Determination of the Galactic Rotation Curve Using Open Star Clusters: Preliminary Results

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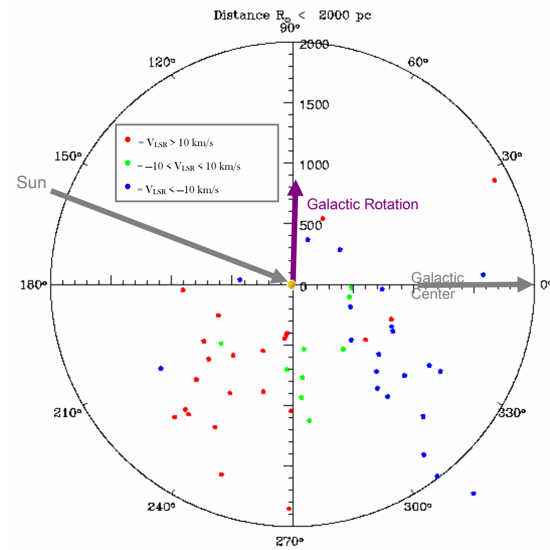
ABSTRACT:

The mass and dark matter fraction of the Milky Way remain among the major unsolved problems about our home galaxy. The masses of other spiral galaxies can be determined from their rotation curves, through long-slit spectroscopy. For the Milky Way obtaining the complete rotation curve is a more complex problem particularly outside the solar circle where HI tangent point analysis in not applicable. Moreover, the rotation curve is referenced to the velocity of the local standard of rest (Θ_0), which is not definitively established We present the first findings from a project to definitively measure the motions of disk tracers, both inside and outside the solar circle. Our tracer of choice is the open cluster population of the Galactic disk, a tracer that has numerous advantages over other, previously tried types; by averaging properties over the ensemble of cluster members, we obtain a very accurate determination of the complete space velocity vector and its distance. We have collected a near uniform sample of spectroscopic data for large numbers of stars in over 100 open clusters. Each measured member star has an accurate radial velocity ($\sigma_v \approx 2$ km/s) and proper motion (from Tycho2), permitting accurate cluster membership determination. From this sample, we present new preliminary measurements of the Galactic rotation at R_0.

MOTIVATION:

Considering the importance of galactic potentials in shaping the chemodynamical evolution of their stellar populations, it is unfortunate that less is known about the surface mass distribution of the Milky Way than for other galaxies. One reason for this shortcoming is the difficulty in determining the Galactic rotation curve outside the solar circle. Star clusters offer many advantages over other tracers, because they lend themselves to relatively easy age, metallicity and distance measurements, requiring only a proper color-magnitude diagram. Compared to an isolated field star at the same location in the Galaxy, the kinematics of a cluster are much easier to establish because of the ability to average over an ensemble of cluster members, which thereby lowers the required, per star precision. We plan to use the 3-D kinematics of clusters, from both proper motions and RVs, to investigate the Galactic rotation curve and local Galactic velocity field. Here we focus on the use of RVs only to constrain the velocity of the Local Standard of Rest.



Visualization of the Milky Way in the (l - distance) plane of the Galaxy. The 56 clusters used in this analysis are shown. Clusters are color coded by their V_{LSR}. Note: the clusters that lie near the solar radius have V_{LSR} near zero, as expected for well-behaved circular Galactic rotation.

DATA & ANALYSIS:

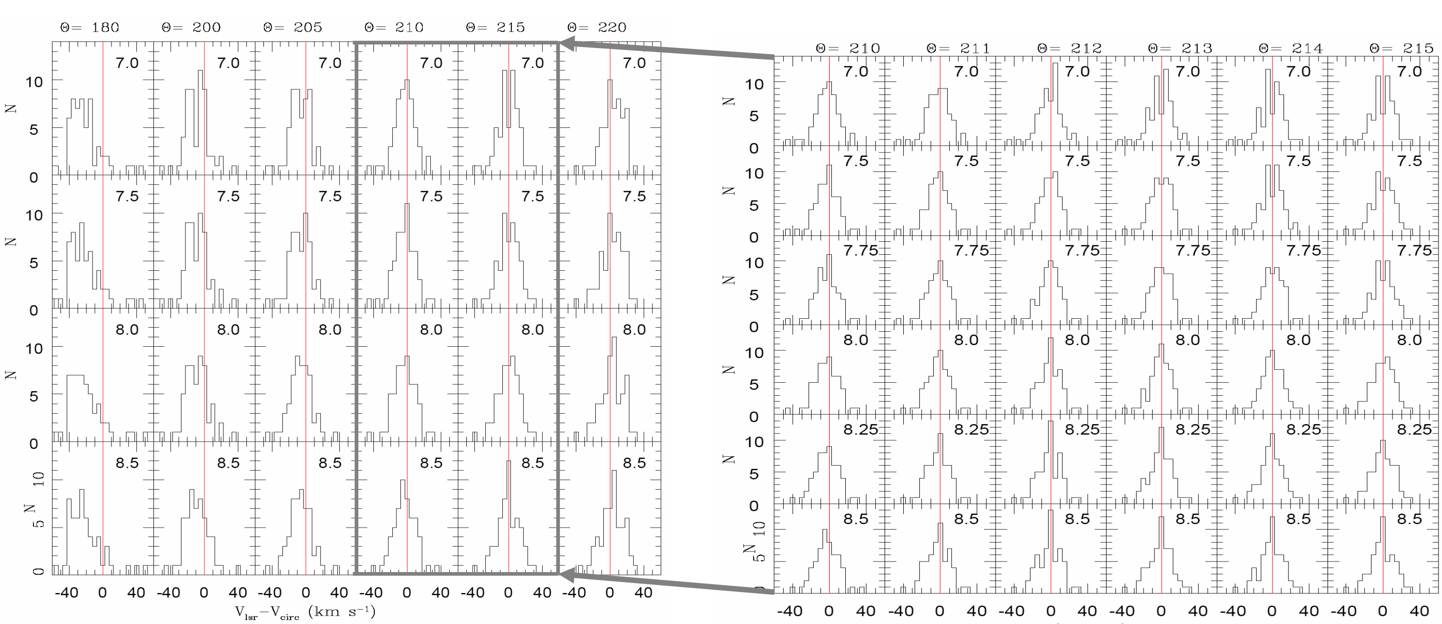
Data for the 56 clusters used in this analysis were obtained using the Hydra Spectrograph on the Blanco 4-meter telescope at CTIO. The data were reduced using standard techniques. Radial velocities (RVs) were determined using the IRAF `fxcor` package as described in Frinchaboy et al. (2005). Cluster members were determined from our RVs and the proper motion membership analysis of Dias et al. (2001, 2002a). Members were limited to ± 5–10 km/s range based on the typical individual stellar RV errors (1–2 km/s) and expected velocity dispersions of these systems. For this conservative preliminary analysis, this yields an average of 8–9 members per cluster. The mean bulk RV error for all clusters used in this analysis is 3.9 km/s.

All distances used in this analysis are taken from the Dias et al. (2001b) catalog of open clusters. All of these clusters have proper motions from Dias et al. (2001, 2002a), however in this preliminary analysis only our RVs data have been used. The analysis was completed using the Dias et al (2001b) data combined with our bulk RVs converted to V_{LSR} using the solar U, V, W velocities given in Binney & Merrifield (1998).

CONCLUSIONS & FUTURE WORK:

Comparison of our measured V_{LSR}'s to derived V_{CIRC}'s (the V_{LSR} a cluster would have in the same position for a flat rotation curve of speed Θ_0) for a range of R_{GC} (7.0–8.5 kpc) and Θ_0 (180–220 km/s) yielded a systematic trend with assumed Θ_0. Over this range of R_0 the mean V_{LSR}-V_{CIRC} difference was closest to zero between Θ_0=210-215. We find that V_{LSR}-V_{CIRC} = 0.0 ± 0.2 km/s for $\Theta_0 = 214^{+6}_{-9}$ km/s. This result is in the middle of the wide range of other recent findings that include Θ_0=184 km/s (Olling & Merrifield 1998) and Θ_0=255 km/s (Uemura et al. 2000), values strongly ruled out if the Milky Way has a well-behaved, simple circular velocity field.

Future work on this project will nearly double the number of clusters available (to approximately 100) and complete the coverage of first and second Galactic quadrants. Additionally the proper motion data will be incorporated to investigate not only the full Galactic rotation curve but also the local velocity field of the disk. Since our sample provides a uniform tracer population across the solar circle, we will also reinvestigate the shape of the rotation curve in the solar neighborhood.



Above: Histograms of the difference of V_{LSR} – V_{CIRC} plotted for a range of R_0 and Θ_0. The red line denotes a difference of zero which corresponds to a match to a flat rotation curve for the given Θ_0.
Right: A finer grid of histograms used to search further for the value of Θ_0 which matches the rotation rate of the open clusters around the Galaxy. We find that Θ_0=214 km/s provides the best match for our preliminary cluster sample.

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