Elusive clusters

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Presentation layout

- Intro
- Elusive (hard-to-detect and study) clusters at z~2
  - New hi-z clusters (Polletta)
  - Detailed studies of know clusters (SA/Kim/Felix)
- Elusive (hard-to-detect and study) population at low/intermediate z
  - X-ray collective analyses
  - Optical properties within r_{200} (Puddu)
  - Optical properties outside r_{200} (Maurogordato/Benoist)
  - Theoretical investigations (Ragagnin)
  - Radio (Chandra/Kale)
  - Detailed studies of individual objects (SA/Trinchieri/Moretti)
  - Weak Lensing masses (Radovich/Gavazzi/Dell'Antonio)
  - Data Science (Castagna)
- Perspectives
  - Mid-term (Euclid/SRT/AtLAST)
  - Immediate (NIKA2/X-ray)
- Funds & Criticalities

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Lack of time,
My apologies

Clusters are at the crossroad of astrophysics and cosmology

In essence:

a) clusters interesting in their own (cluster gastrophysics, galaxy populations, effect of the extreme environment)

Clusters are at the crossroad of astrophysics and cosmology

Tension caused by new physics or lack of knowledge about cluster physics?

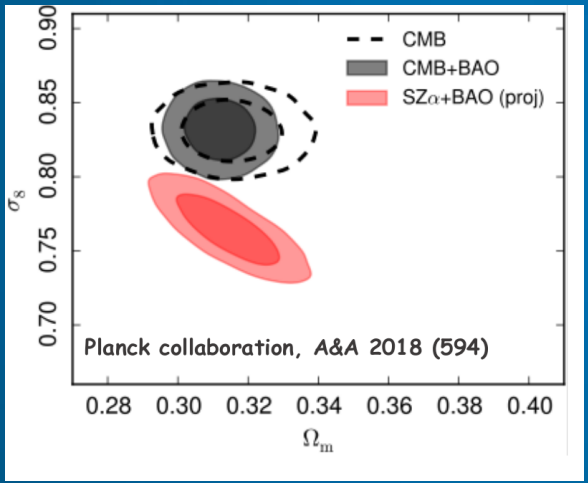
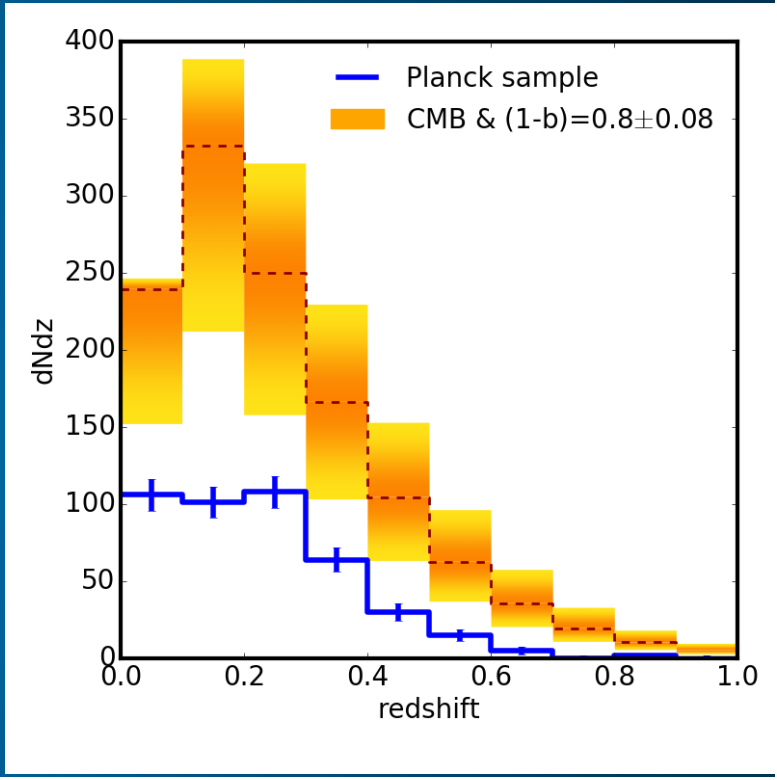


Figure from Salvati et al. 2018, see also Planck Coll, XX 2014



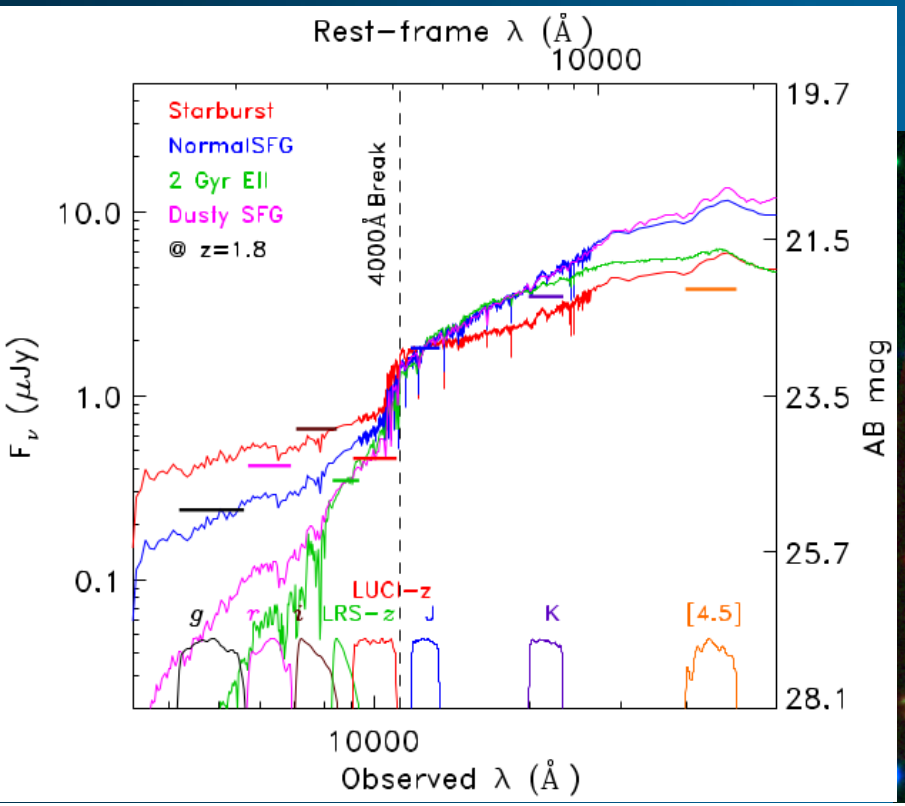
Hi-z Universe

Z~2 is the key epoch for cluster mass assembly and for shaping galaxy population properties

Goal: discover new clusters and collect good data for individual objects to understand clusters in this key epoch.

