A Study of Properties of Open Star Clusters

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Abstract

Gaia is an astrometry mission by the ESA, which has helped in cataloguing numerous objects in our galaxy in unprecedented detail. The cluster membership information based on Gaia DR2 data of open clusters will be used to understand the effect of dynamical evolution on the observed properties of star clusters. In particular, star clusters with a clear binary track are examined to study the radial distributions of these binary stars with respect to the radial distribution of single stars. Alongside, the morphology of star clusters is examined to look for the presence of any tidal tails in the star clusters.

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Introduction

1.1 Gaia Mission

We have come a long way in observing the skies, from the naked eye to the mural instrument, from telescopes to space missions. The Gaia mission[1][2] is one such astrometry mission launched in 2013. The spacecraft aims to measure the positions, distances and motions of celestial objects. The mission aims to be the most precise 3D catalogue of the sky, mapping every object it can while also measuring their motions which can give clues about the origin and evolution of our galaxy, the Milky Way.

The mission aims to determine the position and parallax of around a billion stars to an accuracy of around 20 μas. The catalogue is set to be released in stages. The first data release took place in 2016[3], based on 14 months of observation. It inlcuded the positions and magnitudes for over a billion stars using only Gaia data. The second data release took place in 2018[4], after 22 months of observations, and improved on the precision of the previous release, as well as adding parallaxes and proper motions.

1.2 Star Clusters

Gravity is one of the 4 fundamental forces which keeps large celestial structures in place. A star cluster is a gravitationally bound group of stars. They share a common origin and provide a way to study stellar evolution. They can be globular or open.

1.2.1 Globular Clusters

A globular cluster is a roughly spherical collection of stars orbiting the galactic core. They have a dense concentration of stars in their centers and are thinly spread out further from the center in the halo. They are composed of thousands of low metal stars. They are generally found in the halo of a galaxy and are generally older than the stars in open clusters.[5] The proportion of metals, called metallicity, is rather low in these stars. The metallicity of a star is an indicator of its age, and the low metallicity of stars in globular clusters shows this.[6]

1.2.2 Open Clusters

An open cluster is a group of a few thousand stars formed from the same molecular cloud. They are named so because often individual component stars can be resolved rather easily with a telescope. They are generally found in the disc of the galaxy. They are rather loosely bound

by gravitational attraction between the member stars. Gravitational effects from other massive bodies as it moves on its journey around the center of the galaxy often disperse the order of these clusters. They are much younger compared to globular clusters, some even showing signs of nebulosity. Properties of the cluster members can be determined easily because they have are at the same distance away from us and they have a similar age and chemical composition[7]. This will also be the focus of this report.

1.3 Gaia Data for Open Clusters

While the Gaia mission provided us with very precise data regarding astronomical objects, they are not classified. The study by Cantat-Gaudin et. al[8] aims to determine a list of members of open clusters and derive mean parameters from them using Gaia data. They obtained a list of 1229 open clusters with associated members and cluster parameters. The cluster members identified by Cantat-Gaudin are available on the VizieR database[9], which is used for this study. The data lists the positions of the clusters and their members, with parallaxes, proper motions and color magnitudes. From the other Gaia data, more information can be queried for individual stars. Combining the data, the properties of these star clusters can be studied. Eventually, we can separate the binary stars from the single ones and study their radial distributions. We can then examine their evolution and morphology.

1.4 Photometry

The art of measuring the electromagnetic radiation from a point source in the sky is known as photometry. Thus, we can use this information to calculate the distance to an object, its mass, its temperature and chemical composition. To determine some of these factors, we will plot a very useful graph known as a Hertzsprung-Russel chart or a color magnitude diagram.

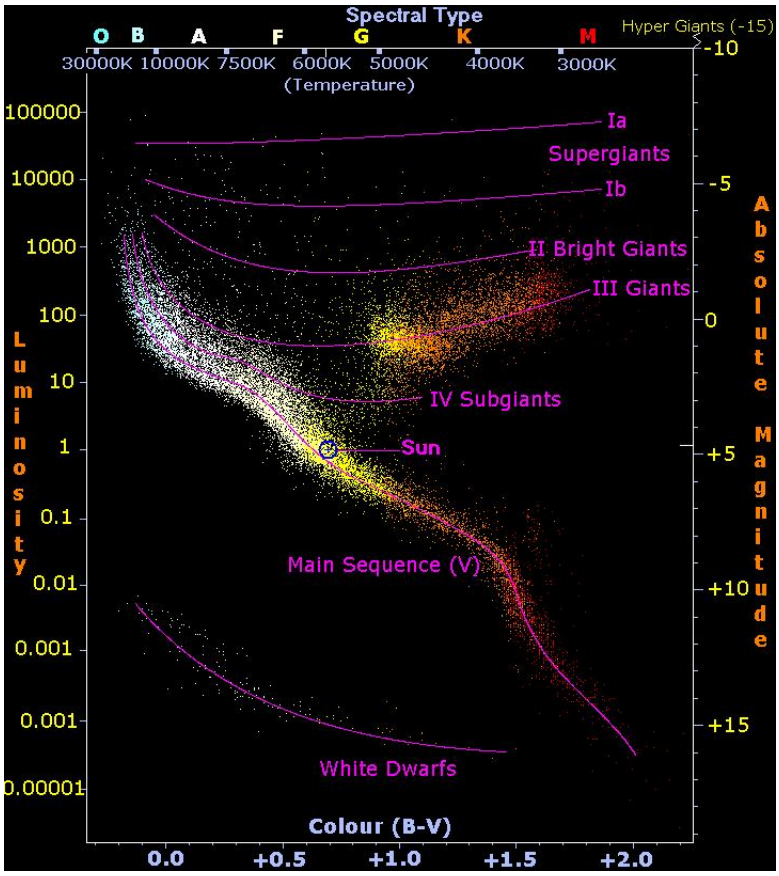


Figure 1.1: H-R Diagram[10]

