The Most Massive Early-type Galaxies Exhibit Tidal Features More Frequently in Lower-density Environments

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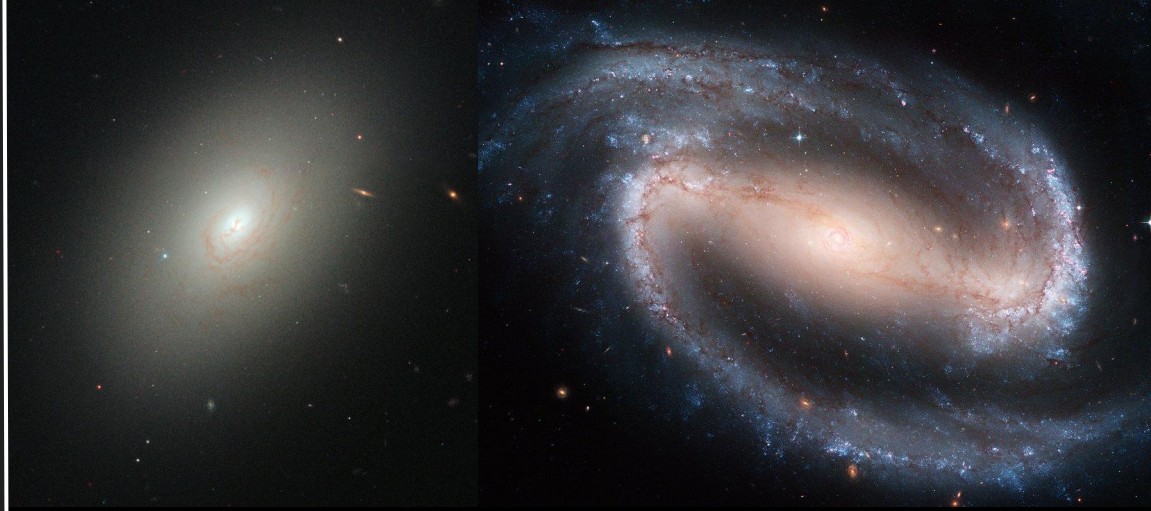
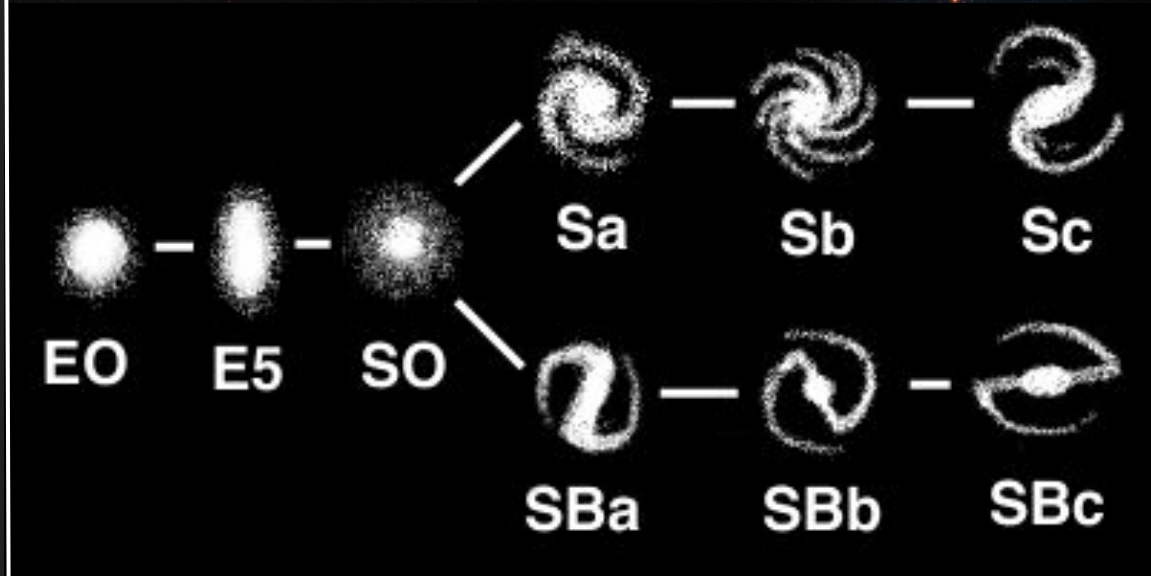
Presentation by Evan Barkus

Background

Galaxy Type

- Early-type
  - Ellipticals
  - Lenticulars
- Late-type
  - Spirals
  - Barred spirals
- Names are misleading!

