OBSERVING THE COSMIC WEB THROUGH THE SZ EFFECT WITH MISTRAL

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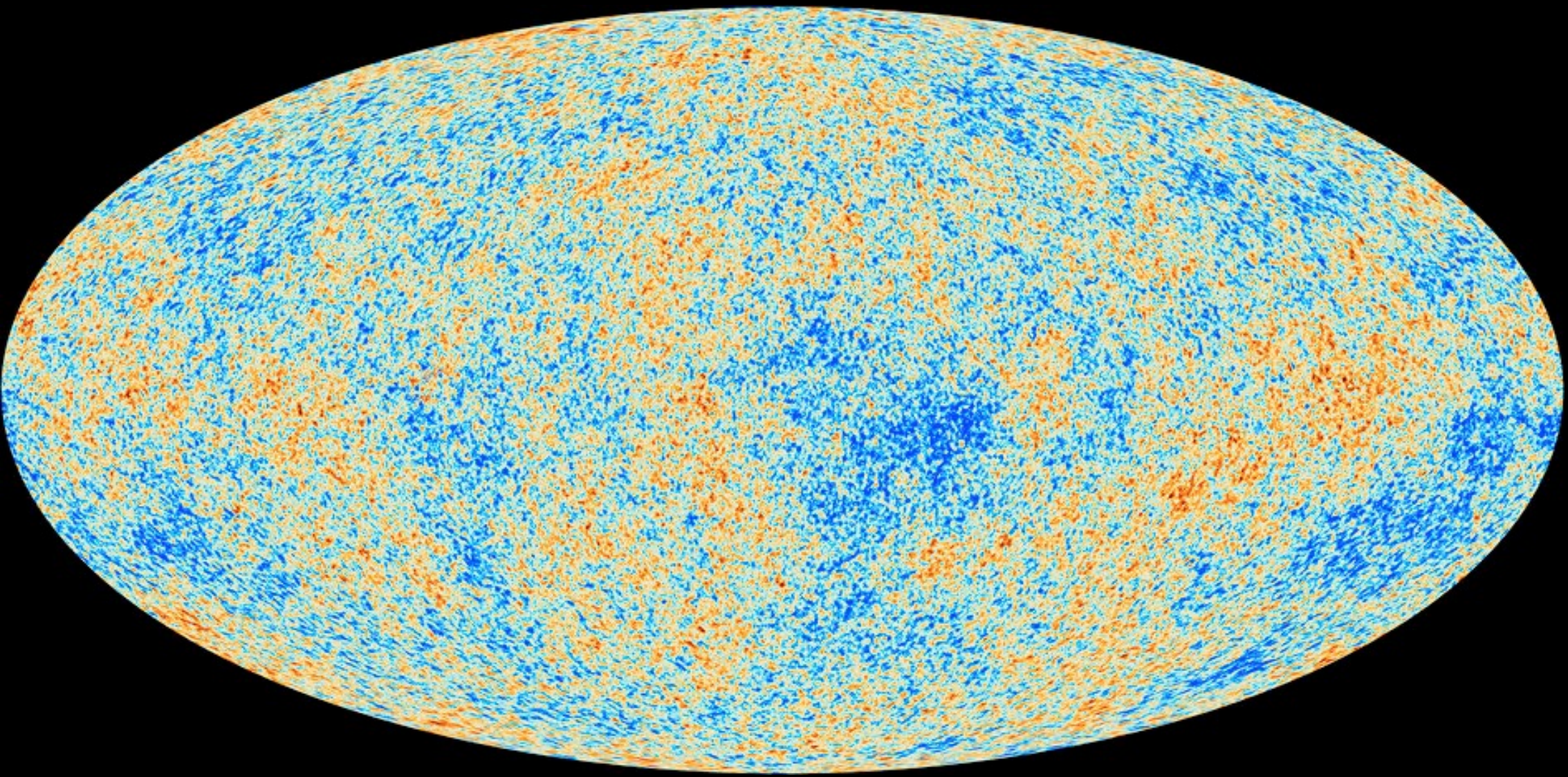
Experimental Cosmology group
Physics department
Sapienza, University of Rome

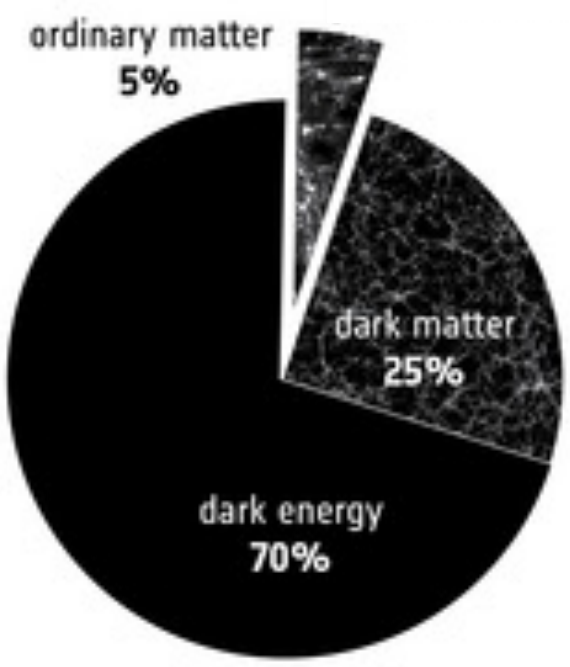
Image credits: cosmic web (http://cosmicweb.kimalbrecht.com/)

COSMIC MICROWAVE BACKGROUND



ESA/Planck Collaboration

ENERGY/MATTER CONTENT



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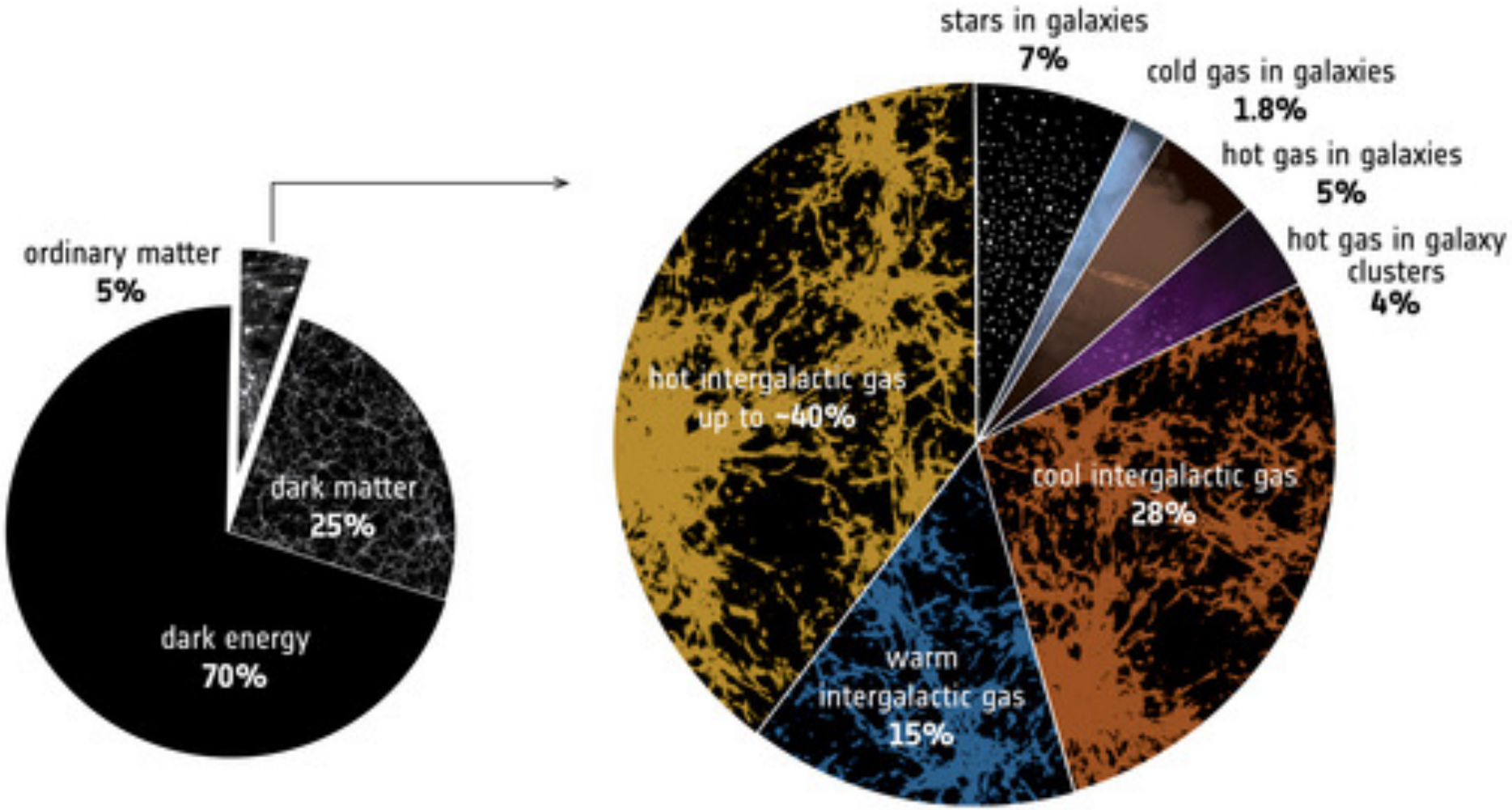


ESA/XMM+Planck Collaboration

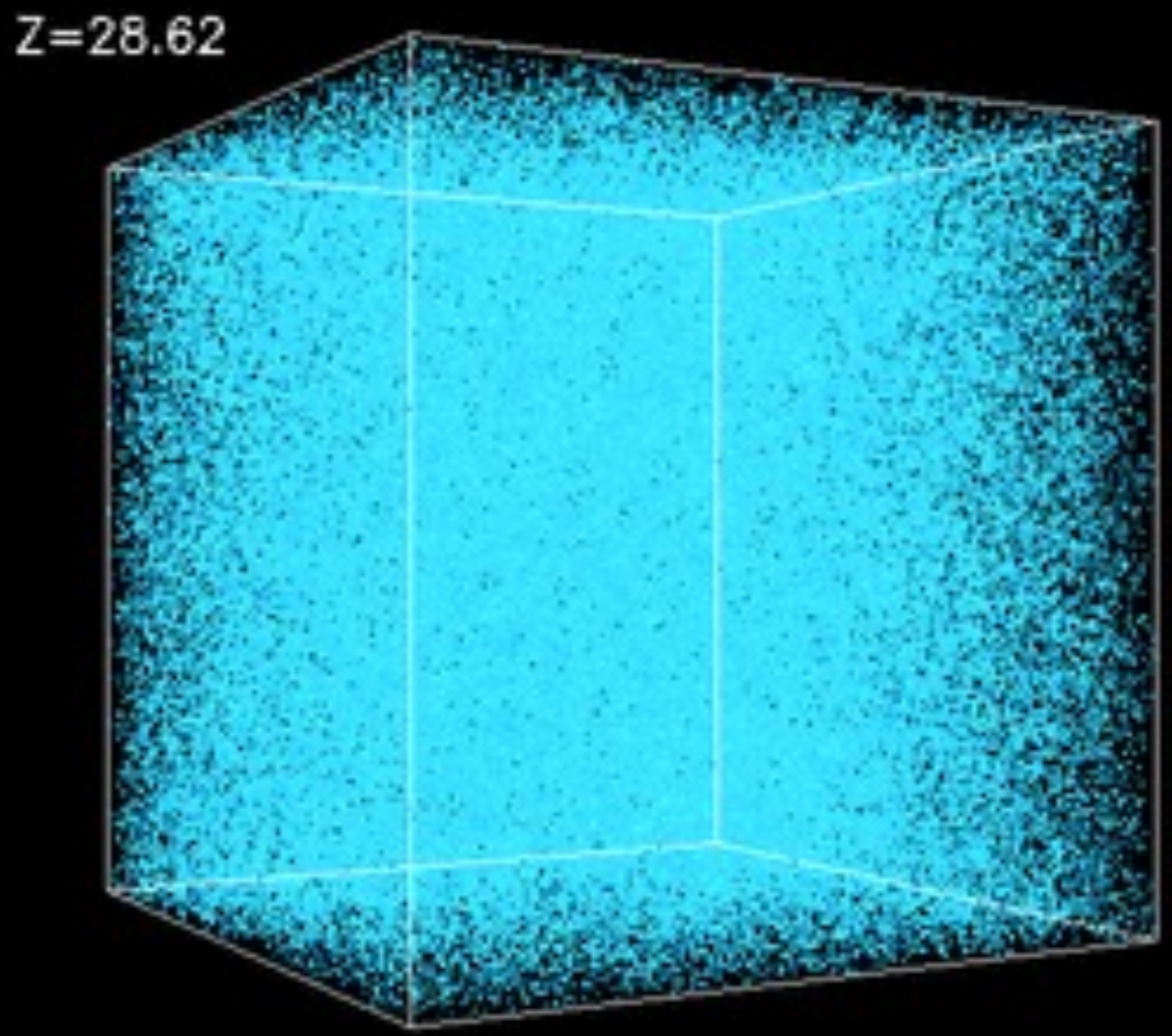
MATTER DISTRIBUTION

- Baryon distribution is still an open issue for modern cosmology: missing baryons problem

- (Magneto-)hydrodynamical simulations predict that matter is distributed in a so-called cosmic web distribution:
  - 1-axis collapse → walls
  - 2-axis collapse → filaments
  - 3-axis collapse → knots (GC)

- The evolution is influenced by dark matter and dark energy

- Missing baryons are expected to be distributed as over-densities in filamentary structures



Acknowledgements: A. Kravstov, http://cosmicweb.uchicago.edu/index.html

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  - 1-axis collapse → walls
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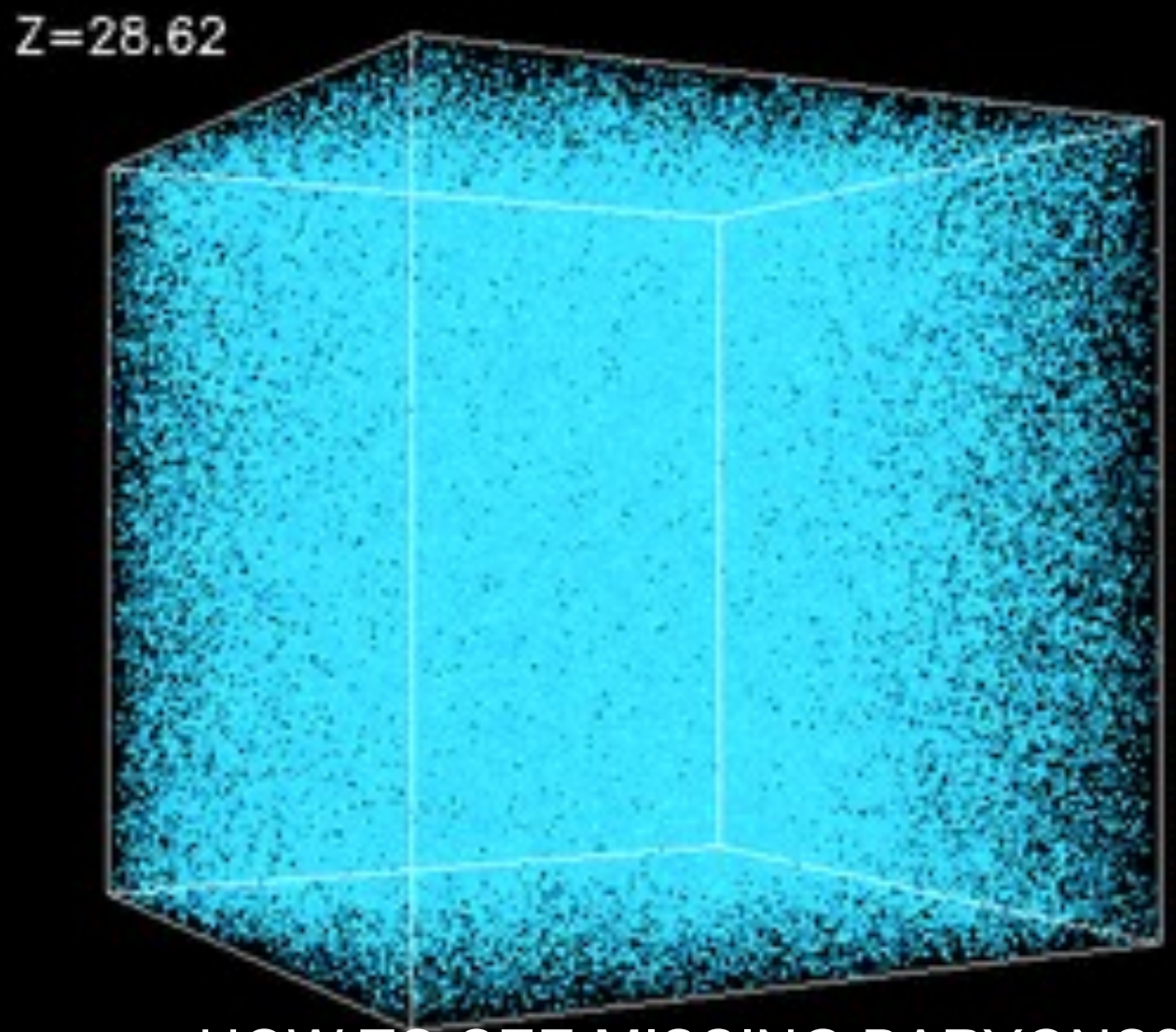
- The evolution is influenced by dark matter and dark energy
- Missing baryons are expected to be distributed as over-densities in filamentary structures
- Structure formation proceeds hierarchically: pre-merging clusters are fundamental



HOW TO SEE MISSING BARYONS?

