Welcome to The Radio JOVE Project Citizen Science Training Modules. I am Professor Chuck Higgins from Middle Tennessee State University, and also one of the leaders of Radio JOVE.

Partnerships and Acknowledgements

sunrise.umich.edu

radiojove.gsfc.nasa.gov

Contributors: Soni, S.L.; Higgins, C.; Akhavan-Tafti, M.; Fung, S.; Blair, S.

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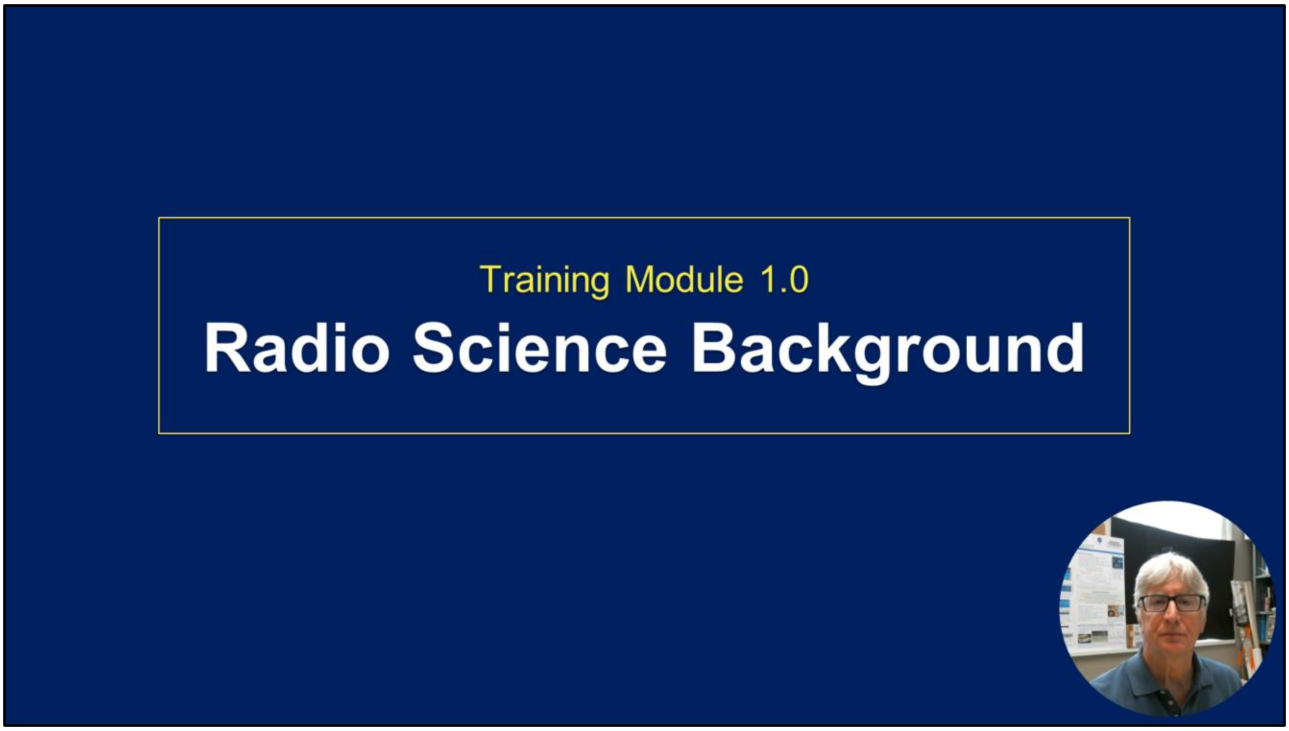

This is Training Module 1.0 – Radio Science Background

Prerequisites for Training Modules

1. High School Reading Comprehension and General Science
2. Scientific Notation
3. Electromagnetic Spectrum
4. Speed, Wavelength, and Frequency of Waves
5. Graphical Interpretation of Data

This is a list of prerequisites needed to be able to understand the material in this module.

