

# The suburbs of galaxy clusters

**Probing substructure**

with

hydrodynamic simulations and Sunyaev-Zel'dovich signals

Edoardo Altamura

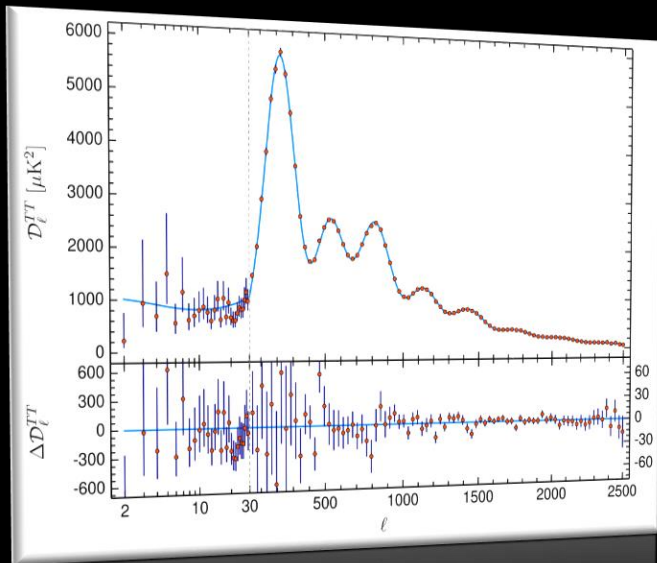
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JODRELL BANK CENTRE FOR ASTROPHYSICS

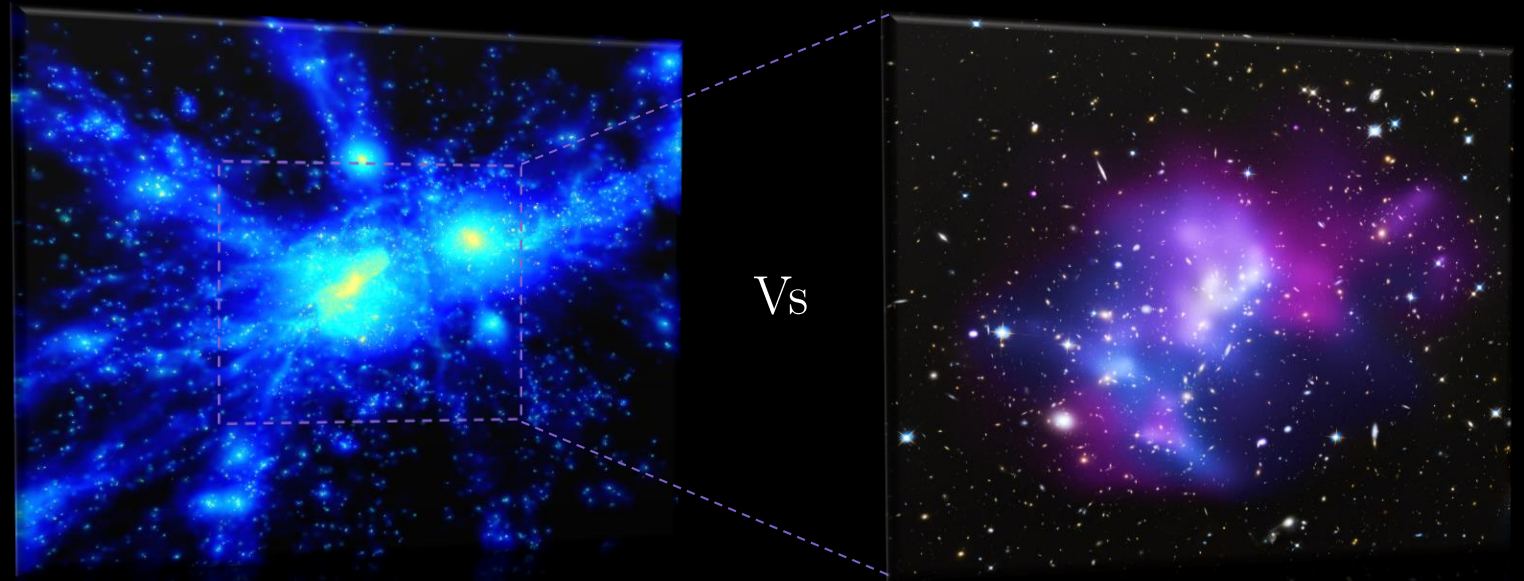
# Simulations of galaxy clusters

## WHY?

- Evolution of galaxy clusters and Large Scale Structures sensitive to *cosmological parameters*.
- Cosmological parameters fully describe the cosmological “*standard model*” of the Universe.



