HI Gas Content of Galaxy Groups: Pre-processing and Mass Assembly in the Present Epoch

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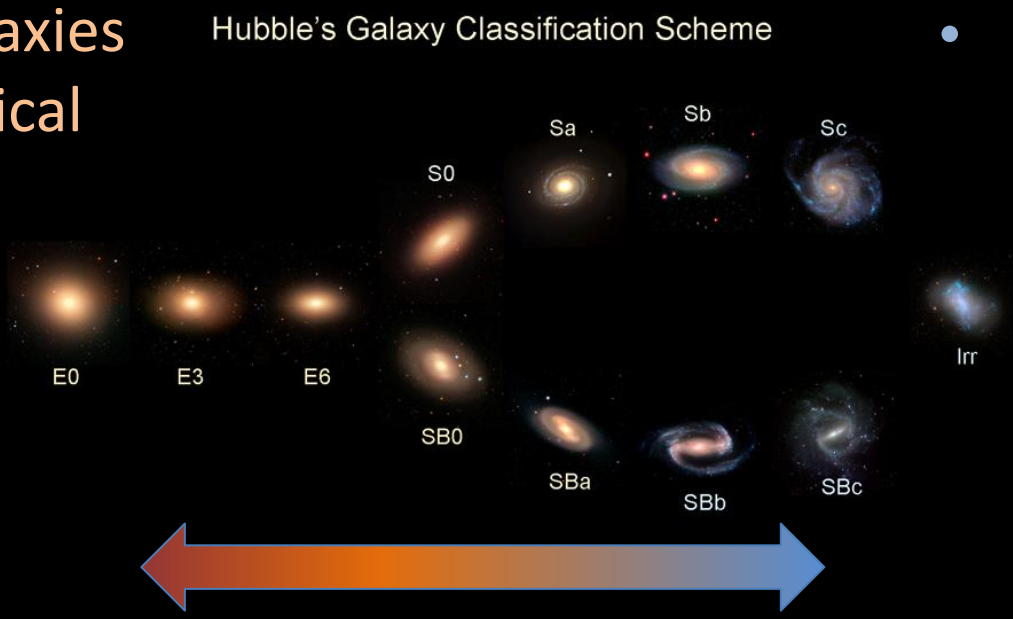
6th PHISCC – Galaxy Velocity Fields from Large HI & Optical Surveys
19 June 2013
SIfA/CAASTRO, University of Sydney

Galaxies and their Environment

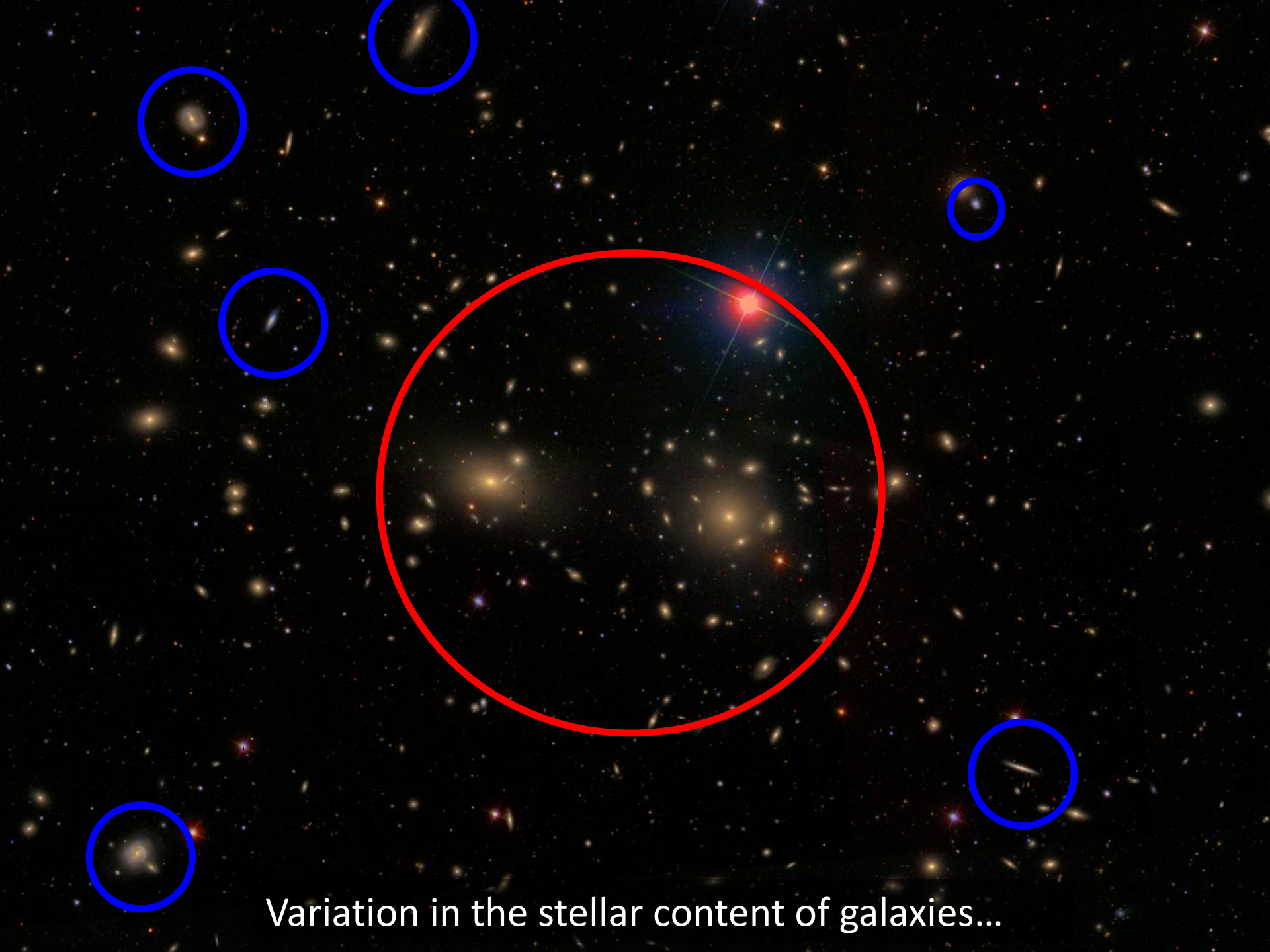
- Dressler (1980) – Morphology Density relationship
  - High density environments dominated by red, early type galaxies