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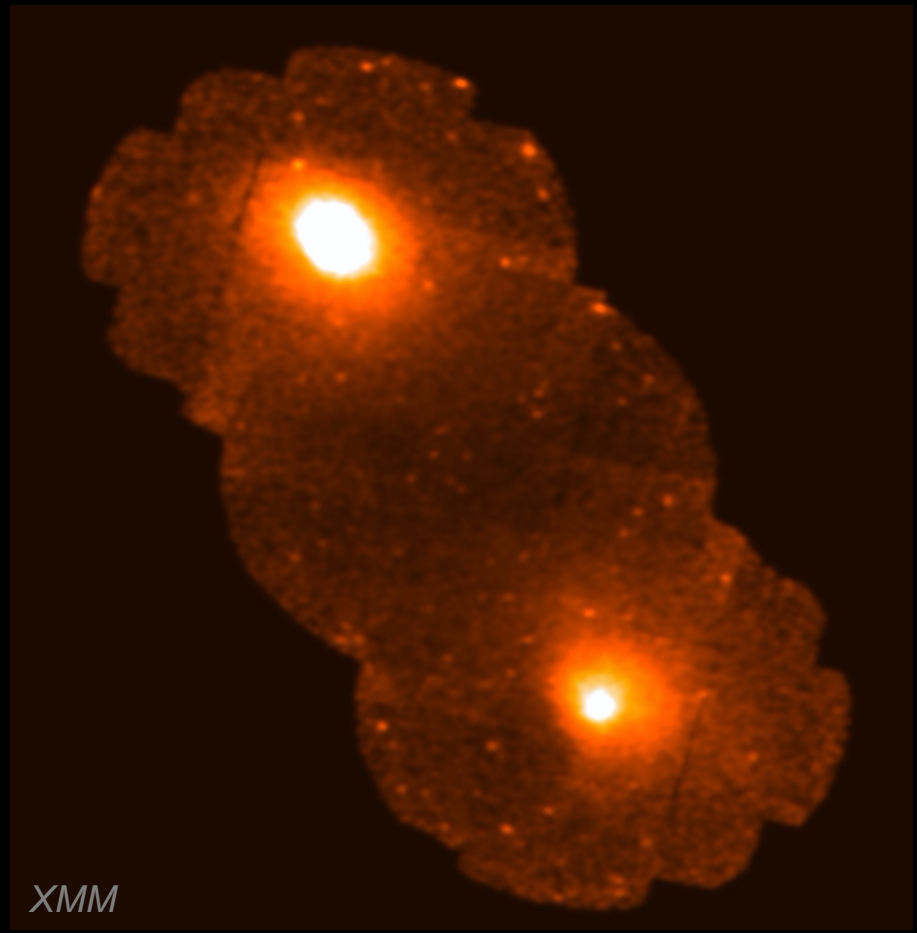
ABELL 401-ABELL 399 PAIR

CLUSTER PAIR: A399-A401

- A401-A399 are two relaxed clusters in pre-merging conditions
- They emit via Brehmstrahlung emission:

$$X_{br} \propto n_e^2 \cdot \sqrt{T_e} \cdot l$$



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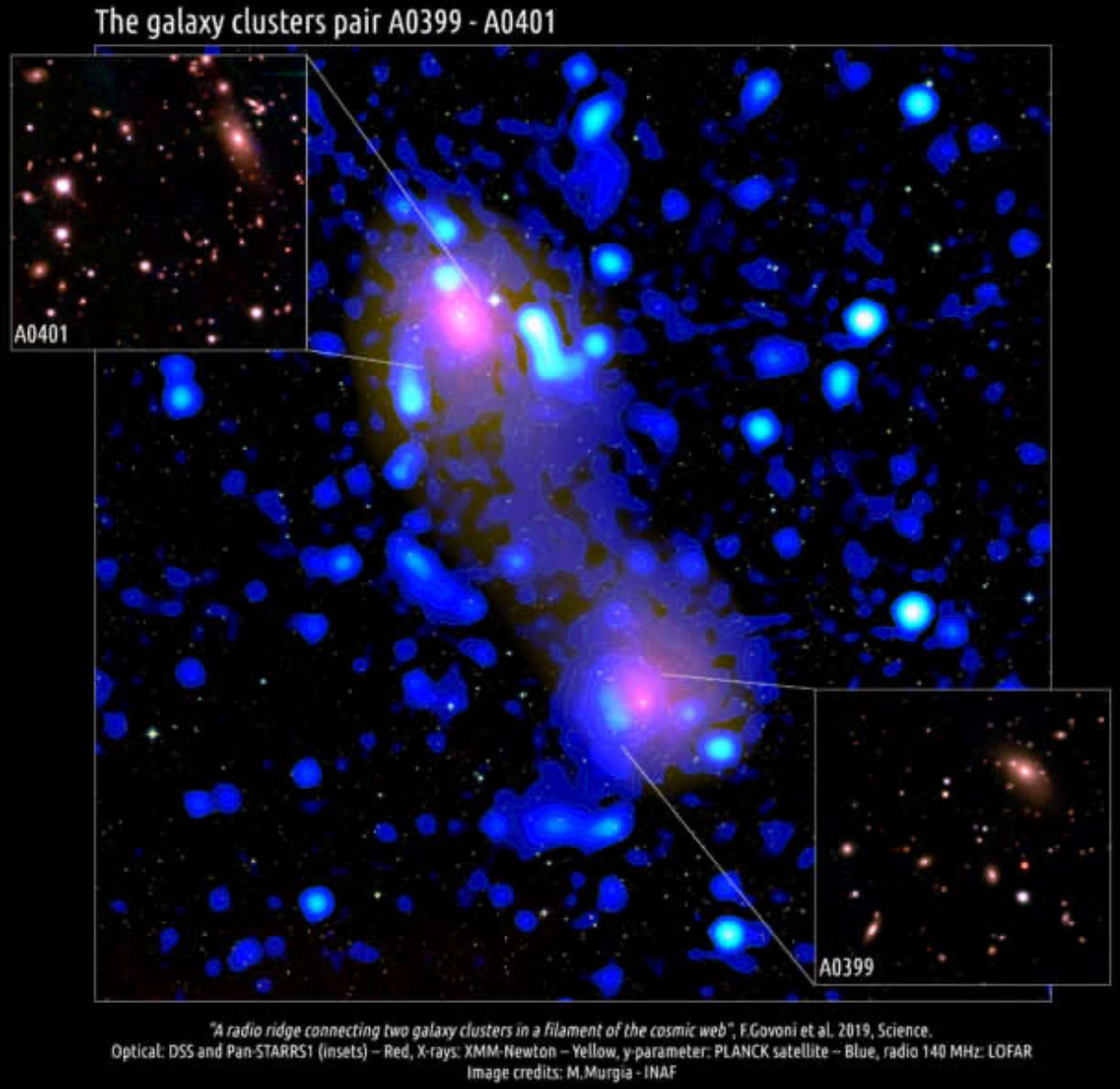

Govoni et al. Science 2019

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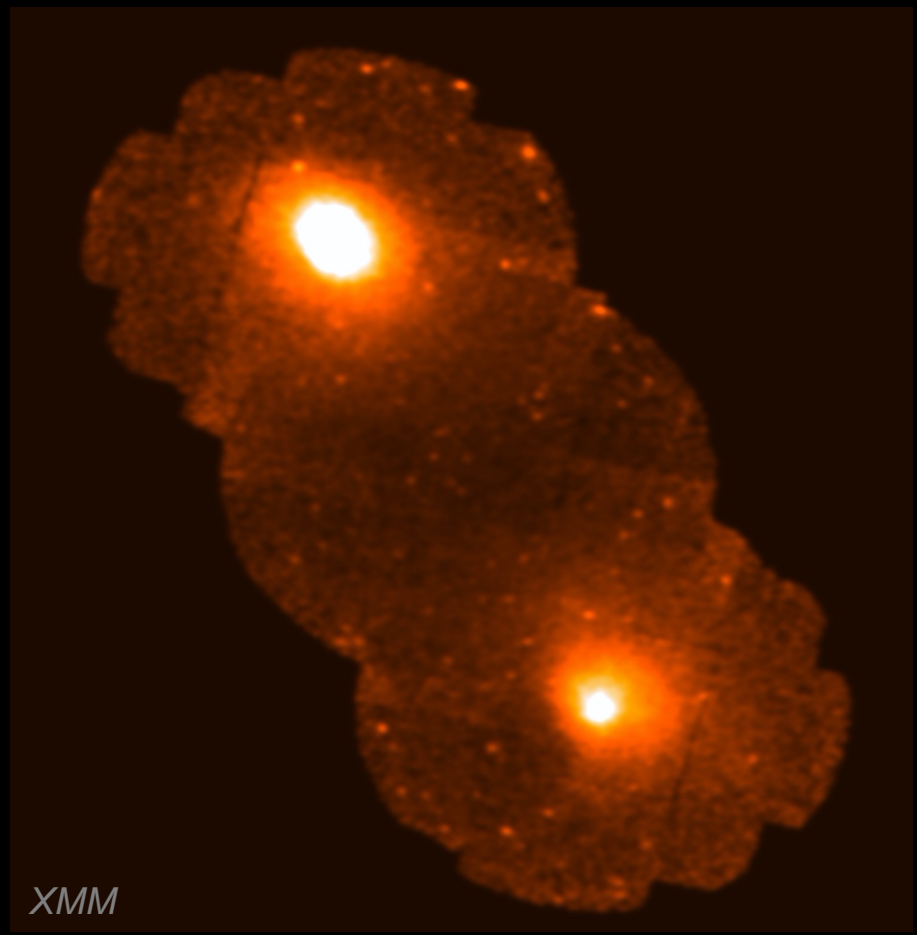

XMM

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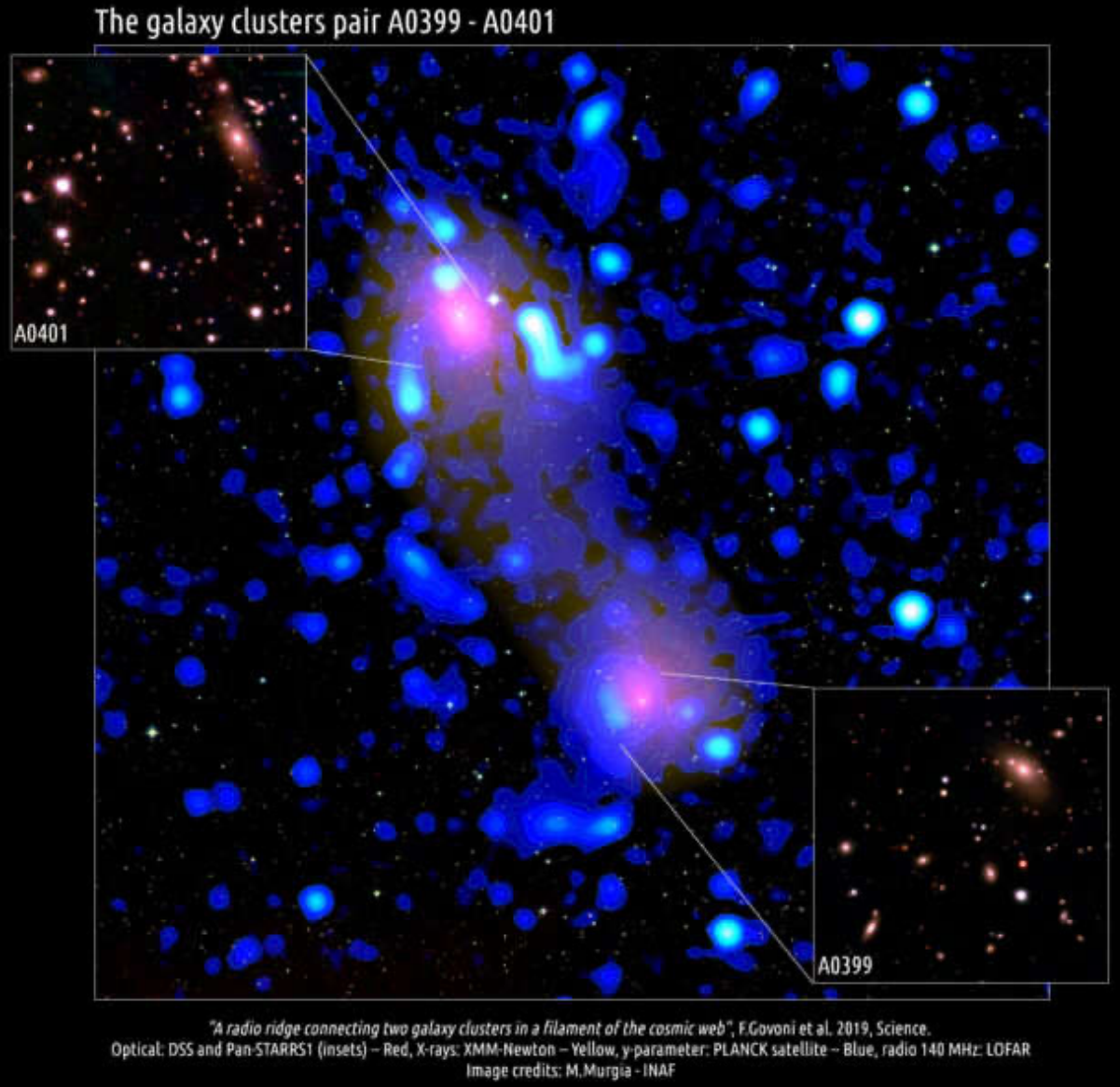
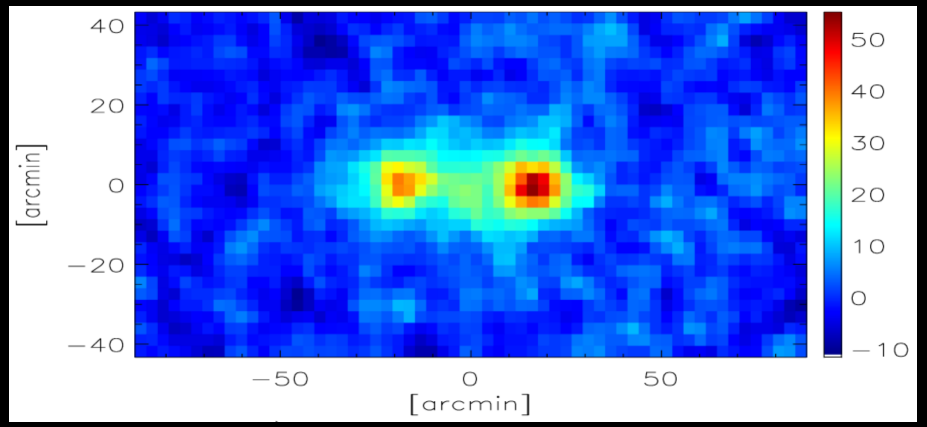
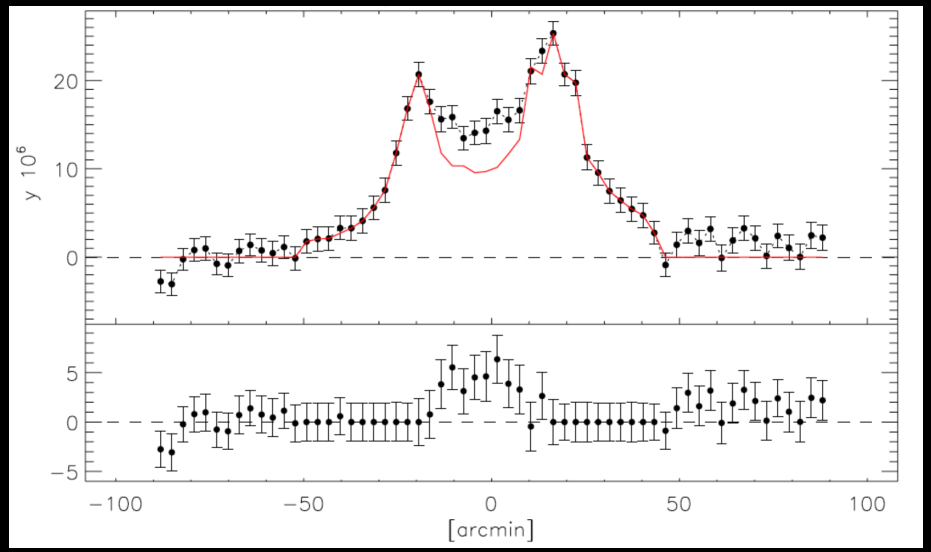


Govoni et al. Science 2019

- SZ is unique for low density envionments:

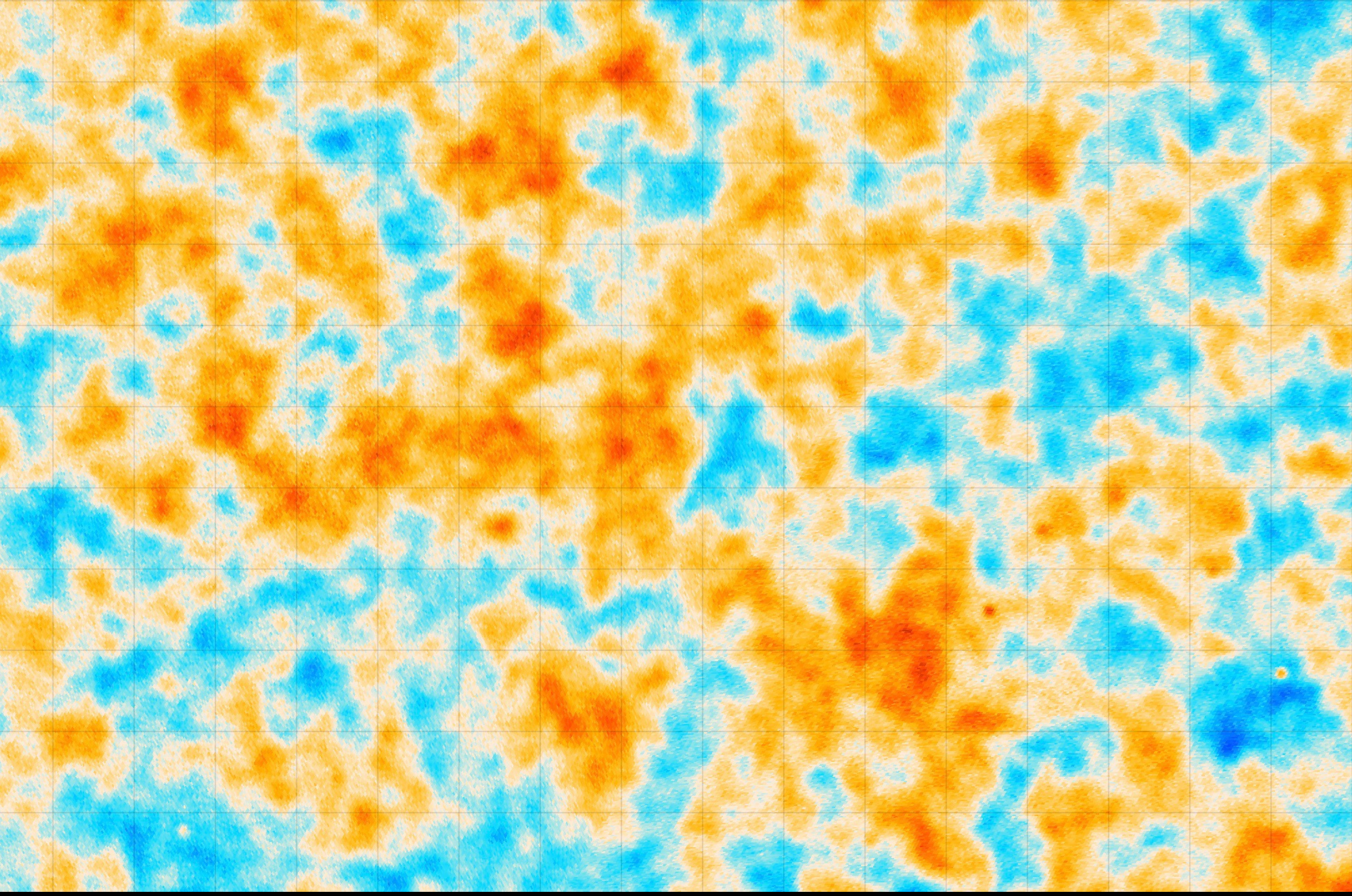
$$y = \int n_e \sigma_T \frac{k_B T_e}{m_e c^2} dl = \tau \theta_e$$





