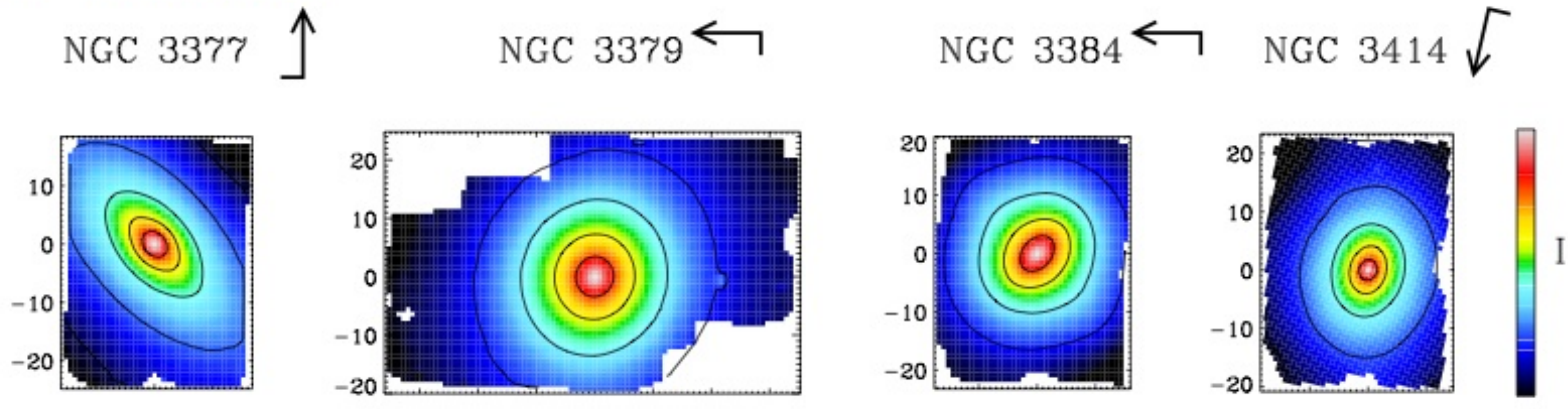
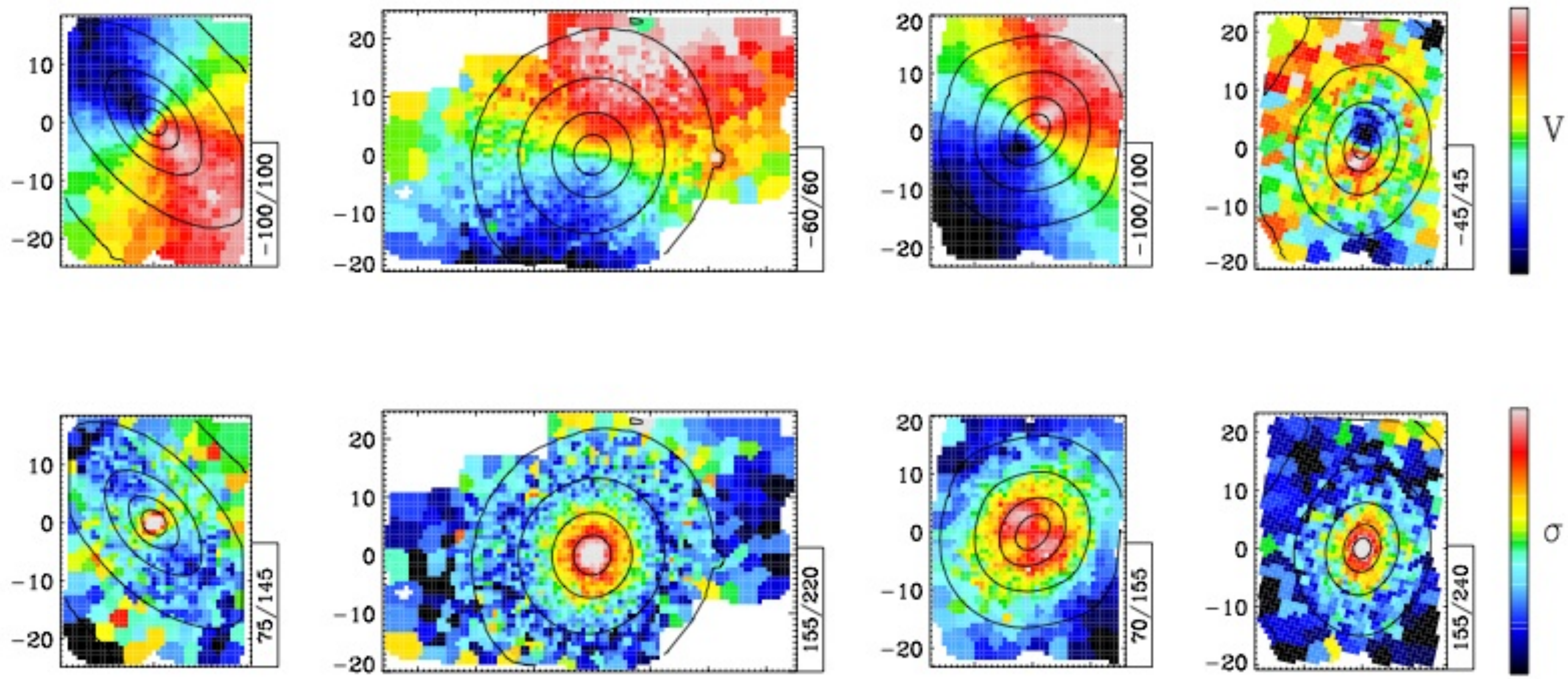


