

$z \sim 1$ のフィールド早期型銀河の

Early-type Galaxies (ETGs)

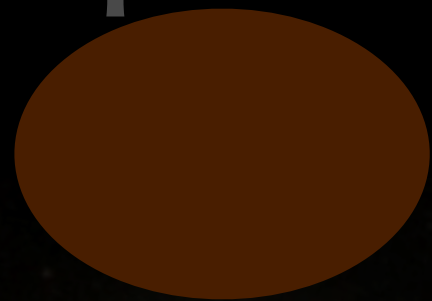
等面輝度形状について

Isophote Shapes

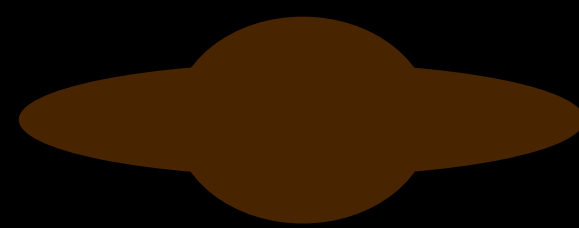
満田 和真 (東京大学)

Early-type Galaxies (ETGs)

Elliptical

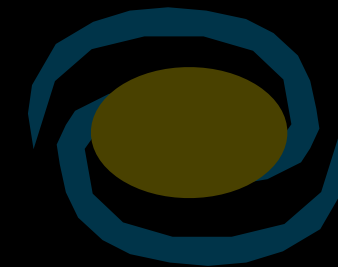


S0



Late-type Galaxies

Sab



Scd



Bulge
Random motion

Disk
Rotation



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Early-type Galaxies (ETGs)

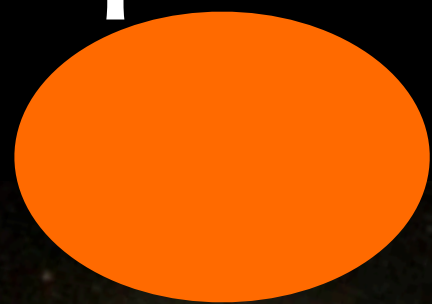
等面輝度形状について

Isophote Shapes

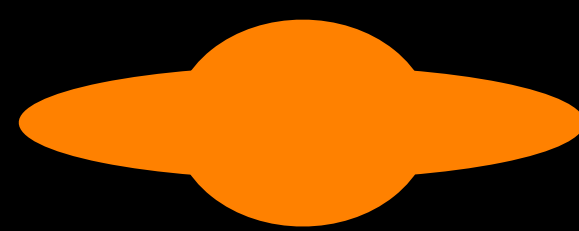
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Early-type Galaxies (ETGs)

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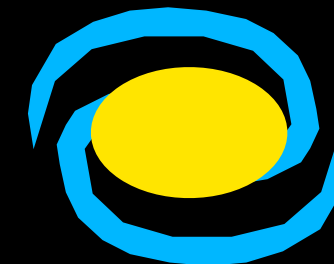


S0

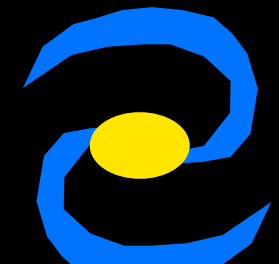


Late-type Galaxies

Sab



Scd



Bulge
Random motion

Disk
Rotation

Outline

1. Introduction

Dynamics and Isophote shapes of early-type galaxies

Slow and fast rotators

Boxy and disky early-type galaxies

2. Isophote Shapes of Field ETGs at $z \sim 1$

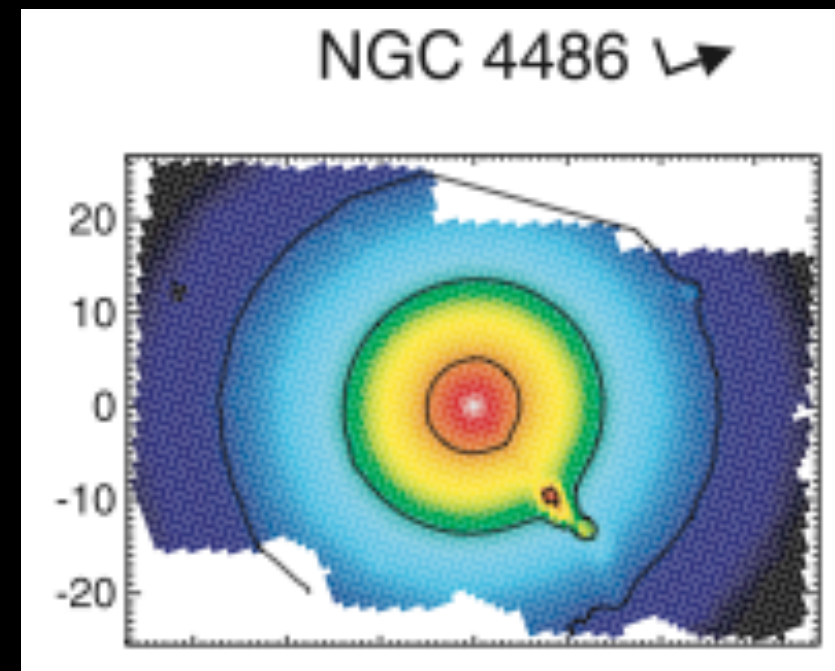
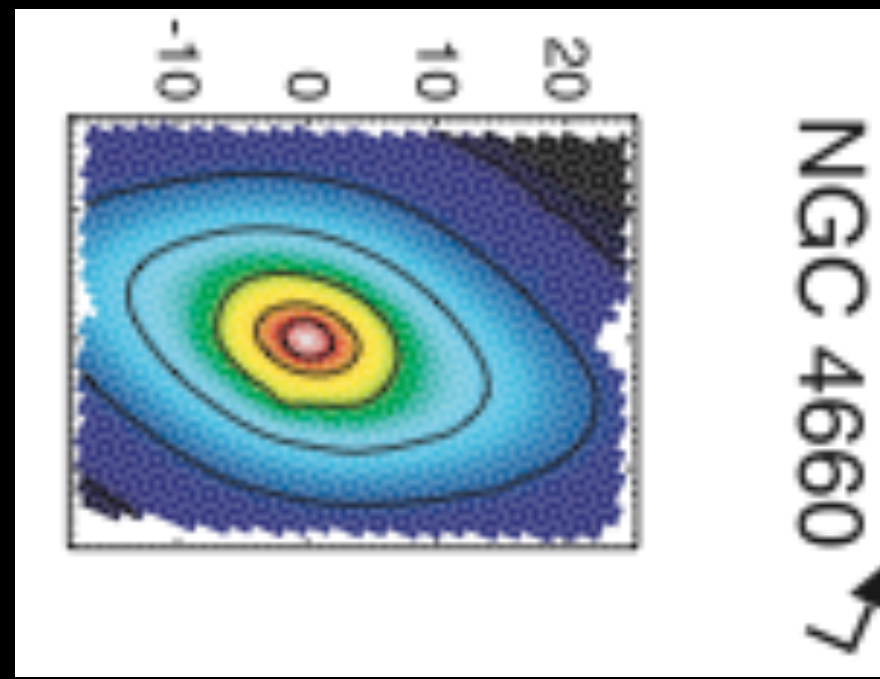
No evolution in disky ETG fraction from $z \sim 1$ to 0

