periods. Although it never points directly at the Sun, the GBT can safely point within a few degrees, and at radio frequencies, the sky is just as black as at night. She illustrated a similarity between radio astronomy and optical astronomy using a chart showing how well various wavelength ranges of the electromagnetic spectrum penetrate Earth's atmosphere. It showed the optical and radio wavelength ranges used to observe astronomical phenomena from the ground. For any other wavelengths, we must put instruments in space at a much higher cost.

Sue Ann showed the Science Center at Green Bank with a couple of diesel buses parked outside. She explained that if you tour the facility in person, you ride these buses because they have no spark plugs. The observatory wants to eliminate the radio emissions from gasoline engines near the telescopes. In fact, she said all sorts of devices with computers, including cameras and cell phones, are a problem. Although cell phones get no signal there, if they are turned on, they generate stronger radio signals than those the radio telescopes observe from space. Sue Ann said the buses also carry Faraday cages to temporarily store devices that are difficult to turn off, such as Fitbits and some "smart shoes."

In addition to the active equipment, Green Bank houses two historical instruments. One is a replica of the antenna Karl Jansky built for Bell Labs to investigate use of the 14-meter band for radio telephones. Although he found static from thunderstorms was problematic for the telephone idea, he also discovered a source that tracked at a sidereal rate, thus revealing the possibility of radio astronomy. The other historical instrument is the first actual radio telescope, built by Grote Reber after he learned of Jansky's discovery. His design included the ability to change out the receiver for different types of observations. After making the first map of radio sources in the sky, Reber eventually disassembled his telescope. Soon after Green Bank was established, he offered to rebuild it there. It is near the Science Center and is a national landmark.

A map of the rectangular National Radio Quiet Zone around Green Bank shows its southeast corner extends to the University of Virginia campus in Charlottesville, its north side reaches the western tip of Maryland, and its southwest corner is near the border between Virginia and West Virginia. Sun Ann then showed the first telescope built there in 1957, with an 85-foot dish. She mentioned Green Bank was chosen by the National Science Foundation because of the surrounding mountains and low population, which was predicted to remain low. One of the first to use that telescope was a newly minted Cornell PhD, Frank Drake, who made measurements of the temperature of Venus and did studies of Jupiter. He also tried to look for signals that might reveal extraterrestrial intelligence, choosing two Sun-like stars, ε Eridani and τ Ceti. Later, he became a founding member of the Search for Extraterrestrial Intelligence (SETI).

Several other telescopes have operated at Green Bank. Sue Ann showed a 20-meter telescope built by the Naval Observatory for geodetic measurements. An array of these telescopes around the Earth observed quasars. Correlating their measurements revealed changes in the separation of pairs of the telescopes caused by changes in Earth's rotation or plate tectonics. After this telescope came to Green Bank, it became available for amateur astronomers to use at a Green Bank star party or through the Astronomical League's observing program. The next telescope she showed is the largest equatorial radio telescope, with a 140-ft diameter dish. At the time that Green Bank was founded, this telescope was planned to be the signature instrument there. However, the choice of an equatorial mount meant it took nearly 10 years to complete, in part because a spherical bearing 17 feet in diameter needed to be accurate to 0.003 inches. One of its strengths was discovering new molecules in space. In addition, two other dishes form an interferometer, a way of getting more resolution, both in radio and optical astronomy. (It's easier in radio astronomy.) These two dishes were the prototype for the Very Large Array (VLA) in New Mexico.

A transit telescope was also built to fill in for the delayed 140-foot equatorial telescope. However, when a gusset plate failed, it collapsed in 1988. Tabloid headlines at the time blamed the collapse on aliens. However, there was a "silver lining." Senator Byrd was able to get an emergency appropriation passed to build the GBT. The construction took 10 years because it had to be designed and built at the same time. The GBT is 485 feet tall,—a little shorter than the Washington Monument—and the dish has an area of 2.3 acres. A small dish at the top of the feed arm refocuses the radio waves and sends them down to the receiver room. Different receivers covering different wavelength ranges can be rotated into place. (For the lowest frequency receivers, a boom can swing out to place them directly in the prime focus between the small dish and the main dish.) The control room is 1.5 miles away and shielded to allow use of digital computers without causing too much radio interference at the telescope.

