UNIVERSITÀ DEGLI STUDI DI TRIESTE

Department of Physics

Basic information

Master degree: Physics SM23

Curriculum: Astrophysics and cosmology

Course: 356SM **Radioastronomy**

6 CFU - 48 hours

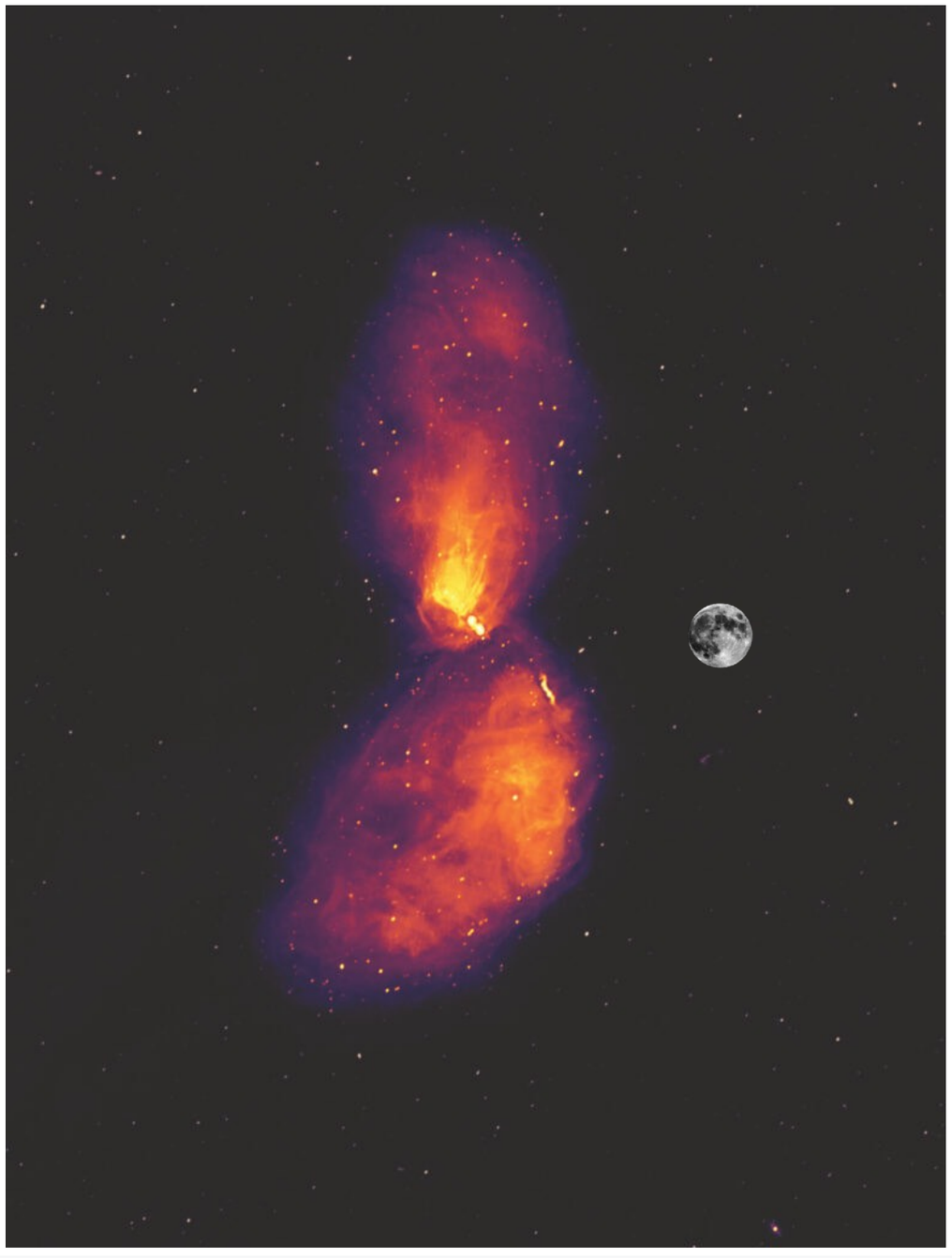
Tuesdays 09 - 11 Room 4B (building H2)

Thursdays 09 - 11 Laboratory T20 (building F)

Rec: Mondays & Wednesdays 15:30-17:00 @ INAF OATs
Via G. Tiepolo 11, Room 1402

Final exam: oral, 3 questions (1 chosen by the candidate)

Contact: **manuela.bischetti@units.it**



Credit: Ben McKinley, ICRAR/Curtin and Connor Matherne, Louisiana State University
Murchison Widefield Array 185 MHz

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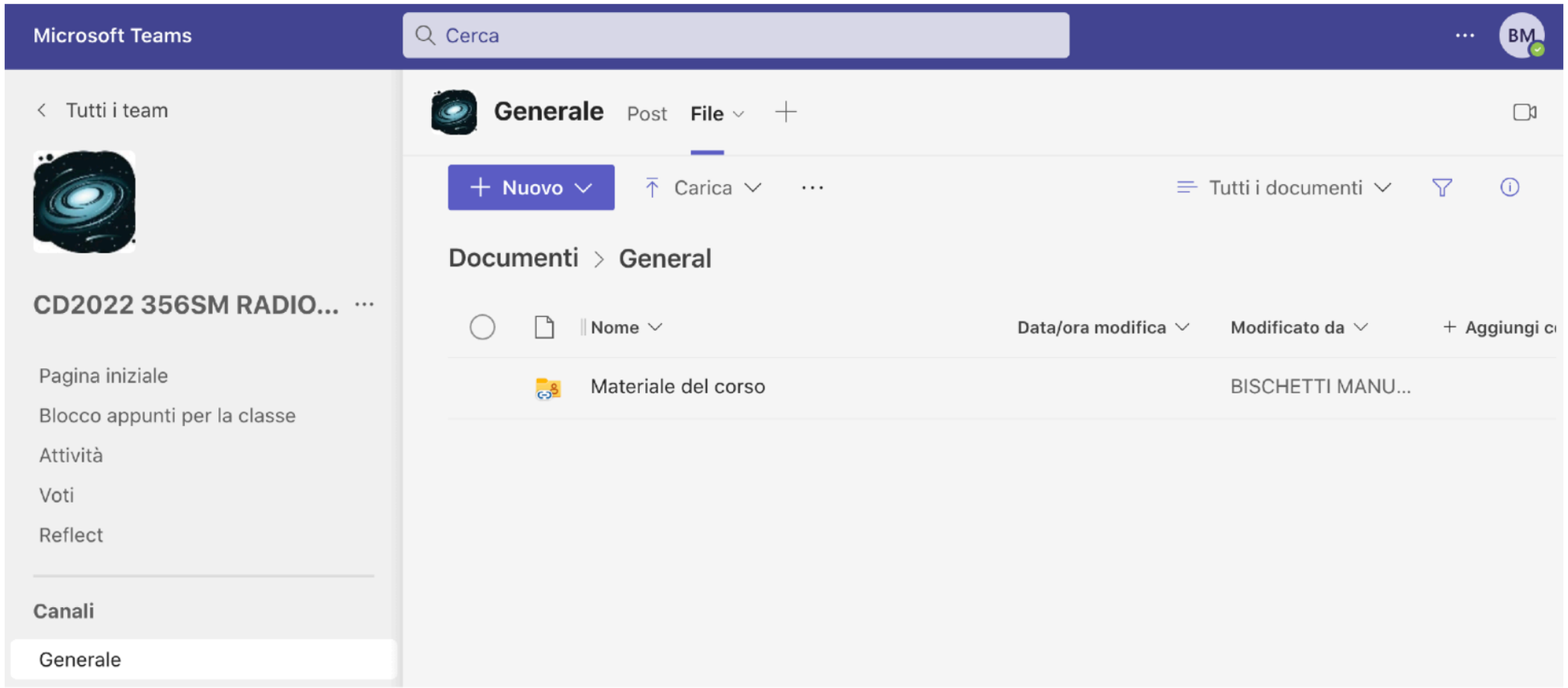
Basic information

Registrations and slides of the lessons will be uploaded on Teams CD2022 356M RADIOASTRONOMIA.



To join the RADIOASTRO teams channel use the code: **h0mddmt**

Information about the course will will also appear on Moodle

Radioastronomy course in a nutshell

- **Birth of Radioastronomy**
- **Overview of modern Radiotelescopes**
- **Fundamentals of Radioastronomy:** single dish antenna and interferometers
- **Emission mechanisms of radio-photons and observables**
- **Gas dynamics:** emission and absorption lines, cold gas tracers at different redshift, molecules
- **Galactic Radioastronomy:** the galactic centre and other compact sources, star forming regions
- **Extragalactic Radioastronomy:** galaxies and active galactic nuclei, galaxy clusters
- **Radioastronomy as a probe of cosmological parameters**

Motivation

Understanding Radioastronomy principles and acquiring a wide overview of the astronomical systems that can be probed at radio-wavelengths

Radioastronomy experienced an **exponential growth** in the last decades

Radiotelescopes are among the most powerful tools we have: large collective area, high sensitivity, high-angular resolution.

And **they will play a major role in future astronomy**: e.g. the Square Kilometer Array (SKA) will be the largest telescope in the world.

