Intergalactic Gas in Groups : Implications for Dwarf Galaxies and the Missing Baryons Problem

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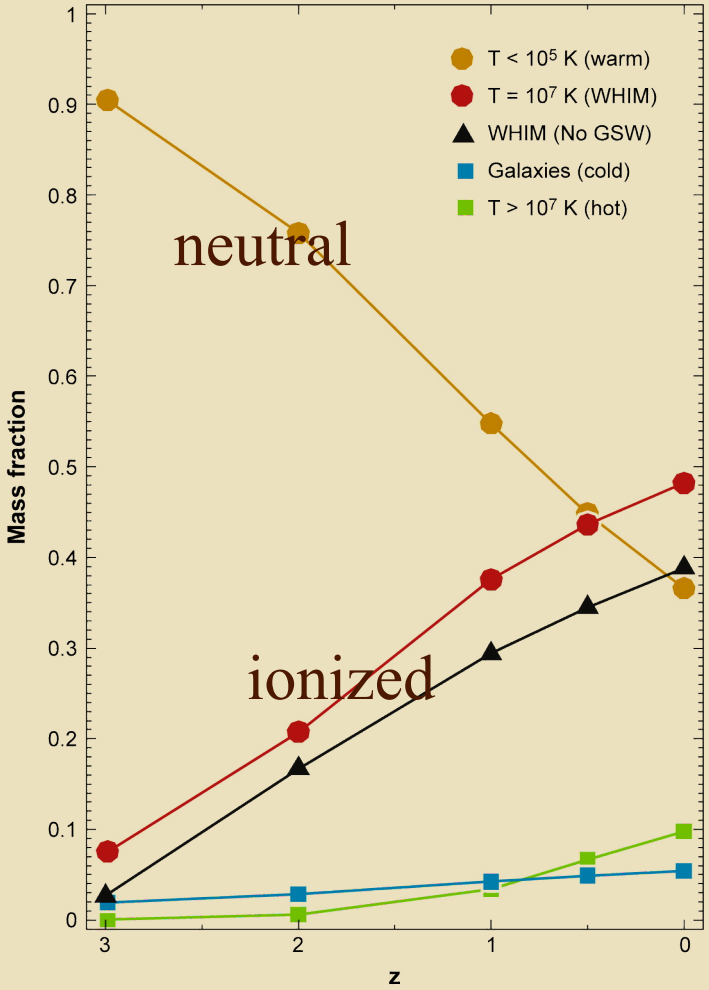
We have not yet located all the baryons that we expect in the local universe.

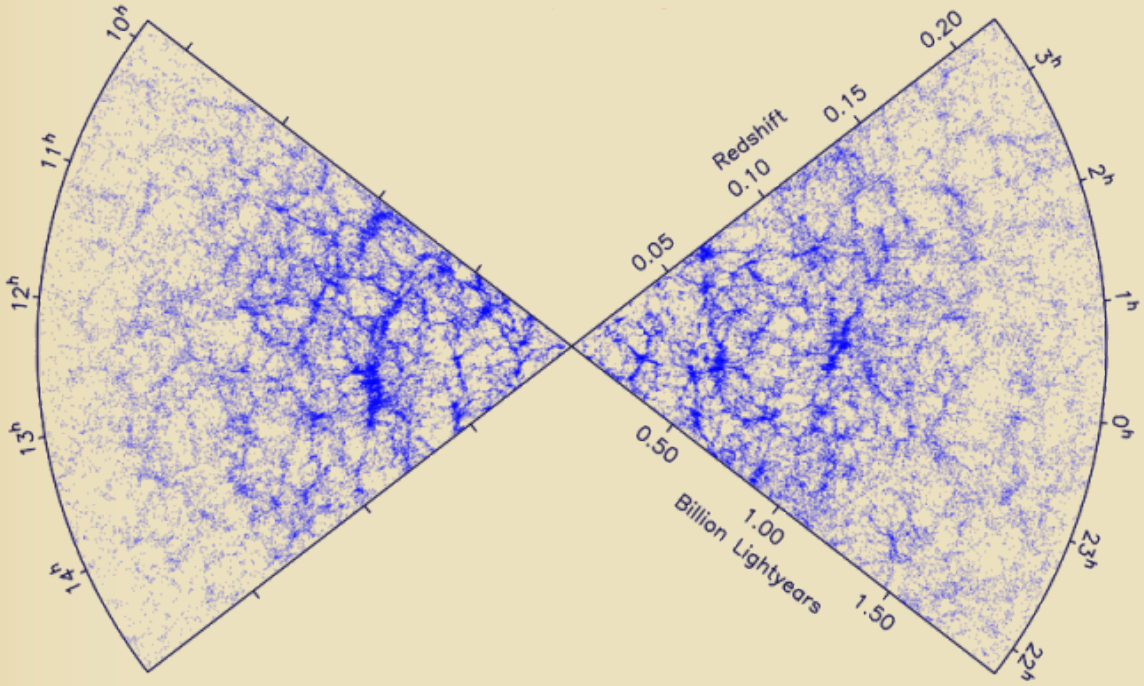
pie image via Dorothy Reinhold

Simulations predict that intergalactic gas is shock heated during structure formation.

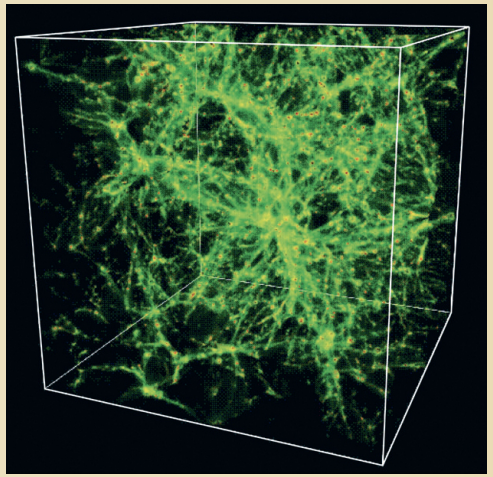


Bregman JN. 2007.
Annu. Rev. Astron. Astrophys. 45:221–59

Simulations show that the missing baryons are distributed along filaments.

