

Radio Astronomy: its dawn and contribution to humanity

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(Ancient) Astronomy

- ★ Calendar (purpose in ancient era)
- ★ stars, planets and comets
- ★ constellations (no physical group)
- ★ Motion of the Sun & Moon, waxing and waning of the Moon, solar & lunar eclipses
- ★ Vision of the Universe -- The earth is the center

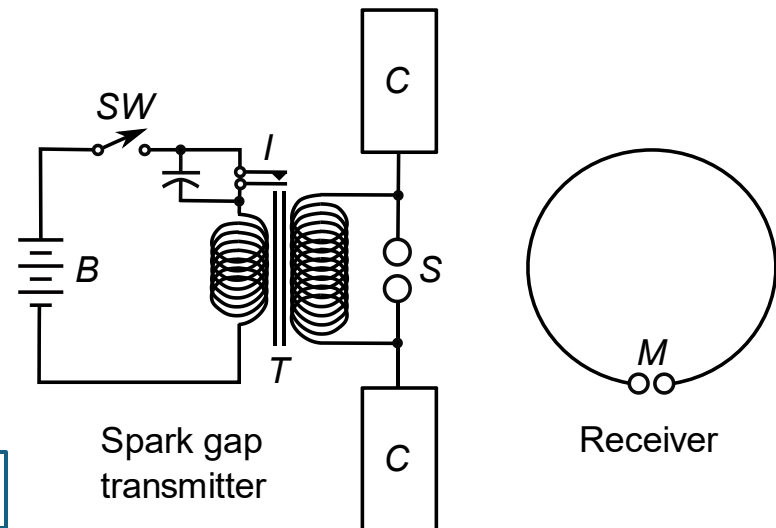
Astronomy is one of the oldest disciplines.
Visible wavelengths only until 19th century.

Discovery of Electromagnetic Waves

- EM waves were predicted by Maxwell in 1864
- Heinrich Rudolf Hertz experimentally verified the existence of EM waves (1887)



H. R. Hertz



Transatlantic Telegraphy by radio waves (1901)



Guglielmo Giovanni Maria Marconi
(Nobel Prize in Physics in 1909)



Discovery of Non-Terrestrial Radio Signals

- Bell Telephone Laboratories
Karl G. Jansky
- Noise investigation for transatlantic radio communication
- @20.5 MHz / $\lambda=14.6$ m
- Since the middle of August, 1931

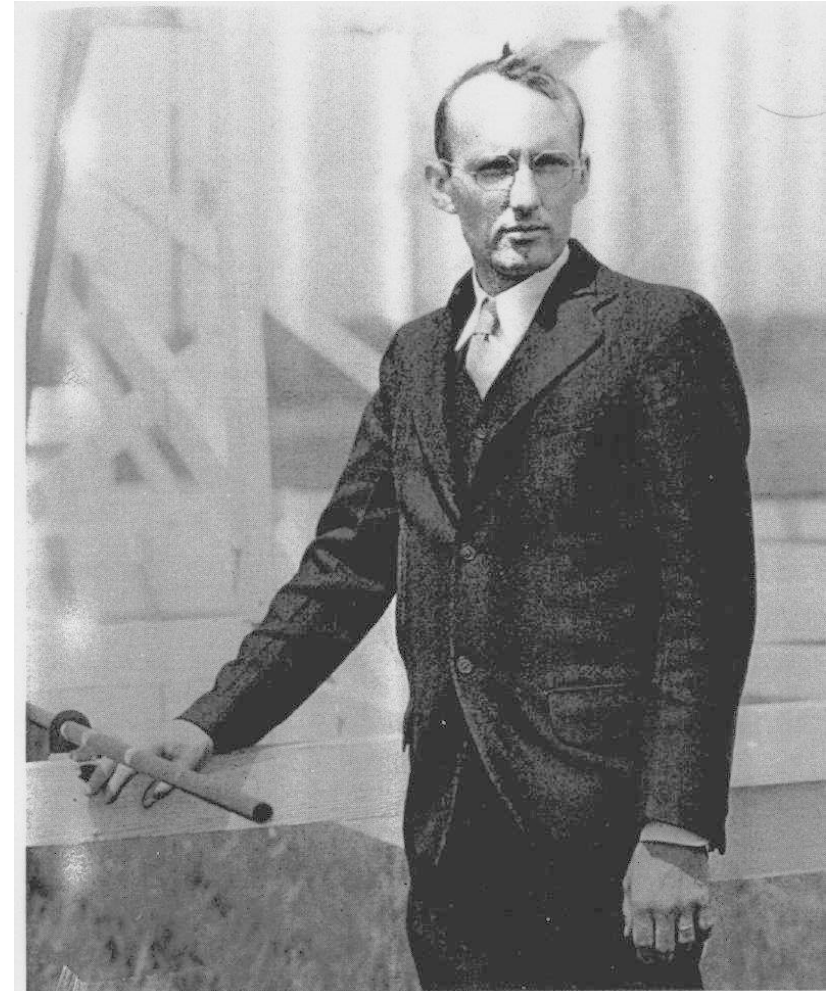


FIG. 1—Karl Guthe Jansky, about 1933.



Seminar on Radio Astronomy

Jansky (Nature, 132, p.66 (1933))

“Radio Waves from Outside the Solar System”

- Observations were made for more than one year
- The radio peak appears at the same position
after one siderial year
- the origin is outside the solar system
- The peak coordinates:
 - Right ascension – 18 hours
 - Declination -- -10 deg
→ close to the Galactic Center

Jansky (or Jy)

