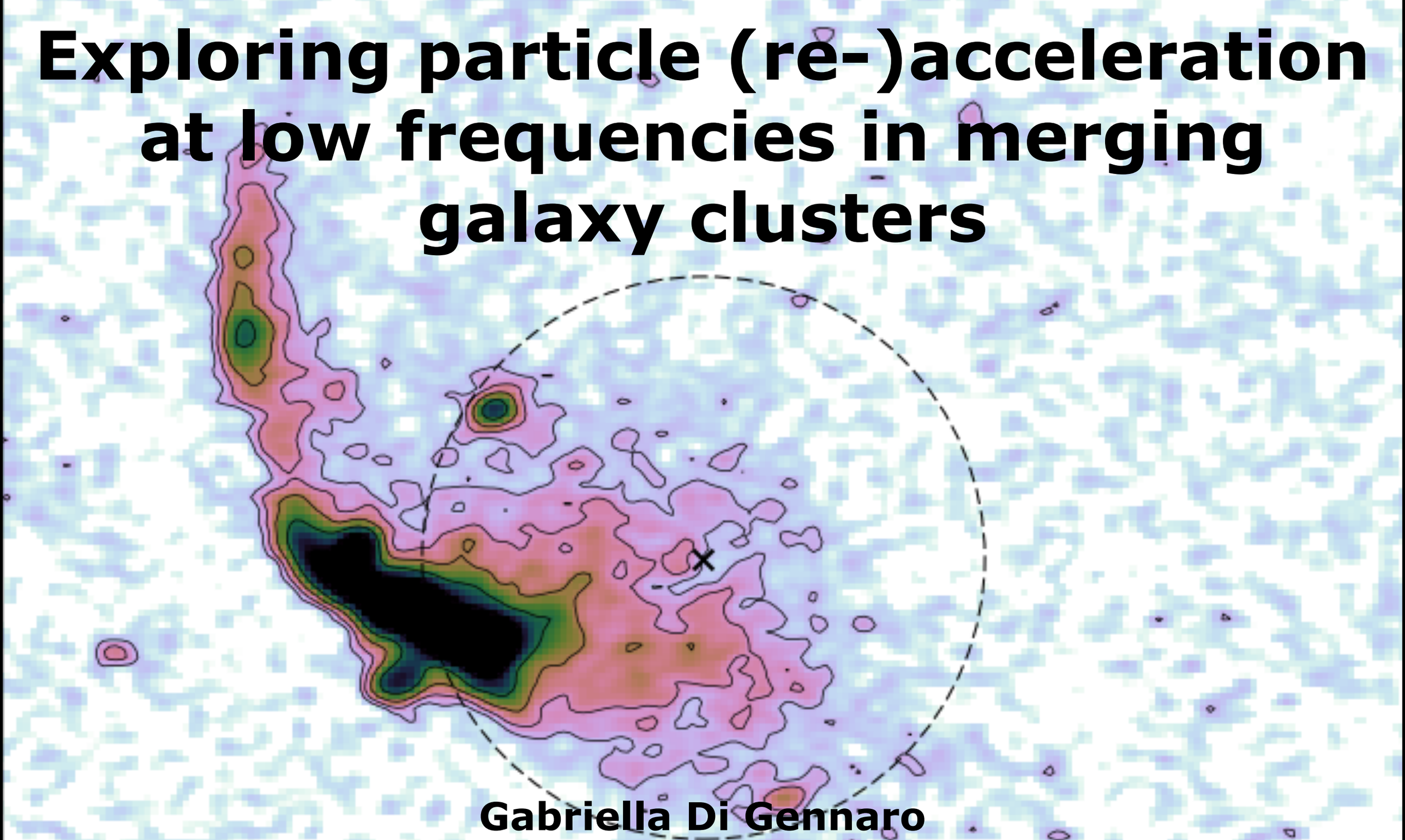
Exploring particle (re-)acceleration at low frequencies in merging galaxy clusters



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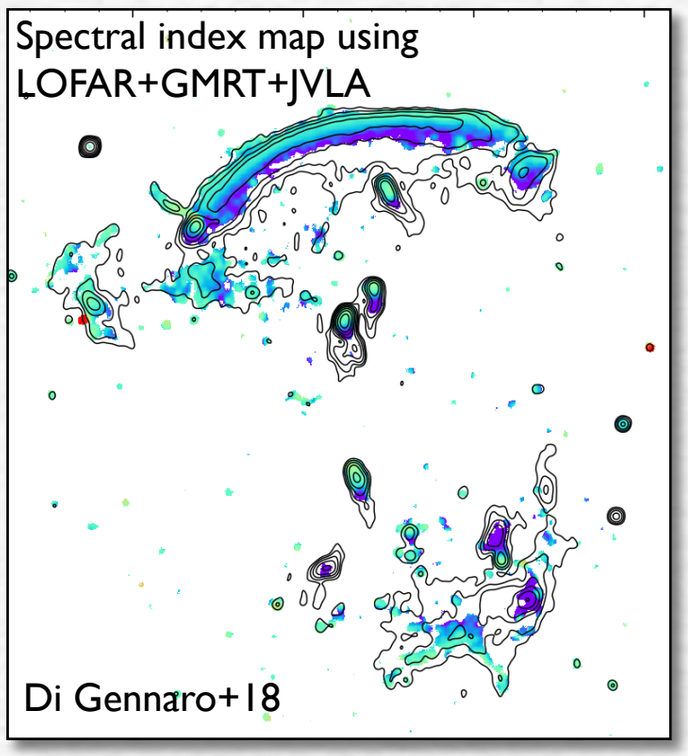
Origin of the Diffuse Radio Emission

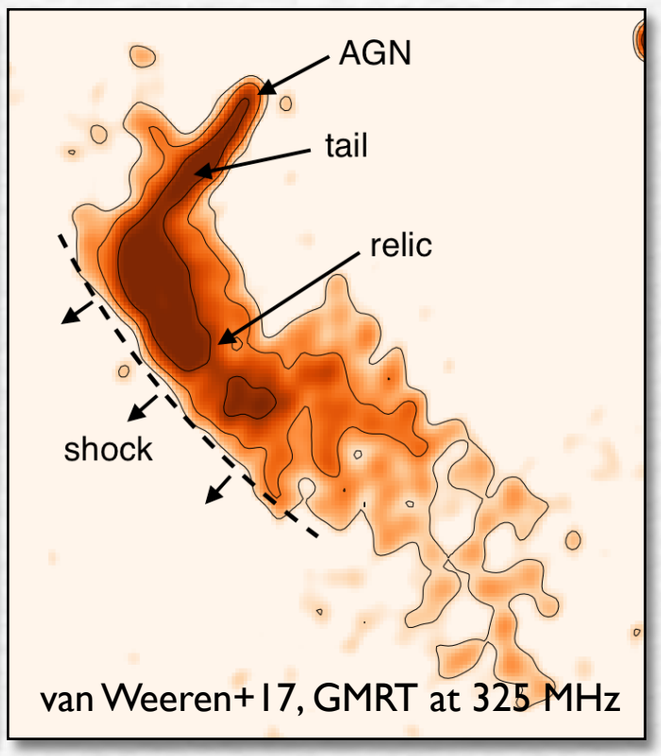
RELICS

- Particles from thermal pool accelerated by multiple crossing of a shock front: **diffusive shock acceleration** (DSA, e.g. Ensslin+98)
  - ➡ "Simple", but not always efficient
- Old plasma **re-accelerated** by the crossing shock wave (e.g. Markevitch+05)
  - ➡ Efficient, but it needs tail-relic connection

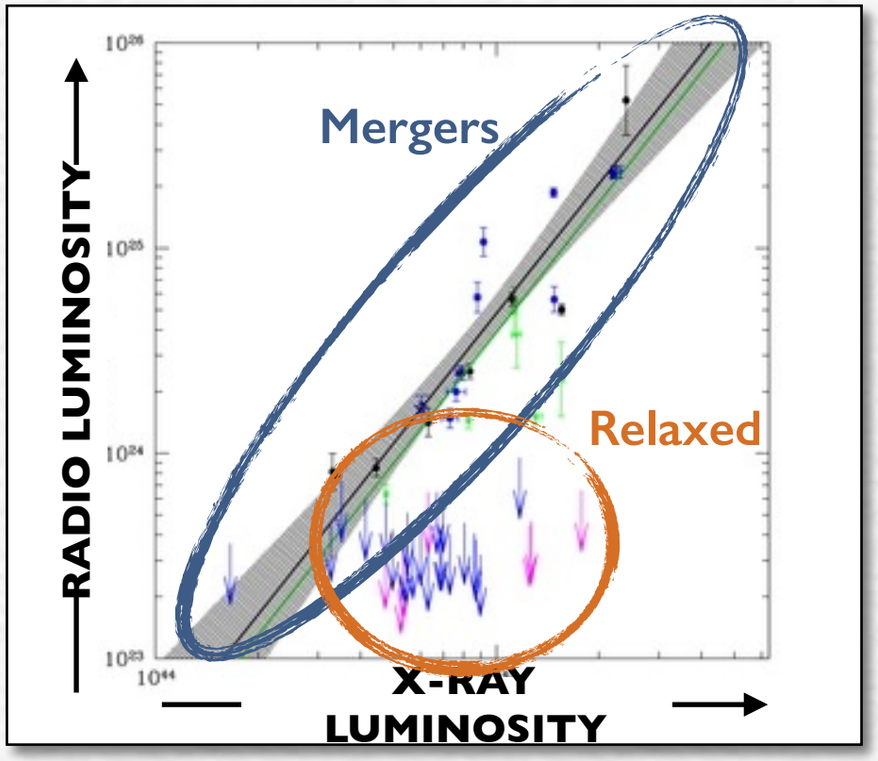
HALOS

- Cluster mergers generate turbulence which re-accelerate electrons (e.g. Brunetti+01)
  - ➡ Only in merging clusters
- Protons inside the cluster collide with thermal electrons (e.g. Ensslin+11)
  - ➡ In all galaxy clusters





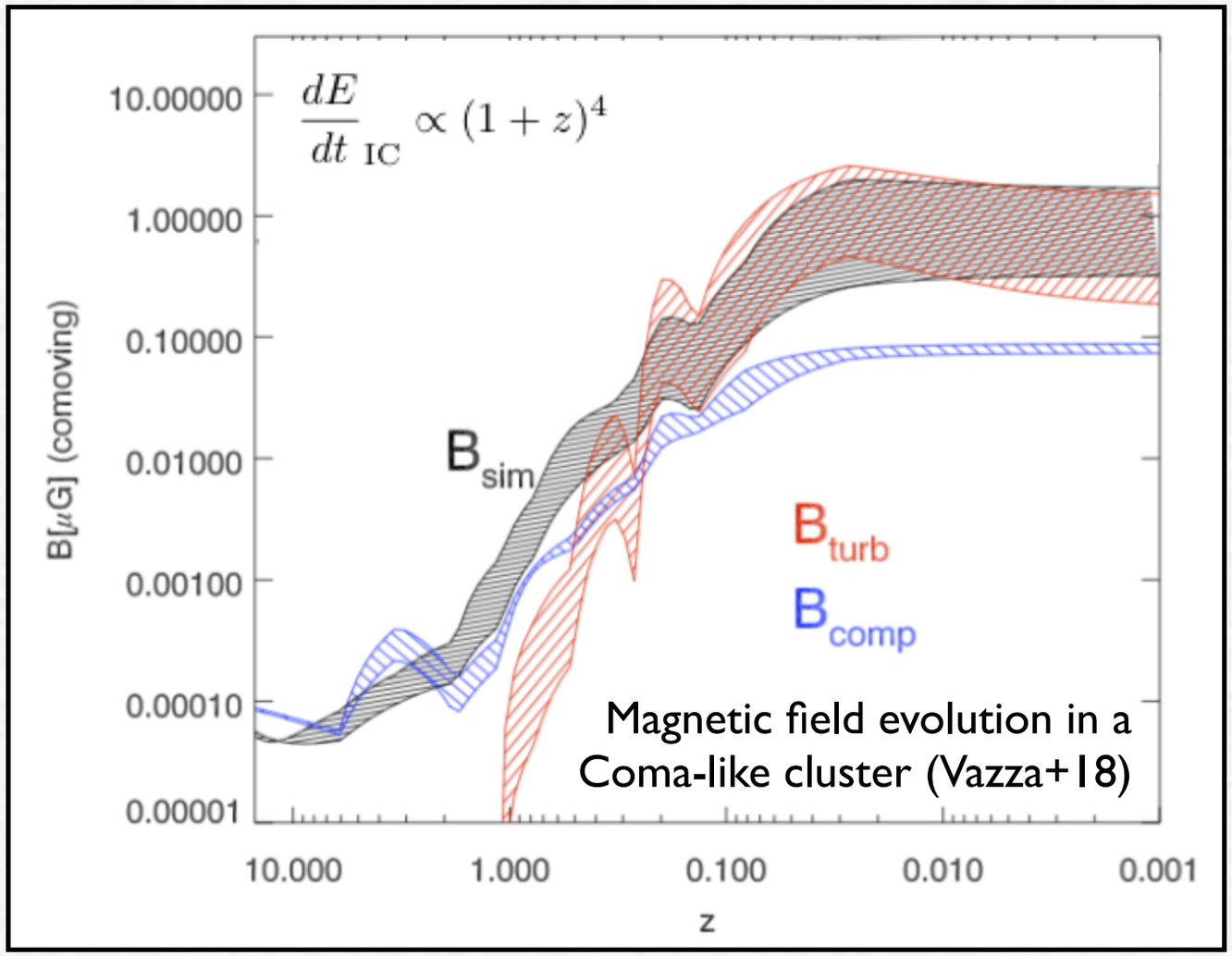
Cassano+13



What do we know about the evolution of the diffuse radio emission over the cosmic time ?

