A kinematic classification of Early-Type Galaxies (ETG's)

Emsellem (2007), Emsellem (2011)

Ids Nieuwstraten, Philip Stoot | Galaxies: Structure, Dynamics & Evolution by Dr. Richard Bouwens

Universiteit
Leiden
The Netherlands

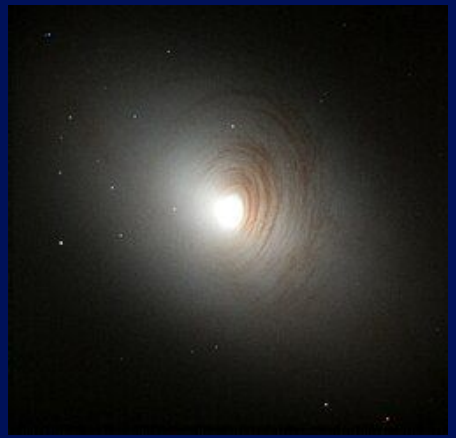
Introduction: Hubble's tuning fork

Edwin Hubble's

Early-Type Galaxies (ETG's)

E-type:
Elliptical galaxy

S0-type:
Lenticular galaxy



Can we find a better classification?

- Hubble fork: purely visual → **misleading**
  - What about inclination?
- Should include physics!

Previous attempts

- ϵ ellipticity → **incomplete**
- (a_4/a) term → 'discy' vs 'boxy' → **unreliable**

Boxy

FIGURE 7. — R-image of NGC 5322, an elliptical galaxy with box-shaped isophotes $(a(4)/a \sim -0.01)$.

Disky

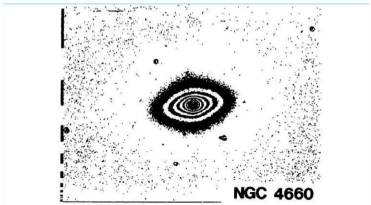
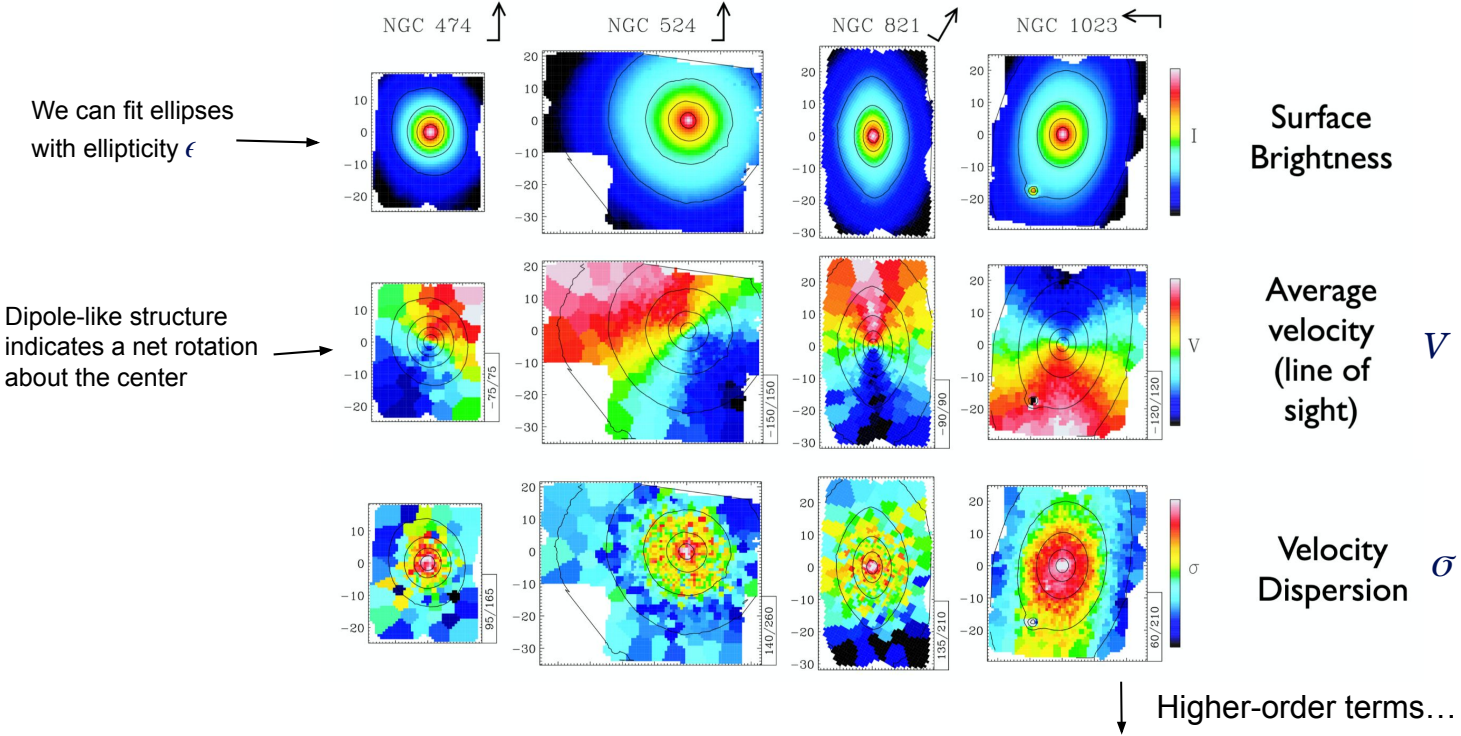


