Galaxy Spin Transition: A New Probe of Cosmology

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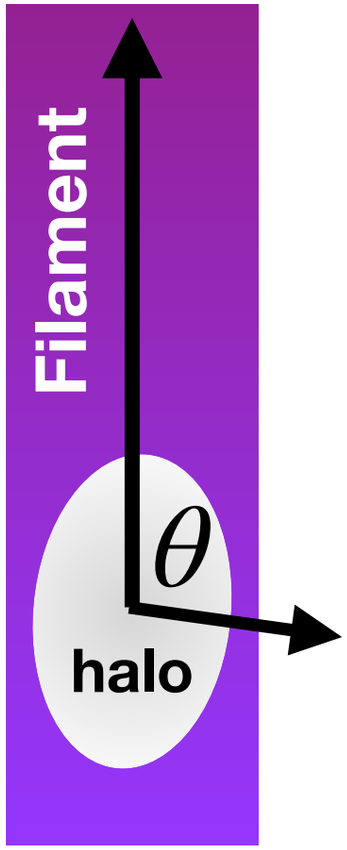
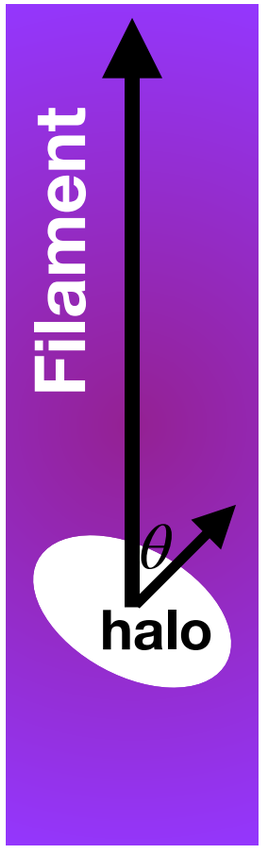
Image credit: A. KHALATYAN/J. FOHLMEISTER/AIP

Conventional Picture of Galaxy Spin Transition



If $M > M_{th}$, then

$\langle \cos\theta \rangle < 0.5$



If $M \leq M_{th}$, then

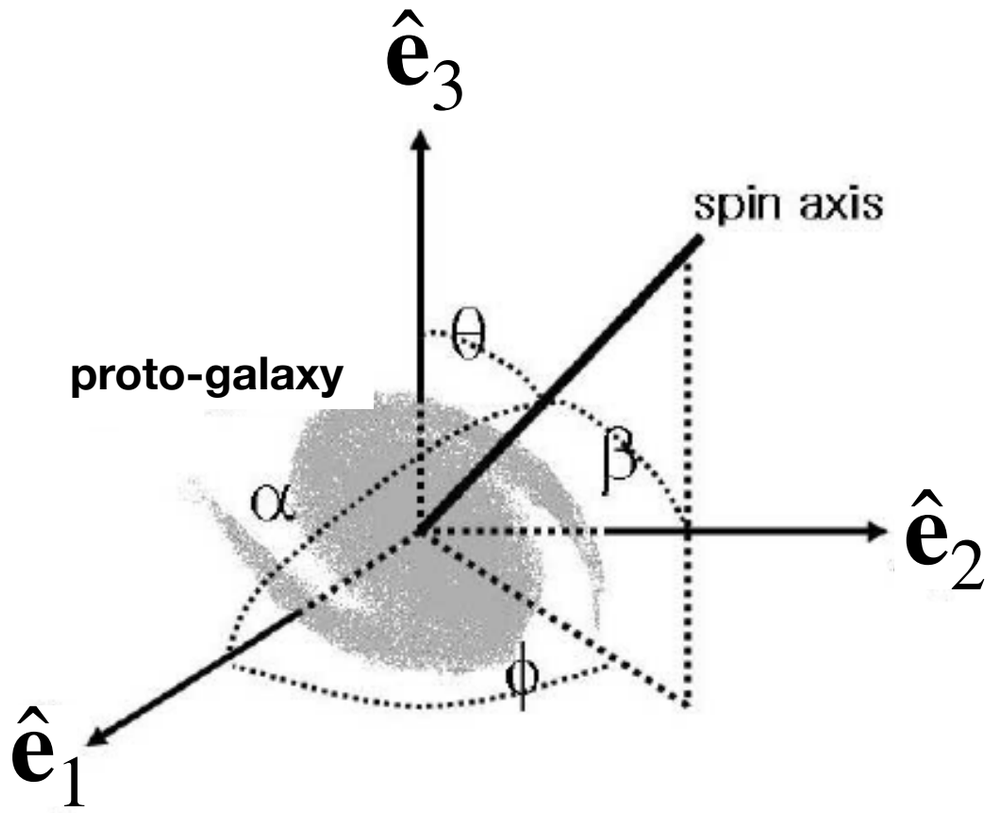
$\langle \cos\theta \rangle \geq 0.5$

Does the Tidal Torque Theory Fail?

- Spin alignments with the Tweb intermediate principal axes, *regardless of mass.*

- *Mergers not taken into account?*

- As a first order theory, doomed to fail?



