Confrontando modelos de galaxias barradas con observaciones

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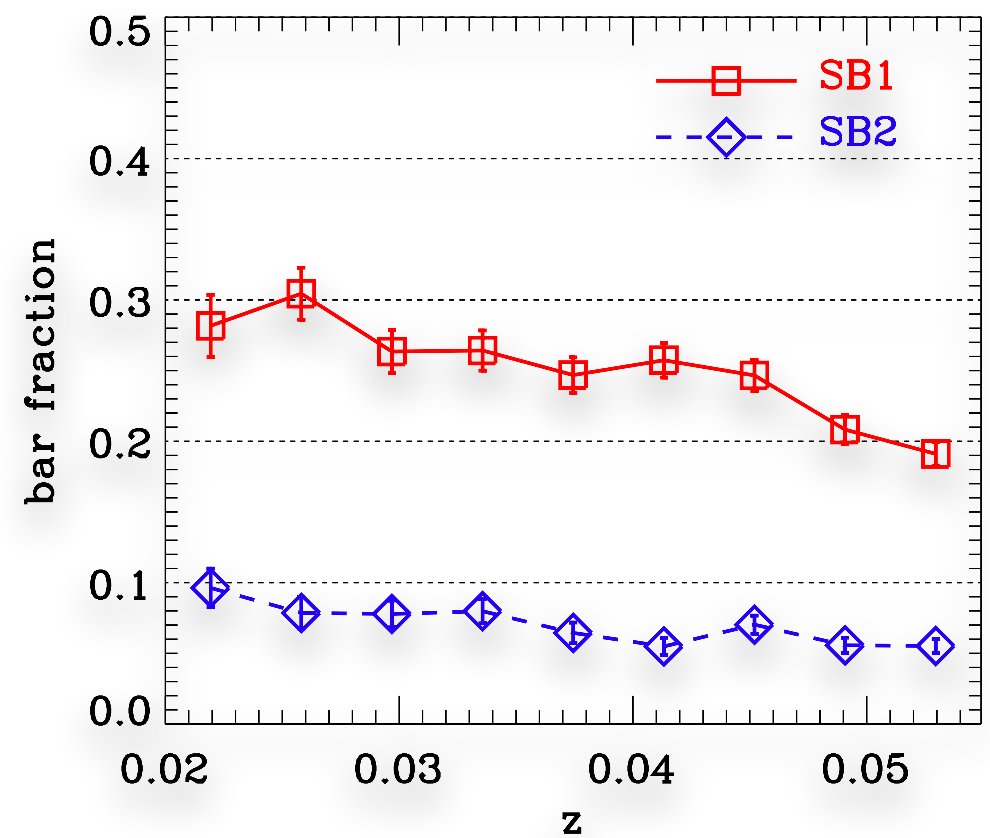
Outline

- The fraction of barred galaxies in the local Universe and expectations from simulations
- Barred fraction as a function of stellar-to-halo mass ratio
- Bars and the galactic spin parameter
- Barred fraction vs. HI gas richness
- Conclusions

Fraction of barred galaxies in the local Universe

$$f_{bar} = \frac{No.\ of\ barred\ galaxies}{Total\ number\ of\ disk\ galaxies}$$

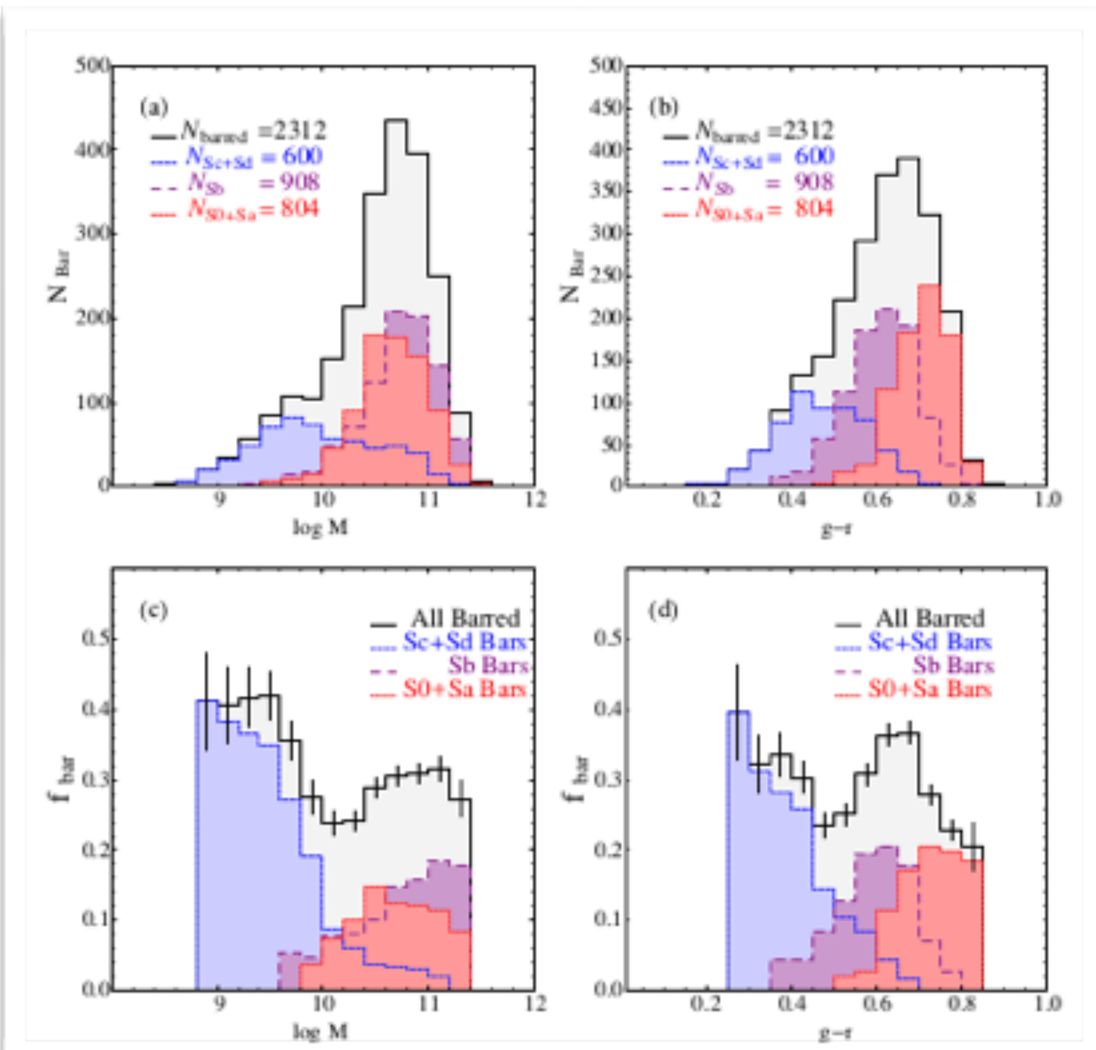
Between 30 and 50% of the spiral galaxies in the local Universe host stellar bars (de Vaucouleurs et al. 1991; Barazza et al. 2008 ; Aguerri et al. 2009 ; Nair & Abraham 2010; Masters et al. 2011; Lee et al. 2012; Cervantes Sodi et al. 2013, 2014).

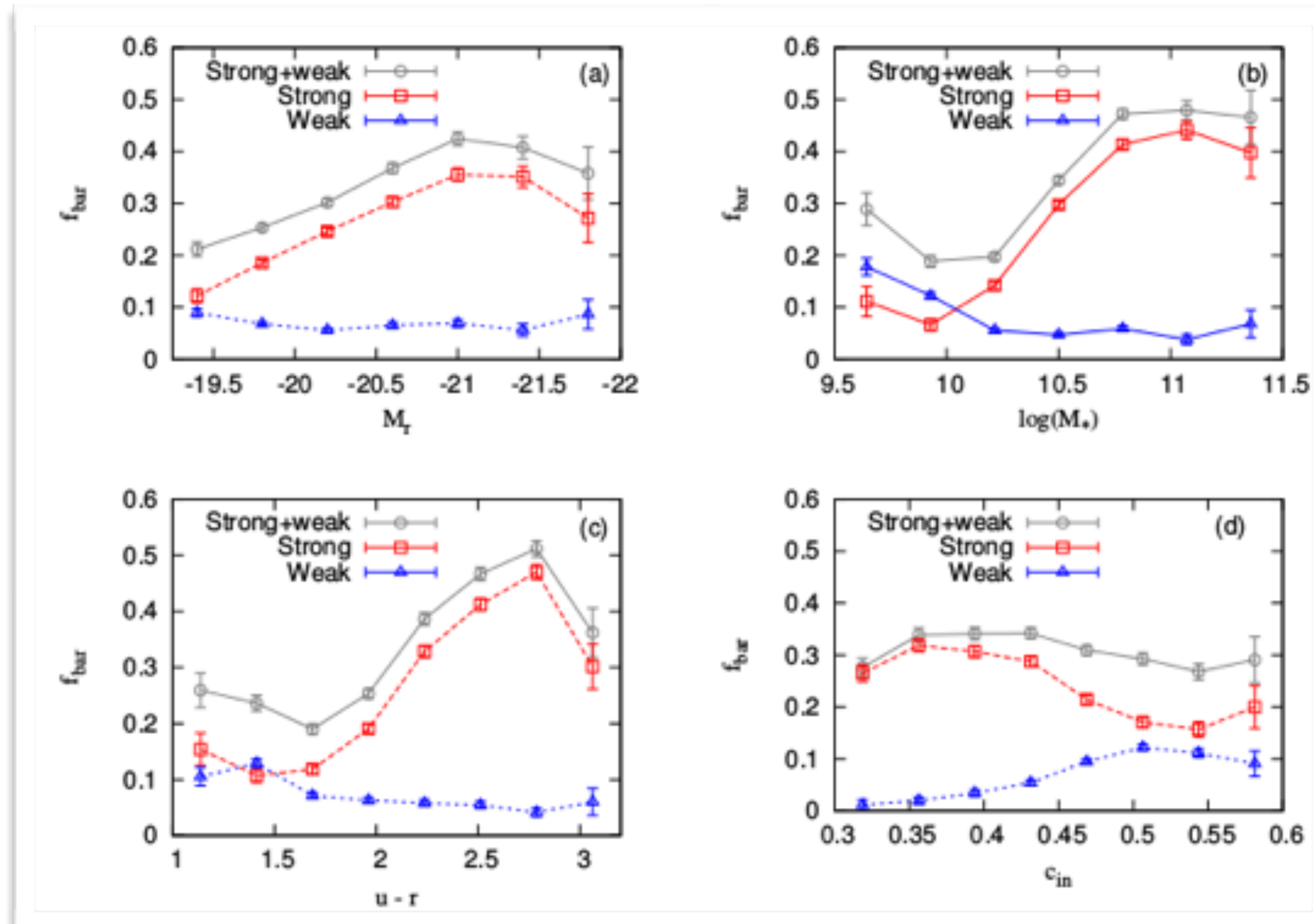


SB1 -> strong bars
SB2 -> weak bars

Lee et al. (2012)

Dependence of f_{bar} on galactic properties





Nair & Abraham 2010

Cervantes Sodi et al. 2013

M101 and NGC1300, similar stellar mass and size

Early simulations

A NUMERICAL STUDY OF THE STABILITY OF FLATTENED GALAXIES: OR, CAN COLD GALAXIES SURVIVE?*

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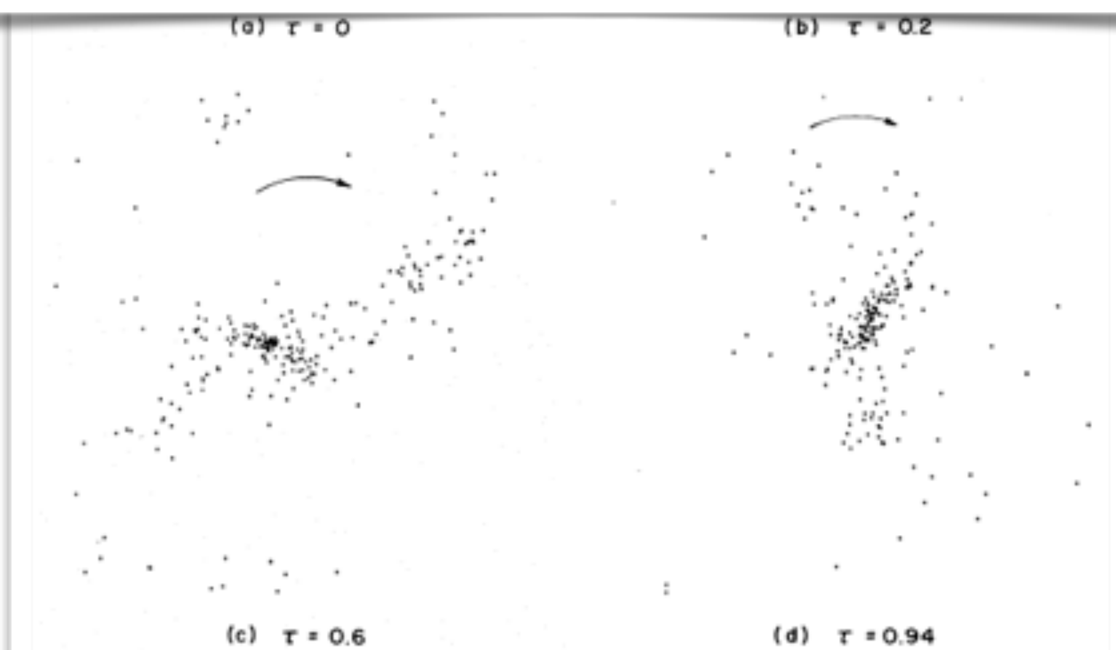
Received 1973 May 29

During the first rotation time period the system of particles goes from a symmetric disk to a highly nonaxisymmetric "barlike" structure, which tends to dissolve and approach rough axial symmetry again. After one orbital period t is roughly comparable to what was indicated as the critical value in analytic studies of fluid models. When a small halo is introduced, this sequence is reproduced in a less pronounced way. When the halo mass is larger, the disk develops random kinetic energy in a manner reminiscent of two-body relaxation processes but does not show a violent instability. For the chosen forms of density distribution in disk and halo components, a halo mass of 1 to $2\frac{1}{2}$ times the disk mass appears to be required to reduce the initial value of t to the stable range $t \simeq 0.14$.



