Morphology-driven evolution of barred galaxies in clusters and the case of barred jellyfish galaxies

Bernardo Cervantes Sodi
Instituto de Radioastronomía y Astrofísica
National Autonomous University of Mexico



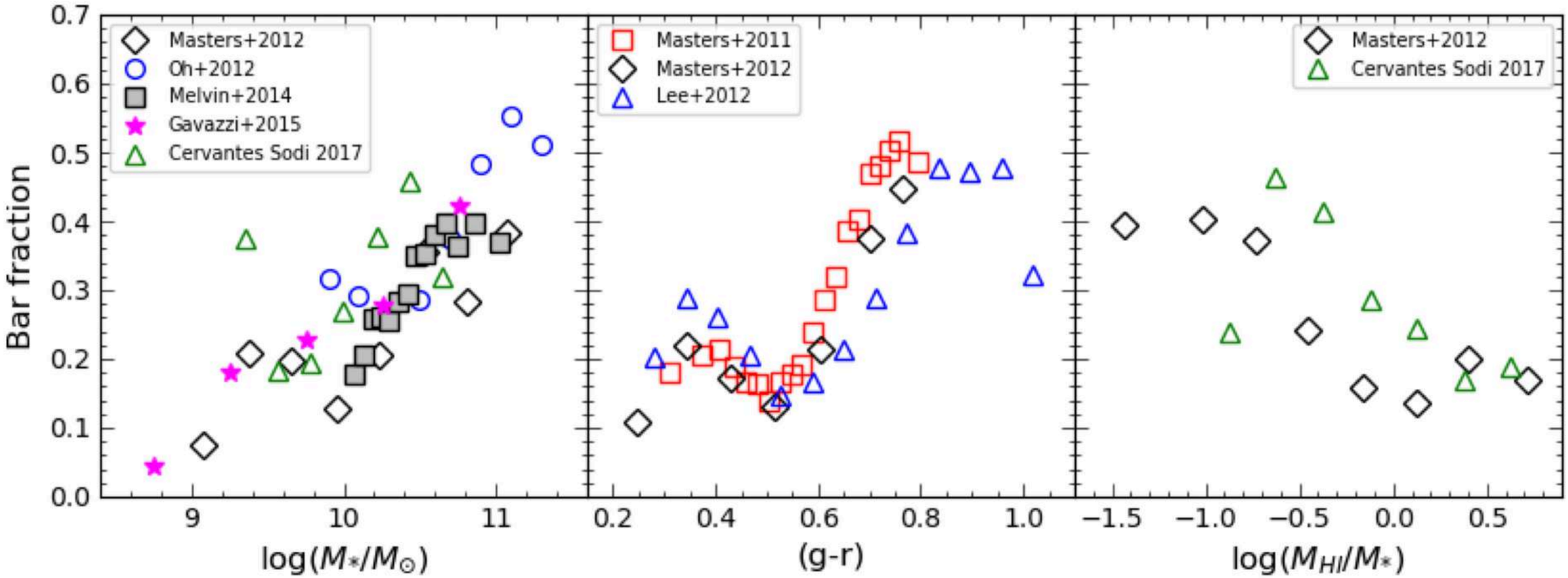


The 11th KIAS Workshop on Cosmology and Structure Formation
Gyeongju, Korea - 2024

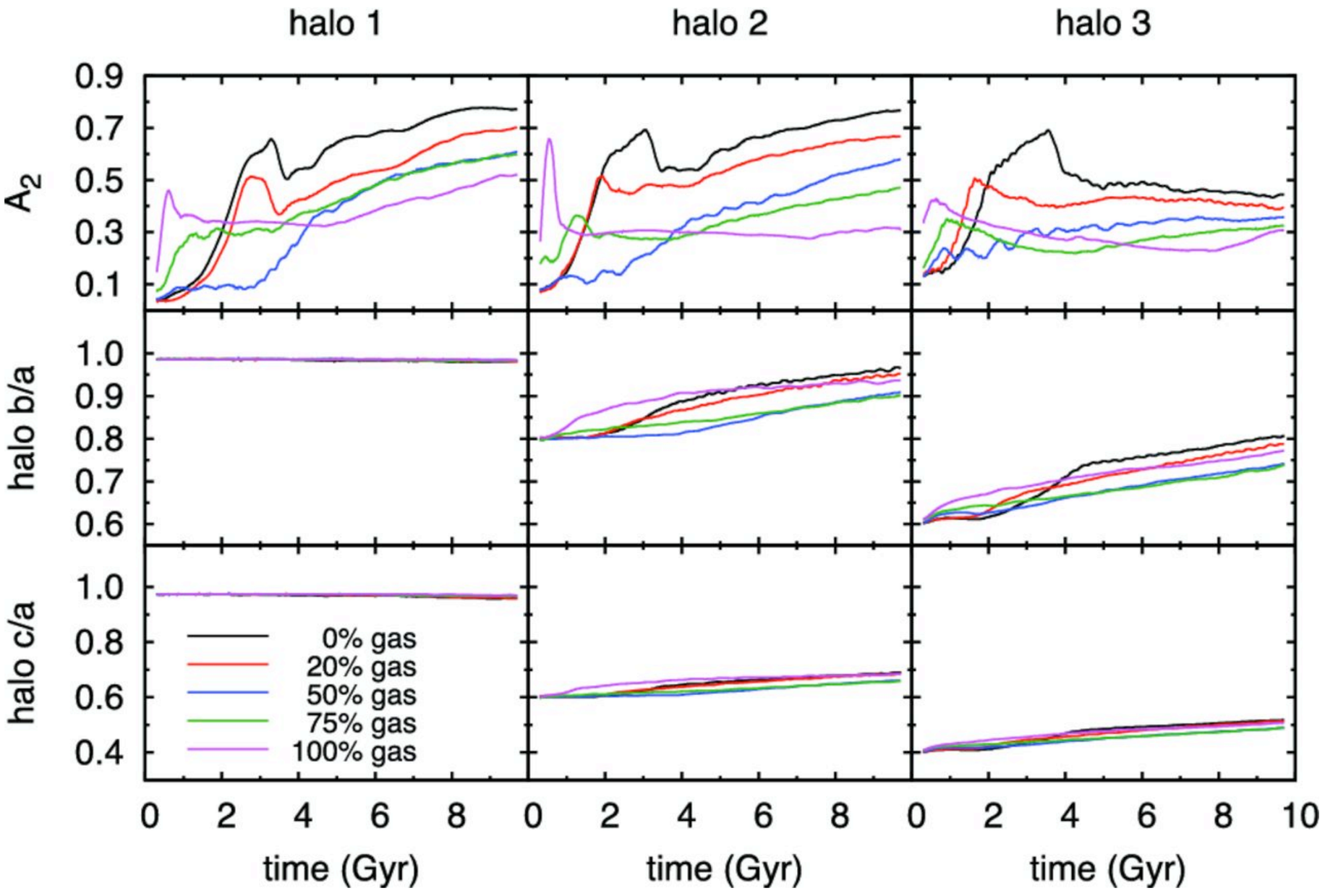
Outline

- Barred galaxies in the local Universe
- Mechanisms of bar formation.
- Dependence on intrinsic physical properties
- Tidal interactions
- Barred galaxies in the cluster environment
- The case of jellyfish galaxies.
- Conclusions.

Bar fraction in the local Universe



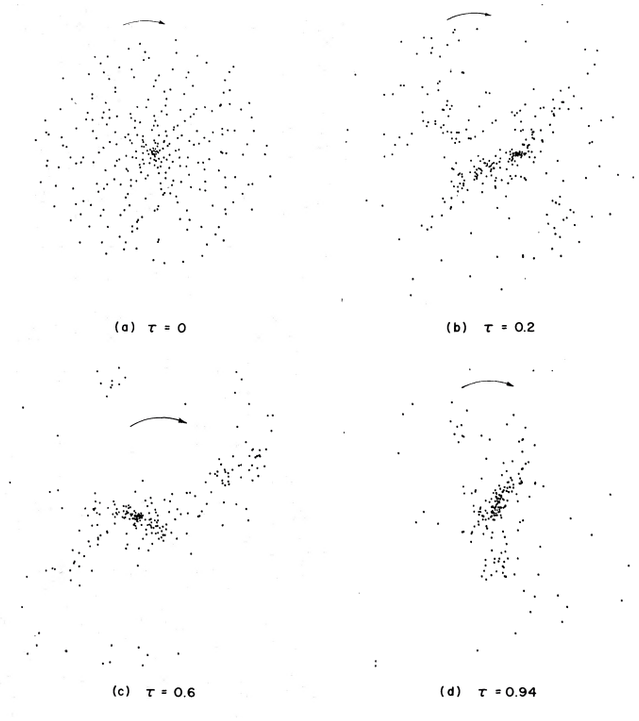
Effect of gas fraction and halo shape on bar formation

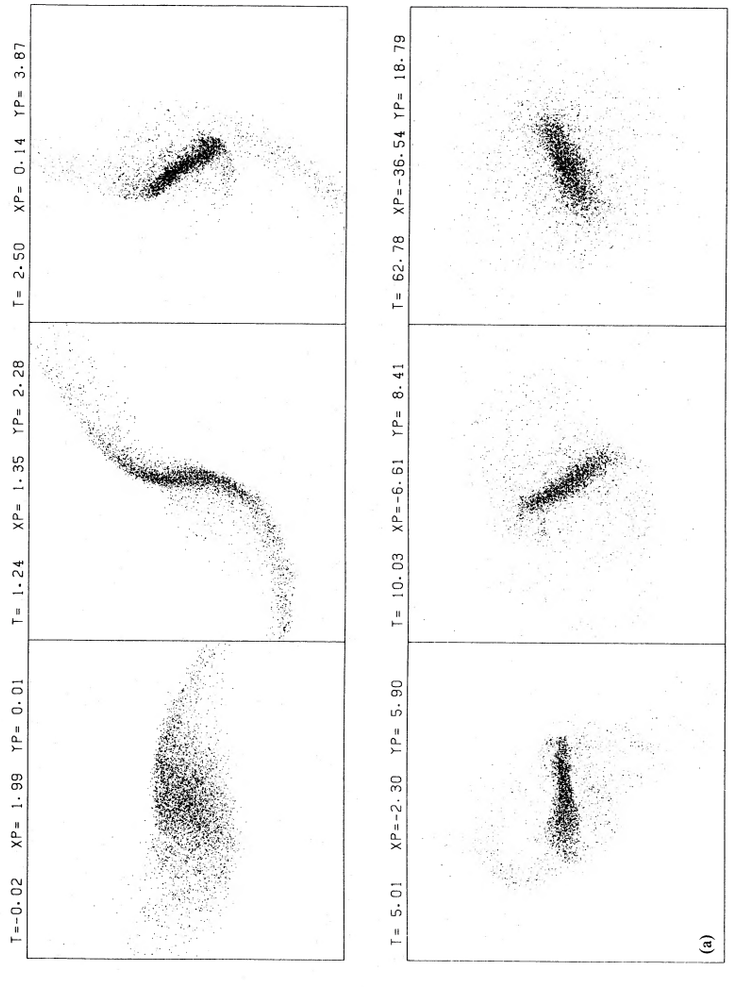


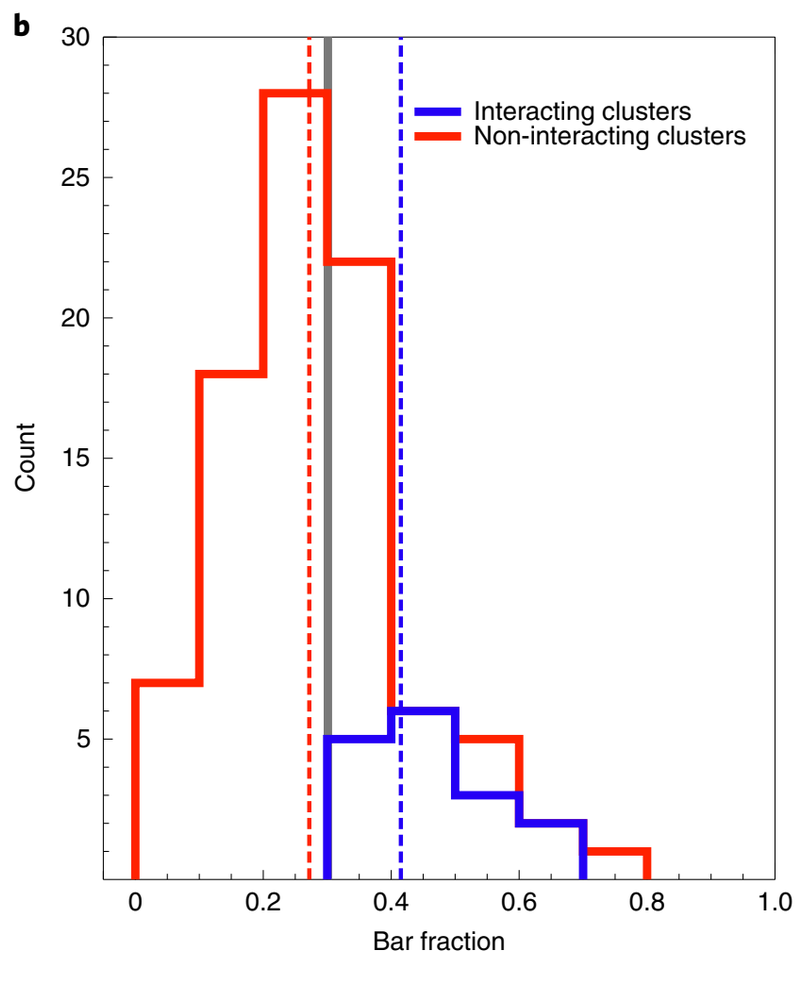
Athanassoula et al. (2013)

Processes of bar formation

- 1) Due to internal processes, internal gravitational instabilities and dependent on the density profiles of the DM halo (Ostriker & Peebles 1973).
- 2) Bar formation triggered by tidal interactions with other galaxies and with galaxy clusters (Noguchi 1987, Lokas 2016, 2020).
- 3) Cluster-cluster interactions (Yoon et al. 2019).



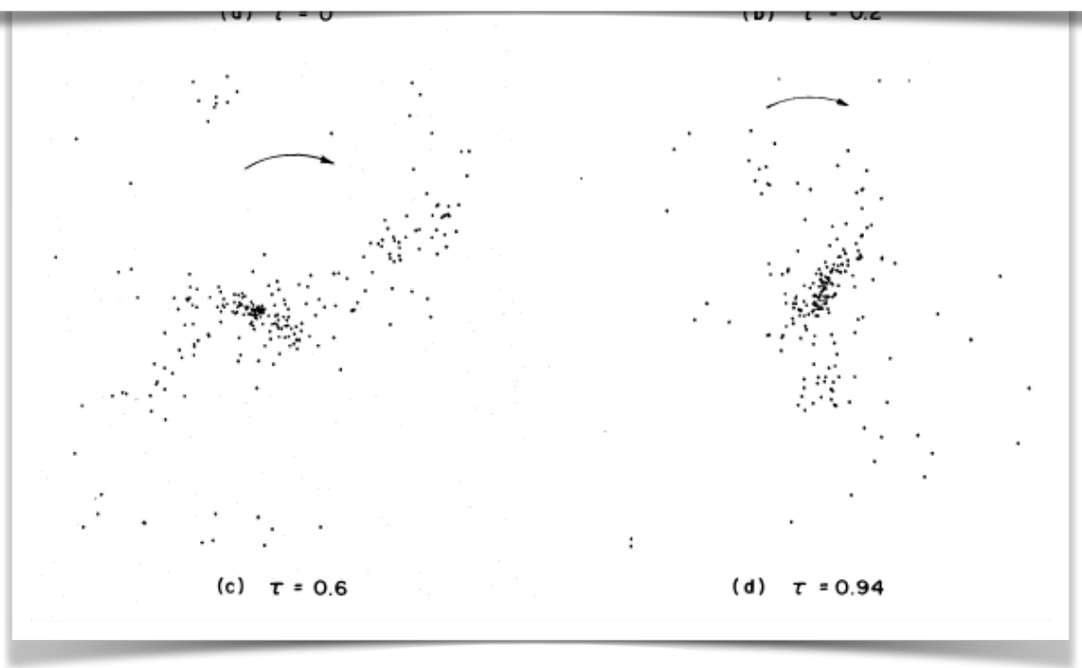




A NUMERICAL STUDY OF THE STABILITY OF FLATTENED GALAXIES: OR, CAN COLD GALAXIES SURVIVE?*

J. P. OSTRIKER
Princeton University Observatory
AND
P. J. E. PEEBLES
Joseph Henry Laboratories, Princeton University
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 $t \simeq 0.14$.

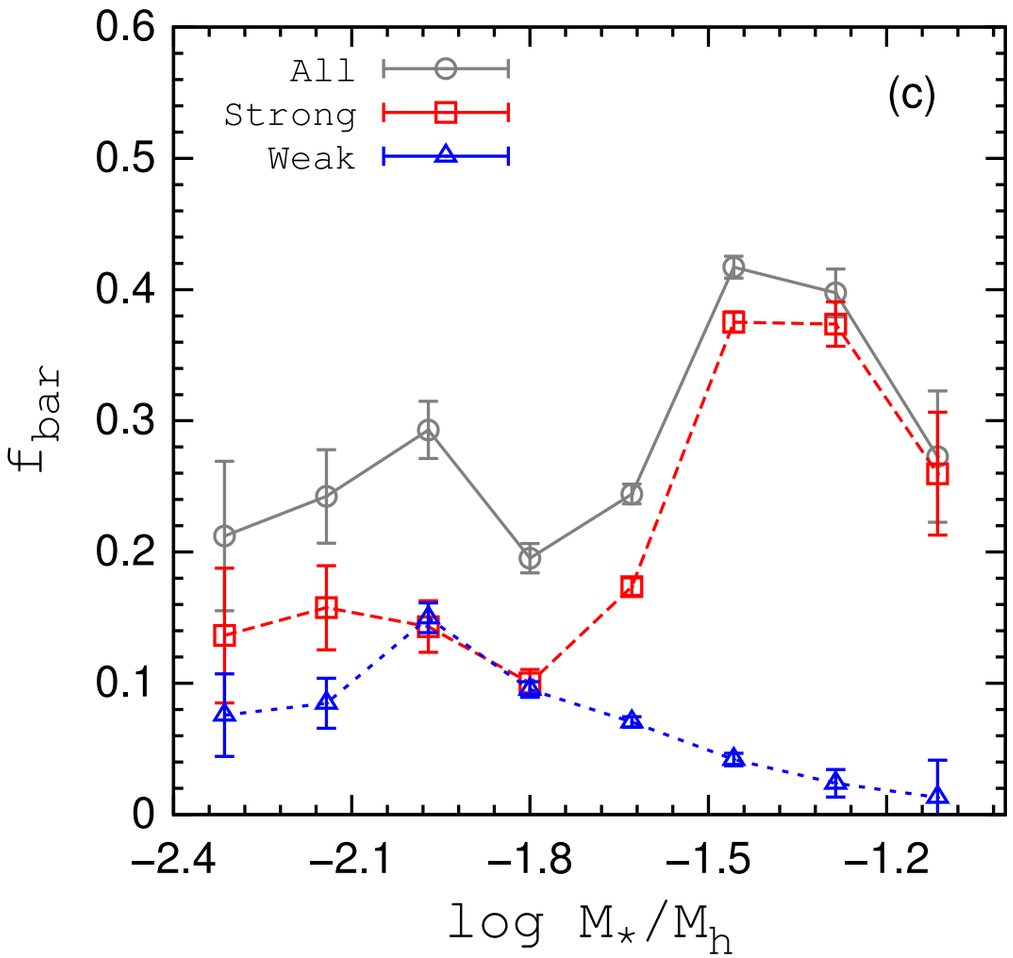


Also: Efstathiou, Lake & Negroponte (1981)

