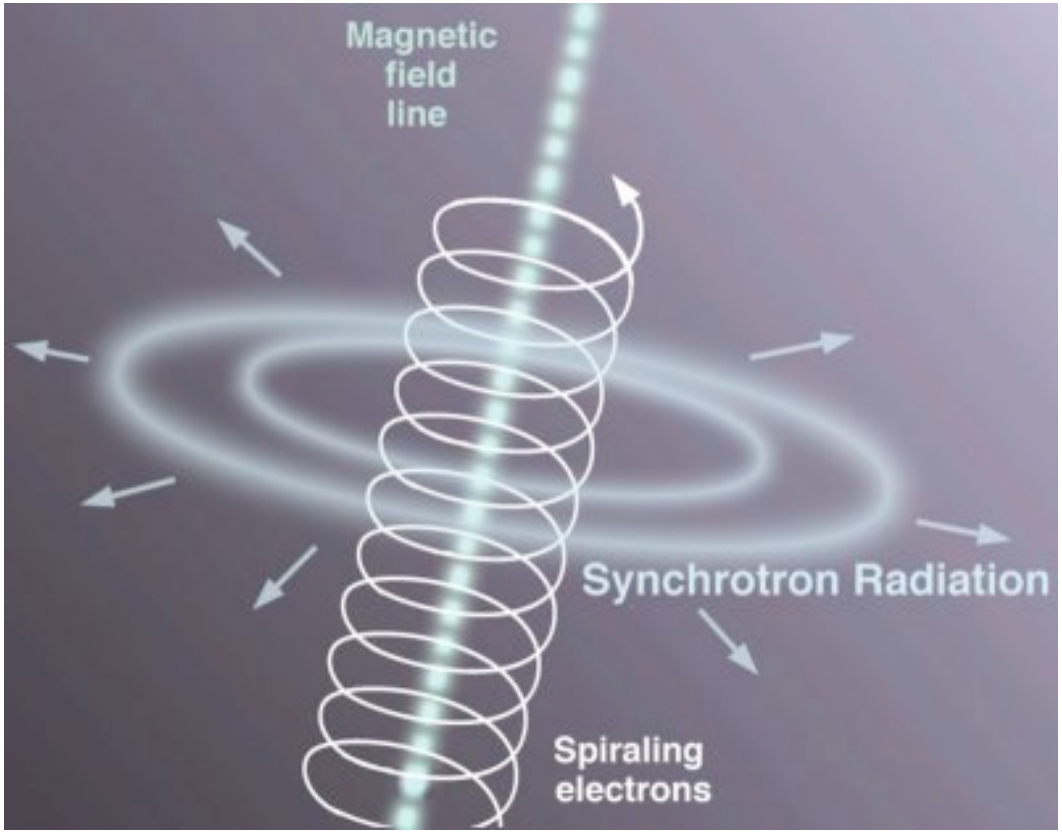
Radio continuum sources in galaxy clusters

Chiara Ferrari

Radio continuum sources in galaxy clusters

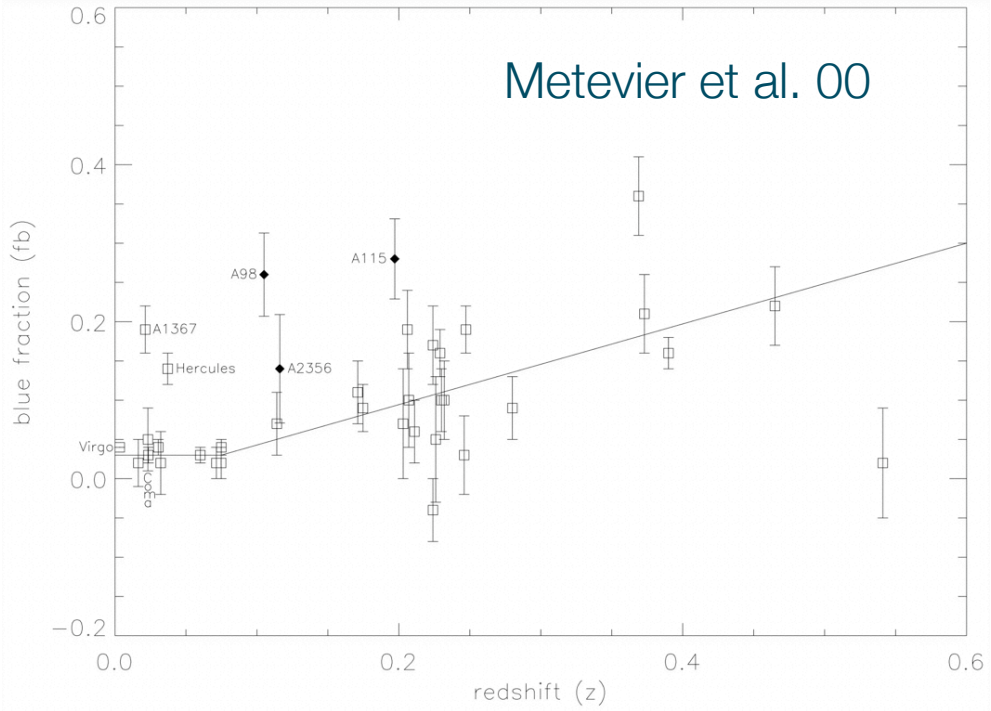
- Active galaxies
  - ✳AGNs
  - ✳Starburst galaxies
- Diffuse radio sources
  - ✳Halos
  - ✳Mini-halos
  - ✳Relics

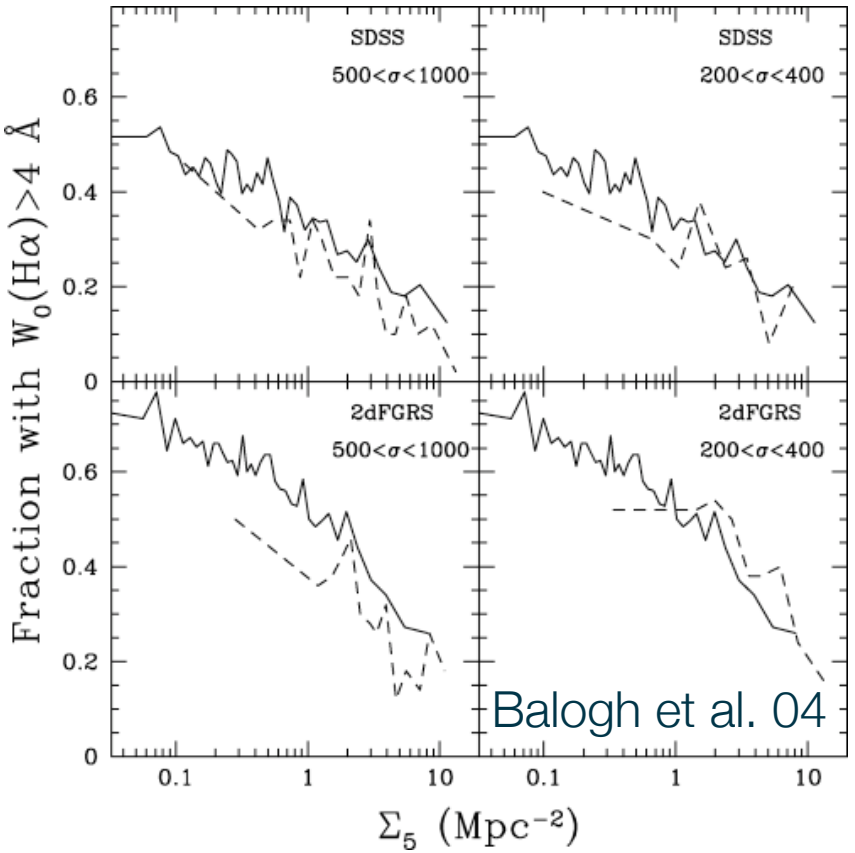


Radio continuum studies of galaxy clusters: main open questions

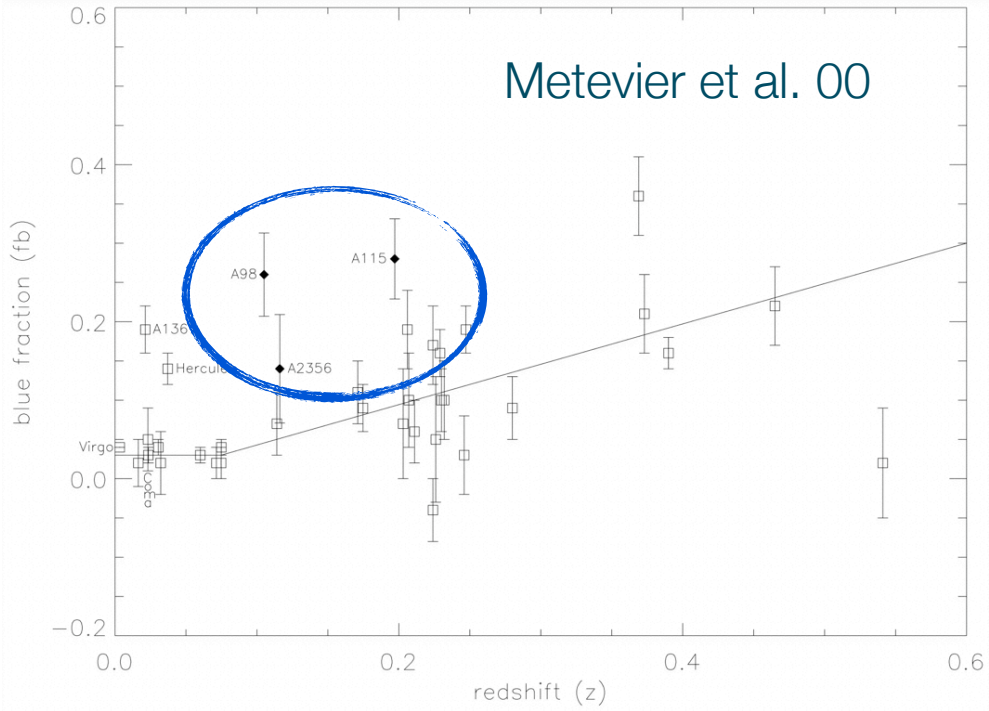
- Cluster environment and galaxy activity (star formation and AGN)
- Statistical studies of cluster extended radio sources:
  - ✳Origin of relativistic particles in clusters
  - ✳Non-thermal component vs. termo-dynamical evolution of clusters
  - ✳Characterization of intra-cluster magnetic fields

