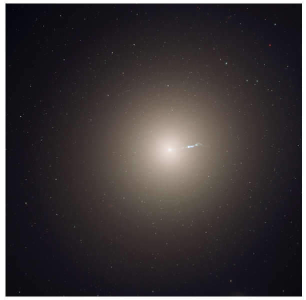
Photometry



- E's span a huge range of luminosity from the brightest to some of the dimmest galaxies in the Universe!

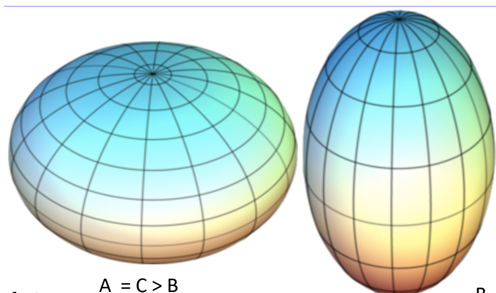
- Useful to divide into 3 classes
  - **Giant ellipticals:** $L > 2 \times 10^{10}\ M_\odot$, $M_B < -20$
  - **Mid-sized ellipticals:** $L = 3 \times 10^{9} - 2 \times 10^{10}\ M_\odot$, $M_B = -18$ to -20
  - **Dwarf ellipticals** ($L < 3 \times 10^{9}\ M_\odot$, $M_B > -18$)
- For E's there is a strong correlation between radius and luminosity

1

Ellipticals vs. spirals

- Very different than spirals.
- Disk is rarely present.
- No cold gas.
- No ongoing star formation.
- Old stellar populations.
- Little or no internal substructure.
- Span a wide range of masses and dominate the most massive galaxy population.
- Can be oblate (like grapefruit) or triaxial (like football).

2



grapefruit

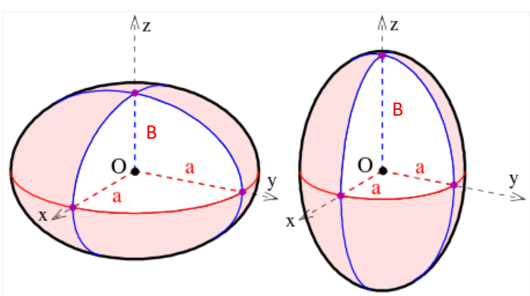
A = C > B

oblate spheroid

football

B > A = C

prolate spheroid



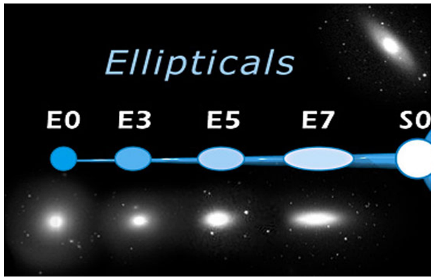
3

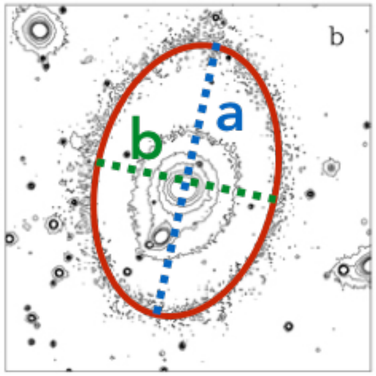
3

Triaxial : Three axes are different , in this case: C > B > A

4

4



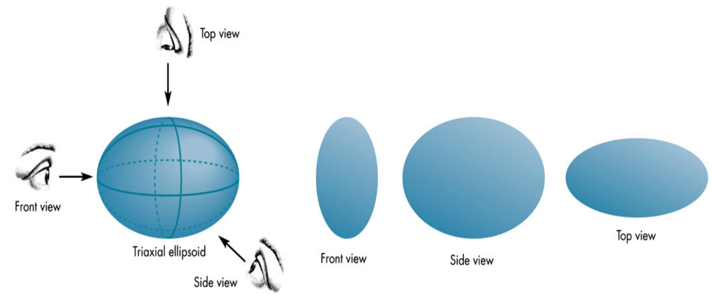


Ellipticity ε = 1-b/a

Ellipticals often labeled by “En” where n=10*ε

E0: circular appearance
E5: ε = (1-b/a) = 0.5

3D Shapes of Elliptical Galaxies



3D shape of any given elliptical is not possible to determine from projection on the sky.

Instead, examine the statistics of the full population..