$$t^* = \frac{v_m}{(\alpha M_D G)^{1/2}}$$

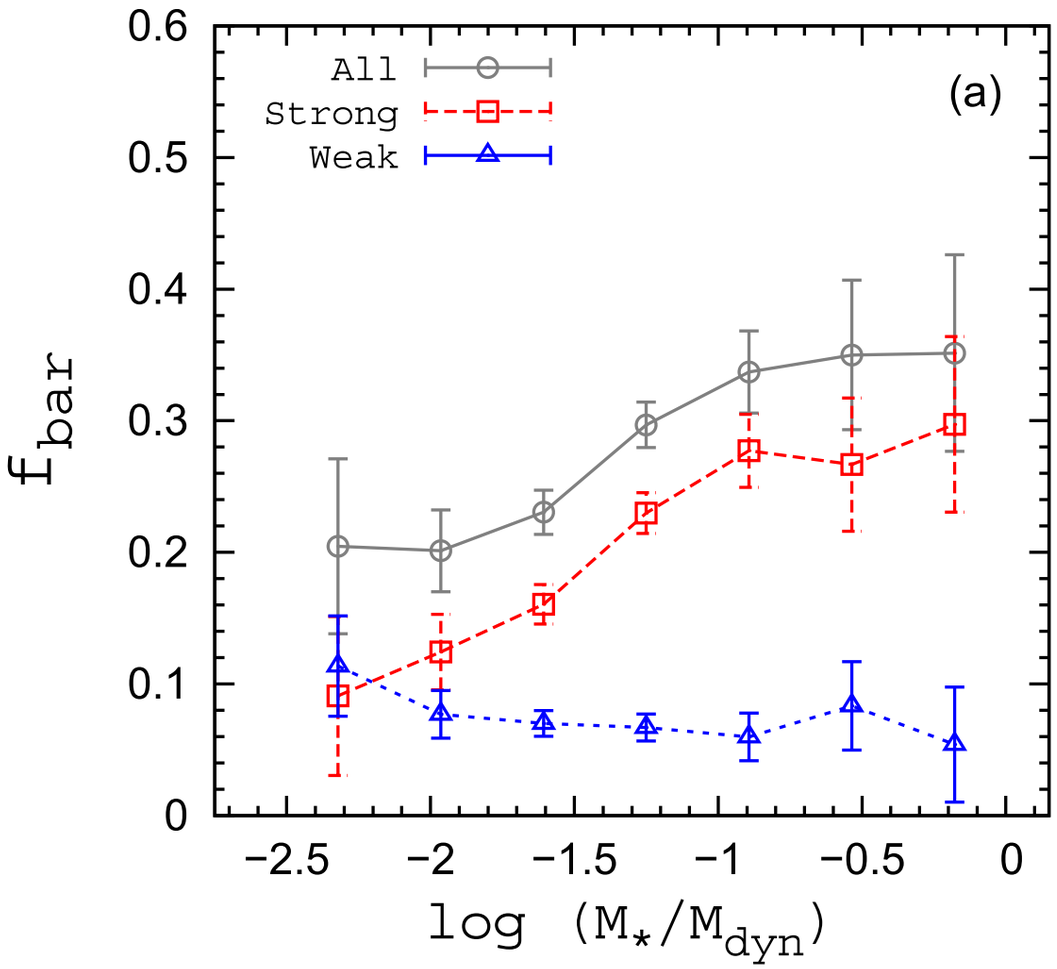
Stellar-to-halo mass ratio

Dark mater halo mass from Yang et al. group catalogue



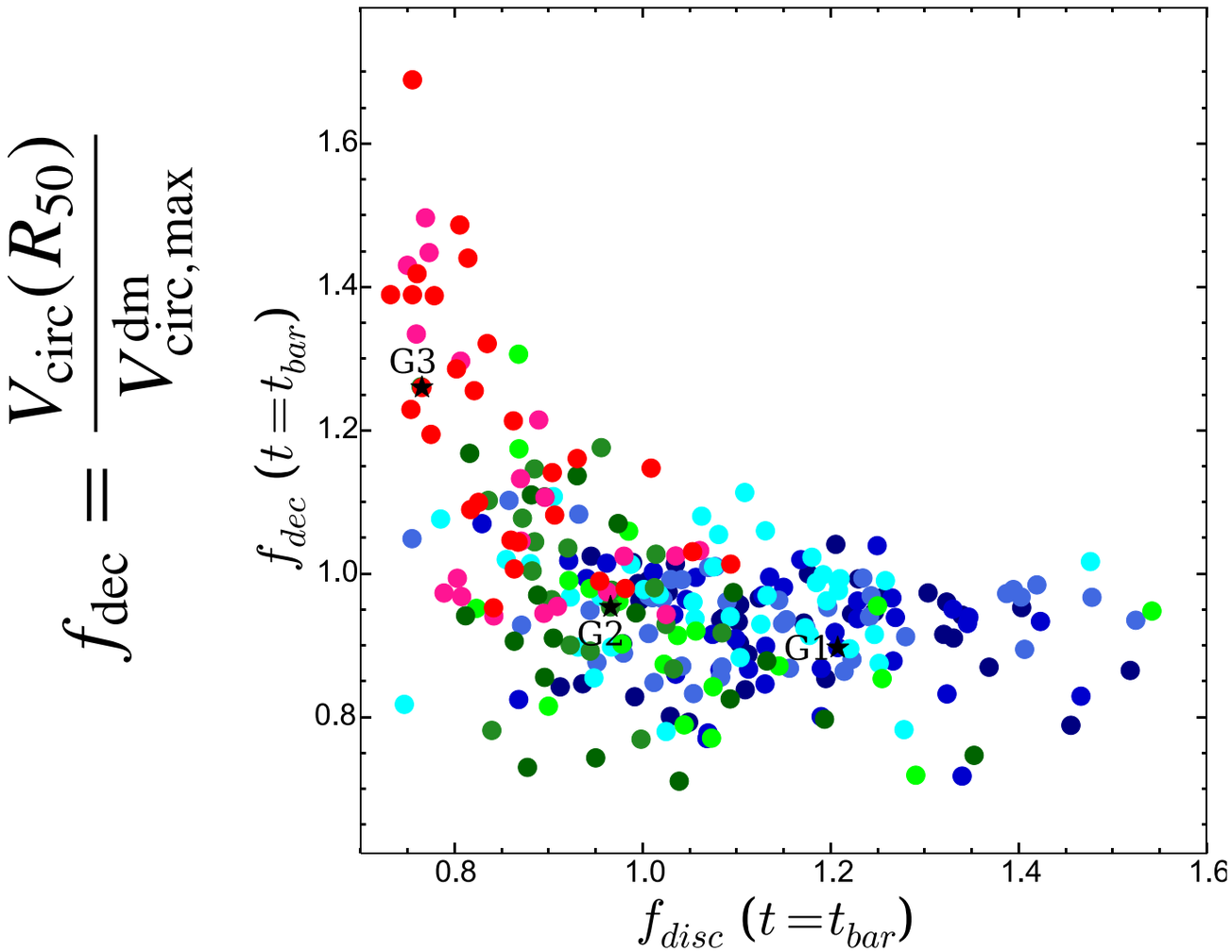
Cervantes Sodi et al. (2015)

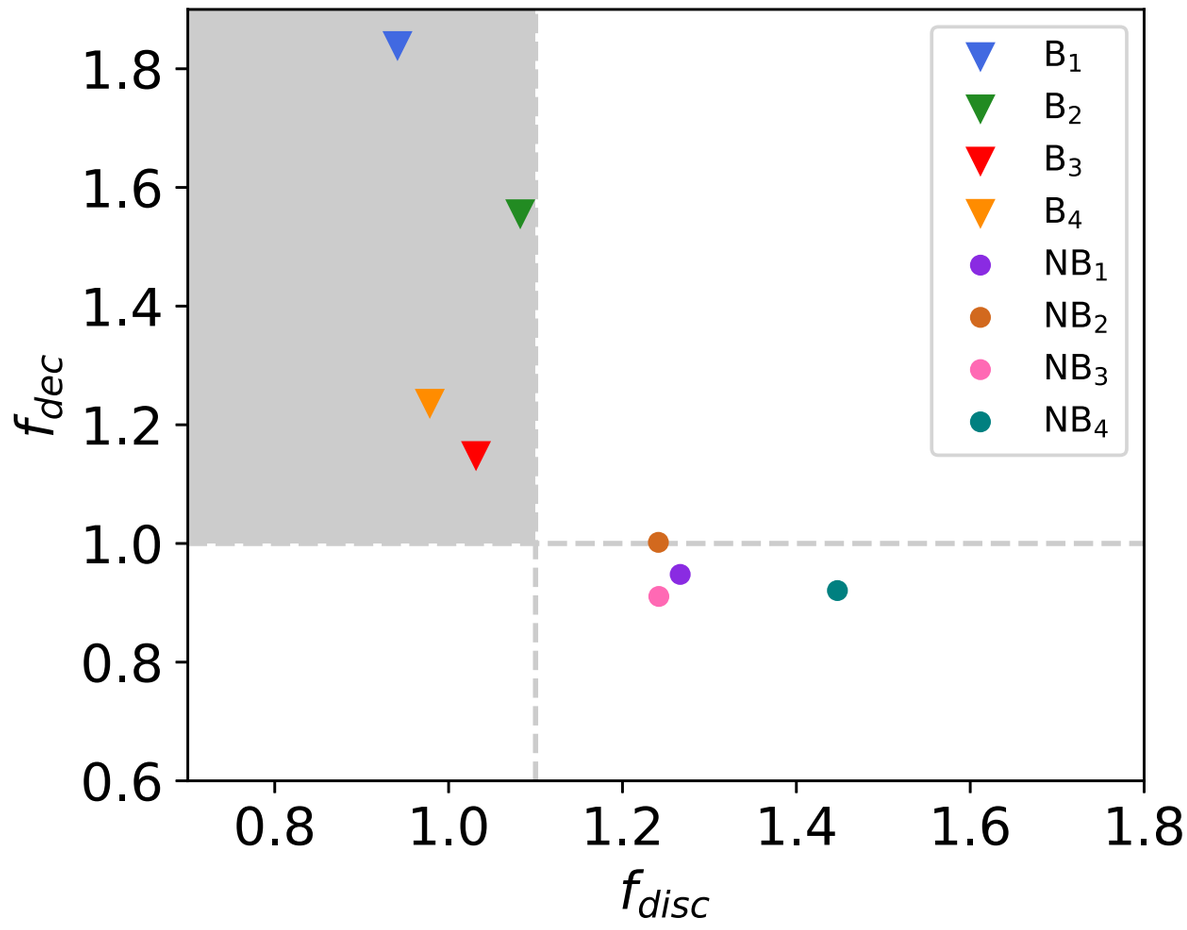
Dynamical masses from HI line widths from ALFALFA



Cervantes Sodi (2017)

Disc instability in cosmological hydrodynamical simulations



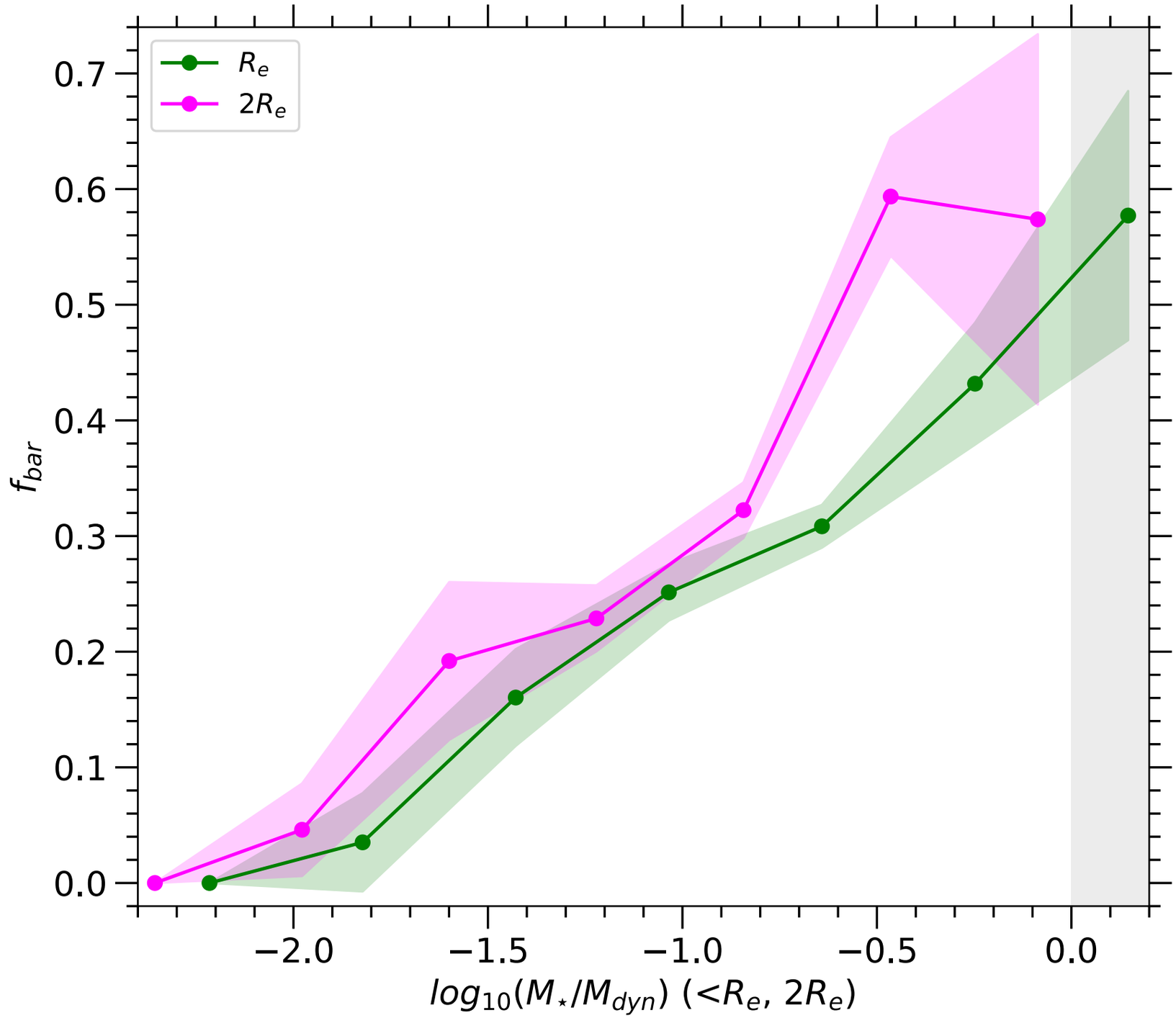


$$f_{\rm disc} = \frac{V_{\rm circ}(R_{50})}{\sqrt{GM_{\rm star}/R_{50}}}$$

EAGLE (Algorry et al. 2017)

TNG50 (López et al. 2024)

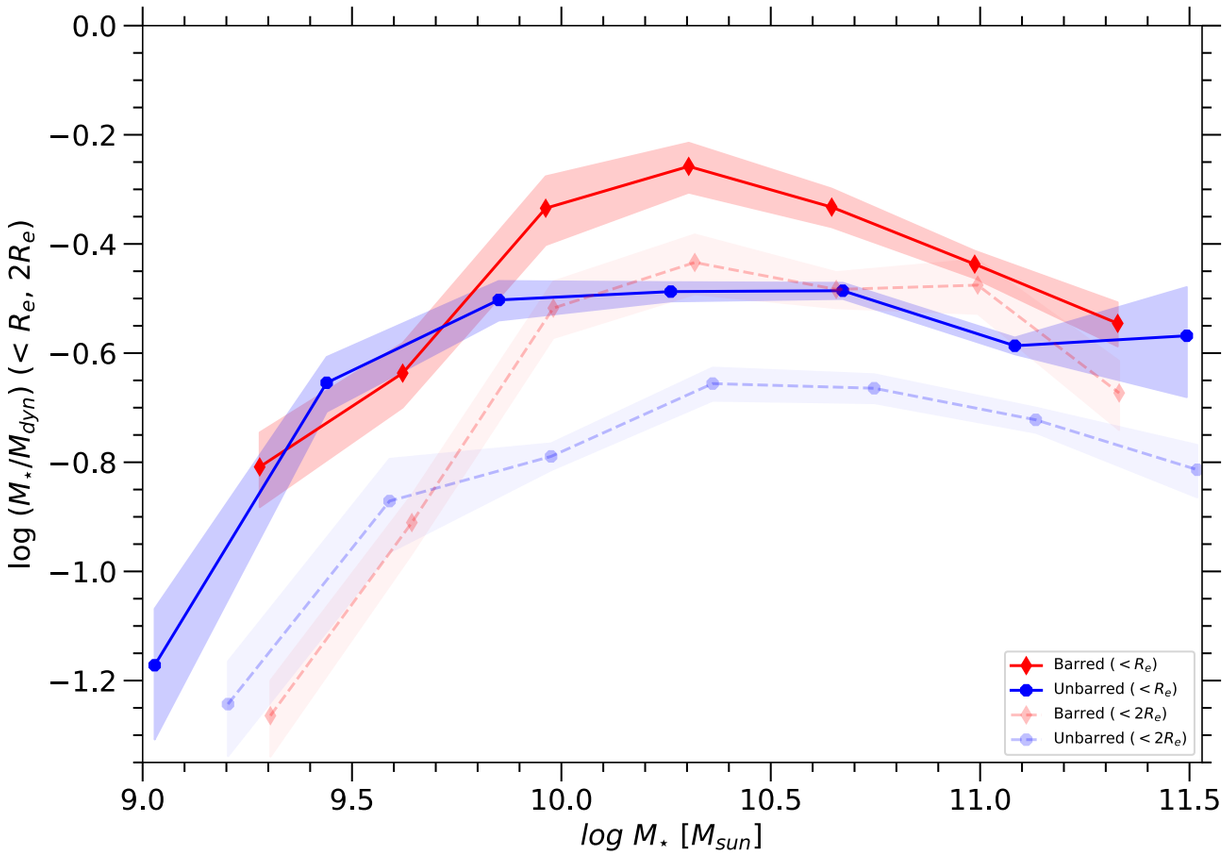
Bar fraction vs stellar-to-dynamical mass ratio within 1 and 2 R_e in MaNGA galaxies



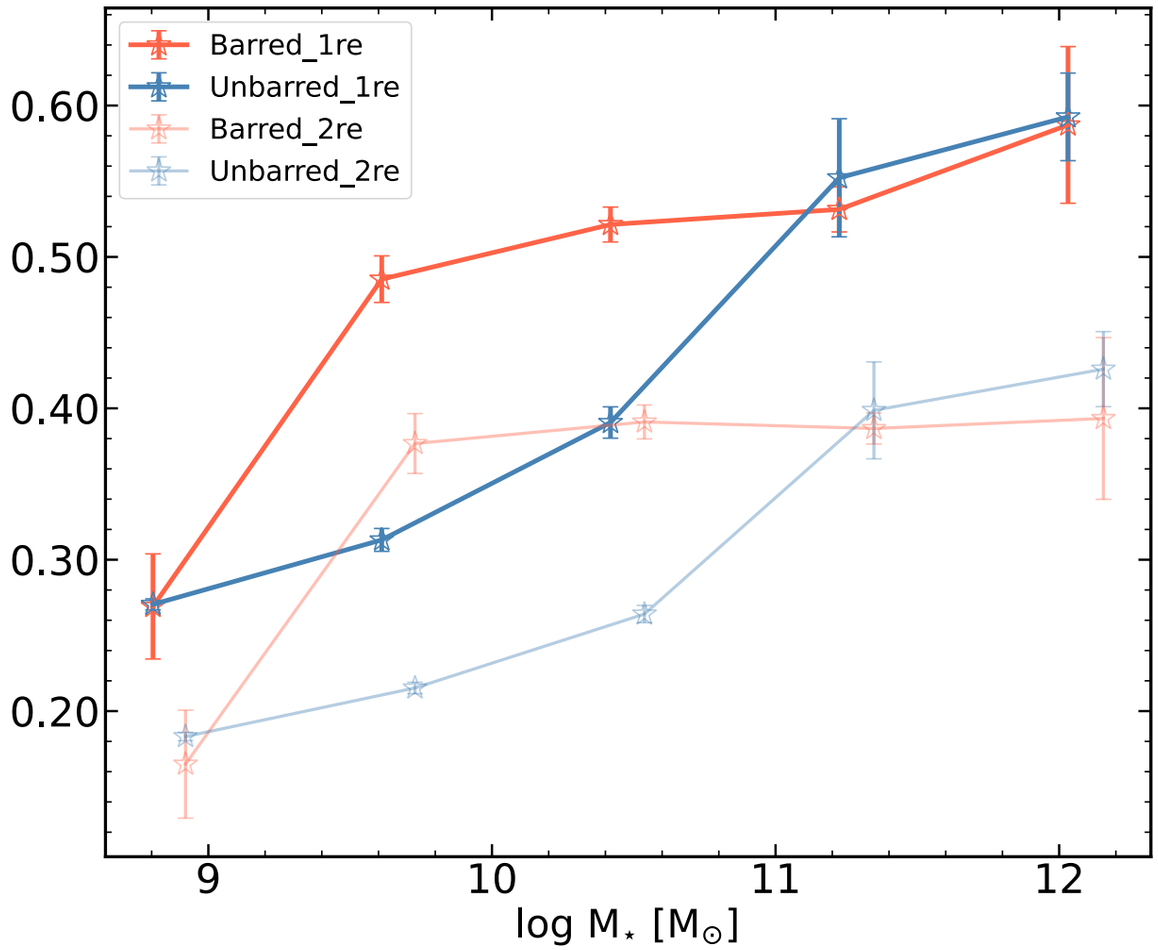
Aquino-Ortiz, Cervantes Sodi, Chim, et al. (2024, in prep.)

