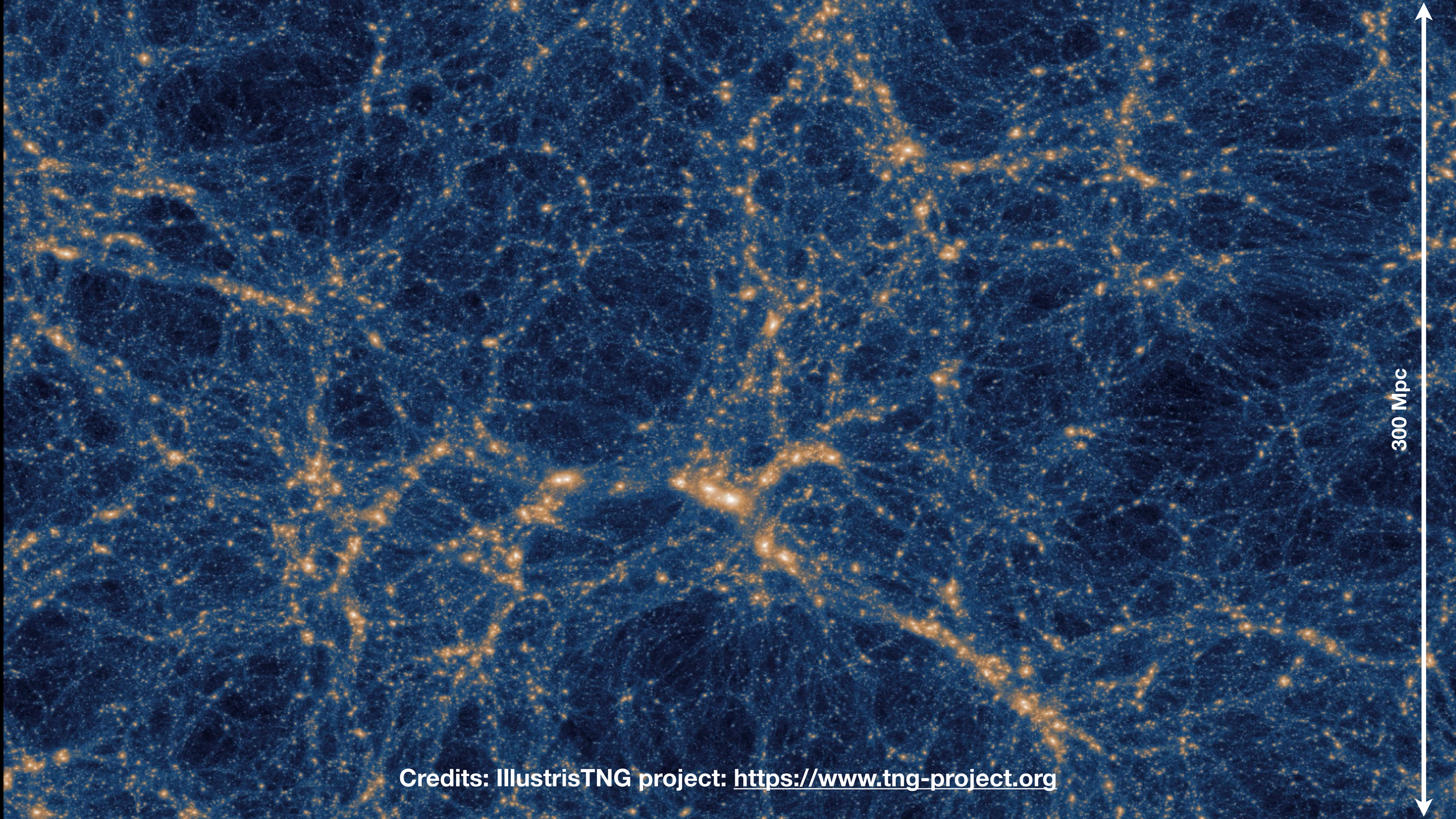
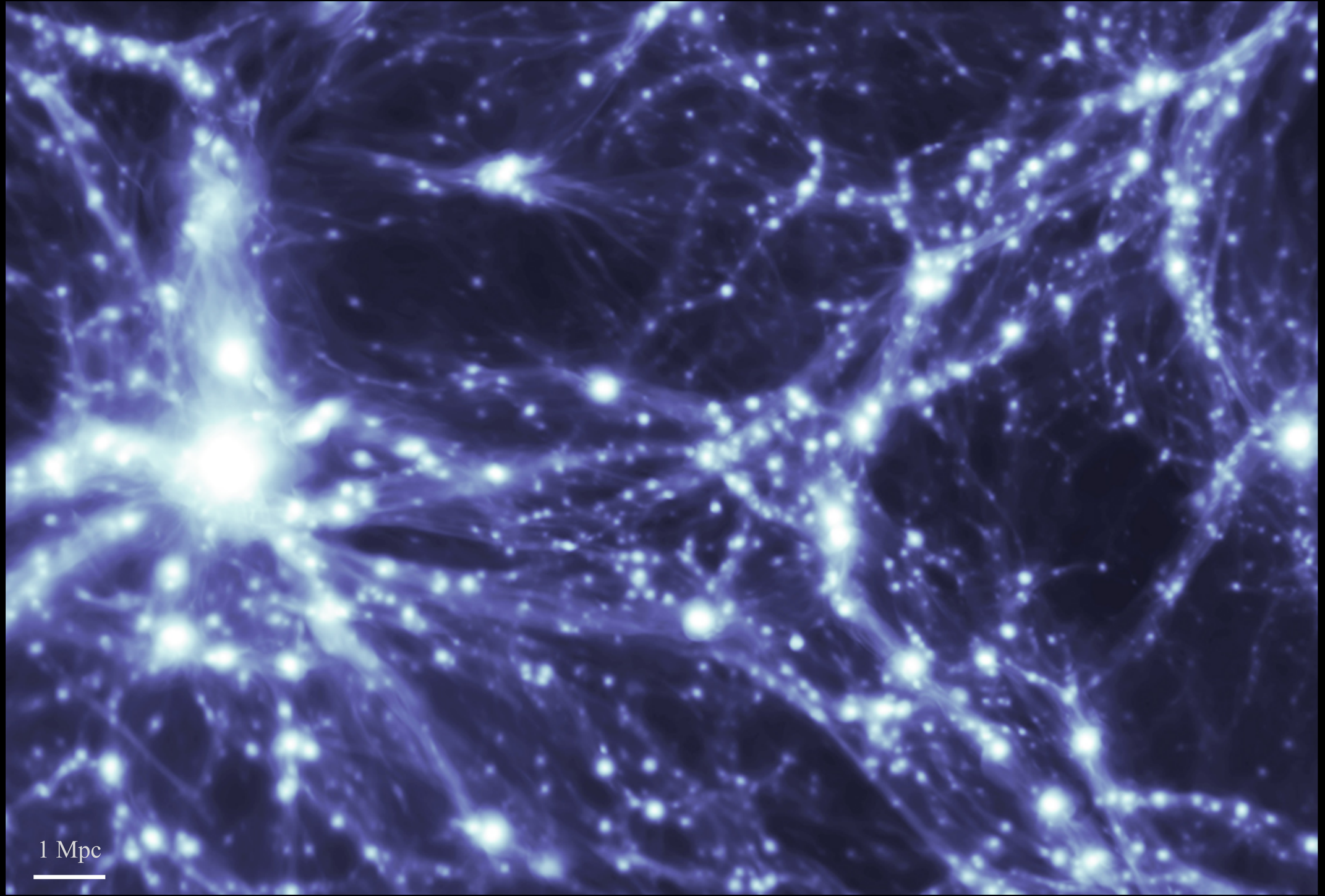
The Large-Scale Structure of the Universe through the SKA lenses

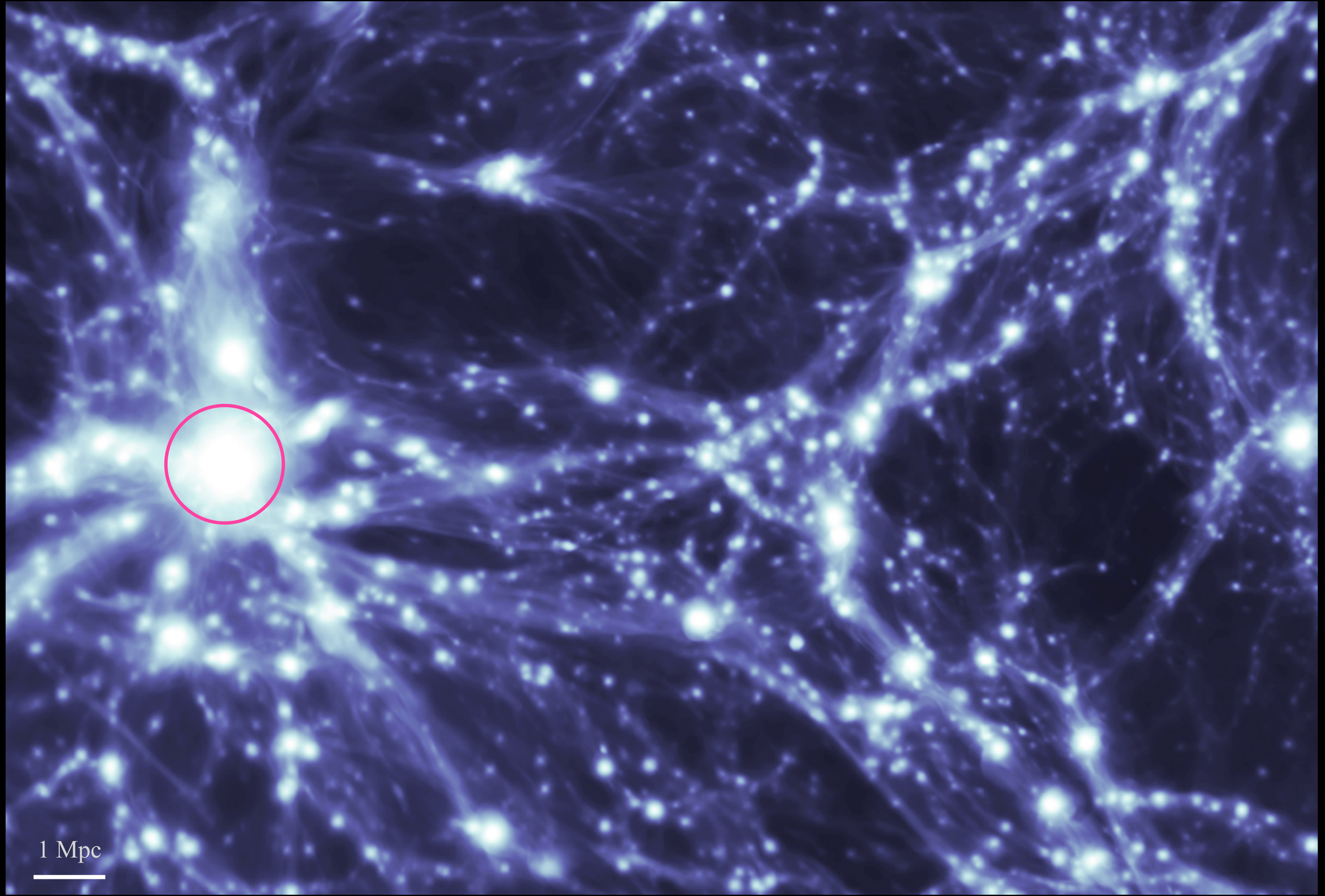
AASKAII chapter (Cuciti, Paul, Parekh et al. sub.)

Virginia Cuciti
(University of Bologna)