- A unit for flux used in radio astronomy

$$1 \times 10^{-26} \text{ W/m}^2/\text{Hz} = 1 \text{ Jy}$$

detection of mJy signals is easy

detection of μJy signals is possible



One of TOP 10
Radio sources
On the sky



Grote Reber: the first radio astronomer in the world

First Radio Maps @ 160 MHz

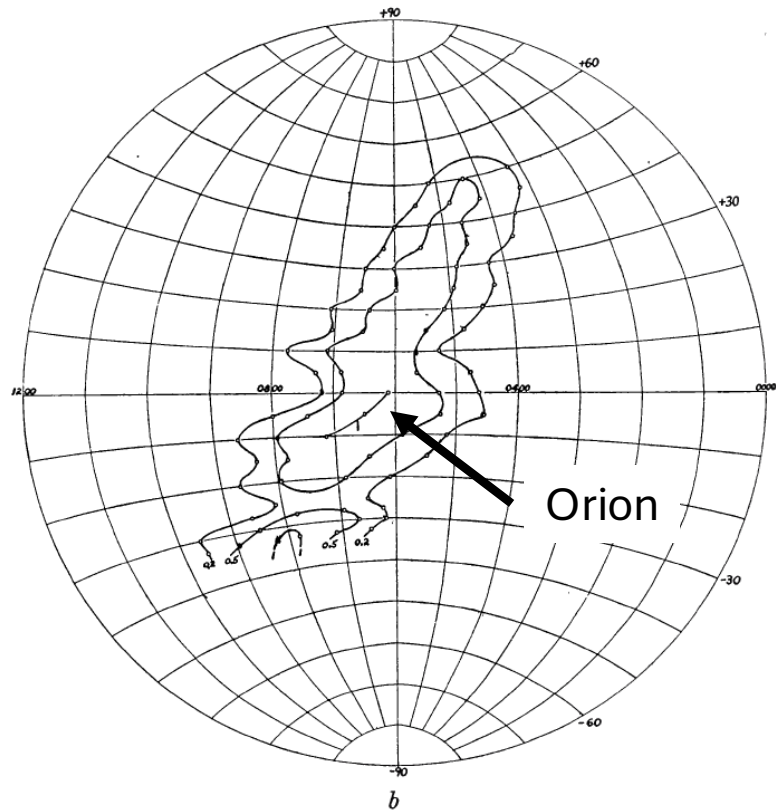
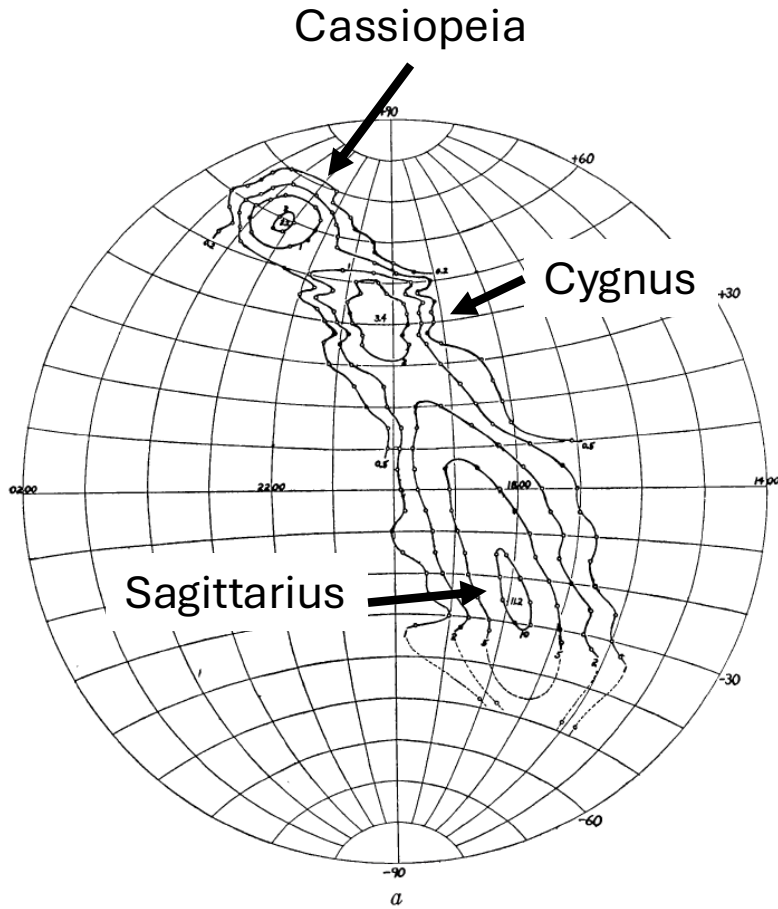
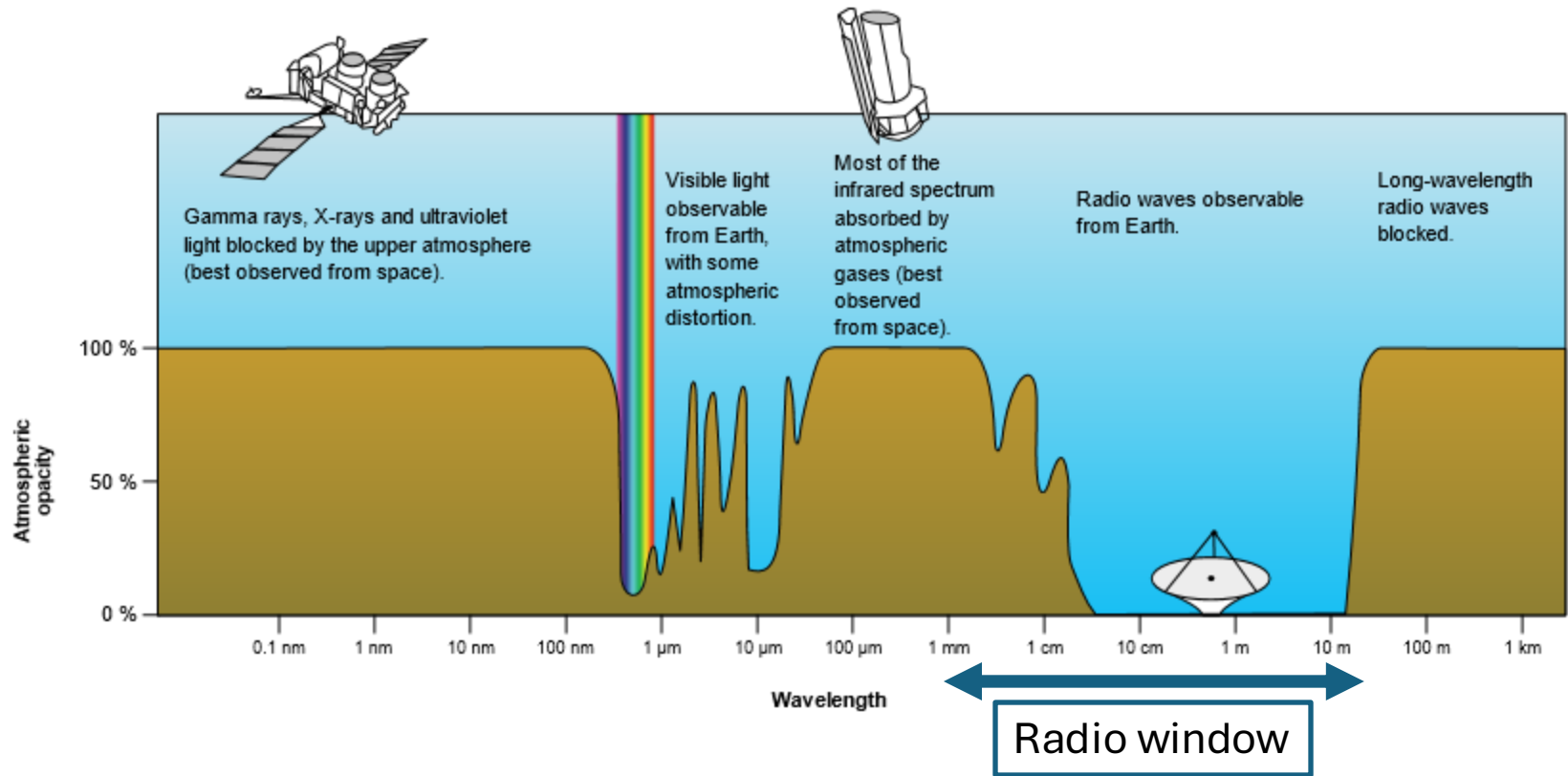


FIG. 4.—Constant intensity lines in terms of 10^{-22} watt/sq. cm./cir. deg./M.C. band

