Evidence for bar-induced secular evolution in massive disk galaxies

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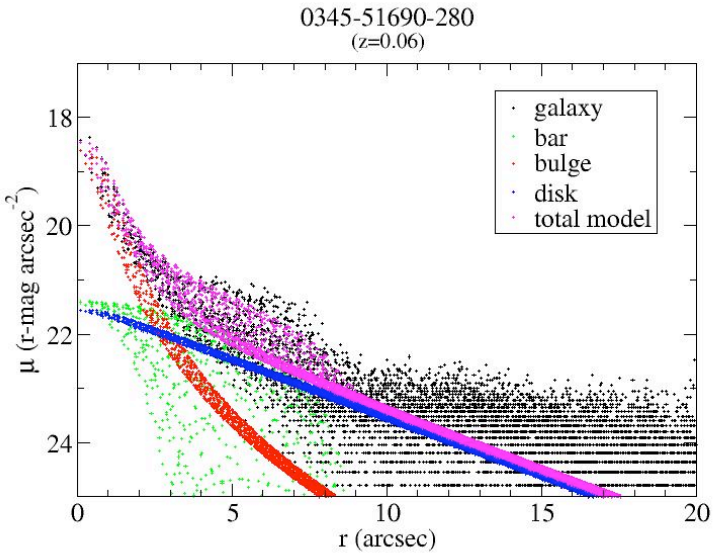
ESO

