Radio astronomy & Yebes Observatory

IWLR 2022, Guadalajara, Spain

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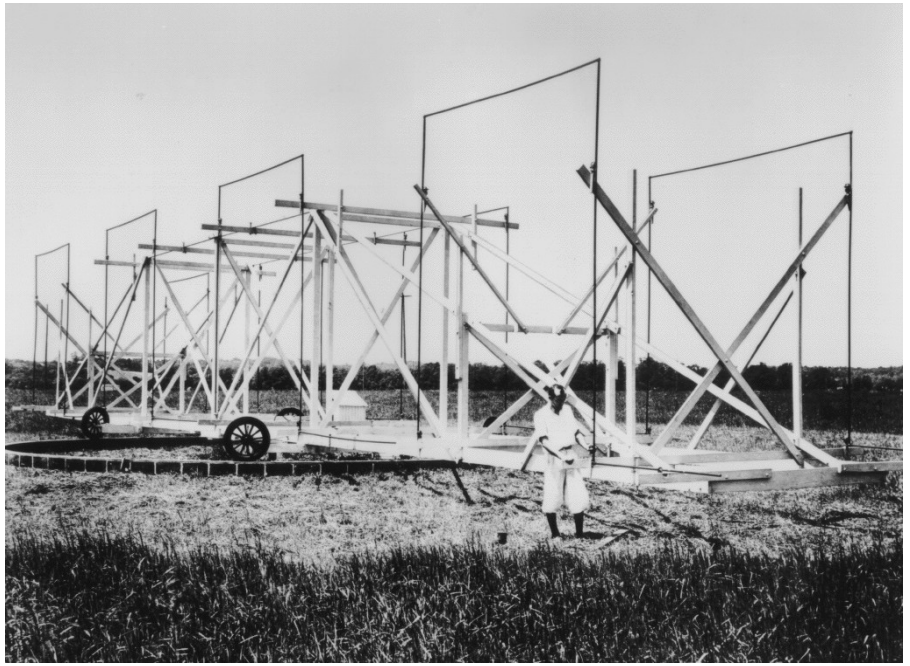
Yebes Observatory. IGN

GOBIERNO DE ESPAÑA
MINISTERIO DE TRANSPORTES, MOVILIDAD Y AGENDA URBANA
INSTITUTO GEOGRÁFICO NACIONAL
YEBES
UNIÓN EUROPEA
Fondo Europeo de Desarrollo Regional

Started in the 1920s - 1930s



Karl Jansky

He built an orientable antenna to receive radiation at **20.5 MHz** (wavelength 14,5 m) and discovered: *a faint steady hiss of unknown origin*.

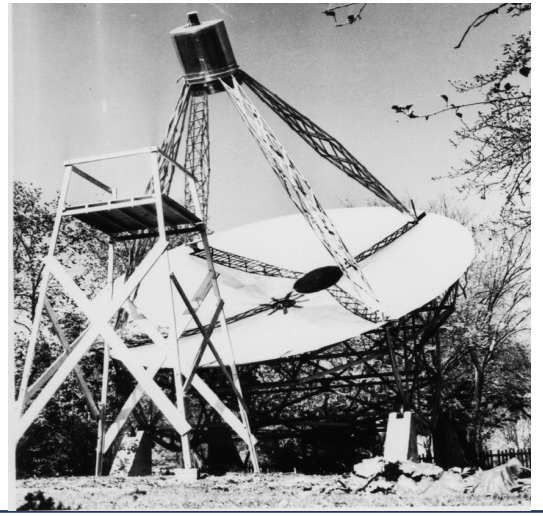
[1933] He noticed the **radiation** came from the Saggitarius region (**center of our galaxy**).

Grote Reber

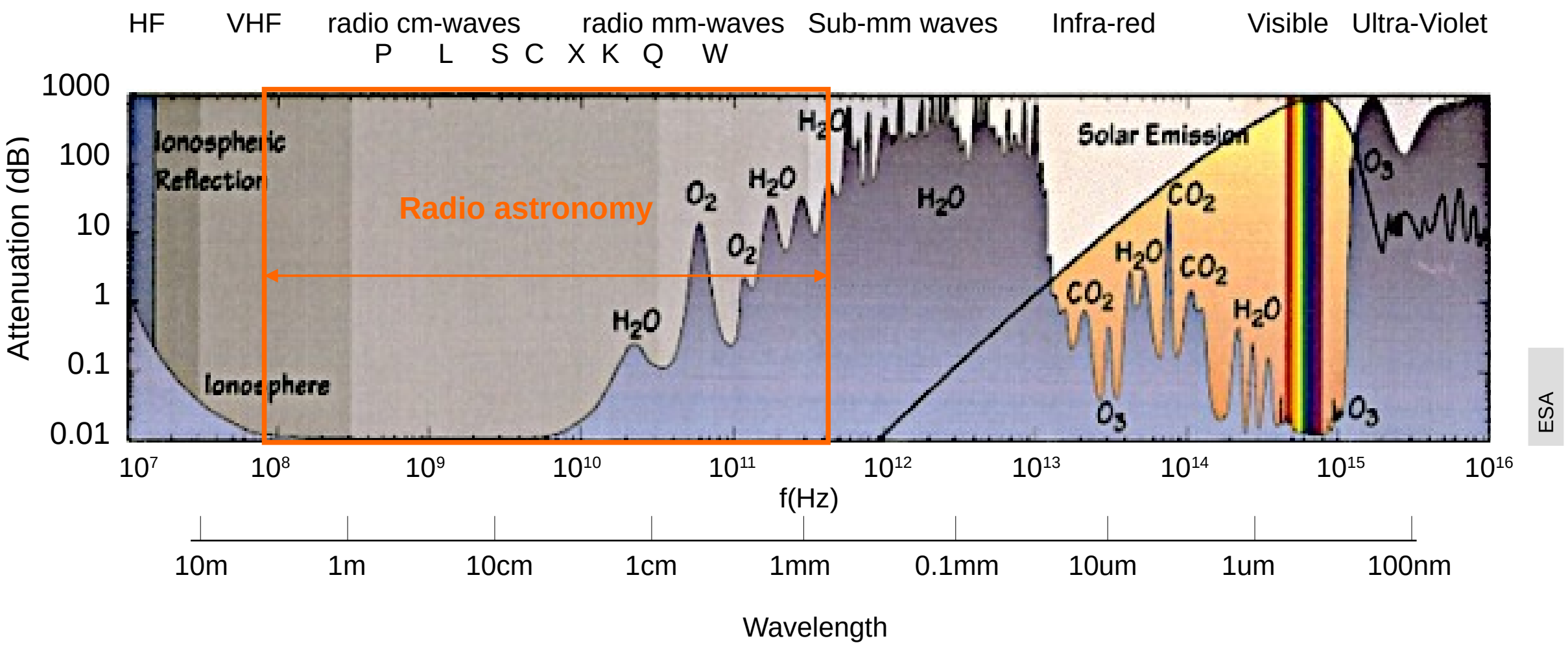
He built a 9.45 m radio telescope in his backyard.

[1938] He discovered **radiation** from the Milky Way at 160 MHz.