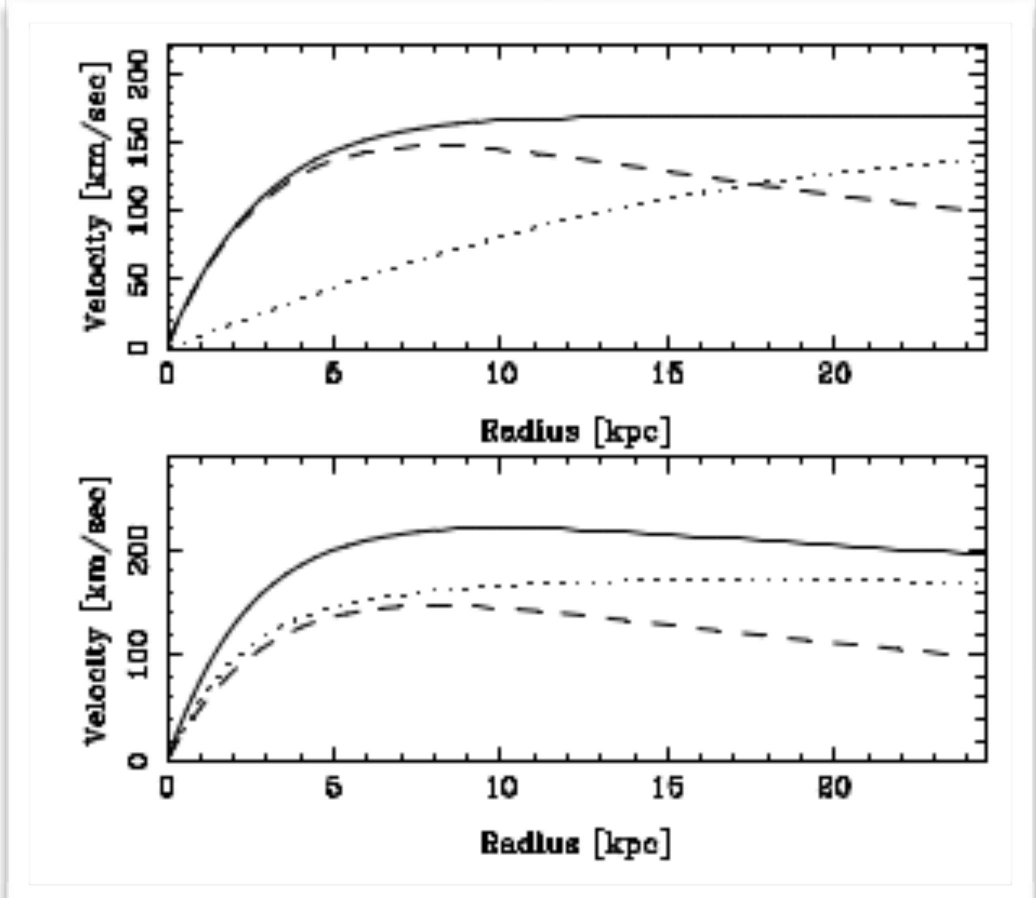
*Fixed potential for the halo

Efstathiou, Lake & Negroponte (1981)

- Numerical experiments on the stability of exponential discs.
- Propose a stability criterion: which is basically a ratio between dynamical and disk mass.
- On their simulations, discs with ε* > 1.1 where stable against bar formation

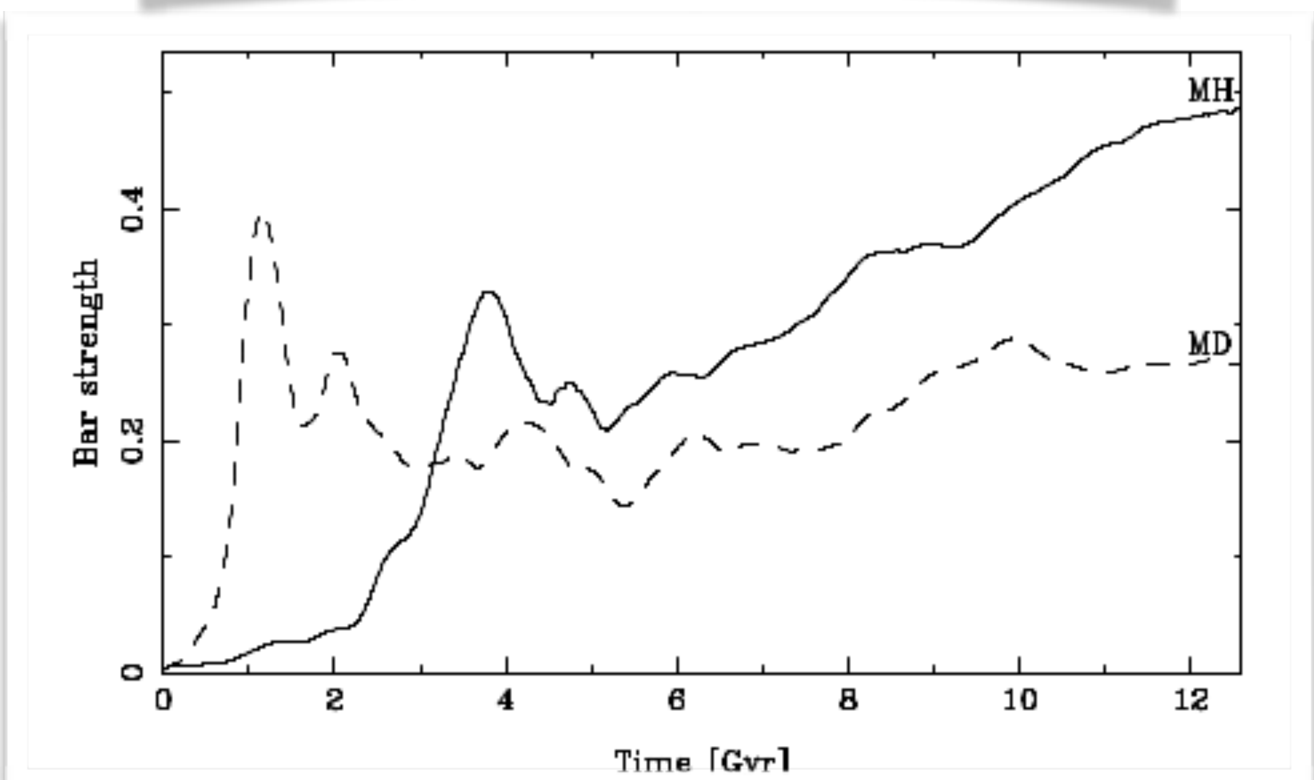
$$\epsilon_c = \frac{V_{max}}{GM_d/R_d} \leq 1.1$$

Using a live halo



Massive disk

Massive halo



Massive halo

Massive disk

Athanassoula & Misiriotis 2002, Athanassoula 2012

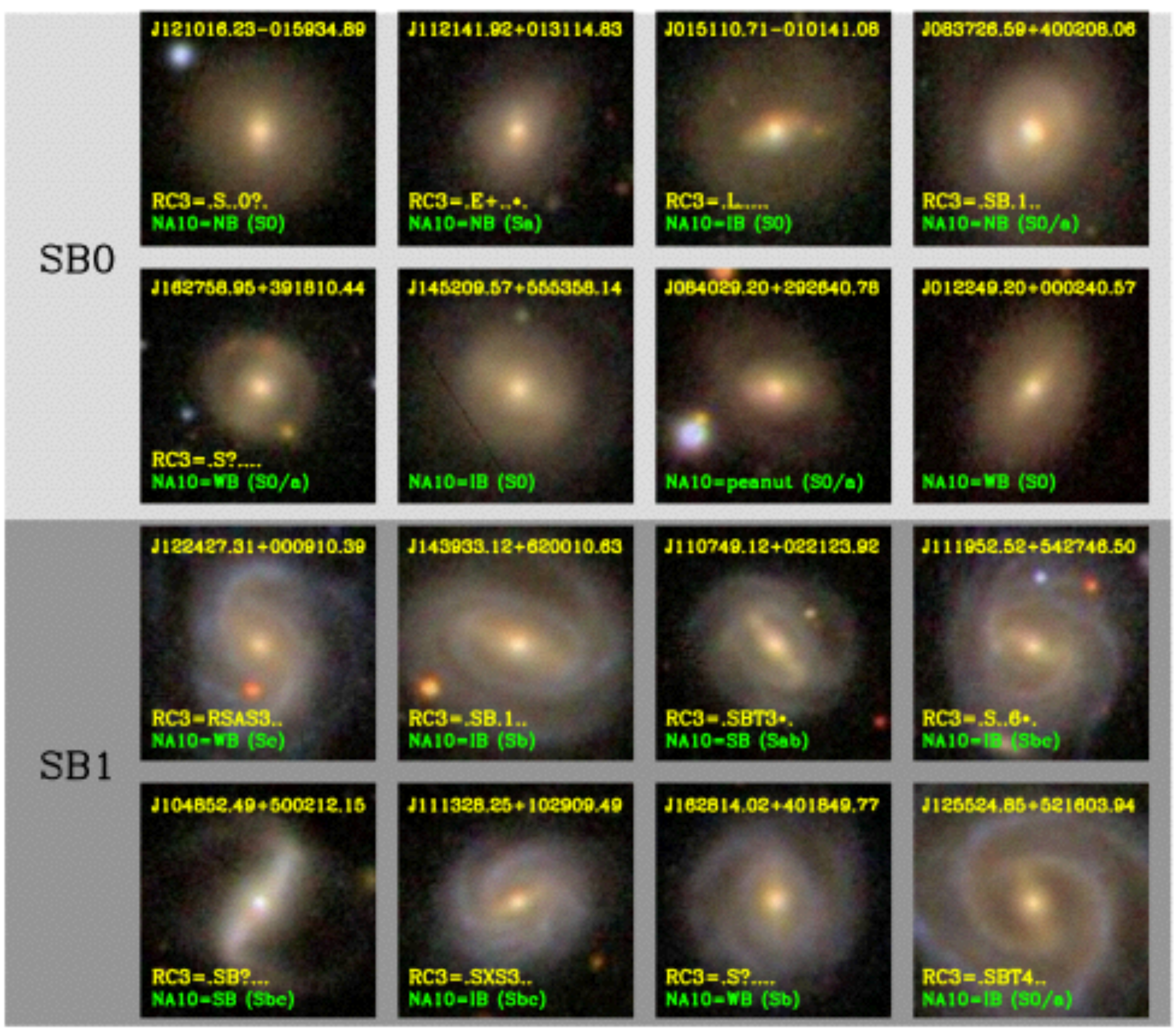
An observational counterpart

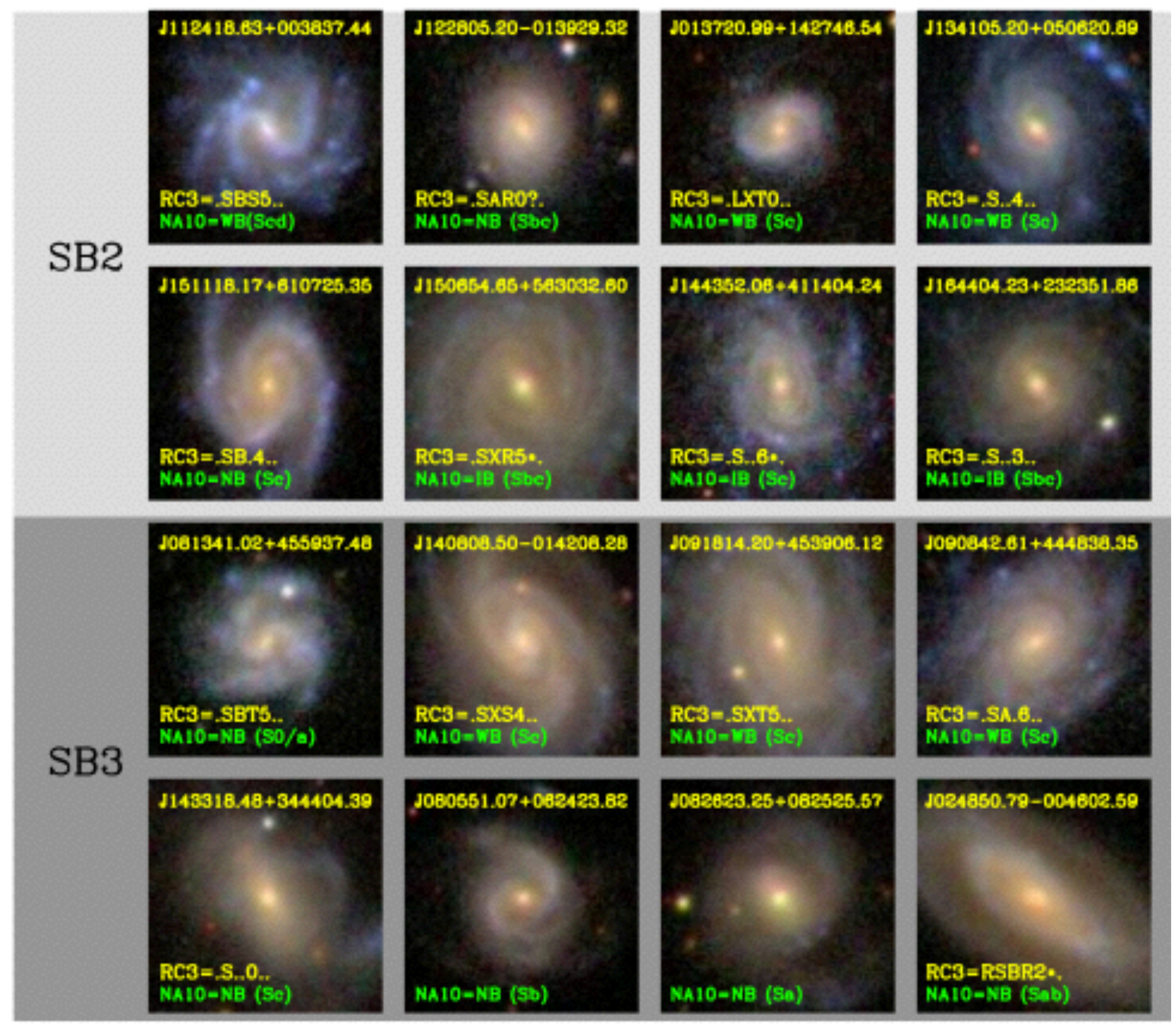
(Cervantes sodi, Li & Park 2015)