HIGH-REDSHIFT (z≥0.6) CLUSTERS

a very simplistic view…



- **<u>Prediction:</u>** occurrence rate at z≥0.6 *should* be much lower than in low-z clusters due to IC losses and they should have steeper spectra, α≲-1.5 (Cassano&Brunetti 05, Cassano+10)
- **<u>Observations</u>** lack because such an emission is very faint and the old generation of radio telescope is not sensitive enough (PLKG147.3-16.6 and "El Gordo")

HIGH-REDSHIFT (z≥0.6) CLUSTERS

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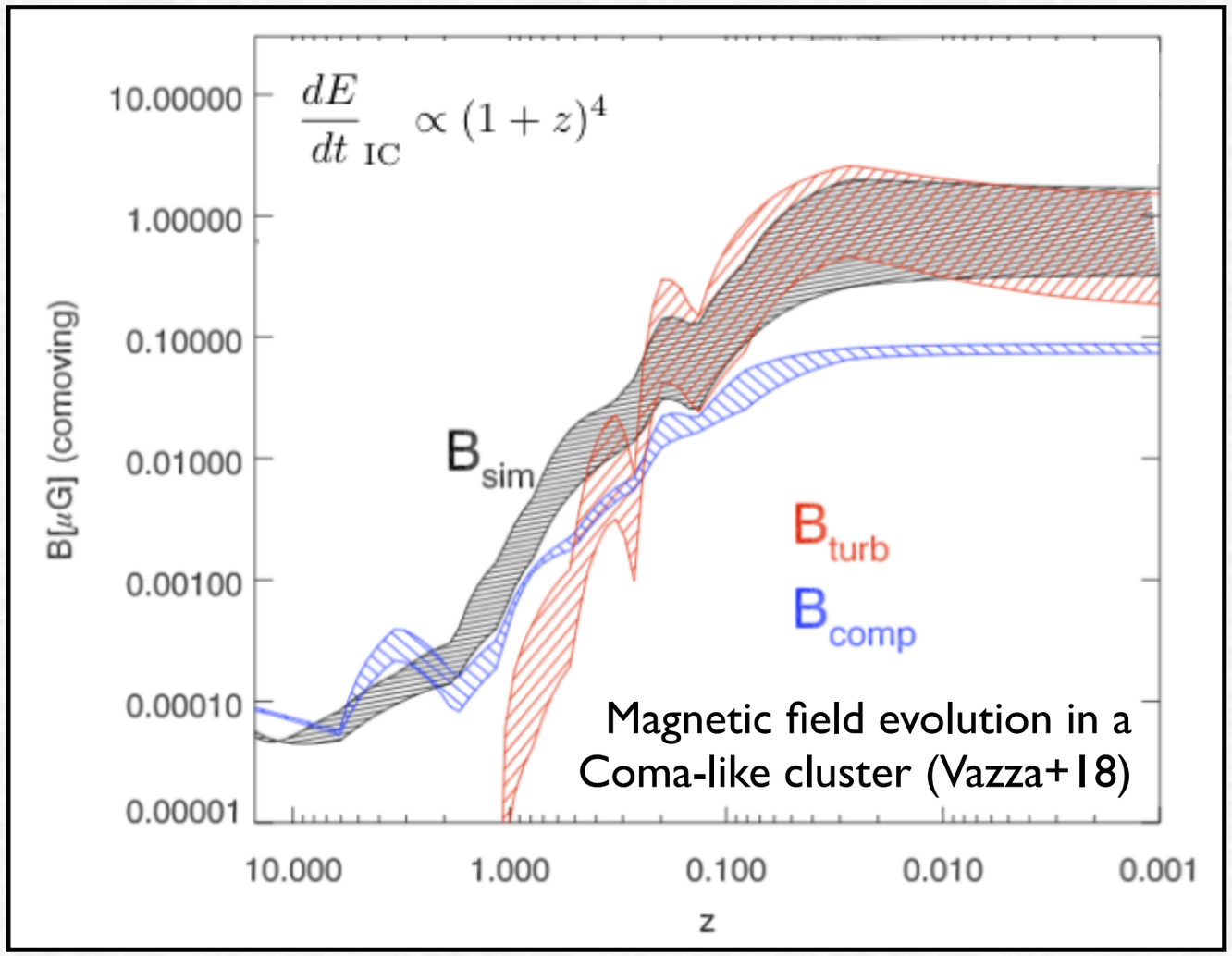

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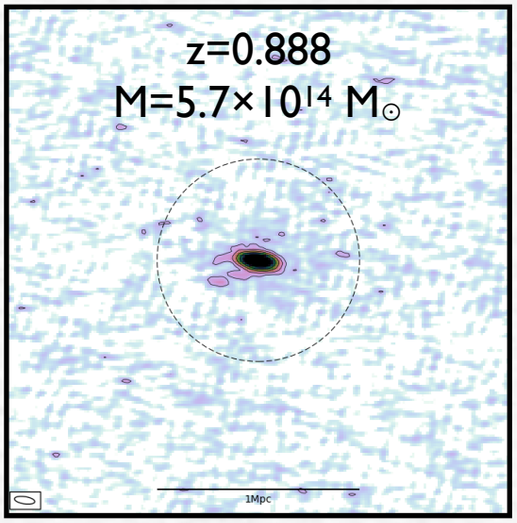
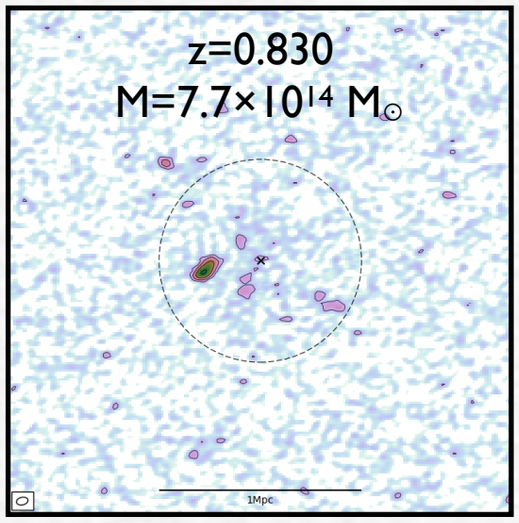
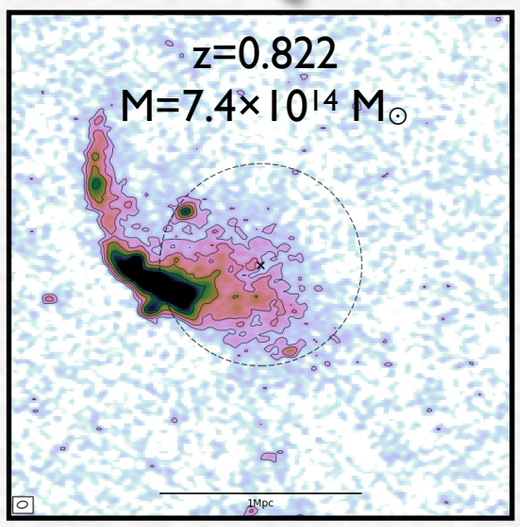
THE LOFAR (120-168 MHz) SAMPLE

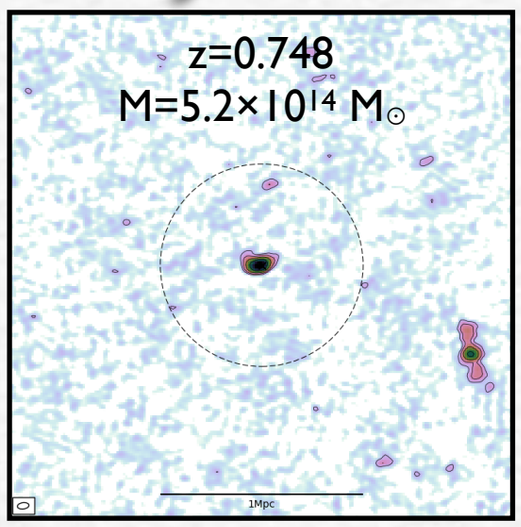
- latest Planck SZ Catalogue, no bias on the dynamical state of the cluster
- DEC > 20 deg
- z ≥ 0.6