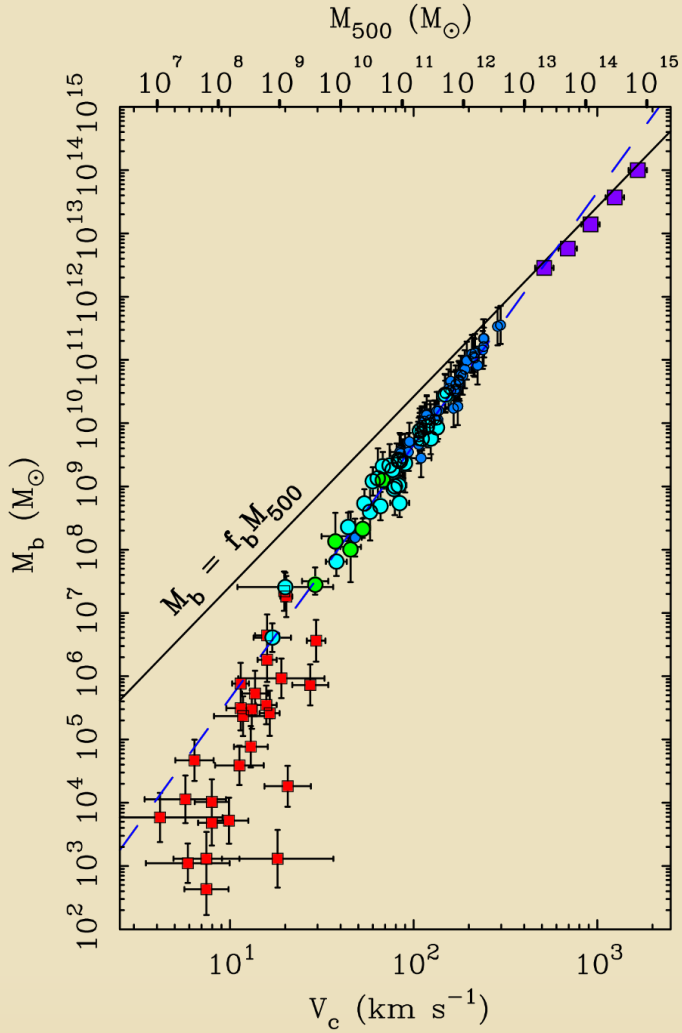


2dF redshift survey



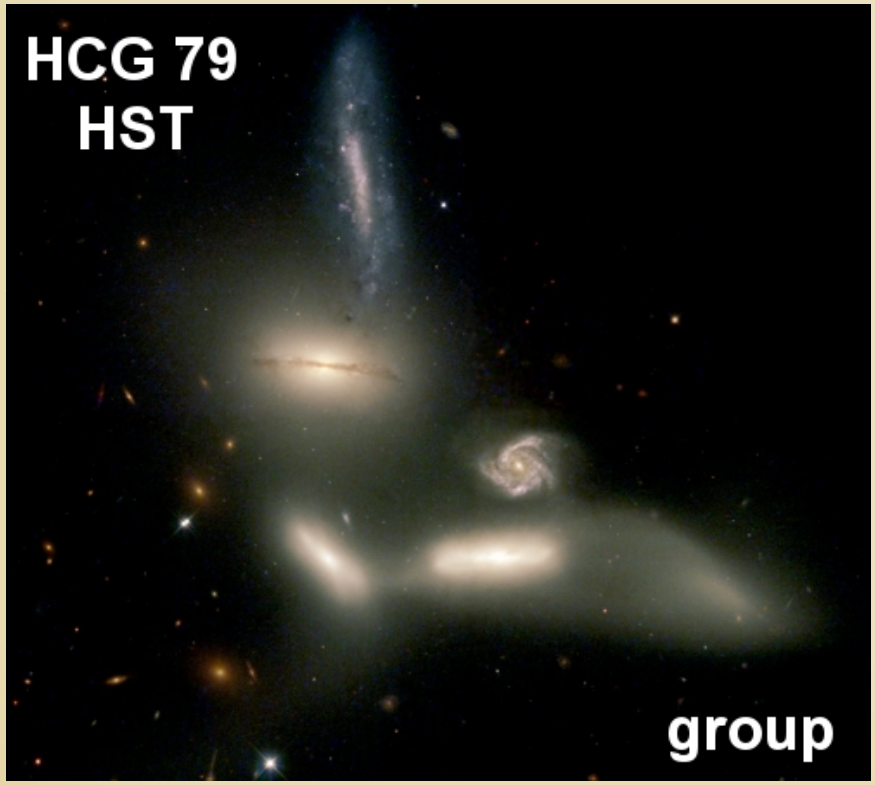
Warm-hot IGM
Cen & Ostriker 2006

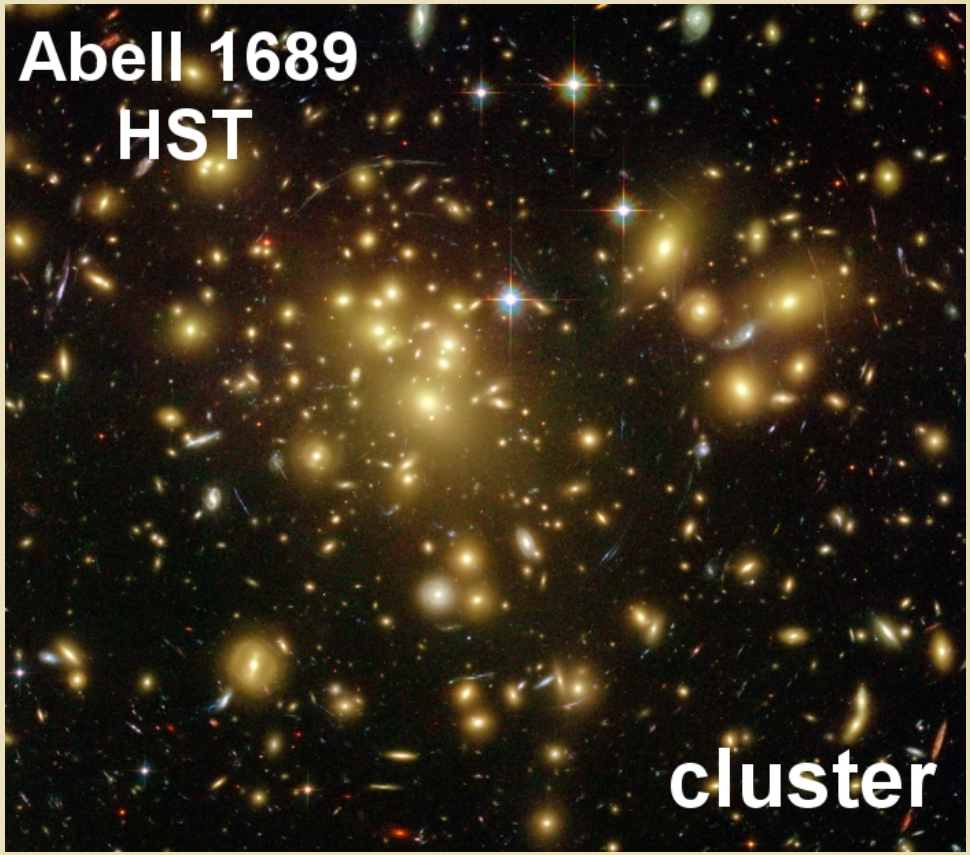
Baryon deficiency is the most extreme on scales of galaxies and galaxy groups.



