Photometry of Ellipticals and Globular Clusters

Ben and John

CLASSIFICATION

- Ellipticals are characterized by their shape and lack of gas/young stars
- 3 classes, defined by total luminosity:

Classification	Luminosity Range
Luminous Giant Ellipticals	$L \geq L_\star$
Midsize Ellipticals	$L_\star \geq L \geq 3 \times 10^9 L_\odot$
Dwarf Ellipticals	$L \leq 3 \times 10^9 L_\odot$

$L_\star = 2 \times 10^{10} L_\odot$

(S+G, p. 242, 2007)

CLASSIFICATION

- Also use isophotes to classify by shape
- Can define ellipticity ϵ:

$$\epsilon = 1 - \frac{b}{a}$$

- Ellipticity is usually constant between isophotes (but not always)

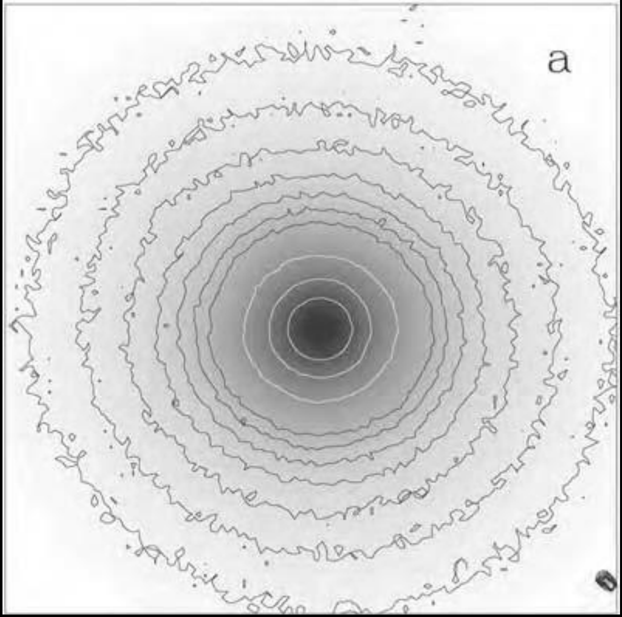


Fig 6.1(a) (S+G, p. 243, 2007)

(S+G, p. 242, 2007)

CLASSIFICATION

- Using ellipticity ϵ, we can define the Hubble type E_n, where

$$n = 10\epsilon$$

- For E_0, the elliptical appears circular ($a = b$)
- For E_5, the major axis appears to be twice the semi-major ($a = 2b$)
- Astronomers usually round to nearest n
- Hubble type depends on viewing direction

(S+G, p. 242, 2007)

LUMINOSITY PROFILE

- Very little absorption by dust
- SB of ellipticals highly concentrated in centre
- Can use Sersic's formula to model SB, with modifications:

$$I(R) = I(R_e)e^{-b\left(\frac{R}{R_e}\right)^{\frac{1}{n}}-1}$$

- R_e is the radius of circle enclosing half the light
- For large galaxies, we take $n = 4$, $b \cong 1.999n - 0.327$
- For small ones, we just use the exponential:

$$I(R) = I(R_e)e^{\frac{-R}{R_e}}$$

(S+G, pp. 242-4, 2007)

LUMINOSITY PROFILE: LARGE ELLIPTICALS

- cD Ellipticals are the largest ones
- Have luminosity significantly brighter than $L_\star$
- Bright cD galaxies like NGC 1399 follow $R^{\frac{1}{4}}$ well
- Note the plateau around 0

