
GMRT observations of radio halo clusters

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Collaborators

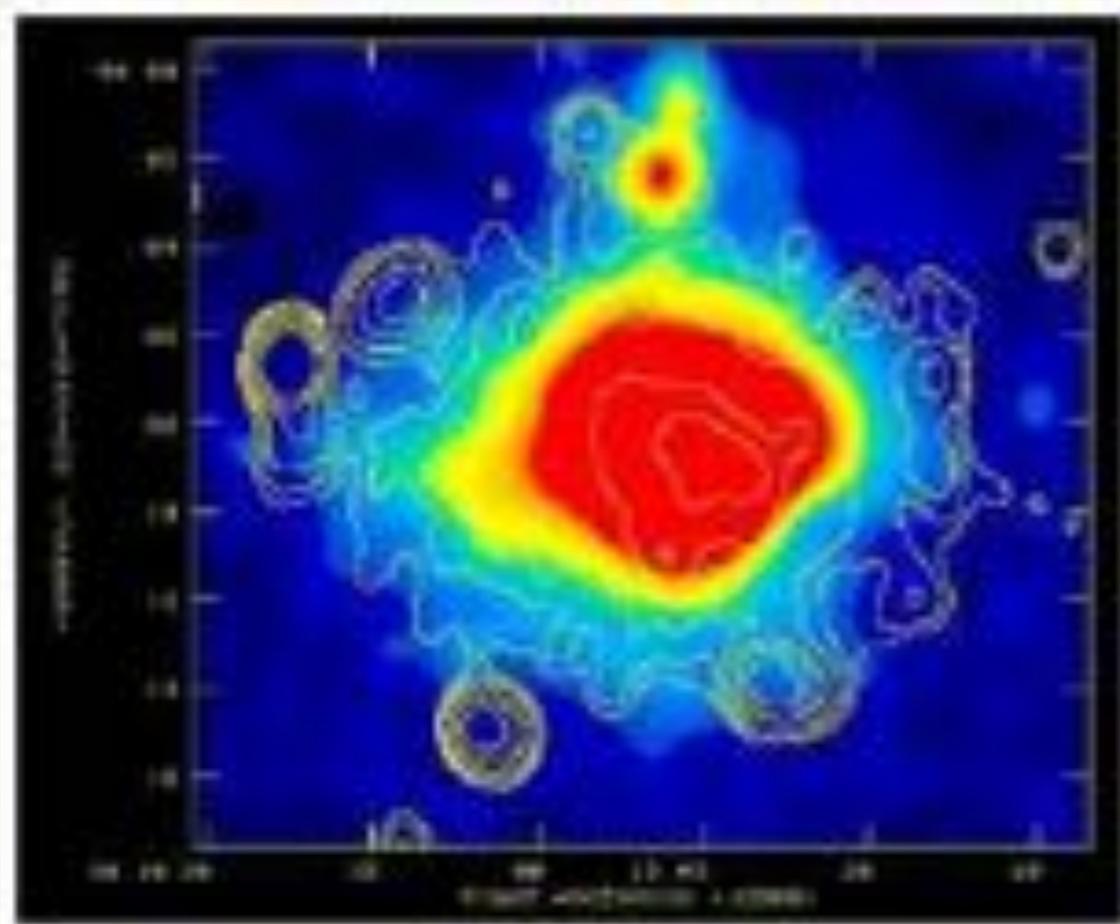
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Huib Intema (Leiden Observatory)



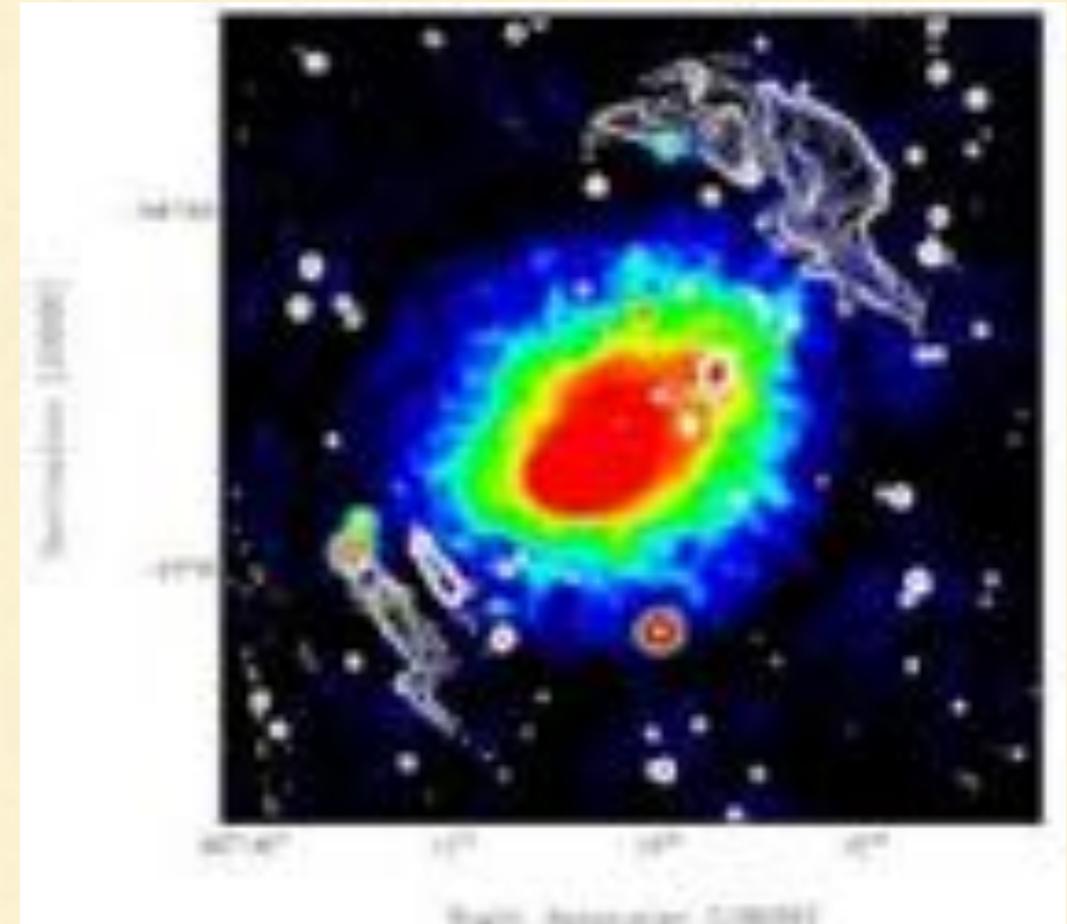
Introduction

- Radio halo and relic; diffuse extended radio sources
- Massive Cluster Survey (MACS) cluster sample (Ebeling et al. 2001)
- This sample comprises a total of 124 clusters ($0.3 < z < 0.7$, $\sim 10^{14}$ to $10^{15} M_{\odot}$)
- Radio halo detection probability increases with clusters having $L_x > 10^{44}$ erg s⁻¹
- Selected six disturbed, luminous (1.5 to 3.6×10^{45} erg s⁻¹) and massive clusters ($> 6 \times 10^{14} M_{\odot}$) in redshift range of 0.3 to 0.44
- GMRT 610/235 MHz dual frequency observations, TGSS 150 MHz, EVLA 1400 MHz, and Chandra X-ray archival data

