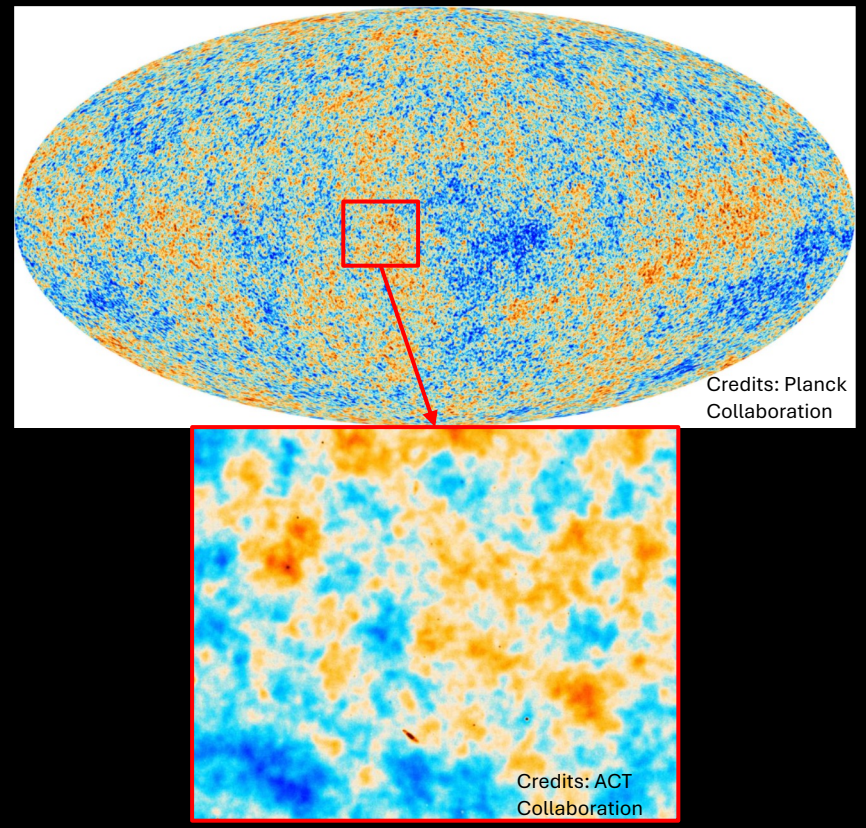
MISTRAL observations during the commissioning phase at the Sardinia Radio Telescope

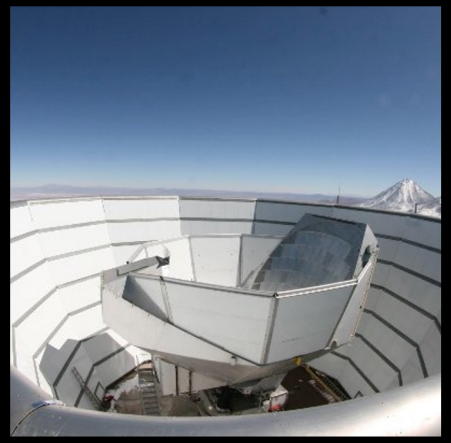
Eleonora Barbavara

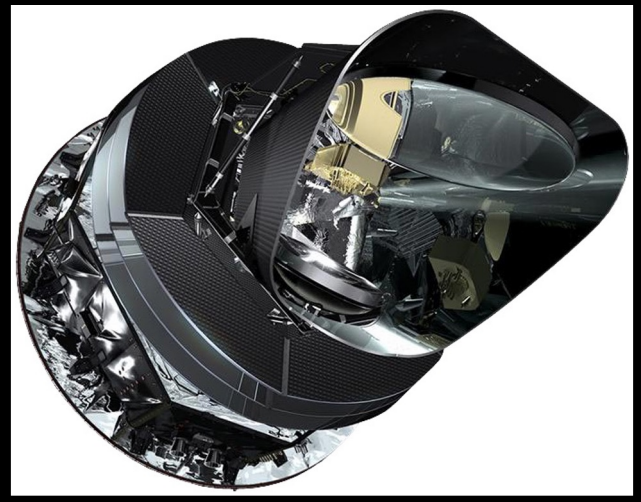
A matter of angular scales

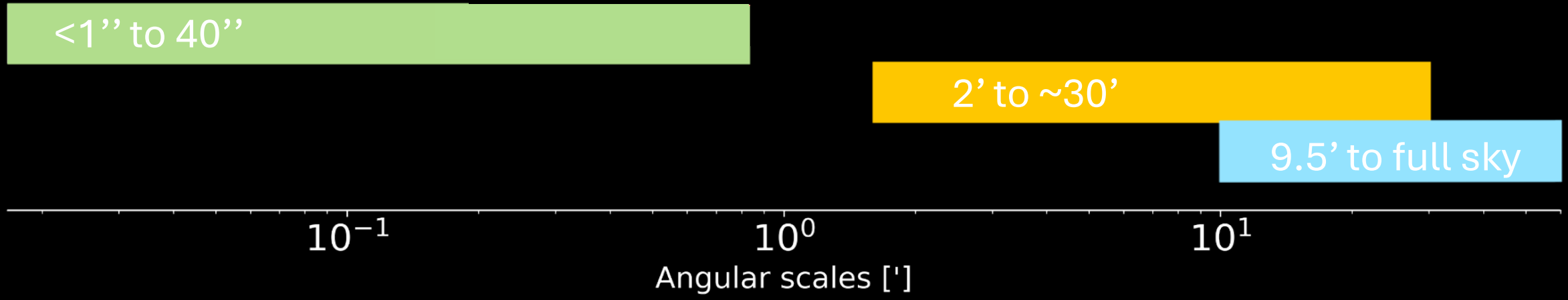
- ➔ CMB surveys observe the sky with excellent sensitivity, but with limited angular resolution.
- ➔ Resolution is limited to ~10’ from space and to ~1’ from the ground.
- ➔ Lots of interesting science at higher resolution (~10’’)
- ➔ To achieve this high resolution, we need a millimeter camera on a large single dish telescope (50 - 100 m class)



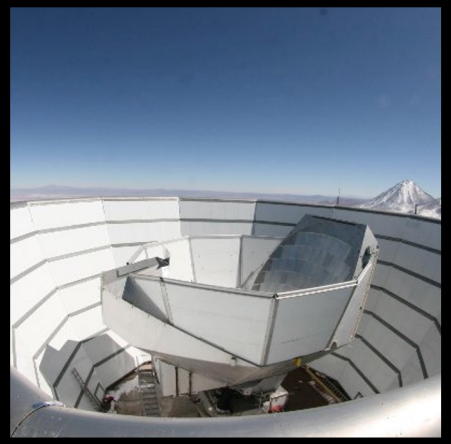
MISTRAL

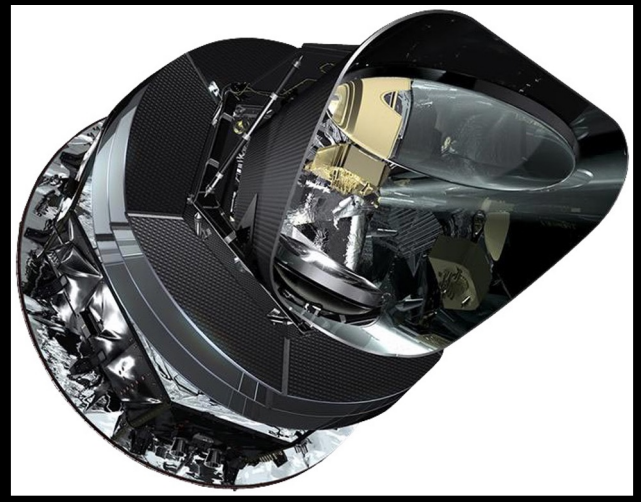




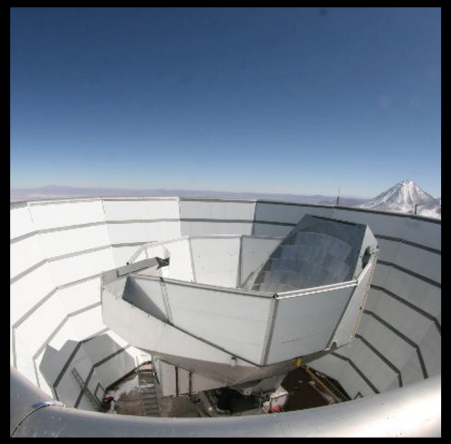


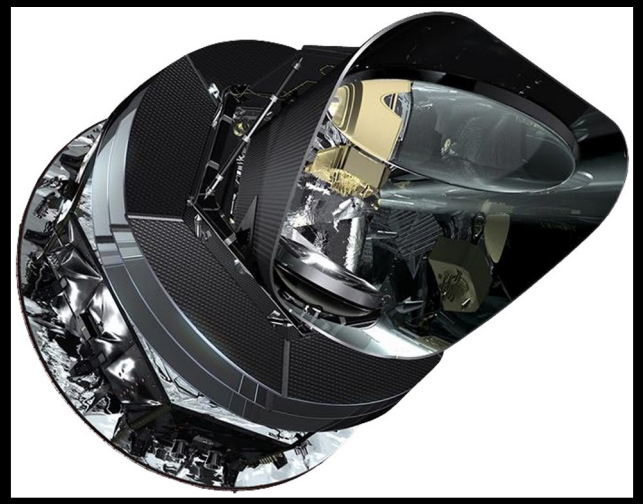
MISTRAL





MISTRAL





12’’ to ~4’

<1’’ to 40’’

2’ to ~30’

9.5’ to full sky

Few of them in the world!!

- ➔ MUSTANG2 @ GBT (100m, 90 GHz)
- ➔ TolTec @ LMT (50m, 150/220/270 GHz)
- ➔ NIKA2 @ IRAM (30m, 150/260 GHz)
- ➔ MKID cam @ Nobeyama (45m, 90 GHz)
- ➔ **MISTRAL@SRT (64m, 90 GHz)**

10^0 10^1

lar scales [']

MISTRAL

MIllimetric Sardinia radio Telescope Receiver based on Array of Lumped elements KIDs (MISTRAL) is a facility instrument open to proposal from the scientific community.

415 LEKIDs camera working at ~ 200 mK
Band: 77-103 GHz
Angular resolution: ~ 12’’
Field of view: 4'

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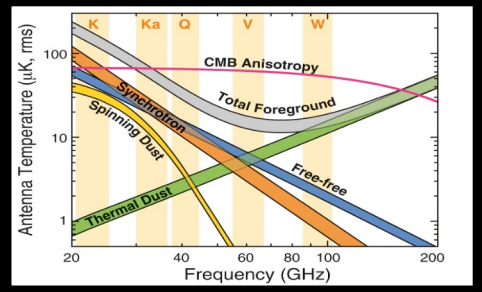
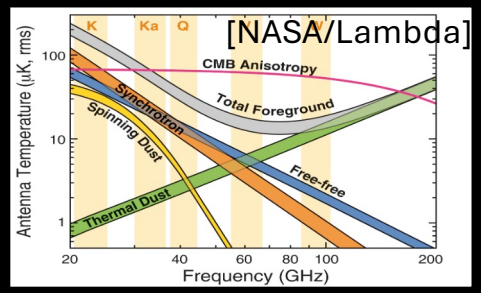
MIllimetric Sardinia radio Telescope Receiver based on Array of Lumped elements KIDs (MISTRAL) is a facility instrument open to proposal from the scientific community.

415 LEKIDs camera working at ~ 200 mK
Band: 77-103 GHz
Angular resolution: ~ 12''
Field of view: 4'

We are close to the foreground minimum and the maximum of CMB emission:
A LOT OF SCIENCE AVAILABLE!!

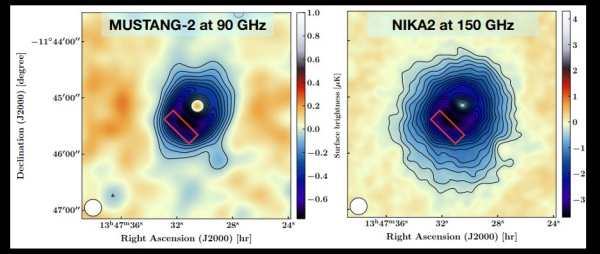


Science with MISTRAL

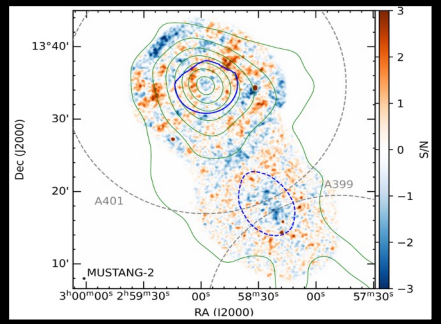


✅ **Small scale anisotropies, lensing, point sources**

✅ **Galaxy cluster substructures**

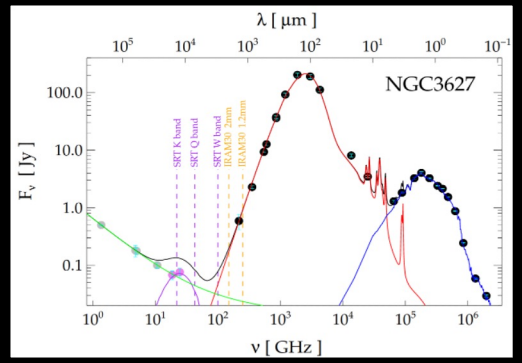


[Ruppin et al.]



