Non thermal radio emission from cosmological filaments

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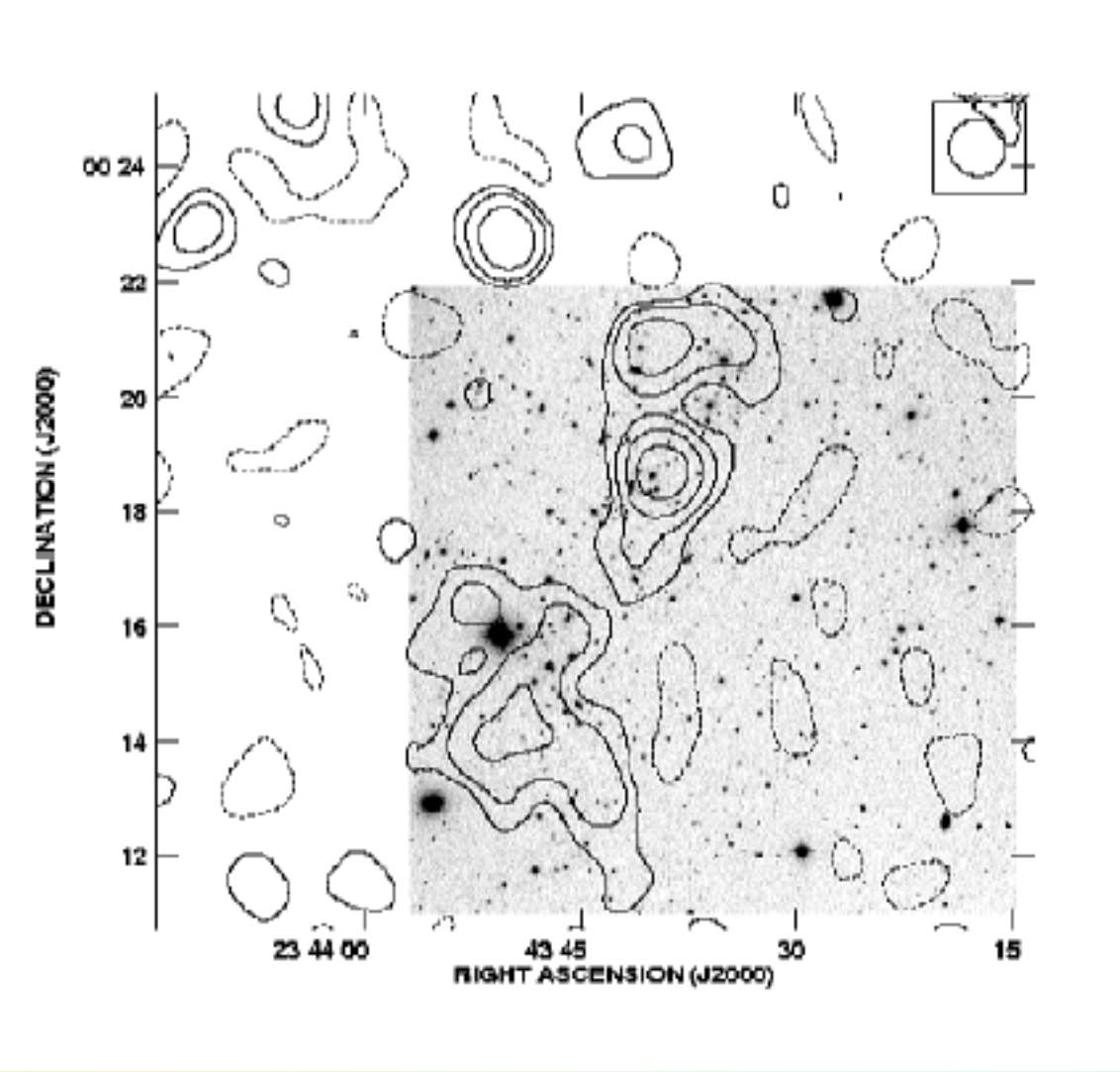
The origin and properties of large scale cosmological magnetic fields are still poorly known.

Cluster observations in the radio and X-Ray band have shown the existence of Mpc scale magnetic fields (see Feretti, Bonafede and other talks….).

I would like to present observational evidences of magnetic fields on larger scale (a few Mpc) and lower density:

galaxy filaments connecting rich clusters
and other low density regions

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

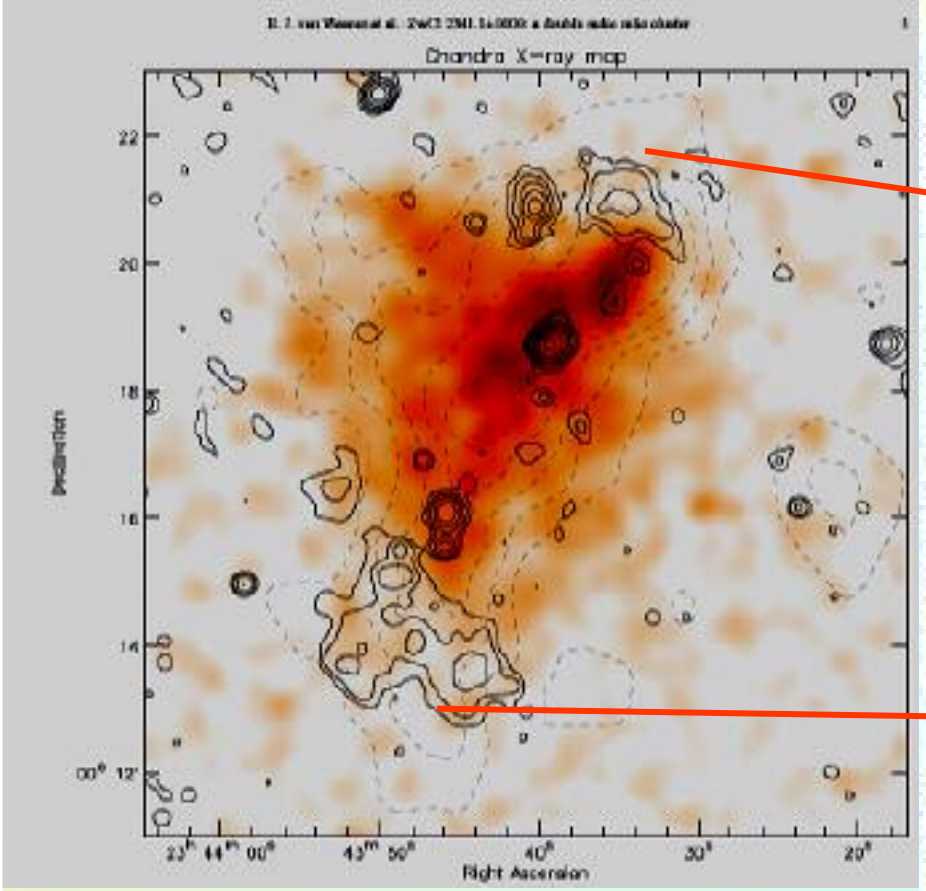


Size ~ 3 Mpc

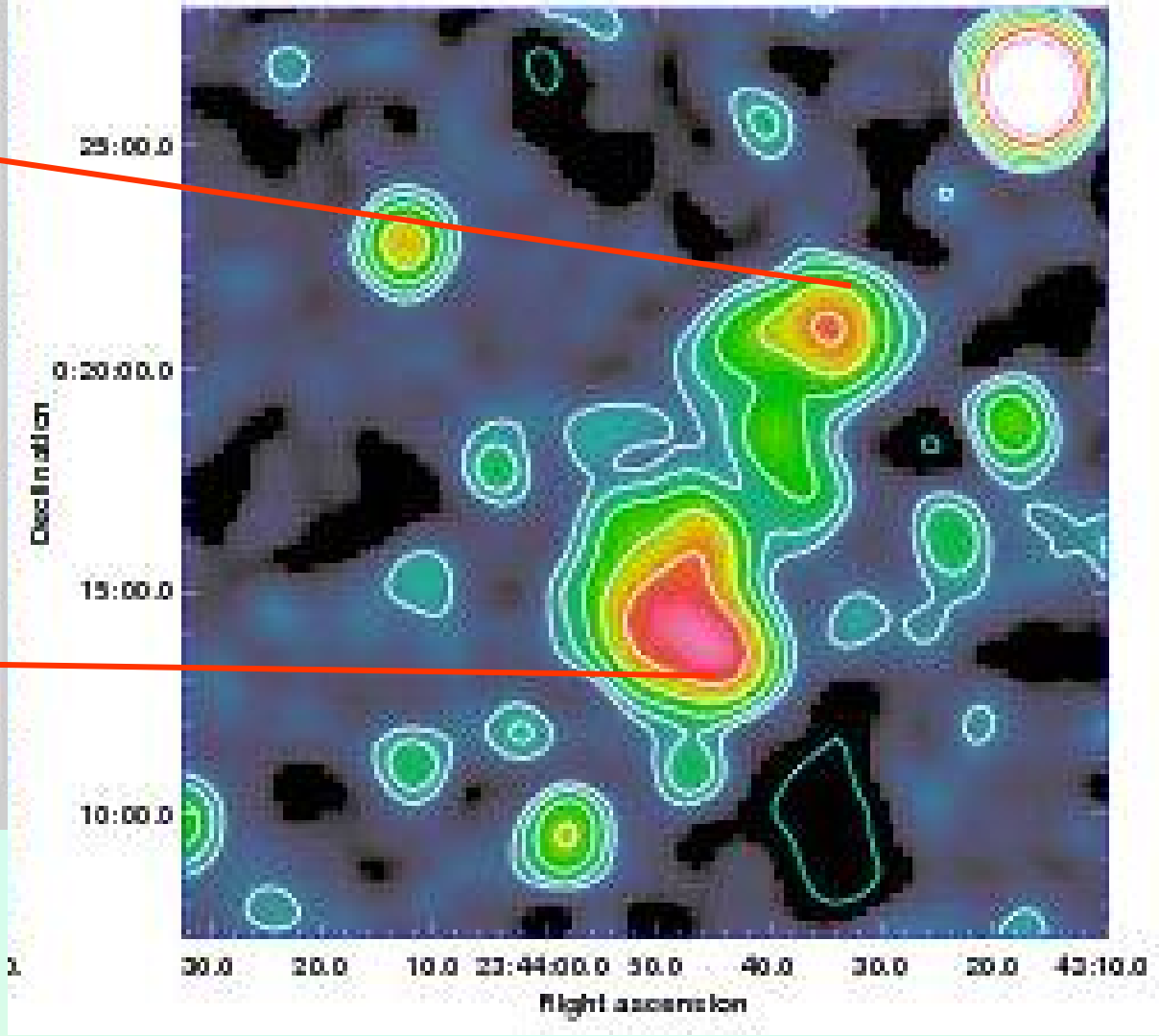
z ~ 0.27

conversion factor: 4.1 kpc/"

(Bagchi et al. 2002)