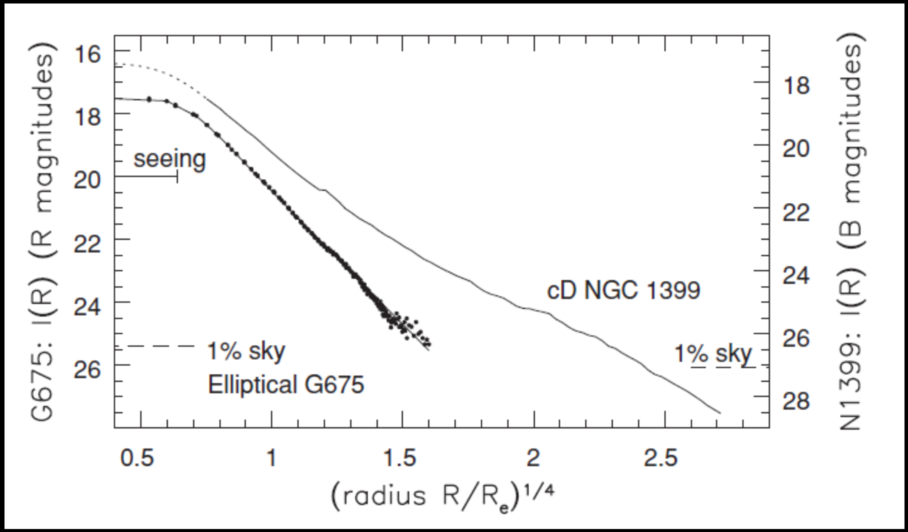


Fig 6.3 (S+G, p. 245, 2007)

(S+G, p. 245, 2007)

LUMINOSITY PROFILE: LARGE ELLIPTICALS

- We can sometimes see arcs in outer regions of ellipticals
- Believed to be caused by debris from small galaxies absorbed in the past

NGC 474 displaying prominent arcs
(APOD Jan 5, 2014)

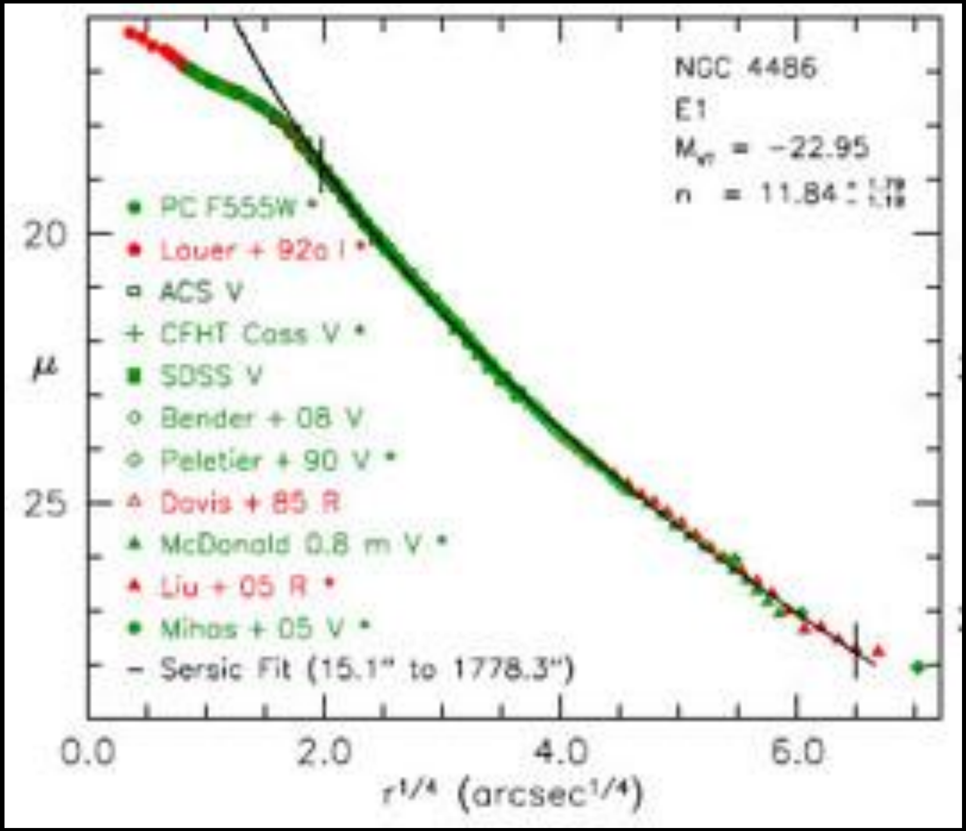
(S+G, pp. 245-7, 2007)