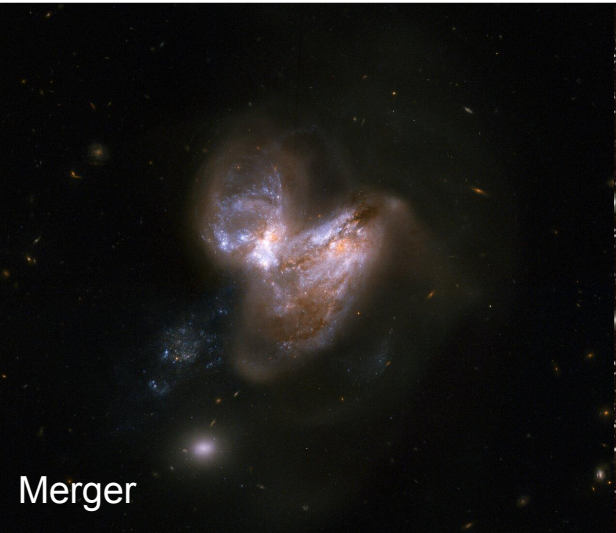




Tidal Features

- Streams, Shells, and Tails
- Caused by mergers and close encounters with other galaxies


Stream


Merger


Shell


Tail

Galaxy Environments

- High density:
  - Clusters
  - Groups
- Low density:
  - Field/isolated galaxies
- Environments are known to have an effect on galaxy evolution
  - ETGs common in high density environments
  - LTGs common in low density environments

Main Goal of the Paper

- To determine how tidal features in massive ETGs are related to the environments they are in.
- Are ETGs with tidal features more common in low density or high density environments and why?

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ABSTRACT

The most massive early-type galaxies (ETGs) are known to form through numerous galaxy mergers. Thus, it is intriguing to study whether their formation in low-density environments, where nearby companions are almost absent, is associated with mergers, which are directly traced by tidal features. Using the 436 most massive ETGs with $M_{star} > 10^{11.2}\,M_\odot$ at $z < 0.04$, we determine the variation in the fraction of massive ETGs with tidal features (f_T) across different environments and verify whether the most massive ETGs commonly have tidal features in very low density environments. Our main discovery is that the most massive ETGs exhibit tidal features more frequently in lower-density environments. In the highest-density environments, like galaxy clusters, f_T is 0.21 ± 0.06, while in the lowest-density environments it triples to 0.62 ± 0.06. This trend is stronger for more extremely massive ETGs, with f_T reaching 0.92 ± 0.08 in the lowest-density environments. One explanation for our finding is that the most massive ETGs in lower-density environments have genuinely experienced recent mergers more frequently than their counterparts in higher-density environments, suggesting that they possess extended formation histories that continue into the present. Another possibility is that tidal features last shorter in denser environments owing to external factors inherent in these environments. Our additional findings that massive ETGs with bluer $u-r$ colors are a more dominant driver of our main discovery and that dust lanes are more commonly observed in massive ETGs in low-density environments imply that gas-abundant mergers primarily contribute to the increased rate of recent mergers in low-density environments.

Keywords: Early-type galaxies (429); Galaxy environments (2029); Galaxy mergers (608); Giant galaxies (652); Tidal tails (1701)

1. INTRODUCTION

Early-type galaxies (ETGs) are preferentially detected in high-density environments, such as galaxy clusters, whereas late-type galaxies show an inverse trend, being more common in low-density environments (Dressler 1980; Postman & Geller 1984; Goto et al. 2003; Houghton 2015; Pfeffer et al. 2023). This morphology–density relation indicates that galaxy evolution is associated with the environments in which galaxies reside.

Although ETGs are less common in low-density environments, they are still present in isolated environments, where there are virtually no nearby companion galaxies (Reduzzi et al. 1996; Mulchaey & Zabludoff 1999; Colbert et al. 2001; Reda et al. 2004, 2005, 2007; Stocke et al. 2004; Han & Forbes 2006; Hernández-Toledo et al. 2008; Lacerna et al. 2016; Rampazzo et al. 2020). Several studies have examined the properties of ETGs in such isolated environments and compared them to those in high-density environments. Many of them found that ETGs in isolated environments share similar properties with those in dense environments, such as color, sizes, star formation rates, kinematics, luminosity function, and scaling relations between the properties (Mulchaey & Zabludoff 1999; Reda et al. 2004, 2005, 2007; Stocke et al. 2004; Han & Forbes 2006; Lacerna et al. 2016). This implies that the crucial formation mechanisms for ETGs are likely common across various environments, although the cumulative number of galaxies influenced by these mechanisms over the history of the universe should be higher in denser environments, contributing to the observed morphology–density relation.

