Spiral Galaxies: Photometric Properties

Global Properties of Spiral Galaxies

Spirals are complex systems, generally more complex and diverse than ellipticals:

- Wide range in morphological appearance
- Fine scale details – bulge/disk ratios, structure of spiral arms, resolution into knots, HII regions, etc.
- Wide range in stellar populations – old, intermediate, young, and currently forming
- Wide range in stellar dynamics:
  - "cold" rotationally supported disk stars
  - "hot" mainly dispersion supported bulge & halo stars
- Significant amounts of cold interstellar medium (ISM)

Spirals tend to avoid high-density regions (e.g., clusters) as they are dynamically fragile, and can be merged and turned into E's

Spiral Galaxies:
Trends Along the Hubble Sequence

	S0-Sa	Sb-Sc	Sd-Sm
Spiral Arms	Absent or tight		Open spiral
Color	Red; late G star	Early G star	Blue; late F star
B-V color	0.7-0.9	0.6-0.9	0.4-0.8
Young stars	few		many
HII regions	Few, small		More, brighter
Gas	Little gas		Much gas
Blue luminosity	$1\text{-}4 \times 10^{10} L_\odot$		$<0.1\text{-}2 \times 10^{10} L_\odot$
Central SB	high		low
mass	$0.5\text{-}3 \times 10^{11} M_\odot$		$<0.2\text{-}1 \times 10^{11} M_\odot$
rotation	Fast rising		Slow rising

Spiral Galaxies: Basic Components

- **Disks:** generally metal rich stars and ISM, nearly circular orbits with little random motion, spiral patterns
  - Thin disks: younger, star forming, dynamically very cold
  - Thick disks: older, passive, slower rotation and more random motions
- **Bulge:** metal poor to super-metal-rich stars, high stellar densities, mostly random motion – similar to ellipticals
- **Bar:** present in ~ 50 % of disk galaxies, mostly older stars, some random motions and a ~ solid body rotation?
- **Nucleus:** central (<10pc) region of very high mass density, massive black hole or starburst or nuclear star cluster
- **Stellar halo:** very low density (few % of the total light), metal poor stars, globular clusters, low density hot gas, little or no rotation
- **Dark halo:** dominates mass (and gravitational potential) outside a few kpc, probably triaxial ellipsoids, radial profile ~ singular isothermal sphere, DM nature unknown

Photometric Properties of Galaxies

Empirically, the surface brightness declines with distance from the center of the galaxy in a characteristic way for spiral and elliptical galaxies

For spiral galaxies, need first to correct for:

- Inclination of the disk
- Dust obscuration
- Average over spiral arms to obtain a mean profile

Corrected disk surface brightness drops off as:

