Alex Clarke

ABELL 1682
An Ultra Steep Spectrum Radio Halo

Science At Low Frequencies II – Albuquerque, New Mexico

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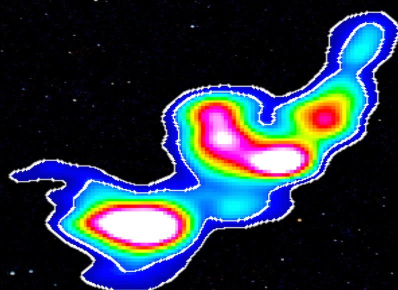
An Ultra Steep Spectrum Radio Halo

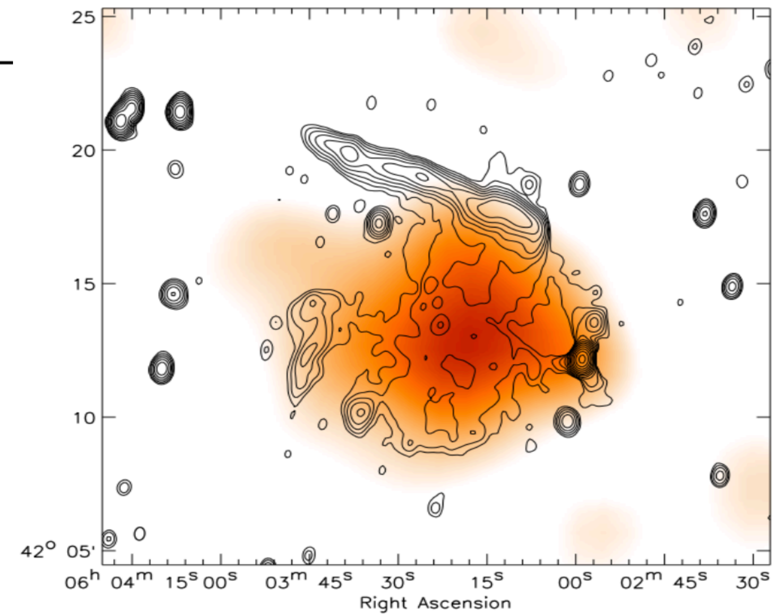


Radio Halos as probes of cluster magnetic fields

LOFAR results from 44–110 MHz

Cluster Magnetic Fields

Method	Strength μG
Synchrotron halos	0.4–1
Faraday rotation (embedded)	3–40
Faraday rotation (background)	1–10
Inverse Compton	0.2–1
Cold fronts	1–10
GZK	>0.3



Radio Halos

Ingredients:

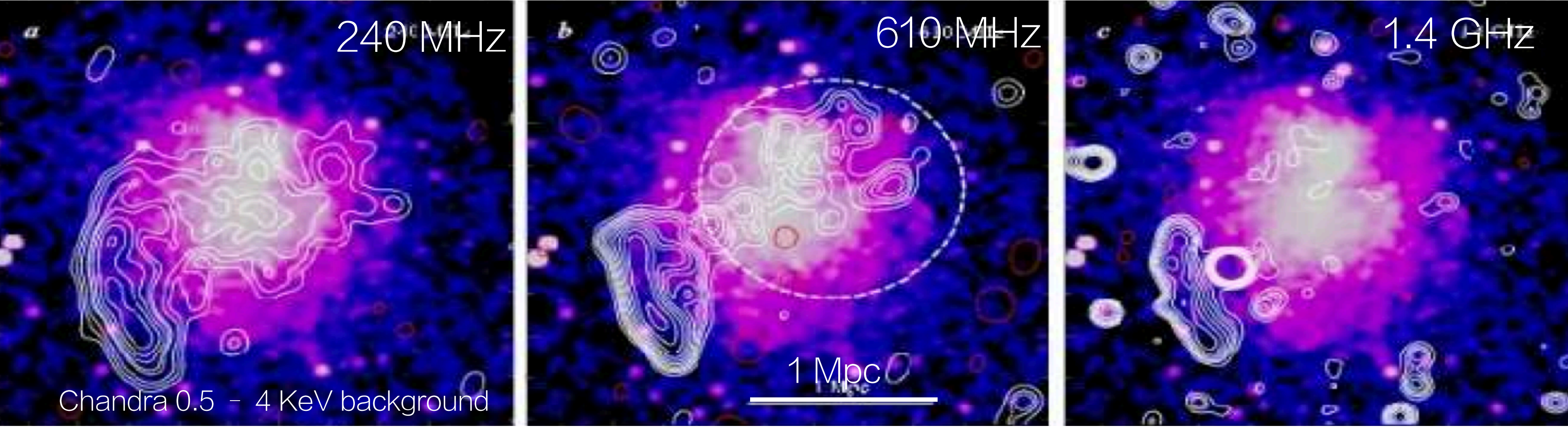
Large scale magnetic fields + Relativistic electrons

