

The origin of stellar breaks as probed by S⁴G

Juan Carlos Muñoz Mateos (ESO)

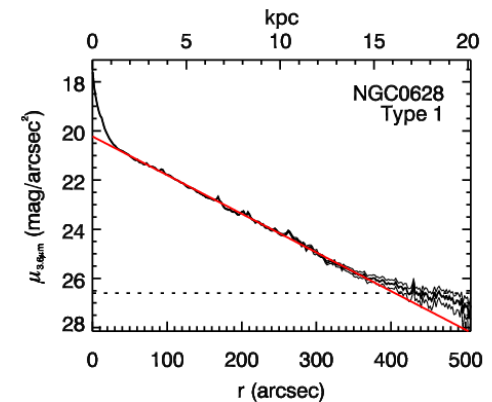
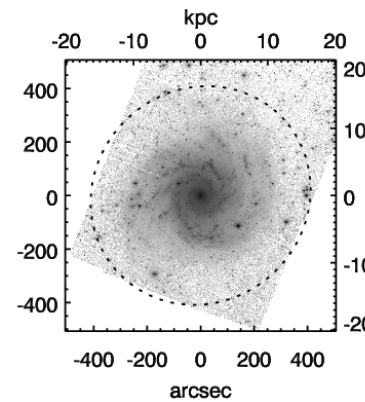
Kartik Sheth, Armando Gil de Paz, Sharon Meidt
+ the S⁴G team



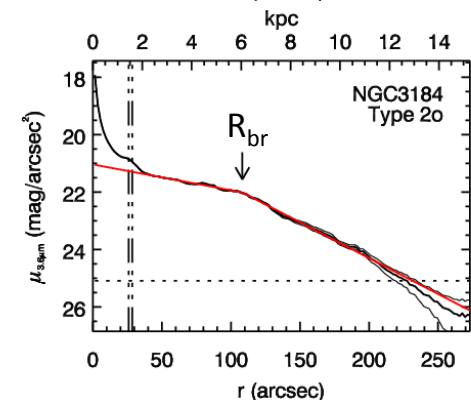
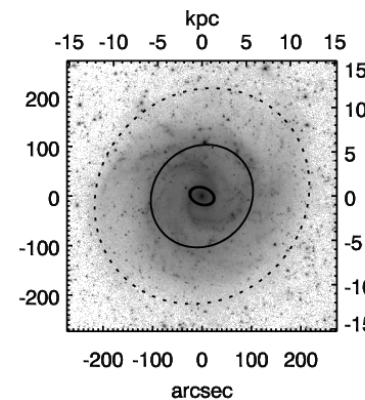
EWASS 2015
June 22-26
Tenerife

Disks come in three flavors

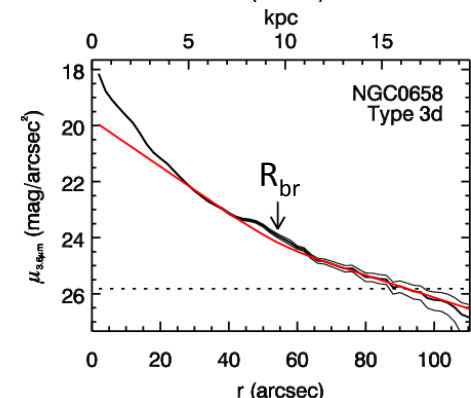
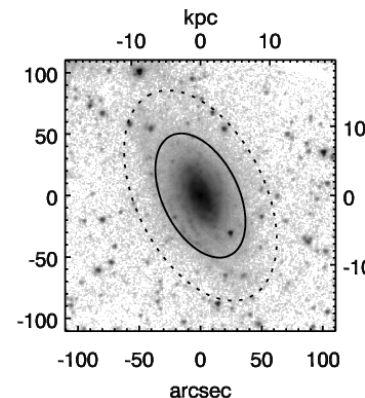
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Single exponential



- ❖ Type II (60%)
Downbending exponential



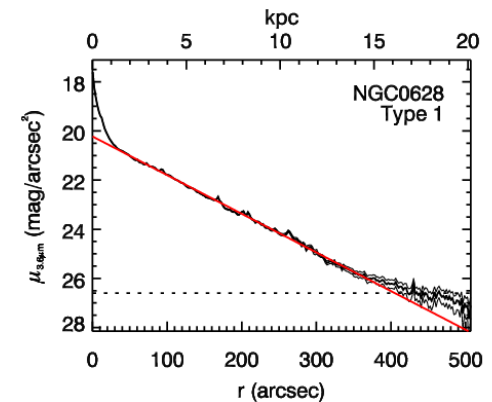
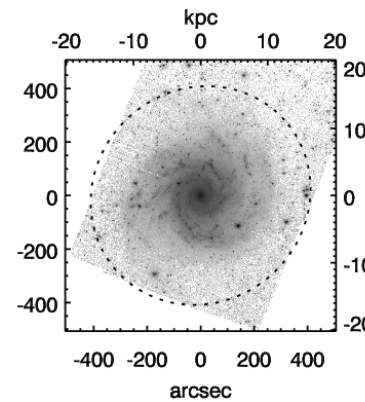
- ❖ Type III (30%)
Upbending exponential



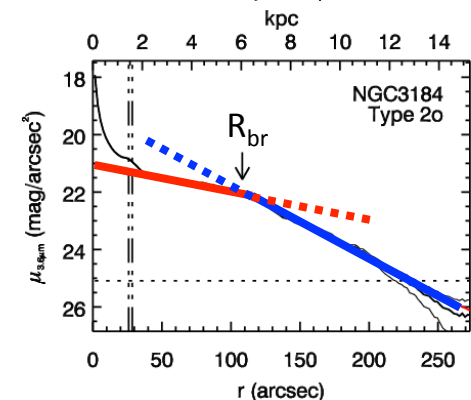
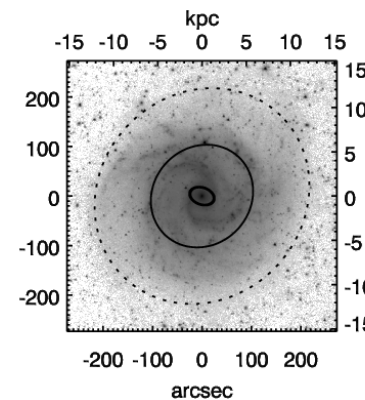
Work by Freeman, van der Kruit,
Erwin, Pohlen, Trujillo...

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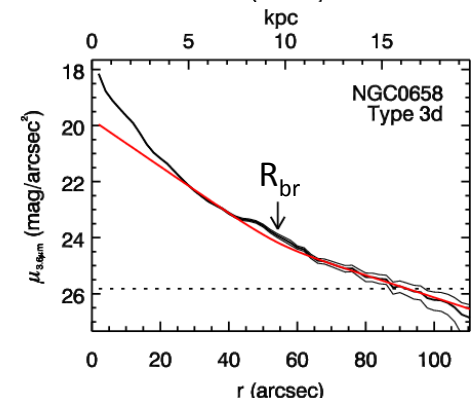
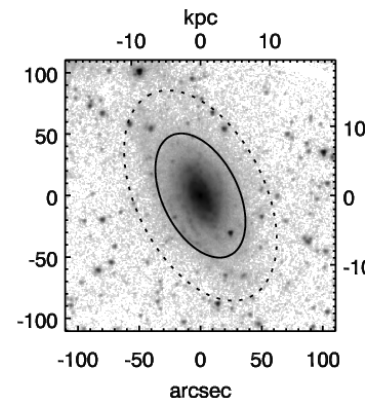
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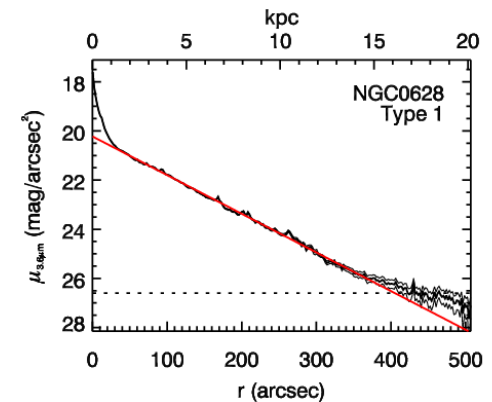
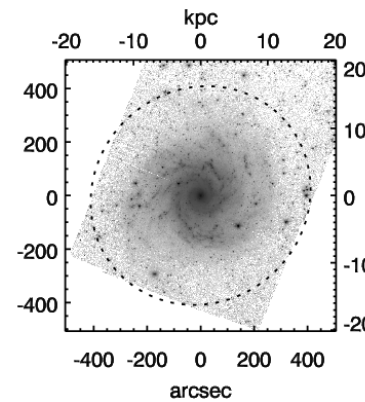
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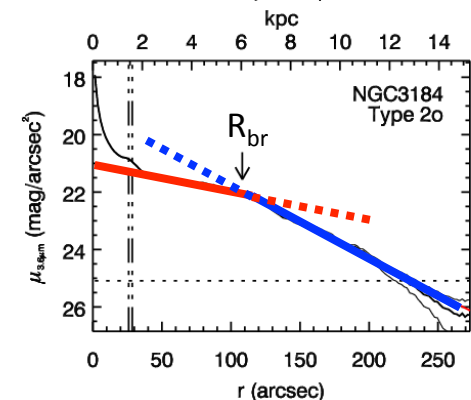
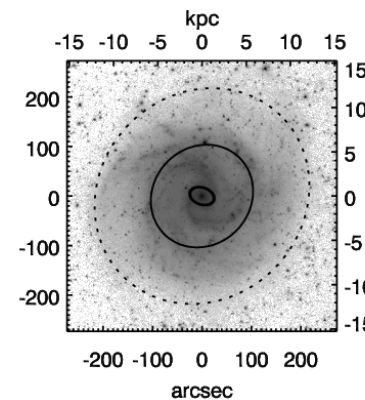
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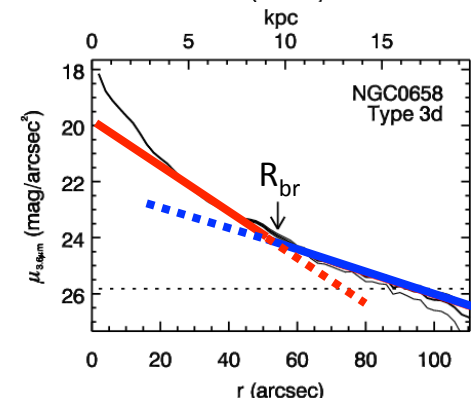
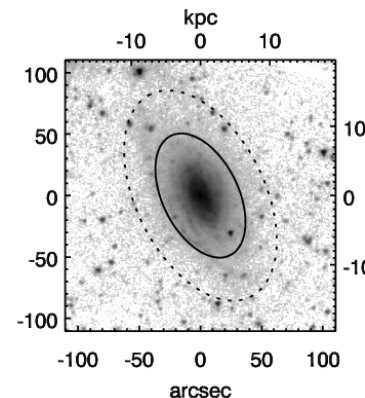
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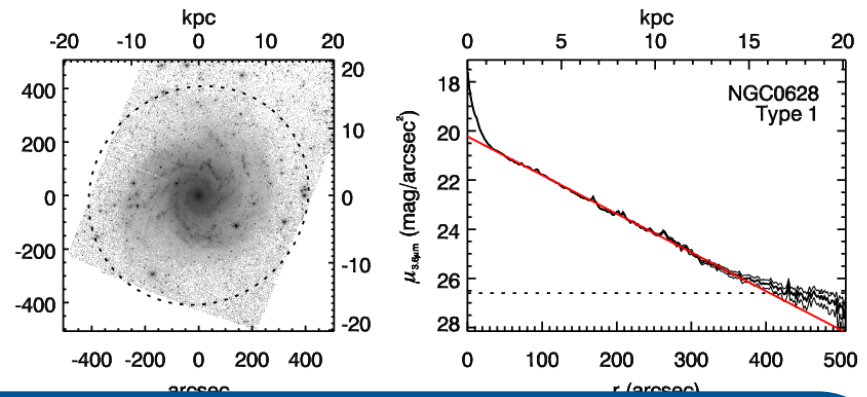
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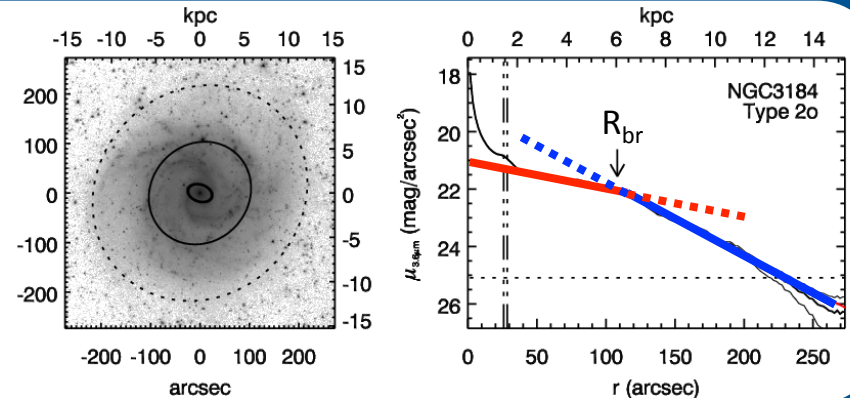
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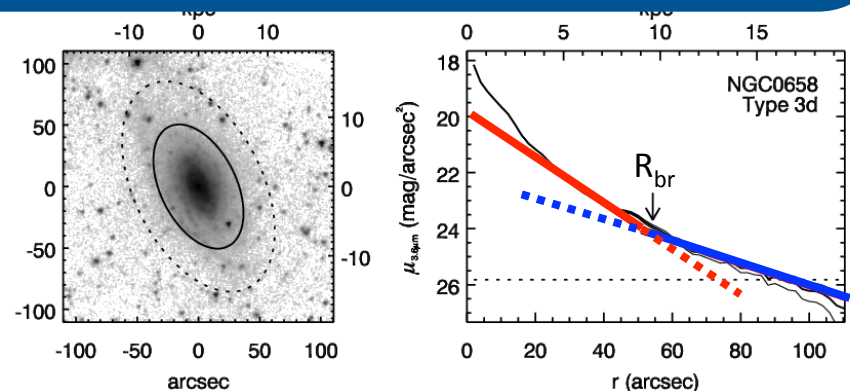
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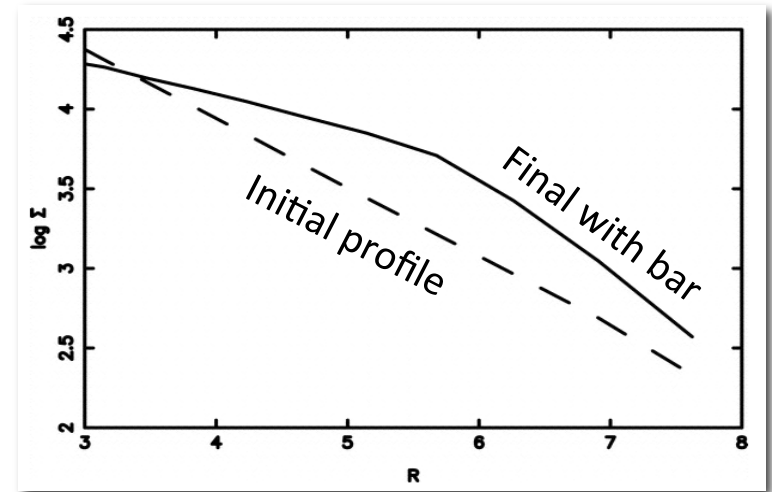
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Work by Freeman, van der Kruit,
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Two scenarios for break formation