Learning Objectives

1. Understand why radio astronomy is used
2. Compare the radio sky with the visible sky
3. Learn some major discoveries in radio astronomy
4. Listen to example sounds of the Sun and Jupiter

This is a list of the learning objectives for this presentation.

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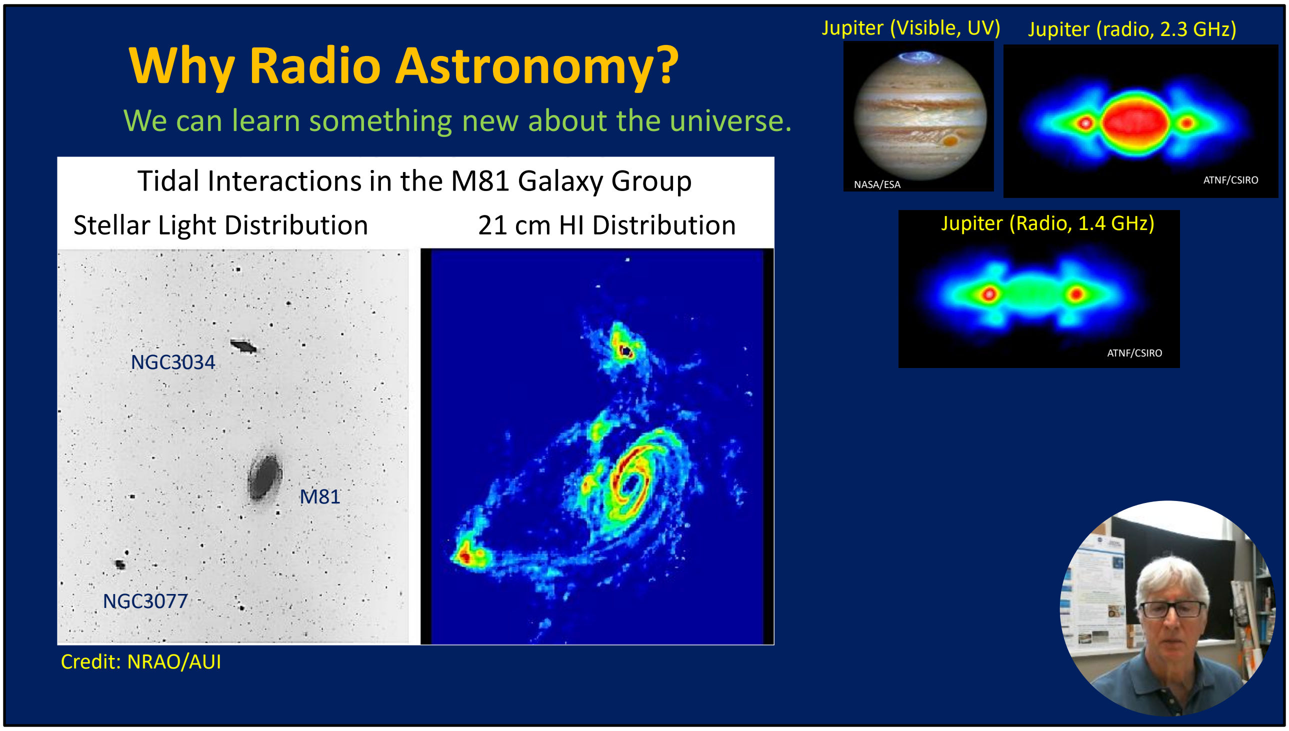
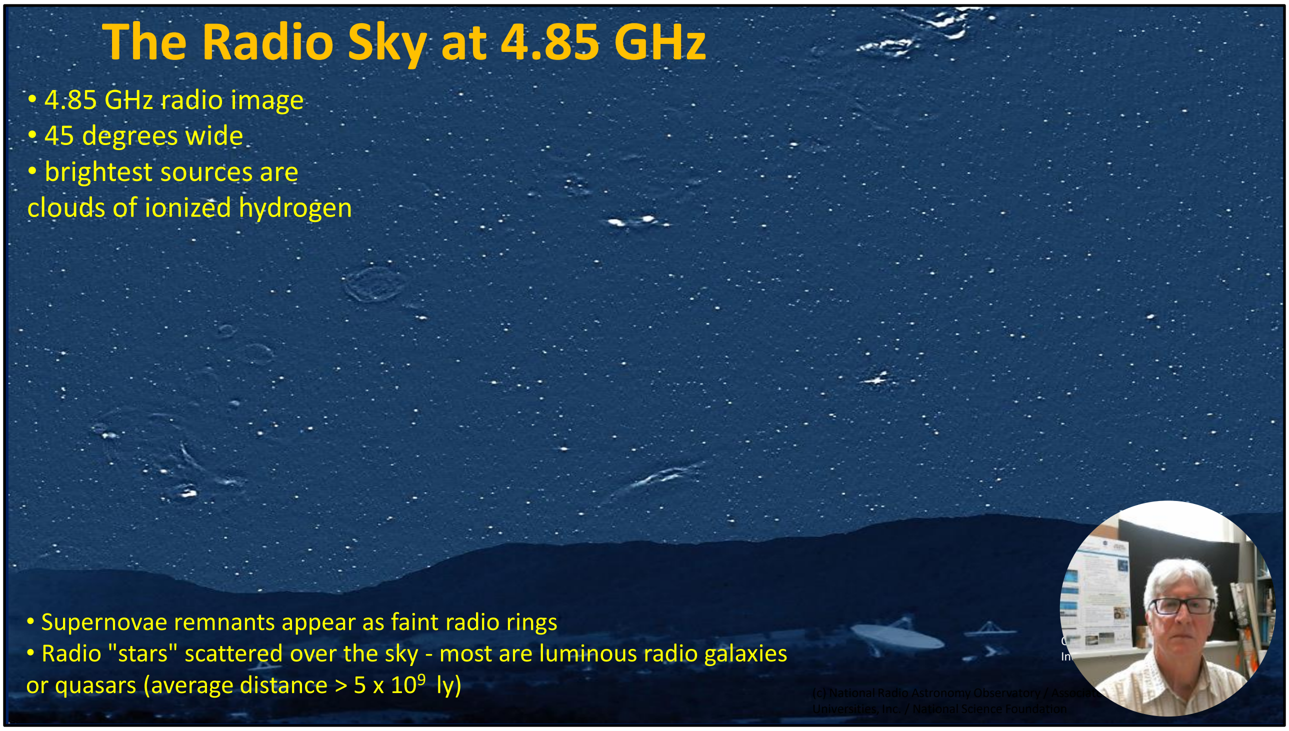