3. Summary

1.1 Dynamics of ETGs : fast/slow rotators

● IFS Survey of Nearby Galaxies

☀ ETG subclass: fast/slow rotators

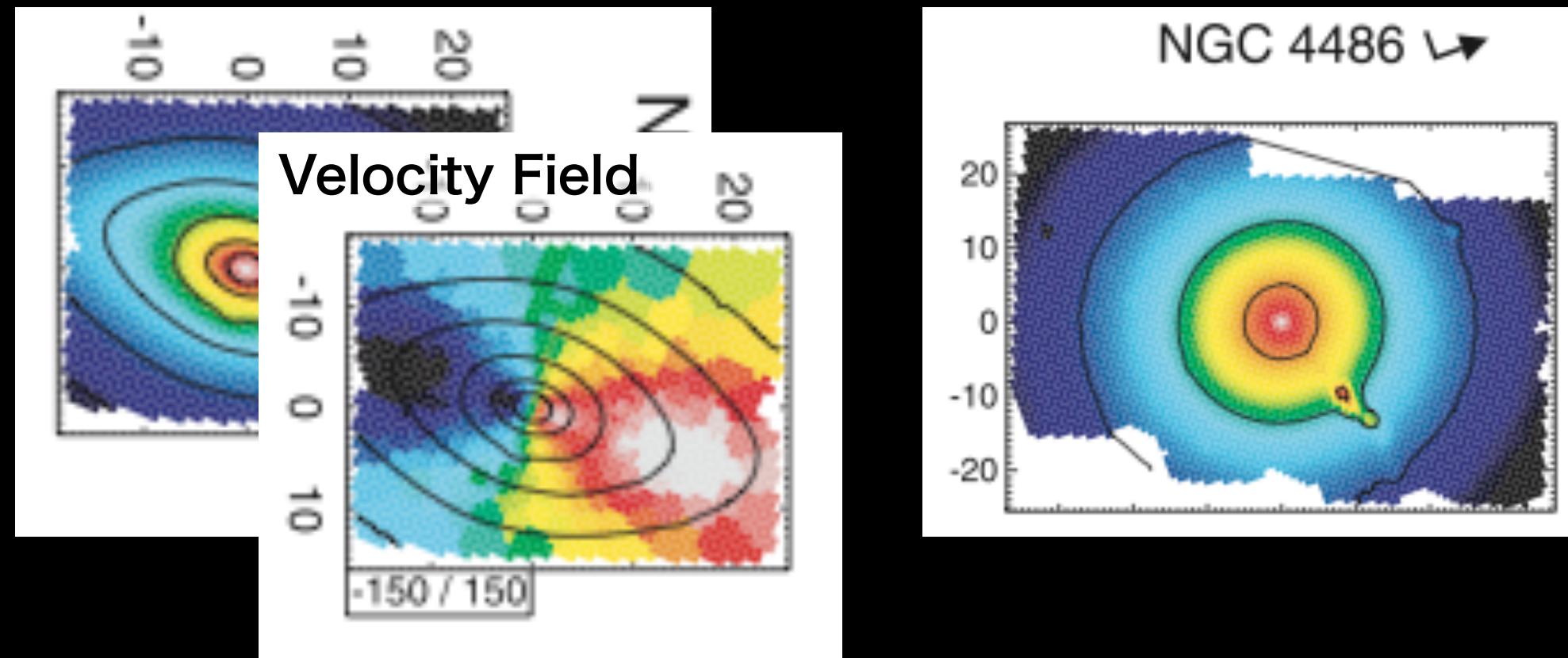


☀ ETGs become dispersion dominated with increasing mass

1.1 Dynamics of ETGs : fast/slow rotators

● IFS Survey of Nearby Galaxies

☀ ETG subclass: fast/slow rotators



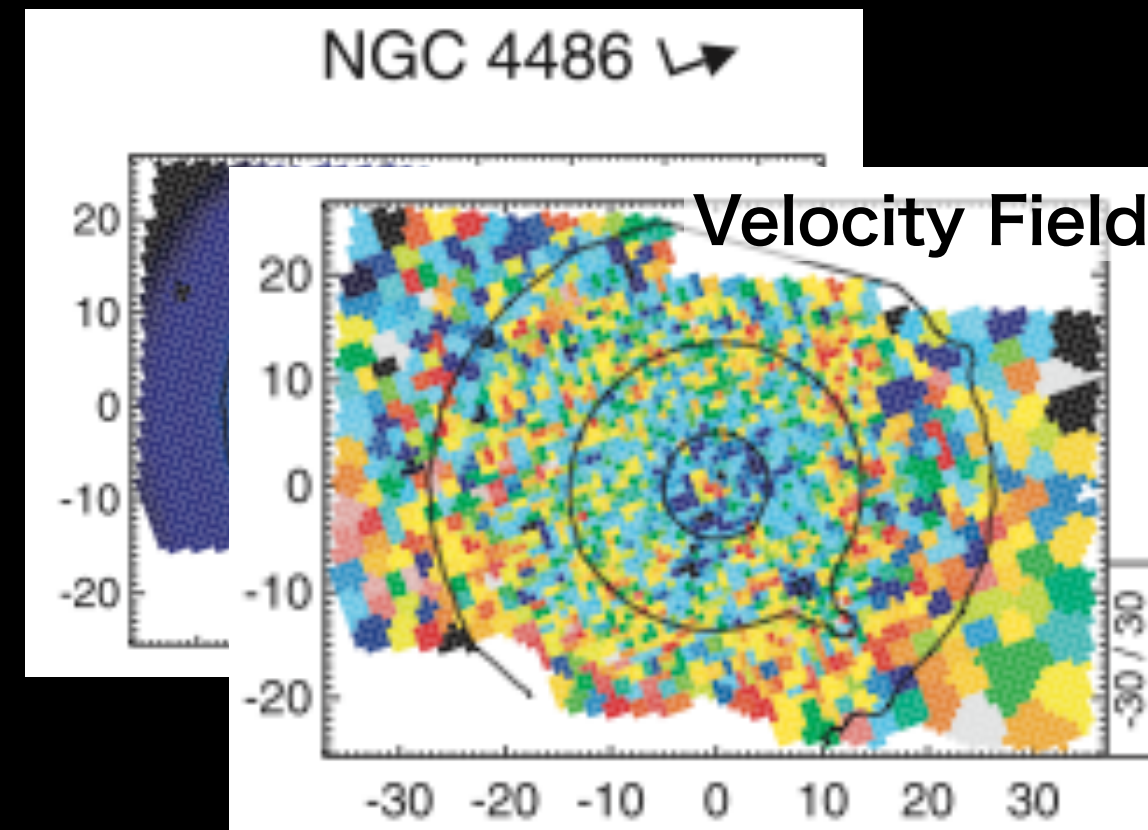
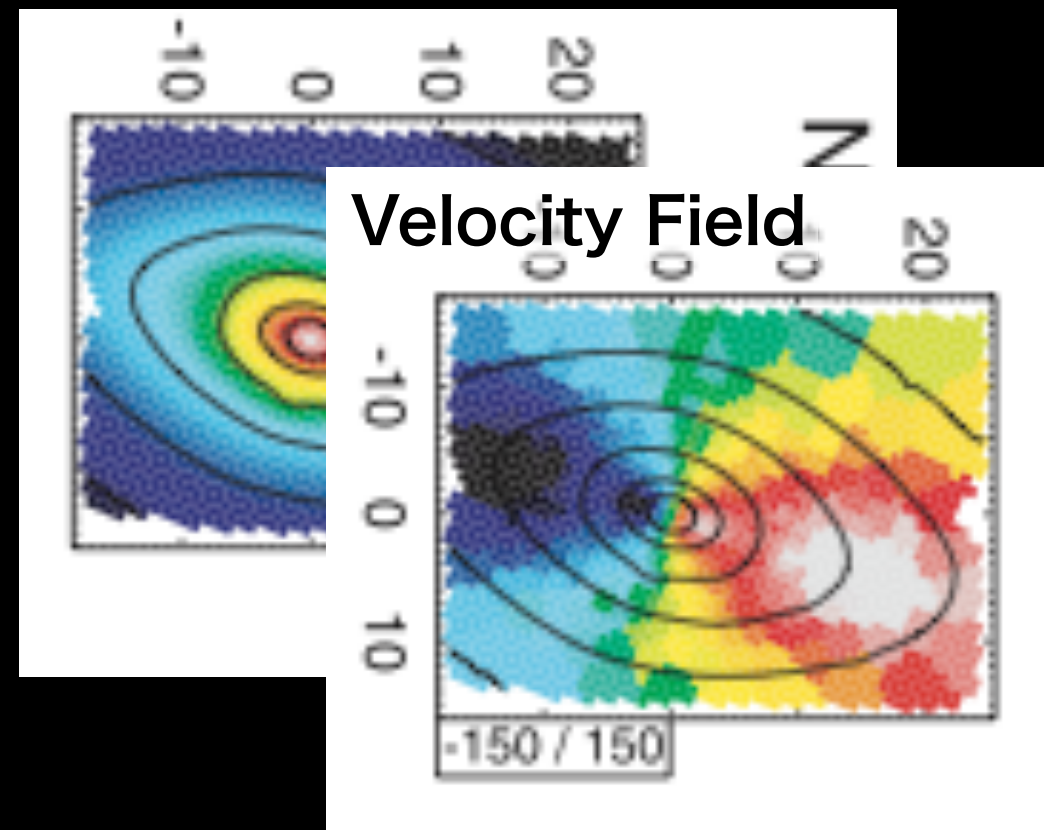
Rotation dominated
= fast rotators

☀ ETGs become dispersion dominated with increasing mass

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● IFS Survey of Nearby Galaxies

☀ ETG subclass: fast/slow rotators

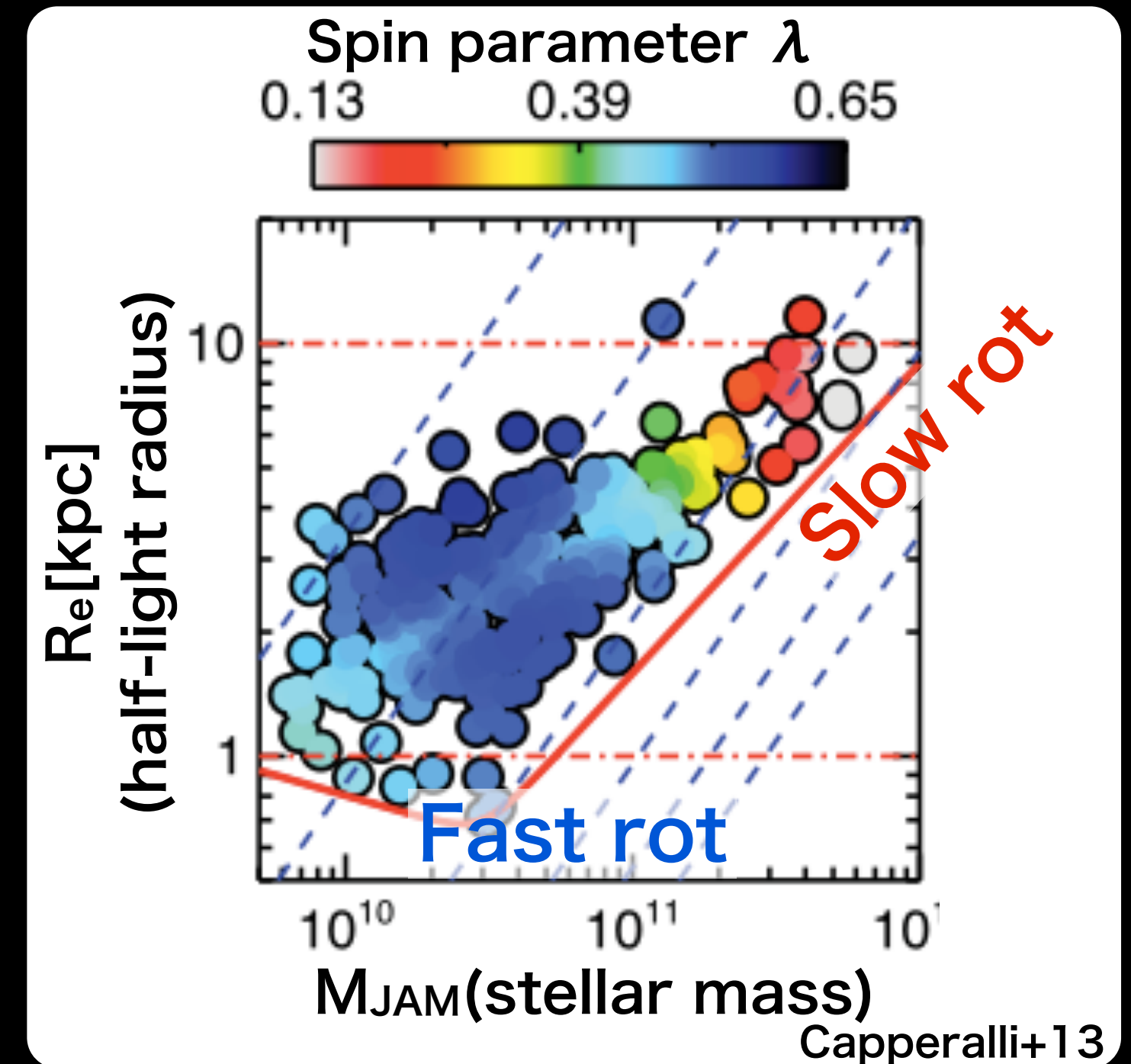
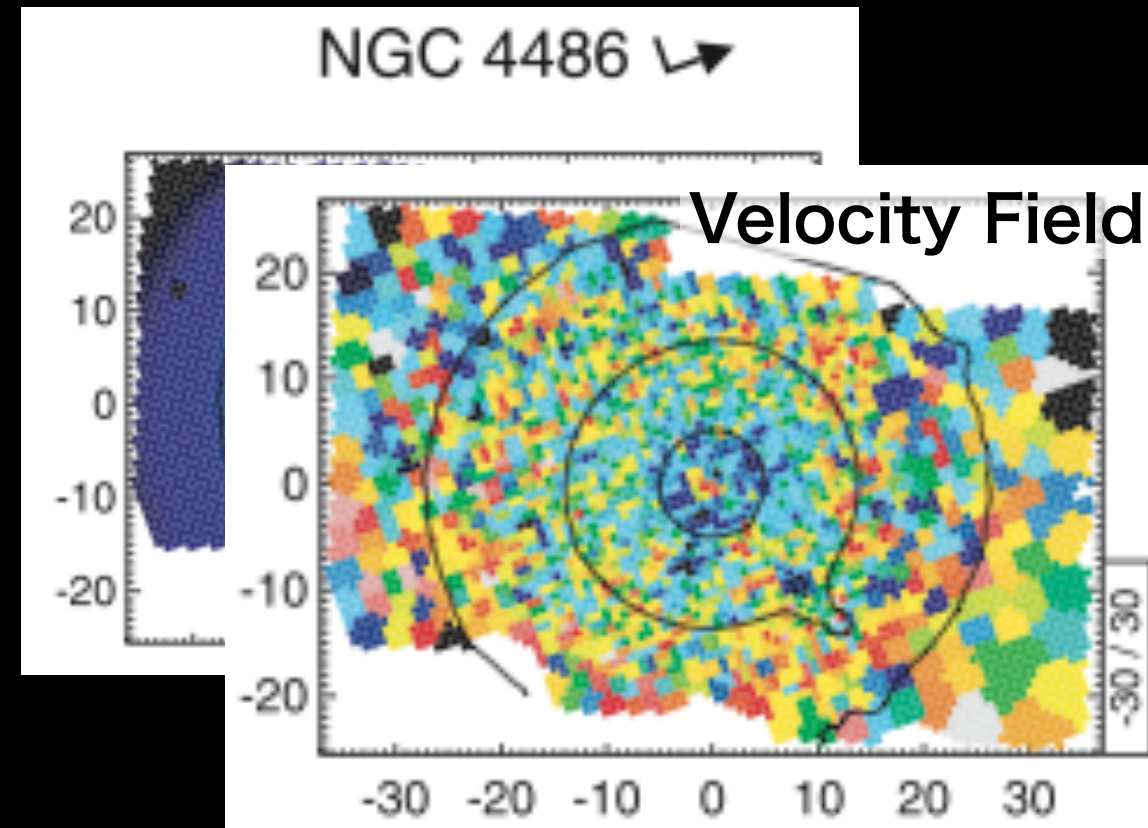
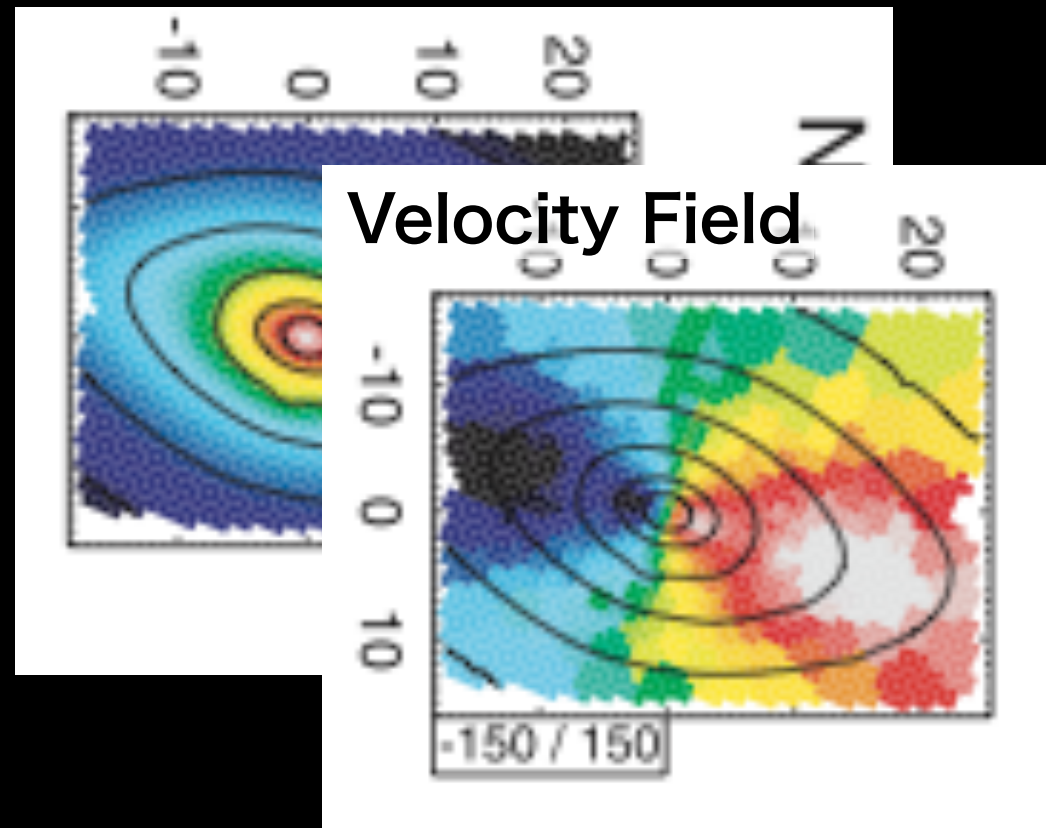


