Radio signatures of ram pressure sweeping in low galaxy density environs – local effect

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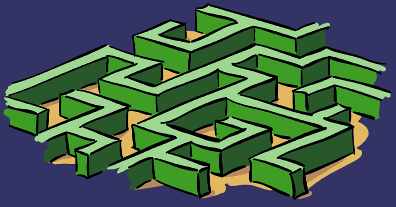


Overview

- HI of galaxies in cluster cores
- Physical processes in poor groups
- Physical processes in cluster outskirts
- X-ray emitting IGM
- Cool HI in IGM – local effects

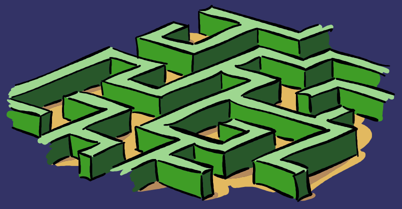
Evolution in cluster cores...

- Clusters (>100), contain ~5% galaxies (Dressler 1984)
  Groups (< 30) host > 65% galaxies (Tully 1987)

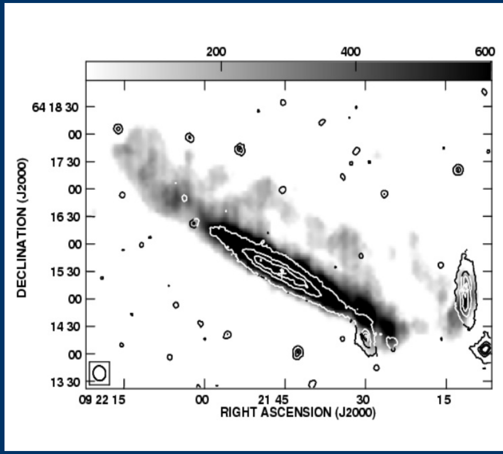
- Evolution of galaxies in groups is important – not well understood - important since significant evolution is expected in groups before they aggregate into clusters (e.g. Lewis et al. 2002)

- Evolution of spiral galaxies in cluster cores – believed to be dominantly driven by ram pressure effects which strip the galaxy of hot and cool gas.

- Spiral galaxies: stellar mass ~ 10^11 solar mass and HI mass ~ few percent of stellar mass.



Evolution of galaxies in clusters observed in HI 21cm signal

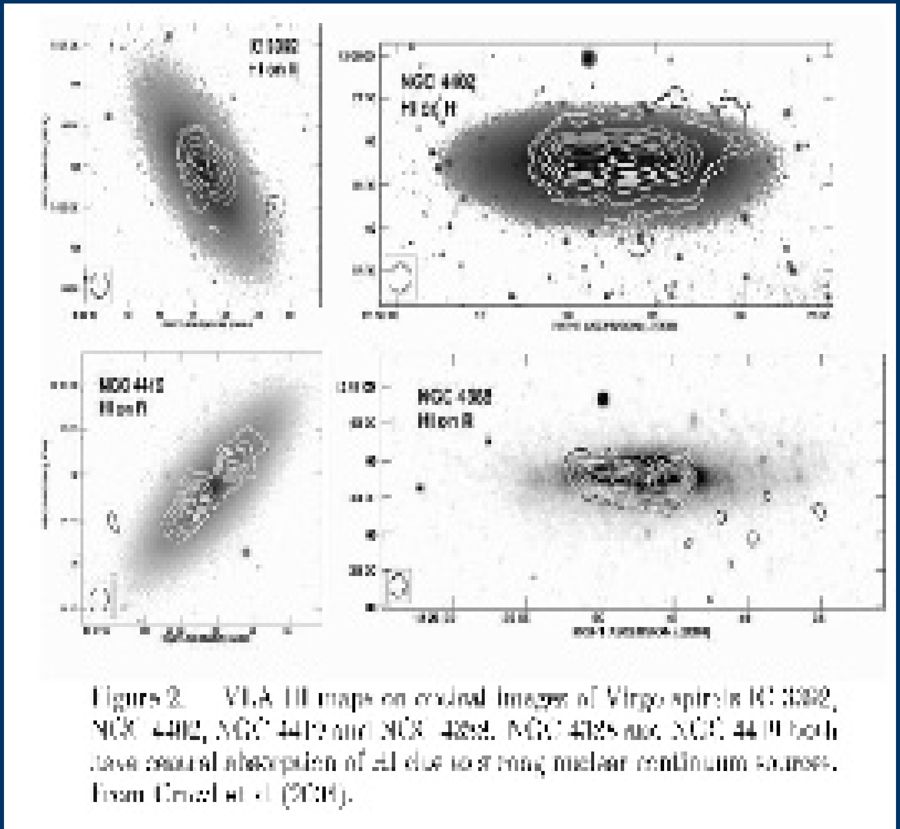


NGC2820 - Grey HI, contours DSS (Kantharia et al.2005)

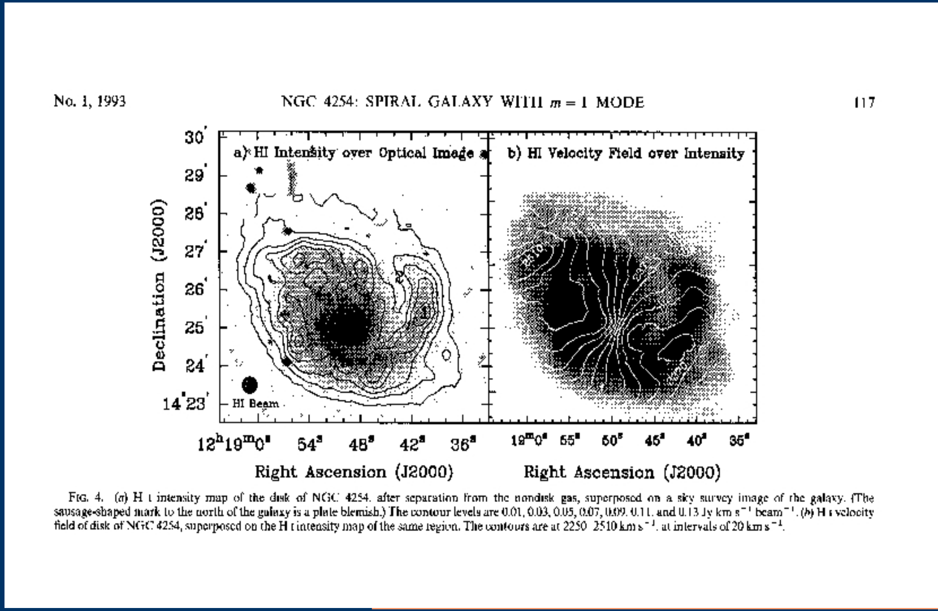
Field galaxies: D(HI)/D(opt) > 1

Cluster core: D(HI)/D(opt) < 1

Galaxies in Virgo cluster – contours HI, grey DSS Note truncated HI disks (Kenney etal. 2003)