✅ **Cosmic web**

✅ **Galactic science**

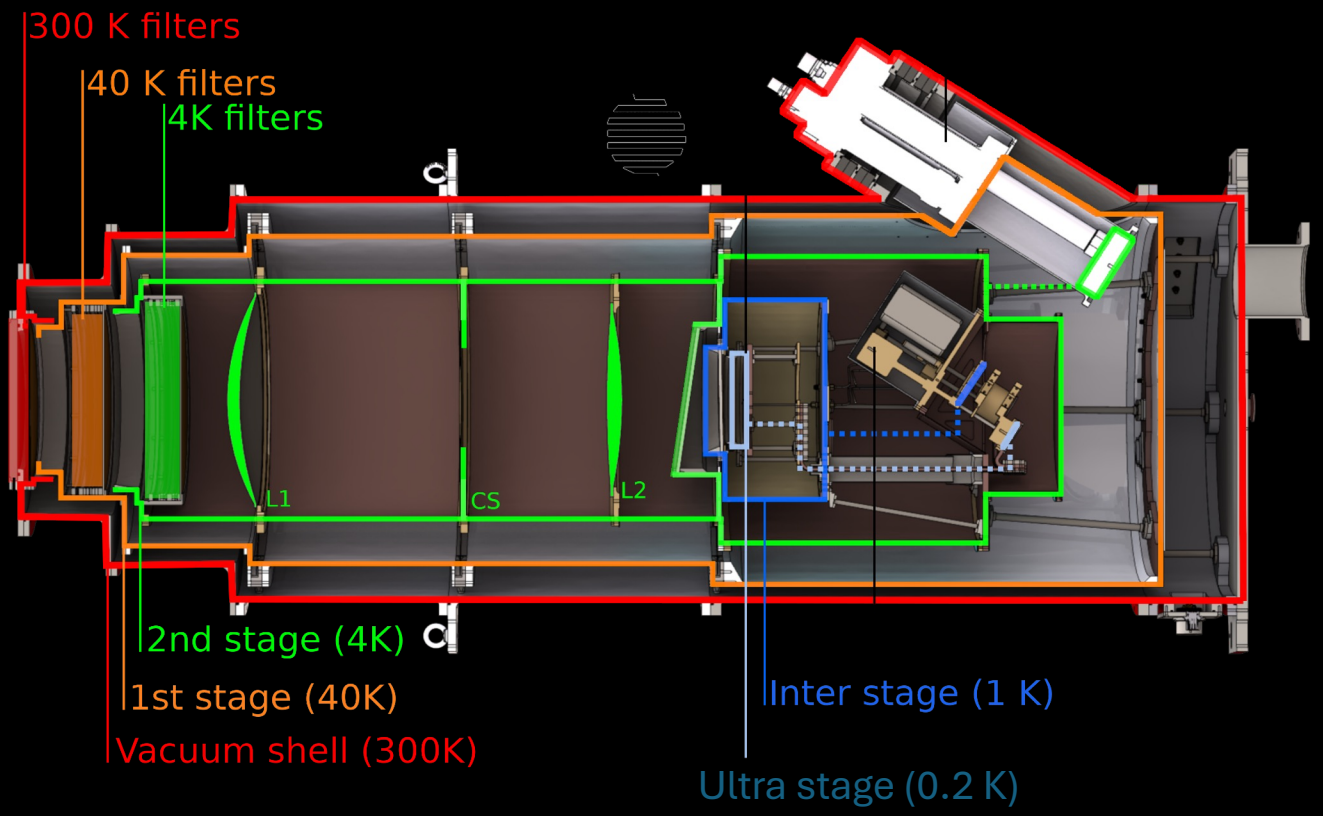


[Bianchi et al. 2022]

Cryogenics

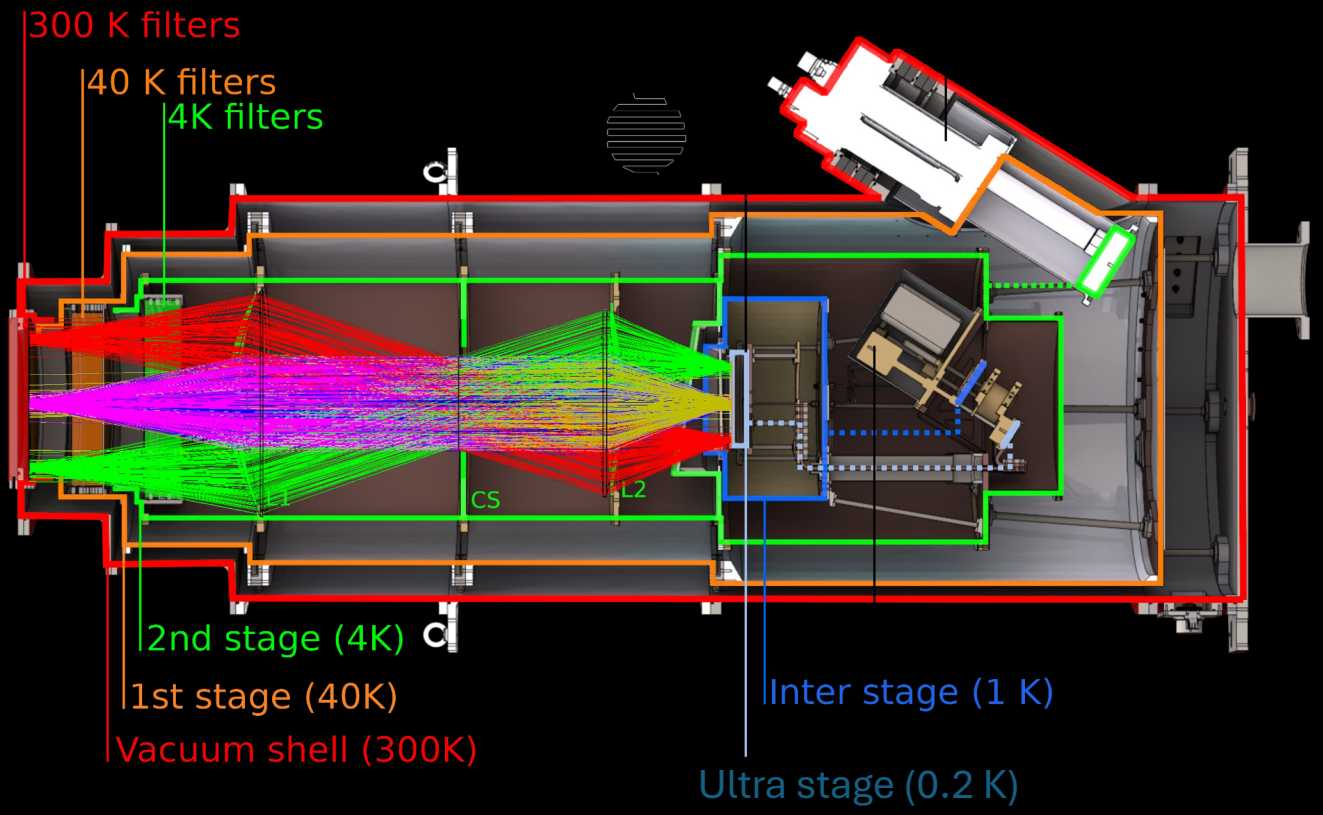
Cryostat with 4 different stages:

- 40 K,
- 4 K,
- 1 K,
- 200 mK



Quasi-optical system

- Two silicon lenses to correct the off axis aberrations
- Cold stop to reject spill-over radiation
- Filters to select the final band: 77-103 GHz
- DL FOV widened from 1.4’ (nominal for SRT at. 90 GHz) to 4’

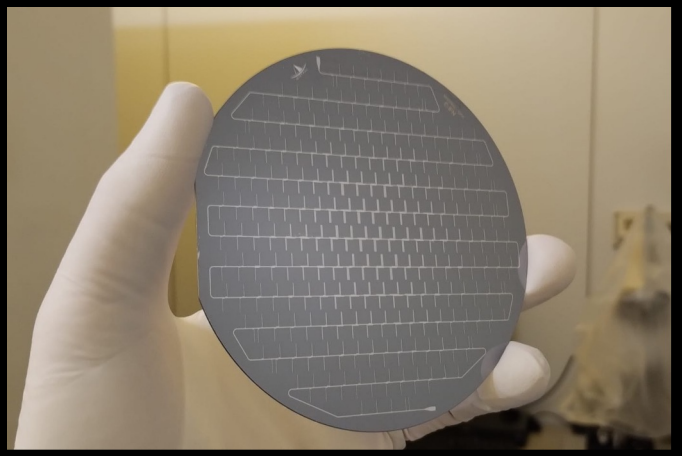


Credits: M. De Petris

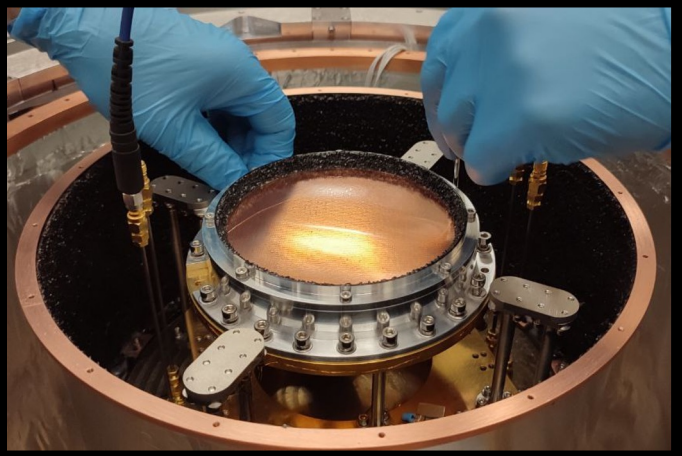
MISTRAL commissioning

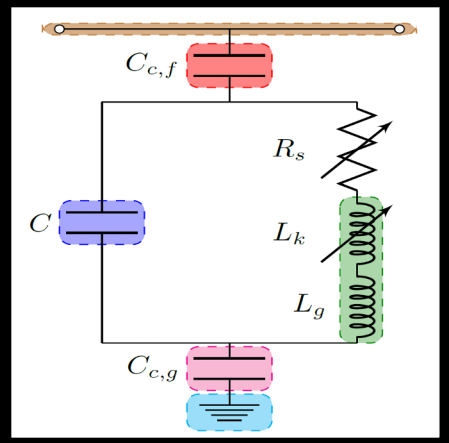
MISTRAL's heart is an array of 415 Kinetic Inductance Detectors fabricated by CNR-IFN.