Credits: IllustrisTNG project: https://www.tng-project.org


1 Mpc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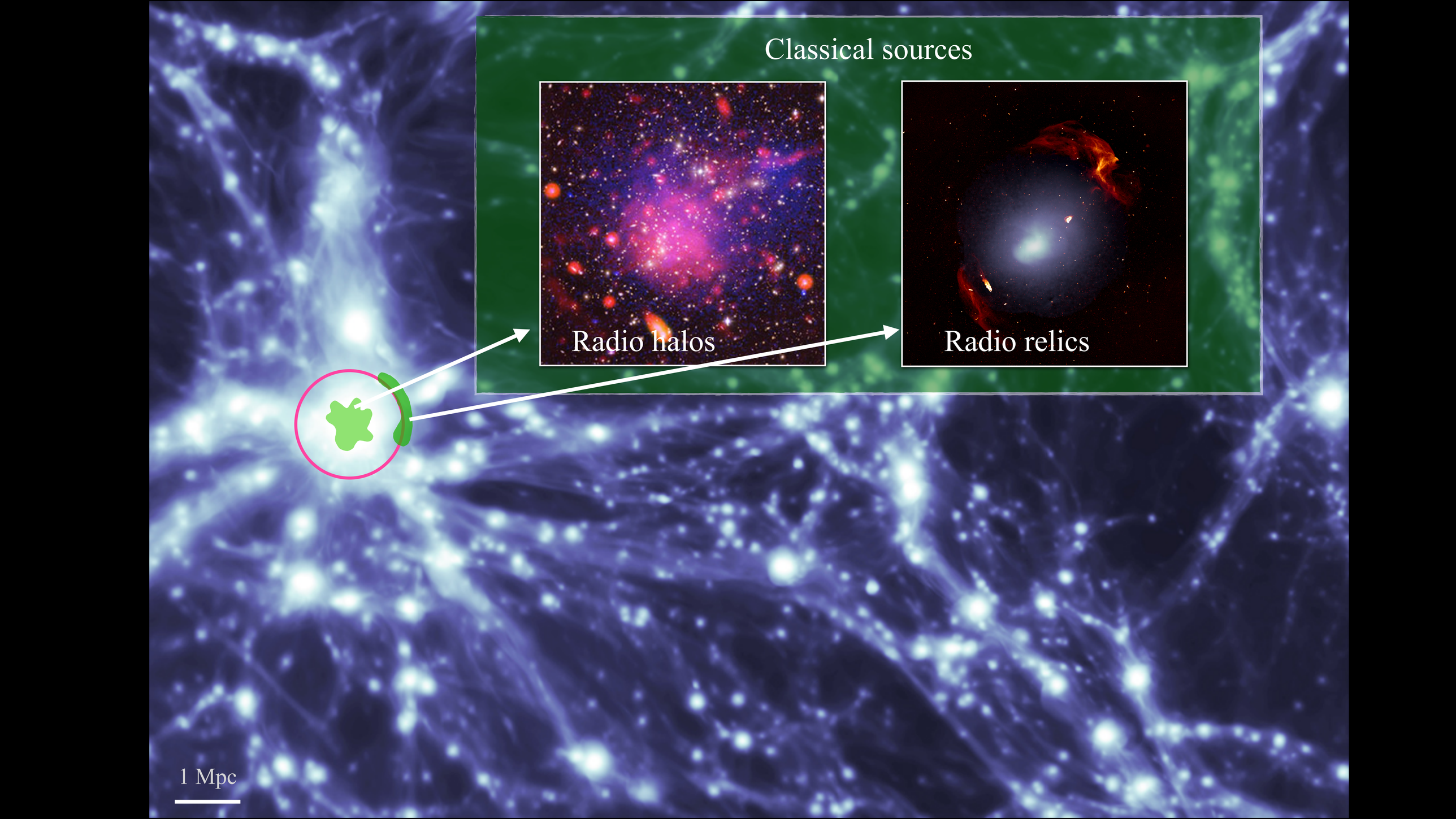
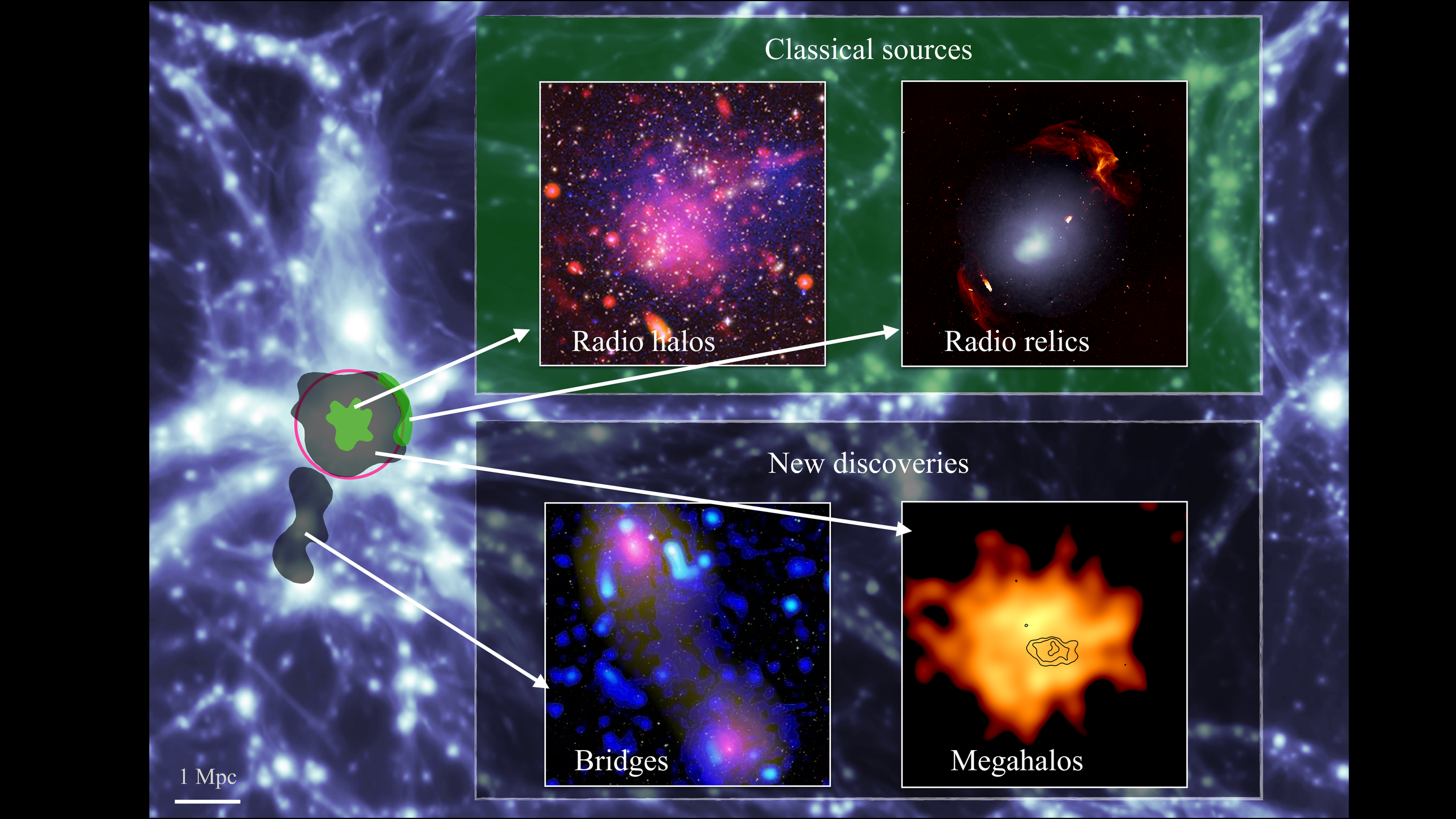
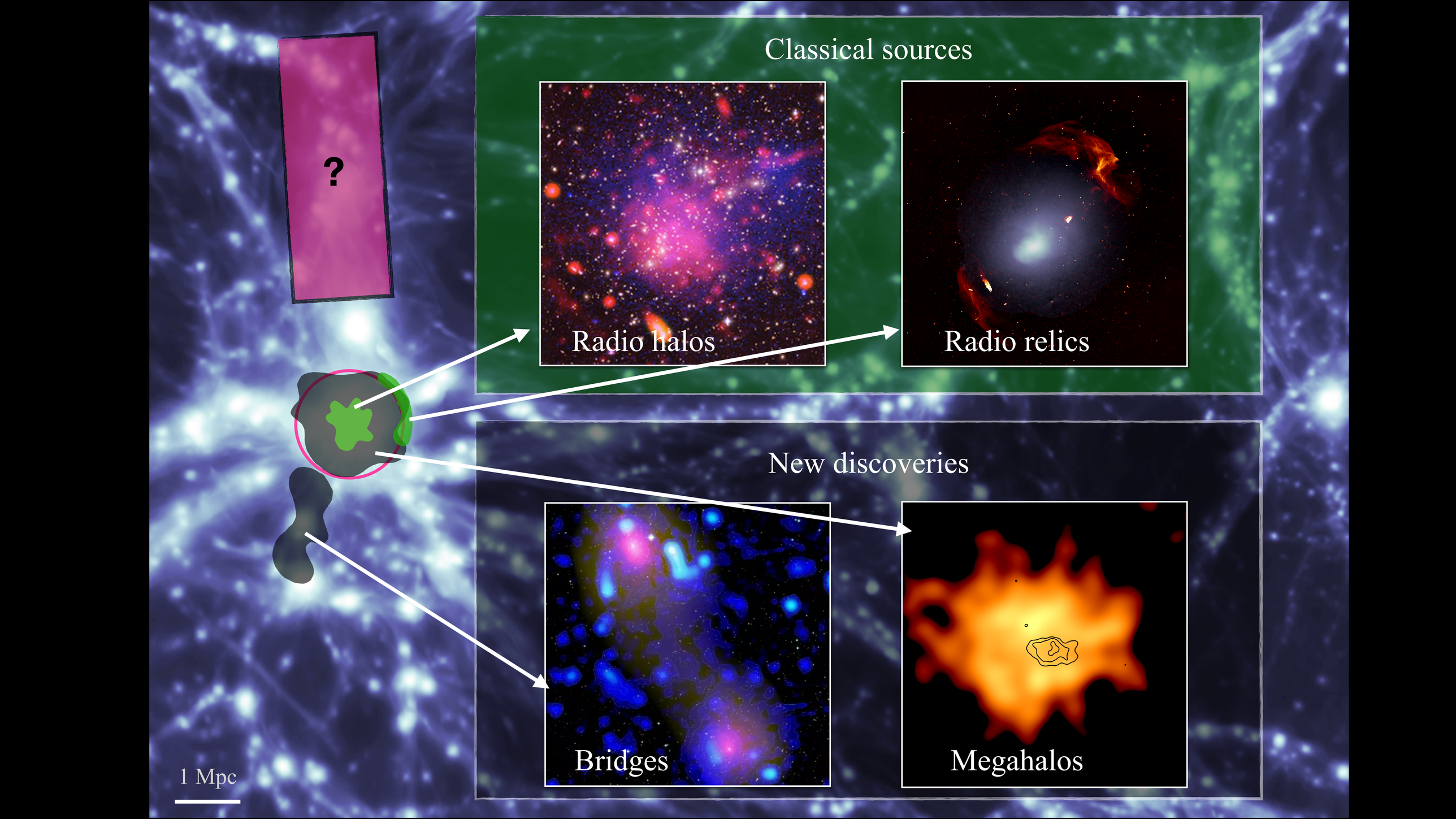
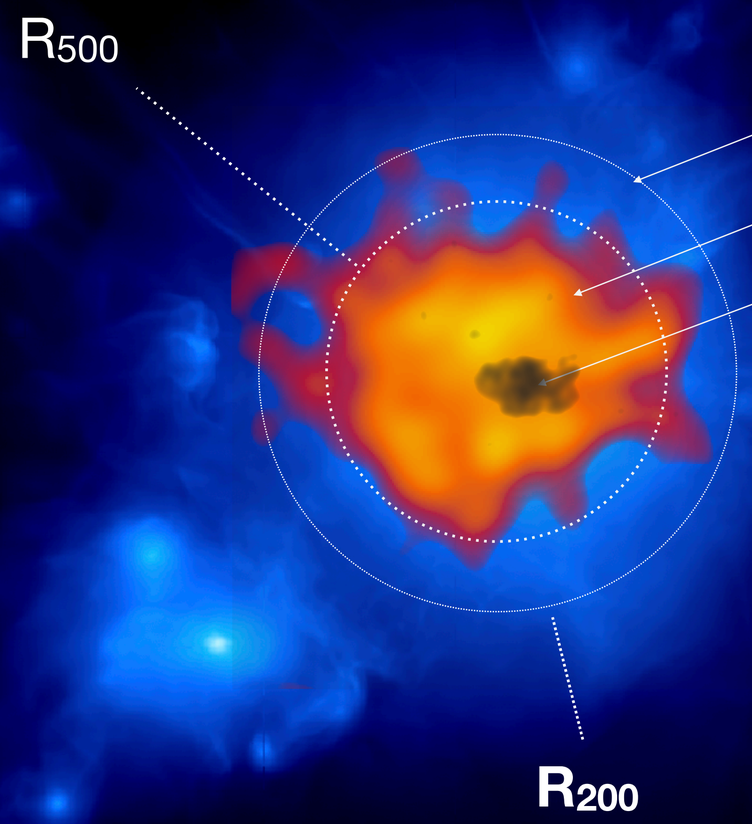

Classical sources
Radio halos
Radio relics
1 Mpc


Classical sources
Radio halos
Radio relics
New discoveries
Bridges
Megahalos
1 Mpc

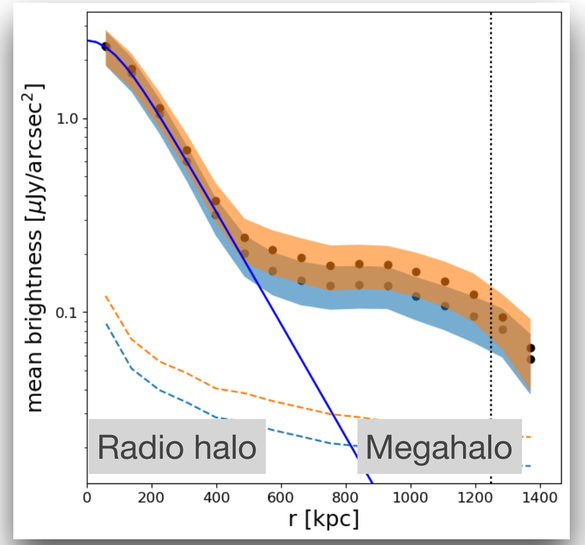

?
Classical sources
Radio halos
Radio relics
New discoveries
Bridges
Megahalos
1 Mpc

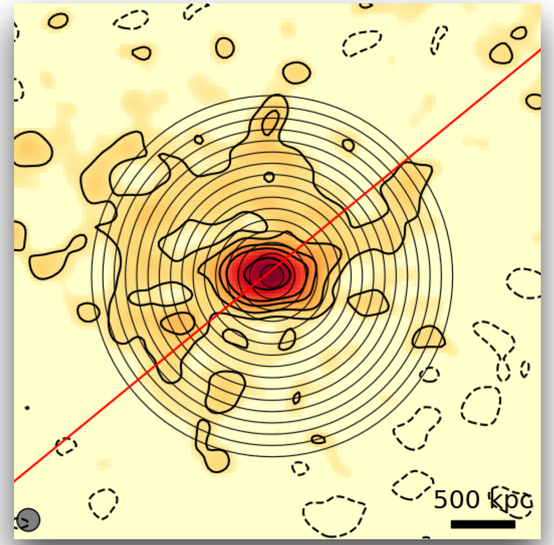
Radio Megahalos *(Cuciti et al., Nature, 2022)*

Zwcl 0634.1+4750



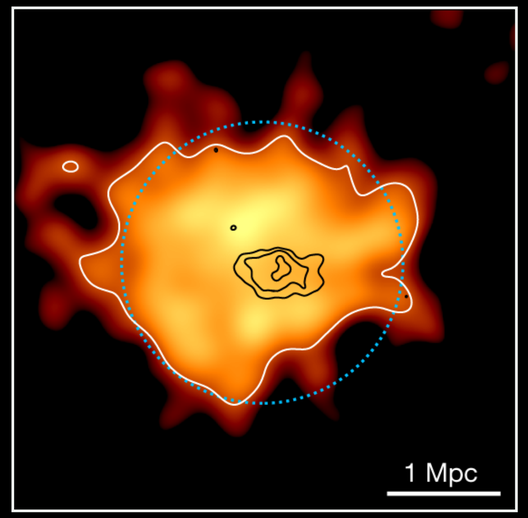
- Gas density (computer simulation)
- Megahalo - radius = 1400 kpc
- Classical halo - radius = 352 kpc

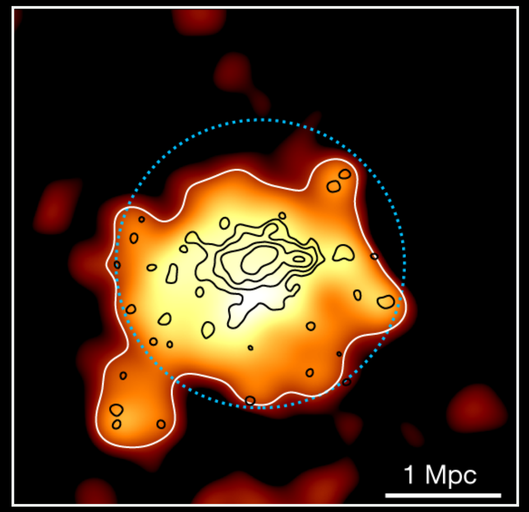


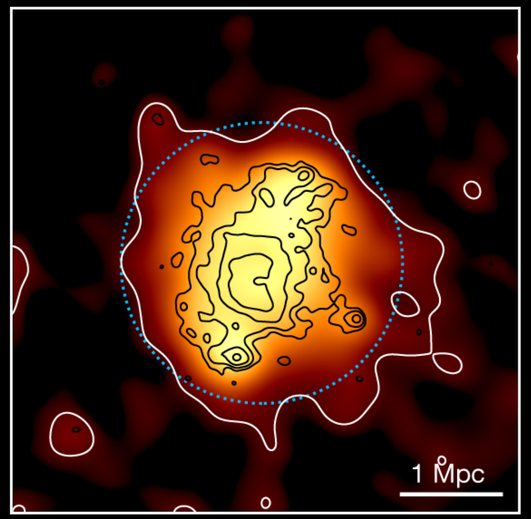


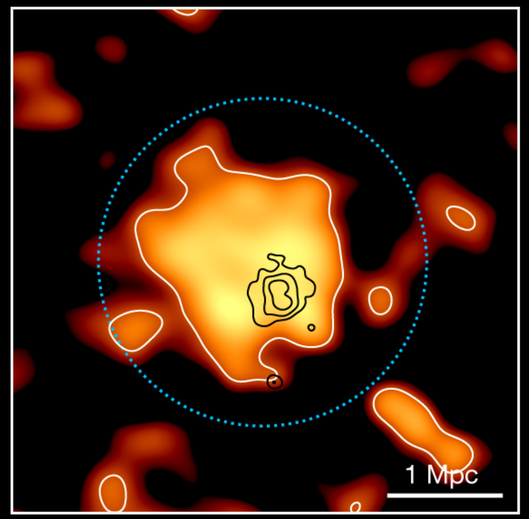
Radio Megahalos

See next talk!









