Galactic and Extragalatic Astronomy
AA 472/672
Spring Semester

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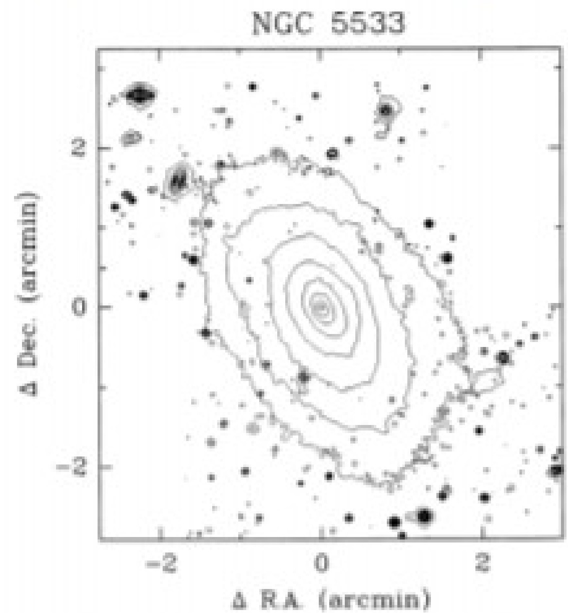
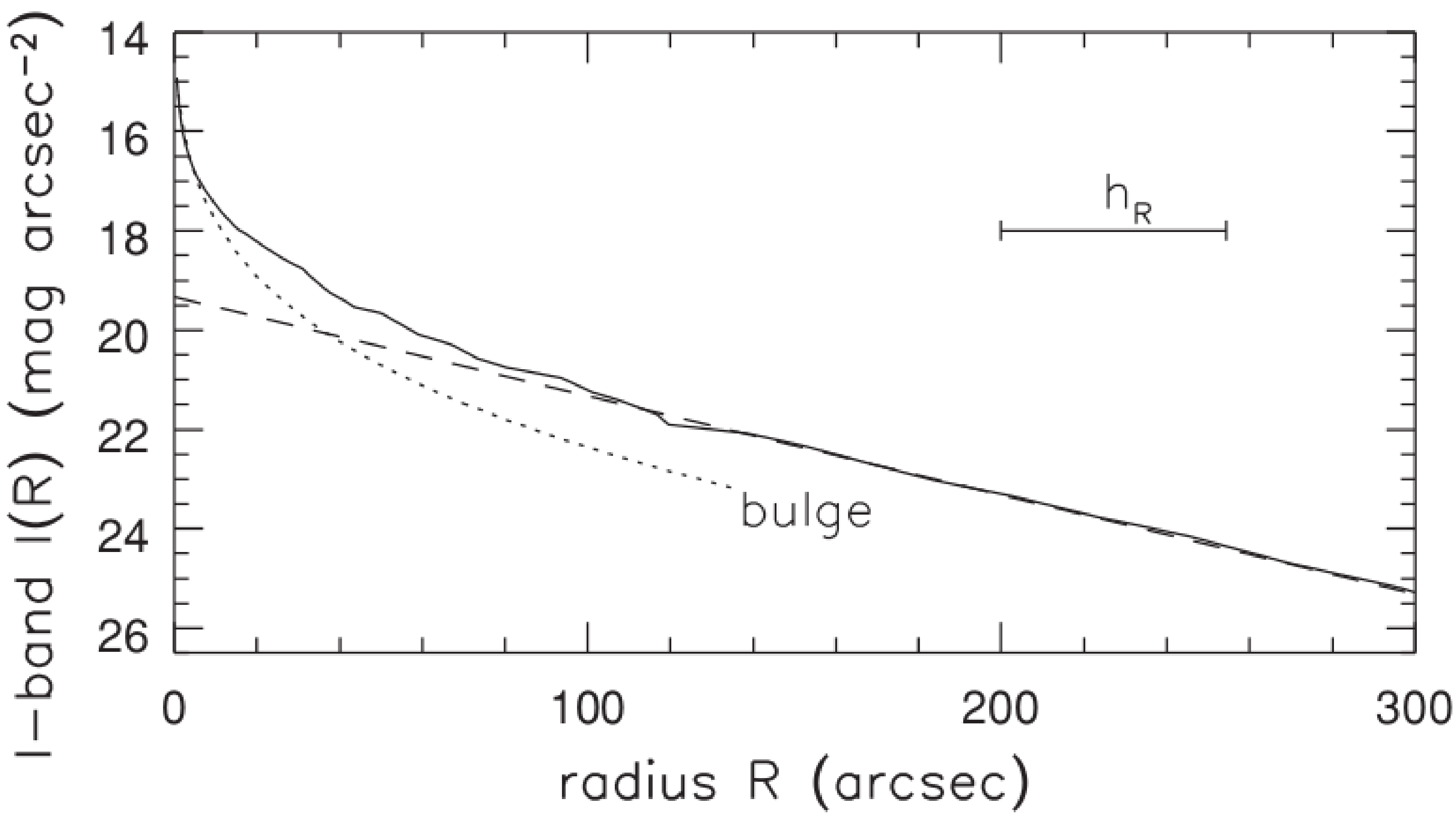
Reference : S&G, Schneider, http://www.astro.yale.edu/astro310/

Color optical image of spiral galaxy

Separate images taken in 3 bands: g, r, i
3 images combined to make color image

Isophotes – contours of equal surface brightness





NGC 7331
Radial light profile showing exponential disk

Functions fit to Galaxy Radial light profiles

Exponential disk: $I(r) = I(0) \exp(-r/r_d)$

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DeVaucouleurs $r^{1/4}$ bulge law: $I(r) = I(r_{eff}) \exp\{-7.67[(r/r_{eff})^{1/4}-1]\}$

Sersic law: $I(r) = I(r_{eff}) \exp\{-b_n[(r/r_{eff})^{1/n}-1]\}$

n = Sersic index [b_n chosen to make r_{eff} the effective radius]

n = 1-4 typically

If n=1 exponential (all disk)

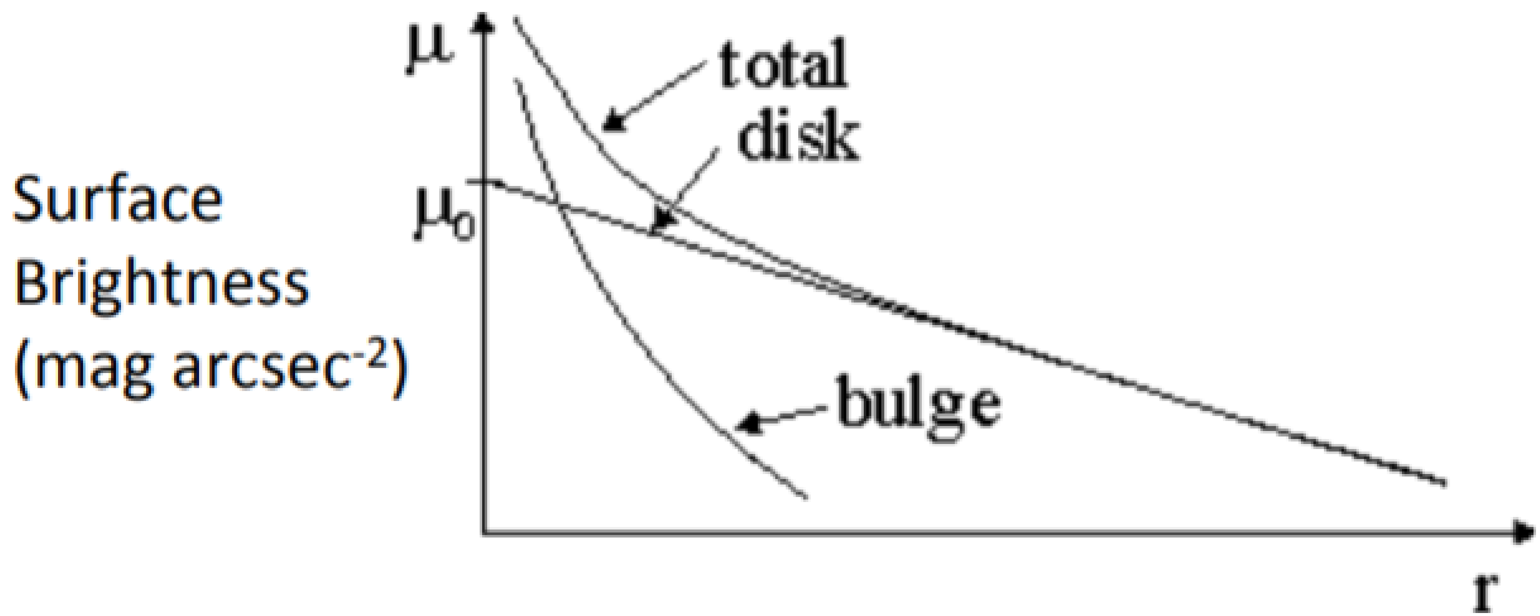
If n=4 deVaucouleurs r/4 law (all bulge)

