MORPHO-KINEMATIC CLUES TO THE ORIGIN OF S0 BULGES

CALIFA Survey

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WHAT DO WE KNOW ABOUT S0 FORMATION?

MAJOR MERGER FORMATION
INSIDE-OUT FORMATION

HIGH-DENSITY ENVIRONMENT EVOLUTION
GAS-STRIPPING & SF QUENCHING

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BULGES ARE KEY TO UNDERSTAND S0 GALAXIES

TWO MAIN BULGE TYPES

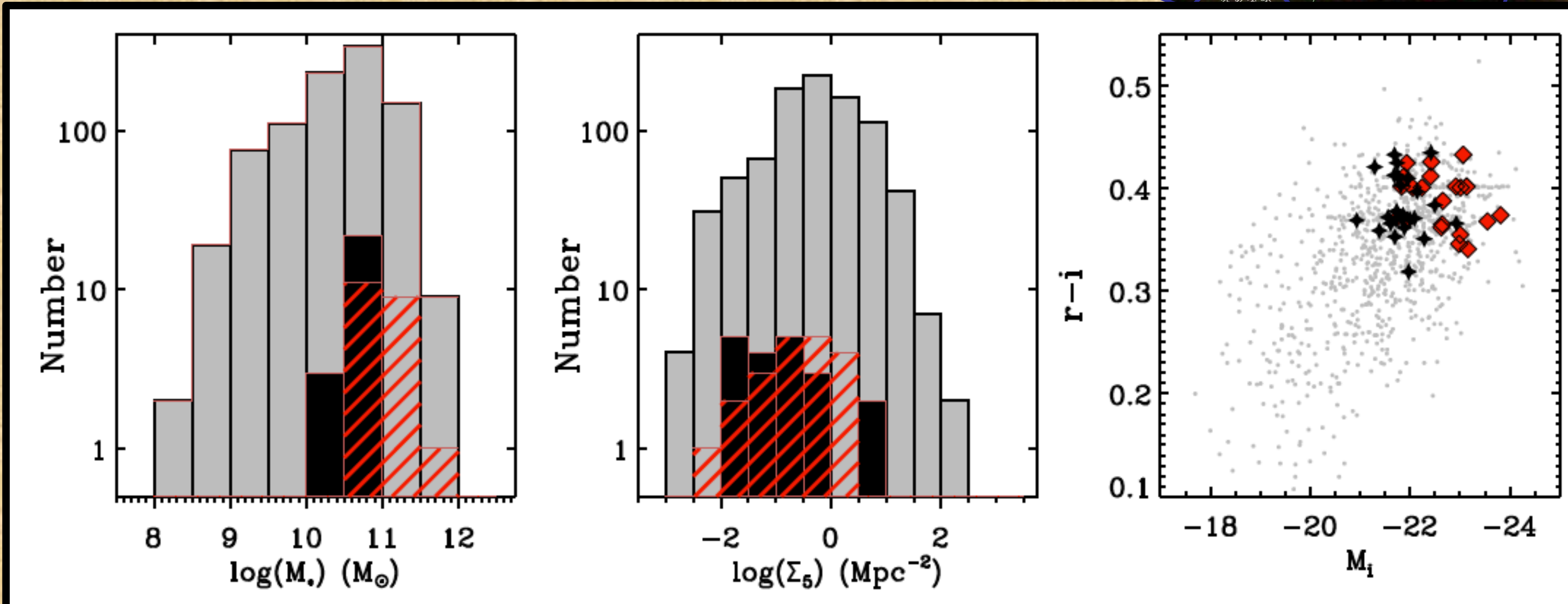
Classical Bulges

- Galaxy mergers Hopkins+10
- Dissipative collapse of gas clouds Eggen+62
- Coalescence of giant clumps Bournaud+07

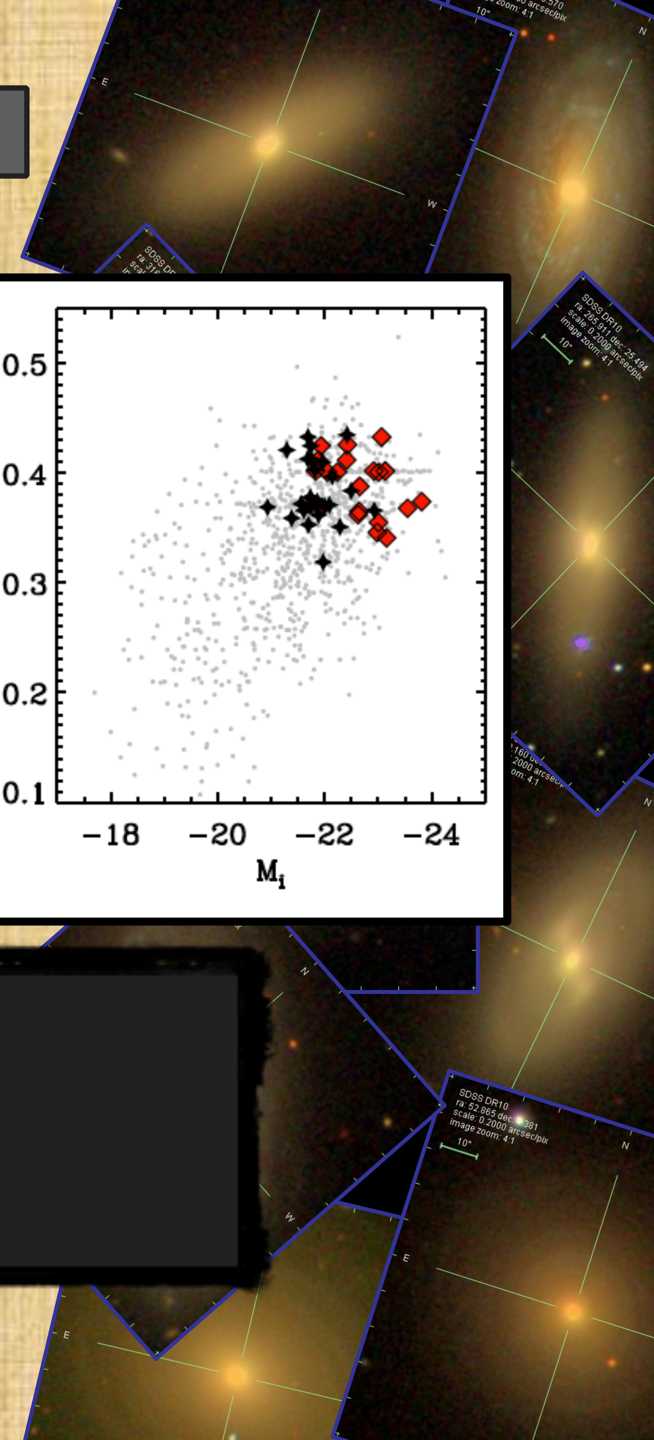
Disk-like bulges (aka pseudobulges)

