Non Thermal Emission Beyond Galaxy Clusters

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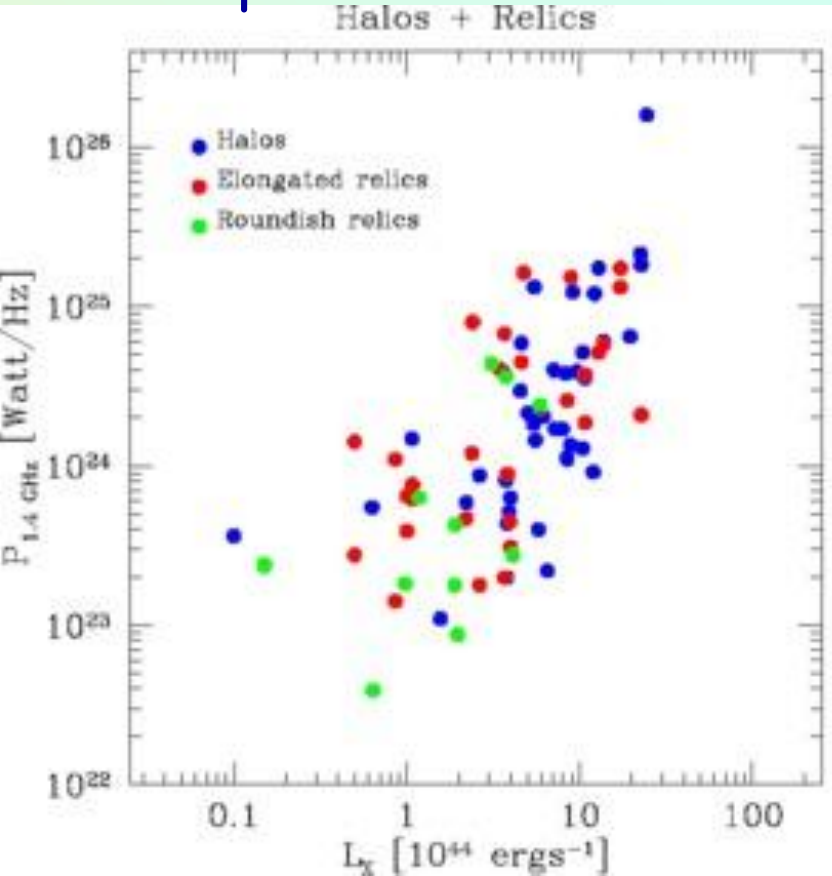
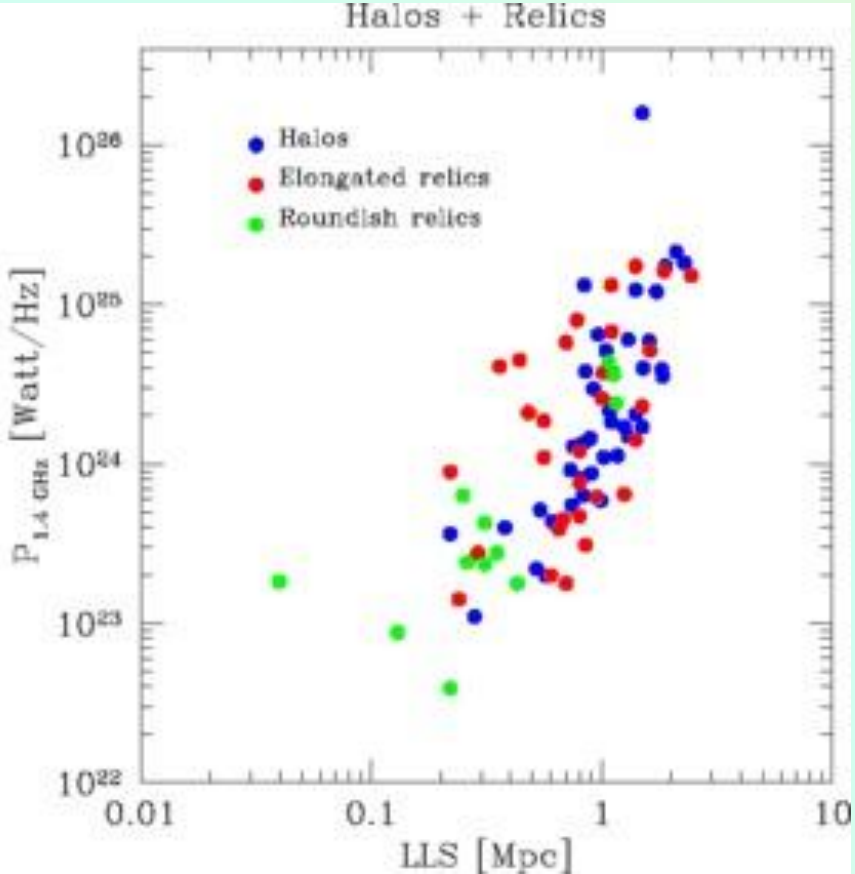
Halos and relics has been detected in several clusters (Feretti + 2012 for a recent review).

A strong correlation is present between the halo and relic radio power and the X-ray luminosity.
Since cluster X-Ray luminosity and mass are related, the correlation could derive from a physical dependence of the radio power on the cluster mass, therefore the cluster mass could be a crucial parameter in the formation of these sources.





I would like to present observational evidences of diffuse, non-thermal emission on larger scale (a few Mpc) and lower density with respect to galaxy clusters:

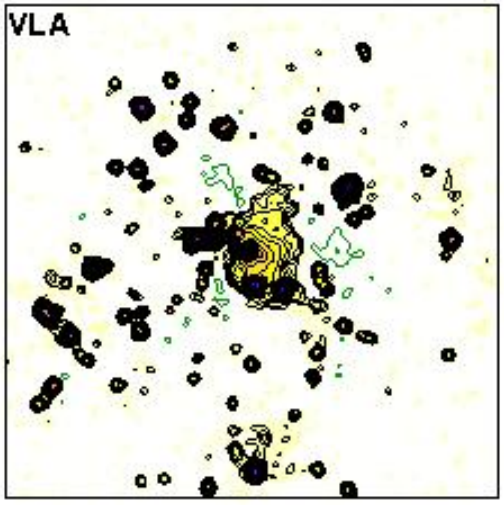
galaxy filaments connecting rich clusters and X-ray underluminous galaxy clusters

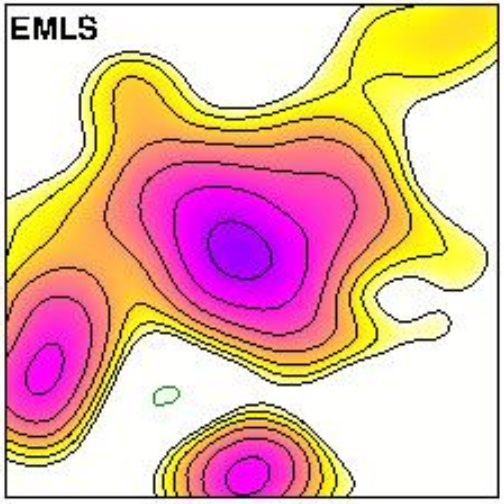
1) Halos could be larger than estimated up to now

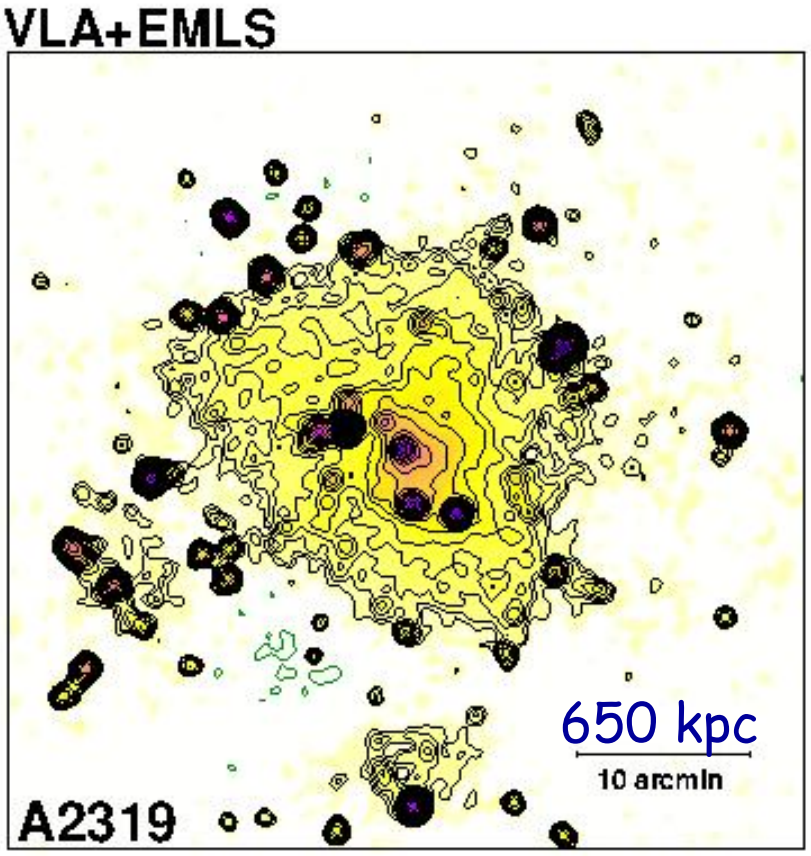
2) Bridges of diffuse radio emission have been found in a few clusters connecting radio halos and peripheral relics. These structures can trace the presence of non-thermal emission in filaments of merging groups into the main cluster.

A2319

Farnsworth + 2013 with GBT find a significant excess of diffuse, low surface brightness emission in 11 of 12 Abell clusters observed. We observed and combined VLA and Eb data for A2319:





