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:

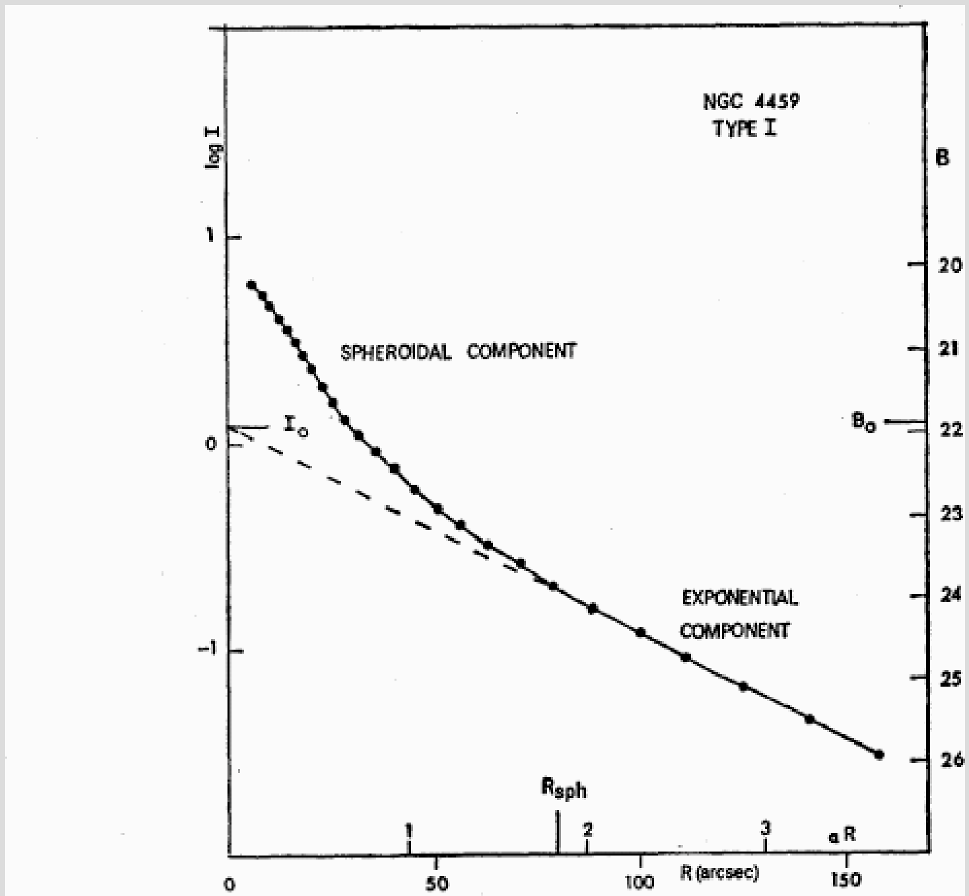
- Inclination of the disk
- Dust obscuration
- Average over spiral arms to obtain a mean profile

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, and h_R is a characteristic **scale length**.

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



surface brightness

radius

Typical values for the scale length are:

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

In many, but not all, spiral galaxies the exponential part of the disk seems to end at some radius R_{max}, which is typically 3 - 5 h_R.

Beyond R_{max} the surface brightness **of the stars** decreases more rapidly - edge of the optically visible galaxy.

The central surface brightness of many spirals is ~ constant, irrespective of the absolute magnitude of the galaxy!

$$I_B(0) \approx 21.65\ \text{mag arcsec}^{-2}$$

Empirical laws, presumably arise from physics of galaxy and / or star formation…

Elliptical galaxies

Surface brightness of elliptical galaxies falls off smoothly with radius. Measured (for example) along the major axis of the galaxy, the profile is normally well represented by the $R^{1/4}$ or de Vaucouleurs law:

$$I(R) = I(0)\ \mathrm{e}^{-kR^{1/4}}$$

where k is a constant. This can be rewritten as:

$$I(R) = I_e\ \mathrm{e}^{\left\{-7.67\left[\left(R/R_e\right)^{0.25} - 1\right]\right\}}$$

where R_e is the **effective radius** - the radius of the isophote containing half of the total luminosity. I_e is the surface brightness at the effective radius. Typically, the effective radius of an elliptical galaxy is a few kpc.

Profile of elliptical galaxies can deviate from the $R^{1/4}$ law at both small and large radius.