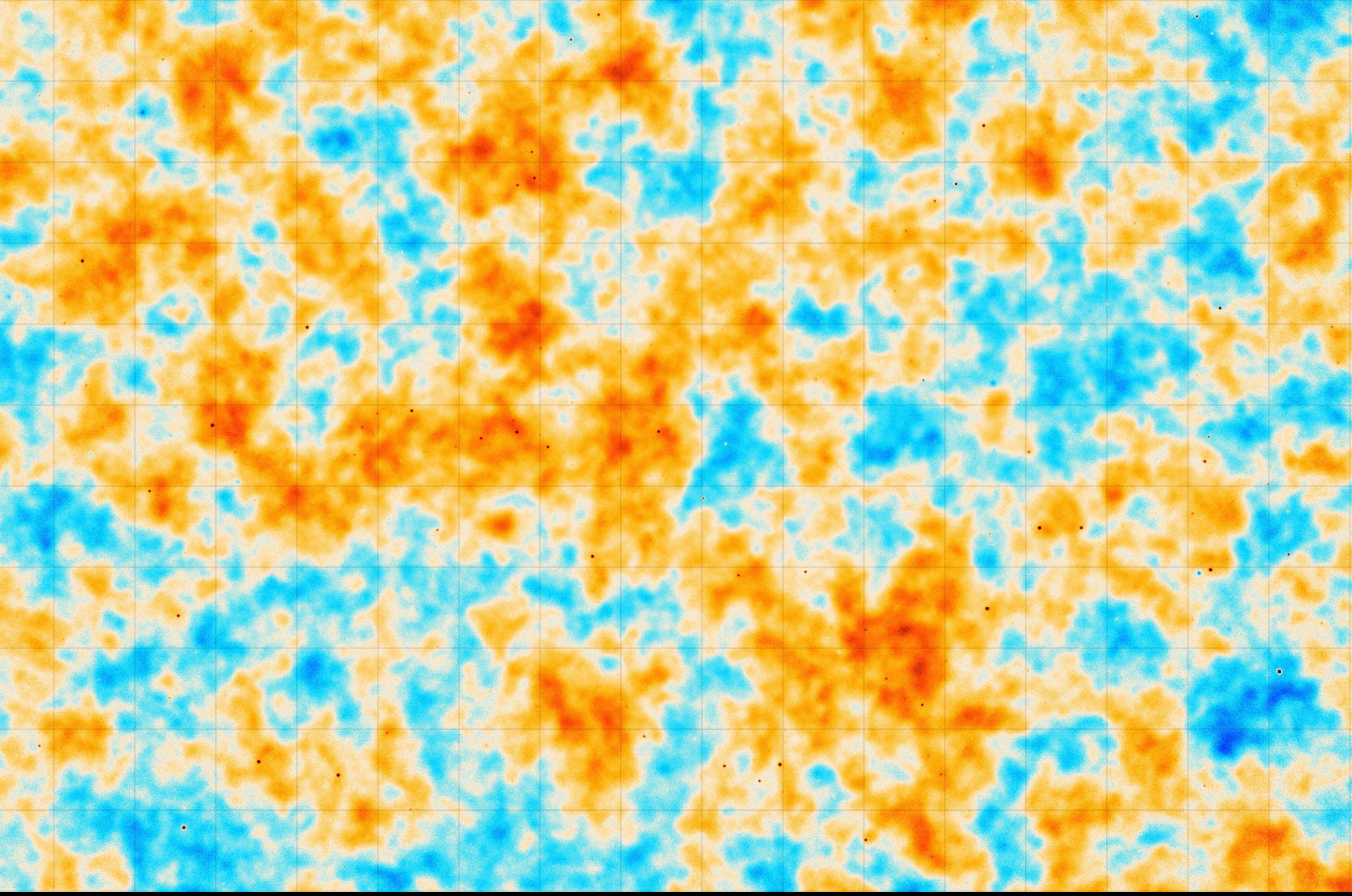
Bonjean et al. A&A 2018

Planck collaboration, A&A 2016



30x22 deg^2 CMB map as seen from Planck (150GHz)

Naess et al. 2020



30x22 deg^2 CMB map as seen from Planck+ACT-DR4 (150GHz)

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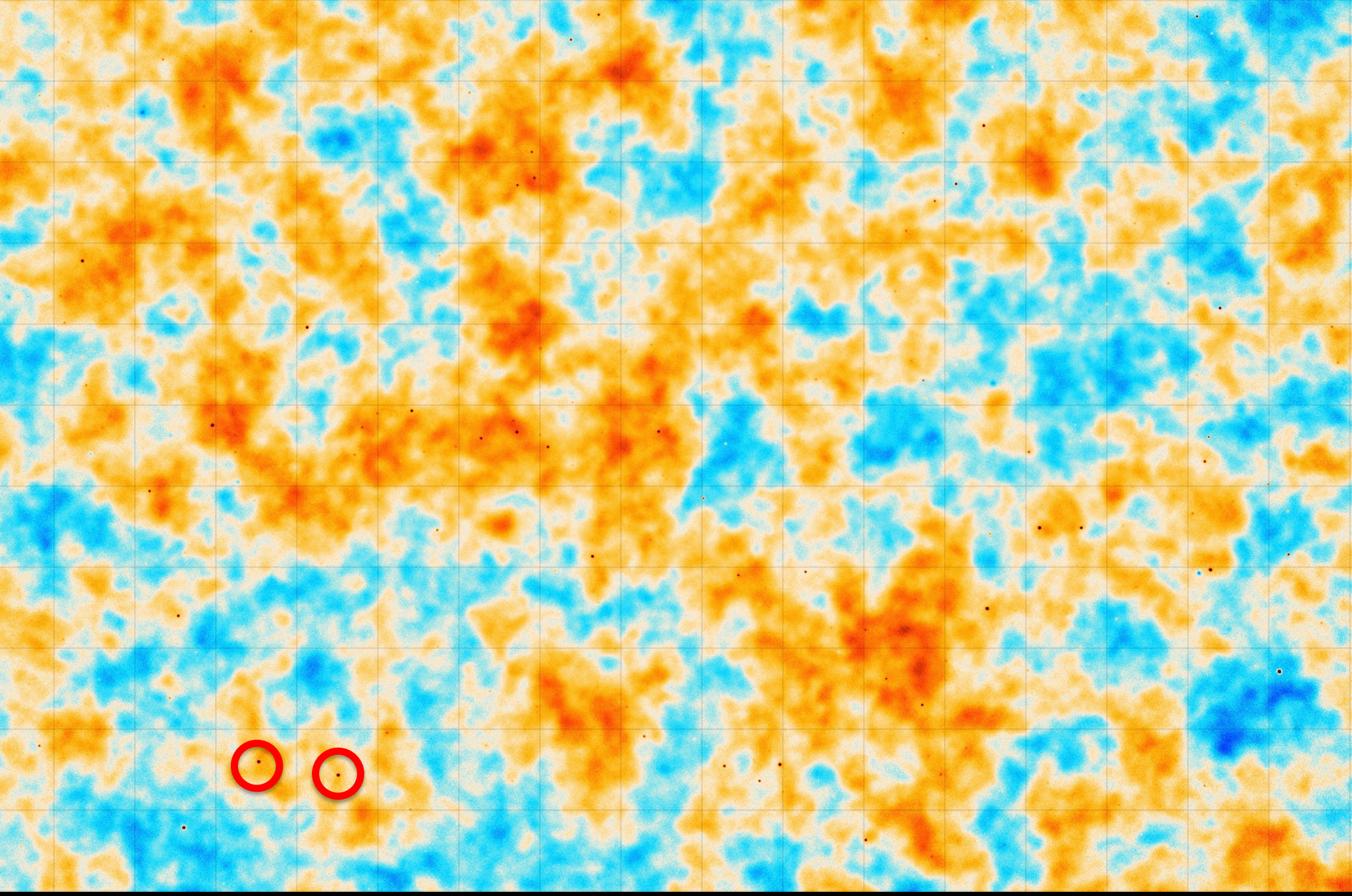

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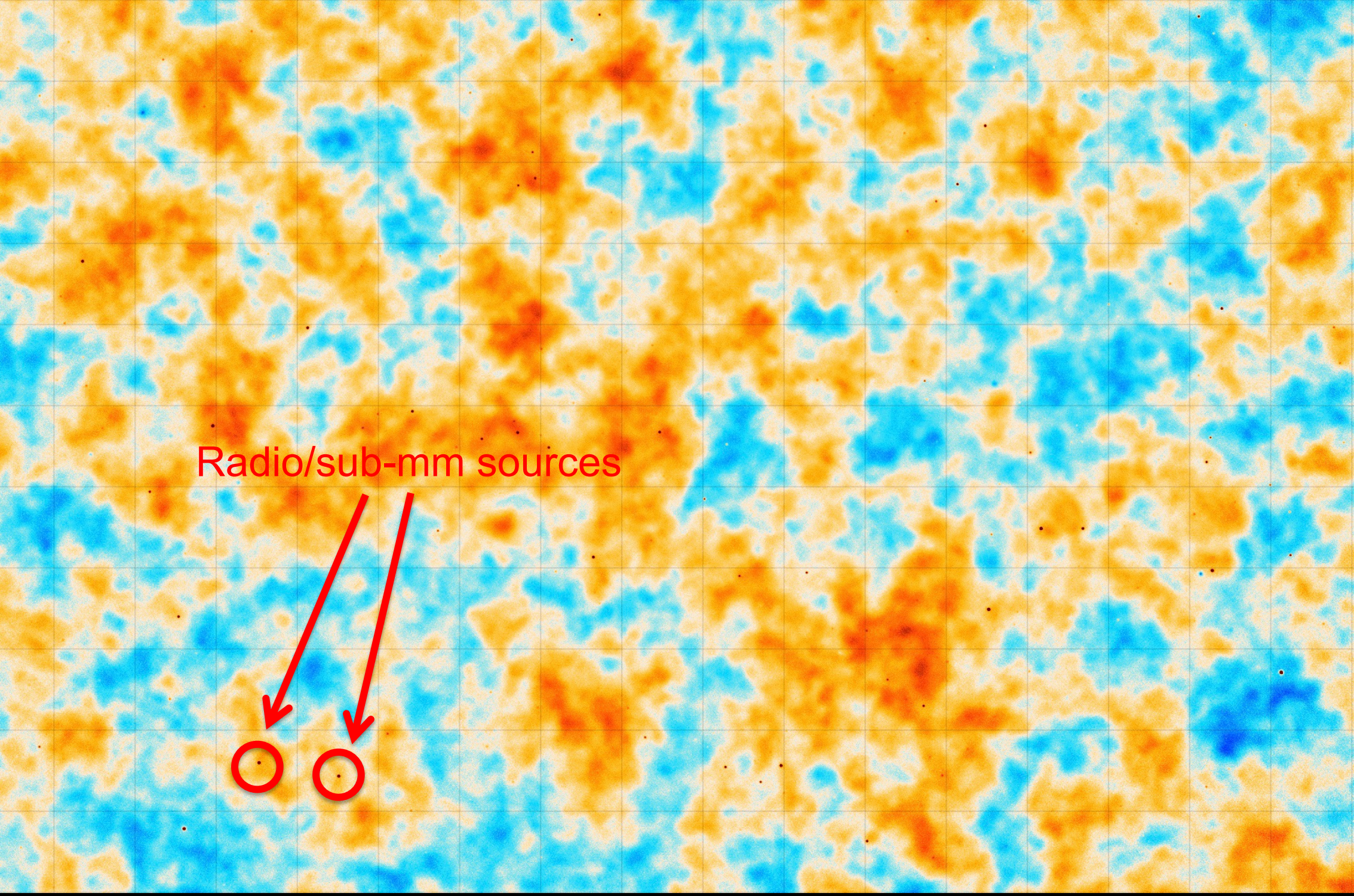

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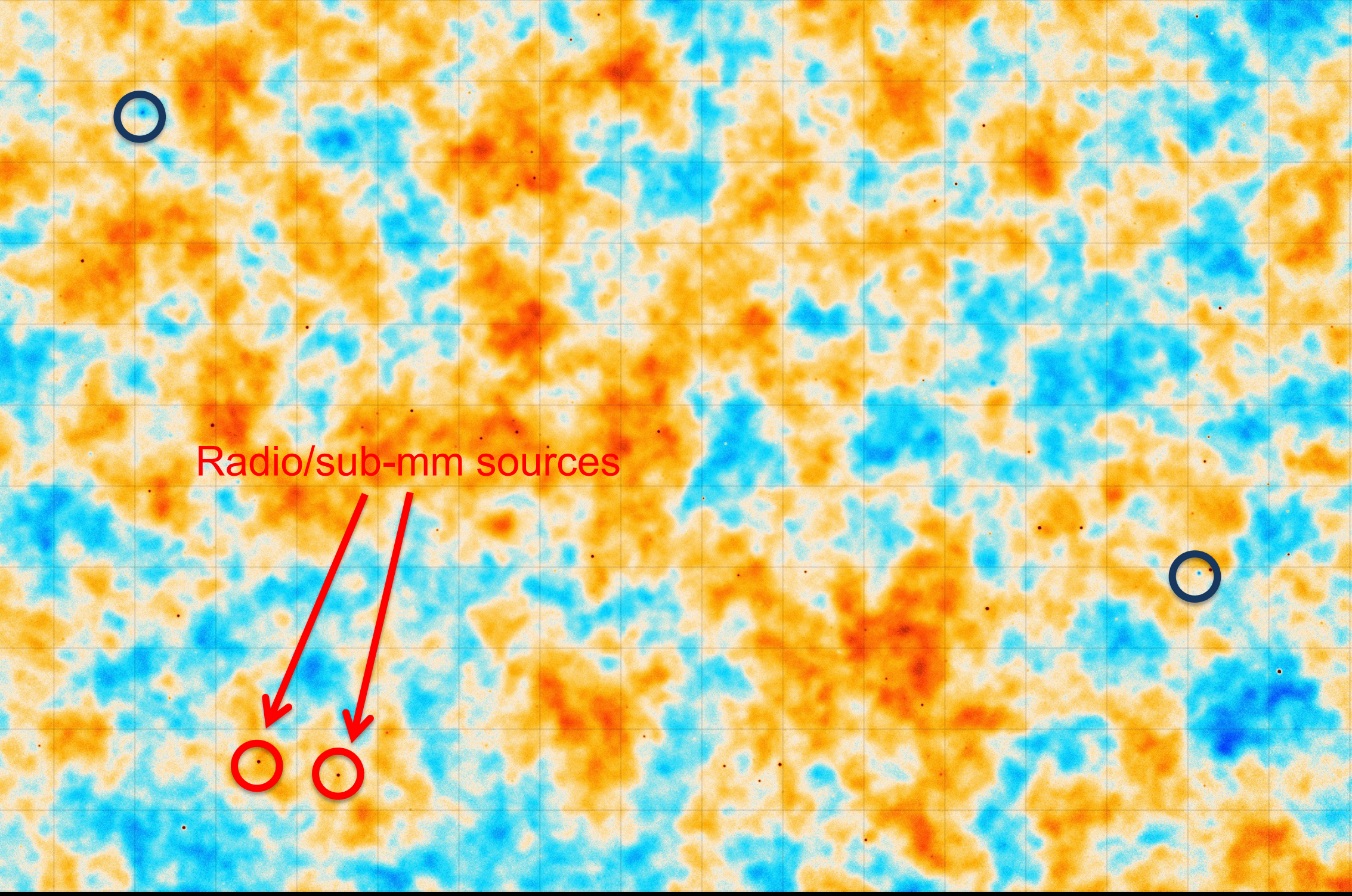

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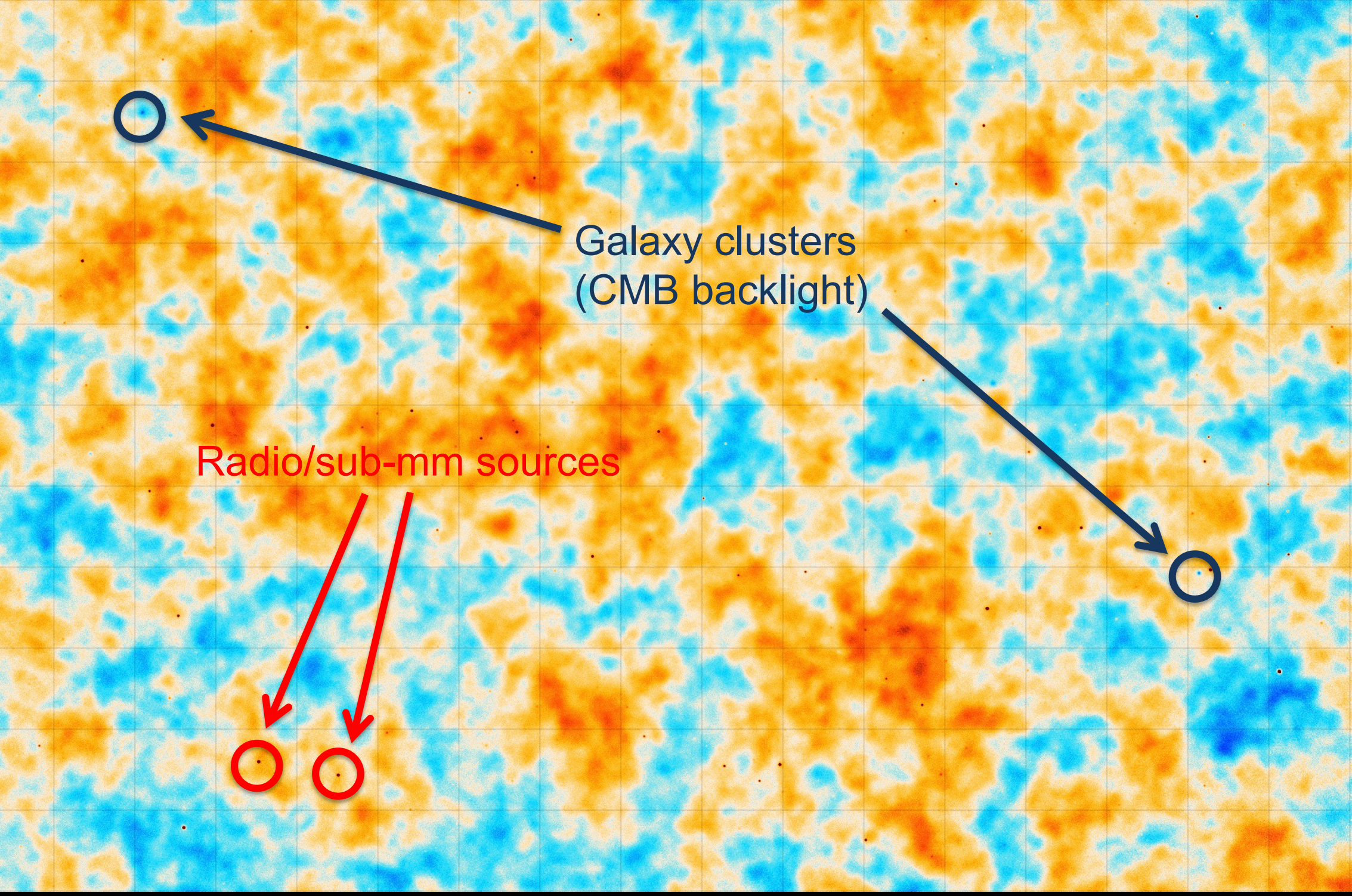

