Dark Matter Halos of M31 Galaxies

“Joe Wolf”

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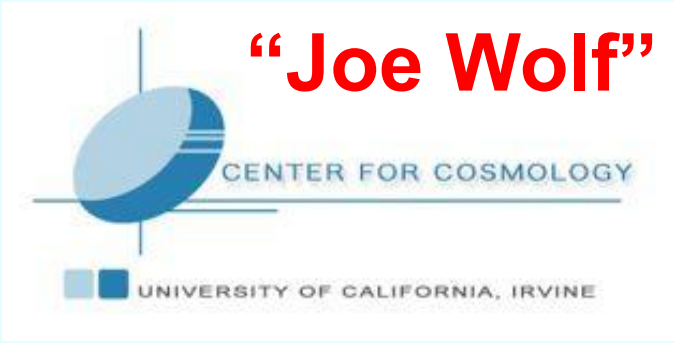

Team Irvine: Louie Strigari, James Bullock, Manoj Kaplinghat

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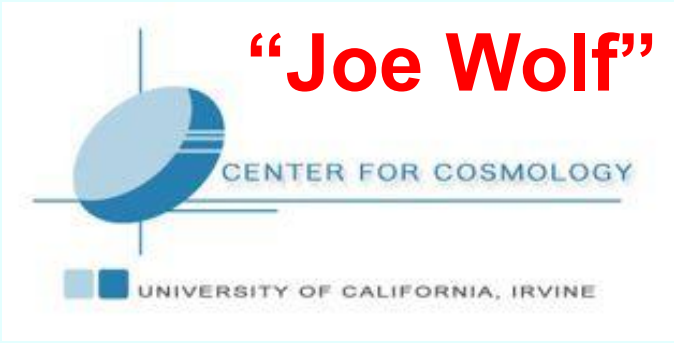

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Team Santa Cruz: Jason Kalirai, Karrie Gilbert, Evan Kirby, Raja Guhathakurta
Yale: Marla Geha
Virginia: Rachael Beaton, Richard Patterson, Steven Majewski
Cambridge: Daniel Zucker

Overview

What is a dwarf spheroidal (dSph) galaxy?

- Typical galaxies have M/L ~1 - ~10, with baryon dominated centers.

- Dwarf spheroidal galaxies are the most dark matter dominated systems known: M/L ~10 - ~1000

- Excellent laboratories to compare DM simulations to observations.

And VI: George Jacoby/WIYN/NOAO/NSF

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- Missing Satellites Problem → Erik Tollerud's talk

- Cusp - Core Problem

- Galaxy formation theories disagree with observations

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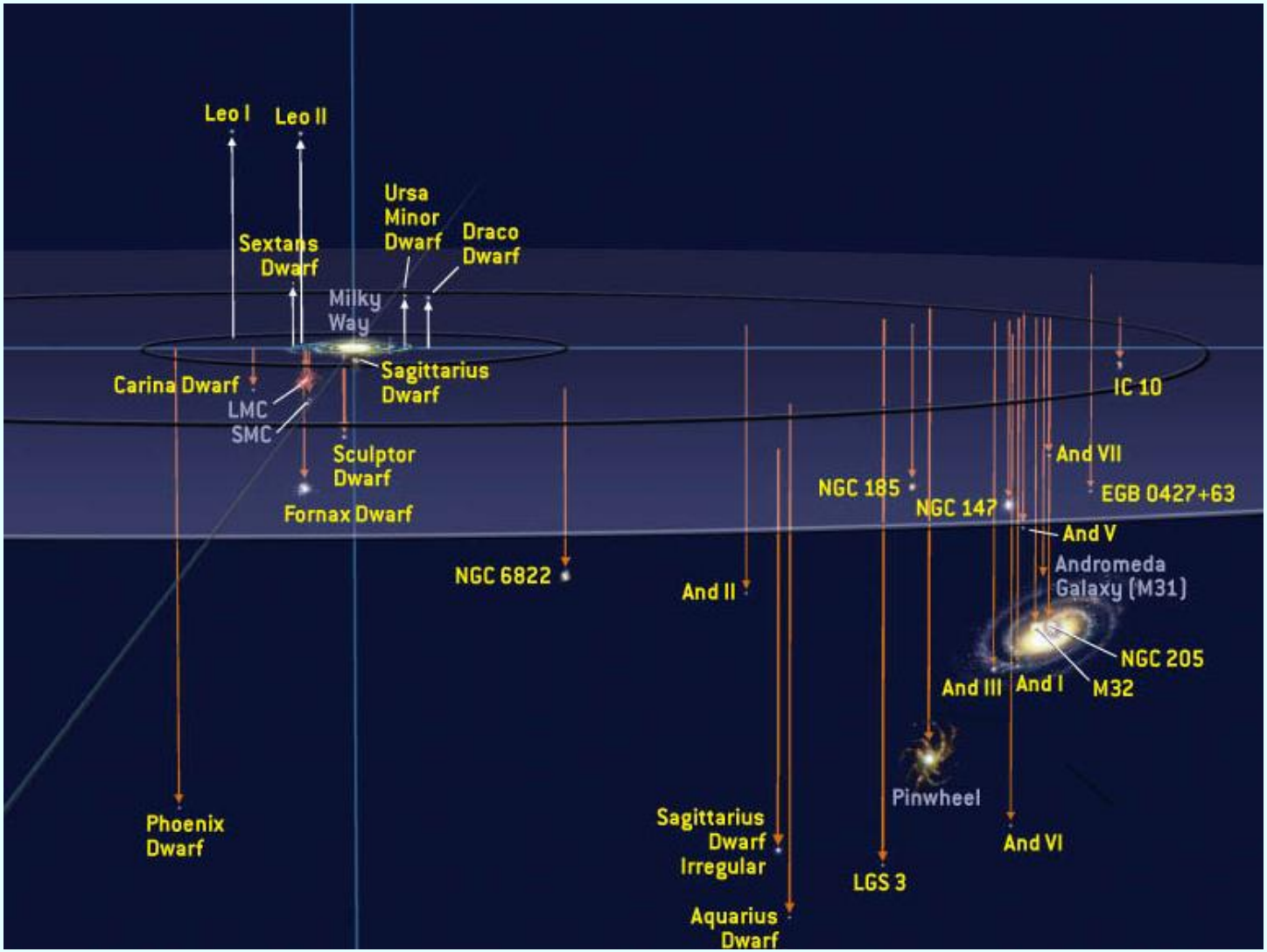
Predictions from mass models:

- Gamma ray annihilation signals → Greg Martinez's talk

And VI: George Jacoby/WIYN/NOAO/NSF

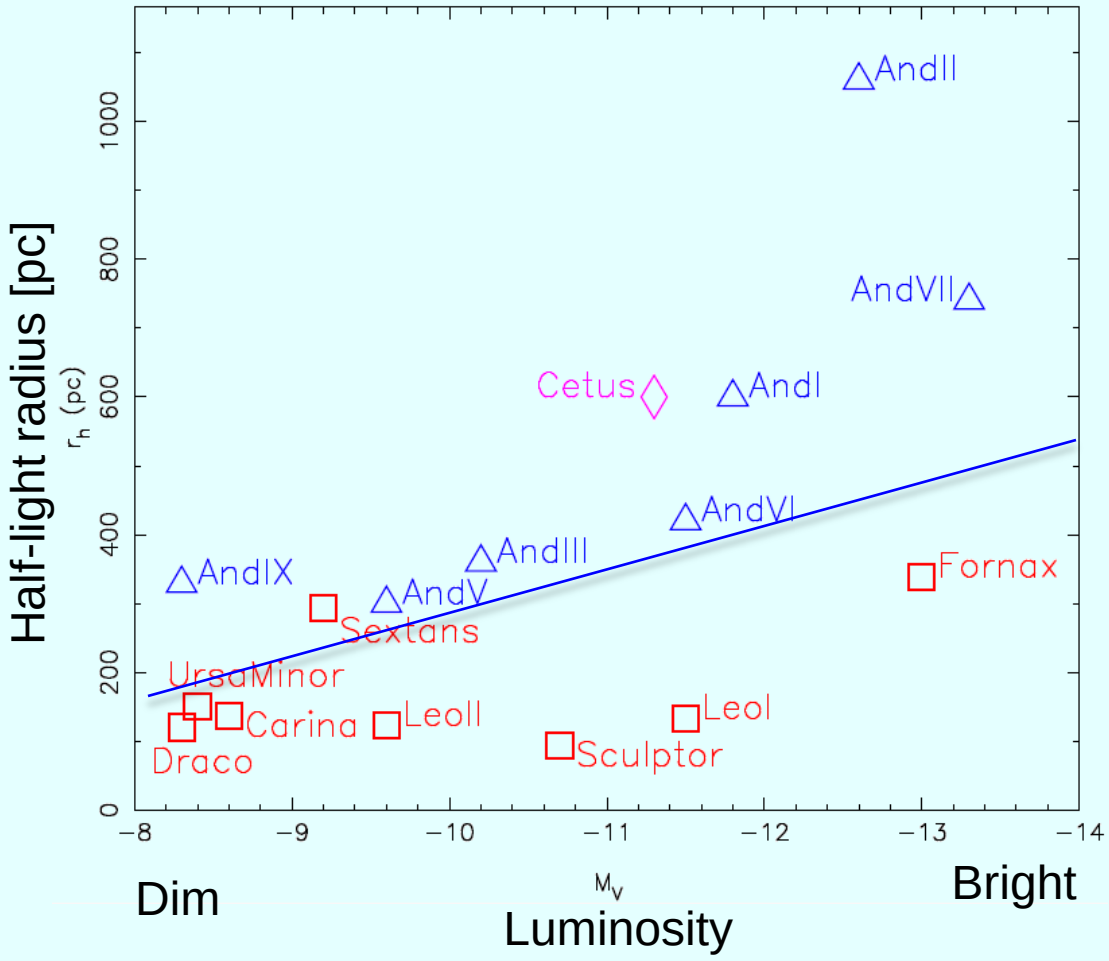
Another Dataset: Andromeda!