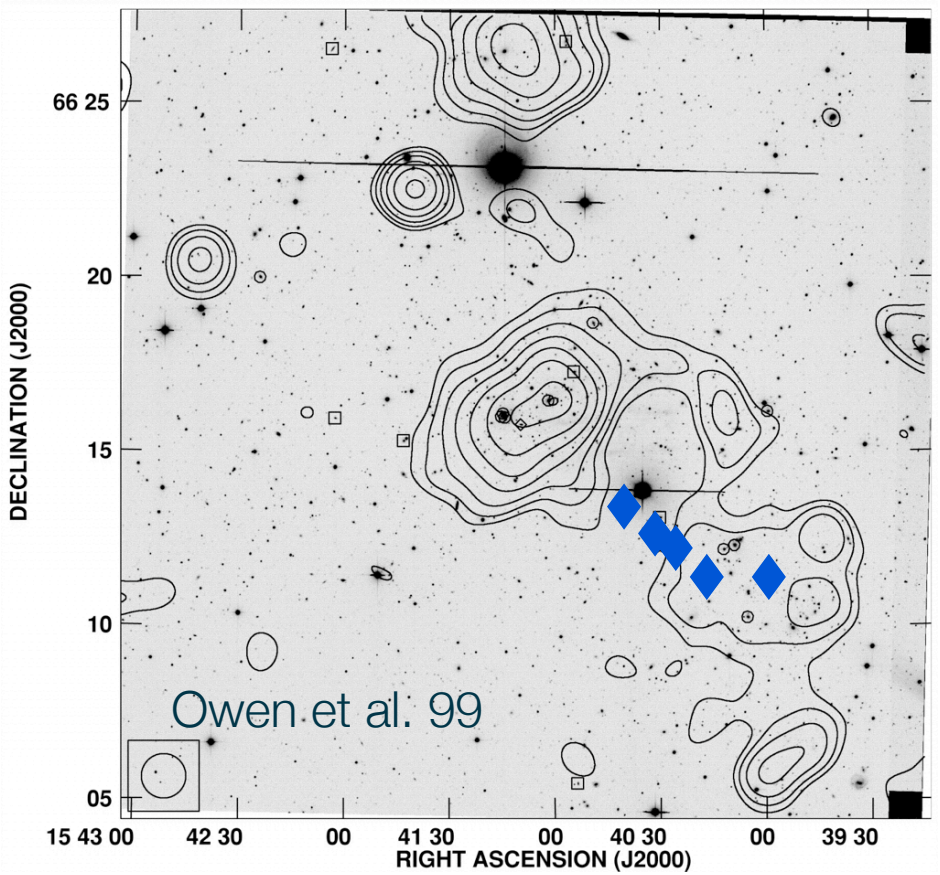
Environment & star-forming galaxies





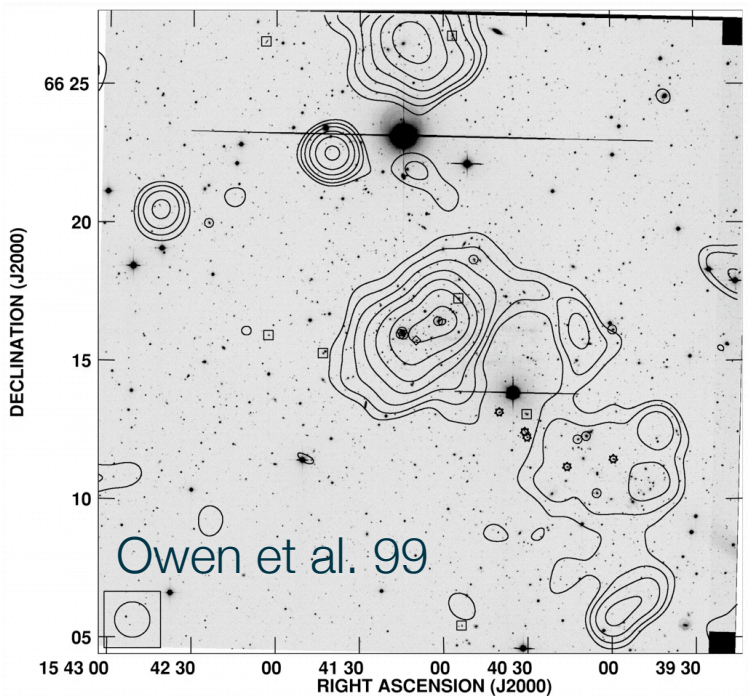
Environment & star-forming galaxies

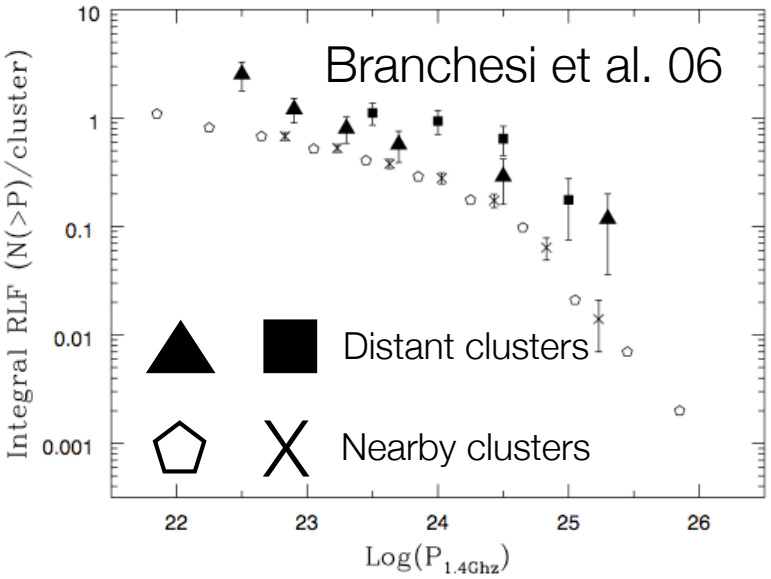




Environment & radio galaxies

- Radio Luminosity Function in clusters
  - ✳ Statistically similar for sources outside and inside rich clusters (Fanti 84; Ledlow & Owen 96)
  - ✳ Higher number of radio galaxies in merging / high-z clusters ? (Owen et al. 99; Branchesi et al. 06)
- Wide and Narrow Angle Tail (WAT & NAT) radio galaxies





Environment & radio galaxies

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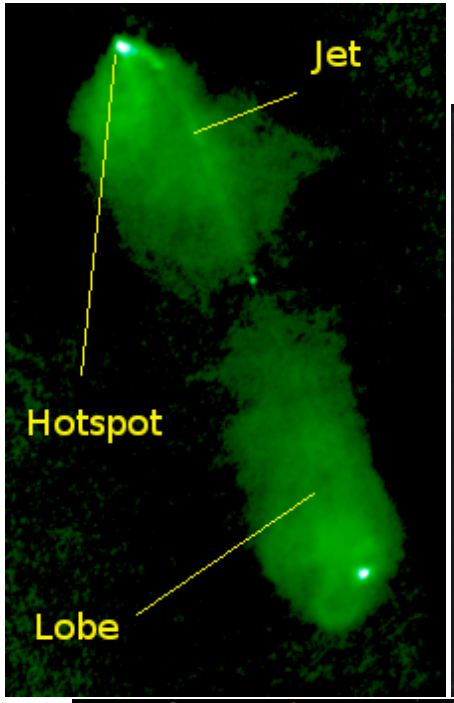
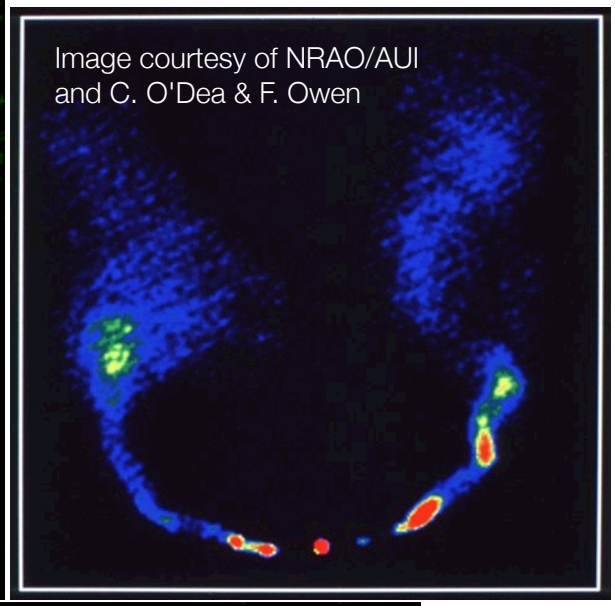
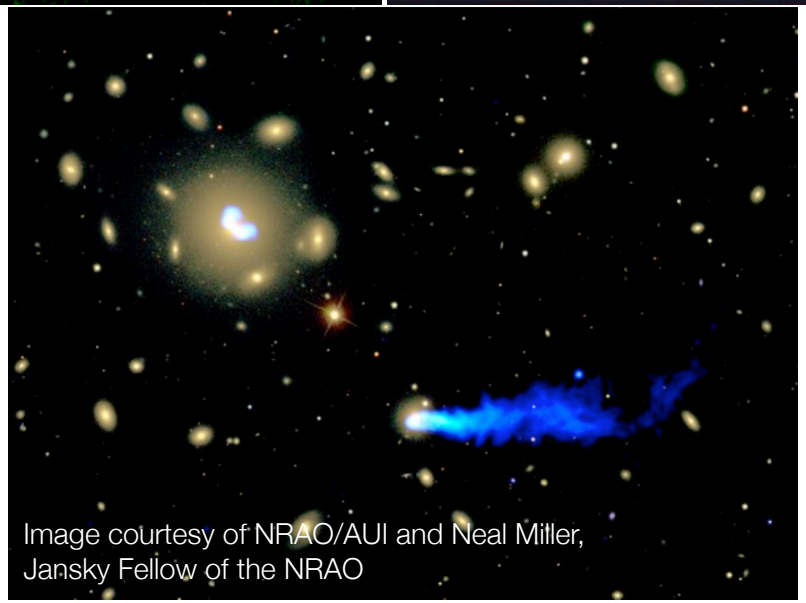
- Wide and Narrow Angle Tail (WAT & NAT) radio galaxies