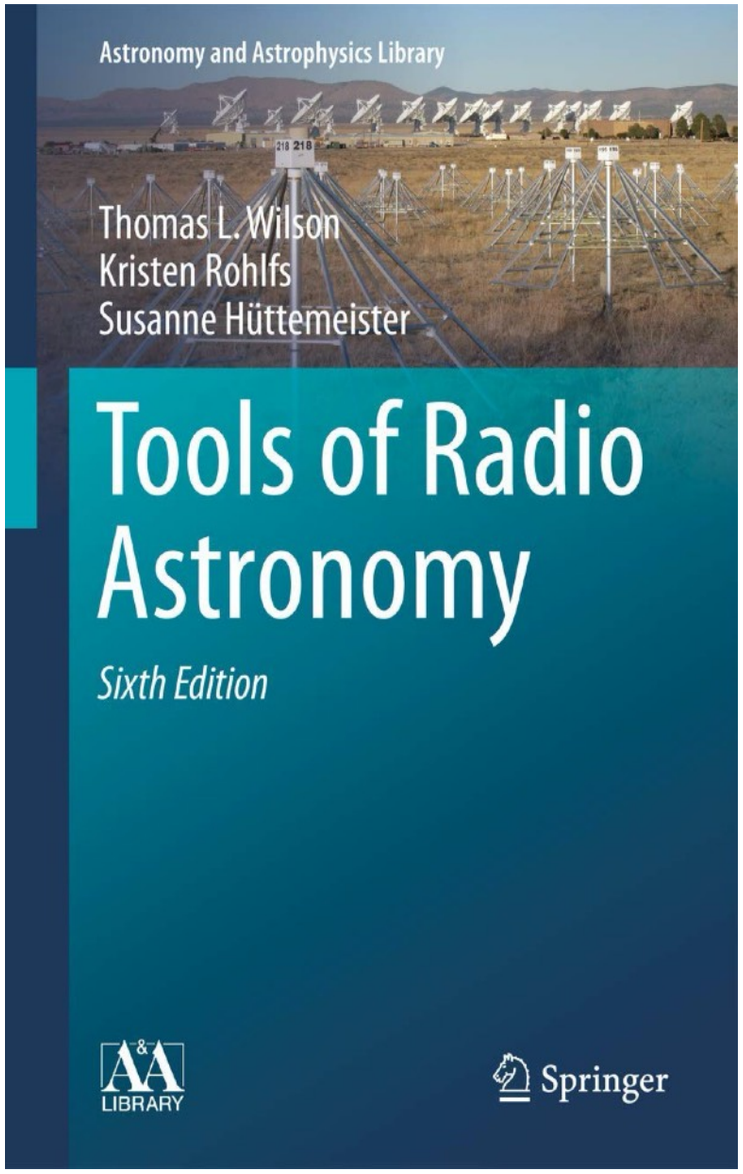
A revolution of our-knowledge of the nearby up to the most distant Universe.

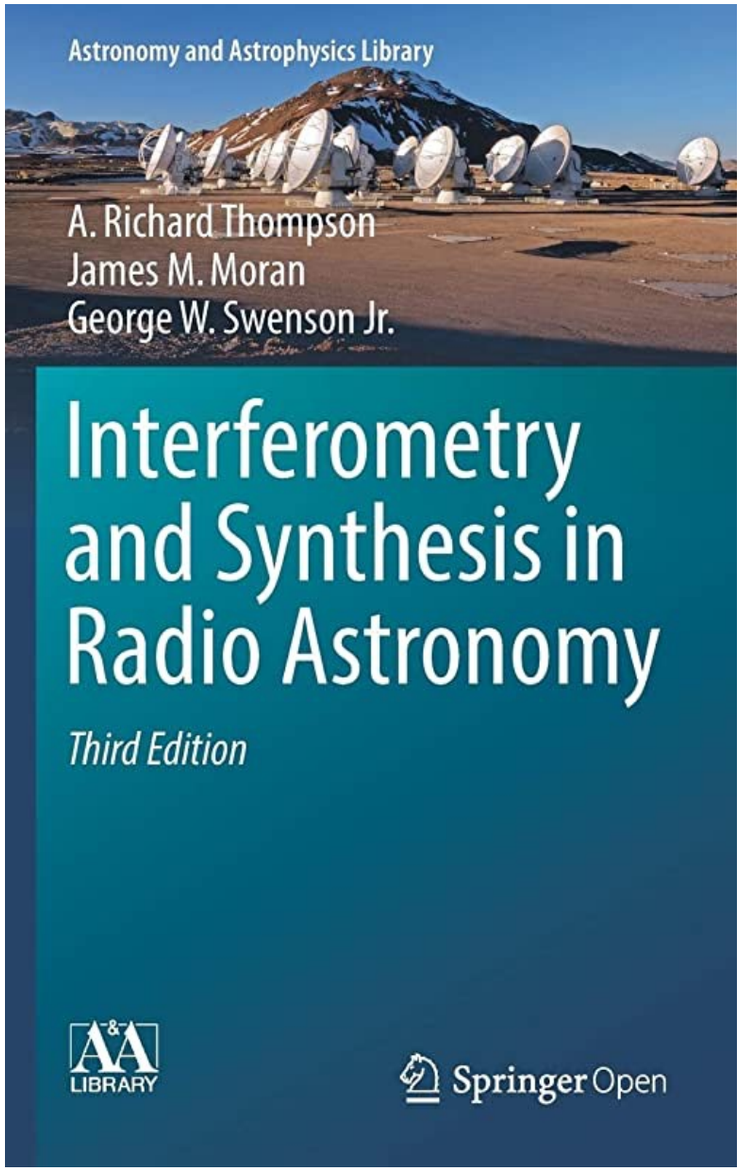
Deep involvement of the Italian astrophysics community in present and future radio observatories: e.g. SRT, LOFAR, MeerKAT, VLBI, SKA

Interest in Master thesis projects

UniTs and INAF staff: Chiara Feruglio (Interstellar medium), Alex Saro (clusters of galaxies), Fabrizio Fiore (supermassive black-holes and compact sources), Stefano Borgani and Pierluigi Monaco (cosmology and large-scale structures) … and many others

Bibliography





PDF (or EPUB) available here:

https://link.springer.com/book/10.1007/978-3-540-85122-6

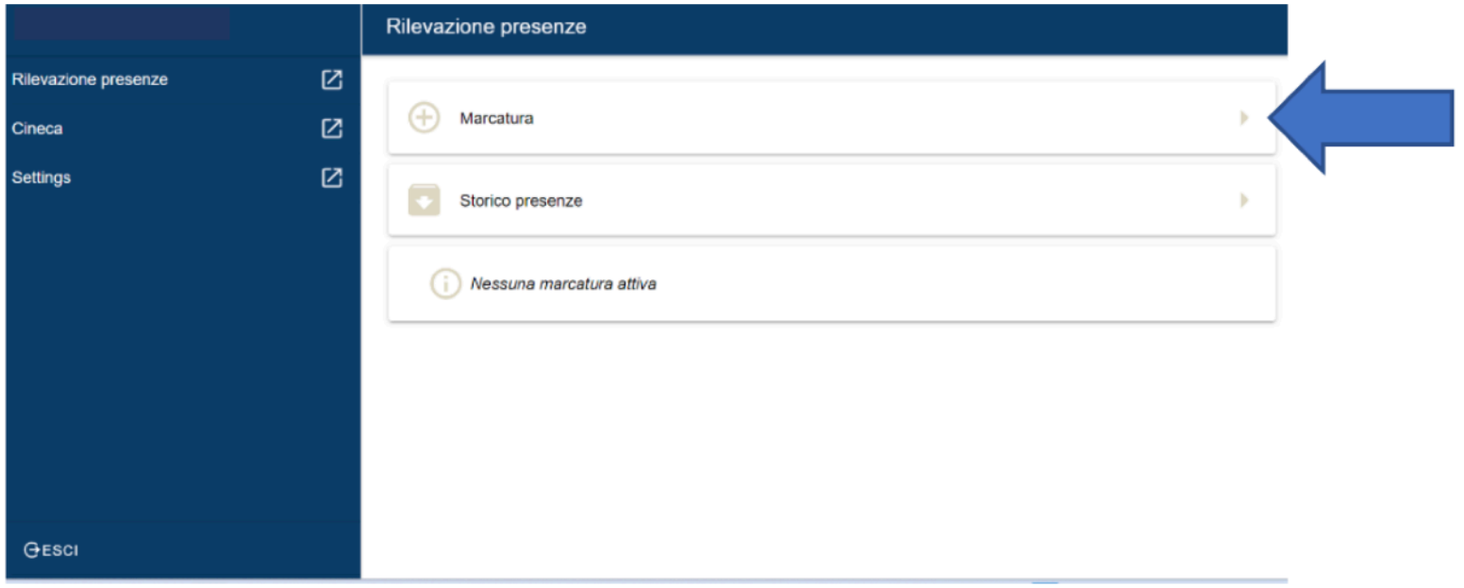
https://link.springer.com/book/10.1007/978-3-319-44431-4

