The removal of HI in group galaxies

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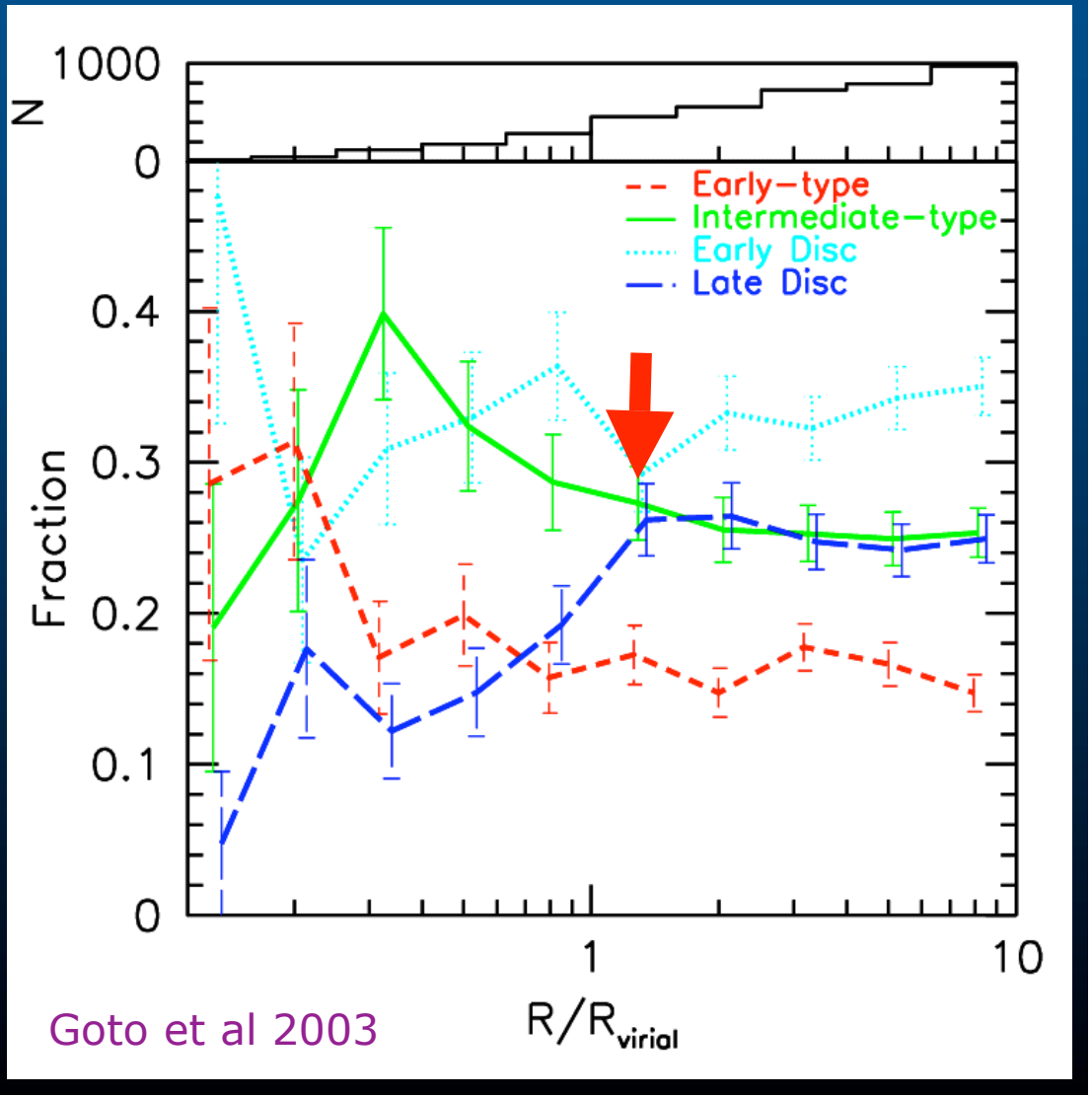
Environmental modification of galaxy morphology

Studies using large samples of galaxies from 2dF and SDSS suggests that galaxy modification sets in outside the virial radius of clusters, in groups or cluster fringes.

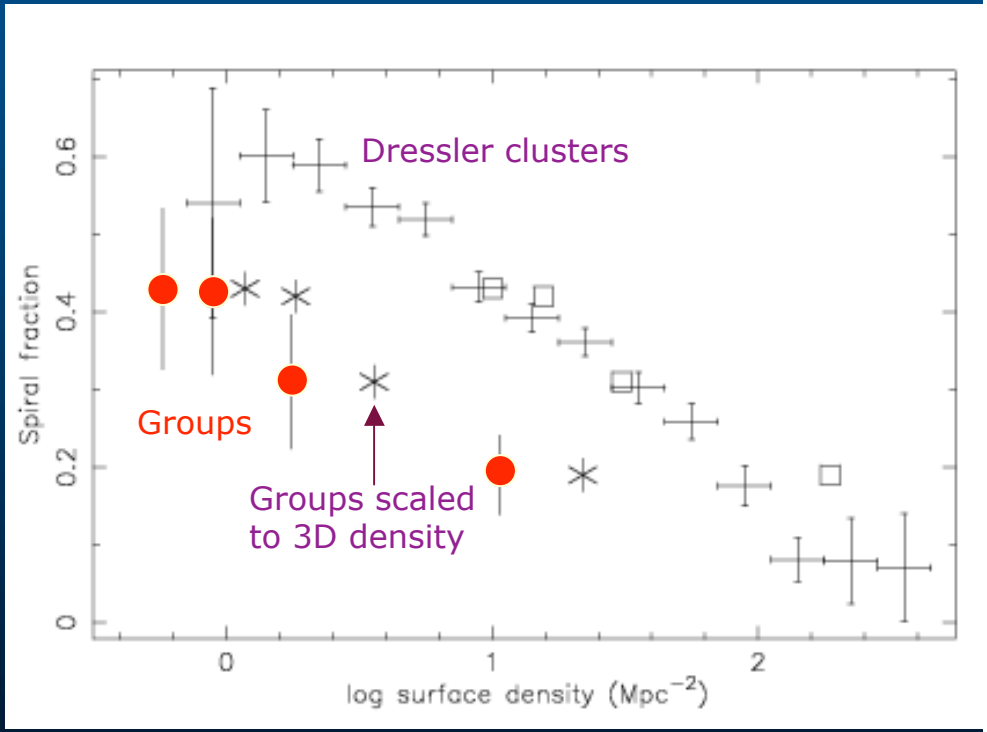


Goto et al 2003

Environmental modification in groups

Galaxy morphology in groups:

- Groups have a very wide range in spiral fraction
- X-ray bright groups show a morphology-density relation similar to clusters - but stronger



Helsdon & Ponman 2003

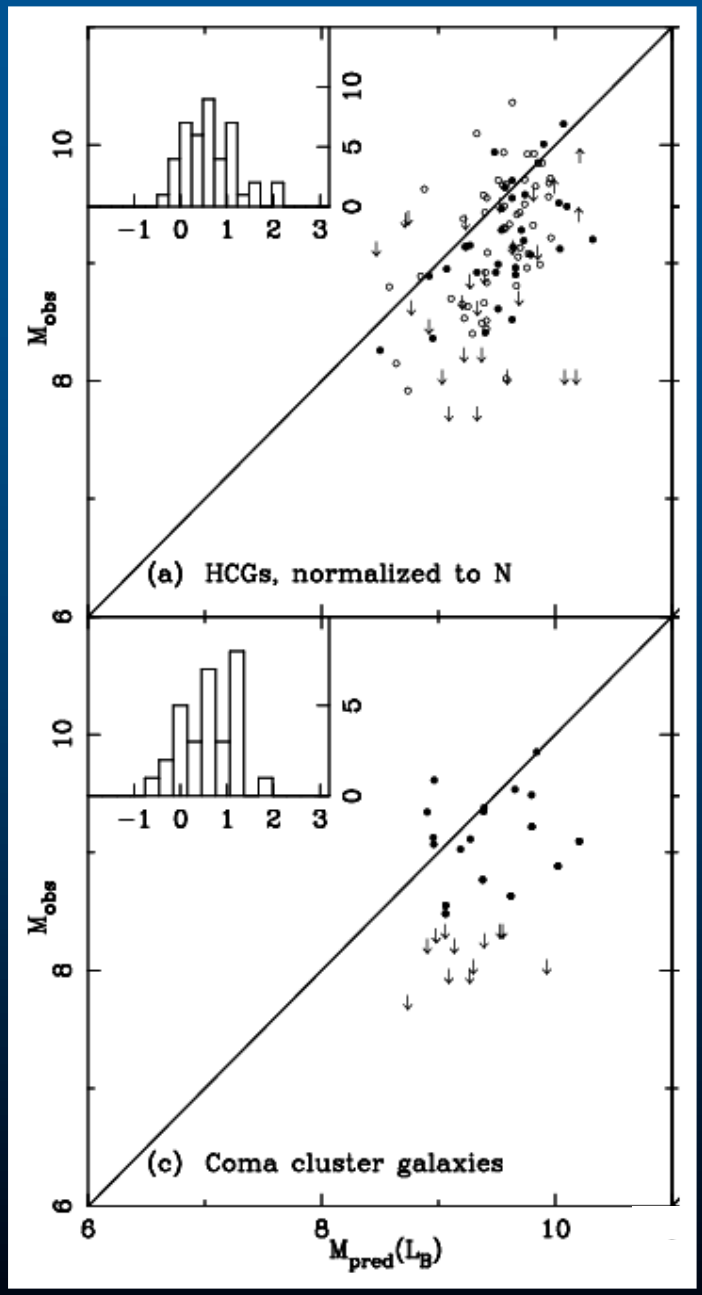
Environmental modification in groups

Verdes-Montenegro et al studied the HI content of 72 Hickson compact groups, and found them to be significantly HI deficient, relative to HI content predicted by Haynes & Giovanelli (1984).

HI deficiency:

$\Delta \equiv \log M_{HI,pred.} - \log M_{HI,obs}$

The deficiency was found to be correlated with the presence of a hot IGM (from Ponman et al 1996).



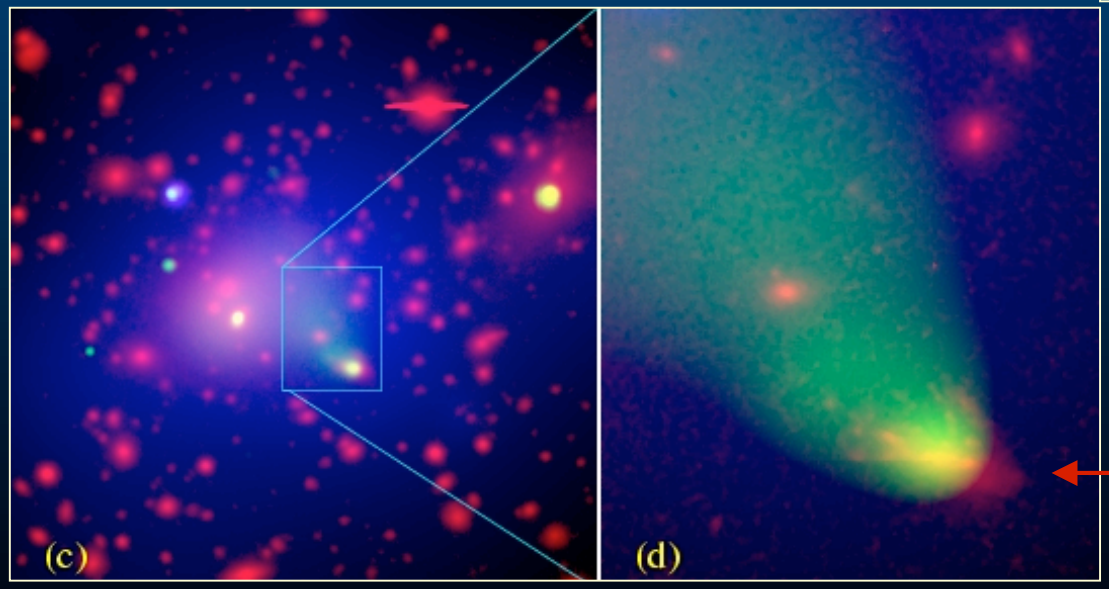
Verdes-Montenegro et al 2001

Environmental modification in groups

Possible mechanisms for gas removal from galaxies:

- Ram pressure stripping

The active disk-like galaxy C153, moving at $v>1500$ km s^{-1} through the complex merging cluster A2125.



Chandra emission (blue/green) superimposed on V band image (red).

C153

Won't work at low σ in groups?

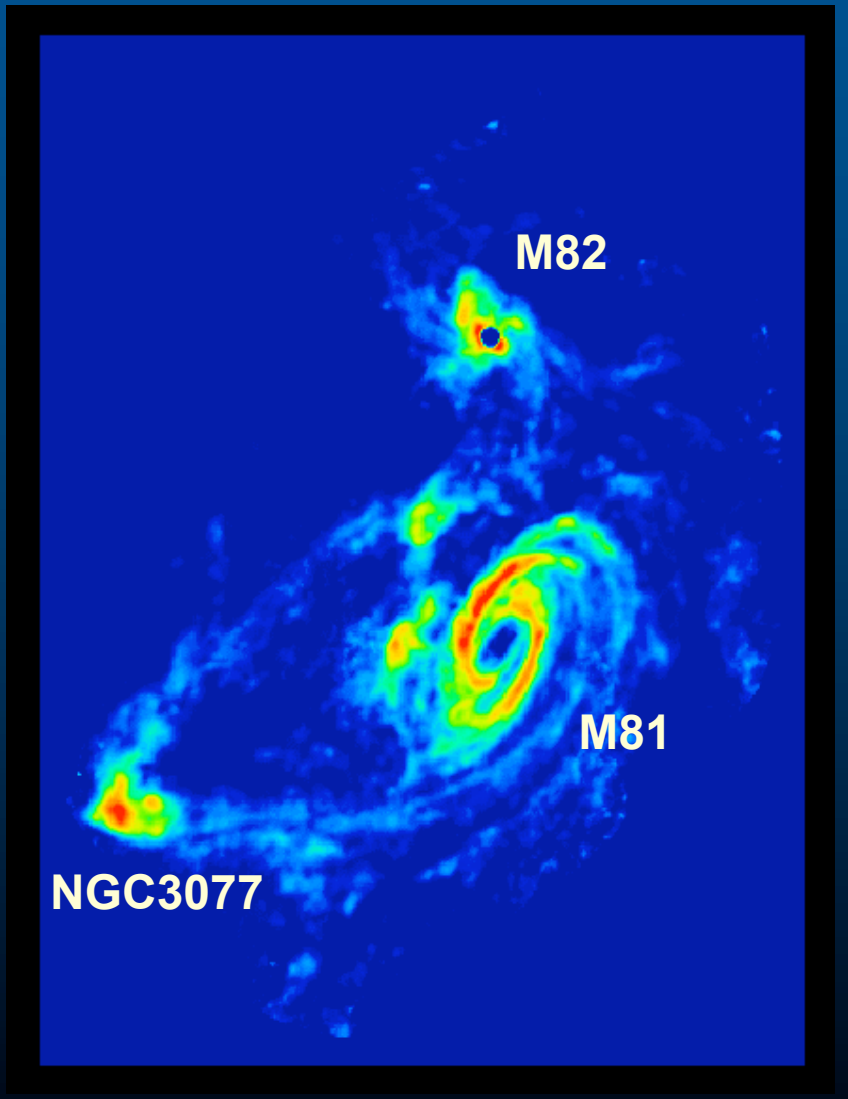
Wang et al 2004

Environmental modification in groups

Possible mechanisms for gas removal from galaxies:

- Ram pressure stripping
- Tidal stripping

Can't remove *all* the HI?



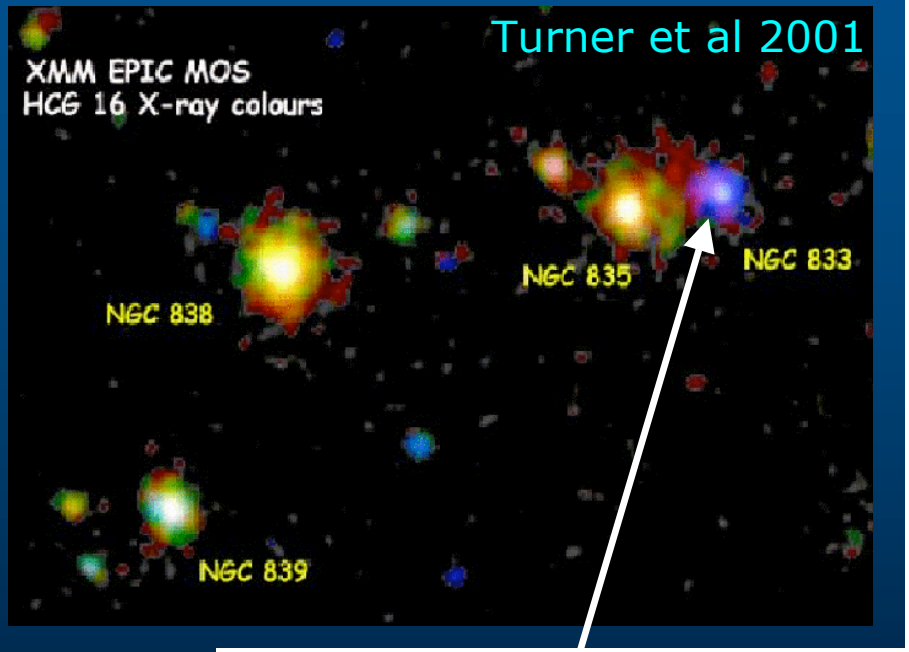
HI in the M81 group - Min Yun

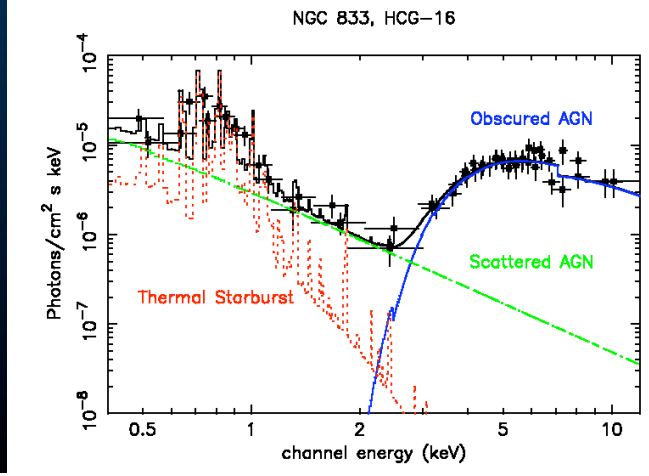
Environmental modification in groups

Possible mechanisms for gas removal from galaxies:

- Tidal stripping
- Ram pressure stripping
- Star formation & strangulation

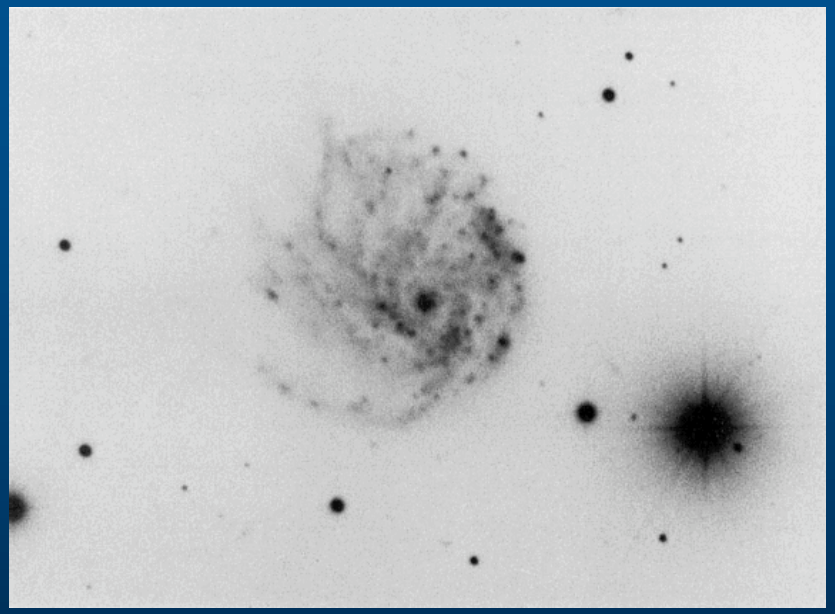
Gas reservoirs are still largely theoretical!

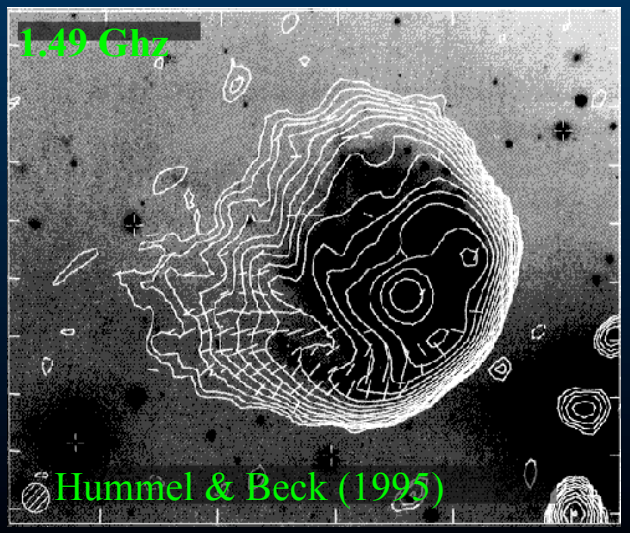


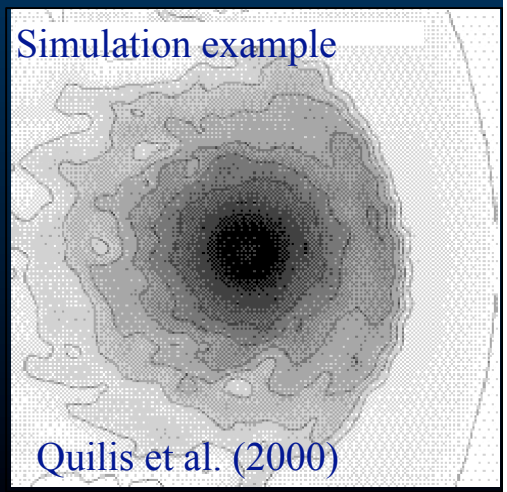


Ram pressure in groups: NGC 2276

- NGC2276 is a star-forming galaxy in the NGC2300 group
- Embedded in T ≈ 10^7 K group gas
- "Tail" of HI+radio continuum emission
- 55% less HI than typical isolated spirals
- High star formation rate (~ 5 $M_\odot$/yr)

