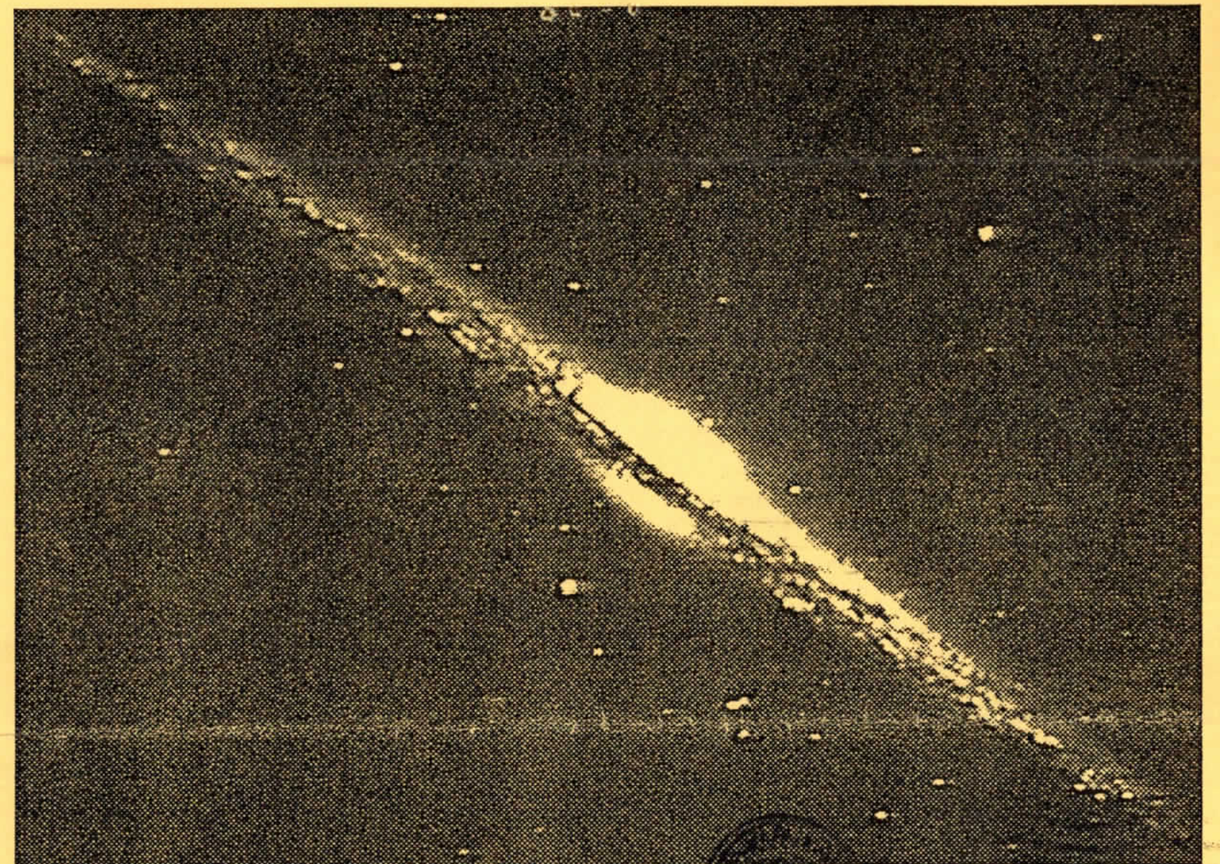

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Radio Astronomy

by Dennis Baldridge and Bert Stevens

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Radio telescopes and optical telescopes have one thing in common: they both collect photons of electromagnetic energy from celestial objects. By studying the resultant data, we can learn more about the universe around us.

The History of Radio Astronomy

The first radio telescope was built by Karl Jansky to try to find the source of interference in the short-wave radio bands. These frequencies were of great interest in the early 1930's since they were considered critical for long-distance radio communications.