Viewing angles for an oblate galaxy

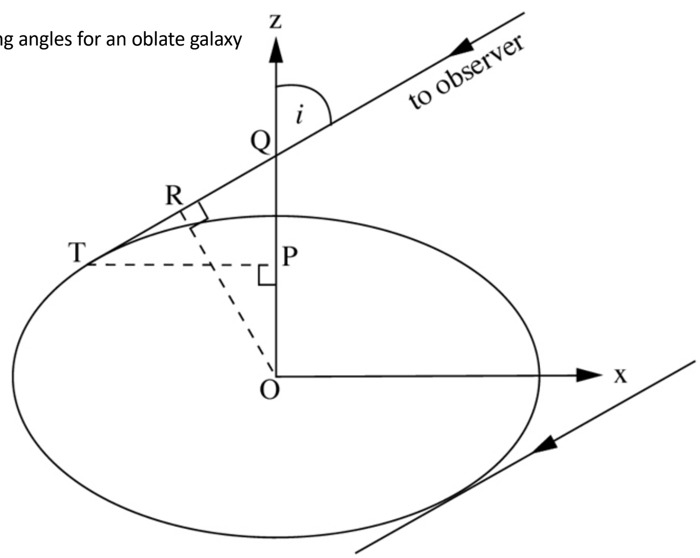


Fig 6.8 'Galaxies in the Universe' Sparke/Gallagher CUP 2007

$$q^2_{prolate} = (B/A)^2 sin^2 i + cos^2 i = 1/q^2_{oblate}$$

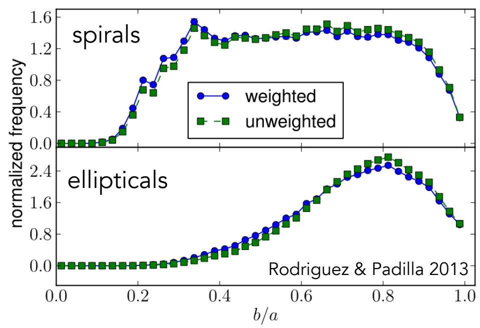
the **observed axis ratio is always lower than the intrinsic axis ratio**, i.e.

b/a < B/A
where (a, A major axes, b, B-minor axes)

3D Shapes of Elliptical Galaxies

Assume that galaxies are on average randomly oriented.

How often you see that axis ratio.



Observed Axis ratio

Mean Ellipticity
ε = 1-b/a ~ 0.26

So b/a ~ 0.74
not very flattened

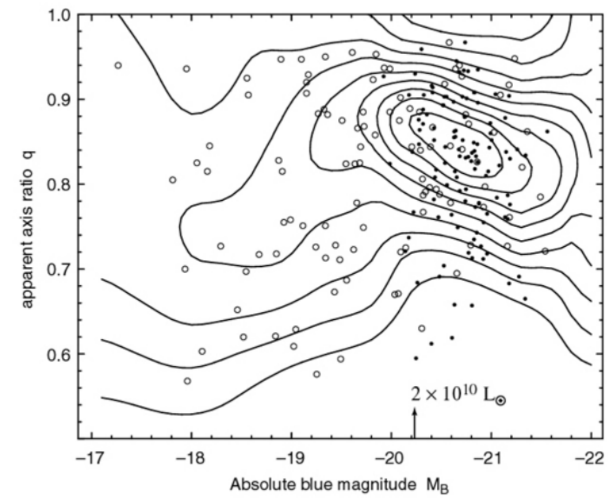


Fig 6.9 (Tremblay & Merritt) 'Galaxies in the Universe' Sparke/Gallagher CUP 2007

Observed axis ratio q and blue absolute magnitude for elliptical galaxies. Bright galaxies (right) on average appear rounder. Contours show probability density: the top contour level is for probability density 4.5 times higher that at the lowest. Tremblay & Merritt 1996 10