Diffuse radio sources



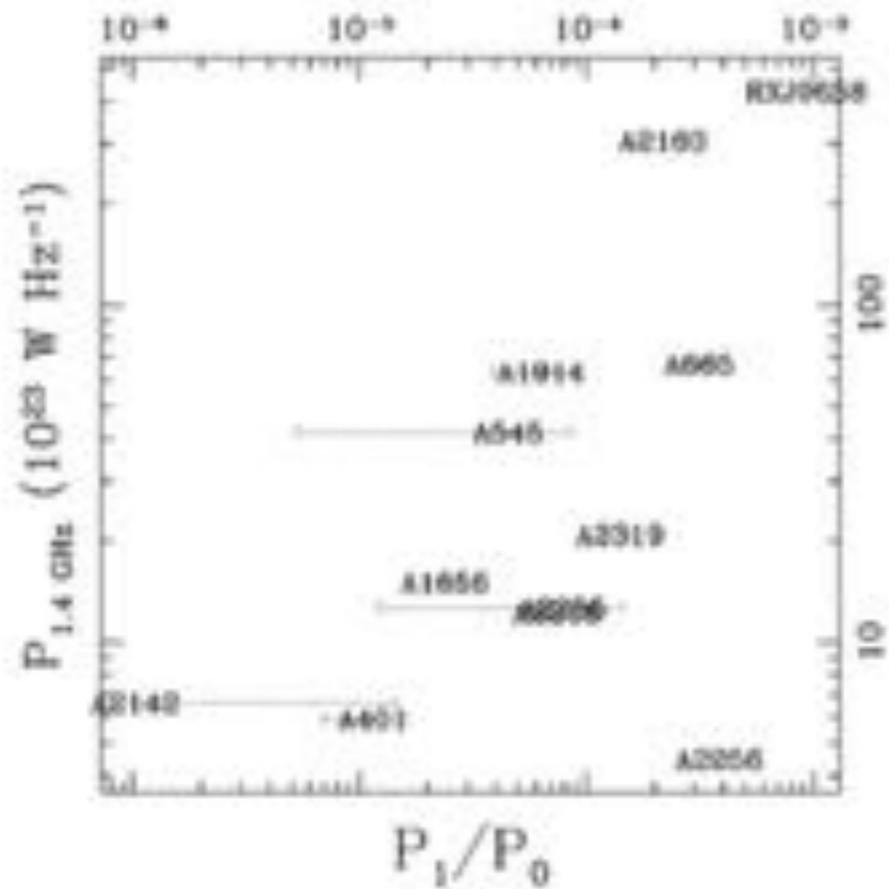
Radio halo



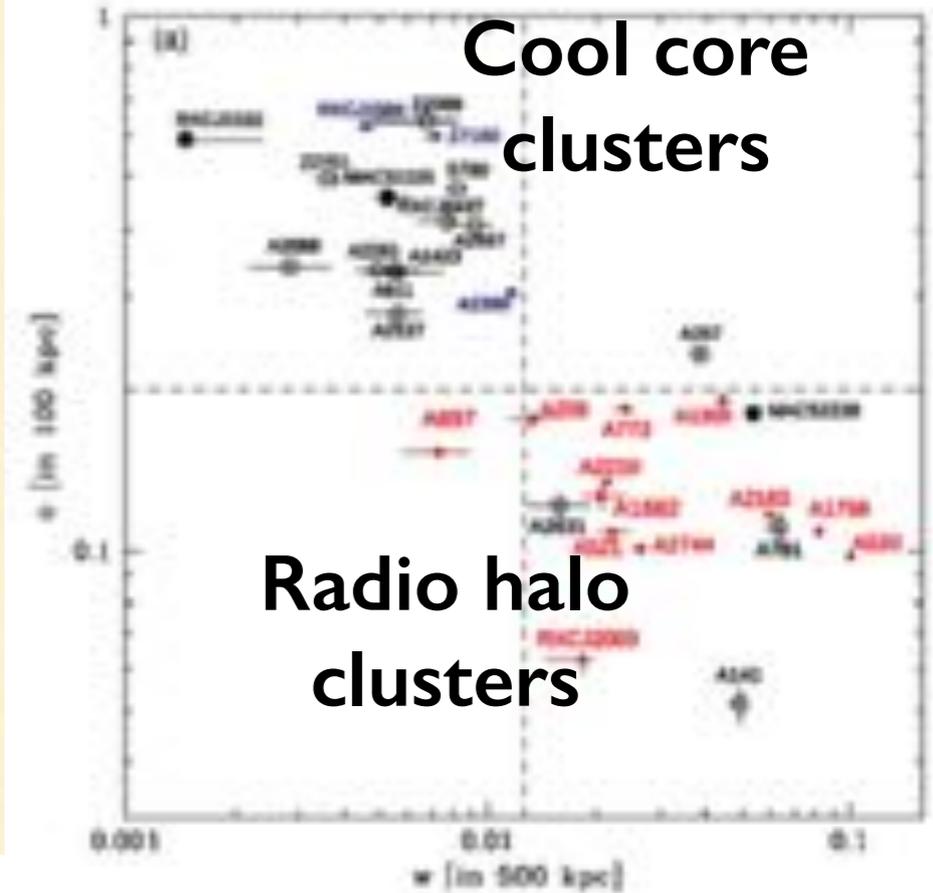
Radio relic

- ▶ **Radio halo:** Centrally located; regular morphology; good spatial coincidence with X-ray brightness distribution; unpolarised; $\alpha=1.2-1.4$, size ~ 1 Mpc
- ▶ **Radio relic:** Cluster periphery; elongated (but also other morphologies); polarised (20-30%); $\alpha=1.2-1.4$; size ~ 1 Mpc