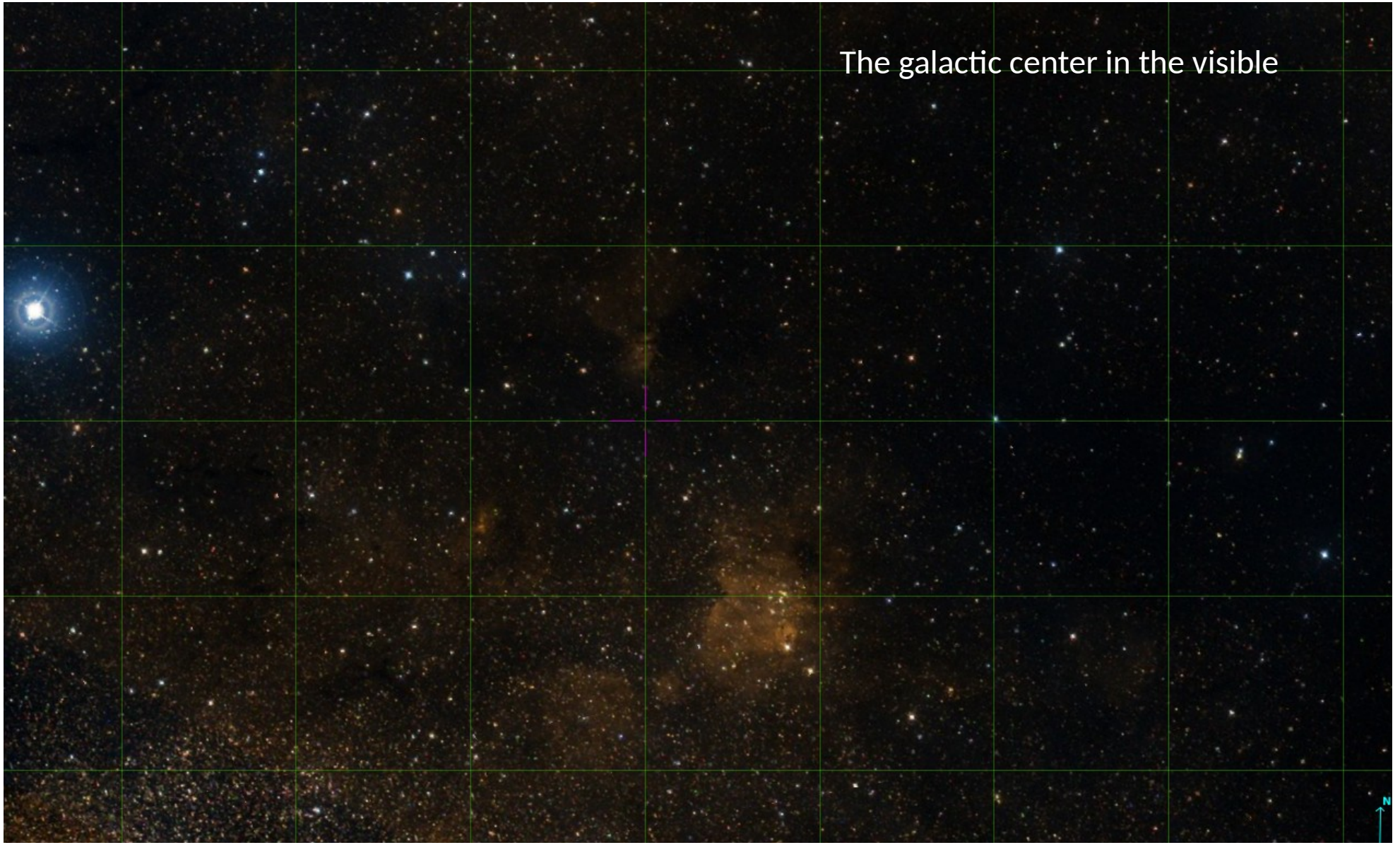
[1944] First radio map of the Galaxy



Radio astronomy: The electromagnetic spectrum

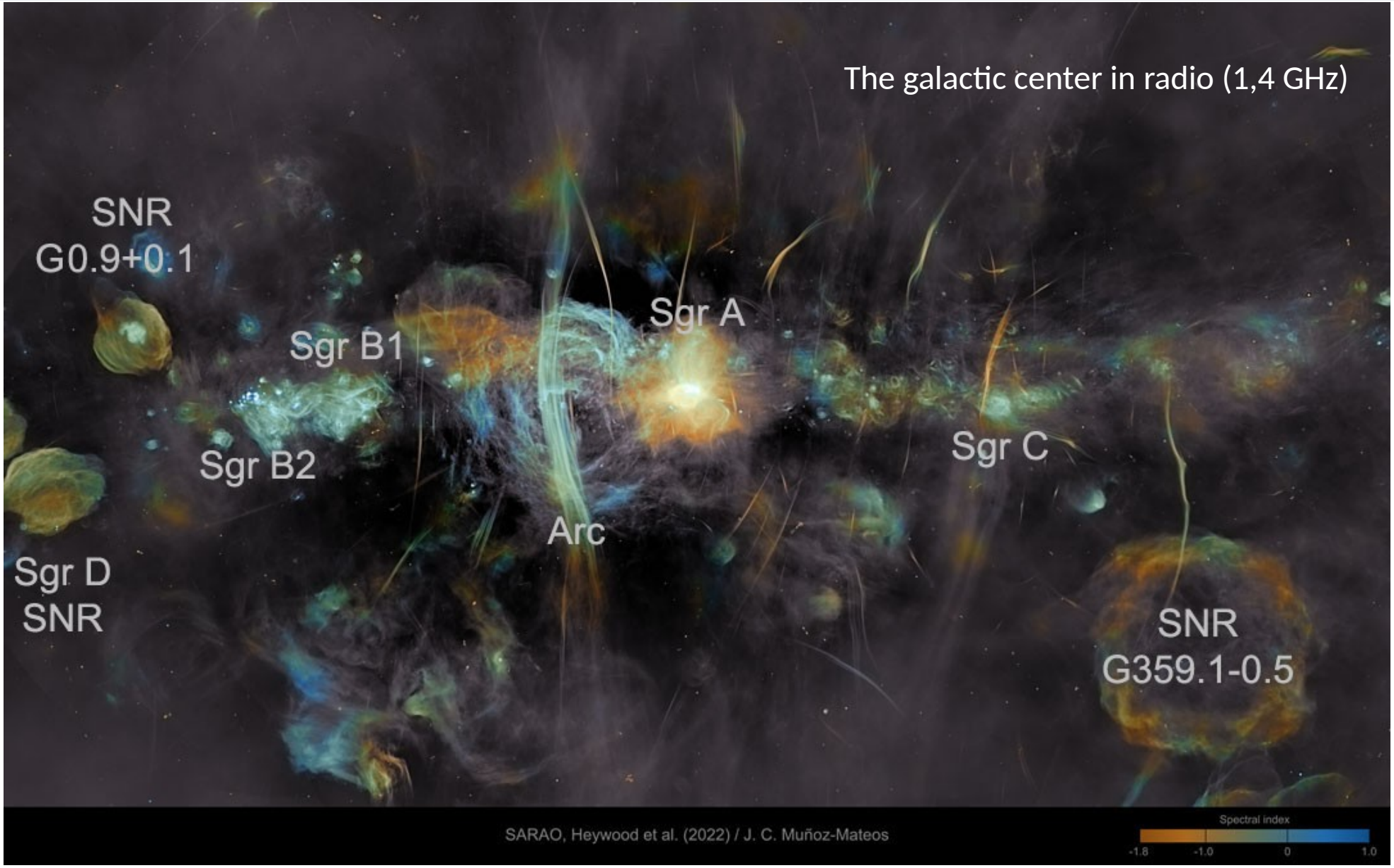


Radio astronomy: The invisible Universe



Digitized Sky Survey - STScI/NASA, Colored & Healpixed by CDS

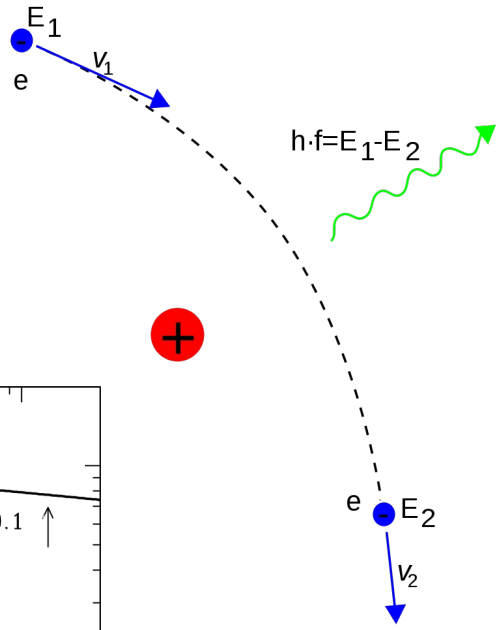
Radio astronomy: The invisible Universe

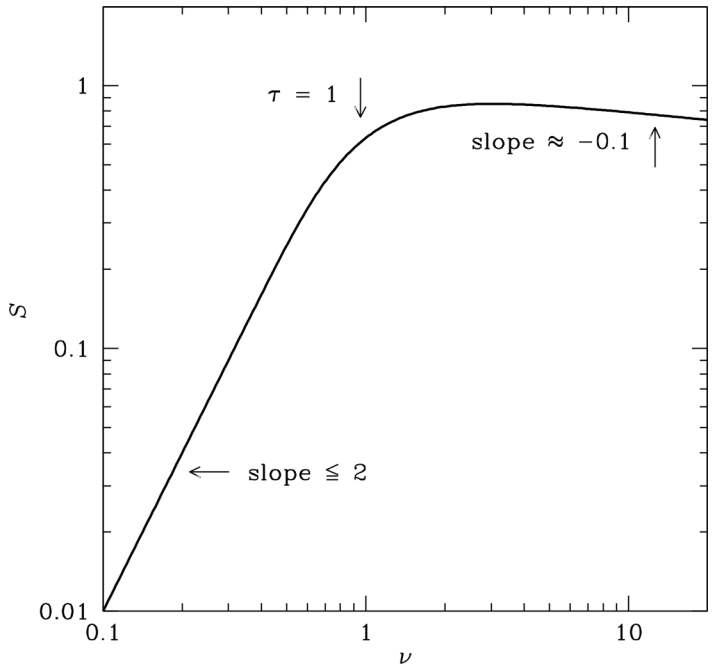


Heywood et al. (2022) / J.C. Muñoz-Mateos (SARAO)

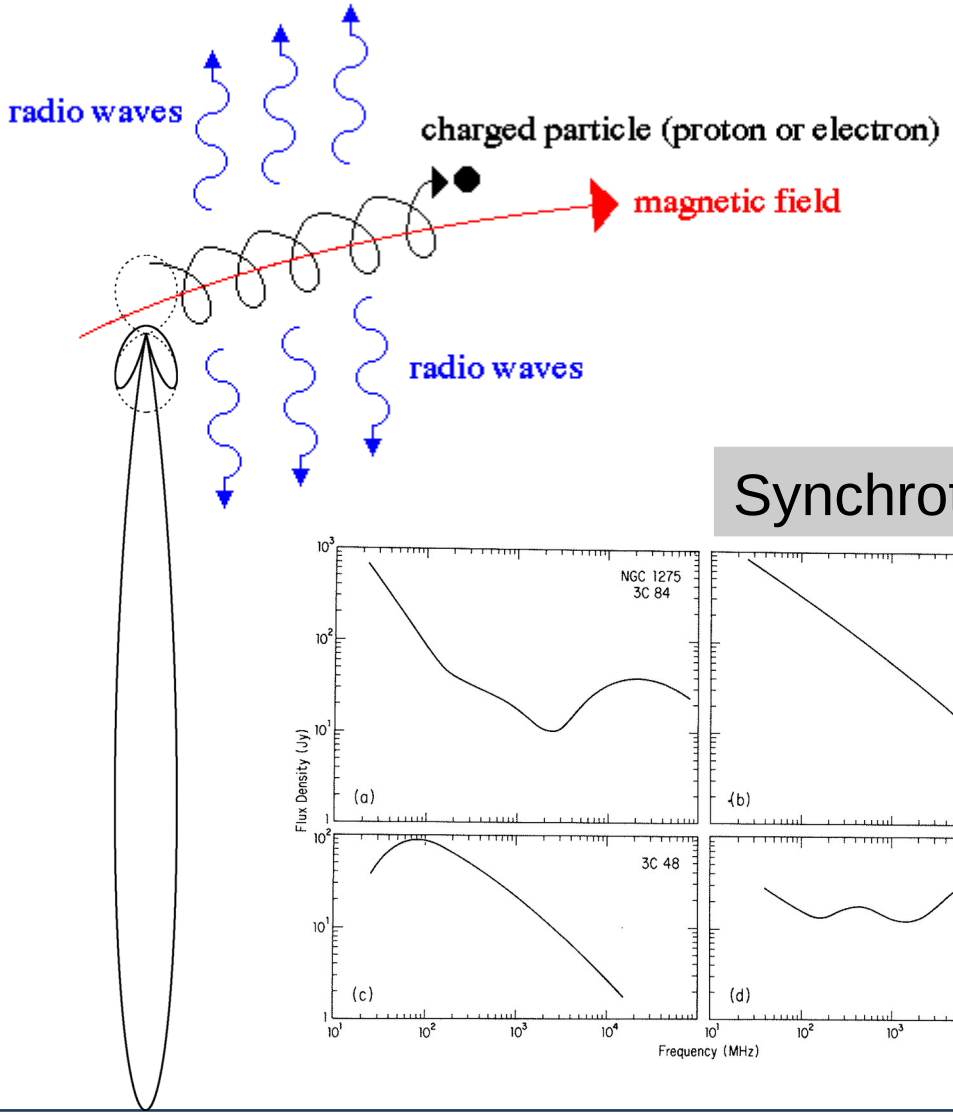
Continuum radiation

Bremsstrahlung





Synchrotron



Synchrotron radiation

(ultra energetic Universe)

Radio Galaxy Hercules A:

- Black hole: M87
- High relativistic jets

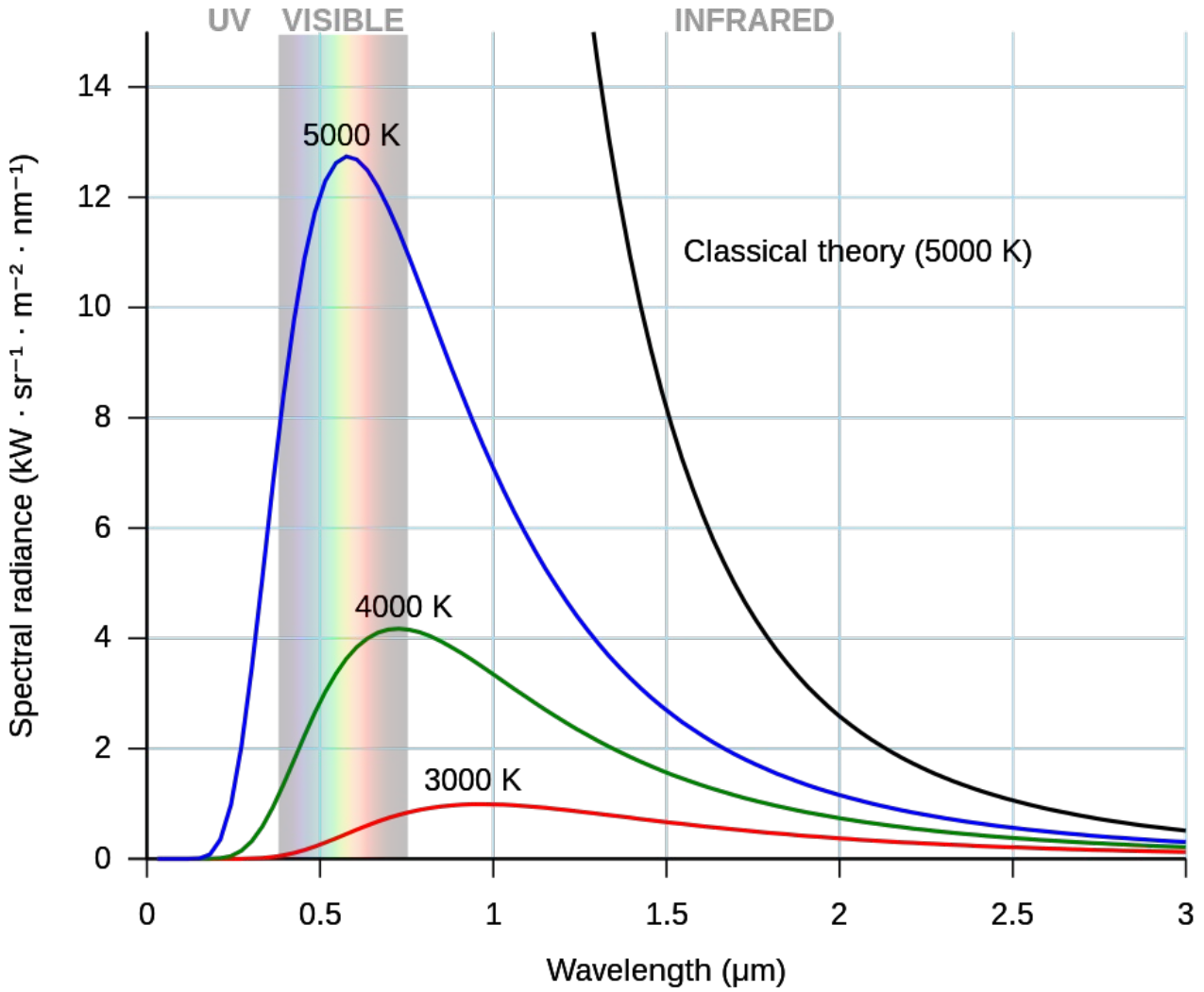
Saxton, Cotton & Perley(2010), NRAO/AUI/NSF