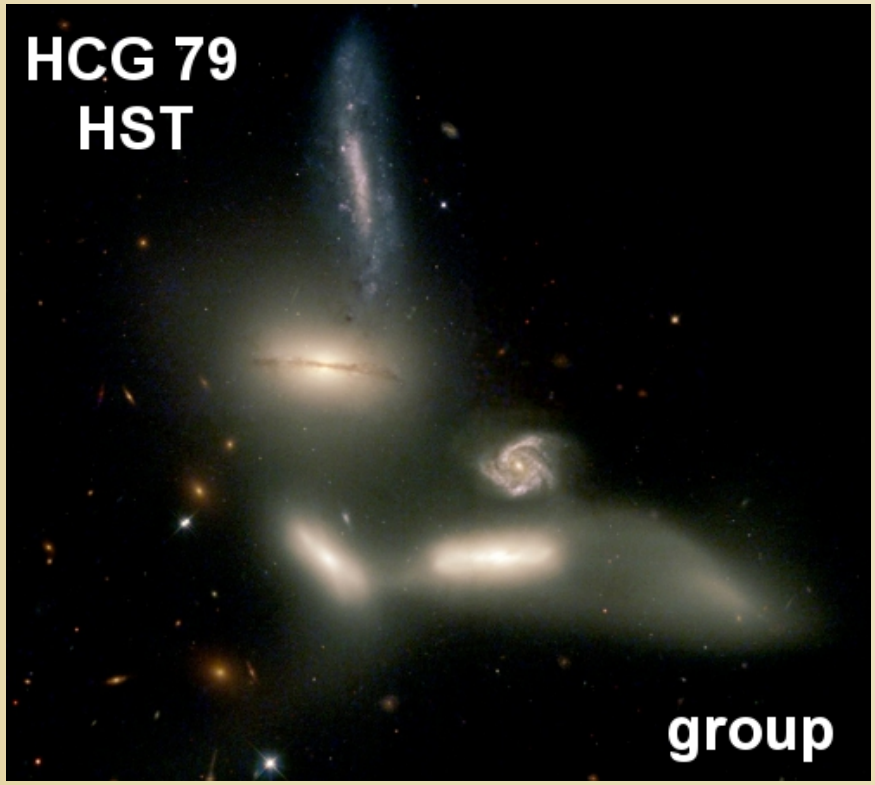
McGaugh et al. 2010

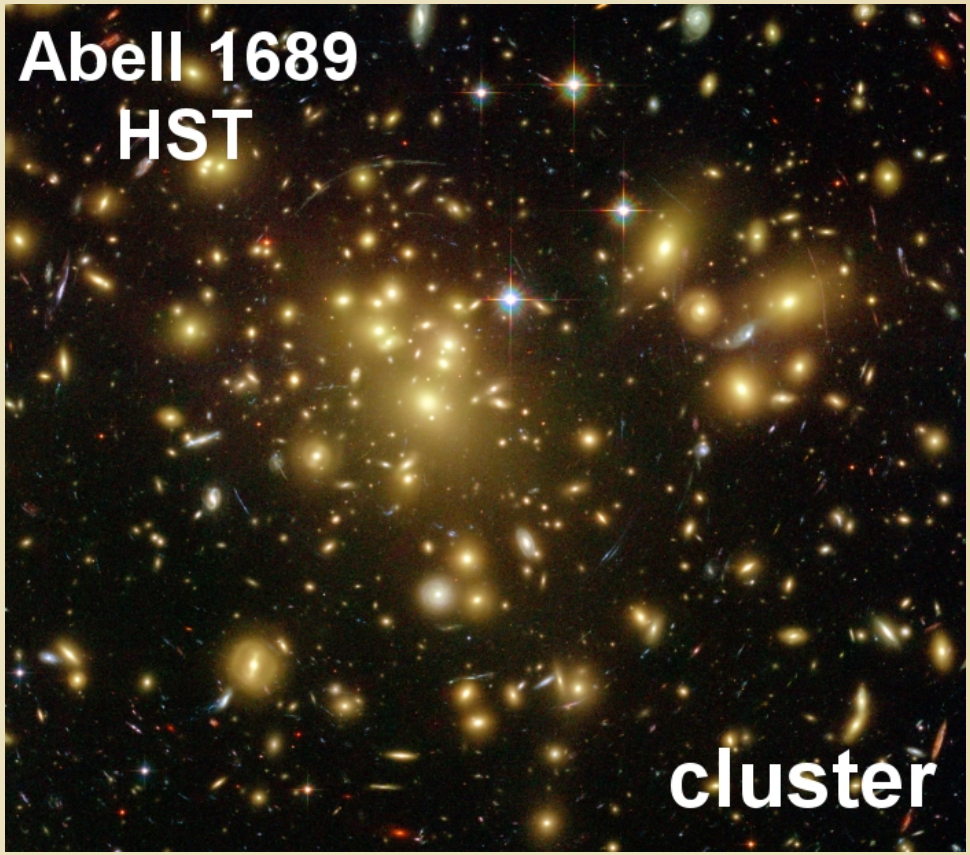
Galaxy groups are intermediate mass structures.





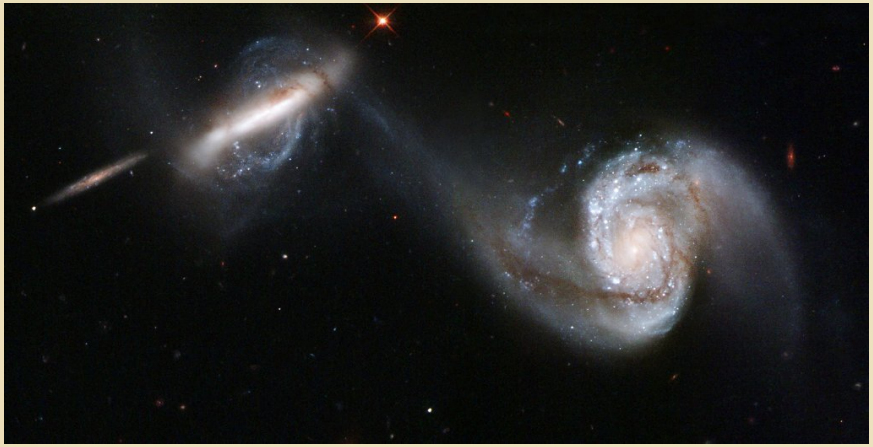
Galaxy colors and shapes vary with environment.



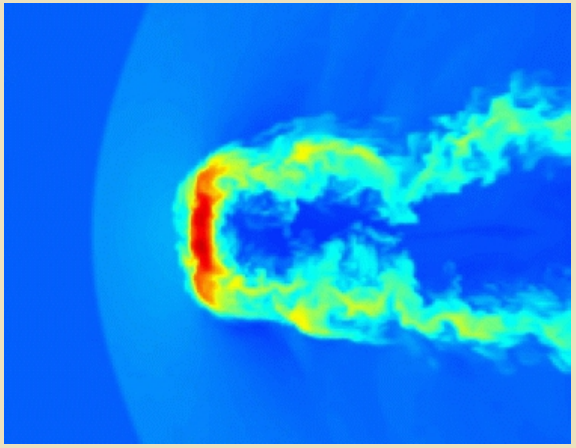


Physical processes that transform galaxies and intergalactic gas.

