Eliptical Galaxies

Elliptical Galaxies

Old view: ellipticals are boring, simple systems

- Ellipticals contain no gas & dust
- Ellipticals are composed of old stars
- Ellipticals formed in a monolithic collapse, which induced violent relaxation of the stars, stars are in an equilibrium state

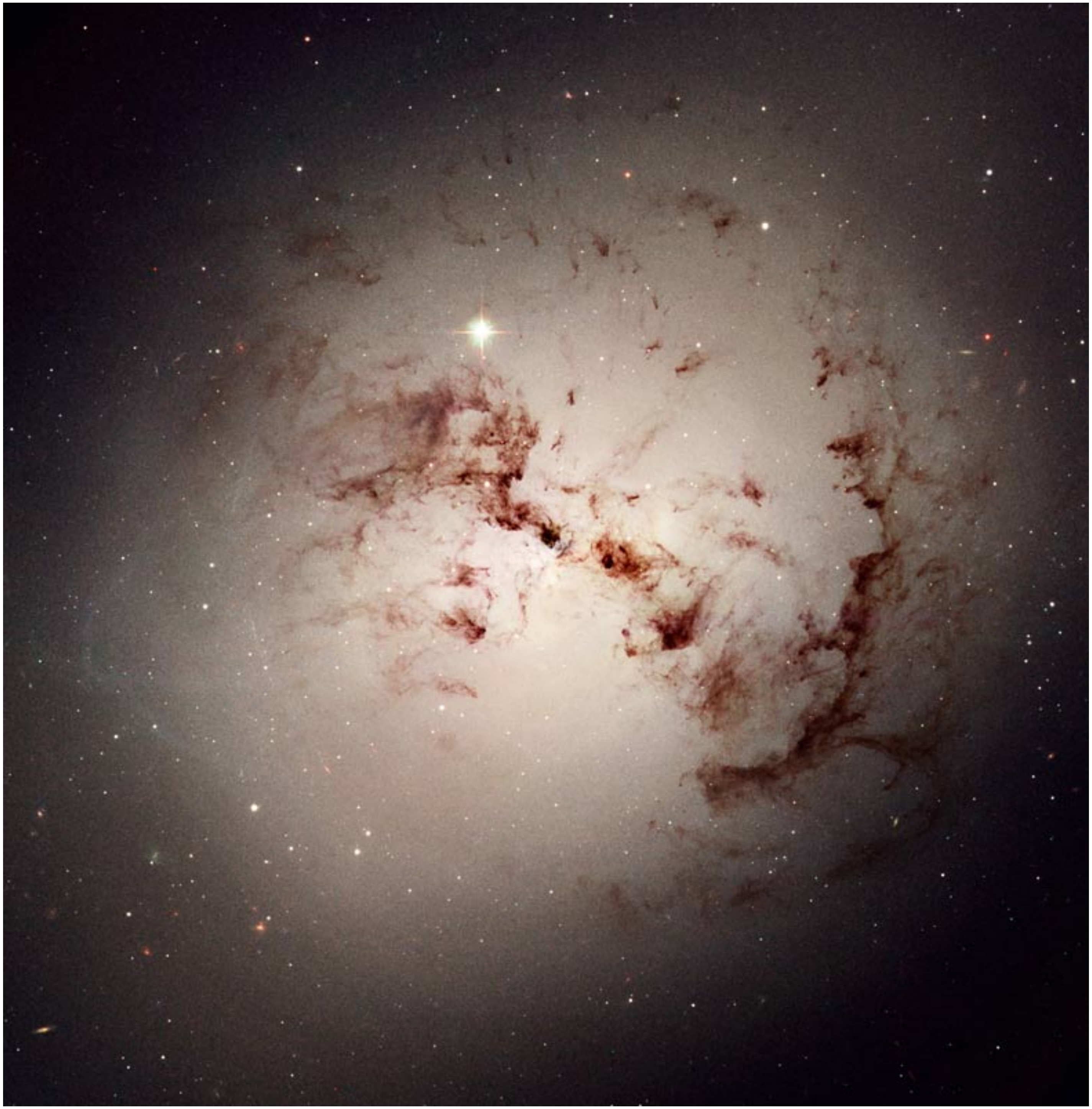
Modern view:

- Most/all ellipticals have hot x-ray gas, some have dust, even cold gas
- Ellipticals do rotate, but most of the kinetic energy support (and galaxy shapes) come from an anisotropic velocity dispersion
- Some contain decoupled (counter-rotating) cores, or other complex kinematics
- Some have weak stellar disks
- Ellipticals formed by mergers of two spirals, or hierarchical clustering of smaller galaxies

Dust lanes in E galaxy NGC 1316

Dust is surprisingly common in E's

Probably it originates from cannibalized spiral galaxies



Fine Structure in E-Galaxies:
A Signature of Recent Merging

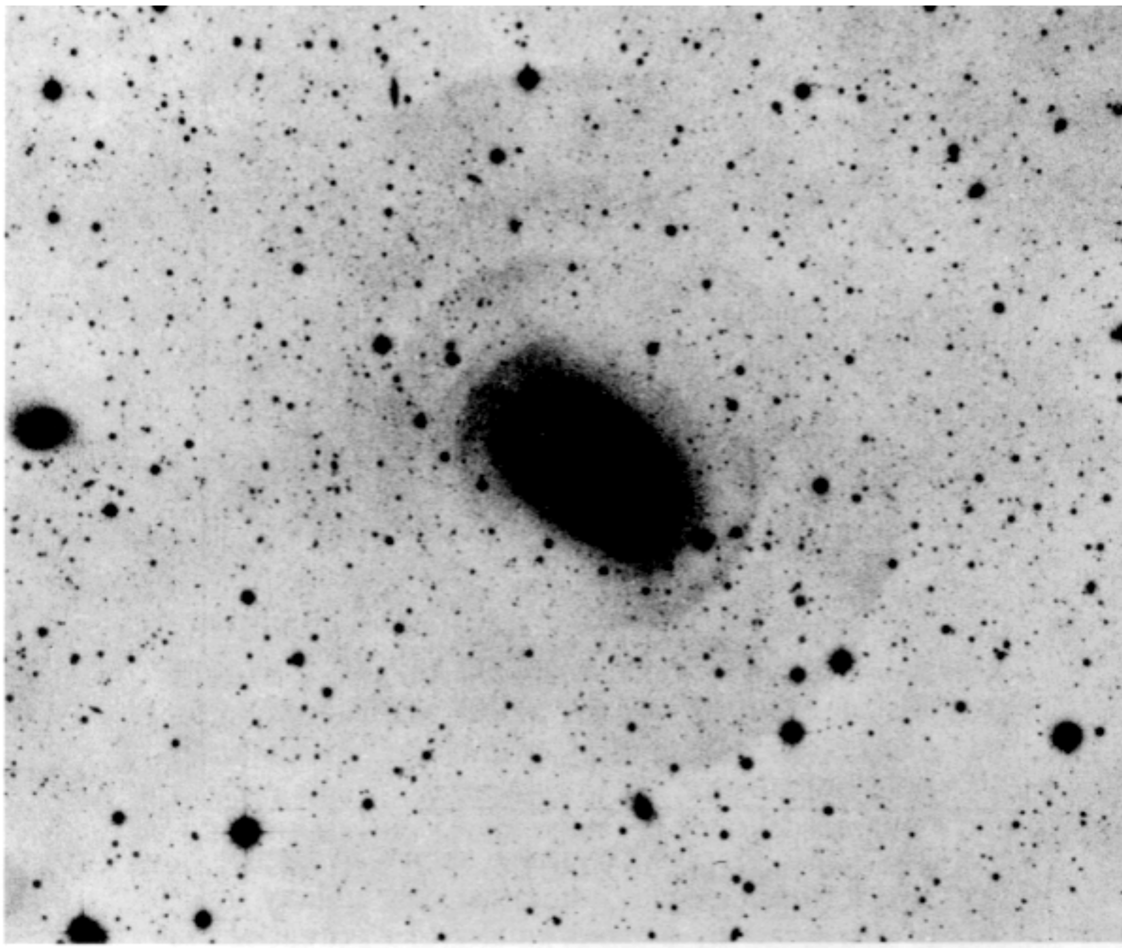


Figure 7-22. The giant elliptical galaxy NGC 3923 is surrounded by faint ripples of brightness. Courtesy of D. F. Malin and the Anglo-Australian Telescope Board.