VLA (NRAO) data

Continuum radiation

Blackbody

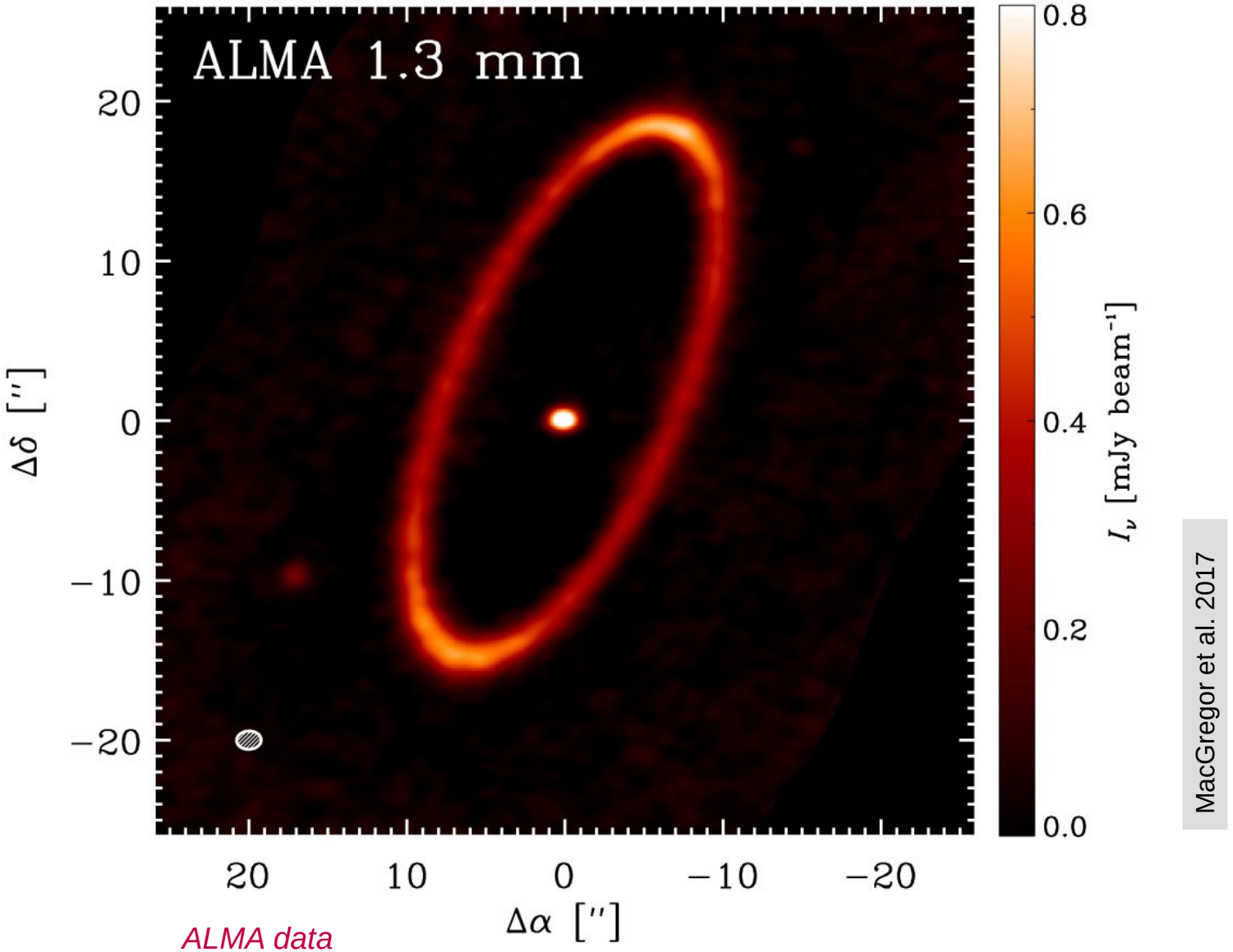
$$B_\nu(T) = \frac{2\nu^2}{c^2}\frac{h\nu}{e^{h\nu/kT} - 1},$$



Blackbody radiation from dust

(cold Universe)

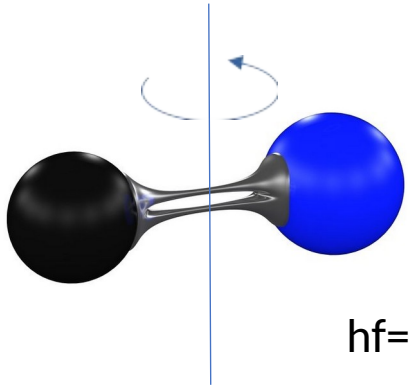
Debris disk in Formahault system (230 GHz)



MacGregor et al. 2017

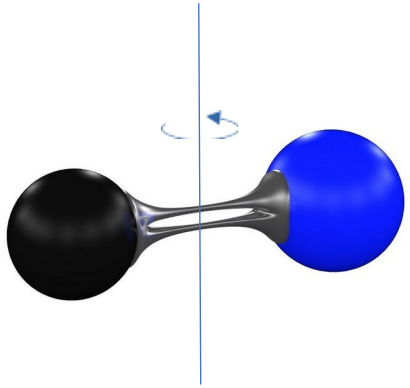
ALMA data

Spectral: rotational molecular transitions



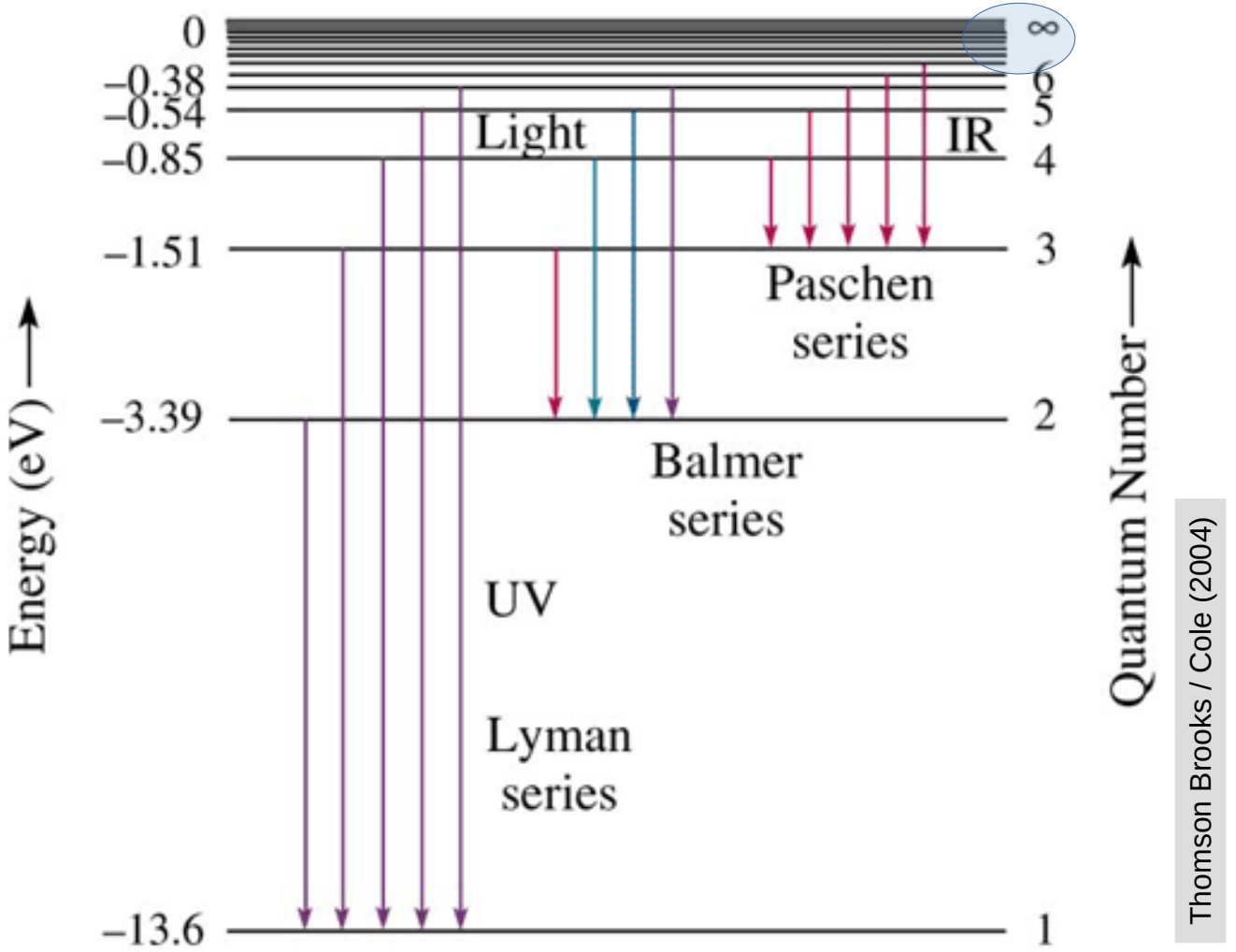
E_{rot1}

$hf = E_{rot1} - E_{rot2}$



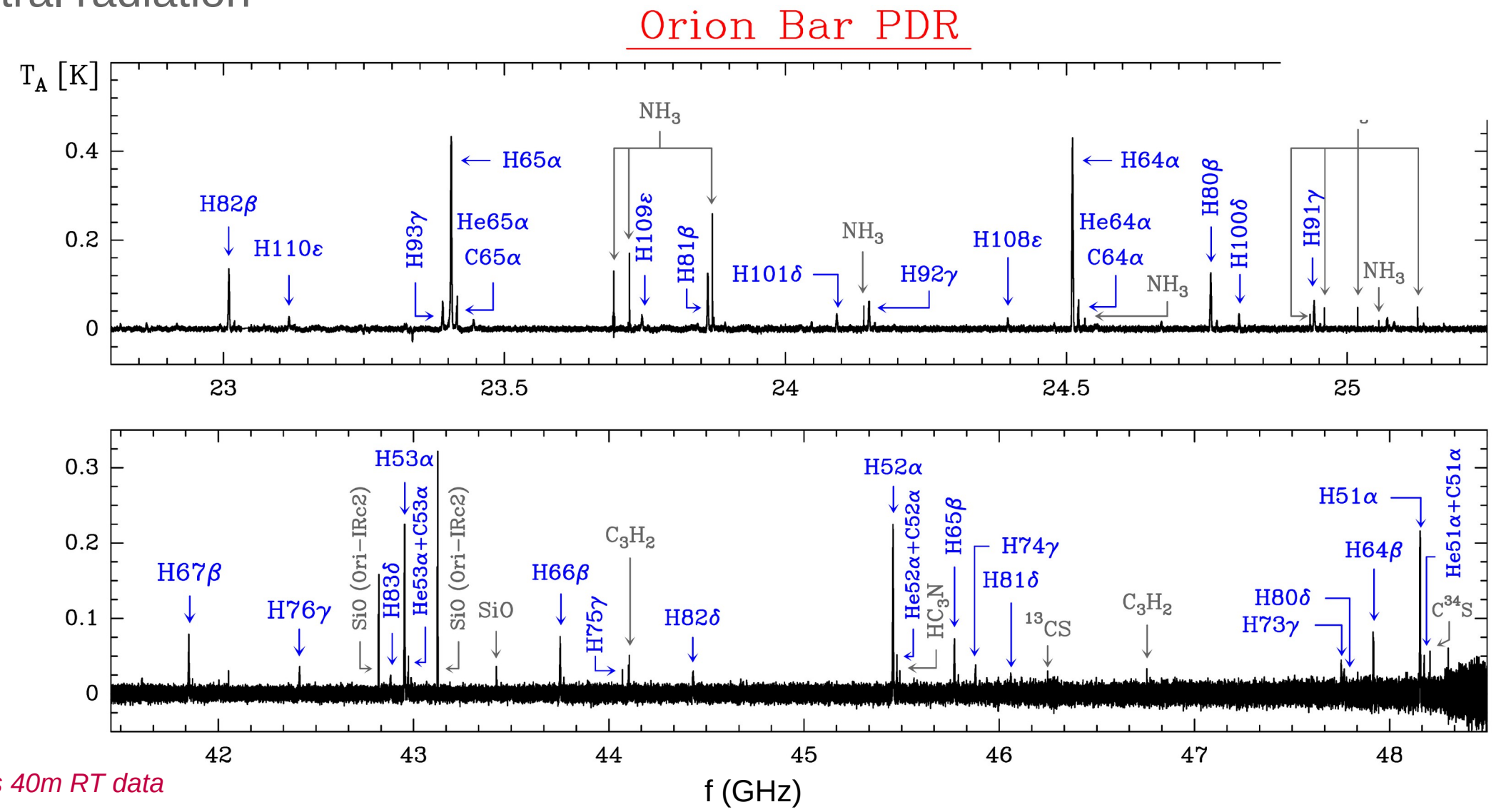
E_{rot2}

Spectral: radio recombination (atoms)



Thomson Brooks / Cole (2004)

Spectral radiation



Cuadrado et al. (2017)

Yebes 40m RT data

Paraboloids

Primary focus
Secondary focus
Nasmyth

Receivers

At focus
Single pixel or multipixel (a few pixels)
Cryogenic (< 15 K, or < 4 K)