If n<2 small bulge-disk ratio

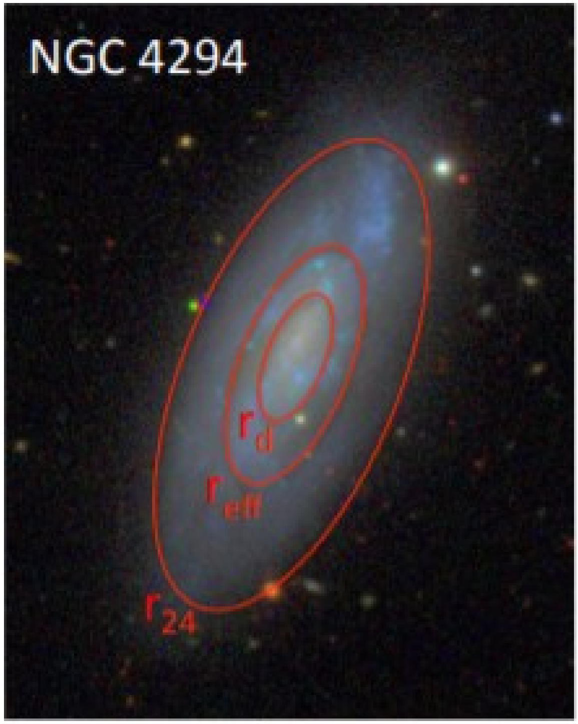
If n>2 large bulge-disk ratio

Advantage of Sersic law: can describe entire profile shape with just one number n

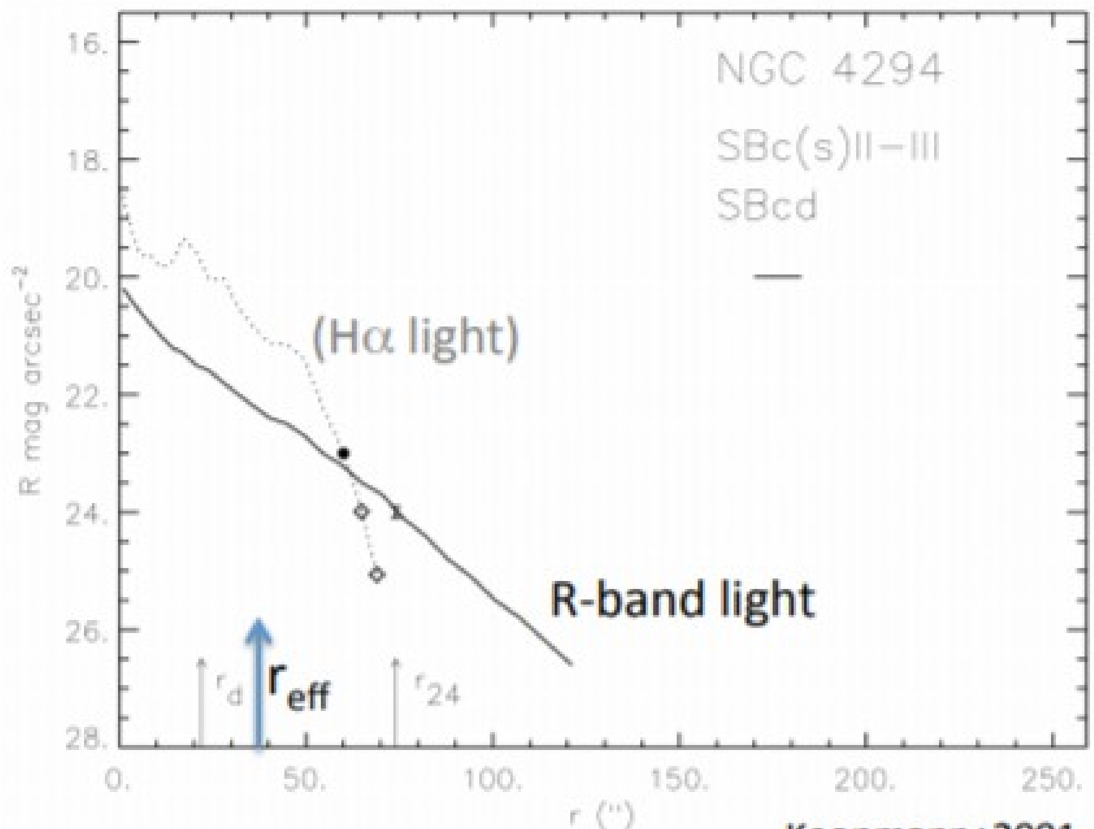
Disks have very different radial light profiles from bulges & ellipticals



Different photometric radii in small-bulge spiral galaxy



SDSS Hogg website



Koopmann+2001

R-band radial light profile shows **pure exponential disk**

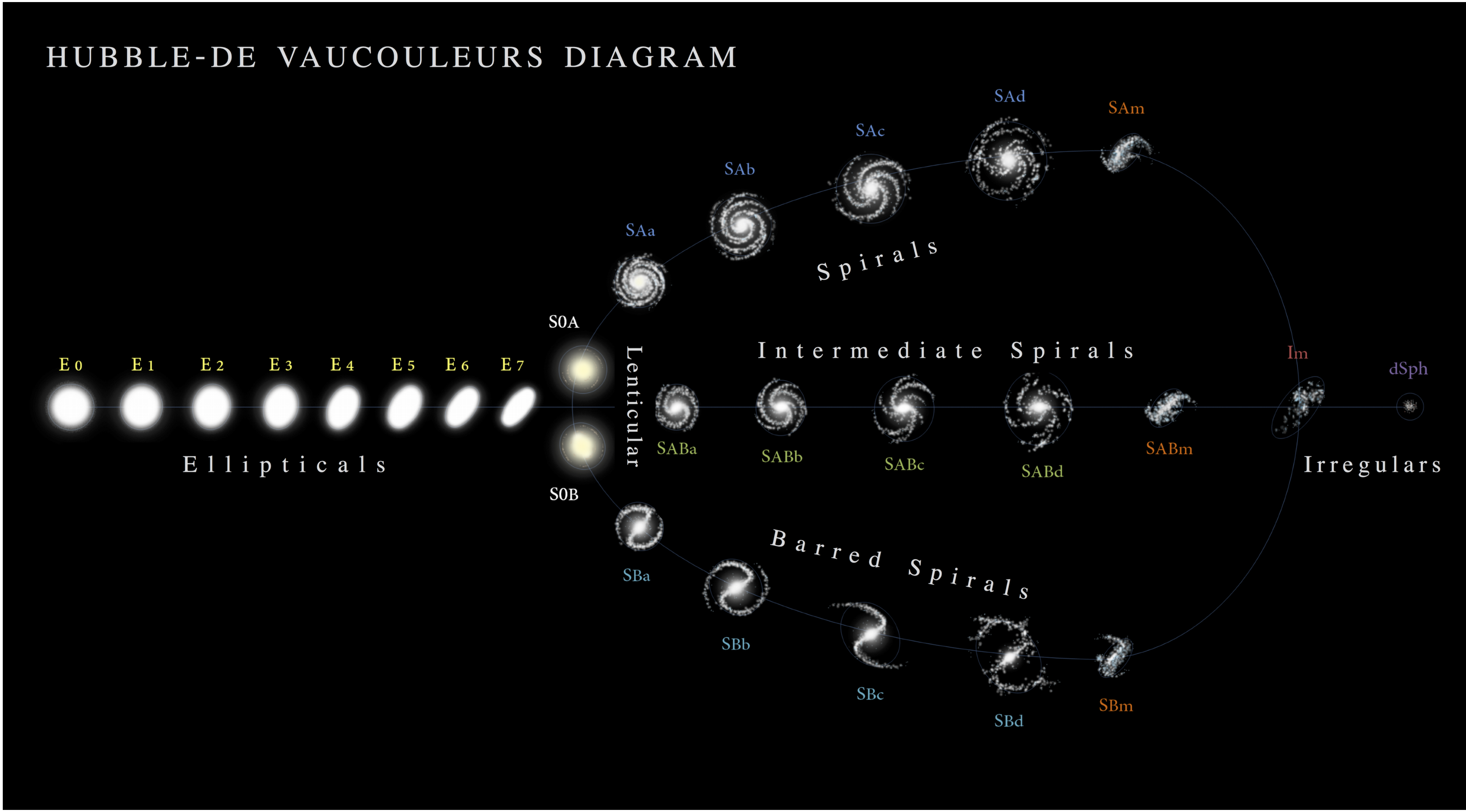
r_d **scale length** of exponential disk ($I \sim I_0 e^{-r/rd}$) = 1.6 kpc

