History of Radio Astronomy

Reading for High School Students
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Introduction

Radio Astronomy, a field that has strongly evolved since the end of World War II, has become one of the most important tools of astronomical observations. Radio astronomy has been responsible for a great part of our understanding of the universe, its formation, composition, interactions, and even predictions about its future path. This article intends to inform the public about the history of radio astronomy, its evolution, connection with solar studies, and the contribution the STEREO/WAVES instrument on the STEREO spacecraft will have on the study of this field.

Pre-history of Radio Waves

It is almost impossible to depict the most important facts in the history of radio astronomy without presenting a sneak peak where everything started, the development and understanding of the electromagnetic spectrum.

Even though scientists like Faraday and Volta performed experiments with electricity and magnetism, it was not until many years later that a scientist was able to relate both as two aspects of the same force. James Clerk Maxwell (1831-1879) developed the theory of electricity and magnetism by the coherent integration of four equations. These equations not only summarized the relationship between electric and magnetic forces, but also predicted that there is a form of radiation involved (soon known as electromagnetic waves). Nevertheless, it was Oliver Heaviside who in conjunction with Willard Gibbs in 1884 modified the equations and put them into modern vector notation.

A few years later, Heinrich Hertz (1857-1894) demonstrated the existence of electromagnetic waves by constructing a device that had the ability to transmit and receive electromagnetic waves of about 5m wavelength. This was actually the first radio wave transmitter, which is what we call today an LC oscillator. Just like Maxwell's theory predicted, the waves were polarized. The radiation emissions were detected using a 1mm thin circle of copper wire.

Now that there is evidence of electromagnetic waves, the physicist Max Planck (1858-1947) was responsible for a breakthrough in physics that later developed into the quantum theory, which suggests that energy had to be emitted or absorbed in small packets or "quanta" of energy. Quantum physics is the primary field for the in depth study of electromagnetic radiation. Other contributors to this field are Albert Einstein with his quantum theory- photoelectric effect, Louis de Broglie and "particle wave duality", and Erwin Shcrodinger and his quantum physics wave equations, among others.

After all these discoveries, scientists were able to apply their studies on electromagnetism and radio waves to develop ways of communication. In

1901, Guglielmo Marconi (1874-1937) was the first to send and receive signals across an ocean from Newfoundland to Cornwall. He improved radio transmissions and, as a result of his contribution, commercial radiotelephone service became available in later years (F. Ghigo, 2003).

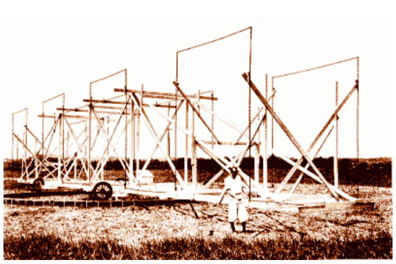
Evolution of Radio Astronomy

Astronomical observations have been greatly improved since the moment it was possible to measure regions on the electromagnetic spectrum outside the optical range. Radio observations became one of the most productive means of astronomical research. Radio astronomy expanded greatly in the twentieth century.

The study of astronomy using radio frequencies started with unsuccessful attempts to find solar radio waves. Such attempts will be discussed in more detail later in this article.

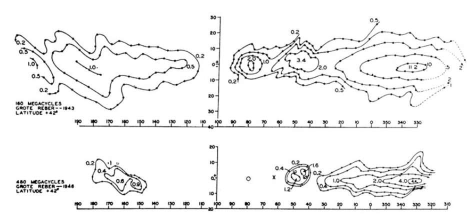
As mentioned earlier, the first significant application of radio waves in the beginning of the twentieth century was the creation of long distance radio communication. Further radio communication investigations led to the discovery of radio waves from the Milky Way. It was the decade of 1930s and the Bell Telephone Company was having trouble with the functioning of their transatlantic service, due to static of some sort. The company asked the physicist Karl Jansky (1905-1950) to find the source of such interference.

In order to track and identify the source of static, Jansky built a big rotating antenna, given the name of “Jansky’s merry-go-round”. The antenna was designed to receive radio waves at a frequency of 20.5MHz, and with its rotation ability it was able to locate the direction of any radio signal.



After several months of studying such static, Jansky was able to classify it into three different types. The source of the first two originated from nearby and distant thunderstorms. However, there was a third source of static that was somehow different. He began to realize that there was a pattern characterizing these wave signals. It was very similar to the known location of the Sun, but after a few months and more accurate measurements (signals repeated every 23 hours and 56 seconds) Jansky concluded that the radiation came from the constellation Sagittarius in the Milky Way Galaxy. This discovery was a fundamental contribution to radio astronomy.

