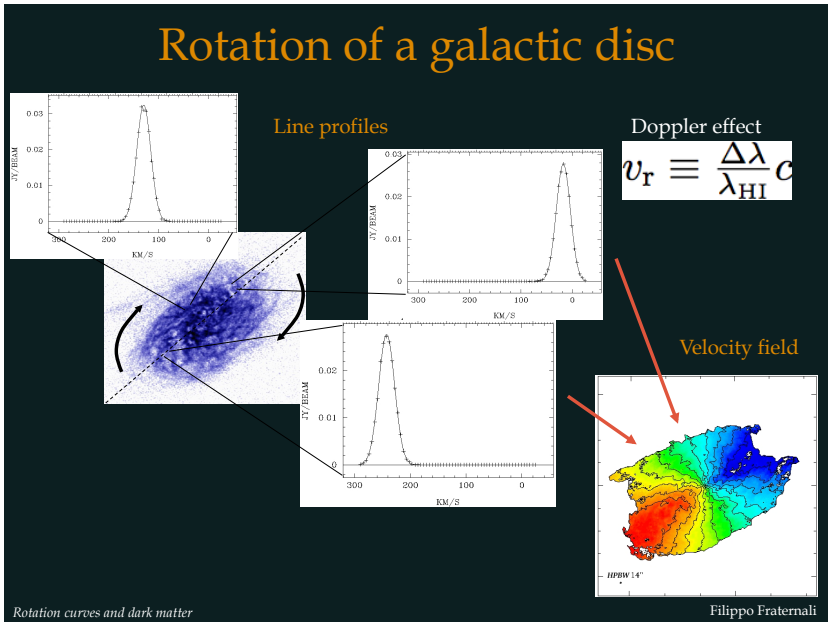
Rotation of a galactic disc



3

The Integrated HI Spectrum of Spiral Galaxies

Double peaked profile is characteristic of galaxies with the flat rotation curve and rising part in the center.

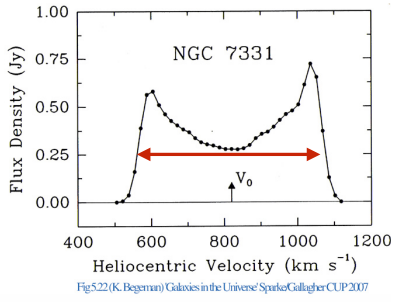


Fig 5.22 (K. Begeman) 'Galaxies in the Universe' Sparke/Gallagher CUP 2007

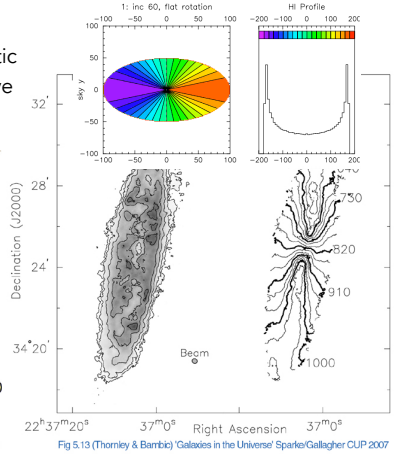
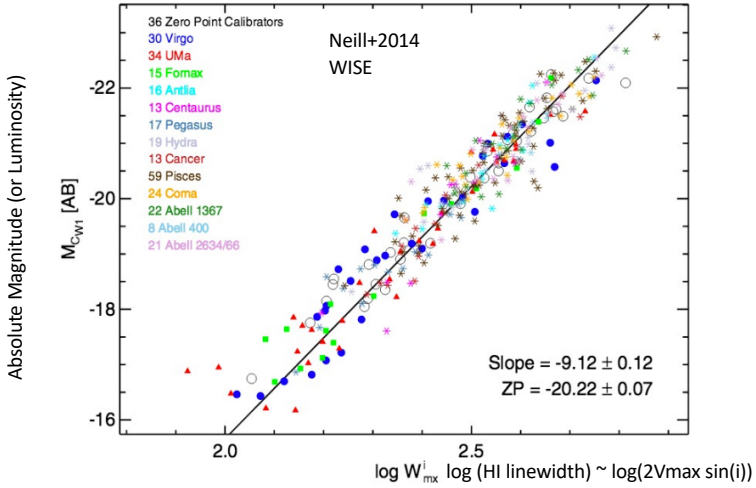


