*Clase tomada del curso del Prof. Cristóbal Espinoza

Introducción a la Astrofísica 2025

Un poco de radioastronomía, astronomía óptica, infrarroja, y de rayos x y gamma.

Clase 17: Instrumentos para leer el cosmos!

Departamento de Física USACH

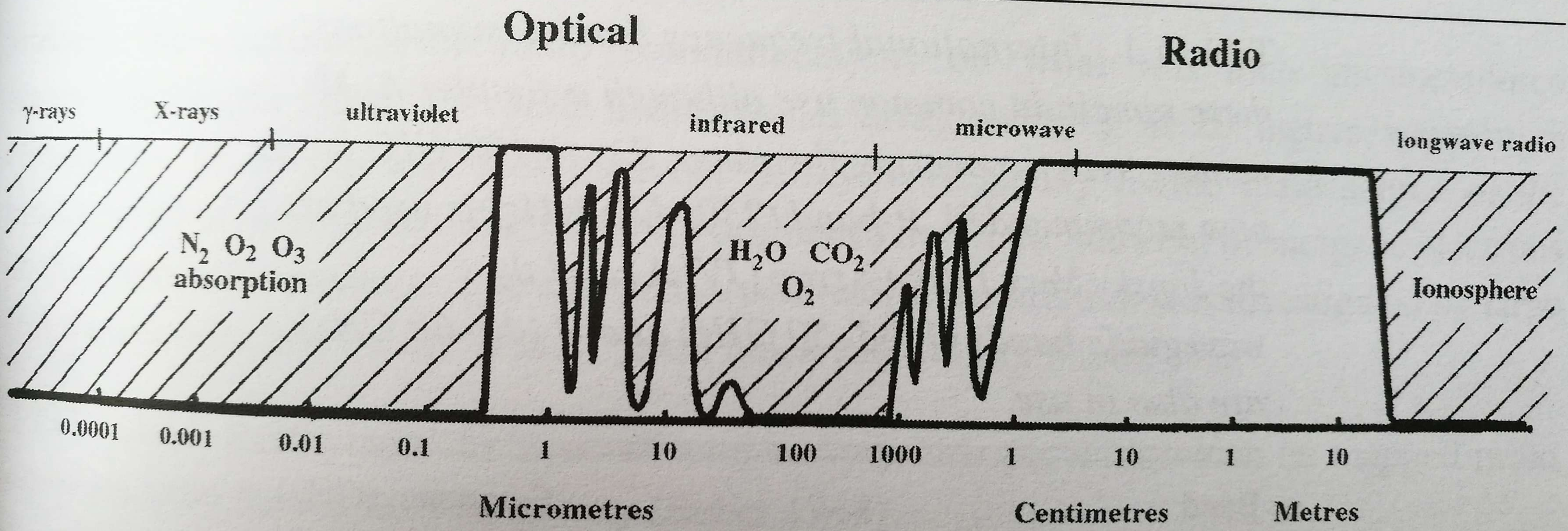


Figure 1.1. The electromagnetic spectrum, showing the wavelength range of the atmospheric 'windows'. The radio range is limited by the ionosphere at wavelengths greater than a few metres, and by molecular absorption in the sub-millimetre range.

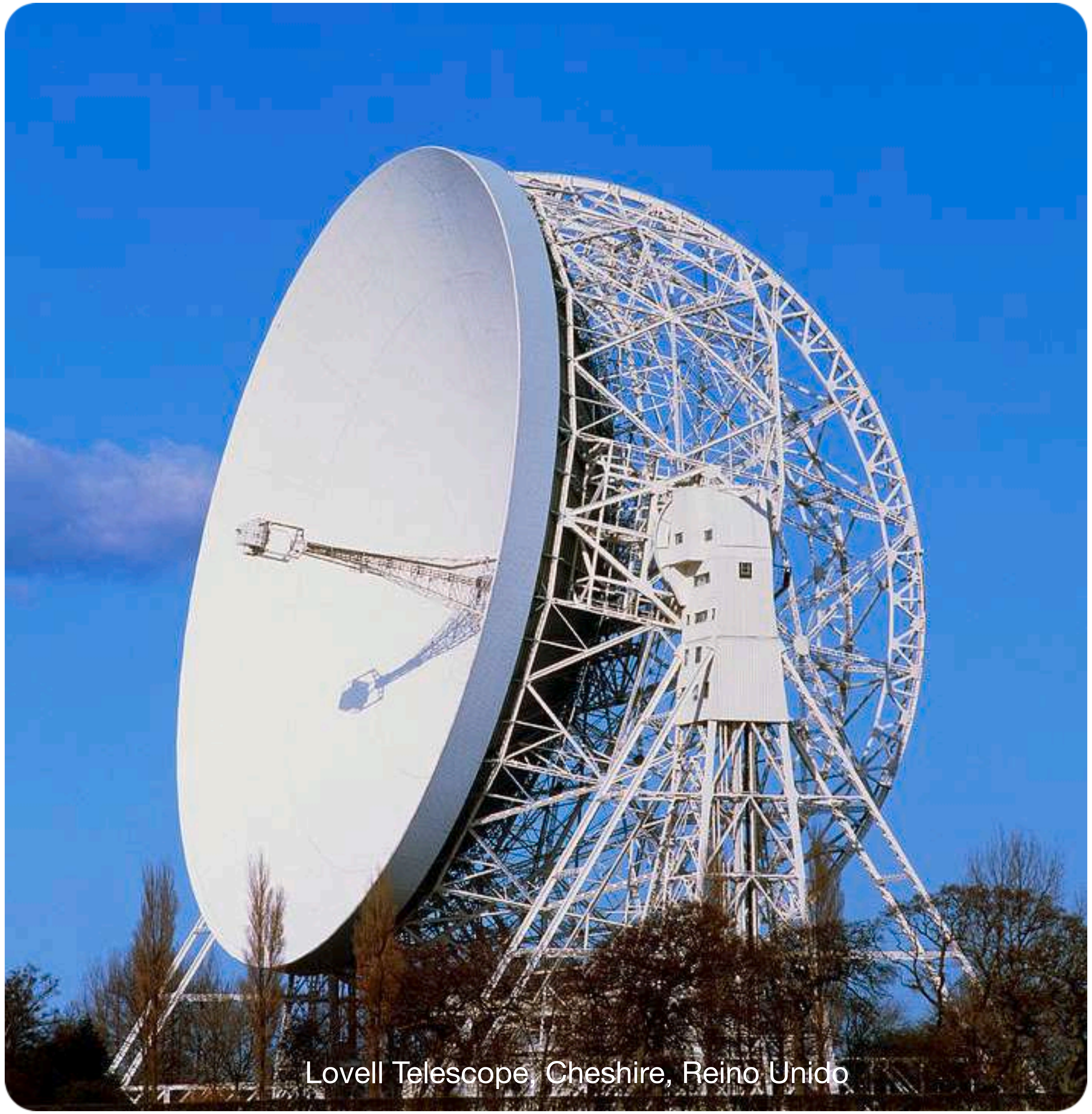
An introduction to Radio Astronomy, Burke, Graham-Smith, Wilkinson (2019).

Radio astronomía

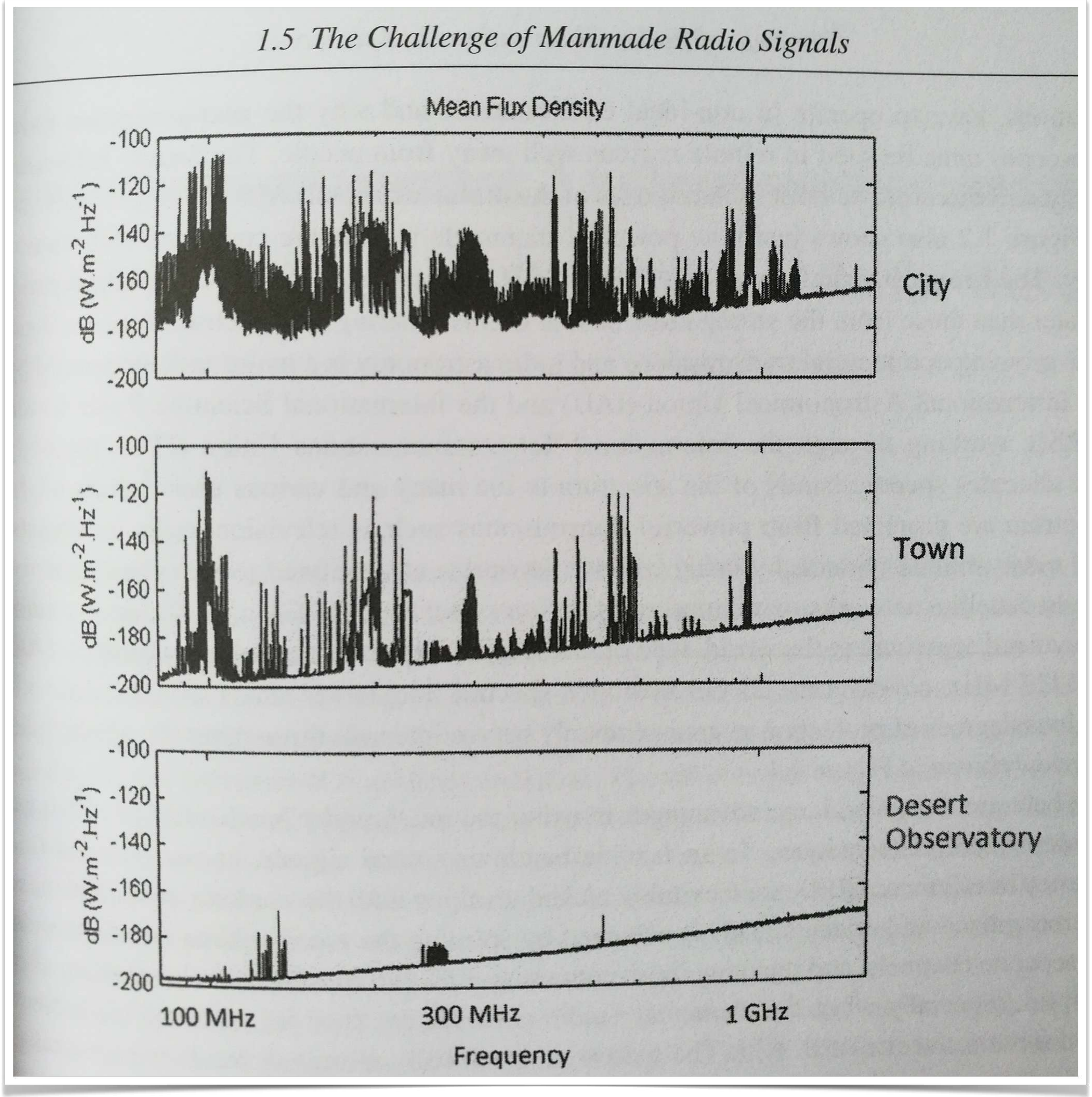
50 MHz - 50 GHz / 6 m - 0.6 cm

— rango aproximado —

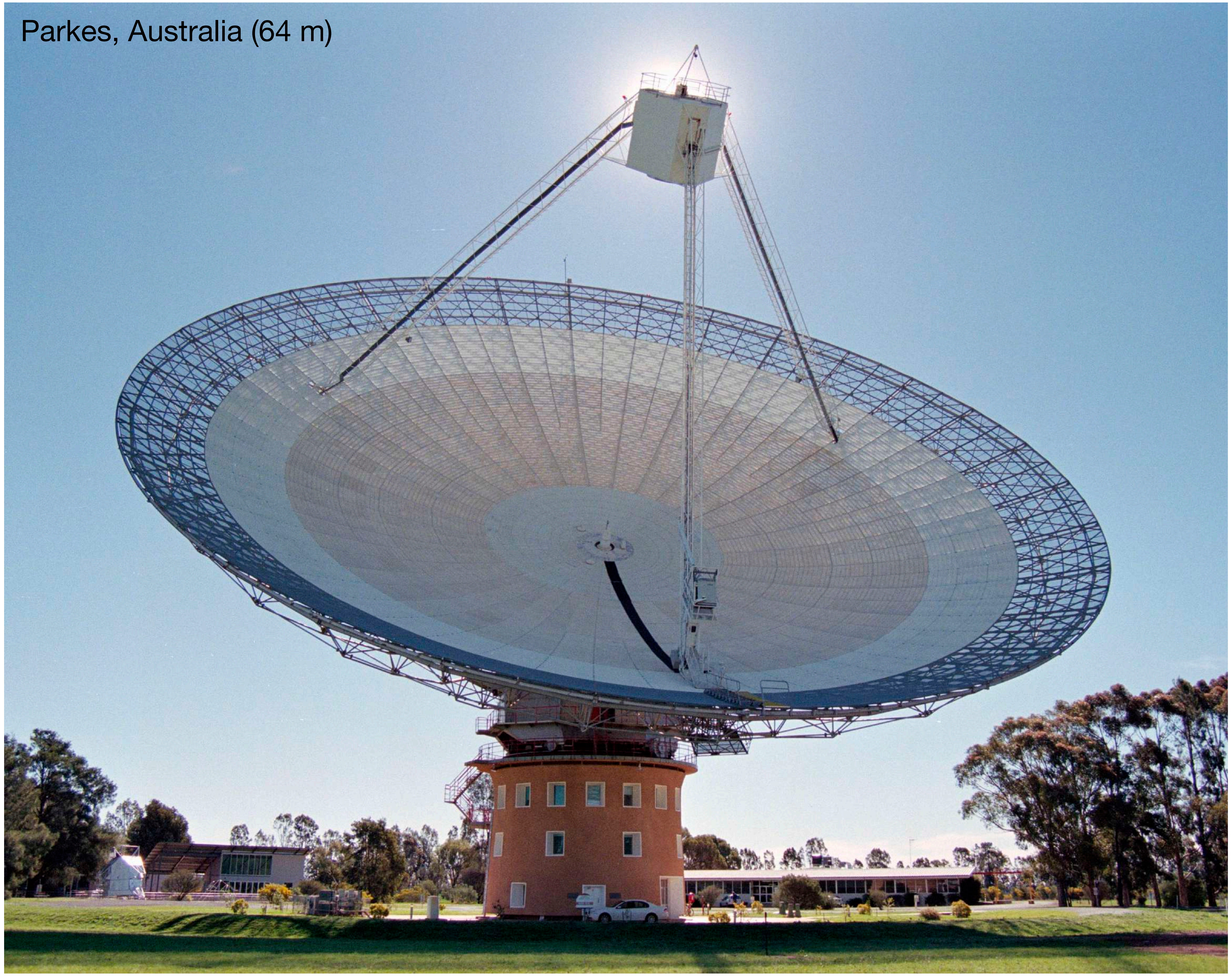
- Uso de antenas
- Las ondas de radio pueden penetrar gas y polvo
- Estudio de
  - Gas ionizado, en atmósferas estelares o en el espacio interestelar.
  - Formación planetaria.
  - Emisión de moléculas en nubes frías.
  - Transiciones comunes del hidrógeno
  - Pulsares
  - Campos magnéticos de gran escala
  - La estructura del universo temprano



El gran problema de la radiointerferencia (RFI)



An introduction to Radio Astronomy, Burke, Graham-Smith, Wilkinson (2019).


Parkes, Australia (64 m)


Arecibo, Puerto Rico (450 m)


Jodrell Bank, Reino Unido (76 m)

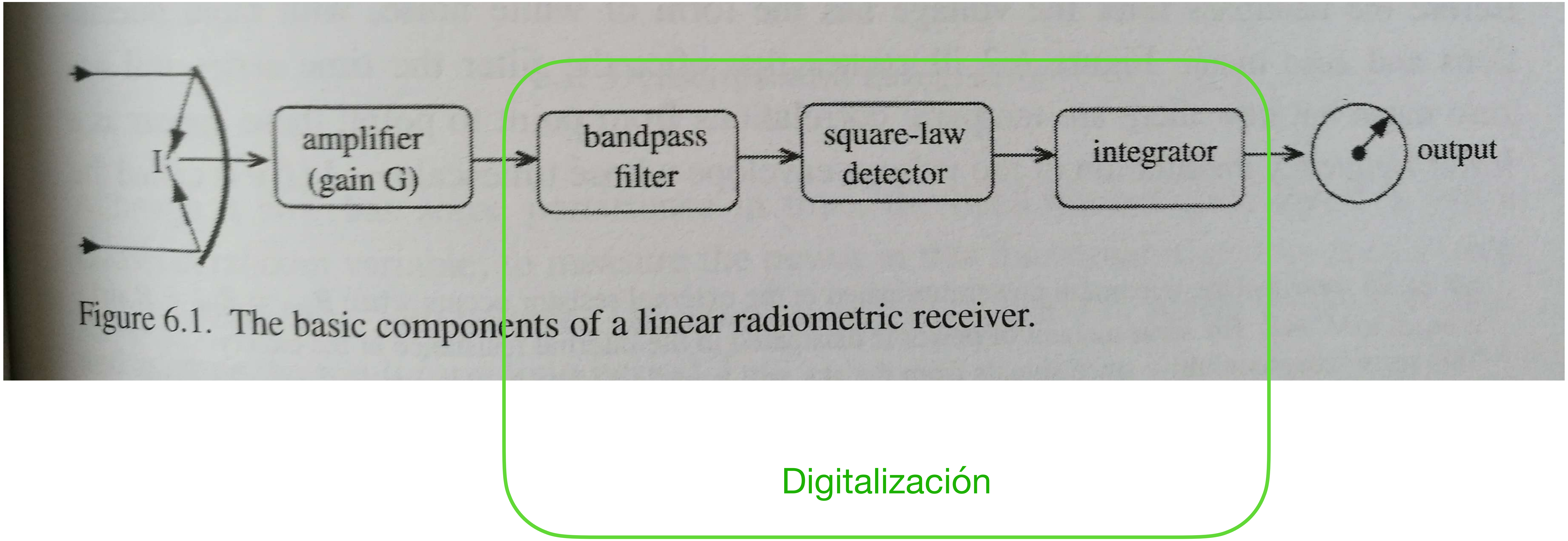
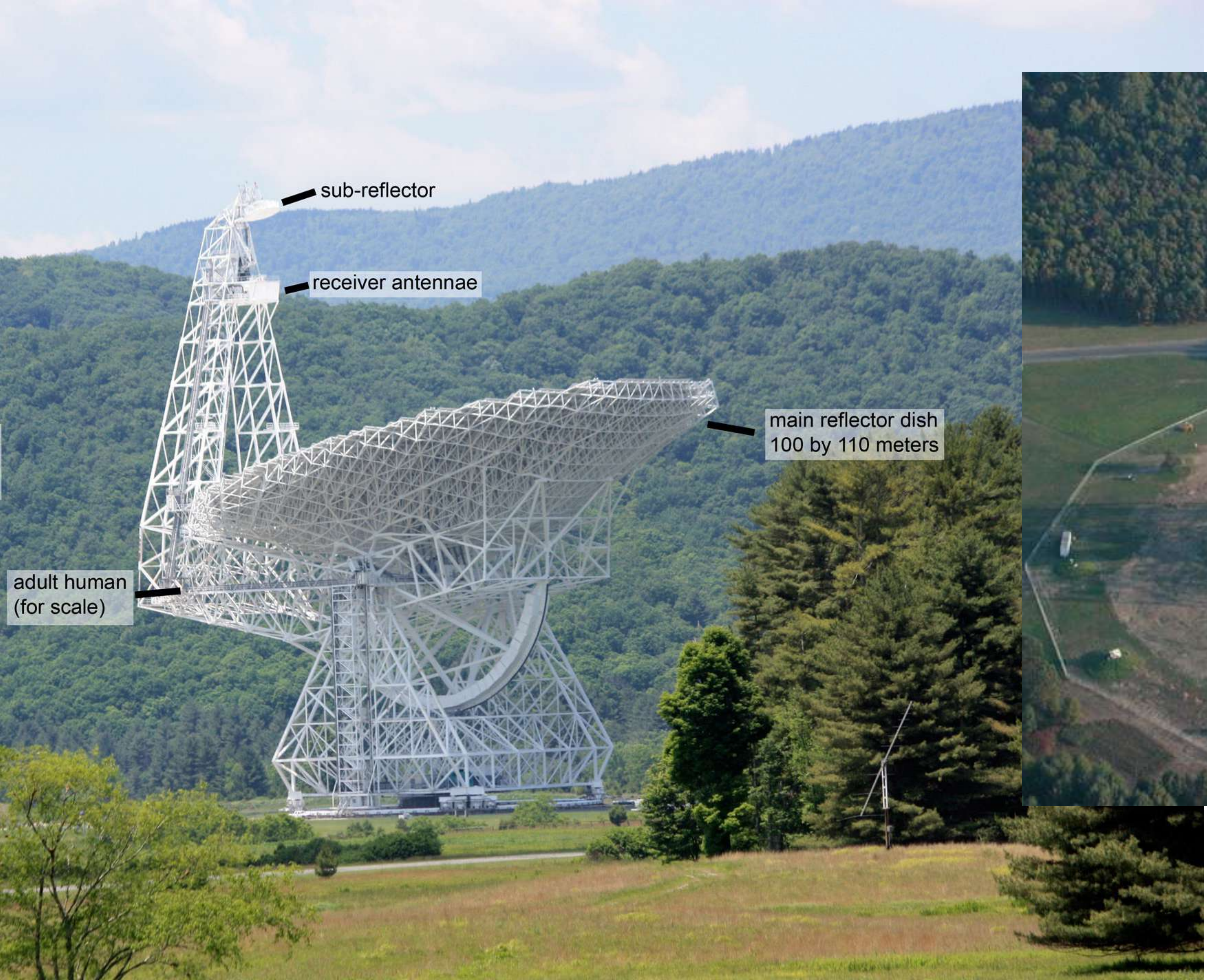


Figure 6.1. The basic components of a linear radiometric receiver.