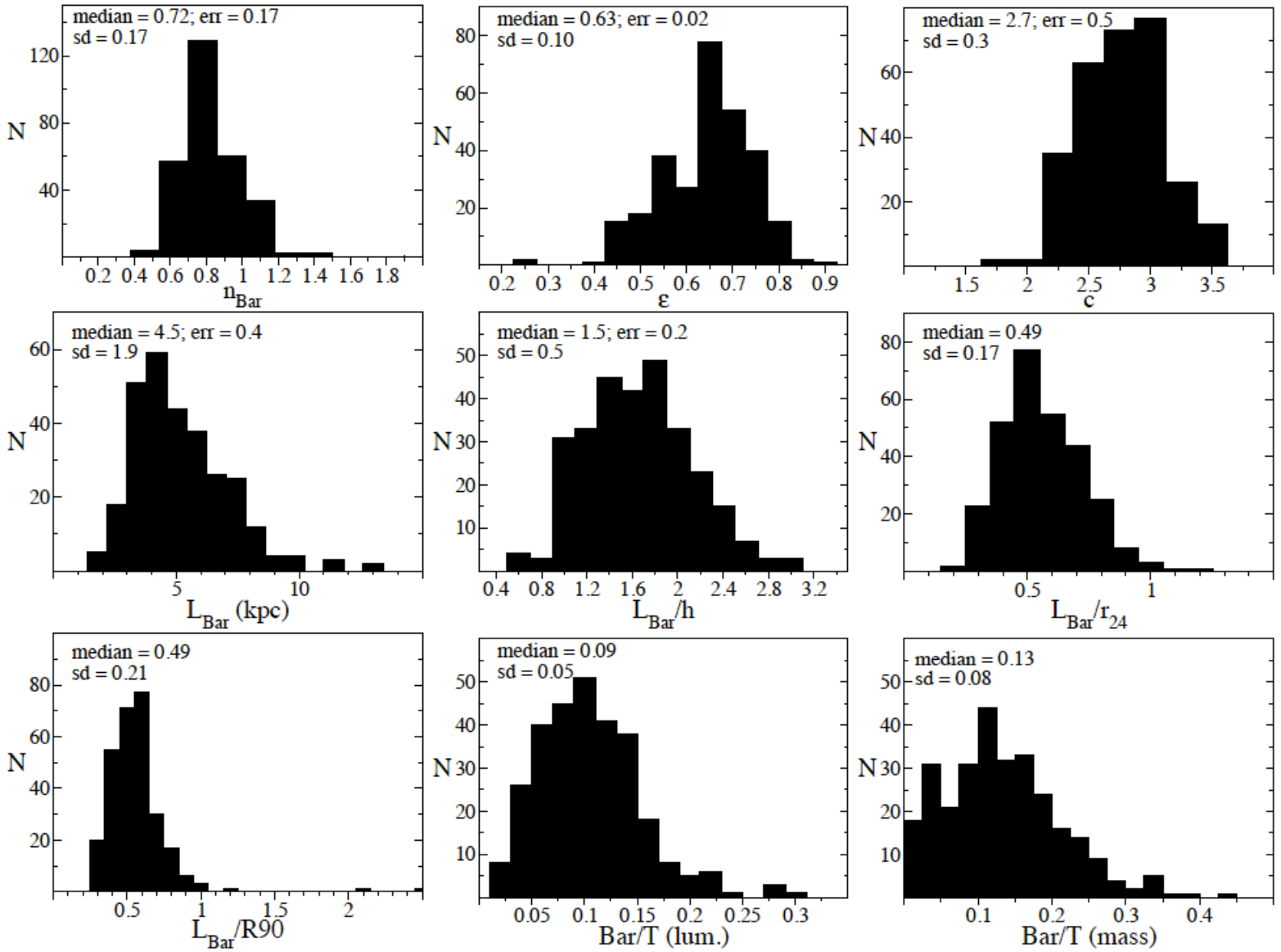
Data

- SDSS data (Gadotti 2009)
  - $0.02 \leq z \leq 0.07$
  - $M_* \geq 10^{10}\ M_\odot$
  - $b/a > 0.9$
  - nearly 1000 galaxies, of which nearly 300 barred
  - 2D *g*, *r*, *i* bulge/bar/disk – individually checked – decompositions with BUDDA (de Souza et al. '04; Gadotti '08)



Structural Properties of Bars

Gadotti (2011)



Structural Properties of Bars

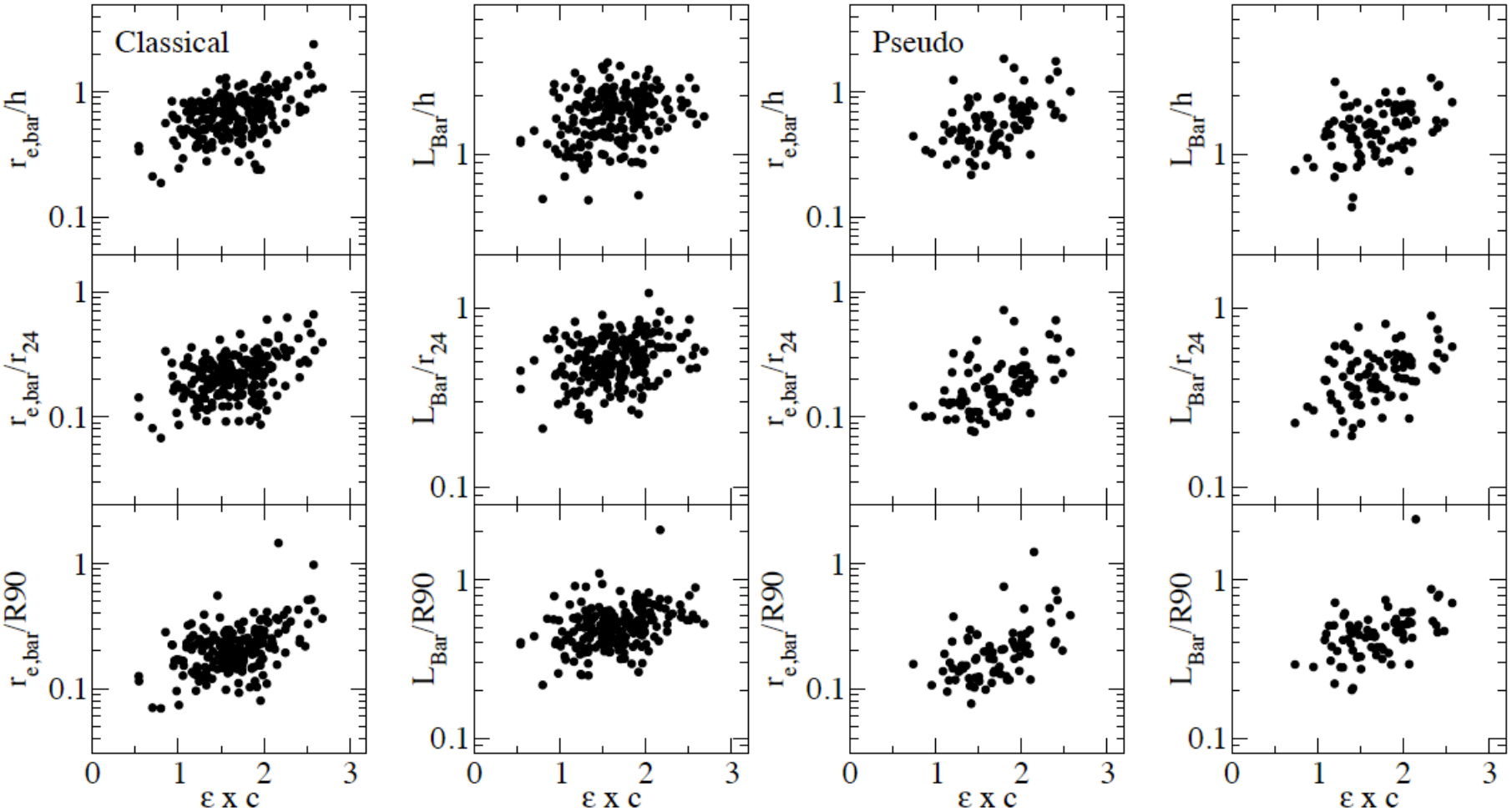
- Bar ellipticities measured through ellipse fits are underestimated by ~20%. Bar ellipticities can be correctly measured through multicomponent decompositions (with at least bulge, bar and disc; Gadotti 2008)