Formation mechanisms:

A) Relativistic electrons injected by proton–proton collisions

B) Old electrons are accelerated
Related to the merging event? Turbulence?

Ultra Steep Spectrum Radio Halos let us explore this



Abell 521 (Brunetti et al 2008 – Nature) – Spectral Index = −2.1

Steep spectrum halos are special cases that let us:

Rule out e^- injection via proton−proton collisions

Strongly favor particle re−acceleration via turbulence

A) Proton–proton collisions

Generating steep spectrum relativistic electrons

Expect thermal energy density to dominate over energy density of relativistic protons

This implies a limit on the spectral index of the electrons
-> we would not see steep spectrum halos via P–P collisions

Does provide possibility that clusters without radio halos have smaller magnetic fields

B) Turbulence induced by a merger event

Generating steep spectrum relativistic electrons

Turbulence injects energy into the electrons

time scales of ~1 Gyr, on spatial scales of ~ sub−cluster size

$$E_e \approx 1.4 B_{nT}^{-1/2} (\nu_c/300)^{1/2} \qquad \tau \approx 0.95 \frac{B_{nT}^{1/2}(\nu_c/300)^{-1/2}}{(1+z)^4 + (B_{nT}/0.32)^2} \ \mathrm{Gyr}$$

Spectral cut off at higher frequencies (steep spectral index) is a signature of turbulent acceleration

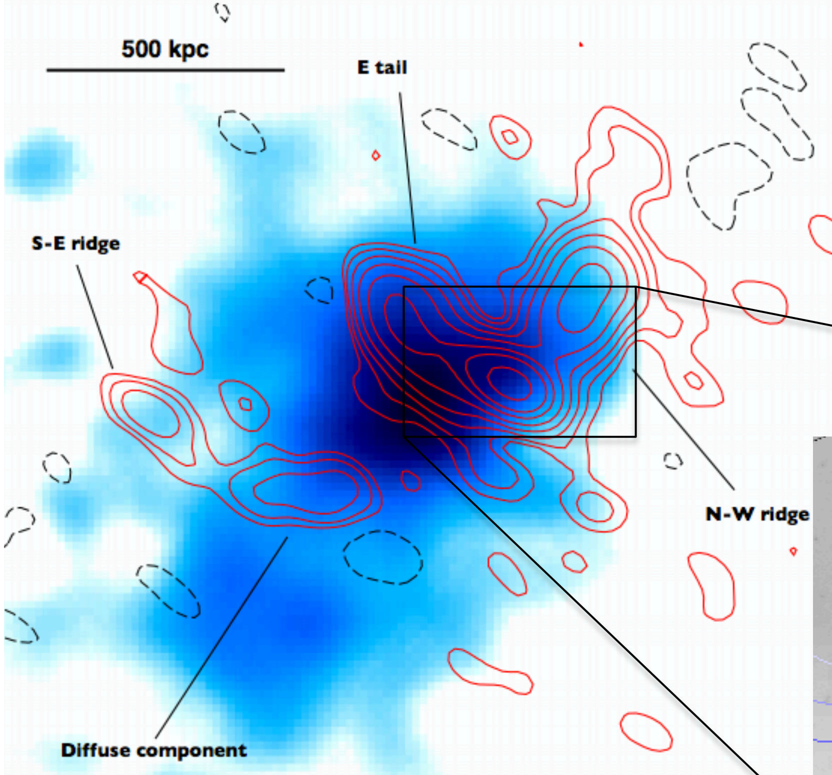
Low frequency observations should detect more halos