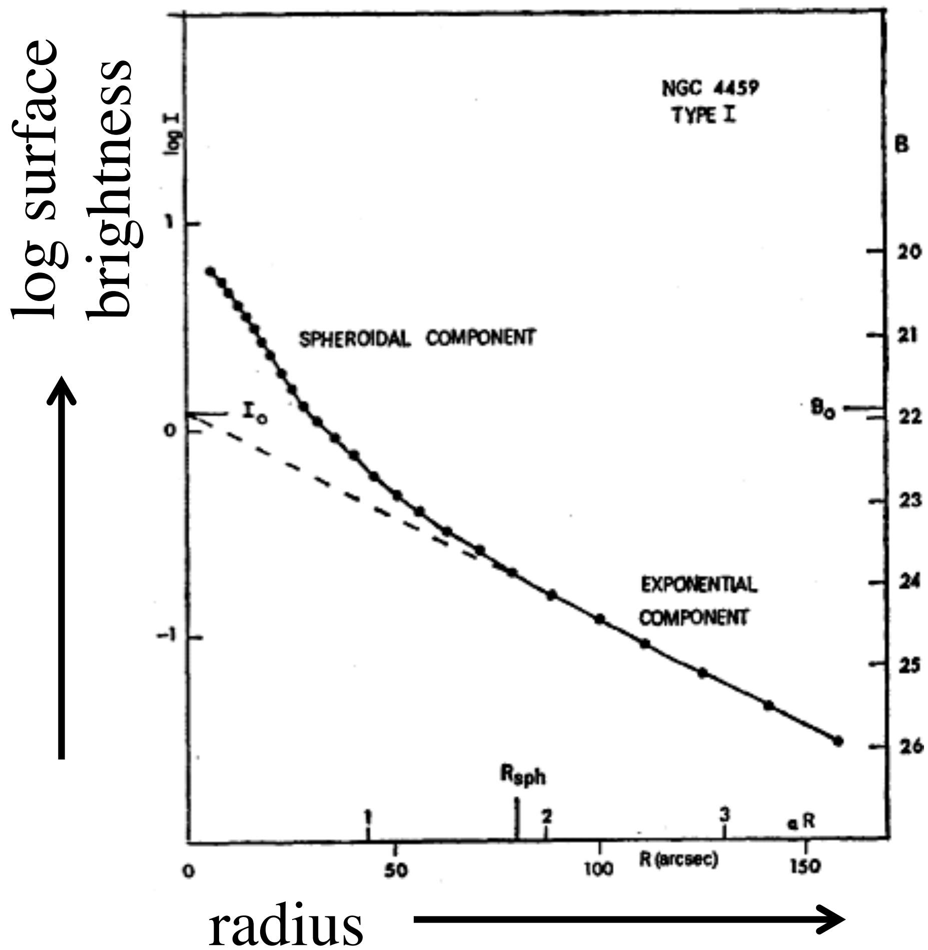
$$I(R) = I(0)\ \mathrm{e}^{-R/h_R}$$

where ***I(0)*** is the central surface brightness of the disk, with a broad range of values, but typically ~ 21 - 22 mag/arcsec^2, and $\boldsymbol{h_R}$ is a characteristic **scale length**, with typical values:

$$1\ \mathrm{kpc} < h_R < 10\ \mathrm{kpc}$$

Bulge-Disk Decomposition

In practice, surface brightness at the center of many spiral galaxies is dominated by stars in a central bulge. Central surface brightness of disk must be estimated by extrapolating inward from larger radii



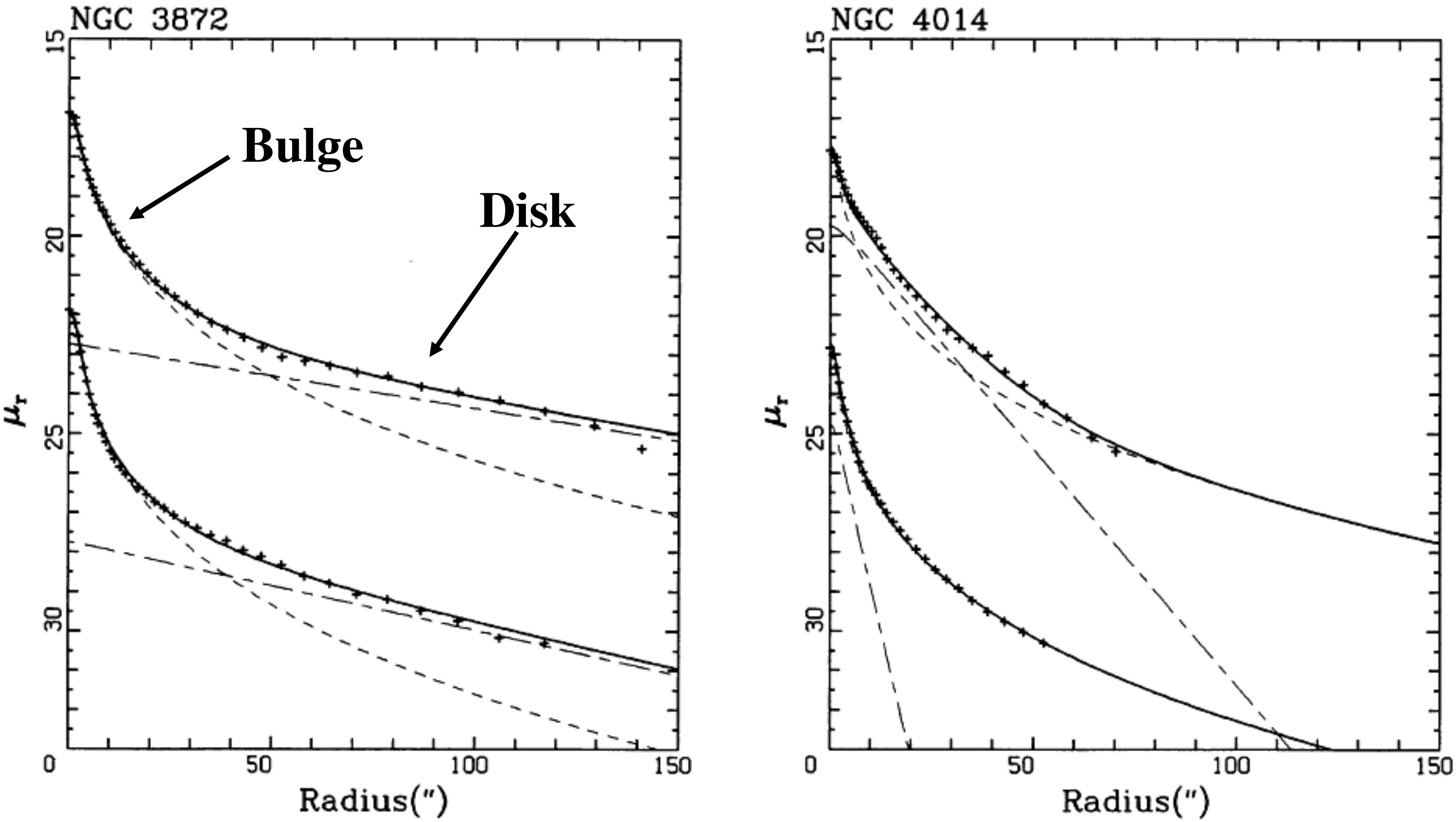
Component profiles (**μ** is the logarithmic surface brightness in mags/arcsec2):