Fig 5.13 (Thornley & Bambic) 'Galaxies in the Universe' Sparke/Gallagher CUP 2007

Width of line ~ $2V_{max}$ sin(i)

4

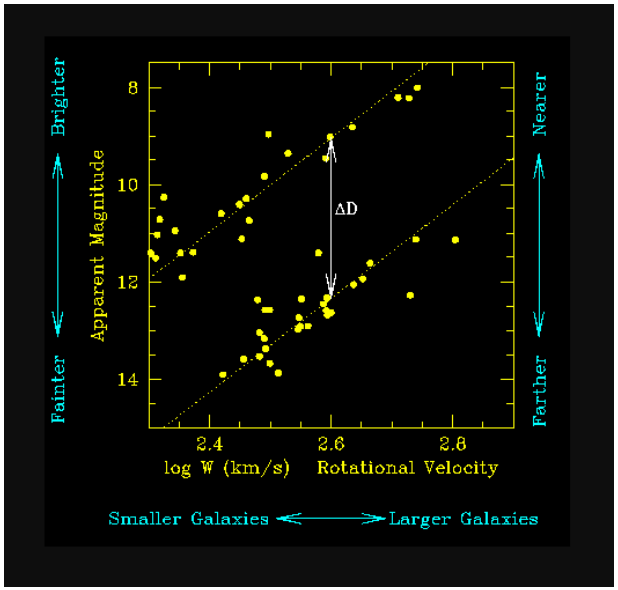
Tully Fisher Relation



- In spirals, luminosity L ~ v_{max}^{α} with α ~ 4.

5

5



6

6

Caveat: Inclination

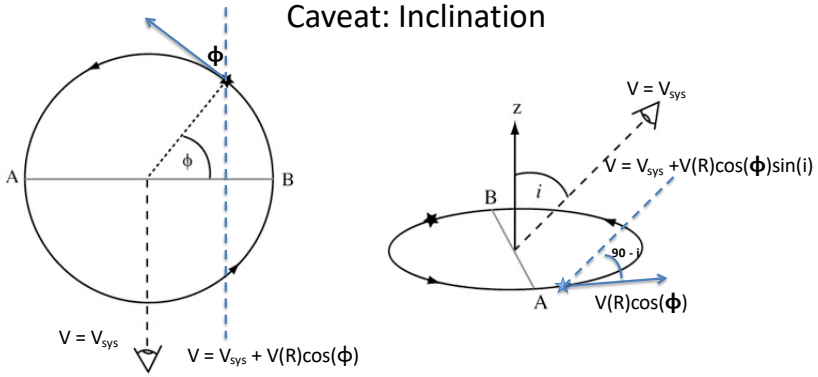
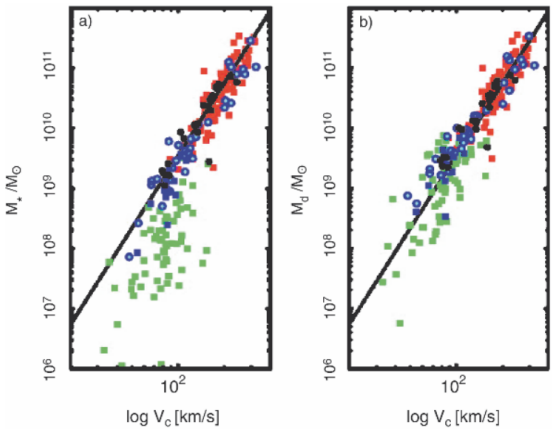


Fig 5.18 'Galaxies in the Universe' Sparke/Gallagher CUP 2007

Left, a rotating disk viewed from above. Azimuth ϕ measured in the disk plane, gives a star's position in its orbit; an observer looks from above the disk, perpendicular to diameter AB (i=0) .