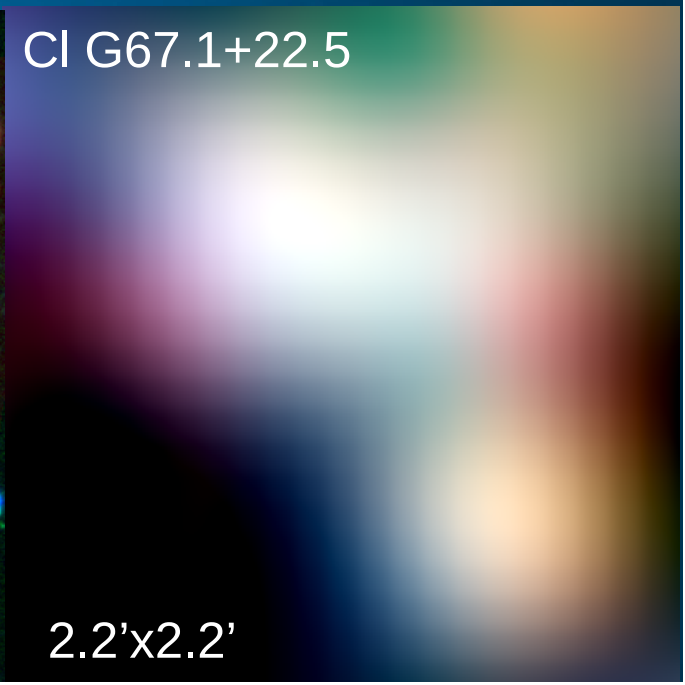
New z~2 clusters (Lead: M. Polletta)

Observational program aimed to
- confirm (red sequence, then spec-z) z~2 clusters
- identify and characterize galaxy members (M_{star}, SFR)
- goal: study quenching mechanism as f(M_{galaxy}, $M_{cluster}$, $R_{cluster}$)



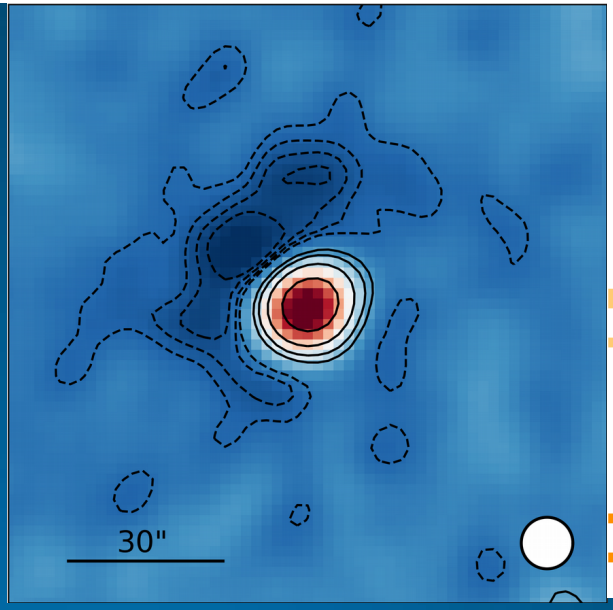
Optical-NIR-Spitzer

Hershel (SF)

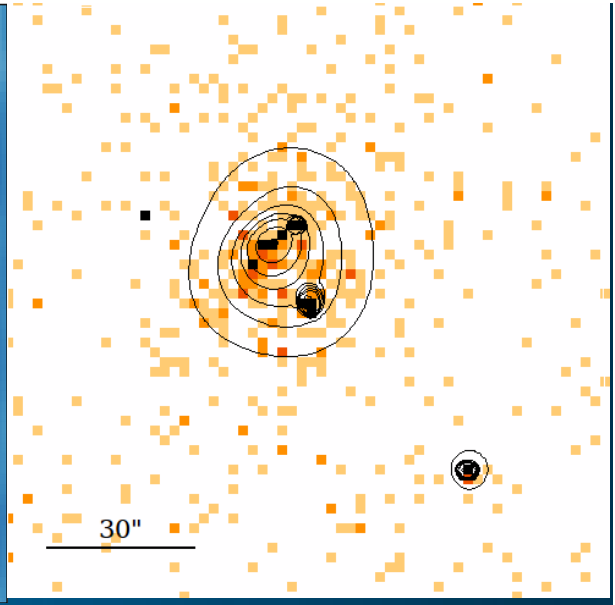


Detailed studies: IDCS J1427.5+3508

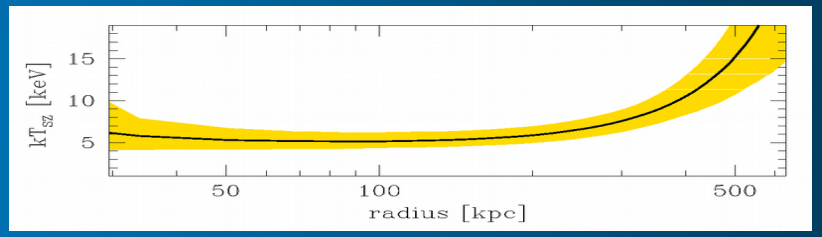
z=1.75, M_{500}~2.5 10^{14} M_{sol}, massive for its z



Mustang2@GBT



Chandra



Unusual T profile

Cluster being assembled

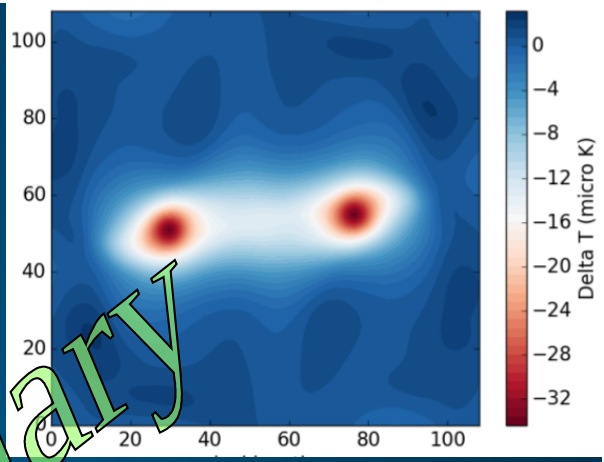
SA et al. (2021) INAF+GBT press releases

New deep XMM data collected (PI C. Sarazin)

Detailed studies: JKCS041

z=1.803,M_{500}~2 10^{14} M_{sol}, massive for its z

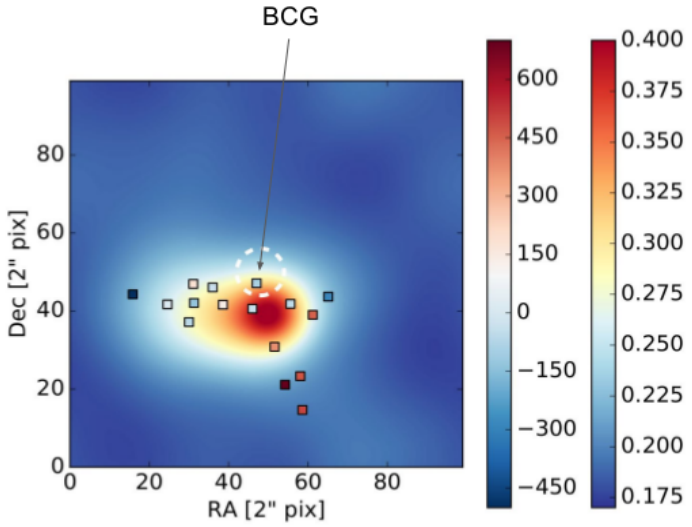
New data (Mustang2, Shear) + tailored numerical simulations (S. Felix, U. Chadayammuri, L. King) to reproduce and interpret the data. Three papers in prep: Kim et al; Felix et al.; SA et al.



