Angular Momenta and Sizes of Galaxies and Their DM Halos

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KITP Conference

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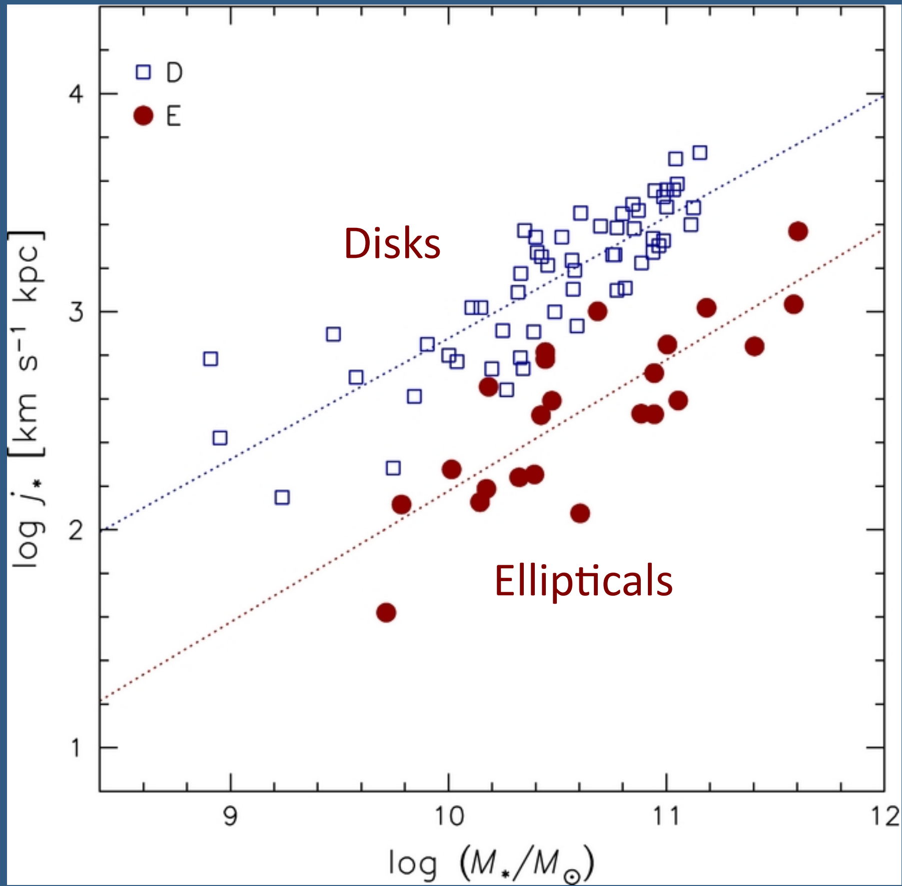
Galactic *j* vs *M* Relation at $z = 0$