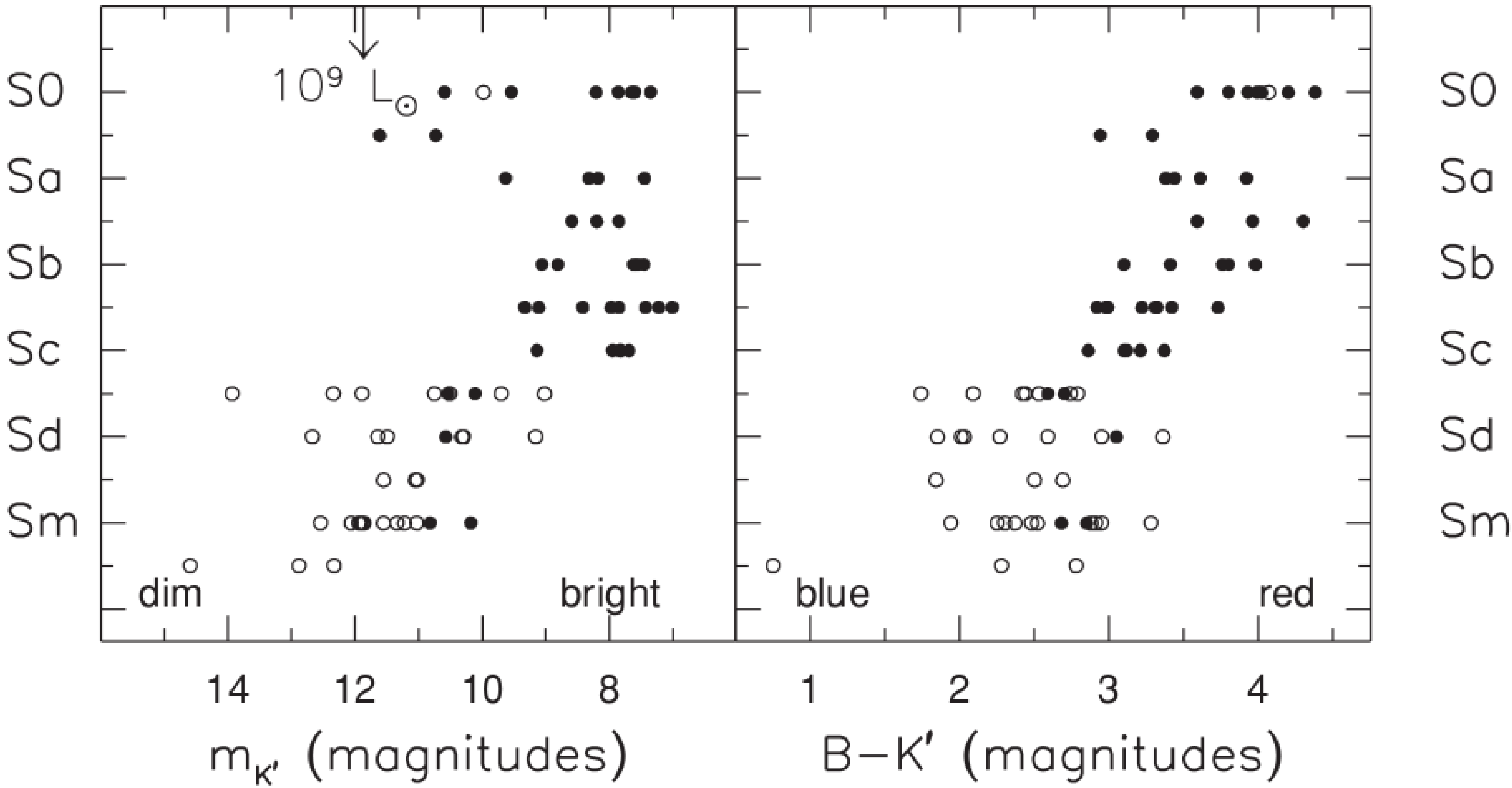
r_{eff} **effective radius** (contains 50% of total light) = 3 kpc

r_{24} **isophotal radius** (SB falls to 24 mag arcsec^{-2}) = 6 kpc

r_{vir} ~ 100-200 kpc

Galaxy classification: Updated Tuning fork





S0
Sa
Sb
Sc
Sd
Sm
10^9 L$_\odot$
dim
bright
14
12
10
8
$m_{K'}$ (magnitudes)
blue
red
1
2
3
4
B−K′ (magnitudes)
S0
Sa
Sb
Sc
Sd
Sm

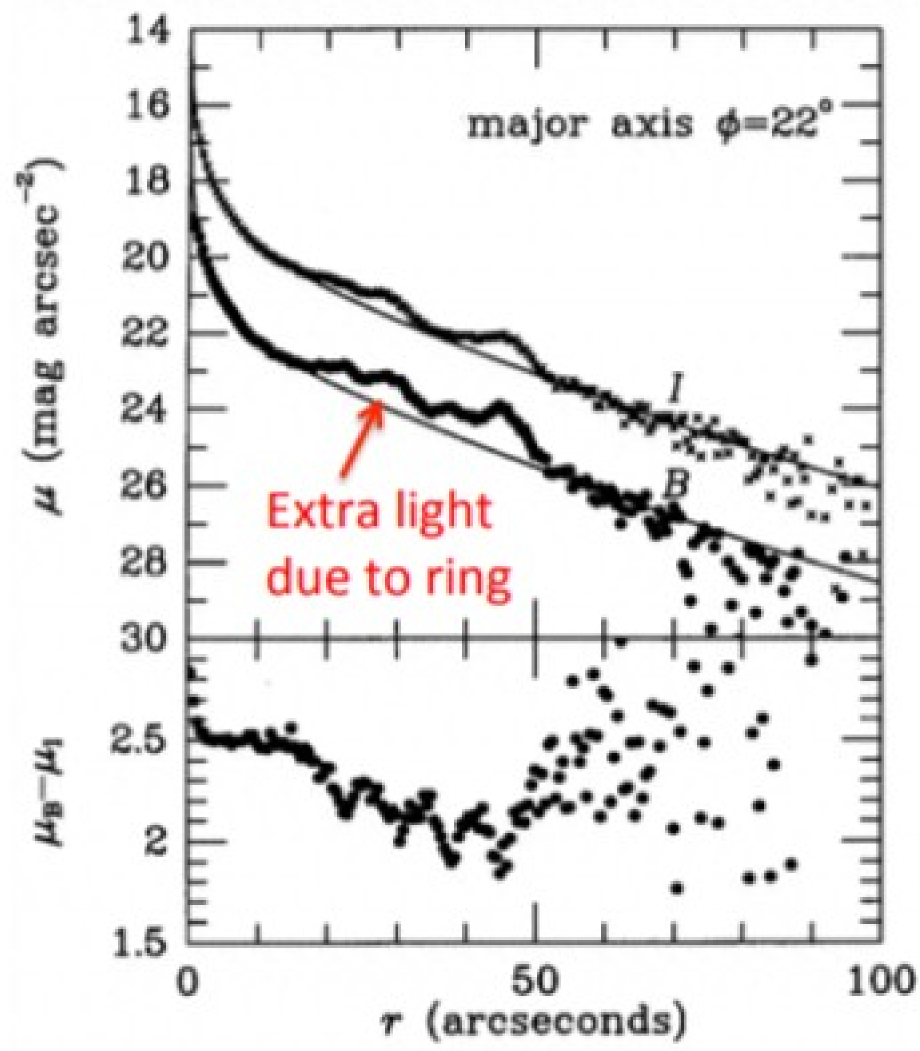
Why are disks exponential?