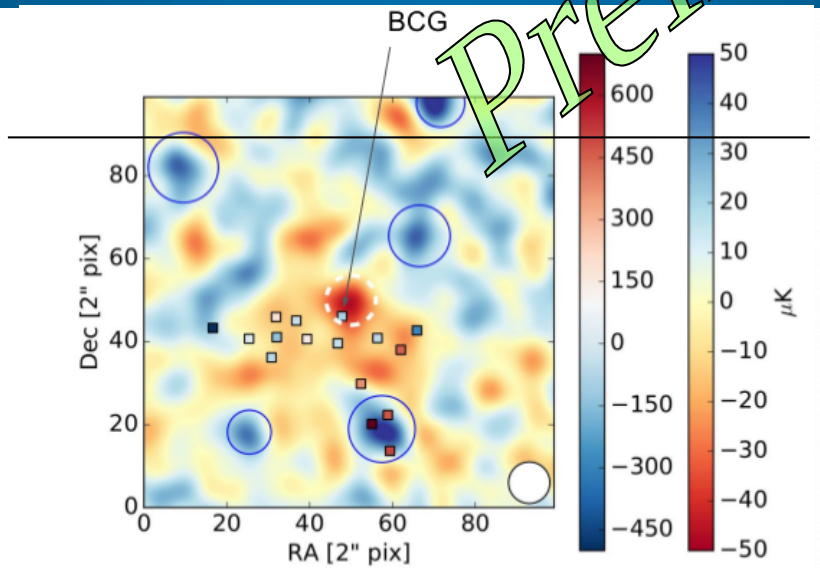
Tailored simulations

Preliminary

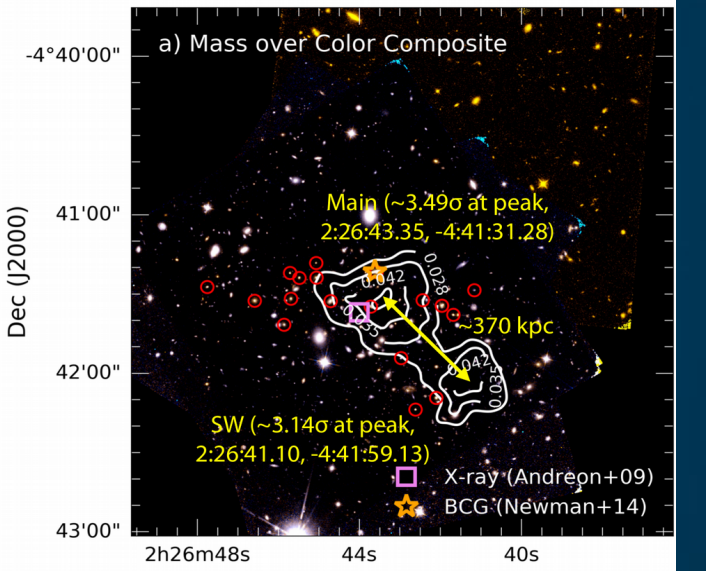
X-ray + gal dynamics



SZ + gal dynamics



Weak lensing (Kim, J)



Low/intermediate z

Focus on ICM of clusters missed in X-ray/SZ surveys because of low surface brightness.

Goal: which are the properties of the missed objects? Does their lack in catalogs (badly) impact on our understanding on clusters?

XUCS, the X-ray Unbiased Sample

30% of the clusters are elusive

- 34 optically selected clusters $0.05<z<0.135$
- No ICM selection at a given M.
- $13.5<\lg M<14.7$

All followed up for ~10-30 ks, mostly with XRT, 420 (median) net photons [0.5-2] keV over a negligible background.

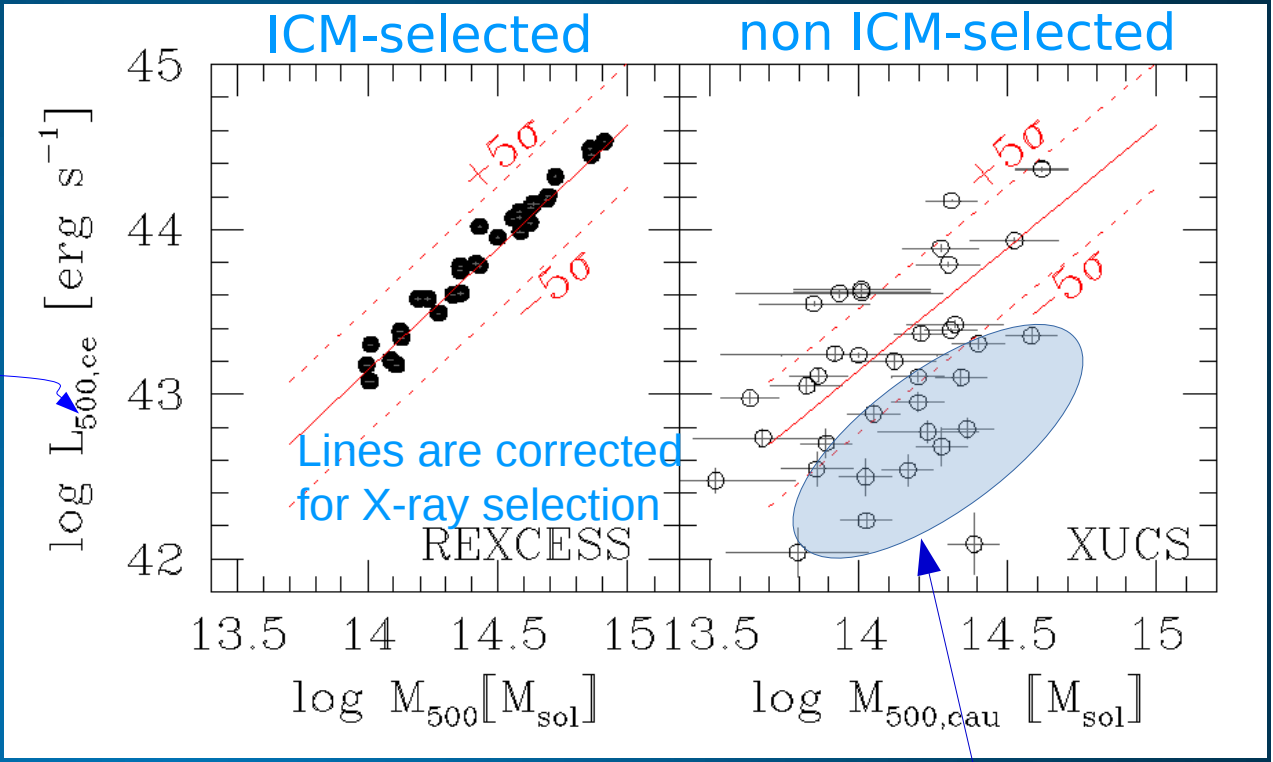
All with caustic masses (based on 116 galaxy velocities on average), plus massed from velocity dispersions and, for some today (mostly tomorrow) weak lensing and hydrostatic masses.

See SA+16, SA+17a, SA+17b for details about the sample.

Discovery of a missed (in X-ray) population

Core excised L_X → Scatter not due to CC

Scatter is 0.5 dex

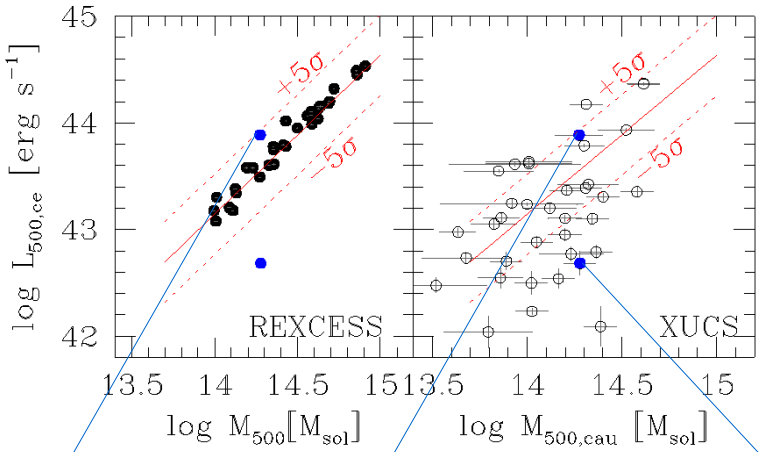


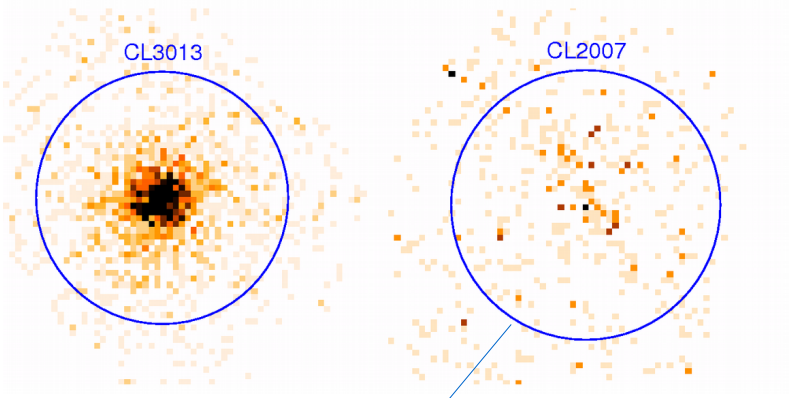
Astrophysical interesting objects, rarely studied (at best) because absent in surveys (and costly to observe).