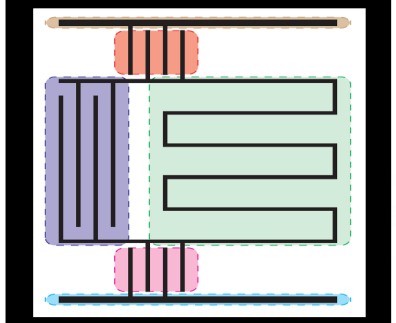
- ➔ RLC resonator
- ➔ Radiation breaks Cooper pairs causing a change in Kinetic Inductance (hence in the resonant frequency)
- ➔ Fast superconducting sensors

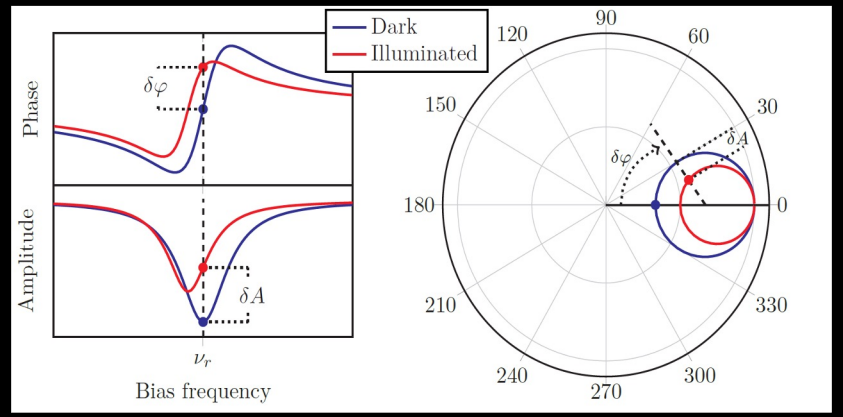


Paiella et al. (2023)



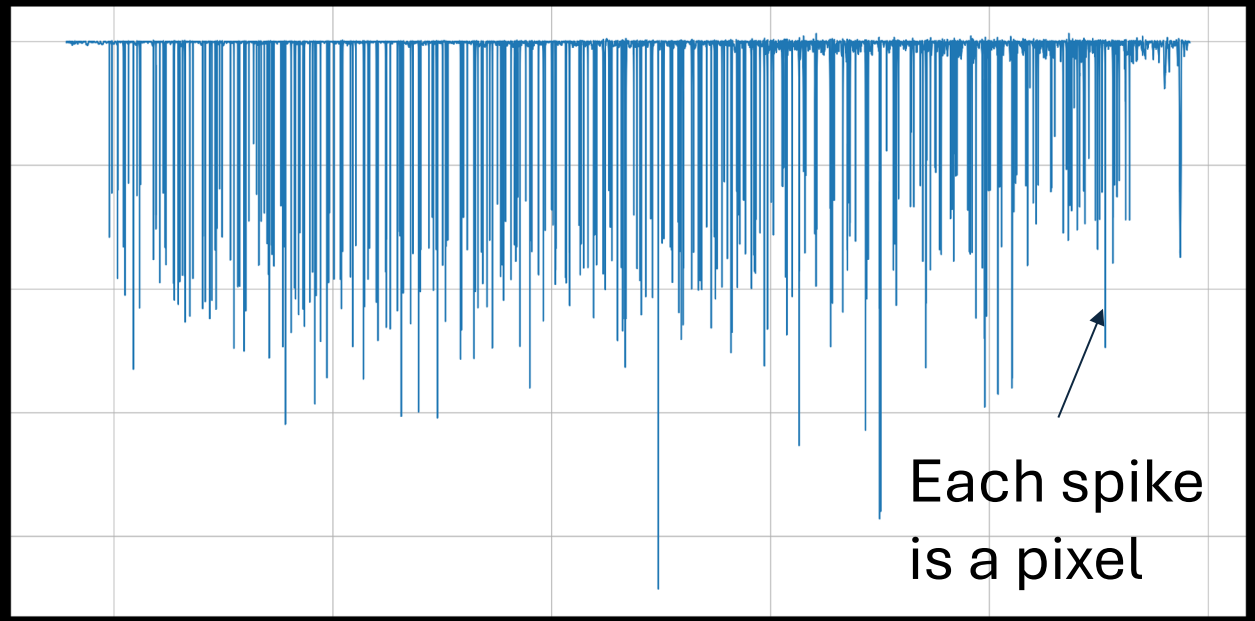


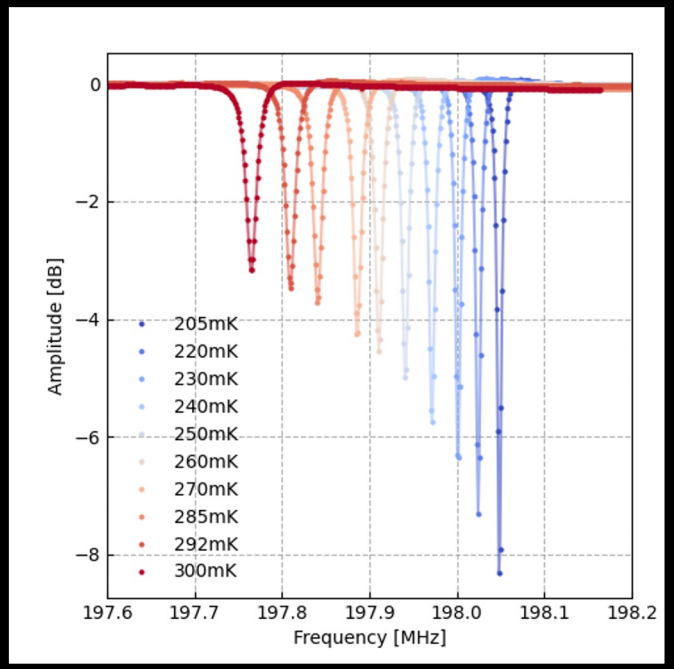




Pixel count after installation

- ➔ We checked the number of alive pixels with a VNA sweep of the transfer function of the array.
- ➔ This value will slightly vary during observations in different background conditions due to resonance collisions.





Cacciotti et al. (2023)

On avarage, we have 350 alive pixel at night.

MISTRAL commissioning

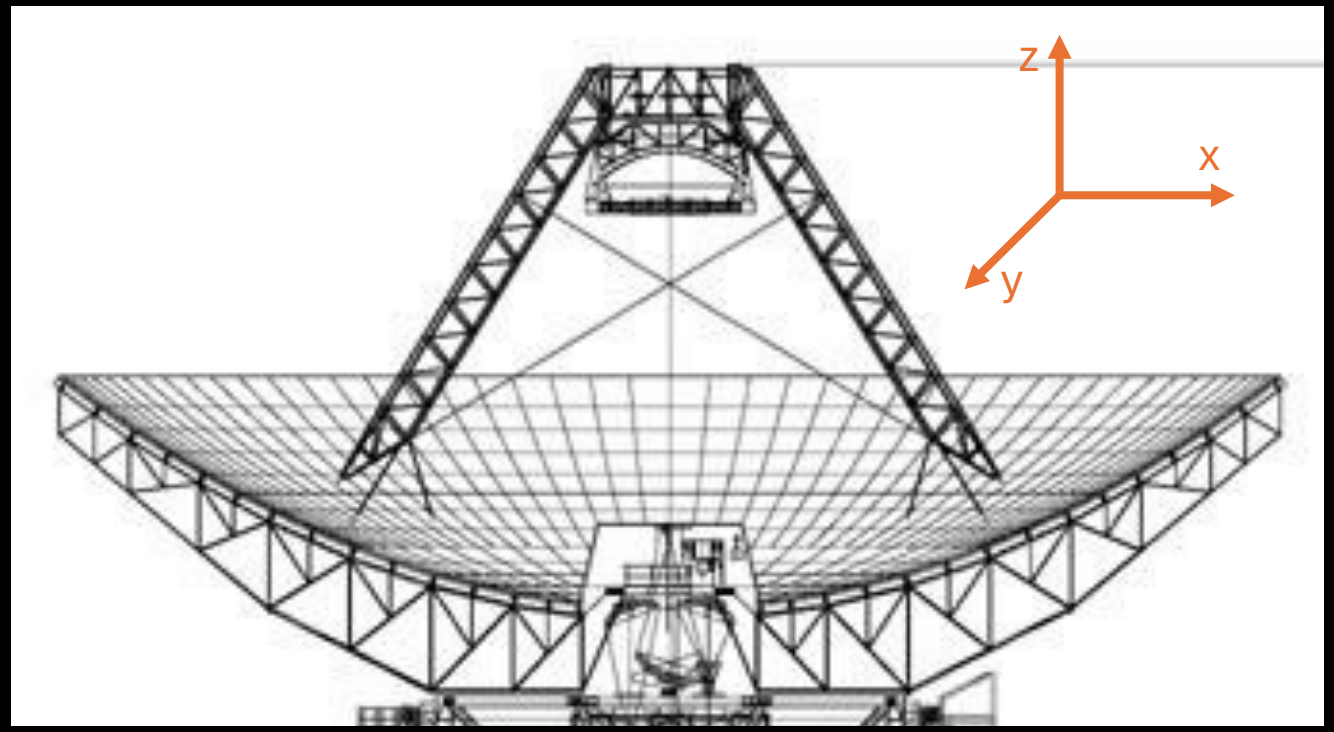
MISTRAL was installed on SRT in May 2023 and started the technical commissiong in April 2024

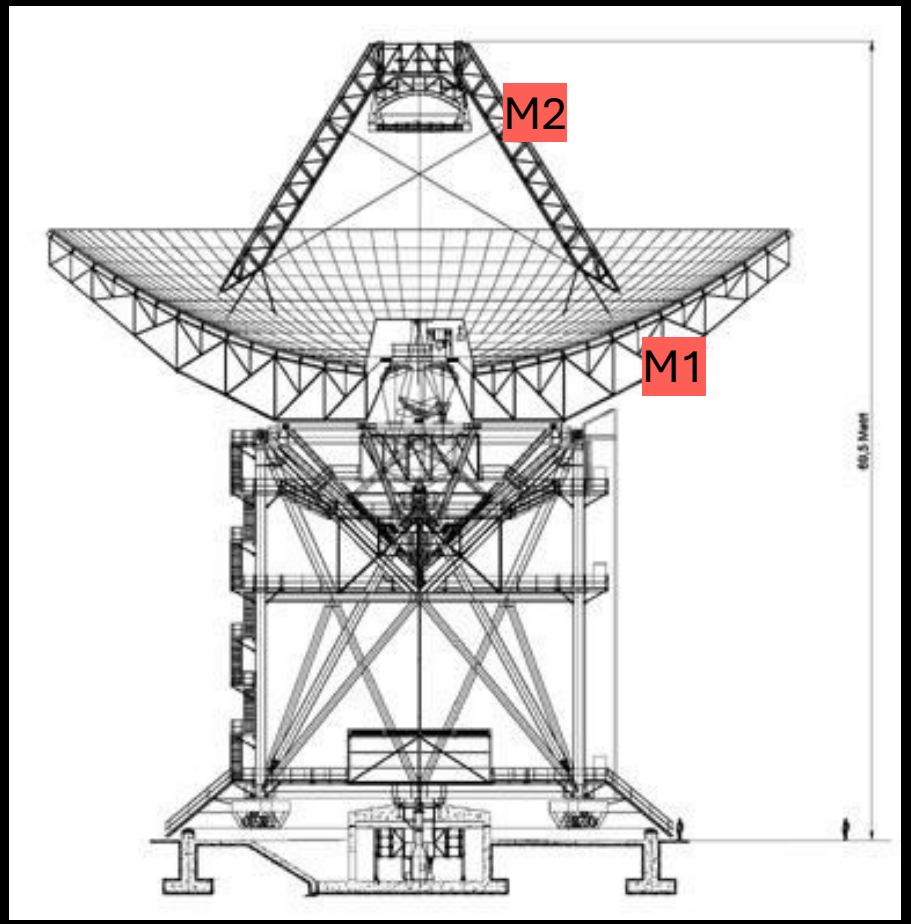
➔ First W-band observations from SRT!

Credits: M. Murgia

Mirror alignment

To align the mirrors and focus MISTRAL, we have to find the position of the secondary mirror that minimizes the beam area and maximizes the amplitude of the signal.