- Not understood in detail
- Stellar disks are thin because they form from gas disks, which experience (energy) dissipation
- Stellar disks are exponential (in radius) because they form from gas disks, which experience energy dissipation and angular momentum transport

Not all disks are perfectly exponential

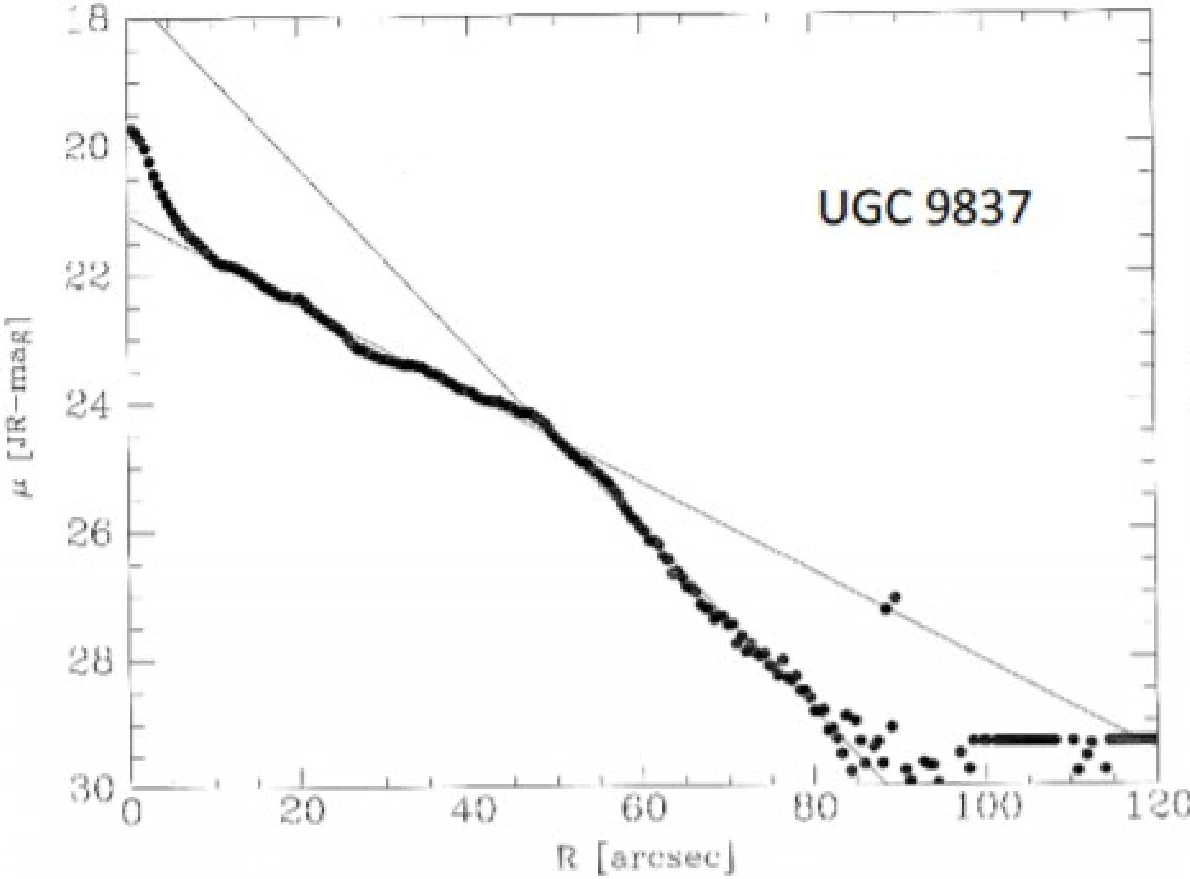
Bars, rings, spiral arms, interactions modify radial distributions