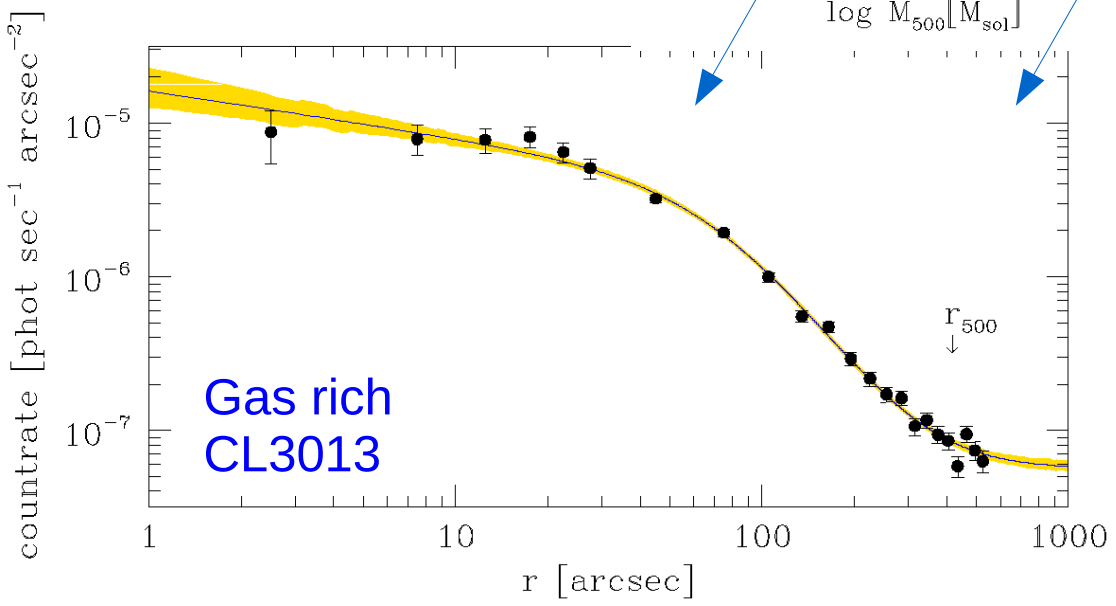
Figure adapted from A+16

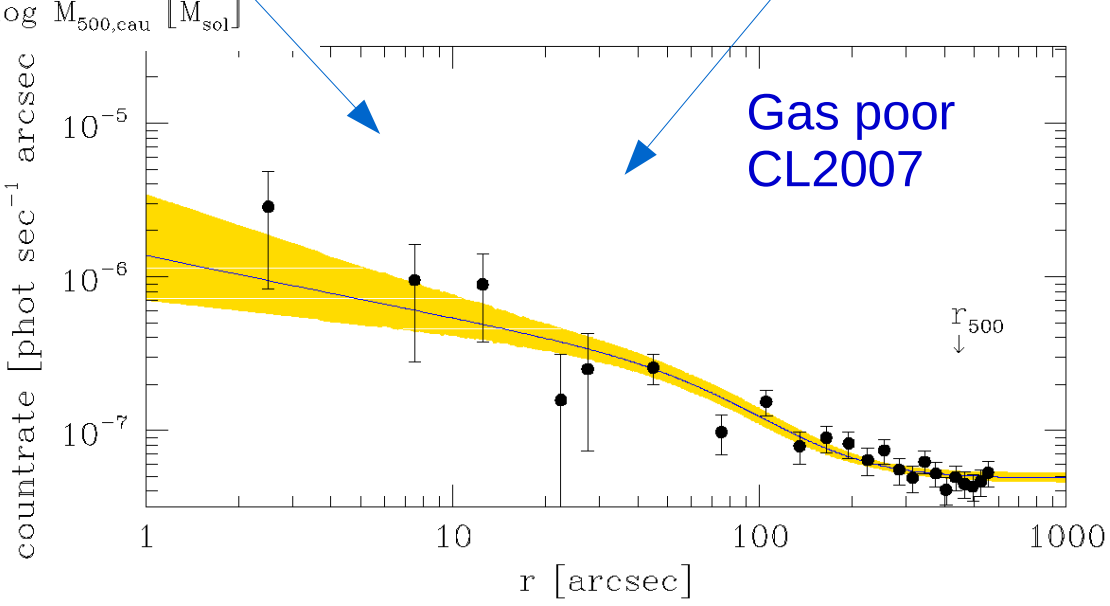
All L_X faint|M are of low surface brightness

Same z, mass, t_{exp},
Galactic absorption but a factor of 10 in surface brightness