NGC 4254 - Grey DSS, contours HI (Phookun etal 1993)



No. 1, 1993 NGC 4254: SPIRAL GALAXY WITH $m = 1$ MODE 117

FIG. 4. (*a*) H I intensity map of the disk of NGC 4254, after separation from the nondisk gas, superposed on a sky survey image of the galaxy. (The sausage-shaped mark to the north of the galaxy is a plate blemish.) The contour levels are 0.01, 0.03, 0.05, 0.07, 0.09, 0.11, and 0.13 Jy km s^{-1} beam^{-1}. (*b*) H I velocity field of disk of NGC 4254, superposed on the H I intensity map of the same region. The contours are at 2250–2510 km s^{-1}, at intervals of 20 km s^{-1}.

Hickson Compact groups

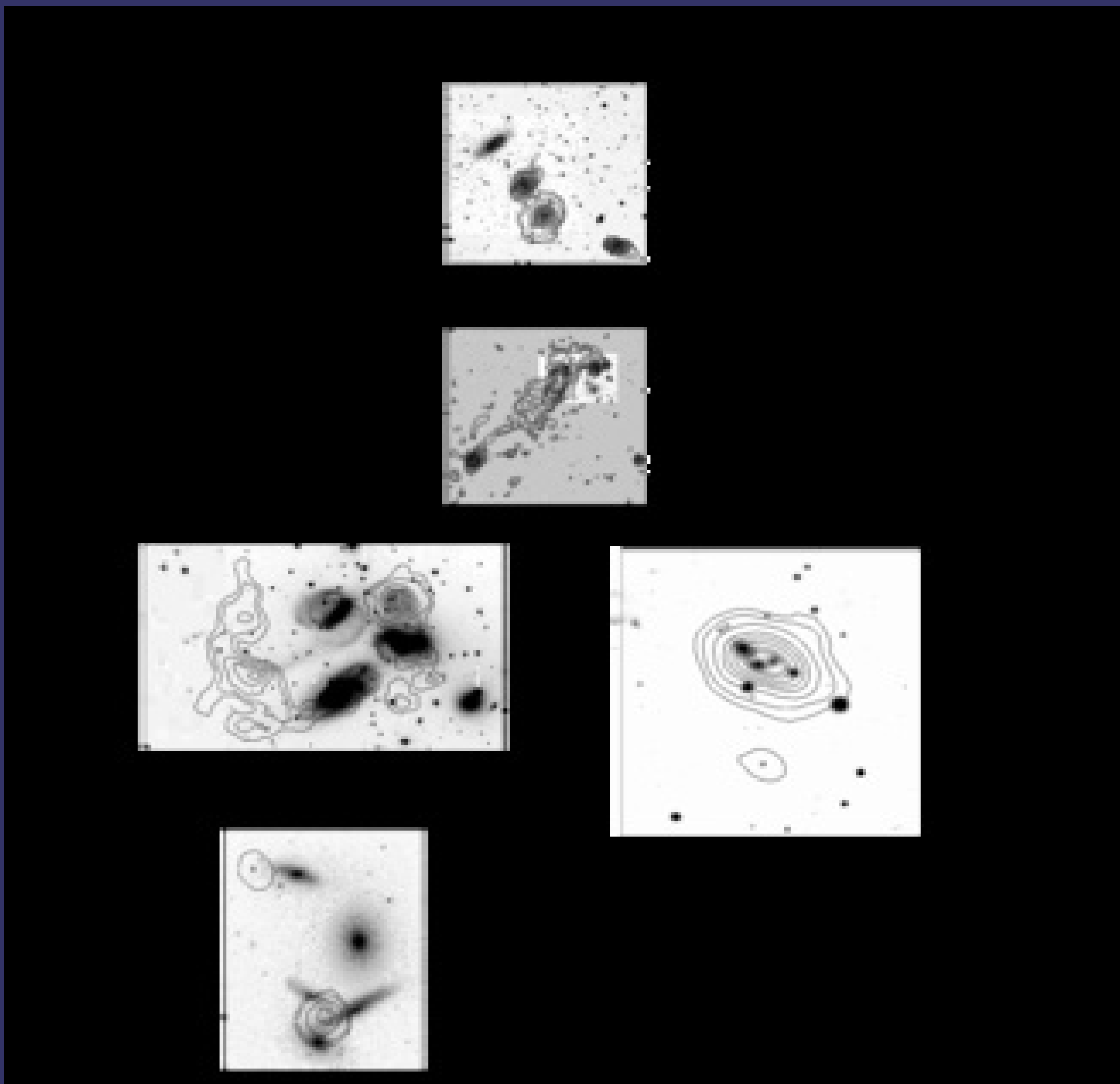
Hickson's Compact group galaxies are HI deficient by 40% - comparable to cluster cores – VLA observations. (Verdes-Montenegro et al., 2001)

Evolutionary scenario for HCGs in different stages of HI deficiency. (Verdes-Montenegro 2001)

Some of the HI is recovered by single dish observations.
 => diffuse HI that is stripped in the group (Borthakur et al. 2009) - HI masses are few times 10^8 to few times 10^10 solar masses.