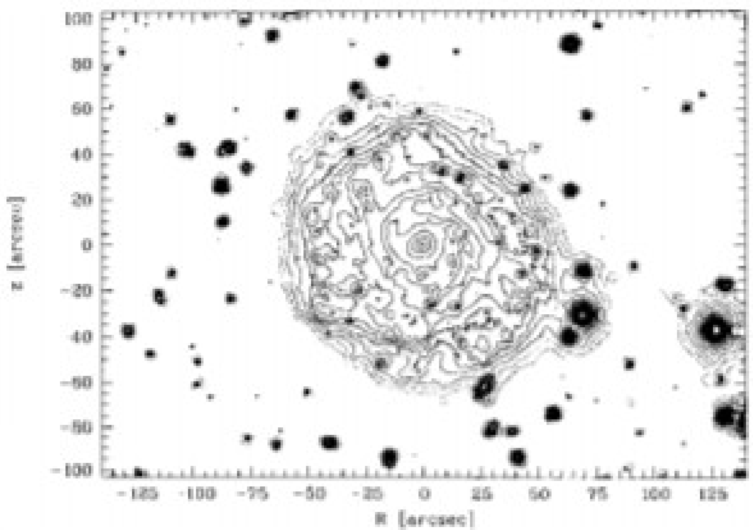
Ringed galaxy NGC 4622



Buta+03

Not all disks are perfectly exponential

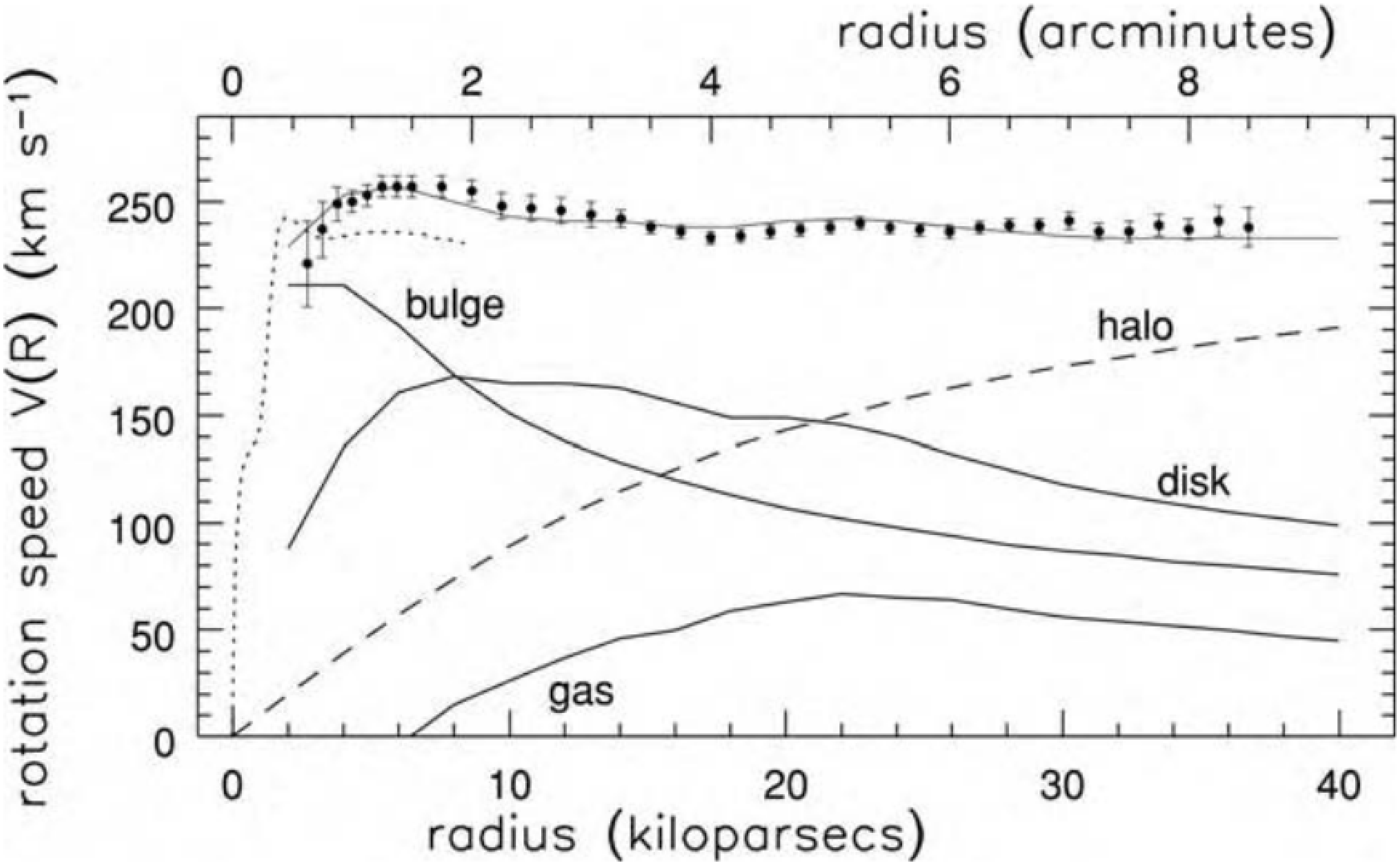




Pohlem+02

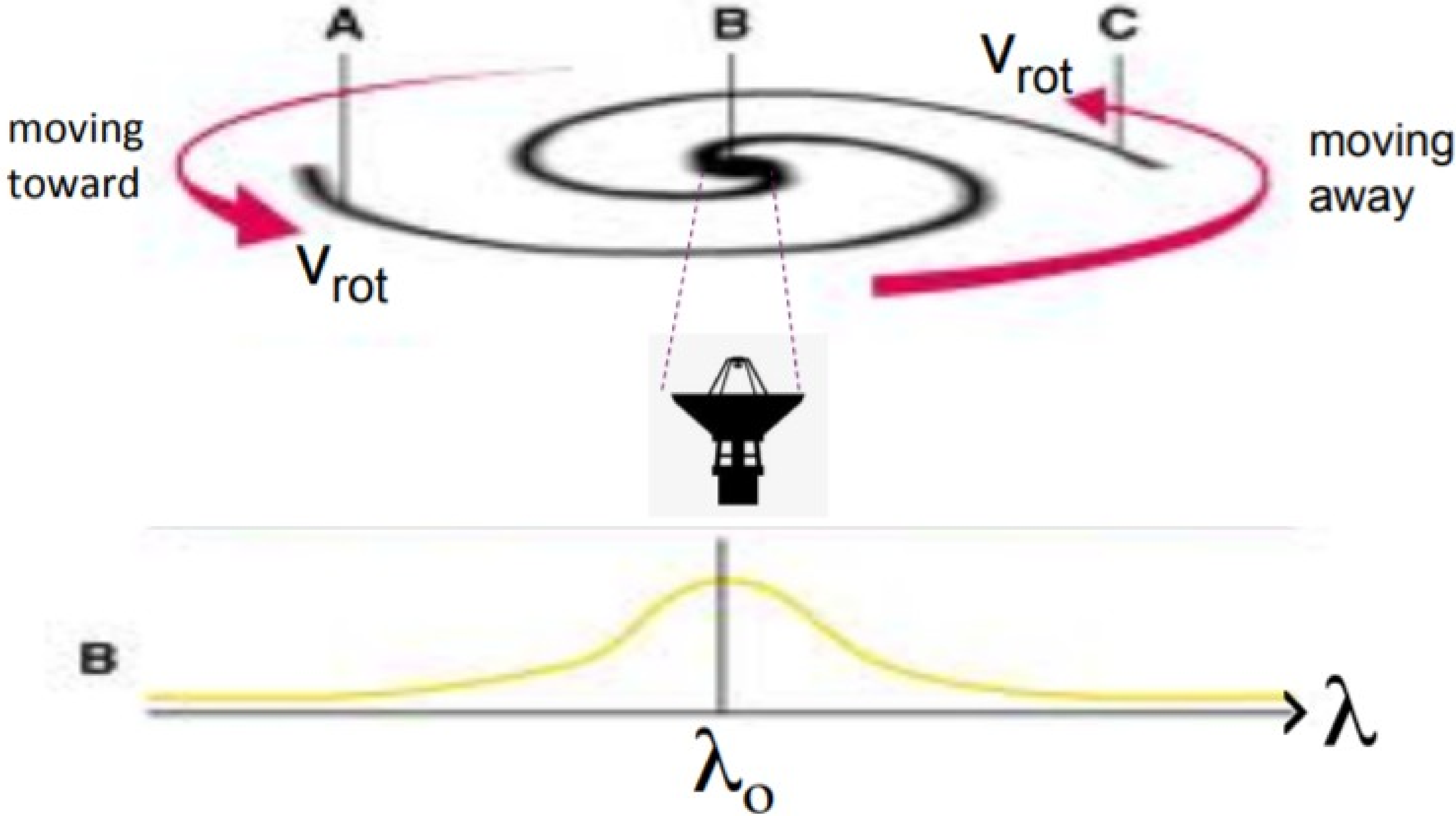
Outer disks of some spiral galaxies fit by steeper exponential than inner disk

not well understood – but clearly not tidal truncation, could be tidal interaction or less efficient SF in outskirts



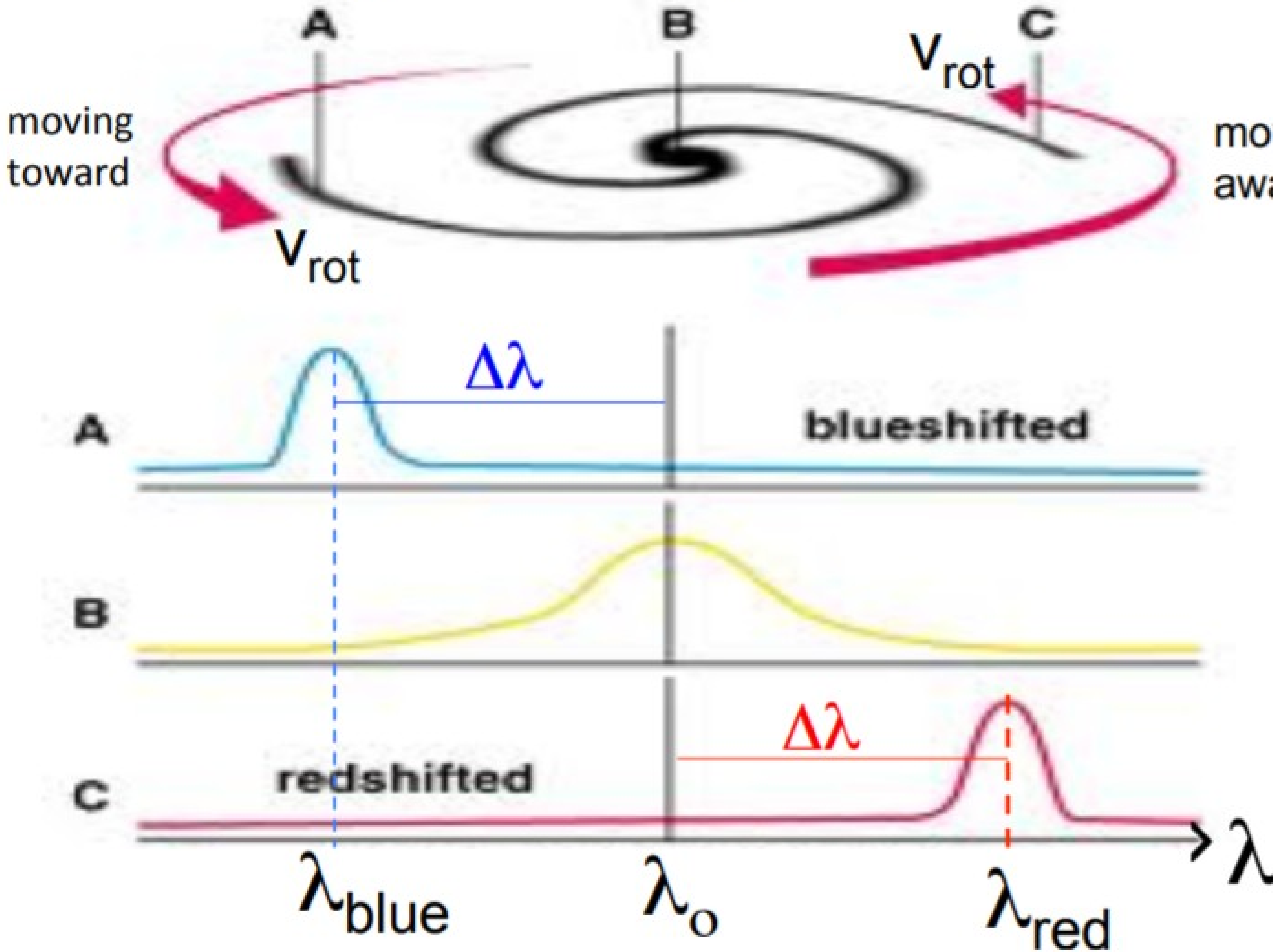
radius (arcminutes)
0
2
4
6
8
rotation speed V(R) (km s⁻¹)
250
200
150
100
50
0
bulge
halo
disk
gas
0
10
20
30
40
radius (kiloparsecs)

