Testing Modified Gravity with the DiskMass Survey

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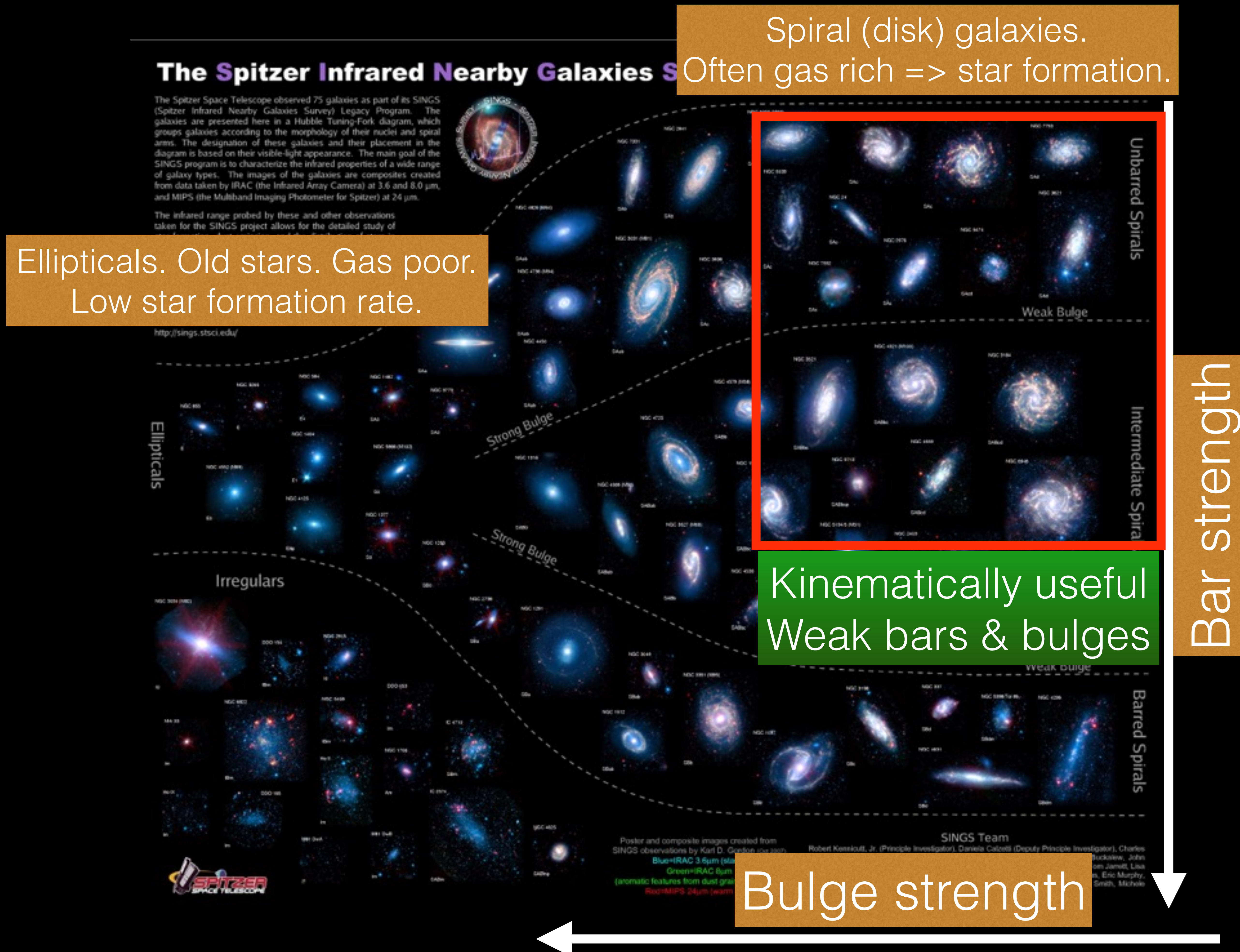
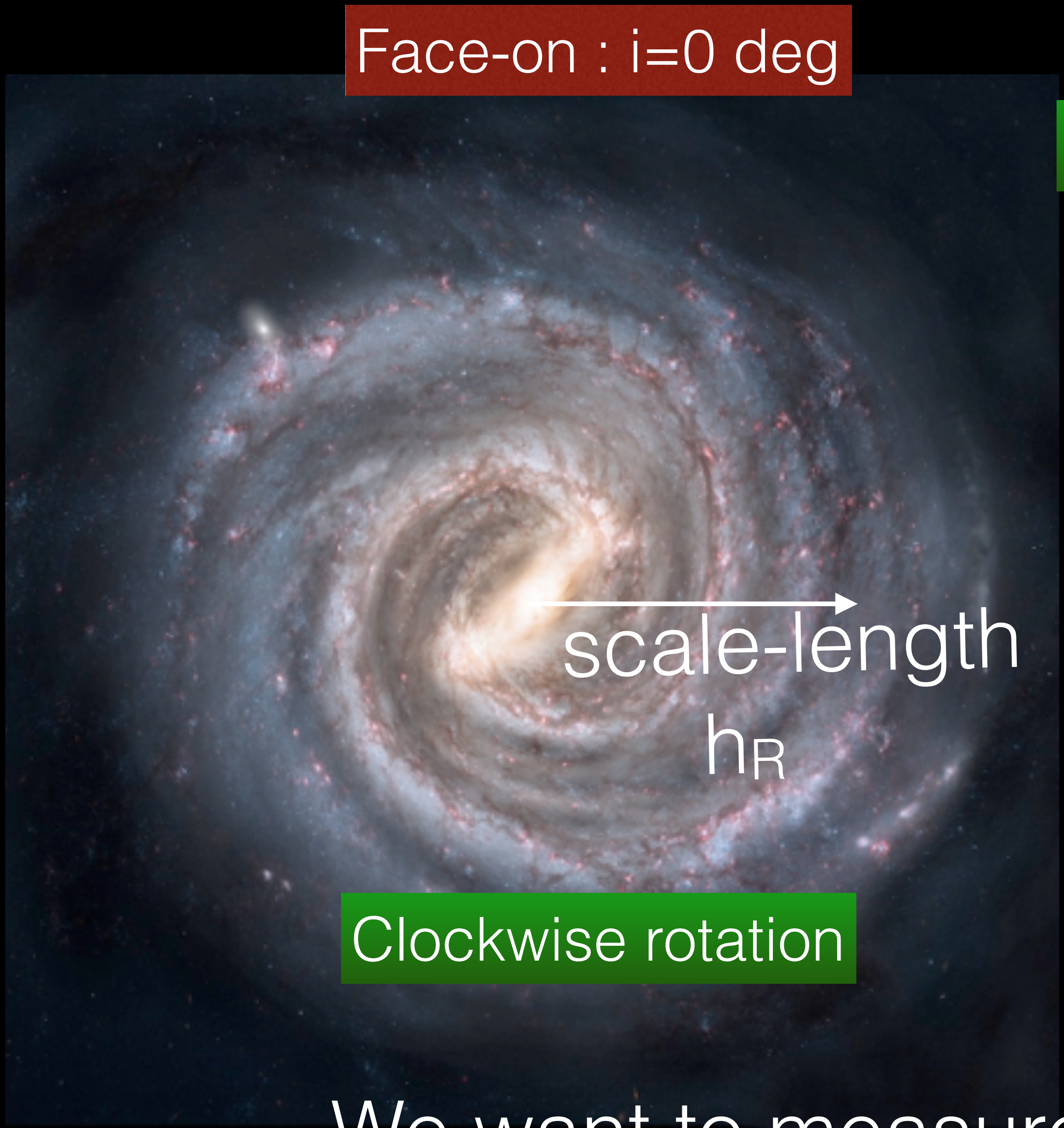
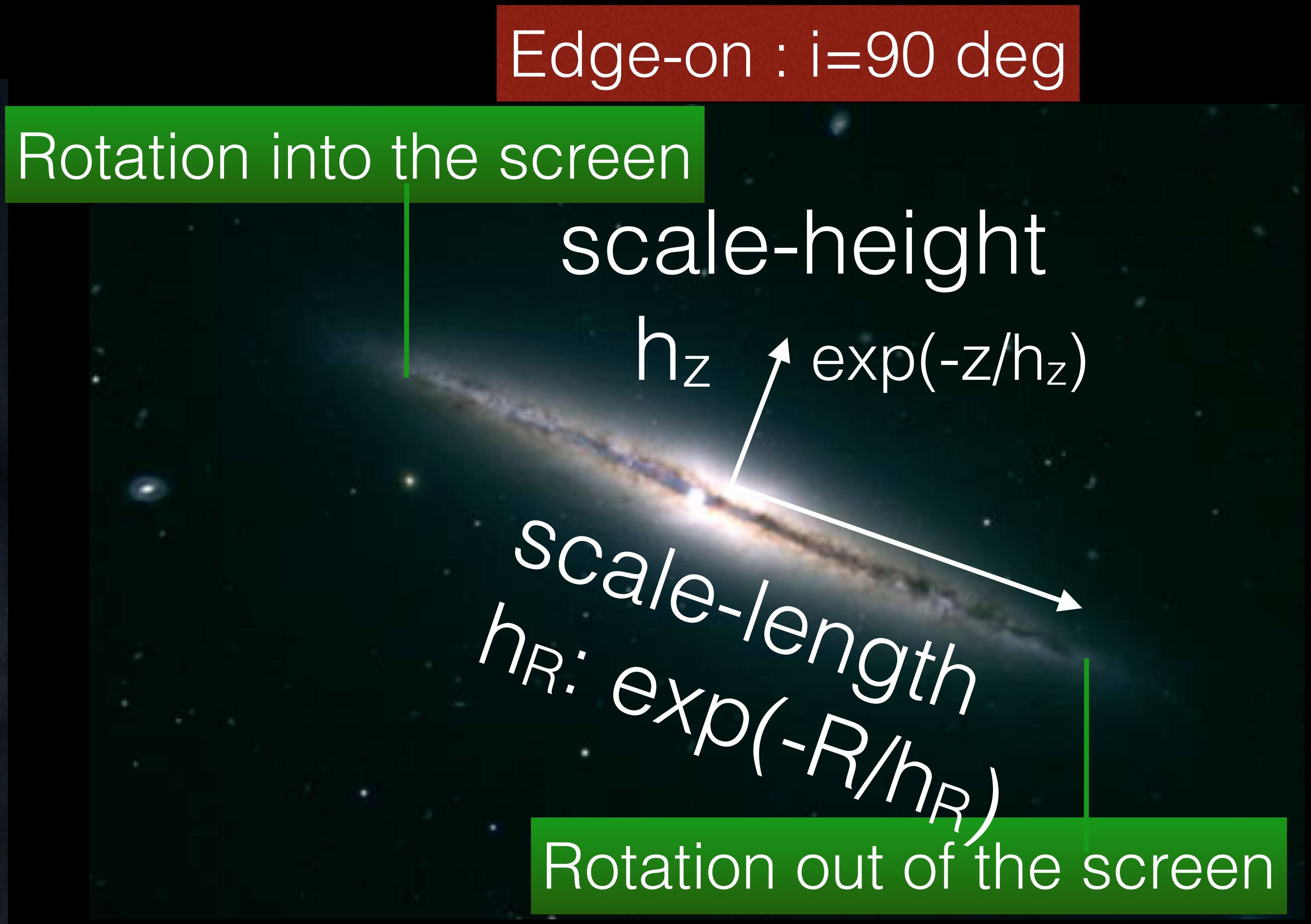