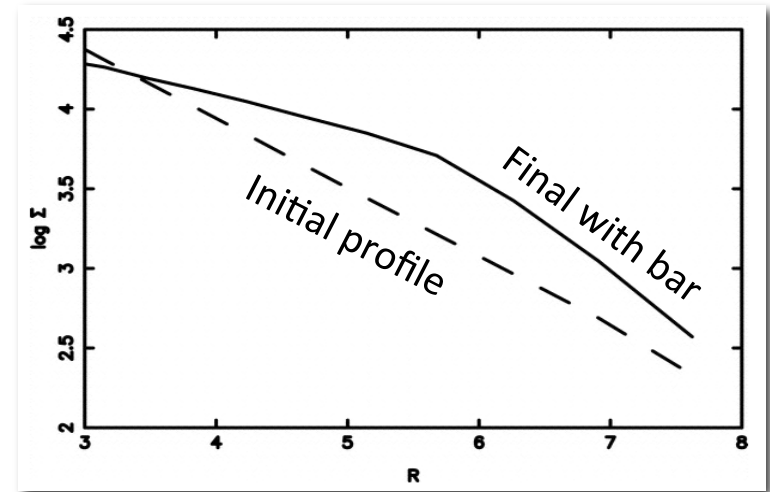
- ❖ Redistribution of angular momentum by bars and/or spirals.



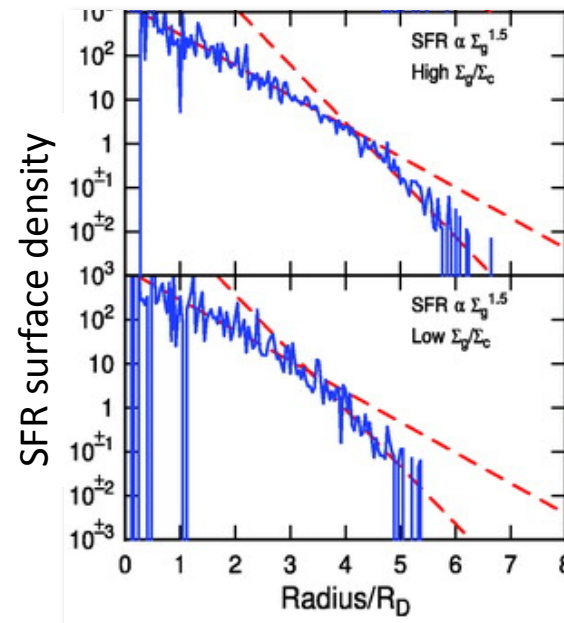
Debattista et al. (2006)

Two scenarios for break formation

- ❖ Redistribution of angular momentum by bars and/or spirals.
- ❖ Radial changes in the star formation efficiency.



Debatista et al. (2006)



Elmegreen
& Hunter (2006)



The Spitzer Survey of Stellar Structure in Galaxies (Sheth+2010)

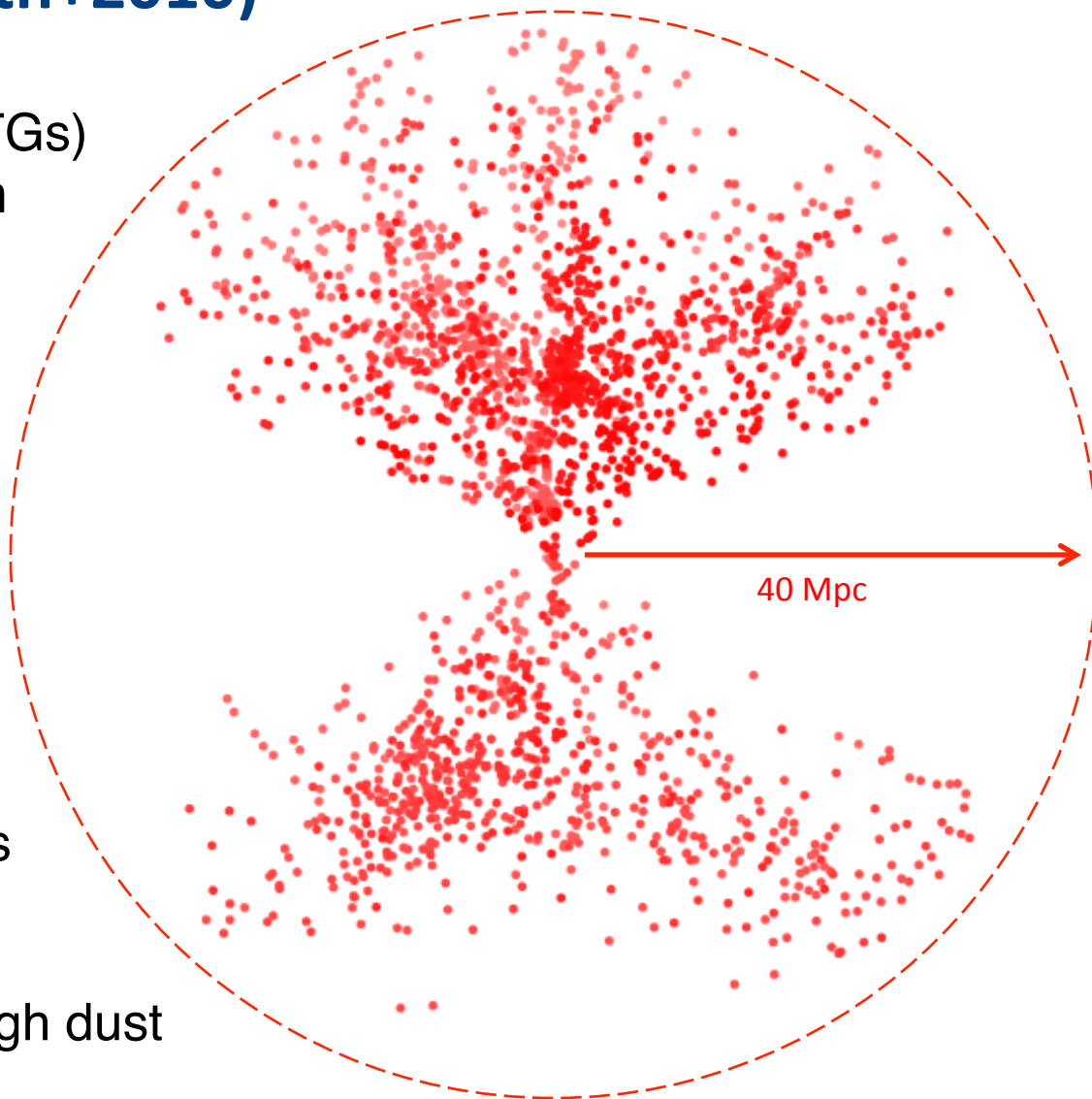
2352 galaxies (+ 465 ETGs)
observed at 3.6 & $4.5\mu\text{m}$

$\text{Dist} < 40 \text{ Mpc}$, $|\text{bl}| > 30^\circ$
 $m_{\text{Bcorr}} < 15.5$, $D_{25} > 1'$

Very deep IR images
 $\mu_{3.6\mu\text{m}} \sim 27 \text{ ABmags/arcsec}^2$
($\sim 1 \text{ M}_\odot/\text{pc}^2$)