FIGURE 6. — R-image of NGC 4660, an elliptical galaxy with a disk-component in the isophotes $(a(4)/a \sim +0.03)$.

What about stellar motion?

We can look at kinematics

From lecture: we can measure **2D (stellar) velocity maps** with an Integrated Field Spectograph:



From lecture:

We talked about a relationship between V/σ and ϵ

What about substructures?

From the observed v/σ versus ellipticity (ε) relationship, it seems clear that there is a qualitative difference between the most luminous elliptical galaxies and lower luminosity elliptical galaxies:

This dichotomy is seen in many of the other properties of elliptical galaxies as well:

Luminosity	High	Low
Physical Mechanism for Flattening	Anisotropy	Rotation
Isophotes	Boxy	Disky
Shape	Triaxial	Oblate
Profile	Core/ Break	Cuspy/ Power-Law
X-ray/radio	Loud	Quiet

This suggests that higher luminosity and lower luminosity elliptical galaxies may form in different ways!

Emsellem 2007: A new kinematic parameter

"Angular momentum per unit mass"

- Derived from spin parameter λ
- Assume conversion factor $\kappa \sim 1$
- For isotropic systems: $\lambda_R \propto \sqrt{\epsilon}$
- Normalized: $\lambda_R \rightarrow 1$ for large V

Why better than (V/σ)?

- Captures decoupled cores and twists better
- Factor of 2 less sensitive to errors

Observational spin parameter

$$\lambda_R \equiv \frac{\langle R\,|V|\rangle}{\langle R\sqrt{V^2+\sigma^2}\rangle}$$