~30,000 galaxies
from the SDSS

KIAS galaxy catalog
(Lee et al. 2012)

Weak bars



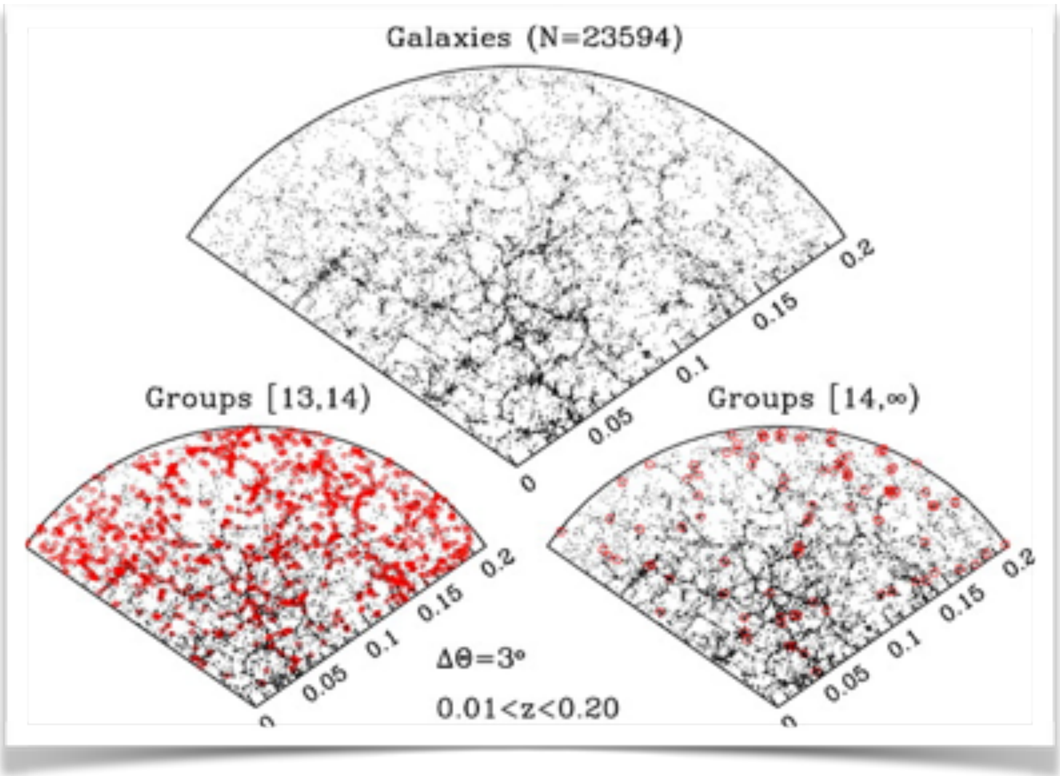


Strong bars

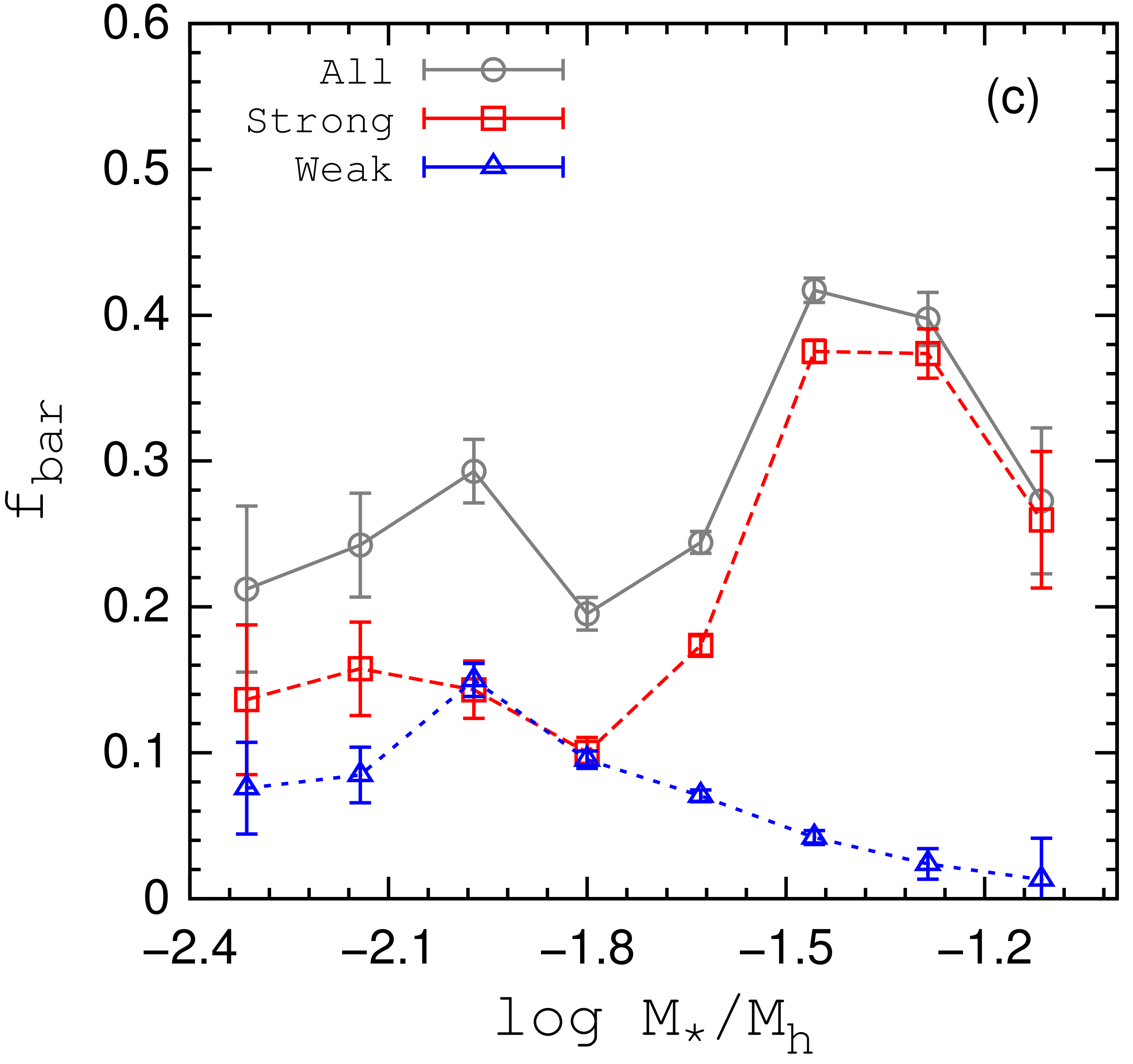
Stellar-to-halo mass estimate

- Stellar mass estimates from VAGC from the MPA/JHU SDSS database based on fits to the SDSS five-band data (Kauffmann et al. 2003; Brinchmann et al. 2004)

- Halo mass estimates from Yang et al. (2007) group catalog

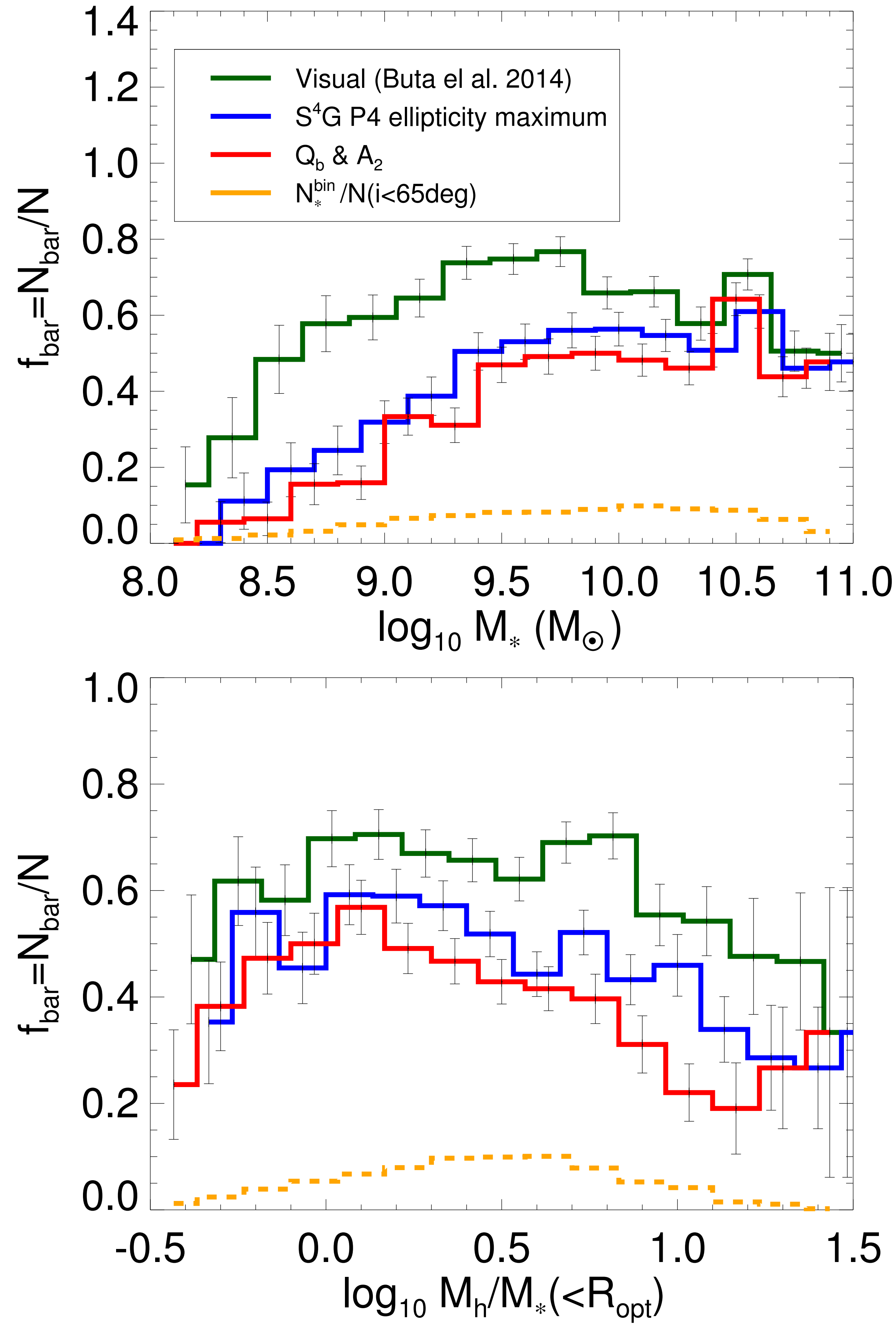


- Galaxies are grouped according to their common halos (FoF algorithm)
- Halo mass is assigned to each group
- The most massive galaxy is defined as the central one



Cervantes Sodi et al. 2015

- Using near-infrared photometry (S4G) of about ~1,000 galaxies.
- HI line widths from the literature to estimate dynamical masses within optical radius.
- No dependence on M_h at fixed M_*



Díaz-García et al. 2016

Strategy

- Using the same galaxy sample for bar classification (Lee et al. 2012 & Cervantes Sodi et al. 2015)
- HI line width estimates from ALFALFA for a more direct and homogeneous approach to estimate dynamical masses
- We looked at the dependence of the bar fraction on disk-to-halo mass fraction and gas content.
- Our original sample reduces from ~10,000 galaxies to ~1,500