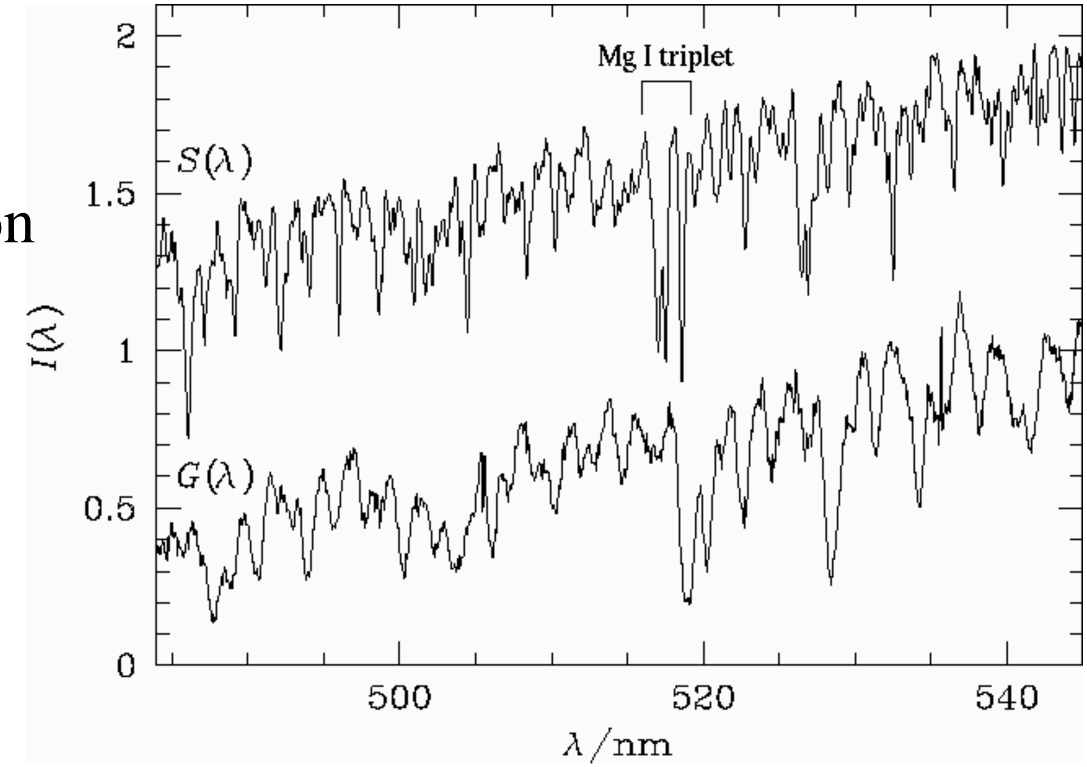
Elliptical Galaxies: Kinematics



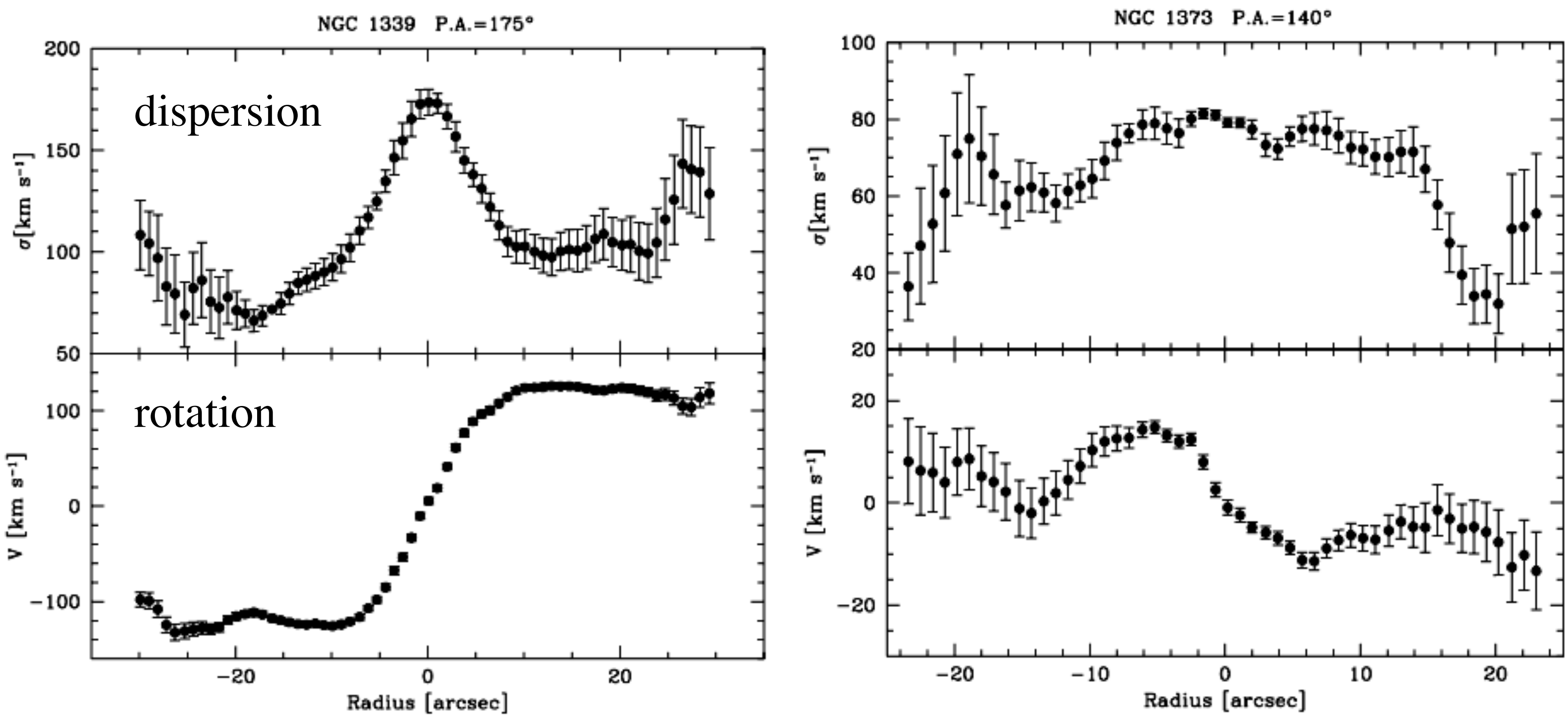
The Kinematics of E-Galaxies

Stars in E galaxies have some ordered motions (e.g., rotation), but most of their kinetic energy is in the form of random motions. Thus, we say that ellipticals are ***pressure-supported systems***

To measure the kinematics within galaxies we use absorption lines. Each star emits a spectrum which is Doppler shifted in wavelength according to its motion. Random distribution of velocities then broadens the spectral lines relative to those of an individual star. Systemic motions (rotation) shift the line centroids.



Kinematical Profiles of E-Galaxies



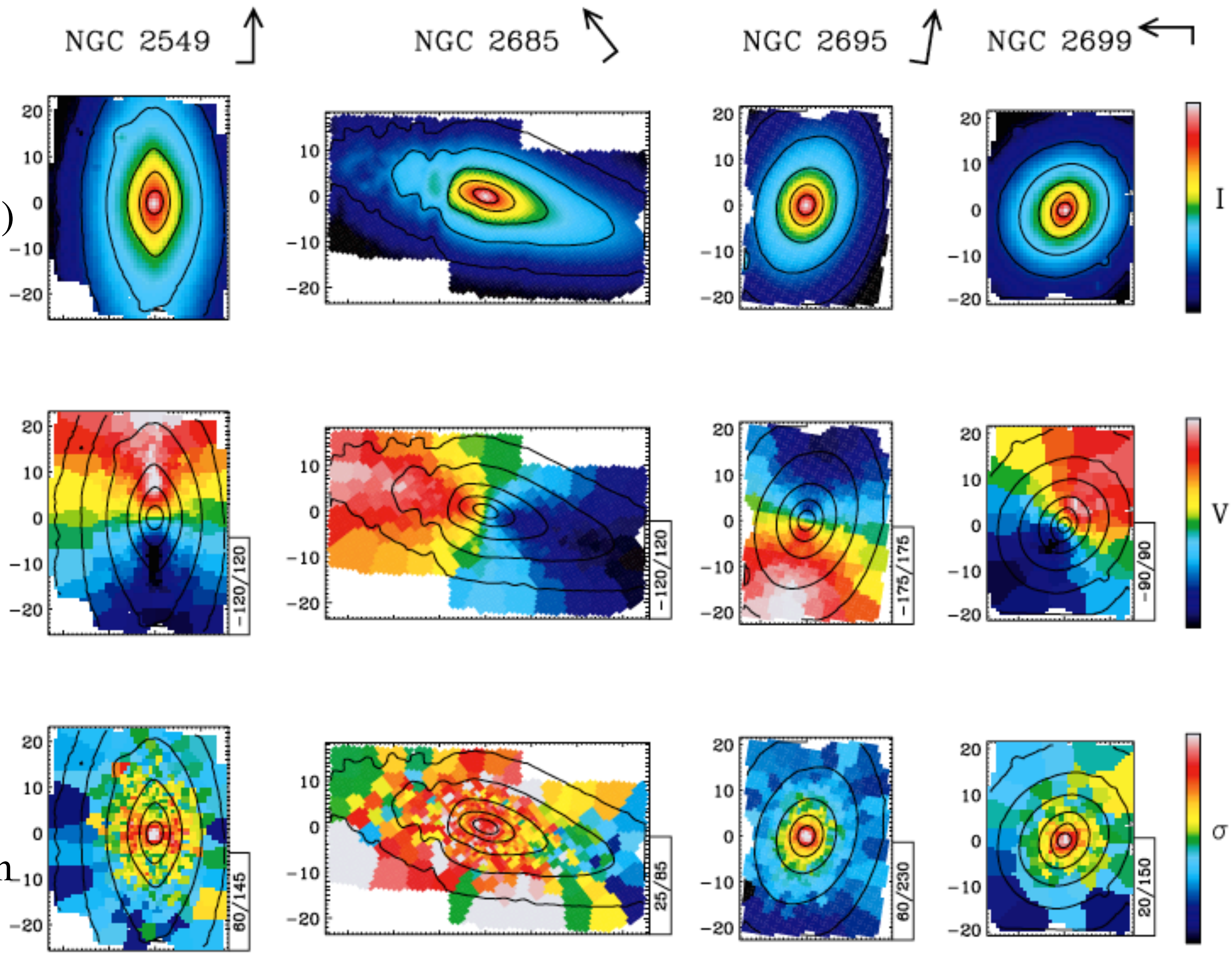
- Rotation is present, but generally not a dominant component of the kinetic energy
- Velocity dispersion tends to be higher closer to the center