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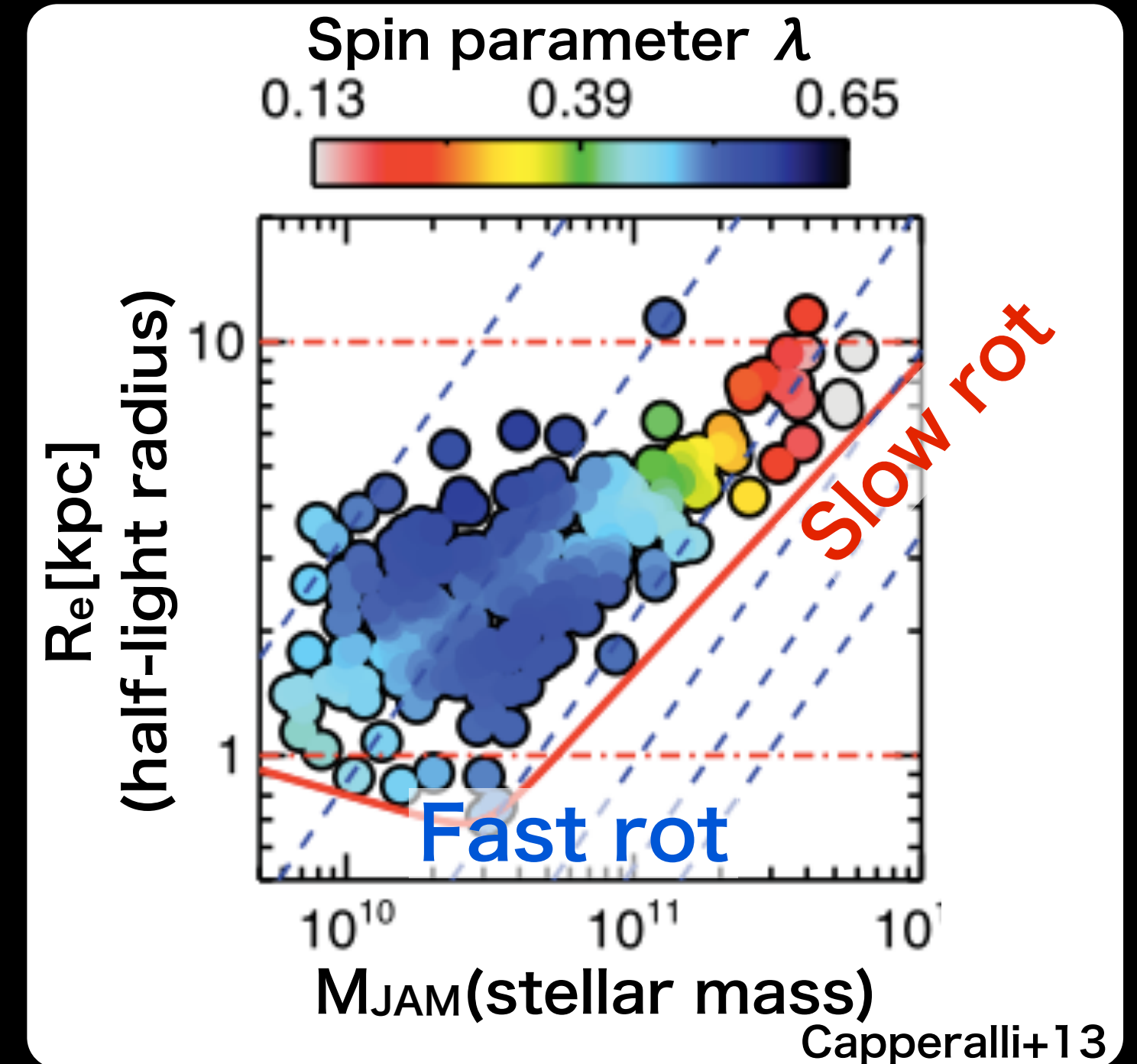
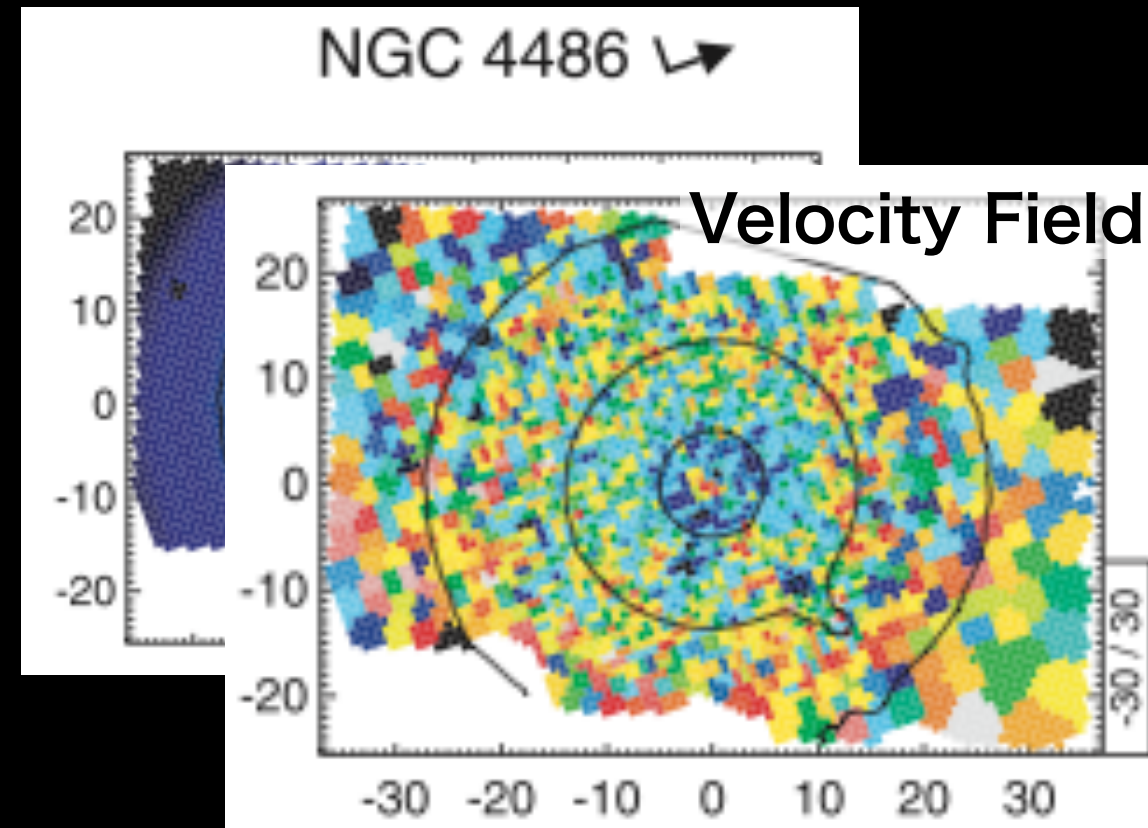
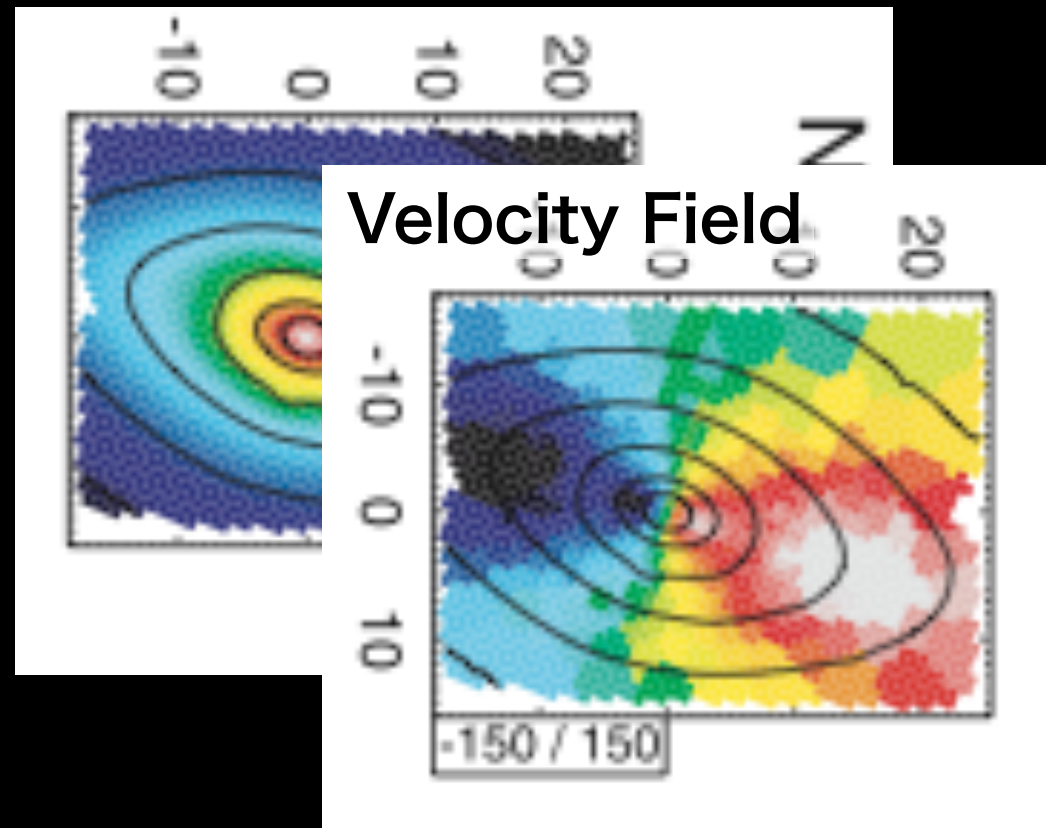


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1.1 Dynamics of ETGs : fast/slow rotators

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☀ ETGs become dispersion dominated with increasing mass

* Spin parameter λ

$$\lambda_R = \frac{\sum_{i=1}^{N_p} F_i R_i |V_i|}{\sum_{i=1}^{N_p} F_i R_i \sqrt{V_i^2 + \sigma_i^2}},$$

F_i : flux, R_i : radius, V_i : velocity,
 σ_i : dispersion at a spaxel i

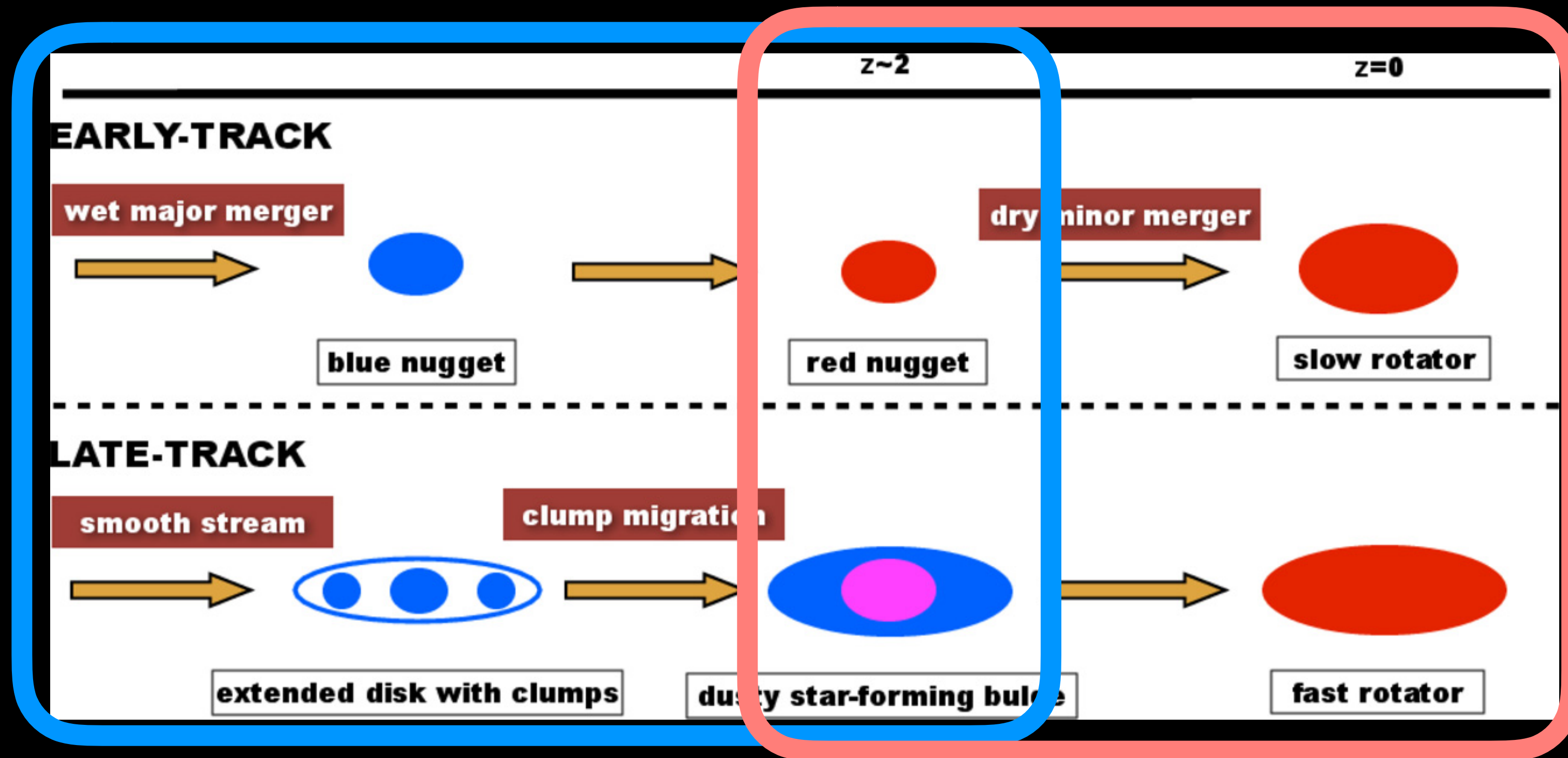
1.2 Two Phase Scenario for ETG Formation & Evolution

Phase I ($z > 2$?)

Bulge formation in
gas-rich processes
 \Rightarrow Fast rotators?