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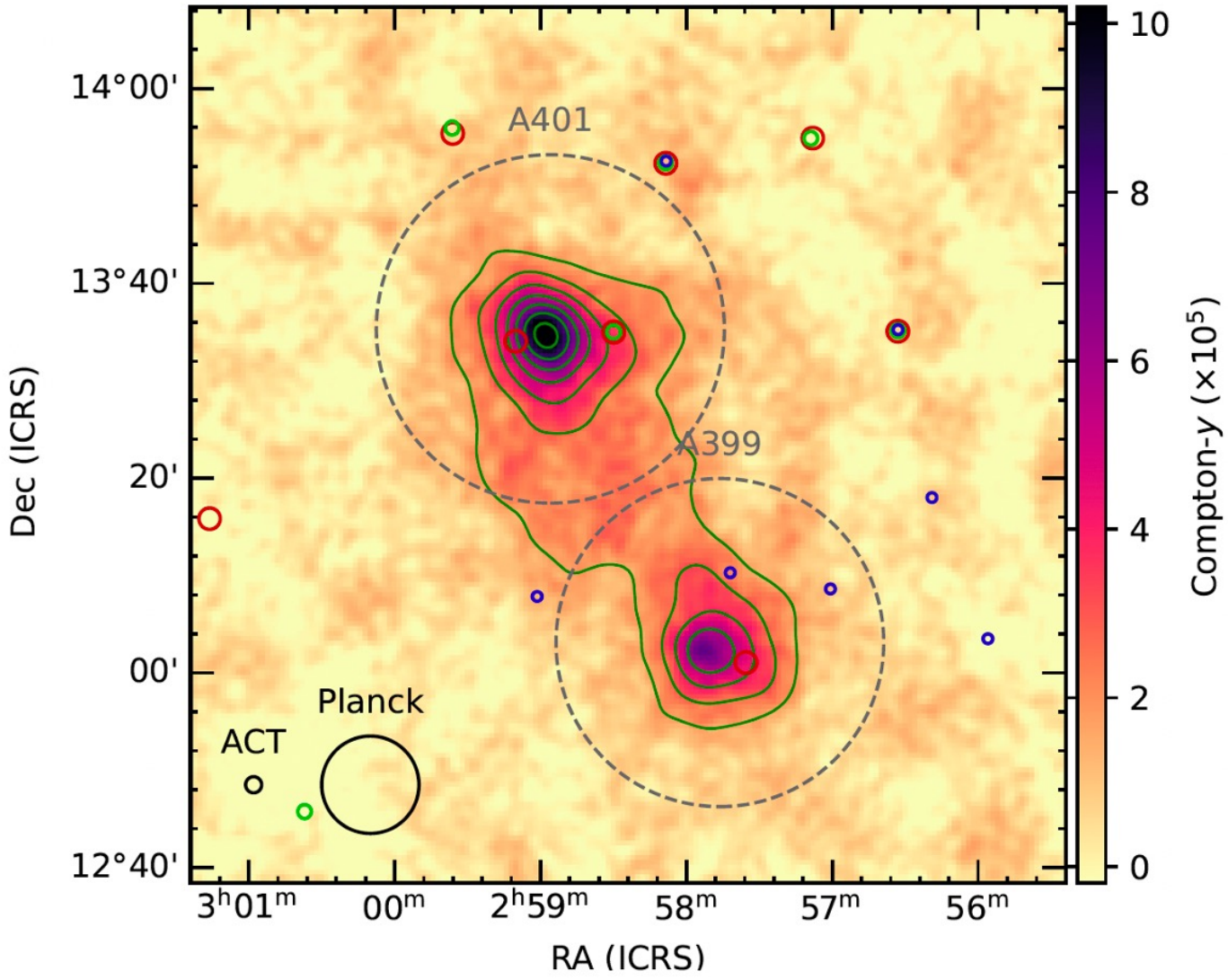
SHARPENING THE IMAGE OF A399-A401: ACT



- Model the image with two clusters only → tension with data
- Model the image with two cluster + a bridge: elliptical β-model + a planar background + a "mesa" model: $y=1.10\pm0.18\ 10^{-5}$
- → good fit with 5.5σ detection
- Total mass = $3.3\pm0.7\ 10^{14}\ M_{sun}$
- Total separation = 12.1 ± 3.9 Mpc (*vs* 3.2Mpc in the sky)

Hincks et al., MNRAS 510, 3335, 2022

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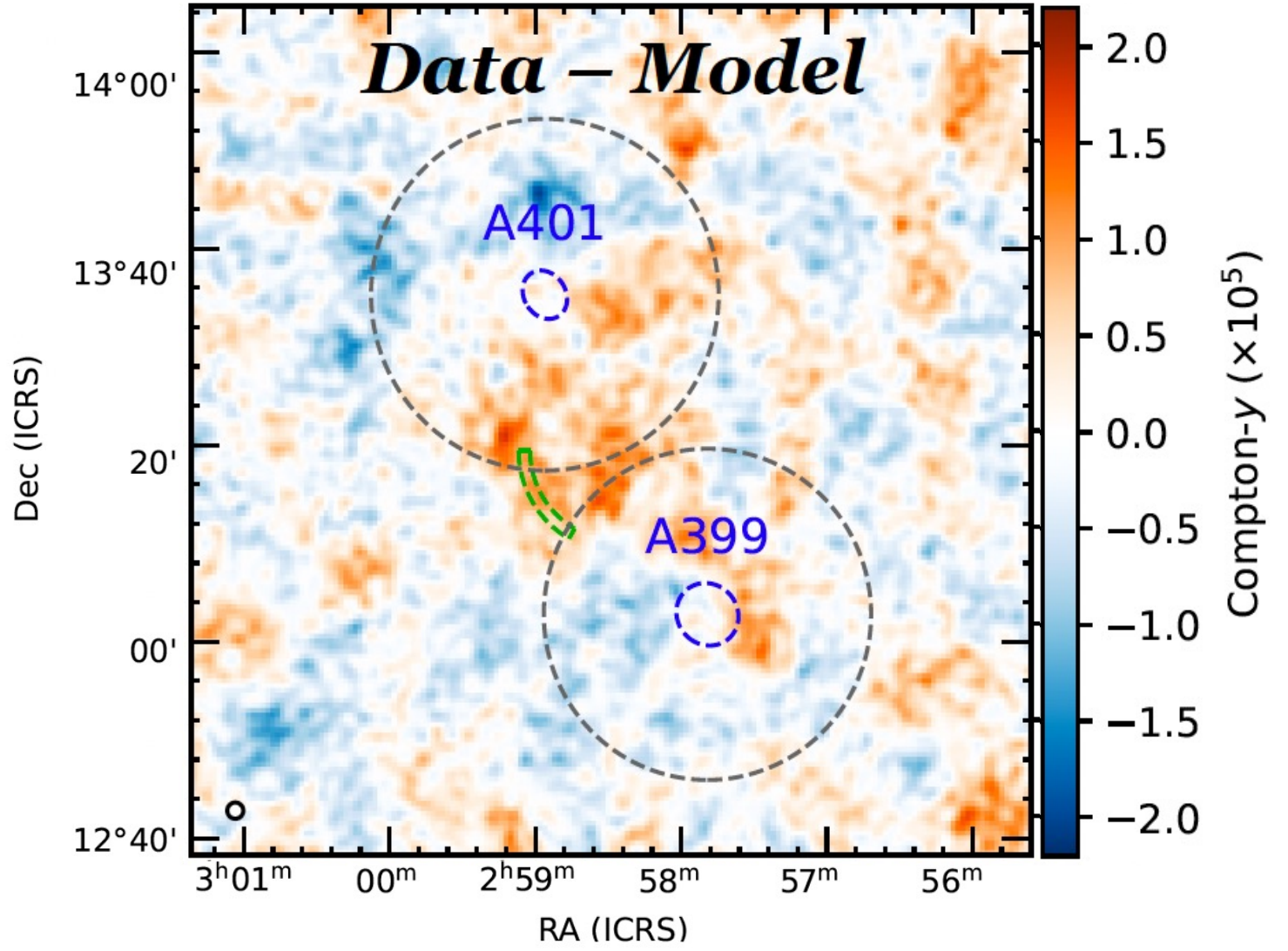

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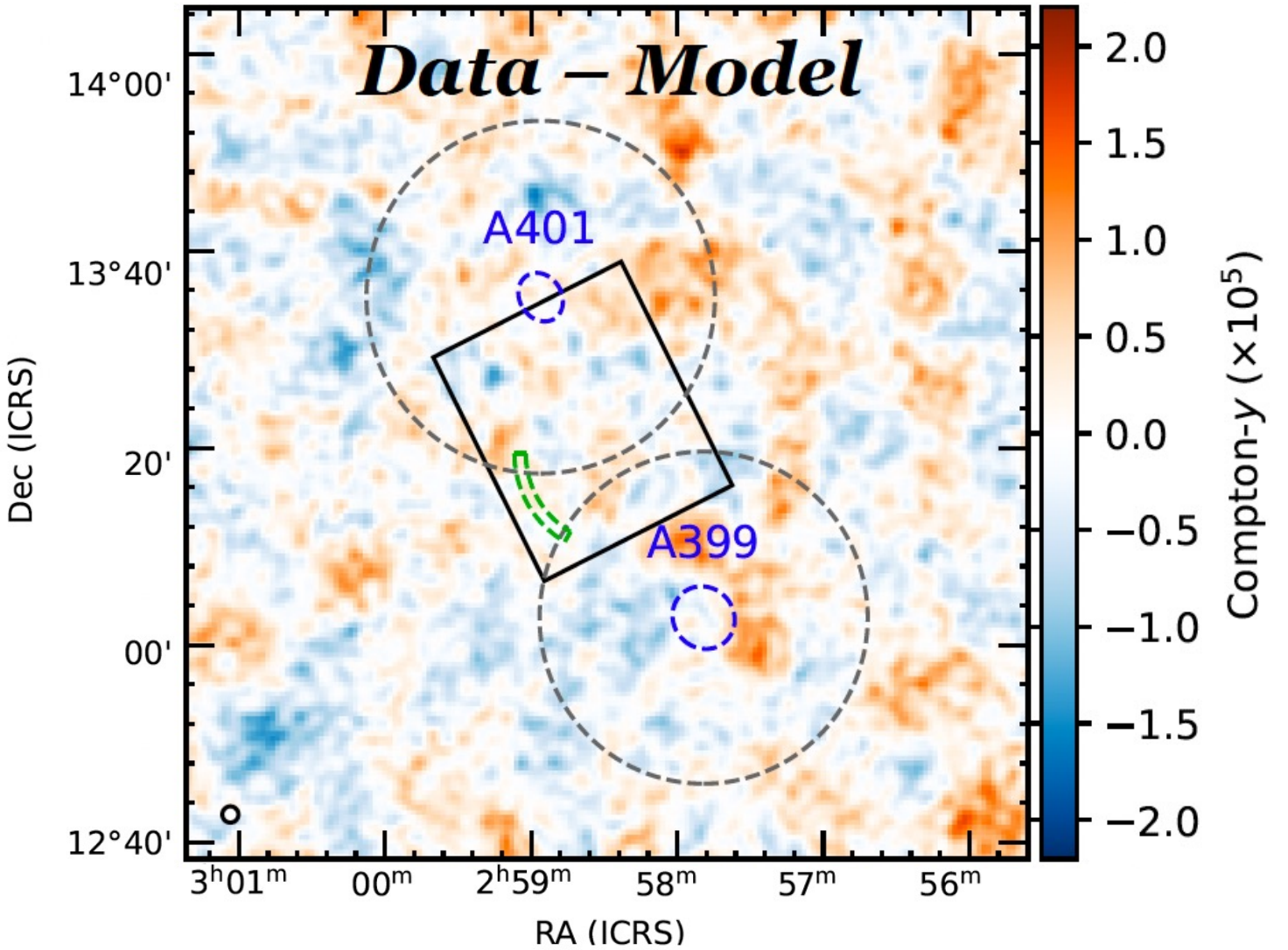

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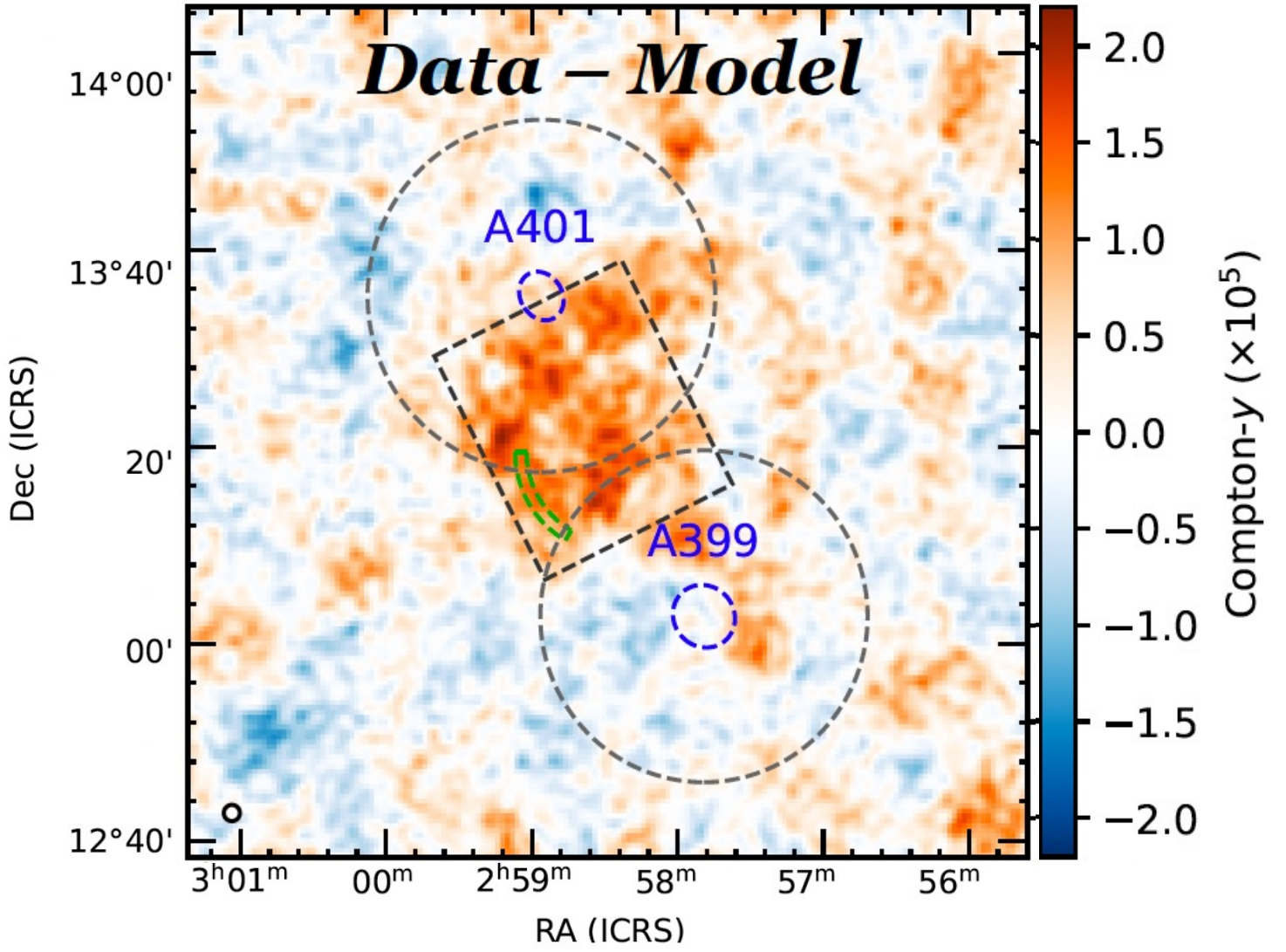

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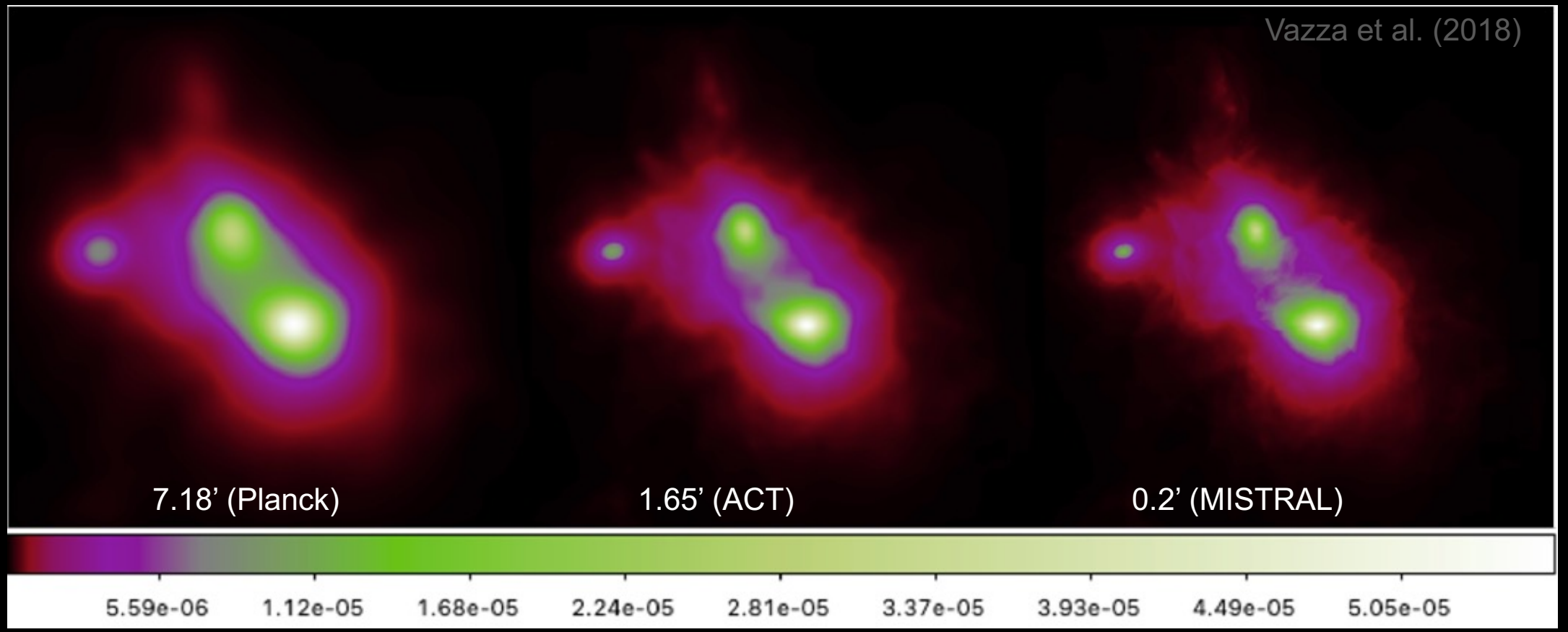
NEED FOR HIGHER RESOLUTION OBS.