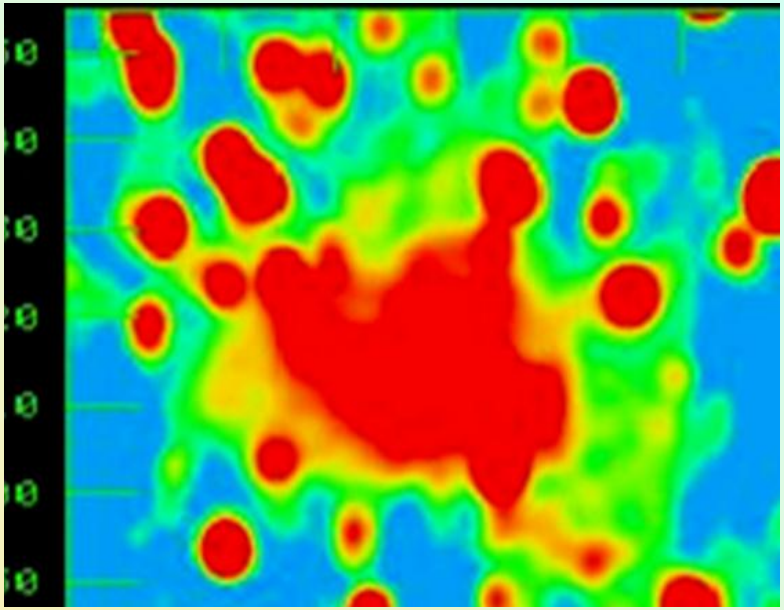


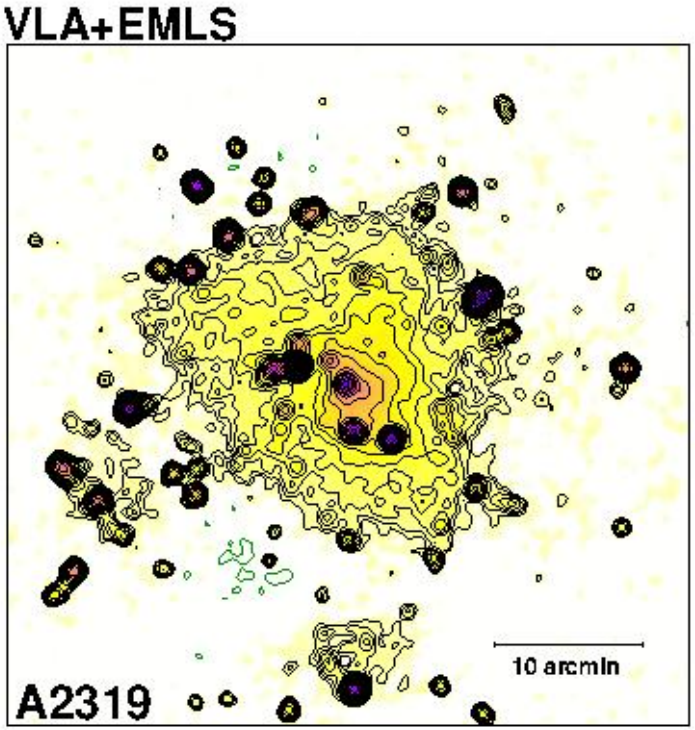
A2319 VLA Effelsberg combined

Murgia et al in preaparation

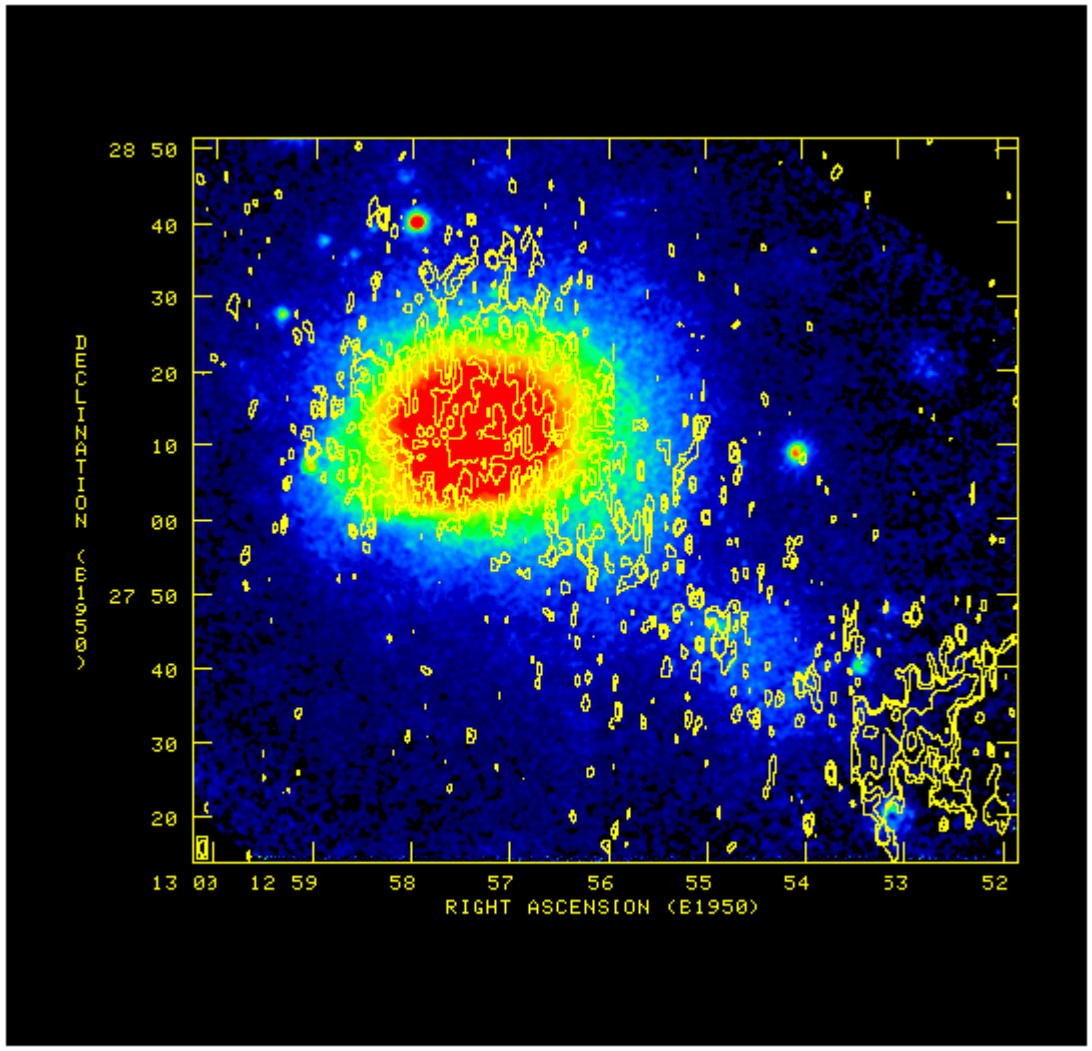
Storm et al. 2014 discuss multi-component nature of the radio halo in **A2319**:
The large-scale component may be the result of merger-driven turbulence
The inner brighter halo region could be related to a cluster slosh around its gravitational potential because of a recent merger

and in Coma…..



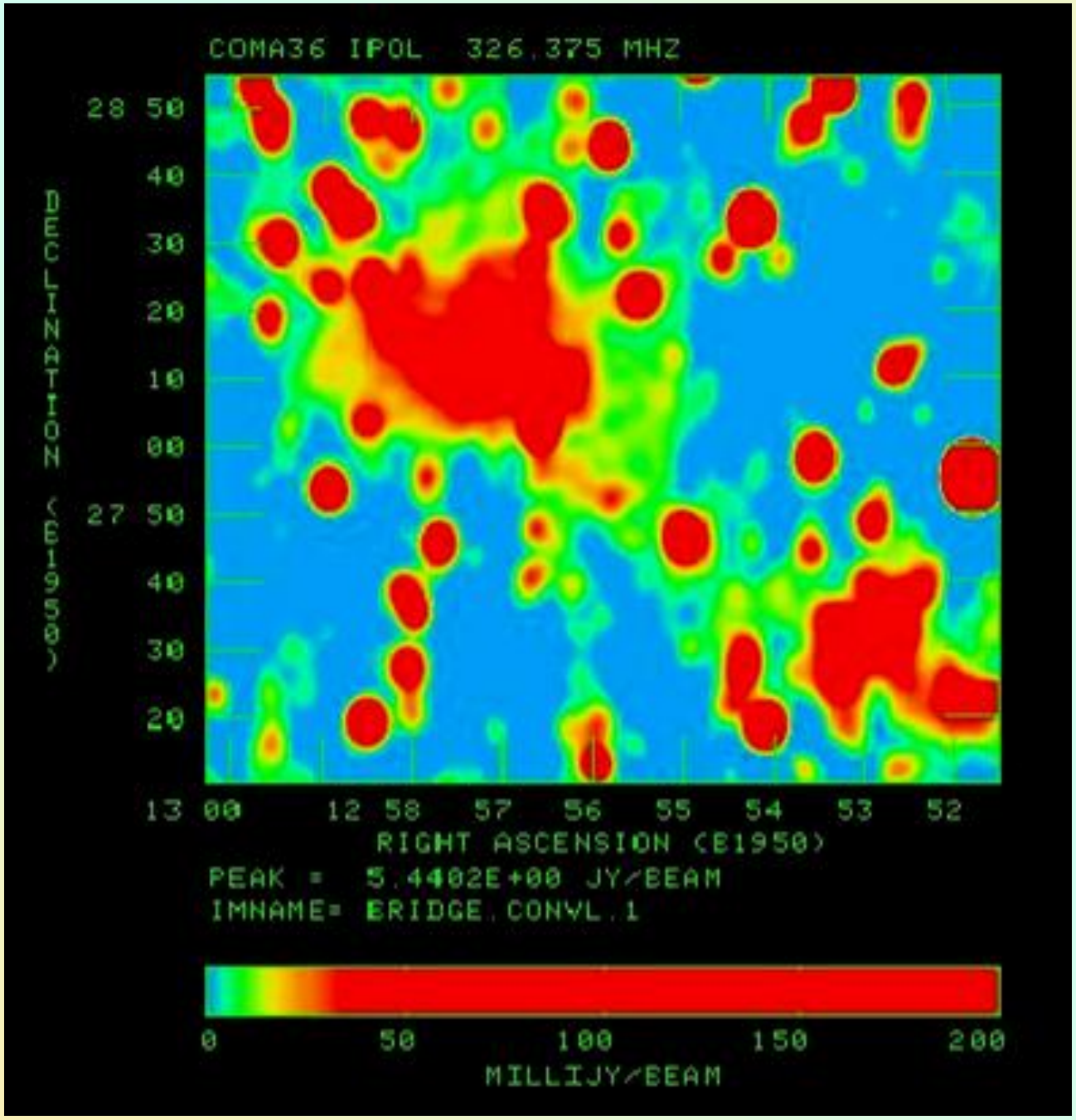


The best case of a radio bridge is the diffuse emission detected in the region connecting Coma and the relic 1253+275



In this region a small galaxy group merging in the Coma cluster is present and a filament structure is visible also in X-ray images.

This structure is oriented as the Coma-1367 supercluster.



Bridge between Coma C and 1253+275

WSRT 90 cm
HPBW 200"

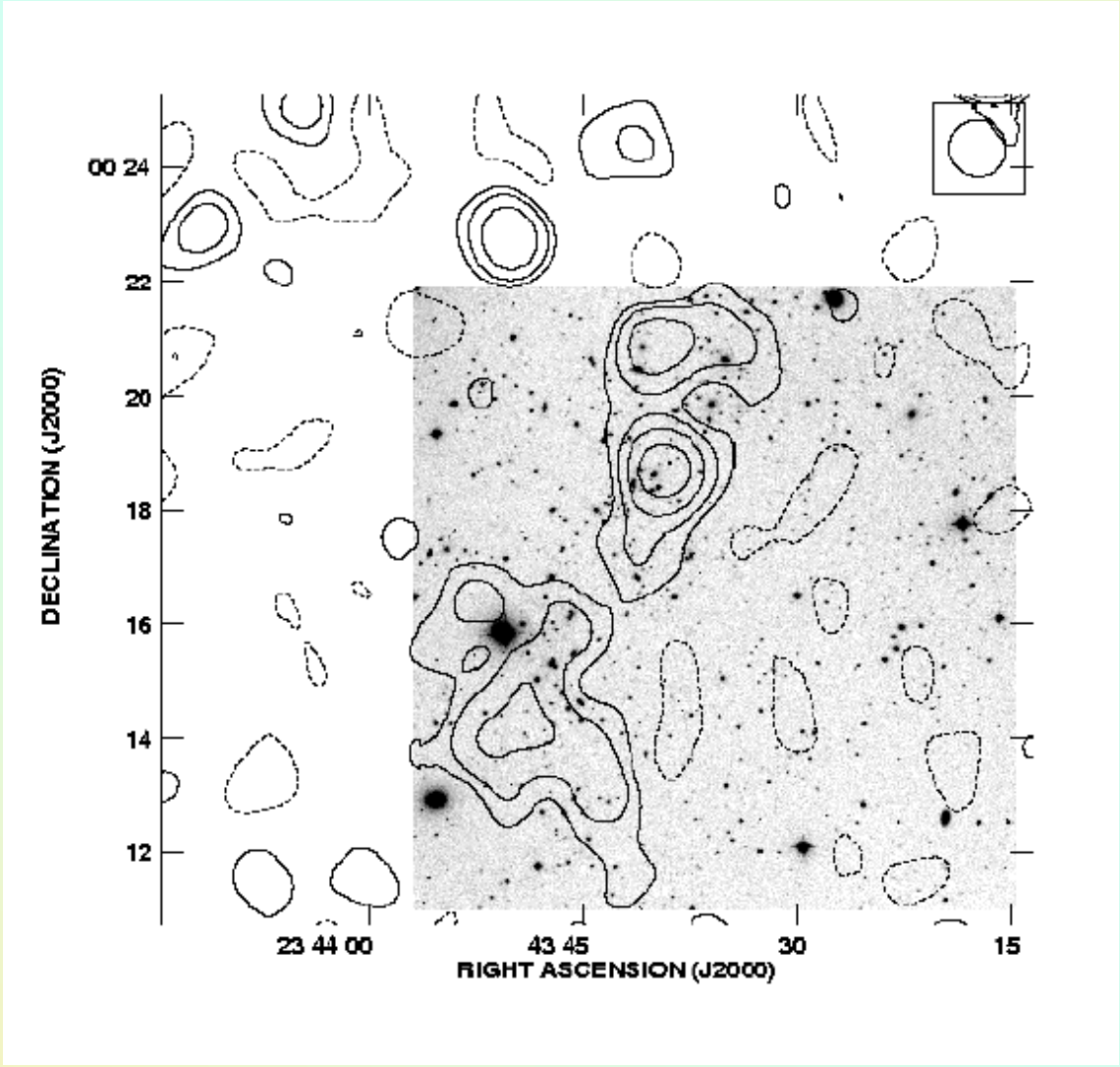
z=0.0232

'bridge' size ~ 1 Mpc

Giovannini et al. 1990
Kim et al. 1989

Similar features have been found in A2255 and A2744 (Feretti et al. 2012)