Directly probing old stars

We can easily see through dust





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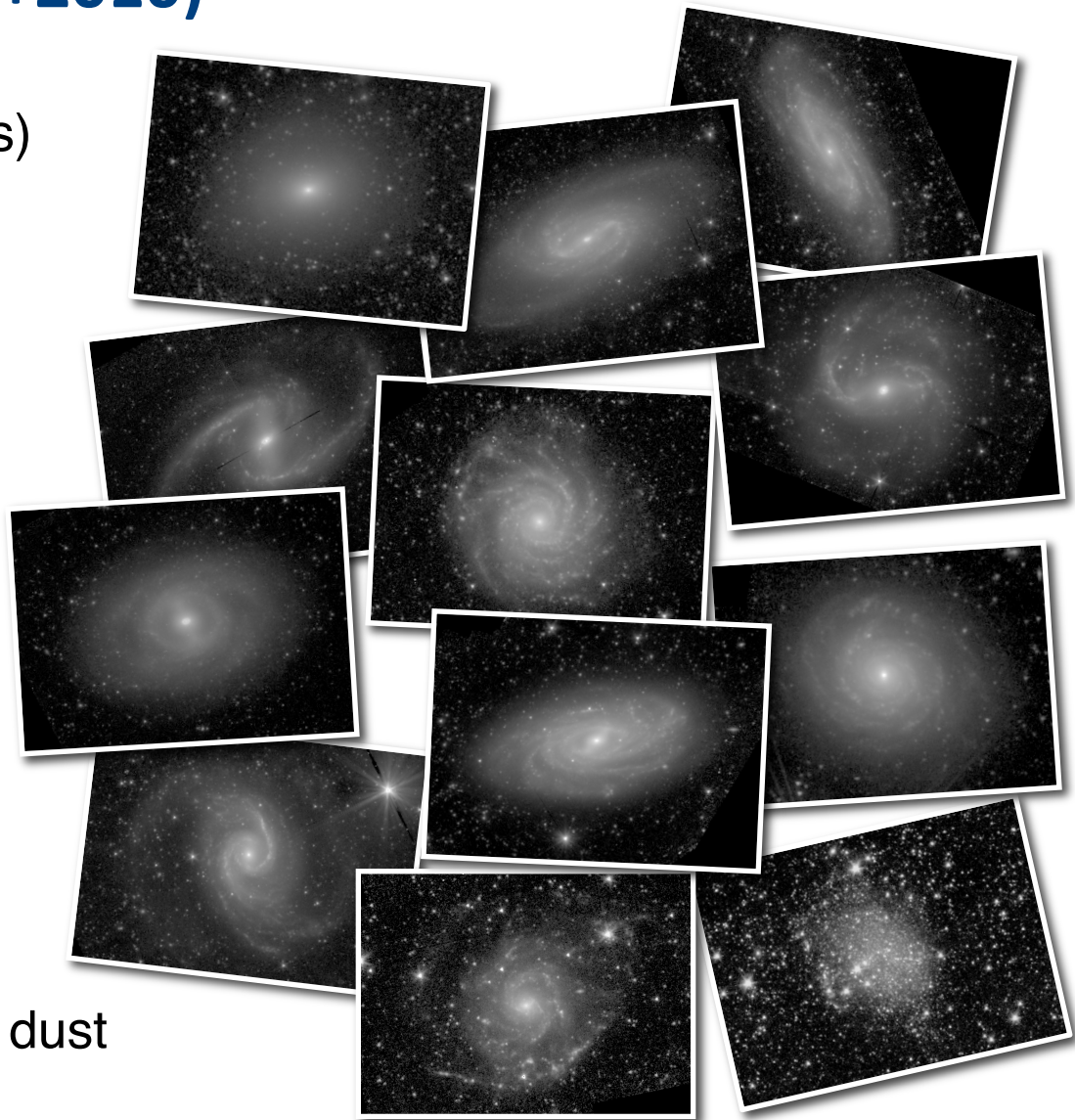
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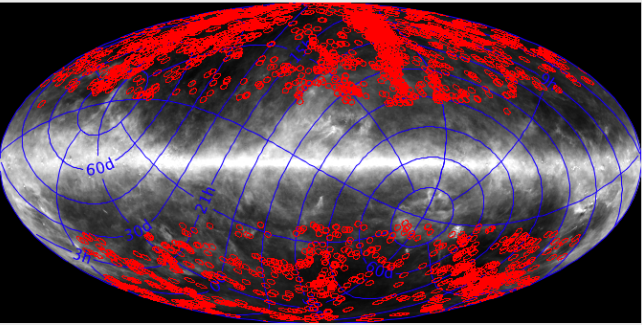
Data access at IRSA

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 1 and 2 (3.6 and 4.5 microns).

IRSA hosts the complete S4G project data set, including results from galaxy modeling using ellipse 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** overlays on the above image, or by typing a coordinate below.

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

The 2,352 S4G galaxies are represented as overlays in **red** on the all-sky [ISSA](#) image above. Use the form below to enter a coordinate or object name to search for data, or click on any red region to get a close-up of the area.

The canonical papers for S4G are [Sheth et al. \(2010\)](#), [Regan et al. \(in prep\)](#), and [Munoz-Mateos et al. \(2013\)](#).

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

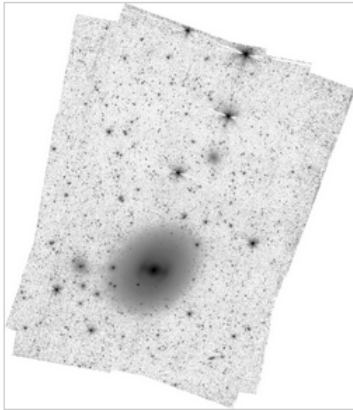
COLUMN CONSTRAINTS/OUTPUT COLUMN SELECTION

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)
ellip1_25p5	Ellipticity (1-b/a) at mu_3.6 = 25.5 AB mag/arcsec2	☒					float(126)
mag1	Asymptotic magnitude at 3.6 microns	☒			AB		float(126)
emag1	Growth-curve fitting error in mag1	☐			AB		float(126)
mag2	Asymptotic magnitude at 4.5 microns	☒			AB		float(126)
emag2	Growth-curve fitting error in mag2	☐			AB		float(126)
c31_1	r75/r25 concentration index at 3.6 microns	☒					float(126)
c42_1		☐					

IRAC Data



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:

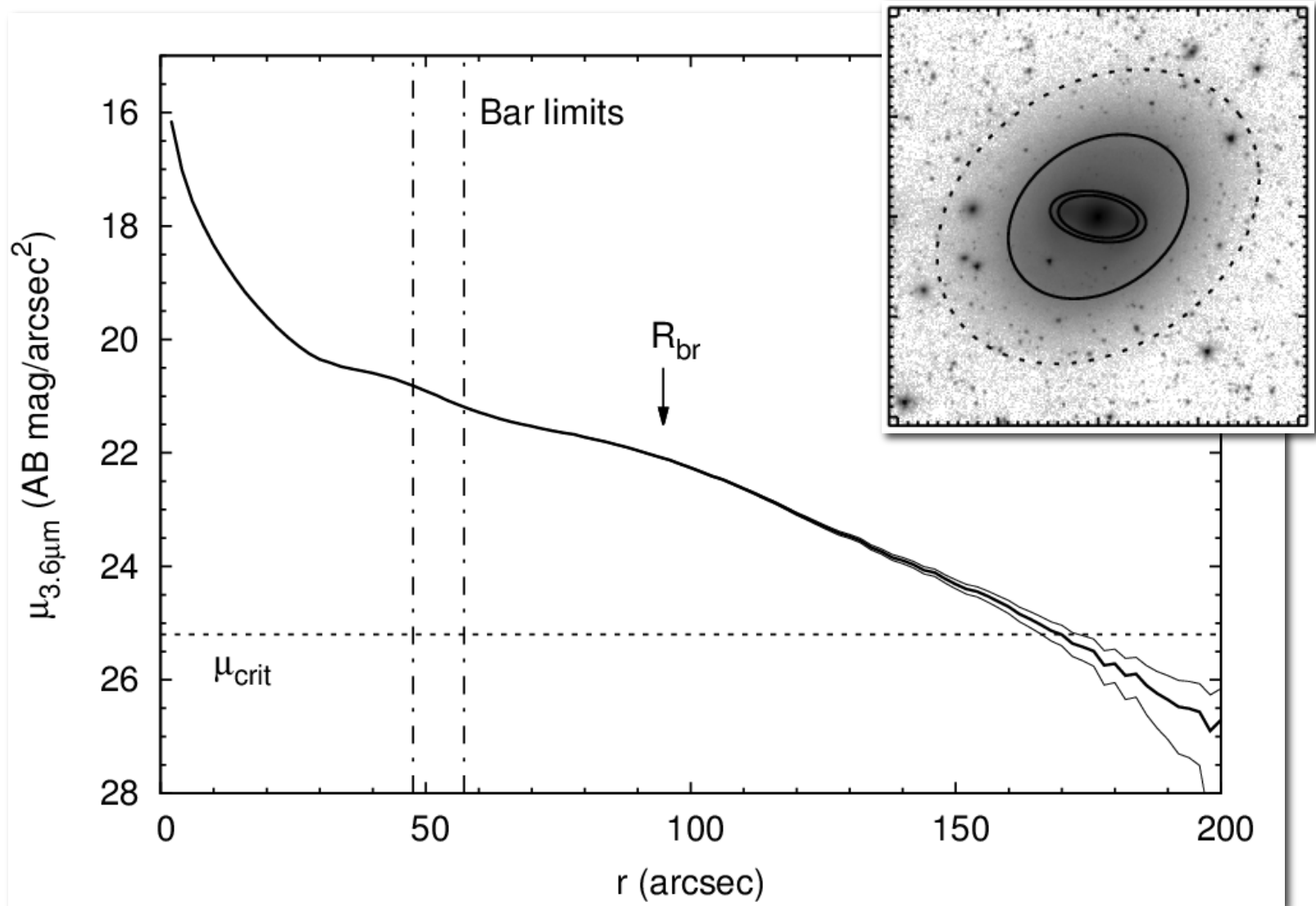
[Download Galfit results](#)

Muñoz-Mateos et al. (2015)

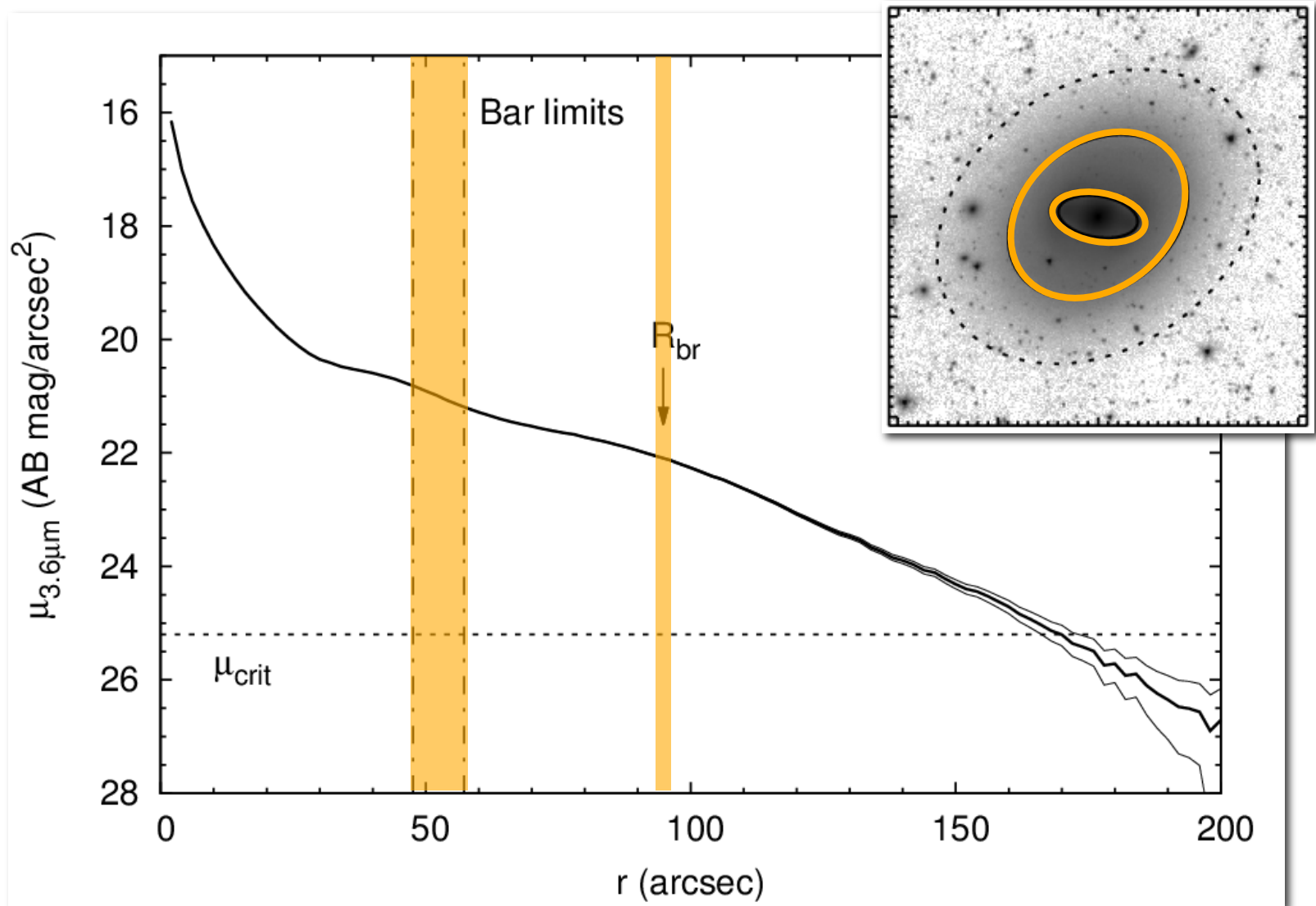
Salo et al. (2015)

Querejeta et al. (2015)

