Clusters of galaxies: high energy emission

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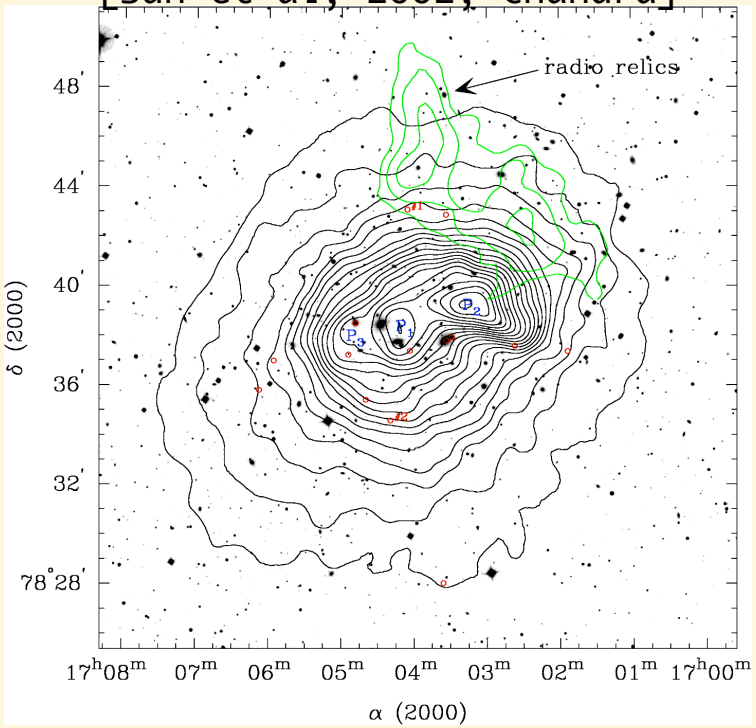
Thermal and non-thermal components

[Sun et al, 2002; Chandra]

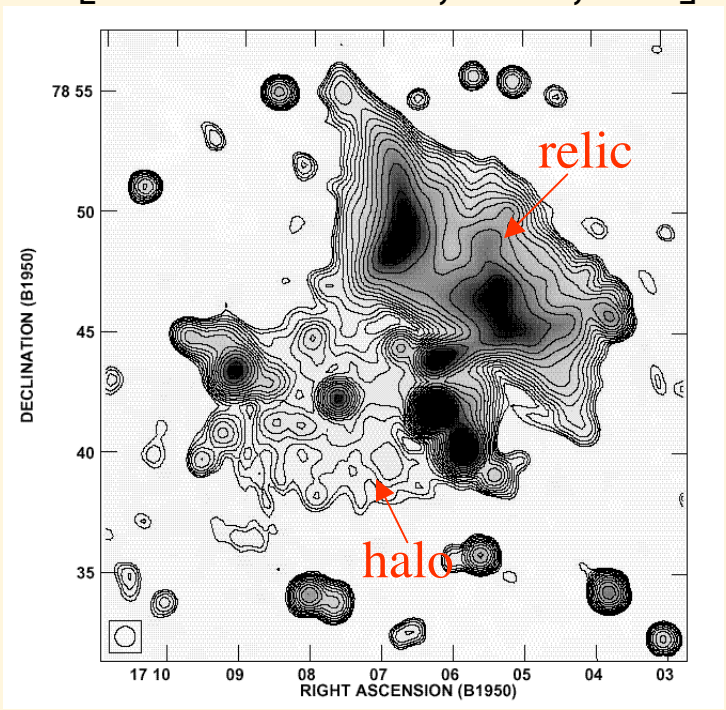


X-ray thermal - diffuse emission

Hot plasma (T ~ 2-10 keV)

main baryonic component
[80% DM, 20% ICM, 5% stars]

[Clarke &Ensslin, 2001; VLA]