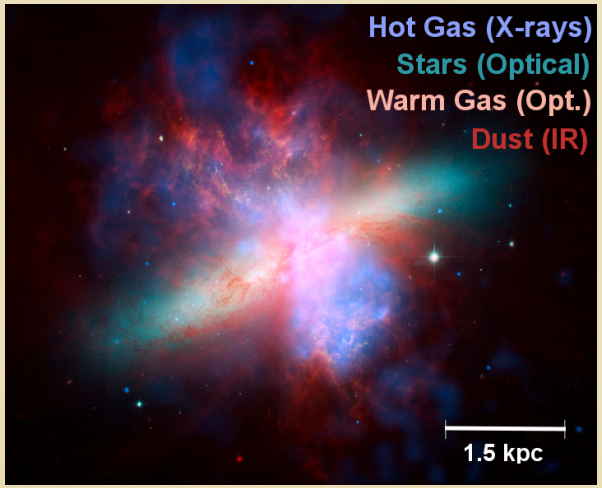
Interactions & Mergers



Ram pressure stripping / Starvation

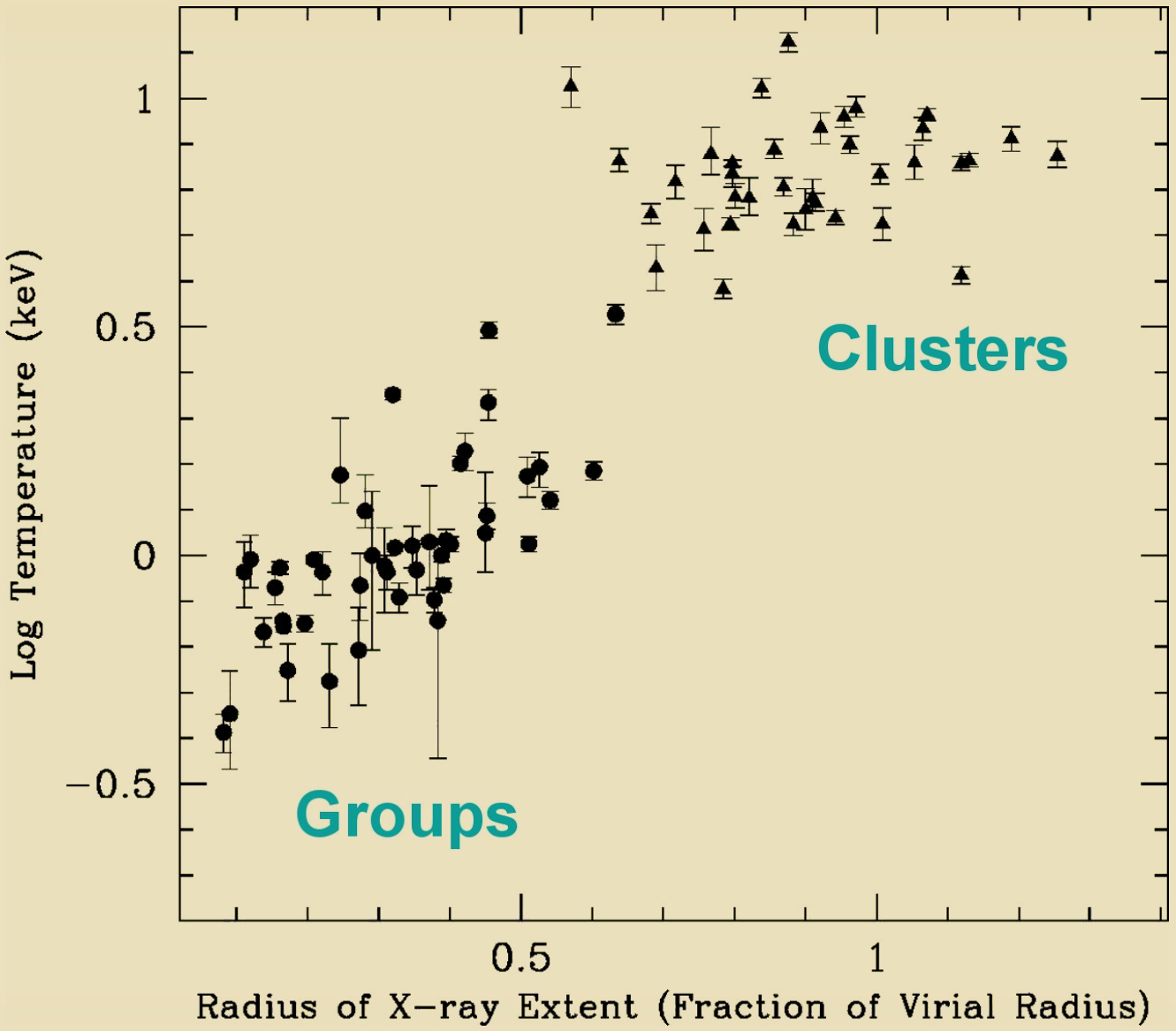


Outflows



- shocks
- turbulent stripping
- thermal evaporation
- AGN heating

X-rays trace hot gas in the center of groups.

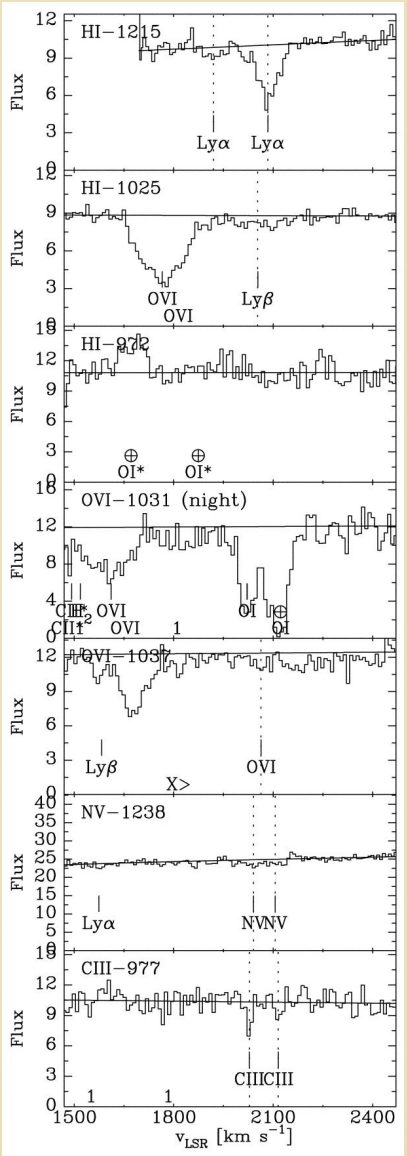


Mulchaey 2000

UV absorption lines can probe intergalactic gas.

- Mrk 817 sightline through GH 144, $\sim$ 370 kpc from nearest galaxy
- assuming photo-ionization from background radiation, metallicity, radiation field, filling factor
- $n > 10^{-4}$ cm^{-3} but size scale < 22 kpc

Pisano et al. 2003



Radio galaxies with bent jets are predominantly located in groups and clusters.