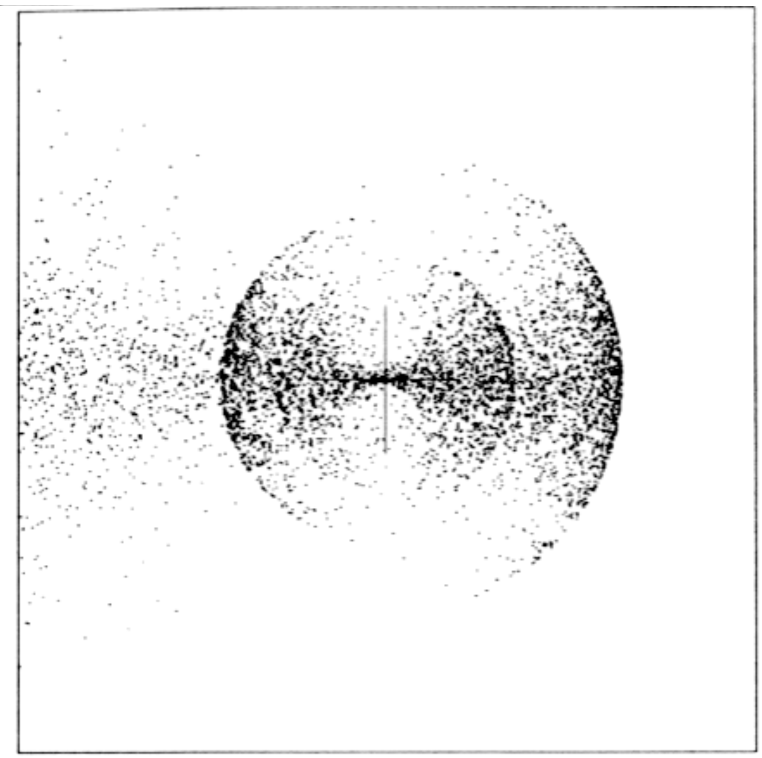


Figure 7-23. Ripples like those shown in Figure 7-22 are formed when a numerical disk galaxy is tidally disrupted by a fixed galaxy-like potential. (See Hernquist & Quinn 1987.)

Elliptical Galaxies: Surface Photometry

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.