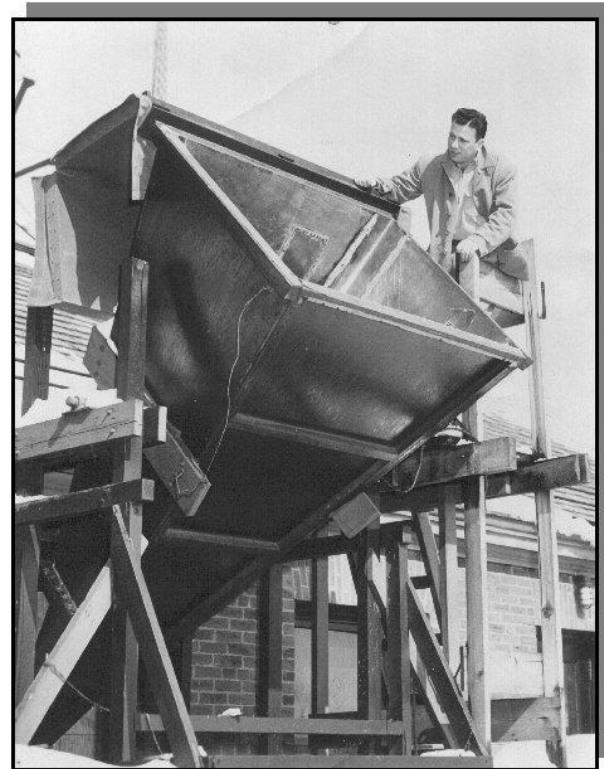
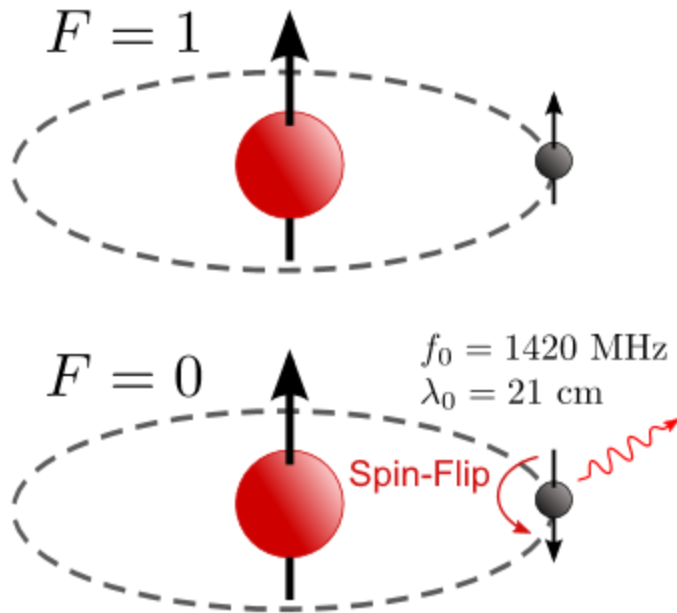
New Atmospheric Window



Plot of Earth's atmospheric opacity to various wavelengths of electromagnetic radiation, by NASA, Public Domain, on wikimedia

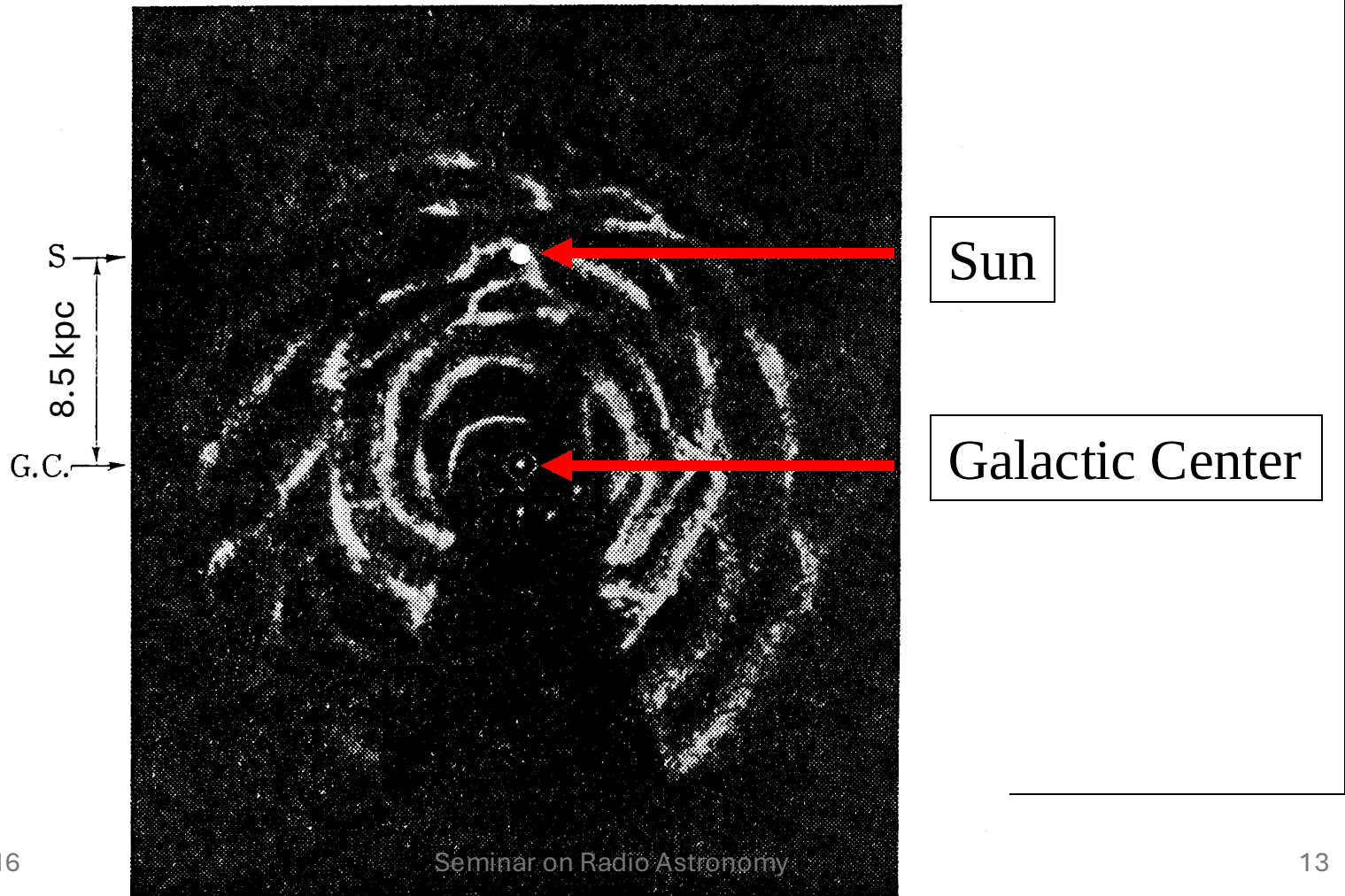
21 cm line of Hydrogen atom

- Predicted by J. van de Hulst (1945)
- Detected by Ewen and Purcell (1951)



21 cm line of neutral hydrogen (HI)

→ Our Galaxy is a spiral galaxy

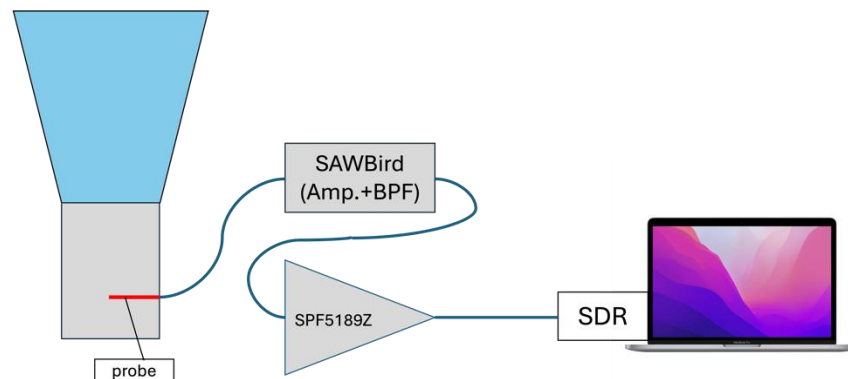


First allocation to radio astronomy

- Given the importance of the HI line, Radio astronomers acted quickly to protect the HI band
- IAU + URSI
- World Administrative Radio Conference of the ITU (1959) allocated the 1400 – 1427 MHz band as the first radio astronomy band

