Moving Towards a Better Kinematic Understanding of Our Milky Way and its Stellar Populations

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Abstract

Modern astronomical catalogs consist of up to billions of stars and measure various properties of these objects. There have been recent data releases from two of these surveys, GAIA which measures positions and distances, and APOGEE which measures radial velocities and stellar physical properties. By combining these datasets we have the full 6D phase space information for each star and can compute orbital characteristics and kinematics properties. APOGEE targeted specific stellar populations in our Milky Way and determined some of their physical properties. By cross matching with GAIA, we are able to fully describe the orbits of these populations and look for potential new members that have the same physical and kinematic properties but are not located in the immediate vicinity. We will present kinematic properties of the full cross matched dataset as well as information on the targeted stellar populations of the Milky Way.

Figure 1: NASA photos of globular clusters M5 (left) and M107 (right). A globular cluster is a gravitationally bound group of stars that are densely packed, contained mainly very old stars, and is located in the outer parts of a galaxy.

Procedure

Historically, stellar populations in our Milky Way (MW) have been categorized using orbital and physical properties. Photometric catalogs provide 3D positions as well as velocities on the sky (2D). On the other hand, spectroscopic surveys provide radial velocities and physical properties of stars. We combined the Global Astrometric Interferometer for Astrophysics (Brown et al. 2018, hereafter GAIA) photometric survey with large spectroscopic survey Apache Point Observatory Galactic Evolution Experiment (Nidever et al. in prep, hereafter APOGEE) by crossmatching stars using their position on the sky. Once we obtain the full phase space information for each star, we are able to calculate orbital parameters using the functionality of the *galpy* Python library (Bovy 2016). Next we do a second cross match with Table 2 from Meszaros et al. (2015), which contained information on confirmed members of various globular clusters, similar to those shown in Figure 1. Following with a metallicity linear fit between Table 6 (Meszaros et al. 2015). Together the kinematic and physical property cuts uniquely describe each of the several clusters and can be applied to the complete data set.