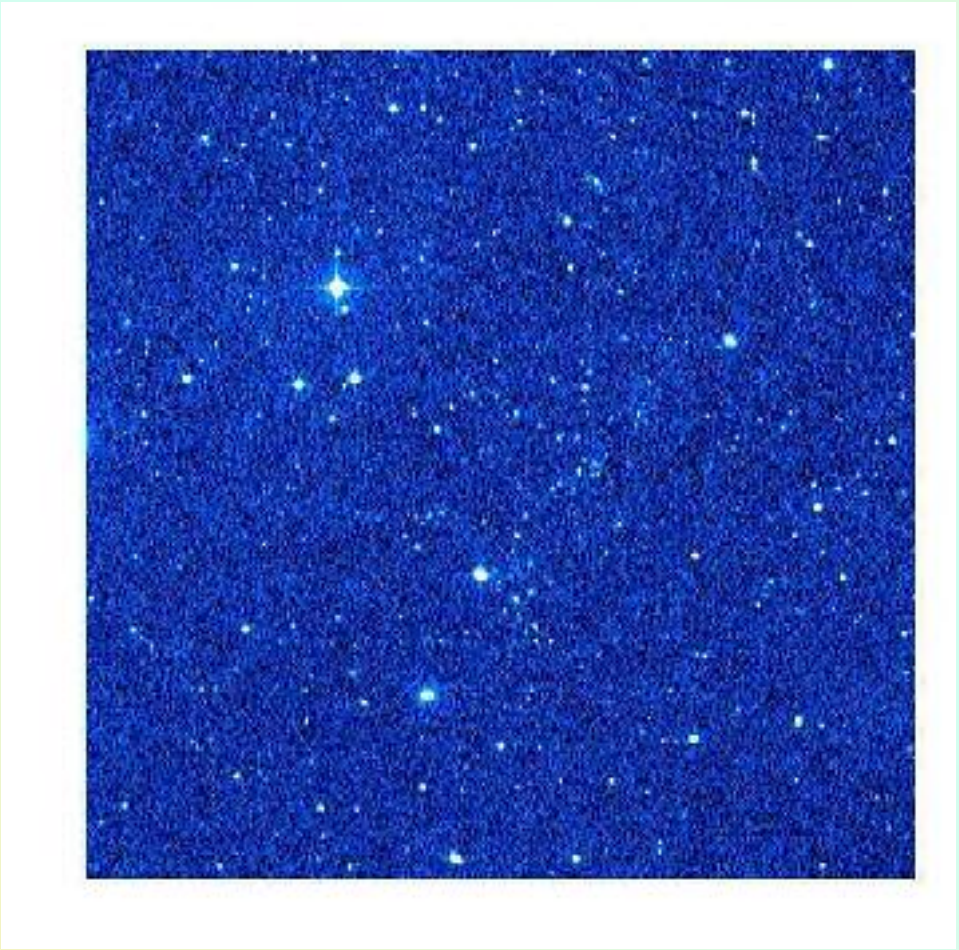


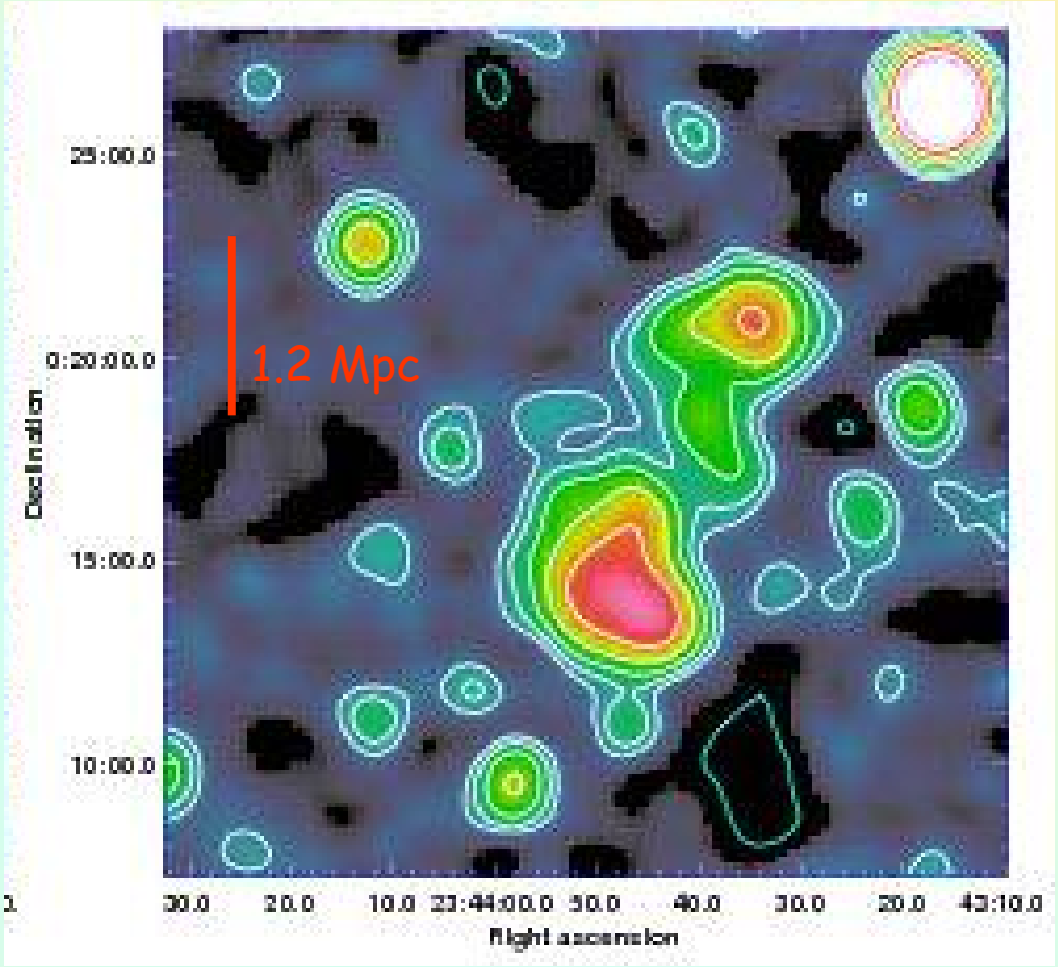
Van Weeren et al 2009
GMRT at 610 MHz



VLA-D at 1.4 GHz

1.4 GHz VLA ~1.2′ resolution

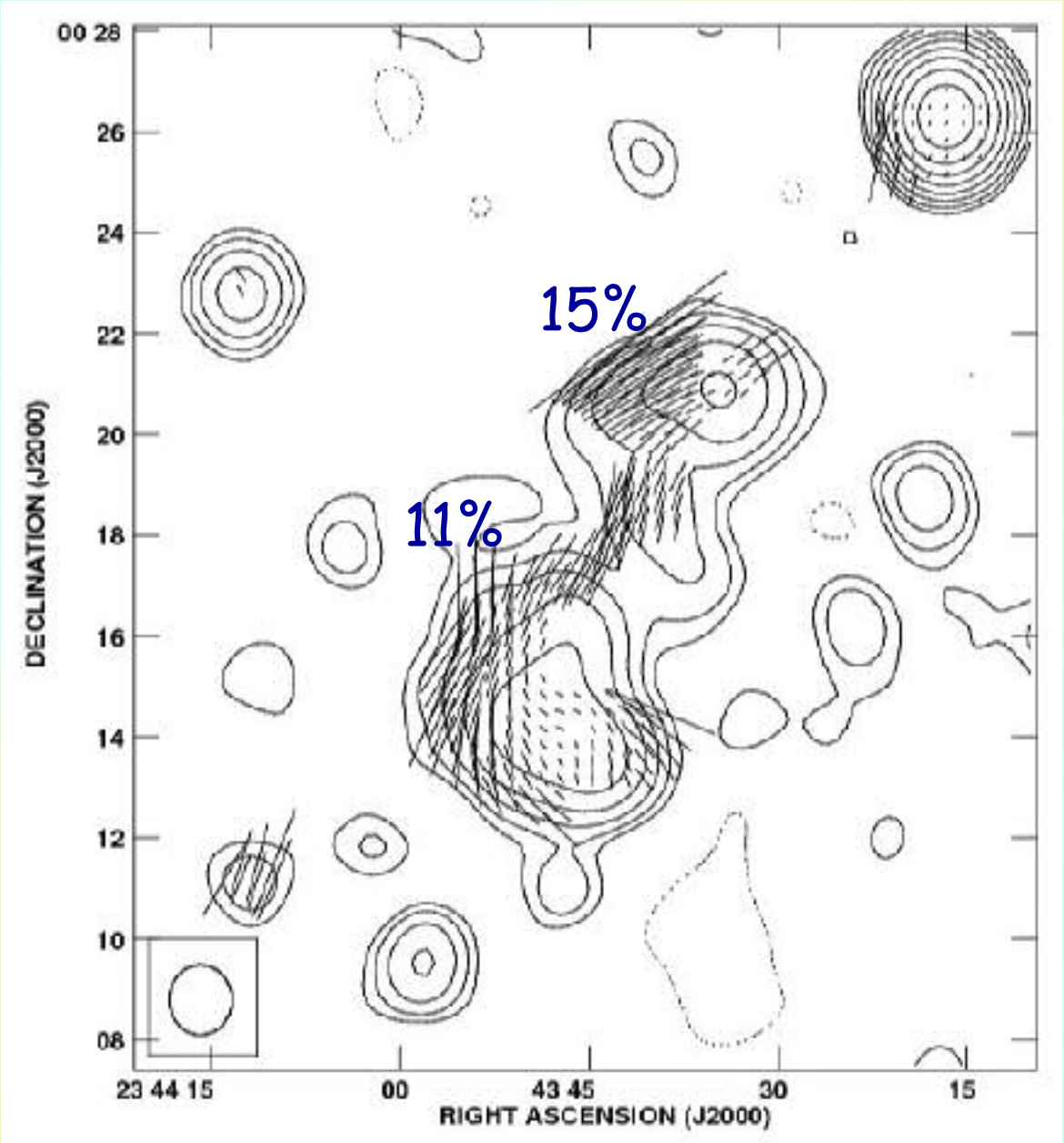




Equipartition magnetic field: 0.28×10^{-6} G
Total size: 2.2 Mpc
Log P(1.4): 23.66 W/Hz
Lx(Rosat): 5.6×10^{43} erg/s

Giovannini et al. 2010

1.4 GHz VLA ~1.2' resolution



Giovannini et al. 2010

Possibile interpretations

1- Large-scale shocks originated by multiple mergers
→ consistent with the detection of polarization and X-ray structure

2- two peripheral relics and a central radio halo
→ consistent with size – power relation
→ difficult to reconcile with polarization

3- two halo clusters (like A399-A401 system) with a radio bridge in-between
→ difficult to reconcile with optical and with polarization

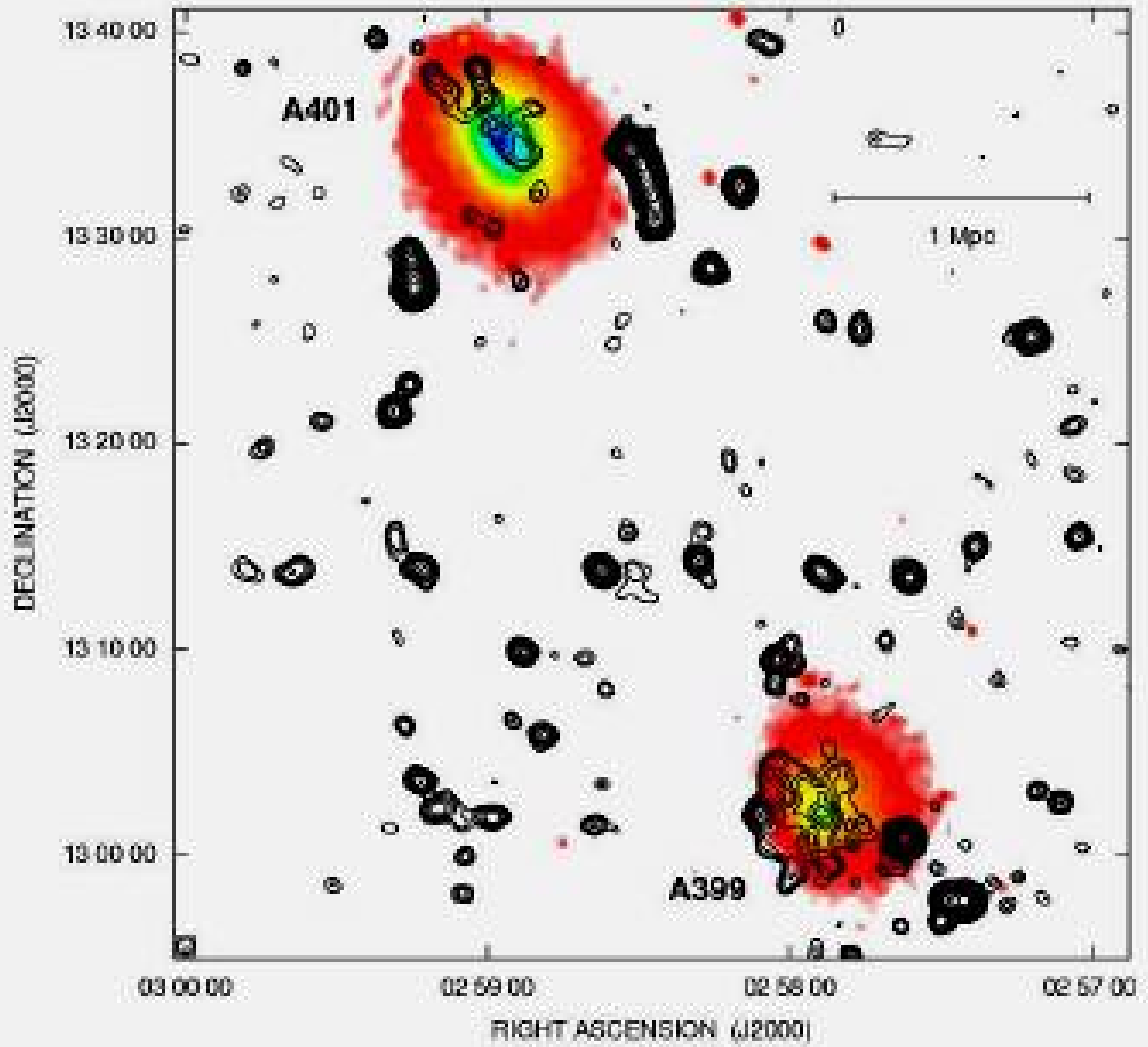


Fig. 4. Total intensity radio contours of the complex A401-A399, obtained by combining the two VLA observations at 1.4 GHz in D configuration of the two clusters, as described in the text. The radio image is shown by the iso-contours and has an FWHM of 45″ × 45″. The first contour level is drawn at 120 μJy/beam and the rest are spaced by a factor of $\sqrt{2}$. The sensitivity (1σ) is 40 μJy/beam. Total intensity radio contours are overlaid on the XMM X-ray image in the 0.2−12 keV band. The X-ray image has been convolved with a Gaussian kernel of σ = 12″.