Why do we need radio astronomy? Radio astronomy, and other non-visible light astronomy, aides us in understanding the universe. Simply put, we can learn something different about the universe by studying it in different wavelengths of the electromagnetic spectrum. For example, the two images show the M81 galaxy group. On the left is an optical view of M81 and nearby galaxies NGC 3034 (above) and NGC 3077 (lower left). On the right is the same field of view from a radio telescope at the 21 cm wavelength of atomic hydrogen (HI) showing the cold hydrogen gas distribution in the system. Invisible in the optical image, the radio image reveals long tidal tails of gas demonstrating that these three galaxies are gravitationally interacting with each other.

Another example is the radio images of Jupiter at wavelengths of 13 cm and 21 cm (2.3 GHz and 1.4 GHz) showing the thermal energy from the planet and the radiation belts of plasma around Jupiter. These radiation belts cannot be seen by optical telescopes and demonstrate that Jupiter has a magnetic field with trapped plasma forming the radiation belts.

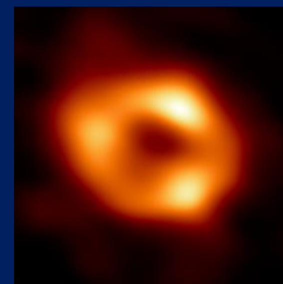


This is what the northern hemisphere sky would look like if we had “radio eyes”. This radio sky image was taken at 4.85 GHz from the National Radio Astronomy Observatory (NRAO) in Greenbank, WV. The dots are not stars; they are radio galaxies from distances over 5 billion light years. The brightest regions are clouds of ionized hydrogen, and the faint rings are supernova remnants, both within the Milky Way. The universe looks completely different in radio waves and that allows scientists to better understand the cosmos.

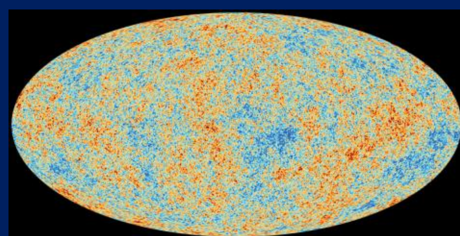
Major Discoveries in Radio Astronomy

- Radio Galaxies
- Cosmic Microwave Background (CMB)
- Gravitational radiation
- Cold interstellar gas
- Neutron stars (pulsars)
- Exoplanets
- Gravitational lensing
- Images of Supermassive Black Holes

Hercules A Radio Galaxy from the Hubble Space Telescope's Wide Field Camera 3, and the Karl G. Jansky Very Large Array (VLA) radio telescope in New Mexico. Credit: NASA, ESA, S. Baum and C. O'Dea (RIT), R. Perley and W. Cotton (NRAO/AUI/NSF), and the Hubble Heritage Team (STScI/AURA) https://www.nasa.gov/mission_pages/hubble/science/hercules-a.html