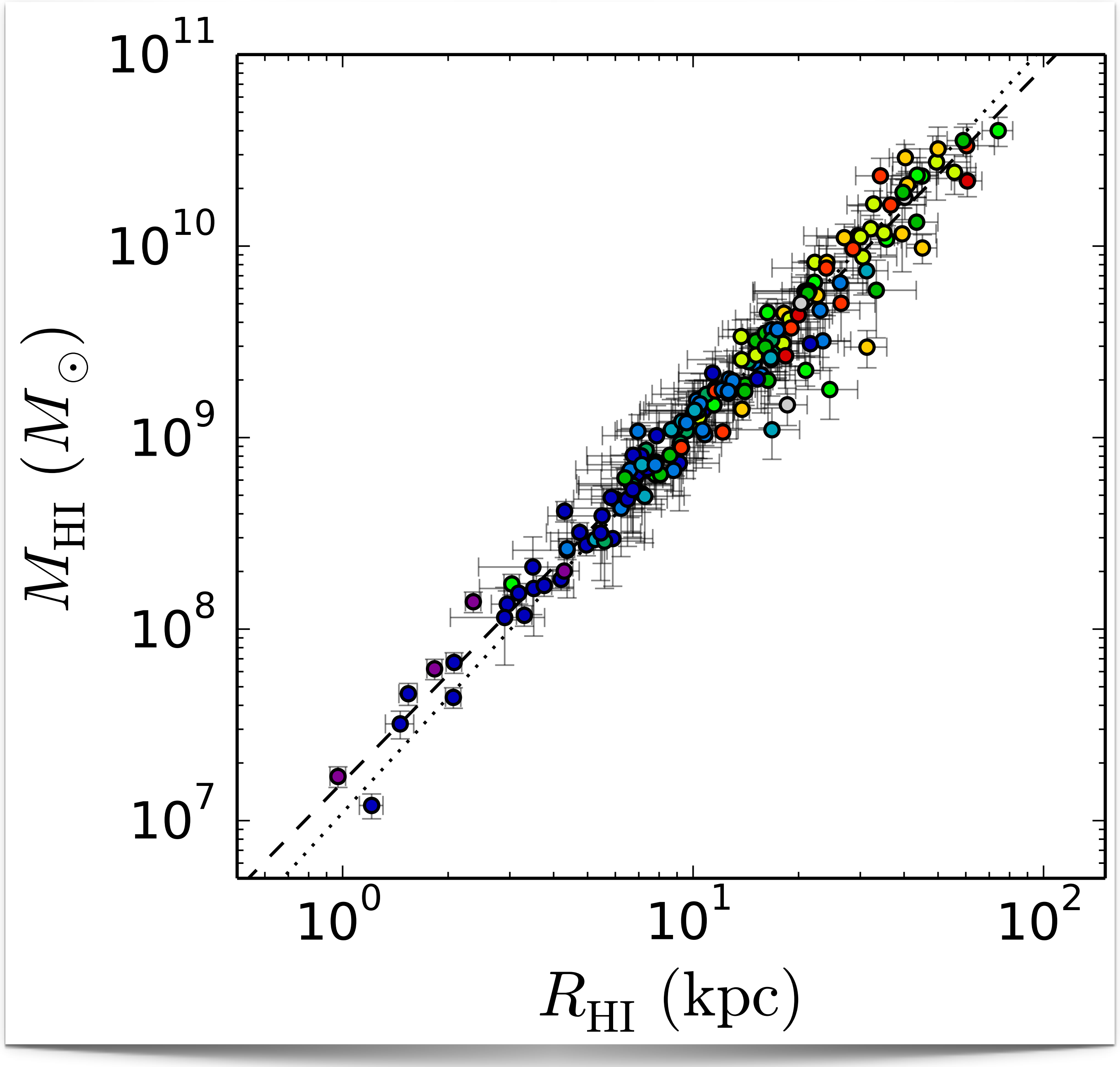
Two different halo mass estimates

- The dynamical mass within the HI disk radius

$$M_{\rm dyn} = \frac{R_{\rm HI} V_{\rm rot}^2}{G}.$$

- Given that we don't count with the HI disk radius, we estimated it though (Lelli et al. 2016)

$$log\ M_{\rm HI} = 1.96\ log\ D_{\rm HI} + 6.52,$$



(half the intrinsic scatter of the BTF)

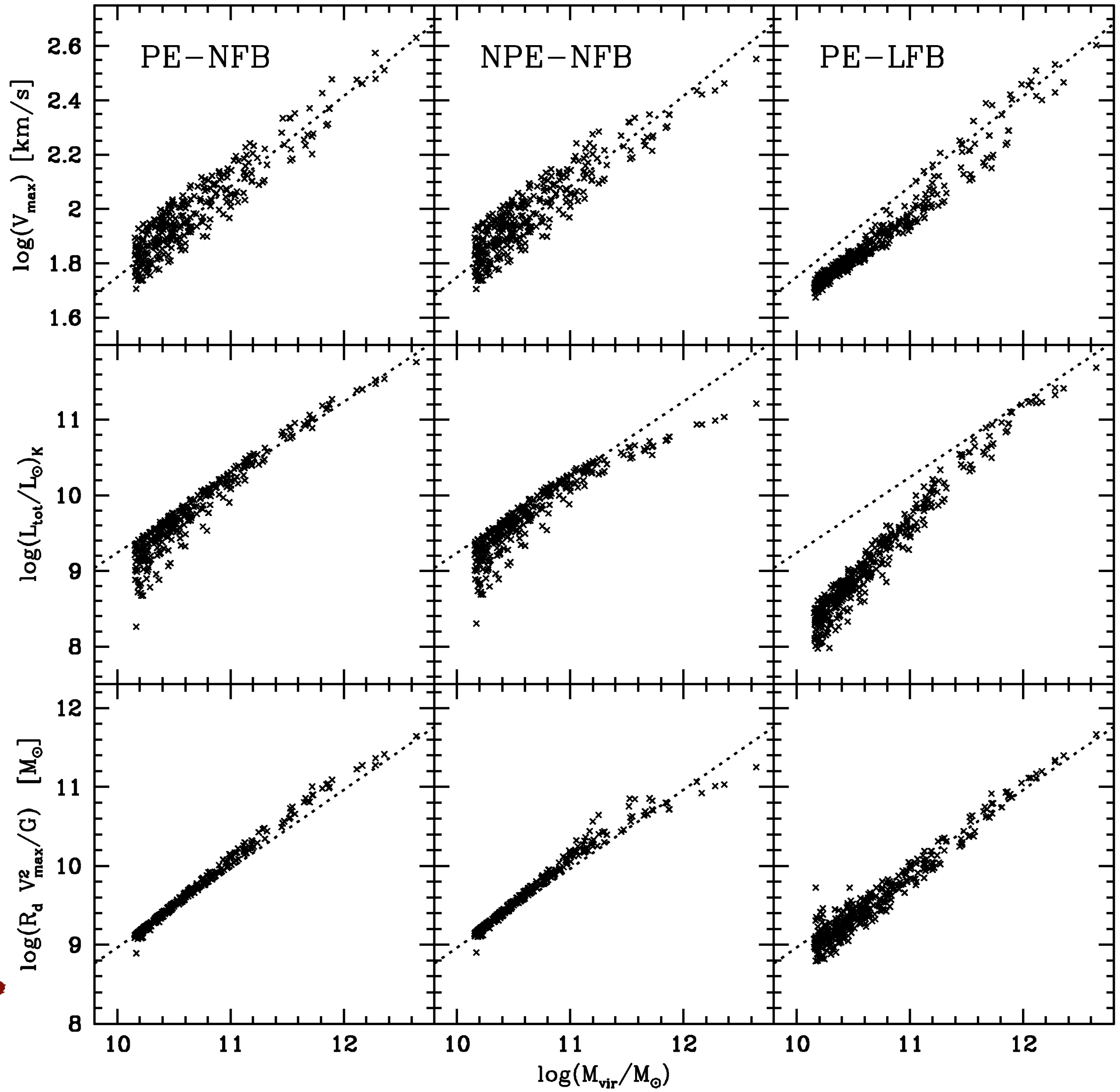
Second halo mass estimate

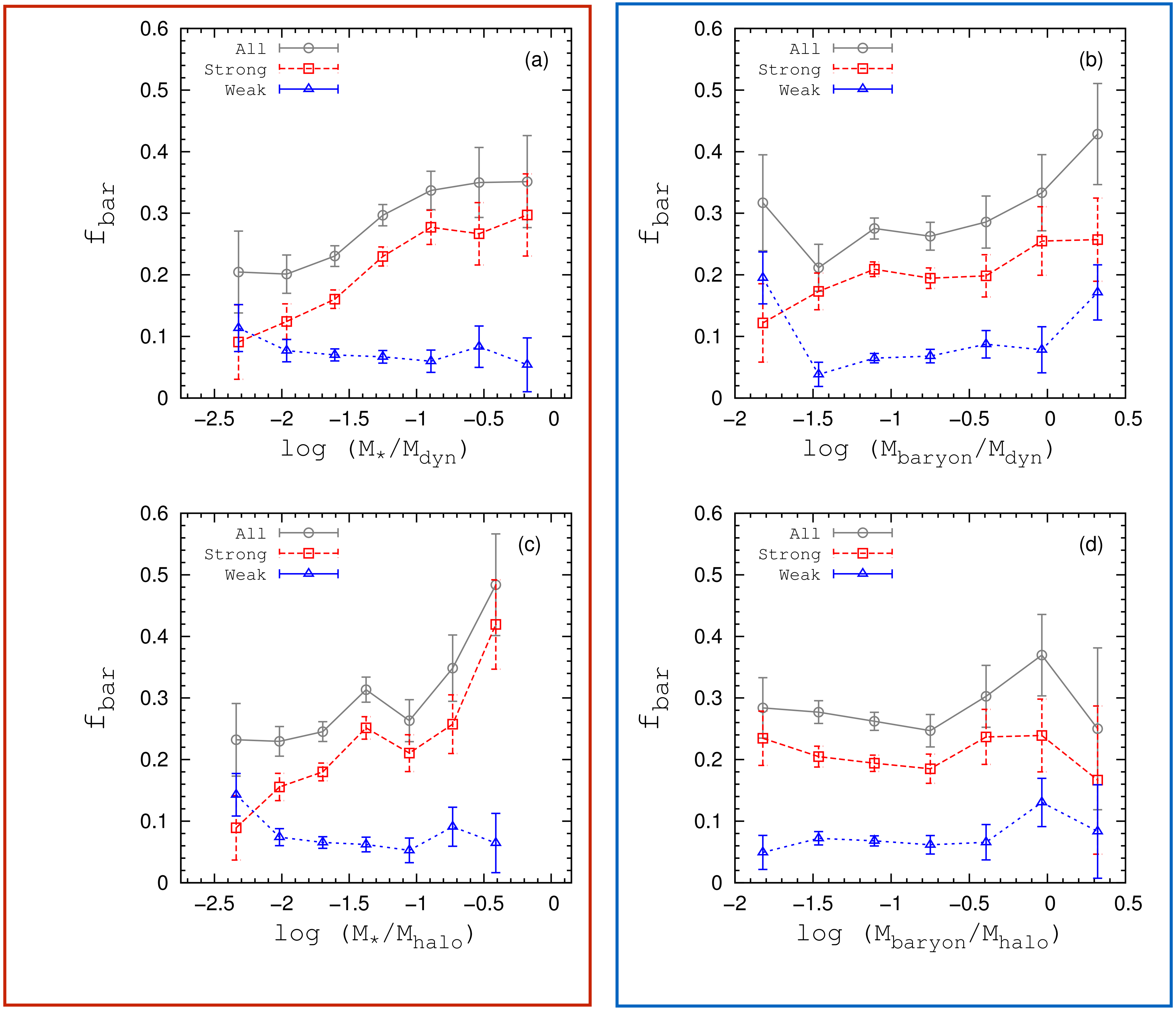
- The halo mass computed using the estimate by van den Bosch (2002):

From the HI line width

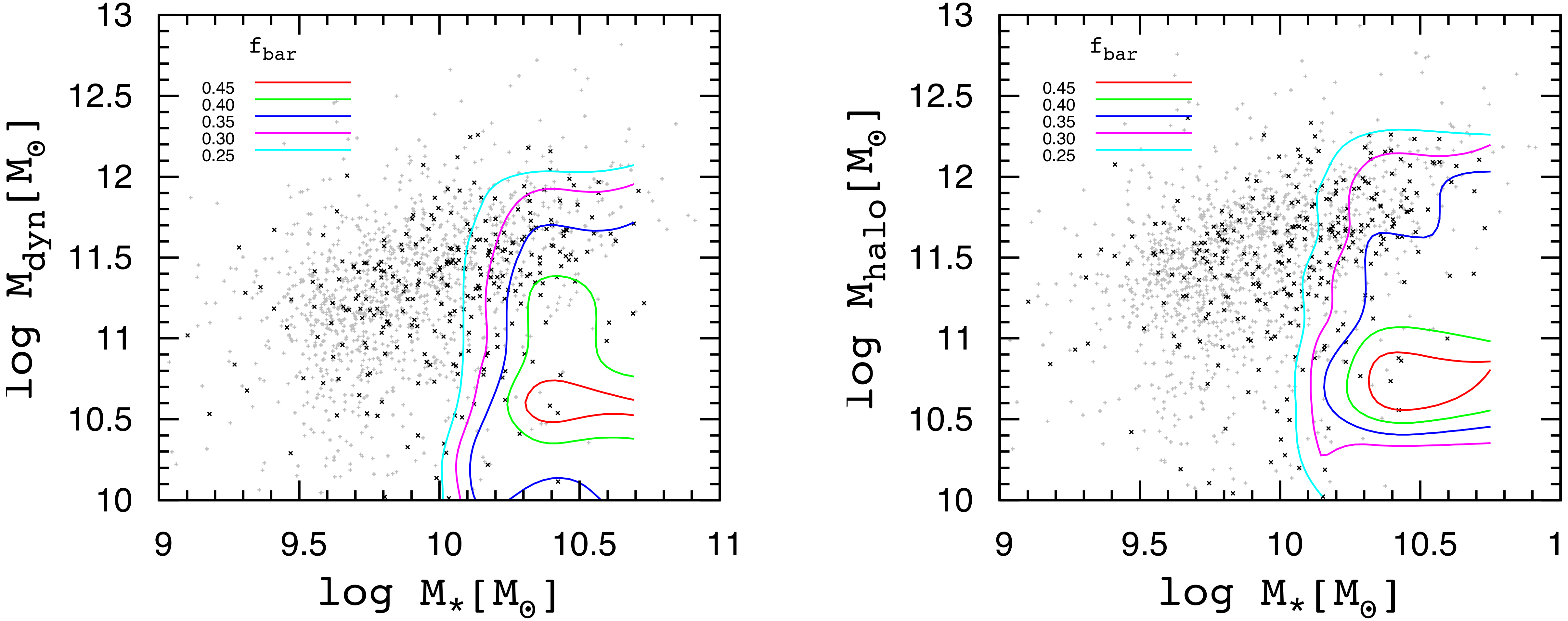
$$M_{\rm halo} = 2.54 \times 10^{10} M_\odot \left(\frac{r_{\rm d}}{\rm kpc}\right)\left(\frac{V_{\rm rot}}{100\ {\rm km\ s^{-1}}}\right)^2$$