- Secular processes driven by bars Kormendy & Kennicutt 04; Athanassoula05

SAMPLE SELECTION



- ★ 25 S0 galaxies
- ★ Stellar masses ($10^{10} < M_{\star}/M_{\odot} < 10^{11}$)
- ★ Red colors
- ★ Relatively isolated environment.



CALIFA PHOTOMETRIC DECOMPOSITION

Méndez-Abreu et al. 2016, A&A, in prep.

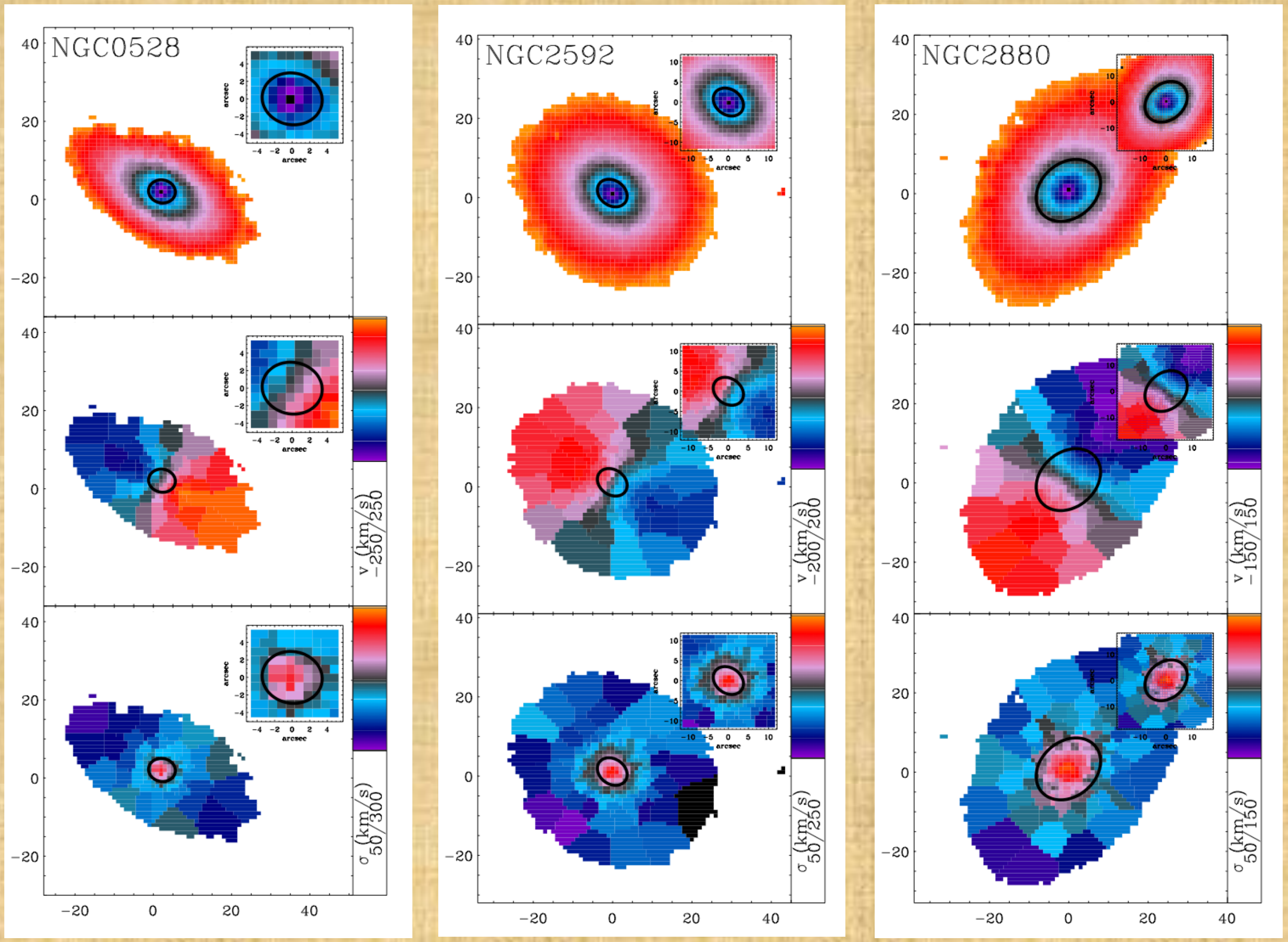
- Two-Dimensional	GASP2D (Méndez-Abreu et al. 2008)
- Multi-Component	Sersic bulge Type I, II, III disks Ferrers bars PSF Nuclear Sources
- Phot. Decomposition	SDSS bands: g, r, i
- CALIFA DR3	400 gals. (exc. edge-on and interacting)