z = 0.07

Murgia et al. 2010

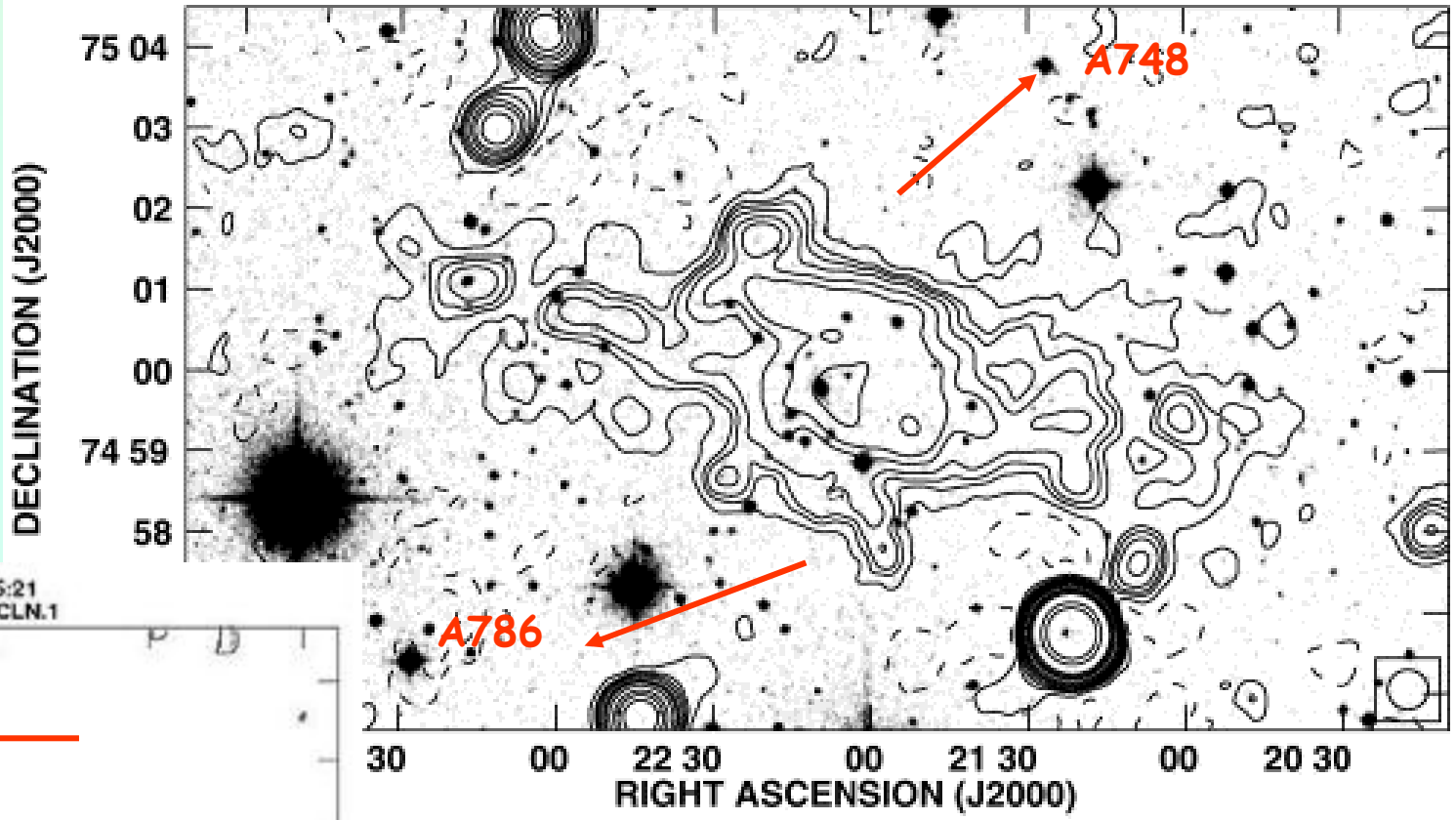
Diffuse emission 0917+75

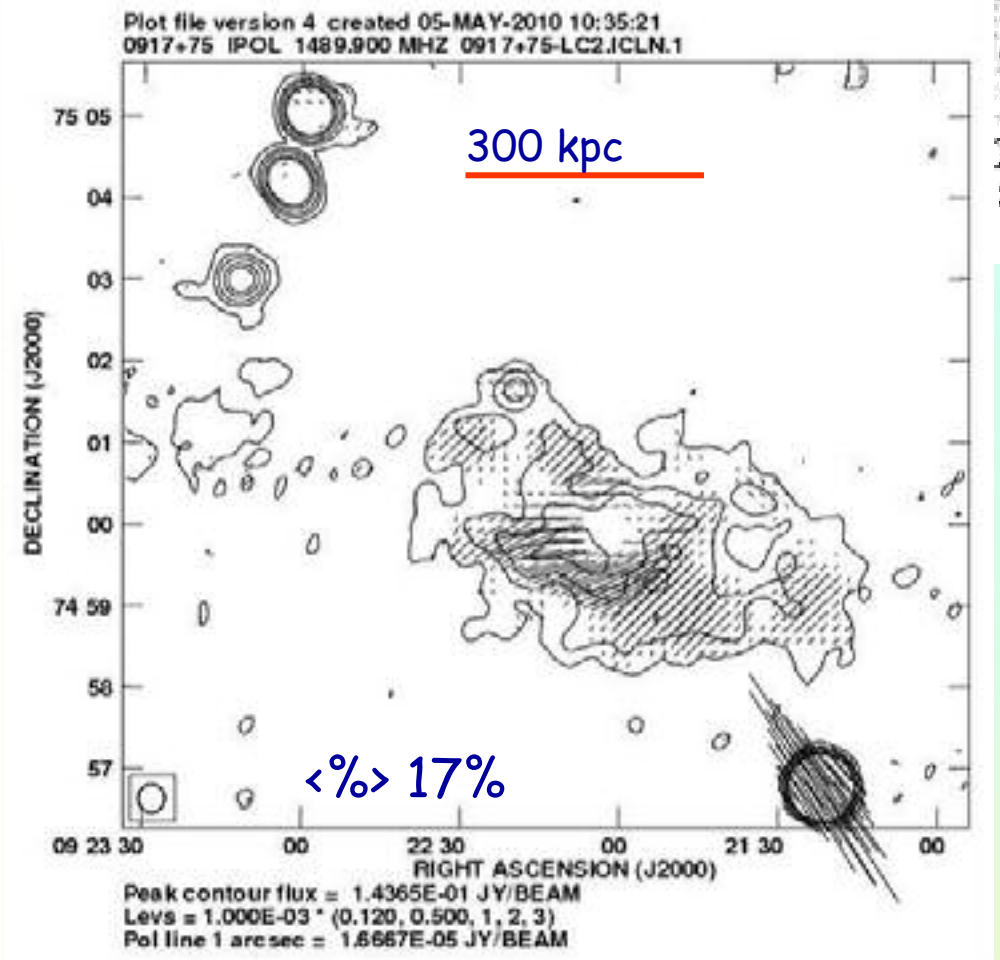
Old diffuse emission from a dead radio galaxy?
Relic radio source?
Radio emission from a galaxy filament?

Studied in detail by:

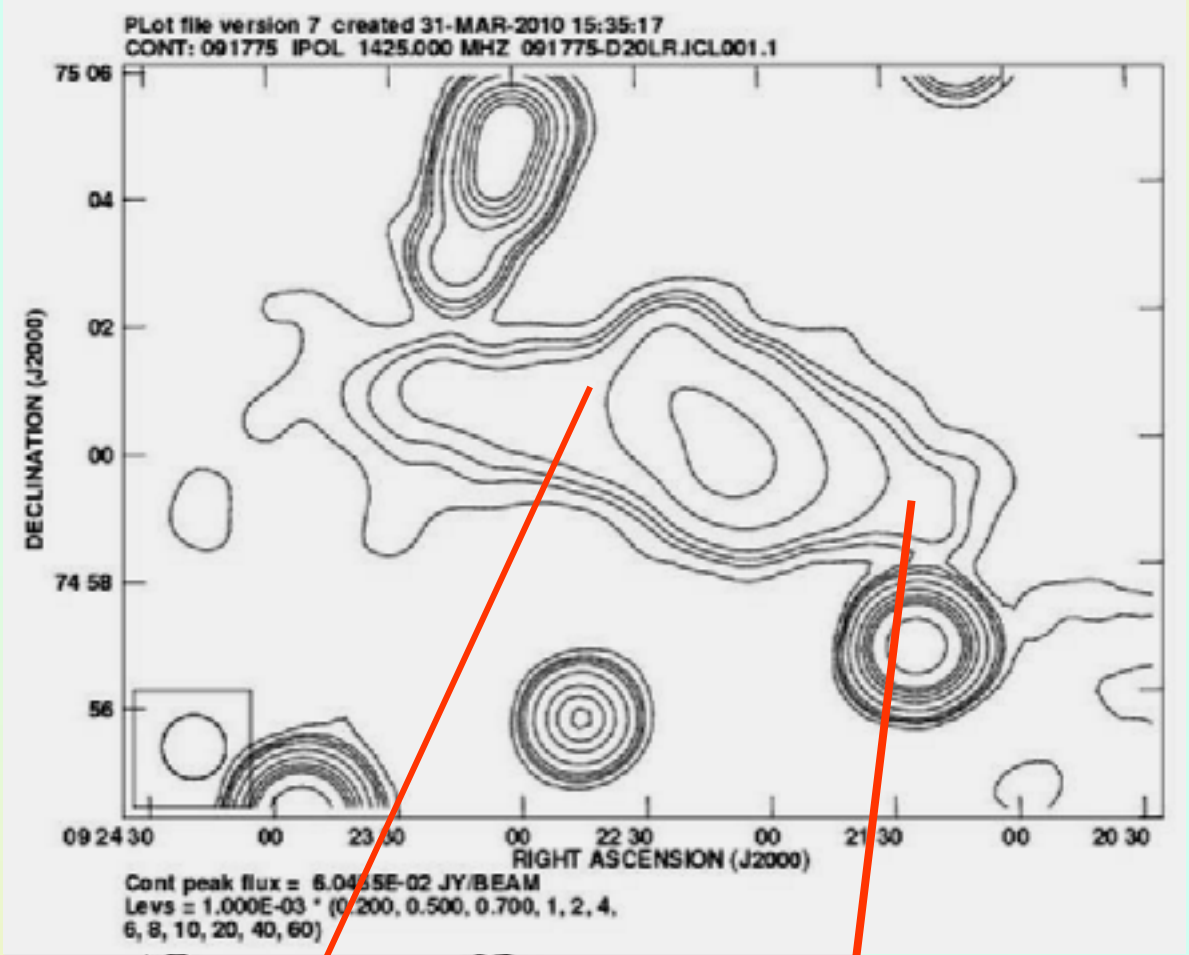
Dewdney et al. 1991 (radio halo)
Harris et al. 1993 (Relic: shape + polarization)
Giovannini & Feretti 2000, peculiar, very far (>4Mpc)
from the nearest rich cluster
New data here