One of the best case is the filament of galaxies ZwCl 2341.1+0000

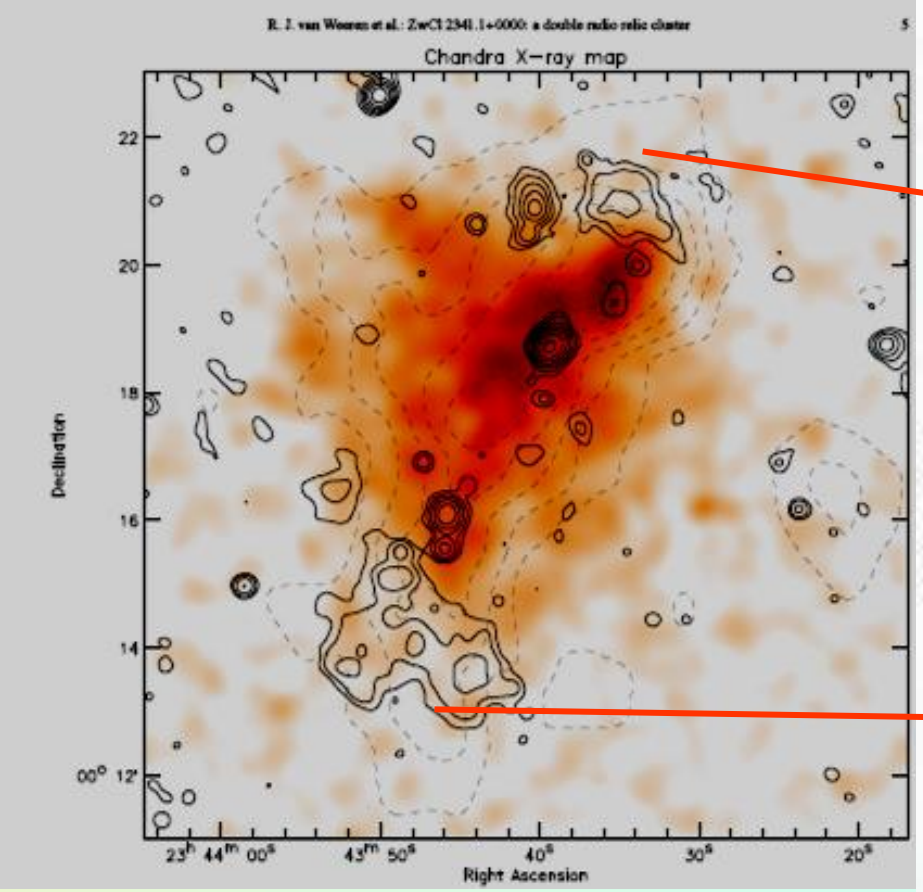


Size ~ 2-3 Mpc

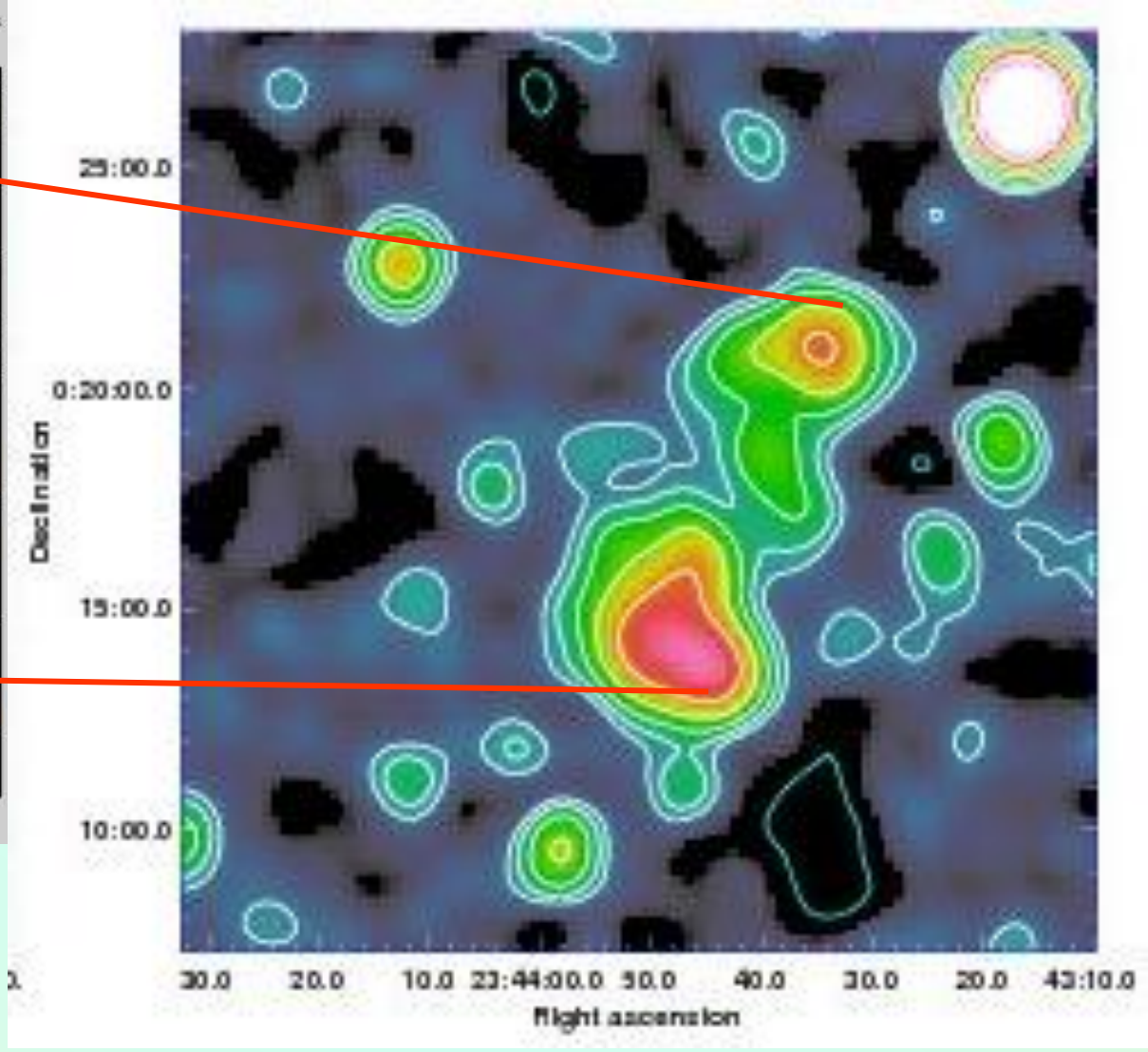
(Bagchi et al. 2002)

z ~ 0.27

conversion factor: 4.1 kpc/"

