

Dark Matter Halos of M31



Galaxies



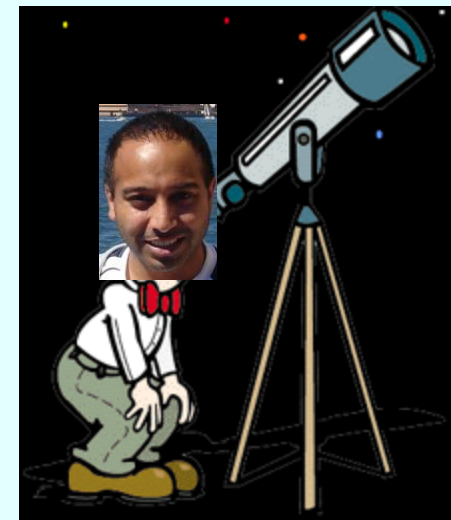
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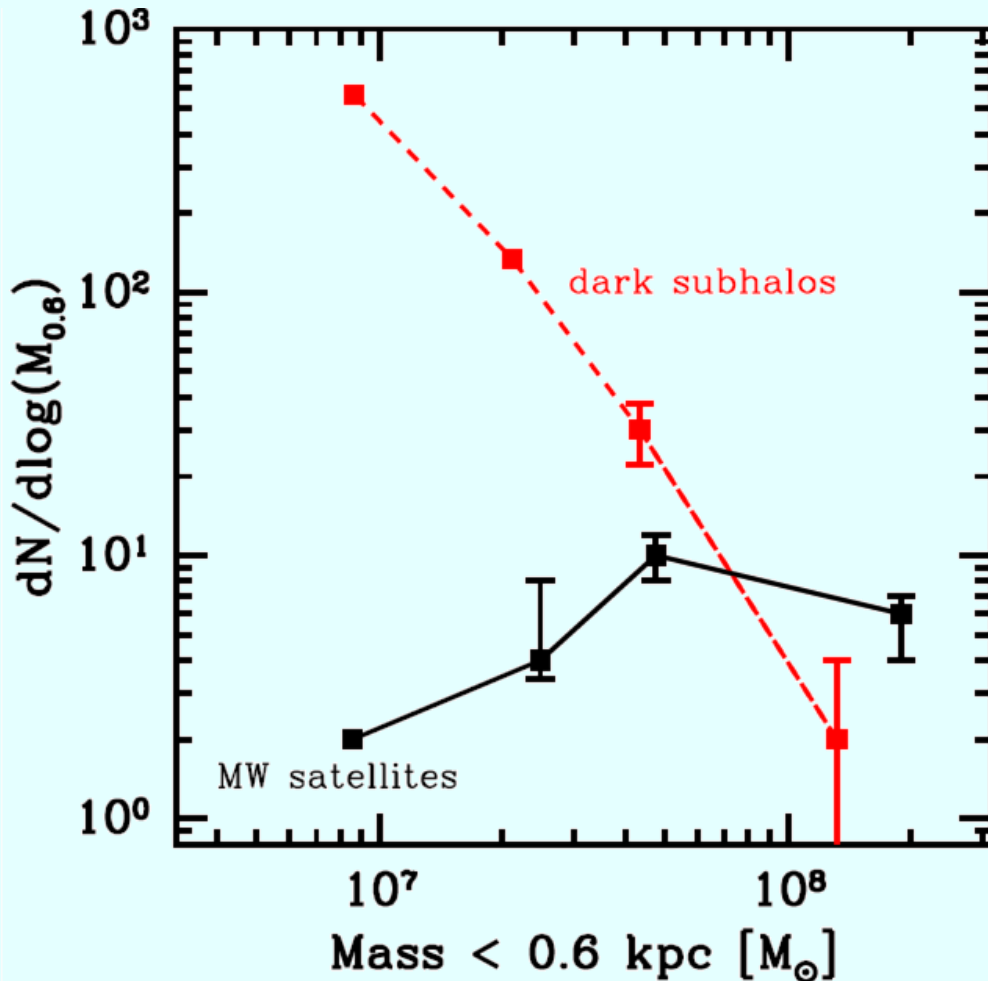
Yale: Marla Geha

Virginia: Rachael Beaton, Richard Patterson, Steven Majewski

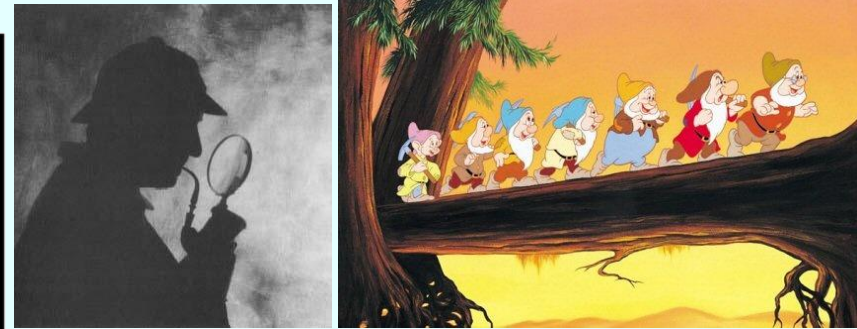
Cambridge: Daniel Zucker



Missing Satellites Problem



Strigari et al., ApJ 2007



Milky Way dSphs have been studied extensively.

Mass function of M31 - same or different?

M31 dSphs: Larger than MW dSphs

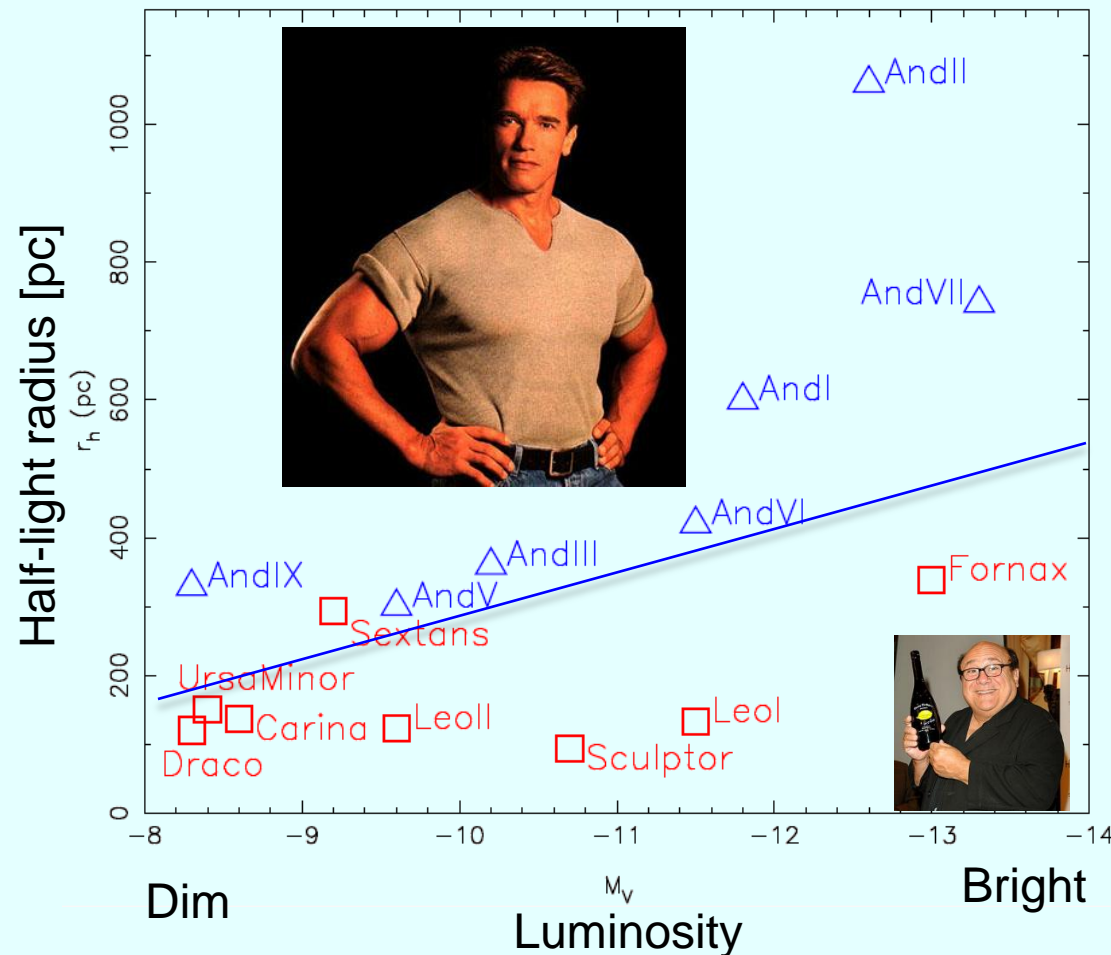
M31 dSphs

Are the DM halos the same or different?

1. If same or larger, M31 dSphs should have a larger stellar velocity dispersion (σ).

(Penarrubia, Navarro, McConnachie ApJ 2007)

2. If DM halos less dense, $\sigma_{M31} \leq \sigma_{MW}$ at fixed luminosity.



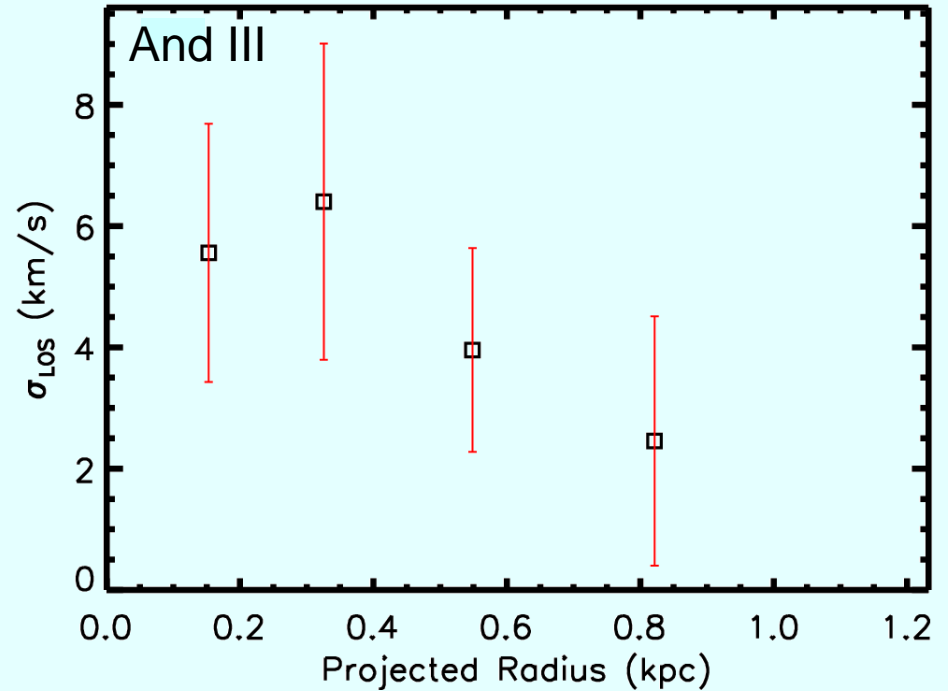
MW dSphs

McConnachie & Irwin, MNRAS 2006

Keck/DEIMOS Spectroscopy

Name	# of Stars	Vel. Dispersion
And I	76	9.1 ± 1.0
And II	95	7.3 ± 0.8
And III	43	4.7 ± 1.0
And X	22	3.9 ± 1.2
And XIV	38	5.4 ± 1.1

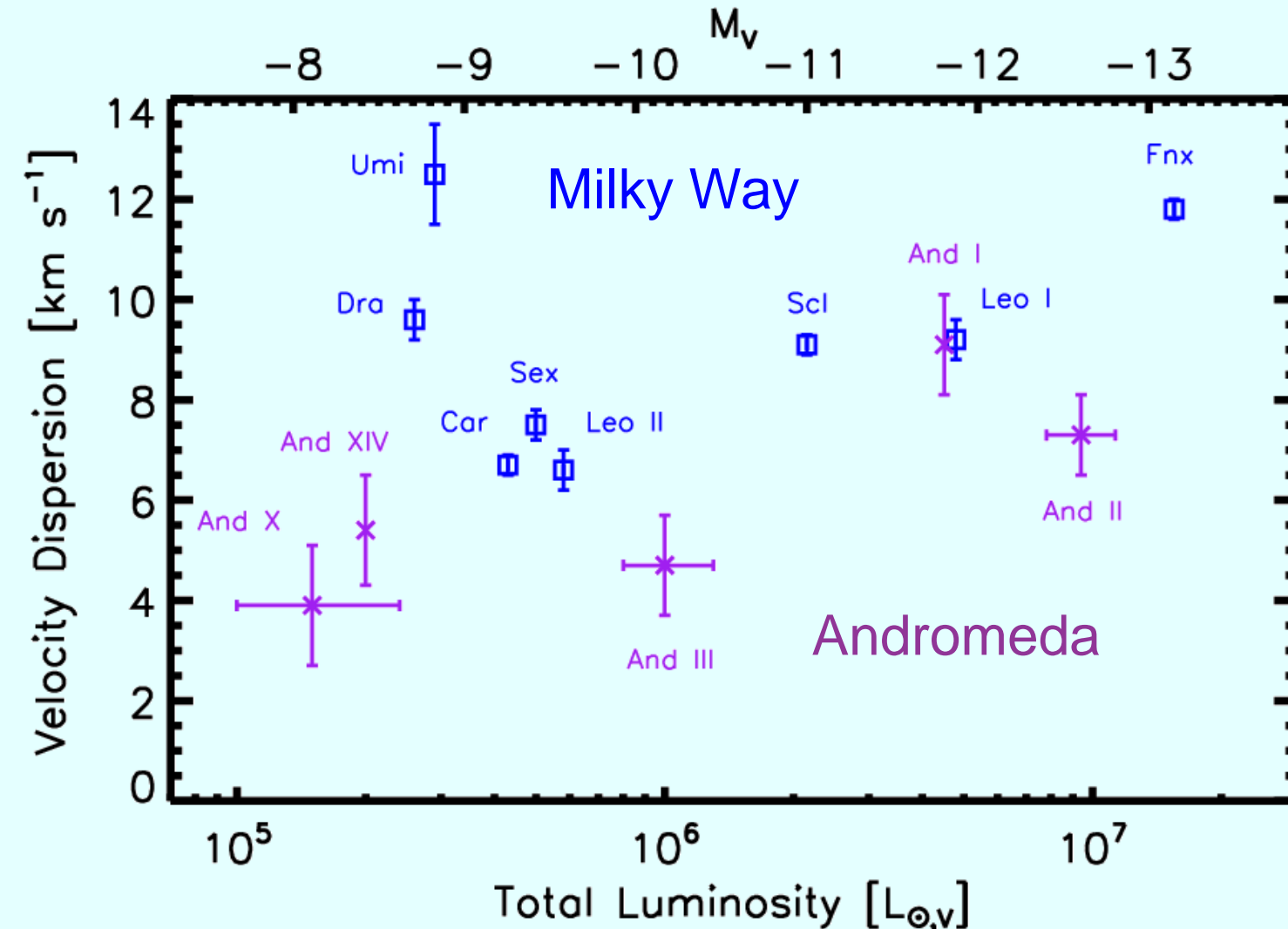
Kalirai et al. 2008, in prep.



Wolf et al. 2008, in prep.

Dispersion profile falls as projected R approaches the stellar extent.

Dispersion vs Luminosity

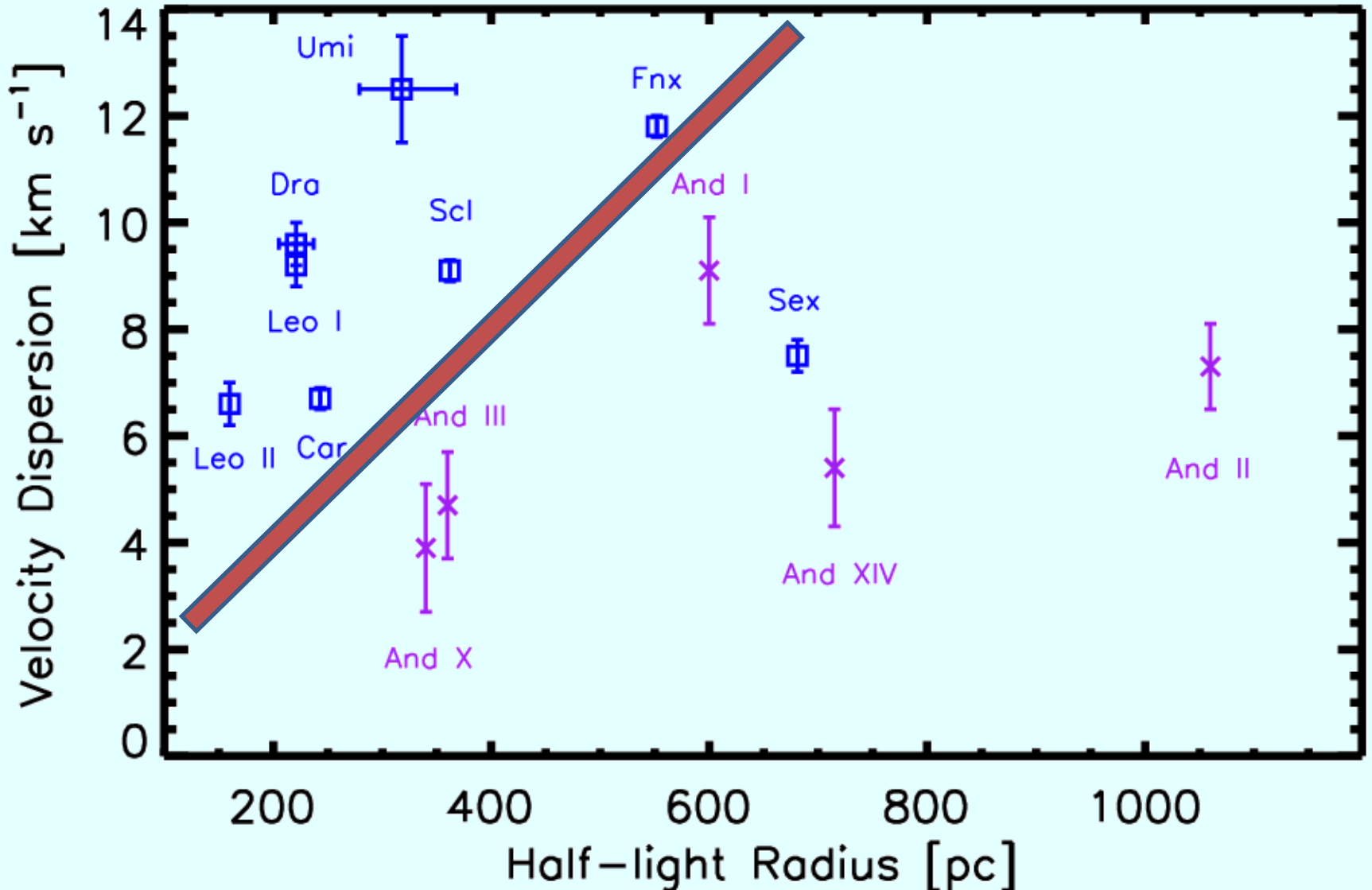


$\sigma_{M31} < \sigma_{MW}$ at fixed L suggests dark matter halos less dense!

Dispersion vs Size

Milky Way

Andromeda



Mass Modeling

What information do we have?

- Stellar kinematics
- Photometry

Spherical Jeans Eq.

$$r \frac{d(\rho_* \sigma_r^2)}{dr} = \frac{-GM(r)}{r} \rho_*(r) - 2\beta(r) \rho_* \sigma_r^2$$

Velocity Anisotropy
(3 parameters)

$$\beta(r) = (\beta_\infty - \beta_0) \frac{r^2}{r_\beta^2 + r^2} + \beta_0$$

Mass Density
(6 parameters)

$$\rho(r) = \frac{\rho_s e^{-r/r_{cut}}}{(r/r_s)^c [1 + (r/r_s)^a]^{(b-c)/a}}$$

Mass Modeling

How do we get a mass likelihood?

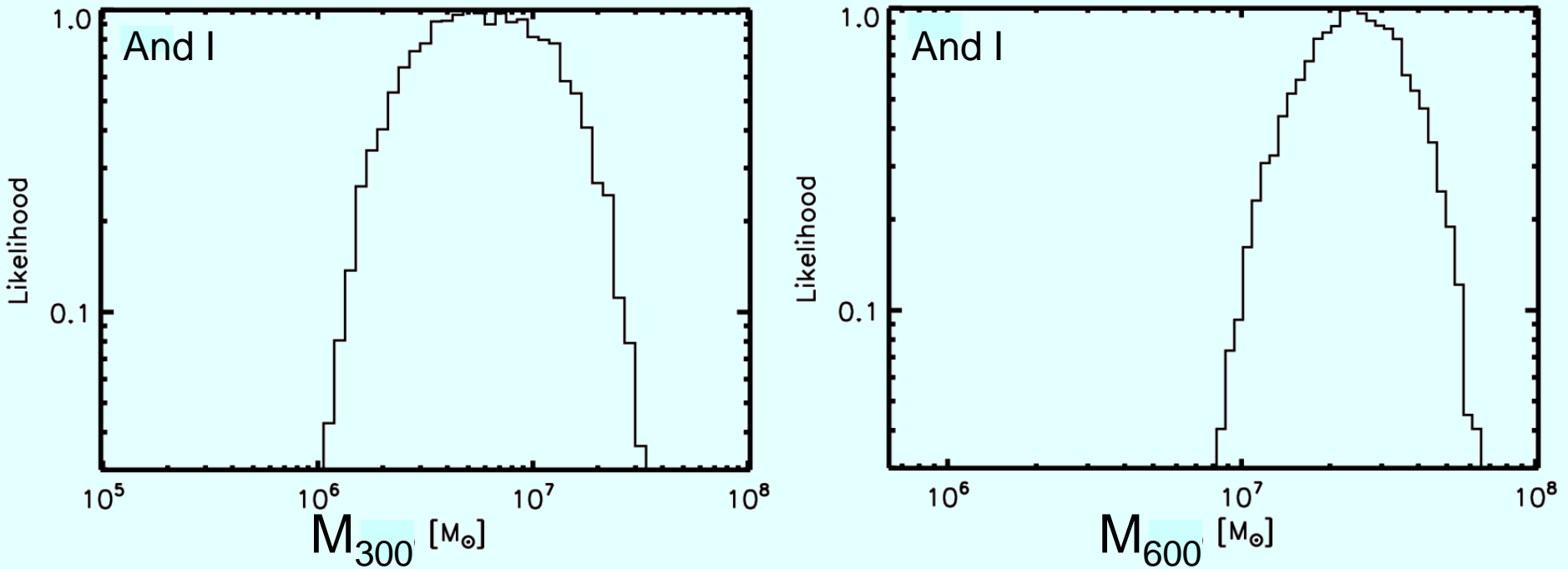
Integrate a probability distribution function

$$P(\mathbf{x}|\boldsymbol{\theta}) = \prod_{i=1}^n \frac{1}{\sqrt{2\pi(\sigma_{t,i}^2 + \sigma_{m,i}^2)}} \exp \left[-\frac{1}{2} \frac{(v_i - u)^2}{\sigma_{t,i}^2 + \sigma_{m,i}^2} \right]$$

$$\mathcal{L}(m) \propto \int P[\mathbf{v} | u, \sigma_{\mathbf{t}}(\vec{\theta})] \delta(m - M) d\vec{\theta}.$$

- Markov Chain Monte Carlo (MCMC): Randomly pick flat deviates from 13 dimensional parameter space to solve Jeans equation. Algorithm accepts or rejects based on likelihood value. Equivalent to integrating over the distribution function.

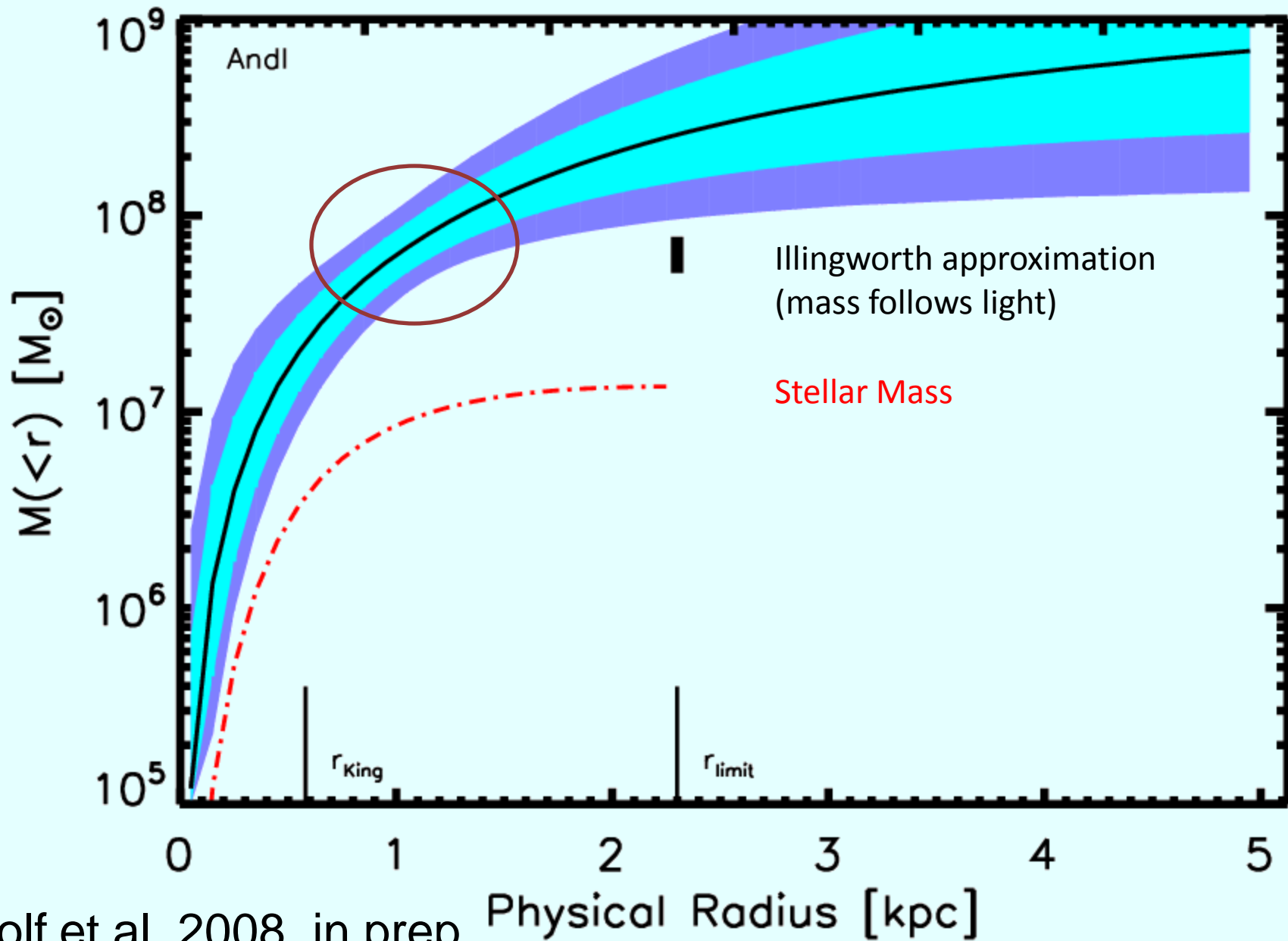
Mass Likelihoods



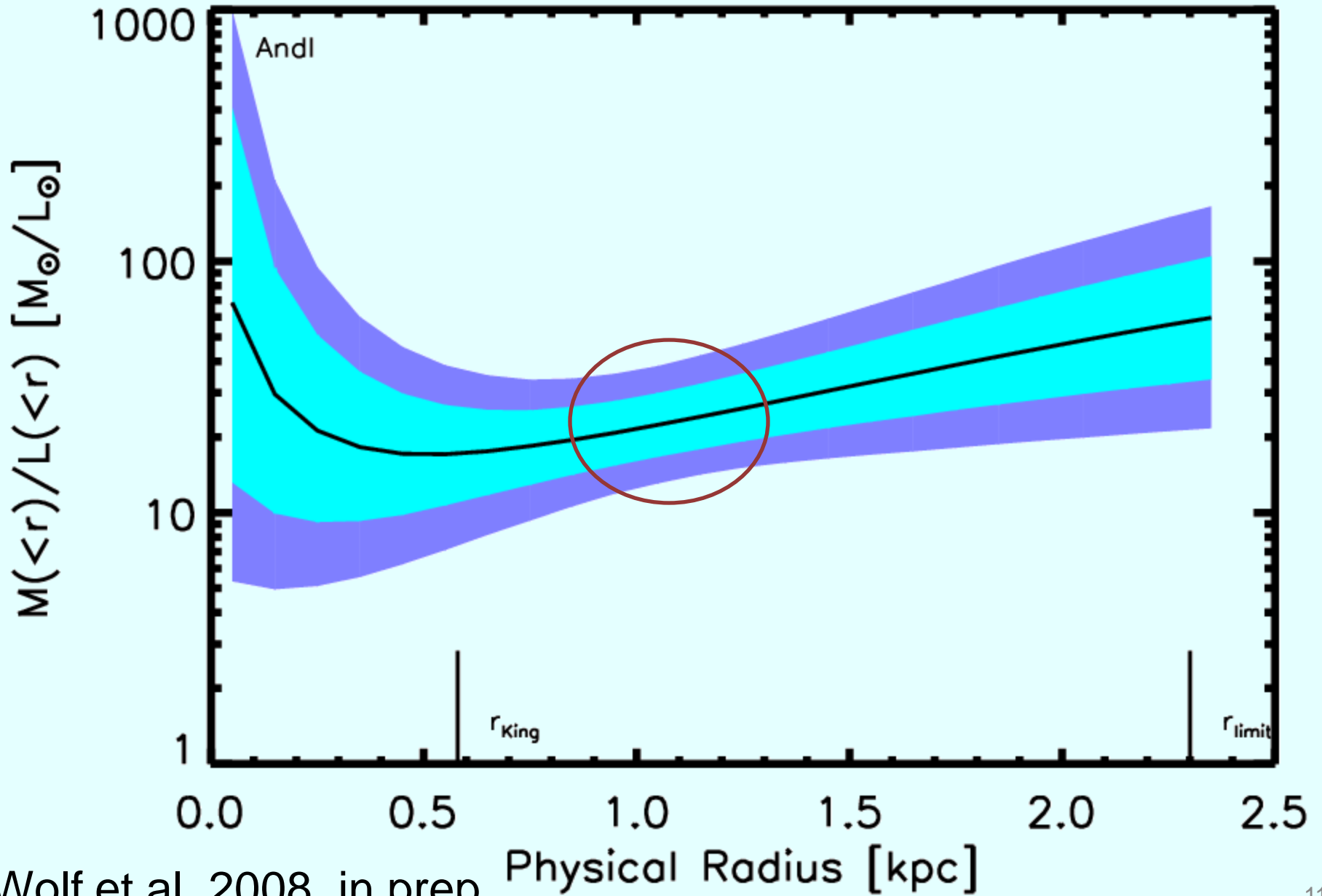
Wolf et al. 2008, in prep.

What is best radius to constrain mass?

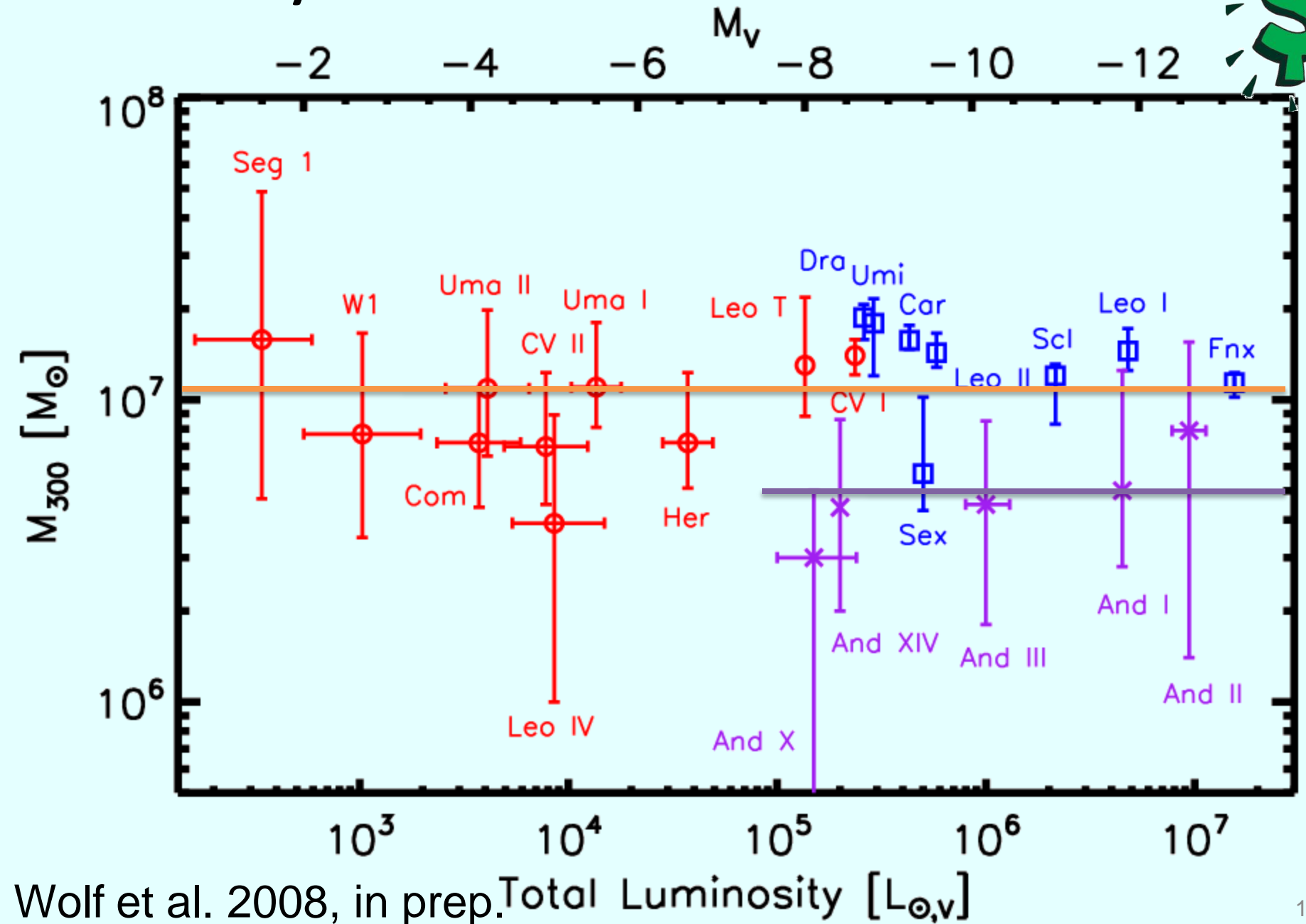
Cyan Plot I



Cyan Plot II



Money Plot



Interpretation/Future Work

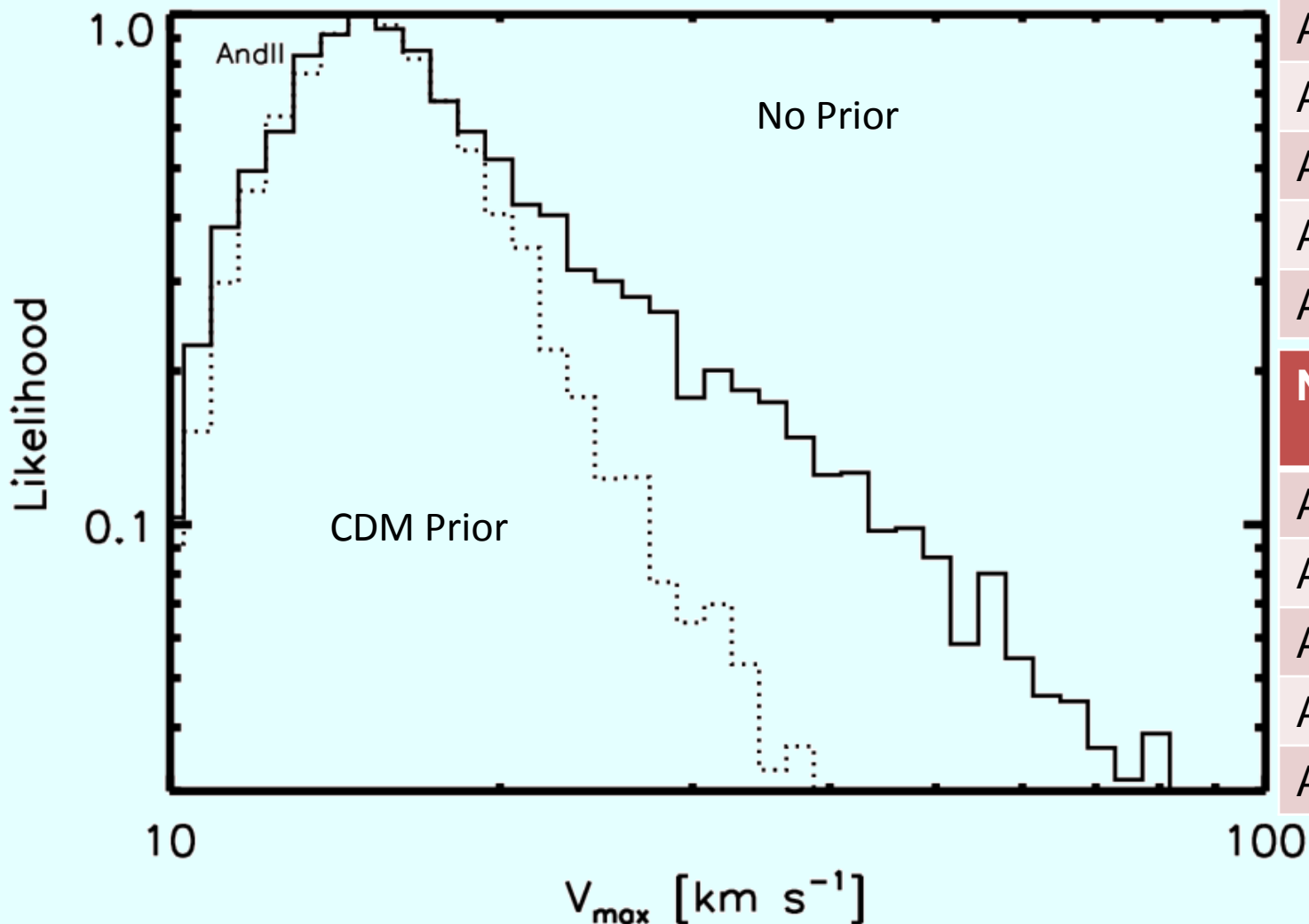
- M31 dSphs are less dense → Galaxy formation may be different for MW and M31.
- Could imply that M31's dark matter halo collapsed later.
- Feedback processes may be different for each galaxy.

Question:

Is there a consistent mass scale or just a threshold?

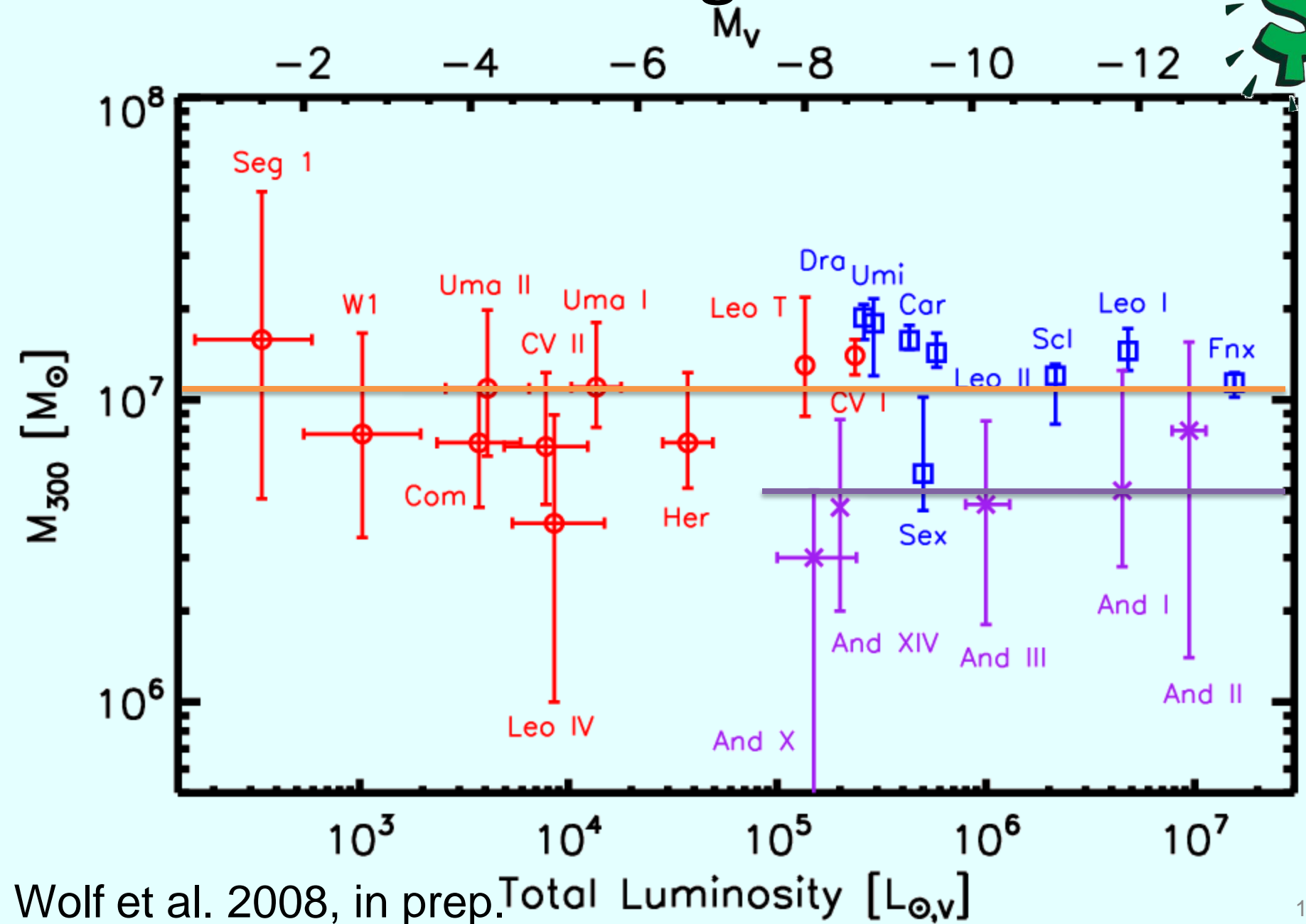
More kinematics are needed to examine the rest of the M31 dSph population.

V_{\max} Likelihoods



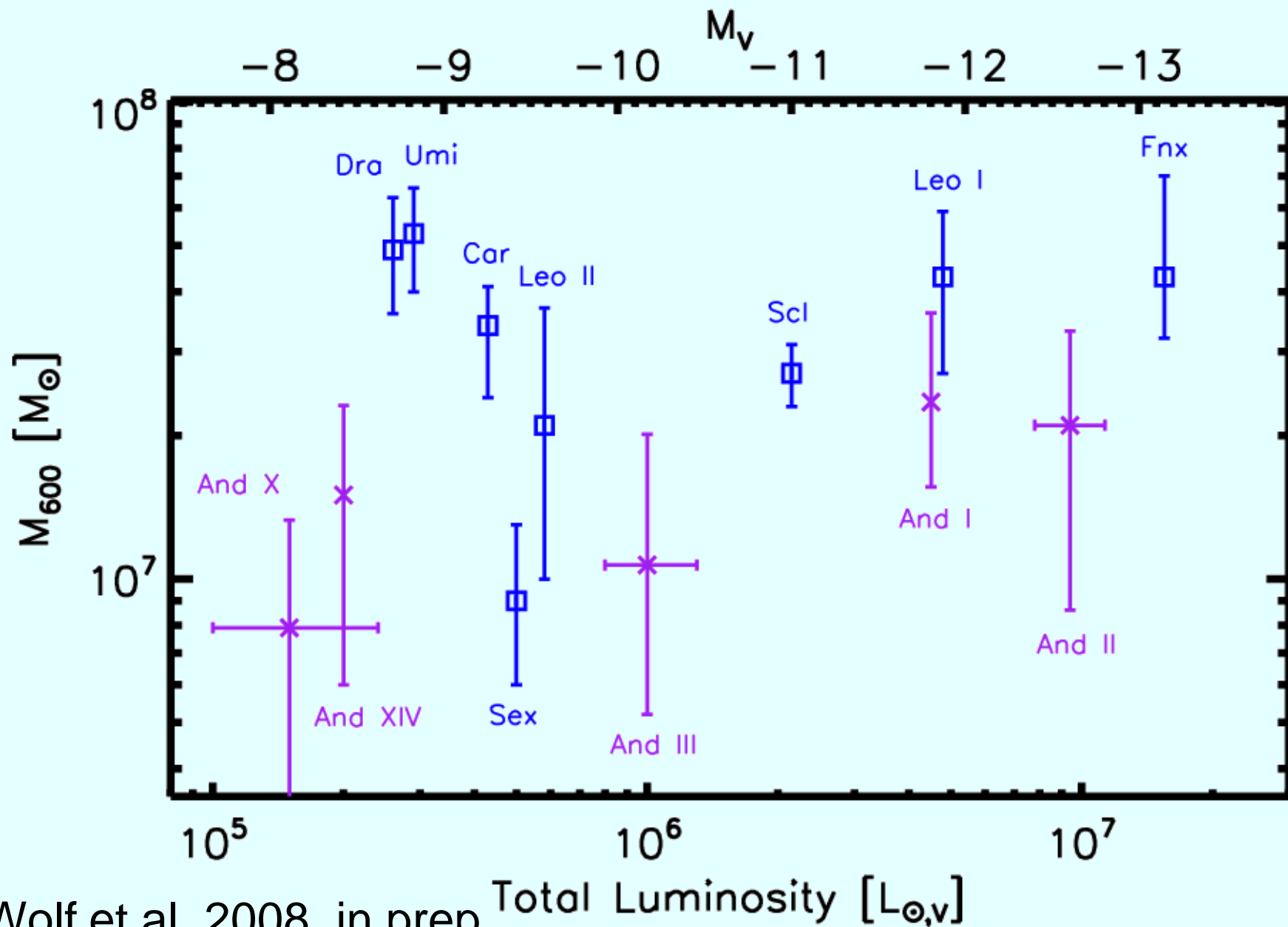
Name	V_{\max}
And I	18^{+31}_{-1}
And II	15^{+15}_{-2}
And III	11^{+8}_{-4}
And X	8^{+8}_{-6}
And XIV	12^{+14}_{-4}
Name	CDM prior
And I	20^{+15}_{-2}
And II	15^{+5}_{-2}
And III	11^{+8}_{-4}
And X	8^{+10}_{-3}
And XIV	12^{+11}_{-4}

Take-Home Message

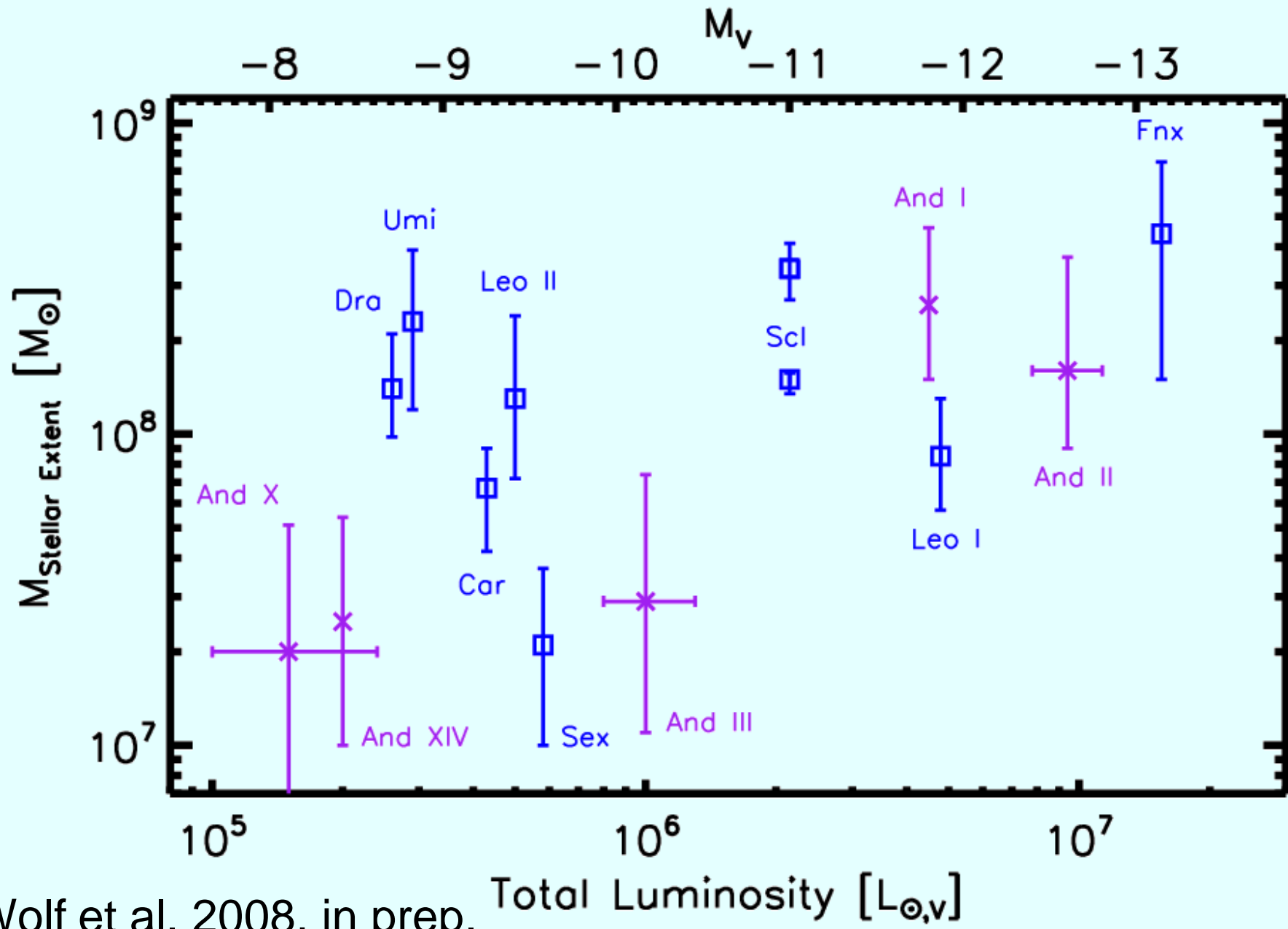


Extra Plots

M_{600} vs L_V



$M_{\text{Stellar extent}}$ vs L_V



$M_{\text{Stellar extent}} / L_V$ vs L_V