Mirror alignment

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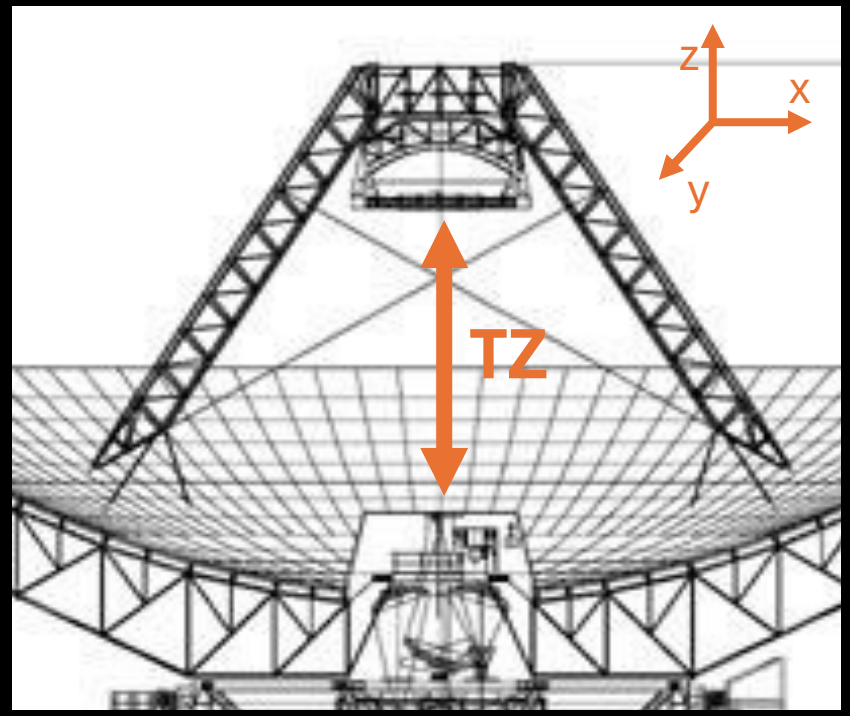
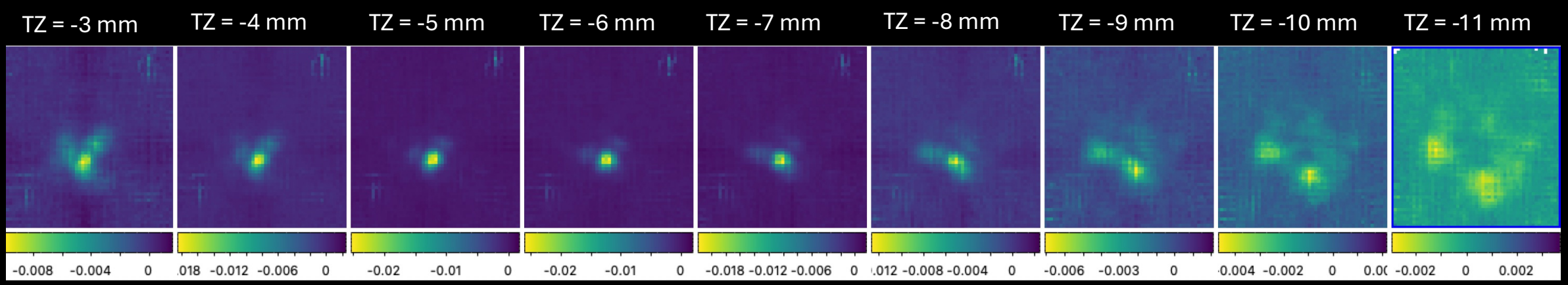
Focusing with maps:

- TZ shift from nominal position: between -3 mm and -11 mm.





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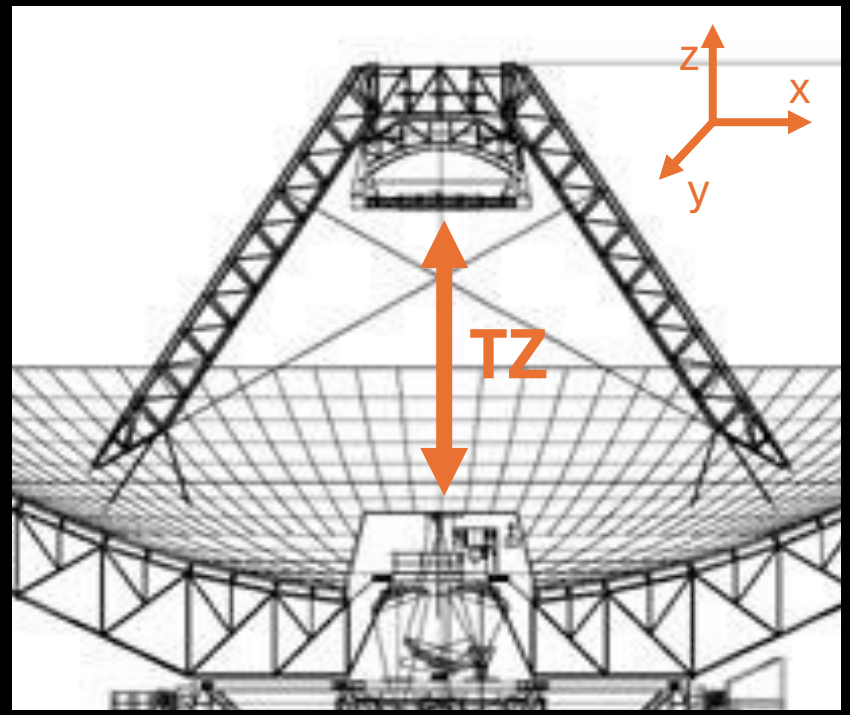

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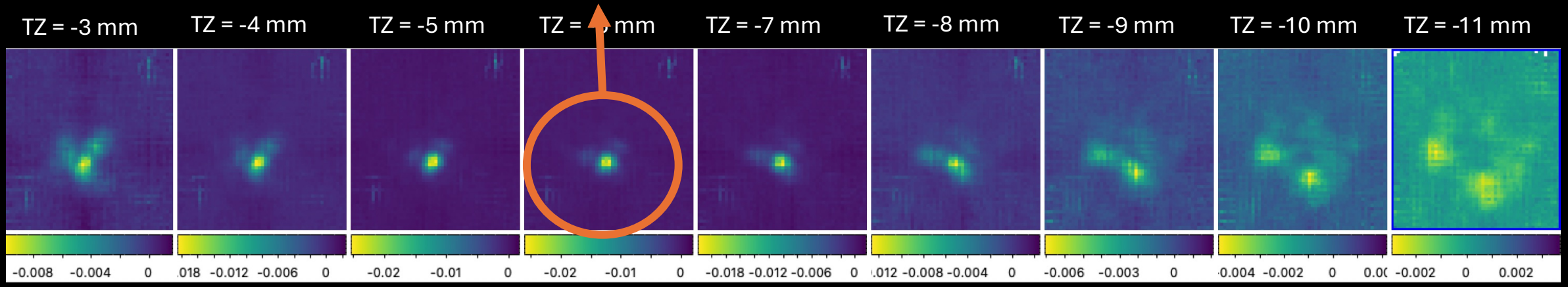
ABERRATION!!



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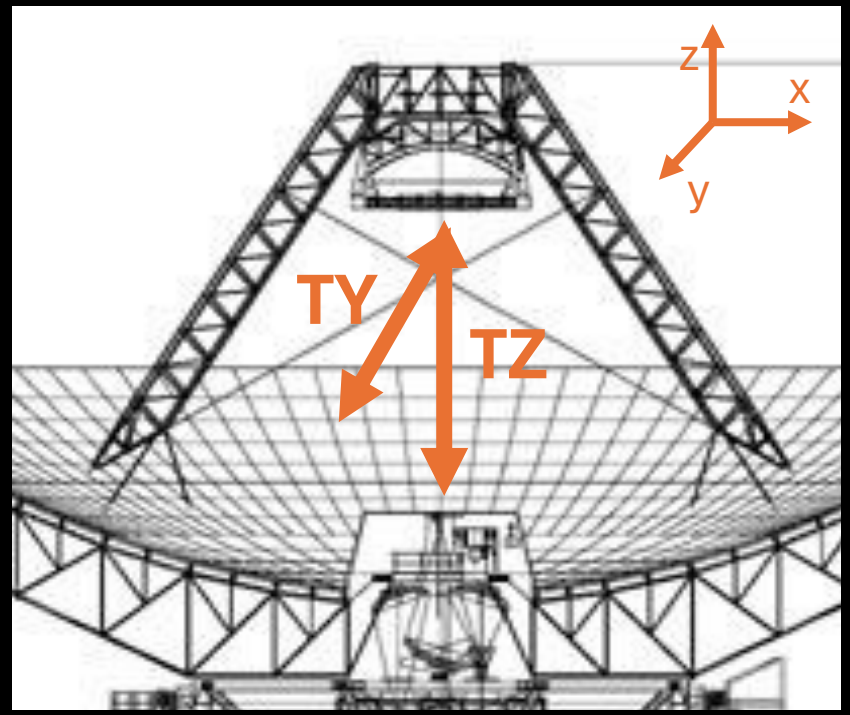

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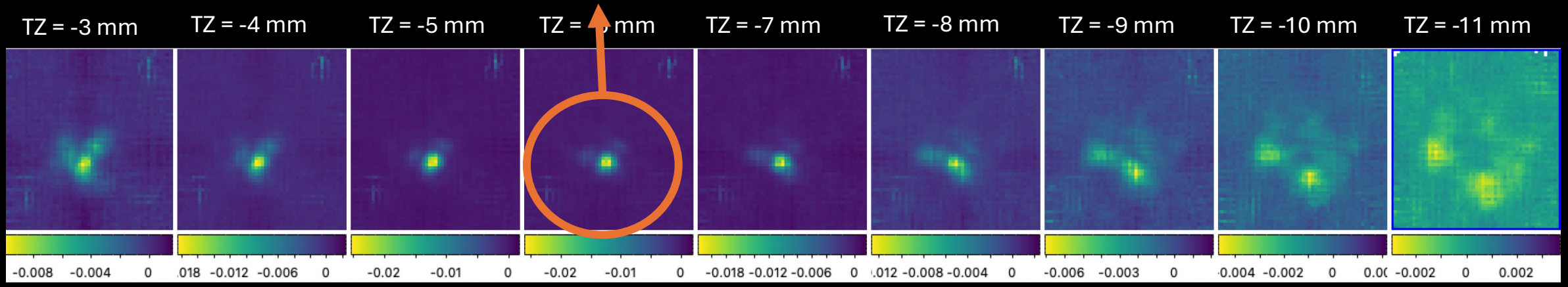
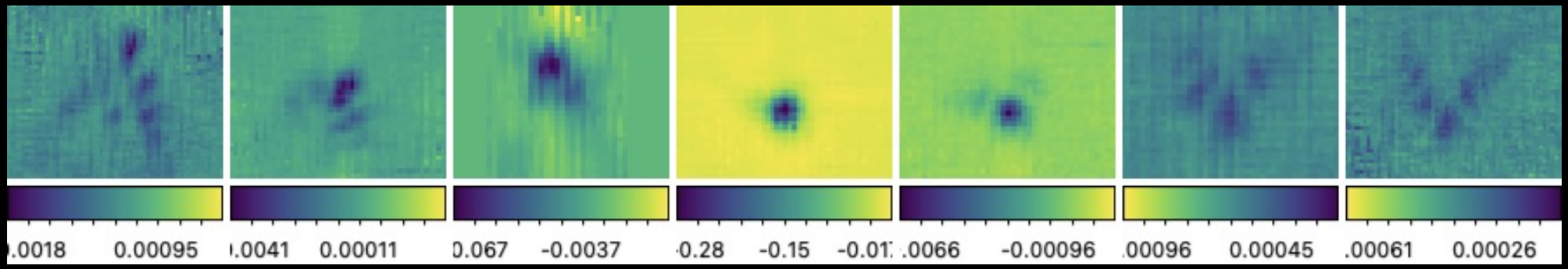


Check for aberrations

When moving the secondary mirror along the TY axis, aberrations appear...



