

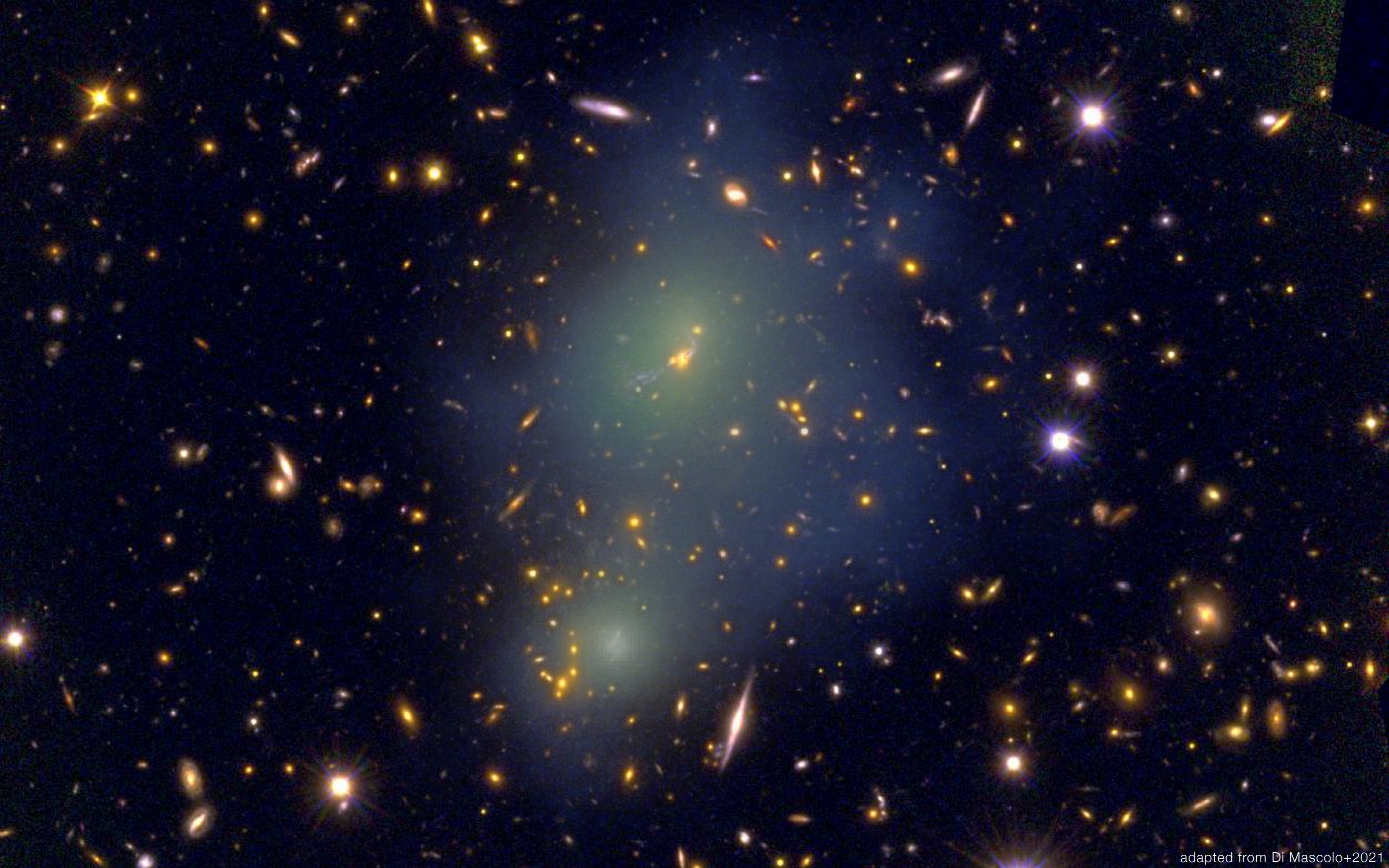
WITNESSING THE BIRTH OF CLUSTERS OF GALAXIES

DETECTION OF FORMING INTRACLUSTER GAS IN A GALAXY PROTOCLUSTER AT $z \sim 2.16$

LUCA DI MASCOLO

SÉMINAIRE @ LAGRANGE
OBSERVATOIRE DE LA CÔTE D'AZUR

23-01-2024





ENVIRONMENT FOR GALAXY EVOLUTION

impact galaxy morphology,
star formation, AGN activity, ...

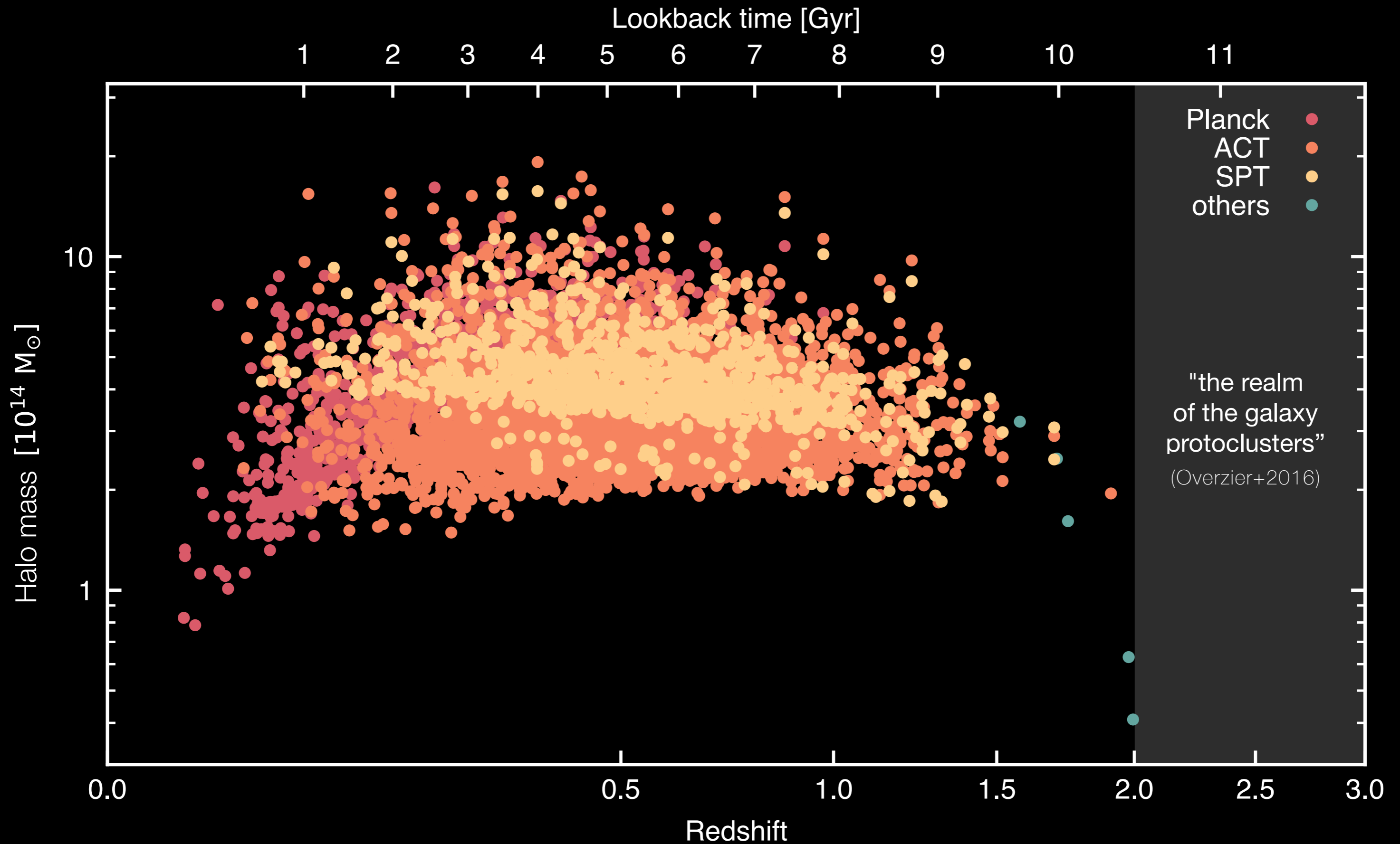
LARGEST STRUCTURES IN THE UNIVERSE

tracers of large-scale structure formation
and mass content of the Universe
window on dark matter properties

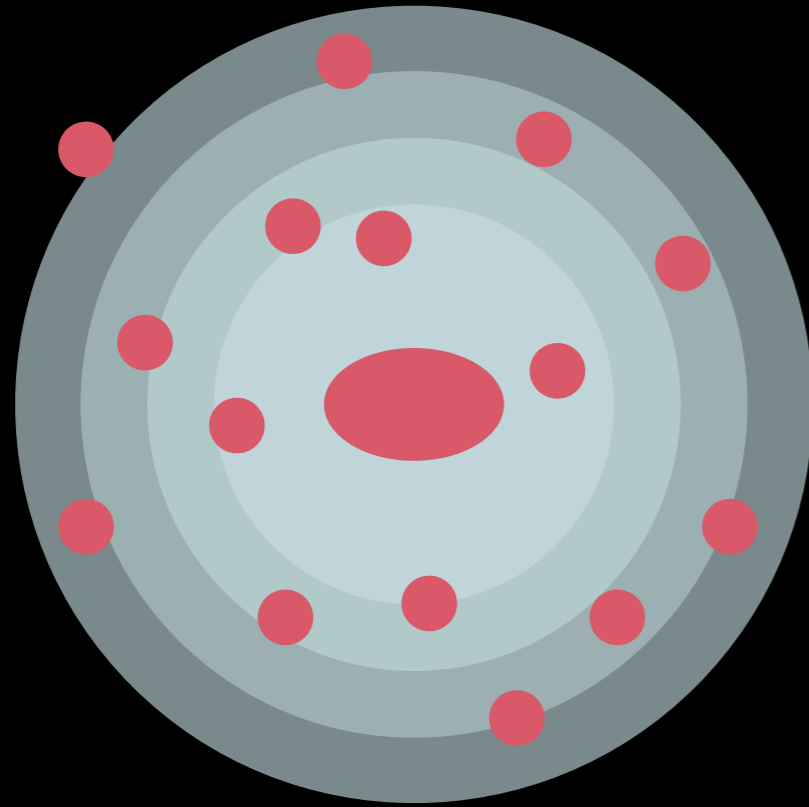
LARGE RESERVOIRS OF PLASMA

host most energetic events in the universe
unique laboratories for plasma physics

clusters across cosmic time

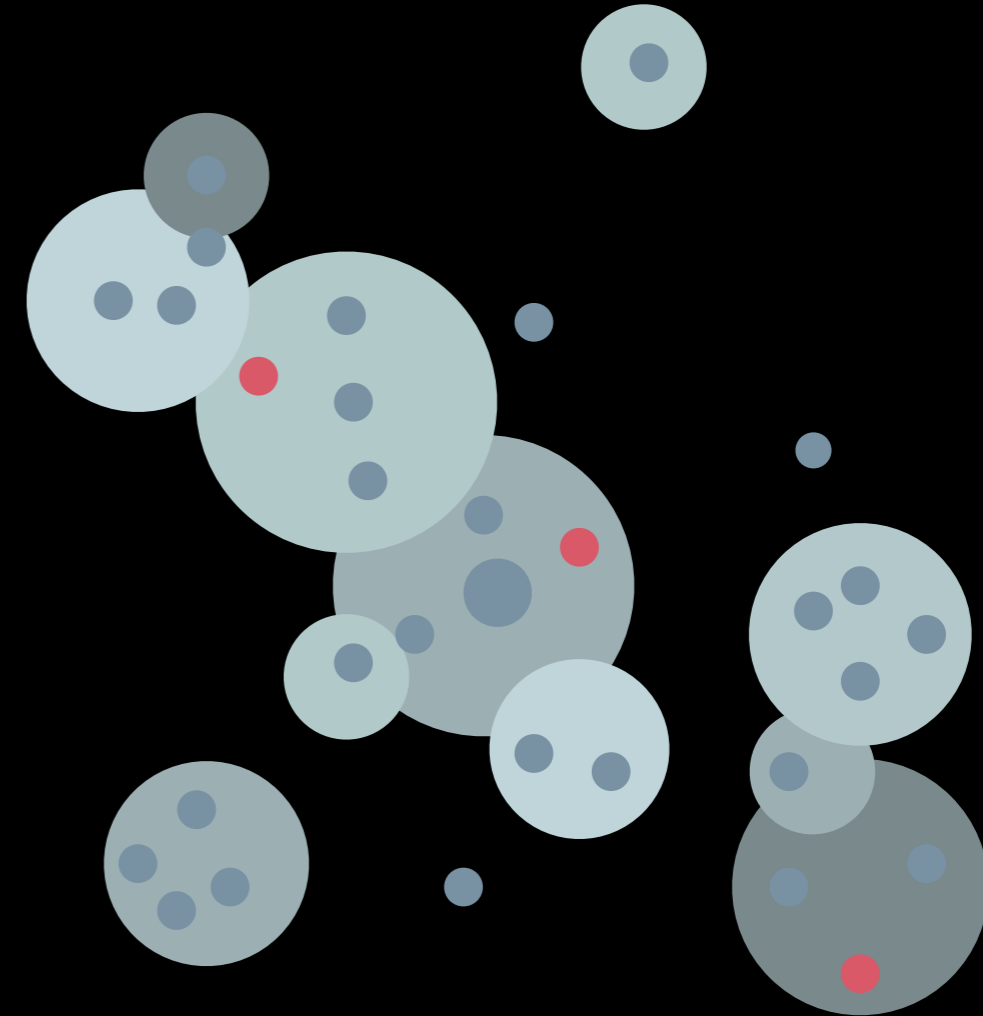


a turning point in cosmic history



mature clusters

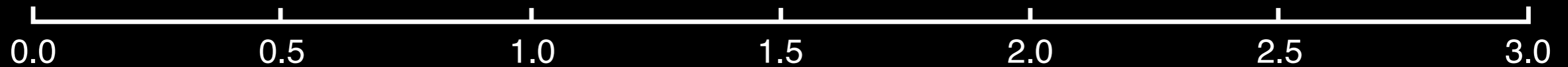
environmental quenching
extended, thermalised haloes
of intracluster medium



protocluster overdensities

energetic AGN feedback
sustained star formation

pre-heated cores
(Saro+2009, Remus+2023)



Redshift

Spiderweb galaxy

Pentericci+1998 - Miley+2006 - Kuiper+2011 -
Emonts+2016,2018 - De Breuck+2022

protocluster galaxies

Kurk+2000 - Pentericci+2000 - Kurk+2004a -
Kodama+2007 - Ogle+2012 - Koyama+2013 -
Tanaka+2013 - Dannerbauer+2014,2017 -
Shimakawa+2015,2018 - Jin+2021 -
Perez-Martinez+2023

AGN activity

Carilli+1997,2022 - Pentericci+1997 - Seymour+2012 -
Gullberg+2016 - Anderson+2022 - Tozzi+2022a

proto-ICM

Tozzi+2022b - Di Mascolo+2023 -
Lepore+2023 (accepted)