Stellar-to-halo mass ratio in MaNGA and TNG50

MaNGA



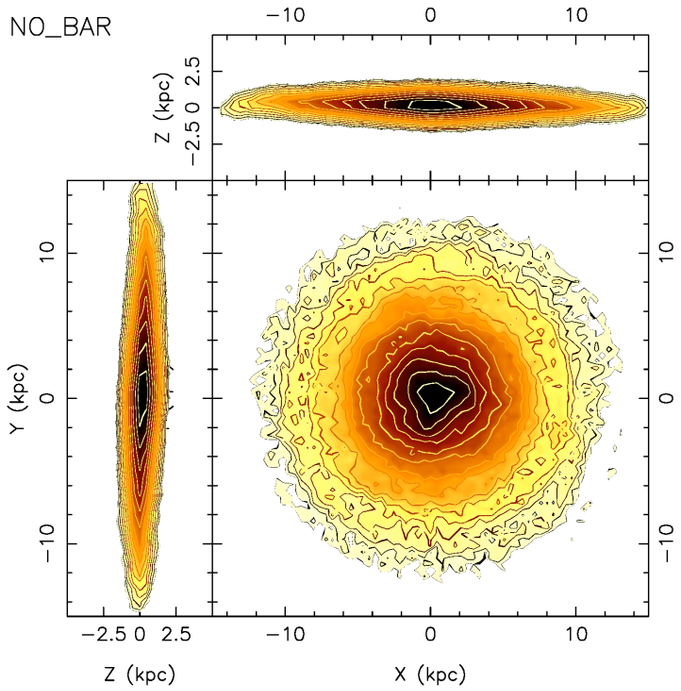
TNG50



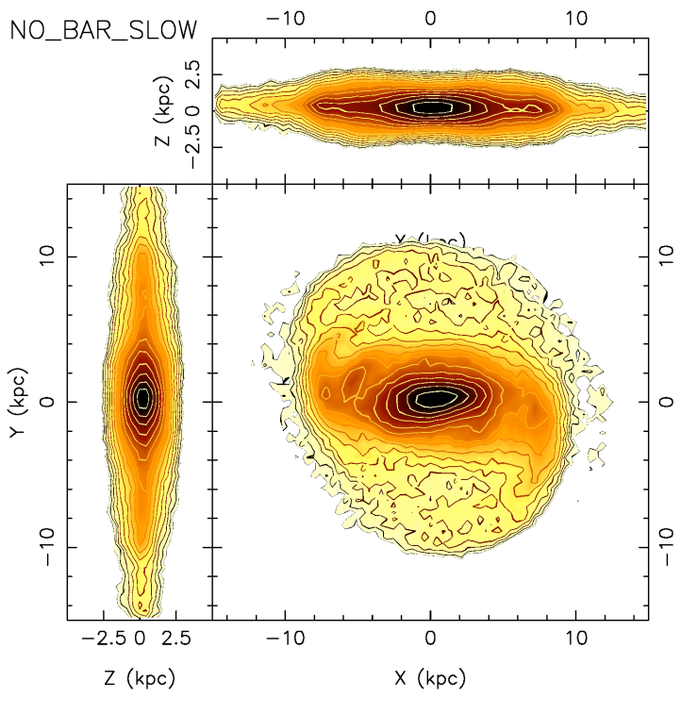
Aquino-Ortiz, Cervantes Sodi, Chim, et al. (2024, in prep.)

Bar triggering by tidal encounters

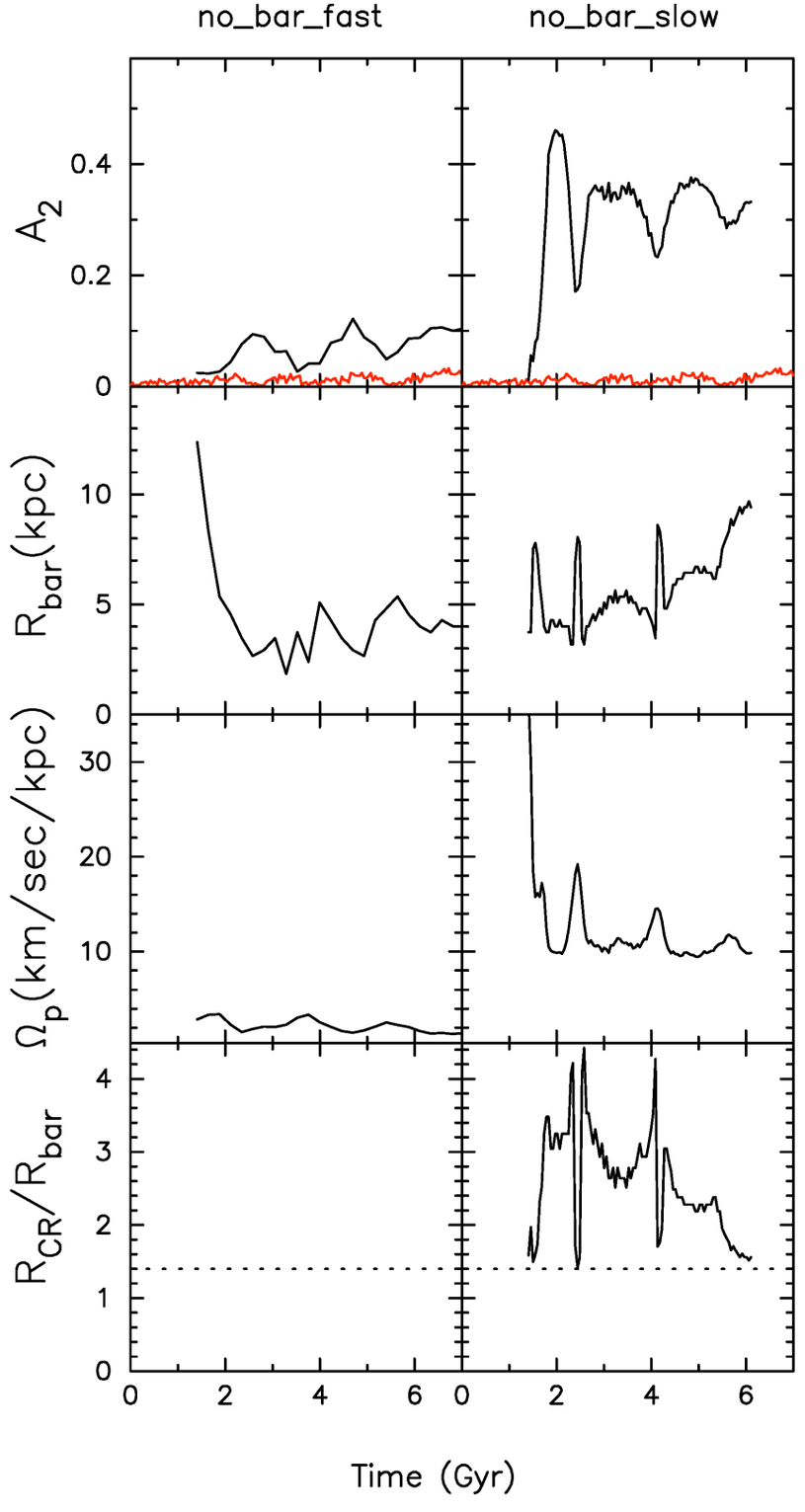
Comparison of a stable disc and its counterpart after a slow flyby by an external perturber.



(a) No bar forming in isolation



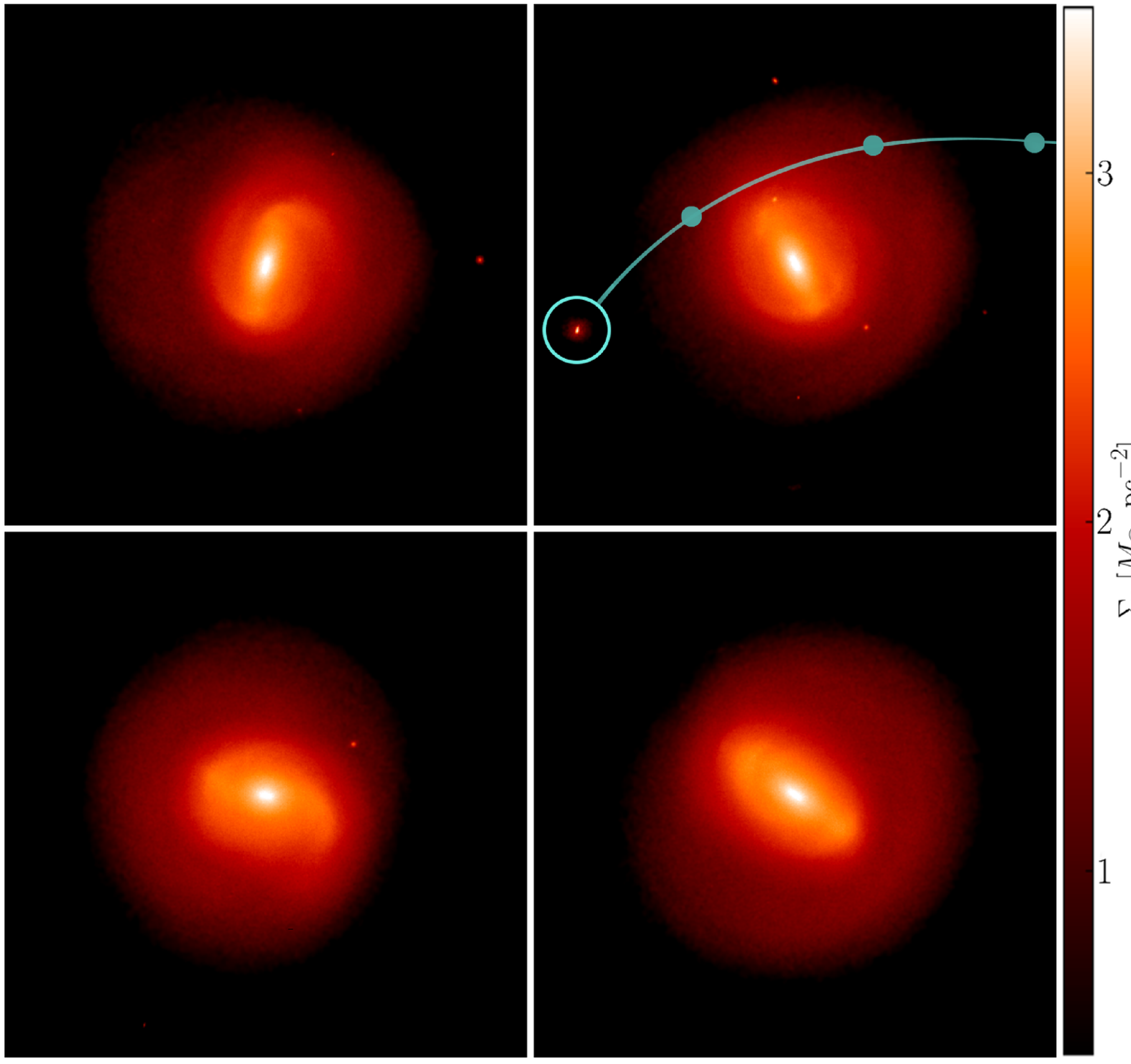
(b) Slow fly-by



(c) Bar parameters

Martinez-Valpuesta et al. (2016)

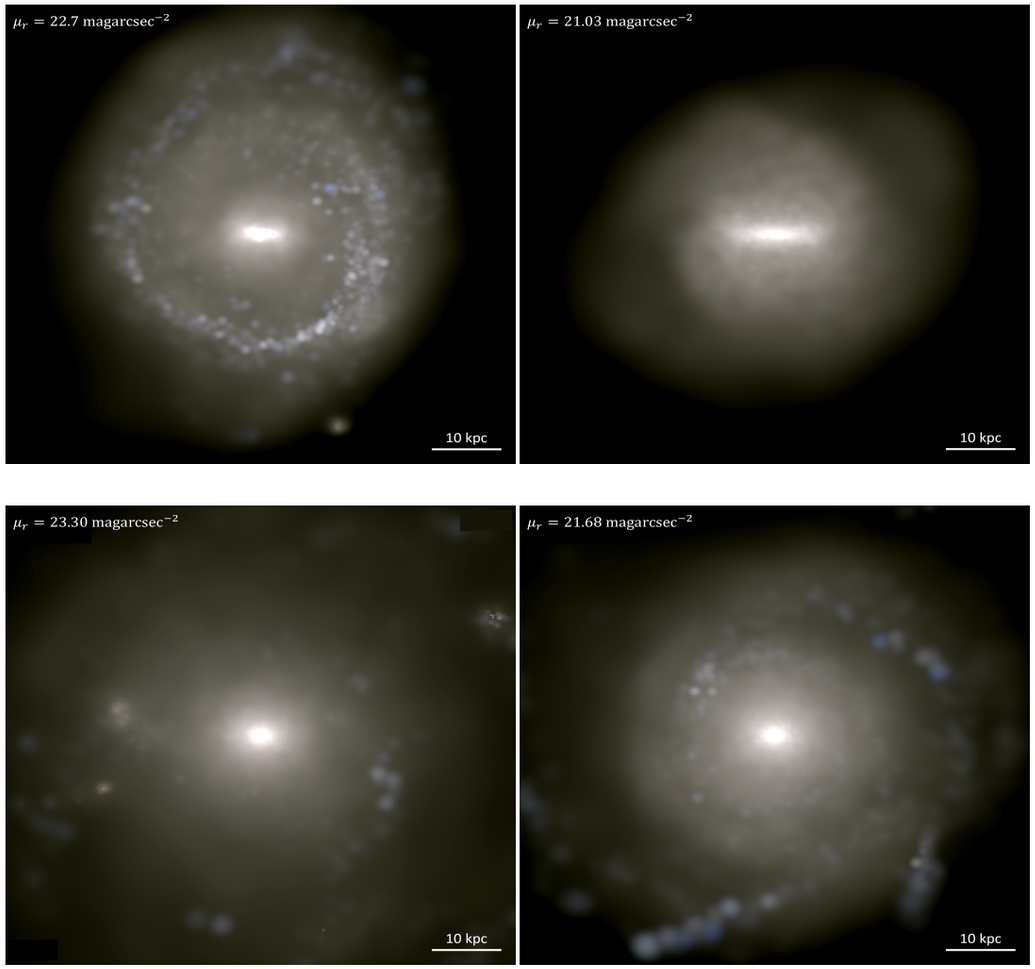
Bar resilience to flybys in cosmological context

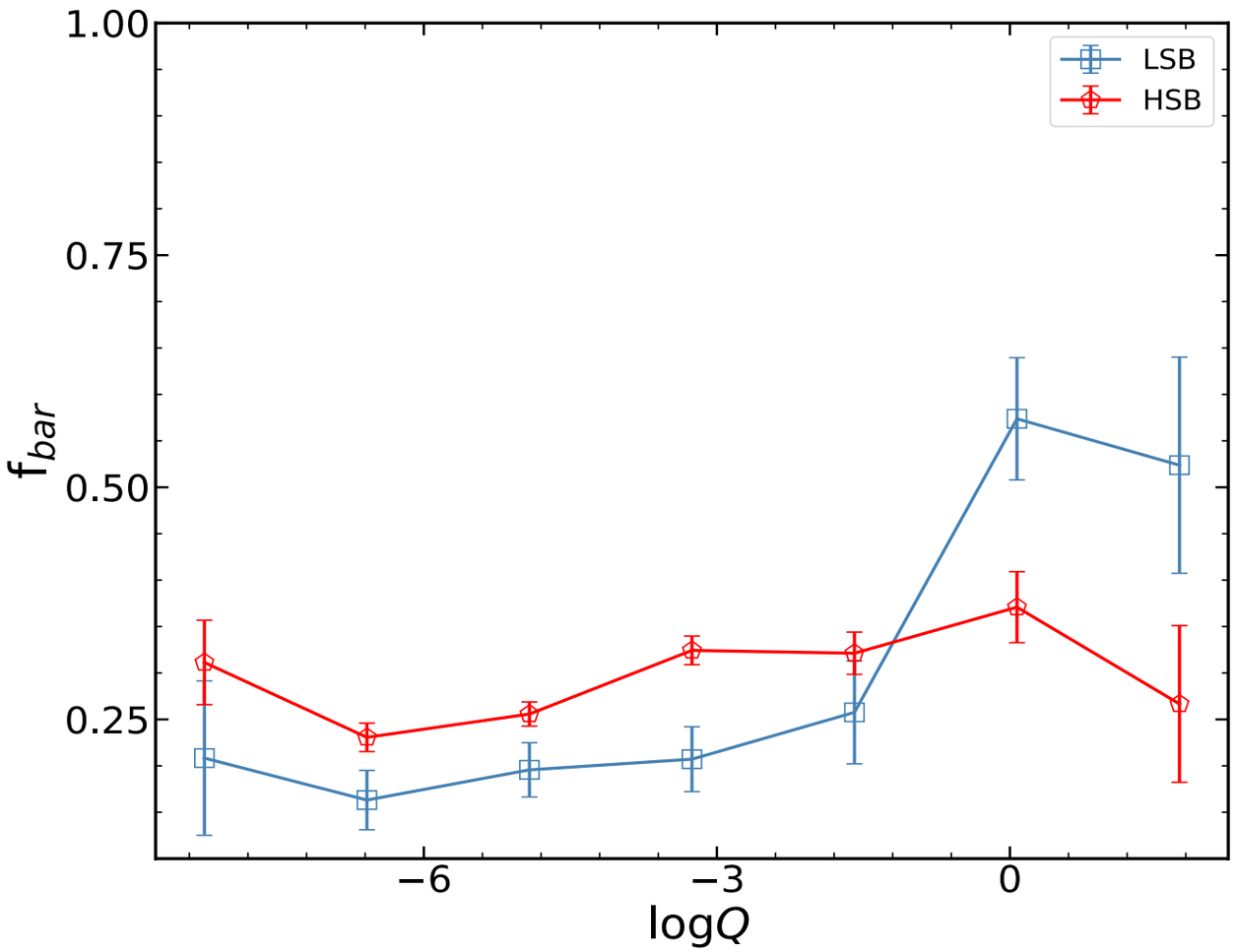


Zana et al. (2018)

Bar triggering by tidal interactions in LSB galaxies in TNG100

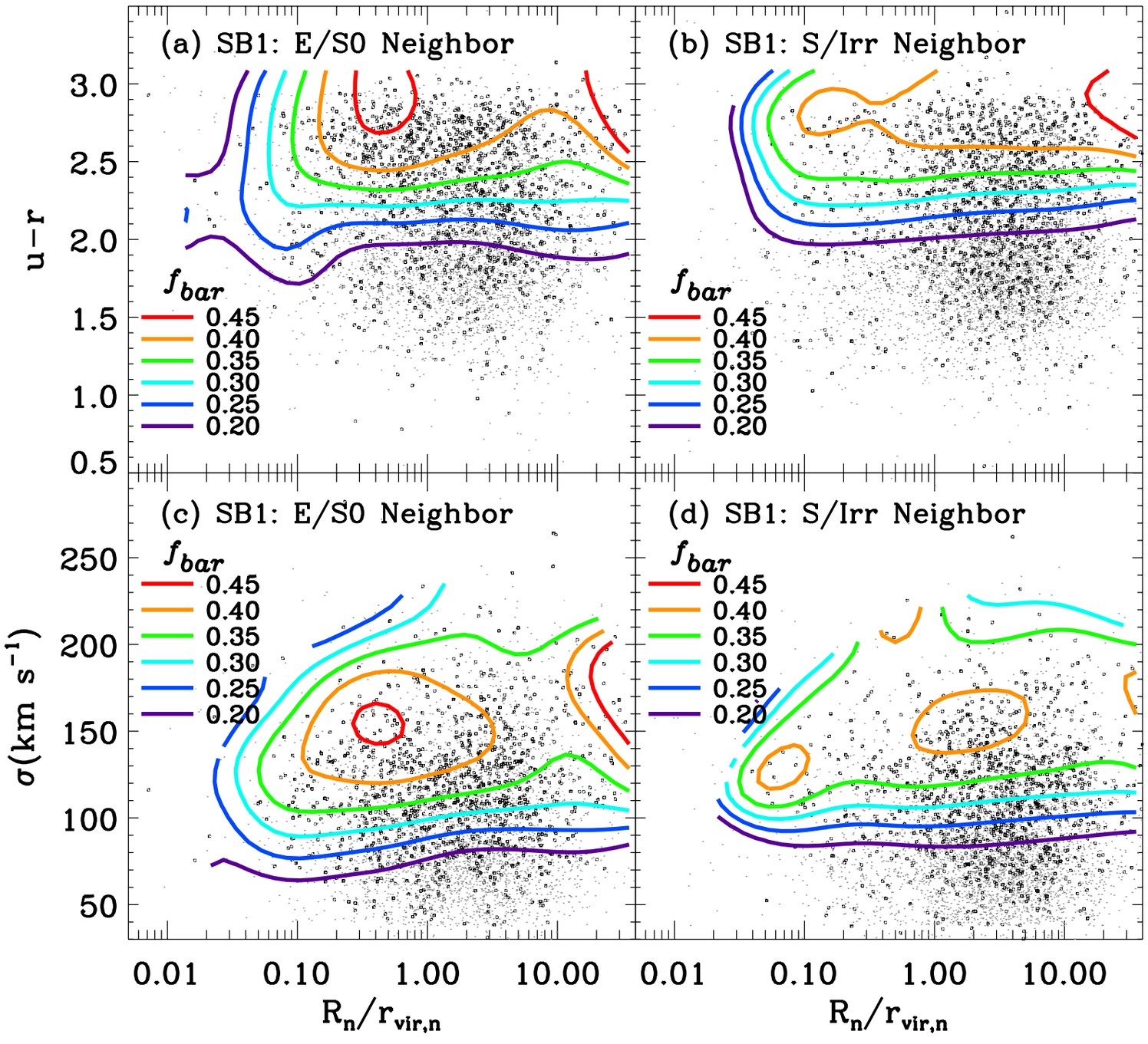
$$Q = \frac{M_i}{M_\mathrm{p}} \cdot \left(\frac{D_\mathrm{p}}{S_\mathrm{ip}}\right)^3$$