$j = J/M \propto M^{\alpha}$ with $\alpha \approx 2/3$

Fall & Romanowsky 2013

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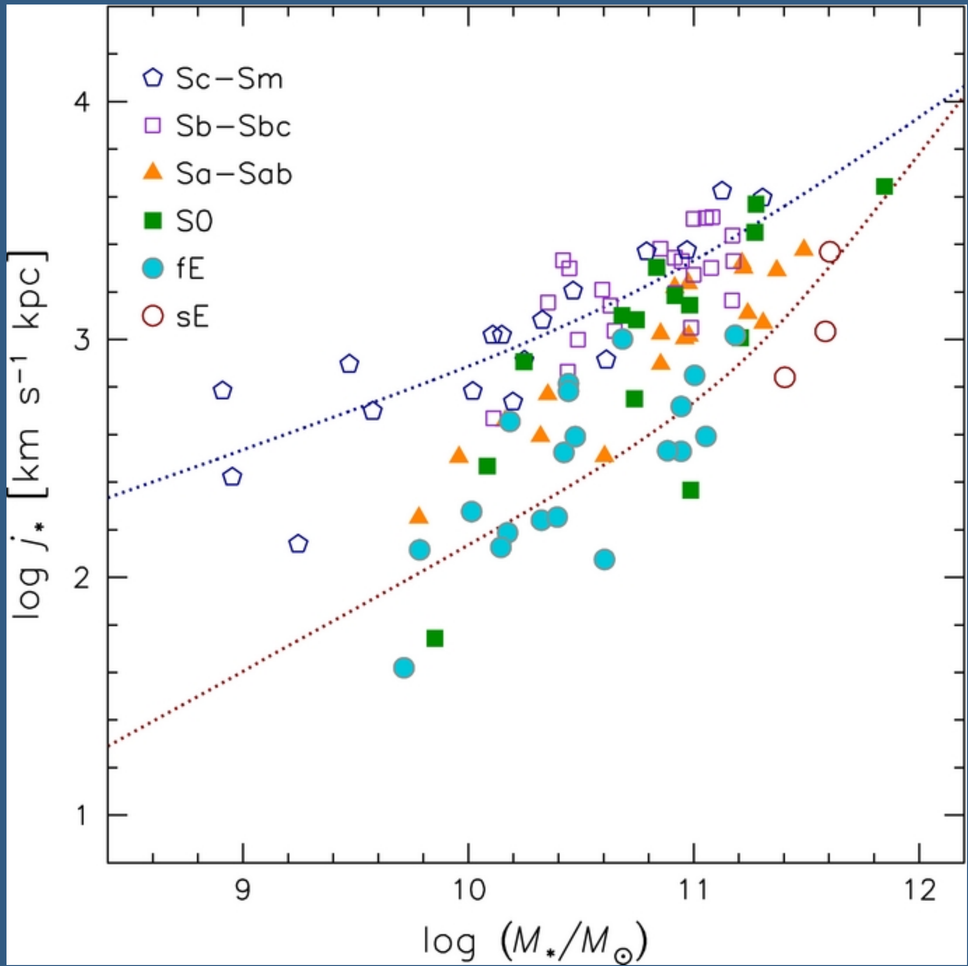
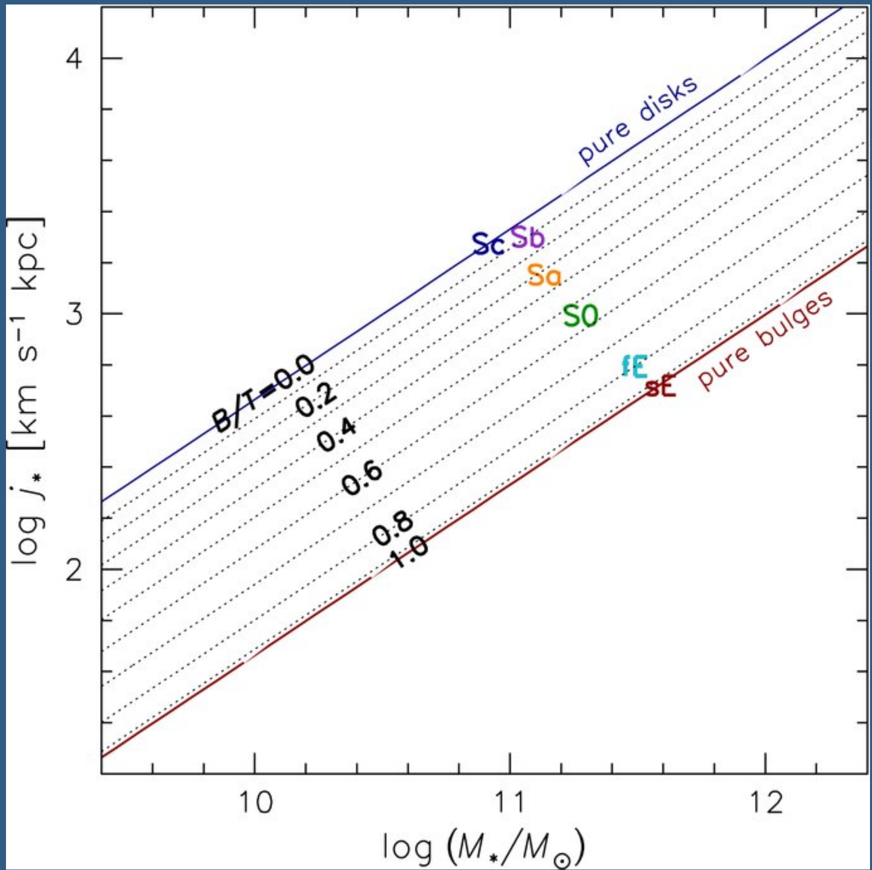
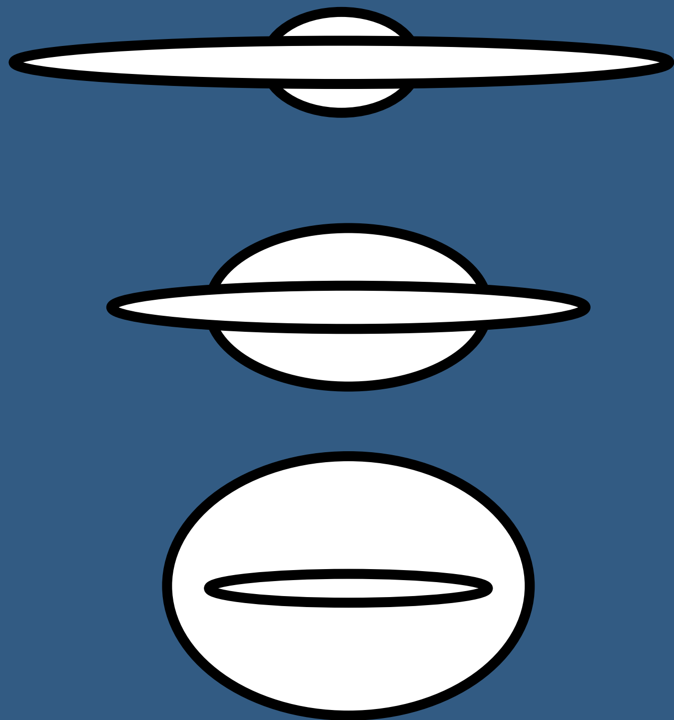