Radio Megahalos

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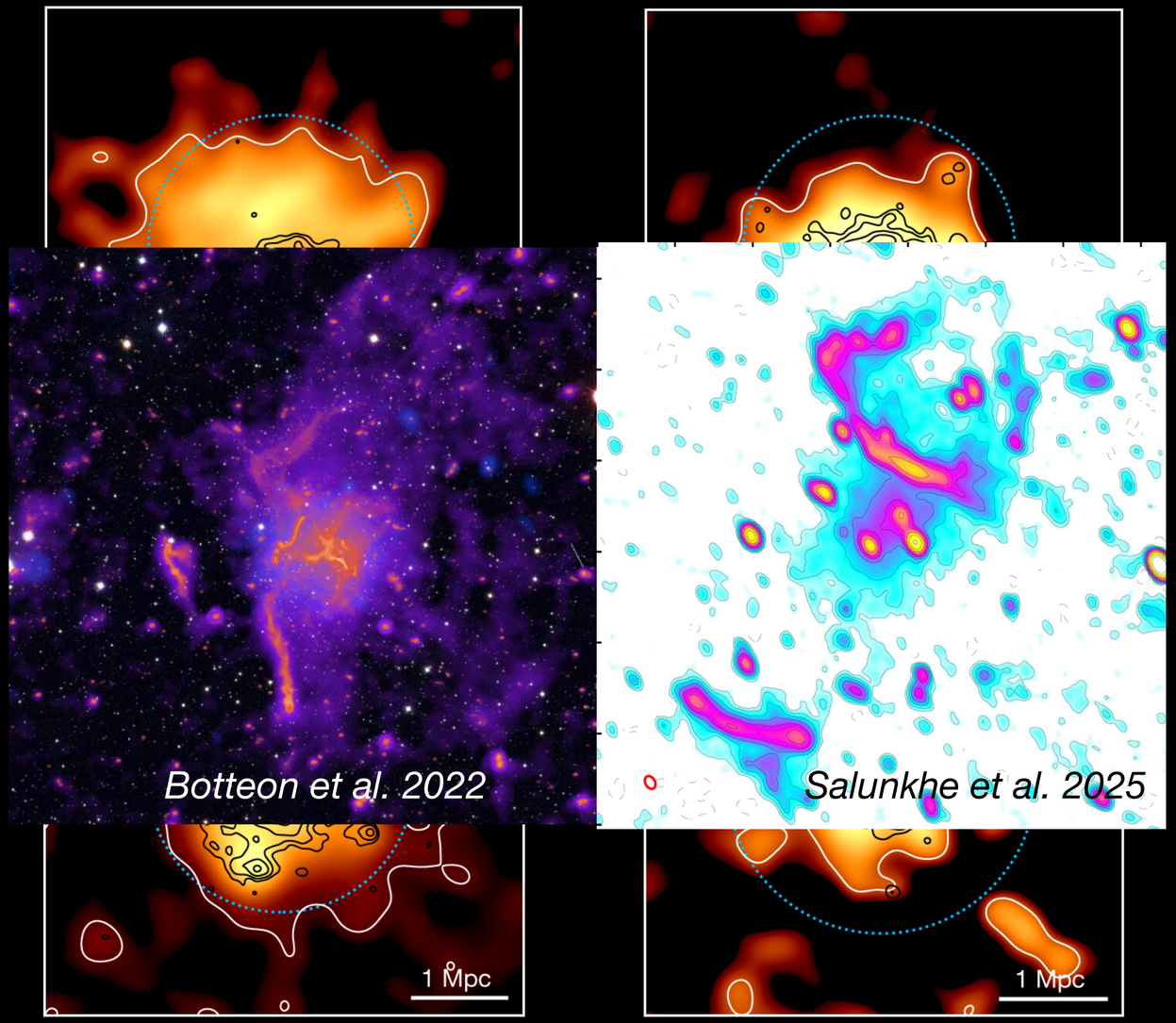

Radio Megahalos

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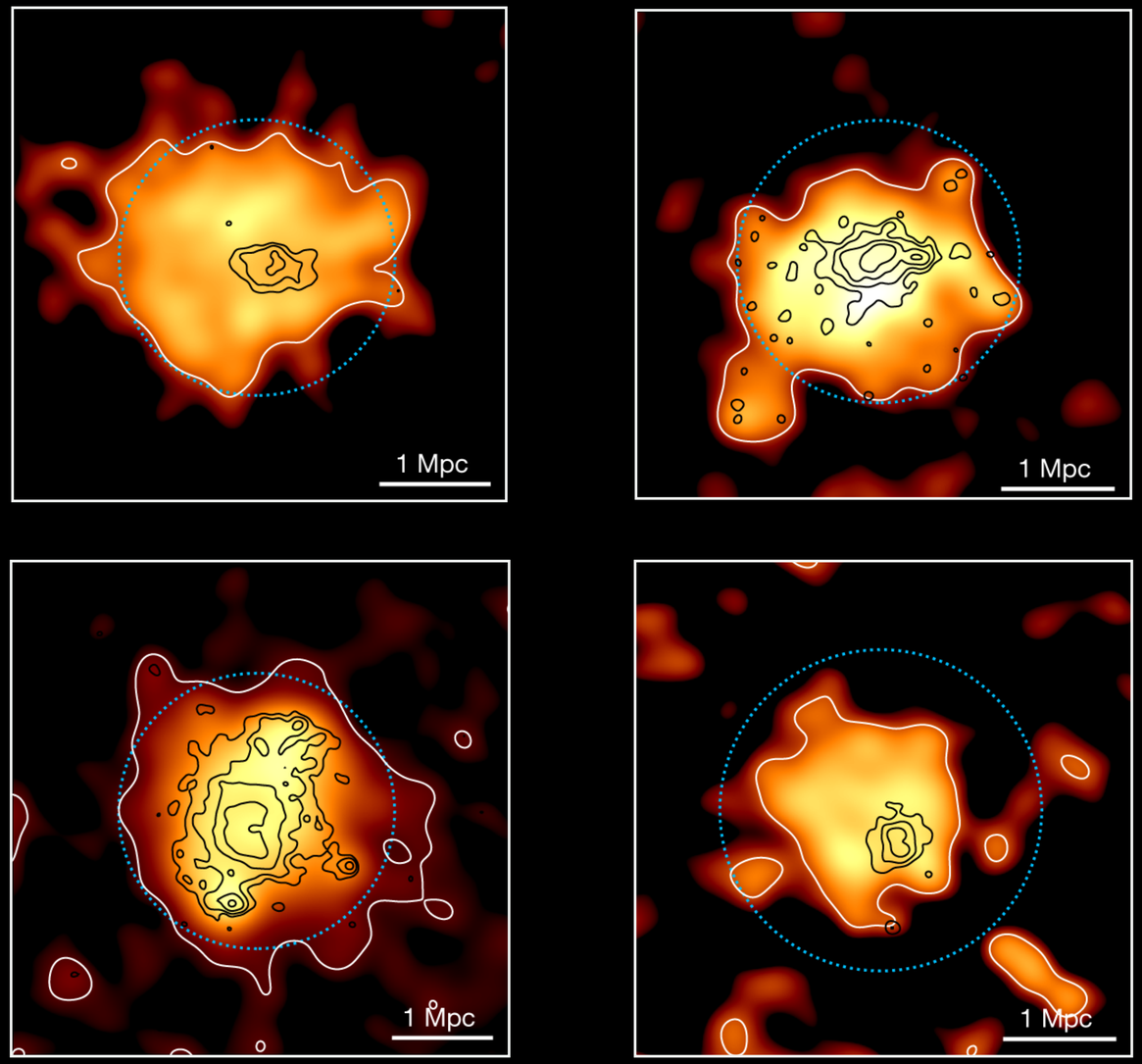
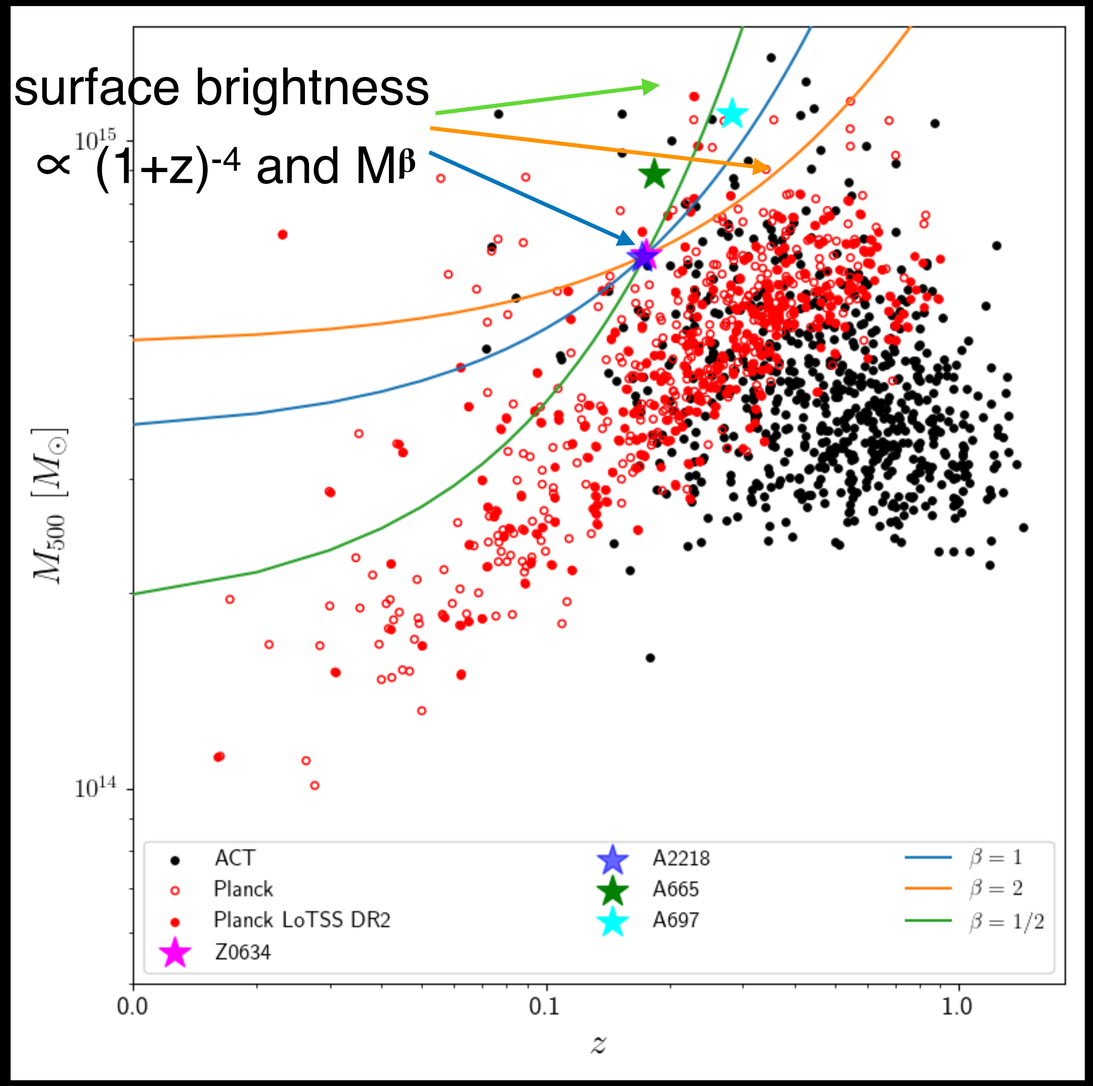
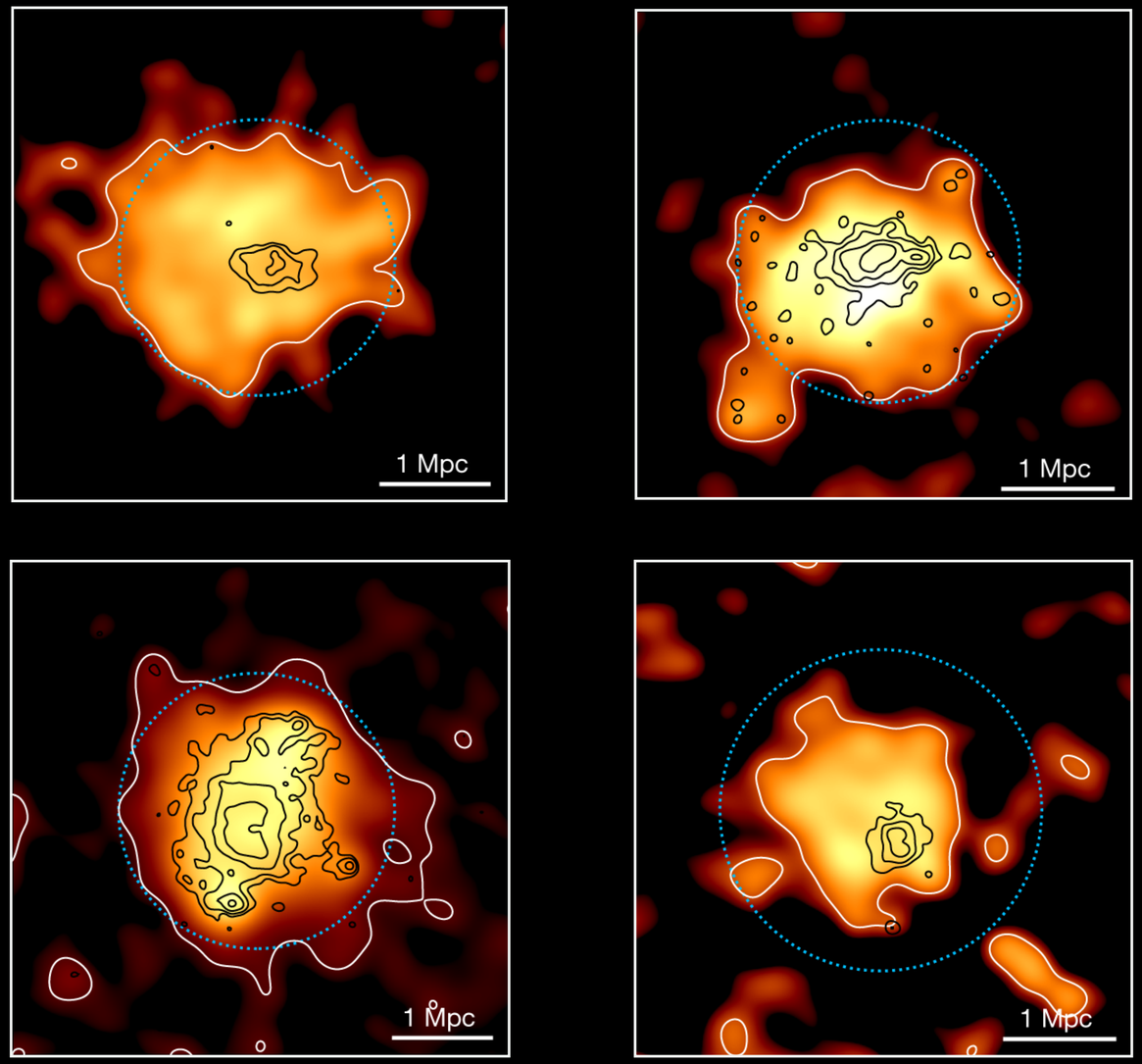
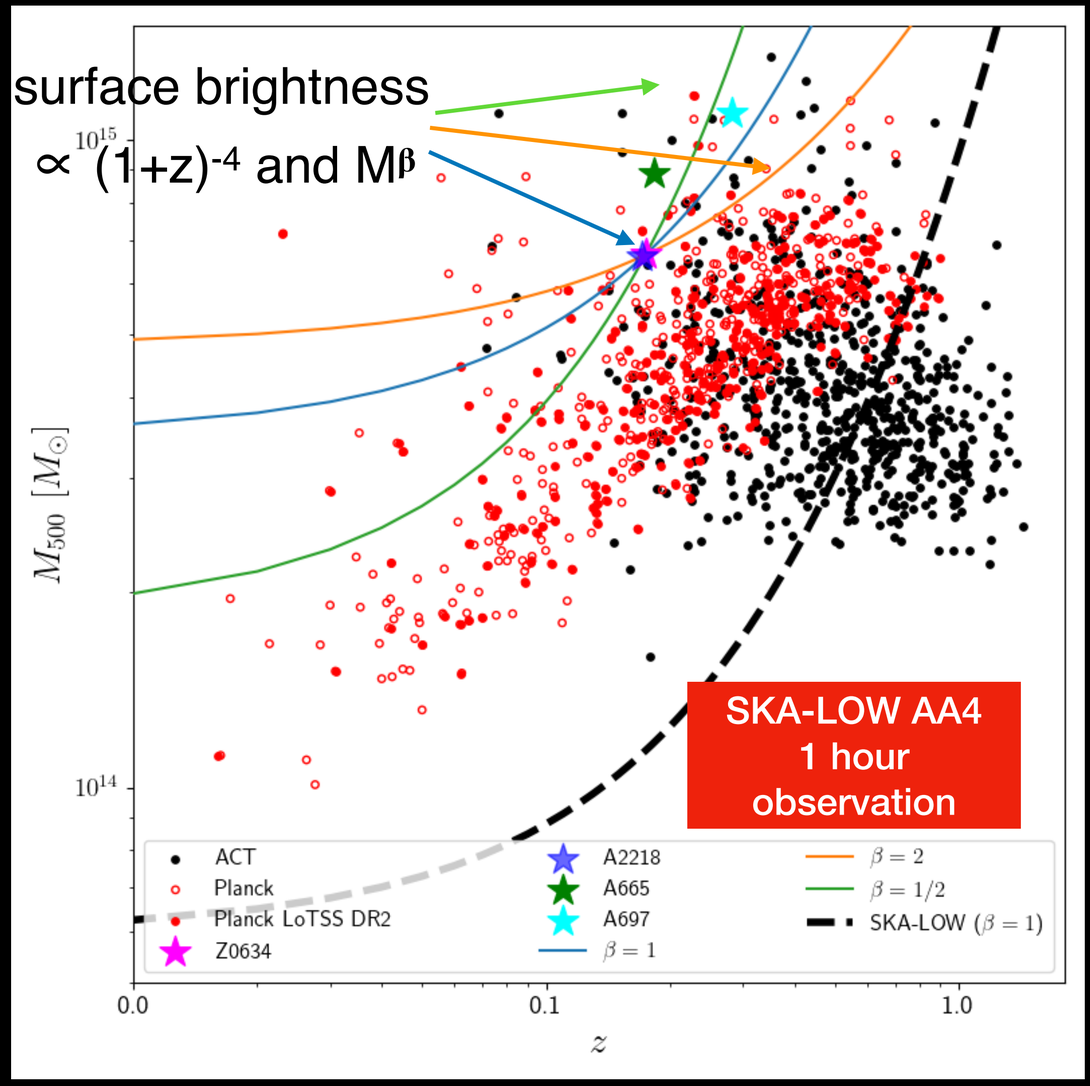