Galaxy mergers are likely to be a universally important mechanism for the formation and evolution of ETGs across various environments, as they can establish the fundamental properties of ETGs (Baugh et al. 1996; Christlein & Zabludoff 2004; De Lucia et al. 2006; De Lucia & Blaizot 2007; Wilman et al. 2013). For instance, galaxy mergers can lead to the creation of red

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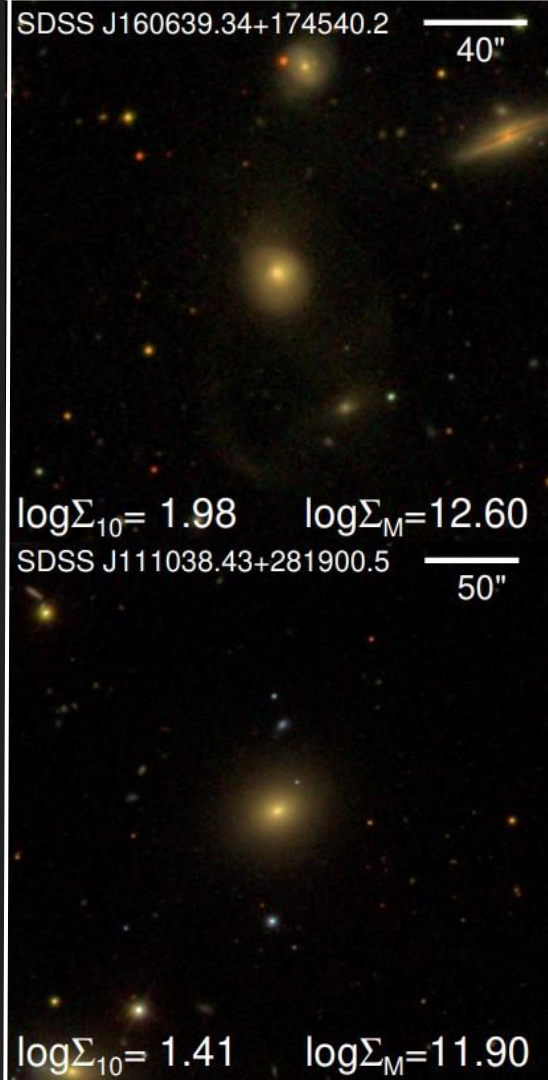
Sample & Methods

Sample

- Massive ETGs with and without tidal features in low and high density environments
- Data from NASA Sloan Atlas
- Cuts:
  - Redshifts from 0.01 to 0.04
  - Galaxies with log(Mstar/M$\odot$) > 11.2
- Tidal features were identified visually by the authors
- Final sample is approximately 436 massive ETGs