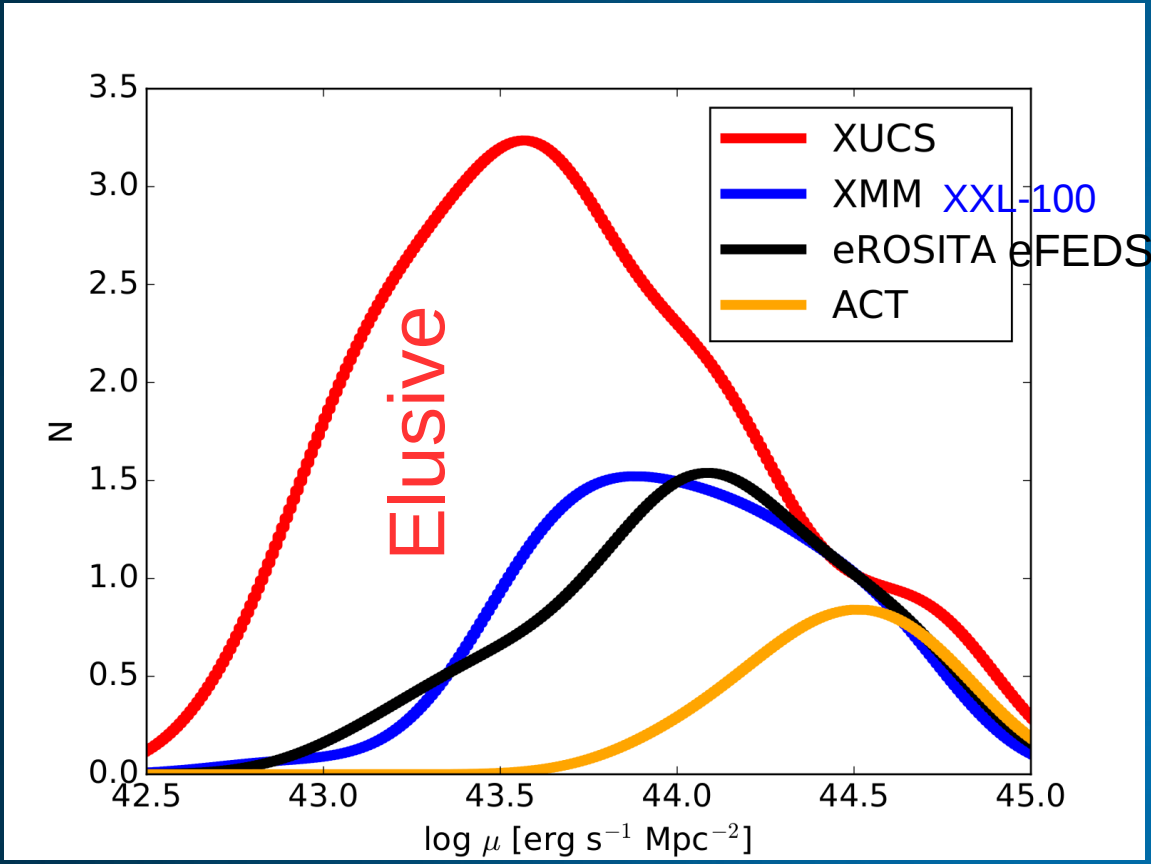








Severely under-represented in X-ray and SZ surveys



μ_{300} ~43.3 erg/s/Mpc2 clusters are under-represented in X-ray selected sample by a factor 10 (2% in place of 30%).

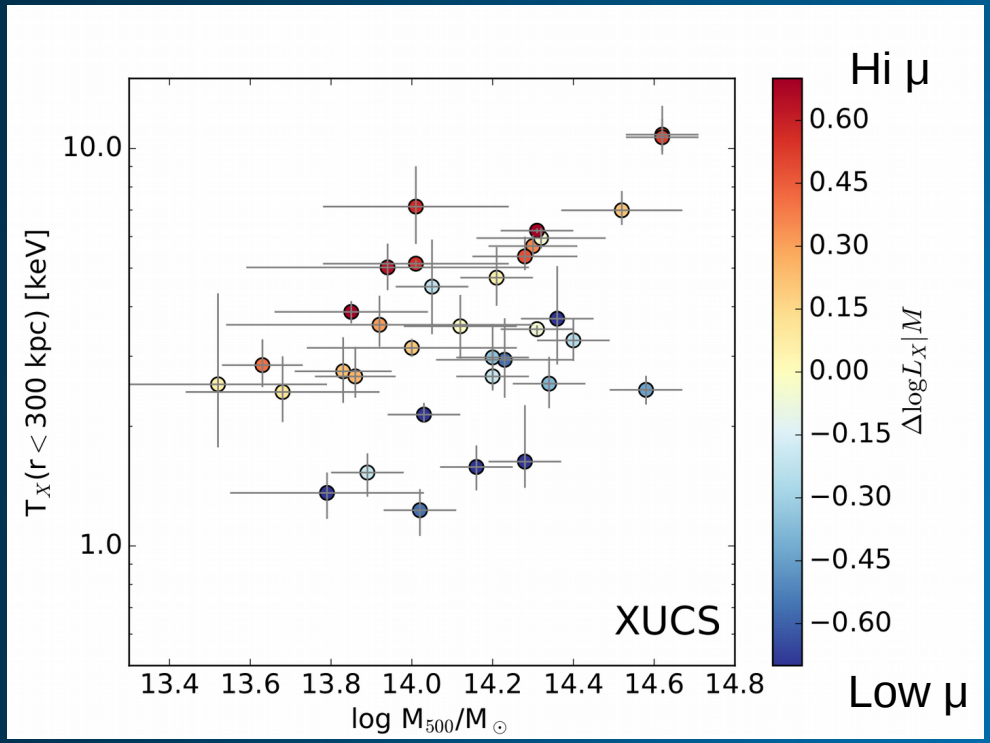
Common μ_{300}~43.5 erg/s/Mpc2 clusters are absent in ACT (and likely SPT as well).

To be explored for Planck.

Selection: r_c>100 kpc, brightness within 300 kpc.

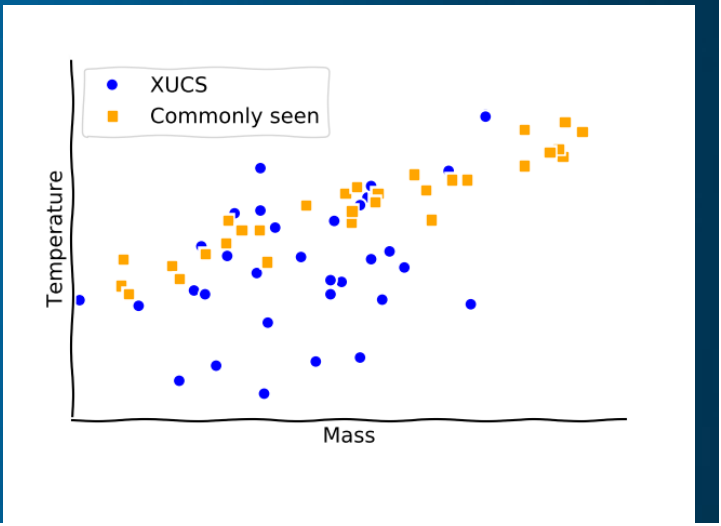
SA et al. (2022b, submitted)

WP 1: X-ray collective analyses



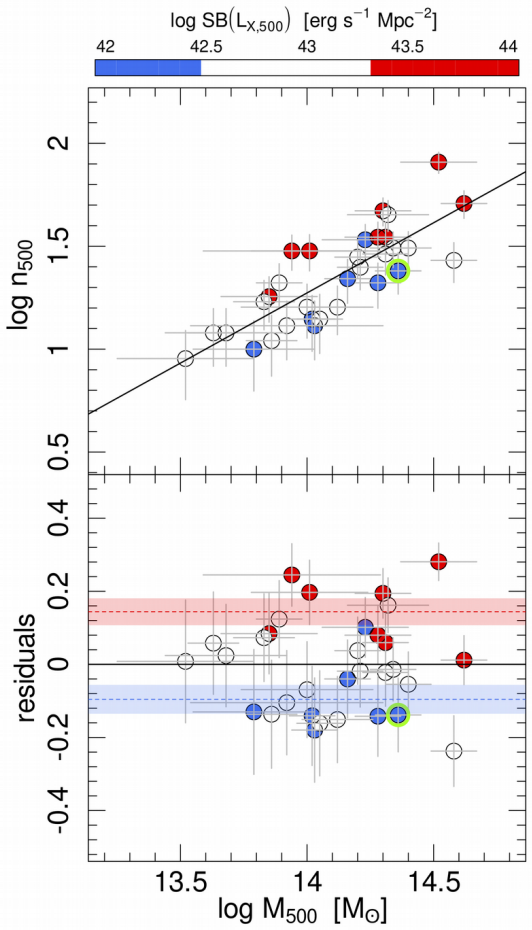
Very scattered T-M, 0.2 dex at fixed mass.

Position in the plane correlated to surface brightness. Low surface brightness clusters have lower T than higher surface brightness clusters.



SA et al. (2022a, MNRAS 551, 4991), INAF press-release

WP 2: optical properties within r_{200} (Lead: E. Puddu)



Low SB are slightly galaxy-poor !