S0s STELLAR KINEMATICS

Flux

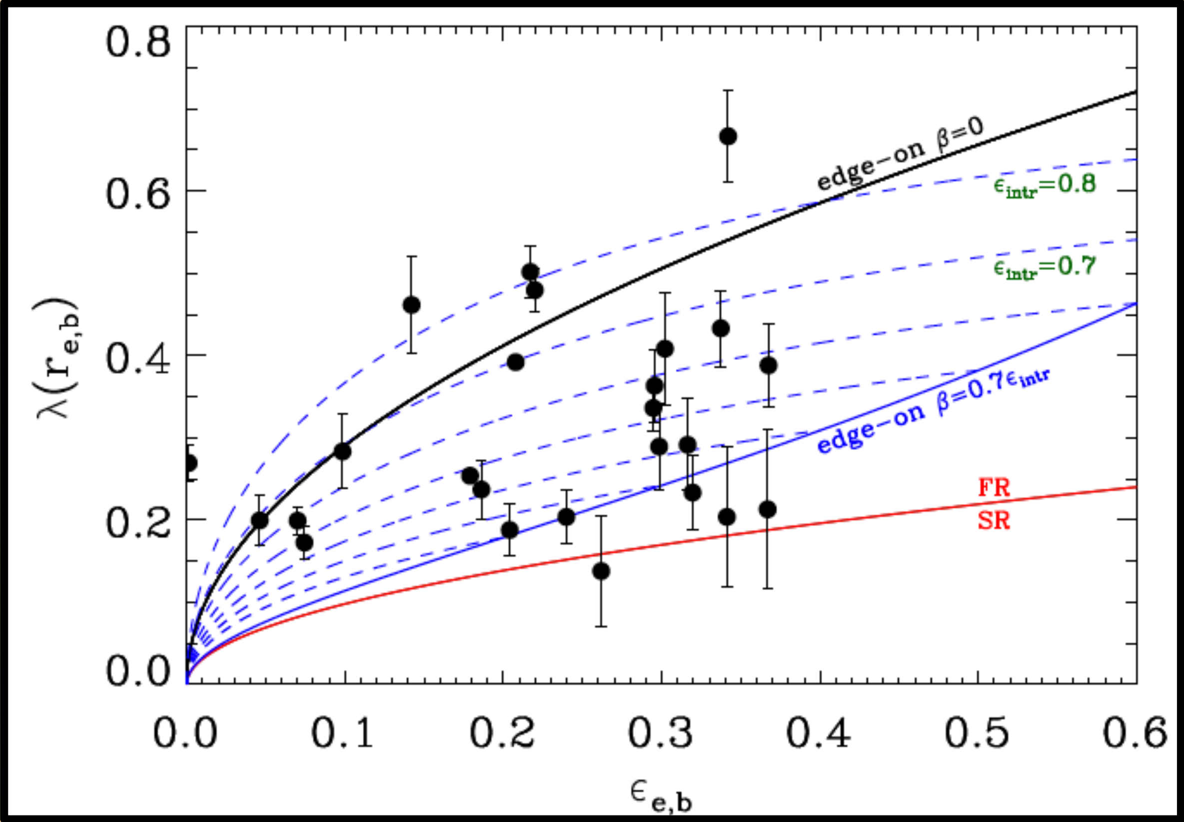
Velocity

Velocity dispersion



Quantifying the rotational support of bulges

S0 BULGES ANGULAR MOMENTUM

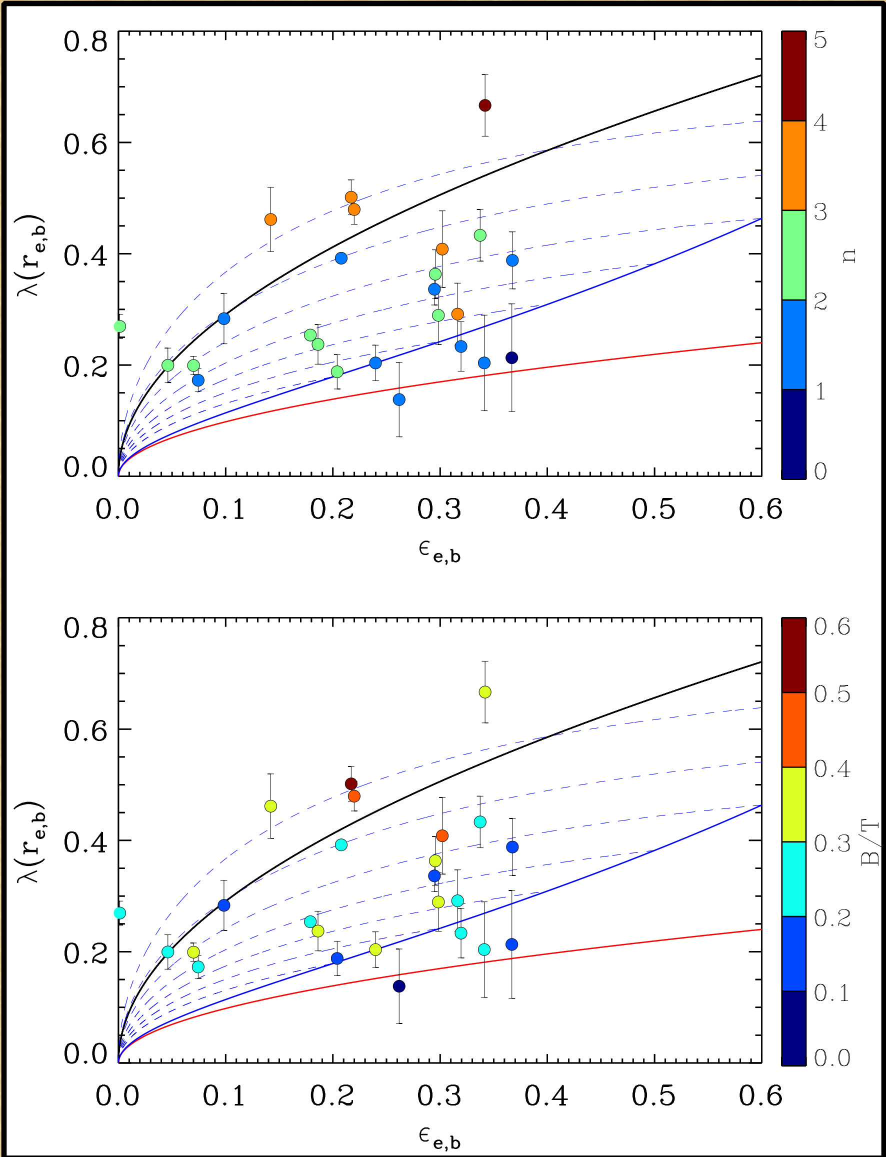


$$\lambda_R \equiv \frac{\langle R\,|V|\rangle}{\langle R\sqrt{V^2+\sigma^2}\rangle}$$

Emsellem+07

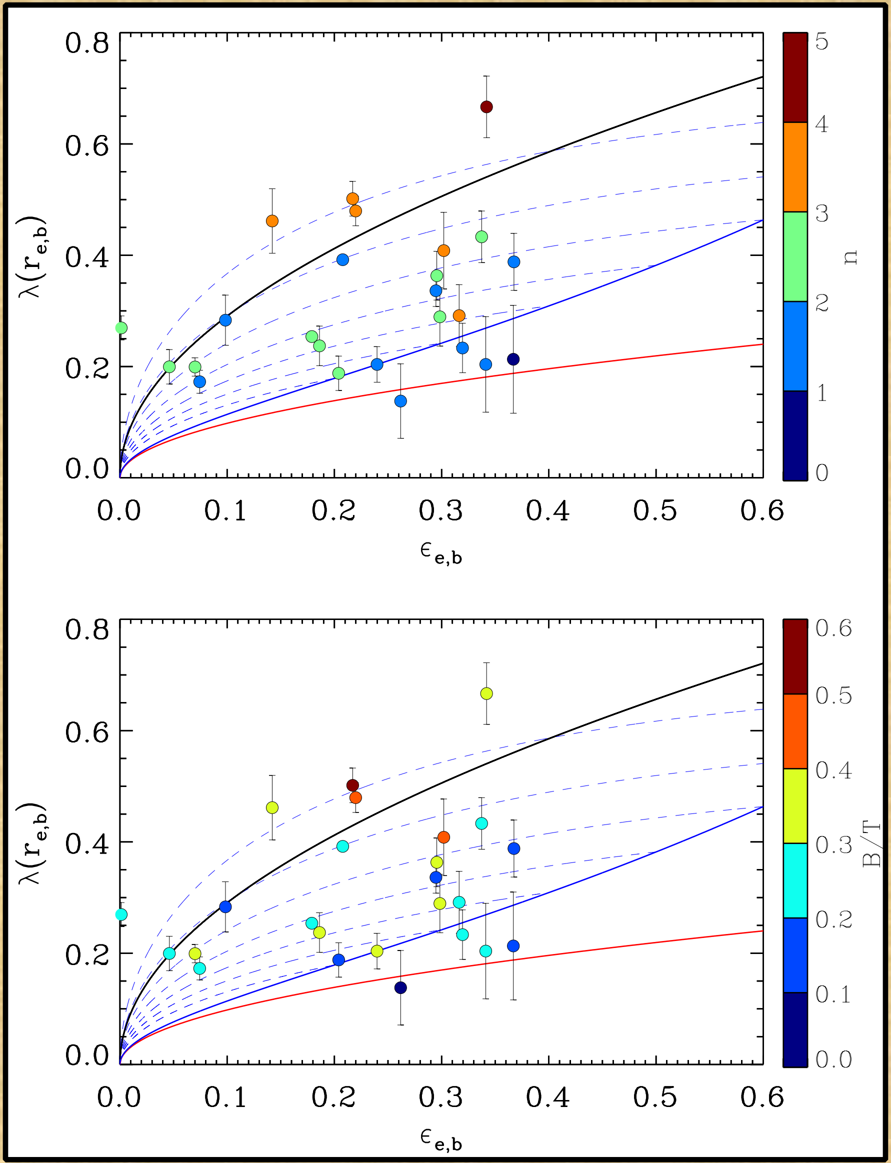
S0 bulges are fast rotators BUT most of them are NOT compatible with an isotropic oblate rotator model.

S0 BULGES ANGULAR MOMENTUM
PHOTOMETRY vs. KINEMATICS



The photometric (n and B/T) and kinematic (λ) quantities of bulges are not correlated

S0 BULGES ANGULAR MOMENTUM
PHOTOMETRY vs. KINEMATICS



The photometric (n and B/T) and kinematic (λ) quantities of bulges are not correlated

Is this an inclination effect or is it intrinsic?