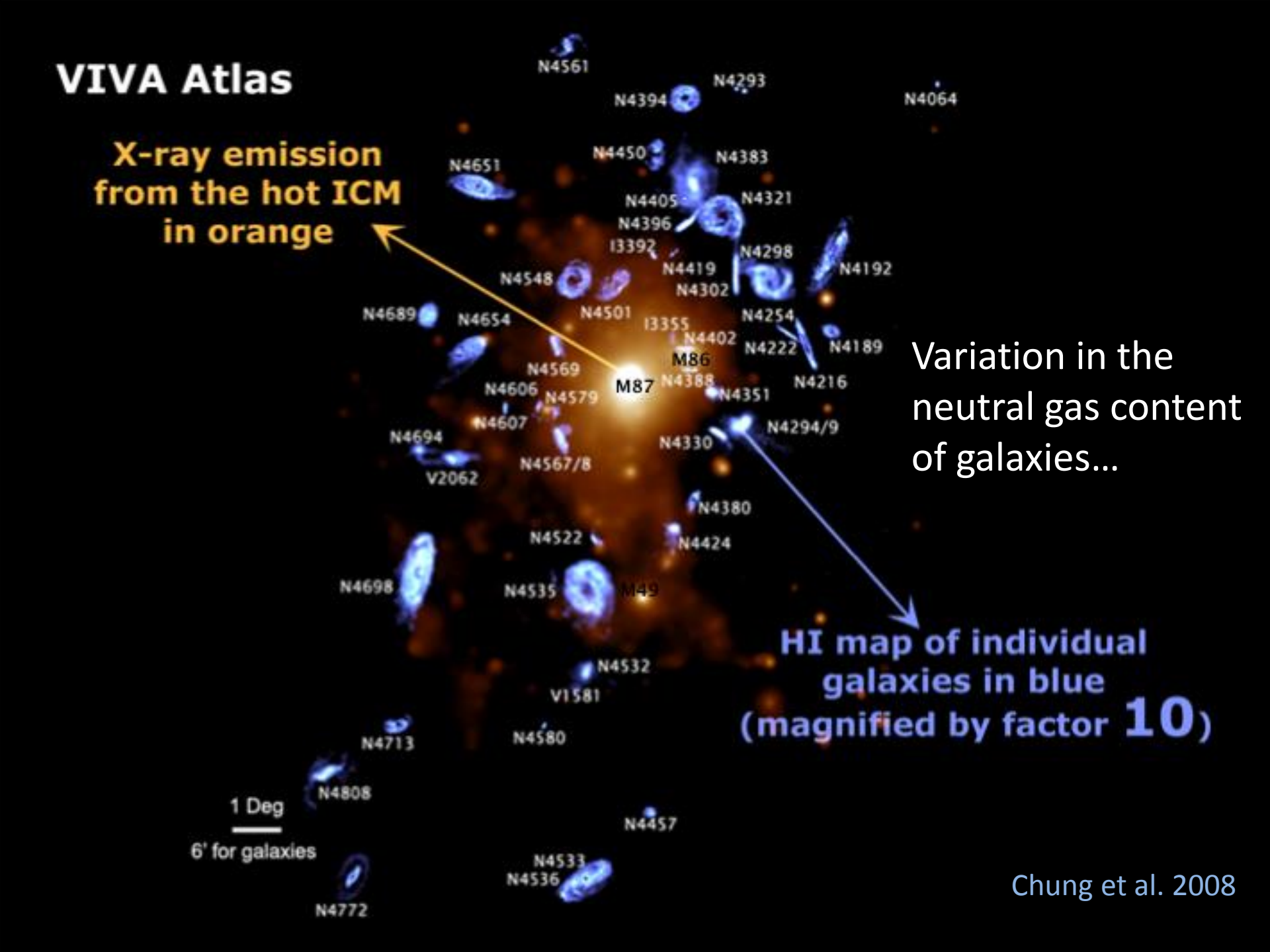
- Cluster Galaxies
  Red, elliptical
  Old Stars
  Gas poor



- Field Galaxies
  Blue, spiral
  Young Stars
  Gas rich

- Nature versus nurture: Want to understand the evolution of galaxies


Variation in the stellar content of galaxies…



Chung et al. 2008

What drives transformation of galaxies & where?

- Fraction of star forming galaxies is suppressed in dense environments (e.g. Balogh et al 1997)
  - Removal of fuel in dense environments?
- "Central" versus "Satellite" galaxies (Wetzel 2010, 2012)
- HI mass function varies as a function of environment.
  (e.g. Verheijen et al 2000; Rosenberg & Schneider 2002; Springob 2005)
  - Paucity of low HI mass galaxies in dense environments

- Ram pressure stripping & harassment in clusters → removal of gas & dynamic heating of disks
- Strangulation/starvation → remove hot halo gas and prevent it from cooling on to galaxies
- Galaxy-galaxy interactions → trigger star formation or remove gas

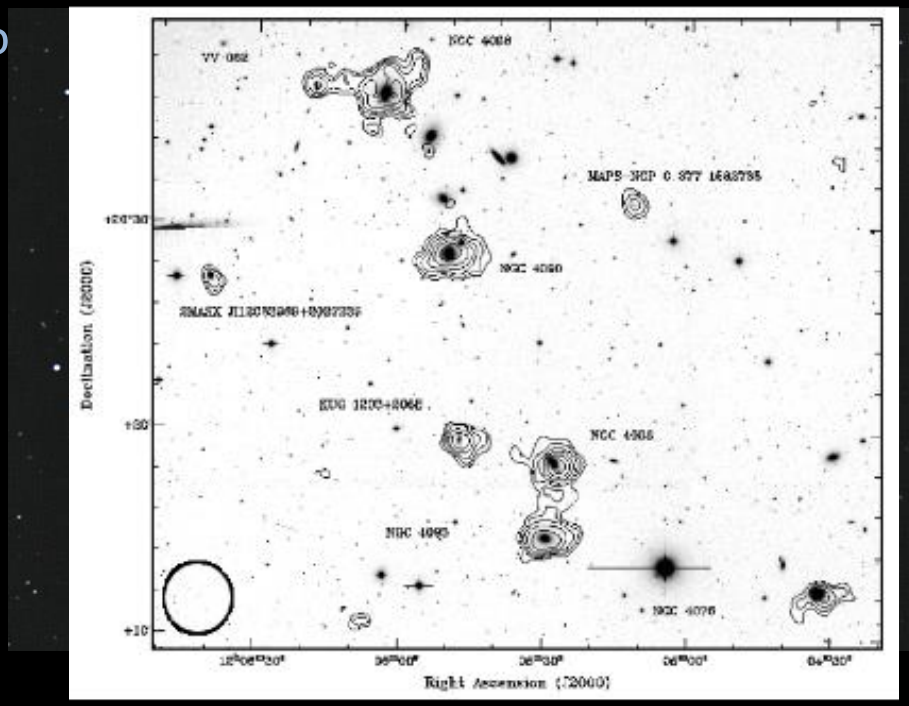
Galaxy Groups as the site of Galaxy Transformation?

- Size and few members make groups difficult to study
- Low velocity dispersion conducive to galaxy-galaxy interactions
- Cases where galaxies sit in common HI envelopes
- Evolved groups: HI detections outside X-ray extent

- From small samples: group HIMF appears flatter than global HIMF

- Large number of optical/infrared (stellar) surveys, need a complimentary HI survey

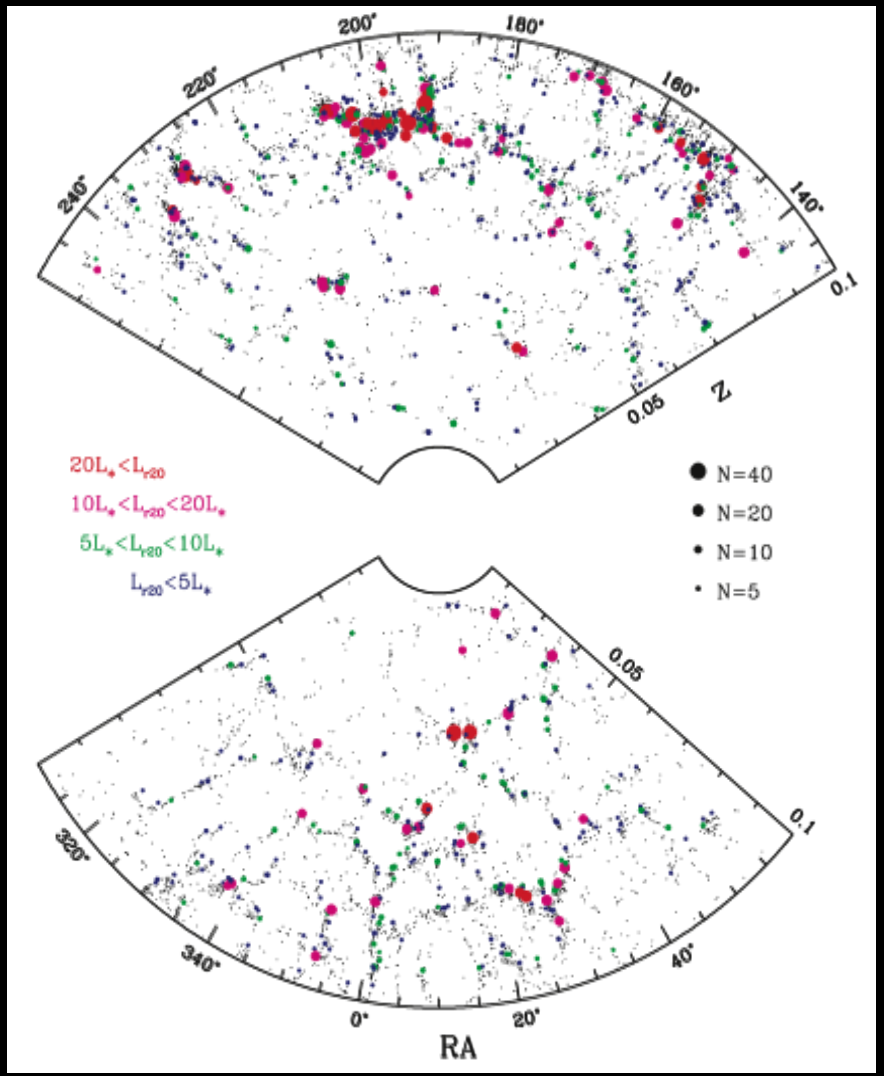
(e.g. Kern et al 2008; Freeland et al 2009; Kilborn et al 2009, Pisano et al 2011)