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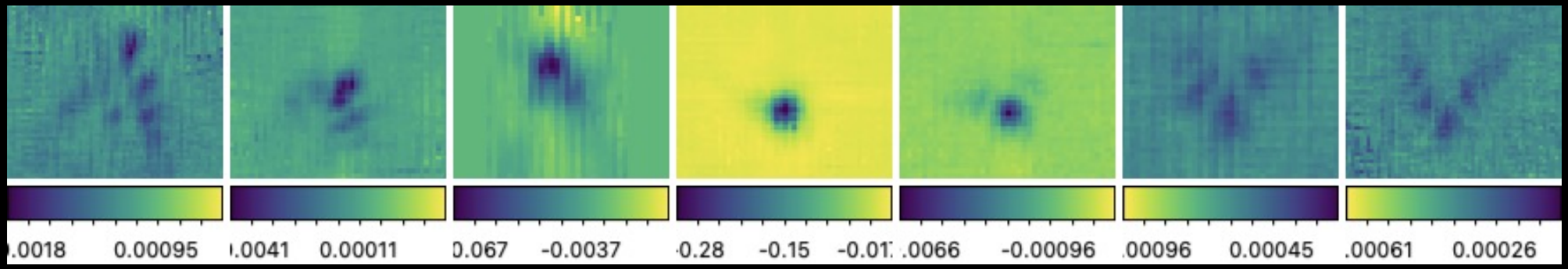
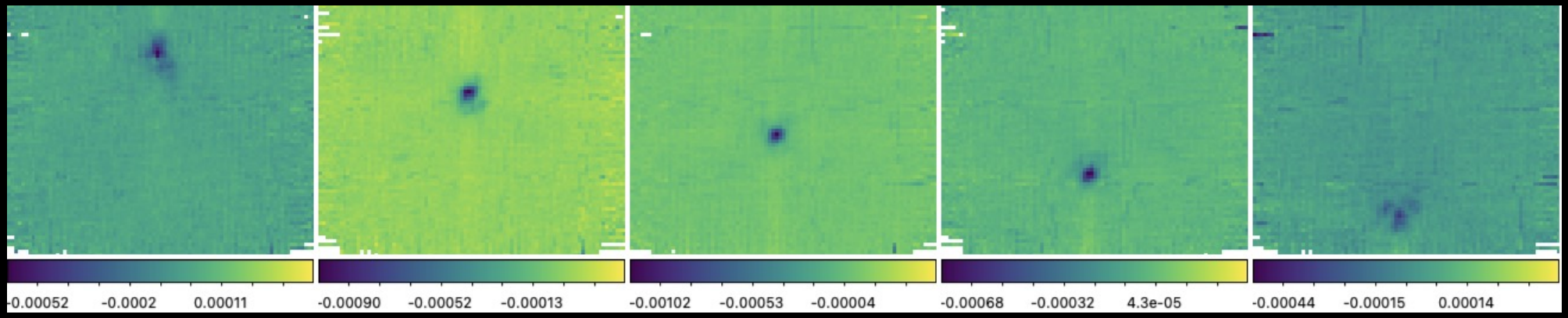
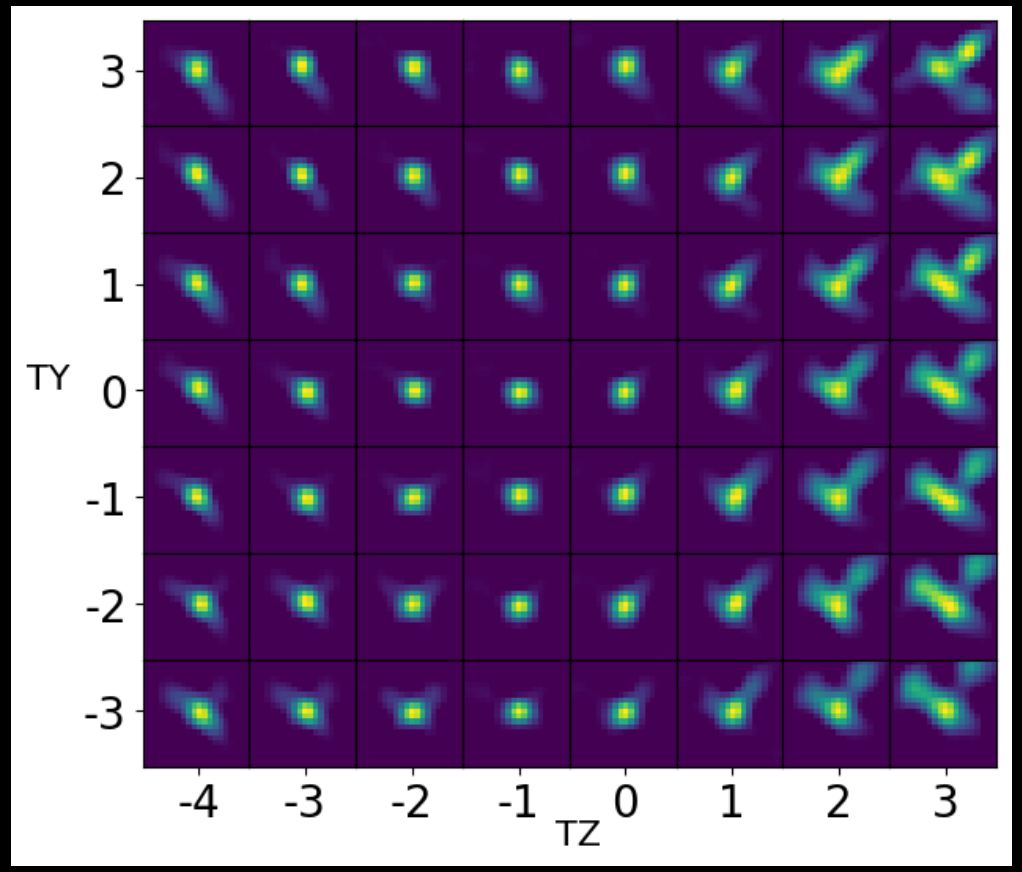


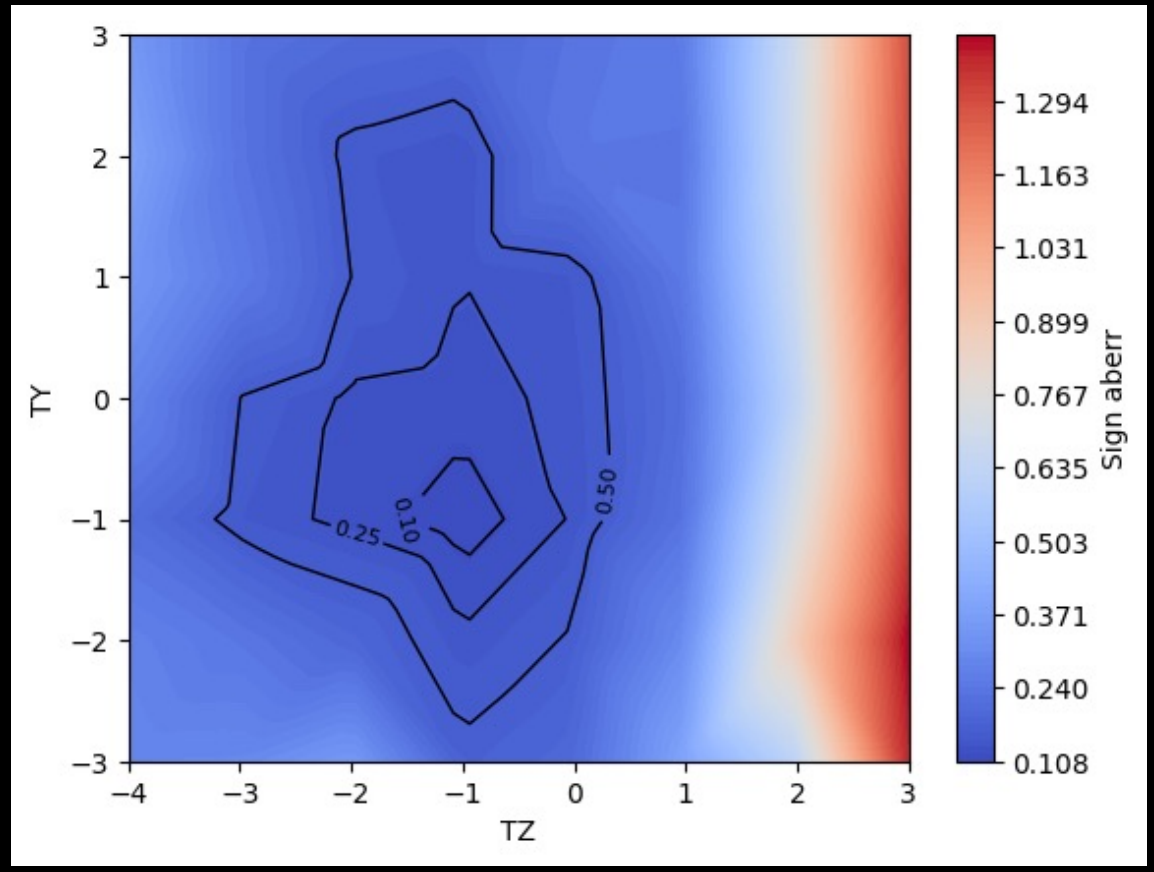
... as well as a pointing offset: re-do the pointing model after finding the best TY position.



MATRIX

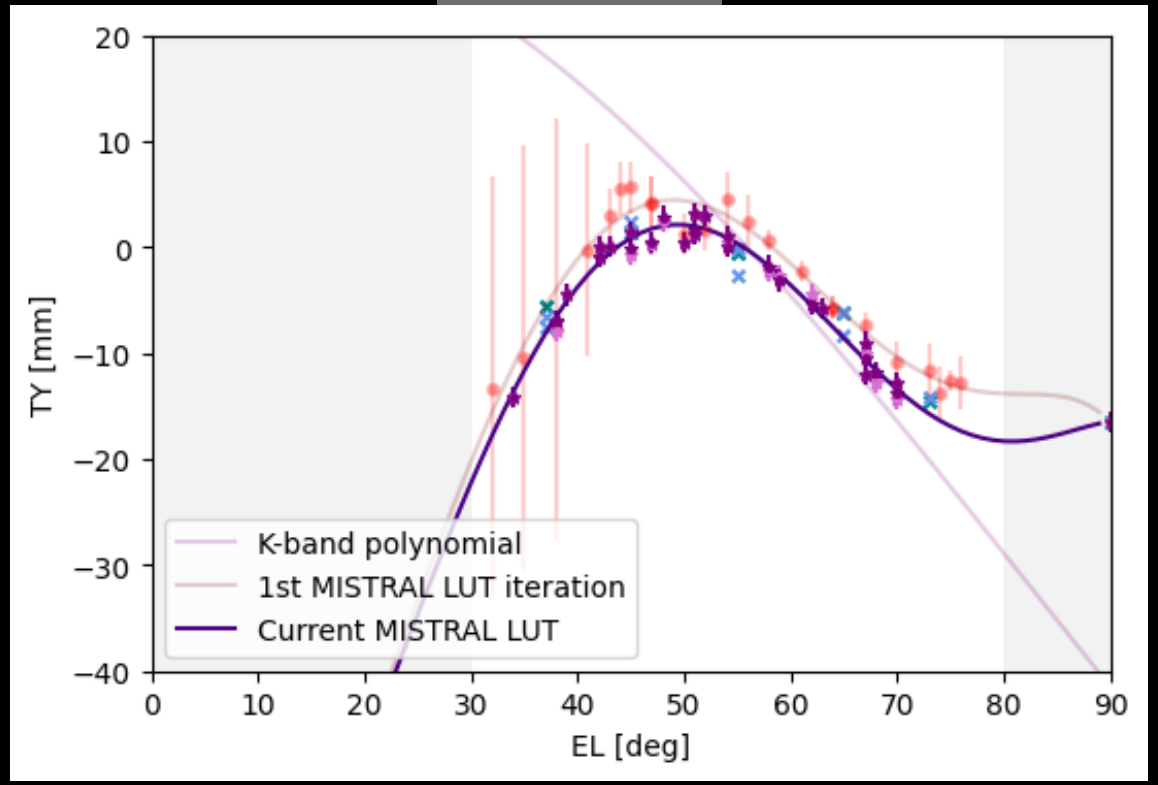
For as many elevations as possible, we observed the TZ-TY «matrices» and, consequently, the aberration merit function to be minimized.