VLA 1.4 GHz





Filament of galaxies same PA of the radio emission. z_{phot} is 0.138 (Girardi pc)
This filament could connect A786 and A748 nearby clusters at the same distance



VLA 1.4 GHz D array

Size: 1.7 Mpc

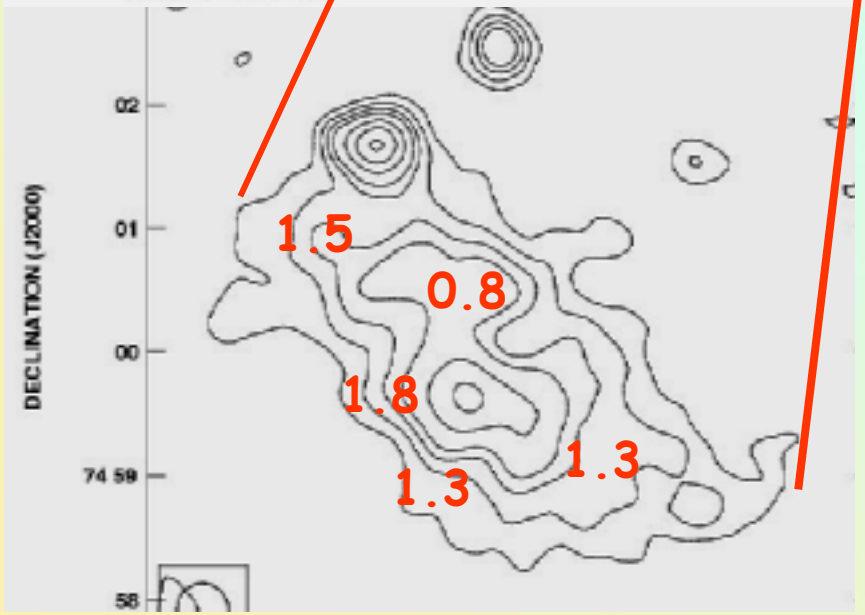
H_{eq} = 0.5-0.7 10^{-6} G

$\log P_{1.4}$ = 24.61 W/Hz

Not detected by ROSAT and XMM ➔

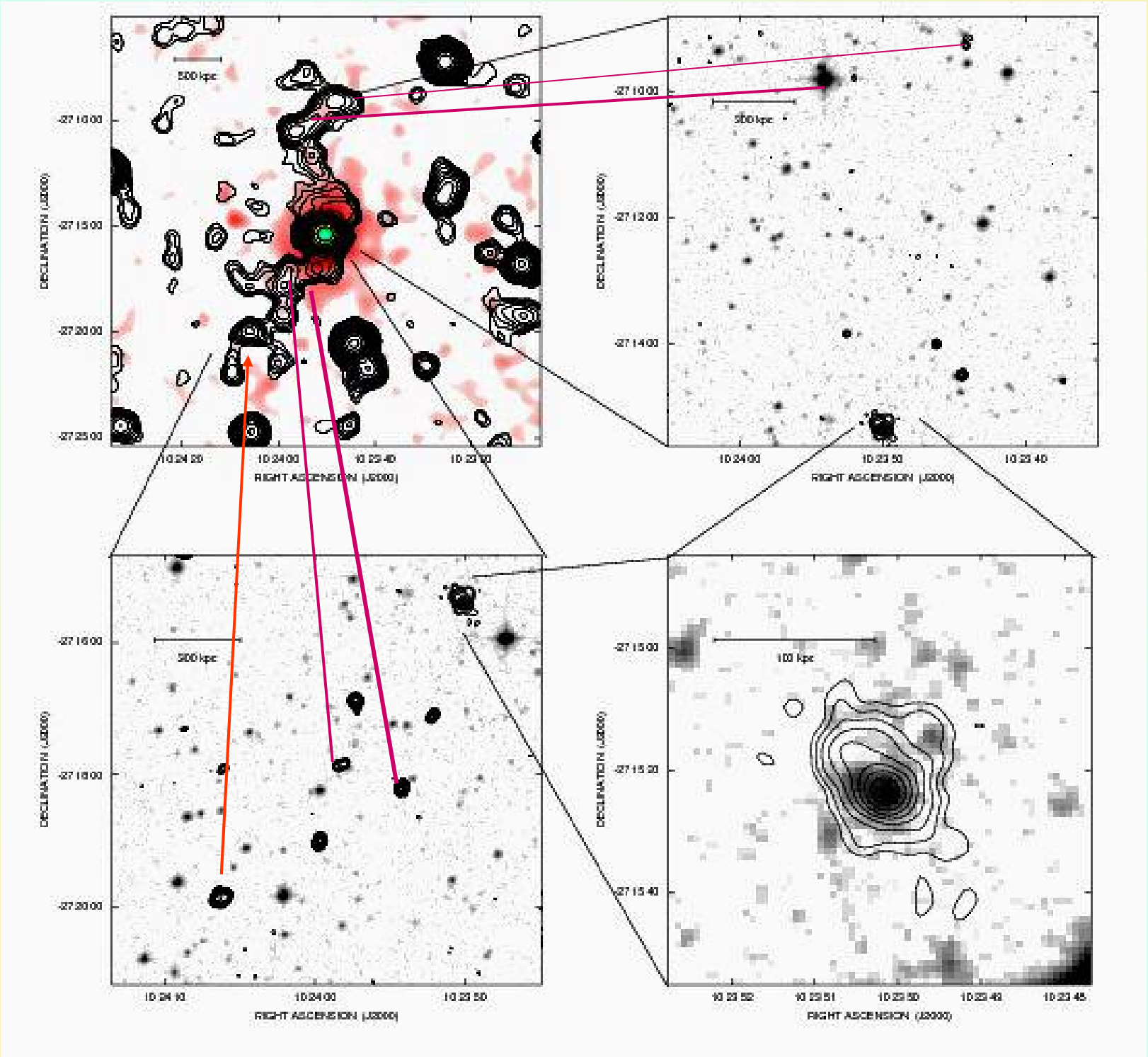
H > 0.99 10^{-6} G

(Chen et al. 2008)



VLA 5 GHZ

Spectral index 1.4 – 5 GHz

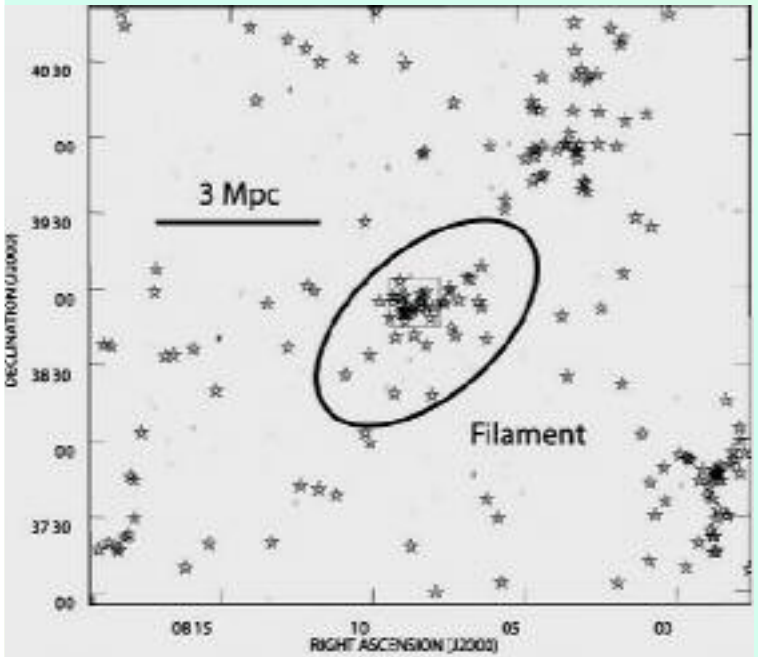


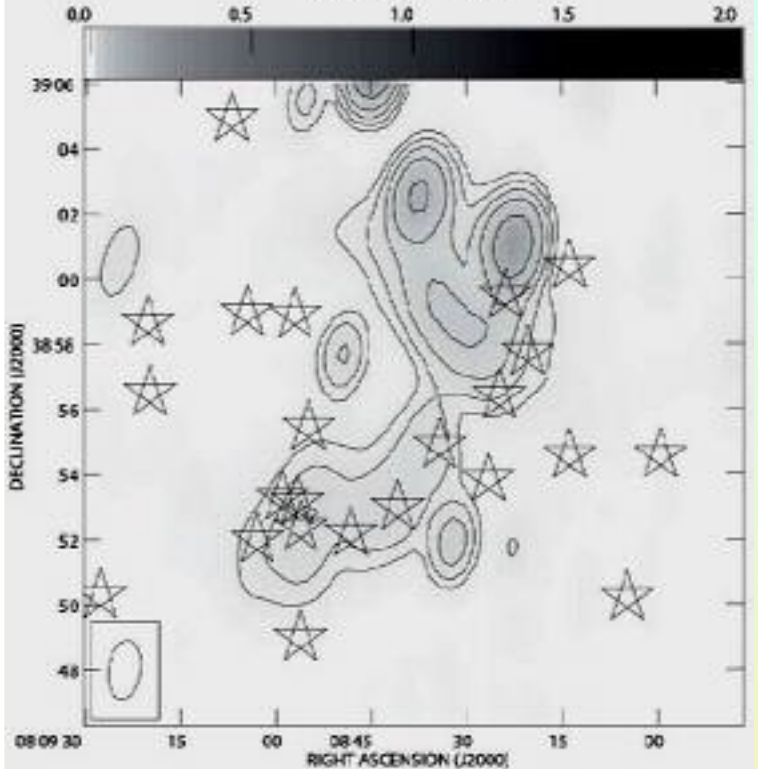
A3444
z= 0.253

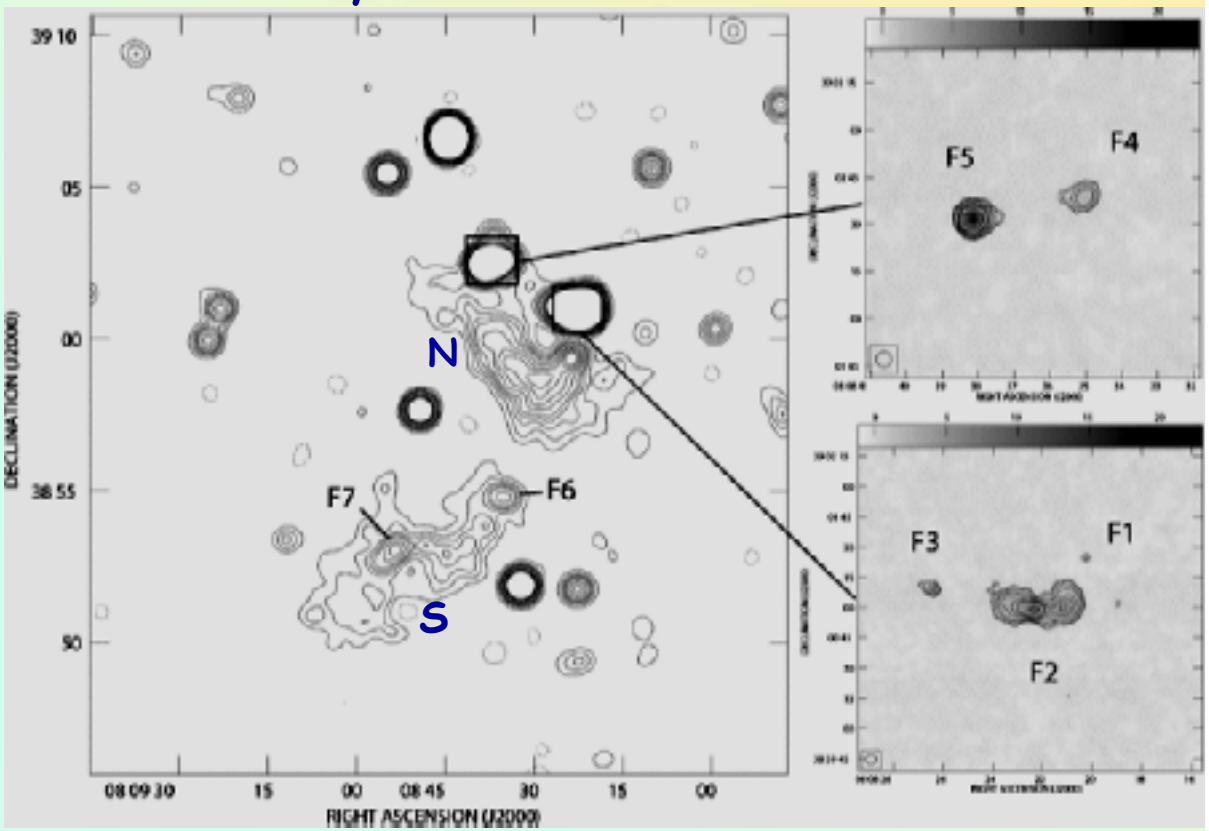
Size: 3.3 Mpc

Giovannini et al. 2009

A small size, nearby filament: 0809+39, by Brown and Rudnick 2009:

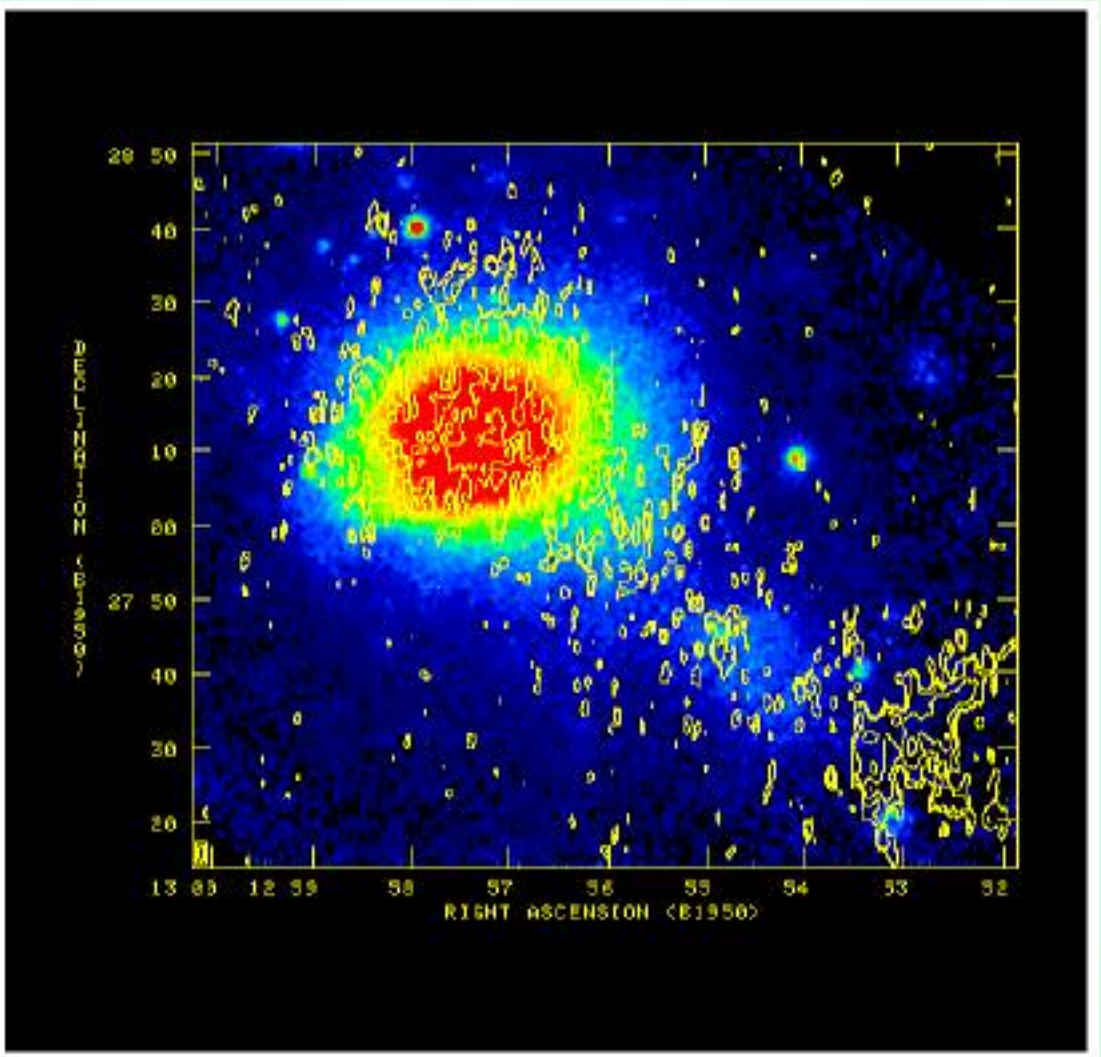


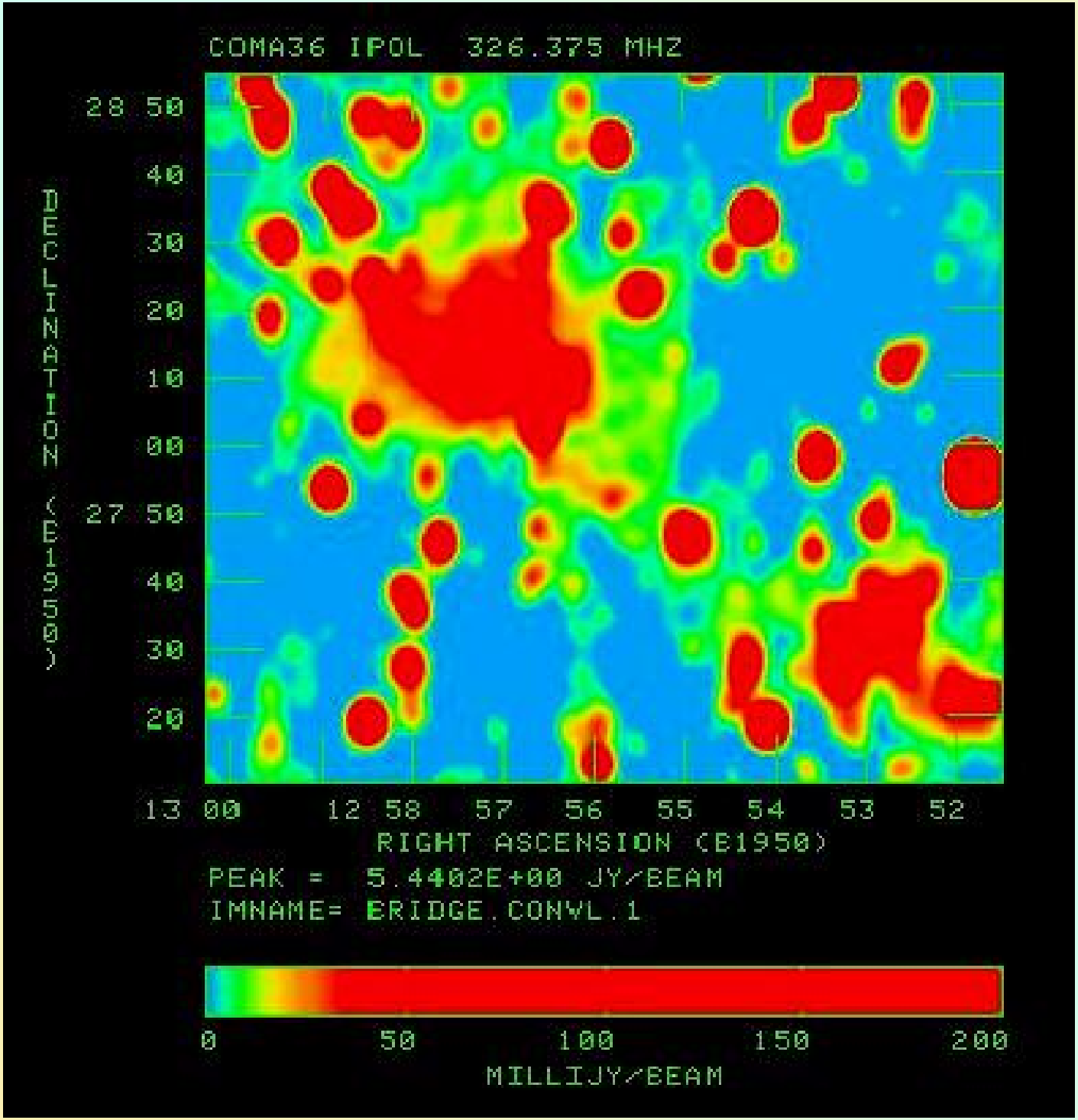




N: z=0.2 relic 0.7 Mpc B_{min} 0.64 microG
S: z=0.04 filament 0.4 Mpc B_{min} 0.57 microG
No X-Ray emission from both sources

Other diffuse emission detected in the regions connecting rich clusters of galaxies: Coma and more.....





Bridge between Coma C and 1253+275

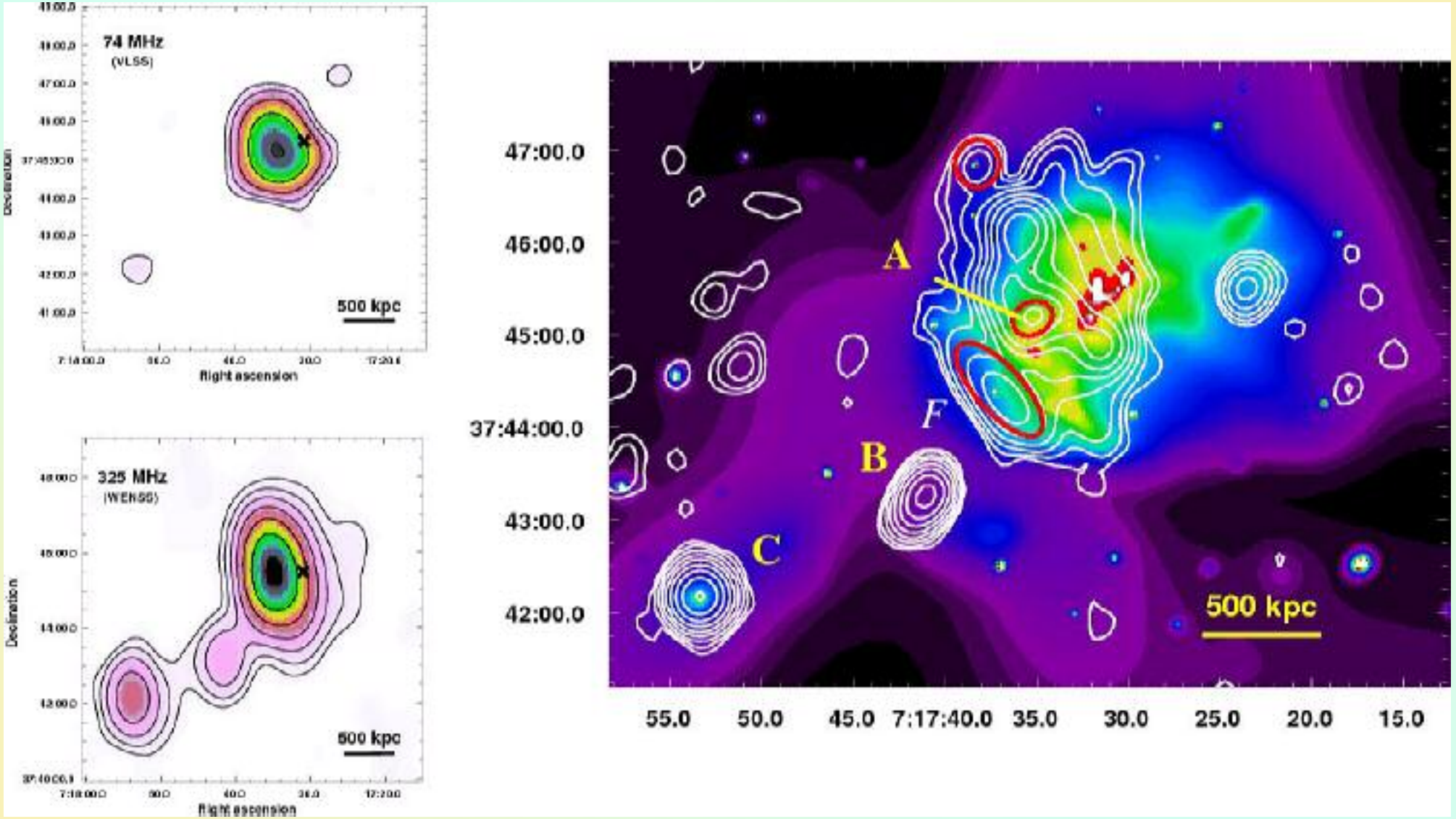
WSRT 90 cm
HPBW 200”

