

The origin of stellar breaks as probed by S⁴G

Juan Carlos Muñoz Mateos (ESO Fellow)

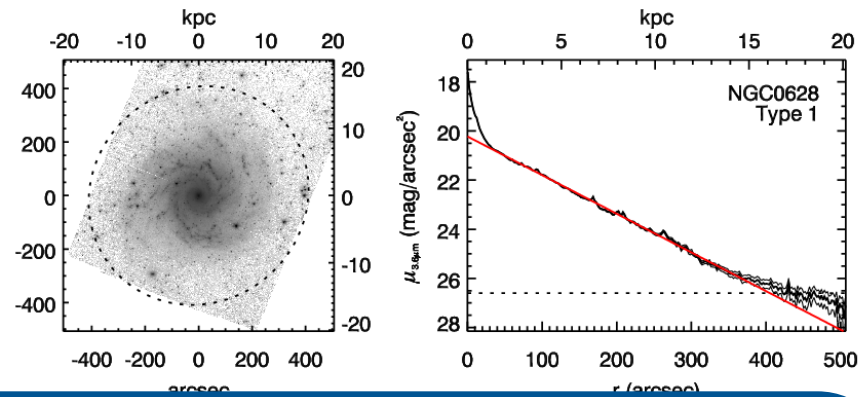
Kartik Sheth, Armando Gil de Paz, Sharon Meidt
+ the S⁴G team



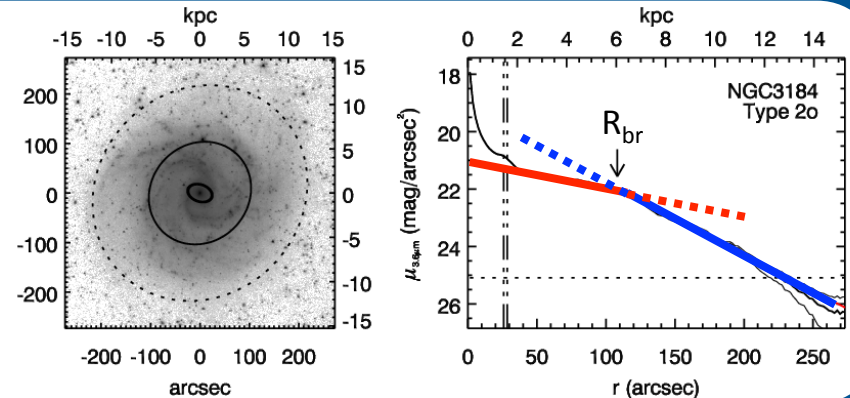
Exponential Disks in Galaxies
Oct 5-9 2014
Flagstaff

Disks come in three flavors

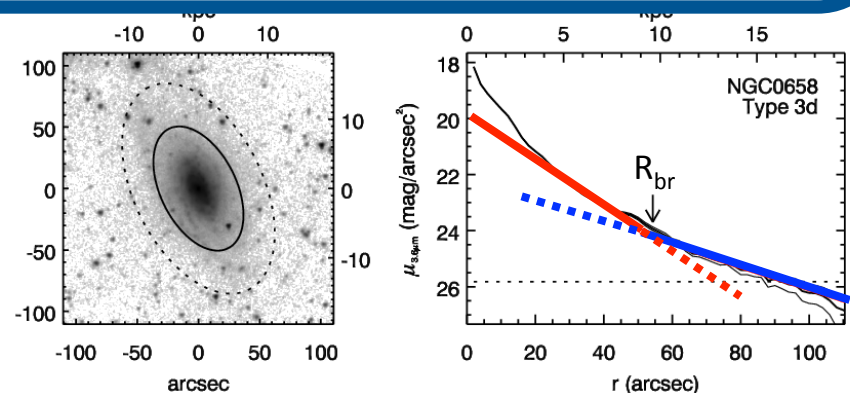
- ❖ Type I (10%)
Single exponential



- ❖ Type II (60%)
Downbending exponential



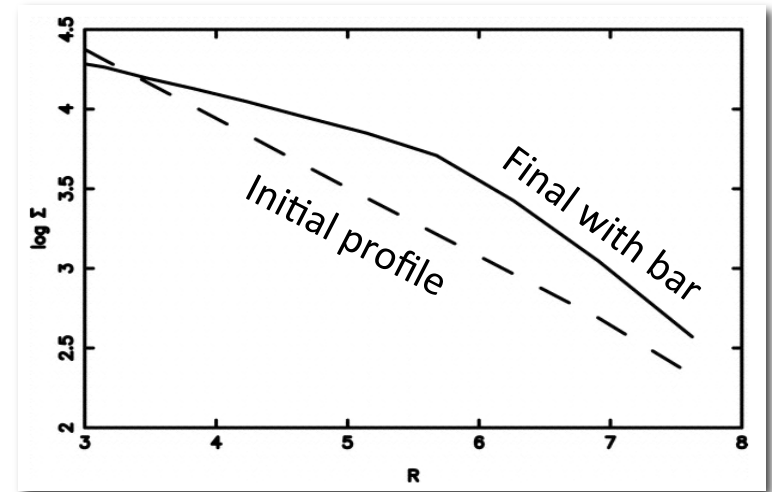
- ❖ Type III (30%)
Upbending exponential



Work by Freeman, van der Kruit,
Erwin, Pohlen, Trujillo...

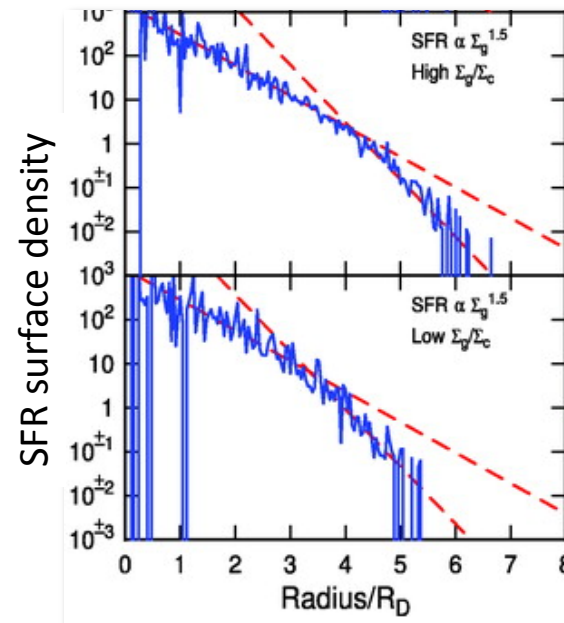
Two(-ish) scenarios for break formation

- ❖ Redistribution of angular momentum by bars and/or spirals.



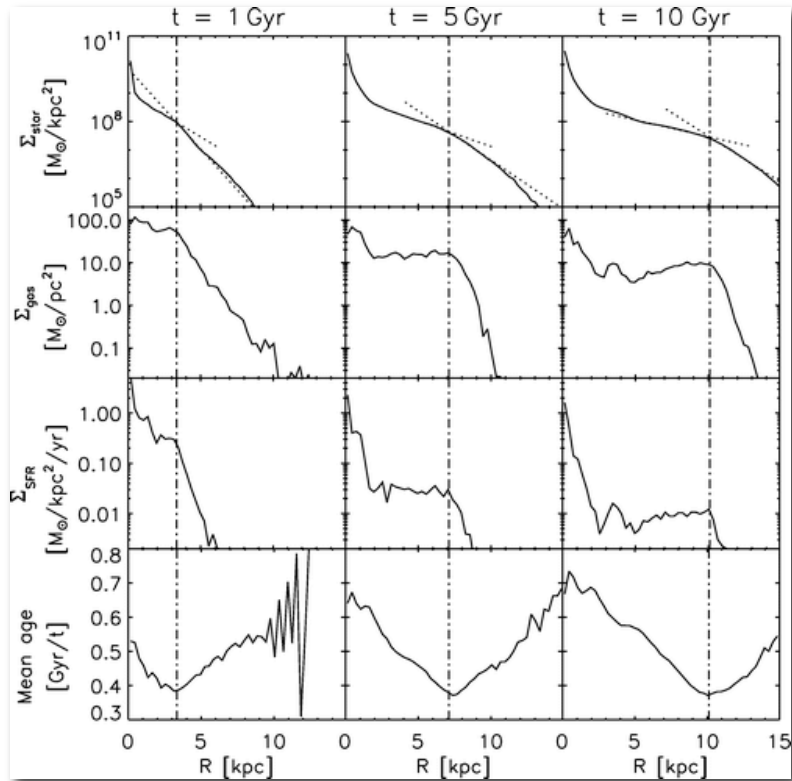
Debatista et al. (2006)

- ❖ Radial changes in the star formation efficiency.

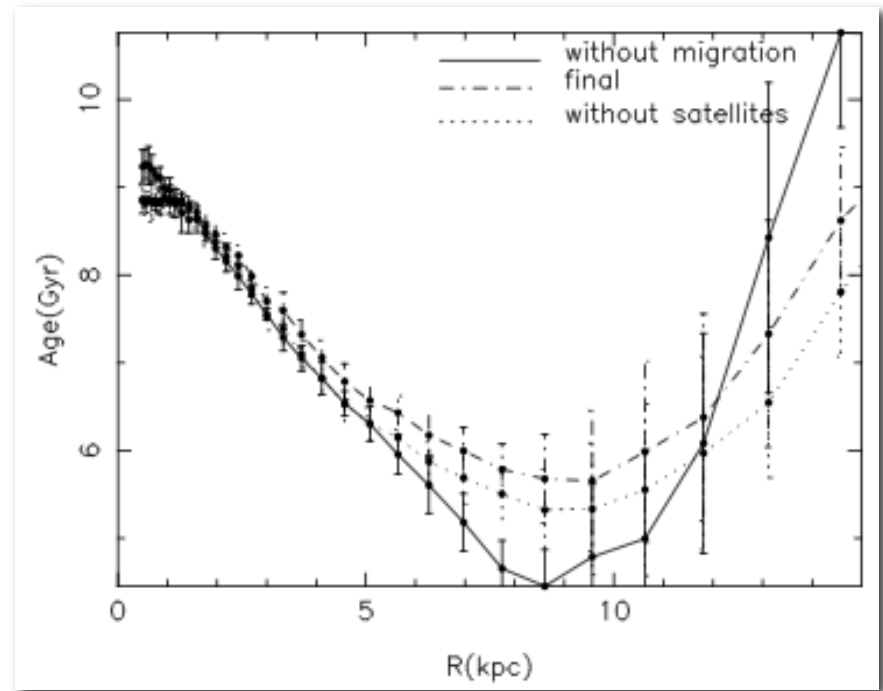


Elmegreen
& Hunter (2006)

Lots of old stars beyond the break!