- This is a detailed, statistically robust representation of the structural properties of bars in massive galaxies in the local universe

  - can be used to test models of bar formation and evolution

  - can be used to compare with properties of bars at higher redshifts and directly probe bar evolution

Bar Length and Strength



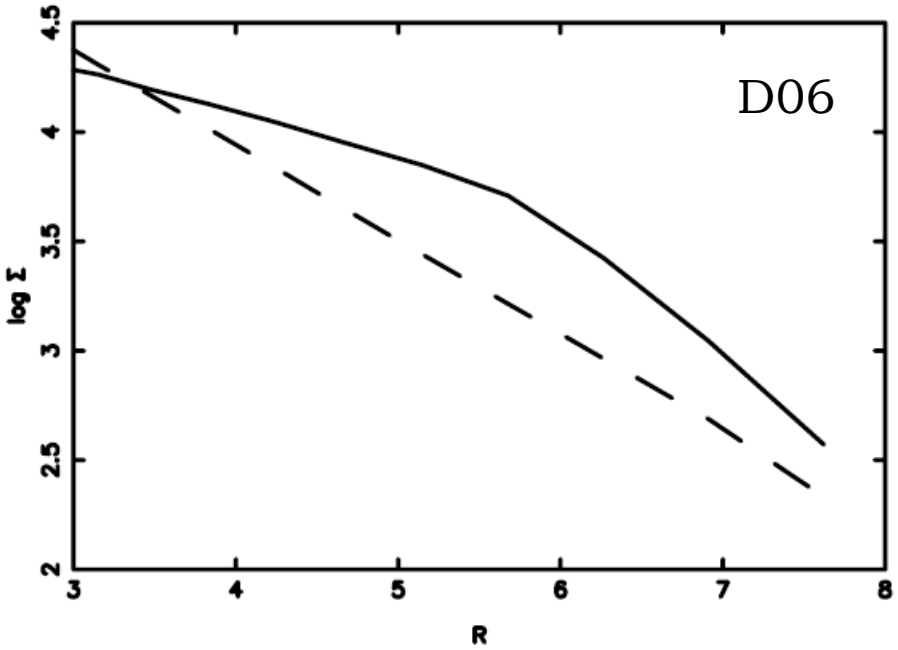
Gadotti (2011)

Bar Length and Strength

- As expected from theoretical work (e.g. Athanassoula & Misiriotis 2002; Athanassoula 2003; Martinez-Valpuesta et al. 2006; Berentzen et al. 2006), bar length and strength are correlated, consistent with a scenario where bars get longer and stronger in time.