Right, the observer's line of sight makes angle I with the disk's rotation axis z.

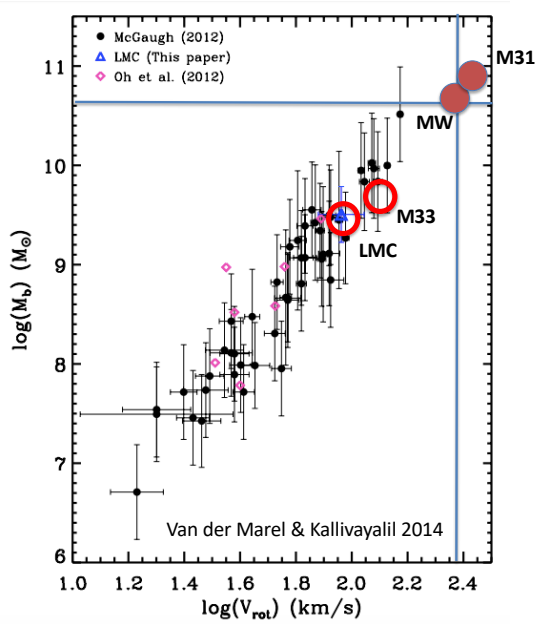
Baryonic Tully Fisher Relation



McGaugh 2011

Deviations from the Tully Fisher relation at the low mass end largely disappear if you include the gas mass in addition to the stellar mass (i.e. total disk mass).

Local Group & TF



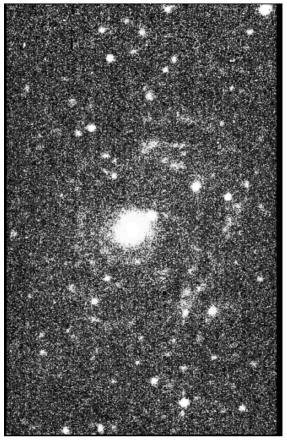
The central surface brightness of many spirals is ~ constant, irrespective of the absolute magnitude of the galaxy!

$$I_B(0) \approx 21.65 \text{ mag arcsec}^{-2}$$ ~100 Lsun/pc^2

OBSERVATIONAL BIAS !!