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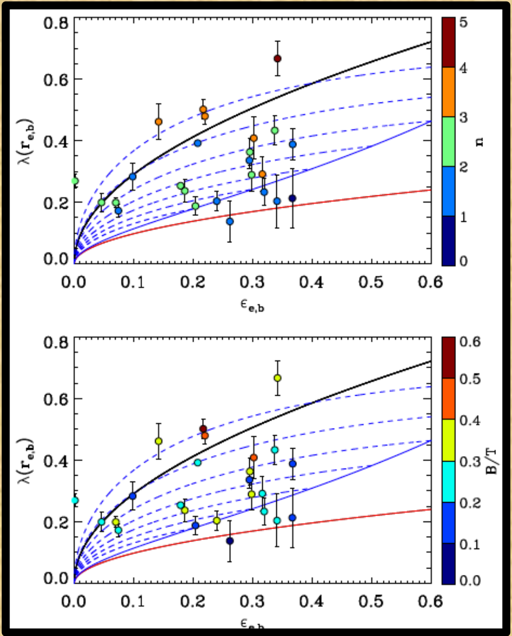
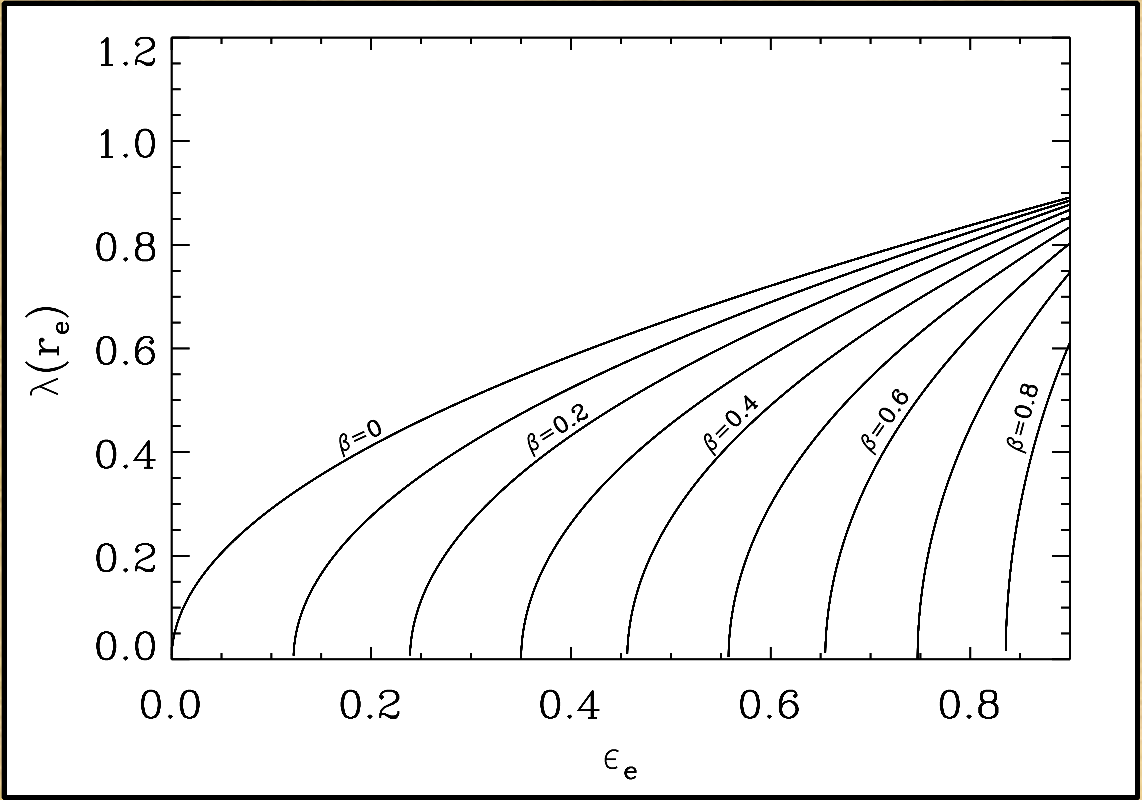
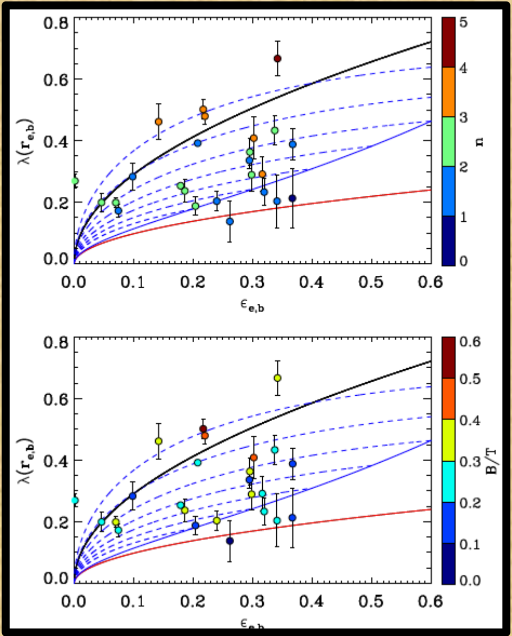
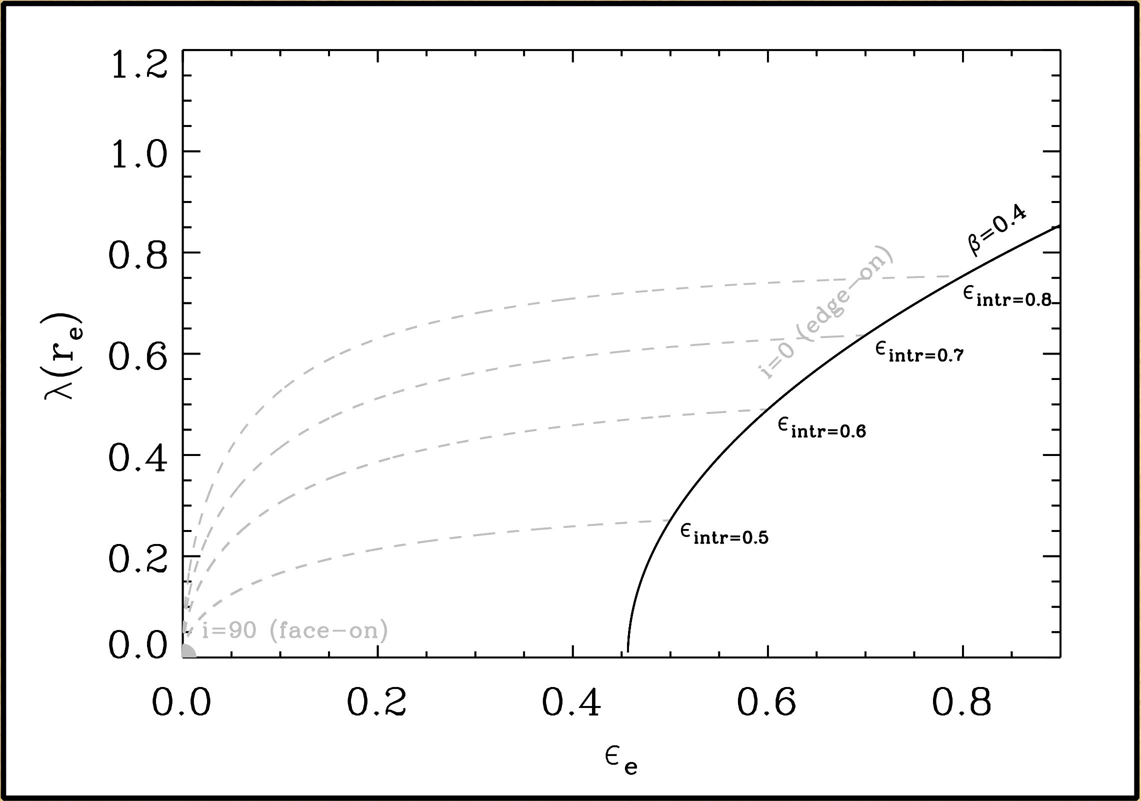
PHOTOMETRY vs. KINEMATICS