LUMINOSITY VS CENTRAL BRIGHTNESS

- Define core as area inside radius r_c
  - r_c is radius where SB drops to ½ central brightness
- Large and midsized galaxies with large total luminosity have low central brightness
- More luminous the galaxy, the lower the central SB and the larger the core
- Believed to be because larger galaxies endured more mergers, so the cores are less tightly packed
- Some plots follow showing the core brightness of three galaxies of decreasing luminosity

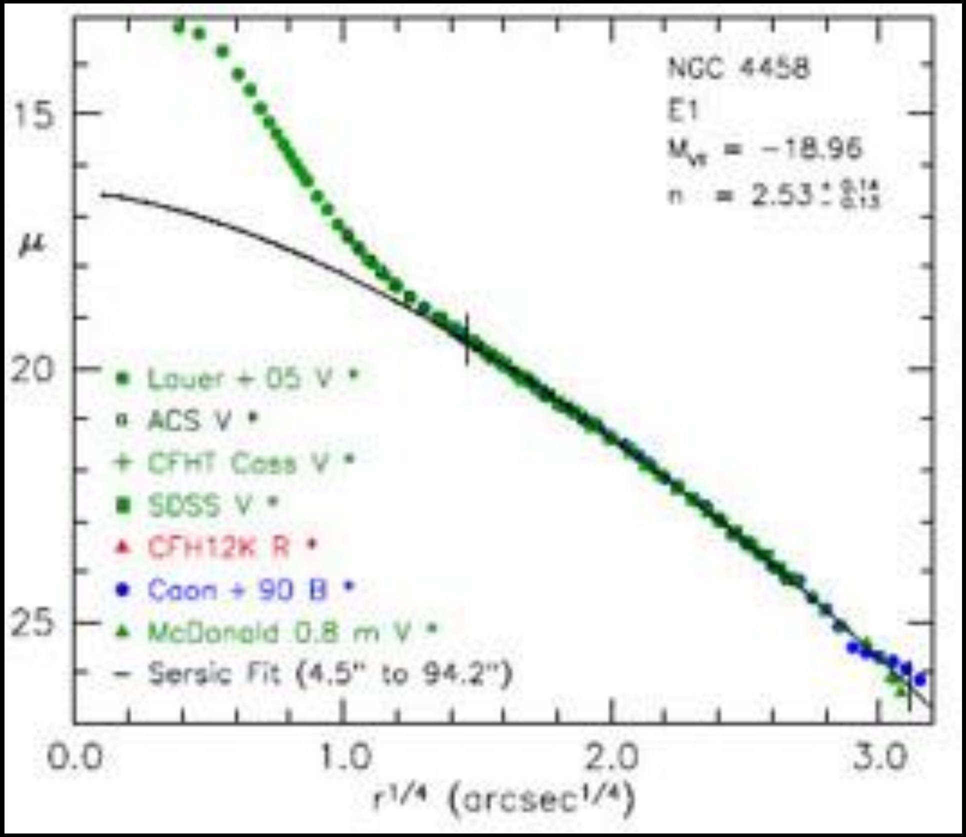
(S+G, pp. 247-9, 2007)