z=0.0232

‘bridge’ size ~ 1 Mpc

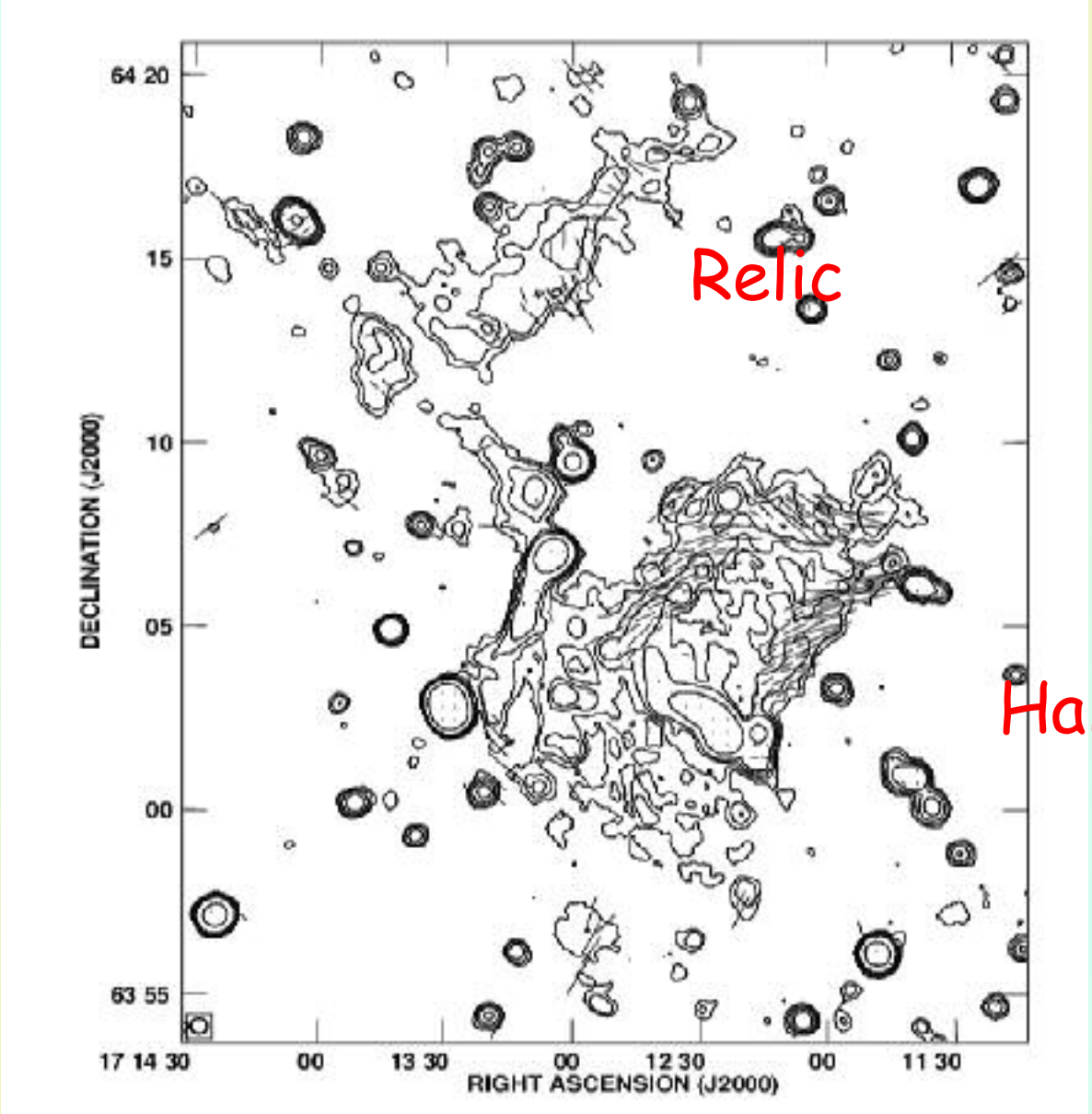
Kim et al. 1989
Giovannini et al. 1990

MACS J0717.5+3745 z=0.55



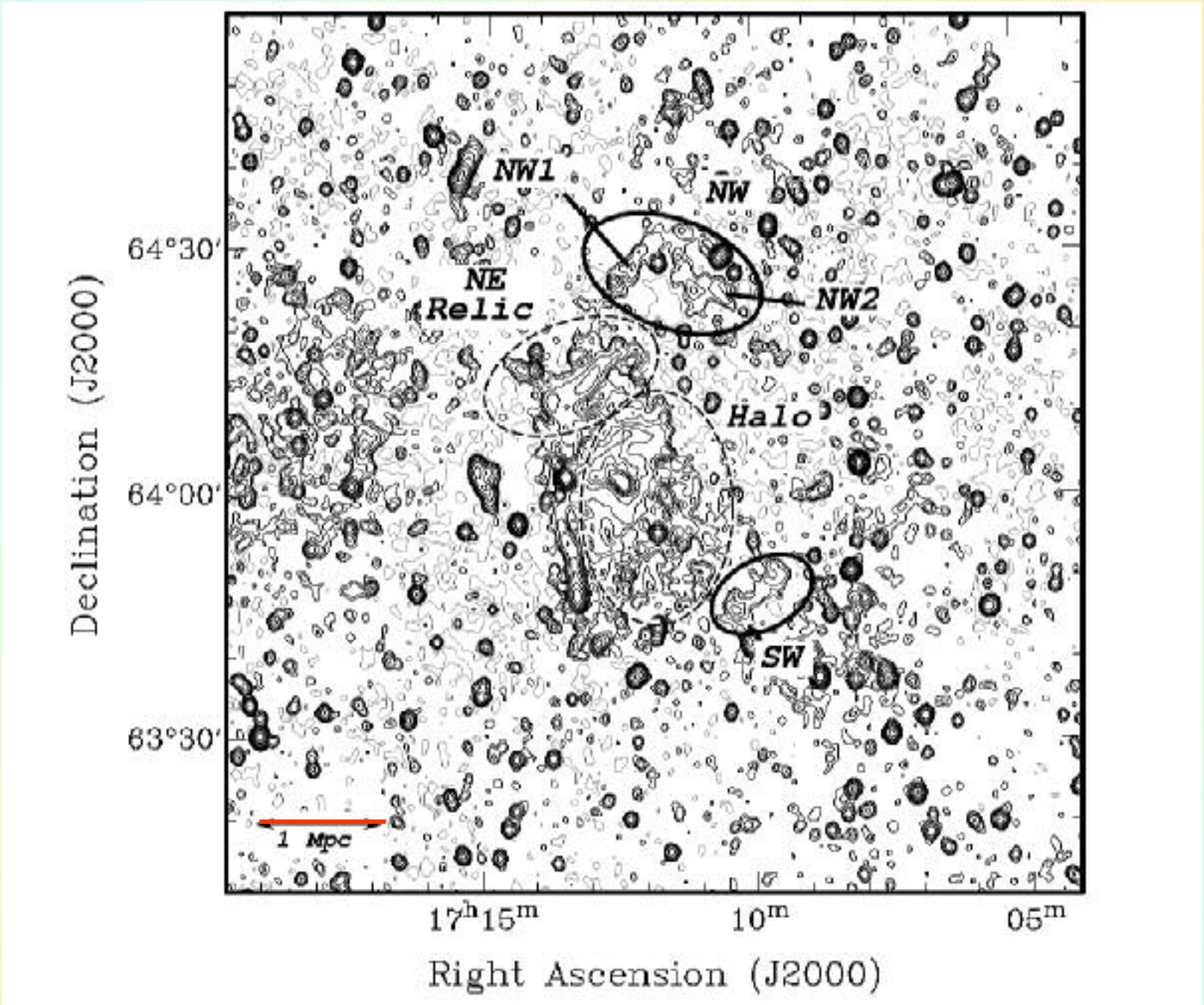
Bonafede et al. 2009

A2255



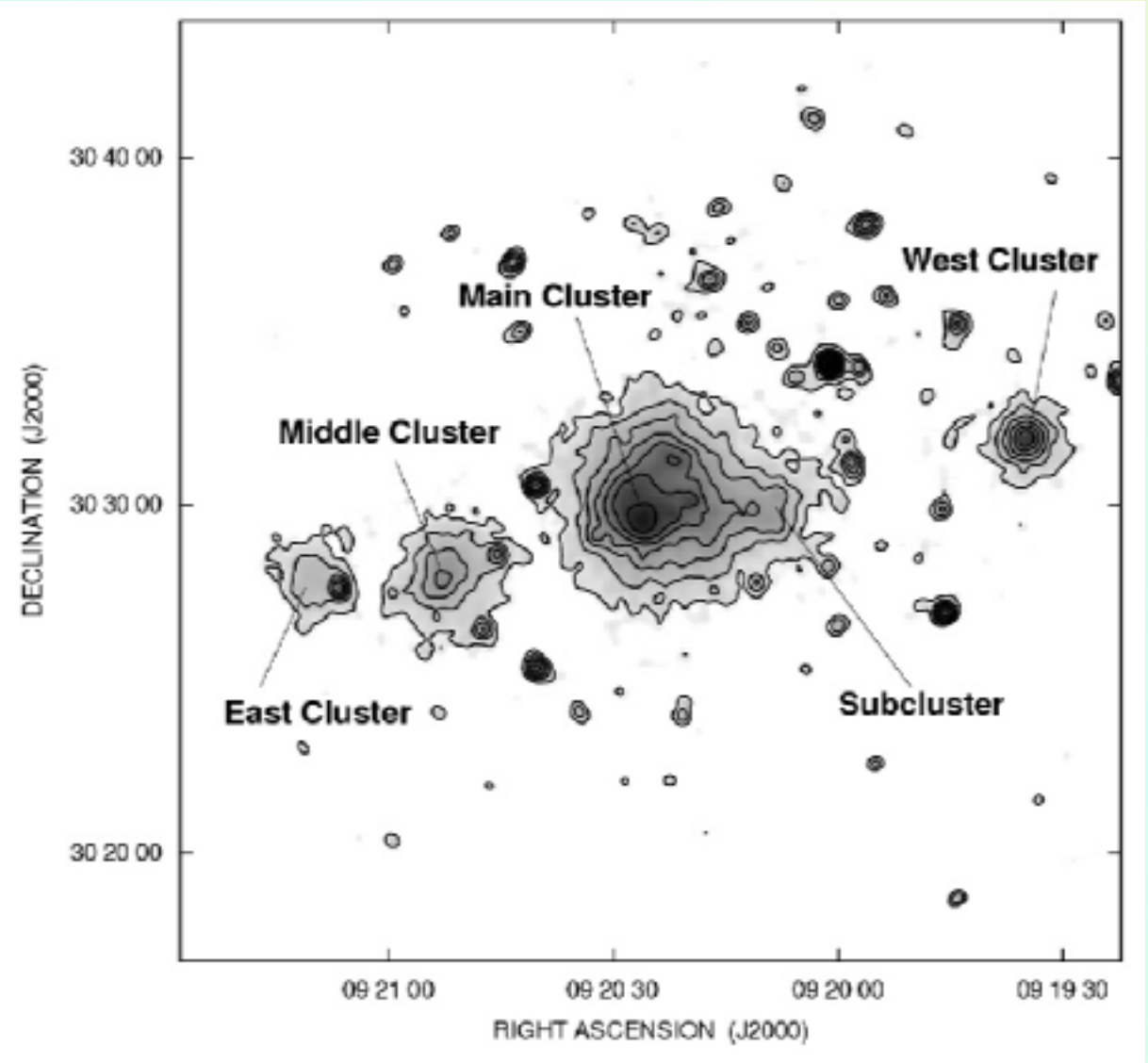
Govoni et al. 2006

A2255 WSRT 85 cm



Pizzo et al. 2009

A781 (z=0.302) belongs to a complex system characterized by extended X-ray sources that may form part of line of clusters of galaxies along a filament. The system consists of a large main cluster connected to a sub-cluster, two smaller clusters to its east, and one to its west.