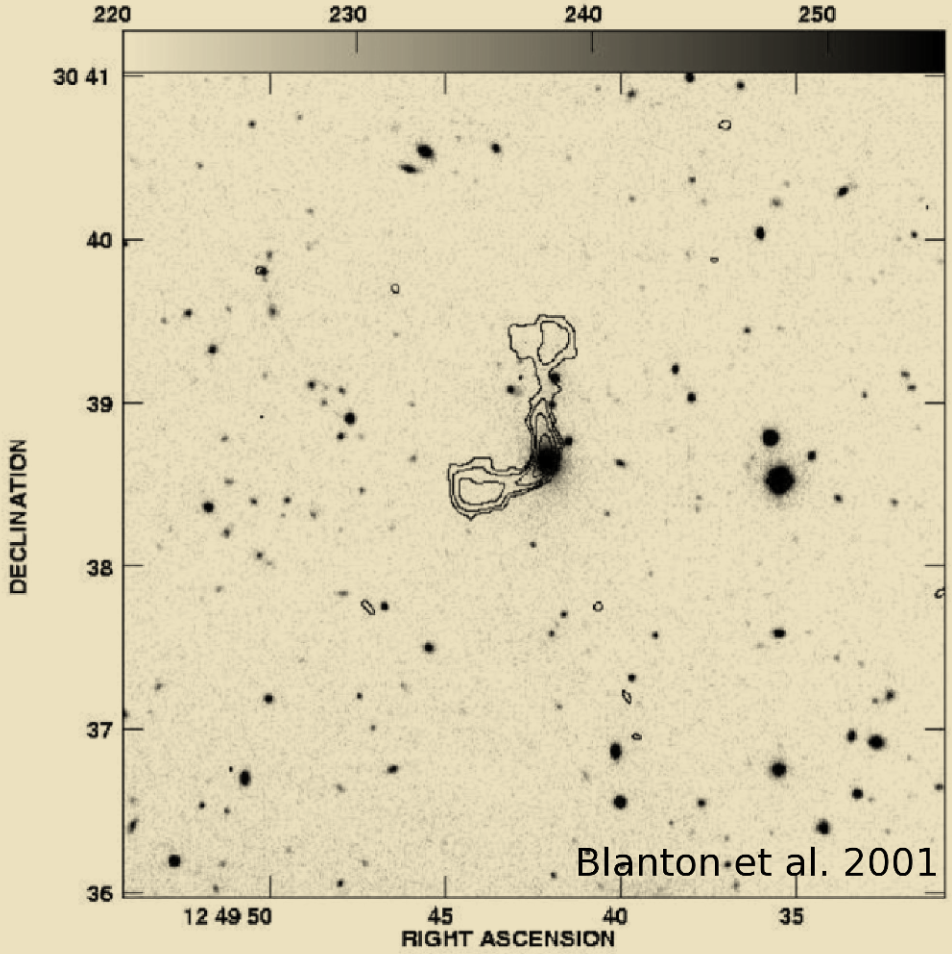
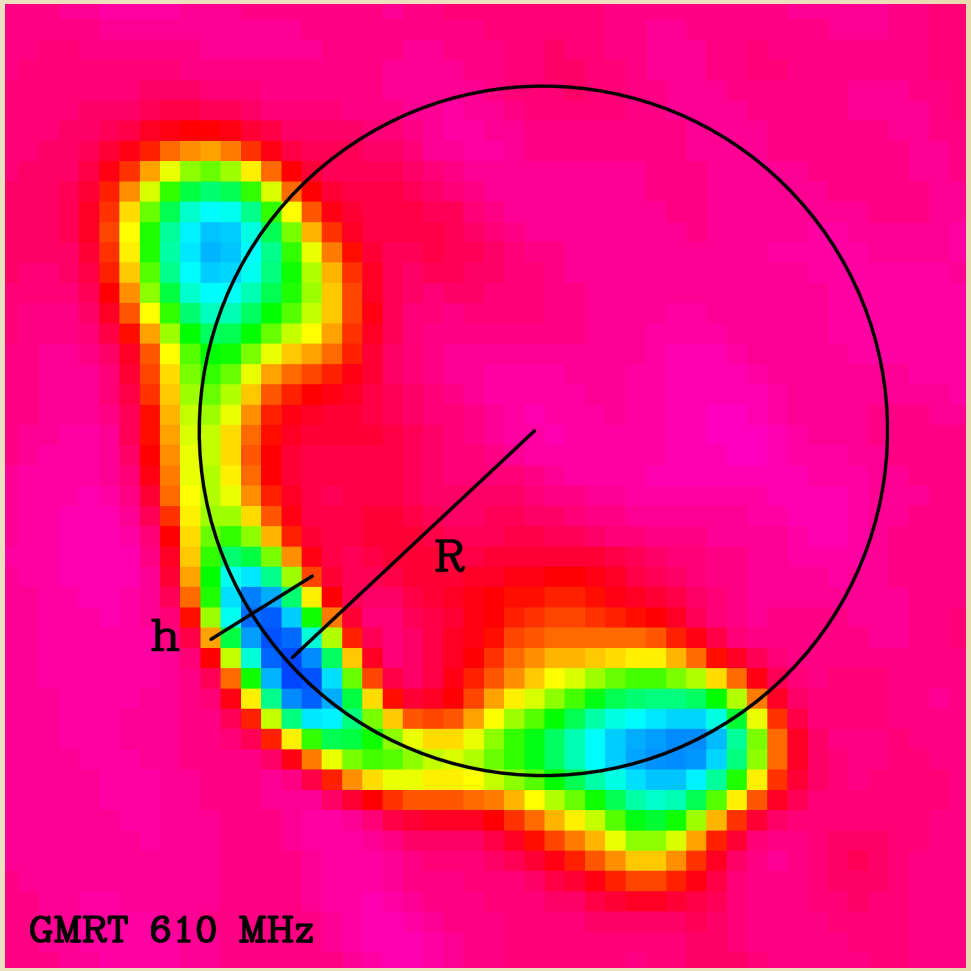


Fig. 3b.— A bent double in a poor environment:1249+3038 (#234) at $z = 0.1935$.