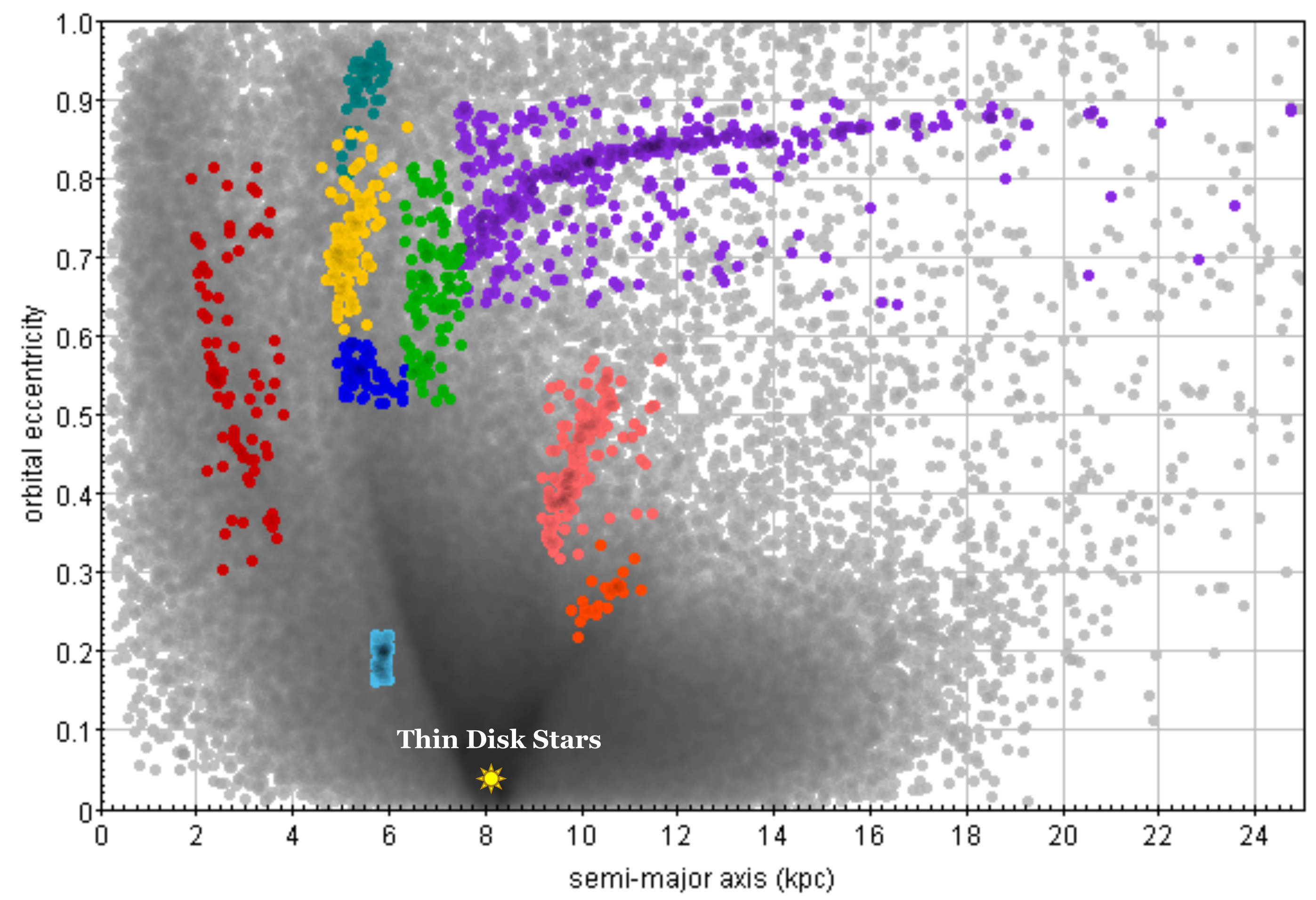

Figure 2: Orbital properties of the full stellar sample (grey) and the globular clusters M2 (green), M3 (pink), M5 (purple), M13 (yellow), M15 (blue), M53 (orange), M71 (light blue), M92 (teal), and M107 (red). The yellow star marks thee position our Sun would be in this plot.

