The Stellar Velocity Distribution Function in the Milky Way Galaxy

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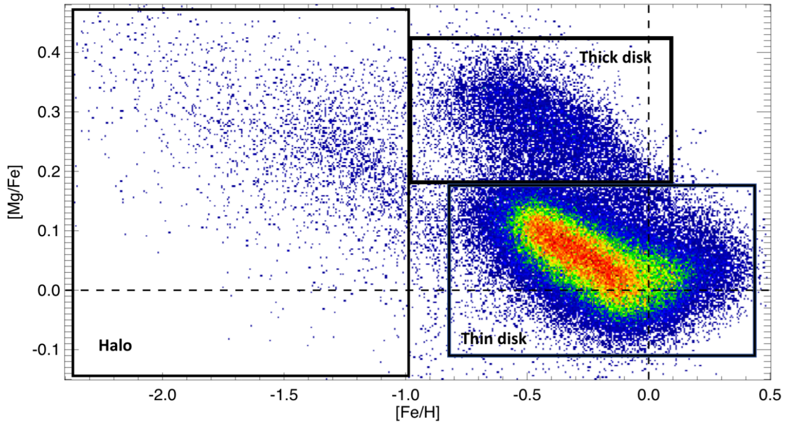
SDSS-IV Paper 0439 on SDSS-IV Project 0692

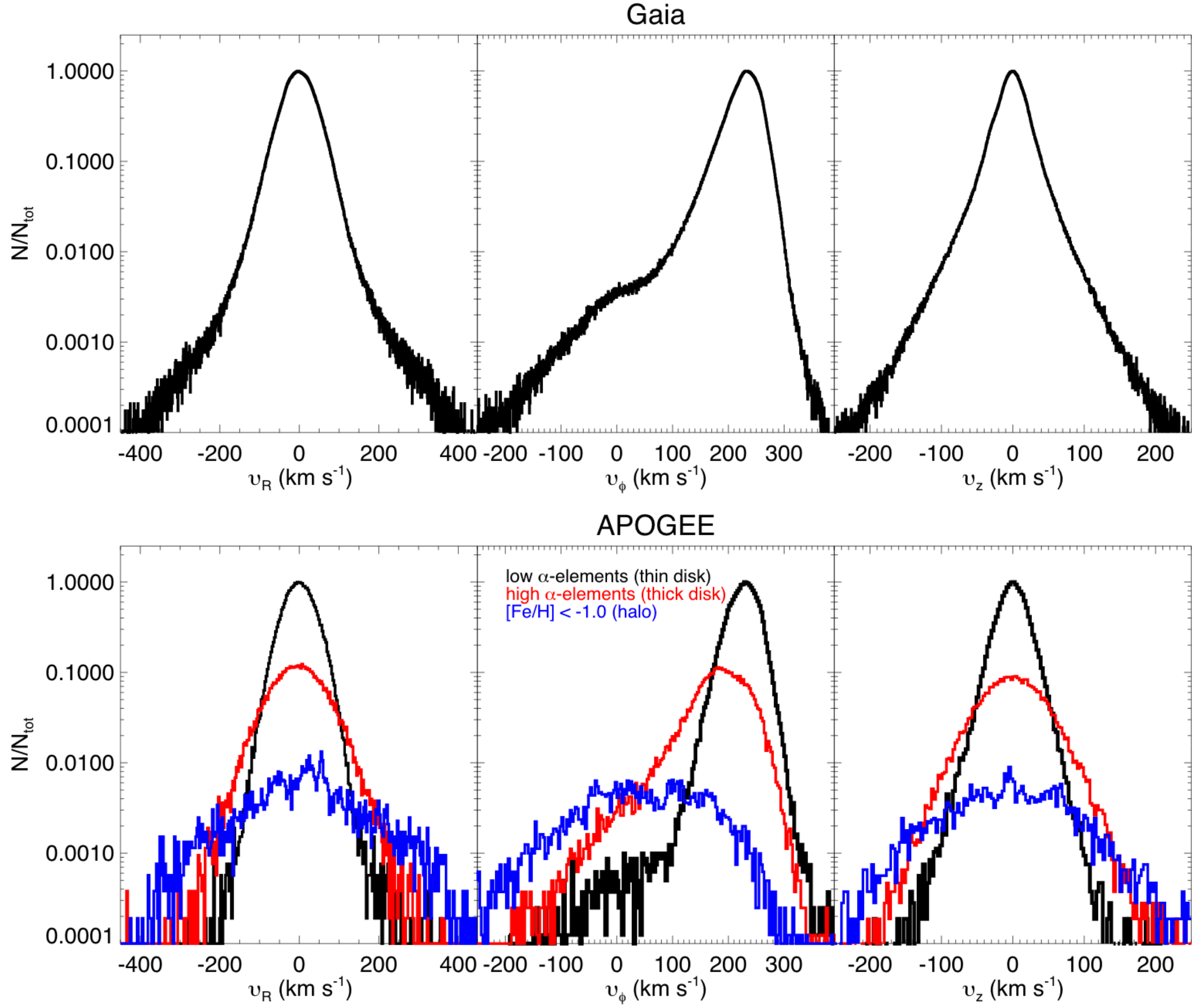
Motivation

- The **velocity distribution function** (DF) of stars in the Galaxy - uncovering the relationships between kinematics, metallicity and age for disk and halo stars - **dynamical history of stellar populations**.
- Unbiased study of the Galactic velocity DFs — derived from Gaia data— for the individual, **chemically-separated stellar populations**, and to explore how these distributions change for different Galactocentric radii and distances from the Galactic mid-plane.
- Built a **kinematical data-driven** model, that we then apply to the full Gaia database to ascertain the contribution of the different Galactic structural components to the velocity-space DF as a function of Galactic cylindrical coordinates, R and z.

