Explaining Galactic Halos with Fuzzy Dark Matter

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Research Questions

Does the fuzzy dark matter model improve the agreement between theory and observation of density profiles?

How does it compare to the NFW and isothermal density profiles?

Background

The core-cusp problem refers to the inconsistency between simulations of the theory of cold dark matter (CDM) and observations of dwarf galaxies. At the center of these galaxies, CDM simulations show the mass density to diverge as $\rho(r) \propto r^{-1}$, a cusp profile, while observed data follow a core profile at small radii with $\rho(r) \propto r^{0}$ [1]. Fuzzy dark matter is thought to rectify this disparity. Fuzzy dark matter differs from other forms of dark matter in its predicted ultra-light mass, which gives it a large Compton wavelength. Dark matter particles are described by the Klein-Gordon equation and the coupled Poisson-Schrödinger equations.

Materials and Methods

The solutions to the Klein-Gordon equation coupled to gravity and Poisson equation for general relativity were found numerically with the use of Mathematica. This solution was fitted to the simulated DG1 and DG2 dwarf galaxies, and the observed The HI Nearby Galaxy Survey (THINGS) dwarf galaxy data (DD0154) [2]. From the fitted solutions, the mass of the particles was determined and compared to the theorized particle mass of fuzzy cold dark matter.