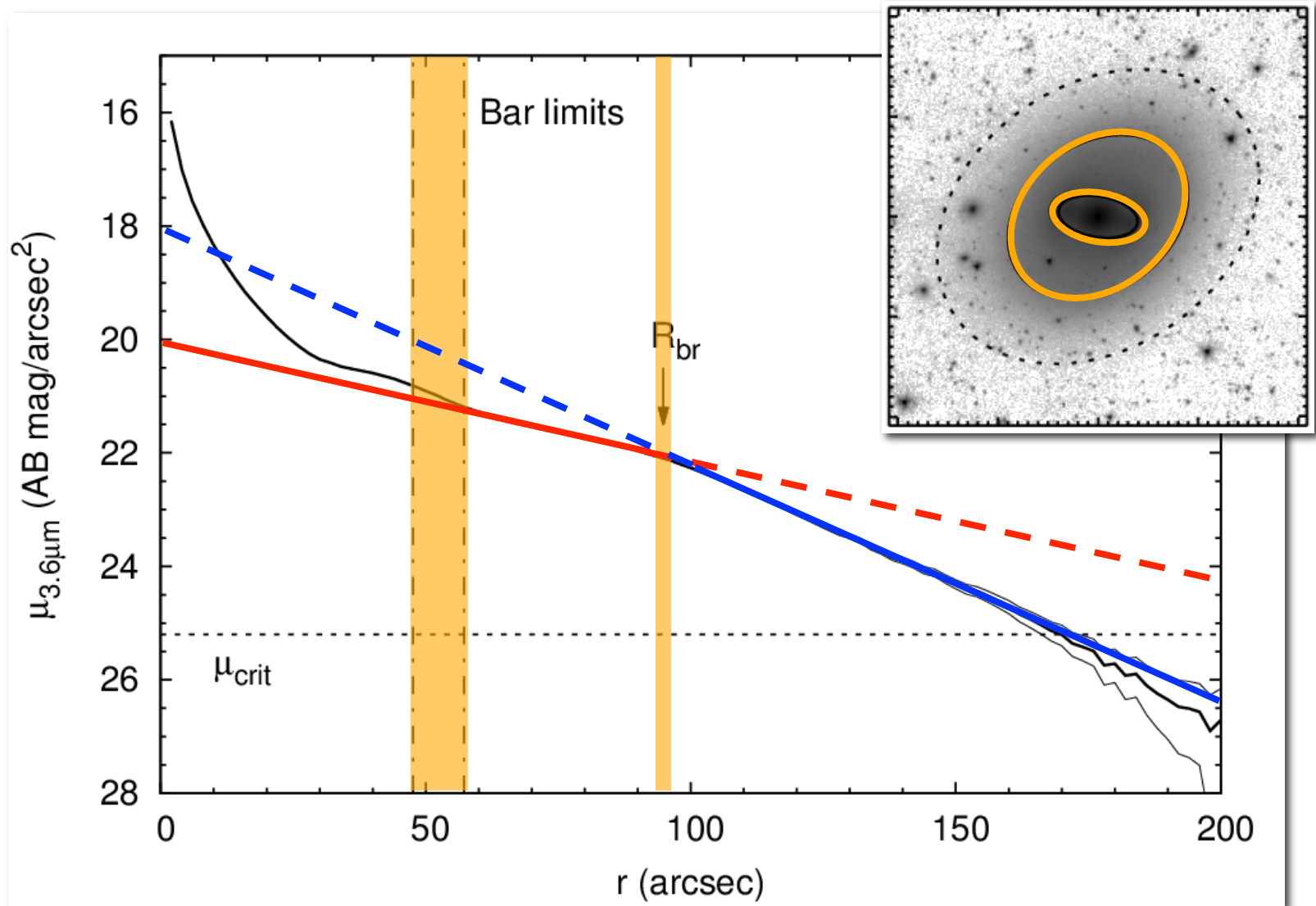
Measuring breaks and bars



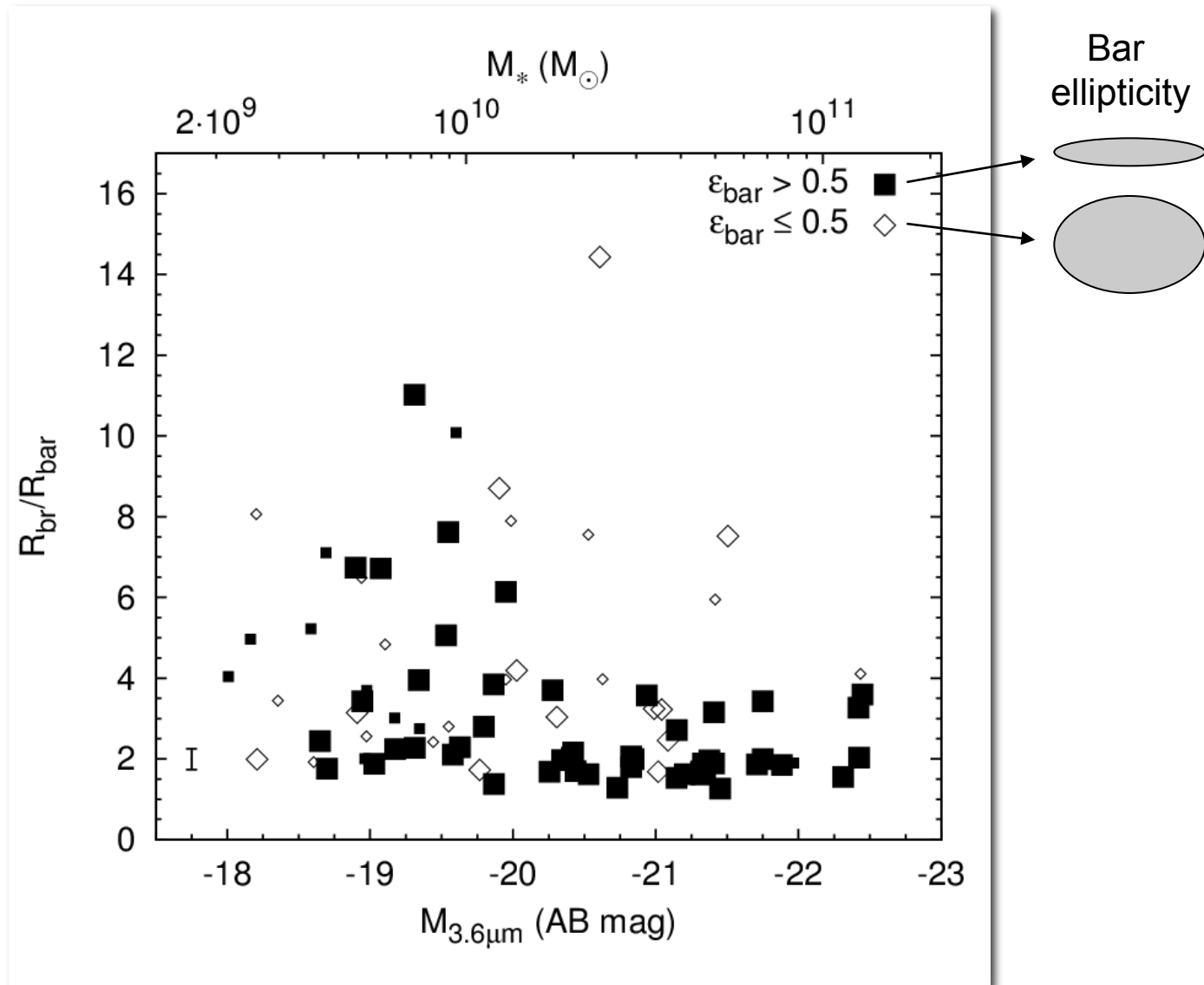
Measuring breaks and bars



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:

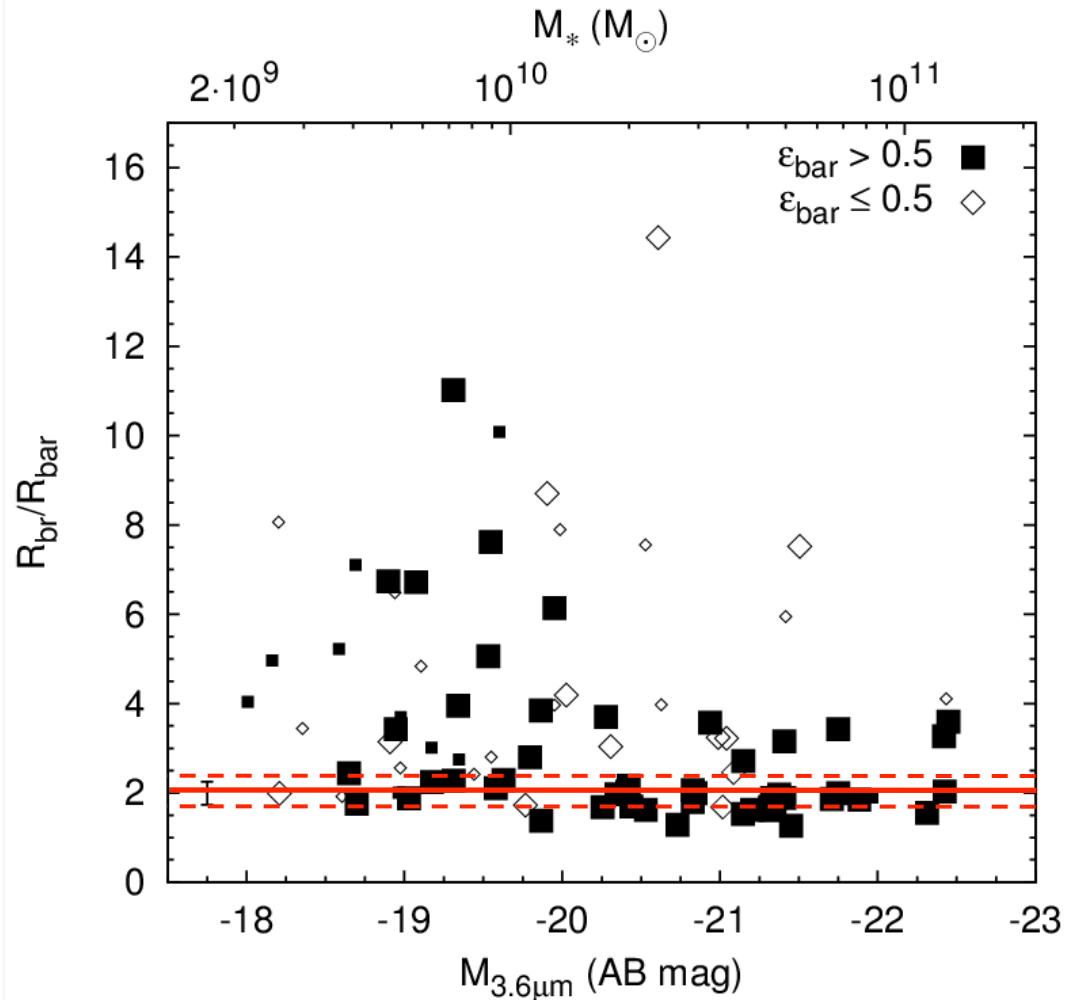
- $V = \text{constant}$
- $\Omega \propto 1/r$
- $R_{\text{OLR}} \sim 1.7 R_{\text{CR}}$

❖ In general:

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

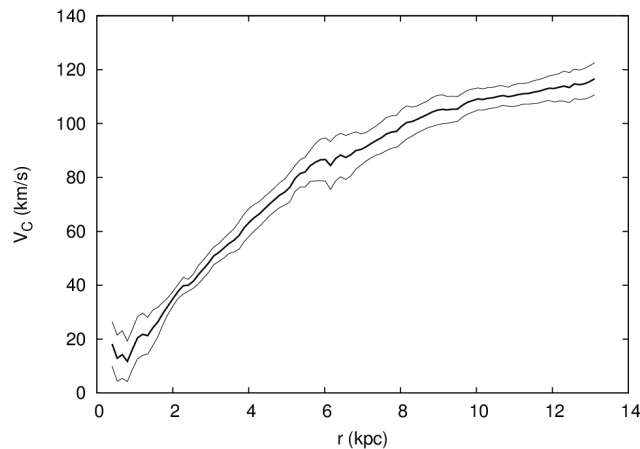
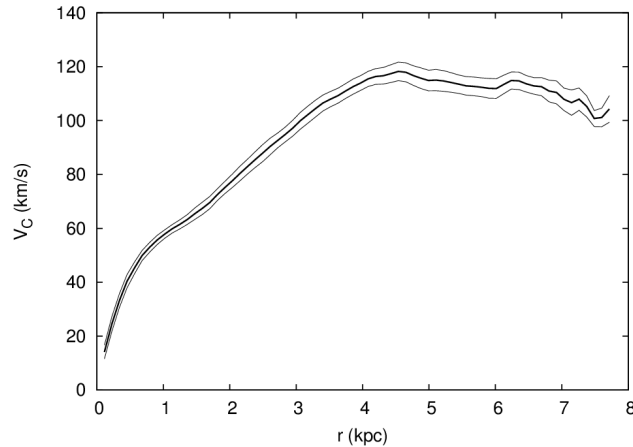
❖ Therefore:

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

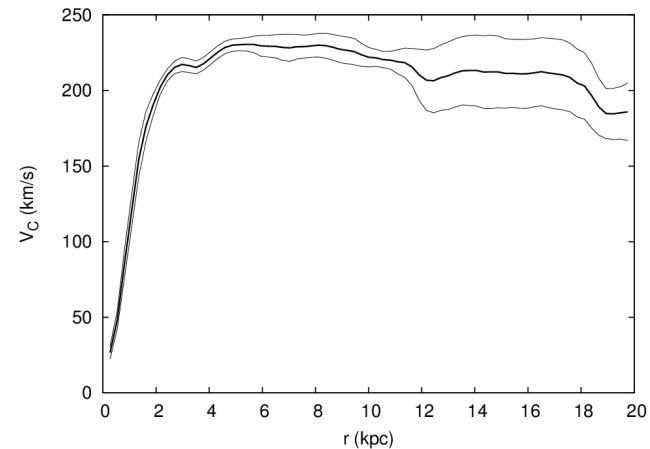
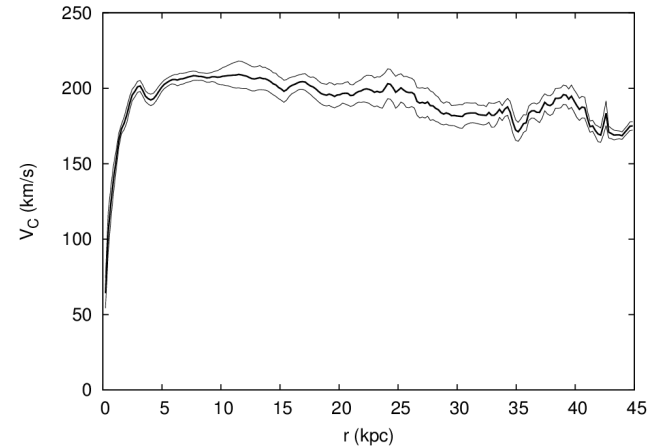


Rotation curves are not always flat

Low mass

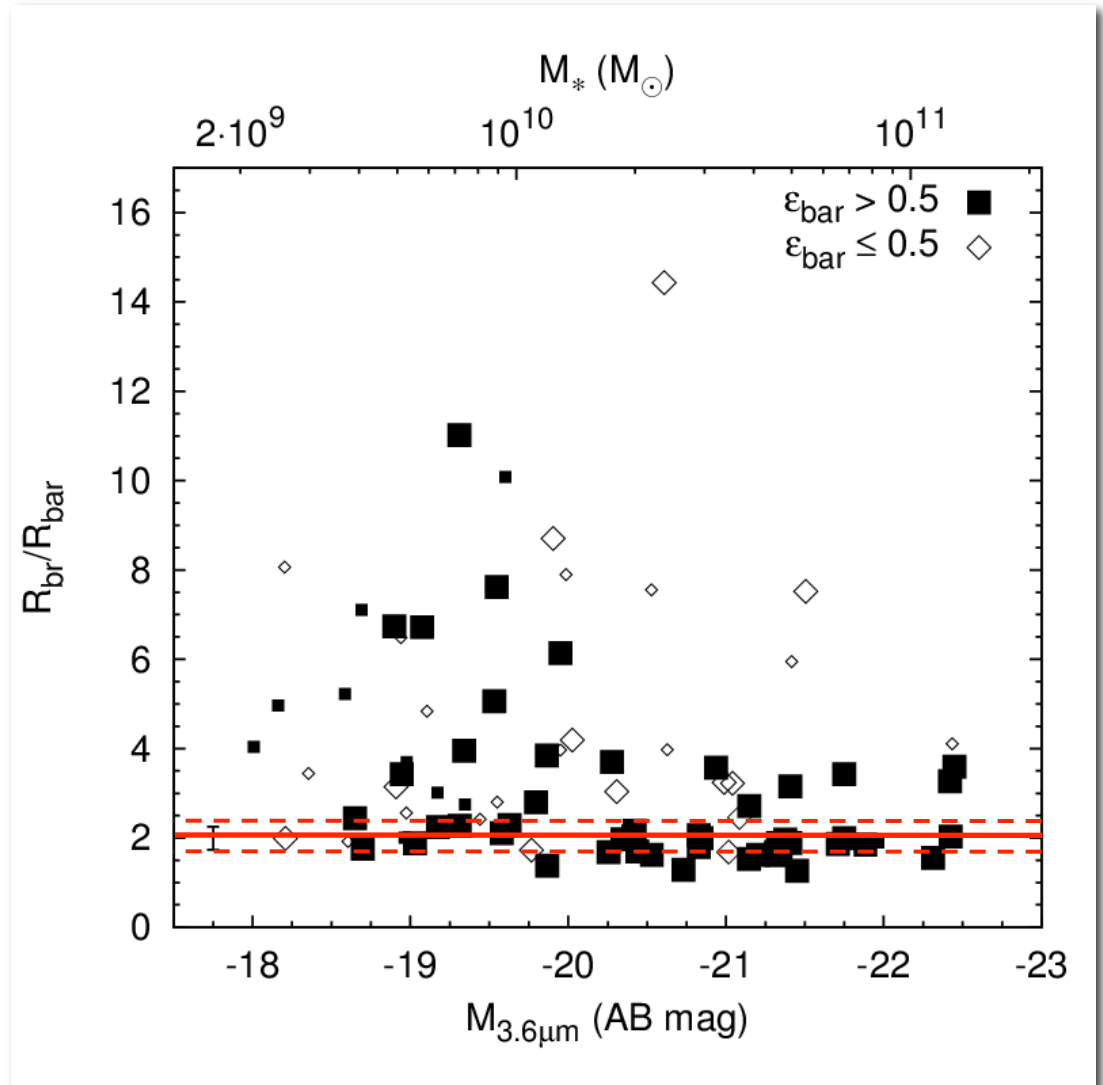


High mass



de Blok et al. (2008)

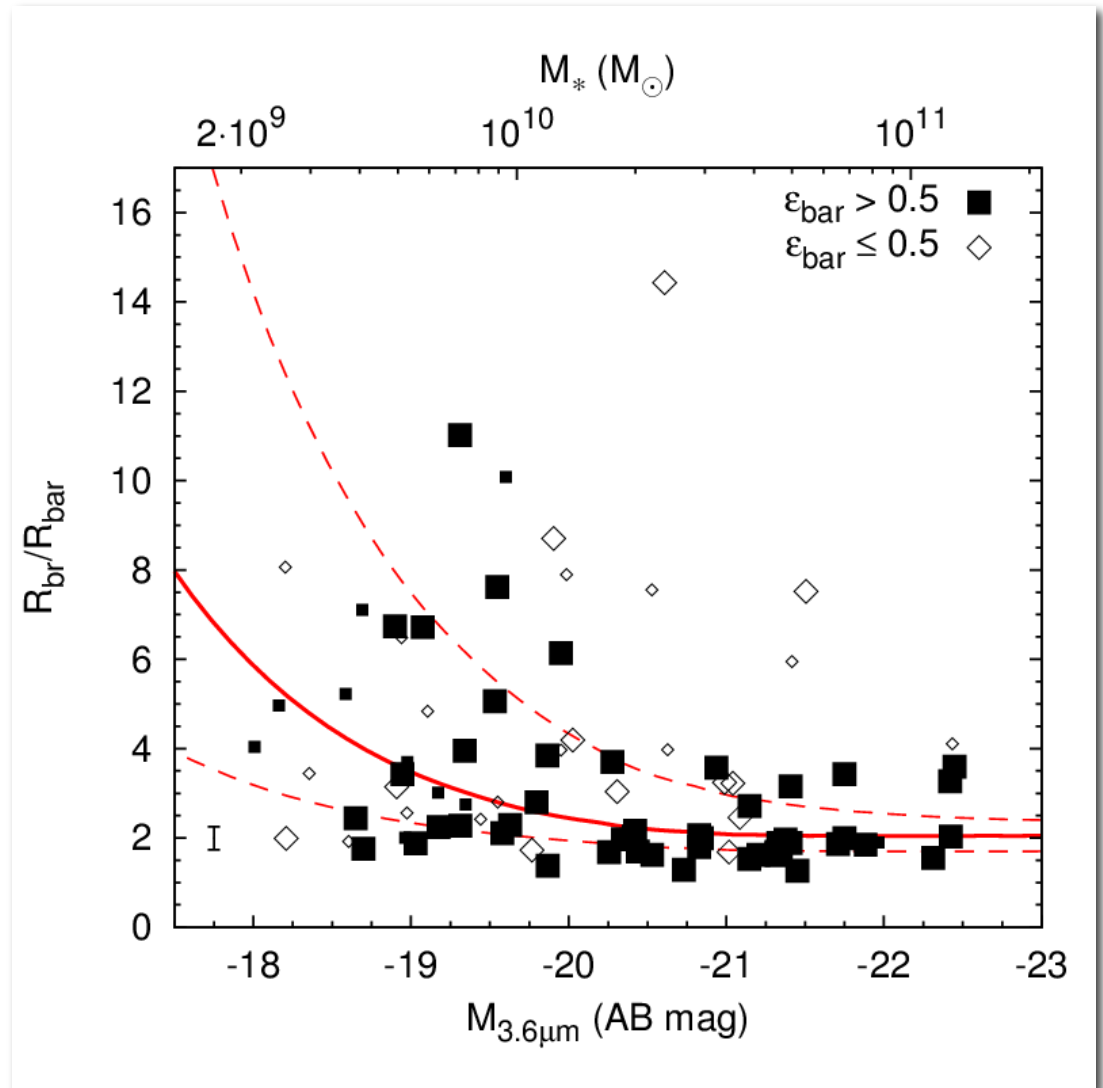
Rising rotation curves push the OLR further out



Muñoz-Mateos et al. (2013)

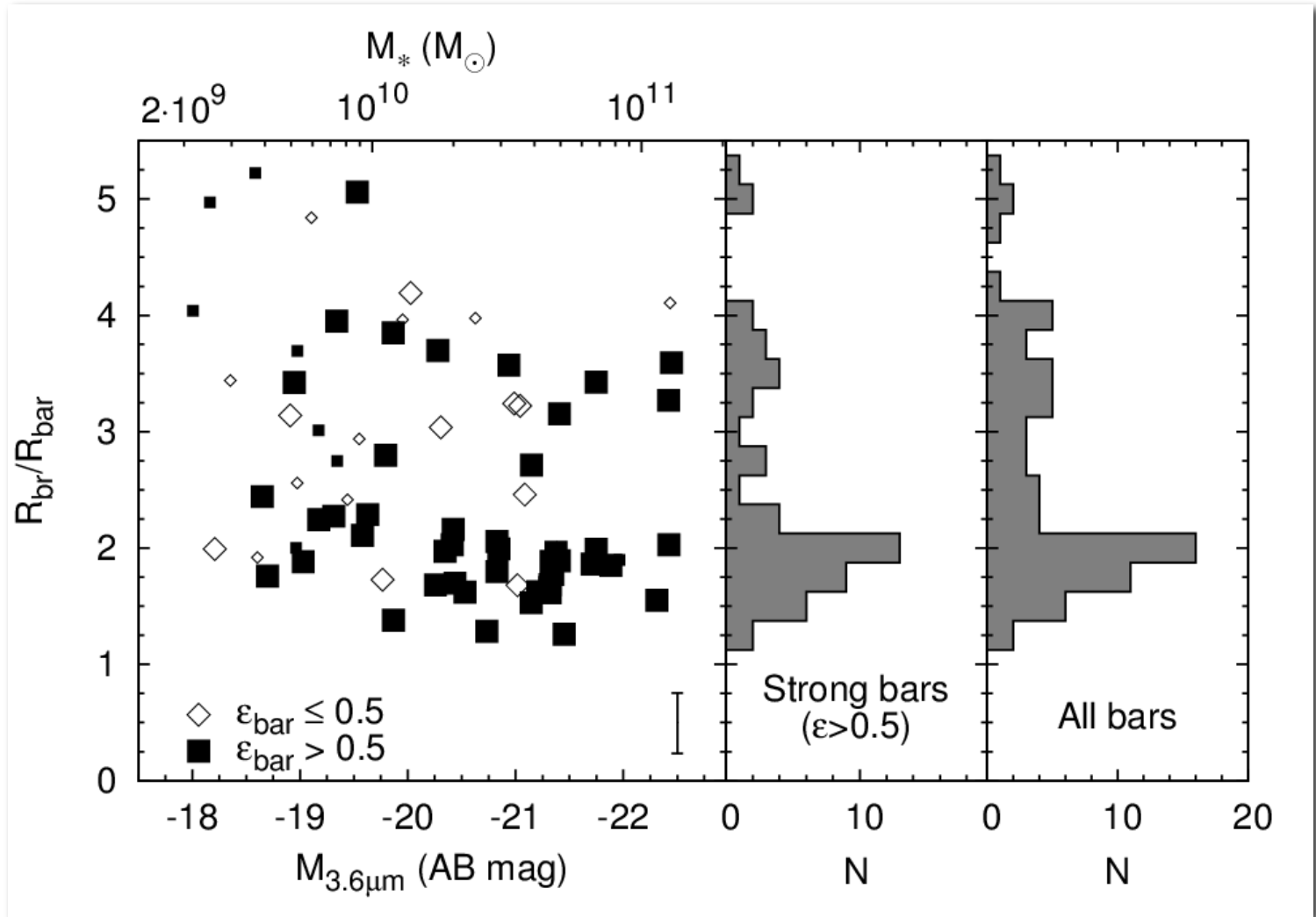
Rising rotation curves push the OLR further out

