



Bar Formation and Enhancement of Star Formation in Disk Galaxies in Interacting Clusters

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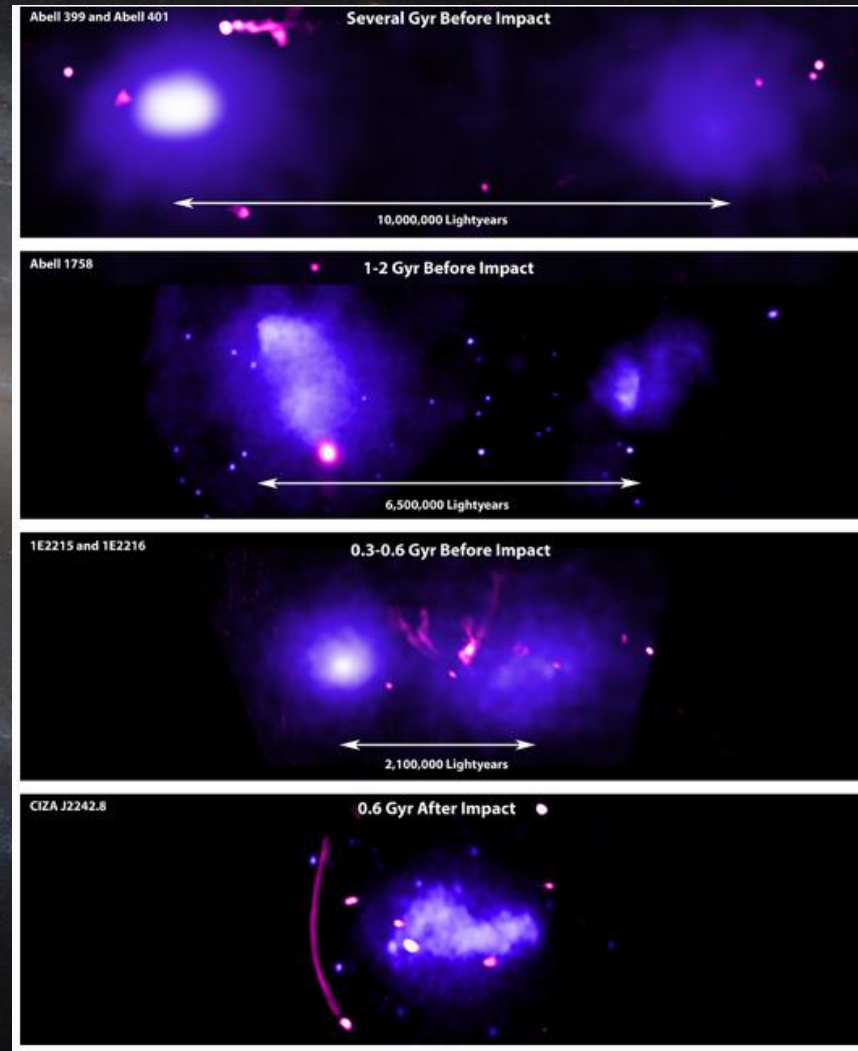
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Introduction

Cluster-cluster interaction: most violent event in the universe

→ Good laboratory to understand galaxy properties under a violent change in the large scale environment.

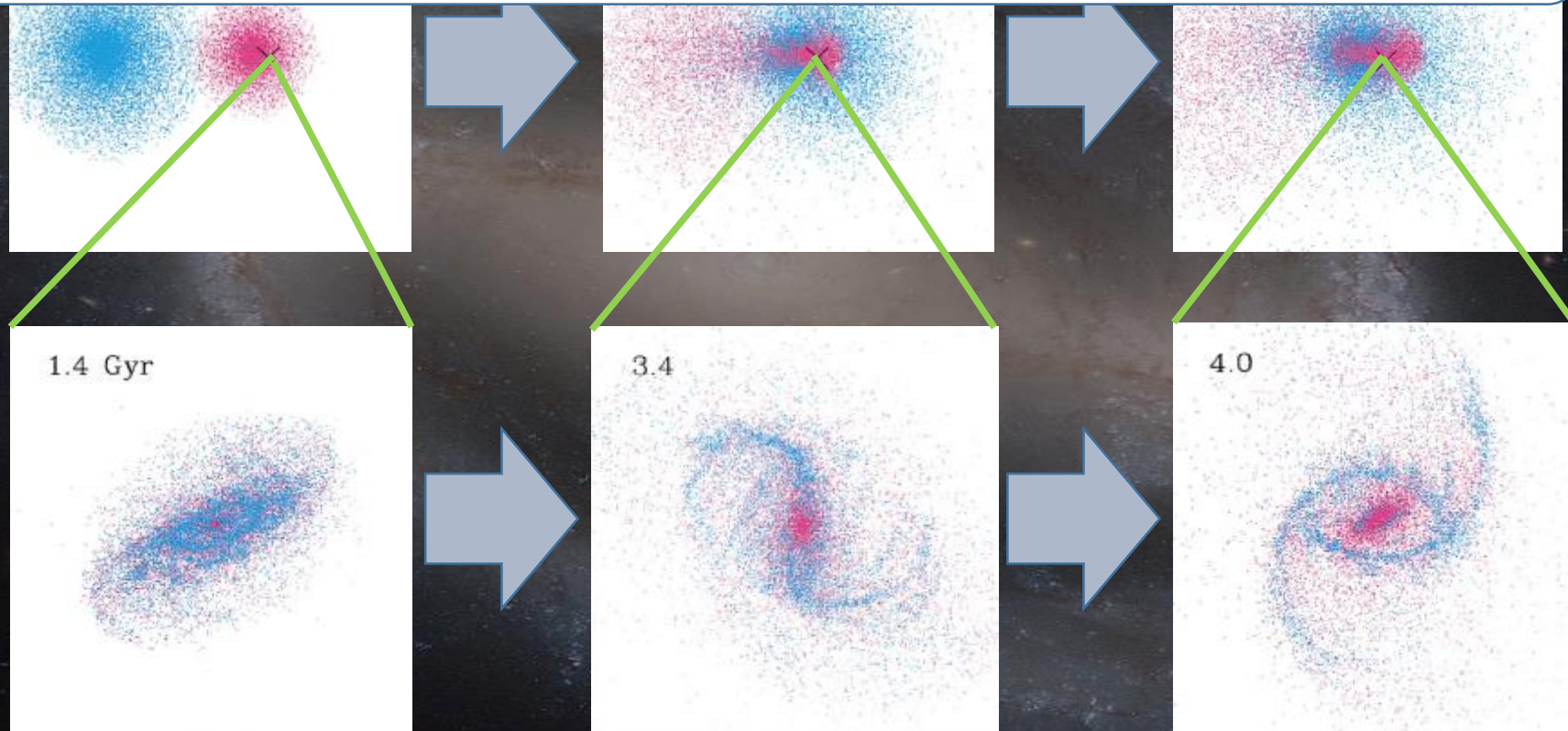


Introduction

Two issues on properties of galaxies in interacting clusters

1. Cluster-cluster interaction induces bars?

No observational studies have been conducted yet.