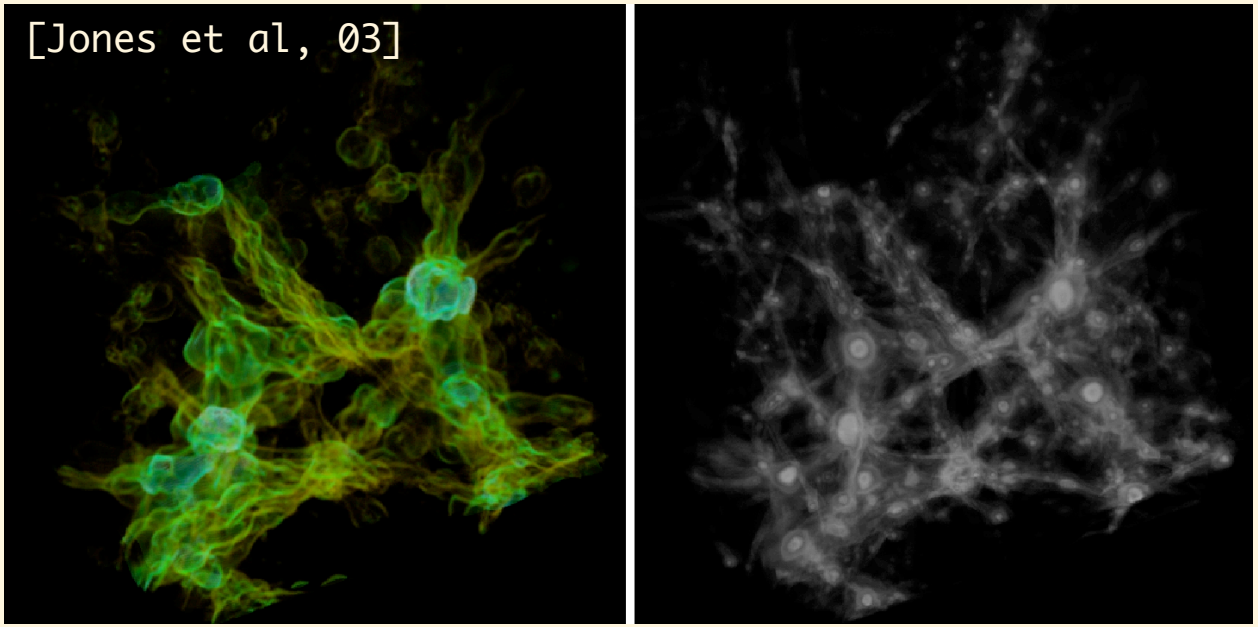
Radio synchrotron - diffuse emission

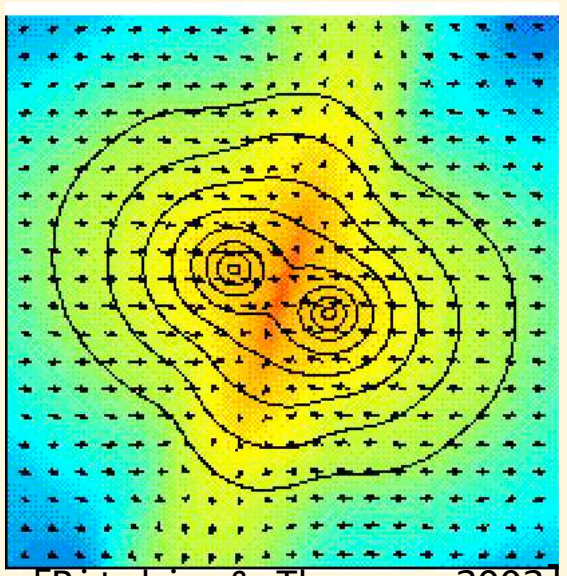
Relativistic electrons (~1-100 Gev)

Magnetic Field (0.1 - 1 G)

IC e- on CMB ==> NT X-ray (power law)

Origin and acceleration of the relativistic electrons ?





[Ritchie & Thomas, 2002]

Cluster hierarchical formation ==> Shocks (heat the gas at T_{virial})

- Clusters: good reservoir of E< 10^6 Gev particules
- Radio halos/relics in unrelaxed (merger) clusters only ; e- accelerated by Shocks?

  Pb: everywhere but t_{life} ~10^7 - 10^8 years << $t_{diffusion}$

  ==> recent creation or acceleration by a mechanism at cluster scale
- Several Models:
  - Thermal electrons accelerated by shocks (high M) /turbulence
  - Non thermal electrons (from above or from AGN/Winds) re-accelerated
  - Secondary electrons from inelastic collisions of NT protons with ICM