Phase II ($z < 2$?)

dynamical evolution
gas-poor processes
 \Rightarrow Slow rotators



Tadaki+14

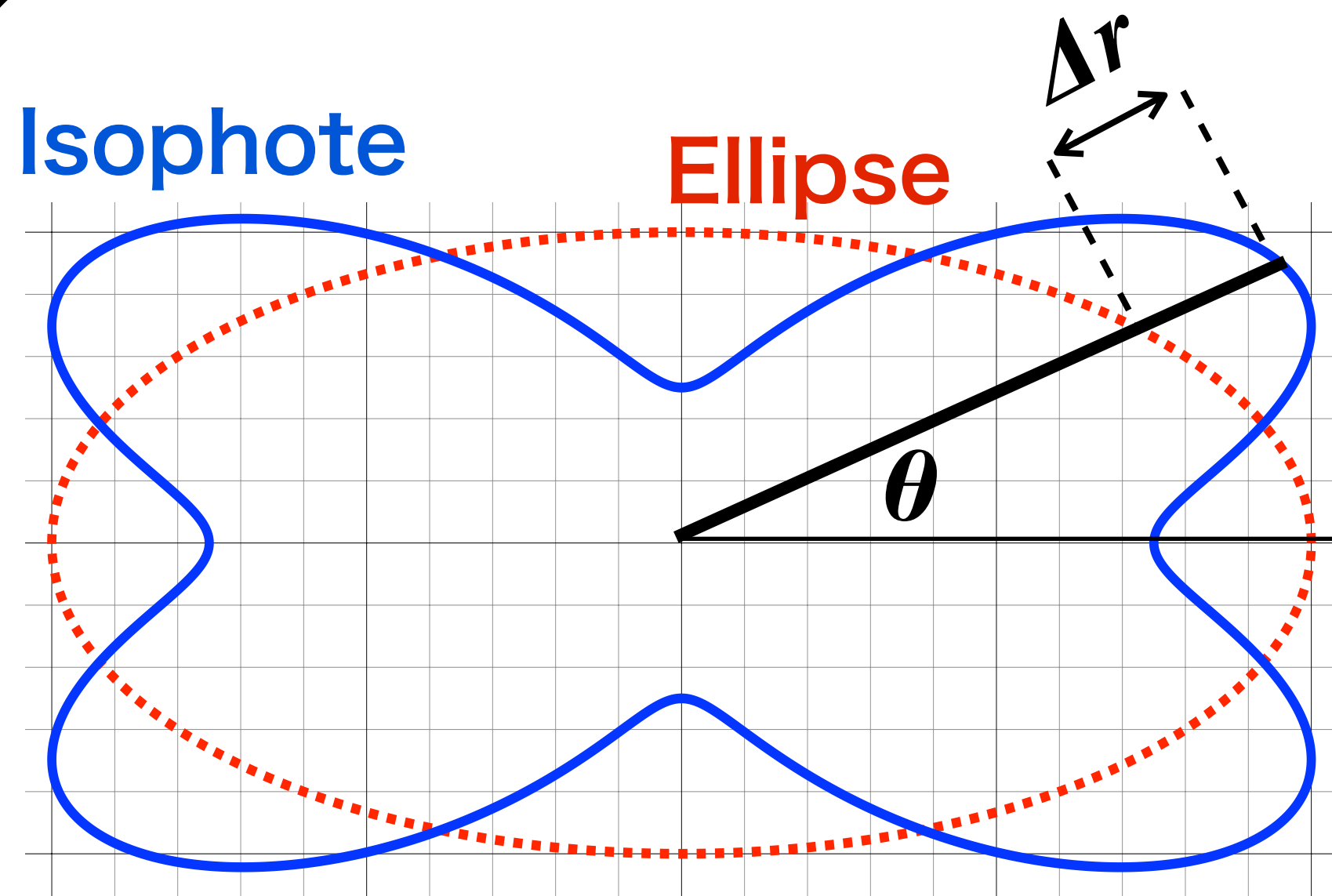
\Rightarrow *Evolution of dynamics of ETGs is expected in $z < 2$*

\Rightarrow *We want to know dynamics of high- z ETGs*

1.3 Isophote Shapes of Early-Type Galaxies: Boxy vs Disky

Boxy

Disky

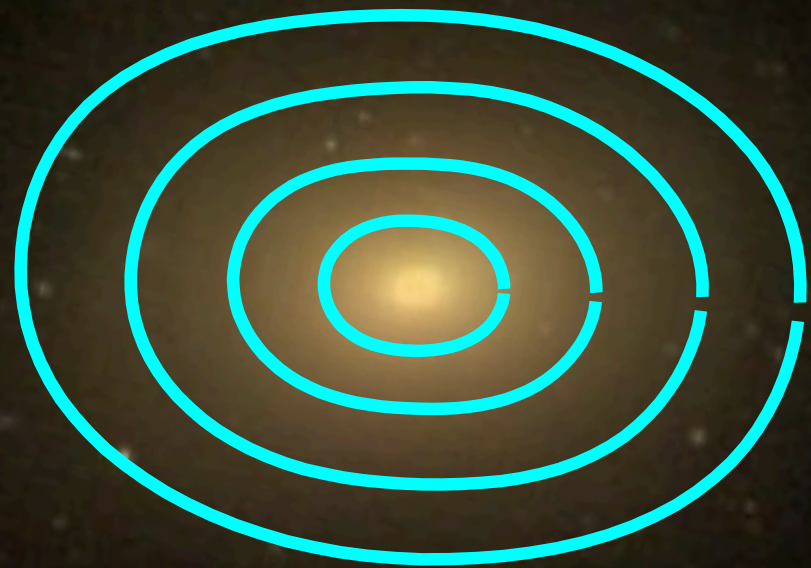


- Ellipse : $x = a \cos(\theta)$, $y = b \sin(\theta)$
(a : semi-major axis, b : semi-minor axis)
- Fourier Expansion of Δr
$$\Delta r = \sum a_n \cos(n\theta) + \sum b_n \sin(n\theta)$$

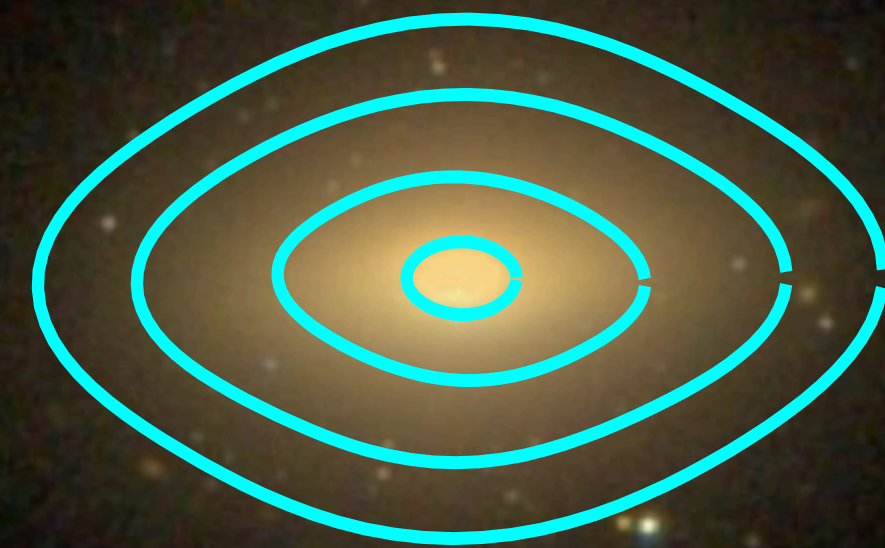
 $\Rightarrow \underline{a_4 < 0 : \text{boxy}}$
 $\underline{a_4 > 0 : \text{disky}}$

1.3 Isophote Shapes of Early-Type Galaxies: Boxy vs Disky

Boxy

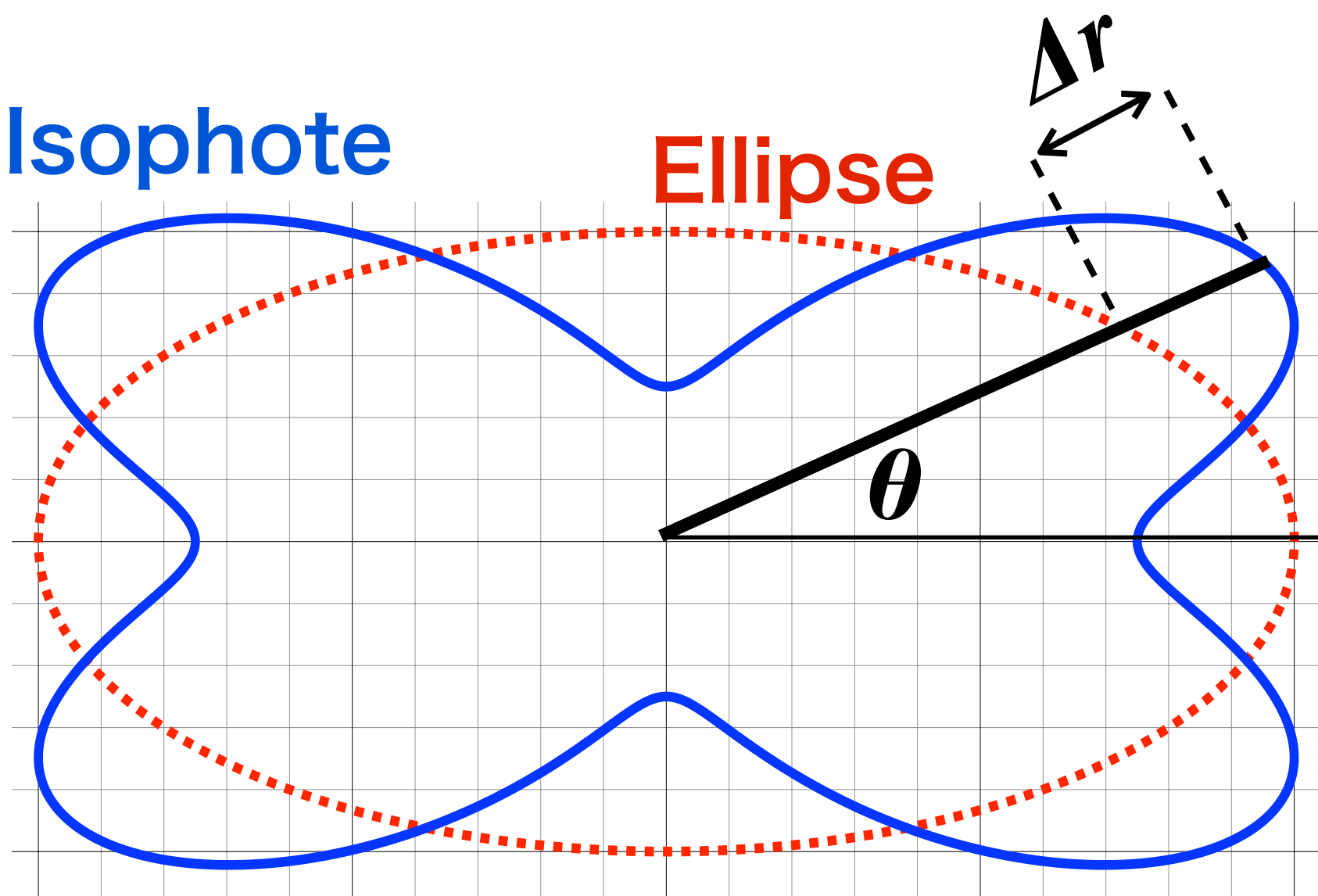


Disky



Isophote

Ellipse



- Ellipse : $x = a \cos(\theta)$, $y = b \sin(\theta)$
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- Fourier Expansion of Δr

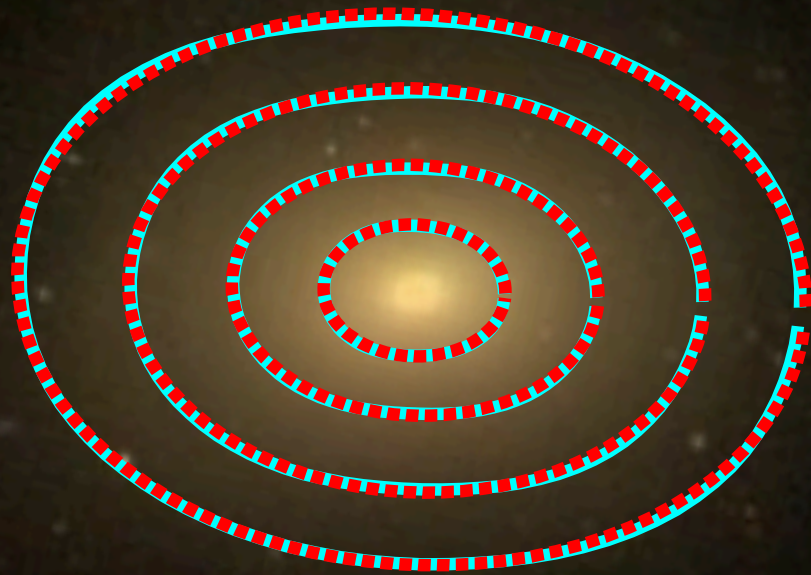
$$\Delta r = \sum a_n \cos(n\theta) + \sum b_n \sin(n\theta)$$