De Vaucouleurs' Law

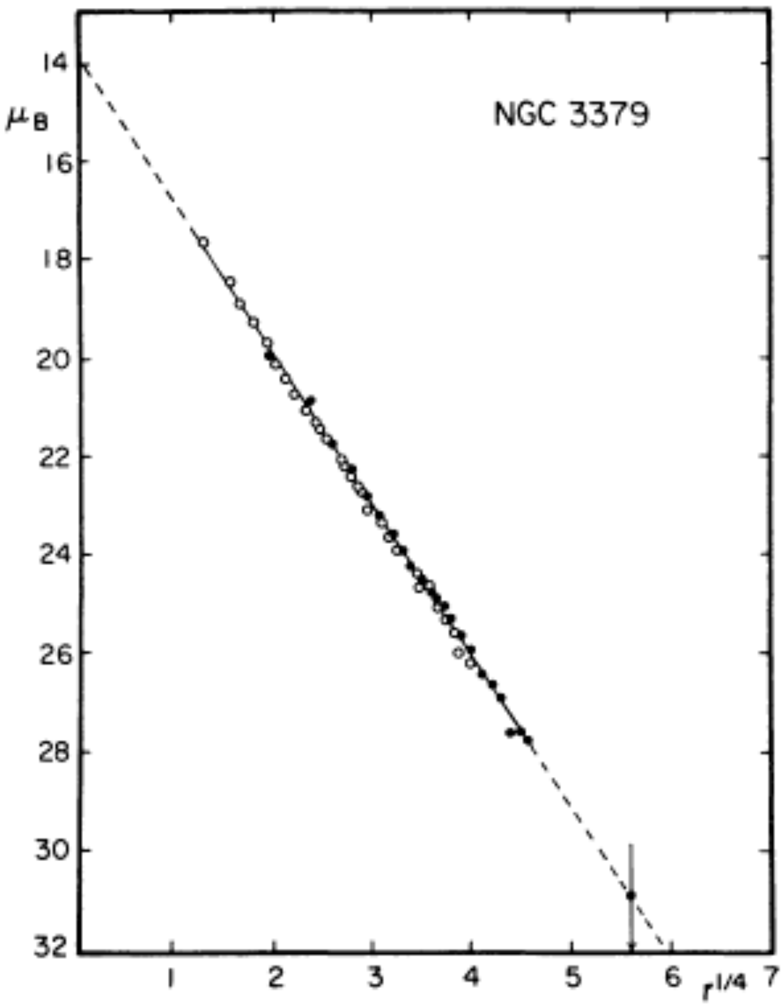
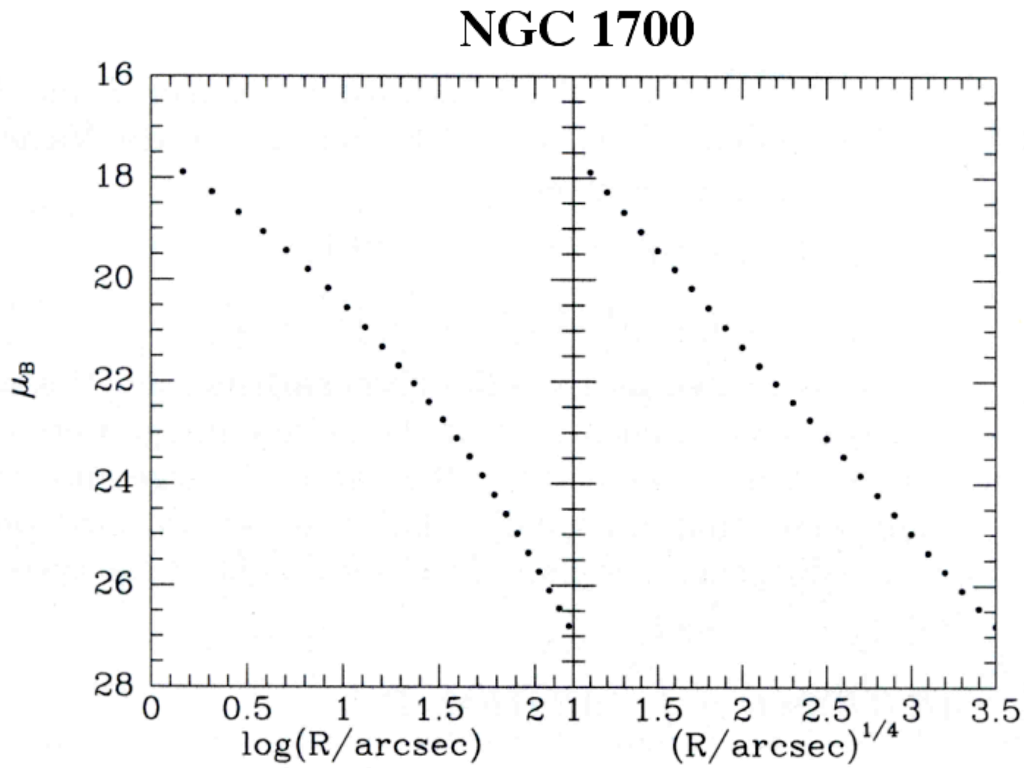


FIG. 2.—Mean E-W luminosity profile of NGC 3379 derived from McDonald photoelectric data. ●, Pe 4 data with 90 cm reflector; ○, Pe 1 data (M + P) with 2 m reflector. Note close agreement with $r^{1/4}$ law.



$R^{1/4}$ profile fits the data very well over some 2 decades in radius

Other Common Profiles

Sersic profile:

$$\Sigma(r) = \Sigma_0 \exp\left\{-b_n\left[(r/r_e)^{1/n}\right]\right\}$$

where $\boldsymbol{\Sigma}$ is the surface brightness in linear units (not magnitudes), $\mathbf{b_n}$ is chosen such that half the luminosity comes from $\boldsymbol{R} < \boldsymbol{R_e}$. This law becomes de Vaucouleurs for $\boldsymbol{n} = 4$, and exponential for $\boldsymbol{n} = 1$.