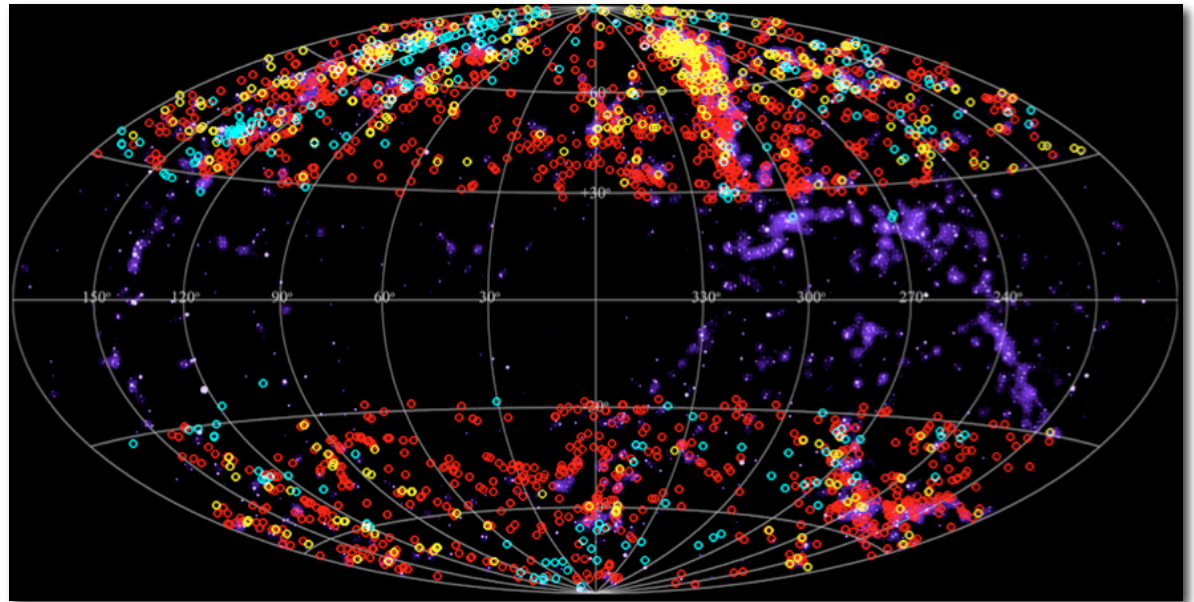
Roskar et al. (2008)
Idealized disk



Sánchez-Blázquez et al. (2009)
Full cosmological simulation

The S⁴G survey

- ❖ Spitzer Survey of Stellar Structure in Galaxies (Sheth et al. 2010).
 - Legacy Science Exploration Program.
 - 637.2 hrs
 - 4 min/pixel
 - $\mu_{3.6\mu\text{m}} \sim 27 \text{ ABmags/arcsec}^2$ ($\sim 1 \text{ M}_{\odot}/\text{pc}^2$)
- ❖ Over 2300 nearby galaxies observed at 3.6 and 4.5 μm .
 - $D < 40 \text{ Mpc}$
 - $|b| > 30^{\circ}$
 - $m_{\text{Bcorr}} < 15.5$
 - $D_{25} > 1'$



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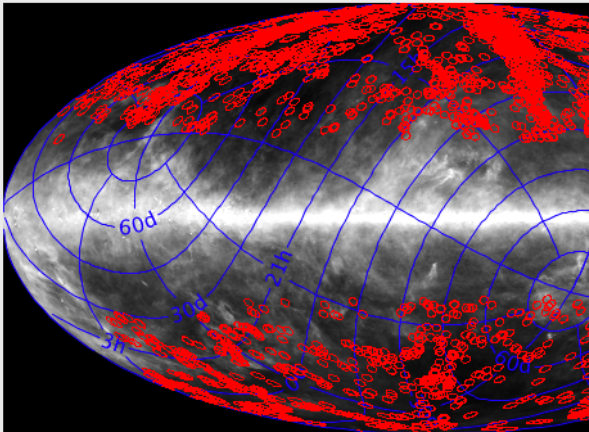
Data access at IRSA

irsa.ipac.caltech.edu/data/SPITZER/S4G

Spitzer Survey of Stellar Structure in Galaxies (S4G)

S4G consists of a sample of 2,352 galaxies, which have been mapped with IRAC channels (3.6 and 4.5 microns).

IRSA hosts the complete S4G project data set, including results from galaxy modeling using fitting and Galfit. A [catalog](#) of photometry, model parameters, measurements from the literature, and a link to the S4G data for each galaxy is also available.



You can get a close-up map of a region by clicking on any of the red image, or by typing a coordinate below.

[Documentation: [Pipelines](#) | [Galfit Models](#) | [S4G Home Page](#) | [S4G Spitzer Exploration Science Programs](#)]

The 2,352 S4G galaxies are represented as overlays in red on the all-sky map below to enter a coordinate or object name to search for data, or to get a close-up of the area.

The canonical papers for S4G are [Sheth et al. \(2010\)](#), Regan et al. (in press, 2013).

[Access](#) all the Spitzer Legacy datasets at IRSA.

COLUMN CONSTRAINTS/OUTPUT COLUMN SELECTION

Select All Columns Clear All Selections Reset

Table Selection

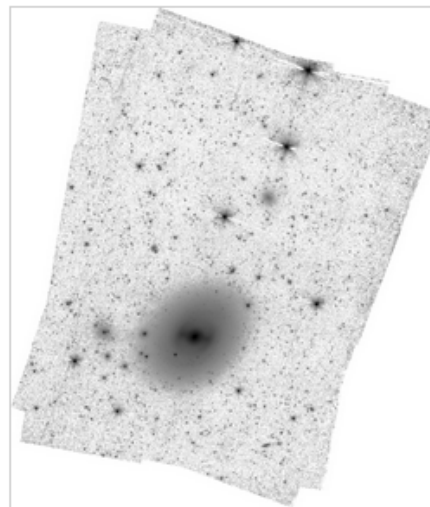
Standard

Long Form

Sexagesimal Output No

Name	Description	Sel	Low Limit (include >=, <=)	Up Limit (include <=, >=)	Units	Indx	DBType
object	Galaxy name	☒					varchar2(17)
ra	Right ascension (J2000)	☒			deg	X	float(126)
dec	Declination (J2000)	☒			deg	X	float(126)
sma1_25p5	Semi-major axis at mu_3.6 = 25.5 AB mag/arcsec2	☒			arcsec		float(126)
PA1_25p5	Position angle at mu_3.6 = 25.5 AB mag/arcsec2	☒			deg		float(126)
sma2_25p5	Semi-major axis at mu_4.5 = 25.5 AB mag/arcsec2	☒			arcsec		float(126)
PA2_25p5	Position angle at mu_4.5 = 25.5 AB mag/arcsec2	☒			deg		float(126)

IRAC Data



NGC0936 IRAC Ch1 Preview

Download IRAC images:

- IRAC 1: [FITS](#), [Preview JPEG](#)
- IRAC 1 Mask: [FITS](#)
- IRAC 2: [FITS](#), [Preview JPEG](#)
- IRAC 2 Mask: [FITS](#)

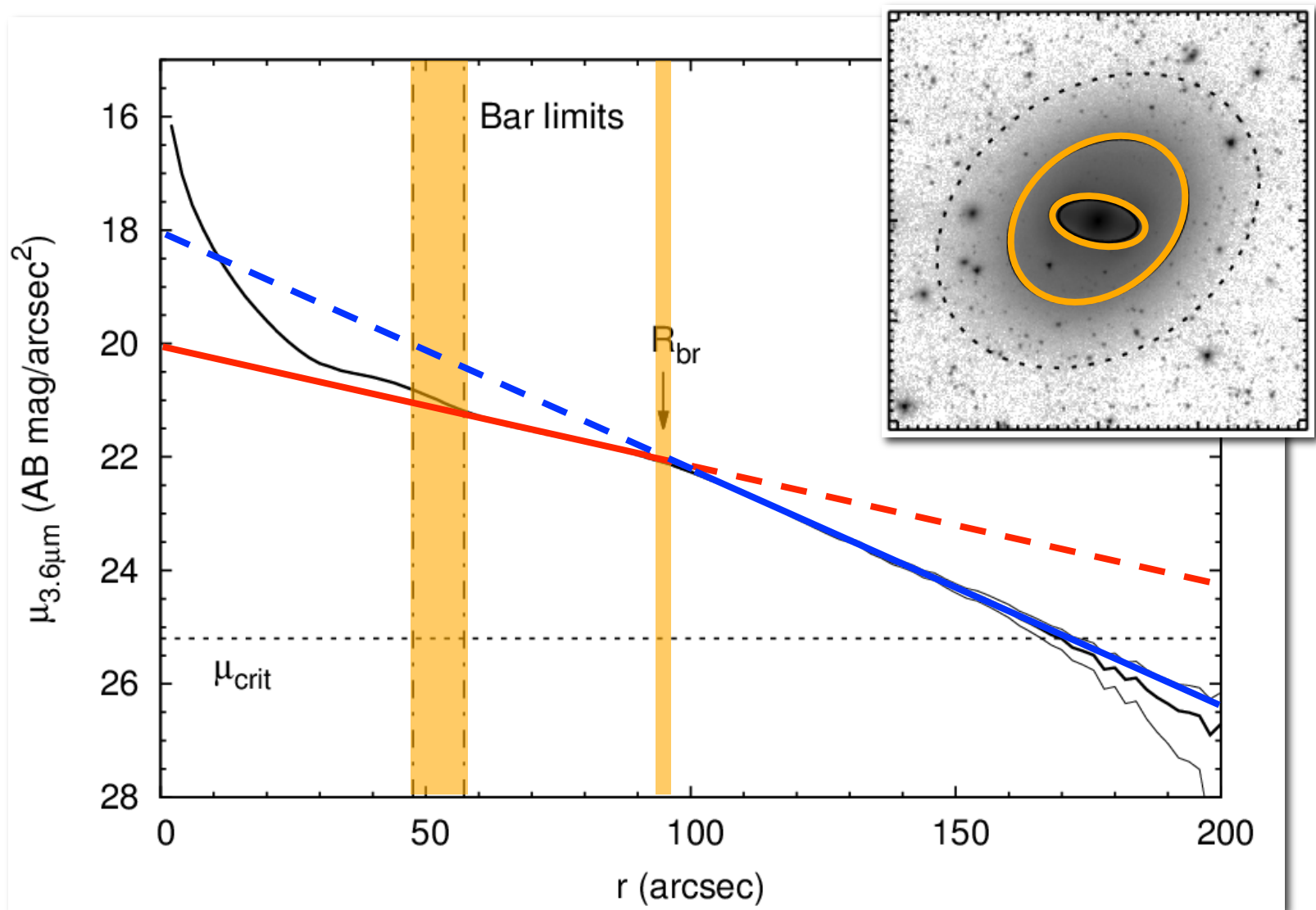
Ellipse Fits:

[Download Ellipse fit output](#)

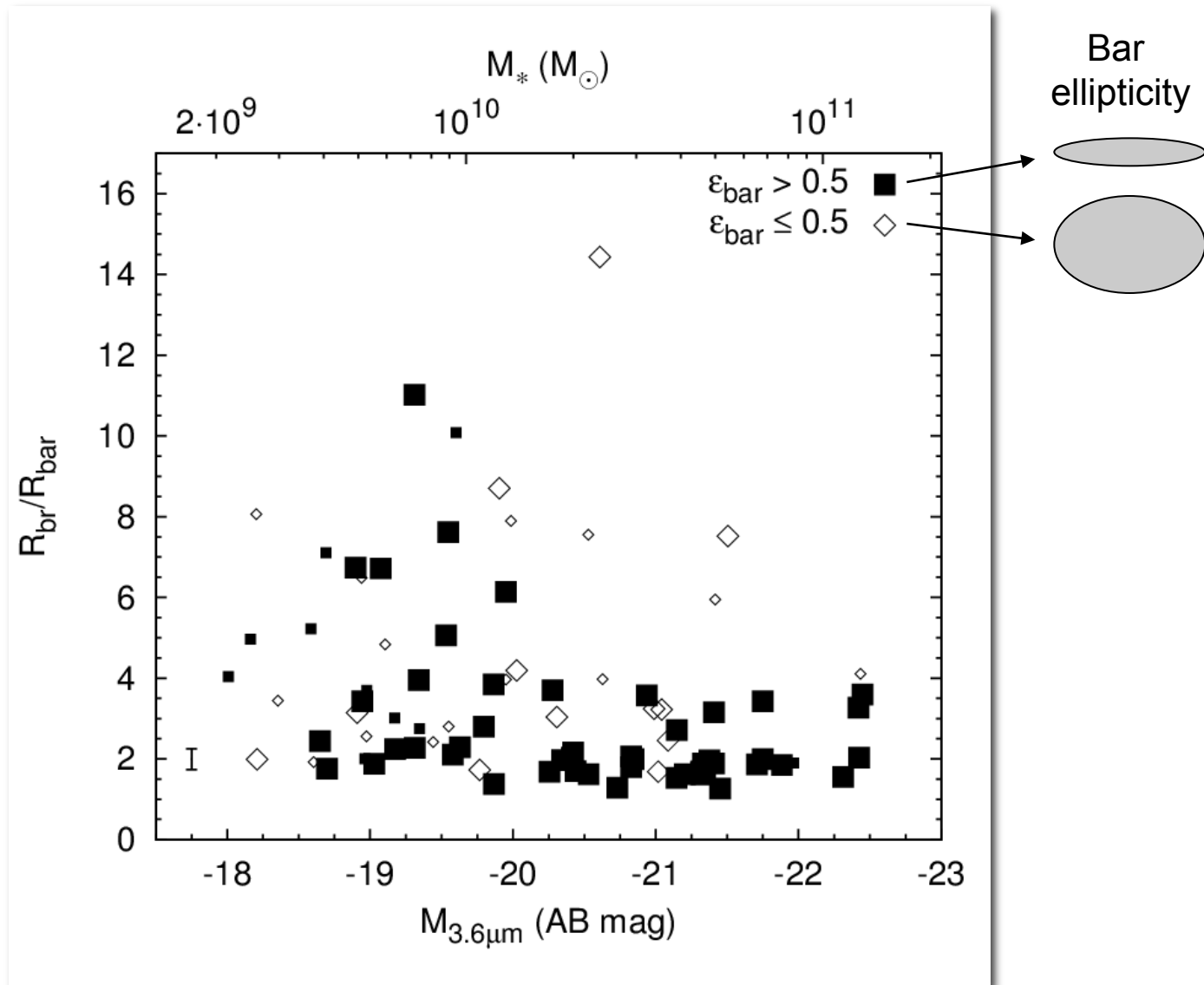
Galfit:

[Download Galfit results](#)

Measuring breaks and bars



The break/bar ratio depends on mass



Muñoz-Mateos et al. (2013)

Many breaks lie at the bar OLR

❖ For a flat rotation curve:

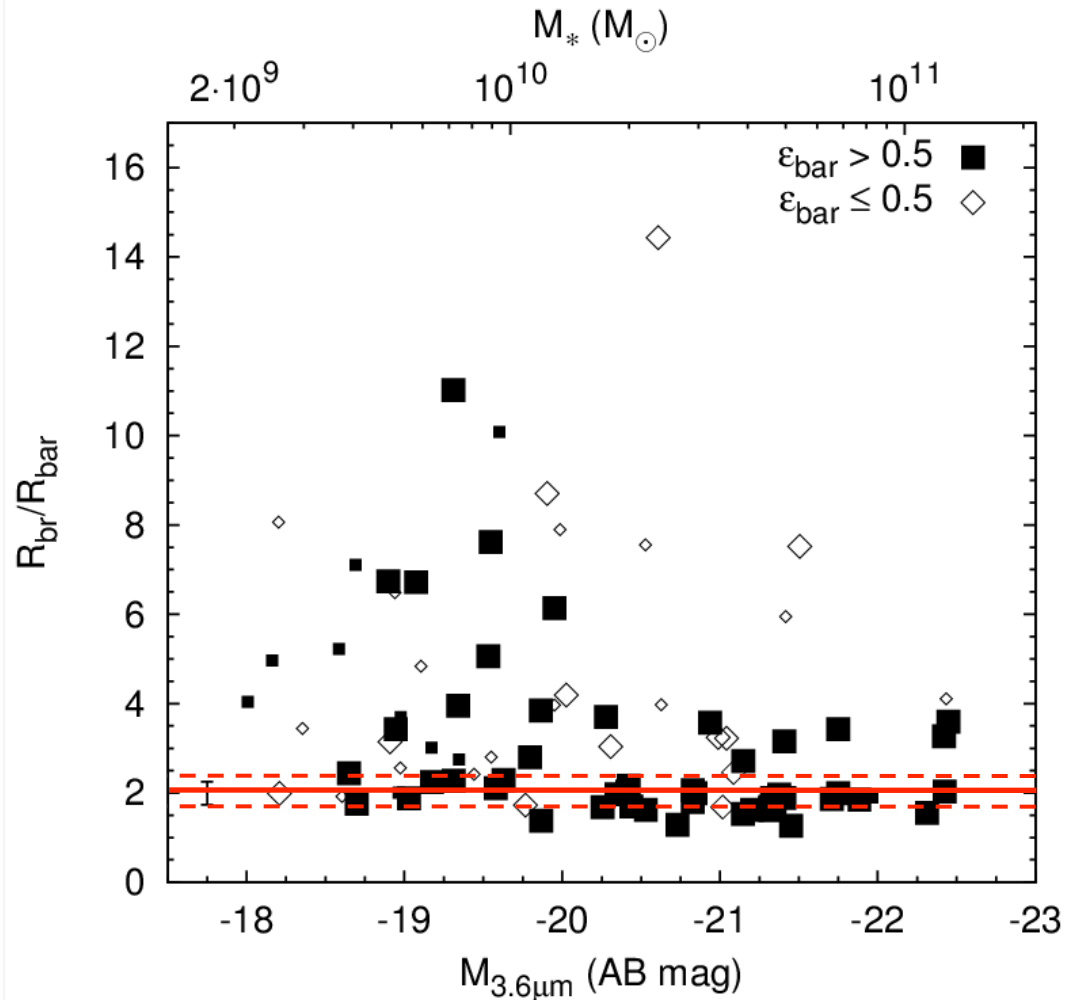
- $V = \text{constant}$
- $\Omega \propto 1/r$
- $R_{\text{OLR}} \sim 1.7 R_{\text{CR}}$

❖ In general:

- $R_{\text{CR}} \sim 1.2 R_{\text{bar}}$
(e.g. Elmegreen et al. 1996)