Intermediate-type galaxies lie between D and E sequences

Schematic Connections Between
j vs *M* Relation, *B*/*T* Ratio, and Hubble Type





Scaling Relation *j* vs *M* for Dark Halos

$$j \;=\; J/M \quad \alpha \quad M^{2/3}$$

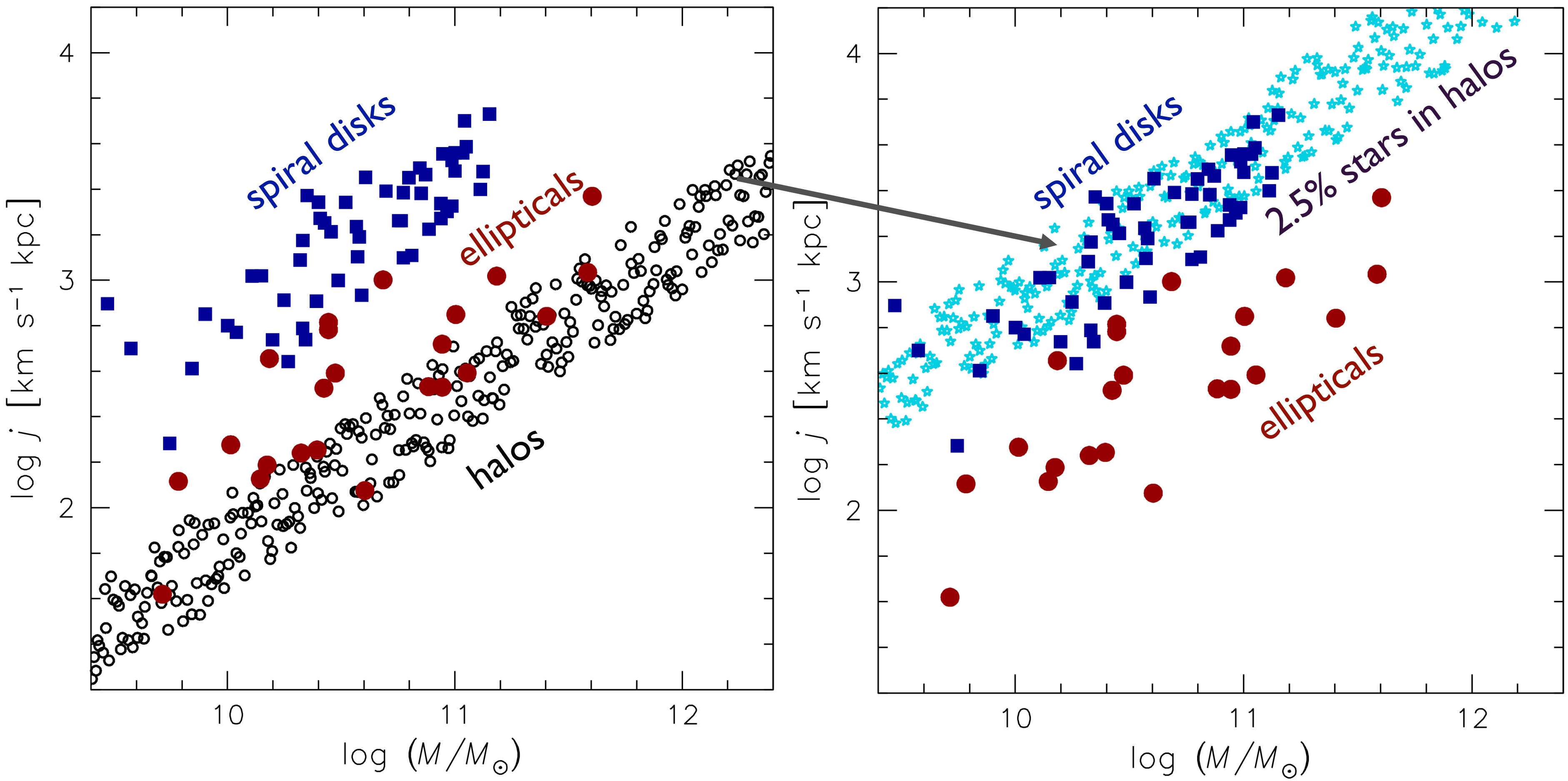
This follows from:

(1) the definition of the spin parameter,
$\lambda = J\,|E|^{1/2} / (G\,M^{5/2})$,

(2) the fact that, in a self-similar hierarchy, dimensionless quantities such as λ must be independent of dimensional quantities such as *J*, *M*, and *E*.

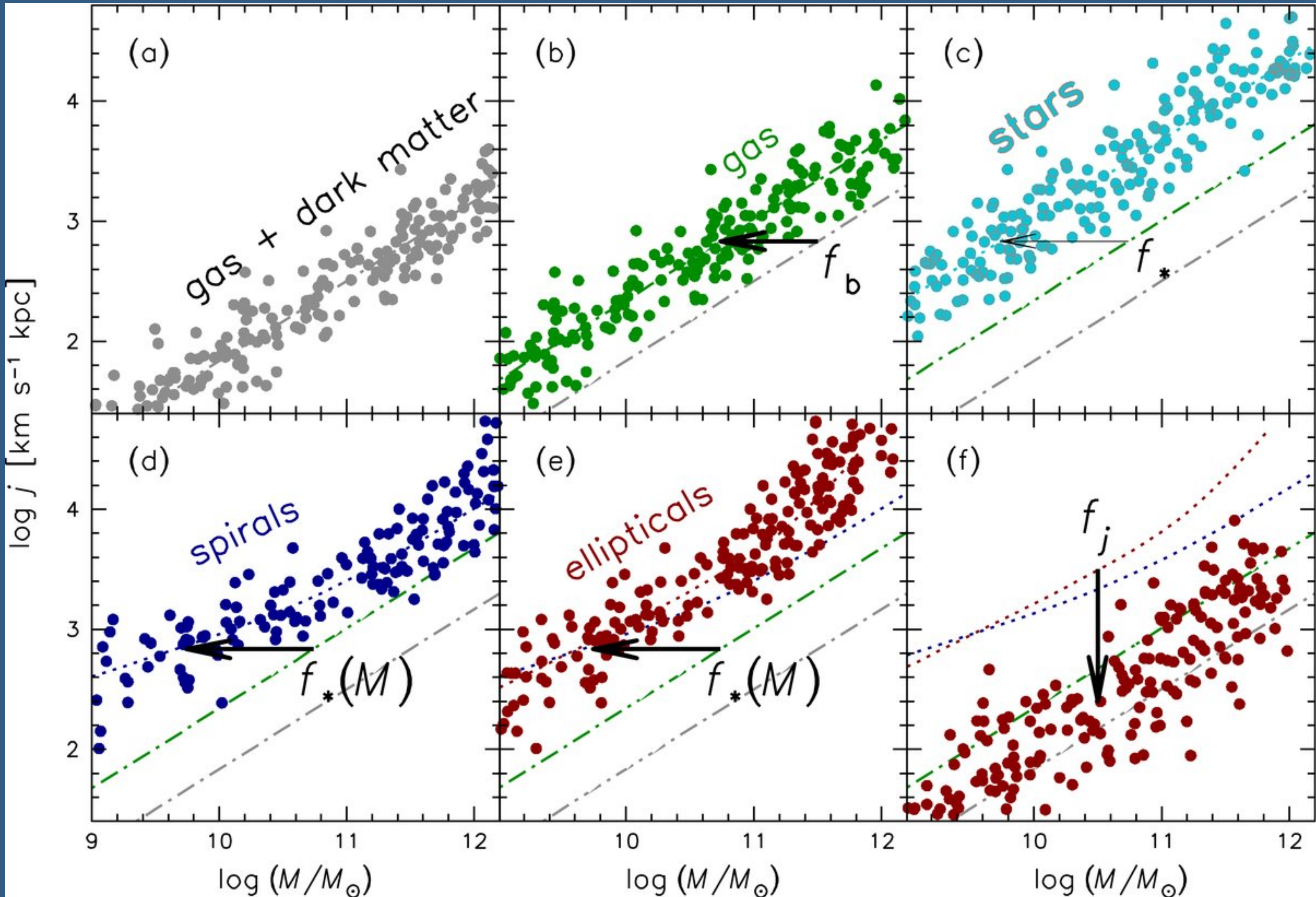
(3) the fact that halos form at a fixed mean density ≈ 200 x the cosmic critical density.