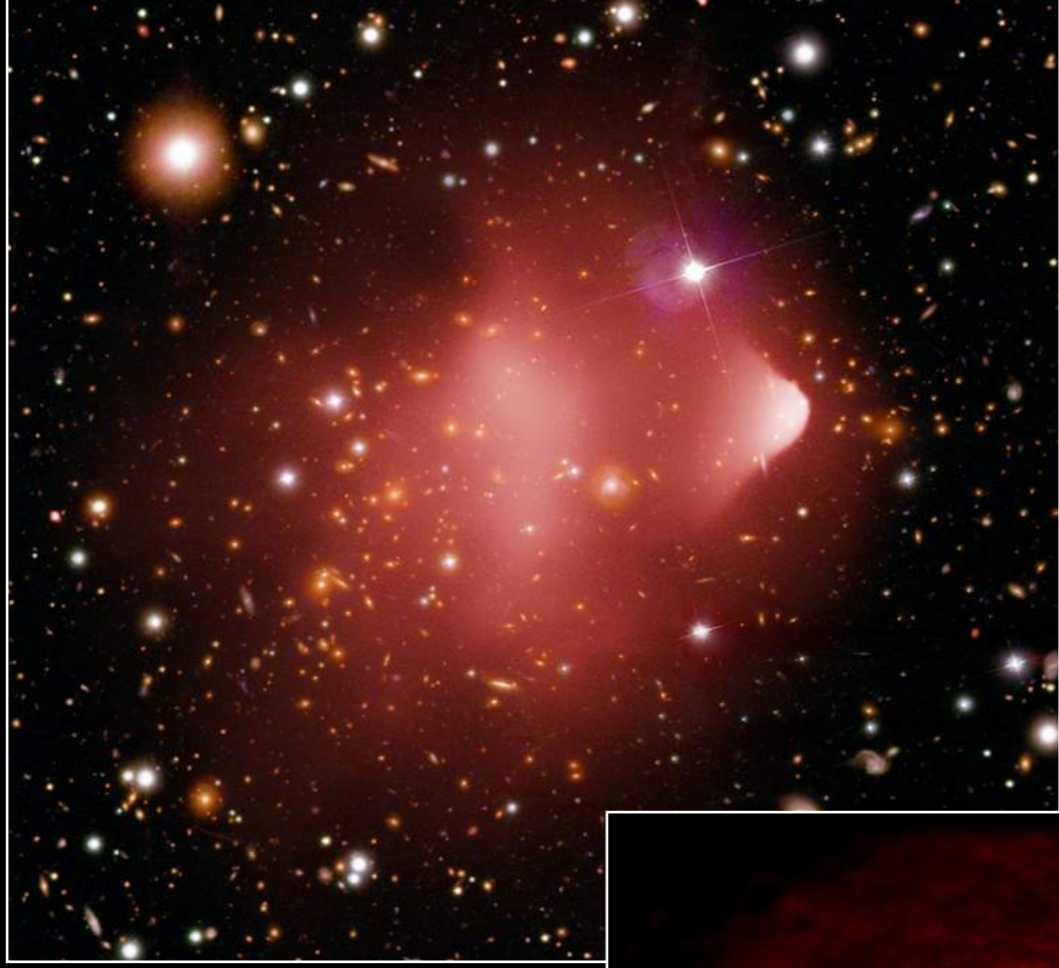
galaxy evolution studies

environment

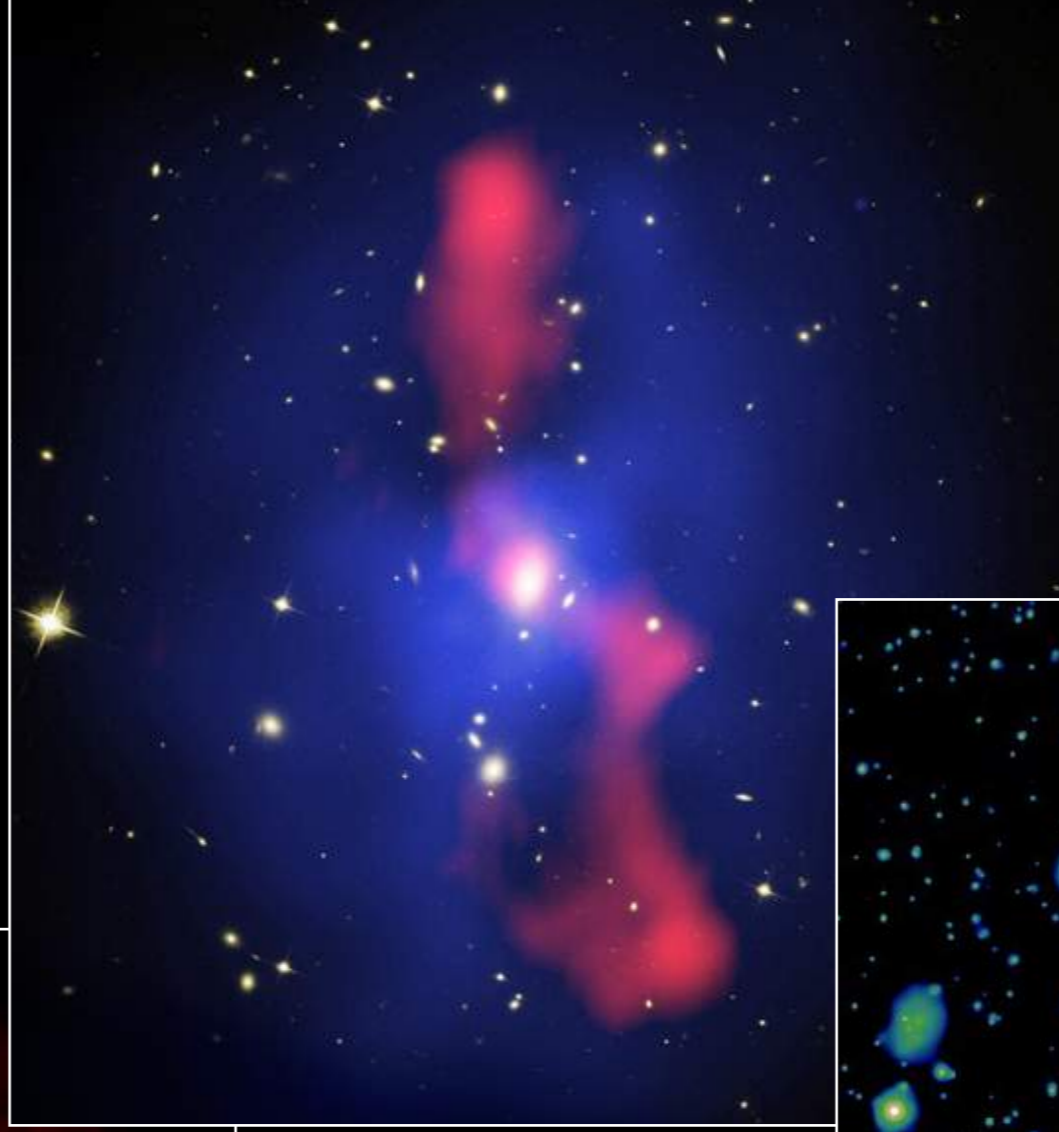


X-ray measurements as key drivers of ICM studies

X-RAY: NASA/CXC/CFAM/M.MARKEVITCH,
OPTICAL: NASA/STScI, MAGELLAN/U.ARIZONA/D.CLOWE

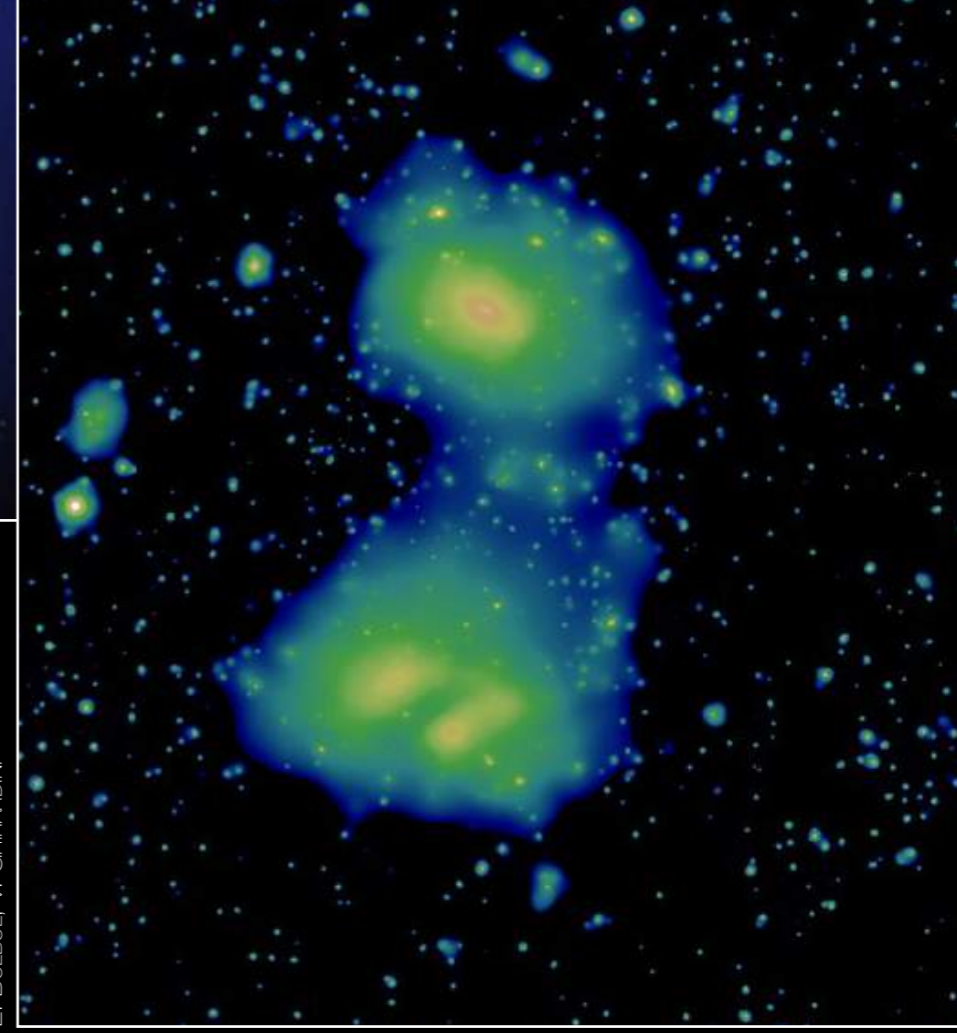


NASA/CXC/GSFC/S.A.WALKER, ET AL.

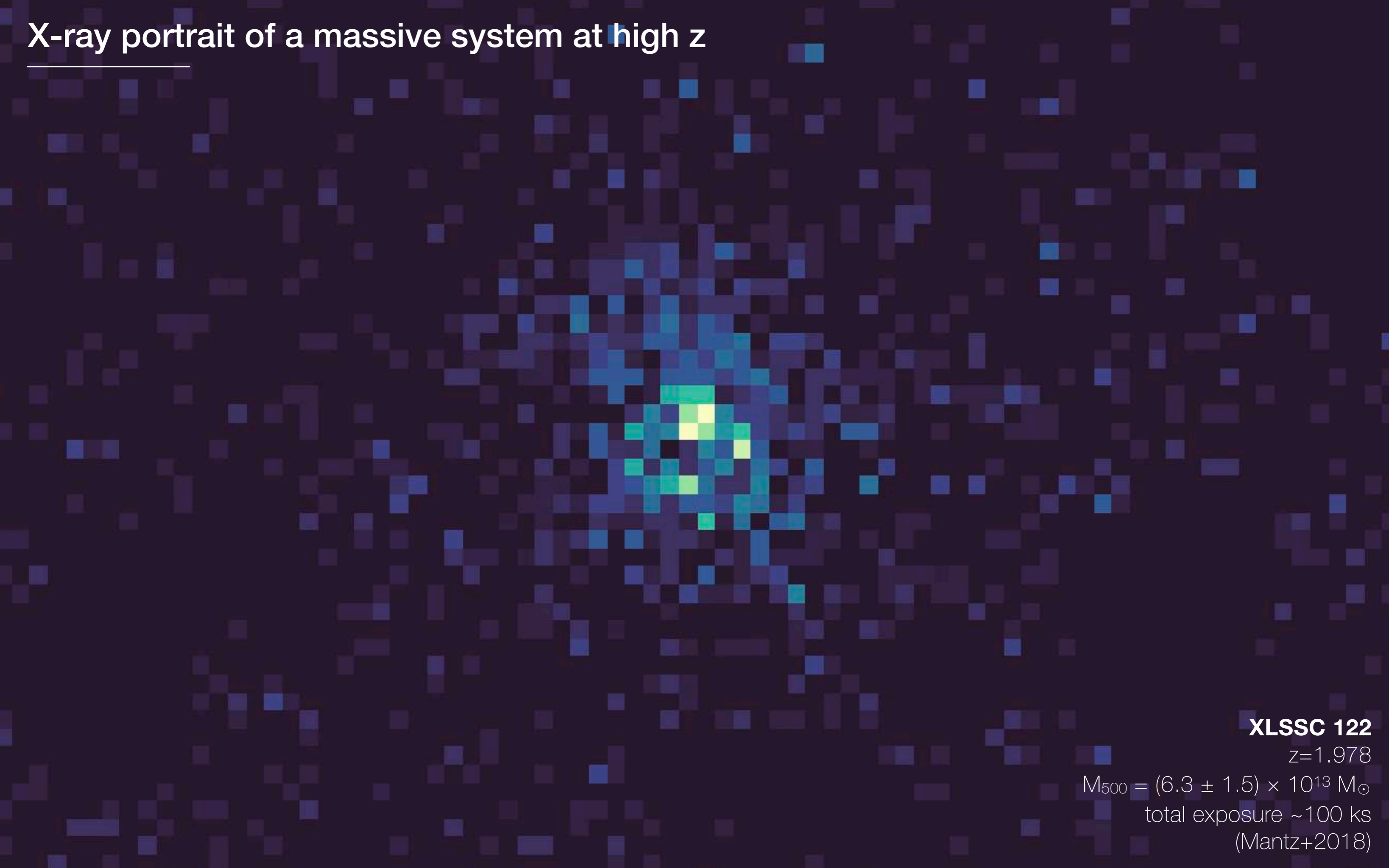


X-RAY: NASA/CXC/UNIV. WATERLOO/
B.MCNAMARA; OPTICAL: NASA/ESA/STScI/
UNIV. WATERLOO/B.MCNAMARA; RADIO:
NRAO/OHIO UNIV./L.BIRZAN ET AL.

UNIV. BONN/T. REPRICH, F. PACAUD
UNIV. GENEVA/D. ECKERT
MPE/M. RAMOS-CEJA, J. SANDERS,
E. BULBUL, V. GHIRARDINI



X-ray portrait of a massive system at high z



XLSSC 122

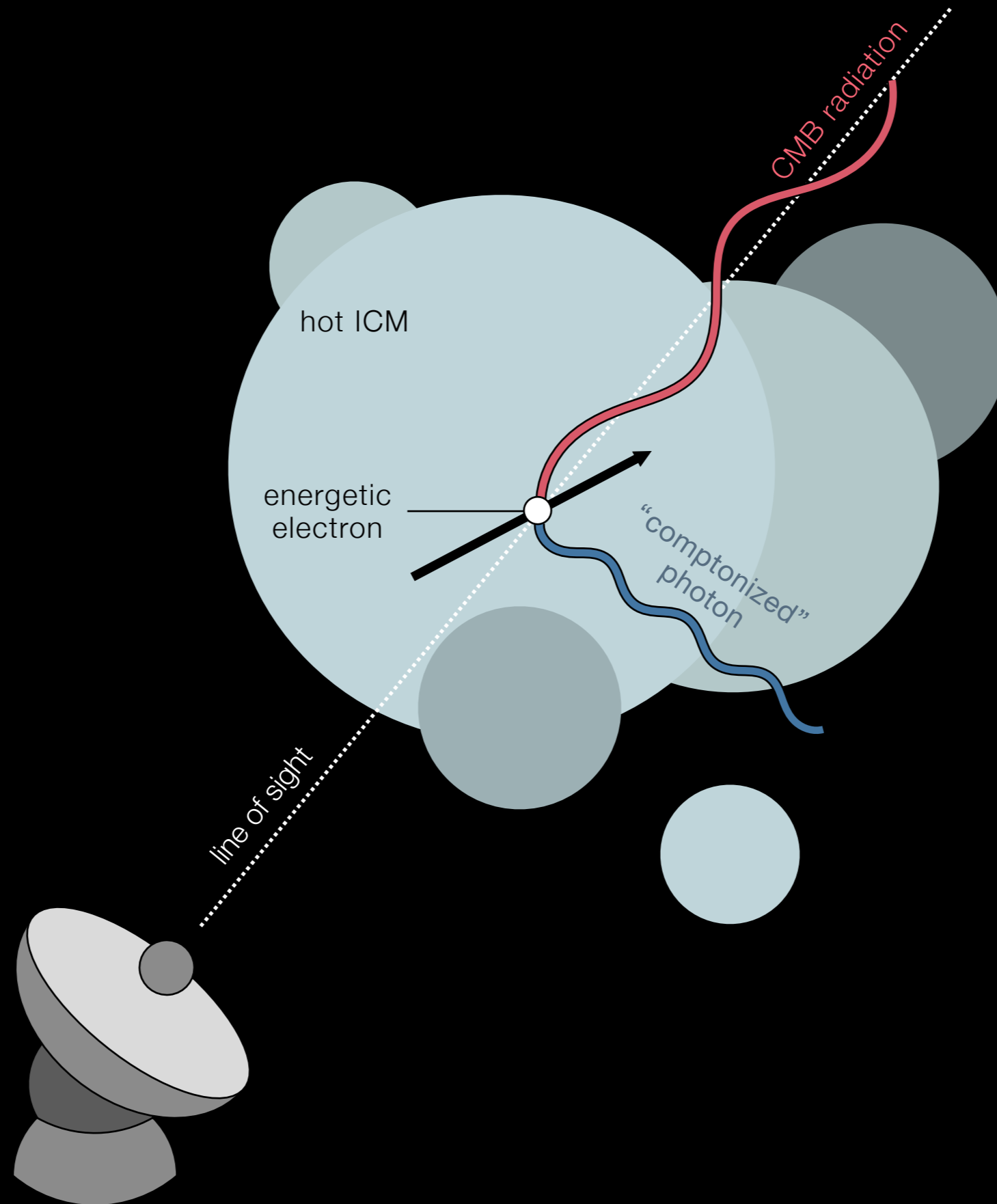
$z=1.978$

$M_{500} = (6.3 \pm 1.5) \times 10^{13} M_{\odot}$

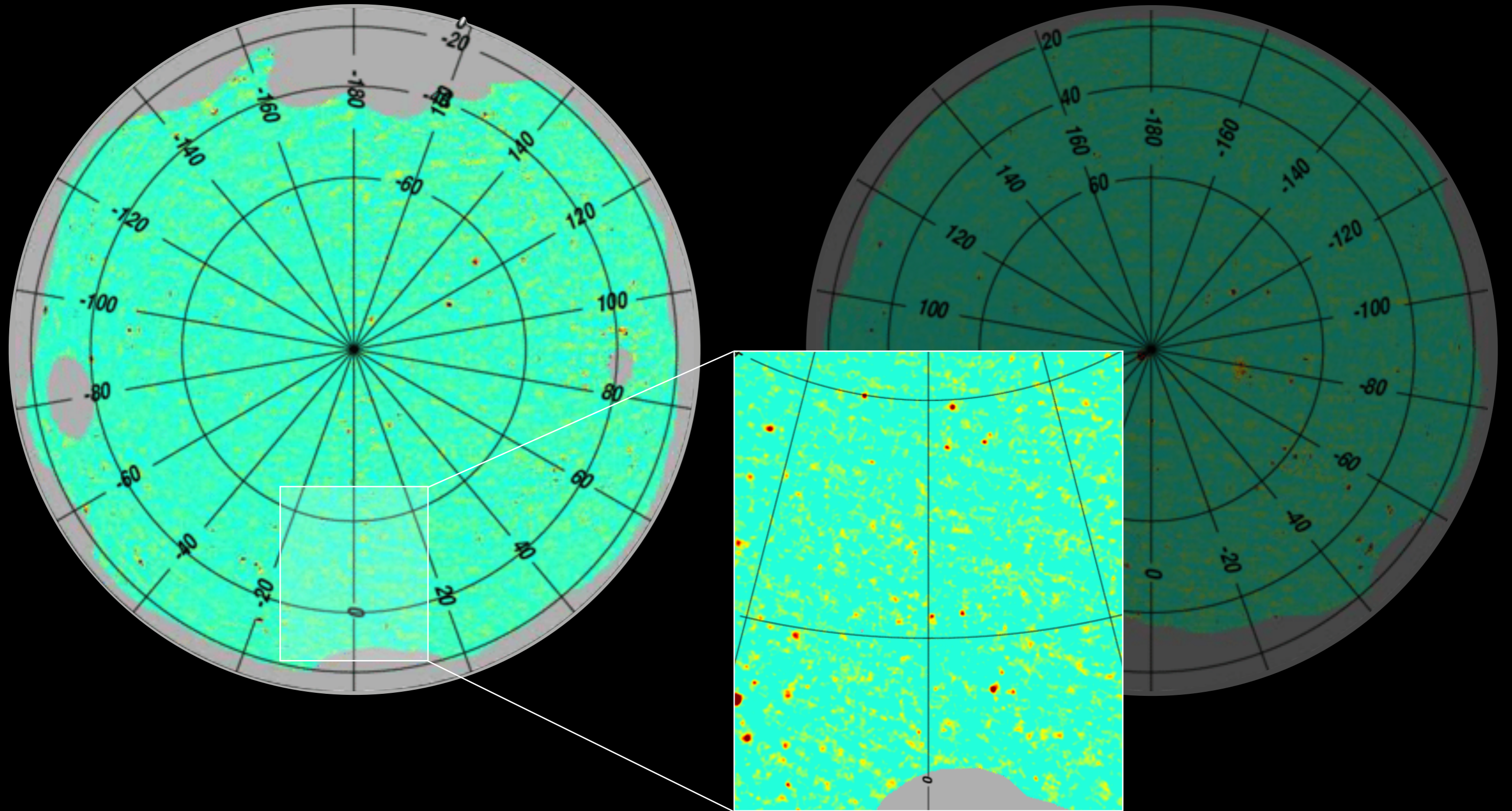
total exposure ~ 100 ks

(Mantz+2018)

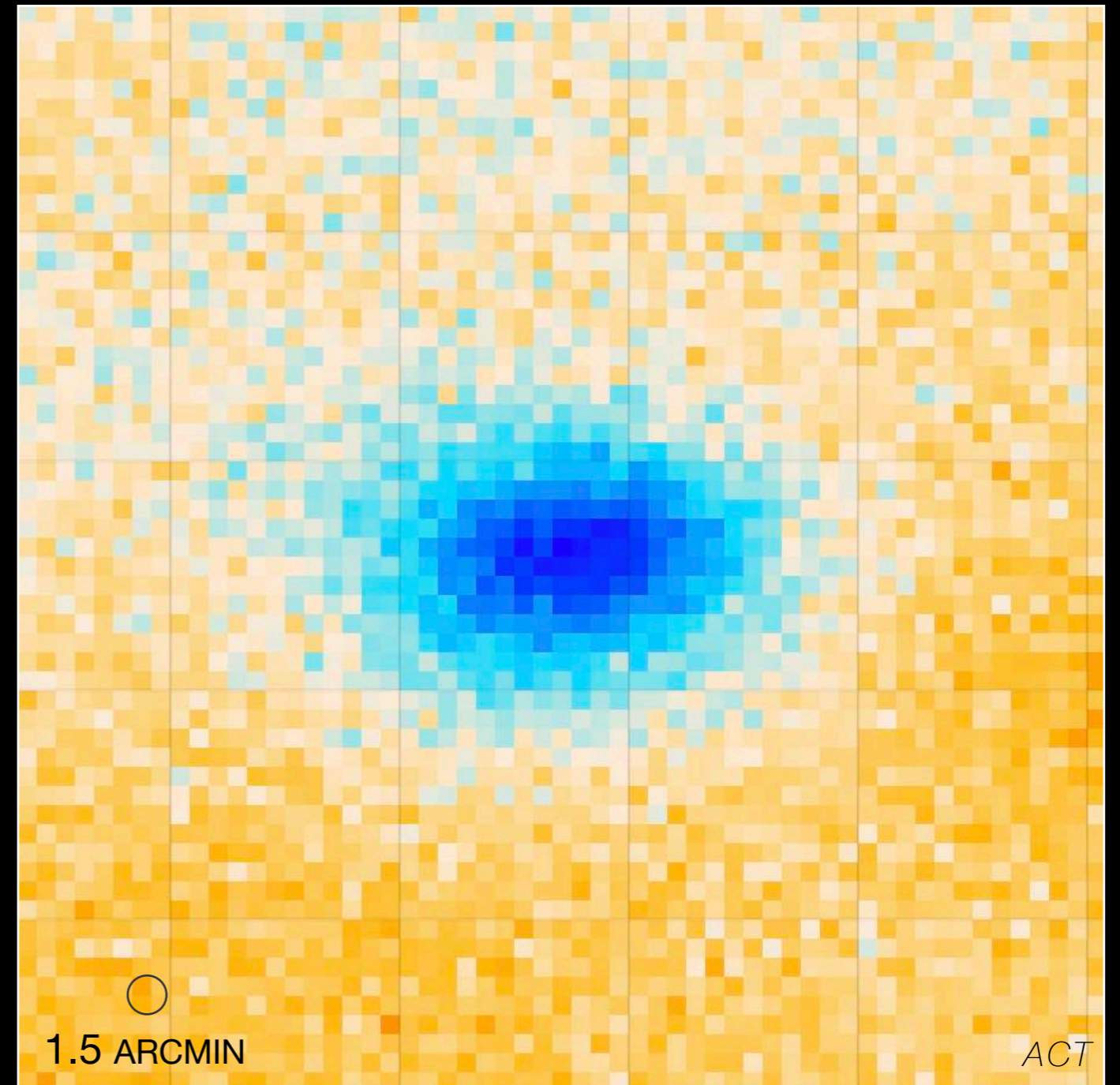
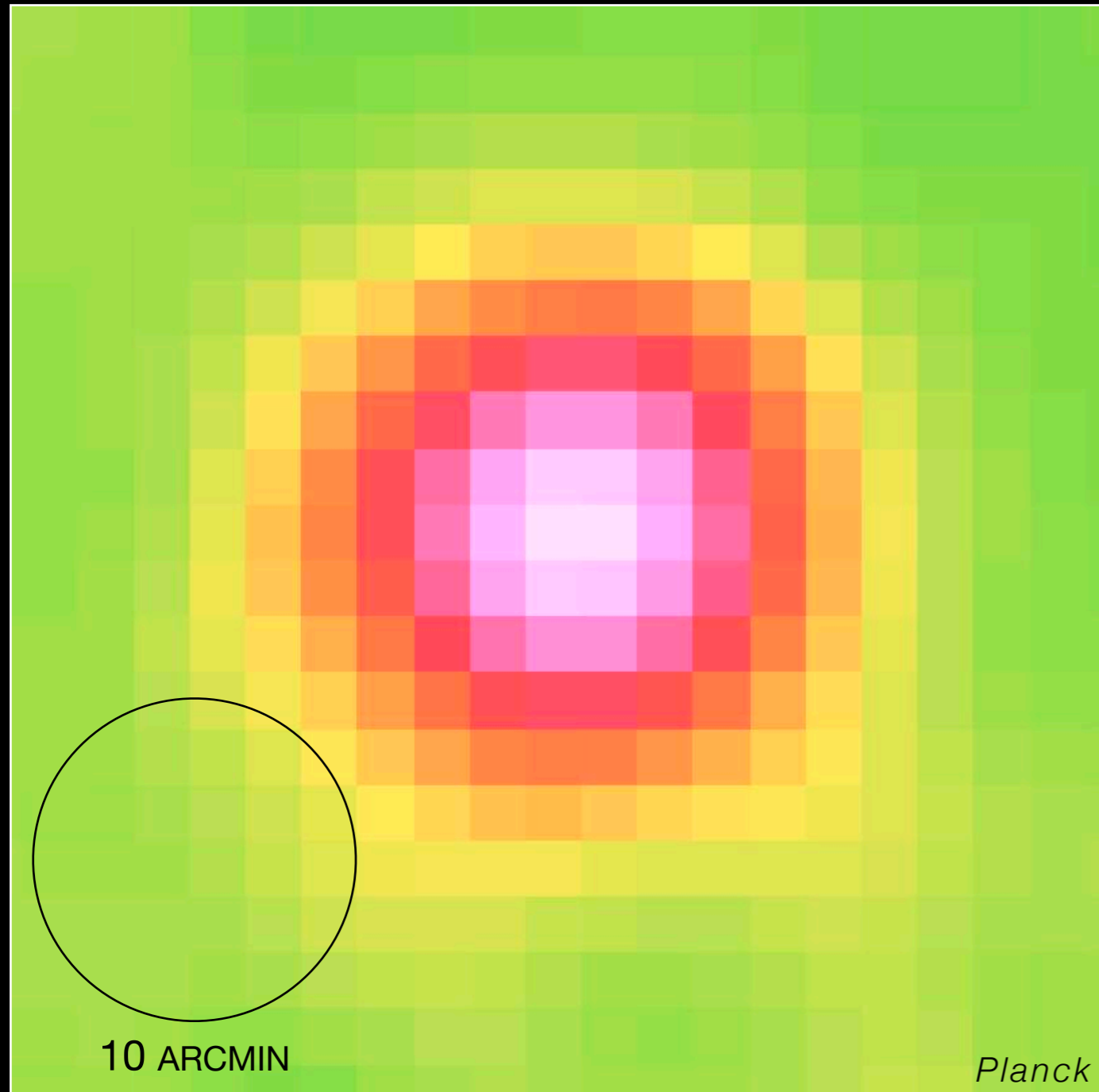
tracing *thermalised* electrons across the Universe