Roen Kelly / Astronomy

M31 dSphs: Larger than MW dSphs

M31 dSphs



MW dSphs

McConnachie & Irwin, MNRAS 2006

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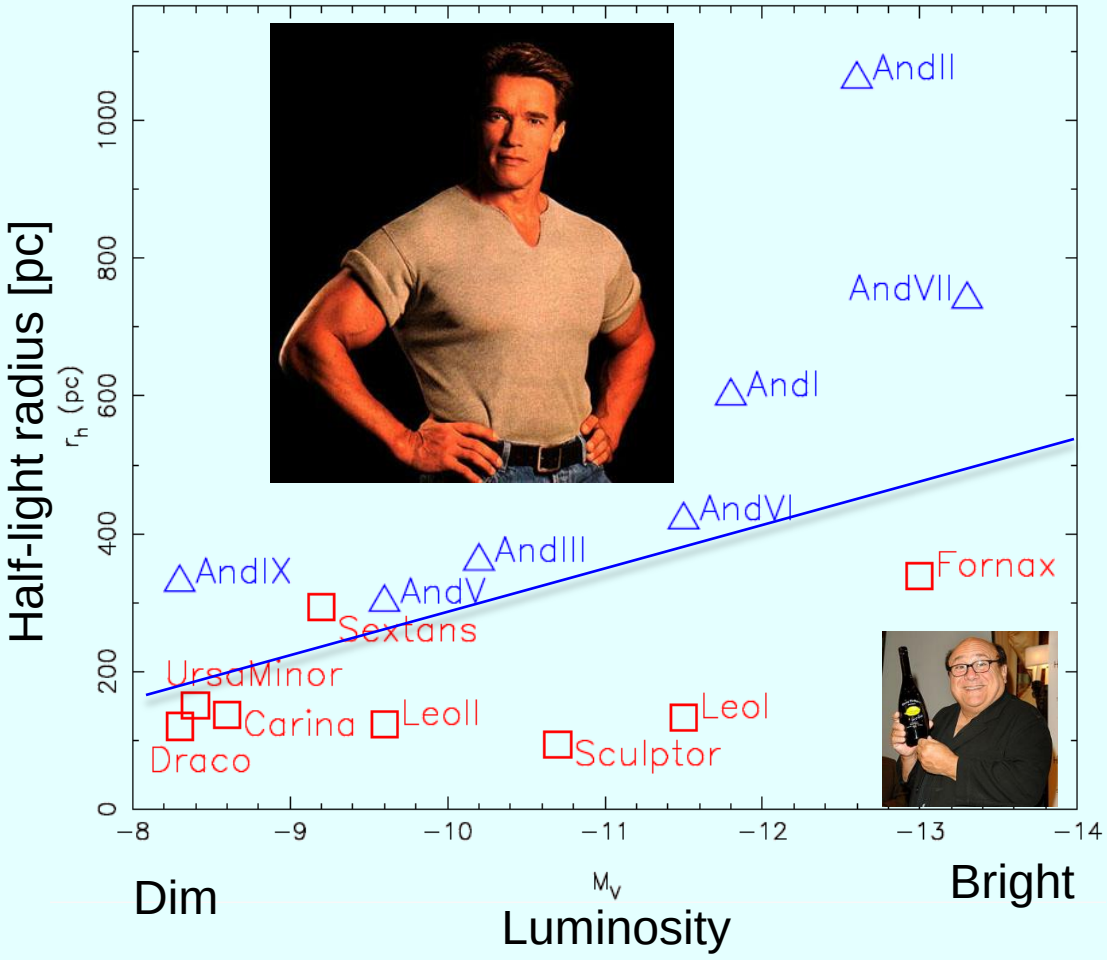
M31 dSphs



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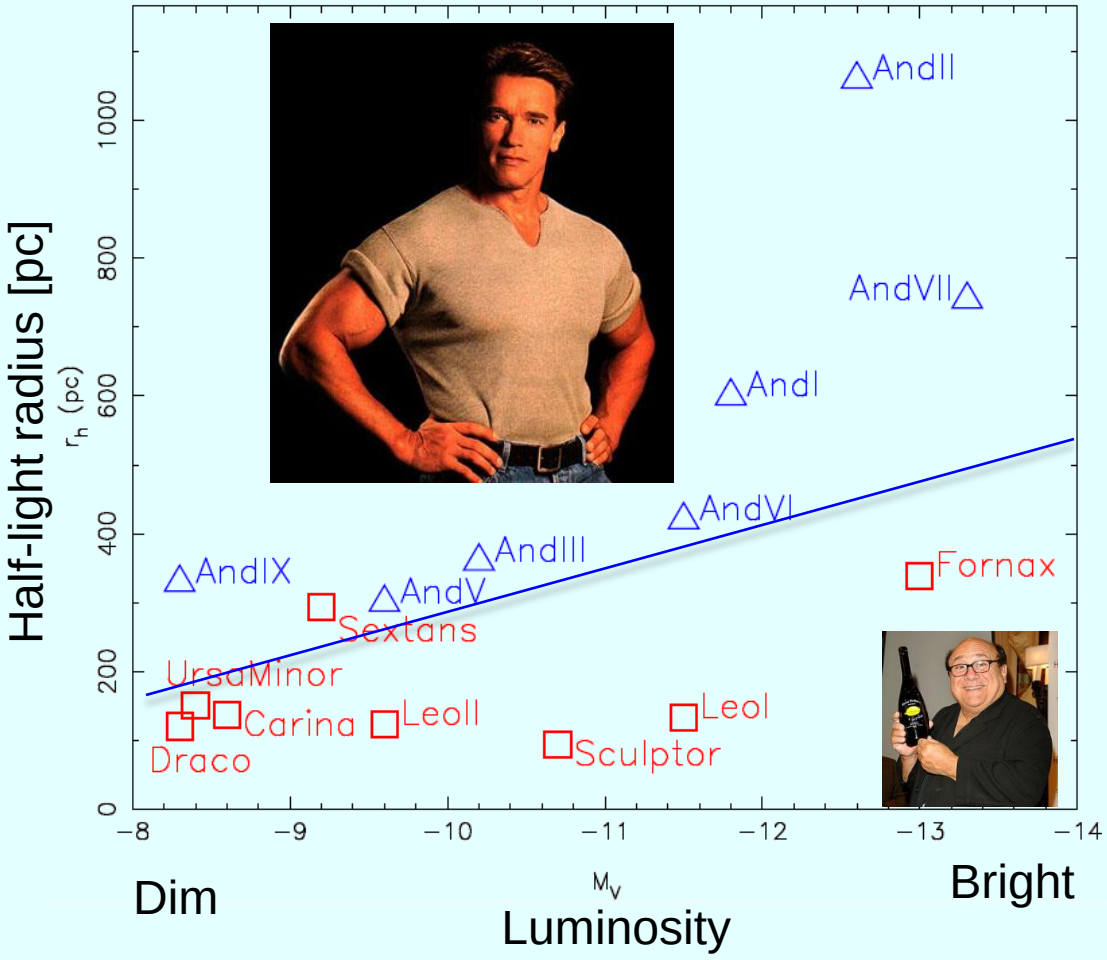


M31 dSphs

Are the DM halos the same or different?