average

Emsellem 2007: The sample

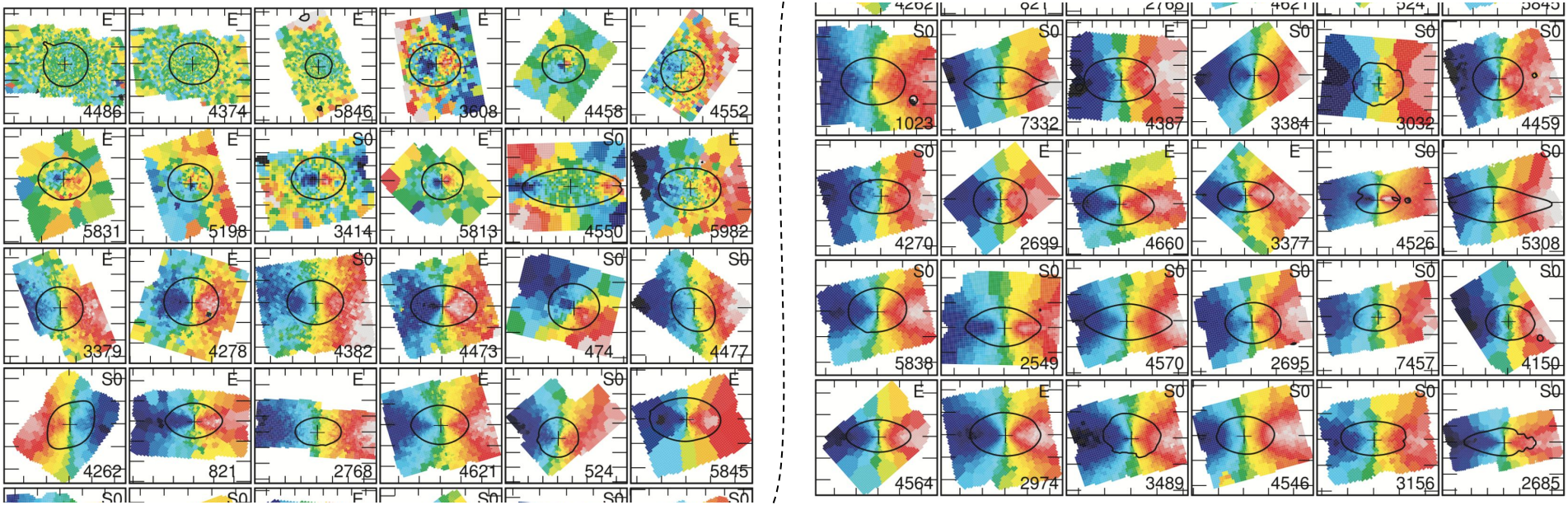


Figure 1. SAURON **stellar velocity fields** for our 48 E and S0 galaxies. Galaxies are ordered by increasing value of λRe. Slow rotators are galaxies on the first two rows.