$$\Rightarrow \underline{a_4 < 0 : \text{boxy}}$$

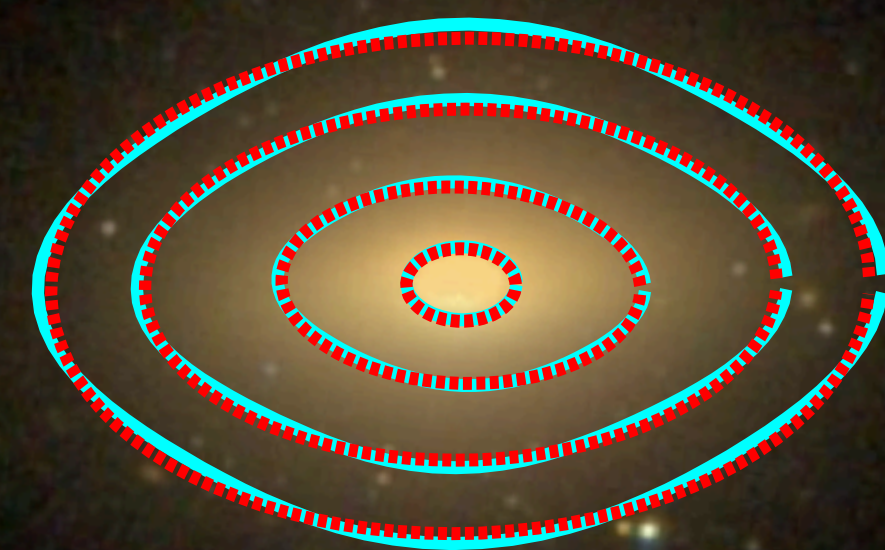
$$\underline{a_4 > 0 : \text{disky}}$$

1.3 Isophote Shapes of Early-Type Galaxies: Boxy vs Disky

Boxy

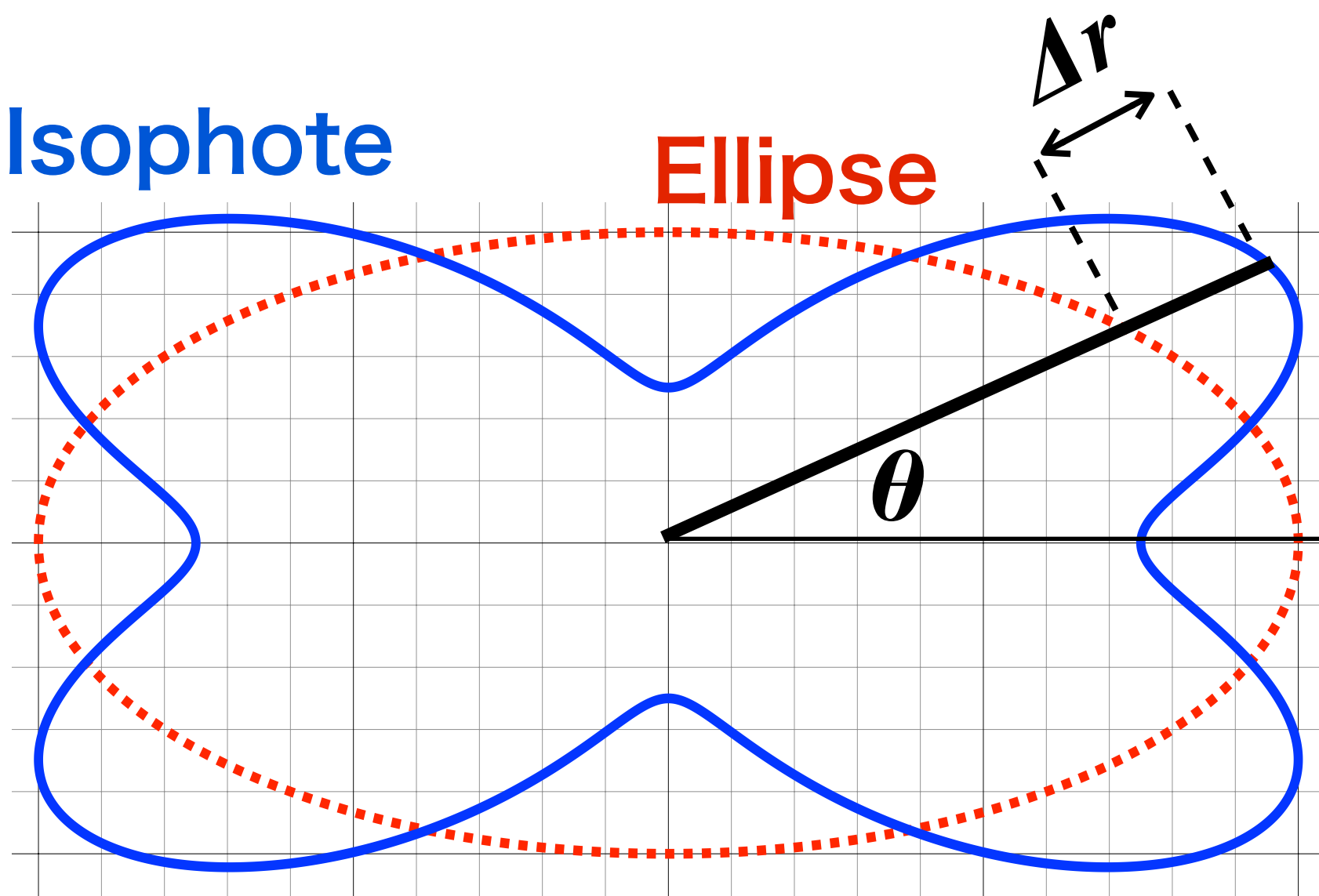


Disky



Isophote

Ellipse



- Ellipse : $x = a \cos(\theta)$, $y = b \sin(\theta)$
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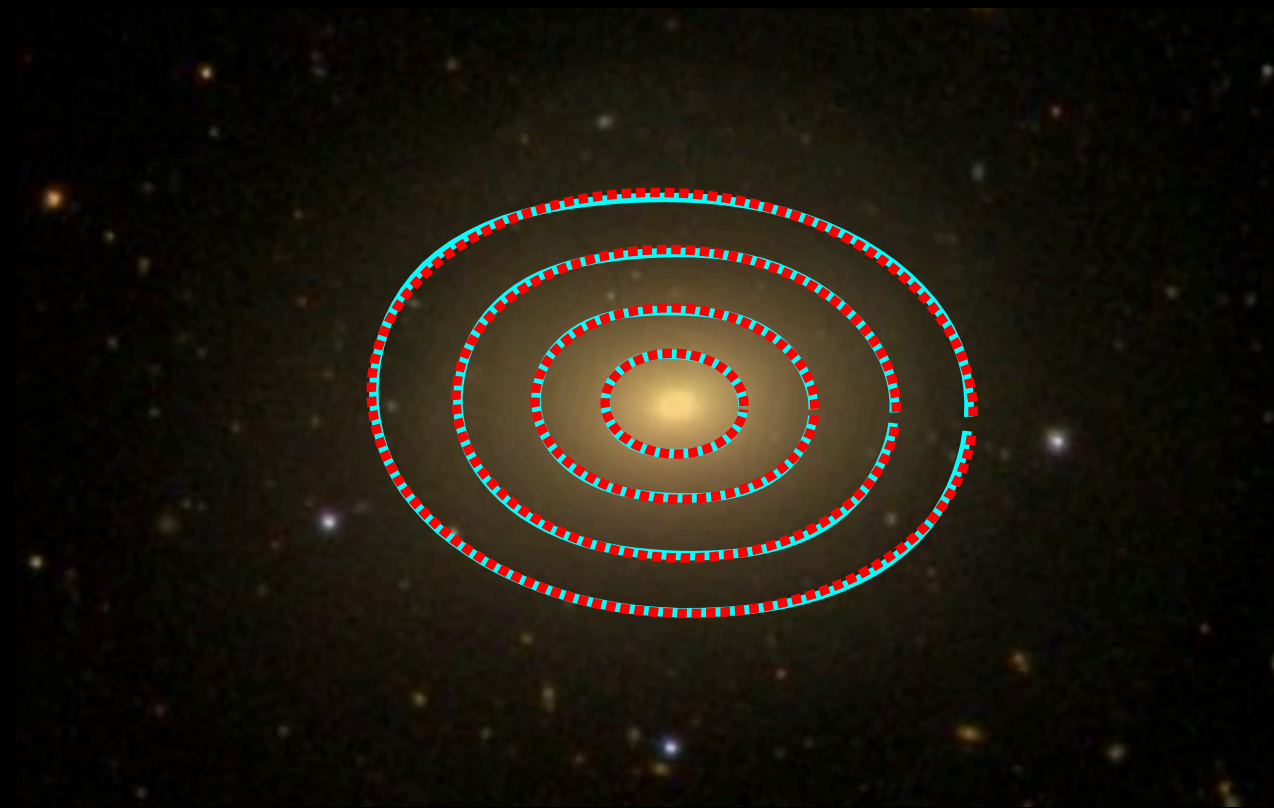
$$\Rightarrow \underline{a_4 < 0 : \text{boxy}}$$

$$\underline{a_4 > 0 : \text{disky}}$$

1.4 Boxy/Disky (a_4) as a Proxy for Slow/Fast Rotators

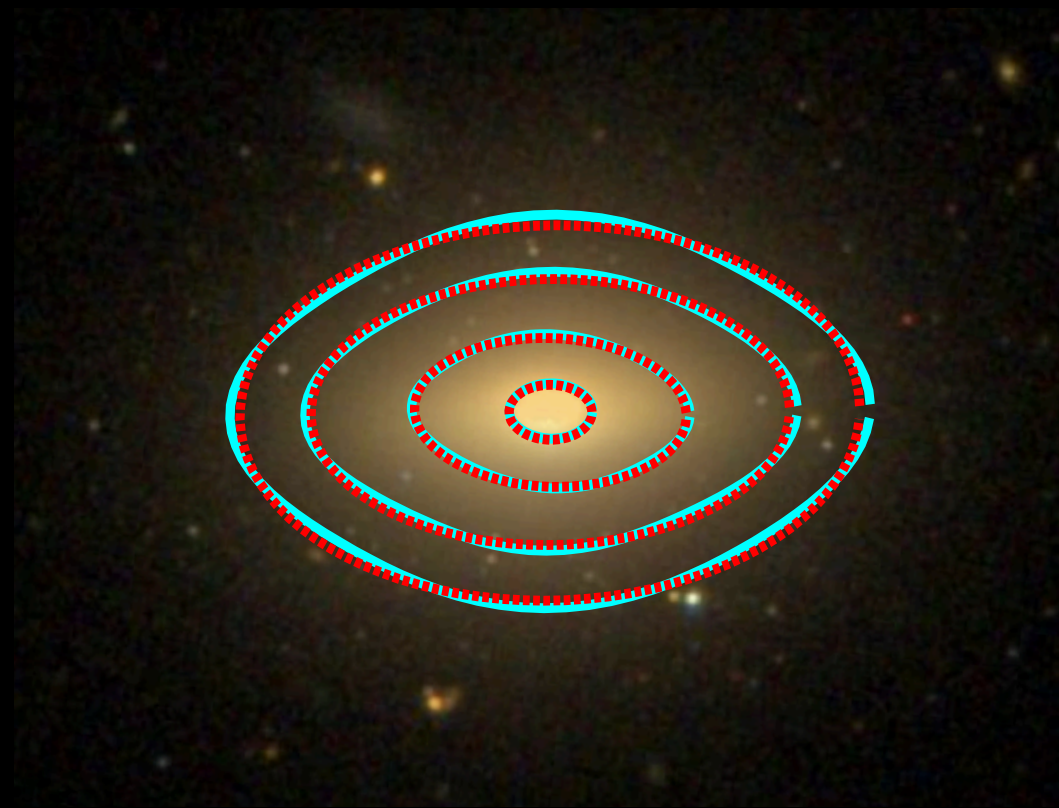
Boxy ($a_4 < 0$)

~ Dispersion supported

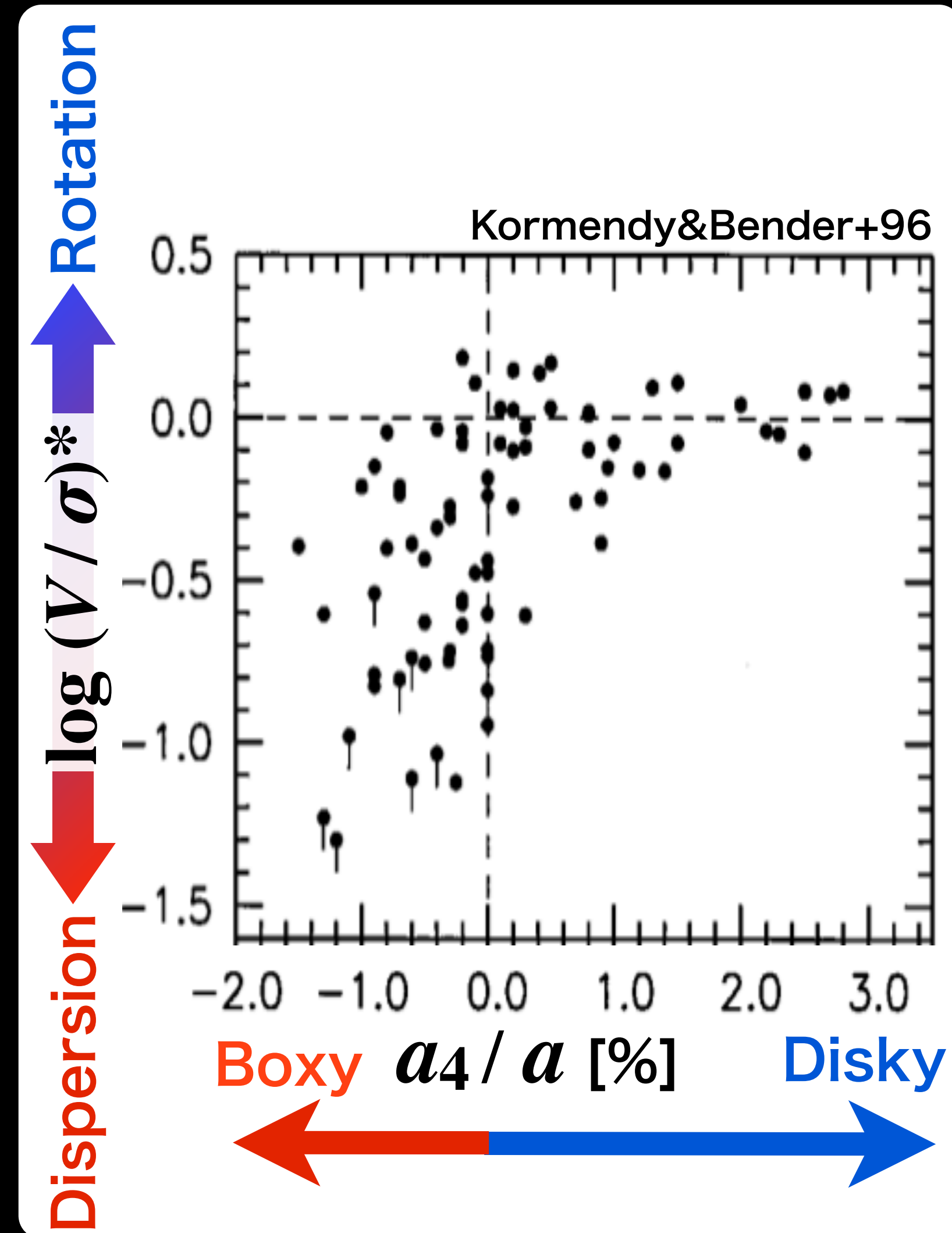


Disky ($a_4 > 0$)