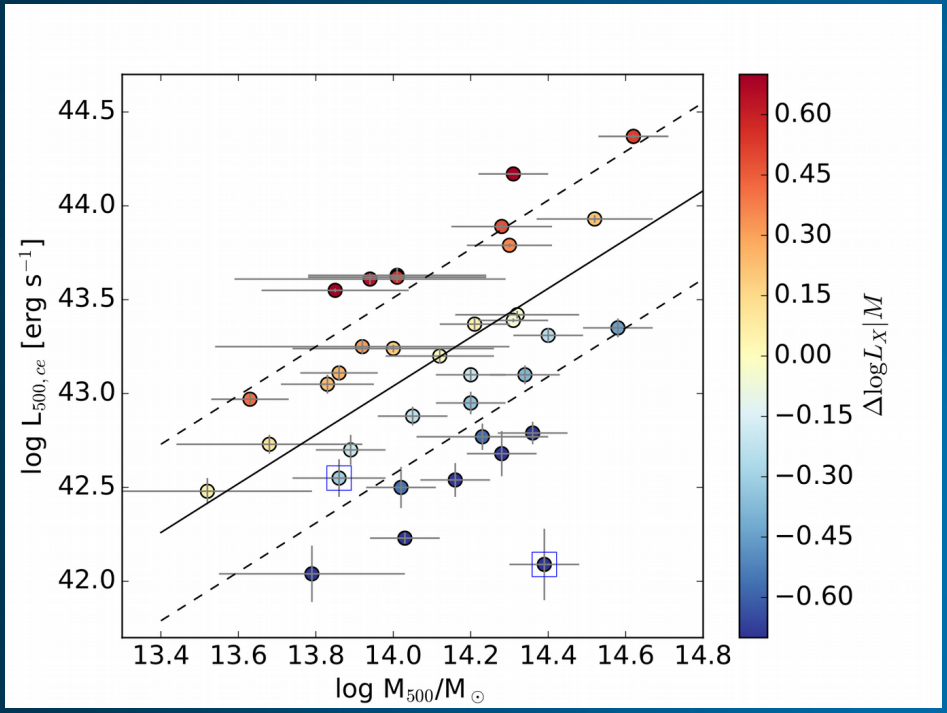
But low surface brightness cluster have unperturbed
-richness concentration,
-width and color of the red sequence,
-colour, luminosity, and dominance of the brightest cluster galaxy.

Puddu & SA 2022, MNRAS 551, 2968

Next steps: deeper data (Legacy Survey) and more cluster properties

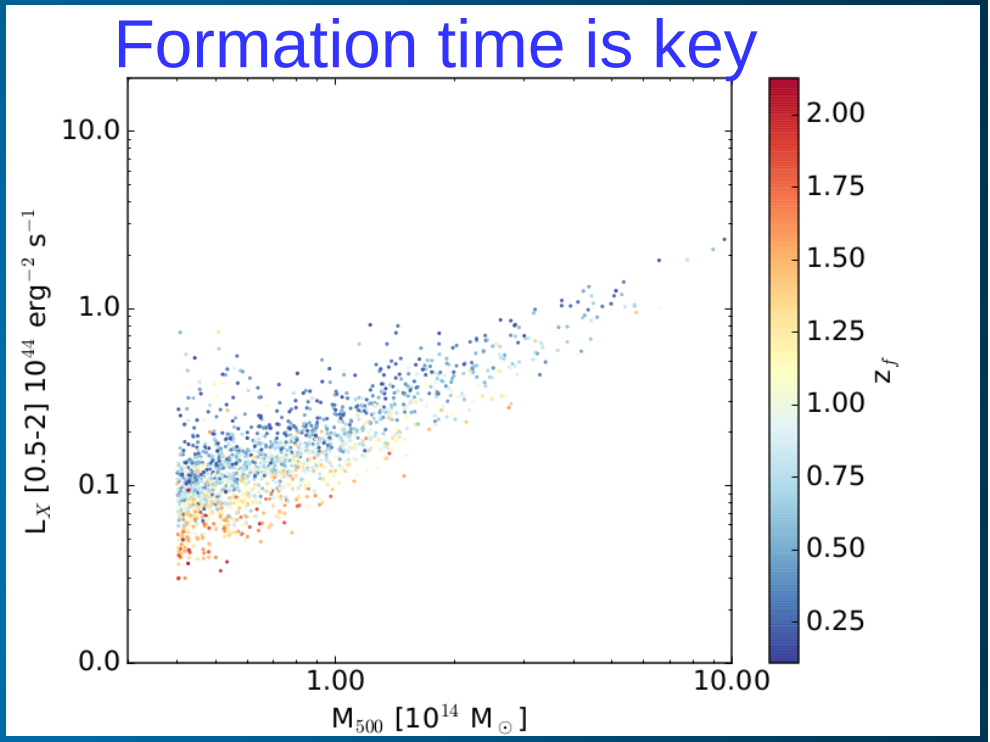
WP 4: Theoretical investigations (Lead: A. Ragagnin)

Real data



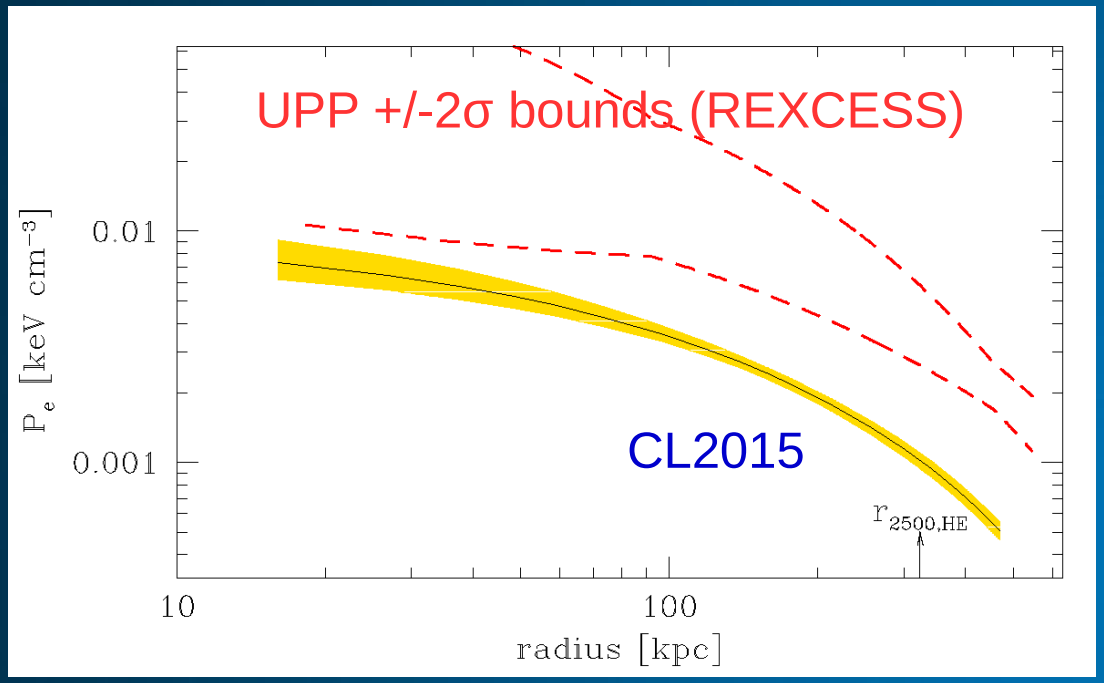
Magneticum (hydro, full physics) simulations

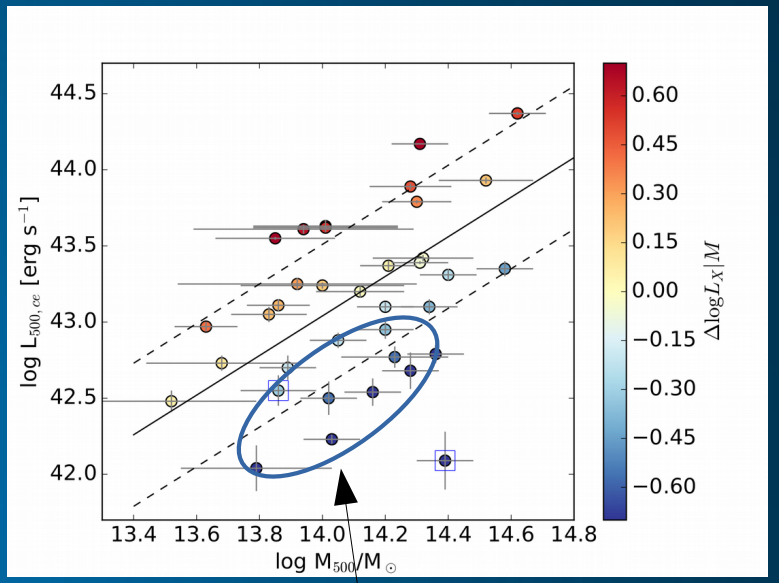
Formation time is key



Ragagnin et al. (in prep.)