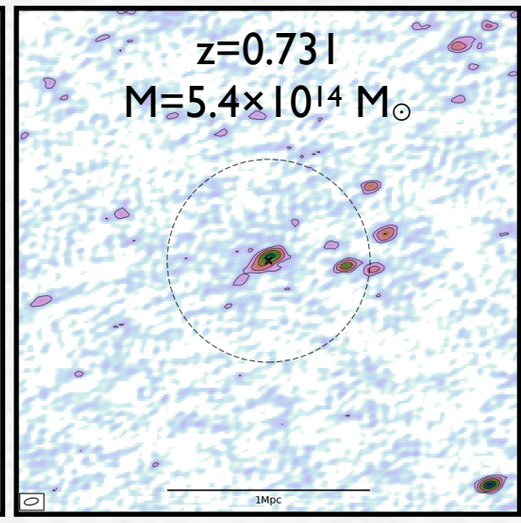
HIGH-REDSHIFT (z≥0.6) CLUSTERS

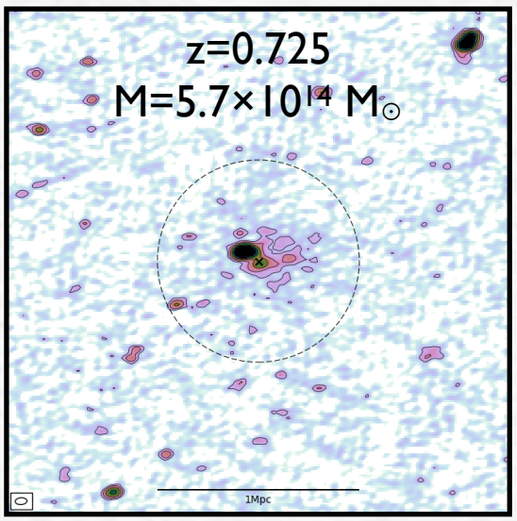


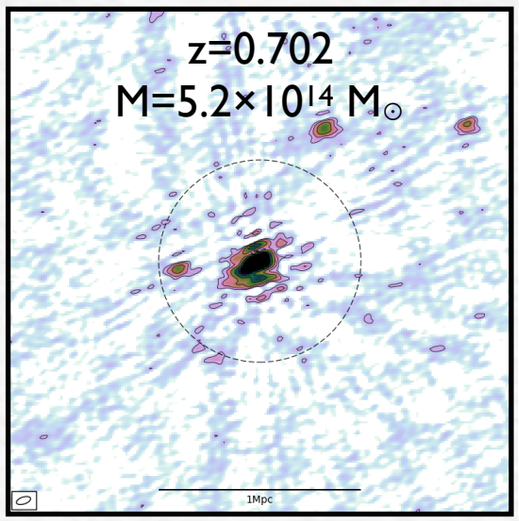


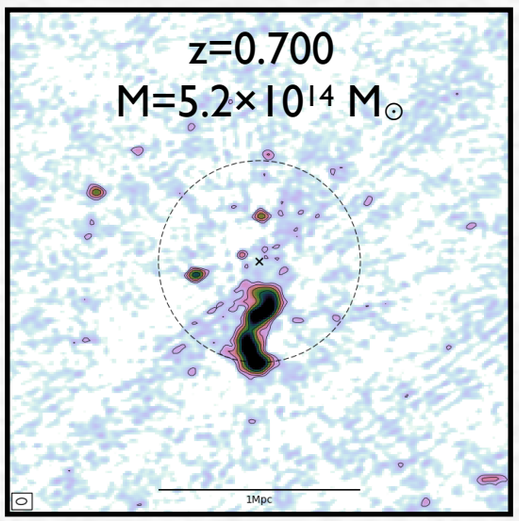


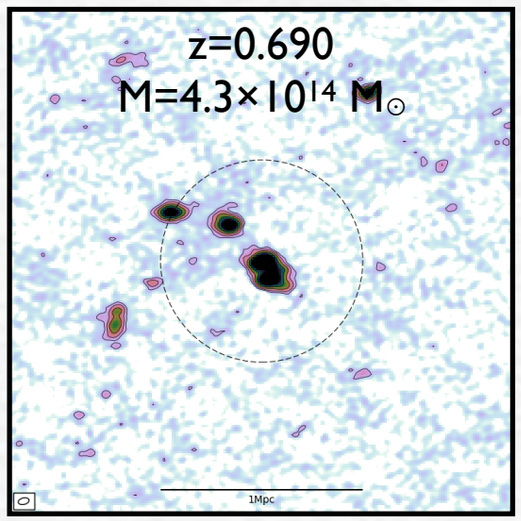


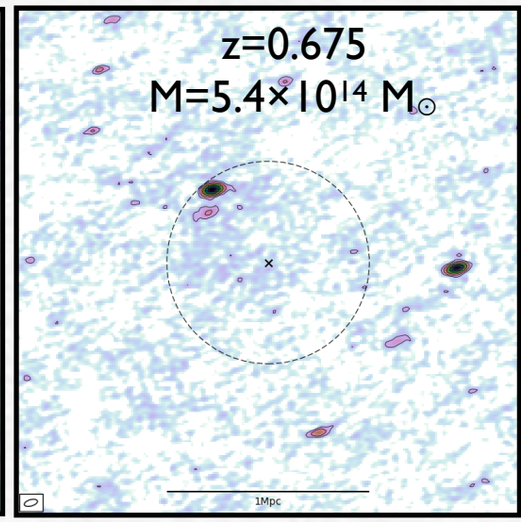


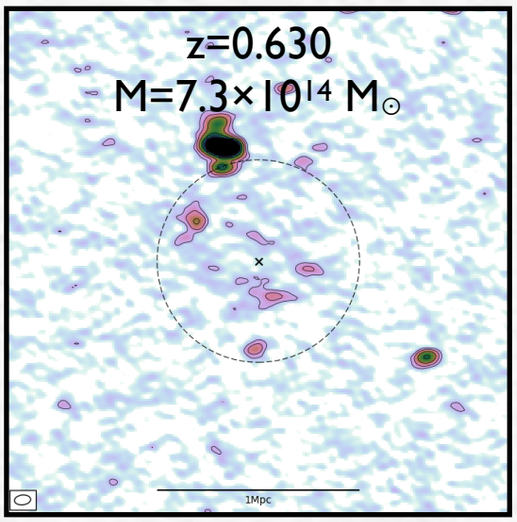


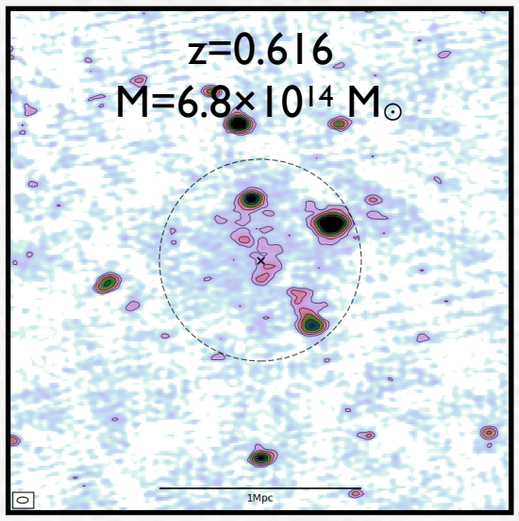


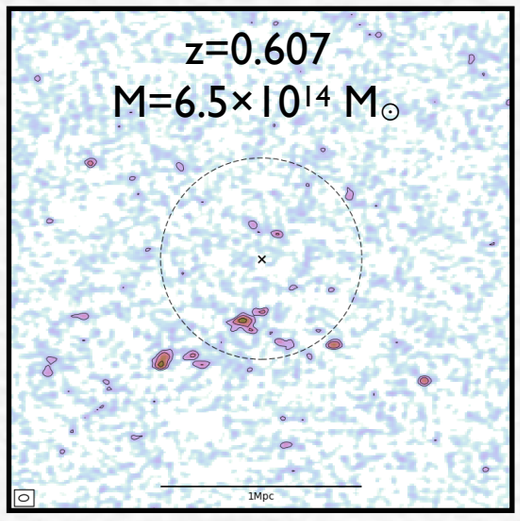


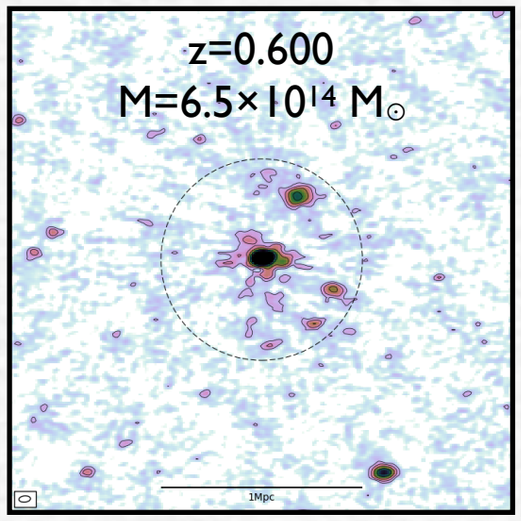








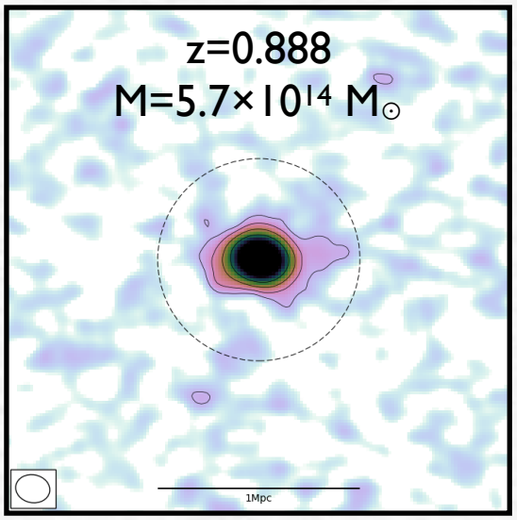


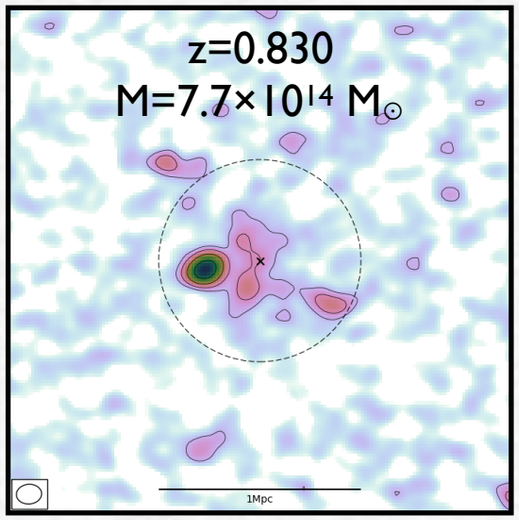


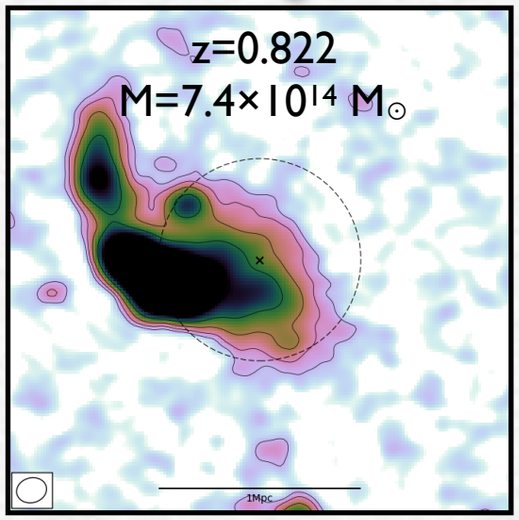
6 more to come (extraction/ reprocessing)

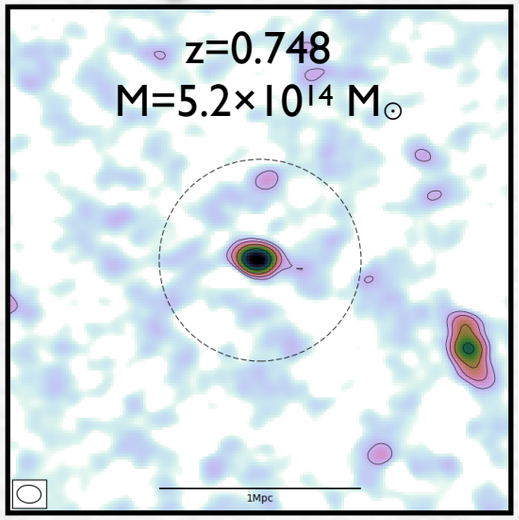
Di Gennaro+ in prep.

