“HI gas properties of galaxy pairs in cluster environments from ASKAP pilot observations”

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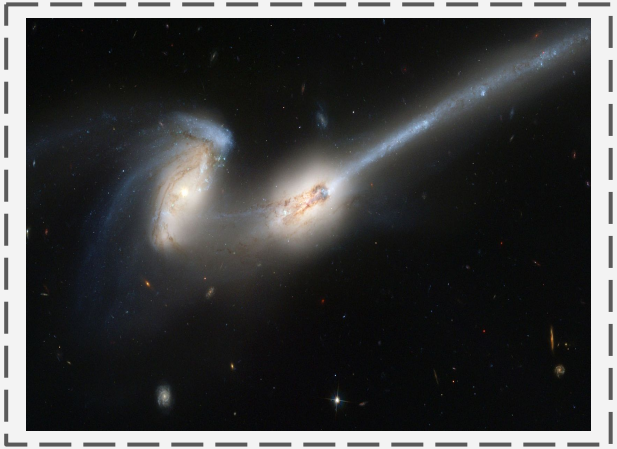
Why galaxy pairs?

- Galaxy mergers and tidal interactions can affect:

- gas properties and star formation
- trigger or quench star formation

➔ galaxy formation and evolution

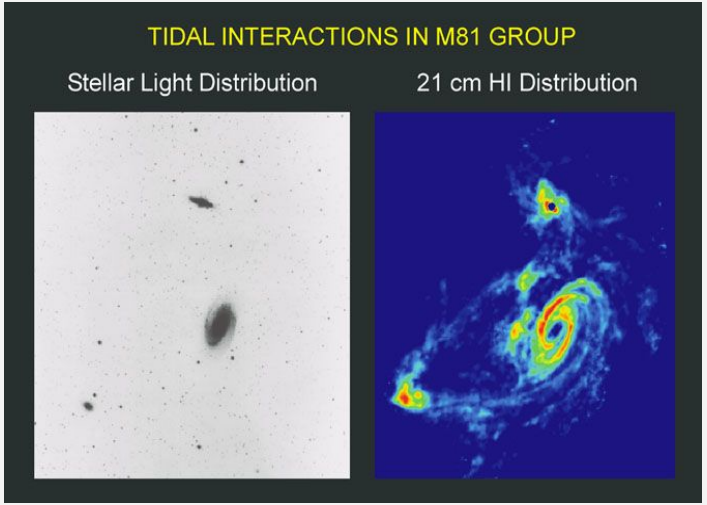


credit: NASA/ESA

HI gas of galaxies

HI gas of galaxies in close pairs is a good tracer for the study of environmental effects on the physical conditions of cold gas in the galaxies.

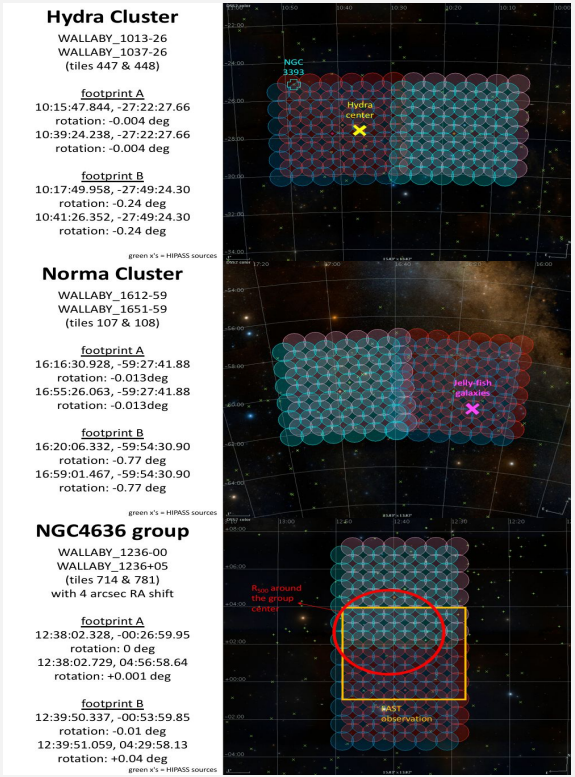
- ➔ HI gas is usually more extended than stellar components in a galaxy.
- ➔ High-resolution HI interferometric observations for close galaxy pairs enable to obtain spatially resolved information about the HI distributions and kinematics



Credit: NRAO/NUI/NSF

WALLABY (ASKAP all-sky HI galaxy survey) pilot survey

WALLABY



- ➔ Neutral hydrogen emission all-sky galaxy survey
- ➔ Aim to detect ~500,000 galaxies at $0 < z < 0.26$
- ➔ High-resolution HI 21 cm data of galaxies in clusters and groups
- ➔ 3 priority fields: Hydra cluster, Norma cluster, and NGC 4636 group

Selection of galaxy pair candidates

Galaxy pair candidates

1) Spectroscopic companion
→ Rp: projected separation between the two galaxies
→ ΔV: relative line-of-sight velocity

Rp <= 50 kpc and ΔV <= 300 km/s or 50 <= Rp <= 100 kpc and ΔV <= 100 km/s (Ventou et al. 2019)

2) Visual inspection
→ 30 galaxy pairs are identified in the Hydra and Norma clusters and NGC 4636 group.