HI structures of 200 kpc in HCGs of IGM temp ~ million degrees can survive ~ few hundred Myr years due to long conduction timescales. (Borthakur et al. 2009)

HCGs in HI -evolutionary scenario



Verdes-Montenegro (2001) – tidal interactions drive the HI loss

Large fraction of E/S0.

Large fraction of galaxies perturbed in HI.

HI envelope around galaxies - HCG49

Hickson compact groups

HI deficiency and X-ray emission – not strongly correlated. Other reasons for HI deficiency in addition to ram pressure unlike cluster environs?

Rasmussen et al. 2008

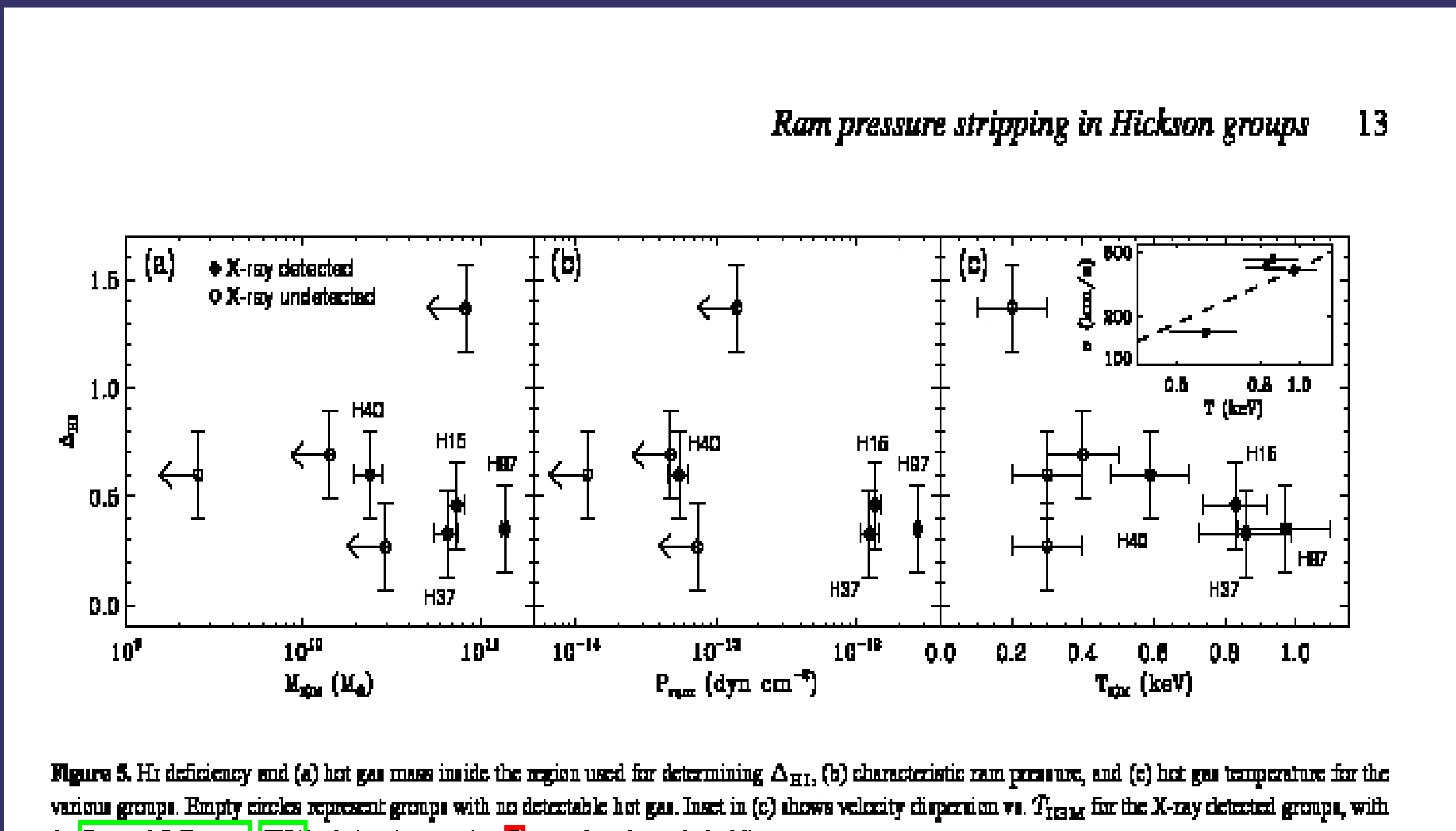


Figure 5. HI deficiency and (a) hot gas mass inside the region used for determining Δ_{HI}, (b) characteristic ram pressure, and (c) hot gas temperature for the various groups. Empty circles represent groups with no detectable hot gas. Inset in (c) shows velocity dispersion vs. T_{IGM} for the X-ray detected groups, with the Osmond & Ponman (2004) relation, i.e. equation (3), overplotted as a dashed line.

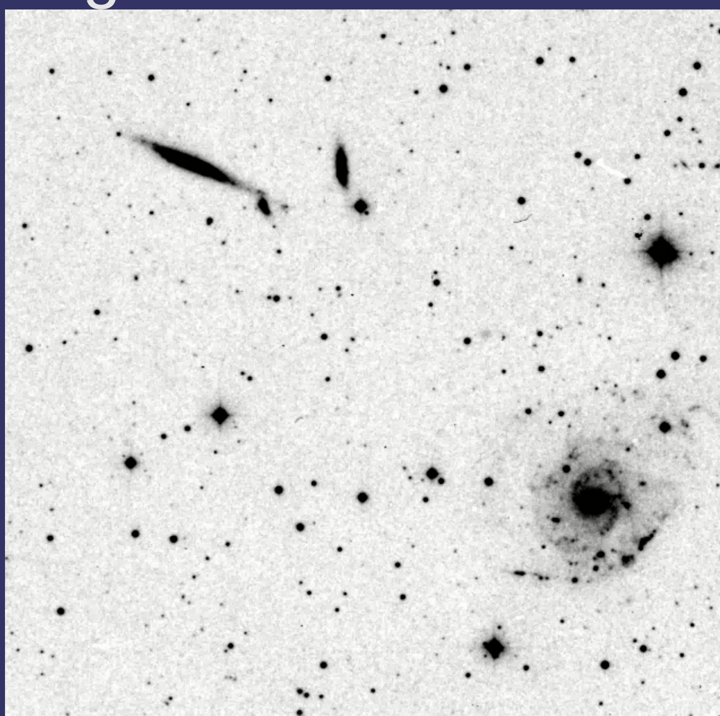
8 highly HI deficient HCGs – 4 detected in Xray

