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Probing Collapsed Dark Matter Halos with Fast Radio Bursts

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The observations of ultra-dense substructures in strong lensing systems challenge the standard cosmology model at small scales. Self-interacting dark matter (SIDM), as one of the alternatives to the cold collisionless dark matter (CDM) of the standard cosmology model, provides a natural mechanism for forming such structures via gravothermal core-collapsing. We show that strong gravitational lensing of fast radio bursts (FRBs) provides a new way to effectively probe these structures and to understand dark matter self-interactions. Core-collapsed SIDM halos exhibit steeper central density profiles than CDM halos, enhancing the lensing cross section and producing longer time delays between FRB images. We model the SIDM core-collapsed halo with a power-law profile whose center is cored, and compute lensing properties for subhalo and host halo lensing, including maximal impact parameters and time-delay distributions. Future observatories, such as BURSTT, SKA2-Low, and SKA2-Mid, could detect 105–106 FRBs over a decade, yielding statistically significant time-delay distributions that can probe core-collapse parameters of SIDM halos including self-interaction cross section strengths to σ/m ⊠ min{18 cm2/g, 40λsub cm2/g}.

Primary authors: Prof. ZHANG, Chen (Tongji University); ZHONG, Yiming; Dr WANG, weiyang (University of Chinese Academy of Sciences); 何, 雨轩 (City University of Hong Kong)

Presenter: 何, 雨轩 (City University of Hong Kong)

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