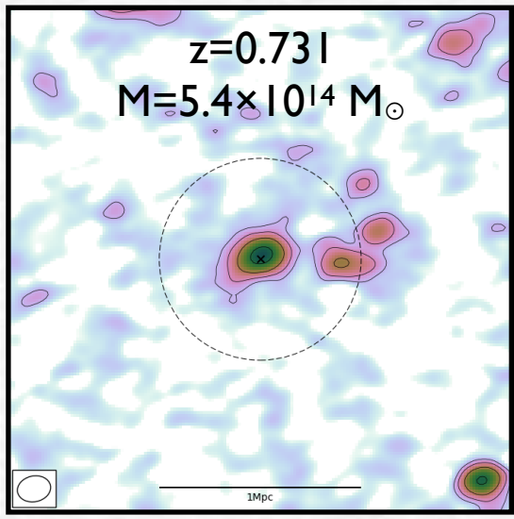
HIGH-REDSHIFT ($z \geq 0.6$) CLUSTERS

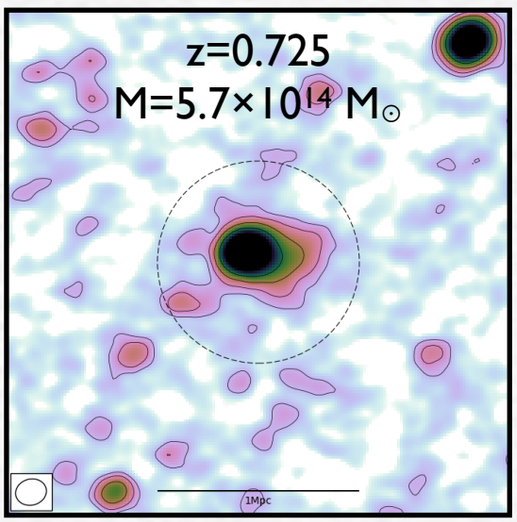


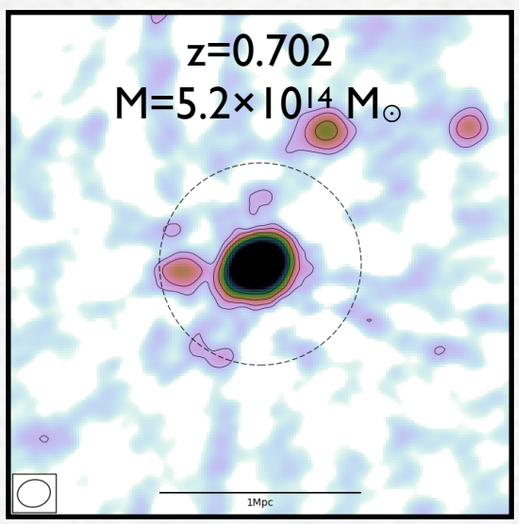


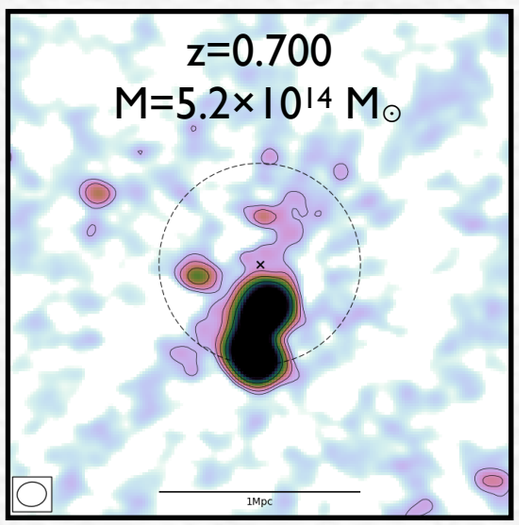


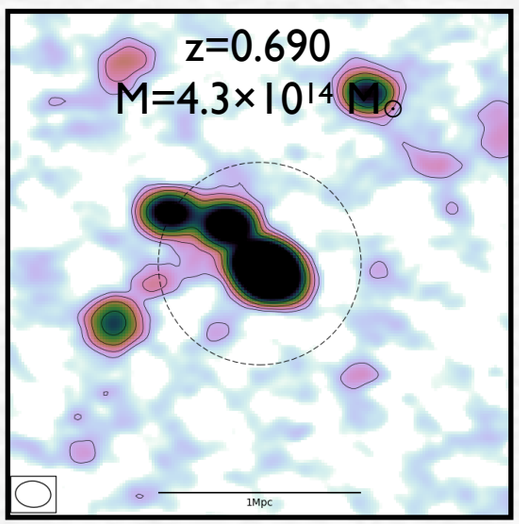


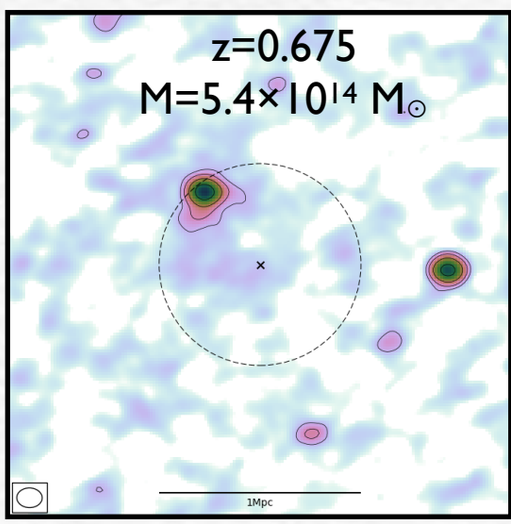


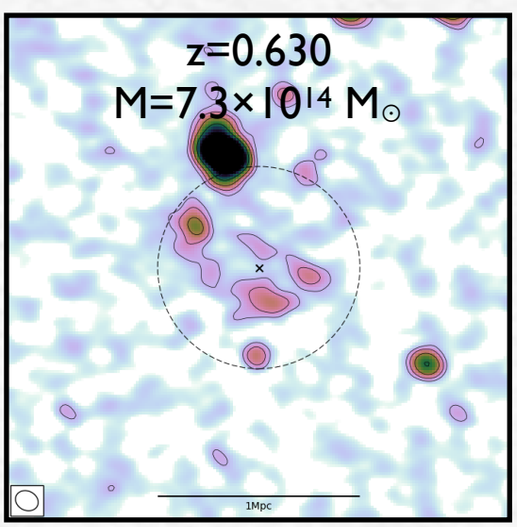


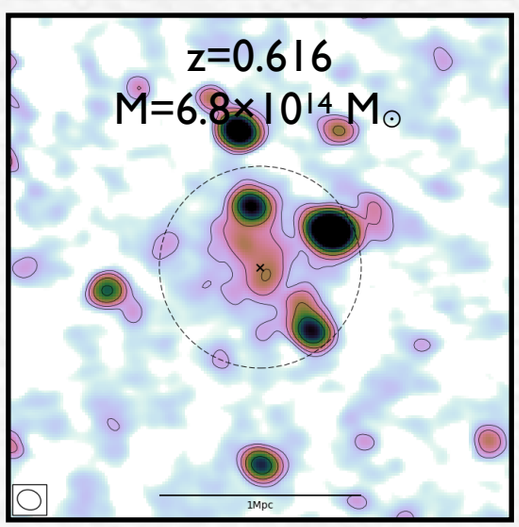


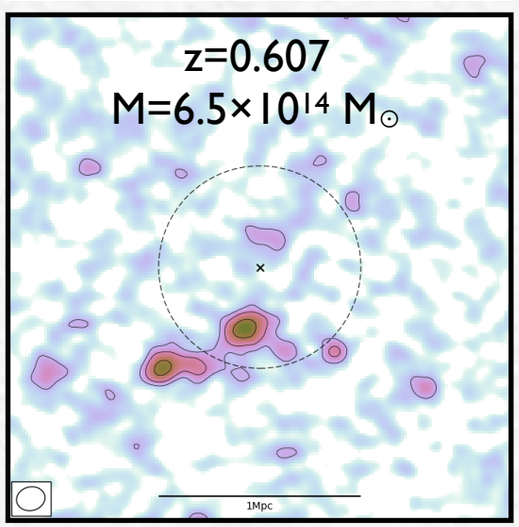


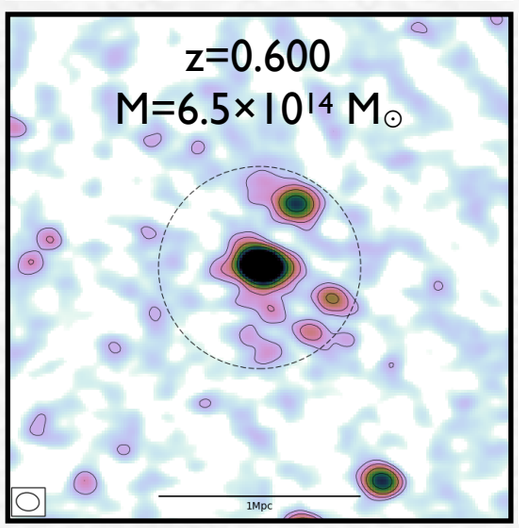










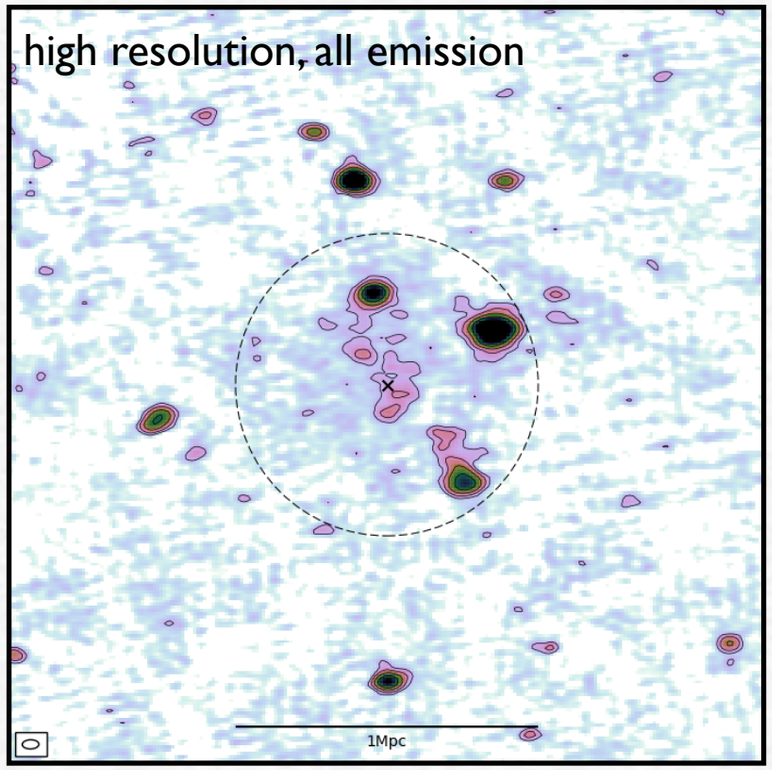


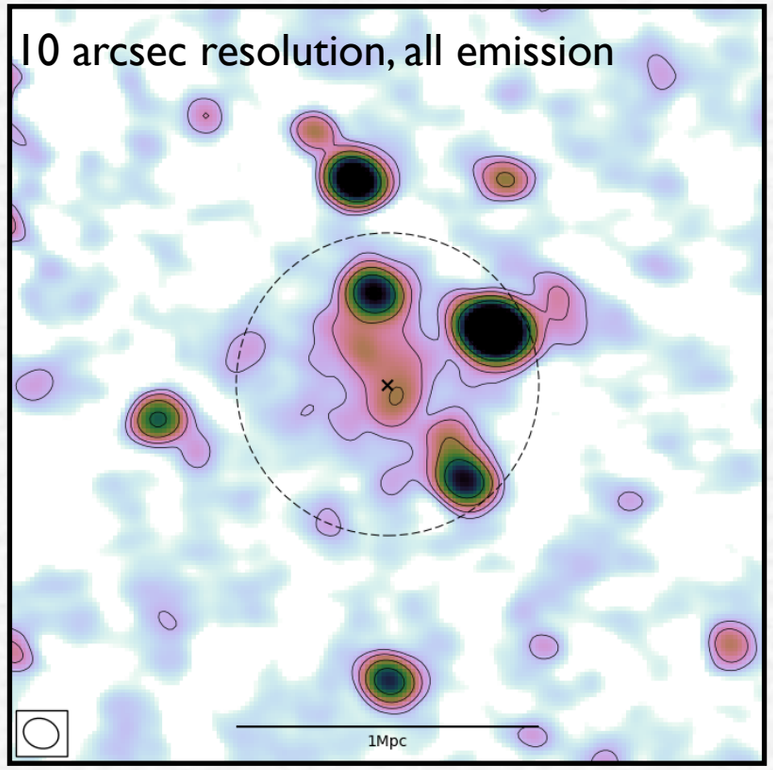
6 more to come (extraction/ reprocessing)

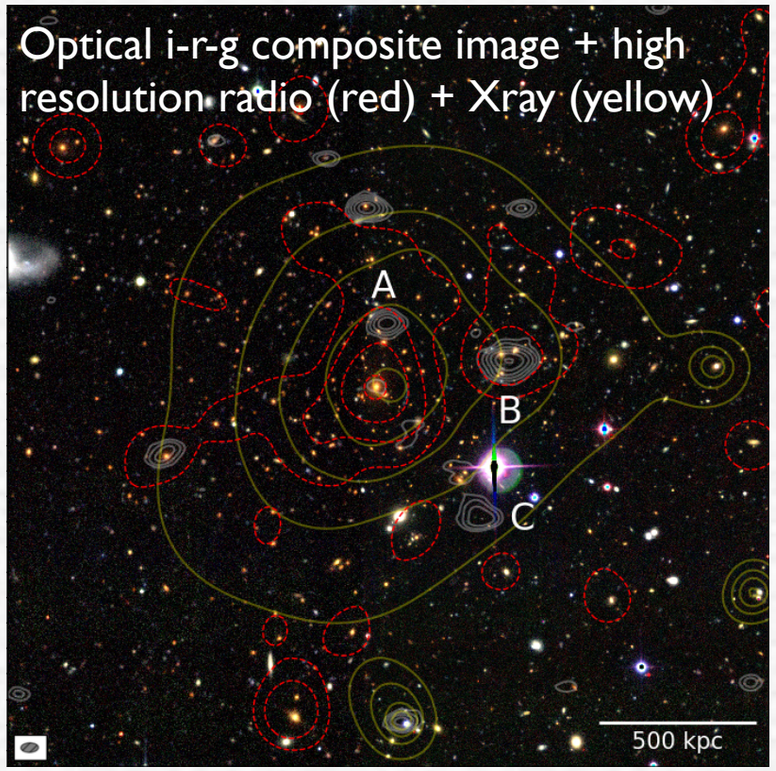
Di Gennaro+ in prep.

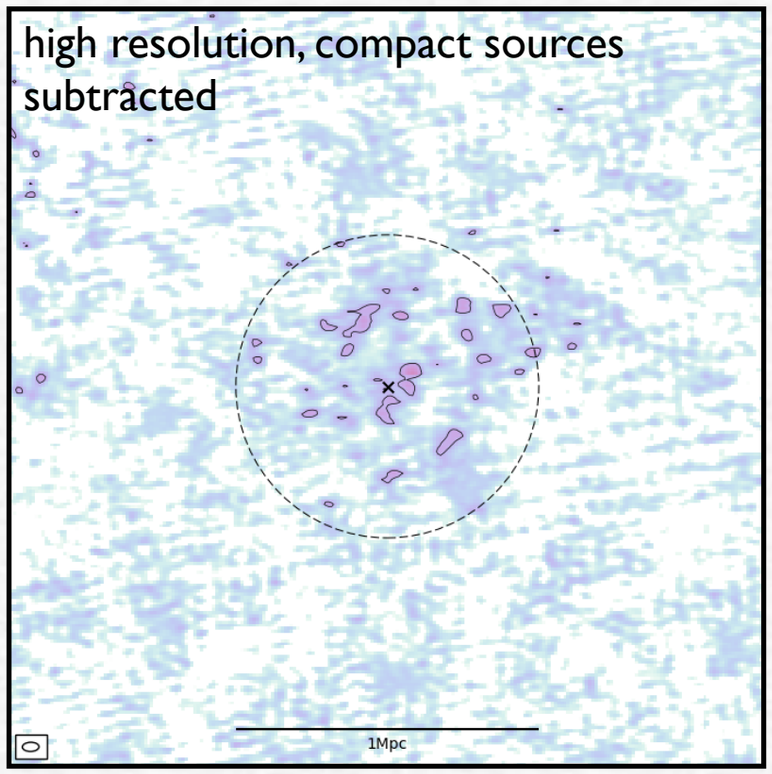
HIGH-REDSHIFT (z≥0.6) CLUSTERS

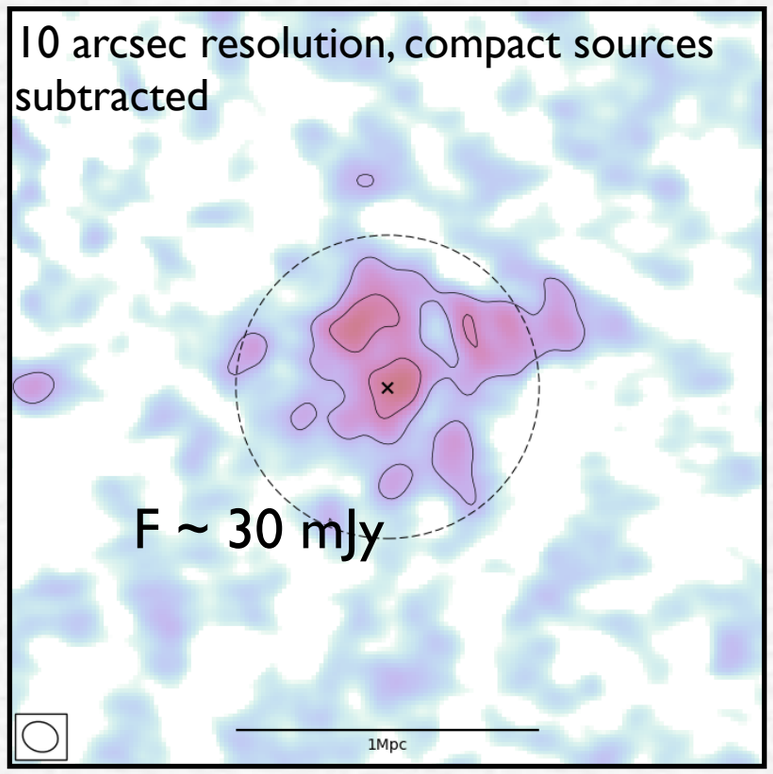
z=0.616; M=6.8×10^{14} M$_\odot$ (Cassano+ in prep)

