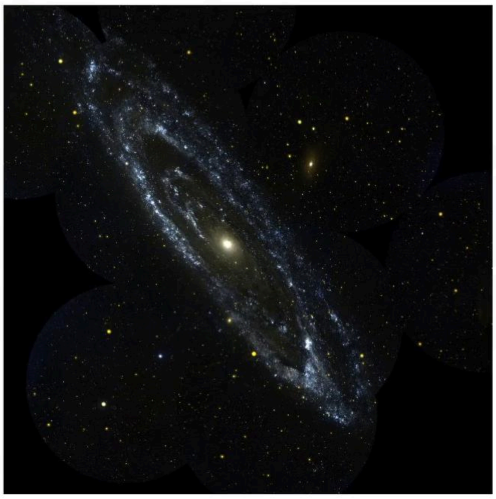
EPFL

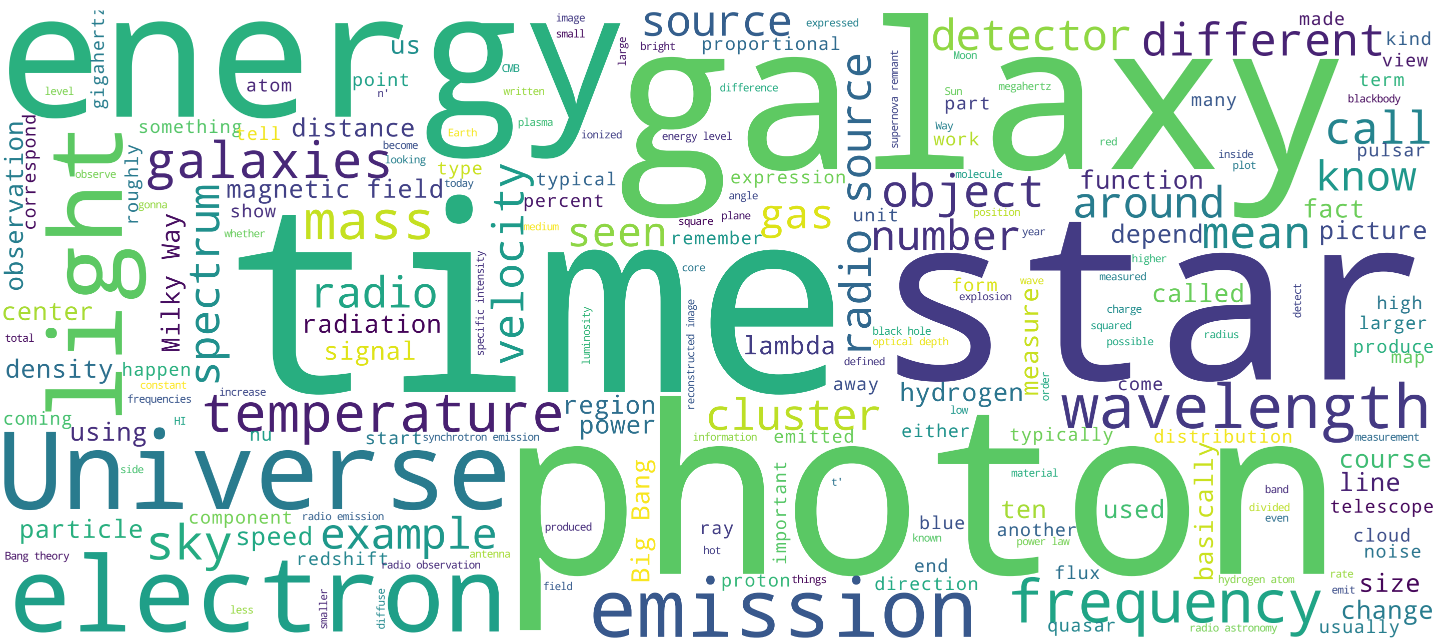
Key Radio Observations

The Universe At Radio Wavelengths

Frédéric Courbin



C: Kenderdine & Baldwin, 1965, The Observatory, 85, 24



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As is often the case when a new wavelength domain is explored, key discoveries come with fast technical developments.