Observed spectral cut off is a measure of the cluster magnetic field

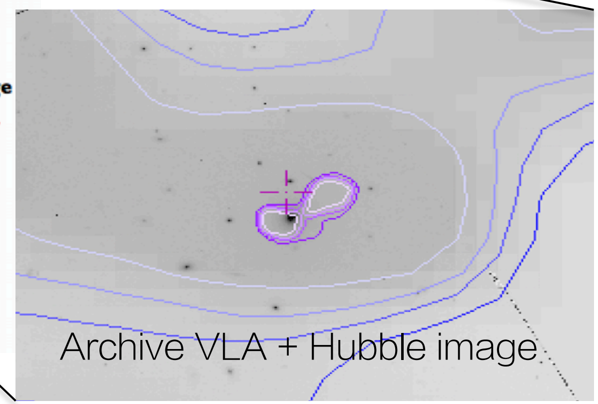
Abell 1682

A massive merging galaxy cluster
(z=0.226, LX[0.2 – 2.4keV] = 7.02 × 10^{44} erg s^{-1})

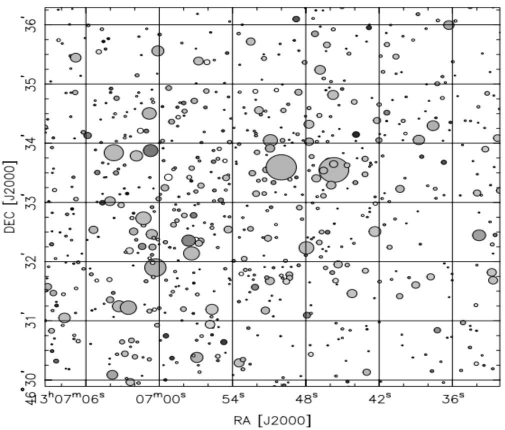
Turbulence following the merging event generates a radio halo – is it steep spectrum?
the "diffuse component"



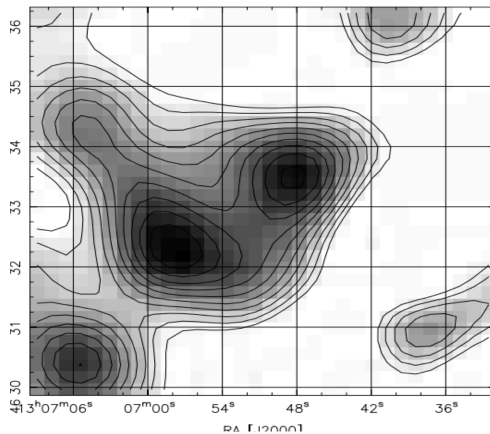
G. Macario et al 2013:
GMRT 150 MHz contours overlaid on Chandra