Jets are bent back by ram pressure from their movement through intergalactic gas.

$$\frac{\rho_{\mathrm{IGM}} v_{gal}^2}{h} = \frac{\rho_{\mathrm{jet}} v_{\mathrm{jet}}^2}{R}$$

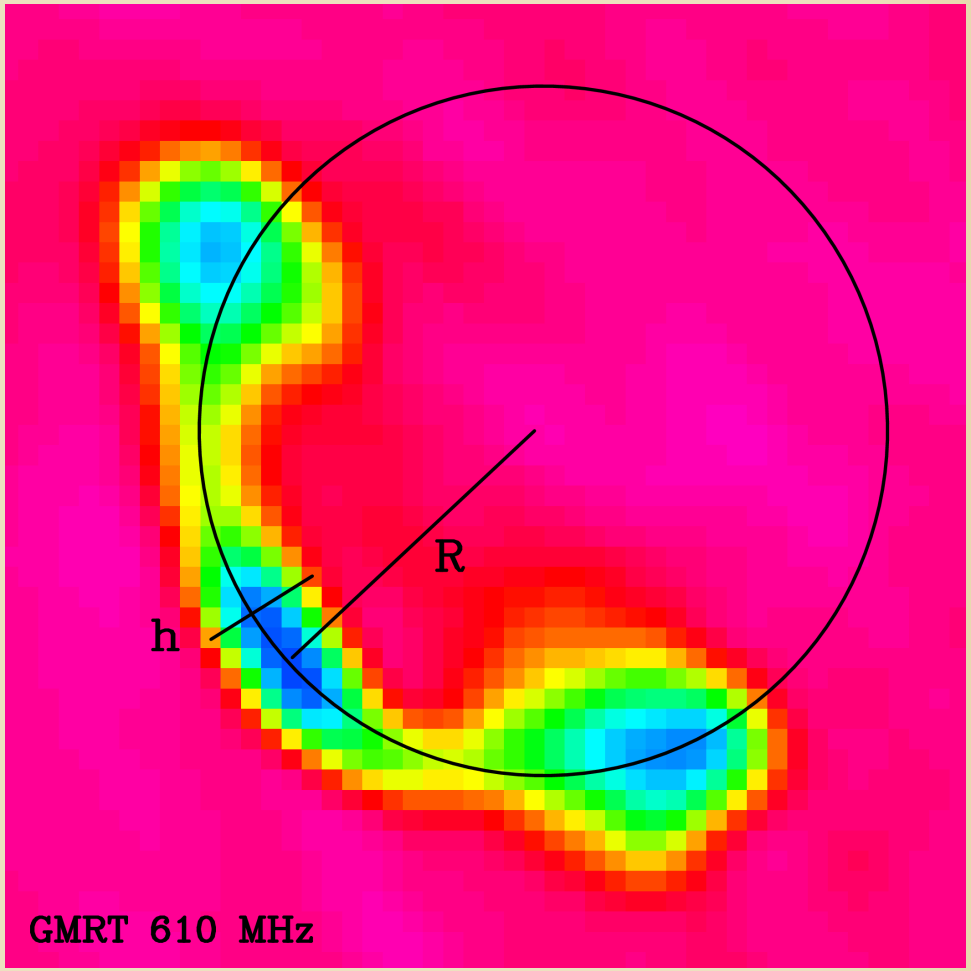
Begelman et al. 1979



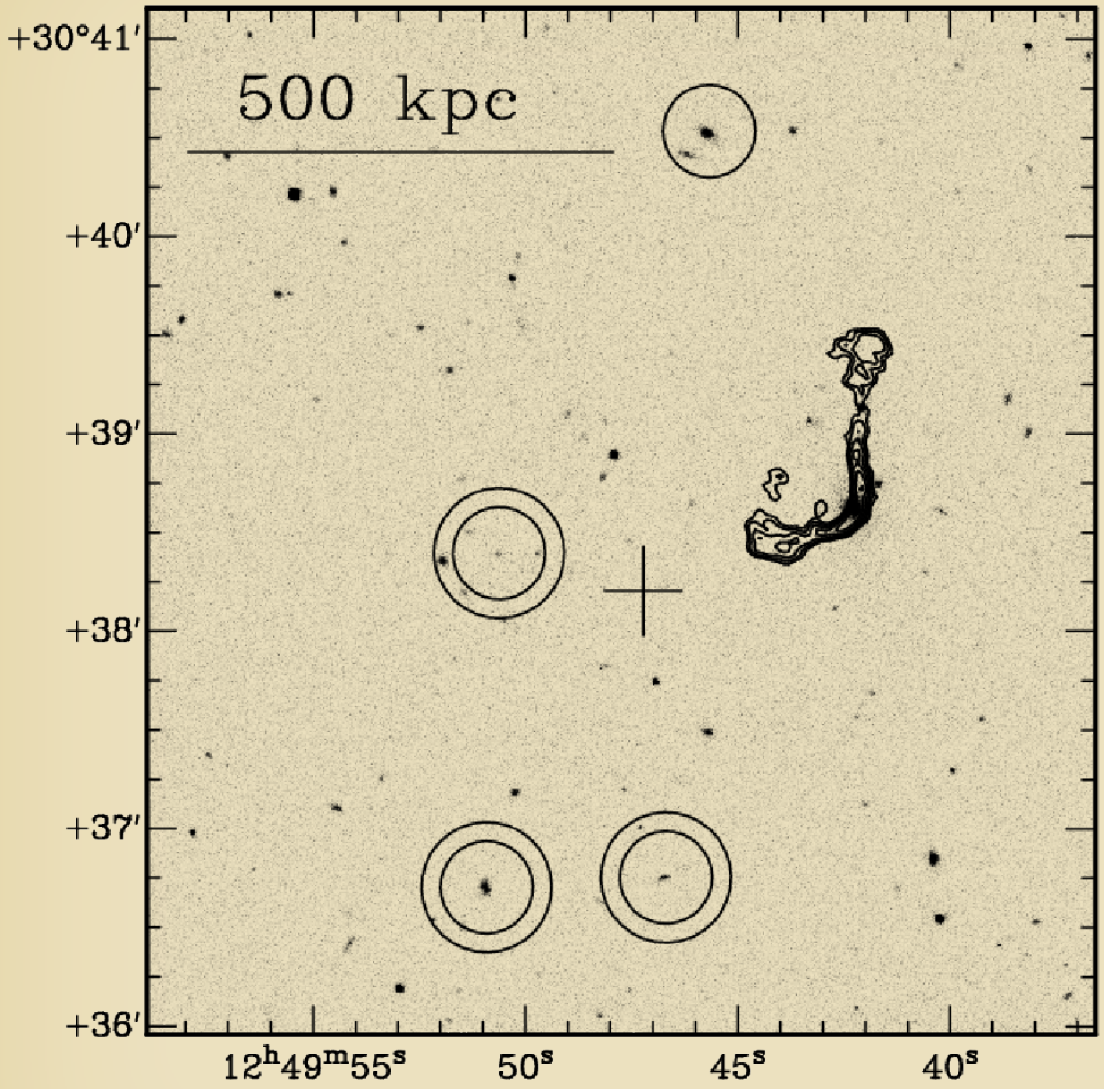
Jets are bent back by ram pressure from their movement through intergalactic gas.