Isolated (control) samples
: without nearby companions

Environmental effects on the resolved HI properties of galaxy pairs

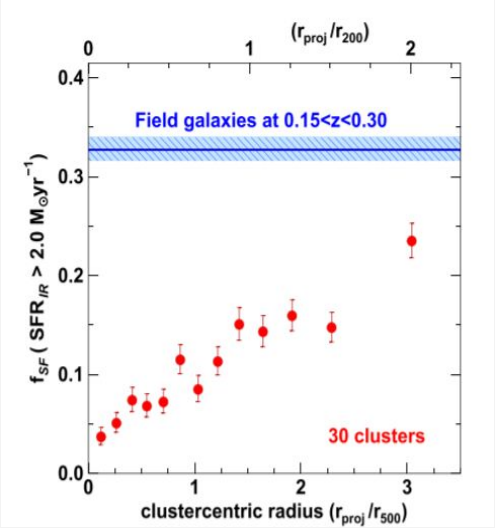
- Galaxy-galaxy interaction
  - triggers/suppresses star formation in galaxies.

- Dense environments (clusters or groups)
  - are more likely to quench star formation in galaxies.

Project Goal
Then how are the HI properties of galaxy pairs affected by cluster environments ?

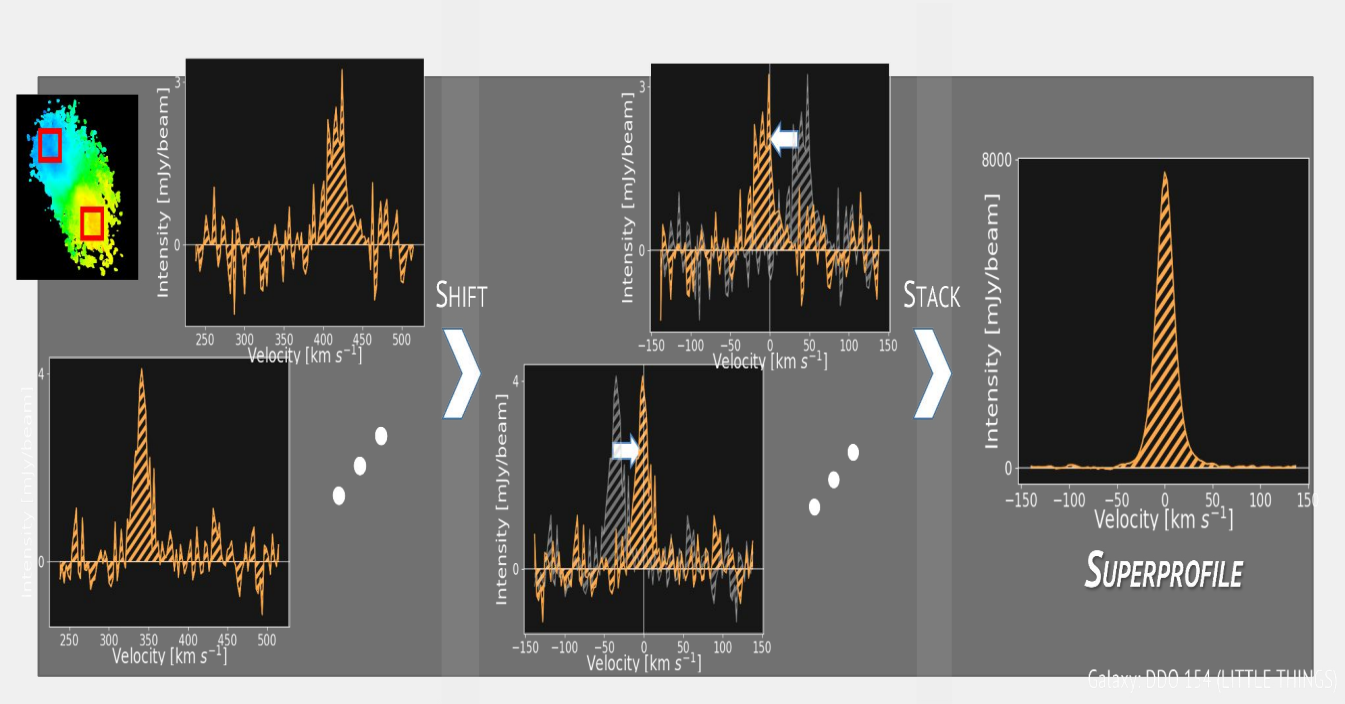
1) Different HI kinematic phases (narrow and broad components)
2) Toomre Q parameters
3) Morphological HI asymmetries