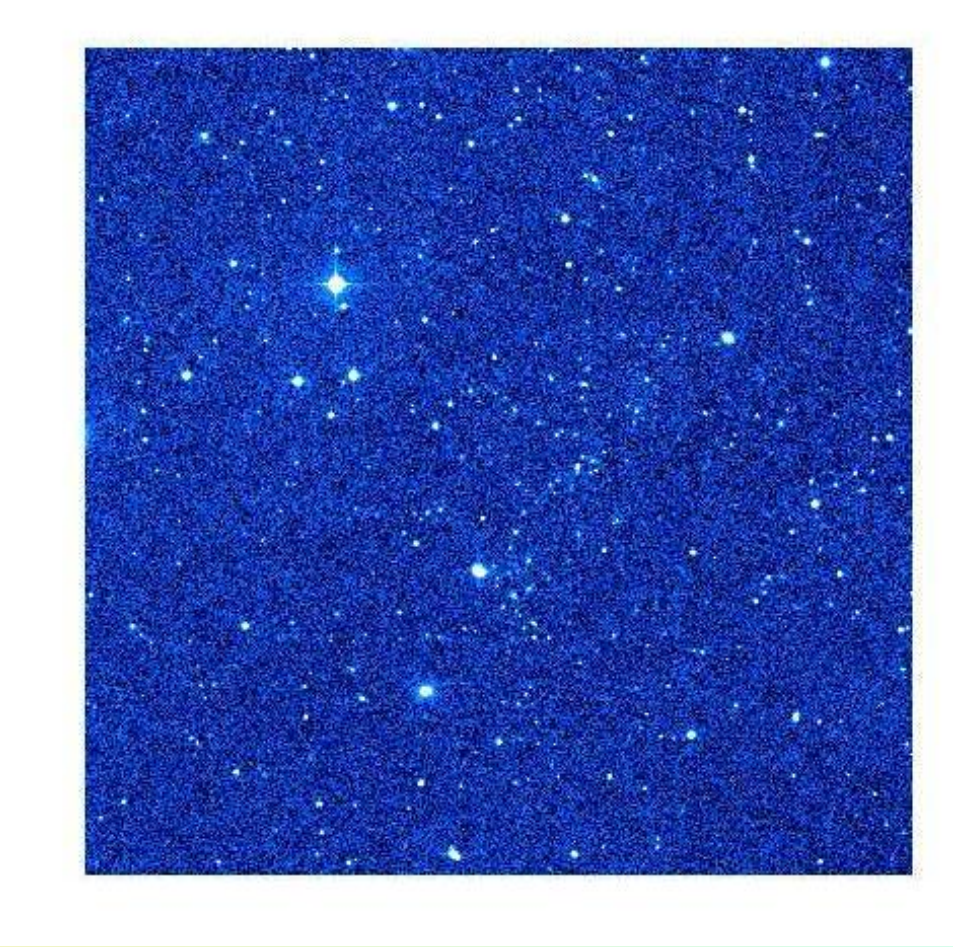


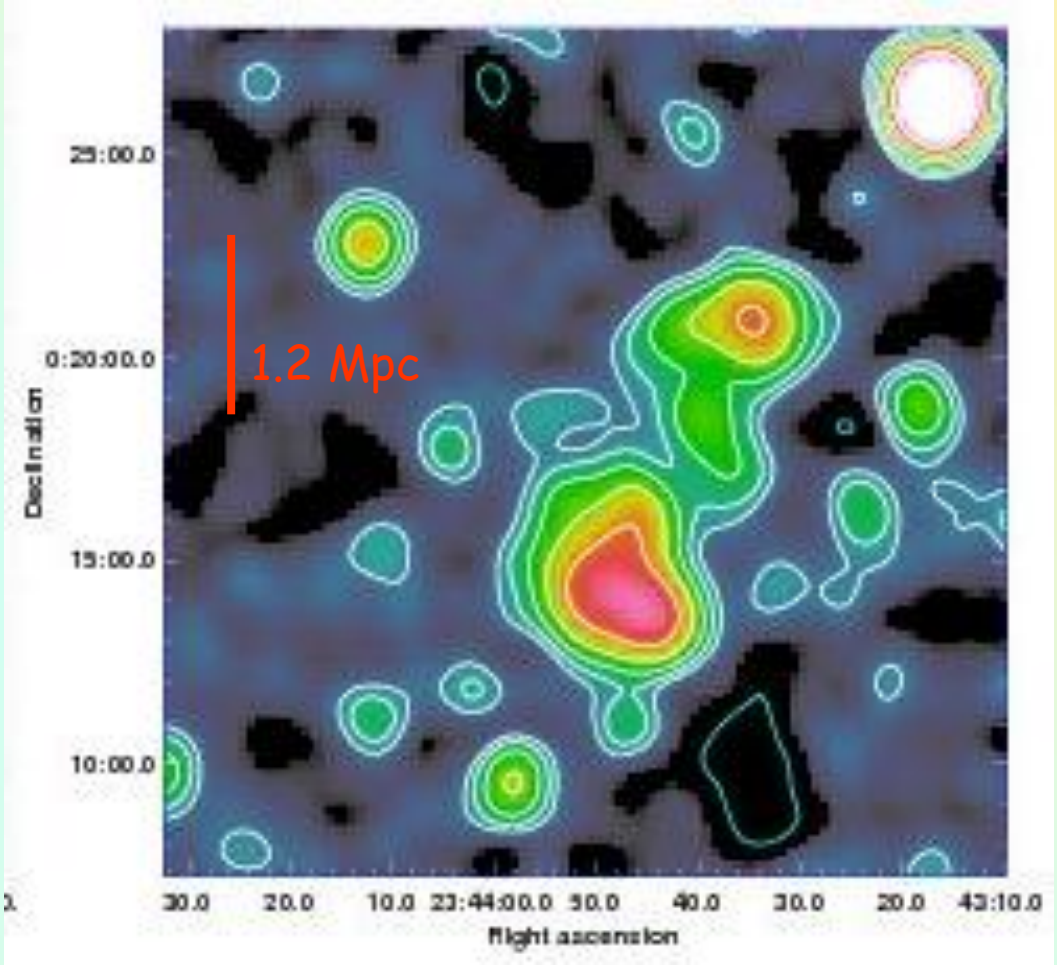
Van Weeren et al 2009
GMRT at 610 MHz



VLA-D at 1.4 GHz Giovannini et al. 2010

1.4 GHz VLA ~1.2′ resolution

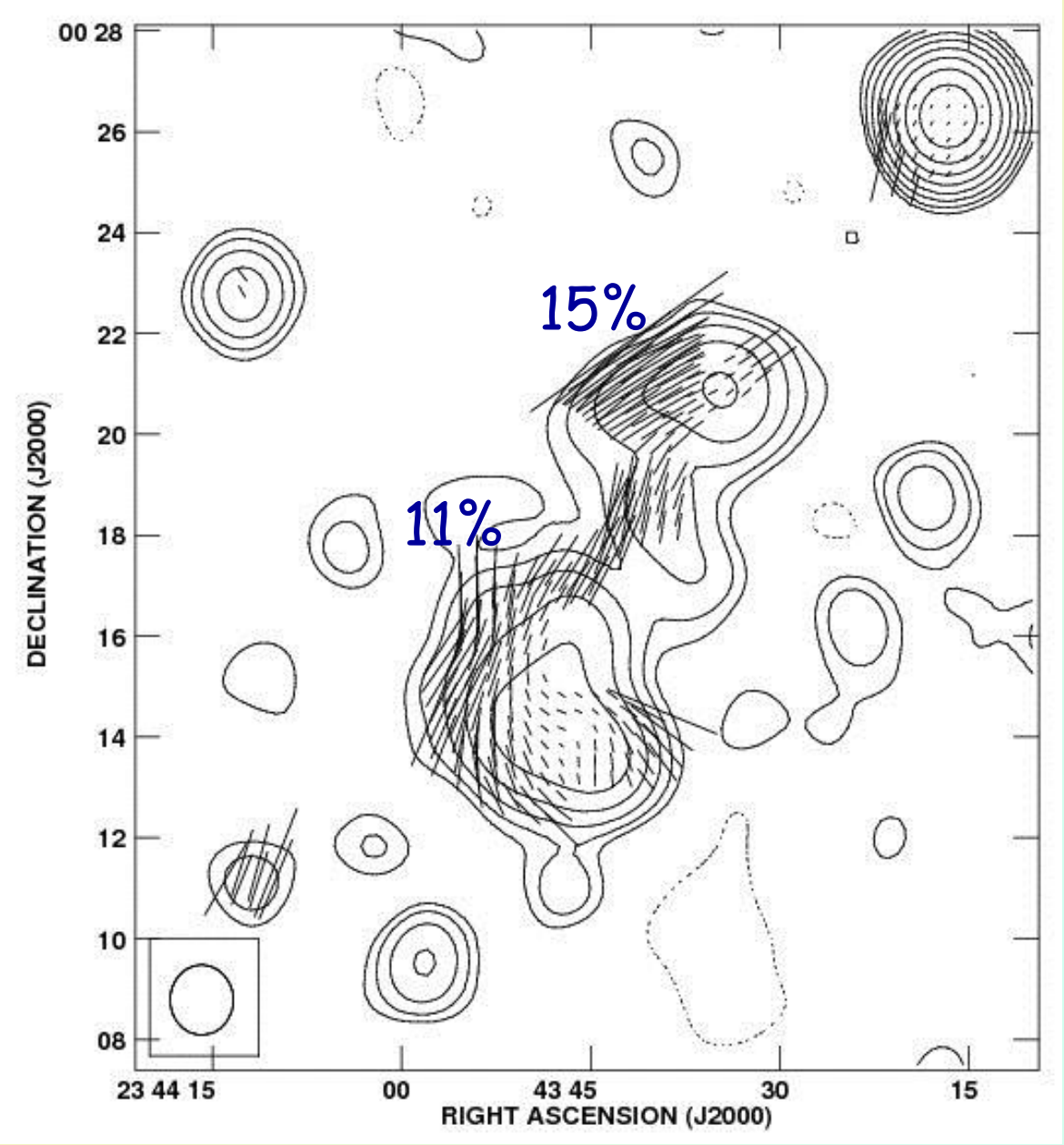




Equipartition magnetic field: 0.28×10^{-6} G
Total size: 2.2 Mpc
Log P(1.4): 23.66 W/Hz
Lx(Rosat): 5.6×10^{43} erg/s

Giovannini et al. 2010

1.4 GHz VLA ~1.2′ resolution



Giovannini et al. 2010

Ogrean et al. 2014: flat integrated spectral index in the two peripheral brightest regions (0.5 and 0.8)

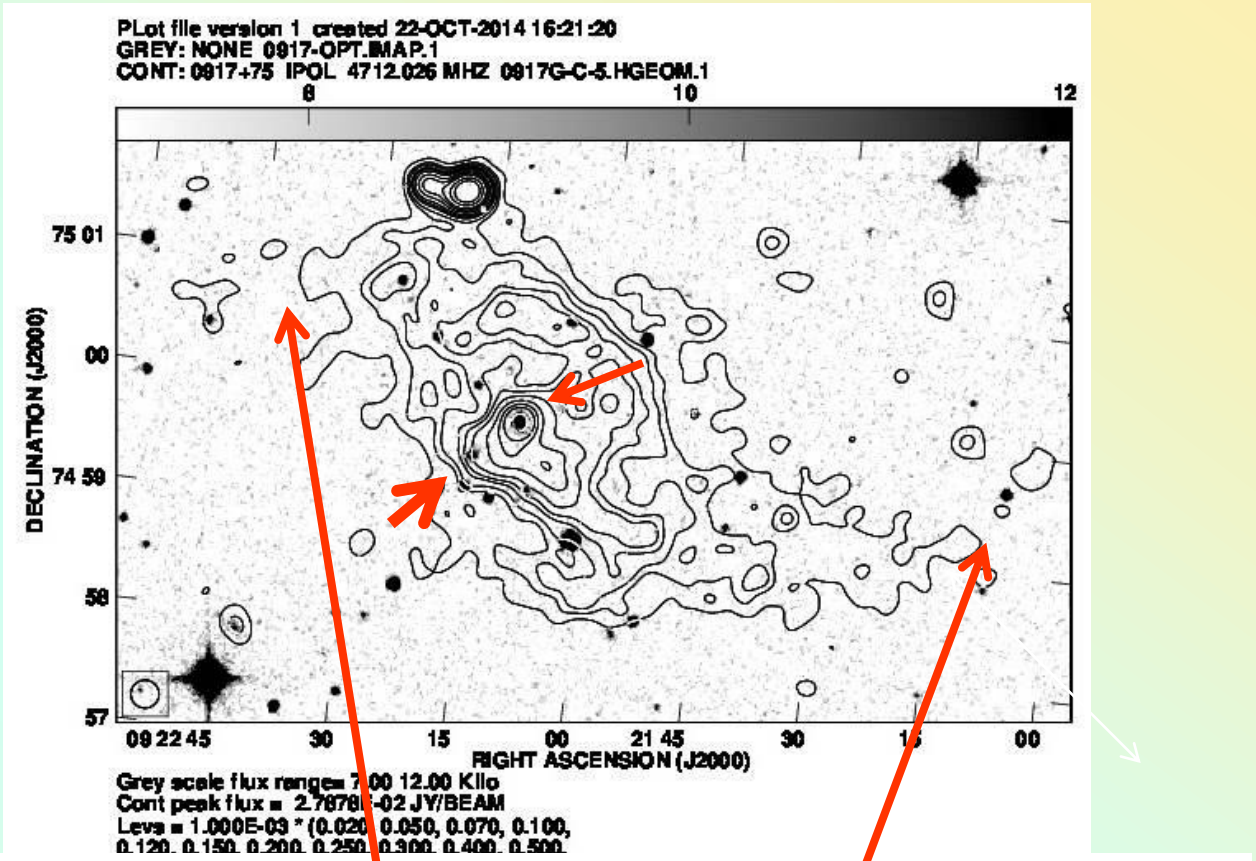
Discontinuity in X-ray emission but not in agreement with the presence of shocks

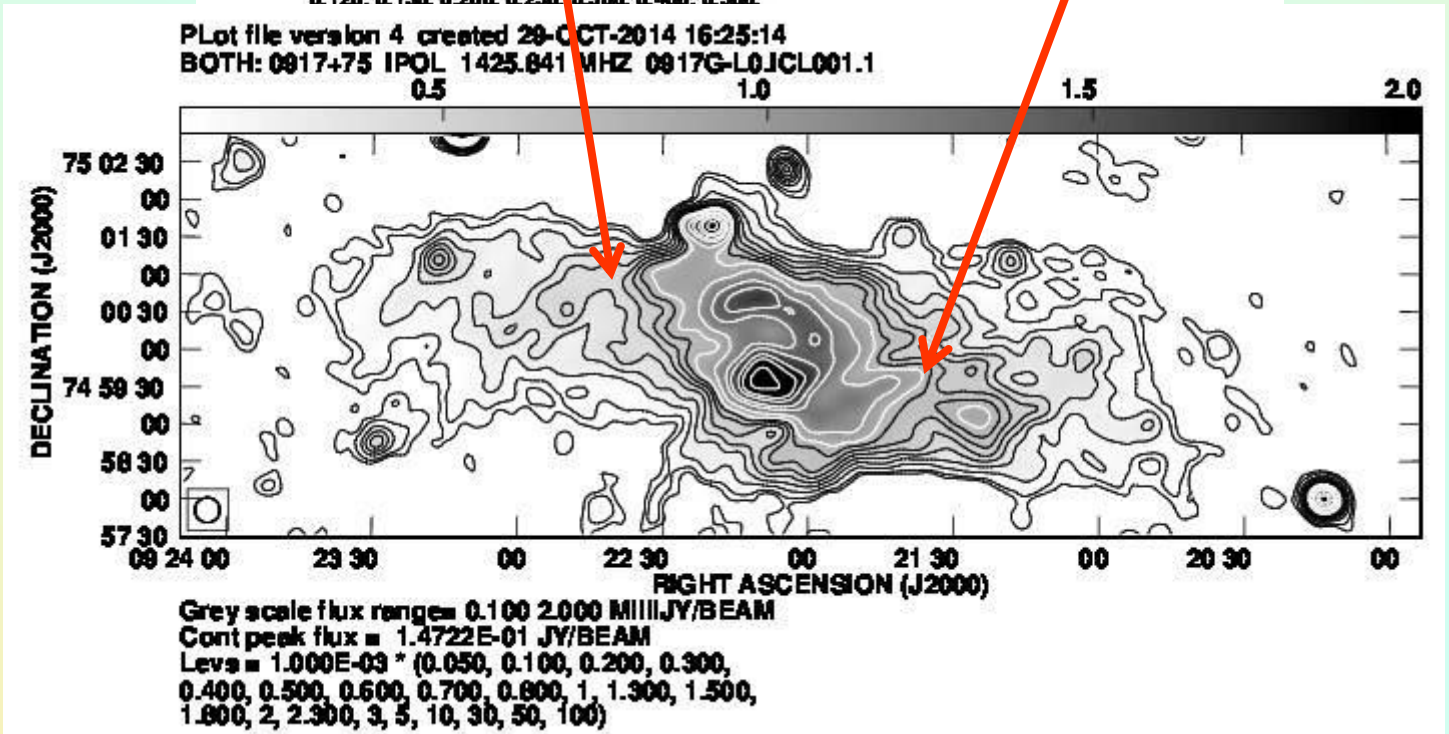
Boschin et al.: 2013: It is a massive system experiencing a large-scale structure formation with a complex multiple merger involving at least 3 bodies

Radio emission detected from galaxy filaments, it is due to peculiar conditions of merging activity among local sub-groups, able to amplify the magnetic fields and accelerate relativistic particles

Diffuse emission 0917+75

Two galaxies at z=0.125



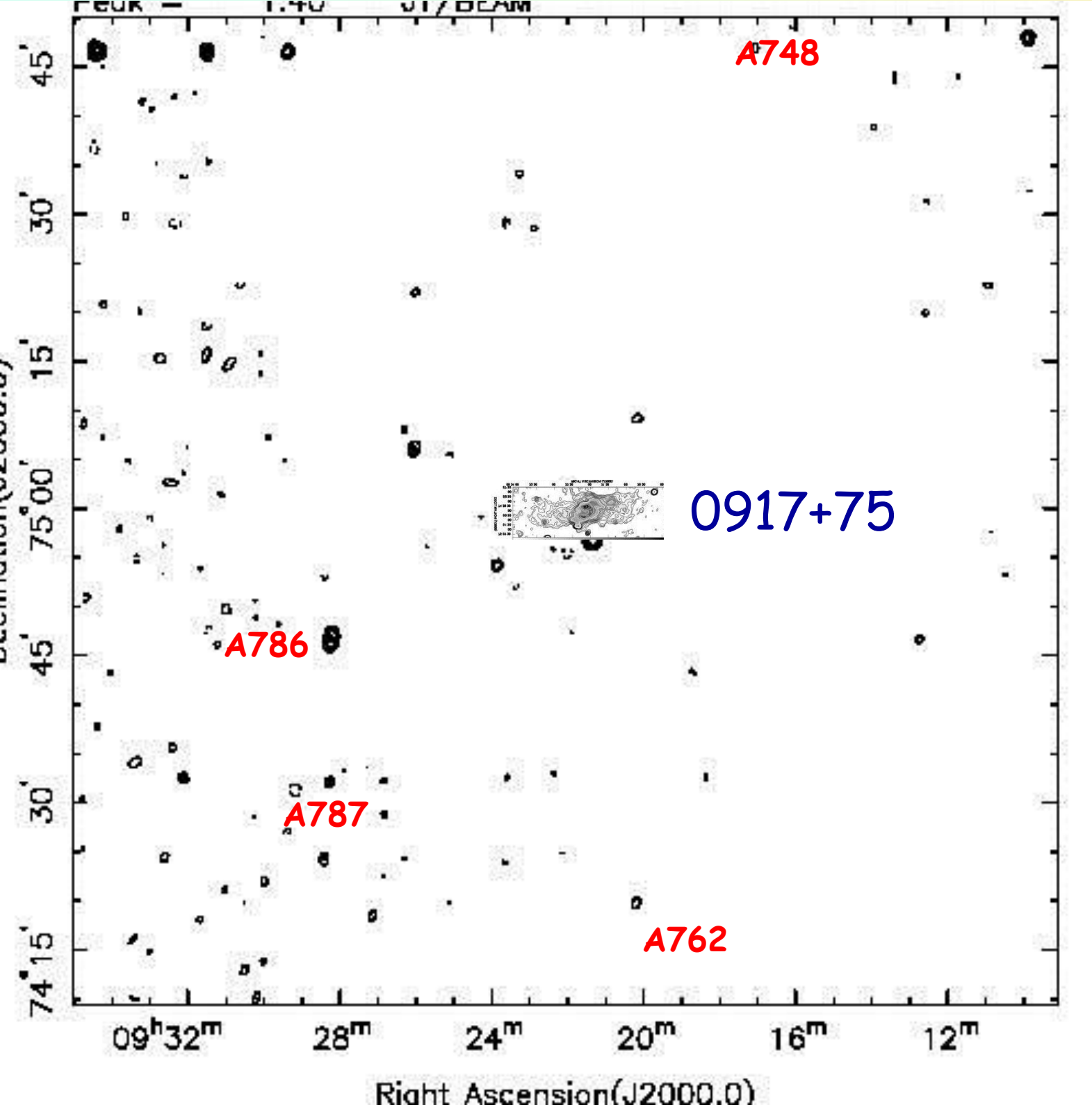


Optical inspection shows the presence of a filament of galaxies with colours in agreement with a redshift of 0.12 -- 0.13.

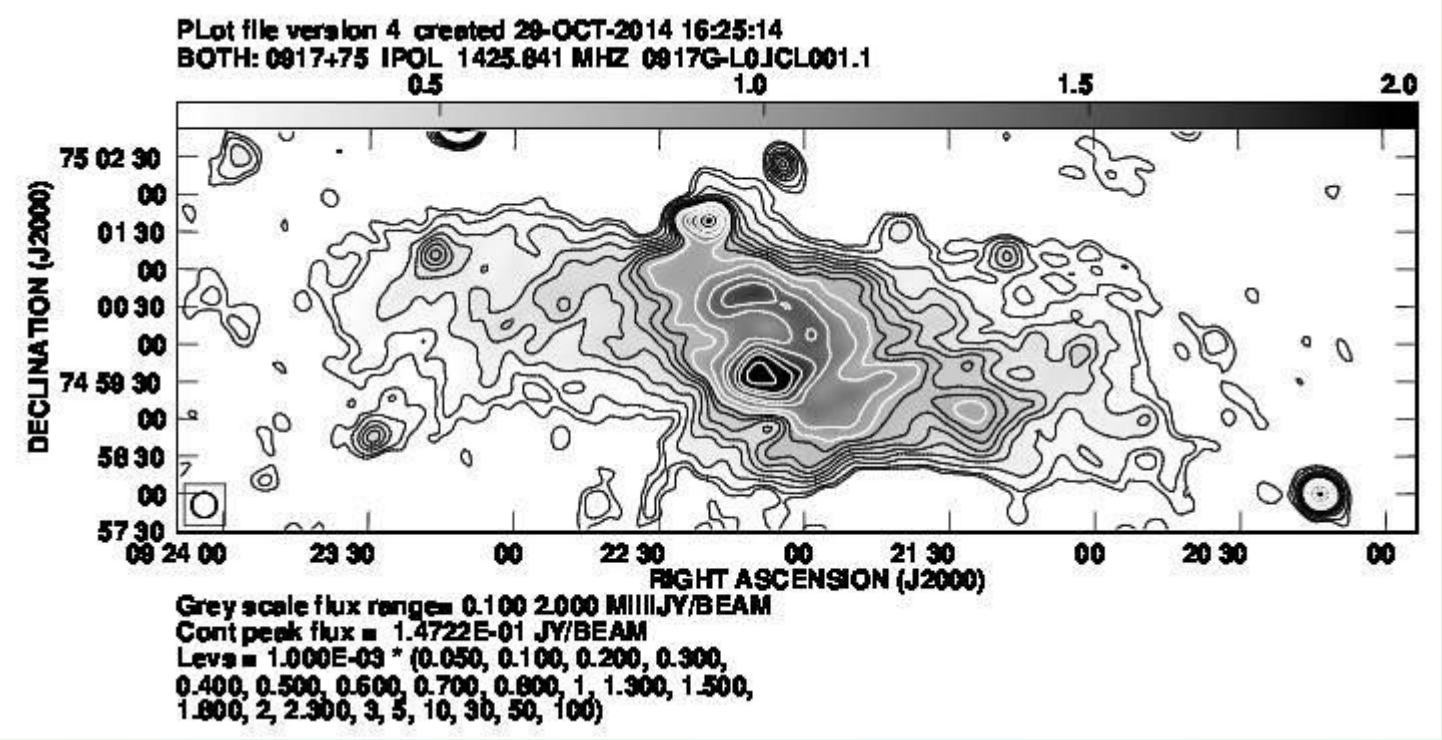
This filament connect nearby clusters at the same distance (Girardi et al., in progress).

A786 (z=0.124) 4Mpc	09 28 50	74 47 55
A787 (z=0.135) 5.6Mpc	09 27 22	74 26 25
A762(z=0.135) 6.3 Mpc	09 19 04	74 17 22
A748(z=0.136) 7.7 Mpc	09 16 24	75 46 31
A765(0.133) 9.9Mpc	09 20 22	73 50 12

Diffuse emission at 09 22 00 75 00 00



From VLSSr
74MHz



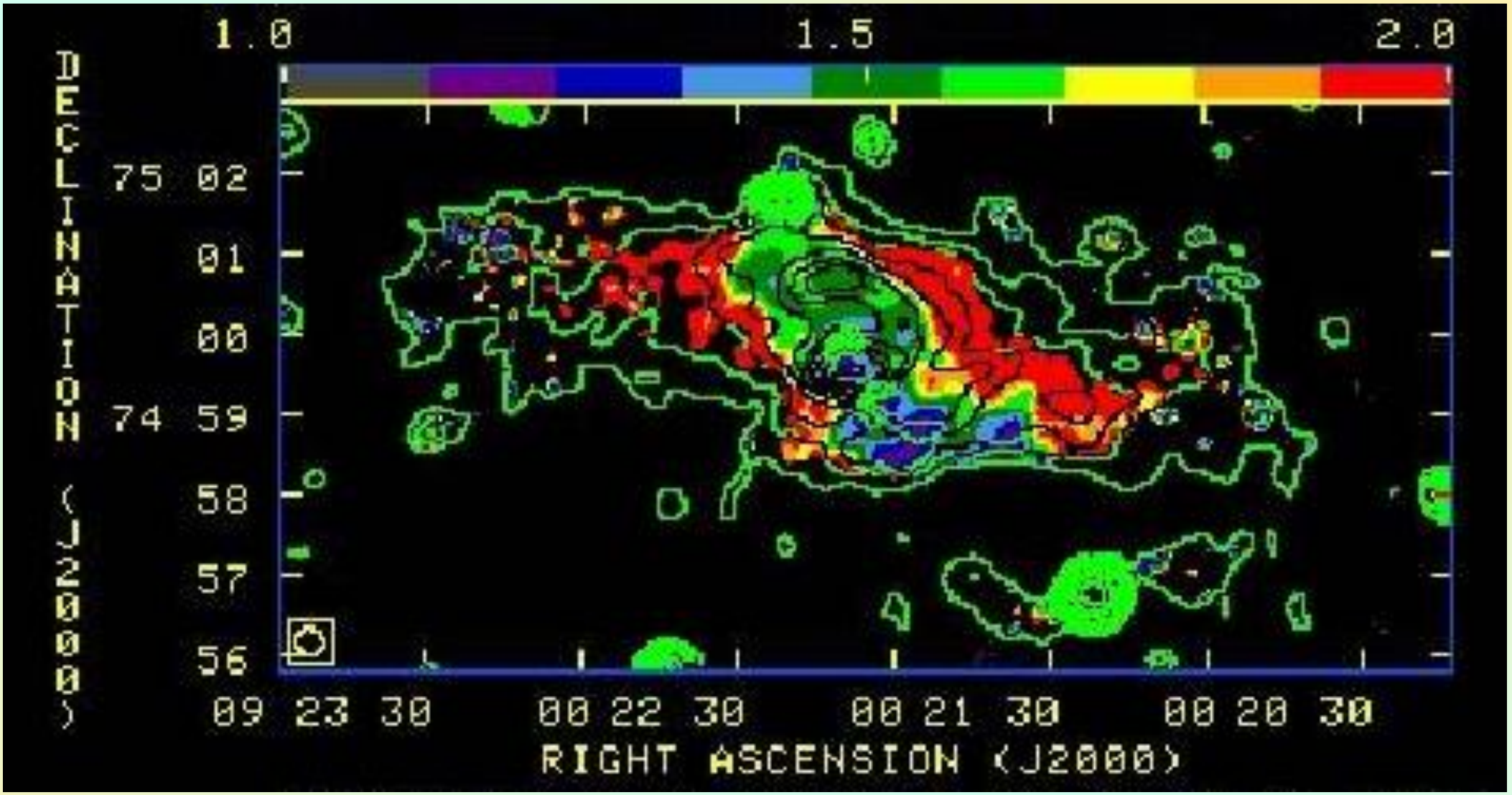
Flux density: (1.4 GHz) 110.22 mJy (5 GHz) 10.9 mJy

Radio power: 4.59×10^{24} W/Hz 4.54×10^{23} W/Hz

LAS: 1.7 Mpc Spectral index (total): 1.93

Harris et al. 1993: 1.2 Jy at 151 MHz (alpha = 1.07 between 151 – 1415)