CMB power spectrum  
([Aghanim et al., 2018](#))



MACSIS 1 (HYDRO)  
([Barnes et al., 2017](#))  
([Altamura et al., 20??](#))

MACS J0717.5+3745  
([Jauzac et al., 2012](#))

# Simulation pipeline

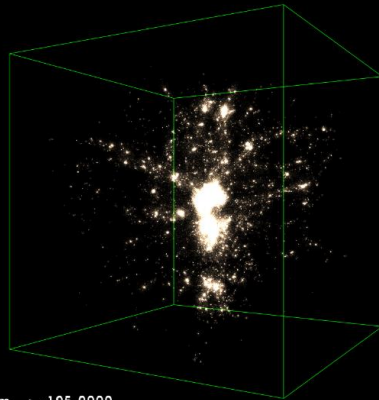
High-Performance Computing (HPC) ~ *Virgo Consortium & DIRAC supercomputer*

Simulation of particle dynamics from initial conditions ( $z = 127$ ) to  $z = 0$ .

GRAVITY ONLY

Tree codes + Particle Mesh

time : 1.0000    MACSIS DMO 1    Gadget3  
nbody : 2023004

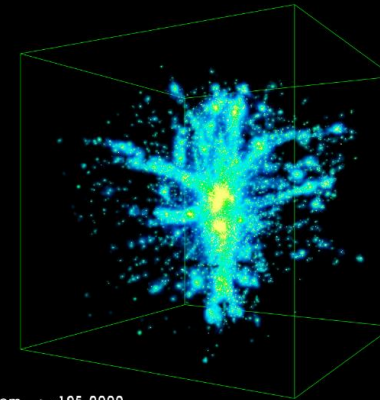


Zoom : -105.0000  
Rot : 90.00 0.00 120.00  
Center : 1091.76 1088.14 1086.72

HYDRODYNAMICS

SPH + Subgrid physics

time : 1.0000    MACSIS HYDRO 1    Gadget3  
nbody : 3997225

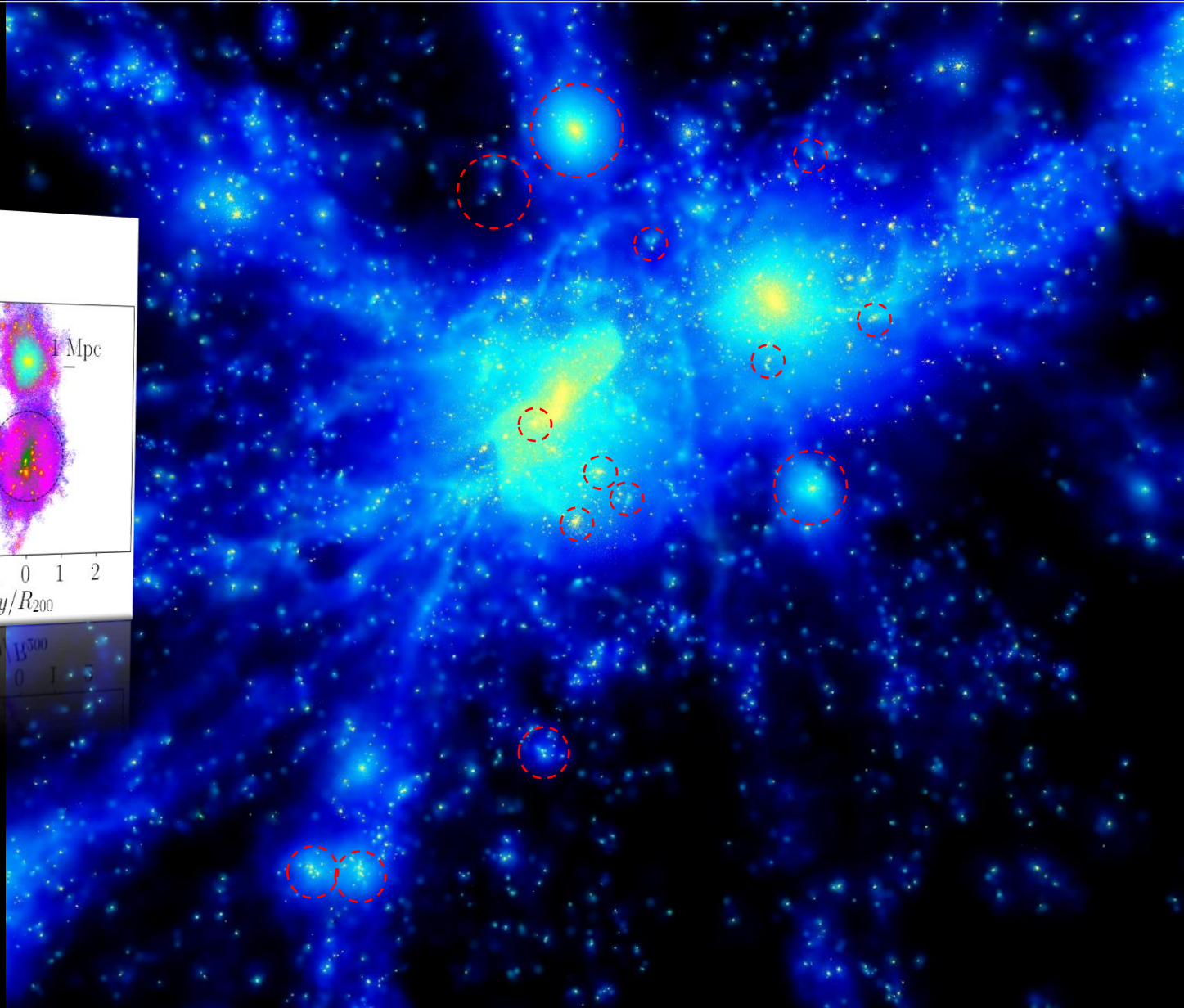
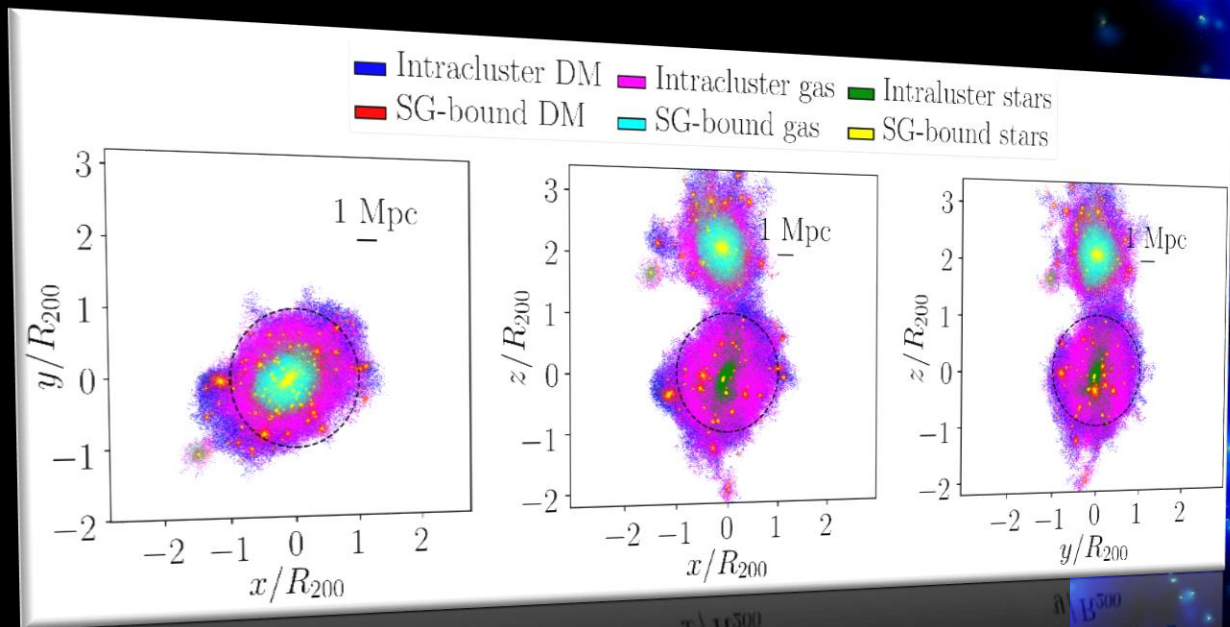