Two families: ‘slow’ vs ‘fast’ rotators

$\lambda_{Re} < 0.1$ $\lambda_{Re} > 0.1$

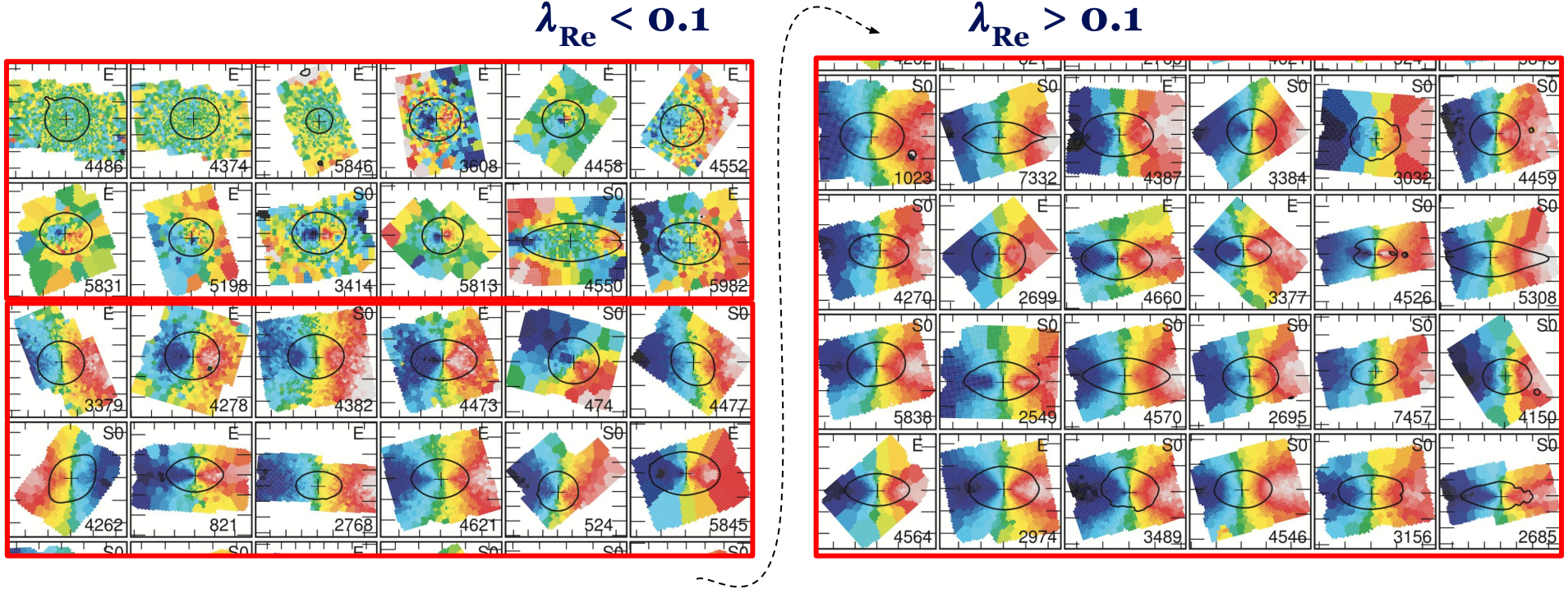


Figure 1. SAURON **stellar velocity fields** for our 48 E and S0 galaxies. Galaxies are ordered by increasing value of λRe. Slow rotators are galaxies on the first two rows.

Two families: 'slow' vs 'fast' rotators

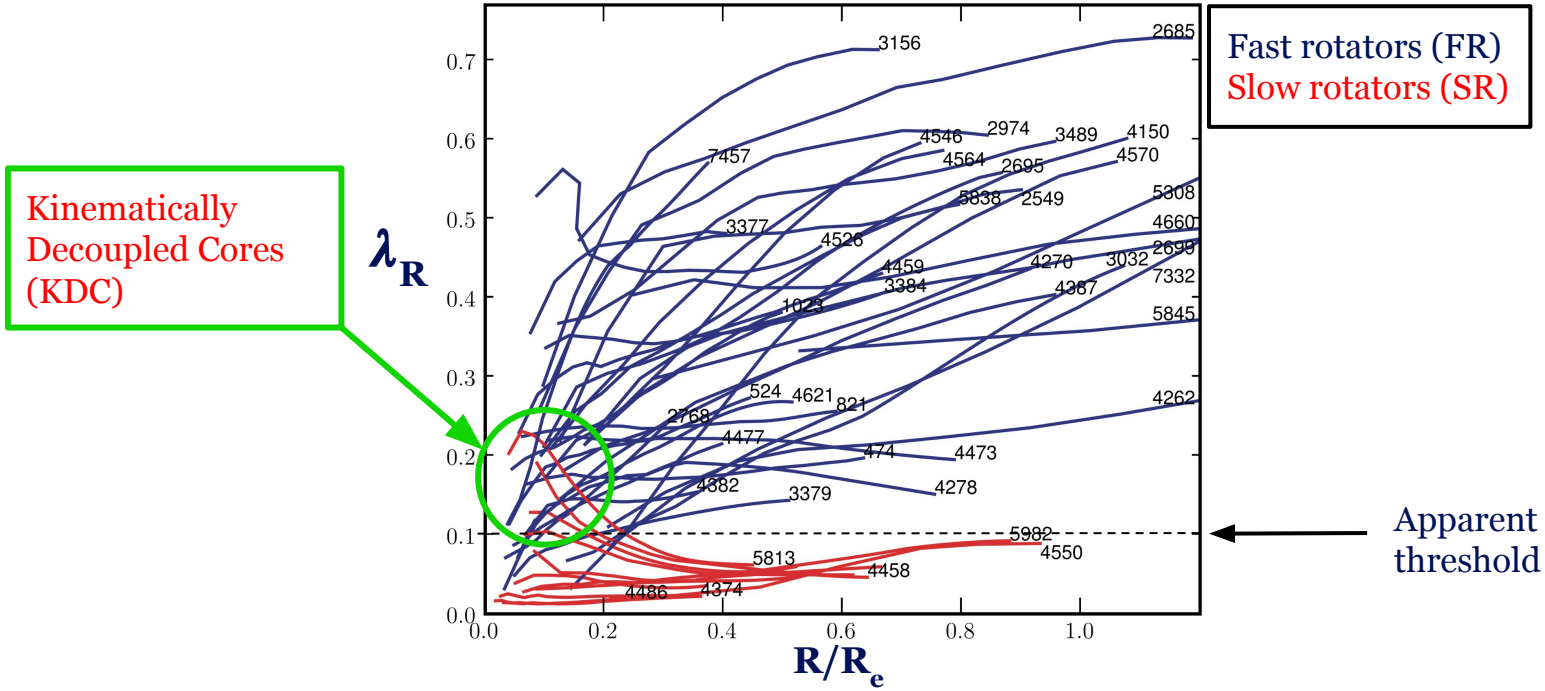


Figure 2. Radial λ_R profiles for the 48 E and S0 galaxies of the SAURON sample.