Notes

Summary

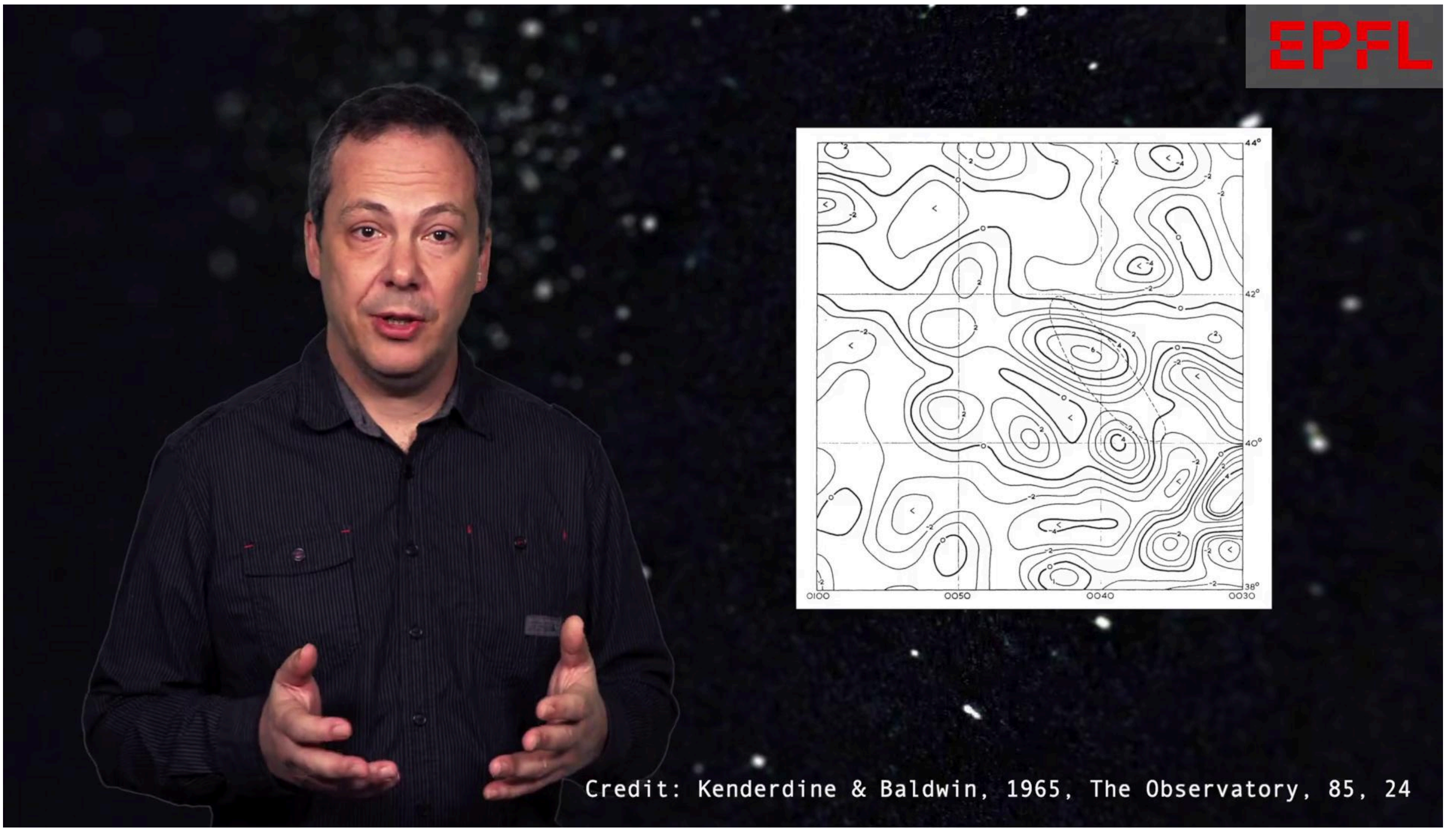
0m 05s

In the 60s when the first radio interferometers became available like the Mullard Radio Astronomical Observatory in Great Britain, it became possible to see fairly small objects on the radio sky. Well, not that small. The resolution so the apparent angular size of the smallest detail that can be seen with the Mullard array was still limited to about 45 arcminutes. 45 arcminutes, this is 50 percent more than the angular size of what you see of the Moon on the plane of the sky.

Notes

Summary

0m 14s



But this was still sufficient to see objects such as the Andromeda galaxy, one of the closest neighboring galaxies of our Milky Way. This is an optical view of it and now this is a much less impressive radio image of it seen at 38 megahertz.

Notes

Summary

0m 48s

But this is one of the very first radio maps of an astronomical object outside of our own galaxy, our Milky Way.

Notes

Summary

1m 10s

It is, in fact, a reconstructed image based on the simultaneous observations by several antenna from the Mullard Radio Array.

Notes

Summary

1m 16s

A significant fraction of this mooc is devoted to the technical ways technical signal processing methods to obtain radio maps from radio arrays. Another key capability of the first radio interferometers was the possibility not to obtain only record reconstructed images but also to obtain spectra so a measure of how much energy is radiated by astronomical sources as a function of wavelength or frequency.

