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Mapping the Asymmetric Thick Disk
II. Kinematics of the Hercules Thick Disk Cloud

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Background – the Kinematics

In addition to the star count excess or over-density in Quadrant 1 (Q1) described in Poster #413.02, Parker, Humphreys and Beers (2004) also found a slower effective rotation rate (V_{LSR} and ω) for the Thick Disk stars in Q1 compared with the similar population in Q4, based on metallicity, that was longitude dependent. A solution for the radial, tangential, and vertical components yielded a significant lag of 80 – 90 km s^{-1} in the direction of galactic rotation compared to 20 km s^{-1} in Q4 for the same stellar population.

We have greatly extended this work to fainter magnitudes and have added velocities for several additional fields above and below the plane. In this poster we report our first results.

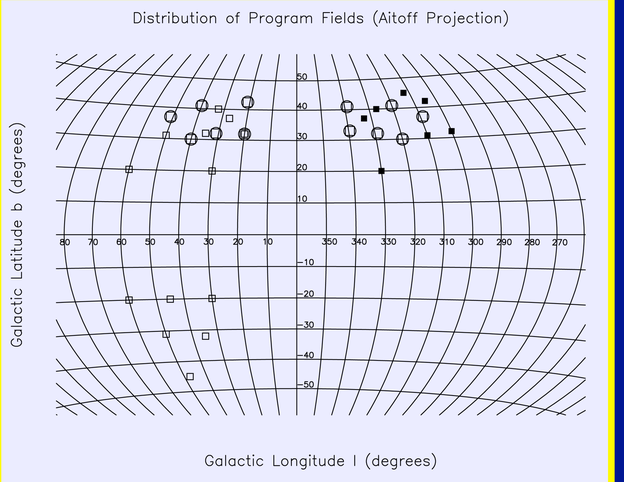

Figure 1: The distribution of Program Fields on the sky. Open squares are MMT/Hectospec Fields we observed and filled squares CTIO/Hydra fields. The circles are fields from Parker et al. 2004.

New Observations

We have added 20 new fields in addition to the 12 observed by Parker *et al* and now have spectra for velocities, spectral classification and metallicities for more than 4400 stars. The spatial distribution of the 32 fields are shown in Figure 1.

The spectra were obtained with the multi-object spectrographs, Hectospec with 300 fibers on the MMT (6.5m telescope) and Hydra with 138 fibers on the CTIO Blanco 4m telescope.

Hectospec – 600 gpm grating in the blue, 4800Å
13 new fields with spectra for V = 17 – 19 mag
2700 new spectra

Hydra – 632 gpm grating in the blue, 4200Å
7 new fields with spectra for V = 16 – 18 mag
1030 new spectra

plus 740 spectra with V = 15 – 17 mag from Parker *et al*.

Both quadrants show a very wide range in velocities as expected for a mixed population of (Thin) Disk, Thick Disk, and Halo stars. After removing the obviously high velocity stars with v_{LSR} greater than ±150 km s^{-1}, the mean velocities are -19.7±1.1 km s^{-1} and -17.3±3.3 km s^{-1} for Q1 and Q4, respectively. For a symmetric population we would expect a similar distribution of velocities but of opposite sign, + in Q1 and – in Q4. It is known that the Thick Disk has a net rotational lag of about 50 km s^{-1} relative to the Disk. But the much greater shift with respect to the expected Disk velocities in Q1 shows an asymmetry between Q1 and Q4. The results for ω confirms the asymmetry. The angular rate of rotation is expected to be higher than the Sun in Q1 and Q4, 30-40 km s^{-1} kpc^{-1}. The mean ω for Q4 is +34.3±1.3 km s^{-1} kpc^{-1}, but stars in Q1 have a slower effective rotation of +22.6±0.3 km s^{-1} kpc^{-1}.

These results with much more velocity data confirm the kinematic asymmetry between Q1 and Q4.