in the principal axis of the local tidal shear

$$J_1 \propto (\lambda_2 - \lambda_3) I_{23},$$

$$J_2 \propto (\lambda_3 - \lambda_1) I_{31},$$

$$J_3 \propto (\lambda_1 - \lambda_2) I_{12}\,.$$

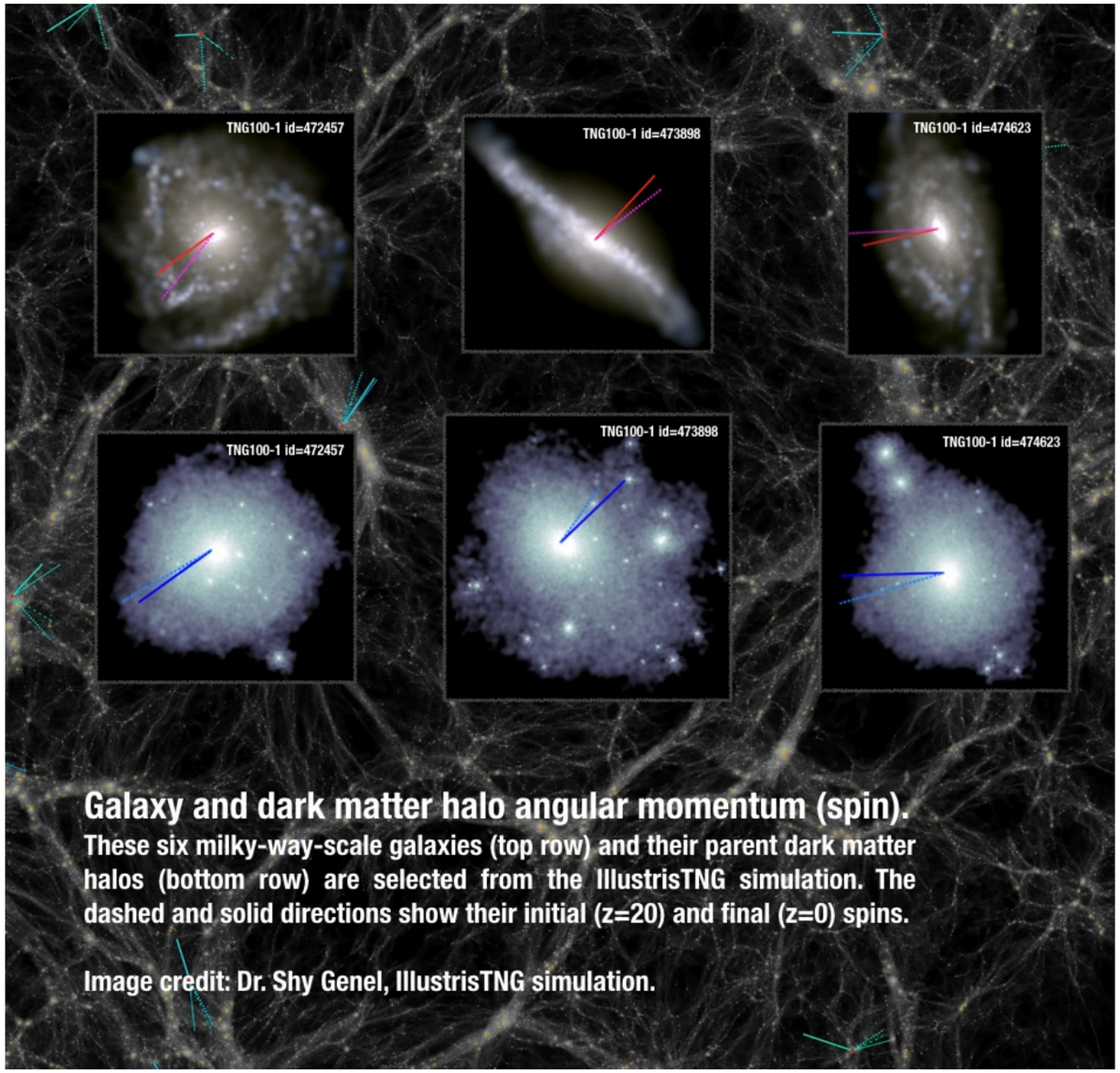
Lee & Pen 2000, ApJL, 532, L5
Lee & Erdogdu 2007, ApJ, 671, 1248

Merger Driven Transition?

- The difference in the alignment tendency between the high and low mass was caused by the mergers.

- A dependence on the latest merger epochs?

- Orbital angular momentum transfer?



Stellar Spins Similar?

- The stellar and DM spins are fairly well aligned with each other…

- Similar stellar mass-dependent spin transition existent?

- Any strong baryonic effect?

- Different radial distances matter?