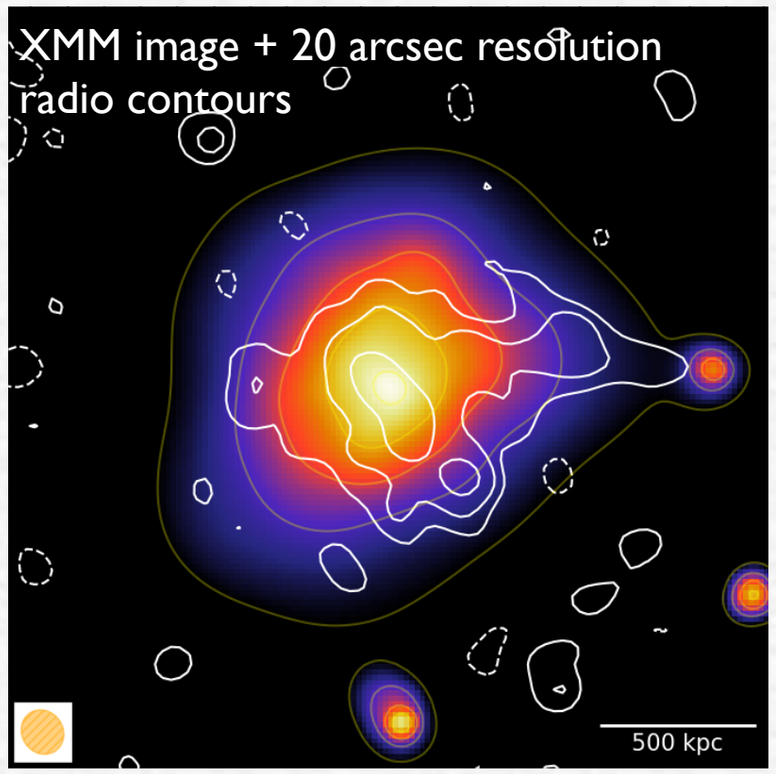








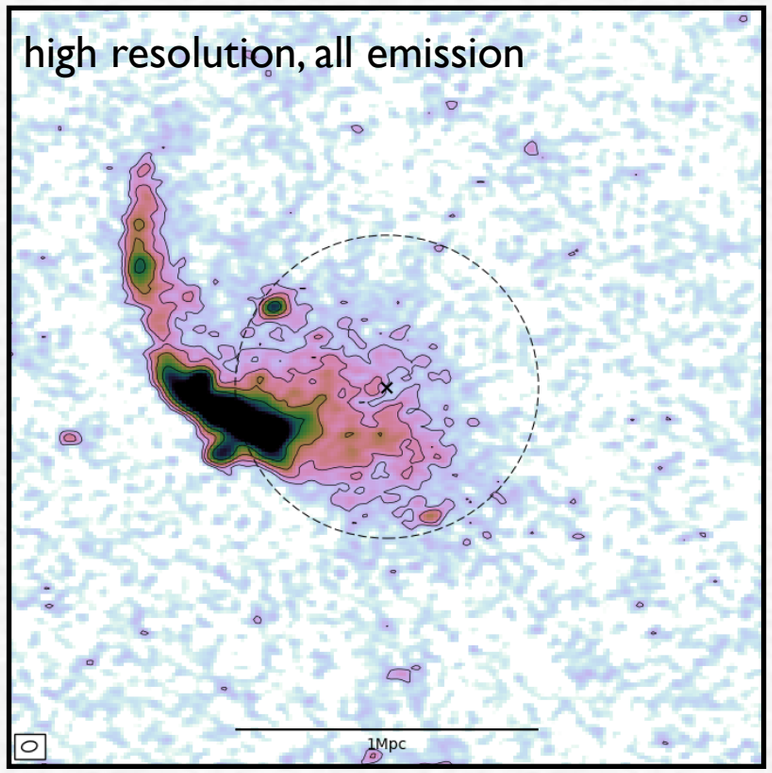


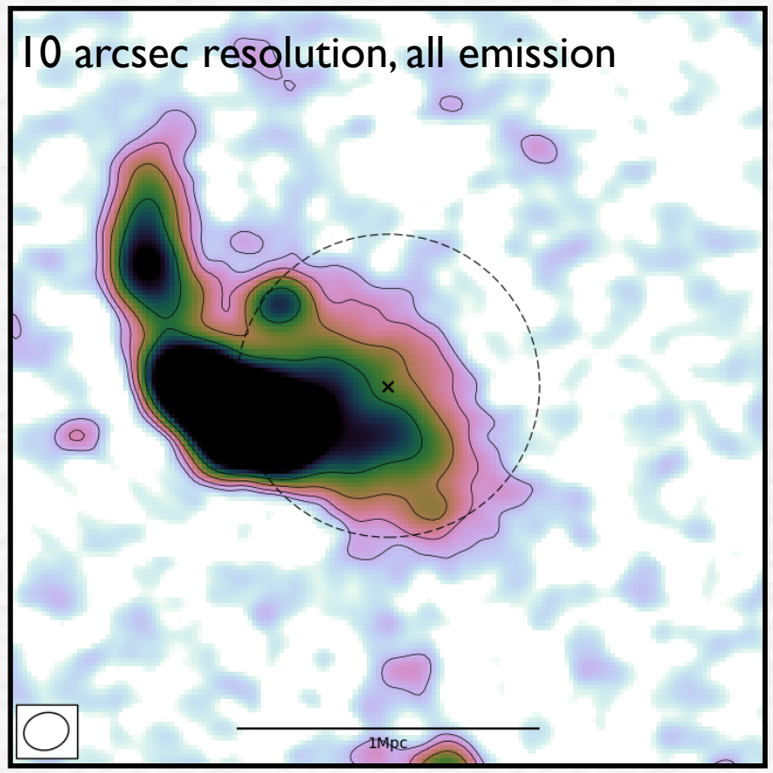


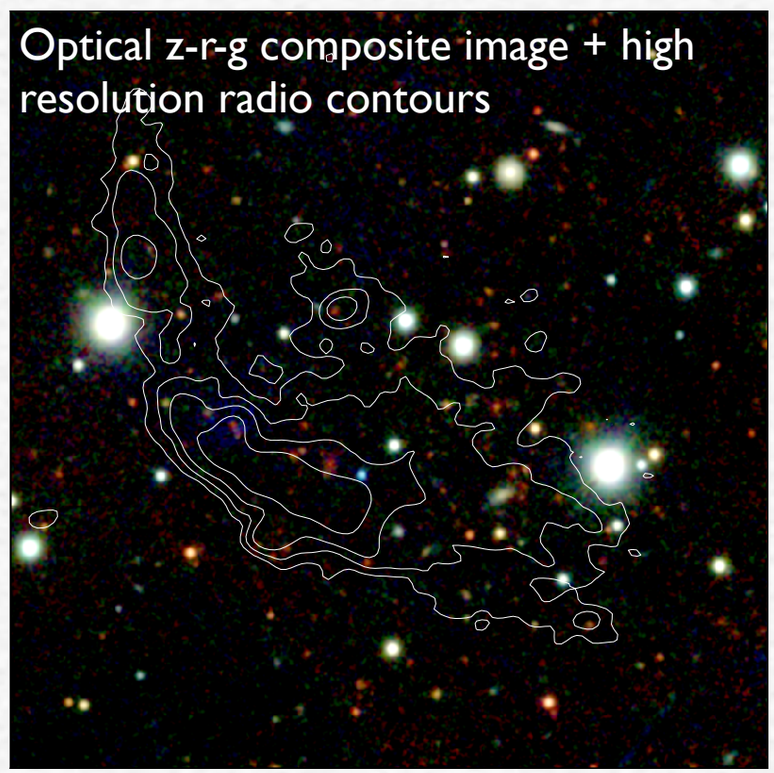
HIGH-REDSHIFT (z≥0.6) CLUSTERS

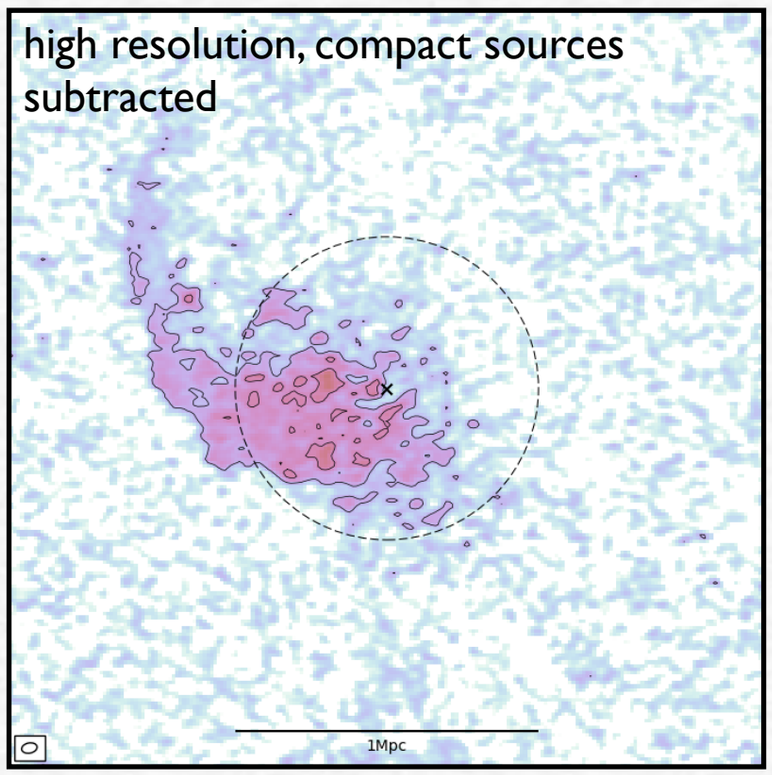
z=0.822; M=7.4×10^{14} M$_\odot$

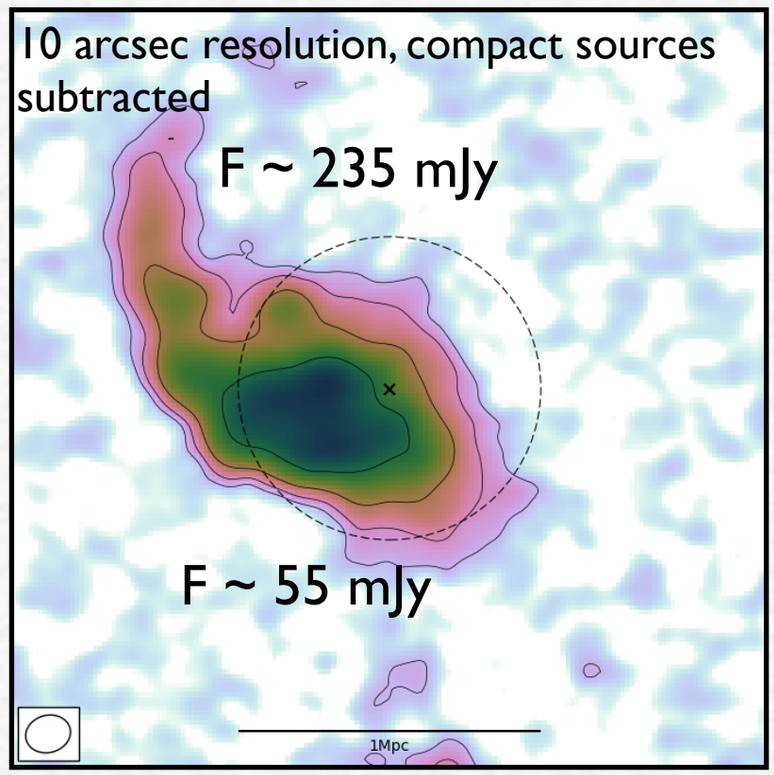
Di Gennaro+ in prep.