Zoom : -105.0000  
Rot : 90.00 0.00 120.00  
Center : 1091.67 1088.11 1086.63

**MA**ssive **Cl**uster**S** and **I**ntercluster **S**tructures

# Cluster substructures

Example:  
MACSIS cluster 1 (HYDRO)



# SZ Astrophysics

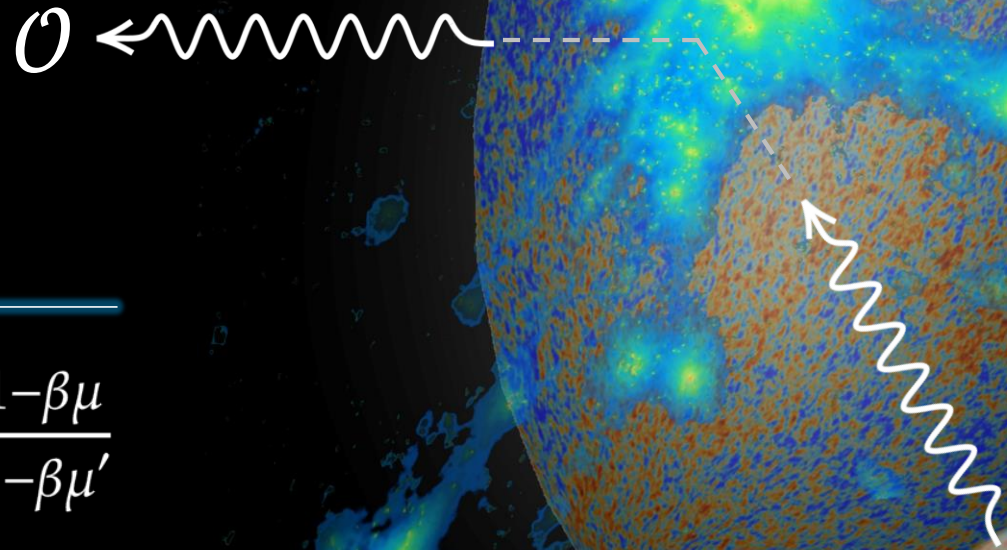
- ❖ Low energy CMB photons
- ❖ High energy IGM electrons

→ Inverse Compton Scattering

Single event  
microscopic level

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$$\frac{\nu'}{\nu} = \frac{1-\beta\mu}{1-\beta\mu' + \frac{h\nu}{\gamma m_e c^2}(1-\mu_{sc})} \approx \frac{1-\beta\mu}{1-\beta\mu'}$$



