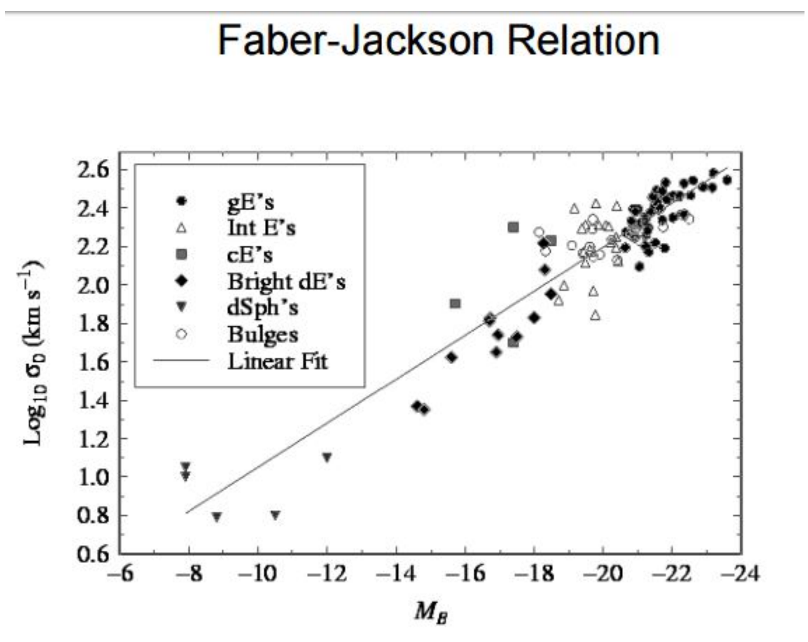
Faber-Jackson relationship

- Faber-Jackson relationship is an empirical relationship that relates luminosity of an elliptical galaxy to the central stellar velocity dispersion.This can be expressed mathematically as:
  $L_B = \sigma^4$
  This relation can be used to estimate the distance to the galaxy from earth. L_B is the luminosity of the galaxy in B band and σ is the central stellar velocity dispersion.
  We take central stellar velocity dispersion because of thick stellar population in the center.
- This relation implies that more luminous galaxies have a higher velocity dispersion.This can be accounted to the fact that more luminous galaxies are host to a higher population of stars.
  Distant galaxies may not be spatially resolved but we can get the velocity dispersion from the spectrum of the galaxy.
- Faber-Jackson relationship in mathematical form:
  $$log L_B = 4 log \sigma_o + constant$$
  $$\frac{-M_B}{10} = log \sigma_o + constant$$
  $$log \sigma_o = -0.1 M_B + constant$$



- Distances derived from Faber-Jackson relationship are not very precise.This is because much of the light from the galaxy comes from the faint outer parts.A better method is to measure the diameter D of the isophote within which the surface brightness averages to a given level.

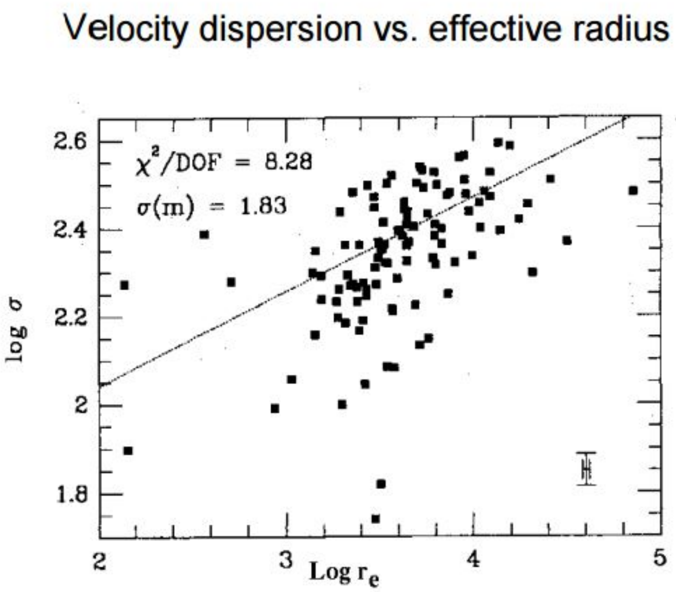


Figure 1: D-σ_o relationship

Fundamental plane

- To minimise the scatter was introduced the idea of fundamental plane.A fundamental plane is a bivariate correlation connecting some of the properties of normal elliptical galaxies.If we plot one variable against the combination of other two it reduces the scatter,also all these three properties are tightly correlated.It is usually expressed as a relationship between the effective radius, average surface brightness and central velocity dispersion of normal elliptical galaxies. Any one of the three parameters may be estimated from the other two,as together they describe a plane that falls within their more general three-dimensional space.
  Correlated plane between L,$\sigma_o and D_n$:
  $L^a D_n^b \sigma_o^c = constant$
  The following correlations have been empirically found for elliptical galaxies:
  ⇒ Larger galaxies have fainter effective surface brightness.
  ⇒ As L^2,more luminous ellipticals have low surface brightness.
  ⇒ More luminous elliptical galaxies have larger central velocity dispersion.
  ⇒ If central velocity dispersion is correlated to luminosity, and luminosity is correlated with effective radius, then it follows that the central velocity dispersion is positively correlated to the effective radius.

Why Faber-Jackson Relationship?

- Why should velocity dispersion of stars be correlated with it's luminosity?

Table 1: Summary for ellipticals

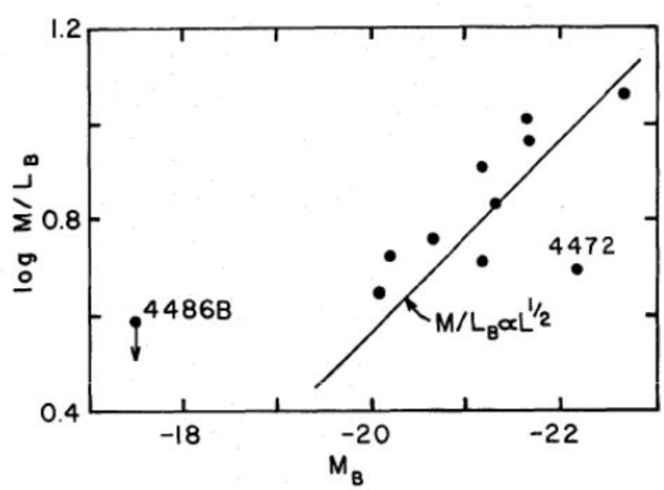
Low Mass Ellipticals	High Mass Ellipticals
Lower Luminosity	Higher Luminosity
Smaller Velocity dispersion	Higher velocity dispersion
Smaller Mass-to-light ratio	Higher Mass-to -light ratio

Potential energy $U = \frac{GM^2}{R}$ and Kinetic energy $K = M\sigma_o^2$

Elliptical Galaxies are virialised structures: $2U + E = 0$
$\Rightarrow \sigma_o^2 \propto \frac{GM}{R} or \sigma_o^2 \propto \frac{GL}{R}$
assuming that mass follows light(at least in the central region of the ellipticals).This assumption is crucial because L can depend on environment.

$L = 4\Pi(\frac{GL}{\sigma_o^2})^2$
$L = \frac{1}{4\Pi G^2 \sigma_o^4}$

- Below plot shows that more massive galaxies have a higher M/L ratio.
- Mass to light vs Luminosity:



Mass to Light ratio in solar units vs absolute magnitude