Limitations & risks

Atmosphere: H_2O & O_2
RFI

Angular resolution

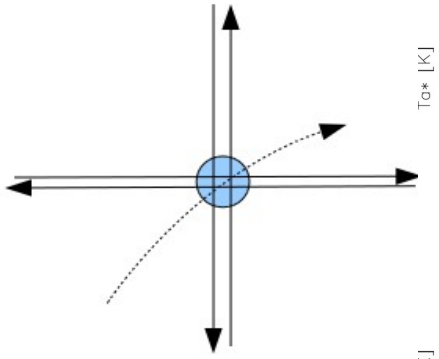
λ/D ➡ Big telescopes

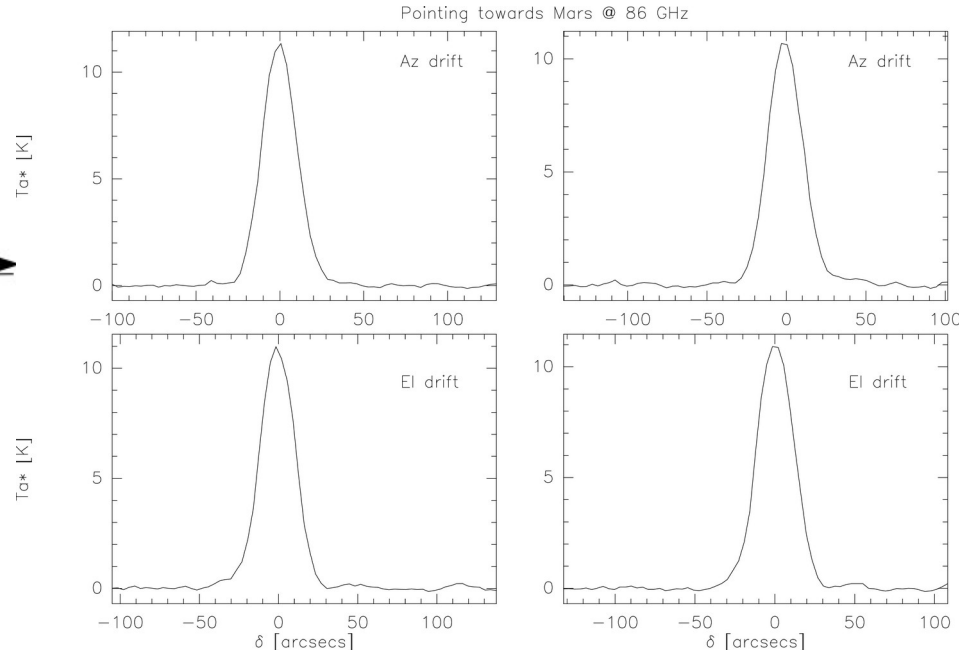
Yebes 40m RT

de Vicente (2015)

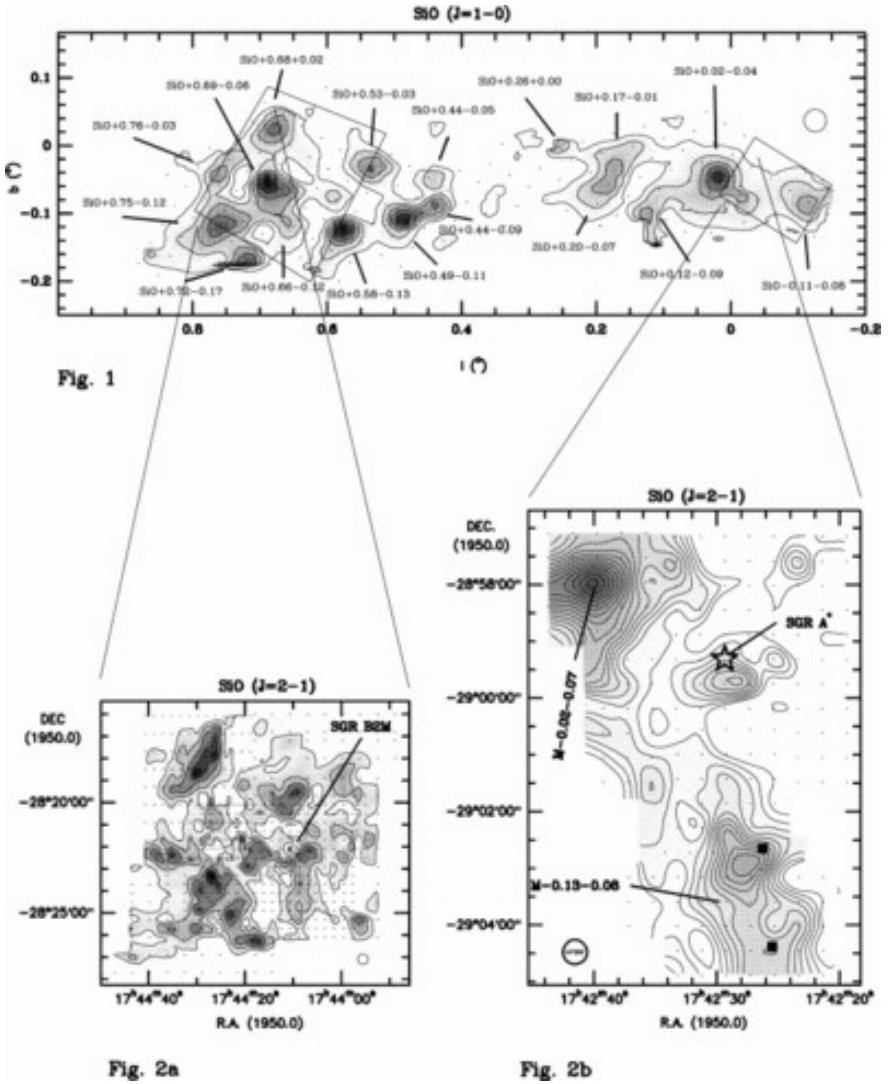
Single dish pointing & mapping

On the Fly acquisition & rasters
Spectral and/or continuum mapping





Yebes 40m RT data



Yebes 14m RT data & IRAM 30m data

CG @ SiO (1-0) Martín-Pintado et al. 1997

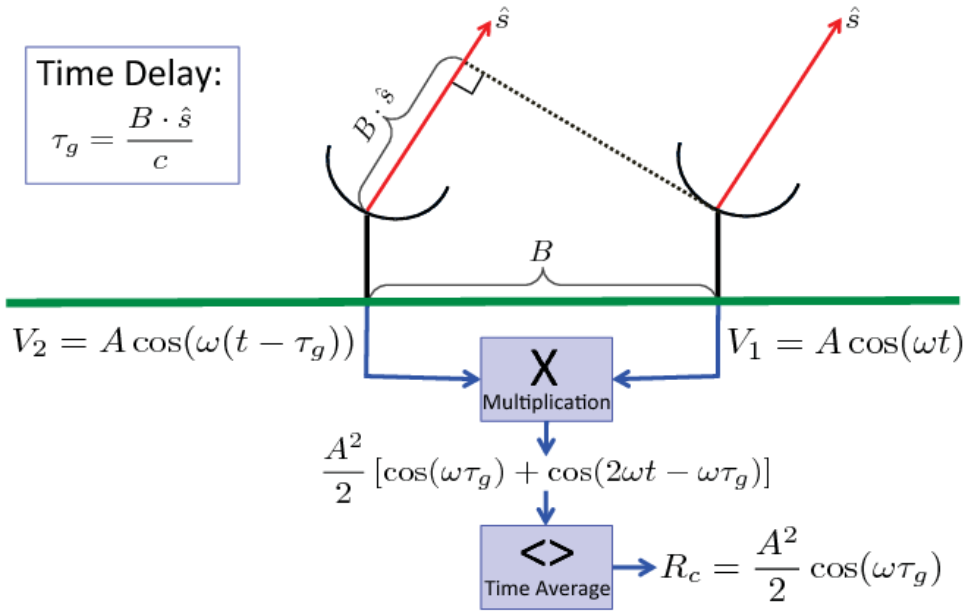
Interferometry

Synthesizing a large telescope:

Multipling data in baselines and integrating

Increases angular resolution: **25 μ arcsecs**!!

Phase & Amplitude calibration



IBouman et al. (2016)

Connected

The VLA (NRAO)

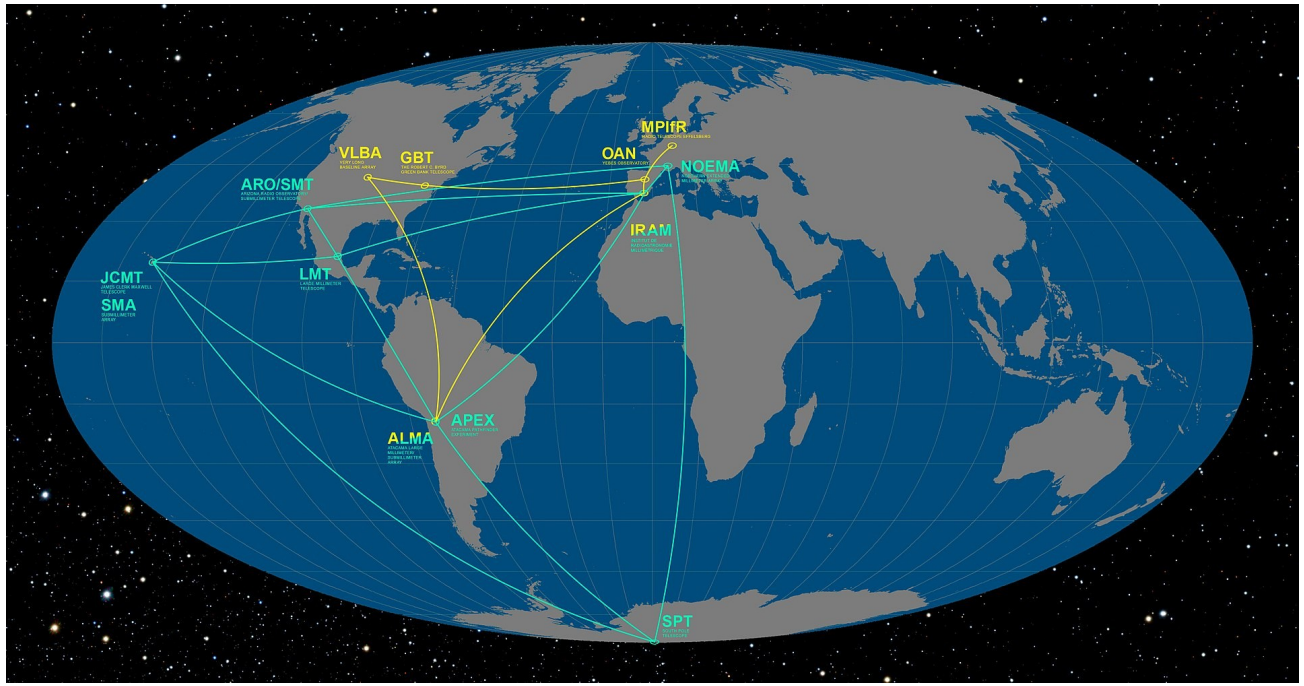
Not connected (VLBI)

The GMVA (EHT, ESO)

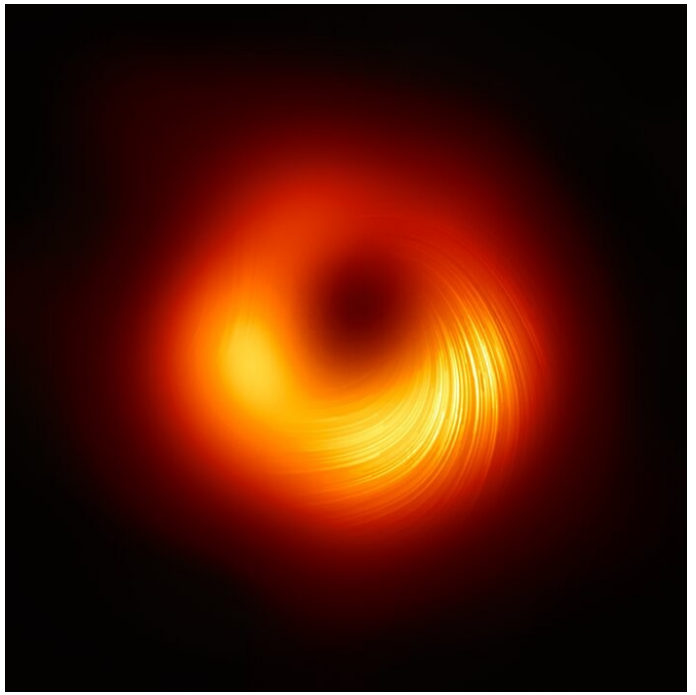
Interferometry Imaging

Aperture Synthesis (& FT)