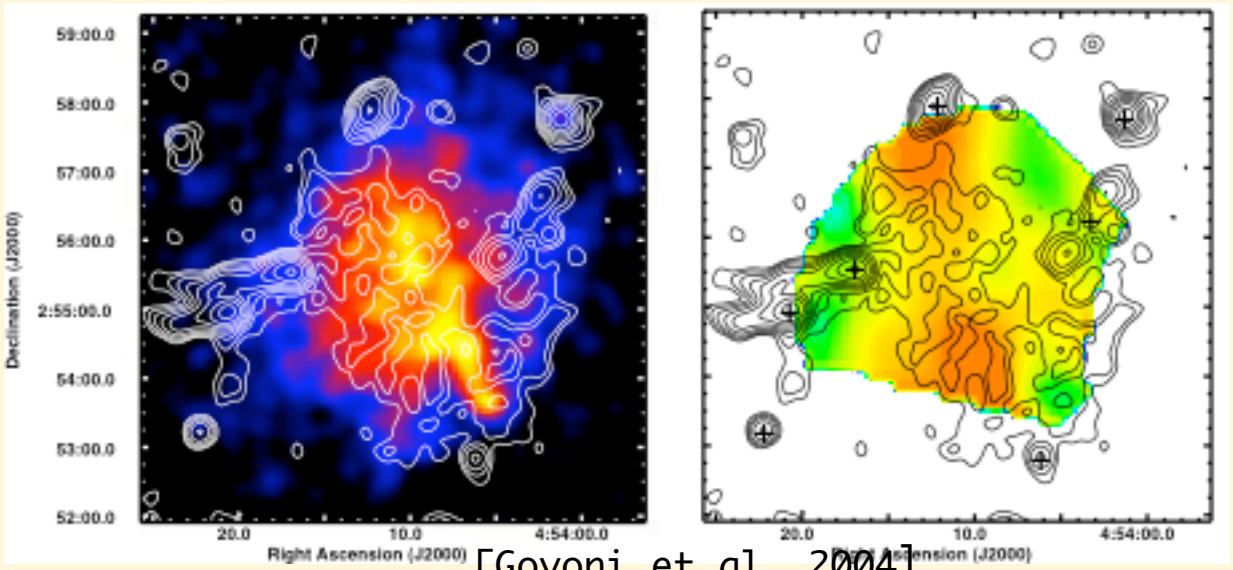
Importance of the Non thermal component (B, energetic particles)

- Diagnostic information on the physics of cluster formation
  - dynamics of hierarchical formation process
  - AGN and galaxy feedback

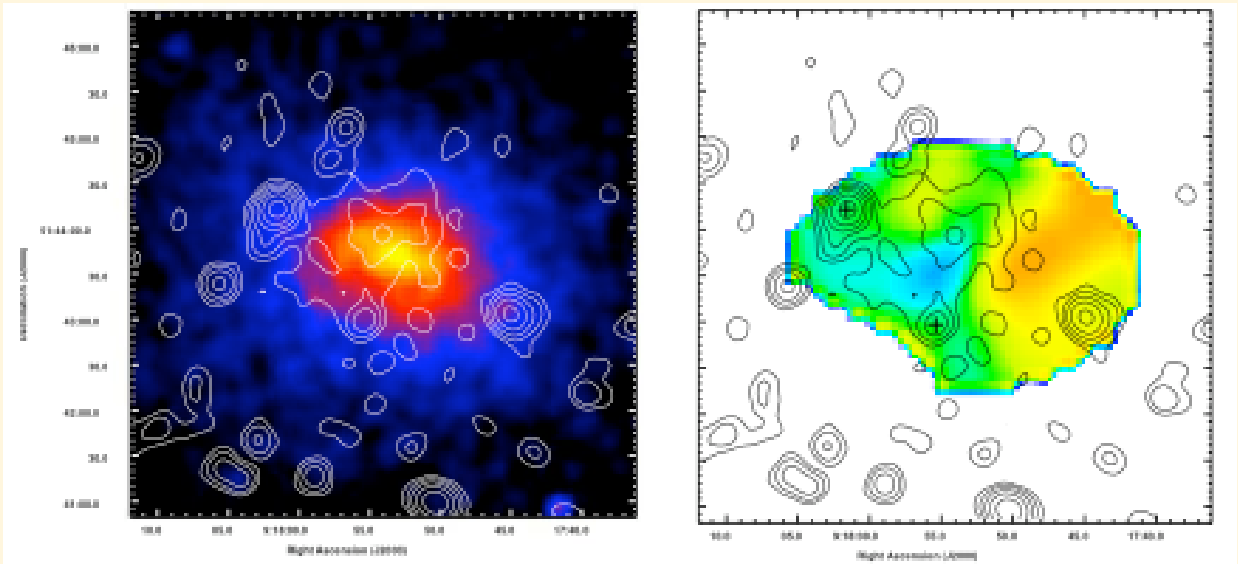
- May influence the thermo-dynamical evolution of the ICM