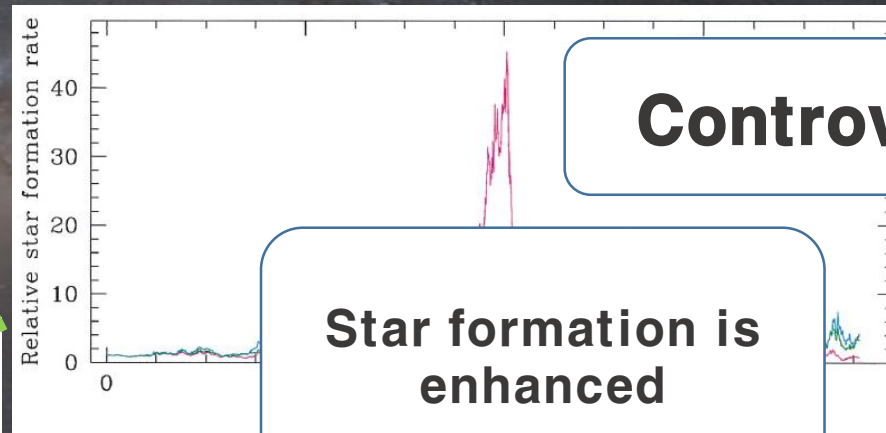
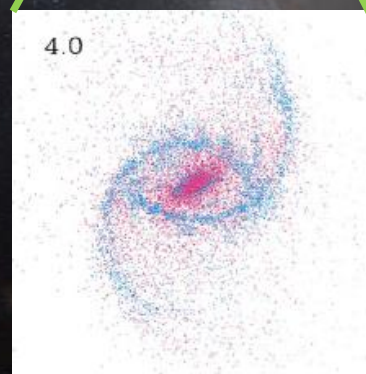
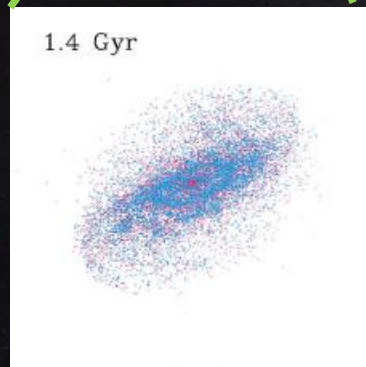
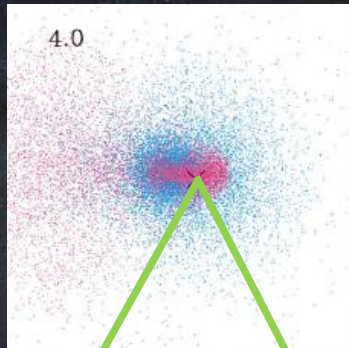
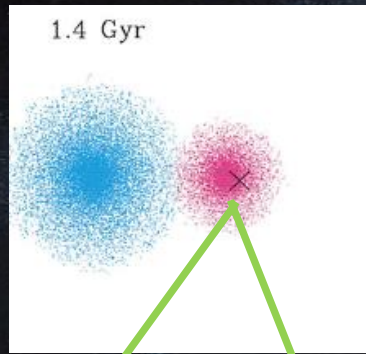


Bekki (1999)

Introduction

Two issues on properties of galaxies in interacting clusters

2. Cluster-cluster interaction enhances star formation rate?



Controversial issue

Star formation is enhanced

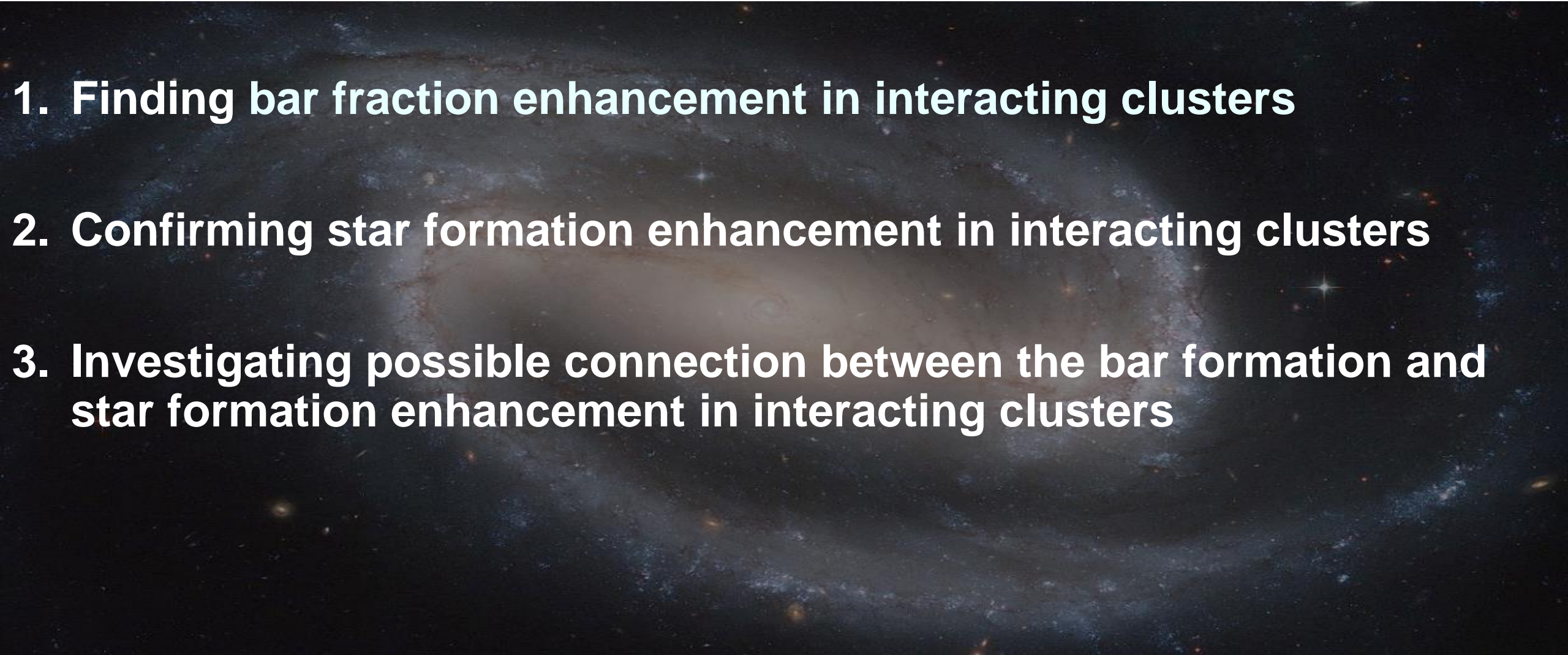
Owen et al. 1999, 2005; Bekki 1999; Miller & Owen 2003; Hwang & Lee 2009; Bekki et al. 2010; Hou et al. 2012; Cohen et al. 2014, 2015; Stroe et al. 2014, 2017; Sobral et al. 2015; Ebeling & Kalita 2019; Soares & Rembold 2019

Star formation is suppressed or NOT enhanced

Tomita et al. 1996; Fujita et al. 1999; Poggianti et al. 2004; Chung et al. 2009; Haines et al. 2009; Shim et al. 2011; Tyler et al. 2014; Deshev et al. 2017; Mansheim et al. 2017