- Turbulence predicted by hydrodynamical simulations of the order of $y \lessapprox 10^{-5}$ at the few hundrends of kpc (Vazza et al. 2018)
- Predictions of the scale at which baryons depart from DM distribution (Galarraga-Espinosa et al. 2022)
- δy up to 10^{-5} expected from the ICM turbulence of GC due to group merging (Khatri et al. 2016)


SAPIENZA
STVDIVM VRBIS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INAF
NATIONAL INSTITUTE FOR ASTROPHYSICS

MISTRAL

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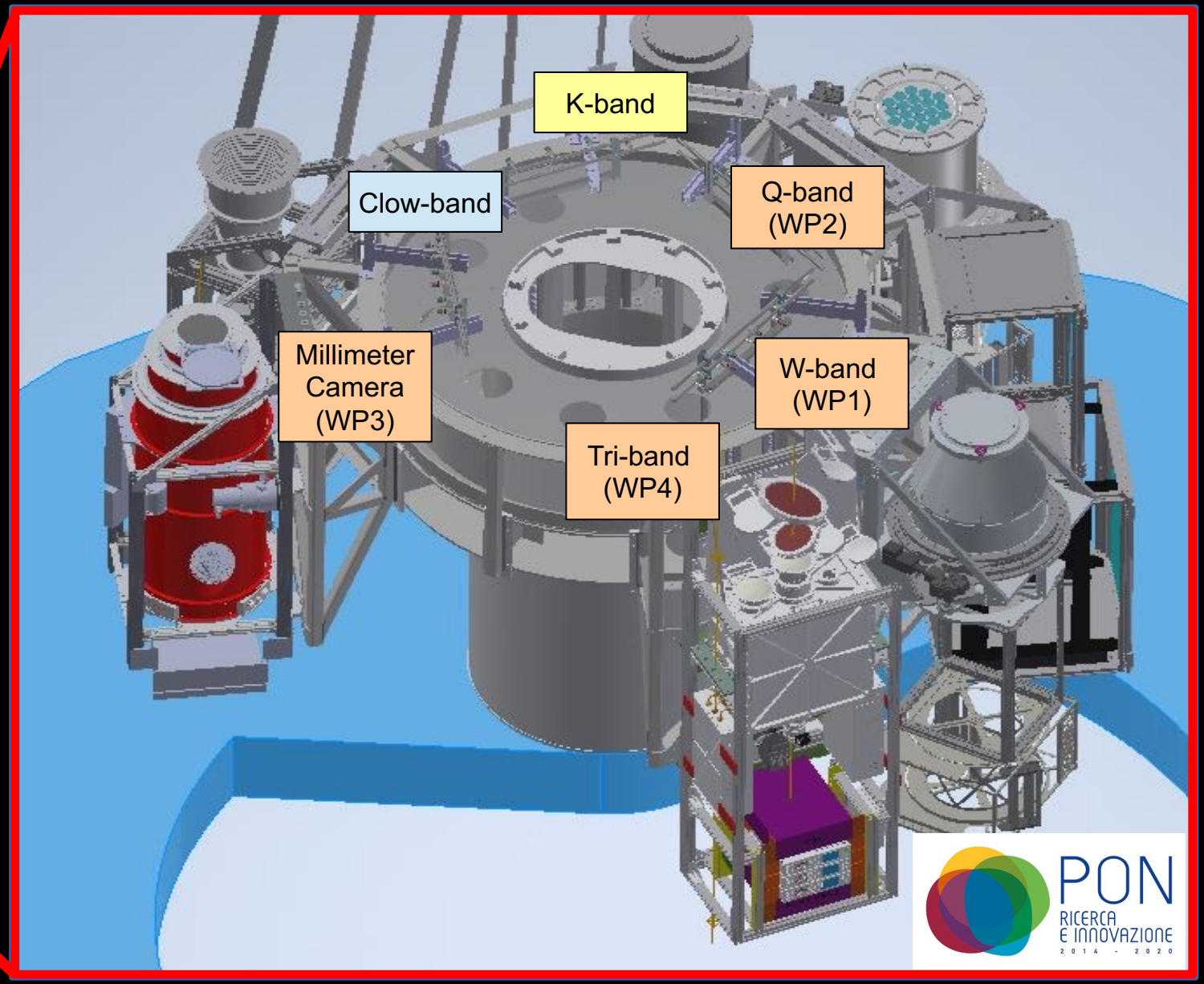
PON responsible: Federica Govoni
Scientific responsible INAF: Matteo Murgia
Scientific responsible Sapienza: Paolo de Bernardis
Project Manager: Elia Battistelli

MILLIMETER
SARDINIA RADIO
TELESCOPE
RECEIVER BASED ON
ARRAY OF
LUMPED ELEMENTS
KIDS



Picture acknowledgment: Sergio Poppi. INAF-SRT: http://www.srt.inaf.it/

Credits Alessandro Navarrini

MISTRAL

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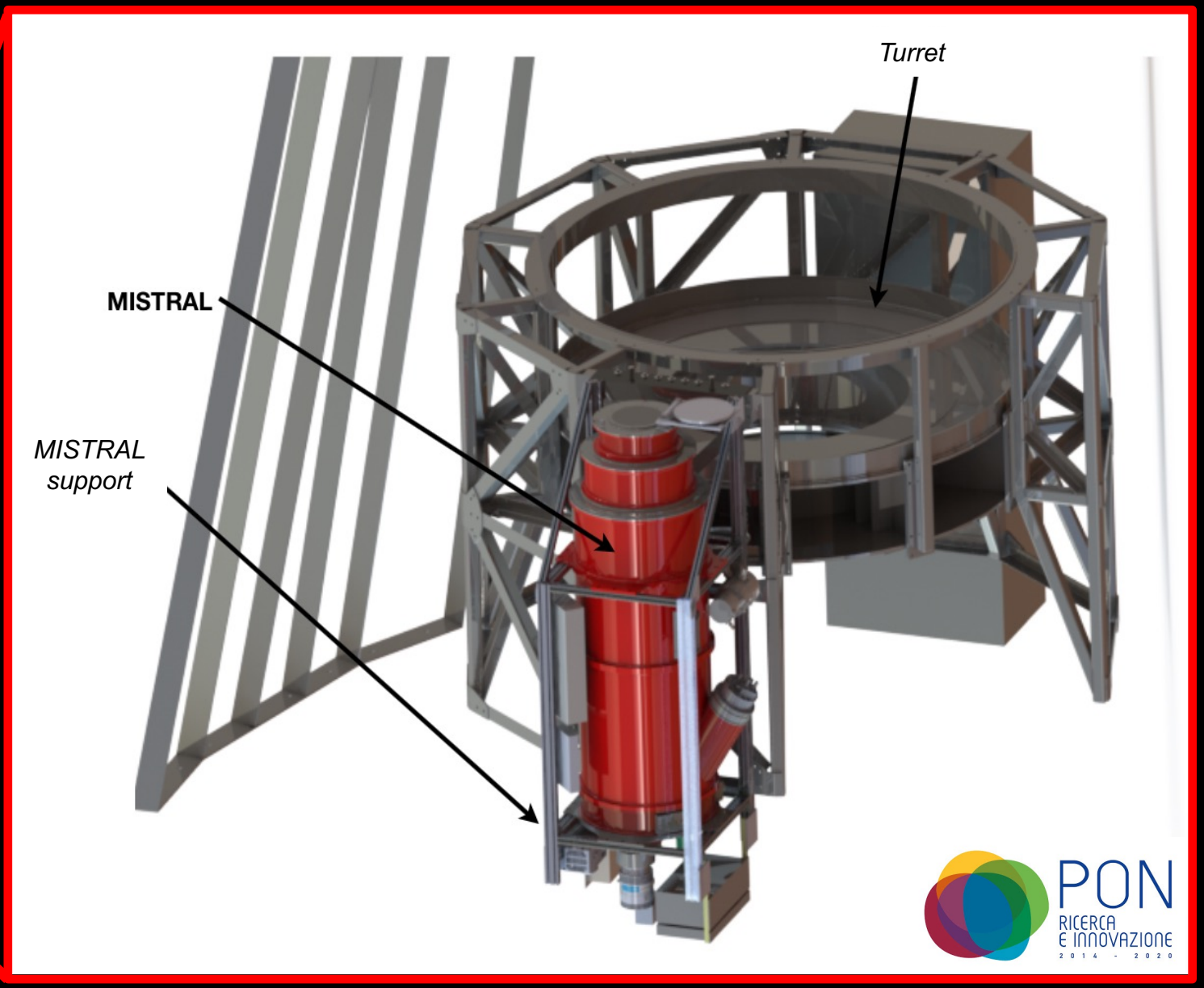

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Credits Giuseppe D'Alessandro

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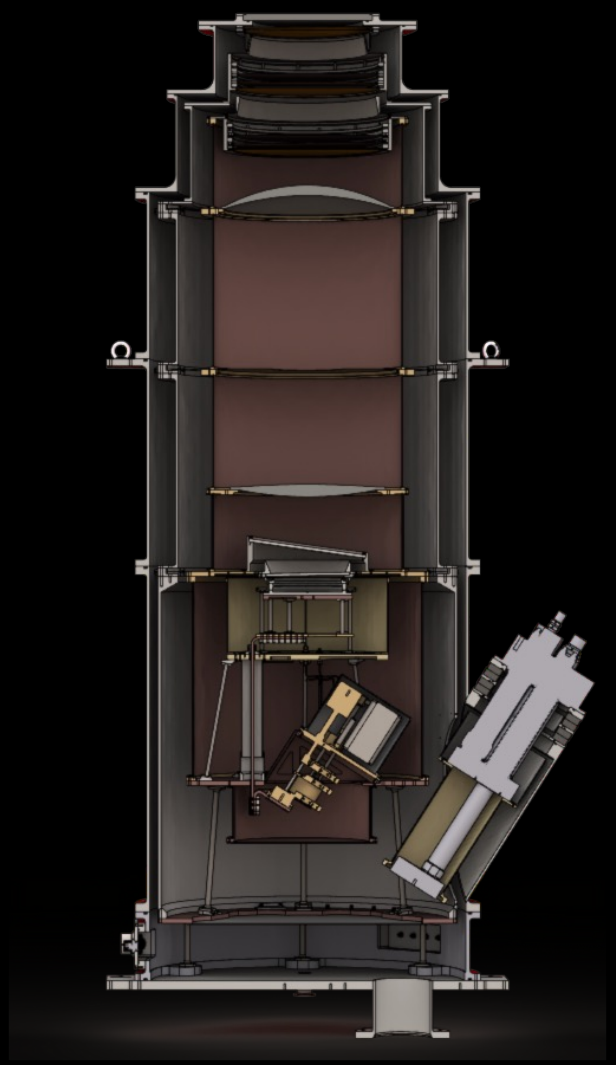
MISTRAL: CRYOSTAT

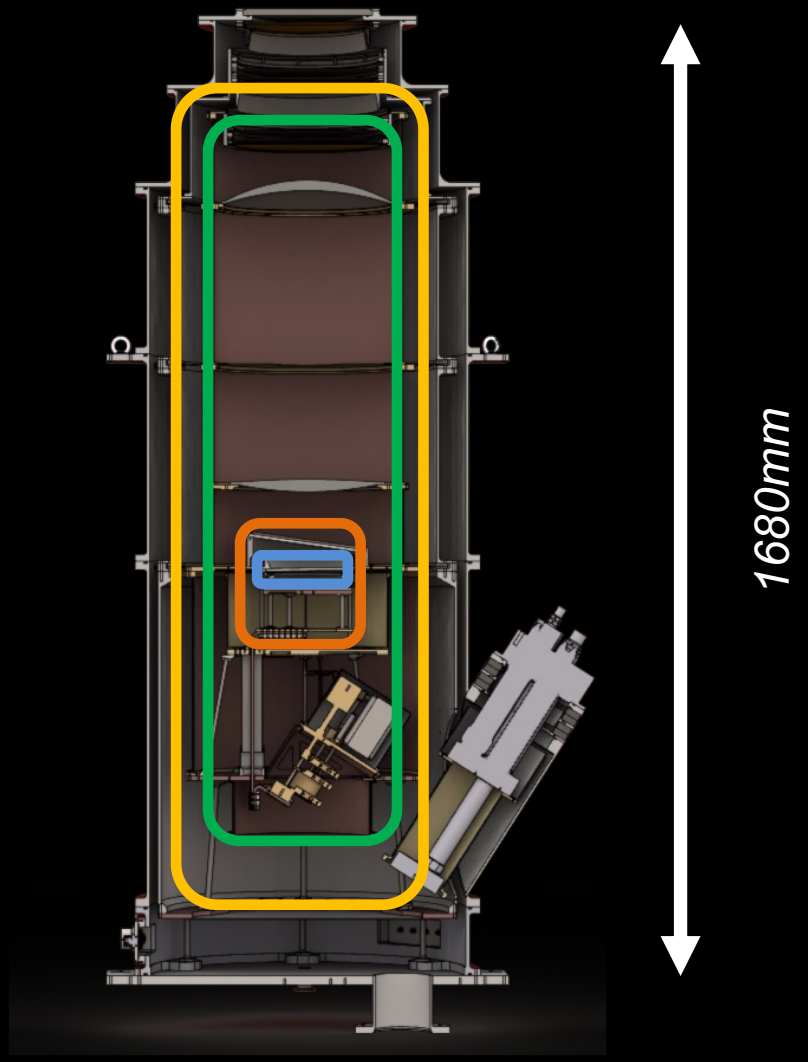


- MISTRAL is a facility instrument. Strong limitations in the Gregorian room:
  - ~250kg maximum
  - 700x700x2400mm
  - RF shielded and quite
  - Should work also when park
  - Long (~120m) cryocooler lines
  - Remote PT compressor (~120m)
  - Not accessible
- *Cryostat built by QMC*
- *Composed of 40K, 4K radiation shields cooled by a 1.5W PT cryocooler*
- *Plus ~0.8K – 300mK -- 200mK He-10 sorption fridge*

Credits Aurora Carbone - Alessandro Coppolecchia – Giuseppe D'Alessandro

MISTRAL: CRYOSTAT

~250Kg ; ~1m³



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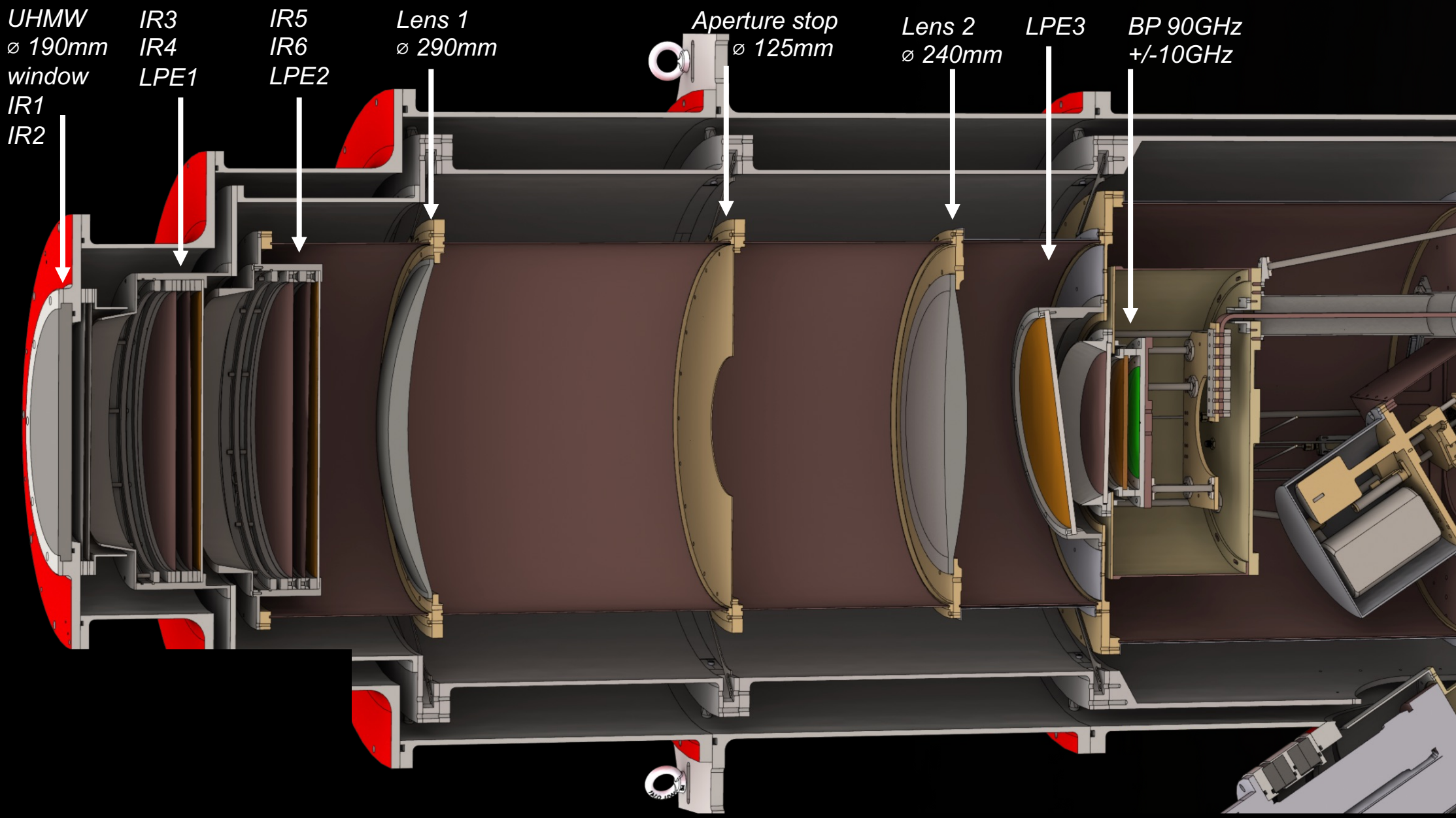
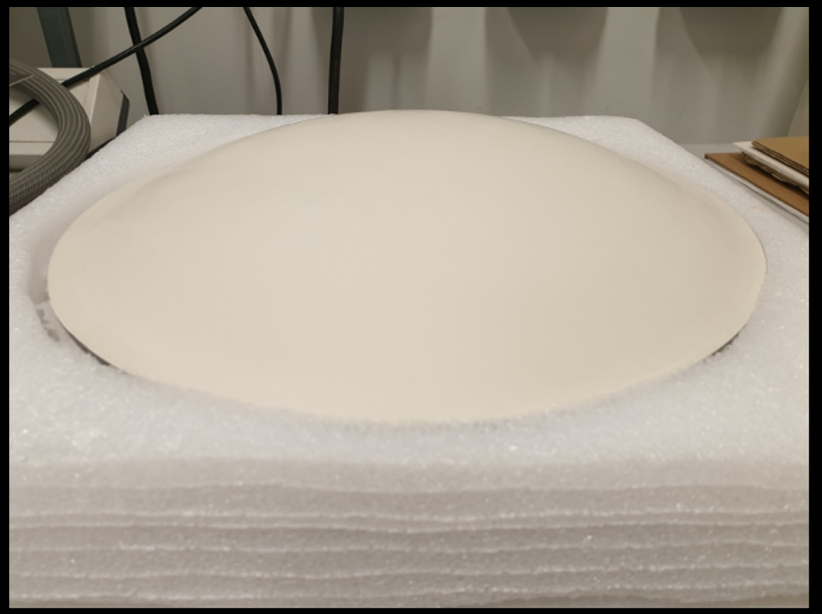
MISTRAL: QUASI-OPTICS