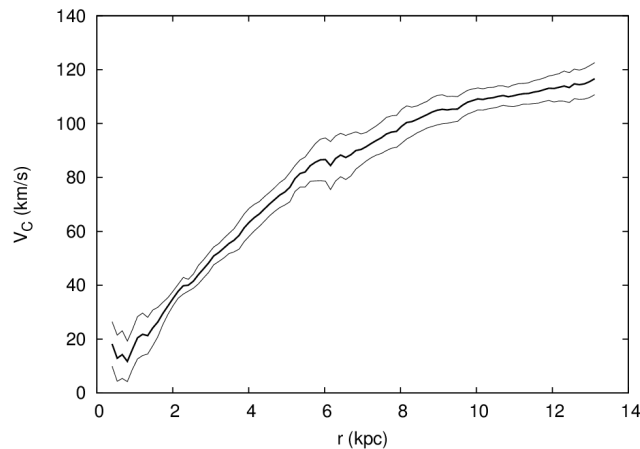
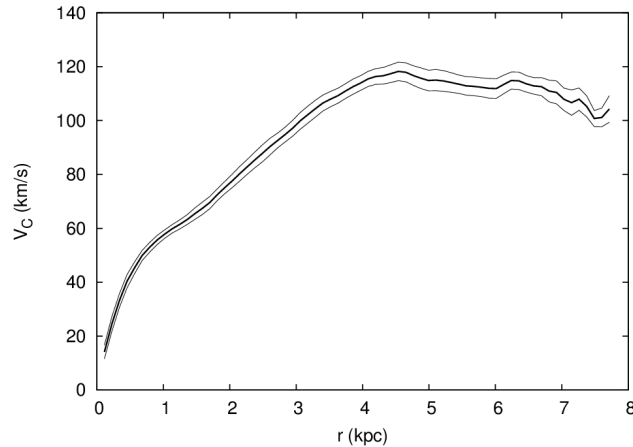
❖ Therefore:

- $R_{\text{OLR}} \sim 2 R_{\text{bar}}$

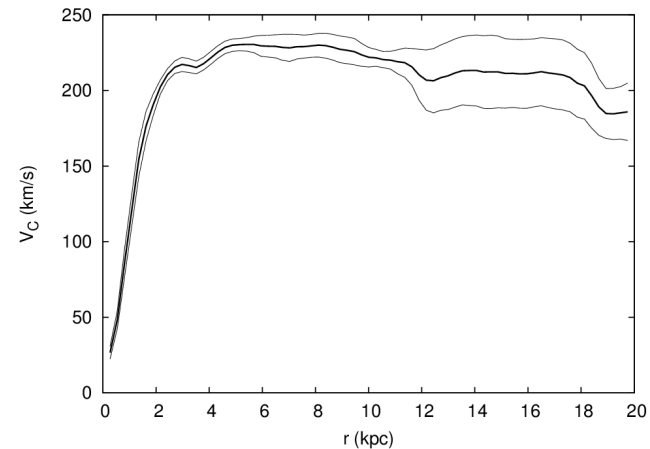
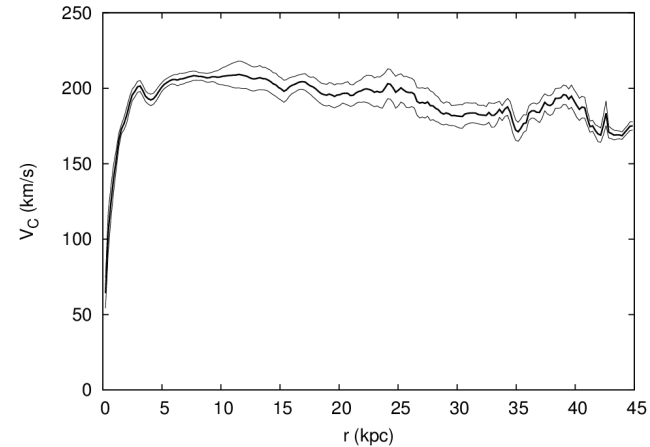


Rotation curves are not always flat

Low mass

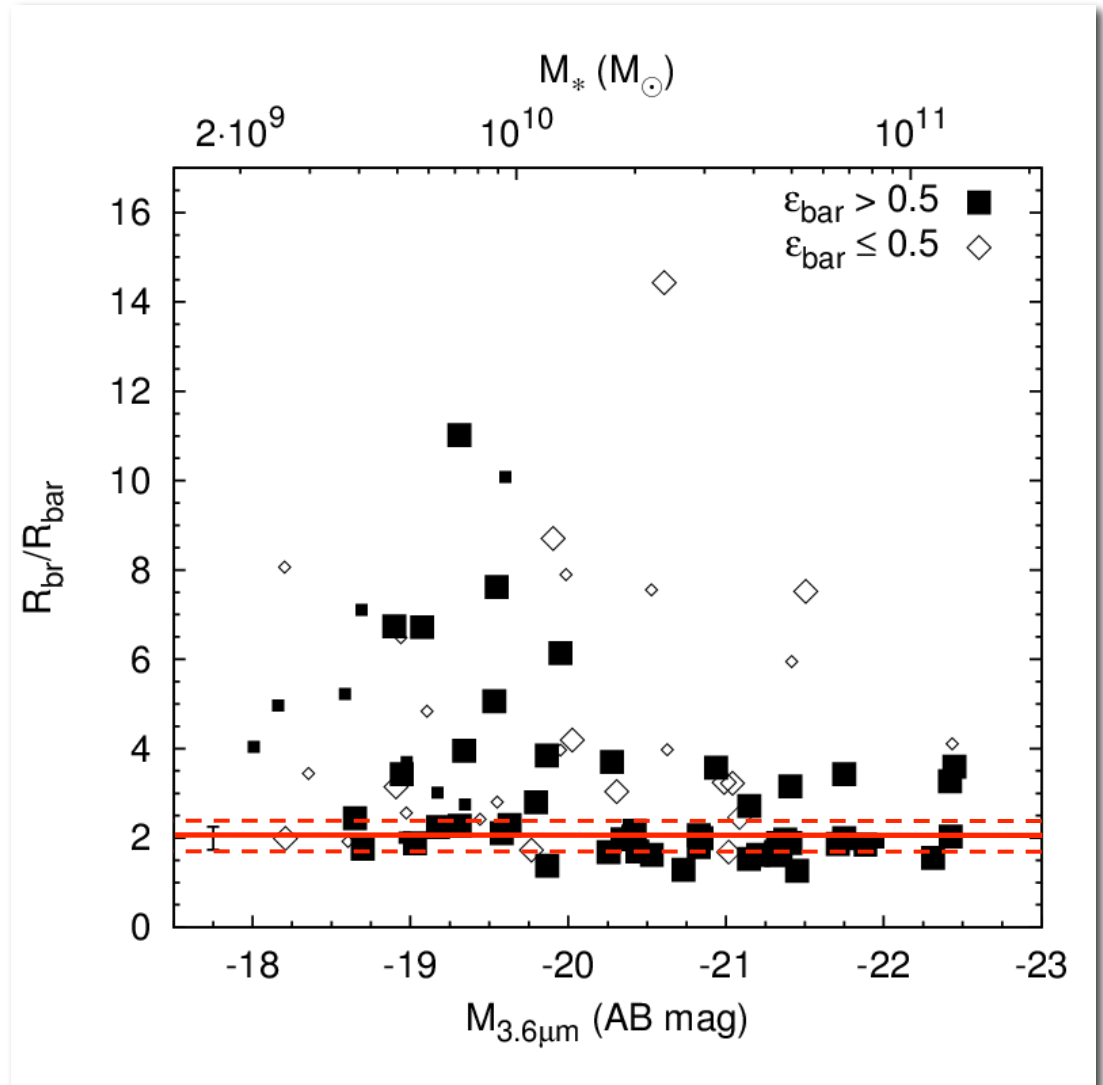


High mass



de Blok et al. (2008)

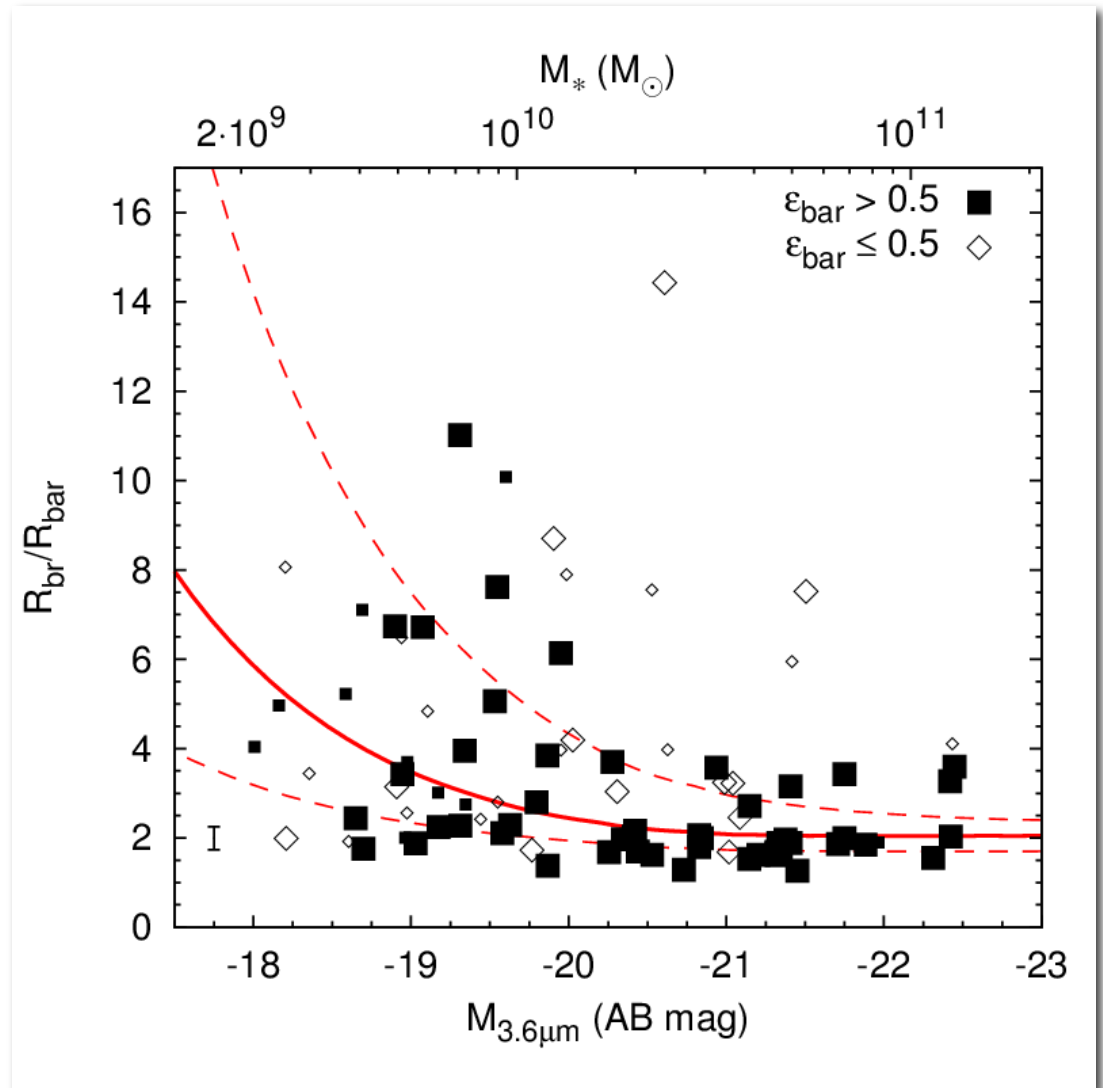
Rising rotation curves push the OLR further out