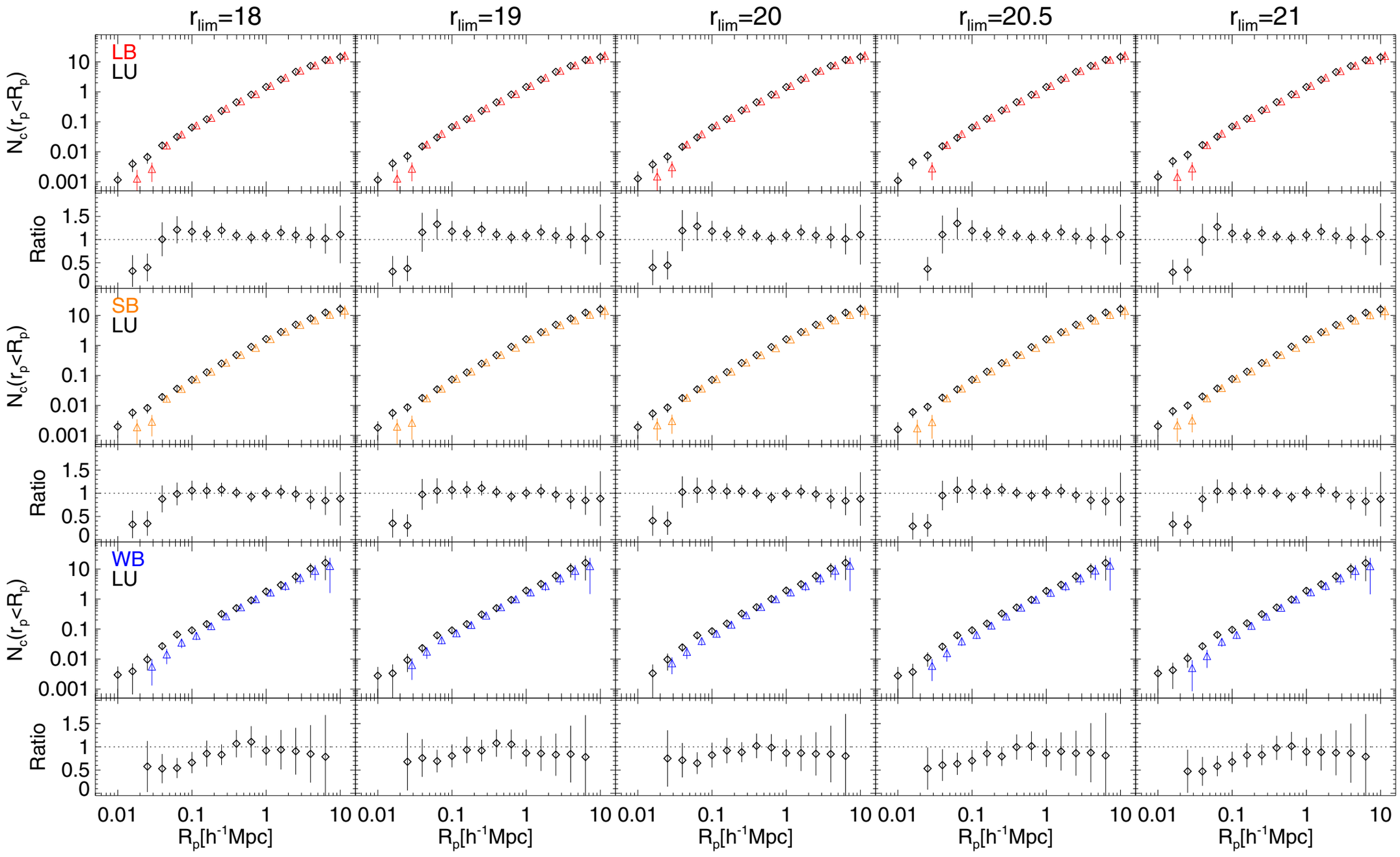
Chim, Cervantes Sodi, Rosas-Guevara et al. (2024, submitted)

Bar destruction by gravitational encounters



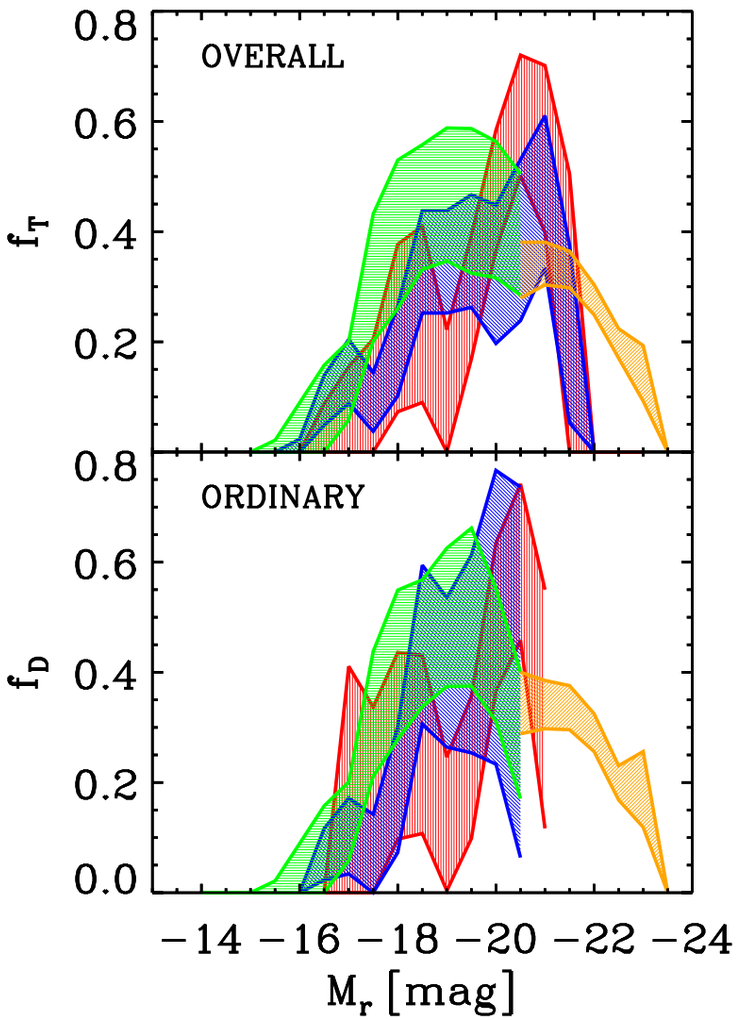
Lee, Park, et al. (2012)

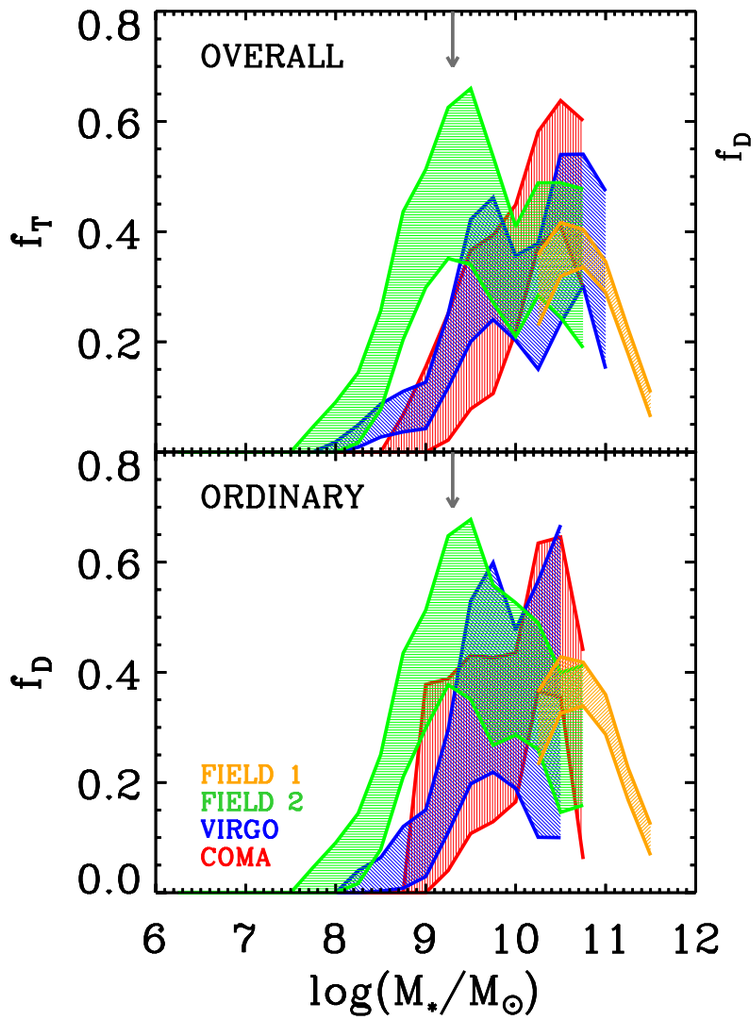
Average counts of galaxies within a given projected radius

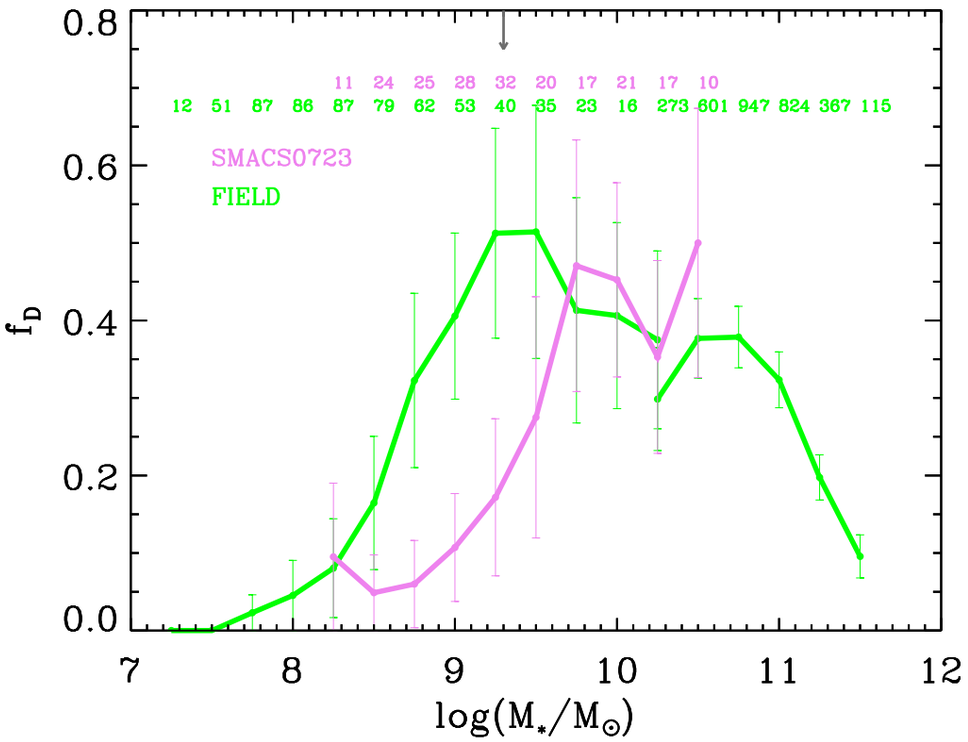


Lin, Cervantes Sodi, Cheng, et al. (2014)

Barred galaxies in clusters







The peak of bar fraction is at higher masses in the cluster environment:

+ At high masses, possible triggering of bar formation while preserving their cold disks
+ At low mass, bar formation inhibited by heating of their discs.

Méndez-Abreu et al. (2012, 2023)

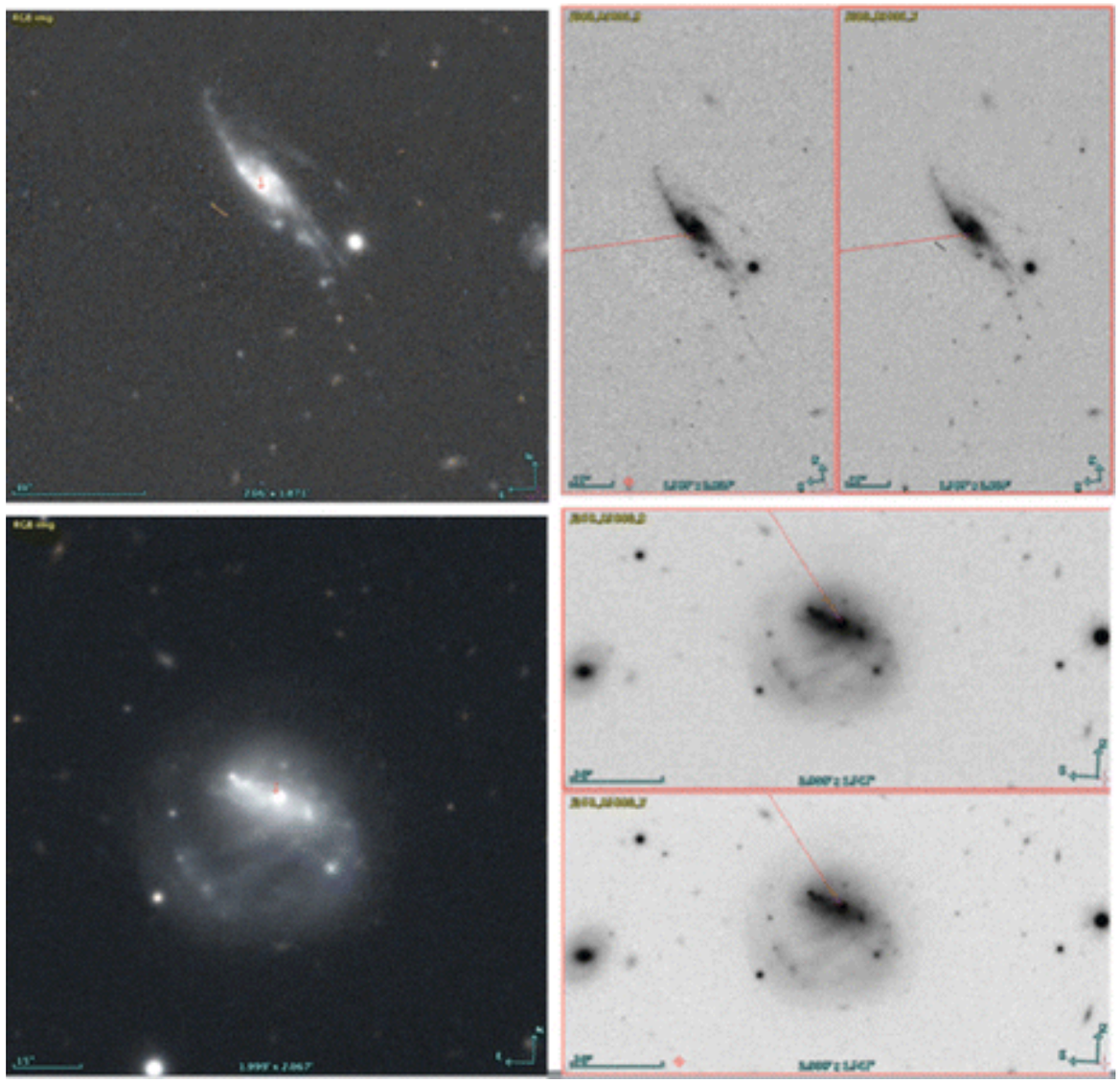
Sample selection from OmegaWings

- Extended WIde-field Nearby Galaxy-cluster Survey (OmegaWINGS,Gullieuszik et al. 2015) that covers up to the outer regions of 32 local X-ray selected clusters

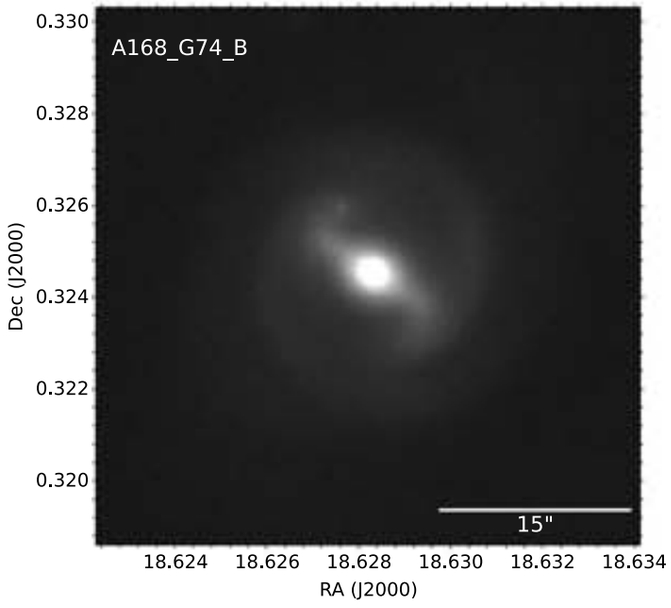
- Redshift range $0.04 < z < 0.07$.

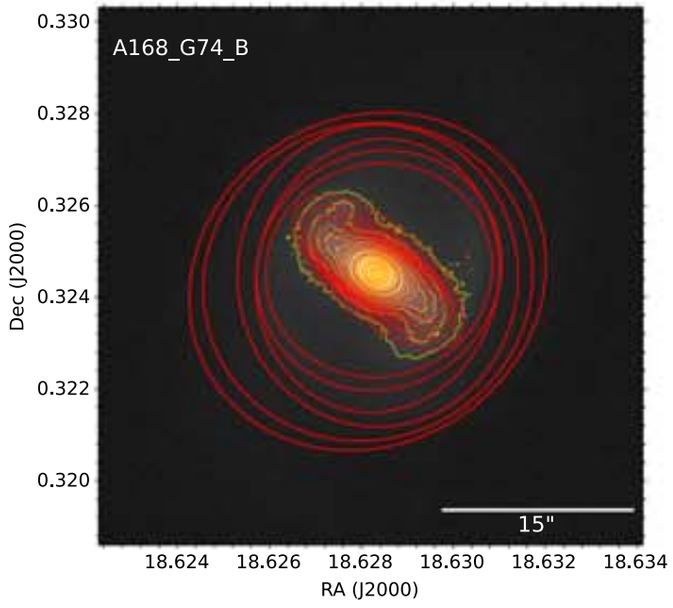
- Two orders of magnitude in X-ray luminosity ($L_X \sim 0.2–5 \times 10^{44}$ erg s^{-1}), roughly $\sim 10^{14}$ to more than 10^{15} M_o

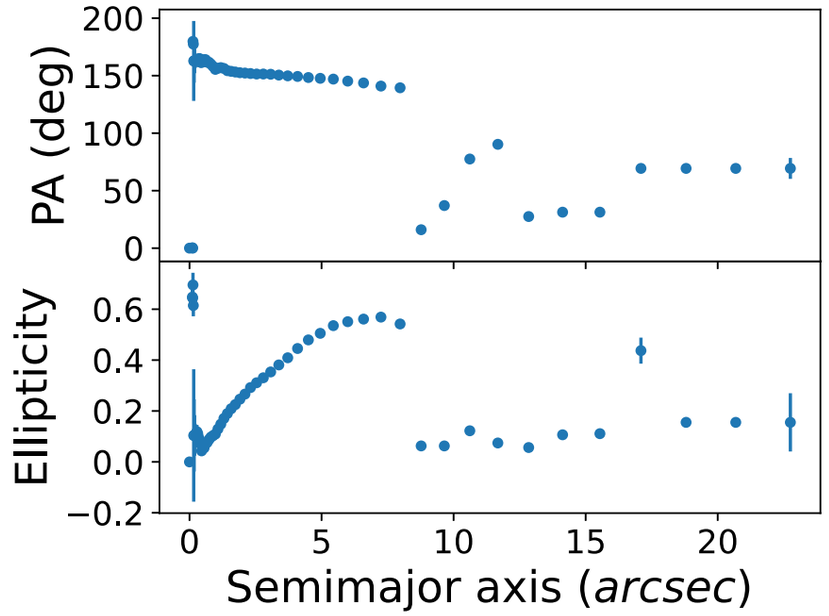
- Morphological with MORPHOT (Fasano, et al. 2006) an automated, nonparametric tool to distinguish ellipticals form S0's