Sue Ann ended her presentation with pictures illustrating what radio telescopes can see and explained the mechanisms that generated the radio waves. First, she talked about hot gases in which electrons are ionized. They move freely, but their paths are bent or accelerated when they pass near a positively charged ion, and acceleration leads to the emission of radio waves. As an illustration, she flipped back and forth between an optical image of the area around Orion and a false-color radio map. The nebulae showed up and the stars disappeared when the radio map was displayed.

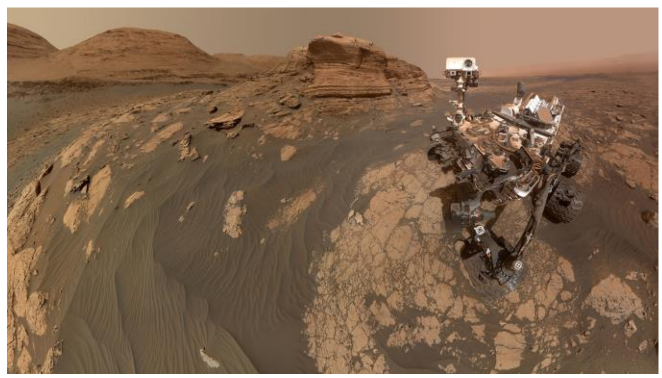
The second mechanism she discussed was spectral lines from atomic and molecular transitions. Typically, rotational transitions of molecules emit energy in the radio spectrum that allow detection of molecules in space. The 21-cm wavelength emitted by hydrogen atoms occurs when the electron's spin flips from parallel to that of the proton to the reverse, or antiparallel. She showed a galaxy in which the emission appeared at 1417.4 MHz instead of 1420.4 MHz. It was an example of the “red shift,” indicating the galaxy had a motion away from us of about 650 km/sec. She said the GBT could measure red shifts of galaxies in just a minute or two each.

Finally, electrons can be accelerated in magnetic fields. They spiral along field lines, and very fast electrons emit “synchrotron radiation” because of the acceleration. Sue Ann gave Jupiter as an example and showed maps of the emission concentrated in a doughnut-shaped region around the planet where the magnetic fields are strongest. Another example was a radio map of the Sun at a solar maximum. Blobs of strong radio emission appeared across the Sun’s surface above locations of sunspots. Sue Ann then talked about the study of pulsars, the neutron-star remnants of supernovae that have very strong magnetic fields that beam radio emission from the magnetic poles. We see pulses produced when the spinning star’s magnetic pole sweeps by in our direction.

The VLA has imaged many pairs of radio sources outside the Milky Way that look like jets emerging in opposite directions from a bright point in the middle. Usually, an optical image overlay of the region reveals a galaxy in the middle. Images of these “radio galaxies” indicate something is shooting material from the middle of the galaxies far out into space around them. The emission indicates interaction with extragalactic magnetic fields. Sue Ann said these were the first indications of the existence of black holes at the center of galaxies. She again showed the map of the radio sky made by the 300-foot telescope that collapsed. She explained all the bright dots in it were radio galaxies. They were too small to be resolved by the 300-foot telescope. The rings (supernova remnants) and other objects of larger angular size (nebulae) were all in our own Milky Way.

October 2021—Mars Rover Curiosity

Staff Engineer Ashley Stroupe started working at the Jet Propulsion Laboratory (JPL) in 2003 and on rover operations in 2004. This presentation focused on Curiosity. She said that trying to cover 6 years of Spirit, 14 years of Opportunity, and 9 years of Curiosity was too much for one presentation. She showed a side-by-side image of a shiny Curiosity at Sol 84 (84 Martian days after landing) and a dusty Curiosity at Sol 3070 (this fall). She said earlier rovers focused on geology and searching for evidence of water while Curiosity’s primary scientific goal is “to explore and quantitatively assess a local region on Mars’ surface as a potential habitat for life, past or present.” It is equipped to study geochemistry, with about a dozen instruments in its science payload. One is for multispectral imaging, and another is for identifying organic molecules.