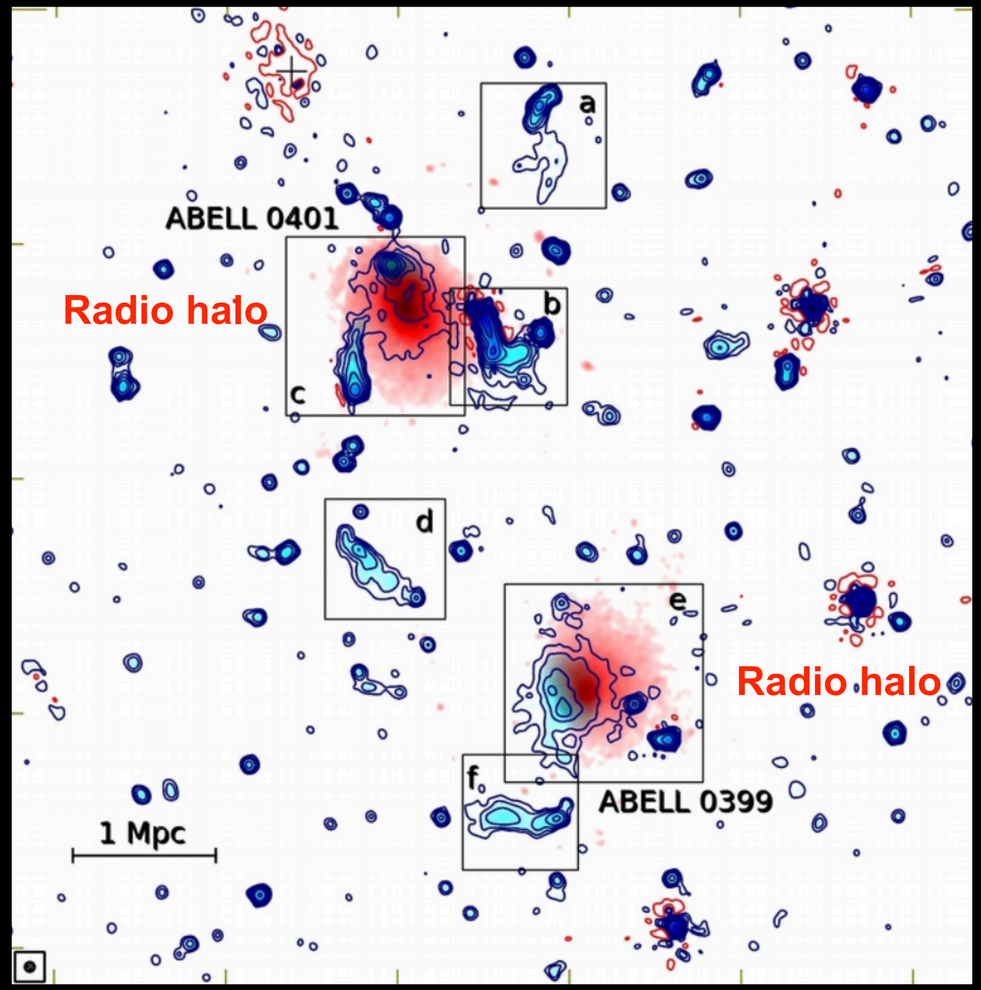


Radio Megahalos



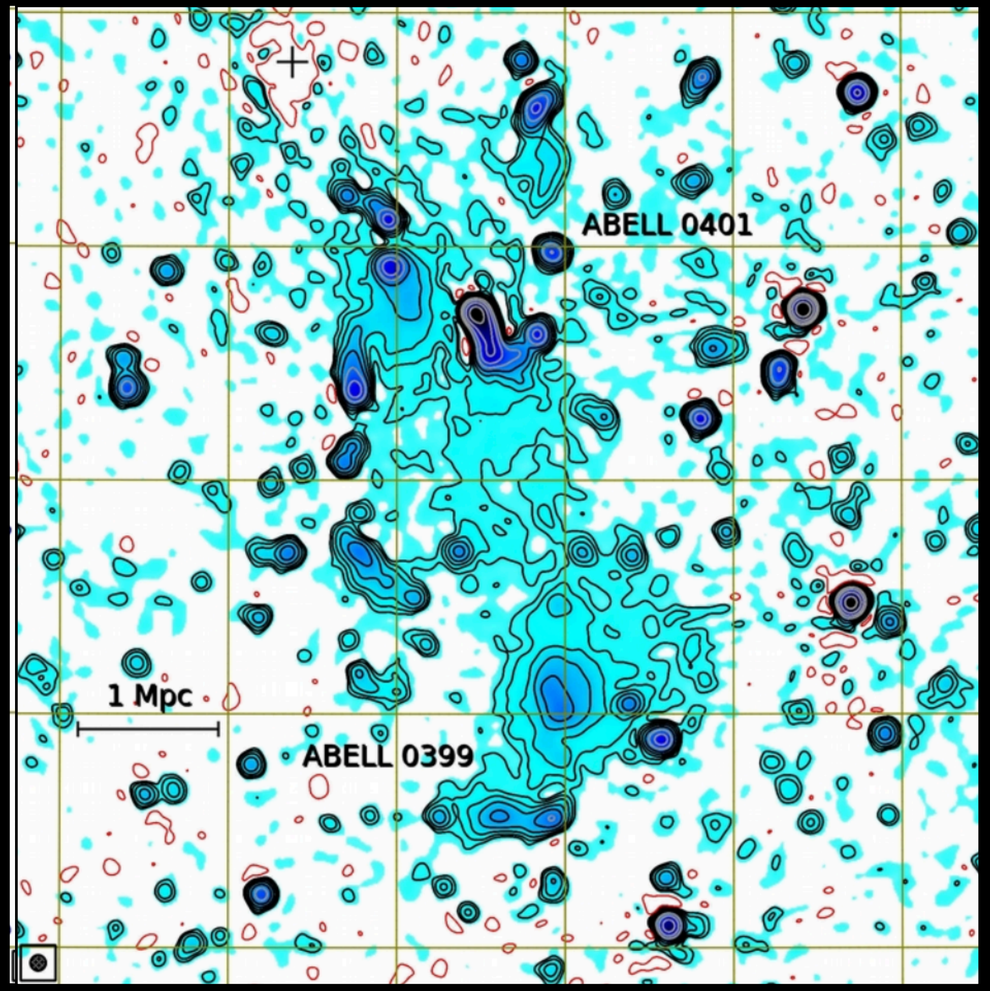


Radio Bridges



Govoni et al. (2019)

Radio Bridges



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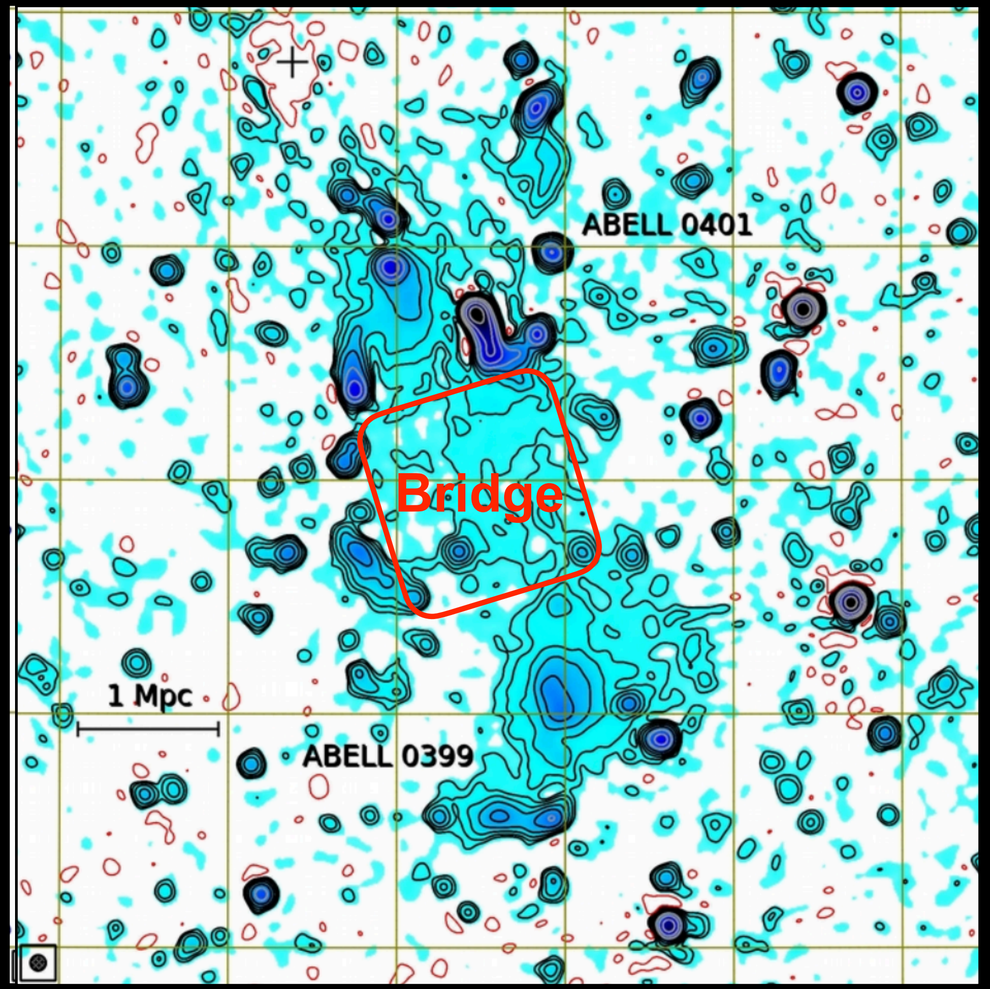
Radio Bridges

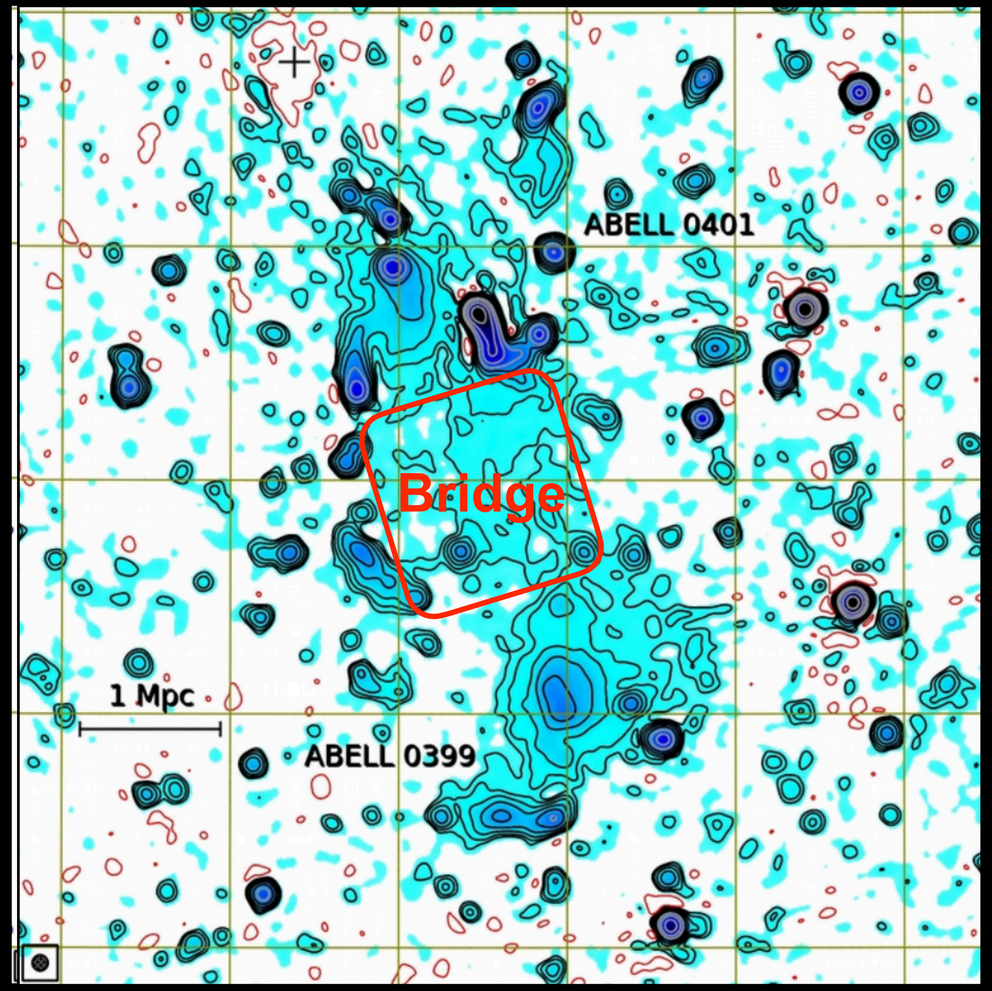


Govoni et al. (2019)

Radio Bridges

Shocks *(Govoni et al. 2019)*:

- **Many weak shocks**
- **Population of pre-existing relativistic electron is required**

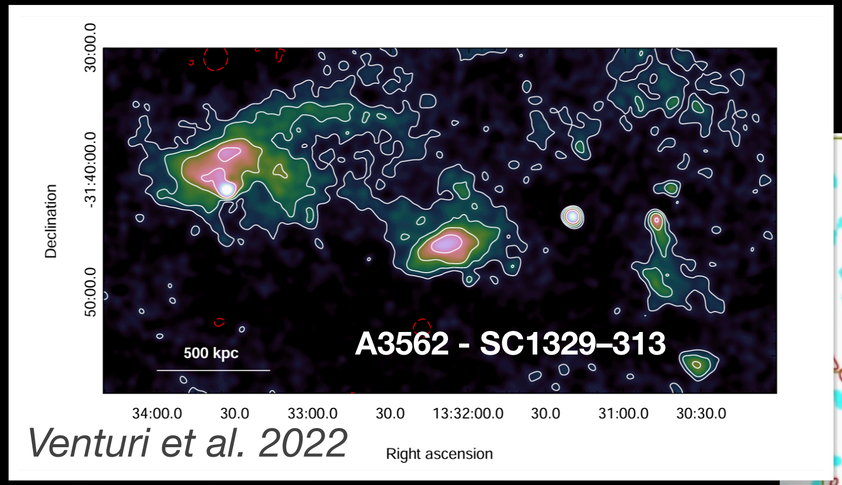


Govoni et al. (2019)

