Rappahannock Astronomy Club

Minutes, September 15, 2021, Online Meeting

In attendance:

Scott Busby
Bart & Linda Billard
Jim Browder
Glenn Faini
Sue Ann Heatherly
Jerry Hubbell
Mark McDonagh
Matt Scott

The meeting began at about 7:10 p.m., with introductions. Eight members and our invited speaker were present.

Program

Sue Ann Heatherly, the Green Bank Observatory senior education officer, gave a presentation on the radio telescopes at Green Bank as a sort of "Tour of Radio Astronomy." She began with an image of the Robert C. Byrd Green Bank Telescope (named after the Senator) in a valley surrounded by mountains. The importance of the mountains is their contribution to shielding from interference by nearby radio sources. She noted that 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."

As she showed time-lapsed video of telescope in operation, Sue Ann said sometimes it moves steadily tracking an object, and sometimes it wiggles. She explained that it is like a single-pixel camera and it wiggles back and forth to build up an image of an area of sky. It does not use arrays of pixels like an optical telescope camera does. When she described its versatility, she said it covers a large frequency range from 100 MHz to 100 GHz by simply rotating different receivers into place at the focus. Scott Busby asked via chat whether the telescope operated 24/7. Sue Ann said indeed it did, apart from some time out for maintenance. She said although they did not point directly at the Sun, they could go within a few degrees, and the sky would be just a black as at night at radio frequencies. She also showed a similarity between radio astronomy and optical astronomy with a chart showing how well various wavelength ranges of the electromagnetic spectrum penetrate Earth's atmosphere. It shows the optical and radio wavelength ranges we can use to observe astronomical phenomena from the ground. For other wavelengths, we have to put instruments in space at a much higher cost.

Sue Ann showed a picture of the Science Center at Green Bank with a couple of diesel buses parked outside. She explained that if we went there to tour in person, we would be taken around to the telescopes on these buses because they have no spark plugs. The observatory does not want the radio emissions from gasoline engines near the telescopes. In fact, she said all kinds of devices with computers, including cameras and cell phones are a problem. Even though cell phones can get no signal there, if they are turned on, they generate much stronger radio signals than the radio telescopes observe from space. Sue Ann said the buses have Faraday cages to temporarily store devices that are difficult to turn off. Examples she mentioned were Fitbits and even some "smart shoes."

Two historical instruments are represented at Green Bank. The first one Sue Ann discussed is a replica of the antenna built by Jansky for Bell Labs to investigate using the 14-meter band for radio telephones. Jansky found static from thunderstorms was a problem for the telephone idea, but he also discovered a source that tracked at a sidereal rate, thus revealing the possibility of radio astronomy. The other 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 or radio sources in the sky, Reber eventually meticulously disassembled his telescope. Then a couple of years after the observatory was established, he offered to rebuild it at Green Bank. It was in the image we saw that showed the Science Center and the diesel tour buses. Sue Ann said it is a national landmark.

Sue Ann's map showing the rectangular National Radio Quiet Zone around Green Bank revealed 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 of Virginia and West Virginia. She 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 (NSF) because of the surrounding mountains and low population, and because of their prediction the population would remain low. Jerry Hubbell asked whether the east coast location was chosen instead of the Rocky Mountains because of the proximity to Washington, D.C. and the universities. Sue Ann agreed that was a factor but also said NSF was funding the National Optical Astronomy Observatory in Arizona, so Green Bank created a balance. Also, she pointed out that there is no need to worry about cloudy skies for radio astronomy. She showed a picture of a "Cornell PhD" who was one of the first to use the telescope, doing measurements of the temperature of Venus and studies of Jupiter. He also tried looking for signals that might reveal extraterrestrial intelligence, choosing two Sun-like stars, ε Eridani and τ Ceti. This was the start of SETI, and he is Frank Drake.

Several more telescopes have operated at Green Bank. Sue Ann next showed a 20-meter telescope that was built by the Naval Observatory for geodetic measurements. An array of these telescopes around the Earth observed quasars and correlating their measurements revealed changes in the separation of pairs of telescopes caused by changes in Earth's rotation or plate tectonics. After this telescope was provided 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 on her tour was what she believes is the largest equatorial radio telescope, with a dish 140 feet in diameter. She had a sketch from the time of the founding of Green Bank, when the telescope was planned to be the signature instrument at the National Observatory. However, the choice of an equatorial mount caused it to take 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 more dishes form an interferometer, a way of getting more resolution, both in radio and optical astronomy. (It's easier in radio astronomy.) The 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. When a gusset plate failed, it collapsed in 1988. Tabloid headlines blamed the collapse on aliens. Sue Ann said there was a "silver lining." Senator Byrd was able to get an emergency appropriation passed to build the Green Bank Telescope (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. It has a small dish at the top of the feed arm that 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 view of the top of the receiver room showed the feed cones of the receivers that rotate with them to the secondary focus to enable observing a particular wavelength band. Sue Ann pointed out the size of the feed horns and noted how impractical it would be to have multiple pixels on a radio telescope. Bart Billard asked whether the receiver room tips with the telescope. She said it did, and that motors and things at the bottom that enable the rotation were replaced several years ago to allow changing receivers at different elevations without having to point the telescope up and level the receiver room each time. She showed a picture of the control room. It is a mile and a half away to allow use of digital computers without causing too much radio interference at the telescope. It also shielded to further reduce the interference. Jerry asked whether there were vestibules at the entrances to prevent radio waves from getting out when someone enters or leaves. She agreed there should be vestibules, but there aren't any. She thought maybe the doors don't have to be opened often.