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

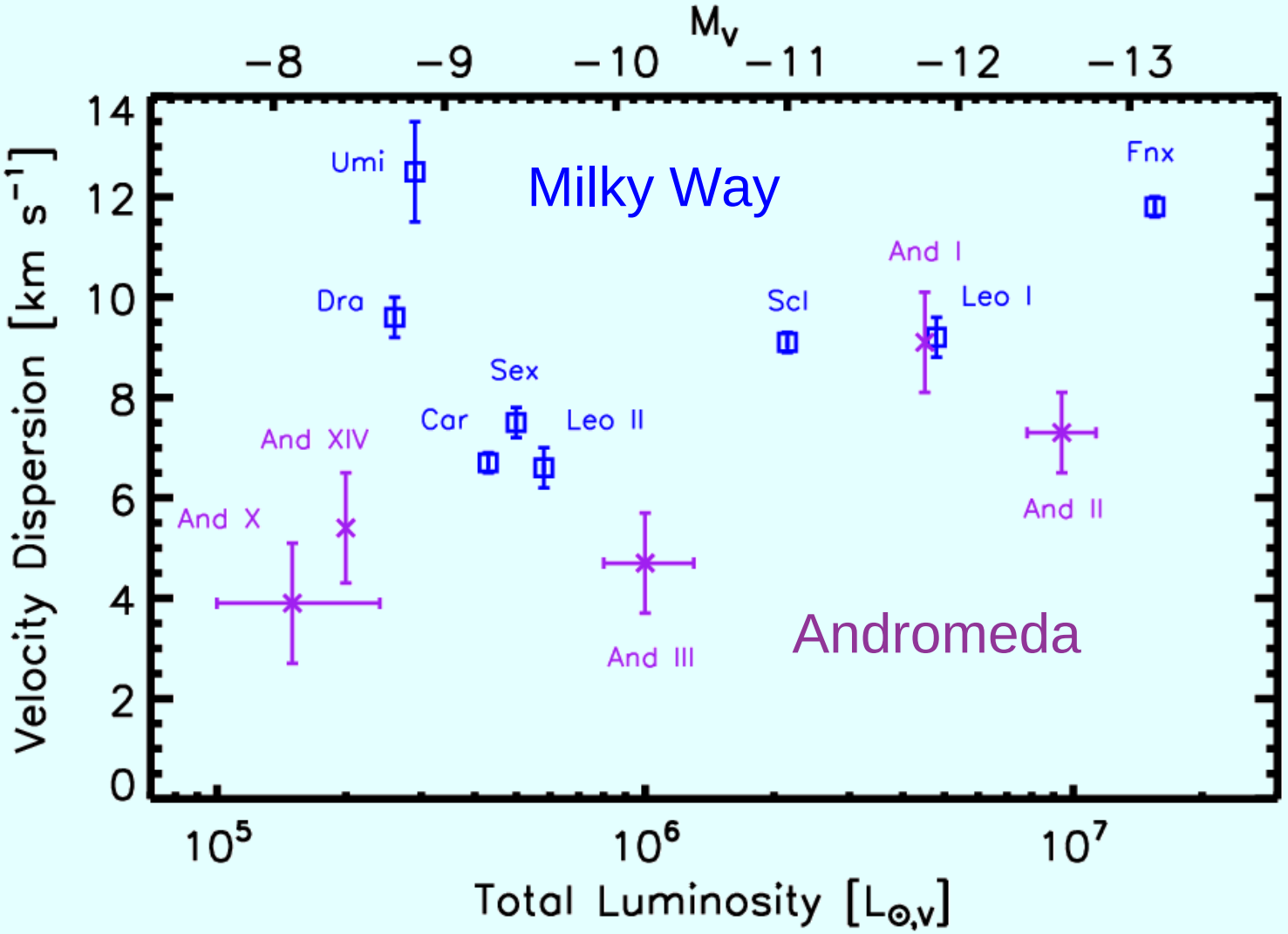
(Penarrubia, Navarro, McConnachie ApJ 2007)

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

MW dSphs

McConnachie & Irwin, MNRAS 2006

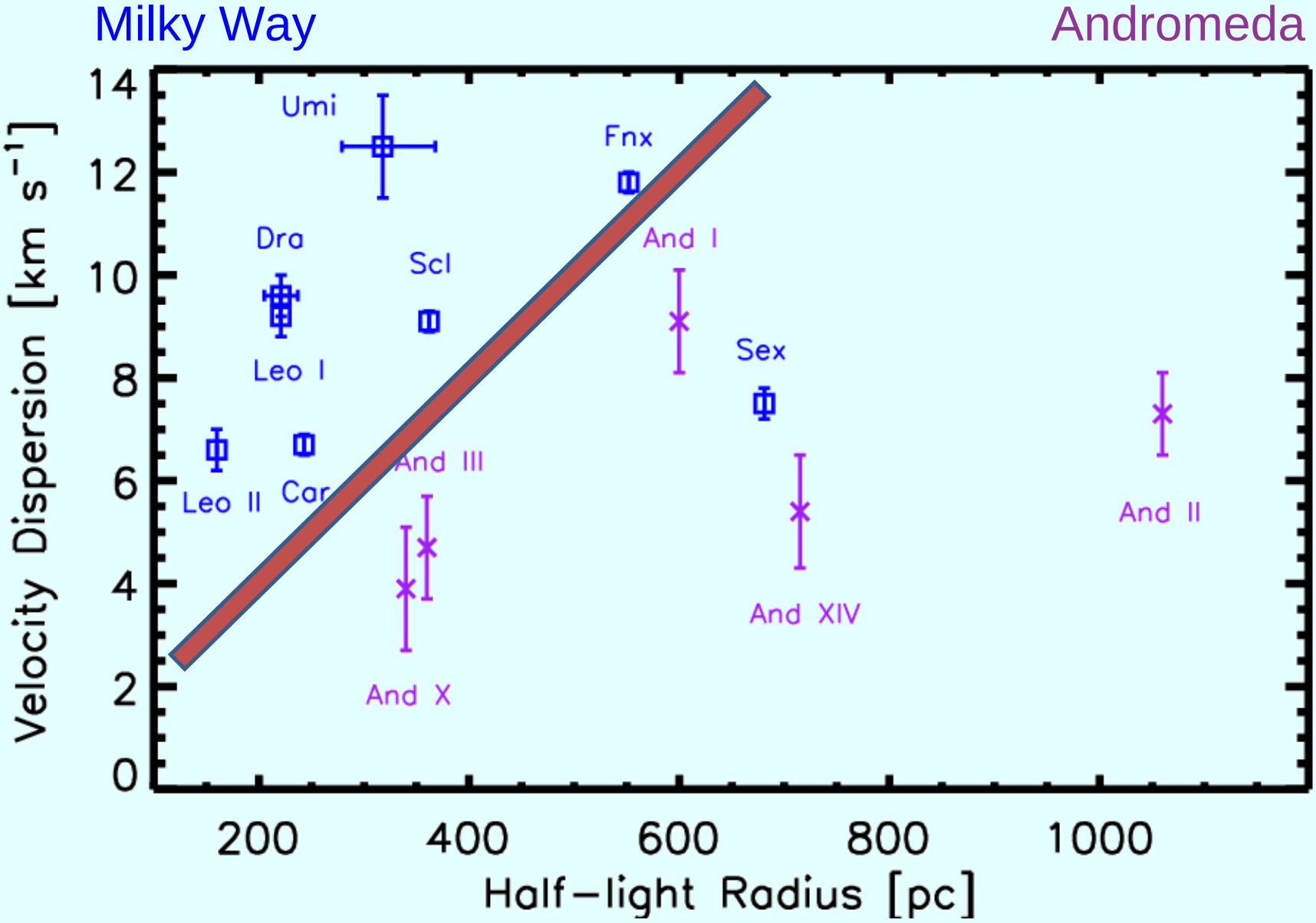
Dispersion vs Luminosity



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

Wolf et al. 2008, in prep.

Dispersion vs Size



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Mass Modeling

What information do we have?

- Stellar kinematics
- Photometry

Spherical Jeans Eq.

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

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(3 parameters)

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Mass Density
(6 parameters)

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

Mass Modeling

How do we get a mass likelihood?

Integrate a probability distribution function

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

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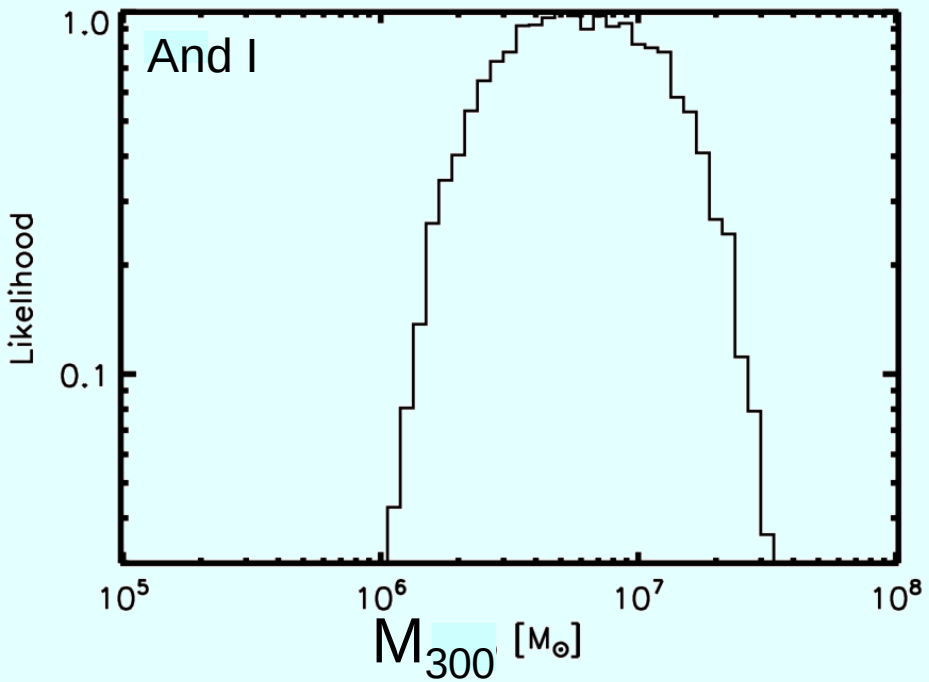
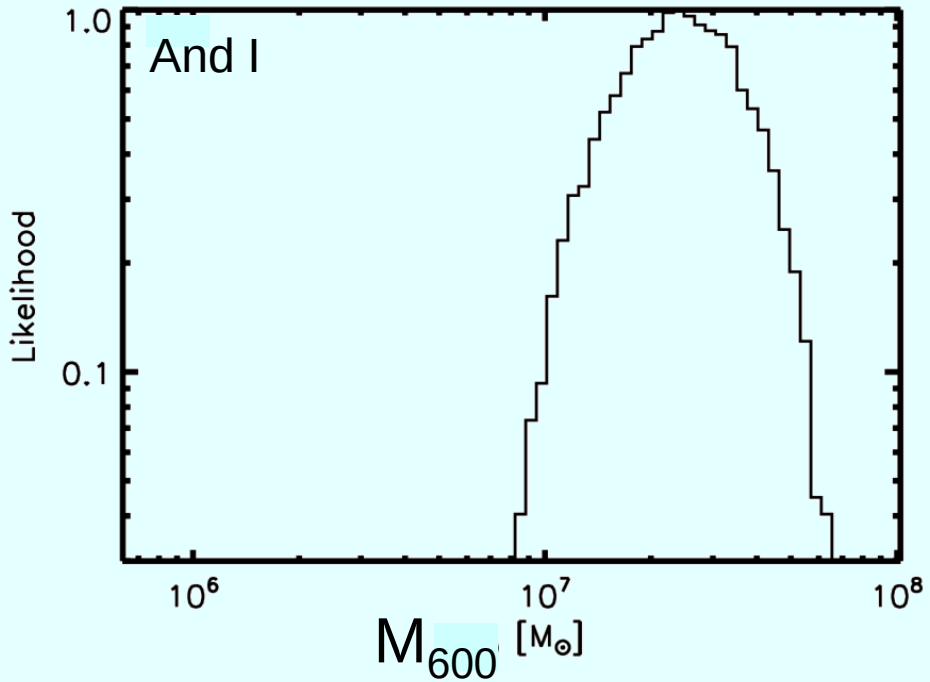
$$\mathcal{L}(m) \propto \int P[\mathbf{v}|u, \sigma_{\mathbf{t}}(\vec{\theta})]\delta(m - M)d\vec{\theta}.$$