Muñoz-Mateos et al. (2013)

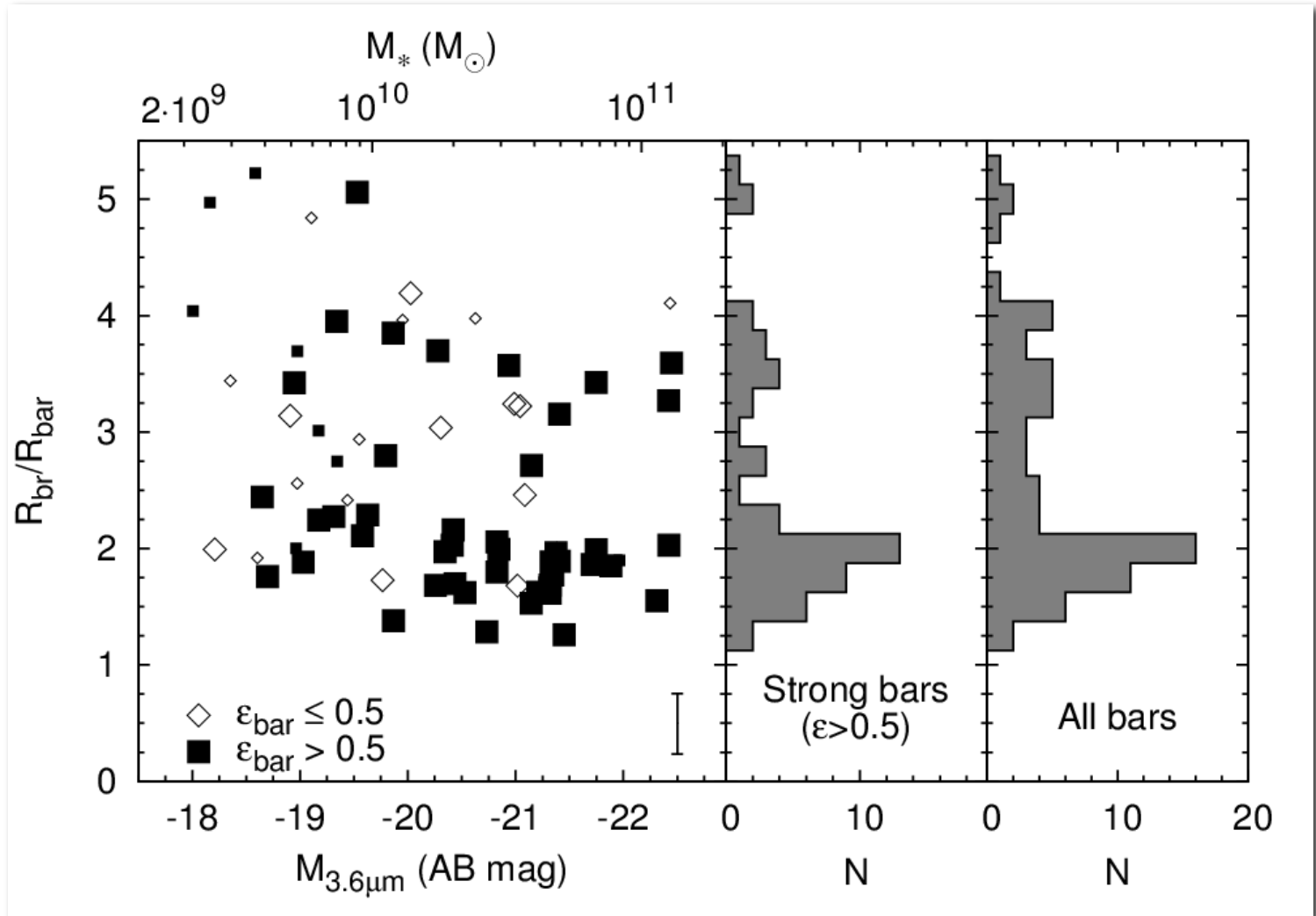
Rising rotation curves push the OLR further out

- ❖ Breaks at large radii in low-mass disks could still have a dynamical origin!



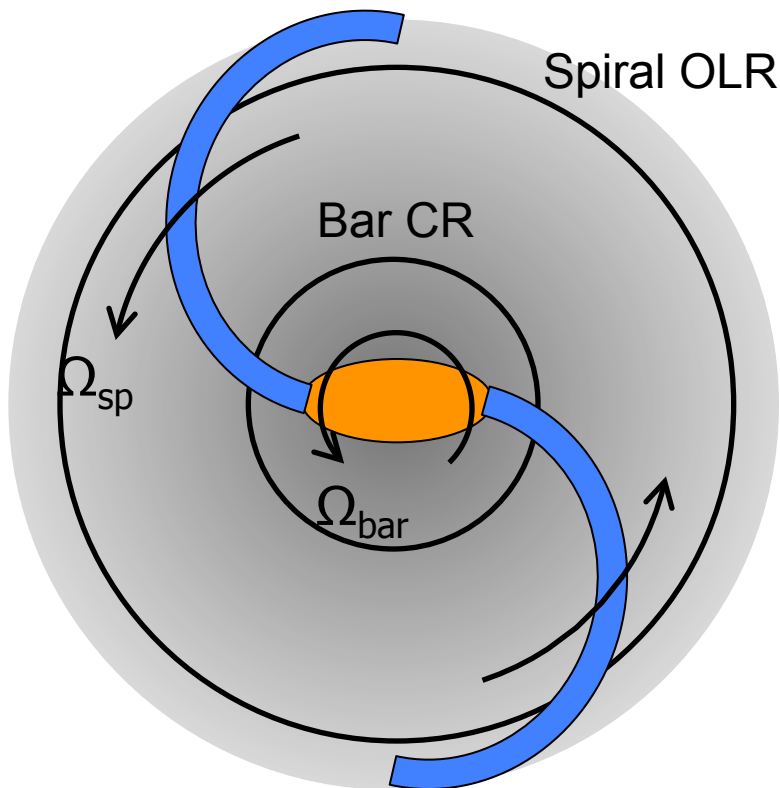
Muñoz-Mateos et al. (2013)

A second family of breaks at $3-4 R_{\text{bar}}$

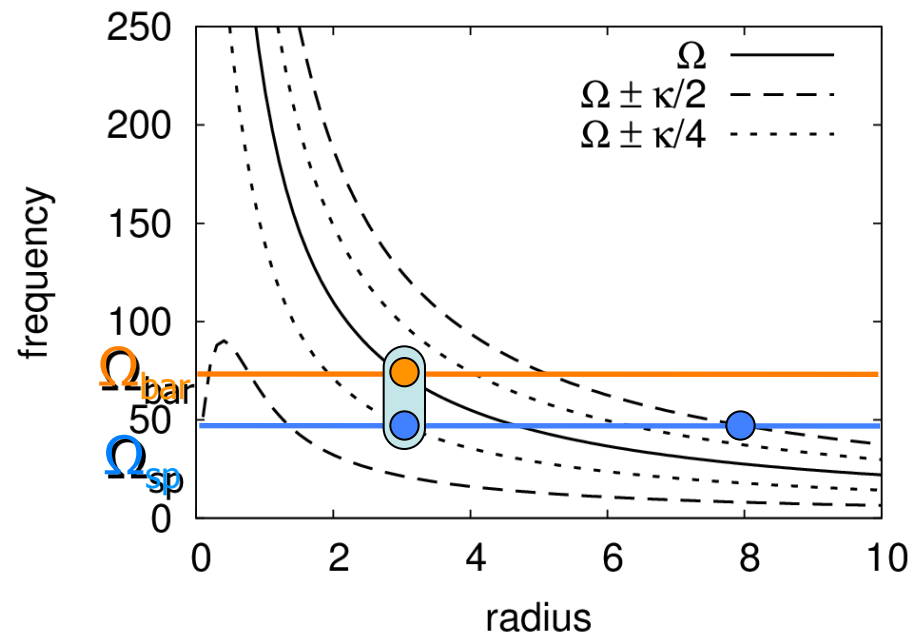


Muñoz-Mateos et al. (2013)