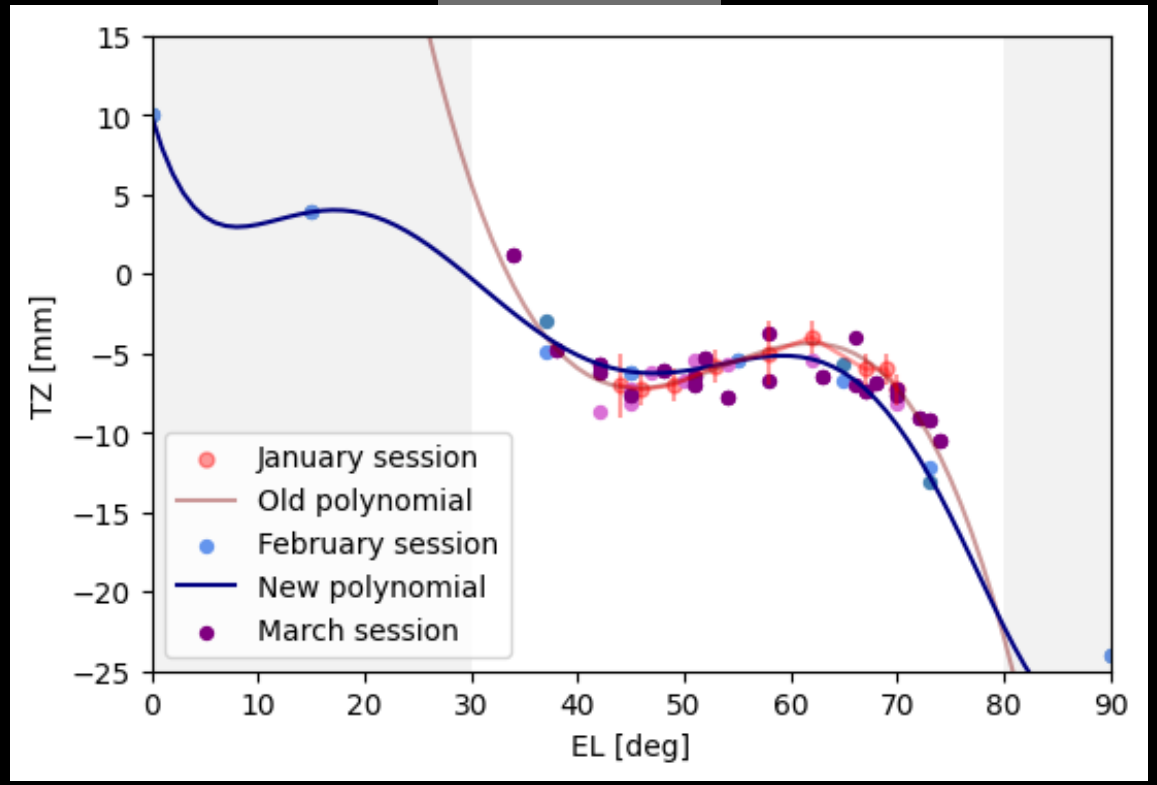


M2 LUT

TY LUT

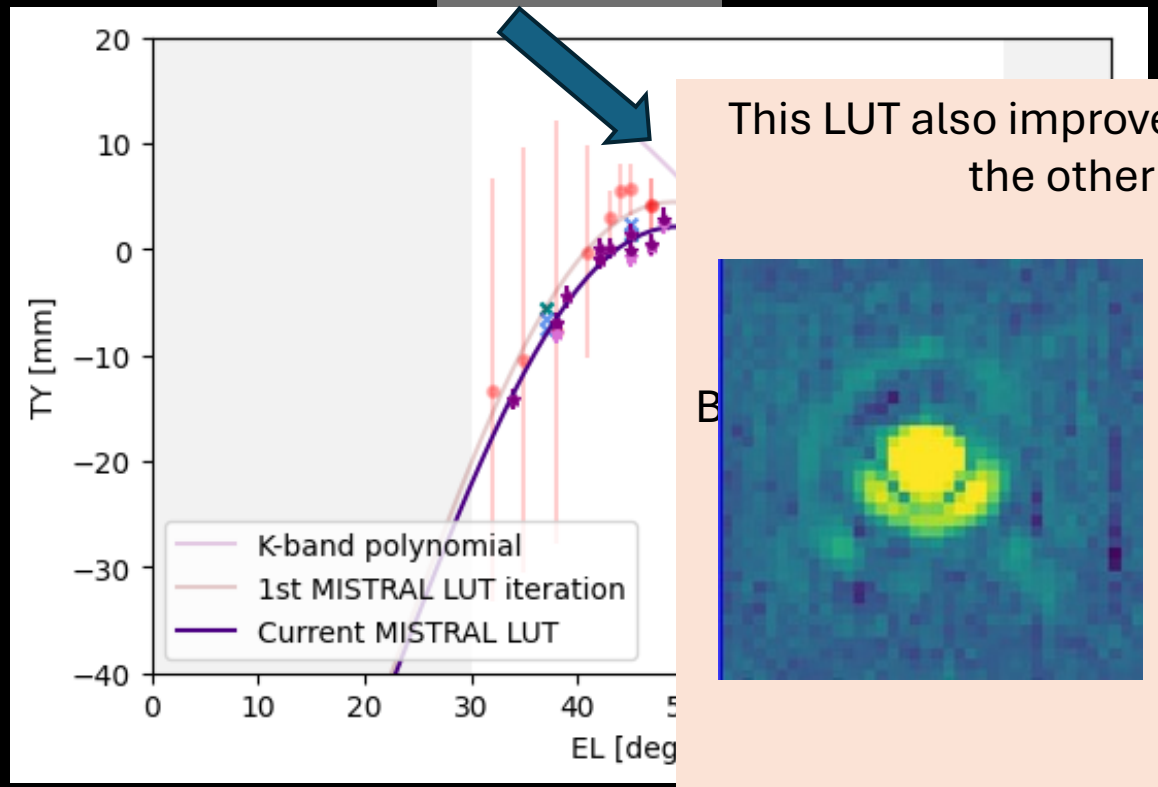


TZ LUT

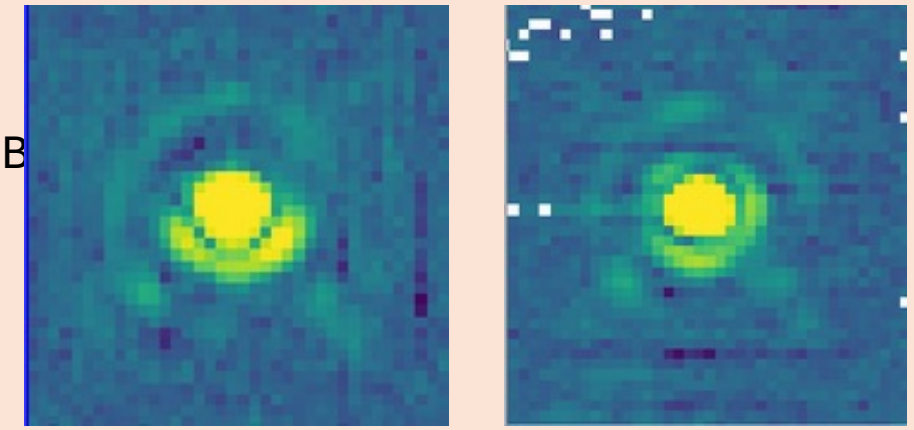


M2 LUT

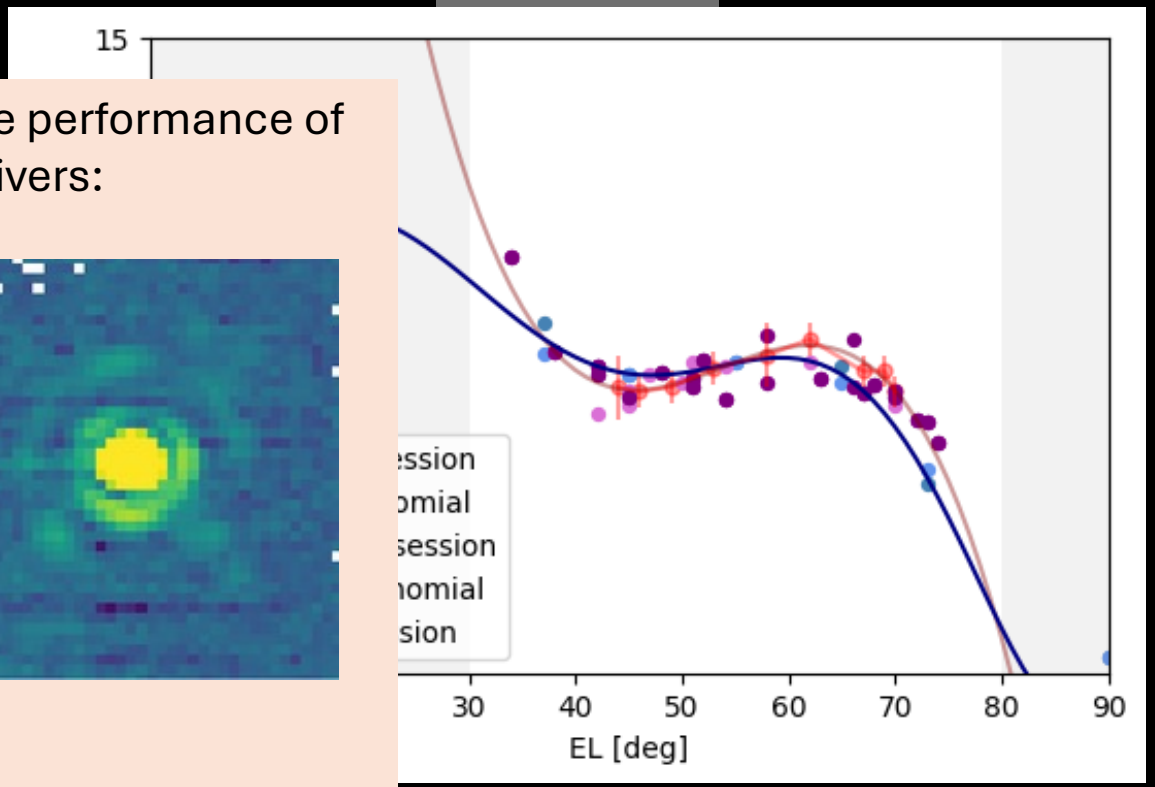
TY LUT



This LUT also improved the performance of the other receivers:



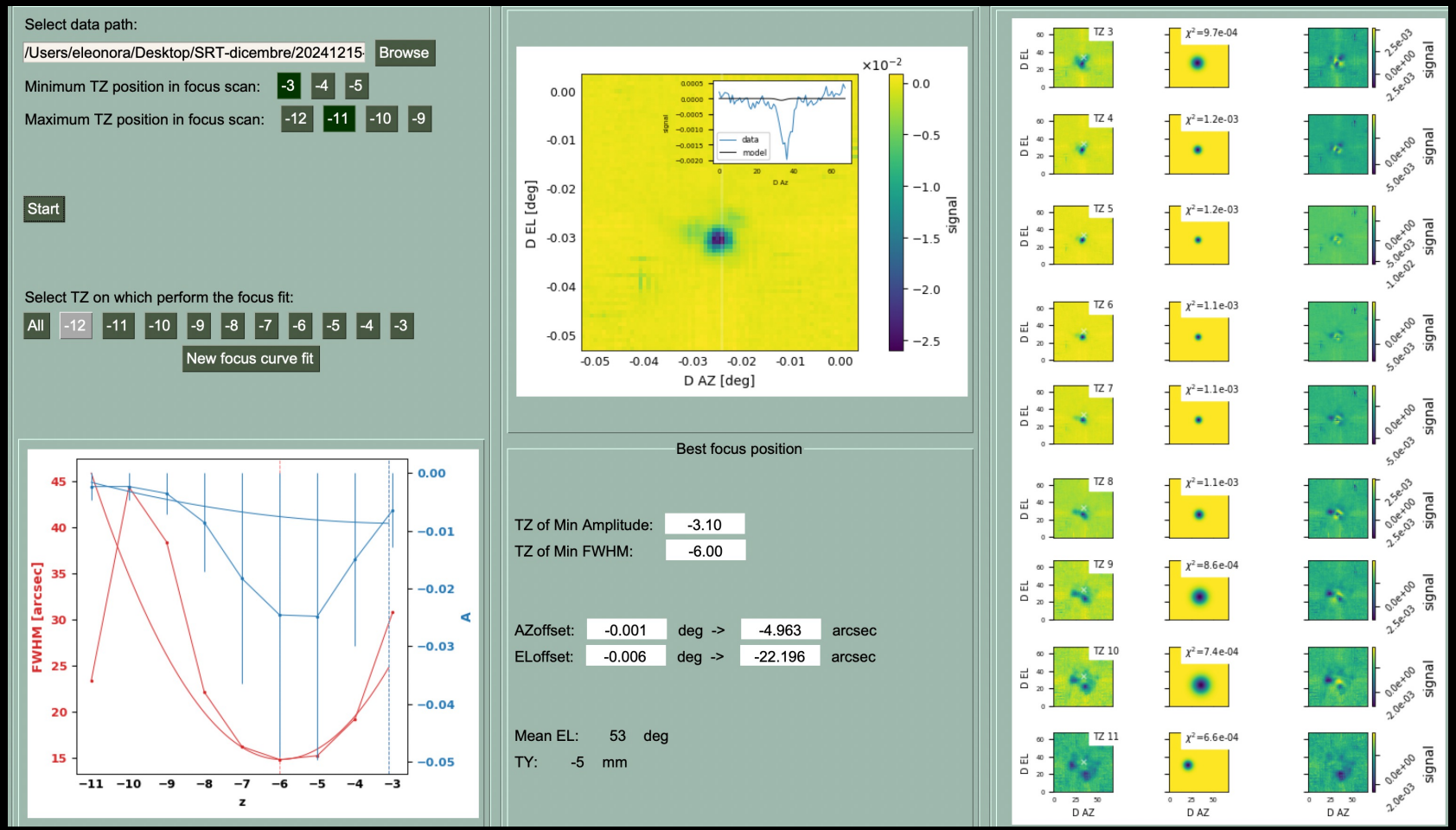
TZ LUT



Focusing during observations

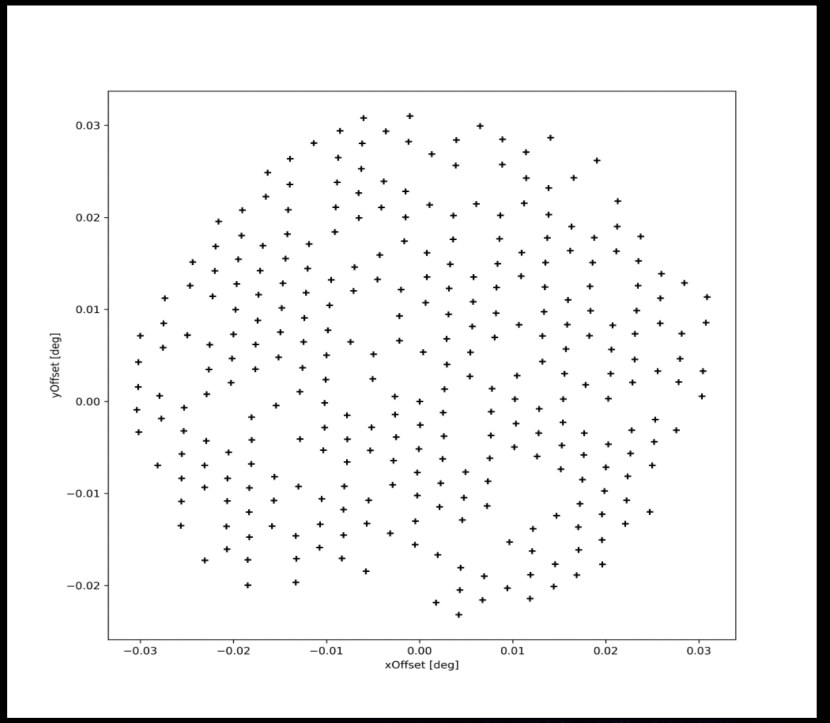
During the observations, the focusing process is almost automatic and takes few minutes.

