

The Evolution of HI in Galaxies as a Function of Environment



Jessica Rosenberg

George Mason University

Derek Fertig, Ilsang Yoon, Jillian Scudder, Sara Ellison, David Patton, Paul Torrey, Preethi Nair, Luc Simard, ALFALFA, and NSF 000167932

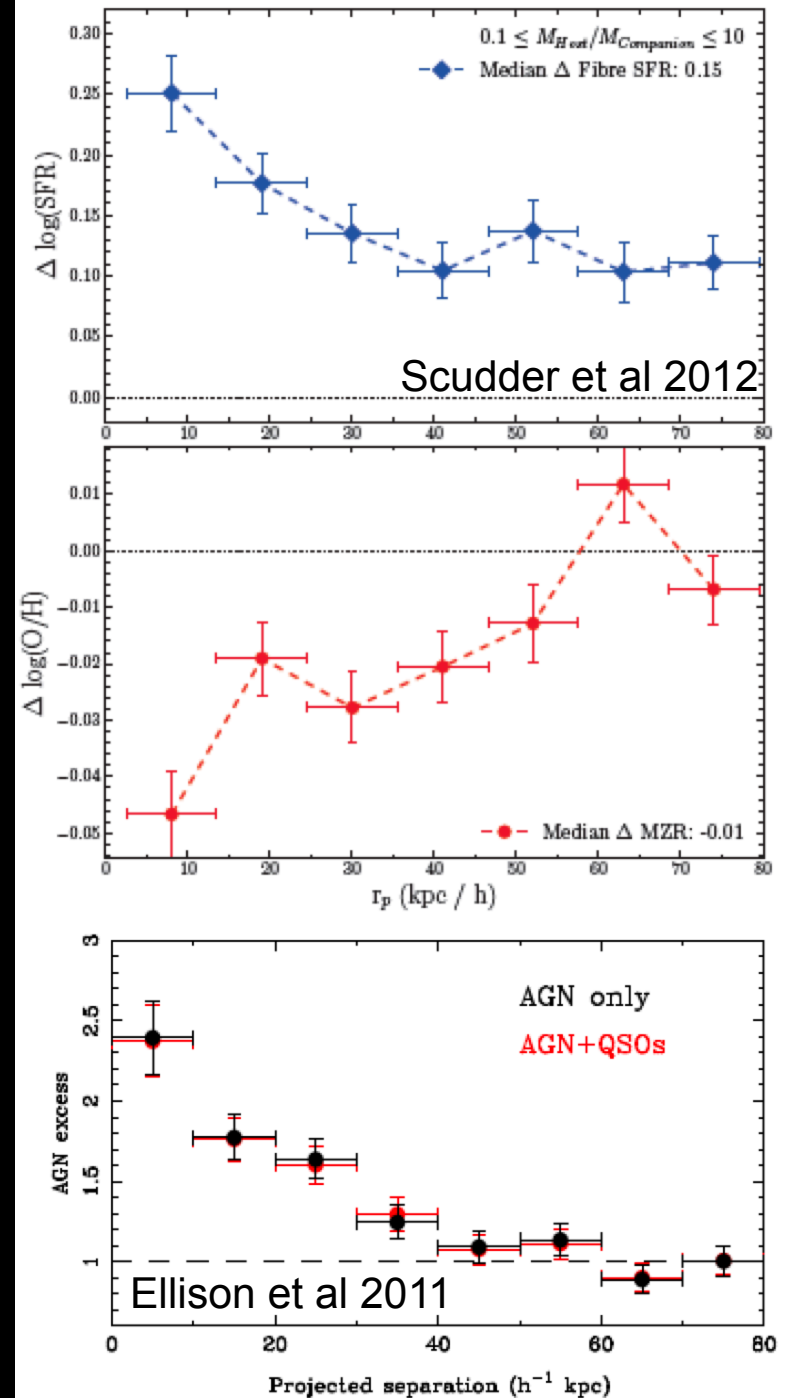
Hubble's Galaxy Classification Scheme



How are different galaxy types in the zoo related?

Impact of Pairs on Evolution

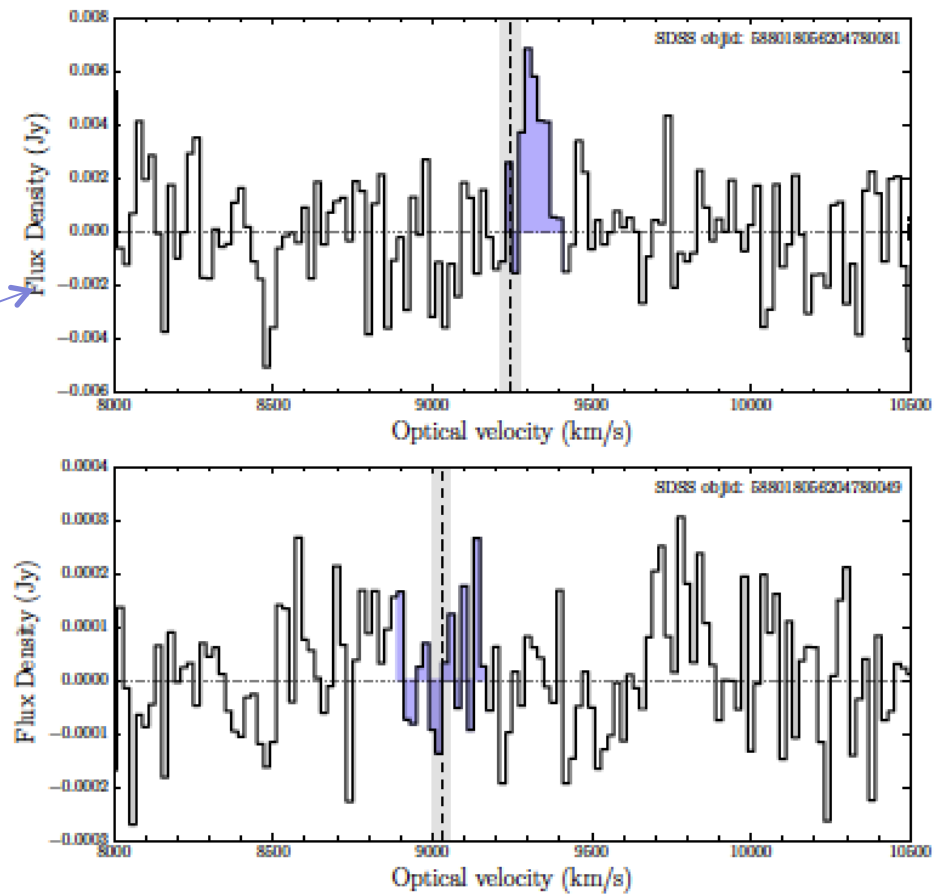
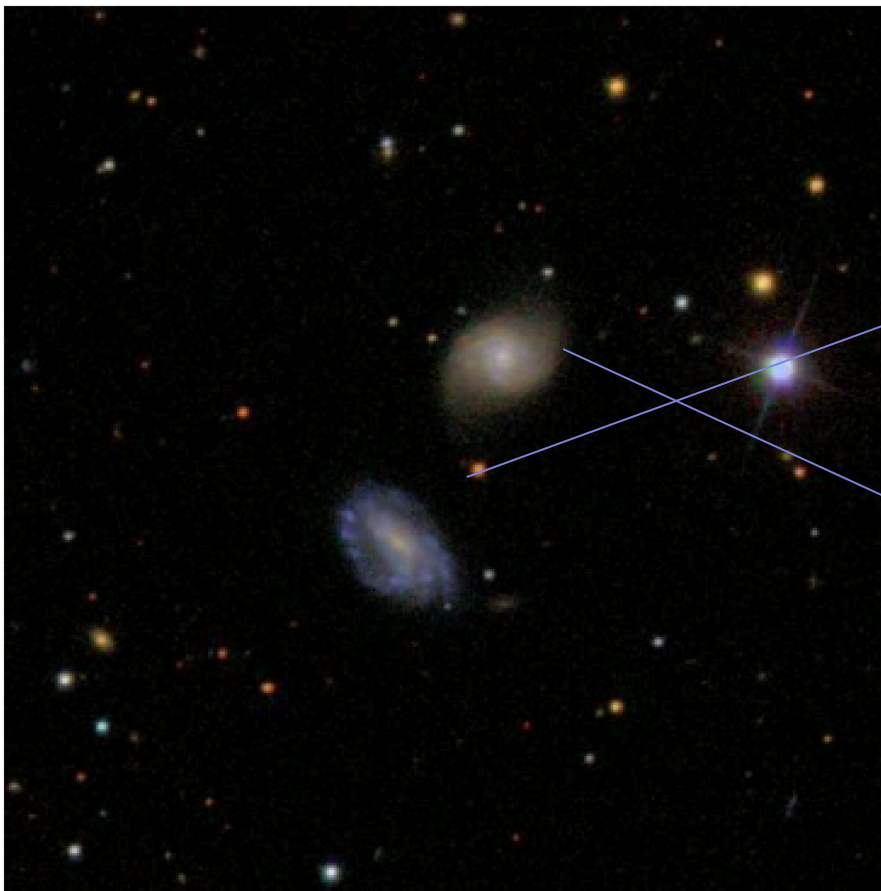
- Galaxy pairs show strong SFR enhancement
- Pairs show AGN enhancement
- Decrease in metallicity points to gas flows driving SFR and AGN
- How is gas content impacted?