Bars and spiral arms can couple

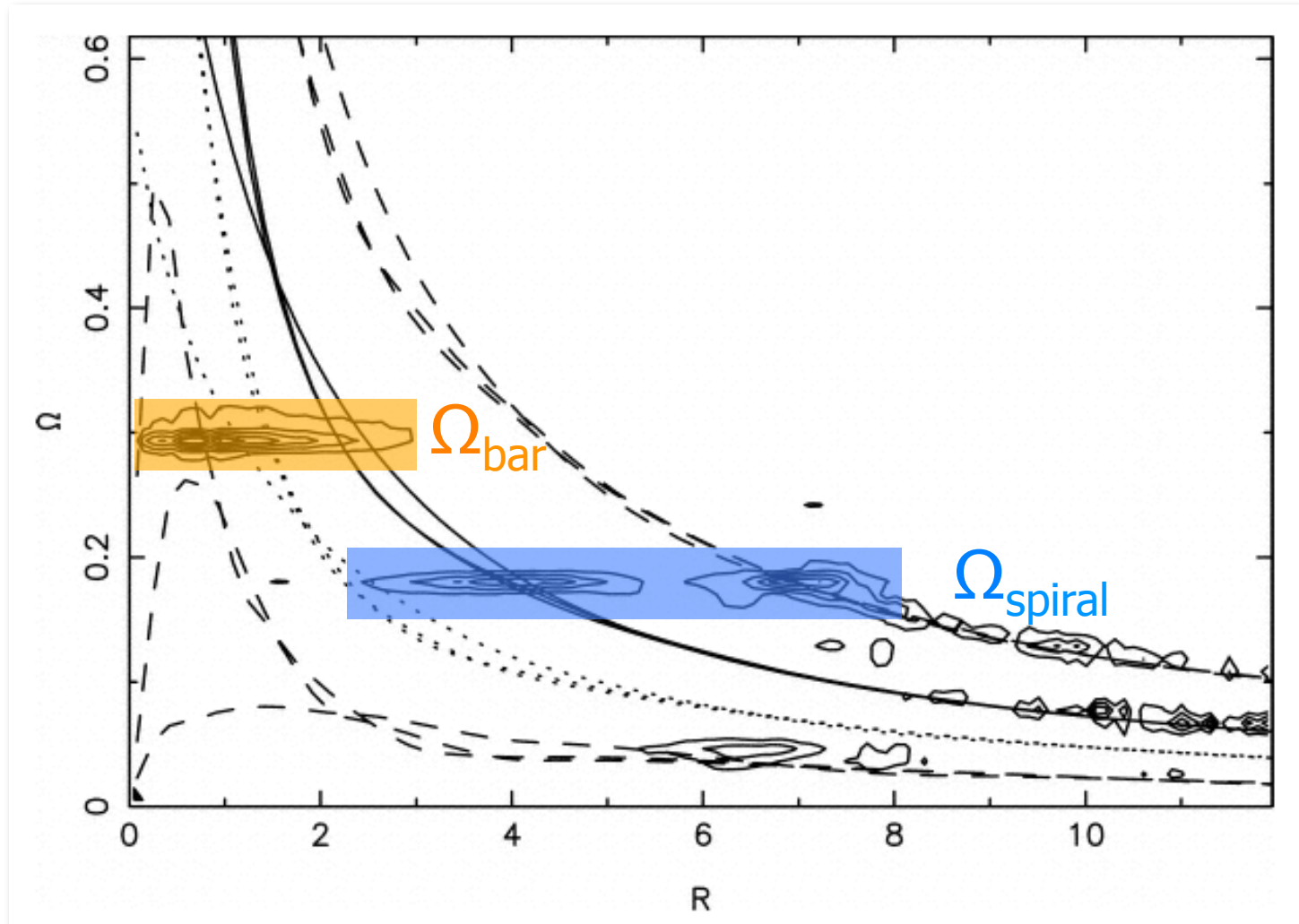


- ❖ The bar and spiral pattern speeds can be different.



- ❖ If resonances overlap, angular momentum is carried much further out!

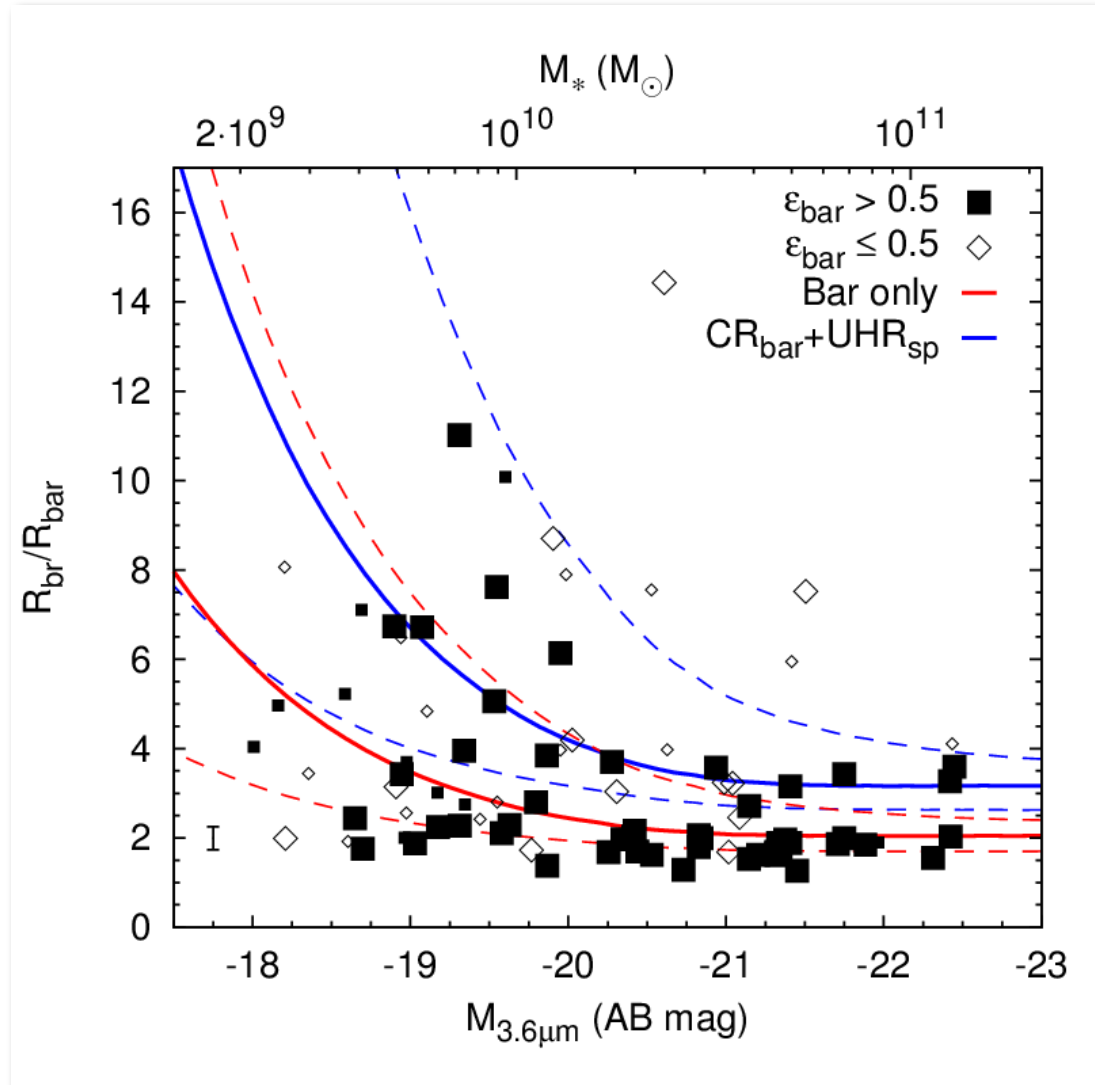
Bars and spiral arms can couple



Debattista et al. (2006)

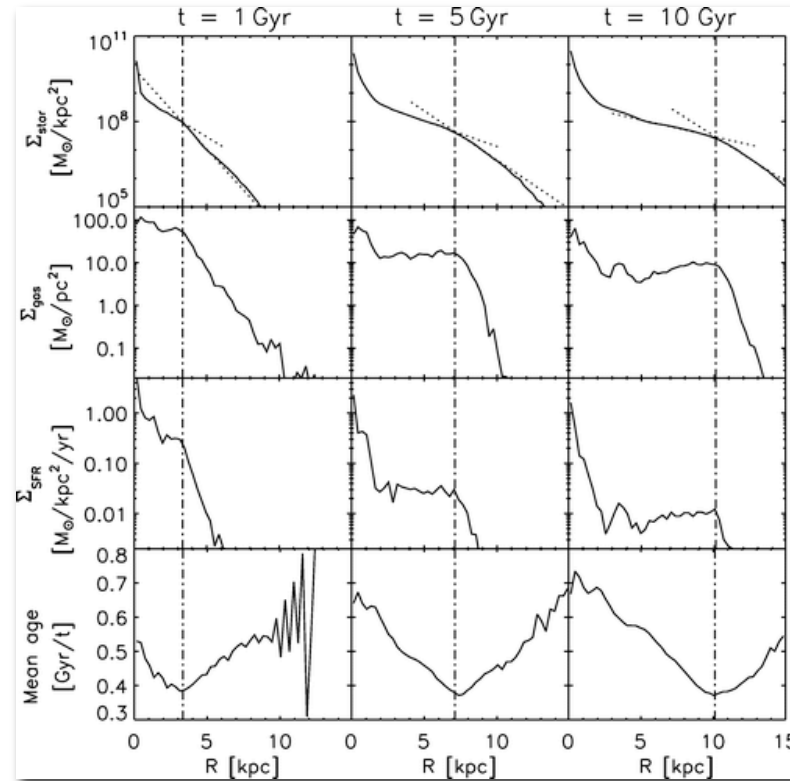
Bar/spiral coupling can yield breaks at large radius

- ❖ More efficient than a single pattern.
- ❖ Radial mixing in only ~ 3 Gyrs!
(Minchev et al. 2010).



Muñoz-Mateos et al. (2013)

Is the H_2 profile broken too?