2-Dimensional Kinematics of E-Gal’s

Intensity (surface brightness)

Rotation velocity

Velocity dispersion



Velocity Anisotropy in Elliptical Galaxies

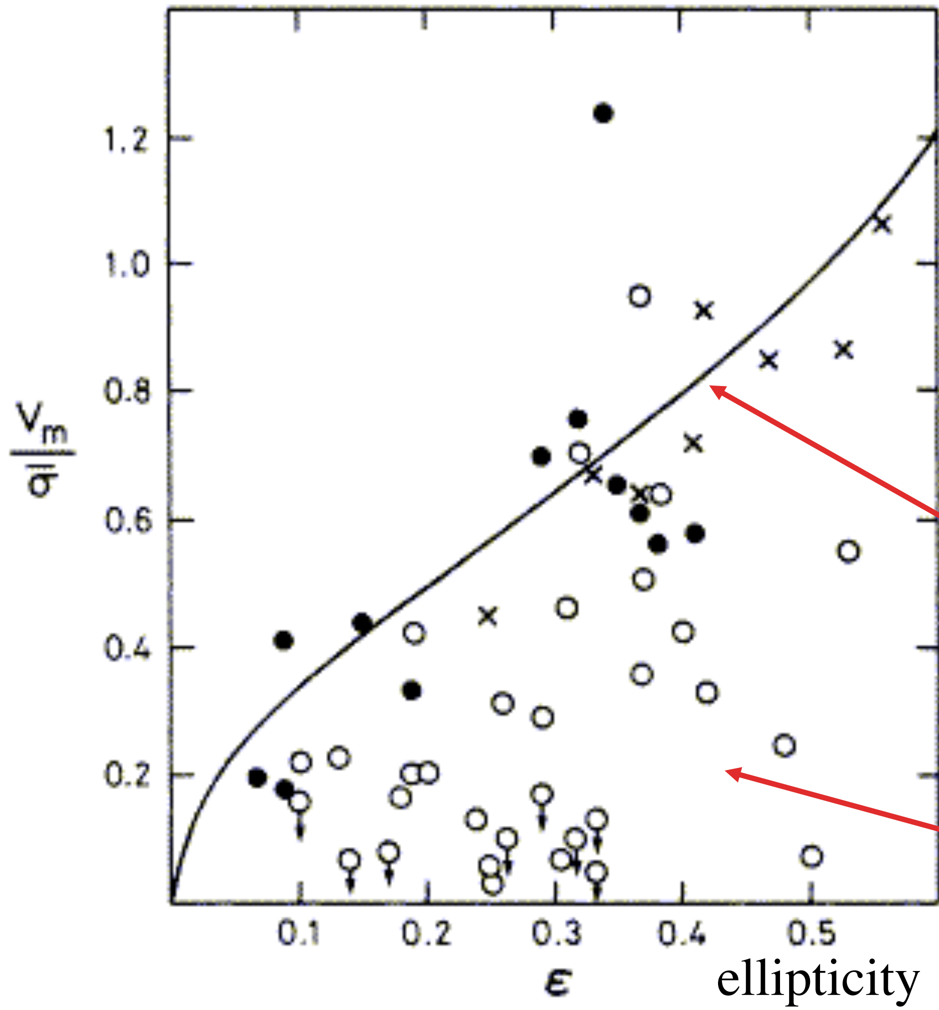


FIG. 3.—The quantity $V_m/\bar{\sigma}$ against ellipticity. Ellipticals with $M_B^{UH} > -20.5$ are shown as filled circles; ellipticals with $M_B^{UH} < -20.5$, as open circles; and the bulges of disk galaxies, as crosses. The solid line shows the $(V/\sigma, \epsilon)$-relation for oblate galaxies with isotropic velocity dispersions (Binney 1978).

The ratio of the maximum rotational velocity V_m and the mean velocity dispersion σ indicates whether the observed shapes of E's are due to rotation or anisotropic pressure