•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

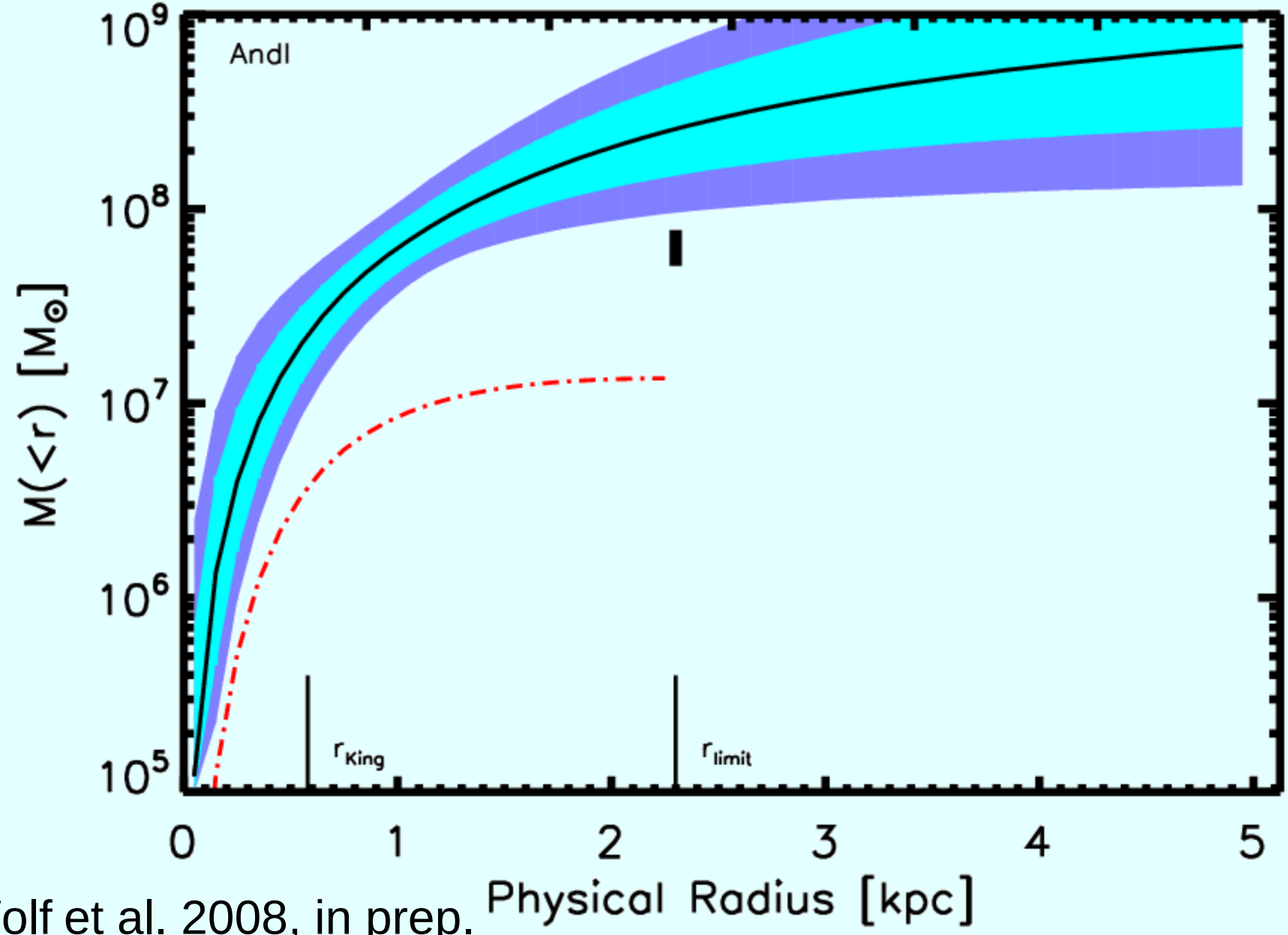




Wolf et al. 2008, in prep.

What is best radius to constrain mass?

Cyan Plot I



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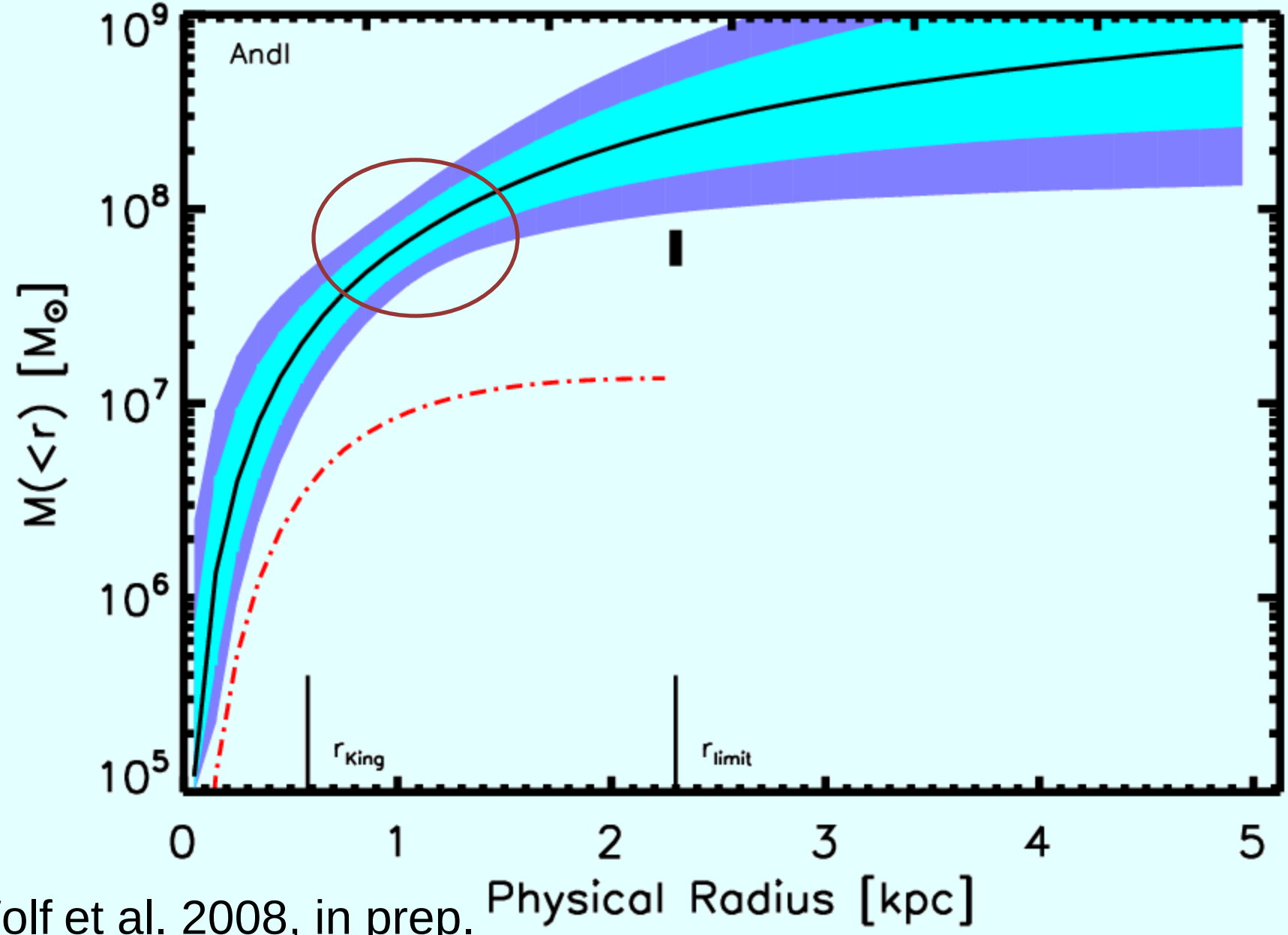