Emsellem 2011: an improved threshold

- Introduces the ATLAS3D
  - 48 galaxies → 260 galaxies
  - Representative sample → volume-limited sample
- New threshold definition
  - Highly flattened VS Round galaxies (λ_R = const.)

Emsellem 2011: an improved threshold

- Previously: $\lambda_R = 0.1$
- Updated: $\lambda_R = (0.31 \pm 0.01)\sqrt{\epsilon}$

- Empirically chosen to limit contamination
  - Regular rotators (purple)
  - Non-regular rotators (red, green and orange)

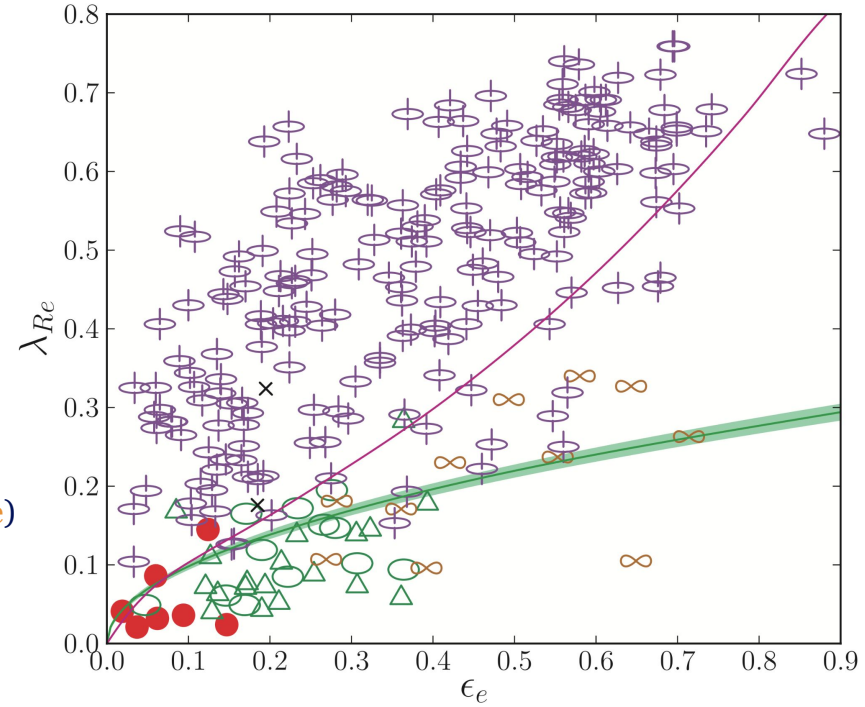


Figure 3. λ_{Re} versus the global ellipticity ϵ of the ATLAS3D sample

Emsellem 2011: distribution of galaxies

- 86% FR's are:
  - Nearly oblate systems
- 14% SR's are either:
  - Massive and rather round/triaxial ($M > 10^{11} M_{\odot}$)
  - Or less massive with 2 counter rotating disc systems
- SR's most comparable to E's, but…
- Classic categorization of ETG's is misleading!