APOGEE - Gaia

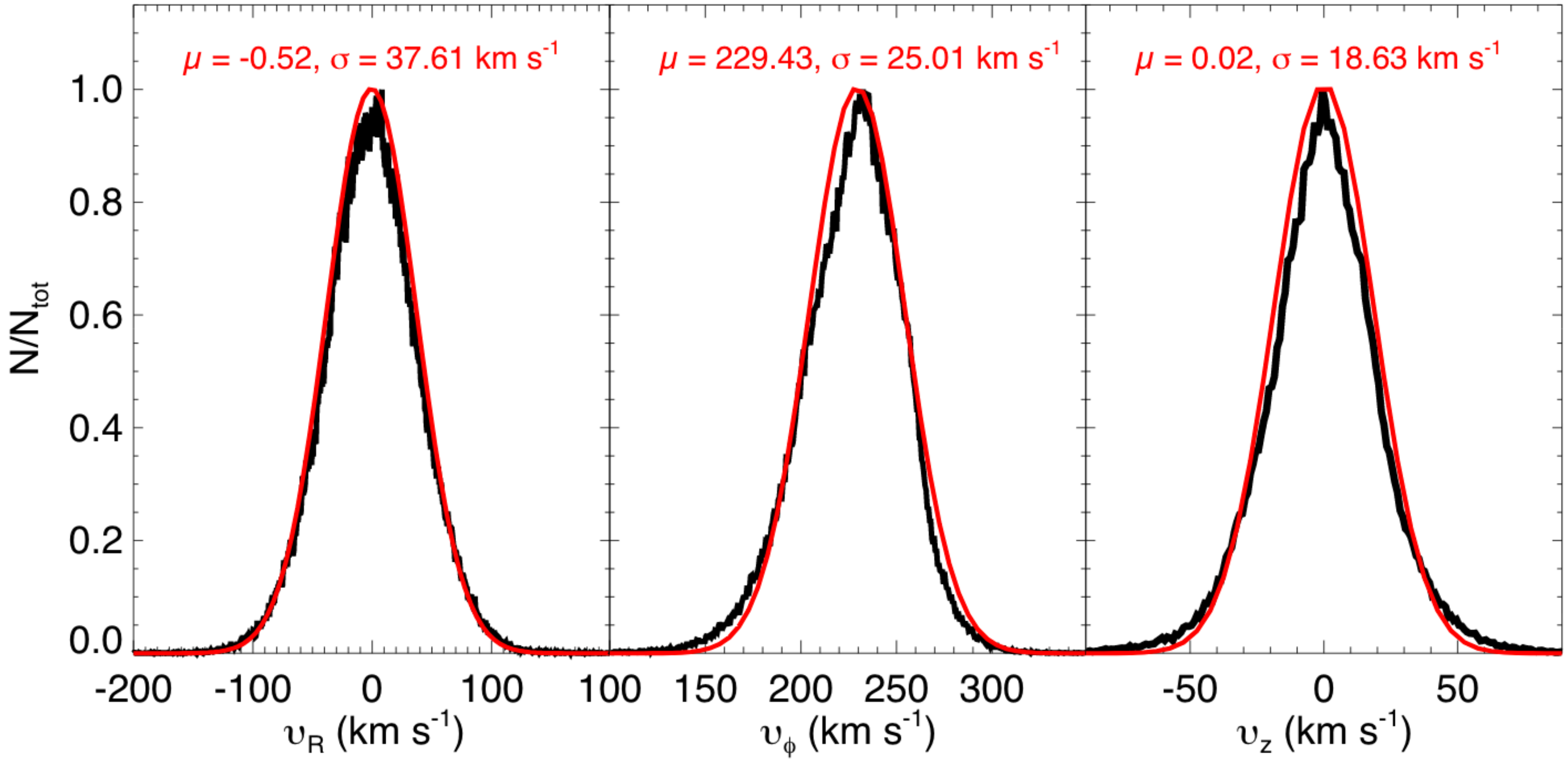
- APOGEE and Gaia are outstanding data-sets. Congratulations to these teams for such an amazing work!





It is not possible on the basis of kinematical data alone to determine with reliability even the relative contributions of the different populations to the net velocity DF on a statistical basis. Figure shows that the velocity DF of the different Galactic components clearly overlap, but also, that individual abundances from high-resolution spectroscopy surveys are a useful tool for apportioning stars to their relative stellar populations.

Galactic thin disk



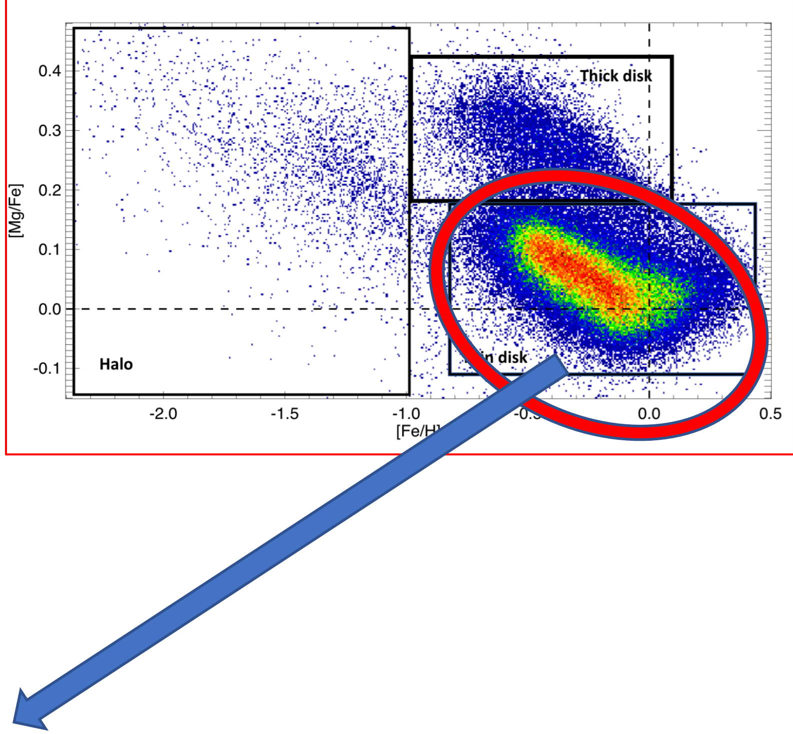
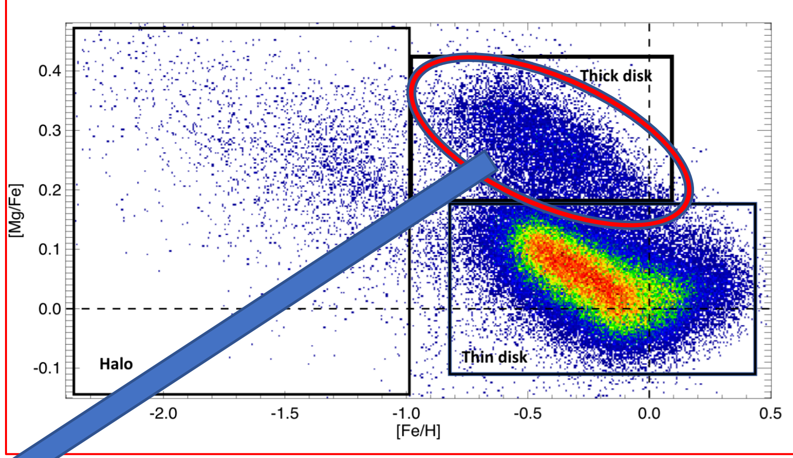