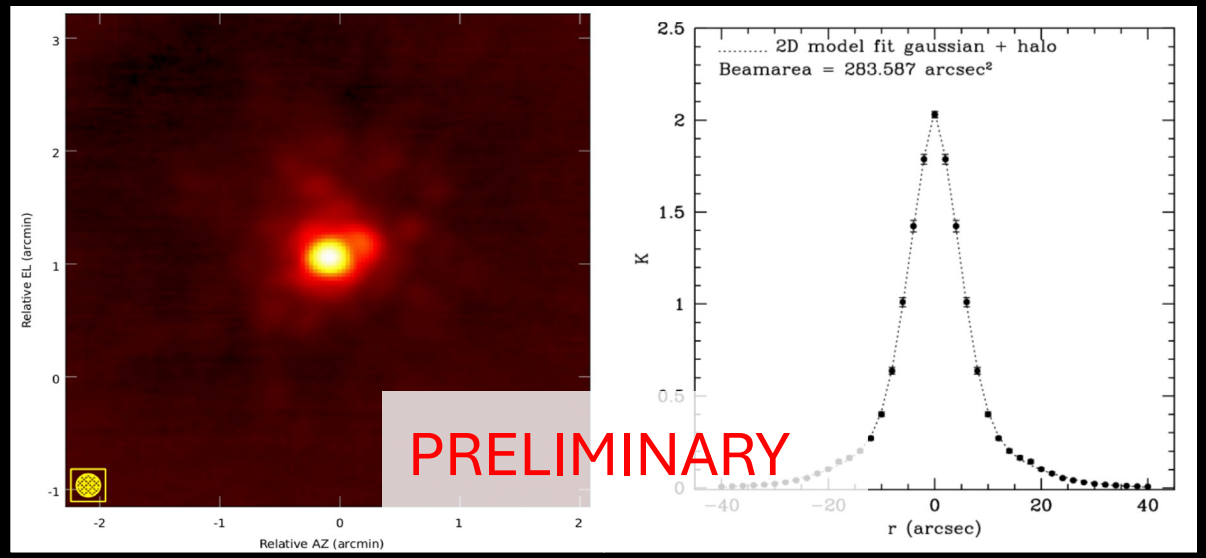
This GUI manages MISTRAL's focusing and displays the focus curve in both amplitude and FWHM and it finds the best TZ position.

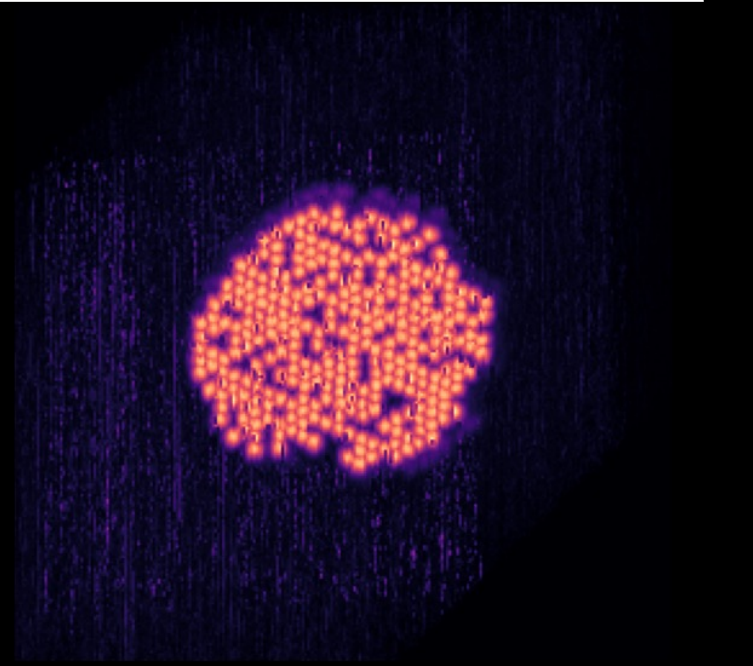


Beam

- ➔ We use observations of point sources (3c84, Mars, Uranus) to map the position of each detector and characterize the beam
- ➔ Primary beam FWHM ~ 12’’ (consistent with expectations 12.2’’)
- ➔ We model the beam with a double Gaussian: primary beam + diffuse halo
- ➔ Active surface of SRT still under improvement



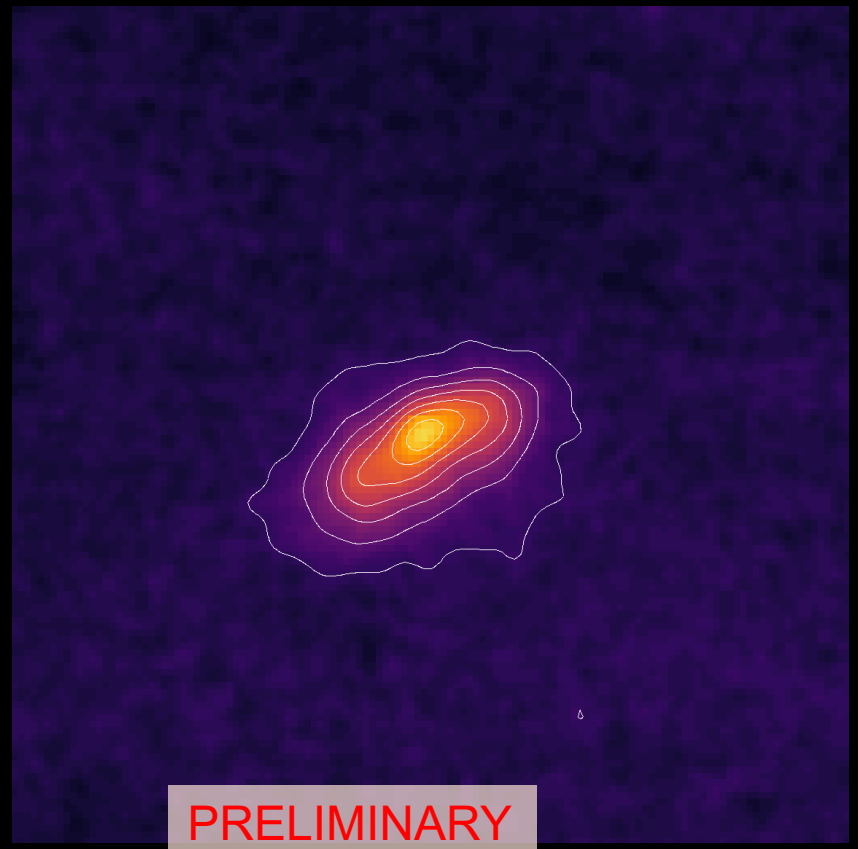




Credits: M. Murgia, M. De Petris

Maps (finally) – **FIRST LIGHT IMAGES**

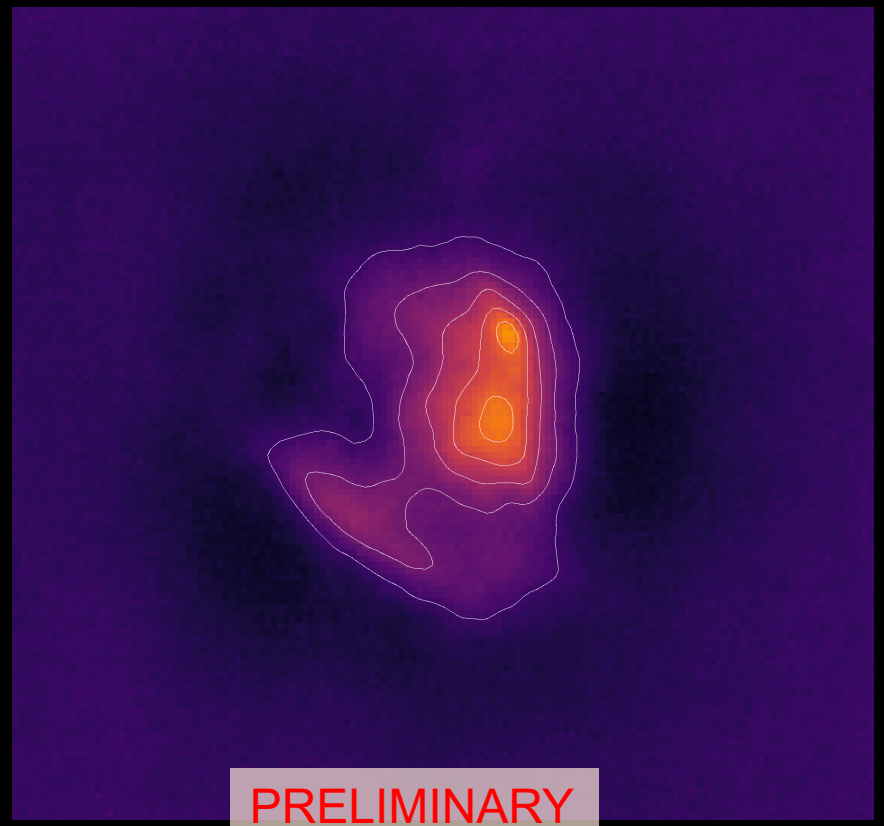
VIRGO A



OACC + SRT/MISTRAL (90 GHz)

Maps (finally) – **FIRST LIGHT IMAGES**

ORION NEBULA



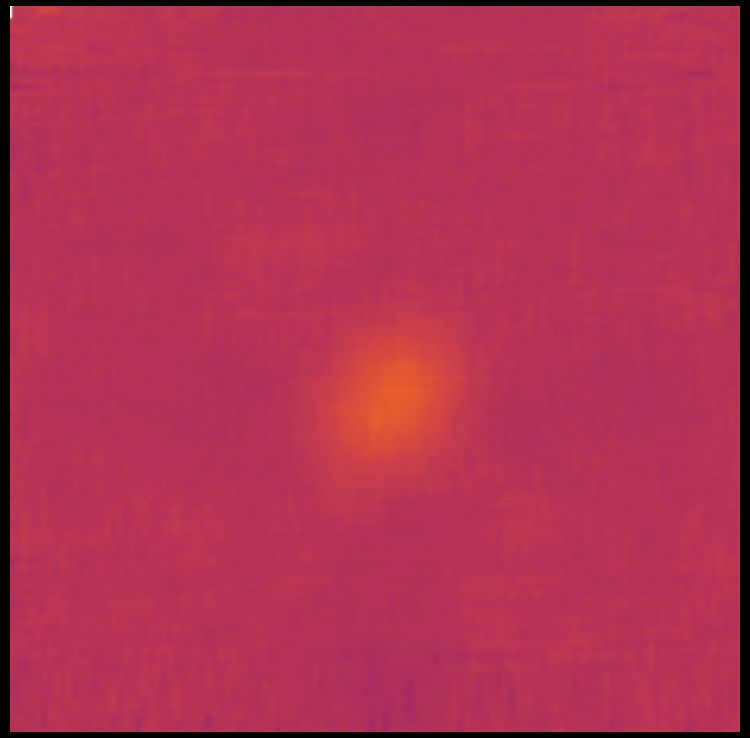
We see also M43 (very faintly)

MISTRAL + HST

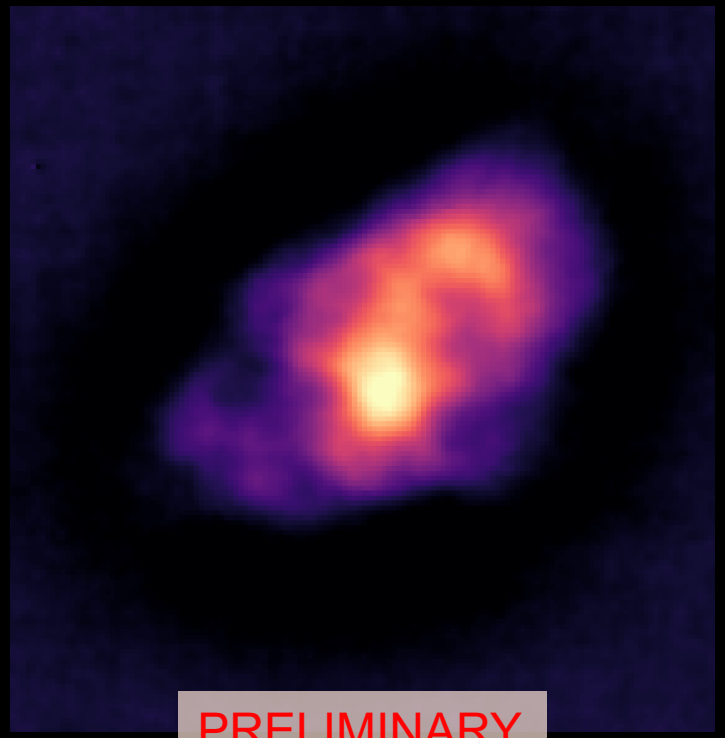
Maps (finally) – work in progress

CRAB NEBULA – before and after.

