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Tracing the rotational velocity of the halo with K-giant stars in LAMOST-Gaia era

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Abstract. LAMOST has obtained a large number of spectra for K-giant stars whose metallicities are well measured and released in DR5. Combining with the distances, radial velocities and proper motions provided by Gaia DR2, the full position and velocity information has been obtained. Using the Bayesian method we have constrained the rotational velocity of the halo and thick disk components in the local volume within 4 kpc from the Sun. The values of the rotational velocity are 27^{+4}_{-5} km s^{-1} and 182^{+6}_{-6} km s^{-1} for the halo and disk respectively, with the velocity of LSR assumed to be 232 km s^{-1}. The dispersions of the rotational velocity are 72^{+4}_{-4} km s^{-1} and 45^{+3}_{-3} km s^{-1} for the two components. What's more, another hot retrogradely rotating component is discovered.

Keywords. Halo, kinematics, Milky Way

1. Introduction

The stellar halo is a complicated component in the Milky Way, where there are lots of substructures embedded, such as dwarf galaxies, globular clusters and stellar streams. Those substructures are proving the hierarchical formation model. After a long time, many stars belonging to those substructures have been phase-mixed and transferring their angular momentum to the halo, those merging events can affect the spin of the halo. In other words, studying the rotation of the halo can help trace back the merging history of the halo. Frenk & White (1980) firstly studied the halo rotation using 66 clusters. A value for the rotational velocity was obtained to be 60 ± 26 km s^{-1}. In the following decade, Morrison *et al.* (1990) also found a progradely rotating halo with speed of 25 ± 15 km s^{-1} using G and K giant stars within 4 kpc to the Sun. More recently, Deason *et al.* (2017) also found the halo rotates progradely, but with a smaller velocity of $14 \pm 2 \pm 10$ km s^{-1}. The second data release of Gaia mission provides an opportunity to constrain the rotational velocity of the halo with a much higher accuracy. Here we show the accurate results of measuring the rotational velocity using the K-giant stars selected from LAMOST DR5.

2. Data & Results

K-giant stars have been selected by Liu *et al.* (2014) from LAMOST DR5. Cross-matching with Gaia DR2, we obtain accurate distances, radial velocities and proper motions from Gaia DR2. Removing the metal-richer stars, [Fe/H]> -1, almost all of the thin disk stars and majority of the thick disk stars are removed. Constraining the uncertainties of the measurements, e.g the relative diantance error lower than 0.2, 3827 K-giant stars are left in the final sample with median proper motion uncertainties around 0.06 mas yr^{-1} and median radial velocity uncertainty lower than 1 km s^{-1}.

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Table 1. Best fit values derived from Bayesian method are listed. The parameters for the halo, the disk and the retrogradely rotating component are marked with H, D and R.

[Fe/H]	f_H	f_D	$V_{T,H}$ km s^{-1}	$\sigma_{T,H}$ km s^{-1}	$V_{T,D}$ km s^{-1}	$\sigma_{T,D}$ km s^{-1}	$V_{T,R}$ km s^{-1}	$\sigma_{T,R}$ km s^{-1}	N
all	$0.74^{+0.04}_{-0.05}$	$0.23^{+0.03}_{-0.03}$	27^{+4}_{-5}	72^{+4}_{-4}	182^{+6}_{-6}	45^{+3}_{-3}	-99^{+47}_{-58}	124^{+23}_{-19}	3827
$-2.5\sim-1.6$	$0.83^{+0.09}_{-0.16}$	$0.05^{+0.04}_{-0.02}$	38^{+9}_{-8}	85^{+5}_{-7}	212^{+12}_{-37}	30^{+21}_{-9}	-47^{+32}_{-58}	113^{+21}_{-9}	1134
$-1.6\sim-1.3$	$0.75^{+0.07}_{-0.07}$	$0.22^{+0.07}_{-0.06}$	11^{+7}_{-7}	63^{+5}_{-5}	159^{+18}_{-18}	56^{+8}_{-8}	-115^{+60}_{-55}	158^{+25}_{-26}	1020
$-1.3\sim-1.0$	$0.55^{+0.06}_{-0.06}$	$0.42^{+0.04}_{-0.04}$	24^{+7}_{-6}	60^{+7}_{-7}	176^{+6}_{-6}	47^{+3}_{-3}	-31^{+23}_{-52}	112^{+25}_{-9}	1673

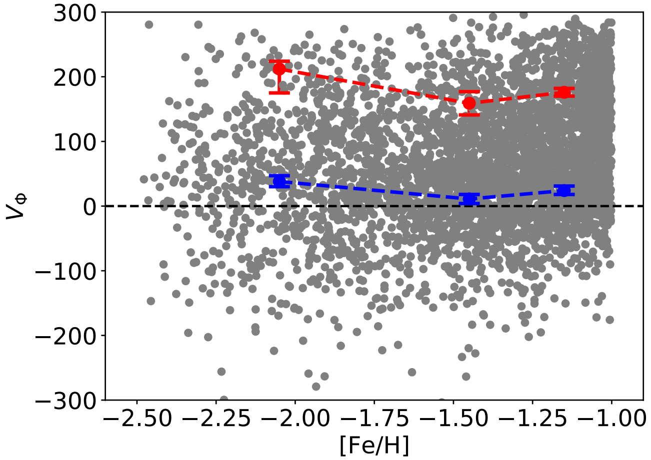

Figure 1. The distribution of K-giant stars in rotational velocity V_Φ versus metallicity [Fe/H]. The red and blue lines represent the distribution of the rotational velocity for the disk and halo components in different metallicity ranges, respectively. The errorbars represent the uncertainties. Those parameters are derived from Bayesian method, which are also listed in Table 1.

Bayesian method is applied on the final sample with a model containing three Gaussian distributions for the halo, the disk and a retrogradely rotating component. Table 1 lists the results of the parameters for the local volume within 4 kpc to the Sun, and the results for subsamples in different metallicity ranges. We find that the halo is progradely rotating with a speed of 27^{+4}_{-5} km s^{-1} with a dispersion 72^{+4}_{-4} km s^{-1}, which is consistent with the results of Morrison *et al.* (1990). Considering the rotational velocity distribution as a function of the metallicity, as shown in Figure 1, we do not find a significant relation between the rotational velocity and the metallicity for the halo (the blue symbols, also listed in Table 1 as $V_{T,H}$), which might be affected by the recently discovered merger event Gaia-Enceladus by Helmi *et al.* (2018). But the dispersion for the most metal-poor subsample is significantly larger. Besides the halo and the disk, we also find another halo component, which is retrogradely rotating with a larger dispersion, 124^{+23}_{-19} km s^{-1}.

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