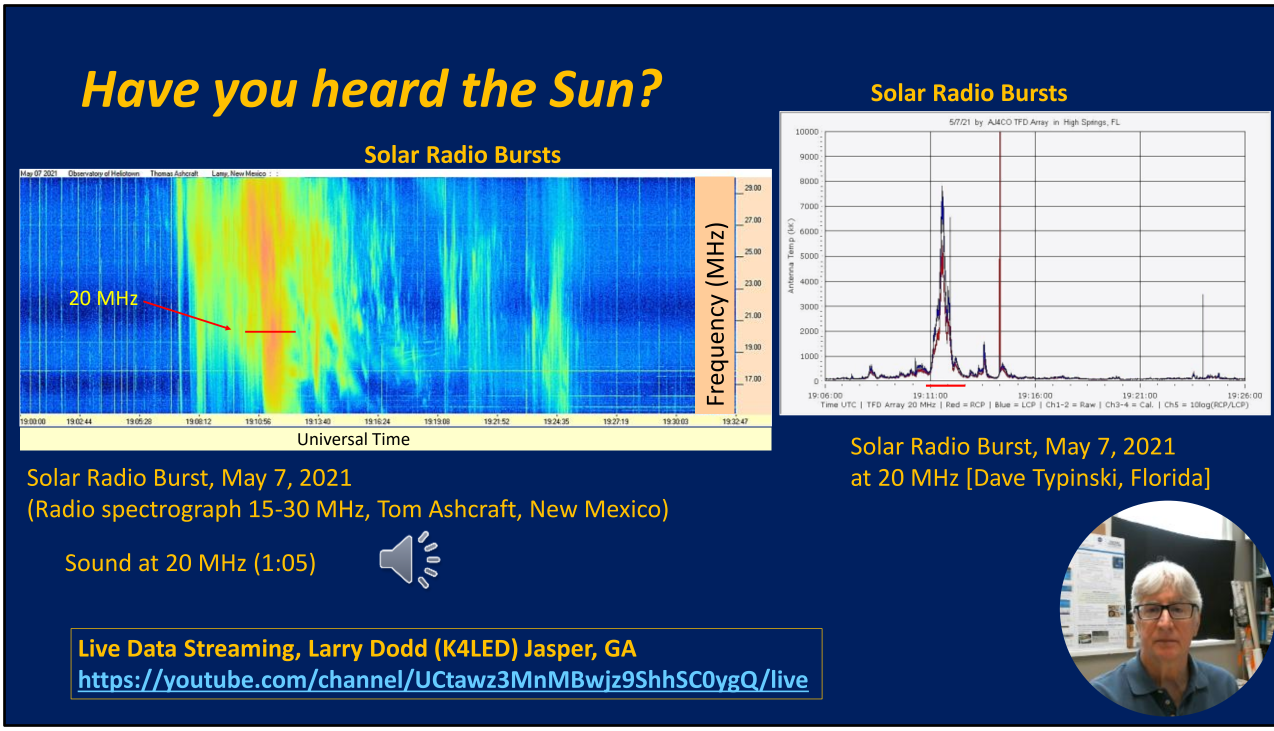


First image of the black hole at the center of the Milky Way. Credit: EHT Collaboration https://eventhorizontelescope.org/blog/astronomers-reveal-first-image-black-hole-heart-our-galaxy