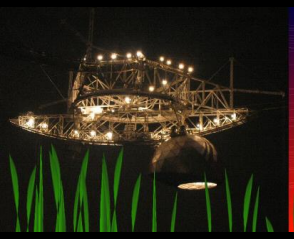
SDSS Mr18 DR7 Group/Cluster Catalog

- ~50-67% of galaxies reside in groups!
  - CfA Redshift (Huchra & Geller 1982)
  - 2MASS Redshift (Crook et al 2007)
  - SDSS DR4 (Berlind et al 2006)

- Magnitude & volume limited galaxy catalog (M_r>18)
- Complete to z=0.042
- Friends-of-friends group finding algorithm

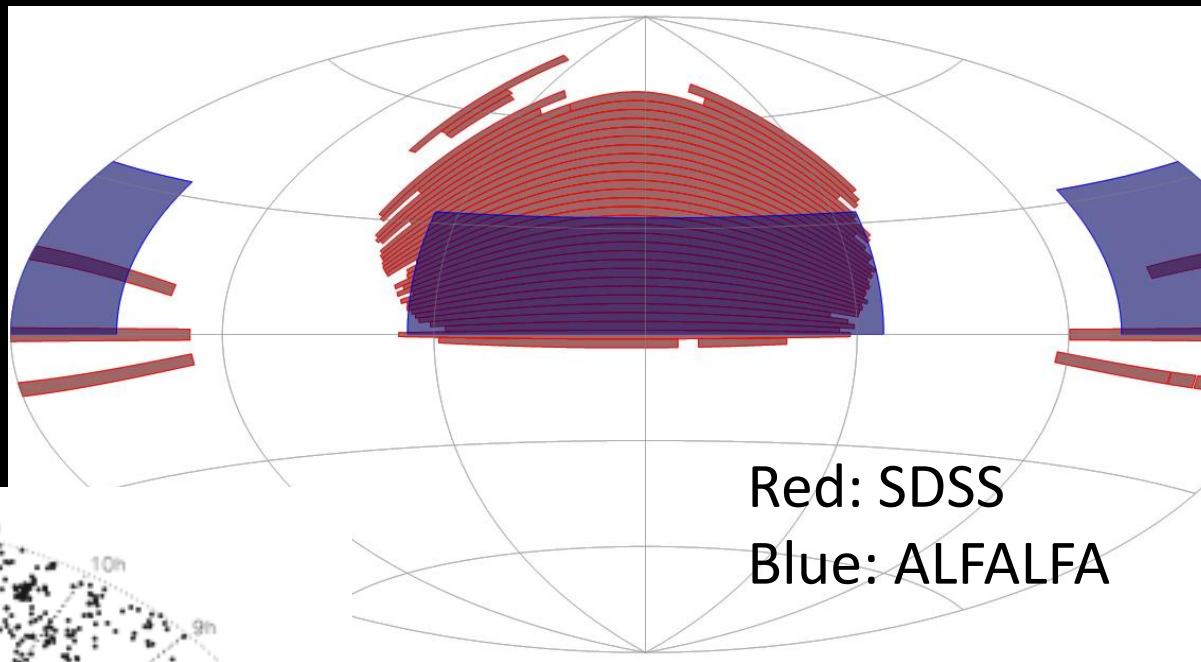


Berlind et al 2006, 2009

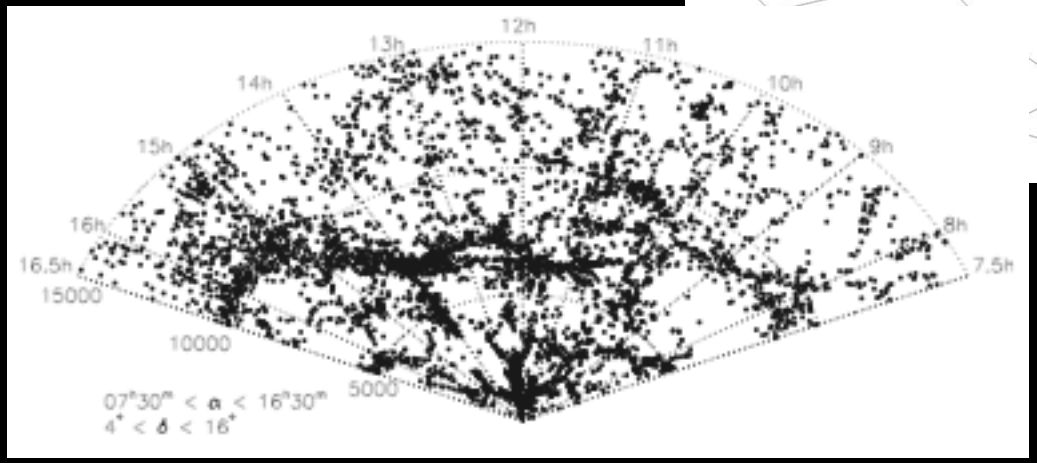


ALFALFA

- Cross correlated ALFALFA α.40 catalog HI detections with SDSS Mr18 group members