$$\mu_{\text{bulge}} = \mu_e + 8.325\left[(r/r_e)^{1/4} - 1\right]$$

$$\mu_{\text{disk}} = \mu_0 + 1.082(r/h).$$

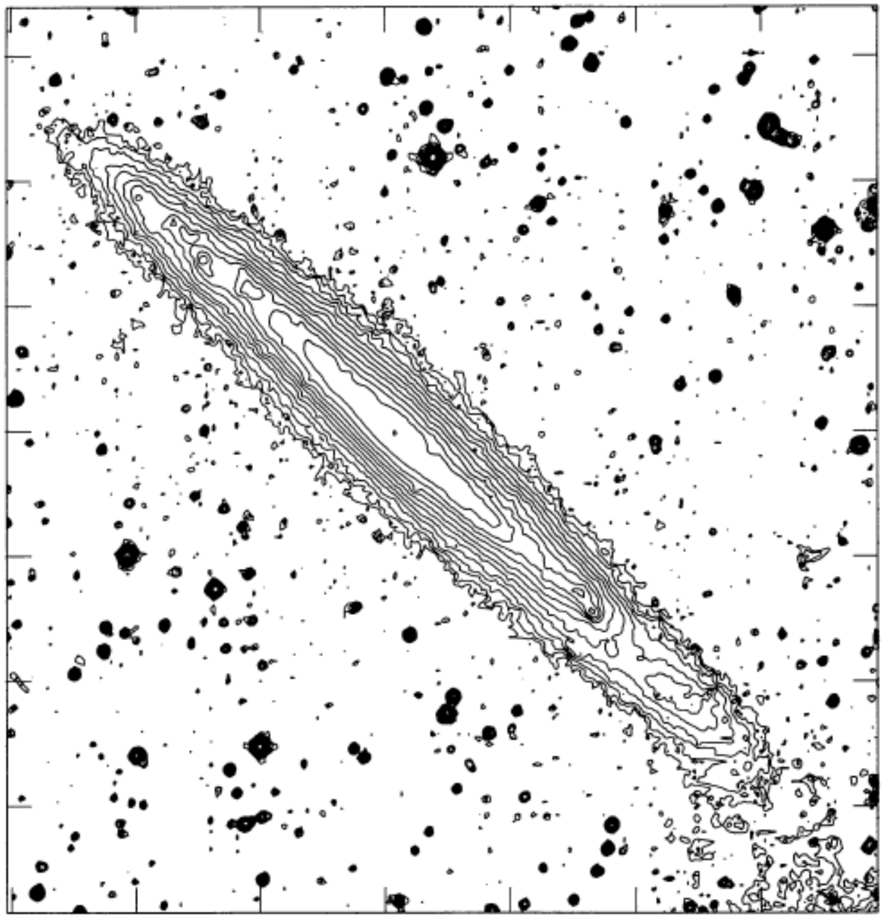
Radial Surface Brightness Profiles of Spiral Galaxies