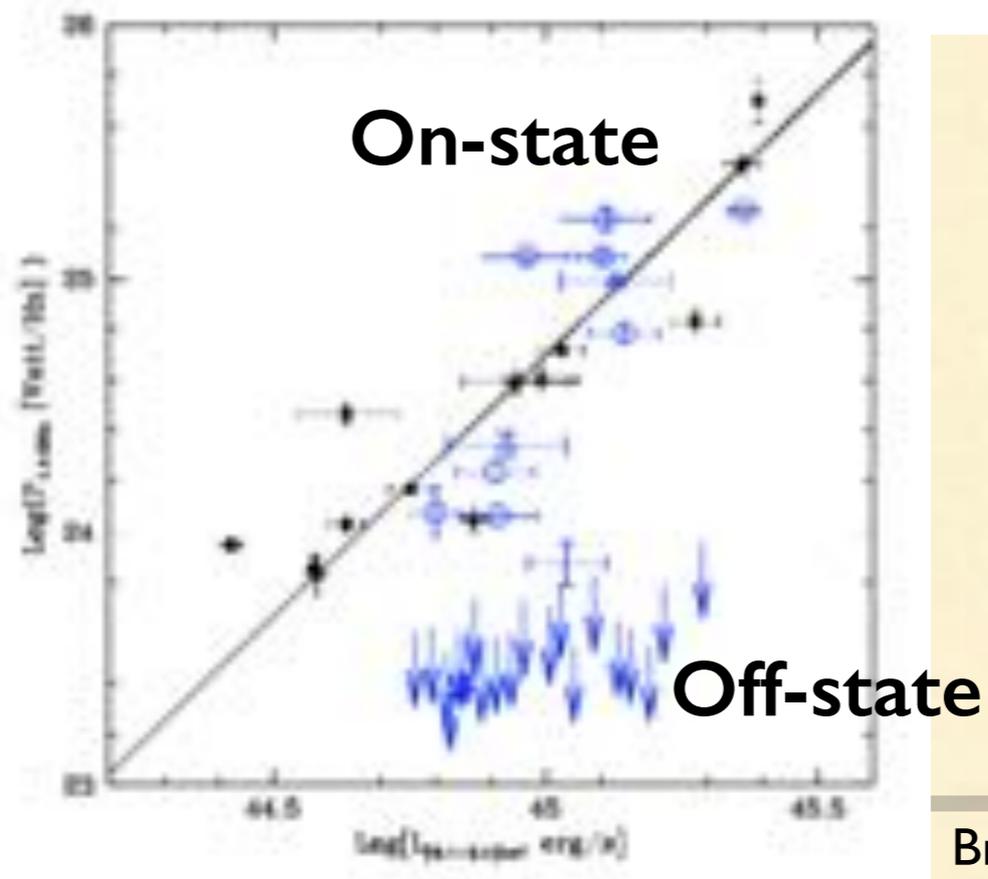
Radio vs. X-ray properties



Buote et al. 2001



Cassano et al. 2010



Brunetti et al. 2009

J0417.5-1154

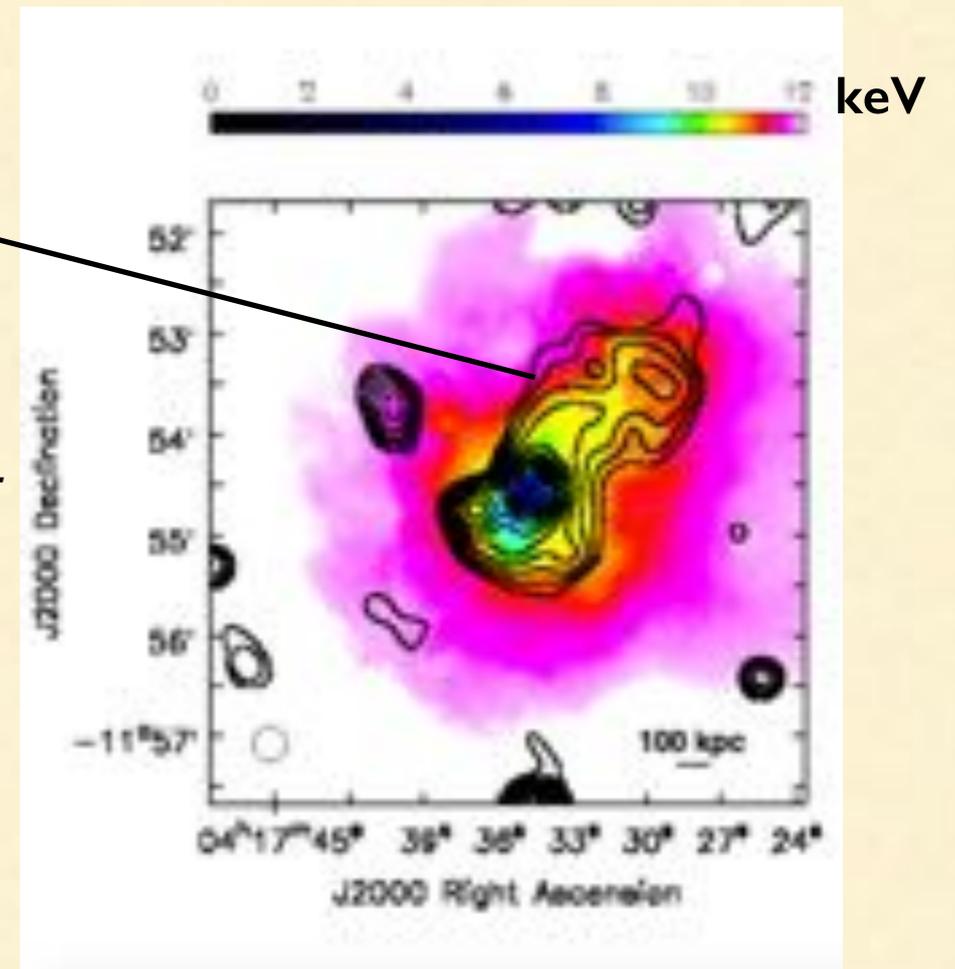
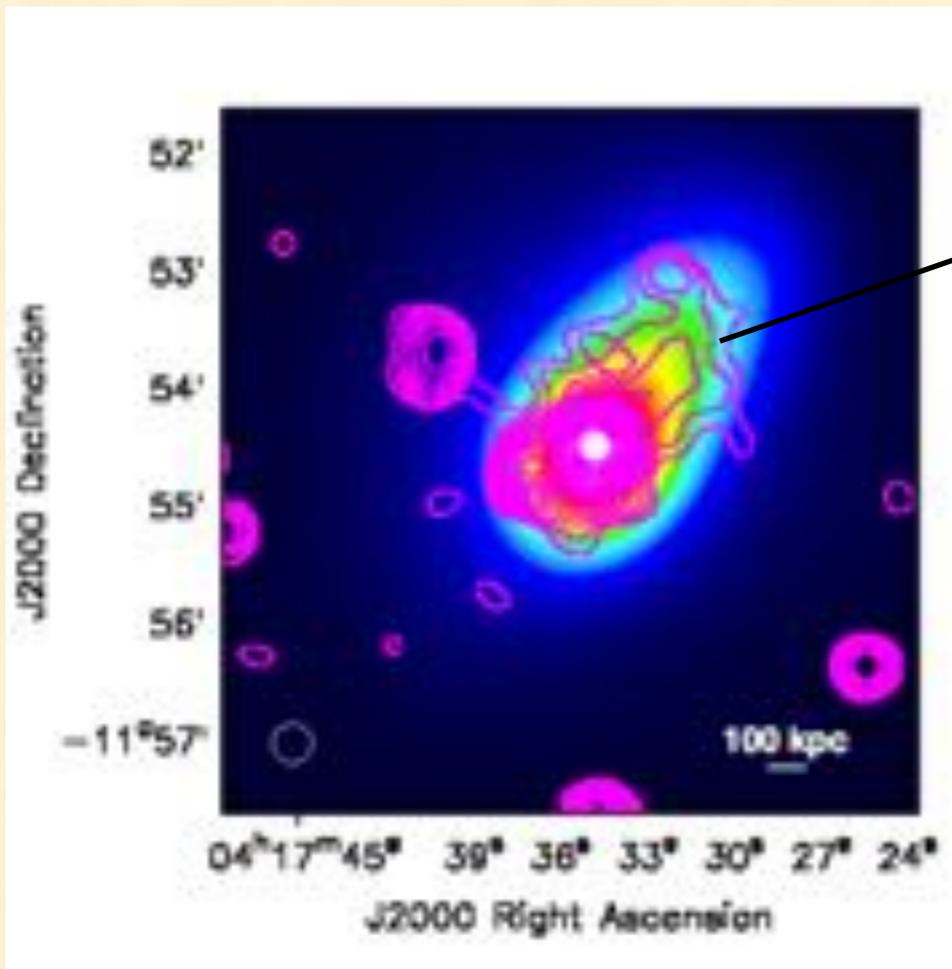
Radio halo

$$\sigma_{610\text{MHz}} = 0.15 \text{ mJy/beam}$$

$$\sigma_{1.5\text{GHz}} = 40 \text{ } \mu\text{Jy/beam}$$

1st contour is drawn at 3σ

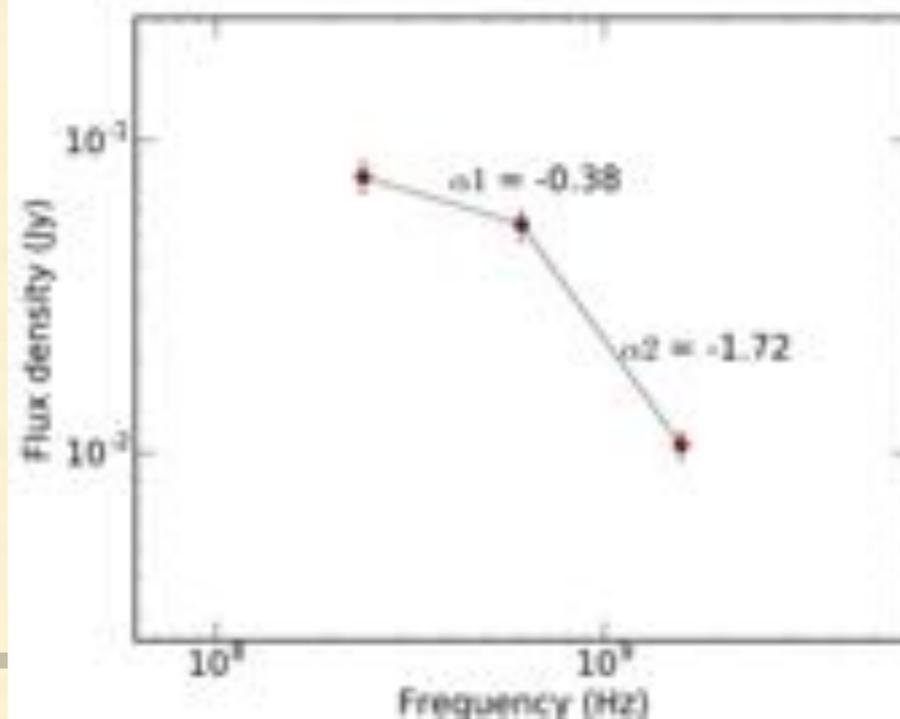
Contour level increases
in steps of $\sqrt{2}$



1.5 GHz contours
on X-ray color image

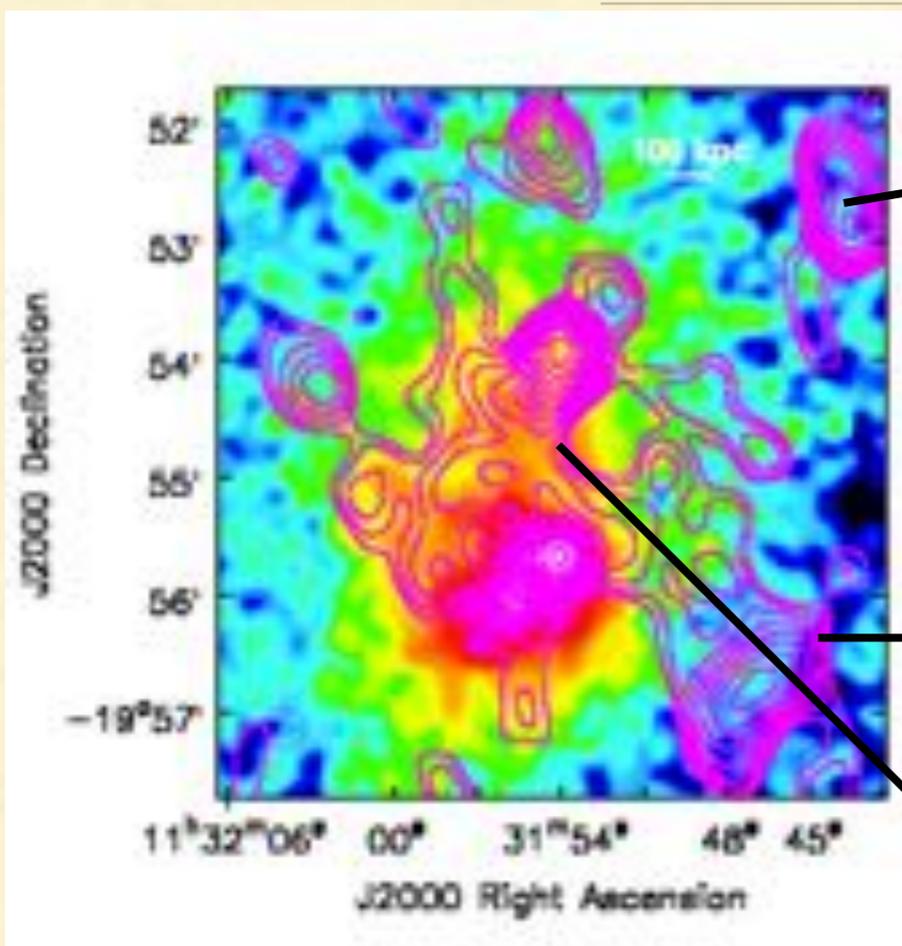
610 MHz contours
on temperature map

Dwarakanath et al.
(2011), Parekh et
al. (2016)



Ultra steep spectrum halo

J1131.8-1955 (A1300)