LUMINOSITY VS CENTRAL BRIGHTNESS



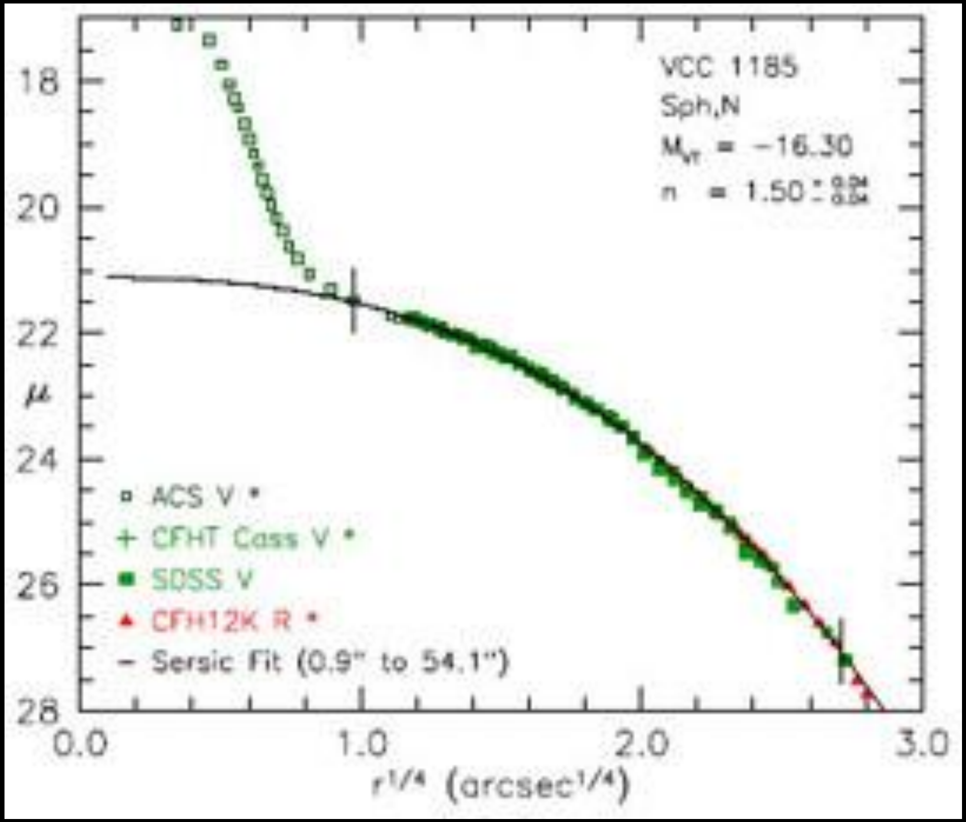
KFCB (2009)

LUMINOSITY VS CENTRAL BRIGHTNESS



KFCB (2009)

LUMINOSITY VS CENTRAL BRIGHTNESS



KFCB (2009)

LUMINOSITY VS CENTRAL BRIGHTNESS

- Dwarf elliptical and spheroidal galaxies with $M_v \geq -18$ ($L \leq 10^9 L_\odot$) display deviations from this trend
- Central SB is lowest in dE and dSph
- Have larger cores than midsized ellipticals

(S+G, pp. 247-9, 2007)

NUMBER DENSITY FROM LUMINOSITY PROFILE

- Ellipticals have almost no dust
  - Observed luminosity can be considered to be total luminosity (B+M, p. 185)
- We assume that SB ∝ $n(r)$, where $n(r)$ is the number density of stars
- Then for most ellipticals, $n(r) \propto r^{-1}$
- But we have central plateaus in large galaxies (NGC 1399)
- Perhaps a limitation in our observation techniques

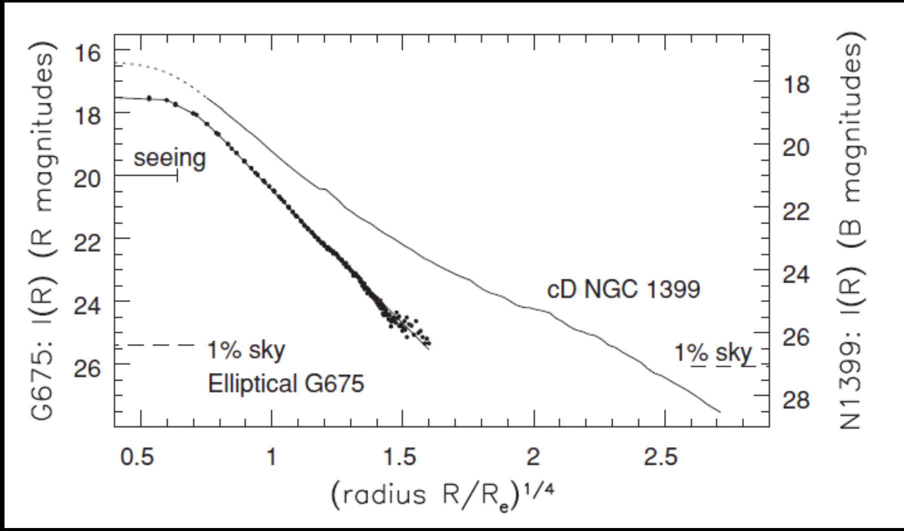


Fig 6.3 (S+G, p. 245, 2007)