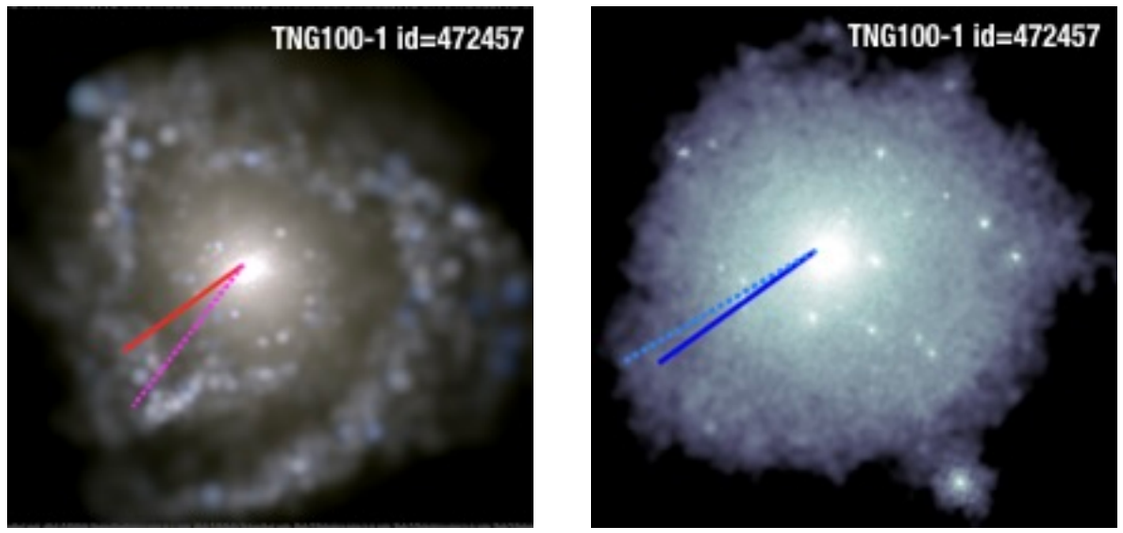
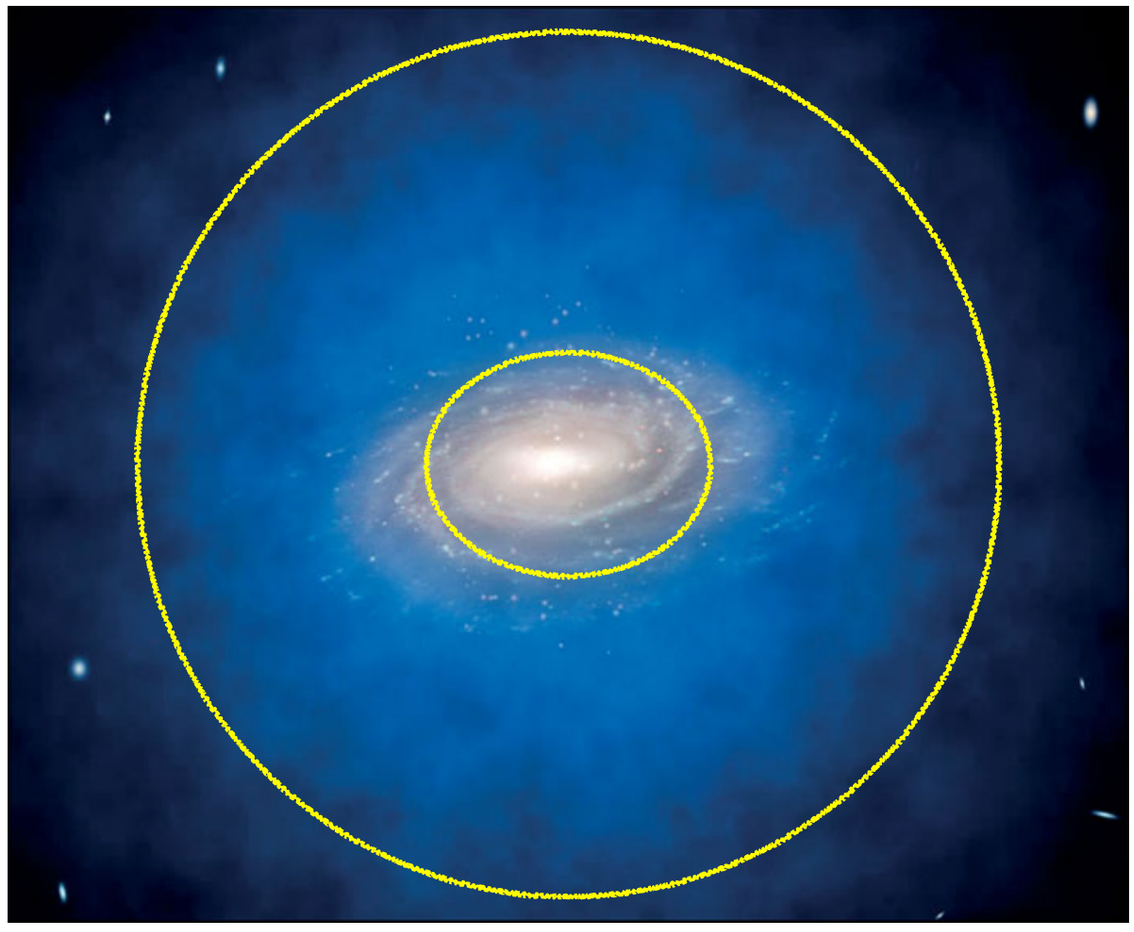


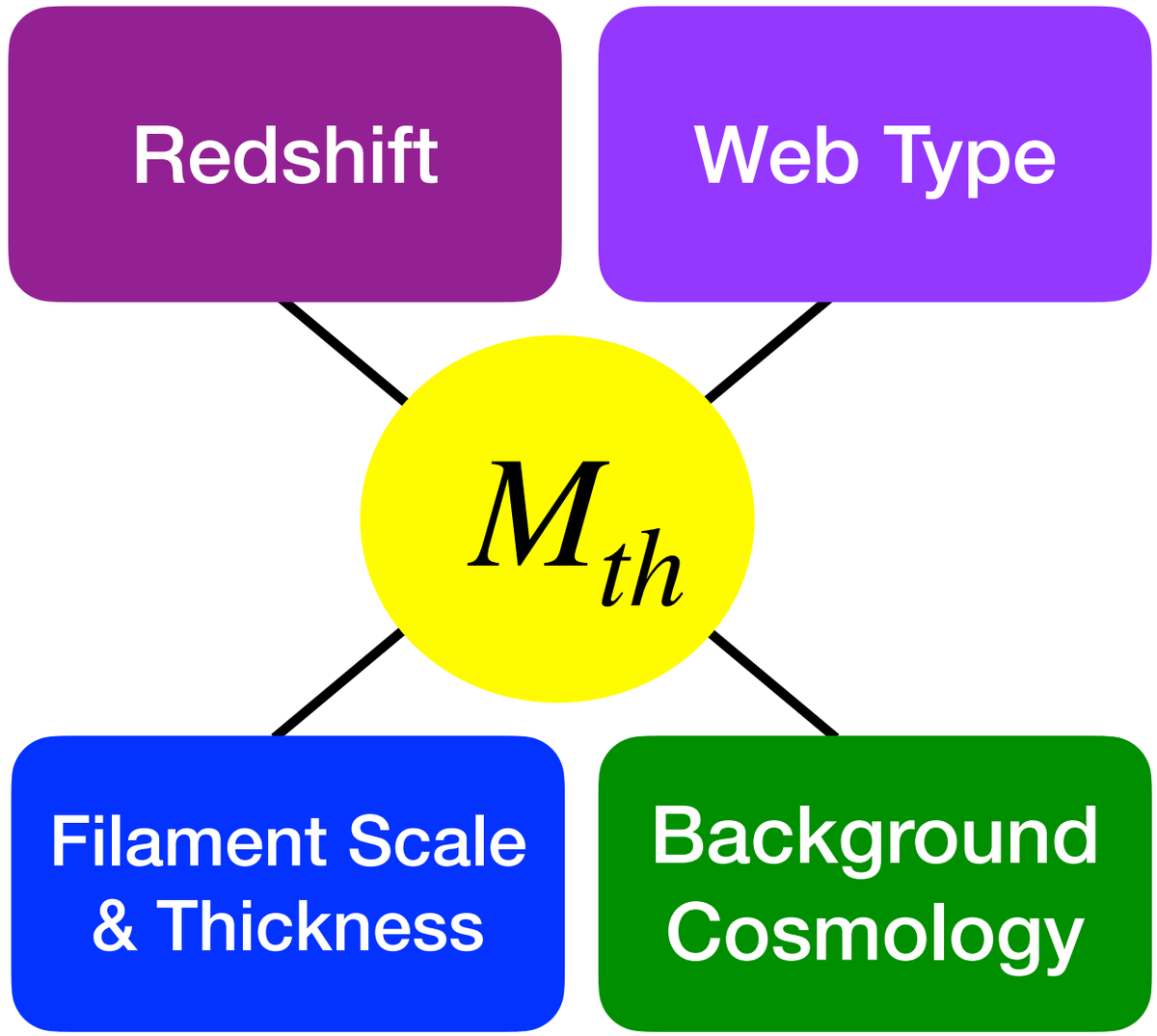
Image Credit: Dr. Shy Genel, IllustrisTNG Simulation



