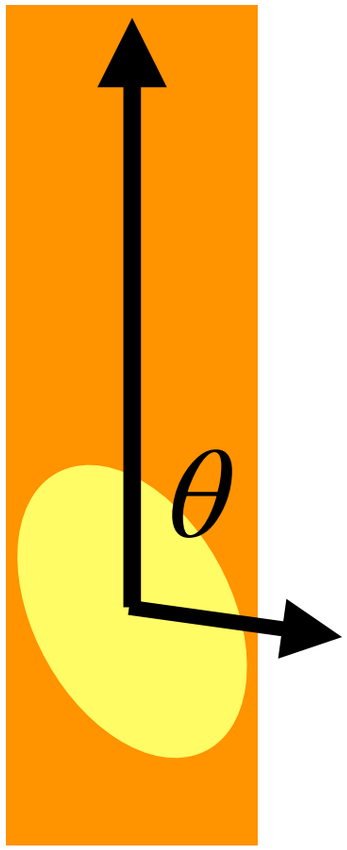
Radius Dependent Spin Transition of Dark Halos

presented by
Jounghun Lee
(Seoul Nat'l U.)

BASED ON

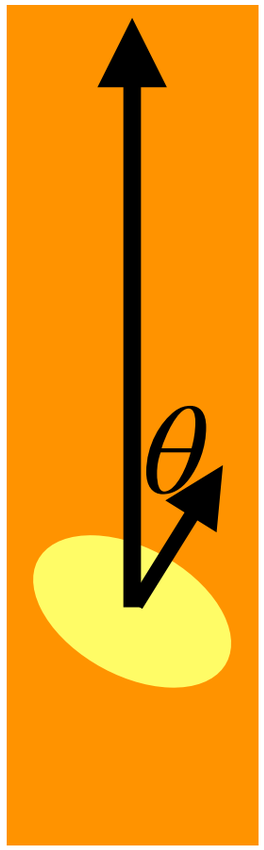
- Lee, Moon & Yoon (2022, ApJ,927,29)
- Lee & Moon (2022, ApJ,936,119)
- Moon & Lee (arXiv:2210.15905)

MASS DEPENDENT SPIN TRANSITION OF HALOS



If $M > M_t$, then

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



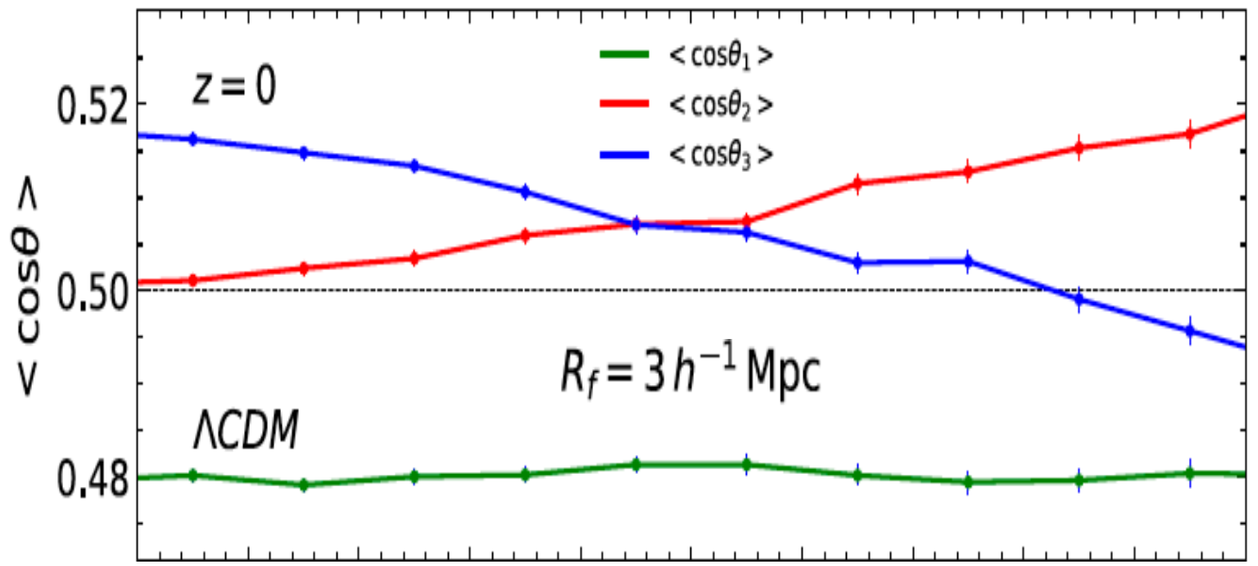
If $M \leq M_t$, then

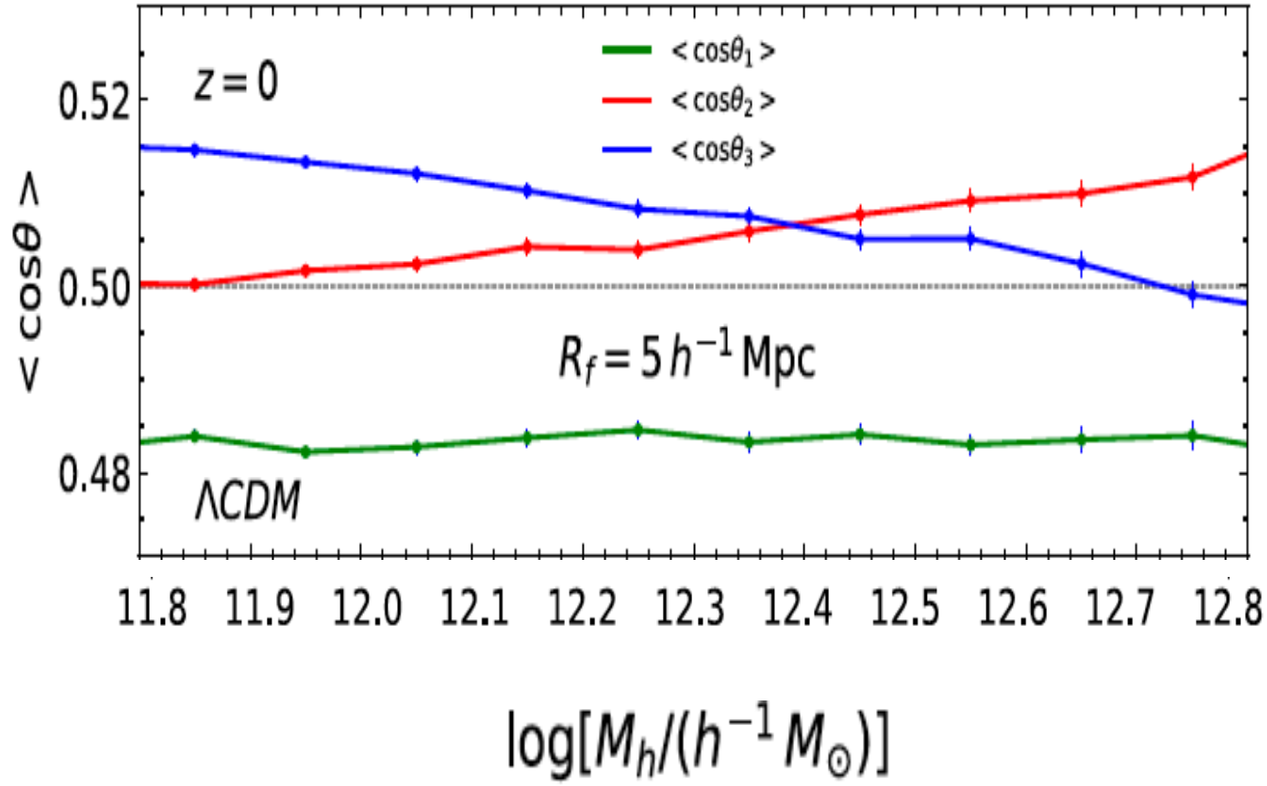
$\langle \cos\theta \rangle \geq 0.5$

SPIN TRANSITION IN THE TWEB PRINCIPAL FRAME

- The transition of the preferred directions of halo spins between the Tweb intermediate and minor principal axes.
  - always perpendicular to the Tweb major principal axes.

- The spin transition zone depends on the redshift, smoothing scale, and background cosmology.