# SZ Astrophysics

Ionised IGM  
macroscopic ensemble

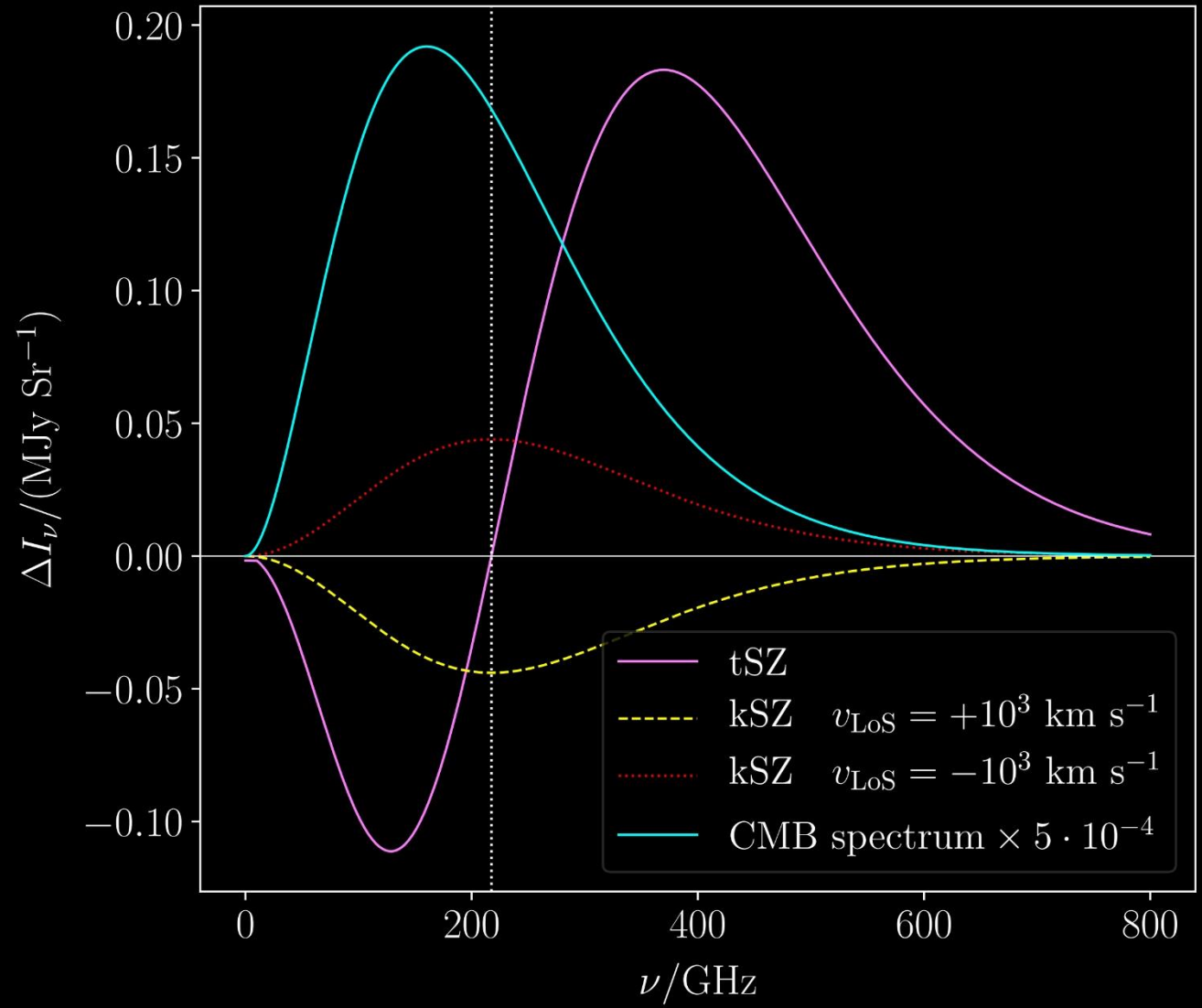
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- ❖ IGM in local thermal equilibrium
- ❖ CMB spectral distortion

