Verifying Membership and Chemical Homogeneity in the Open Clusters NGC 2682 and NGC 6819

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Abstract

Using data from both the Apache Point Observatory Galactic Evolution Experiment (APOGEE) and WIYN Open Cluster Study (WOCS), we wanted to have a better means of determining open cluster membership. By matching stars from both data sets via right ascension and declination, we were able to determine a cluster's radial velocity and metallicity and generate membership probabilities for all stars in both data sets.

In the end, we were able to see if there were stars whose memberships were questionable and if stars had been missed in membership identification. We were also able to verify if the member stars truly show evidence for chemical homogeneity as expected for open clusters.

Introduction

Open clusters are groupings of a few thousand stars that are loosely bound by gravity and are only found in the plane of the Milky Way Galaxy. The stars that are considered to be members of the cluster were created at the same time from the same cloud of dust and gas, which implies that members of the cluster should exhibit chemical homogeneity—meaning they share similar chemical composition known as metallicity.

Along with composition, members of an open cluster should have similar radial velocities (RV)—meaning they should move in space together relative to the cluster. Previous studies have examined both of these membership qualities but have not utilized both of them. The goals of this research were: (1) to combine the WOCS and APOGEE data sets to see if there was an offset of each's determinations of these clusters' radial velocities (2) to determine which stars are truly members of their respective cluster and (3) to see if WOCS classified members exhibited chemical homogeneity.

Fig 1: Picture of NGC 2682. From the picture it is easy to see how it is impossible to visually discern member stars of the cluster from nonmembers (field stars).

Methods

Our membership analysis began by matching stars from the WOCS and APOGEE data sets by their celestial coordinates (Right Ascension and Declination) and putting their combined data new record array in Python. We refined this new data by performing a 3-sigma cut using both data sets' values and errors of radial velocities.

From this refined data set, we determined each cluster's average radial velocity and average metallicities of [Fe/H] and [O/Fe] from WOCS classified Single Members. From here, we determined a radial velocity (and its offset), [Fe/H], and [O/Fe] probability for every star in the data sets using these cluster averages in a normal distribution. Any star with a probability greater than or equal to 0.3 in any of these three criteria was assigned a type of membership status, depending on how many criteria were met.

Results

We found the offset of radial velocity measurements between the data sets using the WOCS Single Members in our 3-sigma cut data set and found:

	APOGEE			WOCS		
Cluster	Radial Velocity (km/s)	σ (km/s)	Average RV Error (km/s)	Radial Velocity (km/s)	σ (km/s)	Average RV Error (km/s)
NGC 2682	33.81	0.86	0.022	33.59	0.81	0.23
NGC 6819	2.26	0.86	0.011	2.02	0.86	0.21

Fig 2: Radial velocity averages, standard deviations, and errors found for both of the open clusters.

We determined that while both data sets agree on the clusters' radial velocities, the APOGEE RV readings are systematically higher than WOCS by ~0.23 ± 0.01 km/s.

After determining the RV for each cluster, we were able to calculate the averages and errors of the metallicities [Fe/H] and [O/Fe]:

	[Fe/H]			[O/Fe]		
Cluster	Mean	σ	Average Error	Mean	σ	Average Error
NGC 2682	-0.01	0.05	0.02	-0.05	0.11	0.04
NGC 6819	0.03	0.10	0.03	-0.01	0.05	0.03

Fig 3: Mean, standard deviation, and error for each metallicity of the clusters. These values are on a logarithmic scale, meaning a difference of 0.1 is actually $10^{0.1}$.

Because the values of the standard deviation and average error are relatively close, we can draw the conclusion that chemical homogeneity is present within our designated member stars.

Lastly, we were able to classify each member star into a group depending on how many membership criteria they met. We plotted each one on a color magnitude diagram (CMD) to see which member stars were passing in one criteria, say RV, but not metallicity. A CMD allows us to see why such problems could occur; however in our analysis, we were unable to draw any conclusions of questionable members because their spectra were broadened too much—making them unusable.