Notes

Summary

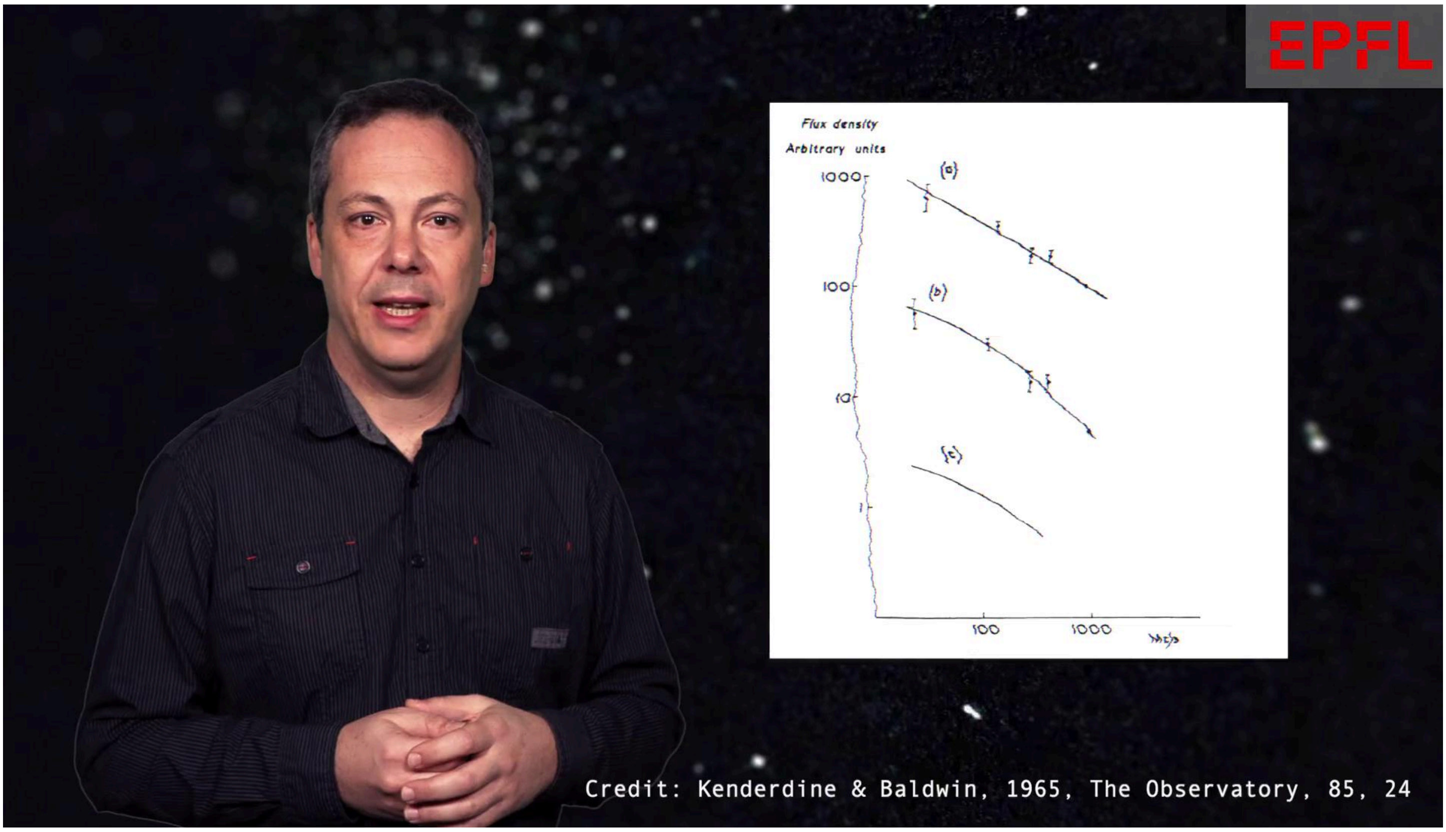
1m 24s

And again an easy target for such observations in the 60s was the Andromeda galaxy of which we see now a radio spectrum between ten and 1000 megahertz.

Notes

Summary

1m 58s

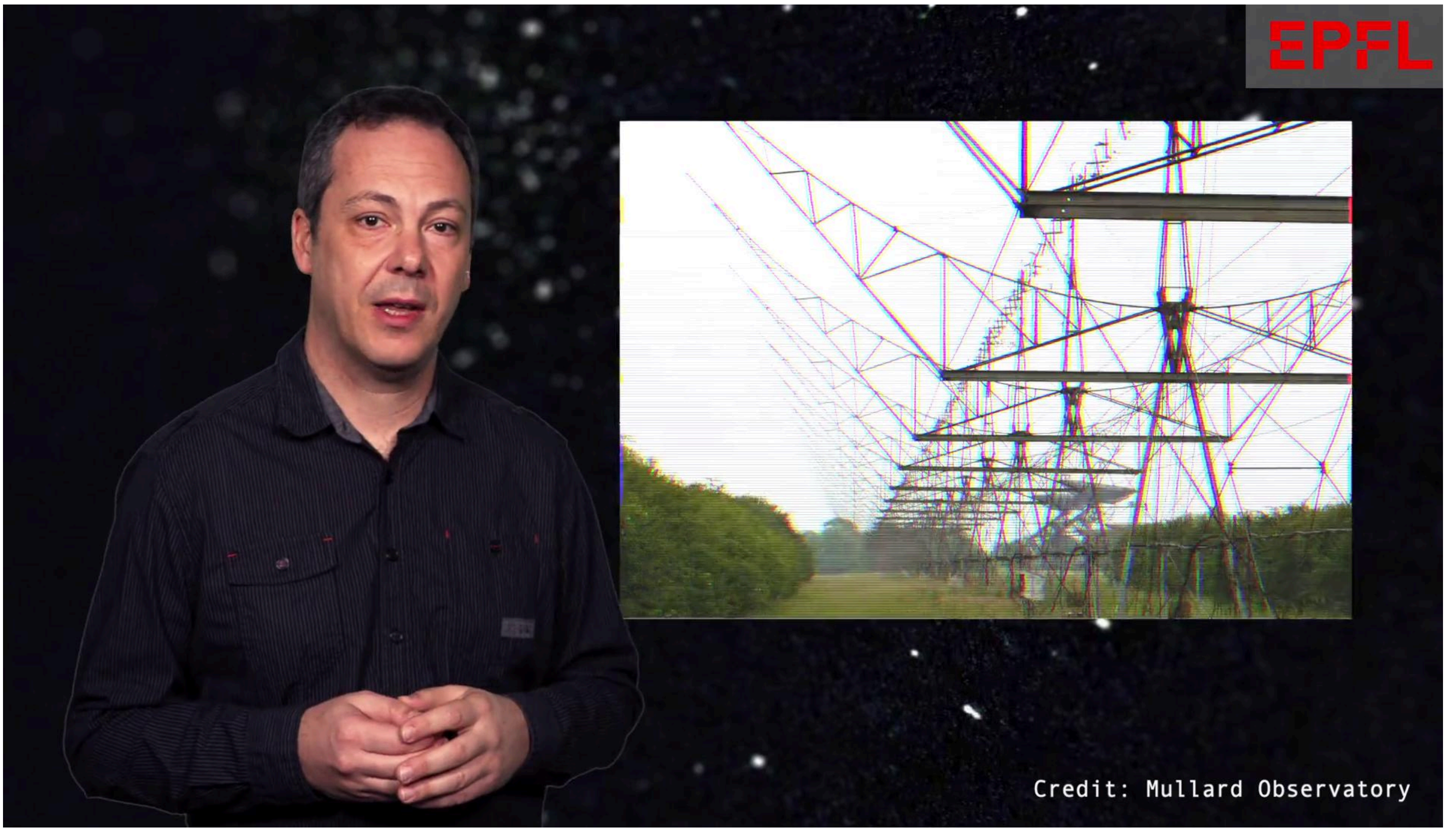


The spectrum you see on the top shows the data directly coming from the telescope. It is a straight line seen here in logarithmic scale so it's, in fact, a power law in linear scale. This spectrum obtained back in 1965 is one of the very first spectrum of an extragalactic source. Most galaxies including ours display such a power law spectrum which is now considered as a typical characteristics of galaxies on the radio domain.