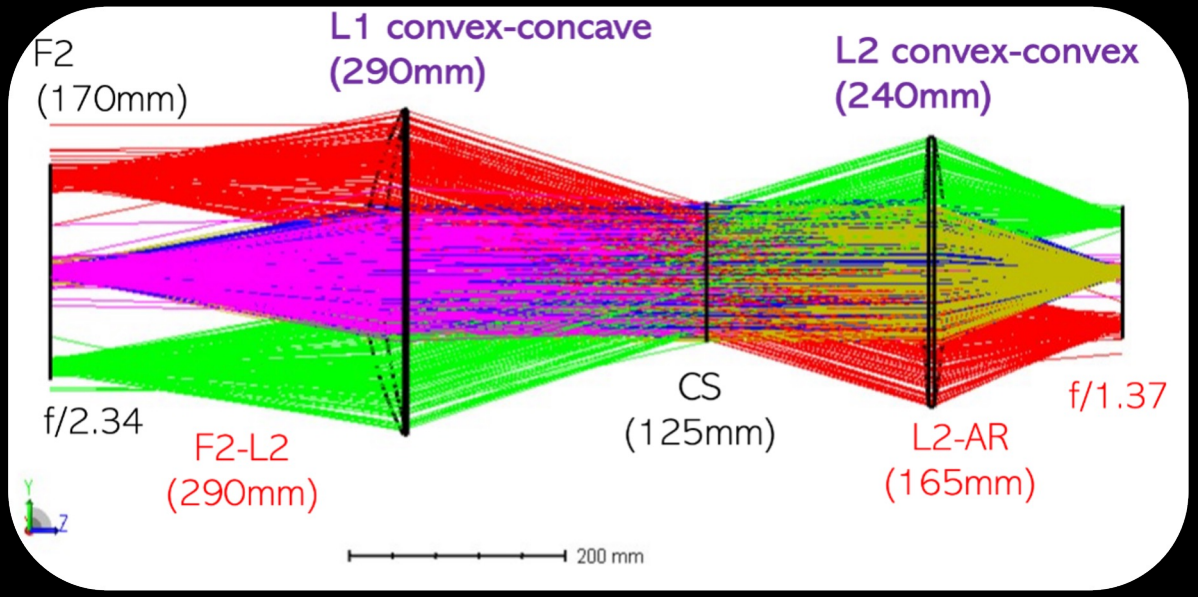


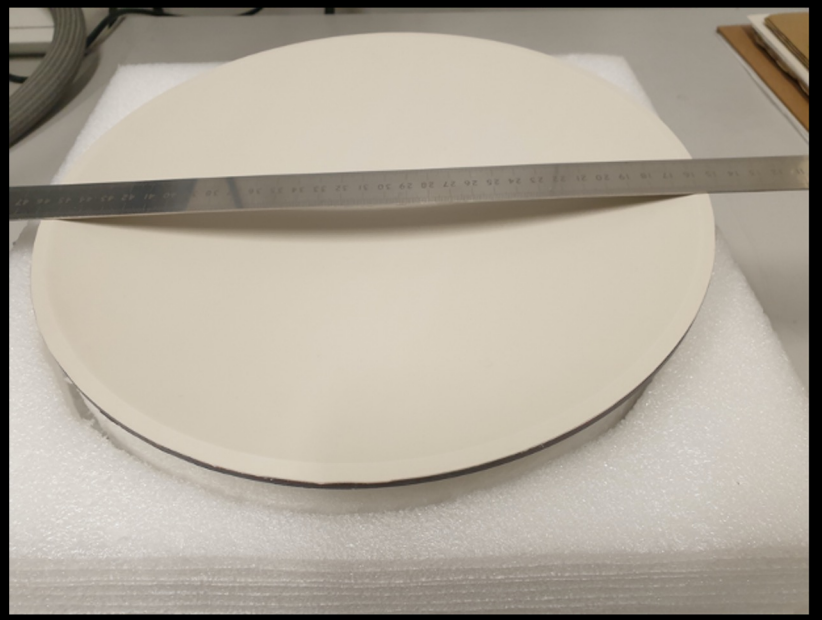
Combination of: Metal mesh filters, thin IR filters, sub-mm low pass filters (LPE), a final 74-103GHz Band pass filter

MISTRAL: OPTICS

- Filled (naked) array of KIDs
- Cold stop at 4K to avoid extra-load on KIDs
- Rogers R30003 ARC silicon lenses: a biconvex and a meniscus ones *(0.91<SR<0.97)*
- angular resolution = 12 arcsec
- F.O.V. = 4 arcmin
- Pixel separation = 10.6 arcsec

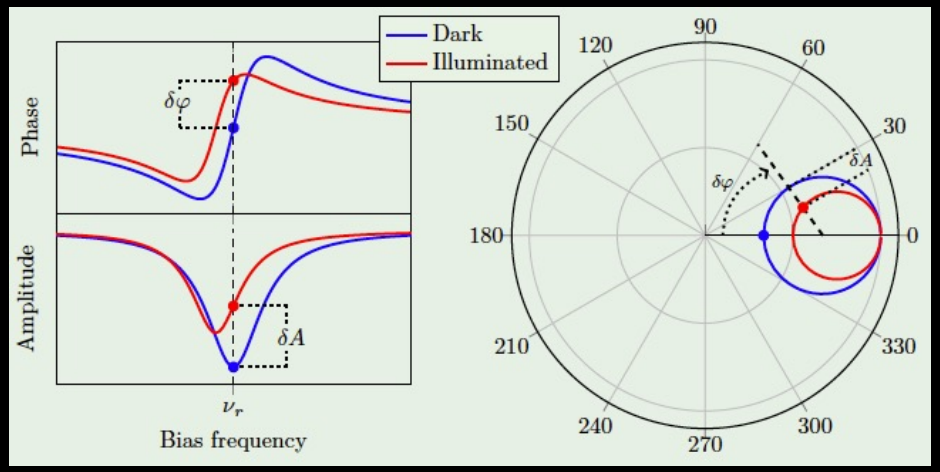






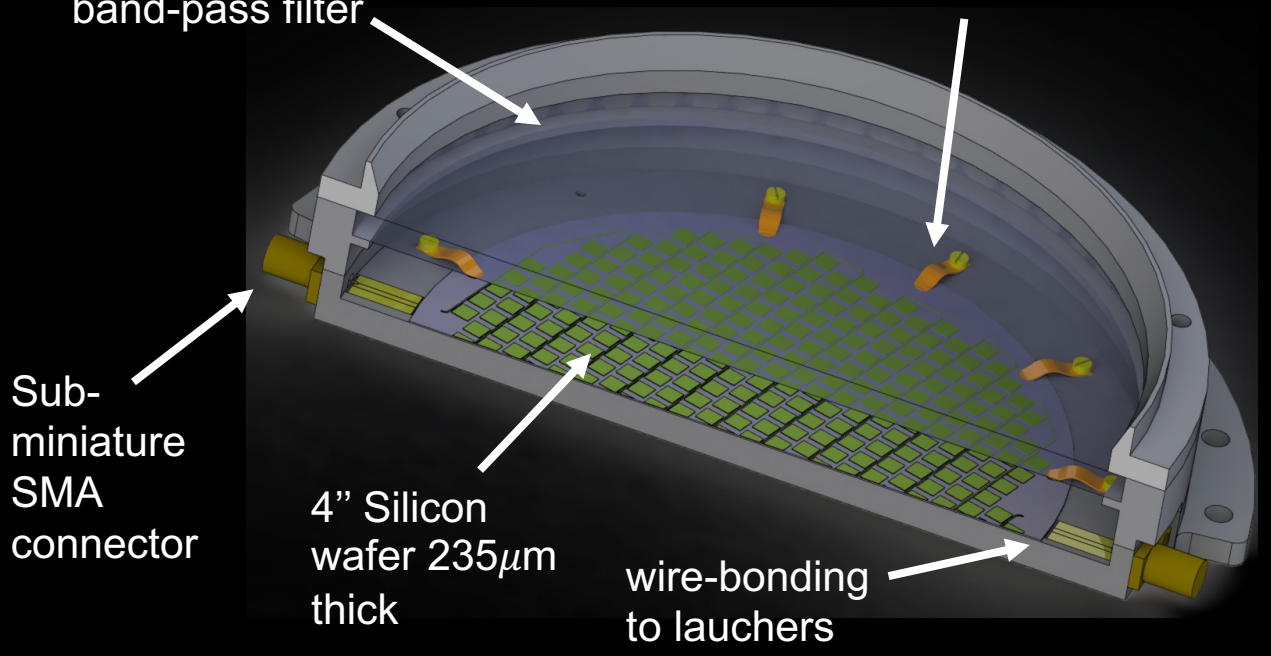
Credits Marco De Petris

MISTRAL: DETECTORS



Acknowledgement Alessandro Paiella, Giovanni Isopi, Alessandro Coppolecchia, Federico Cacciotti, Giorgio Pettinari Francesco Piacentini

- 415 KIDs: Ti-Al bilayer 10 + 30 nm thick (T_c=945mK) *[Catalano et al. A&A 580 A15 2015]* *[Paiella et al. JLTP 209 889 2022]*
- 3mm x 3mm absorbers every 4.2mm
- Pixel separation = 10.6”



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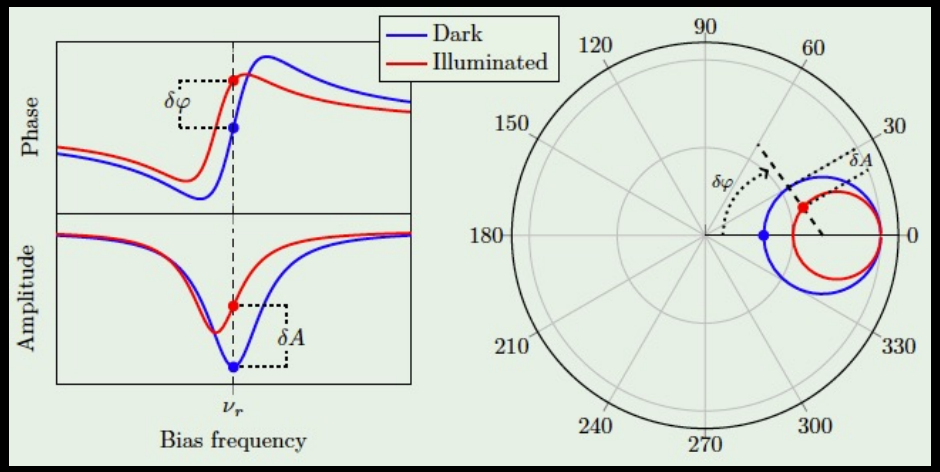

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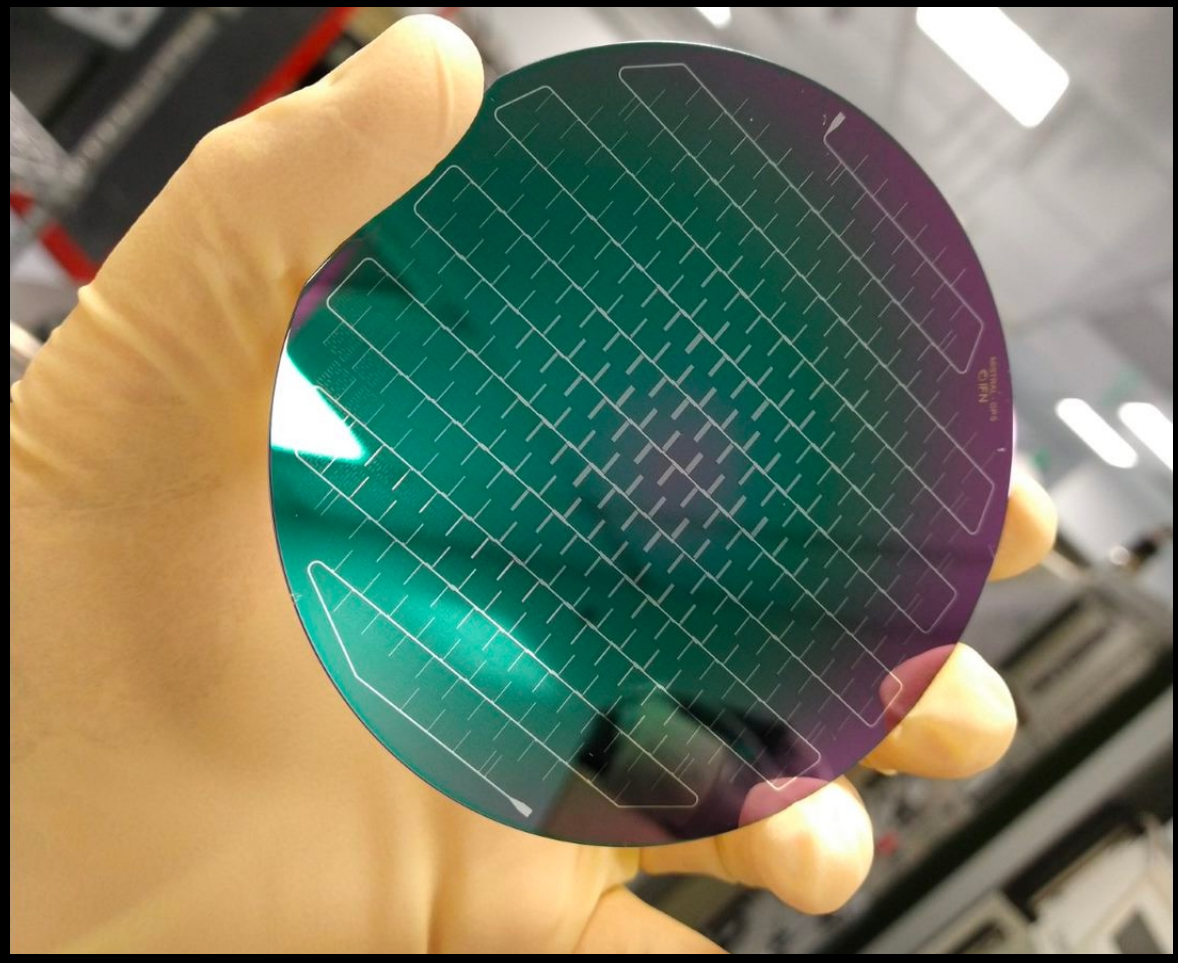

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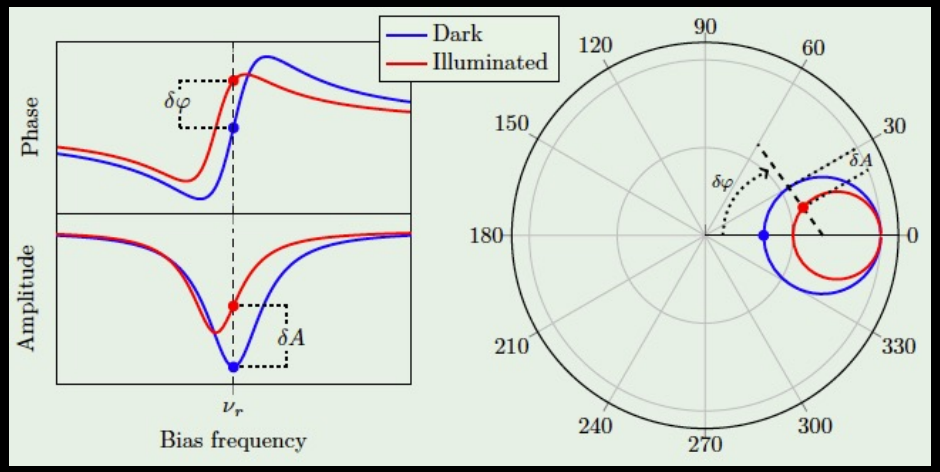

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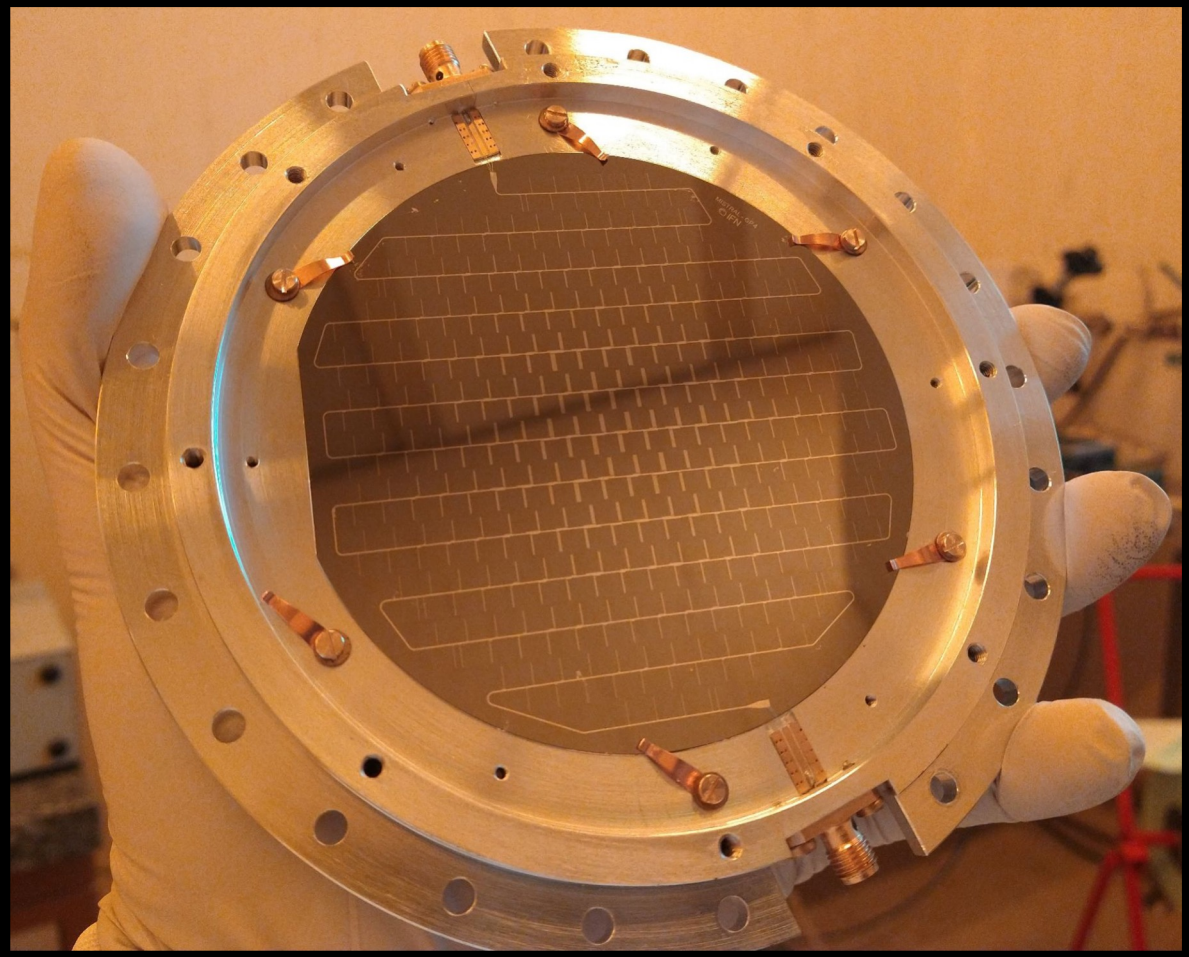

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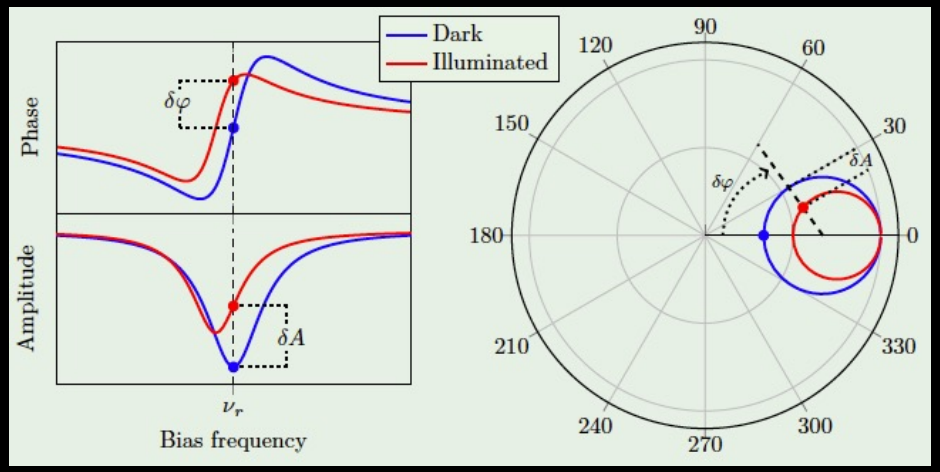