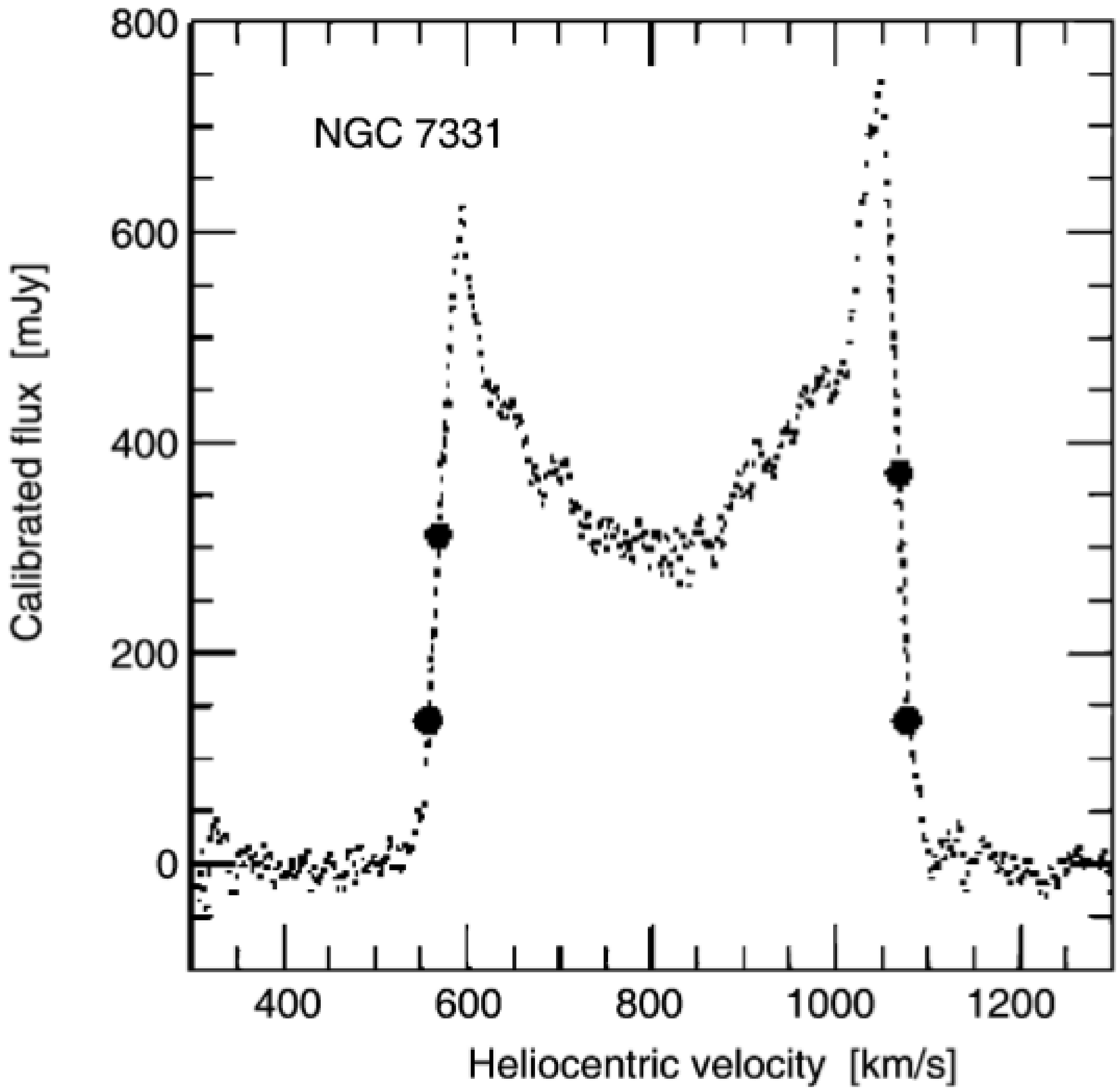
measuring rotation velocities in spiral galaxy using doppler shifts of spectral lines



HI in disk of inclined, rotating spiral galaxy

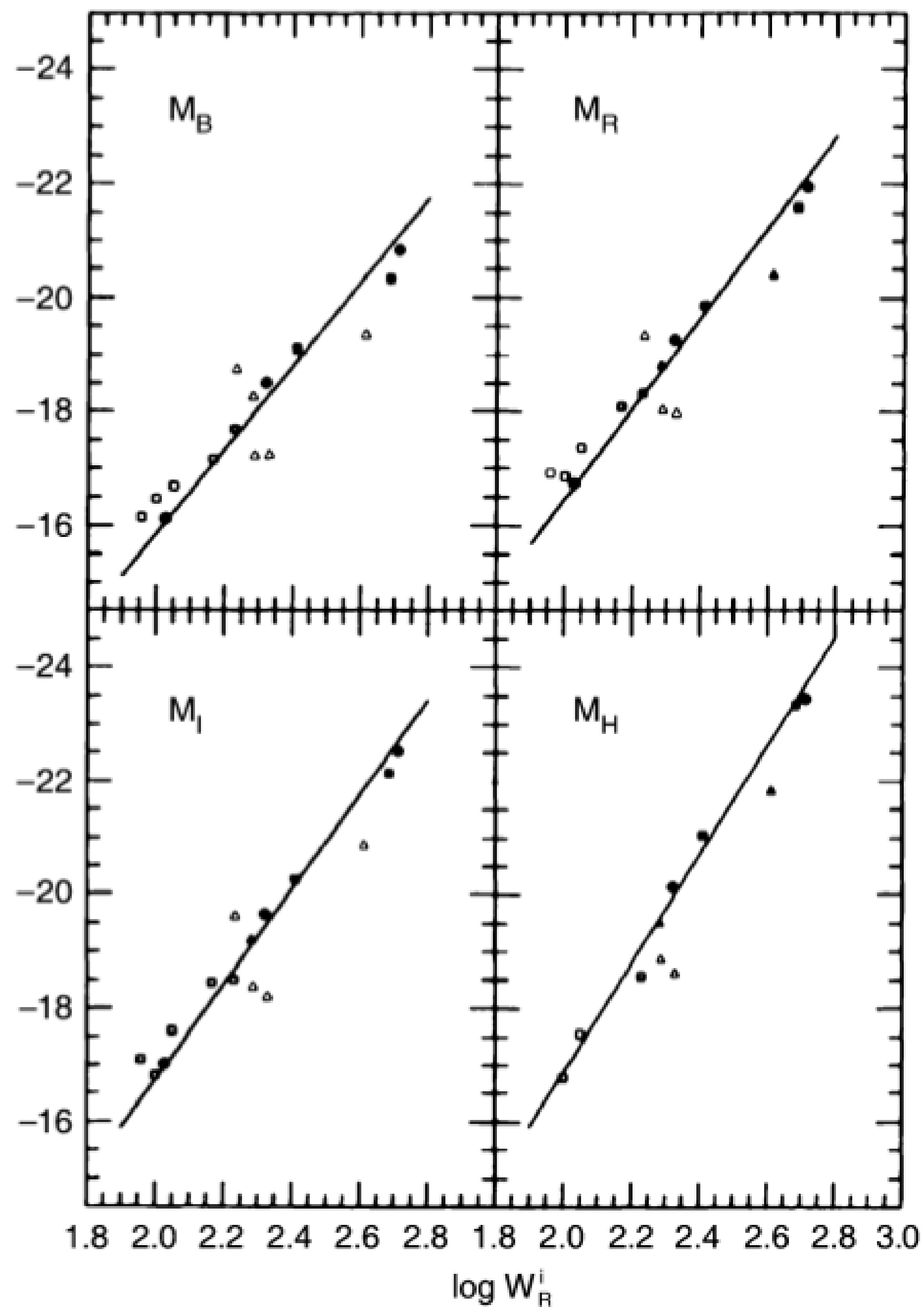
measuring rotation velocities in spiral galaxy using doppler shifts of spectral lines