Curiosity’s Selfie at Mont Mercou. NASA’s Curiosity Mars rover used two different cameras to create this selfie in front of Mont Mercou, a rock outcrop that stands 20 feet (6 meters) tall. *Courtesy NASA*

Curiosity’s landing site was in Gale Crater. Ashley mentioned the rover’s size led to a new, and at the time, frightening way of landing payloads on Mars. After a parachute slowed the descent, Curiosity was suspended from the descent stage that maneuvered it to the landing site, lowered it down gently on a cable, and cut the cable to fly away to crash at a safe distance. This landing technique has now worked successfully for two rovers and a lander. Ashley said her story picked up once Curiosity landed. Gale Crater was selected because it appeared to have been the site of a river delta, with the mountain at the center built up by sedimentation. Orbiters had found evidence of clay formations that are interesting because clay could be a result of life on Mars and because it indicates that samples of what was present when the formations built up could be preserved.

Ashley explained why real-time communication is impossible for working with Mars rovers. A signal between Earth and Mars takes 4–23 minutes each way. Waiting even 4 minutes to see an obstacle ahead and then 4 more minutes for the rover to receive a command to put on the brakes is no way to operate. Communications resources are in high demand, allowing different missions only limited slices of time to send instructions and receive data back from their probe or rover. For example, currently, Mars is near conjunction and interference from the Sun prevents communications for 2–3 weeks. Instead, Curiosity is designed to operate autonomously. On a typical day, the team on Earth spends about 8 hours planning the day’s mission, sends the instructions, waits about 8 hours for reports and data back from the rover, and then uses the rest of the time to analyze the results. The planning includes choosing waypoints for the rover to decide how to get from one to the next.

The central mountain, Mount Sharp, is a sedimentary formation. Ashley displayed a picture looking toward the mountain that revealed the layered structure showing different chemistries with the passage of time. She identified three of the layers going upward as a hematite-bearing unit that only forms in the presence of water, a clay-bearing unit that signals good preservation, and a sulfate-bearing unit that is more inert. Curiosity has essentially moved forward in time as it crosses this terrain. A view from above, with Curiosity's path and position in September 2021 marked, showed it had crossed the hematite unit and explored the clay unit, arriving a valley near the transition between three different units.

Ashley showed a mosaic of Curiosity images of the 33 drill-holes it has completed so far. The last 4 were done during the pandemic, with the team members working from their homes. The drill is a key instrument that allows Curiosity to collect powdered samples of the rocks to analyze the minerology and look for organics. The images showed a wide variety of colors and textures.

Ashley introduced the topic of autonomy, which the rover needs on board because of the communication constraints she had described earlier. This autonomy is her area of specialization. The rover must "look out for herself," especially when driving. Her team works by studying a 3-D model of the terrain based on orbiter and ground data. They choose a set of waypoints they want the rover to pass through on her way to the goal and allow her to choose her path between them. They also choose operating modes based on how much information they have and how much navigation difficulty they expect—and how much "paranoia" they want the rover to have about navigating each segment.

Curiosity has several modes of navigation planners can choose for travel between waypoints: Blind Driving (driving without imagery), Visual Odometry (position tracking), and Autonav (hazard detection and avoidance). Ashley's showed examples for each. Blind Driving terrain is flat and clear. It allows quicker progress because the radiation-tolerant computers on the rover are not as fast as someone's phone and would require the rover to slow down to allow time for negotiating hazards or slipping on slopes. Visual Odometry is best for slopes or sand, and Autonav allows the rover to be especially careful on unknown terrain. Visual Odometry and Autonav can be combined.

Ashley paused for questions and was asked what the rover used for positioning since there is no GPS on Mars. She said they used a local coordinate frame based on positions relative to nearby landmarks. They use gyros and motion integration to track position and reset every so often to zero out the errors. She said they were less worried about exact latitude and longitude, but someone checks rover images and satellite data once a day to provide approximate geographic location. In response to questions in the chat window, she said that JPL had indeed "given up on English units" some time ago, especially because they use international contributions. In response to another question, she said that impact history helps with determining age of rocks, but Curiosity can analyze age more accurately with radioisotope measurements.

Autonav hazard avoidance can also use "keep-out" zones (effectively artificial hazards), "keep-in" zones (drive boundaries), and adjustable "bravery" among other options. Ashley described a case where Perseverance, which also has Autonav, was told to go straight across some terrain that appeared clear and flat. Afterward, the image she included in the slide showed where its track paused and made a sharp turn to go around a pile of rocks that its hazard avoidance had detected.