Hubble's profile:

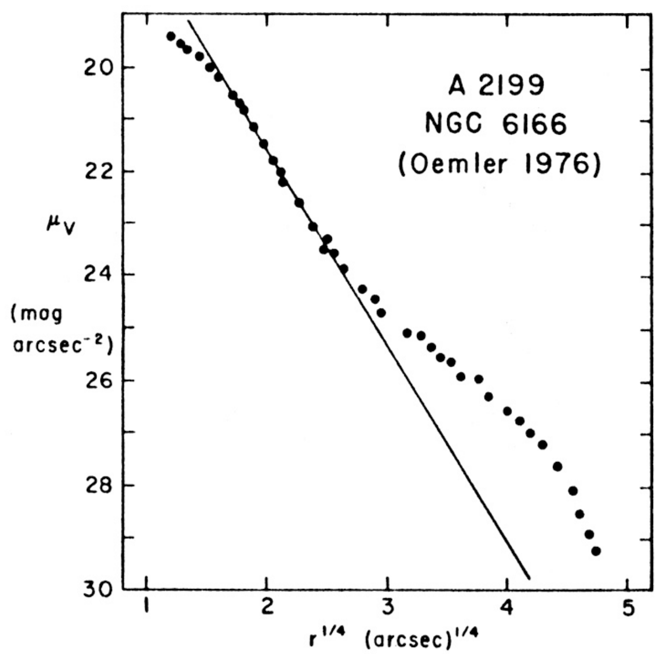
$$\Sigma(r) = \frac{\Sigma_s}{(1+\frac{r}{r_s})^2}$$

with $\boldsymbol{\Sigma}_0$ the central surface brightness, and $\boldsymbol{r}_0$ the "core" radius interior to which the surface brightness profile is approx. constant. Note that the integral under the Hubble profile diverges!

De Vaucouleurs Profile: Deviations

It is remarkable that such simple, 2-parameter profiles, fit the data of many ellipticals rather well. However, when these galaxies are studied in detail it is apparent that there is an individual behavior. It seems that deviations with respect to the de Vaucouleurs profile depend upon the total intrinsic luminosity of the galaxy.

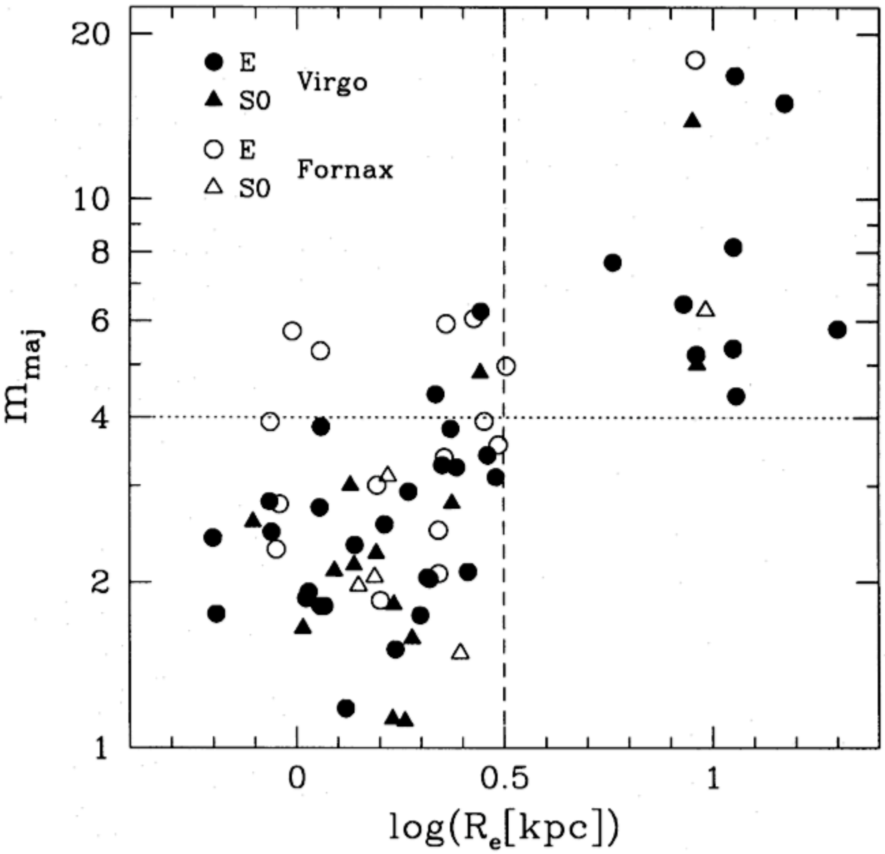
The figure below shows the example of a cD galaxy:



There is an excess of brightness in the outer parts of the galaxy with respect to the standard de Vaucouleurs profile.

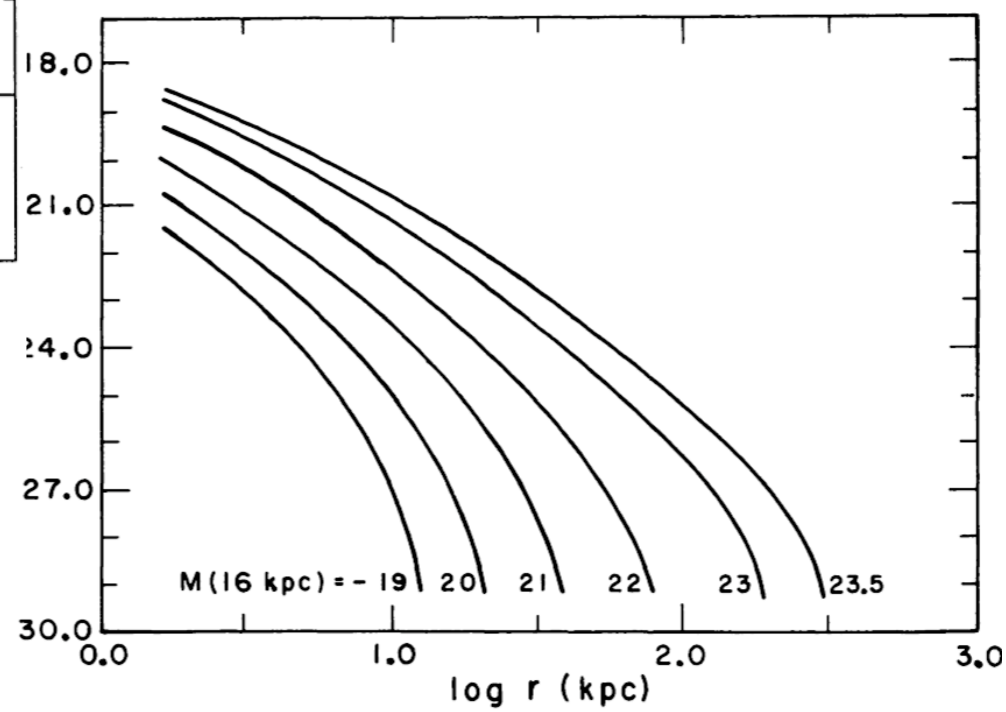
In the case of dwarf ellipticals, the deviations occur in the opposite direction.

Breaking the Homology: Density Profiles



← Sersic profile index ($r^{1/n}$) correlates with the galaxy size *(D'Onofrio et al. 1994)*

More luminous ellipticals have shallower profiles → *(Schombert 1986)*



The Cores and Nuclei of Ellipticals

Profiles of elliptical galaxies can deviate from the $R^{1/4}$ law at both small and large radii. Close to the center:

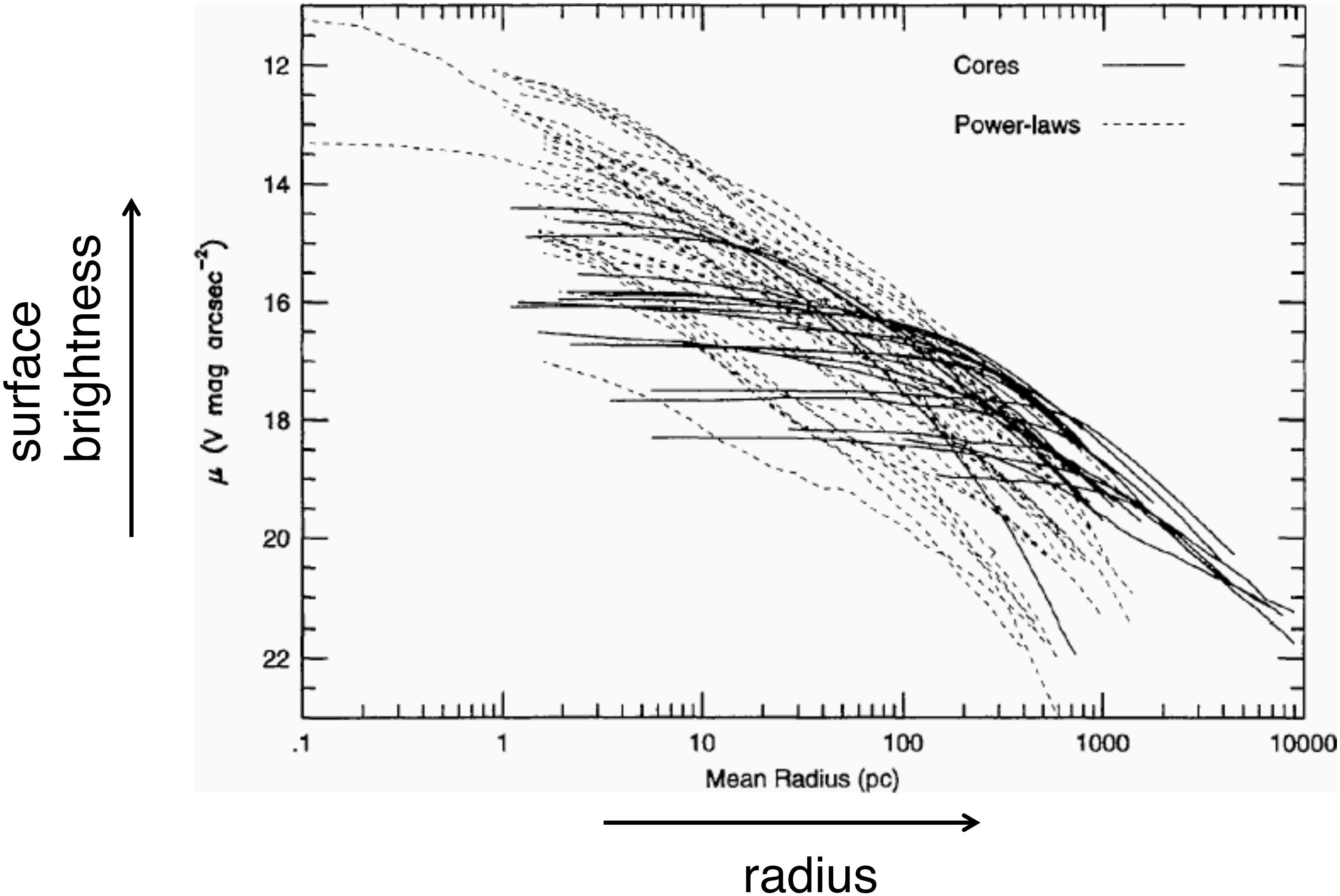
- Some galaxies have **cores** - region where the surface brightness flattens and is ~ constant
- Other galaxies have **cusps** - surface brightness rises steeply as a power-law right to the center

A cuspy galaxy might appear to have a core if the very bright center is blurred out by atmospheric seeing. Thus, HST is essential to studies of galactic nuclei!

It turns out that:

- The most luminous ellipticals have HST-resolved cores
- Low luminosity ellipticals have power law cusps extending inward as far as can be seen