Mapping Dark Halos to Visible Galaxies



- Theory and observations here are robust
- Spiral disks preserve angular momentum, ellipticals lose it

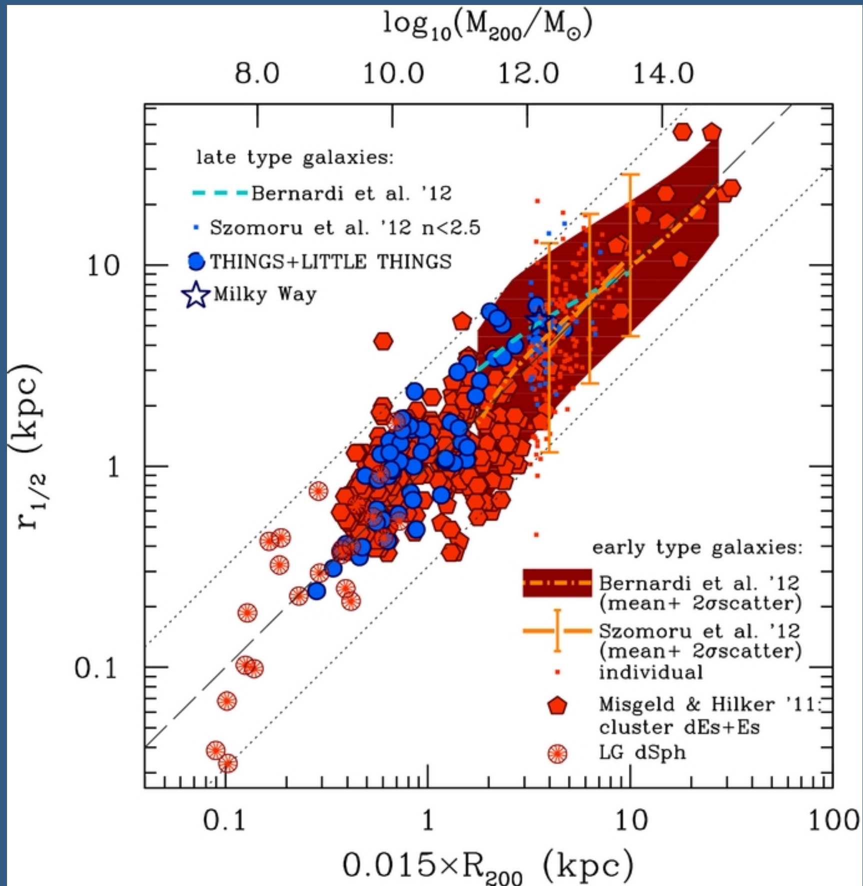
➢ Basic target for galaxy formation simulations



This comparison gives f_j ~ 80% for disk-dominated galaxies and f_j ~ 10-20% for spheroid-dominated galaxies