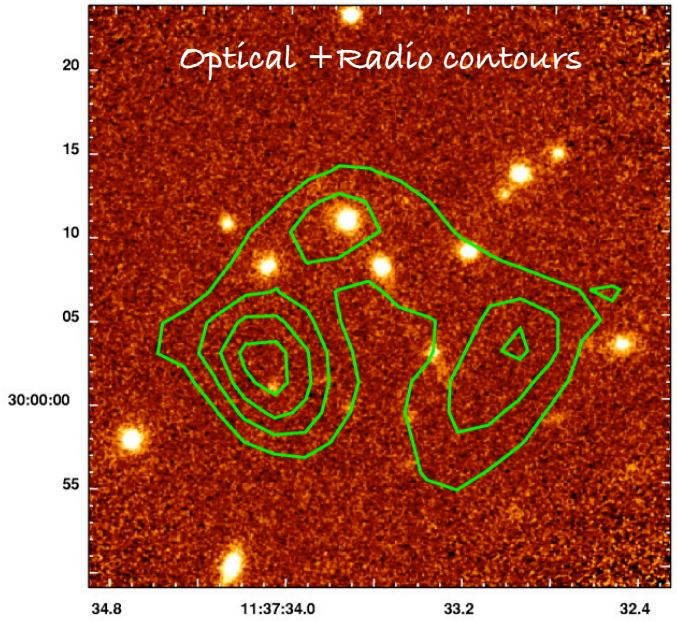


VLA continuum observations

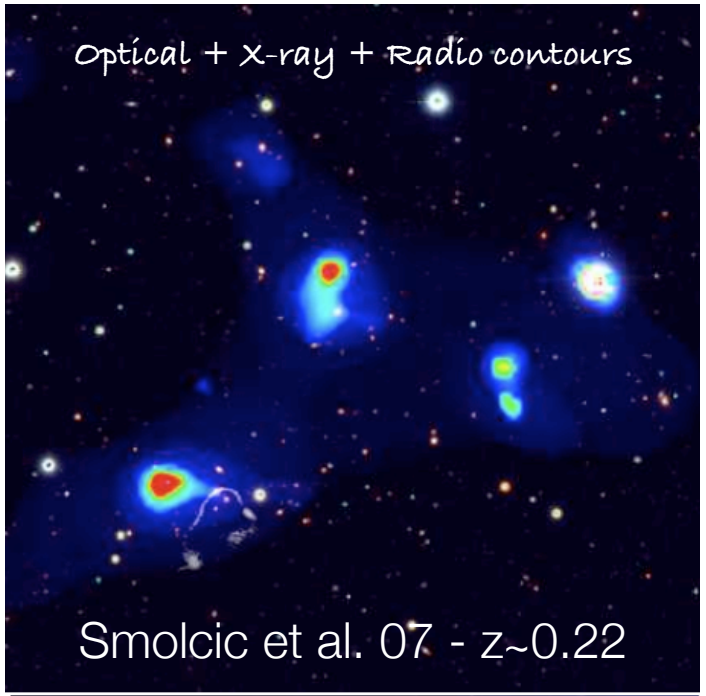
Resolution:

~ 10 arcsec (left)

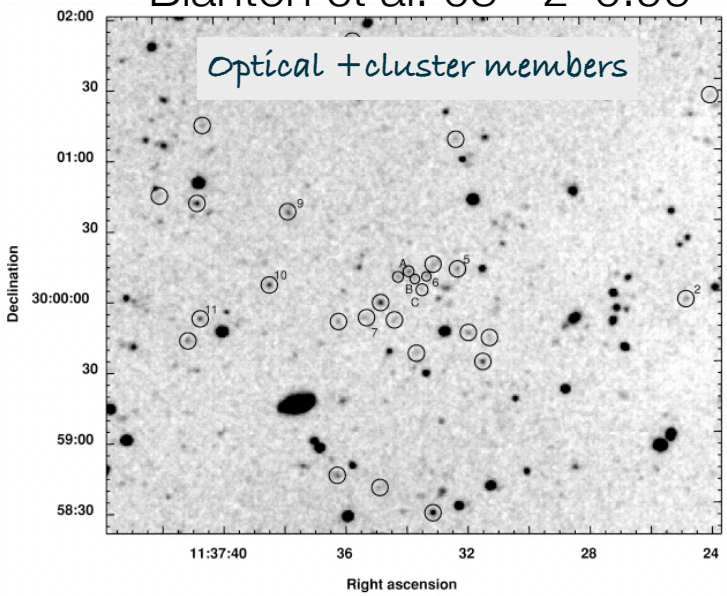
~ 1 arcsec (right)

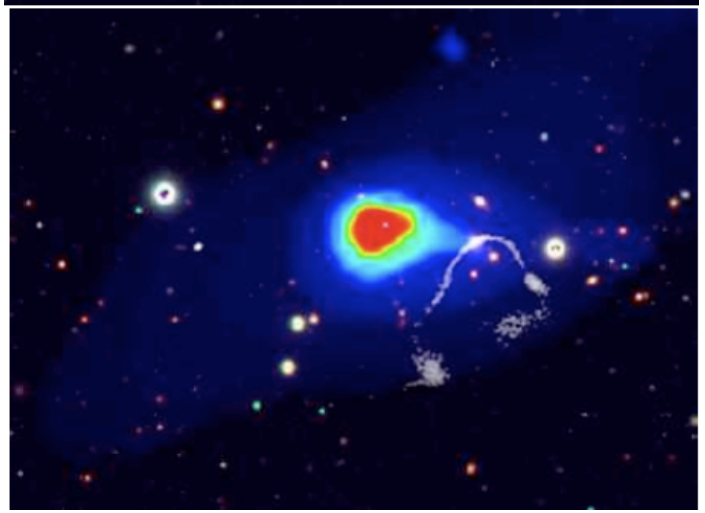


Blanton et al. 03 - z~0.96



Smolcic et al. 07 - z~0.22





Cluster detection

WAT or NAT radio sources

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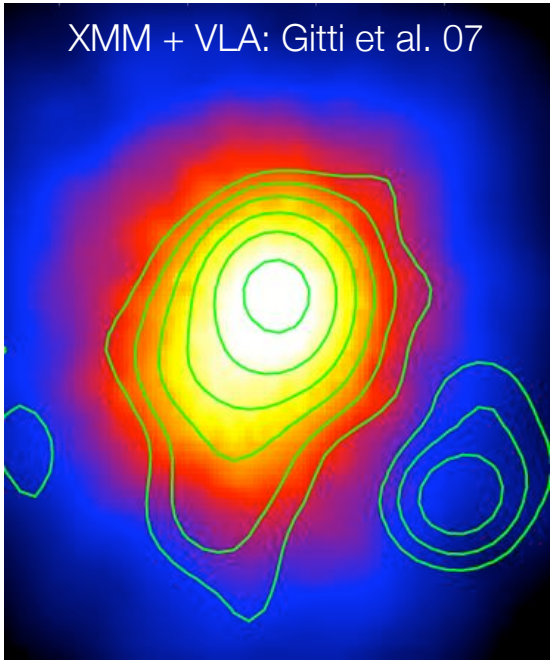
  - ✳Non-thermal component vs. termo-dynamical evolution of clusters
  - ✳Characterization of intra-cluster magnetic fields

Radio continuum - Diffuse radio sources

intermediate extension
(≤ 500 kpc)

at the centre of clusters
with AGN & cooling-core

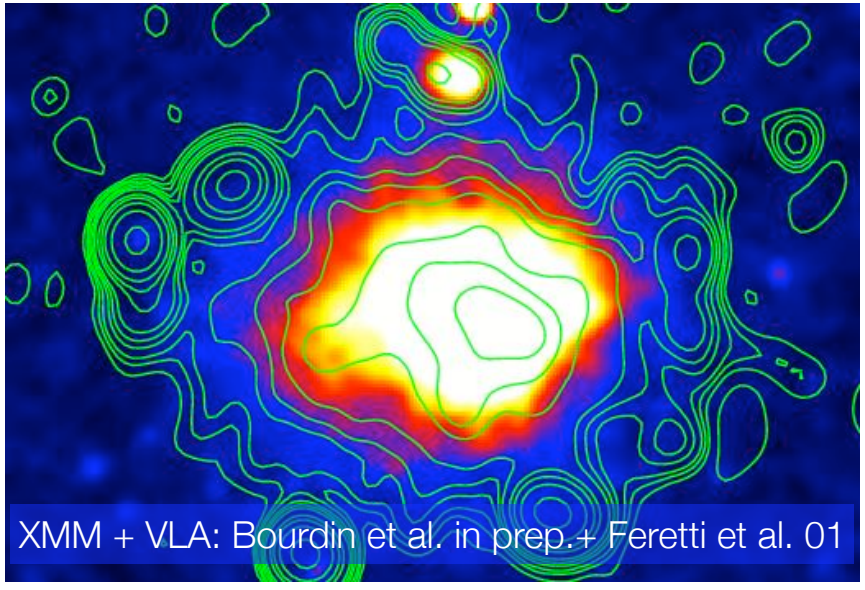


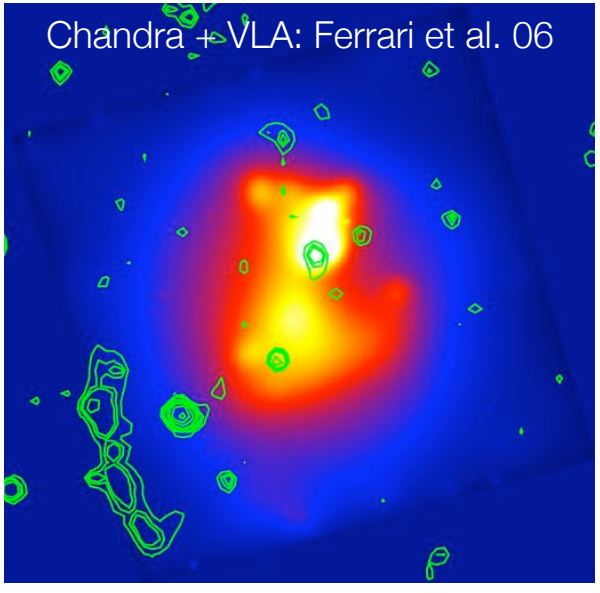
- Mini-halos
- Halos
- Relics

extended
(≥ 1 Mpc)

cluster centre

regular
morphology
(~X-rays)





