Excess entropy in intracluster medium and AGN heating

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We study the effects of heating of the diffuse hot gas in groups of galaxies by AGNs in order to explain the observed entropy excess in the gas. X-ray observations have shown that groups of galaxies do not follow the scaling relations (e.g, between the X-ray luminosity and temperature of the gas) obeyed by galaxy clusters. Specifically, gas in galaxy groups appear to be less dense than expected from simple extrapolations from the case of rich clusters, assuming that the gas density profile is determined mainly by the dark matter density distribution. These observations require non-gravitational processes such as heating or radiative cooling.

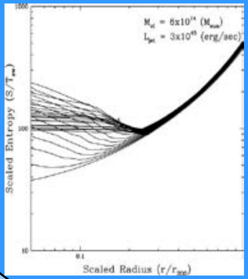
Why AGN heating?

- AGNs can deposit large amount of energy. If ~10^{61} erg is deposited (for a AGN with mechanical luminosity of ~3×10^{45} erg/s with a life time of ~ 10^8 yr), then it implies ~ 1 keV per particle for a group of 3×10^{13} $M_\odot$.
- Radio-loud AGNs preferentially reside in galaxy groups (Best 2004)

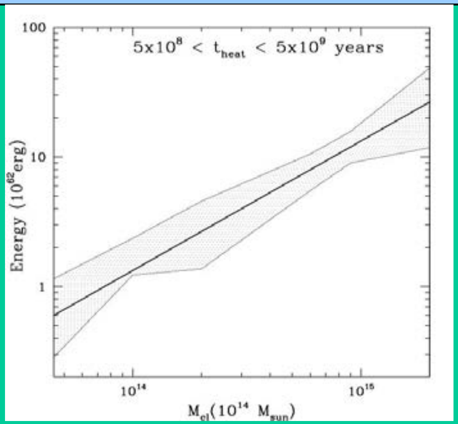
Effervescent heating

- Buoyant bubbles of relativistic plasma rise in the cluster atmosphere and deposit energy into the ambient gas by doing pdV work.
- For a large flux of such bubbles, the volume heating rate can be related to the energy output of the AGN (Begelman 2001)

We studied the evolution of entropy profiles of gas with effervescent heating (for a duration of t_{heat}), cooling and convection, and compare with observed entropy after a Hubble time.



Example of the evolution of scaled entropy profile, shown at the intervals of 5×10^8 yr, for t_{heat} ~ 5×10^9 yr. The entropy profile is seen to rise and then fall as the gas cools.



- The required energy output is correlated with group/cluster mass
- If M_{AGN} ~ f M_{cl}, M_{BH} ~ 10^{-3} M_{AGN}, and if a fraction η of BH mass is converted to energy, then need η ~0.15 and f~0.01 (Roychowdhury et al 2004, ApJ, 615, 681)

The resultingchange in the CMB power spectrum via Sunyaev-Zel'dovich effect is found to be larger than previously thought (Roychowdhury et al 2004, submitted)

(before heating)

(after heating to explain excess entropy)