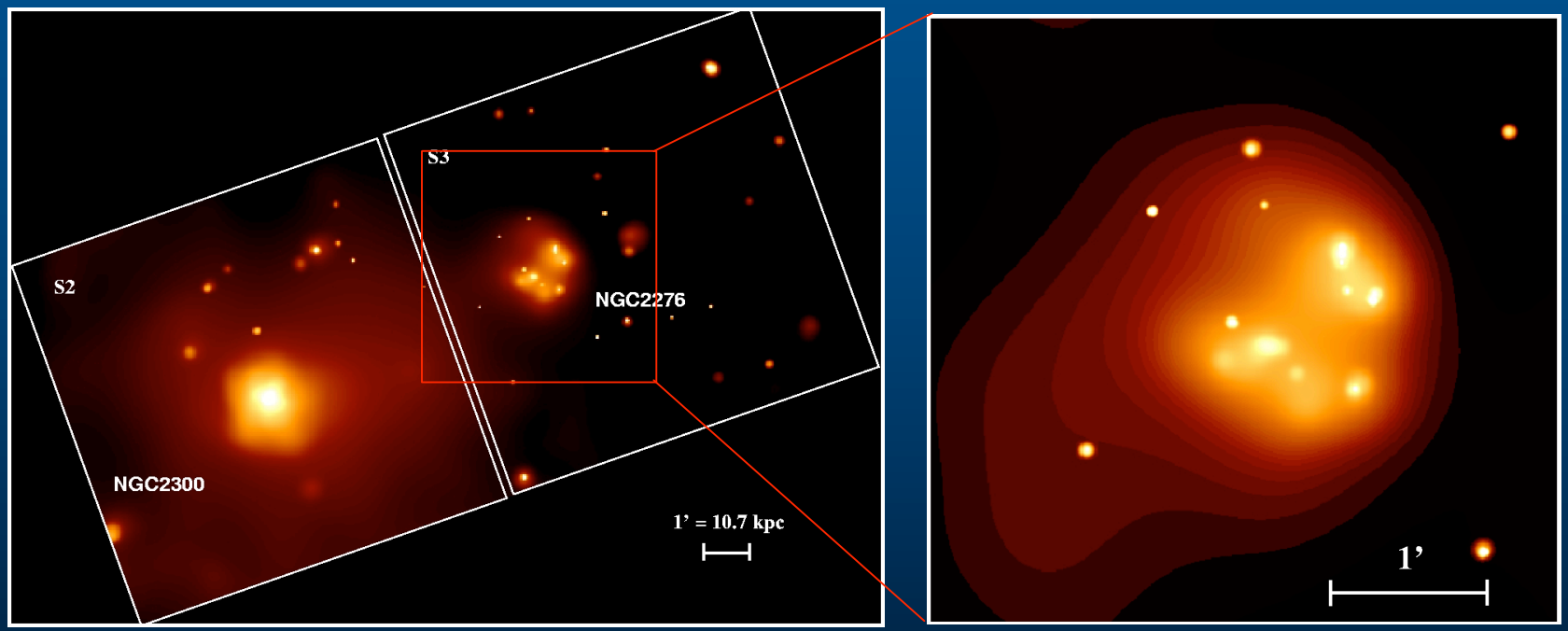






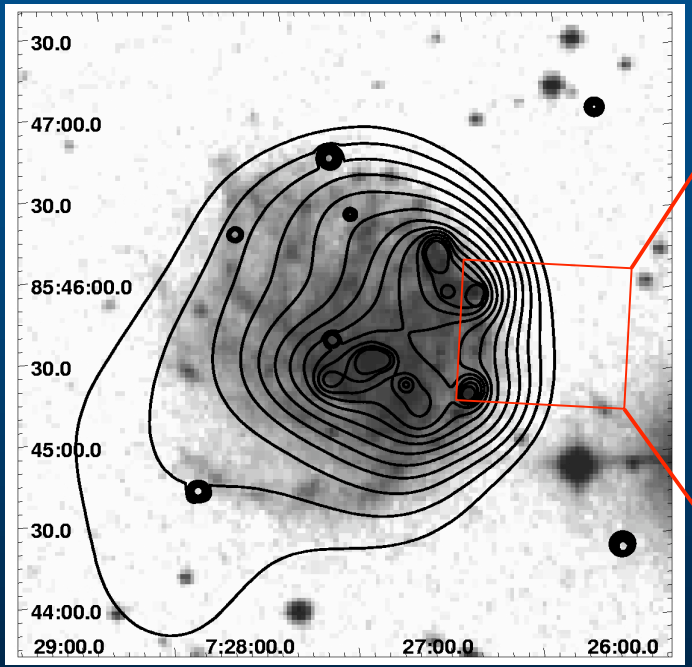
Morphology strongly suggests ram pressure stripping.
→ Investigate with Chandra observations.

Chandra imaging

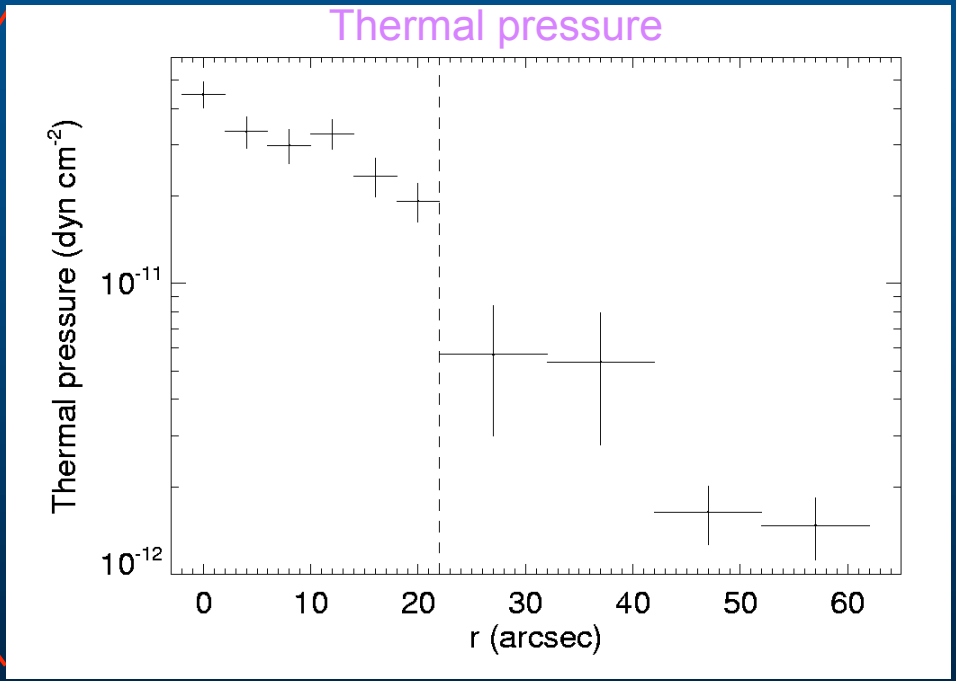


0.3-2 keV adaptively smoothed images
45 ks exposure (D = 37 Mpc).