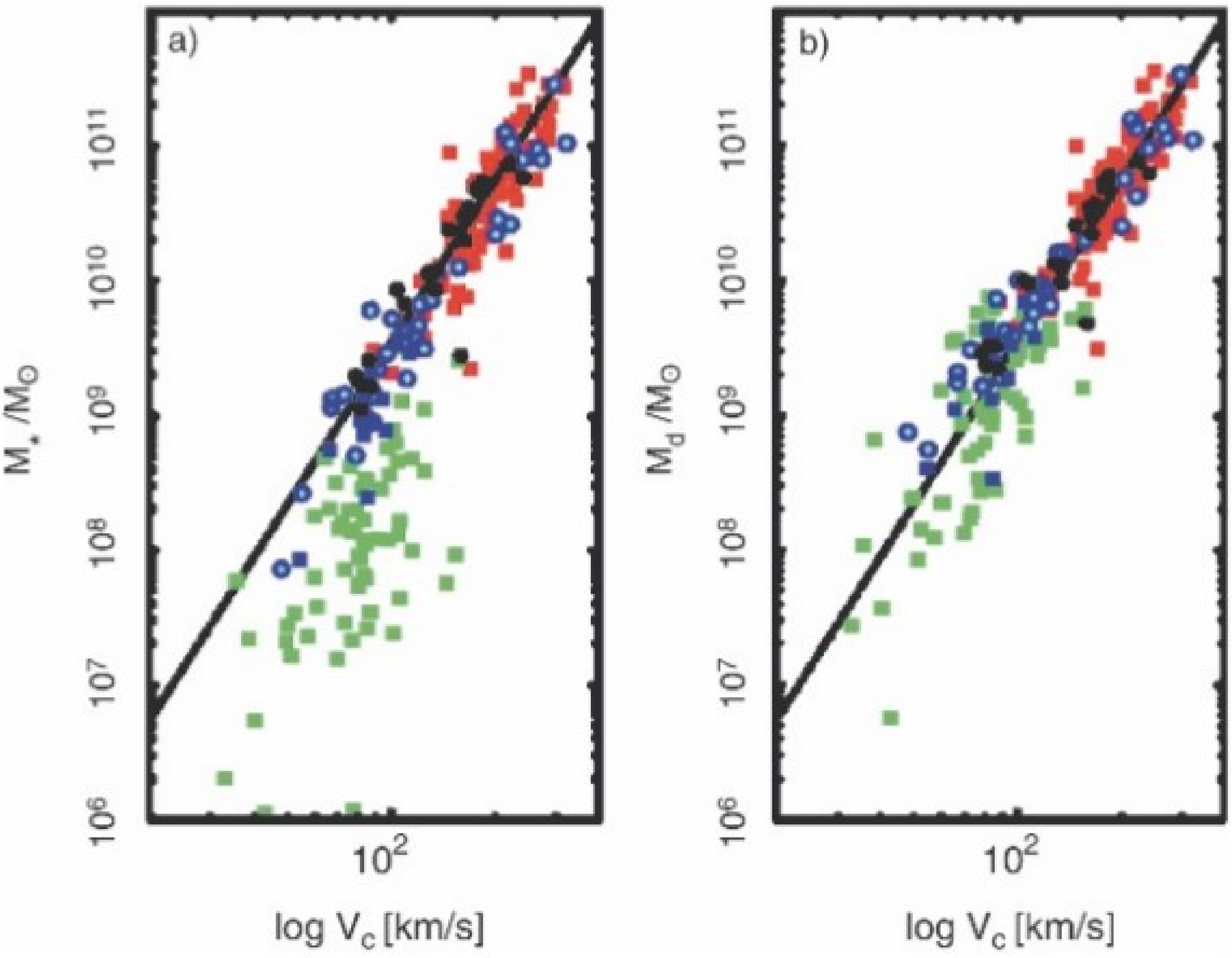

NGC 7331
Calibrated flux [mJy]
800
600
400
200
0
400
600
800
1000
1200
Heliocentric velocity [km/s]

	Sa	Sb	Sc	Sd/Sm	Im/Ir
M_B	−17 to −23	−17 to −23	−16 to −22	−15 to −20	−13 to −18
M ($M_\odot$)	10^9–10^{12}	10^9–10^{12}	10^9–10^{12}	10^8–10^{10}	10^8–10^{10}
$\langle L_{\rm bulge}/L_{\rm tot}\rangle_B$	0.3	0.13	0.05	–	–
Diam. (D_{25}, kpc)	5–100	5–100	5–100	0.5–50	0.5–50
$\langle M/L_{\rm B}\rangle$ ($M_\odot/L_\odot$)	6.2 ± 0.6	4.5 ± 0.4	2.6 ± 0.2	~ 1	~ 1
$\langle V_{\rm max}\rangle$(km s^{-1})	299	222	175	–	–
$V_{\rm max}$ range (km s^{-1})	163–367	144–330	99–304	–	50–70
Opening angle	$\sim 6°$	$\sim 12°$	$\sim 18°$	–	–
$\mu_{0,\rm B}$ (mag arcsec^{-2})	21.52 ± 0.39	21.52 ± 0.39	21.52 ± 0.39	22.61 ± 0.47	22.61 ± 0.47
$\langle B - V\rangle$	0.75	0.64	0.52	0.47	0.37
$\langle M_{\rm gas}/M_{\rm tot}\rangle$	0.04	0.08	0.16	0.25 (Scd)	–
$\langle M_{\rm H_2}/M_{\rm HI}\rangle$	2.2 ± 0.6 (Sab)	1.8 ± 0.3	0.73 ± 0.13	0.19 ± 0.10	–
$\langle S_{\rm N}\rangle$	1.2 ± 0.2	1.2 ± 0.2	0.5 ± 0.2	0.5 ± 0.2	–