Galaxies on this line are flattened by rotation

Galaxies below it are flattened by anisotropy

Velocity Anisotropy in Elliptical Galaxies

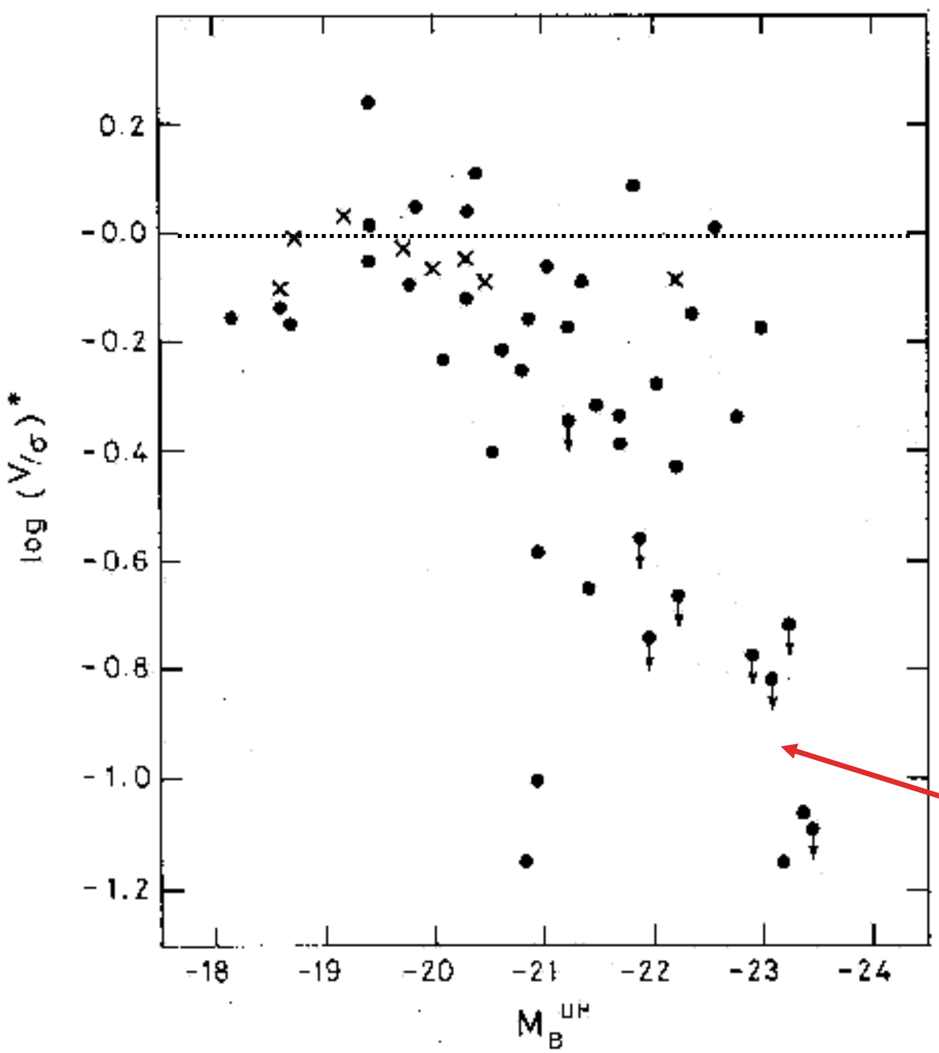


FIG. 4.—Log $(V/\sigma)^*$ against absolute magnitude. Ellipticals are shown as filled circles and the bulges as crosses; $(V/\sigma)^*$ is defined in § IIIb.

Now normalize by the "isotropic rotator" line

Rotational Properties of Elliptical Galaxies:

Anisotropy parameter:

$$\left(\frac{v}{\sigma}\right)^* \equiv \frac{v/\sigma}{\sqrt{\frac{1-b/a}{b/a}}} = \frac{(v/\sigma)_{\text{observed}}}{(v/\sigma)_{\text{rot. flattened}}}$$

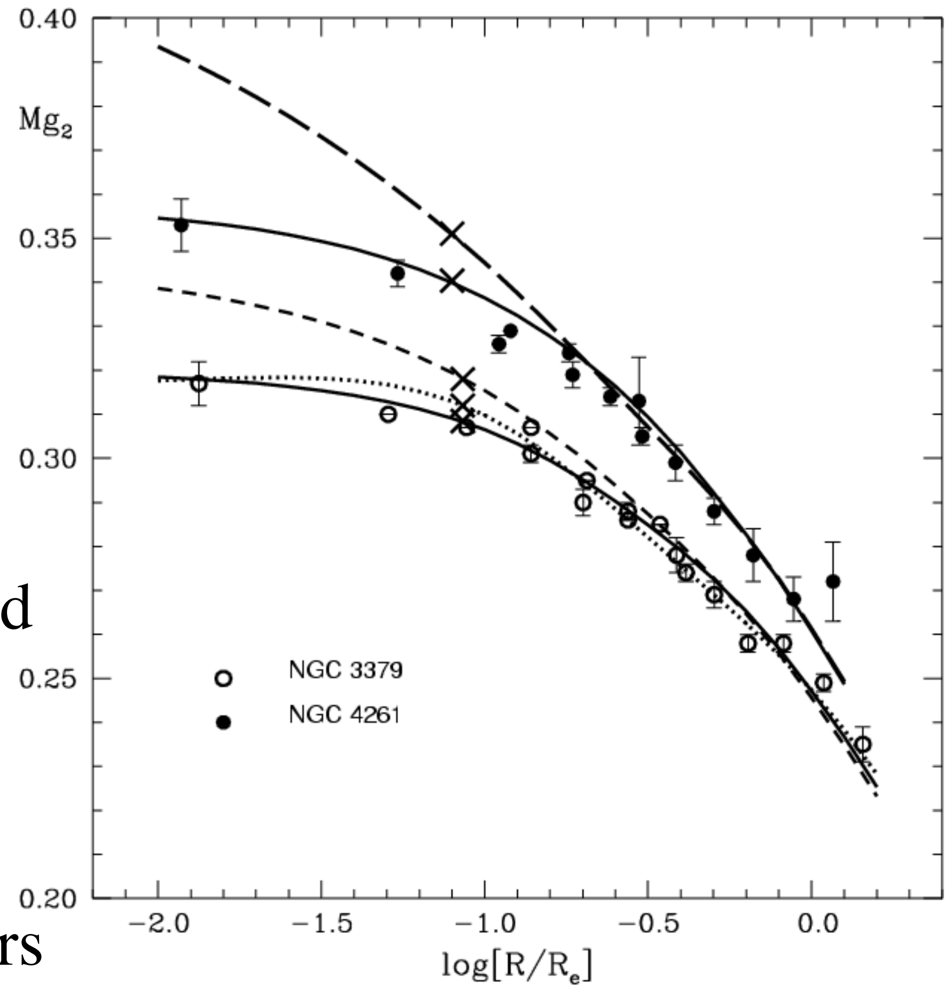
More luminous ellipticals tend to be anisotropic

This can be understood as a consequence of merging

Stellar Populations in Ellipticals

- Ellipticals are made mostly from old stars, ages > 1 Gyr and generally ~ 10 Gyr
- They have a broad range of metallicities (which indicate the degree of chemical evolution), up to 10 times Solar!
- More metal rich stars are found closer to the center
- This is observed as line strength gradients, or as color gradients (more metal-rich stars are redder)