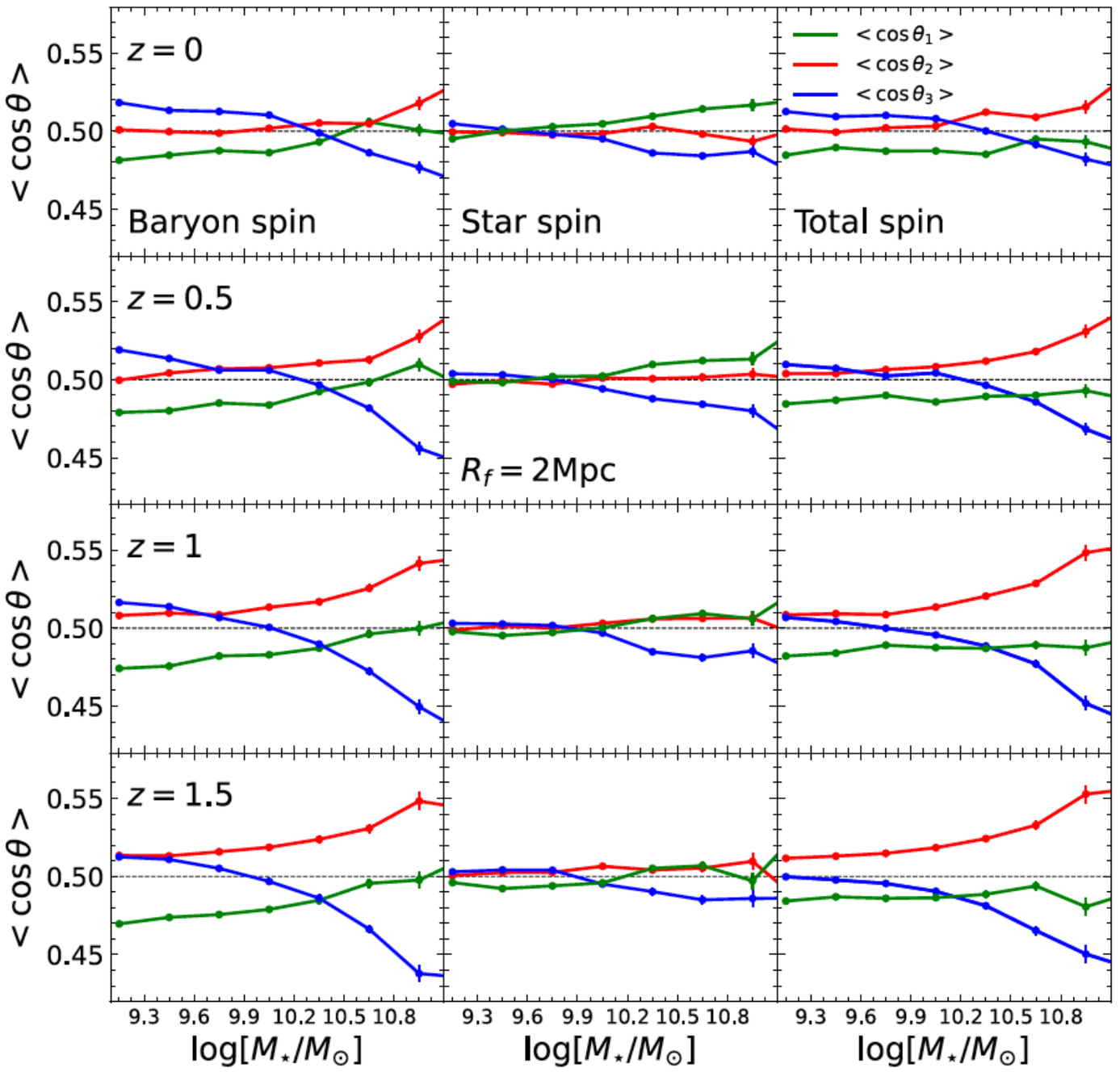




Lee & Libeskind (2020, ApJ,902,22)

PECULIAR TIDAL CONNECTION OF STELLAR SPINS

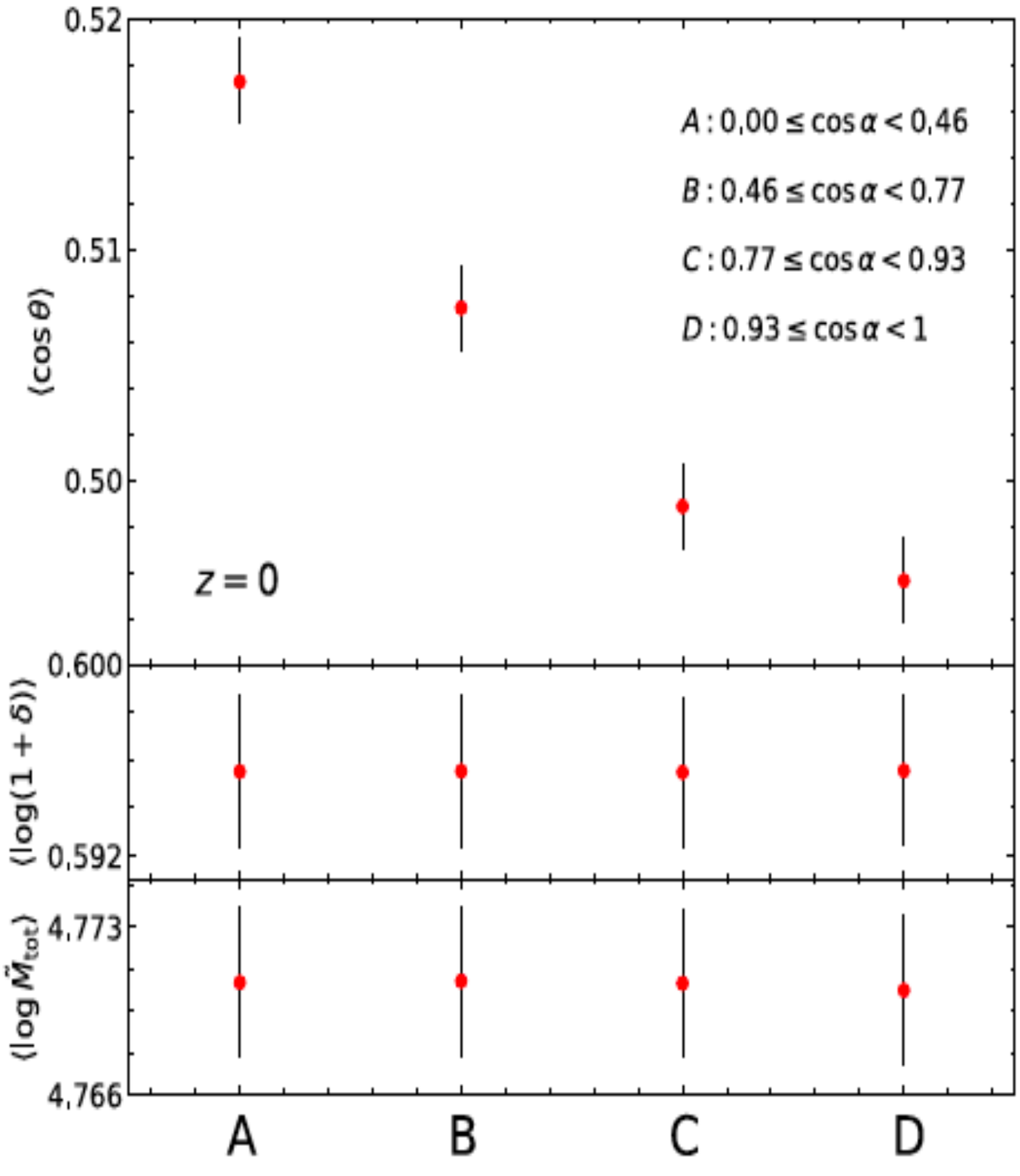
- The stellar spins of halos from the IllustrisTNG 300-1 exhibit peculiar alignments with the Tweb major principal axes.
- This peculiar stellar spin alignments occur only at low redshifts, $z < 1$.
- Its strength increases as the smoothing scale decreases.