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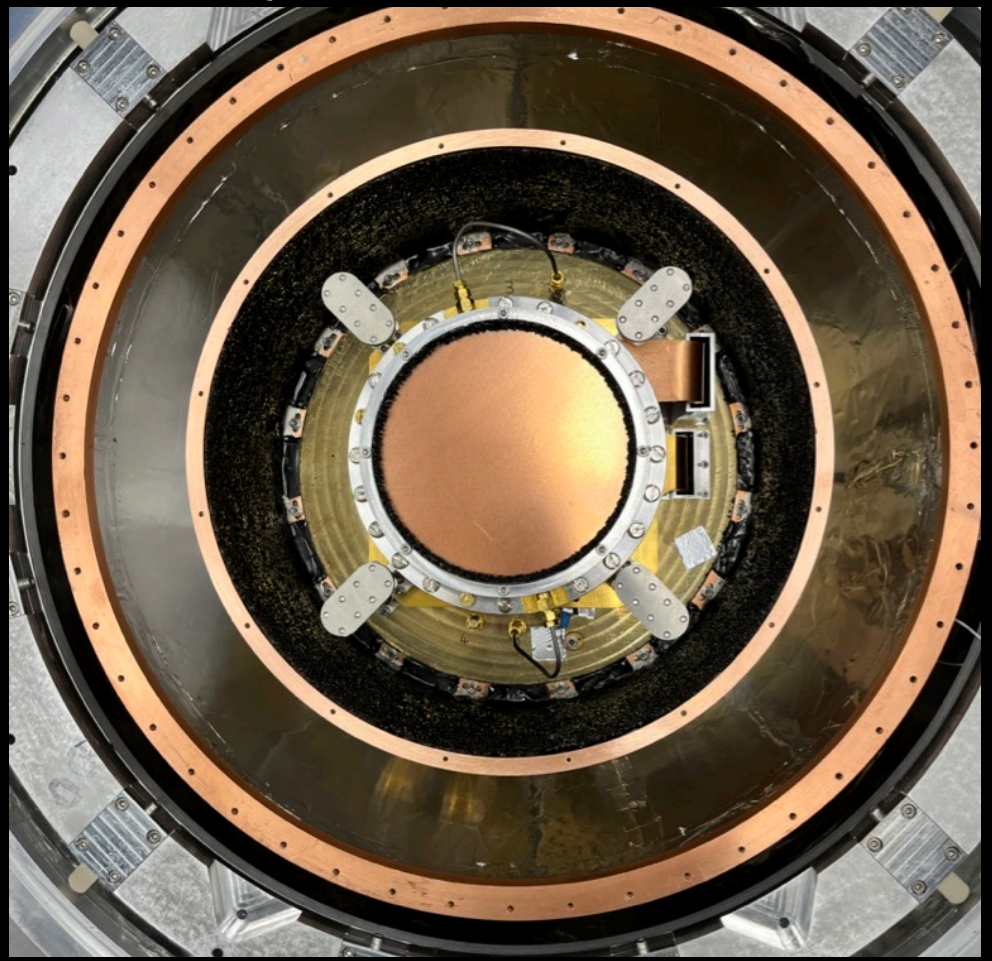
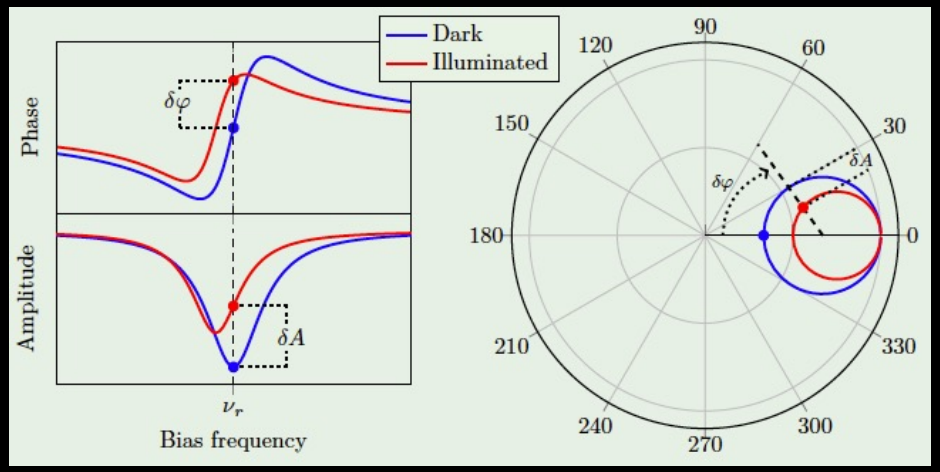
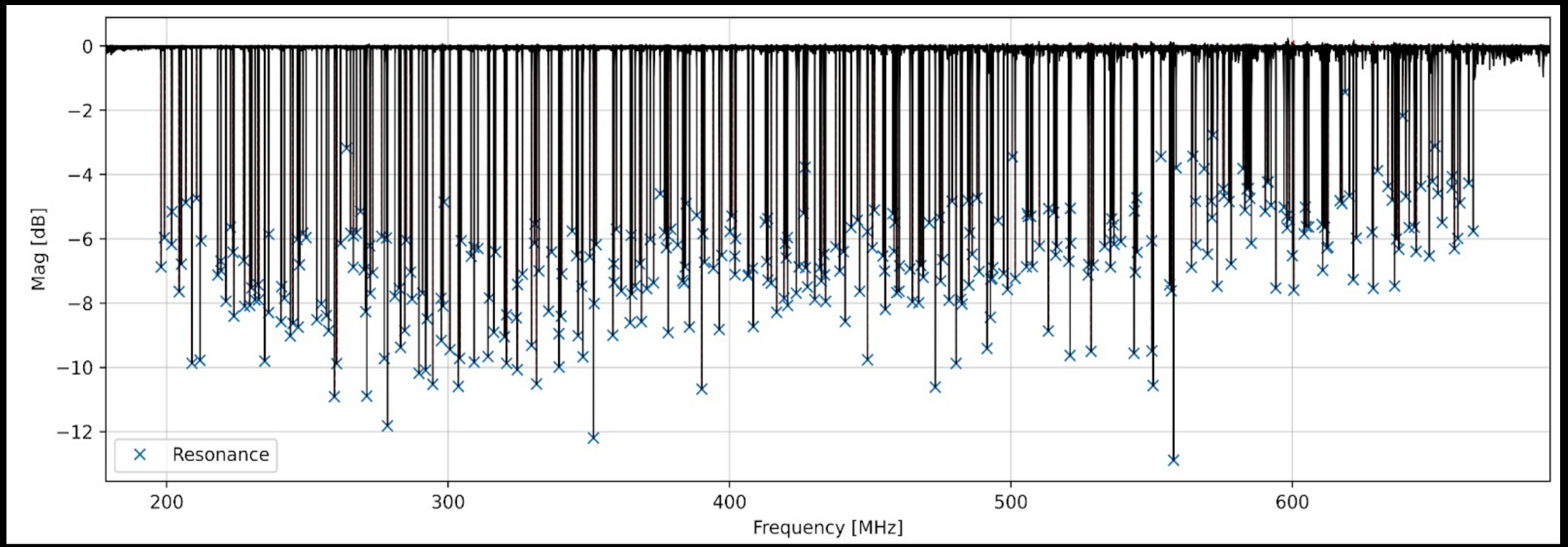


MISTRAL: DETECTORS

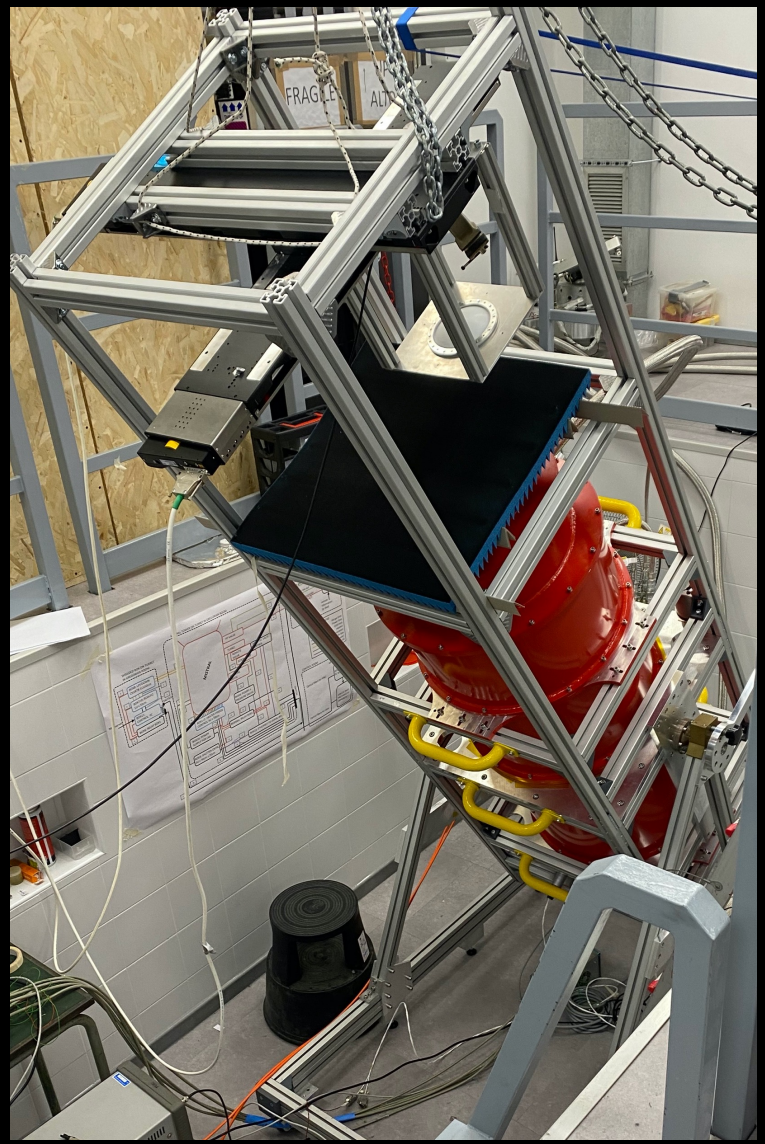


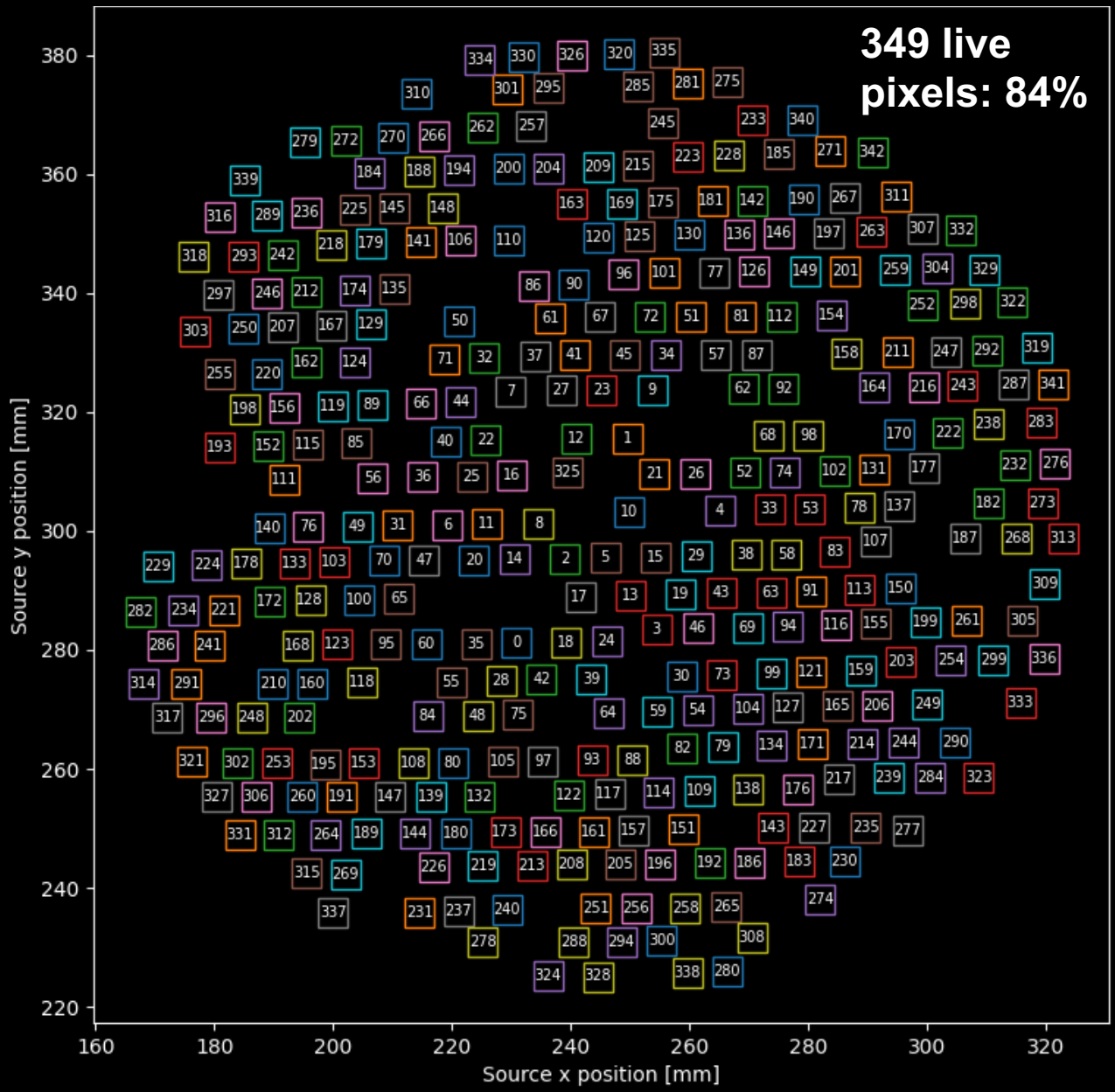
- 415 KIDs: Ti-Al bilayer 10 + 30 nm thick (T_c=945mK) *[Catalano et al. A&A 580 A15 2015]* *[Paiella et al. JLTP 209 889 2022]*
- 3mm x 3mm absorbers every 4.2mm
- Pixel separation = 10.6”
- 0.96MHz (median) pixel separation



Credits Alessandro Paiella, Federico Cacciotti, Giovanni Isopi

MISTRAL CALIBRATION





Credits Fabio Columbro, Elia Pappalardo, Edoardo Levati

Credits Alessandro Paiella, Federico Cacciotti, Giovanni Isopi

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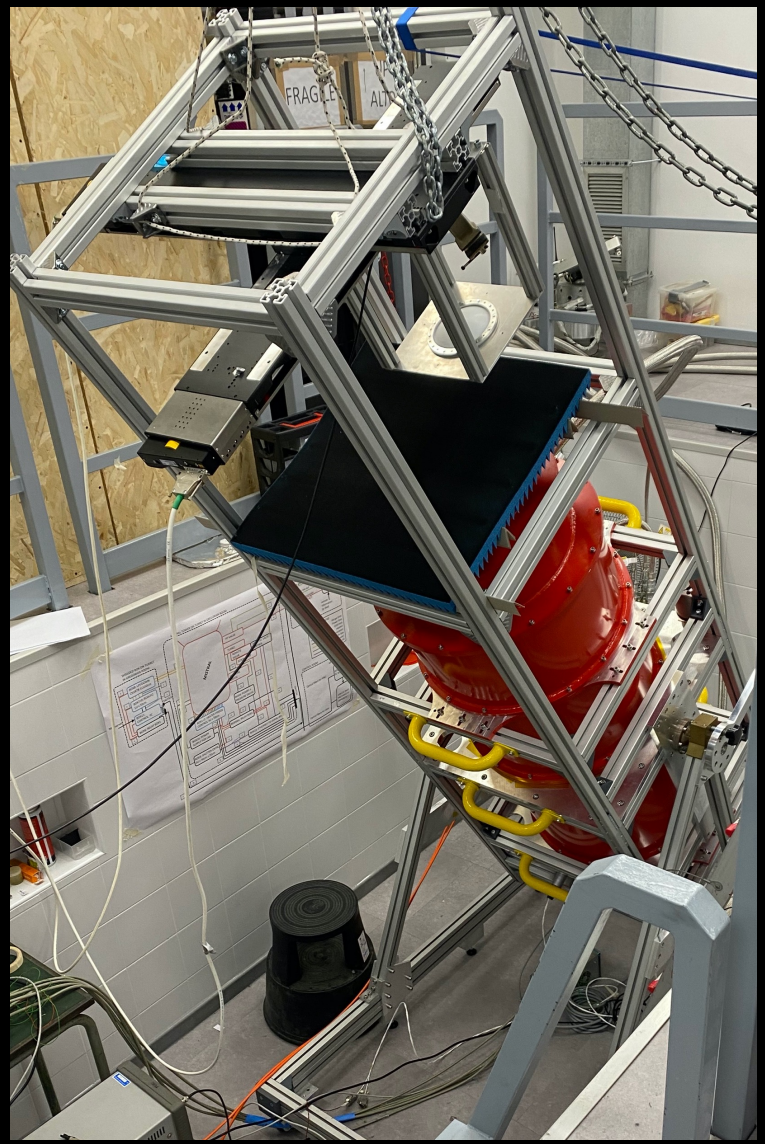