~ Rotation supported

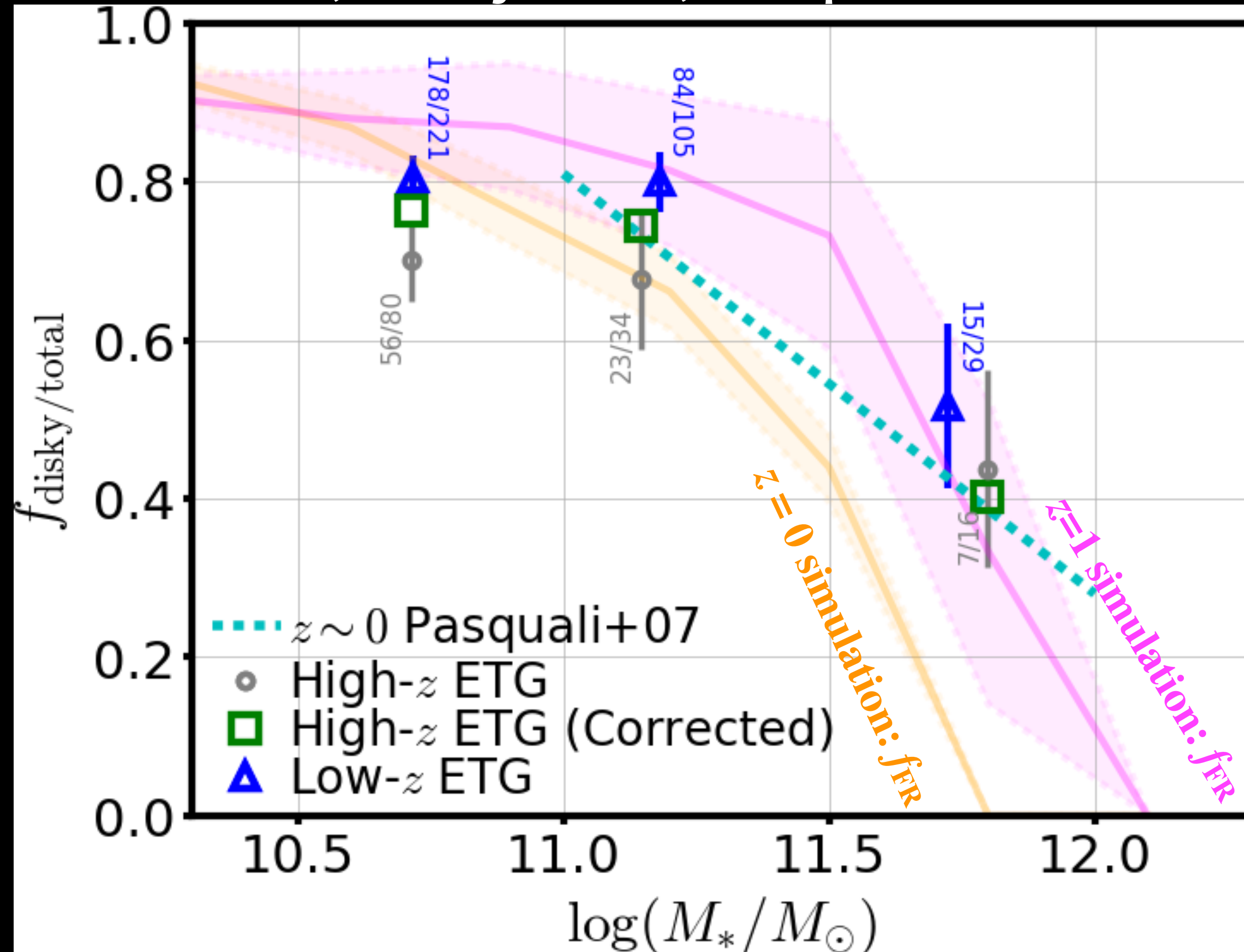


- Isophote shapes (**boxy** vs **disky**) can be used as a proxy for dynamics (**slow** vs **fast** rotation)



1.5 Redshift Evolution of Disky ETG fraction from $z \sim 1$ to 0

Mitsuda+17; Penoyre+17; Pasquali+07



\triangle : $z \sim 0$ cluster ETGs

\square : $z \sim 1$ cluster ETGs

— : $z \sim 0$ simulation

— : $z \sim 1$ simulation

● Simulation
evolution of fast rotator
fraction from $z \sim 1$ to 0

● Cluster observation
no evolution of disk ETG
fraction from $z \sim 1$ to 0
 \Rightarrow environmental effect?

→ We investigate evolution of disk fraction in normal fields

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No evolution in disky ETG fraction from $z \sim 1$ to 0

3. Summary

2.1 $z \sim 1$ Field ETG Sample from Five 3D-HST Fields

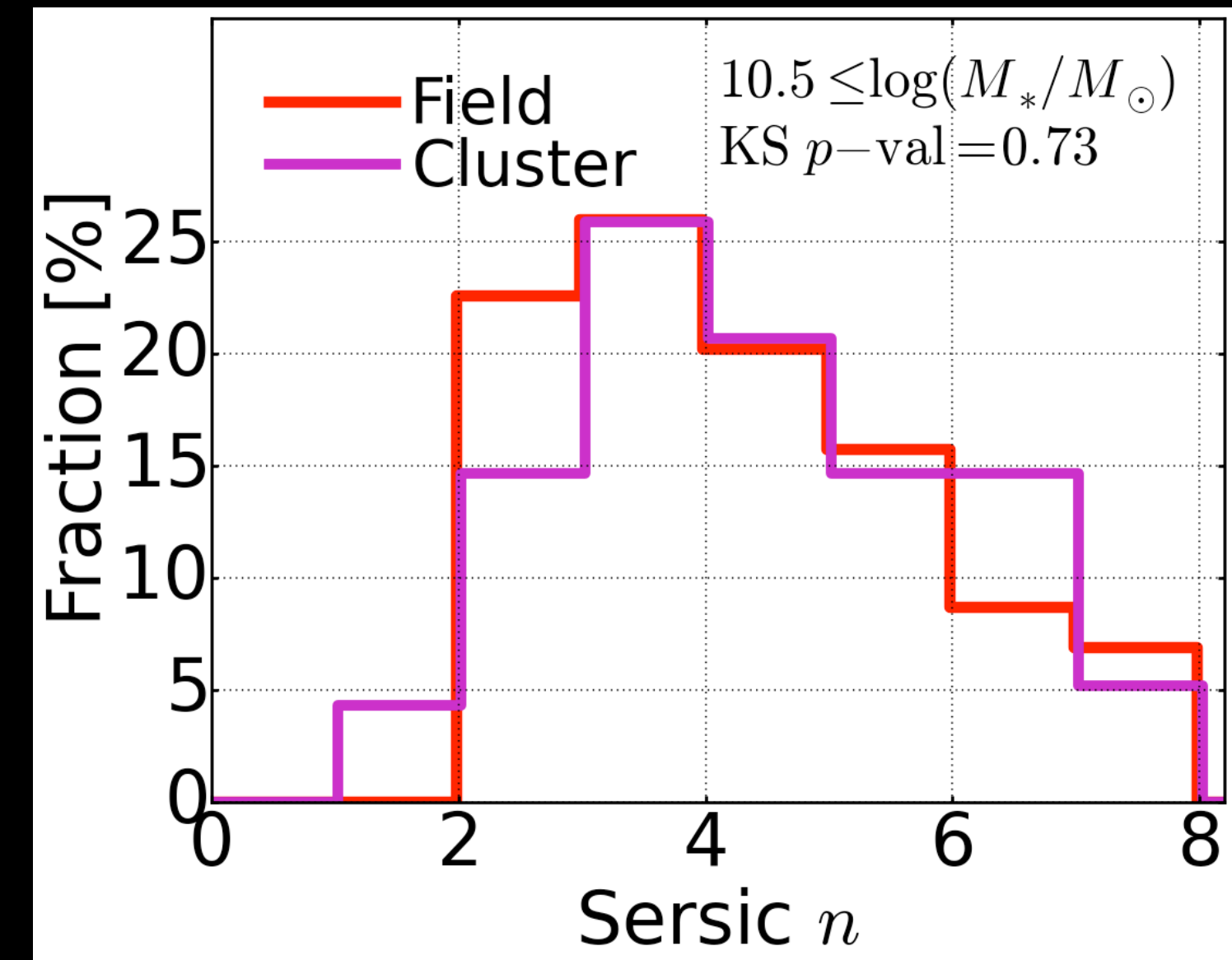
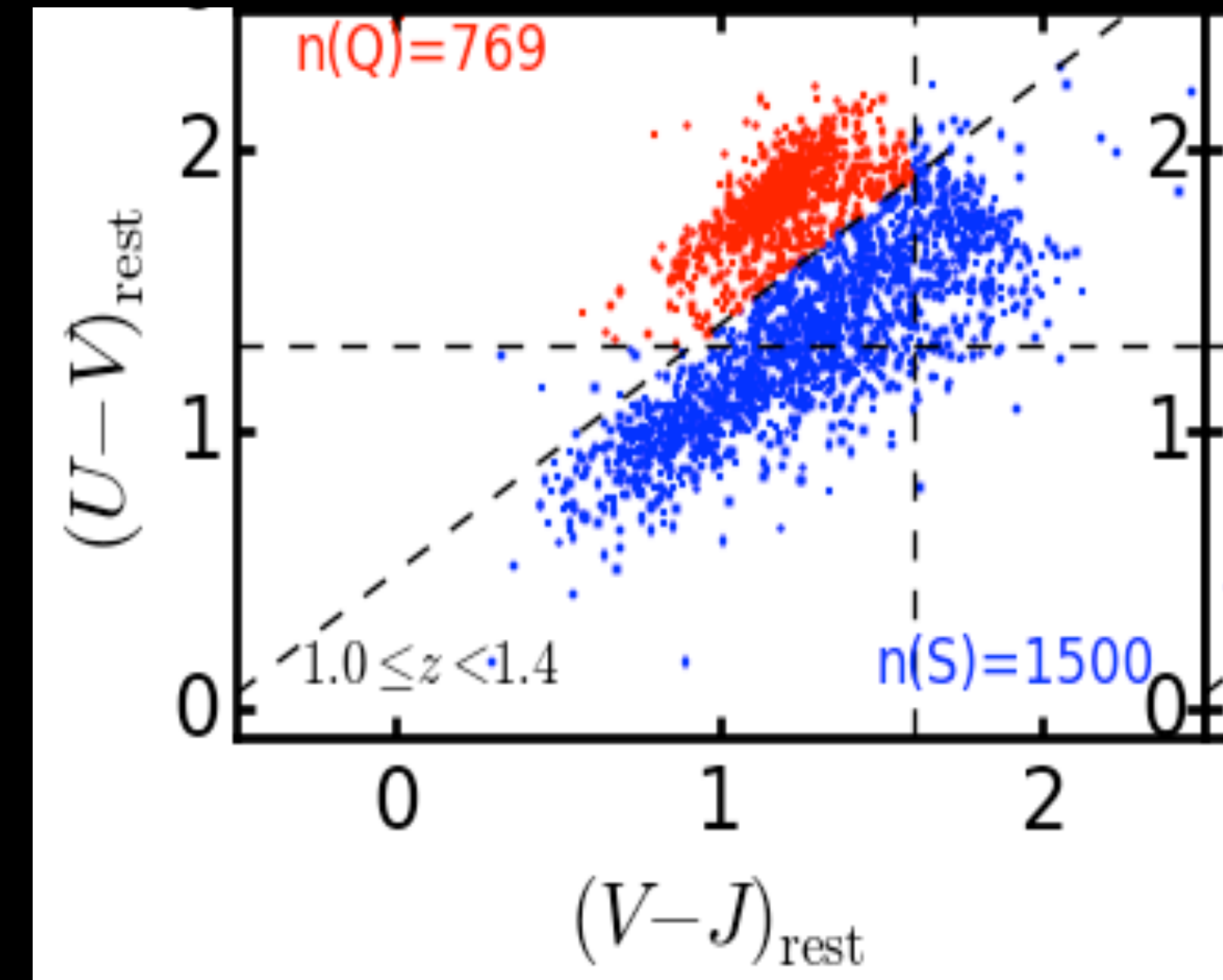
▷ 3451 galaxies in $0.8 < z < 1.4$

- Quiescent galaxy selection with UVJ diagram
- Stellar mass limit with $\log(M_*/M_\odot) > 10$