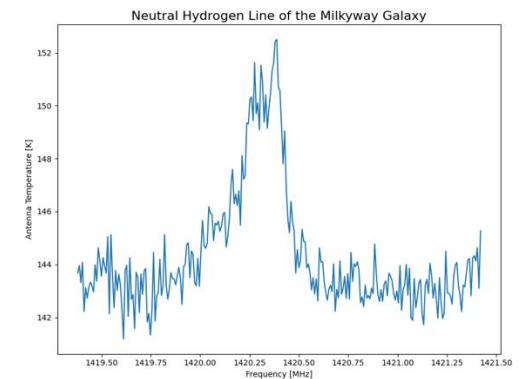
Allocation to Services		
Region 1	Region 2	Region 3
1 350 — 1 400 FIXED MOBILE RADIOLOCATION 349	1 350 — 1 400 RADIOLOCATION 349	
1 400 — 1 427 RADIO ASTRONOMY 350		

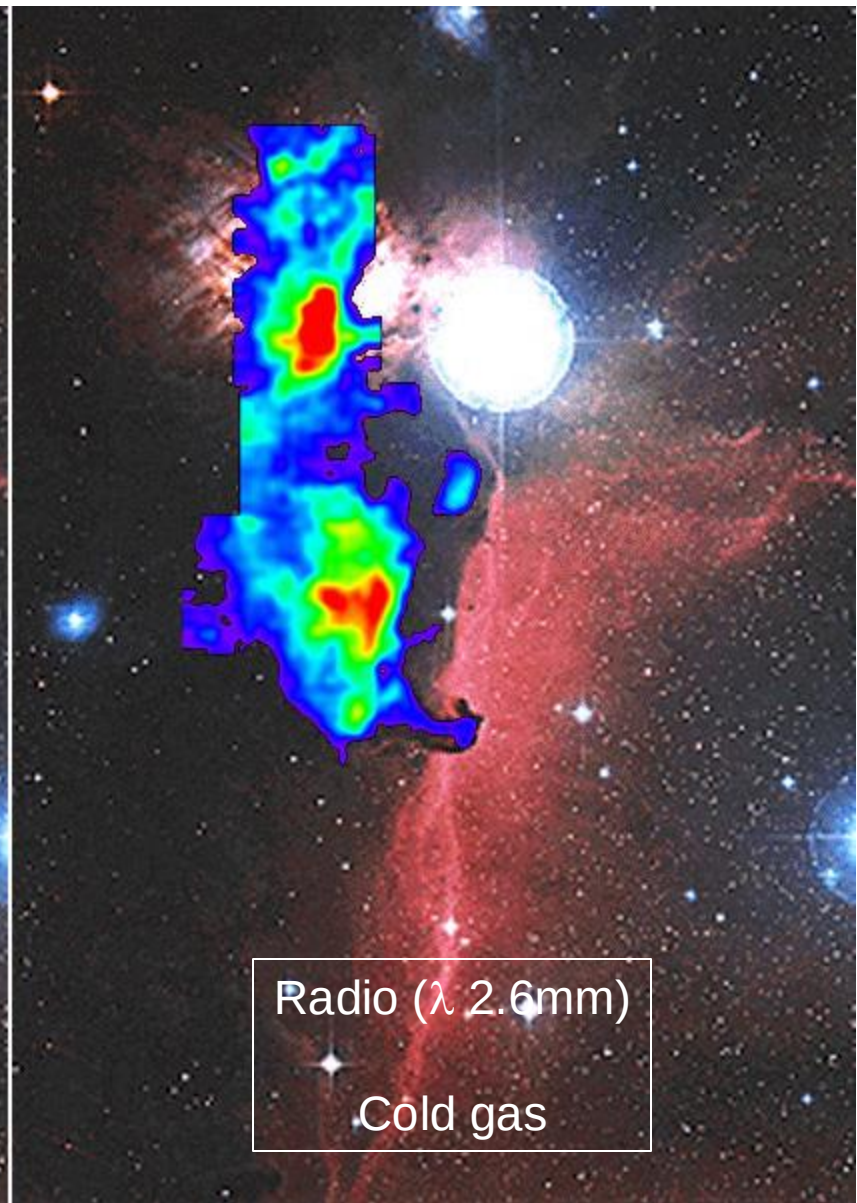
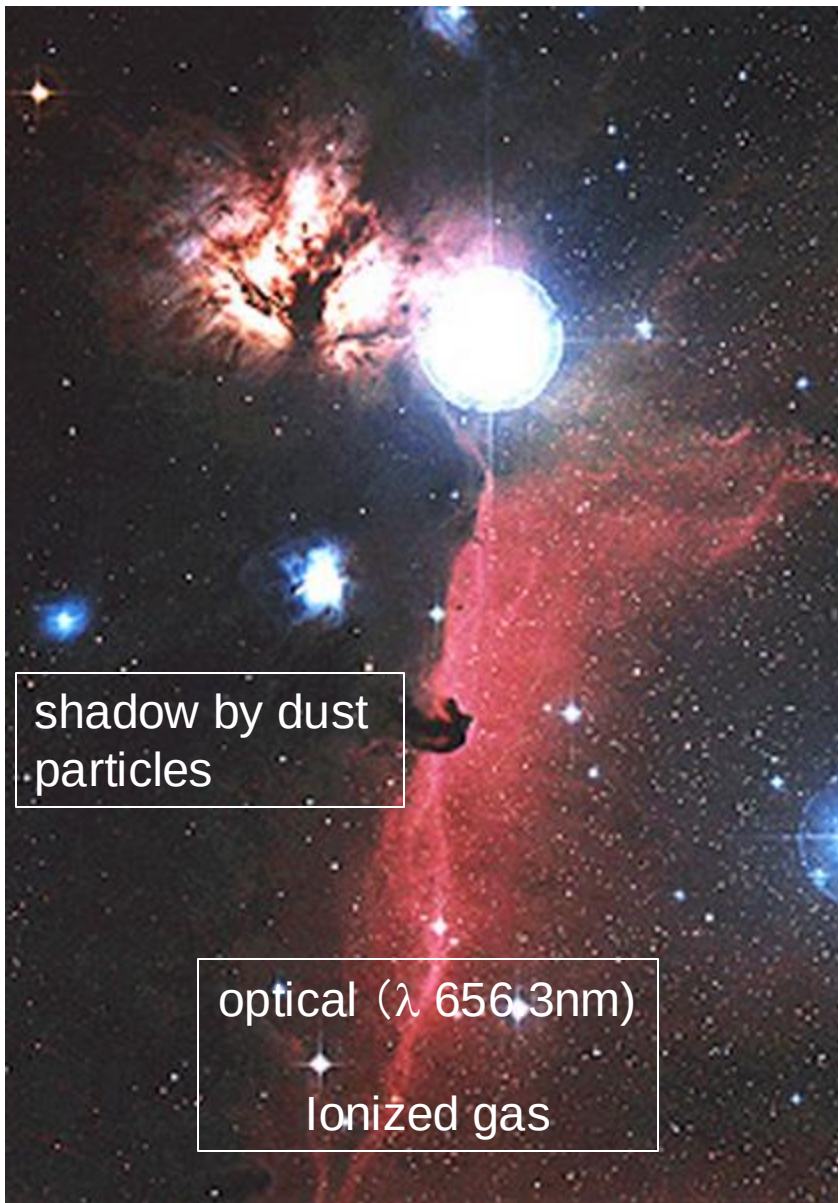
“Amazon”-made radio telescope for HI



SDR: Software Defined Radio

cost ~ USD 140 ~ KZT 70,000
(except for the computer)





The evidence of “Big Bang”

Discovery of **the Cosmic Microwave Background (CMB)** (1963)