r_d from r-Band





Cervantes Sodi 2017



Cervantes Sodi 2017

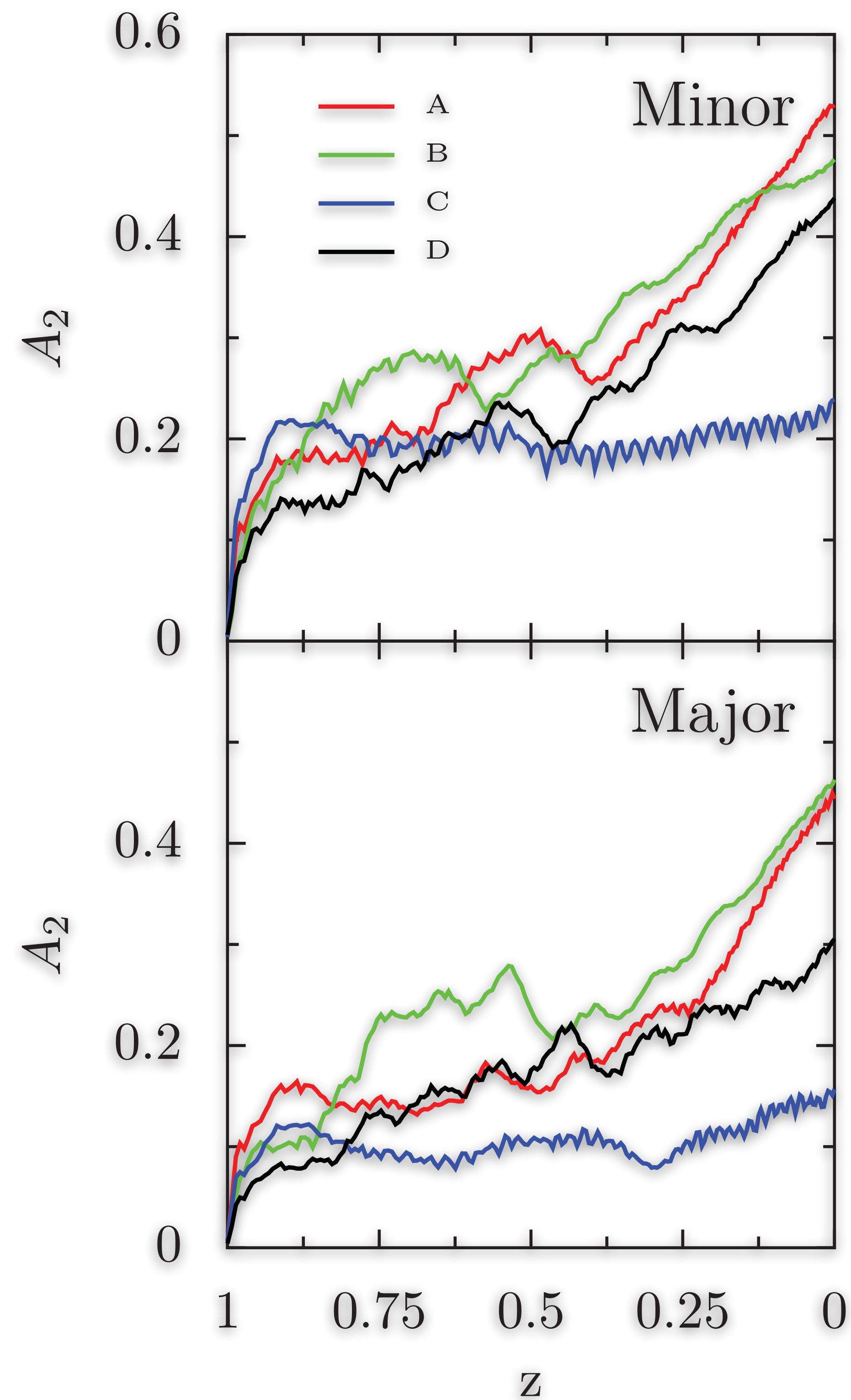
DeBuhr et al. 2012

- Live stellar disks in dark matter halos from the Aquarius Project

- Halo masses:

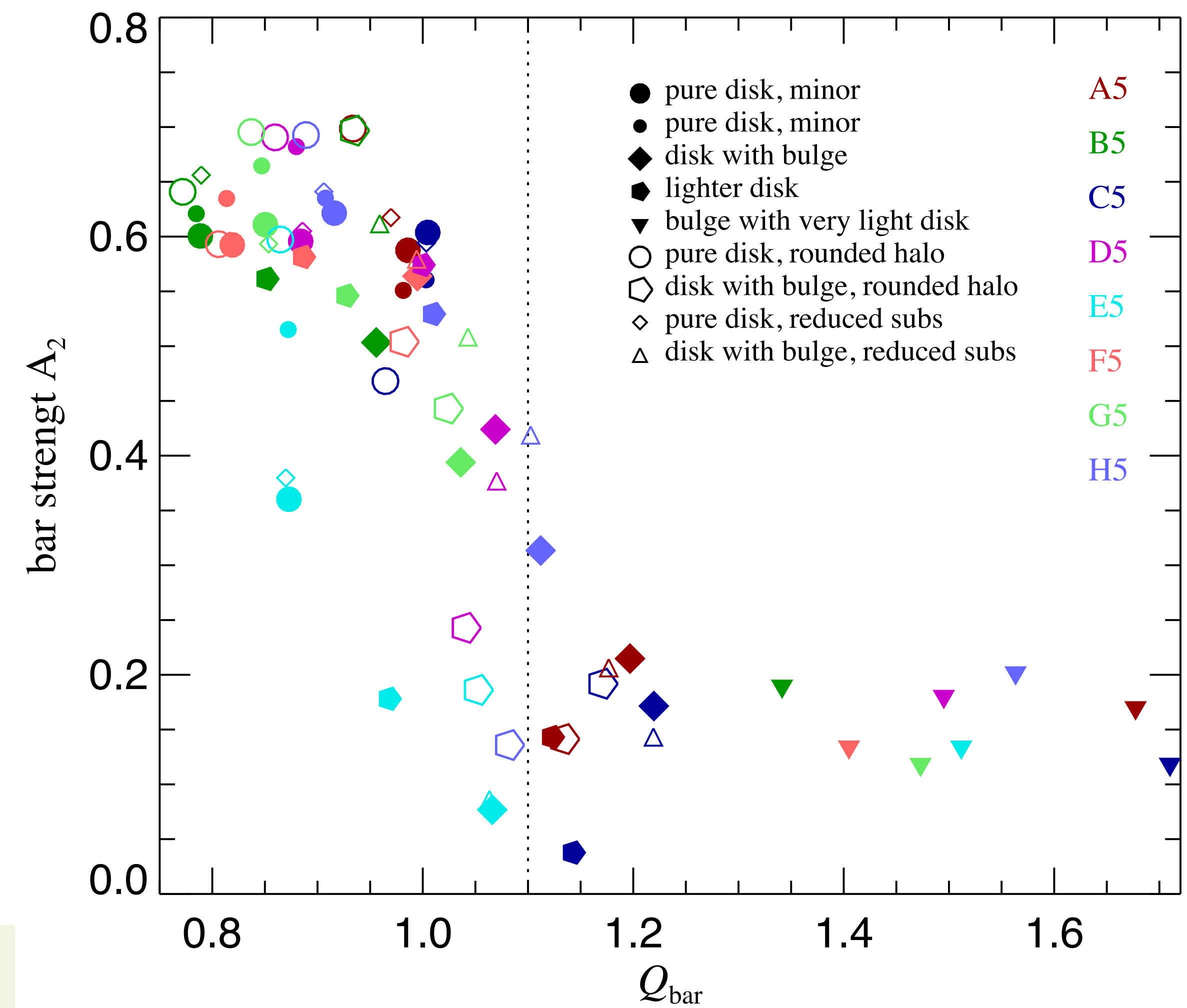
  C > D > A > B

amplitude of the disc surface density. The bars are not destroyed by the buckling but continue to grow until the present day. Bars are largely absent when the disc mass is reduced by a factor of 2 or more; the relative disc-to-halo mass is therefore a primary factor in bar formation and evolution. A subset of the discs is warped at the outskirts and contains prominent non-coplanar



Yurin & Springel 2015

- Also using Aquarius galaxies but using a different prescription to plant the disk in the DM halo



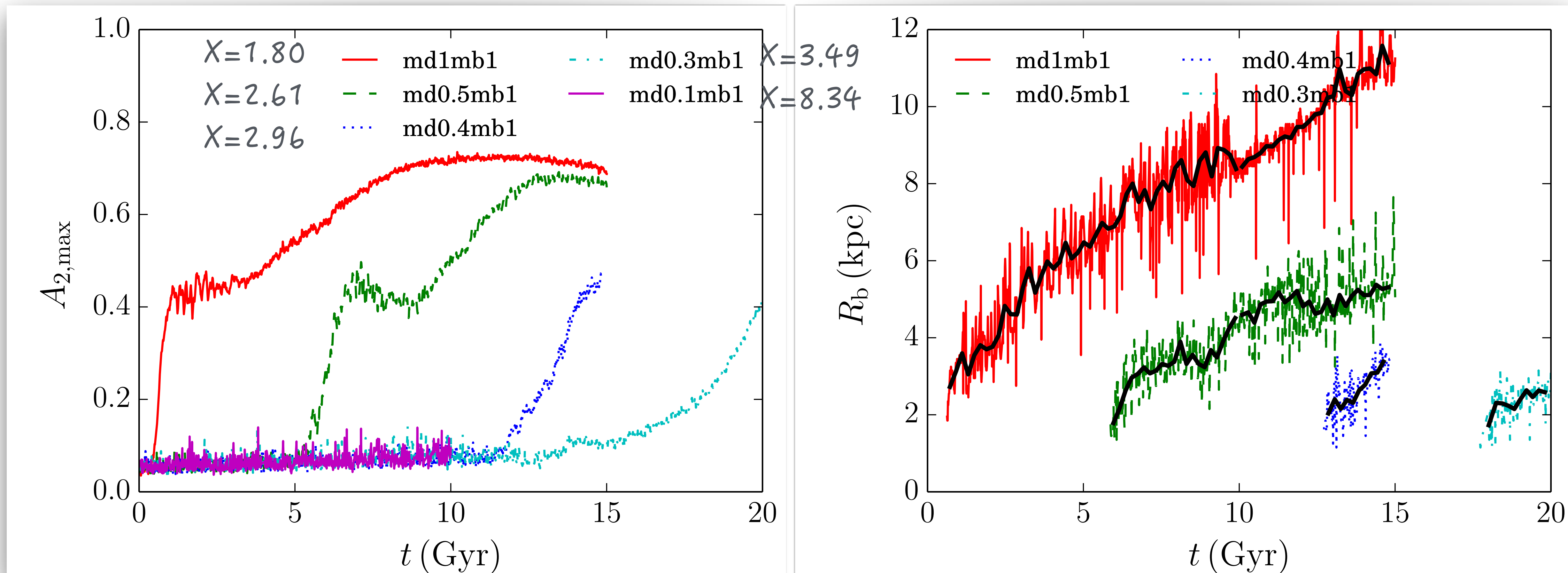
haloes, etc. Irrespective of these factors, it appears that the strength of the disc self-gravity relative to the supporting spheroidal potential is by far the most decisive parameter for governing stability against the formation of strong bars. We note that this therefore can-

$$Q_{\rm bar} \equiv \frac{v_{\rm max}}{(GM_{\rm d}/R_{\rm d})^{1/2}}$$

Fujii et al. 2018

- Pure N-body simulation with live halo, including disk and bulge components

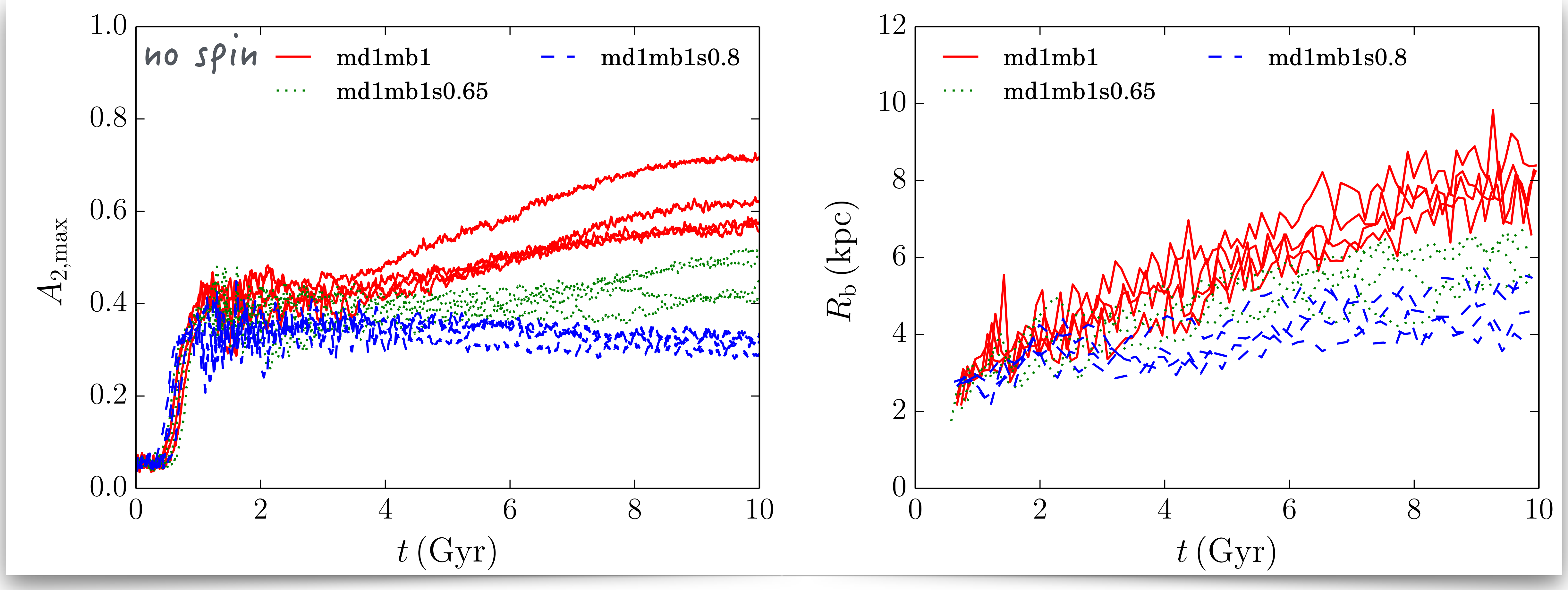
$$X' \equiv 1/f_{\rm d} = \left(\frac{V_{\rm c,tot}(R)}{V_{\rm c,d}(R)}\right)^2_{R=2.2R_{\rm d}}.$$