Introduction

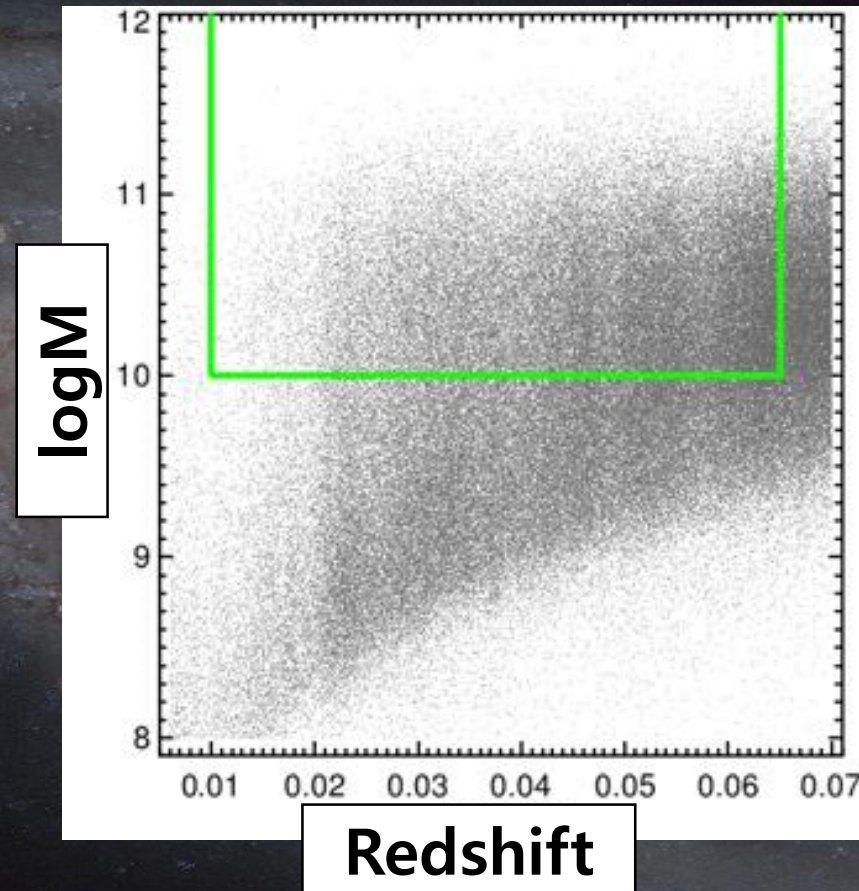
Aims of this study

- 1. Finding bar fraction enhancement in interacting clusters**
 - 2. Confirming star formation enhancement in interacting clusters**
 - 3. Investigating possible connection between the bar formation and star formation enhancement in interacting clusters**
- 
- The background of the slide is a deep space image showing a galaxy cluster. A large, bright, yellowish-white bar structure is visible in the center, surrounded by numerous smaller, distant galaxies and stars. The overall color palette is dark blue and black, with highlights from the galaxies and stars.

Sample & Method

SDSS MPA-JHU catalog

$0.010 < z < 0.065$, $\log(M_{\text{star}}/M_{\text{sun}}) > 10.0$

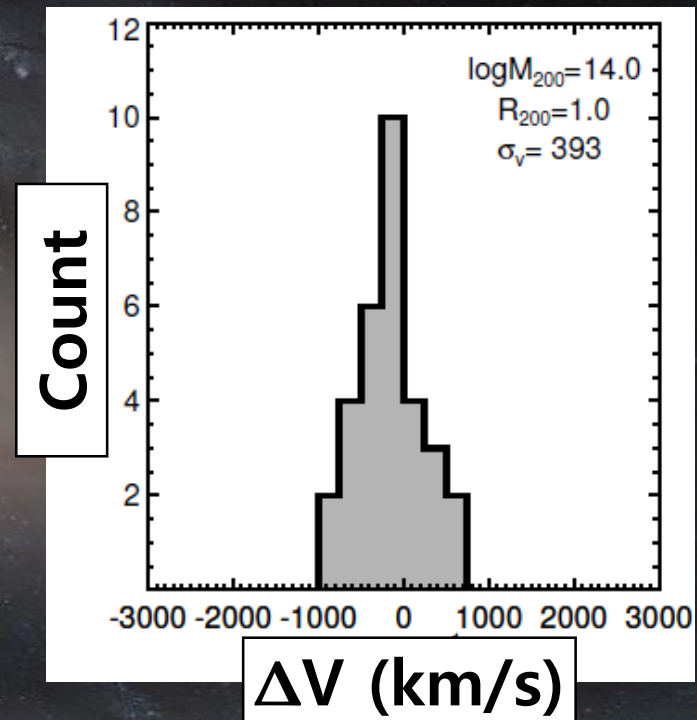
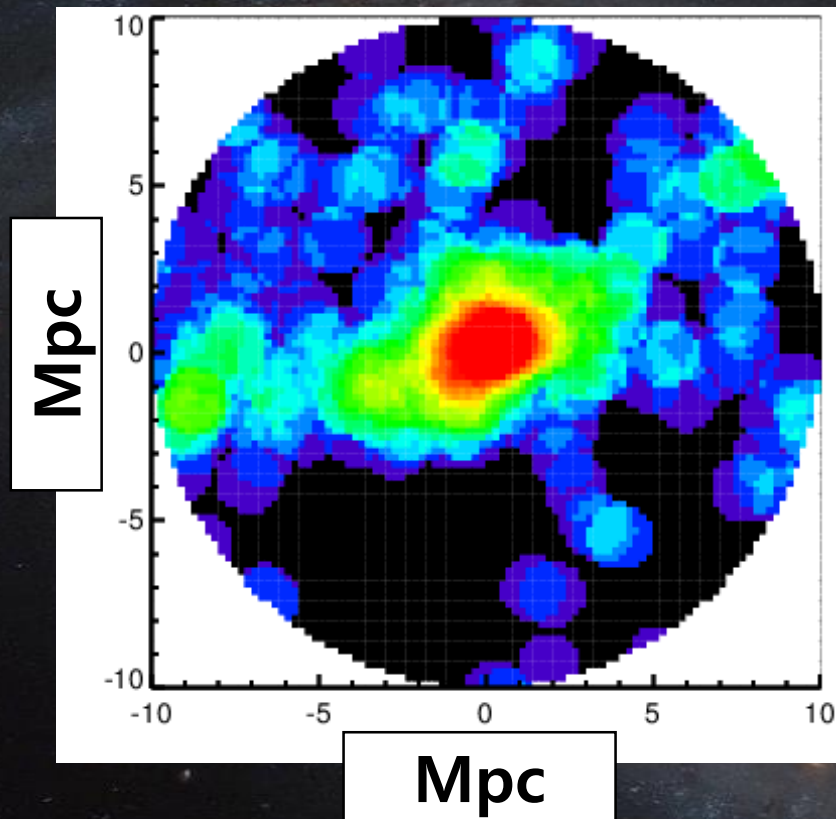


Sample & Method

Cluster identification:

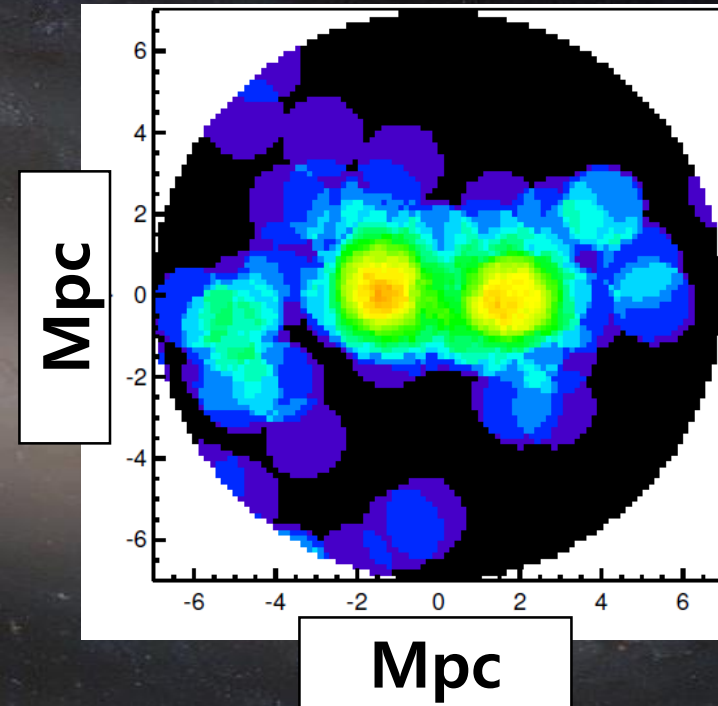
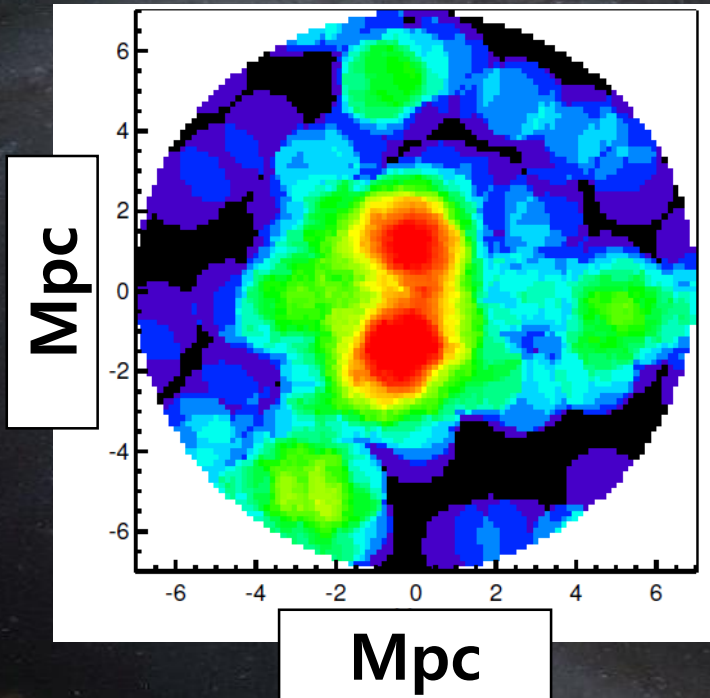
Finding overdense regions (2σ) and measuring dynamical masses

105 clusters with $\log(M_{200}/M_{\text{sun}}) > 13.85$ are found in $0.015 < z < 0.060$.



Sample & Method

Selecting clusters in pairs using criteria for radial velocity & projected distance
7 cluster pairs (14 clusters) are found.

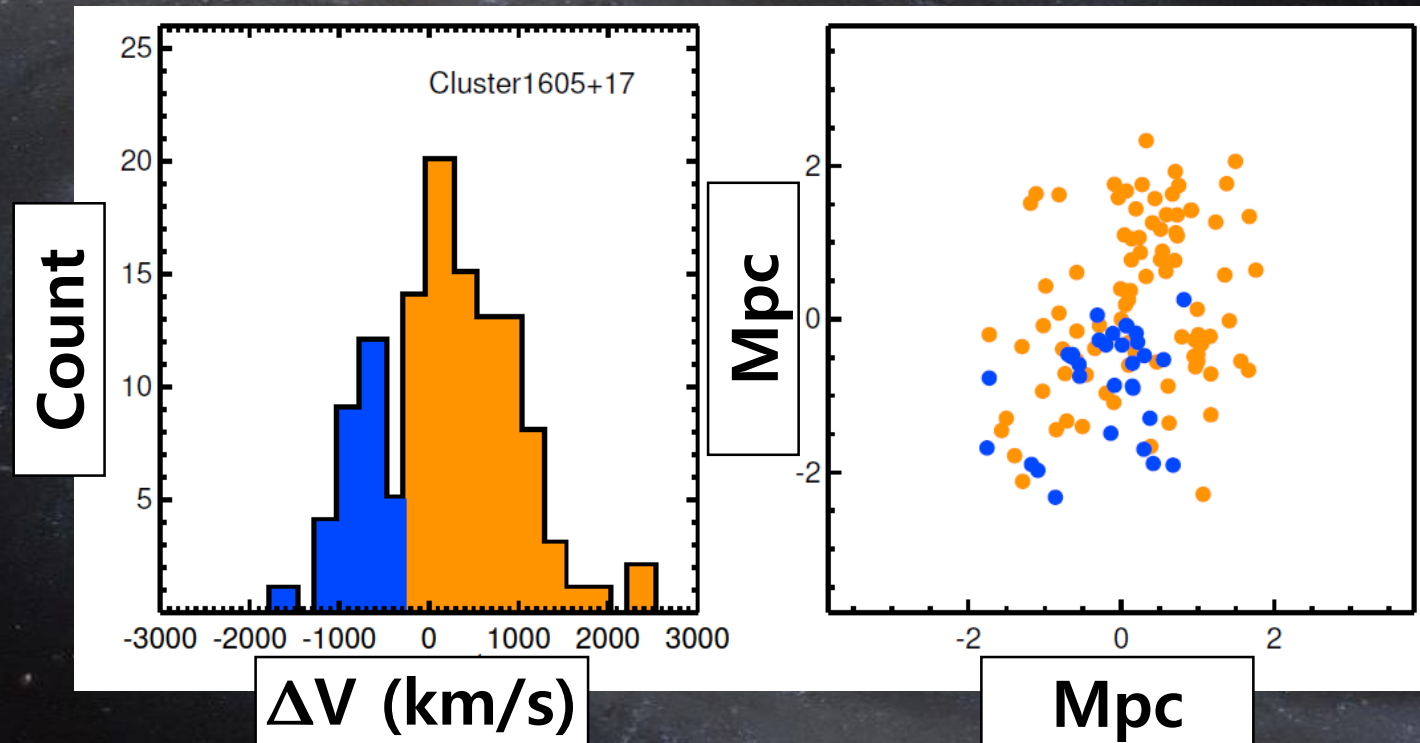


Sample & Method

Selecting clusters having substructures using DS test (Dressler & Shectman 1988)

5 cluster are found (3 clusters are also in pairs).