- May contribute to the overall pressure
  ==> Mass higher than estimated from the HE equation and P_{therm} only
  ==> Impact on cosmological parameters estimated from N(M) or f_{gas}

Radio - X-ray complementarity



[Govoni et al, 2004]



- Radio - thermal X-ray

e.g Insight on acceleration process (shock, turbulence)

BUT

\+ Radio

Synchrotron (B, NT e-)

==> degenerate

Faraday Rotation (B, Te-)

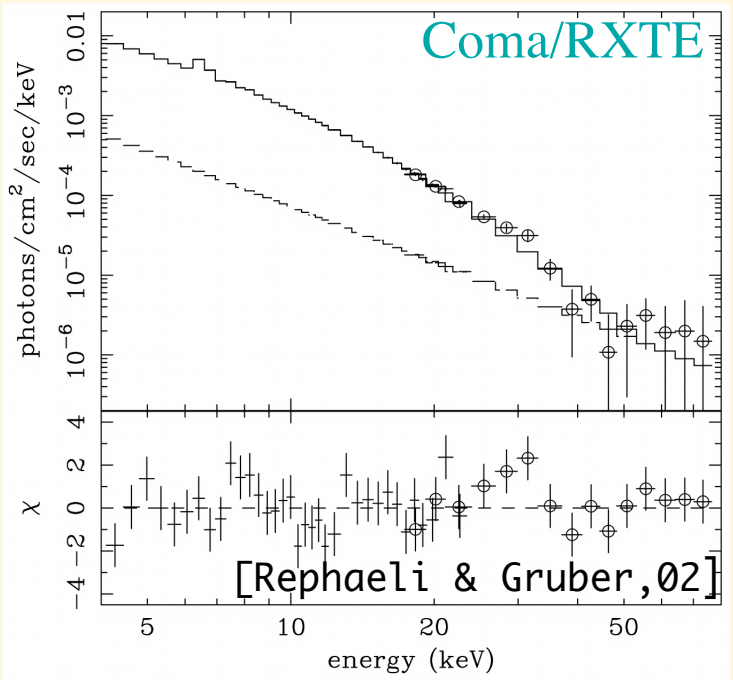
==> B in few directions

\+ IC (NT e-)