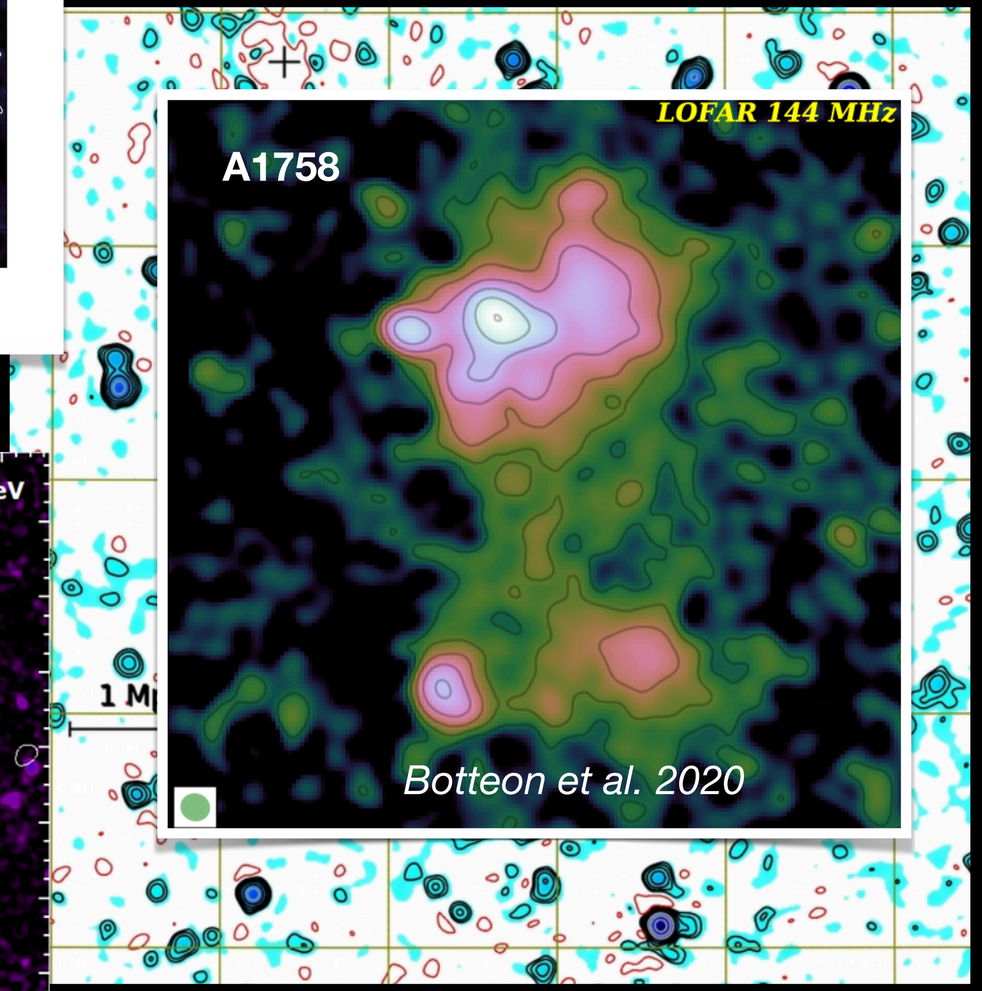
Turbulence *(Brunetti & Vazza 2020)*:

- **Volume filling emission**
- **Steep spectrum**

Radio Bridges



Venturi et al. 2022



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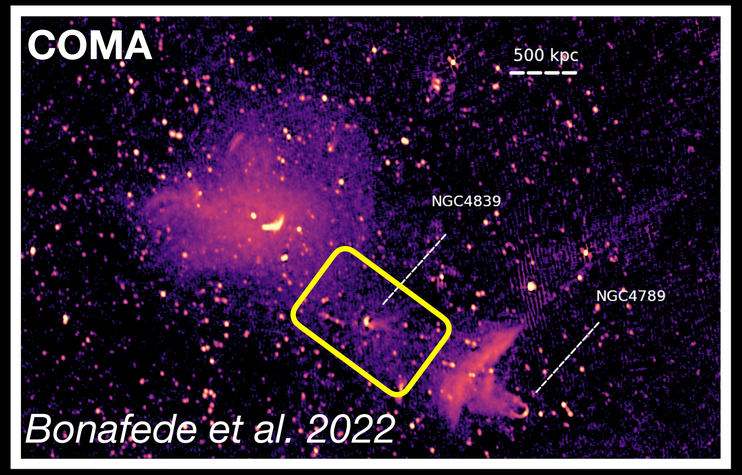
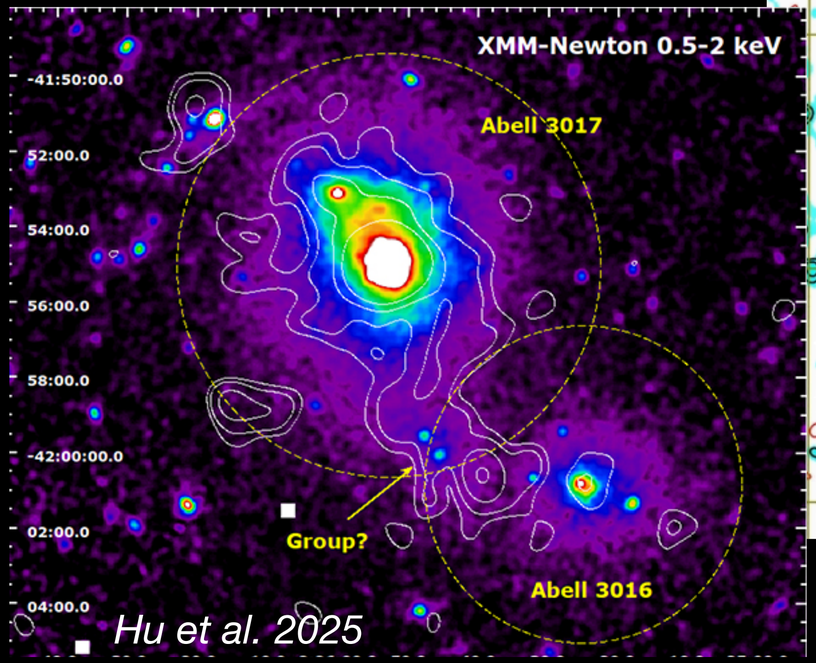
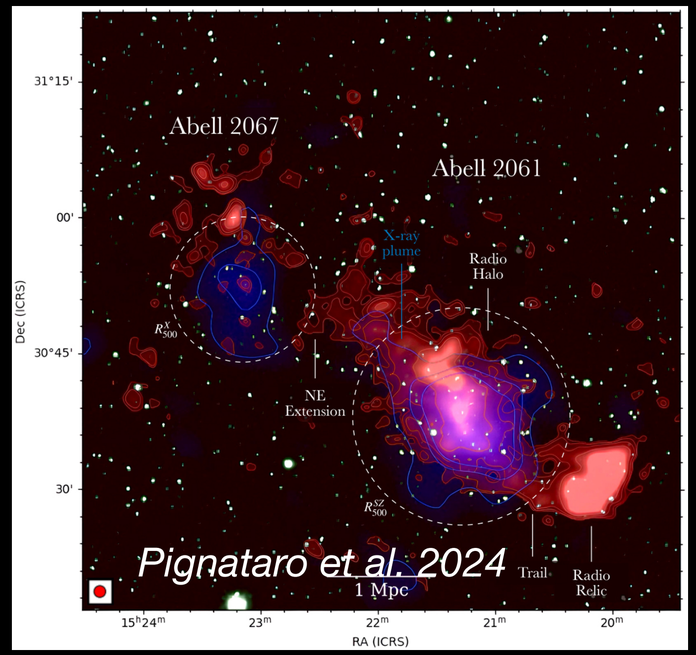


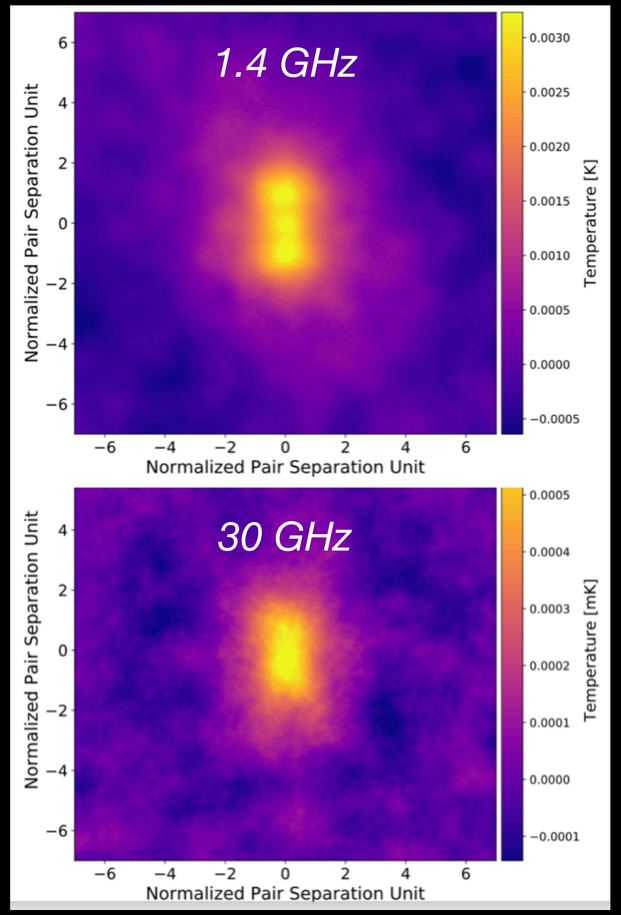




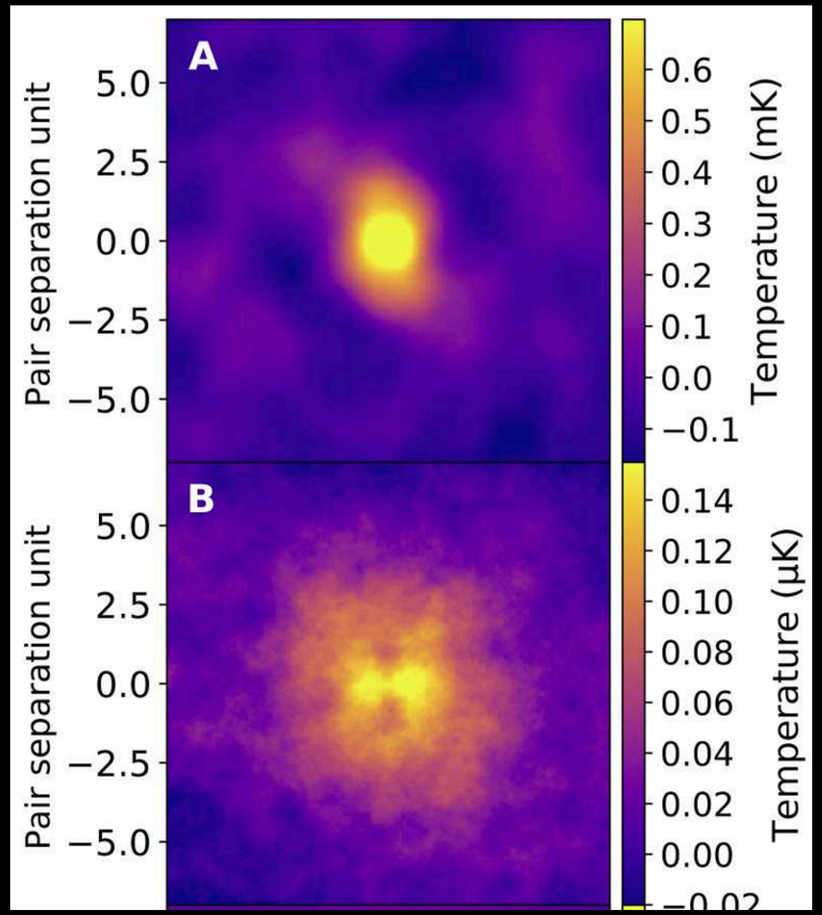
Stacking filaments *(Vernstrom et al. 2021, 2023)*

Using Luminous Red Galaxies from SDSS as tracers.
See also results from Hou et al. (2023) on the staking of LWA data around clusters

Total intensity



Polarised intensity



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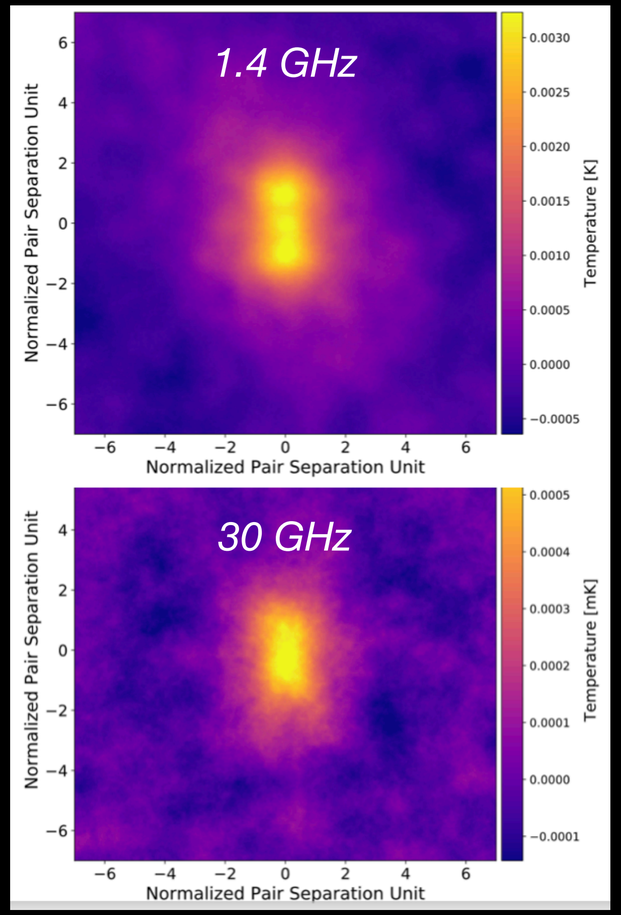

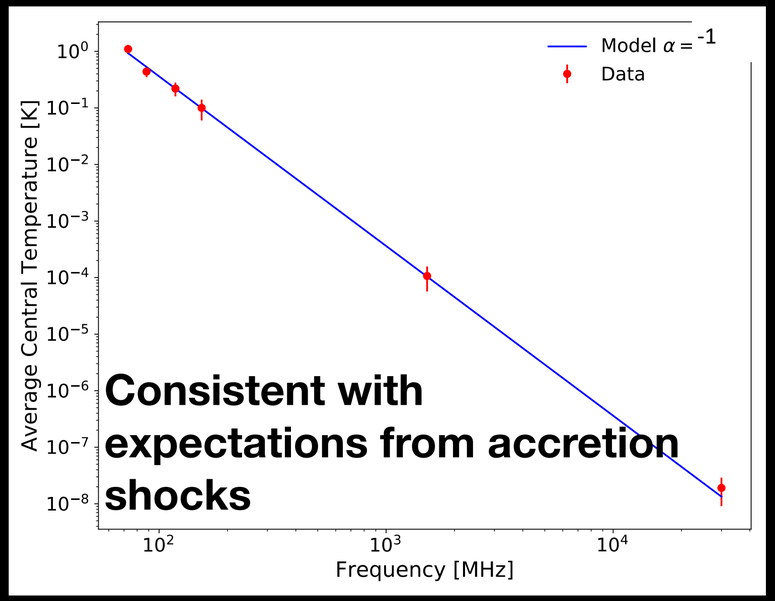

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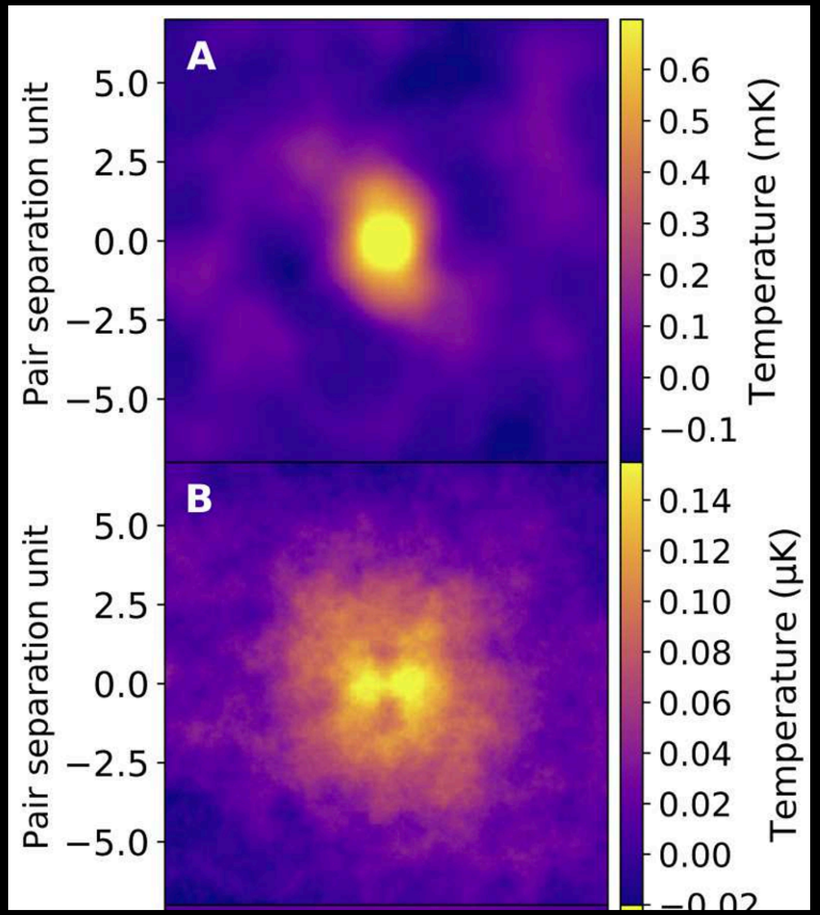

