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Measure the local dark matter density with LAMOST spectroscopic survey

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Abstract. The local dark matter density plays the key role in the distribution of the dark matter halo near the Galactic disk. It will also answer whether a dark matter disk exists in the Milky Way. We measure the local dark matter density with LAMOST observed stars located at around the north Galactic pole. The selection effects of the observations are well considered and corrected. We find that the derived DM density, which is around $0.0159^{+0.0047}_{-0.0057}$ $M_\odot$ pc^{-3} providing a flat local rotation curve.

Keywords. Galaxy: kinematics and dynamics – Galaxy: disc – dark matter

1. Introduction and observation data

The local dark matter density is important not only for the astronomers in constraining the total mass of the dark matter halo of the Milky Way, but also for the physicists in the searching of the dark matter particles. Since Oort (1932) firstly measured this value, a great amount of works have been done to constrain the quantity of the dark matter in the solar neighborhood (Read 2014; Piffl *et al.* 2014; Bienaymé *et al.* 2014). However, the results are quite diverse and sometimes are not in agreement with each other. Comparisons of the various results of the measurement are difficult in the sense that either dynamical models or the observed samples are different.

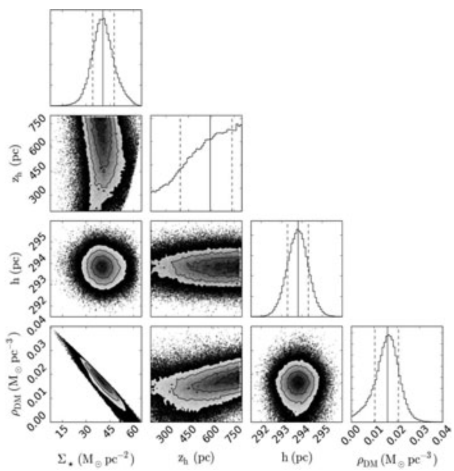

Figure 1. The MCMC result of the model parameters. The parameters from the left to right are $\Sigma_\star$, z_h, h, and ρ_{DM}, respectively. The parameters from top to bottom are z_h, h, and ρ_{DM}, respectively. The contours display the 0.5, 1, 1.5, and 2 σ levels. The solid lines in the histogram panels indicate the median values, and the dashed lines indicate the 1-σ region.

In this work, we carefully select more than 1400 G/K dwarf stars located at around the north Galactic pole (NGP) from the LAMOST DR2 catalog (Cui *et al.* 2012, Zhao *et al.* 2012, Deng *et al.* 2012). Because the Galactic latitude of these stars are larger than 85°, the line-of-sight velocities approximately equal to the vertical velocities. The uncertainty of the measured line-of-sight velocity is about 4-5 kms^{-1}. We adopt the distance obtained by Carlin *et al.* (2015) for the sample with uncertainty of 20%.

The selection effect is considered for the selected stars. Because the LAMOST survey does not explicitly bias to specific color index for the high Galactic latitude area in its targeting strategy, we can safely assume that the luminosity function of the spectroscopic stars is same as the photometric sample within a small sky region and color–magnitude diagram. Then we can use the number of the local photometric stars to correct the selection effect of the spectroscopic stars.

2. Dynamical model and result

We assume that

(a) The star tracers are in dynamical equilibrium.

(b) The Milky Way disk is axisymmetric.

(c) The rotation curve is flat and the local dark matter density is constant with z in the solar neighborhood.

From Jeans equation, we obtain

$$\frac{d}{dz}[\nu(z)\sigma_z^2(z)] = -\nu\frac{d\Phi(z)|_{R_\odot}}{dz}, \tag{2.1}$$

where ν, σ_z, and Φ are the vertical density profile, velocity dispersion, and gravitational potential, respectively. According to the Poisson's equation, we obtain

$$4\pi G(\rho_{disc}(z) + \rho_{gas}(z) + \rho_{\mathrm{DM}}(z))|_{R_\odot} = \frac{d^2\Phi(z)|_{R_\odot}}{d^2 z}, \tag{2.2}$$

where ρ_{disc}, ρ_{gas}, are ρ_{DM} the mass volume densities for the stellar disk, gas disk, and the dark matter halo, respectively. Finally, we give an analytical form for K_z force as (Zhang *et al.* 2013)

$$K_z(z) \equiv -\frac{d\Phi(z)}{dz} = -2\pi G\left\{\Sigma_\star\left[1-\exp\left(-\frac{\mathrm{z}}{\mathrm{z_h}}\right)\right] + \Sigma_{gas} + 2\rho_{\mathrm{DM}}z\right\} \tag{2.3}$$

We apply the Markov chain Monte Carlo (MCMC) simulation to derive the parameters based on the above equations and show the result in Figure 1. The surface density of the gas disk is adopted as $13\,M_\odot\ \mathrm{pc}^{-2}$ (Zhang *et al.* 2013). We finally find that the local dark matter density is $0.0159^{+0.0047}_{-0.0057}\ M_\odot\ \mathrm{pc}^{-3}$.

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