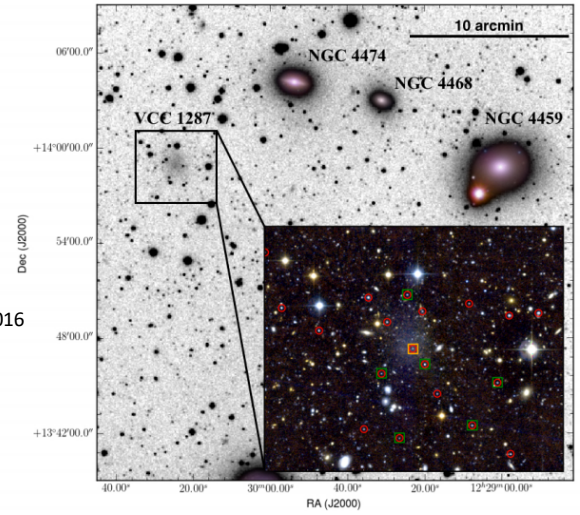
M101

Malin 1



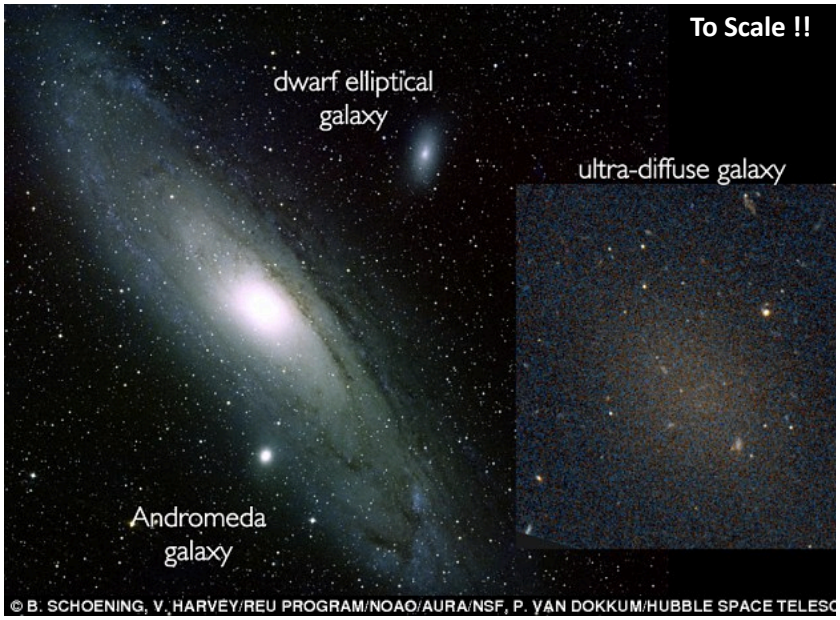
Ultra Diffuse Galaxies

Size of the MW, but the luminosity of a massive dwarf → Very low surface brightness



Beasley 2016

11



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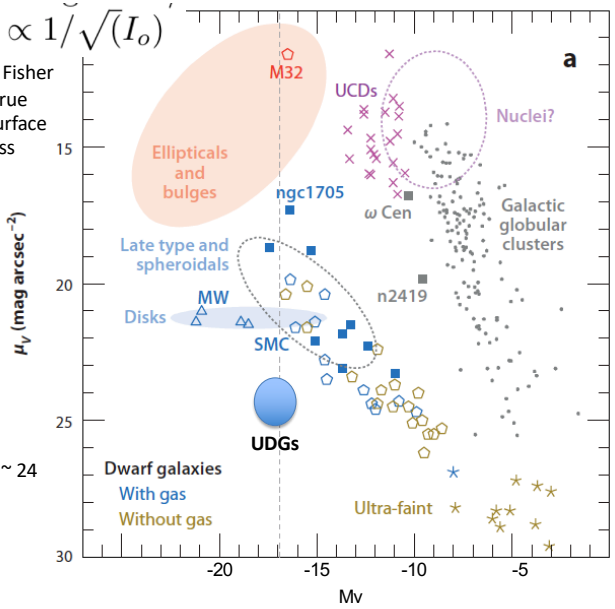
$M/L \propto 1/\sqrt{(I_o)}$

For Tully Fisher to hold true At low surface brightness

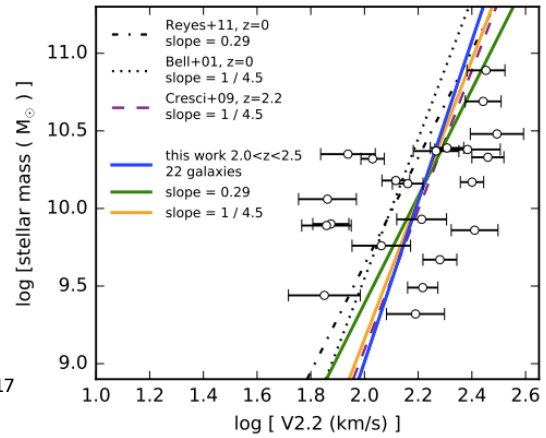


UDGs Central surface brightness ~ 24

13

Evolution of Tully Fisher?

- Lots of debate! Slope? Zero Point?



Straatman+17

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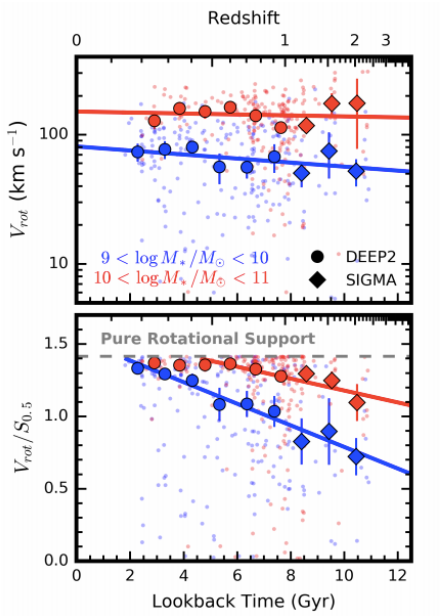
Evolution of Tully Fisher?