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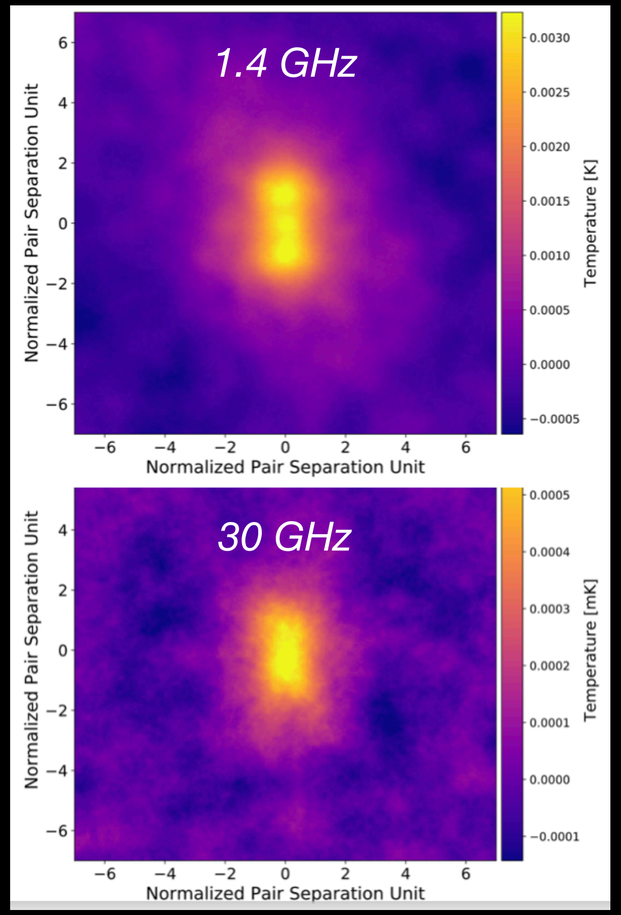
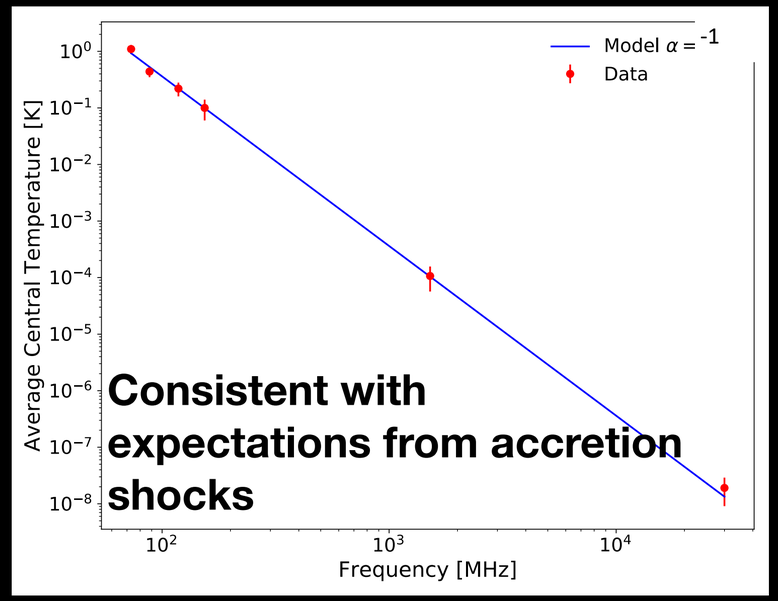
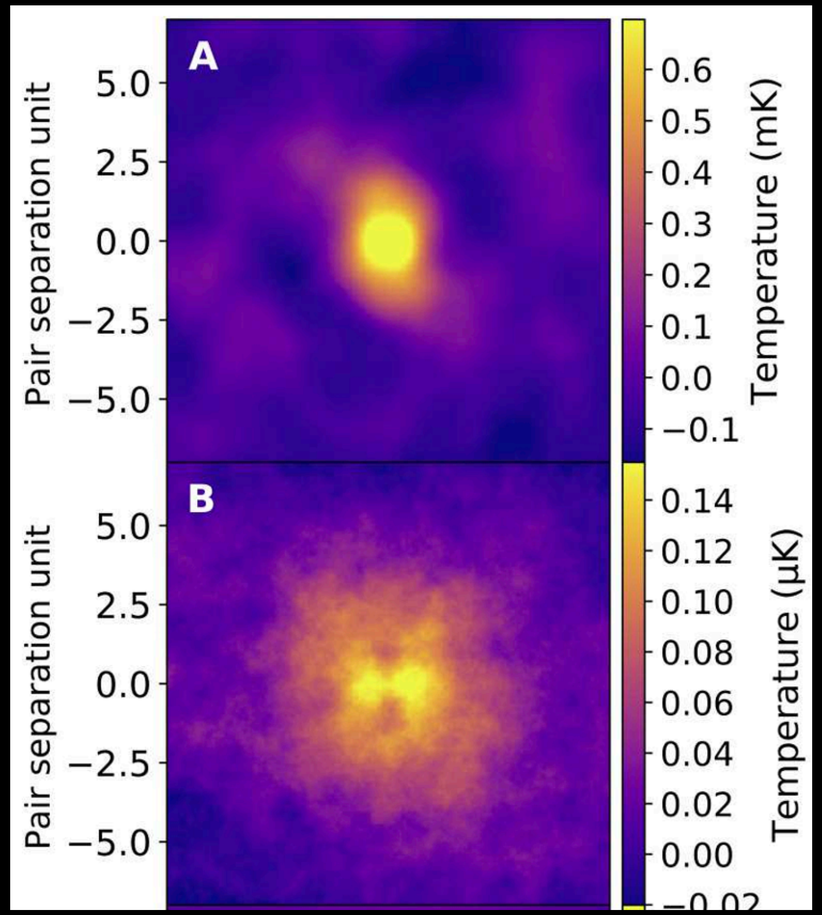




Tentative estimate of magnetic field strength in filaments
30-60 nG

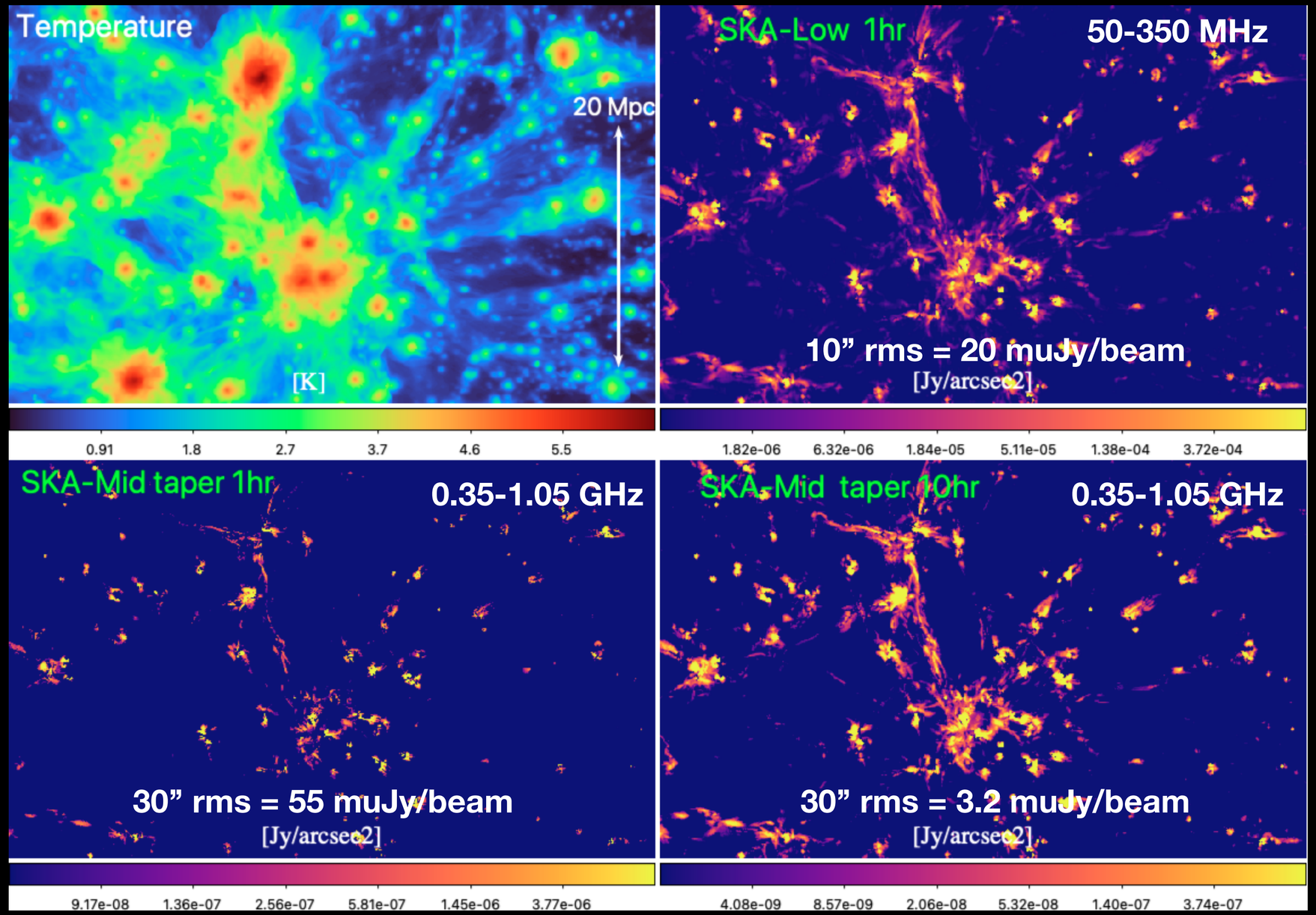
Polarised intensity



Predictions for SKA (Cuciti et al. ASKAII submitted)

Will SKA be able to detect cosmic filaments?

Predictions for SKA (Cuciti et al. ASKAII submitted)



Starting from simulations presented in Vazza et al. (2025)

Snapshot at z = 0.15 (similar to the average redshift of filaments in Verstrom et al 2023)

Take home messages

- Big steps forward in the past few years in the exploration of the cosmic web with radio telescopes, in particular with LOFAR
- SKA-Low will be around 6-8 times more sensitive than LOFAR, but lower resolution
- According to our simulations, with 1 hour observing time SKA-Low will detect at least the brightest part of cosmic filaments
- With a larger investment of time, SKA-Mid (Band 1) will reach similar sensitivities to faint steep spectrum emission

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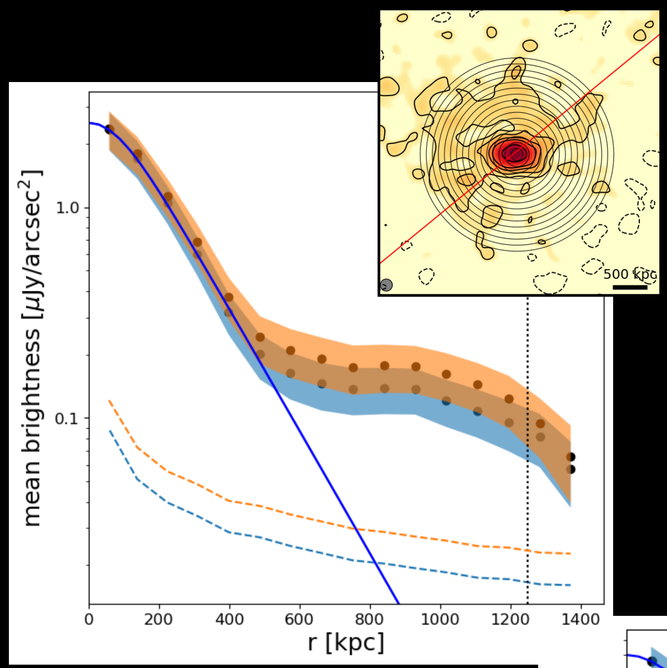
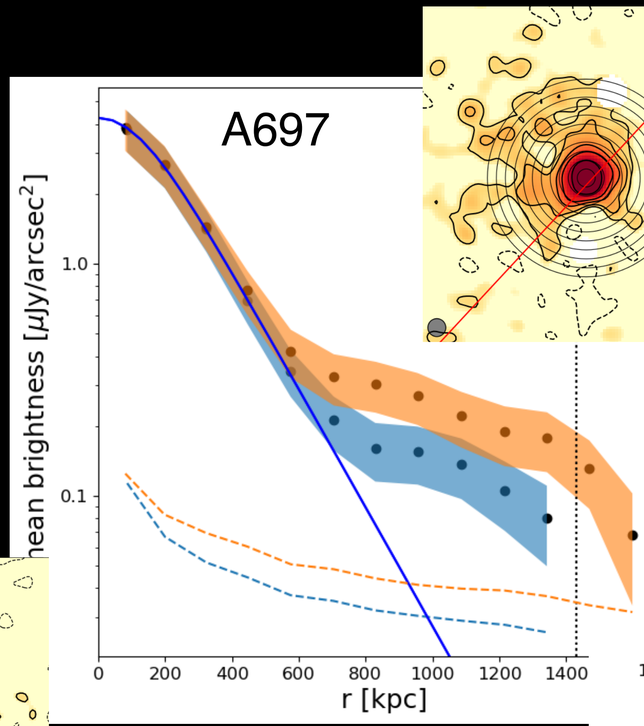
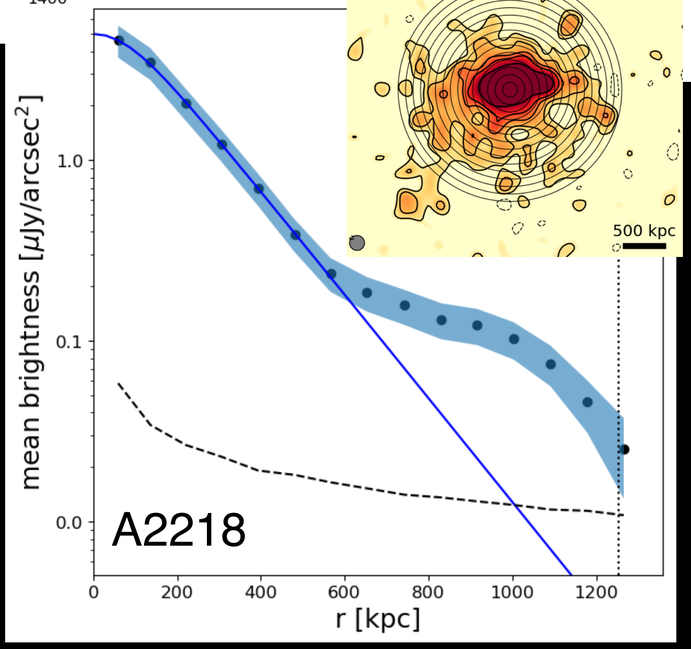
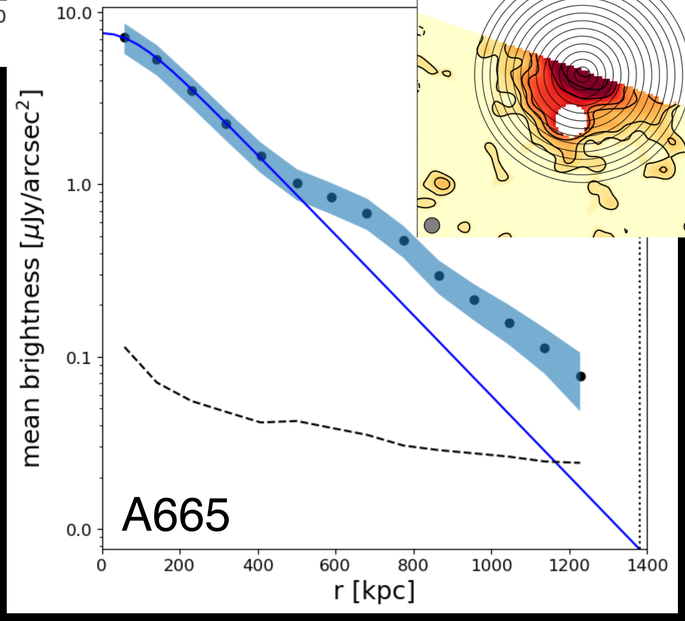
Thank you!