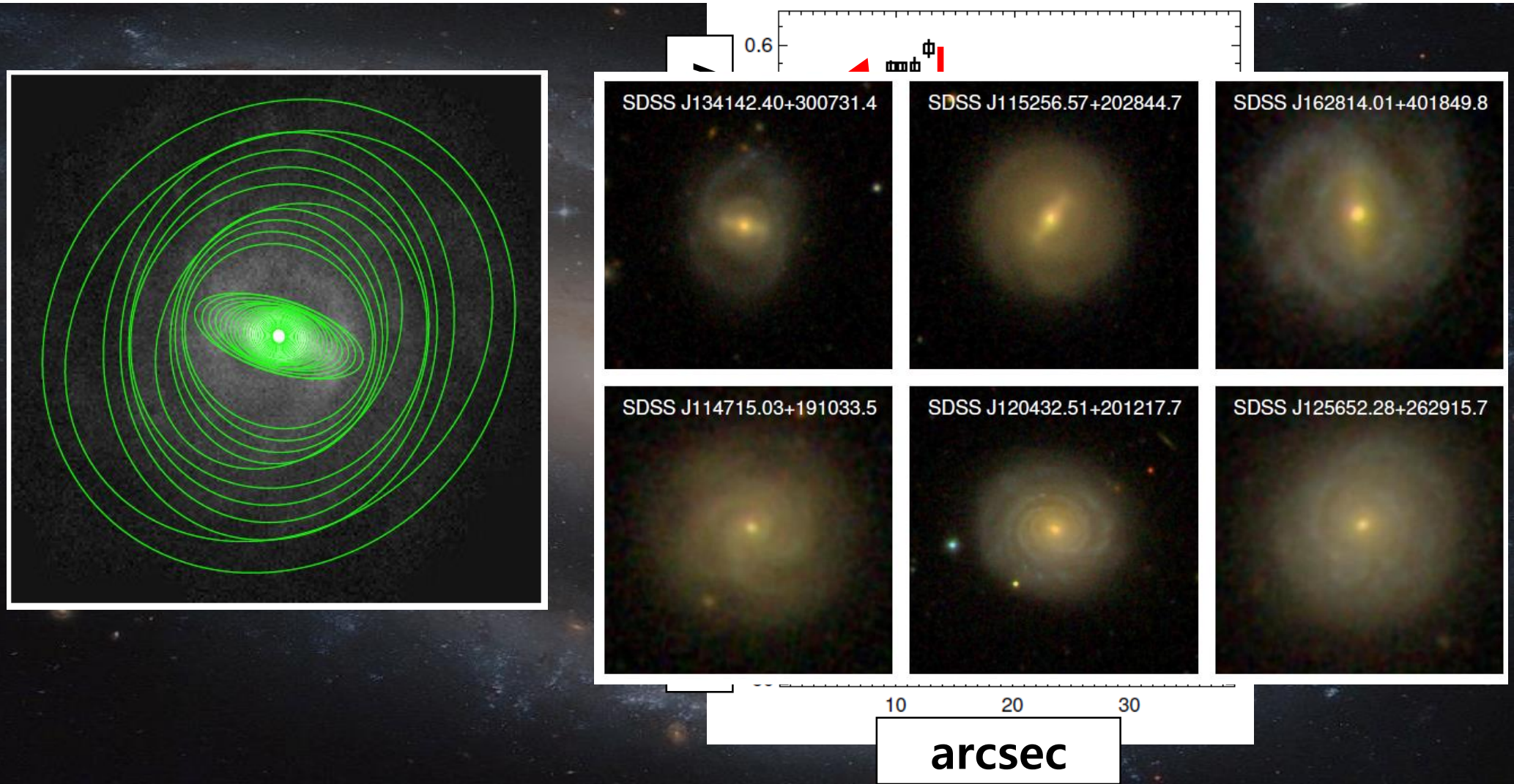
In total, 16 clusters in pairs or with substructures → Interacting clusters



Sample & Method

Classification of bars for member galaxies

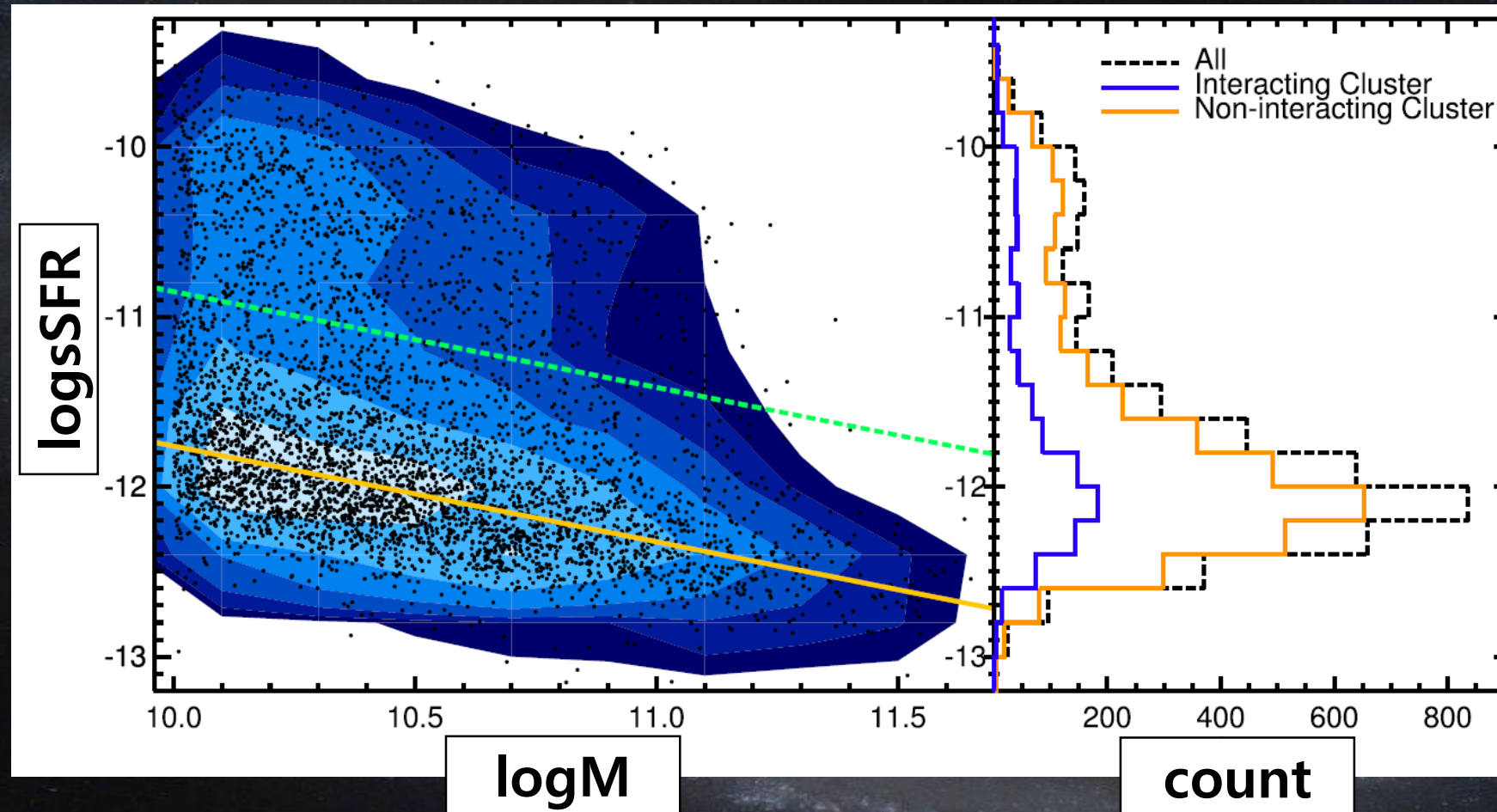
Using the Ellipse task & visual inspection