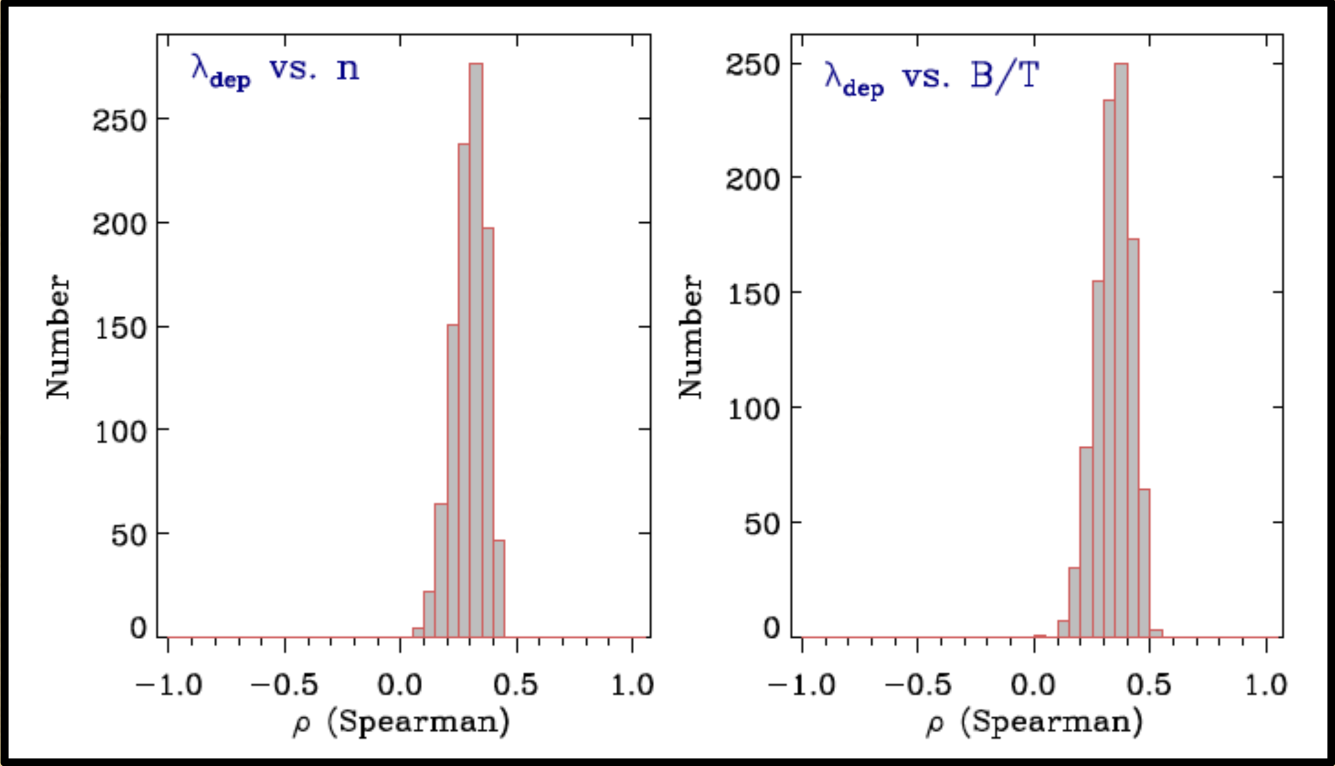


S0 BULGES ANGULAR MOMENTUM
PHOTOMETRY vs. KINEMATICS





S0 BULGES ANGULAR MOMENTUM PHOTOMETRY vs. KINEMATICS



The lack of correlation is independent of the viewing angle and it is intrinsic to the bulges

CONCLUSIONS

- ★ Our galaxy sample is representative of S0s with
  - ★ **High stellar masses ($10^{10} < M_\star/M_\odot < 10^{11}$)**.
  - ★ **Red sequence**
  - ★ **Field and loose groups**.