FIG. 4.— Velocity distribution function for the chemically selected APOGEE thin disk (black distribution) for the υ_R, υ_ϕ and υ_z velocity components, respectively. The red distributions in the three panels show the best-fit following a single Gaussian function. The mean and the standard deviation of the normal distributions are shown in each panel.

Galactic thick disk



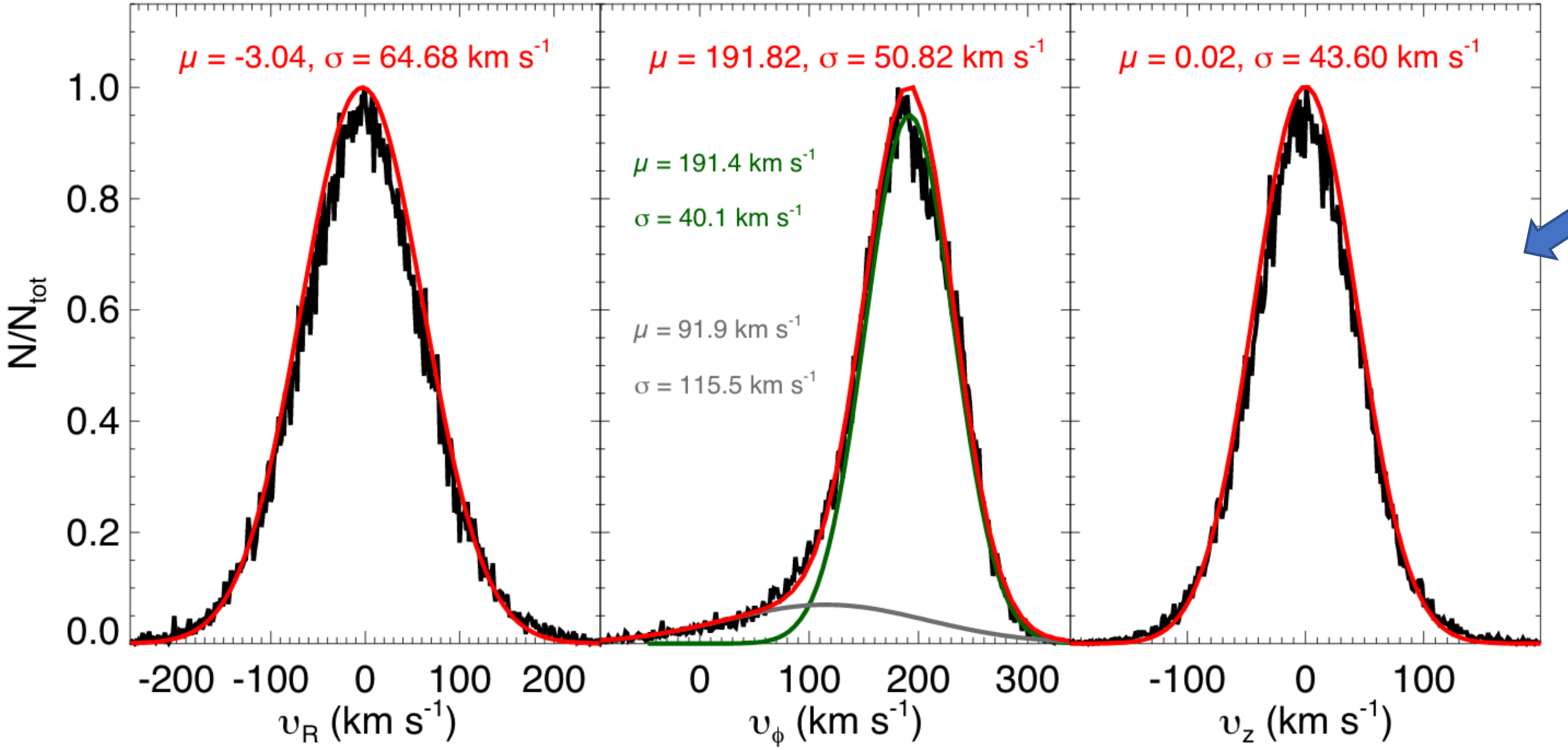
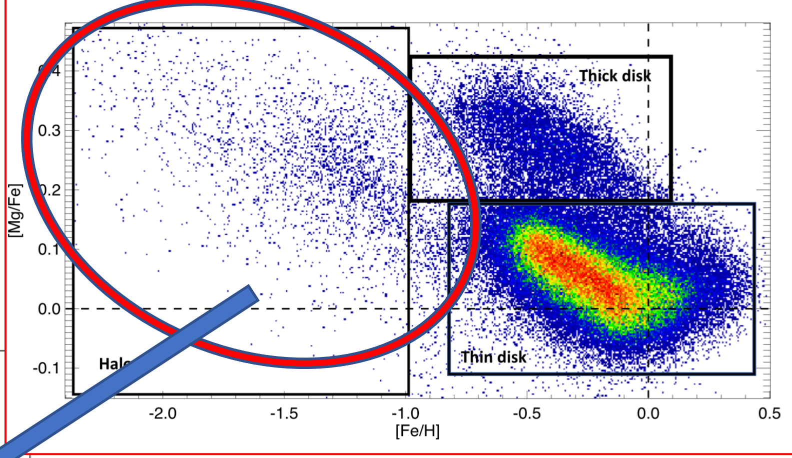


FIG. 5.— Same as Fig. 4, but for the thick disk. However, for the υ_ϕ component the red curve represents the sum of a two-component Gaussian decomposition of the distribution, needed to account for the asymmetric tail due to a broader spread in asymmetric drift (see text). The components of this two-component fit are shown by the green and grey curves and listed values.

