A Proper Motion Study of Globular Cluster M71 Using the PPMXL

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Abstract

With the advent of proper motion catalogs, we may now be able to accurately witness the motions of individual stars within a cluster. The idea of proper motion catalogs is not a new one. Several have been made past including PPM and the extensive catalog produced by the USNO. These however, rely on the accuracy of old technology and thus have large errors associated with stellar positions. The recent release of the Position and Proper Motion Catalog Extended (PPMXL) may prove to be a reliable source for resolving stars with minimal errors in positions. We attempt to quantify the how reasonable future scientific endeavors could be using this catalog as a primary data source.

Introduction

Globular clusters are perhaps one of the most interesting parts of our galaxy. Harboring hundreds of thousand of stars, these structures form a spherical distribution about the milky way. Globular clusters are thought to have formed around the same time as the milky way. Most clusters have formed from the same material which gives us a good way to estimate the age of the cluster and therefore the galaxy. Relatively accurate age estimates come from the distribution of stars of each spectral type. More accurate estimates could be made from considering the dynamical evolution of globulars as well. Energy equipartition is one of these. Energy equipartition can drive mass segregation as well as low mass loss which leads to a preference in higher mass stars. It is widely known that energy equipartition can occur given a sufficient amount of time. The two-body relaxation times proposed by (Gunn & Griffin 1979) and others have suggested that the universe is not old enough to have seen this phenomena occur. These models may have overlooked parameters associated with a cluster's position in the galaxy. Gravitational interactions with other milky way structures could have accelerated mass segregation in some clusters. This has been suggested by (Martinazzi et al. 2014) regarding NGC 6397. While many have modeled cluster dynamics, there appears to be a dearth in empirical evidence of mass segregation. We intend to propose a method of interpreting data from the Position and Proper Motion Catalog Extended (PPMXL) (Roeser et al. 2010) to gain accurate measurements of relative proper motions of cluster stars.

Methods

In order to study the internal dynamics of our cluster, we chose to use PPMXL. We found this to be an excellent source for such data. Combining the USNO-B1.0 with the Two Micron All Sky Survey (2MASS), this catalog provides a sufficient baseline to base proper motions off of. The long baseline is especially helpful for the reliability of this source because individual cluster members have proper motions on the order of miliarc seconds per year. The parameters for M71 were taken from the most recent literature of this cluster. We chose the cluster distance to M71 to be 3600 ± 250 pc (Geffert & Maintz 2000). The center of the cluster was most recently placed at RA = 19hr53m46.25s and Dec = +18deg.46M46.7s by Goldsbury et al. (2010). The observed limiting radius r = 9.6448' is taken from Trager et al. (1995). The online database allowed us to choose our data to contain a minimum of 3 observations as well as data from 2MASS. Thus we had proper motion data as well as photometry in the J and H bands. We chose to perform two cone searches on the PPMXL online database. One of within the r of the cluster center and the other within r/2 of the cluster center. We intended to subtract the inner portion of stars from the outer This gave us two sample to work with that we may reduce separately. We did this to compare the velocity dispersion and the number of stars in each field. By plotting the Proper Motion Vector Point Diagrams, we were able to visually pick out the most probable cluster members from the field stars. With its galactic latitude of l = -4.56 degrees (Roeser et al. 2010), the image of M71 is likely to contain more interlopers than cluster members. We compare the data before and after removal of estimated interlopers in the results.

Results

The cluster areas before the removal of interlopers can be seen in figure (2). We have also provided a preliminary color magnitude diagram in figure (3). Cluster contamination proved to be extensive. The location of this cluster has forced the data to have been taken through many field stars. We have performed the preliminary methods behind the removal of these stars. In a vector point diagram of the proper motions, cluster members can easily be seen to bunch up around one point. In figure (1) we plot the vector diagrams from both areas of the cluster. From this it is clear that cluster members bunch up around the zero point of proper motion in right ascension and declination. In these diagrams we have plotted a circle indicating the most probable cluster members based on transverse motions alone. Following our analysis, out of the 1936 stars we began with in the cluster field, 698 stars remain. This result is expected as the majority of the cluster's members are dimmer than the limiting magnitude of this study. On the right side of figure (2) we plot the locations of the remaining stars in each area differentiated by color. The right diagram of figure (3) displays the decontaminated CMD. A statistical analysis has also been performed to compare the viability of determining an accurate velocity dispersion for globular cluster data using PPMXL. The standard deviation proved to vary substantially from the median absolute deviation (MAD) using the data before decontamination. This result is expected due to the number of outliers in this particular field. For the standard deviation: σ_{center}= 116.3278 ± 5.343, $\sigma_{outer\ ring}$= 79.588 ± 2.614. For the MAD: σ_{center}= 27.436 ± 2.959, $\sigma_{outer\ ring}$= 22.390 ± 2.959. From figure (4) it can be seen that by using the MAD as an estimator for σ, we can provide a much more robust method of viewing the spread of motions in a cluster.when there are many interlopers.