Notes

Summary

2m 10s

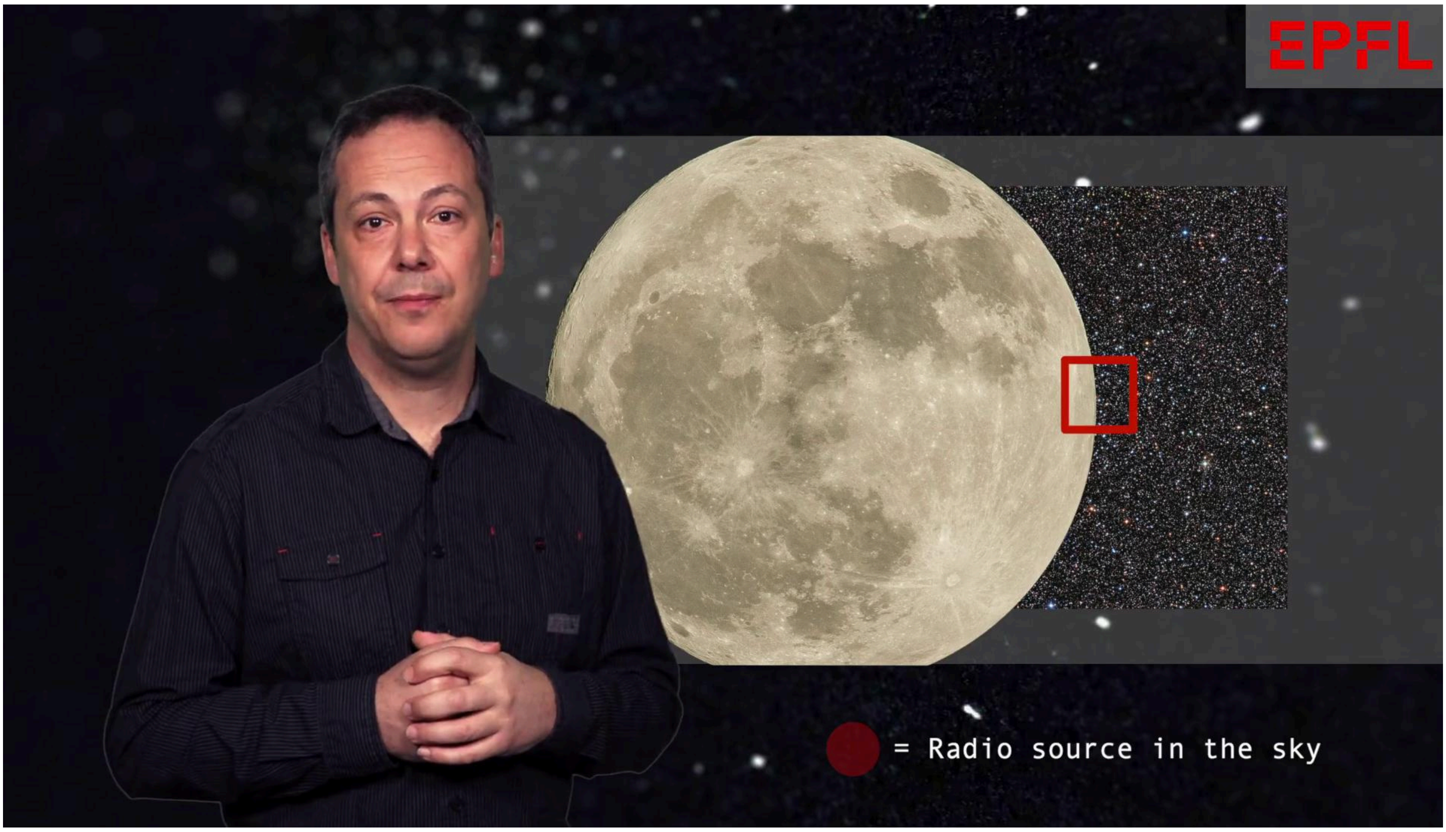


With continuous progress made on the sensitivity of radio dishes and arrays, cataloging radio sources became a very active field from the late 60s to the early 90s, especially with the Cambridge radio astronomy group starting a systematic observational campaign resulting in a series of catalogues of radio sources in the northern sky.

Notes

Summary

2m 42s



The first one named 1C, so 1C for the first Cambridge catalogue, was containing about only 50 sources but it was quickly updated to 2000 sources with the 2C catalog and then to much larger numbers with the seven successive updates in different areas of the sky and different frequencies. Of course, because the resolution of radio data at that time was much poorer than that of optical images, it was also almost impossible to see any reliable optical counterpart to radio sources because many optical sources were seen within the angular area covered by radio sources on the sky. Matching radio and optical sources has, nevertheless, been possible using a very smart technique called lunar occultation. Indeed, as the Moon moves along the night with respect to the stars and to the galaxies it occults them one after the other and this is the technique that Cyril Hazard in 1963 used to discover quasars.