A Coherent Description ever Possible?

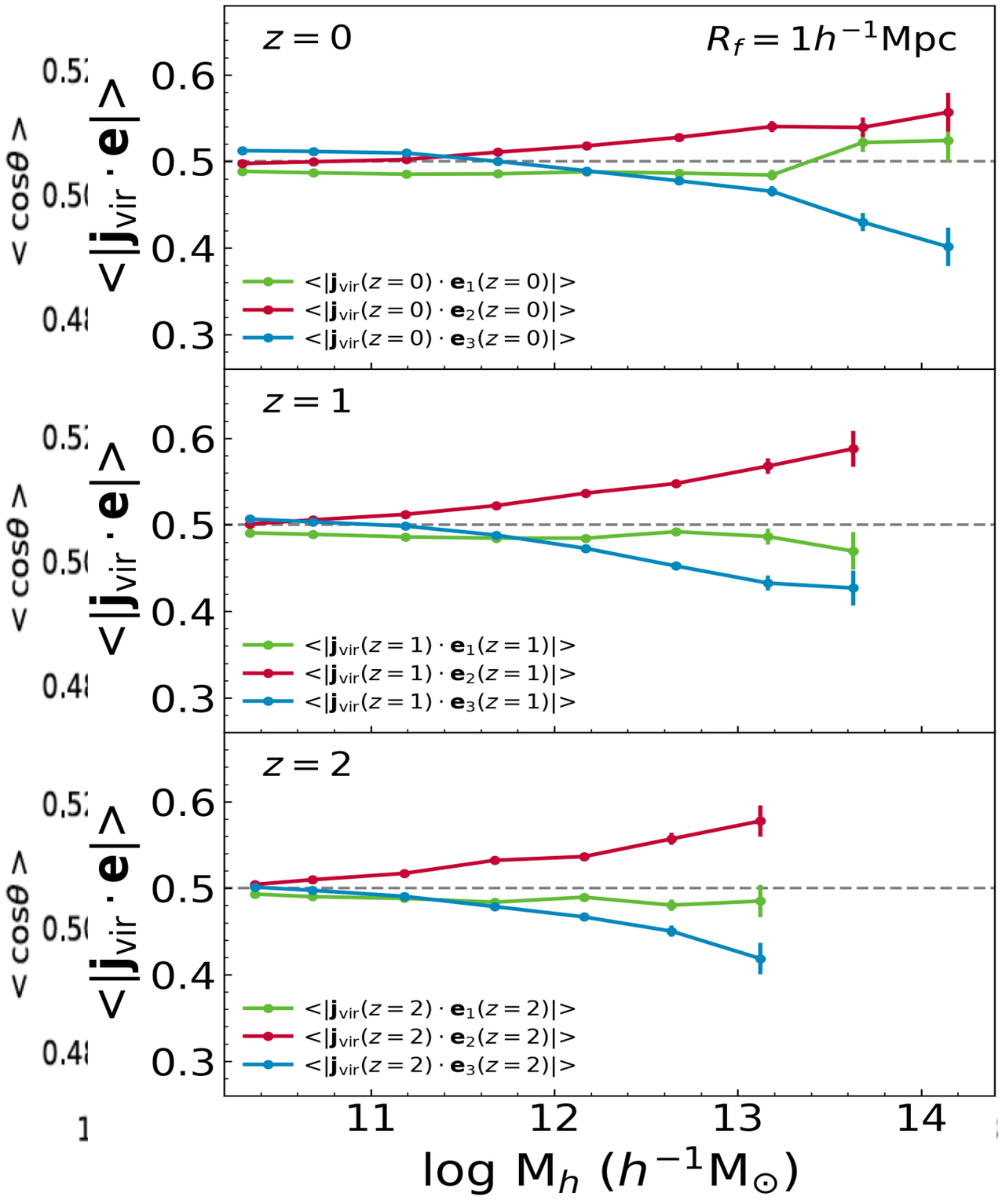
- An empirical formula of M_{th}(z) can describe its evolution.

- But, it depends on many other factors in a complicated way.



Does the TTT Fail? - Not Really

- The spins of massive halos with $M \geq M_{\rm th}$ are well aligned with the Tweb intermediate principal axes.
  - consistent with the TTT predictions.
  - M_{th} becomes lower at higher redshifts and on the larger smoothing scale.
  - M_{th} also depends on the background cosmology.