Sample & Method

Dividing galaxies into high-sSFR and low-sSFR galaxies

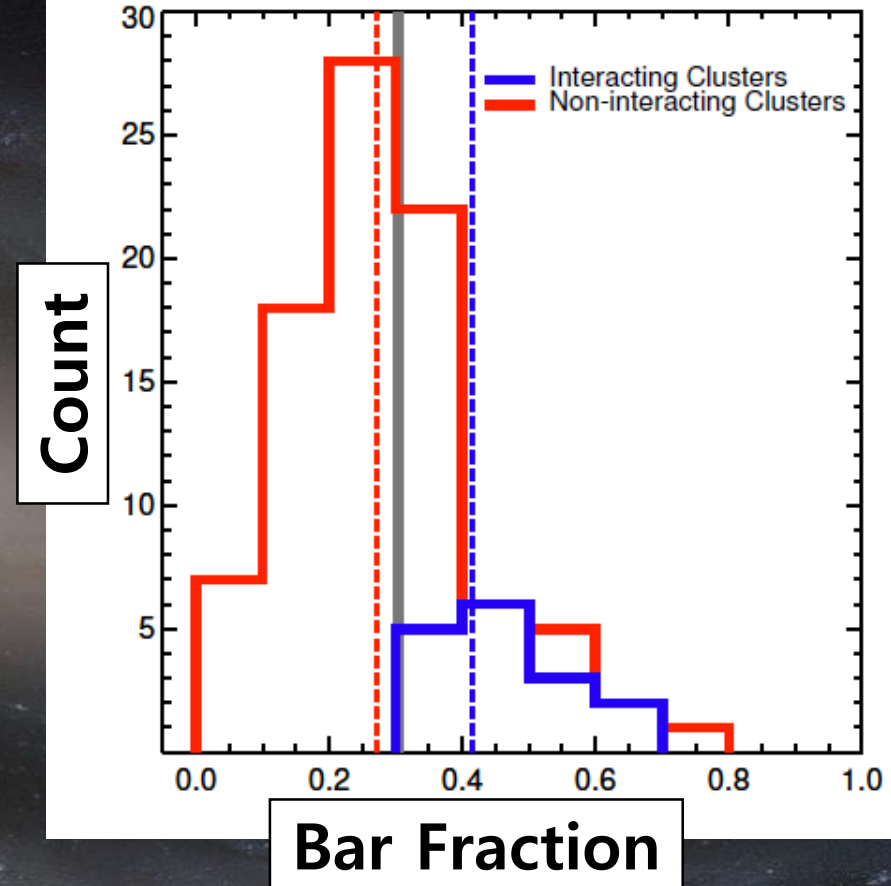
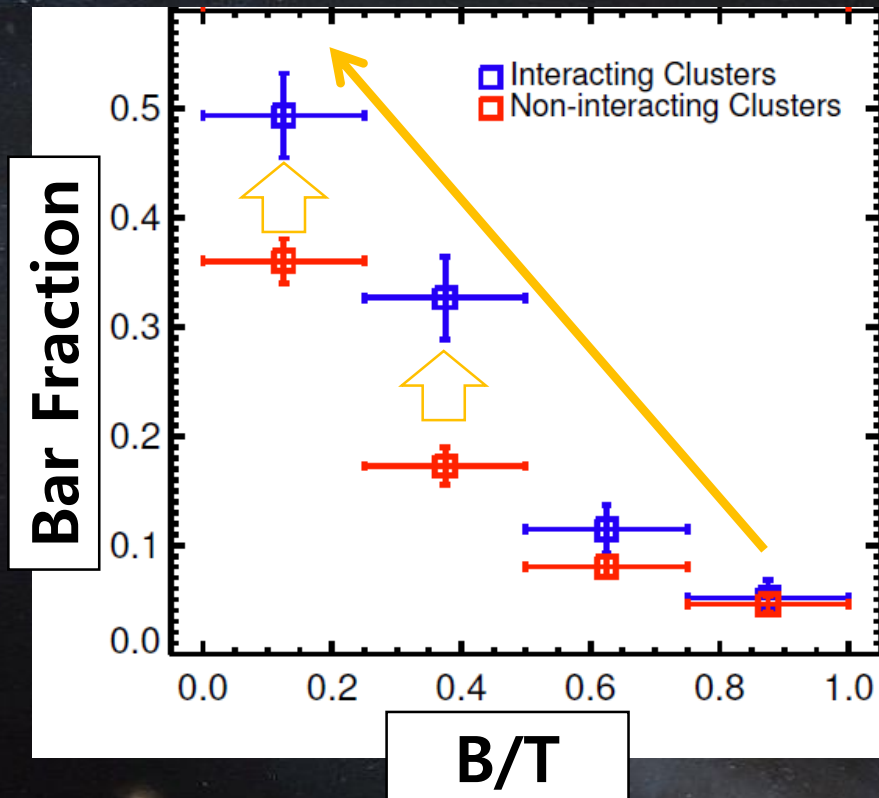
$$\log(\text{sSFR}/\text{yr}^{-1}) = -0.56 \log(M_{\text{star}}/M_{\odot}) - 5.22$$



Results

Bars are more abundant in galaxies with lower B/T.

Bar fraction is enhanced (~1.5 times) in interacting clusters.

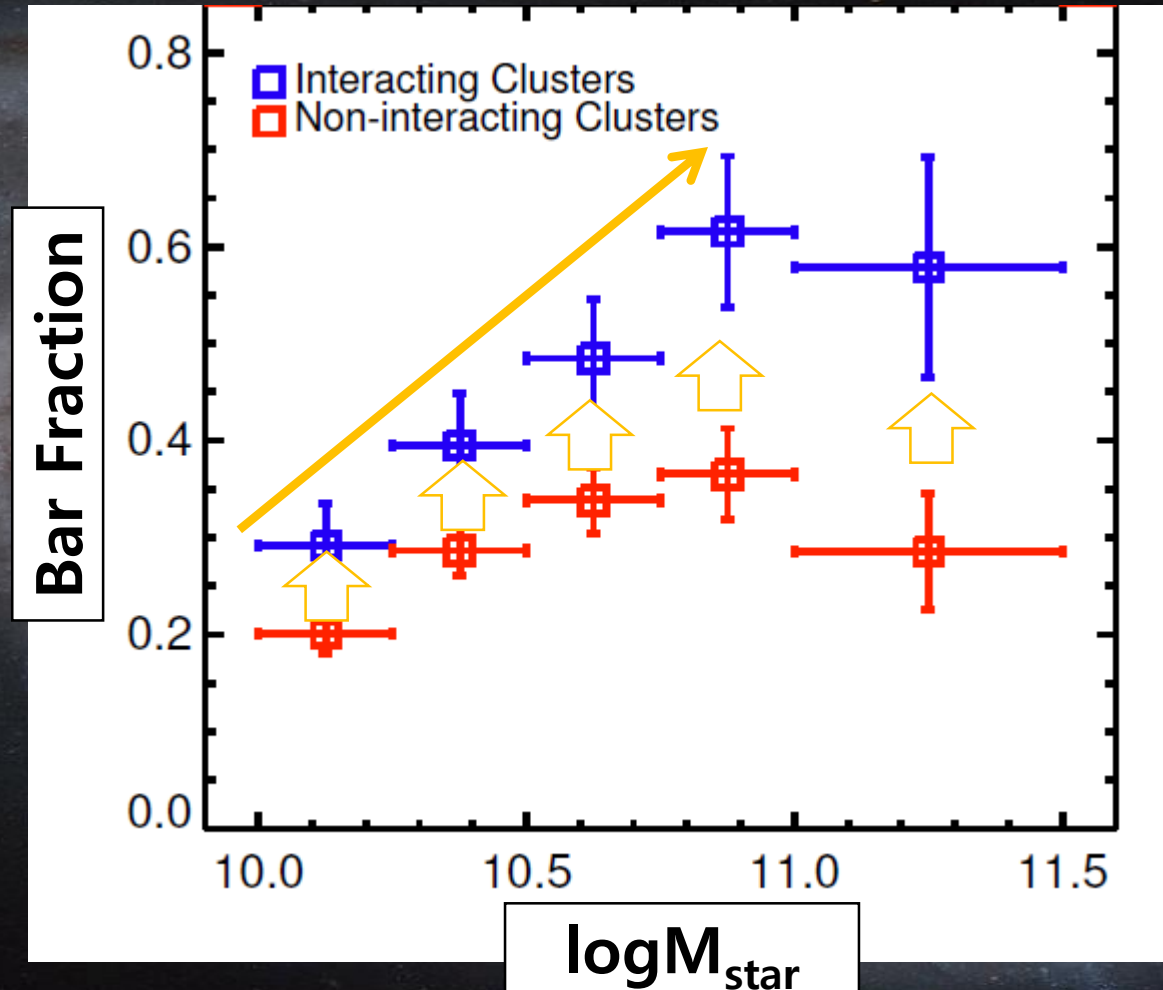


KS test: 99.999% (4.5σ)

Results

Bars are more abundant in galaxies with higher stellar mass.