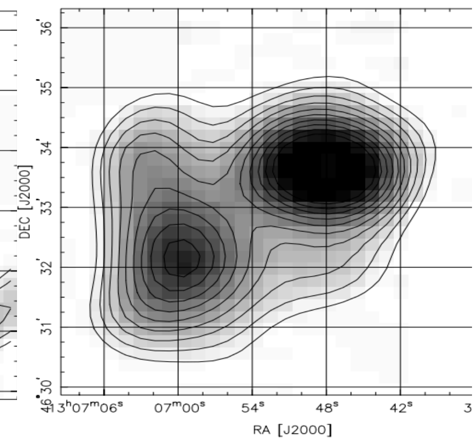
Bimodal mass distribution



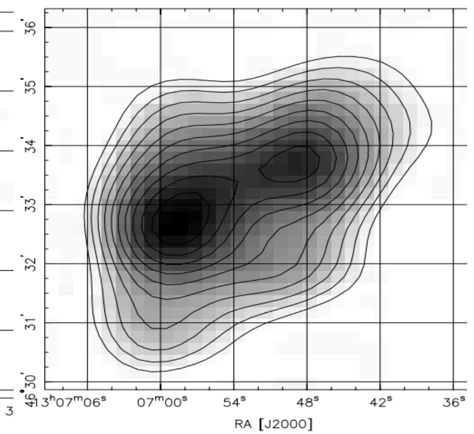
Galaxy Distribution



Projected mass density from lensing



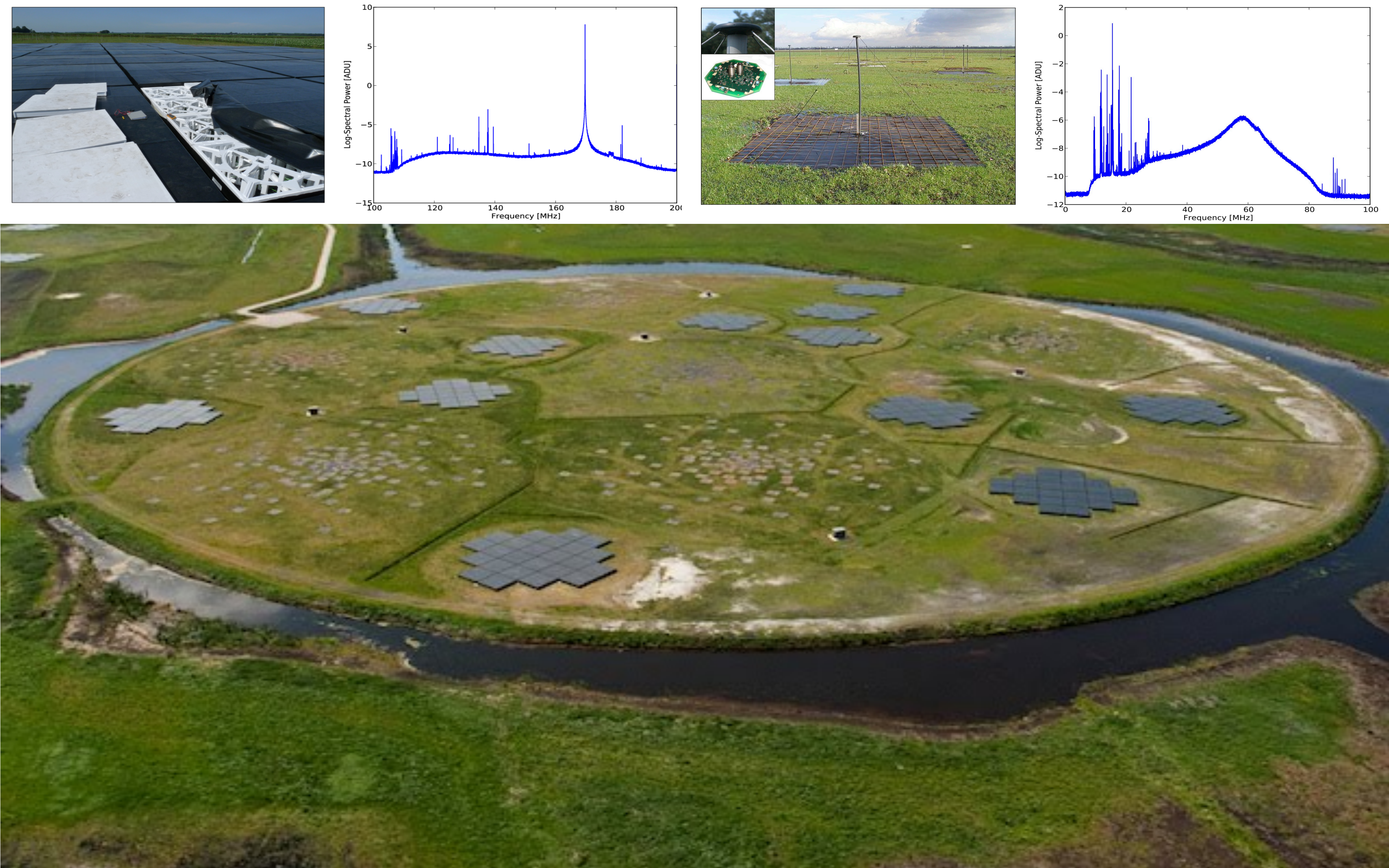