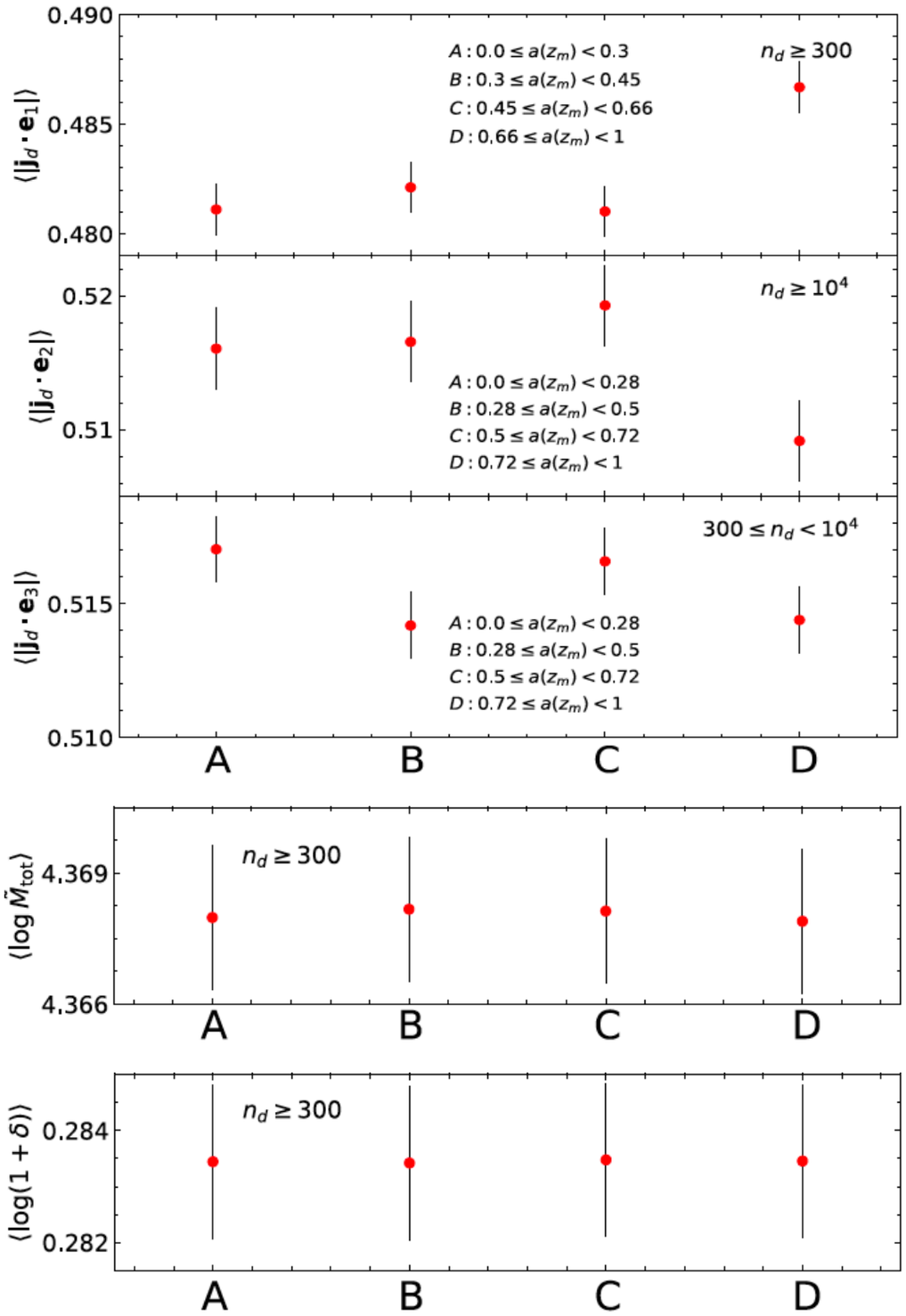
Moon & Lee 2022, ApJ in press, arXiv:2210.15905

Is It Caused by Merging? - Probably Not

- The strength of the alignments between the halo spins and the Tweb principal axes are almost independent of the latest merging epochs.

  - despite that the densities and masses are all controlled to be identical.

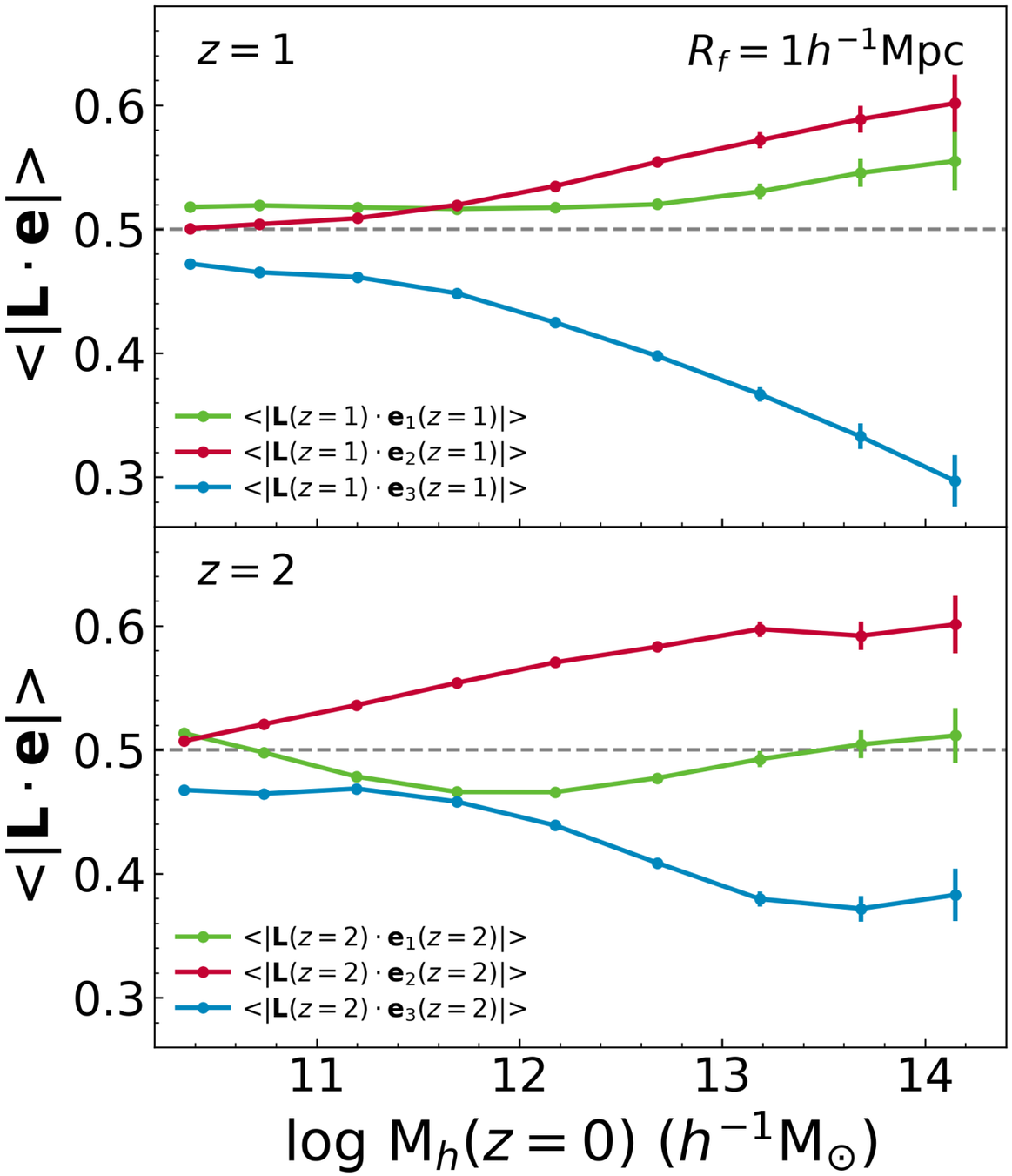
  - inconsistent with the conventional picture.