Sue Ann ended with pictures illustrating the kinds of things radio telescopes can see and explained the mechanisms involved in making 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. We could see 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 and allow us to detect molecules in space. The 21-cm wavelength emitted by hydrogen atoms comes about when the electron's spin flips from parallel to the proton's 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. In response to Jerry's question, she said the pictures of the Sun and Jupiter were taken using interferometry by the VLA. The Cassiopeia A supernova remnant also illustrated radio emission from magnetic fields. 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. She recommended looking for recordings on the Internet when she found her sound would not work to play the pulses from the Vela pulsar.

Outside the Milky Way, the VLA has imaged many pairs of radio sources 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. These are called radio galaxies, and the radio images indicate something is shooting material from the middle of the galaxies far, 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 showed again the map of the radio sky that was being 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 things of larger angular size (nebulae) were all in our own Milky Way.

Afterward, Jerry asked for clarification about what was in the jets outside the radio galaxies. Sue Ann explained that we see the emission from electrons in actual matter that was ejected out of the centers of the galaxies. She said the jets were material flung off before reaching the event horizon of the black hole, but that she had not yet heard a good explanation of how that happens. Mark McDonagh asked about the comparison between Arecibo (before its collapse) and the GBT. She said the difference was mainly sensitivity, because Arecibo's disk was 1,000 feet in diameter compared with 300 feet for GBT. Both searched for pulsars, and the hope is to use pulsars to detect gravitational waves. Arecibo had limitations on pointing. One special capability it had was radar, which was useful for planetary and asteroid studies. GBT does a little radar work with Goldstone doing the transmission.

Old Business

- Treasurer's Report—Matt Scott reported three new members signed up in August, accounting for $62.57 incoming funds. He said we had $99.05 outgoing for the picnic. Glenn Faini said we were now up to 57 members, a new high.
- Vice President's Report—Glenn Faini said the star party was held but no other club members were there. He attributed it to being on Labor Day weekend. He did have one visitor email saying he wanted to join and asking to attend. So, this visitor was there with two children. Glenn F. gave the son and daughter the last two patches. He was not sure whether we should order more patches because giving them out to new members had lapsed since we started virtual meetings. Jerry suggested thinking about something different to give new members, perhaps mugs.
- Secretary's Report—Bart Billard said he had nothing to report.
- *StarGazer* Report—Linda had nothing to report except interest in members contributing articles for the next issue due out at the end of the next month.
- MSRO Report—Jerry said Myron was working on new equipment and had purchased a single-board computer for StationFOUR. It was nearly ready for operation. Jerry said he had done some upgrades, including a PMC-EIGHT upgrade for StationONE. He had not done StationTWO yet. Jerry mentioned the pointing had improved such that the telescope can slew to an object from parked and center it without the need to plate solve an image and make an adjustment.
- Facebook Page—Myron said he had not posted a lot on the MSRO Facebook page because he was seeing little activity.
- Equipment Inventory—Scott said Sabrina Maxwell visited him recently. (She came to pick up the pressure washer he was selling.) He gave her a tour and invited her to come back with her class some time for an outreach, and to bring her telescope that she was interested in getting his help with.

New Business

- Presentations and Speakers—Glenn F. said Ashley W. Stroupe (Jet Propulsion Lab) would present on Mars rovers in October. David Eicher (*Astronomy* magazine) would give a presentation on galaxies in December. He told Jerry that an email request about giving a presentation was enough for David Eicher. He thought about emailing David Levy but did not do it because Levy had already done a presentation for the club. Jerry offered to help if Glenn changed his mind. Glenn also said he had contacted Brian May (singer, songwriter, astrophysicist, and lead guitar for Queen, among other things). Brian was currently too busy remastering his solo catalog in order to put out a new compilation. He suggested he might be able to do something in the future if Glenn could try again later on.
- Officer Nominations —Glenn F. noted that officer nominations were scheduled for the October meeting. He encouraged members to consider running for one of the officer positions, especially for the vacant Vice President position.
- Other Items—Jim Browder reported that the SpaceX launch scheduled to take place during our meeting was successful and the civilian astronaut crew had reached orbit. They were scheduled to orbit for 3 days.

Next Meeting

The next meeting is on Wednesday, October 20, 2021. It is planned as an online meeting with a presentation. Officer nominations are on the agenda.