Evolution at low masses?

Simons+2017

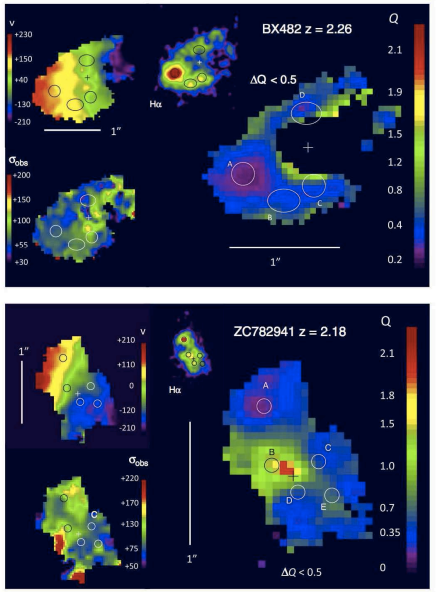


Morphology of high z galaxies

$$\sigma^2 = \frac{1}{N}\sum_{i=1}^{N}(v - \langle v \rangle)^2$$

$$\langle v \rangle = \frac{1}{N}\sum_{j=1}^{N} v_j$$

Genzel+2011



Faber-Jackson relation

- Stars move (dispersion) faster in more luminous galaxies. Similar to Tully-Fisher relation for spirals, ellipticals obey so called Faber-Jackson relation:

$$\frac{L_V}{2 \times 10^{10} L_\odot} \approx \left(\frac{\sigma}{200\,\mathrm{km\,s^{-1}}}\right)^4$$

- Can be used to determine distances: less precise than T-F. harder to measure total light from an elliptical.

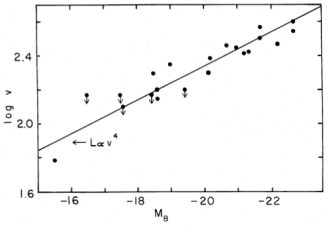
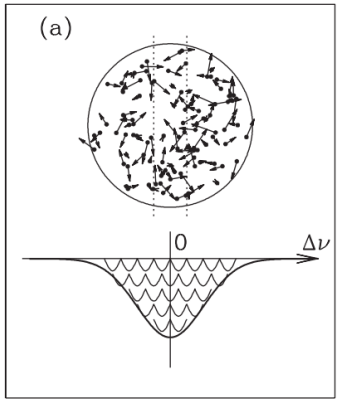


FIG. 16.—Line-of-sight velocity dispersions versus absolute magnitude from Table 1. The point with smallest velocity corresponds to M32, for which the velocity dispersion (60 km s^{-1}) was taken from Richstone and Sargent (1972).

From Faber and Jackson 1976

Measuring Velocity Dispersion from the spectrum of many stars simultaneously



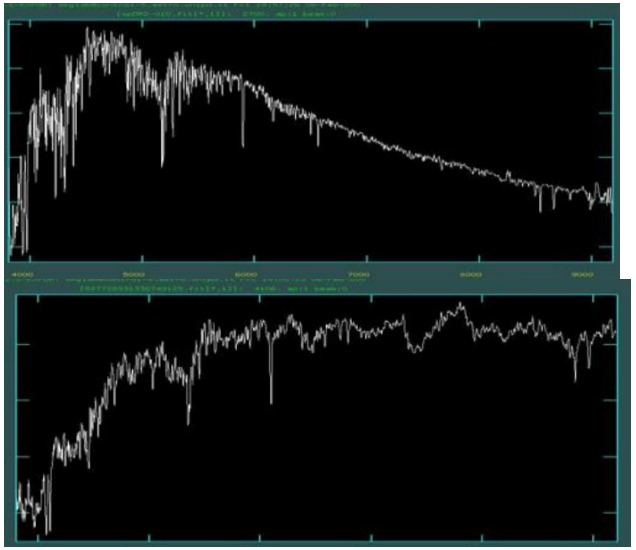
For nearby galaxies, can measure individual Vr for stars we see and measure σ

In distant galaxies, light from all stars is blended together.