Spiral (disk) galaxies.
Often gas rich => star formation.
Ellipticals. Old stars. Gas poor.
Low star formation rate.
Kinematically useful
Weak bars & bulges
Bar strength
Bulge strength
The Spitzer Infrared Nearby Galaxies S
The Spitzer Space Telescope observed 75 galaxies as part of its SINGS (Spitzer Infrared Nearby Galaxies Survey) Legacy Program. The galaxies are presented here in a Hubble Tuning-Fork diagram, which groups galaxies according to the morphology of their nuclei and spiral arms. The designation of these galaxies and their placement in the diagram is based on their visible-light appearance. The main goal of the SINGS program is to characterize the infrared properties of a wide range of galaxy types. The images of the galaxies are composites created from data taken by IRAC (the Infrared Array Camera) at 3.6 and 8.0 μm, and MIPS (the Multiband Imaging Photometer for Spitzer) at 24 μm.
http://sings.stsci.edu/
Ellipticals
Irregulars
Strong Bulge
Strong Bulge
Weak Bulge
Unbarred Spirals
Barred Spirals
SINGS Team

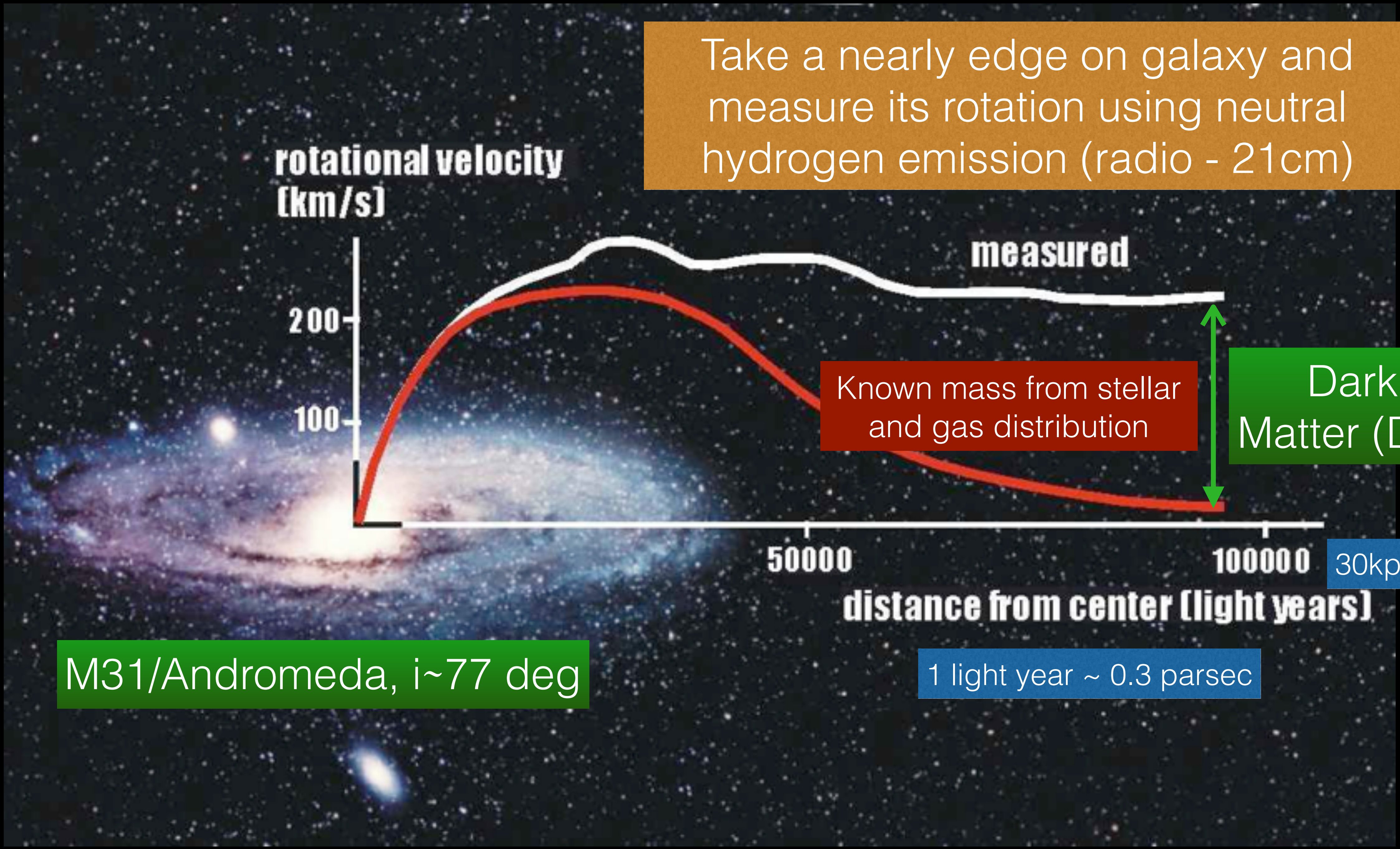
The inclination is important





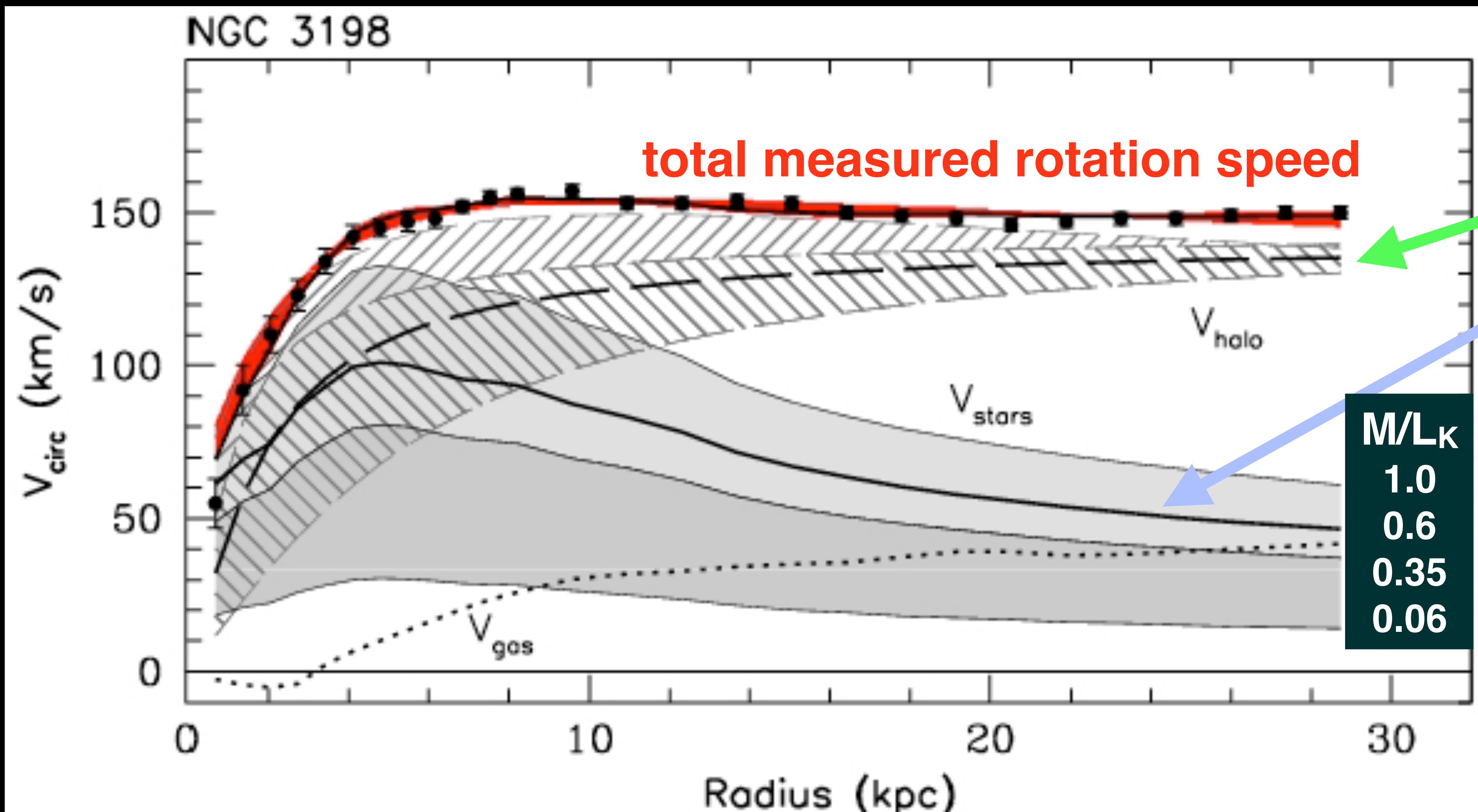
We want to measure rotation speed of galaxy as function of radius, $V(R) \Rightarrow M(R)$

if it helps: V(R) -> M(R)