Fujii et al. 2018

- Bar amplitude and size for models with and without spinning halos

$$\lambda = \frac{L \mid E \mid^{1/2}}{GM^{5/2}}$$



Efstathiou, Lake & Negroponte (1982)

- Stability criterion: $$\epsilon_c = \frac{V_{max}}{GM_d/R_d} \leq 1.1$$

- which in terms of the galactic spin (λ_d) and the disk mass fraction (f_d), becomes:

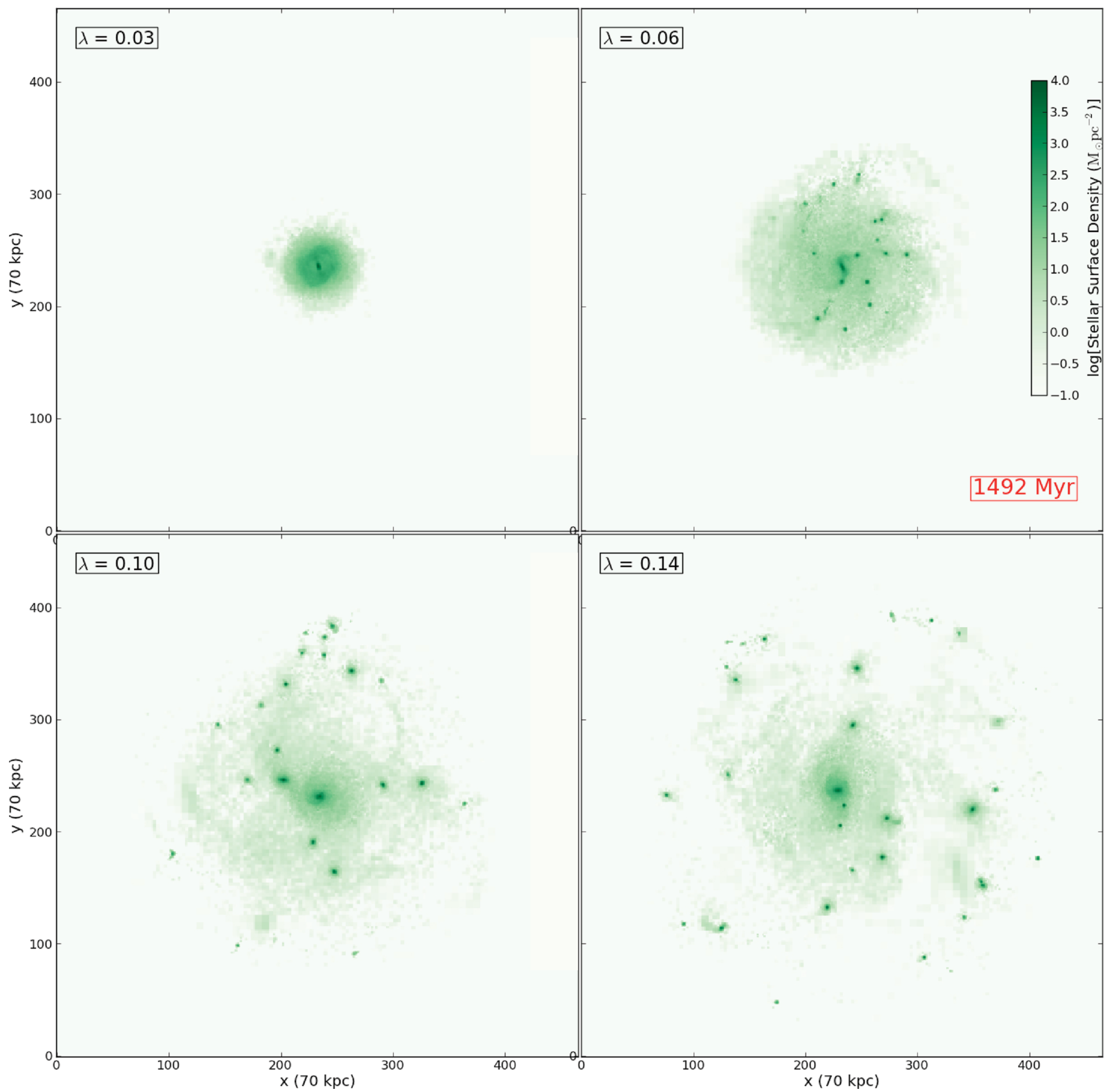
$$\epsilon_c = \frac{\lambda_d}{2^{1/2} f_d}$$

- where: $\lambda = \frac{L \mid E \mid^{1/2}}{GM^{5/2}}$ and $f_d = M_d/M_H$

- Galaxies with high spin and low disk-mass fractions are less susceptible to the formation of bars

Low surface brightness (LSB) galaxies formed in high spinning haloes

1704 *J. Kim and J. Lee*

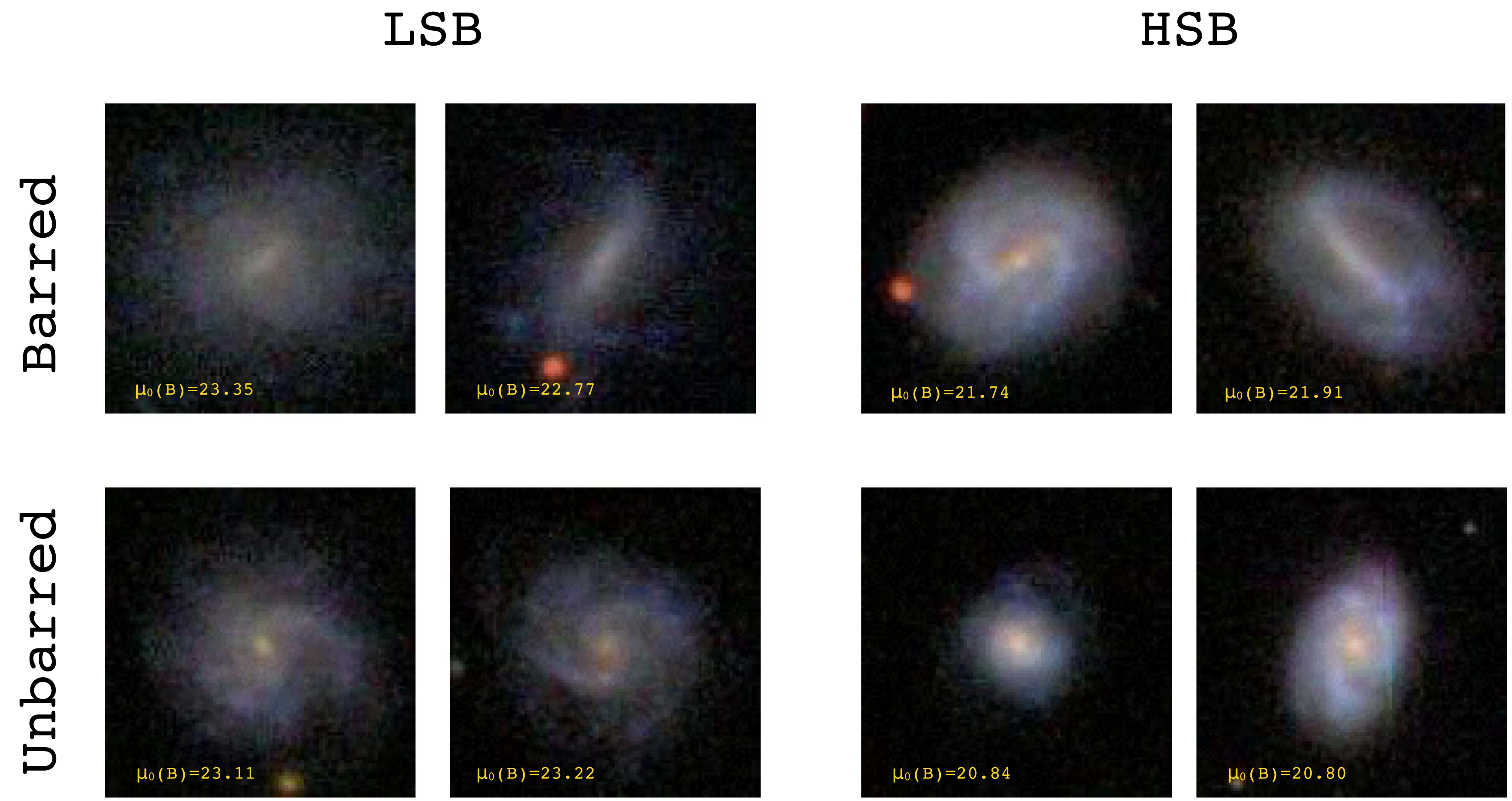


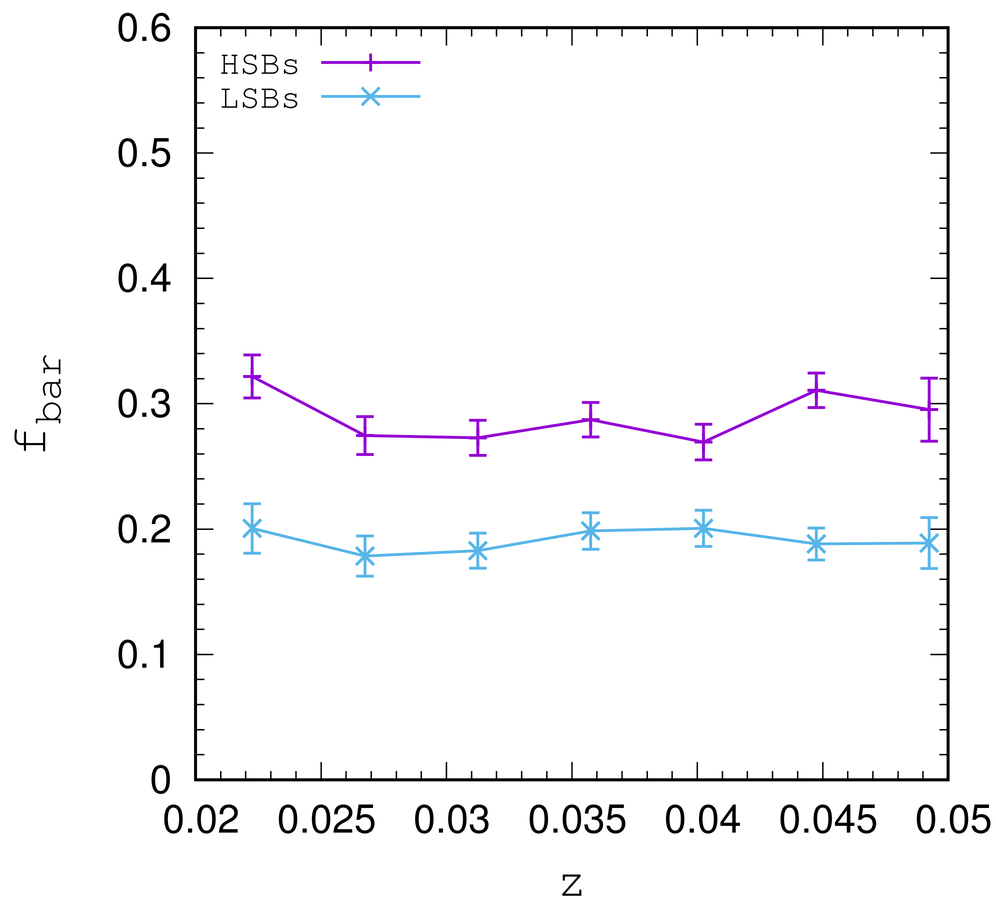
LSBs are galaxies with central surface brightness in the B band lower than $\mu_0(B)$~22 mag/arcsec^2