Surface brightness profile



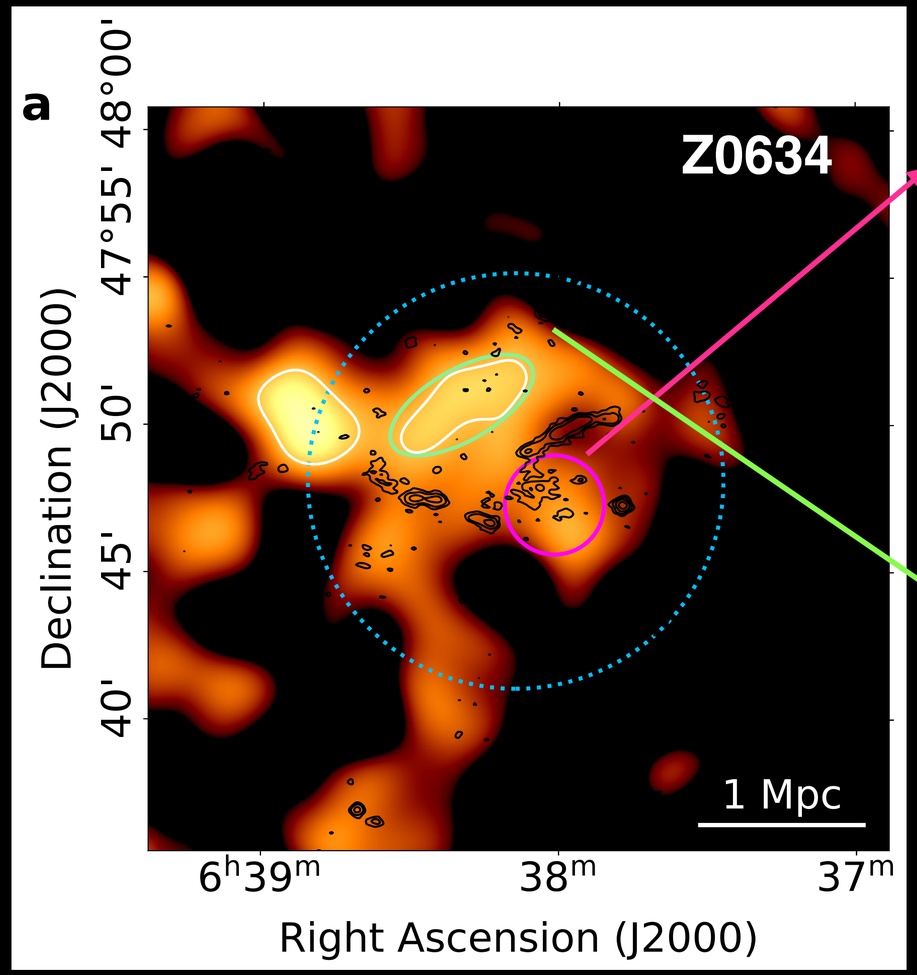






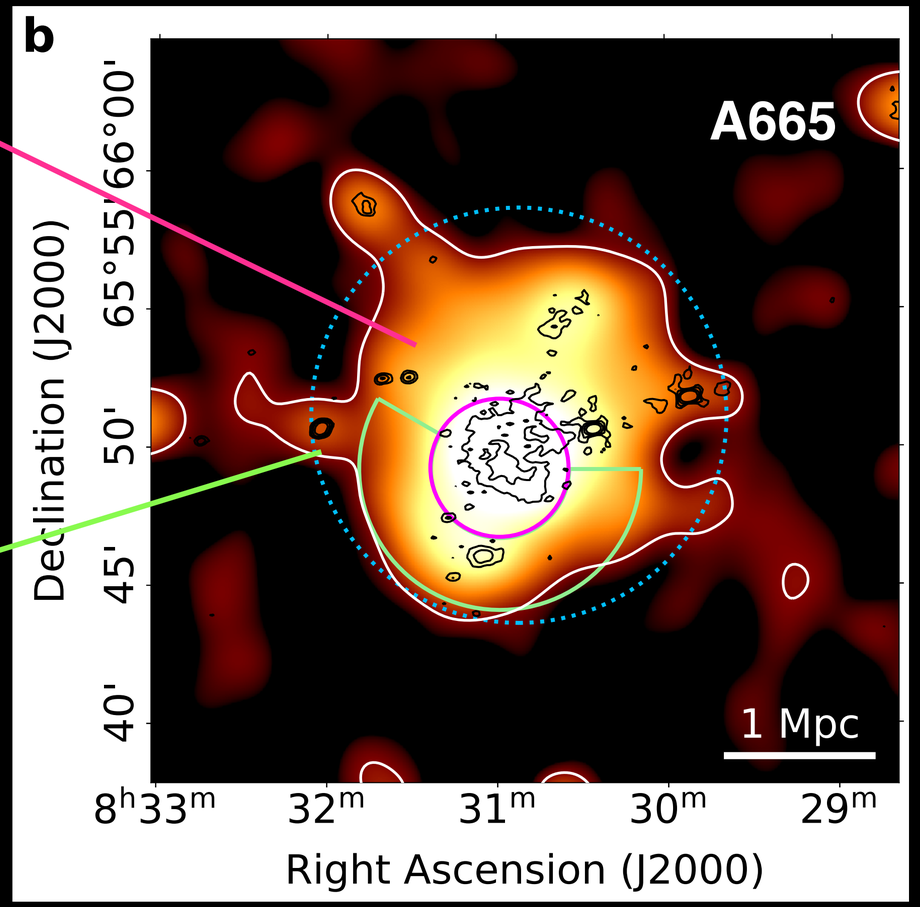
Spectral index

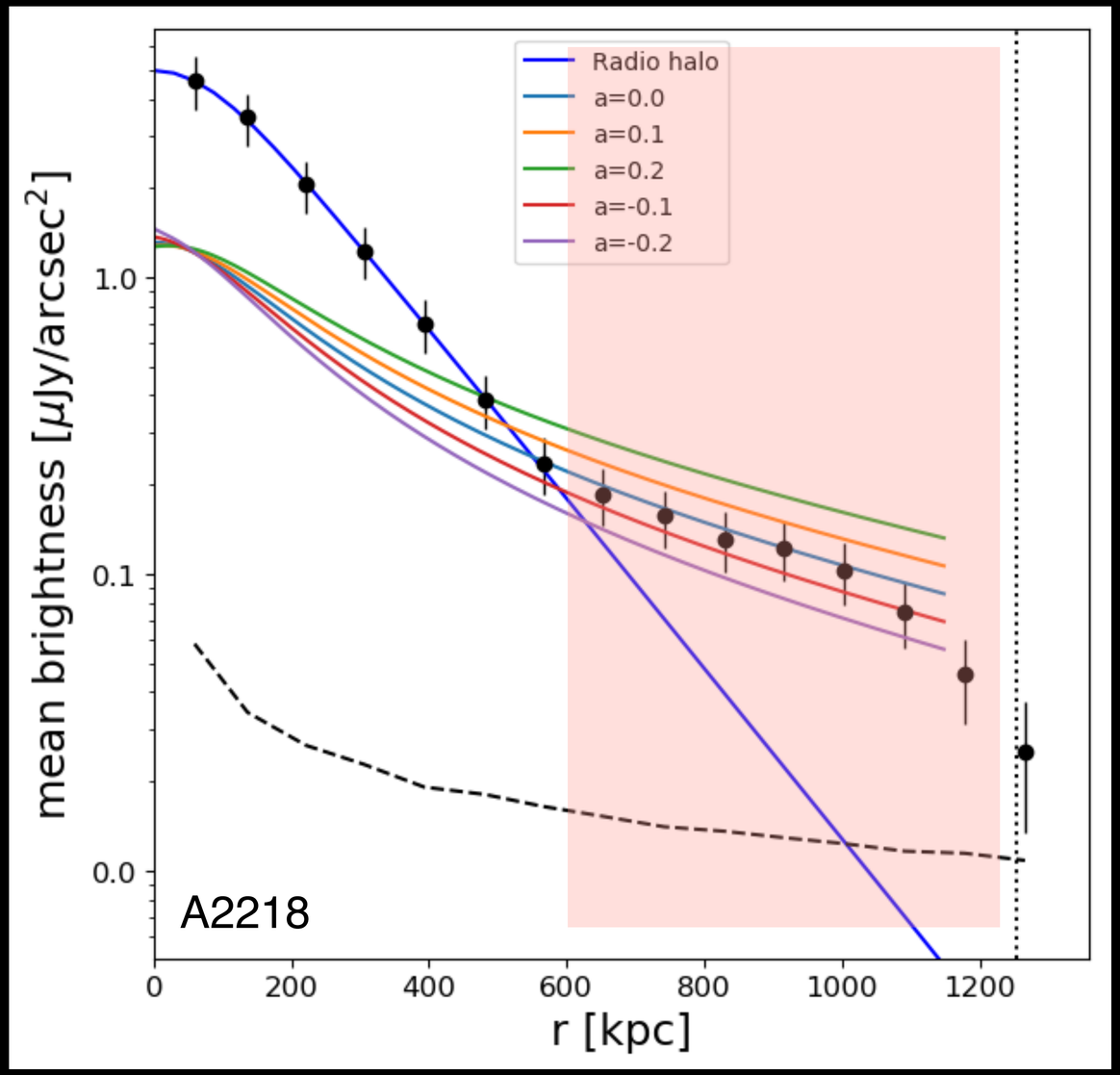
Using LOFAR 50 MHz and 140 MHz images



Radio halo
spectral index 50-144 MHz
$\alpha \approx -1.2$-1.3

Megahalo
spectral index 50-144 MHz
$\alpha \approx -1.6$





n_{icm} (r)
(Pratt et al. 2005)

$B^2 \propto n_{icm}$
(Bonafede et al. 2010)

$SB \propto k_e(r)\ B^{(1+\alpha)}$

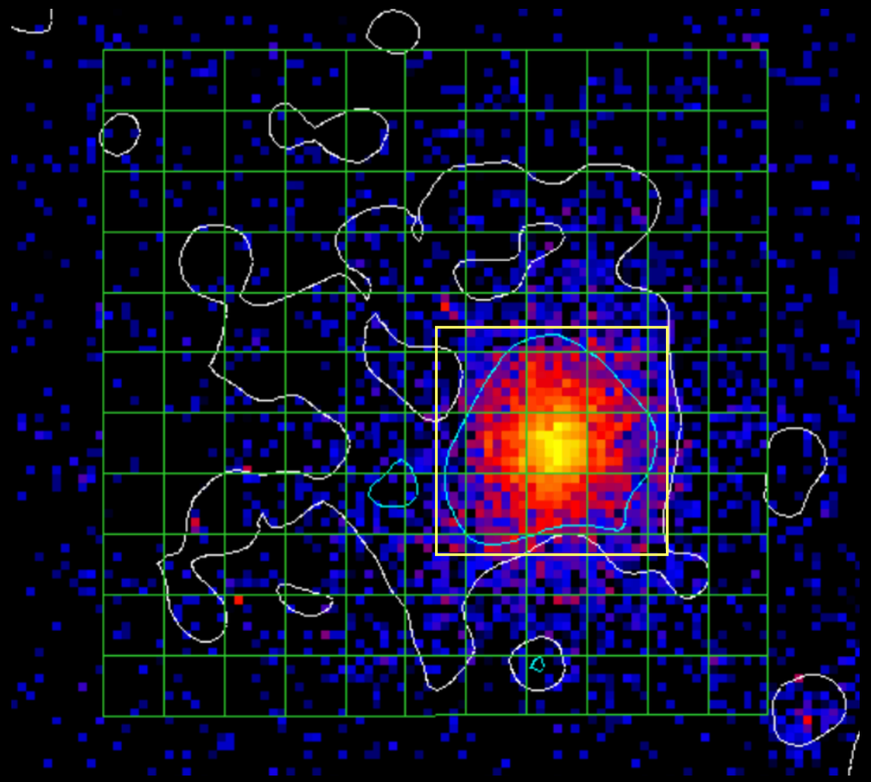
$k_e(r) = r^a$

- k_e ~const can reproduce the observed SB profile
- In the range 600-1200 kpc n_{icm} goes down by a factor ~3

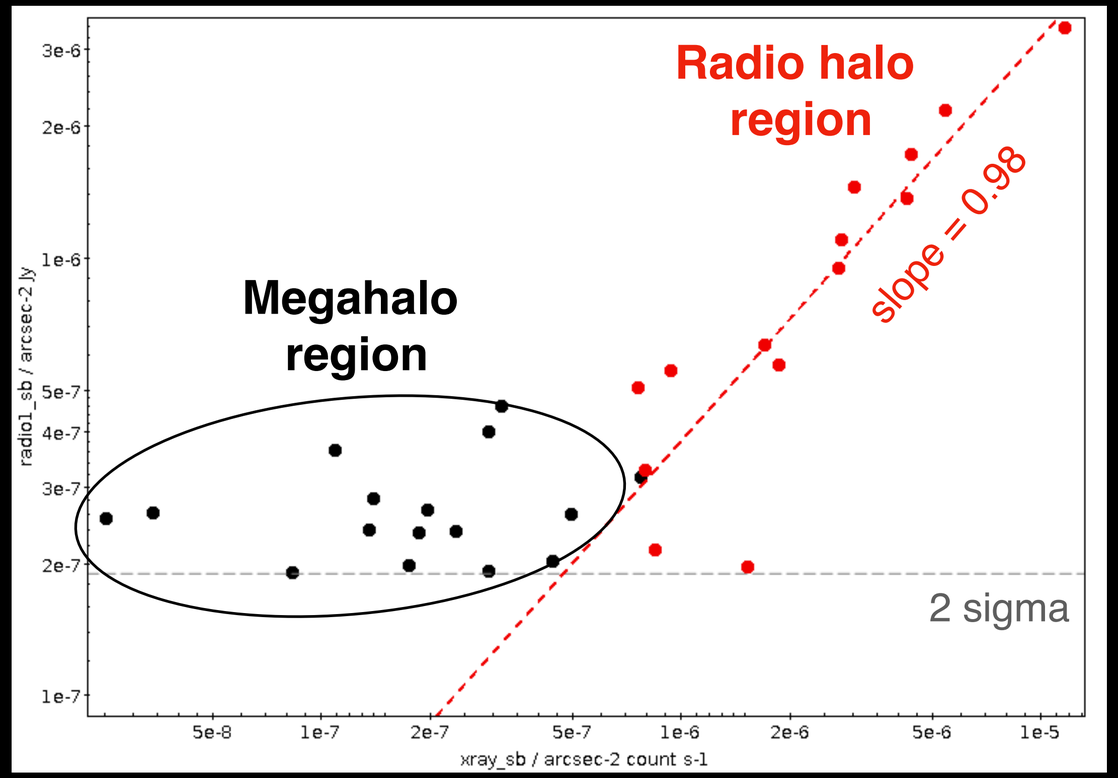
1) ratio between the energy density of non-thermal electrons and the thermal gas energy must increase by a factor 3
or
2) B must increase by a factor $\sqrt{3}$ (at variance with what observed in Coma)