$M_\star = L_\star \times M/L_K$ → Mass-to-light ratio K-band - NIR

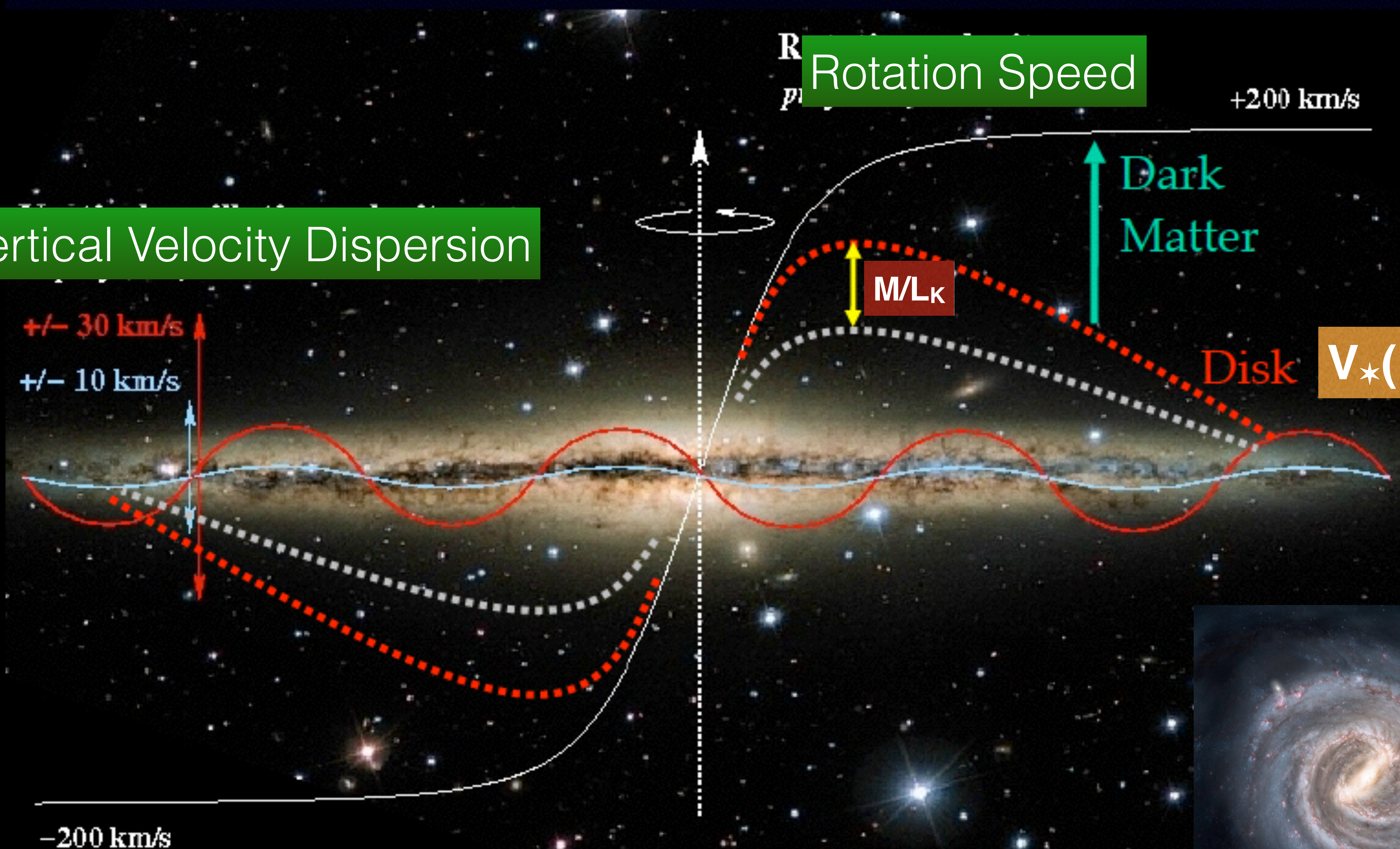
Influence of M/L$_K$ on DM halo

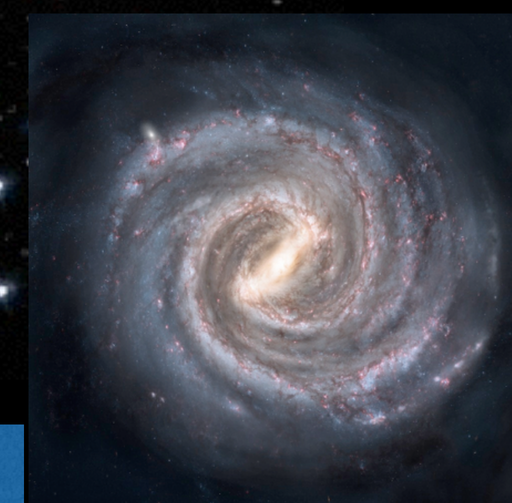


DM halo abundance depends on mass of stars (**M/L$_K$**). Numerical stellar evolution models favour **M/L$_K$~0.6**. Can we measure **M/L$_K$** directly?

Bahcall (1984)

What if we had a 2nd (independent) measure of the dynamics?





Stellar Vertical VelDisp gives

$\boldsymbol{\sigma_z^2 \propto \Sigma_{total} \times h_z \propto M/L_K \times h_z}$