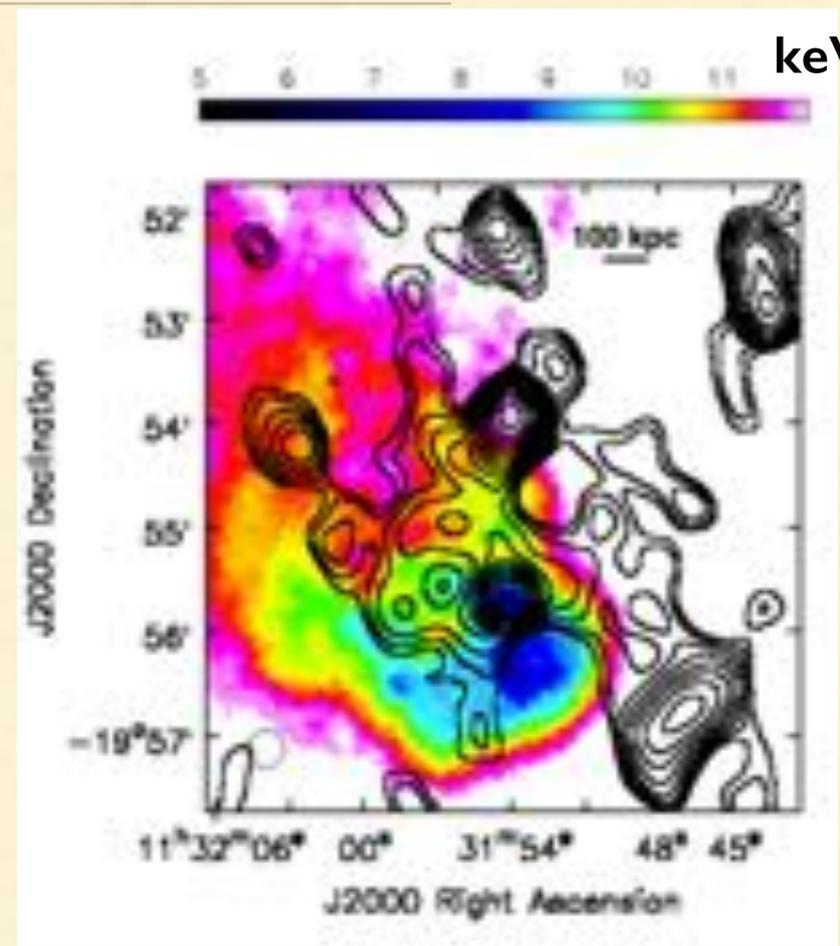
NW Candidate relic

$\sigma_{610\text{MHz}} = 0.30 \text{ mJy/beam}$
 1st contour is drawn at 3σ
 Contour level increases
 in steps of $\sqrt{2}$

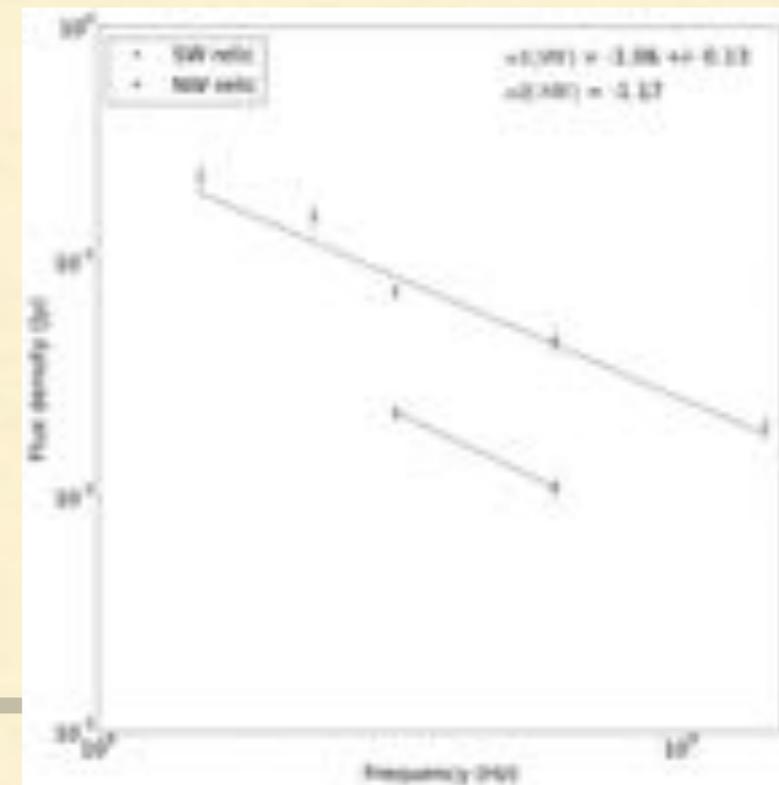
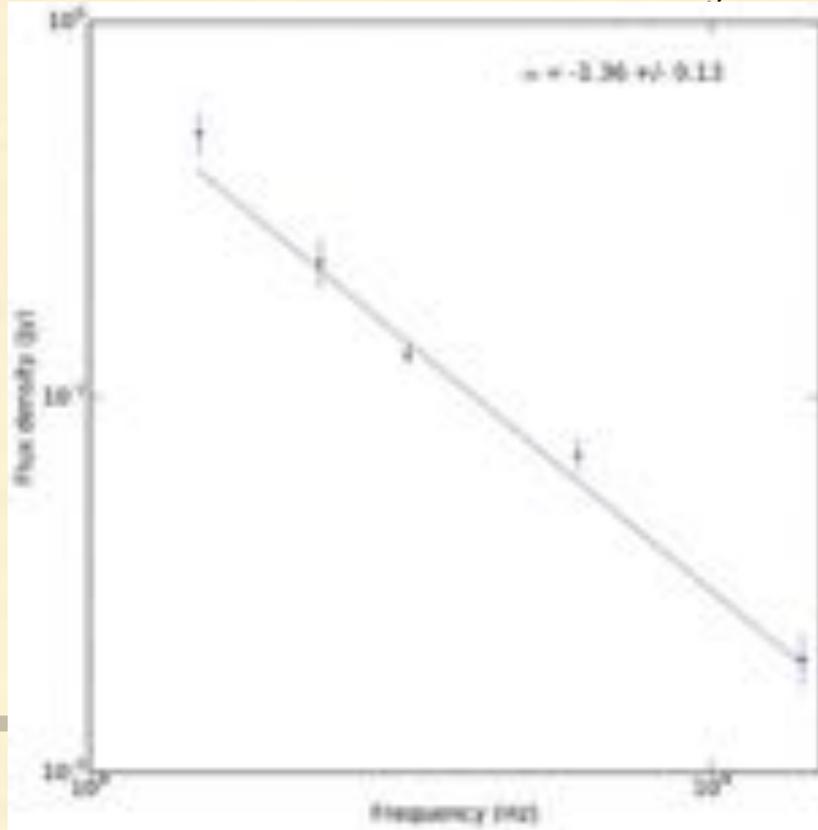
SW relic