[Fe/H] < -1.0 — Halo population



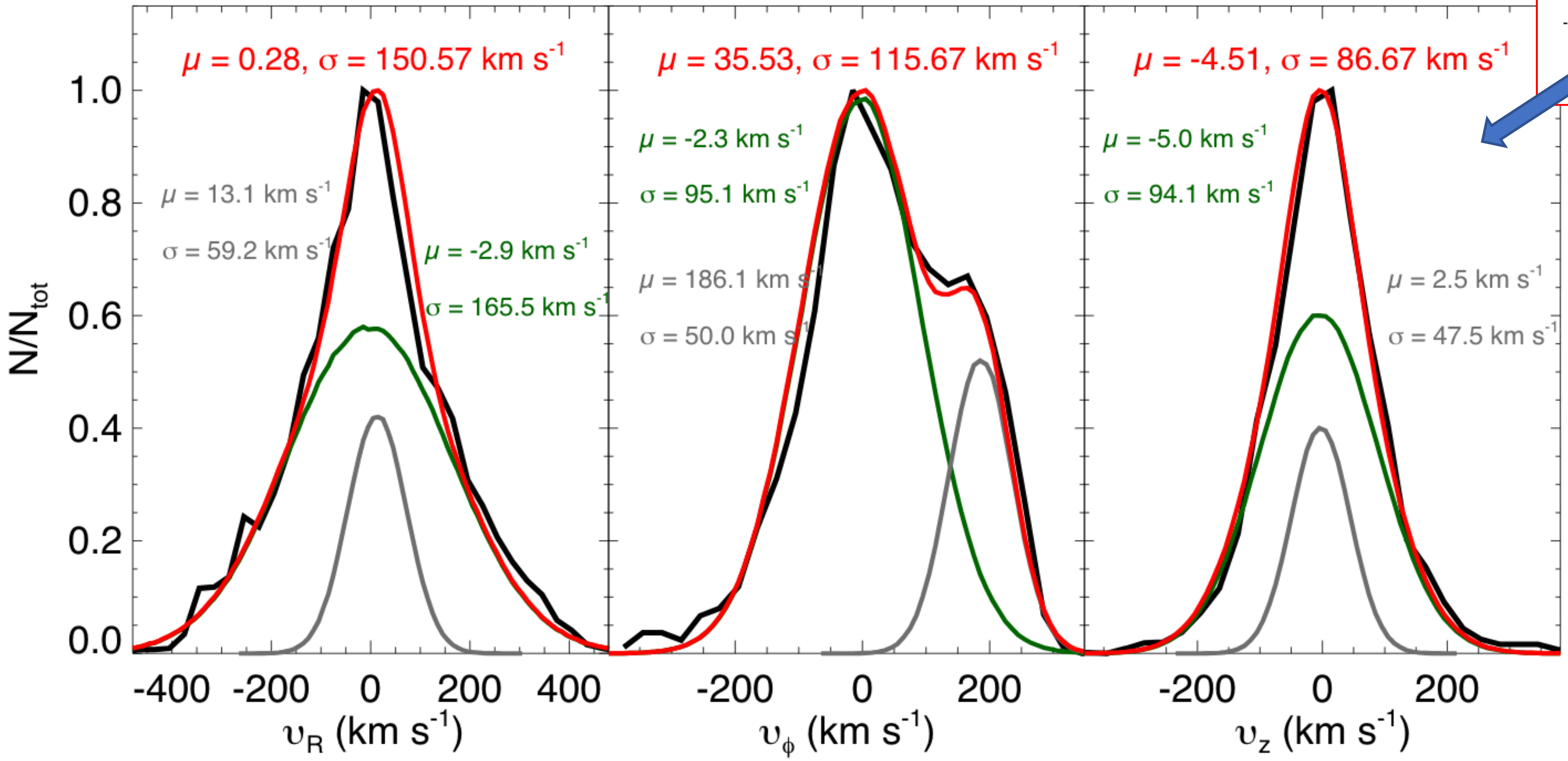


FIG. 6.— Same as Figs. 4 and 5, but for the Milky Way halo, defined by stars with [Fe/H] < -1.0 (black distribution). In this case, all three velocity components are fitted by a mixture of two Gaussian components (see text for details). The mean and the standard deviation of the mixture distributions are shown in the top of each panel in red, and for each Gaussian component in grey and green.