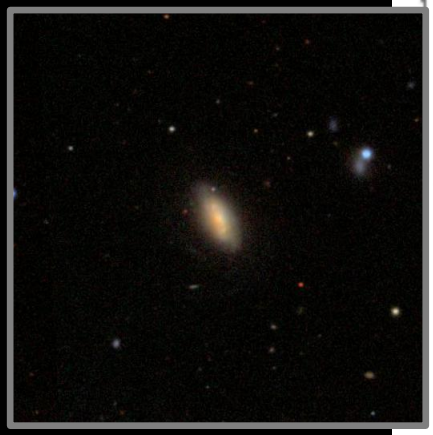
Red: SDSS
Blue: ALFALFA

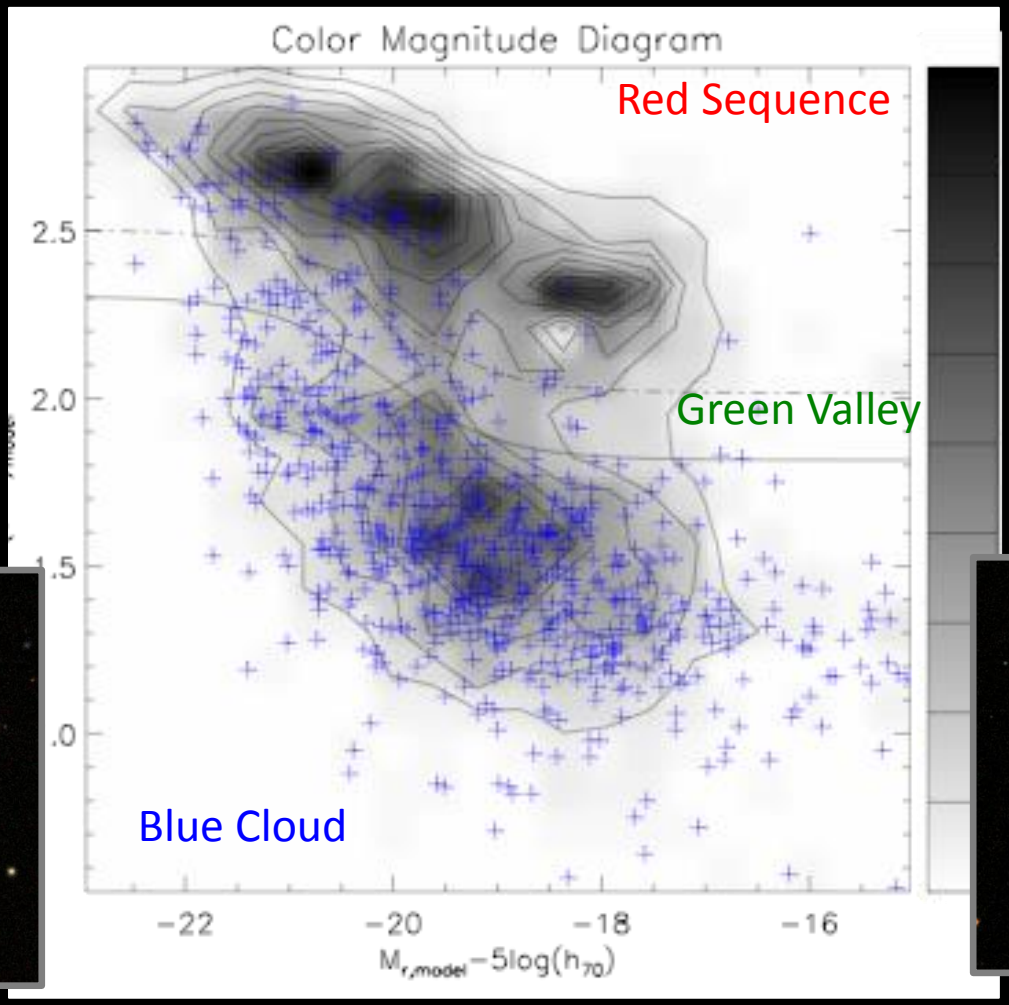


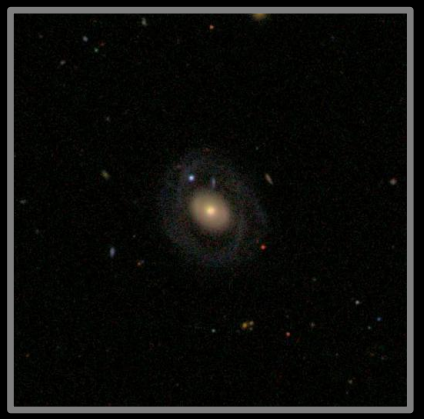
Martin et al 2010; Haynes et al 2011

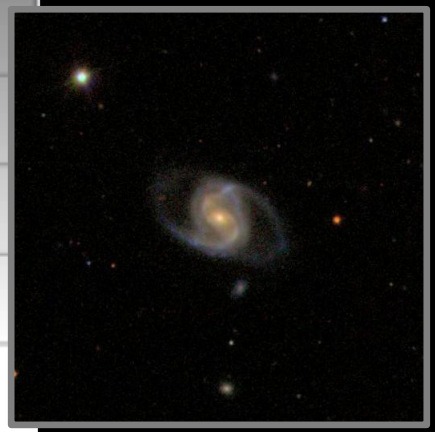
~2000 deg^2; 6000-12,600 km/s

SDSS/ALFALFA
Color Magnitude Diagram









Grey scale: optical galaxies Blue symbols: ALFALFA detections

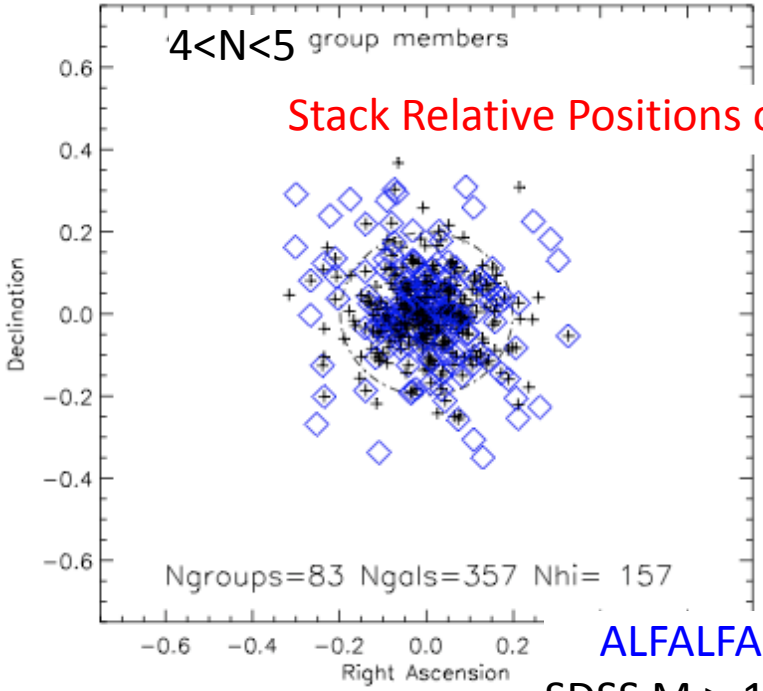
SDSS + ALFALFA Group Catalog

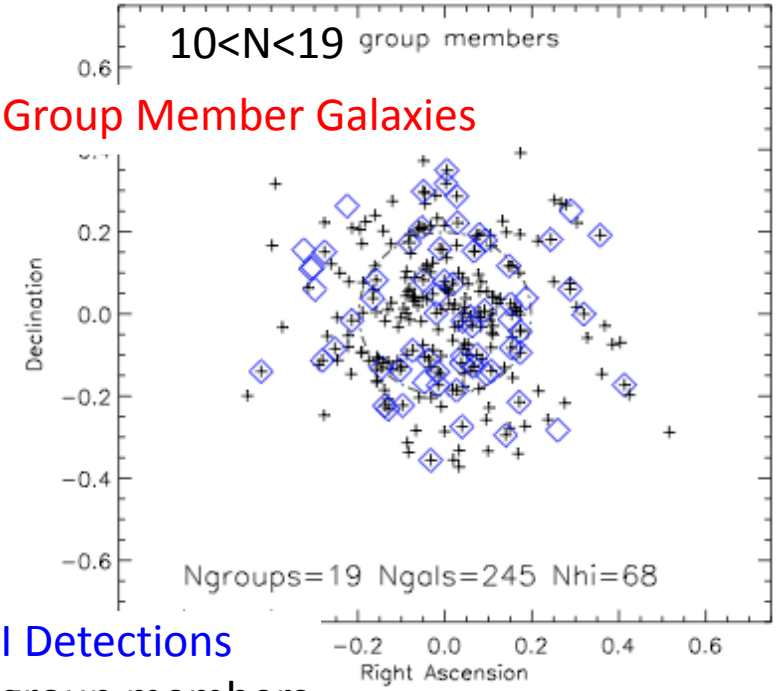
- 742 SDSS groups
- 4852 SDSS group members
  (spectroscopic objects with Mr < -18)

- Same volume: 6515 ALFALFA HI sources
  …of which 1675 HI sources reside in 603 SDSS groups

→ 23% of HI sources appear to reside in groups
  (compared to 50-66% of all optical sources)