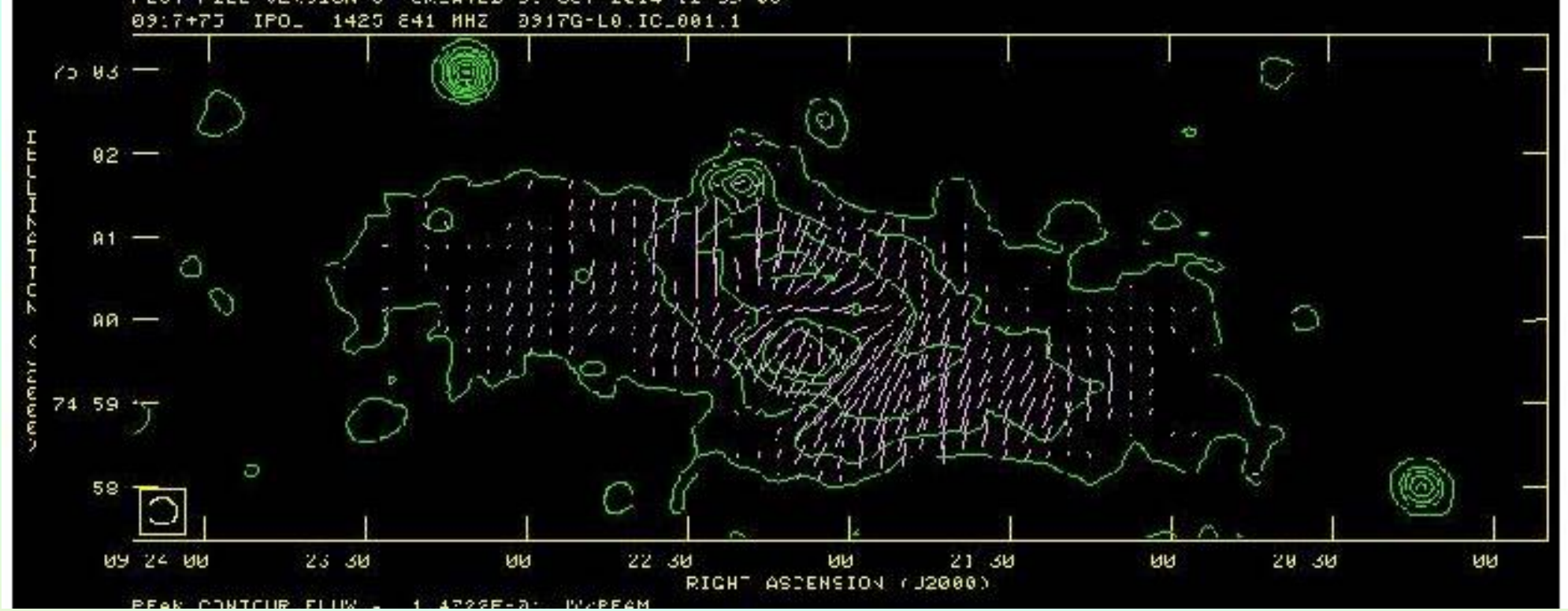
Not detected by ROSAT and XMM ➔ $H > 0.81\ 10^{-6}$ G
at 3 sigma level (Chen et al. 2008)

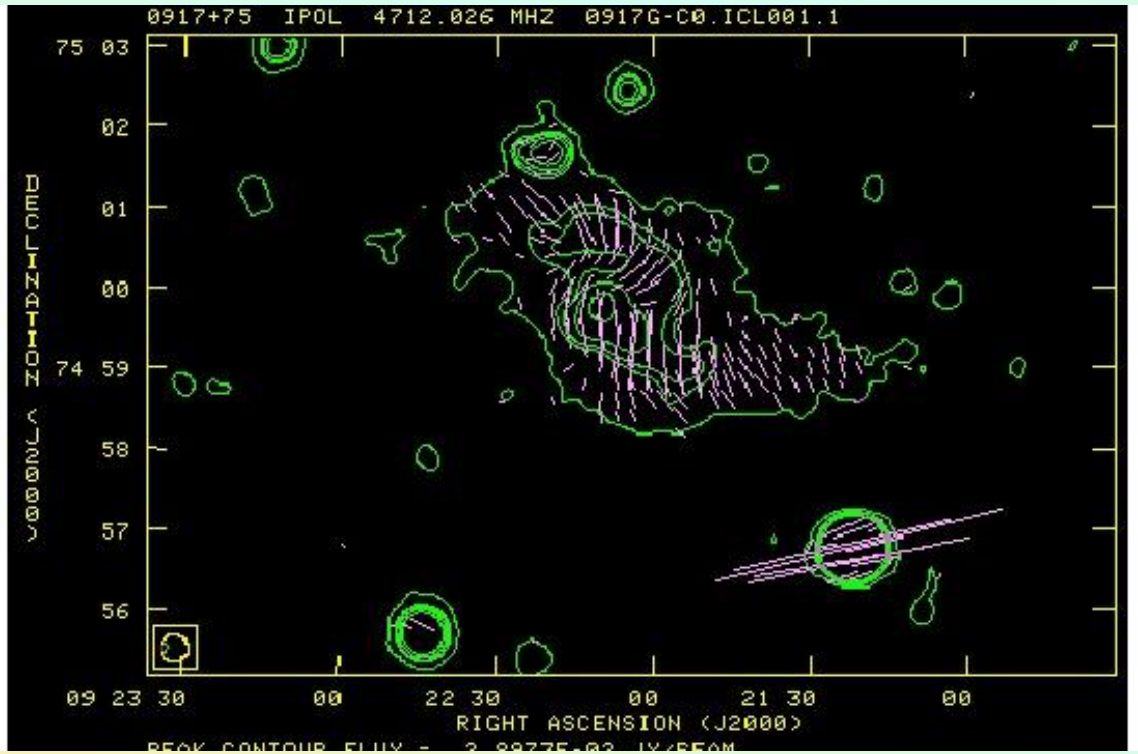


Spectral index of the radio peak coincident with the galaxy at the center: 1.1

1.3 in the surrounding region (S)

1.5 (N)





Pol average:

31% at 1.4
29% at 5.0

Relic radio source?
Morphology - no evidence of shocks – no Xray – central bright
missing merging clusters - polarized emission but not from a shock

Radio halo?
Elongated morhology – polarization – no Xray – central bright +
spectral index trend as in Coma C

Radio emission from a galaxy filament?
missing X-ray emission – central brighter emission –
origin relativistic particles? – high magnetic field - Cold gas?

Old diffuse emission from a dead radio galaxy?
too extended – still visible the core, but no jets – spiral structure?
morphology? Central brighter region
Electrons + magnetic fields in the filament weather