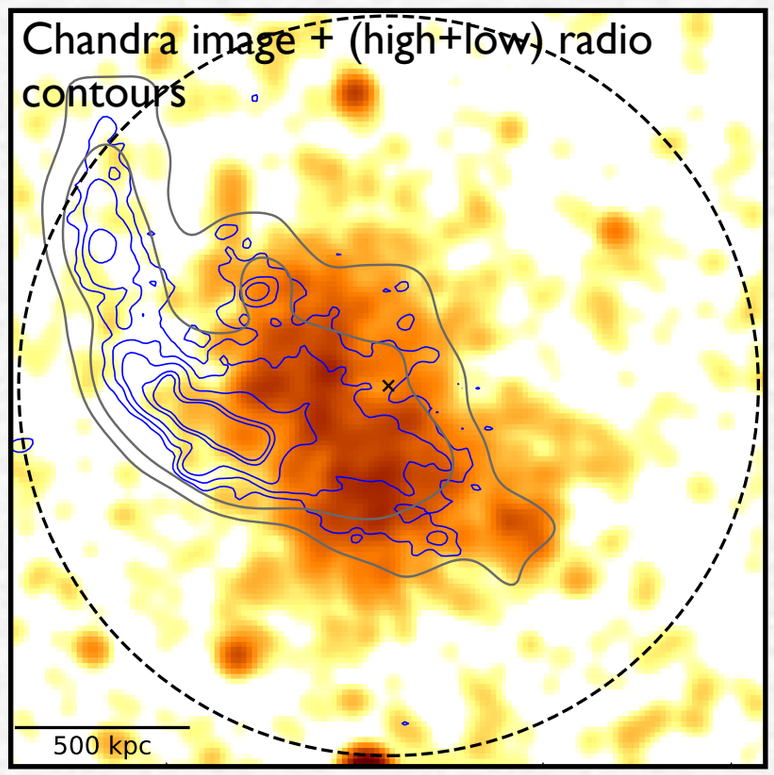








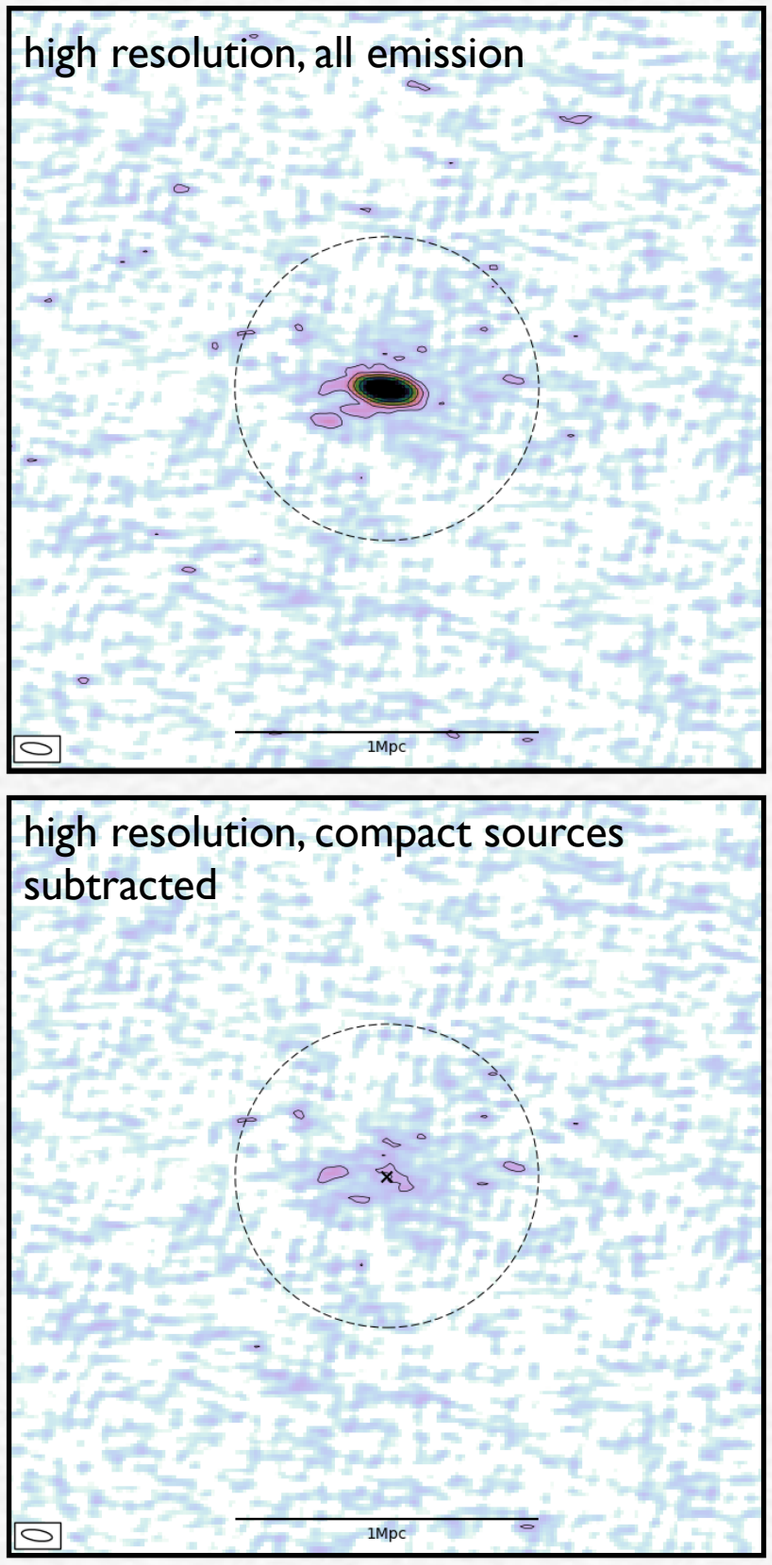


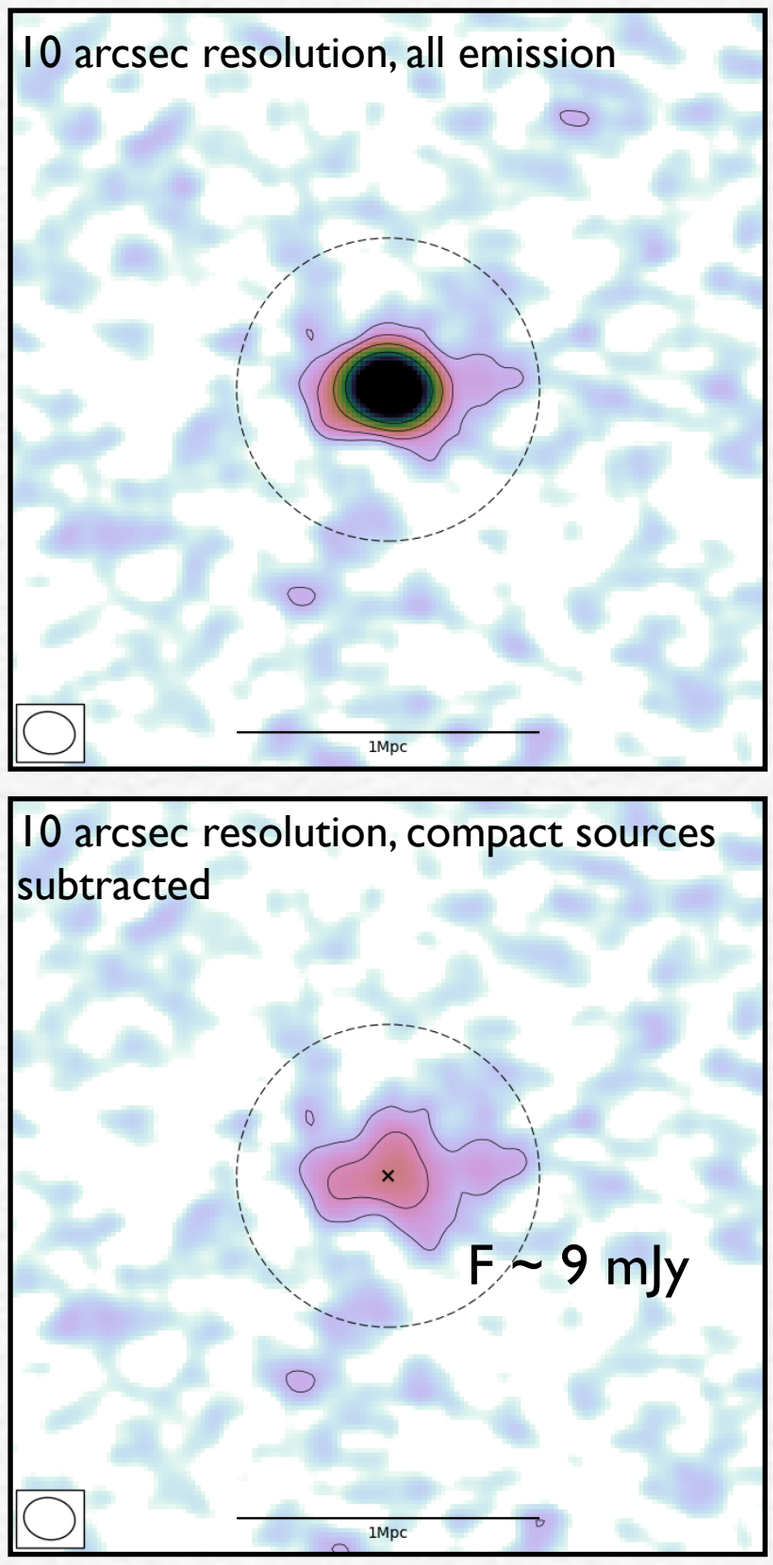


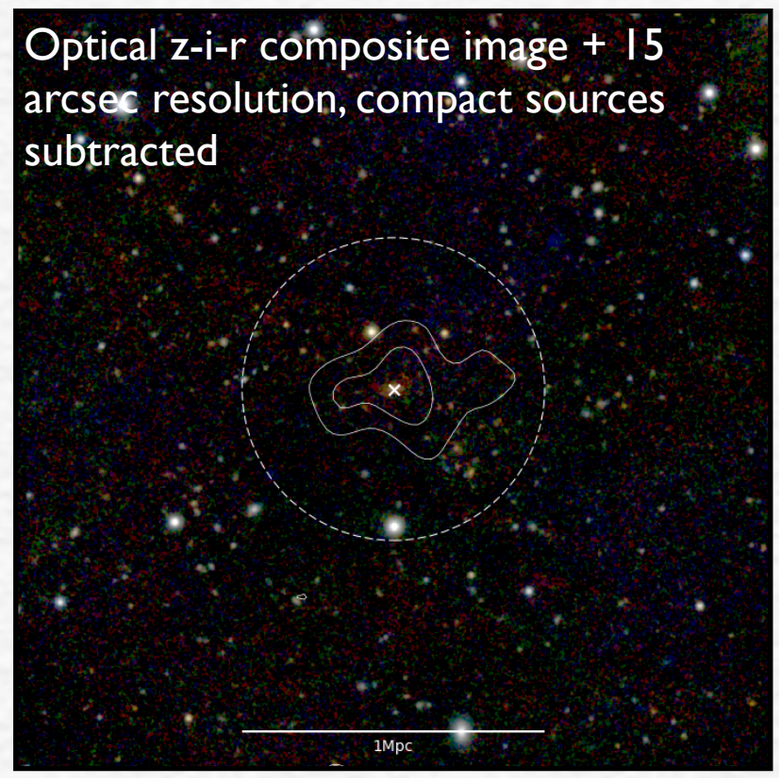
HIGH-REDSHIFT (z≥0.6) CLUSTERS

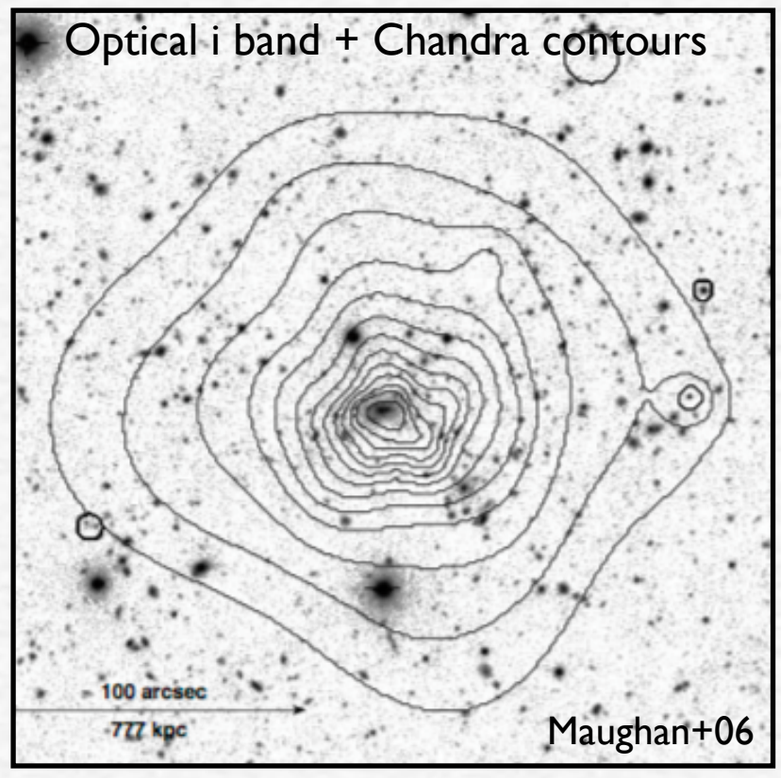
z=0.888; M=5.7×10^{14} M$_\odot$

Di Gennaro+ in prep.