A. Penzias & R. Wilson
→ Nobel prize in Physics
in 1978

3K radiation from all
direction



1983 in Nobeyama, Japan

Discovery of Anisotropy of CMB

Uniform CMB

= uniform energy
distribution

= uniform mass
distribution

↔ our Universe
is NOT uniform

COBE (Cosmic Background
Explorer) detected anisotropy
of the CMB at a level of a part
in 100,000! (1991)

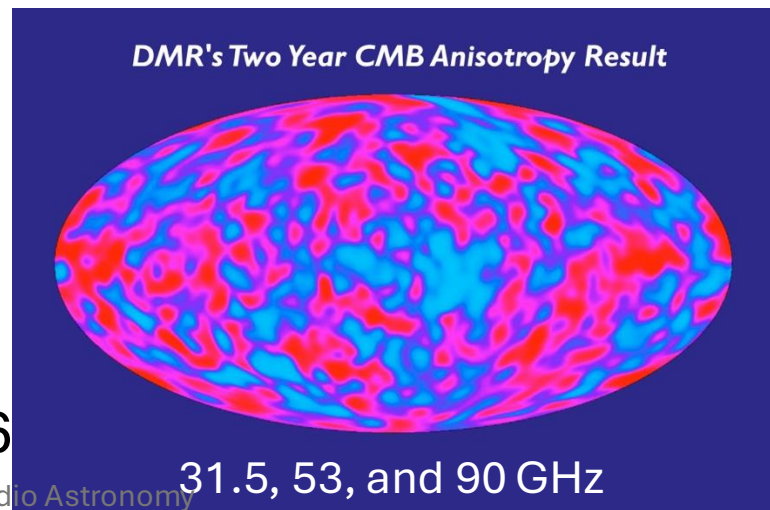
→ Nobel prize in Physics 2006



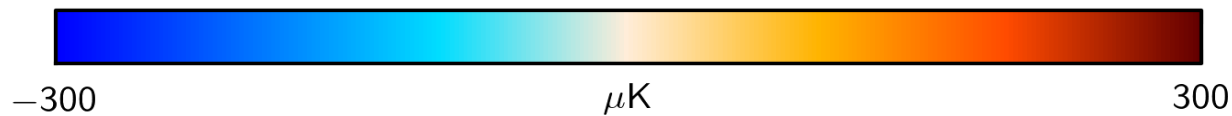
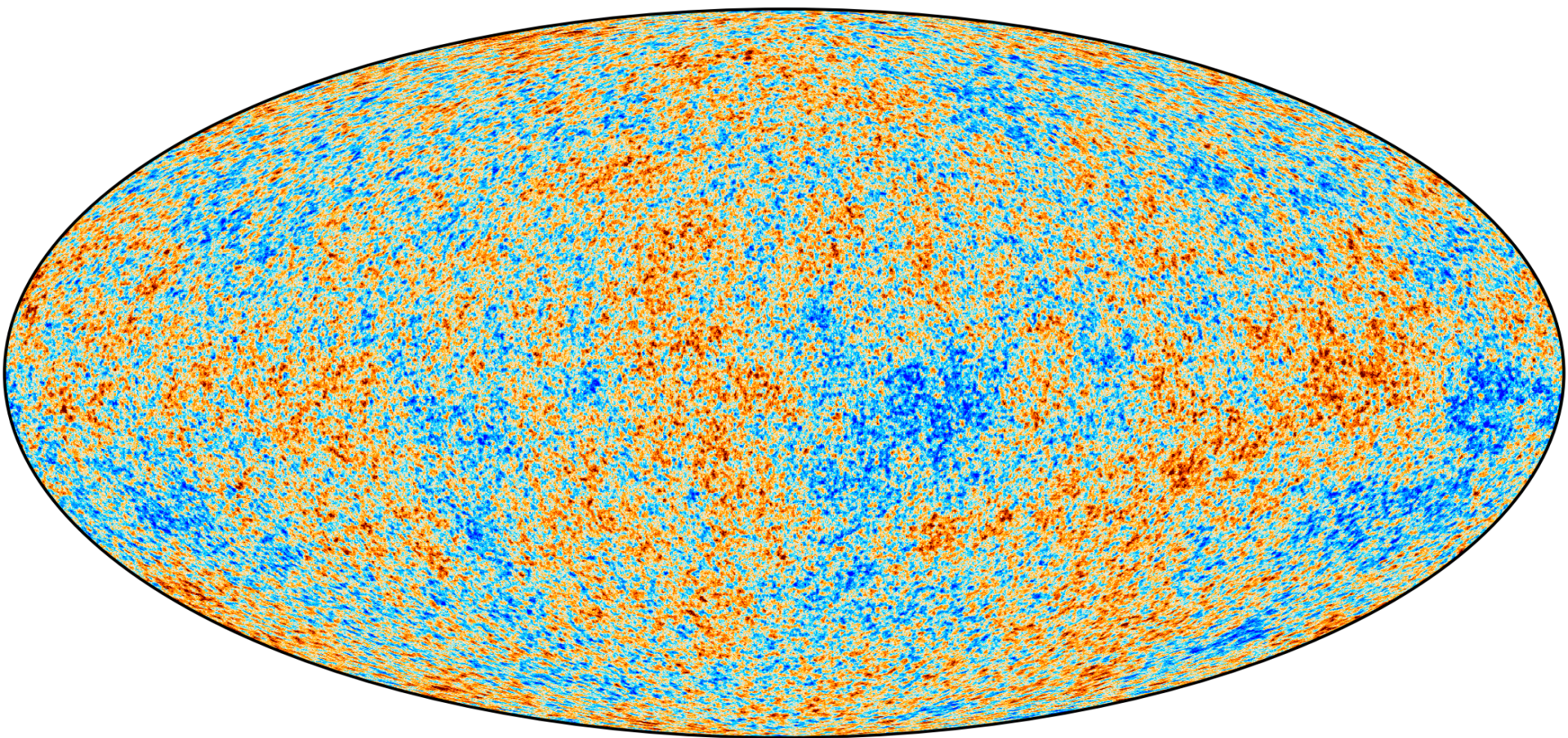
John Mather



George Smoot

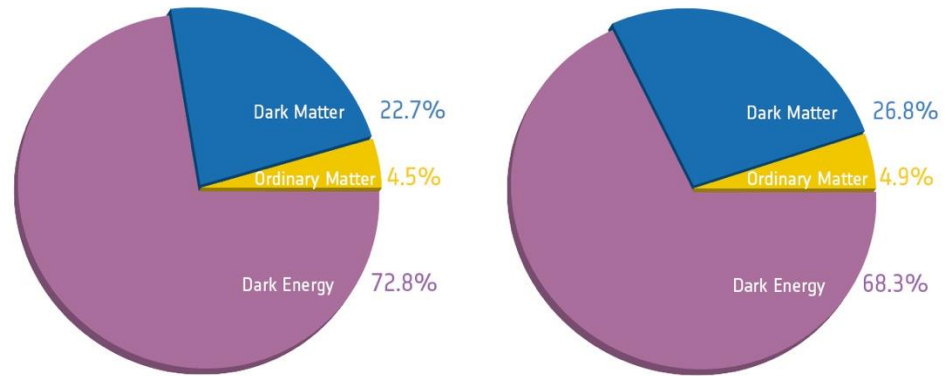


Planck (CMB fluctuations $\sim 10^{-6}\text{K}$)
30 – 357 GHz



Planck tells us:

- Age of the Universe:
 13.8 ± 0.3 Gyrs
- Hubble constant:
 $H_0 = (67.4 \pm 0.5)$
 $\text{km s}^{-1} \text{Mpc}^{-1}$



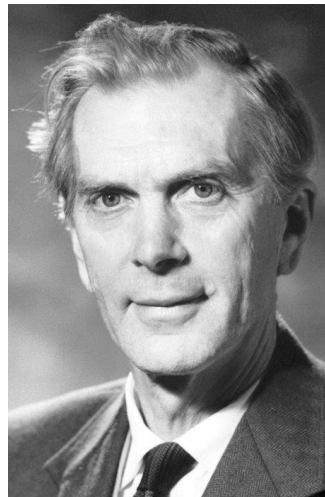
Ordinally matter is 4.9 % only!