Galaxy Size-Halo Size Relation: $z = 0$

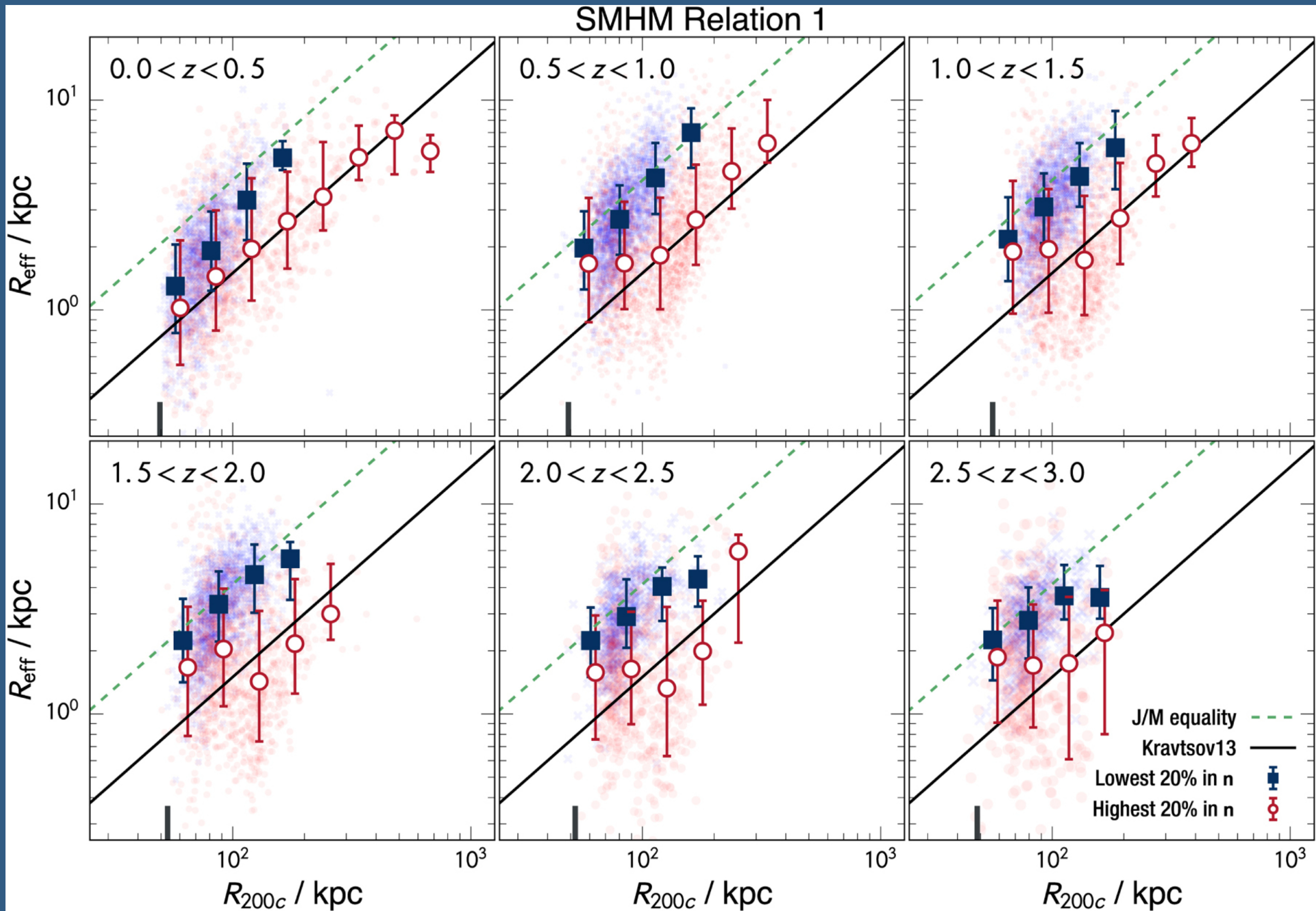
Derived by abundance matching



Kravtsov 2013

Galaxy Size-Halo Size Relation: 0 < *z* < 3

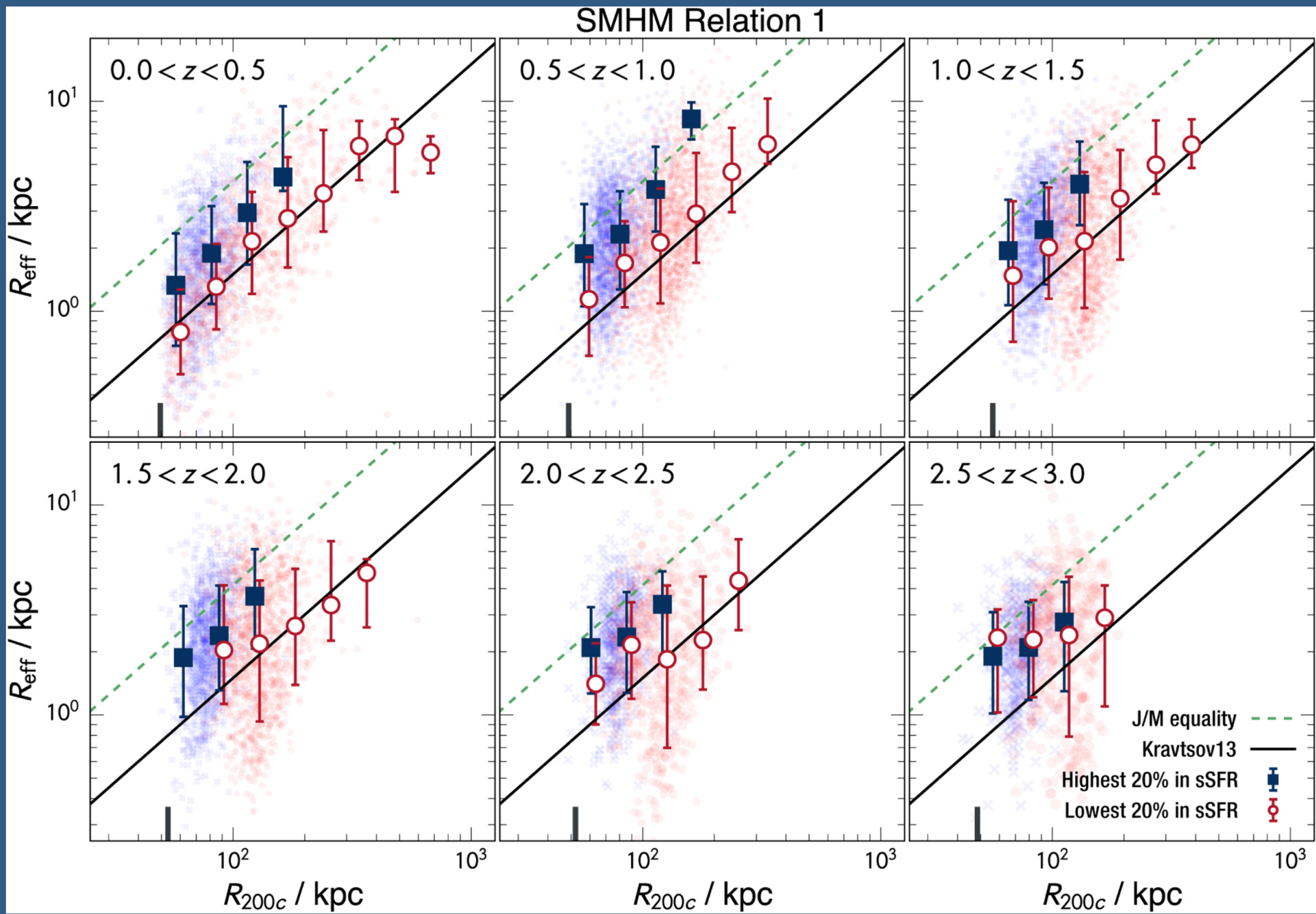
Derived by abundance matching



Huang, Fall, Ferguson, et al 2017

Galaxy Size-Halo Size Relation: $0 < z < 3$

Derived by abundance matching



Huang, Fall, Ferguson, et al 2017

Simple Model of Galactic Disks in DM Halos

Assume equality of specific angular momentum in exponential disks in isothermal halos