Studying Gas-SFR Relation in Pairs

Lead by Jillian Scudder

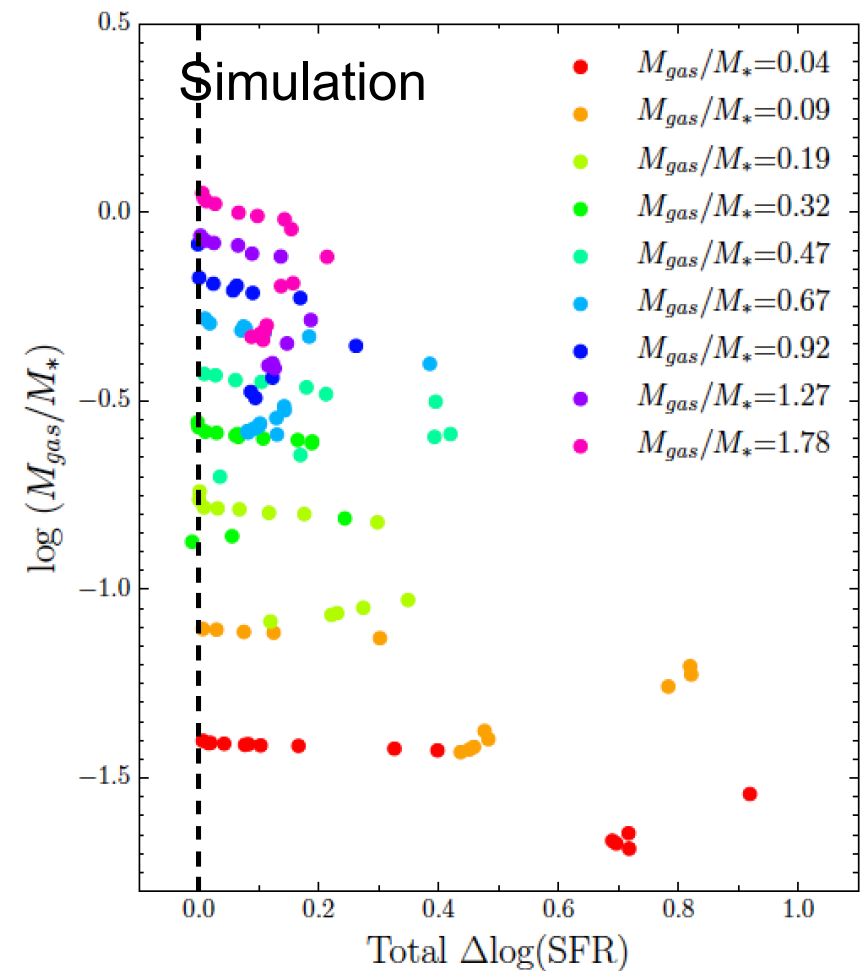
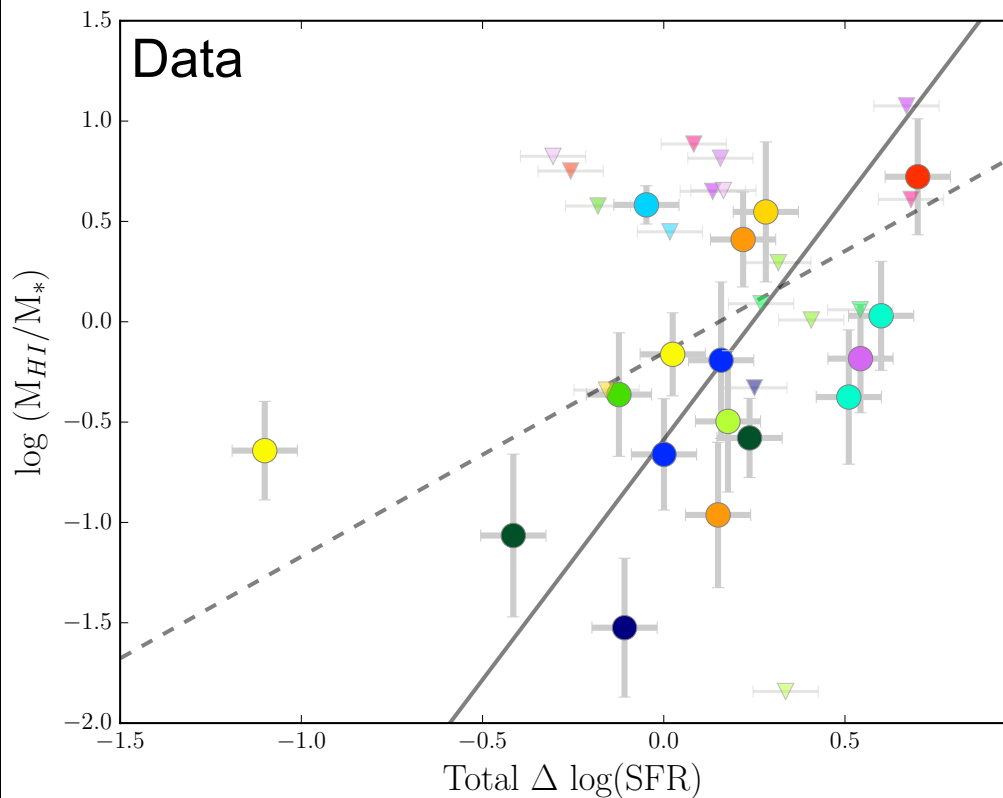
- 17 pairs studied in VLA C-array
- Pairs plus controls to compare SFR at a given gas fraction
- Separations 15-30 kpc projected separation