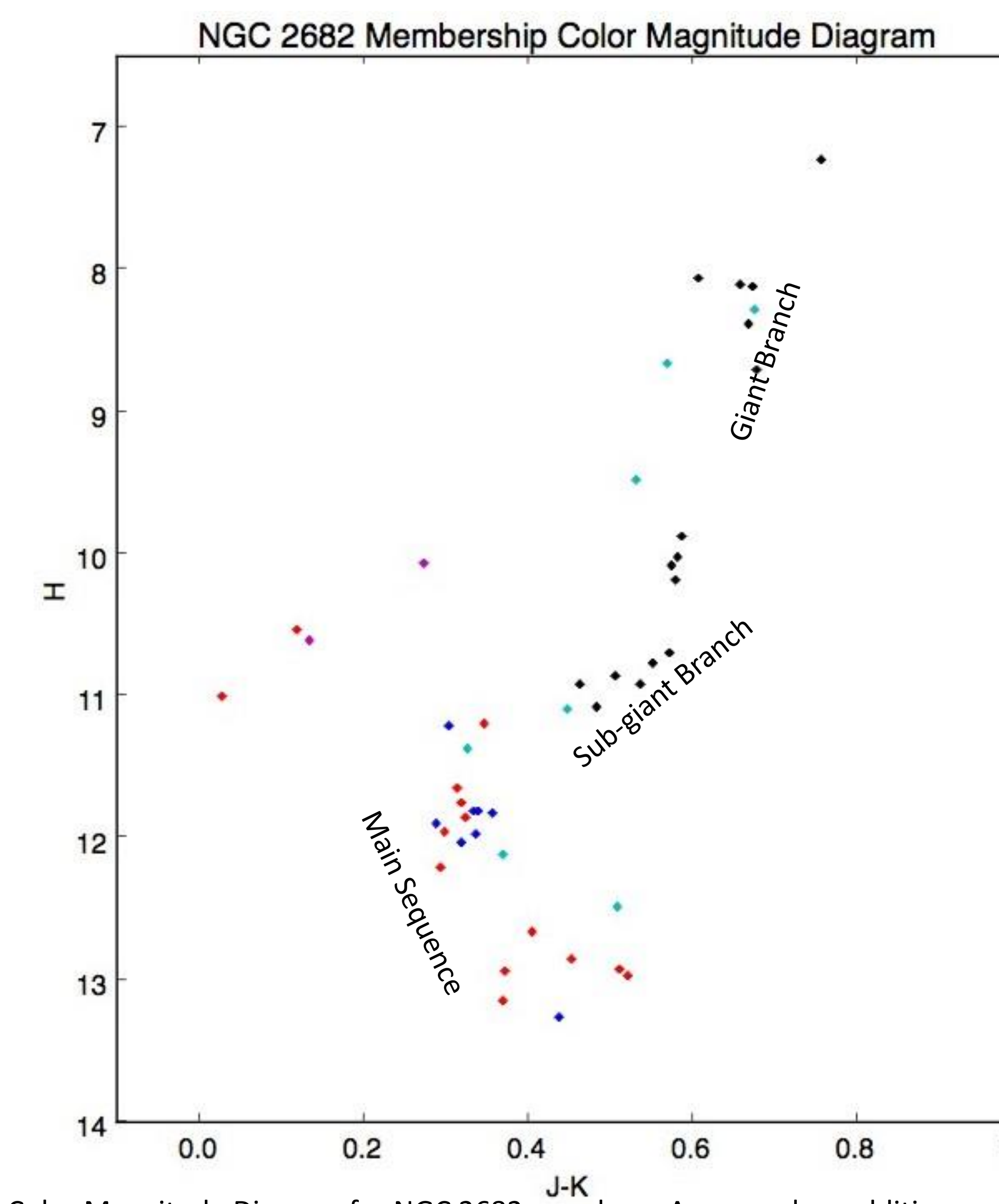

Fig 4: Color Magnitude Diagram for NGC 2682 members. Any member oddities can be noticed here. Stars that meet all three criteria are Black-Single Members (SM) and Green-Binary Members (BM); stars that meet RV but not Metallicity: Red-SM, Magenta-BM; stars that meet Metallicity but not RV: Blue-SM, Cyan-BM

Conclusions

The results of this research provide answers that can be used to further study these and other clusters. Knowing the offset of the APOGEE data will allow for calibration corrections to be made in the future. These calibrations can only be bettered by knowing the which stars are truly members of certain clusters. Such a process that we performed will allow for a more precise measurement of the chemical distribution throughout the Milky Way, ultimately leading to a better understanding of its evolution. Hopefully with better spectra we can refine membership by ruling out contaminated spectra as a reason for questionable membership. The next step in this research would be to include all metallicities in our analysis, for true members should be similar in composition beyond just Fe and O.

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