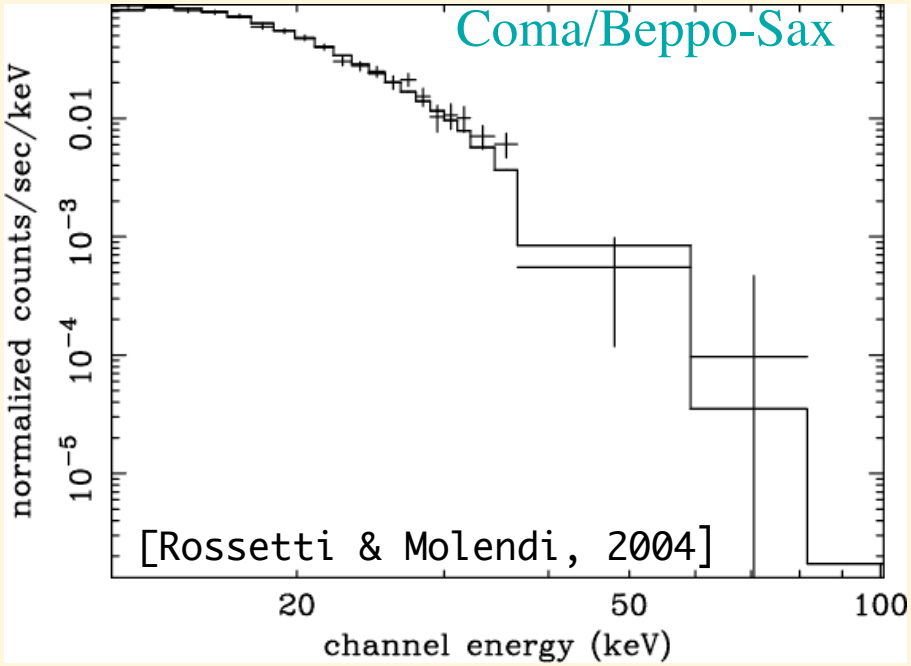
==> B, NT e-

The (difficult) search for IC emission

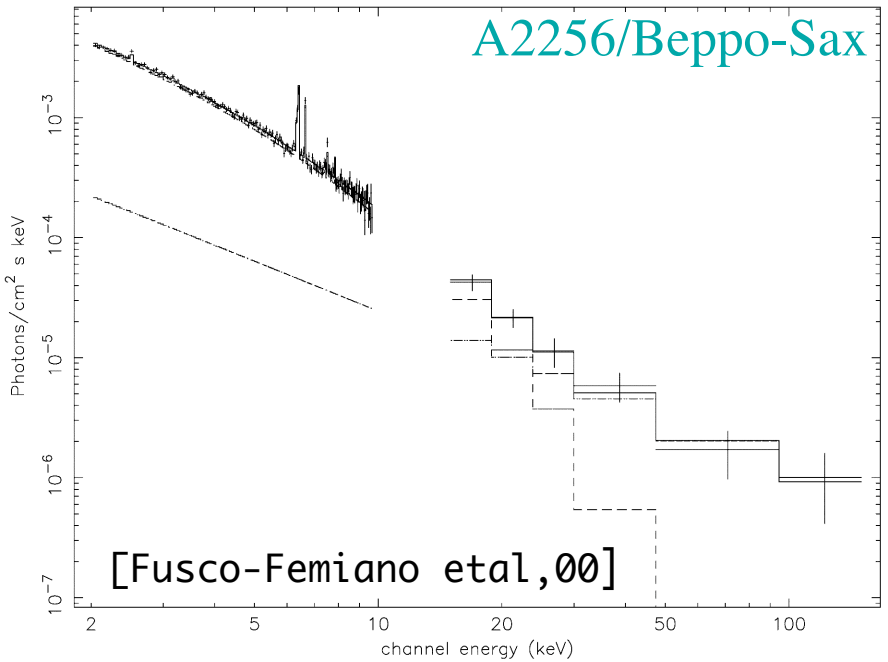
- Powerlaw e- spectrum ==> power law X-ray IC spectrum
- Dominates the thermal emission only at very low E or high E (> kT~ 10 keV)
- First detections only recently with RXTE and Beppo-SAX (5 clusters!)



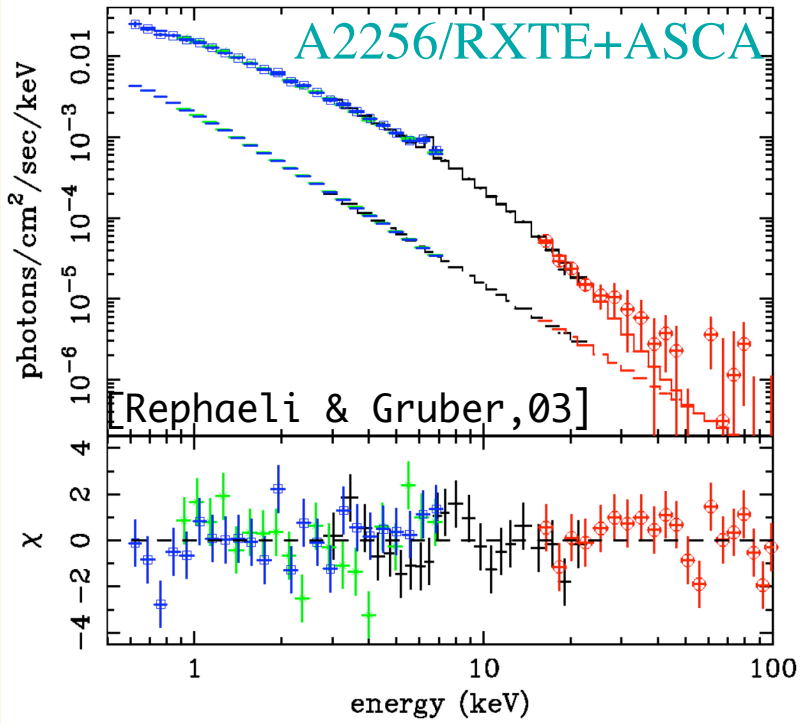
Very faint signal (a few □)



detection sensitive to bkg systematics
e.g earlier Sax detection infirmed



Detection at 4.6 □



Significant hard tail but
spectrum also fitted with 2 kT
(NB expected in mergers)