Secular Evolution of Barred Disks

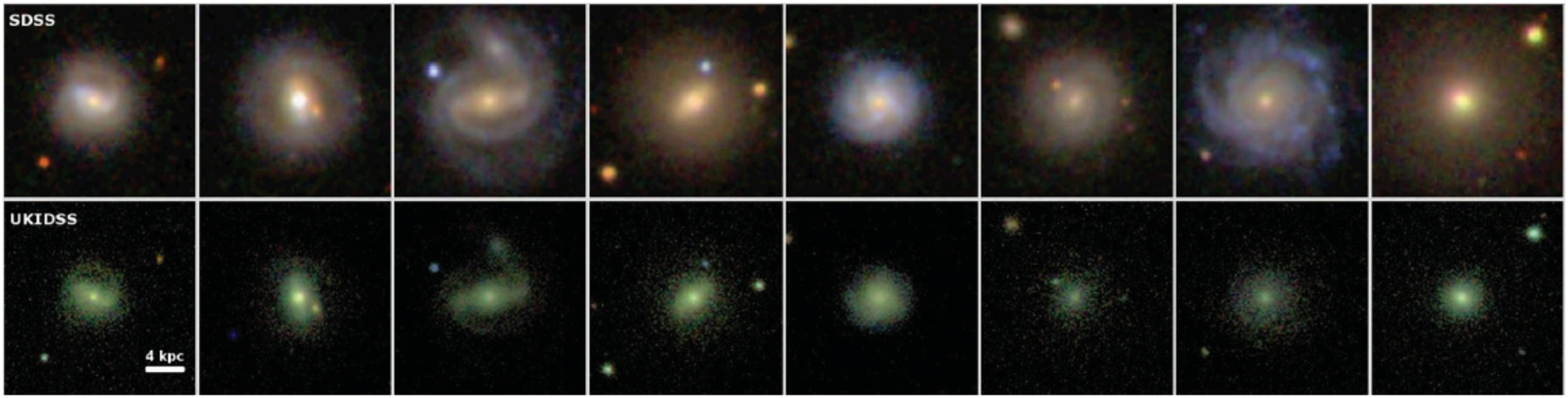
In models, transfer of angular momentum driven by the bar throughout the galaxy (Athanassoula 2003) is followed by an increase of the disk scale length *h* (Valenzuela & Klypin 2003; Debattista et al. 2006).



Variation in *h* depends strongly on initial conditions, especially the disk kinematics. Reported changes are factors of 1.2 – 1.5 (VK03) and 1.0 – 2.4 (D06). What observations can tell us?