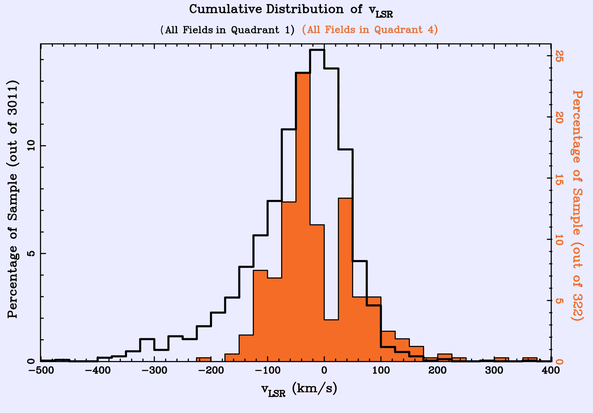

Figure 3: The normalized LSR velocity distributions for program stars in Quadrant 1 versus Quadrant 4. Quadrant 4 data from Parker et al. 2004.

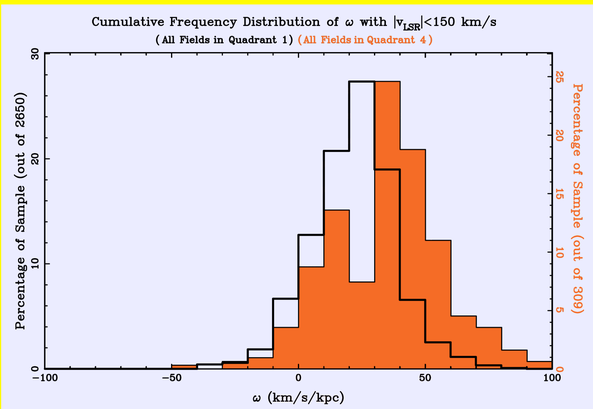

Figure 4: The normalized ω distributions for program stars in Quadrant 1 versus Quadrant 4. Quadrant 4 data from Parker et al. 2004.

Population Separation and the Kinematics

To separate the stellar populations, we used metallicity parameters derived from the Segue Stellar Parameter Pipeline (SSPP) (Lee et al 2008a,b, Prieto et al 2008). ***Only the new Hectospec spectra have been analyzed so far with SSPP, so only those data are included in the following discussion.***

To separate the Disk and Thick Disk stars, we used a plot of [α/Fe] vs [Fe/H], see Figure 6. It has been shown that the α elements are more enhanced in the Thick Disk stars (Wyse 2008). In our fields closest to the Galactic plane, we see a locus of stars in most of our fields distributed from [Fe/H] near zero to about -0.5 with [α/Fe] less than 0.2 which we attribute to the (thin) Disk population.

For this preliminary look at the kinematics of the different populations we adopted the parameters shown below. The observed mean [Fe/H] for each group is also shown.

		Mean [Fe/H]
(Thin) Disk:	[α/Fe]>0.2 and 0>[Fe/H]>-1.4	-0.38±0.01
Thick Disk:	[α/Fe]≤0.2 and [Fe/H]>-0.7	-0.91±0.01
Halo:	[Fe/H]<-1.4	-1.91±0.01

For the fields in the region of the asymmetry *l* = 20 to 50 :			
Quadrant 1 (Above the Plane)			
Population	**N**	**v_{LSR} (km s^{-1})**	**ω (km s^{-1} kpc^{-1})**
(Thin) Disk	96	-0.8±8.5	27.3±2.5
Thick Disk	570	-26.7±6.7	19.9±2.0
Halo	290	-85.0±11.2	2.6±4.2
Quadrant 1 (Below the Plane)			
(Thin) Disk	134	-0.3±8.2	27.1±1.9
Thick Disk	376	-19.9±6.5	23.1±1.5
Halo	209	-87.5±15.7	8.5±3.6
Quadrant 4 (from Parker et al 2004)			
(Thin) Disk	8	-16.1±12.6	30.7±3.7
Thick Disk	55	-24.1±8.4	36.4±2.9

The comparison in the above table illustrates the similarity of the Q1 stellar population above and below the plane and the asymmetry with Q4, but using a much smaller data set.

It also shows the lag of the Thick Disk population relative to the Disk Q1 stars and the Q4 Disk and Thick Disk stars, confirming the kinematic asymmetry between Q1 and Q4. A significant population of Q1 stars are rotating slower. The results for the Q1 Disk stars also suggest that some of them may be rotating slower than expected. This seems to be most apparent for the fields at higher Galactic latitudes.