Synthesizing a large telescope: Telescopes + Earth rotation



ESO/ O. Furtak



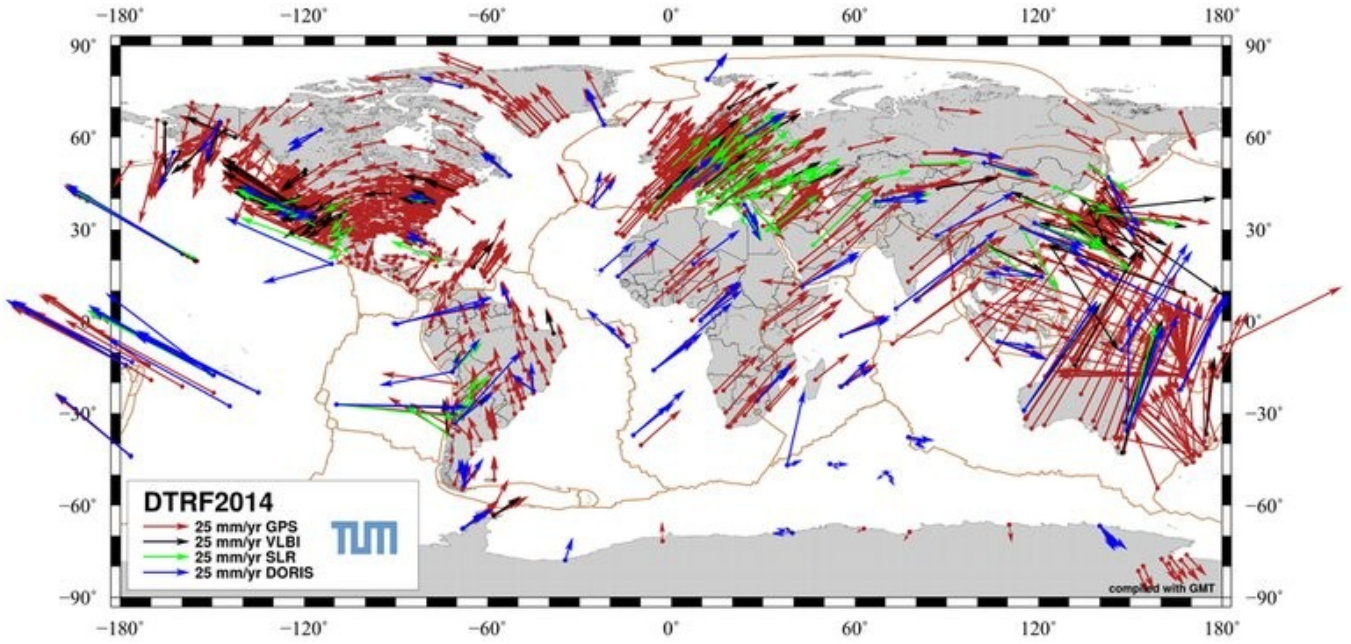
EHT Collaboration

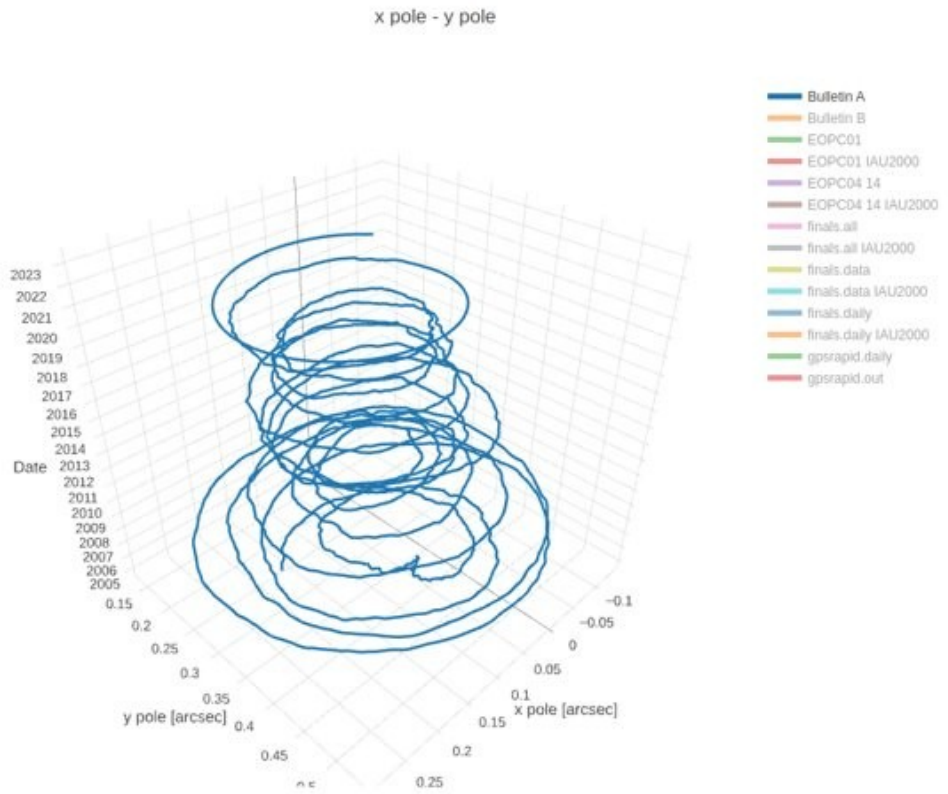
Interferometry

The **geodetic** connection: IVS (**Rüdiger Haas** talk later)

Measuring baselines with precissions ~ 1 mm

Measuring the EOP & contributing to the ITRF and ICR



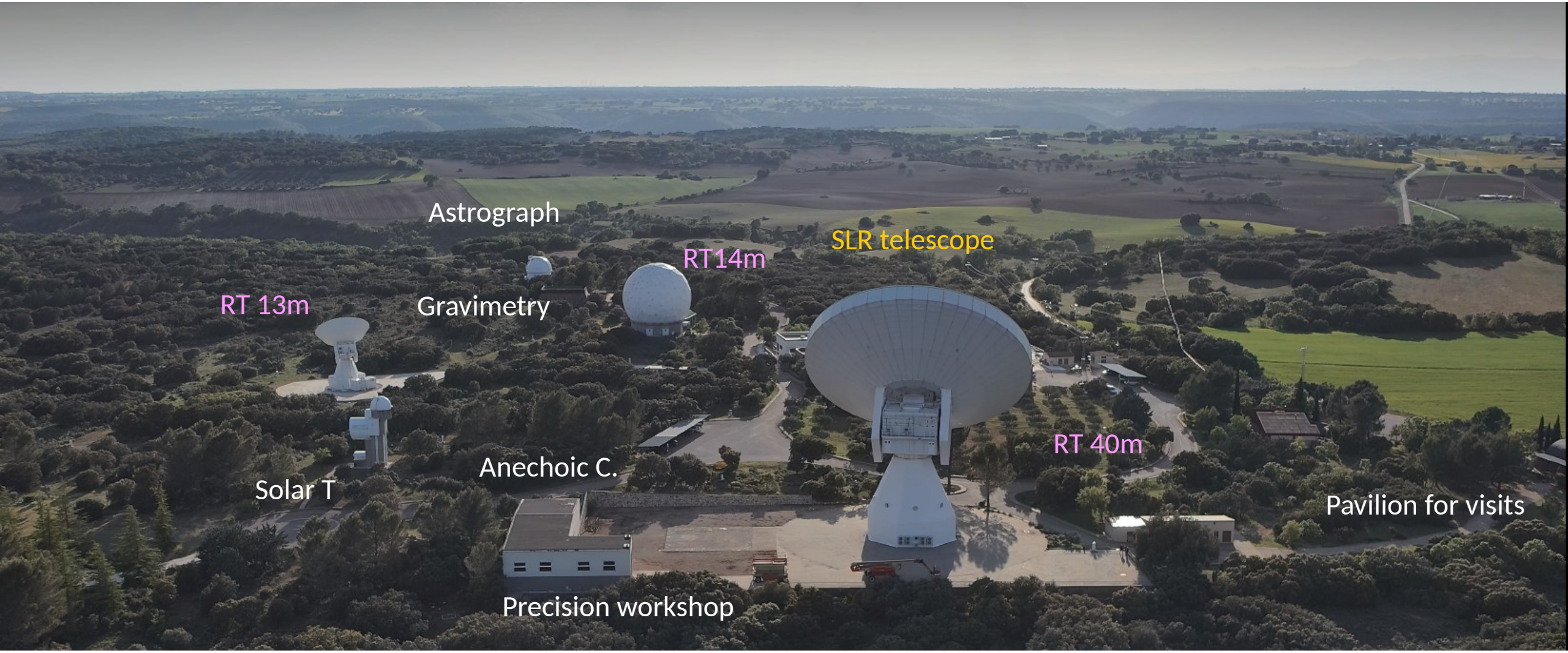


Technische Universität München

Yebes Observatory:

- Radio Astronomy observatory
- Technological development center for Radio Astronomy
- Future Geodetic Fundamental Station

Yebes Observatory: Infrastructures



First single dish observations: **1979 @ 45 GHz** (7 mm)

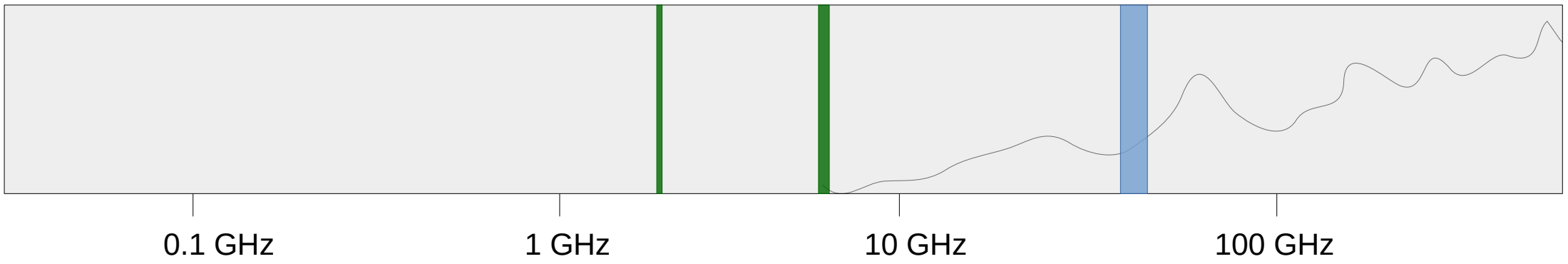
First interferometer successful observation: **1989**

First geodetic observations @S/X: **1992**

Receivers designed & built in house

Ctrl. System written in house

Ceased operations: **2003**



Flagship of Yebes Observatory

Open Skies policy: Scientists across the world

Operates as **single dish** (2 calls)

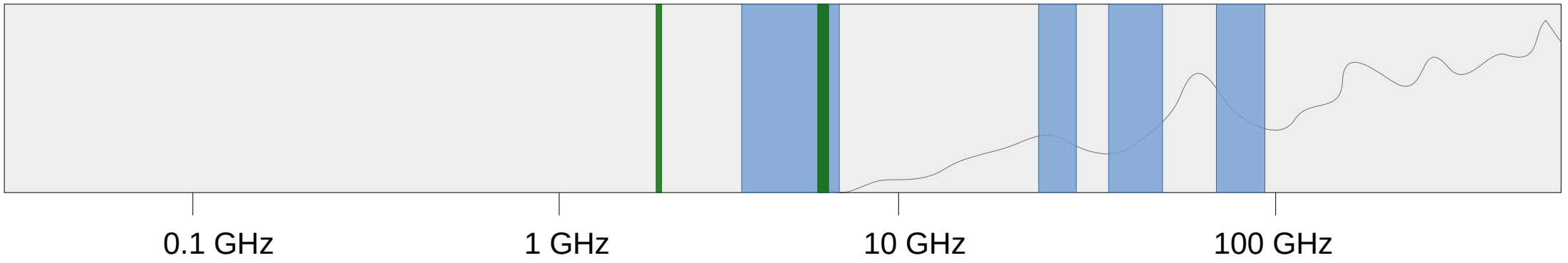
Operates as **interferometer** element

- European VLBI Network (3 calls)
- Global Millimeter Array (2 calls)

Geodetic IVS observations (to be dropped)

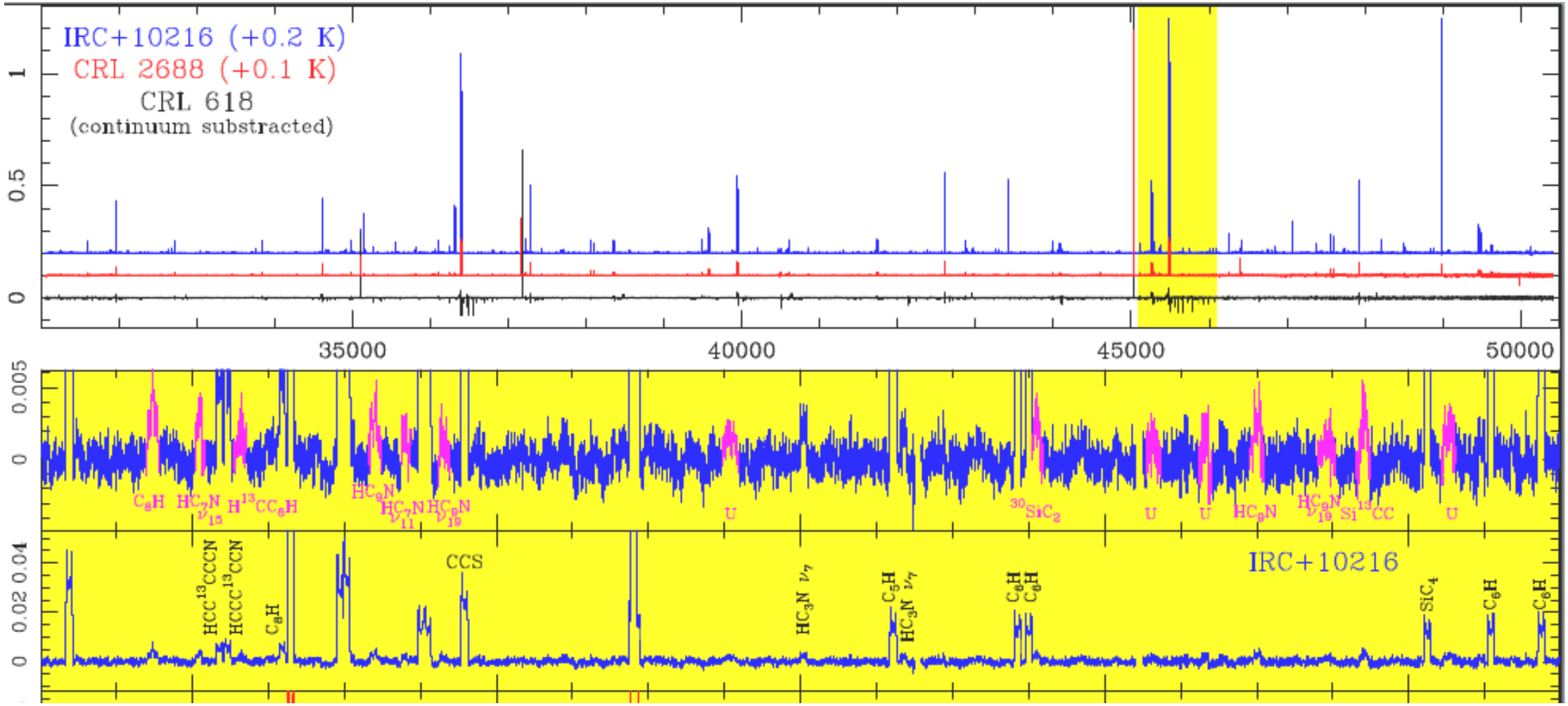
Receivers designed and built **in house**