X-ray analysis

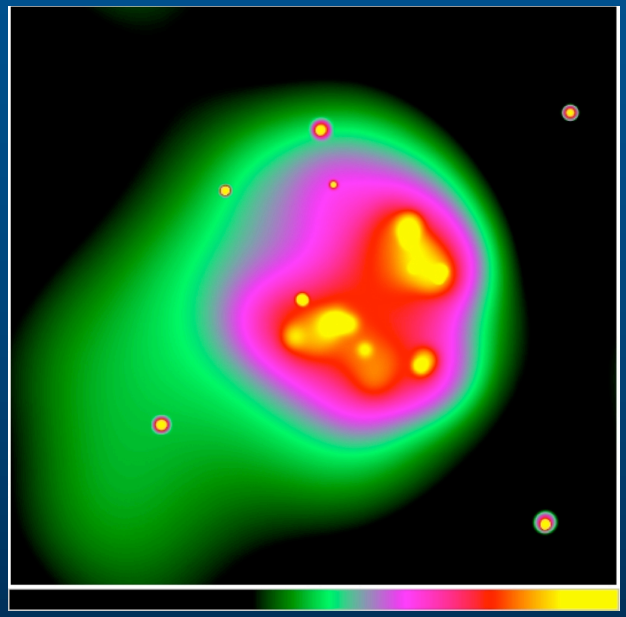


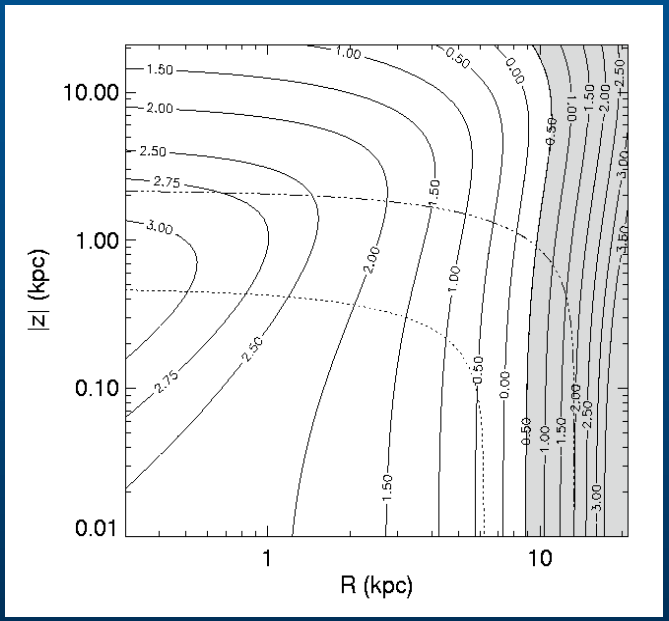
X-ray contours over DSS image



Shock conditions:
$M \approx 1.7$
→ $\mathbf{v_{gal} \approx 850\ km/s}$

Results: Role of ram pressure





Shock conditions:

$M \approx 1.7$

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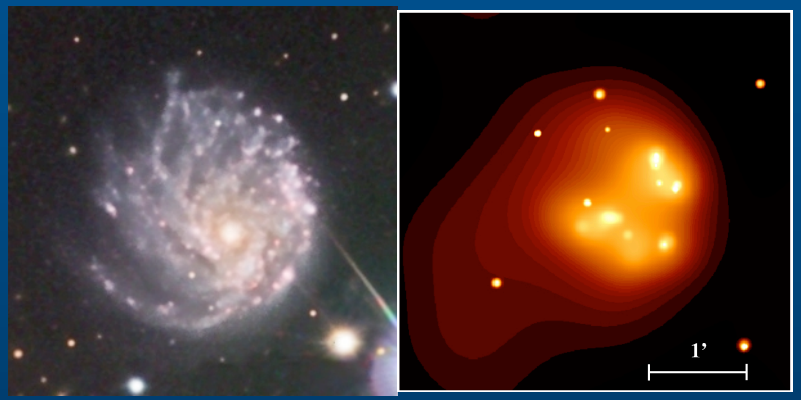
Effects of ram pressure:

$$\Sigma_g \left(\frac{\partial \Phi_b}{\partial z} + \frac{\partial \Phi_h}{\partial z} + \frac{\partial \Phi_g}{\partial z} + \frac{\partial \Phi_*}{\partial z} \right) < \rho_1 (v_1 \sin\xi)^2$$

- Trigger starburst + outflows
- Sweep back stellar outflows
- Peel off gas from edge of disk via hydro-instabilities

Rasmussen, Ponman & Mulchaey 2006

Implications for galaxy evolution



Current mass-loss rate of gas: ~ 5 $M_{\odot}yr^{-1}$.

↓

Remaining gas should be lost in another 1-2 Gyr.

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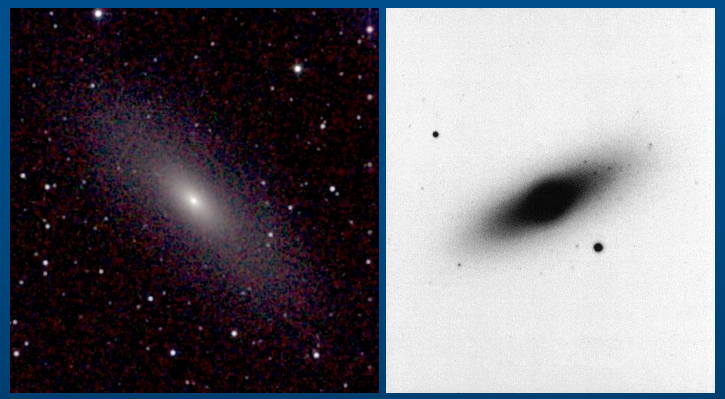
Star formation will cease “soon”.



End product:

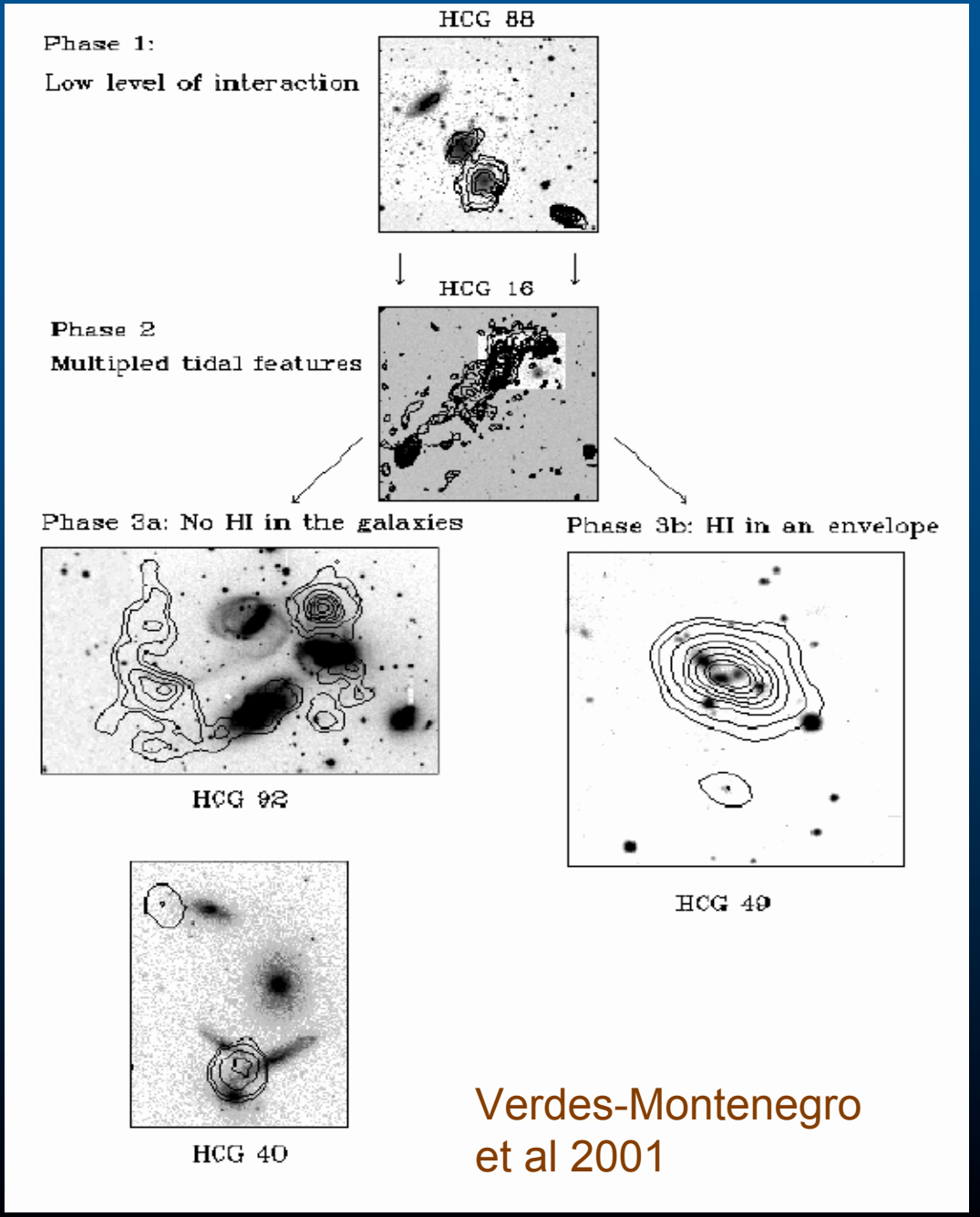
No gas, little star formation.

Large bulge-to-disc ratio

~ S0 galaxy.

Intergalactic gas in groups

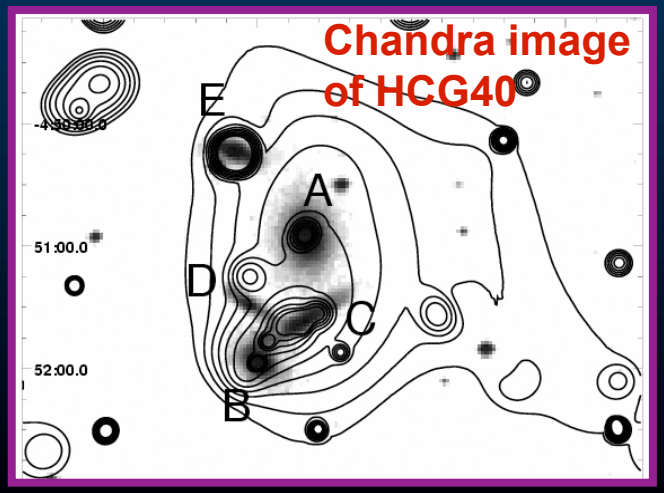
So - could ram pressure stripping be responsible for all the HI deficiency seen in groups? →
Look in detail at the HI-deficient HCGs.

