Radio Astronomy

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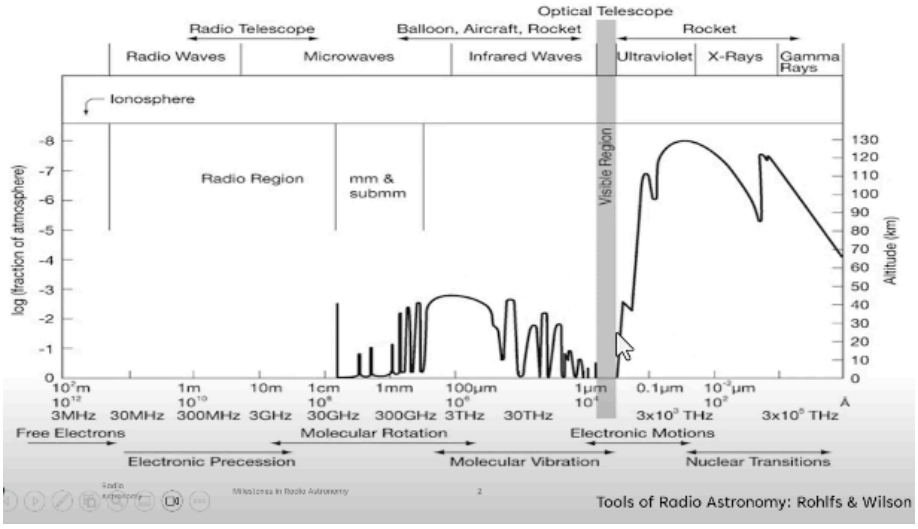
Lec-05

Milestones in Radio Astronomy

Welcome, everyone, to this second week of this course on Radio Astronomy. We will be happy to offer this course as a first time in NPTEL. Last week, what we did, we introduced the subject of radio astronomy, informed you about a few ongoing projects, future prospects, as well as pre-established radio telescopes and basic science, what is done through radio astronomy. We also introduced you to some basic prerequisites of electromagnetics. I have taken you through different derivations, a little bit of pointing vector, pointing flux, introduced again back the Maxwell's equations and also the polarization of electromagnetic energy. We also shared a little bit of tutorial which should have helped you with the assignments. They are very normal.

This week, we have a couple of things in mind. The first one is to introduce you to some important milestones in the history of radio astronomy, how this all came to being, who are the main contributors towards this astonishing field of radio astronomy and what are the important telescopes that paved this way in the early stages. So with that, we just proceed.

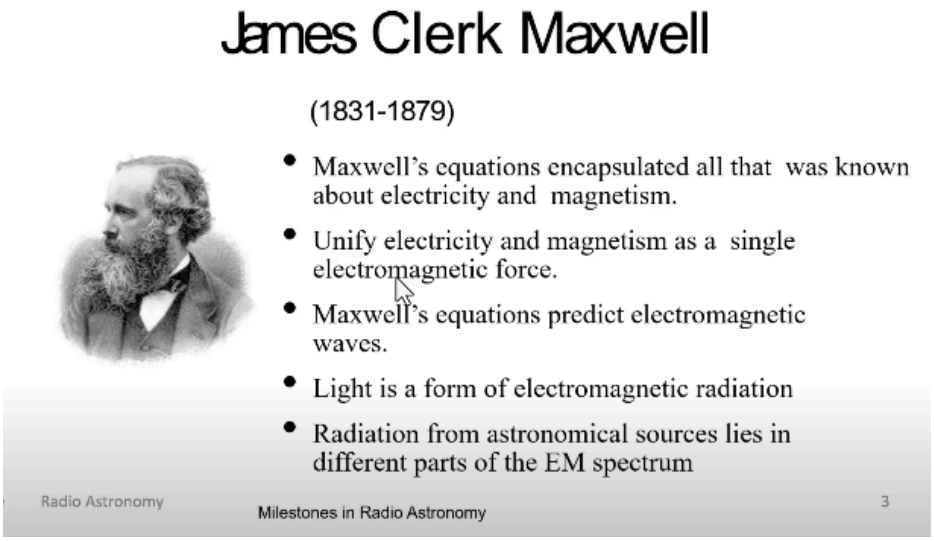


This is again a brief overview of the electromagnetic spectrum. We have shown it in a different way earlier. You can see the percentage of transmission and through the atmosphere. So you can see near the radio frequency, 3 MHz to about 30 GHz or so. The