Curiosity can also autonomously select and observe science targets (AEGIS, or Automated Exploration for Gathering Increased Science), using image analysis of a photo from the Navcam to select targets. For example, in an area with a lot of light-colored sandstone, if the team told it dark things are interesting, Curiosity might then select the darkest rock for analysis. It can use the ChemCam to take high-resolution color images and do spectroscopy on emissions obtained from blasting material off the surface with its laser. Before and after images showed exactly where the laser sampled based on the lack of dust on the spot.

In another pause for questions, Ashley was asked whether the colors in the images were actual ones we would see if we were there or whether they were artificial in some way. Ashley's short answer was "all of the above." She said some multispectral images were artificially stretched to show more detail The pictures with orange sky are usually true color, and pictures with blue sky have been stretched. There was an exception for sunset images. Unlike on Earth, the color of the dust in the atmosphere gives the sky the orange color during the day, but at sunset, the sunlight goes through enough dust to leave a blue color. Blue sky at sunset could be true color.

Ashley next covered science results from the mission. Curiosity provided more evidence of bedrock that had water flowing through it for a long period. The example image she showed had many bright veins visible in the rock indicating mineral deposited from water that flowed through, while the rock above the layer with veins was dark and had none because it was formed later. She also showed evidence of sandstone buildup indicating surface water flowed on Mars in the past. The search for organic molecules has successfully found a large variety, many of which have a sulfur component that makes them more resistant to degradation. Curiosity found an environment with the key ingredients required by life: water; chemistry involving carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur; and chemical energy sources usable for microbial metabolism. The early Mars environment was similar to Earth in habitability, and now Perseverance can look for evidence of whether any life formed to take advantage of it.

Curiosity is currently exploring the transition from clay-bearing to sulfate-bearing strata that likely records the transition from a wetter to drier climate. Ashley turned to discussion of Martian weather with a video showing "dust devils" form on Mars, one showing beautiful cloud formations lit from underneath by the setting Sun, and three images of a rock that changed from slightly reddish tan to orange to red at the height of the dust storm that ended the Opportunity mission on the other side of Mars. The winds on Mars do not exert enough pressure to affect the rovers, but they can pick up fine dust particles. Ashley said they were still not sure whether the clouds were water or carbon dioxide or a mixture.

Ashley's final topic was astronomy, which she began with a true-color image of a sunset on Mars. The sky definitely looked blue, especially around the Sun. Next were three movies on the same slide showing eclipses that can be seen on Mars. Phobos and Deimos can eclipse the Sun (though only partially), and Phobos can eclipse (occult) Deimos. She said they were actually able to refine the orbits of Phobos and Deimos with movies like these and she was told that one of their orbits is actually decaying and the other moving out. She pointed out the features visible on Phobos in the movie with Deimos disappearing behind it. Another image of the night sky was obtained when the microscope was used to look for photoluminescence of Martian sand at night and it captured Phobos and some stars. She also had in image of Vega and a sequence following the comet Siding Springs.

After the presentation, a young attendee asked why they would not bring Curiosity back to Earth. Ashley explained it took a really big rocket to get it to Mars and would take another big rocket to get it back. She said they were planning to bring samples back some time in the next 10 years, but they would be very small samples and would not require such a big rocket. Someone else asked about Curiosity's health and whether there was any deviation in capabilities. Ashley said its health was good, and the only deviation was a work-around for using the drill, which had a failure of the motor used to extend the bit into rocks. Now they use the arm the drill is on to push the bit into the rocks the way we use a hand drill.

Image of the Quarter: M103, the Christmas Tree Cluster

By Myron Wasiuta

Unguided image taken October 24 using the MSRO Station 3 telescope (102 mm f/7 APO and QHY 178 C camera), The image was obtained using the Live Stack feature in SharpCap, which is the program we will be using during the upcoming RAC Virtual Stargaze observing session called "The Clusters of Cassiopeia." During the event, of course, you will see the objects live in real time! No date has been set yet but stay tuned!

Messier 103 is an open cluster discovered in 1781 by Charles Messier's friend and collaborator Pierre Méchain. It is one of the more distant open clusters—8,000 to 9,500 light-years from the solar system. M103 is about 25 million years old. While it appears to have a few hundred, mainly very faint, stars, it actually has only about 40 *member* stars, two of which have magnitudes 10.5, and a 10.8 red giant, which is the brightest within the cluster. A bright known foreground object is the star Struve 131, which is not a member of the cluster.