Jansky identified three primary sources of noise. The most obvious was nearby thunderstorms that gave off great crackles of static as each lightning discharge occurred. The second was distant thunder storms whose lightning strokes added up a continuous, though much fainter, crackling sound. The final source seemed to be localized, but moved from east to west each day. Jansky correctly identified the source of this continuous hiss as the center of our galaxy.

In the late 1930's, Grote Reber wanted to study Jansky's results more carefully, but could not get any major institution interested in providing money for the project. He finally used his own money to build an antenna in his own back yard in Wheaton, Illinois.

Reber first tried to hear the galactic center on 3,300 MHz. The equipment of the era was not up to the task, and he was unable to record any signal. He then rebuilt his equipment to work at 910 MHz. Again, he was unable to get any signal. Finally, after rebuilding his equipment again, he was able to register the galactic center at 600 MHz. He now lives in Tasmania and is still observing with a long-wave radio telescope.

Reber's original design was a 9-meter dish with a 12-degree field-of-view. For simplicity, the original dish could only be steered in altitude, but he later modified it so it could also rotate to scan in azimuth. When asked why he made the dish 30-feet in diameter, he said that that was the longest lumber he could find.

Grote believed that the radio waves were being caused by hot objects at or near the galactic center radiating in the radio part of the electromagnetic spectrum. This "black-body" radiation is emitted by any object whose temperature is above absolute zero. The temperature of the object controls the frequency or color of the electromagnetic radiation emitted by the object: The higher the temperature, the "bluer", or more energetic, the black-body radiation it emits.

Grote Reber started at the high frequency (short wavelength) because it was believed that the radio signal from the galactic center was caused primarily by hot stars residing there. While there is a signal detectable from the galactic center at 3,300 MHz where Reber first tried, the equipment of that day was too noisy to detect it.

Unknown to Reber, there are also other sources of radio signals besides the thermal radiation. These non-thermal sources include vibrating molecular hydrogen and synchrotron radiation from electrons spiralling along magnetic lines.

Experimentation and theory show that the long wavelength radio signals are primarily non-thermal, while the short wavelength radio signals are primarily thermal. In between, at medium-wavelength radio frequencies, the "noise" from these two sources is at a minimum. There the 21-cm radio signal that is characteristic of atomic hydrogen can be found.

The 21-cm "line" is also in a part of the radio spectrum that can pass easily through the Earth's atmosphere, making it even easier for radio telescopes to record this signal. Since hydrogen is the most abundant element in the universe, by mapping the strength of the 21-cm radio signal all over the sky, we can map the density of matter in the universe.

The Radio Telescope

A radio telescope works by concentrating the radio energy over a large area to a central point where it is collected by the actual antenna. The collecting surface must be very large to get as much radio energy as possible. The larger the dish, the higher the sensitivity of the telescope. Another factor in the sensitivity of the radio telescope is the noise generated by the antenna and the first amplifier in the receiver system. This noise is generated both by the antenna itself and the electronics of the amplifier. Both are designed to minimize this noise, and they are often cryogenically cooled to reduce the thermal contribution to the noise.

The noise is most critical in the first amplifier. The noise from the antenna and the first amplifier is boosted by the entire receiving system. The first amplifier is the only amplifier in the receiver for which this is true. It usually has a high gain factor, amplifying both the signal and its own noise equally well. So it is critical to make this the lowest noise amplifier in the system, and in many radio telescopes usually is a maser (Microwave Amplification by Stimulated Emission of Radiation).

Noise in the radio telescope is the same as visually observing from a light-polluted site: The light pollution reduces the eye's sensitivity to faint objects, just as the amplifier noise reduces the radio telescopes sensitivity to faint radio objects.

Also like optical telescopes, the larger the diameter of the collecting area, the higher the resolution of the telescope. Consider the view of Jupiter you would get from a 1.6-inch (40 mm) telescope versus the view through a 16-inch telescope. For the same reasons, a 100-meter radio telescope will give you an image that has ten times the resolution of a 10-meter telescope.