WP 5: detailed studies of individual objects (Lead: SA, G. Trinchieri, A. Moretti)

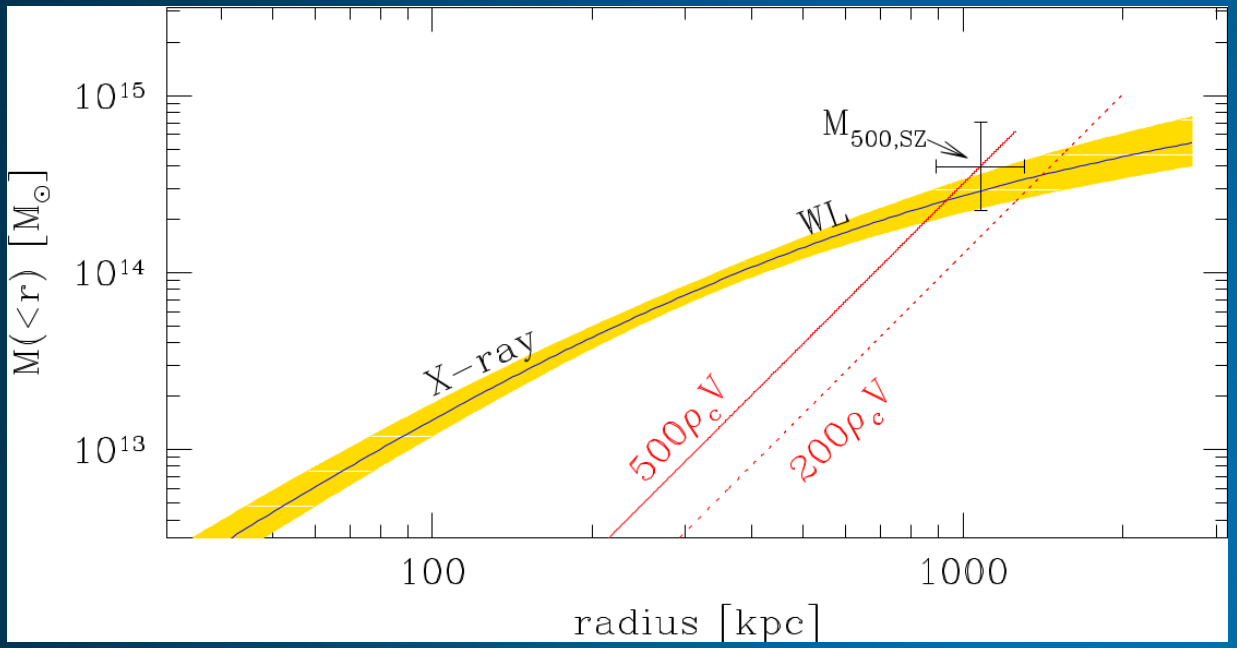




Deep X-ray follow-up

SA et al. (2019, A&A 630, A78), depressed cluster. If average over the cluster population is 15% lower, no tension between cluster and CMB cosmology. INAF press-release

WP 6: weak-lensing mass (PI: M. Radovich, R. Gavazzi, I. Dell'Antonio)



X-ray + WL (+SZ) break the mass-concentration degeneracy

Precise mass profiles to r_{200}

WP 7: Data Science
(Lead: F. Castagna)

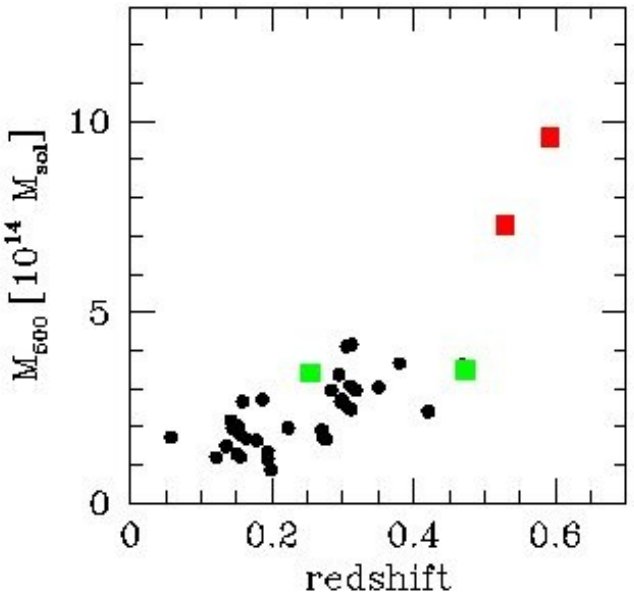
Some of the analyses benefit from/modify astrostatistics methods described in ``scheda" BigData Analytics per gli ammassi di galassie. These methods will be central in the future, when we will be faced to larger samples and more complex inferences (on clusters and cosmology, ask V. Cardone for the latter).