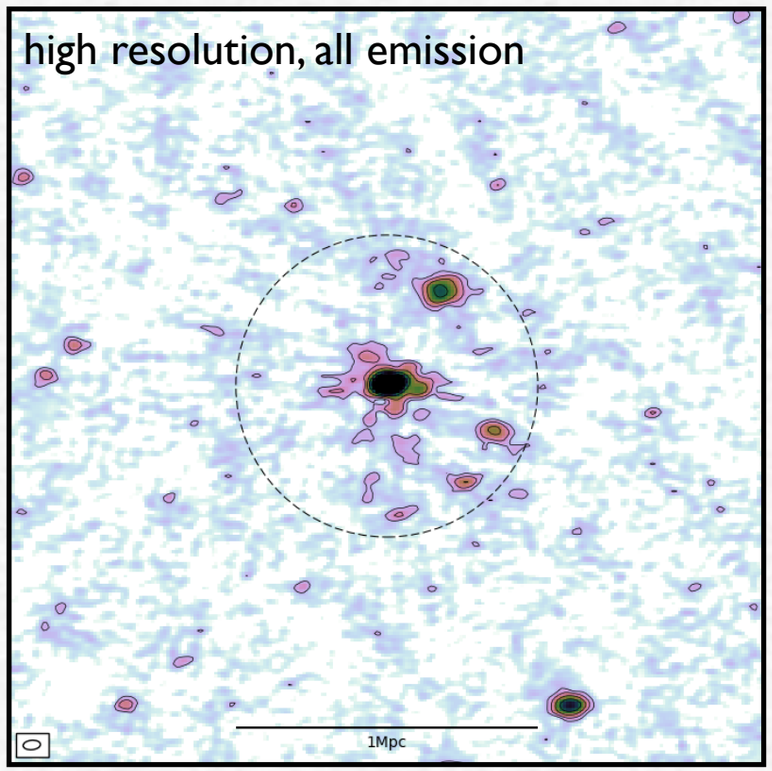


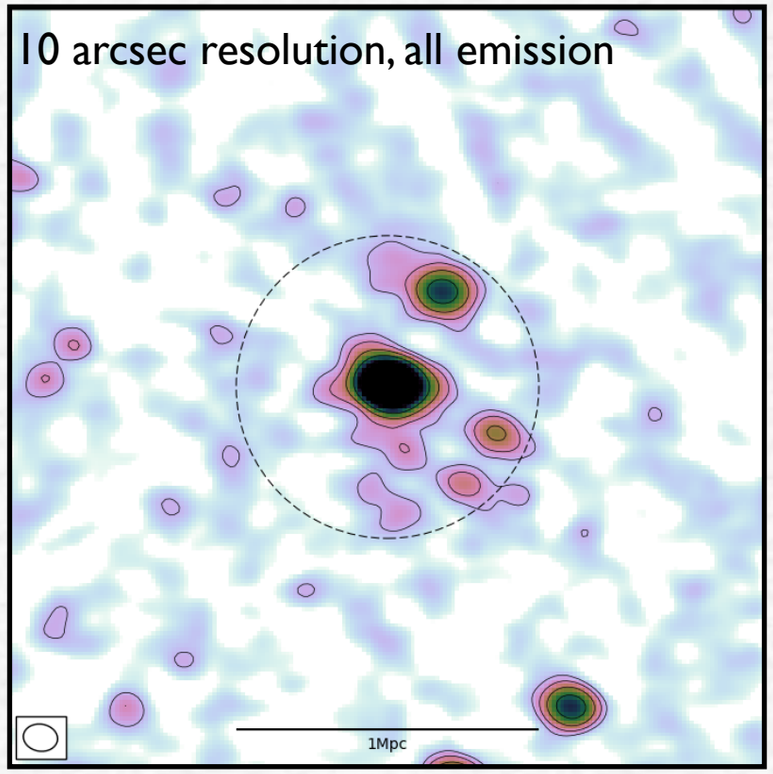


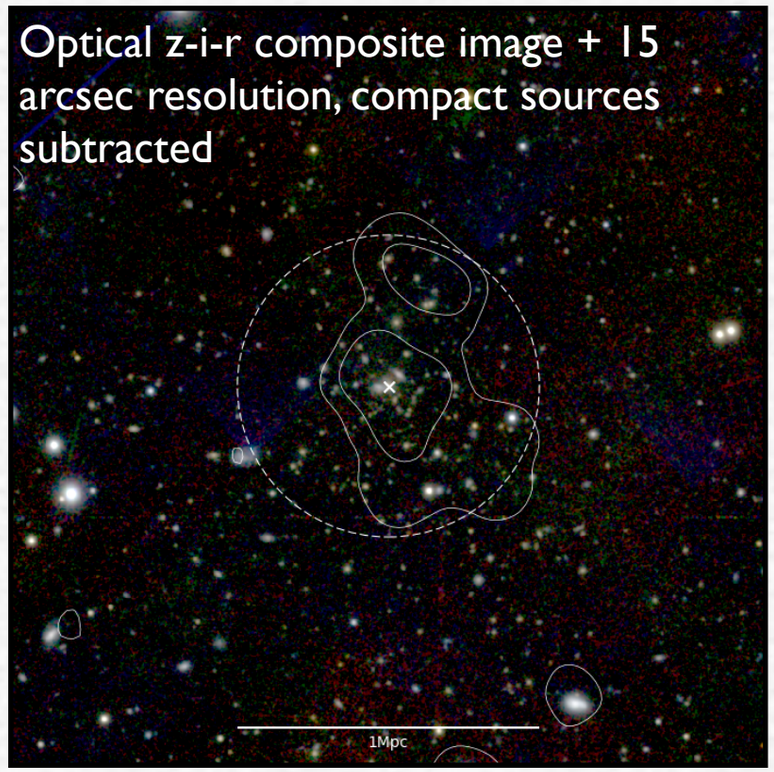
HIGH-REDSHIFT (z≥0.6) CLUSTERS

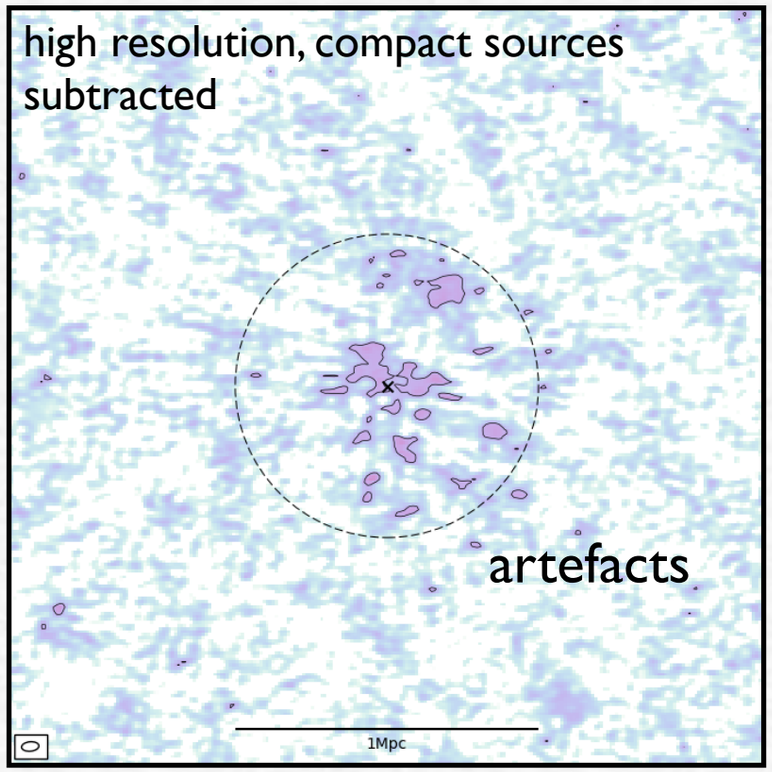
z=0.600; M=6.5×10^{14} M$_\odot$

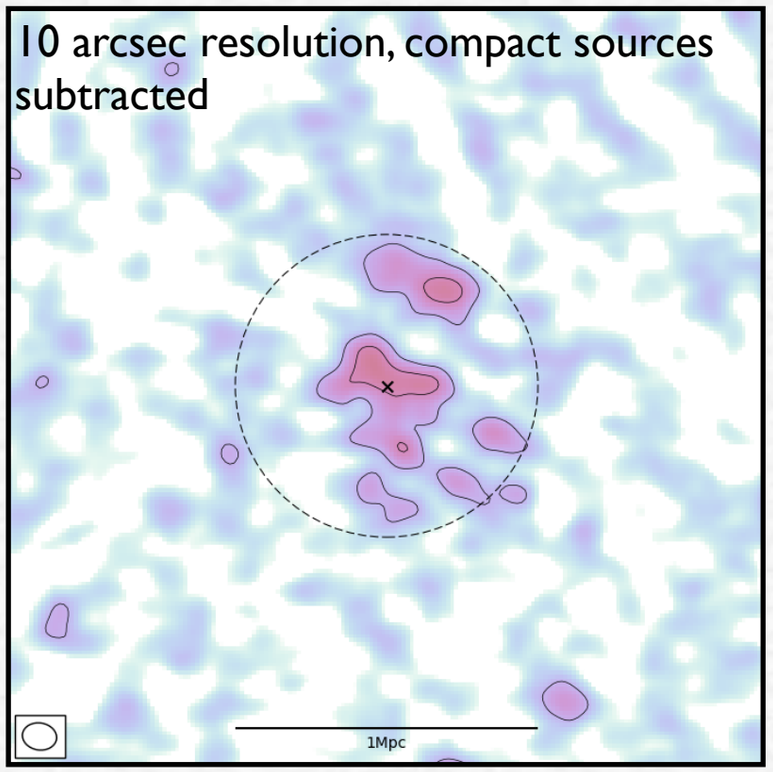
Di Gennaro+ in prep.





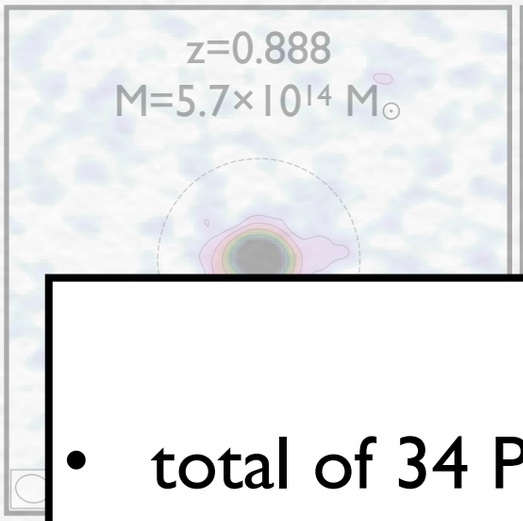


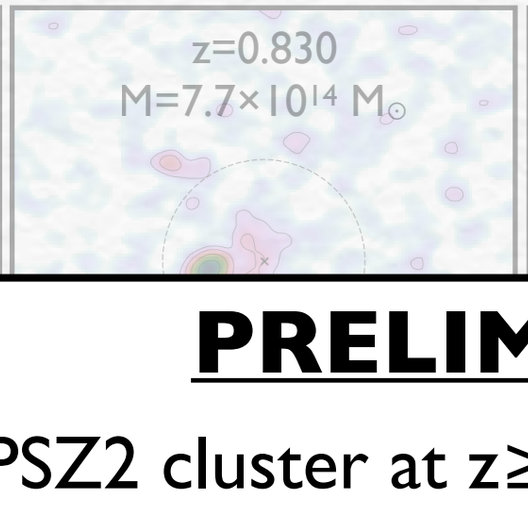


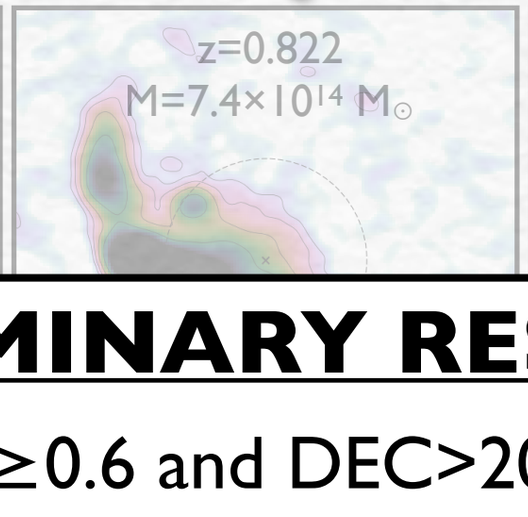


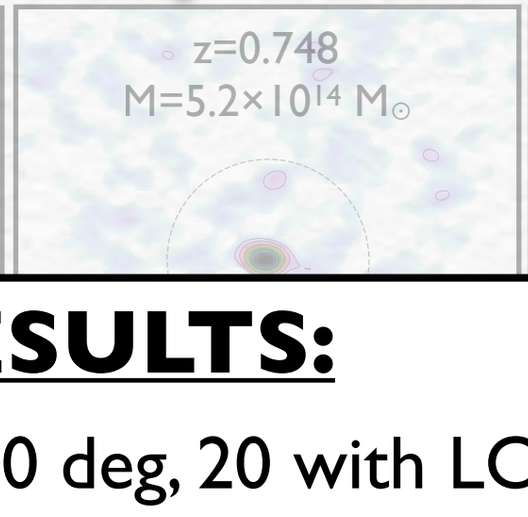
Xray ?