Scudder et al. 2015, MNRAS, in press

More Gas-Rich Galaxies Don't Necessarily Lead to More Star Formation

High gas fraction galaxies have higher pre-simulation SFRs

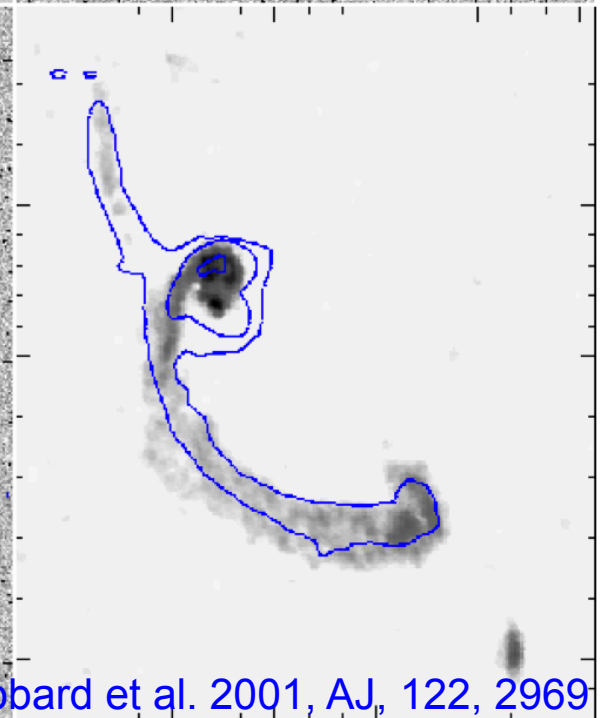
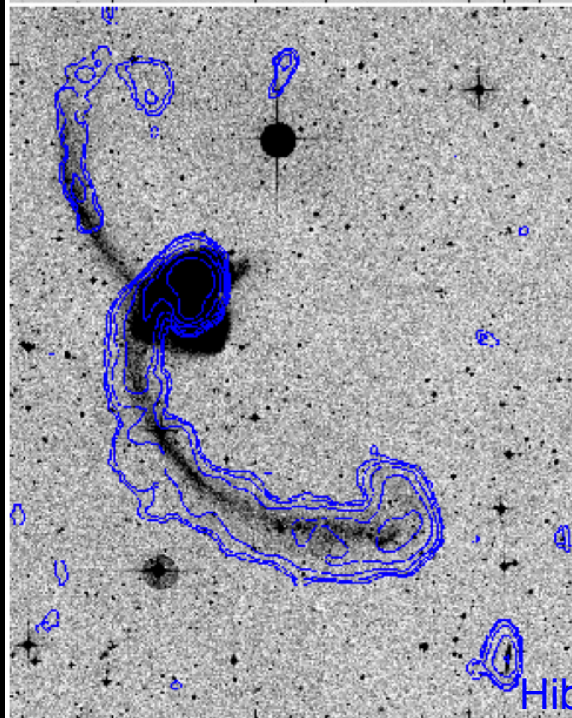
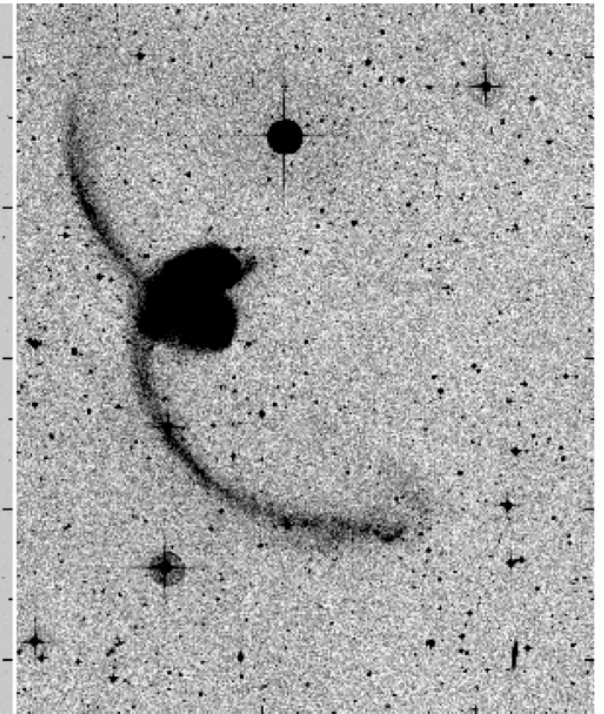
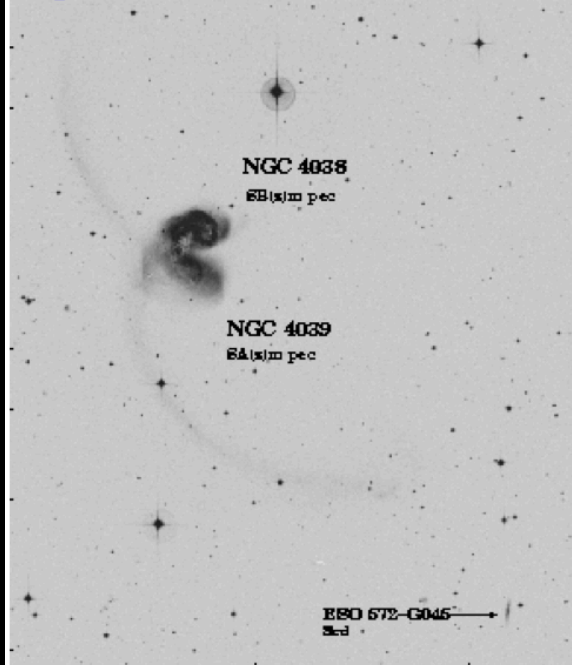


Scudder et al. 2015, MNRAS, in press

Tidal Tails Observed in HI

- Galaxy interactions remove gas from galaxies
- Does the gas escape the potential well?
- How do interactions impact the evolution of the system?

Arp 244 = "The Antennae"