Notes

Summary

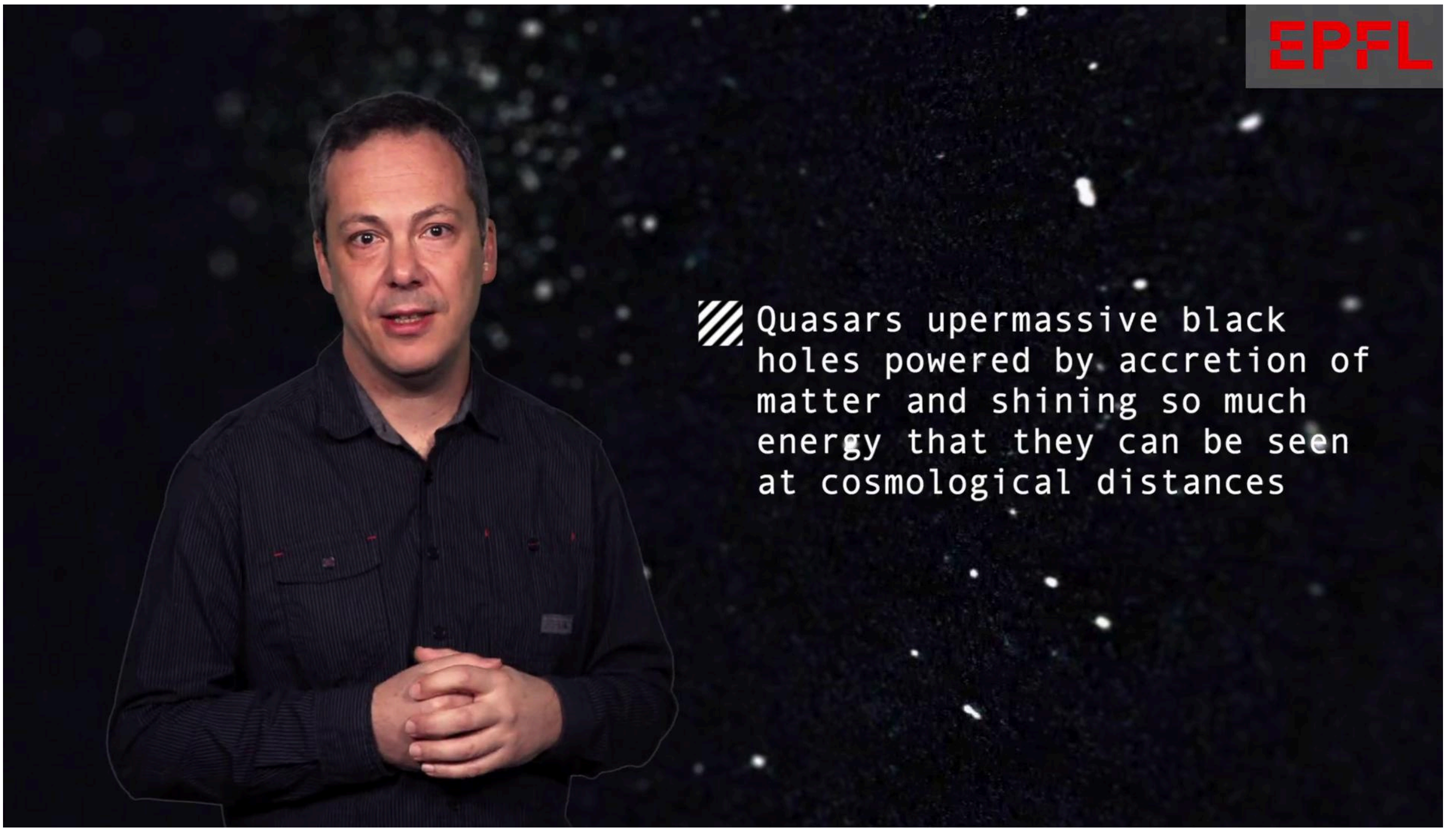
3m 06s

So Cyril Hazard took advantage of this natural phenomenon of lunar occultation to observe the bright radio source 3C 273 from the third Cambridge catalogue shortly before it disappears behind the Moon. To do so he used this antenna, a 64 meter antenna at the Parkes Observatory in Australia. He pointed the antenna towards the radio source and on the exact moment of the occultation he knew that the position of the radio source was somewhere along the limb of the Moon. He then compared with optical images of the same region of the sky and identified optical point source that could be, you know, the optical counterpart of the radio source.

Notes

Summary

4m 21s

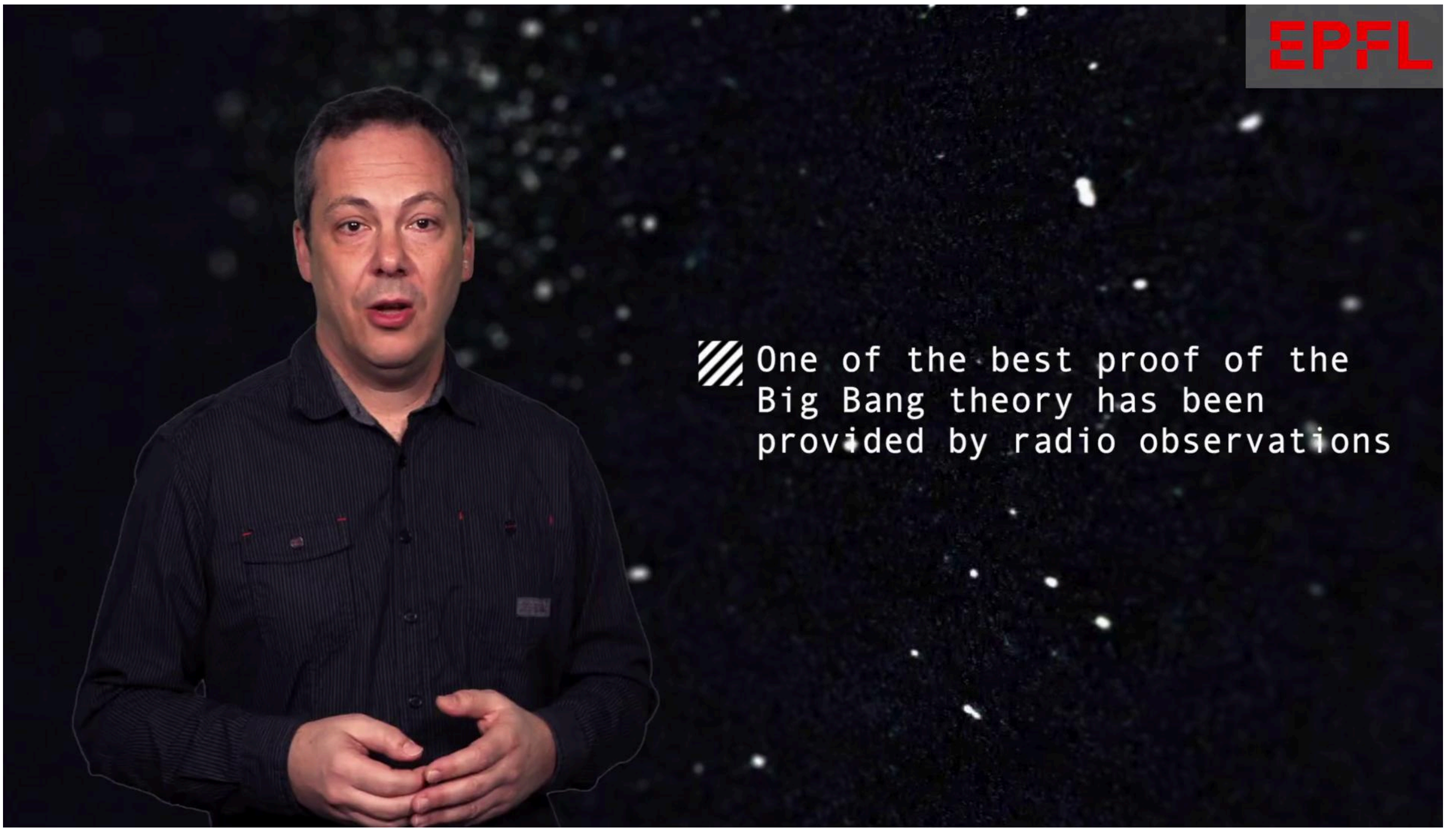


Then Marteen Schmidt and Bev Oke eventually took a spectrum of this radio source and this led to the discovery of a new category of distant objects now known as quasars. So quasars are supermassive black holes powered by the accretion of matter and shining so much energy that they can, in fact, be seen at cosmological distances.