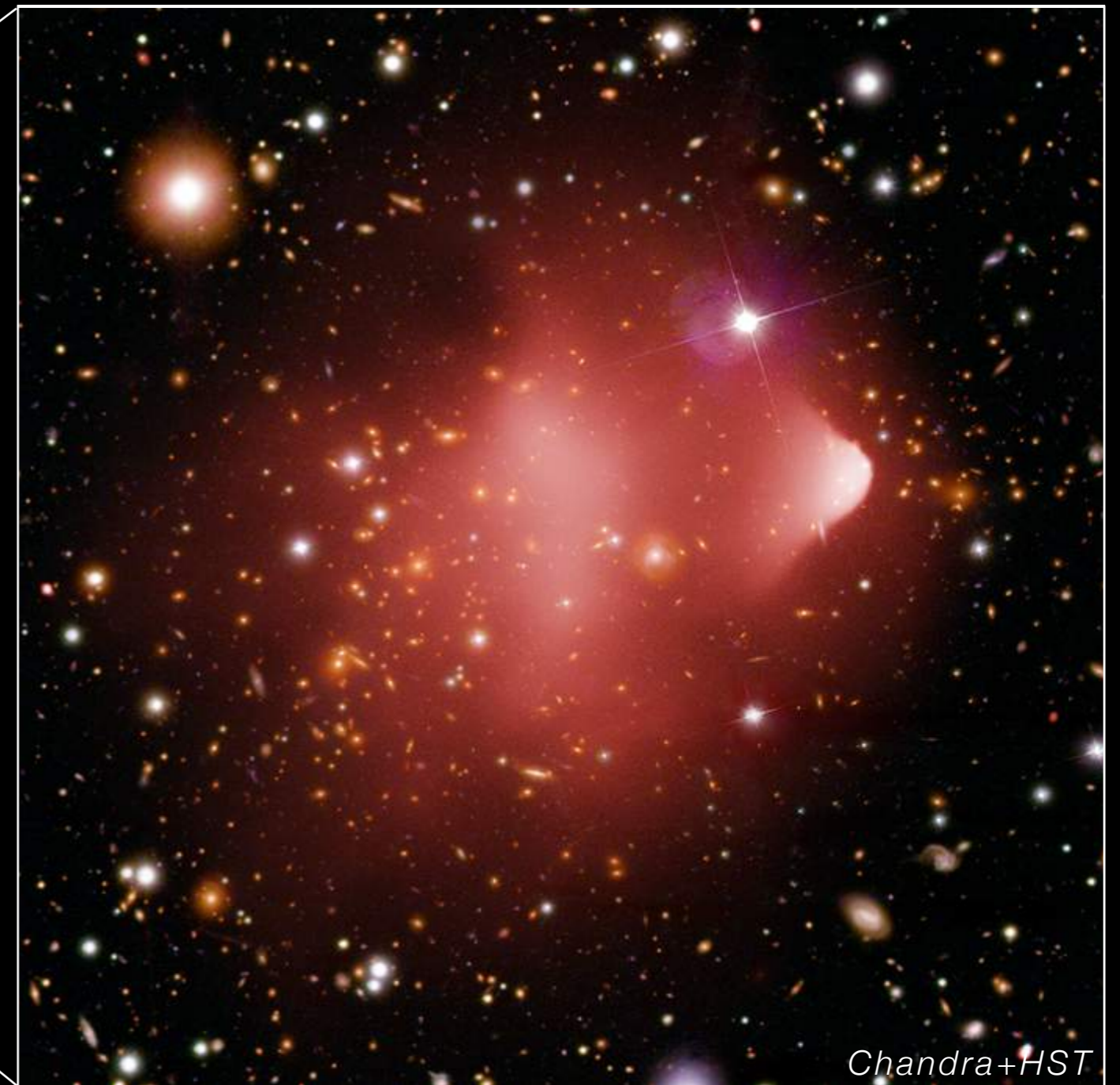
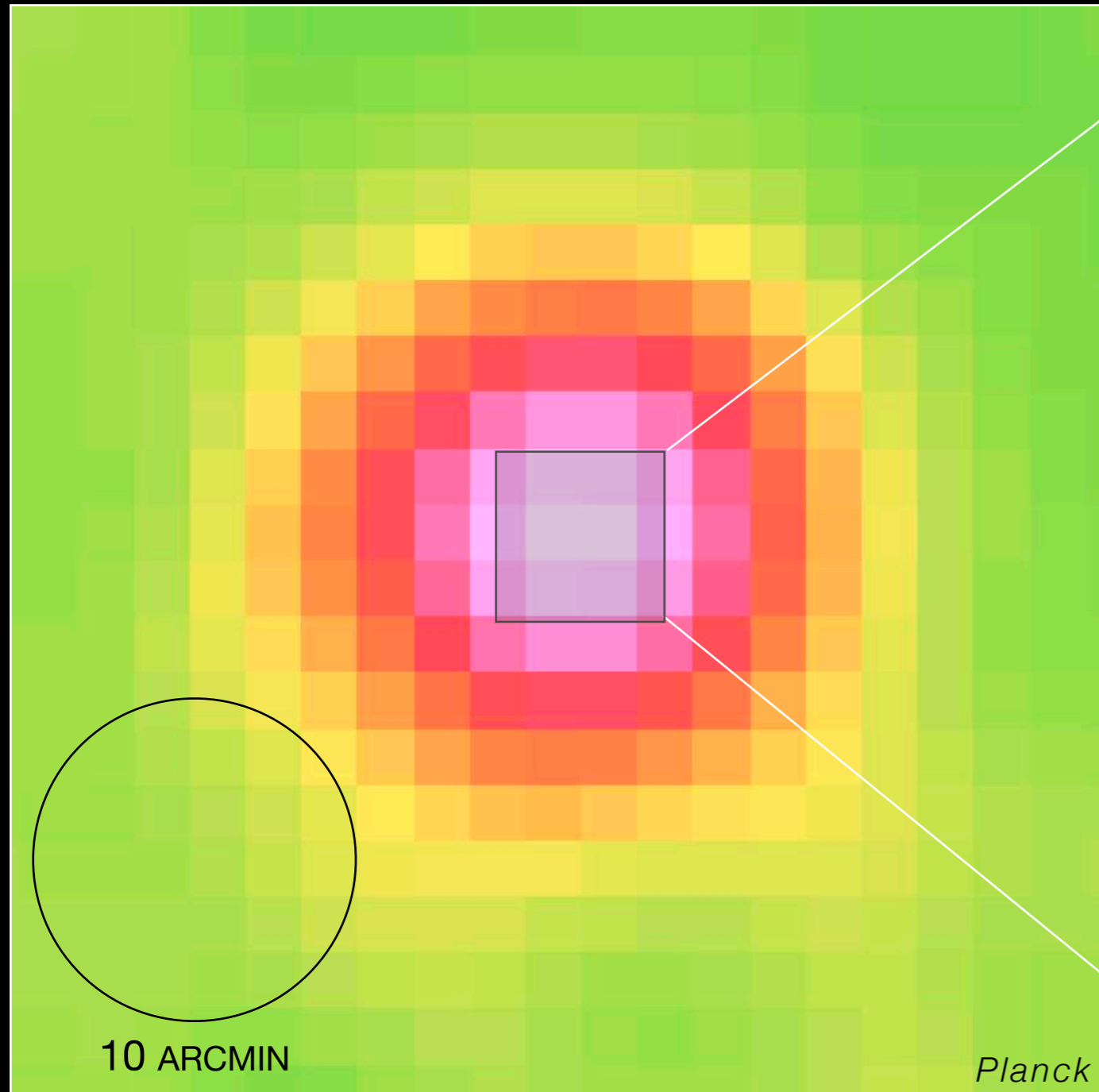
a great tool for finding clusters...



...but low angular resolution

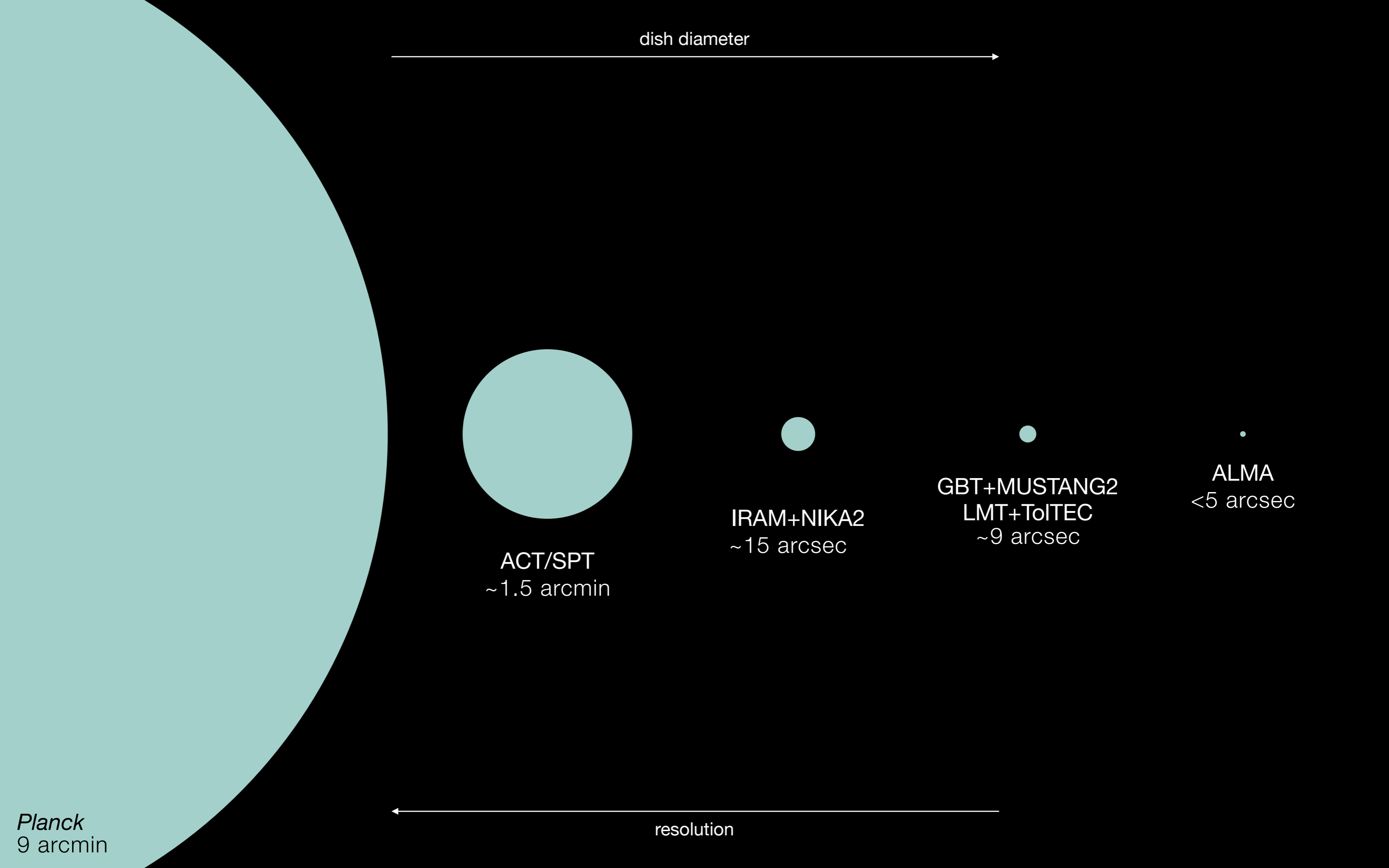


...but low angular resolution

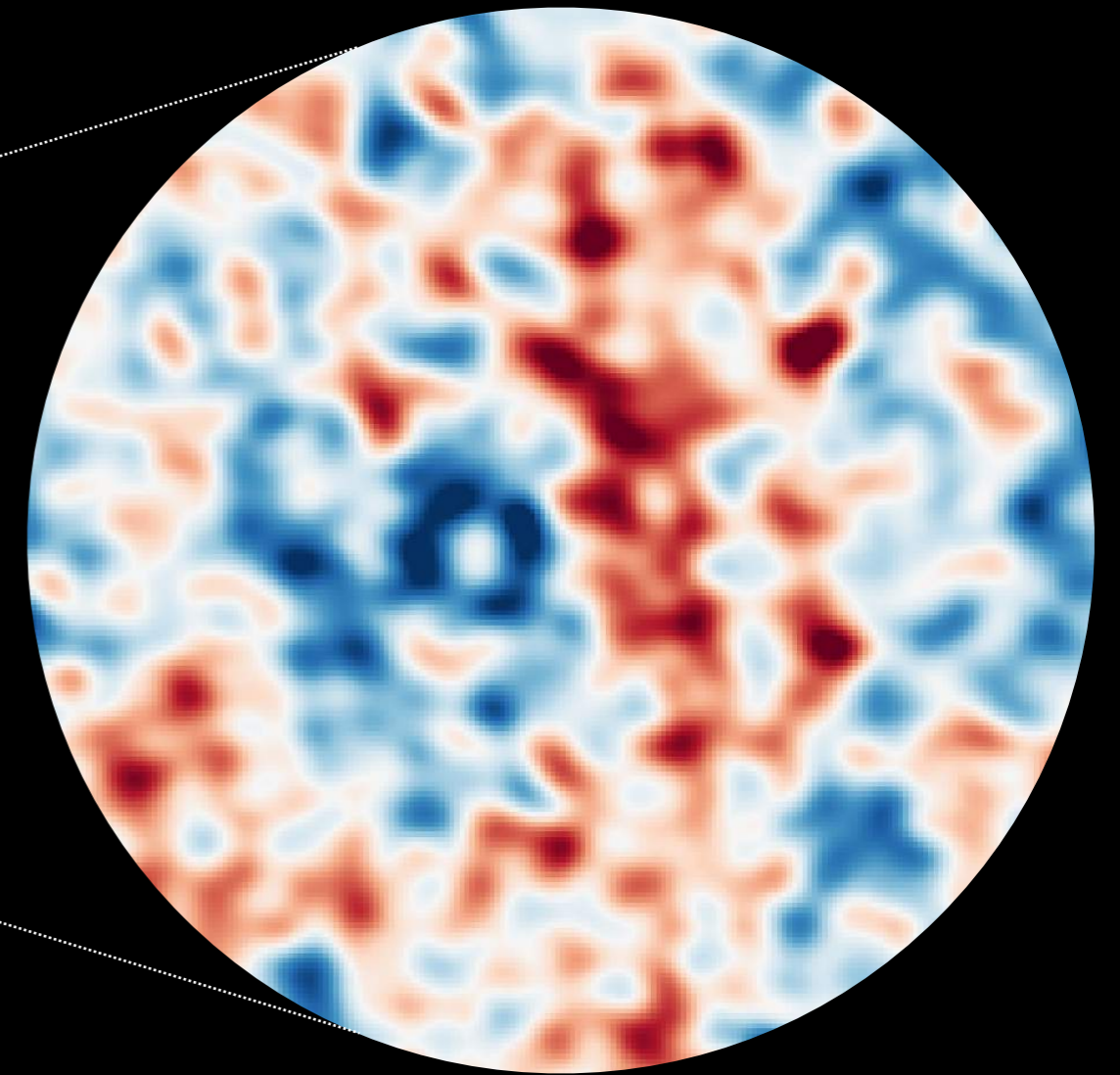
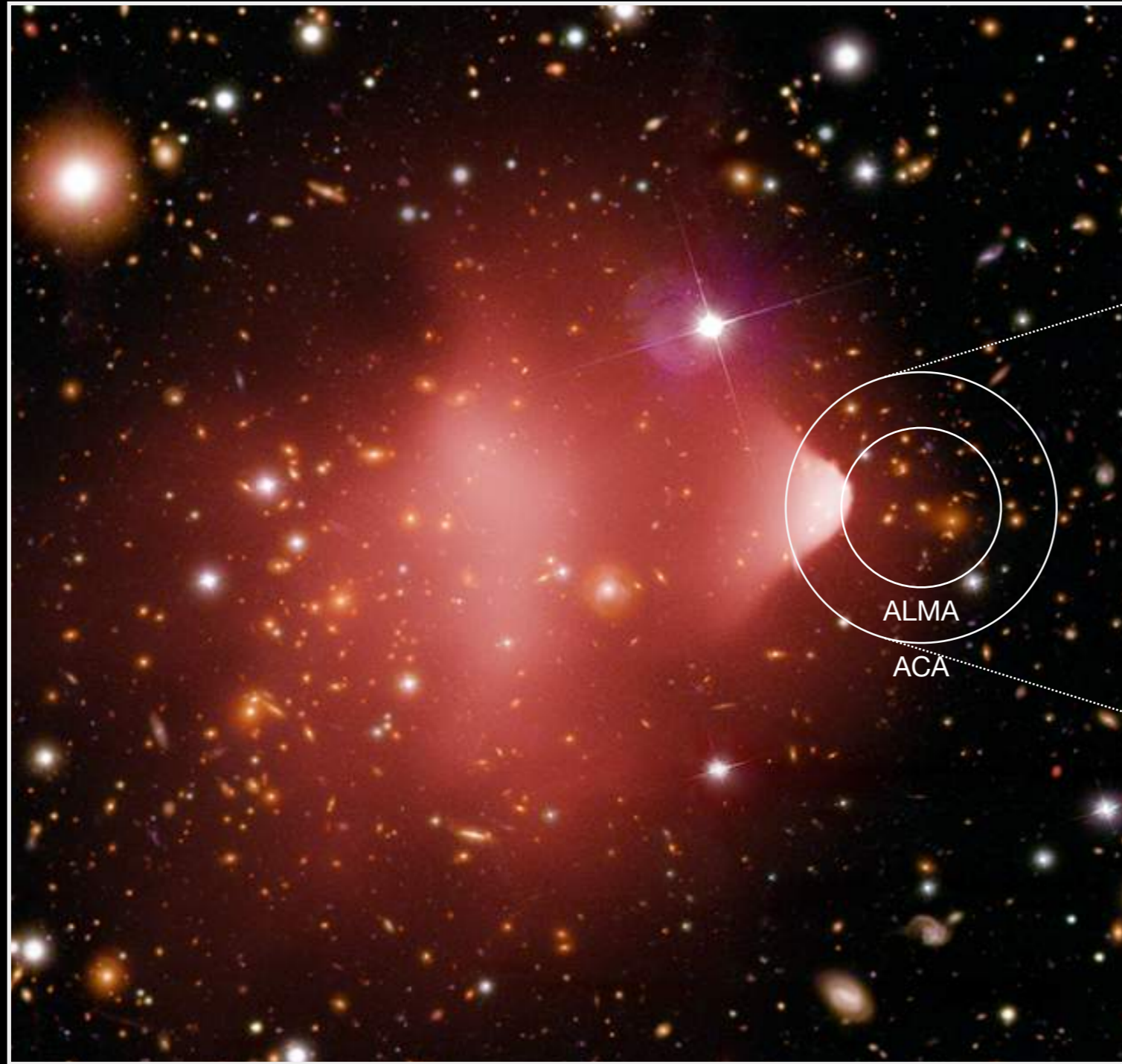