Core Profiles From the HST



Central Surface Brightness Profiles

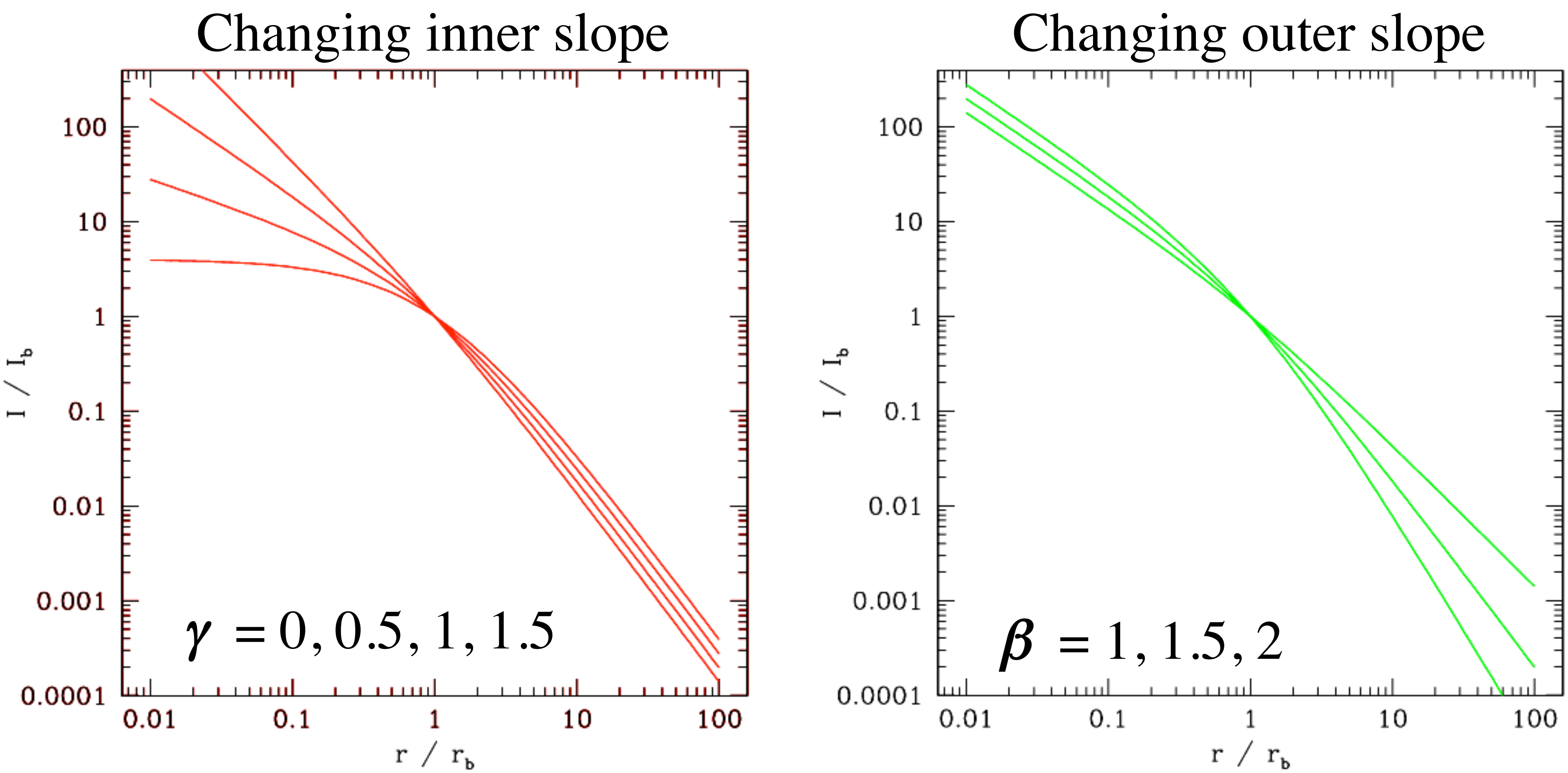
To describe these observations, we can use a new profile suggested by the "Nuker" team:

$$I(R) = I_b 2^{(\beta-\gamma)/\alpha} \left(\frac{R}{R_b} \right)^{-\gamma} \left[1 + \left(\frac{R}{R_b} \right)^{\alpha} \right]^{(\gamma-\beta)/\alpha}$$

It is a broken power law:

- Slope of $-\gamma$ at small radii
- Slope of $-\beta$ at large radius
- Transition between the two slopes at a break radius R_b, at which point the surface brightness is I_b
- Remaining parameter α controls how sharp the changeover is

The "Nuker" Profile



Next:

Elliptical Galaxies: Shapes