Nançay, Francia

Green Bank Telescope (GBT), EEUU (100 m)



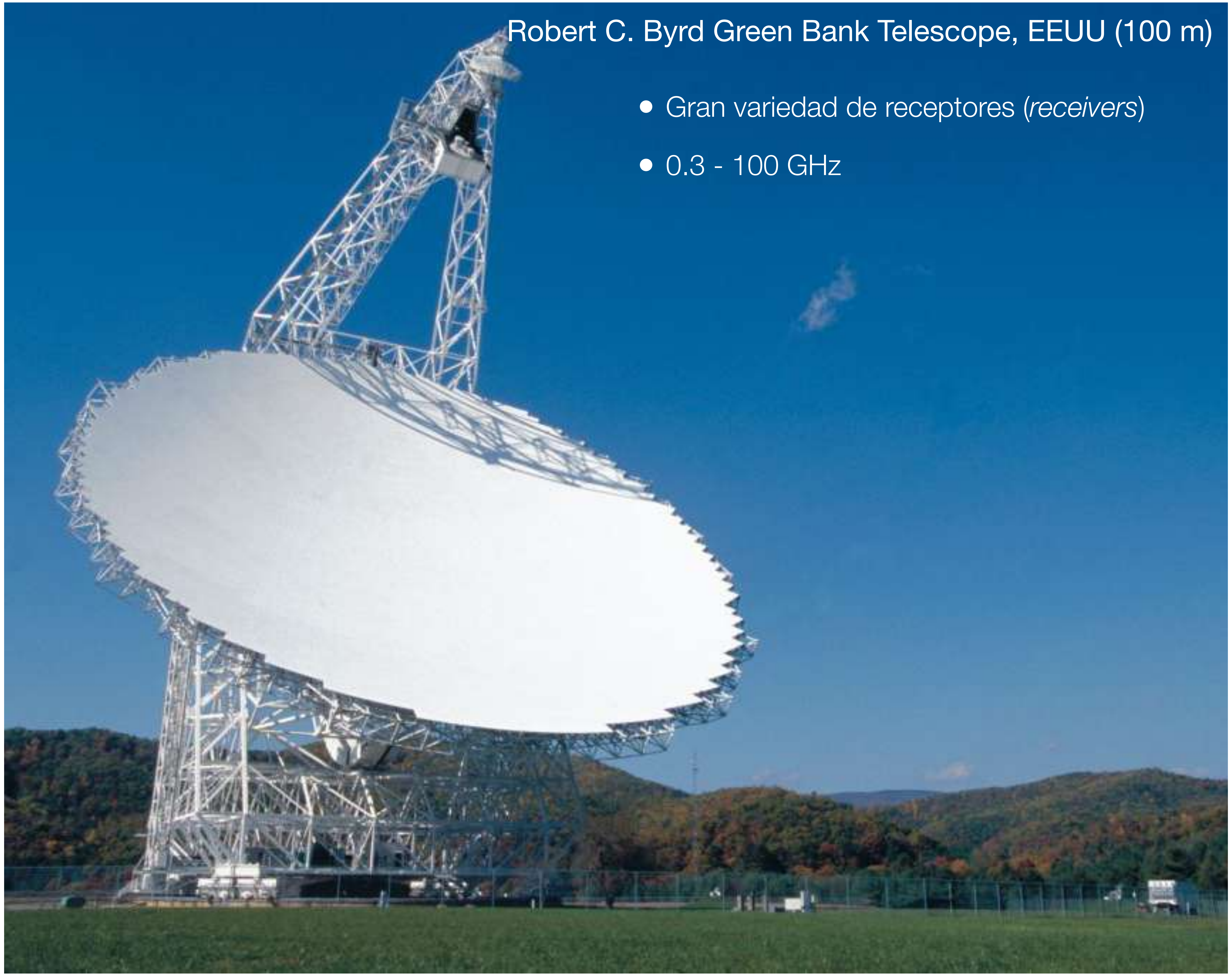

Radio-telescopio Green Bank (1988)


Arecibo (2020)


Arecibo (2020)

Robert C. Byrd Green Bank Telescope, EEUU (100 m)

- Gran variedad de receptores (*receivers*)
- 0.3 - 100 GHz

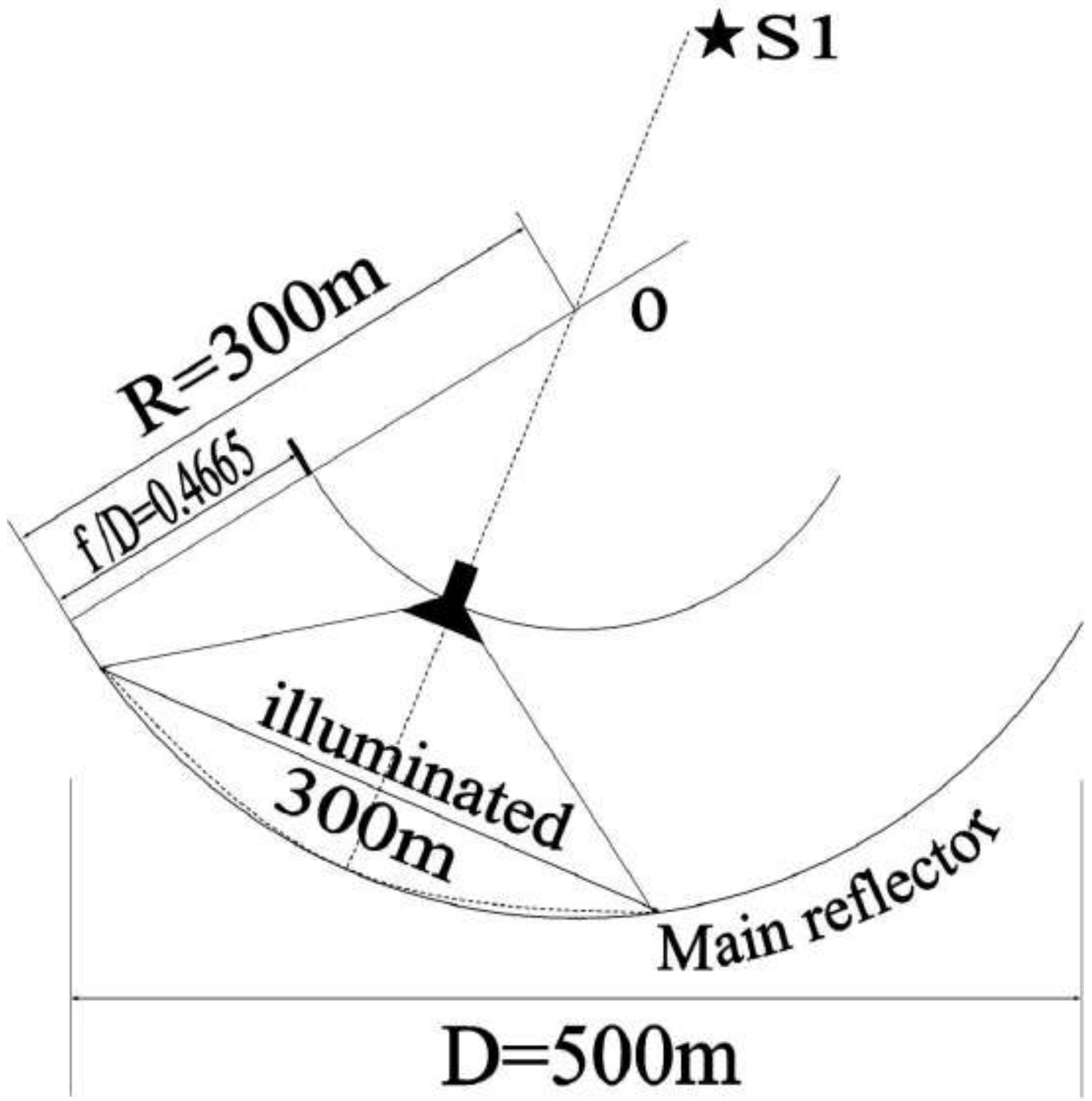


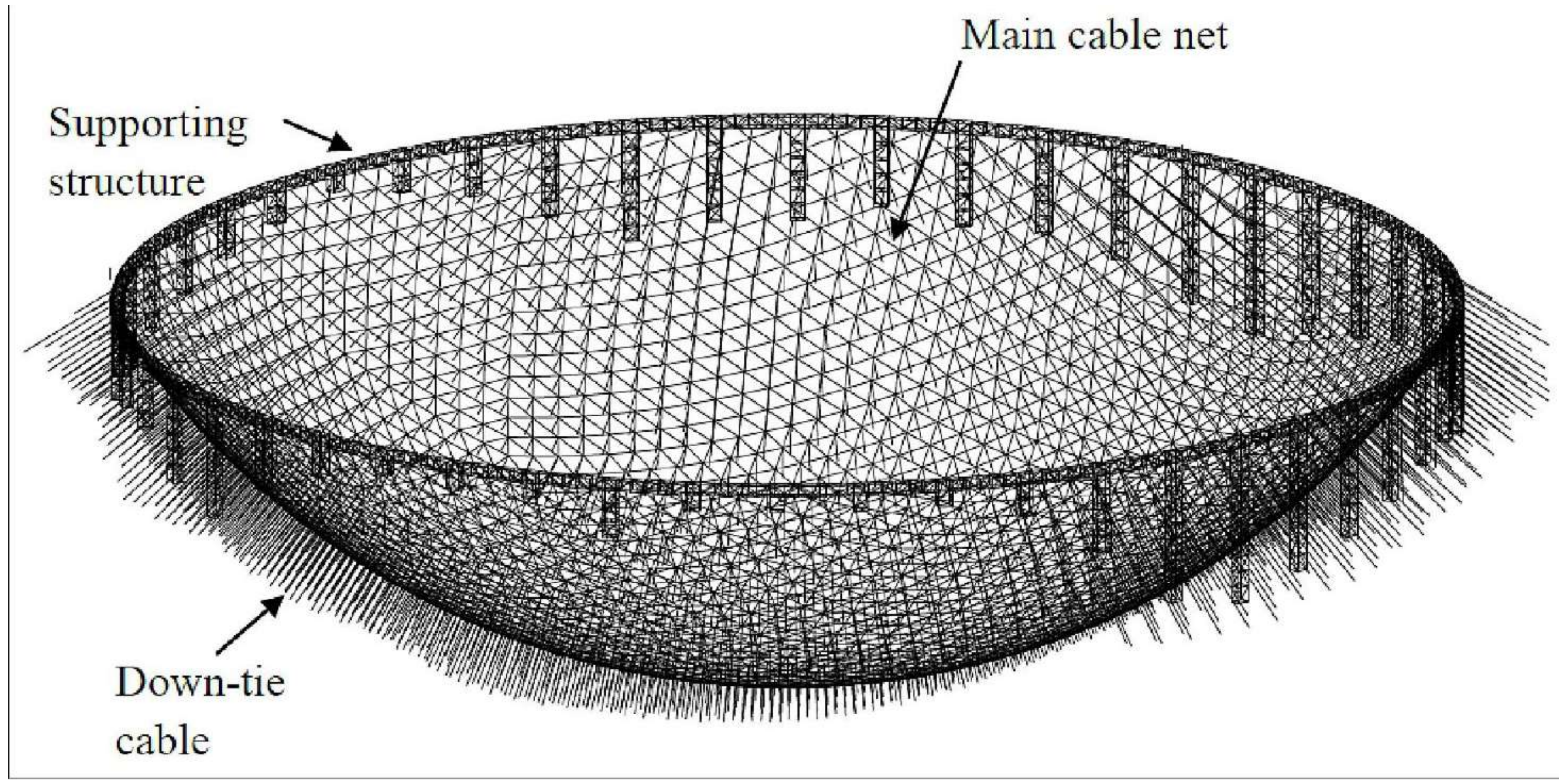
Sardinia Radio Telescope (SRT), Italia (64 m)

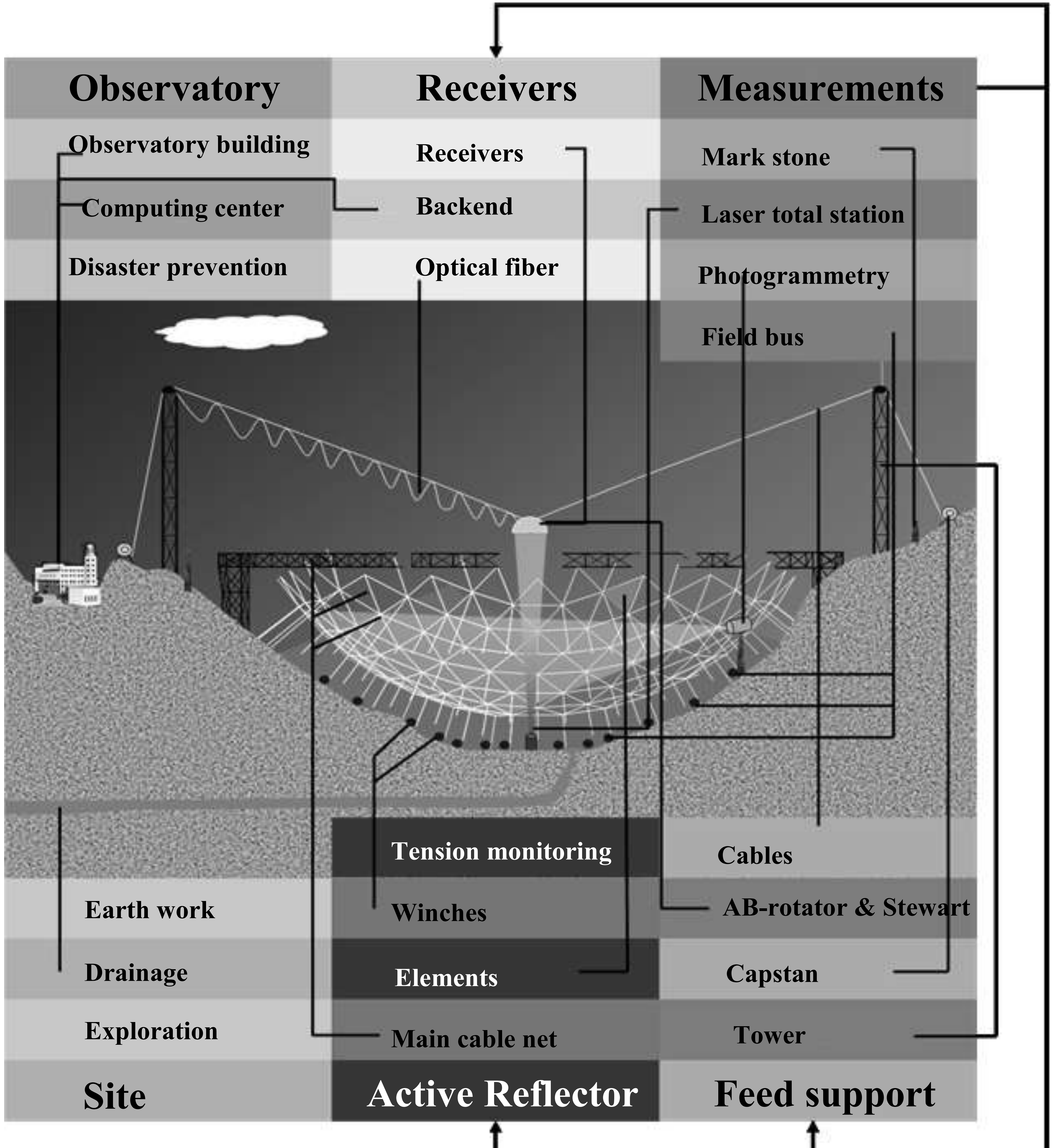
Five-hundred-meter Aperture Spherical radio Telescope (FAST), China (500 m)

- Reflector de 300 m
- 70 MHz - 3 GHz

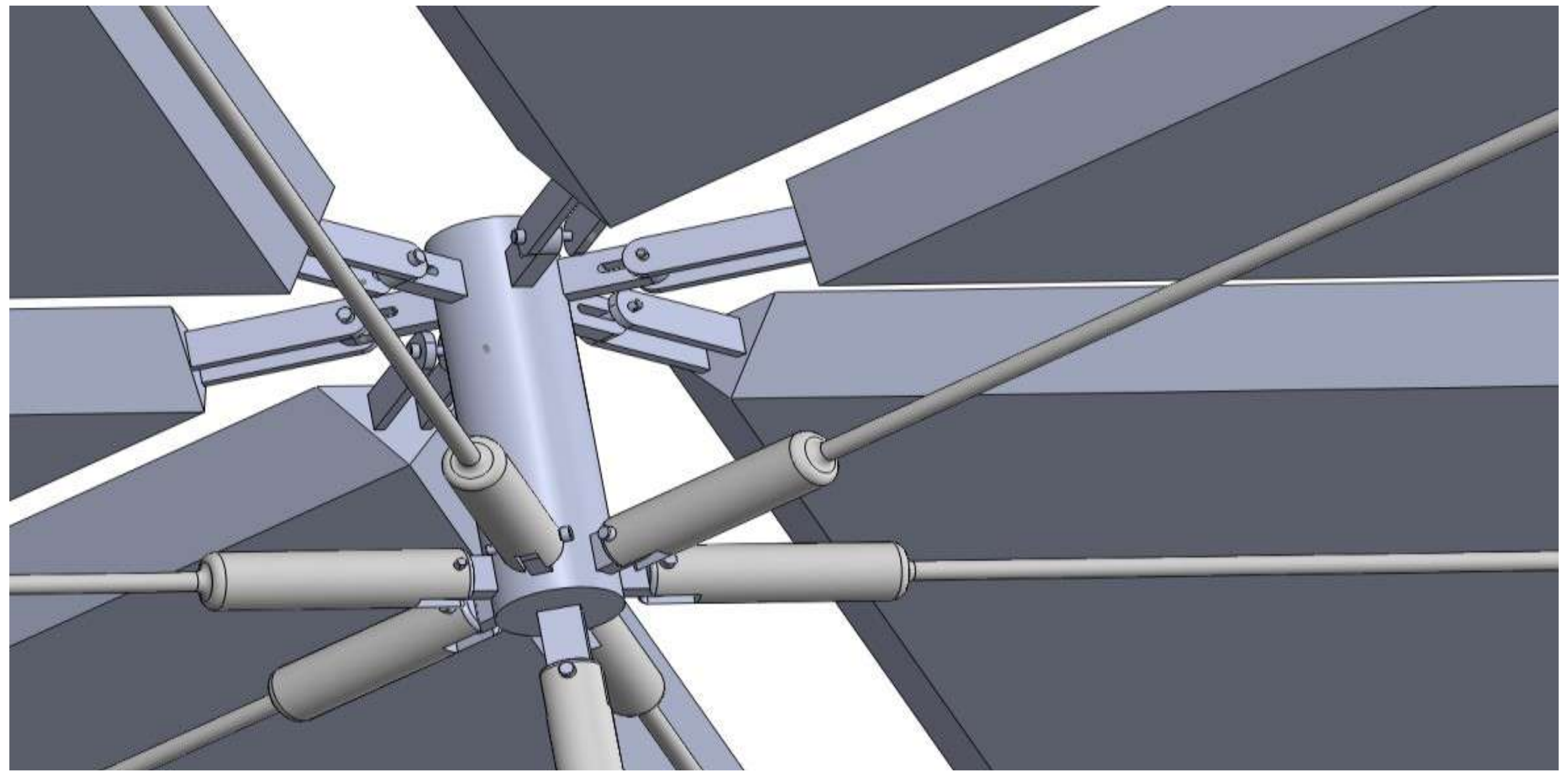
https://www.eoportal.org/other-space-activities/fast#some-background







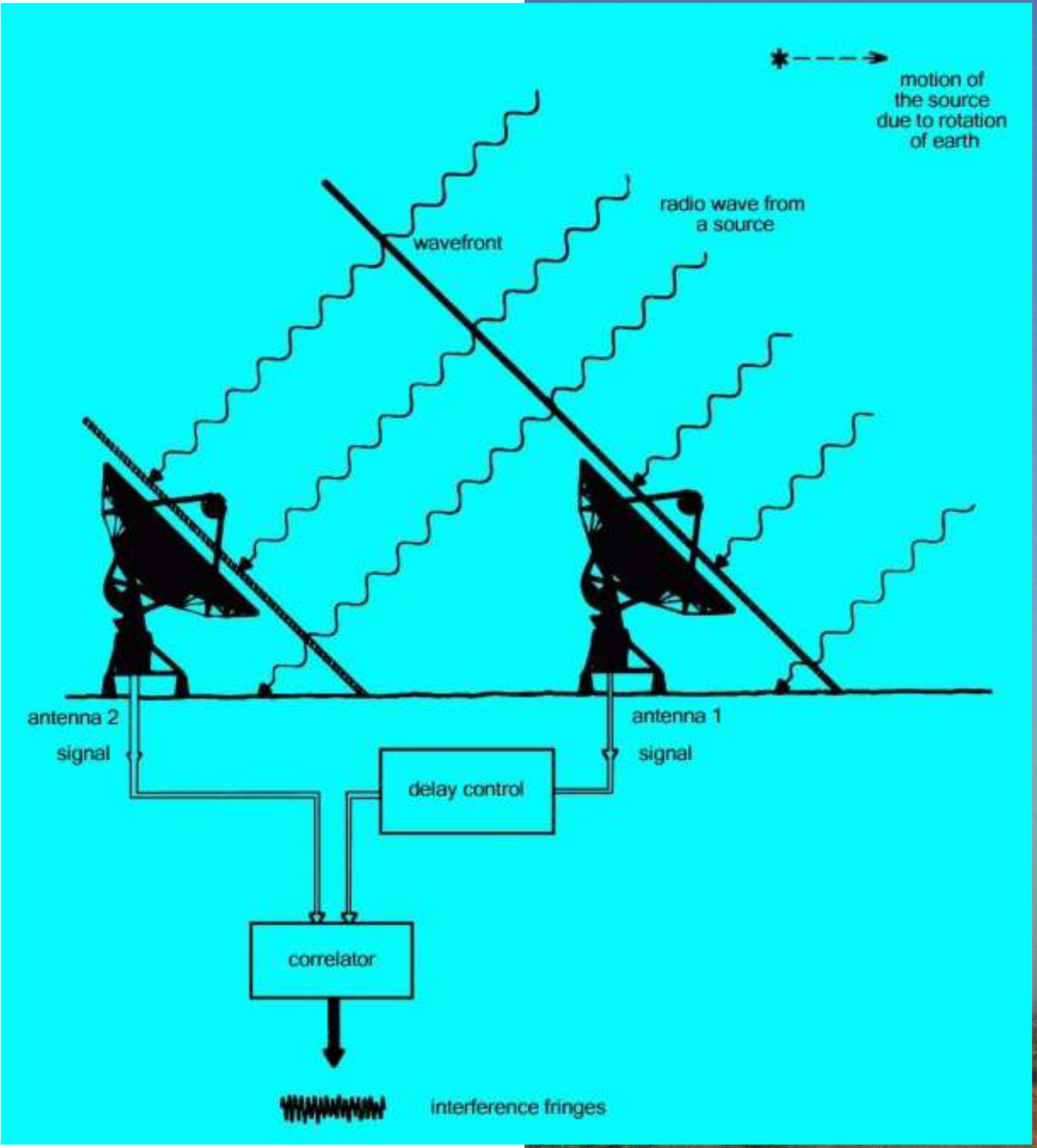
Prototipo de elemento reflectante



Un nodo de la malla de cables
que va por debajo de los paneles reflectantes

Giant Meter-wave Radio Telescope (GMRT), India (45 m cada antena)

- 30 antenas
- 50 - 1500 MHz



Very Large Array
(VLA, Nuevo Mexico, EEUU)

- 27 antenas de 25-m de diámetro
- 74 MHz - 50 GHz

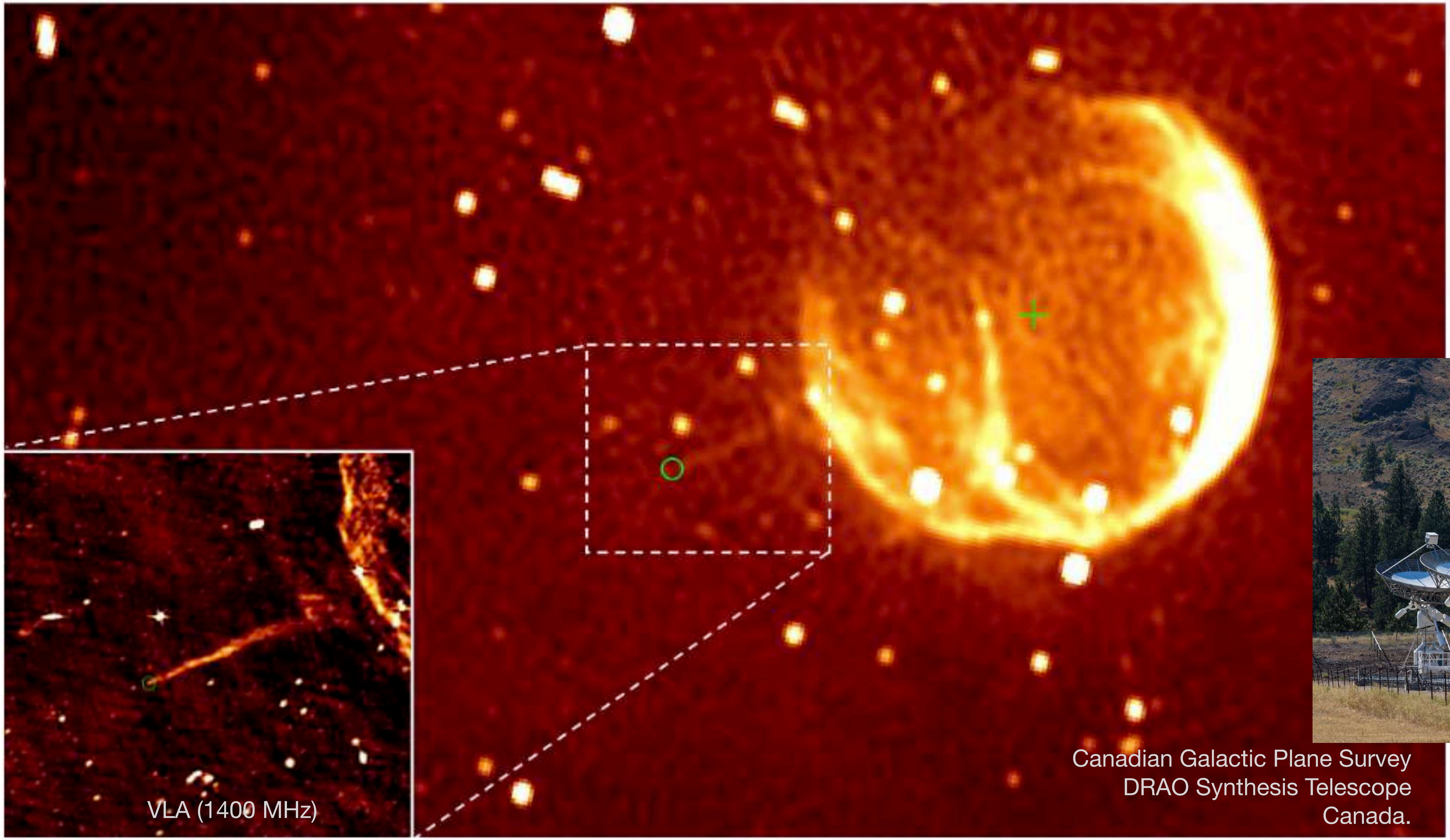


Figure 4. Total intensity image of the SNR CTB 1 from CGPS at 1.42 GHz. False colors start at brightness temperatures of 5.5 K and the maximum is at 8.9 K. The angular resolution and field of view are approximately 1′ and 1°.9 × 1°.1, respectively. A green cross marks the location of the geometric center of the SNR (Landecker et al. 1982), while circles indicate the position of PSR J0002+6216 (Clark et al. 2017). A faint tail of emission is visible from the PSR to the SNR, pointing back toward the geometric center. The inset is our higher angular resolution 20 cm VLA image of the dashed region taken from Figure 3.


Sudafrica / Australia
SKA
Equivalente a una antena de 1 km²

Square Kilometre Array (SKA)

MWA, SKA pathfinder (Australia)

(ilustración)


MeerKAT radio telescope (South Africa)
Fase 1 del SKA-MID
64 antenas

A NEW ERA IN PLANET FORMATION

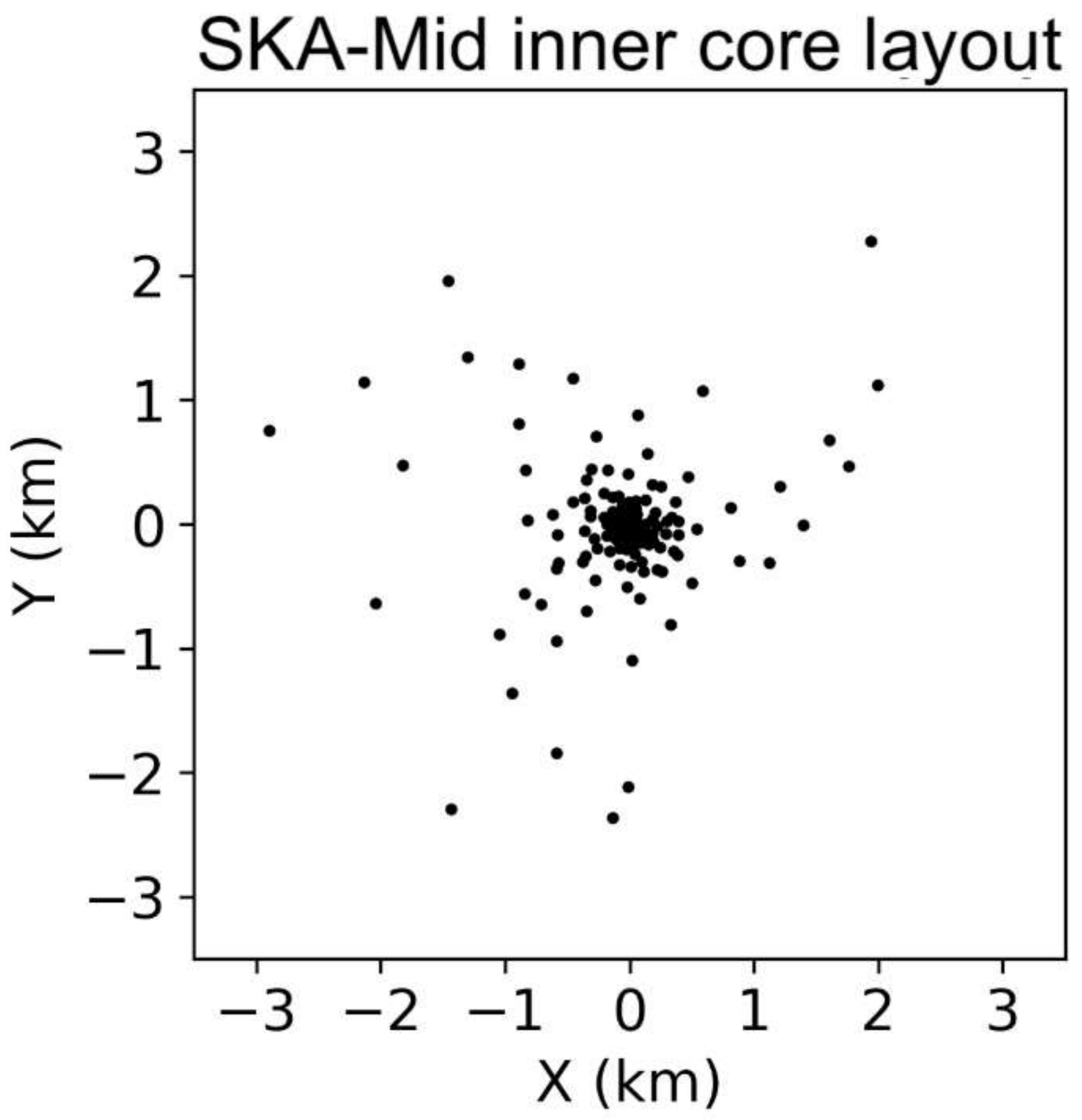
Planet-Forming Disks With SKAO

Antonio Garufi, Sebastián Pérez and the Cradle of Life group

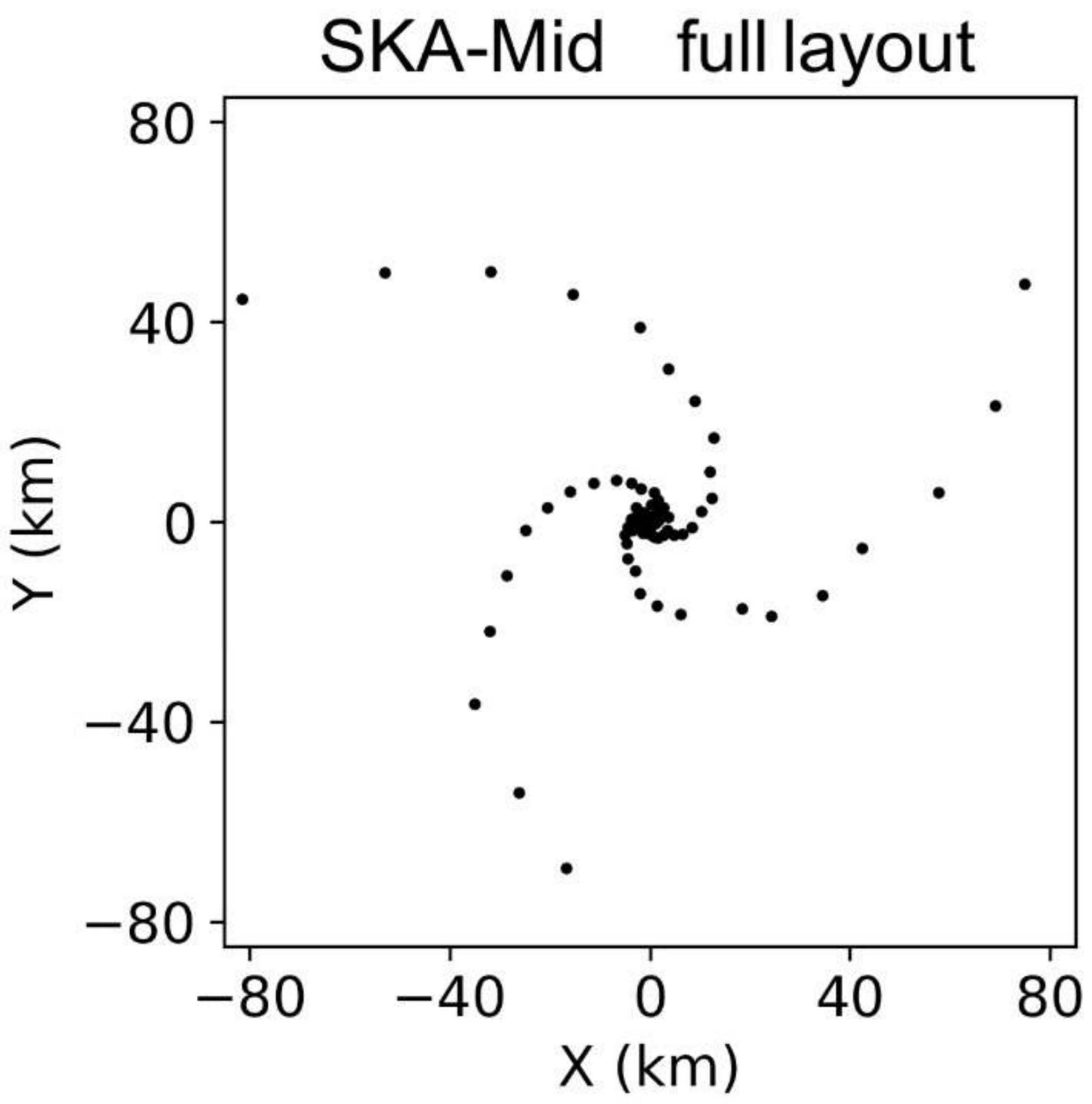
Milestone Event	Mid Dishes	Mid Date	Low Stations	Low Date
AA0.5	4 (4 SKA + 0 MeerKAT)	2026 Q2	4	2025 Q3
AA1	8 (8+0)	2027 Q1	16	2026 Q1
AA2	64 (64+0)	2027 Q4	68	2026 Q4
Science Verification begins 2027				
AA*	144 (80+64)	2028 Q3	307	2028 Q2
Operations Readiness Review		2029 Q1		2028 Q3
End of Staged Delivery		2029 Q1		2029 Q1
Early Operations begin 2029 (shared risk)				
AA4 (Full Design Baseline SKA1)	197 (133+64)	TBD	512	TBD

SKA-Mid

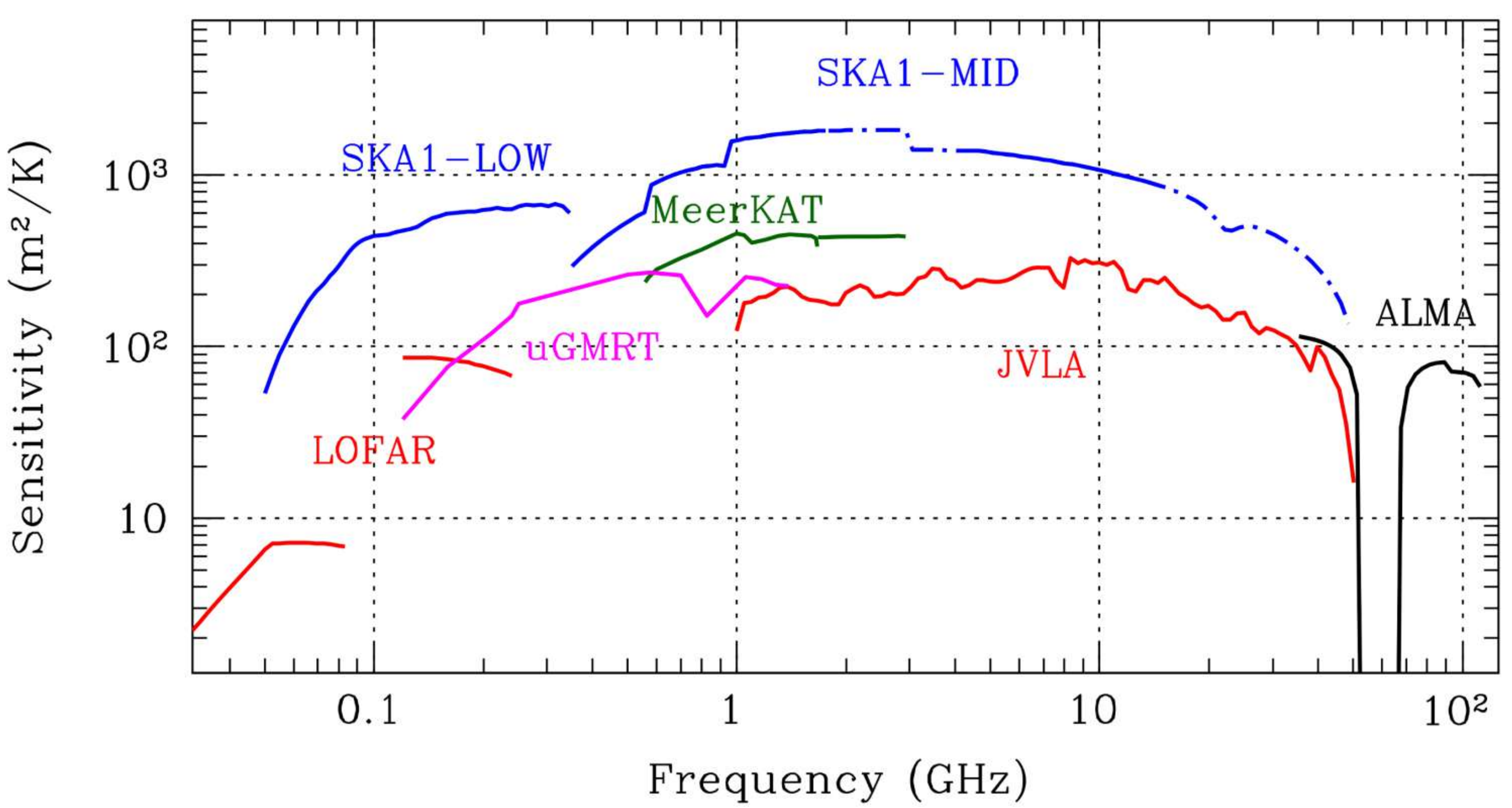
SKA-Mid will consist of 133 15-m SKA dishes and 64 13.5-m Meerkat dishes at the Karoo Radio Astronomy Reserve in the Northern Cape of South Africa. The core will be composed of around 50% of the dishes, randomly distributed within 2 km. The remaining dishes are spaced logarithmically on three spiral arms providing baselines out to 150 km.



Layout of the inner core of SKA-Mid. The figure show the core and the first few dishes in the spiral arms. The dots represent individual dishes.



SKA-Mid full array layout. The black dots represent individual dishes



Frequency Bands

SKA-Low has a single frequency band, while SKA-Mid initially has 4 frequency bands deployed ("first generation", Bands 1, 2, 5a, 5b). For SKA-Mid, Bands 3 and 4 are part of the Design Baseline, but won't be deployed until funding becomes available.

Telescope	Band	Frequency Range (MHz)	Available Bandwidth (MHz)	Notes (MHz)
SKA1-Low	N/A	50 - 350	300	(1)
SKA1-Mid	1	350 - 1050	700	(1)
	2	950 - 1760	810	(1)
	3	1650 - 3050	1400	(2)
	4	2800 - 5180	2380	(2)
	5a	4600 - 8500	3900	(1)
	5b	8300 - 15400	2 x 2500	(1)

El centro galáctico. Imagen inaugural del radio telescopio MeerKAT.

El centro galáctico (MeerKAT)

Solo con observaciones en radio es posible ver el centro galáctico.
En el óptica el gas y el polvo absorben y bloquean la mayor parte de la emisión.

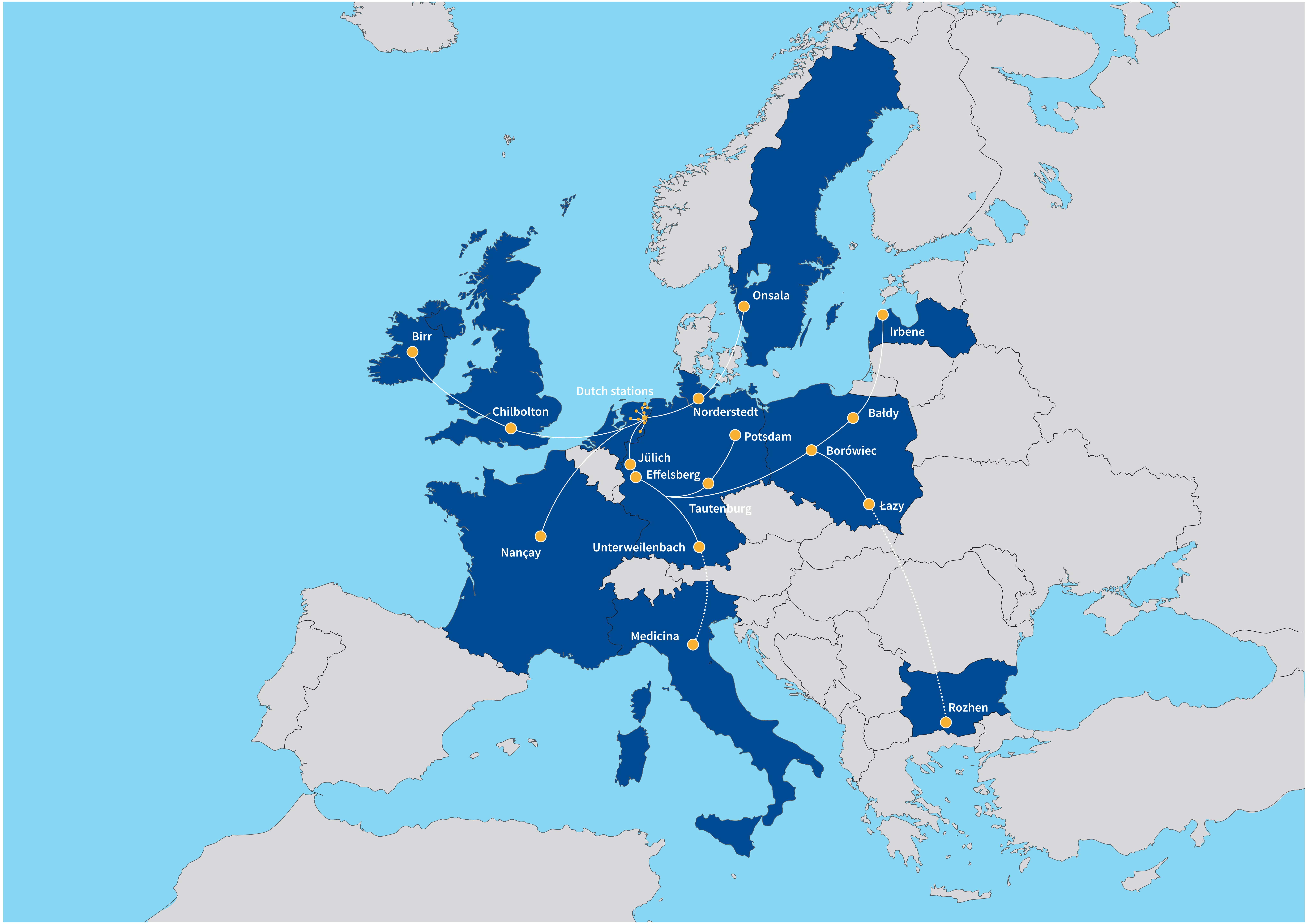
SARAO, Heywood et al. (2022) / J. C. Muñoz-Mateos

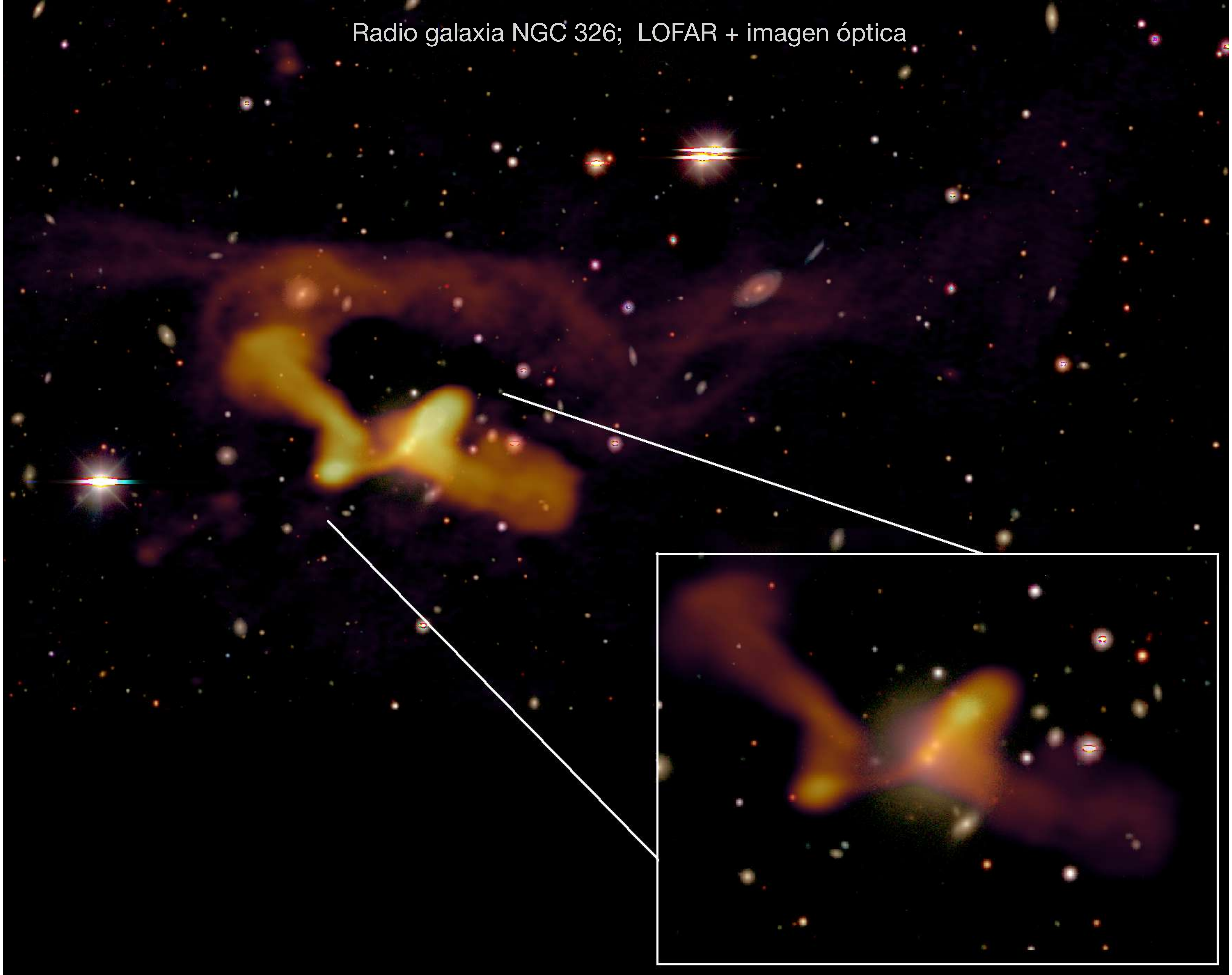
Low Frequency Array (LOFAR)

Países bajos + otros 7 países en Europa

~1 km^2 de área colectora

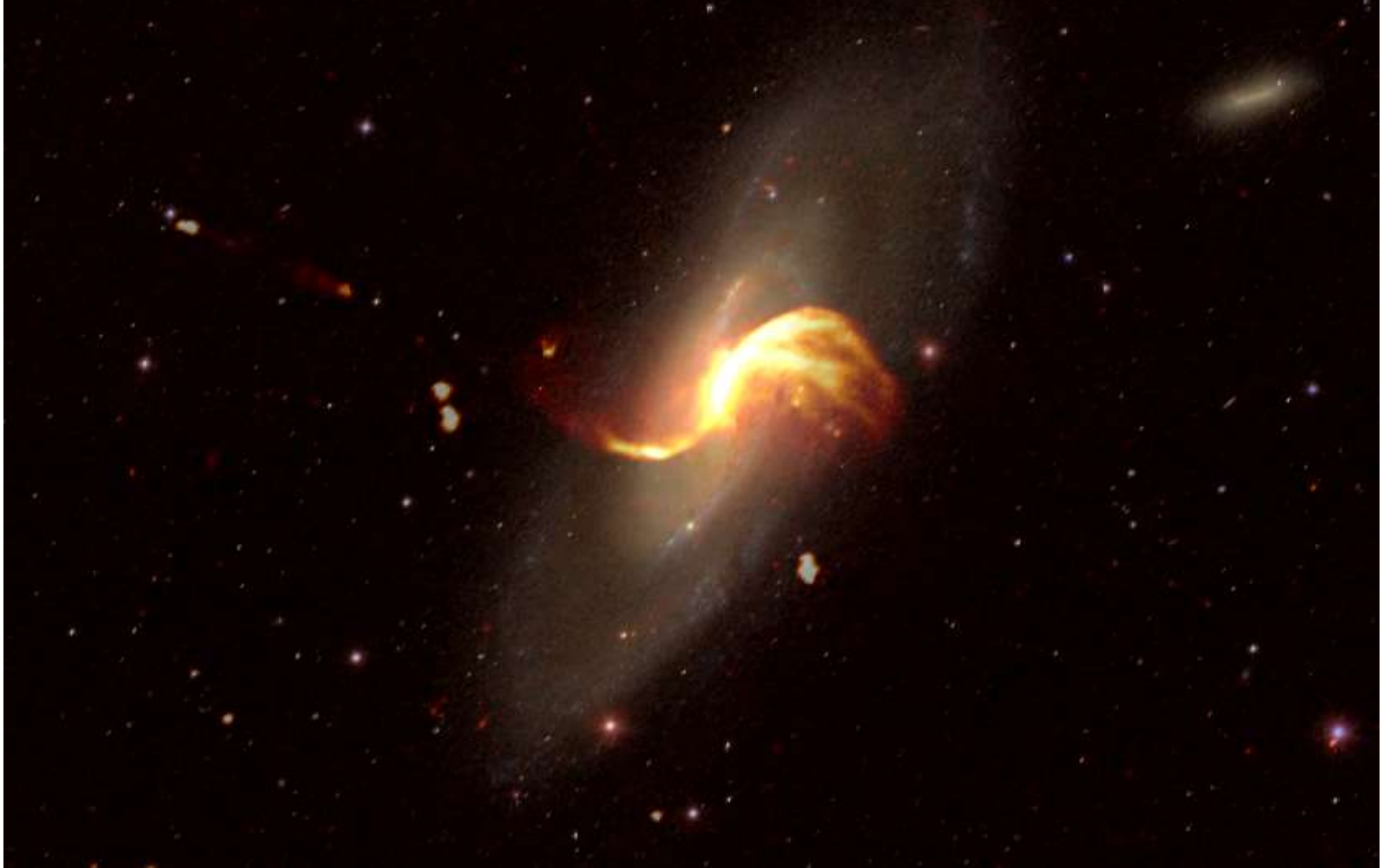
10 MHz - 240 MHz


Onsala
Irbene
Birr
Dutch stations
Norderstedt
Chilbolton
Bałdy
Potsdam
Borówiec
Jülich
Effelsberg
Łazy
Tautenburg
Nançay
Unterweilenbach
Medicina
Rozhen


Radio galaxia NGC 326; LOFAR + imagen óptica

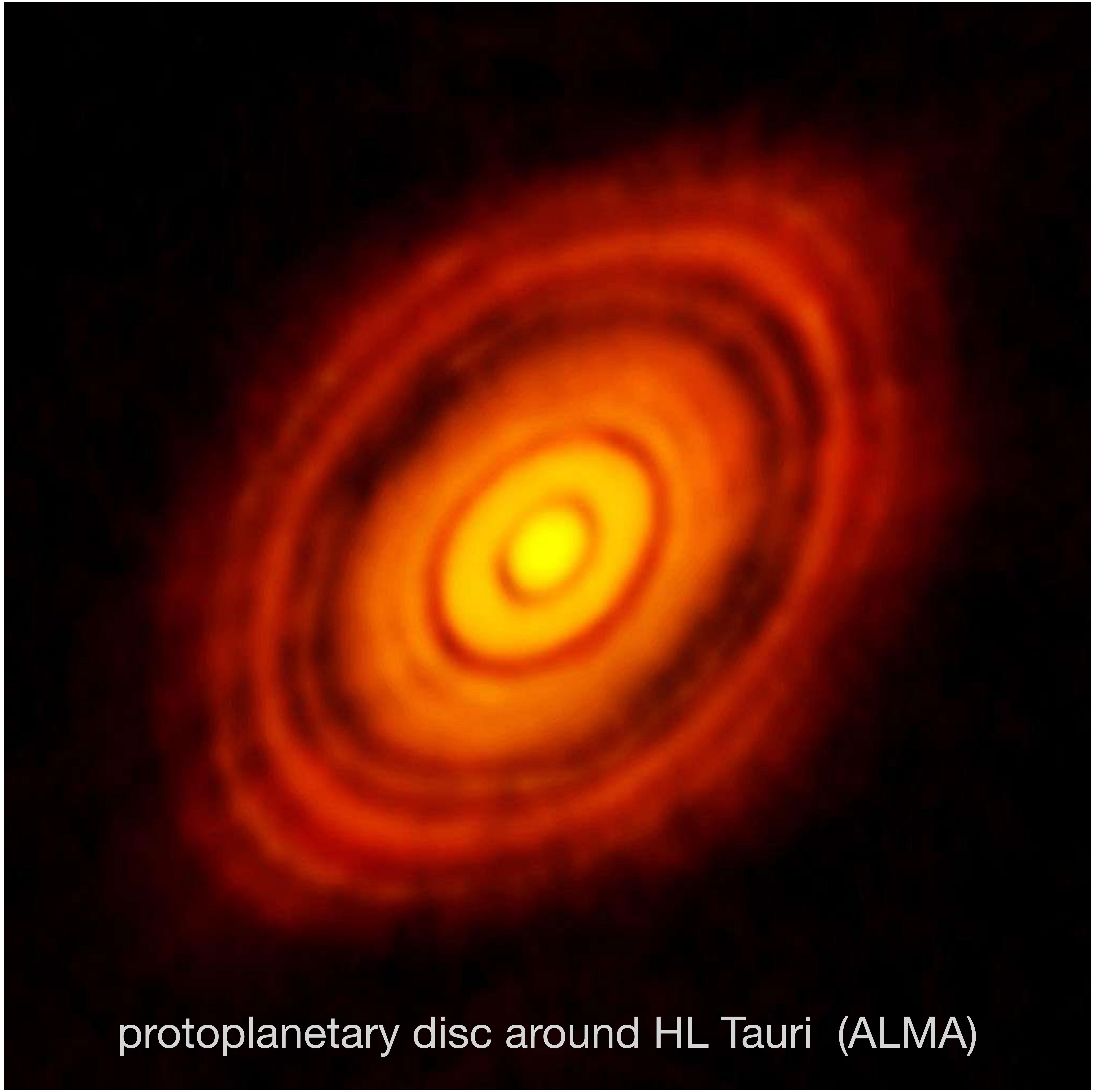
Radio galaxia M106; LOFAR

The bright radio structures in the centre of the galaxy are not actually true spiral arms, but are believed to be the result of activity from the galaxy's central supermassive black hole.
Credit: Cyril Tasse and the LOFAR surveys team.



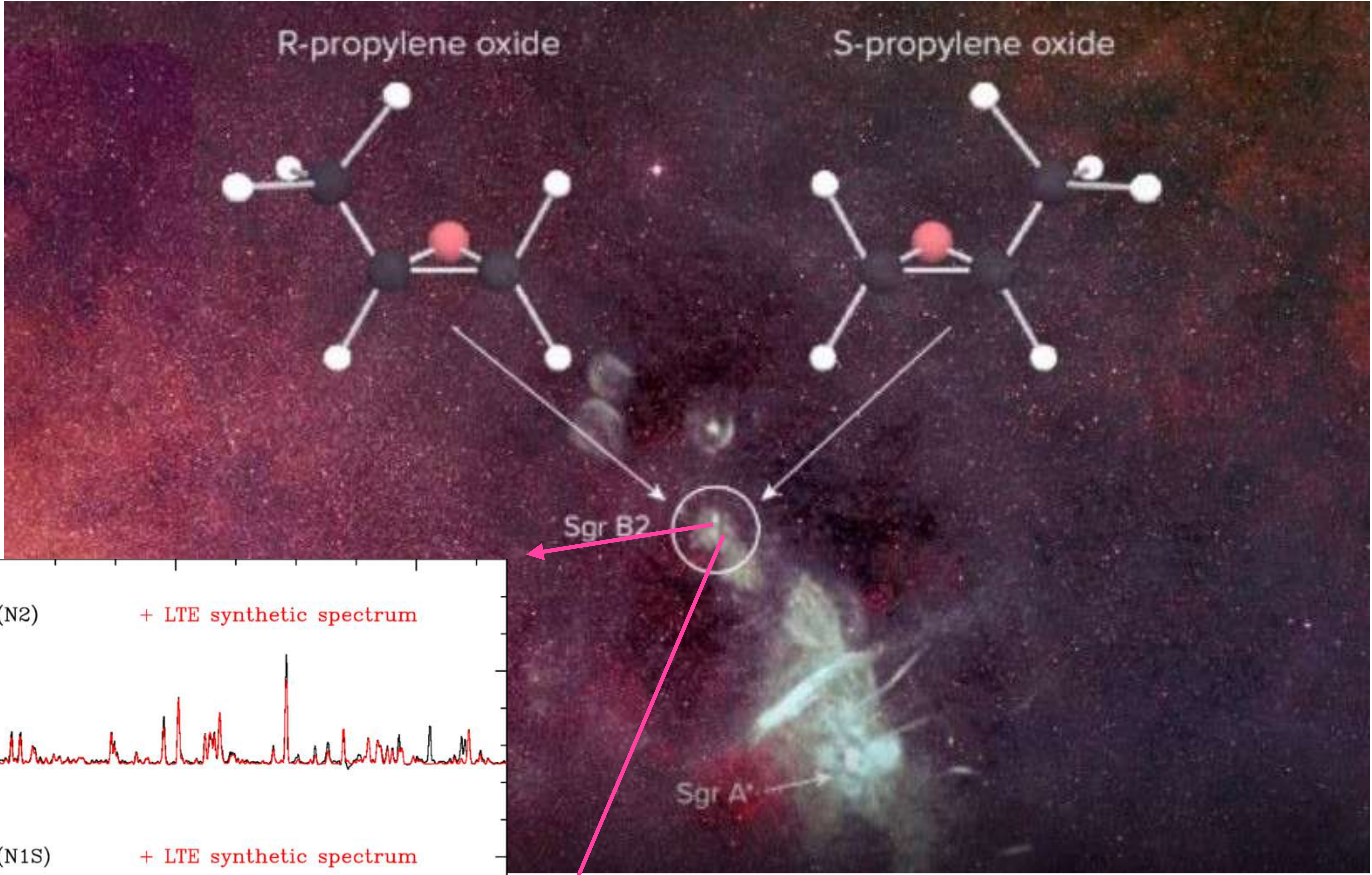
Atacama Large Milimetre Array (ALMA); Chile.
66 antenas; 31 - 1000 GHz (milimétrico)

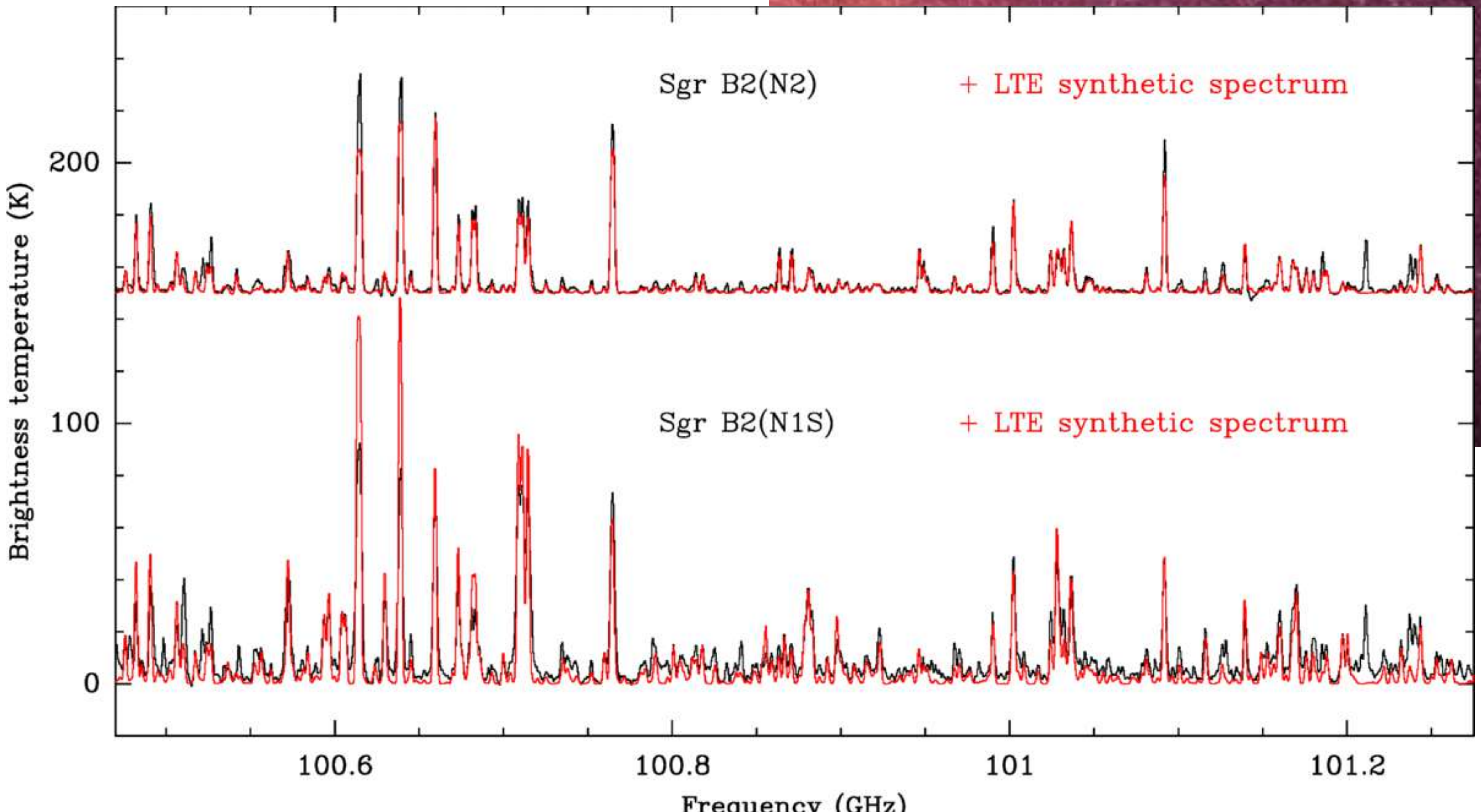
Distancia máxima entre un par de antenas: 16 km.



protoplanetary disc around HL Tauri (ALMA)

Espectro de dos nubes moleculares en región de formación estelar (ALMA)





La Radio astronomía nos permite estudiar:

The cosmic microwave background (CMB) The early Universe is observable as a black body whose $\sim 2.7\,\mathrm{K}$ temperature has maximum emissivity at millimetre wavelengths.

High energy processes in galaxies and quasars These emit intense radio waves from charged particles, usually electrons, moving at relativistic velocities.

Cosmic magnetic fields These are revealed in radio sources and in interstellar space by the polarization of radio waves.

Astrochemistry Molecular constituents of clouds in the Milky Way and in distant galaxies are observable by radio spectroscopy.

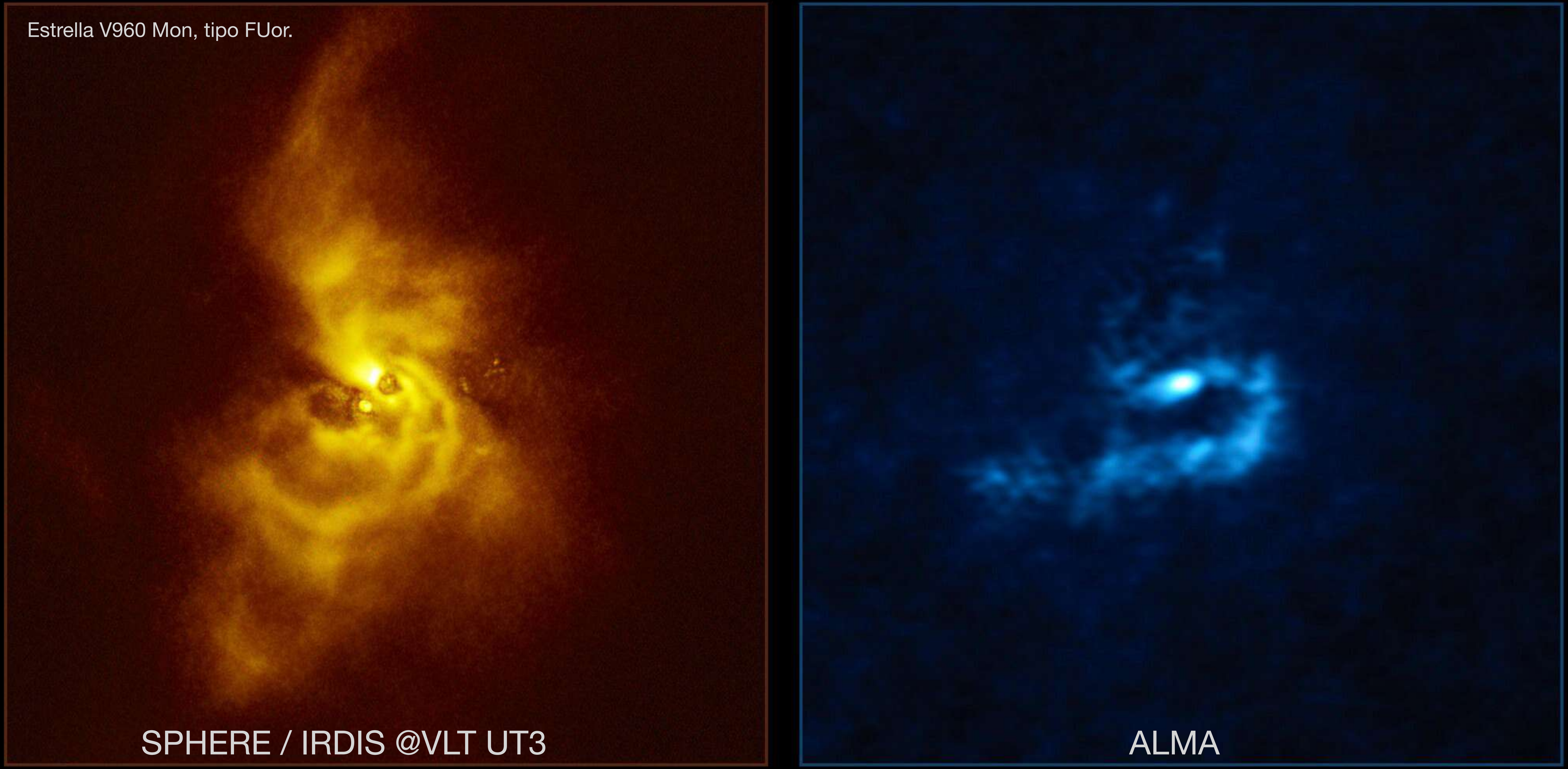
Star and planet formation Condensations of atoms and molecules are mapped by millimetre-wave synthesis arrays.

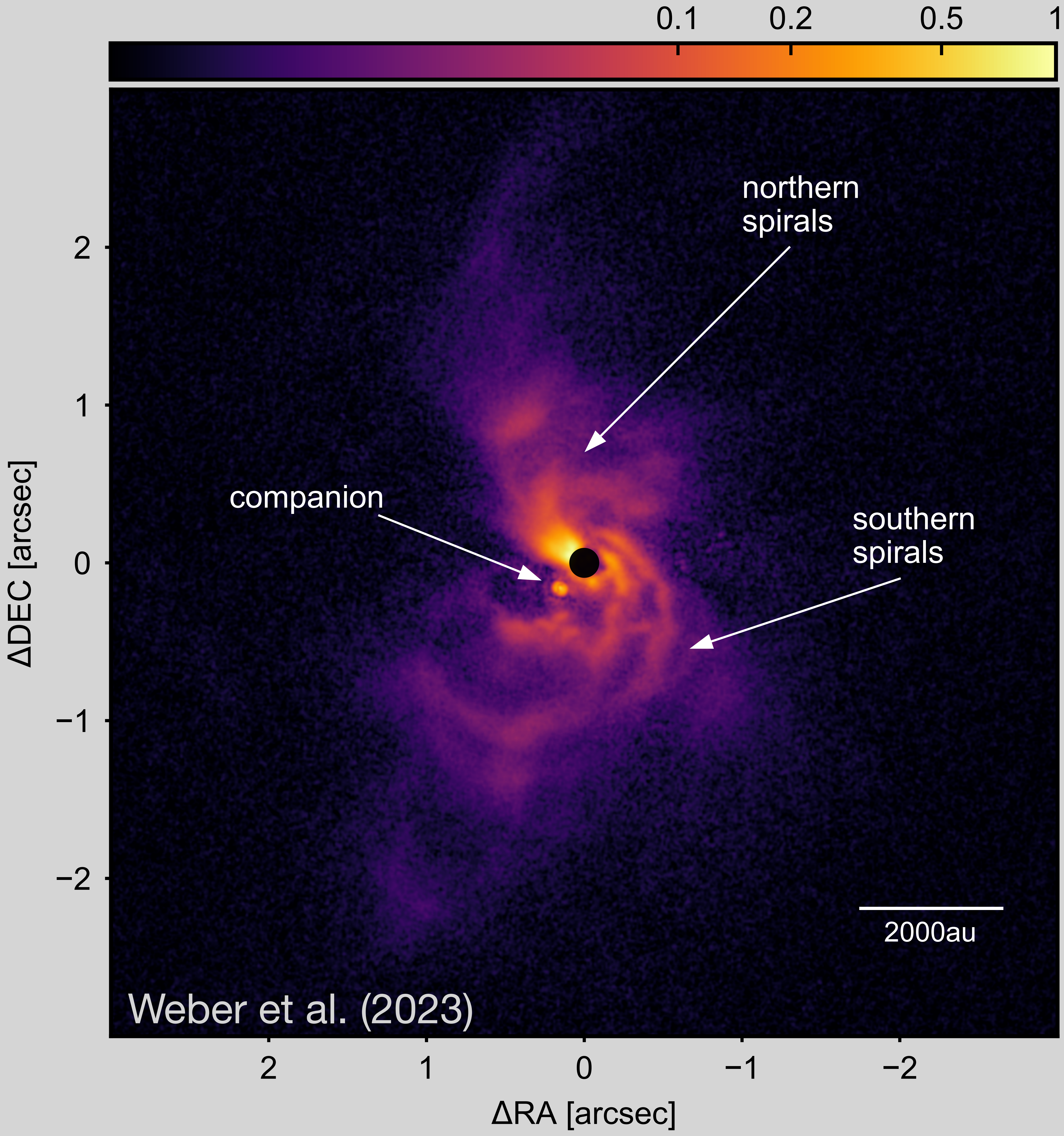
Kinetics of galaxies Radio spectroscopy, especially of the 21 cm hydrogen line, reveals the dynamic structure of galaxies.

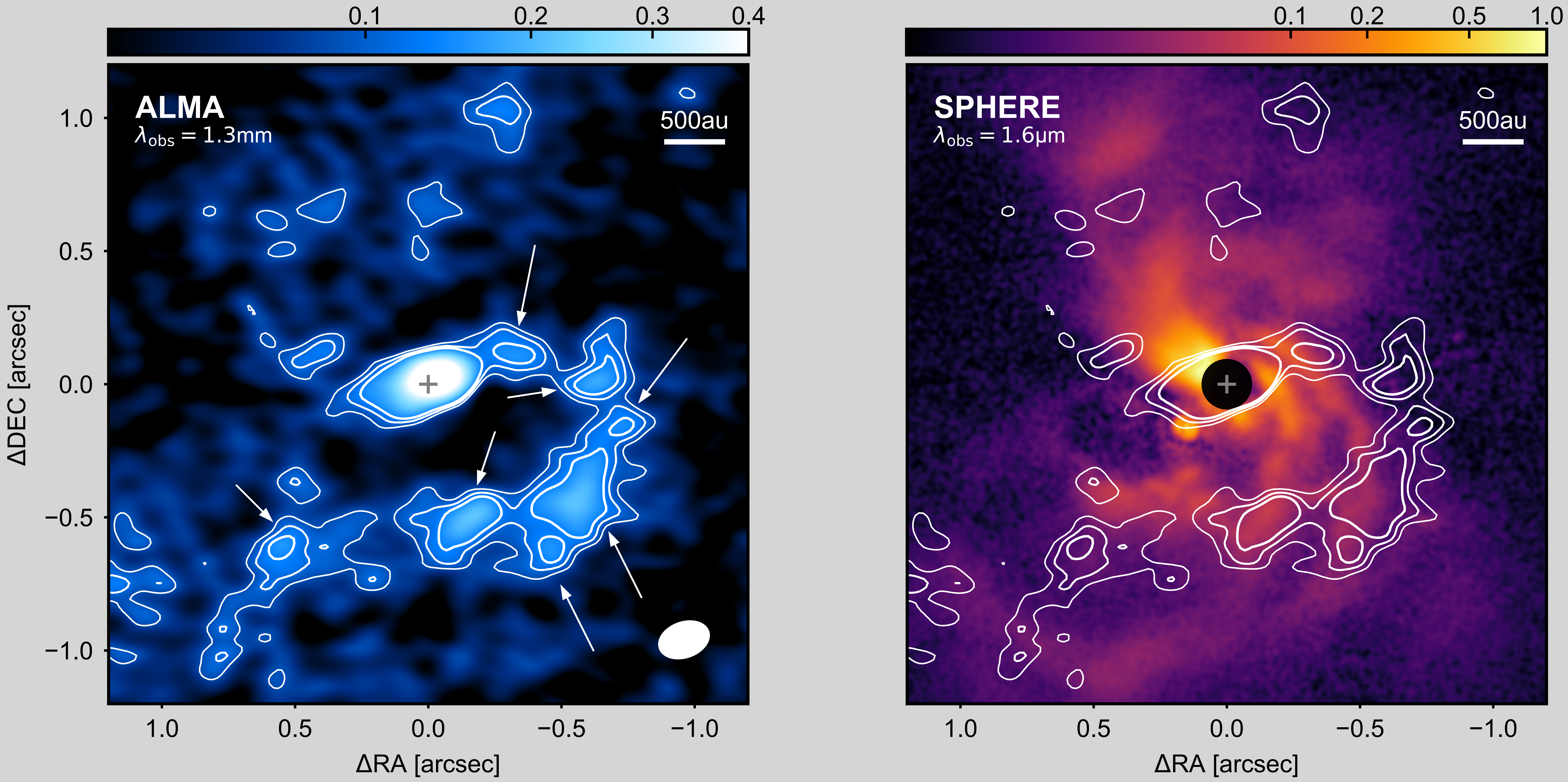
Neutron stars The timing and structure of pulses from pulsars opens a wide field of research, from condensed matter in neutron star interiors to the gravitational interactions of binary star systems.

General relativity Pulsars, the most accurate clocks in the Universe, are used to measure the geometry of space–time.

An introduction to Radio Astronomy, Burke, Graham-Smith, Wilkinson (2019).

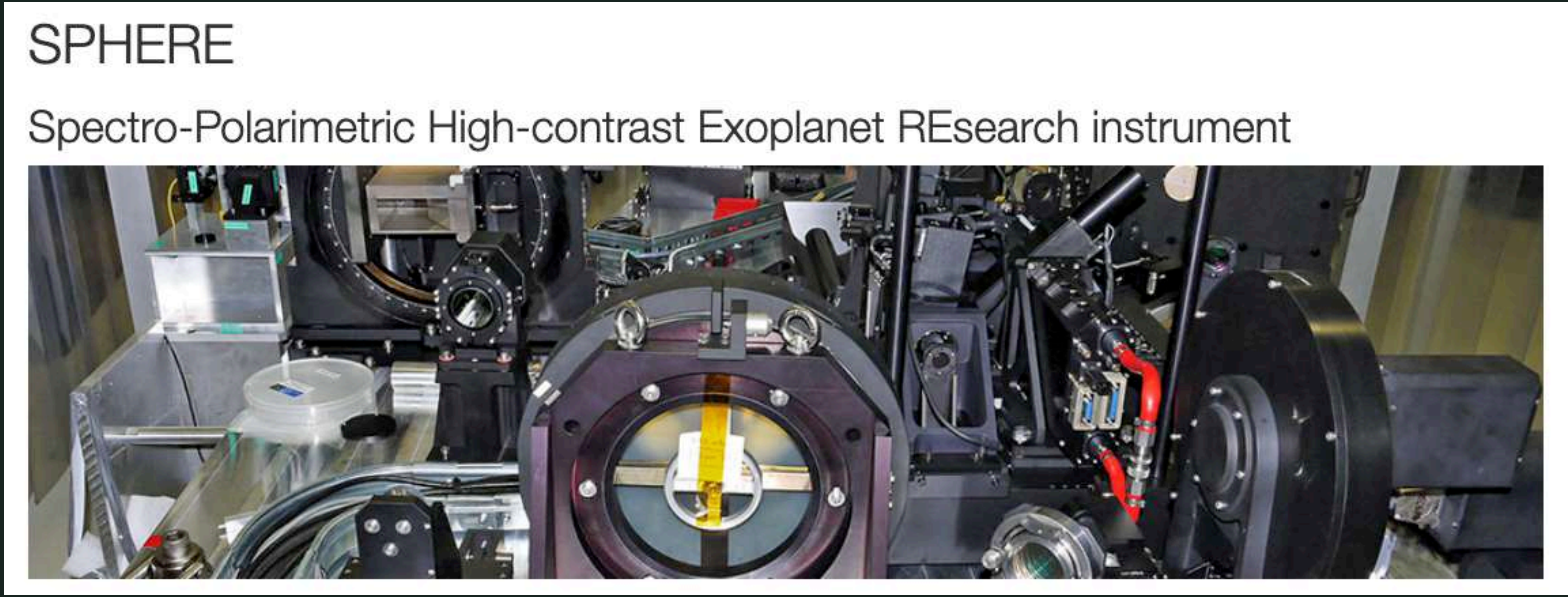

Estrella V960 Mon, tipo FUor.
SPHERE / IRDIS @VLT UT3
ALMA


0.1
0.2
0.5
1
northern
spirals
companion
southern
spirals
2000au
Weber et al. (2023)
2
1
0
−1
−2
ΔDEC [arcsec]
ΔRA [arcsec]



Weber et al. (2023)

Imagen fue tomada como parte de una campaña
que observó varias estrellas de este tipo usando el instrumento SPHERE, en el VLT UT 3

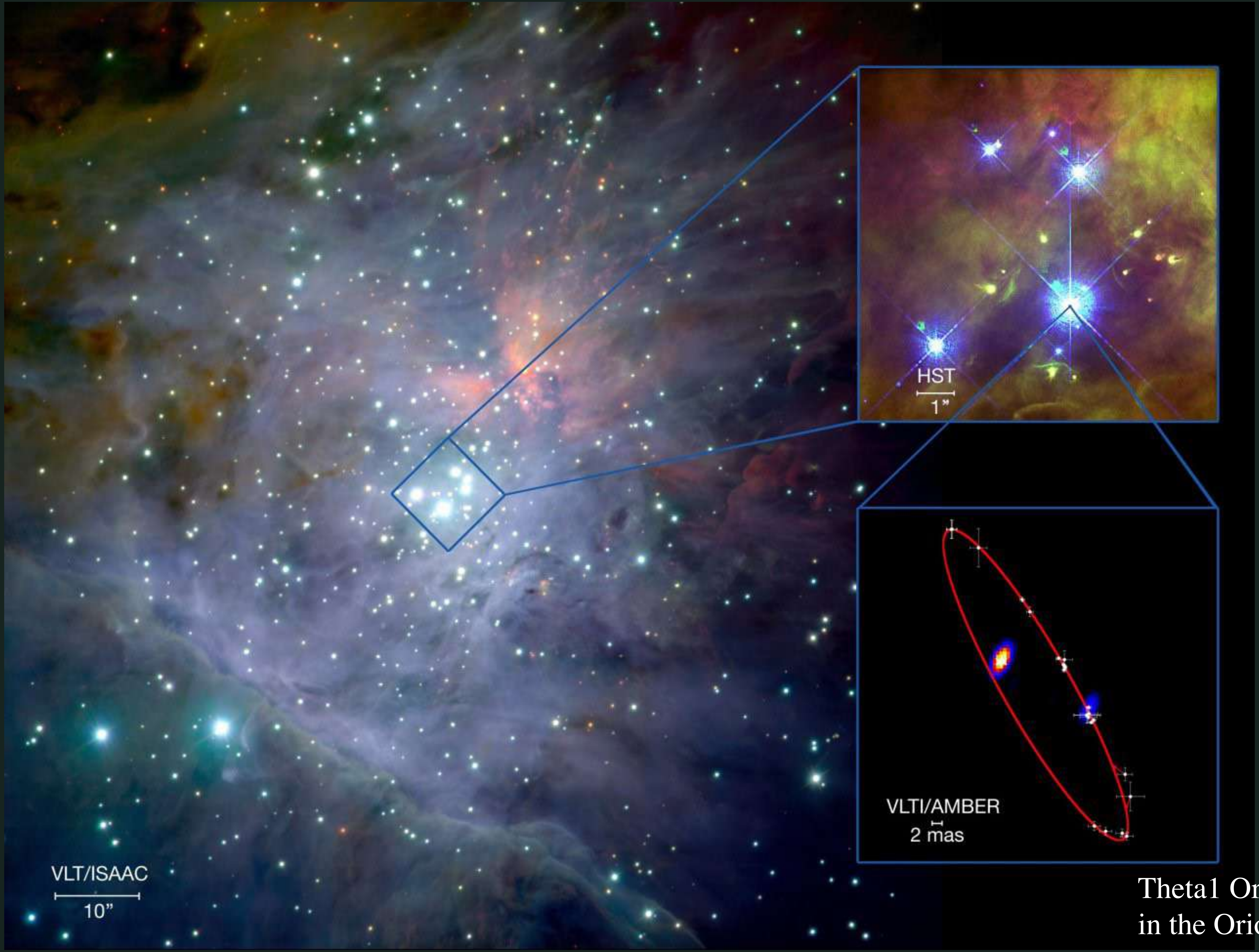


IRDIS: InfraRed Dual-band Imager and Spectrograph.
Es una de las cámaras disponibles en SPHERE,
que opera entre 900 y 2300 nm (infra rojo cercano).