Projected mass density from galaxies

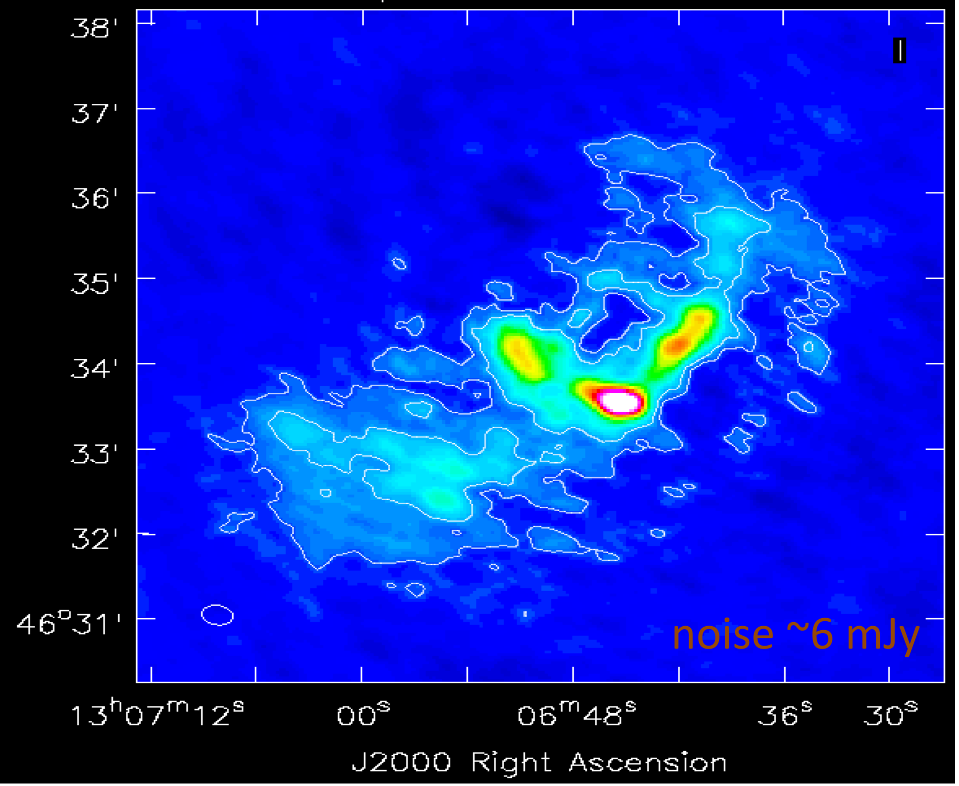


Galaxy number density

Dahle et al. 2002

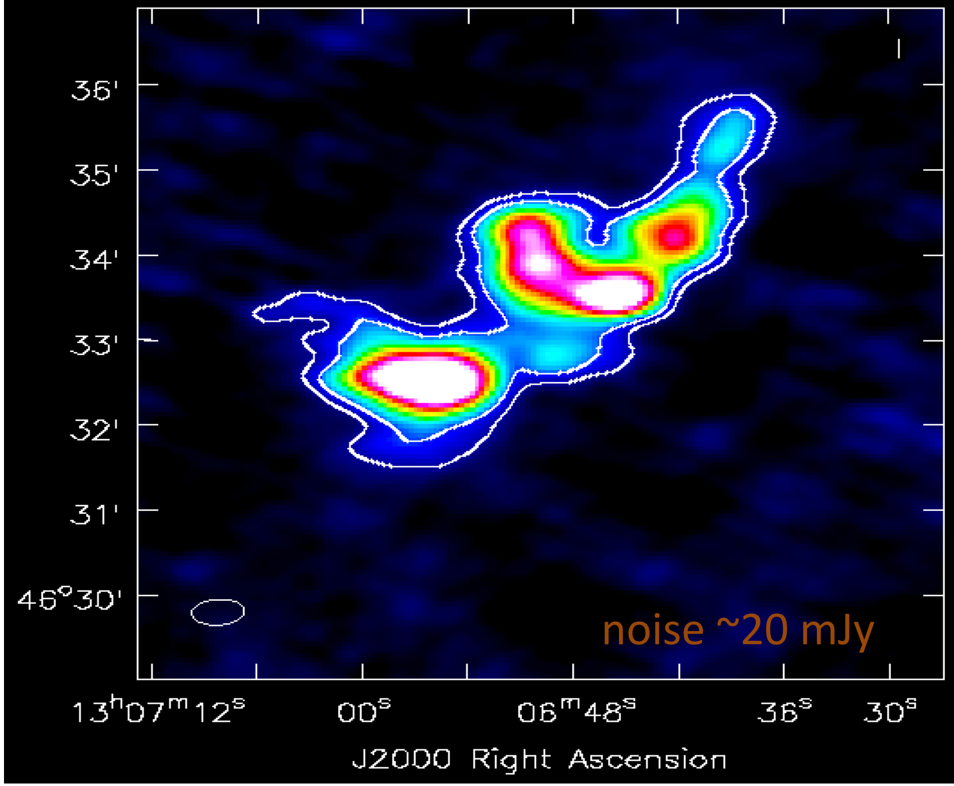

This observation
Onsala
Dutch stations
Chilbolton
Norderstedt
LOFAR Core (NL)
Potsdam
Bałdy
Borówiec
Jülich
Effelsberg
Tautenburg
Łazy
Unterweilenbach
Nançay
ASTRON


Log-Spectral Power [ADU]
Frequency [MHz]
Log-Spectral Power [ADU]
Frequency [MHz]