$$\Delta I_\nu \approx I_0 y \frac{-x^4 e^x}{(e^x - 1)^2} \equiv I_0 y g(x)$$

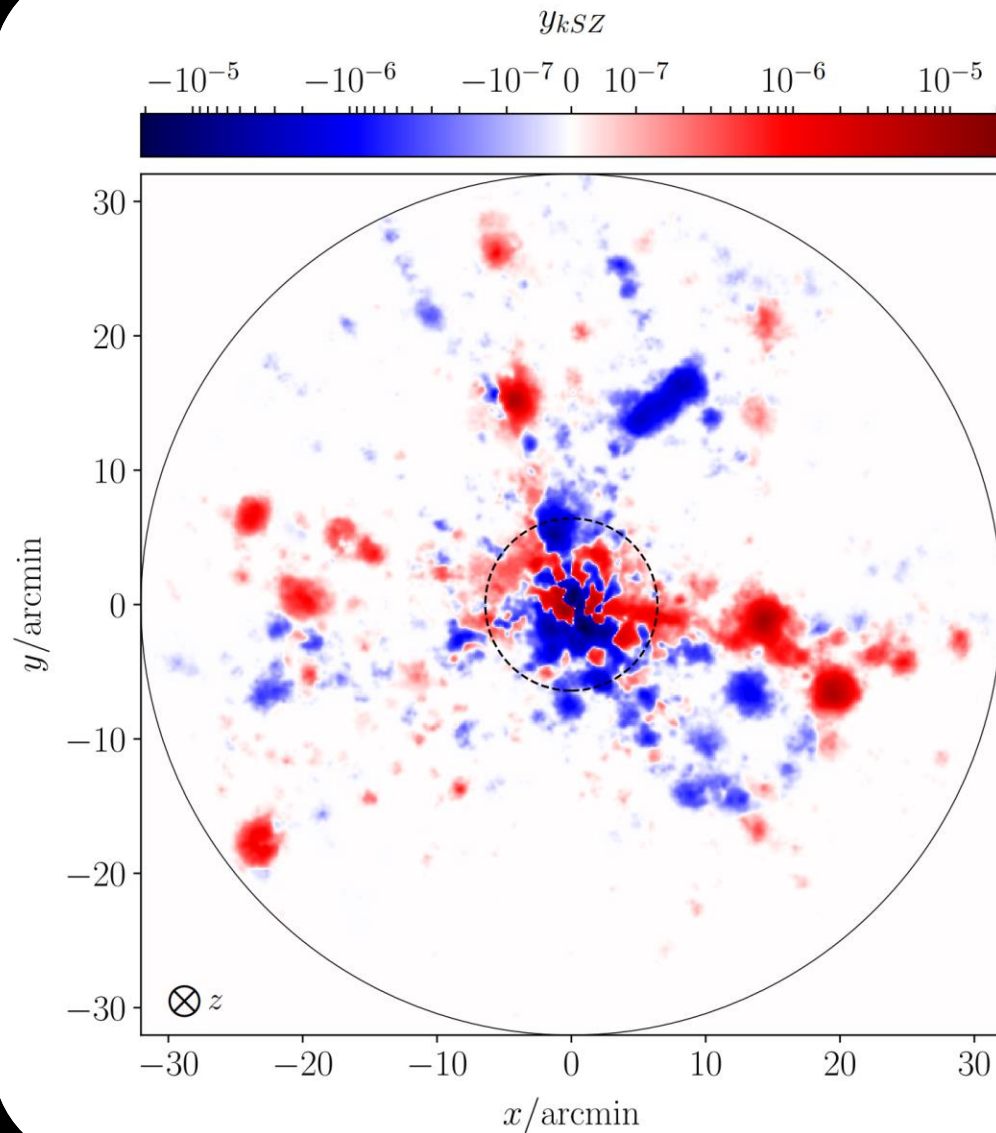
$$y_{\text{tSZ}} \equiv \int_{\text{LoS}} \frac{k_B T_e}{m_e c^2} n_e \sigma_T dl = \frac{\sigma_T}{m_e c^2} \int_{\text{LoS}} P_e dl$$

$$y_{\text{ksz}} \equiv \int_{\text{LoS}} \sigma_T n_e \mathbf{n} \cdot \boldsymbol{\beta}_p dl$$