Secular Evolution of Barred Disks

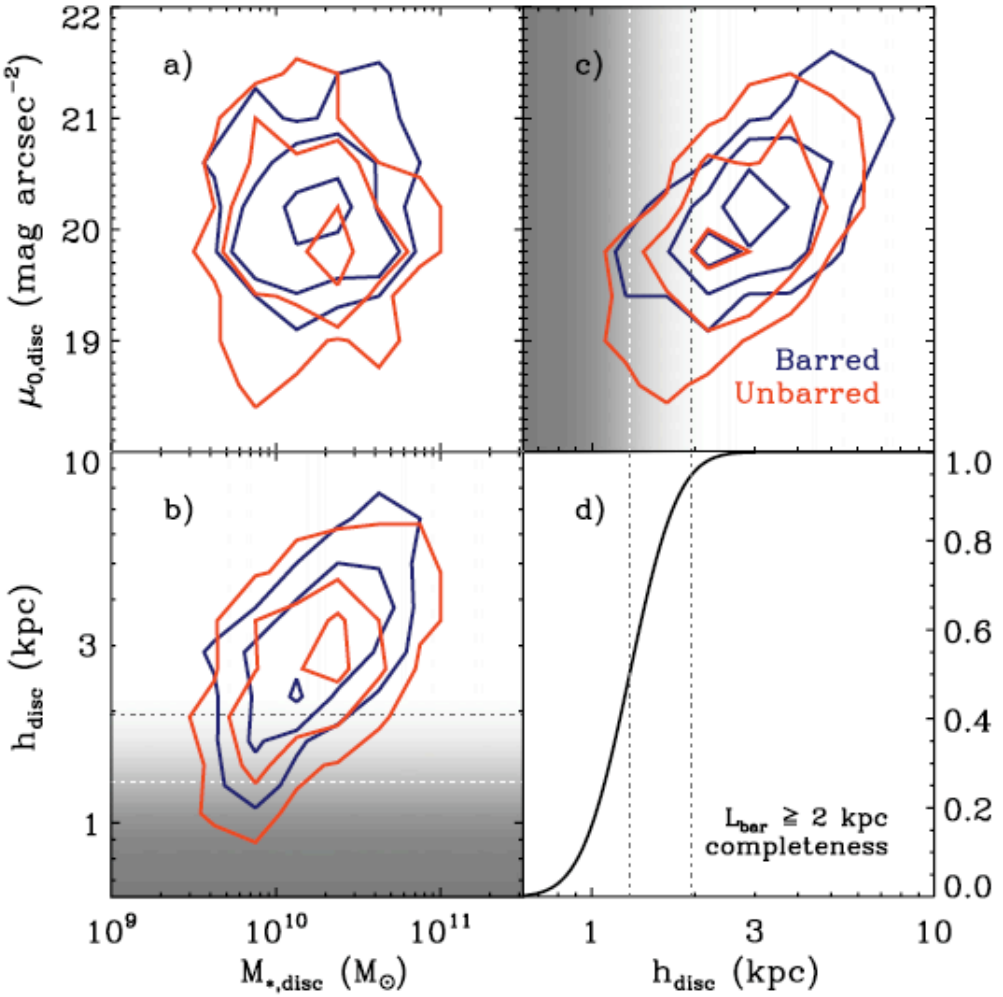
Sánchez-Janssen & Gadotti (2013)



Sample from Gadotti (2009): bars with semi-major axis larger than 2 kpc are robustly detected even in the presence of dust.

Secular Evolution of Barred Disks

Sánchez-Janssen & Gadotti (2013)



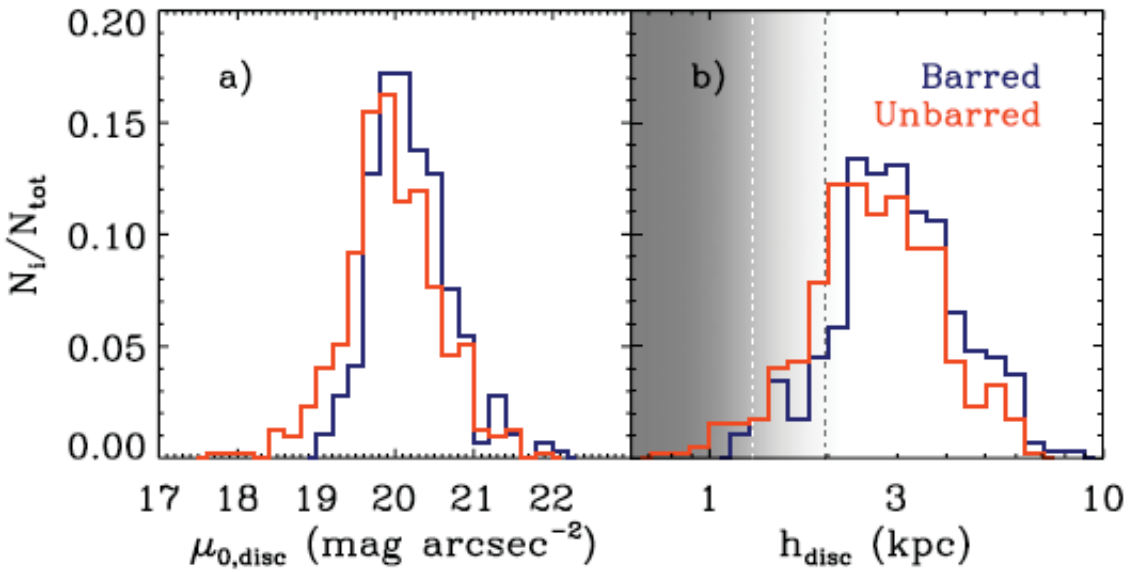
- 291 barred, 393 unbarred
- bar fraction of 42±3% (not including overly weak bars)
- subsamples matched in disk stellar mass