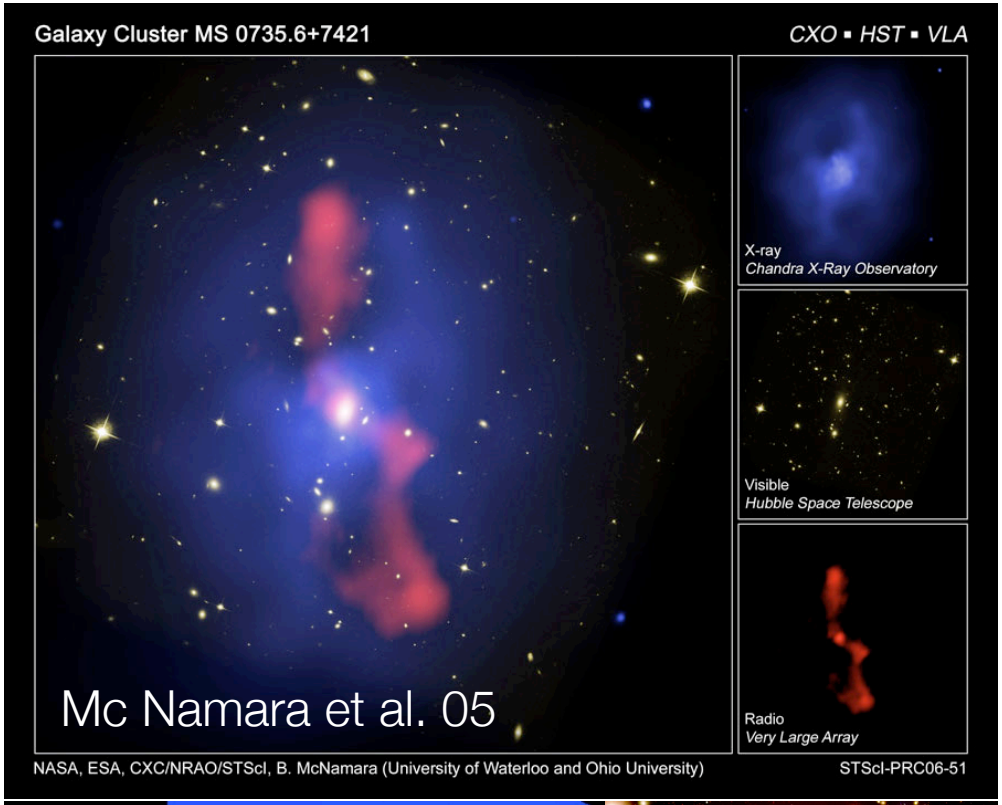
extended
(≥ 1 Mpc)

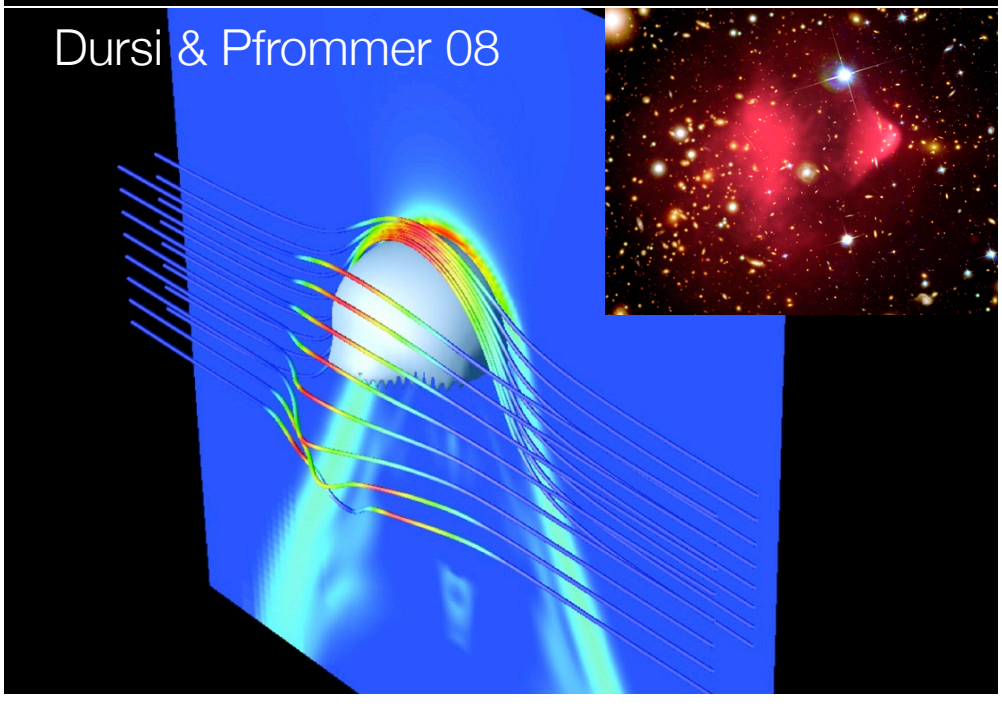
cluster
outskirts

elongated
morphology

Non-thermal component

- Origin of the non-thermal component
- Effect of magnetic fields on thermal conduction
- Hydro-dynamical effects of magnetic fields





Intra-cluster magnetic fields

see Govoni & Feretti 04 for a review

- Equipartition assumption

$$B_{eq} \propto \left[\frac{L(1+k)}{\Theta V}\right]^{2/7}$$

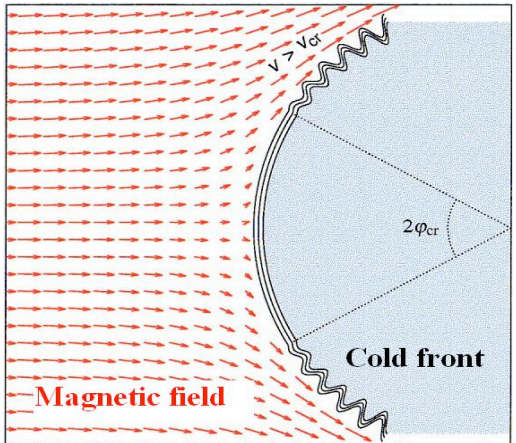
- Compton scattering of CMB photons

$$B_{IC} \propto \left(\frac{f_{syn}}{f_{HXR}}\right)^{2/(\delta+1)} \left(\frac{\nu_R}{\nu_X}\right)^{(\delta-1)/(\delta+1)}$$

- Faraday rotation measure of background or embedded galaxies

$$RM\ _{[\mathrm{rad\ m^{-2}}]} = 812 \int_0^{L_{[\mathrm{kpc}]}} n_{\mathrm{e}\ [\mathrm{cm^{-3}}]} B_{\parallel\ [\mu\mathrm{G}]} d\mathrm{l}.$$