Radio Interferometers: improvement of spatial resolutions

- Spatial resolution $\sim \lambda/D$
- Optical: $\lambda \sim 500 \times 10^{-9} \text{ m}$
 $D \sim 1 \text{ m} \rightarrow \lambda/D \sim 0.1 \text{ sec}$
- Radio: $\lambda \sim 10 \text{ cm}$
 $D \sim 10 \text{ m} \rightarrow \lambda/D \sim 34 \text{ min}$
- Radio interferometers
 $D = \text{distance of two antennas}$
- $D=1600 \text{ m} \rightarrow \lambda/D \sim 13 \text{ sec}$



One-Mile Telescope



Sir M. Ryle

Nobel prize in Physics 1974
together with A. Hewish

Major Interferometers

ALMA

SKA

VLA

NOEMA

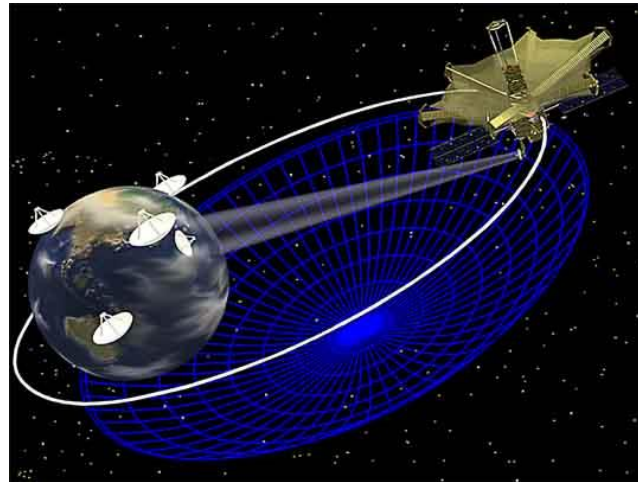


VLBI

(Very Long Baseline Interferometry)

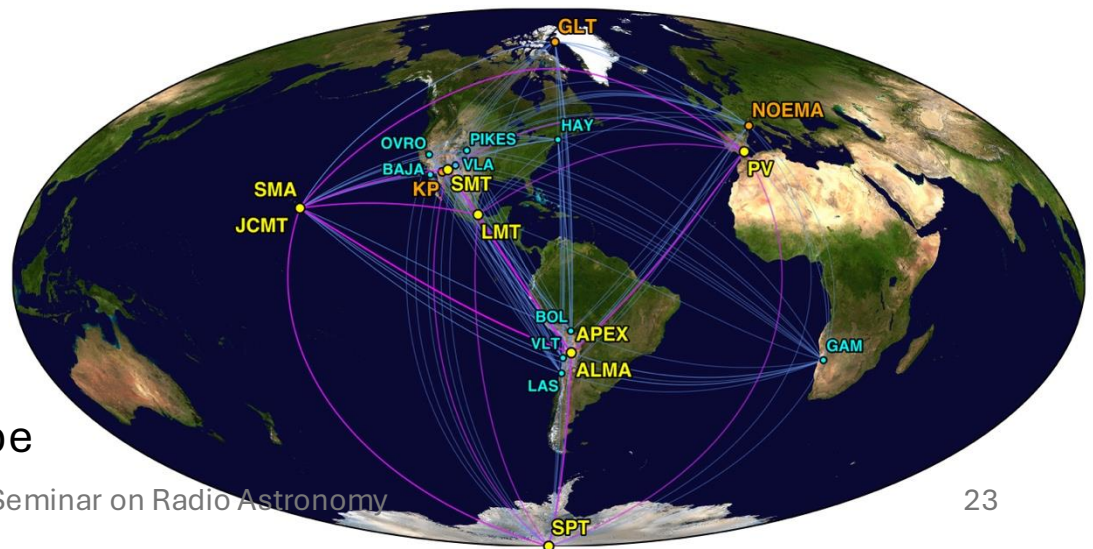


VLBA (US)

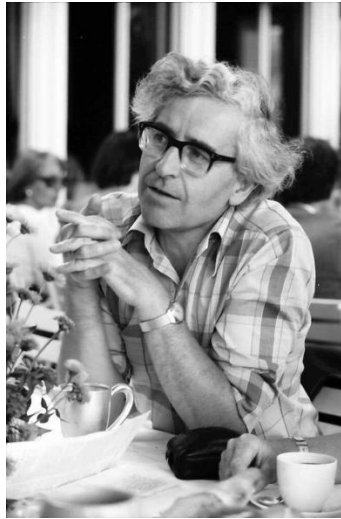


VSOP:
0.0003 sec
resolution

Event Horizon Telescope



Pulsars: Two Nobel Prizes!



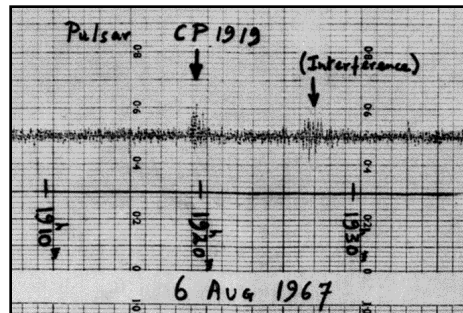
A. Hewish

Discovery of pulsars
Nobel Prize in Physics
1974

(Landesarchiv Baden-
Württemberg, Fotograf)



← Jocelyn Bell



Russell Hulse and Joseph Taylor Jr.