▷ 1181 mass-limited quiescent galaxies

- Sérsic index $n \geq 2$

▷ 923 Field ETGs



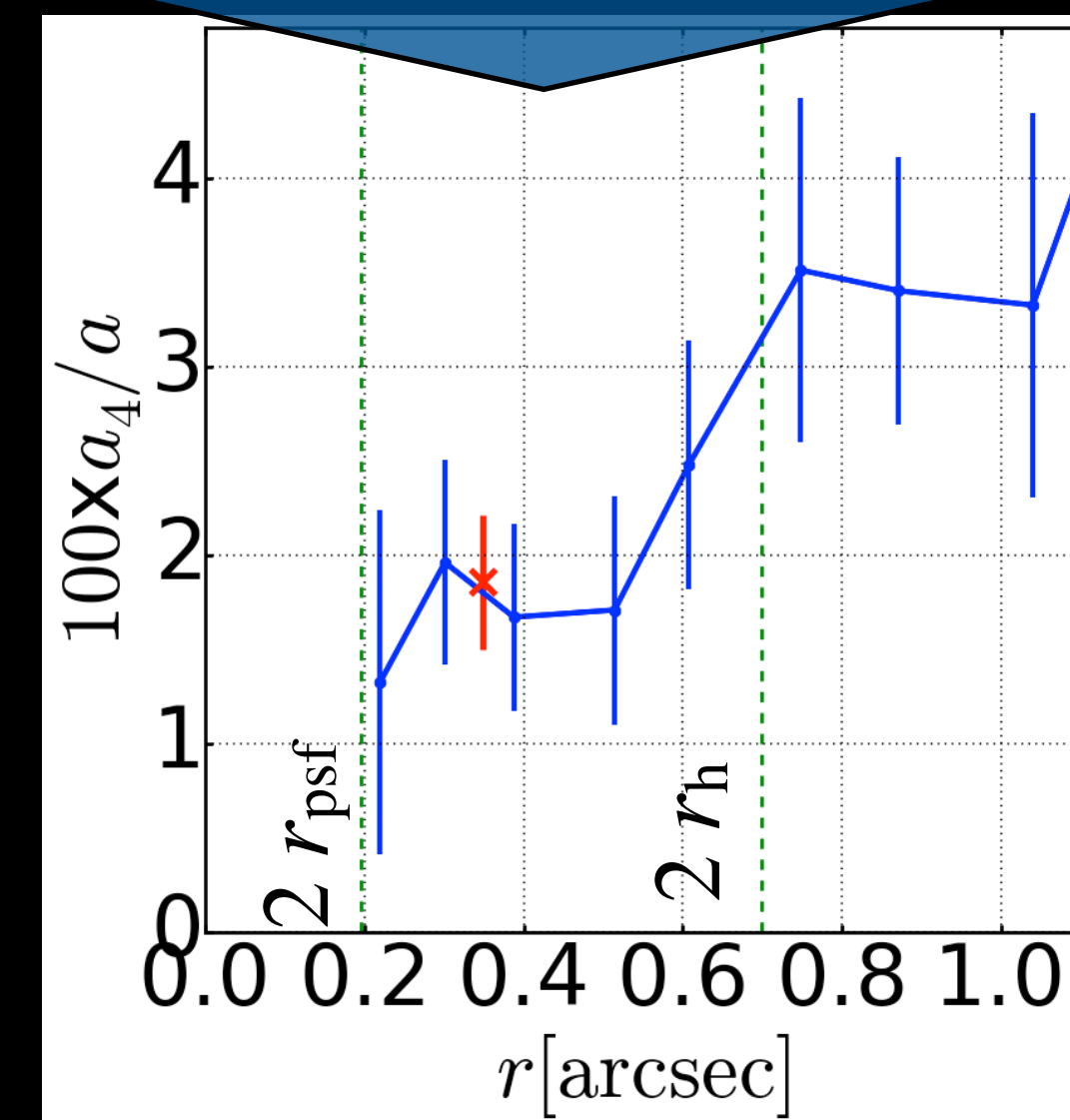
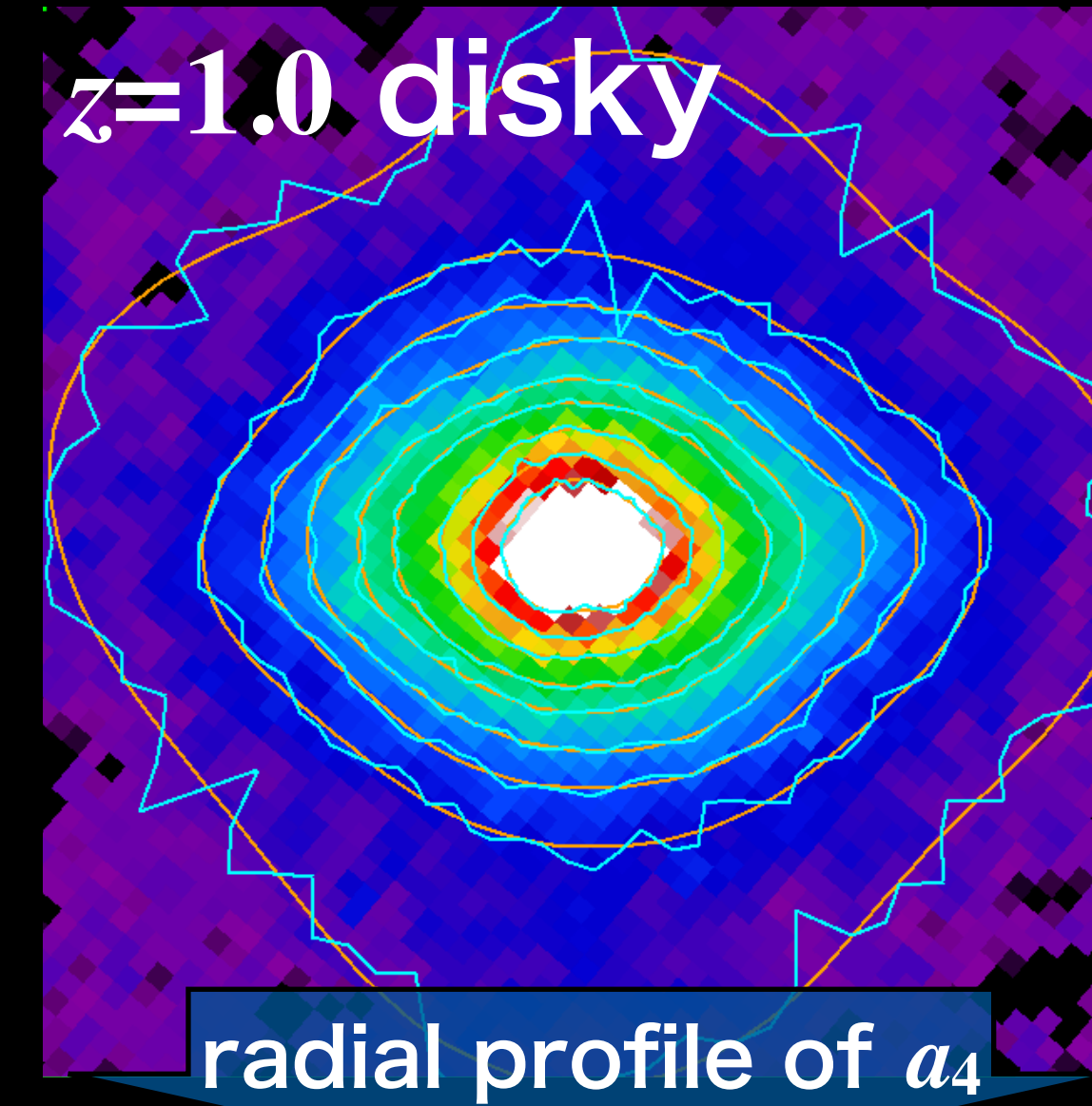
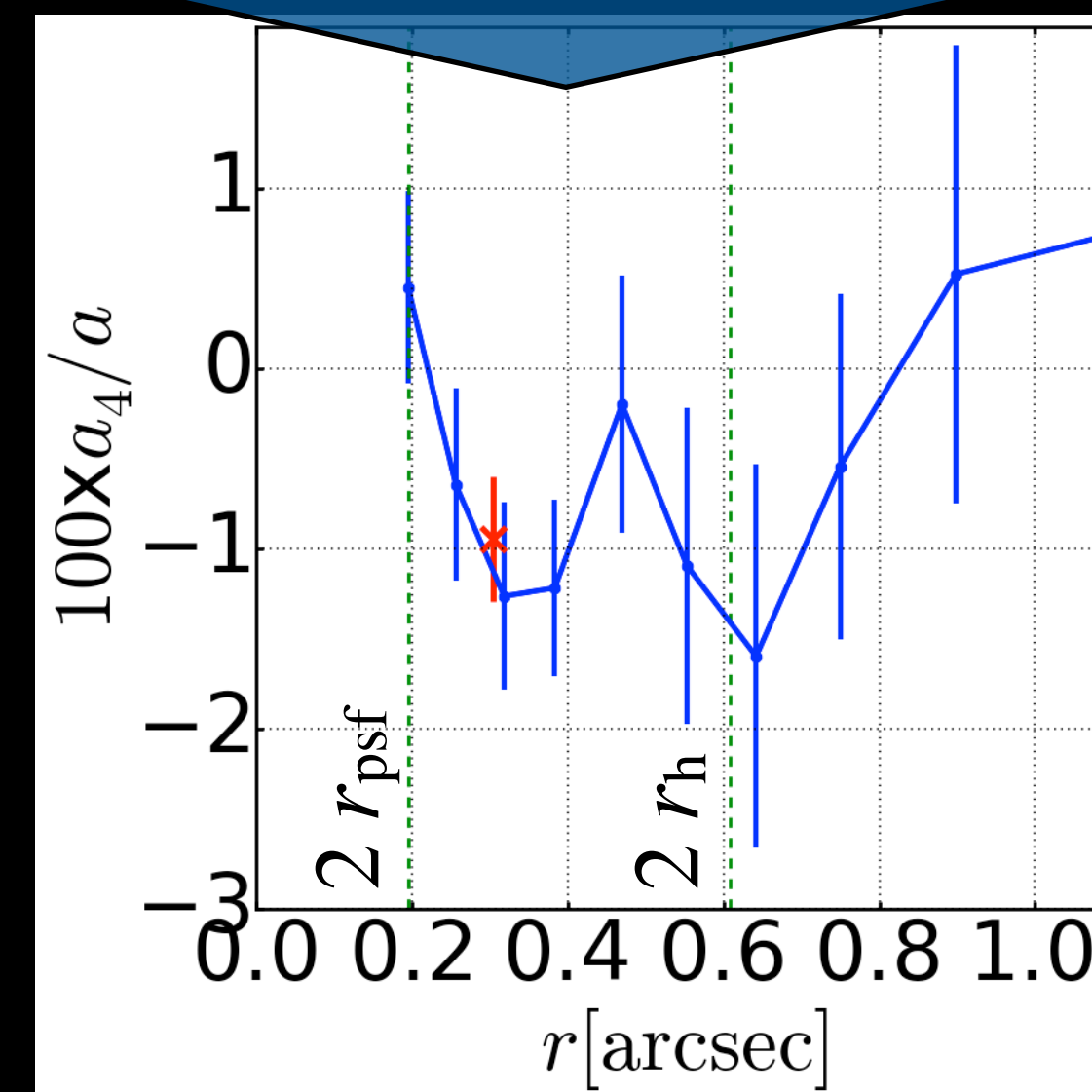
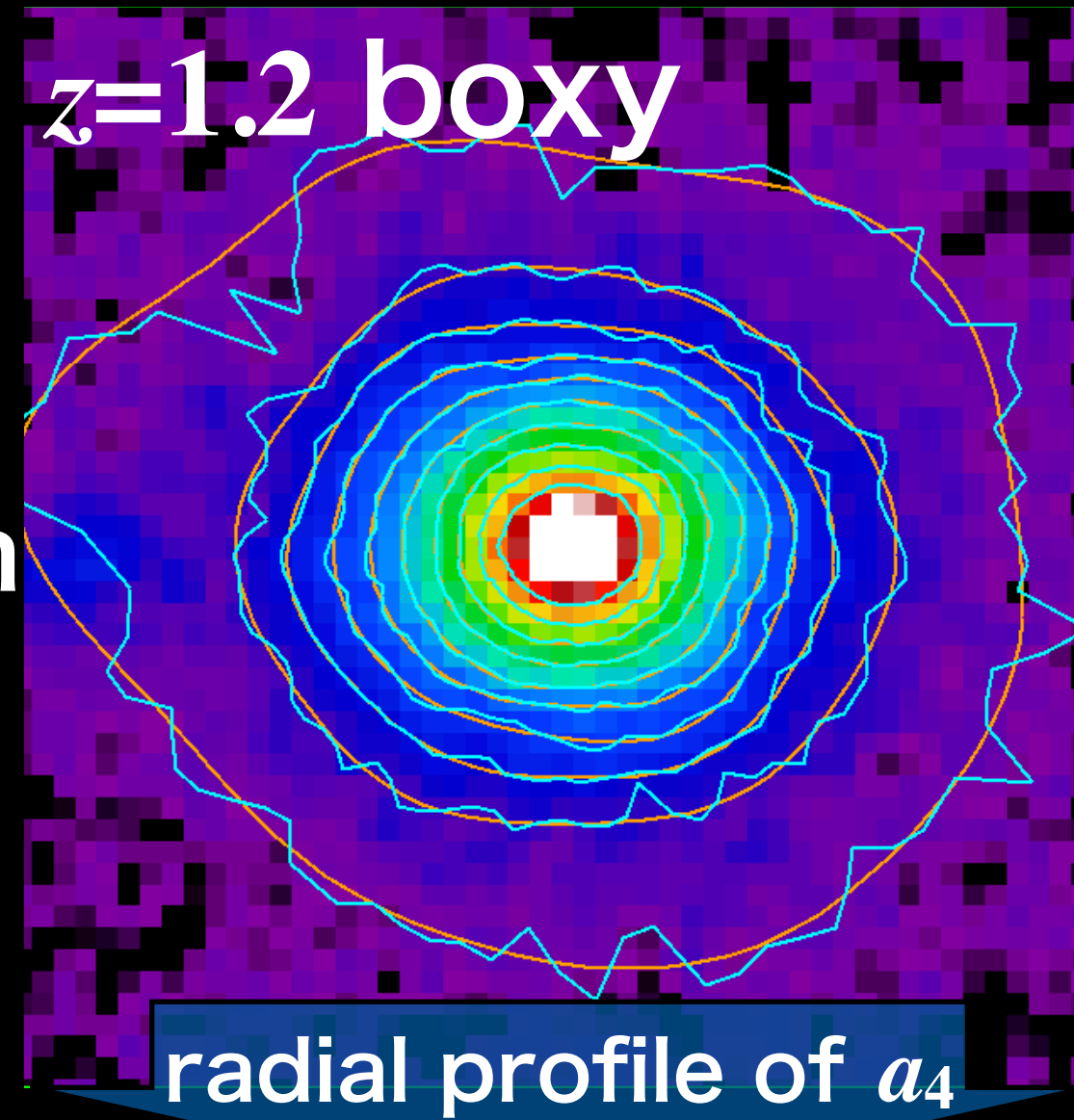
2.2 Measuring Isophote Shape Parameter a_4

- ① Determine isophote contours
w/ HST WFC3 F160W image
- ② Fit ellipses with Fourier deviation
Radial profiles of a_4 parameter
etc... are derived.