Note: semi-log profiles

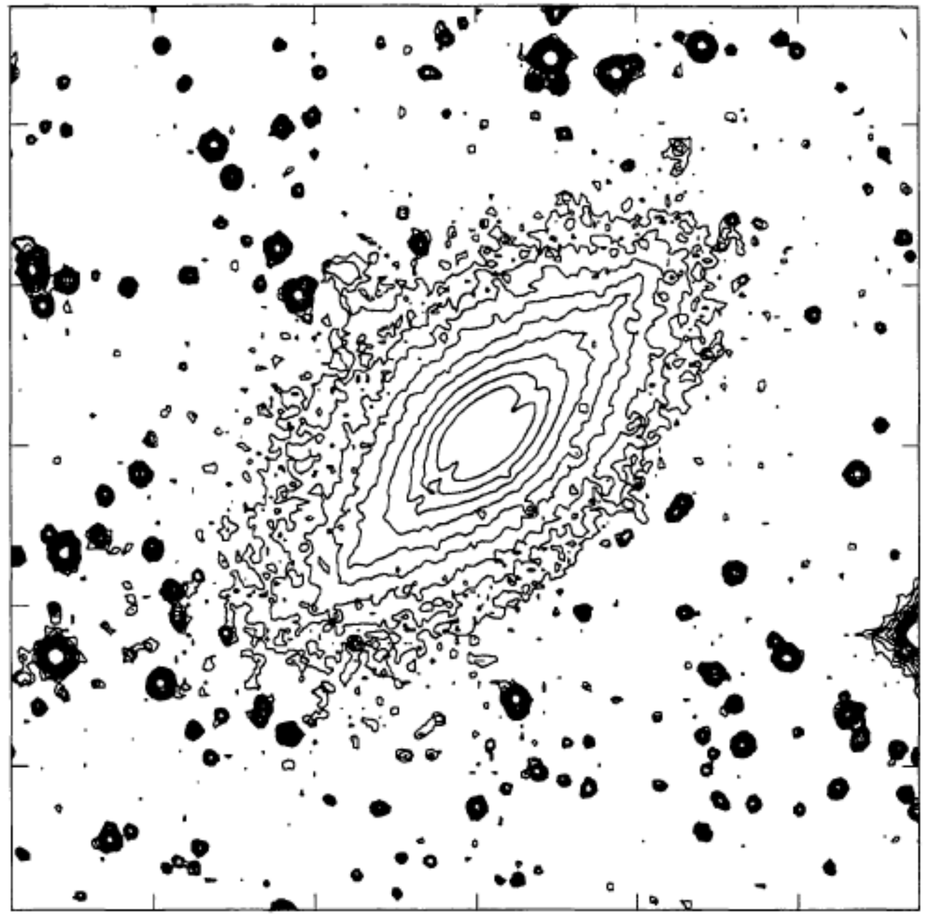


(from S. Kent)