Additional papers for specific arguments will be given lesson by lesson (and in the slides). Starting point for the first argument to be discussed during the final examination

myUniTs app or

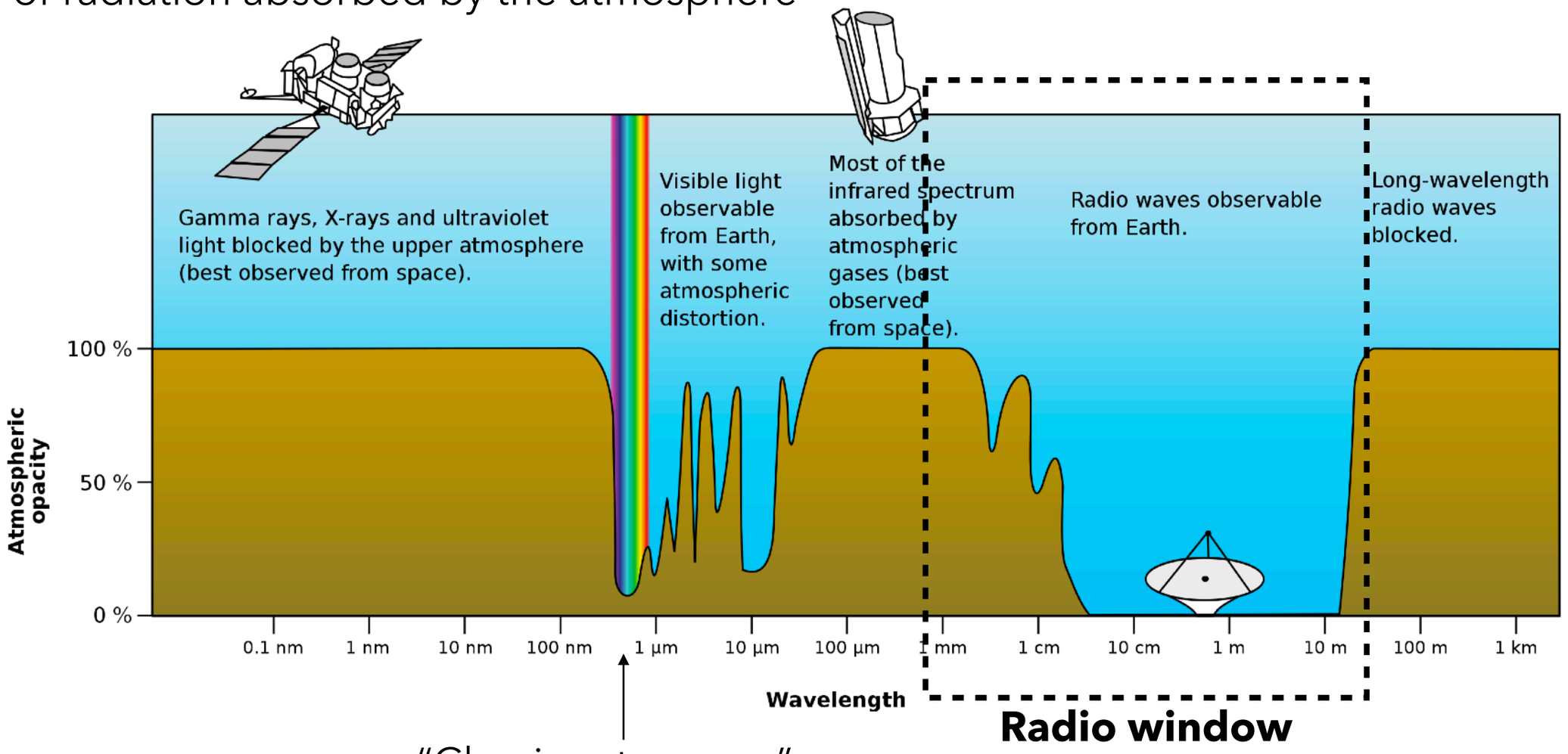
https://units.appmobile.cineca.it/

to register your attendance



Introduction to radioastronomy

Fraction of radiation absorbed by the atmosphere

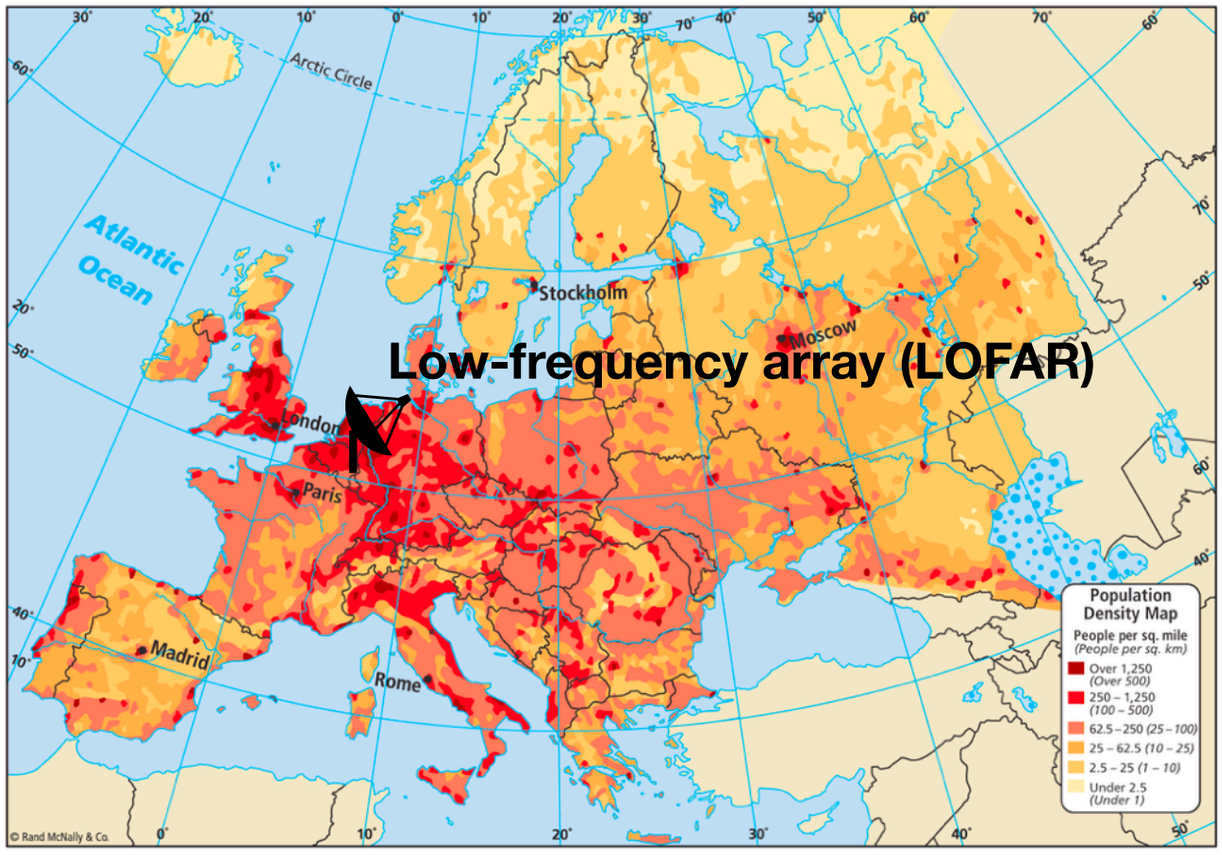


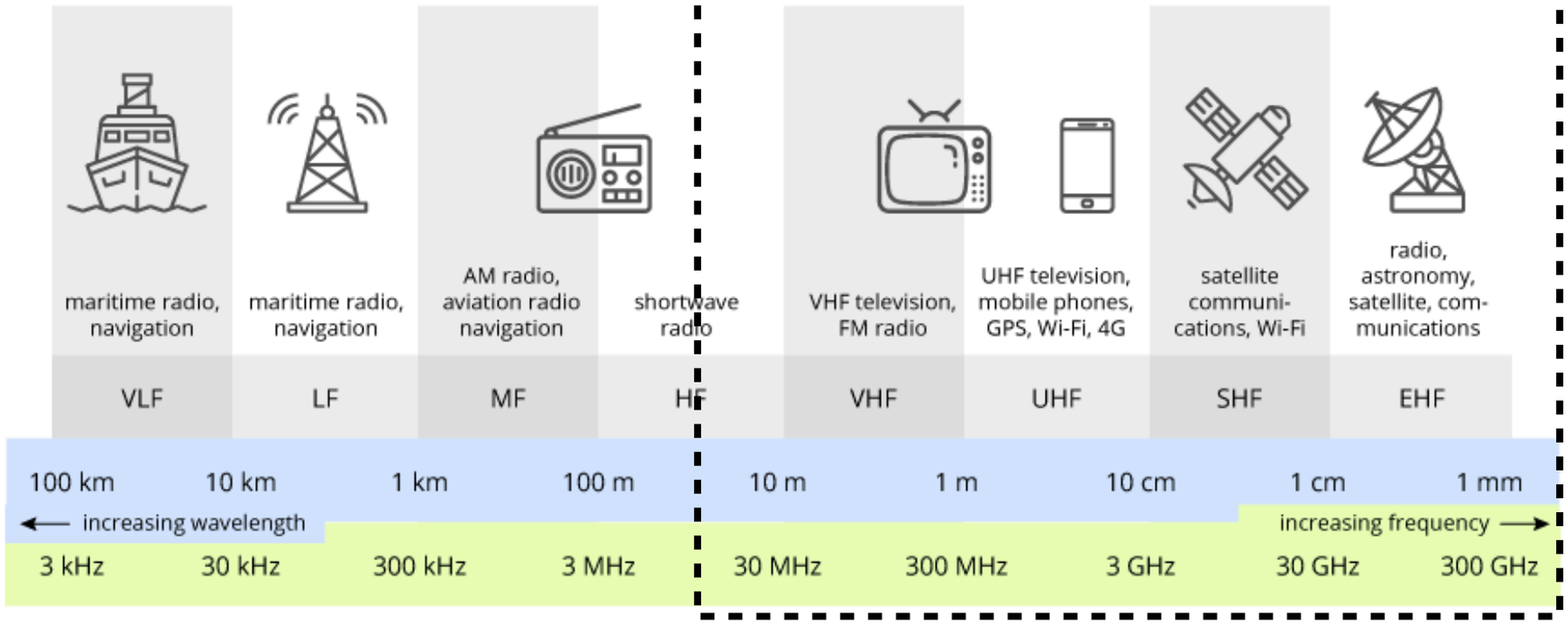
"Classic astronomy"
Optical band

- At long wavelengths ($\lambda >> 10$ m) the ionosphere reflects radio wavelengths: radio frequency smaller than the characteristic plasma frequency
- At short wavelengths ($\lambda << 1$ mm) most photons are absorbed by the atmosphere gases
- At $\lambda \sim 1$ mm water vapor absorption. Observations from high-altitude and dry sites: (sub-)mm astronomy

Introduction to radioastronomy

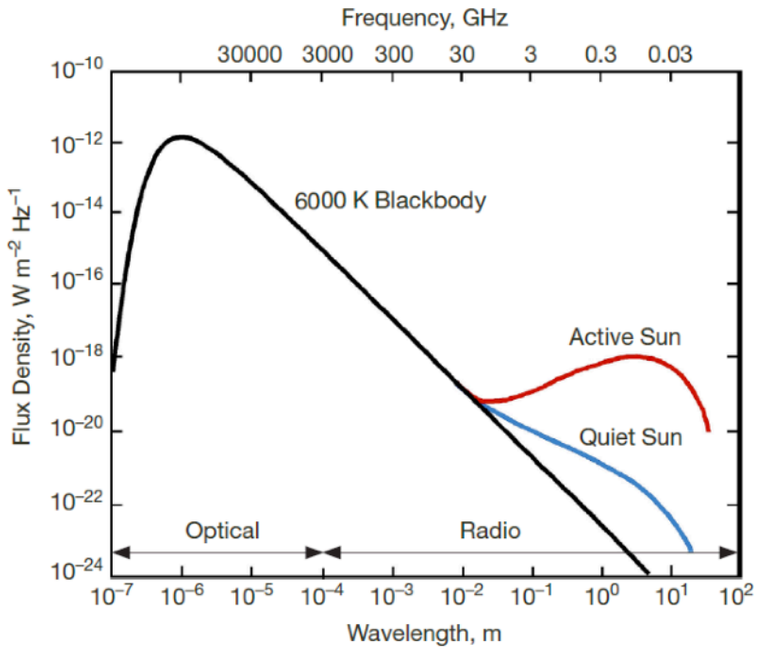
- Transmitting devices on Earth may cause radio-frequency interference. Because of this, many radio observatories are built at remote places.