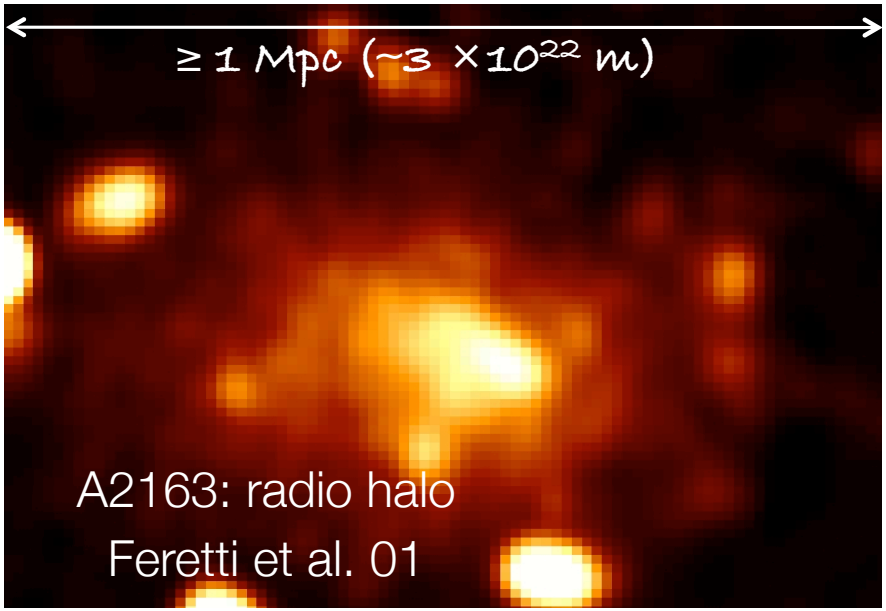
- X-ray analysis of cold fronts

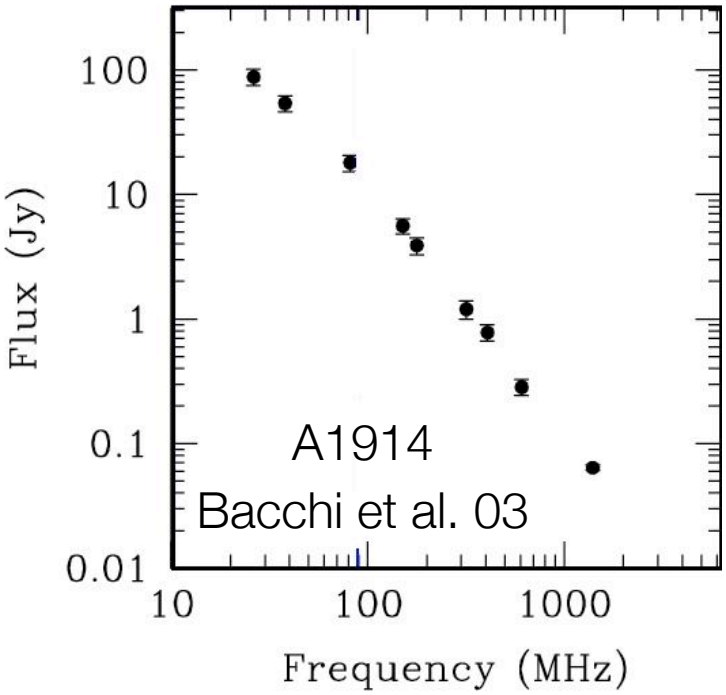


Intra-cluster magnetic fields: discrepant results

- Faraday rotation measure: ~1-10 μG (e.g. Feretti et al. 95, 99; Govoni et al. 01, 06; Guidetti et al. 07; Taylor et al. 93, 01, 07)
- Compton scattering: ~ 0.1–0.3 μG (e.g. Fusco-Femiano et al. 99, 00, 01; Rephaeli et al. 99, 03, 06)
- Equipartition assumption: ~0.1–1 μG (e.g. Giovannnini et al. 93; Kim 99; Pfrommer & Enßlin 04; Tierbach et al. 03)
- X-ray analysis of cold fronts: ~10 μG (Vikhlinin et al. 01)

Origin of relativistic particles in clusters





Dimensions: ~ 1 Mpc

Crossing time of e^-: ~9.5 Gyr

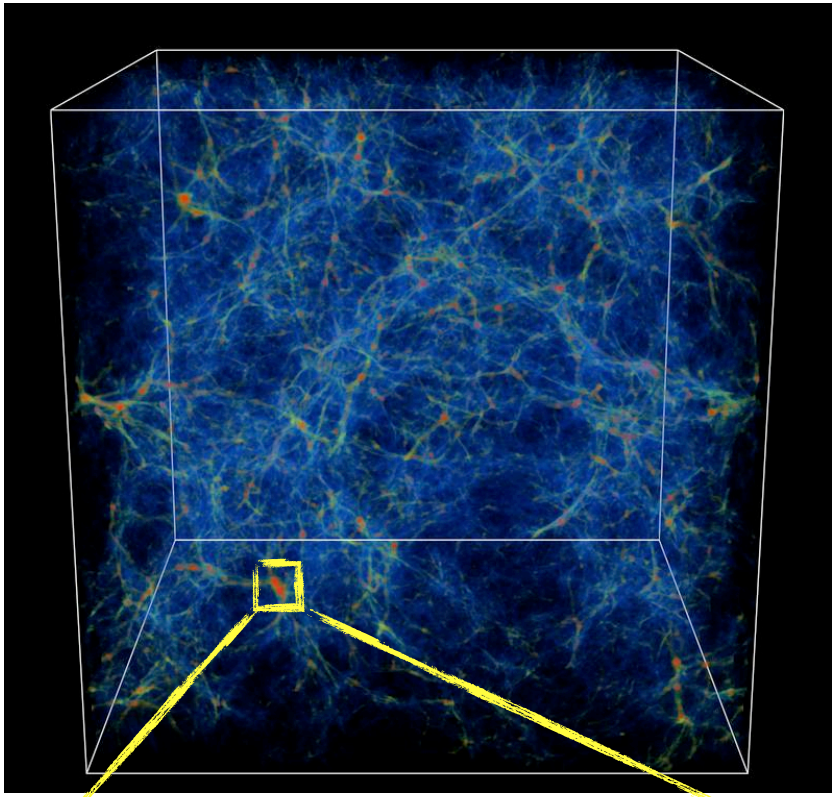
Life time of e^-: ~ 0.1 Gyr

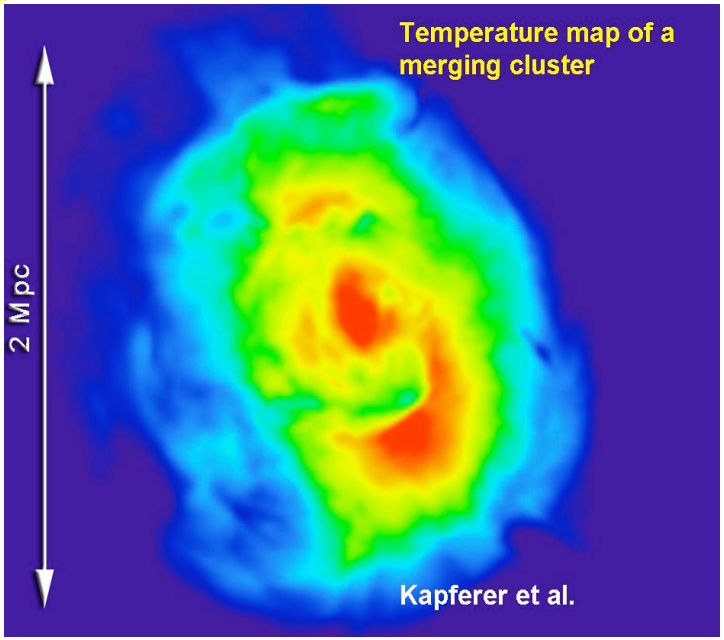
→ *In situ acceleration of relativistic electrons*

Acceleration mechanisms

- Primary models: (re-)acceleration due to shocks/turbulence
- Secondary models: hadronic collisions of relativistic p^+ with the ICM

see Ferrari et al. 08 for a review





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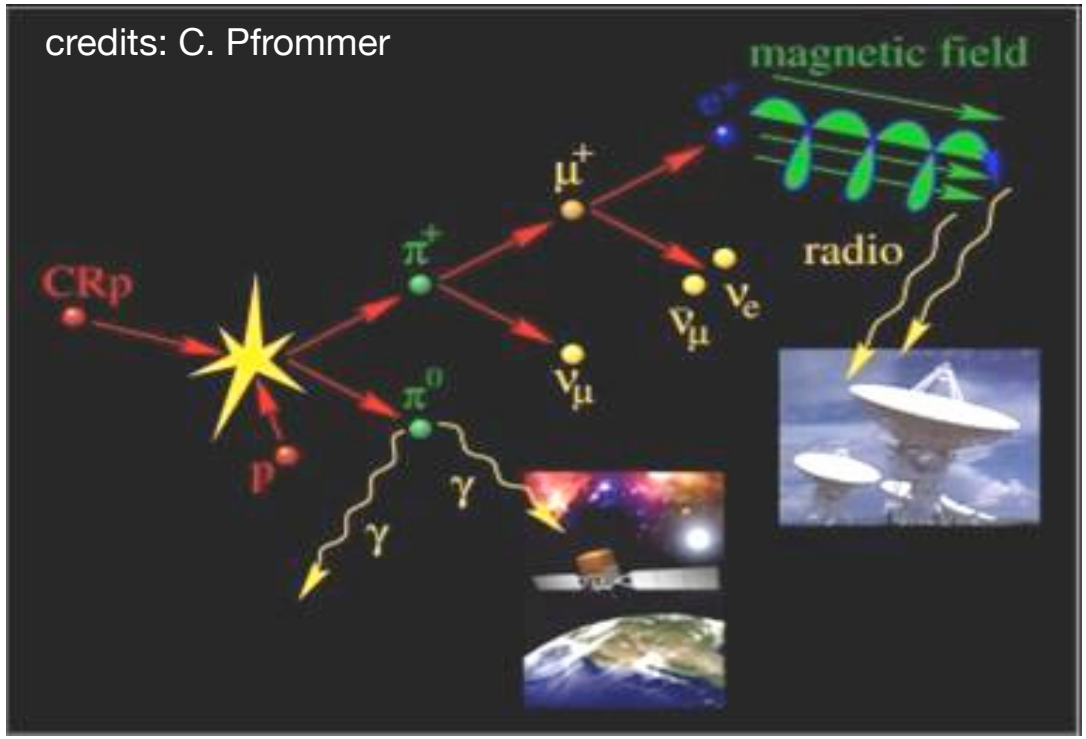

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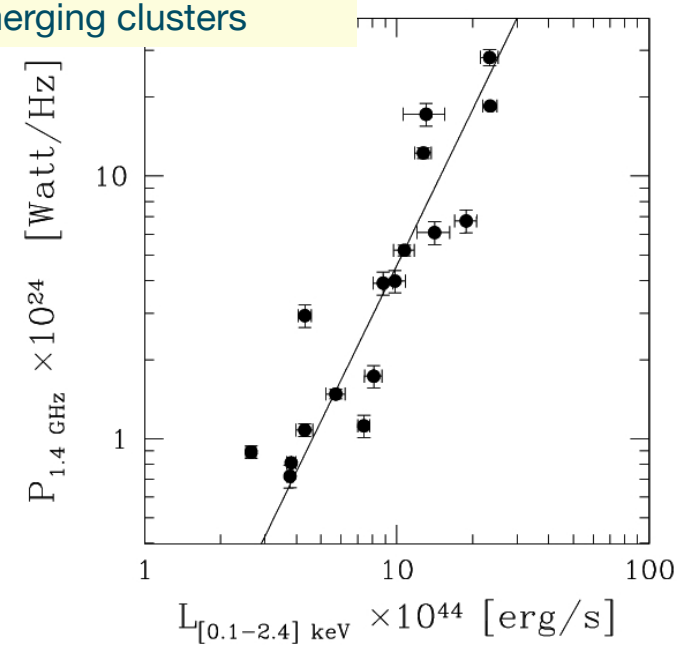
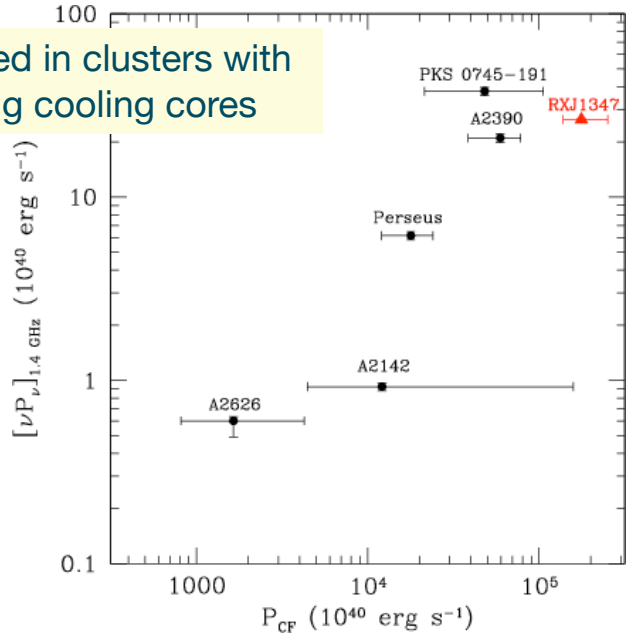
Halos & Relics detected only in the brightest merging clusters