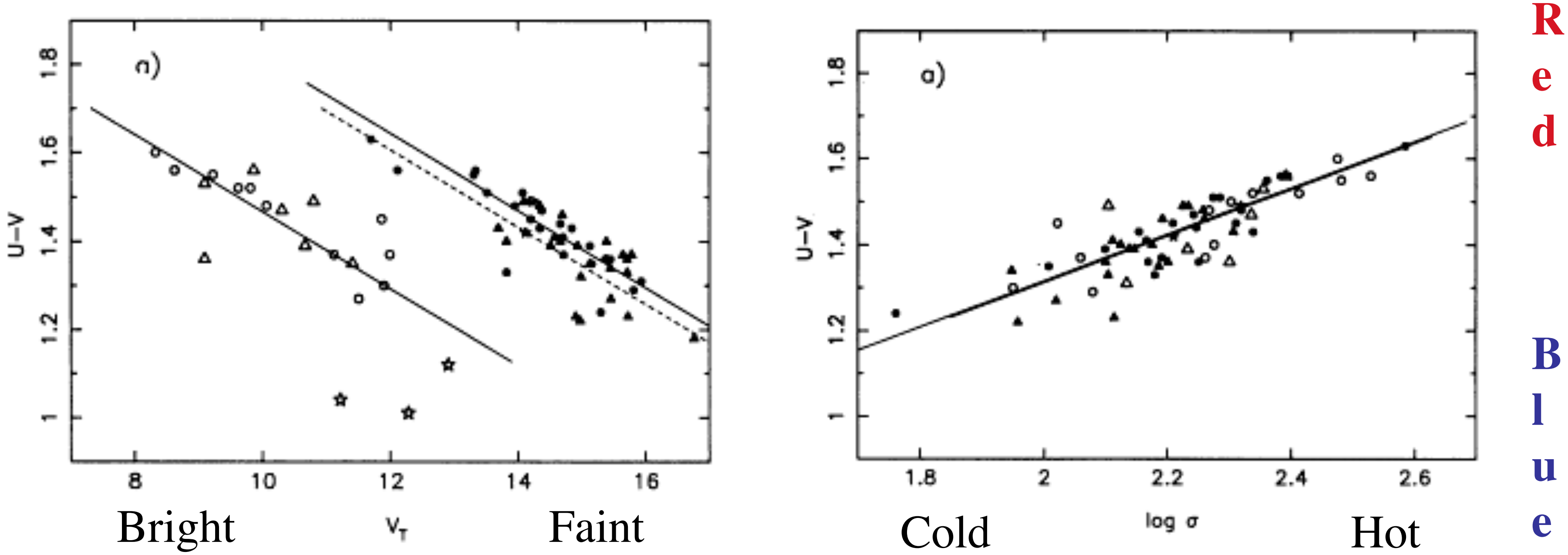
Mg line strength vs. radius



Metallicity-Luminosity Relation

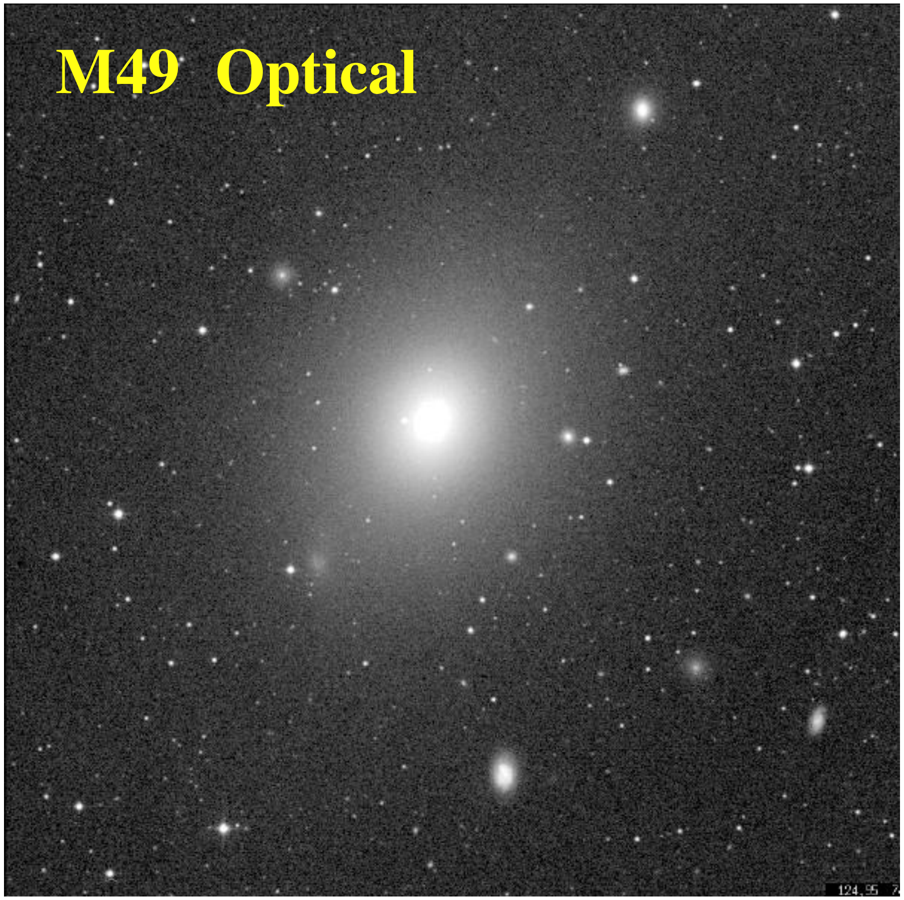
also known as the Color-Magnitude Relation

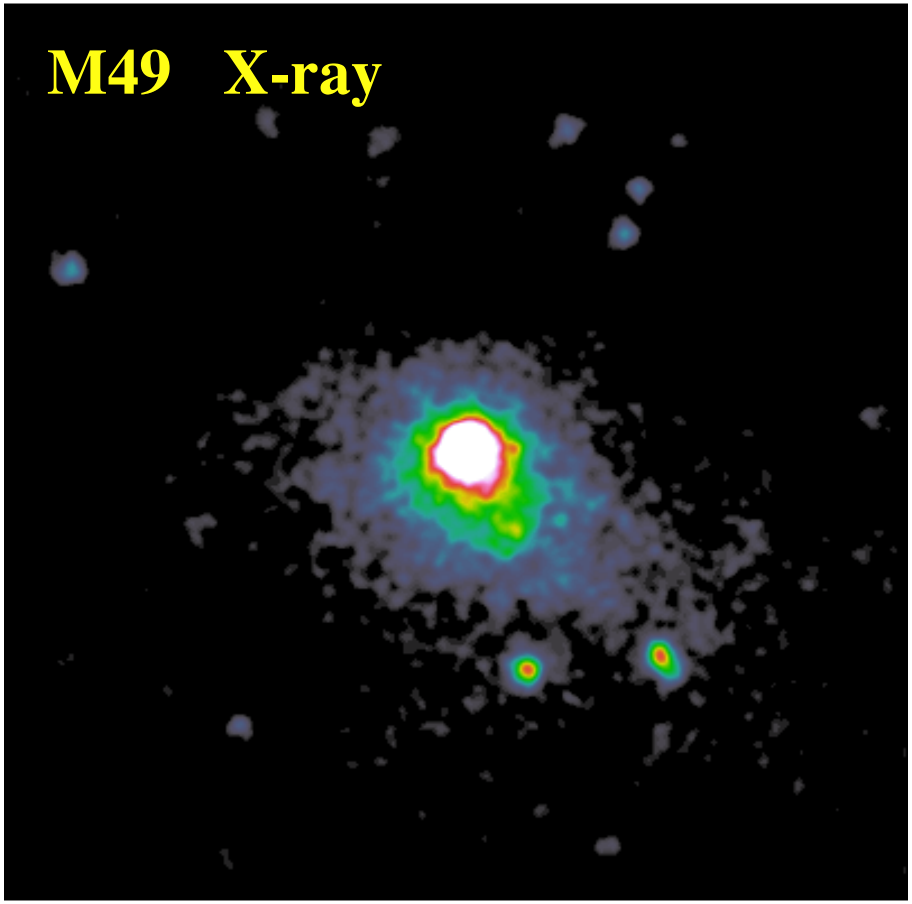
There is a relation between the color (a metallicity indicator) and the total luminosity or velocity dispersion for E galaxies:



Brighter and dynamically hotter galaxies are redder. This could be explained if small E galaxies were younger or more metal-poor than the large ones. More massive galaxies could be more effective in retaining and recycling their supernova ejecta.