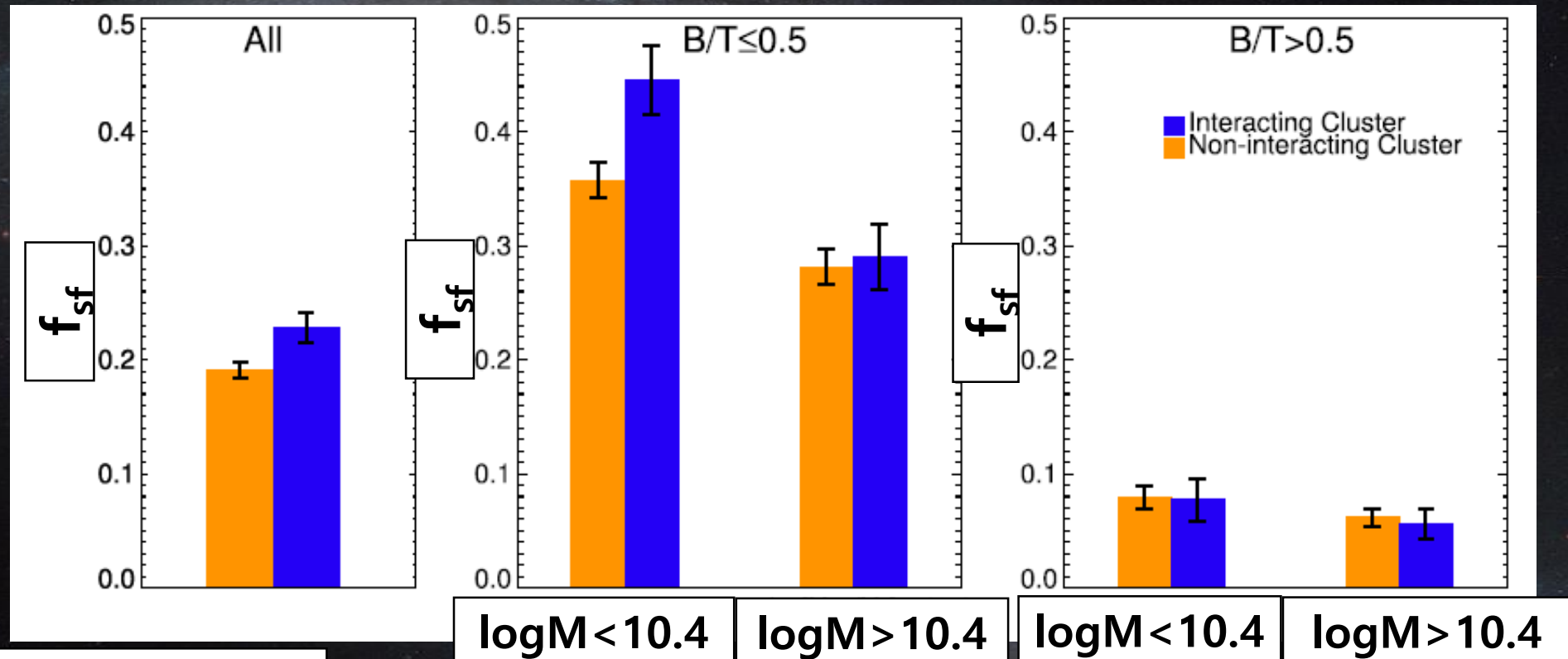
Bar fraction is enhanced in interacting clusters.



Results

f_{sf} is 1.2 times higher in interacting clusters.

The enhancement of f_{sf} occurs only in galaxies with $B/T < 0.5$ and $\log(M/M_{sun}) < 10.4$.