Jansky’s discovery motivated Grote Reber (1911-2002) a radio operator and engineer to apply for jobs with Karl Jansky and Bell Laboratories to further investigate radio waves. He wanted to find out what was the process that lead to the development of radio waves in space and verify if the waves were in fact coming from the Milky Way or other celestial objects. However, since all of this happened during the Great Depression, Bell Labs were not hiring at that time. Reber was determined to achieve his goals and answer his questions, even if it meant he had to do it all from his back yard… which he did. Reber decided to investigate on his own, and in 1937 he constructed a telescope that had a parabolic dish reflector and 3 receivers: 3300MHz, 900MHz and 160MHz. A year later, in 1938, the last receiver mentioned gave him what he was looking for, galactic radio waves. Reber presented the data as contour maps showing the Milky Way as bright areas.



Reber became one of the pioneers of what we call today radio astronomy. Thanks to his work, after World War II, many scientists began to build bigger and better antennas to study the universe.

Nowadays, we have radio telescopes as big as the Arecibo Radio telescope in Puerto Rico, with a 305m (1000 feet) diameter and 167 feet deep, covering an area of about twenty acres (NAIC, 2004).

Also, techniques such as radio interferometry became available as early as 1946. This technique— using multiple antennas to record radio data— became more sophisticated over the years including a technique known as Very Long Baseline Interferometry (VLBI) and the latest one, Space Very Long Baseline Interferometry (SVLBI). SVLBI uses a space-based antenna as one of its elements. Projects like the JPL SVLBI, funded by NASA, use this kind of technique to provide "3 to 10 times the resolution of VLBI" (Wikepedia, 2004).

Improvements in the radio astronomy field made possible the detection of radio emissions from planets like Jupiter (see Journal of Geophysical Research, vol. 60, pp 213-217, 1955), observations of energetic objects such as pulsars, quasars, and radio galaxies, and "imagery" of many astronomical objects by recording multiple overlapping scans and putting them together in an image.

Solar Radio Observations

As previously mentioned, solar radio data had its beginnings very early in the radio astronomy field. The Sun was the first astronomical object scientists thought of as a source for radio waves, from the idea that it is the closest energetic body to Earth. However, many of these early investigations were unsuccessful.

The first recorded attempt to detect radio waves from the Sun was made by Thomas Alva Edison in 1890. Kennelly, his laboratory assistant sent a letter to Lick Observatory describing the construction of a detector made by winding a number of cables around a mass of iron ore. However, there is no further evidence of this effort. Nonetheless, we know that the detection of solar radio waves would not have been possible since the ionosphere prevents the long waves – the only waves the apparatus could detect– from reaching the Earth.

Sir Oliver J. Lodge around 1897-1900 built a more sophisticated solar radio detector than the one Edison did. Still, it was not sensitive enough to have detected the Sun. Following this attempt, the astrophysicists Johannes Wilsing and Julius Scheiner constructed a device and tried the experiment for eight days, but they were also unable to detect radio radiation from the Sun. However, they were the first ones to formally write up and publish their attempt to detect solar radio data (Ann. Phys. Chem. 59, 782, 1896, in German). They incorrectly concluded that the atmosphere was absorbing the radio waves.

A few years later in 1900— trying to solve problems from previous attempts— a French graduate student Charles Norman constructed a long wire antenna and set it up on a glacier on the alpine mountain Mont Blanc at about 3100m (10000ft). He reasoned that if Wilsing and Scheiner were right, the solution was to gather data at a higher altitude. He was very close to detecting low frequency radio bursts. Unfortunately, the experiment was performed in solar minimum.

Solar radio observations were neglected for many years. It was not until the 1920s, when Oliver Heaviside demonstrated the existence of the ionosphere, that many questions about solar radio data were answered. After this discovery was made, radio astronomers realized that they had to develop high frequency radio receivers (around 20MHz) in order for these waves to penetrate the ionosphere.

World War II not only had an influence on the foundation of radio astronomy, it also had a direct impact on the history of solar radio observations. In February 26-27, 1942, an English radar station received a strong noise signal thought to be a new source of interference created by enemy transmitters. It turned out to be radio wave emissions from the Sun associated with a group of sunspots that appeared at that time. That same year, Dr. G.C. Southworth detected solar microwaves at wavelengths of 1 and 10cm, while he was working at the Bell Telephone Laboratories in New York.