Future Work

This is a preliminary report based on the first SSPP results. Additional processing is in progress that will refine the metallicity and other spectroscopic parameters. The data discussed here are from the Hectospec spectra for Q1. The Hydra data for Q4 have yet to be processed by SSPP.

Future work will include:
1. the addition of more than 1000 new spectra for Q4
2. analysis of the kinematics and metallicities as a function of location, and magnitude range/distance. There is some evidence in this look that the "fainter" Disk stars especially in the higher latitude fields may also participate in the slower rotation.

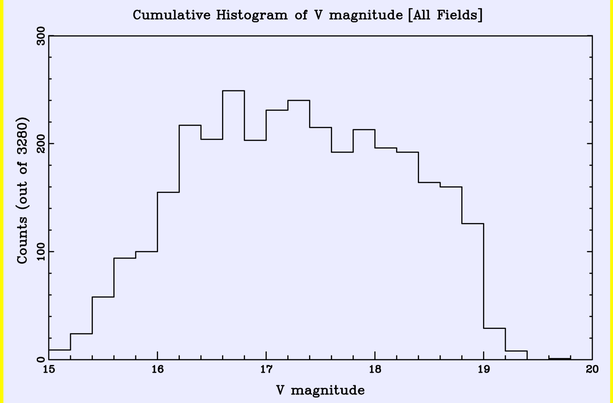

Figure 2: A histogram of the V magnitudes of our observed program stars.

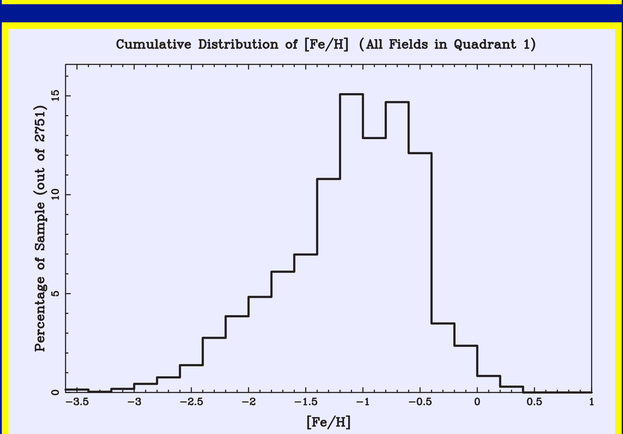

Figure 5: The normalized [Fe/H] distributions for program stars in Quadrant 1.

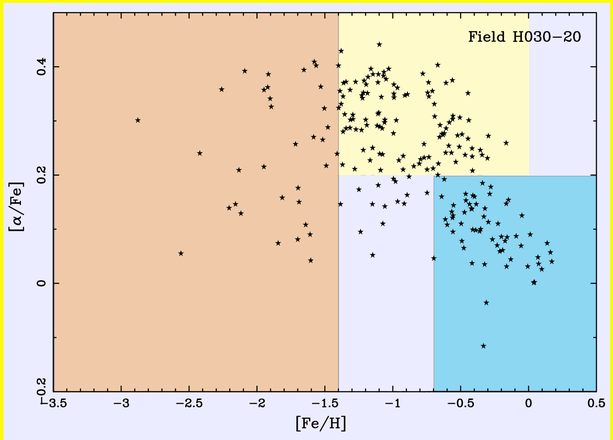

Figure 6: A plot of [α/Fe] vs [Fe/H] for one of our program fields closest to the Galactic plane. An orange background indicates metallicity criteria for Halo stars, yellow background is metallicity criteria for Thick Disk stars, and blue background indicate metallicity criteria for (thin) Disk stars.

eSPECROAD: External Hectospec Reduction Package

As external users of the Hectospec at the MMTO, we were unable to use CfA computers to reduce allow us to reduce the Hectospec data. Unfortunately, the CfA/SAO SPECROAD package was only designed to run on a few specific CfA computers. Therefore, working with Doug Mink and the CfA staff, we developed a version of the CfA/SAO SPECROAD package for reducing Hectospec data that can be used on any Linux or MacOS X computers, even those outside of CfA. This external version of SPECROAD is available online at:

http://iparrizar.mnstate.edu/~juan/research/ESPECROAD/

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