June 2024

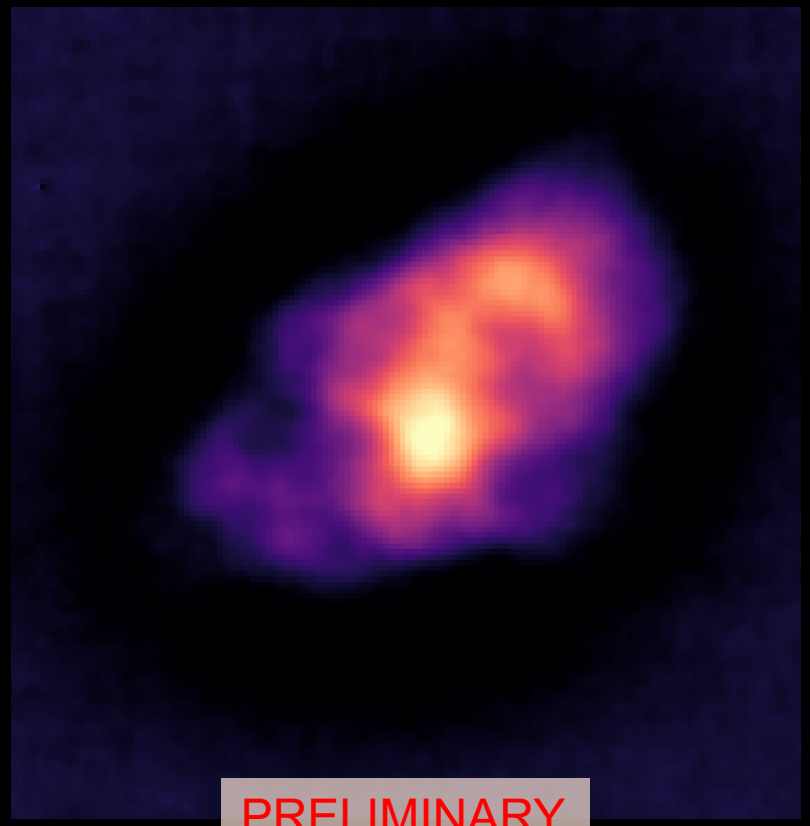


March 2025



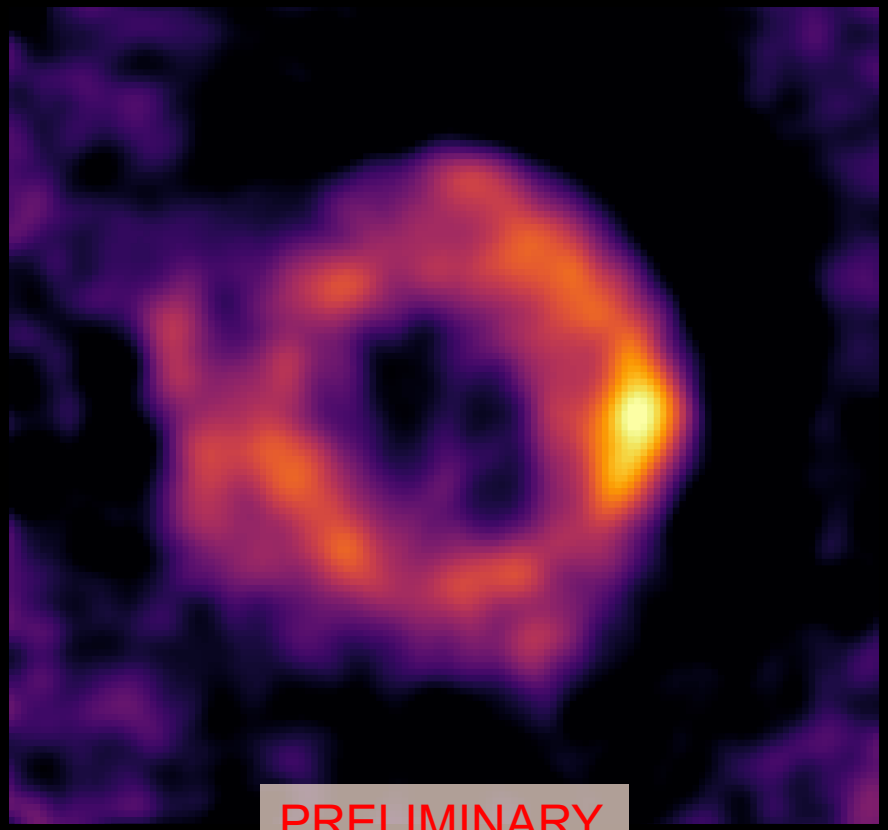
Maps (finally) – work in progress

CRAB NEBULA



Maps (finally) – work in progress

CASSIOPEIA A

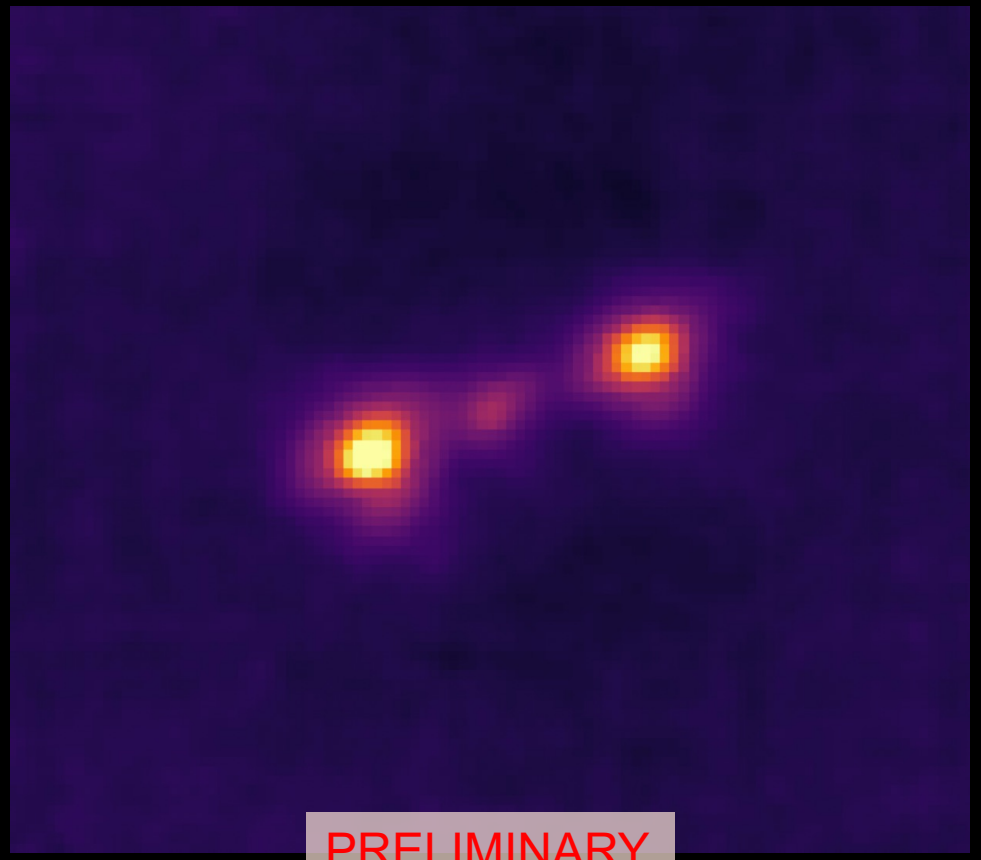


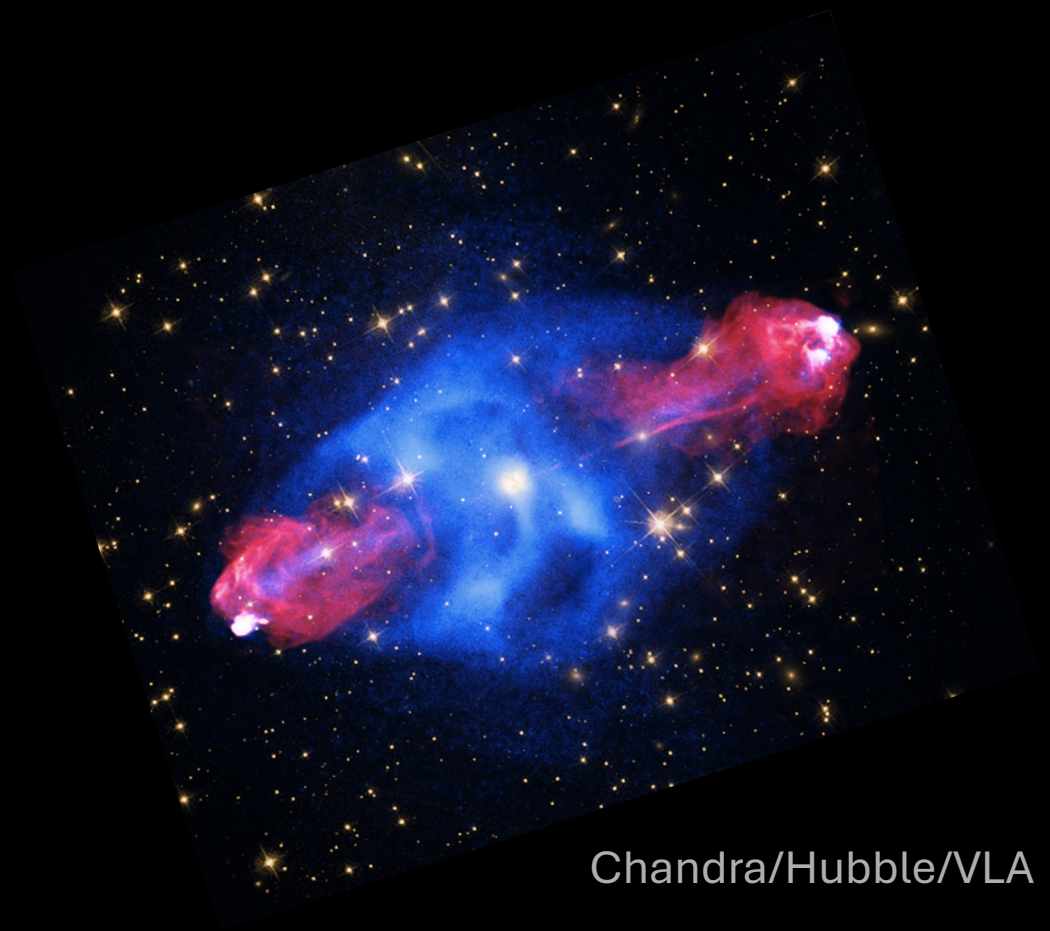
PRELIMINARY

JWST

Maps (finally) – work in progress

CYGNUS A





Chandra/Hubble/VLA


Thank you for your attention!