Pathfinding with the Old Breed: Using the Old Open Clusters for Galactic Tracing

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1. Abstract

The study of open clusters has been a keystone in the study of the Milky Way. They are large scale stellar laboratories and lend themselves to the study of stellar evolution due to the homogeneity of their stellar population. The use of open clusters in mapping the milky way is an old process of comparing the age of open clusters against their spatial distribution. With the progression of photometry and high-resolution astrometric studies, many open clusters can be re-examined with more detail on both the cluster parameter and the interplay between cluster age and distribution throughout the galactic disk. 8 clusters of varying age and disk location are proposed for a total of 58 minutes.

2. Description of the proposed programme

A) Scientific Rationale:

Open clusters give one of the most relevant insights into both stellar and galactic evolution. Open clusters are classified as populations of sparsely bound stars. The study of open clusters is done primarily by studying stellar populations by creating a colour-magnitude diagram (CMD). CMDs allow for the estimation of age, distance, metallicity, among other attributes of an open cluster. This is specifically done by the fitting of stellar isochrones, which are fitted to the CMD of the open cluster. Stellar isochrones are ways of fitting data on a CMD that allow the stellar evolutionary path to being determined directly from optical photometry, see Montgomery et al. (1990) for a comprehensive example.

This has been shown to give accurate insight into both stellar and galactic evolution.

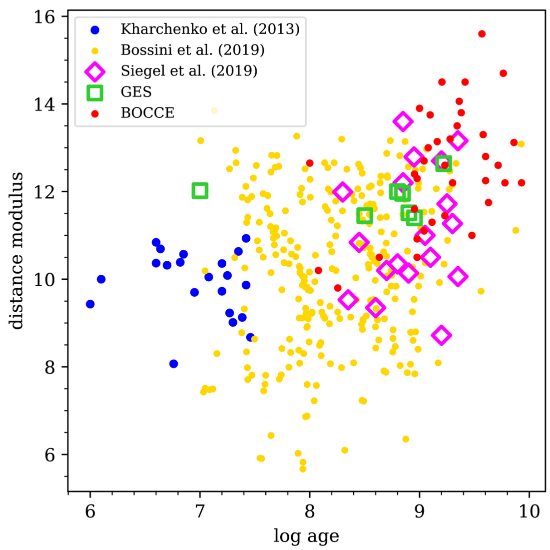
It has been shown by van den Bergh & McClure (1980) that open clusters with an age of 1 Gyr are preferentially located on towards the galactic anti-centre. Oort (1950) found that there was an underabundance of old clusters relative to the number extrapolated by the population of their younger counterparts assuming uniform stellar formation rate throughout the galactic disk during its lifetime. Spitzer (1958) deemed that the small number of old clusters was from disruptive interactions massive clouds towards the galactic core. However, the first large scale study of open clusters analysed by Janes et al. (1988) found that the disruptive processes were too efficient to support the population of the old breed of open clusters. Moreover, this first large scale analysis of the Lynga catalogue (Lynga, 1982) found that the resultant cluster populations were determined through a nuanced relationship between inherent cluster properties, internal dynamics and overall environment in the galaxy.

Since then, Gaia has performed a large astrometric and photometric survey giving the first panoptic view of the galactic disk, which has allowed for a growth in catalogues like WEBDA. Studies such as Cantat-Gaudin et al. (2020) have classified reddening, distance and age of ~ 2000 clusters. Thus since many galactic tracing surveys have been completed, there has been a substantial improvement on the means to determine cluster parameters through isochrone fitting using supplementary high-resolution spectroscopic surveys such as Tojeiro et al. (2009) and Jackson et al. (2022).

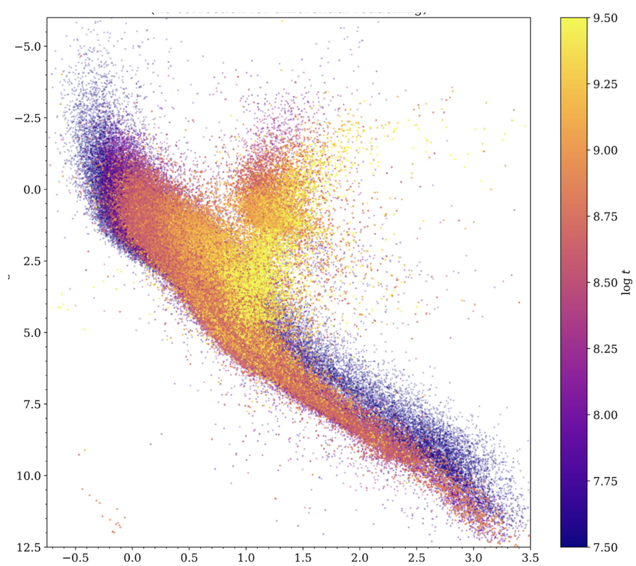
Despite recent surveys, there are still many open clusters that lack sufficient cataloguing and parameters. This study proposes to study the position of open clusters in Milkey Way's disk and show how the inclusion of modern isochrone fitting can consolidate previous research in galactic tracing such as Lynga (1982).