ALMA

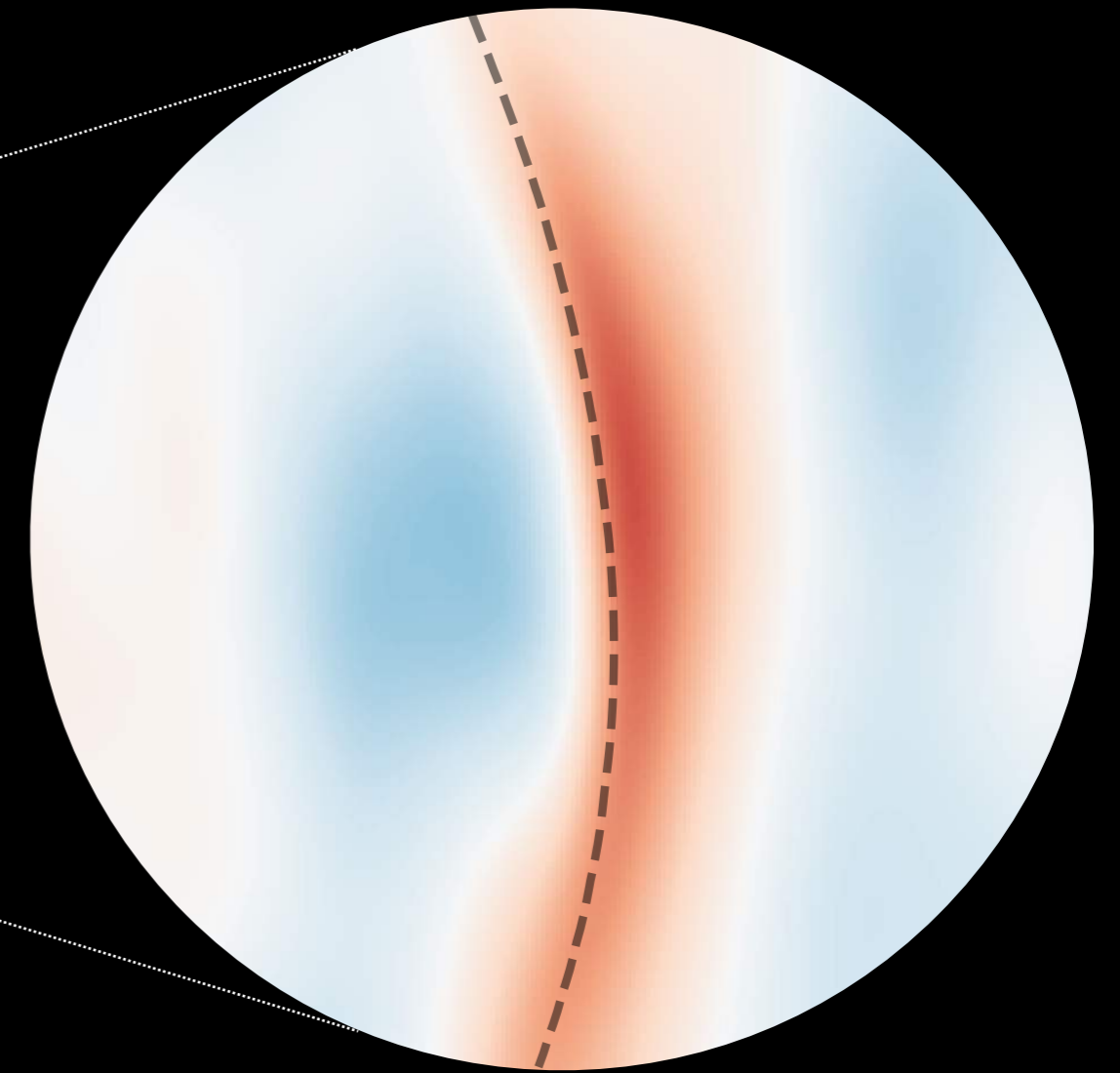
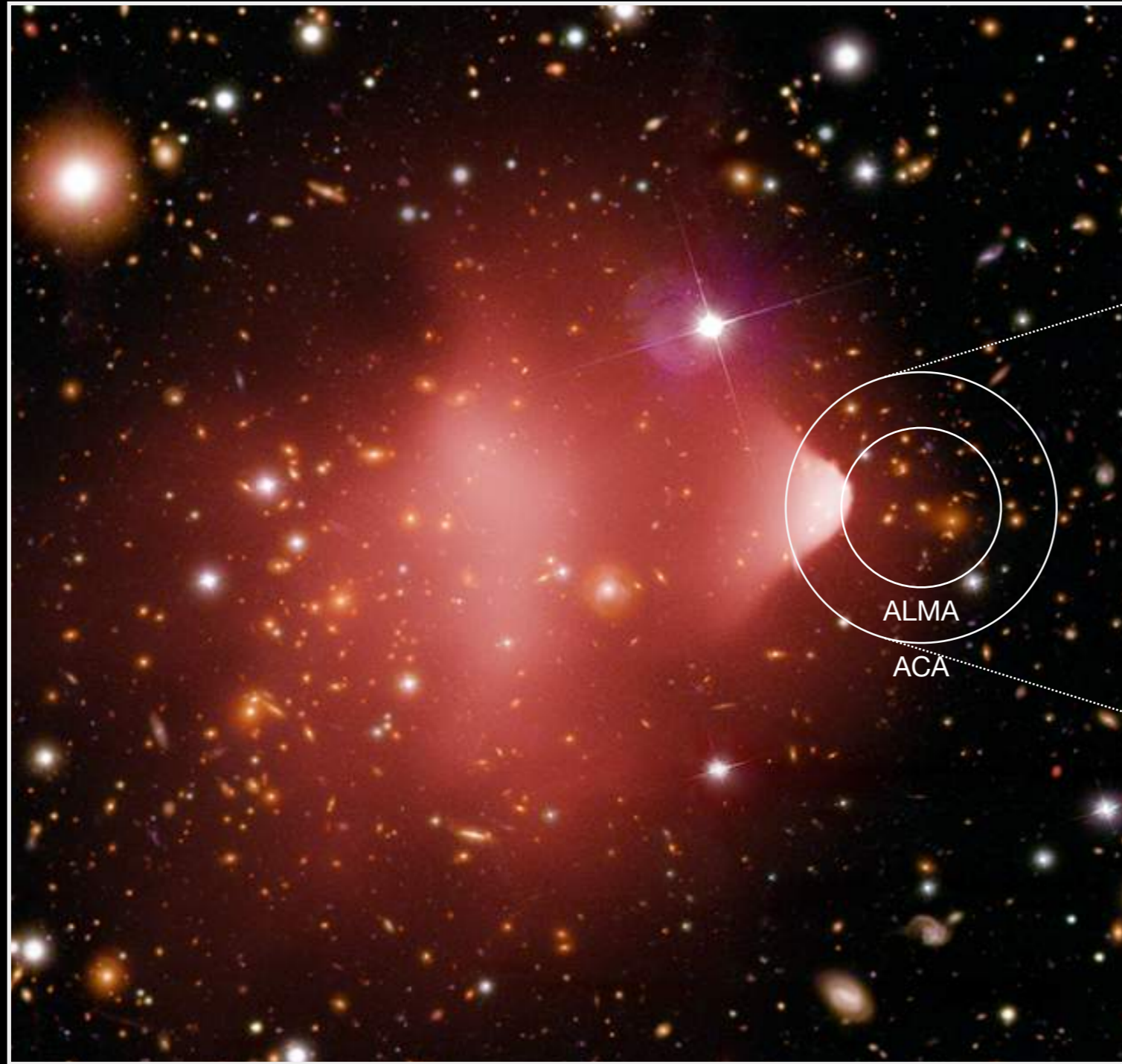


how ALMA sees galaxy clusters



data

how ALMA sees galaxy clusters



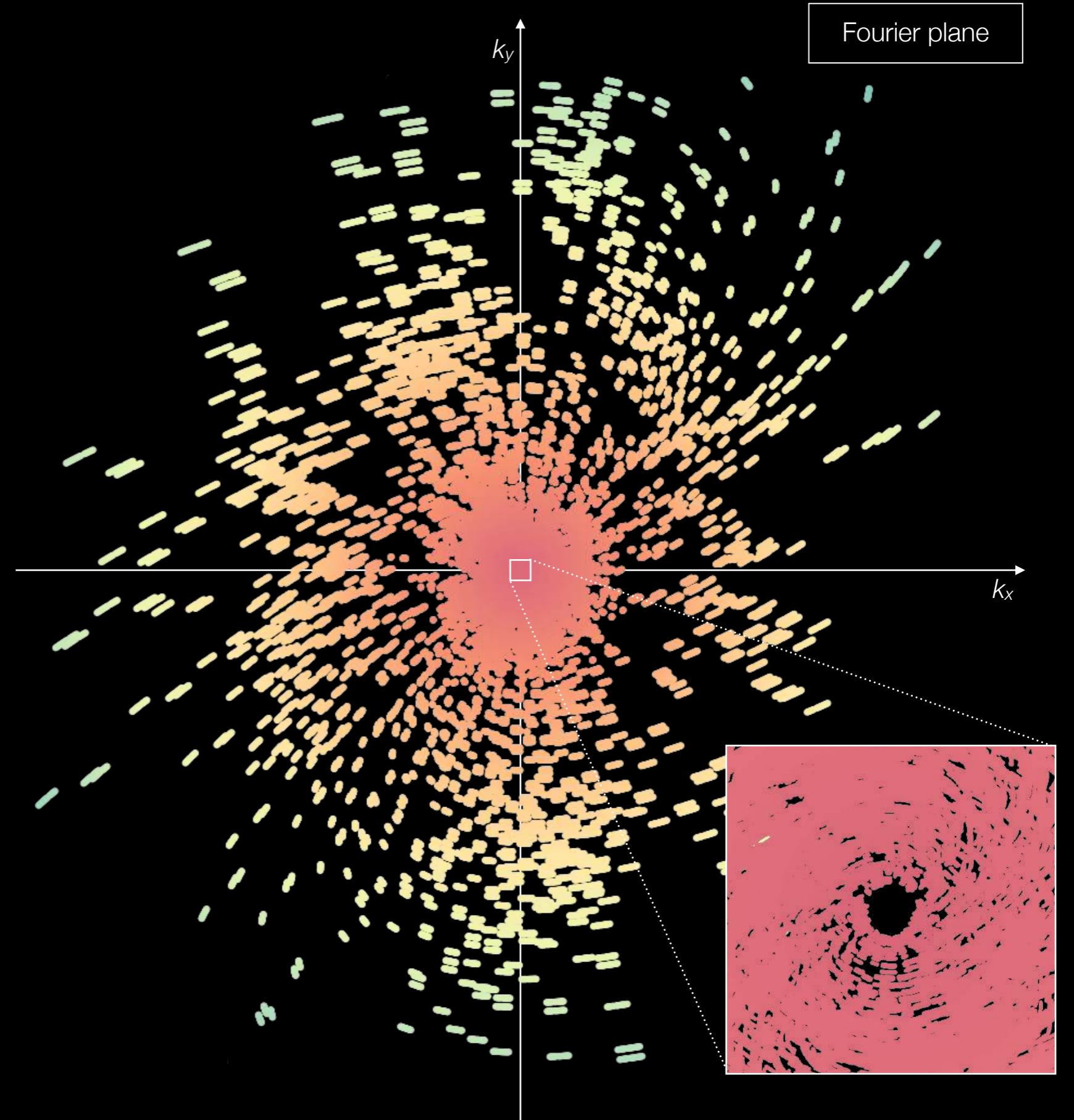
model

a high-pass filtered view of the Universe

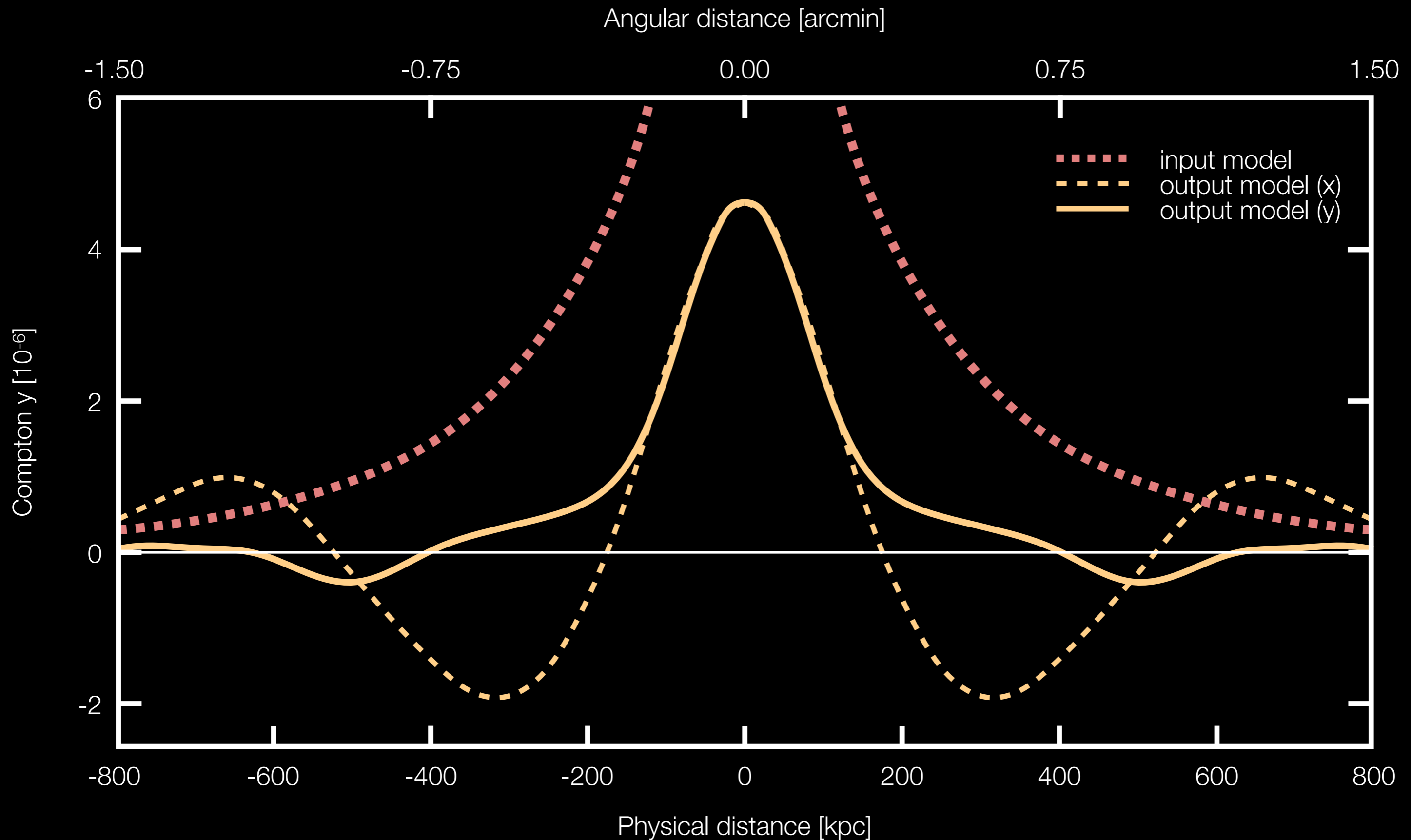
large-scale Fourier modes not observed,
resulting in **dramatic information loss**

existing imaging tools not optimised
for reconstruction of large-scale/SZ signal

modelling techniques limited by
lack of adequate descriptions



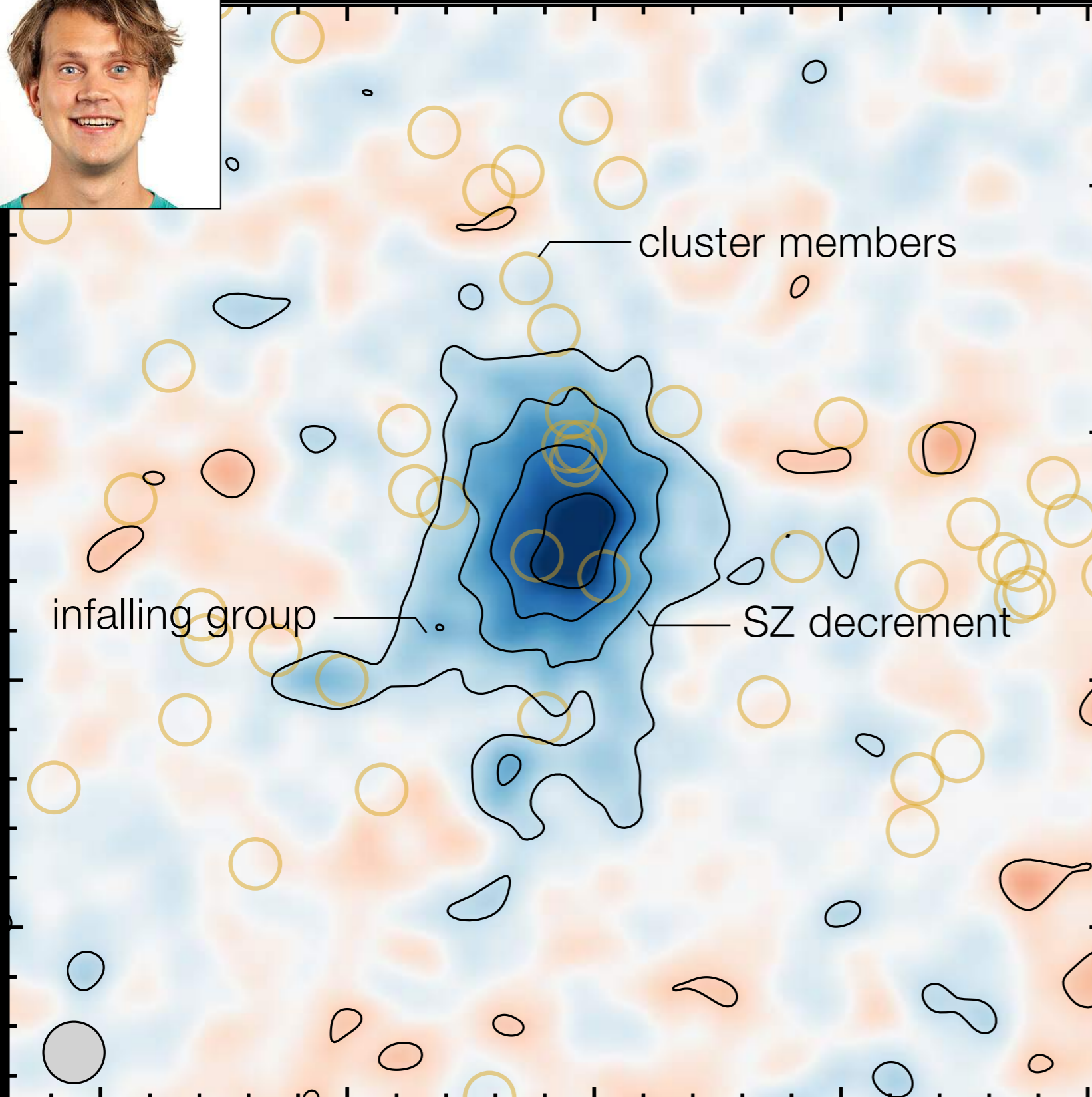
a high-pass filtered view of the Universe