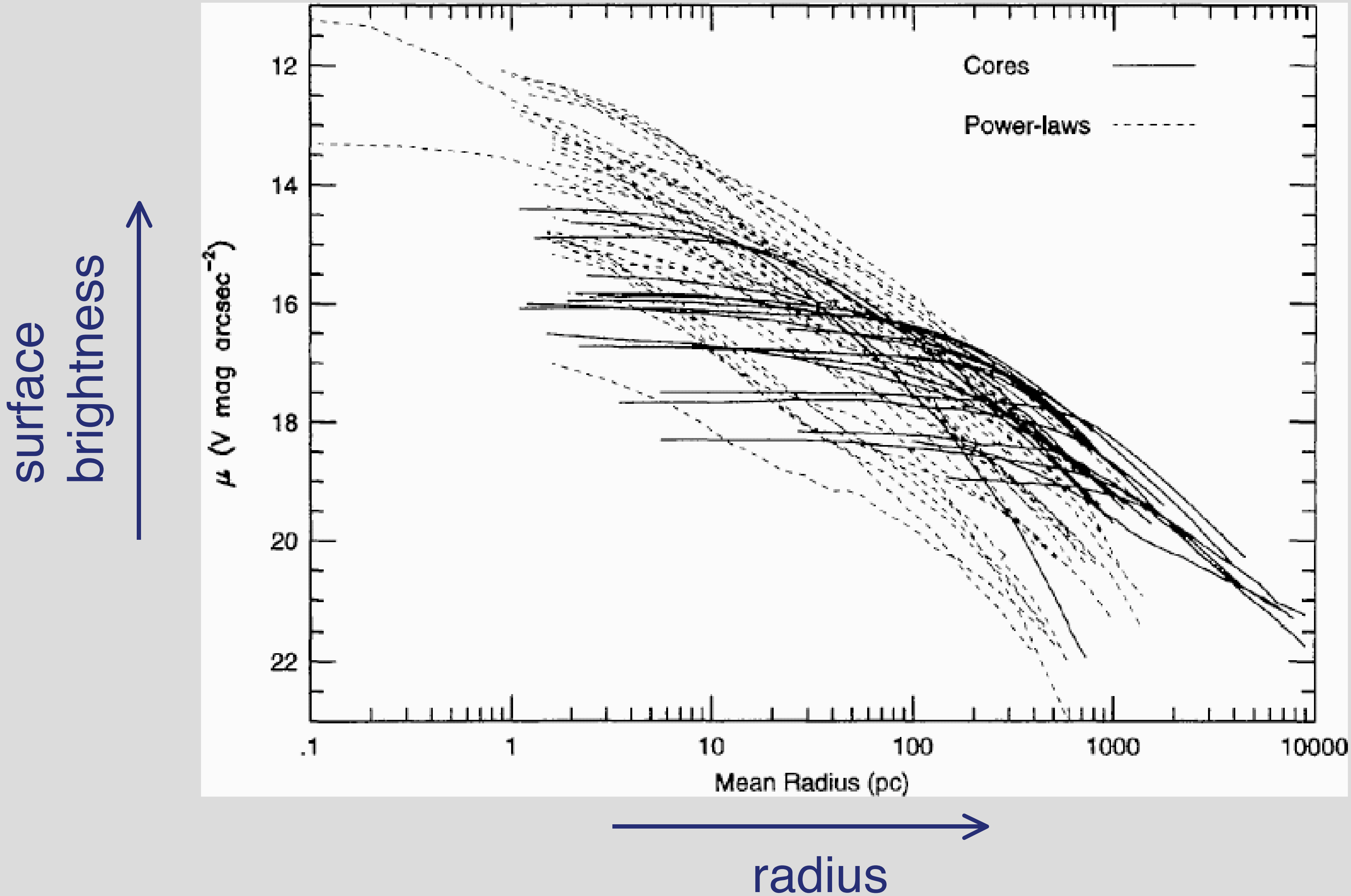
Close to the center:

- Some galaxies have **cores** - region where the surface brightness flattens and is ~ constant
- Other galaxies have **cusps** - surface brightness rises steeply as a power-law right to the center

A cuspy galaxy might appear to have a core if the very bright center is blurred out by atmospheric seeing.

→ HST essential to studies of galactic nuclei.

Results from HST



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Surveys of elliptical galaxies show that:

- The **most luminous** ellipticals have cores (typically a slope in the surface brightness distribution $\sim R^{-0.3}$ or flatter)
- **Low luminosity** ellipticals have power law cusps extending inward as far as can be seen
- At intermediate luminosities, mixture of cores and cusps

Unknown why elliptical galaxies split into two families…

In giant elliptical galaxies (cD galaxies) found at centers of some galaxy clusters, surface brightness at *large* radius may exceed that suggested by $R^{1/4}$ law:

- HST image of galaxy cluster Abell 2218.
- Lens (the cluster) is at a redshift z~0.3
- Galaxies behind are at redshifts up to 5.58, and are strongly magnified and distorted: