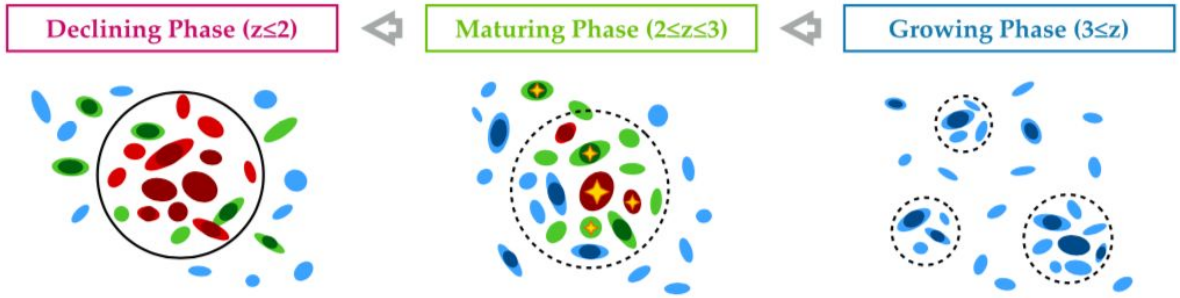
Galaxy formation, ICM heating and AGN feedback: the turbulent youth of a proto-cluster at z=1.7

National SKA workshop 2021

Quirino D'Amato

I. Prandoni, R. Gilli, M. Mignoli, C. Vignali, M. Massardi, M. Brienza

AGN role in the large-scale structure formation



	Declining Phase	Maturing Phase	Growing Phase
Galaxies	Starvation / Environmental quenching	Energetic AGN feedback	Massive galaxy formation
Halo Gas	Cold gas depletion / Superheated plasma	Pre-heating / Core collapse	Cold gas stream in hot gas

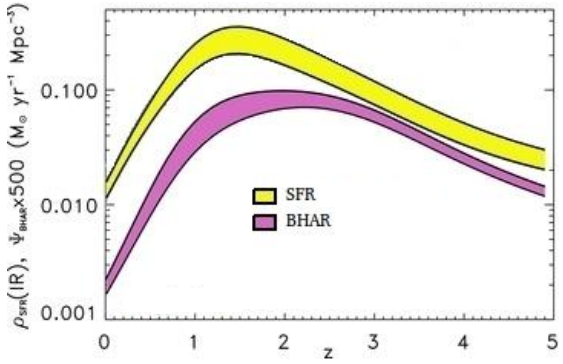
Shimakawa+18

Many open questions…

-Star formation/black hole accretion relation

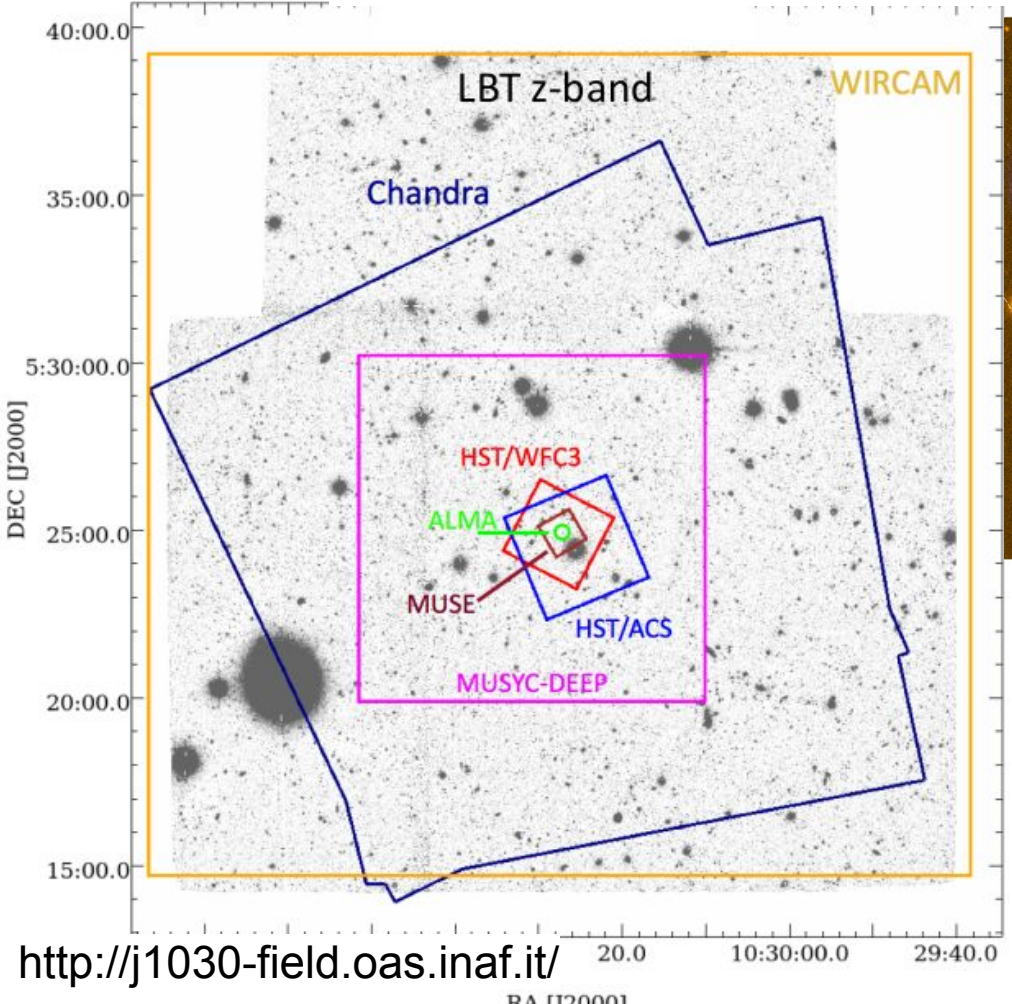
-positive/negative AGN feedback

-ICM heating

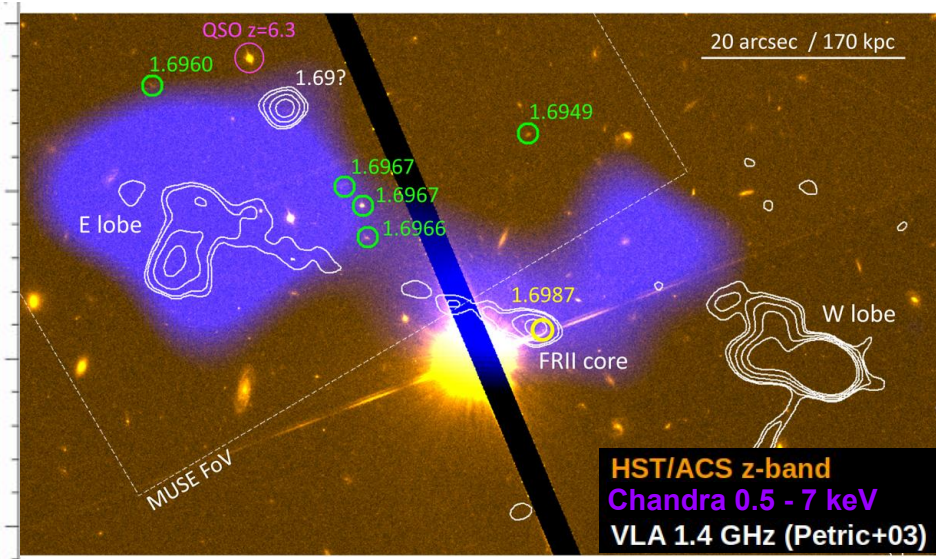


Gruppioni+11

J1030 Field around the QSO J1030+0524 at z=6.31



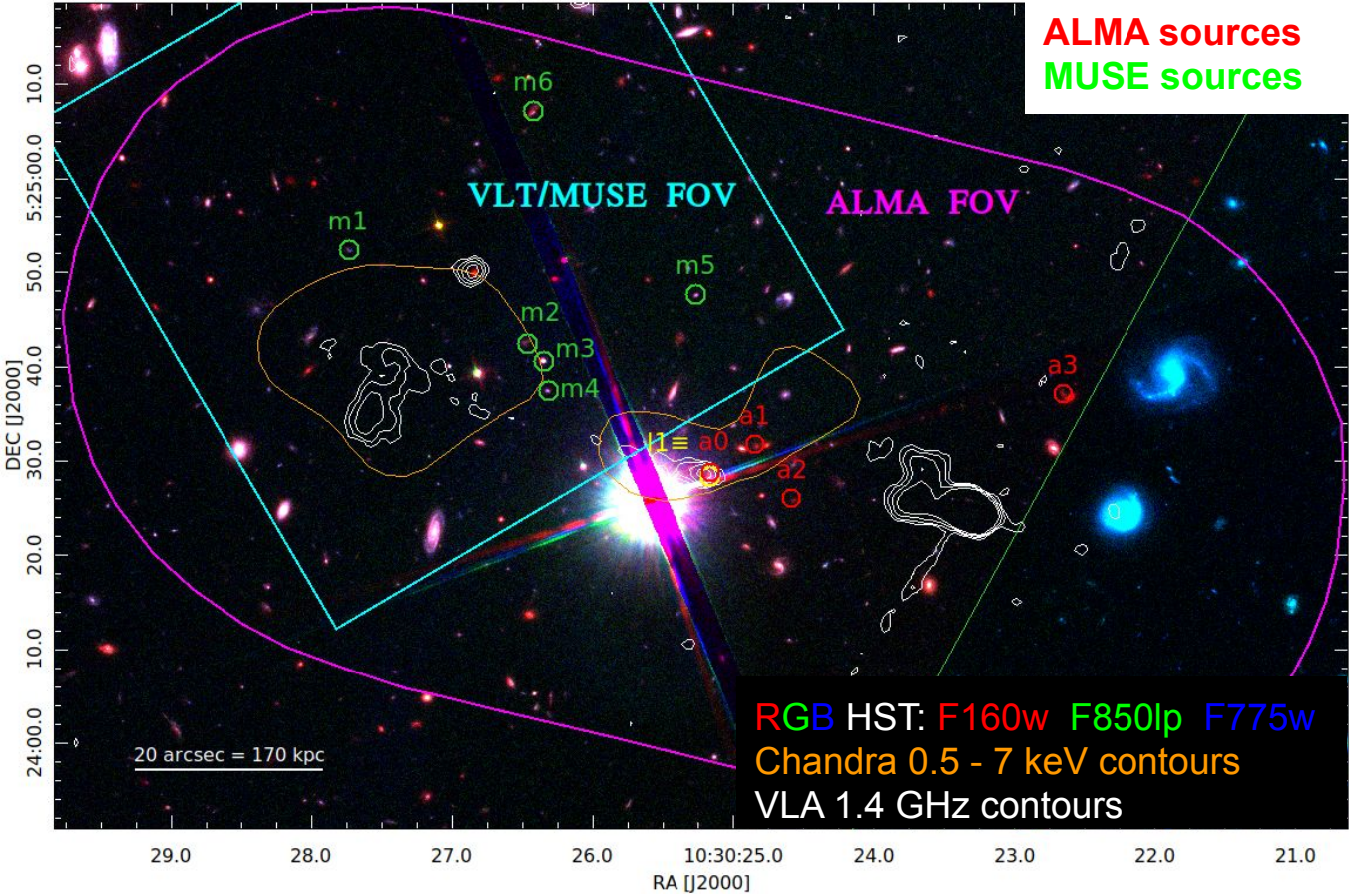
http://j1030-field.oas.inaf.it/



8 SFGs (6 VLT/MUSE + 2 LBT/LUCI) found at z~1.7 around a powerful FRII at center of the field.

X-ray extended emission likely linked to positive AGN feedback on nearby galaxies. (Gilli+19)

ALMA CO(2-1) observation



We discovered **3 new gas rich (M_{H2}~1.5-4.8×10^{10} $M_\odot$) members (a1, a2, a3)** of the overdensity, and unveiled the presence of a **large molecular gas reservoir around the FRII host galaxy (a0)**

MUSE sources are not detected in ALMA

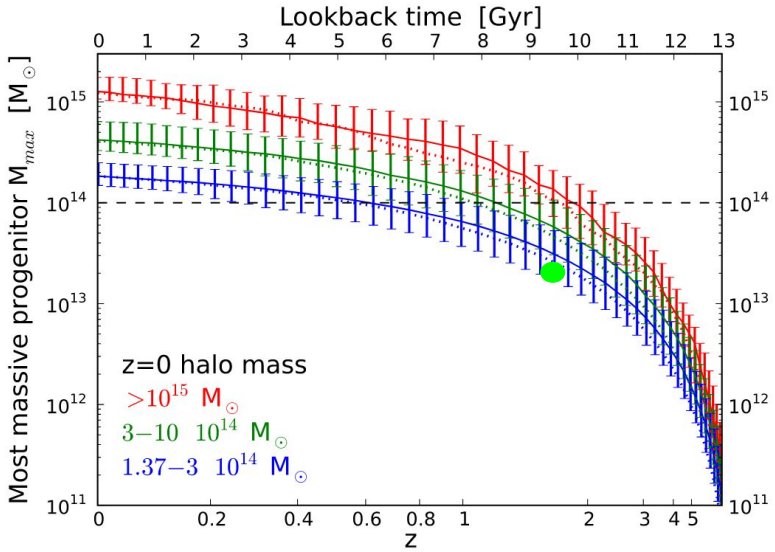
3σ-upper limit to $M_{H2} < 2.8-4.8 \times 10^{10}\ M_\odot$

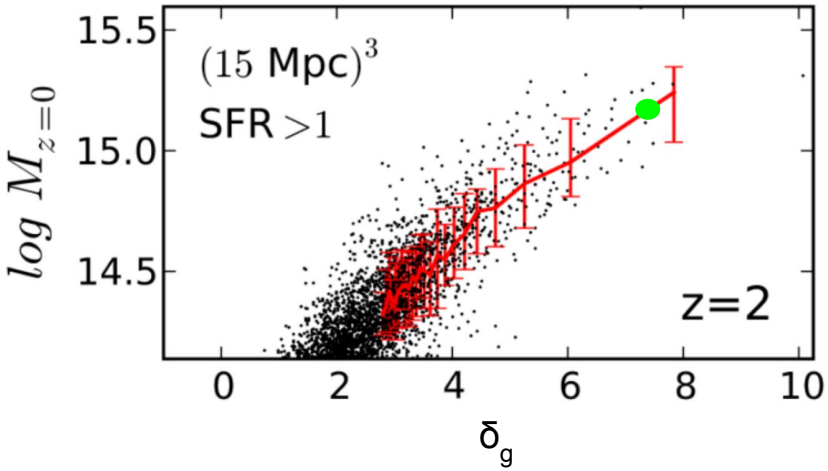
D'Amato+20b

A protocluster signpost

Most massive halo mass:
$40 \times M_{*,BCG} \approx 2 \times 10^{13}\ M_\odot$ (Behroozi+13)

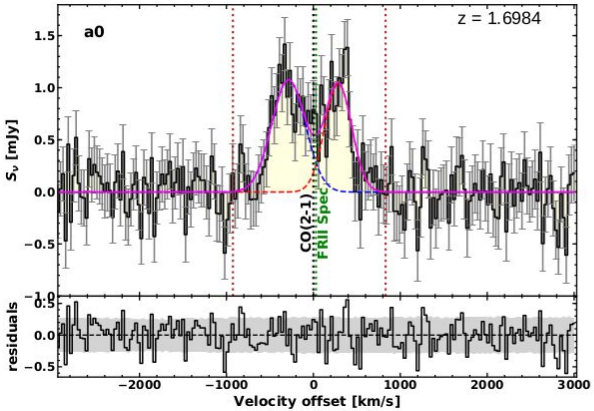
$\delta_g \gtrsim 7.4$ (Gilli+19, D'Amato+20)

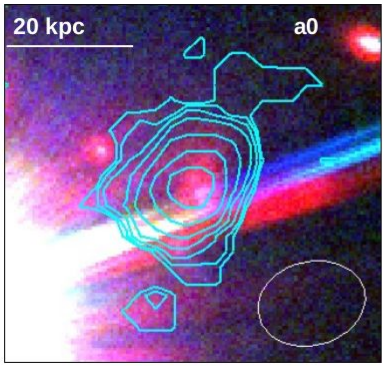


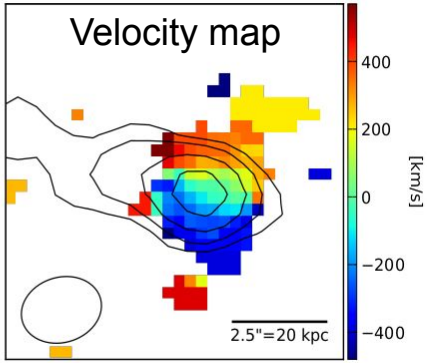


Based on the expected evolution of the most massive halo and of the overdensity level (Chiang+13) we estimate that **the system will likely evolve into a $\gtrsim 10^{14}\ M_\odot$ cluster at z=0**

FRII host galaxy: the future BCG







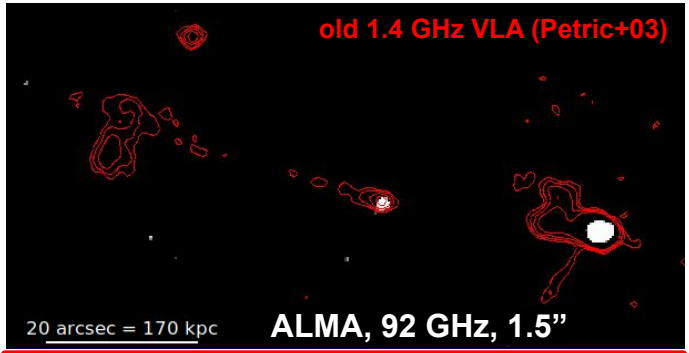
We discovered a large gas reservoir (M_{H2}≈2×10^{11} $M_\odot$) on a scale of ~27×17 kpc^2 around the powerful FRII core.

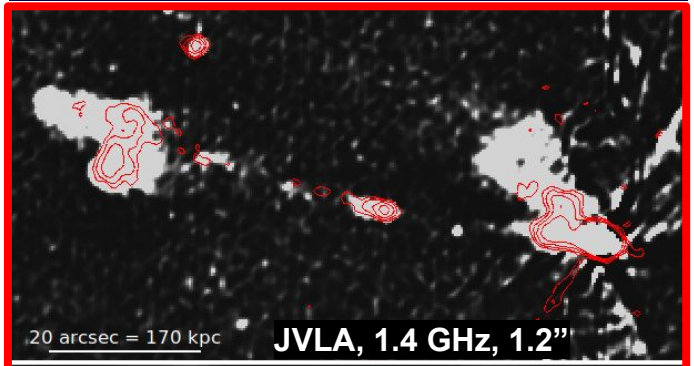
($L_{2-10\ keV}$~1.3×10^{44} erg/s; $P_{408\ MHz}$~10^{26} W/Hz/sr, M_* = 3 × 10^{11} $M_\odot$, **SFR~200-600 $M_\odot$/yr**)

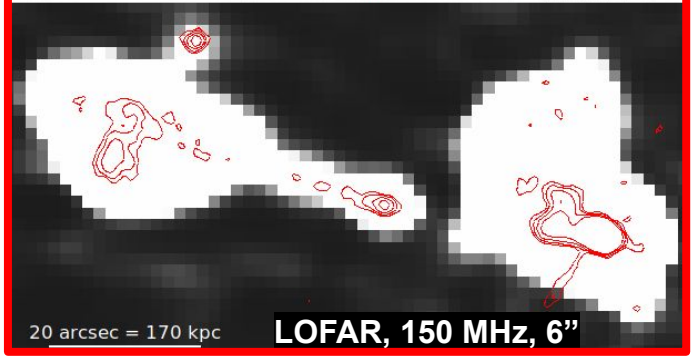
All this, coupled with the central position and $v_{peak,off}$ = 200 km/s (compared to σ_v~ 440 km/s)

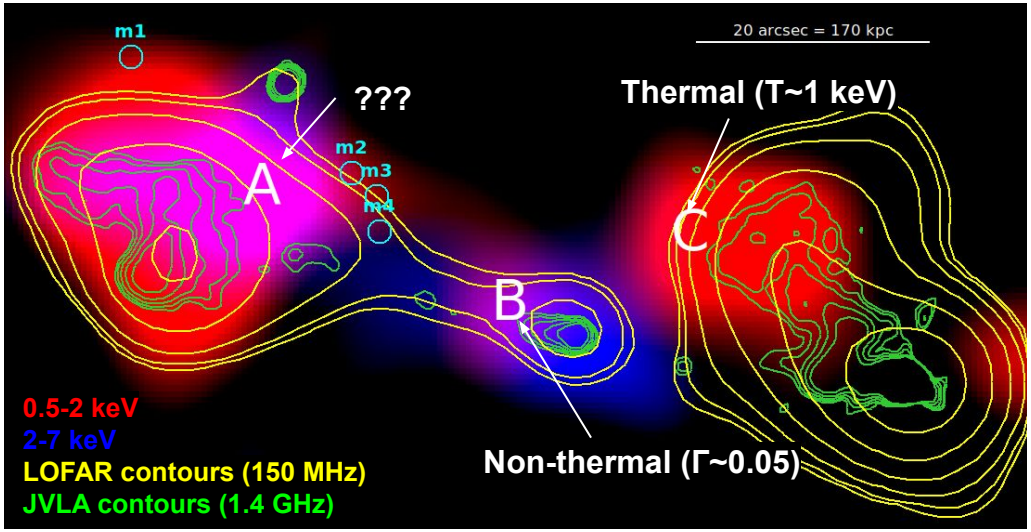
strongly suggests that the FRII will likely evolve into the future BCG.

FRII emission: relation to X-ray?









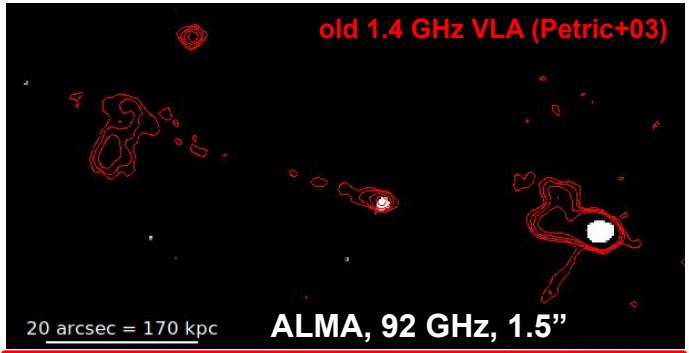
Component A: possible combination of thermal and non-thermal (IC-CMB) emission

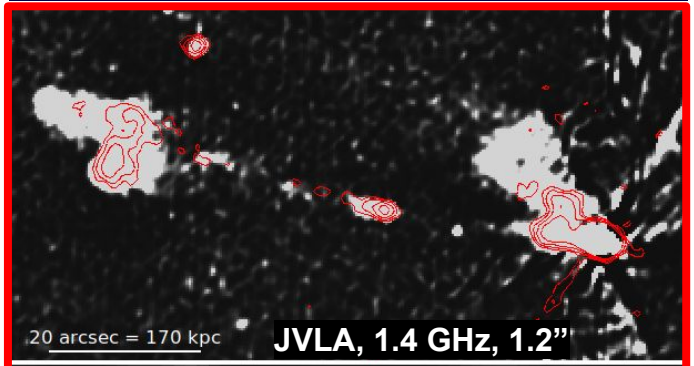
From old **VLA** east-lobe flux: (Gilli+19)

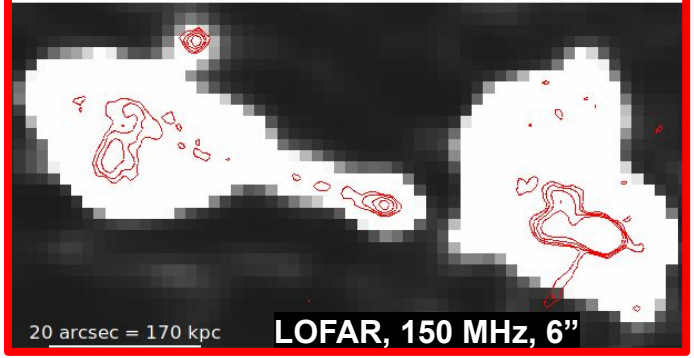
B_{eq}~5 μG (Miley 1980) ⟶ expected IC-CMB f_X ~ 60 times lower than measured by Chandra (Harris & Grindlay 1979)

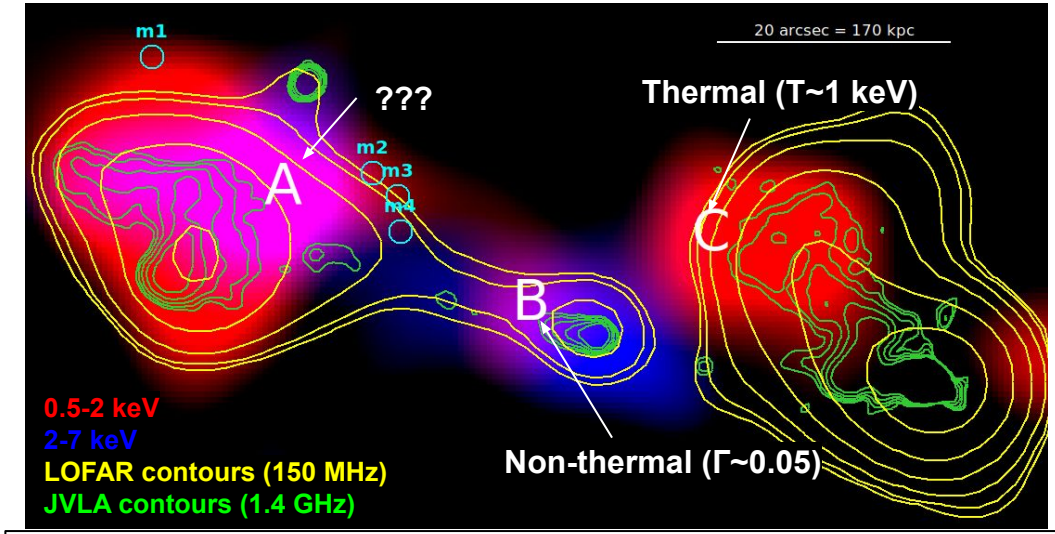
In case thermal emission is dominant: P_{hot}/P_{cold}~10^5

FRII emission: relation to X-ray?









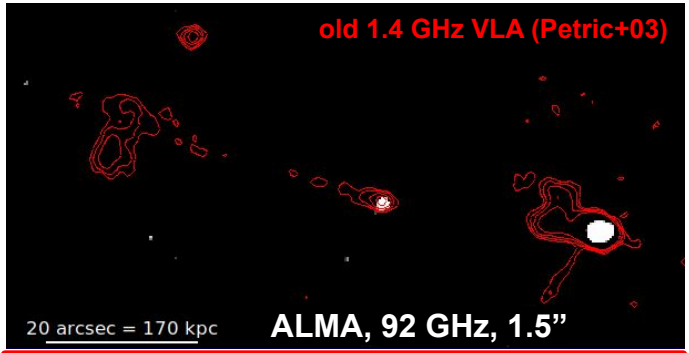
Component A: possible combination of thermal and non-thermal (IC-CMB) emission

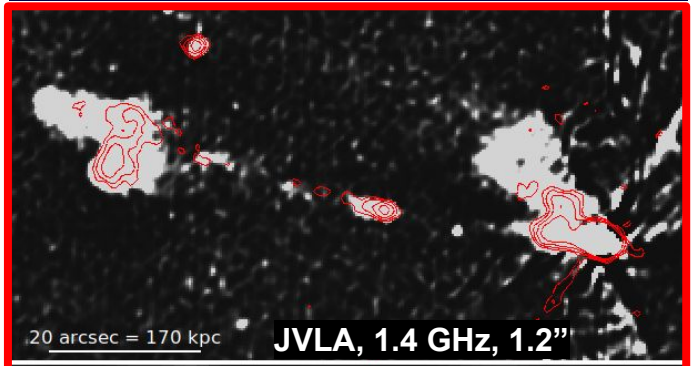
From new **LOFAR** east-lobe flux: (probes larger volume filled by magnetized plasma)

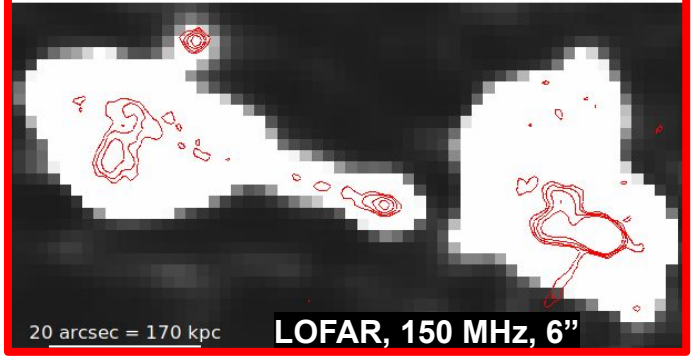
B_{eq}~3.5 μG (Miley 1980) ⟶ expected IC-CMB f_X ~ at least 40-90 % of that measured by Chandra. However, also in the IC-CMB scenario: $P_{tot} = 7/(72\pi)*B^2$ (state of minimum energy)

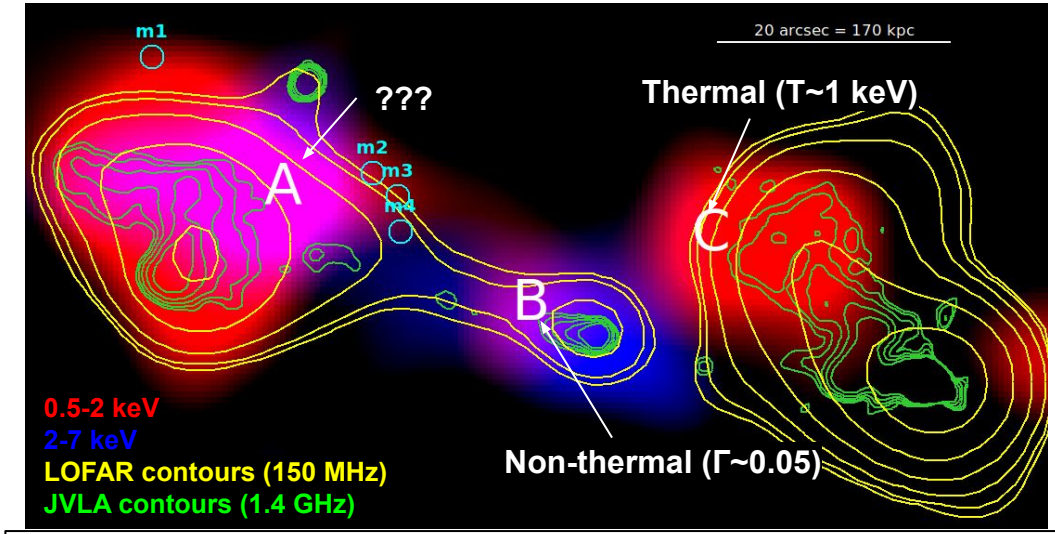
P_{hot}/P_{cold}>100 (Brienza et al.)