Very Large Telescope (VLT), cerro Paranal, Chile.


Telescopios auxiliares móviles

Óptica adaptativa



Theta1 Orionis C,
in the Orion Trapezium Cluster

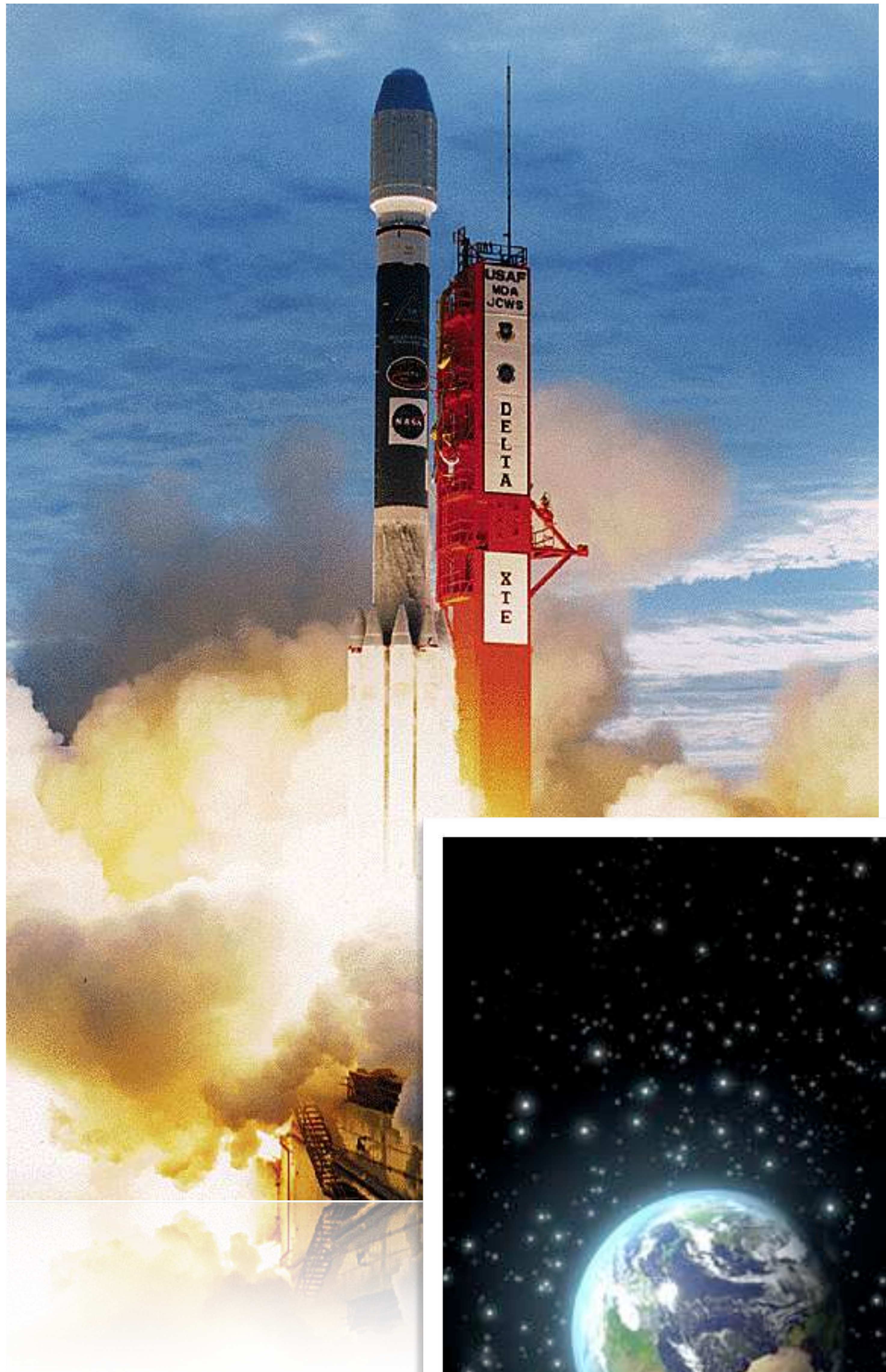
https://astronomynow.com/090402OrionNebulabinarystarresolvedbyVLTI.html

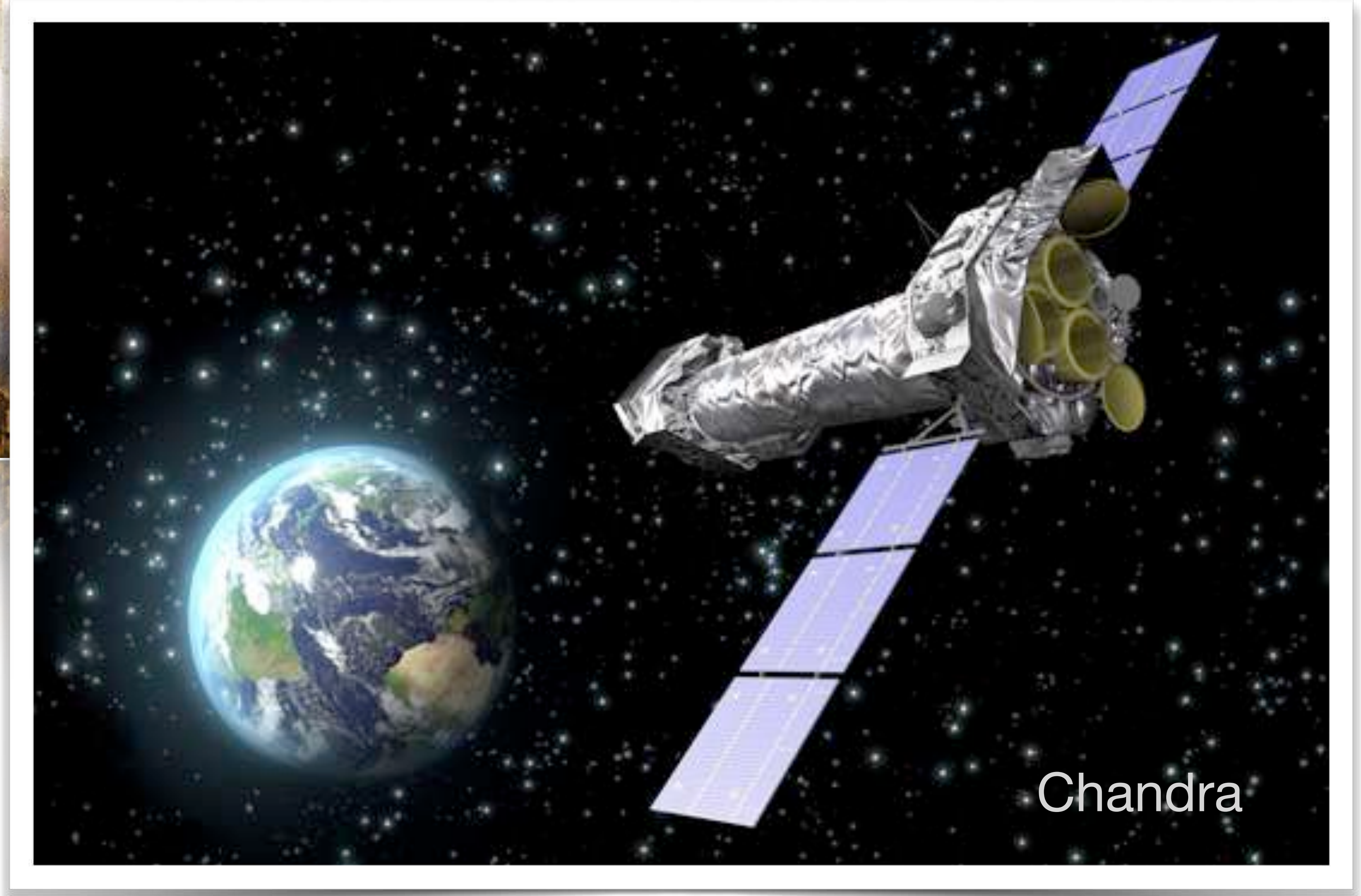
Astronomía de rayos X

Astronomía de rayos X

Desde fuera de la atmosfera

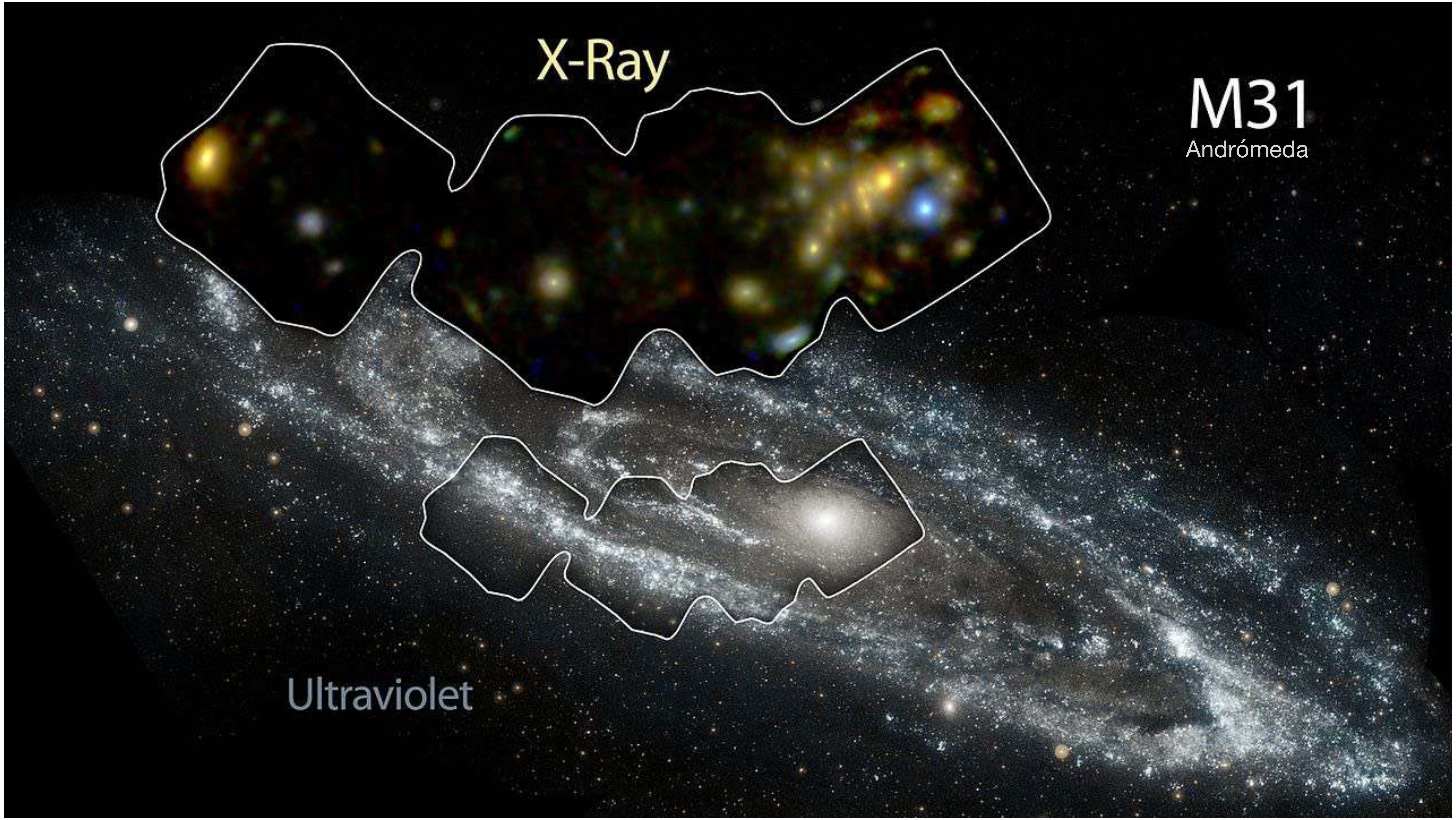
- Técnicas distintas a las astronomía óptica/IR y de radio.
- Emisión normalmente producida por objetos a altas temperaturas, de cientos de MK.
- Primera fuente extrasolar de rayos X: Scorpius X-1 (1962).



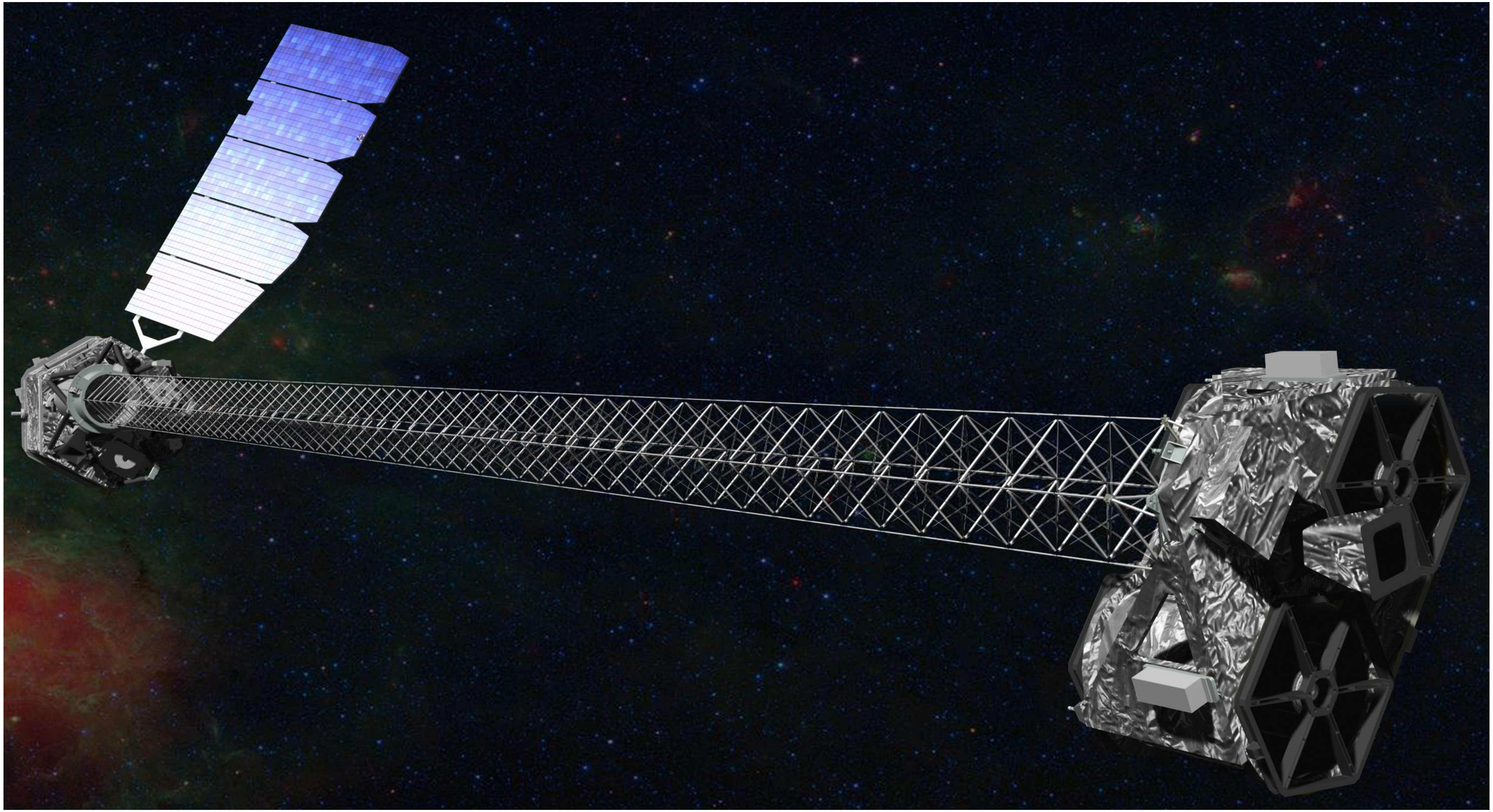



ROSAT PSPC
0.1–2.4 keV
Satélite ROSAT

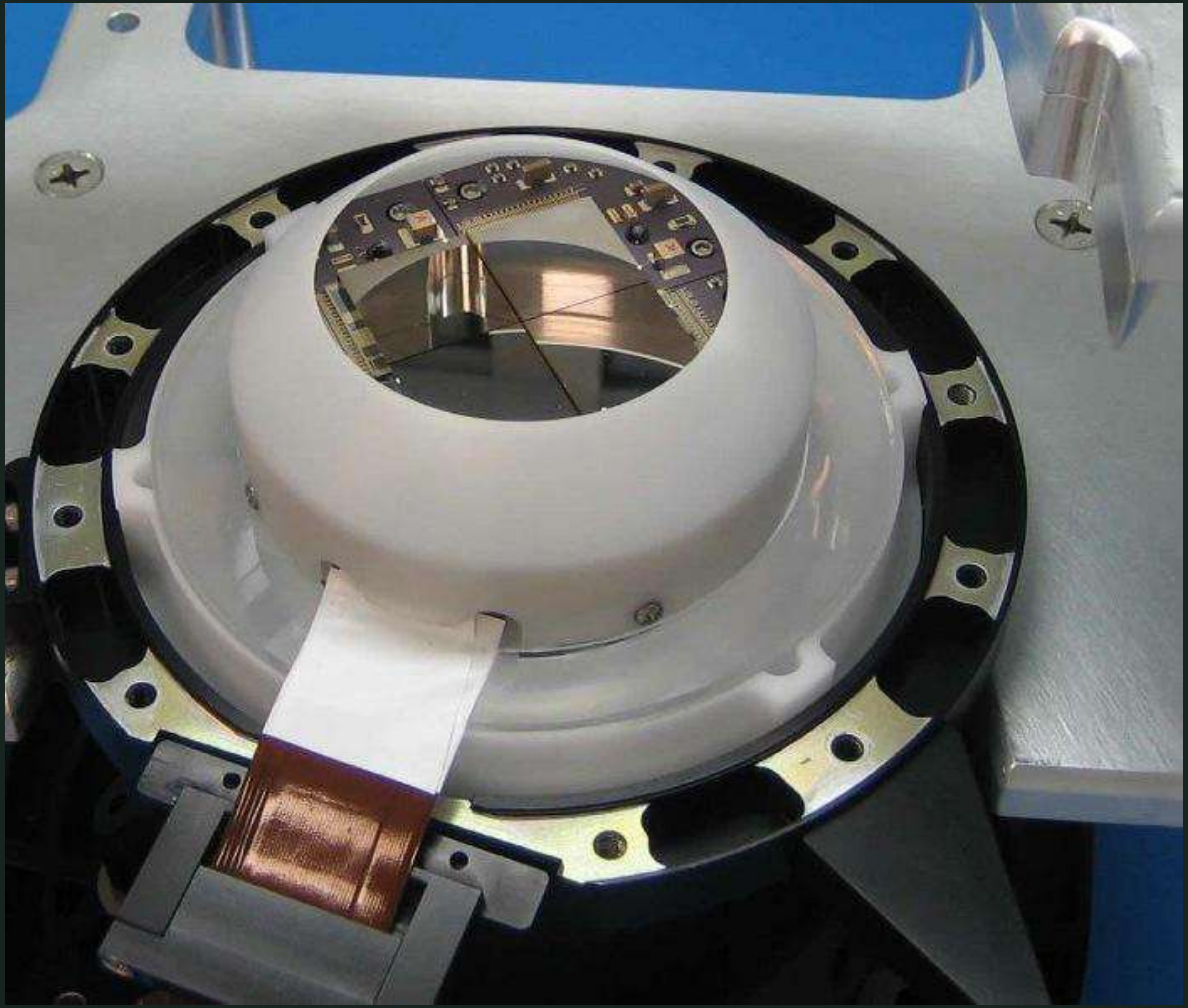
- End stages of stellar evolution and supernovae
- Supernova remnants
- White dwarfs and cataclysmic variables
- Neutron stars
- X-ray binaries
- Isolated and accreting pulsars
- Black holes
- Microquasars
- Pulsar wind nebulae