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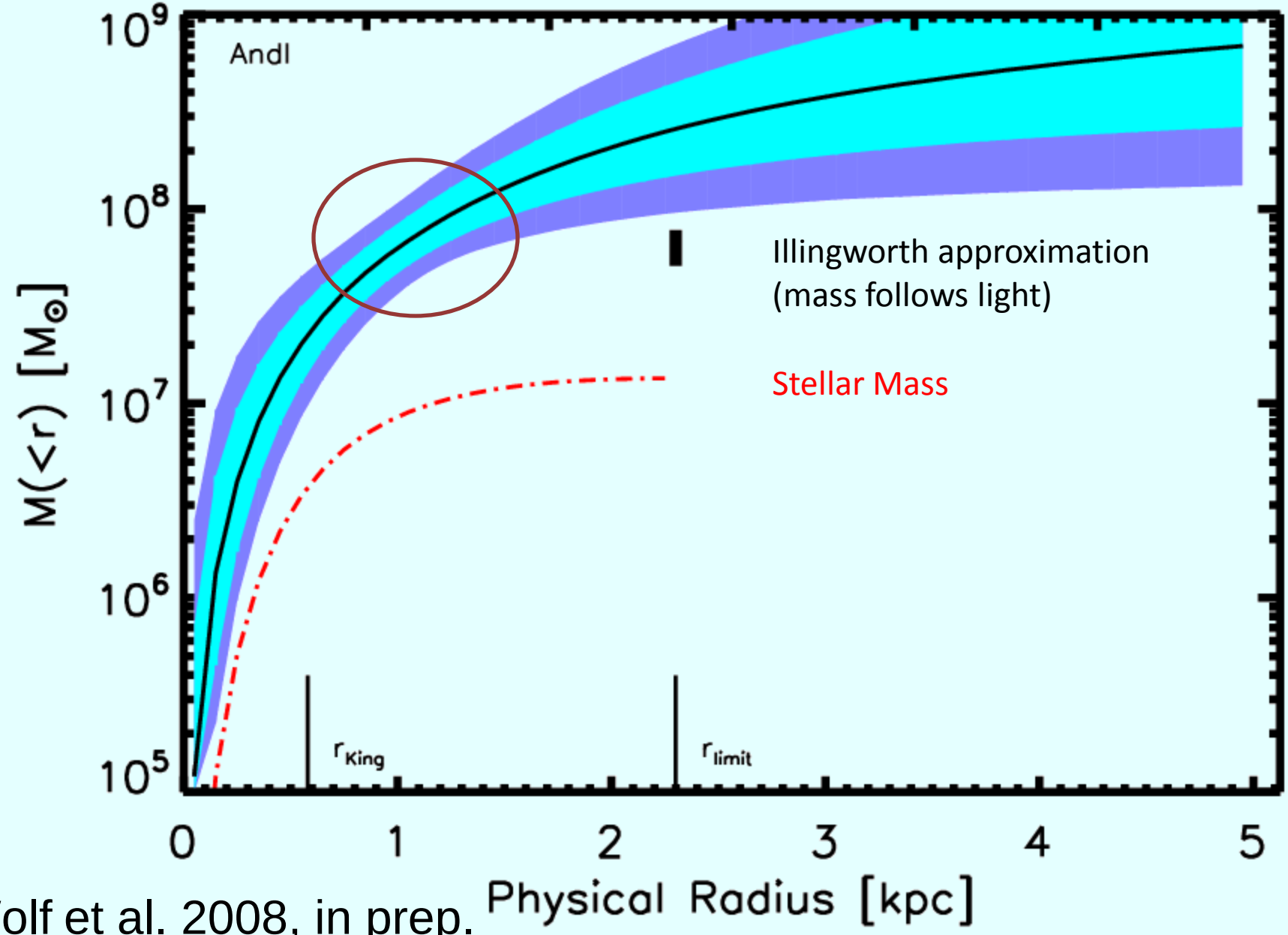
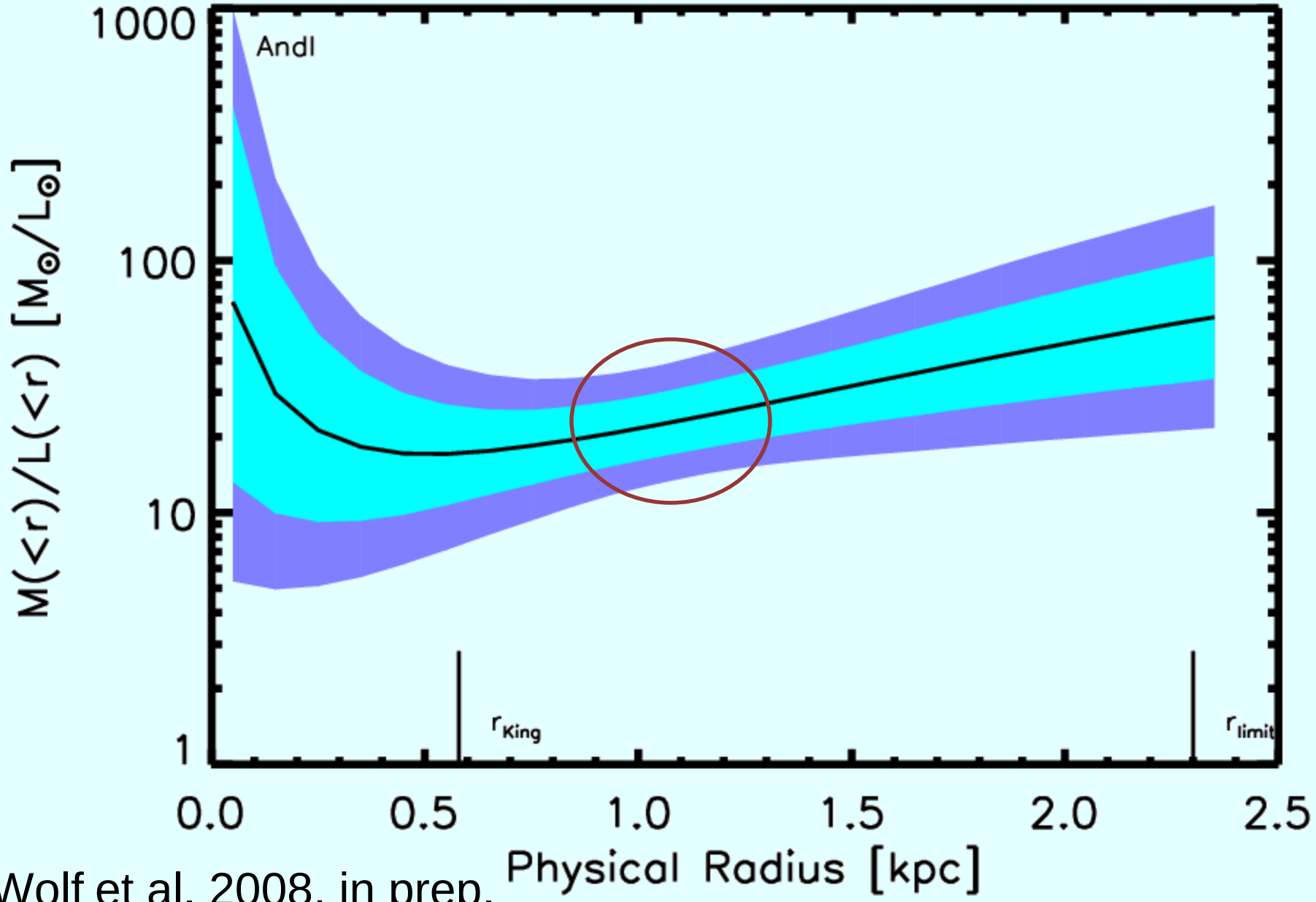