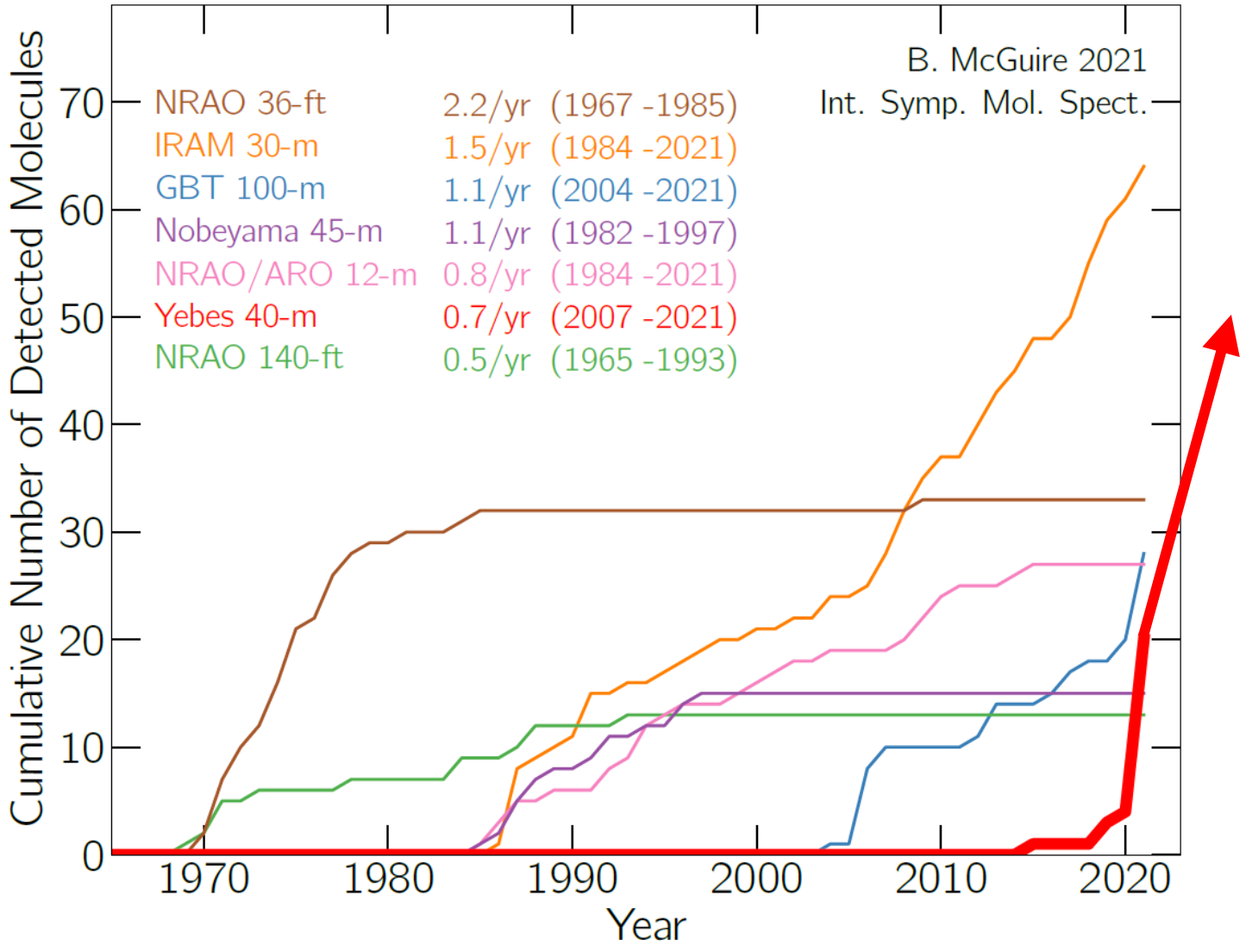
Ctrl. System and pipeline desgined & built **in house**



Molecular spectroscopy instrument:

- Detection of **molecules** in the galactic and extragalactic interstellar medium. “Surveys”.
- Study of **molecular clouds** (emission/absorption, maps)

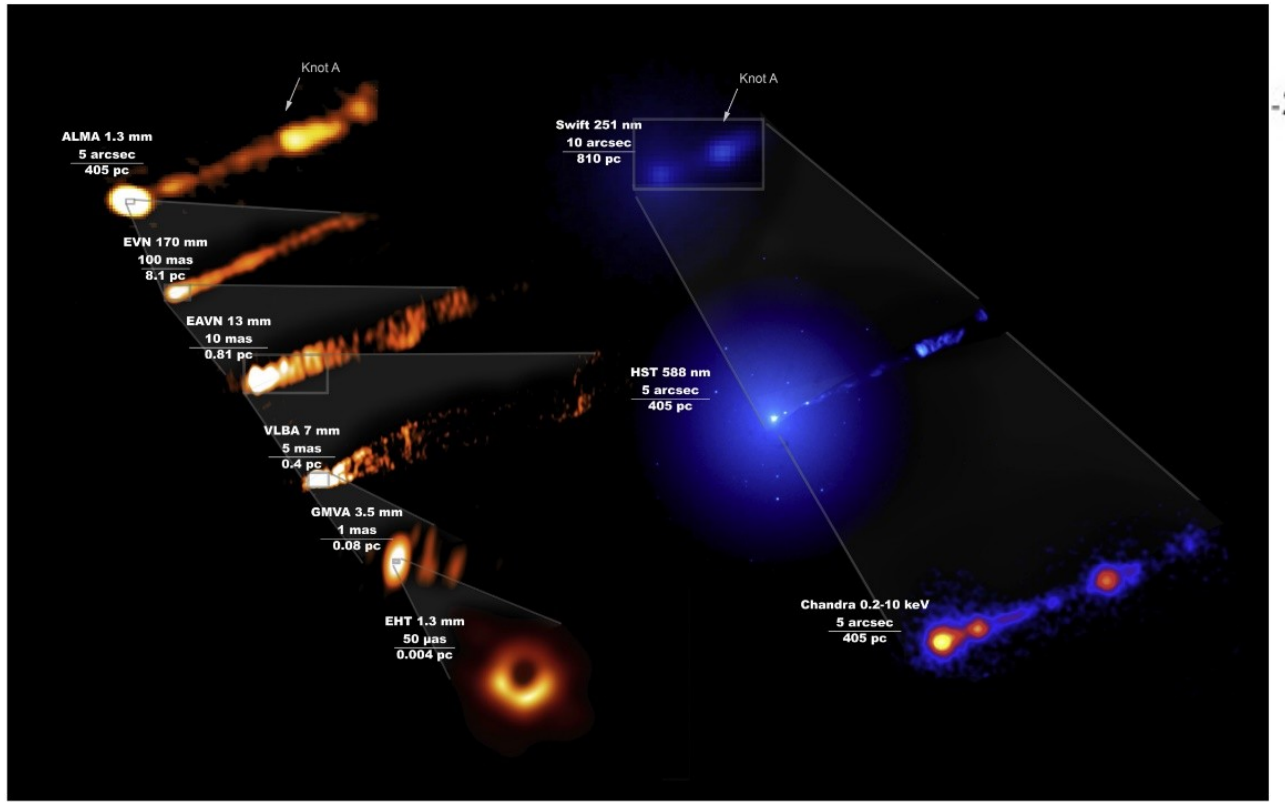




⟷20 molecules below the IRAM 30m telescope (in 2 years !!!)

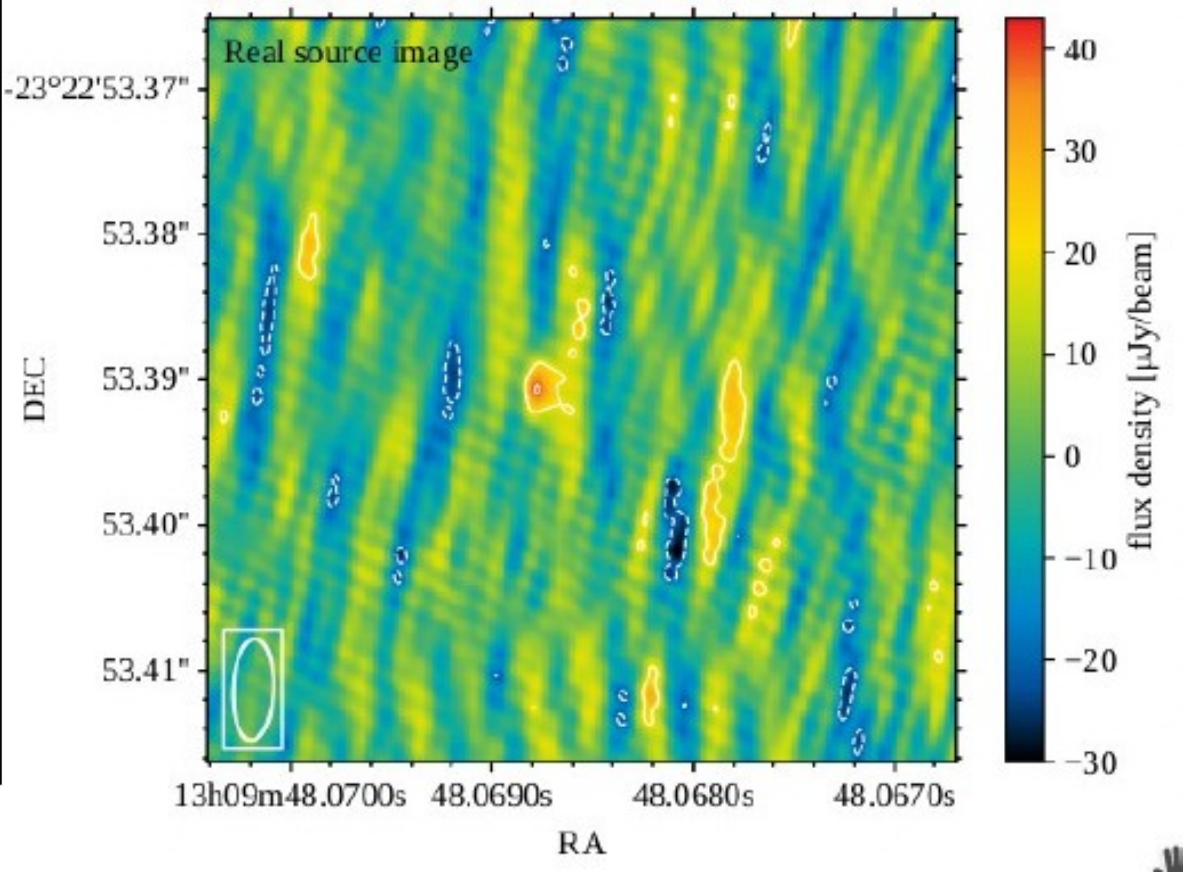
QUIJOTE (NANOCOSMOS)
+31 since Sep 2020
+12 in the queue
+4 in IRC+10216
+4 from other teams

M87 black hole and relativistic jets



The EHT MWL Sc. Group (2021)