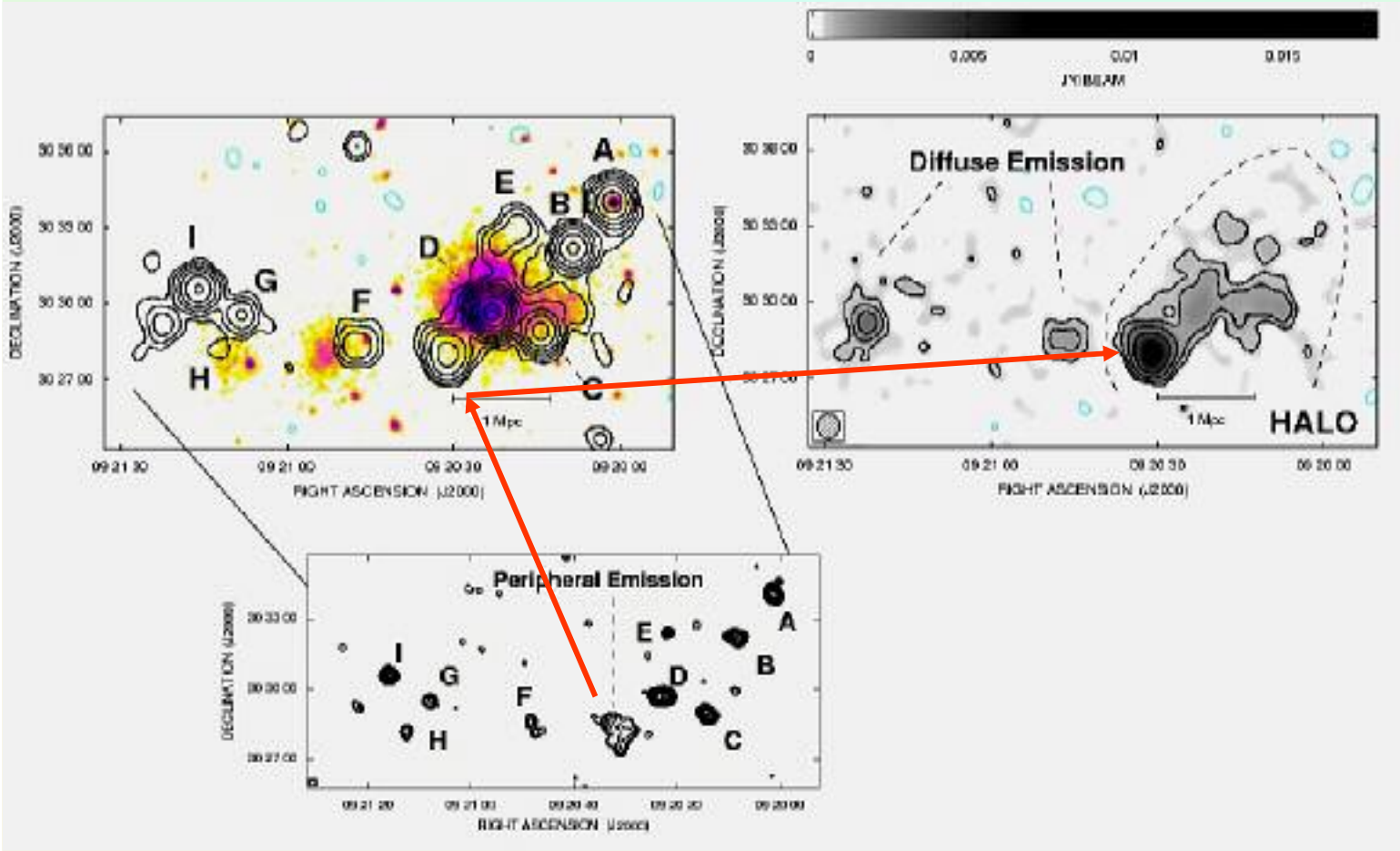


XMM-Newton image

XM

The radio halo has a quite irregular structure and presents the typical properties of the other known halos. On a larger scale a hint of diffuse emission, elongated versus east, may trace the relativistic electron and magnetic field distribution along a large scale radio filament.

Govoni et al. 2010, submitted



Extended diffuse radio emission in low density regions: (I will not include Relic sources)

A1213
0217+70

(Delain & Rudnick 2006) report also:

0914+30: extended radio emission at 400 kpc from a merging poor group (HCG37) L_x $10^{41.5}$ no clear identification

1421+25 (NGC5580) diffuse emission radio halo or old emission from a bright galaxy (no X-ray detection)

A1213

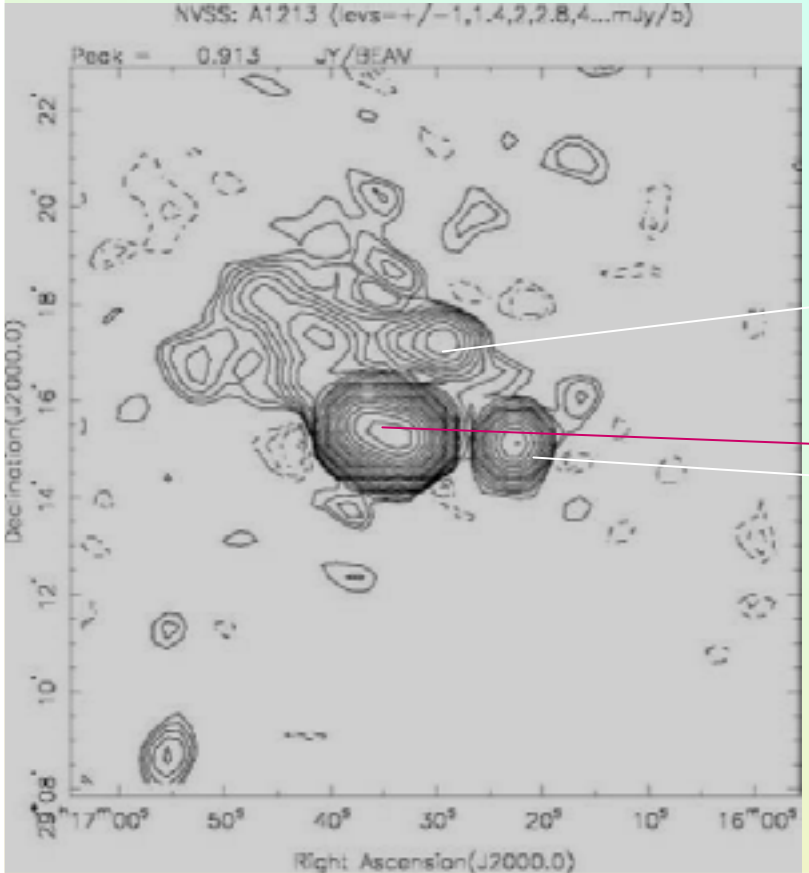
Low X-Ray luminosity cluster: 10^{43} erg/s by Rosat 0.1-2.4 KeV band; not relaxed

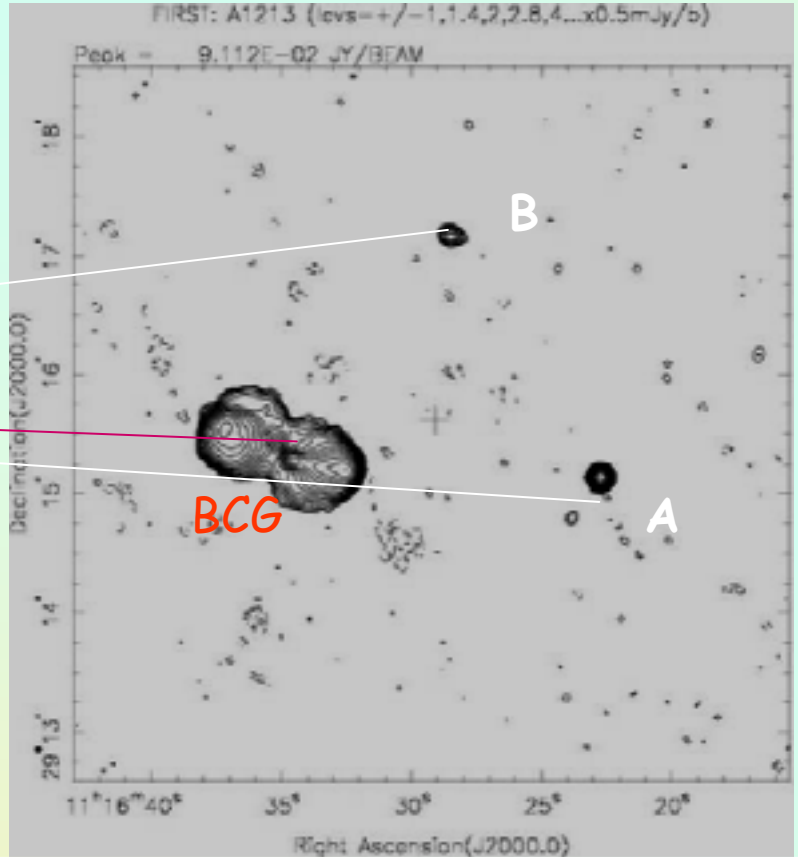
1) Is it real the diffuse radio extended source?

   Yes: present in NVSS, confirmed by two pointed observations by us (C and C/D configuration)

2) Could it be due to many unrelated discrete sources?

   No: we have old but good WSRT data at 1.4 GHz and no discrete source is present (HPBW 20")
   no discrete source in the FIRST image



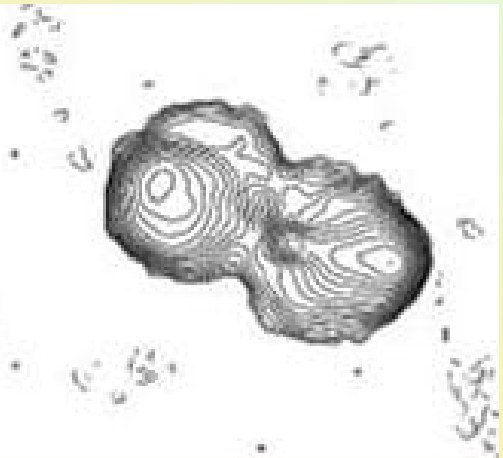


3) Could the extended emission be related to the activity of one or more cluster galaxies?