Need galaxies with i~15-40 deg to simultaneously measure **V(R)** and **σ_z**

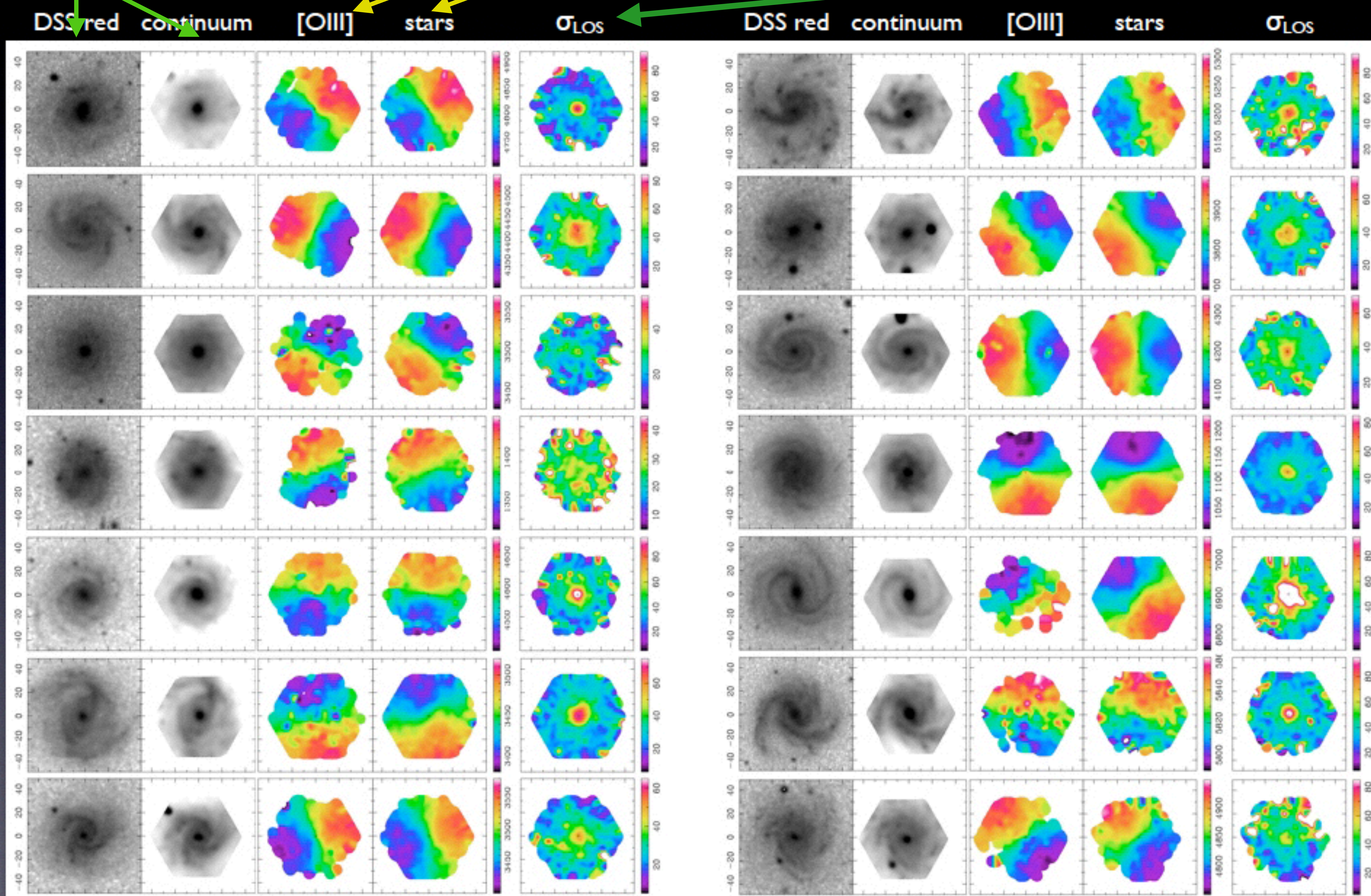
The DiskMass Survey

Bershady et al. 2010

Surface brightness

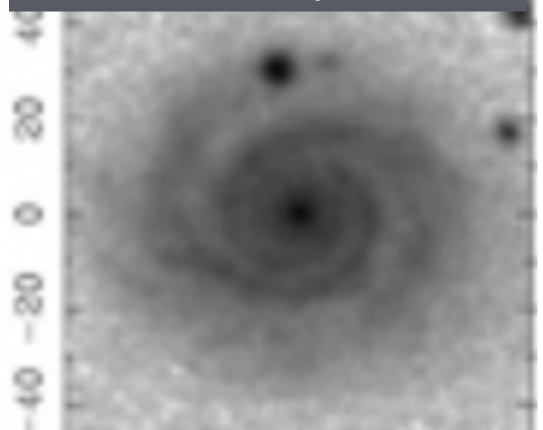
Rotation speed

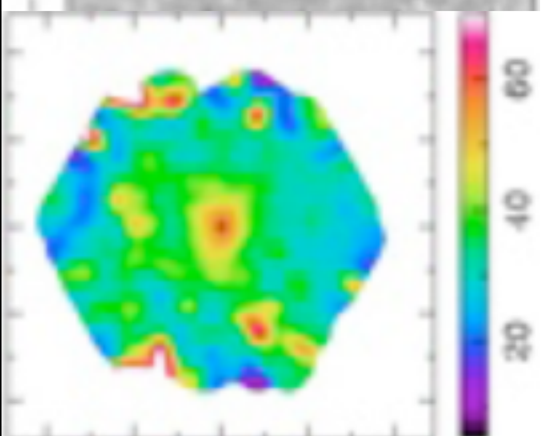
stellar velocity dispersion



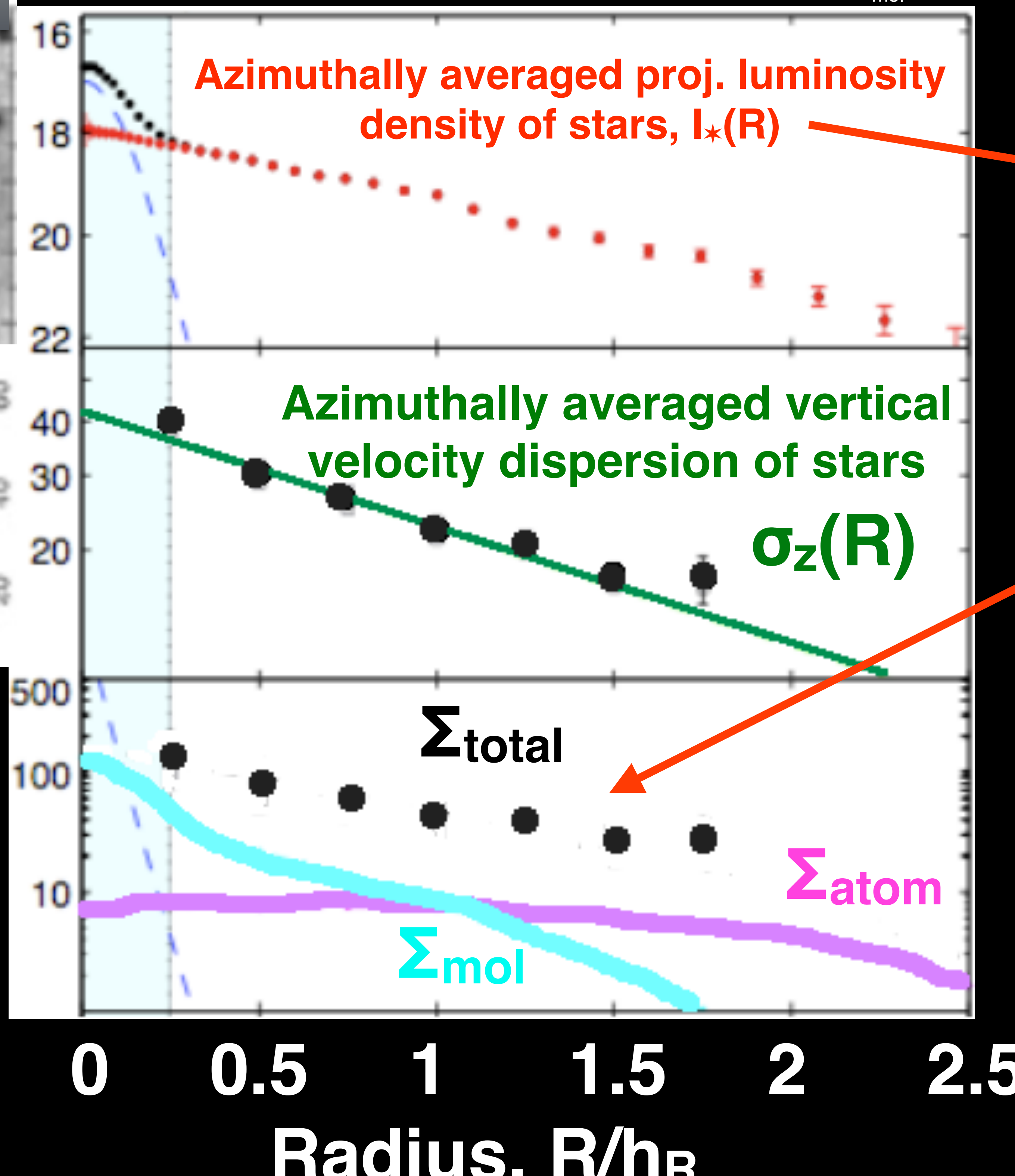
k is a parameter fixed by the vertical stellar distribution.
G is Newton's constant.
h_z is the exponential scale-height of the galaxy disk.
$\Sigma_\star$ is the stellar disk surface density.
Σ_{total} is the total disk surface density.
Σ_{atom} is the atomic gas (HI, He) surface density.
Σ_{mol} is the molecular gas (H2) surface density.

Surface Brightness
=Proj. Luminosity Density
=Luminosity/Area





Martinsson et al. 2013ab



$M_\star = L_\star \times M/L_K$
$\Sigma_\star = I_\star \times M/L_K$

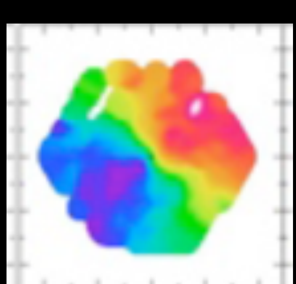
$\Sigma_\star / M/L_K$

$\Sigma_{total} \simeq \sigma_z^2 / \pi G k h_z$

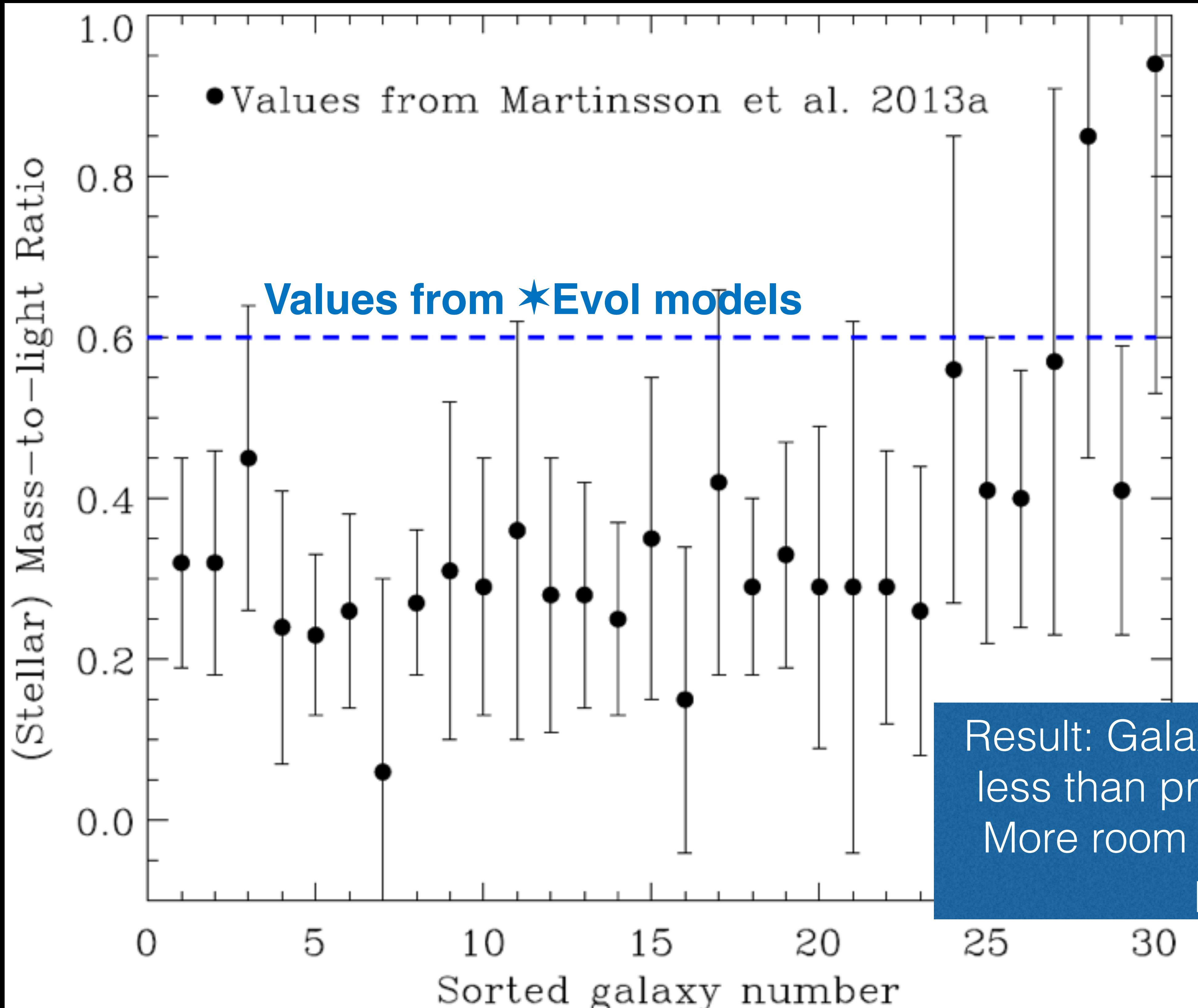
Combining all this info gives

$\Sigma_\star = \Sigma_{total} - \Sigma_{atom} - \Sigma_{mol}\ (-\Sigma_{DM})$

Surface Density



Galaxy disks have been dieting



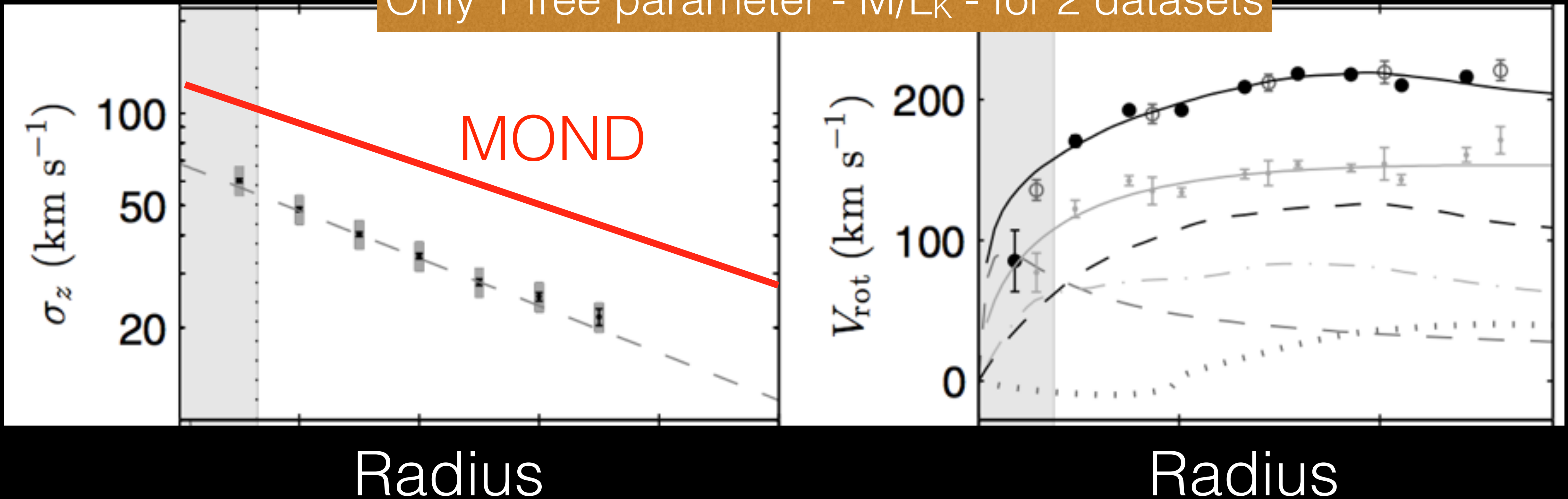
Result: Galaxy disks weigh 2x less than previously thought. More room for DM in central parts.

Modified Newtonian Dynamics (MOND)

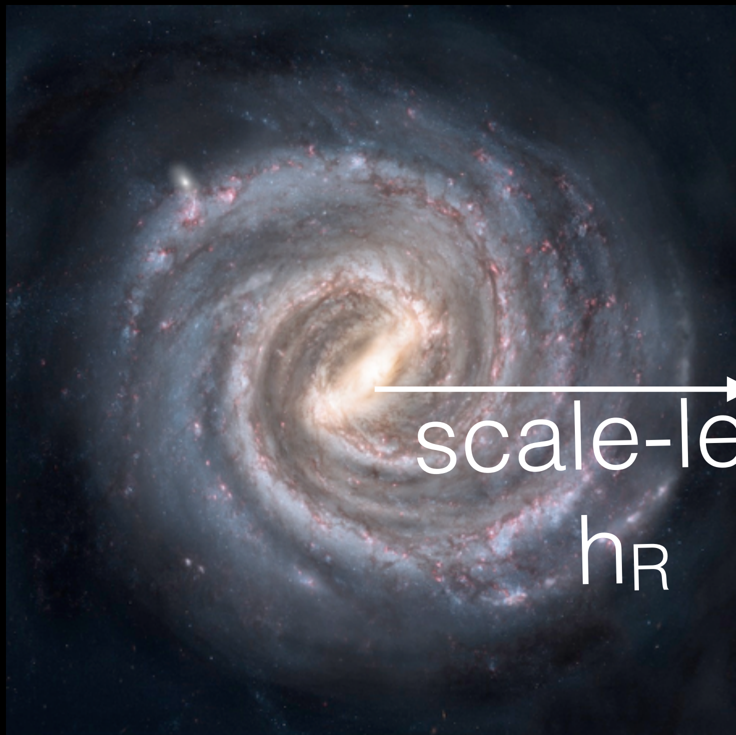
$a_N >> a_0$ -> Newtonian dynamics: $1/r^2$ (Milgrom 1983)
$a_N << a_0$ -> Modified force law : $a \sim \mathrm{sqrt}(a_N a_0) \sim 1/r$

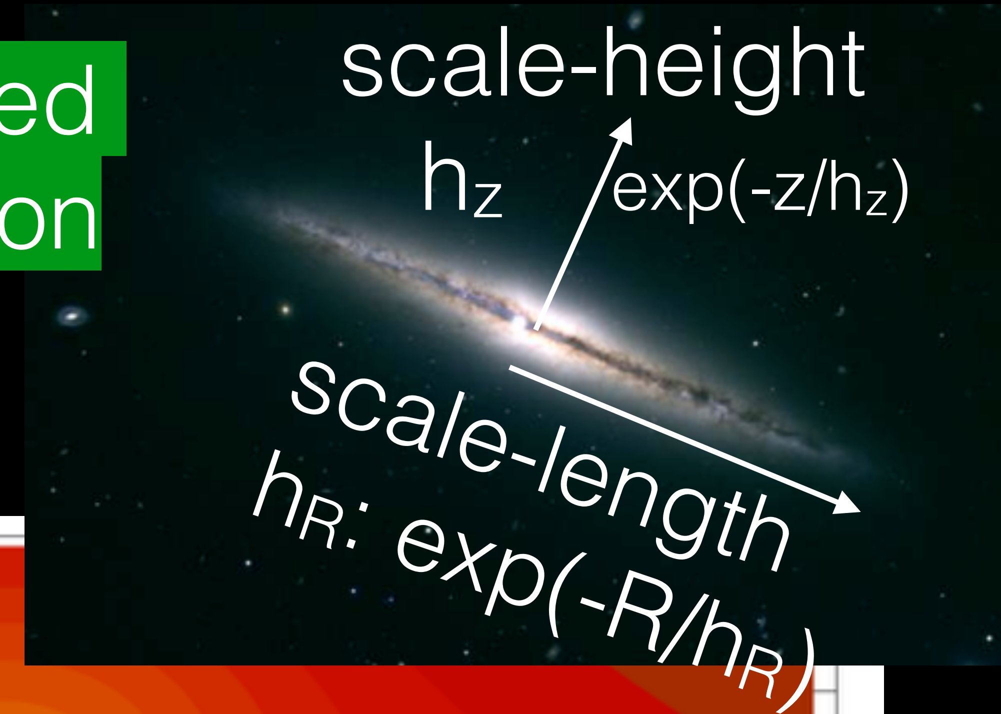
Angus, Diaferio, et al., 2015, MNRAS

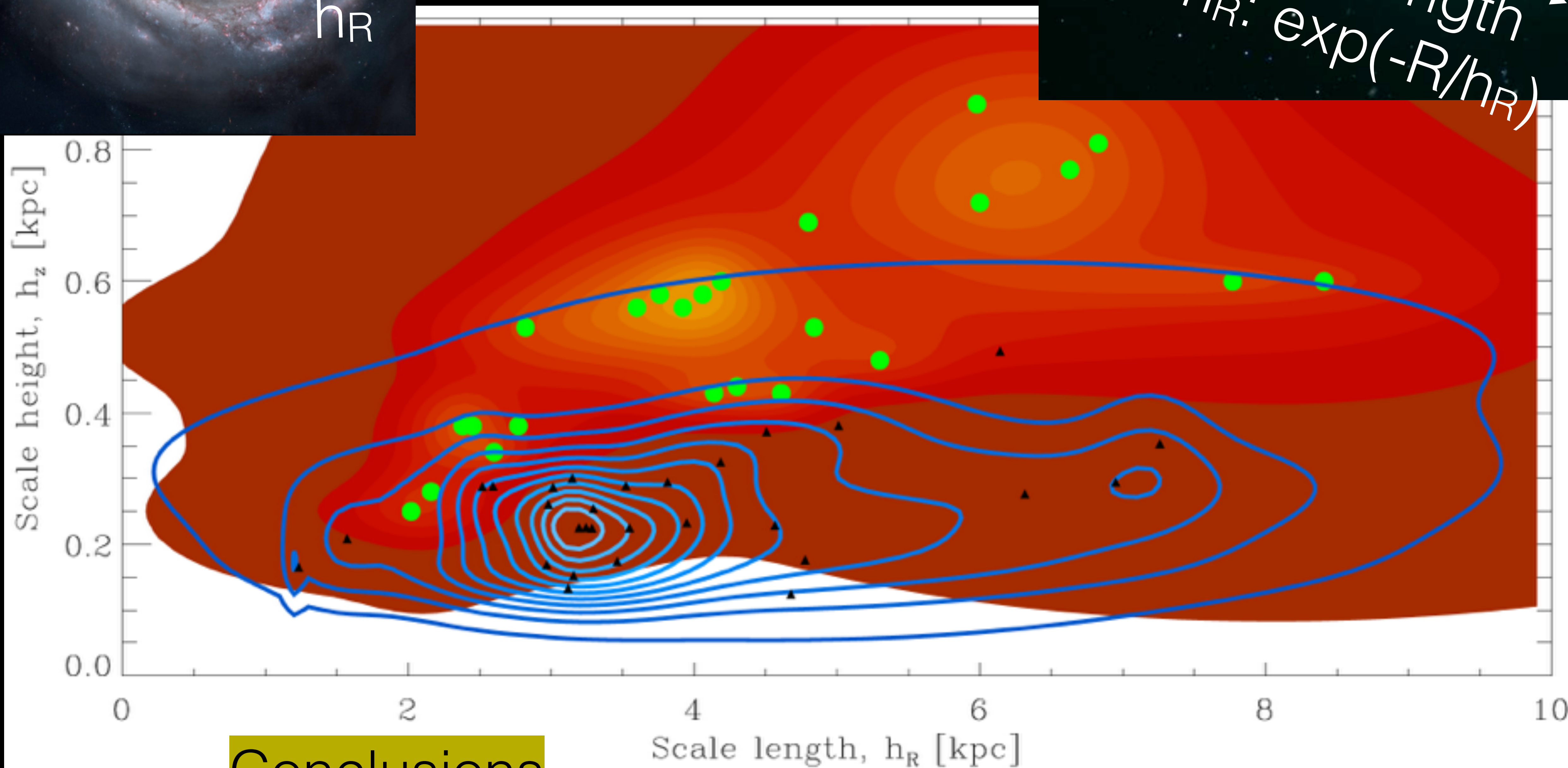
Only 1 free parameter - M/L_K - for 2 datasets



