Halo K-Giant Stars from LAMOST: Kinematics and Galactic Mass Estimate

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ABSTRACT

We analyze the line-of-sight velocities of several thousand halo K-giant stars from the third data release of the spectral survey LAMOST. We make use of a new method to estimate the enclosed mass of the Milky Way within 85 kpc from the Galactic Center using the velocities and distances of these K giants. We derive estimates for the virial mass and radius and concentration parameter from our mass profile. Tens of thousands of such stars are expected to become available to this analysis by the end of the five year survey. We find a nearly constant line-of-sight velocity dispersion profile, no large dips or peaks, in a Galactocentric radial range of 15 to 85 kpc, where such dips have been seen in other surveys. The flatness of the profile may be an indication that the Milky Way's halo star velocity ellipsoid is isotropic.

Halo K-Giant Sample

We use the third data release of the Large Sky Area Multi-object Fiber Spectroscopic Telescope (LAMOST, Fig. 1) survey (Cui et al. 2012, Deng et al. 2012, Luo et al. 2012, Zhao et al. 2012).

Based on the following criteria, we select over 5700 stars as halo K giants from the 700,000 stars classified as K giants by the LAMOST pipeline (Wu et al. 2011; Luo et al. 2012). A major advantage of LAMOST is the quantity of spectra which it collects per pointing using 4000 fibers and a large field of view. With these it is well equiped to add tens of thousands of stars to this study. Fig. 2-3 shows the spatial distribution of the current sample, Fig. 4 the density profile, and Fig. 5 the line-of-sight velocities as a function of Galactocentric radius.

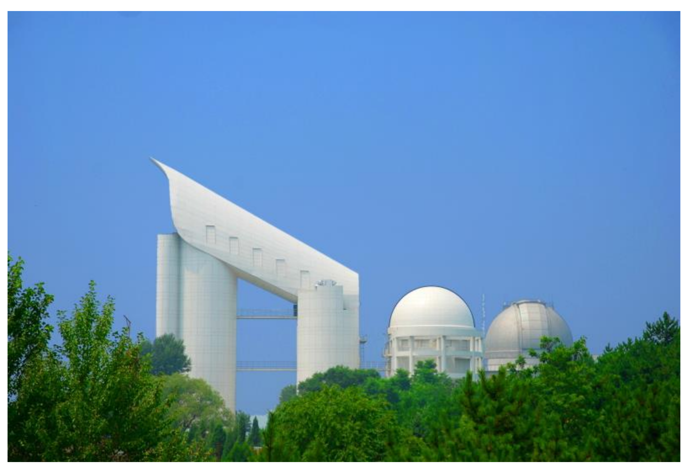

Fig. 1 LAMOST, 4 m Schmidt telescope located in Xinglong Station, China

Selection Criteria

- $4000 < T_{eff}$ /K <5600
- surface gravity log(g) < 4
- Exclusion of red clump stars based on Mg_b lines (Liu et al. 2014)
- Distance measurements from Carlin et al. 2015
- Galactic vertical height |Z| > 5 kpc
- [Fe/H] < -1.3 dex

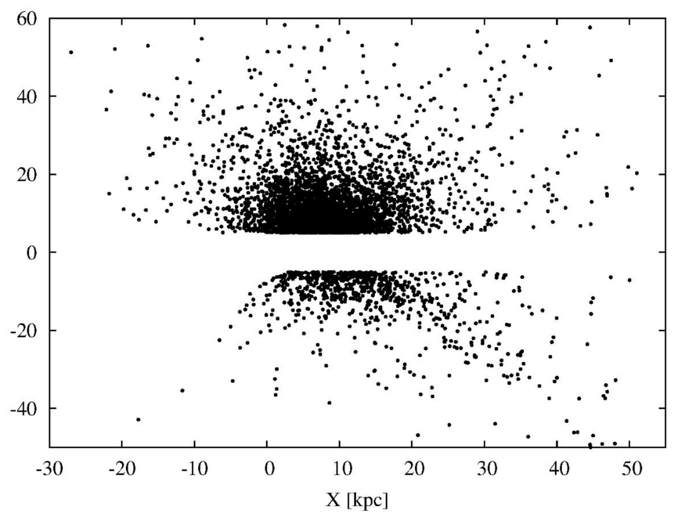

Fig. 2 Spatial distribution of our selected LAMOST halo K-giant stars. Galactocentric Cartesian coordinates for X and Z

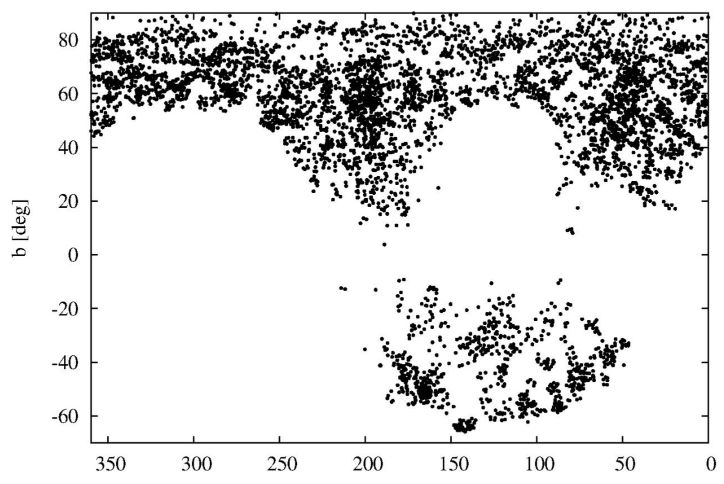

Fig. 3 Spatial distribution in Galactic longitude and longitude (l,b) of our selected LAMOST halo K-giant stars.

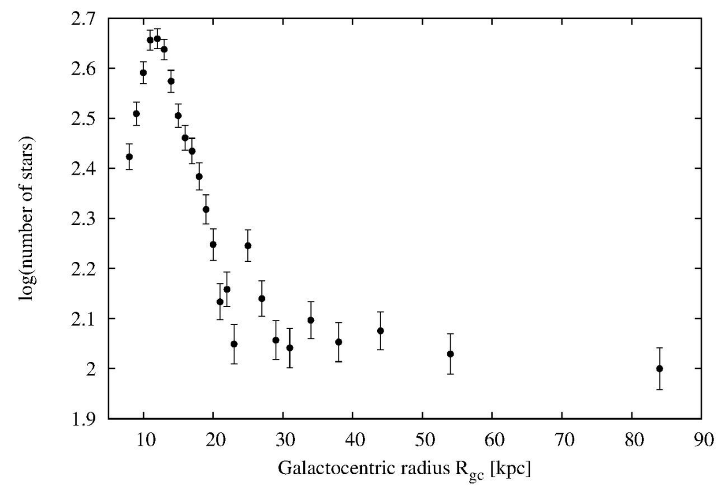

Fig. 4 Observed density distribution of our selected LAMOST halo K-giant stars along logarithmic Galactocentric radius in spherical coordinates. No corrections have been made for the LAMOST selection function (Carlin et al. 2012).

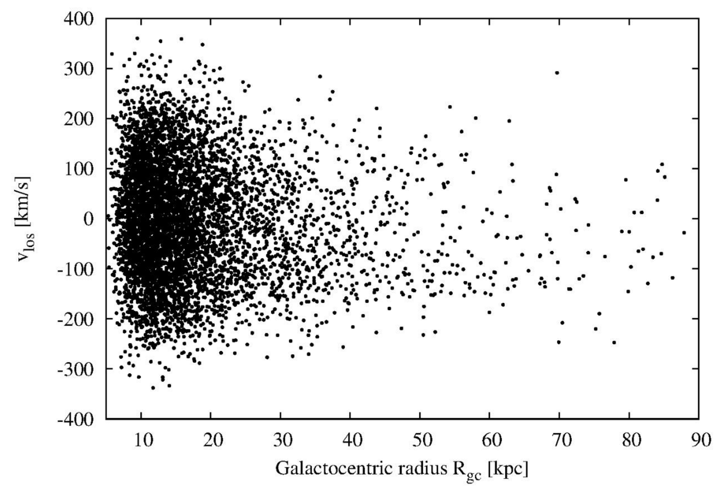

Fig. 5 Distribution of the Galactocentric line-of-sight velocities for our selected LAMOST halo K-giant stars as a function of Galactocentric radius in spherical coordinates

Results (I): Mass Estimate of the Milky Way

We estimate the mass profile (Fig. 6) and the virial mass of $M_{vir} = 7 \pm 2 \times 10^{11}$ $M_{\odot}$. This is slightly smaller as compared to previous studies (Table 1). We use the scale-free mass estimator Evans et al. 2011, a convenient method to use the observed line-of-sight velocities and distances of halo objects to estimate the mass of the Milky Way. In the range of 15-85 kpc from the Galactic Center, we use our line-of-sight velocities to estimate the enclosed Milky Way mass profile (Fig. 6). The enclosed mass within 85 kpc is $M = 5 \pm 2 \times 10^{11}$ $M_{\odot}$. Fitting the mass profile with an NFW profile (Navarro et al. 1996), we find the virial mass, virial radius R_{vir}=250 kpc, and concentration parameter c = 30. We assume an isotropic velocity distribution and stellar density distribution represented by a power law with index of 3.

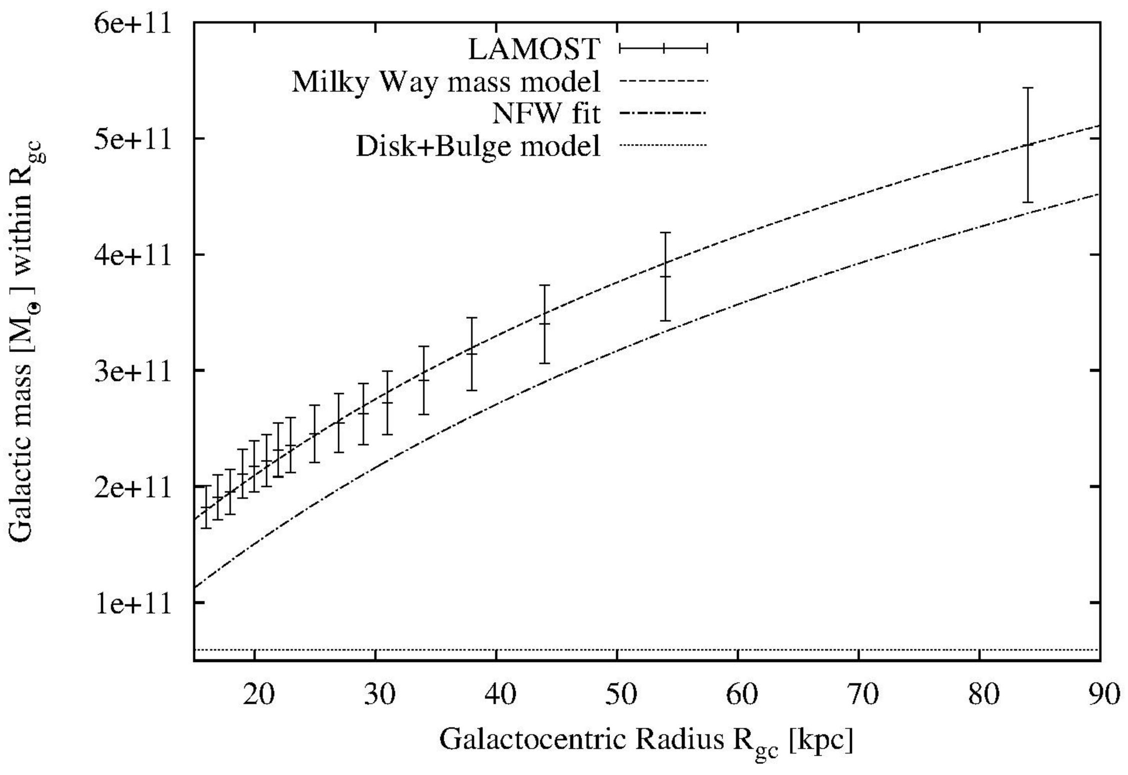

Fig. 6 Profile (dash-symbols with 10% errorbars) of the mass enclosed for our selected LAMOST halo K-giant stars as a function of Galactocentric radius in spherical coordinates out to 85 kpc. The data is fit (dashed line) with a mass model consisting of the bulge and disk components 5.9 x 10^{10} $M_{\odot}$ (dotted line) of Bovy & Rix (2013) and the NFW profile (Navarro et al. 1996, dot-dashed line).

Table 1. Recent spectroscopic stellar halo investigations

Tracer Stars	Number	Distance Range [kpc]	Velocity	Virial Mass [10^{12} $M_{\odot}$]	concentration parameter	r_{vir} [kpc]	Survey	Reference
K giant	**5740**	**3 - 155**	**line-of-sight**	**0.7±0.2**	**30**	**250**	**LAMOST**	**Bird+16**
K giant	6036	5-125	line-of-sight	---	---	---	SDSS/SEGUE	Xue+14
K giant	5140	5 - 155	radial	$0.90^{+0.46}_{-0.26}$	20	543	SDSS/SEGUE	Kafle+14
Blue horizontal branch	4664	5 - 60	radial	$0.90^{+0.4}_{-0.3}$	12	249	SDSS/SEGUE	Kafle+12
Subdwarf	1717	6 - 12	radial	...	...	...	SDSS/SEGUE	Smith+09
Blue horizontal branch	2558	5 - 60	line-of-sight	$0.91^{+0.27}_{-0.18}$	12	267	SDSS/SEGUE	Xue+08

Results (II): Line-of-Sight Velocity

The line-of-sight velocity dispersion profile of our sample as compared to recent studies using different halo objects in Fig. 7. Studies using stellar tracers are described in Table 1. The LAMOST K-giant line-of-sight velocity dispersion profile is flat and agrees well with previous studies (Fig. 7).

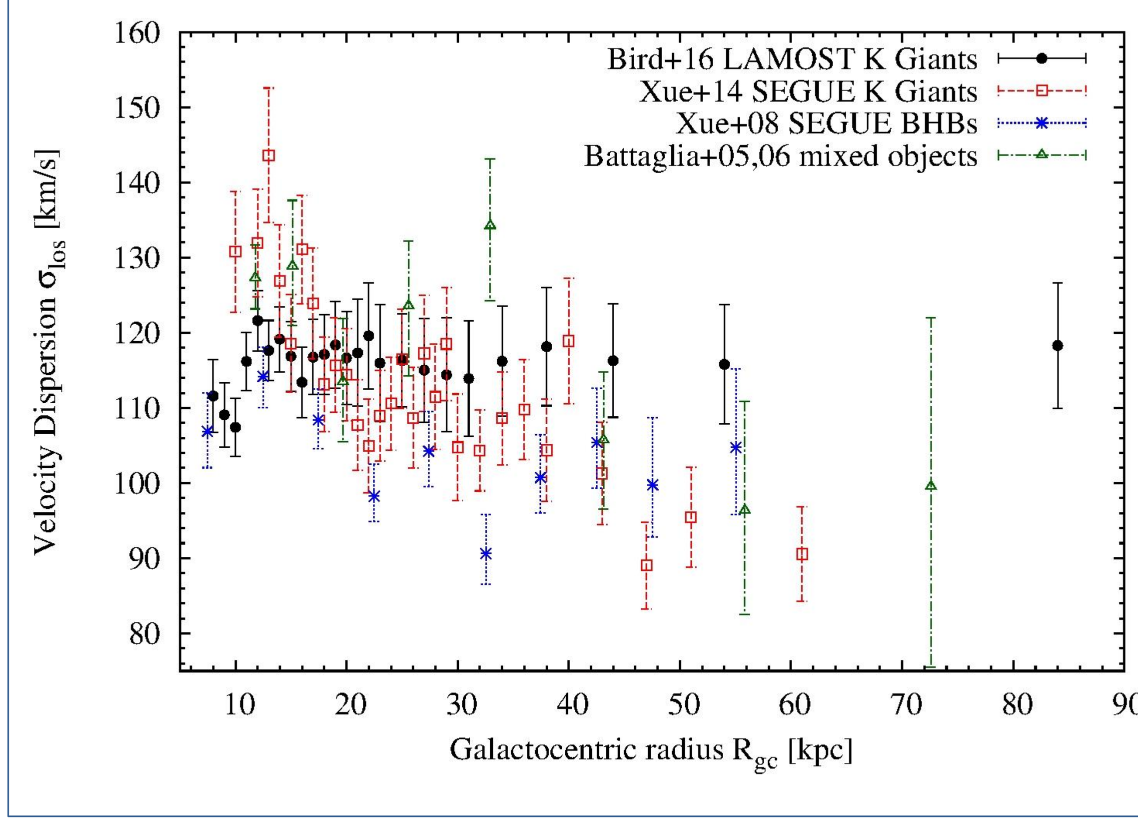

Fig. 7 Comparison of Galactocentric line-of-sight velocity dispersion for our selected LAMOST halo K-giant stars and previous studies as a function of Galactocentric radius in spherical coordinates. The profiles follow a flattened distribution.

Future Steps and Summary of Results

- Quantify how different the velocity dispersion profile can be when using observable line-of-sight velocites as substitutes for true radial velocites
- Collect more stellar spectra with LAMOST
- Get the tangential velocities from Gaia
- Preliminary estimate of the Milky Way's dark halo mass out to the virial radius is $M_{vir} = 0.7 \pm 0.2 \times 10^{12}$ $M_{\odot}$.
- Galactocentric line-of-sight velocity dispersion profile of halo K giant stars is flat, showing no large drops or peaks as seen in the previous studies of the radial velocity dispersion.

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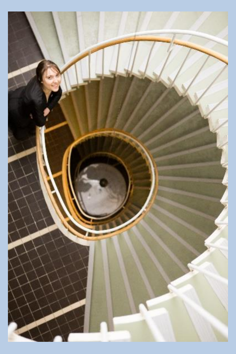

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