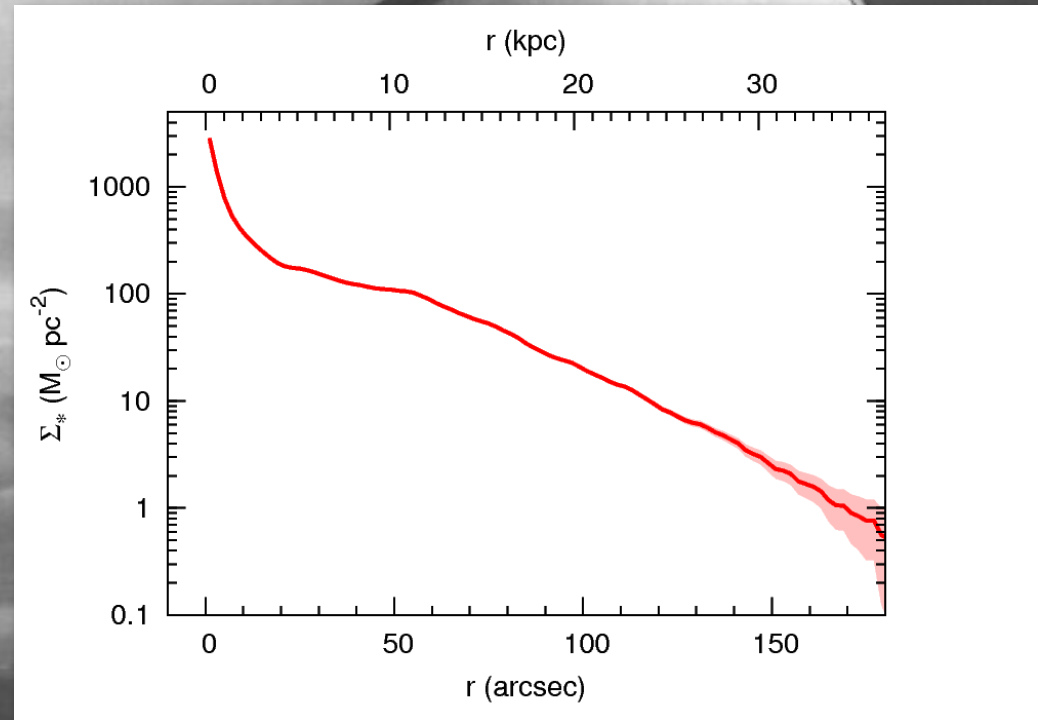
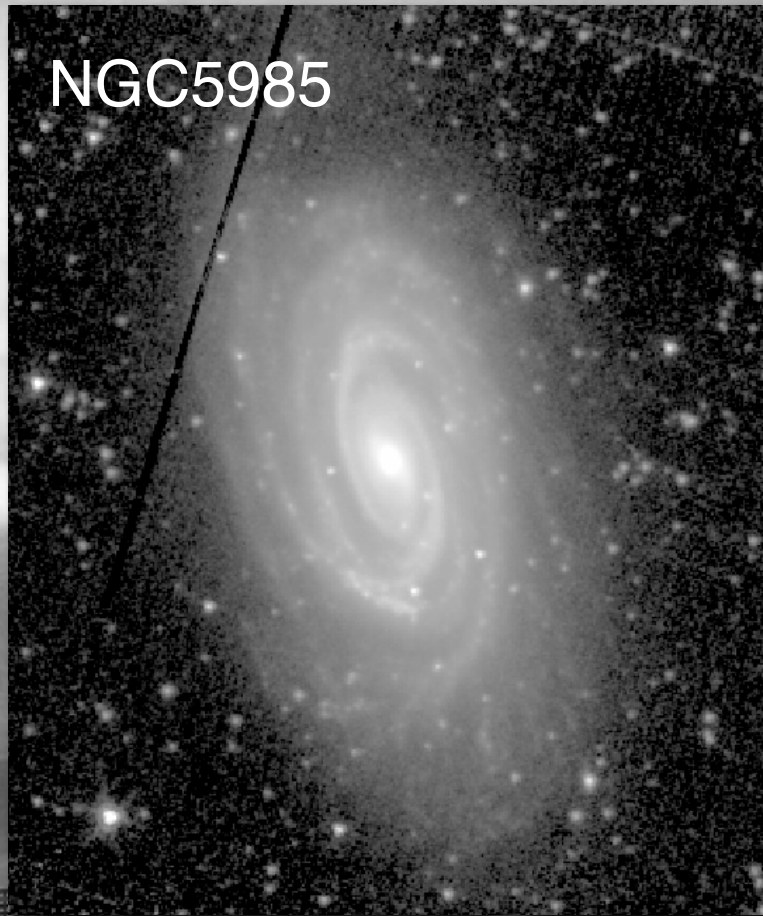