a cluster caught in the act of growing up



Joshiwa van Marrewijk PhD student @ ESO

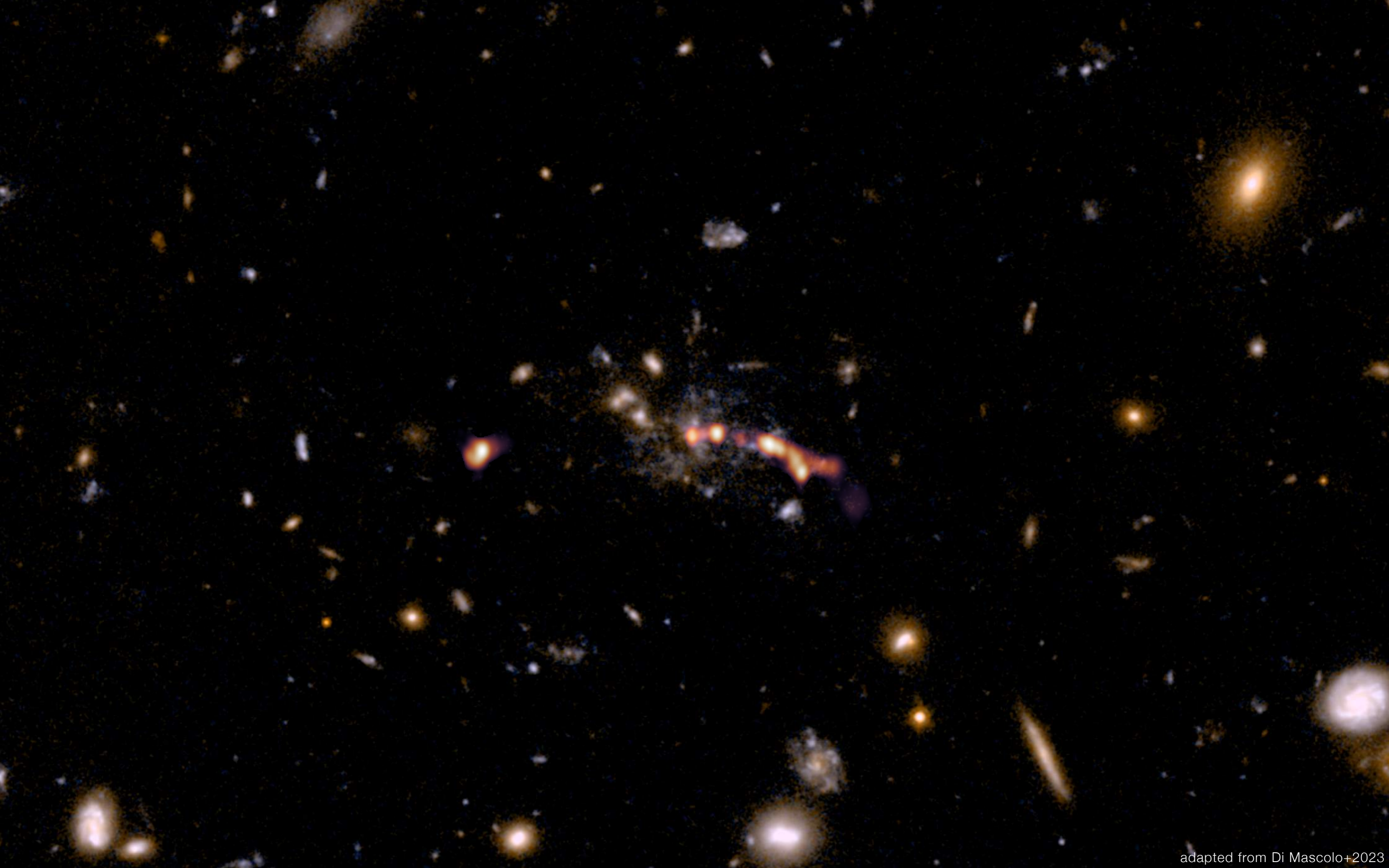


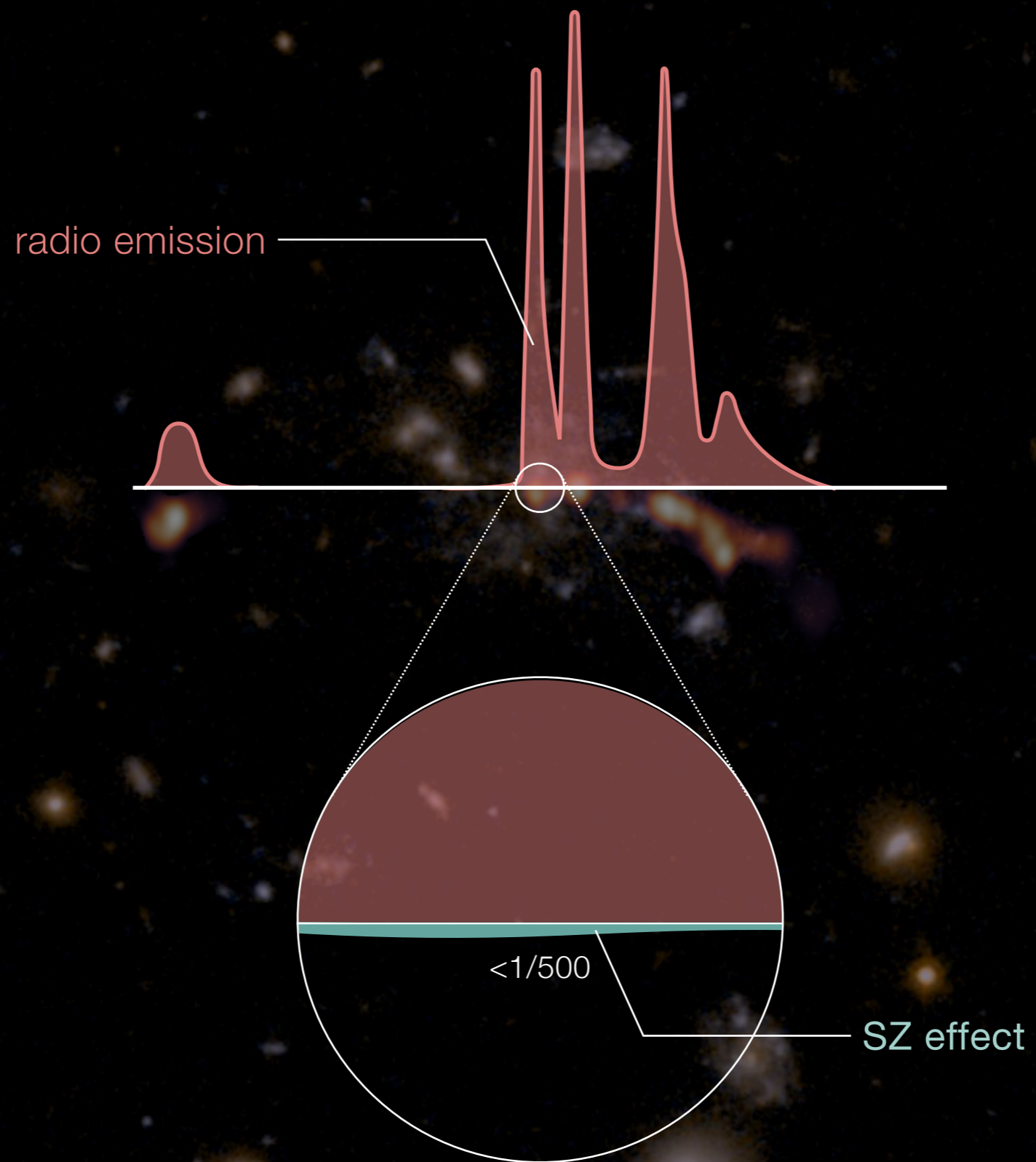
joint ALMA+ACT analysis
of the SZ signal from XLSSC 122

Bayesian imaging+inference unveils
structures associated to dynamical states

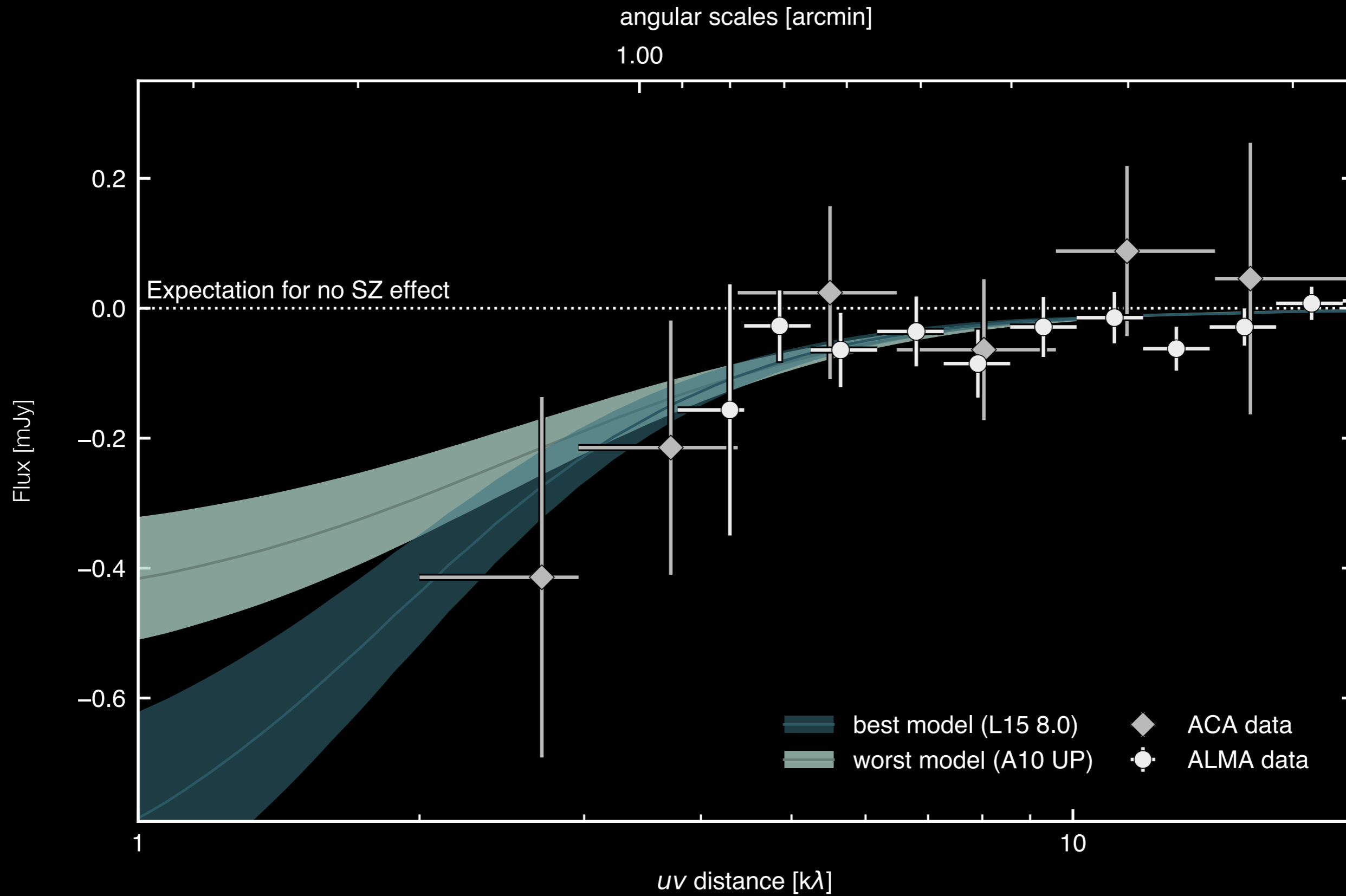
pressure profile from the core
till roughly the virial radius

dominant role of merger processes in
driving ICM heating
(instead of small-scale accretion)





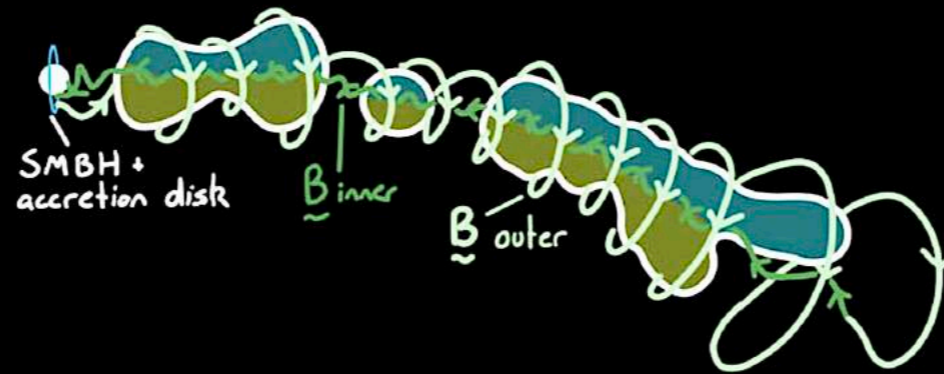
let's put our Fourier glasses on



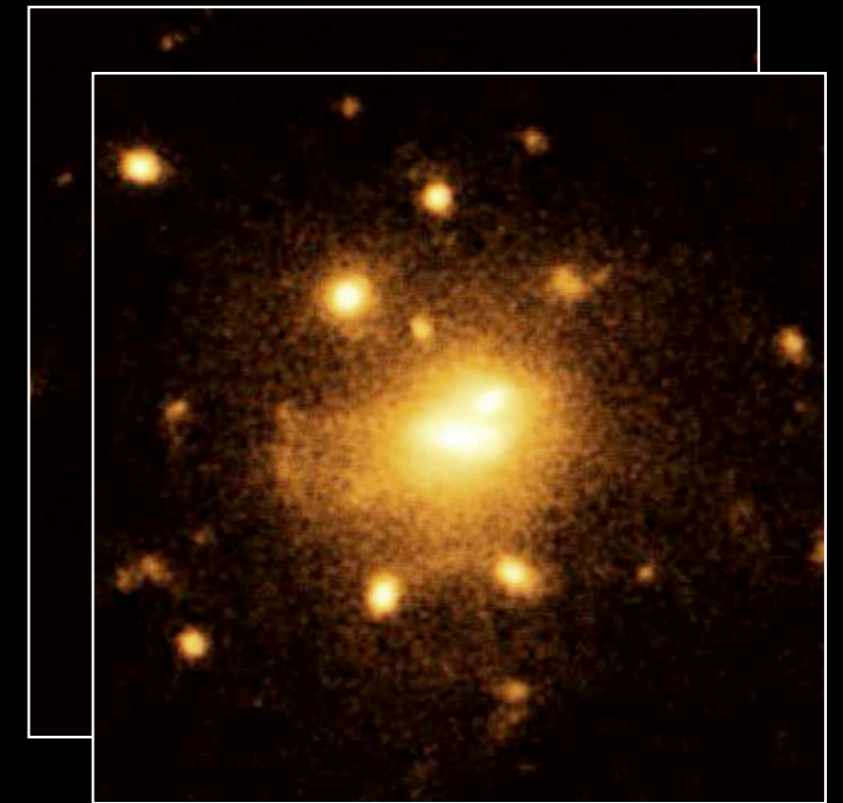
confirmation of long-standing predictions



Pentericci+1997, Hatch+2009
Star-bursting proto-BCG fed by
“cooling flow”-like precipitation
(but not the only scenario)

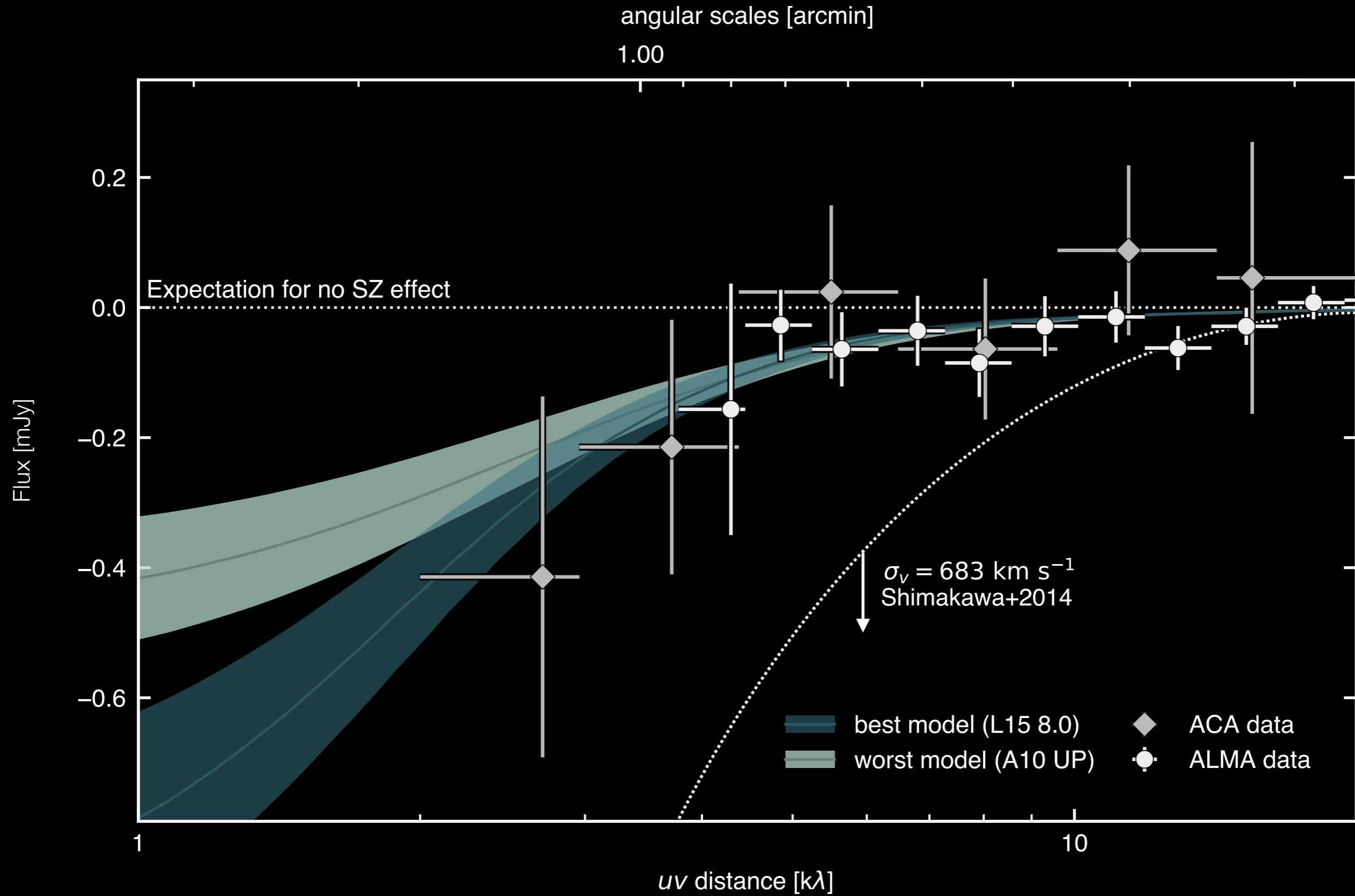


Carilli+1997, Anderson+2022
RMs generate in thin sheath of
hot gas around the radio jet