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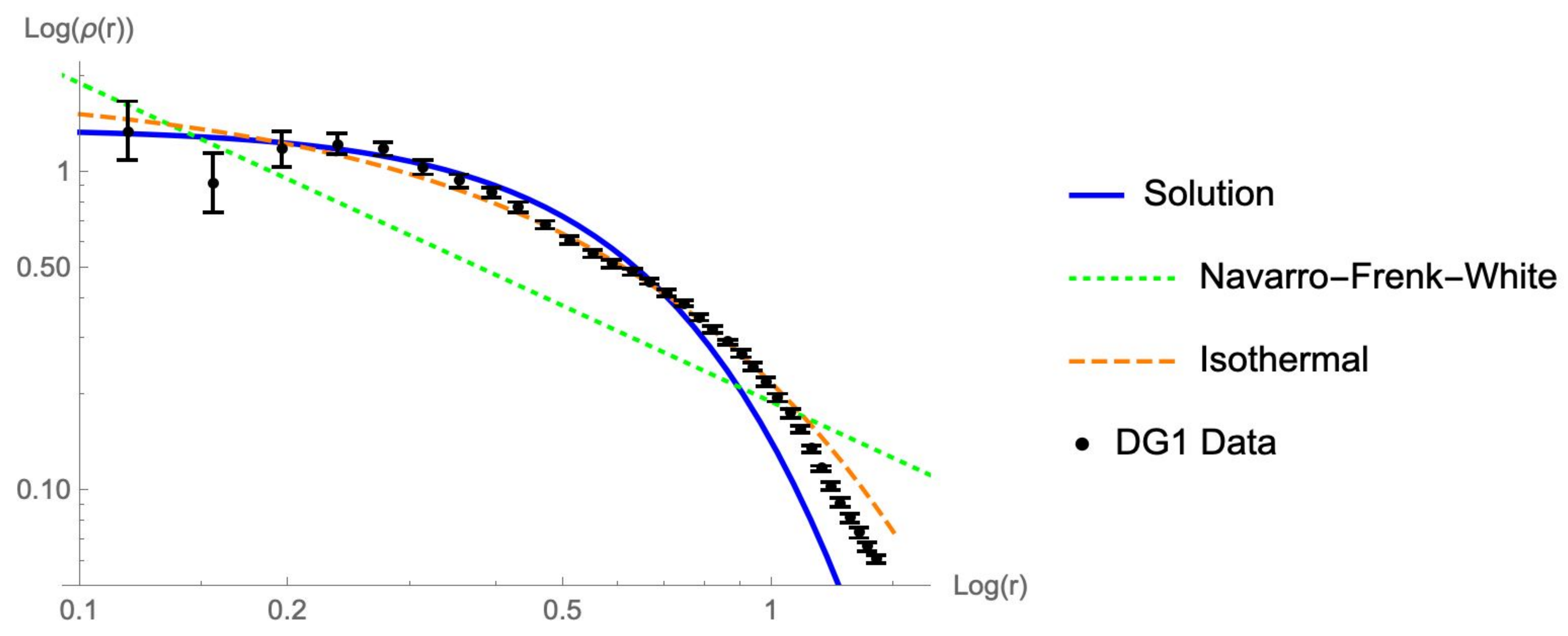
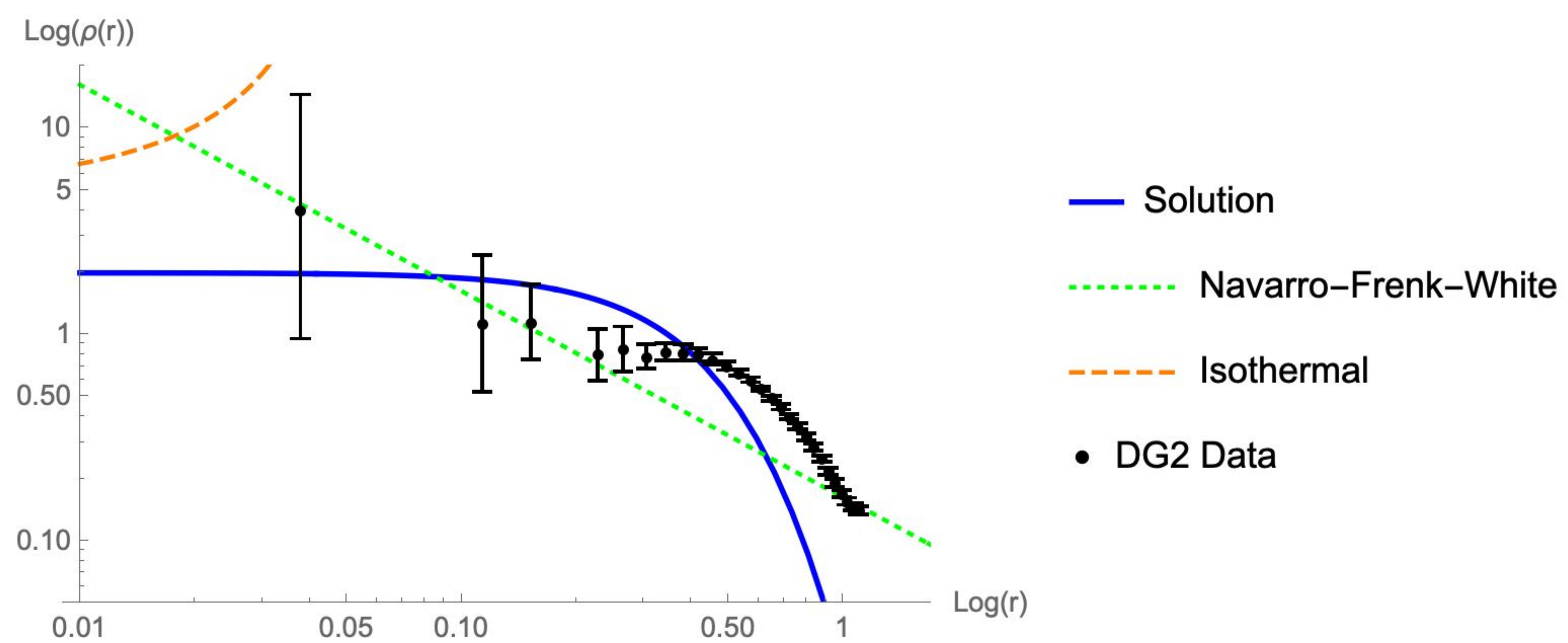
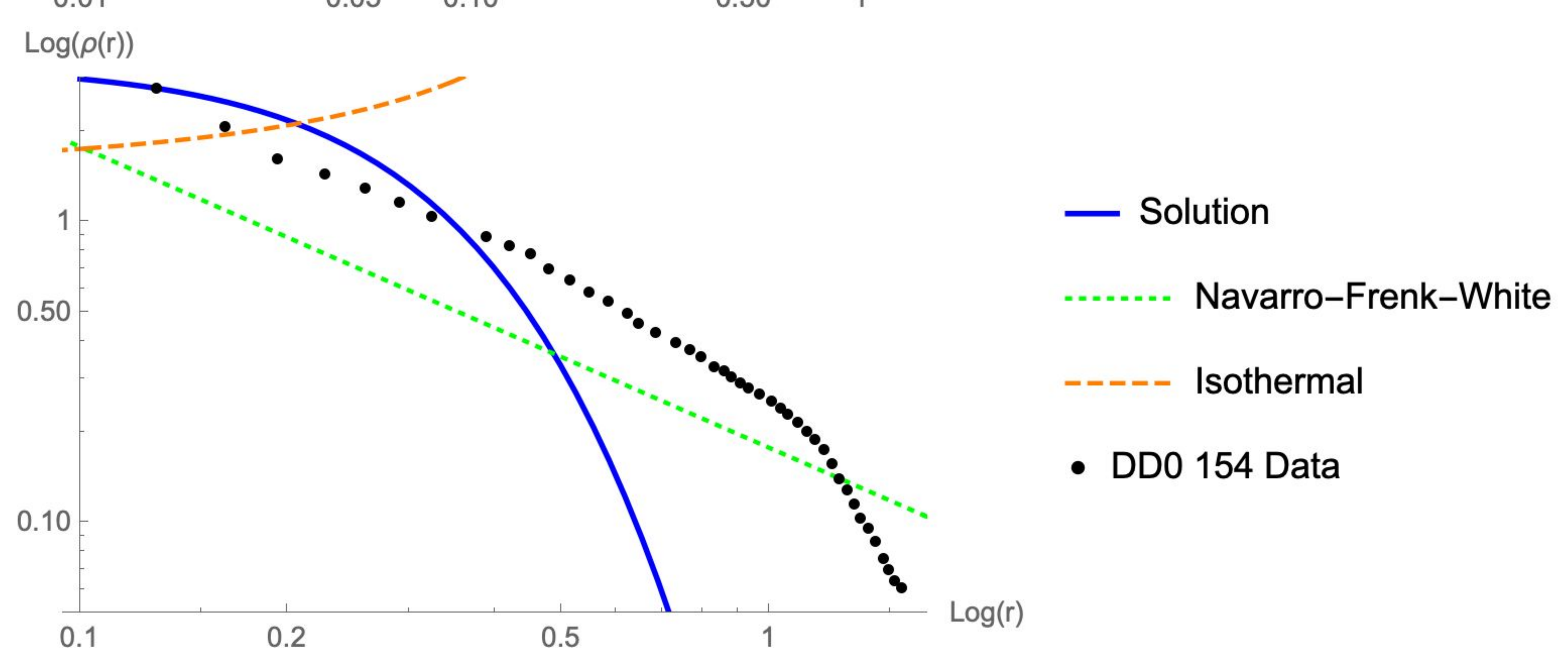
Results