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Observing Chairman's Report

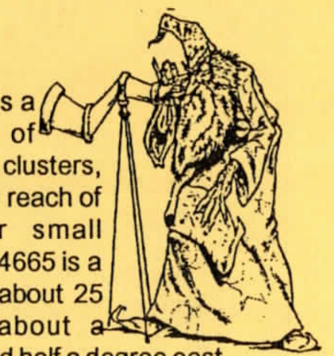
by Dave Knisely

THE NEXT SCHEDULED STAR PARTIES WILL BE HELD FRIDAY MAY 29th AND JUNE 26th AT THE ATLAS SITE. The early summer sky offers a number of beautiful star clusters that hint at the wonders to come in the following months. But first, take a look at a "hold over" galaxy high up in Draco, namely NGC 5866, also known as M102. This is an added Messier object which may not have been part of the original list, but stil is worth looking for. It can be found about 3.25 degrees south and 2.5 degrees west of Iota Draconis, and is visible in a three inch as a faint fuzzy oval. Moderate sized apertures will show this object's pointed ends, but little other detail is visible.

Several other galaxies can be found nearby, so those of you with larger telescopes may want to do some sweeping in the area. Also in Draco is the bright planetary nebula NGC 6543, located in a rather sparse region 5.1 degrees east and 3/4 north of Zeta. It is star-like in small instruments, with a six inch showing its small bluish oval form. A good eight inch will sometimes show the faint central star, while a ten will hint at vague inner detail.

Globular clusters are the hallmark of summer viewing, and none is more spectacular than the great Hercules Cluster M13, located 2.5 degrees south and a third west of Eta Herculis. Visible to the unaided eye under good conditions, this object appears as a fuzzy ball of light which is brighter towards the center when viewed in small telescopes. A four inch will reveal some stars in the outer haze, while anything over a six inch resolves the cluster into many thousands of faint stars. Moderate to large instruments will show some interesting star chains running out from the core.

Another spectacular globular, M92, can be found three degrees south and 2.5 degrees west of Iota Herculis. It is more compressed than M13, but is still a beautiful sight in moderate telescopes.



Ophiuchus holds a number of interesting star clusters, many within the reach of binoculars or small telescopes. IC 4665 is a large group of about 25 bright stars about a degree north and half a degree east of Beta Ophiuchi. It is best seen in binoculars or rich field instruments, with larger telescopes showing a rich but faint background. A similar big group is IC 4756, located four degrees west and 1.5 north of Theta Serpentis. It is very large and fairly rich, being somewhat oval in shape. Moderate to large apertures will reveal a rich background of faint stars, along with some possible dark nebulosity. Ophiuchus also contains some interesting globular clusters.

M10 is a moderate sized cluster located about a degree west of 30 Ophiuchi, and appears as a small fuzzy ball in a 2.4 inch refractor. A six inch will show a few stars at the edges, while an eight or ten will show as a rich ball of faint stars. About four degrees east and four south of Lambda is M12, another moderate globular which is visible in binoculars. An eight inch will resolve it fairly well except for the very center, while a ten inch at 240x makes it seem almost loose.

In Scorpius is one of the finest globular clusters in the entire sky, namely M4. It is quite easy to find, being about a degree west of Antares. A four inch will show many of its stars, with a six inch resolving it well. This cluster has an interesting line or bar of stars near the center which runs roughly east to west. An eight inch at low power makes M4 look a bit like a barred spiral galaxy, while a ten at high power fills the field with stars.

Tides: The Untold Story

by Dr. Fred Hess

[This article was transcribed from a lecture by Dr. Fred Hess of the Hayden Planetarium to the Westchester Amaetur Astronomers and appeared in their newsletter]

The Chinese thought that tides were the rhythmic breathing of the earth. The ancient Greeks believed them to be the life-giving heart beat of the earth. Most of us don't make our livelihood from the sea, so we tend to take the tides for granted. But tides are a fascinating wonder that should be understood.