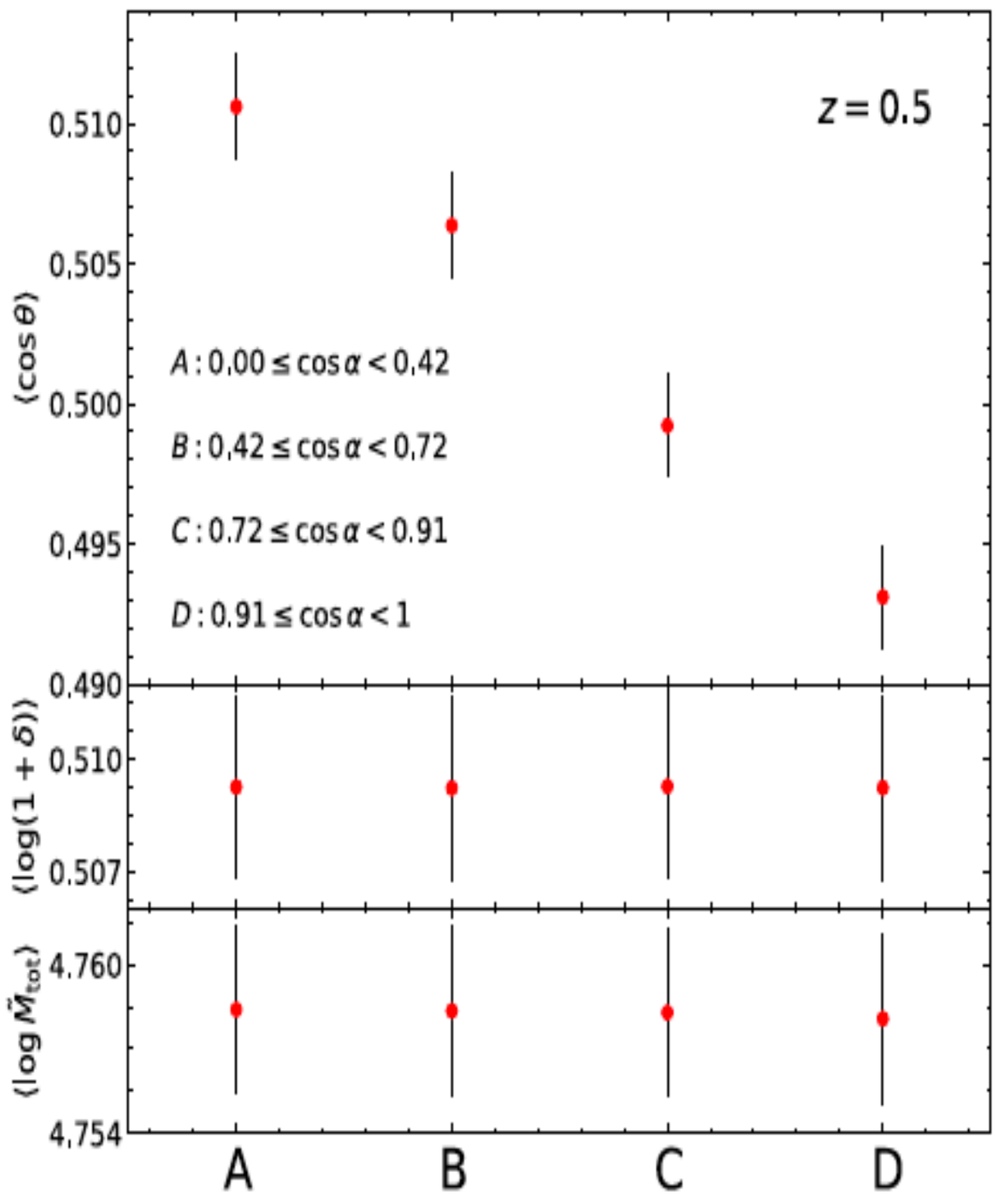
Lee et al. (2021, ApJ,922,6)

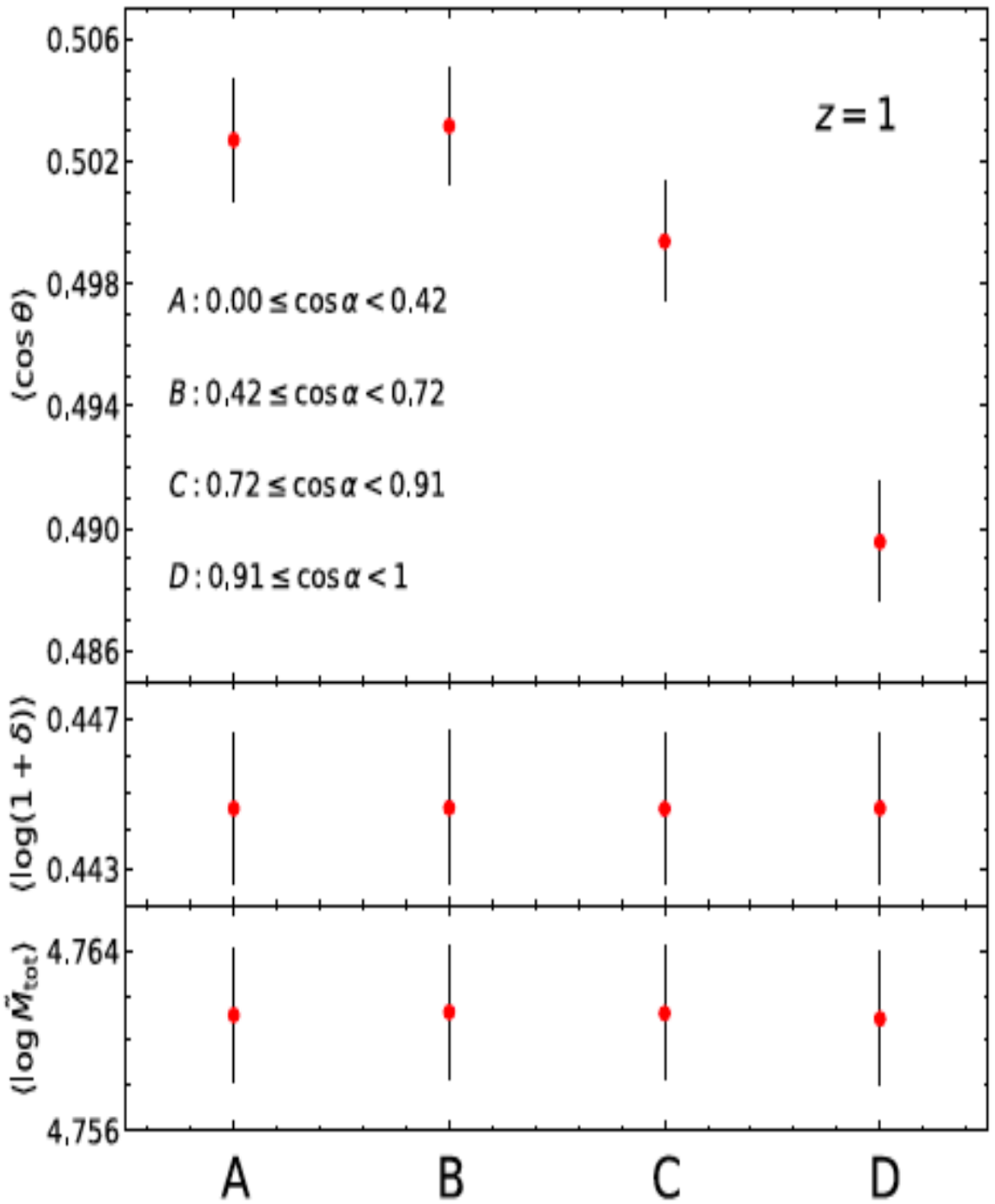
DEPENDENCE ON THE STELLAR-DM SPIN ALIGNMENTS

- The strength of the peculiar stellar spin alignment depends on that of the DM-stellar spin alignment:
  - The more strongly the DM-stellar spins are aligned, the less strong the peculiar stellar spin alignment with the Tweb major principal axes.



Lee, Moon & Yoon (2021, ApJ,927,29)