X-Ray
M31
Andrómeda
Ultraviolet

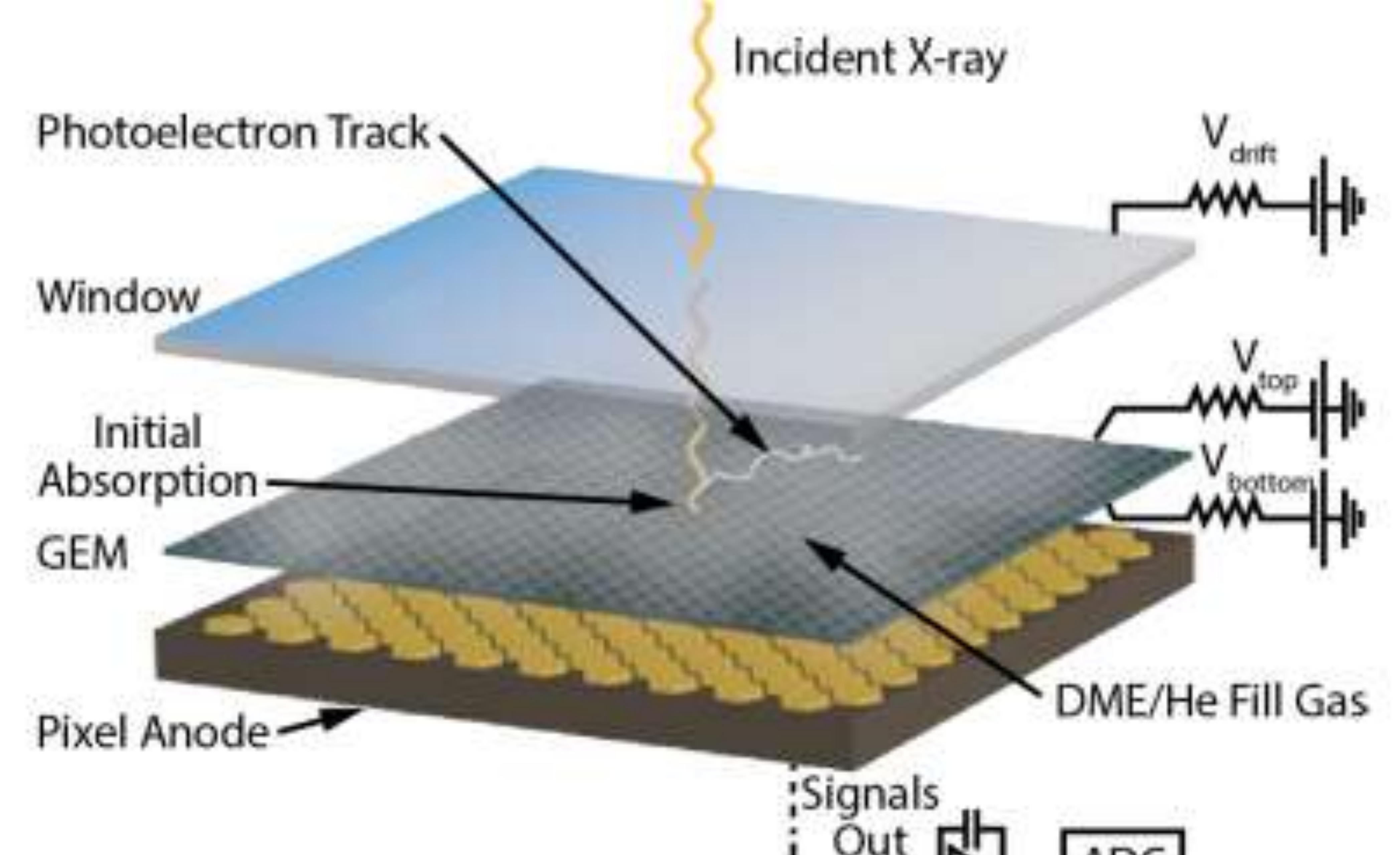
NuSTAR (Nuclear Spectroscopic Telescope Array)



Parabolic mirrors
"Spider"
Incoming X-rays
Hyperbolic mirrors
Focus



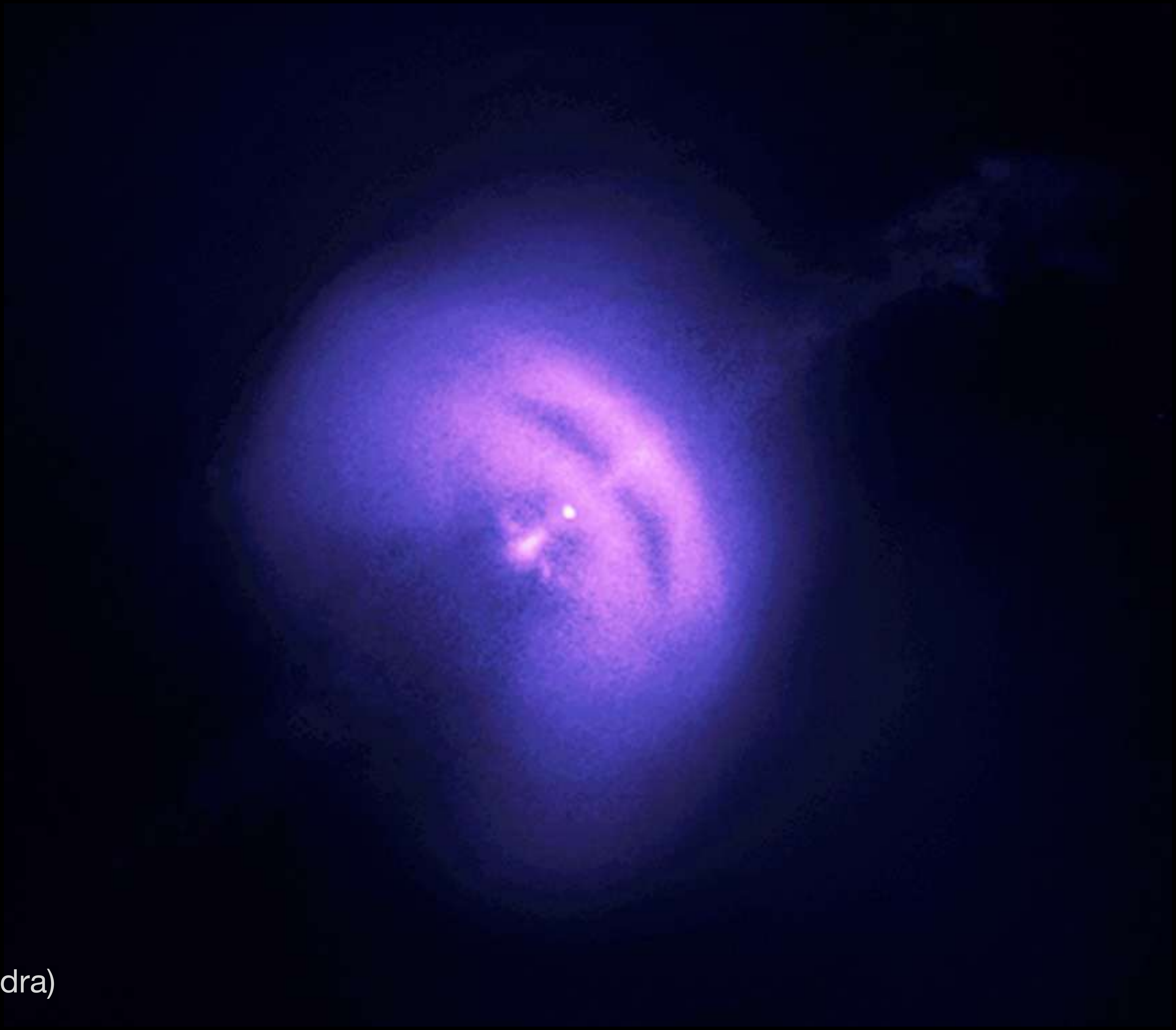
- Detector de estado sólido.
- Cadmio - zinc - telurio (NuSTAR)



Proyecto IXPE

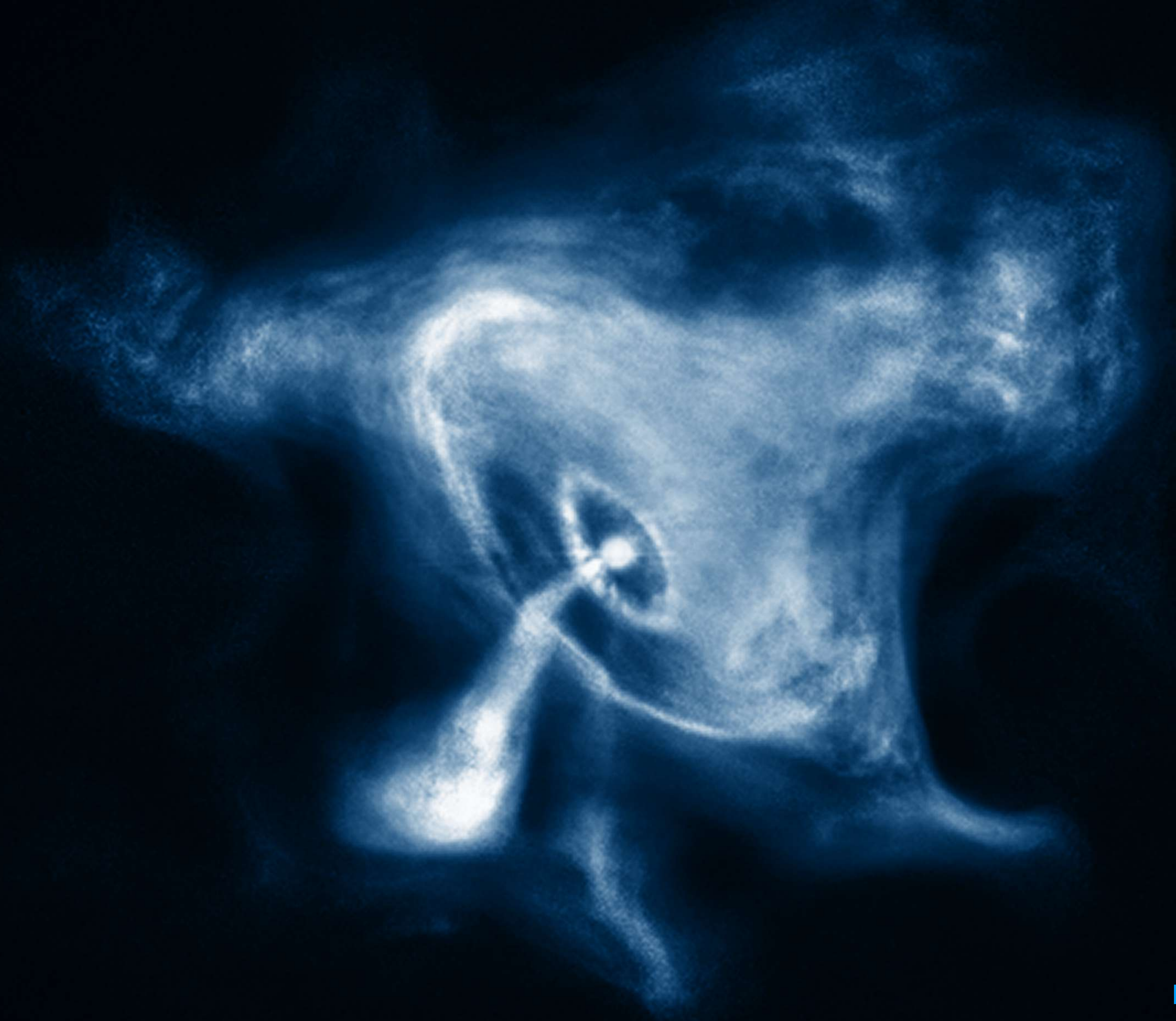
Vela en óptico (Hubble)

Vela en óptico y X-rays



Vela en X-rays (Chandra)

Vela en X-rays (IXPE)



Más imágenes de Chandra:

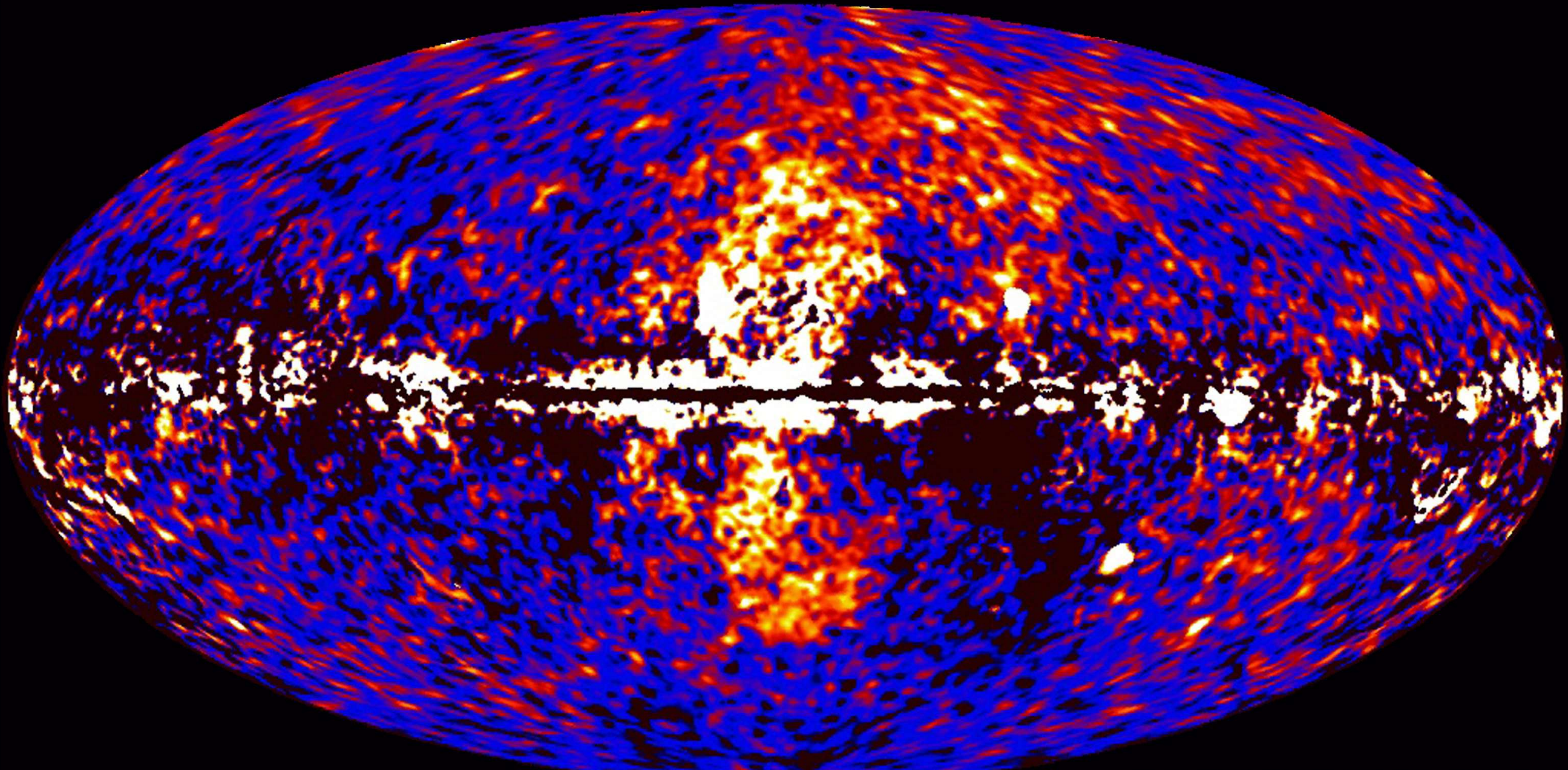
https://chandra.harvard.edu/photo/

Nebulos del cangrejo en rayos x (Chandra)

Astronomía de rayos Gamma

El cielo en rayos gamma, por telescopio Fermi

Fermi data reveals giant gamma-ray bubbles



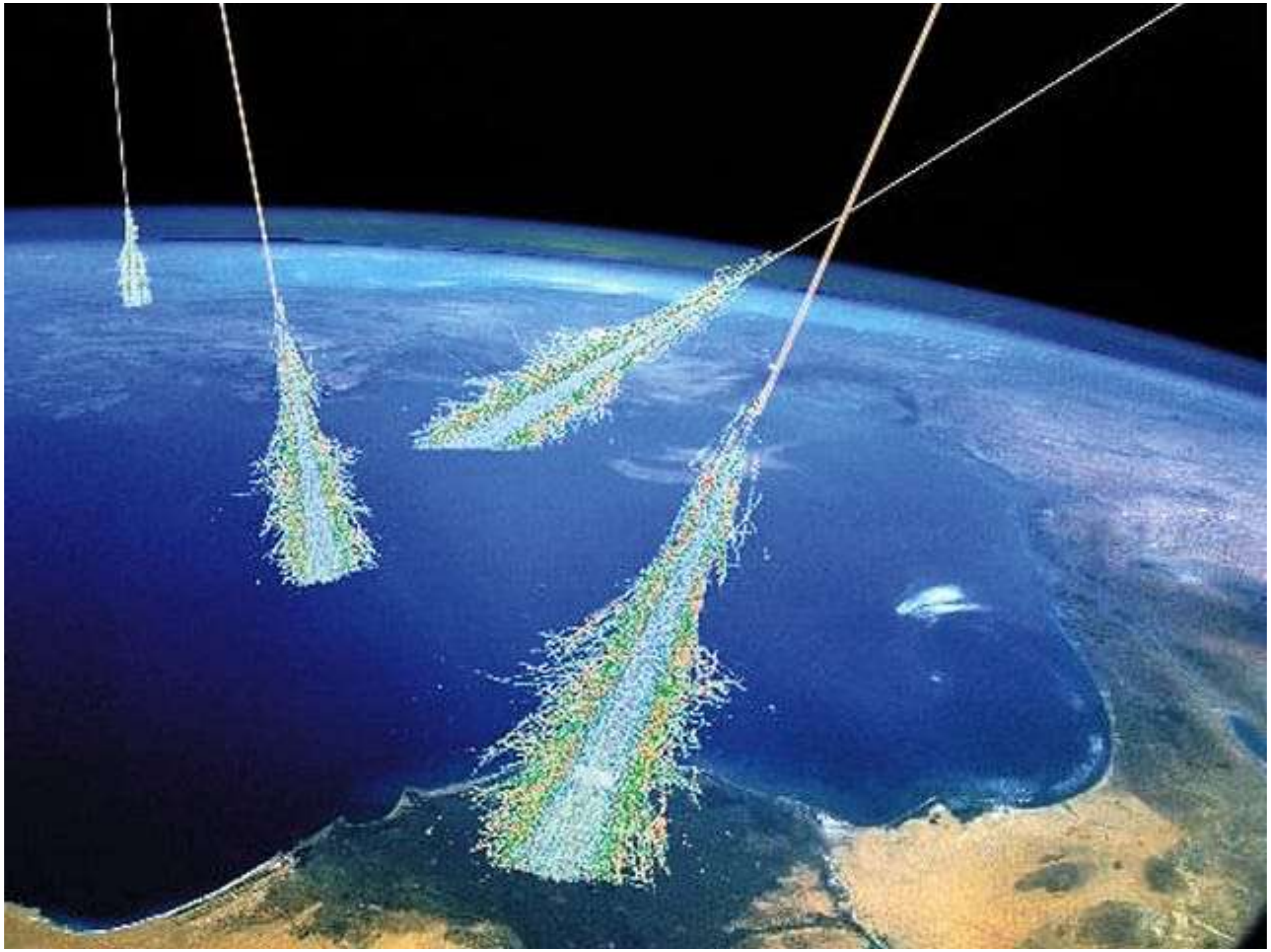
Credit: NASA/DOE/Fermi LAT/D. Finkbeiner et al.