Notes

Summary

5m 00s



Last but not least one of the best proof of the Big Bang theory has been provided by radio observations.

Notes

Summary

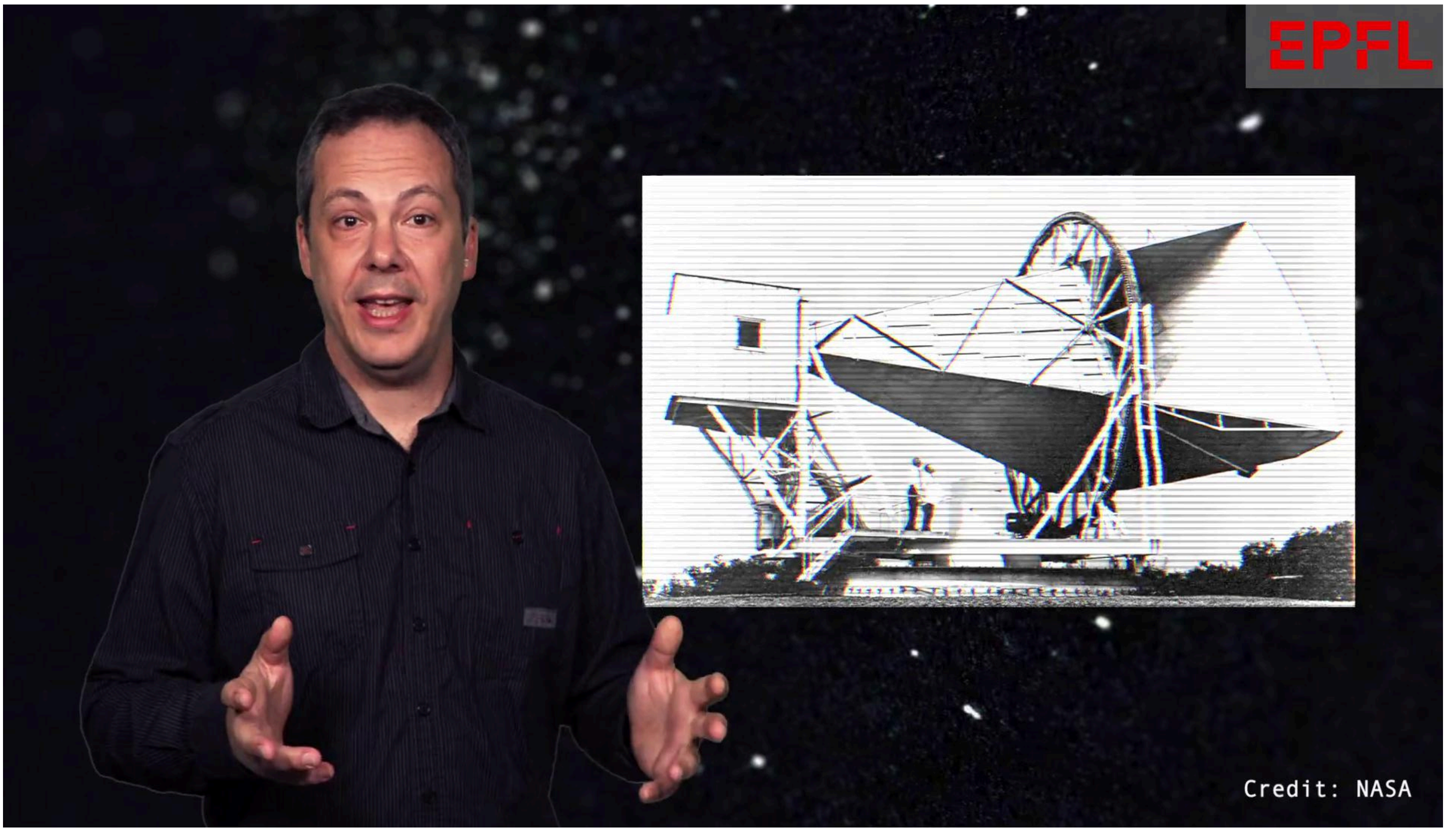
5m 22s

Right after the Big Bang, the Universe was very hot and started to expand at extreme velocities. This is called inflation. But as time passes, the finite energy of the Universe dilutes and the Universe cools down and at present times about 13.7 gigahertz after the primordial explosion so after Big Bang the energy density of the Universe is such that the sky background emits a blackbody radiation corresponding to a temperature of 2.73 K. And this has been discovered in 1964 by Penzias and Wilson with this very simple antenna and the radio.