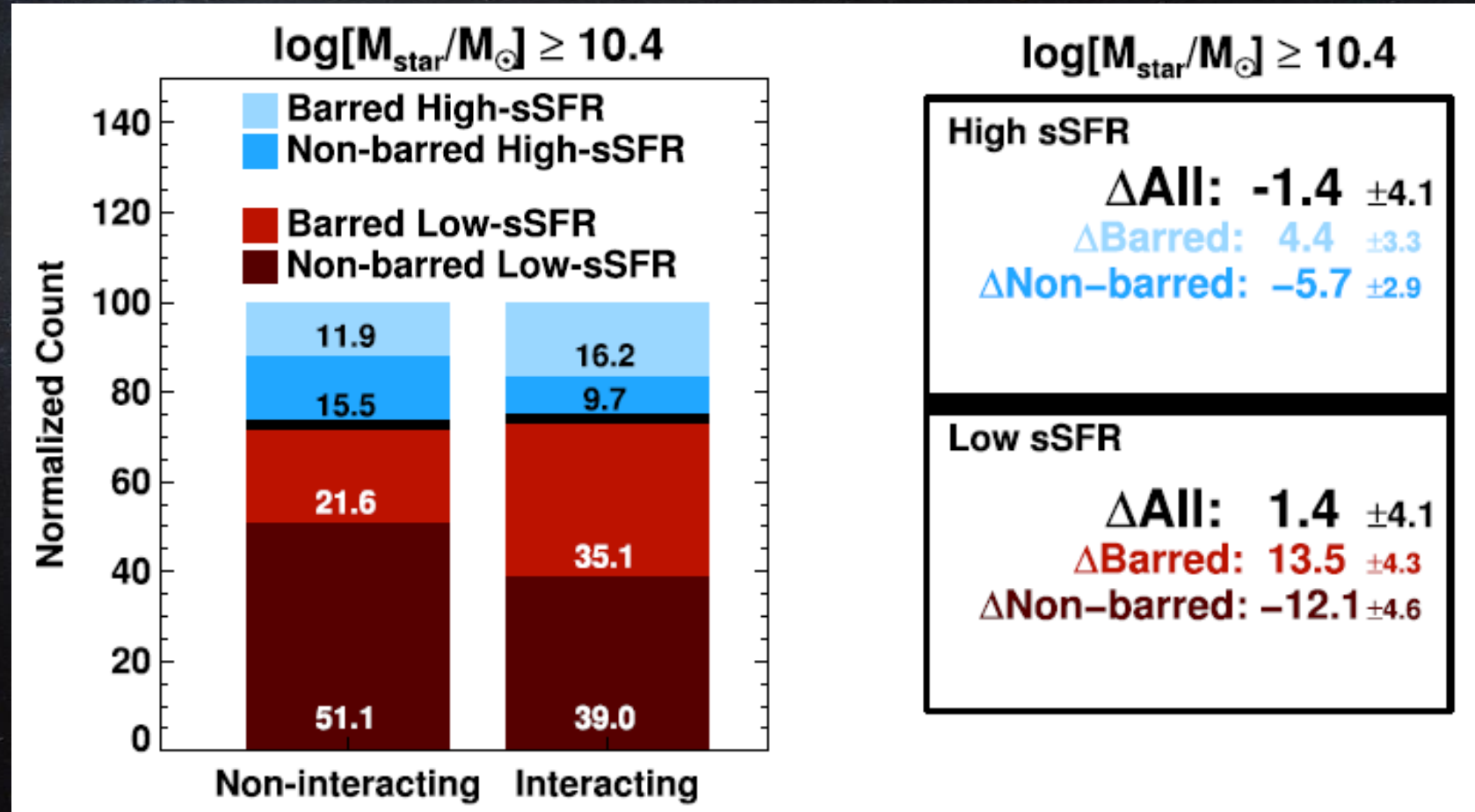


$$f_{sf} : N_{high}/N_{all}$$

Results

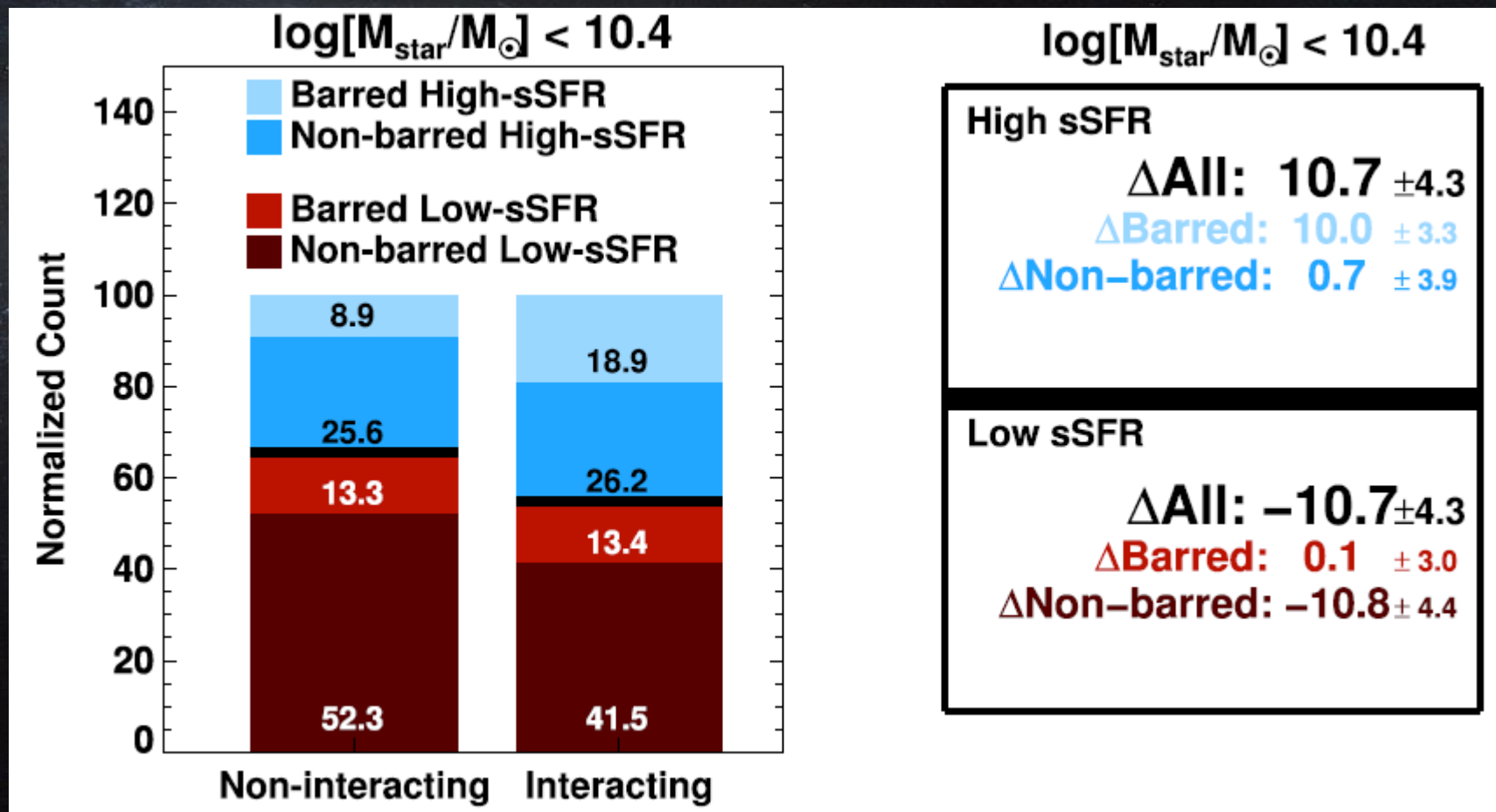
For $\log(M/M_{\text{sun}}) > 10.4$, no transition between high-sSFR and low-sSFR galaxies

Bar fraction increases by a factor of 1.5 in interacting clusters within each low- or high-sSFR bin.



Results

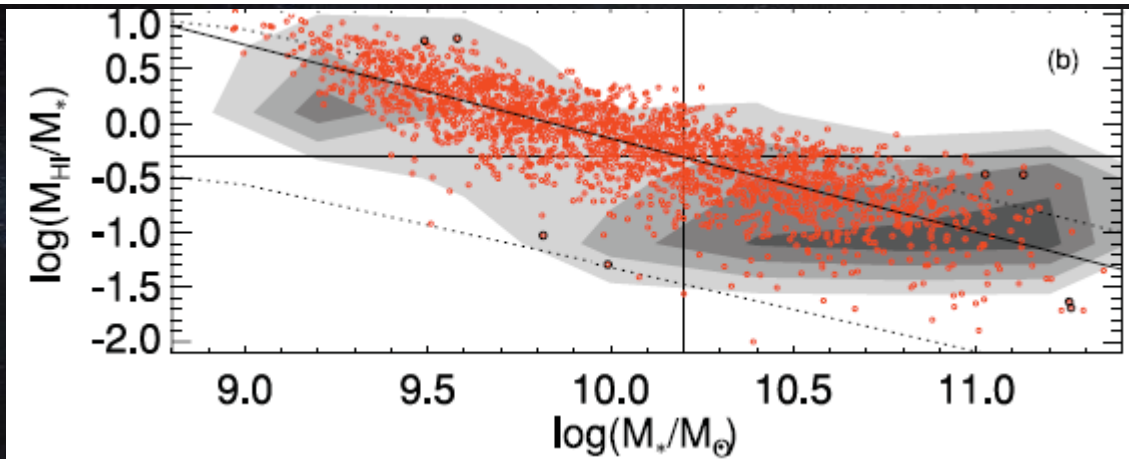
For $\log(M/M_{\text{sun}}) < 10.4$, enhancement of f_{sf} in interacting clusters is related to bar fraction enhancement.
→ Connection between star formation enhancement and bar formation by cluster-cluster interaction.



Results

M_{star} -dependent trend in the f_{sf} enhancement and bar formation:

Explained by gas fraction dependent on M_{star}



Master et al. (2012)

Gas fraction vs M_{star}

Low gas abundant:
Good for bar formation

High gas abundant:
Good for star formation



High-mass galaxies:
Substantial bar formation
No star formation enhancement

Low-mass galaxies:
Low efficiency in bar formation
Star formation enhancement is possible

Summary

Aims and results of this study

- 1. Finding bar fraction enhancement in interacting clusters**
→ Bar fraction is significantly enhanced.
- 2. Confirming star formation enhancement in interacting clusters**
→ Confirmed. But only in low-mass disk galaxies.
- 3. Investigating possible connection between the bar formation and star formation enhancement in interacting clusters**
→ The connection is found only in low-mass disk galaxies.

Conclusion

Cluster-cluster interaction is an important mechanism that can induce bars and star formation in disk galaxies.