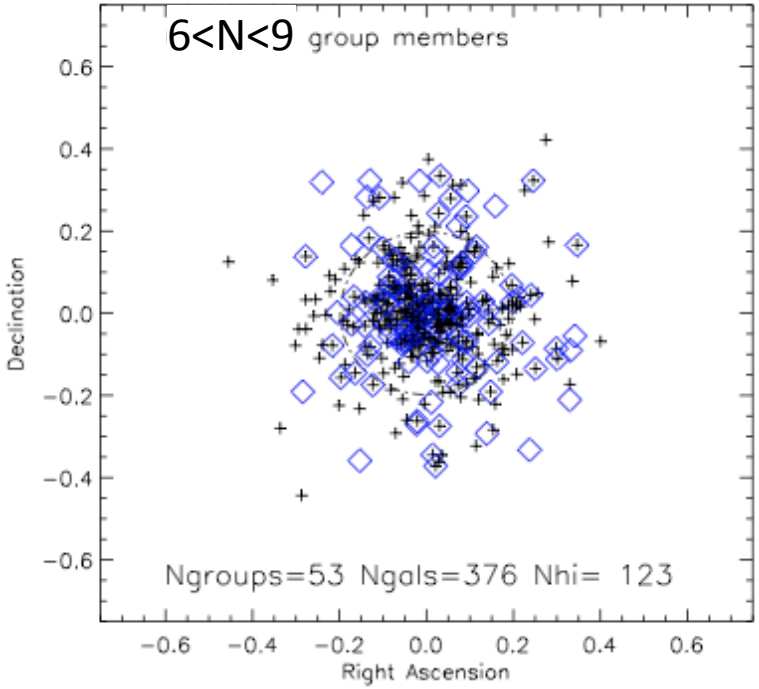
Stack Relative Positions of Group Member Galaxies

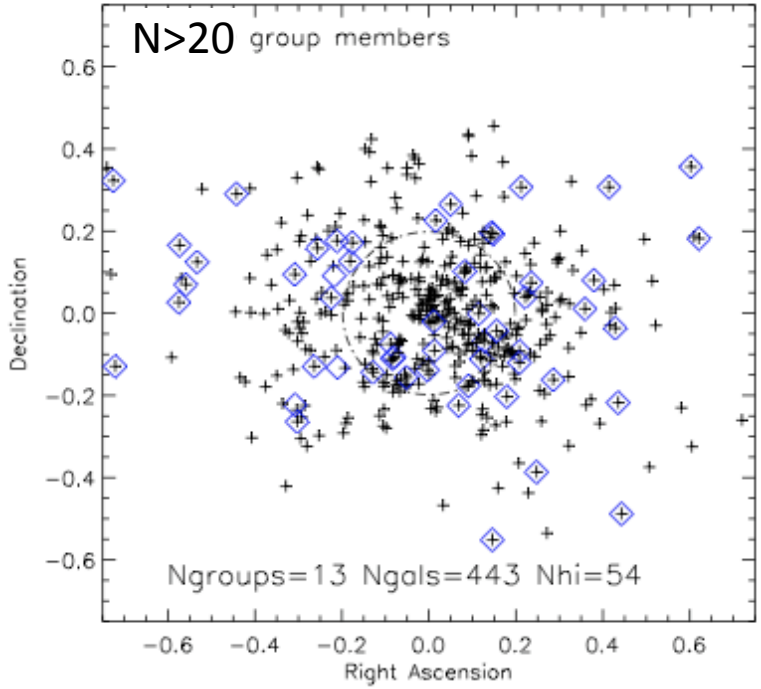




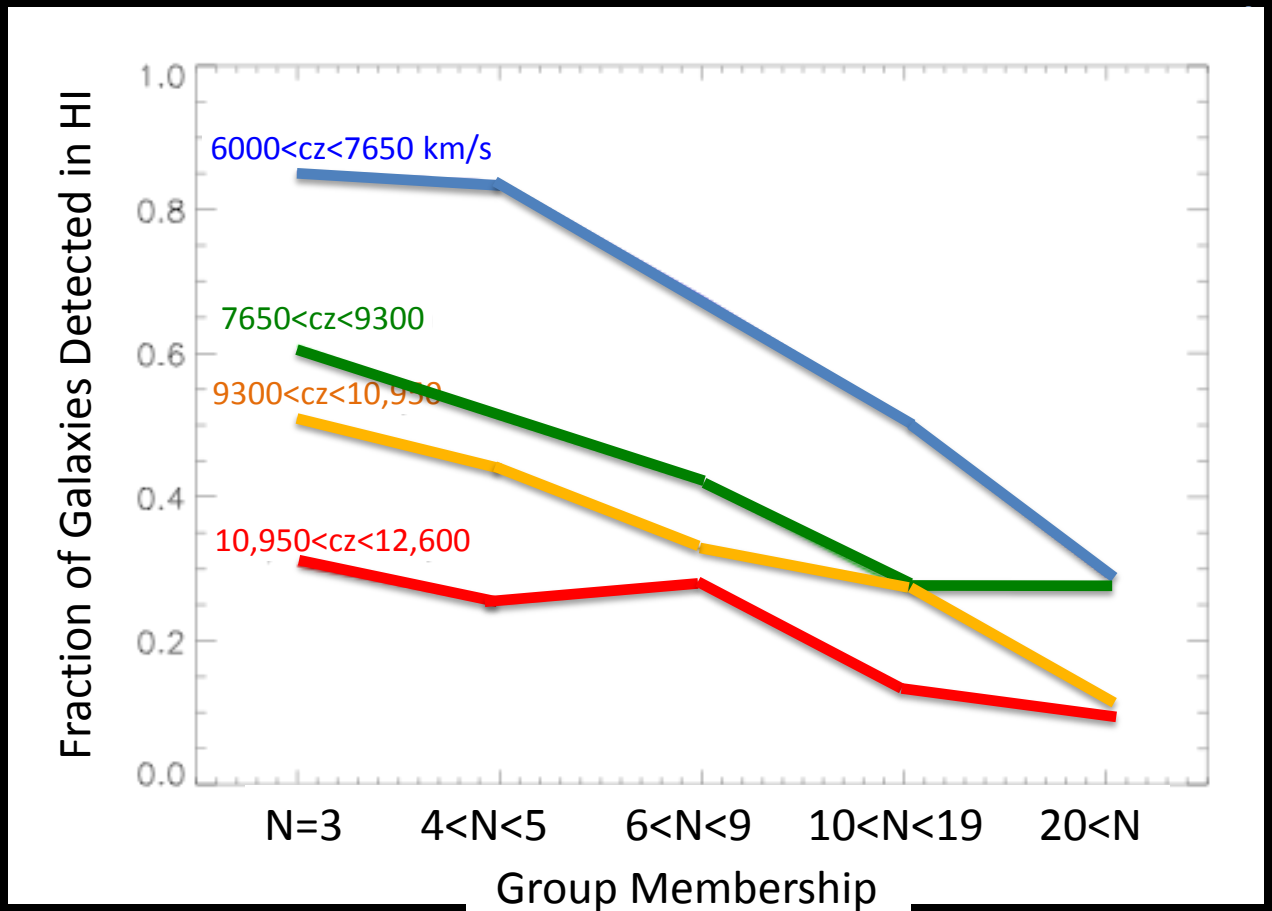
ALFALFA HI Detections

SDSS M_r>-18 group members





Fraction of Galaxies Detected in HI as a Function of Redshift



At low redshift (blue) low HI mass galaxies are in sample.