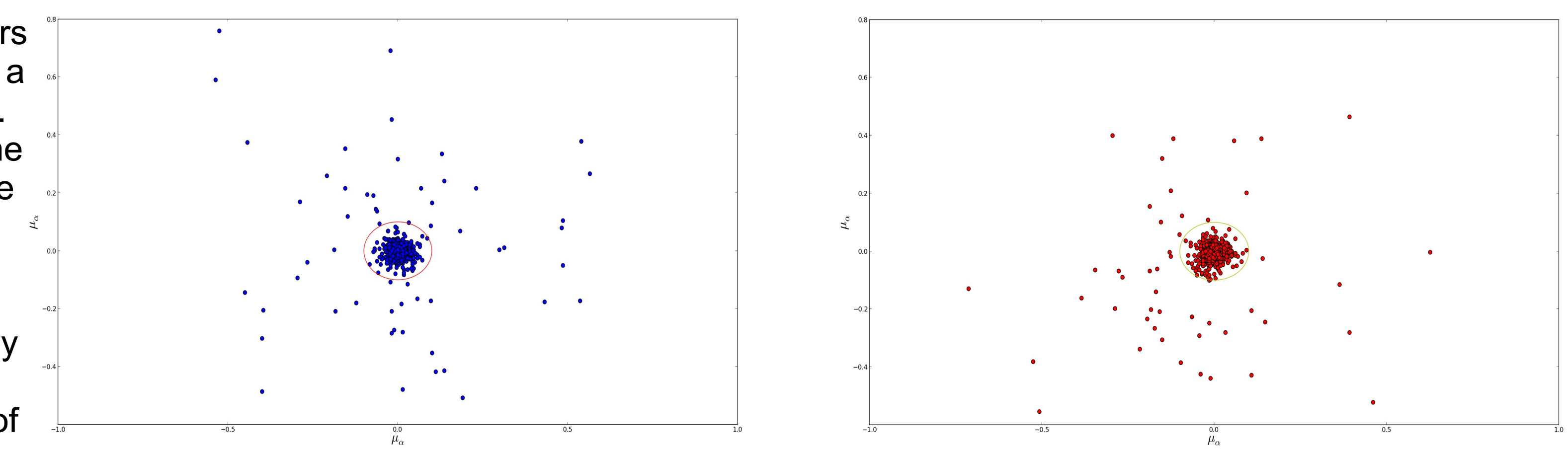

Figure (1)

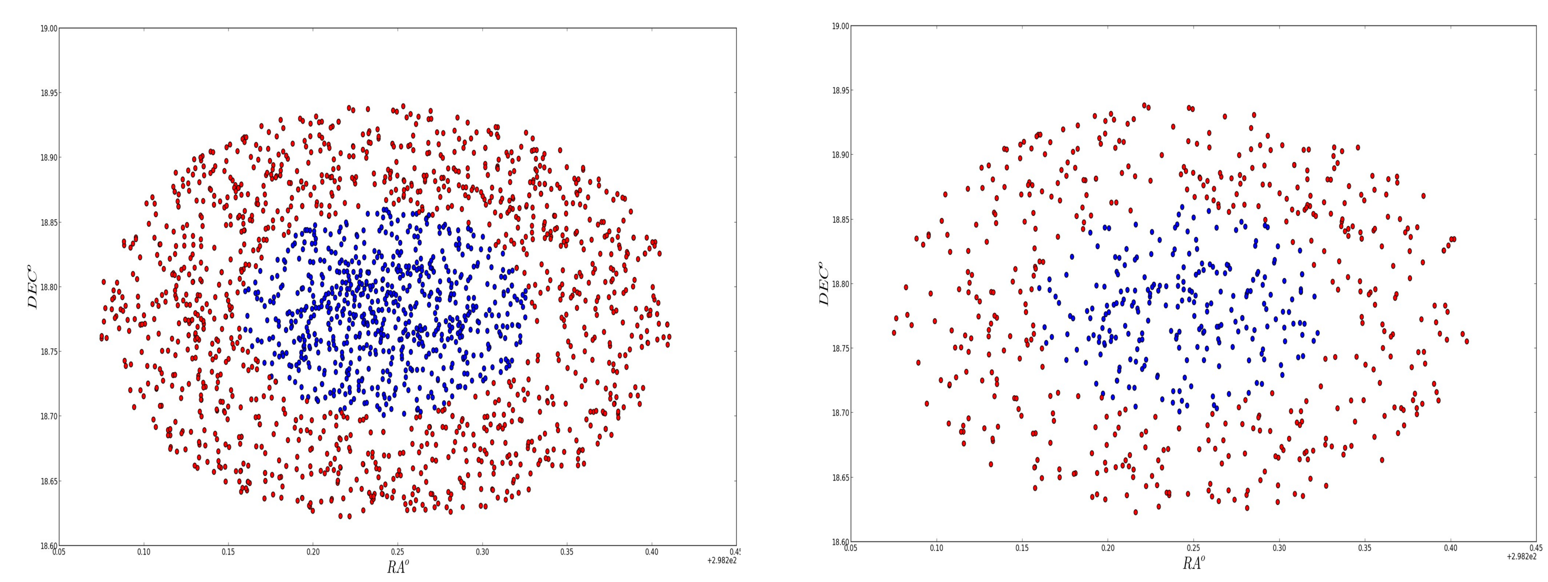

Figure (2)