Lee, Moon & Yoon 2022, ApJ, 927, 29

Is It Caused by Merging? - Probably Not

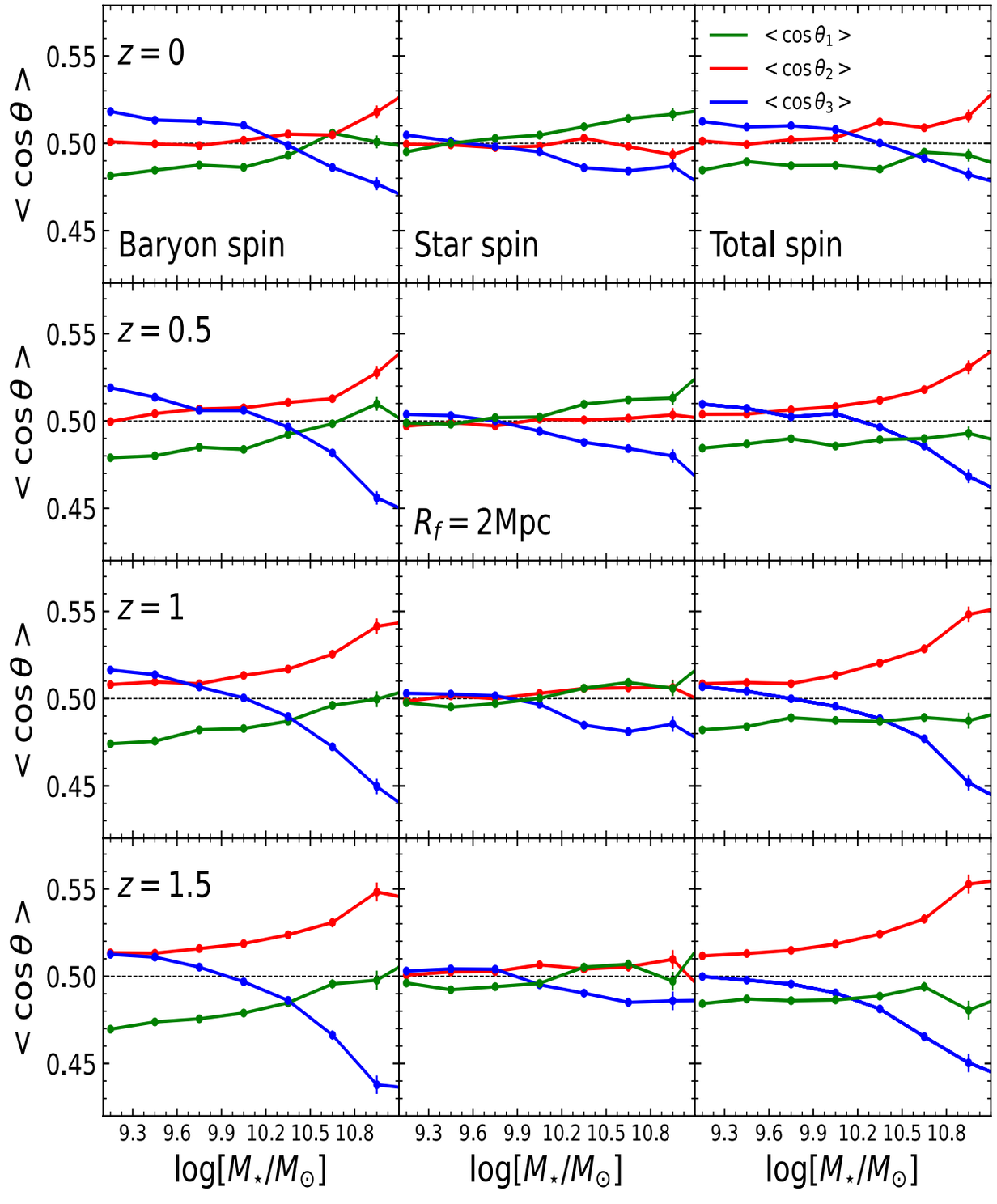
- The spin directions swing via mergers.
- BUT, the mergers do NOT destroy the spin alignments with the Tweb intermediate principal axes.
  - The orbital angular momentum of their progenitors are also aligned with the Tweb intermediate principal axes.
  - What changes after mergers is only the scales.



Moon & Lee 2023b, in preparation

Are Stellar Spins Similar? - Not Really

- A different kind of mass-dependent transition:
  - between the Tweb minor and major principal axes.
- In contrast to the DM spins that are always perpendicular to the Tweb major principal axes.