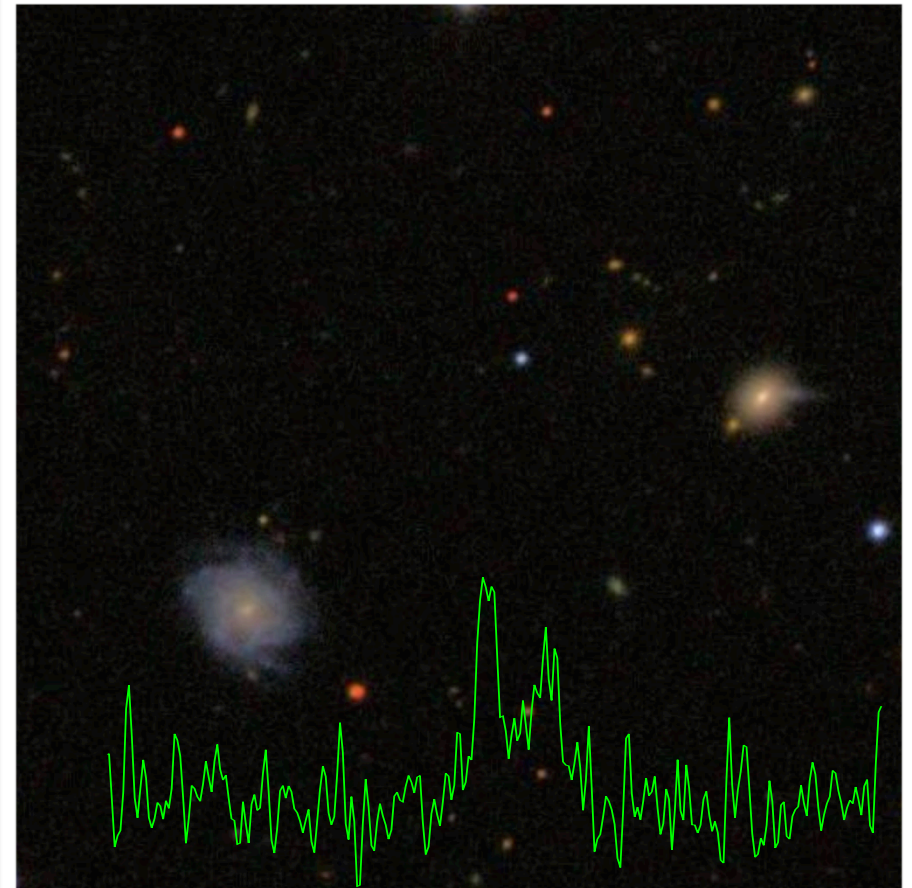
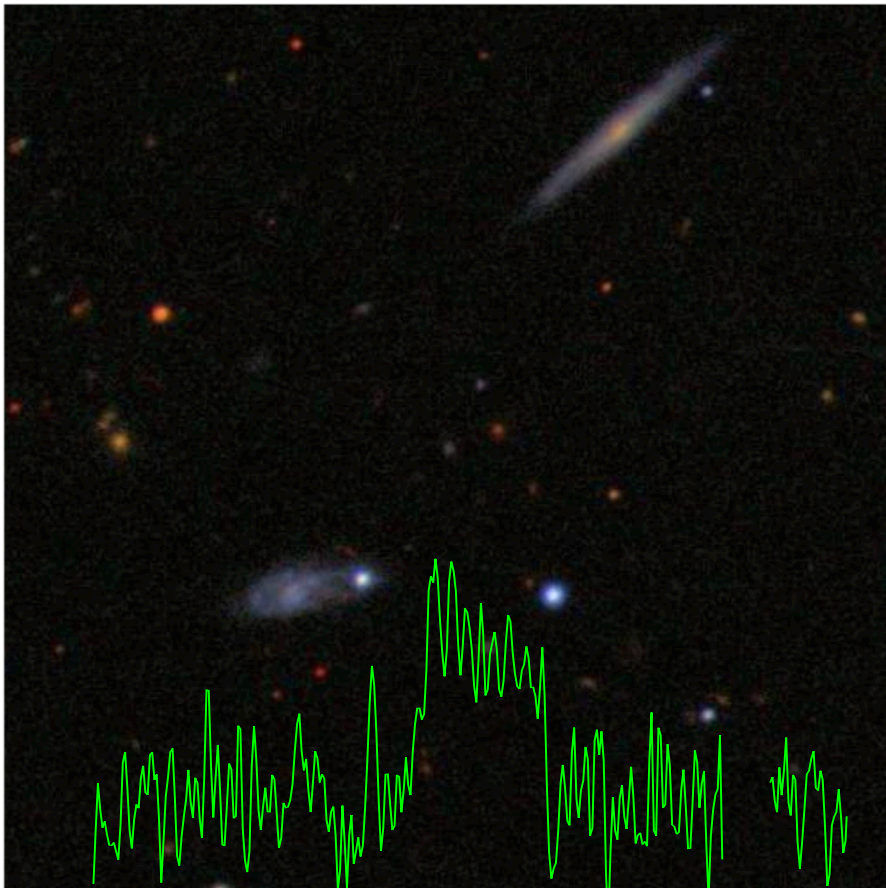


Hibbard et al. 2001, AJ, 122, 2969

HI Pairs Sample

Lead by Derek Fertig

Study of HI gas depletion in galaxy pairs relative to a field sample



HI Pairs Sample

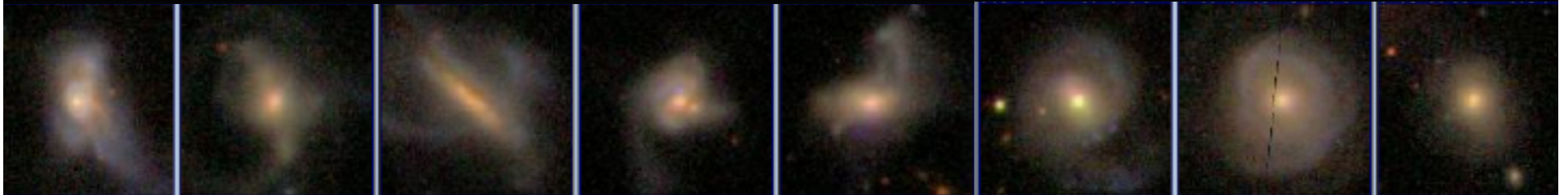
Lead by Derek Fertig (MNRAS submitted)

- One HI measurement for the pair
- Selected from ALFALFA and SDSS
- Primary sample of 94 pairs with $r_p < 100$ kpc
- $\Delta v < 500$ km s⁻¹
- $14.0 \leq m_r \leq 17.77$, $0.02 < z < 0.06$, $z\text{Conf} > 0.7$
- $M_{1,*}/M_{2,*} < 10$ and $\text{Log } M_1 + M_2 \geq 9.5$
- No third galaxy within 150 kpc
- Compare to wide separation pairs (controls)