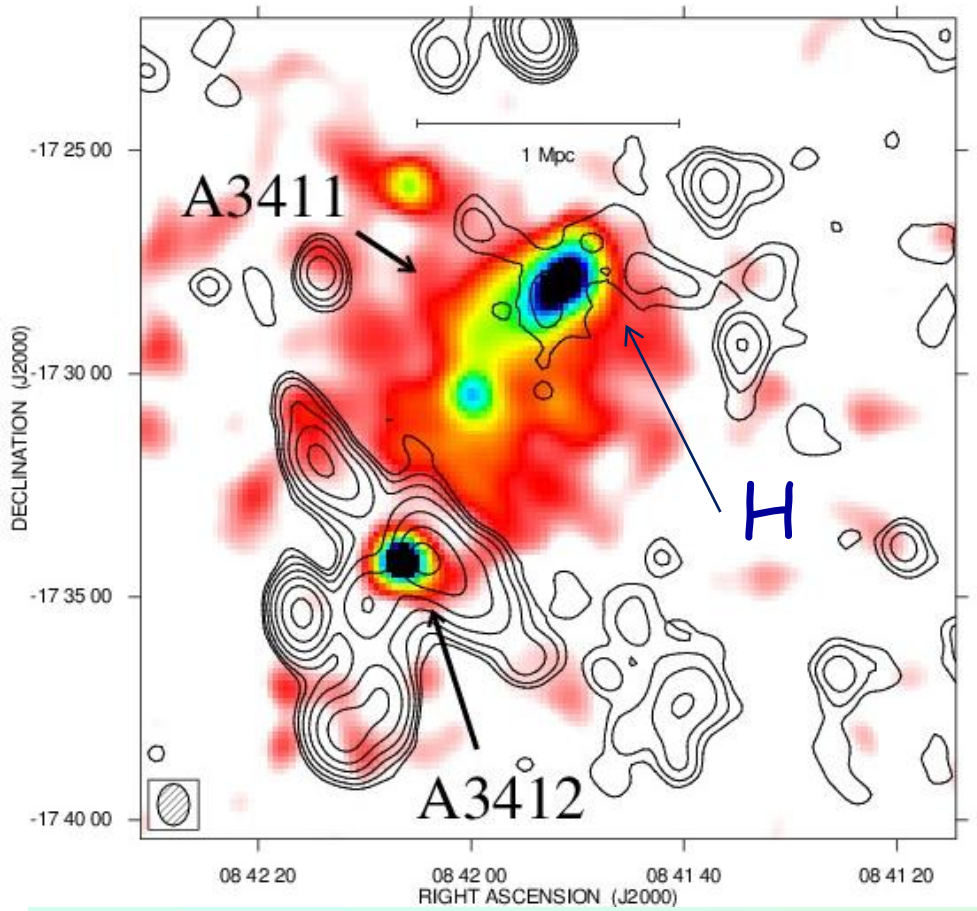
A3411+A3412: an interesting case

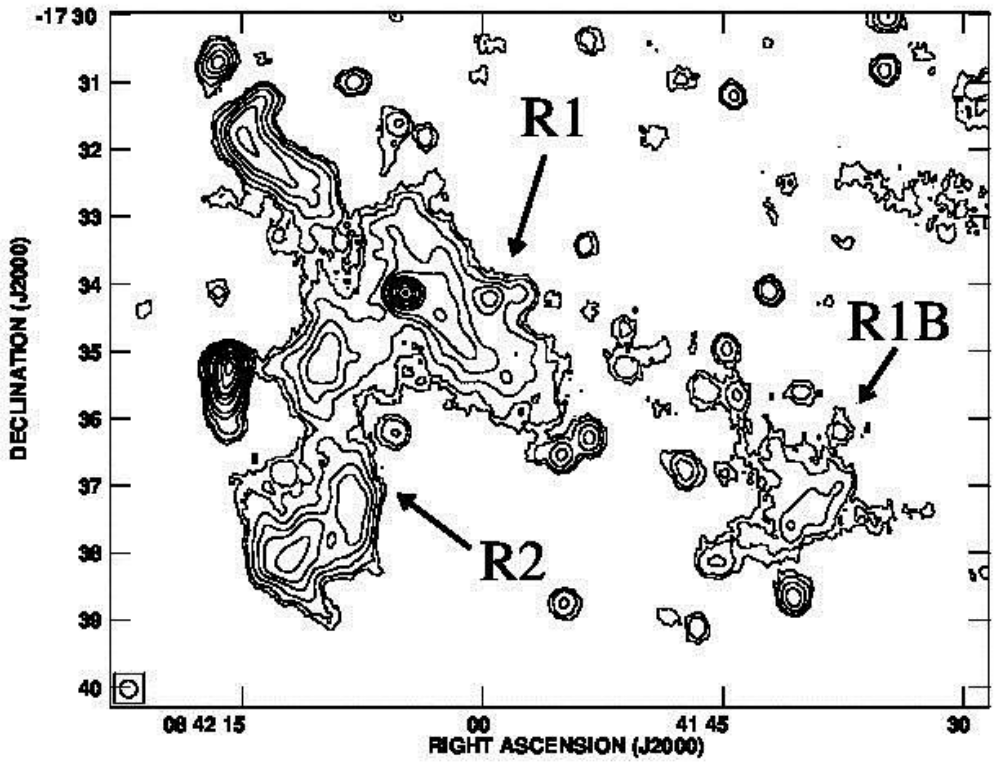
z=0.1687

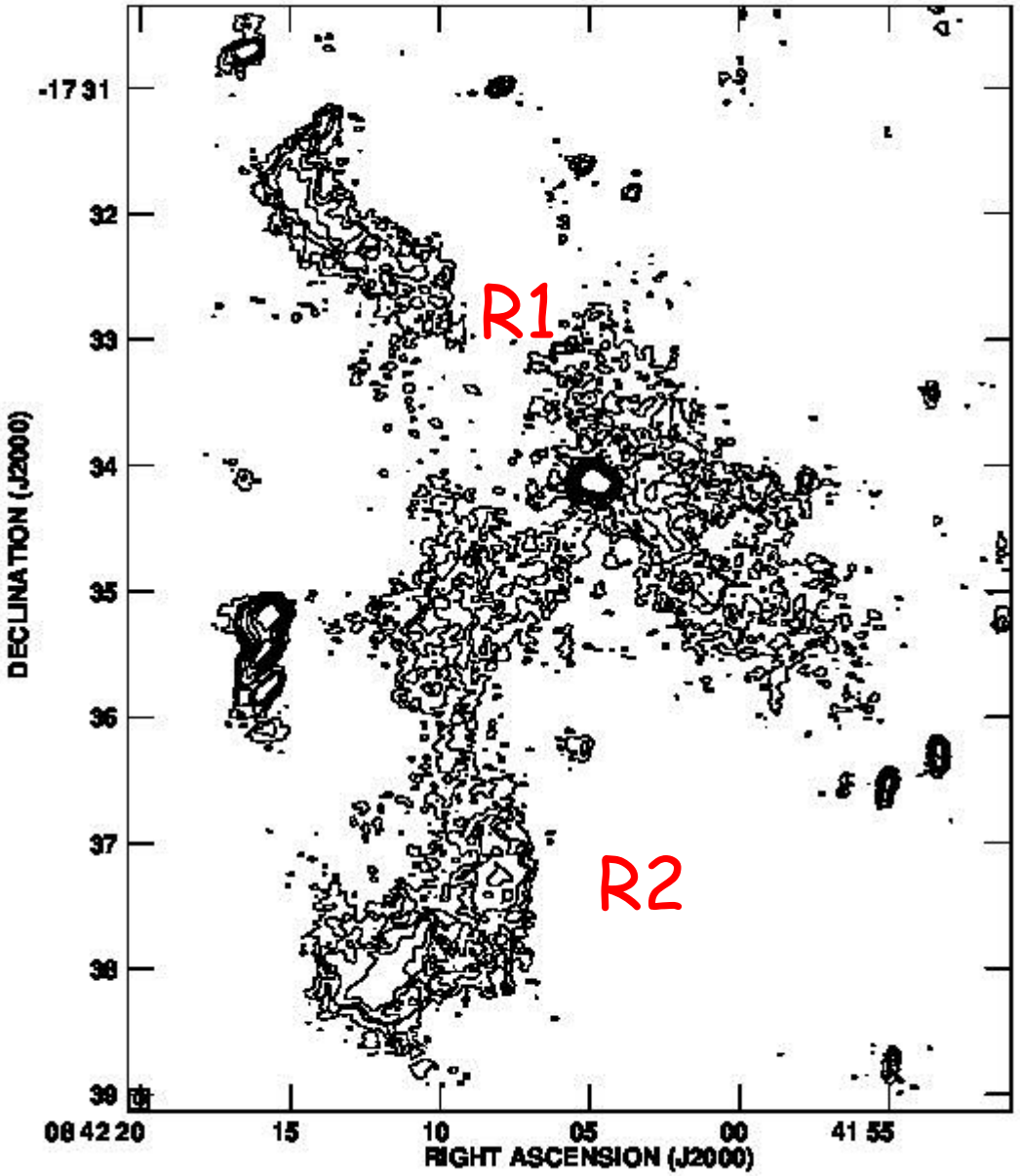
Optical+X-ray 2 main clusters at the same distance in a merging phase + filament.

Halo at the 3411 center

R1 R1B R2 structure







R1 a Relic source?

R1B connected but too far?

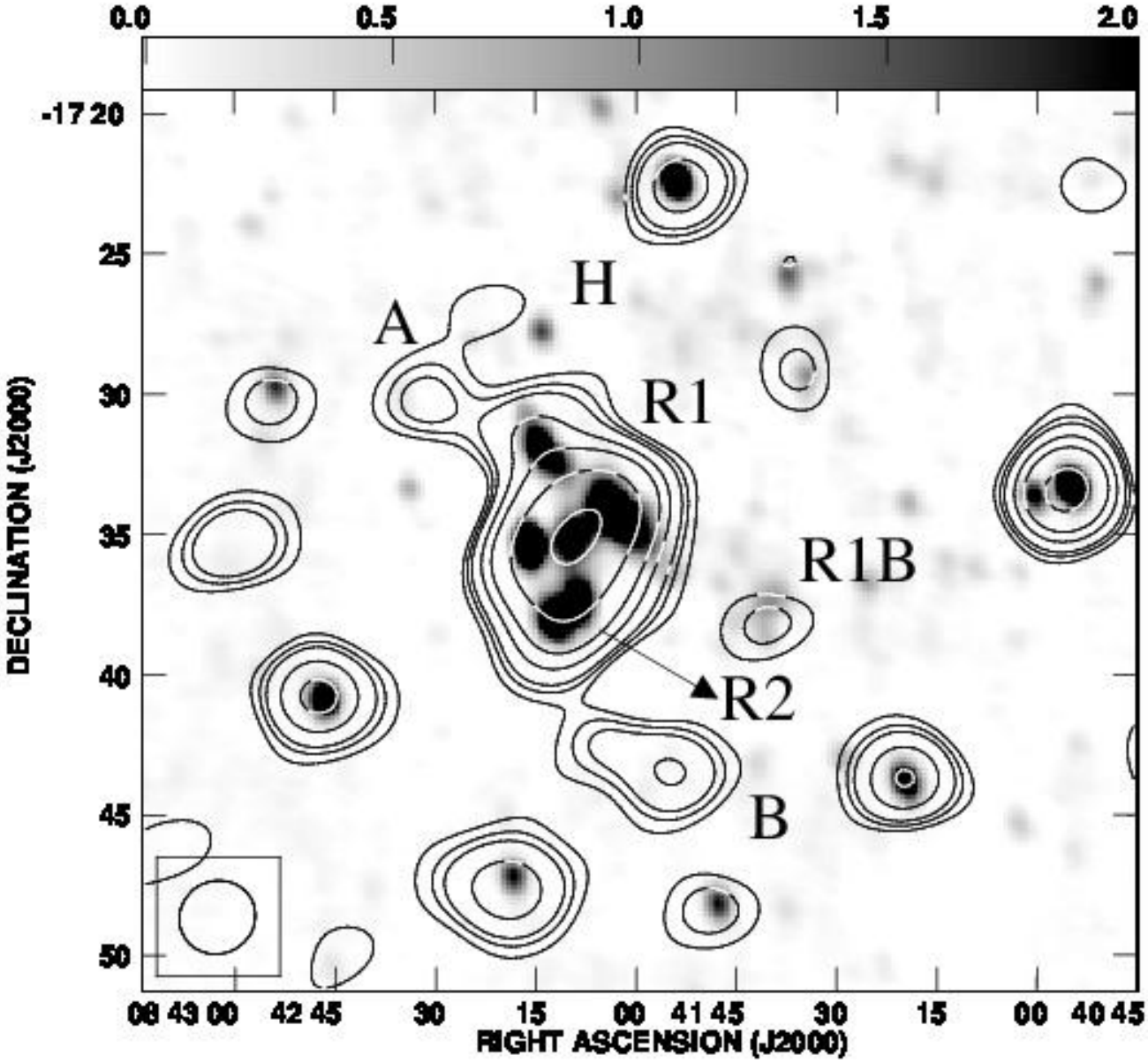
R2 is oriented along the giant filament merging into A3411. This structure could be powered by accretion shocks or turbulence inside the filament.

NO X-ray from this region

Diffuse morphology, no evidence of shocks

Once again a complex condition with accretion shocks able to accelerate electrons, combined with turbulence in the thermal gas connected to the presence of multiple mergers of the A3411 – A3412 structure – but no (bright) X-Ray emission S to A3412

VLA & KAT-7

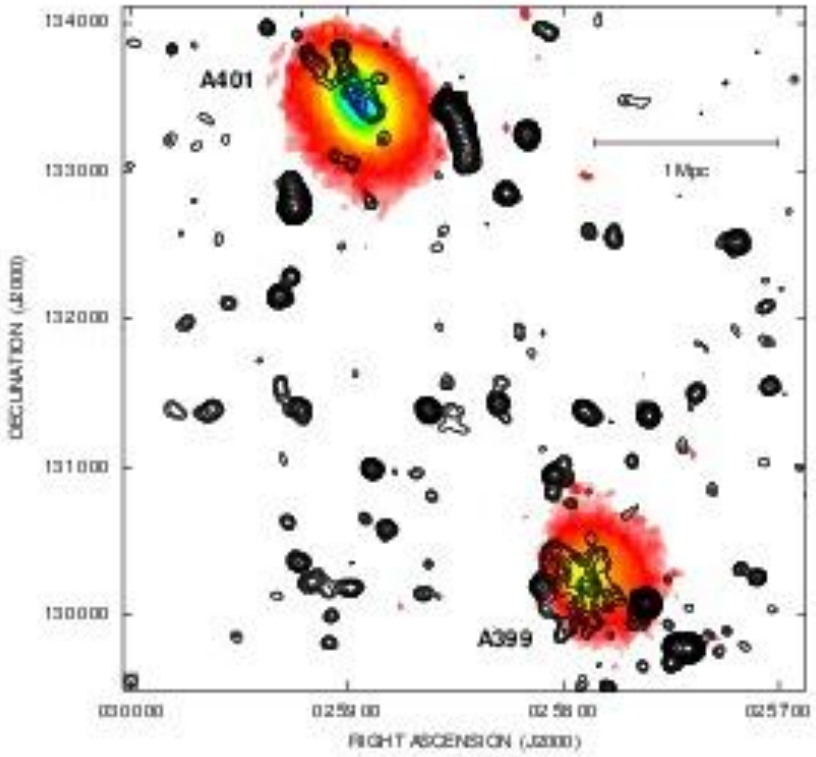


R1+R2 in VLA (1.4GHz):
75 mJy

In KAT-7 (1.8GHz) – same region:
59 mJy
Spectral index = 0.89
Agreement or missing flux in VLA?

In KAT-7 2 more extended faint regions (A B) possibly connected not visible (brightness sensitivity) in VLA

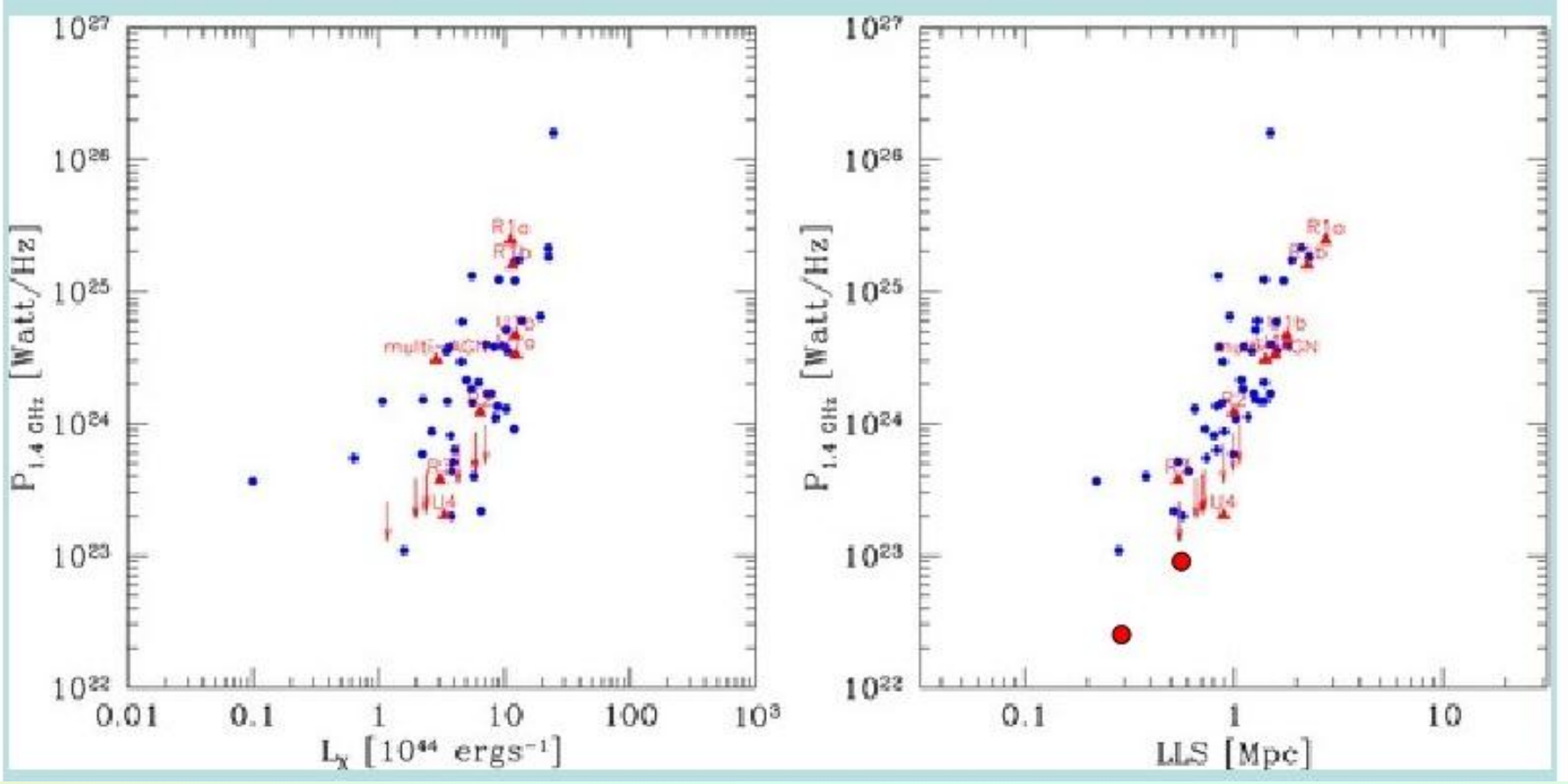
To be investigated (JVLA submitted)