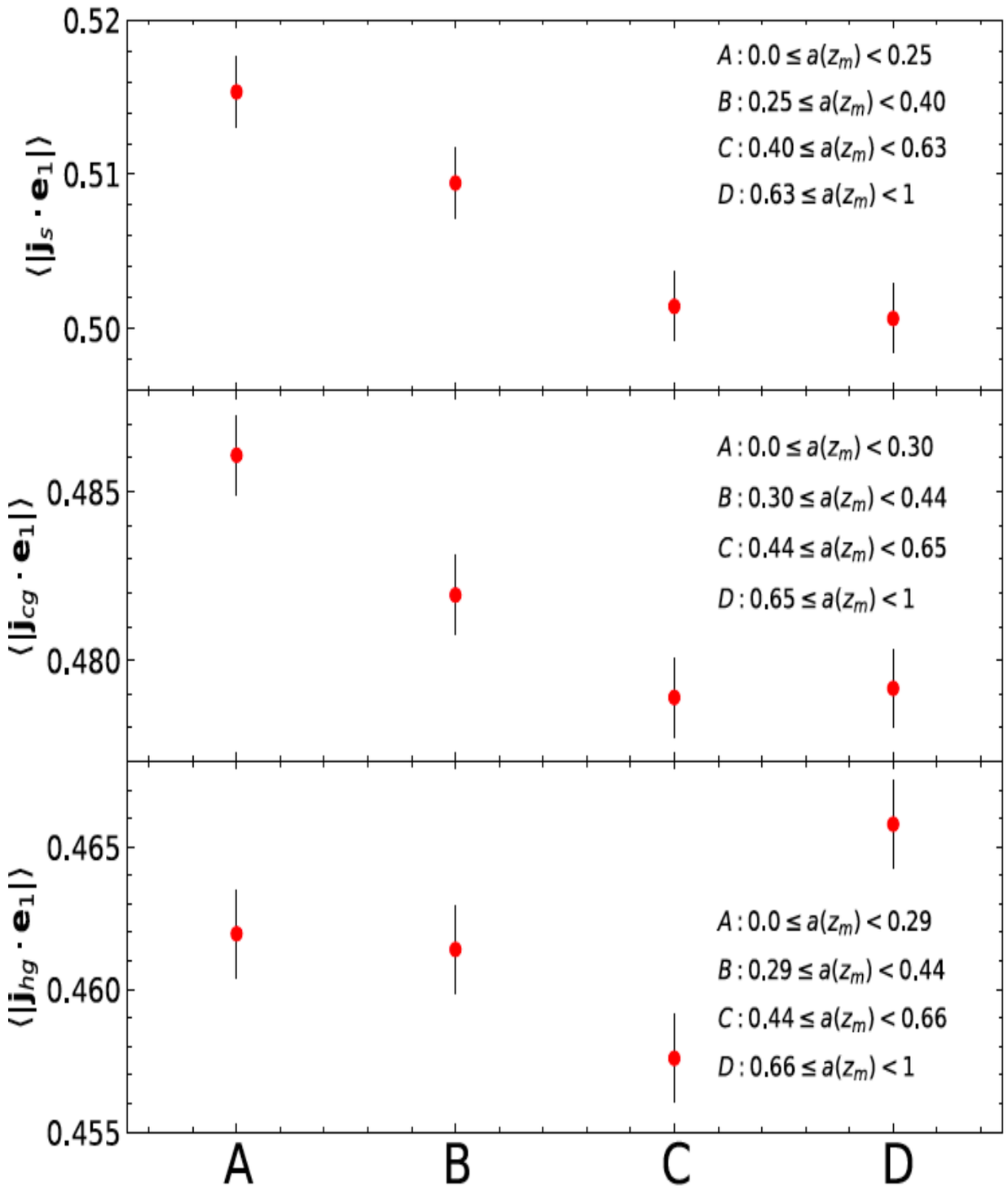




Lee, Moon & Yoon (2021, ApJ,927,29)

MERGER EFFECT ON THE PECULIAR ALIGNMENTS

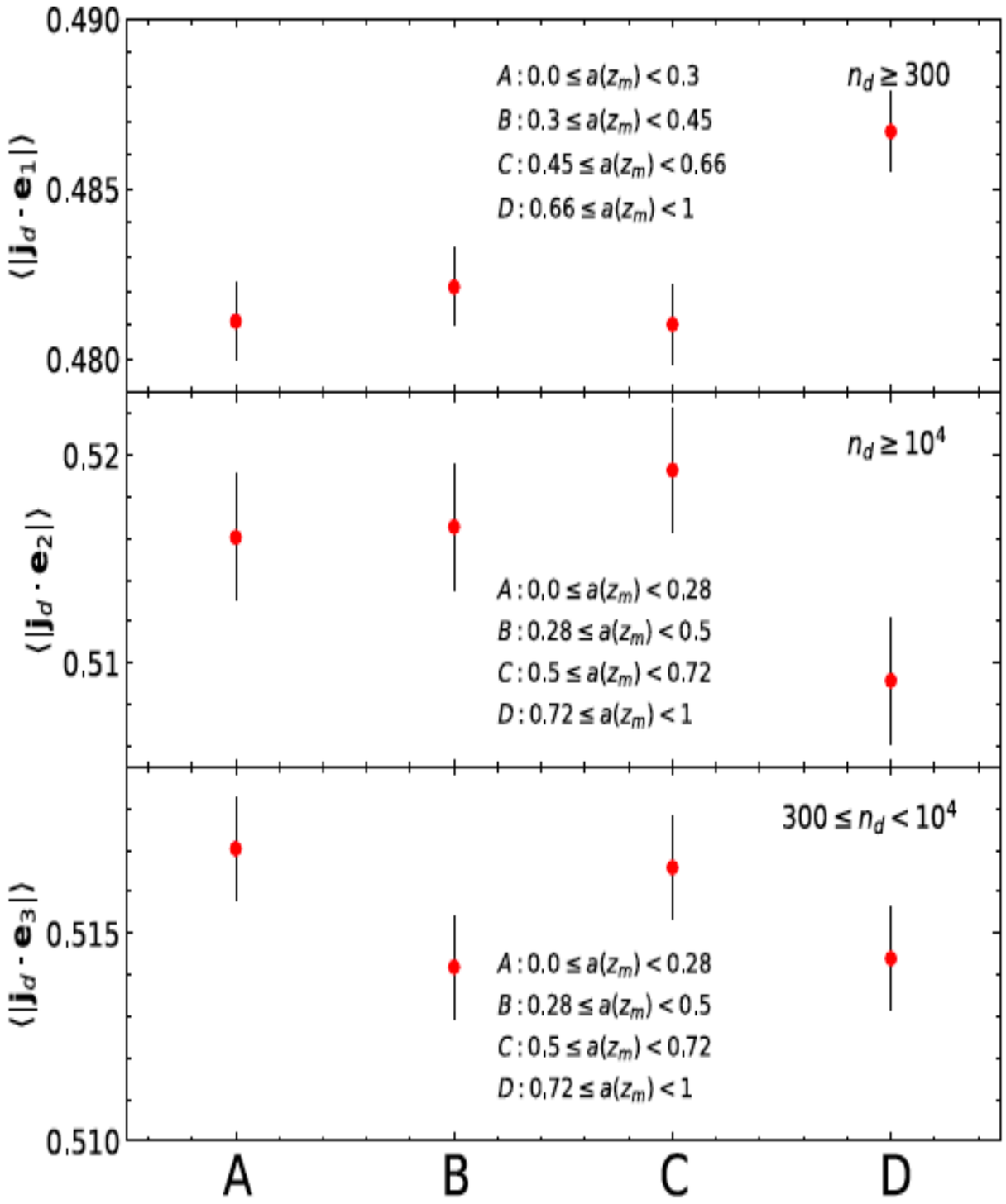
- The peculiar spin alignment depends on the latest merger epoch.
  - The earlier the merger epoch is, the stronger the peculiar spin alignment is.
- The non-stellar gas does not show peculiar spin alignment.
  - The cold gas spins, however, show a similar variation with the merger epoch.



Lee & Moon (2022, ApJ,936,119)

DEPENDENCE ON THE MERGER EPOCH

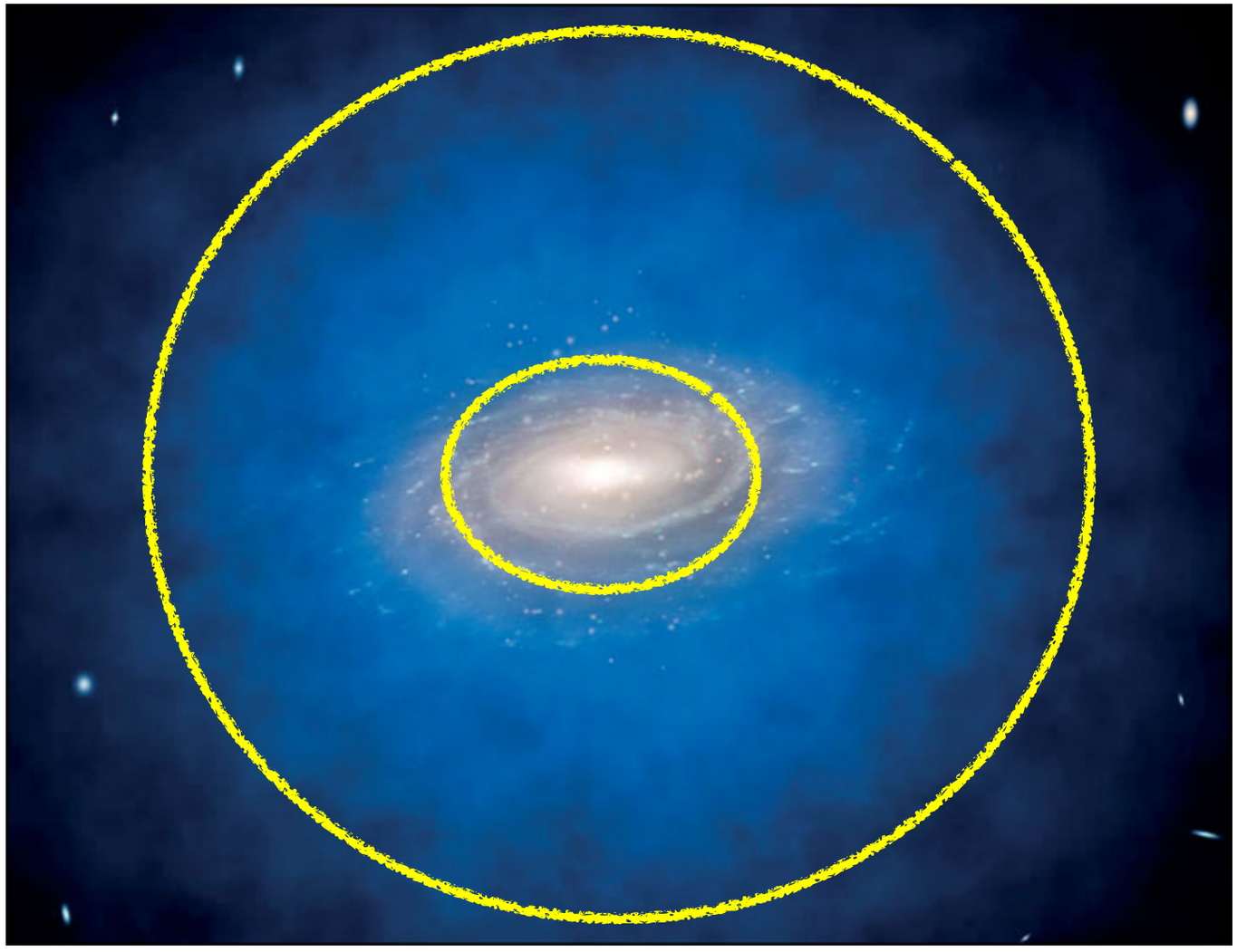
- The DM spin alignments with the Tweb principal axes do not show strong variation with the latest merger epochs.
  - This result casts a doubt on the scenario that the mass-dependent spin transition of DM halo originate from the merging process.