Let's look at some tides. In California, there are two daily high and low tides for the first half of the month, then only one daily high and low tide for the second half of the month. In Florida, there is one high and low tide each day, and in Tahiti high tide occurs only at noon and at midnight and low tide happens only at sunrise and at sunset. It is obvious that the following unwritten commandment about tides should be made: "Thou shall not take thy knowledge of tides to someone else's puddle," because no two tides are exactly the same!

Not only are the rhythms of the tides different for each part of the world but their magnitude varies from place to place as well. In the Pacific, high and low tide may vary by 12 to 13 inches. But in places where there are large bays the difference between high and low tide can be as much as 50 feet! The Bay of Fundy in Canada exhibits just this type of behavior. Then there are tidal bores: A dramatic wall of water that moves up rivers such as the Severn River in England and Yellow River in China. What causes these drastic changes in the oceans of the world, the liquid part of the planet, "the part that is loose and juicy"?

To understand tides we must look at the unique relationship between the earth and the moon. Most people think that the attraction of the moon alone causes a lifting of the water under the moon to produce high tides. But this is not the case; it is a little more complicated that that. The earth and the moon revolve around one common gravitational center. This center of balance between the moon and earth is called the barycenter. Since the earth is more massive than the moon, the center of balance falls under the earth's crust. (This is somewhat similar to two people on a see-saw. The heavier person sits closer to the center and the lighter person sits farther out.) As the earth and moon revolve around this barycenter, forces of revolution (centripetal, directed inward and centrifugal, directed outward), generate the tidal forces that pull the surface of the planet into an egg-shape object: a bulge on the side under the moon and a bulge on the far side of the earth with two depressions in between. Most of this tidal force is horizontal which moves the water across the surface of the earth causing it to pile up into these bulges. Locations on the earth will pass underneath this two bulges twice during the course of one complete earth rotation.

If the earth were completely covered with water, as the planet rotated the tidal force would appear to travel westward around the globe, producing an even high tide. But the earth has continents, which block the flow of water, causing the water to pile up along the coast and in large bays. This piling up of water can causes tides to reach 40 and even 50 feet in height!

The only location on earth where the tidal forces have an opportunity to travel unhindered around the planet is near Antarctica. It is here that the southern tip of South America catches this tidal force and directs it up around the cost of Argentina, through the Caribbean, and up along the eastern seaboard to Newfoundland. If you look at the cities along these coasts you can follow the times of high tide as they begin early in Tierra del Fuego and get later and later as they proceed up to St. John's. The high tide in our New York harbor originates in Antarctica!

Tides can also be affected by the change in distance of the earth and moon, earth and sun, alignment of sun and moon, local storms, declination of the moon, and by the natural shape and size of bays, coves and basins. Surely tides are a very dynamic and complicated physical wonder. ■

Resolution is also effected by the wavelength of the radio signal to which the receiver is tuned. Resolution is limited by diffraction-induced blurring of the image. Diffraction is a physical property of electromagnetic radiation, and for telescopes the amount of blurring is proportional to the wavelength of the signal divided by the diameter of the telescope. You can increase your resolution by either making your aperture larger (very expensive), or by observing at a higher frequency (inexpensive). Therefore radio astronomers try to observe at the highest frequency possible for the object to get the best resolution in the images.

Radio astronomers are also able to use a trick that has so far been unavailable to visual astronomers. They can connect two radio telescopes, even when separated by great distances, and use them together as though they formed one gigantic telescope. Through this trick, called long-baseline interferometry, they can observe as though they had the resolution of a telescope the size of the distance between the two telescopes. Future plans include radio astronomy satellites that will allow the "baseline" to be increase to many times the diameter of the Earth, allowing higher and higher resolution views of radio objects. Someday, radio telescopes on the Moon will be paired with radio telescopes on Earth to provide resolutions as fine as 0.00001 seconds of arc.