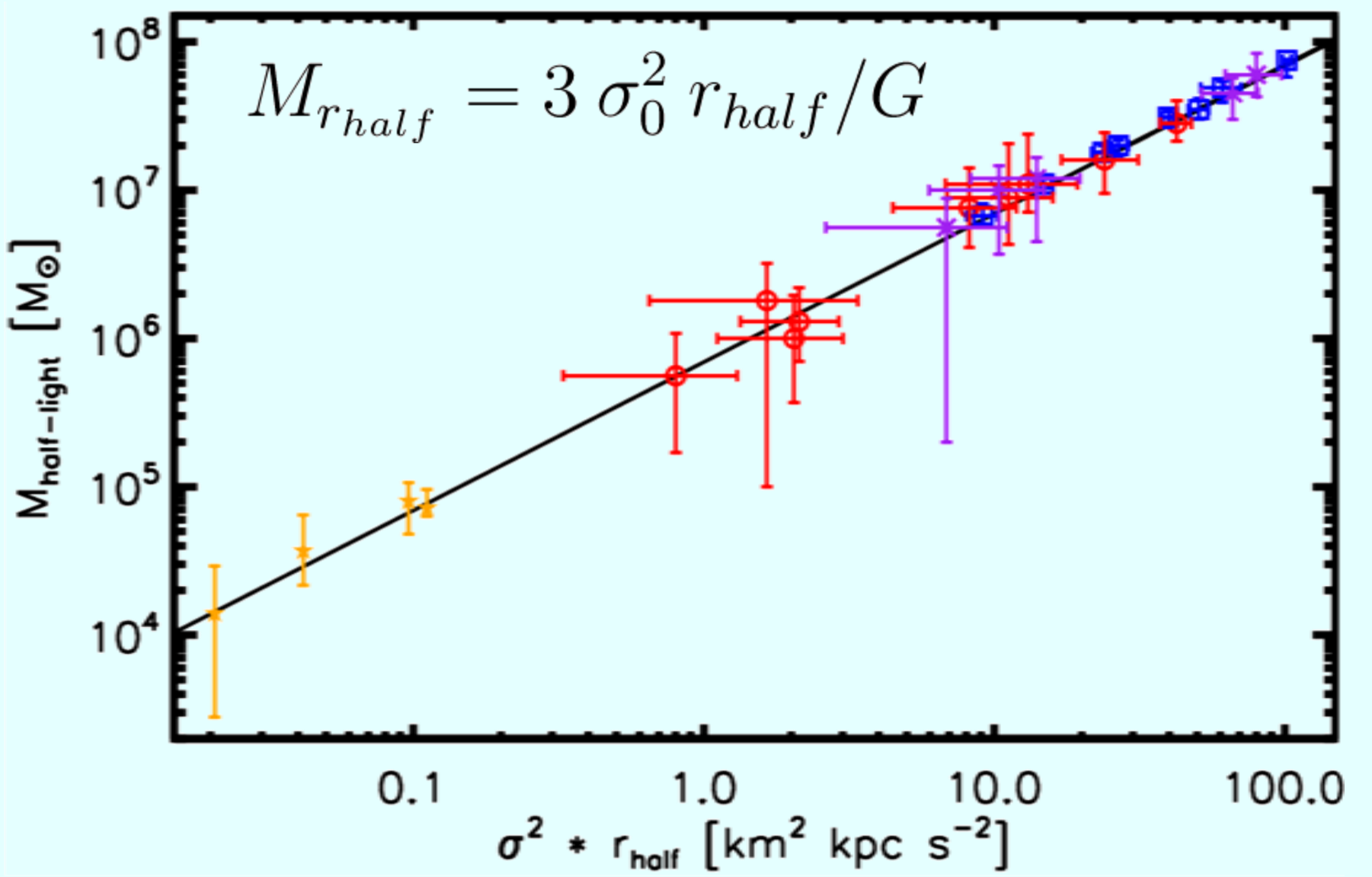
Wolf et al. 2008, in prep.

Cyan Plot II



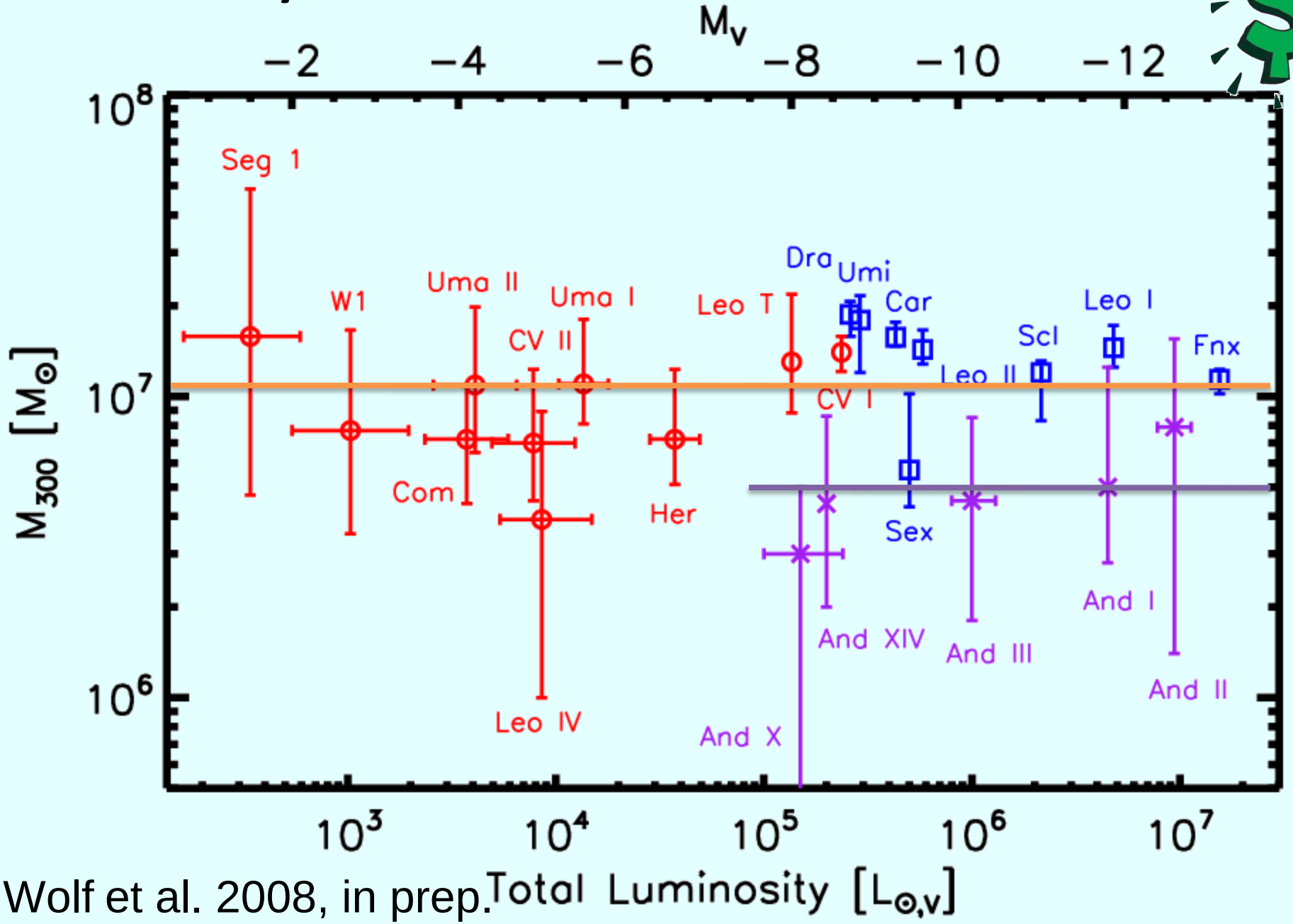
Wolf et al. 2008, in prep.

Approximating Mass



Wolf et al. 2008, in prep.

Money Plot I



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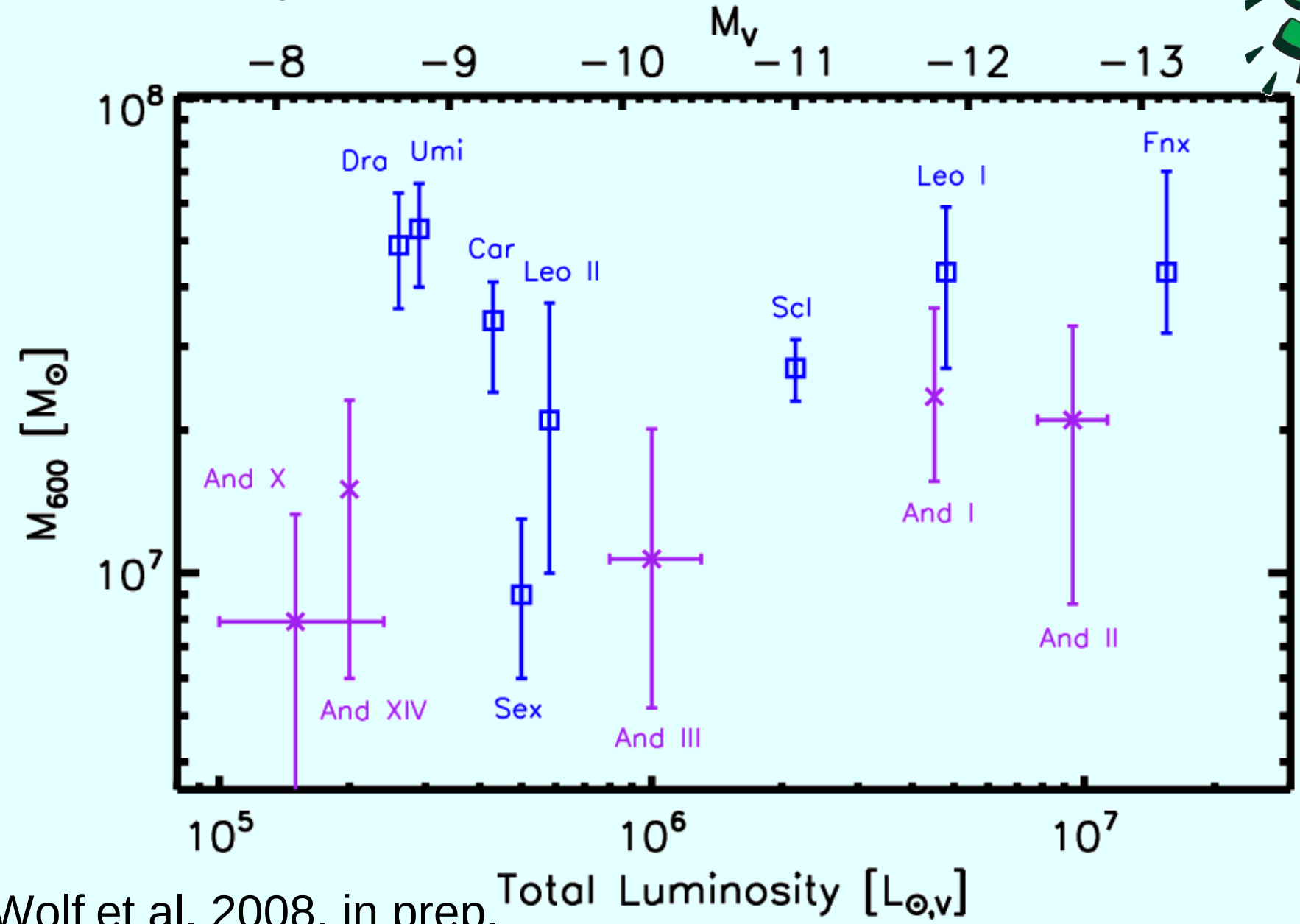
Money Plot II



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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.