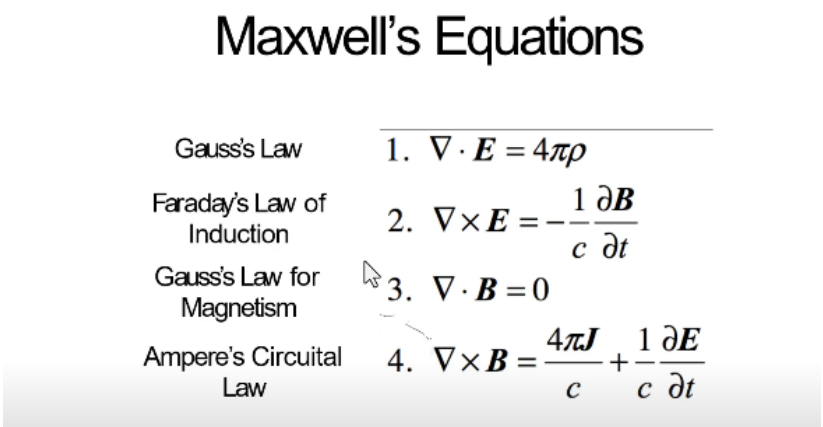
band is very clean.

You can observe it from the ground. But as you go to higher and higher frequencies, things become not that easy. And you have to rely on space-based observations. Of course, there is a minor fraction in visible region where you can still observe from the ground but the atmosphere of the earth becomes a bit of a problem. So you typically see very powerful optical telescopes are typically at a very higher altitude.

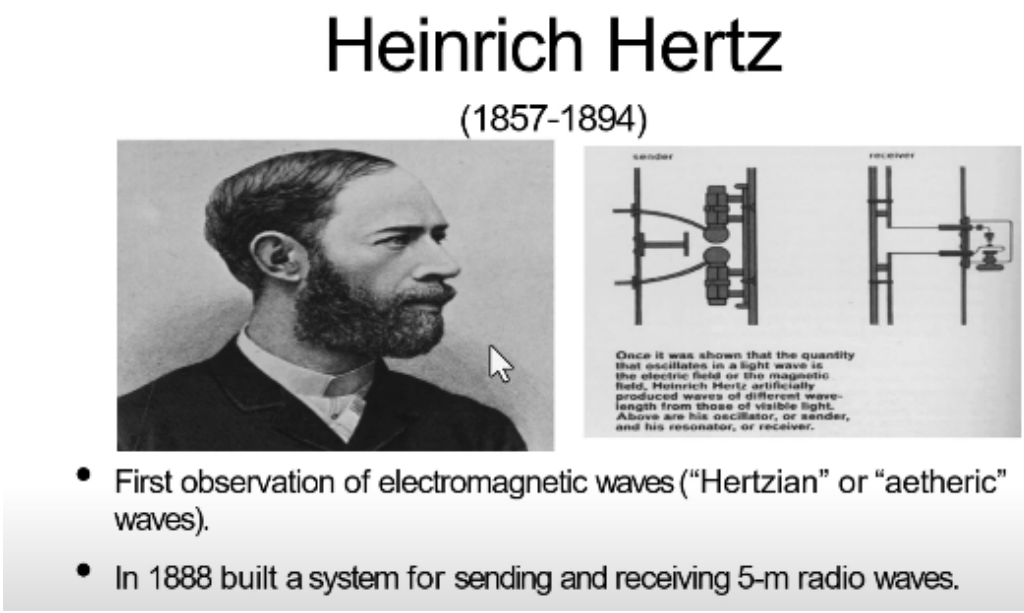
Okay. So with that, we proceed to our current narration. So we have already introduced Maxwell's equation. So James Clerk Maxwell is really the founder of the basic physical theories in electricity and magnetism that defines the platform on which the entire radio astronomy stands today. We have already discussed Maxwell's equation.