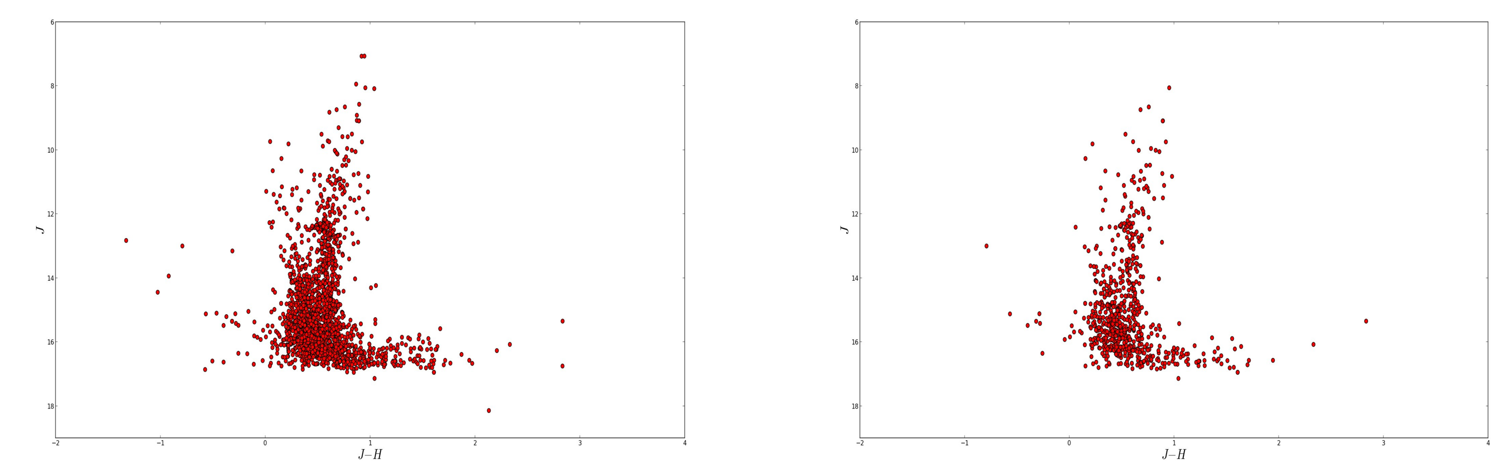

Figure (3)

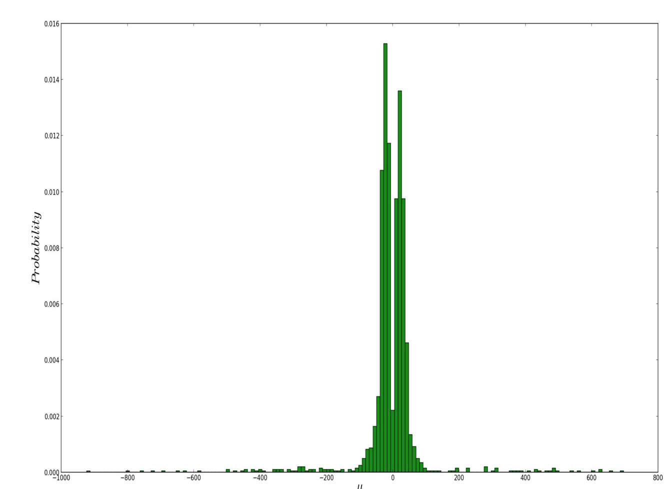

Figure (4)

Conclusion

This study aimed to test the feasibility of using catalogued proper motion data in order to gain insight on the internal dynamics of a globular cluster. Upon preliminary results, it would appear that we can move on to perform more in depth studies using this PPMXL. While the number of stars that remained in the field available to study pale in comparison to the true stellar density of M71, it is clear that we have been able to produce a sufficient sample to study. One of the most important points to make here is that we have produced a distrution of stellar spectra. Without being able to compare the types of stars we are looking at, our efforts would be feudal. Indeed further improvements of PPMXL should allow us to have deeper photometry and therefore more cluster members. Future work that will use these results will include:

- A search for evidence of energy homogeneity throughout the cluster
- Estimating the probability of significant mass segregation and mass loss
- Evidence of an intermediate mass black hole at the center of the most massive clusters
- Blue Straggler time evolution

Resources

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Gnedin et al. (2002), AJ, 568, 1, L23-L26
Goldsbury et al. (2010), AJ, 140, 6, 1830-1837
Gunn & Griffin (1979), AJ, 84, 752-773
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Roeser et al. (2010), AJ, 139, 2440-2447
Samara et al. (2012), Apj , 751, L12

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GMT

HETDEX Illuminating the Darkness
Hobby-Eberly Telescope Dark Energy Experiment

LSST Large Synoptic Survey Telescope

DARK ENERGY SURVEY

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