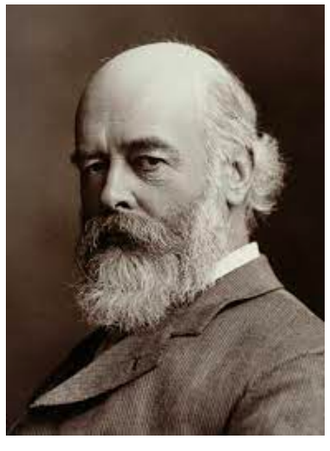


The birth of radioastronomy

- Before 1900s, physicists speculated that radio waves could be observed from astronomical sources. In the 1860s, Maxwell's equations had shown that electromagnetic radiation could exist at any wavelength.
- 1896: Johannes Wilsing and Julius Scheiner attempted (without success) to detect radio emission from the Sur



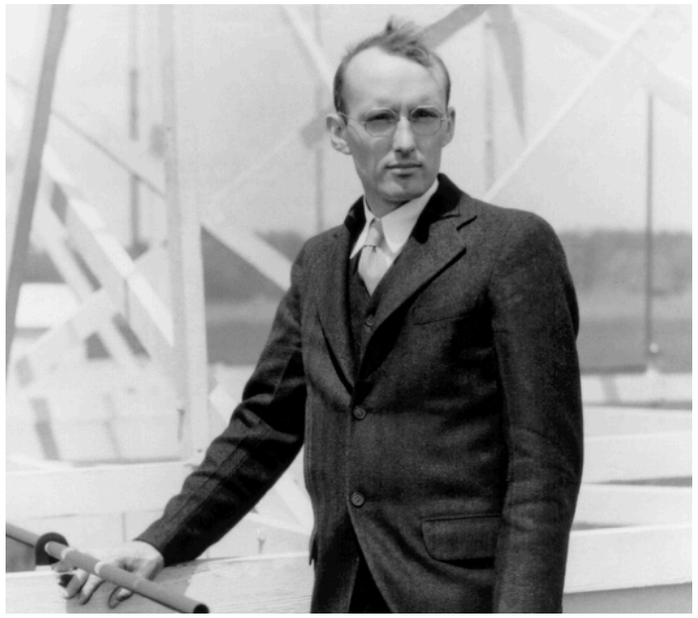
- 1897-1900: Oliver Lodge built and apparatus to detect centimeter wave radiation from astronomical sources, in competition with the Marconi's family. No success

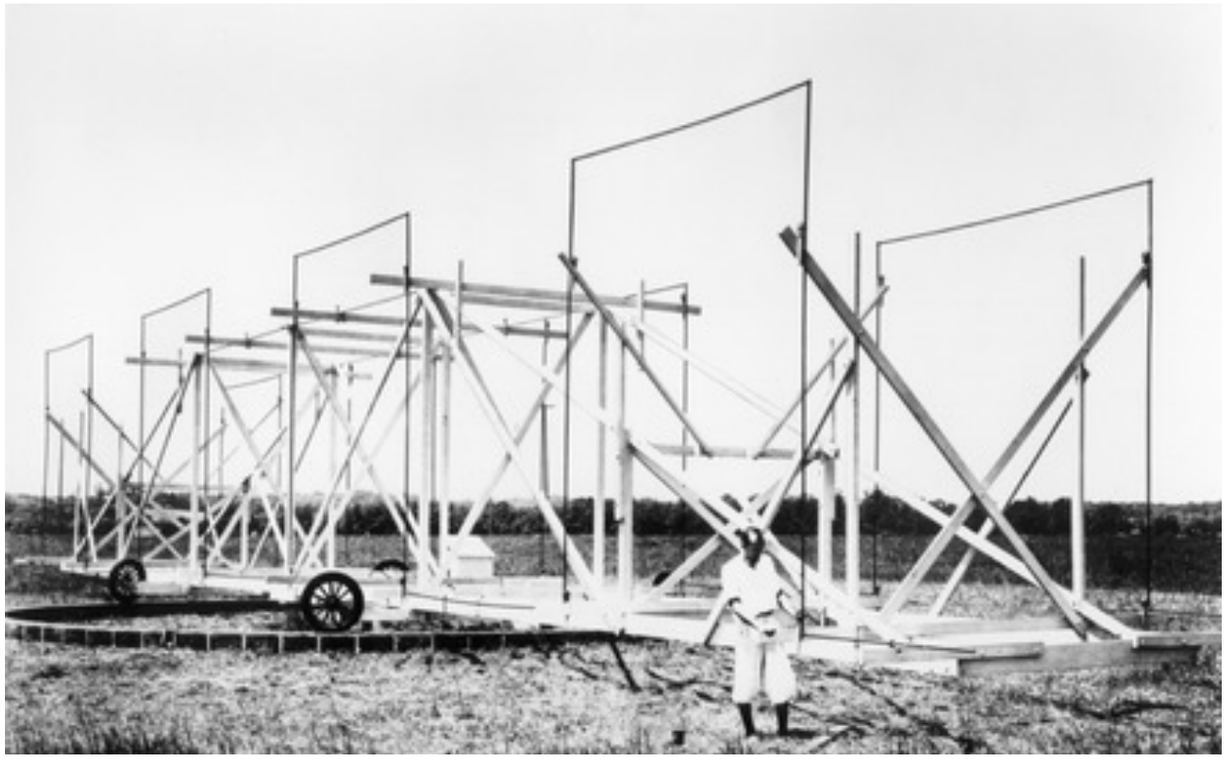


- 1902: Kennelly & Heaviside discover the ionosphere, an ionized layer in the upper atmosphere reflecting Marconi's signals. Astronomical radio transmissions might be undetectable.

The birth of radioastronomy

- 1933: Karl Jansky serendipitously detected the first astronomical radio source. He was a radio engineer with Bell Telephone Laboratories, and had the task to investigate interferences with transatlantic voice transmissions.