Notes

Summary

5m 29s

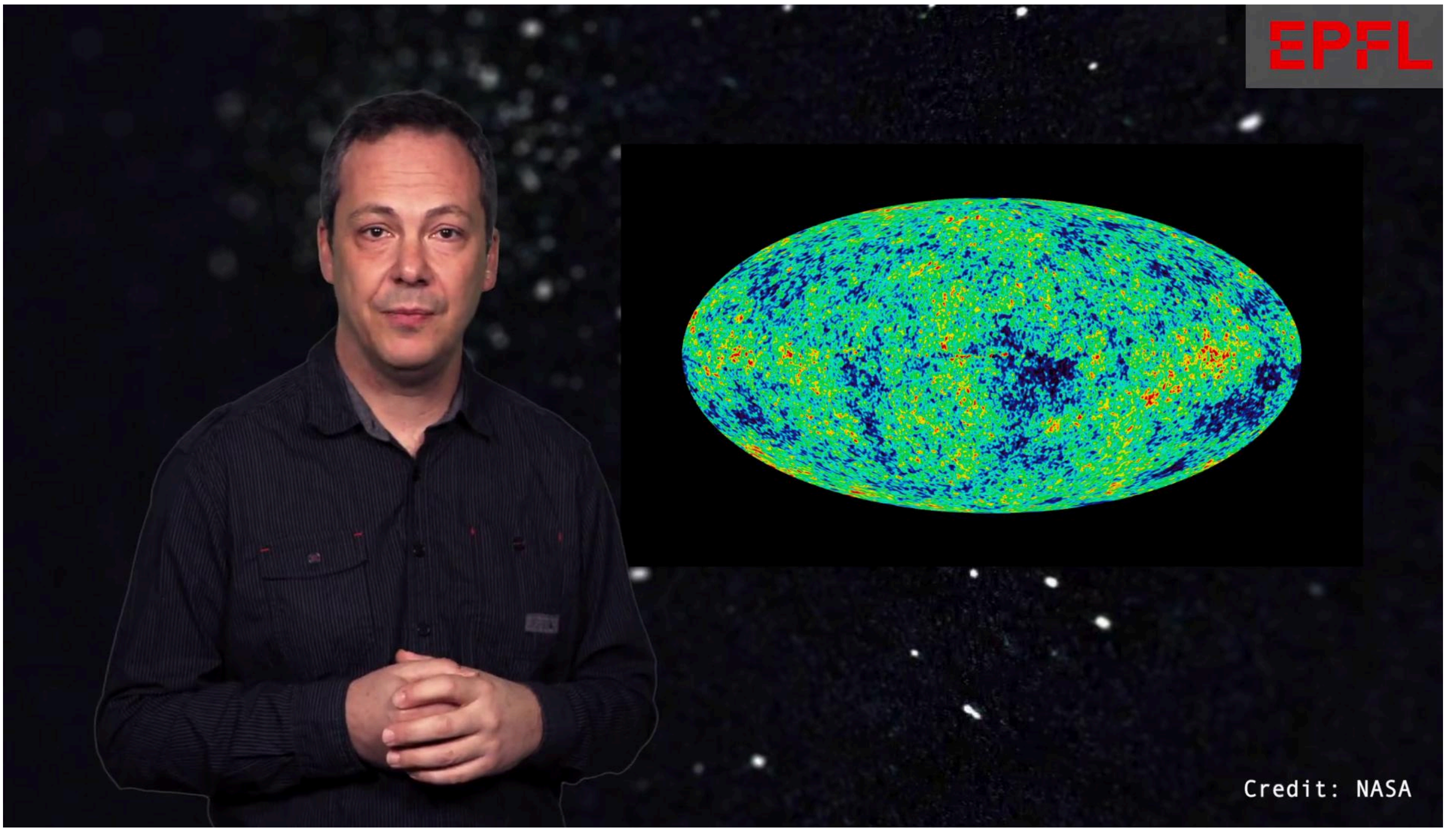


Even better the Big Bang theory predicts that this radio radiation this microwave radiation is almost but not fully isotropic.