Radio halo

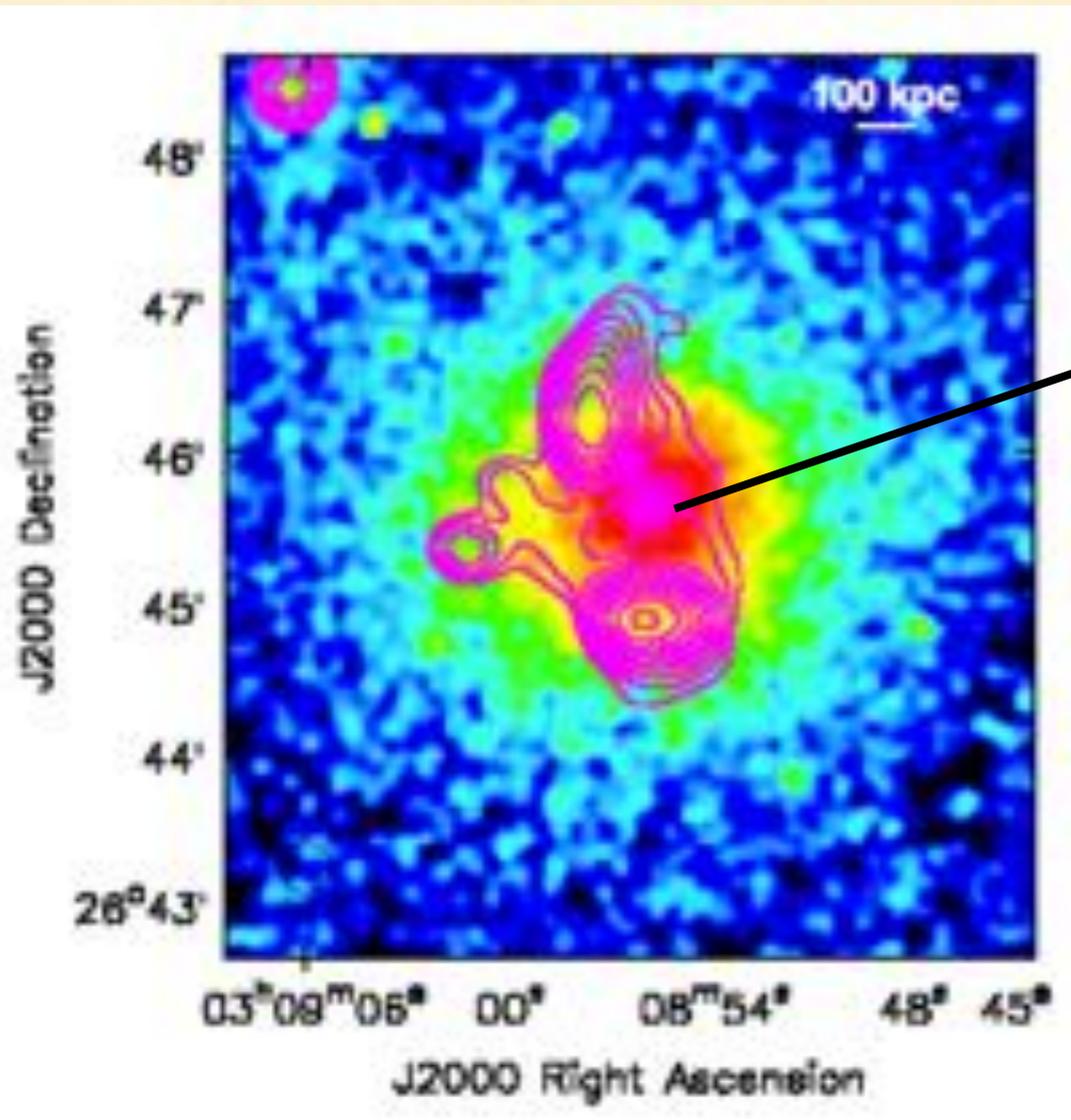
610 MHz contours on X-ray map



610 MHz contours on temperature map

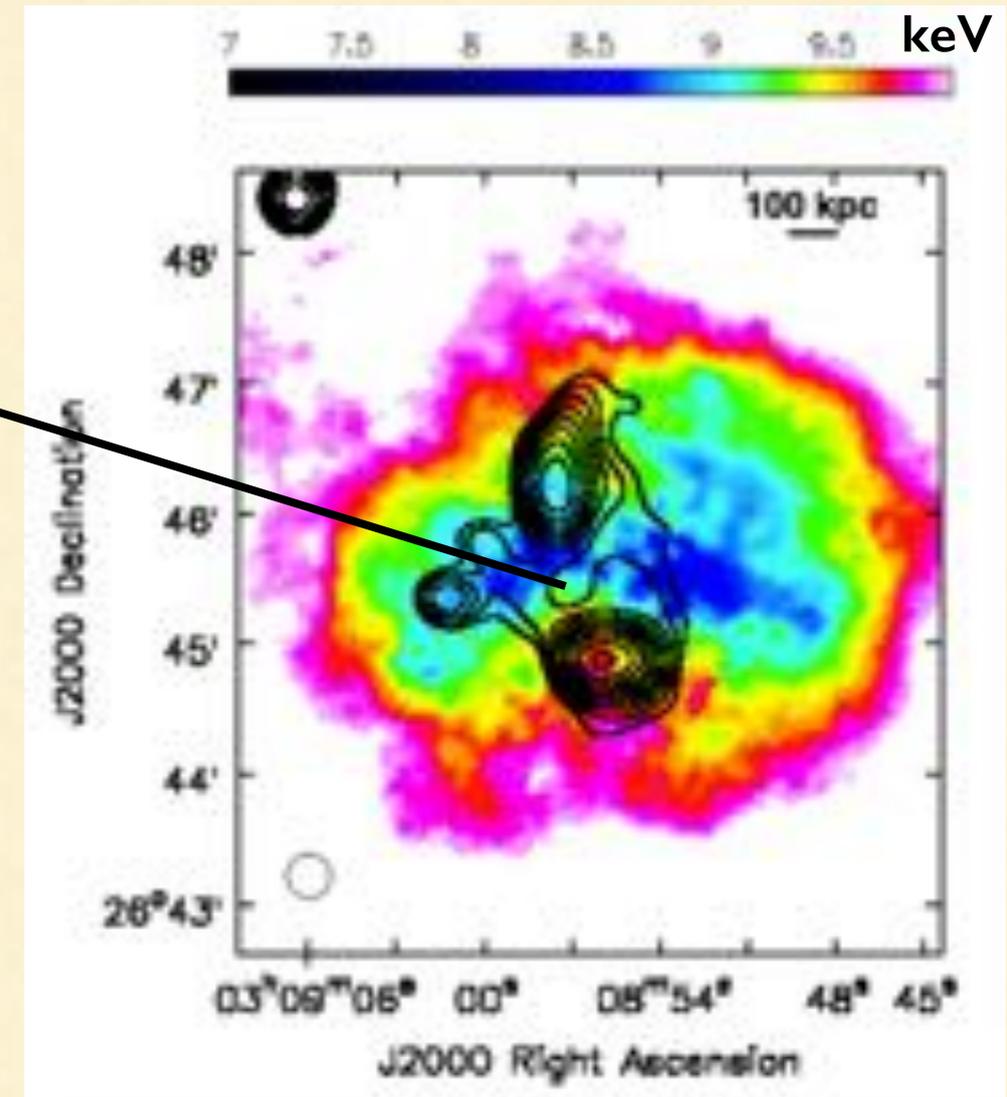


J0308.9+2645



610 MHz contours on X-ray map

Radio halo



610 MHz contours on temperature map

$\sigma_{610\text{MHz}}=0.38$ mJy/beam, 1st contour is drawn at 3σ
Contour level increases in steps of $\sqrt{2}$