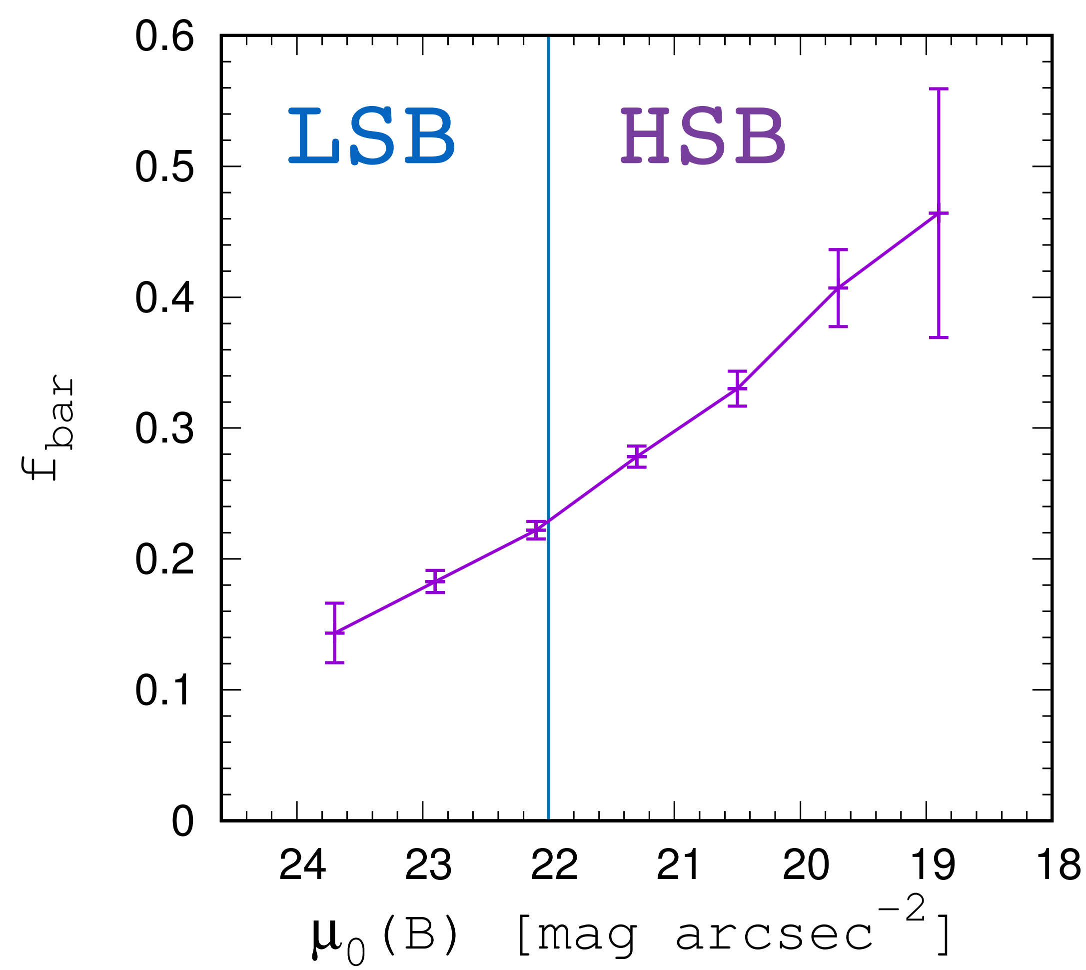
Kim & Lee 2013

Bars in LSBs

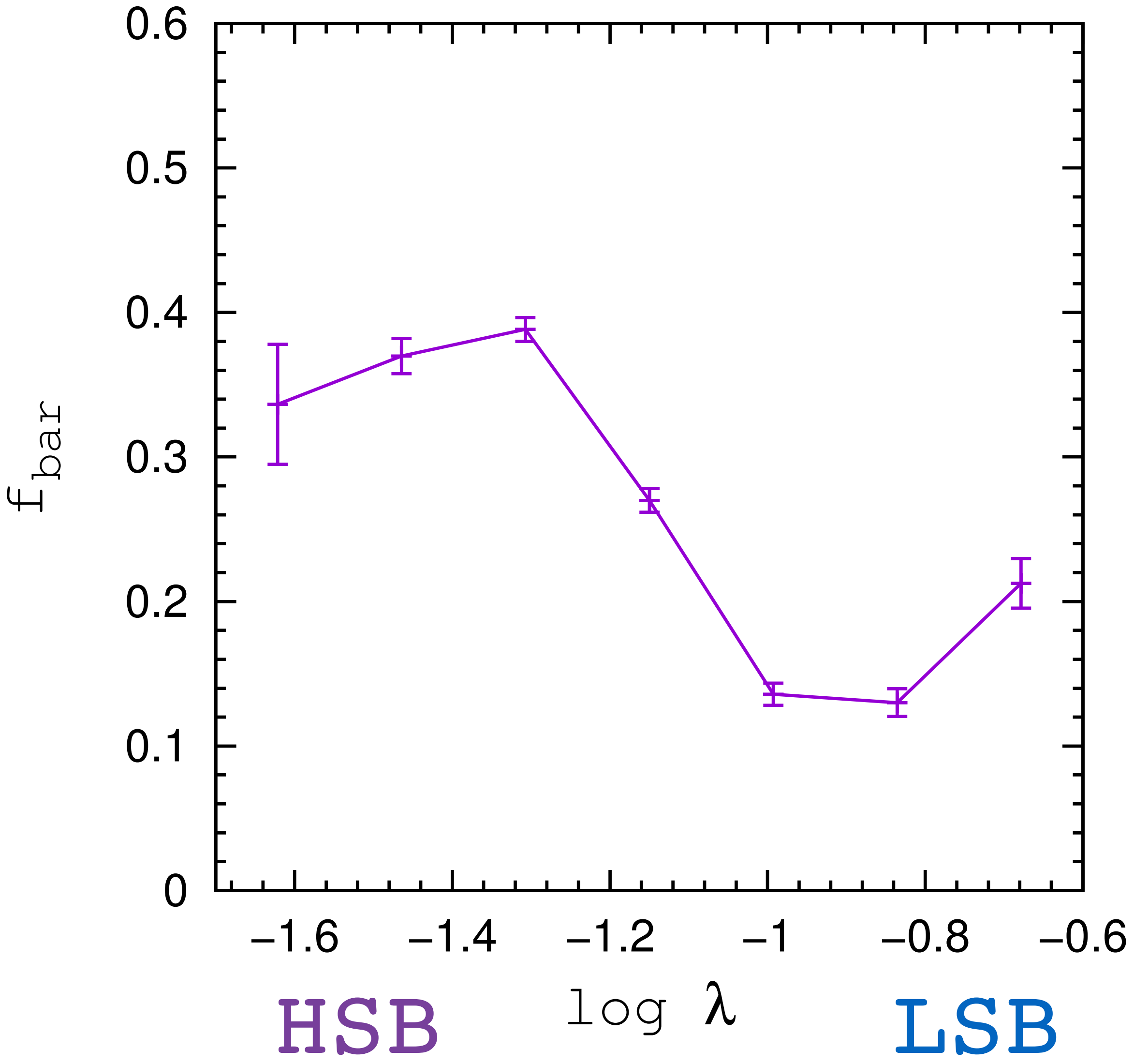
Cervantes Sodi & Sánchez García 2017
Using ~10,000 galaxies

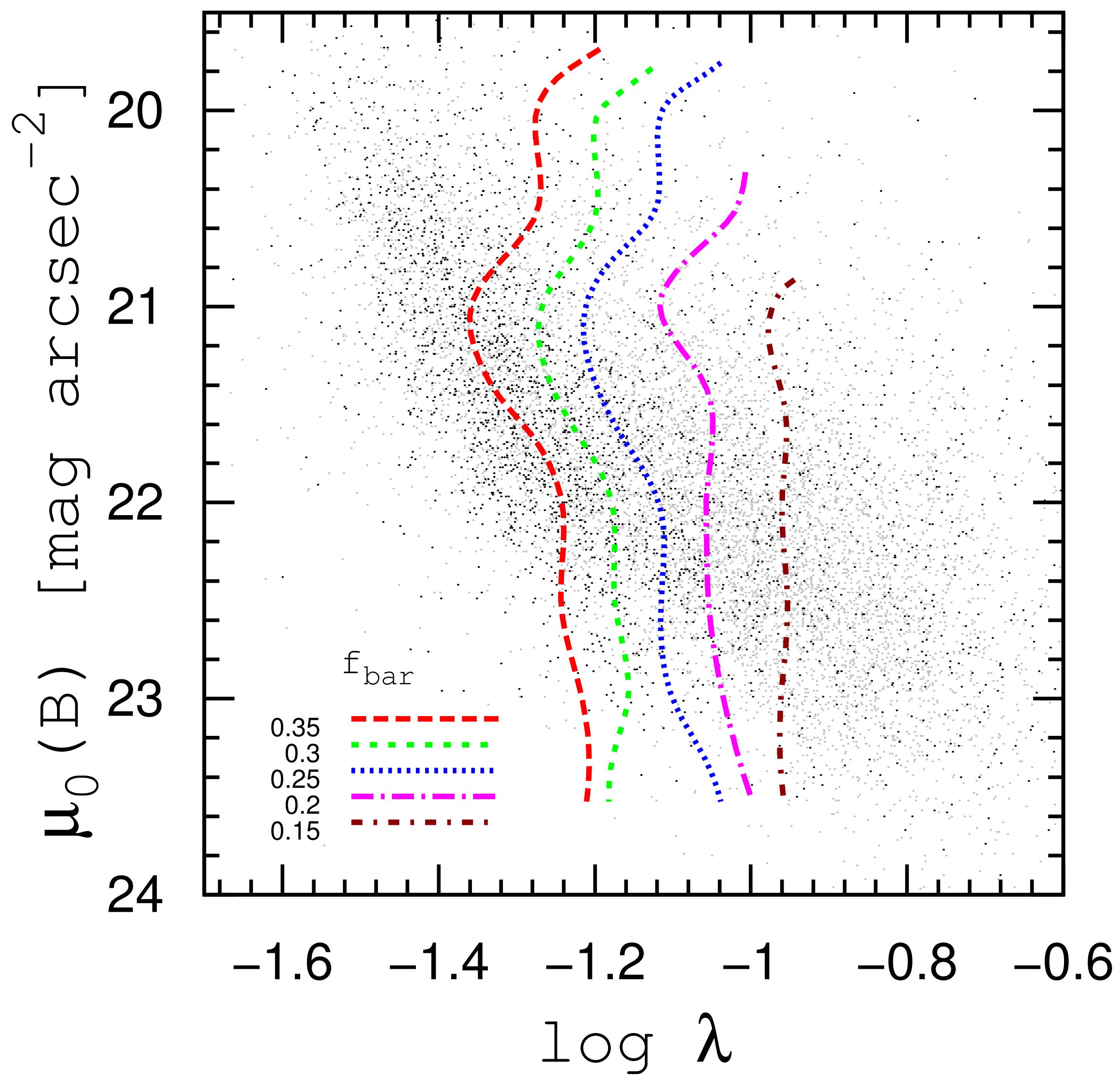






Dependence on μ_0(B) or on λ?

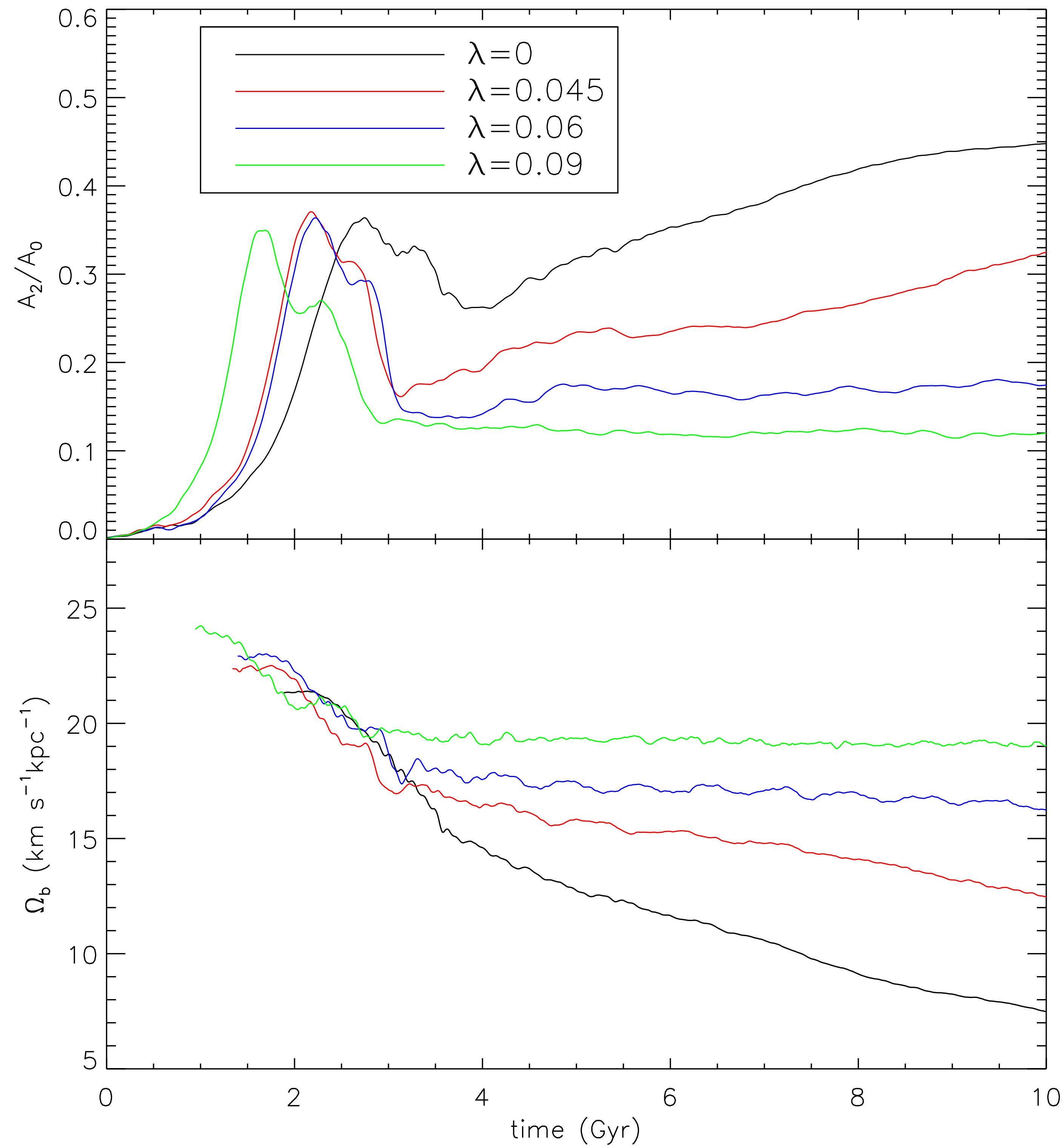




Cervantes Sodi et al. 2013
Cervantes Sodi & Sánchez García 2017

Corroboration from theoretical studies.