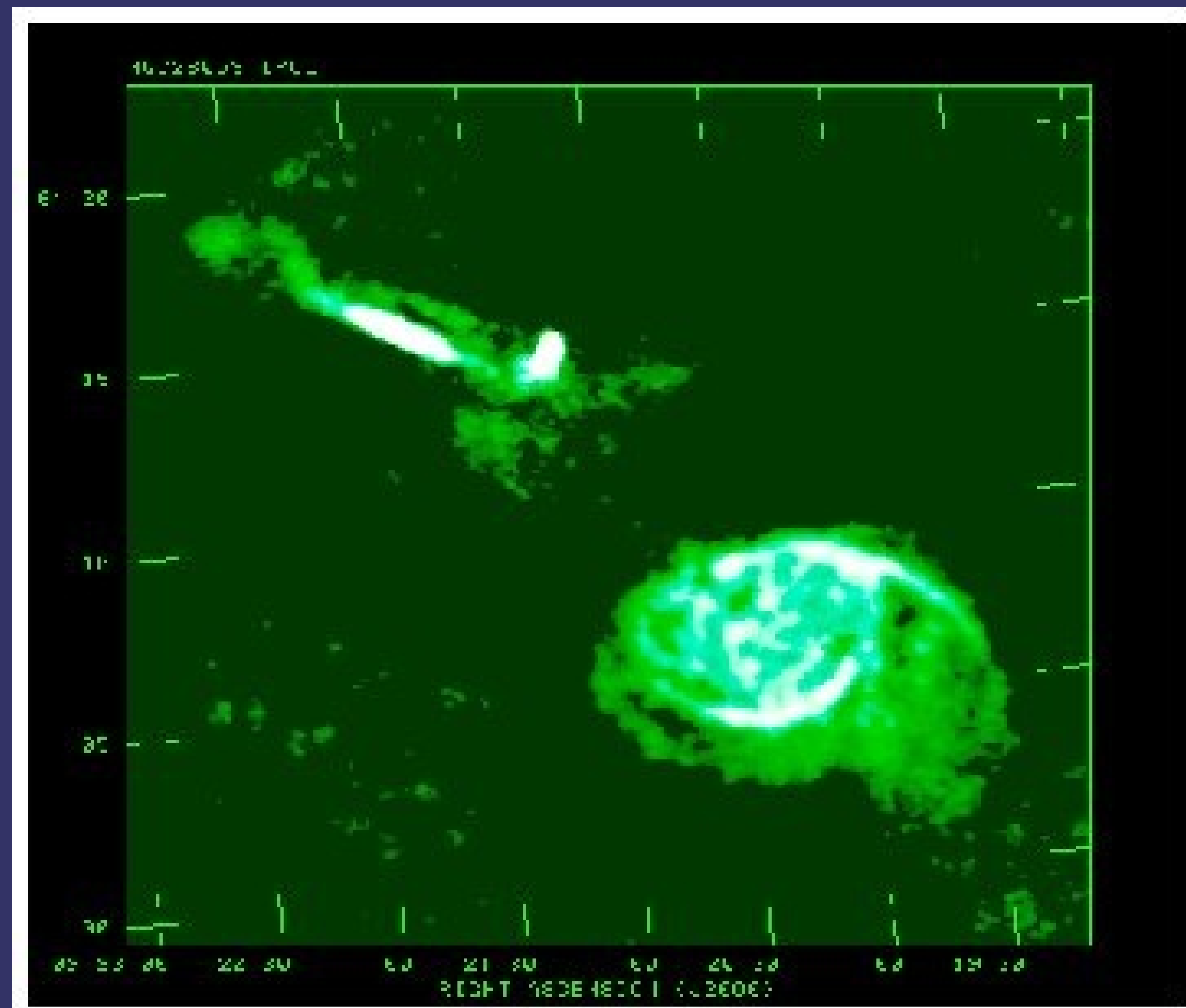
Tidal stripping, ram pressure, strangulation – affect HCGs

Physical processes in loose groups

signatures of tidal interaction – but also ram pressure-like sweeping – displaced gas disk, sharp cut-off in HI, star forming ridge...