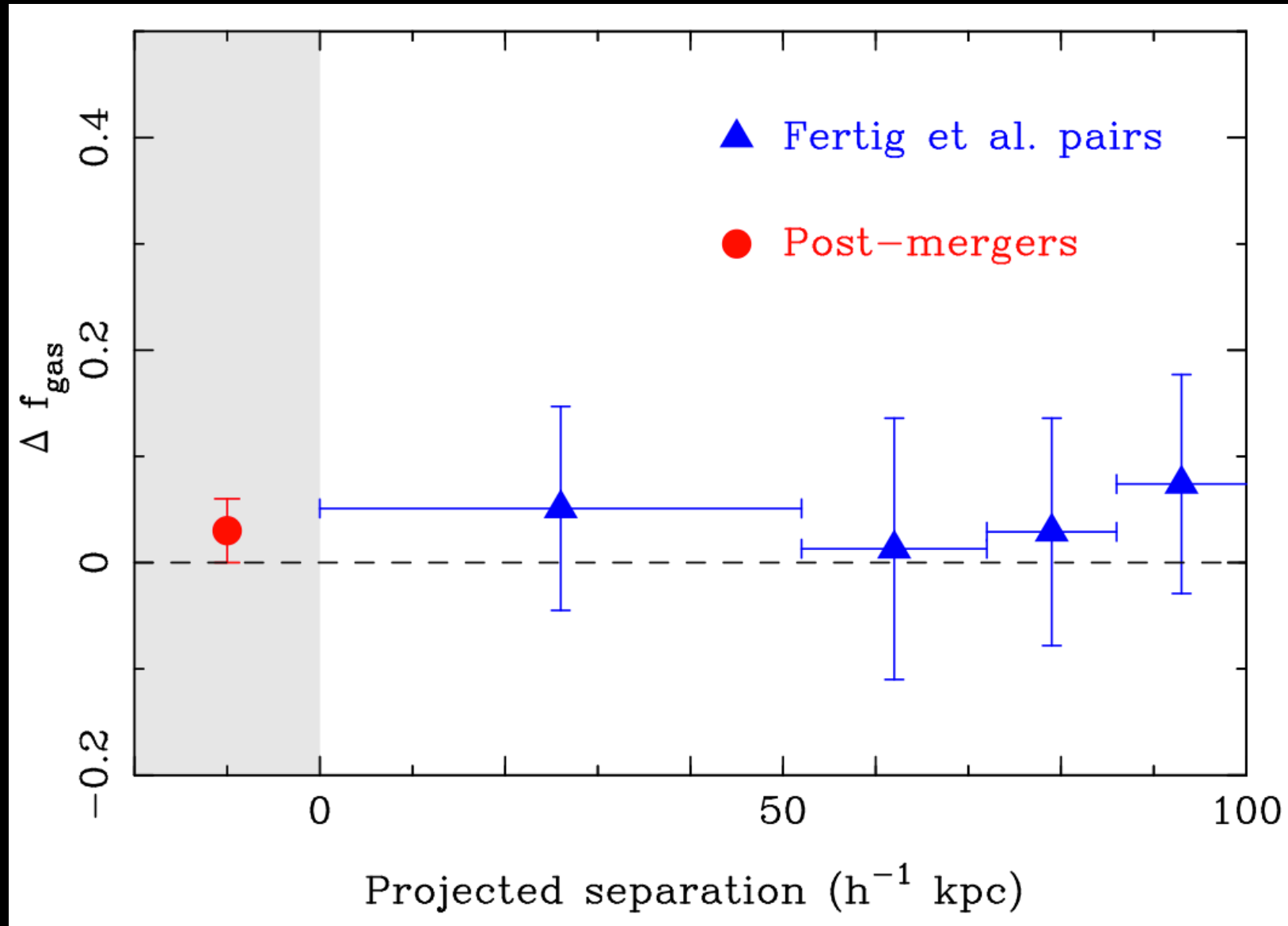
HI Postmergers Sample

Lead by Sara Ellison (2015, MNRAS, 448, 221)

- Selected from SDSS (Darg et al 2010; Nair & Abraham 2010)
- Single galaxy in SDSS
- Disturbed morphologies
- HI detections from ALFALFA (31) and additional Arecibo observations (12)
- HI upper limits for 50 postmergers
- Isolated galaxies are used as controls

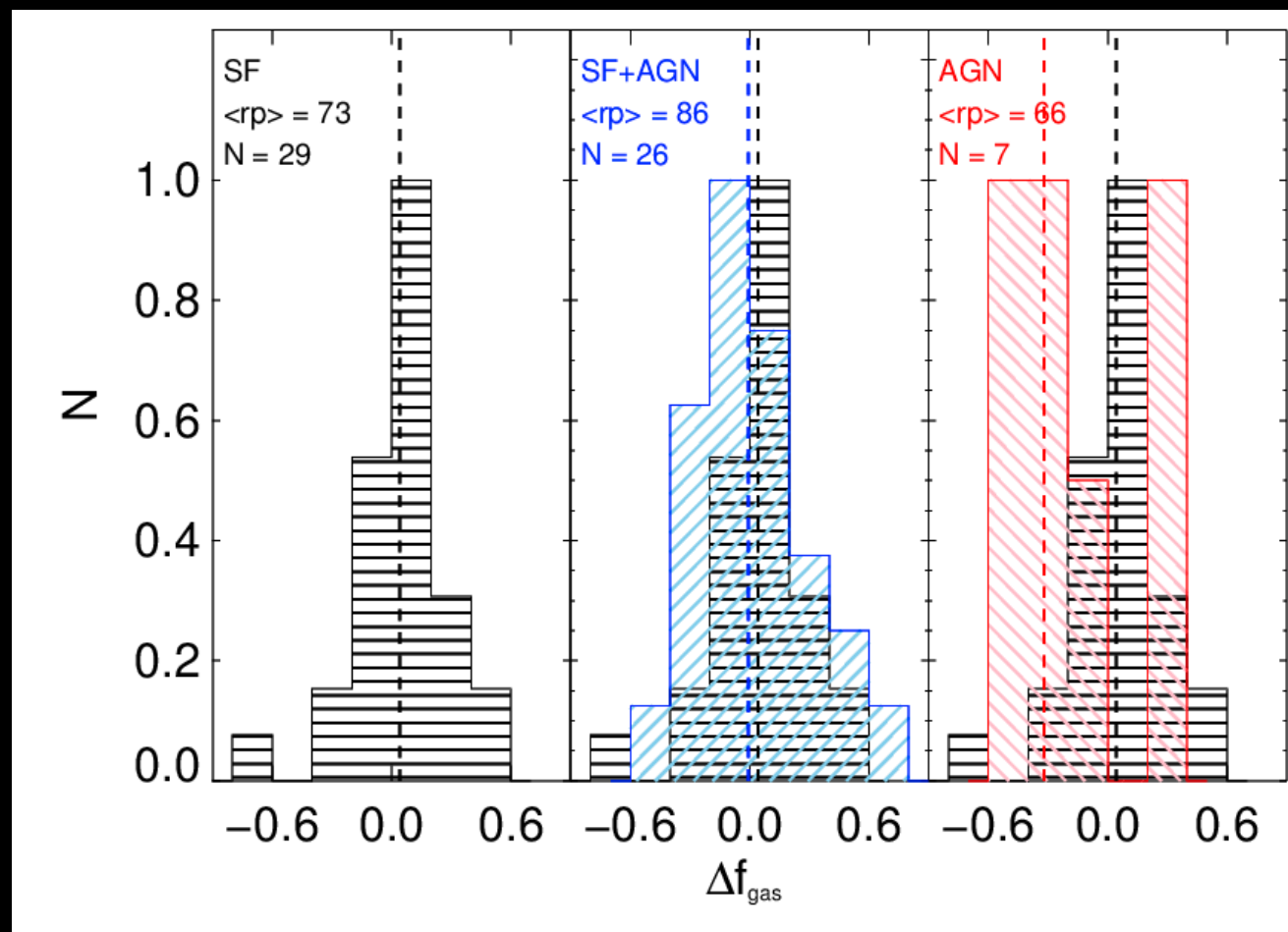


HI Depletion not Observed in Interacting Systems



Does AGN Activity Impact Gas Content?

- Numbers are too small to tell
- Pairs with 2 AGN do have $\Delta f_{\text{gas}} < 0$
- Triggering 2 AGN might be important for depletion
- Need better statistics!



