Galaxy Spin Transition: A New Probe of Cosmology

Jounghun Lee
in collaboration with
Jun-Sung Moon
(Seoul National University)
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?

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

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

\[
J_3 \propto (\lambda_1 - \lambda_2) I_{12}.
\]

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 $M \geq M_{th}$ 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.

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.

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.

Stellar Spins Similar to DM Inner Spins

- 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.

Moon & Lee 2023a, arXiv:2302.00679


Moon & Lee 2023a, arXiv:2302.00679
A Coherent Picture? - The Density Parity Model

Compression

\( \hat{j}/\hat{e}_1 \)

Transition of \( \hat{j} \) between \( \hat{e}_1 \) & \( \hat{e}_2 \)

Shear

\( \hat{j}/\hat{e}_2 \)
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.