Sixteenth Marcel Grossmann Meeting

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Constraining the dark matter self-interaction cross section in low-mass halos with quadruple image strong gravitational lenses

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Collapsed structures, or halos, formed in models with self-interacting dark matter (SIDM) have unique properties that distinguish them from structures formed in cold dark matter (CDM). In particular, momentum and energy exchange inside SIDM halos drives the formation of a central core that may eventually undergo core collapse, such that the halo becomes extremely centrally concentrated. We demonstrate that the flux ratios in quadruply imaged quasar strong lens systems (quads) provide an avenue to statistically constrain the unique features of SIDM in halos with masses below $10^9 M_{\odot}$, providing a new, purely gravitational probe of SIDM structure on sub-galactic scales. In the low-mass halos probed by lensing, particles move at relative velocities below 30 km/sec, and thus an analysis of quads can provide a new window on the self-interaction cross section below the velocity scales accessible with galaxies or galaxy clusters. To determine how a sample of quads can constrain SIDM models, we implement a structure formation model that predicts the properties of cored and core collapsed halos given an interaction cross section, and show that SIDM structure produces flux ratio perturbations distinct from those arising in CDM. We then forecast, with simulated datasets, that a sample of 30-50 quads, a sample size attainable in the next few years, can place stringent constraints on the amplitude and velocity dependence of the cross section, potentially ruling out certain SIDM models, or falsifying CDM.

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