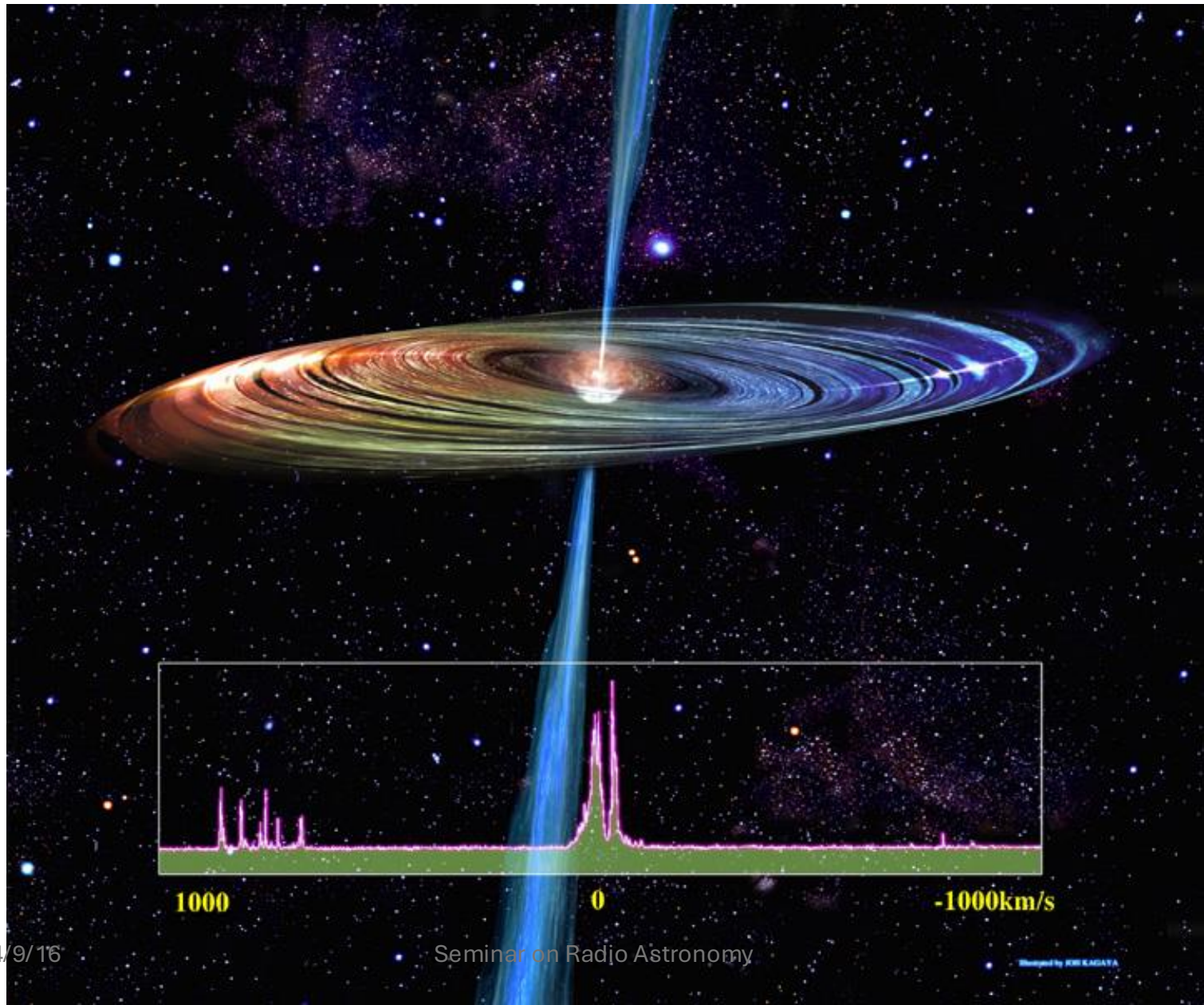
Discovery of Binary pulsars
→ evidence for gravitational waves
& confirmation of general relativity

→ Nobel Prize in Physics 1993

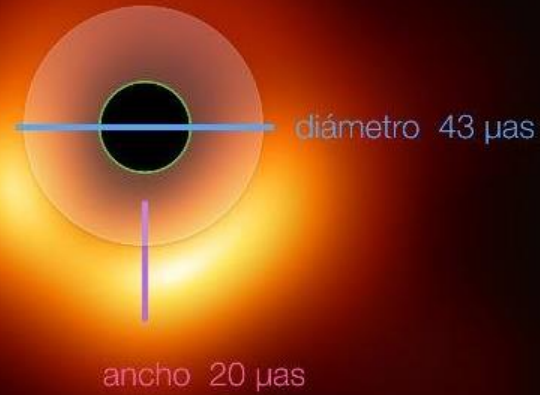
Flavor of scientific results

Other speakers will talk in detail.

Discovery of a Black Hole by H₂O line (22GHz)