- Disks in barred galaxies are characterized by having fainter central surface brightness and larger scale lengths

- Note the lack of bars in galaxies having compact, high surface brightness disks

Secular Evolution of Barred Disks

Sánchez-Janssen & Gadotti (2013)



According to a Kolmogorov–Smirnov test, the corresponding distributions of μ_0 and h are statistically inconsistent at the 5.2σ and 3.8σ levels, respectively.

As a population, disks in barred galaxies tend to have ≈ 0.25 mag fainter central surface brightness and ≈15 per cent larger disk scale lengths.

Bulge Building in Barred Galaxies

Coelho & Gadotti (2011)

- Bars are able to drive gas from the outer to the inner disk (Sellwood & Wilkinson '93; Athanassoula '05; Knapen '07; Gadotti '09a; Sakamoto et al. '99; Sheth et al. '05)

Bulge Building in Barred Galaxies

Coelho & Gadotti (2011)

- *Current* formation of stars appears enhanced in the centers of barred galaxies (see Huang et al. '96; Ho et al. '97; Alonso-Herrero & Knapen '01; Ellison et al. '11)

- But are stars generally younger in the centers of barred galaxies?

- Previous work (Gadotti & dos Anjos '01; Peletier et al. '07; Pérez & Sánchez-Blázquez '11) show difficulties, such as:

  - color-metallicity degeneracy, dust
  - poor statistics

Aim

Coelho & Gadotti (2011)

➢ Compare mean stellar ages of bulges in matched samples of barred and unbarred galaxies

Data

Coelho & Gadotti (2011)

- Bar classification by visual inspection of image, 2D surface brightness radial profile and isophotal contours