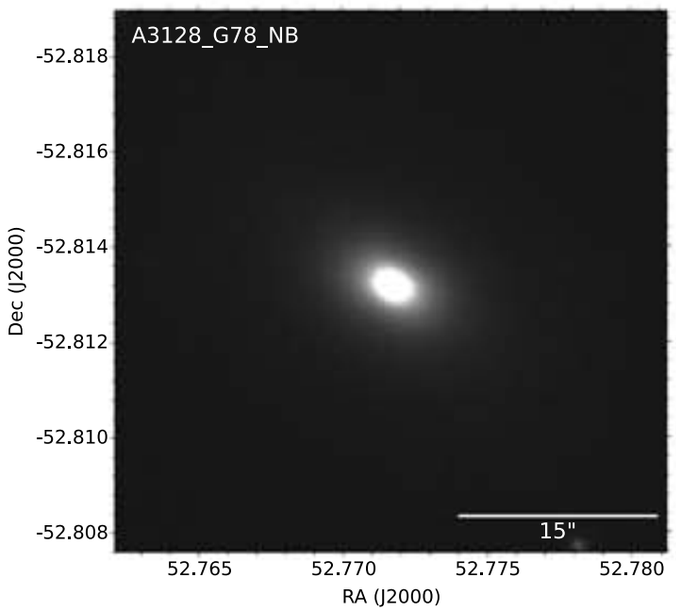


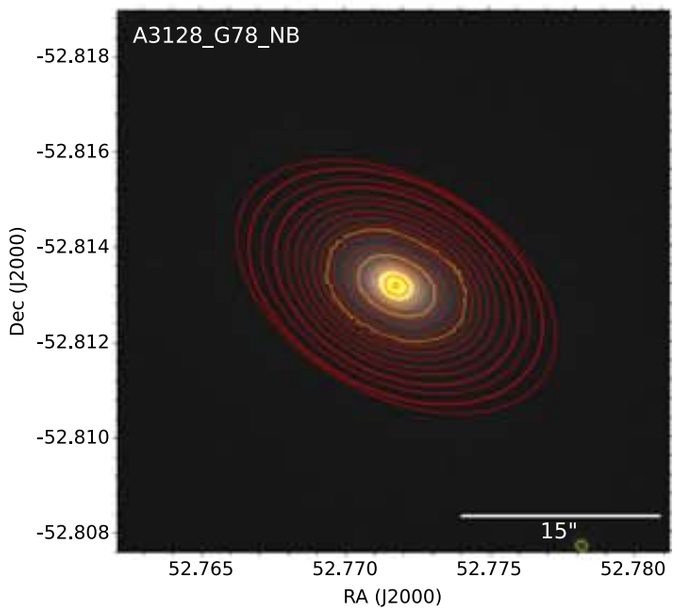
Bar identification and characterization

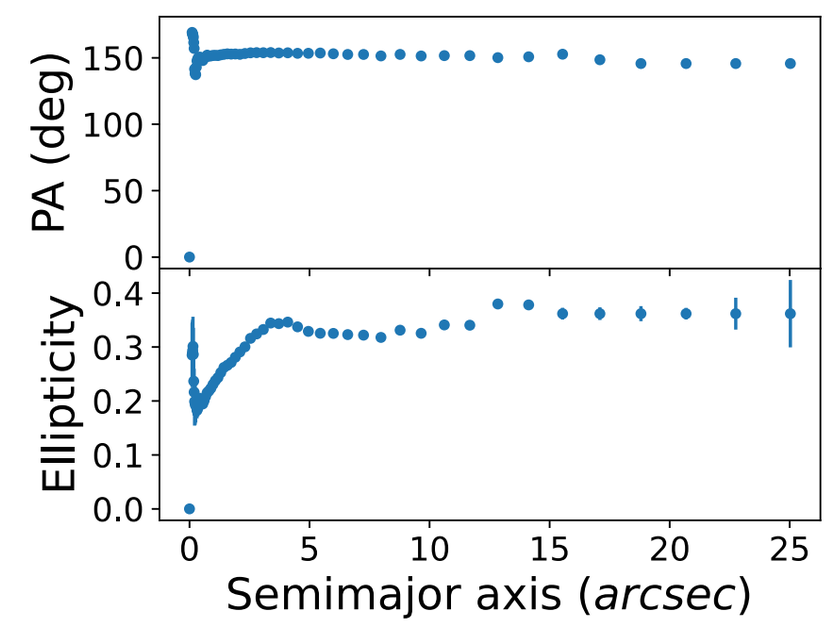






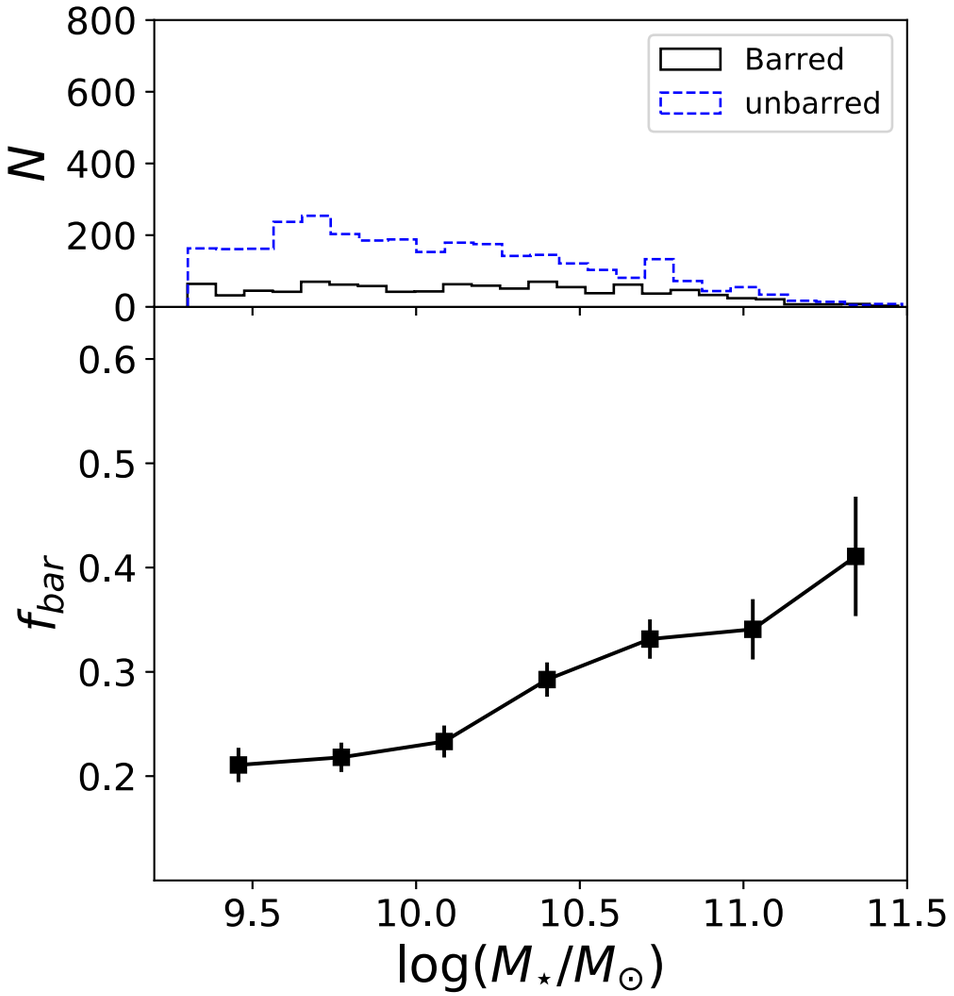


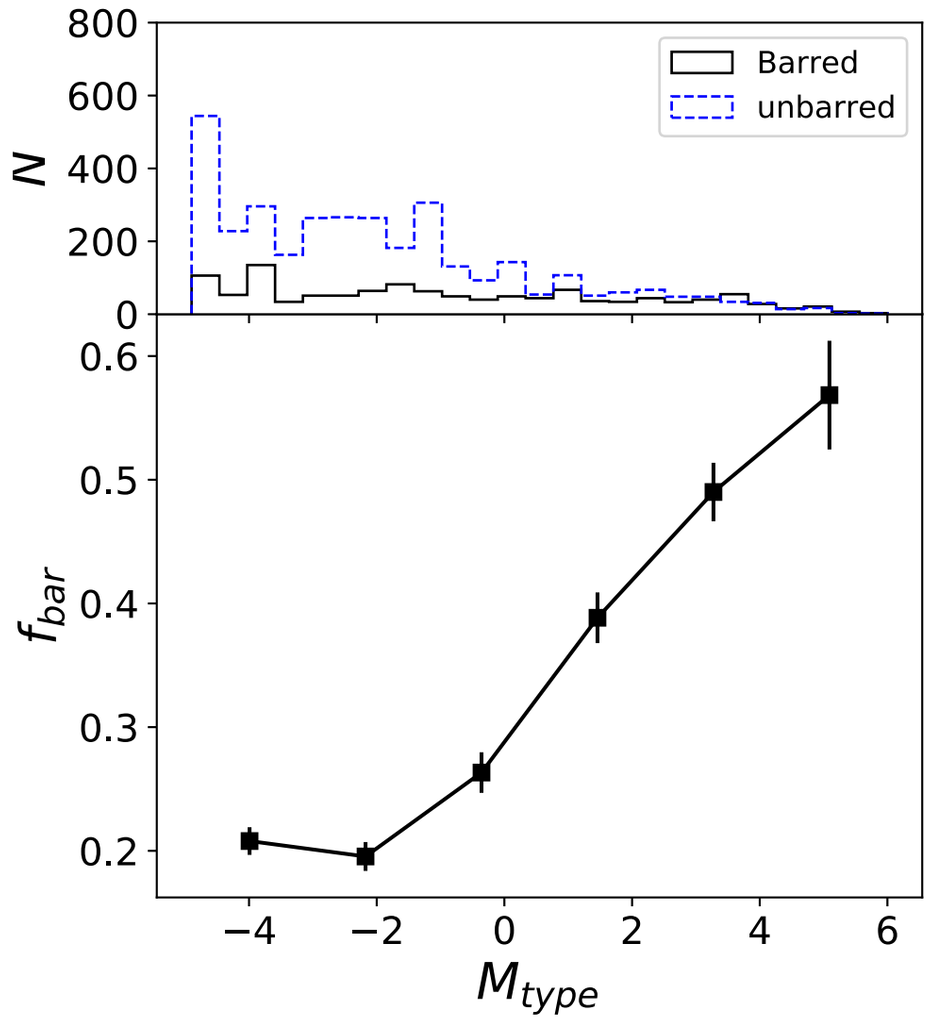




Tawfeek, Cervantes Sodi, Fritz, et al. (2022)

Bar fraction as a function of stellar mass and morphology



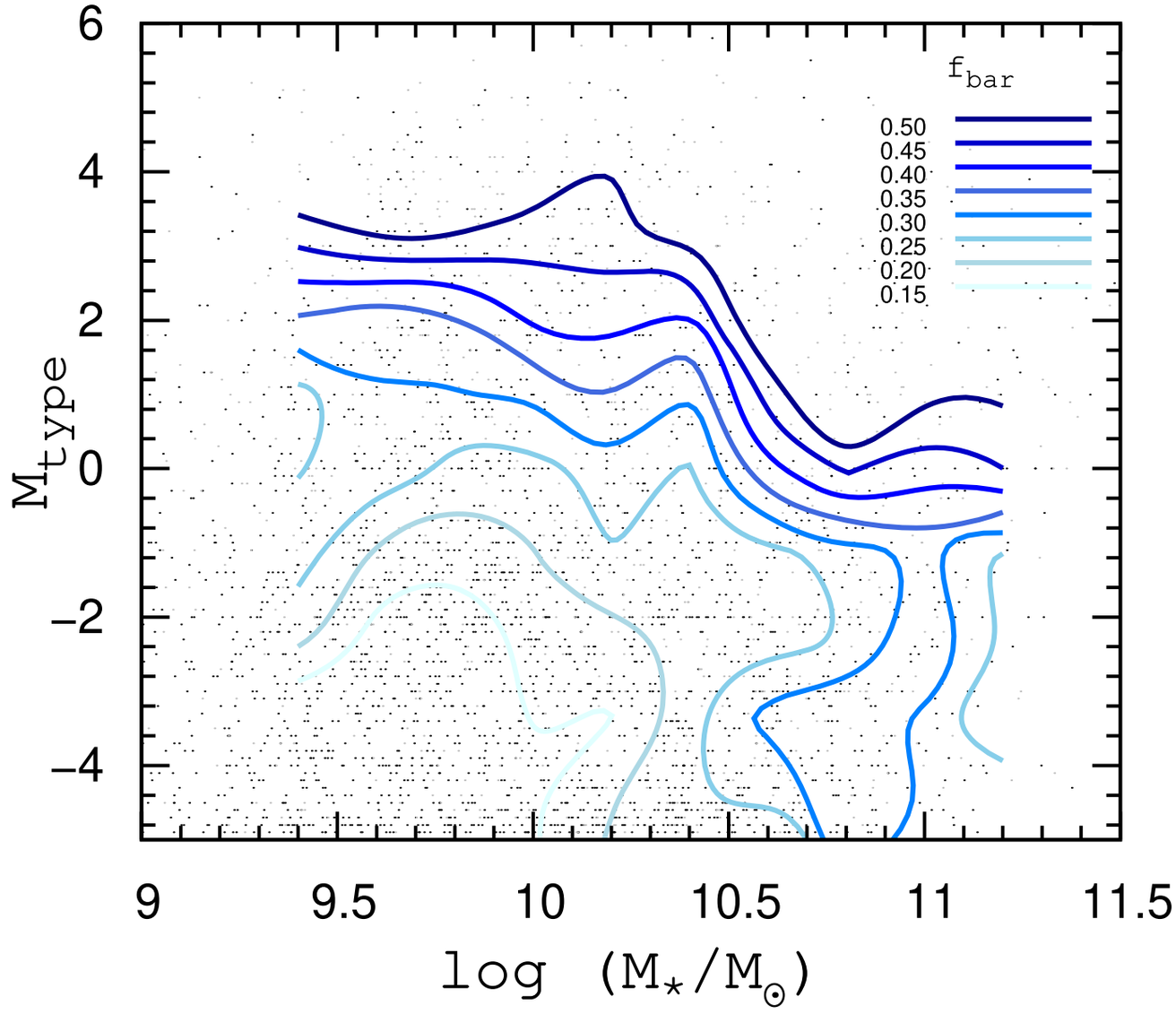


Tawfeek, Cervantes Sodi, Fritz, et al. (2022)

Bar fraction in the morphology-stellar mass plane

- For low mass galaxies, the strongest dependence is with morphology, disc dominated galaxies present the highest fraction of bars.

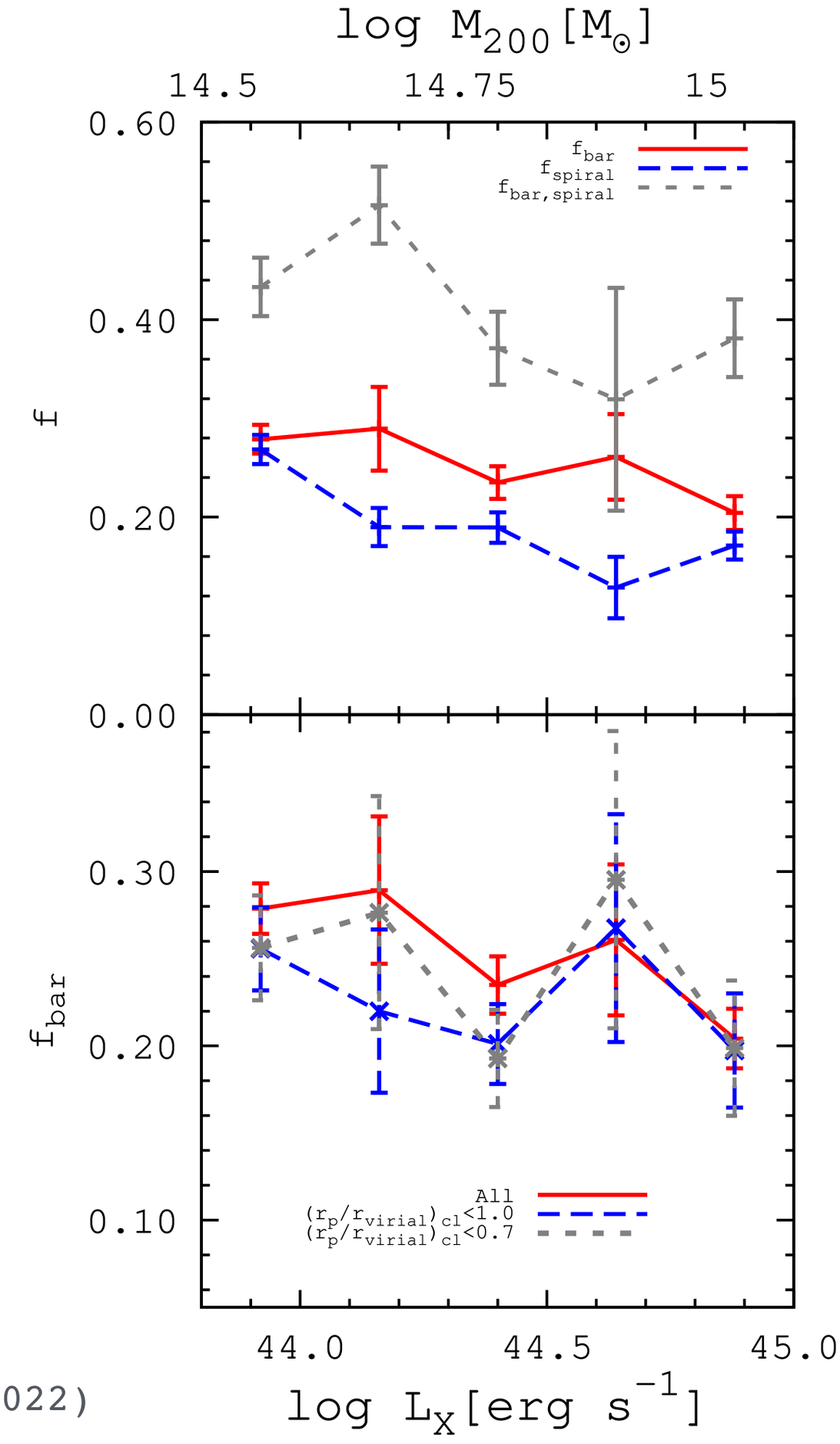
- For high mass galaxies, the likelihood of finding barred galaxies increases with stellar mass in earlier type galaxies.



Tawfeek, Cervantes Sodi, Fritz, et al. (2022)

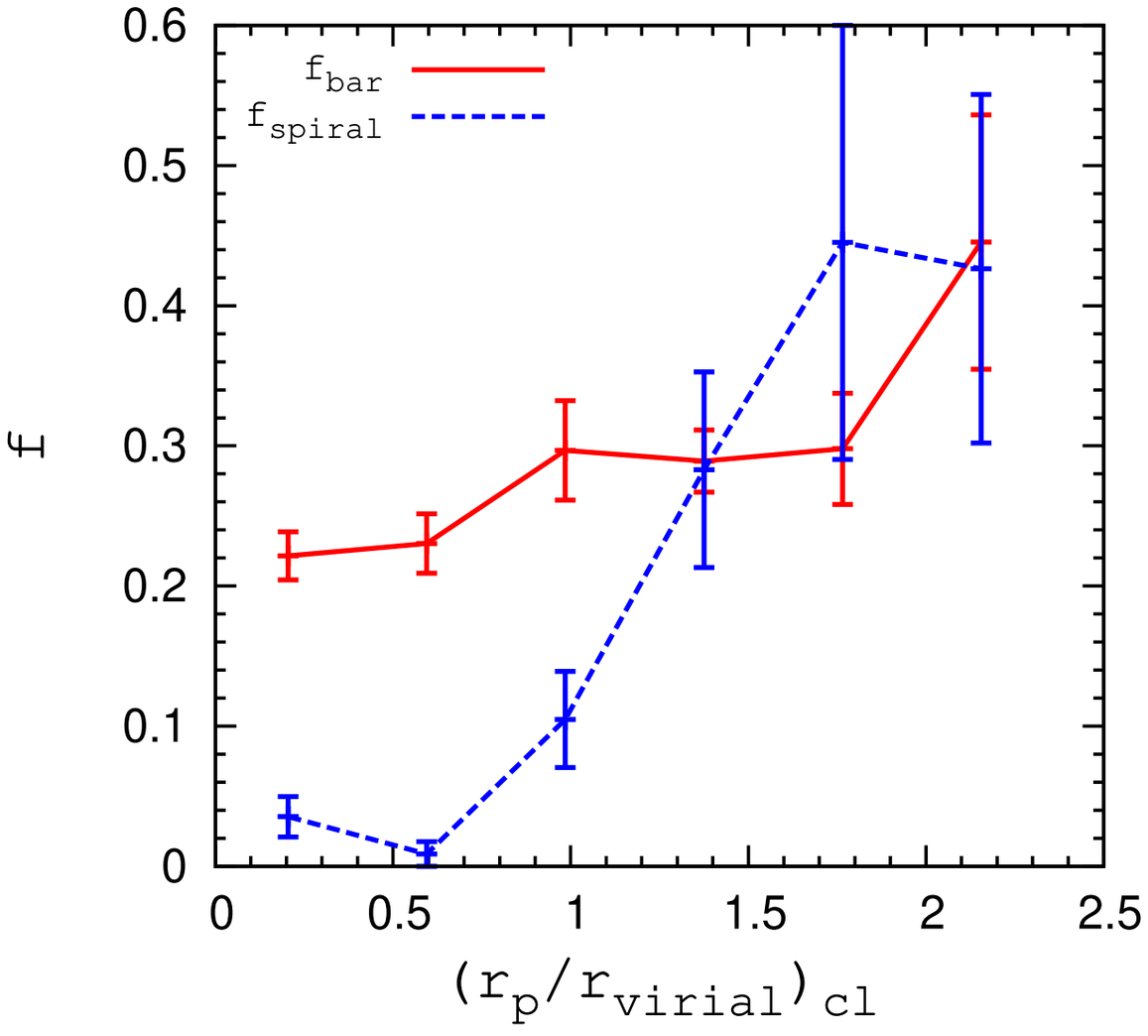
Abundance of barred galaxies as a function of cluster virial mass/X-ray luminosity