Column density of HI in the group Holmberg 124 observed with GMRT

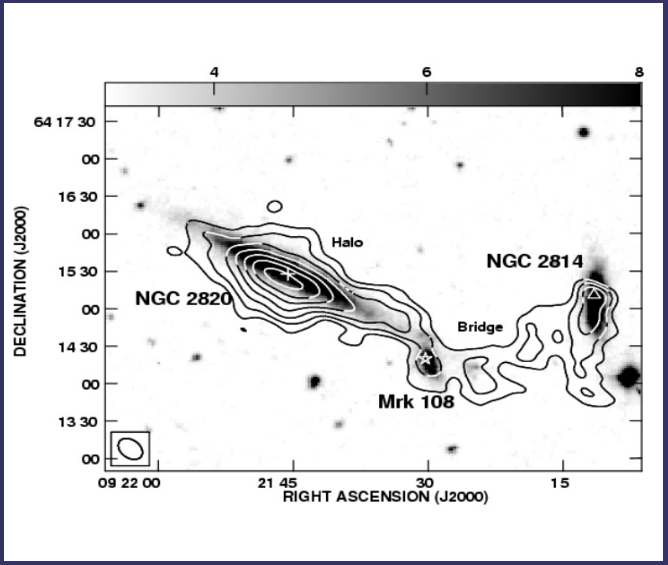




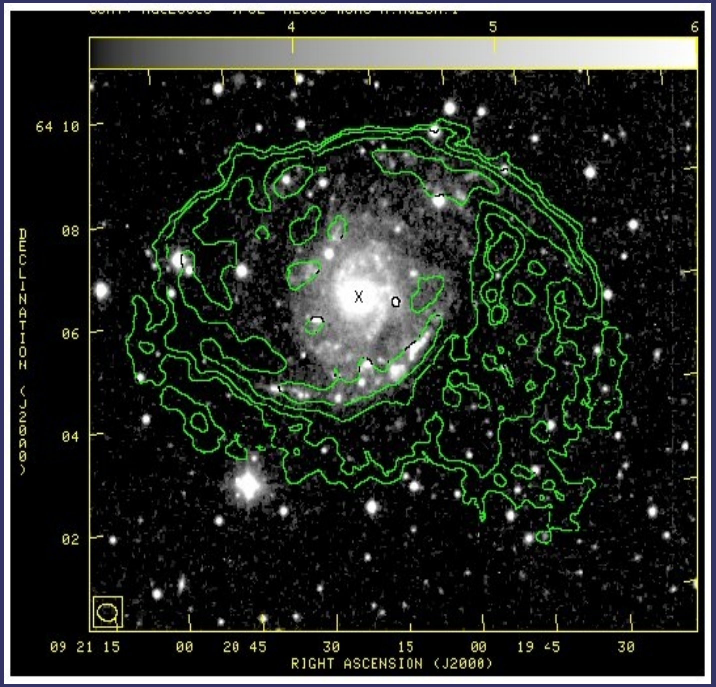
(Mishra et al.)

Holmberg 124

- Upper limit on X-ray emission from ROSAT PSPC: 2.88×10^{40} erg/sec (Mulchaey et al. 2003)
- Velocity dispersion is ~285 km/s.
- Tidal interaction and ram pressure or turbulent viscous stripping ?
- North of NGC 2814 – truncated HI, radio continuum disk + sharp cutoff - edgeon approach to IGM wind– turbulent viscous stripping?



(Kantharia et al. 2005)



Other examples:

- NGC 1961, NGC 2276 (Davis et al 1997, Rasmussen et al. 2006)
- Tidal interaction and ram pressure or turbulent viscous stripping ?

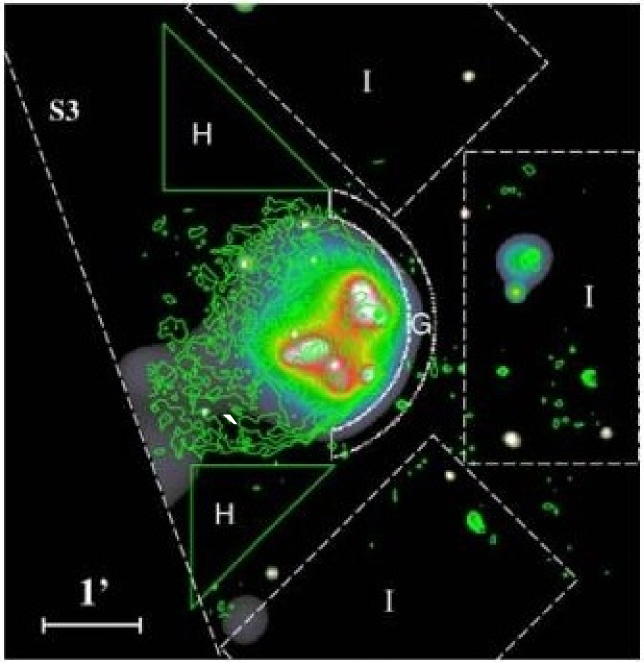
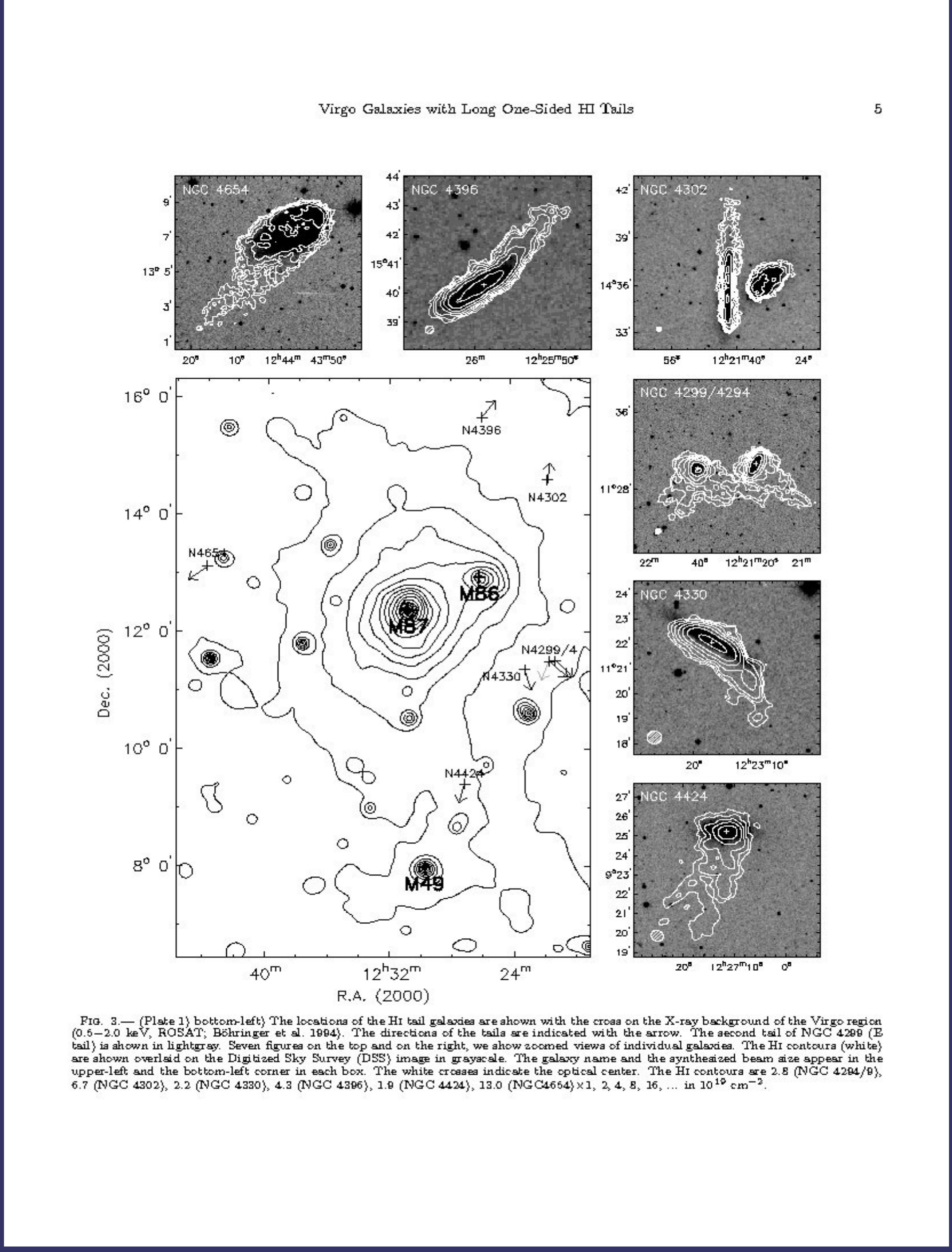