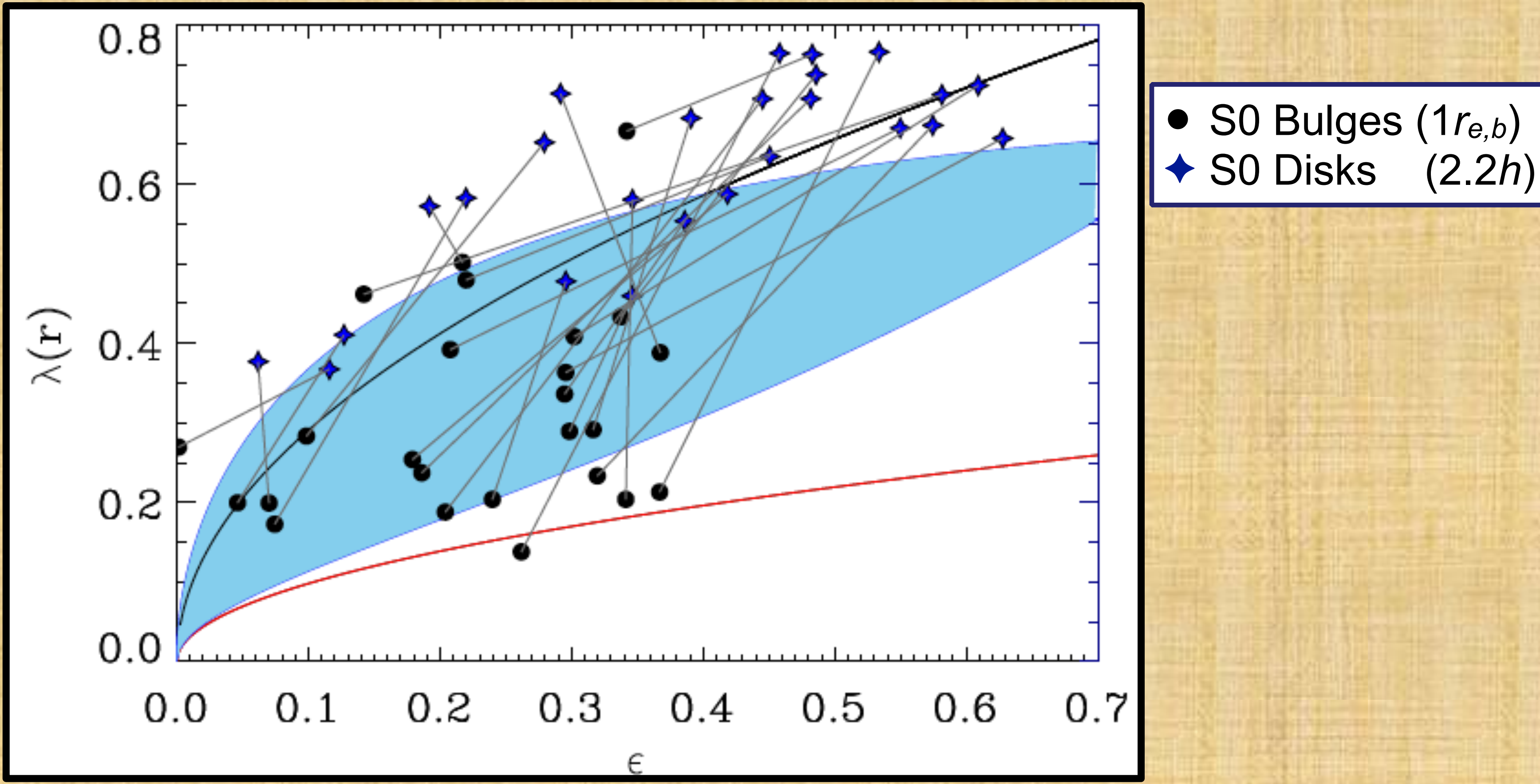
- ★ Our **S0 bulges are fast rotators**

- ★ Anisotropy is needed to maintain their structure

- ★ The **photometric (n and B/T) and kinematic (λ) properties of the S0 bulges are not related.**