Edge-On Spirals: Contour Maps

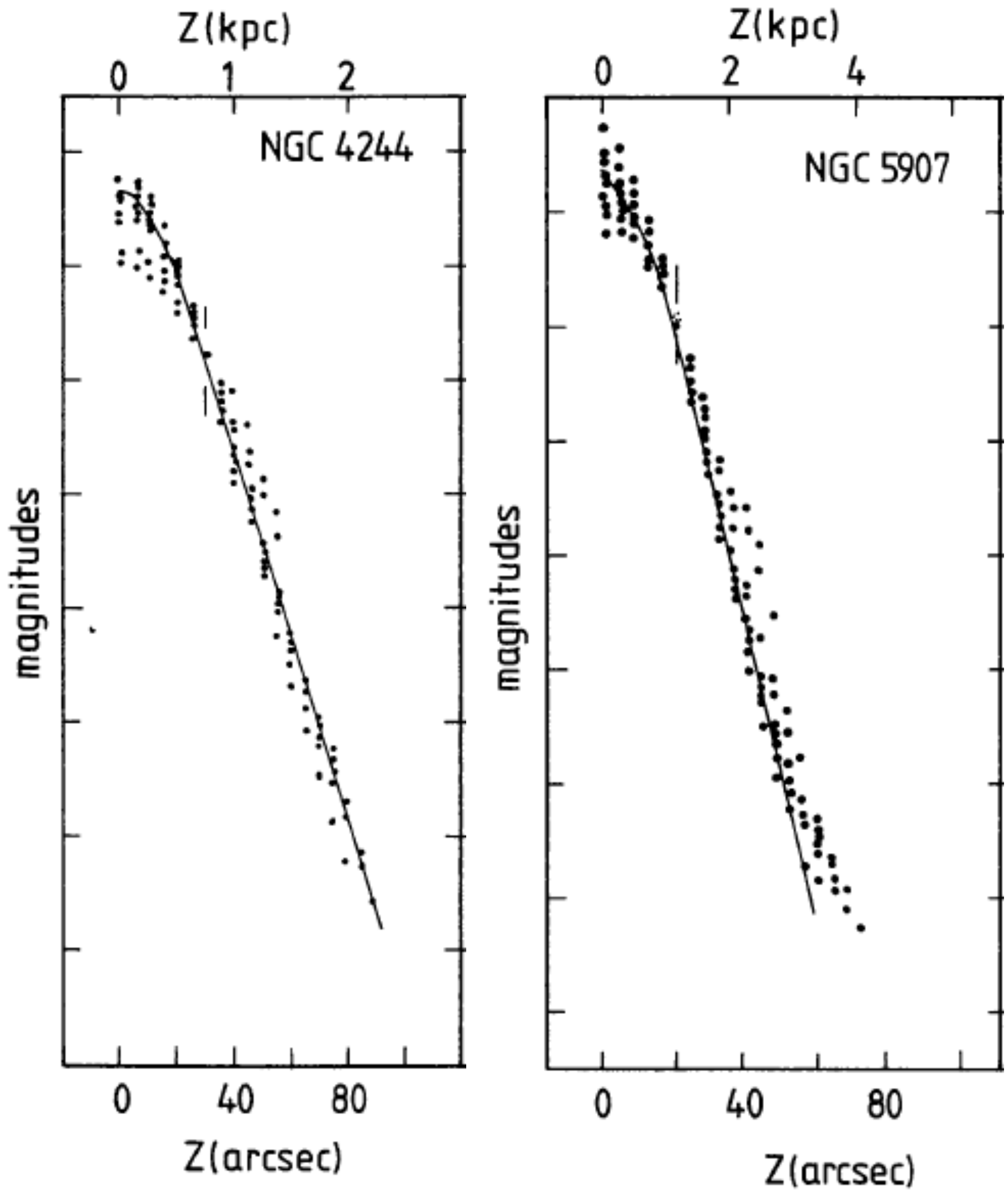


Nearly a pure disk:
NGC 4244



Bulge dominated:
NGC 7814

Vertical Structure of Galaxy Disks



Stellar density
~ $exp(-z/z_0)$

[Actually, more like
sech ^{2} $(-z/z_0)^2$ …]

Also seen in star counts
in our Galaxy

Typical values of z_0 range
from ~ 0.1 kpc (young
disk) to ~ 1 kpc (old thick
disk)