$$\frac{\rho_{\mathrm{IGM}} v_{gal}^2}{h} = \frac{P_{synch}}{R}$$

Begelman et al. 1979



FIRST J124942.2 + 303838



Freeland et al. 2008

$z_{gal} = 0.194$

$\sigma_{group} = 250^{+20}_{-100}$ km s^{-1}

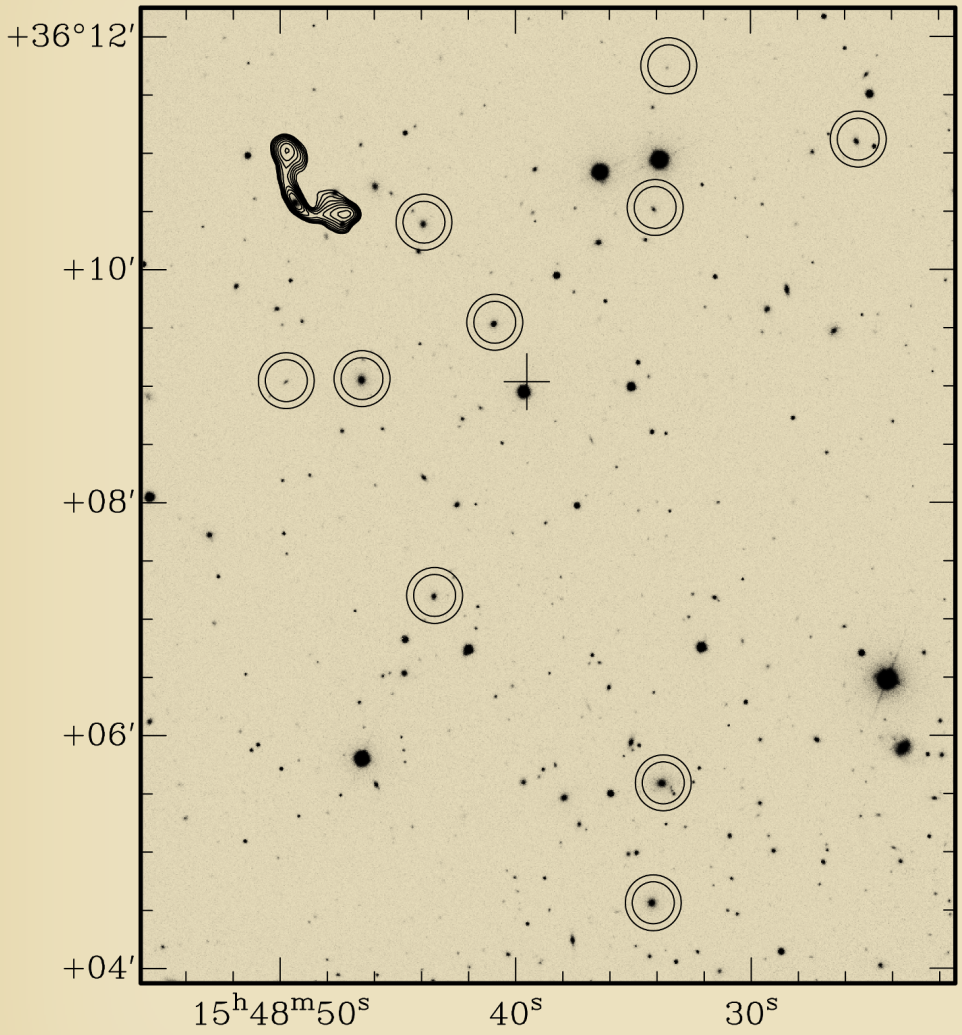
$r \sim 300$ kpc

$n_{\rm IGM} = 3 \pm 2 \times 10^{-3}$ cm^{-3}

Chandra : 35 ksec

$T < 2 \times 10^6$ K

SDSS J154849.35 + 351035.3



Freeland & Wilcots 2011

$z_{gal} = 0.233$

$\sigma_{group} = 550^{+120}_{-80}$ km s^{-1}

$r \sim 700$ kpc

$n_{\rm IGM} = 5 \pm 2 \times 10^{-4}$ cm^{-3}

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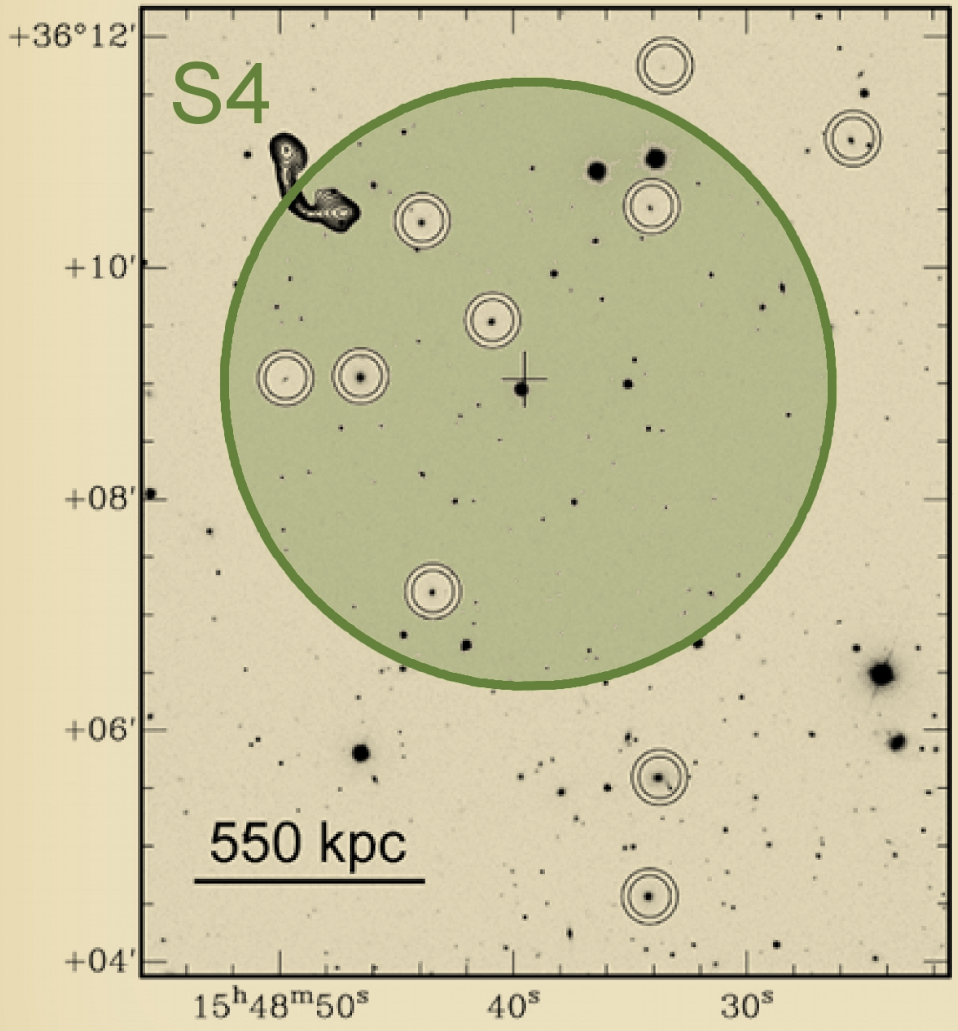