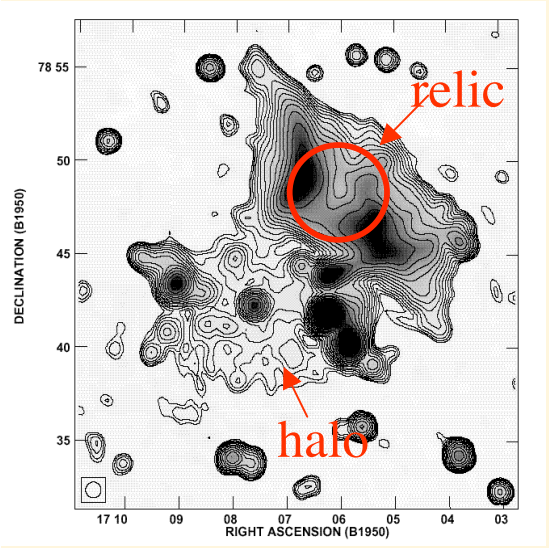
With Proportional Counters (Beppo-Sax, RXTE):

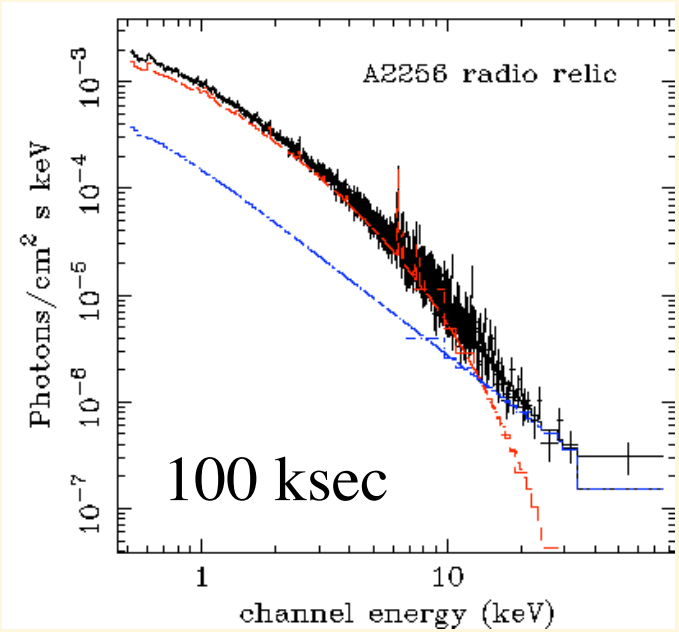
- Global spectrum ==> ambiguous interpretation (multi kT; AGN contamination)
- Low S/N if localised emission

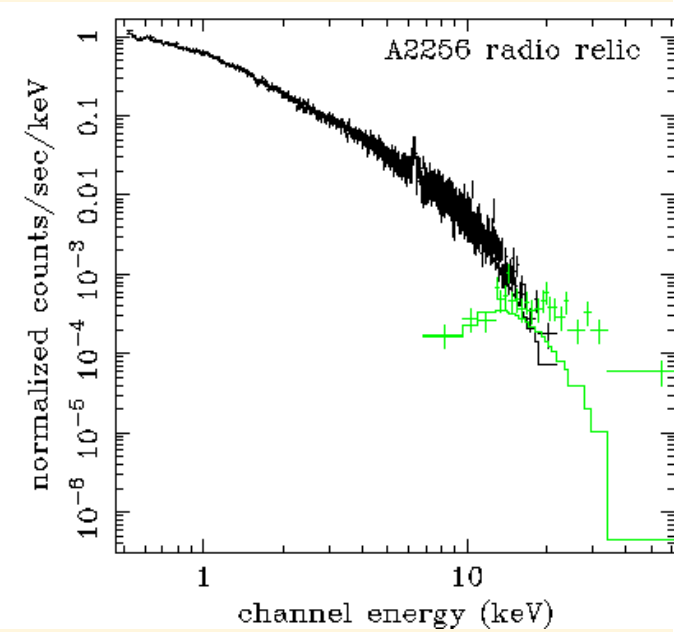
NEED

focusing optics at high E = SIMBOL-X

What SIMBOL-X can do (an exemple)







- exclude AGNs in FOV
- extract spectrum in isothermal regions (kT variations at ~ several arcmins)
  ==> unambiguous evidence of hard X-ray excess

- S/N gain. Specially powerful for relics (region of high IC, low thermal emission)
- Characterization of power law: normalization: 15 % accuracy
  slope: 4%

Conclusion

- The study of the non thermal component (B, high energy particles) in clusters is important for cosmology

- A relatively new, but very active field

- Study of high energy emission essential and complementary to radio study

- New imaging capabilities of Symbol - X at high E essential