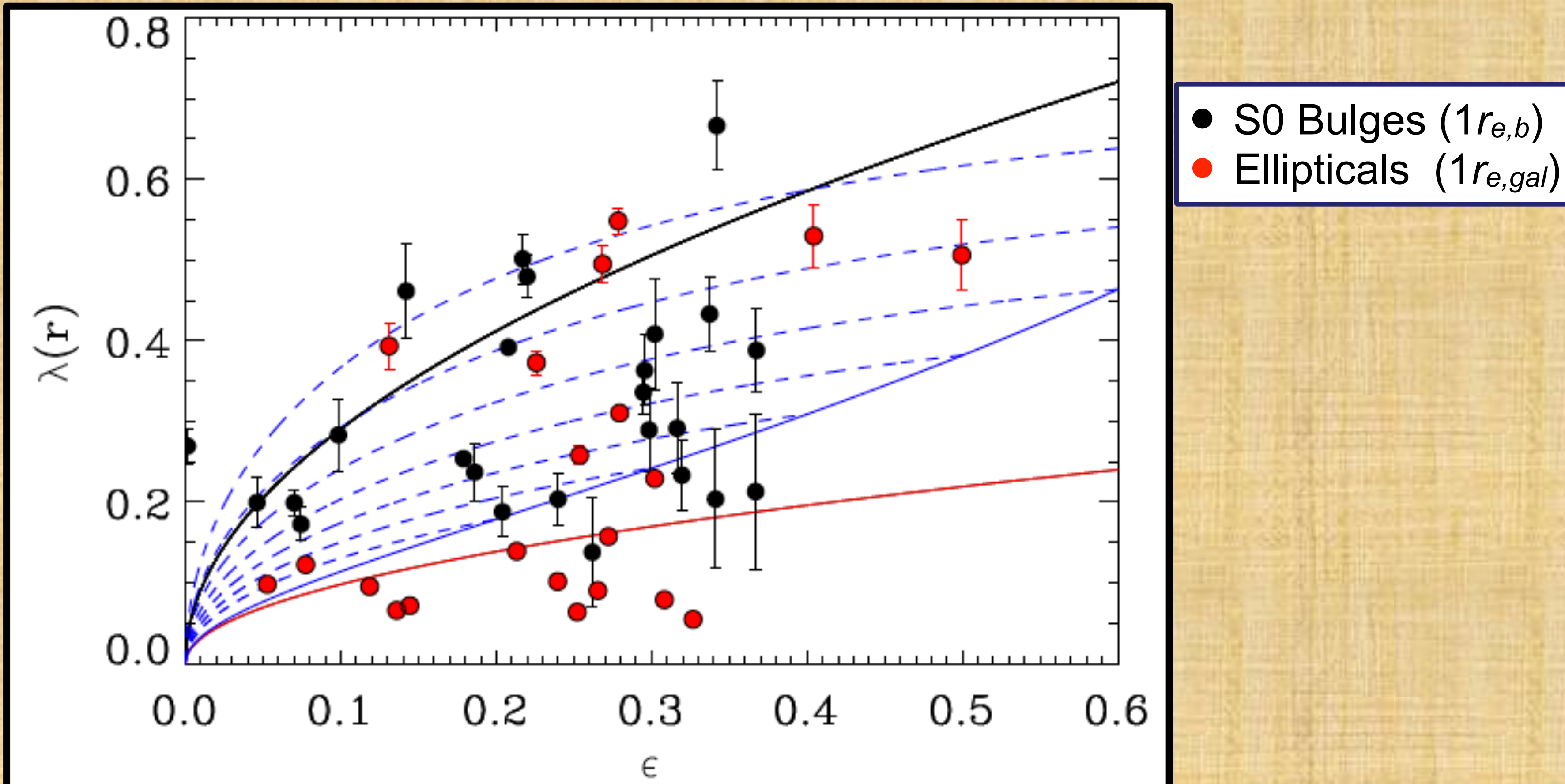
- ★ The bulge (photometry and kinematic) and galaxy (masses and environment) suggest that our **S0 bulges were mainly formed through dissipational major mergers at high redshift.** Then, galaxies evolved secularly through both external accretion of satellite galaxies (inducing changes in the bulge properties) and internal bar-induced mechanisms in gas-devoided disks (with no creation of central structures).

S0s ANGULAR MOMENTUM - BULGEs vs. DISKS



SO disks lie along the isotropy line and with larger angular momentum than bulges.

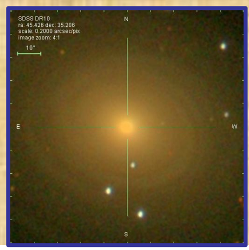
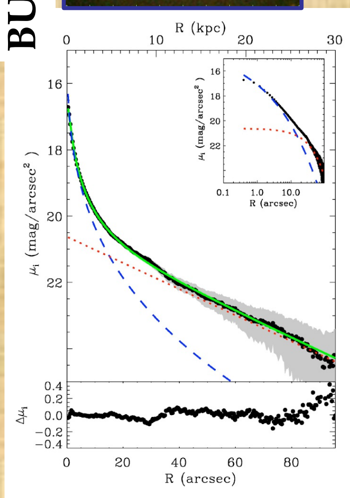
S0s ANGULAR MOMENTUM - ELLIPTICALS vs. BULGES



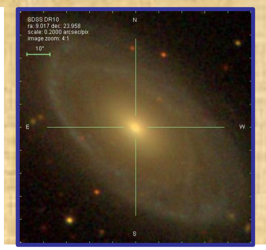
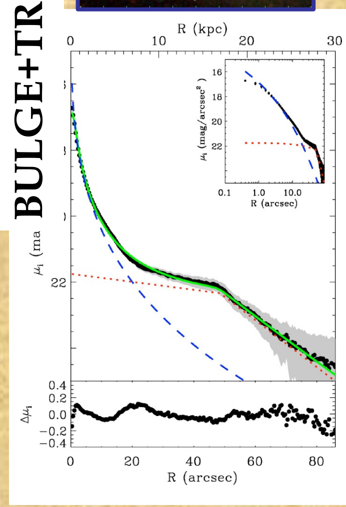
Ellipticals have lower angular momentum than bulges and some of them are slow rotators.

PHOTOMETRIC DEFINITION OF BULGE

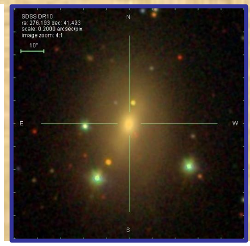
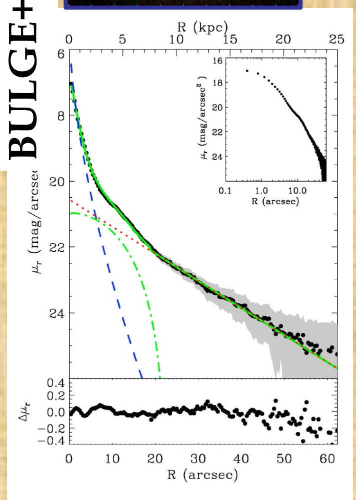
BULGE+DISK

BULGE+TRUNC. DISK

BULGE+DISK+BAR

BULGE+TRUNC. DISK+BAR