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## A dark matter solution to the $H_0$ and $\sigma_8$ tensions, and the integrated Sachs-Wolfe void anomaly

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The significant tensions in constraints on the Hubble constant ( $H_0$ ) and clustering amplitude ( $\sigma_8$ ) between early- and late-universe observations challenge key assumptions of the  $\Lambda$ CDM cosmological model. One of these assumptions is the presence of cold dark matter, a yet-to-be-detected non-relativistic particle with minimal interaction with the Standard Model that dominates the mass budget of the universe.

We propose a phenomenological model where dark matter's pressure-to-energy ratio, or equation of state,  $w$ , evolves over time, enabling it to influence both the universe's expansion rate  $H_0$  and structure formation  $\sigma_8$ . The model reduces the  $H_0$  tension from  $\sim 5\%$  to  $\sim 3\%$  and the  $\sigma_8$  tension from  $\sim 3\%$  to  $\sim 1\%$ .

Moreover, this model explains the anomalously large Integrated Sachs-Wolfe (ISW) effect observed in cosmic voids, a key puzzle in large-scale structure analyses. Observations suggest an unexpectedly strong ISW signal from voids, which our model enhances by a factor of  $\sim 2$ . This provides a testable prediction and supports the idea that dark matter properties influence both small- and large-scale cosmology.

These results extend to unified or interacting dark matter-energy models, with void ISW signals offering a promising avenue for resolving cosmological tensions.

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