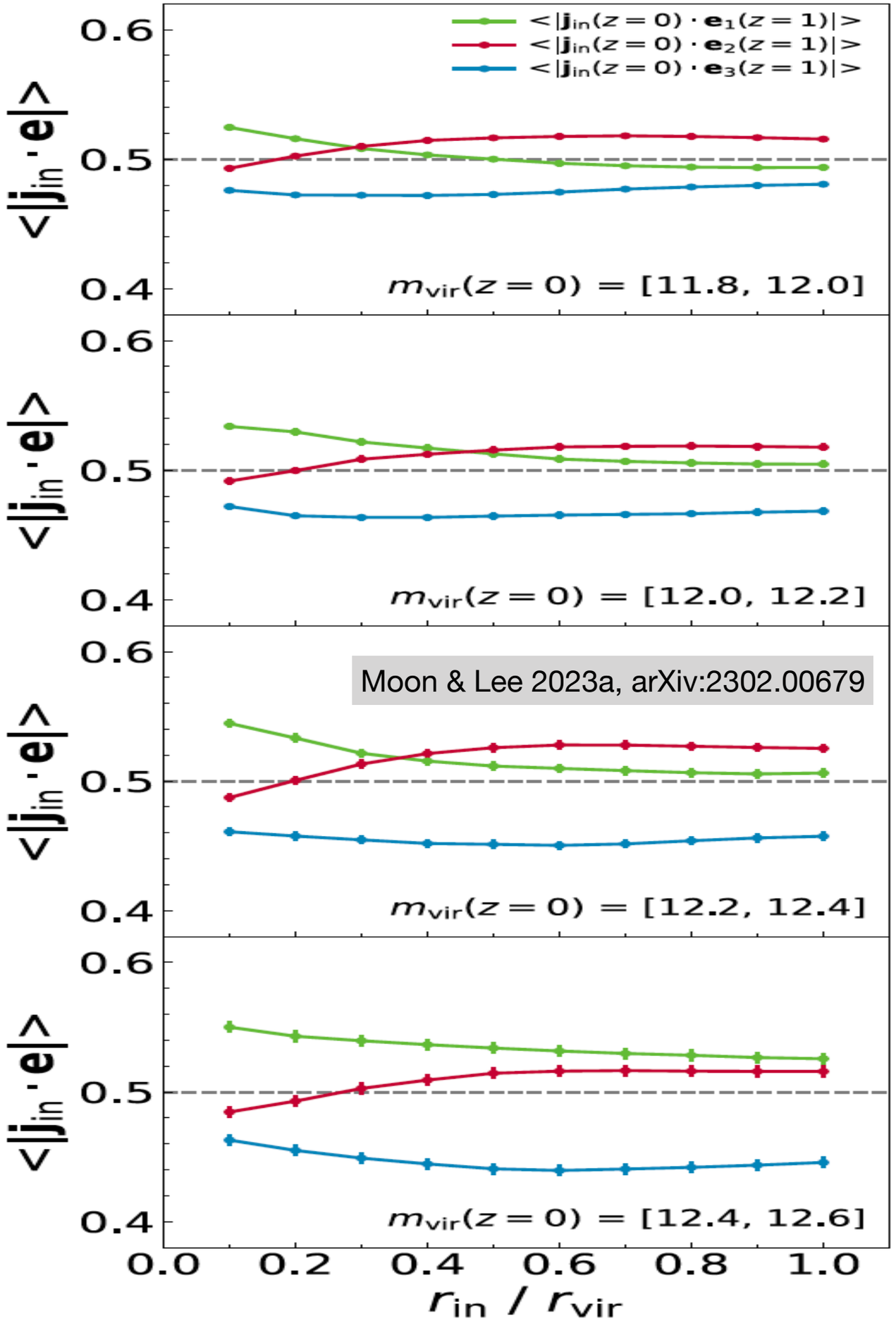
Lee et al. 2021, ApJ, 922, 6

Stellar Spins Simila

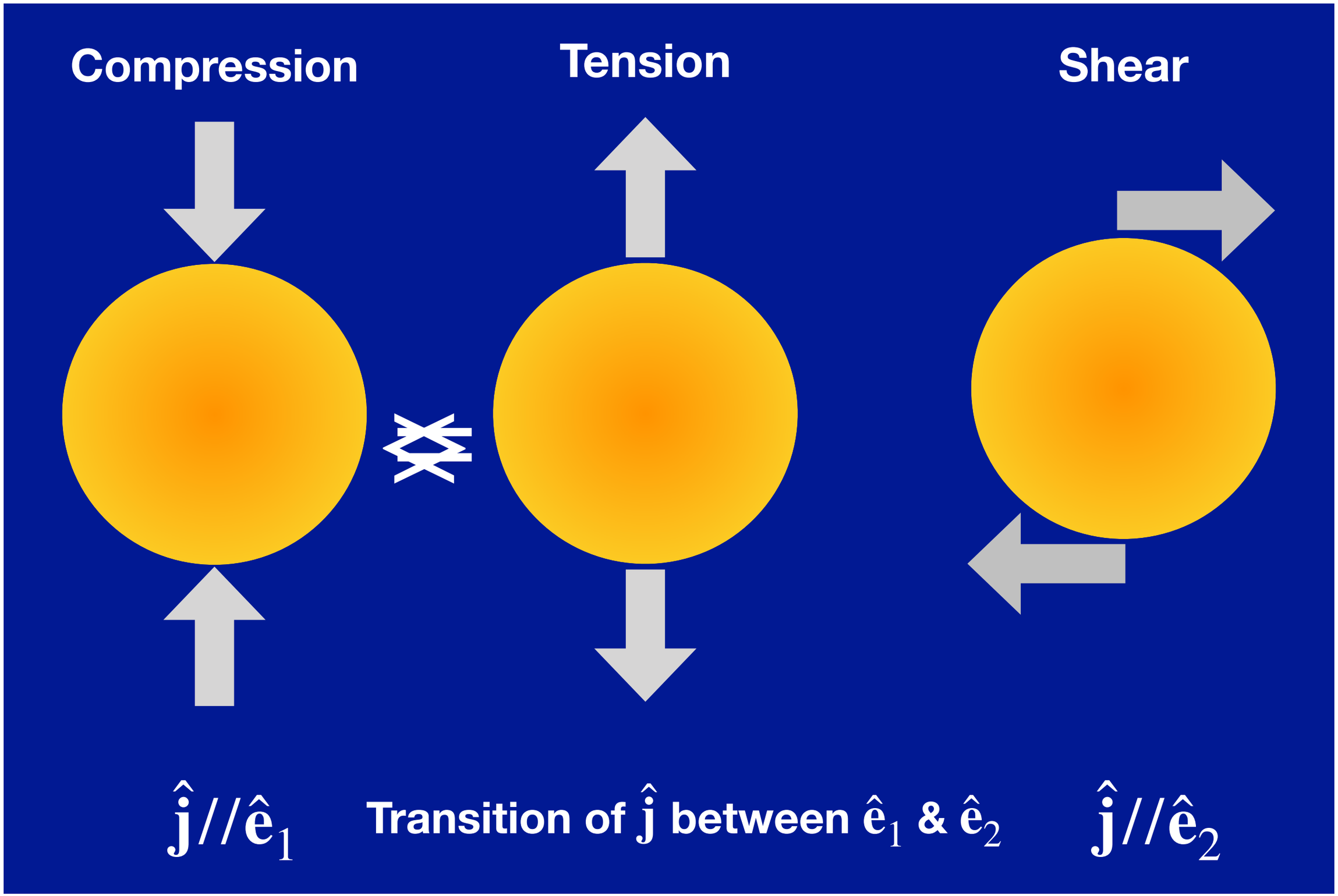
- Due to the observational limits, the stellar spins are measured at the radii much more inner than the virial boundaries.