- SDSS fiber spectra

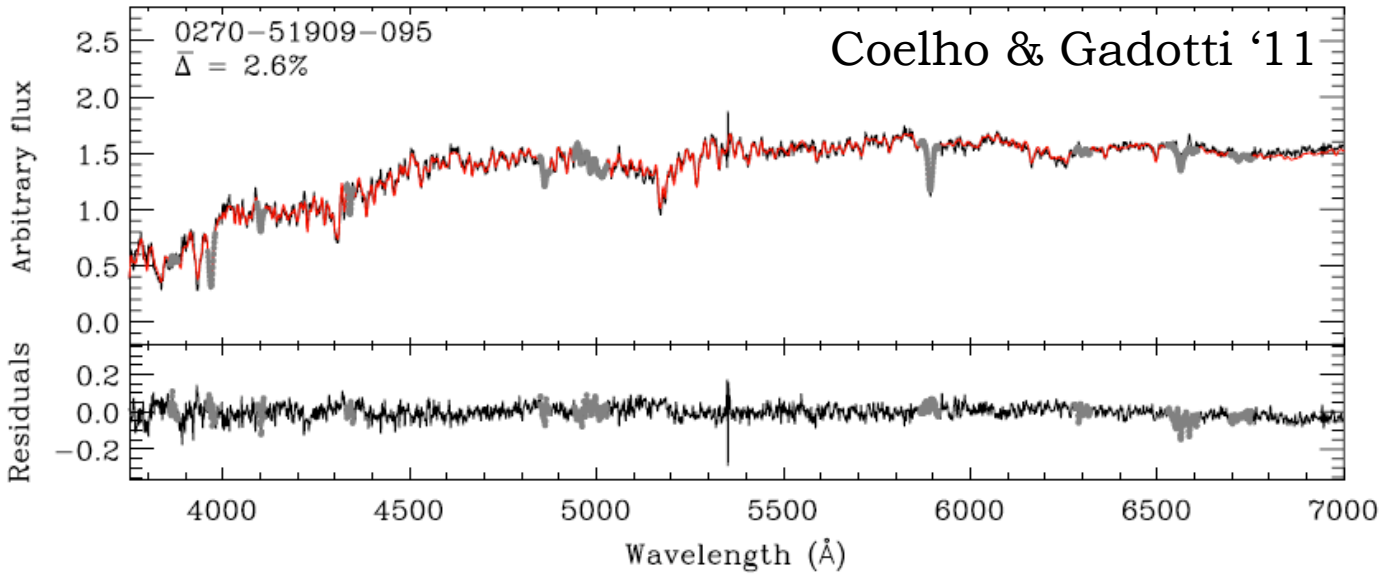
- Bulge stellar masses are determined

- Disk contamination inside the fiber is measured (it's low, typically below 20%)

- Samples of barred and unbarred galaxies are matched in *bulge* mass and disk contamination in the fiber (never done previously)

Spectral Fits

- Spectral fitting w/ STARLIGHT (Cid Fernandes et al. '05)
  - S/N > 10, typically ~ 20