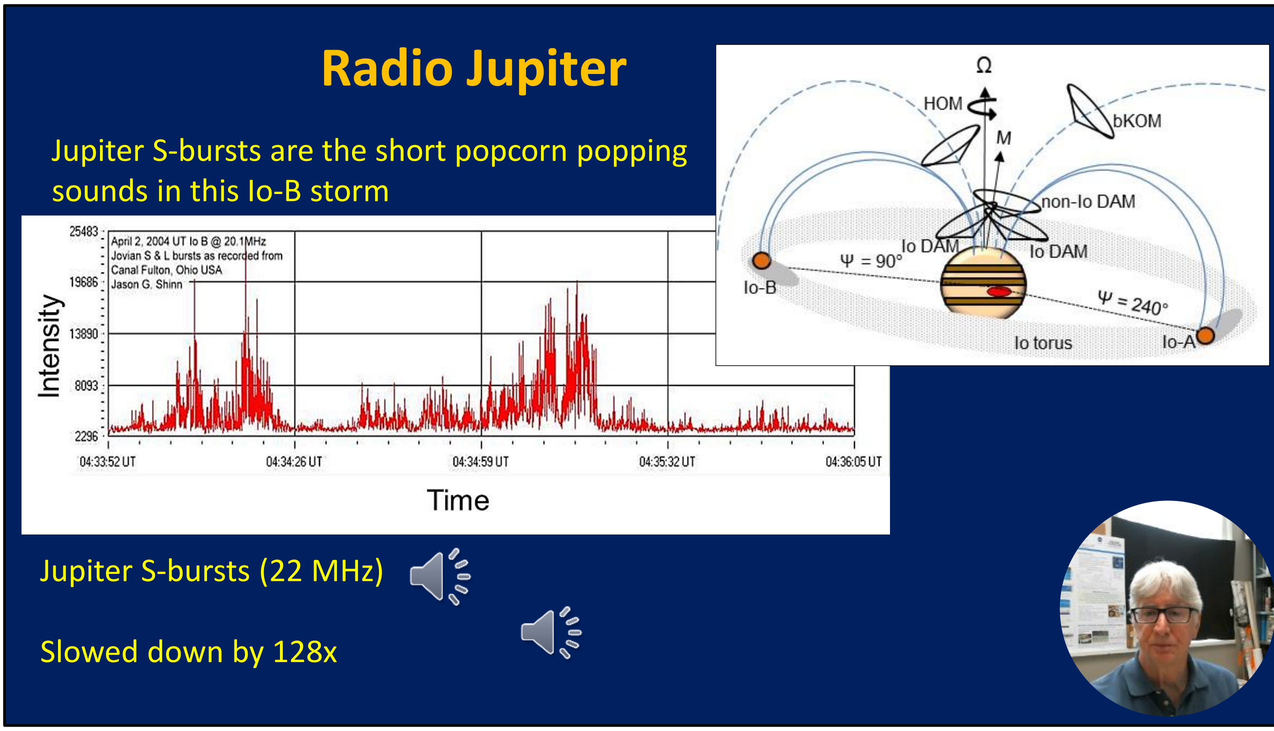


All-sky map of the Cosmic Microwave Background (CMB) radiation Credit: ESA / Planck Collaboration https://www.esa.int/ESA_Multimedia/Images/2018/07/Planck_s_view_of_the_cosmic_microwave_background

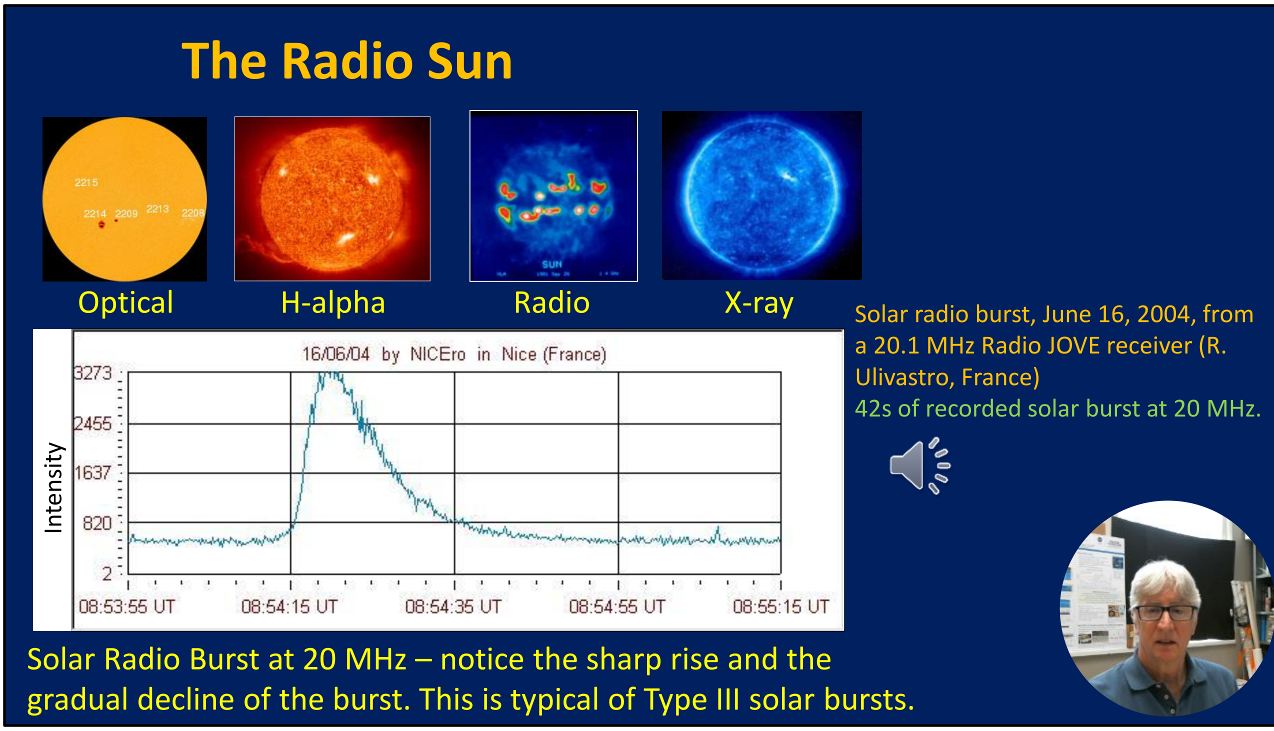
Some of the major discoveries in radio astronomy include: 1) Radio Galaxies – the optical image of the elliptical galaxy Hercules A combined with a radio map showing huge jets of energy coming from the supermassive black hole at the center of the galaxy; 2) The Cosmic Microwave Background (CMB) – first discovered in 1964 using a microwave radio telescope, the CMB is the leftover thermal energy from the Big Bang that occurred 13.8 billion years ago; 3) Gravitational radiation; 4) Interstellar gas and intergalactic gas (see previous slide); 5) Pulsars – pulses of radio energy from rapidly spinning neutron stars; 6) Exoplanets; 7) Gravitational Lensing; 8) Images of supermassive black holes - combining radio wavelengths from many telescopes allowed astronomers to first image the supermassive black hole at the center of the Milky Way galaxy.