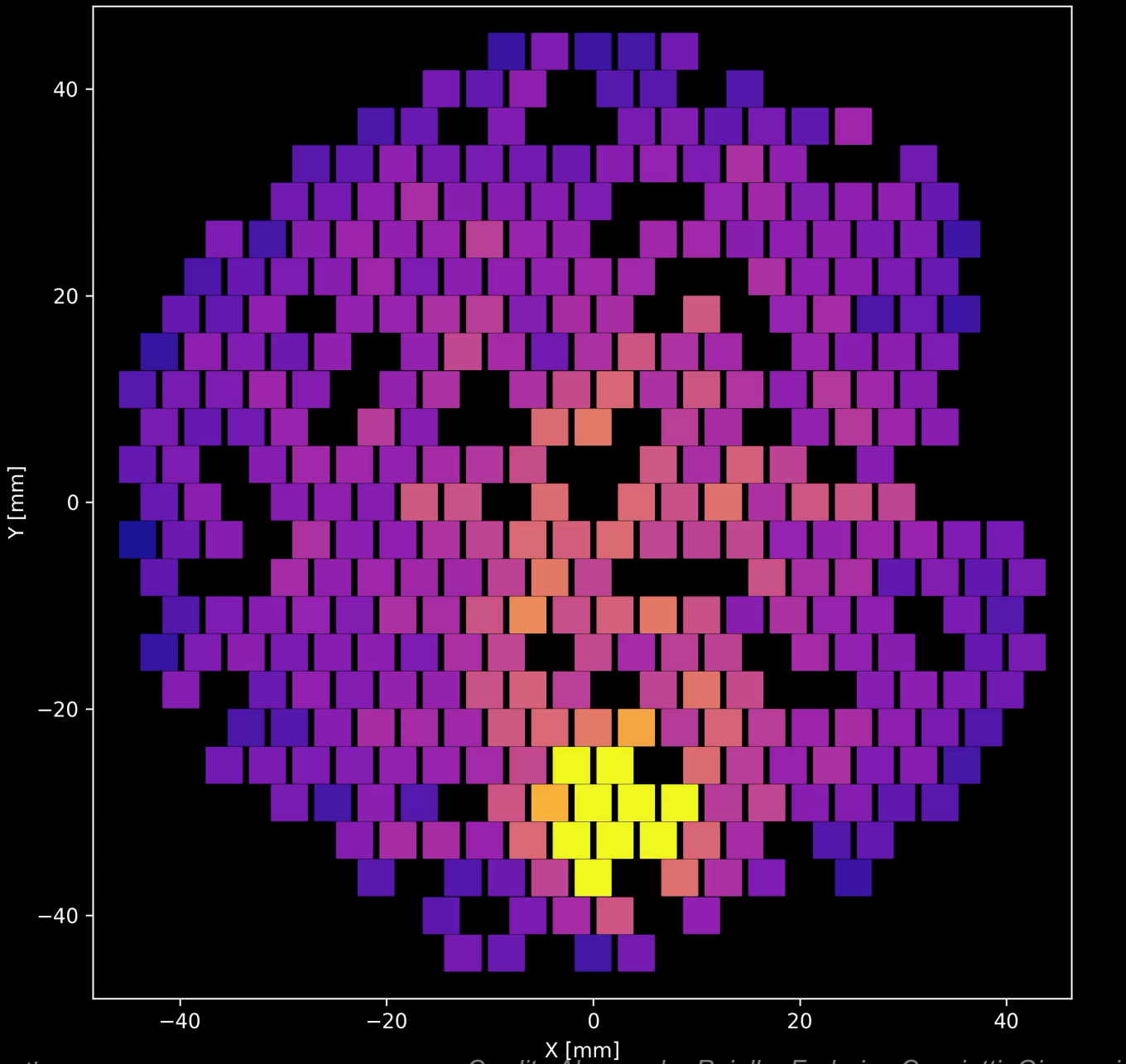

Credits Fabio Columbro, Elia Pappalardo, Edoardo Levati

Credits Alessandro Paiella, Federico Cacciotti, Giovanni Isopi

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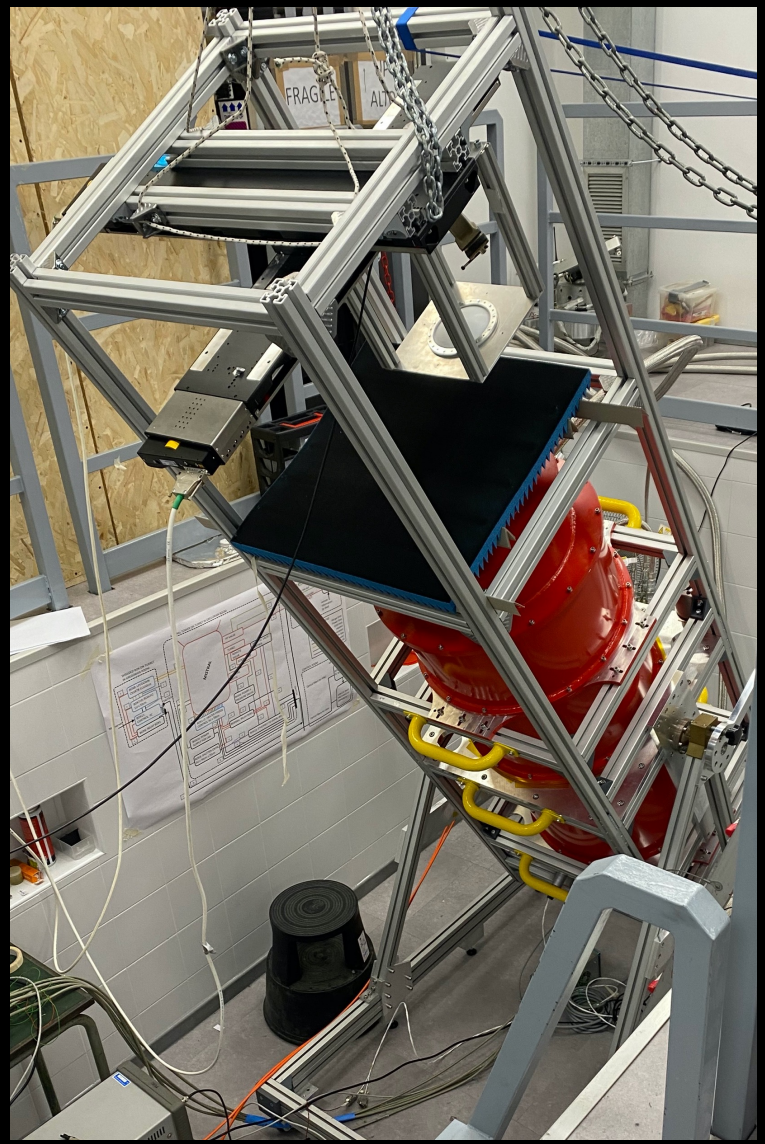
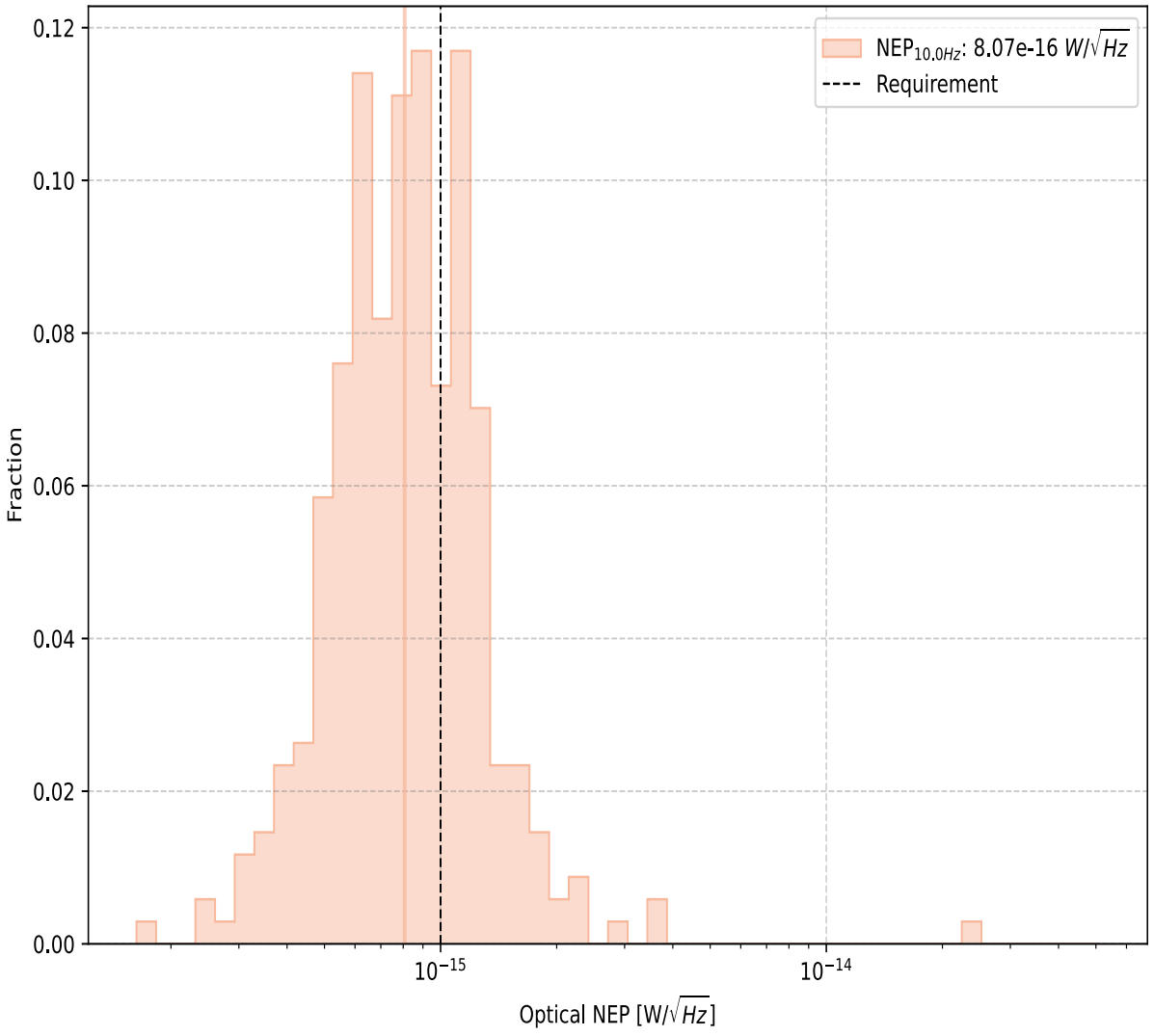


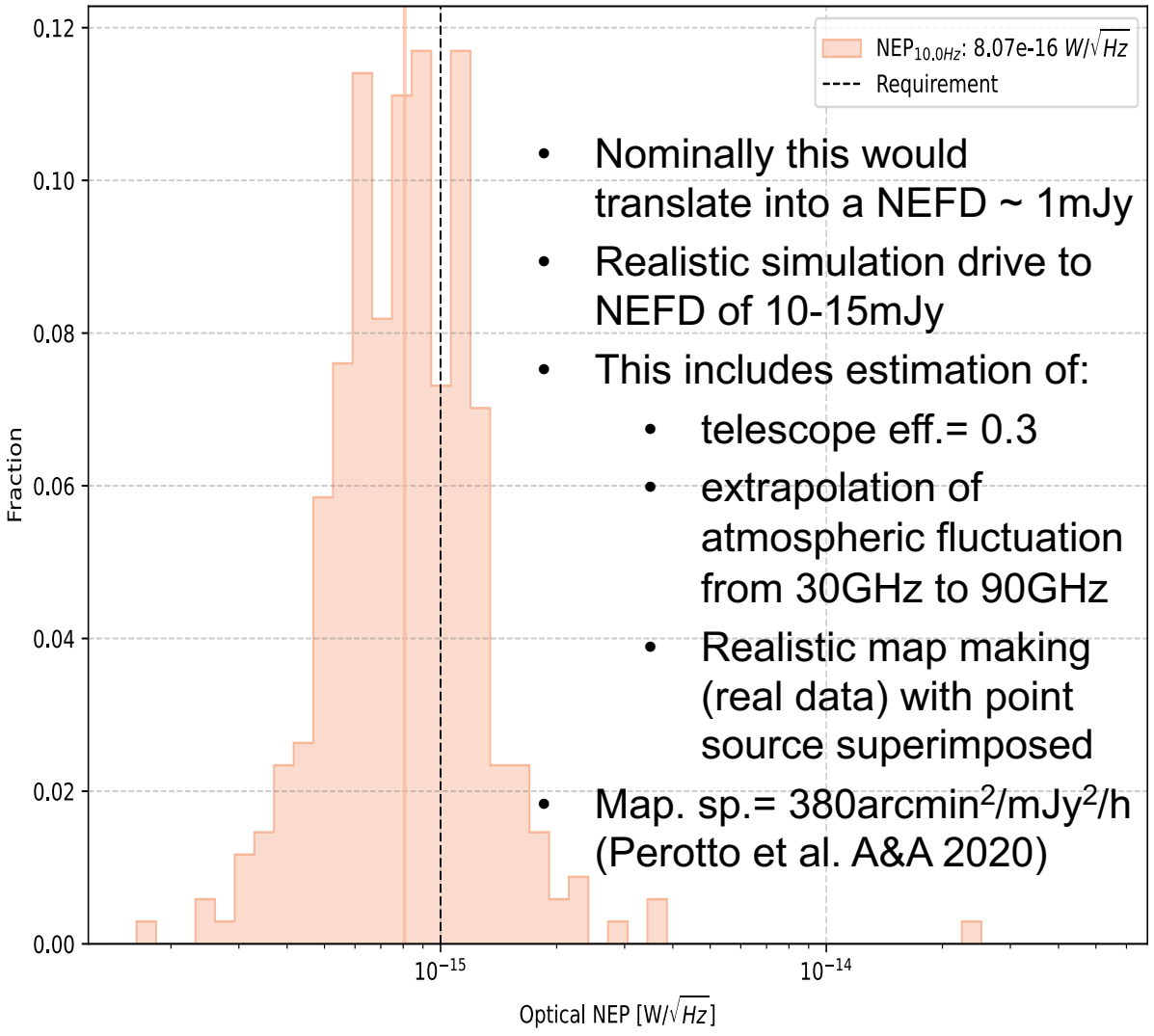


Credits Fabio Columbro, Elia Pappalardo, Edoardo Levati

Credits Alessandro Paiella, Federico Cacciotti, Giovanni Isopi

MISTRAL CALIBRATION

Credits Alessandro Novelli Eleonora Barbavara



- Nominally this would translate into a NEFD ~ 1mJy
- Realistic simulation drive to NEFD of 10-15mJy
- This includes estimation of:
  - telescope eff.= 0.3
  - extrapolation of atmospheric fluctuation from 30GHz to 90GHz
  - Realistic map making (real data) with point source superimposed
- Map. sp.= 380arcmin^2/mJy^2/h (Perotto et al. A&A 2020)

Credits: Giovanni Isopi

MISTRAL TRASPORTATION

MISTRAL TRASPORTATION

June 2023

May 2023

Credits Matteo Murgia

MISTRAL: FACILITY INSTRUMENT

Observing with the Italian radio telescopes

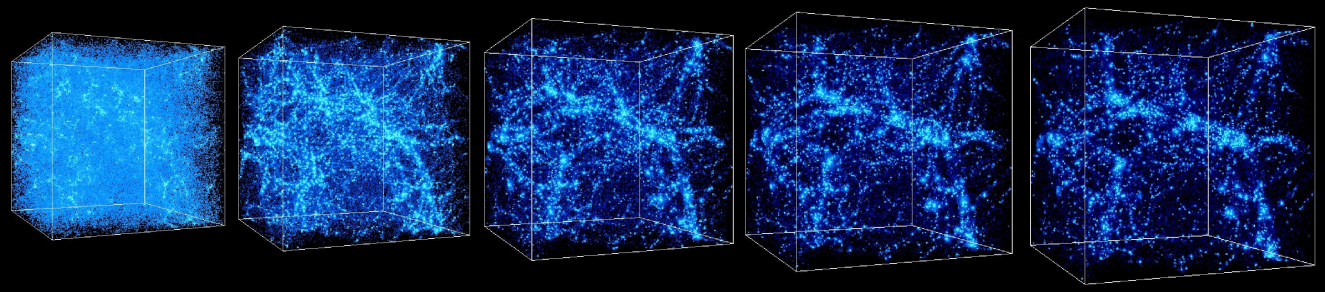
Welcome to the Italian radio telescopes users' page

Here you can access all of the resources needed to achieve successful single-dish and extra-EVN interferometric observations

Contact us

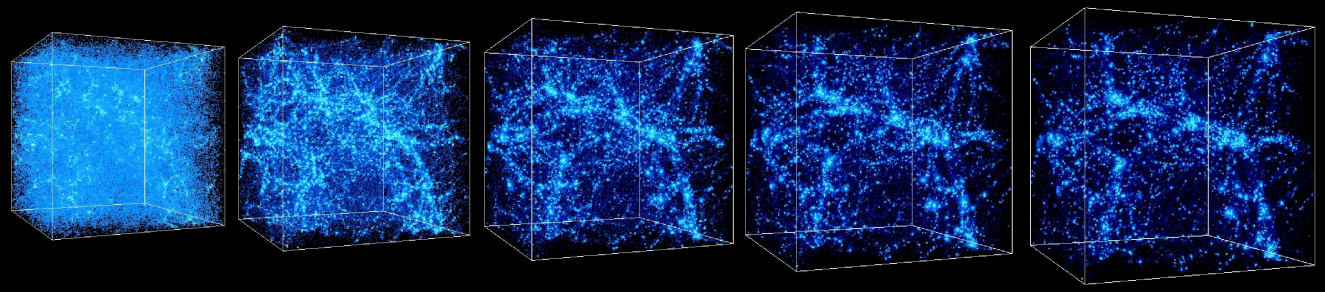
Regular call is closed. Next deadline will be in October 2023.
Proposals for ToOs and DDT can be submitted anytime.
The offered instrumentation is listed here.

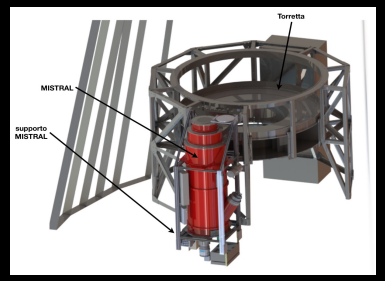
CONCLUSIONS

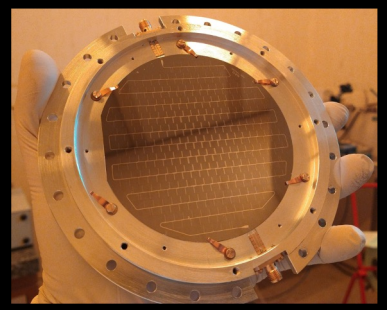


- SZ is a unique tool for studying Galaxy Clusters and the Cosmic web
- MISTRAL a new (agile) millimetric camera just been installed at the SRT
- Commissioning will start very soon (actually already started)
- MISTRAL will be a facility instrument…ready for observations soon

CONCLUSIONS







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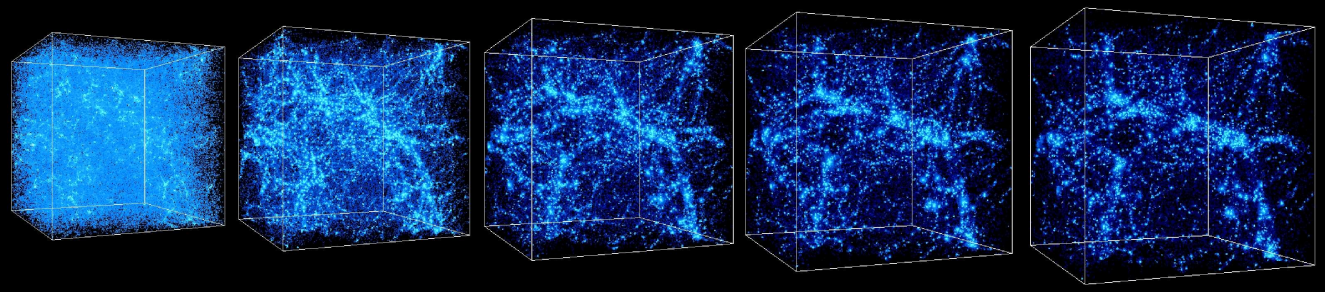

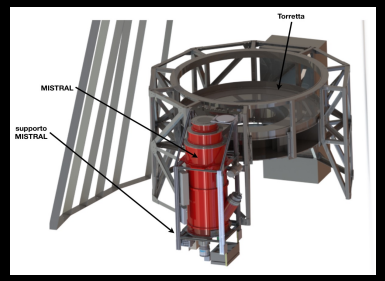

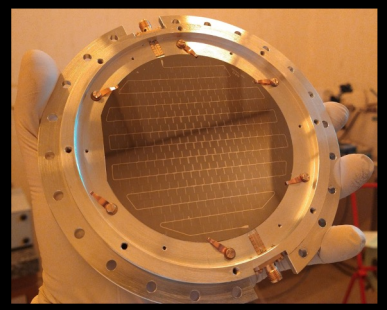

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PON RICERCA E INNOVAZIONE 2014 - 2020

SAPIENZA UNIVERSITÀ DI ROMA

ISTITUTO NAZIONALE DI ASTROFISICA
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