Discussion and Conclusion

The Navarro-Frenk-White (NFW) density profile, based on cold dark matter simulations, suggests inner density "cusps" of dark matter halos around galaxies. These cusps describe densities that increase as the radii decrease. However, the NFW profile does not fit well to observed data, such as the dwarf galaxies measured by THINGS. The isothermal density profile suggests inner density "cores", which fits better to the data than the NFW profiles. Dark matter density cores predict a constant density at inner radii.

Our solutions suggest a cored inner density similar to those predicted by the isothermal profile. Therefore, while the theory of cold dark matter does not accurately describe galaxy observations, our results show that the proposed fuzzy dark matter particle redresses this discrepancy.

From our solution, fitted to the DG1 data from THINGS, we calculated the particle mass to be $m \sim 10^{-27}$ eV. This is smaller than fuzzy dark matter particle masses found by other researchers by 4-5 orders of magnitude. This difference could be attributed to error in our data selection methods and rounding. Our calculated mass does agree with the theory that fuzzy dark matter particles are ultra-light.

References

[1] W. J. G. de Blok. The core-cusp problem. Advances in Astronomy, 2010:1–14, 2010.

[2] Se-Heon Oh, Chris Brook, Fabio Governato, Elias Brinks, Lucio Mayer, W. J. G. de Blok, Alyson Brooks, and Fabian Walter. THE CENTRAL SLOPE OF DARK MATTER CORES IN DWARF GALAXIES: SIMULATIONS VERSUS THINGS. The Astronomical Journal, 142(1):24, Jun 2011.