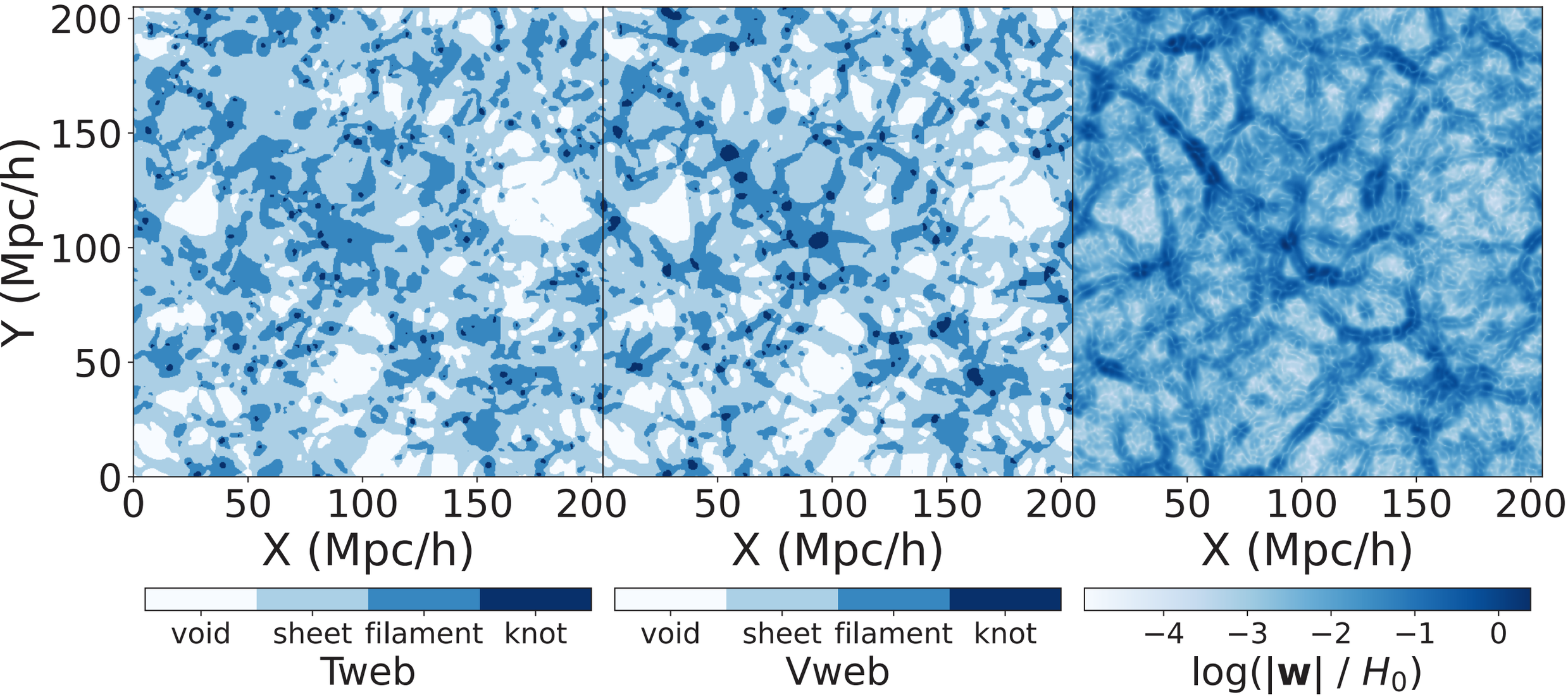
Lee & Moon (2022, ApJ,936,119)

BOUNDARY FOR THE SPIN MEASUREMENT

- The DM spins are measured at the viral boundaries.
- The stellar spins are measured at (twice) half the stellar mass radii, much smaller than the viral counterparts.
  - due to the observational limitations.



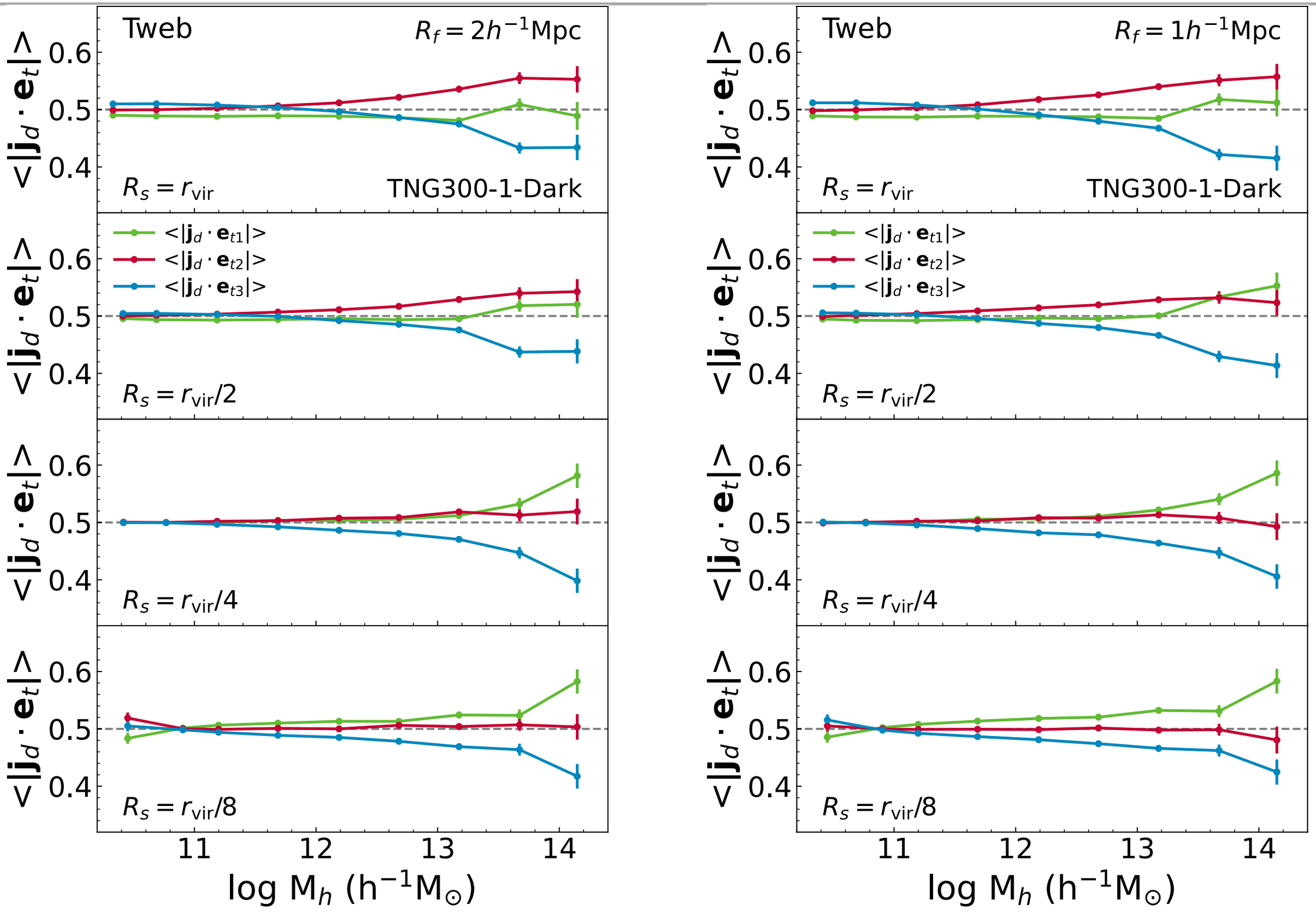
Moon & Lee (arXiv:2210.15905)