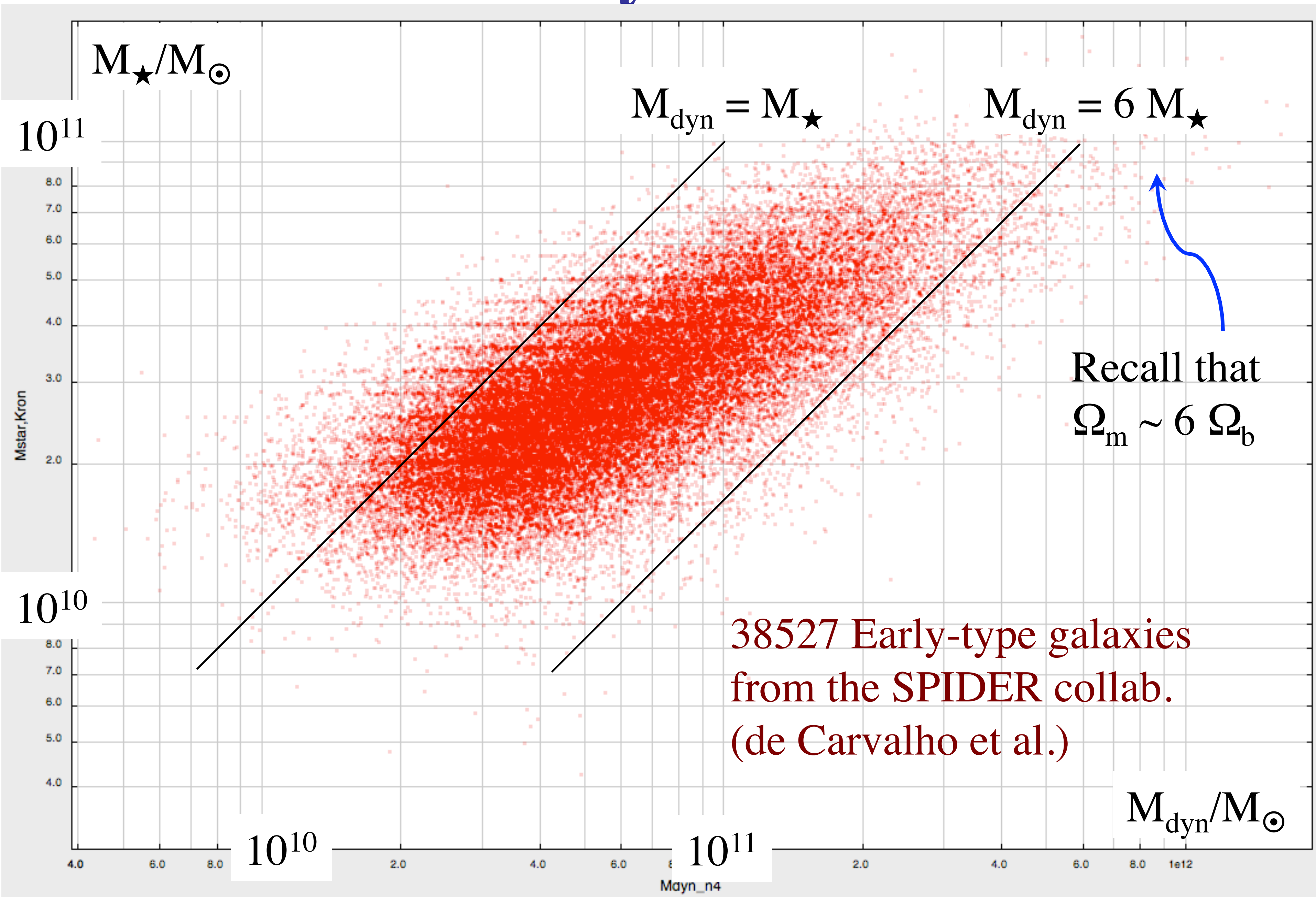
Hot Gas in Elliptical Galaxies





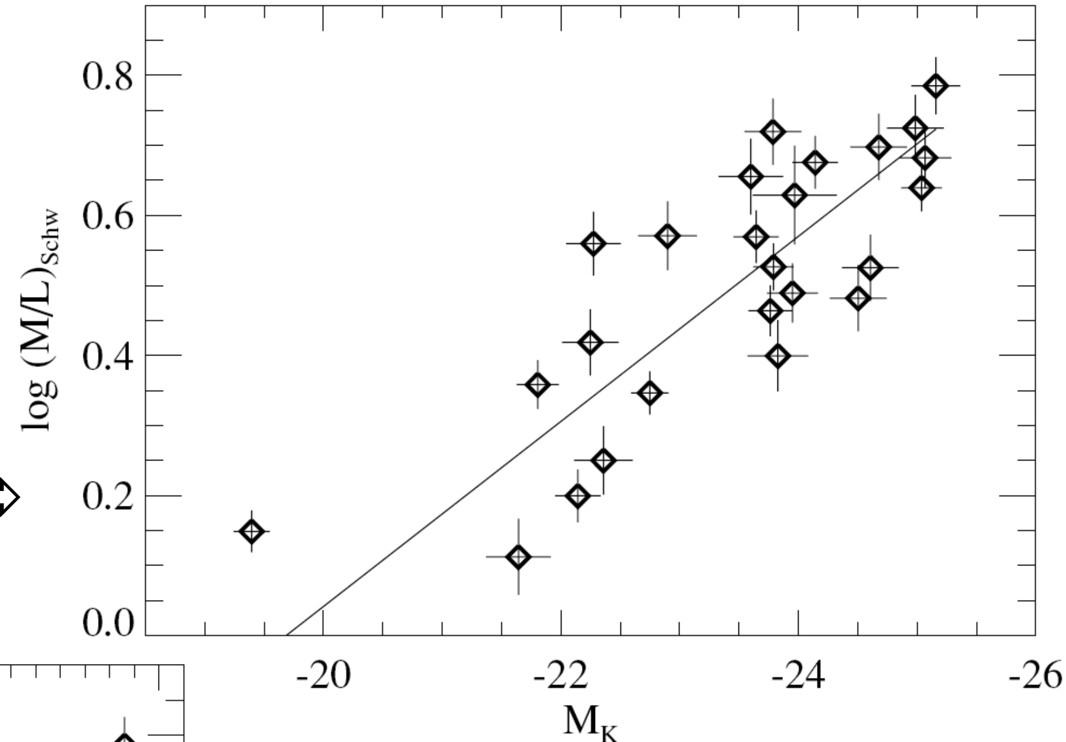
The gas is metal-rich, and thus at least partly a product of stellar evolution
It is at a virial temperature corresponding to the velocity dispersion of stars
Another good probe of dark matter in ellipticals…