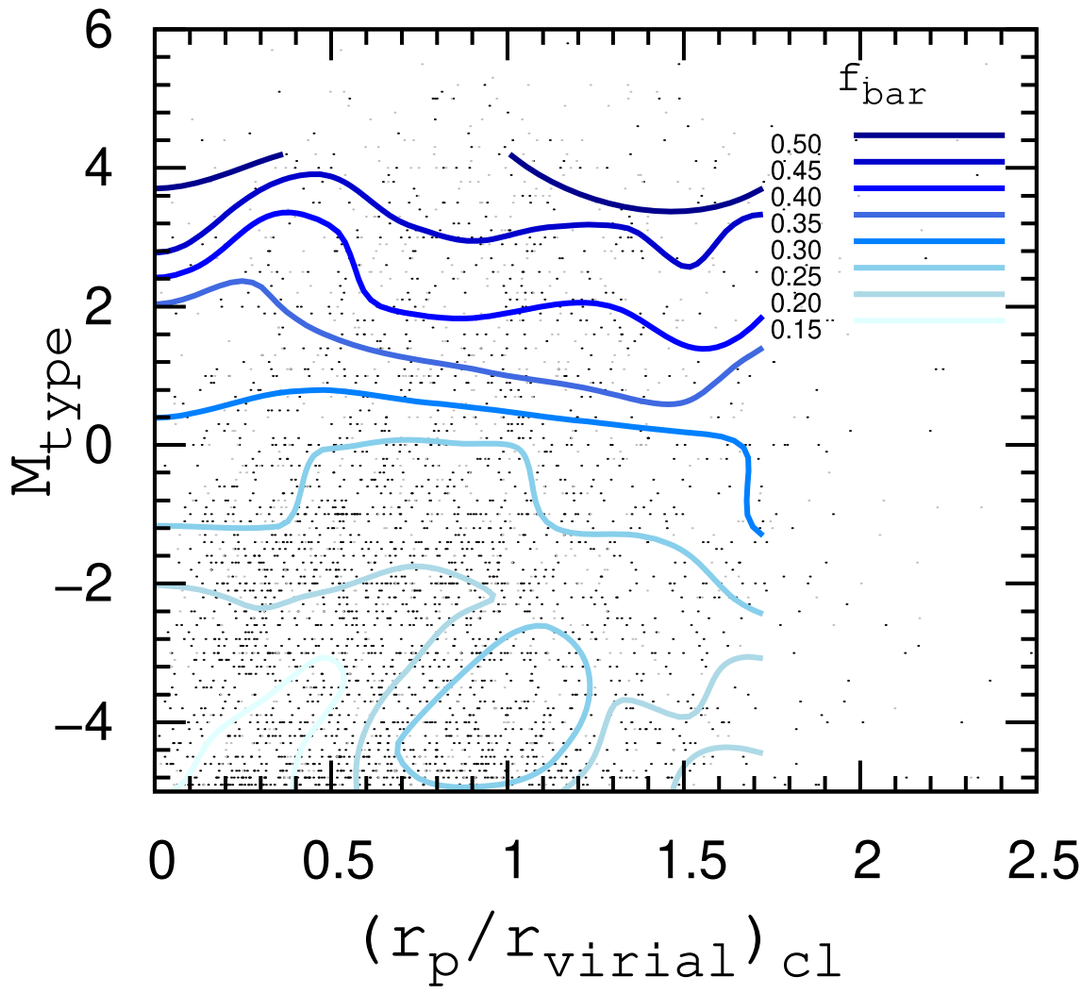
- We find a mild decrease of the spiral and bar fraction for increasing cluster virial mass/X-ray luminosity.



Tawfeek, Cervantes Sodi, Fritz, et al. (2022)

Spiral and bar fraction vs clustercentric distance

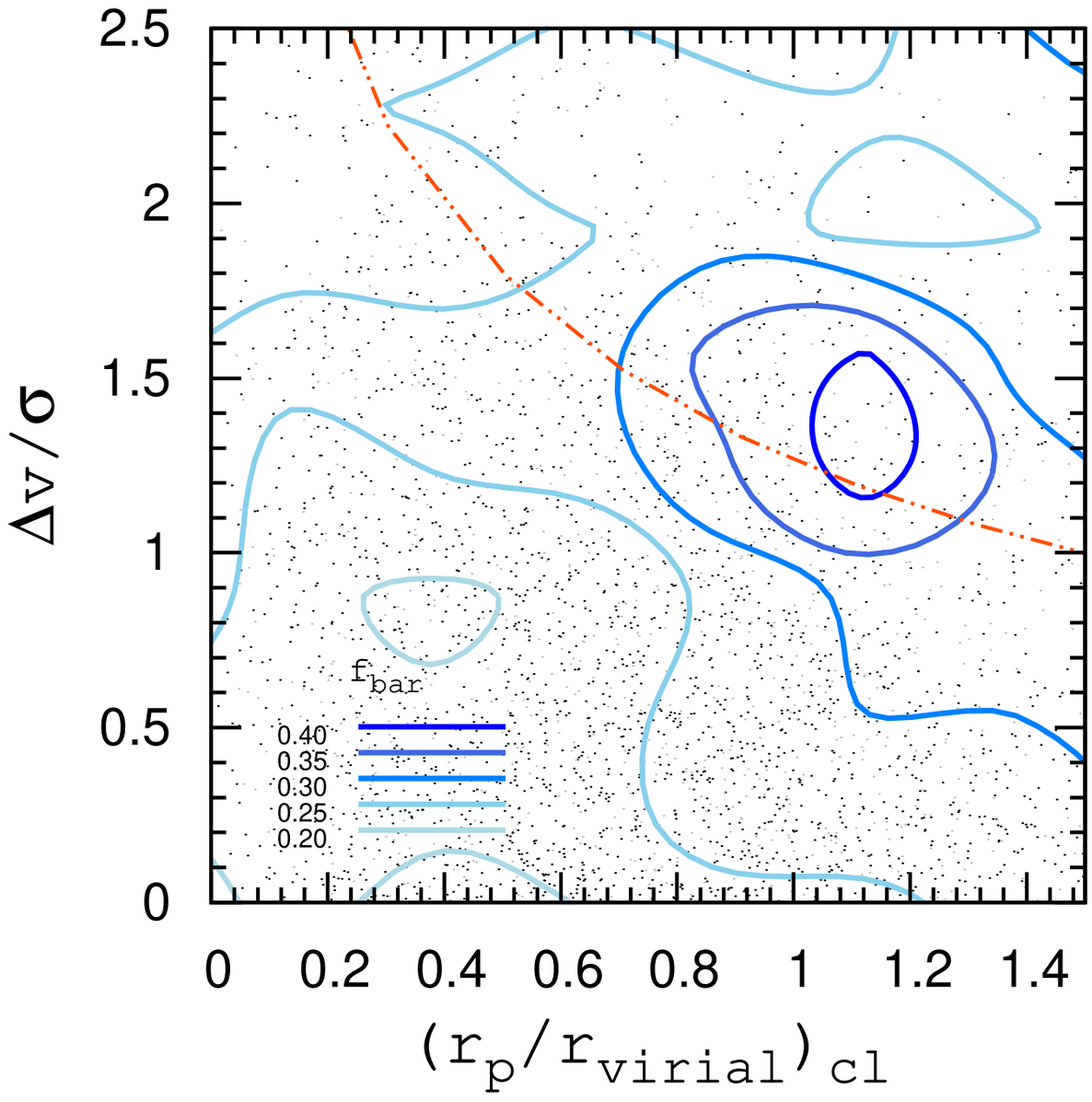




Tawfeek, Cervantes Sodi, Fritz, et al. (2022)

Bar fraction isocontours in the phase-space diagram

- The highest occurrence of bars is at large clustercentric distances and high velocities, with a peak of the bar fraction just above the escape velocity demarcation line, an indication that barred galaxies are recent infallers.

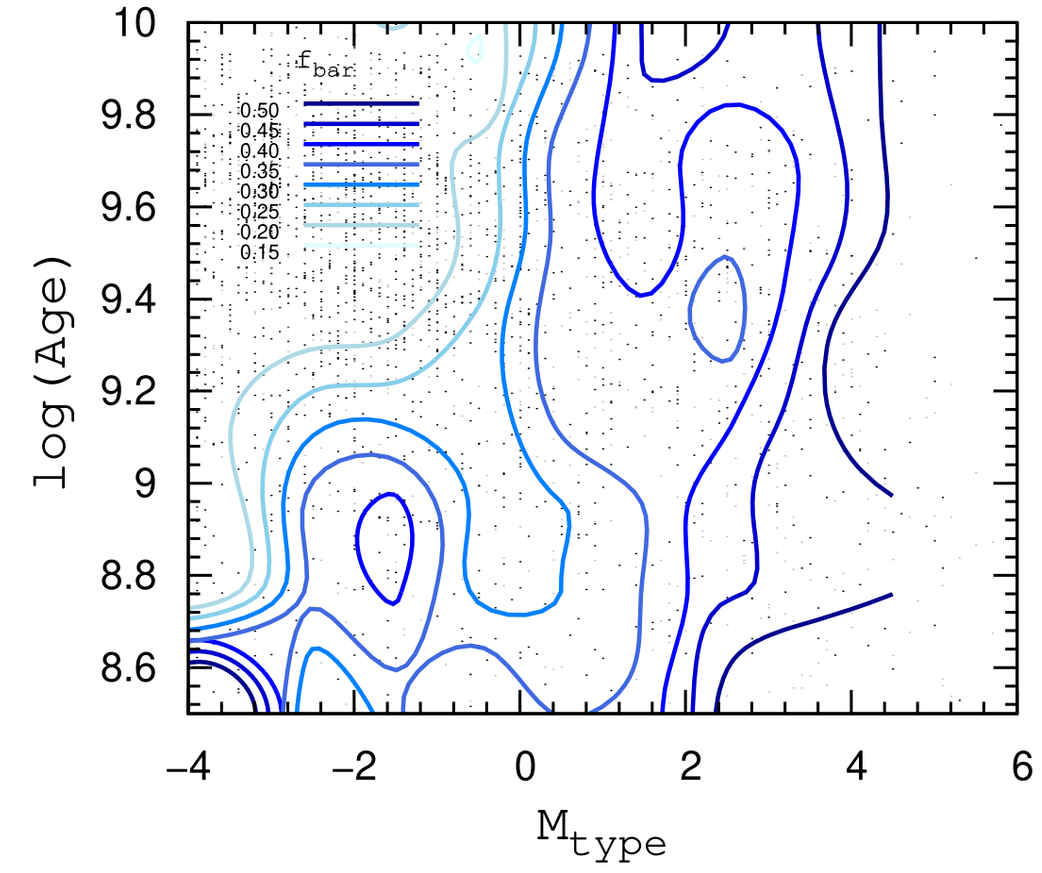


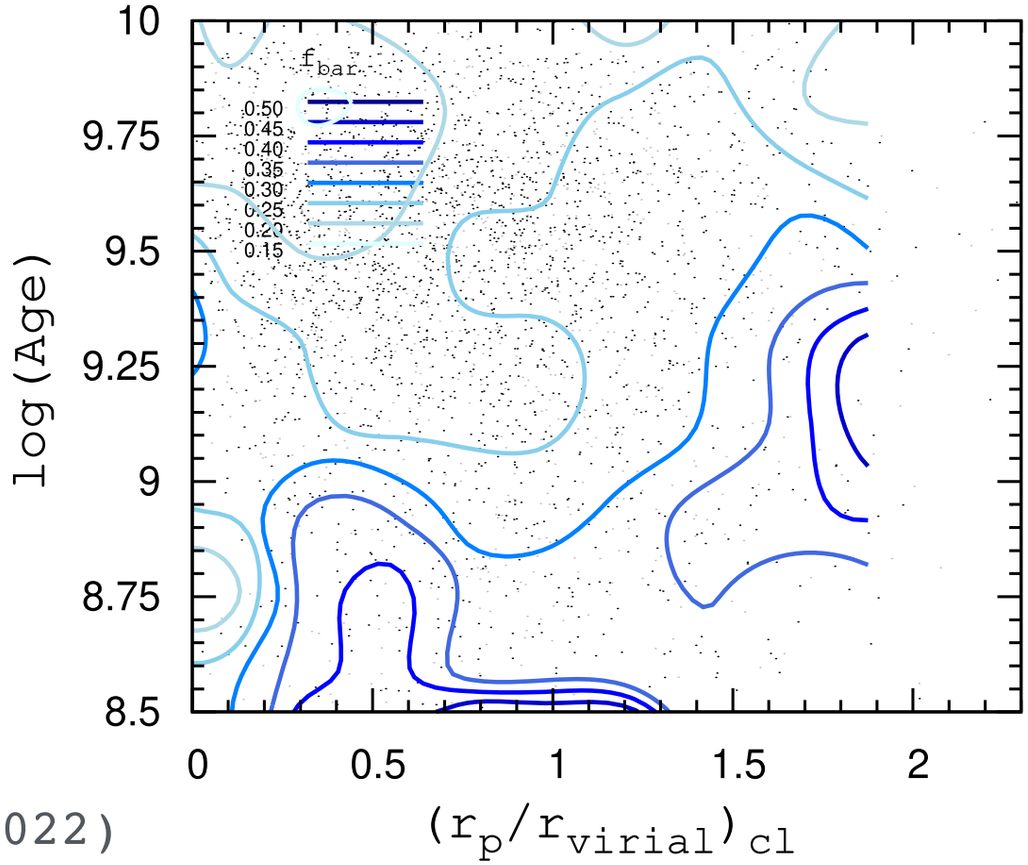
Tawfeek, Cervantes Sodi, Fritz, et al. (2022)

Central rejuvenation of barred galaxies by bars in the cluster environment

- Barred galaxies in our sample are either early-type, star-forming galaxies located within the virial radii of the clusters or late-type quenched galaxies found beyond the virial radii of the clusters.

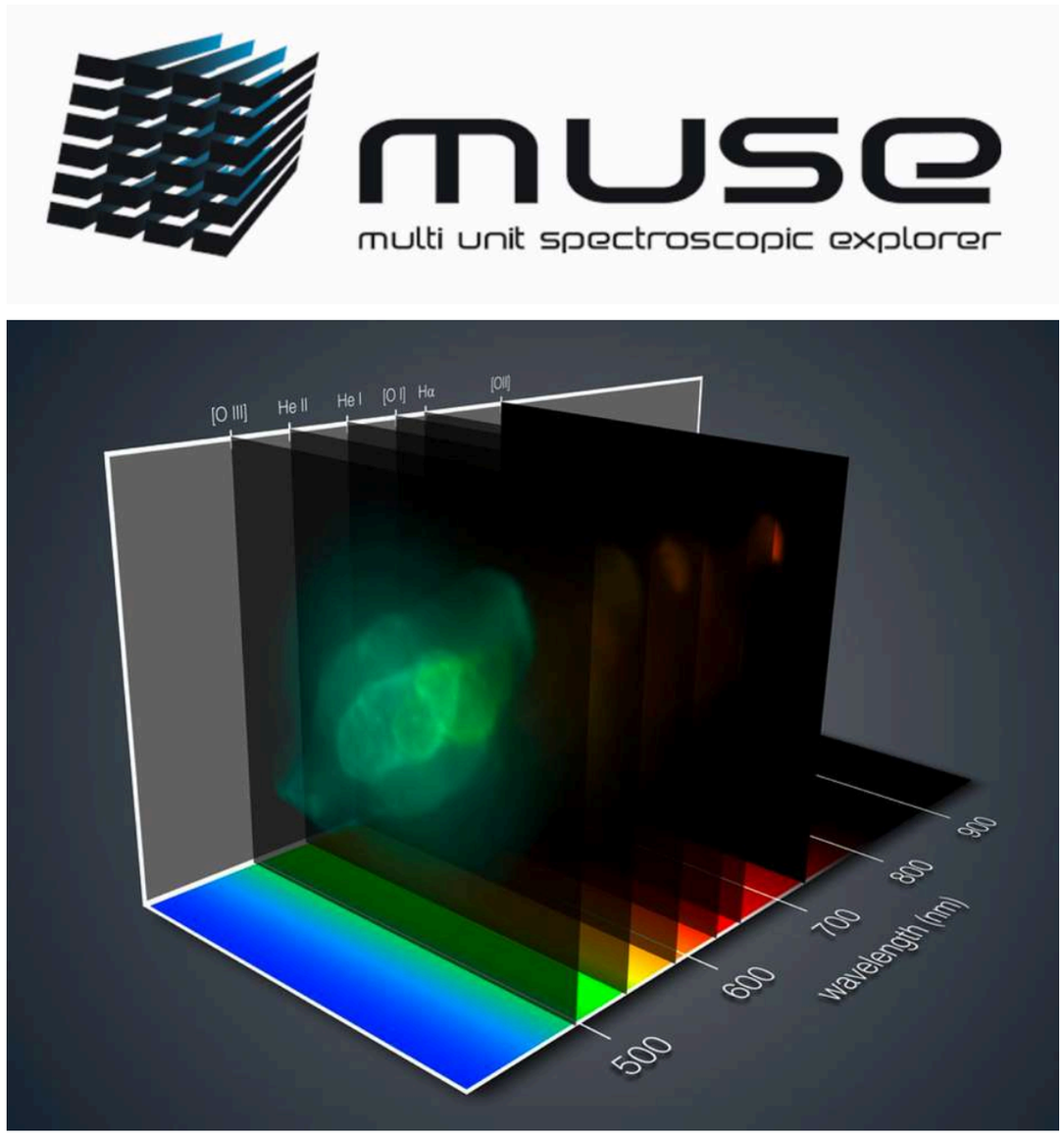
- We propose a scenario in which already quenched barred galaxies that fall into the clusters are centrally rejuvenated by the interplay of the perturbed gas by ram pressure and the bar, in galaxies that are undergoing a morphological transformation.