Figure 5. As Fig. 1, but for a 7 × 7-arcmin^2 region around NGC 2276 and with IGM emission subtracted. Also shown are the regions (G+H) outside the western edge and inside the Mach cone used to search for evidence of shock heating of the IGM (see Section 4.1 for details), with the dashed regions (I) used for comparison spectra. Overlayed are Very Large Array 1.49-GHz contours from the data presented by Davis et al. (1997), starting at 0.05 mJy beam^{-1} and spaced by a factor of $\sqrt{2}$.

- NGC2276 in NGC 2300 group of four galaxies.
- IGM – Xray detected; IGM density ~ 6e-4 /cc. T ~ 0.81 keV.
- Authors say that turbulent viscous stripping may play a major role by stripping about 5 solar mass/year.
- We think mass loss due to turbulent viscous stripping (Nulsen 1982) in this system could have been over-estimated by a factor of at least 10-20.

(NGC 2276 - Rasmussen et al. 2006)

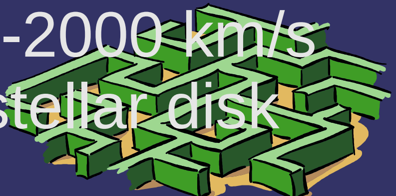
Cluster outskirts



Virgo Galaxies with Long One-Sided HI Tails 5

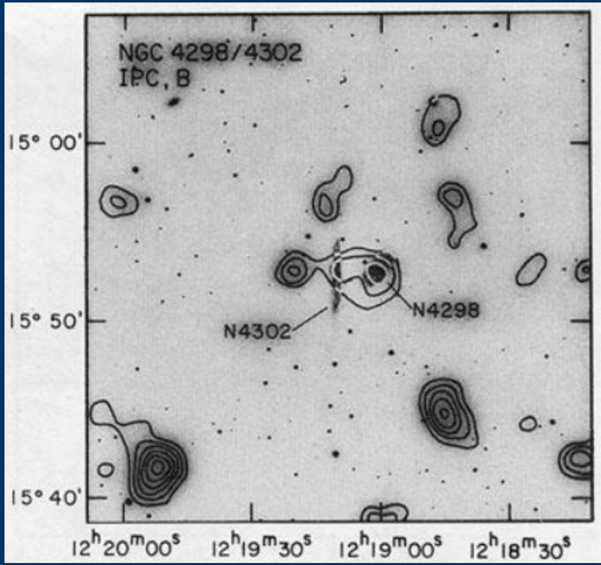
FIG. 3.— (Plate 1) bottom-left) The locations of the HI tail galaxies are shown with the cross on the X-ray background of the Virgo region (0.5−2.0 keV, ROSAT; Böhringer et al. 1994). The directions of the tails are indicated with the arrow. The second tail of NGC 4299 (E tail) is shown in lightgray. Seven figures on the top and on the right, we show zoomed views of individual galaxies. The HI contours (white) are shown overlaid on the Digitized Sky Survey (DSS) image in grayscale. The galaxy name and the synthesized beam size appear in the upper-left and the bottom-left corner in each box. The white crosses indicate the optical center. The HI contours are 2.8 (NGC 4294/9), 6.7 (NGC 4302), 2.2 (NGC 4330), 4.3 (NGC 4396), 1.9 (NGC 4424), 13.0 (NGC4654) × 1, 2, 4, 8, 16, ... in 10^{19} cm^{-2}.

- HI maps, X-ray ICM (Chung, van Gorkom et al. , 2007)
- Notice most galaxies show a tail directed away from M87 – a classic signature of ram pressure sweeping
- Rapid motion of galaxy in ICM causes ISM to experience a pressure if $\rho\, \sigma^2 > 2\pi\, \Sigma(star)\, \Sigma(HI)$ (Gunn & Gott 1972)
- ICM: T = $10^6 – 10^7$ K; $\rho = 10^{-3}$ 10^{-4} cm^{-3}
- HI deficiencies: range from 0 to 0.8! velocity ~ 1000-2000 km/s
- Gas disk affected – stellar disk undisturbed

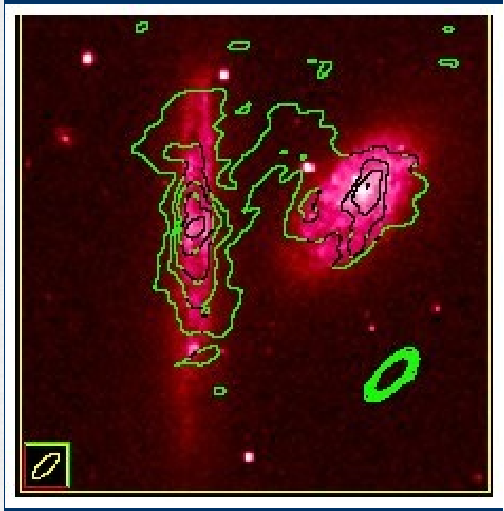


Cluster outskirts, loose groups...