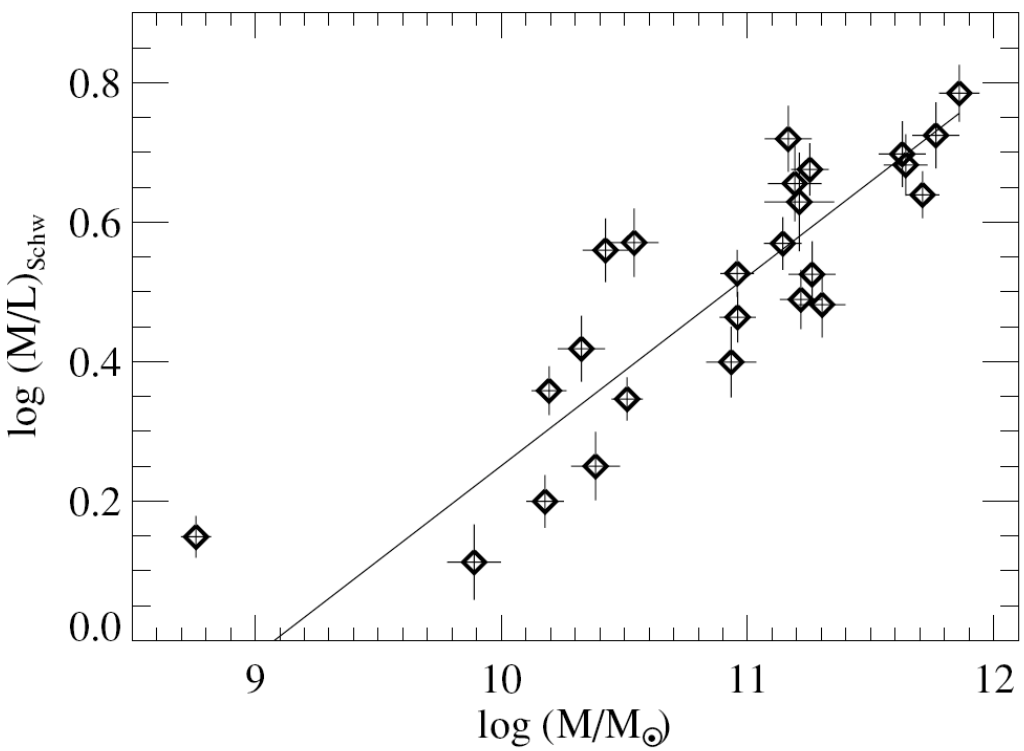
Stellar vs. Dynamical Mass



More Massive Galaxies Have Larger (M/L)