Tawfeek, Cervantes Sodi, Fritz, et al. (2022)

Barred jellyfish galaxies from GASP (GAs stripping phenomena)

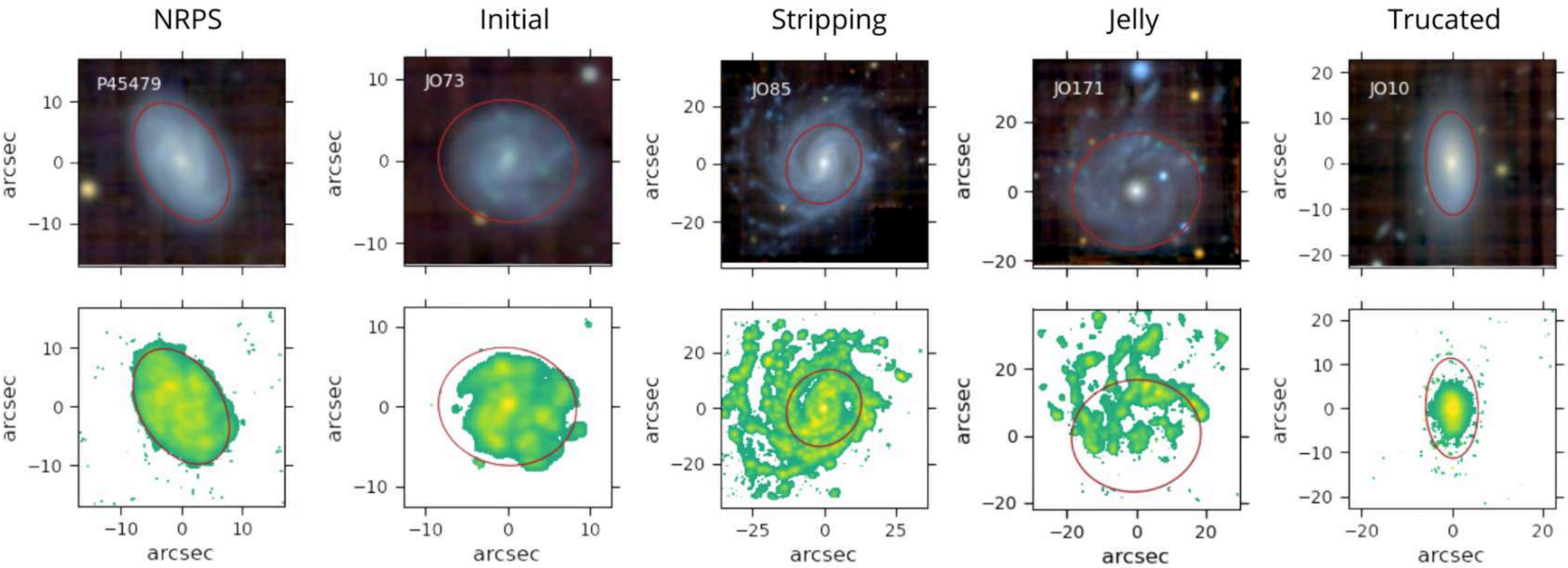


- **114 galaxies (they are all disk galaxies)**
- **z = 0.04 - 0.07**
- **10^9.2 - 10^11.5 Mo**
- **Different environments (clusters and groups)**
- **Morphology information (Sb to Sd)**
- **Spatially and spectroscopically resolved**

Poggianti+2017

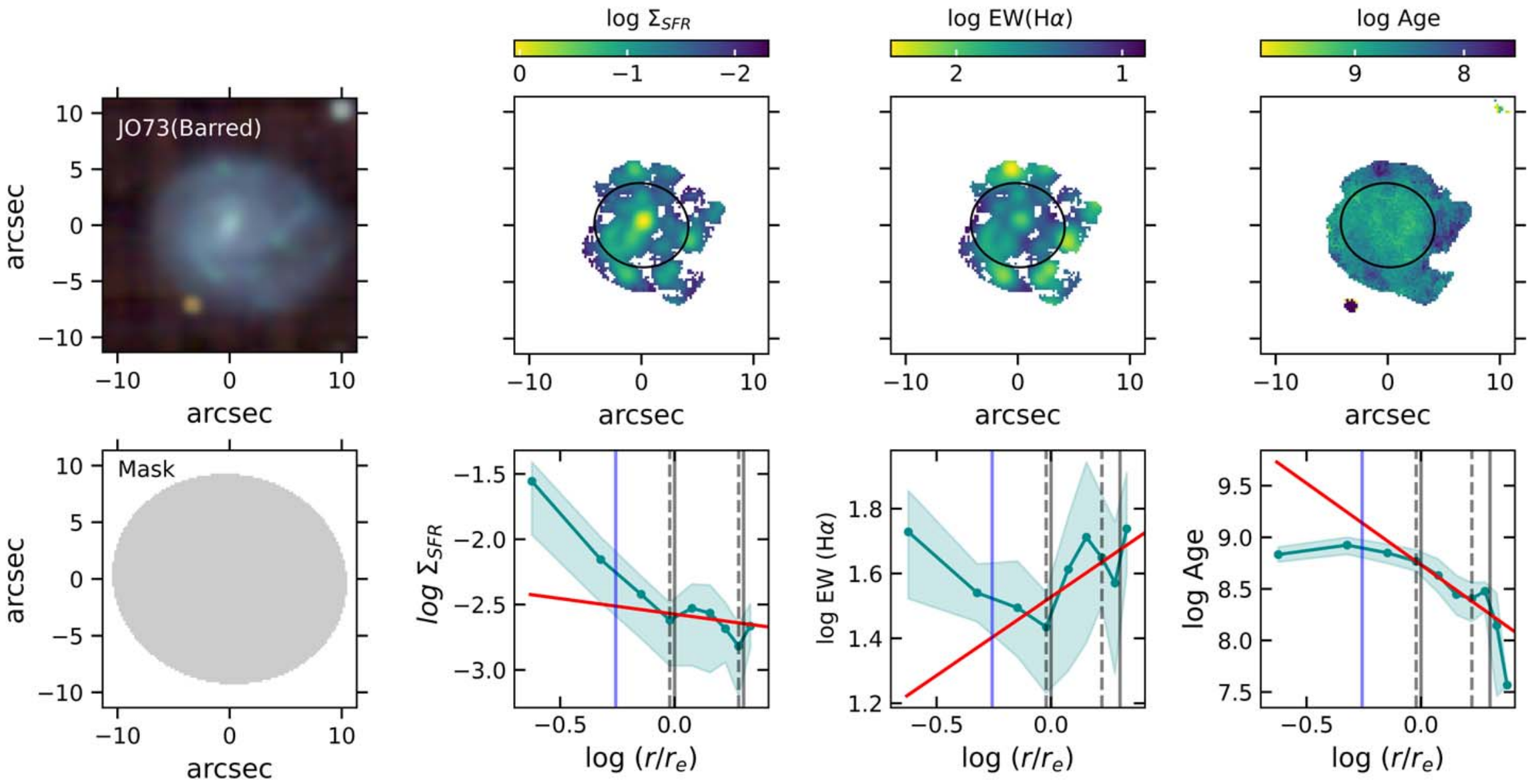
Sánchez-García, Cervantes Sodi, Fritz, et al. (2023)

Identification of different stages of RPS



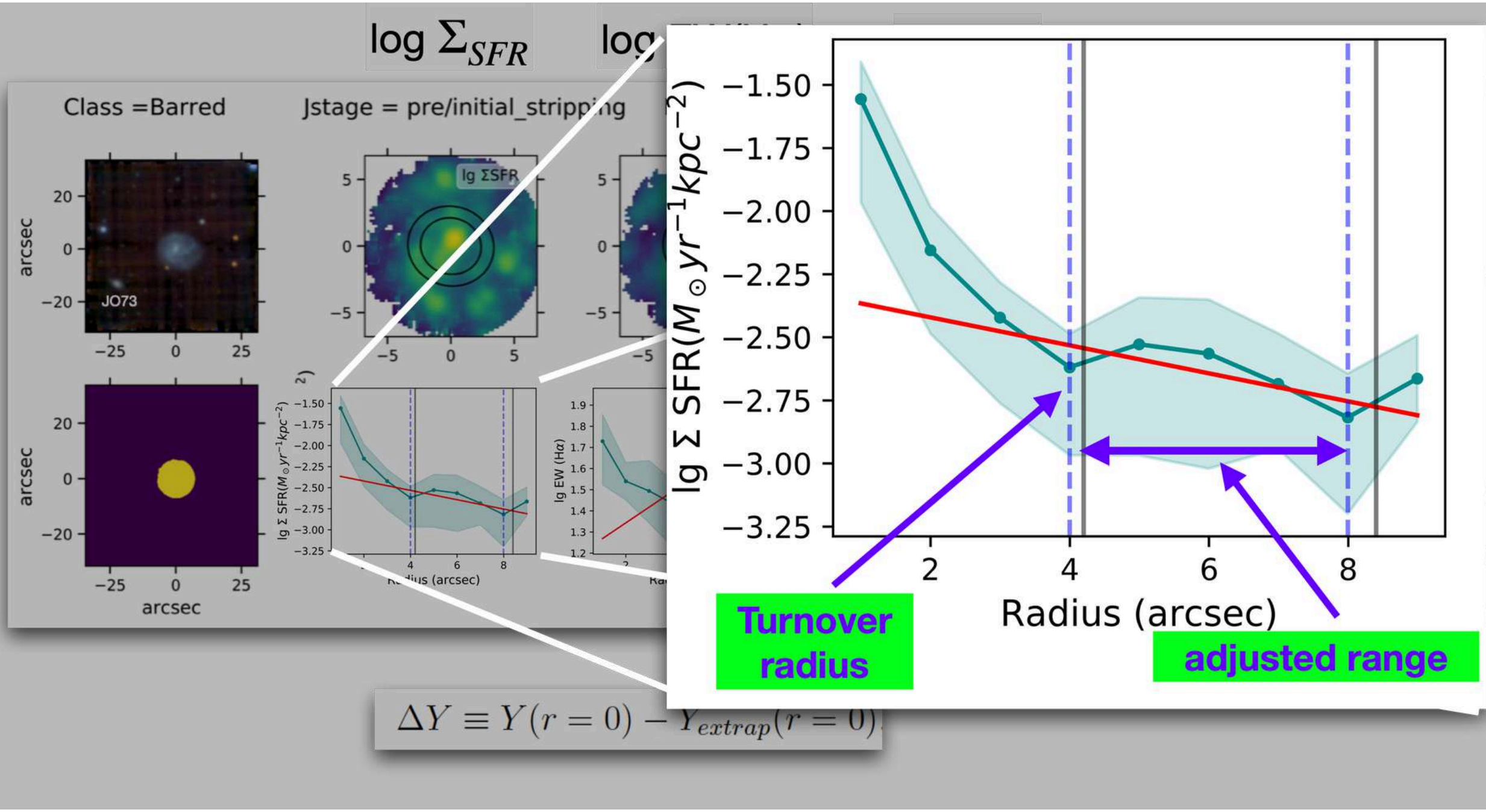
Sánchez-García, Cervantes Sodi, Fritz, et al. (2023)

Turnover identification

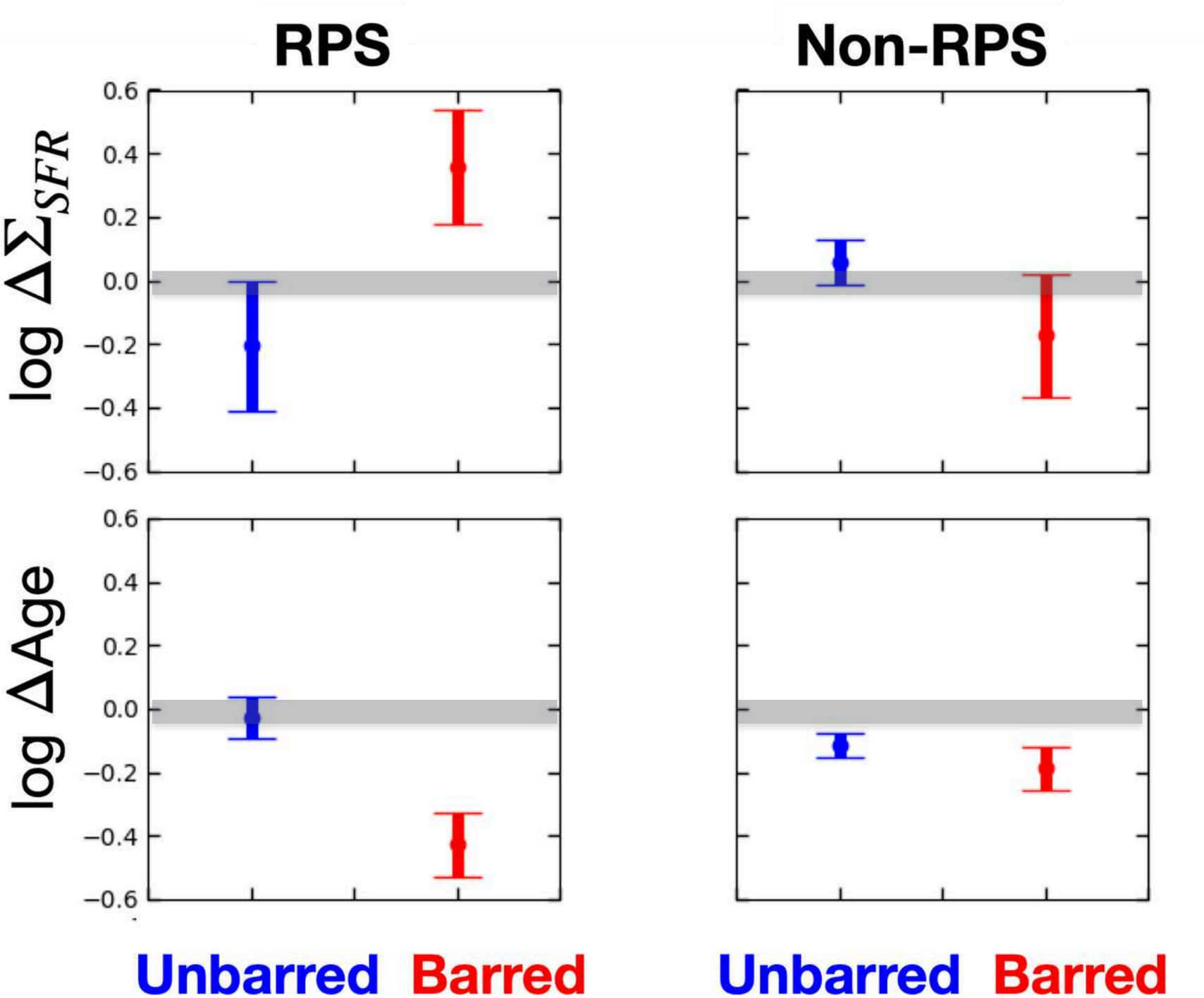


Sánchez-García, Cervantes Sodi, Fritz, et al. (2023)

Turnover radius identification

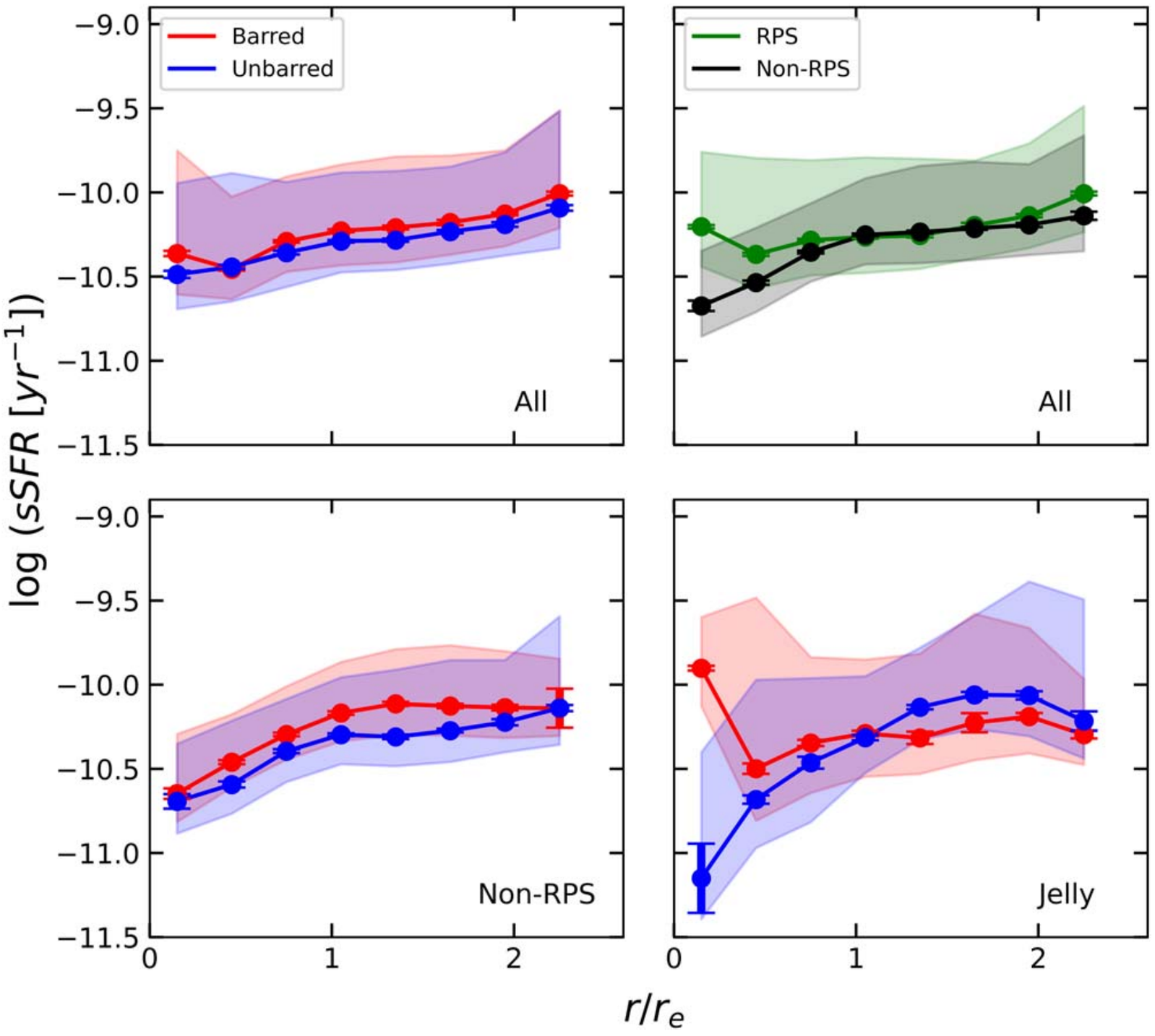


$$\Delta Y \equiv Y(r=0) - Y_{extrap}(r=0)$$



Sánchez-García, Cervantes Sodi, Fritz, et al. (2023)

Specific SFR profiles



Sánchez-García, Cervantes Sodi, Fritz, et al. (2023)

General conclusions

- Bars are more common in galaxies with high M_*/M_h values, as expected from early theoretical works that showed that systems with massive dark matter halos are more stable against bar instabilities.

- While tidal interactions can trigger bar formation, for late-type galaxies, we find fewer neighbors within ~50 kpc around the barred galaxies when compared to unbarred galaxies from the control sample, suggesting that tidal forces from close companions suppress the formation/growth of bars.

- The fraction of barred galaxies decreases with increasing cluster mass and with decreasing clustercentric distance, a dependence that vanishes once we control for morphological type.

- We found an increase in central SFR in ram- pressure-affected galaxies when compared with unperturbed ones. The most extreme cases of increased SFR and central rejuvenation occur in barred galaxies that are at advanced stages of ram pressure stripping.

- Our results indicate that the combined effect of the presence of a bar and strong perturbation by ram pressure is able to trigger the central star formation activity

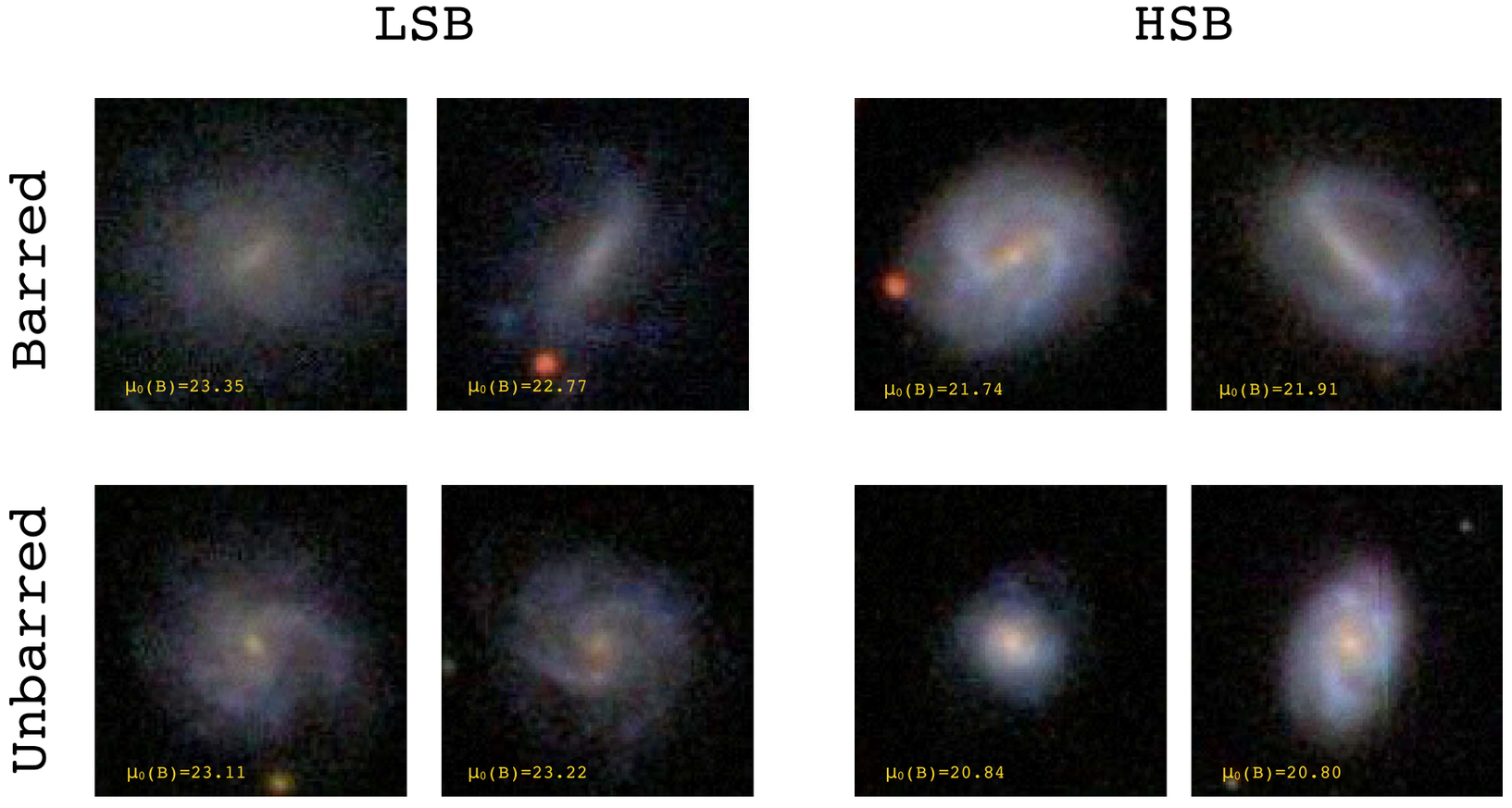
.