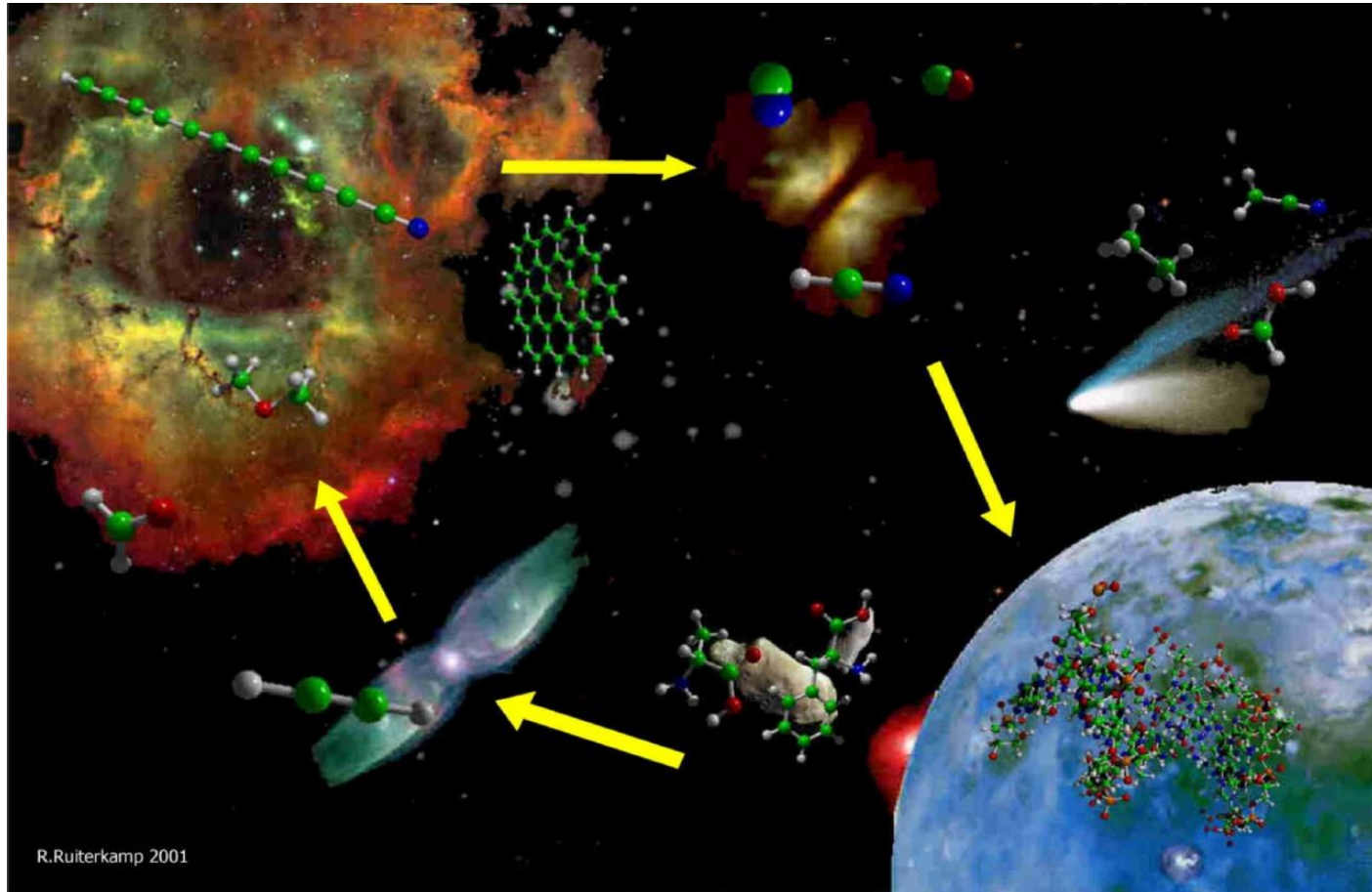
Captura de fotones

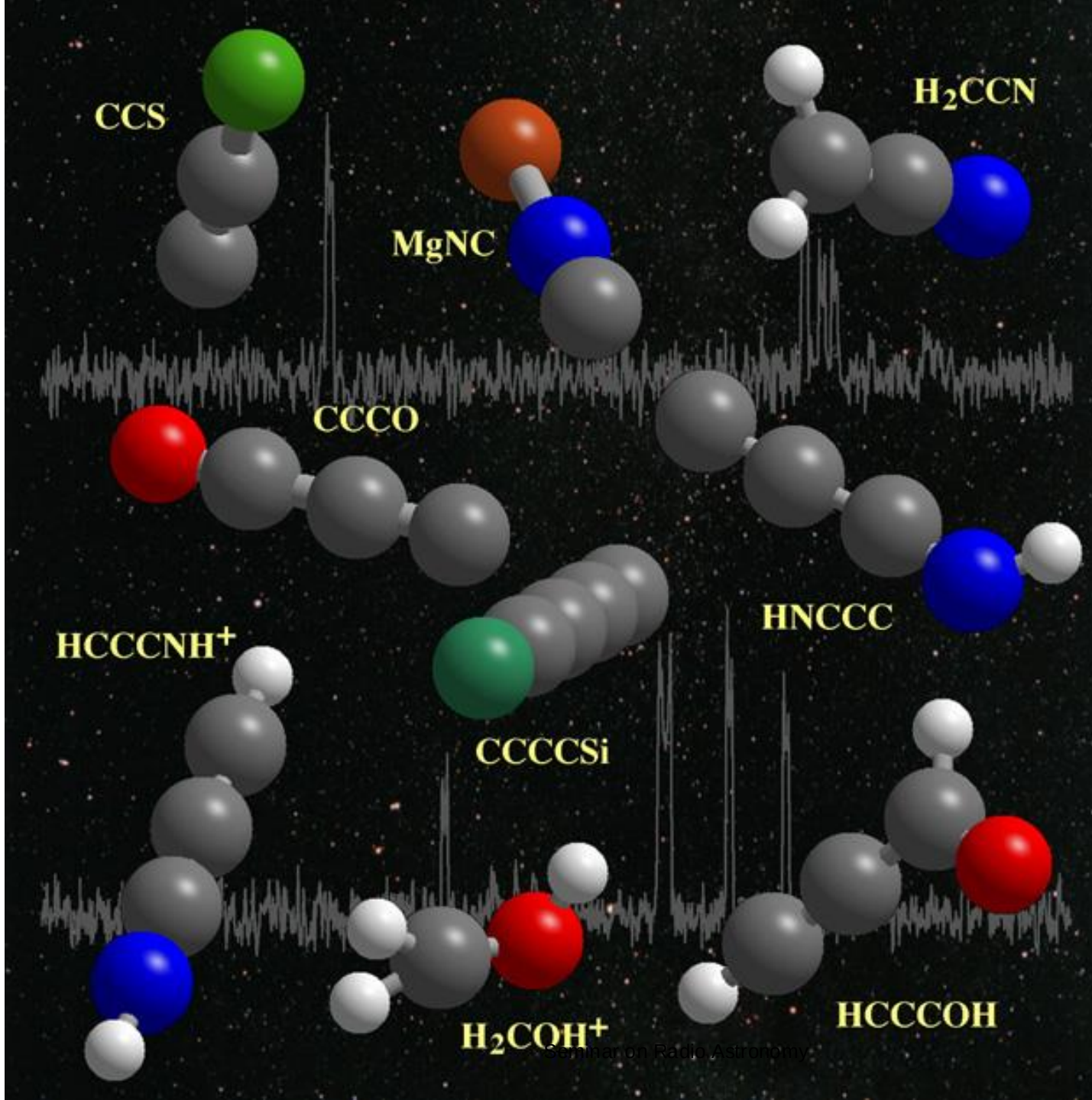


$$1 \text{ arcosegundo } (\mu\text{as}) = 0.00000000028^\circ$$

Black Hole Shadow by ETH

Molecular Gas and Star/Planet Formation



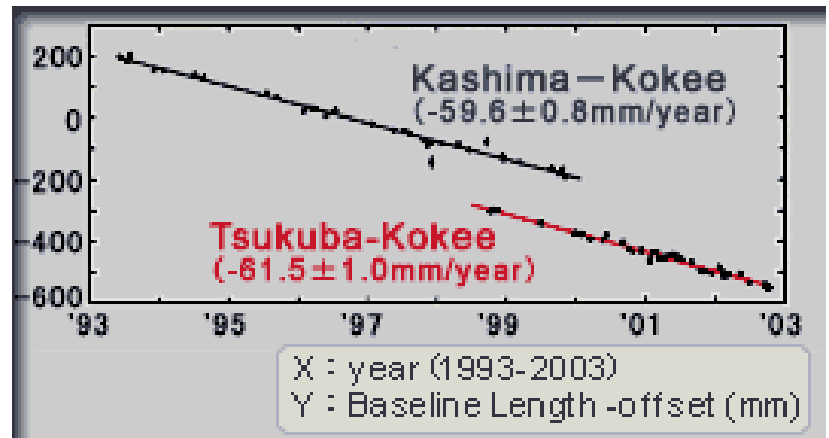
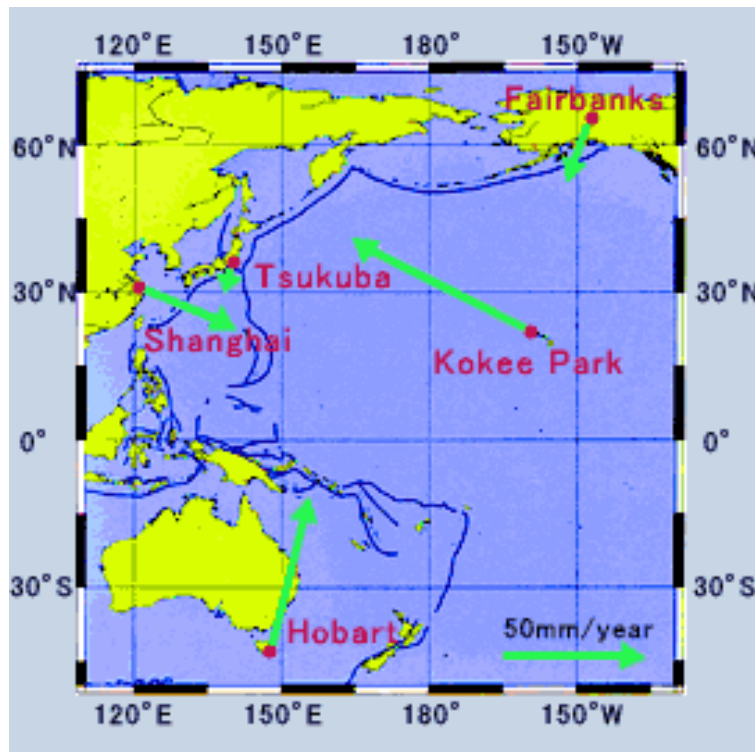


300+
 Molecular
 Species
 so far
 detected

A large, high-resolution image of the HL Tau protoplanetary disk, showing a central bright yellow-white core surrounded by several distinct, concentric rings of varying brightness and color (ranging from orange to red). The rings are separated by darker, less dense regions. The overall shape is roughly circular but slightly elongated.

Planet
formation
(HL Tau)
imaged by
ALMA

Plate movement measured by VLBI



<https://www.spacegeodesy.go.jp/vlbi/en/whatisvlbi/objectives01.html>

Astronomy and Society

- WiFi: developed by radio astronomers in Australia
- Communication: useful tools, devices, and data-processing methods.
- Magnetic Resonance Imaging (MRI) :
an application of radio interferometry technologies
- For more details, please visit at
<https://iau.org/static/archives/announcements/pdf/ann19022a.pdf>

Summary

- Radio astronomy is a relatively new area in astronomy (~ 90 yrs)
- Radio astronomy revealed invisible Universe, and expanded our knowledge on the Universe
- 4 Nobel Prizes
- New technologies to detect extremely weak signals and to manage huge amount of data are useful for our society