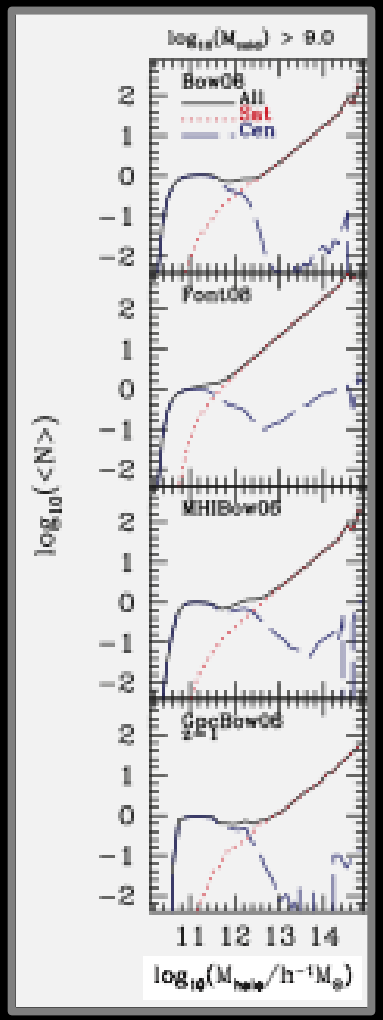
Variation in slope means low mass galaxies preferentially lose their gas first!

→ Ram pressure stripping of dwarf galaxies in groups?

(Freeland et al 2011)