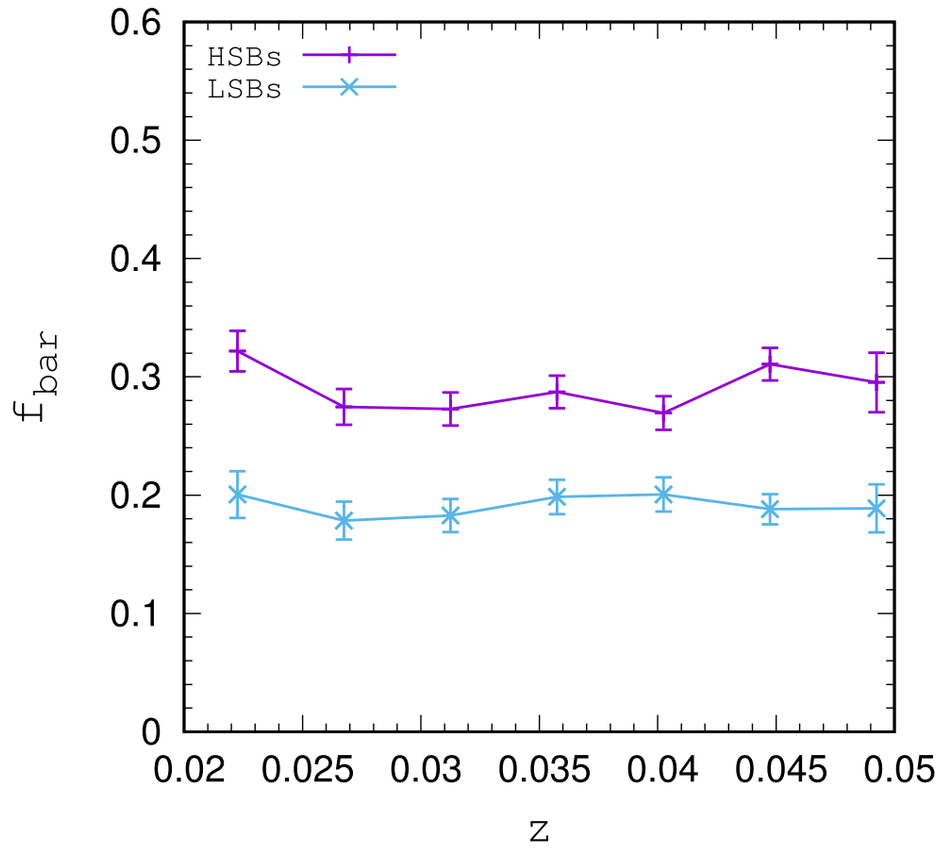
Thank you.

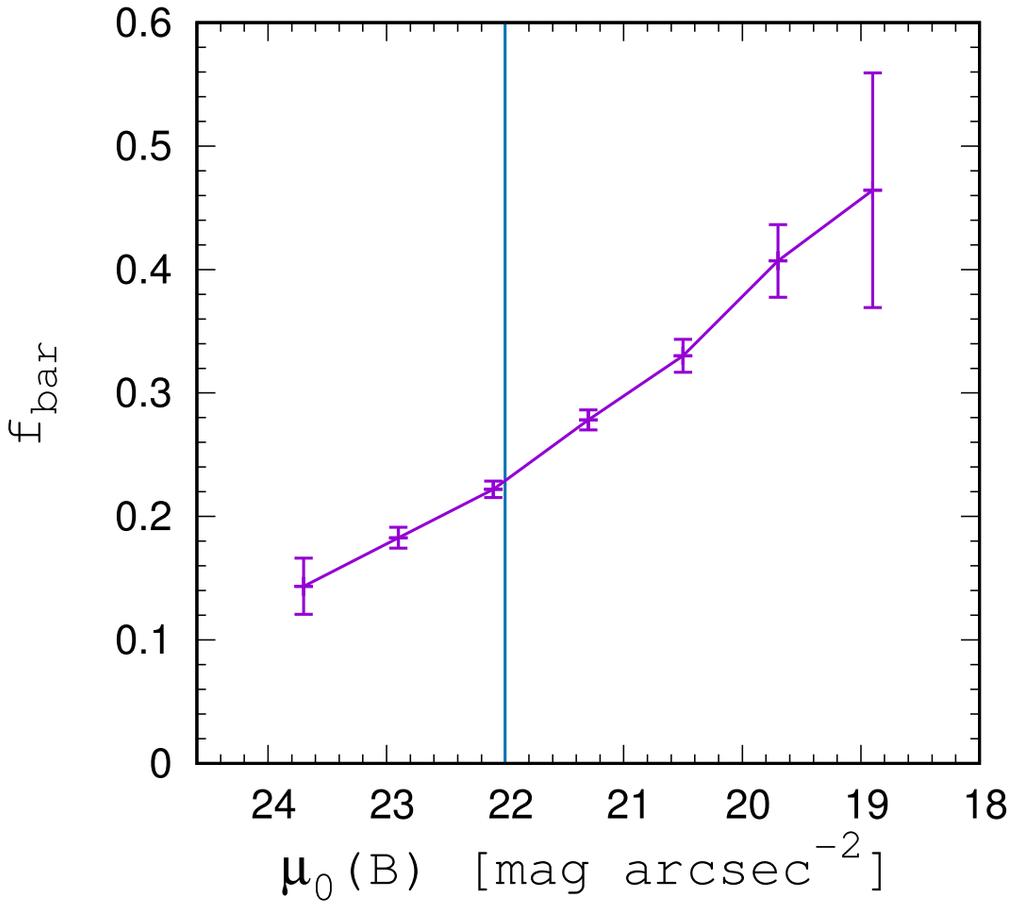


Bars in LSBs

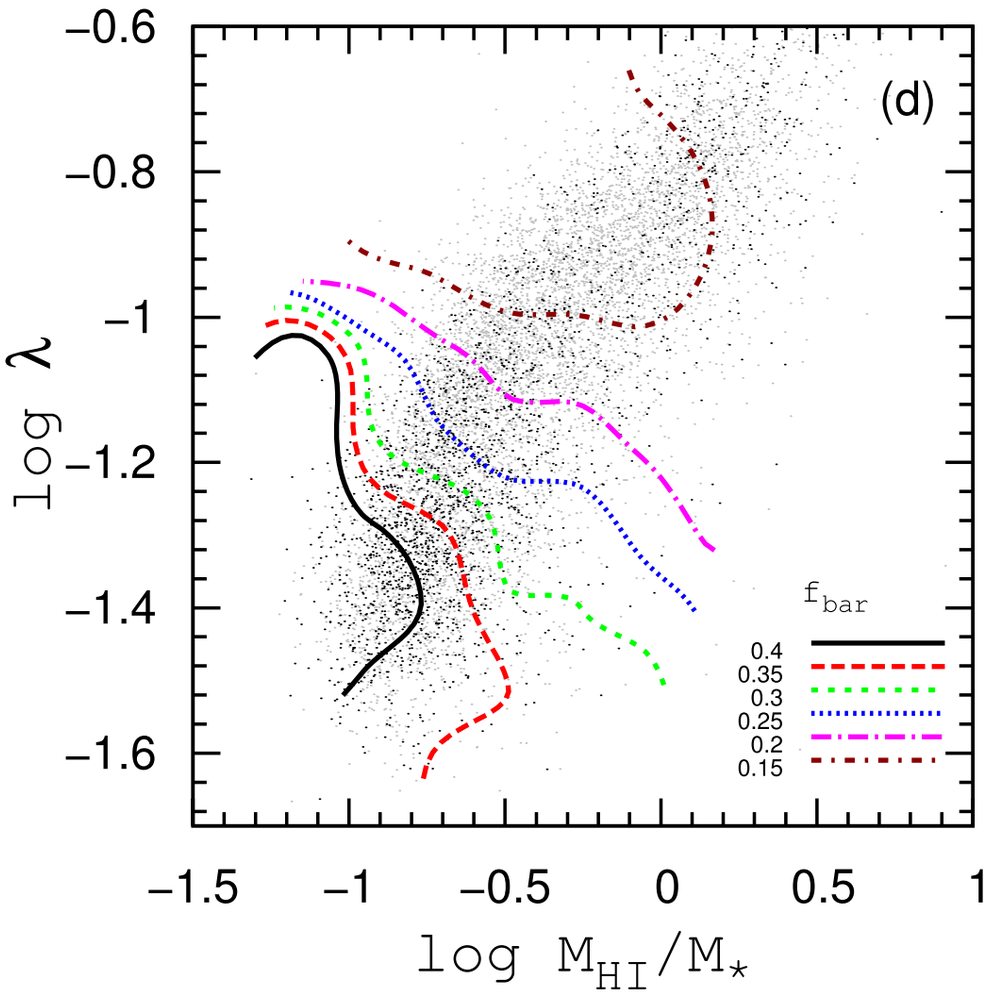
Cervantes Sodi & Sánchez García 2017

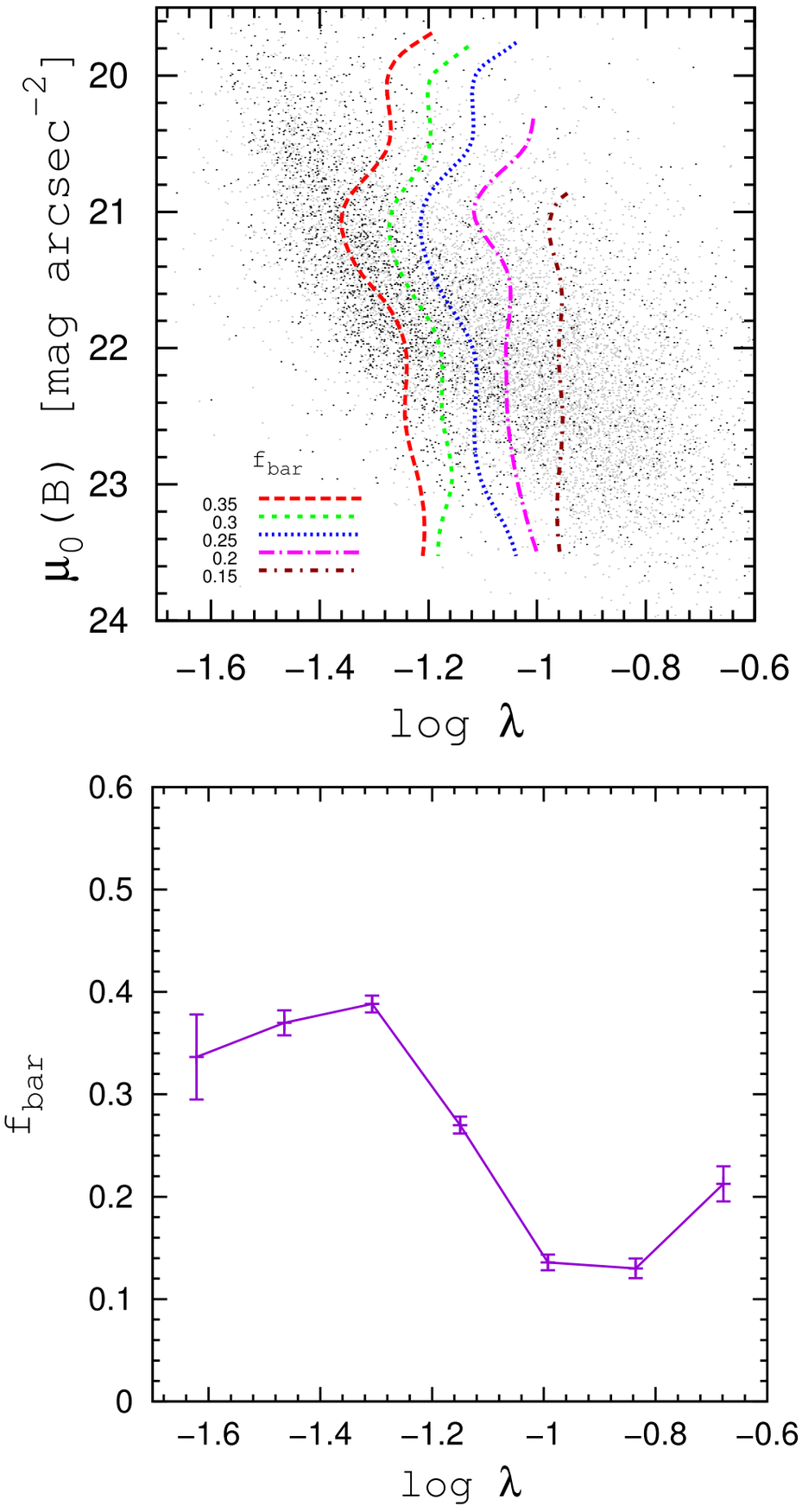






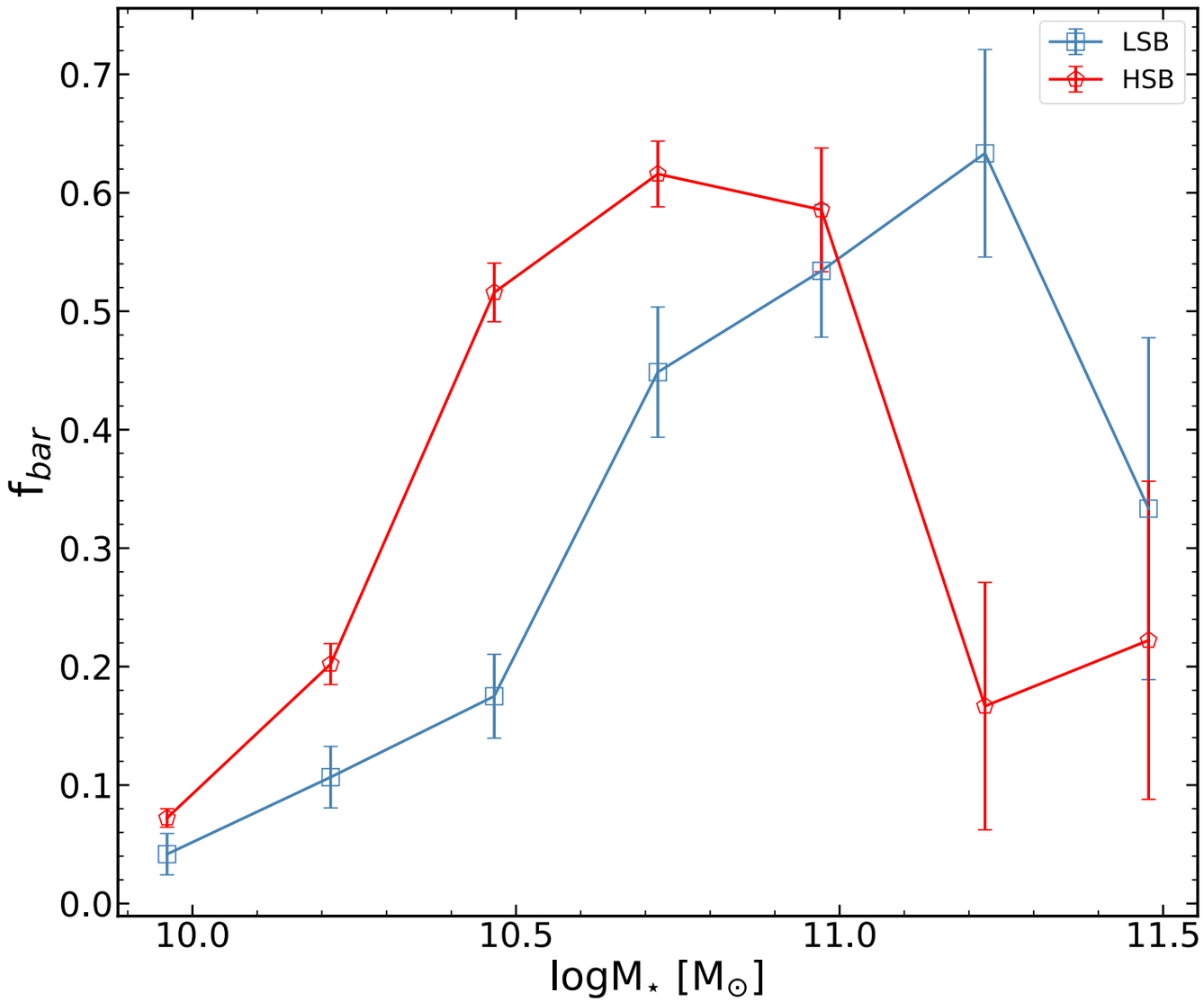
Dependence on μ_0(B) or on λ?





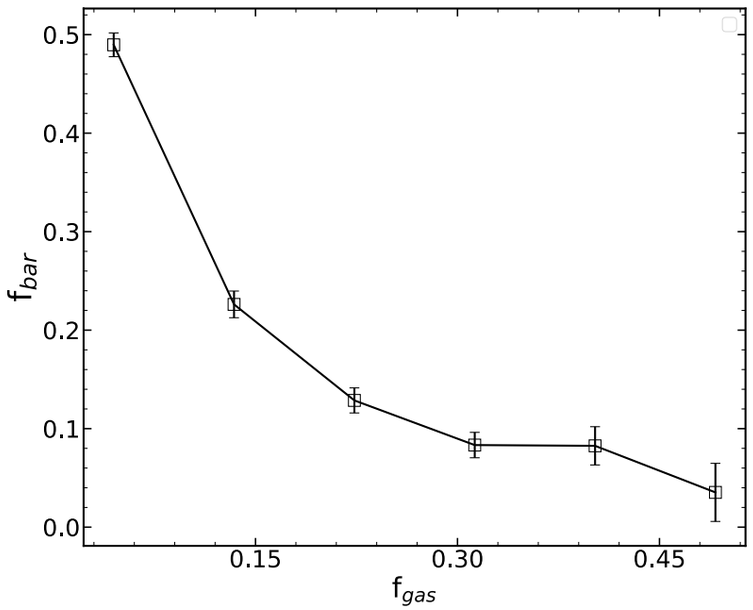
Cervantes Sodi & Sánchez García 2017

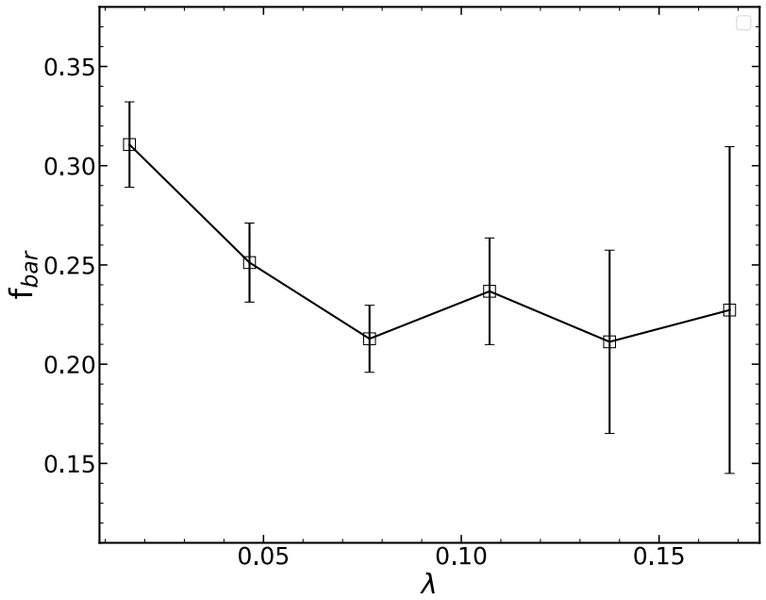
Barred LSBGs in TNG100

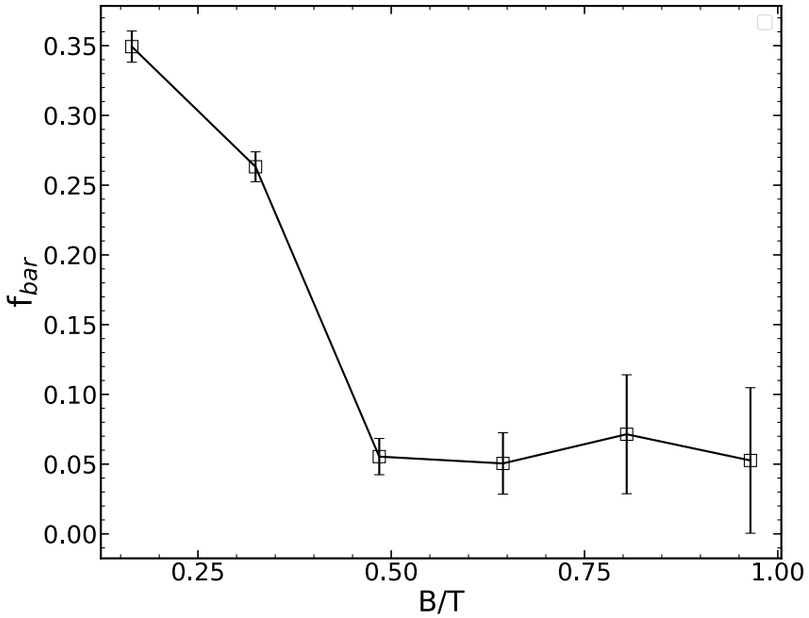


Chim, Cervantes Sodi, Rosas-Guevara et al. in prep.

Dependence of the bar fraction on the gas fraction, spin and bule-to-total ratio







Chim, Cervantes Sodi, Rosas-Guevara et al. in prep.