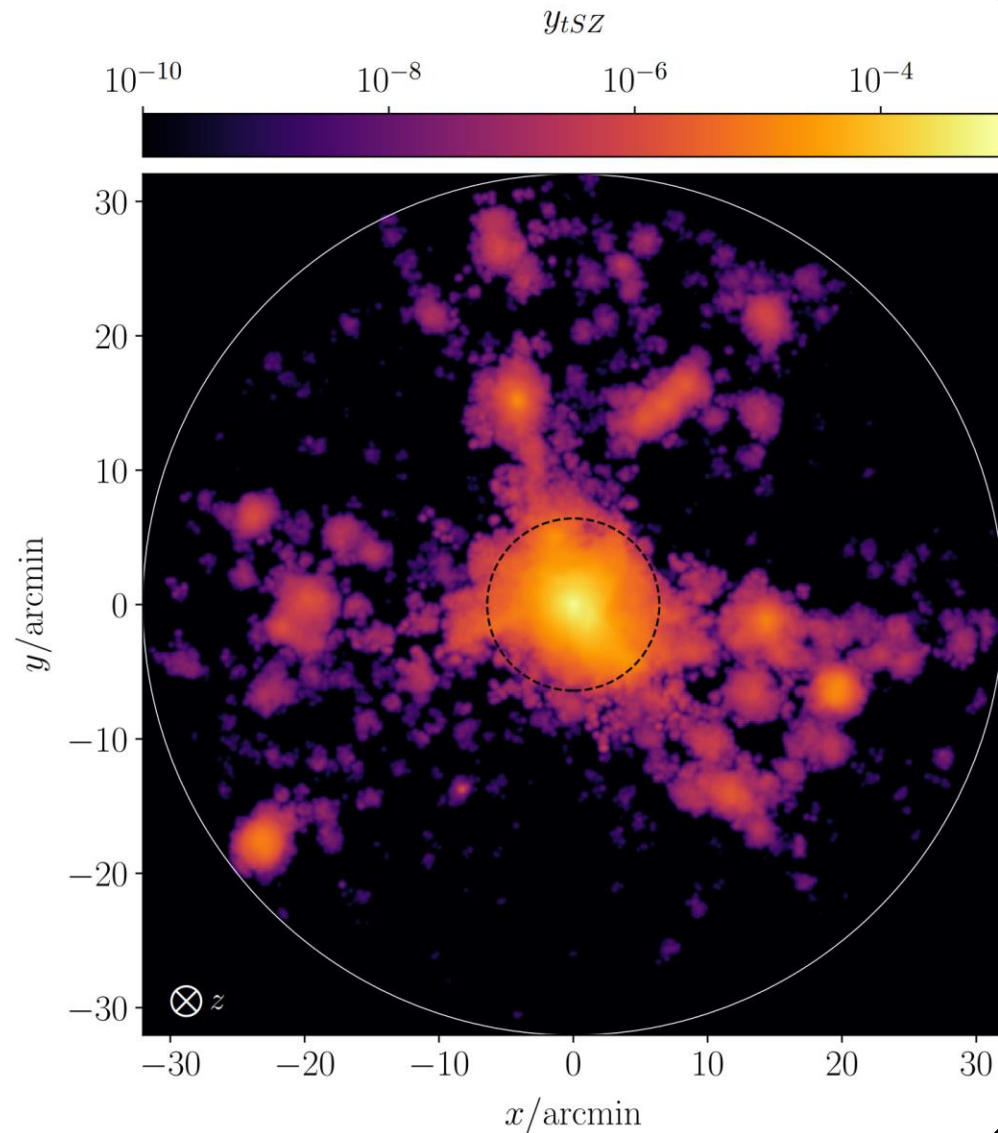


# SZ intensity mapping

kinetic



thermal





What is the probability of observing substructures?

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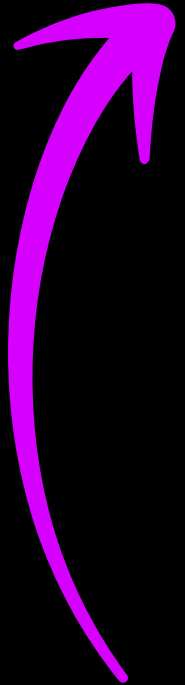
Come to my  
**poster** session!

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*Scan me*

A screenshot of a personal profile page. At the top is a blue header with a galaxy image. Below the header is the name "Edoardo Altamura" and a short bio. There are four social media links: LinkedIn, Github, ICPS Poster - NEW! (drive.google.com), and Master Thesis - NEW! (drive.google.com). At the bottom is a purple button that says "SHARE THIS PAGE".

**Edoardo Altamura**  
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