Roskar et al. (2008)
Idealized disk

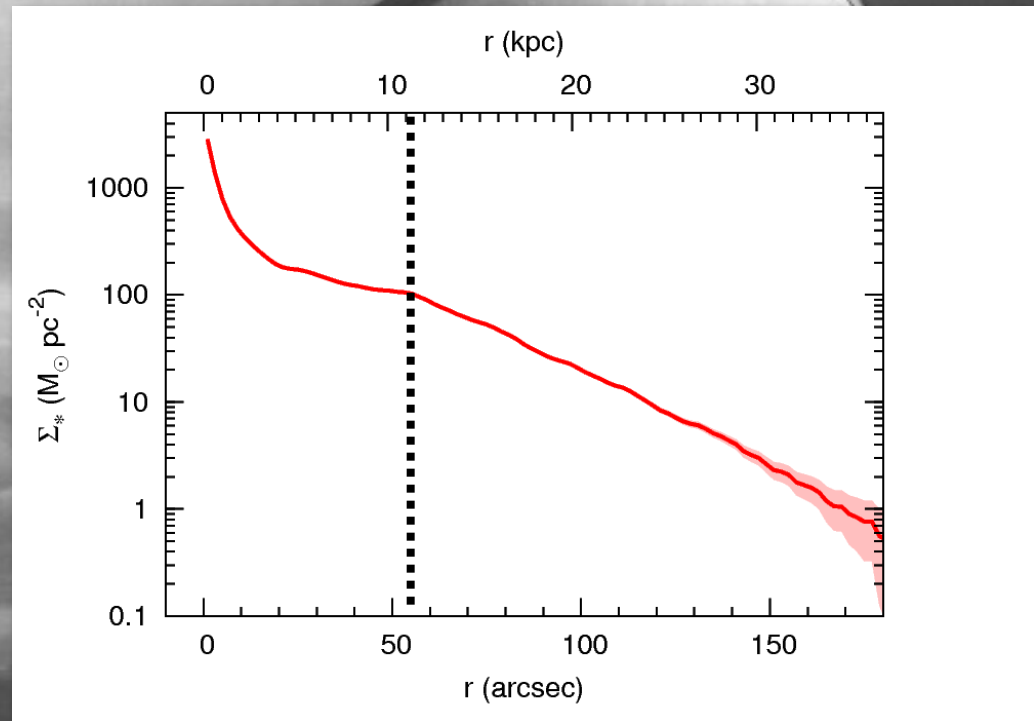
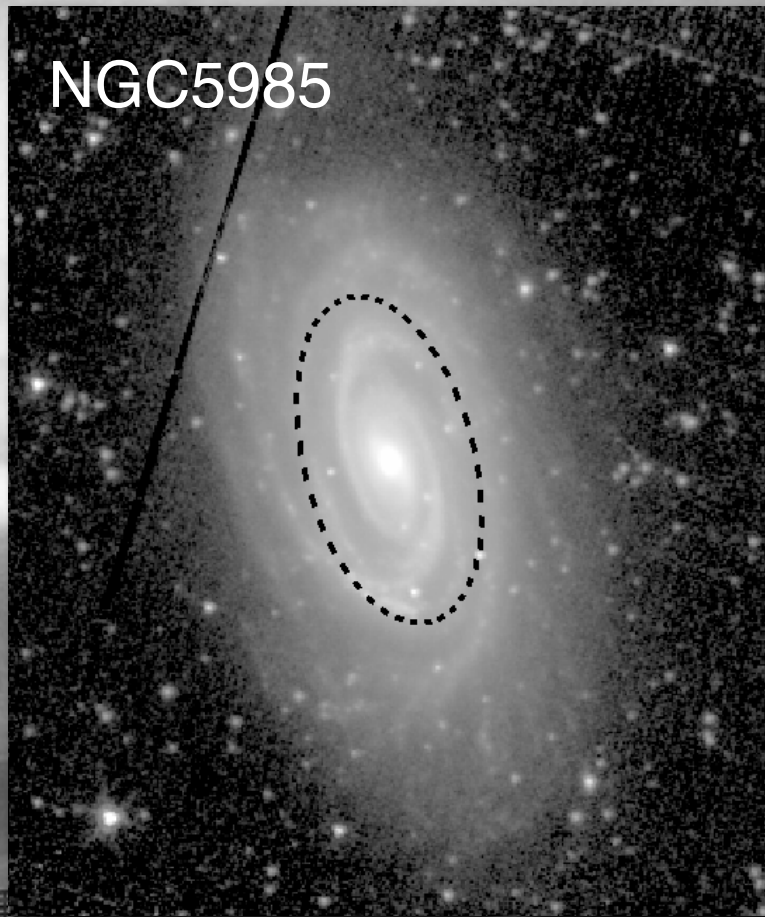
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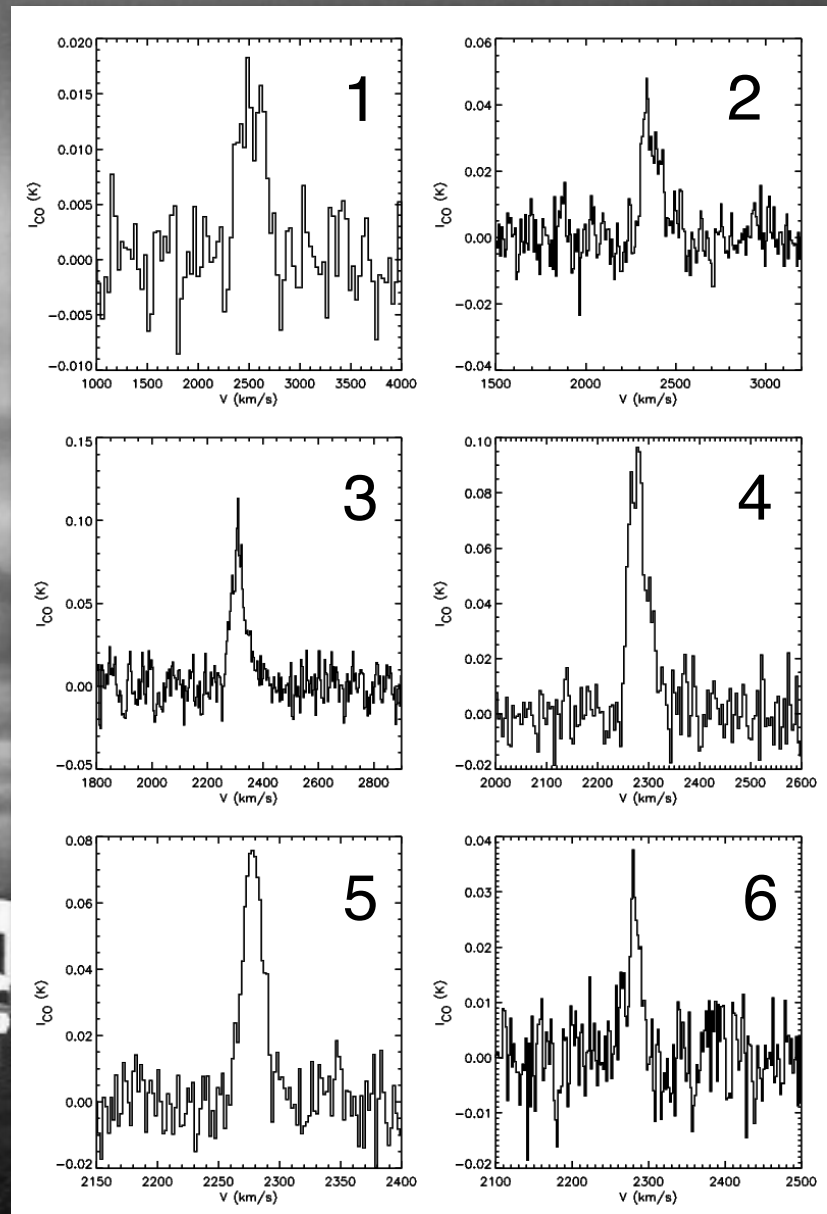
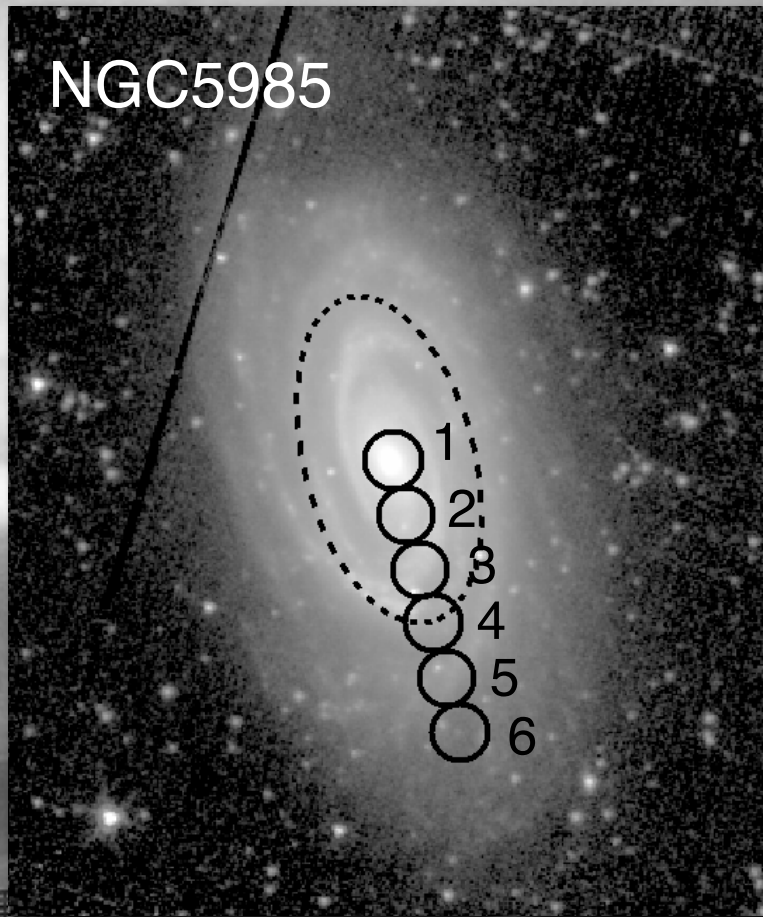
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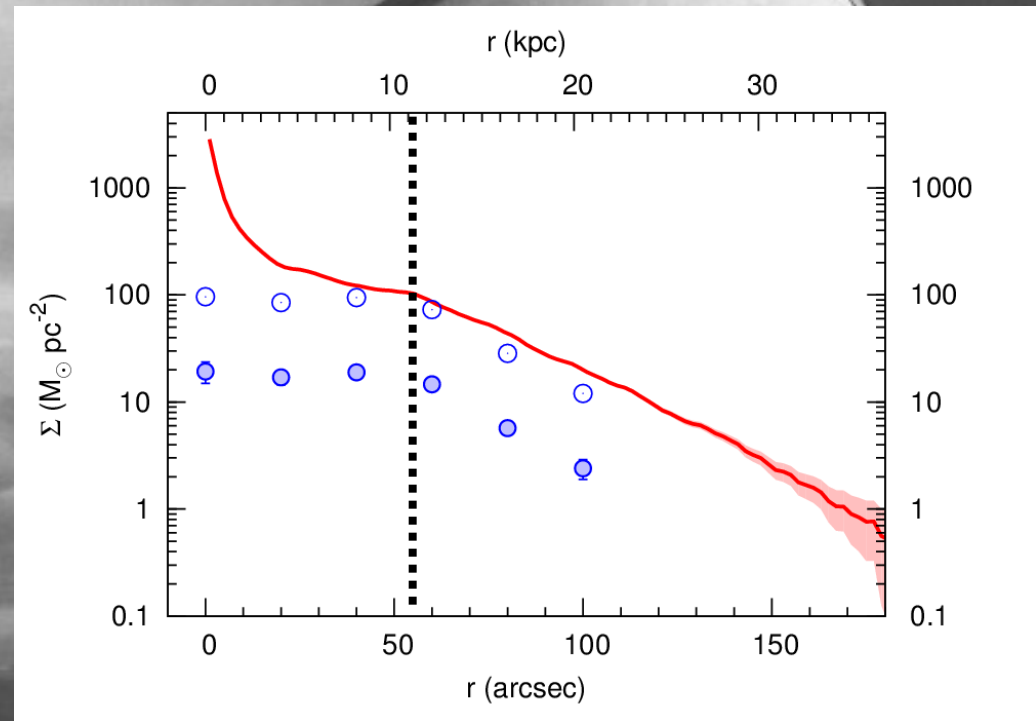
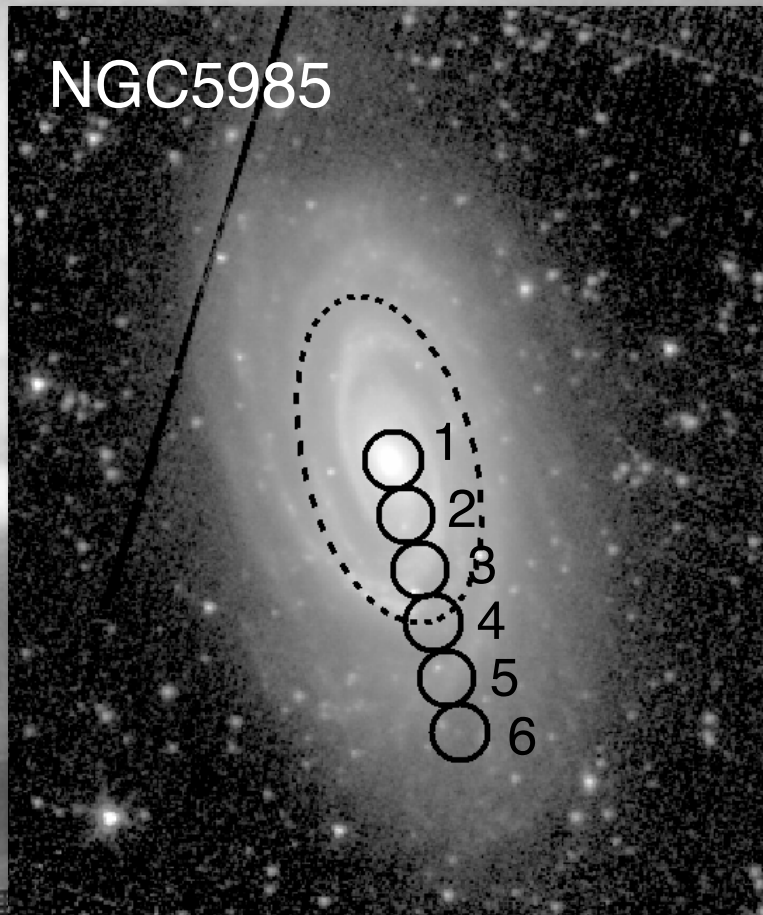
Is the H_2 profile broken too?



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Is the H_2 profile broken too?



Conclusions

- ❖ Breaks are signposts of disk assembly.
 - In-situ star formation?
 - Radial stellar migration?
- ❖ Migration can create breaks at large radii.
 - Rising rotation curves (in low mass disks).
 - Spiral/bar coupling.
- ❖ Molecular profiles are broken too.
 - Sharper break than in the stellar profile.