So I think that most of the work through Maxwell is already discussed. We know that all the four important Maxwell's equation and the different variants of that for different usage,



The next important figure in this discussion will be Henrik Hertz who did the first observation of electromagnetic waves.



Maxwell did the hard work of all the theoretical derivations, formalism, etc. Henrik Hertz actually did the first observation. In 1888, he built a system for sending and receiving five-meter radio waves over short distances. Extremely important to note this.

Then Guglielmo Marconi improved the transmitter designs and actually received a Nobel Prize for the first long distance radio wave communication. And so that was a very powerful discovery. It was made and first transmitters, receivers, which actually can do these communications were discovered initially at the stage by Marconi. He received Nobel Prize for that.

However, we have a little bit of different take on that. Closer to home, Professor Acharya Jagadish Chandra Bose was the first person who actually demonstrated way before Marconi did the transmission of radio signals for more than 1.5 miles. In 12th December 1901, Marconi used actually Bose's 1899 improved version of the cohort to receive the first transatlantic wireless signal.

It's all documented. However, for whatever reason, Marconi received the Nobel Prize and Bose's contribution now has really come to everybody's acknowledgement and he's really acknowledged for his initial work. However, the Nobel Prize for the first communication still goes to Marconi. Coming that was the important discoveries and important milestones regarding radio waves and communication without which the following discussion from henceforth would not be possible. But if you really come to the what was the first epoch, first instance where radio astronomy was essentially born, it was by an accident.

We call it serendipity, but it was really an accident. What happened was this gentleman called Ruth Jansky, he was an engineer at Bell Telephone Laboratory and he was investigating interfering static signals in the wireless communication. So they were building a built a 20 megahertz directional antenna and was receiving a static signal which keeps repeating at a sidereal rate. So Jansky was the one who inferred this is not coming from any interference nearby, but it is in instead indeed a cosmic signal which has been received from towards Sagittarius which lies to the center of our Milky Way galaxy. And this really, I mean they were not supposed to be looking for radio waves coming from cosmic sources.

They were doing some experiment to understand some systematic static signal in their system and this is what they end up getting. So in 1933, this first detection of radio waves was announced and Carl Jansky undoubtedly is the father of radio astronomy across the world because of this. He did the observations which later on Woodruff Sullivan actually converted them to this contour map where Jansky observed and it was a phenomenal discovery. But the take away point from there was they were not looking for this extra cosmic signal. They were looking for something else.

It was essential in an accident or serendipity, whatever you want to call it. This was great. I am glad that it happened. So Carl Jansky is really the first radio astronomer in its true sense that who did it by accident but then followed up with the observations. However, looking at Carl Jansky's work, I mean the next person, Grot Reber, got very excited and he actually jumped in as a first radio astronomer.

So if you really want to claim that, his debate is still out, I mean Grot Reber is knowingly built a 9 meter parabolic reflector in 1937 in his own backyard and then observed at three different frequencies, conducted the first sky survey at radio frequencies, truly the radio astronomer by hobby of a profession. So that was Grot Reber in front of 32 meter, 32 inch feet antenna. This is currently lying in the Green Bank Observatory of National NREL in the US. This next slide shows us the contour maps, the strip charts on the top and the contour map of the galaxy at 160 megahertz. So if I go back, if you go to Jansky's observations in 1932, they were made at 20.

5 megahertz. And unfortunately, Jansky was taken off the project and it didn't quite materialize after that. But looking at his work, Grot Reber got excited and he built a new telescope and that observing at a little bit higher frequency at 160 megahertz. The next person in the list to be mentioned is Joseph Posse. He developed microwave technology for Australian Navy during World War II. And this in the figure over here is the famous sea interferometer on the Dover Heights, which is near Sydney.

It's basically the same concept as Lloyd's mirror. And so you have a direct ray and a reflected ray from the sea surface and they all come and interfere near the antenna. So this was used as a very powerful technique at those times. The next person to mention is Sir Martin Ryle, who worked on airborne radar during World War II. Now World War II is a very important aspect in the development of radio astronomy.