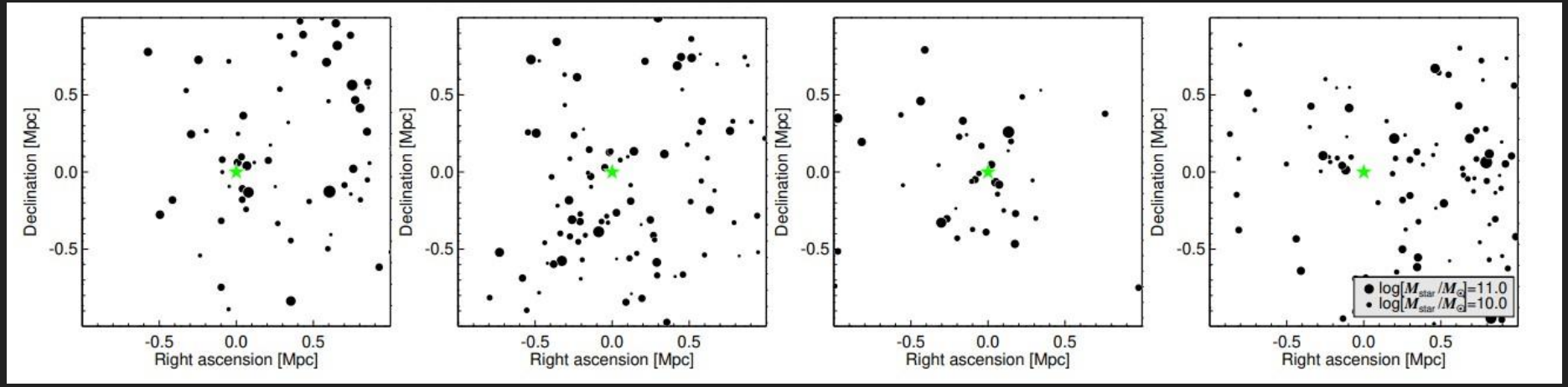
Important Quantities

- Surface Densities
  - Surface Number Density
  - Surface Mass Density
  - Units of \Mpc^2 and M⊙\Mpc^2
  - Restricted to galaxies within a certain range of recessional velocities (±1000 km/s)
- Used to characterize the galaxy's environment
- Fraction of ETGs with tidal features (fT)

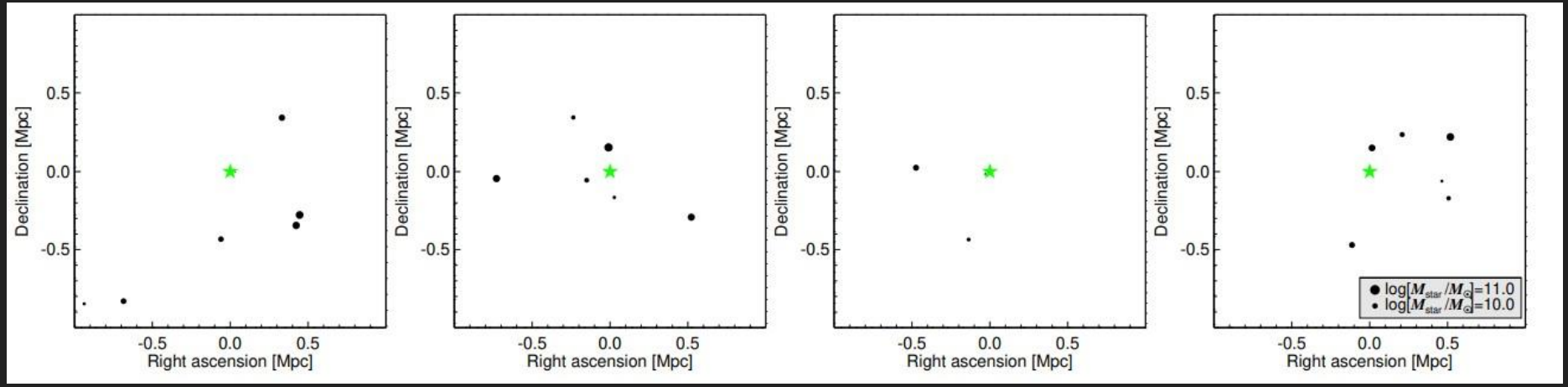
$$\Sigma_{10} = \frac{10}{\pi {r_{10}}^2},$$