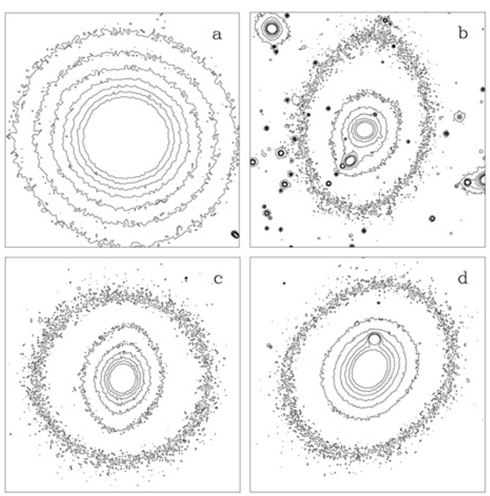
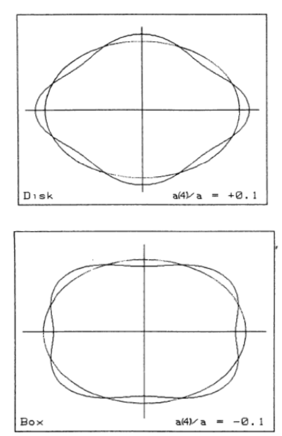
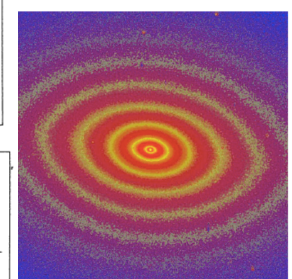


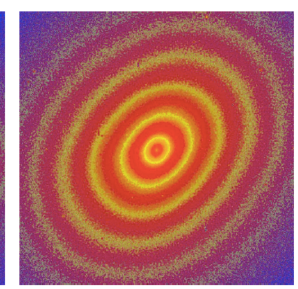
Fig 6.1 (R. de Jong) 'Galaxies in the Universe' Sparke/Gallagher CUP 2007

Isophotes in the R band of four giant elliptical galaxies. A) Isophotes are elliptical (NGC 5846)
B) The long axis of the inner isophotes is roughly horizontal, twisting to near-vertical at the outer contour (EFARJ16WG); C) Diamond-shaped 'disky' isophotes (Zw 159-89 in Coma);
D) Rectangular 'boxy' isophotes (NGC 4478). Compact objects are mainly foreground stars. 11





NGC 821: a_4/a ~ +0.02, disky



NGC 2300: a_4/a ~ -0.02, boxy

12

Boxy or disky?

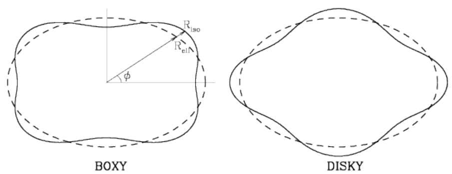
- We fit the isophote with an ellipse in parametric form:

$$x = a\cos t, \quad y = b\sin t$$

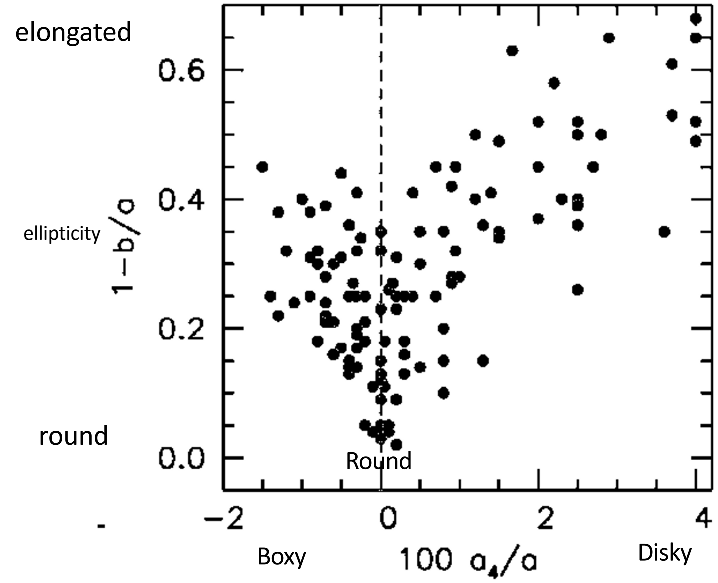
- And look for functional form of deviation (Fourier expansion in azimuth):

