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Studying Dark Matter with Pulsar Timing, Stellar Streams and Strong Lensing

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We aim to understand the distribution of dark matter within both the Milky Way (MW) and external galaxies. In the MW, the dark matter distribution can be constrained now through direct acceleration measurements using pulsar timing and through indirect kinematic methods. My work aims to calibrate indirect methods of characterizing the Galactic potential, such as from analysis of stellar streams, to direct acceleration measurements. In so doing, we are aiming to develop an “acceleration ladder”, in analogy with the distance ladder. We combine potential constraints using action space clustering of stellar streams and local measurements of the potential from pulsar timing. Our results indicate that the streams underestimate the local matter density, while the pulsars provide much stronger local constraints. Meanwhile, stellar streams provide superior constraints on the global properties of the potential. The combination of these methods produces stronger overall constraints on the MW potential. For external galaxies, we focus on understanding the utility of gravitationally lensed supernovae (glSNe). These systems contain information about the dark matter substructures within the lensing galaxy and along the line of sight. Accurate time delay measurements can also produce strong independent constraints on the Hubble constant. I have generated simulations of Type Ia and Type II-P glSNe that include the effects of microlensing. Our simulations indicate that accurate measurements of time delays can be recovered by using color curves in type Ia glSNe, which are largely insensitive to microlensing in the first ~30 days after the explosion. For Type II-P glSNe, spectral observations can produce accurate time delays by measuring line velocities, especially FeII, which decay following a power law. Detections of these sources are predicted to be more numerous than Type Ia glSNe, so measuring time delays in these systems is valuable. They can be used both for constraining the Hubble constant and in the search for dark matter substructures. While supernovae are affected by microlensing, they are also sensitive to low mass dark matter substructure. This low mass sensitivity potentially allows for study of the relatively unexplored low mass end of the dark matter substructure distribution.