B) Immediate Objective:

The observation expedition proposes to observe a sample of open clusters from the WEBDA catalogue of varying ages and disk positions. This follows on from studies such as Lynga (1982) and VandenBerg & Stetson (2004). However, with the added advantage of using stellar isochrones from the MIST catalogue. These isochrones take full advantage of recent astrometric studies and improved isochrone models (see. Choi et al., 2016). This allows parameters such as reddening, metalicity and convection overshooting to be estimated to a more satisfactory degree than prior studies of a similar nature. This includes things such as



(a) Distance modulus against the log age of a sample of open-clusters.



(b) A comprehensive Hertzprung-Russell diagram which is colour-coded by cluster age.

Figure 1: Both plots provided by Galactic tracing study by Cantat-Gaudin et al. (2020).

the oversight of convection overshooting when fitting isochrones as shown by VandenBerg & Stetson (2004). Convection overshooting shows large discrepancies in the later stage of the main sequence. Correcting for this allows for cluster age to be interpolated at finer increments as a more reliable fit can be attained.

Each cluster's stellar population will be analysed and classified based on the Trumpler system (Trumpler, 1930). This will be done by means of photometric analysis using `photoutils` to create CMD plots for each cluster (fig. 1 (b)). Following classification, a plot against distance age (fig. 1 (a)) The distance of the cluster will be plotted against age to examine the abundance of older clusters on the outer disk and comment on the disruptive interactions with molecular clouds. Using provided CMD's, the presence of pre-main-sequence stars towards the galactic centre will examine. The main-sequence stage of intermediate aged clusters will also be examined. Following this, a comment on the interplay between age, distance and galactic environment can be postulated. Giving insight both into the shape of the milky way disk through tracing distance progression of clusters at varying ages.

3. Justification of requested observing time, feasibility and visibility

This observation expedition proposes the observation of 12 open clusters of varying age. The clusters will be broken into three sets. Each set will comprise of 3 clusters of the following age categories, 'Young': age $<$ 200 Myr, 'Intermediate': 200 Myr $<$ age $<$ 1 Gyr and 'Old': 1 Gyr $<$ age. Each set will be observed at different areas of the galactic disk, see fig. 3.

A list of suitable targets with backup targets can be found in table 1. Table 1 is organised by right ascension (RA) into groups (segregated) with varying ages in each RA window. A list of backup targets is also listed to be compatible with the corresponding group for the primary, and the study suggested if the main objective is not feasible.

Exposure time was selected to have a signal to noise ratio (SN) of $\sim$10 for the most feint members of a cluster population. However, doing this in some cases will cause either source to be saturated if bright or too noisy if feint. In this case, the exposure that adequately observed $\sim$98% of the stellar population was chosen (fig. 2).

Each target will be observed in both **B** and **V** Johnson filters. As mentioned, each cluster will have SN

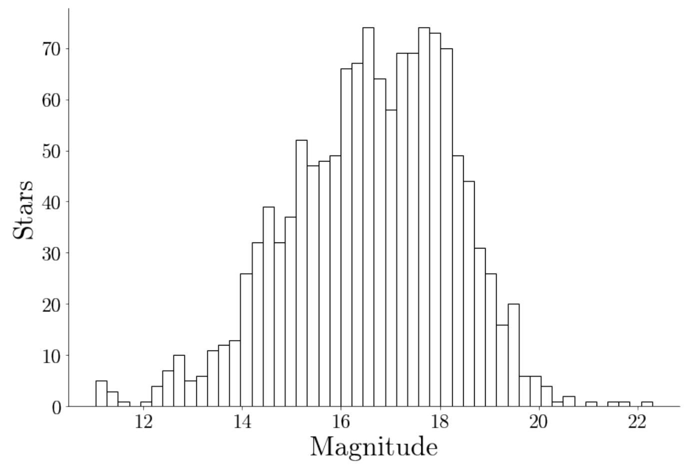


Figure 2: Example distribution of magnitude for stellar population of NGC2129

≃10 for most feint members of the population. In turn, this provides an instrumental error on the magnitude of 0.1 or less. If inadequate samples from across the galactic disk are attained for a sufficient number of clusters, further numbers can be taken from archived data. In the case where the primary objective *cannot* be completed, the observed data can be homogenised and used to catalogue membership and classification of each cluster, producing membership probability along with Trumpler classification of each cluster. This would provide cataloguing of poorly documented clusters see table 1. As discussed with the use of MIST isochrones, ages, convections, and metalicities would be investigated to produce an elegant stellar catalogue for all observed clusters. This secondary objective would take a similar form to VandenBerg & Stetson (2004).