Unlike optical telescopes, radio telescopes have side-lobes that will pick-up very bright sources as well as the faint object that you are trying to observe. These means that observations must be planned so that the Sun or another bright radio source is not in one of the side lobes. Even though radio observing can be done during the day, there are intervals when the Sun interferes with observation of a particular radio object. This interference is either directly, when the Sun is very near the object, or indirectly when the Sun is in a side-lobe of the telescope. Indirect interference varies from telescope to telescope, since each telescope has different side-lobes. Radio observing is also impossible when the moisture in very dense clouds blocks the radio signal from reaching the telescope.

The major factor in getting the high resolution images is the computer processing that reduces the noise from the side-lobes as well as reducing the overall interference. As in so many fields of astronomy, the computer makes radio astronomy many times more effective than before computers were readily available to help with data collection, reduction, and presentation.

The largest radio telescope array is the Very Large Array, or VLA, near Soccoro, NM. This array consists of twenty-seven 30-foot dishes. Each of these dishes can be placed along one of the three 13-mile-long arms that form a Y shape in a bowl in the San Mateo mountains. There, protected from man-made radio interference, these 27 antennas can be paired to form up to 340 combinations of antennas. The high speed computers located at the VLA control center can use to develop very high resolution images, typically around 0.1 second-of-arc. When combined with telescopes on the opposite sides of the Earth, the resolution improves to 0.001 second-of-arc.

Another well-known radio observatory is the National Radio Astronomy Observatory at Green Bank, West Virginia. This is the site of the 300-foot dish that collapsed a few years ago, and is now in the process of being rebuilt. There is also an interferometer composed of three 76-foot diameter dishes as well as a few smaller instruments. These include a 140-foot equatorially mounted dish and a 40-foot dish. There is a one-and-a-half year waiting list to observe with the 140-foot dish. They welcome visitors and will show you through the Observatory.

I (Dennis Baldridge) had an opportunity to use the 40-foot meridian scanning radio telescope located at Green Bank. Working at 1400 MHz (the hydrogen line), this instrument has a beamwidth of one degree.

Among other famous radio telescopes is the Jodrell Bank telescope in England, the first fully streerable dish radio telescope. At Arecibo, Puerto Rico, the dish is built into a natural bowl, and the feed horn, which is suspended by heavy cables above it is moved around to observe different areas of the sky. At Ohio State University near Columbus, they built a large reflector is tilted up and down to direct the radio waves from different objects at the fixed collector.

The Radio Sky

There are many different types of objects in the radio sky. Each one radiates electromagnetic energy in different parts of the electromagnetic spectrum in different amounts at different times. By studying the radiated energy, we can learn much about the objects, their structure and composition.

The closest radio object is the Moon. Since there are no plasmas or magnetic fields there, the emissions from the Moon are primarily thermal, so it is strongest at lower frequencies, weakening as you move up the radio spectrum. The brightest radio object in the sky is the Sun. The Sun radiates in every part of the radio spectrum. Twice a year we can do radio astronomy with our television sets. In early March and late September, the Sun passes behind the geosynchronous satellites that provide television signals to cable-tv systems. As the Sun passes behind the satellite, the static from the Sun overpowers the TV signal for about ten minutes.

The Sun is routinely monitored in a variety of radio wavelengths to study the activity on its surface. These measurements are combined with other monitoring systems to provide a warning when the Sun explodes into furious activity. The Sun is so bright, that highly sensitive dish antennas are not required to hear the Sun shouting at us.