Fusion of neutron stars.
Electromagnetic after-glow gravitational wave



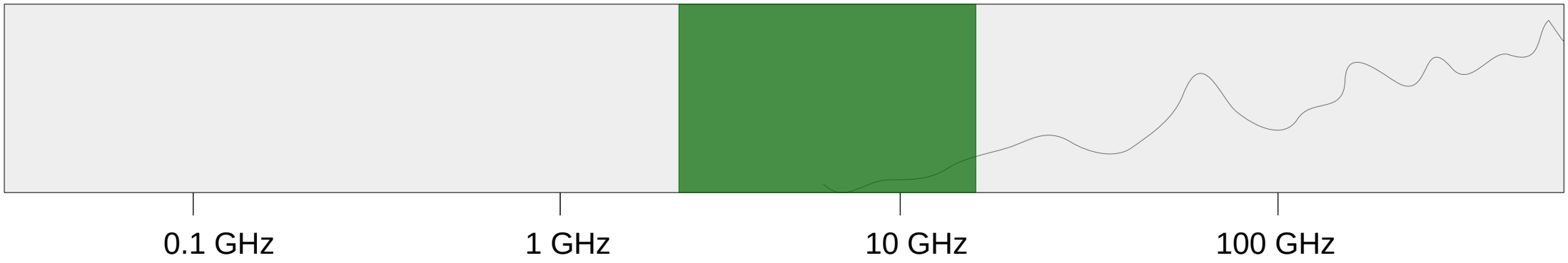
Devoted to geodetic radio astronomy observations

Part of the **IVS (VGOS** project**)**

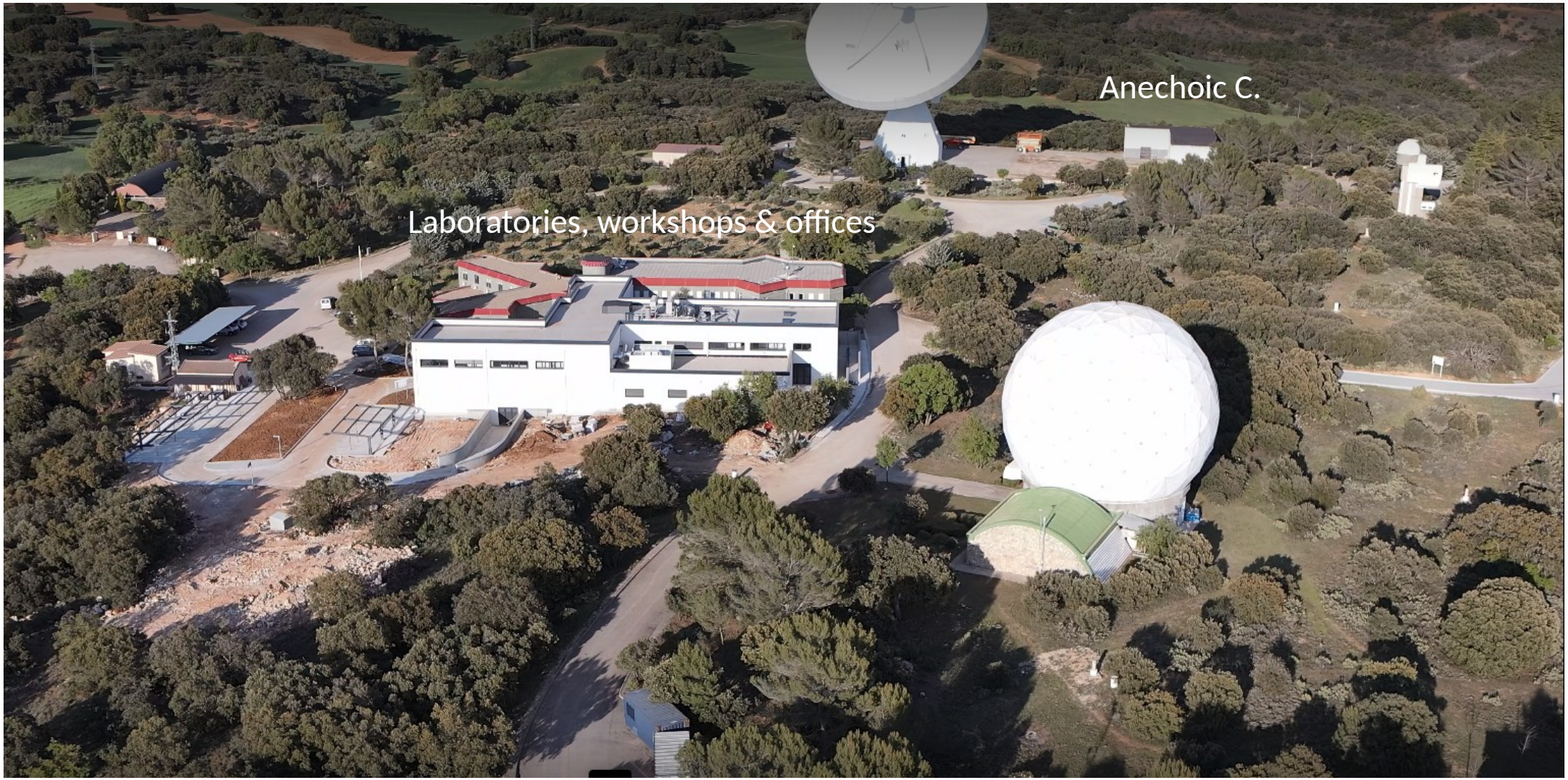
First element of the **RAEGE** network

Receivers designed and built **in house**

Ctrl. System and pipeline designed & built **in house**

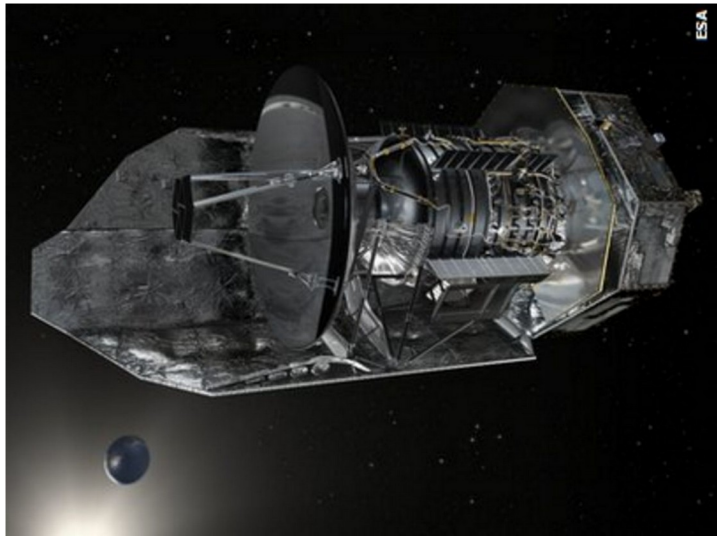


A Technological Development Center for Radio Astronomy



Technological experience in radio astronomy (> 37 years)
Well known in the radio astronomy world
International collaborations:

- **IRAM**. NOEMA
- ESA. **Herschel** HIFI
- **ESO**. **ALMA**
- **SRON**. **ALMA**
- SKA
- NARIT. TNTRT
- IVS: NMA, FGI, GSI, BKG
- EU-VGOS
- Radionet, ORP, RADIOBLOCKS
- Non radio astronomical:
    - Quantum computing
    - Dark matter candidates: axions