Notes

Summary

6m 11s

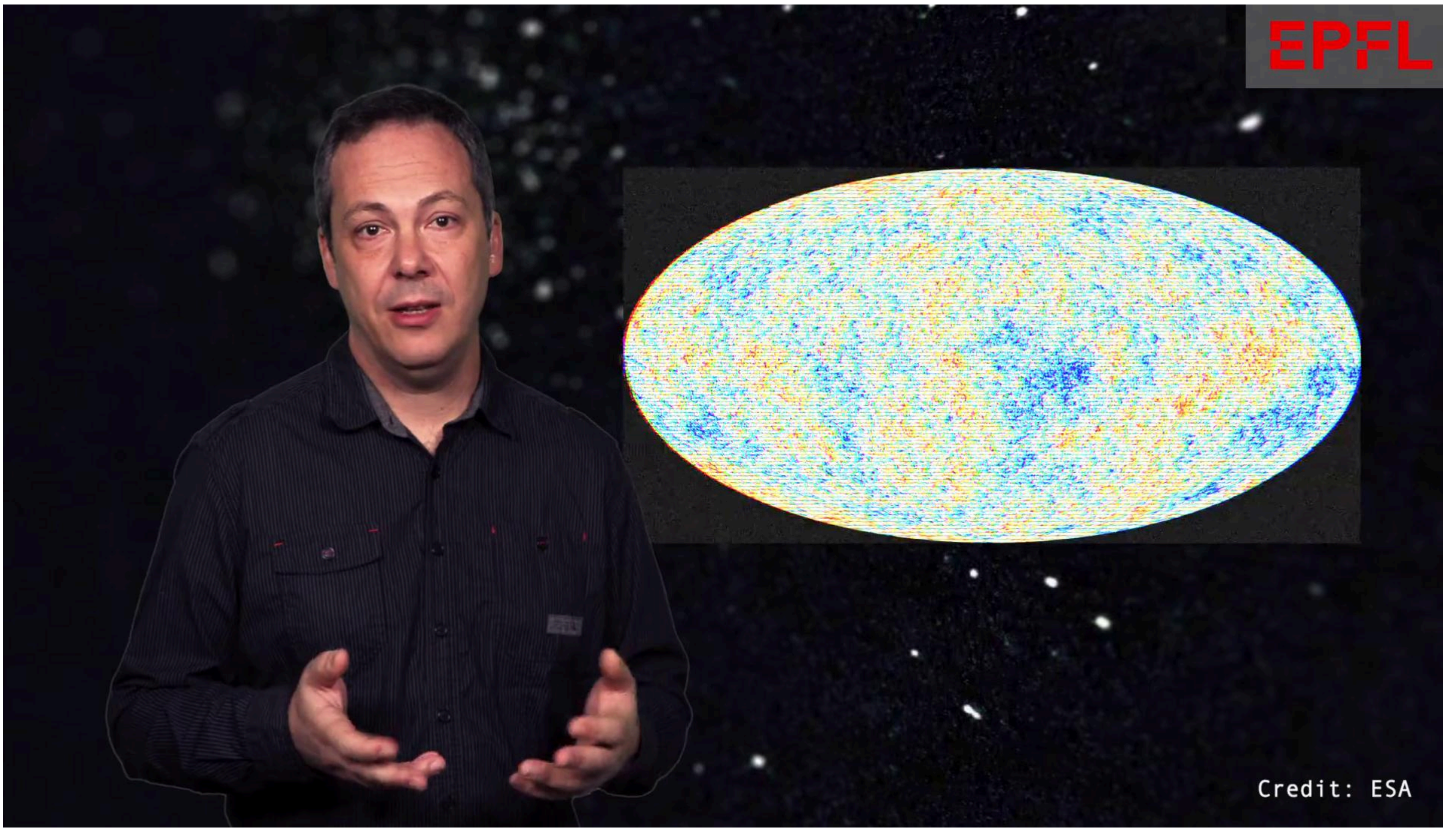


Again, more detailed radio observations by the COBE satellite showed here showed small fluctuations of temperature across the sky and this is an excellent agreement again with the predictions of the Big Bang theory. And when going to higher angular resolution, for example, with the WMAP satellite of which the map of the sky is shown here then again you see all these clumps of temperature, these fluctuations of temperatures that agree with the predictions of the Big Bang theory.

Notes

Summary

6m 20s

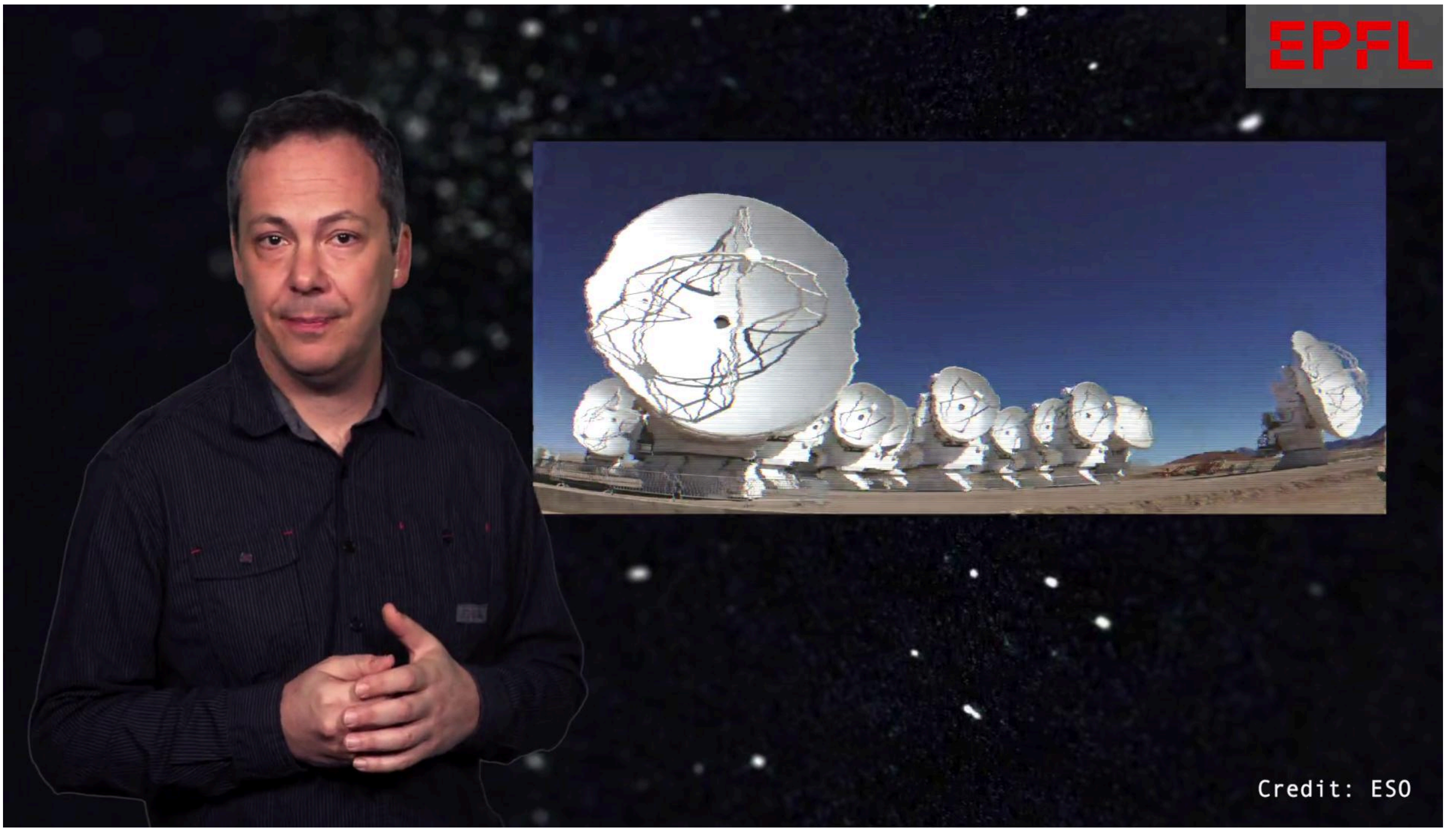


And again you're going to higher resolution with a Planck satellite. Again the observations agree with theories. All the explorations were provided in the microwave domain so in the radio.

Notes

Summary

6m 51s



Nowadays, we know countless radio sources on the plane of the sky and we can even make high-resolution images of them, reconstructed images with arrays containing tens of antenna like the ALMA array operating in Chile in the millimeter domain or like the MeerKAT array based in South Africa and which is the precursor of the future Square Kilometer Array, the SKA.

Notes

Summary

7m 03s

These beautiful images reconstructed in the radio was obtained in 2018 and shows the center of the Milky Way with the MeerKAT array in the centimeter domain. Lots of fine details can be seen such as plumes of gas generated by rotating stars, bubbles of gas due to explosions of supernovae and, of course, the diffuse gas in the interstellar medium of the Milky Way. There is no doubt radio astronomy will continue its exponential growth and to provide a wealth of information on the formation, the evolution and the content of our Universe.

Notes

Summary

7m 25s