(M/L) vs. Luminosity ⇨
~ Stellar mass



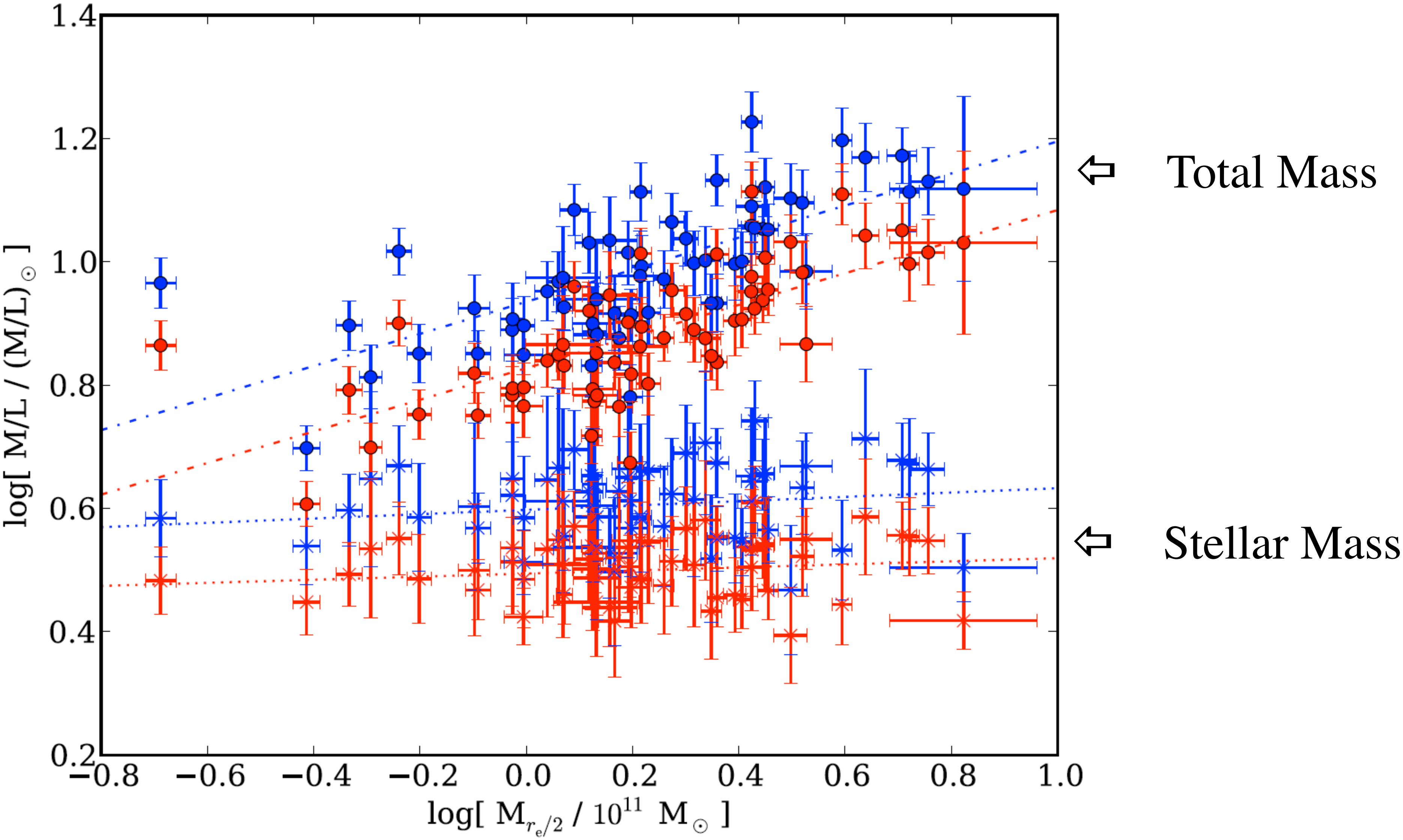


⇦ (M/L) vs. Mass

$$(M/L)_{\mathrm{vir}} \propto L^{0.27\pm0.04}$$

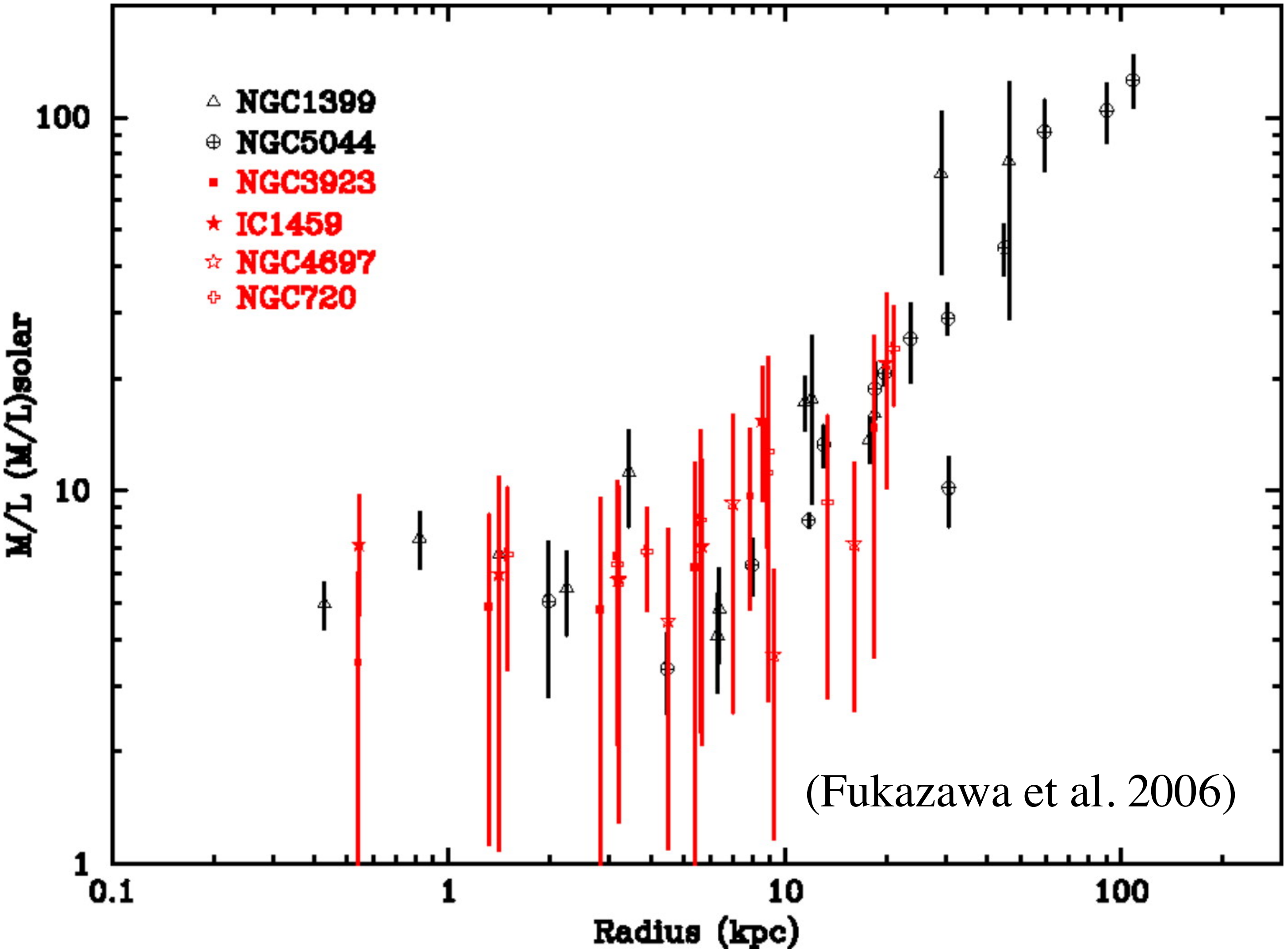
(Cappellari et al. 2006)

(M/L) vs. Mass From Gravitational Lensing



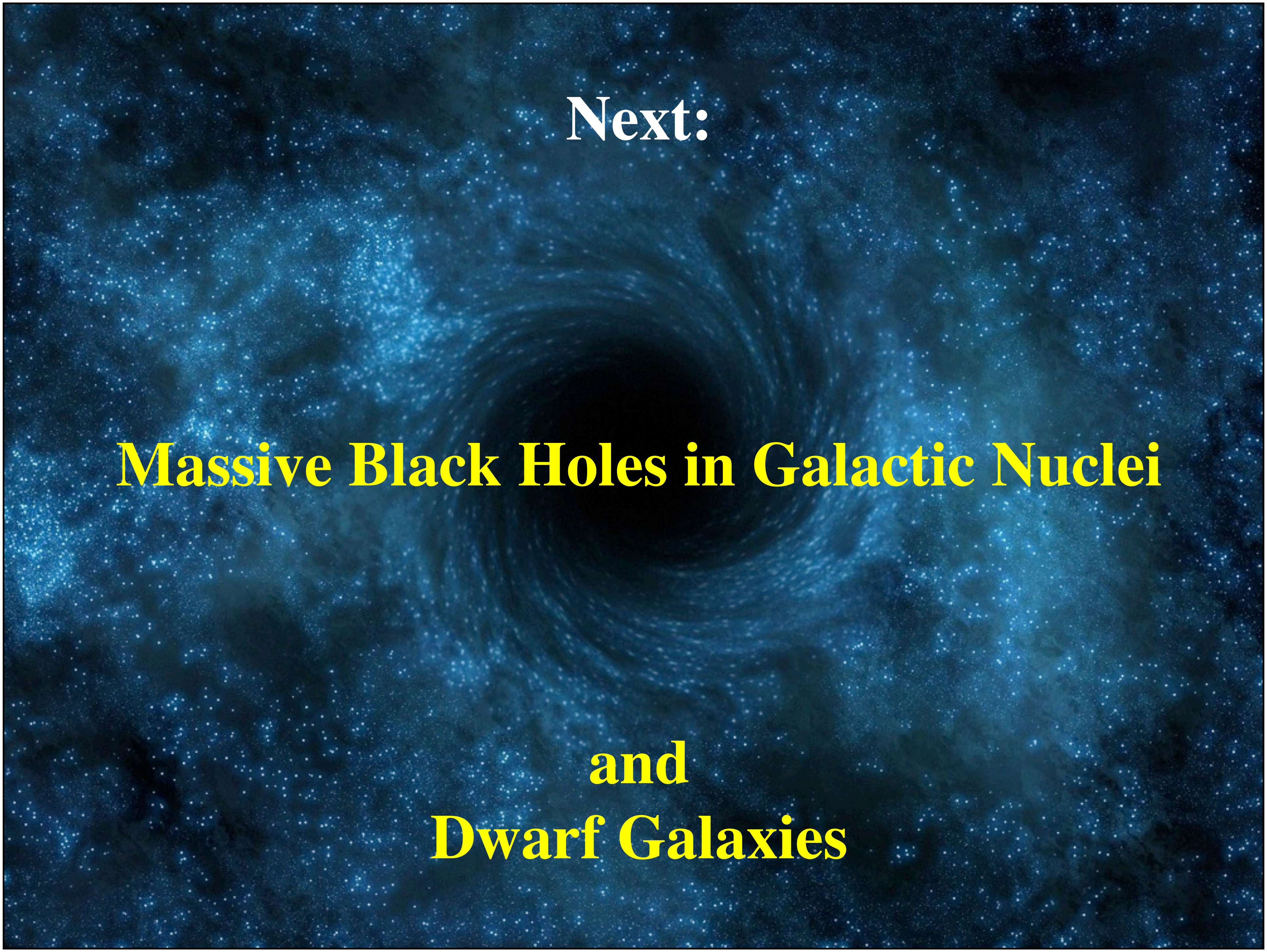
red = V band, **blue** = B band *(Auger et al. 2010, the SLACS collab.)*

(M/L) Increases With Radius



From X-ray profiles and modeling

Fully consistent with dynamical modeling of optical data


Next:
Massive Black Holes in Galactic Nuclei
and
Dwarf Galaxies