Impact of Pairs on Evolution

- HI tidal tails show impact of interactions
- No measurable gas depletion even through post-merger stage but detection fraction \sim double controls
- Post-mergers may be, on average, more gas rich than isolated galaxies
- Star formation does not significantly deplete gas reservoir during interactions
- AGN might contribute to gas depletion
- Need resolved images to determine impact on gas

**Tidal interactions do not usually
transform galaxies?!**

Virgo, A Laboratory for Studying Galaxy Evolution

- Group environment can have profound impact on evolution of galaxies
- More severely stripped galaxies towards cluster center
- Evidence for tidal interaction on cluster outskirts

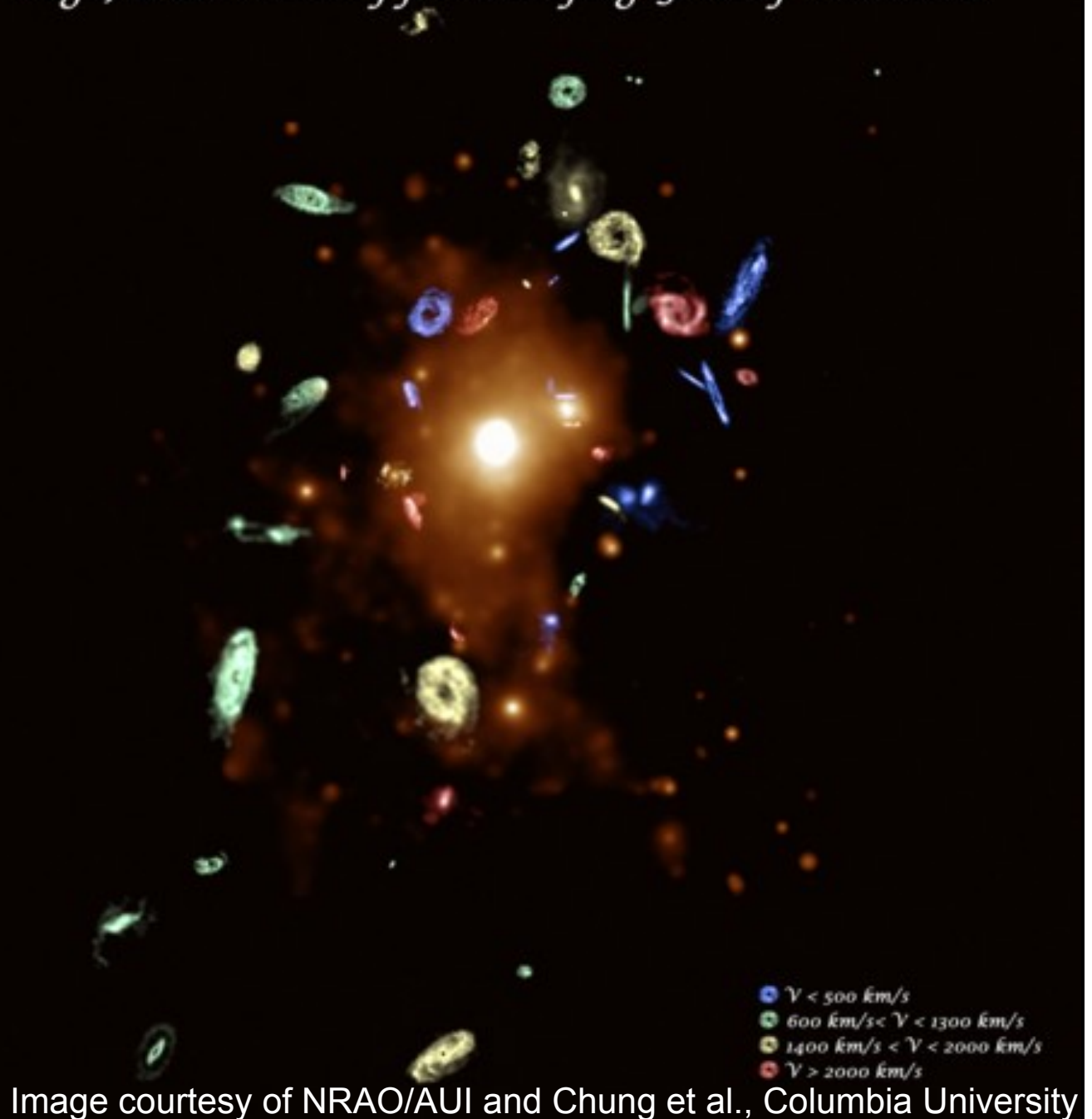


Image courtesy of NRAO/AUI and Chung et al., Columbia University

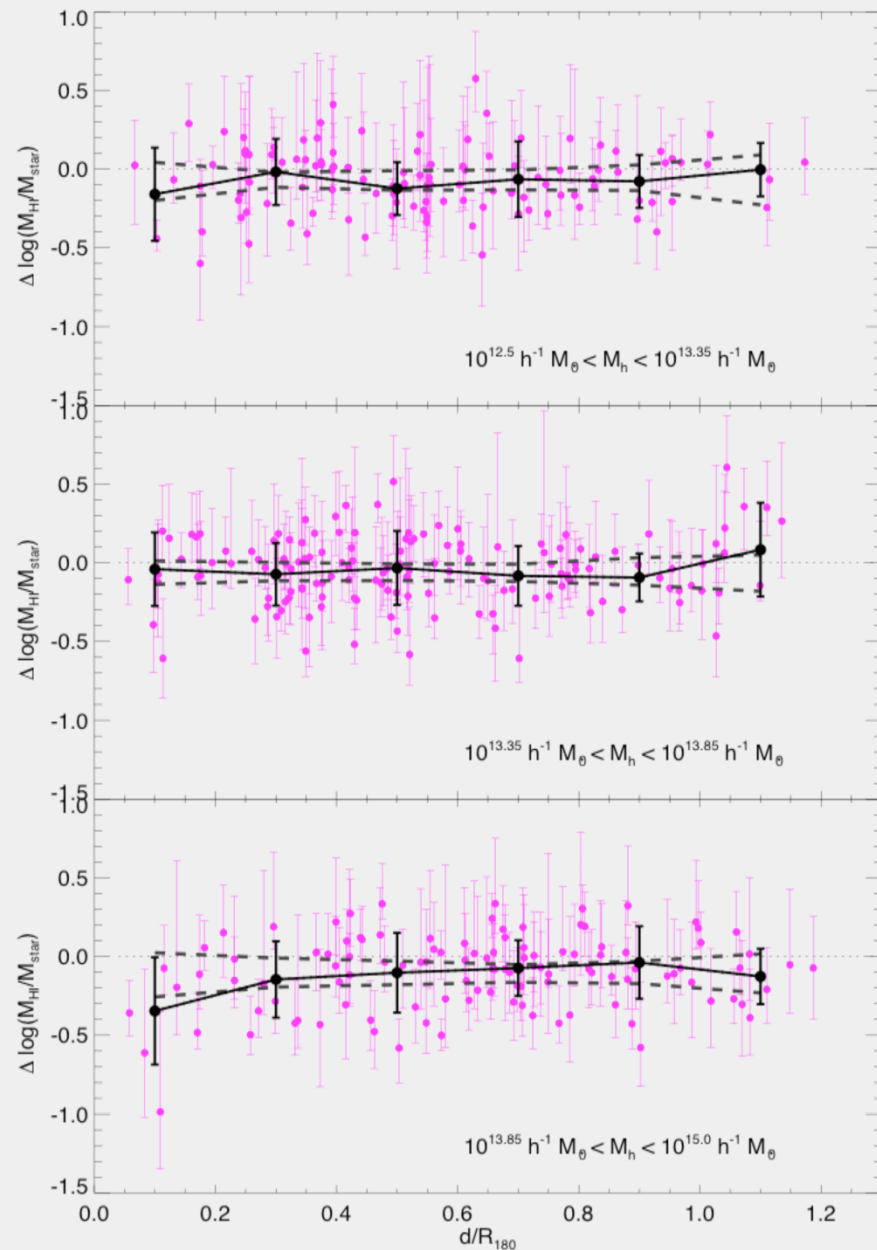
Group Sample

Lead by Ilsang Yoon (ApJ submitted)