- IllustrisTNG300-1 simulations for the Planck Cosmology
- DM only: $L_{\rm box} = 250\,h^{-1}{\rm Mpc}$, $m_{\rm d} = 7 \times 10^7\,h^{-1}M_\odot$, $N_{\rm d} = 2500^3$
- Hydrodynamics: $m_{\rm d} = 5.9 \times 10^7\,h^{-1}M_\odot$, $m_{\rm g} = 1.1 \times 10^7\,h^{-1}M_\odot$

Moon & Lee (arXiv:2210.15905)

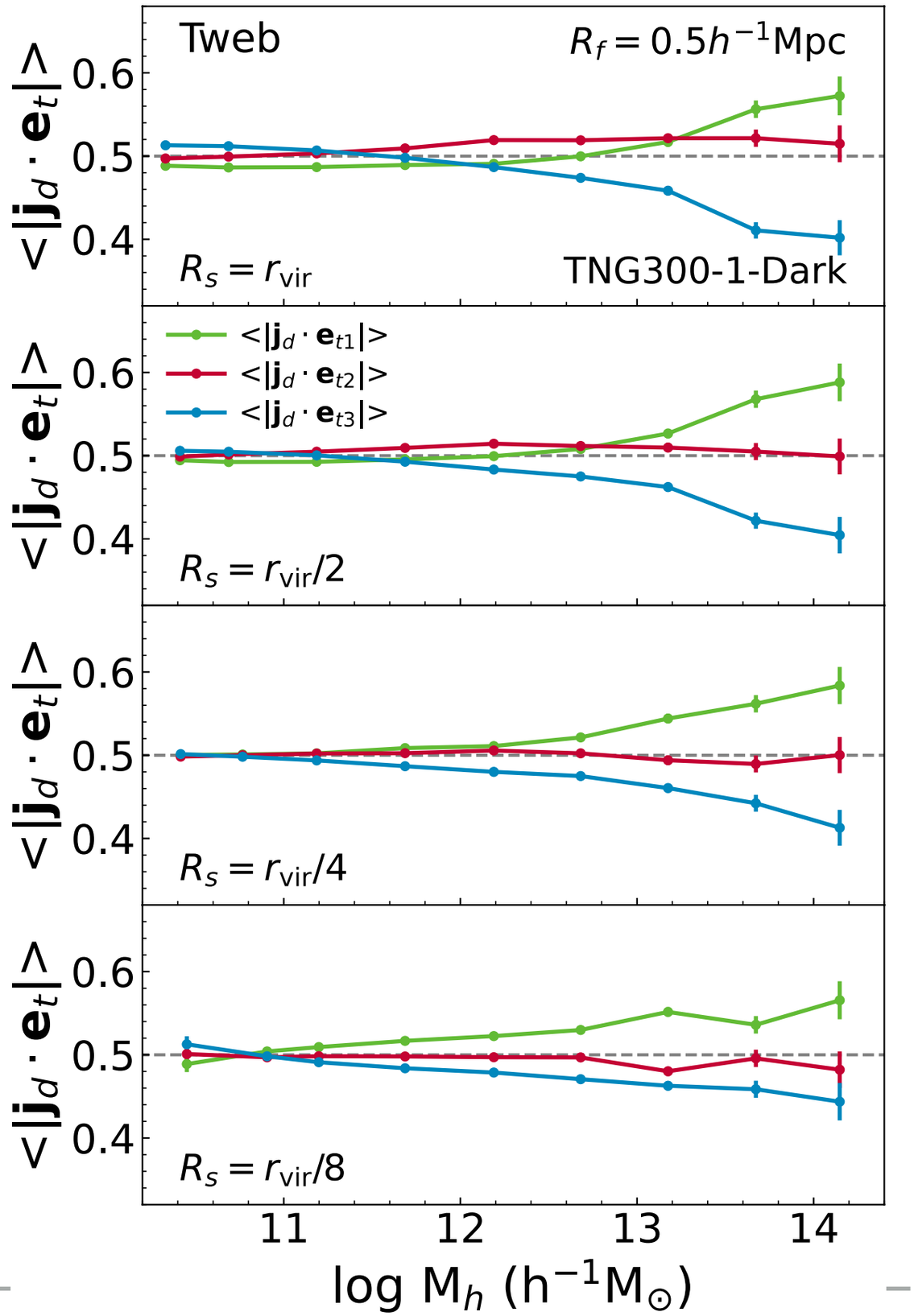
INNER SPIN ALIGNMENTS



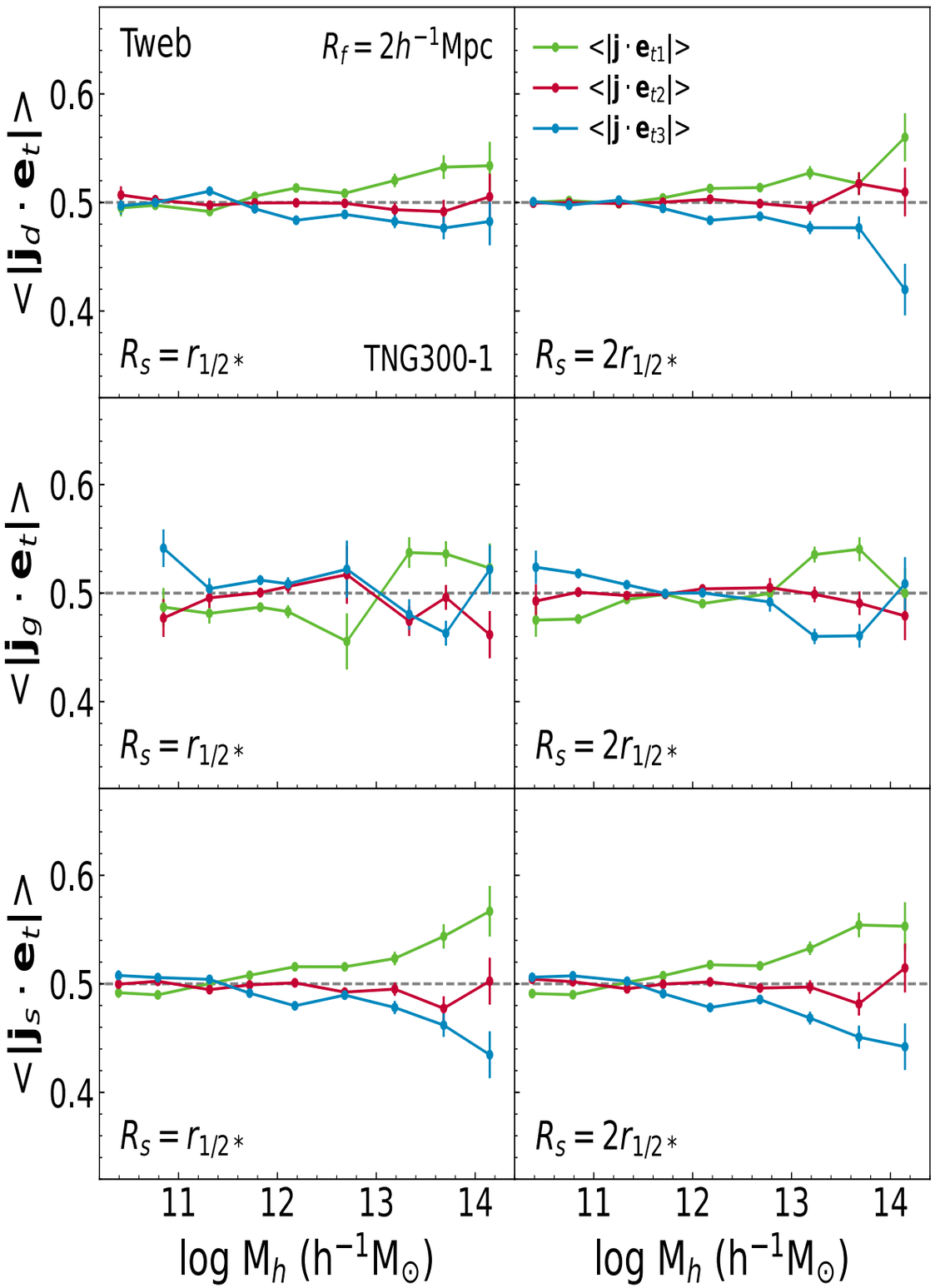
Moon & Lee (arXiv:2210.15905)