A401 & A399

Exceptional, owing to the rarity of halos and given that X-ray data suggest that the two clusters are in a pre-merger state.

Planck data revealed a signal between A399 and A401.
The SZ signal ➔ IC region with material from the clusters and the IGM ➔ a bridge of matter connecting the two systems.
also relativistic particles and magnetic fields could be present in this bridge witnessing the process of a large-scale structure formation,where cosmic shocks originated by complex merger events are able to amplify magnetic fields and accelerate electrons.



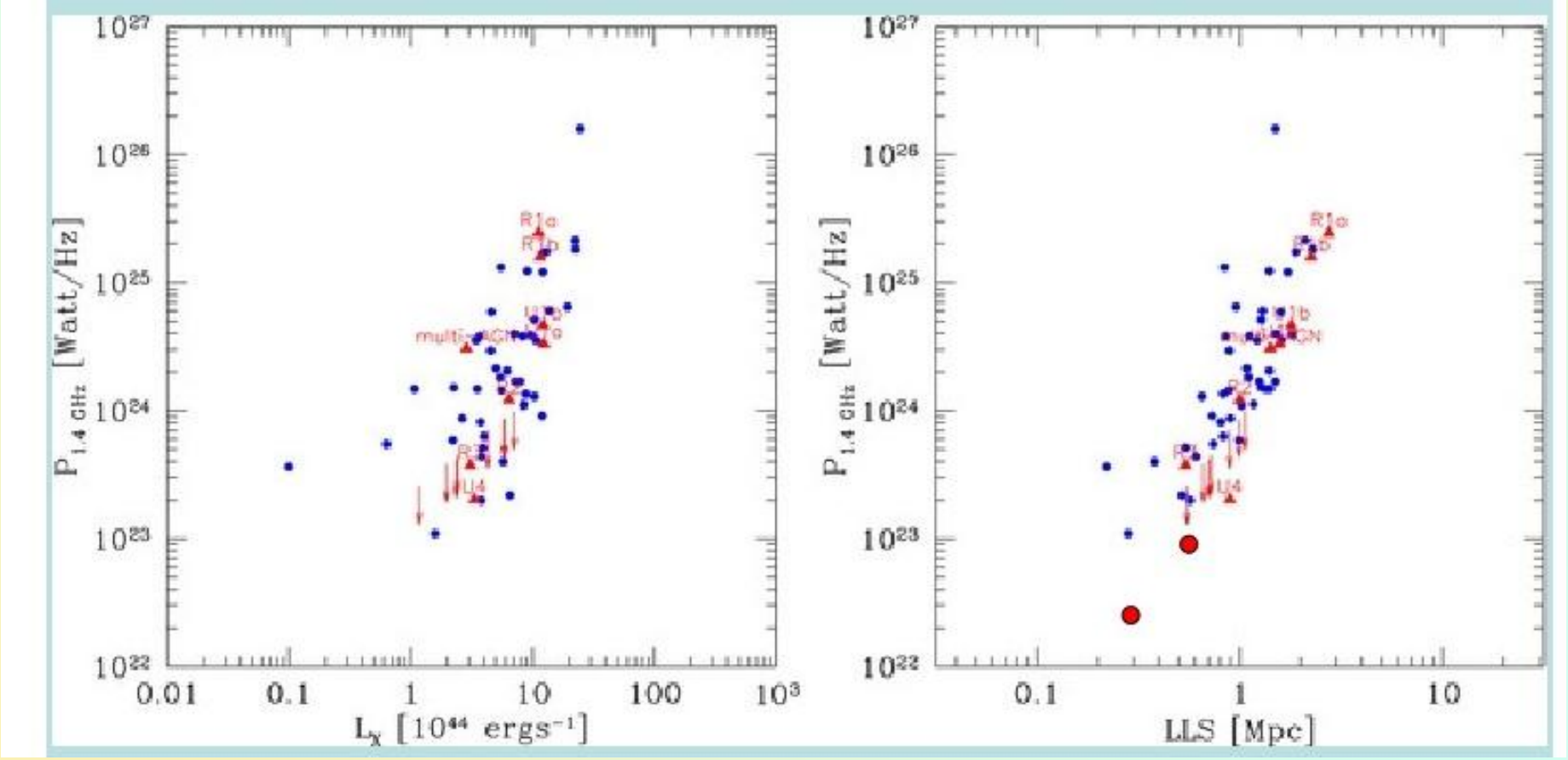
synthetic radio halos generated by Xu et al. 2012: initial magnetic fields are injected into the ICM by AGN at high redshift.

The synthetic radio halos agree with the observed correlations between the radio power versus the cluster X-ray luminosity and between the radio power versus the radio halo size.

Out of 16 simulated clusters, eight present a radio halo detectable by present radio telescopes (e.g. JVLA)

The eight faint simulated clusters will need deeper radio observations.

Undetected clusters should host at z = 0.2 radio halos with a 1.4 GHz surface brightness 0.3 mJy/beam, assuming a 3" HPBW.
We need SKA1-MID observations in 2 hrs



A caveat is that the angular size of radio emission connected to galaxy filaments is unknown.

Moreover, low power sources are best detected at low redshift because of higher flux density, but they could show a large angular size.

The bridge of emission in the Coma cluster, as well as the Coma-C radio halo, are not detected by JVLA at 1.4 GHz, not because of sensitivity limit, but because of missing short spacings.

Single dish observations are confusion limited

Conclusions

Diffuse extended non-thermal emission is present at larger scales with respect to classical halos:

Diffuse Halos (Coma, A2319) – Bridges (Coma, A2255) – emission outside rich clusters along merging filaments (A3411, ZwCl)

The origin of these sources can be related to peculiar conditions in filamentary merging structures with turbulence and shocks able to produce the non-thermal emission

0917+75 a peculiar not yet understood source.
If it is the old emission of a radio galaxy, it could be the origin of relativistic electrons and magnetic fields in a filamentary structure (LAS as large as 2 Mpc).

In this source as well as in the A3411-A3412 filament X-ray emission is not present in the radio emitting region: cold or low density/low mass regions?

The resolution and sensitivity values expected to be obtained in future sky surveys performed at 1.4 GHz with SKA pathfinders are very promising to detect non-thermal emission in more large scale filaments, provided a good uv-coverage at short baselines.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3rd Korean Astrophysics Workshop: August 16-20, 2004, Pusan Nat. Univ., KOREA
"International Conference on Cosmic Rays and Magnetic Fields in Large Scale Structure"
주관: 우주구조와 진화연구센터, 한국천문학회
후원: 천문연구원, 아태물리재단, 학술진흥재단, 부산대학교

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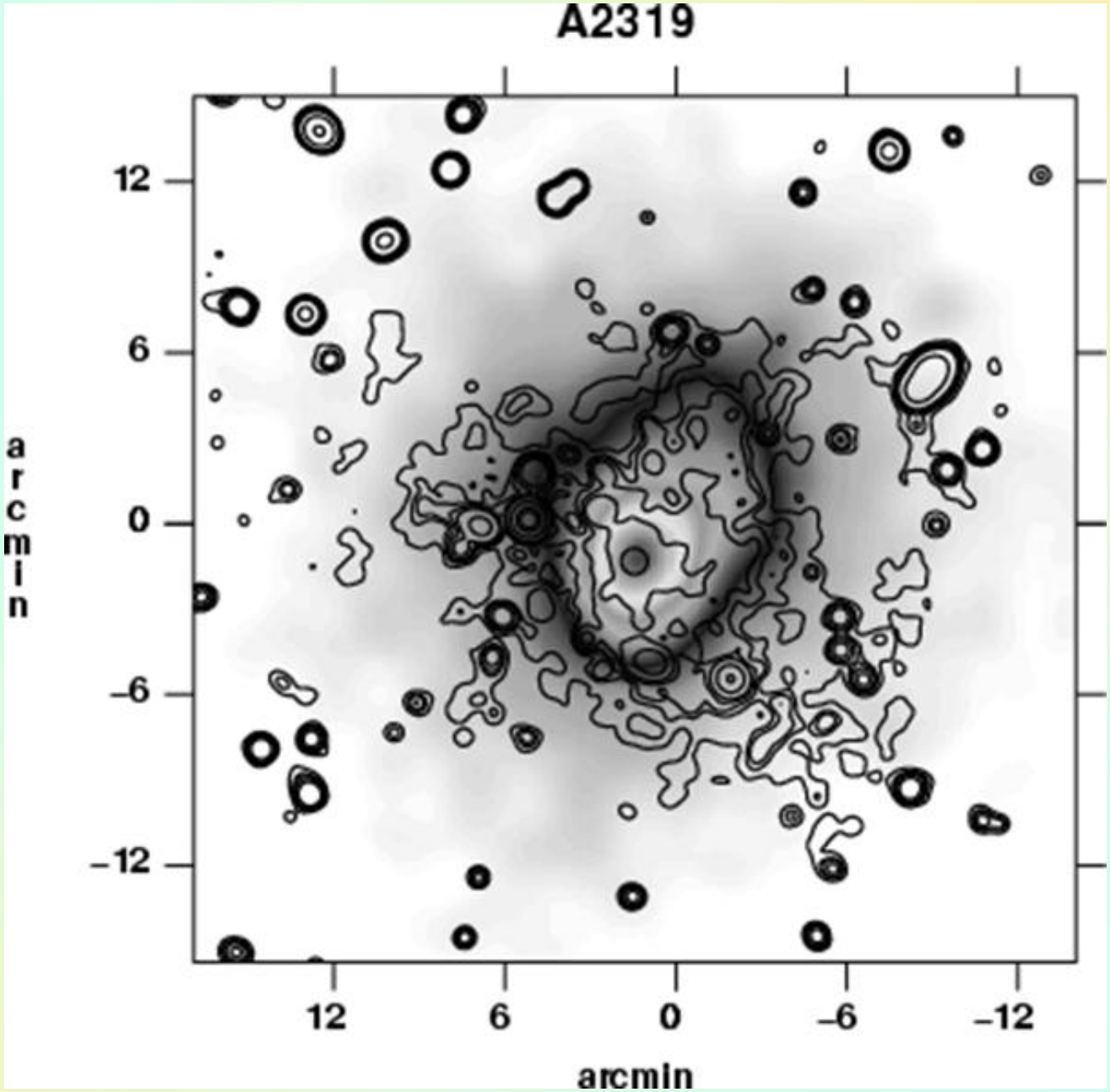

A2319 WSRT 20 cm sources subtracted