- 390 group ($N > 4$) galaxies with M_* , M_{HI} , M_h
- Matched NASA Sloan Atlas (Blanton et al. 2011) and Yang et al. (2007) group catalog within $5''$ and 300 km/s
- Matched HI ALFALFA catalog (Haynes et al 2011) within $40''$ and 300 km/s plus no secondary source within $1.75'$
- 8 controls per group galaxy

Gas Depletion in Galaxy Groups

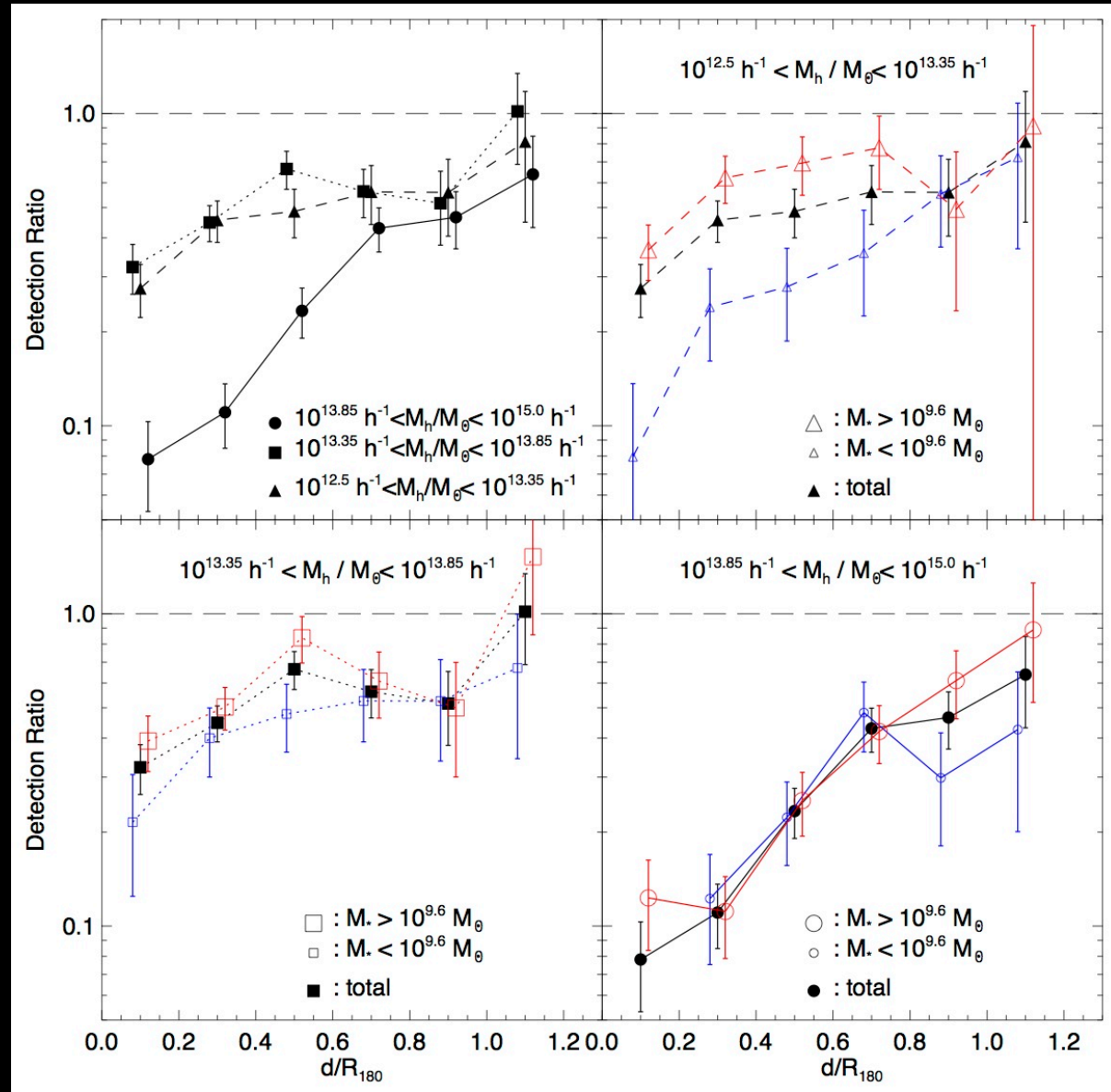
- Marginal depletion of gas seen in the centers of massive halos
- Effect of depletion appears to be small
- Is this lack of depletion real or due to the drop in detectability?



Fraction of Galaxies Detected by ALFALFA

Yoon & Rosenberg
(submitted)

- Detection fraction is smallest in the most massive halos
- In lower mass halos, detection fraction is smallest for low mass galaxies
- Low mass galaxies depleted relative to field in cluster outskirts