Mass assembly → age of group

Halo Occupation Distribution: Comparison to simulations

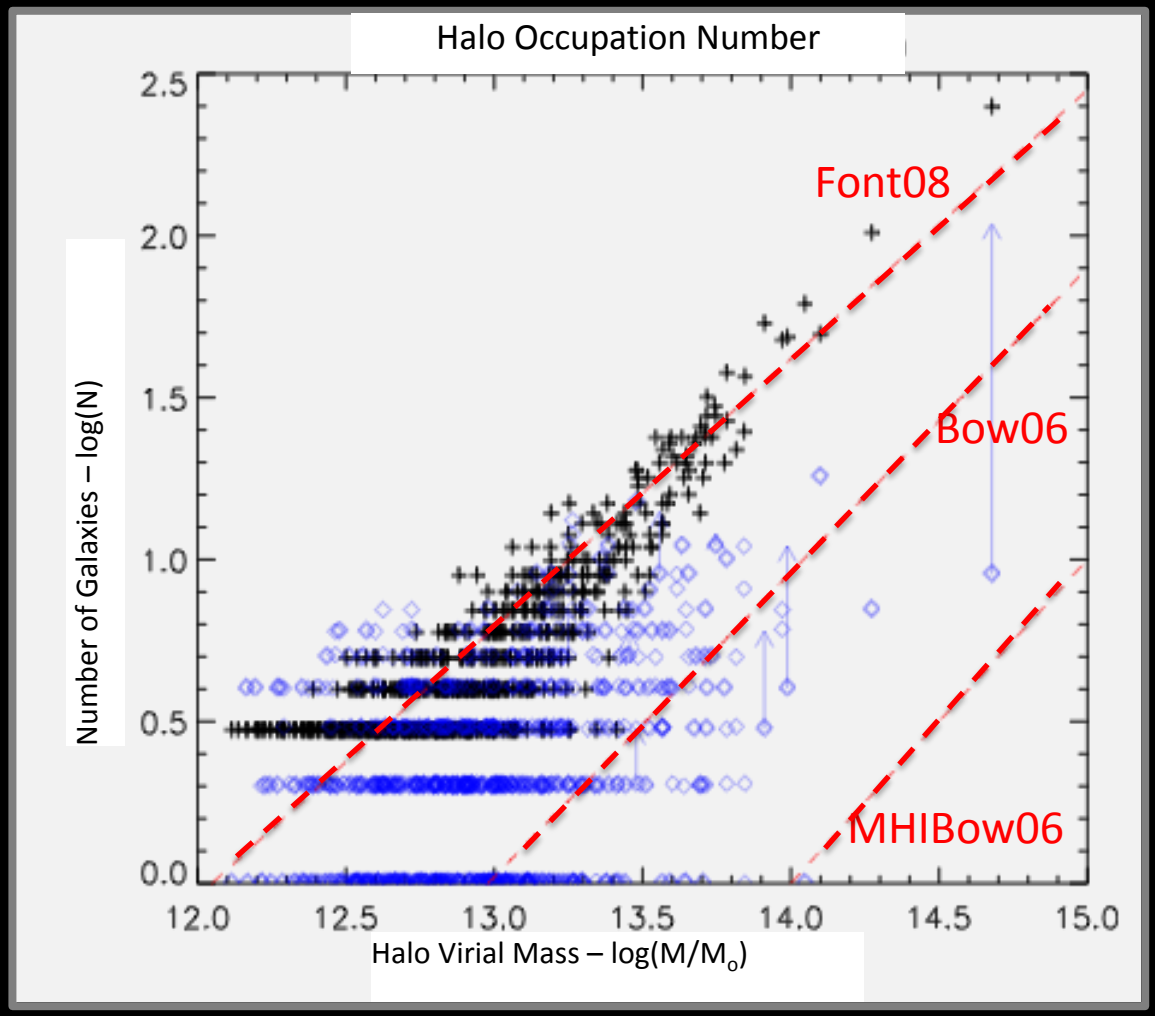


Bow06

Font08

MHIBow06

Kim et al 2011



Hess & Wilcots, submitted

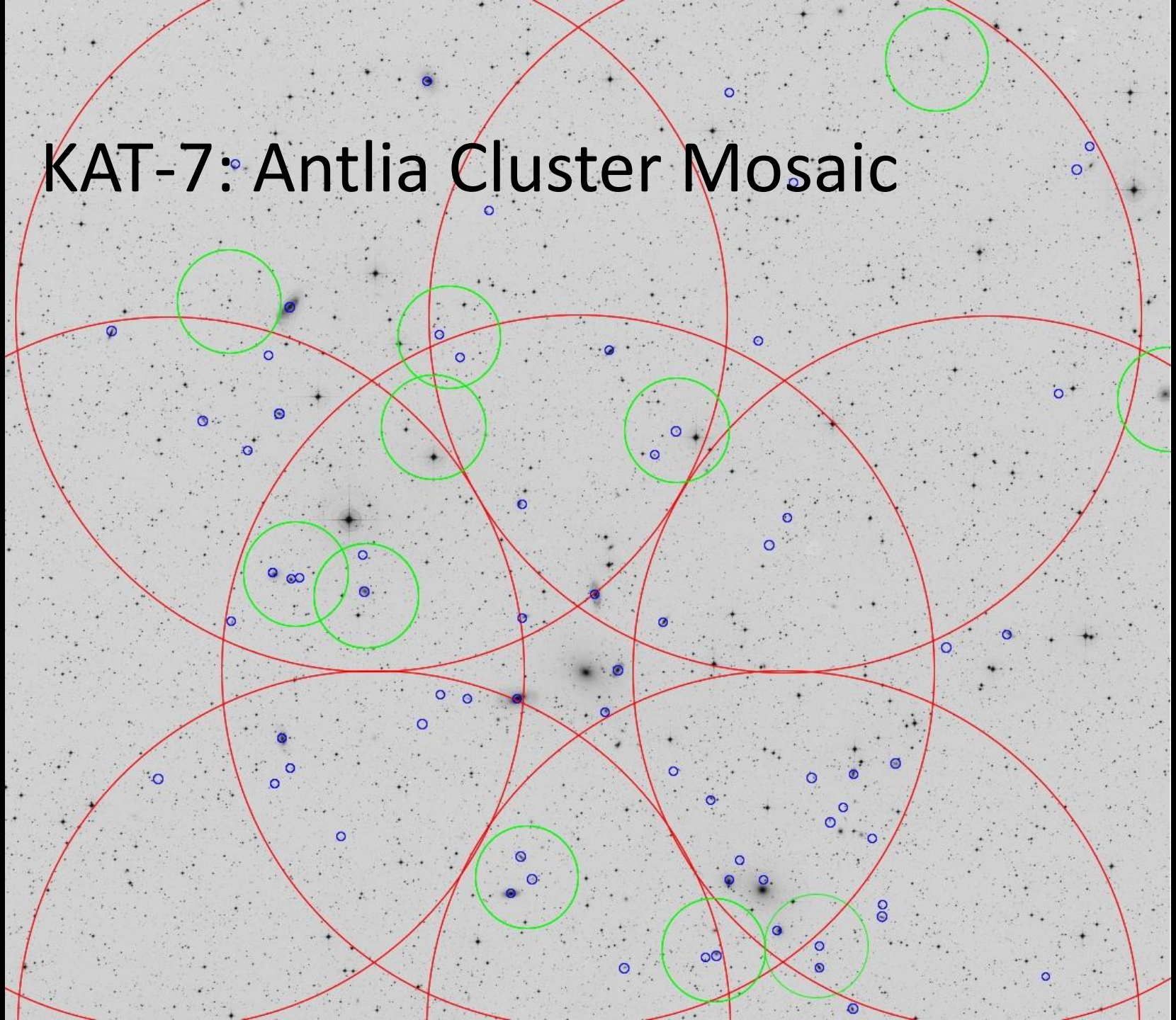
Results

- The fraction and distribution of HI sources is correlated with halo mass
  - Fraction of HI galaxies detected in a group/cluster decreases with increasing parent DM halo mass
  - Transformation from inside out: galaxies at center of groups have lost or consumed their gas.
- Low HI mass galaxies in groups lose their gas earlier
- Semi-analytic models cannot yet simultaneously reproduce the stellar (optical) and gas (21 cm line) properties of galaxies.
- Strangulation/starvation may be the most important mechanism

Conclusions

- Only ~23% of HI detected sources are in groups
  - Compared to 60% of optical sources
- Local field/group/cluster environment has greatest impact on gas content of galaxies
- Largest groups, binned by membership, show strongest evidence of evolution
- In-fall of galaxies (mass assembly) is responsible for replenishing gas supply in groups

KAT-7: Antlia Cluster Mosaic



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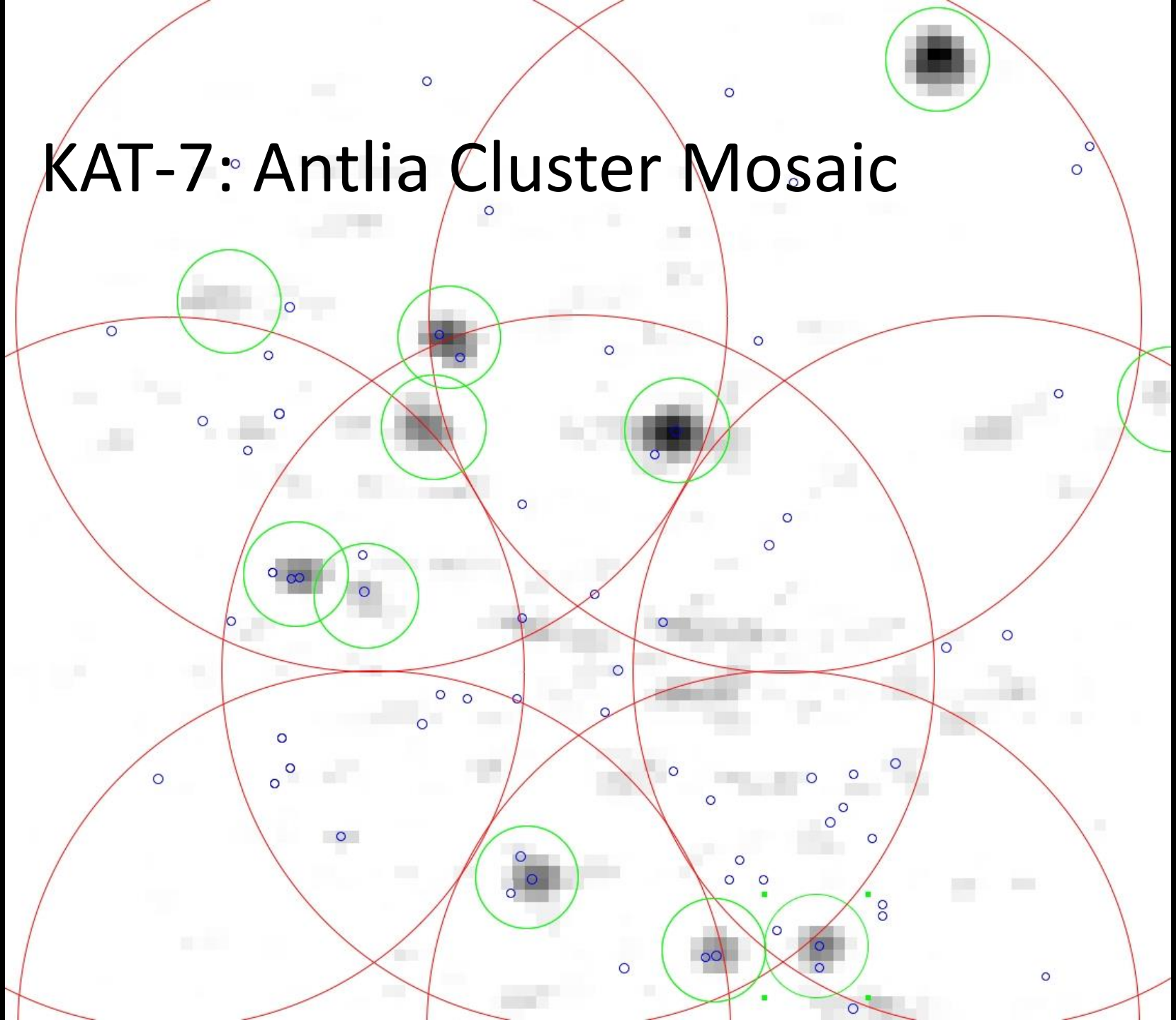
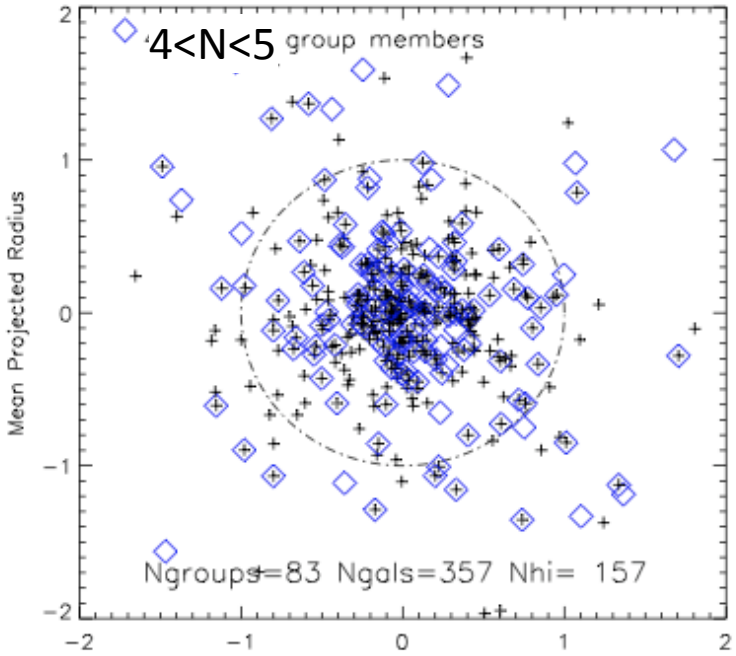
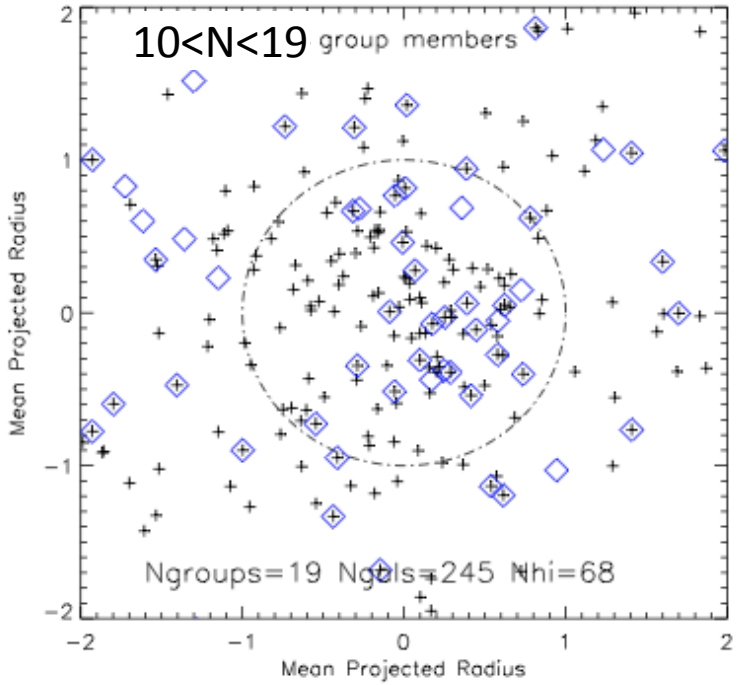