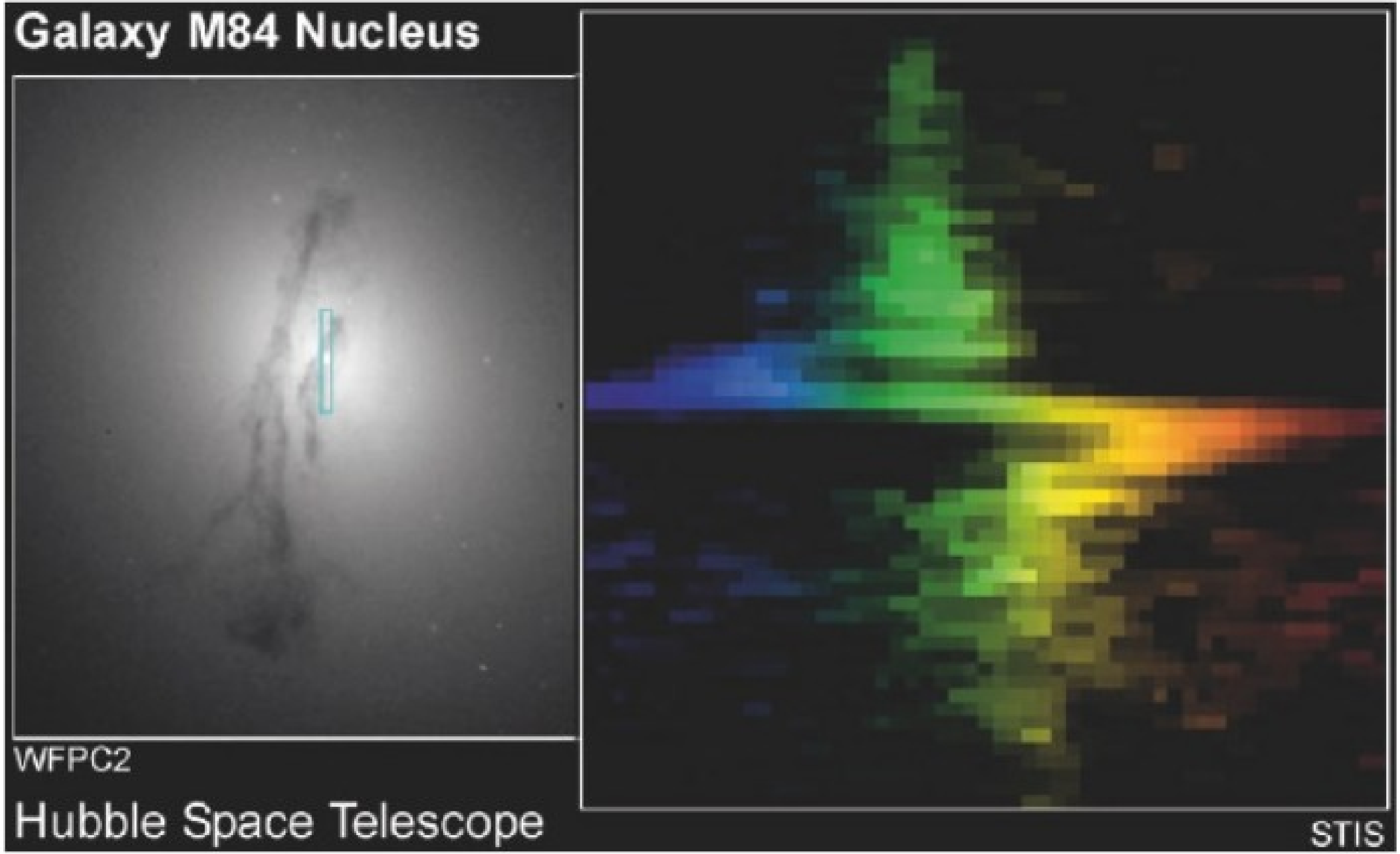
Fig. 3.14. Types of spiral galaxies. Top left: M94, an Sab galaxy. Top middle: M51, an Sbc galaxy. Top right: M101, an Sc galaxy. Lower left: M83, an SBa galaxy. Lower middle: NGC 1365, an SBb galaxy. Lower right: M58, an SBc galaxy

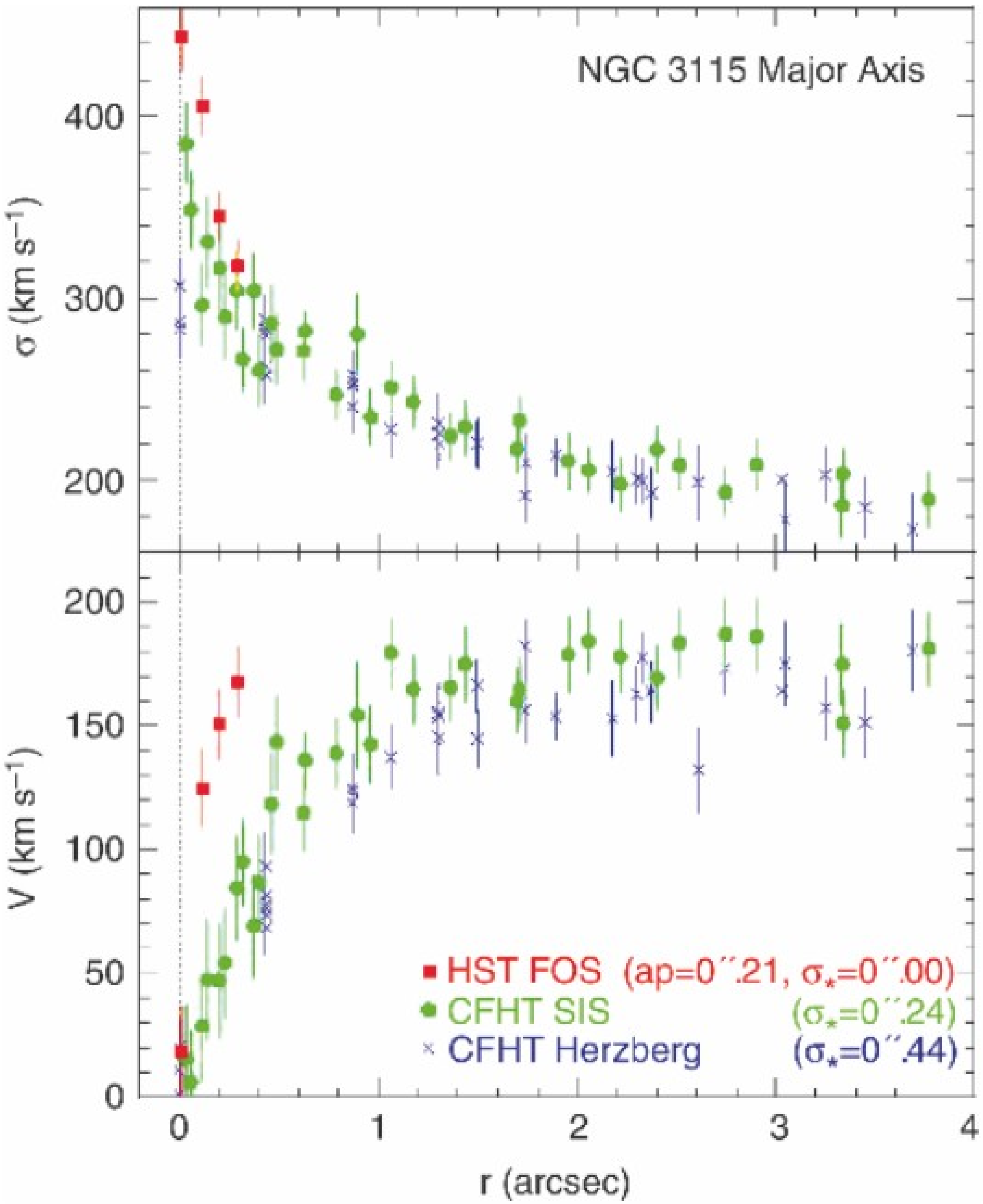


M_B
M_R
M_I
M_H
−24
−22
−20
−18
−16
1.8 2.0 2.2 2.4 2.6 2.8 1.8 2.0 2.2 2.4 2.6 2.8 3.0
log W_R^i



The 'classical' Tully Fisher Relation


Galaxy M84 Nucleus
WFPC2
Hubble Space Telescope
STIS



NGC 3115 Major Axis
σ (km s⁻¹)
400
300
200
V (km s⁻¹)
200
150
100
50
0
HST FOS (ap=0´´.21, σ*=0´´.00)
CFHT SIS (σ*=0´´.24)
CFHT Herzberg (σ*=0´´.44)
0
1
2
3
4
r (arcsec)