Outstanding Questions: Pairs

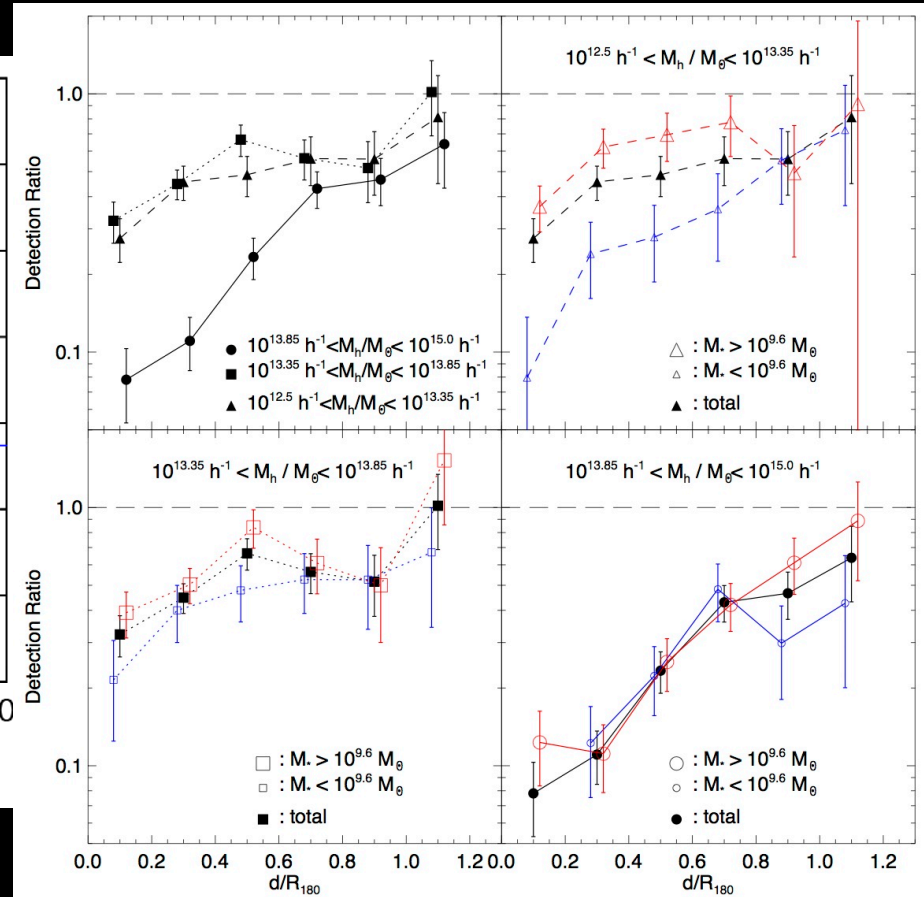
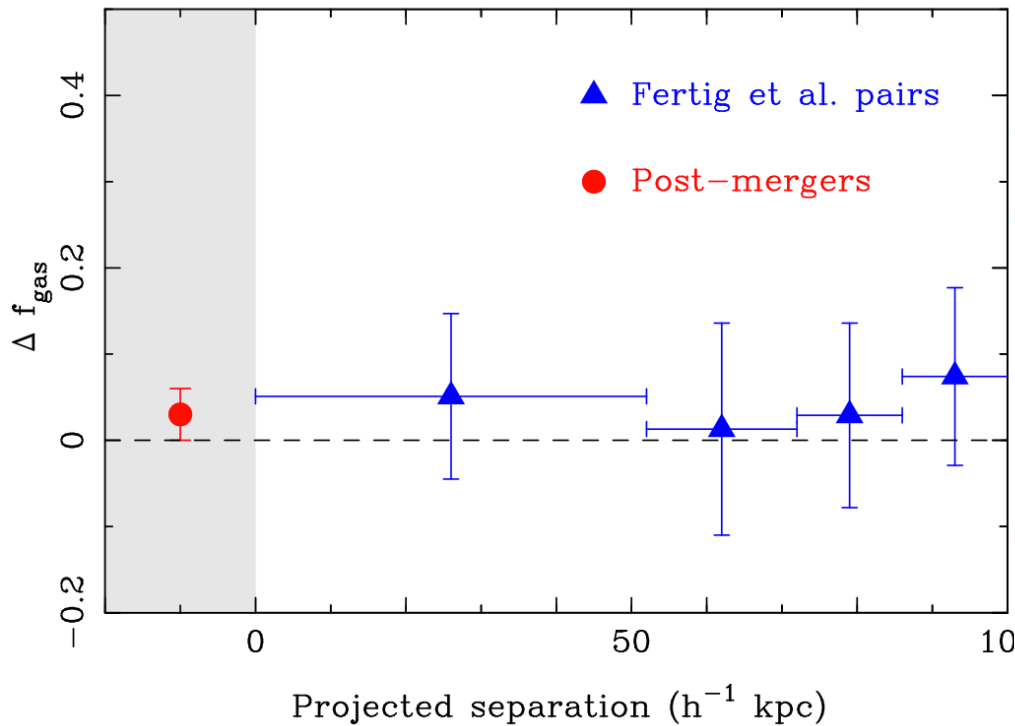
- No gas depletion is seen in galaxy pairs
- Most present day pairs won't transform into ellipticals
 - Can we get better limits on depletion in pairs with deep surveys?
 - Is there evidence for accretion from halos during mergers?
- Dual AGN triggering in pairs may be important for gas depletion
 - How do AGN impact the transformation of galaxies?

Outstanding Questions: Groups

- Depletion is hard to detect in groups and clusters
- Detection fraction drops towards the center of groups and clusters
- Some evidence for preprocessing – small galaxies less detected in groups and missing in outskirts of clusters
- As with the pairs, deeper observations to get detections and/or more stringent limits on gas fraction in groups

Summary:

We need more detailed measurements of gas in interactions and groups to see where the gas goes

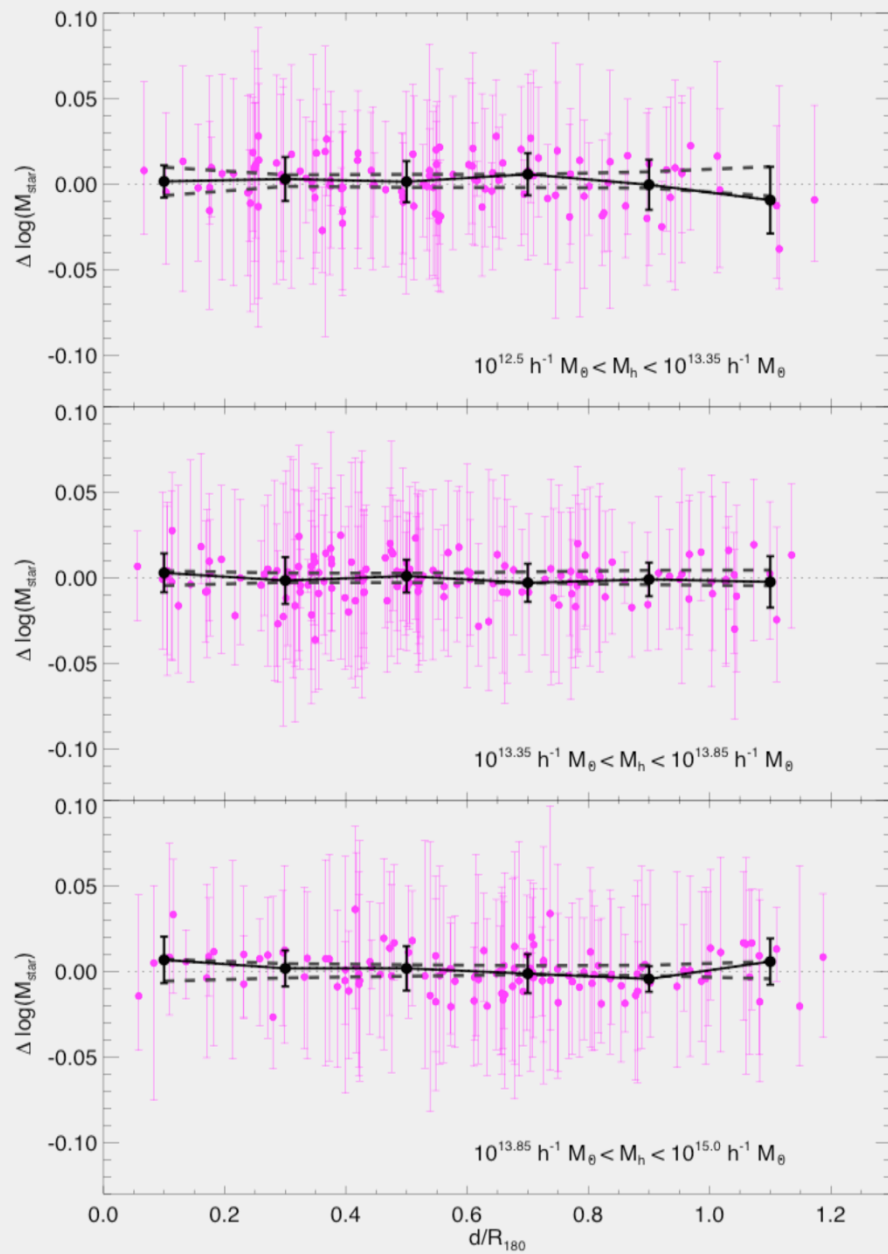


Impact of Groups on Evolution

- Hard to measure decrease in gas content in groups
 - Marginal evidence for depletion
- Find that decrease in detection fraction implies gas depletion

Preprocessing

- Smallest galaxies missing towards group centers
- Marginal evidence that smallest galaxies missing at edge of clusters



Ram Pressure Stripping