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



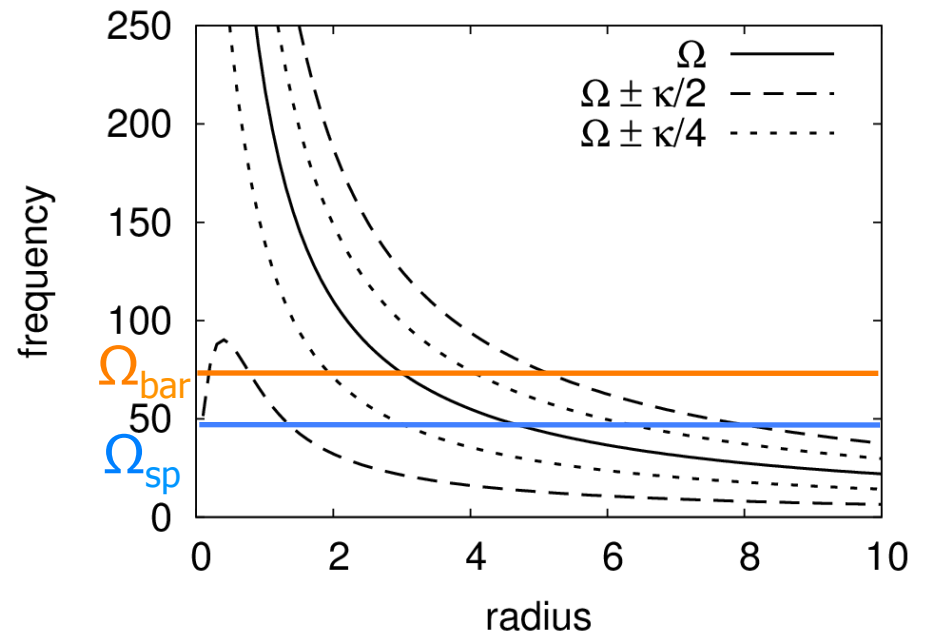
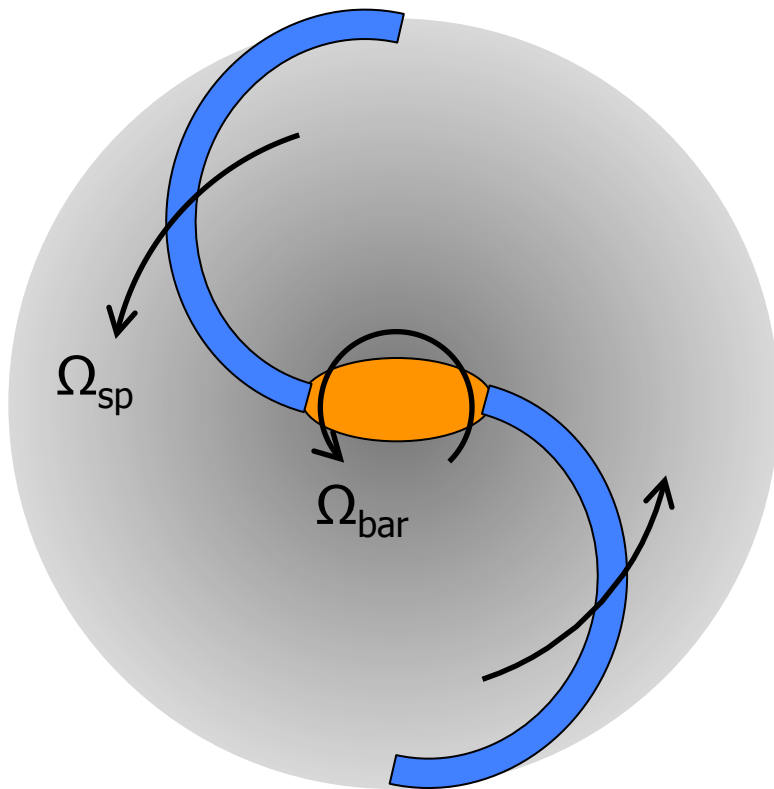
Muñoz-Mateos et al. (2013)

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

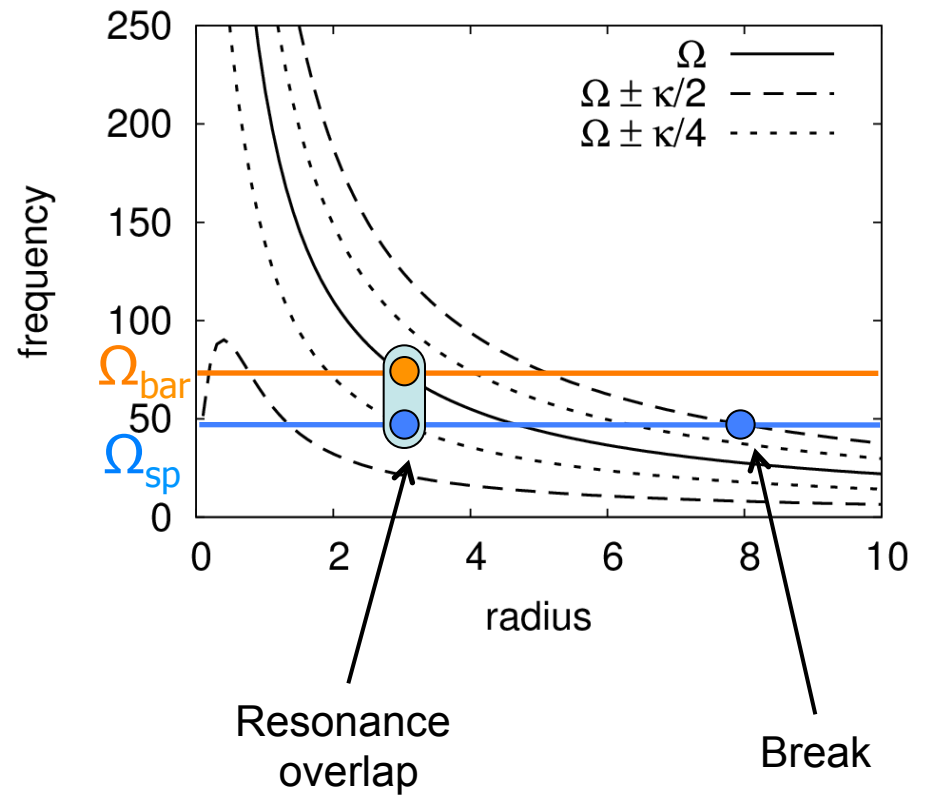
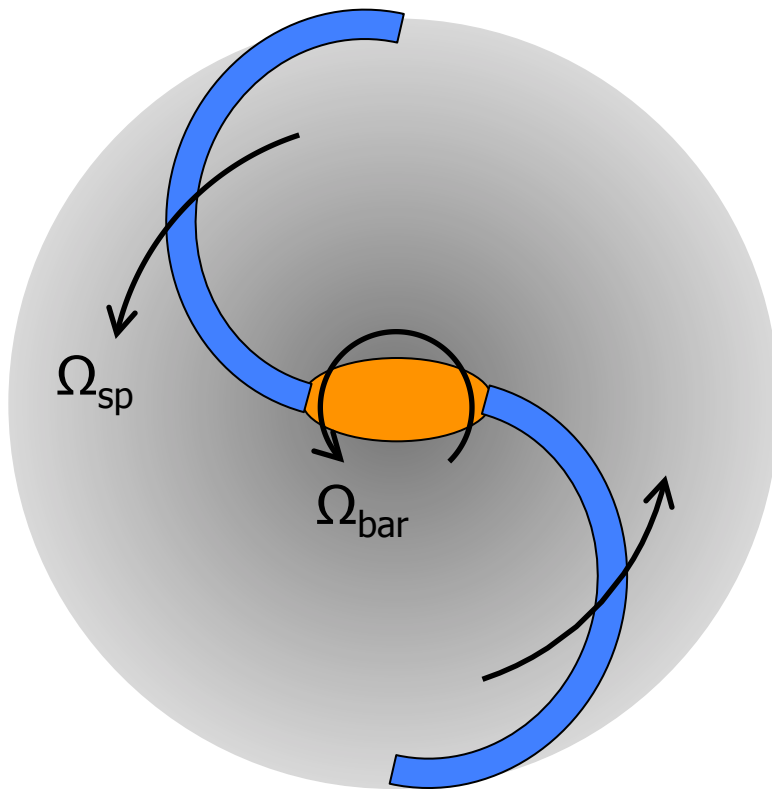


Muñoz-Mateos et al. (2013)