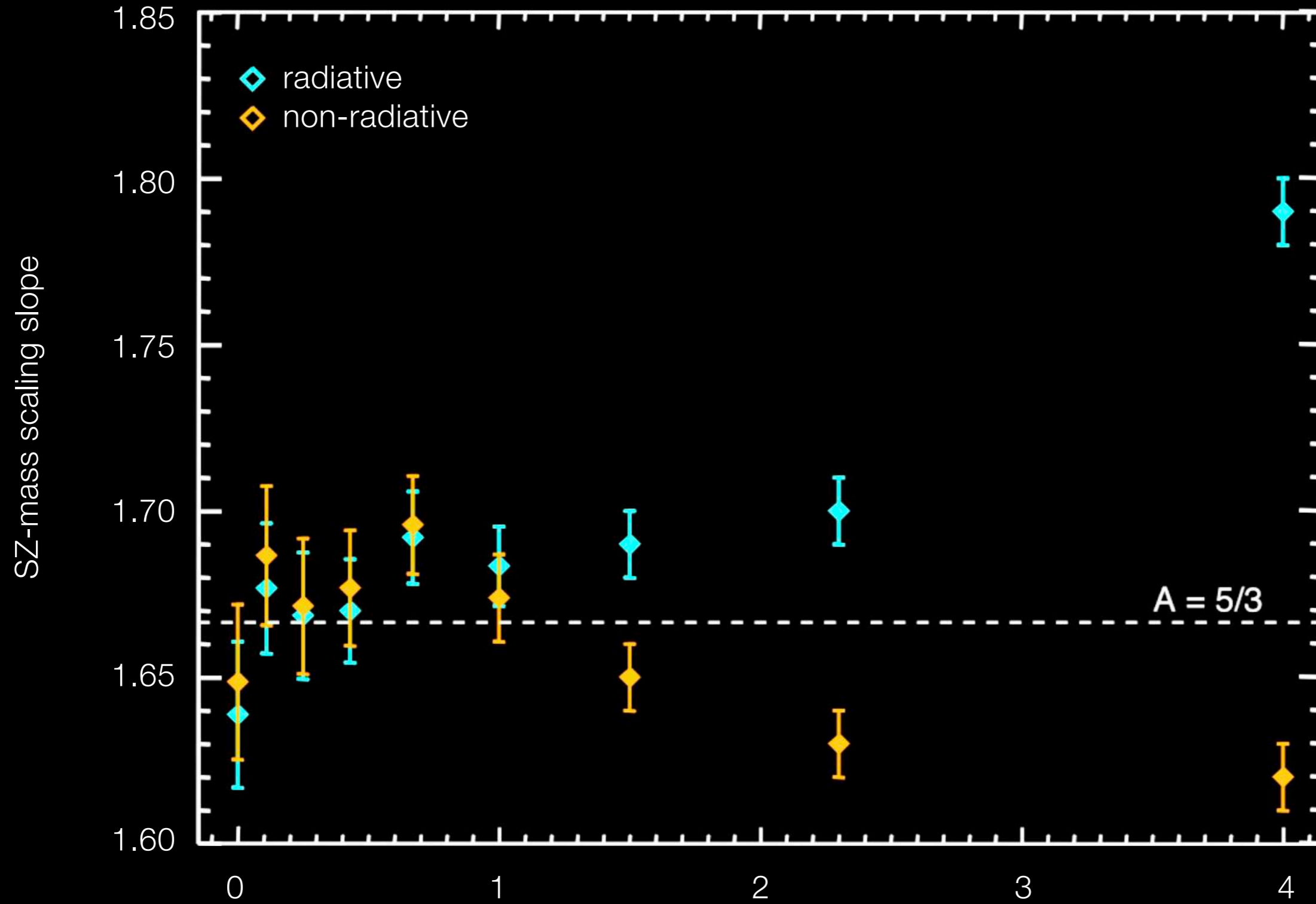


Saro+2009
simulated protoclusters with
gravitational potential permeated
by ICM at 2-5 keV

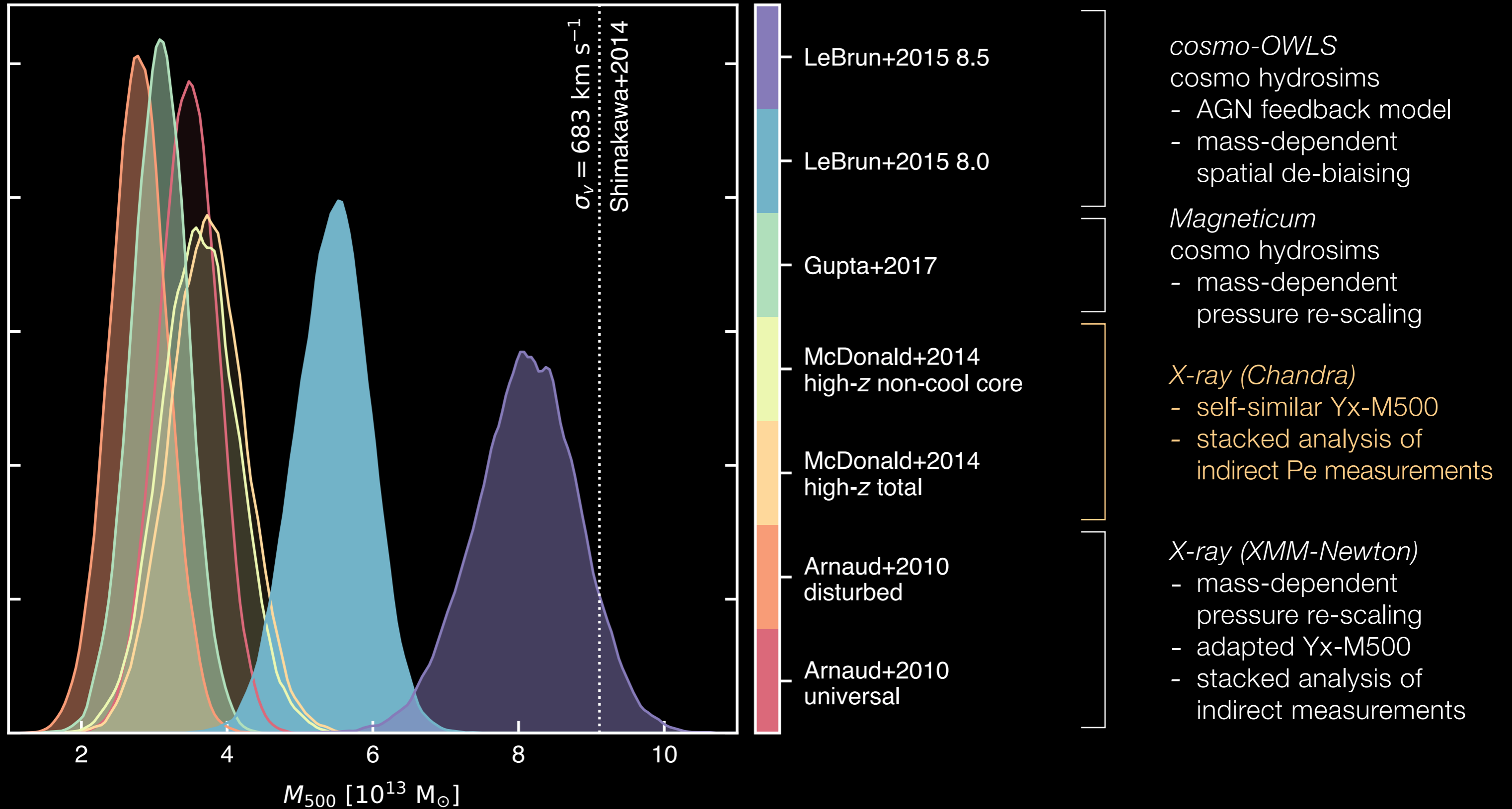
faint SZ signal



faint SZ signal...or deviation from self-similarity?

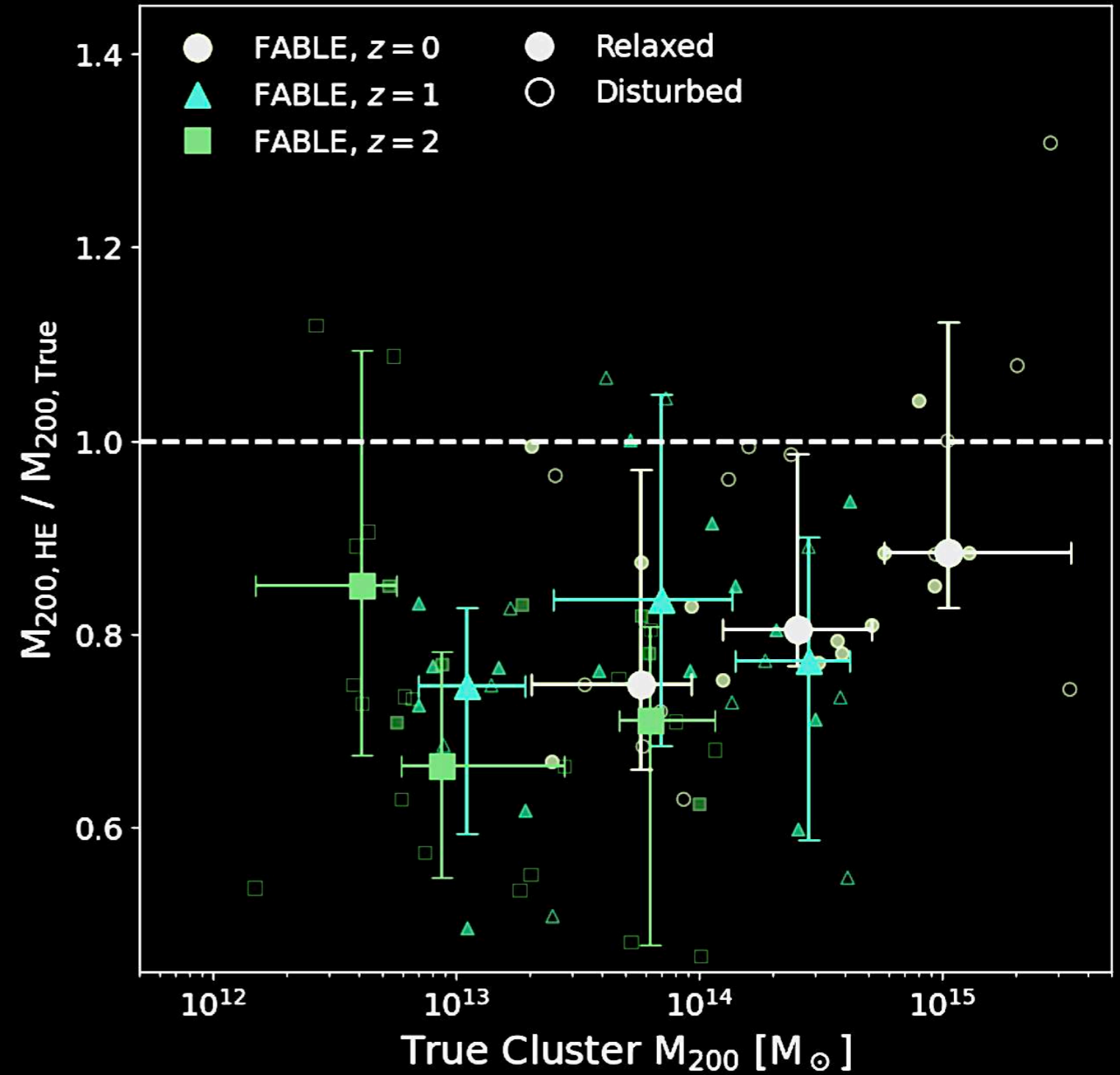


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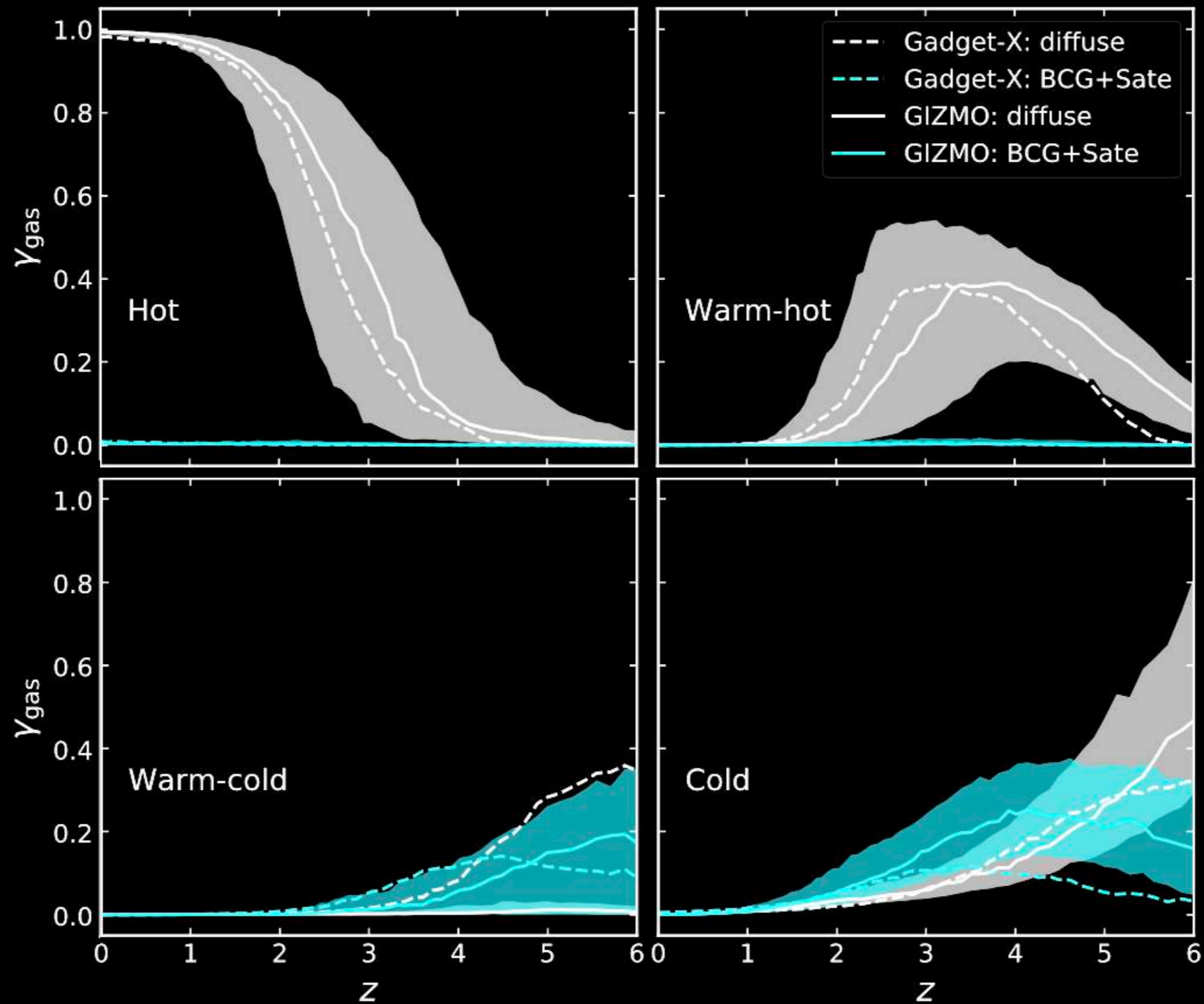
faint SZ signal...or systematics?

1. non-thermal pressure support



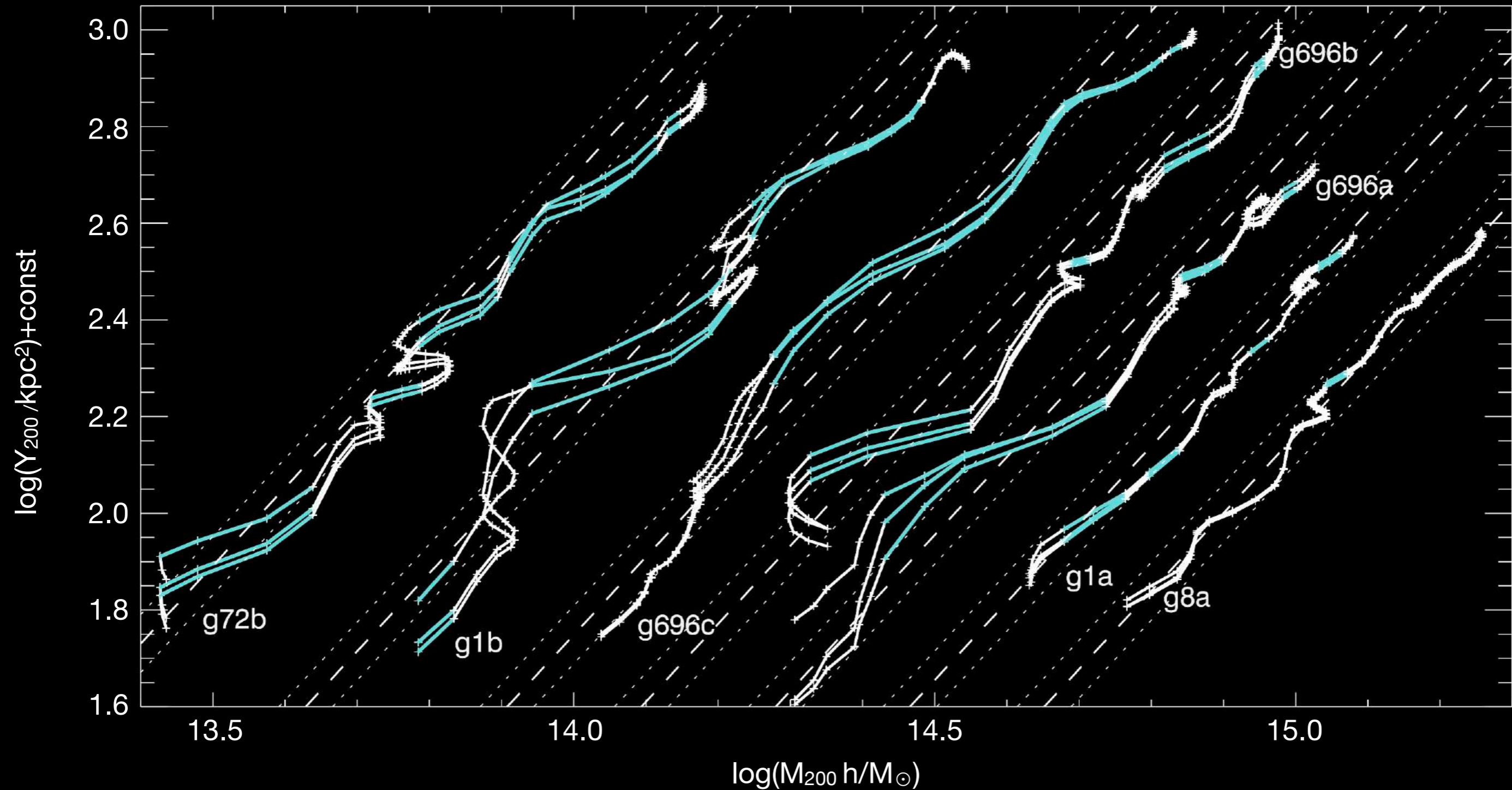
faint SZ signal...or systematics?

1. non-thermal pressure support
2. deviation from thermalization



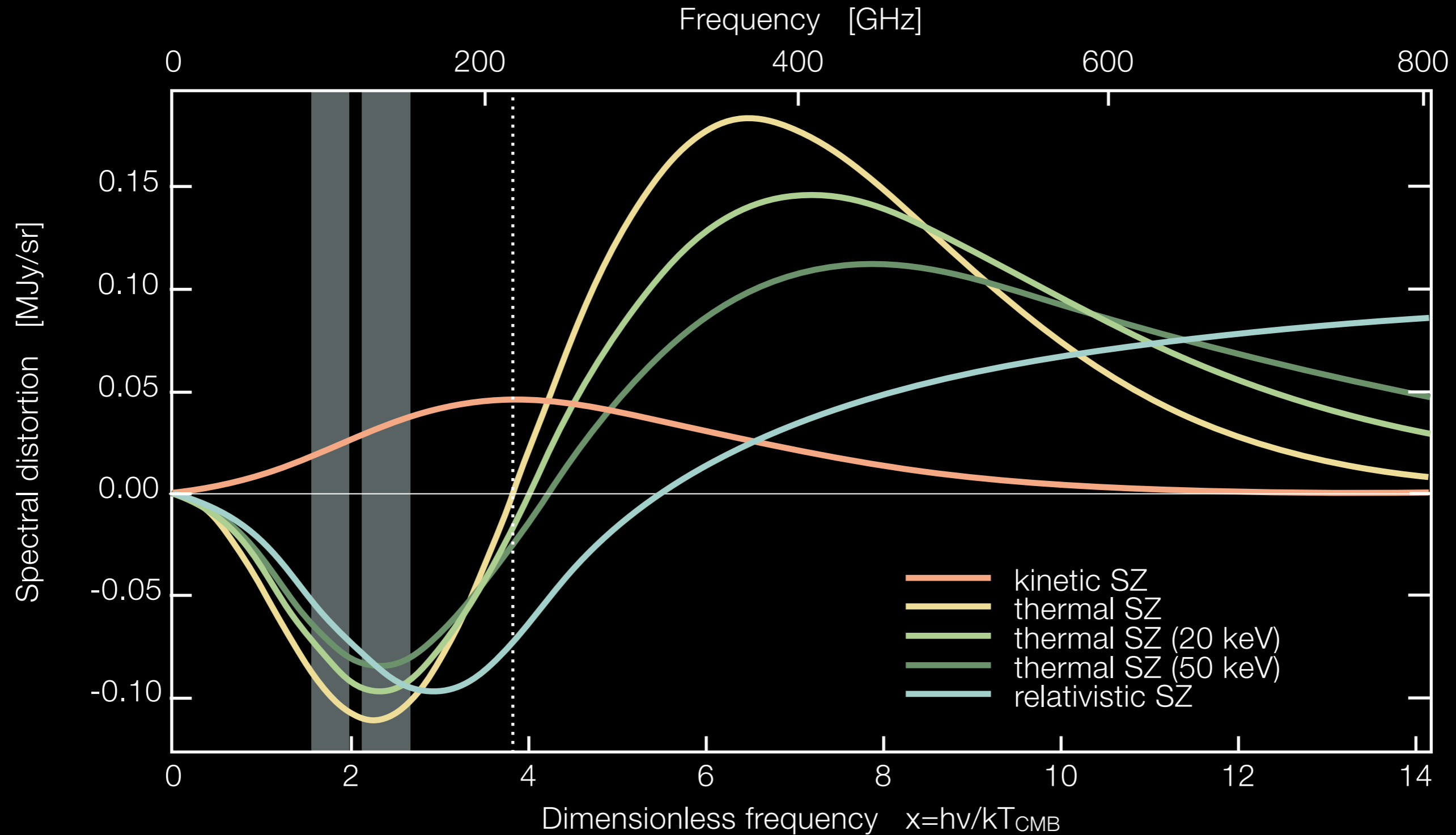
faint SZ signal...or systematics?