- He recorded a signal of unknown origin, repeating every ~24 h and suspected the source was the Sun. However, the source was repeating every 23 hours and 56 minutes. Jansky discussed the puzzling phenomena with his astrophysicist friend, Albert Melvin Skellett: the signal peaks every sidereal day, the time it took for "fixed" astronomical objects to pass in front of the antenna. The radiation source was coming from the densest part of the Milky Way in the constellation of Sagittarius.

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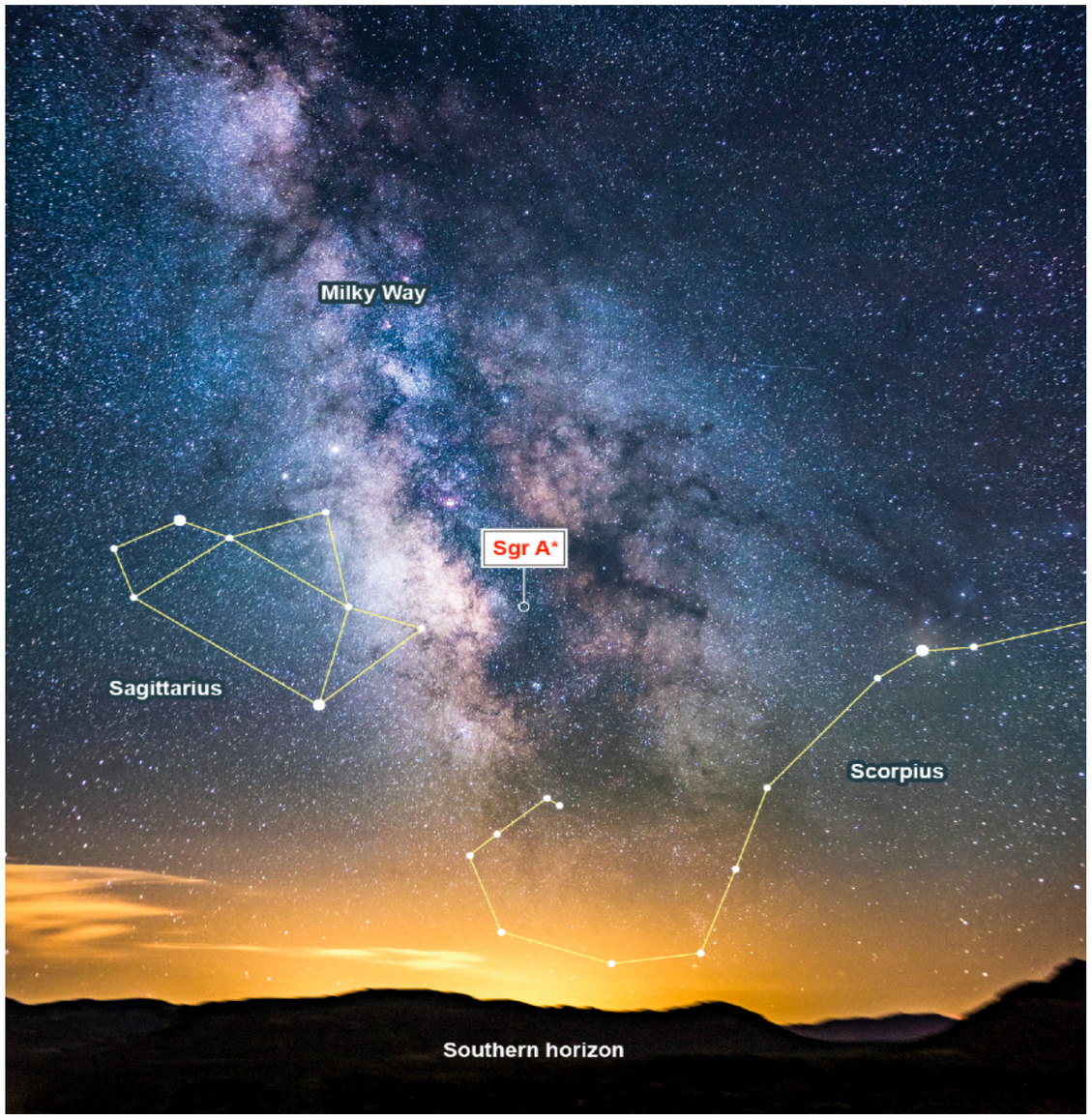
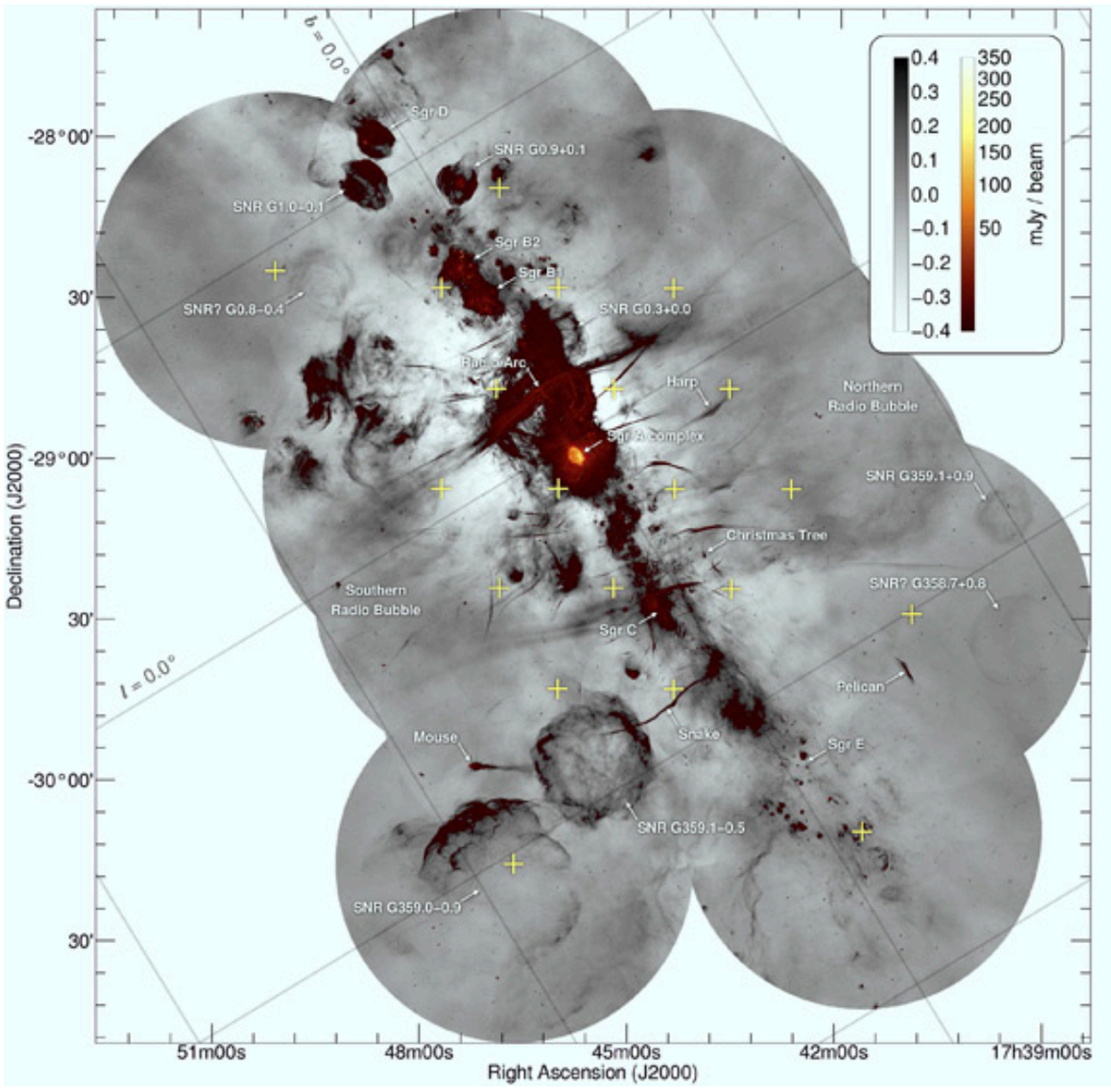
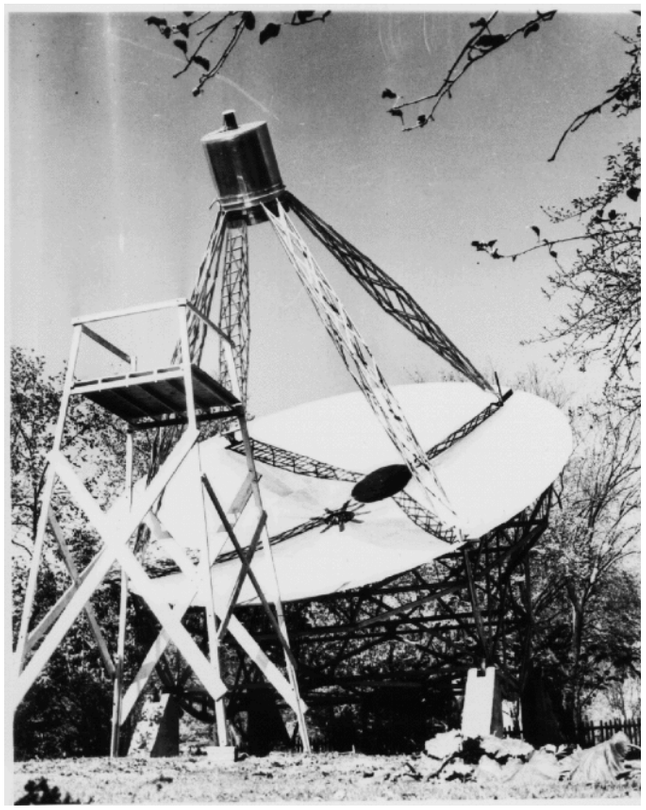
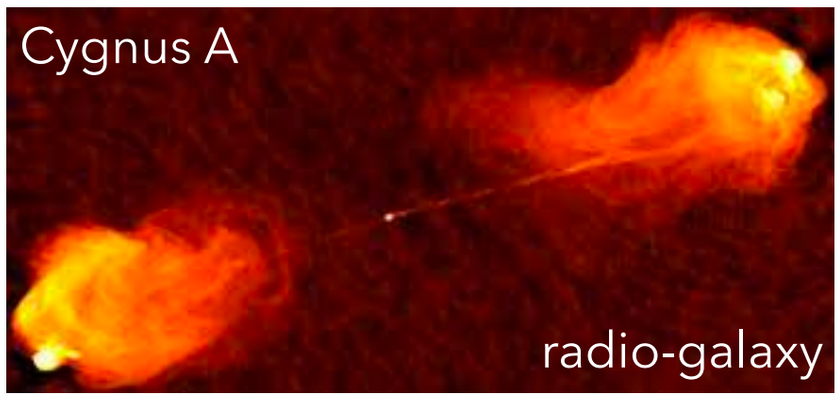