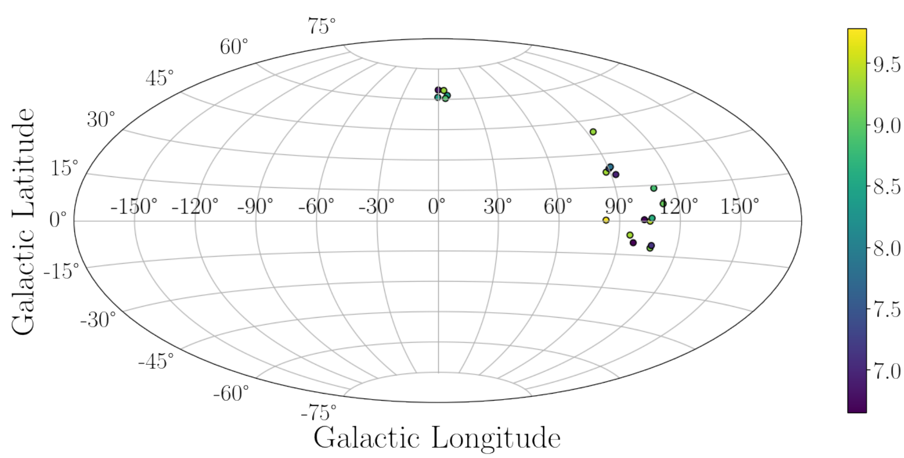


Figure 3: Suggested open-cluster targets plotted in Galactic co-ordinates. Where the cluster age is shown using the color bar. Targets taken from the WEBDA database.

4. Previous/complementary data

A) Preliminary Data:

Lynga (1982)[1] provided the first large scale database on open cluster it has all discussed parameters with specific bib information on where to find any missing parameters. WEBDA[2] is an online version of the BDA created by Mermilliod (1995) it was the primary means of sourcing targets of it has collected most published data on open clusters with over 700 entries from the BDA and cross-references with other available catalogues. WEBDA provided all data seen in table 1. SIMBAD[3] was also used to cross-reference WEBDA during target selection process.

B) Complementary Data:

As there is no spectroscopic photometry performed or use of a U filter, the colour excess and the metalicity will need to be referenced. In the case of metalicity, the values will be inferred directly from observations through isochrones but will need to be supplemented by spectroscopic databases such as Tojeiro et al. (2009). The second Gaia data release can be used for supporting astrometric data provided by studies such as Cantat-Gaudin et al. (2020). In the case where a larger sample size of clusters can give extra data, Jackson et al. (2022) and Bonatto et al. (2006).

References

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[1] https://heasarc.gsfc.nasa.gov/W3Browse/star-catalog/lyngaclust.html

[2] https://webda.physics.muni.cz/

[3] http://simbad.u-strasbg.fr/simbad/

Cluster Name	**RA**	**DEC**	**Age**	**Modlus**	**Diameter**	**B exp.**	**V exp.**	**Total Exp.**	**Obs. Window**
	HH:MM:SS	DEG:HH:SS	log	$m - M$	arcmin	seconds:frames	seconds:frames	seconds	(date) time
King 15	00 32 54	61 52 00	8.40	14.67	3	60 : 4	60 : 4	480	(a)21:00 - 05:00
Stock 18	00 01 37	64 37 3	6.78	14.41	6	60 : 3	60 : 3	360	(a)21:00 - 05:00
King 1	00 22 04	64 22 5	9.3	13.56	9	60 : 3	45 : 4	360	(a)21:00 - 05:00
Berkeley 20	05 33 00	00 13 00	9.78	14.99	2	45 : 2	30 : 3	180	(9)21:00 - 01;30
NGC 2192	06 15 17	39 51 18	9.30	12.11	5	60 : 4	60 : 2	240	(12) 22:30 - 05:30
vdBergh 80	06 30 48	-09 40 00	6.65	0.38	2	110: 2	65 : 3	415	(11) 22:00 - 02:00
Bochum 2	06 48 54	00 23 00	6.665	0.831	1	110: 2	65 : 3	415	(10) 22:00 - 02:00
Berkeley 34	07 00 24	-00 15 00	9.45	15.8	2	60 : 4	120: 3	600	(10) 22:00 - 03:00
NGC 2355	07 16 59	13 45 00	8.85	12.08	7	60 : 4	45 : 4	420	(9) 21:00 - 04:00
Backup targets									
Berkeley 2	00 25 18	60 24 00	8.90	16.08	2	60 : 4	115: 2	410	(a) 21:00 - 05:00
Berkeley 21	05 51 42	21 47 00	9.34	15.85	5	60 : 3	115: 2	350	(13) 21:00-03:00
NGC 2129	06 00 41	23 19 06	7.318	12.9	5	60 : 4	60 : 4	480	(11) 22:30–04:00
Berkeley 73	06 22 00	-06 21 00	9.36	14.5	2	100: 4	100: 4	800	(9)21:00 - 02;00
Berkeley 76	07 06 41	-11 43 30	9.18	17.21	5	100: 4	100: 4	800	(11) 22:30–03:30
Haffner 3	07 04 00	-06 08 00	/	/	/	100: 4	120: 3	760	(12) 22:00–02:30
NGC 2394	07 28 36	07 05 12	9.05	9.25	8	60 : 4	120: 3	600	(9) 21:00-03:30

Table 1: Propesed Open Clusters for obsercation using WEBDA catalog. For the observation window most targets are obserble each night however preffered observation times have been listed. (a) denotes that there is no favoured night for observation.