Radio-X ray point to point analysis

A697 XMM image + LOFAR contours

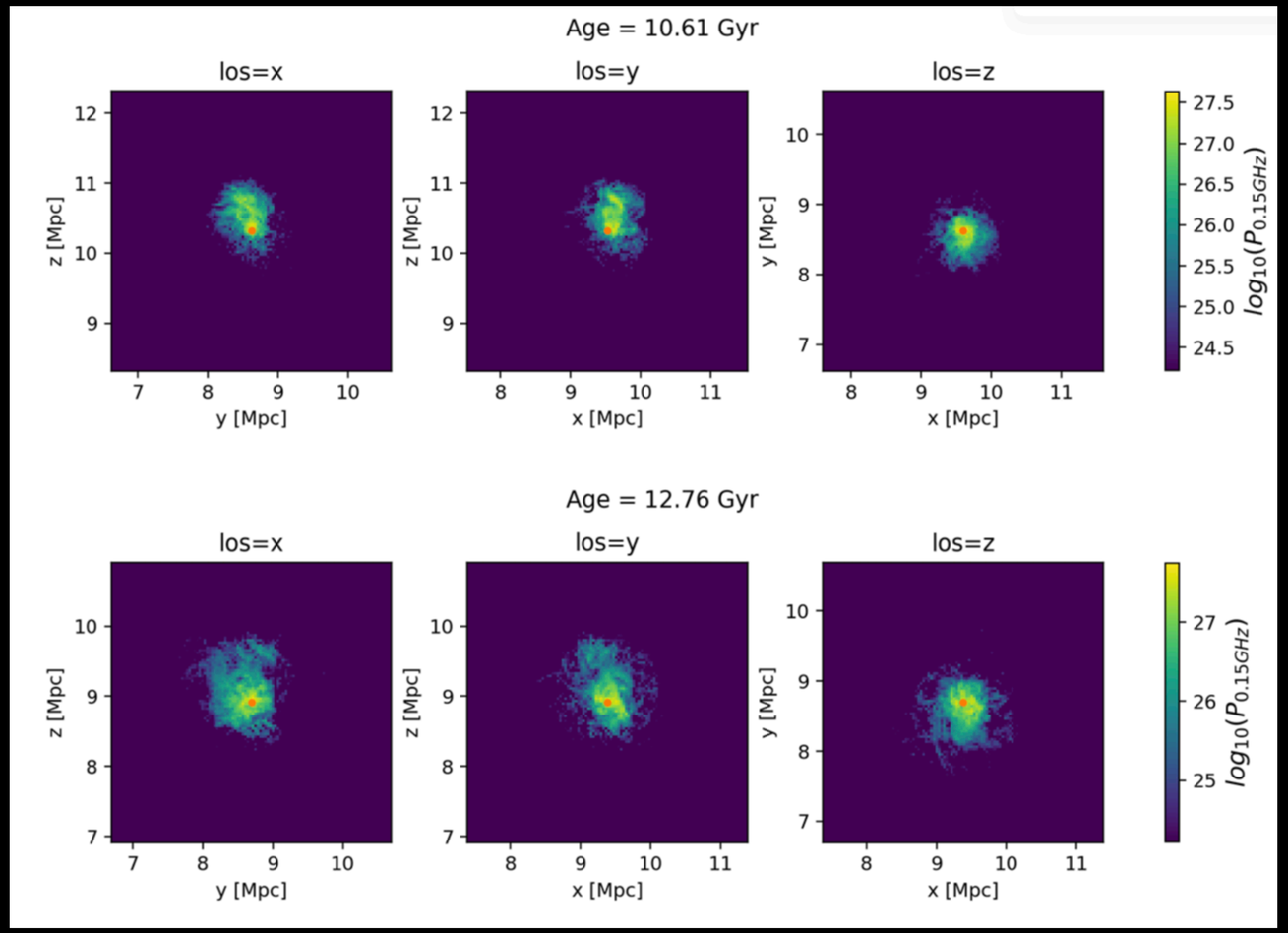


Radio vs X-ray surface brightness

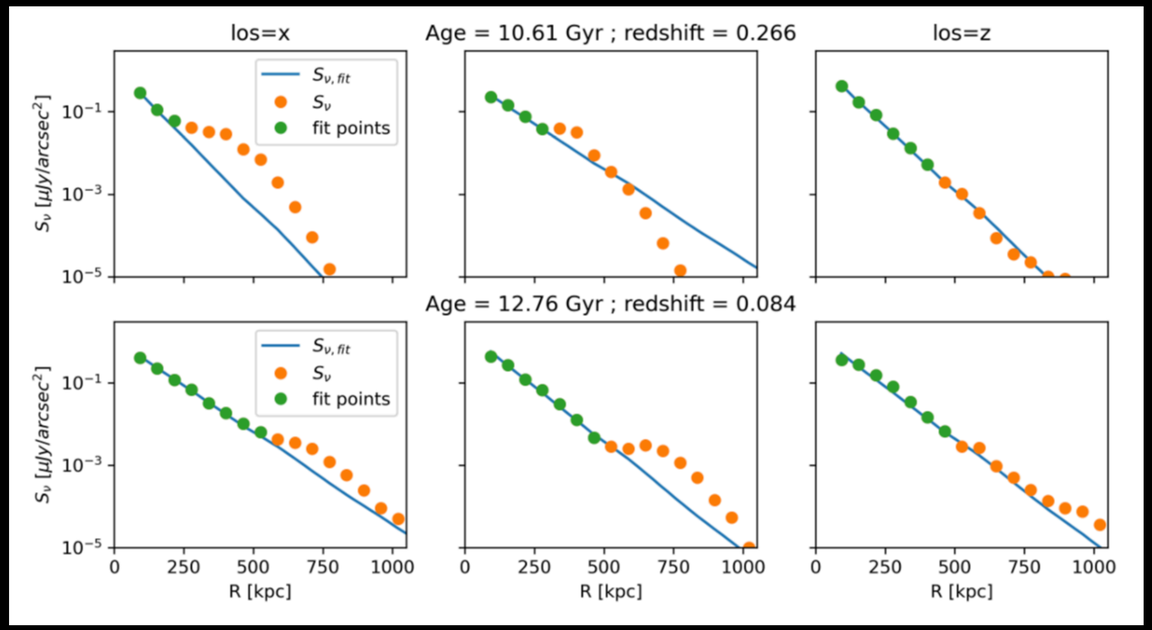


On the origin of megahalos

Simulated 140 MHz radio images



Simulated radial profiles

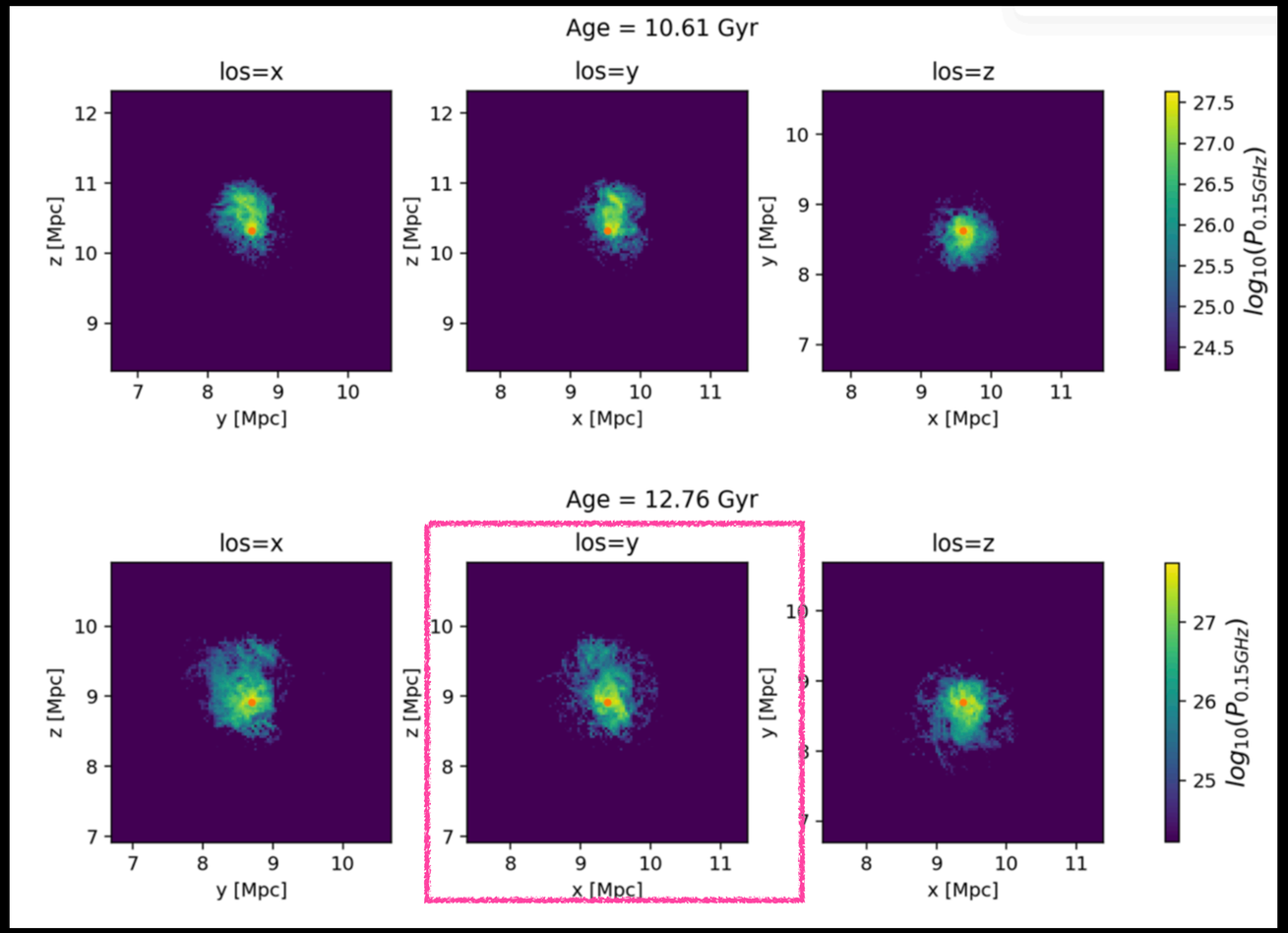


Beduzzi, Vazza et al. 2024

When the line of sight is perpendicular to the merger axis a second component in the profile stands out

On the origin of megahalos

Simulated 140 MHz radio images



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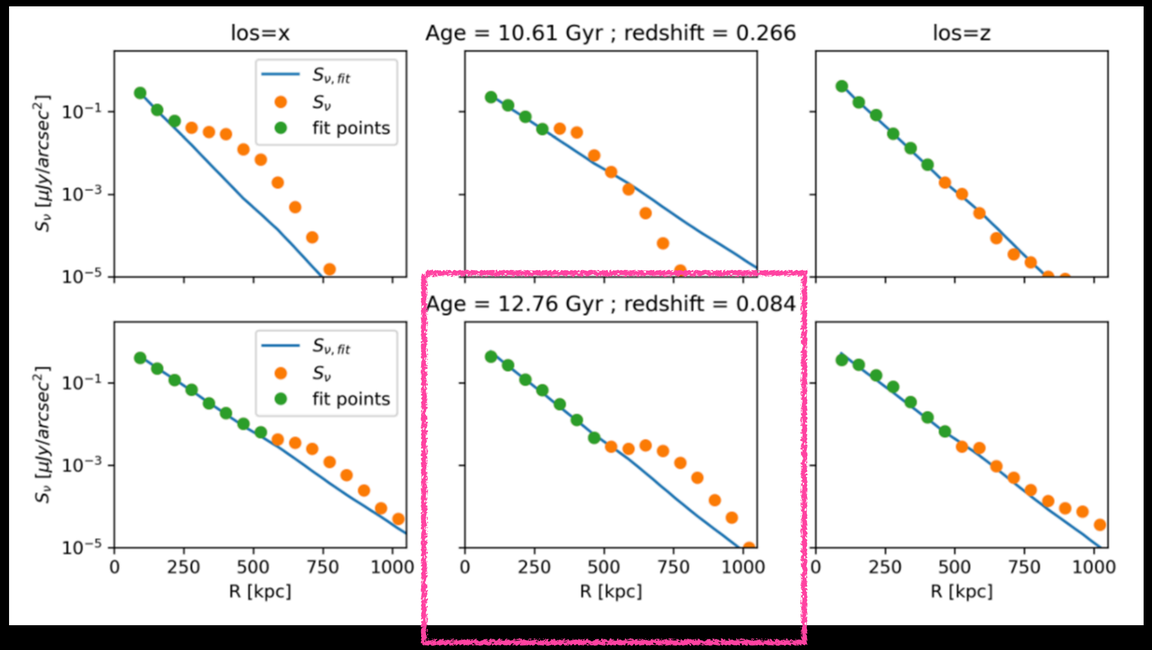
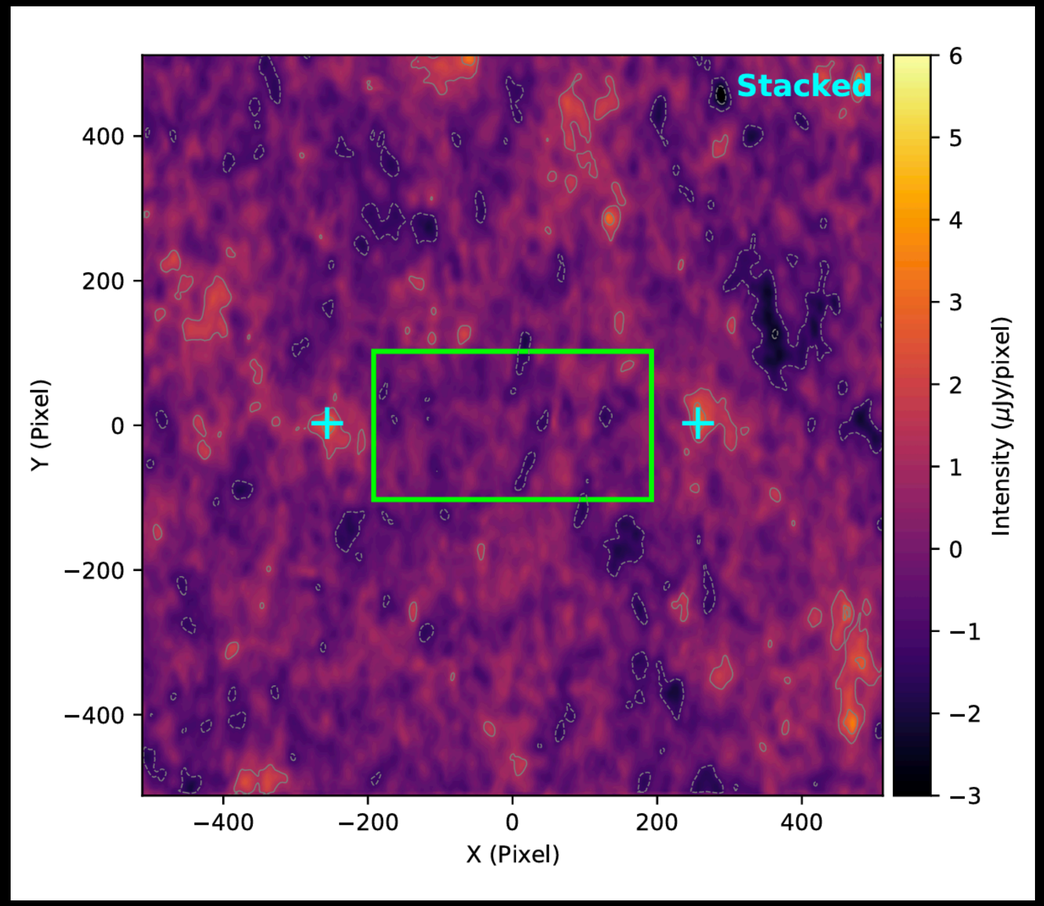


Beduzzi, Vazza et al. 2024

When the line of sight is perpendicular to the merger axis a second component in the profile stands out

Stacking bridges (Hang et al. 2023)

106 pairs of clusters detected with eROSITA and observed with LOFAR at 14 MHz



No detection of radio or X-ray emission in the stacked images

Mean radio emissivity

$$J < 1.2 \times 10^{-44} erg\ s^{-1} cm^{-3} Hz^{-1}$$

Upper limit of magnetic field under equipartition: 70 nG