INNER SPIN ALIGNMENTS

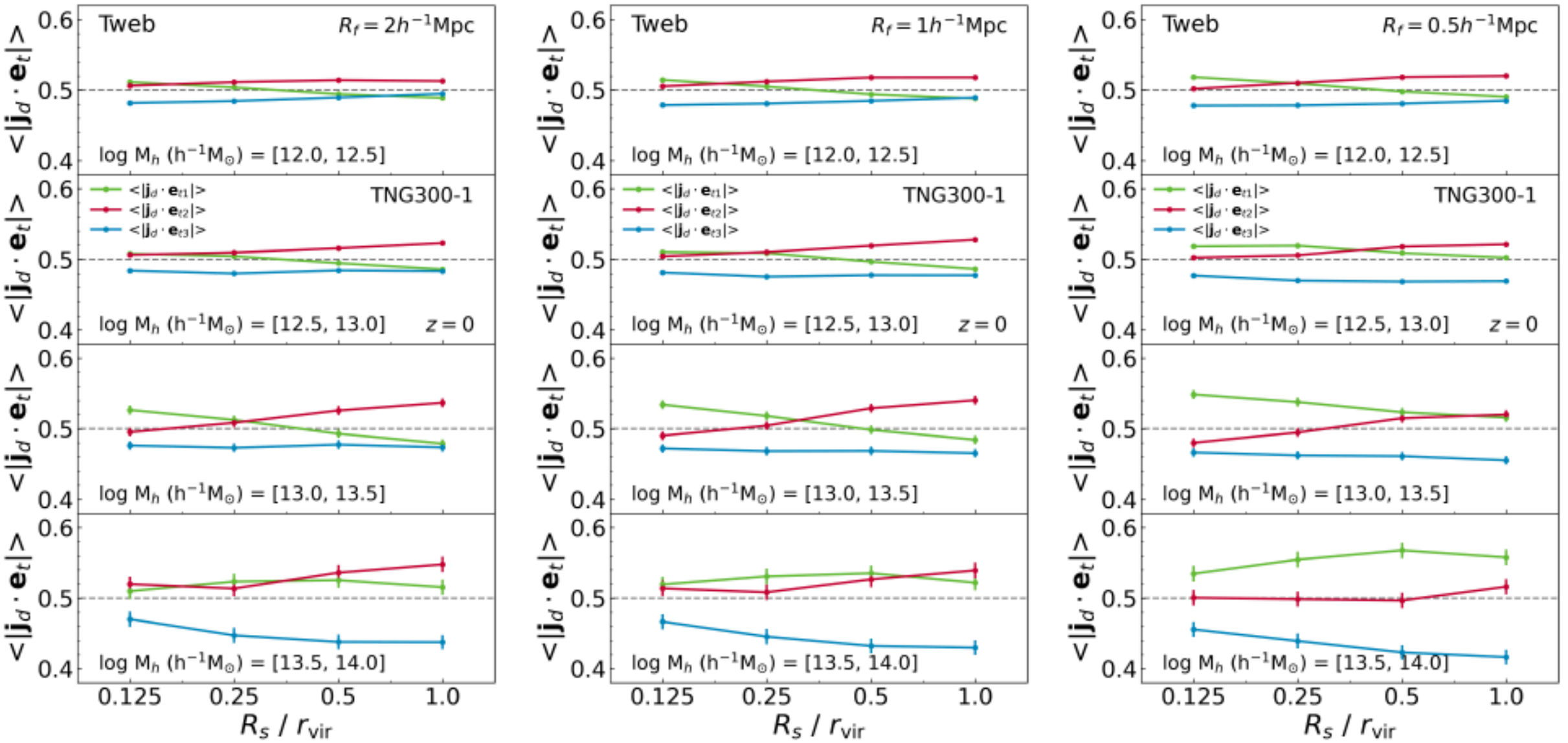
- The DM inner spins exhibit the peculiar alignment with the Tweb major principal axes.
- The strength depends on the smoothing scale as well as on the inner radii.
  - It is stronger at more inner radii.
  - It is stronger on the smaller smoothing scale.



Moon & Lee (arXiv:2210.15905)

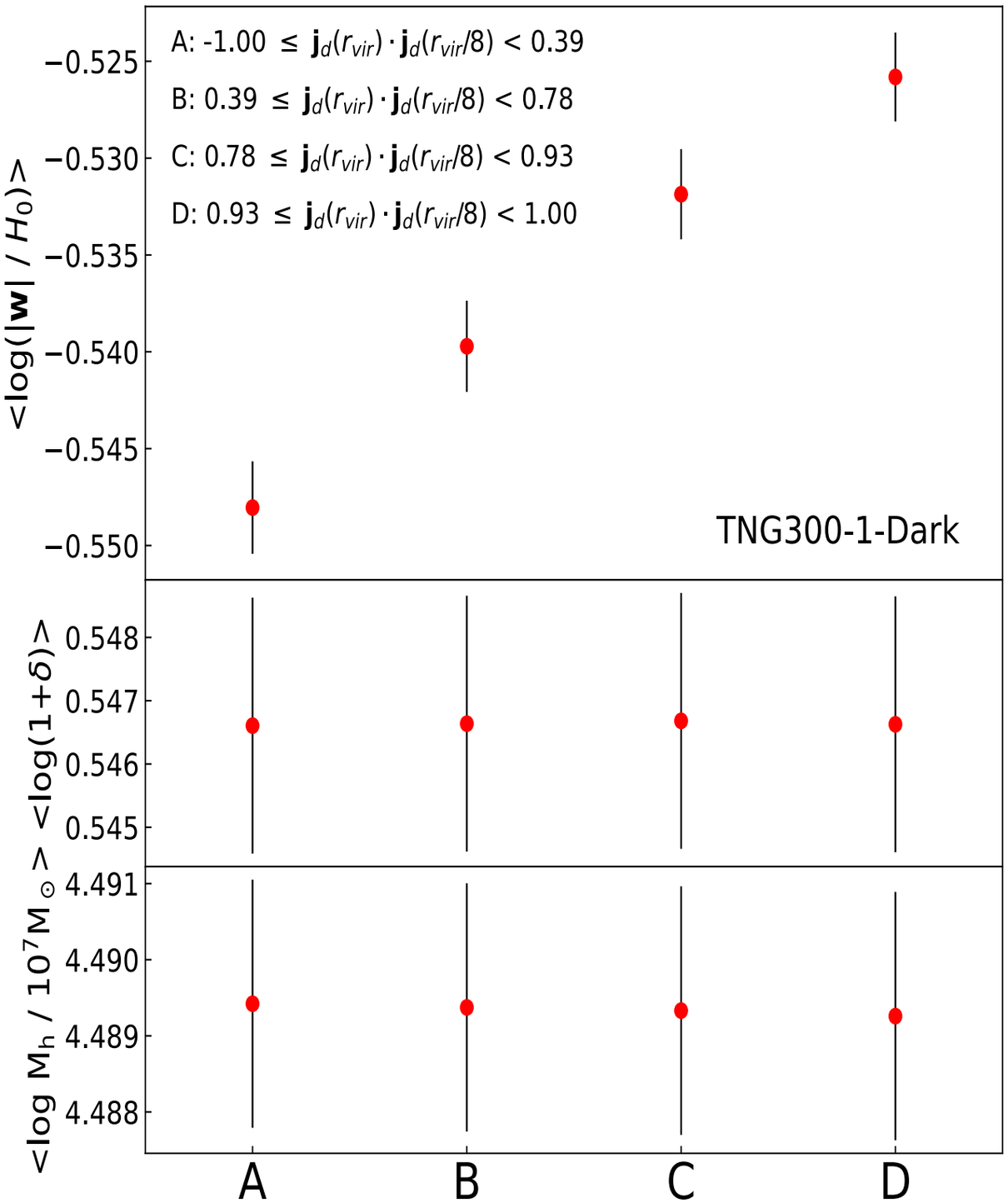


Moon & Lee (arXiv:2210.15905)


Tweb
$R_f = 2h^{-1}$Mpc
$R_f = 1h^{-1}$Mpc
$R_f = 0.5h^{-1}$Mpc
TNG300-1
$<|\mathbf{j}_d \cdot \mathbf{e}_{t1}|>$
$<|\mathbf{j}_d \cdot \mathbf{e}_{t2}|>$
$<|\mathbf{j}_d \cdot \mathbf{e}_{t3}|>$
log M_h ($h^{-1}M_\odot$) = [12.0, 12.5]
log M_h ($h^{-1}M_\odot$) = [12.5, 13.0]
log M_h ($h^{-1}M_\odot$) = [13.0, 13.5]
log M_h ($h^{-1}M_\odot$) = [13.5, 14.0]
$z = 0$
$<|\mathbf{j}_d \cdot \mathbf{e}_t|>$
0.4
0.5
0.6
0.125
0.25
0.5
1.0
R_s / $r_{\rm vir}$