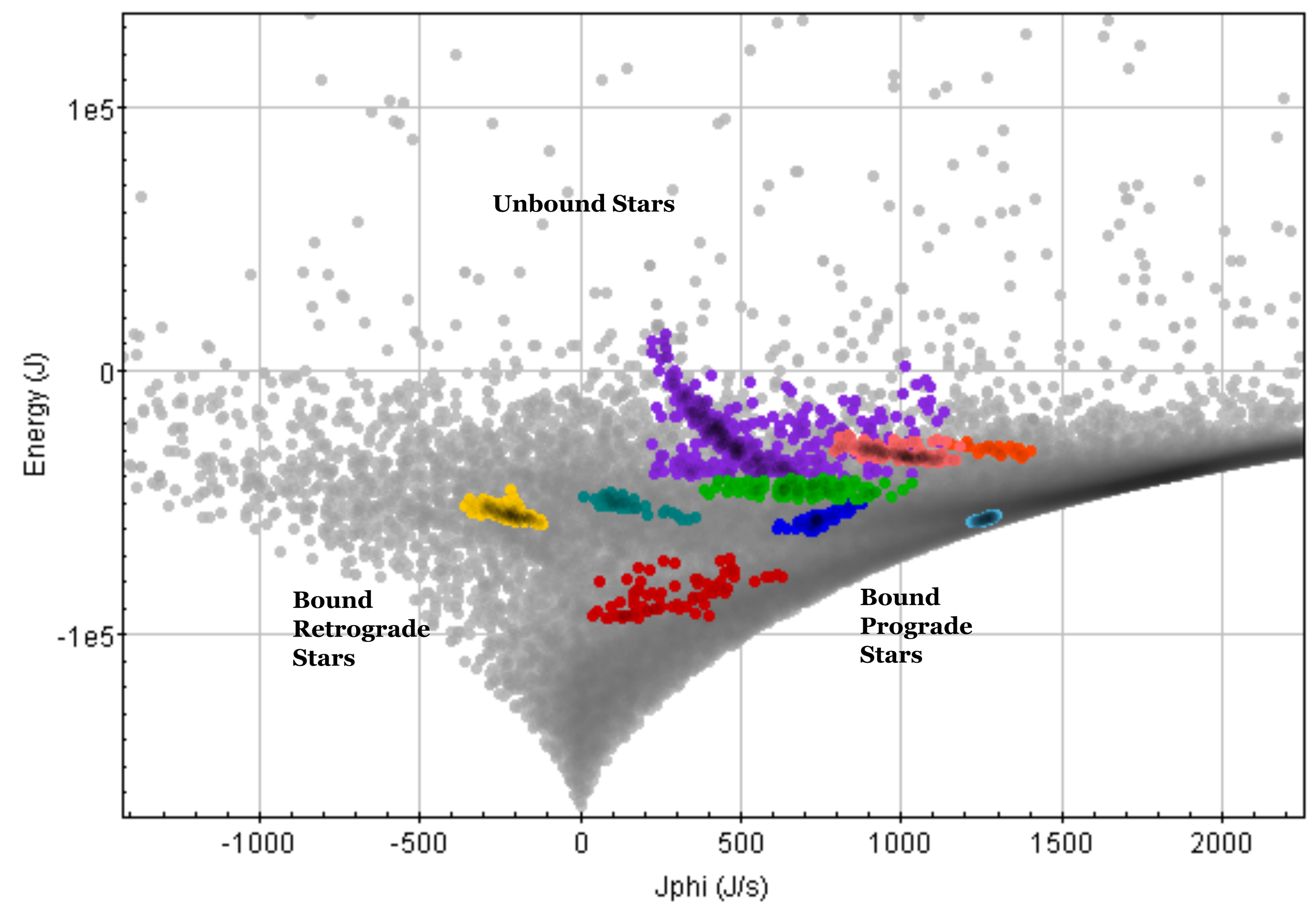

Figure 3: Orbital energy and angular momentum of the full stellar sample (grey) and the globular clusters M2 (green), M3 (pink), M5 (purple), M13 (yellow), M15 (blue), M53 (orange), M71 (light blue), M92 (teal), and M107 (red).