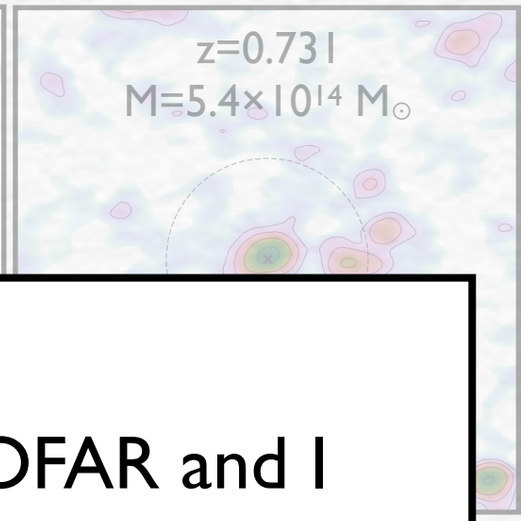
HIGH-REDSHIFT (z≥0.6) CLUSTERS





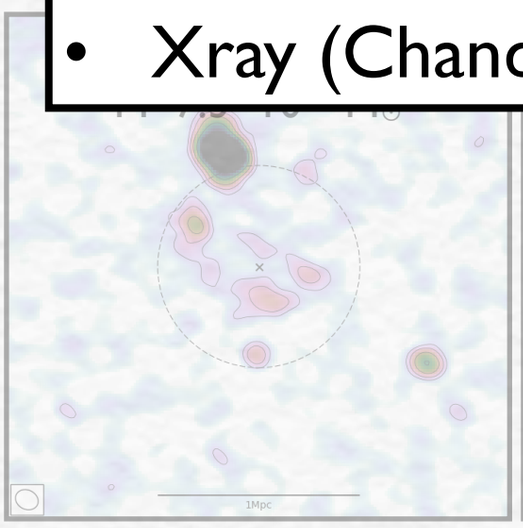


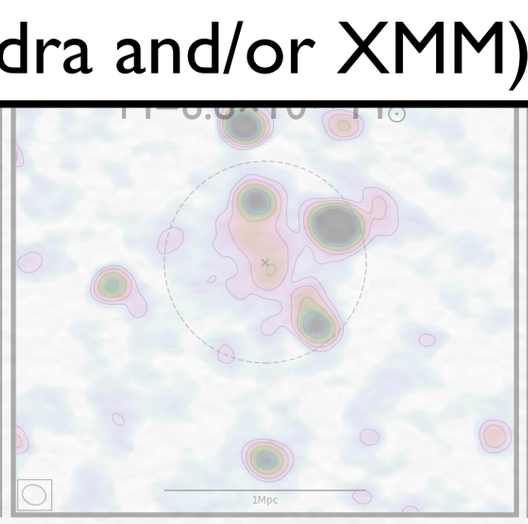


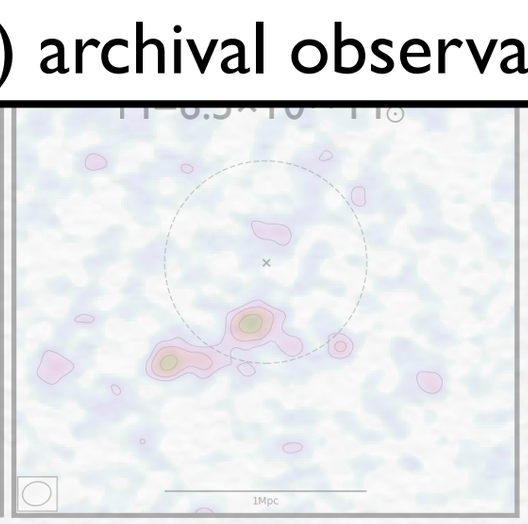


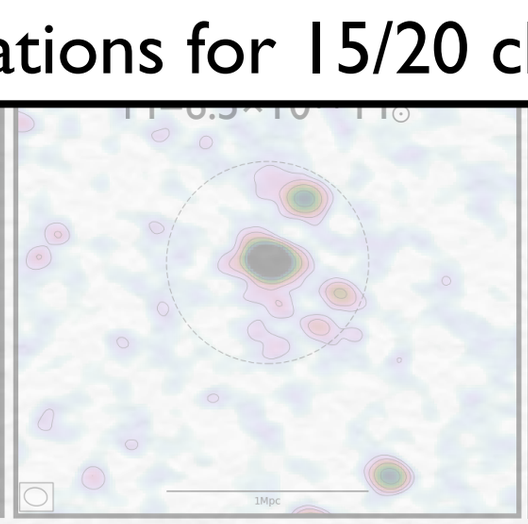
PRELIMINARY RESULTS:

- total of 34 PSZ2 cluster at z≥0.6 and DEC>20 deg, 20 with LOFAR and 1 GMRT (610 MHz, van Weeren+14) observations, 3 spurious PSZ2 detections;
- High-fidelity image for 16/20 observations;
- Clearly-detected diffuse radio emission in 7/16 observations (+ diffuse emission detected in the GMRT observation);
- Likely-detected diffuse radio emission in 5/16 observations;
- Xray (Chandra and/or XMM) archival observations for 15/20 clusters.





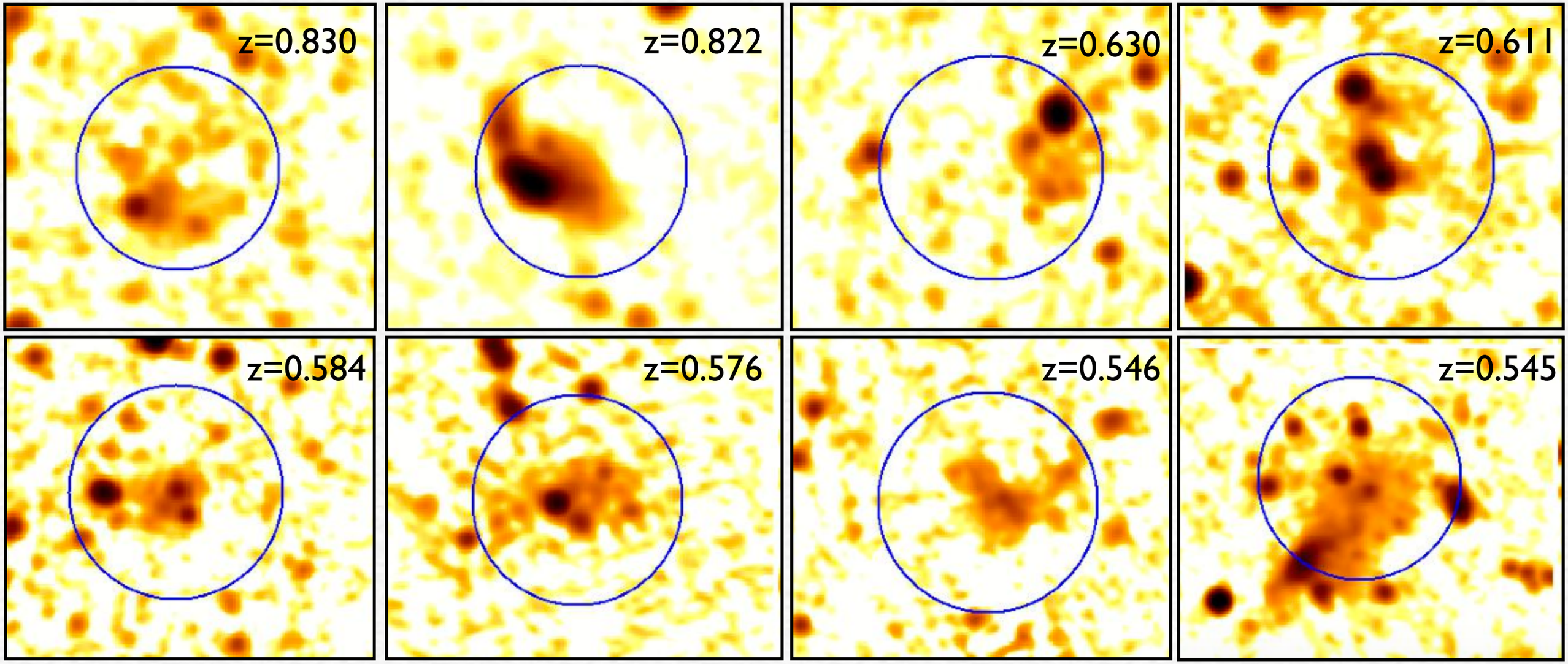




6 more to come (extraction/ reprocessing)

SPECTRAL INDEX STUDY
LOFAR-uGMRT

- latest Planck SZ Catalogue, no bias on the dynamical state of the cluster
- X-ray available for all clusters (PI: Rossetti), thermal-non thermal comparison
- DEC > 20 deg
- $M > 7\times10^{14}\ M_{\odot}$, "most" powerful radio halo are expected (Cassano+13, Cuciti+15,…)
- $z \geq 0.5$

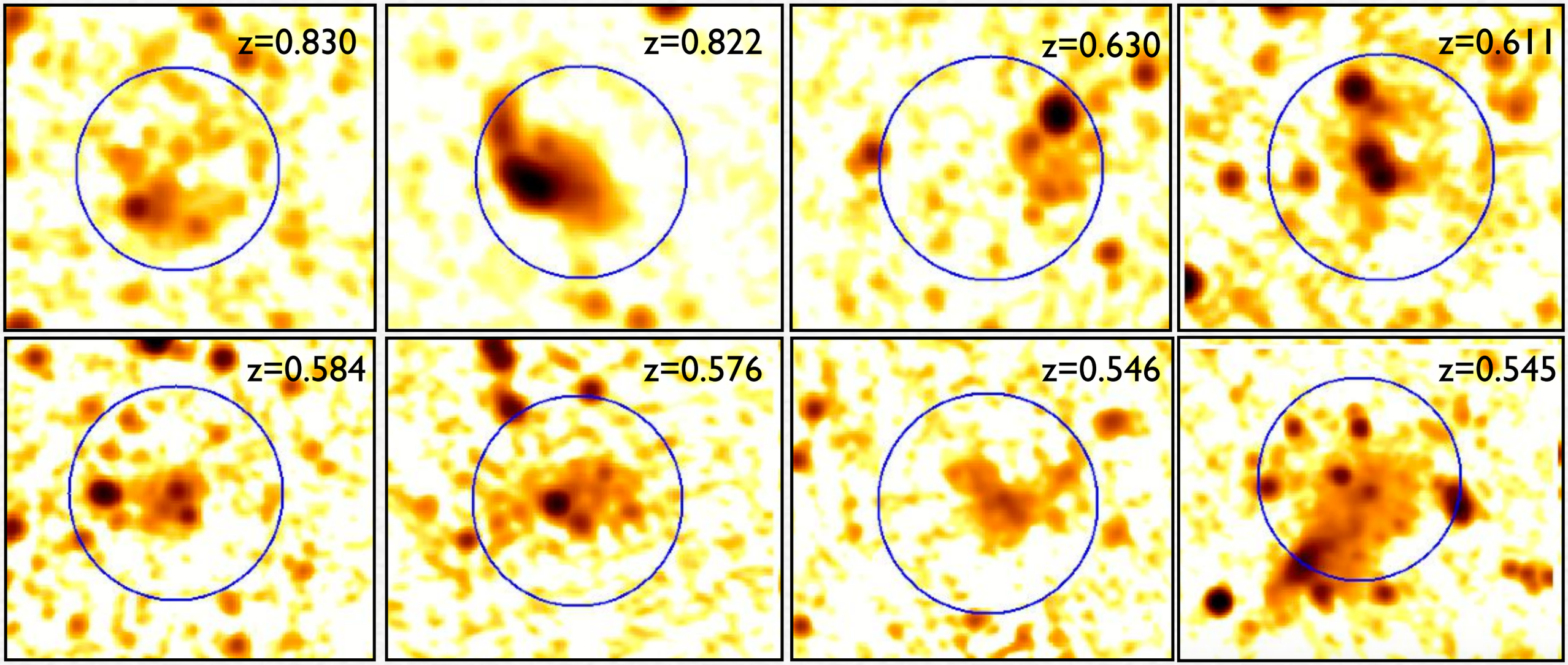


SPECTRAL INDEX STUDY

LOFAR-uGMRT

ARE THOSE HIGH-z CLUSTER REALLY STEEPER ($\alpha \lesssim -1.5$) THAN THE LOW-z ONES ?

waiting for the uGMRT…



SUMMARY

- LOFAR observations of a sample of Planck-selected galaxy clusters at **z≥0.6**

  - occurrence rate of diffuse radio emission between 47-68% from preliminary inspection

    ➡ do they challenge the current (re)acceleration models ?

    ➡ what is their dynamical state ?

- uGMRT follow-up for spectral index studies of a sample at $z \geq 0.5$ and $M > 7 \times 10^{14}\ M_{\odot}$

  ➡ are high-z cluster steeper than the low-z ones ?

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Thank you