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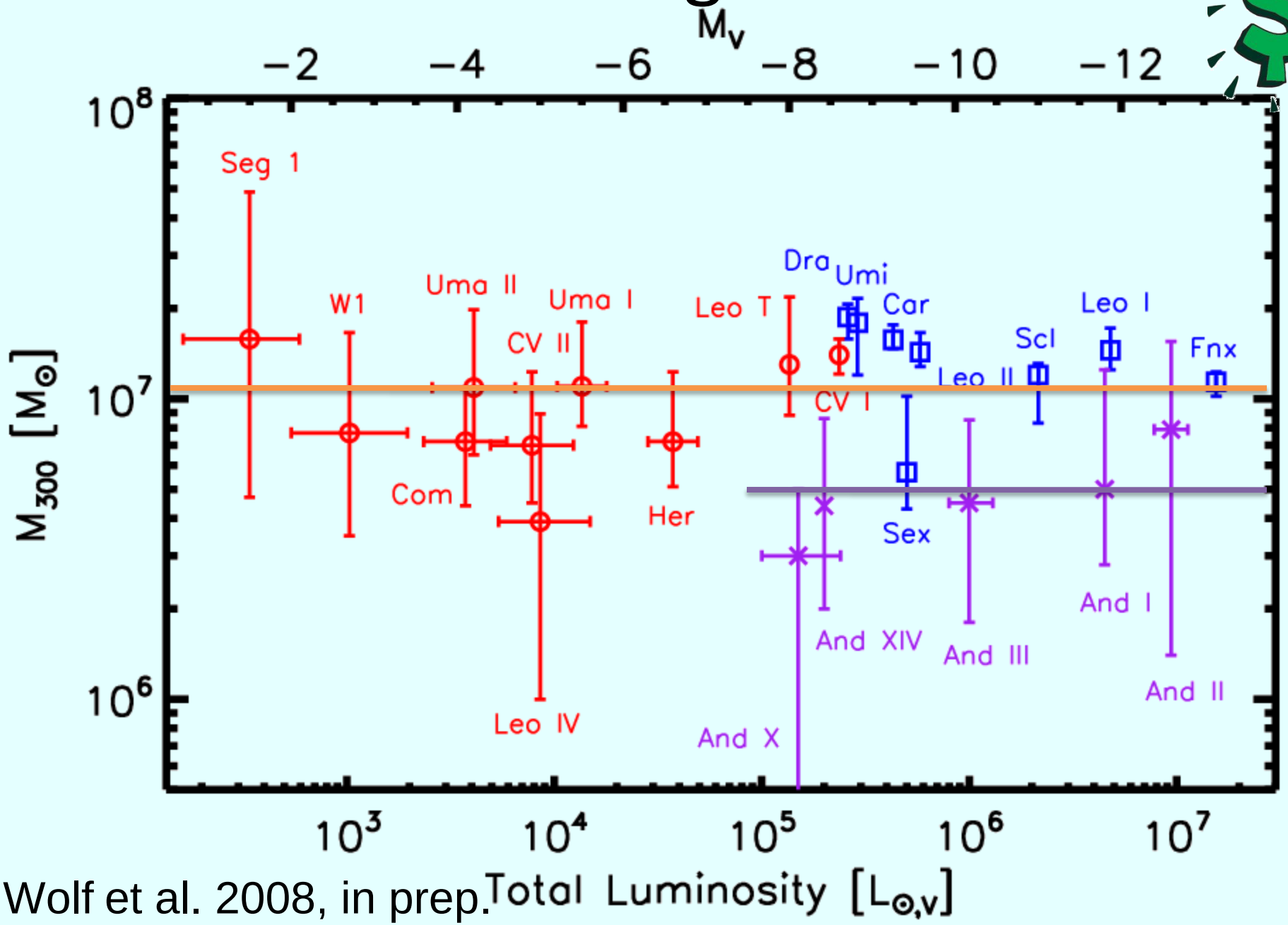
Question:
Is there a consistent mass scale or just a threshold?
More kinematics are needed to examine the rest of the M31 dSph population.

Take-Home Message



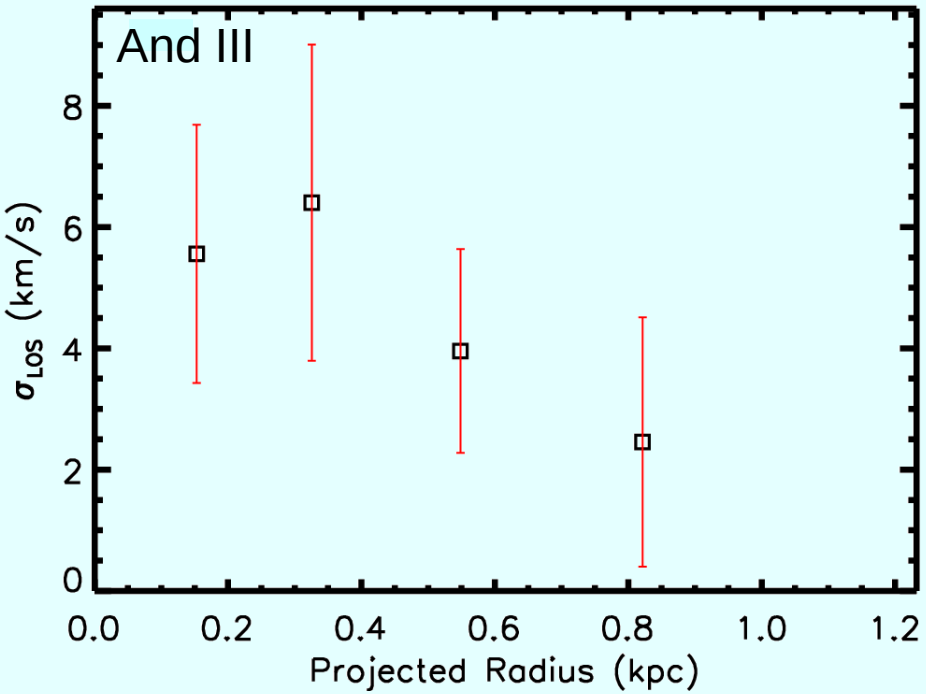
Wolf et al. 2008, in prep.

Extra Plots

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

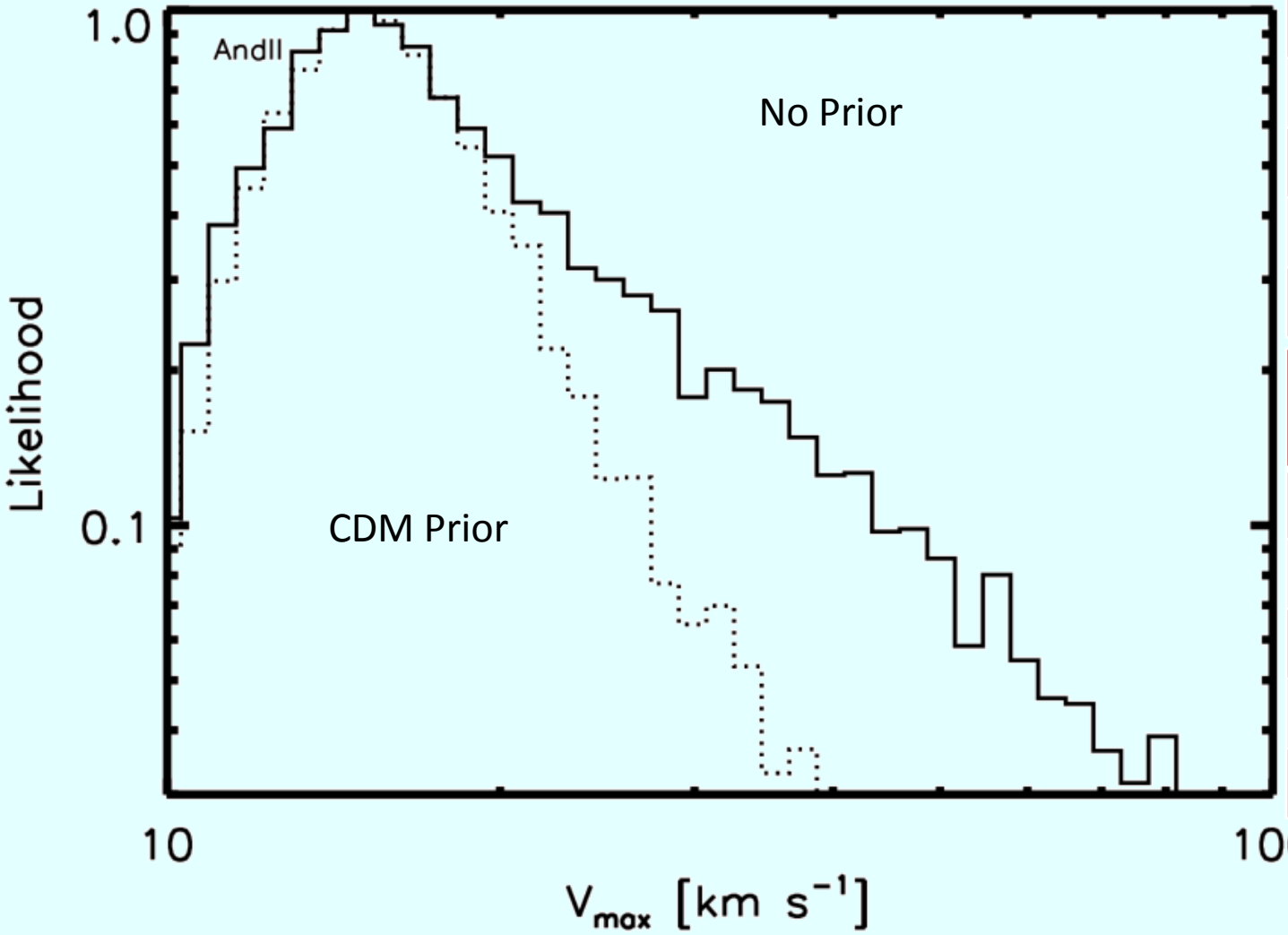
Kalirai et al. 2008, in prep.