Mini-halos detected in clusters with AGNs and strong cooling cores



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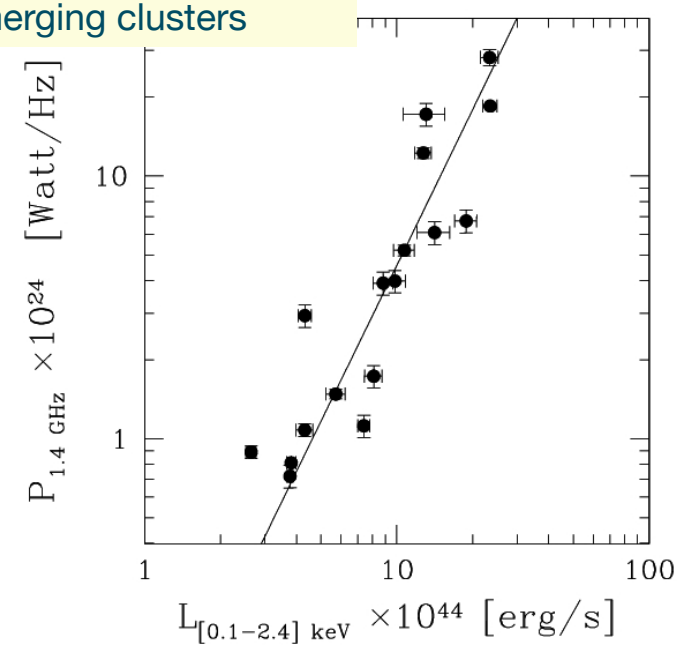

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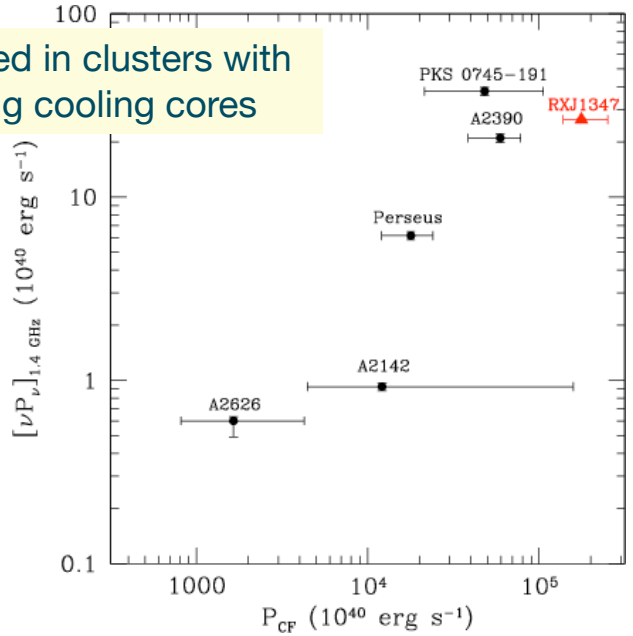

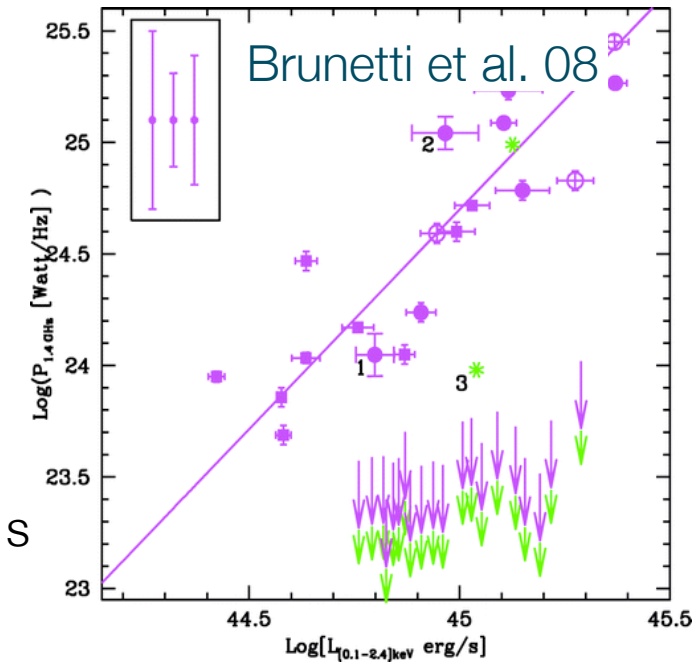

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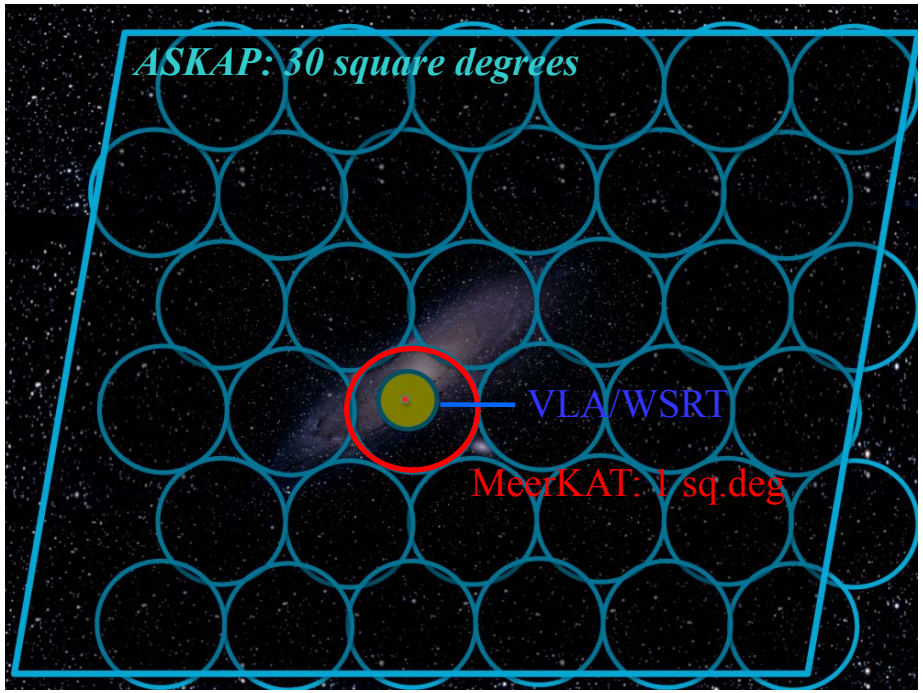
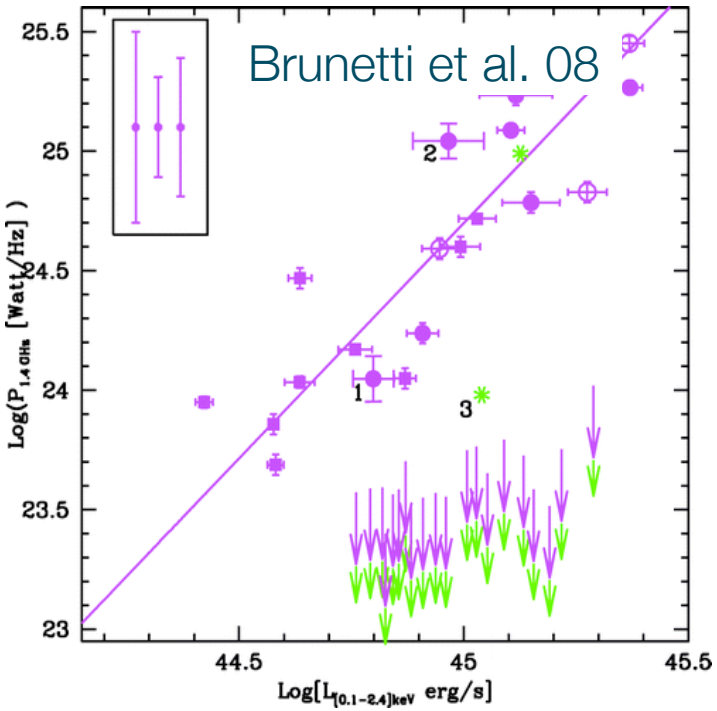
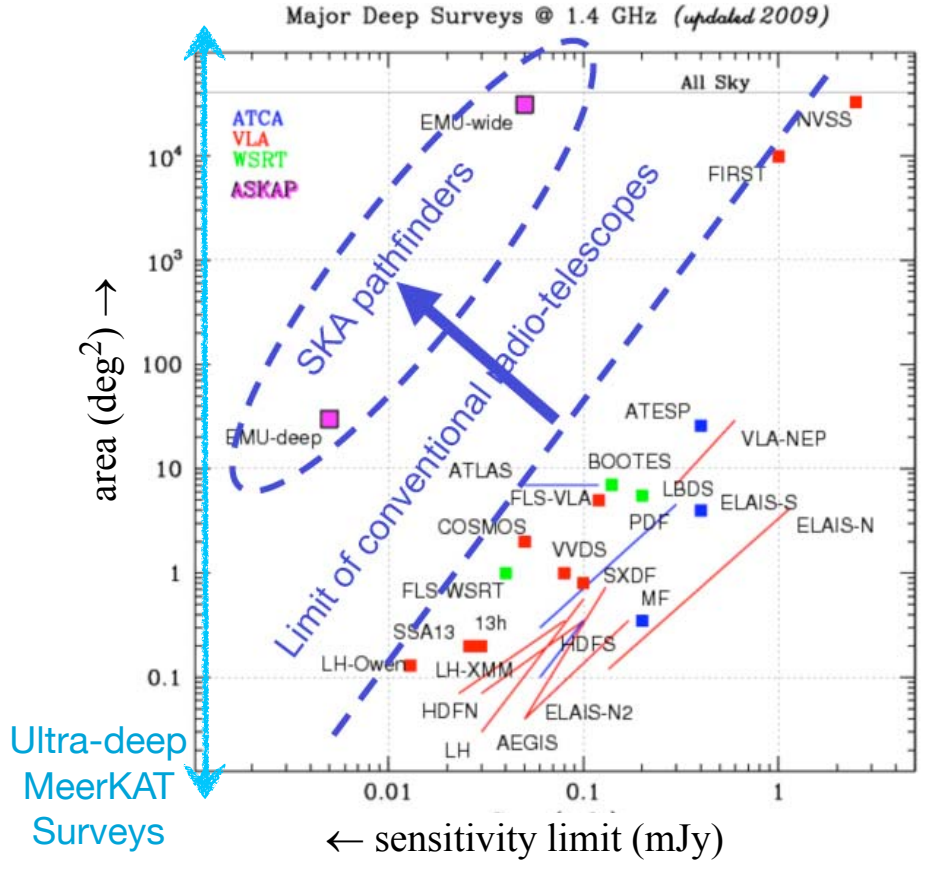
ASKAP & MeerKat:
continuum studies among science drivers