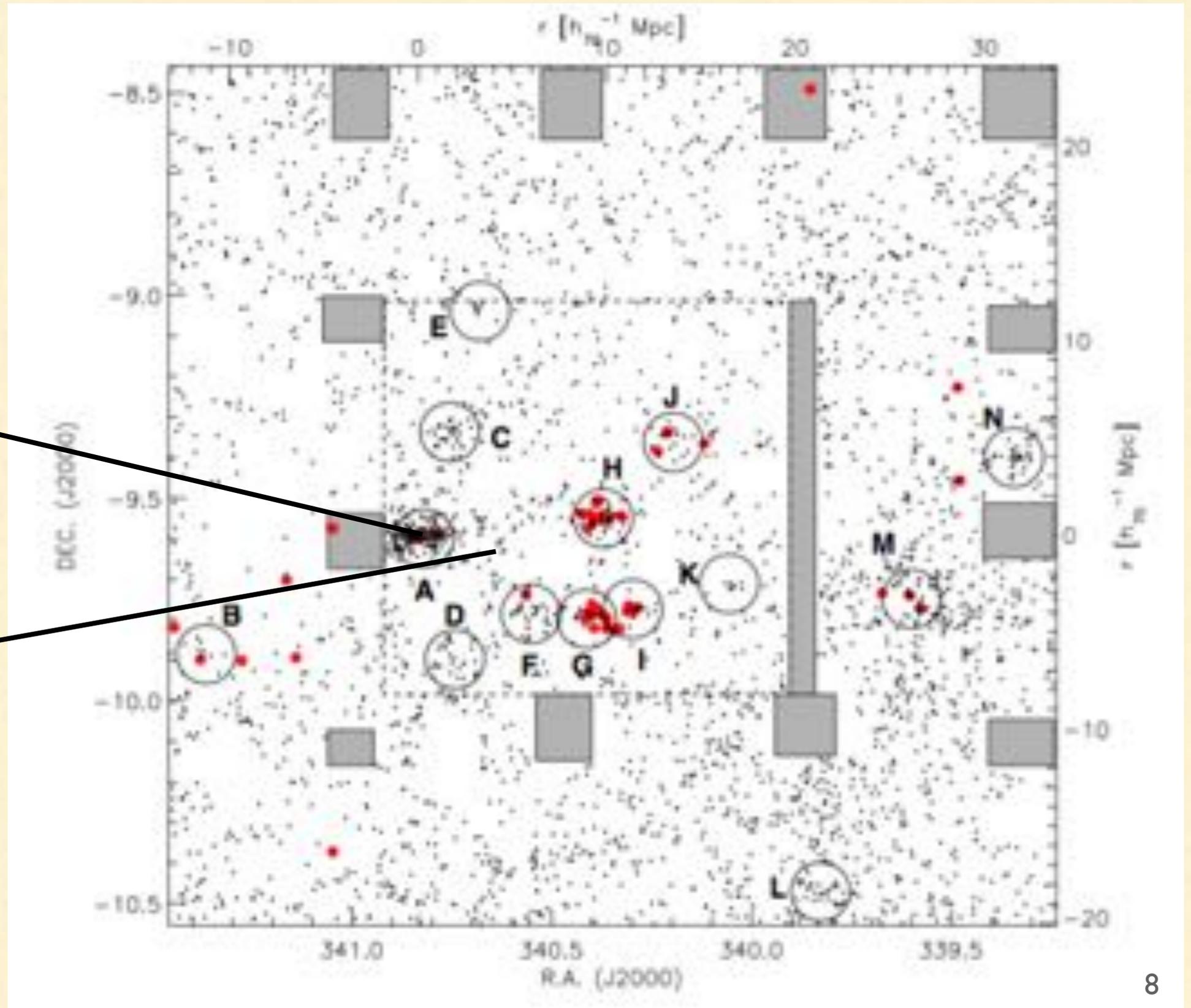
J2243.3-0935

J2243.3-0935

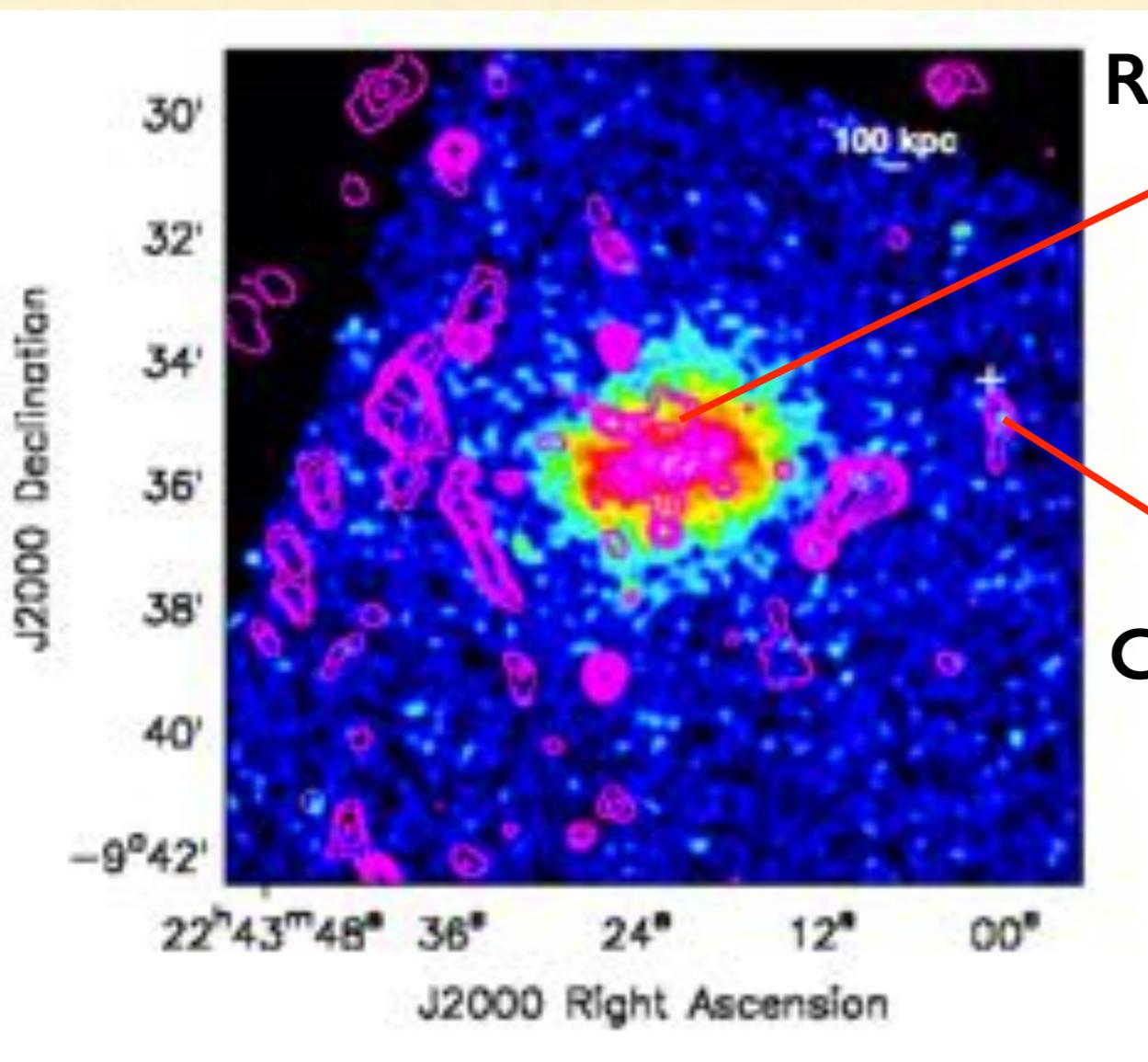
AC, AH and AFDGI
filaments

~5-15 Mpc

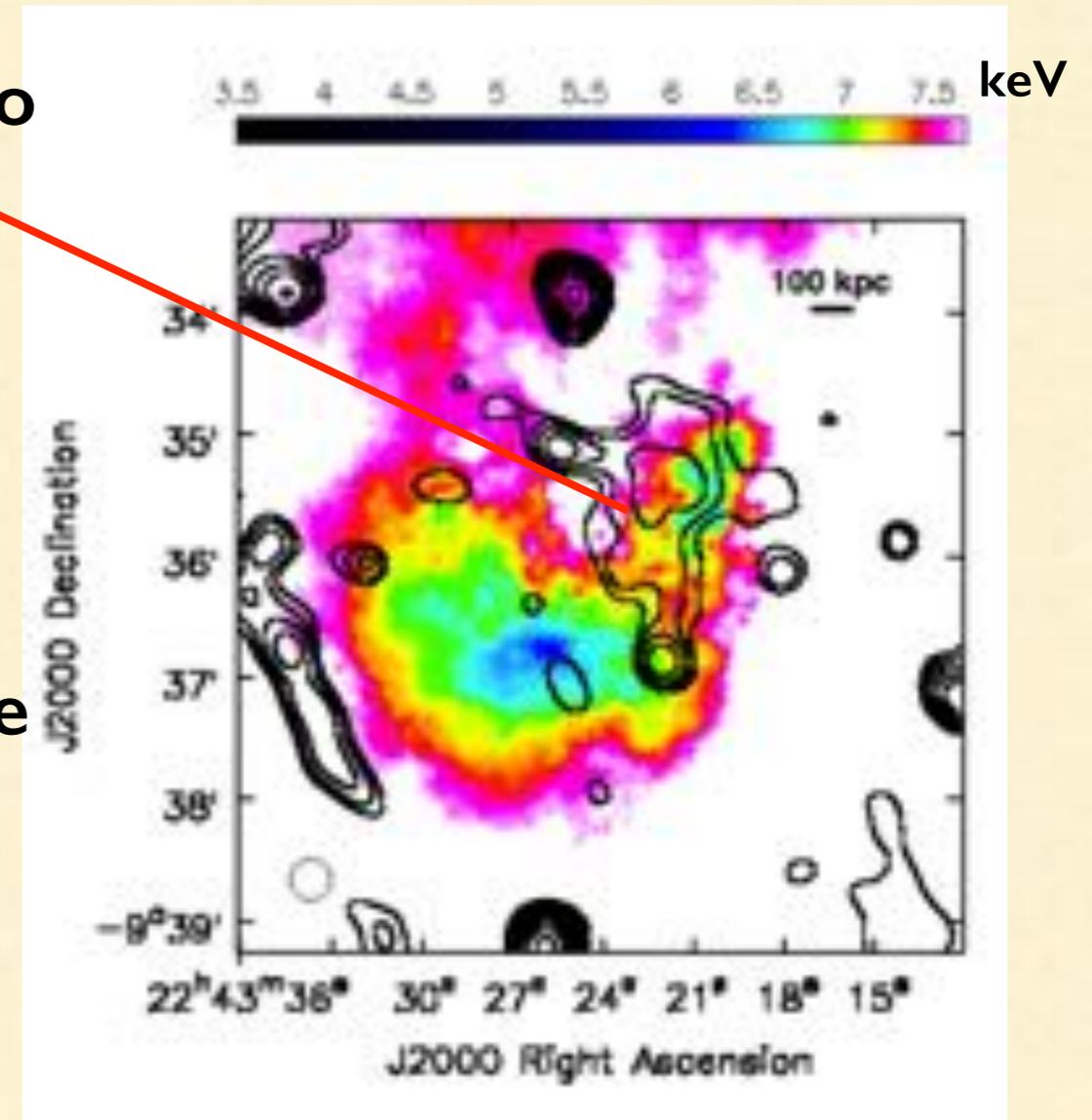
~ $10^{15} M_{\odot}$



J2243.3-0935



610 MHz contours on X-ray image

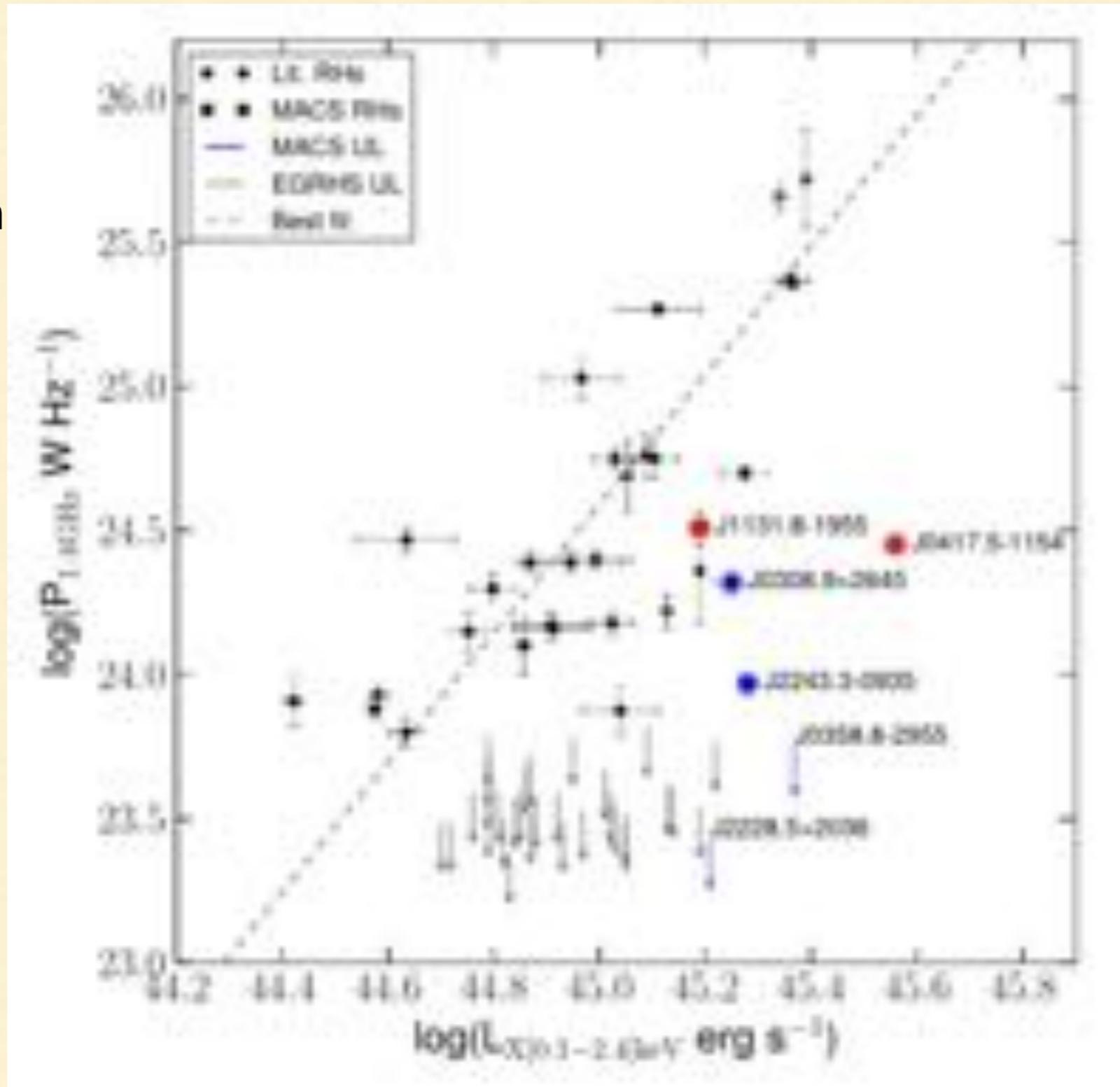


610 MHz contours on temperature map

$\sigma_{610\text{MHz}}=0.10$ mJy/beam, 1st contour is drawn at 3σ
Contour level increases in steps of $\sqrt{2}$

P_{1.4 GHz} Vs. L_x

Applied K-correction
to radio luminosity
with $(1+z)^{(1+\alpha)}$

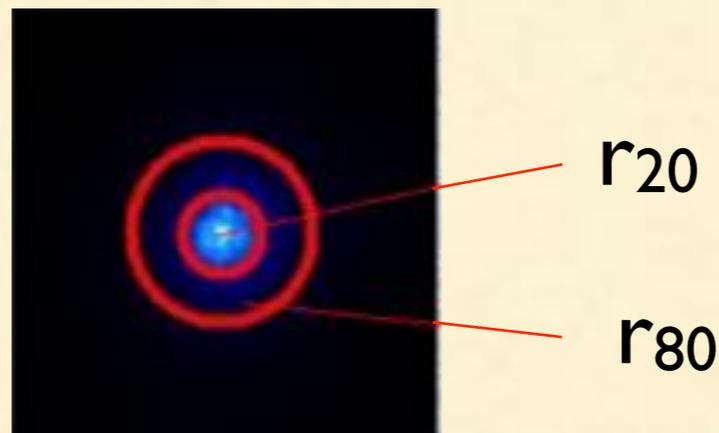


data points and best fit line from Kale et al. 2015 along with six MACS sample clusters

X-ray cluster morphology parameters

- **Gini** :- It measures the distribution of flux density for a given physical size of X-ray cluster, irrespective of the location of pixels; varies from 0 (most disturbed) to 1 (most relaxed).
- **M₂₀** :- It measures the second order moment of 20% brightest pixels around the cluster centre. It varies from -2.5 (most relaxed) to 0.7 (most disturbed). Most important parameter to separate relaxed and non-relaxed clusters.