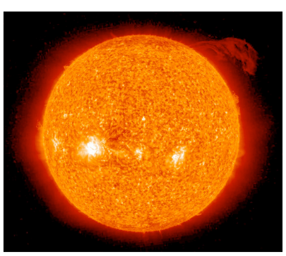
These observations were published years later, but Grote Reber, who continued to record radio observations since his great accomplish of 1937, was the first one to publish solar radio observations (1944).

Once the war was over, astronomers began to closely observe the Sun and by that time they started to discover many properties of the Sun, such as types of radio bursts, noise storms, and even to establish the relationship between radio bursts and solar flares (Appleton and Hey, 1946).

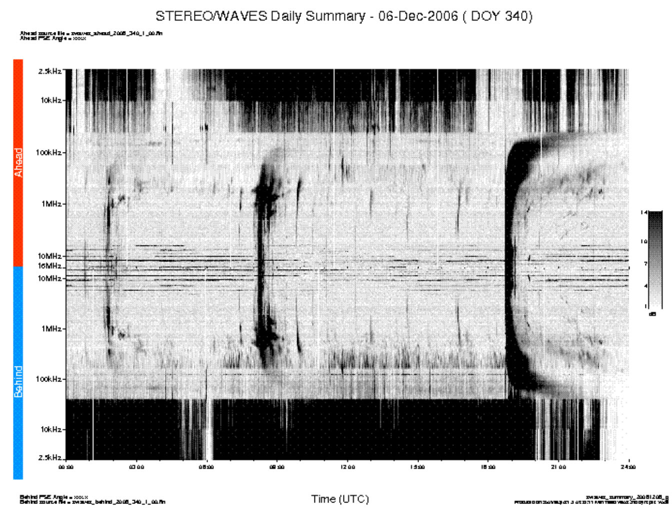
Many countries like Australia, Great Britain and Canada joined forces in the study of the Sun using radio data. This became more popular after the International Geophysical Year (July 1957-December 1958) and the International Year of the Quiet Sun (IQSY: 1964-1965).

Since then, many satellites have been launched to study closely the Sun and its impact on Earth. Knowing that receiving radio data from the Sun is essential for the understanding of the components of space weather, scientists decided to construct satellites capable of detecting solar radio waves. Some of these satellites are: the Radio Astronomy Explorer (RAE-1 and 2), Helios- 1 and 2, International Sun Earth Explorer (ISEE- 1,2 and 3), Voyager- 1 and 2, Ulysses, Galileo and Cassini.

At this moment in time, the latest satellites created to study the Sun are called STEREO *(Solar TErrestrial RElations Observatory)* launched on October 25th, 2006. *STEREO employs two nearly identical space-based observatories- one ahead of Earth in its orbit, the other trailing behind to provide continuous stereoscopic measurements to study the Sun and the nature of its coronal mass ejections (CMEs). STEREO is a mission that provides stereo viewing of the Sun from vantage points along Earth's orbit . The satellite is able to image and track space weather disturbances from Sun to Earth and to image solar activity with in-situ measurements of energetic particles at 1AU* (See STEREO's mission and concepts from website).



More relevant to our topic, the STEREO mission is the first to conduct radio triangulation with two identical satellites to determine the position of interplanetary shocks. This capability is provided by the integration of the instrument STEREO/WAVES.



Data sample from S/WAVES showing type II and type III radio bursts from December 6, 2006.

This instrument uses three mutually orthogonal monopole antennas (each 6m long) as its primary sensors. Connected to each of the three antennas there is a high input impedance preamplifier. The instrument also includes five radio receivers that cover frequency ranges of 10-40KHz, 40-160KHz, 0.125-16.075 MHz, 50 MHz (fixed frequency) and a Time Domain Sampler (TDS) that provides 250,000 sample/second time series snapshots. All of these components make it possible to *measure type II and type III radio bursts, track and probe CME-driven shocks and flare electrons, measure electron density and temperature from quasi-thermal noise properties in regions of cold dense plasma, and study the role of plasma microphysics in CME-driven shocks* (Fragment taken from STEREO/WAVES Science Goals). Achieving these goals will make the STEREO mission a major contributor to solar radio astronomy.

Conclusion

Radio astronomy had its beginnings with the discovery and application of electromagnetic waves and it has gradually evolved since then. History proves that radio observations expanded astronomy's horizons. It was primarily responsible for the discovery of objects such as pulsars, quasars and radio galaxies. It is also "partly responsible for the idea that dark matter is an important component of our universe; radio measurements of the rotation of galaxies suggest that there is much more mass is galaxies than has been directly observed (see Vera Rubin)". Overall, it provides a better understanding of the components and interactions of the universe.

It is expected that radio astronomy will continue to evolve in the following years, perfecting its techniques and providing many astronomical discoveries.

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