FRII emission: relation to X-ray?





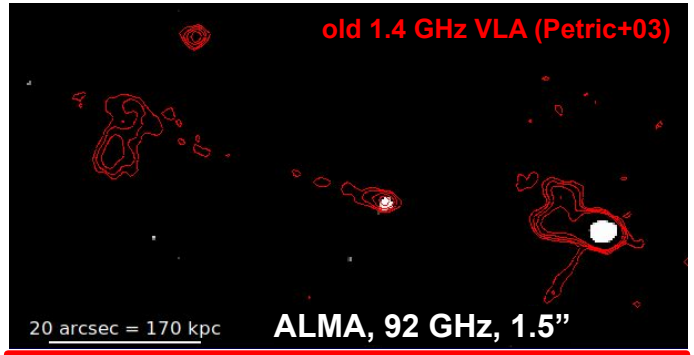


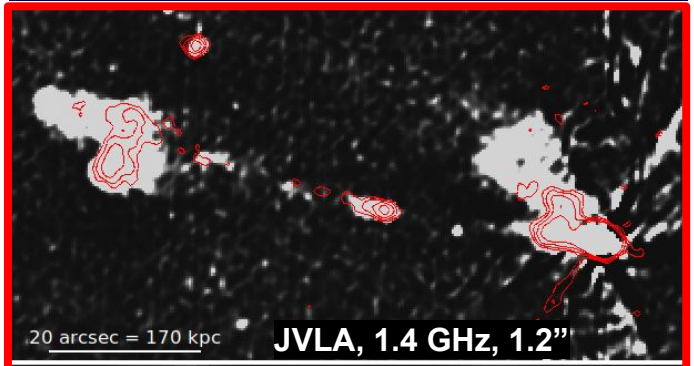


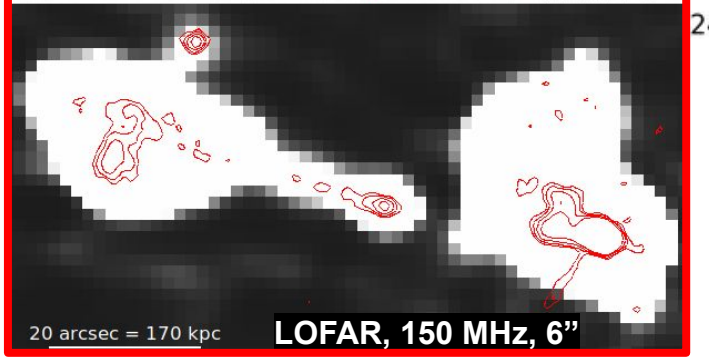
Component A: possible combination of thermal and non-thermal (IC-CMB) emission

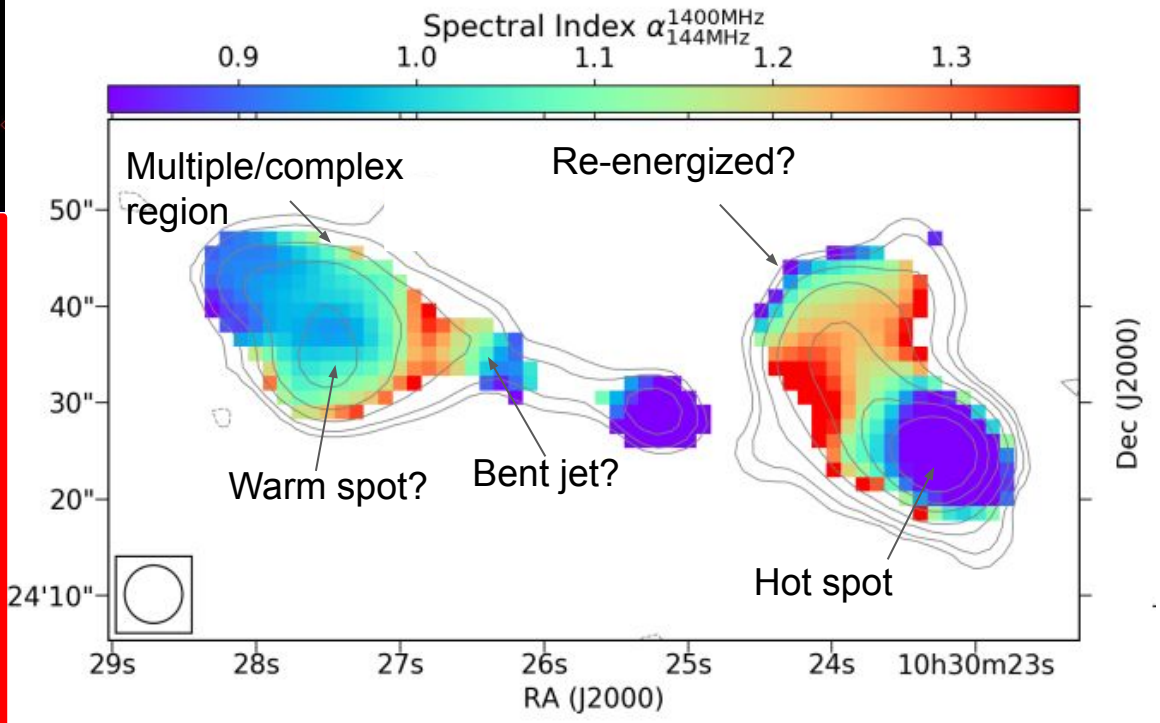
- System may not be at equipartition state (Migliori+07, Isobe+11)
- Large uncertainties on the physics and geometry of the source
- Actual cold medium distribution and size?
- Missing WIM?