ASKAP & MeerKAT: complementarity

- Field of View
- Sensitivity

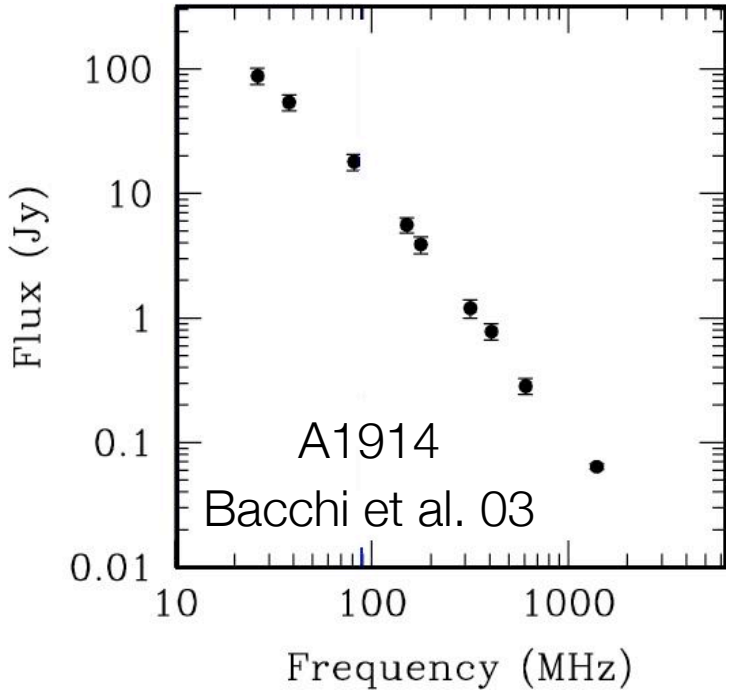


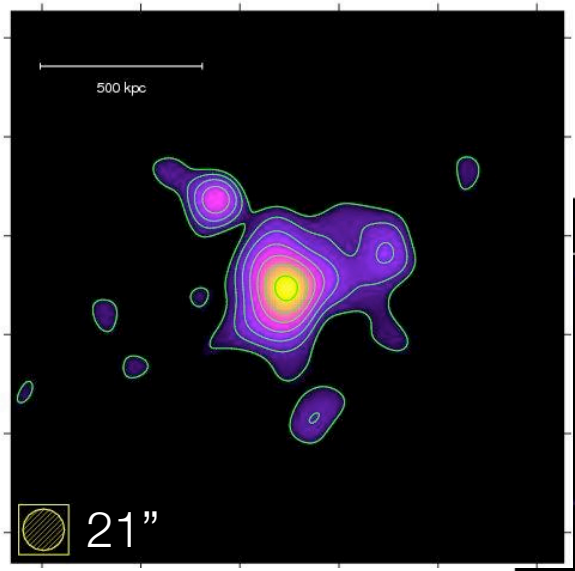




ASKAP & MeerKAT: complementarity

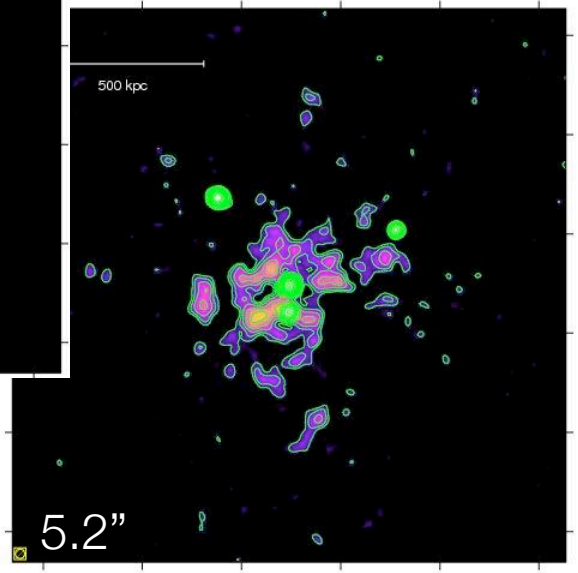
- Frequency coverage
  - ✳ASKAP: 0.7 - 1.8 GHz
  - ✳MeerKAT: 0.58 - 15 GHz
- Resolution
  - ✳ASKAP: 10”-30”@1.4 GHz
  - ✳MeerKAT: 1”-90”@1.4 GHz