- The DM spins, if measured at much inner radii like the stellar spins, exhibit a similar transition.

- Spin transition type is radius dependent.

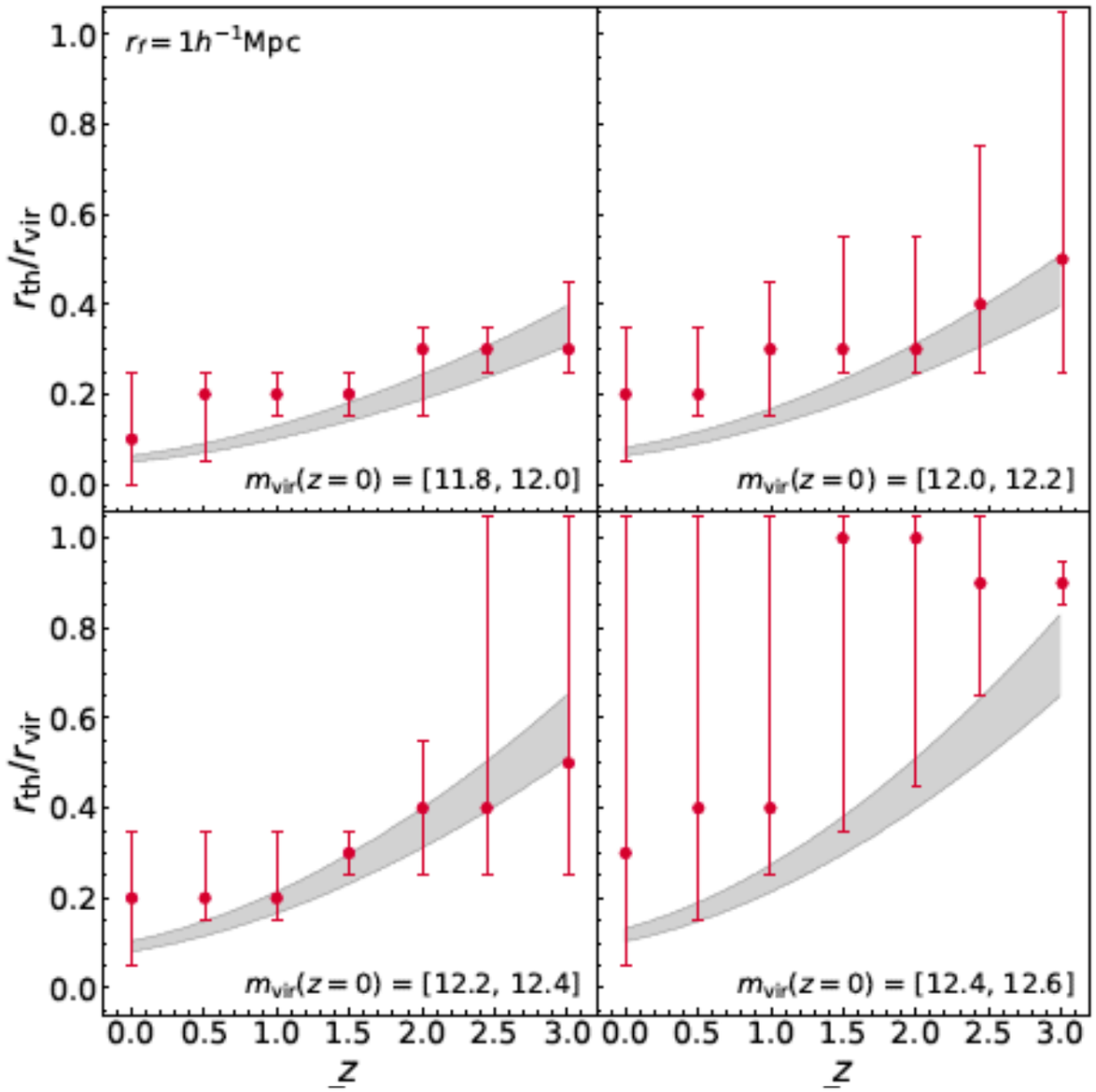


A Coherent Picture? - The Density Parity Model



A Coherent Picture? - The Density Parity Model

- It physically explains why the radius dependent spin transition occurs.
  - in good agreement with the numerical results
  - naturally predicting strong alignments between the present inner spins and the Tweb principal axes at the progenitor locations.



Moon & Lee 2023, arXiv:2302.00679

Take Home Messages

- The spin transition mass threshold depends on the background cosmology.

- The stellar spins exhibit a different type of transition.

- The DM inner spins exhibit **radius dependent spin transitions.**

- **The density parity model** can coherently describe and physically explain the radius dependent spin transition.