Cluster environmental effects

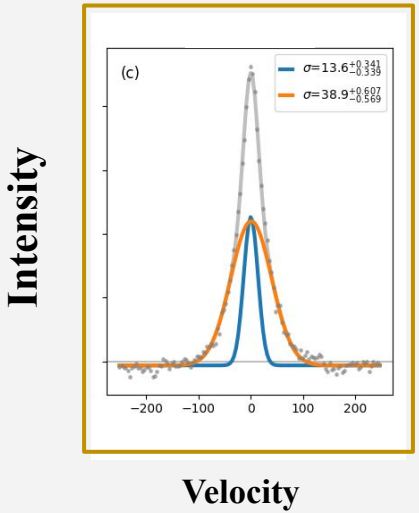


@ Haines et al. 2015

HI superprofiles of sample galaxies



HI superprofiles of sample galaxies



(orange): kinematically broad HI gas components with broader velocity dispersion

(blue): kinematically narrow HI gas components with narrower velocity dispersion

total HI = kinematically narrow + kinematically broad HI

➔ Construct HI superprofiles by stacking individual line-of-sight velocity profiles of HI data cube.
➔ Decompose an HI superprofile into narrow and broad Gaussian components.

Kinematically decomposed narrow HI gas

kinematically narrow HI gas → Molecular hydrogen (H_2) gas → SF

- ➔ H_2 gas in galaxies is fuel for star formation, which is sustained or fed from cold HI gas (Bigiel et al. 2008).
- ➔ HI gas should have passed the kinematically narrow (cold) HI gas phase before turning to H_2.
- ➔ Kinematically narrow HI gas can be associated with the H_2 component in galaxies (Ianjamasimanana et al. 2012)

Toomre Q parameter

- Toomre Q parameter

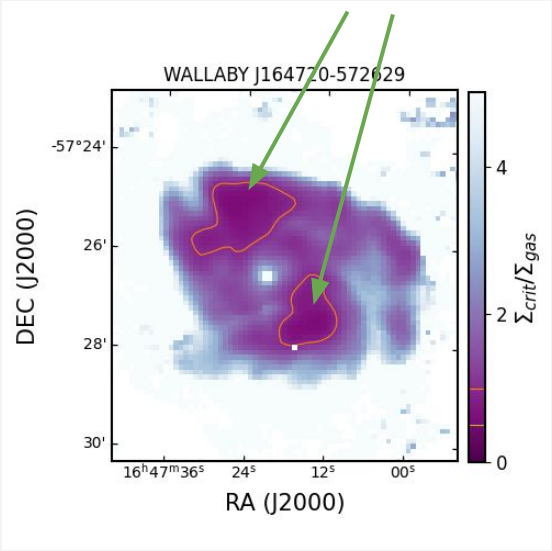
Gas velocity dispersion

Epicycle Frequency

$$Q_{gas} = \alpha \frac{\sigma_g \kappa}{\pi G \Sigma_{gas}} \qquad \Sigma_{crit} = \alpha \frac{\sigma_g \kappa}{\pi G}$$

Gas surface mass density

Unstable region
(Q < 1)



- Q < 1: unstable against gas collapse and star formation
  → Gas surface density is larger than critical gas surface density
- Median Q value of entire disk region is ~ 2.2.

