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Comment on "The Dispersion Velocity of Galactic Dark Matter Particles"

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In a recent Letter [1], Cowsik et al. claim that a self-consistent treatment of the dark Galactic halo, which takes into account the gravitational effect of luminous matter and allows for a nonspherical halo, requires that the local velocity dispersion of dark-matter particles be 600 km s^{-1} or greater, more than a factor of two larger than the canonical value of 270 km s^{-1}. If true, this would significantly affect rates and signatures for detection of baryonic and nonbaryonic dark matter.

This work contradicts the assembled results of a long history of work in Galactic dynamics, which among other things holds that the velocity dispersion of the halo should be close to 270 km s^{-1}, the value that obtains for a spherically symmetric isothermal halo, $\sqrt{3/2}$ times the asymptotic rotation velocity of around $220\,\mathrm{km\,s^{-1}}$. We believe that this work is incorrect, probably because not all the observational constraints were taken into account and because the models were forced to satisfy arbitrary constraints on the halo density.

Cowsik et al. construct their models for the distribution of halo dark-matter particles by assuming an isothermal (i.e., Maxwell-Boltzmann velocity distribution with a constant dispersion), axisymmetric distribution of dark-matter particles that move in the combined gravitational potential of the bulge, disk, and halo. They solve the coupled Boltzmann and Newton equations iteratively, subject to the arbitrary boundary conditions: $\rho_{\mathrm{DM}}(r=0) \sim 1\,\mathrm{GeV/cm^3}$ and $\rho_{\mathrm{DM}}(r = 8\,\mathrm{kpc}) \sim 0.3\,\mathrm{GeV/cm^3}$. We call these arbitrary because the density of dark-matter particles at the center of the Galaxy and at the solar circle are not observed quantities, but are derived from models for the Galaxy. They obtain the velocity dispersion of 600 $\mathrm{km\,s^{-1}}$ (or larger for other assumed values of the local projected mass density of the disk) by fitting the calculated equatorial rotation curve for the model to the data from 2 kpc to 18 kpc.

There are a number of things we do not know about their results, e.g., how broad is the minimum of their χ^2 and does it include the canonical value for the halo velocity dispersion? Why is it that the curves in their Figure do not asymptote to $\sqrt{2/3}$ times the velocity dispersion as they should for an isothermal halo?

However, we do know that their model conflicts with several important observational facts. In the neighborhood of the solar circle the velocity dispersion of the halo has been determined from velocity measurements of halo stars and globular clusters and is found to be around $200\,\mathrm{km\,s^{-1}}$ [2]. Since these objects trace the halo gravitational potential this is in severe conflict with their result. In addition, the rotation curves for several of their preferred halo models exceed $250\,\mathrm{km\,s^{-1}}$ at 20 kpc and are still rising. This is likely to be in conflict with determinations of the rotation speed ($\simeq$200–250 km s^{-1}) at distances from 30 kpc to 100 kpc based upon the proper motions of the Milky Way's satellites.

Finally, others have studied the effect of the bulge and disk on the halo as well as flattening of the halo and find that the velocity dispersion in the halo is not changed significantly. That the bulge and disk do not affect the halo is easily understood: the mass of the bulge is small ($\sim 2 \times 10^{10} M_\odot$) and so its effects are restricted to near the center of the Galaxy; the velocity dispersion within the disk is only around $30\,\mathrm{km\,s^{-1}}$. While flattening the halo can increase the local halo density [3], it can be shown by use of the virial theorem that it does not significantly affect the velocity dispersion. Kuijken and Dubinski [4] find that the local halo velocity dispersions in several self-consistent models for the disk, bulge, and halo of the Milky Way range from 246 to 323 $\mathrm{km\,s^{-1}}$.

Without repeating their numerical calculations we cannot be certain where Cowsik et al. went wrong. However, we are confident that their lower limit to the dark-matter velocity dispersion is not correct because it disagrees with observations and because previous work found that the effect of the luminous matter on the halo was small.

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