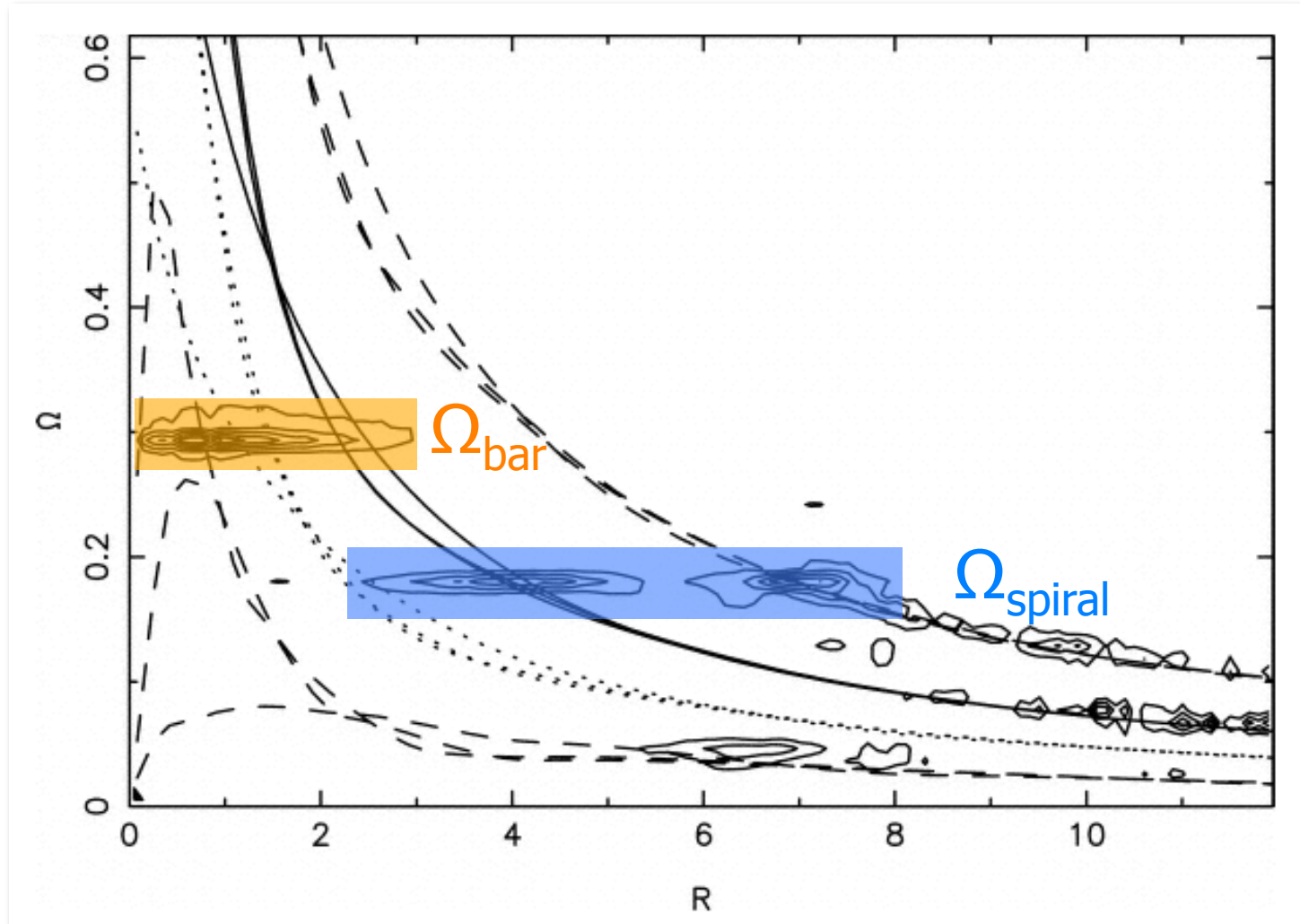
Bars and spiral arms can couple



Bars and spiral arms can couple



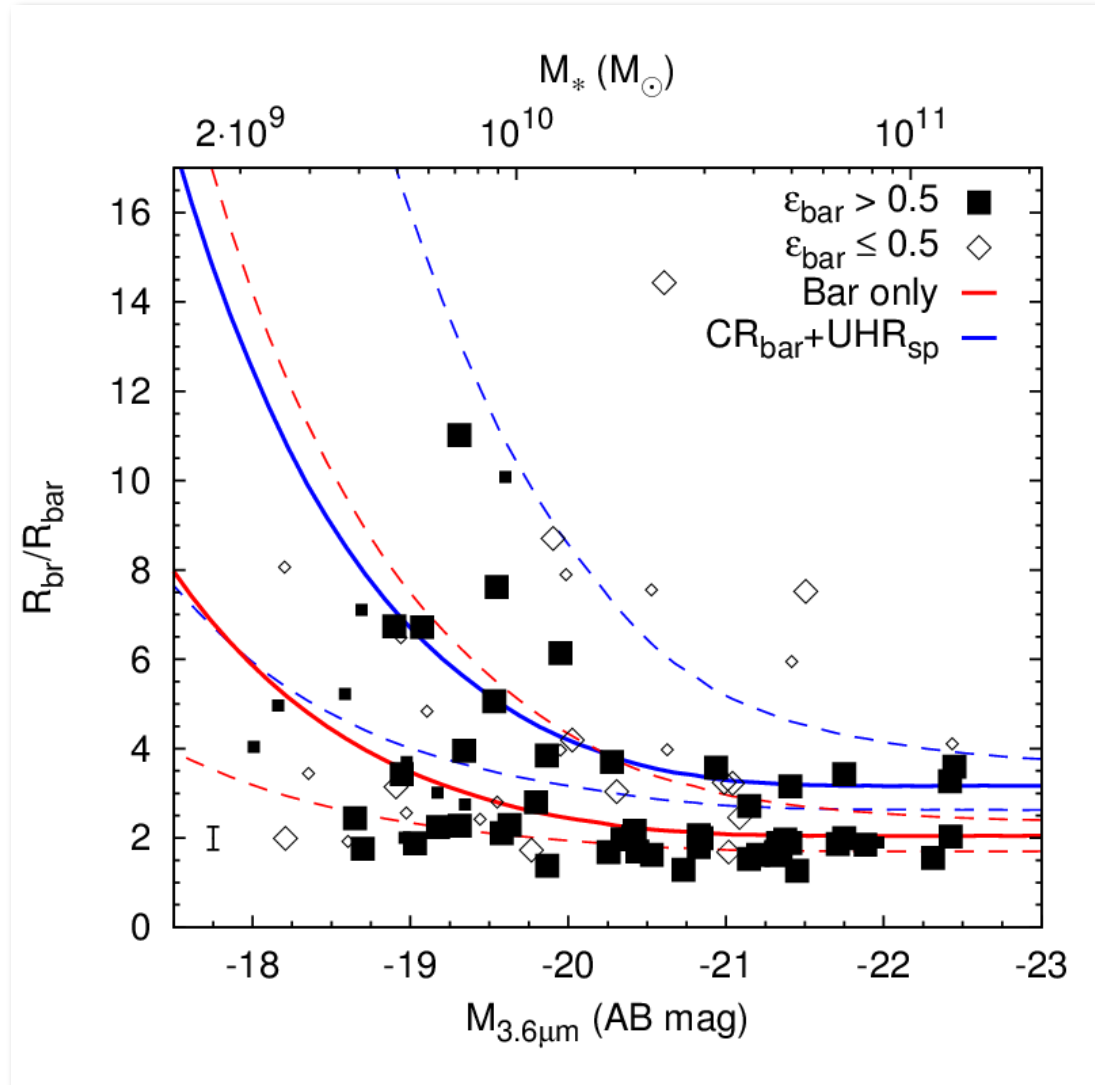
Bars and spiral arms can couple



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).

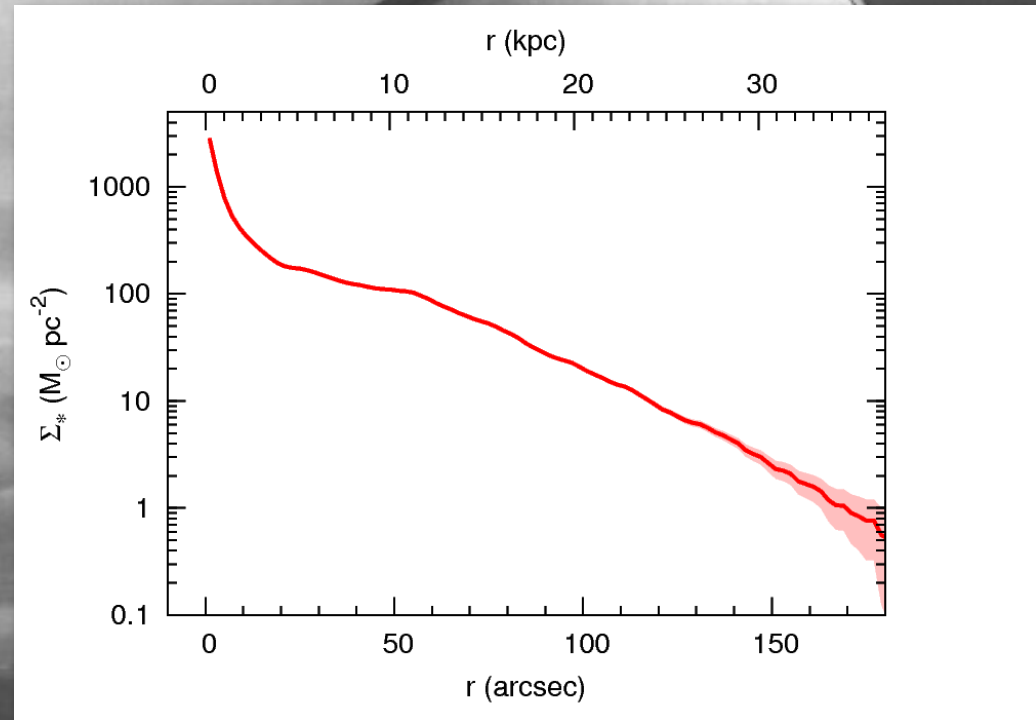
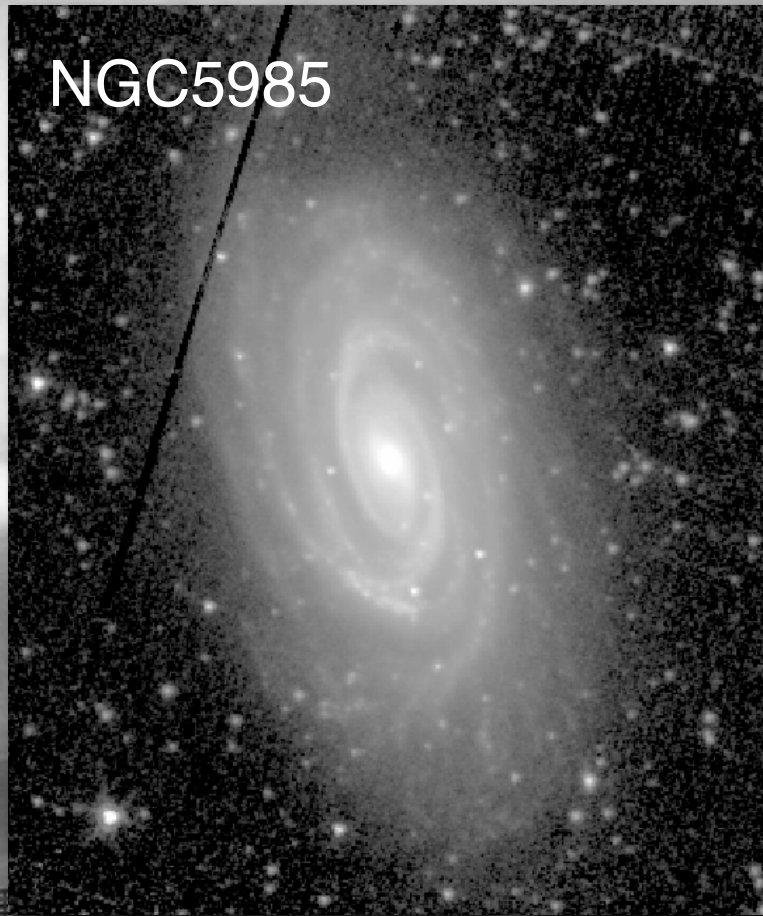


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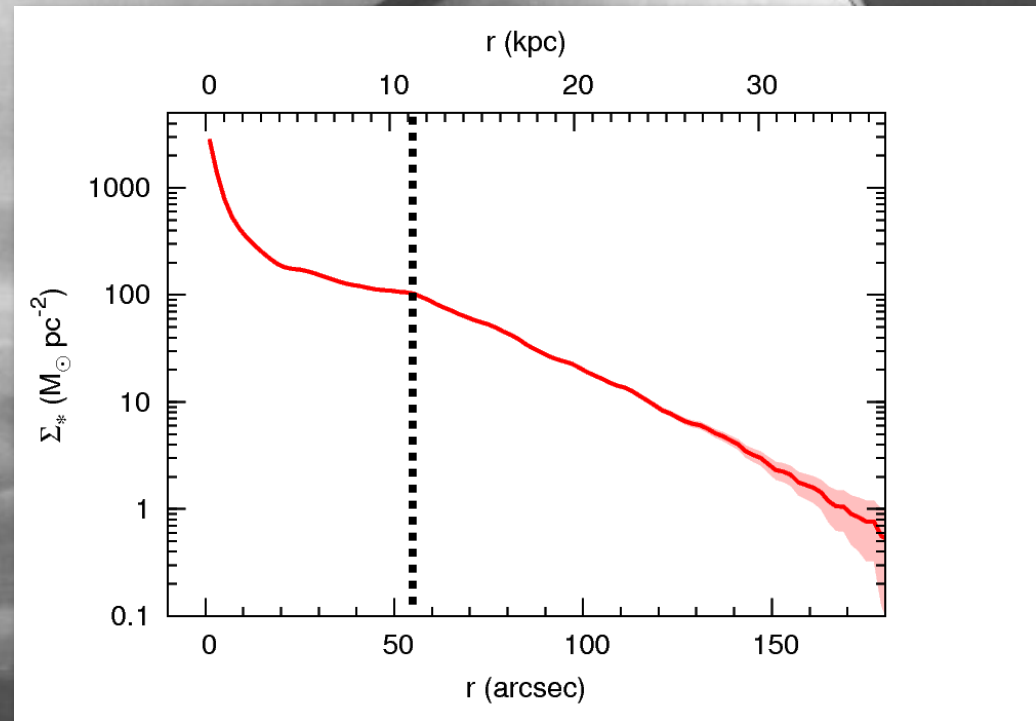
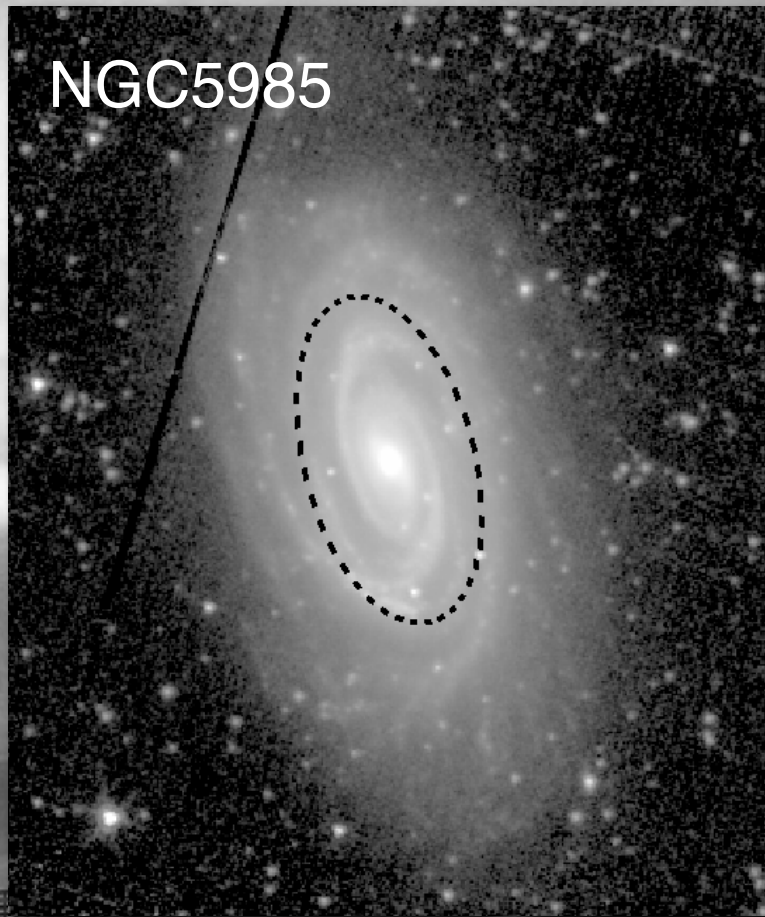
Is the H_2 profile broken too?