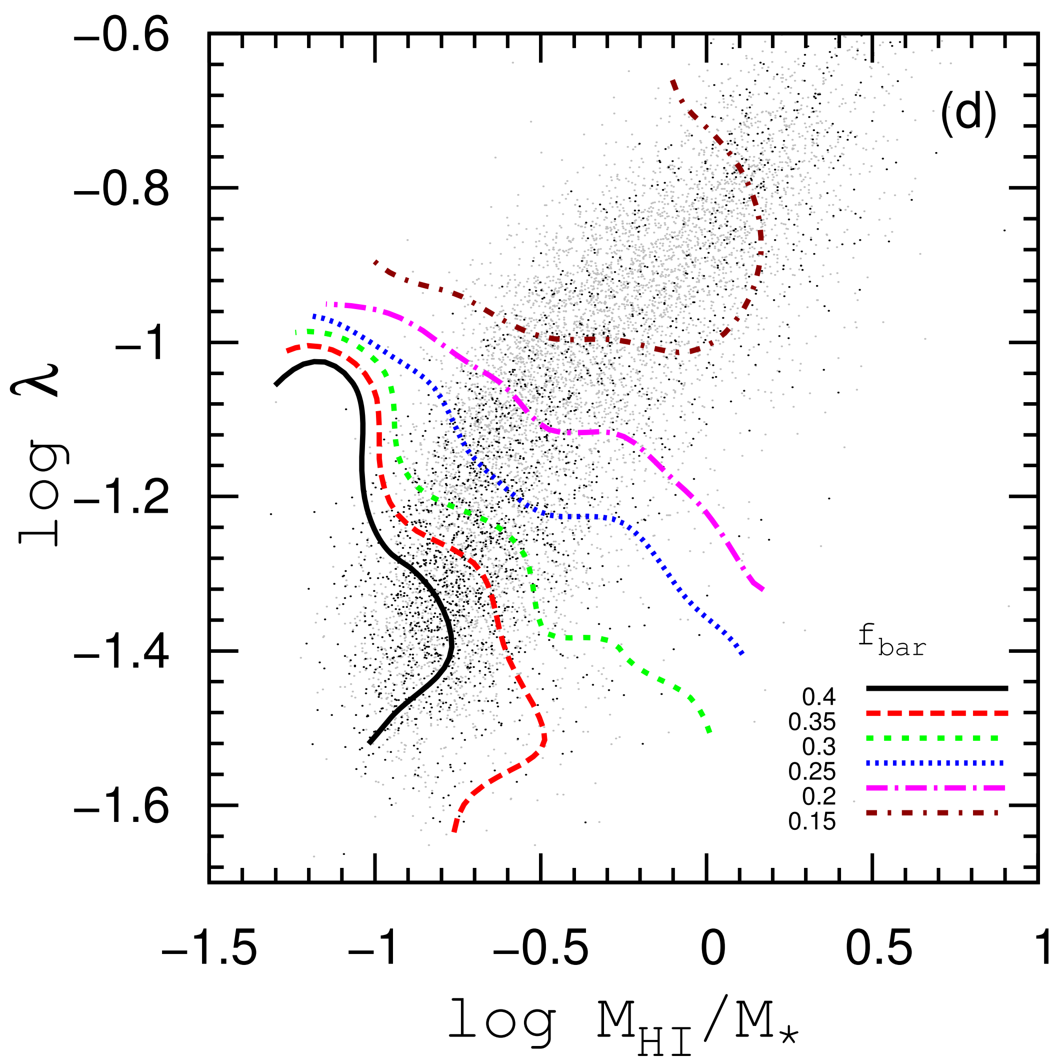
Long, Shlosman & Heller 2014



ABSTRACT

We demonstrate using numerical simulations of isolated galaxies that growth of stellar bars in spinning dark matter halos is heavily suppressed in the secular phase of evolution. In a representative set of models, we show that for values of the cosmological spin parameter $\lambda \gtrsim 0.03$, bar growth (in strength and size) becomes increasingly quenched. Furthermore, the slowdown of the bar pattern speed weakens considerably with increasing λ until it

LSBs, galaxies rich on gas with high spin parameter



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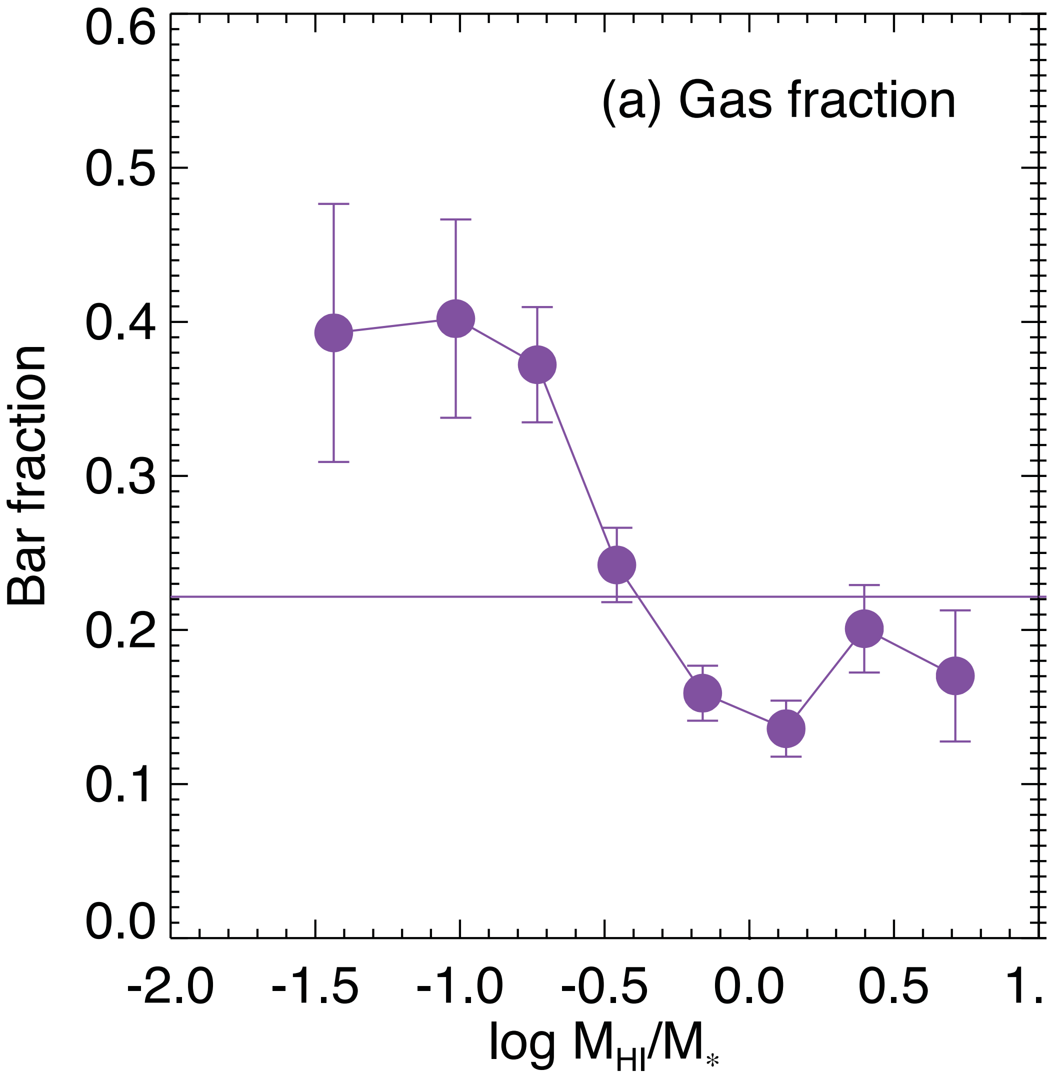
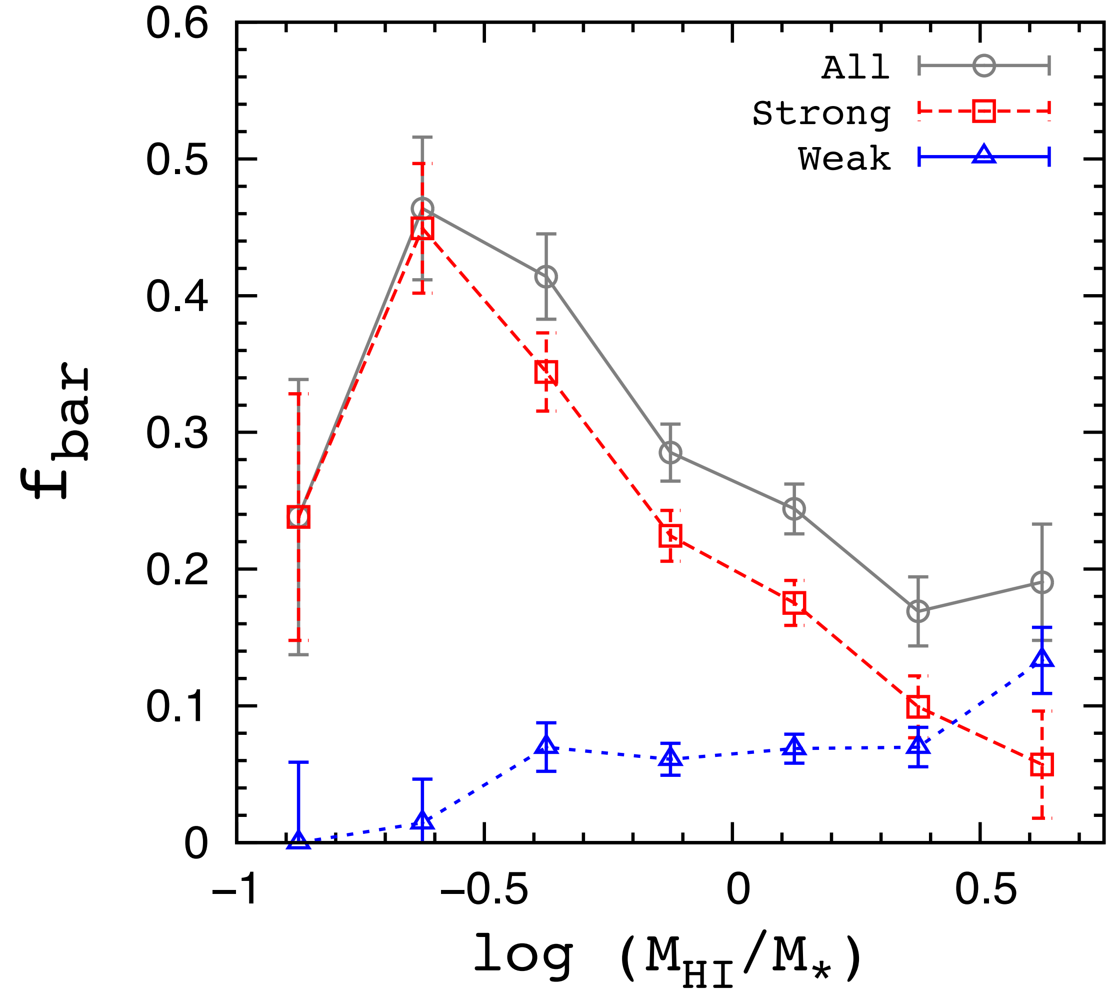
Bar fraction vs. HI gas abundance



Masters et al. 2012



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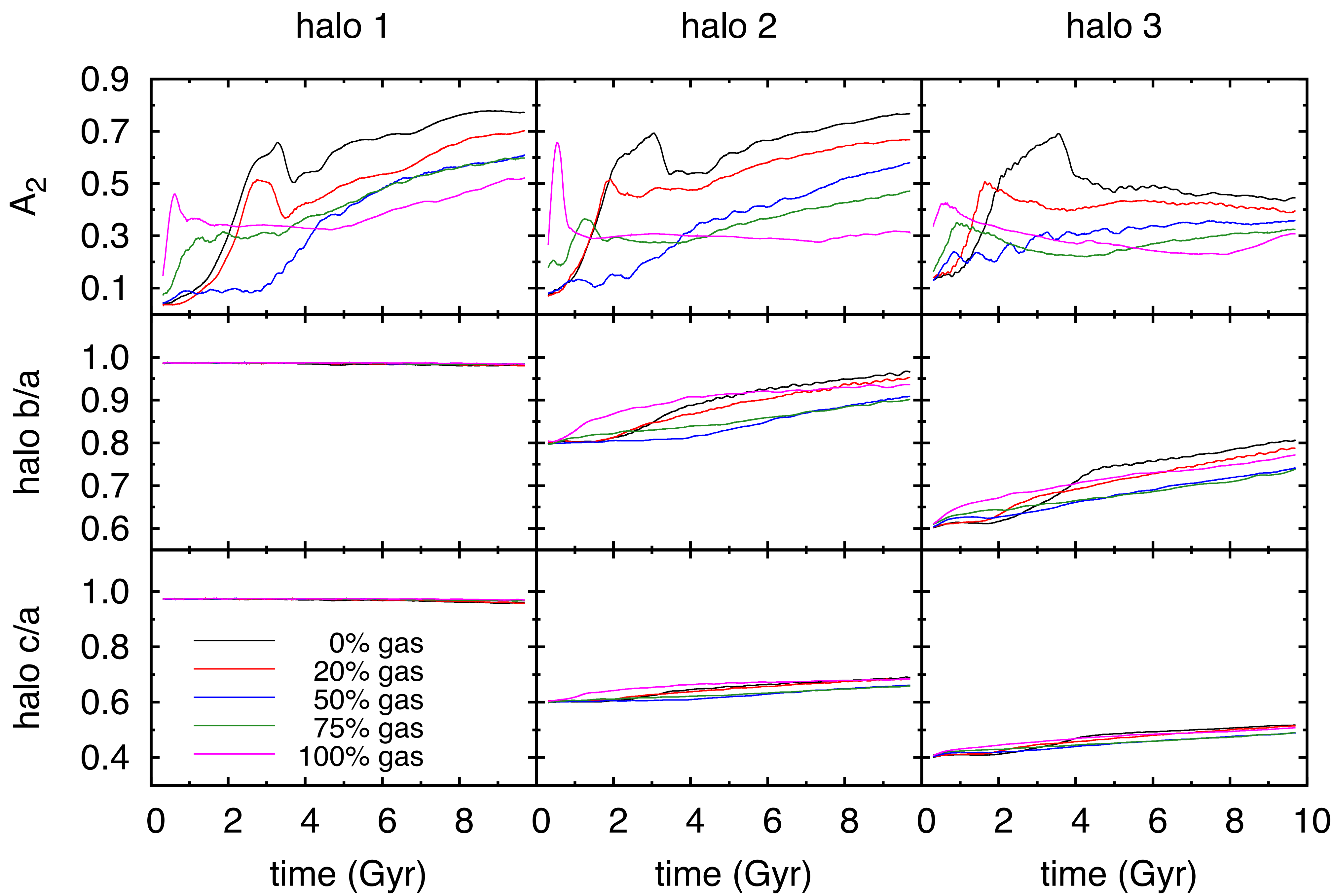
Athanassoula, Machado & Rodionov 2013

Bar amplitude



Conclusions

- At fixed stellar mass, the bar fraction decreases with increasing halo mass. This result is reproduced using three different halo mass estimates.

- Our study suggests that massive dark matter halos help to stabilise galaxies against the formation and/or growth of bars. This is enhanced in the case of high spinning systems.

- In a similar way, we conclude that the strong anti-correlation between the likelihood of a galaxy hosting a bar with the gas richness of the galaxy results form the inhibiting effect the gas has in the formation of bars.

- These results are reproduced by simulations that include hydrodynamics and halos with non-vanishing angular momentum

Thanks!

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