Have you heard what the Sun sounds like with a radio telescope? These data come from Radio JOVE equipment. The left graph shows a solar burst from a 15-30 MHz frequency-time radio spectrograph where the audio is from the 20 MHz channel. The intensity-time graph on the right shows the same solar burst at 20 MHz. Live streaming Radio JOVE data are found on a YouTube channel from K4LED in Georgia, USA: https://youtube.com/channel/UCtawz3MnMBwjz9ShhSC0ygQ/live.



Have you heard Jupiter radio emissions? The data come from Radio JOVE equipment, a Jupiter radio event recorded at 20.1 MHz with an original Radio JOVE receiver and antenna (the audio is from a different event). The audio signatures are sometimes unique to the source, for example, the pops from Jupiter come from electrical and magnetic interactions between Jupiter and the moon Io. The cartoon figure shows Jupiter's northern hemisphere radio source emission "cones" and the moon Io and the plasma torus. The decametric emission (DAM) is what Earth-based observers detect.



Four images of the Sun at different wavelengths showing different features and structures on the Sun. The radio map shows regions of high magnetic activity near the surface of the Sun; they correlate well with sunspots. The graph shows an example of a Type III solar radio burst recorded with a radio antenna at 20 MHz.

Resources

1. Basics of Space Flight - https://solarsystem.nasa.gov/basics/
   i. Chapter 2: Reference Systems - https://solarsystem.nasa.gov/basics/chapter2-1
   ii. Chapter 6: Electromagnetics - https://solarsystem.nasa.gov/basics/chapter6-1

2. Atacama Large Millimeter/submillimeter Array (ALMA) - https://www.almaobservatory.org
   ALMA Radio Astronomy Manual https://www.eso.org/public/archives/education/pdf/edu_0072.pdf

3. The National Radio Astronomy Observatory (NRAO) - https://public.nrao.edu
   i. The Science of Radio Astronomy - https://public.nrao.edu/radio-astronomy/the-science-of-radio-astronomy
   ii. What are radio telescopes - https://public.nrao.edu/telescopes/radio-telescopes

4. Goldstone-Apple Valley Radio Telescope (GAVRT) - https://gavrt.lewiscenter.org
   Basics of Radio Astronomy - https://www2.jpl.nasa.gov/radioastronomy/radioastronomy_all.pdf

5. Society of Amateur Radio Astronomers (SARA) - https://radio-astronomy.org
   i. Introduction to Radio Astronomy (41 min video) - https://www.radio-astronomy.org/node/240
   ii. Getting Started in Radio Astronomy - https://www.radio-astronomy.org/getting-started
   iii. Beginner Booklet - https://www.radio-astronomy.org/pdf/sara-beginner-booklet.pdf

6. Commonwealth Scientific and Industrial Research Organisation (CSIRO) - Australia's National Science Agency
   What is radio astronomy? - https://www.csiro.au/en/research/technology-space/astronomy-space/What-is

This is a short list of good resources on basic radio astronomy.

Thank you for your attention!

Next, you will learn more about radio astronomy …

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