- **Concentration** :-



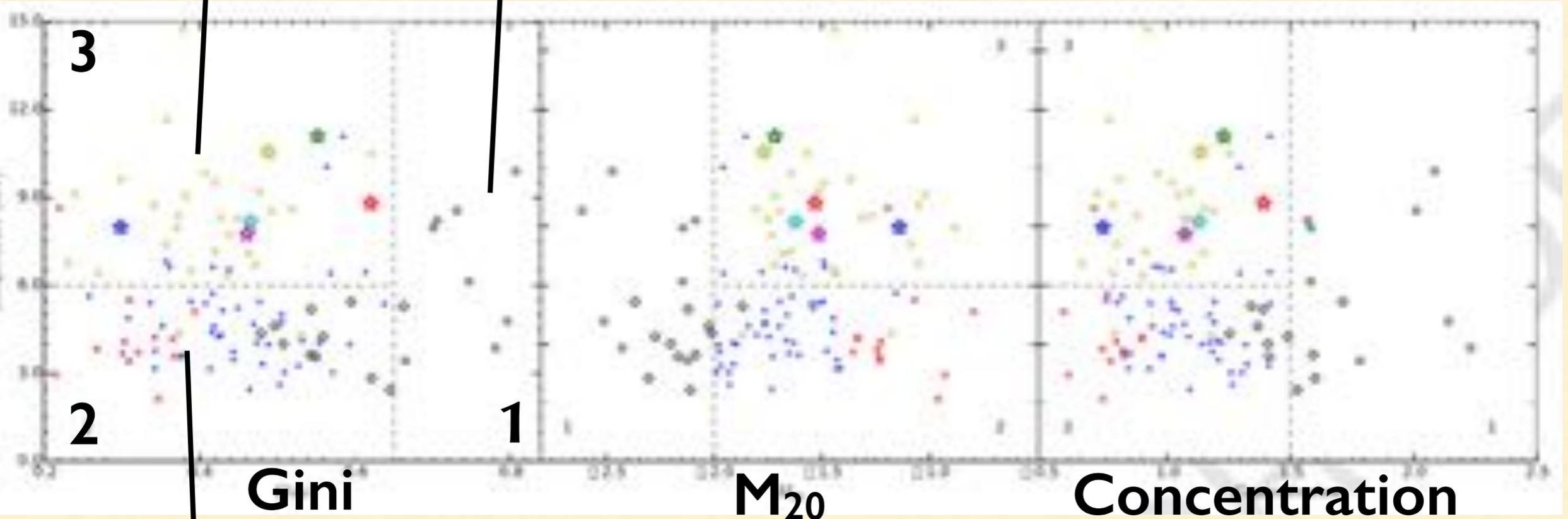
$$C = 5 \log \left(\frac{r_{80}}{r_{20}} \right)$$

Cluster morphology

Radio loud merger clusters

Relaxed clusters

Temperature(keV)



Radio quiet merger clusters

(Parekh et al. 2015)

Conclusion

- Six high-z, massive and disturbed MACS clusters
- Two are confirmed radio halos, two are candidate radio halos and remaining two are 'off-state' clusters
- J0417.5-1154 is a peculiar radio halo shows ultra steep spectrum between 610 and 1400 MHz
- diffuse radio halo clusters (confirmed and candidates) are close to the $P_{1.4 \text{ GHz}}-L_x$ best fitting line, while 'off-state' clusters are ~ 11 times below it

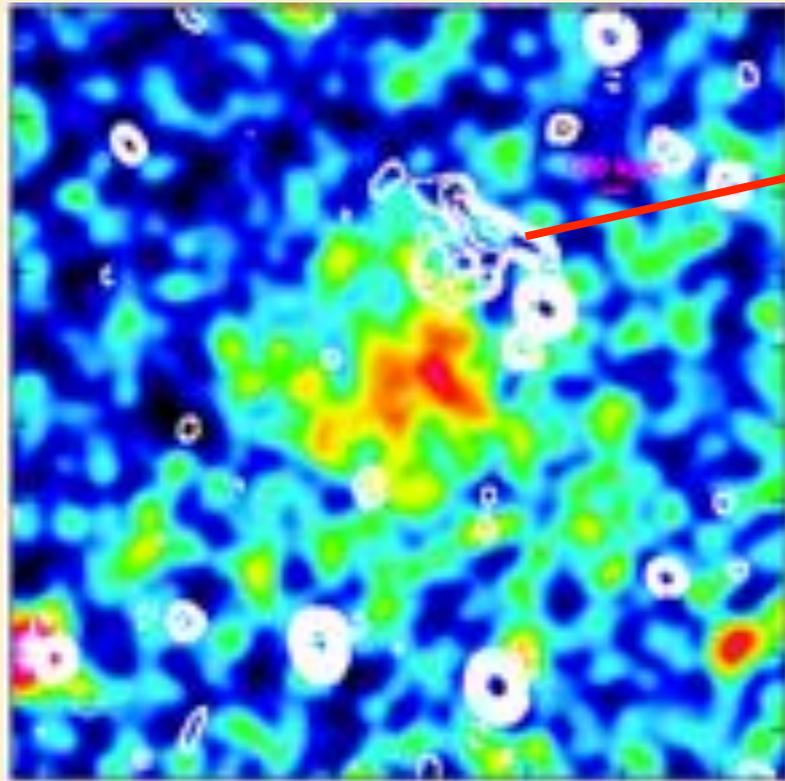
Outlook

- Selection bias effects
- Radio halos in cool core clusters (CL1821+643, A2390, A2261....)
- Uniform sample (including low mass clusters) with same observation setup
- GMRT short spacing and RFI mitigation
- Low resolution MWA GLEAM survey
- Future high resolution SKA1-LOW survey