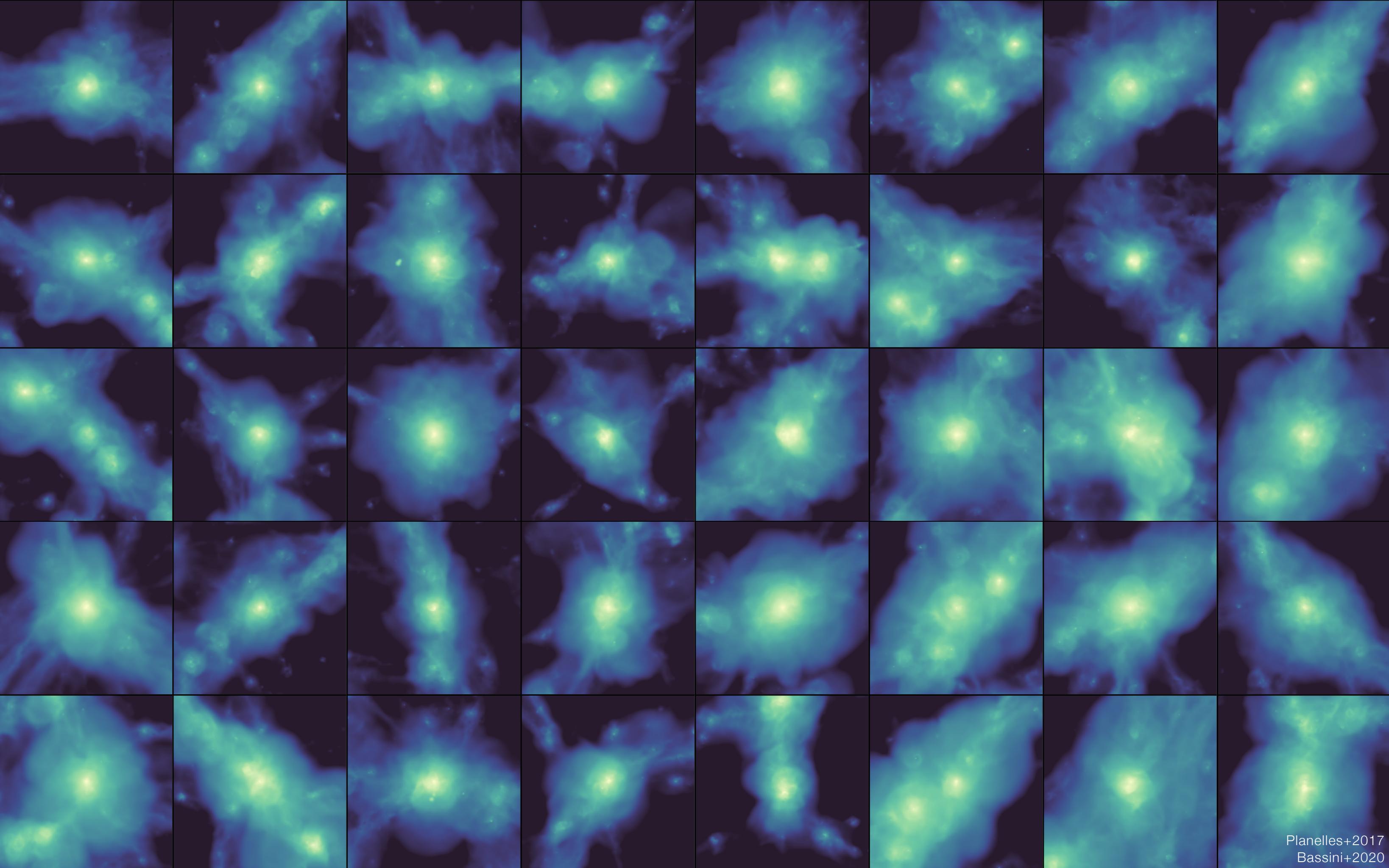
1. non-thermal pressure support
2. deviation from thermalization
3. dynamical effects



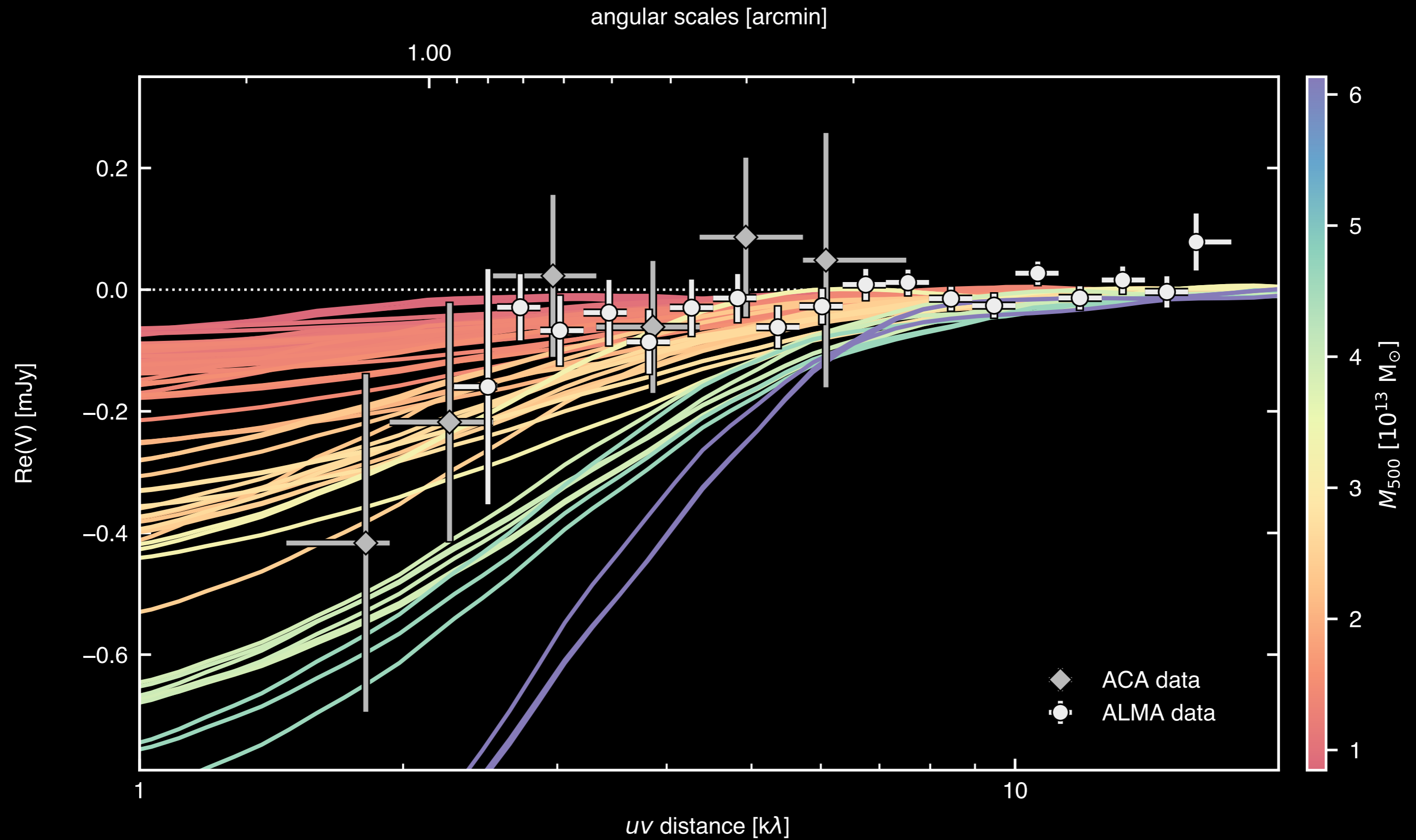
faint SZ signal...or systematics?

1. non-thermal pressure support
2. deviation from thermalization
3. dynamical effects
4. many SZ flavours, residual contamination, ...





consistent results from cosmo hydrosims



hints of complex interactions and dynamics

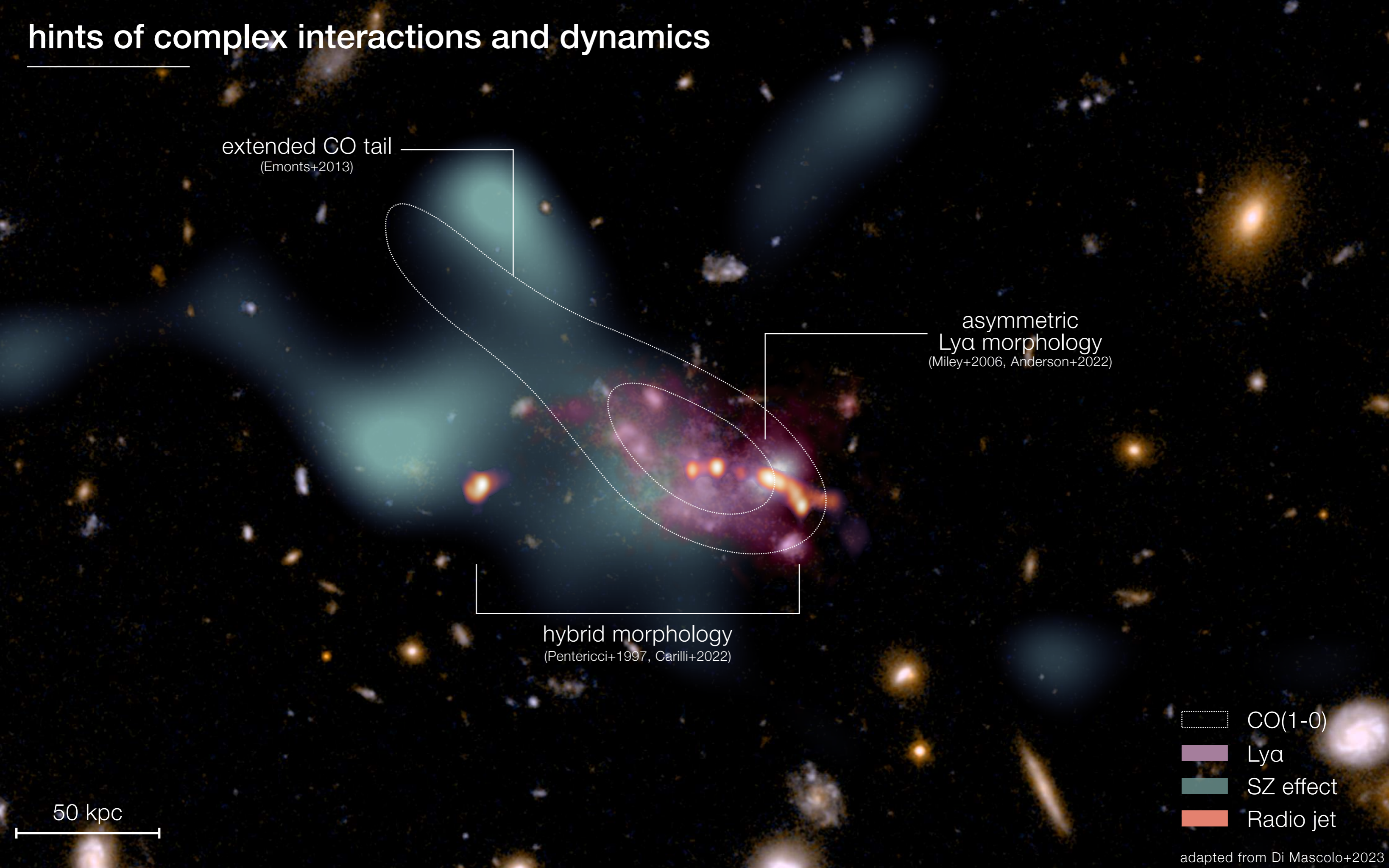
extended CO tail
(Emonts+2013)

asymmetric
Ly α morphology
(Miley+2006, Anderson+2022)

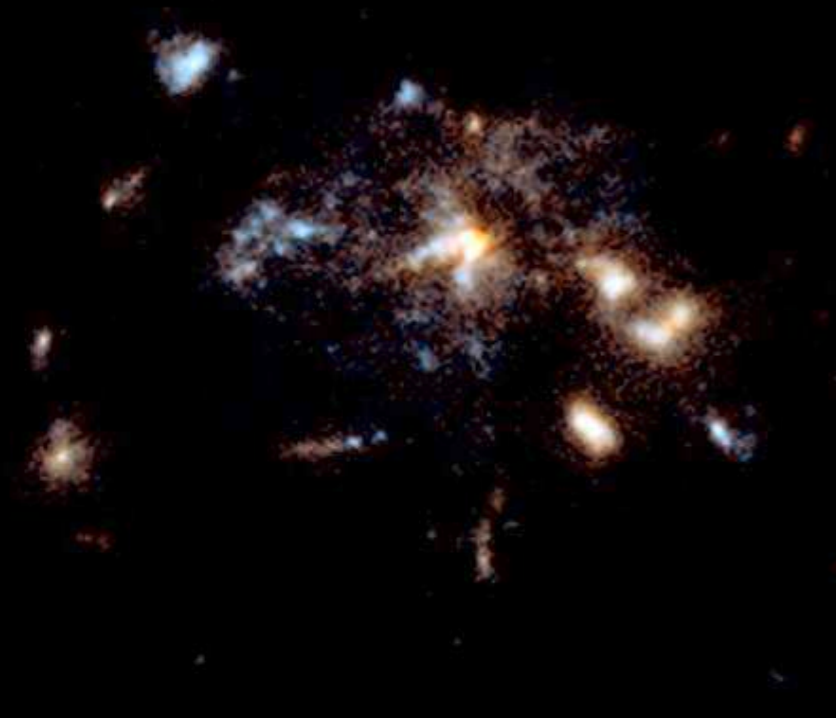
hybrid morphology
(Pentericci+1997, Carilli+2022)

- CO(1-0)
- Ly α
- SZ effect
- Radio jet

50 kpc



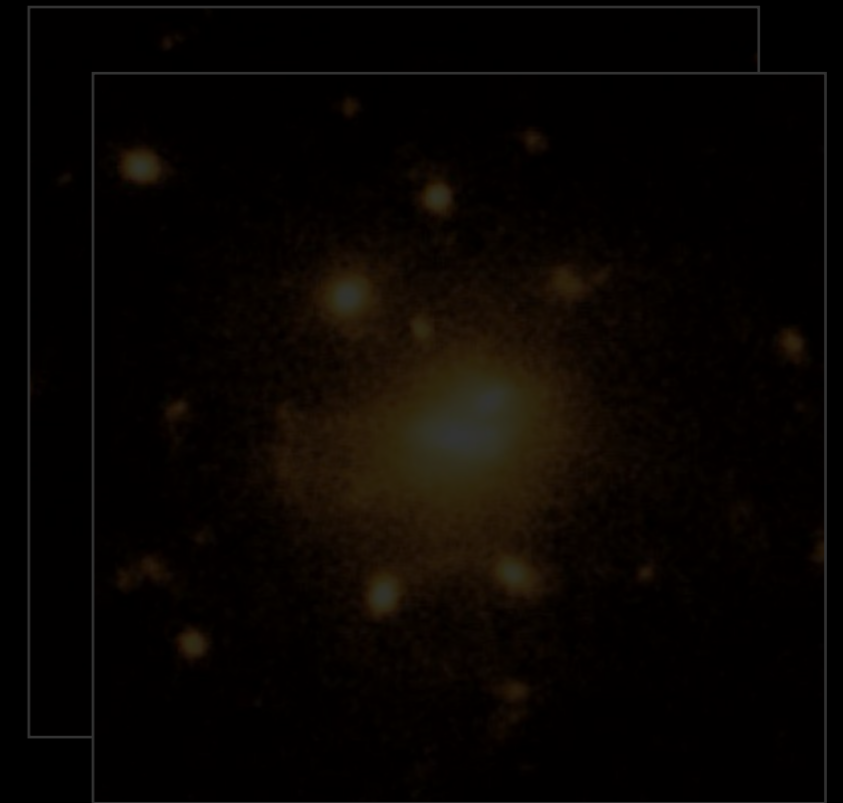
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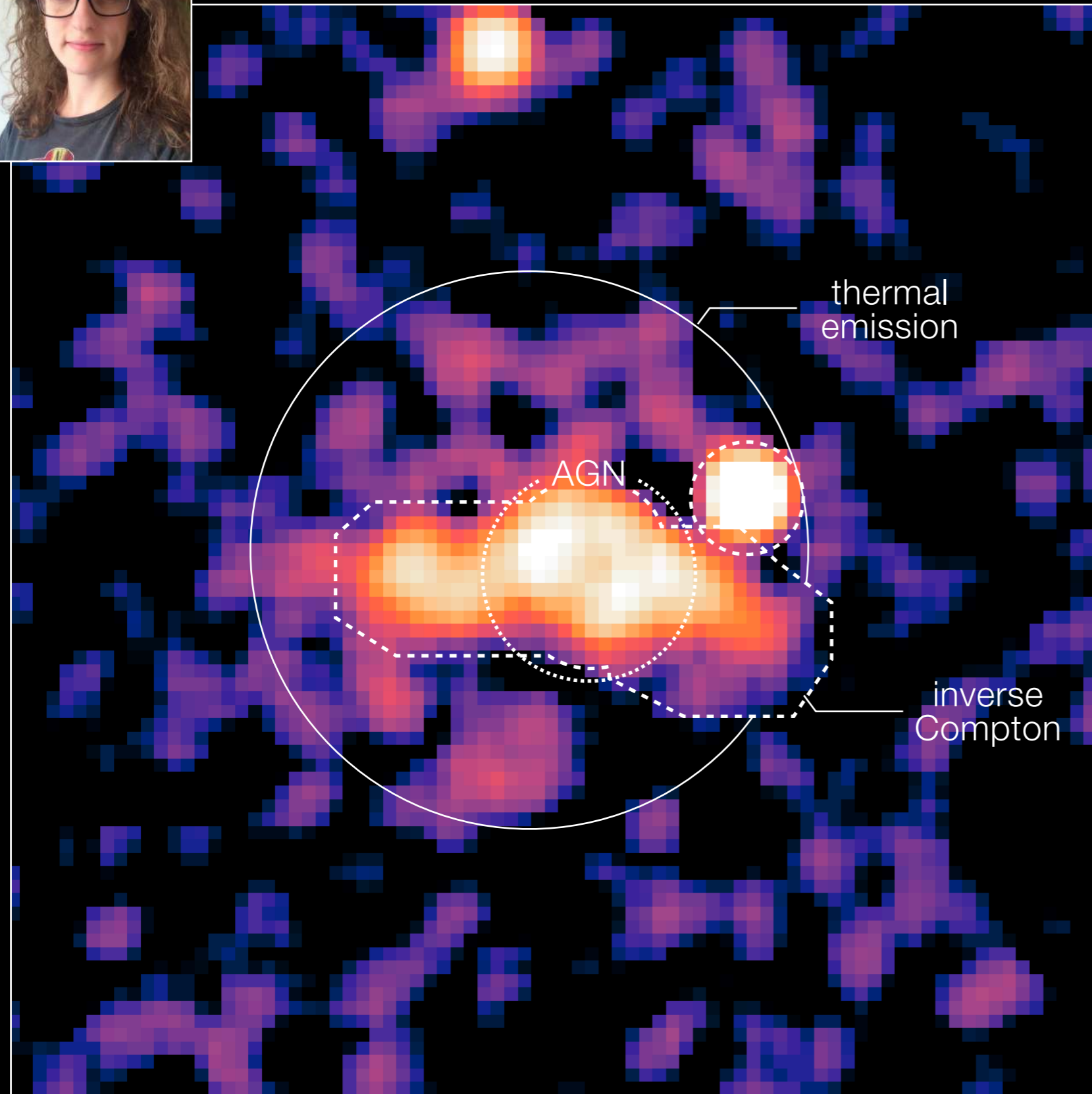