Jupiter is another nearby radio source. It emits radio waves both by thermal emission and by synchrotron emission. The giant planet's magnetic field spirals charged particles from the Io flux tube around the lines of magnetic force, emitting synchrotron radiation in a complex hydrogen line. Meanwhile, the disc of the planet is a source of thermal emission more powerful than would be expected from the Sun's heat alone. This may be energy coming from Jupiter's core as it continues to collapse from the tremendous weight of the planet.

Outside our Solar System, there are many bright radio sources. One of the brightest is Cygnus-A. Located in Cygnus, it was the first radio source discovered in that constellation. Cygnus-A is a giant elliptical galaxy shooting out jets in opposite directions from its nucleus. The radio emissions from this galaxy are primarily synchrotron radiation. Many radio galaxies have two lobes from opposing jets.

Sagitarius-A is not quite so far away: it is the center of our galaxy. It can not be seen in visible light because of the intervening dust clouds, but radio waves can get through. Our galactic nucleus can be mapped in the 21-cm radio line of hydrogen. By mapping with longer and longer baseline interferometry, radio astronomers can get higher and higher resolution maps of Sagitarius-A.

Each wavelength provides a different view of the sky and we need to map the sky in each wavelength to get the maximum amount of information about our universe.

An Amateur Radio Telescope

Amateur radio astronomers do exist. I (Dennis Baldridge) have built a radio telescope on the roof of Ollivett University's Science Building near Kankakee, IL from an old 8-foot satellite dish. It has a meridian scanning mount, built out of the rear end of an old Blazer and a TV-antenna rotor. At the focus, I have two dipole antennas, for 610 MHz and 1420 MHz reception. The antenna feeds a low noise receiver. While professional telescopes are cooled to reduce the noise level, I heat the equipment to provide thermal stabilization. Even though this is noisier, the resulting stability is more important.

An old IBM XT is housed next to the radio telescope for data acquisition. The signal from the radio receiver is fed into a 13-bit analog-to-digital converter. The computer takes 100 measurements per minute, averages them and stores the average on the disk. Three days worth of data fit on a floppy disk.

My first successful observation was on Christmas Day in 1989 of Cassiopia-A on 608 MHz. I have also seen Virgo-A.

I have more data than I can process. I have used the data from this radio telescope in a lab course at Ollivett University.

What can amateurs do?

Even though amateur astronomers do not often consider the possibilities of radio astronomy, they can contribute to the science of astronomy. Amateur radio telescopes can scan other frequencies than the professionals use. This opens up the possibility of new discoveries in the new wavelengths.

Amateurs can also scan the sky for signs of extra-terrestrial intelligence. These SETI searches are not high priority for the professional astronomers. Amateurs can work on different frequencies and in different sections of the sky from the professional radio astronomer.

Other possible discoveries may also come from the amateur community. It is up to the amateur astronomers to open their ears as well as their eyes to the prospects of radio astronomy. ■

President's Message

by Dave Knisely

Well, Astronomy Day 1992 is history, and the results were a bit mixed. We did show our hobby to quite a number of people, but the numbers were down from last year, and many of those who came through the display just looked briefly and then left. One possible cause for this lower turnout might have been the fact that UNL Graduation was on that same day. Still, the display looked good, with plenty of telescopes, video, and computer graphics on hand. I am especially pleased with the turnout of club members. This shows our club is really active when it comes to showing the public what amateur astronomy is all about.

I want to personally thank everyone who participated, and particularly, thank Jack Dunn of Mueller Planetarium for the use of the lobby.

The next challenge our club will face will be the 1993 Mid-States Convention. Assuming we get the bid, this undertaking will tax our club in terms of time and people. We may want to consider cancelling or scaling back Astronomy Day next year, due to the time requirements of the convention the following month. We will need help from all our members, so even if you can only do a little, please let us know.

The next scheduled meeting of the Convention Commitee will be Tuesday June 23rd, at 7:30 p.m. at Hyde Observatory (you WILL be there, won't you Ron?). This will give us a chance to discuss what some of us saw at the last convention.

See you at the next meeting. ■