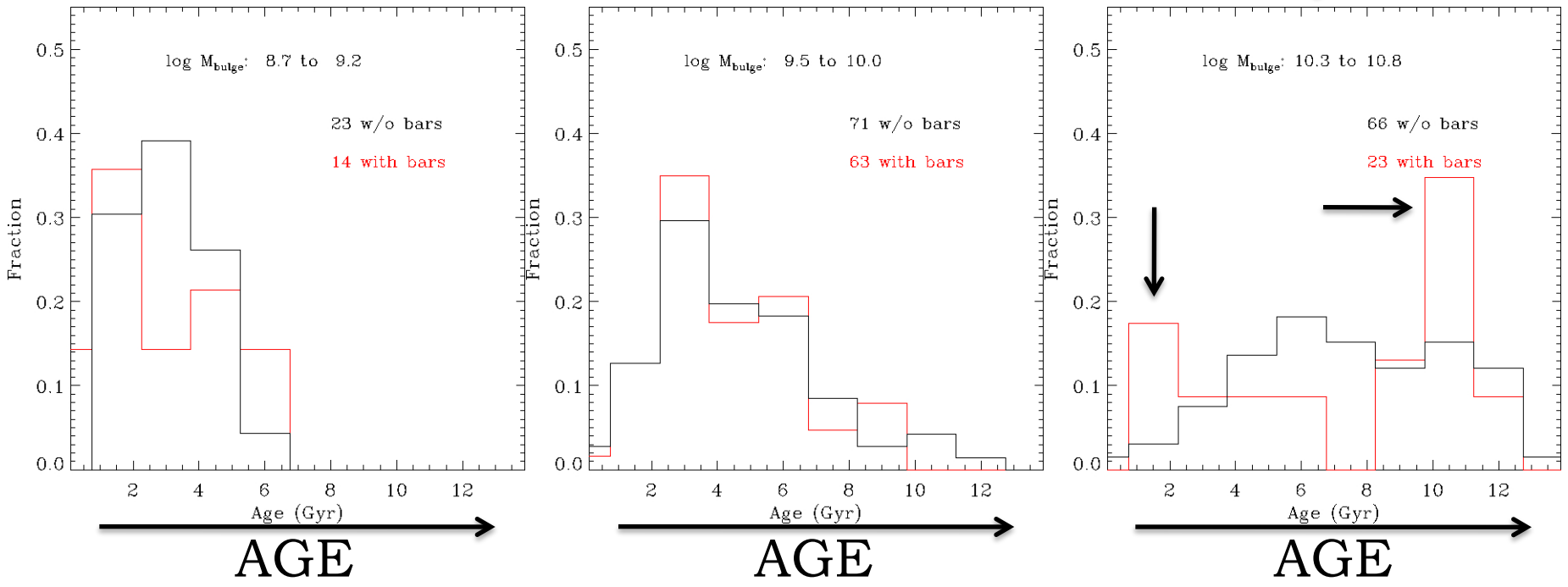
Results

➢ Distributions of bulge mean stellar ages for barred and unbarred galaxies in bins of same bulge mass

➢ Bulges in non-AGN massive barred galaxies show bimodality and younger component at 4σ!

MASS

Coelho & Gadotti '11



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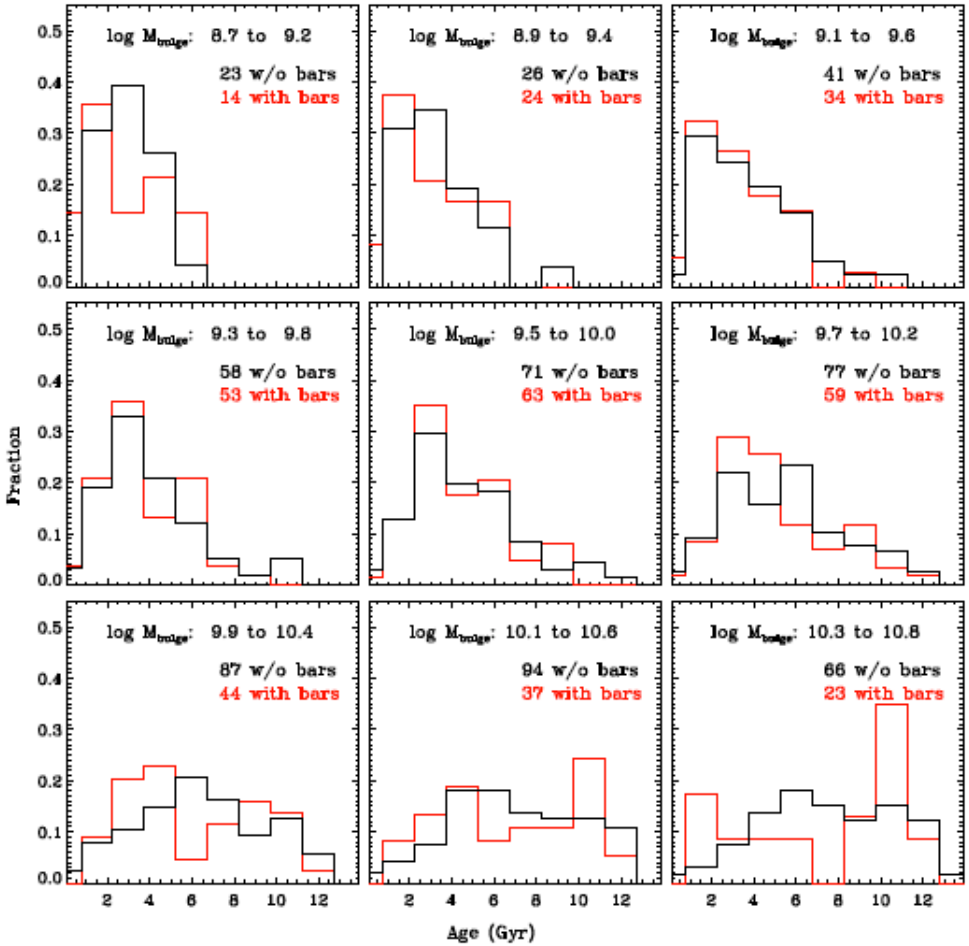

Bulge Building in Barred Galaxies

Coelho & Gadotti (2011)

- Bars do alter significantly the mean stellar ages of bulges in disk galaxies

Bars can rejuvenate bulges