Take an optical spectrum of an elliptical and a template star (usually a K-giant). Convolve the template with a gaussian of width σ until it matches the galaxy.

Template K star

Elliptical



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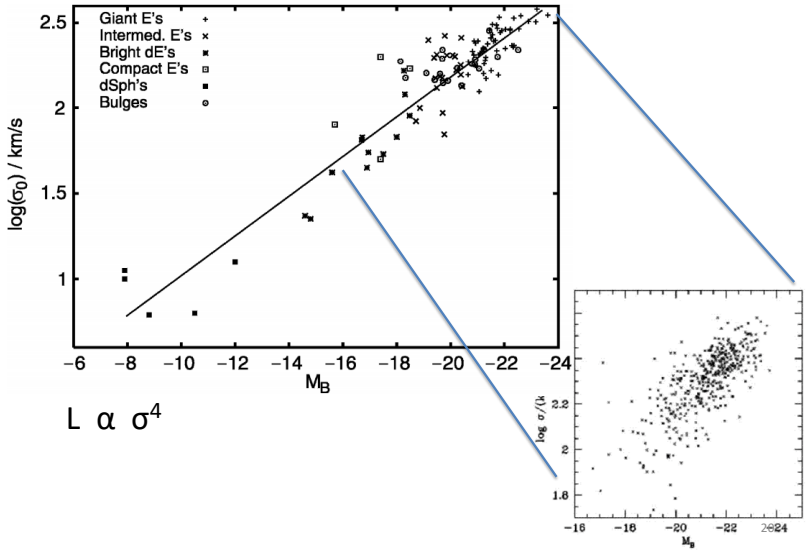
Faber-Jackson Relation

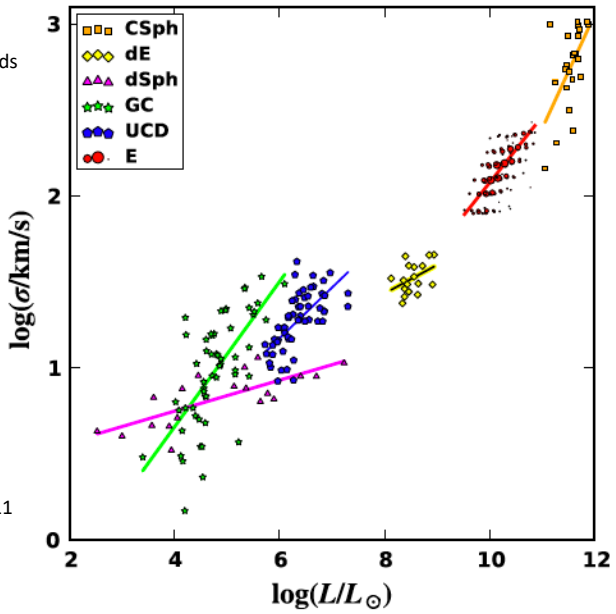


$L \alpha \sigma^4$

20

CSph:
Cluster Spheroids

Tollerud + 2011



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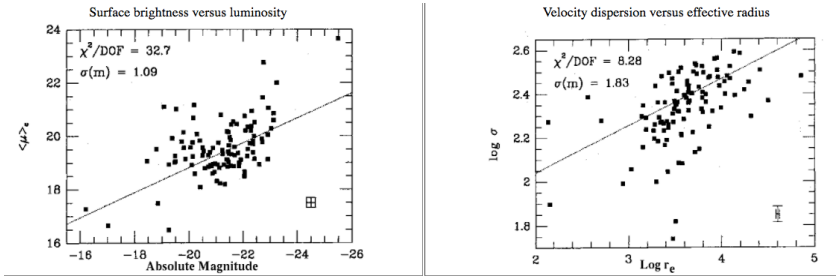
2 quantities .. Get scatter