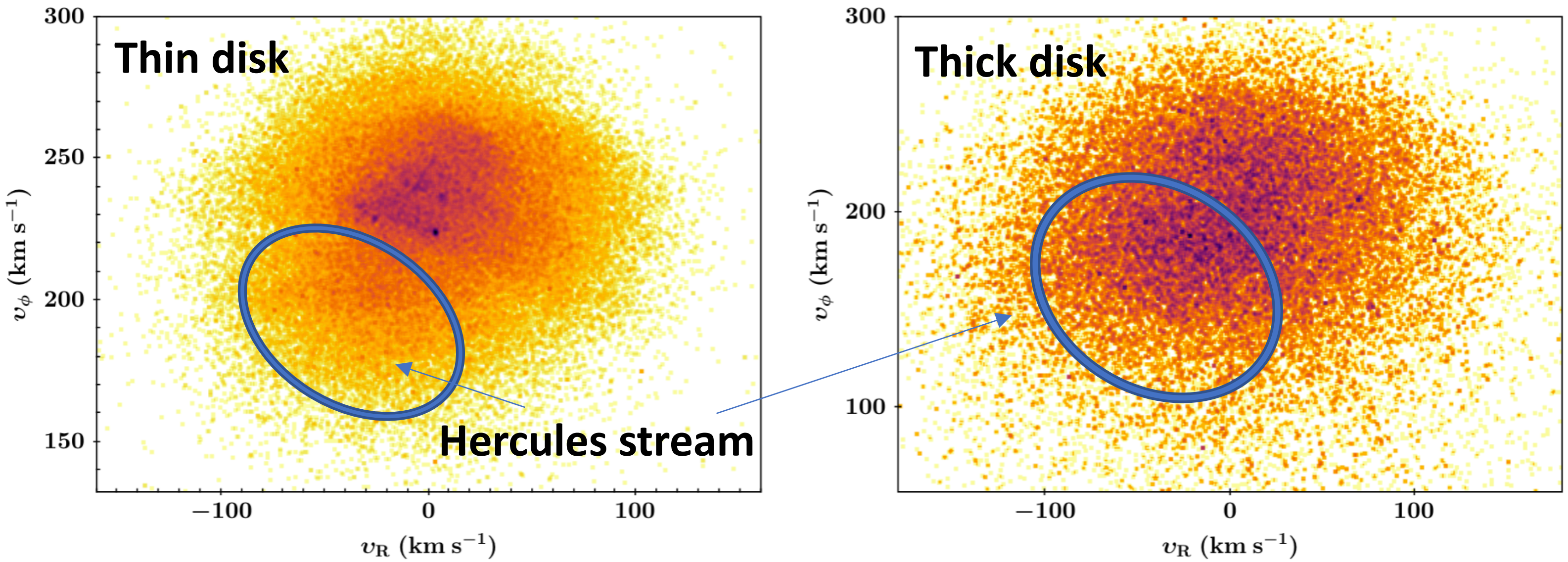
Disk(s) and halo Kinematical properties

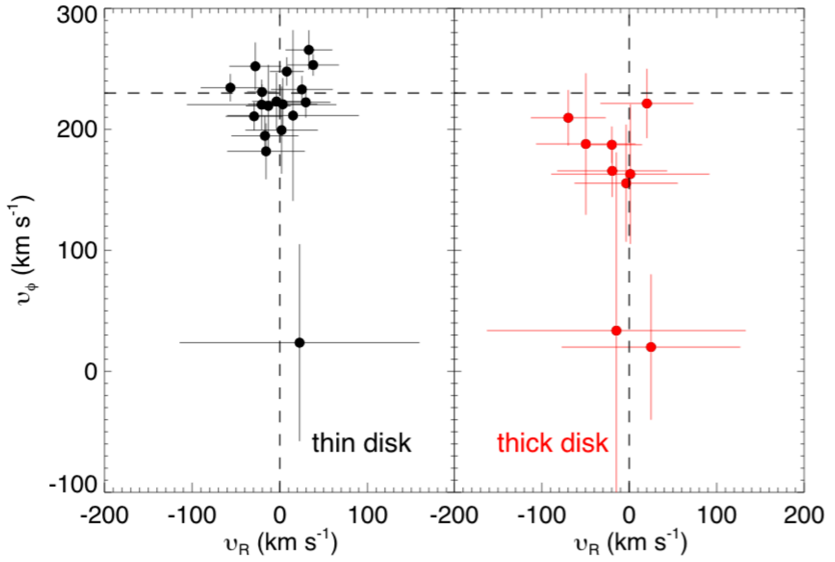
TABLE 1
SUMMARY OF THE KINEMATICAL PROPERTIES FOR DIFFERENT POPULATIONS SUBSAMPLES

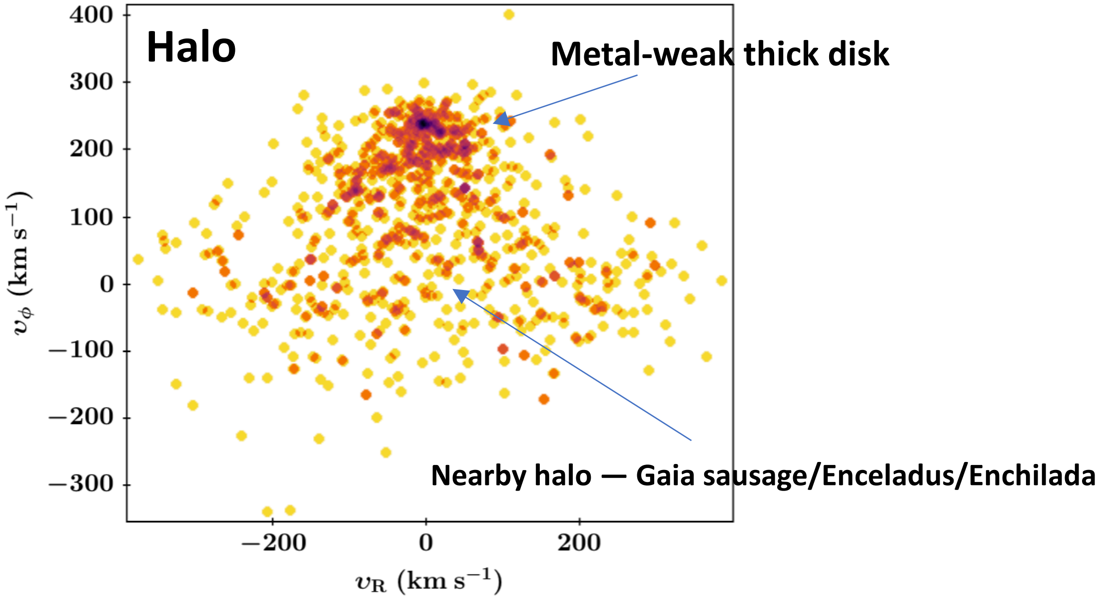
	$\overline{v_\phi}$ (km s^{-1})	σ_R (km s^{-1})	σ_ϕ (km s^{-1})	σ_z (km s^{-1})	σ_ϕ/σ_R	σ_z/σ_R
Chemically selected thin disk	+229.43 ± 0.54	37.61 ± 0.07	25.01 ± 0.04	18.53 ± 0.03	0.66 ± 0.01	0.49 ± 0.01
Chemically selected thick disk	+191.82 ± 0.24	64.68 ± 0.20	50.82 ± 0.15	43.60 ± 0.13	0.78 ± 0.01	0.67 ± 0.01
Halo ([Fe/H] < -1)	+35.53 ± 1.28	150.57 ± 1.58	115.67 ± 1.21	86.67 ± 0.91	0.77 ± 0.02	0.57 ± 0.01
Disk-like rotation	+186.10 ± 1.66	59.23 ± 1.39	50.00 ± 1.17	47.55 ± 0.85	0.84 ± 0.03	0.80 ± 0.02
Non-rotation	–2.35 ± 1.57	165.51 ± 1.94	95.12 ± 1.11	94.10 ± 1.16	0.57 ± 0.01	0.57 ± 0.01

The metal-weak thick disk has kinematic parameters are pretty close to the regular thick disk.

The $V_R - V_\phi$ plane



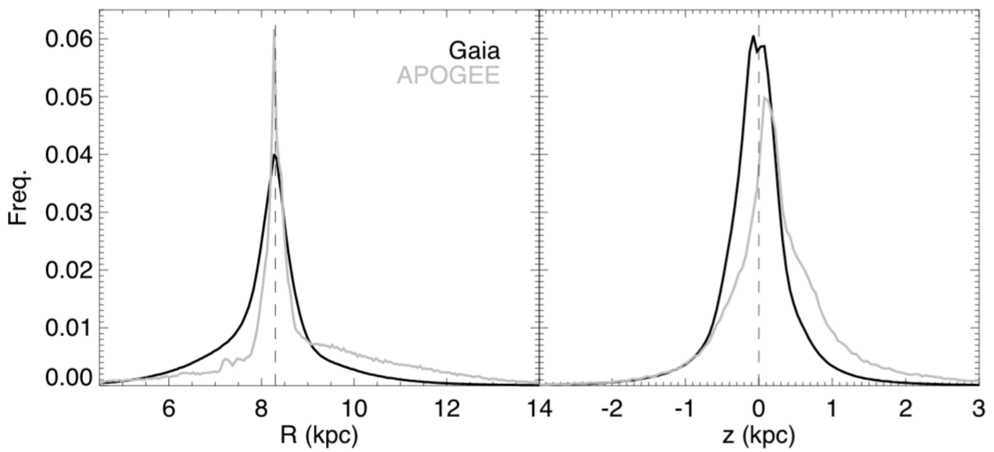




The sub-structure seen in the phase space for the thin disk is not detected for the thick disk stellar density.

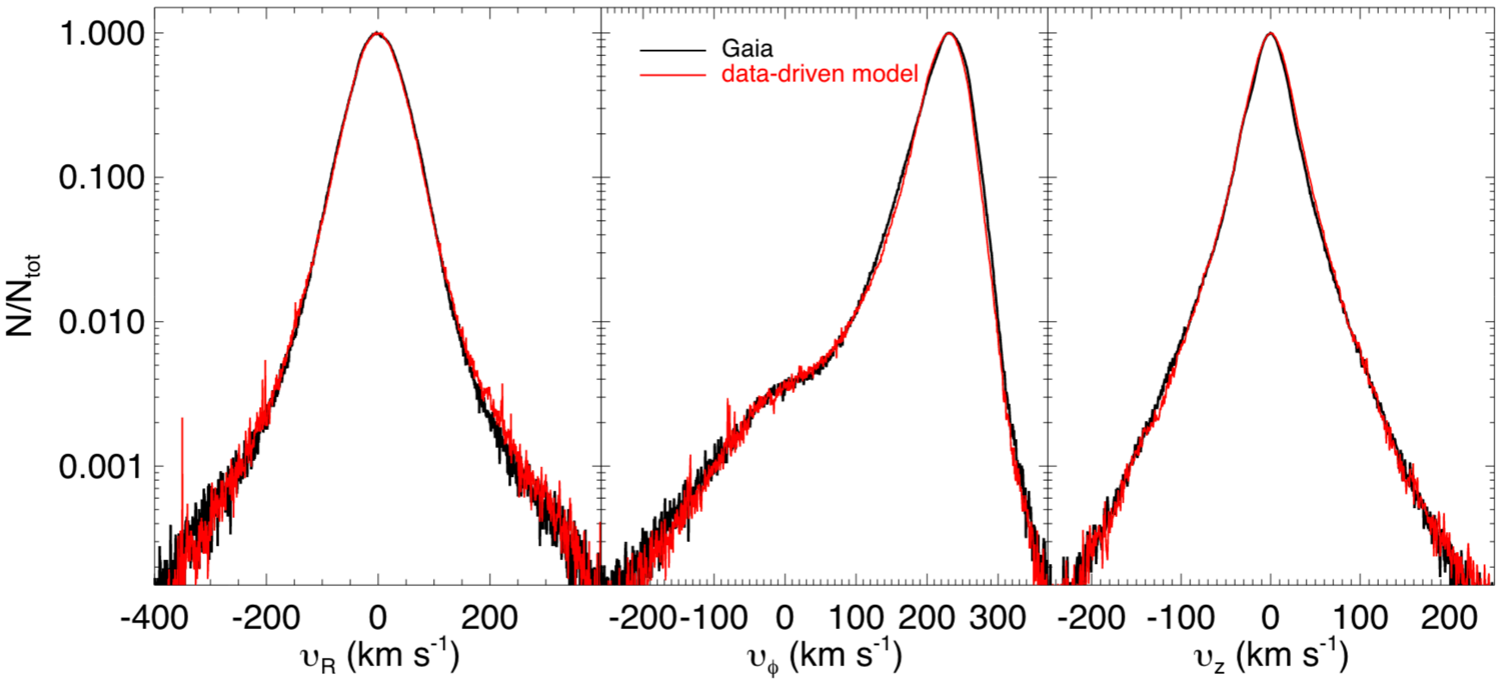
Variational Bayesian Gaussian mixture modeling of the distribution of thin and thick disk stars in the υ_R – υ_φ plane

Data-driven model

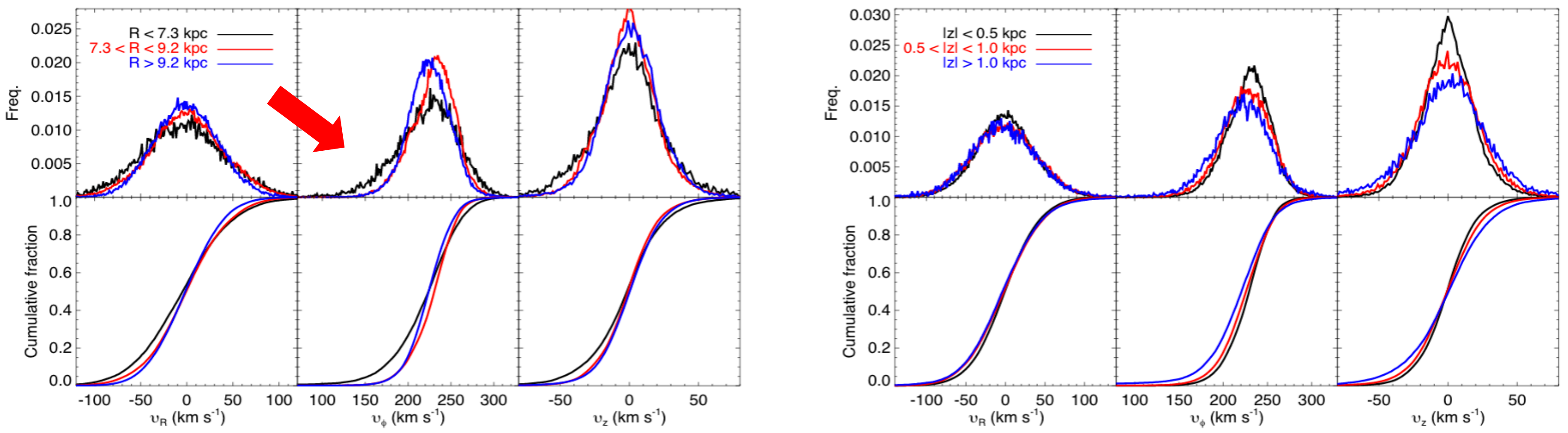


The spatial distributions for the two samples are remarkably similar, despite the fact that the APOGEE sample studied here is predominantly a survey dominated by giant stars, whereas the larger Gaia sample studied here is parallax-error-limited and dominated by dwarf stars

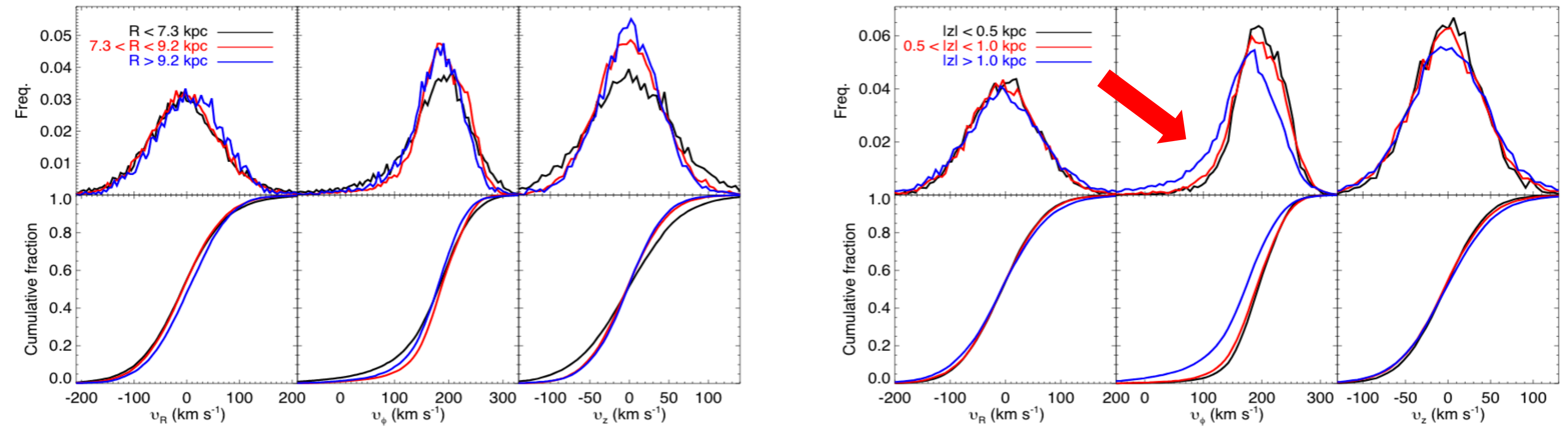
We estimate that 81.9 ± 3.1 % of the objects in the selected Gaia data-set are thin disk, 16.5 ± 3.2 % are thick disk stars, and 1.6 ± 0.1 % belong to the Milky Way halo.