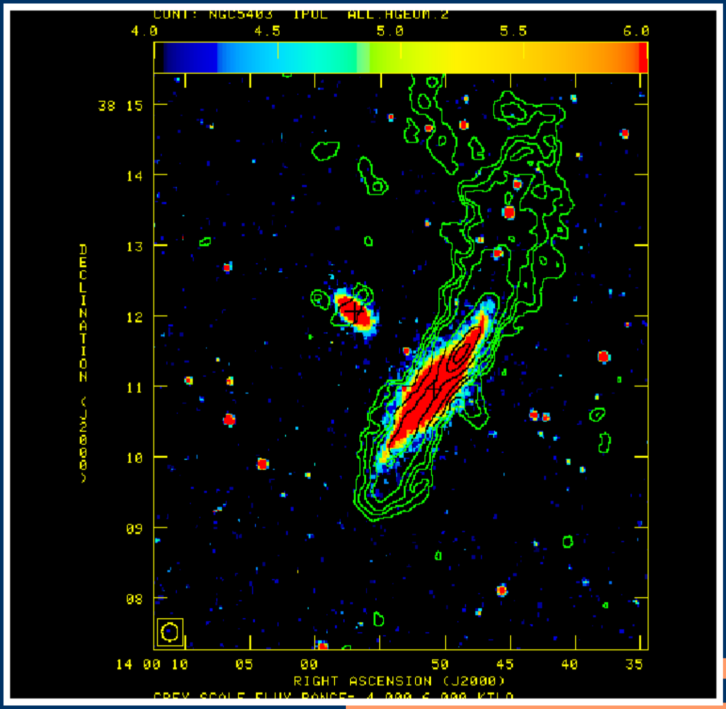
- Several binary galaxies such as NGC 4302 show tidal interaction – radio continuum bridge + X-ray bridge. No HI bridge.



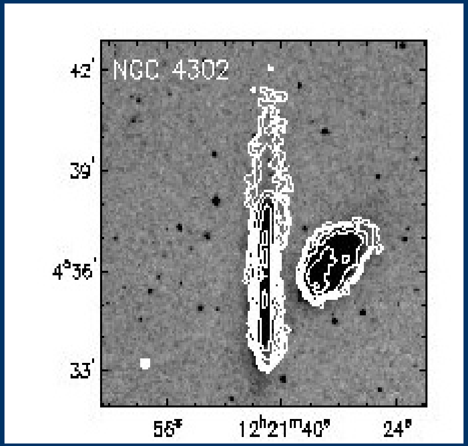
X-ray bridge (Fabbiano et al 1992)



GMRT 330 MHz radio contm



Holmberg 565
VLA 21cm archival data – note the HI tail in the north.
Companion gas is also extended in the same direction.



– HI – Chung et al 2008

Ram pressure due to hot IGM

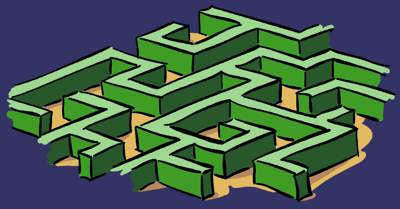
- Typical mass of groups -> log M(IGM) = 12 to 13 in solar mass (Mulchaey 2000)
- Typical galaxy mass -> 10^12 solar mass
- Typical IGM mass -> 10^10 to 10^12 solar mass
- Equal mass in galaxy and hot IgrM.
- Hot IGM distributed over ~ 100-150 kpc
- Typical matter densities ~ 10^(-5) /cc
- Typical velocities ~ 300 km/s
- Ram pressure < 10^(-13) dyne/cm2.

Ram pressure due to cold IGrM

- Searches for HI in IGM. HCG observations show presence of HI in IGM (Borthakur et al 2010).

- Since tidal interaction between galaxies in groups can remove HI in form of tails and bridges; this can lead to increased matter densities in the vicinity of the galaxy.

- Cool HI can exist - thermal conduction timescales (Spitzer conductivity) are large – so tidally stripped HI will take a long time to ionize and thermalize with the hot X-ray emitting IGM.
  Thus – the cooler HI, if in sufficient quantities can affect the galaxy evolution – in the most gentle form by acting on the morphology. Could be a local phenomenon...

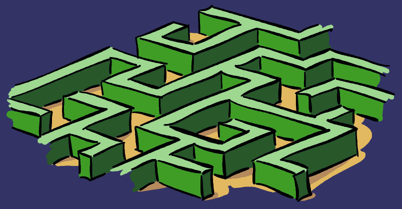


Adequate HI densities ?

- For a typical spiral galaxy with HI mass of few times 10^9 solar mass of HI and diameter of 15 kpc – the HI surface density will be about 4.4 solar mass/ kpc^2. Thus grav restoring force on disk for a typical rotation velocity of 225 km/s will be about 2 x 10^(-12) dyne/cm^2

- Can the ram pressure predominantly due to cooler HI affect the galaxy morphology?   This will depend on tidally stripped HI mass in groups, extent in addition to velocity dispersion.

- In groups which have a central dominant elliptical – due to mergers of spirals – the spiral would have lost much of their HI to the IGM – hot/cold IGM . Cooler HI mass can range from 10^10 solar mass to 10^8 solar mass which forms dwarf galaxies in some cases.

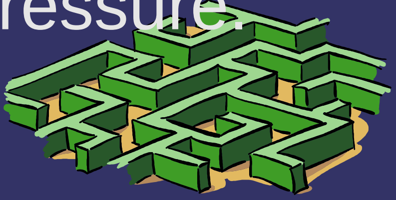


Adequate HI densities?

- Assuming that HI is distributed over a sphere of radius 50 kpc; the ram pressure in dyne/cm2:

HI mass	n	σv=300	σv=100
solarM	/cm3	10^(-13)	10^(-13)
1. 5x10^9	10^(-3)	9	1
2. 10^9	10^(-4)	1.8	0.2
3. 10^8	10^(-5)	0.18	0.02

- Ram pressure for case 1 ~ grav pull of the disk and would be effective. In all other cases velocity disper-sion needs to be significant. However assuming gas is dispersed over 25 kpc the density would increase by about a factor of 10 leading to higher ram pressure.