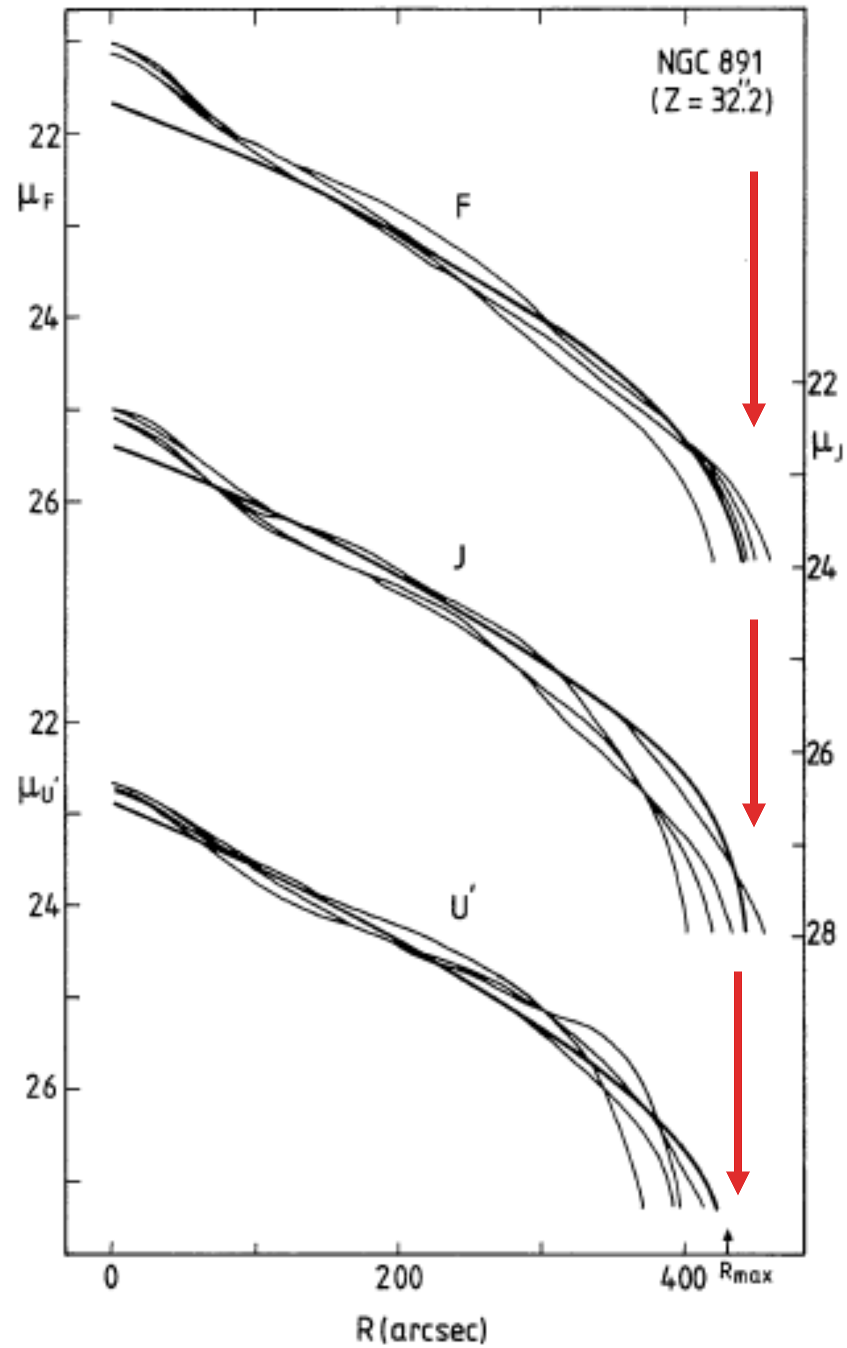
Disks Have Cutoffs

Stellar disks have finite radii, R_{max}, typically 3 - 5 h_R

This is not seen in ellipticals: we have never seen their edges

Note that the H I gas extends well beyond the visible cutoff, and of course so does the dark matter

There is a trend that the stars are younger at large radii in disks: inside-out formation?



Inclination Effects

- We can integrate surface brightness to obtain a total apparent magnitude (in a given filter), but we need to correct for:
- Inclination – face-on ($i = 0^o$), edge-on ($i = 90^o$)
  - To first order, $cos\ i = b/a$ where a and b are the observed major and minor axes (assume disk is intrinsically circular)
  - But disks also have an intrinsic thickness, c, so we find

$$cos^2\ i = \{(b/a)^2 - q^2\}/1 - q^2$$

  where q^2 is the intrinsic ratio of $c/a \sim 0.13$
- Dust (both in the MW, and internal absorption)
  - Internal absorption is corrected for using empirical formulae, e.g. in the B band: $A_B(i) = 0.70\ log[sec(i)]$ (in mags), or in the I band, $A_I = 1.12(\pm 0.05)\ log\ (a/b)$

Next: Spiral Galaxies: Gas Content