Detection possibility of low mass 'Galaxy clusters'

using Numerical modelling of Radio synchrotron emission and Large Scale Cosmological Simulation

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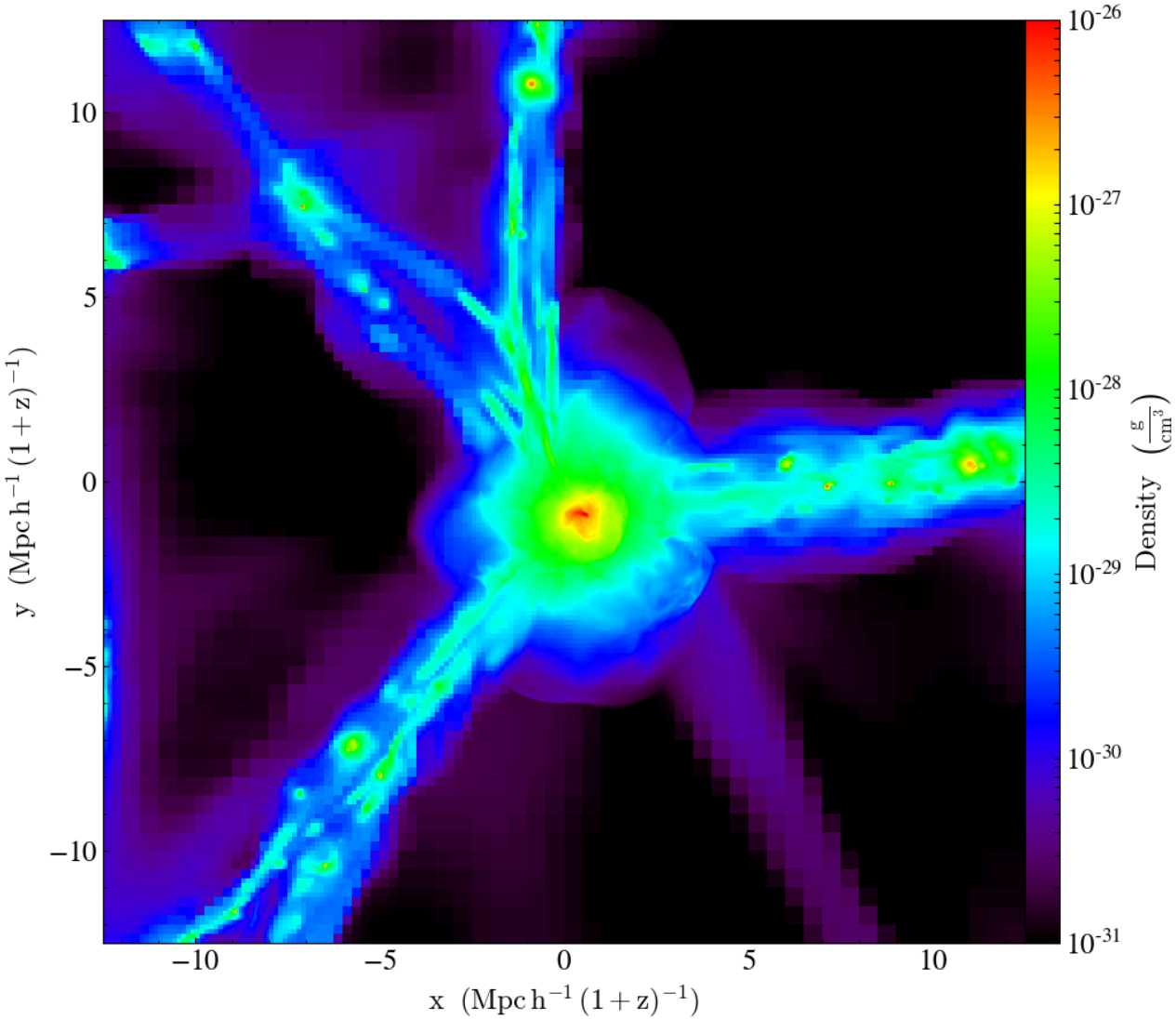
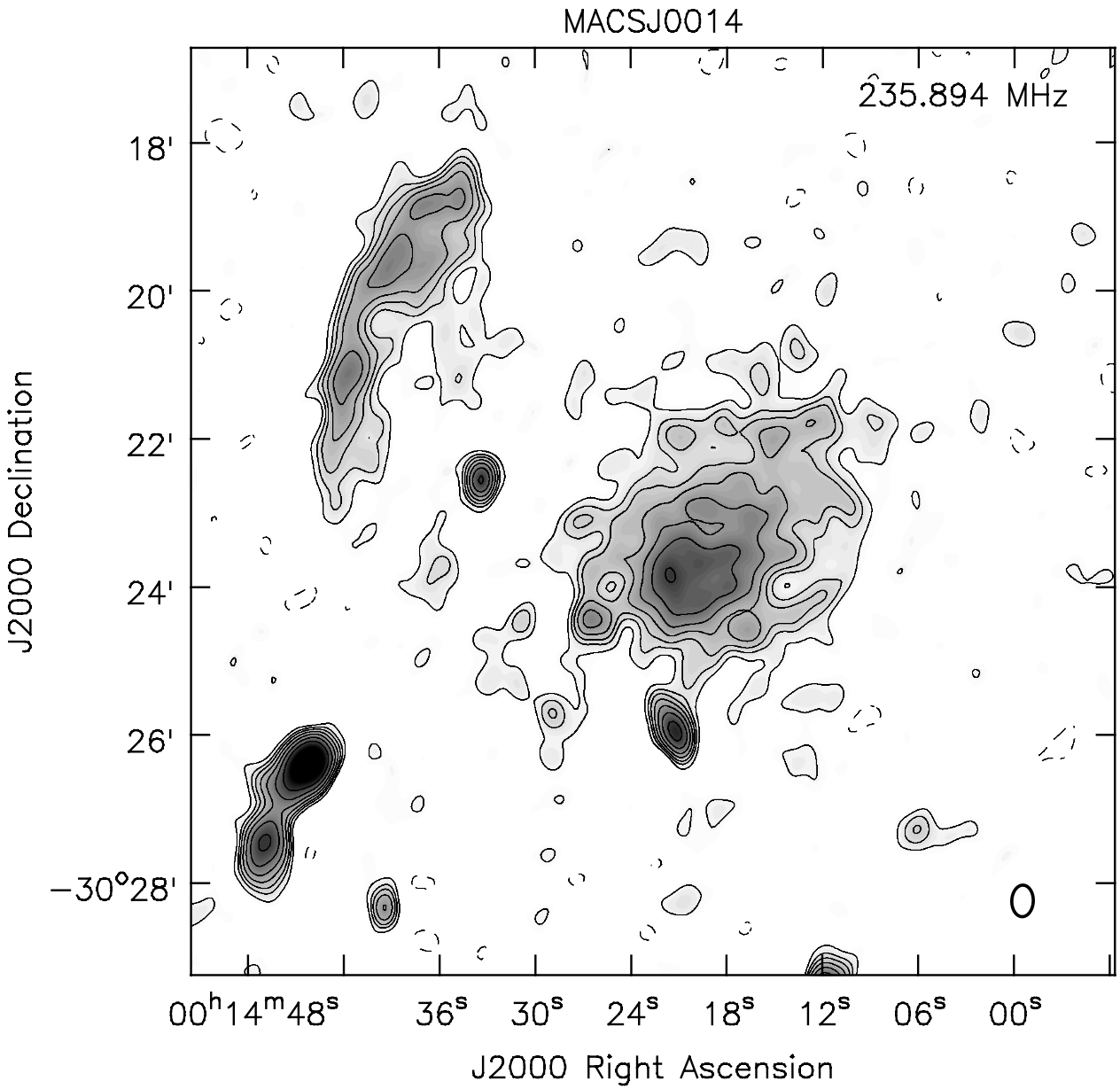
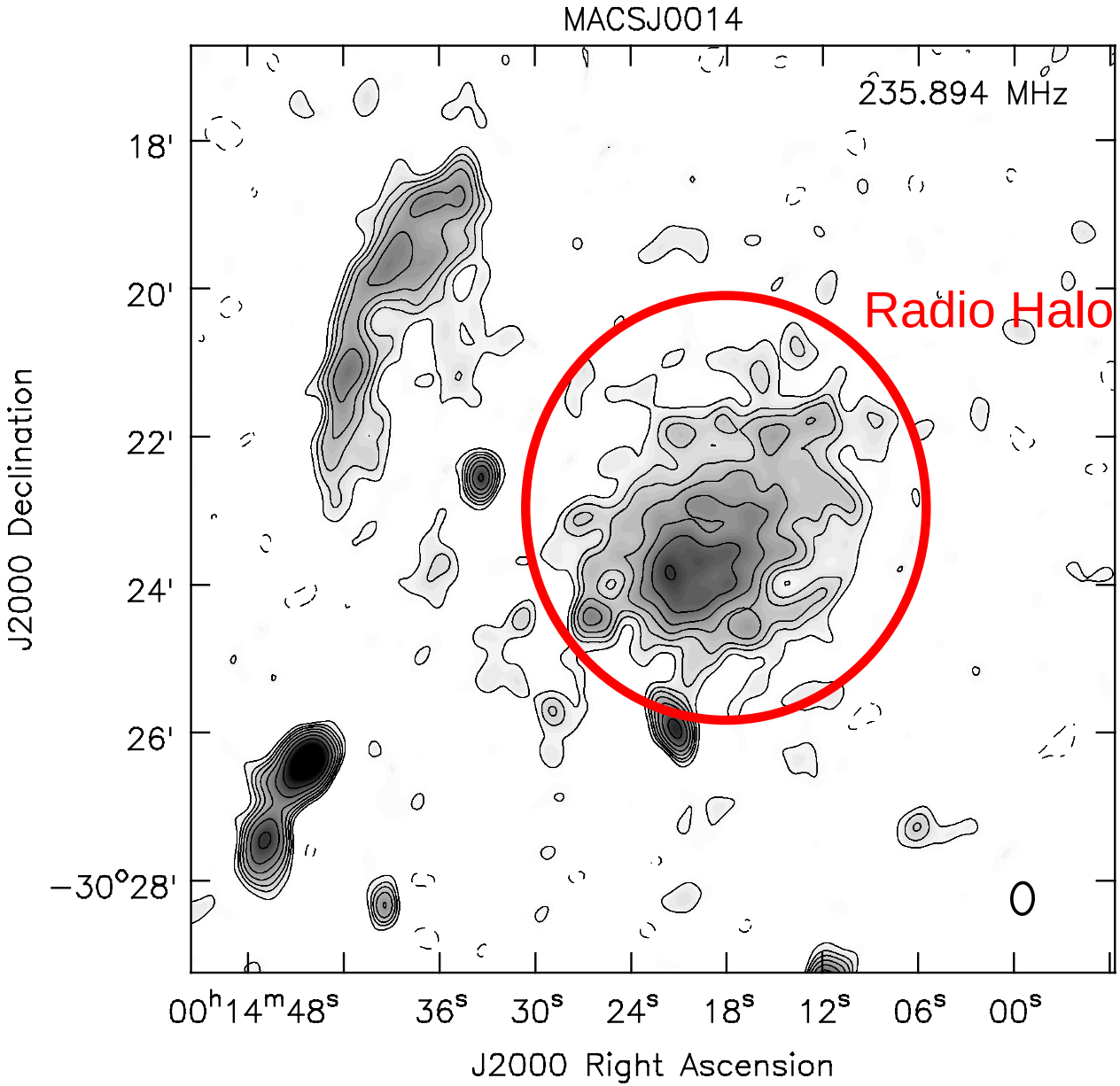
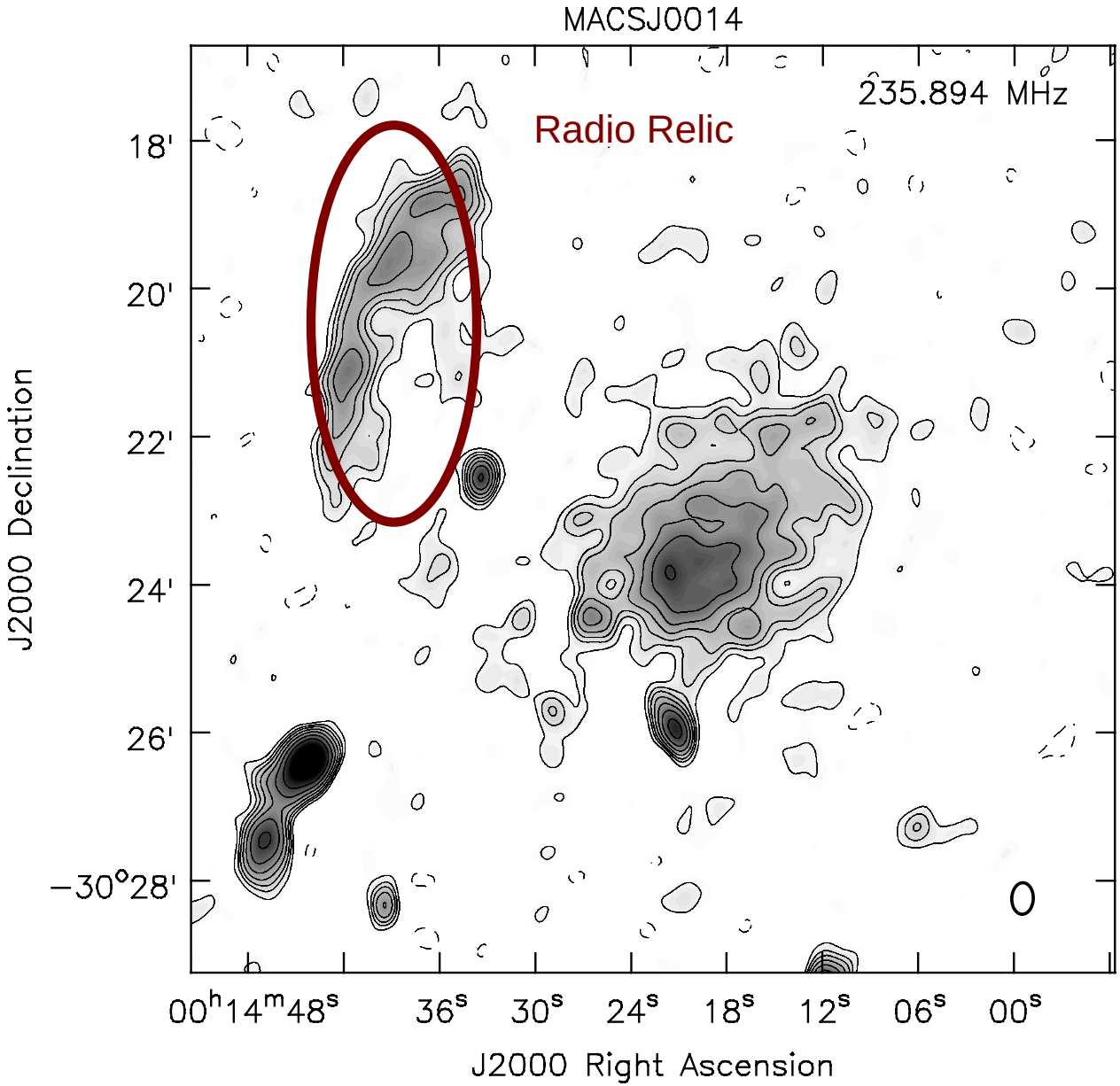
Galaxy Clusters:



Radio emission from Galaxy Clusters:




MACSJ0014
235.894 MHz
Radio Halo
18'
20'
22'
24'
26'
−30°28'
J2000 Declination
00h14m48s
36s
30s
24s
18s
12s
06s
00s
J2000 Right Ascension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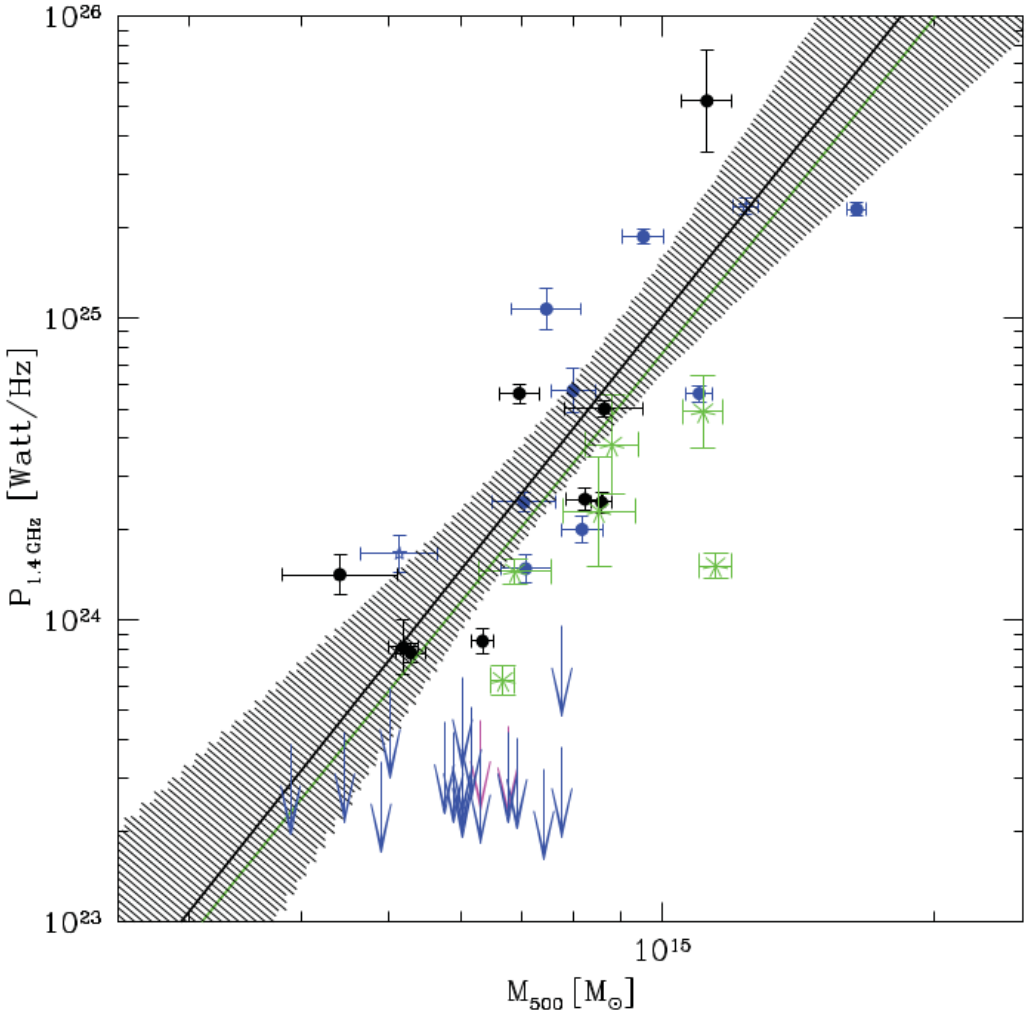
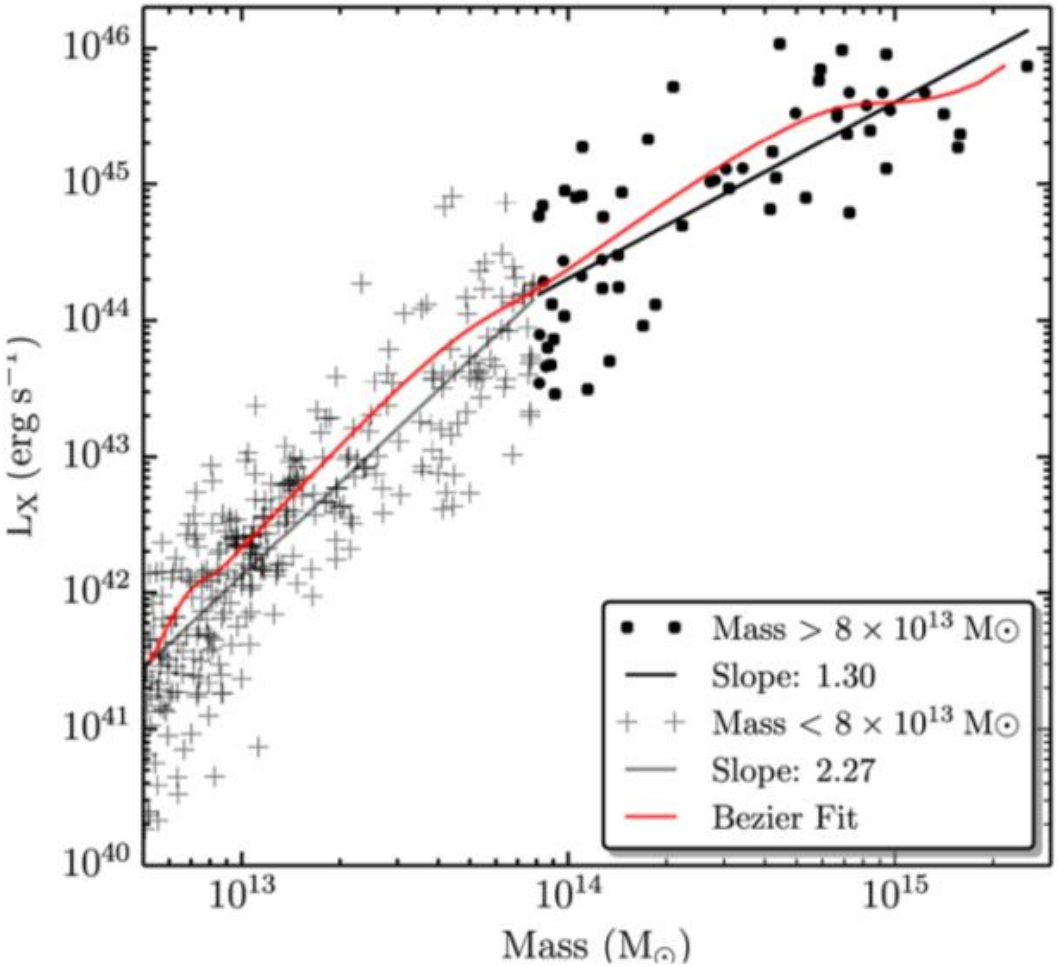
Motivation:



The Slope of $P_{1.4GHz} - M_{500}$ correlation:

- BCES-Bisector - 3.70 ± 0.56

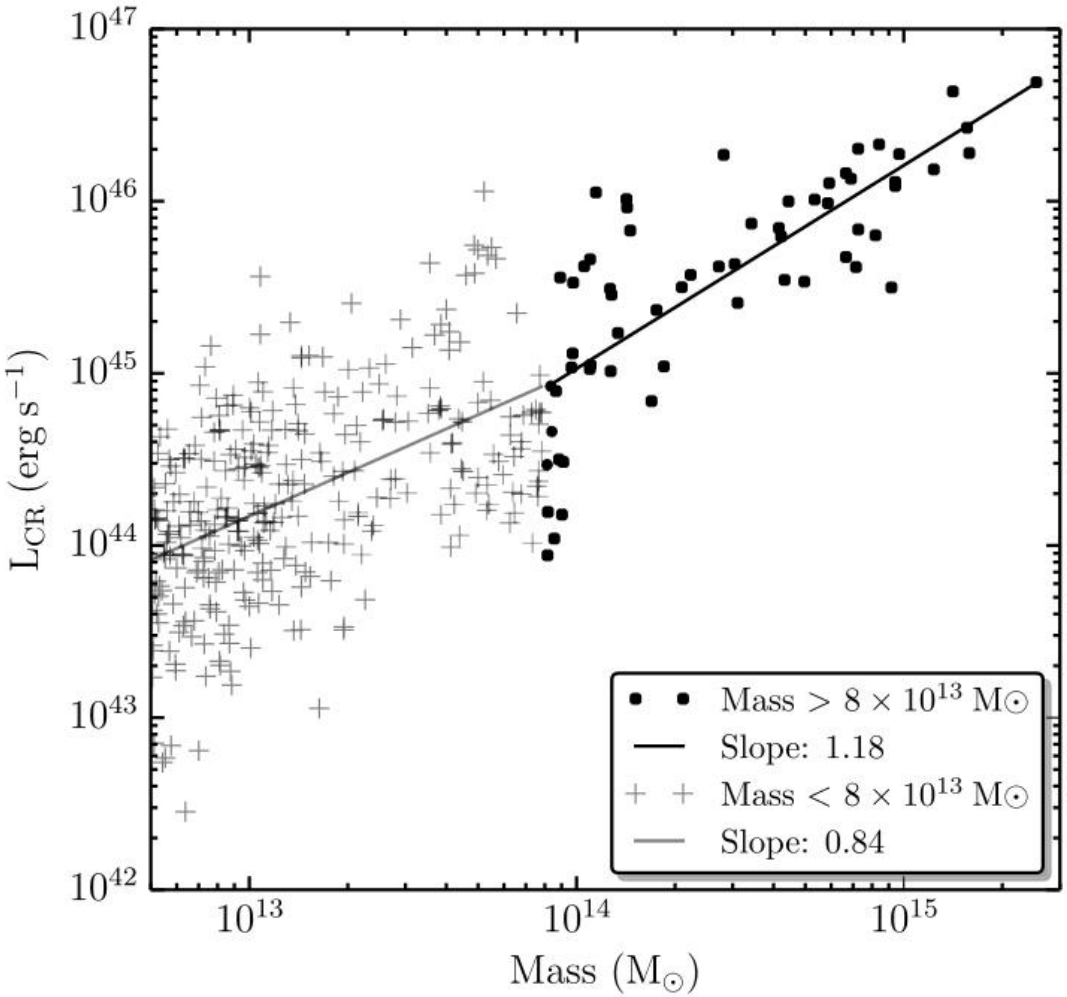
Credit: Cassano et. al. 2013



Paul et. al. 2017, MNRAS, 471, 2-11, reported:

- low mass objects do not follow any of the clusters self-similar laws.

- very high cosmic-ray luminosity - better visibility in the non-thermal regime.



Also shown in **Reju et. al. 2019, MNRAS, 488, 1301-1319**

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- Whether **Cassano's** scaling laws holds for the low mass objects ???

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If NO

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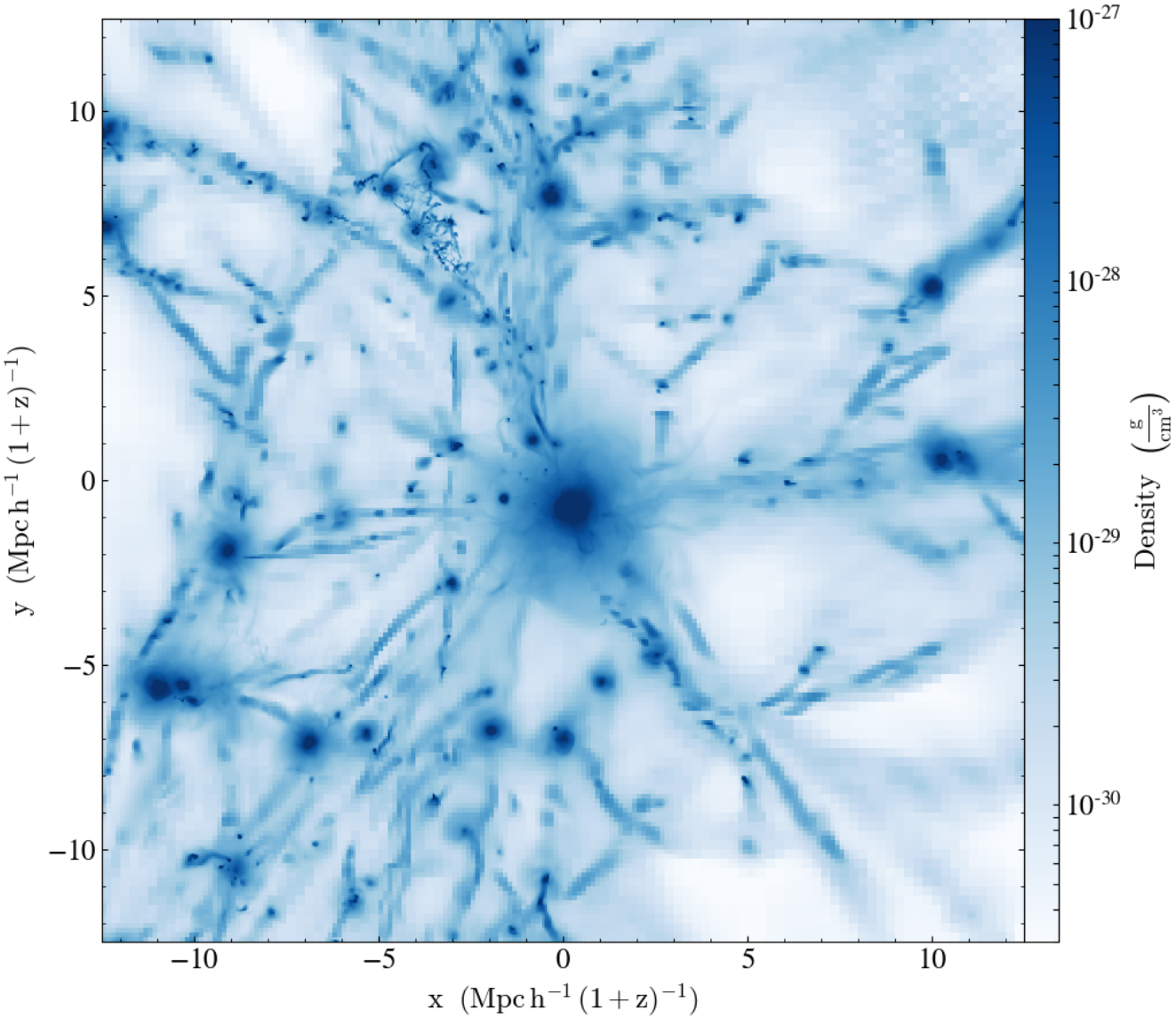
If NO

- Any possibility of detecting low mass objects, either with the existing one or the upcoming radio telescopes (like SKA) !!!

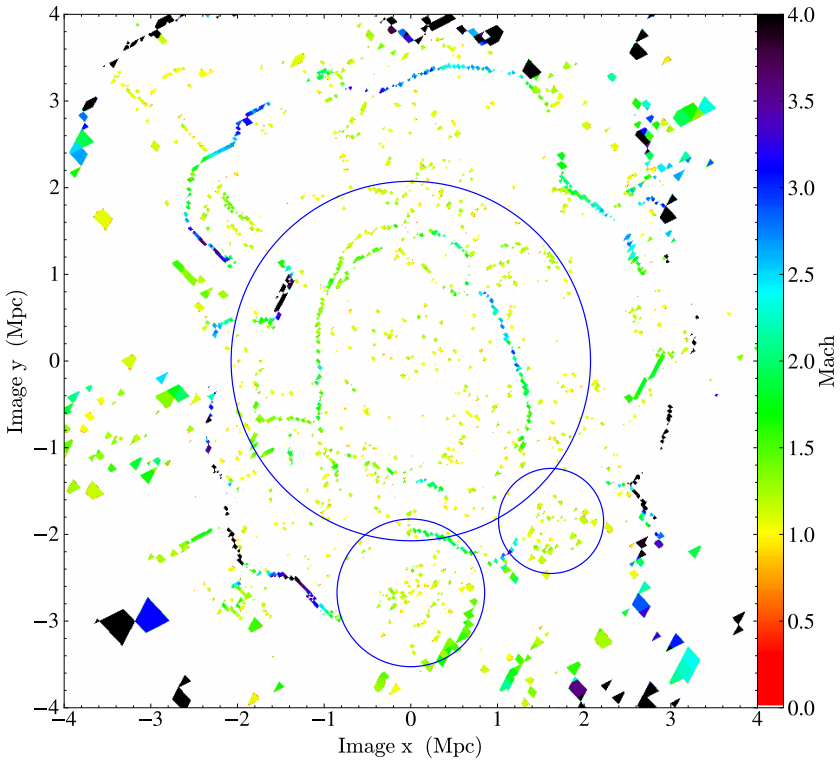
Simulation:

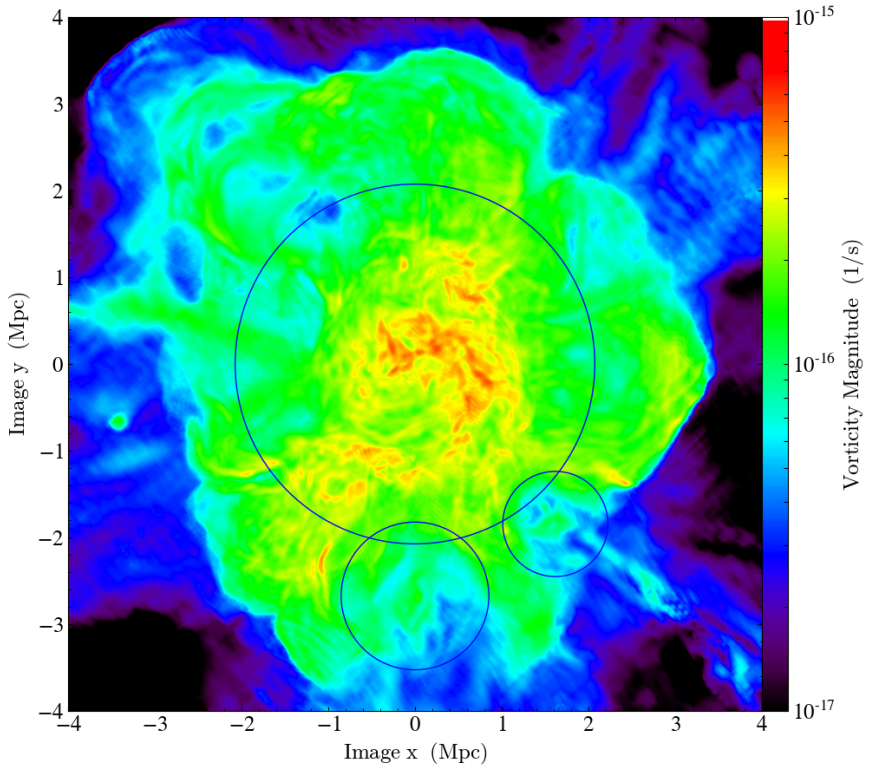
- Cosmological structure formation scenario:
  - Co-moving periodic box of $(128 Mpc)^3$ volume
  - 0.3 million particles of mass range $\approx 10^8 - 10^{10} M_\odot$.
  - Hybrid (N-body + hydro-dynamical)
- A flat ΛCDM cosmological model is assumed.
  - dark energy density parameter, $\Omega_\Lambda = 0.7257$
  - matter density parameter, $\Omega_m = 0.2743$
  - baryon density parameter, $\Omega_b = 0.0458$
  - hubble parameter, h $= H_0/(100 kms^{-1} Mps^{-1}) = 0.702$
- Cluster $\rightarrow 31.25 kpch^{-1}(1+z)^{-1}$ effective spatial resolution.

At large scale Universe has cosmic-web like structure :

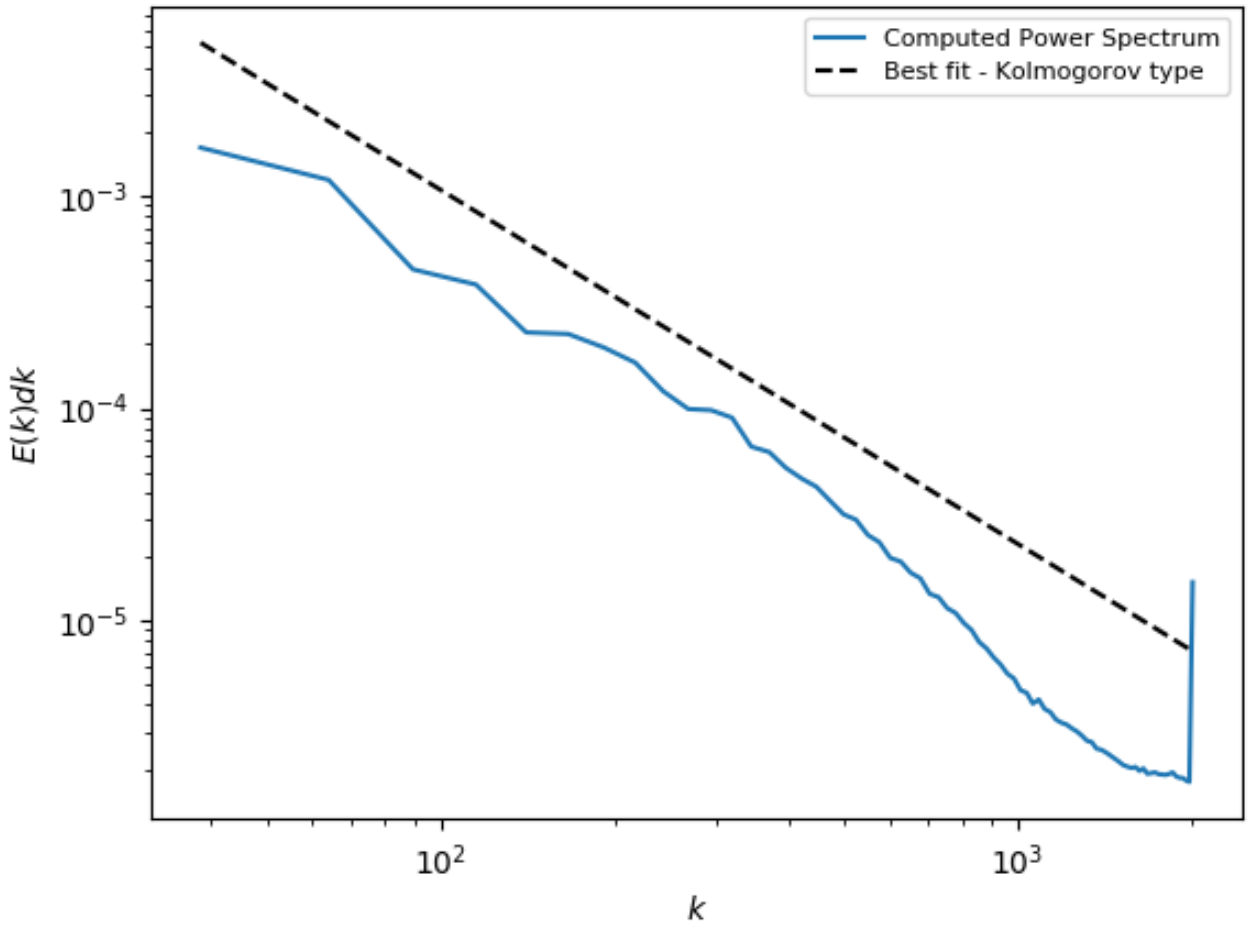


Shock and turbulence in galaxy clusters:





Turbulence kinetic energy density spectra:



Model Magnetic Field in Large scale structures

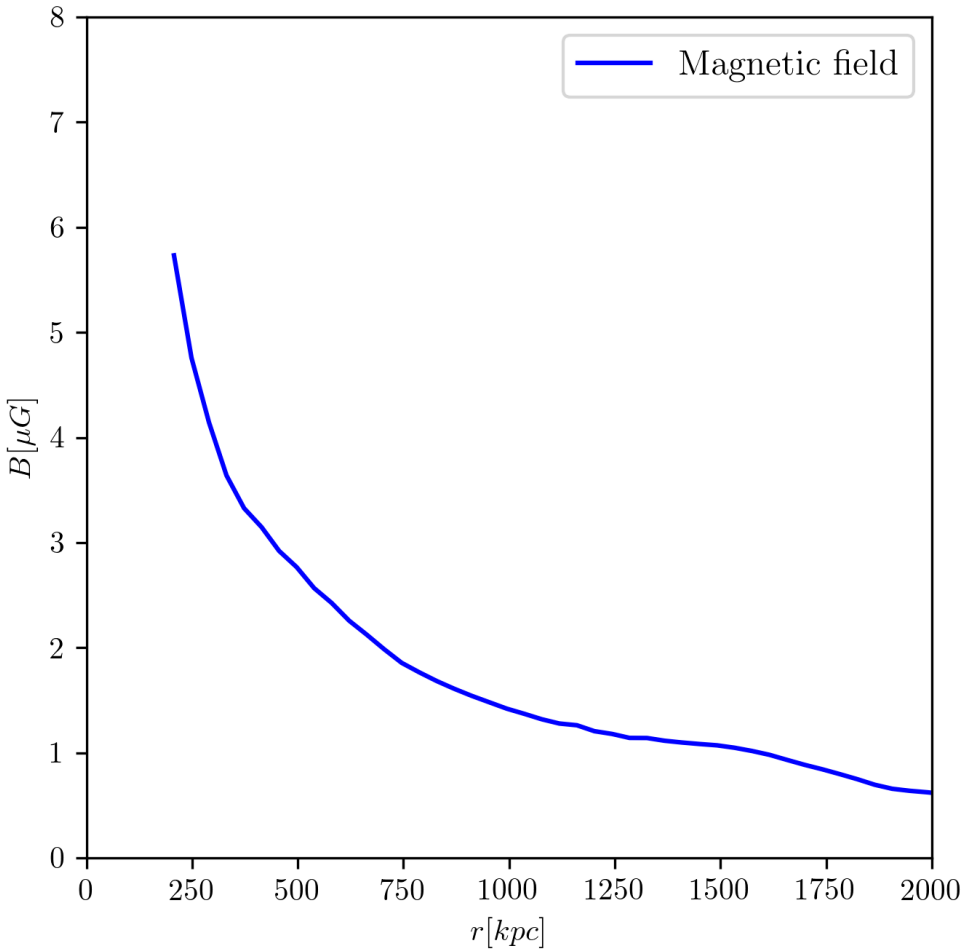
• Fully developed turbulence in medium $\rightarrow \frac{B_{\rm sat}^2}{8\pi} \propto \rho\epsilon_{\rm turb}$
(Subramanian et al. 1998, Iapichino et al. 2012)

• With this we compute the magnitude of saturated magnetic field from hydrodynamic parameters:

$$B_{\rm sat} = \sqrt{C_E.4\pi.\rho v_{\rm turb}^2}$$

where, $v_{\rm turb}$ is the turbulent velocity.

Magnetic Field from the proposed model:



In good agreement with the observations, the radial profile of magnetic field in Coma cluster, using Faraday rotation measurements (Bonafede et al. 2010)

Model Synchrotron radio emissions:

Synchrotron Radio power emission is given by;

$$\frac{d^2P(\nu_{obs})}{dVd\nu} = \frac{\sqrt{3}e^3B}{8m_ec^2} \int_{E_{\min}}^{E_{\max}} dE_e\, F\left(\frac{\nu_{obs}}{\nu_c}\right) \frac{dn_e}{dE_e}$$

where, $F(x) = x\int_x^\infty K_{5/3}(x')dx'$ is the Synchrotron function, which peaks at x = 0.29, $K_{5/3}$ is the modified Bessel function,

and ν_c is the critical frequency of synchrotron emission,

$$\nu_c = \frac{3\gamma^2 eB}{(4\pi m_e c)} = 1.6\left(\frac{B}{1\mu\mathrm{G}}\right)\left(\frac{E_e}{10\mathrm{GeV}}\right)^2 \mathrm{GHz}.$$

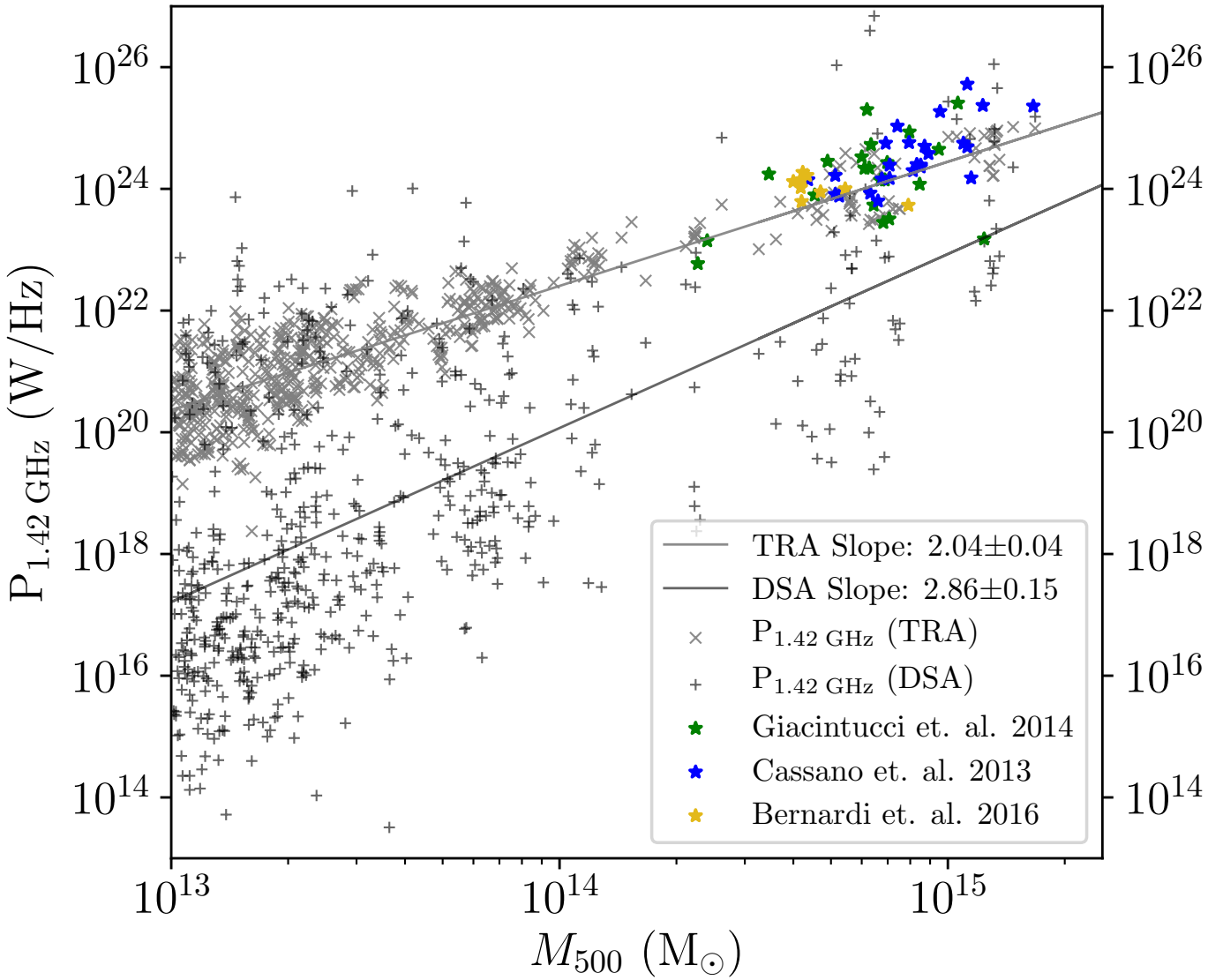
Objects selection and Computation:

The sample of more than 600 simulated objects obtained:

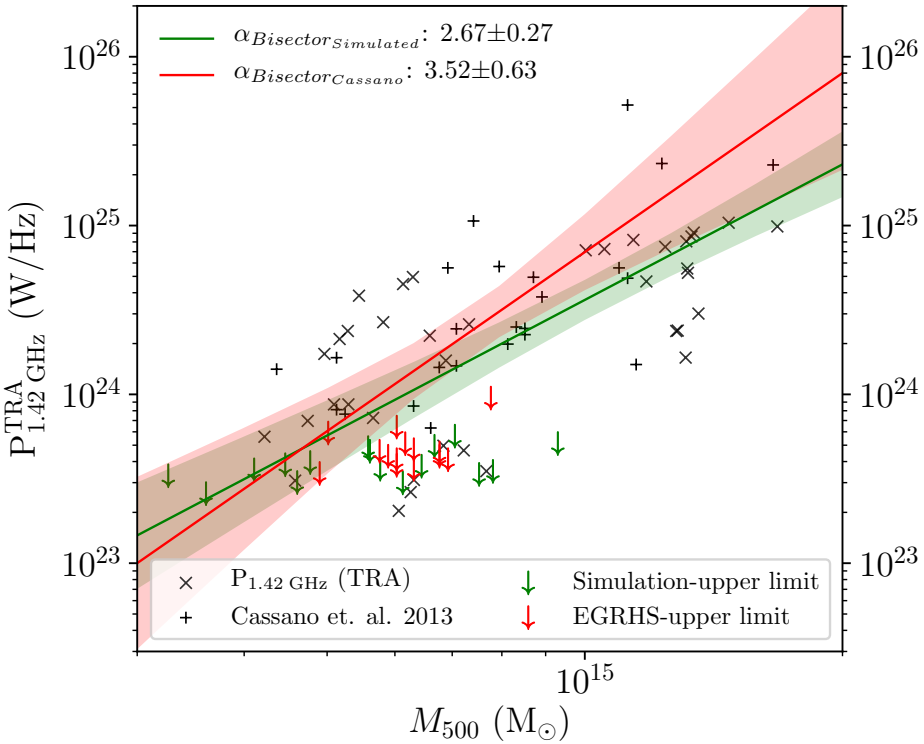
- mass range (10^{13} to $10^{15} M_{\odot}$)

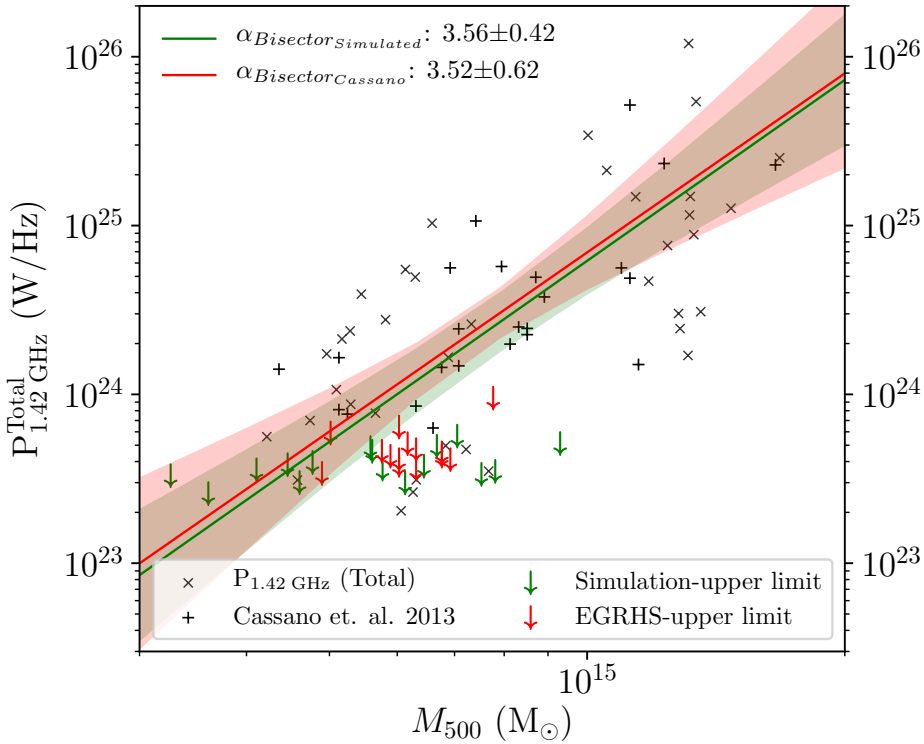
Radio Power at $1.4 GHz$ is being computed within R_{1000} radius of the sampled objects.

Results: Radio Power (TRA and DSA)

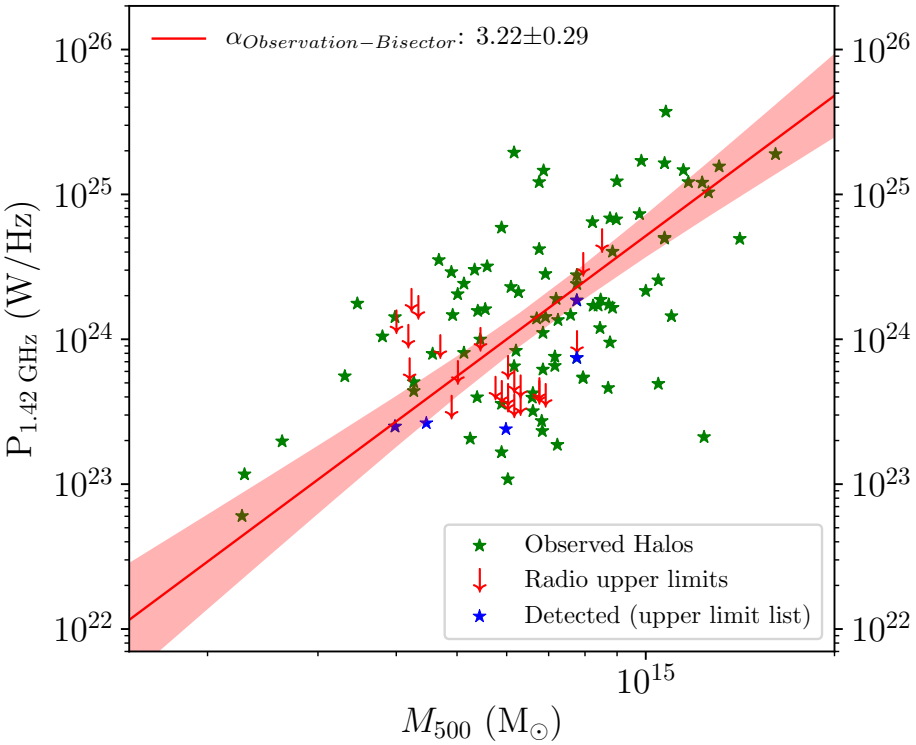


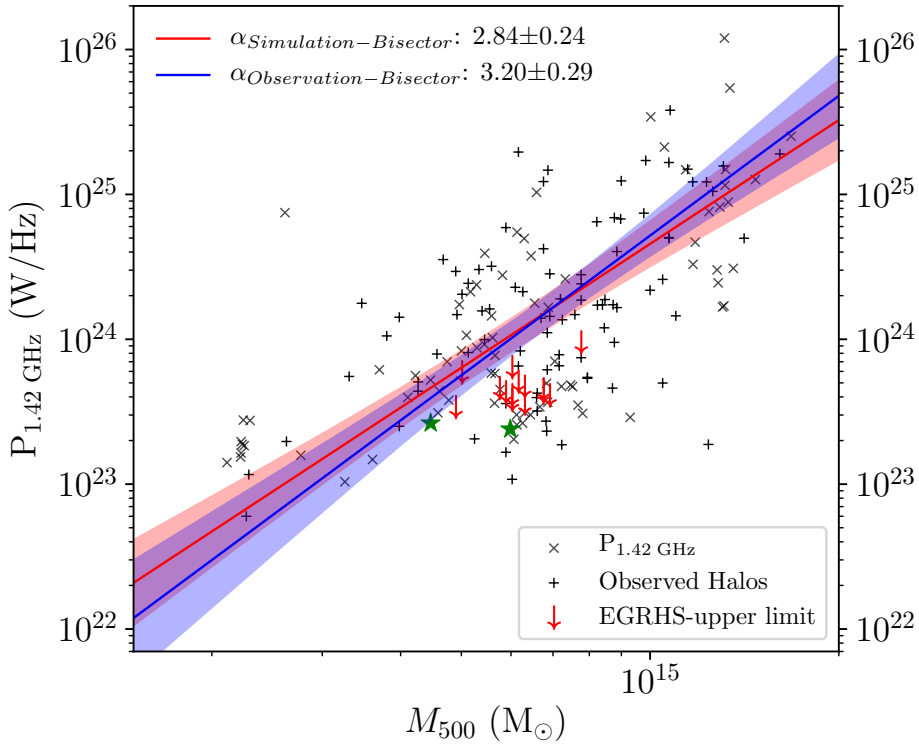
Results: Sample like Cassano:



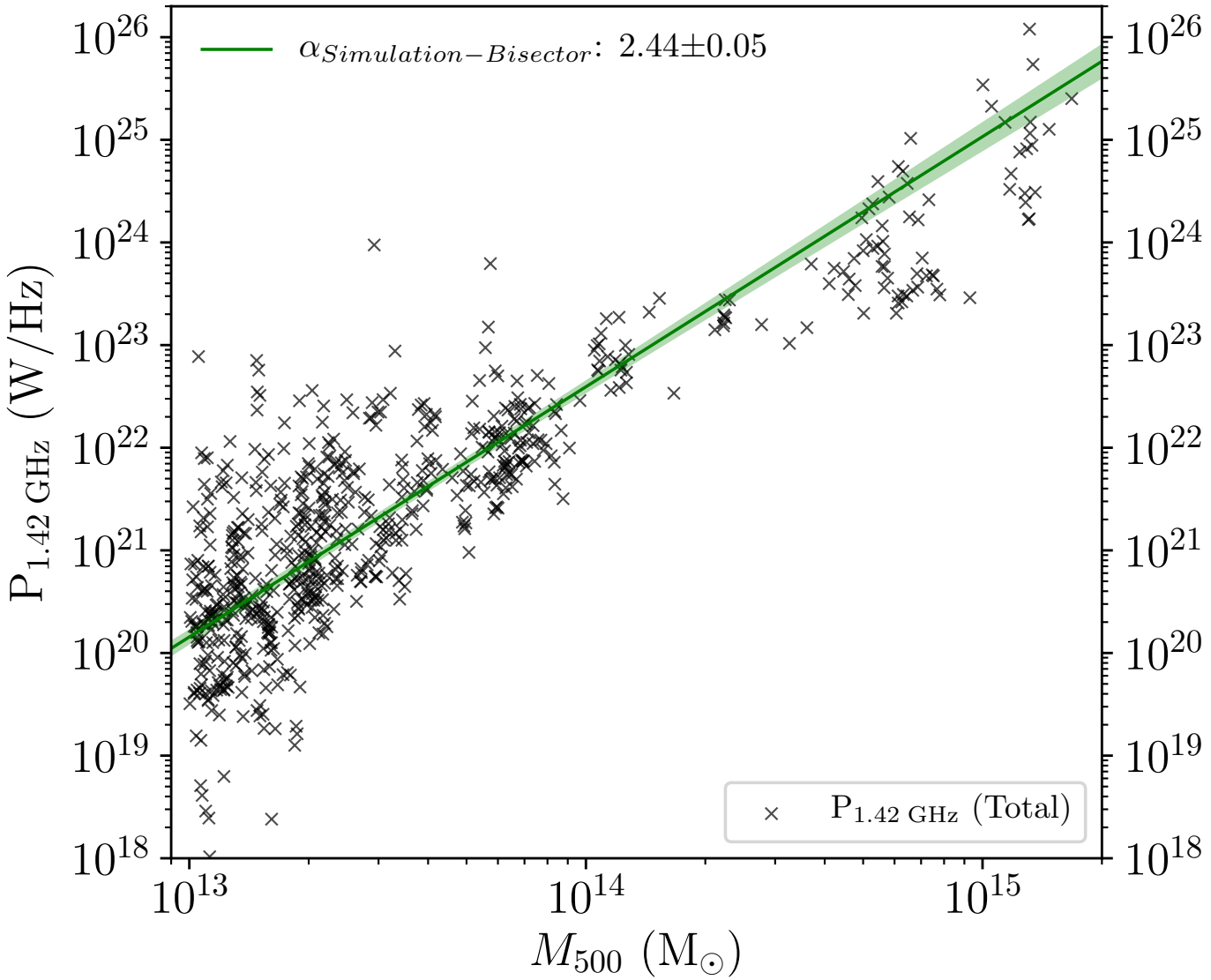


Results: Radio Halos observed till now:

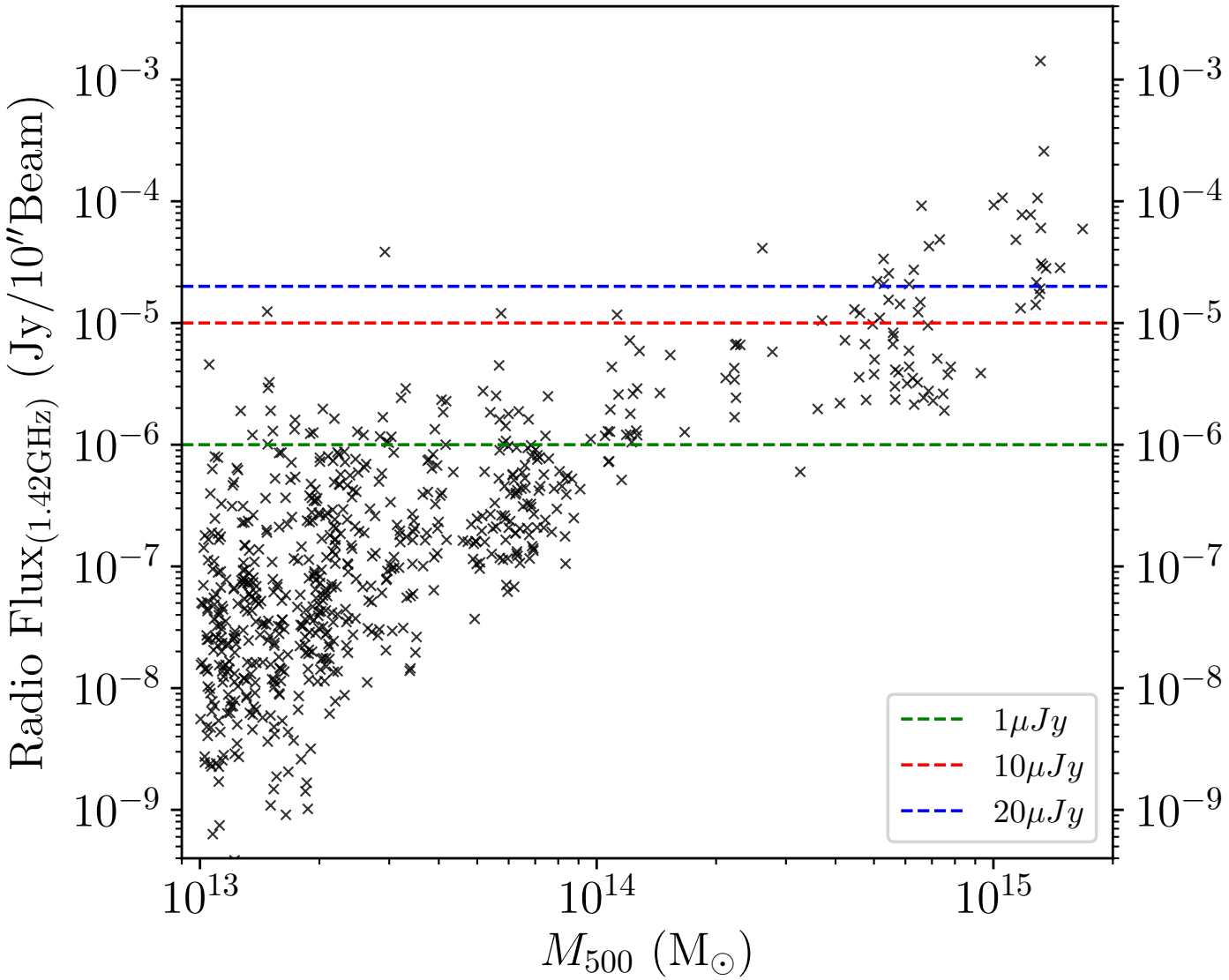




Results:


$\alpha_{Simulation-Bisector}$: 2.44±0.05
$P_{1.42\ GHz}$ (Total)
$P_{1.42\ GHz}$ (W/Hz)
M_{500} ($M_\odot$)
10^{26}
10^{25}
10^{24}
10^{23}
10^{22}
10^{21}
10^{20}
10^{19}
10^{18}
10^{13}
10^{14}
10^{15}

Results: Radio Flux from Simulated Galaxy cluster



Summary and Conclusion:

- Radio emission cannot be explained only with TRA model.
- Merger shocks play significant role in radio emission from Halos.
- Hope for detecting WHIMs.
- Shed light on the outstanding missing baryon problem.

Thank you

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