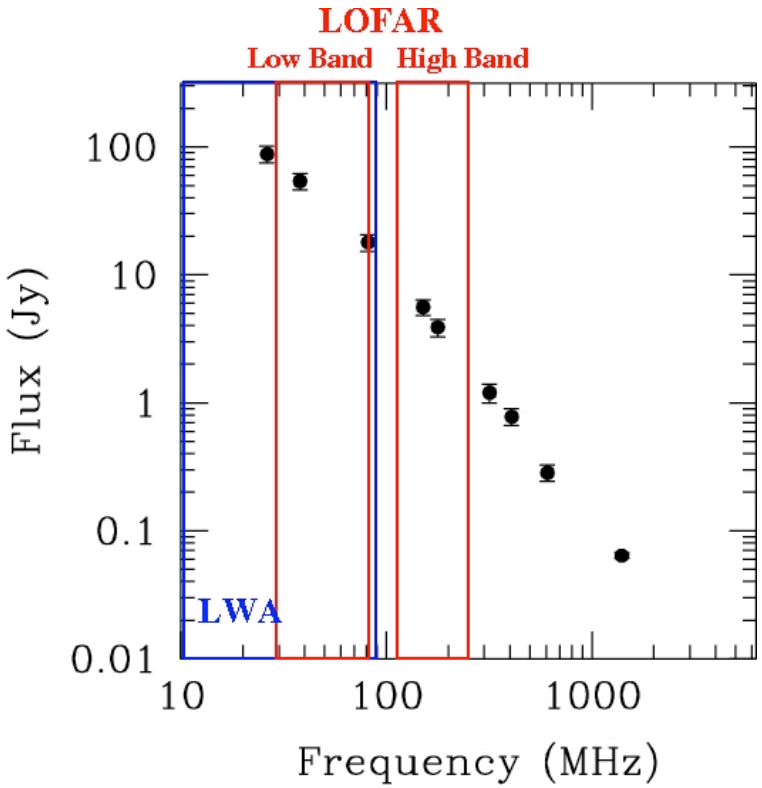


Murgia & Govoni 08

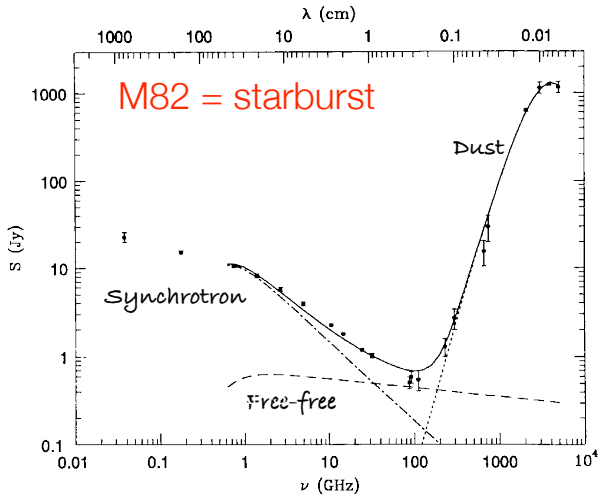
Simulations of
Halo + AGNs @ z=0.5



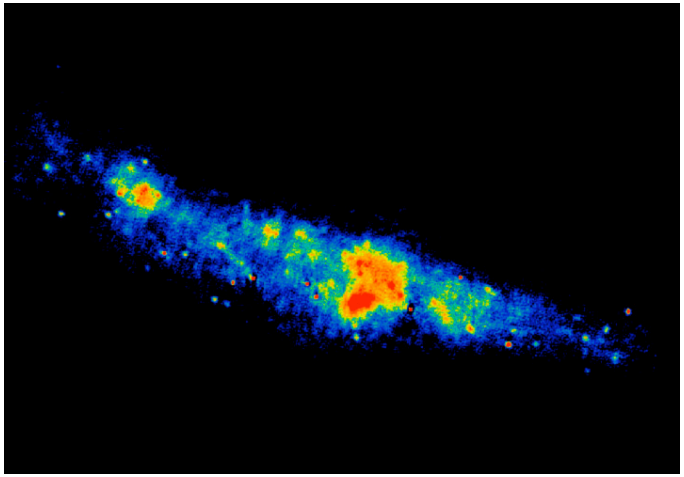
Some complementary projects



Spectrum of the radio halo in A1914



- Low-frequency (30-240 MHz): *LOFAR*



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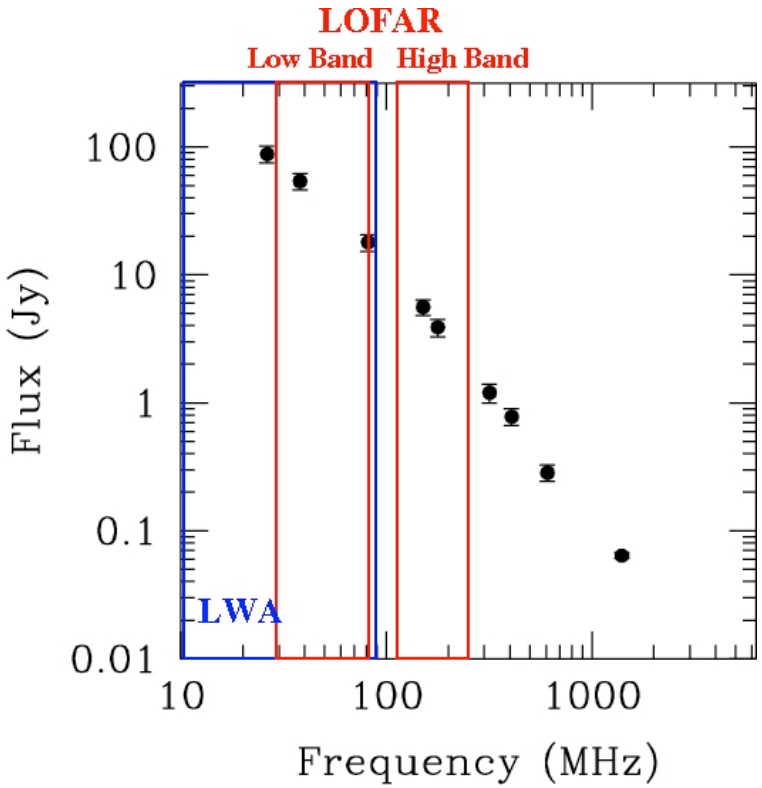

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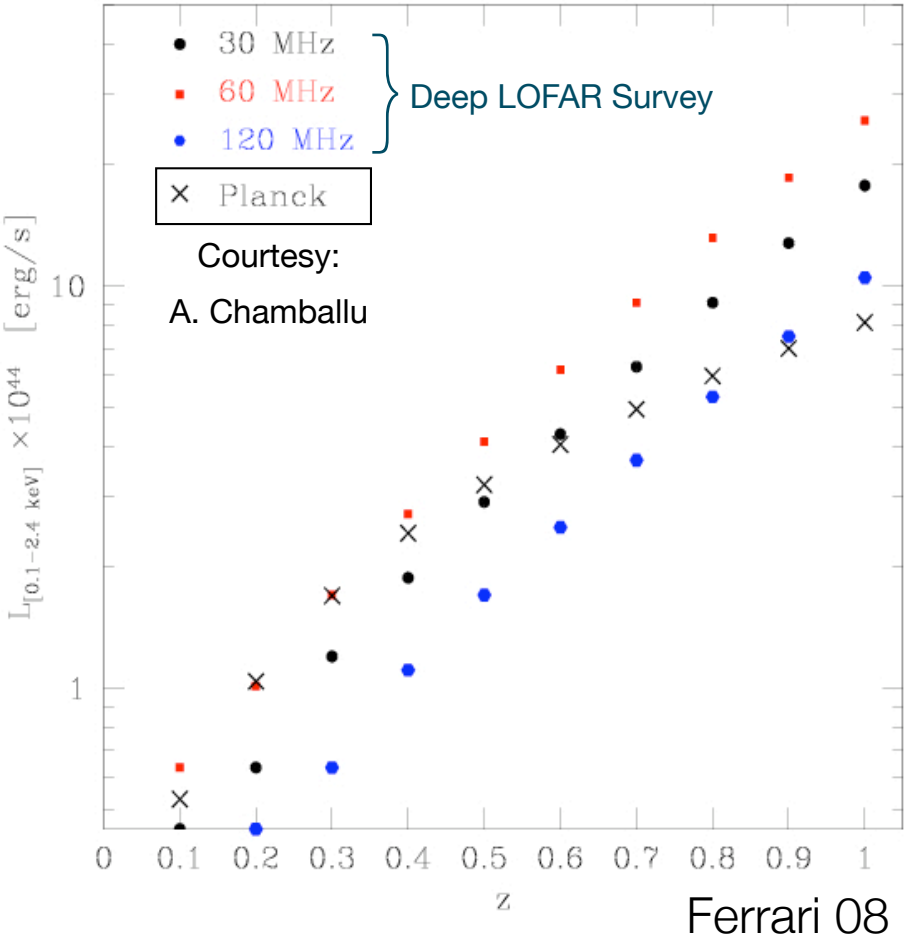
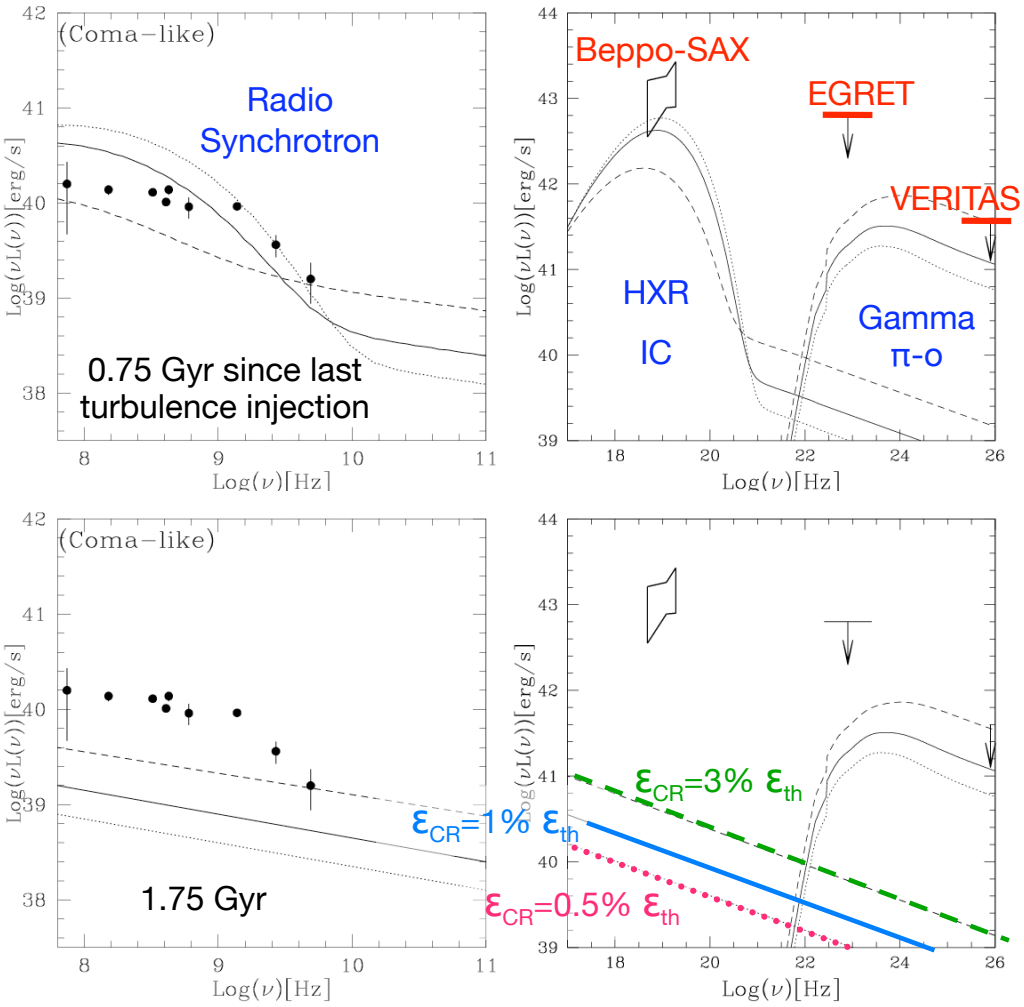


- Low-frequency (30-240 MHz): *LOFAR*
- Microwave (30-857 GHz): *Planck*

Ferrari 08

Some complementary projects

- Low-frequency (30 - 240 MHz): *LOFAR*
- Hard-X-rays (6-80 keV): *NuStar*
- Gamma-rays (8 keV - 300 GeV): *Fermi*



Brunetti et al. 08

Conclusions

- Deep interest of the French community for the study of continuum radio sources in clusters through ASKAP and MeerKAT
- Complementary projects exist
- Link to HI studies concerning the evolution of the star-formation properties of cluster galaxies

ASKAP and continuum studies of galaxy clusters

ASKAP Continuum Science

ASKAP
Australian SKA Pathfinder

1. To trace the evolution of star-forming galaxies from z=2 to the present day, using a wavelength unbiased by dust or molecular emission.

2. To trace the evolution of massive black holes throughout the history of the Universe, and understand their relationship to star-formation.

3. To use the distribution of radio sources to explore the large-scale structure and cosmological parameters of the Universe.

4. To explore an uncharted region of observational parameter space, almost certainly finding new classes of object.

Johnston 09

MeerKAT and continuum studies of galaxy clusters

MeerKAT Science: L & S-band

- Low column density HI associated with the Cosmic Web and galaxy environments
- Ultra-deep narrow-field HI survey out to z=1.4 using gravitational lense amplification
- High spatial dynamic range HI imaging of 1000 galaxies
- Ultra-deep narrow-field continuum surveys down to micro-jansky detection limits
- Mapping magnetic fields in clusters
- All-sky continuum survey at 600 MHz
- Pulsar timing and monitoring
- SNR detection and GRB follow-up
- OH mega-masers and Zeeman splitting
- Galactic gas dynamics and magnetic fields

de Block 09