The 3D velocity DF as a function of R and z



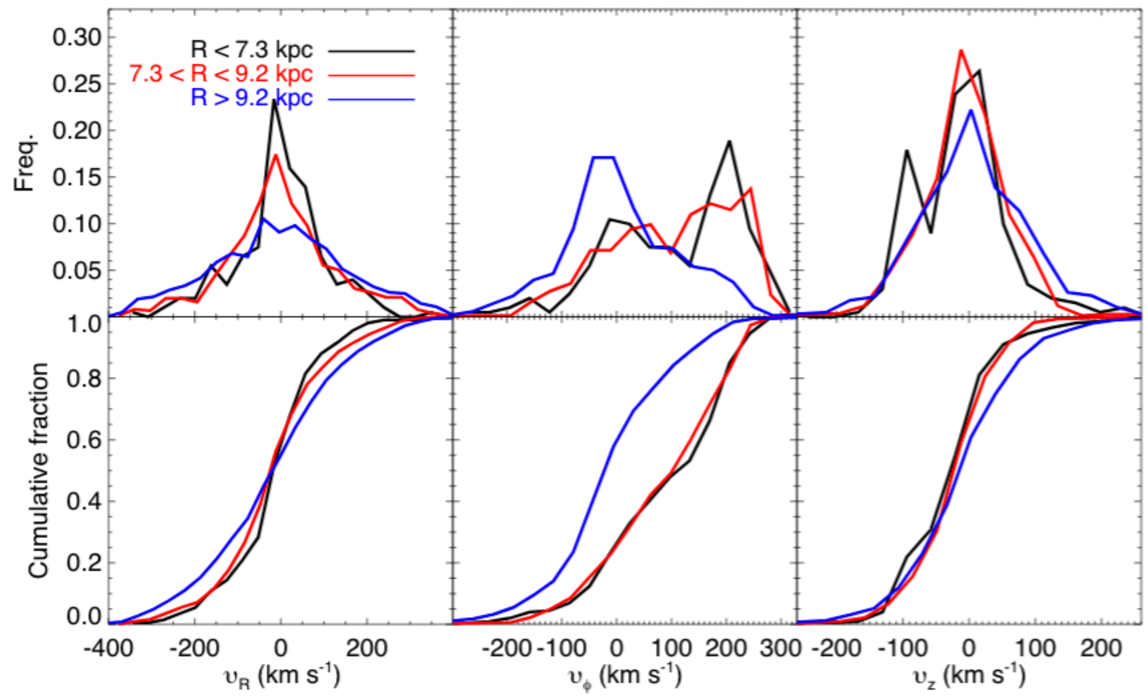
Thin disk

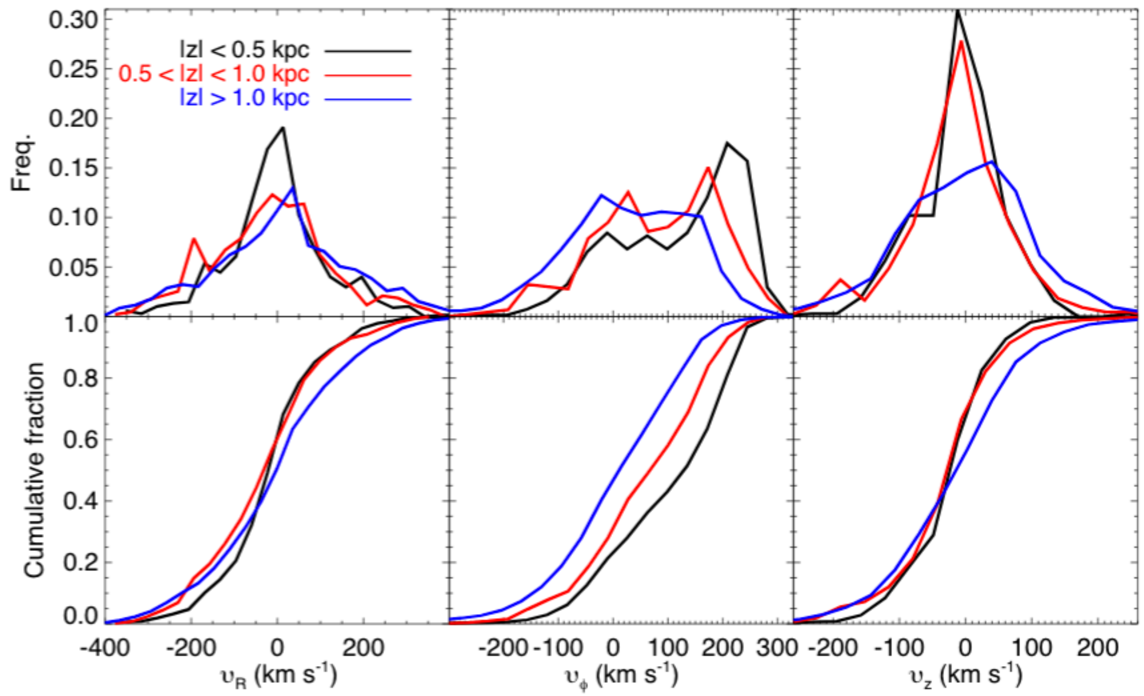


Thick disk

The 3D velocity DF as a function of R and z

Halo — [Fe/H] < -1.0





Thick disk normalization – fp = (ρ_T/ρ_t)

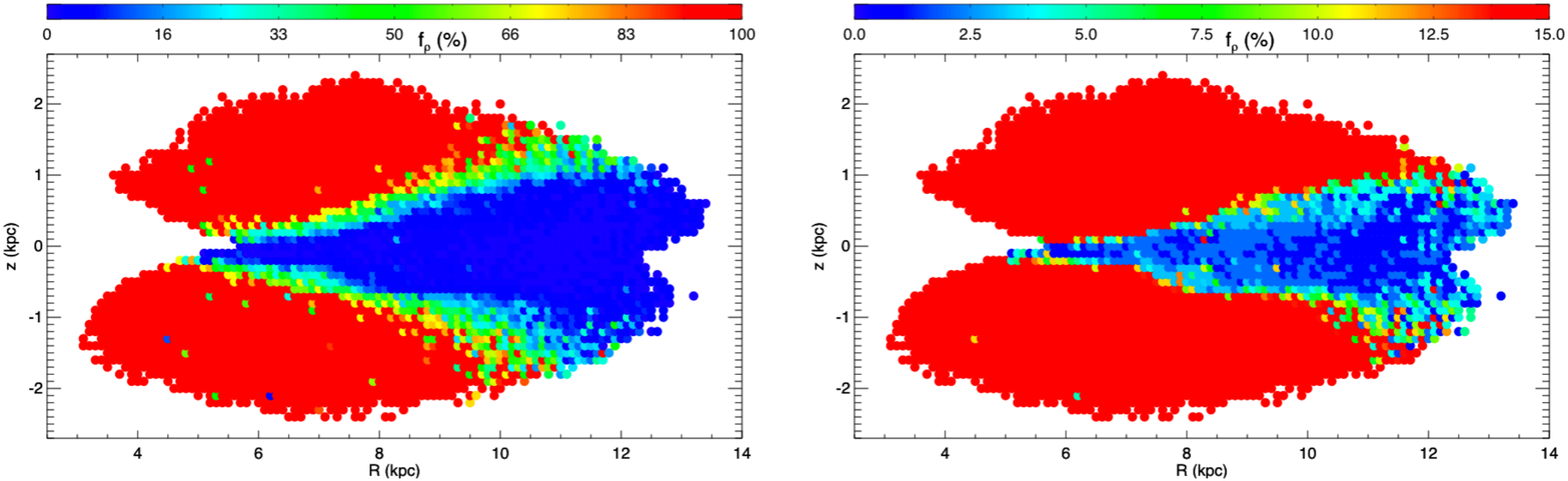


FIG. 15.— The relative density of *Gaia* stars in the R-z plane color-coded by f_ρ for the fraction of stars that belong to the thin disk and thick disk. The right panel is the same as the left panel, but with a different color-coding that highlights differences at lower thin disk fractions.

$\rho_T(R_\odot)/\rho t(R_\odot)$ = 2.1 ± 0.2 %, a result consistent with, but determined in a completely different way than, typical starcount/density analyses.