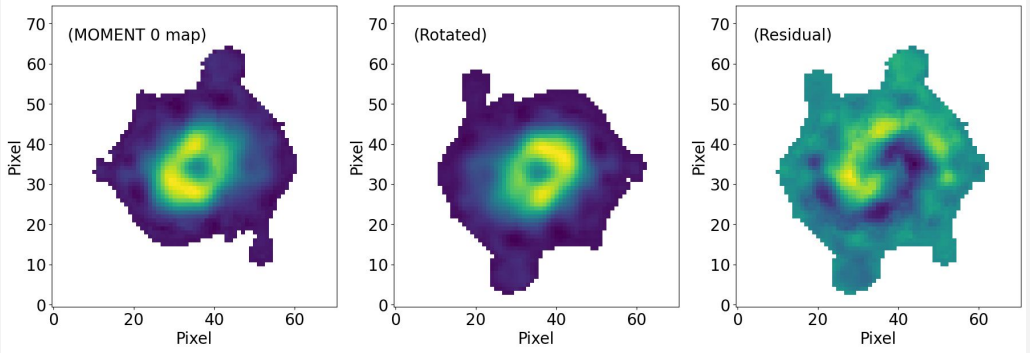
HI asymmetry

$$A_{map} = \frac{\Sigma_{i,j}|I(i,j) - I_{180}(i,j)|}{2\Sigma_{i,j}|I(i,j)|}$$

Integrated intensity

180 degree rotated Integrated intensity

Integrated intensity | Rotated map | Residuals

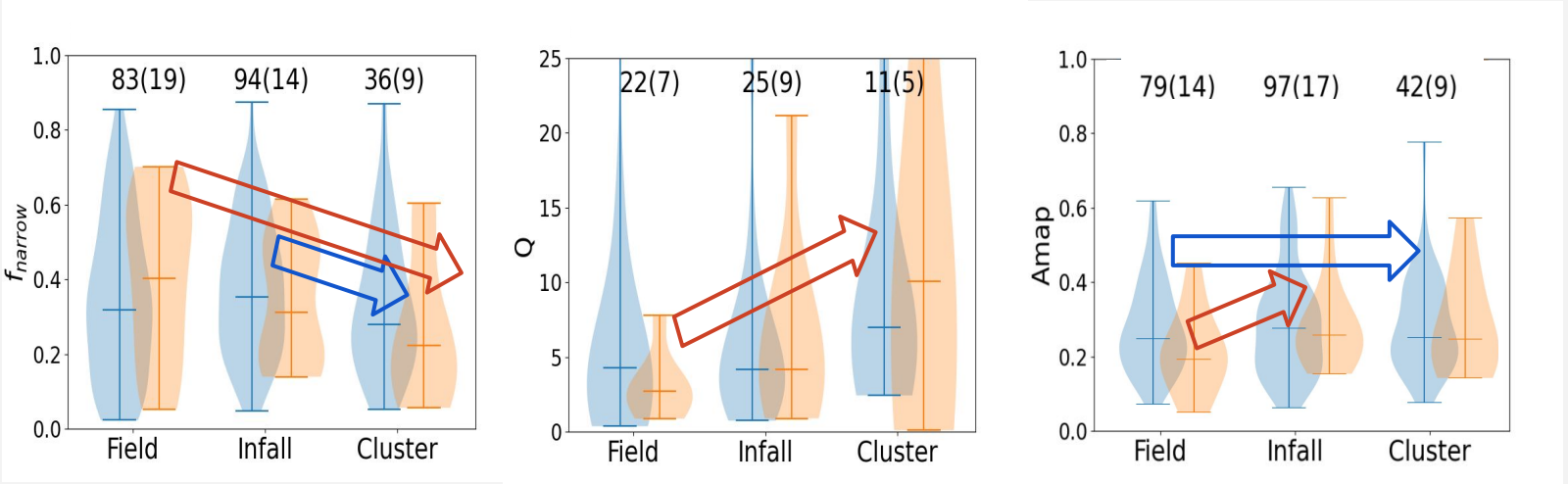


- ➔ Quantify HI morphological disturbances of the sample galaxies using their integrated intensity maps.
- ➔ An example galaxy has Amap = 0.19
- ➔ The higher asymmetries, the more disturbed.

Environmental effects on the resolved HI properties of galaxy pairs

As the galaxies are infalling into the deep cluster, the properties of galaxies are affected:

fnarrow = (kinematically narrow HI gas mass / total HI mass)
: isolated galaxies, galaxy pairs
N(N): number of control samples (paired galaxies)



1) kinematically cold HI gas components: Decrease

2) Toomre Q parameters: Increase

$$Q_{gas} = \alpha \frac{\sigma_g \kappa}{\pi G \Sigma_{gas}}$$

3) HI morphological asymmetry: No trend

→ preparing for submission to the journal

Summary

We investigate the environmental effects on the resolved HI properties of galaxy pairs.
The main results are:

1. Cluster environment seems to impact the HI gas properties of galaxies in a way of decreasing the kinematically narrow HI gas, and increasing the Toomre Q values of the infalling and cluster galaxies.
   → It might be resulted from that ram pressure stripping or/and tidal interactions in the denser environments increase the gas turbulent motions with higher velocity dispersions.

   → This trend is more evident for the galaxy pairs being closer to the cluster.

2. No clear trend is found for the Amap values in our analysis. More deep future observations are needed in order to investigate the environmental effects on HI morphological disturbances.

→ HI properties of galaxies that are associated with star formation can be spectrally affected by local densities inducing higher velocity dispersions, which is further enhanced in galaxy pairs.