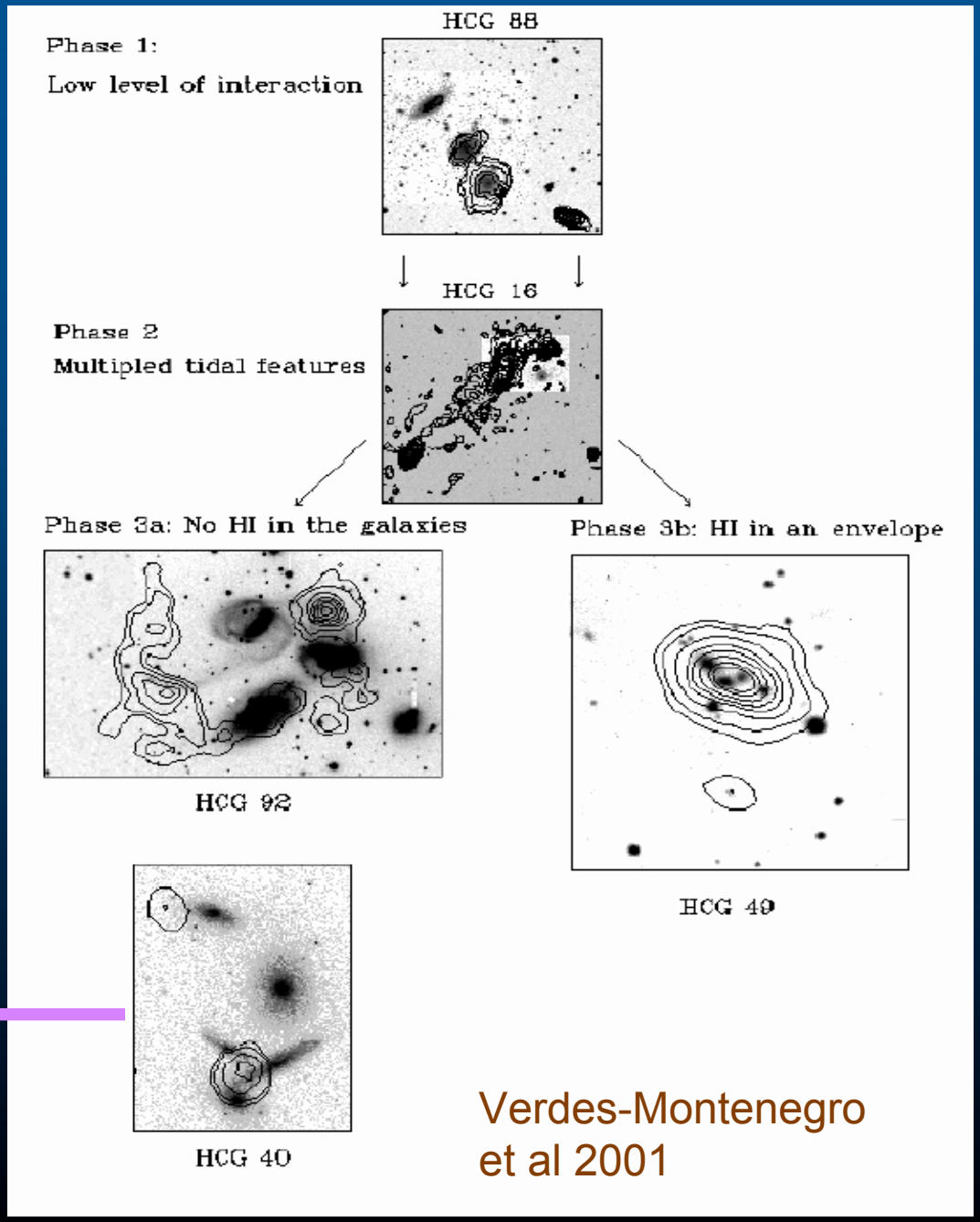


Verdes-Montenegro et al 2001

Intergalactic gas in groups

X-ray plus VLA mapping of hot gas and HI in 8 of the most HI-deficient groups from the Verdes-Montenegro et al study.

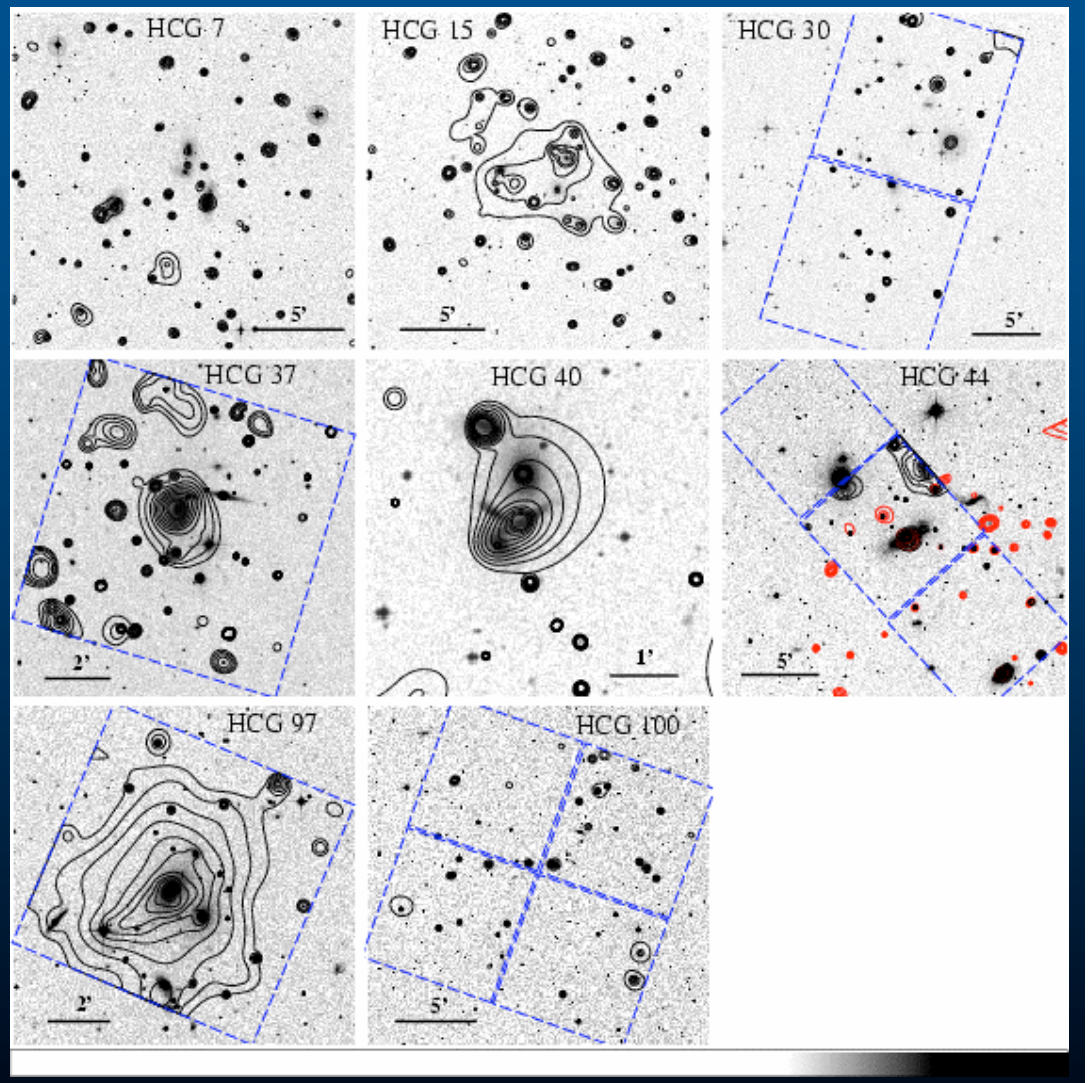




Verdes-Montenegro et al 2001

Intergalactic gas in groups

- The X-ray properties are found to be very diverse.
- Several, such as HCG30, show no hot IGM.
- Ram pressure stripping cannot be the dominant effect in removing HI in many of these groups.



Rasmussen et al, in prep.

Conclusions

- Galaxy groups must play a crucial role in removing gas from galaxies and establishing the morphology-density relation.
- Ram pressure stripping can operate in groups, when it acts in conjunction with starburst activity, which may be induced by galaxy interactions.
- A study of HI-deficient compact groups shows that ~half have no detectable hot IGM.
- Hence, ram pressure stripping cannot be the only mechanism leading to HI loss in groups - tidal stripping, galaxy winds and gas exhaustion by star formation are other possible mechanisms.