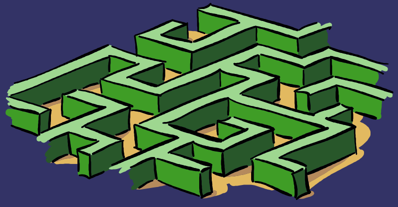


Summary

- Groups with reasonable dispersion of about 300 km/s and-where HI >~ 5 x 10^9 solar mass is available in the IGM can remove gas from the galaxies.   Lower dispersion groups with only 10^8 solar mass in IGM will not be able to strip HI.

- Low velocity dispersion groups – low Tx would not show ram pressure effects due to cool HI gas either even if latter is present. In such cases stripping could be due to turbulent viscous stripping. Rate of stripping due to turbulent viscous proceses appears to have been over-estimated by a factor of 10-20.

- Origin of HI deficiency in compact groups is not clear.

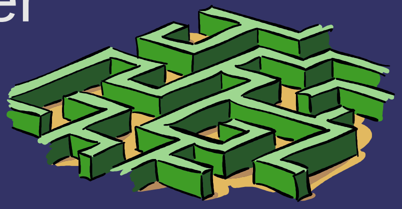


Summary

- Need to study a carefully selected sub-group of a complete sample of groups like Sullivan's CloGs – especially loose systems of galaxies in HI 21cm also.

- Groups should be studied in high resolution HI for signatures of ram pressure sweeping and also in low resolution HI for higher surface density sensitivity allowing detection of extragalactic diffuse HI in vicinity of galaxies possibly experiencing ram pressure effects. Deep observations.

- GMRT Polarisation studies of Holmberg 124 to look for polarised ridge on the compressed leading edge - evidence for ISM-IGM interaction. Studied in Virgo spirals (Vollmer 2007)



Giant Metrewave Radio Telescope

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TIFR GMRT Sky Survey (TGSS)

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TGSS Data Release 2

We announce the second data release of the TIFR GMRT Sky Survey (TGSS) - the radio continuum survey at 150 MHz using the Giant Metrewave Radio Telescope (GMRT) on 9 June 2011. This data release, which includes the DR1 fields, covers about 2100 square degrees of the southern sky as shown in the adjoining figures. The images have an angular resolution of 24" x 15" at position angle 30d and typical rms noise is less than 9 mJy/beam. All the images have been generated by the automated data analysis pipeline running in the AIPS++ environment.

TGSS images released in DR2 are now available for download. The catalogue browser can be used to get a listing of sources in a field.

Download TGSS data products

TGSS Image Server (plots contours and grey scale,slow: jpeg, FITS)

TGSS Image Server (plots grey scale, quicklook: jpeg, FITS)

TGSS Catalogue Browser

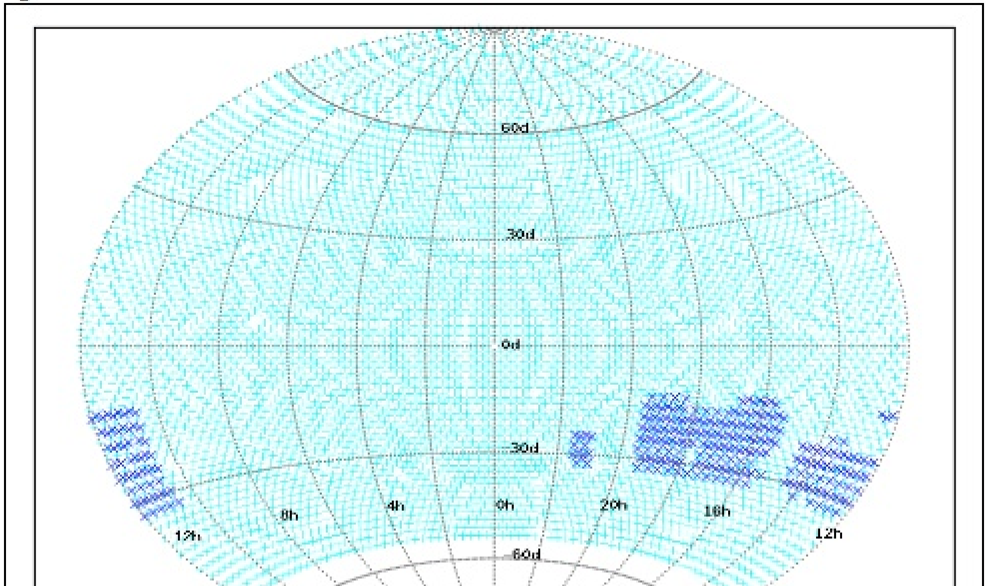
FITS files (4.5dx4.5d)

Important notes on TGSS DR2 - must read before using TGSS data products!

1. The images and catalogues have been corrected for the system temperature variation

Sky covered in TGSS DR2:

Aitoff projection of Equatorial coordinates showing the TGSS pointings. The light blue points mark the observable sky from GMRT which will be covered by TGSS. Originally, TGSS was to cover the sky north of declination -35 degrees. However positive results on a few test fields south of -35 degrees have enabled the TGSS team to propose covering the entire sky accessible to GMRT. The dark blue points indicate the fields that are being released in TGSS DR2. Right ascension increases towards the left as annotated in the figure.



Turbulent viscous stripping over-estimated....

- The Mdot estimates used thus far (Rasumussen et al) should be multiplied by a drag coefficient C_v (since F_drag in a turbulent flow = C_v rho U^2 S)
- The drag coefficient due to turbulent viscosity C_v = 13 Re^(-1/2)
- Even assuming Spitzer viscosity, with v = 300 km/s, d = 30 kpc T=10^6 and n = 10^-3, Re ~ 10^6 and C_v ~ 0.06 (The first statement follows from this value of C_v)
- Tangled magnetic field – reduces viscosity and in-creases Reynold's number.