Compare with observed scale-height distribution







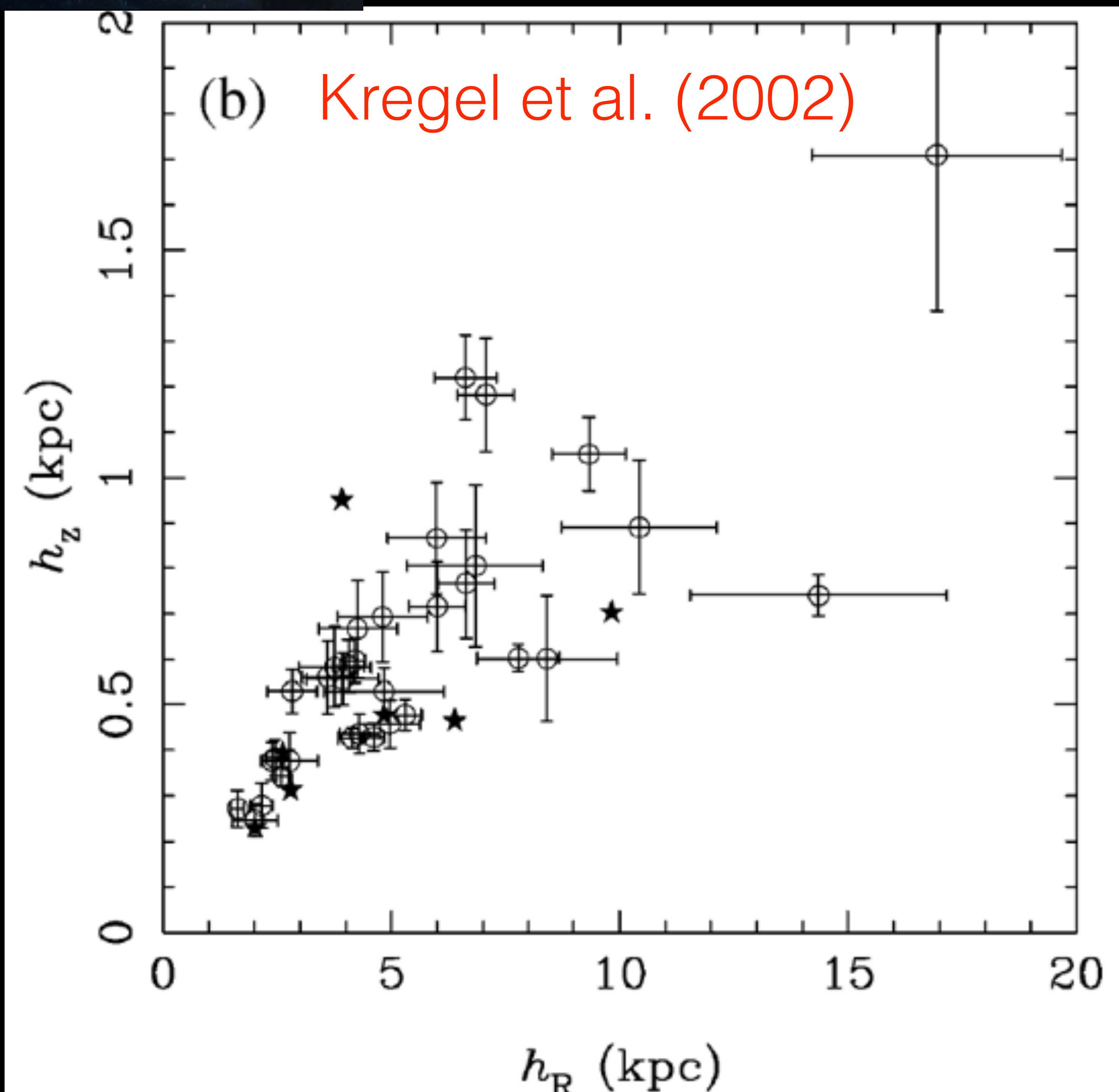
Conclusions

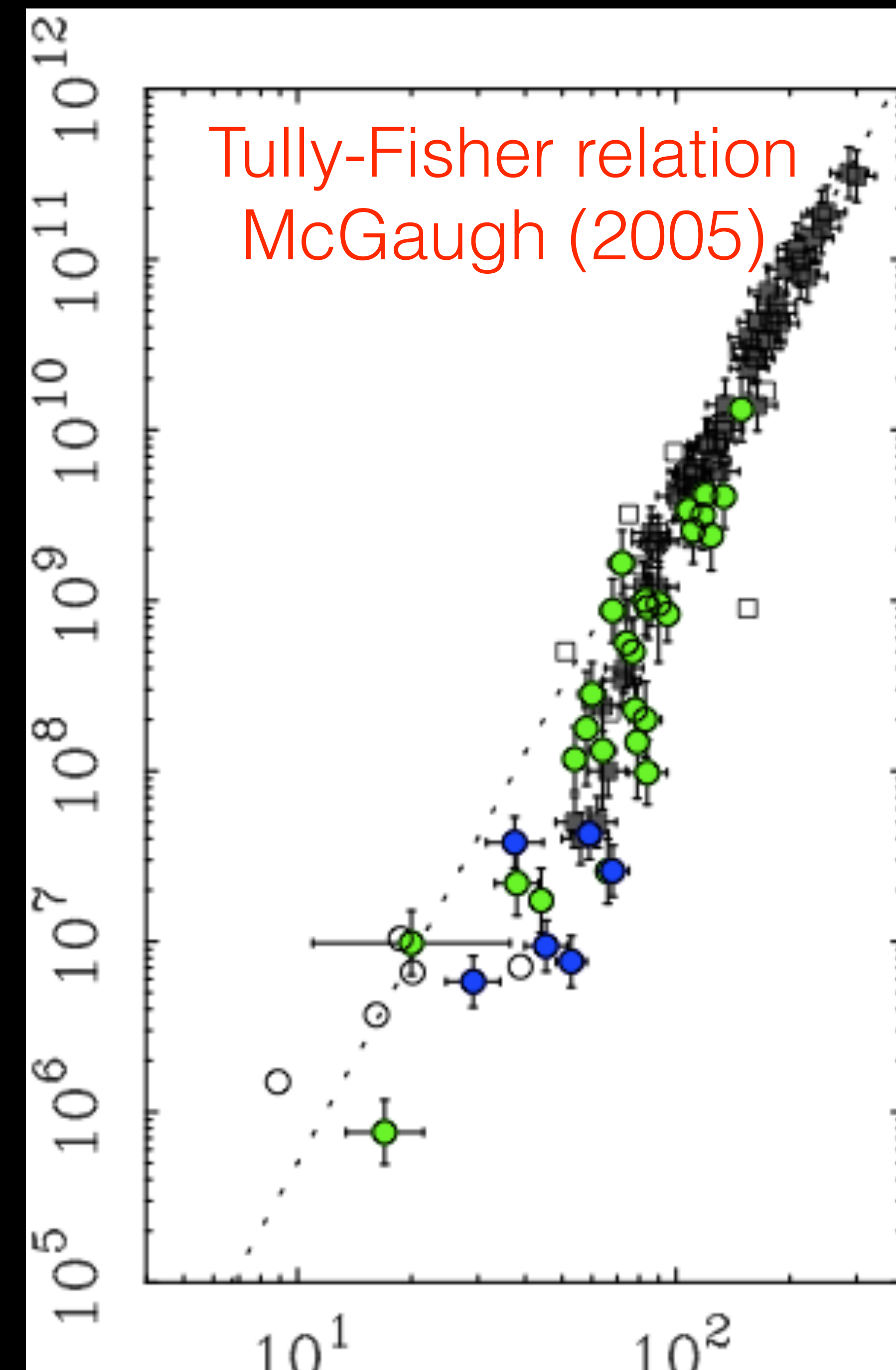
Galaxy disks are significantly lighter than previously thought.

Modified gravity theories are at odds with the DiskMass Survey data.

Using scaling relations to find

scale-height, h_z and inclination, i





After accounting for DM