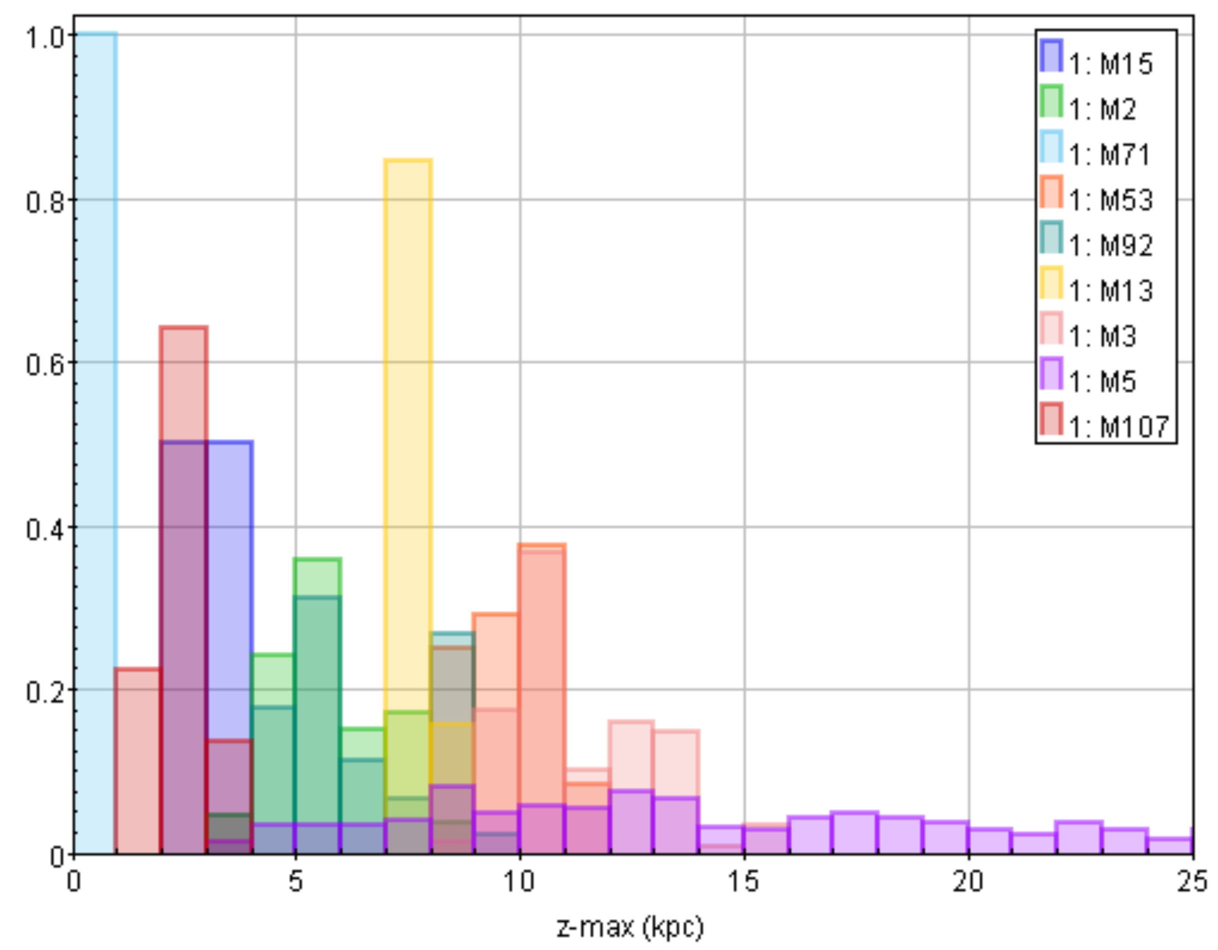

Figure 4: A histogram of the z-max for different globular cluster in our sample (see legend).

Analysis

Figures 2, 3, and 4 display orbital characteristics of the clusters in our sample. Thin disk stars have semi-major axes are spread throughout the entire disk, generally low eccentricities, and low z-max. Thick disk stars have similar semi-major axes as thin disk, generally higher eccentricities, and higher z-max. A majority of the clusters orbit display similar properties to halo stars, with z-maxes near the outer parts of the MW. In Figure 3, we can see that almost all the stars are on bound orbits around our MW. Another observation that can be made is M13 (yellow) is on a retrograde orbit, moving in the opposite direction than the others.

Figure 5 displays different metal abundance characteristic of the cluster populations in our sample. In this figure we can see many of the clusters formed in more iron poor and more alpha rich environment than our Sun. Although it appears that M71 formed in an environment similar to our Sun, it actually form in a more iron rich environment.