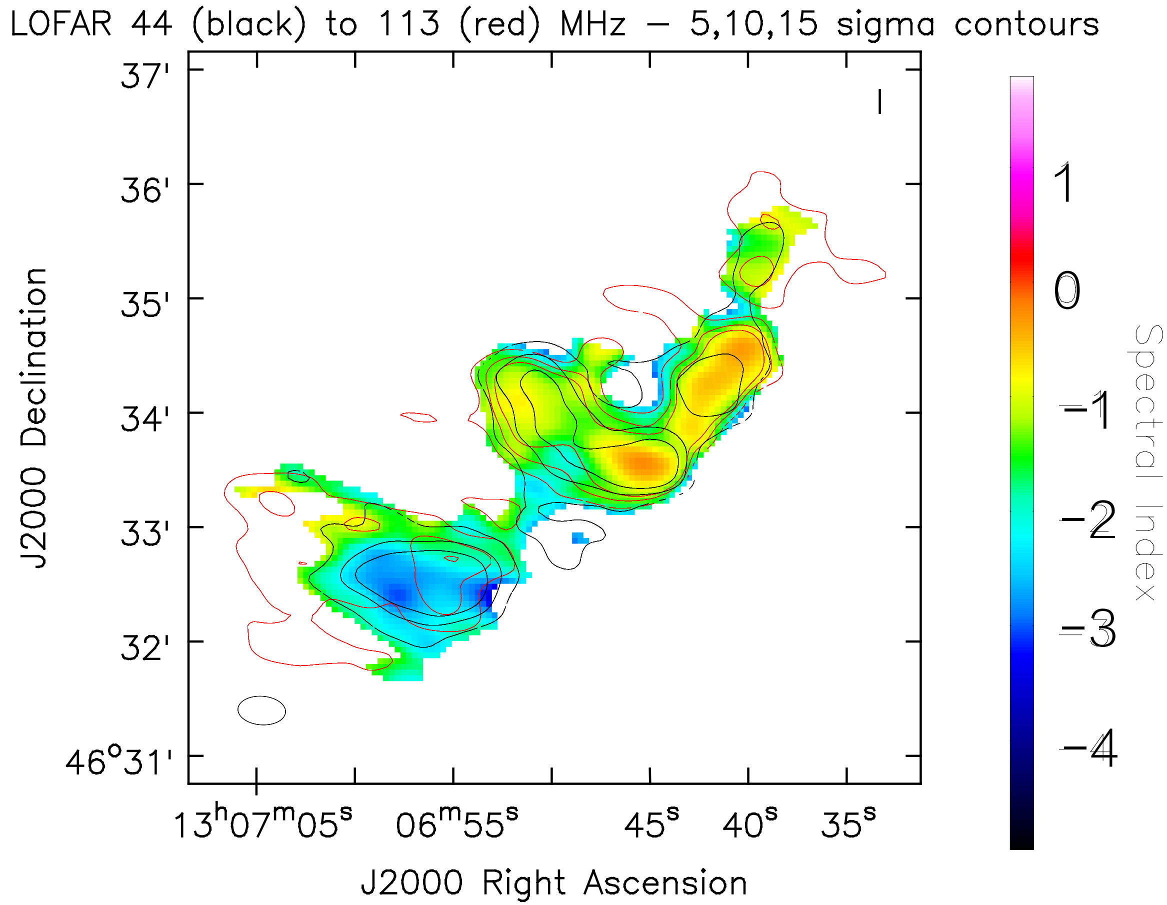
LOFAR HBA

116 MHz, robust 0, contours at 5 & 10 σ
15” x 20” beam

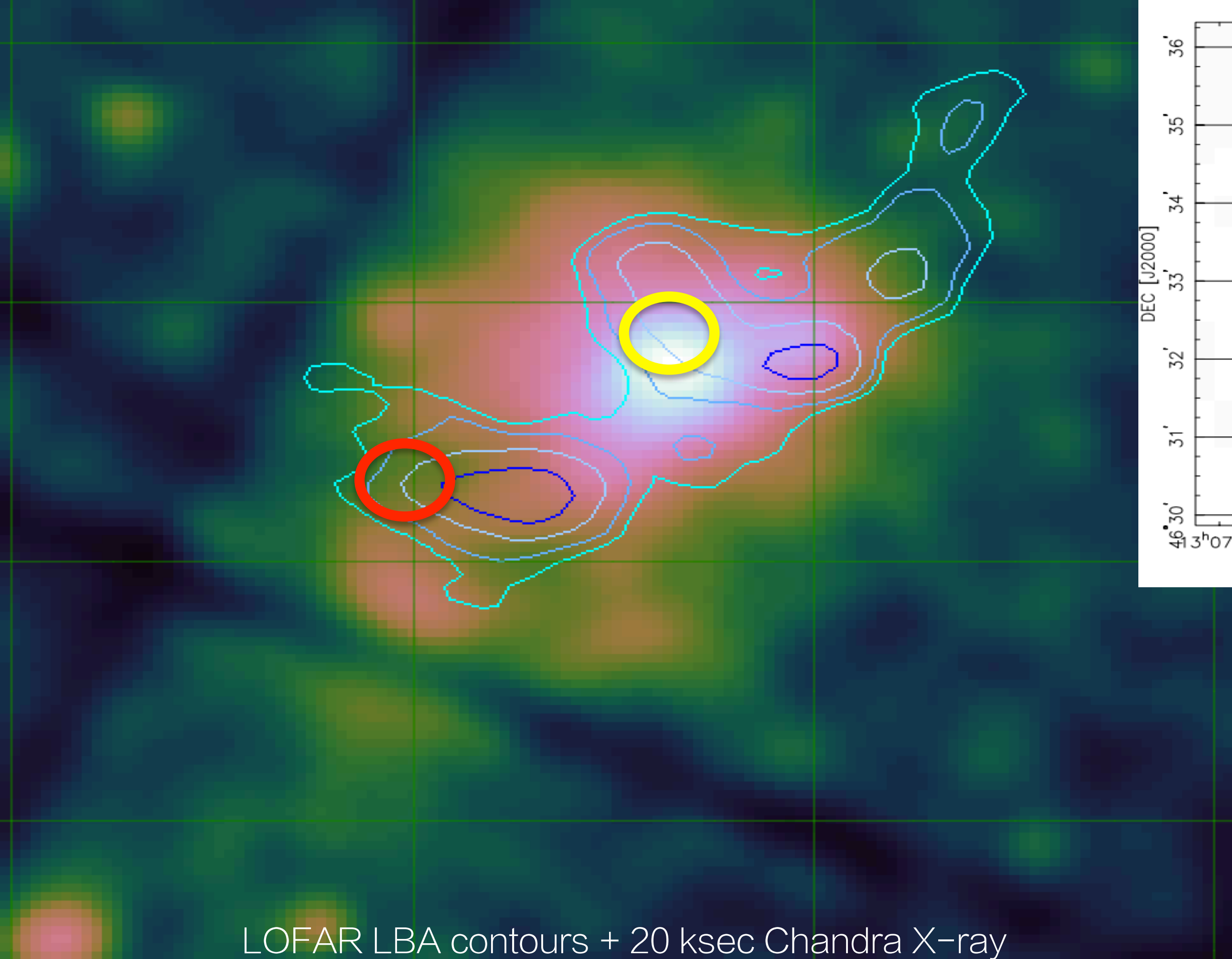


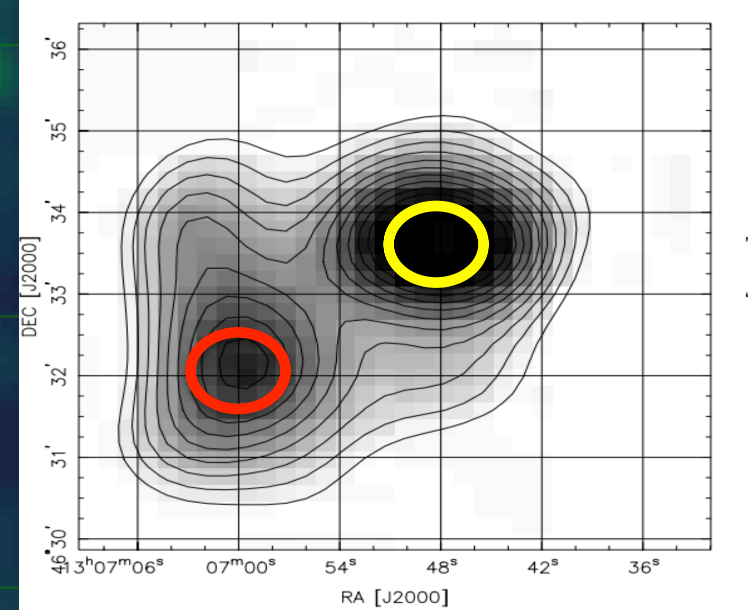
LOFAR LBA

44 MHz, robust 0, contours at 5 & 10 σ ,
20” x 30” beam



HBA-LBA Spectral Index Map


LOFAR LBA contours + 20 ksec Chandra X-ray


DEC [J2000]
RA [J2000]
-46°30'
31'
32'
33'
34'
35'
36'
13h07m06s
07m00s
54s
48s
42s
36s

Conclusions

Radio Halos let us probe cluster magnetic fields

A1682 presents a case where low frequency observations are essential

Merger dynamics gives a cause for the halo formation mechanism

Favors the re-acceleration model for halo formation

Thanks for listening!

Alex Clarke