Back to Hubble…

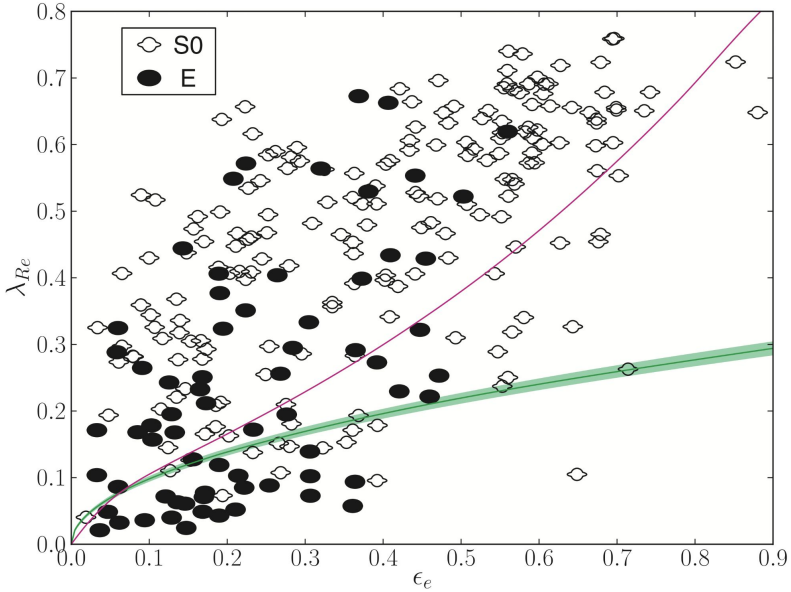


Figure 4. λ_{Re} versus the global ellipticity ϵ of the ATLAS3D data. Galaxies are catagorized to be either lenticulars or elipticals.

Emsellem 2011: a evolutionary interpretation

- FR's form through:
  - Complex combination of dissipative processes
  - Or minor mergers
  - **Retain their angular momentum**

- SR's form through major or repeated mergers
  - **Disrupted kinematic identity**

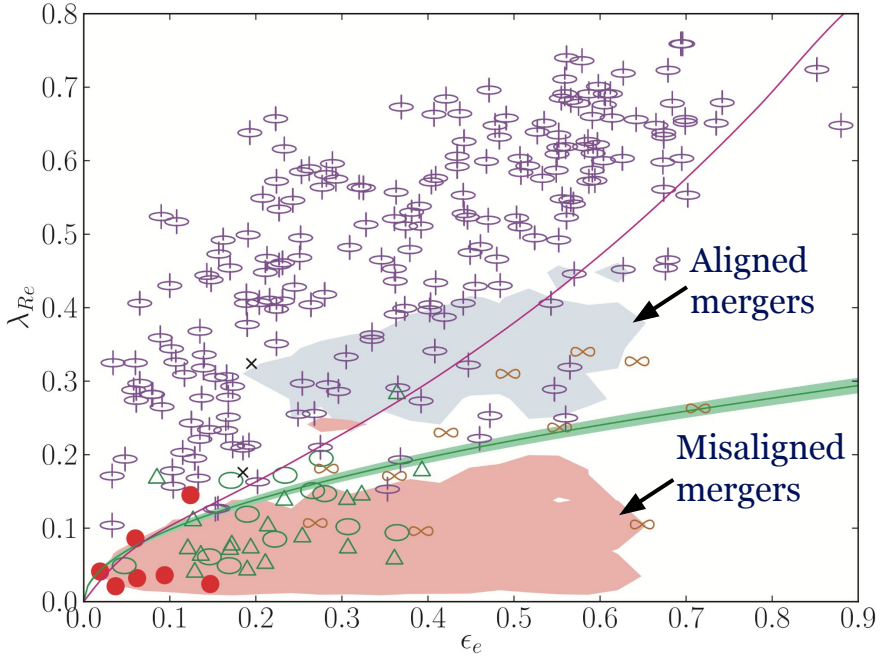


Figure 5. λ_{Re} versus the global ellipticity ϵ. The colored areas represent the distribution of galaxies formed through major mergers based on numerical simulations.

Overview - Questions?

In addition:	**~15%: Slow Rotators**	**~85%: Fast Rotators**
Luminosity	High	Low
Kinematic features	Complex (cores, twists)	Regular
Mass	High	Low
Shape	Triaxial	Oblate
Formation	Major mergers, disruption	Minor mergers/reaccretion

N.B: (naturally) some overlap in properties!

Observational spin parameter

$$\lambda_R \equiv \frac{\langle R\,|V|\rangle}{\langle R\sqrt{V^2+\sigma^2}\rangle}$$

Threshold ~ $0.3\sqrt{\epsilon}$