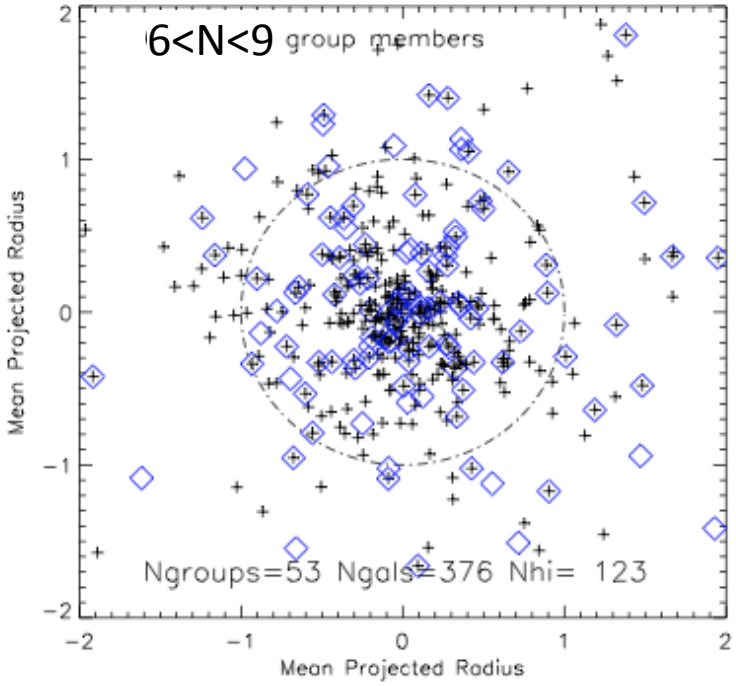
Future Work: The Fate of HI in Groups

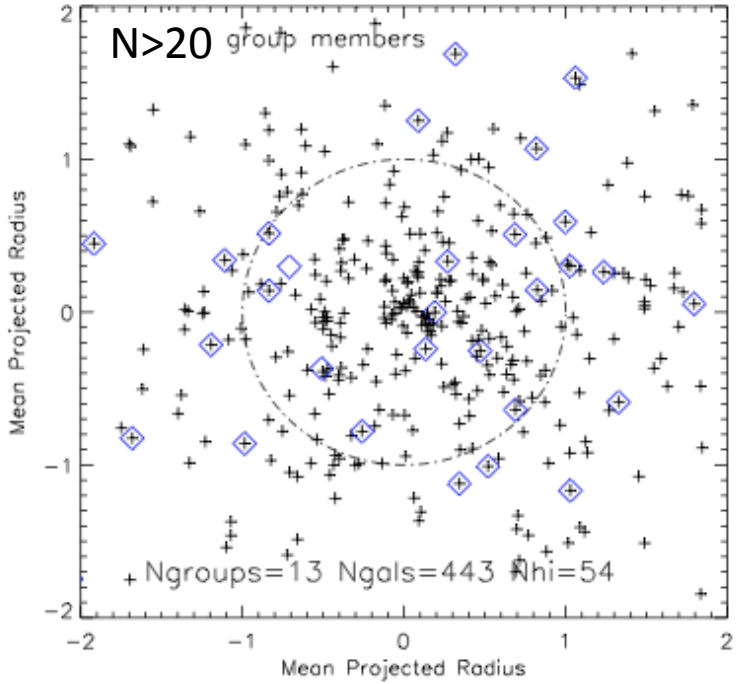
- SALT – Fabry Perot Imaging
  - Kinematics of the diffuse ionized gas
- JVLA – High resolution HI imaging
  - Signatures of gravitational / hydrodynamical interactions
- Stacking X-ray observations
  - Measure the warm intragroup medium

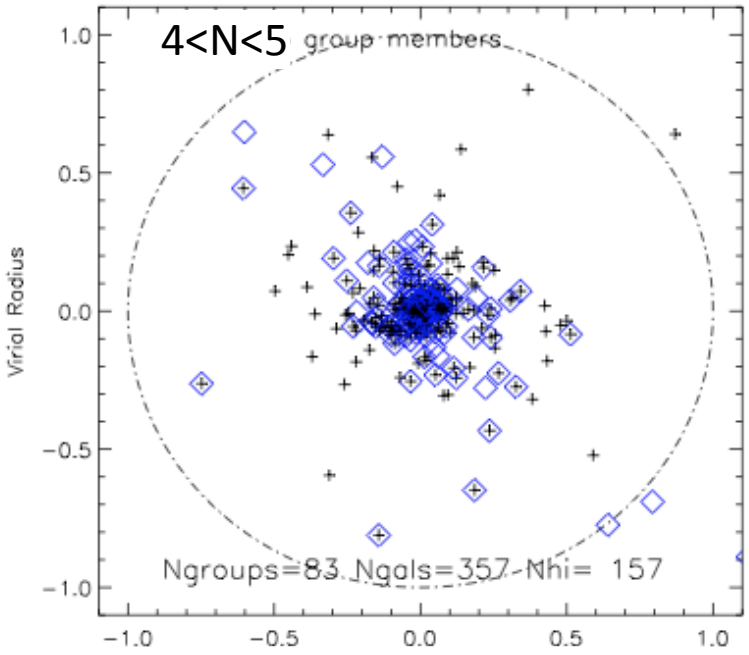


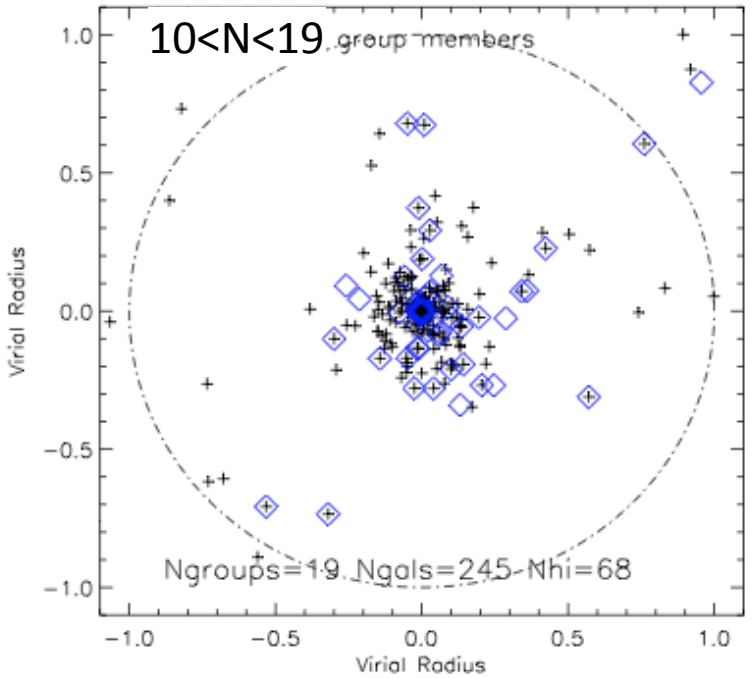


Scale by Mean Projected Radius









Scaled by Virial Radius