Comment on “The Dispersion Velocity of Galactic Dark Matter Particles”

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(June 1996)

PACS numbers: 95.35+d, 98.35-a, 98.35 Gi, 98.62 Gq, 98.35 Df

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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 dyna-
mics, 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 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: \(\rho_{DM}(r = 0) \sim
1\) GeV/cm\(^3\) and \(\rho_{DM}(r = 8\) kpc) \(\sim 0.3\) 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 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 \(\chi^2\) 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 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 km s\(^{-1}\) at 20 kpc and are still rising. This is likely to be in conflict
with determinations of the rotation speed (\(\sim 200-250\) 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 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 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.
REFERENCES