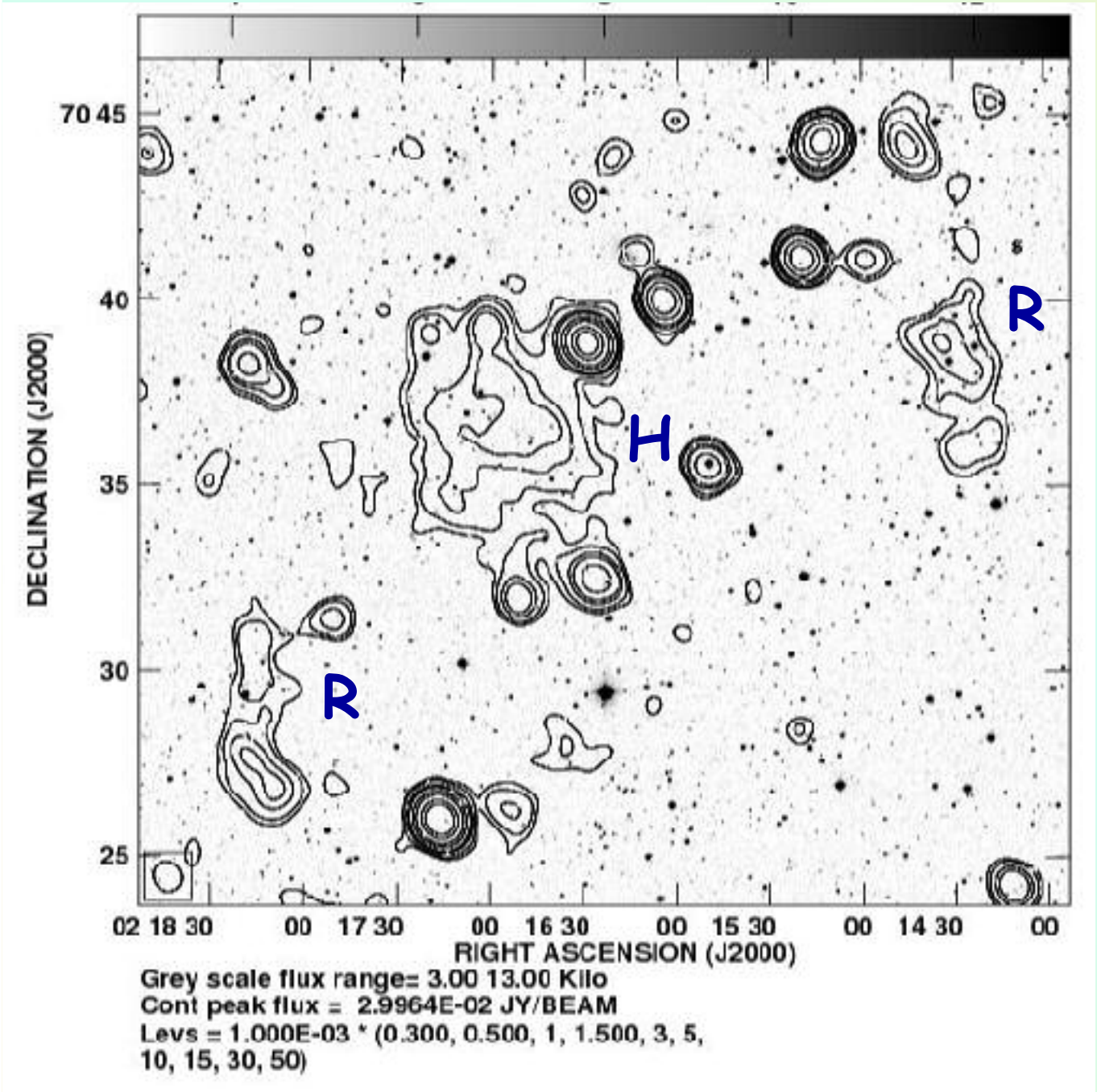
No 4C31.04 BCG – If the extended emission is the tail of 4C31.04 we have to assume that this source (or the ICM) was fast moving in the past and now is at the cluster center at rest – see the radio structure. Assuming a velocity on the plane of the sky = 1000 km/sec (very high for a BCG!!!) we need 2.3 x 10^8 yrs to 'create' the diffuse emission ➔ unreliable

The cluster galaxy (B) – it is a peripheral galaxy and can move faster than the BCG, but still the age can be a problem, moreover at present is very faint, marginally resolved in FIRST images (on the opposite side with respect to the extended emission) ➔ very unlikely

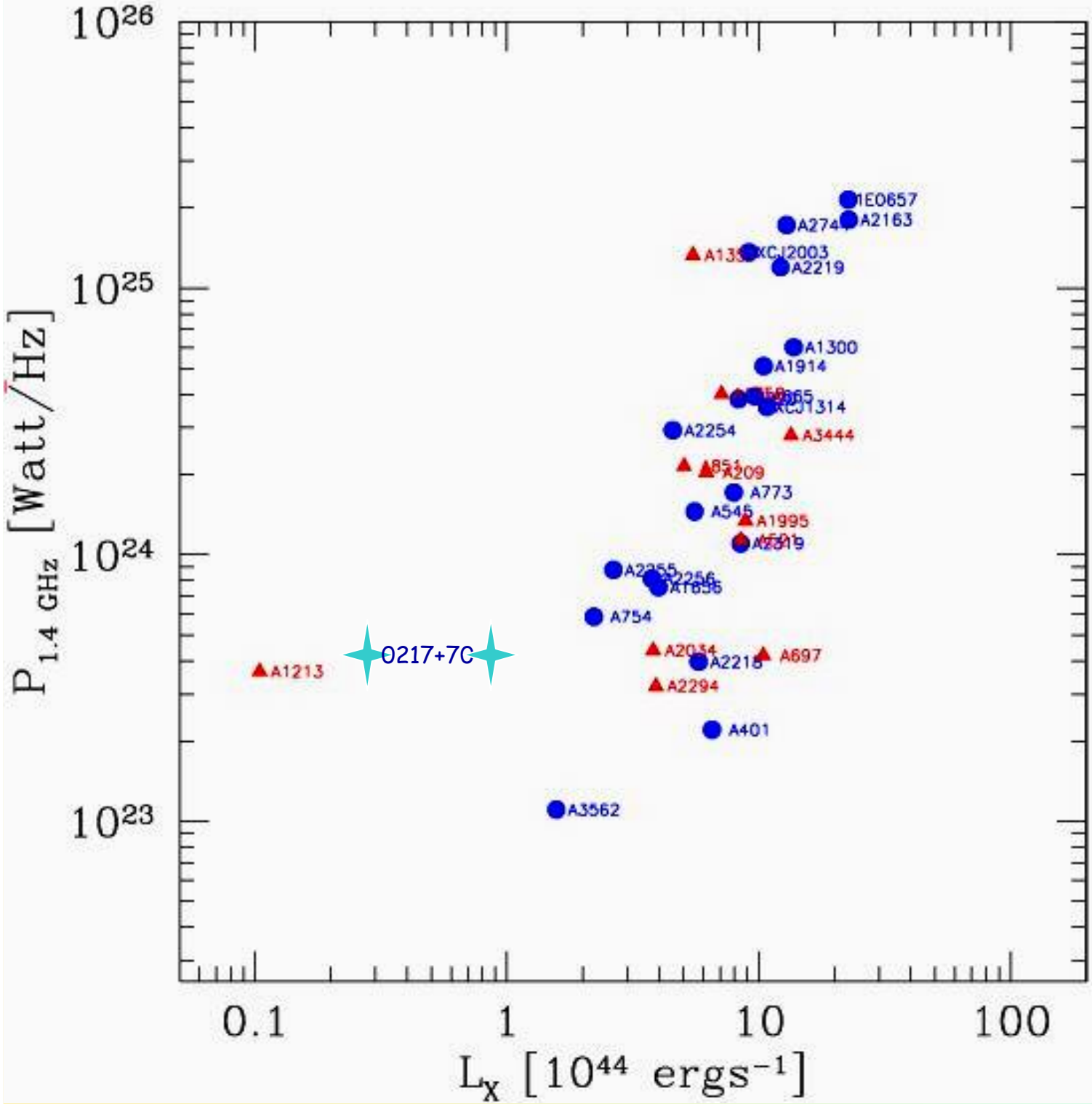
➔ **The diffuse source in A1213 is a small size radio halo.**

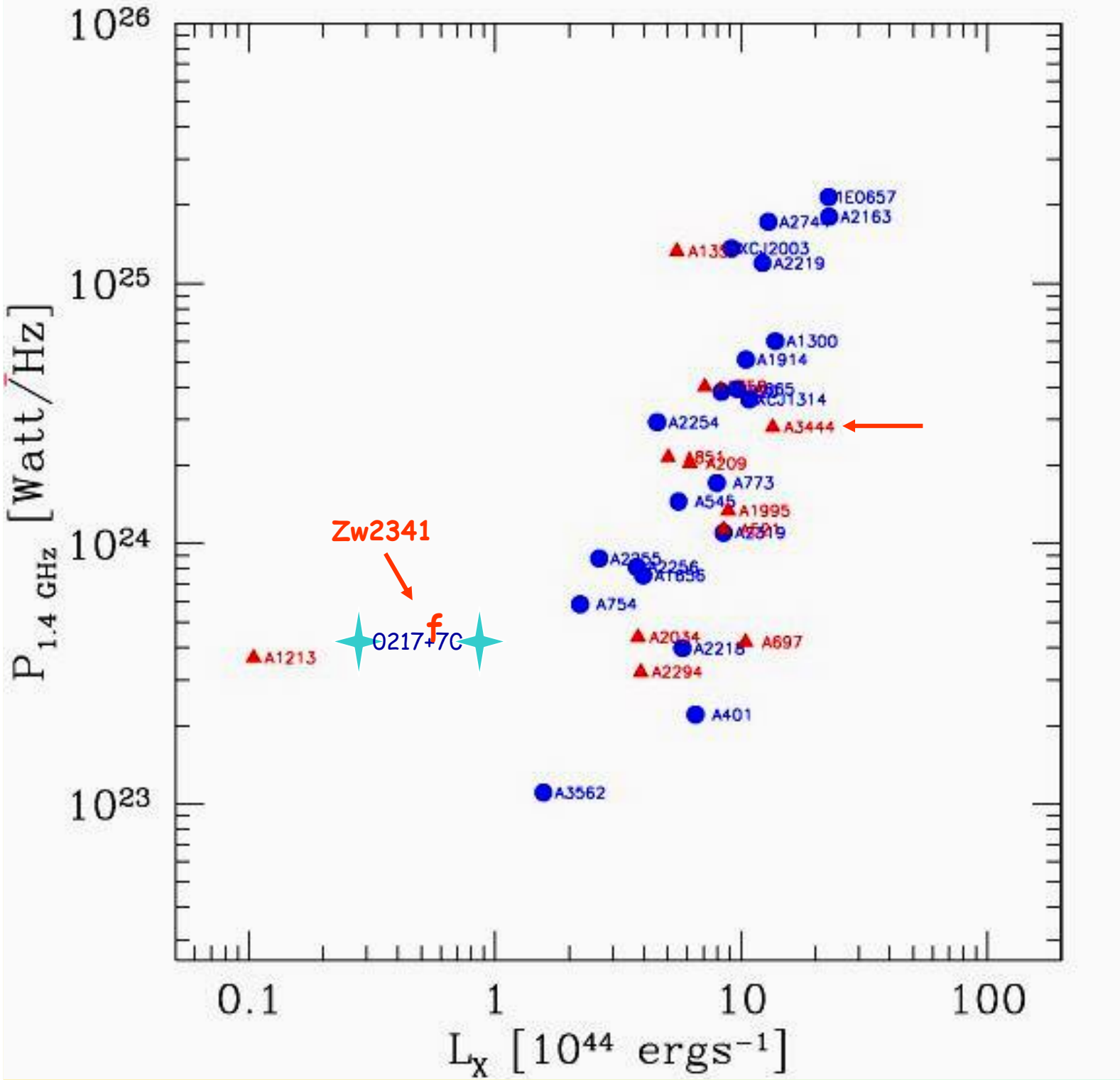


A radio selected cluster: 0217+70 by Brown et al. 2010



Poor group at z=0.0655
H spectral index: 1.34
R: 1.34 (N) 1.54 (S)
ROSAT:
1RXS J021649.0+703552
Log L_x=43.8 erg/s (total)
43.4 Halo


10^{26}
10^{25}
10^{24}
10^{23}
$P_{1.4\ GHz}$ [Watt/Hz]
0.1
1
10
100
L_X [10^{44} ergs^{-1}]
1E0657
A2163
A2744
A2219
A1300
A1914
A2254
A3444
A773
A1995
A754
A697
A2218
A2294
A401
A3562
A1213
0217+70



With filaments and Extended radio sources with no X-Ray emission:
0917+75
0809+39

Summary

-Magnetic fields have been detected also outside the center of rich clusters in regions where filaments of galaxies connecting rich clusters, are present (few Mpc scale). In most but not all of them, X-Ray emission has been detected.

-Magnetic fields have been detected also in a few poor groups where the galaxy density is low and X-ray Luminosity is < 10^{44} erg/s. Evidence of merging is always present but these points are outside the correlation between radio and X-ray Luminosity.

Thanks