(S+G, pp. 248-9, 2007)

SHAPES OF ELLIPTICAL GALAXIES

- Usually we model ellipticals as oblate spheroids
- For elliptical that satisfies,

$$m^2 + \frac{x^2 + y^2}{A} + \frac{z^2}{B}$$

the picture describes the perceived shape for viewing angle i

- The ratio q of semi and minor axes is

$$q_{obl}^2 = (B/\mathrm{A})^2 \sin^2 i + \cos^2 i$$

- For prolate spheroid:

$$q_{prol}^2 = [(B/\mathrm{A})^2 \sin^2 i + \cos^2 i \quad]^{-1}$$

(S+G, pp. 249-51, 2007)

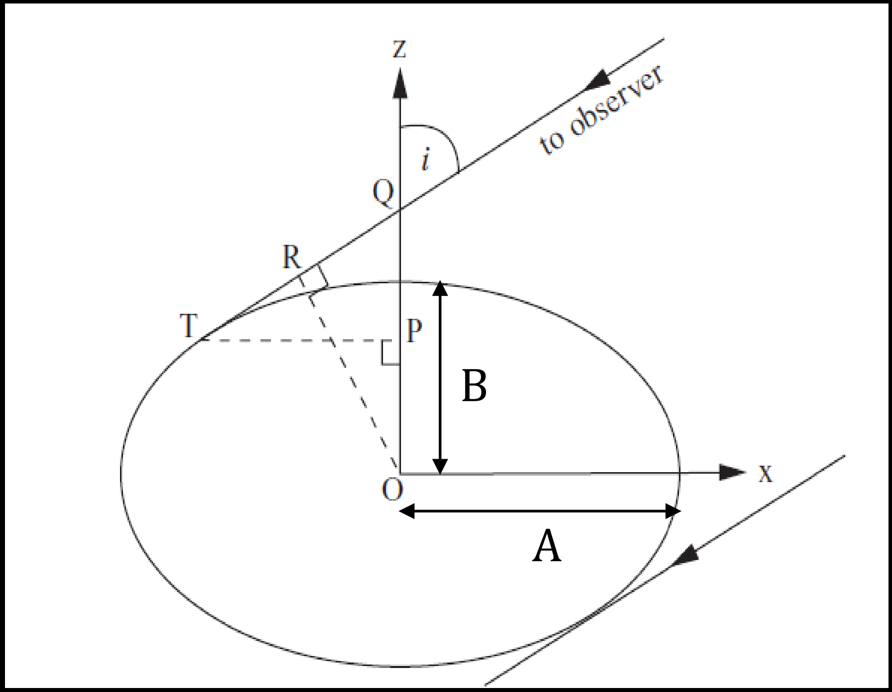


Fig 6.8 (S+G, p. 250, 2007)

SHAPES OF ELLIPTICAL GALAXIES

- Obviously not all galaxies are oblate or prolate, some are triaxial
- This can cause some interesting observations, namely isophotes twisting