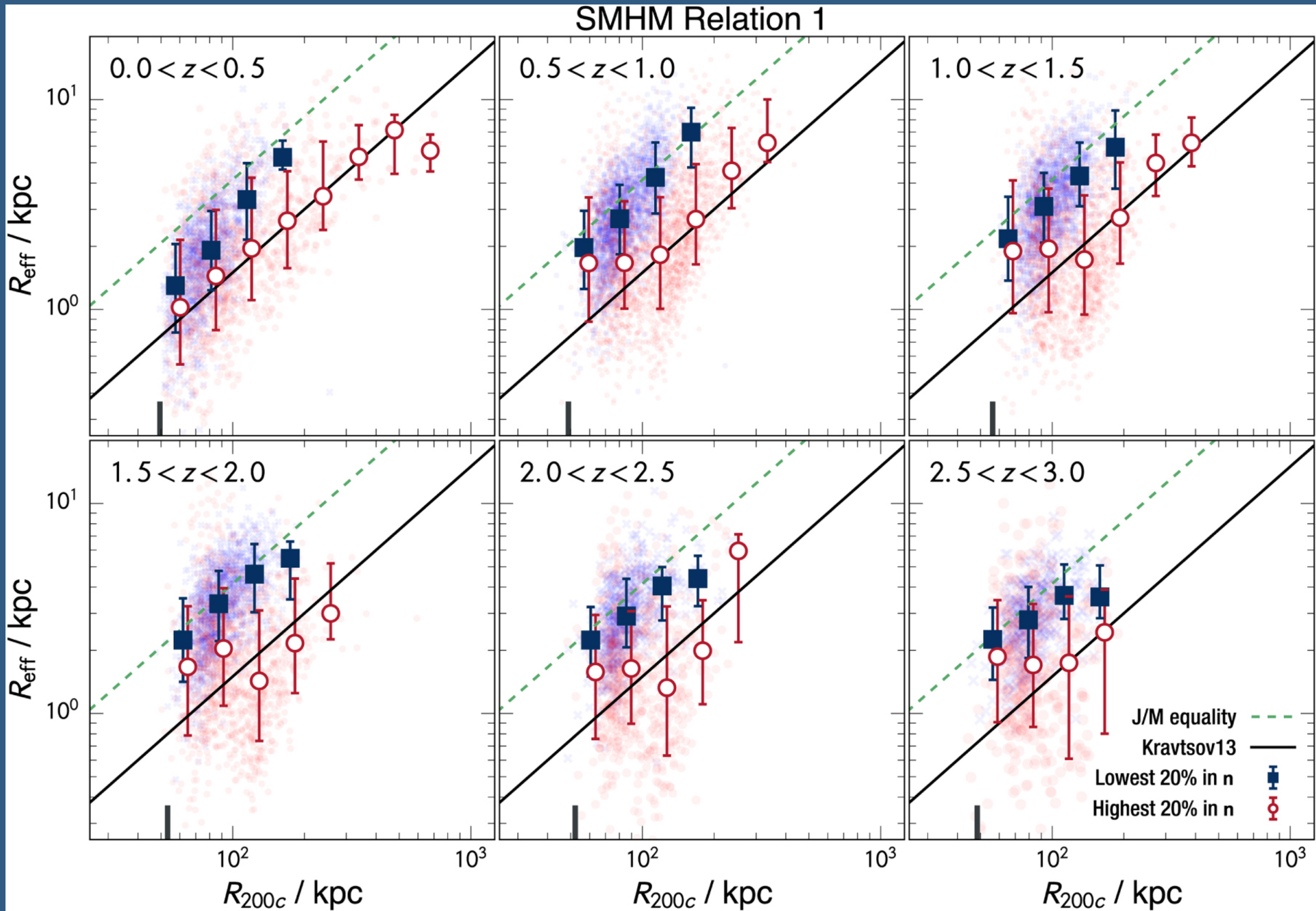
Halo: $J_h/M_h = \sqrt{2}\,\lambda\, V_c\, R_h$