1.4.1 Color Magnitude Diagrams

To study about the life cycles of stars, their evolution, we plot the luminosities of stars against their color. This is essentially a plot of the total energy given by a star against the surface temperature. This is known as a Hertzsprung-Russel diagram (HR diagram) or a color magnitude diagram (CMD). There are four major groups of stars in this plot. The smear in the bottom left representing the white dwarfs. They are among the older stars in the life cycle and most open clusters don't have them. They undergo hydrogen fusion and take up the bulk of a star's life. The horizontal branch breaking away from the main sequence corresponds to the red giant stars and the top right belongs to the supergiants. There are other minor divisions in the clusters, such as blue stragglers as well.[6]

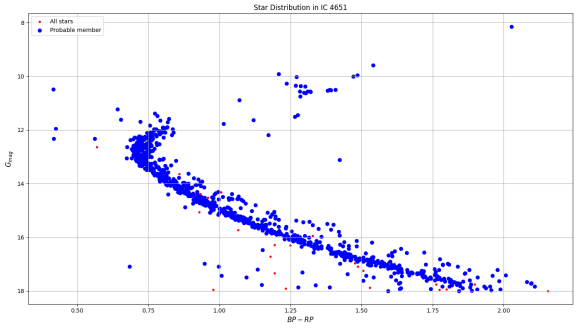
1.4.2 Isochrones

A stellar isochrone is a curve on the color magnitude diagram indicating a population of stars of the same age. They can be used to date stars in open clusters because they all approximately have the same age. Isochrone data is available in the internet and they can be downloaded to test which one gives the best fit. The best fitting isochrones don't just reveal the age of the cluster, but much more information.

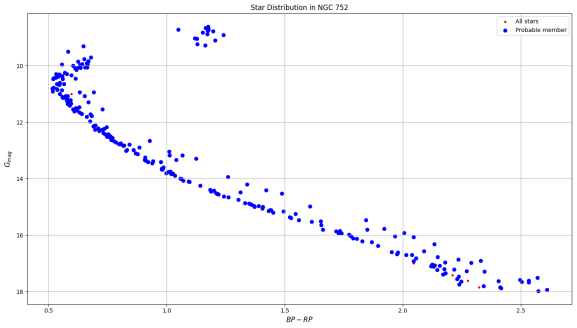
Preprocessing the data

2.1 Acquiring the data

Initially the data from Gaia is queried from the VizieR database[9]. The results obtained by Cantat-Gaudin[8] can be obtained in a tabular form. Hence we obtain the data for 1229 clusters. The database enables us to access position, motion, cataloguing and color information. We require only the photometric data - the color magnitude and the photometric magnitude for the first part. This data was scraped from the website. This enables us to plot a color magnitude diagram for all the clusters. The probablity of being a member was also considered and the clusters with a probability of more than 0.7 were marked with larger points. The plots of these clusters were analysed, and ten clusters (IC 4651, IC 4756, NGC 752, NGC 1664, NGC 2281, NGC 2287, NGC 2527, NGC 6281, NGC 6405, NGC 6475) were shortlisted for further analysis.



(a) IC 6451



(b) NGC 752

Figure 2.1: CMD for star clusters

Bibliography

[1] Gaia Collaboration et. al. Description of the Gaia mission (spacecraft, instruments, survey and measurement principles, and operations), 2016.

[2] ESA. Gaia: fact sheet. 2013.

[3] Gaia Collaboration et. al. Summary description of Gaia DR1, 2016.

[4] Gaia Collaboration et. al. Gaia Data Release 2 : Summary of the contents and survey properties, 2018.

[5] Jon Talpur. A guide to globular clusters. 1997.

[6] Simon F. Green, Mark H. Jones, and S. Jocelyn Burnell. *An Introduction to the Sun and Stars*. 2004.

[7] Christine Frommert, Hartmut; Kronberg. Open star clusters. 2008.

[8] T. Cantat-Gaudin et. al. A Gaia DR2 view of the open cluster population in the Milky Way. *A&A*, 2018.

[9] Ochsenbein F. et. al. The VizieR database of astronomical catalogues.

[10] Wiki Education Foundation. Wikimedia Commons.

[11] Gaia Collaboration et. al. Gaia DR2 primer: Everything you wish you had known before you started working with Gaia Data Release 2. 2019.

[12] Crowley et al. On-orbit performance of the gaia ccds. 2016.

[13] Arenou et al. Catalogue validation. 2018.

[14] Hambly et al. Calibration and mitigation of electronic offset effects in gaia data. 2018.

[15] Fabricius et al. Pre-processing and source-list creation. 2016.

[16] Lindegren et al. The astrometric solution. 2018.

[17] Riello et al. Processing of the photometric data. 2018.

[18] Katz et al. Properties and validation of the radial velocities. 2018.

[19] Salgado et al. Gaia archive data access facilities. 2017.

[20] Moitinho et al. Gaia archive visualisation services. 2018.

[21] Luri et al. On the use of gaia parallaxes. 2018.