Saro+2009
simulated protoclusters with
gravitational potential permeated
by ICM at 2-5 keV

circulating gas in a strongly cooling core



Marika Lepore PhD student @ INAF-Arcetri



observation of steep gradient in density and temperature in the central 10 kpc

extremely short cooling time (<1 Gyr)

early formation of
(probably overdense)
cool core structures

mass deposition rate consistent
with fueling of star formation
by **direct ICM condensation**

conclusions

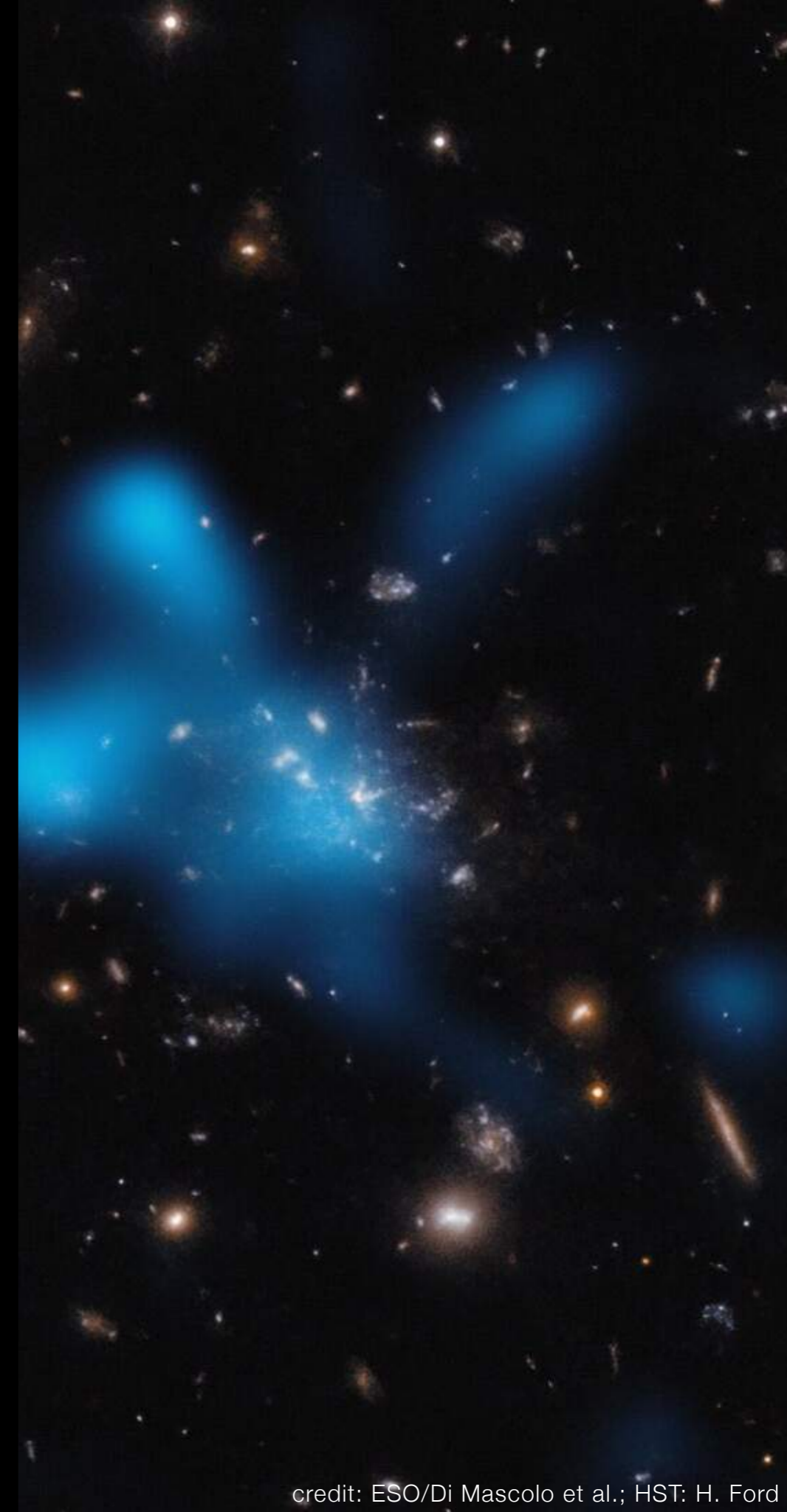
For the first time, ALMA is allowing us to witness the **emergence of proto-ICM** in a protocluster complexes

The SZ effect provides a reliable observational probe for detecting hot (thermalised) gas with **virtually no limit in redshift**

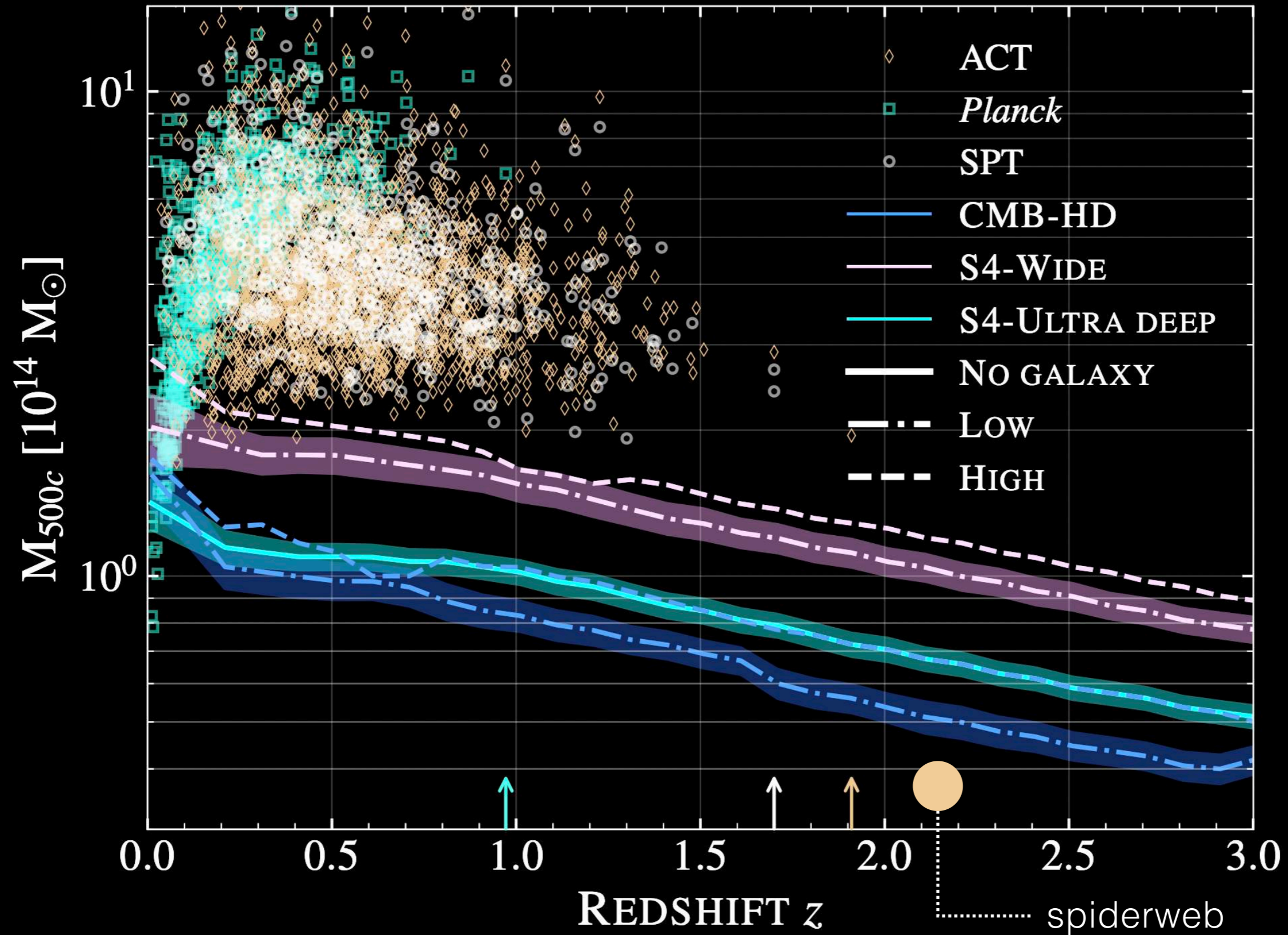
Multiwavelength characterisation of high- z systems highlights **extreme dynamical states**, with complex interplay between multiple gas phases

how and **when** the multi-phase protocluster gas turn into extended ICM?

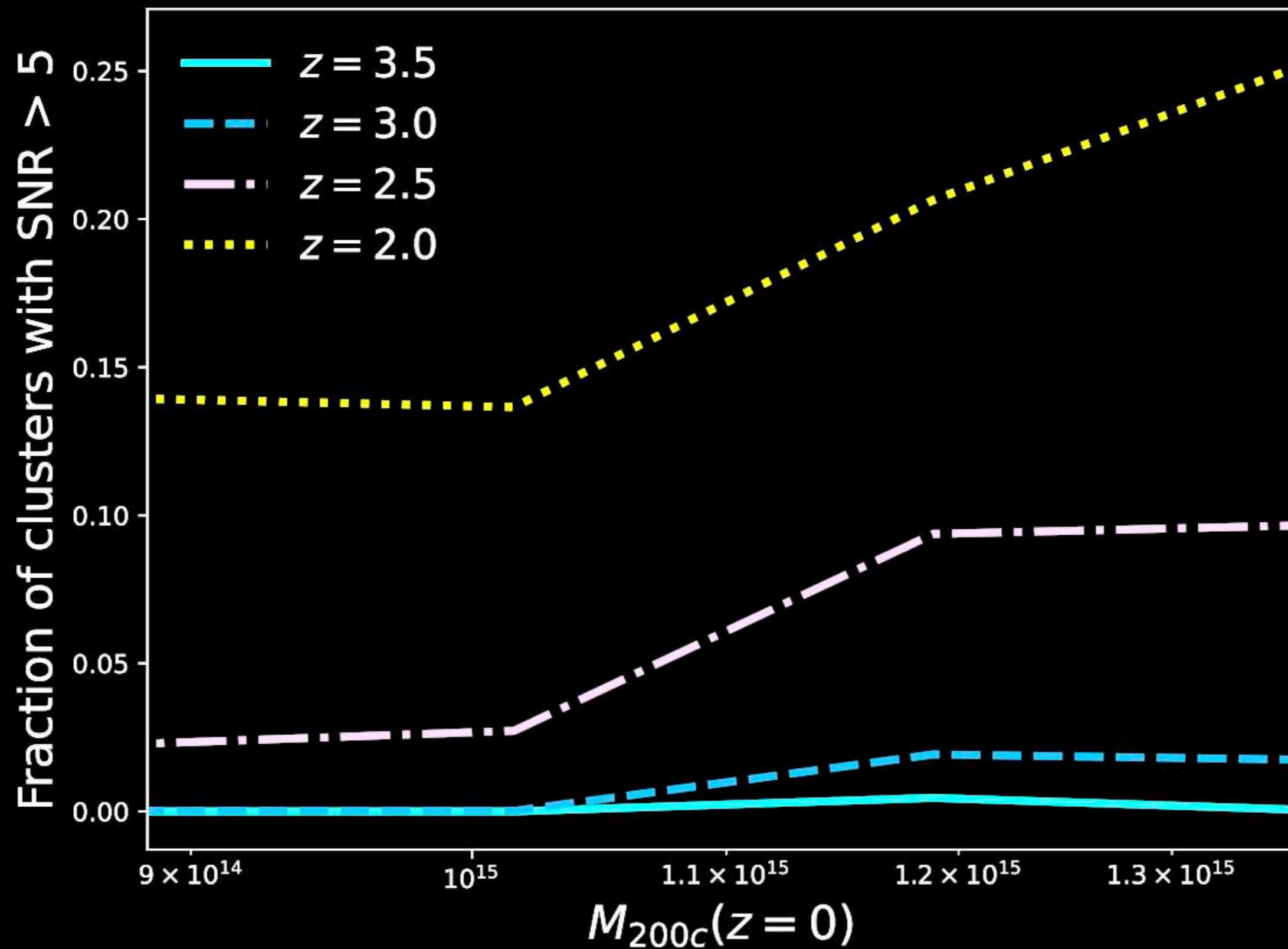
how different mechanisms contribute to **heating** the proto-ICM?



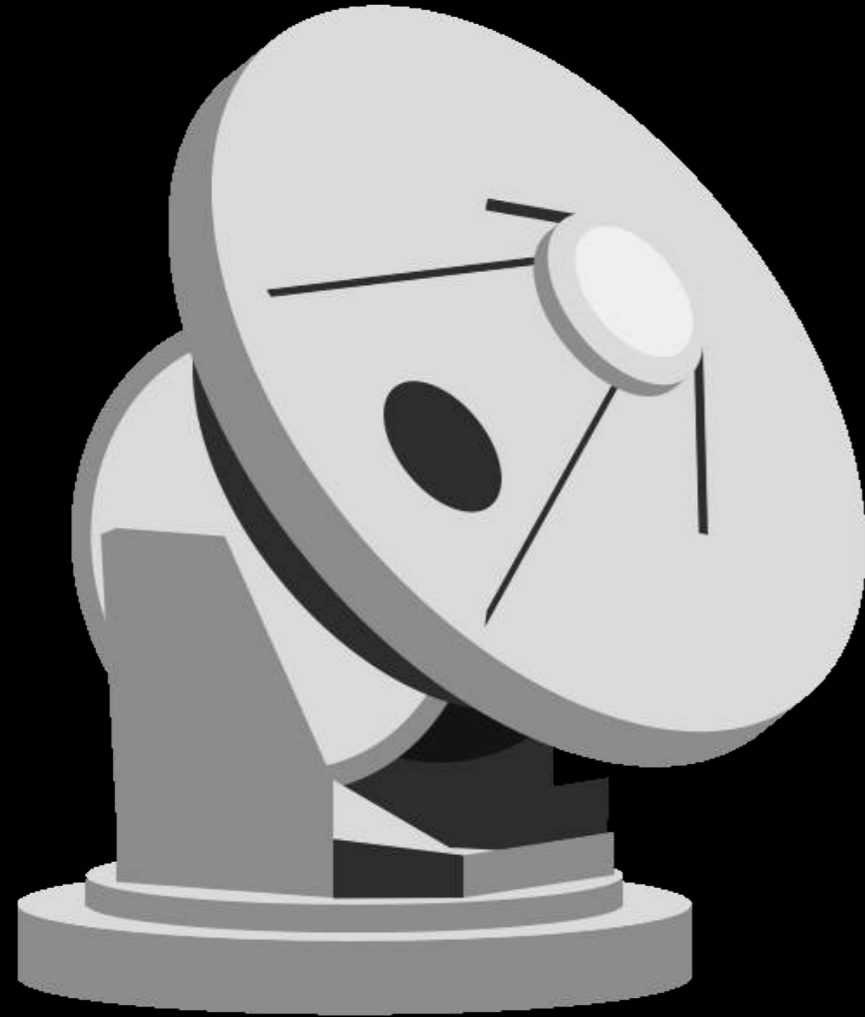
looking forward, at last



looking forward, at last



Atacama Large Aperture Submillimeter Telescope



A new telescope whose design is driven by transformational and unique science goals

- The most complete sub-mm surveys ever!
- Life cycle of the Local Universe
- Baryon Cycle of the Distant Universe
- New measures of SZ and the Early Universe

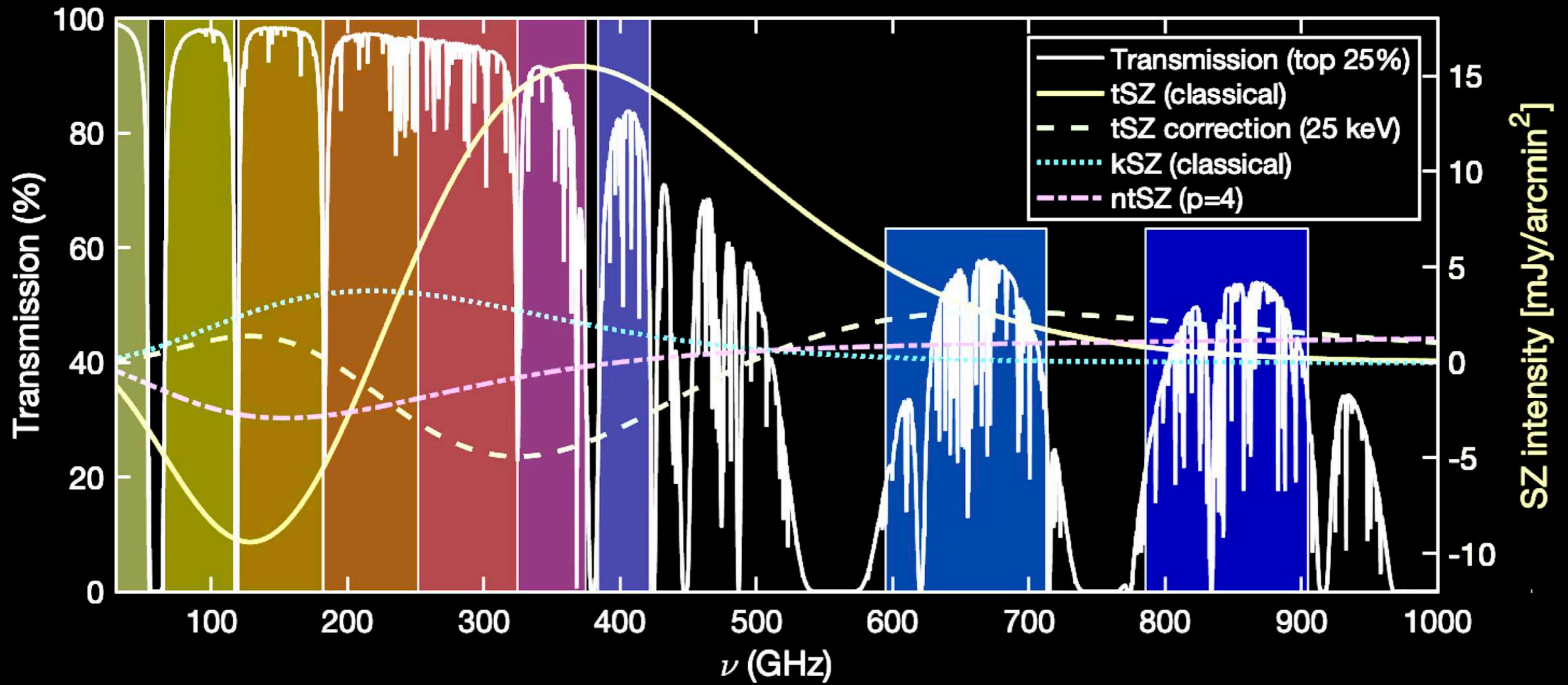
50-m diameter single dish, with a high throughput and FoV of 2 degrees in diameter

Located at a high dry site in the Atacama desert, enabling observations at $\nu_{obs} > 500$ GHz

A facility telescope with open time and flexibility to host multiple instruments

The first astronomical observatory to include renewable power generation & storage solutions in the design study

- plan to be fully sustainable



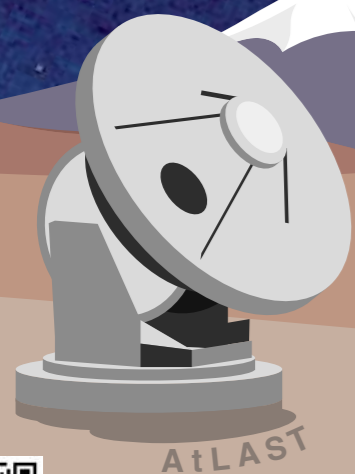


The Atacama Large Aperture Submillimeter Telescope Design Study

Results, science, and next steps

Johannes Gutenberg University Mainz
Mainz, Germany | 21-24 May 2024

<https://www.atlast-telescope.org/atlast2024.html>



TOPICS

mm/submm observations, near and far, including polarimetry • the Sun and Solar System • Milky Way • Local and Distant Galaxies • the Warm and Hot inter- and intra-cluster/group/galactic media • the Circumgalactic medium • Cosmology and Large Scale Structure • Time-domain and Transients

ORGANIZERS

Claudia Cicone • Pamela Klaassen • Tony Mroczkowski • Matthias Reichert

Image credits: Luca Di Mascolo, Tony Mroczkowski, and Giuseppe Puglisi. AtLAST has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 951815.

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