VORTICITY EFFECT I

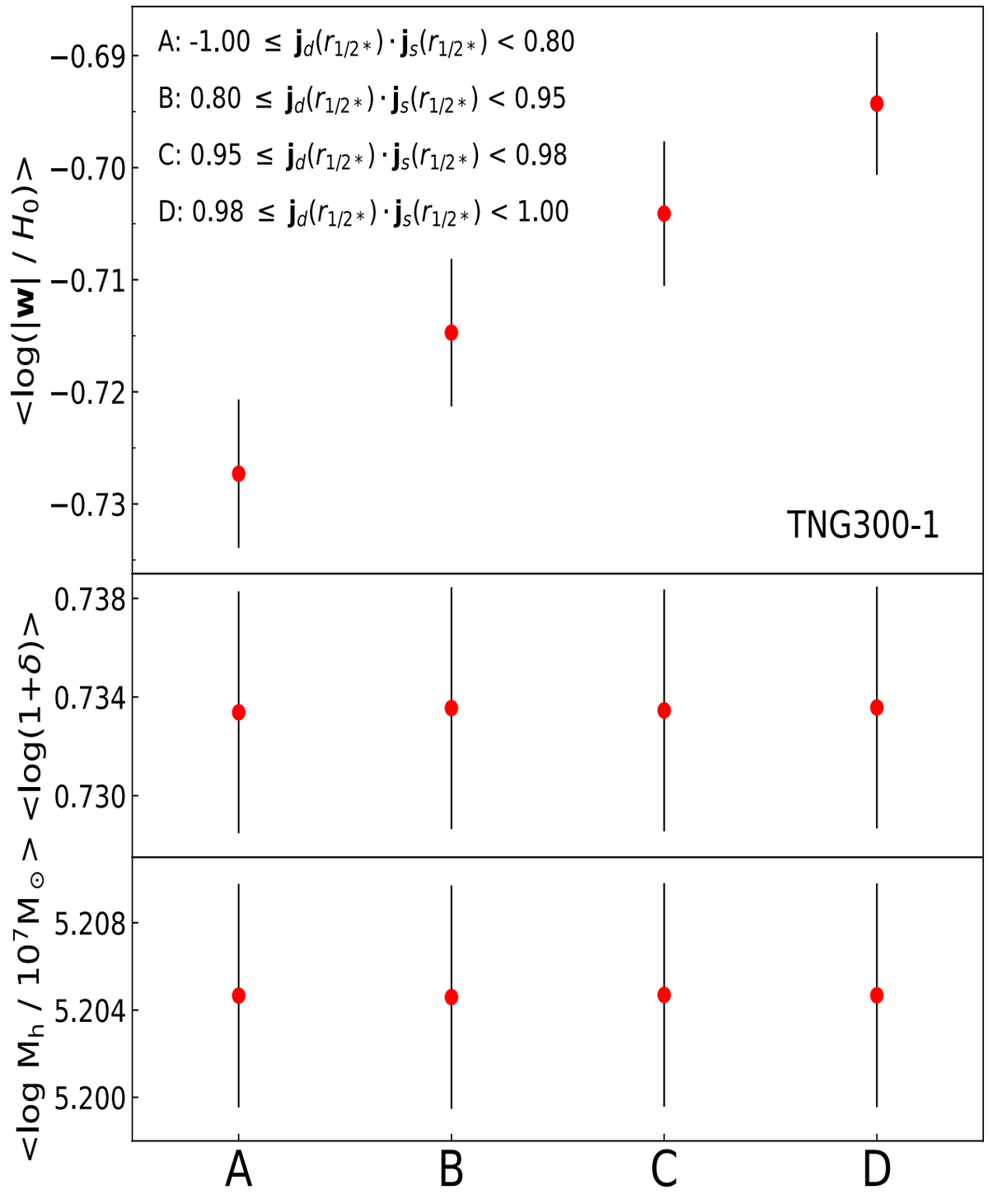
- The alignment between the halo viral and inner spins depend on the vorticity magnitude:
  - It is stronger in the regions with higher vortices
  - The signal is significant even though the mass and density effects are nullified.



Moon & Lee (arXiv:2210.15905)

VORTICITY EFFECT II

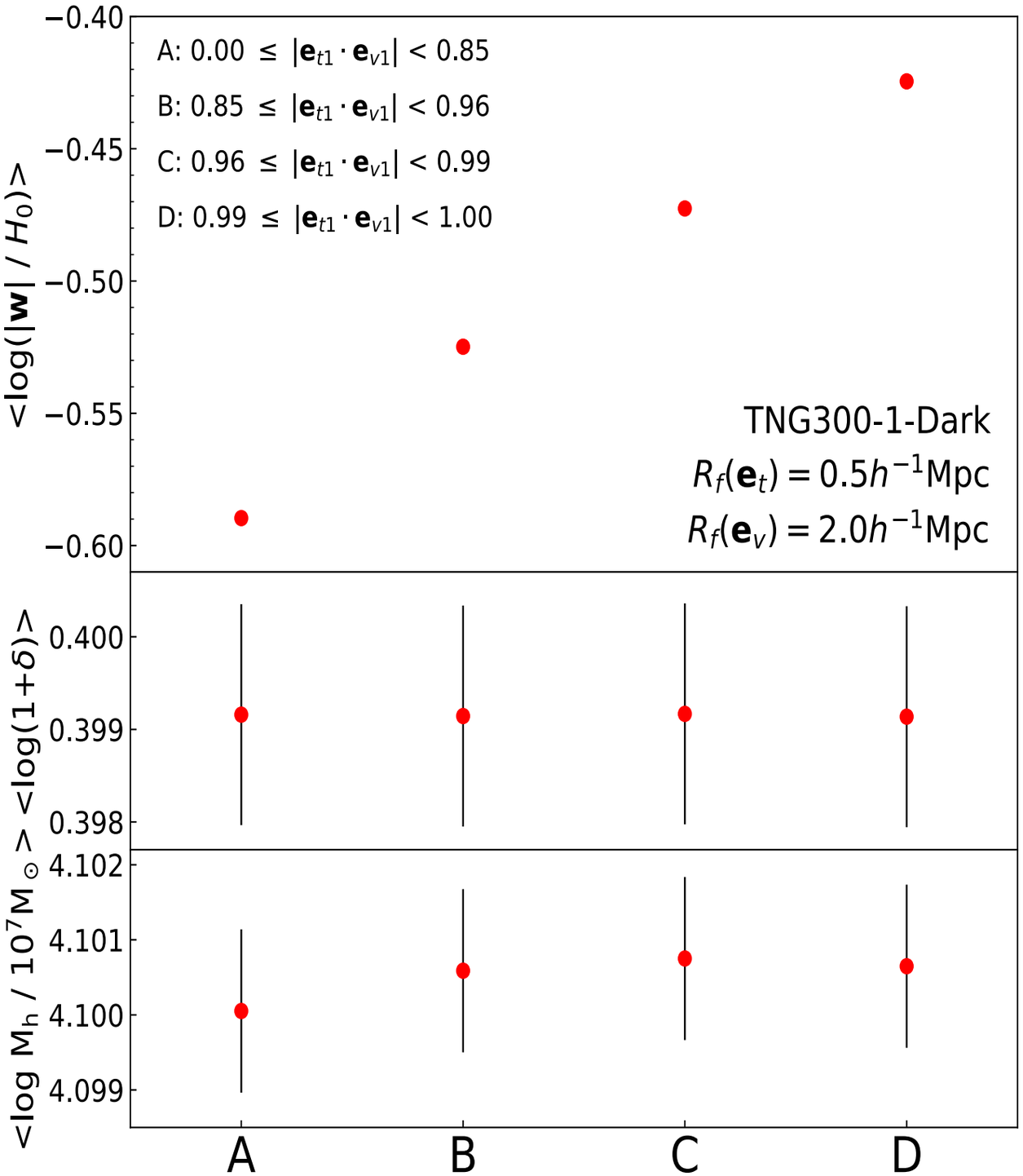
- The alignment between the halo DM and stellar spins depend on the vorticity magnitude:
  - It is stronger in the regions with higher vortices
  - It shows almost linear variation with the logarithm of the vorticity magnitude.



Moon & Lee (arXiv:2022.15905)

VORTICITY EFFECT III

- The alignment between the Tweb major principal axes on two different scales depends on the vorticity magnitude:
  - It is stronger in the regions with higher vorticity.
  - The vorticity is not responsible for the generation of the peculiar spin alignment.



Moon & Lee (arXiv:2210.15905)

SUMMARY

- The DM halo inner spins exhibit a radius dependent transition from the Tweb intermediate to major principal axes, as it is measured at more inner radii.
  - **The transition threshold radius becomes larger on the smaller smoothing scales for the case of more massive halos.**

- Both of the DM and stellar spins measured at $r_{1/2,*}$ show the peculiar alignments with the Tweb major principal axes.
  - **The halos whose latest merger occur earlier exhibit stronger peculiar alignments.**

- The vorticity has an effect of enhancing the alignments between the halo viral and inner spins and between the DM and stellar spins.