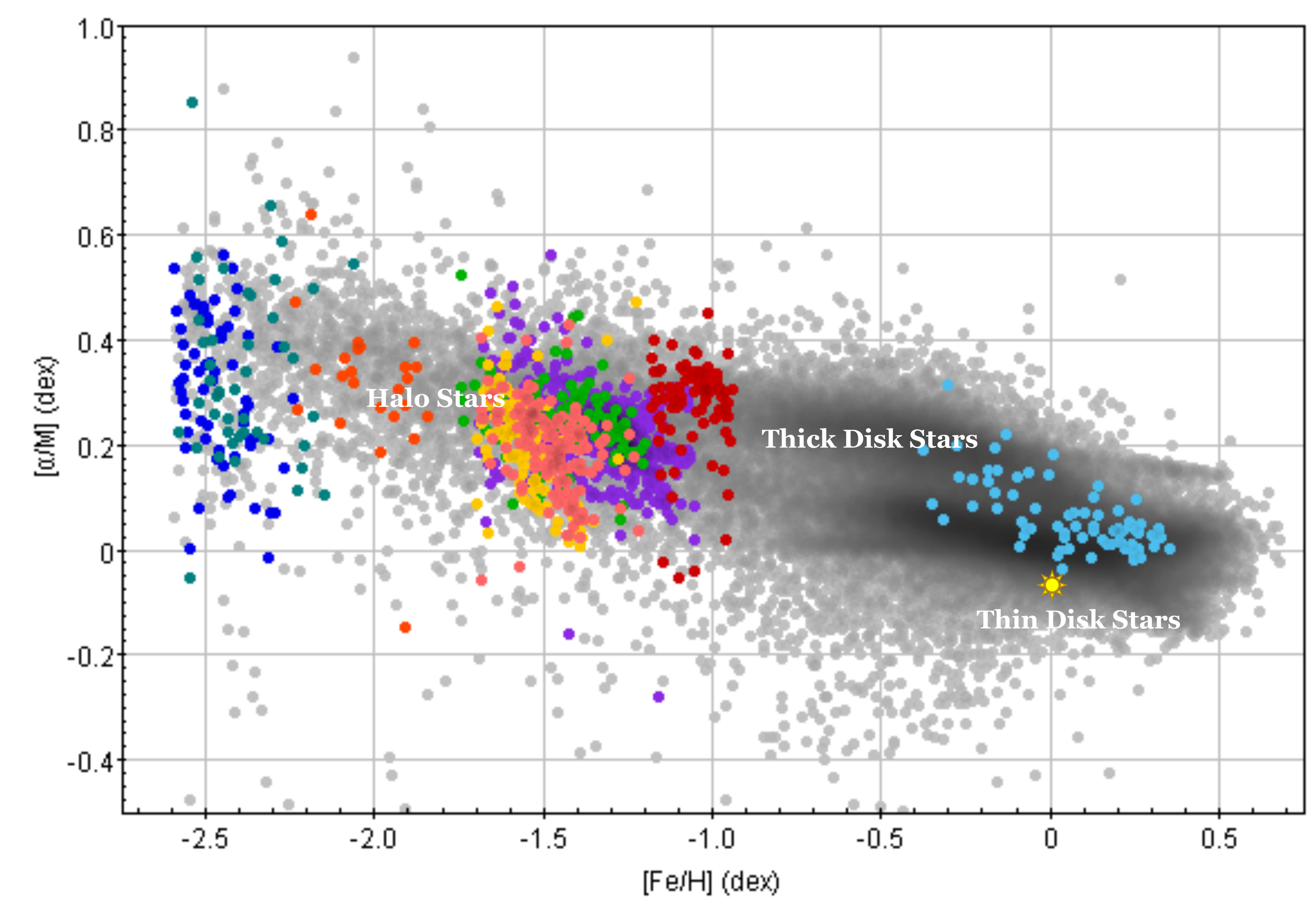

Figure 5: Relationship between iron and alpha element abundances for the full stellar sample (grey) and the globular clusters M2 (green), M3 (pink), M5 (purple), M13 (yellow), M15 (blue), M53 (orange), M71 (light blue), M92 (teal), and M107 (red). The yellow star marks the values for the Sun.

Conclusion

Using our combined data set, we are able to provide multiple globular cluster with kinematic properties to describe their orbits. With additional cuts in metallicity, we found one star has the potential of being a cluster member. Due to globular cluster gravitational properties, the group stays bounded together for very long periods of time and very few stars leave their group, which explains our single star finding. This process as a whole allows us to remove populations in our combined data set to examine our MW with only MW stars.

References

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