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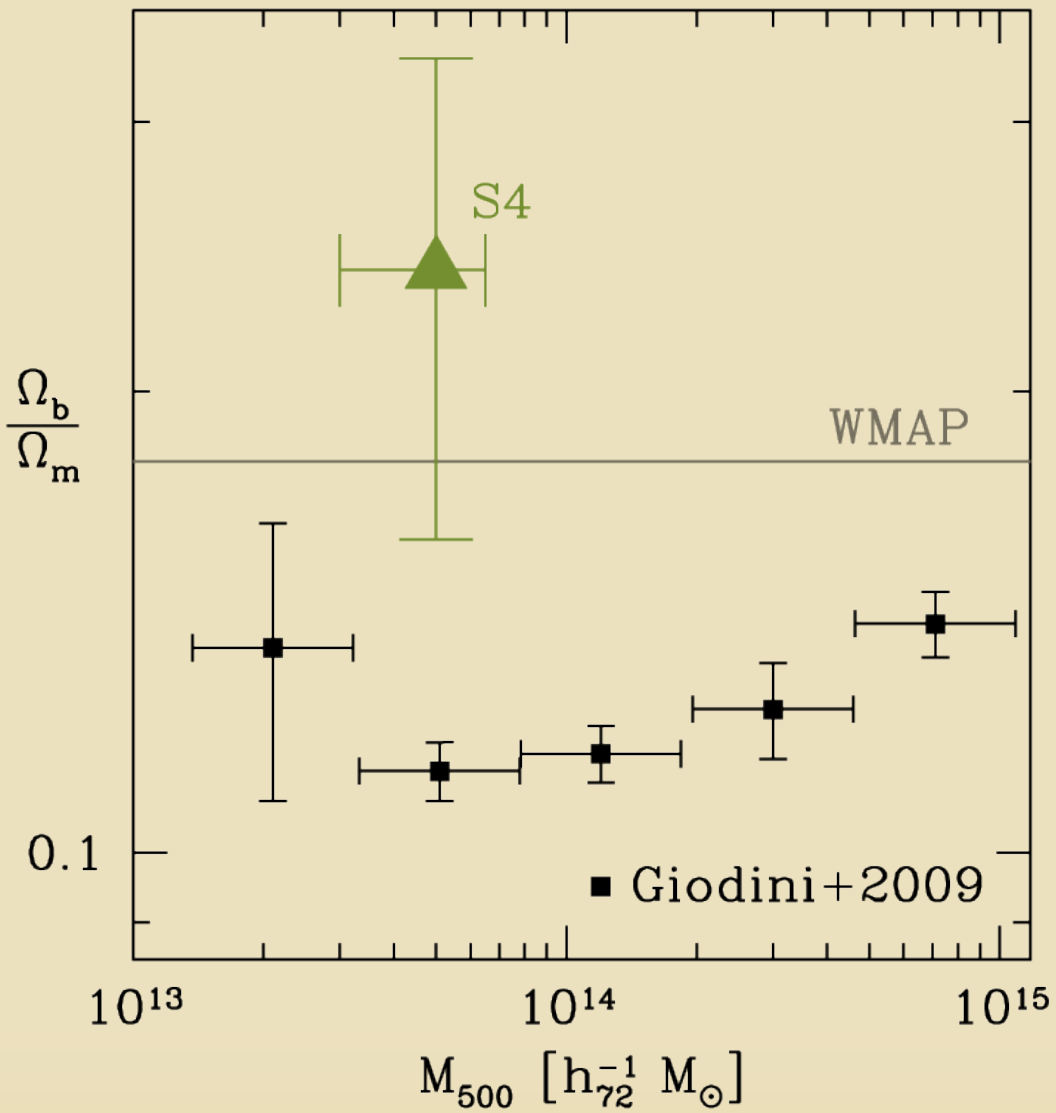
This estimate is consistent with the missing baryons being located in the intragroup medium in galaxy groups.



Freeland & Wilcots 2011

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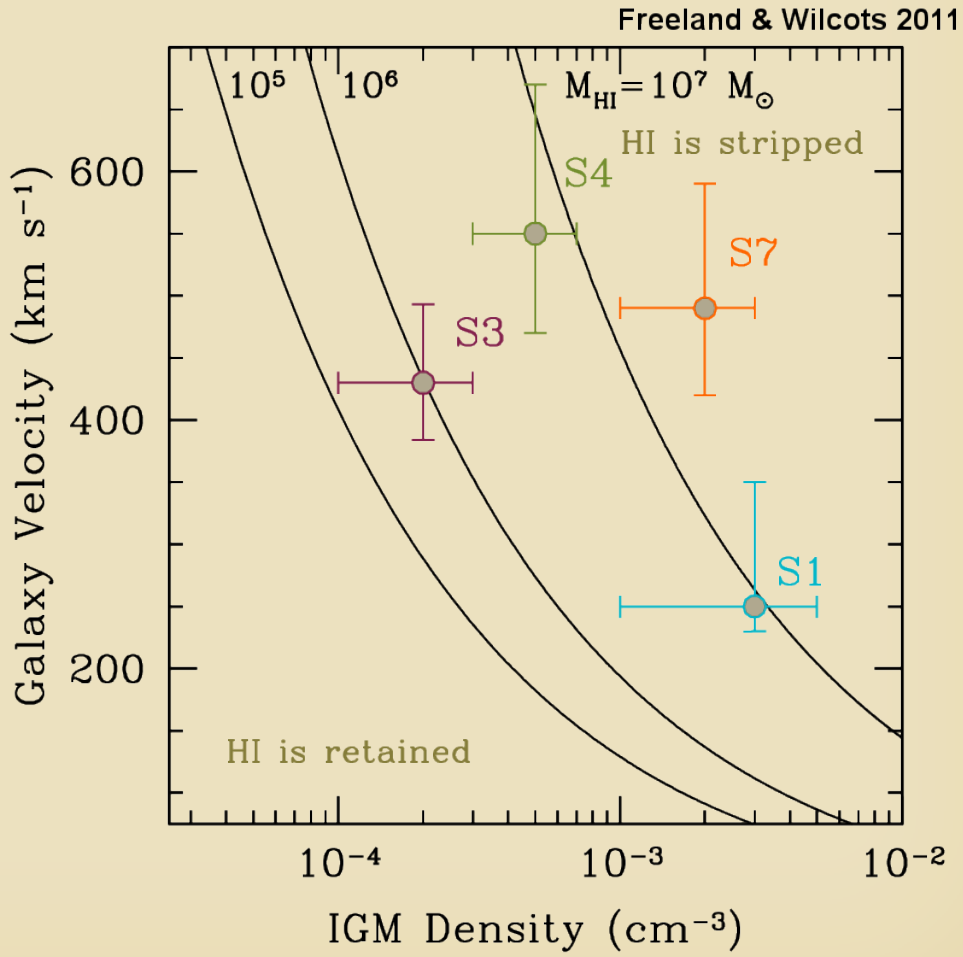
Consider three generic dwarf galaxies ...

$$3v^2 n_{IGM} = \sigma_*^2 n_{gas}$$



Dwarf galaxy morphologies and gas content depend on distance to the MW or M31 in our Local Group.