Gamma-ray emissions
X-ray emissions
Milky Way
50,000 light-years
Sun

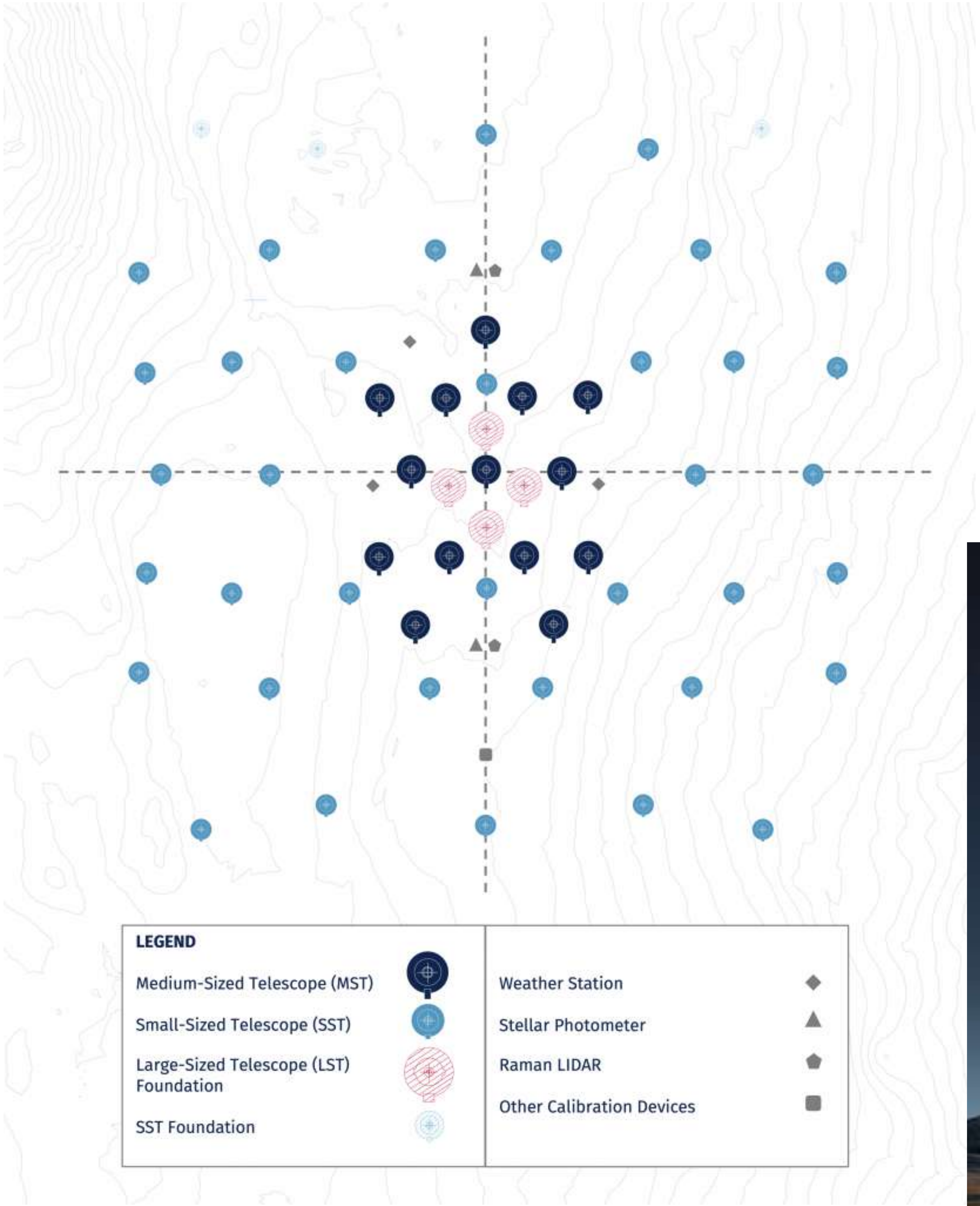
Rayos gamma de muy alta energía

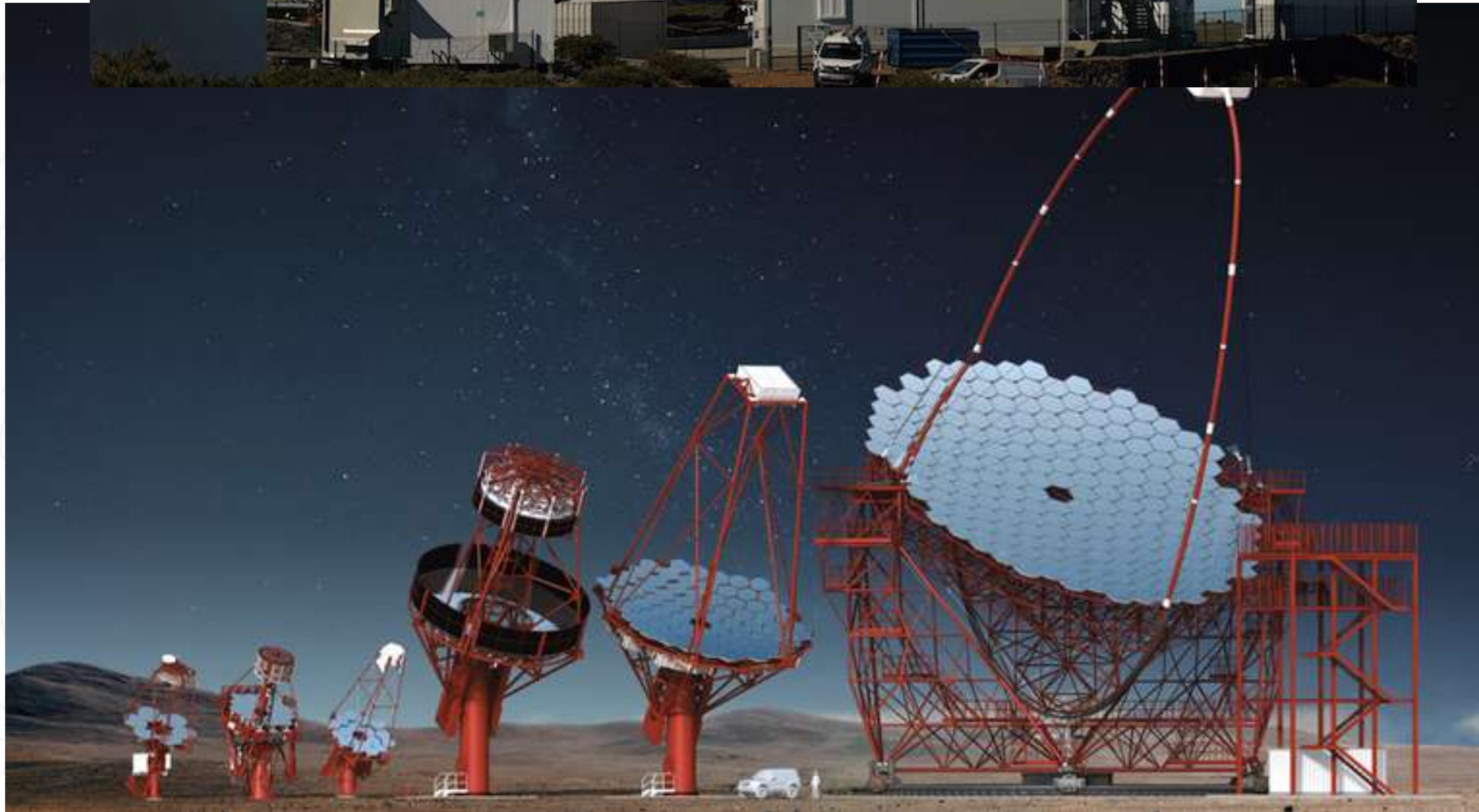
Very High Energy gamma rays (VHE)

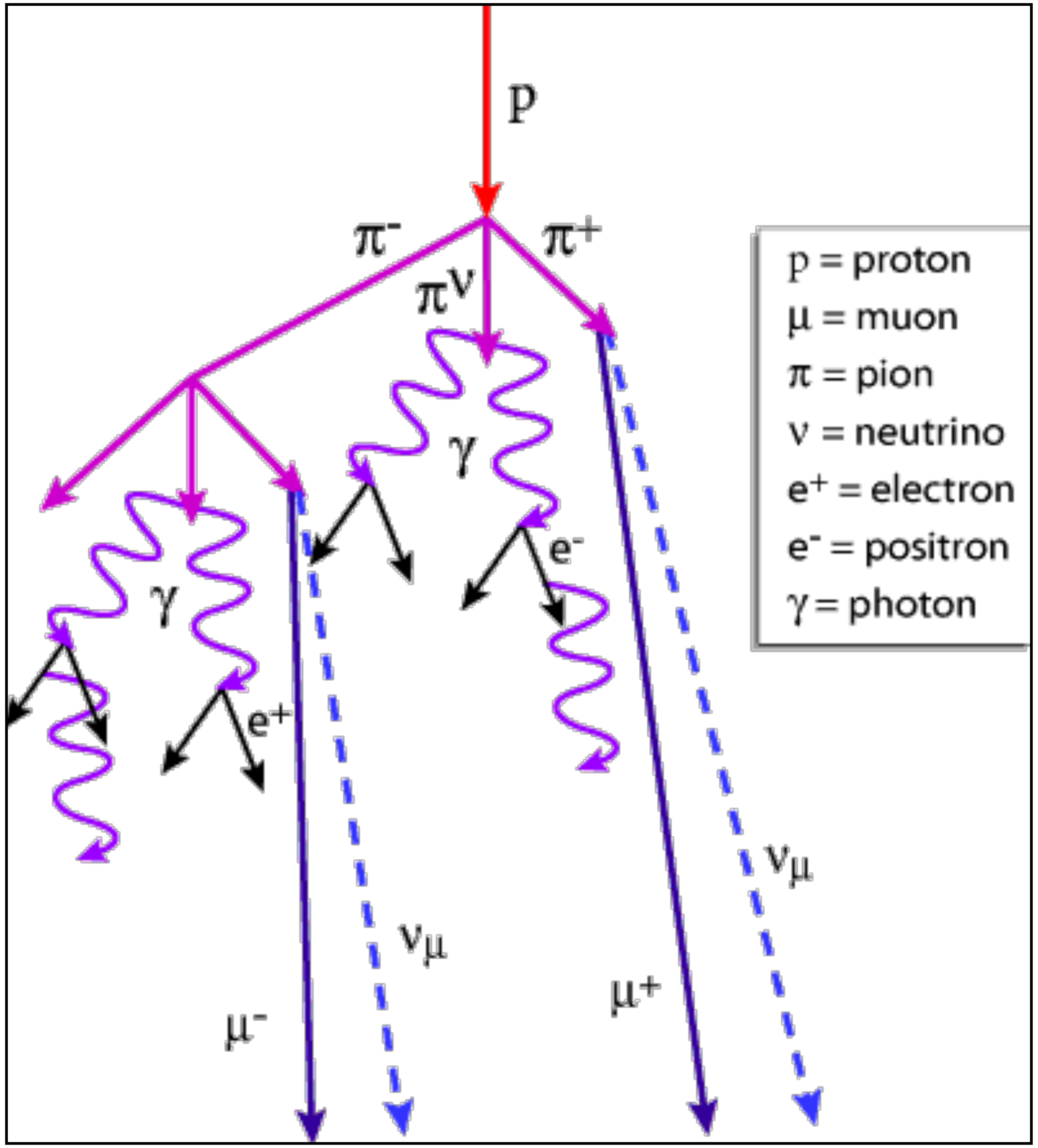
- Cherenkov Telescope Array: CTA
  - Atacama, Chile
  - La Palma, España.



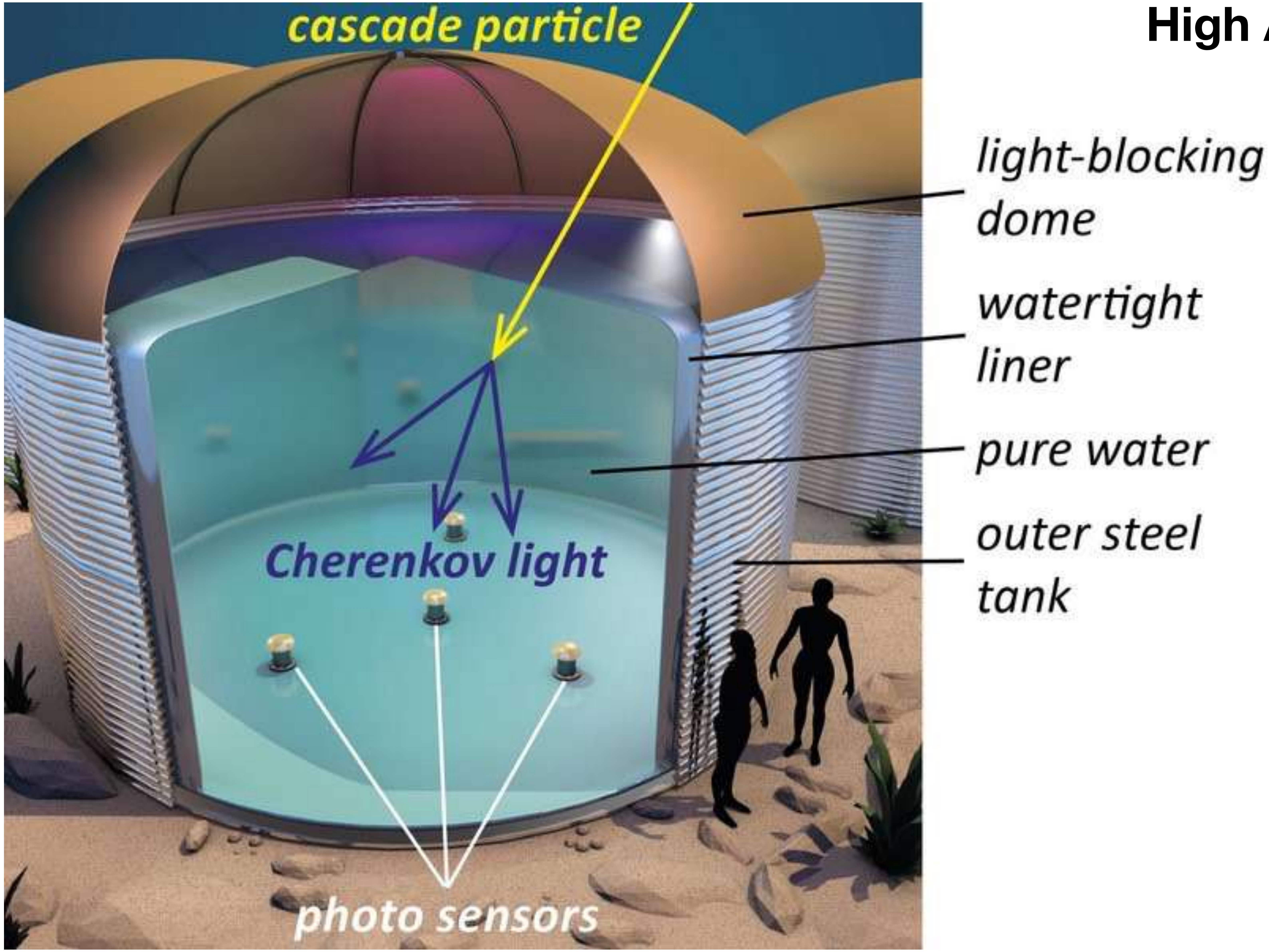

Gamma
20000 m
15000 m
10000 m
5000 m
500 m
Proton
20000 m
15000 m
10000 m
5000 m
500 m
Carbon-13
20000 m
15000 m
10000 m
5000 m
500 m


LEGEND
Medium-Sized Telescope (MST)
Small-Sized Telescope (SST)
Large-Sized Telescope (LST) Foundation
SST Foundation
Weather Station
Stellar Photometer
Raman LIDAR
Other Calibration Devices

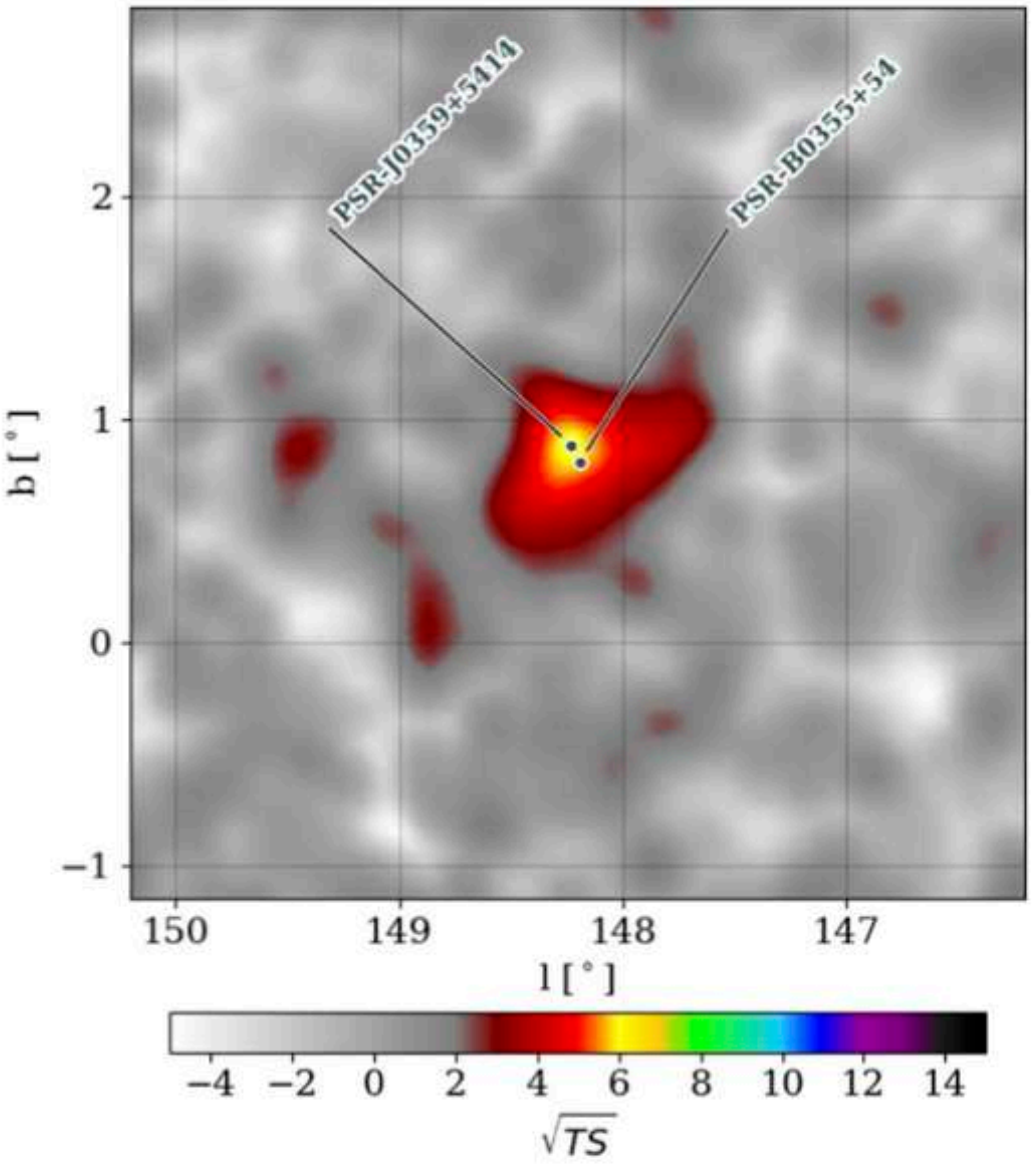



p
π-
πν
π+
γ
γ
e-
e+
νμ
νμ
μ-
μ+
p = proton
μ = muon
π = pion
ν = neutrino
e+ = electron
e- = positron
γ = photon

HAWK
High Altitude Water Cherenkov




V2
V1



HAWK: Halo de emisión TeV (VHE gamma rays) alrededor de dos pulsares