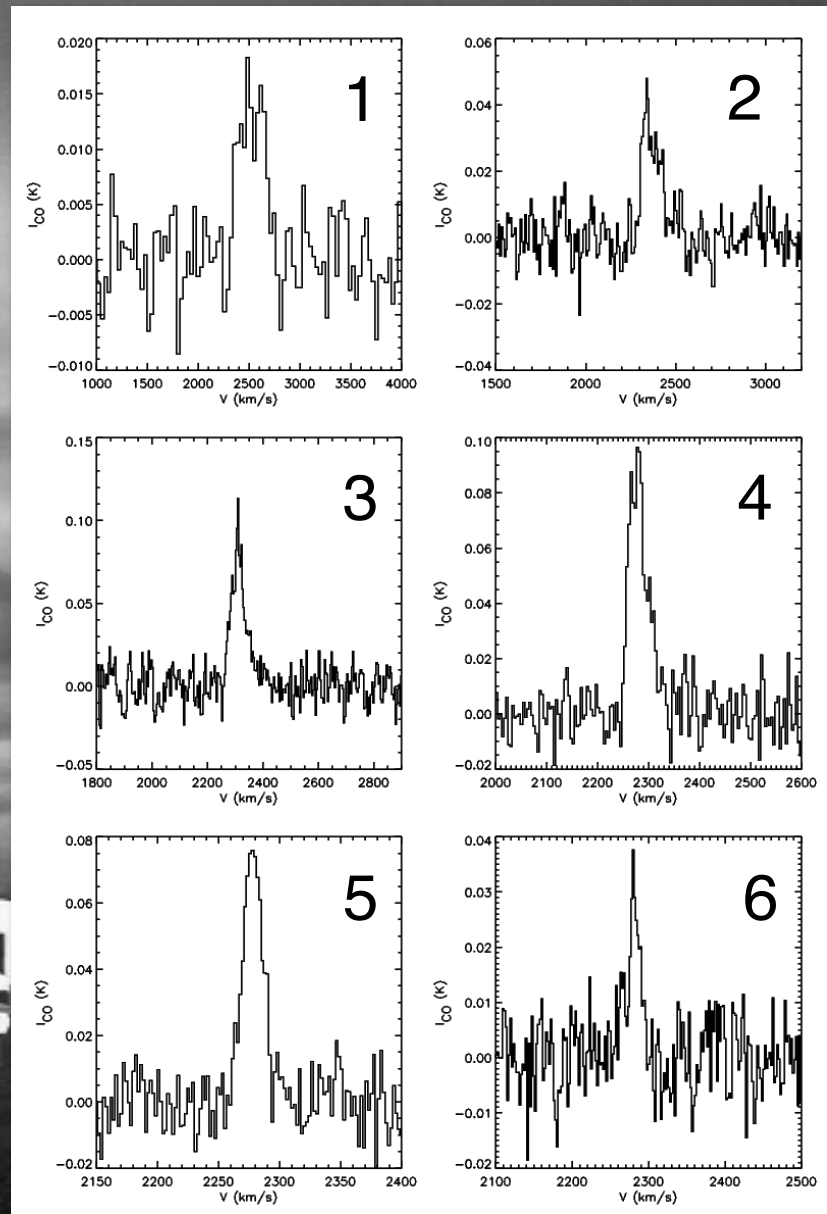
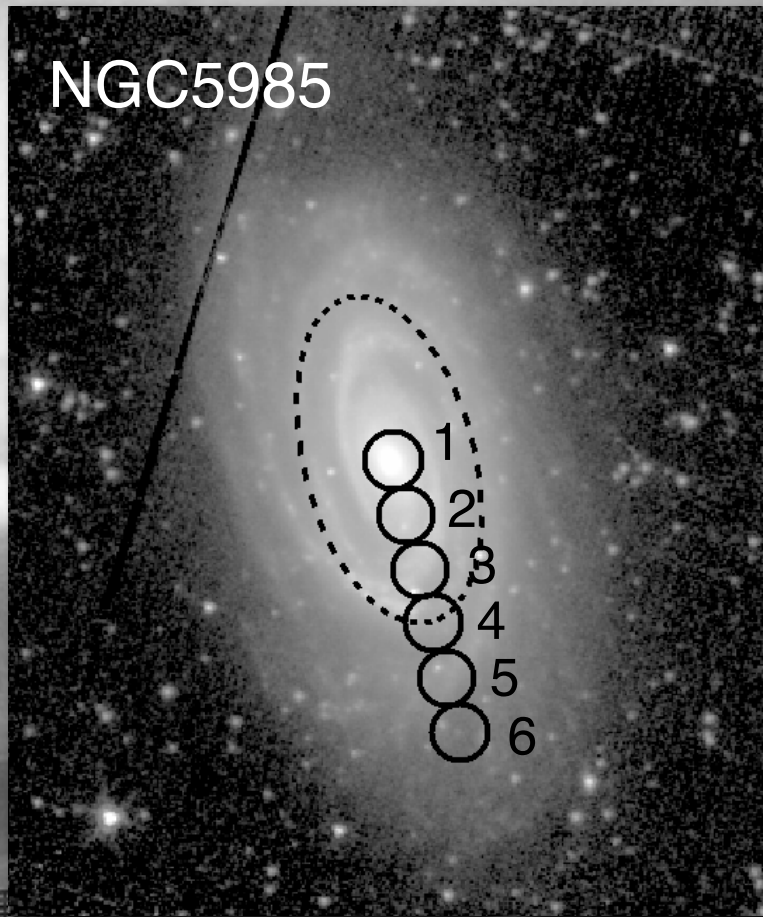
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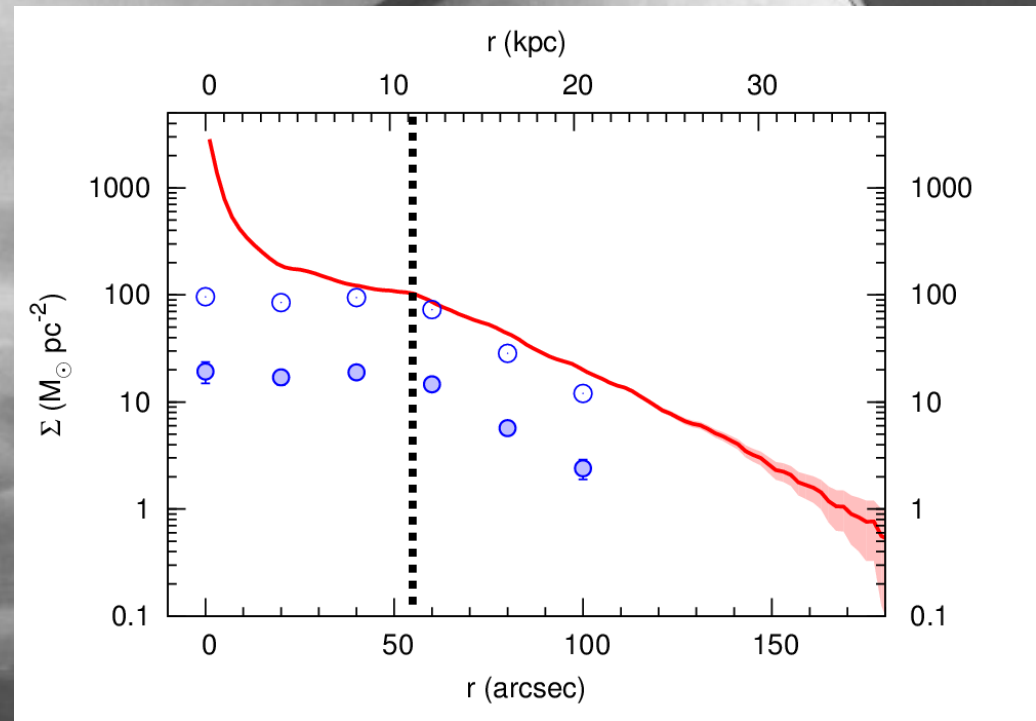
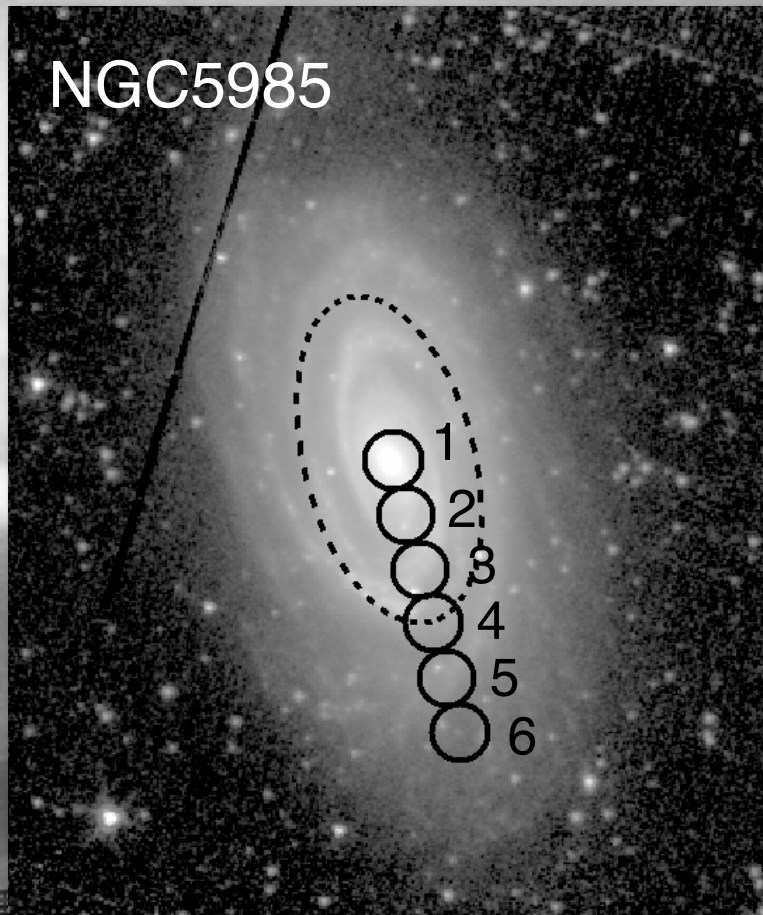
Is the H_2 profile broken too?



Is the H_2 profile broken too?



Is the H₂ 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.