The Geometry of the Milky Way's Dark Matter Halo: Bayesian Inference of Kinematic Properties Across Stellar Streams and the Galactic Rotation Curve

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Cosmological simulations expect that dark matter halos are triaxial and undergo figure rotation. However, values for its triaxiality remain disputed, and its tumbling, though fundamental to galactic evolution, has never been observationally measured. Therefore, this study aims to provide not only a description of the shape and orientation of the Milky Way's dark matter halo but also a first observational measurement of its tumbling rate. Four stellar streams (GD-1, Pal 5, Jhelum, Orphan-Chenab) observed by Gaia and DESI were jointly fitted with the galactic rotation curve using Bayesian inference. A novel 14D rotating NFW halo model ran against a static model for fair comparison, with the Large Magellanic Cloud included as a moving gravitational perturber with reflex motion correction. Mock streams were generated by spraying particles from each progenitor and integrated through billions of years in an evolving potential. This inference ran millions of times across 16,384 CPU cores on the Aion supercomputer. A Bayes factor (lnB) of 2.07 provides moderate evidence for prograde figure rotation at 0.405 +0.151/-0.193 km/s/kpc. Additionally, critical values include a strongly oblate halo with vertical flattening q_z = 0.629 +0.061/-0.040 and in-plane flattening q_y = 0.784 +0.054/-0.058, and a fitted model systematic uncertainty of sigma_sys = 0.396 +0.077/-0.057 degrees. This study finds compelling evidence for tumbling, suggesting that time dependent models are all systematically biased. However, increased sampling resolution tests are ongoing to determine a higher Bayes factor.

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