Wolf et al. 2008, in prep.

Dispersion profile falls as projected R approaches the stellar extent.

V_{max} Likelihoods

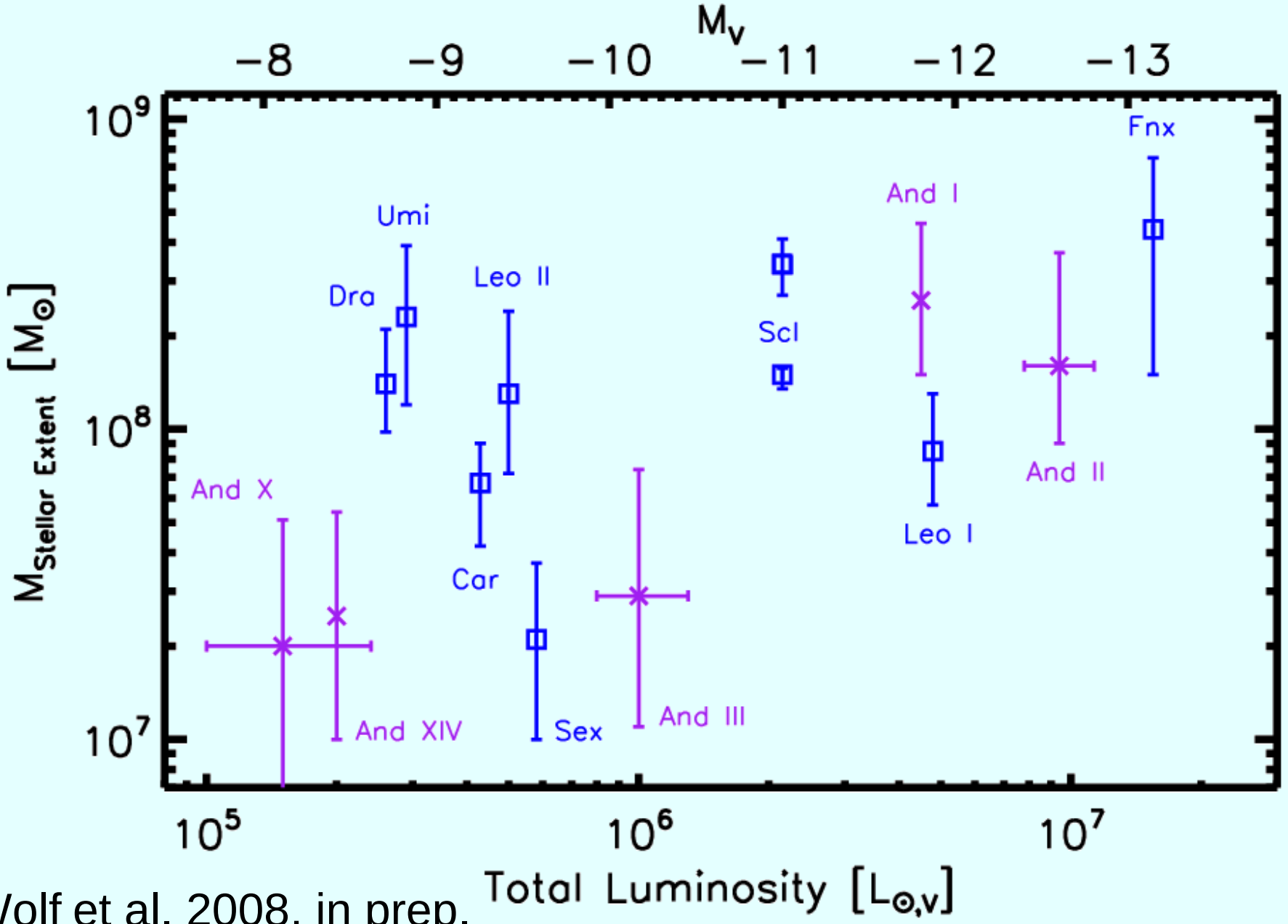


Name	V_{max}
And I	18^{+31}_{-1}
And II	15^{+15}_{-2}
And III	11^{+8}_{-4}
And X	8^{+8}_{-6}
And XIV	12^{+14}_{-4}

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}

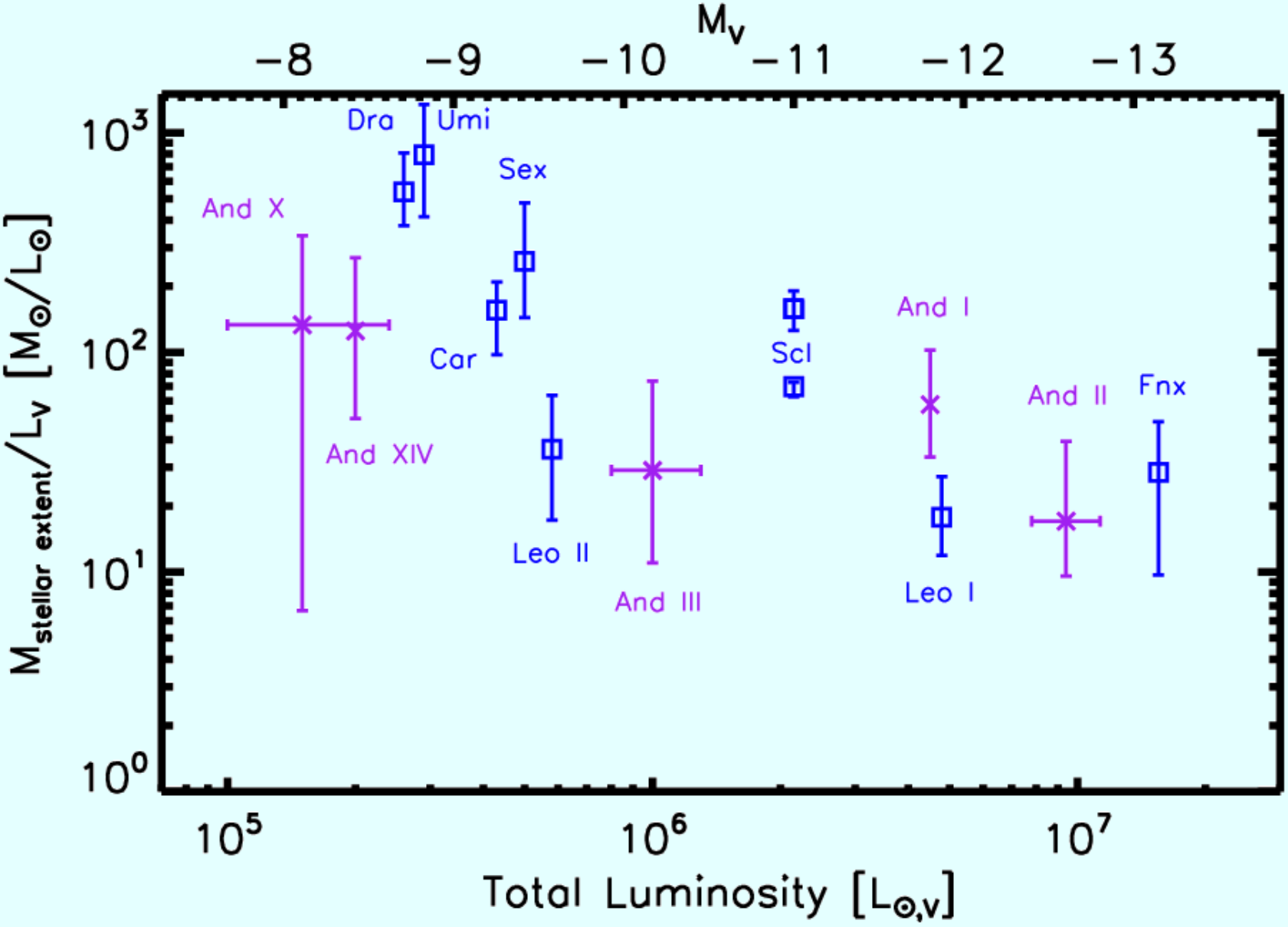
Wolf et al. 2008, in prep.

$M_{Stellar\ extent}$ vs L_V



Wolf et al. 2008, in prep.

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



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