Disk: $J_d/M_d = 2\, V_c\, R_d$

$J_d/M_d = J_h/M_h \Rightarrow R_d/R_h = \lambda/\sqrt{2}$

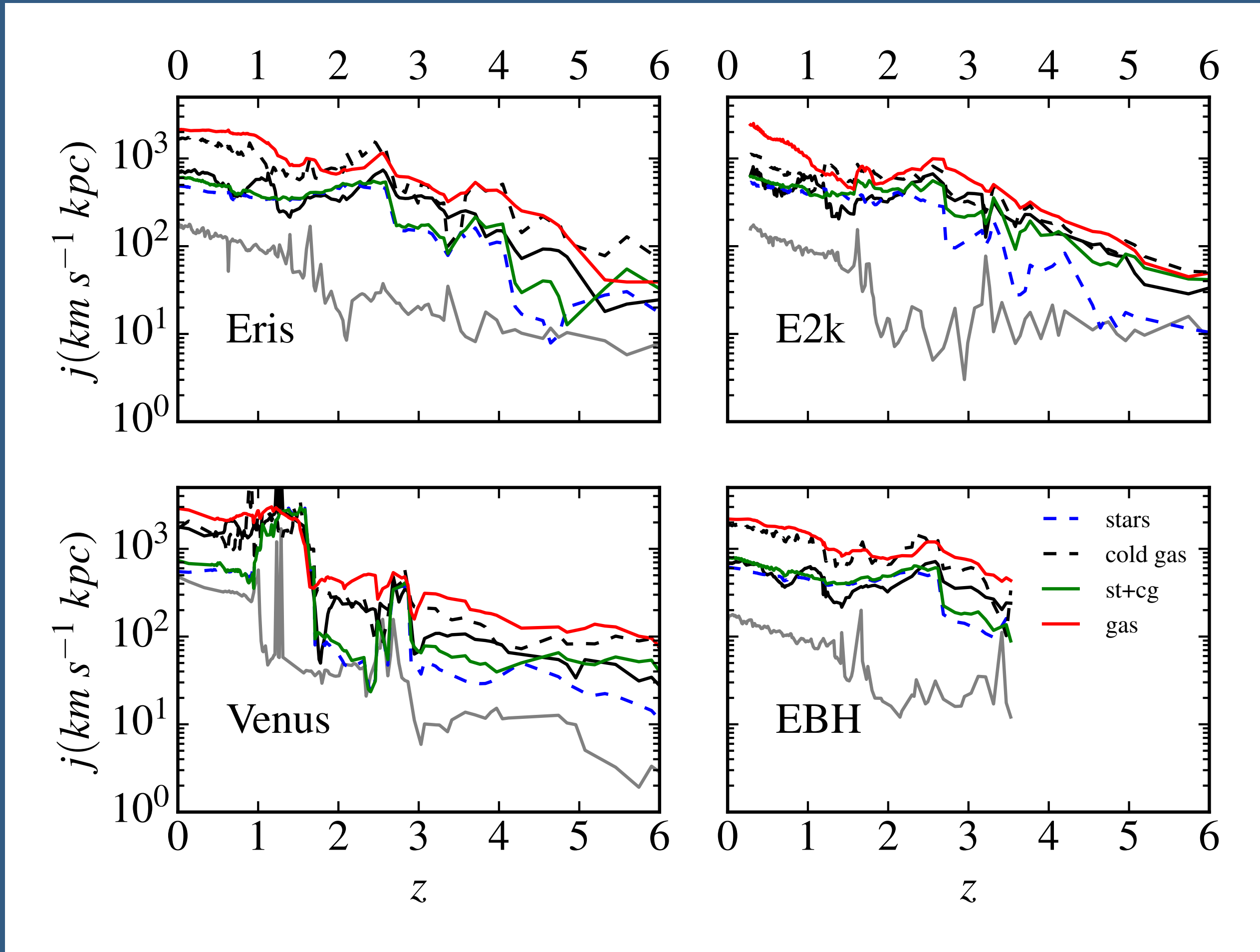
Fall & Efstathiou 1980, see also Fall 1983

Real Galaxies Agree with the Simple Model



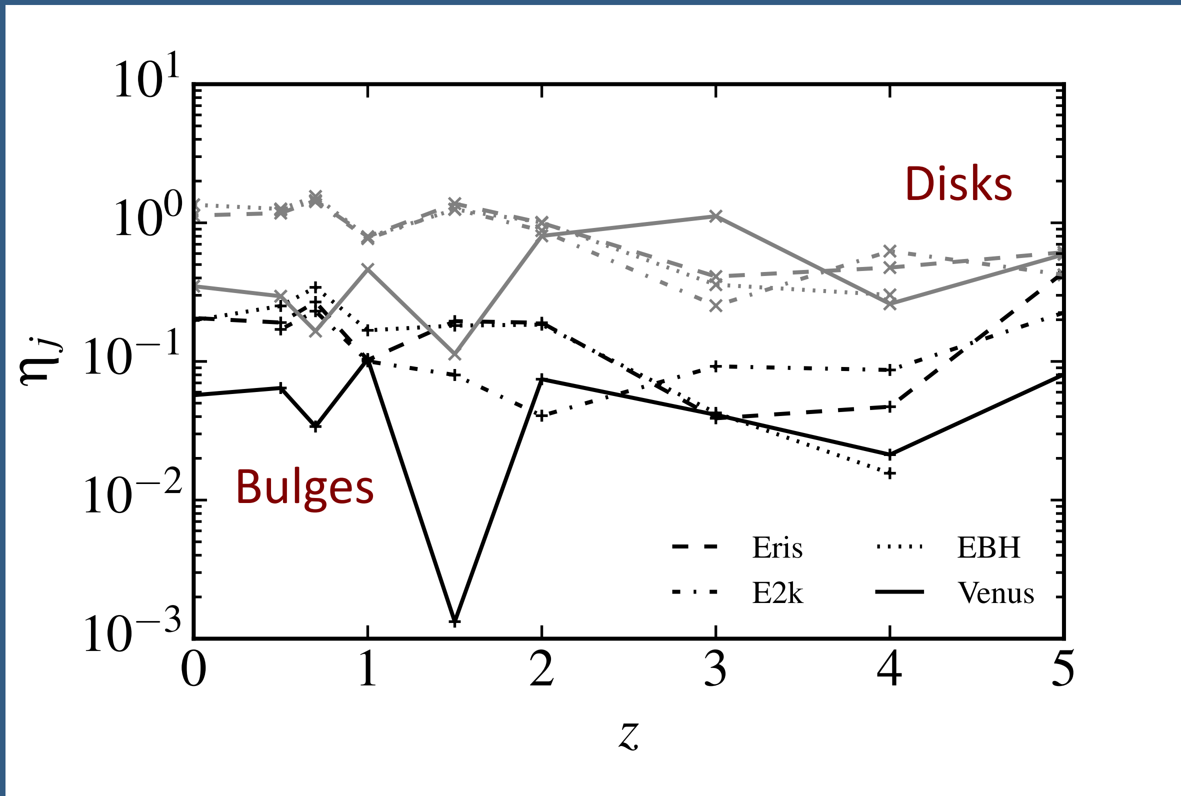
Huang, Fall, Ferguson, et al 2017

Evolution of *j* = *J*/*M* in High-Resolution Zoom-In Simulations



Sokolowska et al 2017

Evolution of η = (*J*/*M*) / (*J*/*M*)$_{halo}$ in High-Resolution Zoom-In Simulations



Sokolowska et al 2017

Potential Effects of Feedback

1. Smoothing of clumps, hence reducing dynamical friction against the dark-matter halo

2. Removing low-*j* gas in a galactic wind, leaving high-*j* gas in the disk

3. Mixing of low-*j* gas in a galactic fountain with incoming high-*j* halo gas (=> "AM sharing")

Quantifying these effects is a topic of current Research. Stay tuned.