$$\Sigma_M = \frac{\sum_{i=1}^{10} M_{\mathrm{star},i}}{\pi {r_{10}}^2},$$

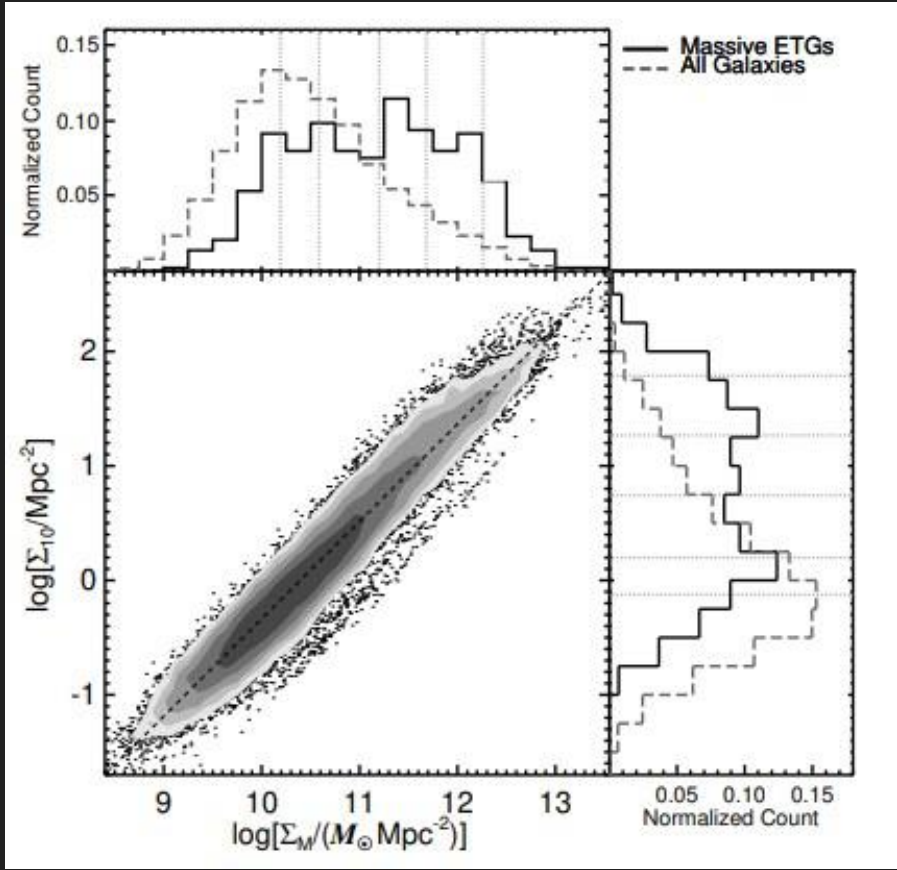
High Density

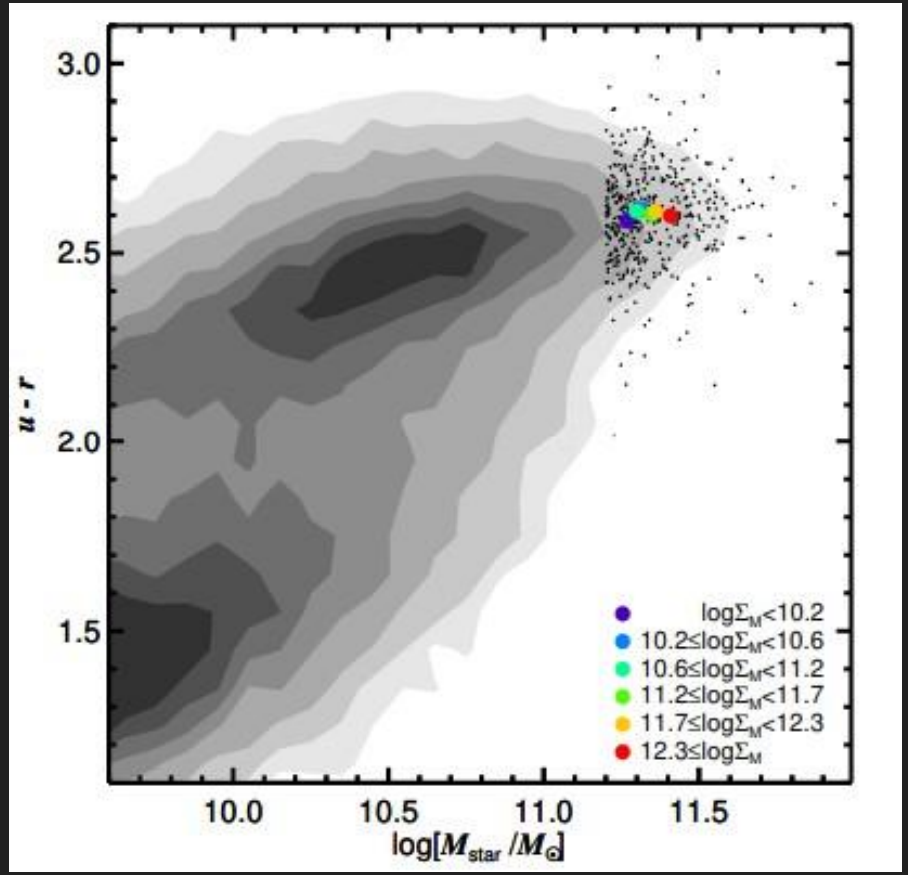


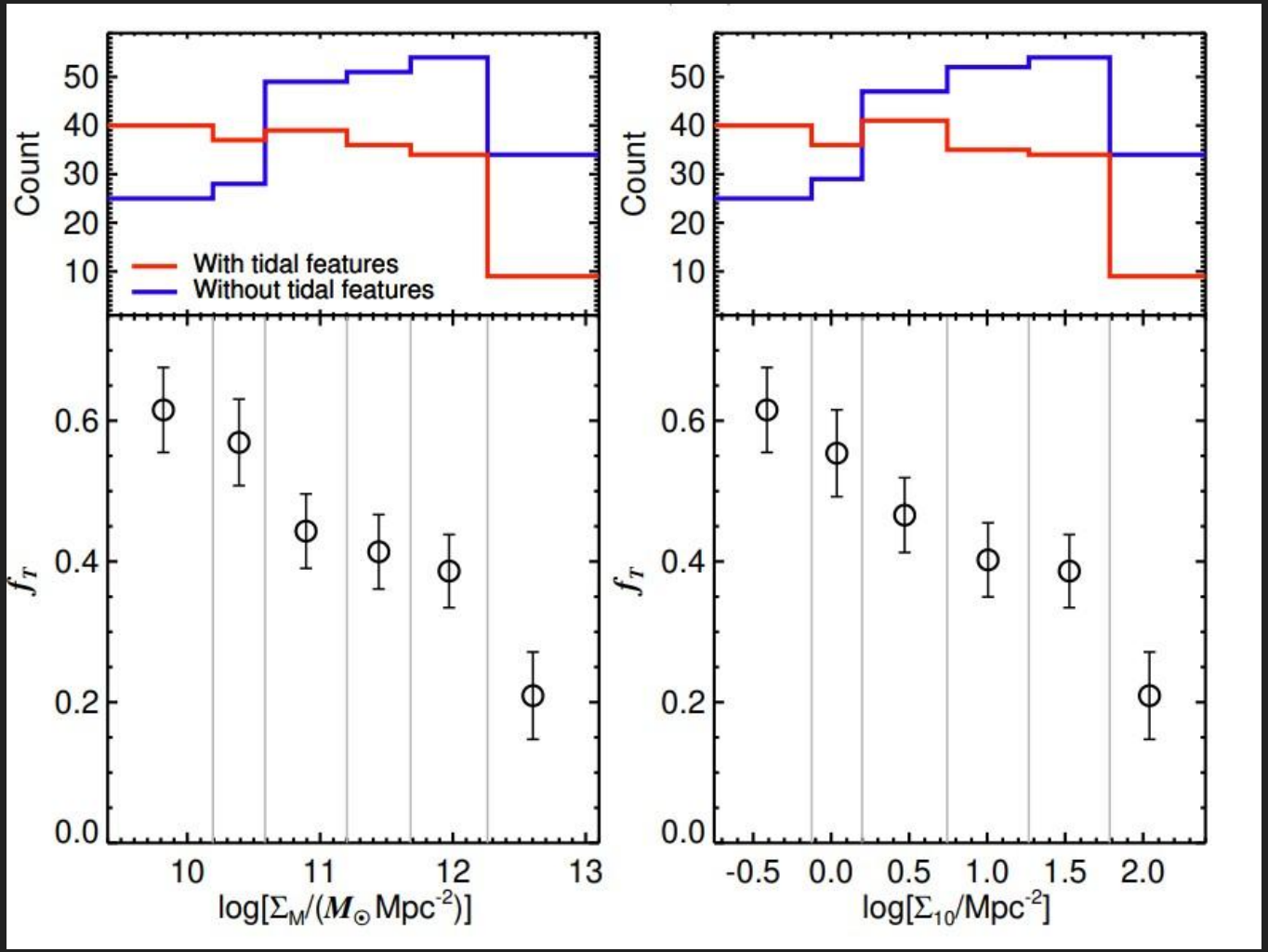
Low Density

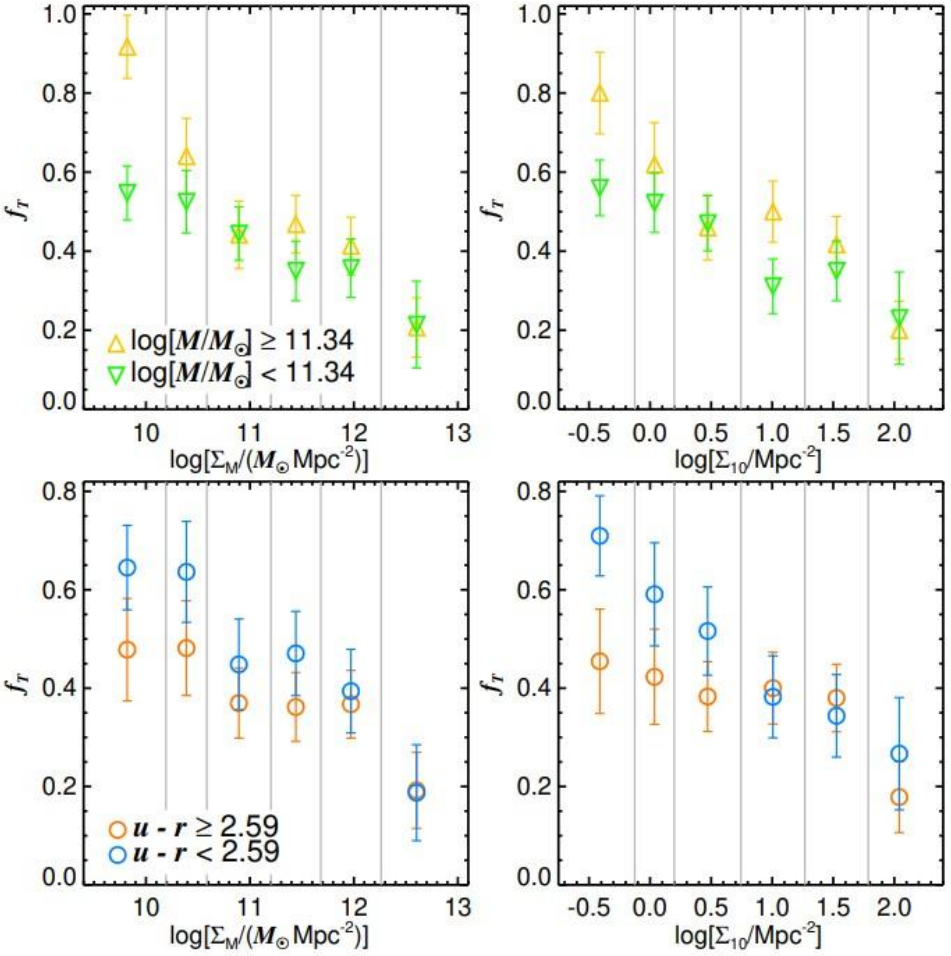


Results


Massive ETGs
All Galaxies
Normalized Count
0.15
0.10
0.05
2
1
0
-1
log[Σ10/Mpc-2]
9
10
11
12
13
log[ΣM/(M⊙ Mpc-2)]
0.05 0.10 0.15
Normalized Count


3.0
2.5
2.0
1.5
u - r
10.0
10.5
11.0
11.5
log[Mstar /M⊙]
logΣM<10.2
10.2≤logΣM<10.6