$$\Delta r(t) \approx \sum_{k\geq 3} a_k \cos(kt) + b_k \sin(kt)$$

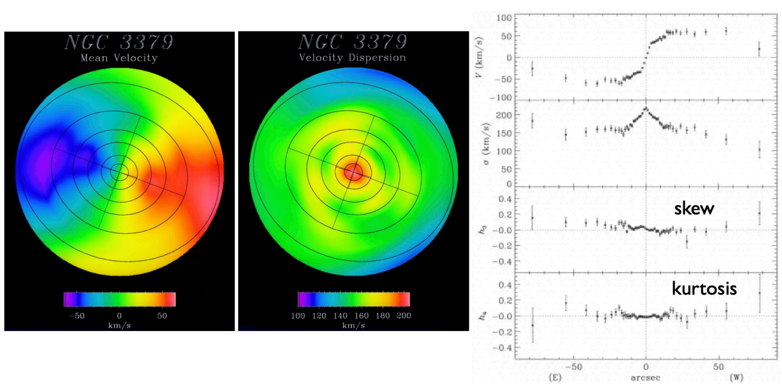
- We fit the best matching ellipse, (for k=0,1,2 all terms are zero) k=3 terms are small but k=4 (a4) is not. a4 > 0 ellipse is "pushed out" on major and minor axes, while if a4 < 0 it bulges out at 45 deg from the axes.



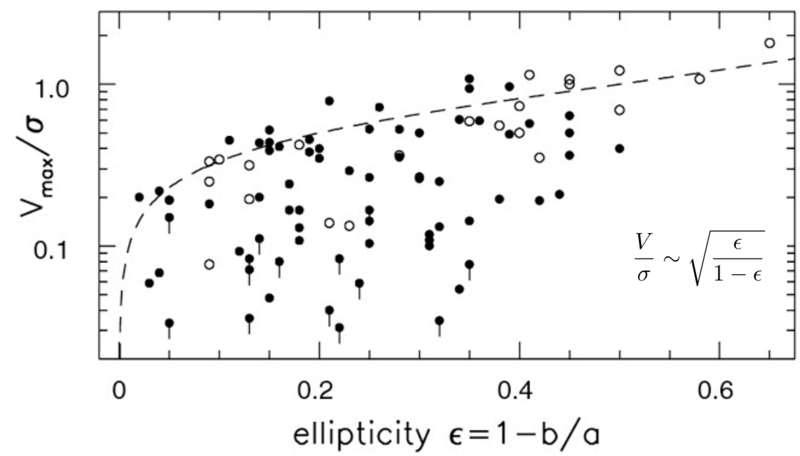
a4 < 0 a4 > 0



Elliptical galaxies do rotate …



- … it's just that their dispersion is larger.



$$\frac{V}{\sigma} \sim \sqrt{\frac{\epsilon}{1-\epsilon}}$$

Fig 6.14 (R. Bender) 'Galaxies in the Universe' Sparke/Gallagher CUP 2007

The ratio of measured peak rotation speed to central velocity dispersion for elliptical galaxies, plotted against apparent ellipticity: filled circles show bright galaxies (Mv< -19.5); open circles are dimmer galaxies. Points with downward extending bars indicate upper limits on Vmax. The dashed line gives (V/ σ)iso, the fastest rotation expected for a given flattening.

Rapid Rotators

Slow Rotators

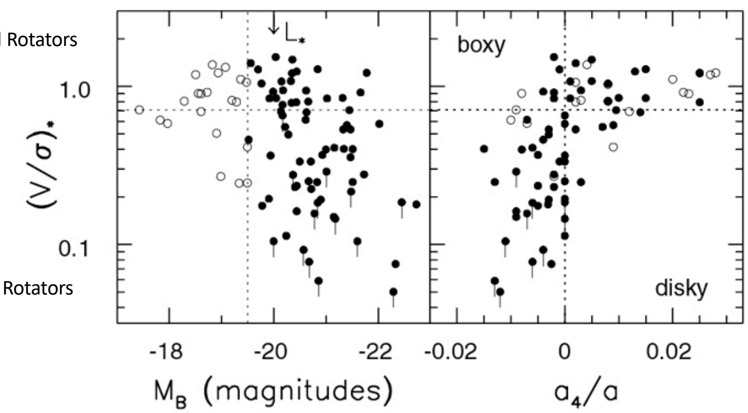


Fig 6.15 (R. Bender) 'Galaxies in the Universe' Sparke/Gallagher CUP 2007

The ratio of the measured Vmax/σ to (V/σ)iso, the rotation expected for an oblate galaxy. Down-ward pointing bars show upper limits on Vmax; filled circles are bright galaxies. Left, luminous galaxies often rotate slowly, falling below the dotted horizontal line at (V/σ)* = 0.6. Right, boxy galaxies with a4<0 are almost all slow rotators; many of these are luminous.