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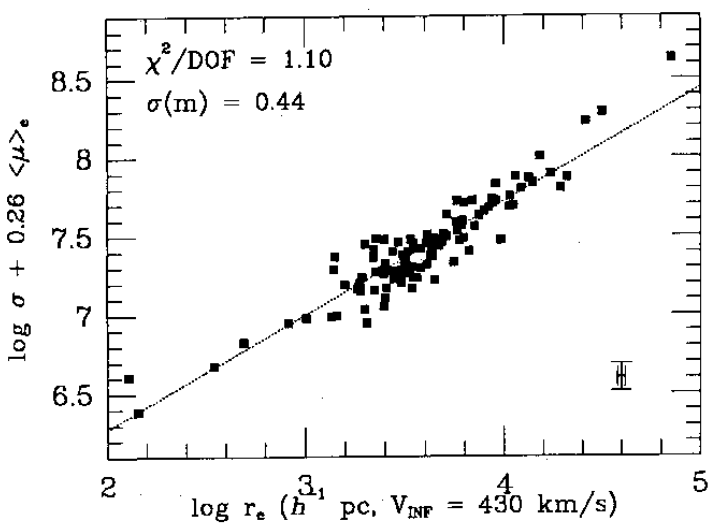
21

22

2 quantities vs a 3rd



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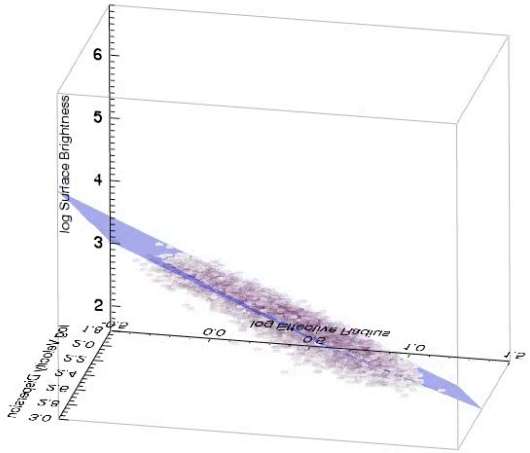
The Fundamental Plane



Courtesy: Rachel Bezanson

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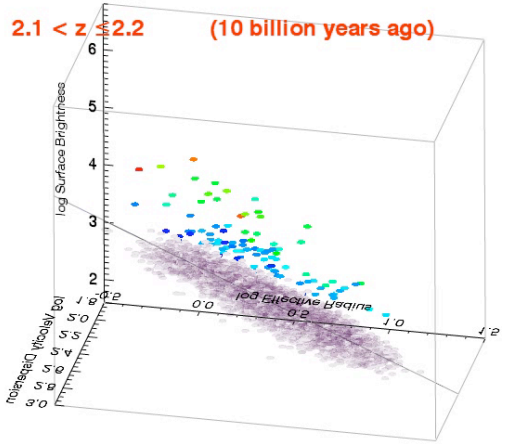
Courtesy: Rachel Bezanson

Redshift Evolution of the Fundamental Plane



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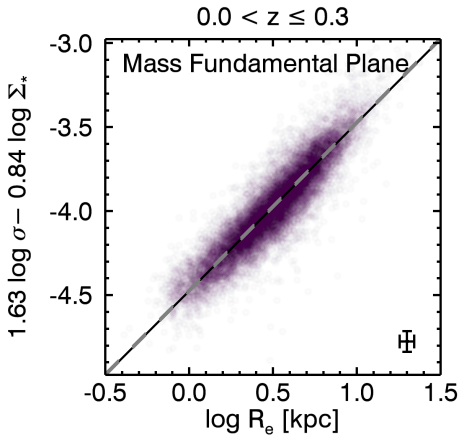
Mass Fundamental Plane
Bezanson+2015



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