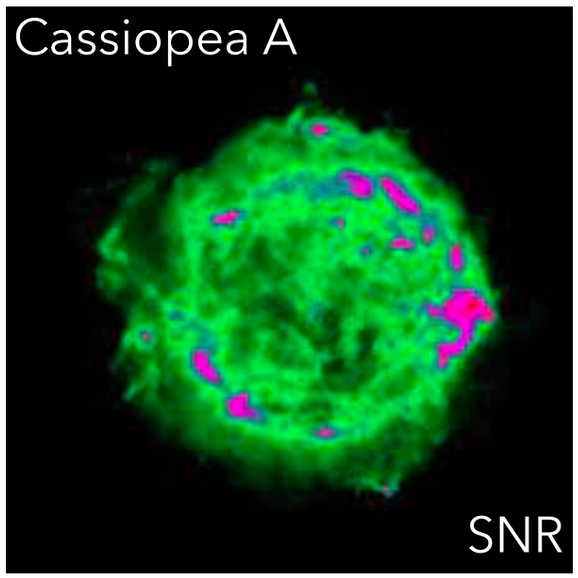


The birth of radioastronomy

- 1935: Jansky was assigned to another project and did no further work in the field of astronomy. A fundamental unit of flux density, the Jansky (1 Jy = 10^{-23} erg $s^{-1}cm^{-2}Hz^{-1}$) is named after him
- 1937: Grote Reber, amateur radio operator and amateur radio astronomer, built the first parabolic radiotelescope in his backyard. He carried out the "first survey" of the radio sky. For about ten years, he was the only radio astronomer in the word



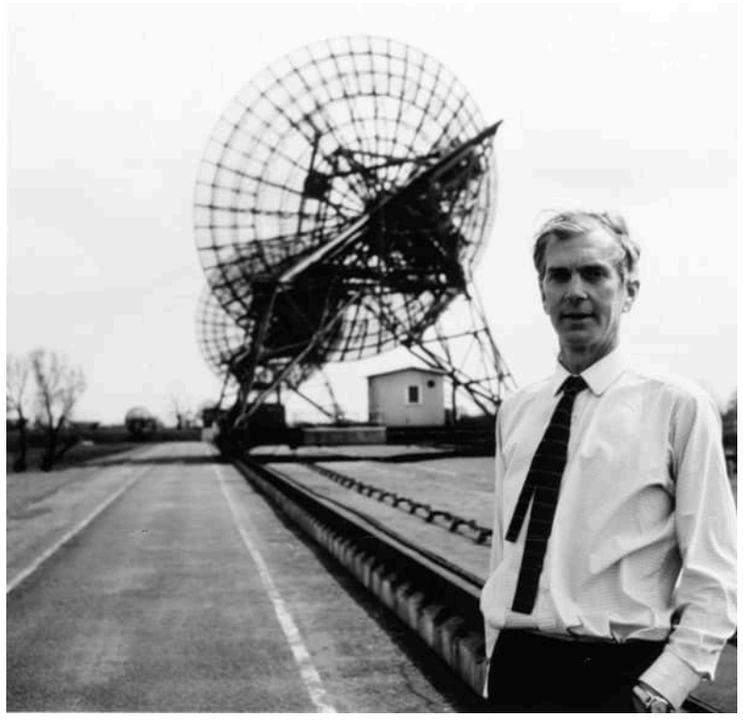


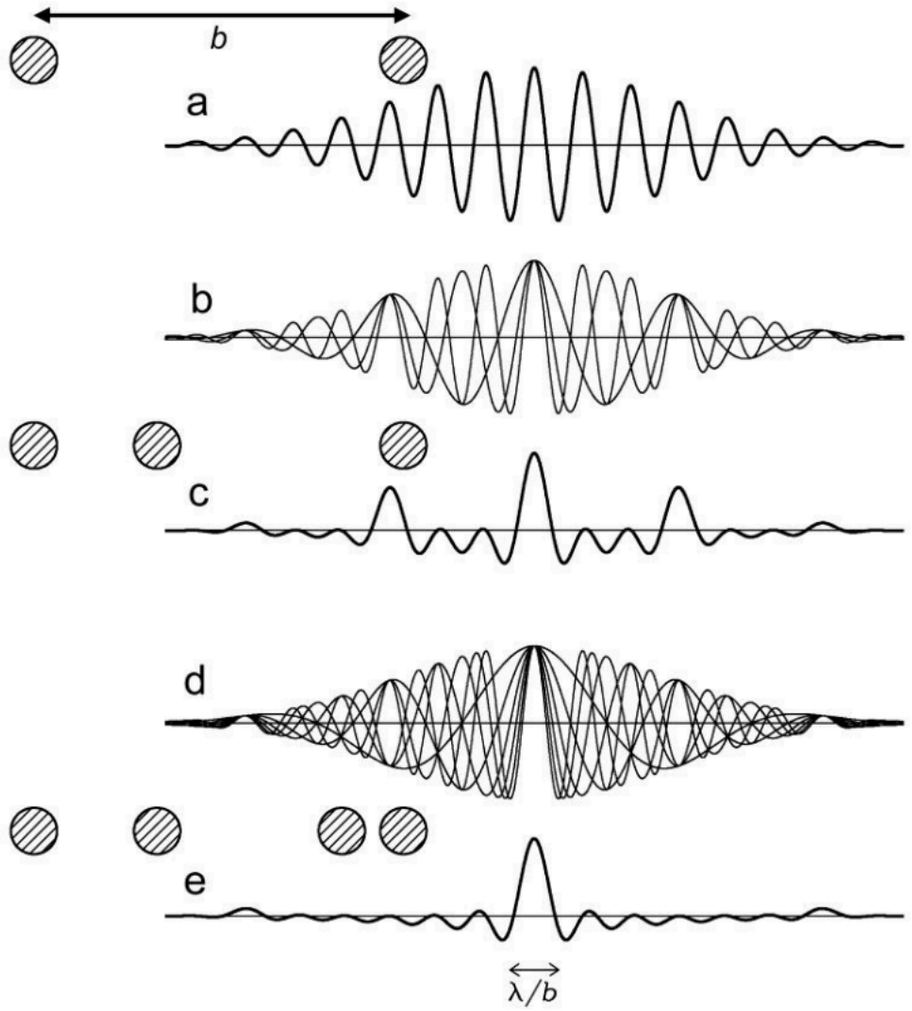


- mid 1940s: radar technology developed for military purposes was used by British and American astronomers to study radio waves emitted by the Sun (J.A. Ratcliffe, James Stanley Hey, George Clark Southworth,…)

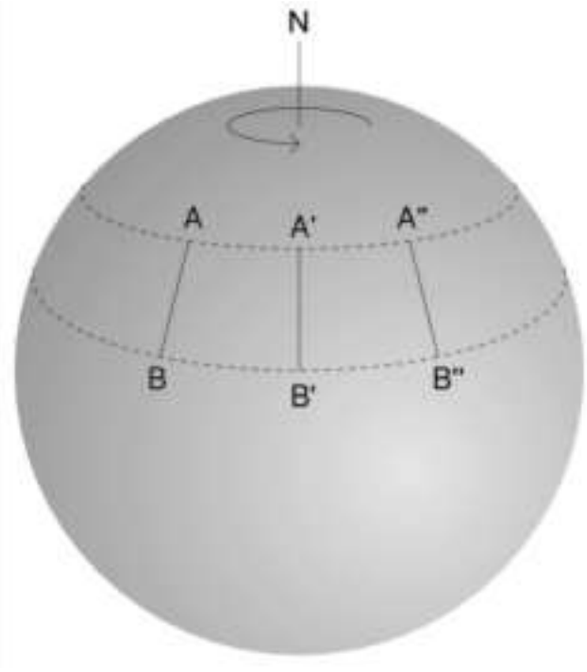
The birth of radioastronomy

- 1950s: Martin Ryle and Antony Hewish (Nobel prizes) at the **Cavendish Astrophysics Group in Cambridge** developed the technique of Earth-rotation aperture synthesis to isolate the angular source of the detected emission





- Late 1960s - early 1970s: as computers became capable of handling the computationally intensive Fourier transform inversions required, aperture synthesis was used to create large effective apertures (2-5 km)



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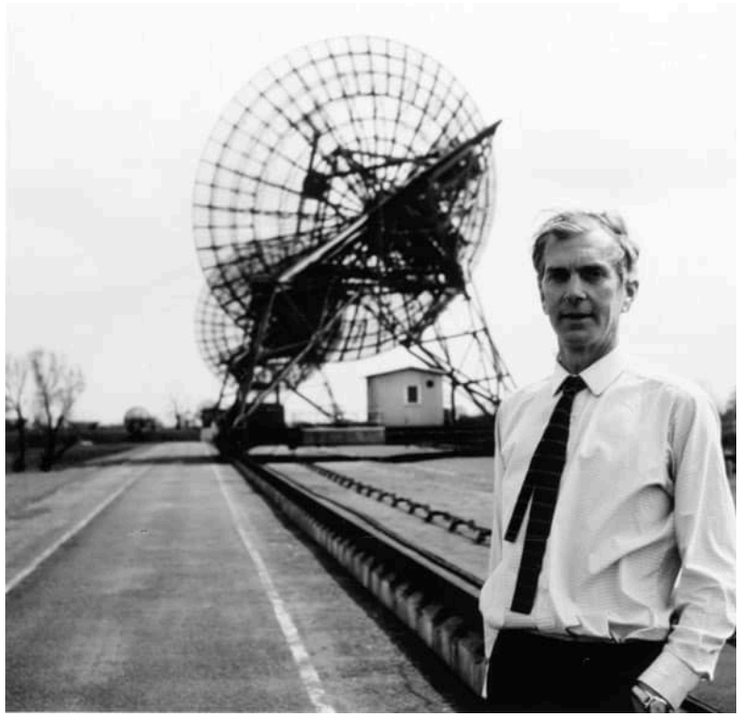


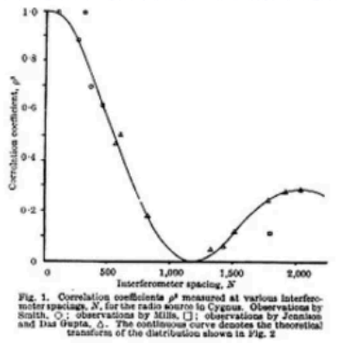


Fig. 1. Correlation coefficients ρ' measured at various interferometer spacings, N, for the radio source in Cygnus. Observations by Smith, ○; observations by Mills, □; observations by Jennison and Das Gupta, △. The continuous curve denotes the theoretical transform of the distribution shown in Fig. 2

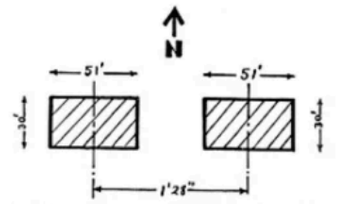
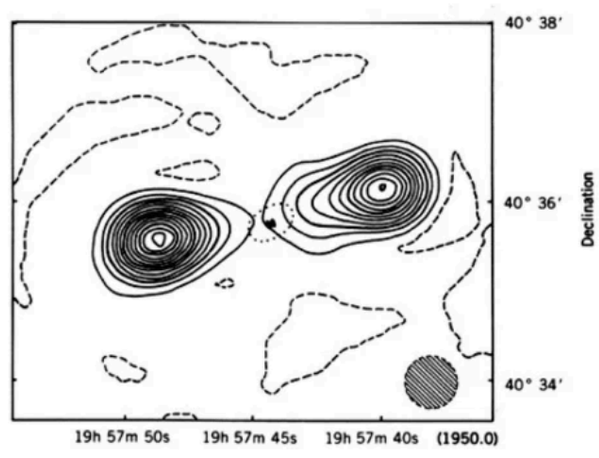


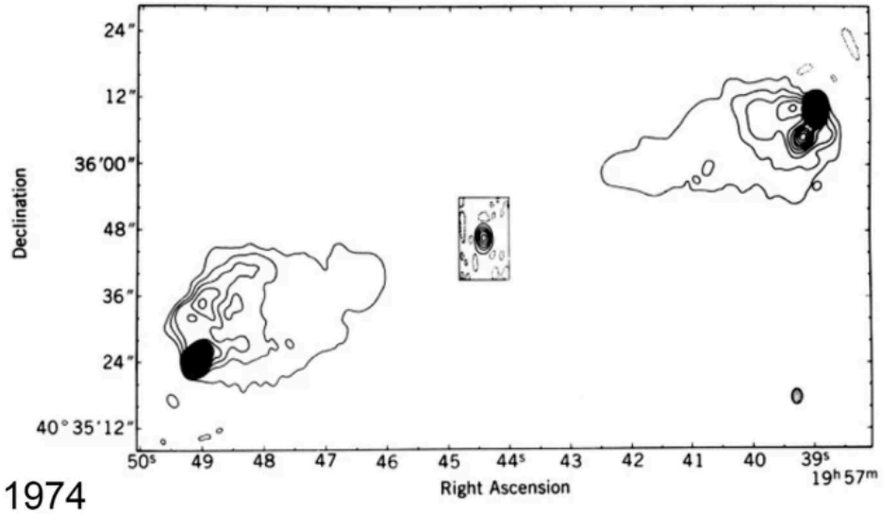
Fig. 2. Approximate intensity distribution of the extra-terrestrial radio source in Cygnus

1953



1965

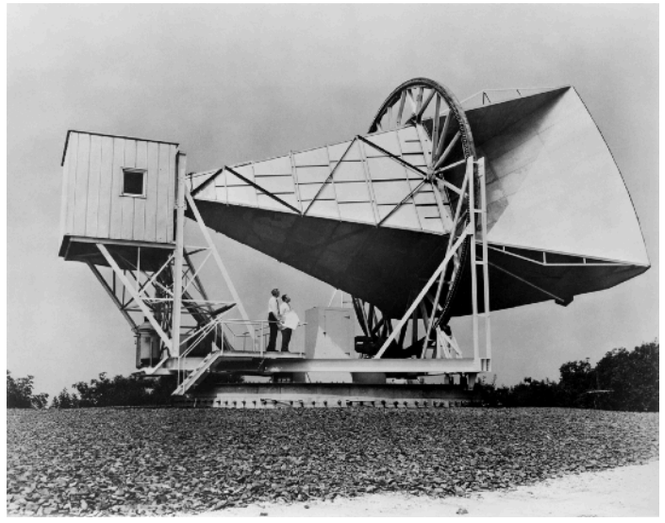
- Late 1960s - early 1970s: as computers became capable of handling the computationally intensive Fourier transform inversions required, aperture synthesis was used to create large effective apertures (2-5 km)

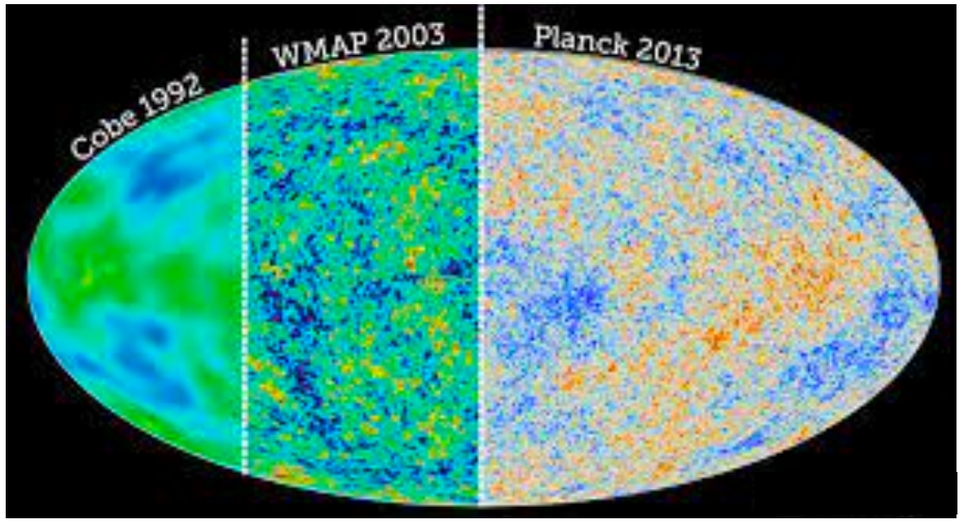


1974

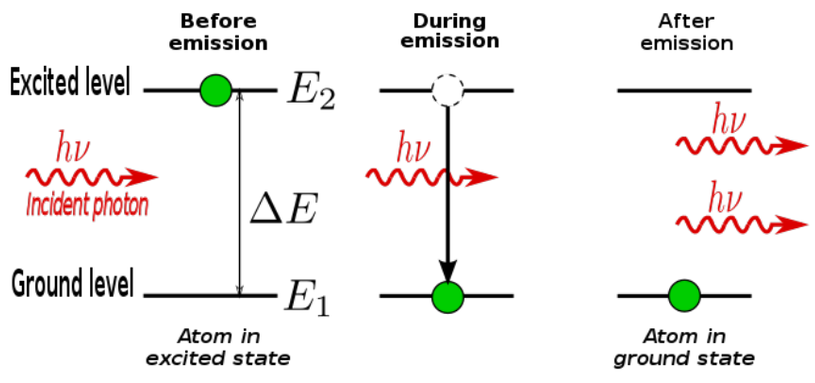
The birth of radioastronomy

- 1964: Arno Penzias and Robert Woodrow Wilson (nobel prizes) accidentally discovered the cosmic microwave background using a horn-reflector antenna built for satellite communications. BB spectrum: evidence for a hot early Universe (Big Bang theory) against the rival steady state theory. Steady-state Universe also inconsistent with the observed higher density of radio sources with increasing distance.



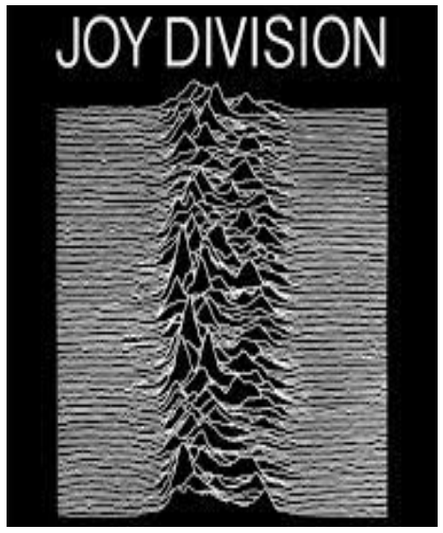


- 1965: first detection of astronomical masers by Harold Weaver, who serendipitously found monochromatic, intense emission lines of unknown origin in star forming regions. OH maser in compact sources within molecular clouds

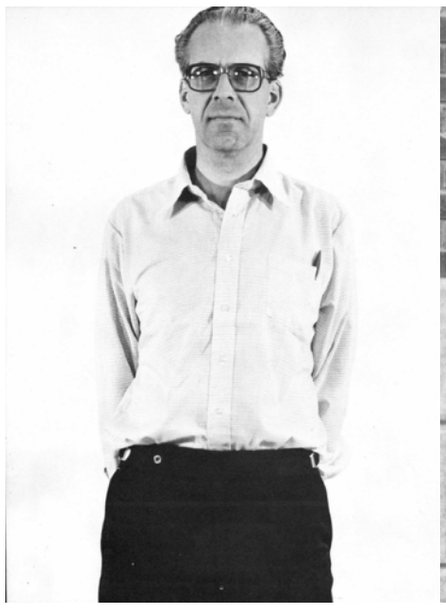


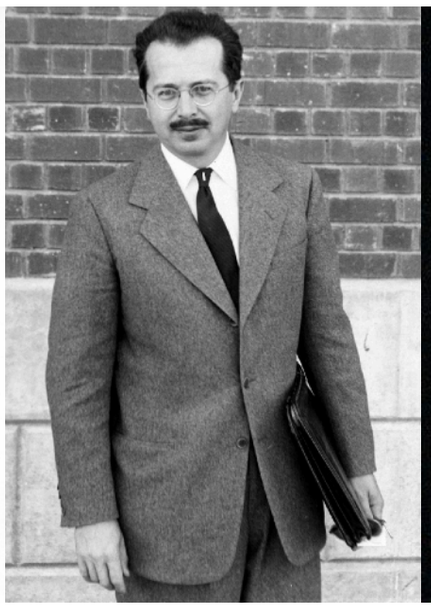
The birth of radioastronomy

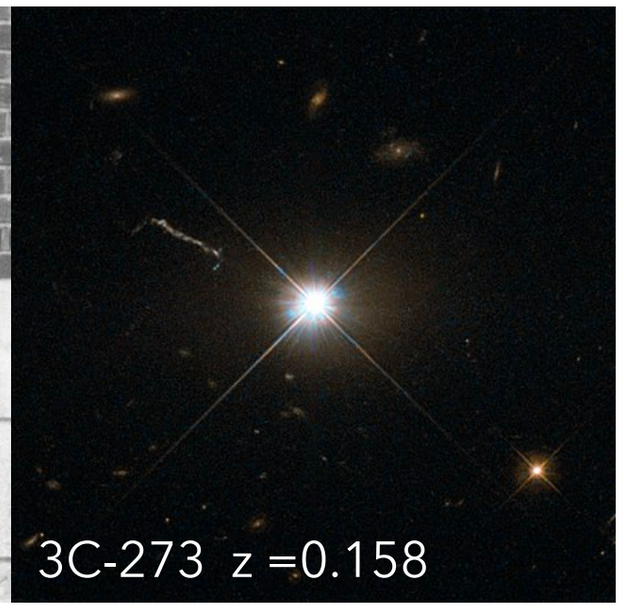
- 1967: Jocelyn Bell Burnell discovered the first radio pulsar (while studying quasars), initially identified as “Little Green Man”, when she was a post-graduate student. The discovery earned a Nobel Prize, which was however assigned to Bell’s thesis supervisor, Antony Hewish.



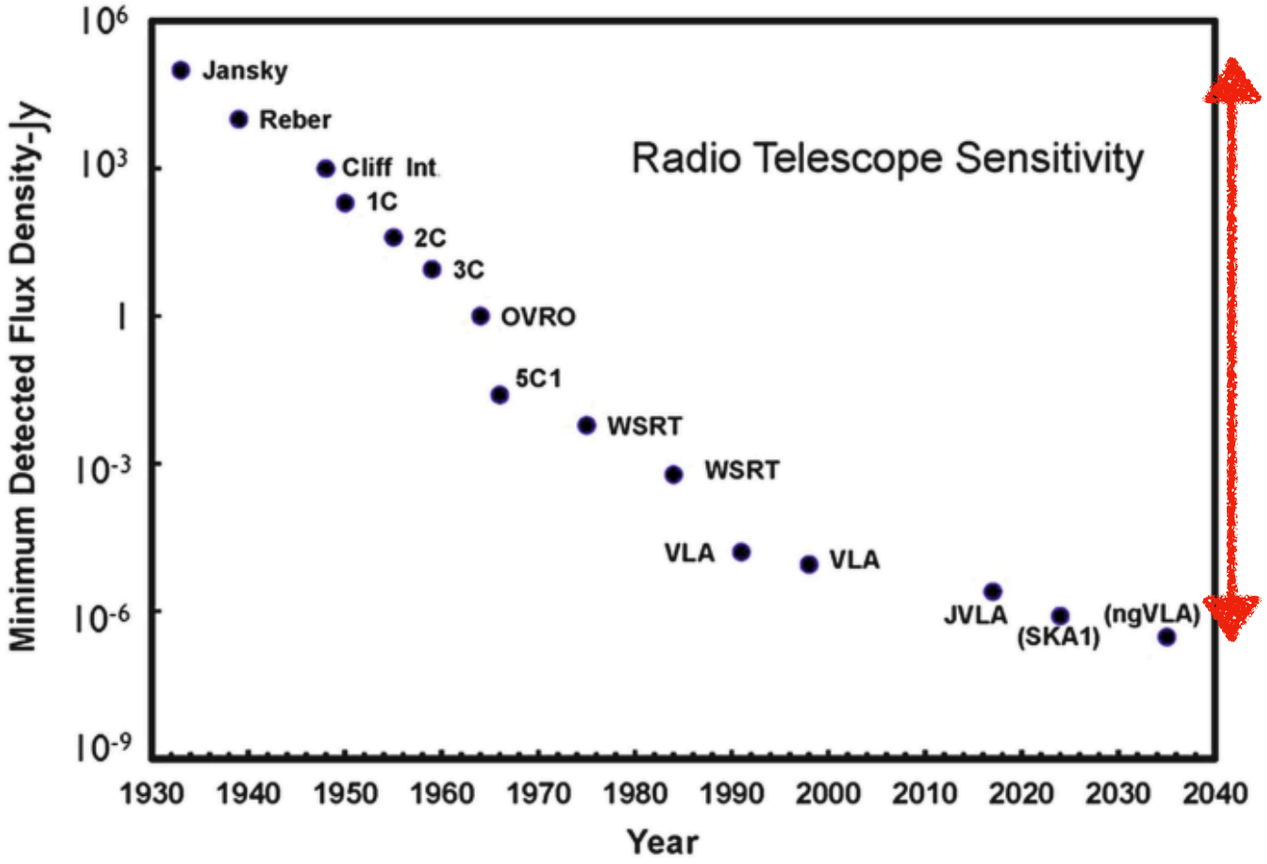
- 1963,1967: first identifications of quasi-stellar radio objects as distant galaxies by Maarten Schmidt and Jesse Greenstein. Quasars were noted in radio sources since 1950s, but were initially mis-interpreted as stars with peculiar spectra due to their compact optical sizes







The birth of radioastronomy



Evolution of the radio telescopes sensitivity in about a century

Number of sources detected by radio surveys