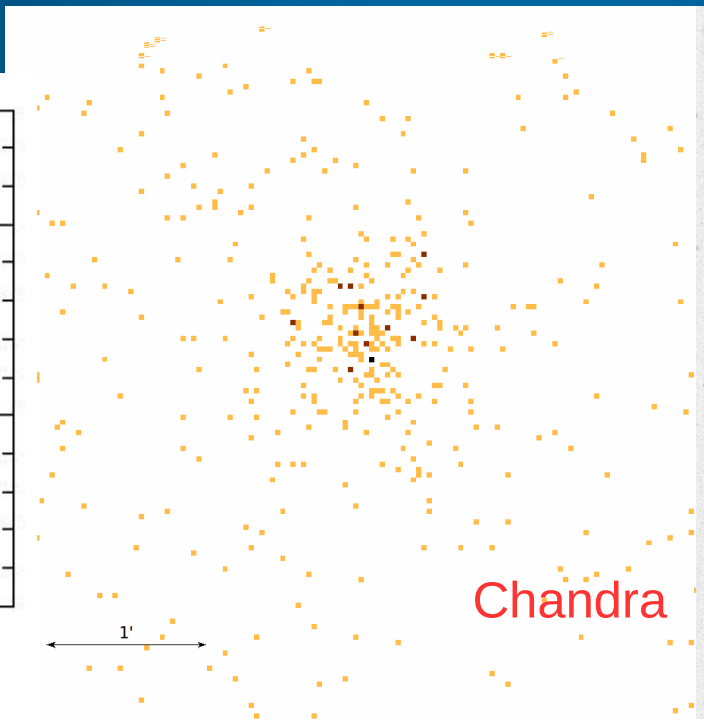
Mid-term Perspectives

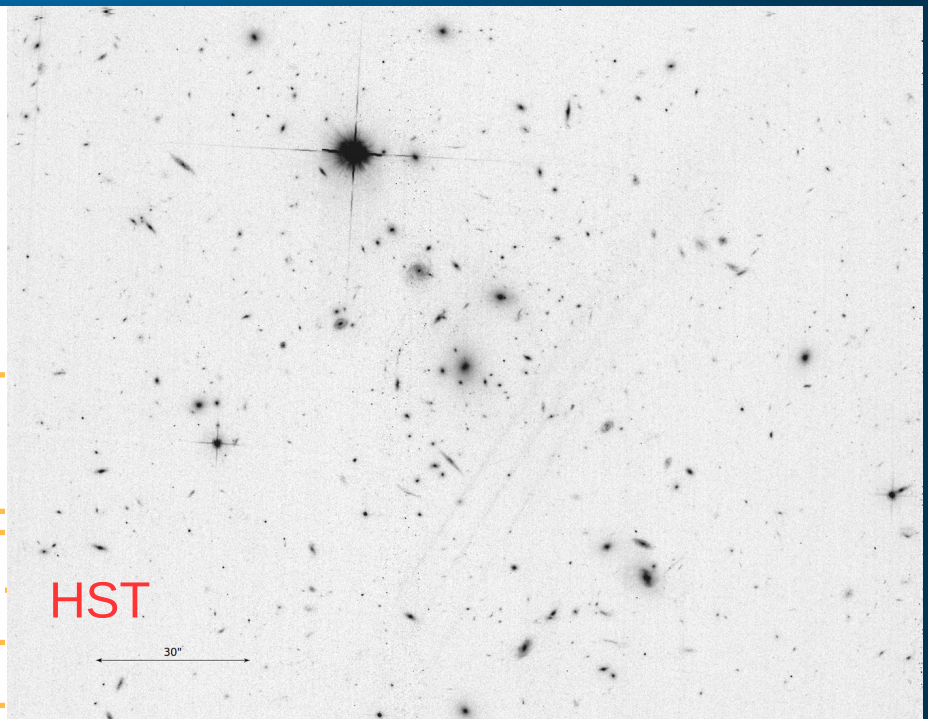
- Low/intermediate z:
  - Elusive clusters is a science case of the proposed 50m deg-wide fov telescope mm AtLAST (``Scheda" AtLAST, long term)
  - Elusive clusters are not missed in weak-lensing-selection: Euclid will deliver >35k wl-selected clustes (SA&Berge 2012,A&A). Our team is part of the WL-selected WG, lead of the PF-Richness PF, etc; (``Scheda" Euclid).
  - Plan to follow-up wl-selected elusive clusters:
    - SRT key project on WL-selected clusters missed in X-ray (e.g. eRosita) and SZ surveys. Our team (Murgia/Govoni/De Petris/De Bernardis/Battistelli/Masi) overlaps the SRT team and the SZ camera development and deployement team, see also ``Scheda" PON-SRT)
    - XRT (``Scheda" Swift) for X-ray follow-up of the above.
- Hi-z:
  - Additional candidates (VIDEO/VEILS/...)
  - Additional follow-up (X-ray, SZ, IRAM, photometry, spectroscopy, etc.)

Immediate Perspectives (pilot program)

Just completed X-ray (Chandra, Swift) and SZ (IRAM) observations of a pilot (wl-selected from HSC survey, without X-ray or SZ counterparts) program.





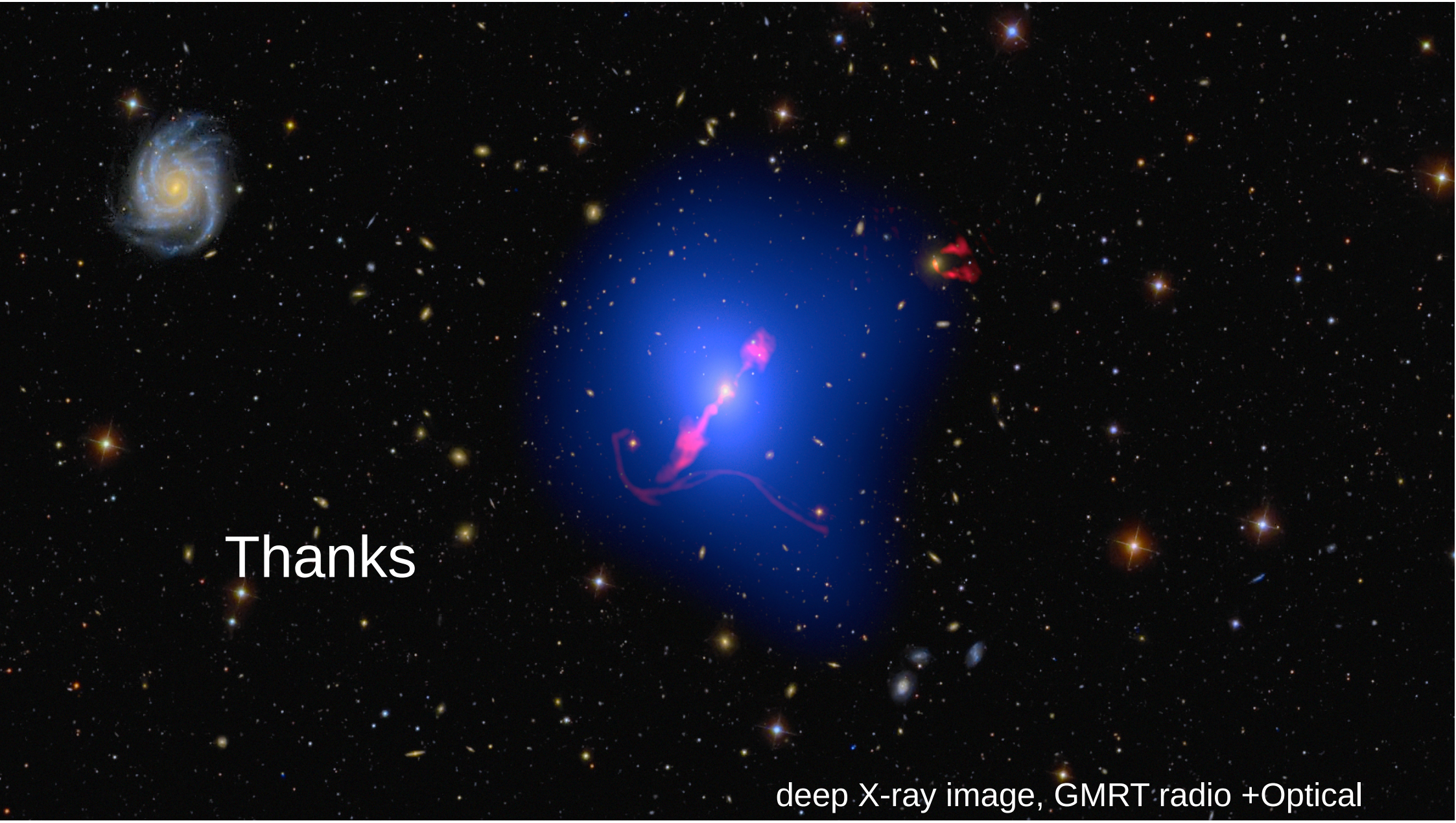


Communication

- General meetings in the last 1.5 yr: 2 for low z +2 for hi-z-ICM, all in remote
- Sub-group meetings every time needed, some at fixed cadence (two/four weeks).
- Web pages with presentations and data sharing
- >20 seminars in 2021 on elusive low-z clusters
- 5 press-releases since 2019

Funds & Criticalities

- Based almost entirely on permanent positions (15 with FTE>0 of which 10 in INAF).
- Available competences, but limited number of human resources with sizeable size (say, >0.3 FTE/yr).
- No funds dedicated to this project (submitted an INAF mini-grant and a PRIN-MIUR).


Thanks
deep X-ray image, GMRT radio +Optical