FRII emission: Spectral index map



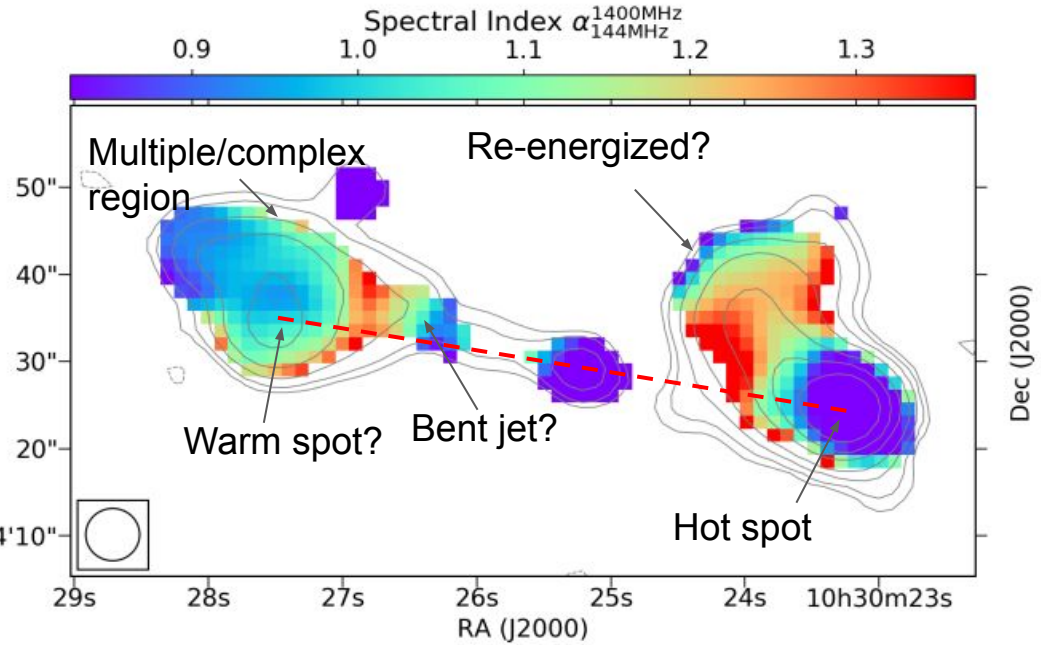






Lobes show flattening of the radio spectra beyond classical hot spots. (Brienza et al., in prep)

FRII emission: Eastern lobe



We see flattening in the multiple spot where the jet ends, but considerations about the jet length, emission and directions point towards the warm spot

Inclination angle:

- From jet base flux ratio:

  R_{jet}=6 β(assumed)=0.75, p=2, α_{jet}=1.25

$$R_{jet} = [(1+k)/(1-k)]^{p+\alpha_{jet}}$$

$$k \equiv \beta cos(\theta)$$

k~0.14 θ~80°

- From jet length ratio:

$$L_j / L_{cj} = (1+k)/(1-k)$$

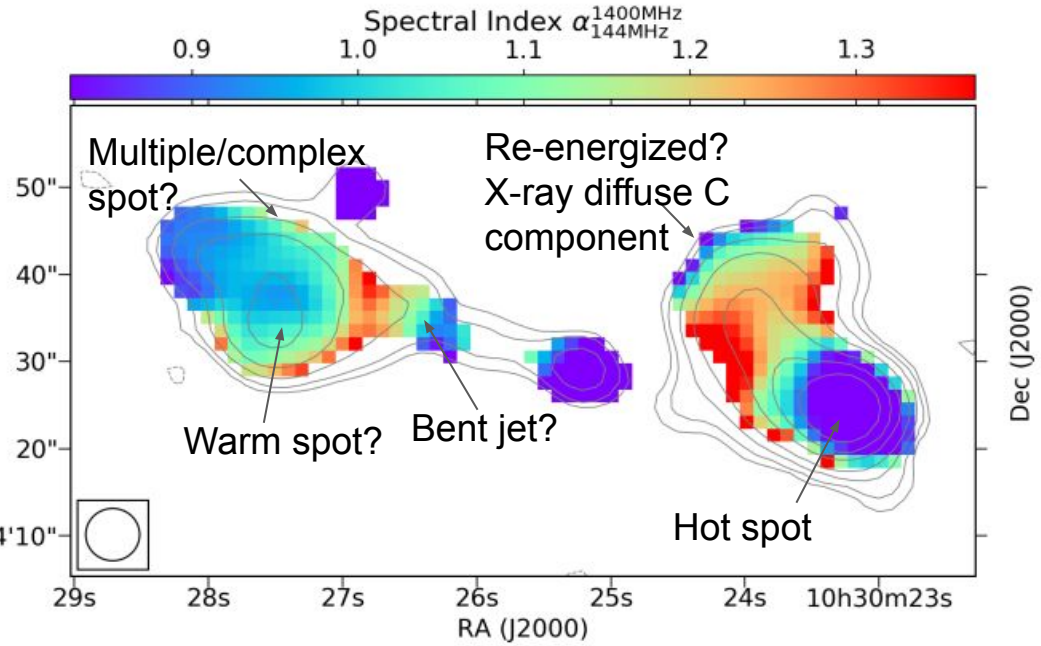
Assuming L_j to warm spot:

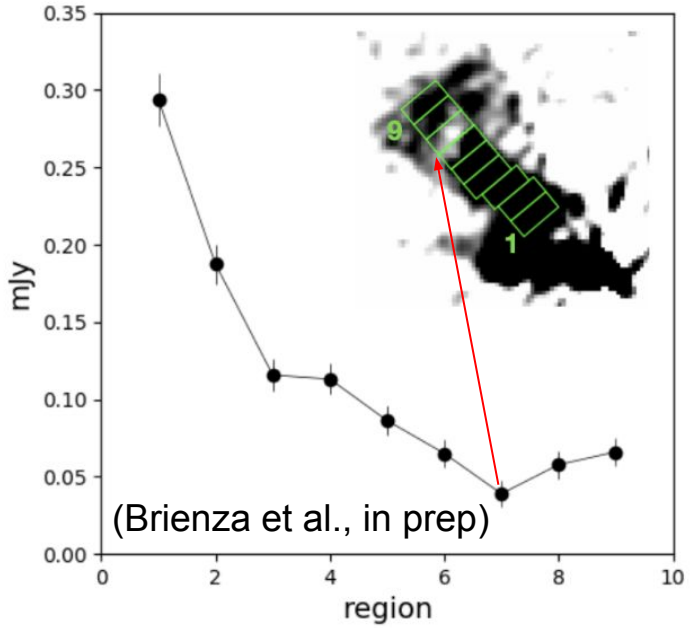
k~0.14

Assuming L_j to end of complex spot:

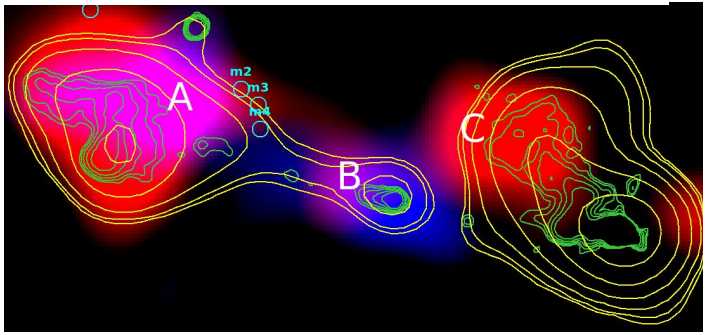
k~0.25

FRII emission: Western lobe





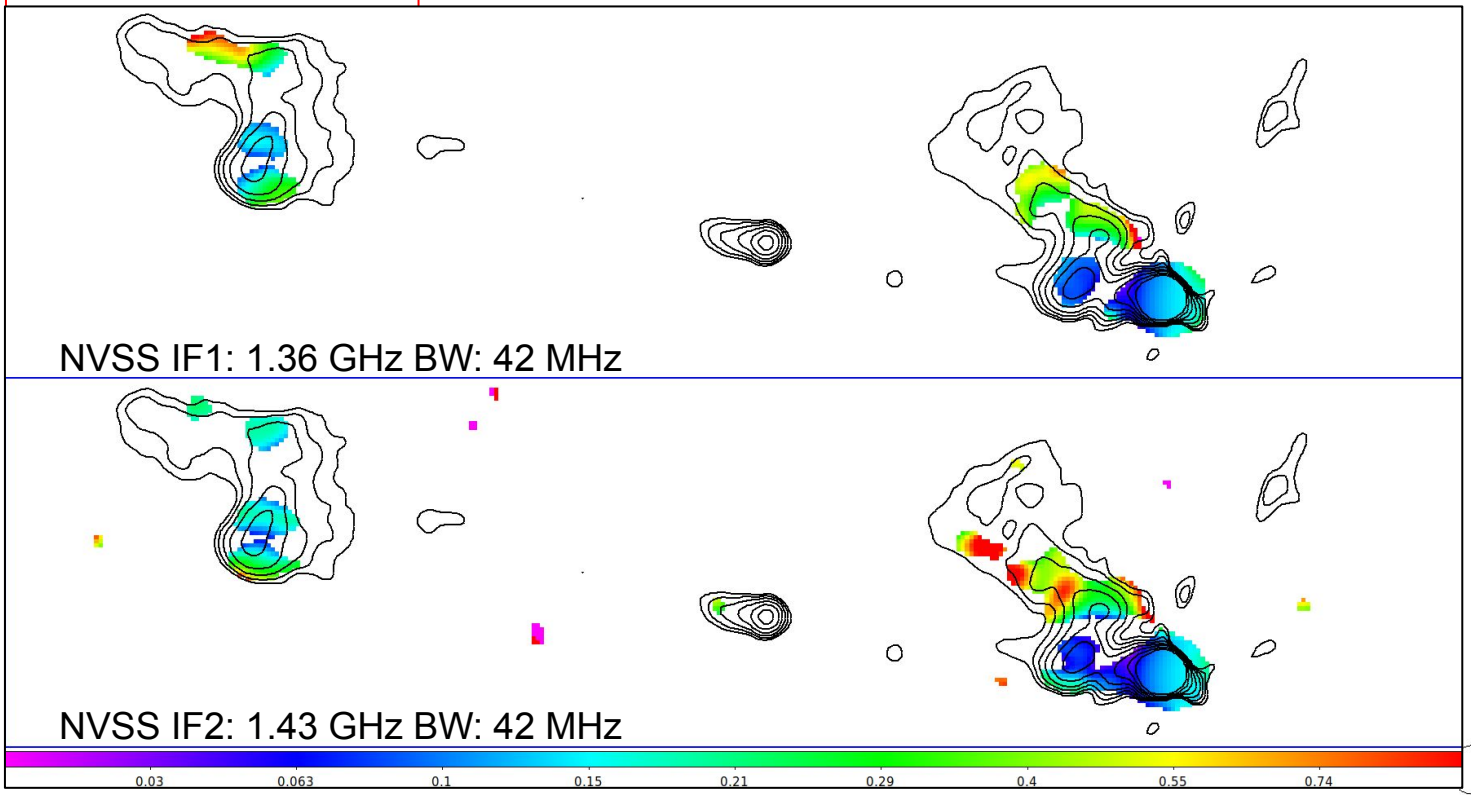
In the Western lobe the flux density increases and the spectral index flattens towards the edge of the diffuse emission, cospatial with the thermal X-ray emission

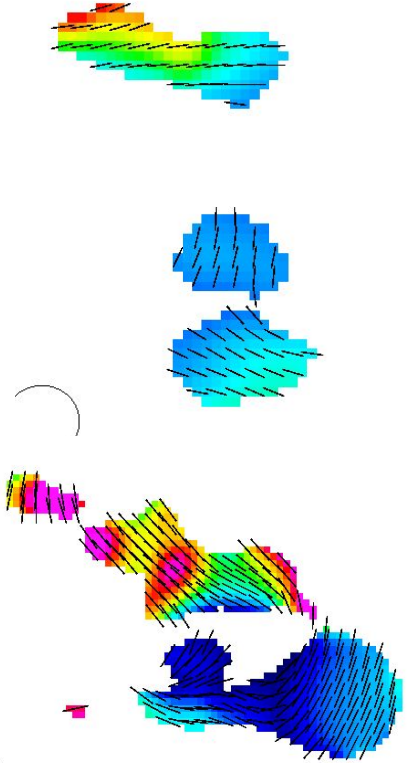


PRELIMINAR RESULTS!!!

FRII emission: Polarization

Shock front?





Conclusions

- We unveiled the presence of at least 11 members of the structure, 4 of which being gas-rich SFGs, and of a large molecular gas reservoir around the FRII host galaxy. We showed that the system will likely evolve into a $\gtrsim 10^{14}$ $M_{\odot}$ cluster at z=0 and that the FRII is likely the future BCG.
- Four SFGs lie in an arc-like shape at the edge of a diffuse X-ray emission around one lobe of the FRII, possibly ascribed to the FRII activity. If confirmed, this would be the first evidence of AGN positive feedback on multiple galaxies at hundred of kpc scale.
- J1030 z=1.7 proto-cluster is a great laboratory to investigate the role of the AGN in the formation and evolution of large scale structures.
  Multiwavelength approach is necessary to unveil the interplay between the several components of galaxies and IGM