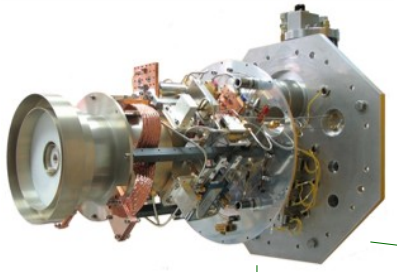


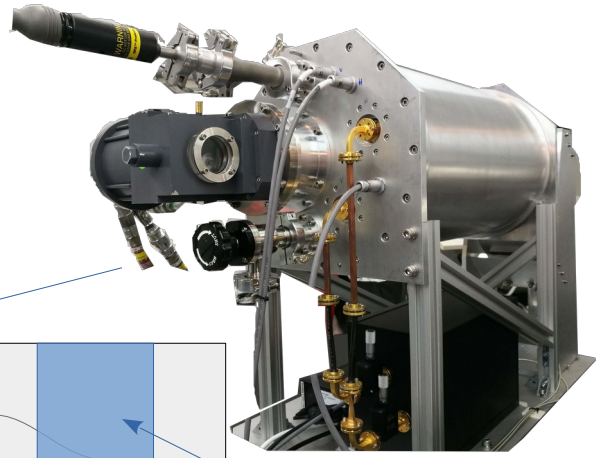
Herschel

ALMA

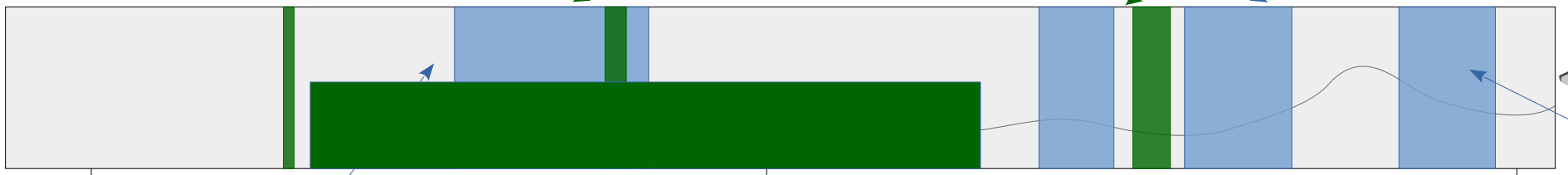
Radio Astronomy receivers

2 - 2.3 GHz
8 - 8.8 GHz
28 - 32 GHz





32 - 50 GHz

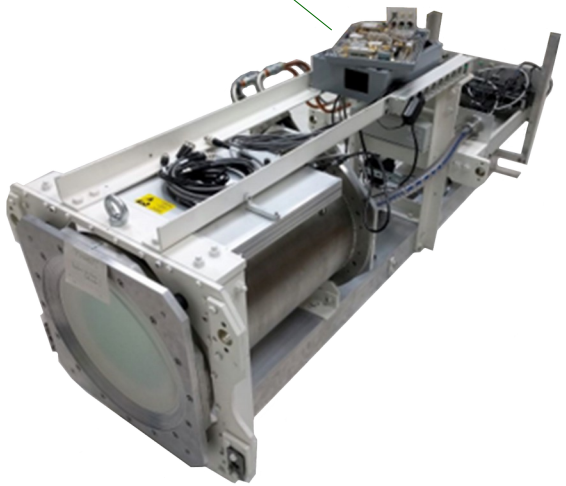


1 GHz

10 GHz

100 GHz

4.5 - 9 GHz

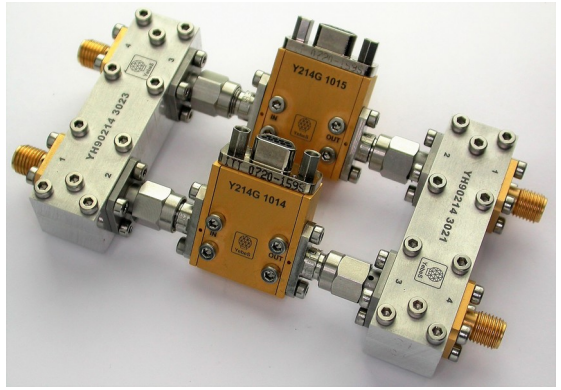


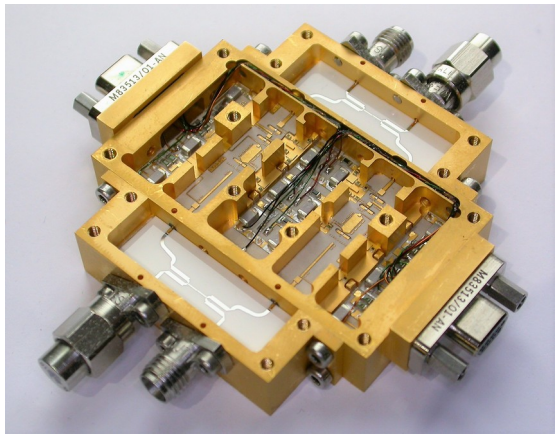
3 - 14 GHz

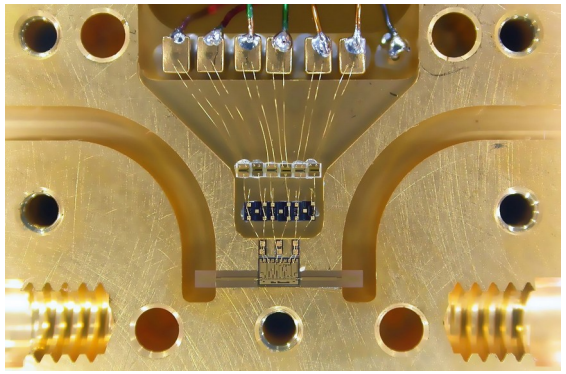
20 - 26 GHz

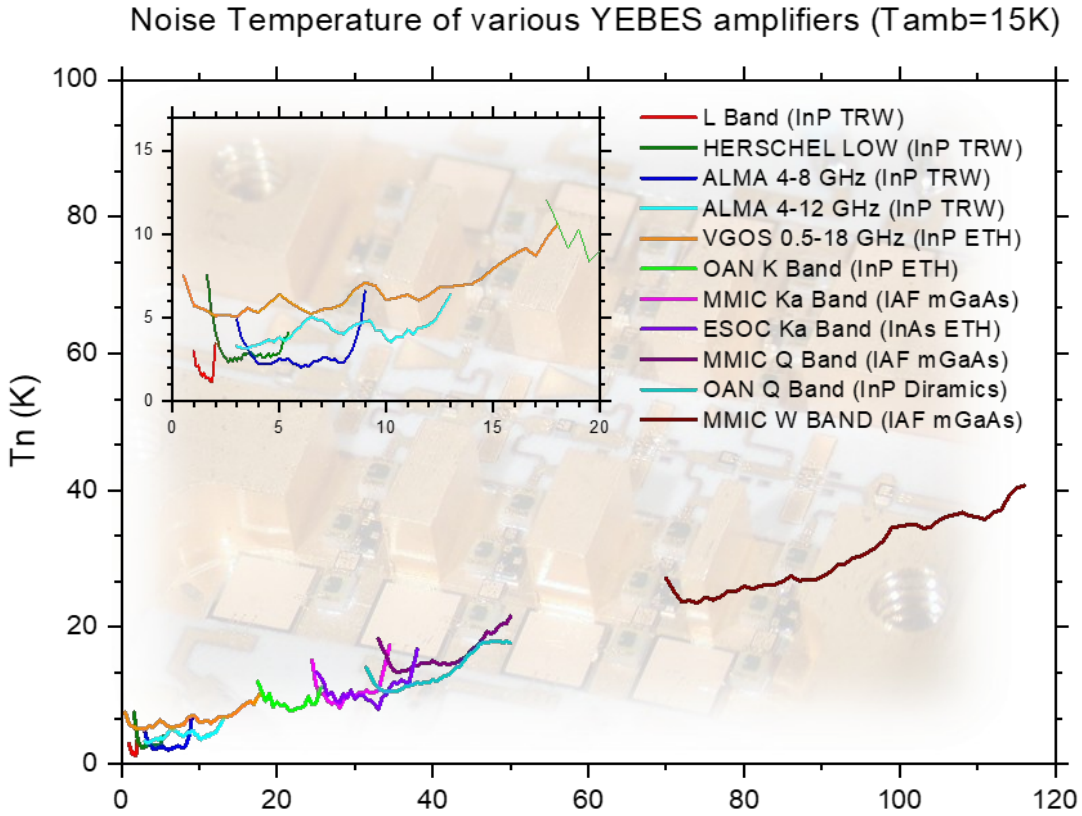
72 - 90 GHz

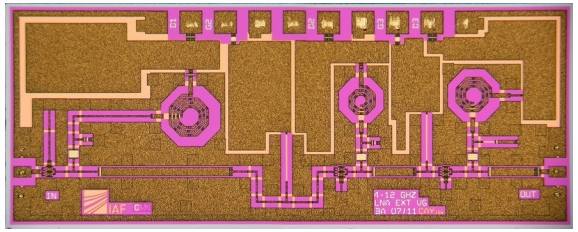
Cryogenic low noise amplifiers and passive devices

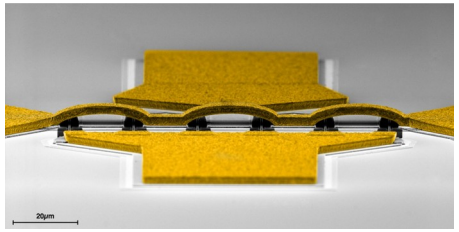


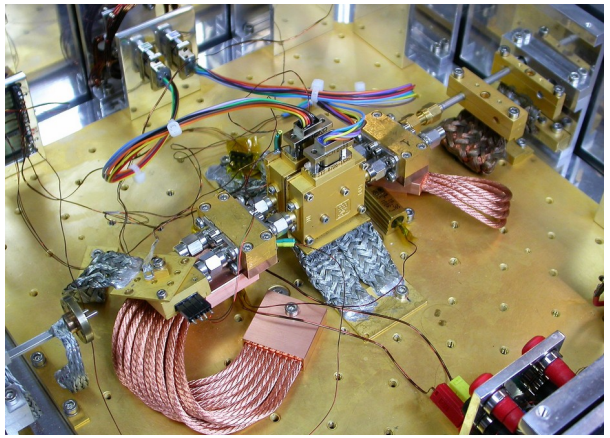




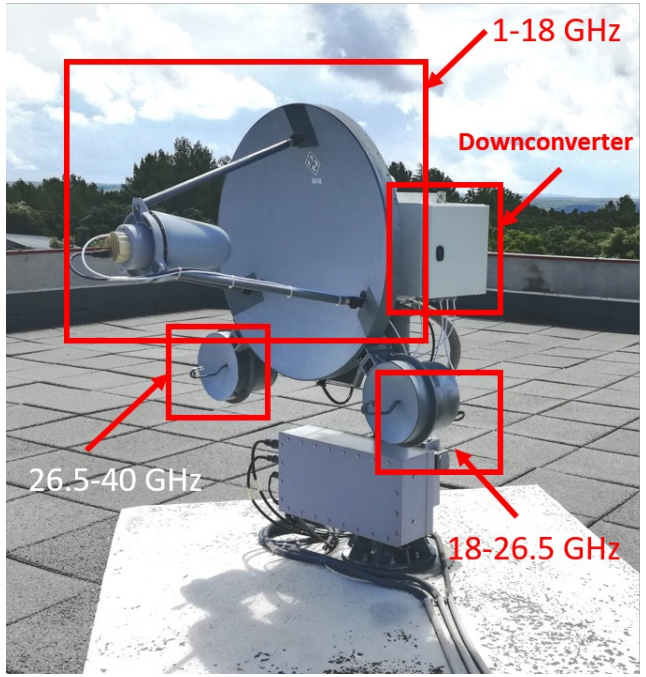


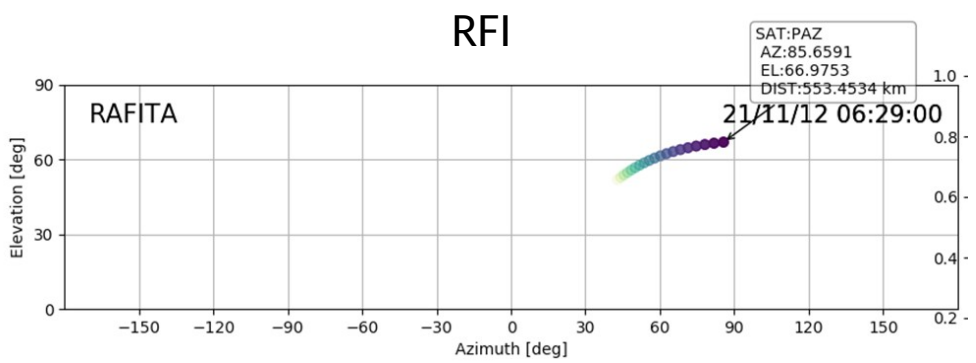




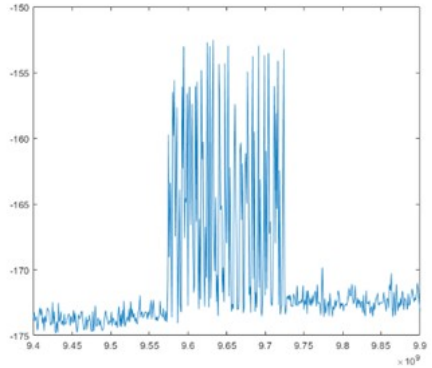


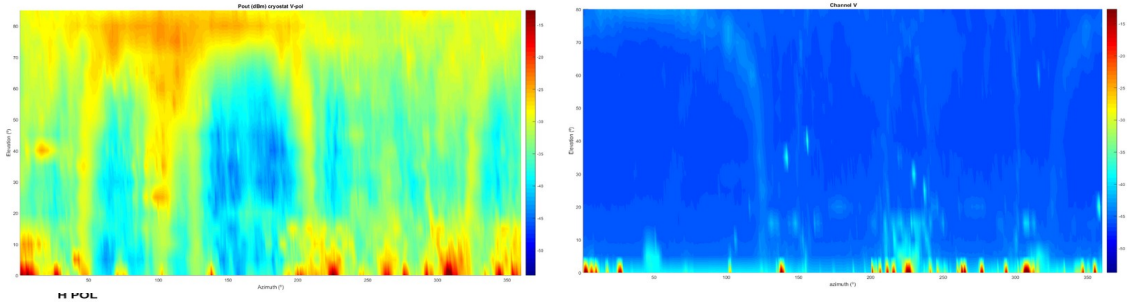
Technological Development Center

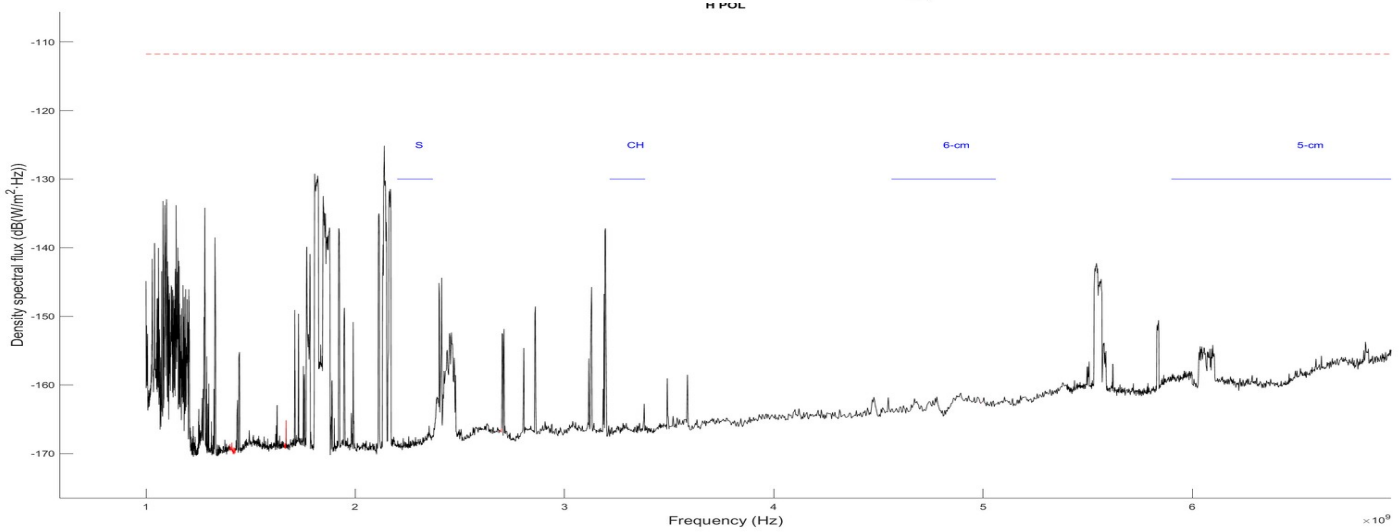


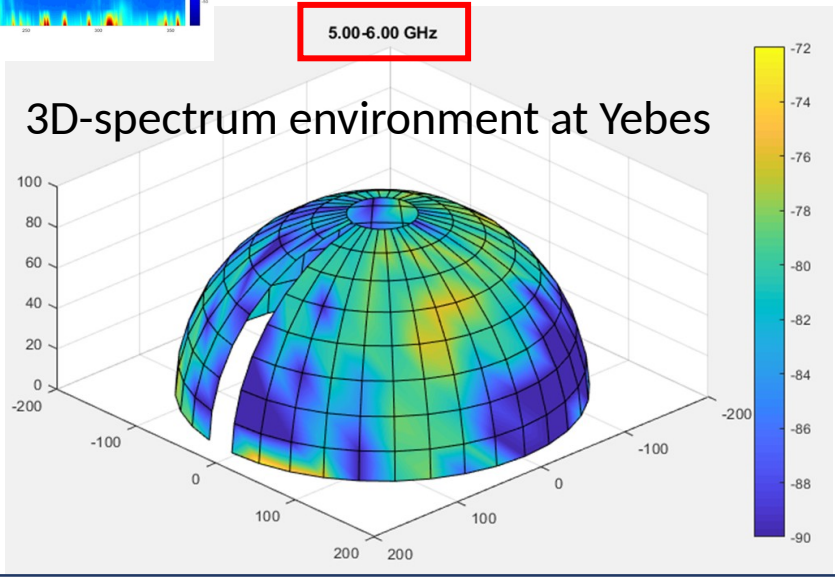


RFI









A future Geodetic Fundamental Station

VLBI

IVS legacy RT 14m (since 1992)
IVS legacy RT 40m (since 2008)
IVS VGOS RT 13m (since 2016)

GNSS

EUREF
IGS (since 2000)
ERGNSS

SLR

Beginning of operations
(mid-2023)

Special funding: **European Regional Development Funds** (ERDF)

ERDF: YDALGO

9.490.000 € (80% EU+ 20% Spain)

- *Laboratories, workshops & equipment for developments in Radio Astronomy*
- *New SLR station*

January 2018 ➡ June 2023

ERDF: YNART

3.735.000 € (80% EU + 20% Spain)

- *Improvements in the 40m radio telescope*
- *New VLBI software correlator*

January 2020 ➡ June 2023

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