- ③ Get mean a_4 from radial profile

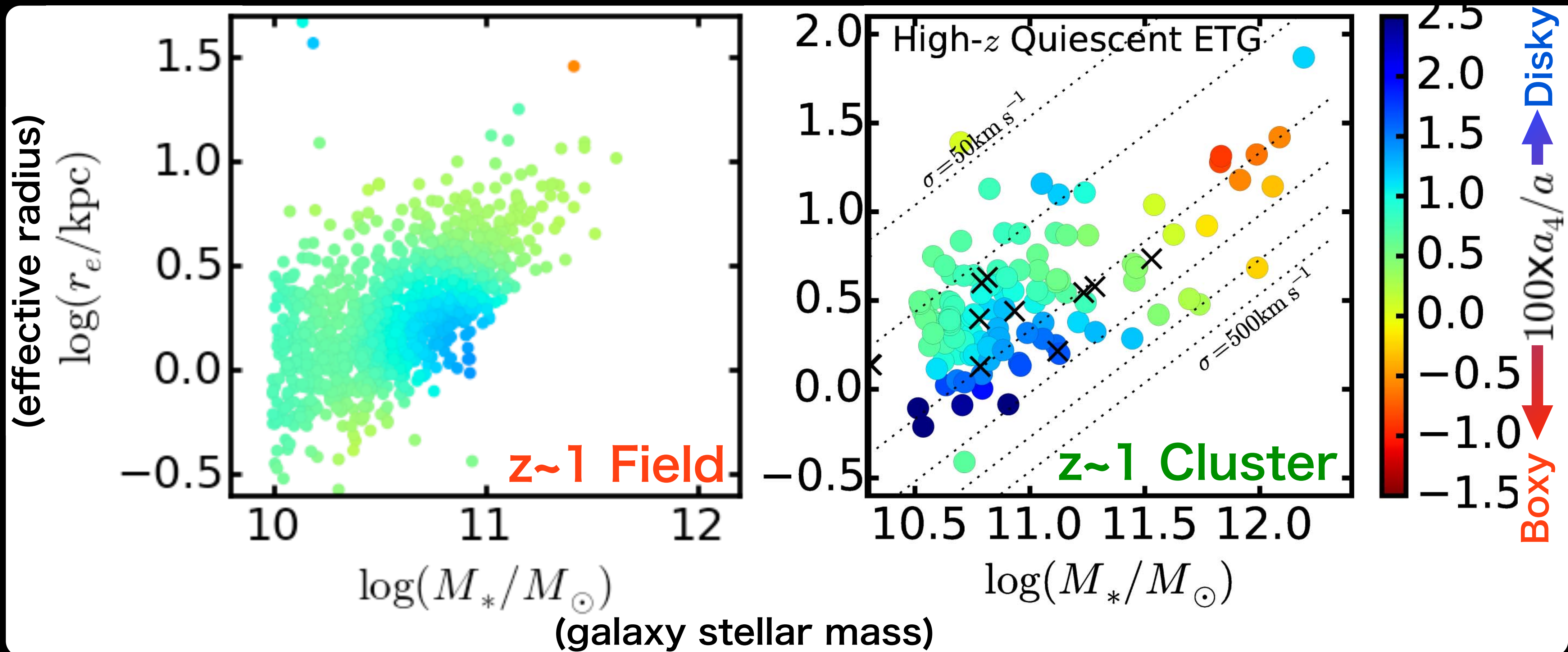
Luminosity weighted mean
within $2 r_{\text{PSF}} < r < 2 r_{\text{h}}$

* r_{PSF} : PSF HWHM,
 r_{h} : half-light radius

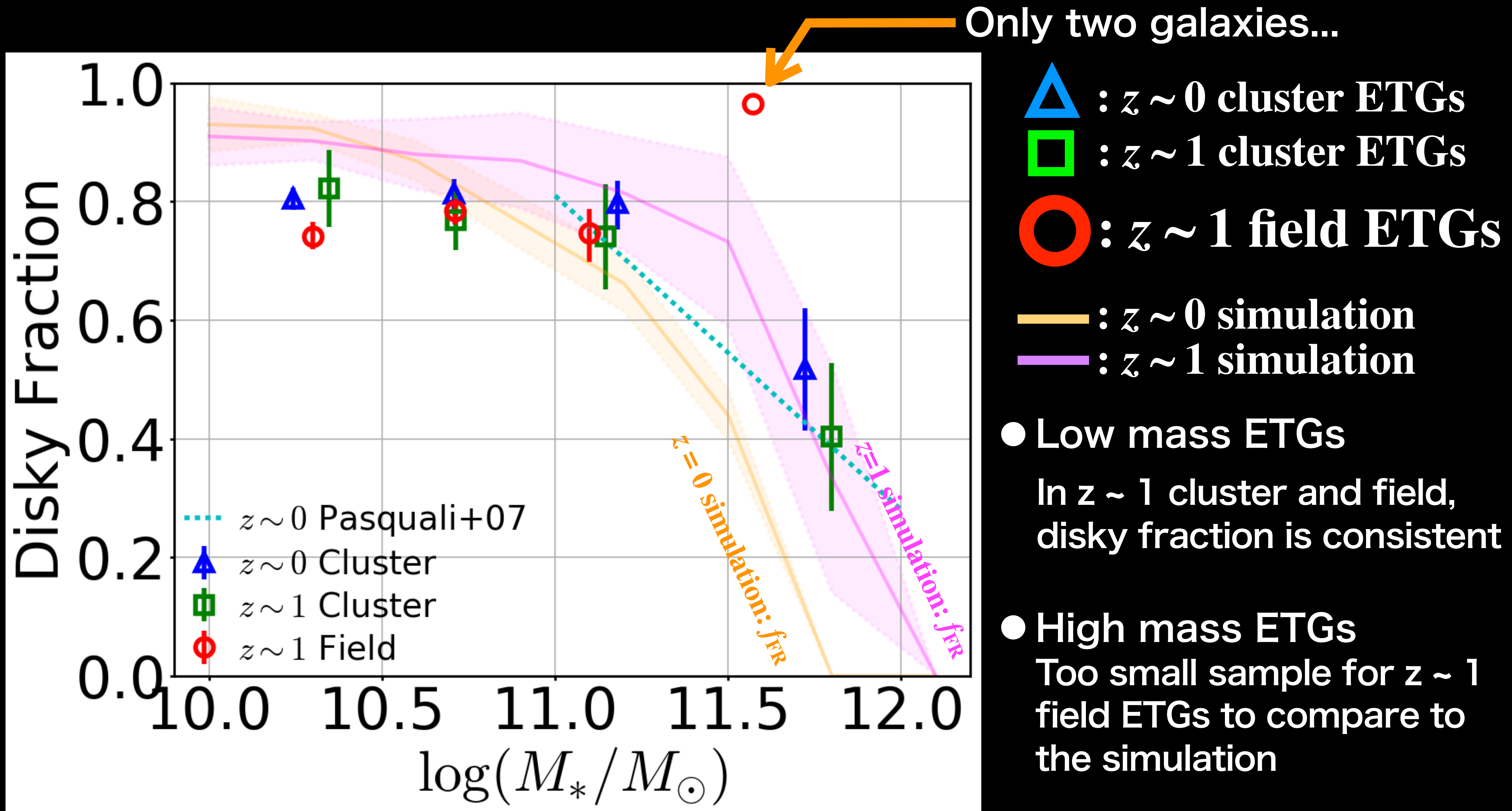


2.3 Dependence of a_4 Parameter on Mass and Size

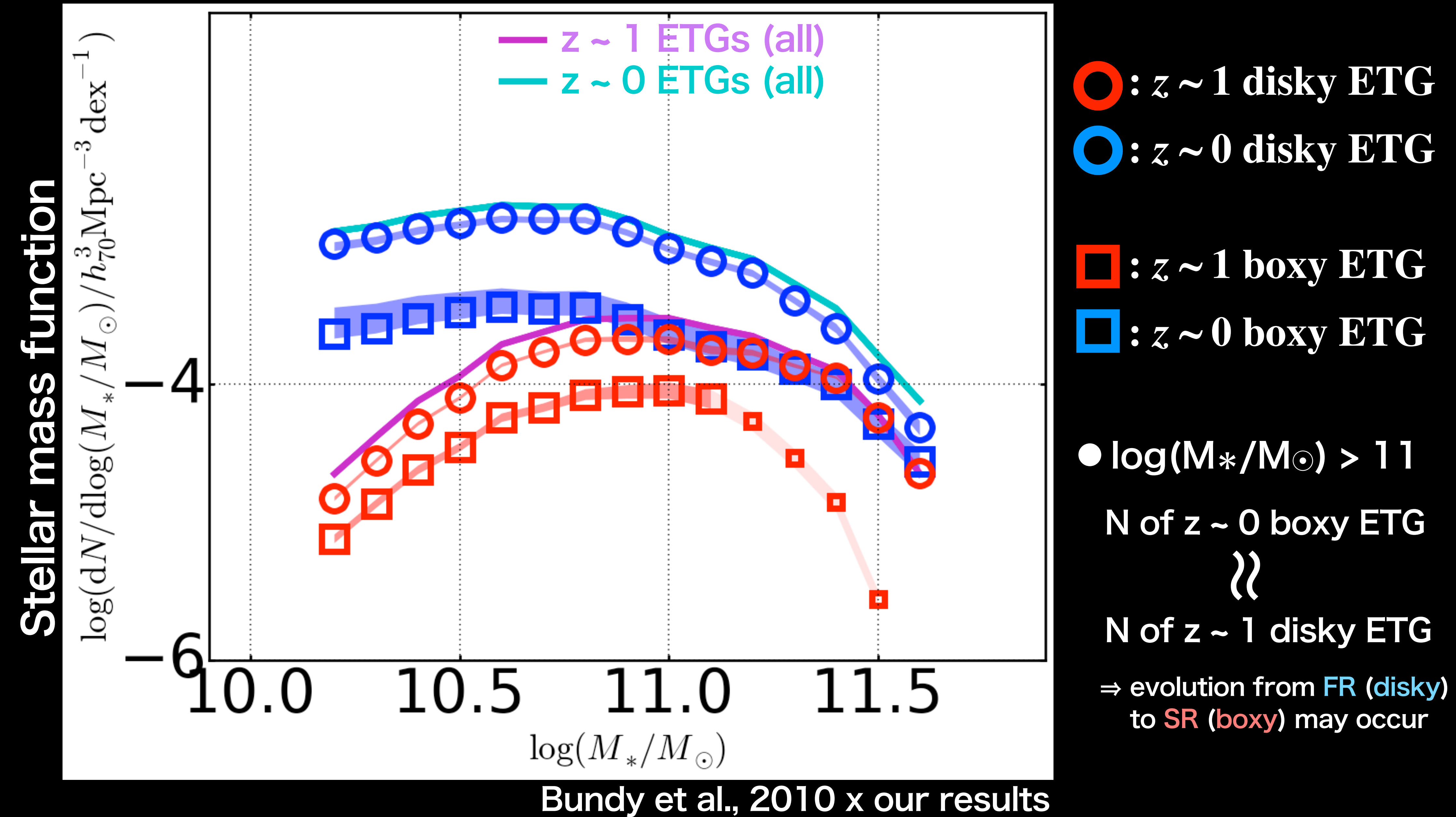
- No massive ($\log(M_*/M_\odot) > 11.5$) boxy ETG in $z \sim 1$ field sample
- For lower mass ETGs, smaller galaxies are more disk-like with larger a_4 value



2.4 Disky ETG Fraction at $z \sim 1$ and 0 in Different Environment



2.5 Number density of Boxy and Disky ETGs



3 Summary

● Introduction

- ☀ Dynamics of early-type galaxies: **slow rotators** vs **fast rotators**
- ☀ Isophote shape (**boxy** vs **disky**) is related to dynamics
- ☀ Evolution from **fast (disky)** to **slow (boxy)** rotators in $z < 1$ is predicted

● Our results

- ☀ No evolution of **disky** fraction in $z < 1$ independent of environments
 - * **Disky** fraction for $z \sim 1$ field ETGs in massive end is uncertain
- ☀ No evolution in **disky** fraction is NOT inconsistent with **disky (FR)** to **boxy (SR)** evolution if the number density is taken into account.