10.6≤logΣM<11.2
11.2≤logΣM<11.7
11.7≤logΣM<12.3
12.3≤logΣM


Count
50
40
30
20
10
With tidal features
Without tidal features
f_T
0.6
0.4
0.2
0.0
10
11
12
13
$\log[\Sigma_M/(M_\odot\,\mathrm{Mpc}^{-2})]$
Count
50
40
30
20
10
f_T
0.6
0.4
0.2
0.0
-0.5
0.0
0.5
1.0
1.5
2.0
$\log[\Sigma_{10}/\mathrm{Mpc}^{-2}]$


1.0
0.8
0.6
0.4
0.2
0.0
f_T
△ log[$M/M_\odot$] ≥ 11.34
▽ log[$M/M_\odot$] < 11.34
10
11
12
13
log[$\Sigma_M/(M_\odot$ Mpc^{-2})]
-0.5
0.0
0.5
1.0
1.5
2.0
log[Σ_{10}/Mpc^{-2}]
○ $u - r \geq 2.59$
○ $u - r < 2.59$

Conclusions

Conclusions

- Summary of Results
  - Massive ETGs exhibit tidal features more often in lower density environments.
  - More massive ETGs ($\log(M_{star}/M_{\odot}) \geq 11.34$) have a more prominent trend.
  - ETGs with bluer u-r colors display this trend more strongly in low density environments as compared to redder ETGs.
- Two Interpretations:
  - Tidal features are short lived in denser environments
  - ETGs in low density environments have had recent mergers (favored interpretation)