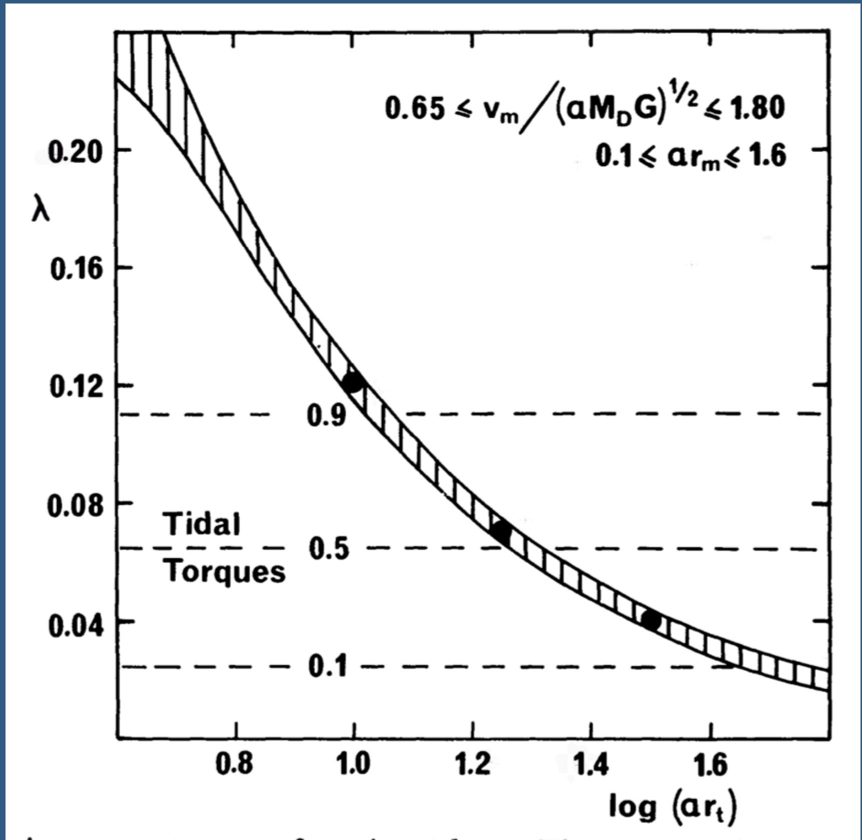
Summary

1. Galaxies grow quasi-homologously with their dark-matter halos (on average).
2. The sizes and specific angular momenta of galaxies and halos are linearly related: $R_{\mathrm{galaxy}}\ \alpha\ R_{\mathrm{halo}}$ and $(J/M)_{\mathrm{galaxy}}\ \alpha\ (J/M)_{\mathrm{halo}}$
3. These relations appear to be stable, at least since $z \sim 3$.
4. Galactic disks have nearly the same specific angular momenta as their halos (on average). Feedback is the key ingredient.
5. There is still some mystery in how this works.

Thanks

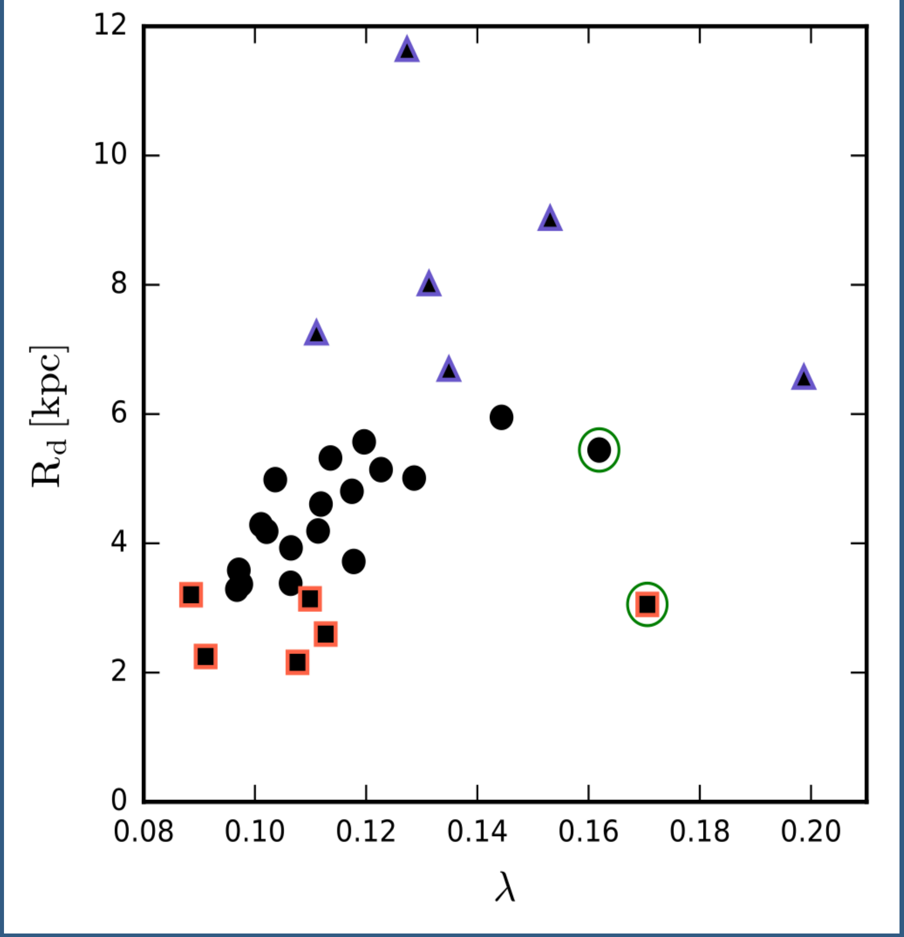
Relation Between the Sizes of Disks and Halos with the Same *J*/*M*

Hatched curve:
$R_d/R_h = \lambda/\sqrt{2}$



Fall & Efstathiou 1980

Disk Size-Halo Spin Relation in Auriga



Grand et al 2016