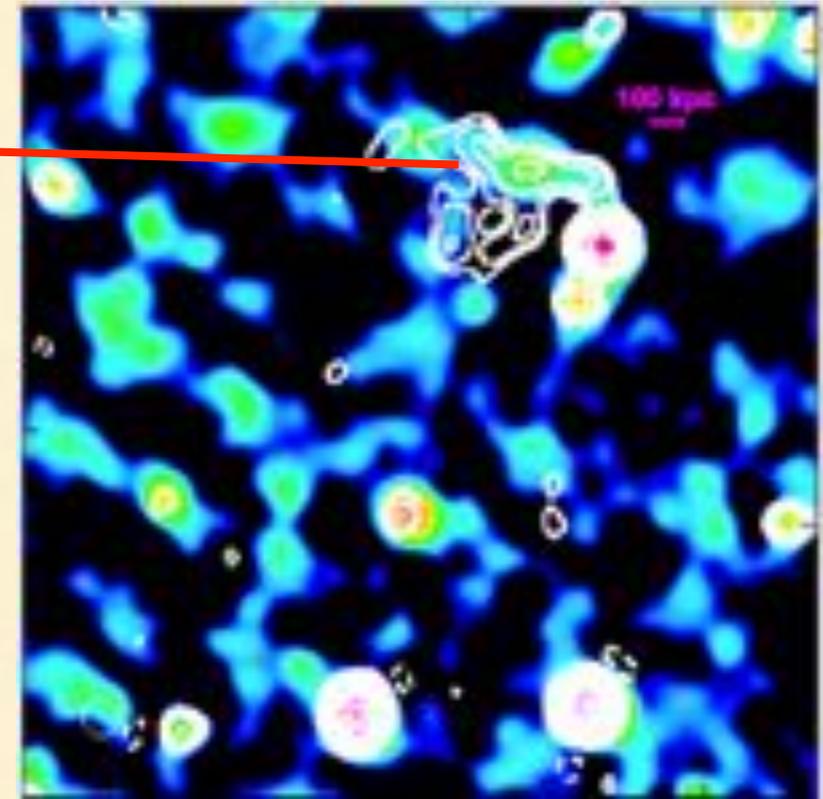
Outlook

- Search new diffuse radio sources in GLEAM (GaLactic and Extragalactic All-sky Murchison Widefield Array) low frequency survey
- South of declination $+25^\circ$
- 200 MHz, wide-band images, FWHM $\sim 2'$, $\sim 7\text{mJy}/\text{beam}$ rms
- Planck, SPT, ACT, MCXC cluster catalogues; ~ 500 , 2° cluster image cutouts
- No mass cut-off, $z < 0.1$
- Follow-up GMRT observations to characterise sources

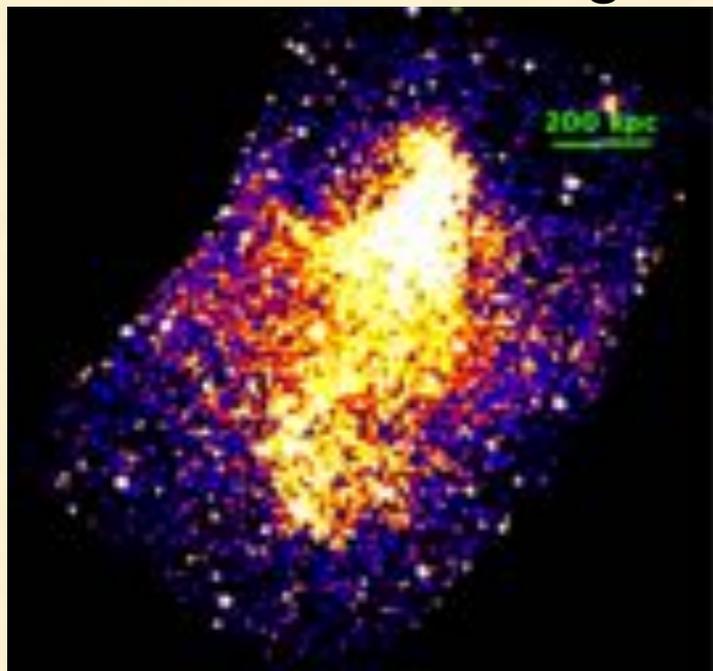
Outlook



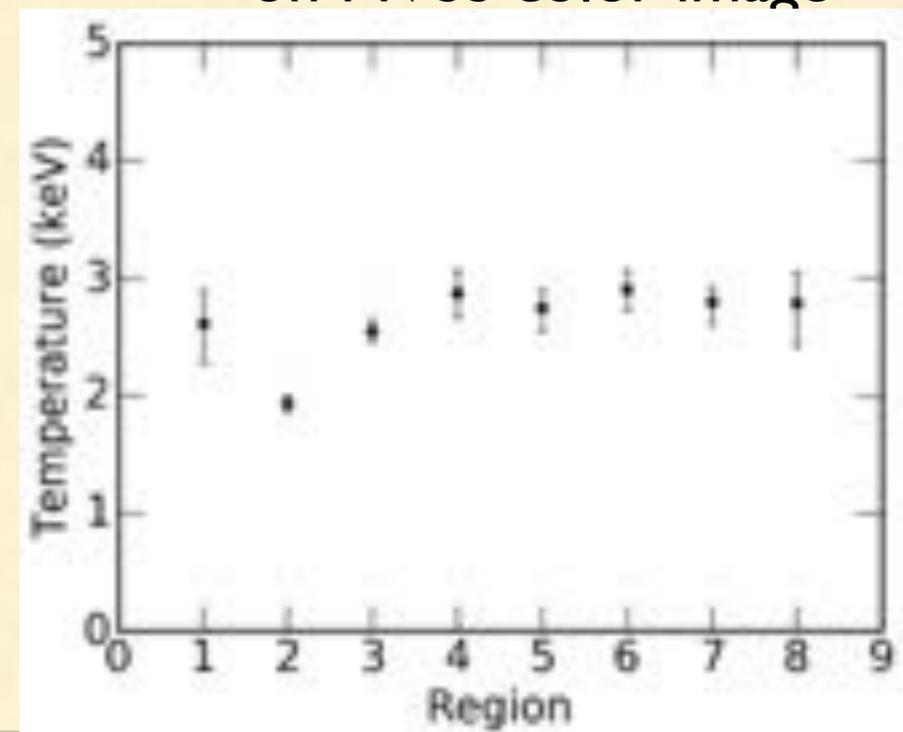
MWA 200 MHz contours (white) on ROSAT colour image



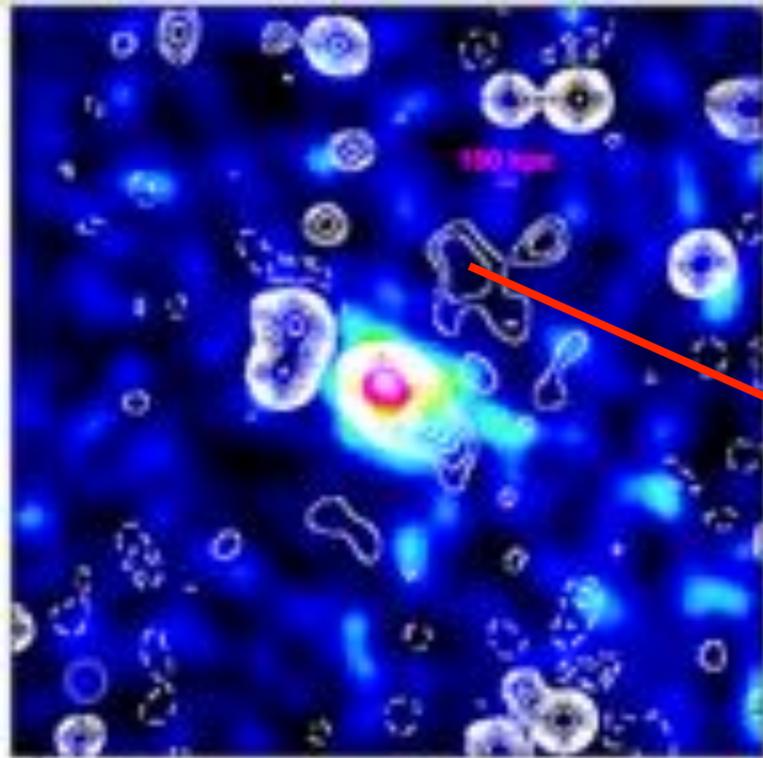
MWA radio contours (white) on NVSS color image



Chandra image

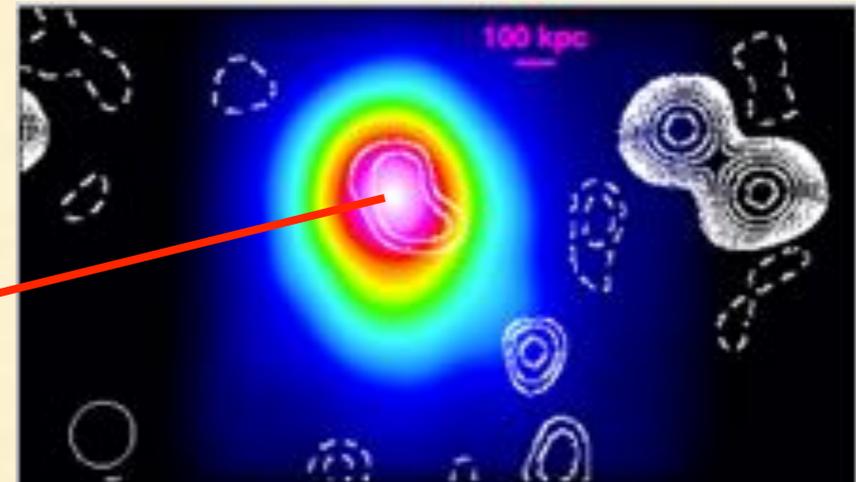


Outlook



MWA 200 MHz contours (white)
on ROSAT colour image

Possible mini
halo?
Possible relic?



MWA 200 MHz contours (white)
on ROSAT colour image