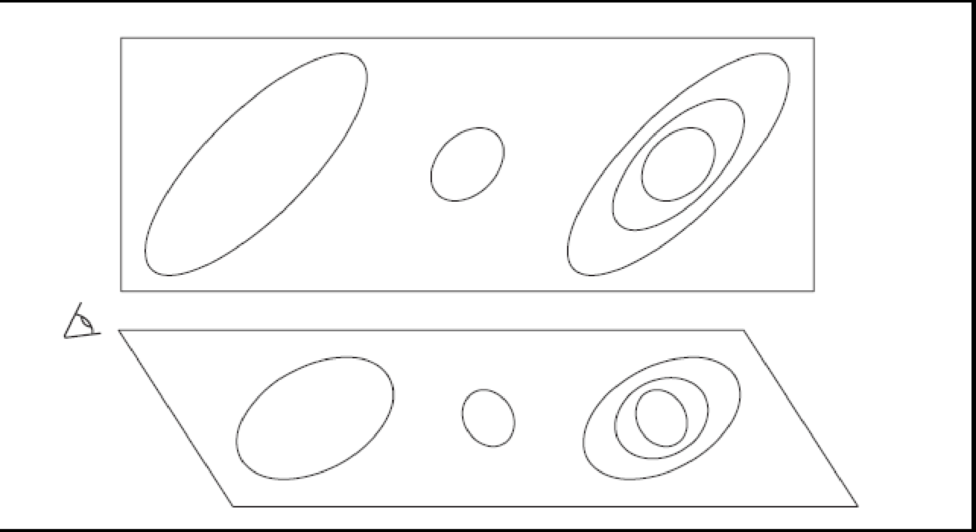


Fig 6.10 (S+G, p. 253, 2007)

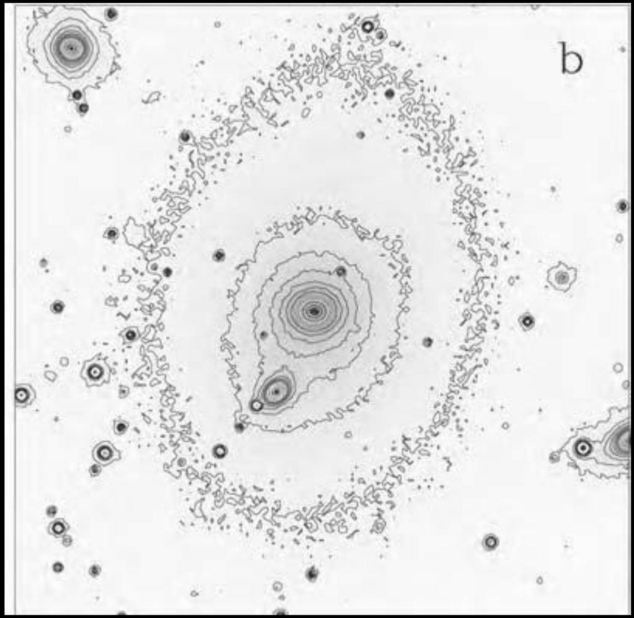


Fig 6.1(b) (S+G, p. 243, 2007)

(S+G, pp. 251-3, 2007)

GLOBULAR CLUSTERS

- We detect globular clusters by making luminosity models of galaxies and then subtracting these models from the recorded image
  - Works well for ellipticals, because luminosity function is fairly smooth
  - Allows us to determine the apparent magnitude of the cluster
- The numbers of clusters of each apparent magnitude are well described by a Gaussian:

$$\frac{dN}{dm} = Ae^{-(m-m_0)^2/2\sigma_m^2}, \qquad m < m_{lim}$$

- The const m_0 is chosen to best fit the data, and varies with distance in the same way that the distance modulus does. This suggests a luminosity function for globular clusters:

$$\Phi(M) = \text{constant} \times e^{-(M-M_0)^2/2\sigma_m^2}$$

(B+M, pp. 235-7, 1998)

GLOBULAR CLUSTERS

- As far as shapes go, clusters within the Milky Way appear to be mostly spherical
- However, clusters seen in the LMC are elongated
- Theory goes that the clusters in the Milky Way are older and have had more time to even out and become spherical

(B+M, pp. 238-9, 1998)

GLOBULAR CLUSTERS

- We estimate the metallicity of extra-galactic clusters by
  - Measuring their line-strength indices, then
  - Assigning a metallicity based on local clusters with similar spectra
- Not a great method because we assume these clusters are as old as those in Milky Way

(B+M, pp. 239-40, 1998)

REFRENCES

Binney, J., & Merrifield, M. (1228). *Galactic Astronomy*. Princeton: Princeton University Press.

CEA;CFHT. (2014, January 5). Galaxy NGC 474: Shells and star streams. Retrieved February 9, 2017, from Astronomy Picture of the Day: https://apod.nasa.gov/apod/ap140105.html

Kormendy, J., Fisher, D. B., Cornell, M. E., & Bender, R. 2009, ApJS, 182, 216 (KFCB)

Sparke, L., & Gallagher, J. (2007). *Galaxies in the Universe: An introduction.* Cambridge: Cambridge University Press.