Lots of dishes, lots of radars were used for communication purposes. And after the war ended, those were lying just like that for somebody to make use of it. And that compelled or aided the motivation of the then radio astronomers or engineers for pursuing this kind of cosmic observations at radio wave fronts. So he first published radio interferometric observations. He actually introduced a very critical concept of earth rotation aperture synthesis to radio astronomy, for which actually he received Nobel Prize in 1974.

So he was instrumental in building this multi-element interferometer. This is the one mile telescope in the Mueller radio observatory and this is the Ryle telescope or five kilometer telescope in Mueller radio observatory. So Sir Martin Ryle also is very important in leading the entire 3C survey, which are basically the first, the third Cambridge survey of sources. This became a very important catalogue of sources, which then people kept on observing on and on and on and to understand the sources, the properties, the radiabilities, etc, etc.

We'll come to all of those. But just to note the contribution that this aperture synthesis is extremely important when we come to interferometry. And interferometry is the most noble way to go after, to combine collecting area and resolution at the same time, which we discussed in the first week. But we will definitely come much more in details as the course progresses. So that's the timeline. The next person to be mentioned is Jan Groot.

He's a Dutch astronomer and father of Dutch astronomy. He was an expert in Milky Way structures. He was instrumental in building the New Telescope 25 meter. It operated 21 centimeter or 1.

4 gigahertz. That's towards the left bottom corner of the slide. It was built in 1956. These timelines are very important because as you see, 1932-33 was Jansky, then came Groot River 1937. Then you see for 1946, the first multi-element interferometer built by Martin Ryle. And then you see this 56 counts, the Doom New Telescope in the Netherlands.

He also built, Jan Groot also built the Westerbork array consisting of 14 dishes, 25 meters in diameter, each of them. They operated between 300 megahertz and 8 gigahertz. It was done in 1970s. So but unlike the VLA, the first that I showed you the picture in

the very first week, and also GMRT, it is not a 2D array. It's along the one-dimensional linear array and have some limitations, but we can discuss it later on.

Also, Jan Groot was very crucial in the crucial role in detection of H1 21 centimeter line emission from the Milky Way. It was done actually by Van der Hulst in 1944, but he played a very important role, which we can discuss when we come to that towards the end of this course. We come next to a person who is Professor Govind Surup, who is the father of radio astronomy in India. And he indeed done a remarkable job of building three telescopes. The first one was built in Kalyan, Kalyan radio telescope.

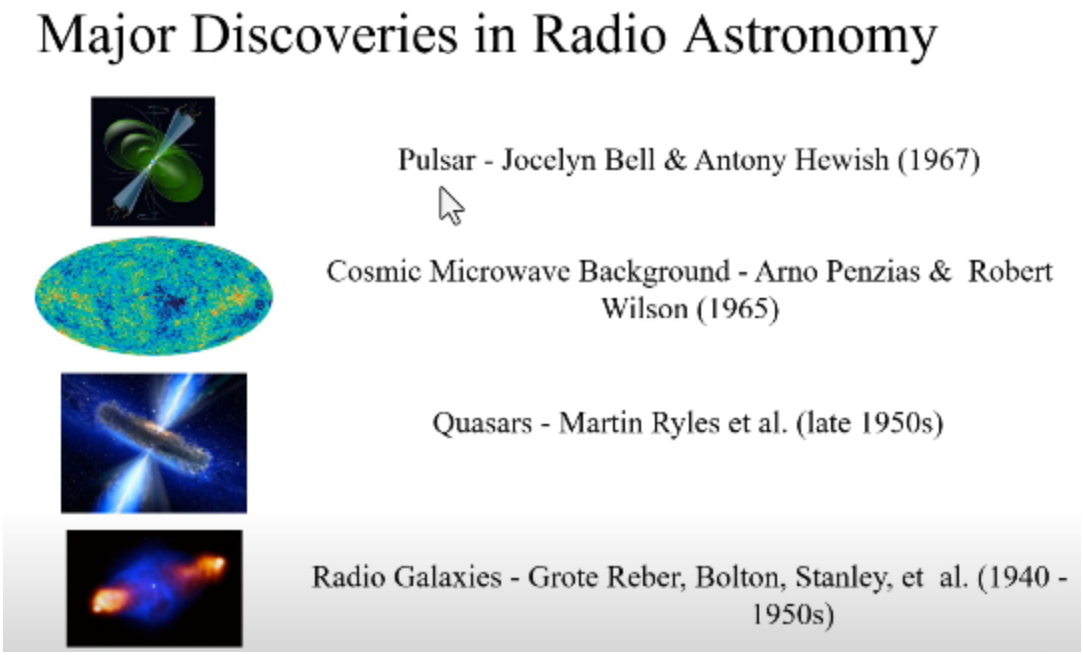
It was built at 610 megahertz, 24 dishes of 1.8 meter diameter each. It was done in 1965. Then he built an OT radio telescope at 326.

5 megahertz, a cylindrical parabolic dish. This is towards the left right corner. You can see this. We'll show you more pictures throughout the course.

It's an OT. It was built in 1970. In 1965, he built Kalyan telescope. Then he from some old dishes from somewhere else. We'll come to that story later. In 1970, he built OT telescope, which is cylindrical parabolic antenna, quite different in design than all the other dishes we have seen so far, but has very, very good relevance to something, some of the telescope which are currently operational in Canada and elsewhere. So in 1970, he built an OT telescope at a different frequency, 326.

5 megahertz. And then finally in 1997, the giant meter wave radio telescope operating below 1.6 gigahertz was actually finished construction. It started earlier. It's 30 parabolic dishes. We discussed it last time with 45 meter diameter, each of them.

So it's truly a remarkable man, a remarkable contribution. And for Indian astronomy, he was really the father. A few other major discoveries in radio astronomy to note Pulsar, the rotating star was discovered in radio. There are lots of other, don't get confused, lots of other discoveries in astronomy. We are focusing here only the ones which were discovered in radio.



Okay, so that's how this thing is done. Not in particular order. Pulsar is the rotating star, a phenomenal object to study. It is so, I know the pulse periods are so constant that it is sometimes often used even for navigation purposes. Jocelyn Bell and Antony Hewish discovered Pulsar (1967), although only Antony Hewish got the credit and got the Nobel Prize. Jocelyn Bell didn't. That's a separate story.

Next is cosmic microwave background was discovered by Arno Penzias and Robert Wilson (1965). Extremely important discovery, particularly to understand how the universe was formed, how it is evolving. I know that there are several theories, but this kind of cosmic microwave background kind of sealed it that there was a big bang and then what followed. So more on CMB later. Then quasars were discovered late 1950s by Martin Rael et al and his group.

Radio galaxies were discovered by Grot Reber, Bolton, Stanley, 1940 to 1950s. Very, very phenomenal discoveries. Radio galaxies, quasars, CMB, pulsar, etc. Now, a few important contributions, Nobel Prizes. As I said, Martin Rael and Tony Heavis received the Nobel Prize in radio astronomy.

In 1978, Penzias Wilson received the Nobel Prize also for the discovery of the cosmic microwave background. Different types of pulsar was discovered and an important probe to study gravitation. For that, Russell Hulse and Joe Taylor received Nobel Prize in 1993. Later, the first important, all the Penzias and Wilson discovered it, the CMB, but they didn't went into details about understanding structures in the CMB and this dipole nature anisotropy in the CMB radiation. That was done by John Mather and George Swoot using the COBE satellite and also to help of WMAP.

And for that, they were awarded Nobel Prize in 2006. So with this, we are coming close to, there are many other discoveries, many other telescopes to be mentioned. This is not exhaustive list. This is just initial, you know, kind of instigation to understand a lot of important works have laid to us what we hear and why this course is relevant. So this is not a new course or a new material. So I have referred to a lot of other existing slides and books for gathering this.

So there's some references. I will also put up exhaustive list at some point in the future slides, future lectures, sorry. So I'm glad if you have enjoyed it and look forward to seeing you to the next lecture. Thank you.