

Pathfinding with the Old Breed:

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ABSTRACT

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*This work is dedicated to my mentor and my friend
Noel White, (1951-2021).*

1. INTRODUCTION

Open clusters have been shown to be an integral part of the astronomers toolbox, readily lending themselves as stellar laboratories. Open clusters are classified as a group of stars around the same age and loosely bound through mutual gravitation. Their similar age allows for in depth observation of the stellar evolution. Through this many attributes of the stellar population can be inferred. As clusters span age ranges from a X to X, many have been present since formation of the disk itself. Through this if clusters of varying ages are examined it's possible to trace out the evolution of the milky way.

Mapping the milky way has always been difficult given the vantage point it can be observed from. This makes it quite difficult to appreciate the shape and dimensions of the milky way. Some of the pioneering studies such as [Herschel \(1785\)](#); [Shapley \(1918\)](#) and [Trumpler \(1930\)](#) first outline the use of open clusters to map the galaxy. Following with studies like [Becker & Fenkart \(1970\)](#) which pathed the spiral arms of the milky way using open clusters and numerous studies by [van den Bergh \(1958\)](#) which explore the evolution of the galaxies scale height. To more recent studies by X

While the precision and accuracy of cluster age estimates are tied to the quality of the observational data and theoretical models the process of estimating cluster age through use of colour-magnitude diagrams is relatively straightforward and been shown to be tried and true. Even early open cluster catalogues like X and X included distance estimates while more recent catalogues like X and X have provided other parameters such as age, metallicity and excess colour. Furthermore

with the second data release from GAIA (X) presents the most in-depth all sky astrometric and photometric study to date.

This increase in available data has allowed for the characterisation of open clusters on mass adding to catalogues such as WEBDA. Determination of all open clusters identified by Gaia is an ongoing task and is being automated using modern techniques and machine learning as shown in studies by X and X.

This study used the 1.25 m optical telescope at the Calar Alto Observatory (CAHA) to observe four open clusters from the WEBDA catalogue. The aim of this work was to classify the four observed clusters and infer details of each cluster. Then use this observational cluster classification in tandem with other open clusters from the WEBDA catalogue to trace the paths of clusters in the galactic disk studying both its structure and evolution.

1.1. Open Cluster Types

As open clusters span many different distributions in both density, size and stellar constituents. Open clusters can contain large stellar agglomerations to just a handful of stars. While classification systems can vary based on the context of the study the scheme coined by [Trumpler \(1930\)](#) sees prominent use.

This scheme classifies cluster based on three factors of the stellar population. a) their range of brightness, b) degree of concentration and c) star population in the cluster. The details of this classification scheme can be seen in table 1.

2. OBSERVATIONS

2.1. Target Selection

2.2. Photometry

Table 1. Trumpler classification scheme.

Range of Brightness	Degree of Concentration	Cluster Population
(a)	(b)	(c)
1 - Majority of stellar objects show similar brightness.	I - Strong central concentration (Detached)	p - Poor ($n < 50$)
2 - Moderate brightness ranges between stellar objects.	II - Little central concentration (Detached)	m - Medium ($50 < n < 100$)
3 - Both bright and faint stellar objects	III - No disenable concentration	r - Rich ($n > 100$)
	IV - Clusters not well detached (Strong field concentration)	

NOTE—Where n denotes the amounts the stellar population in a given cluster. For example Pleiades is a I3rn cluster and Hyades is a II3m cluster. Where the 'n' flag on a classification relates if the cluster shows nebulosity.

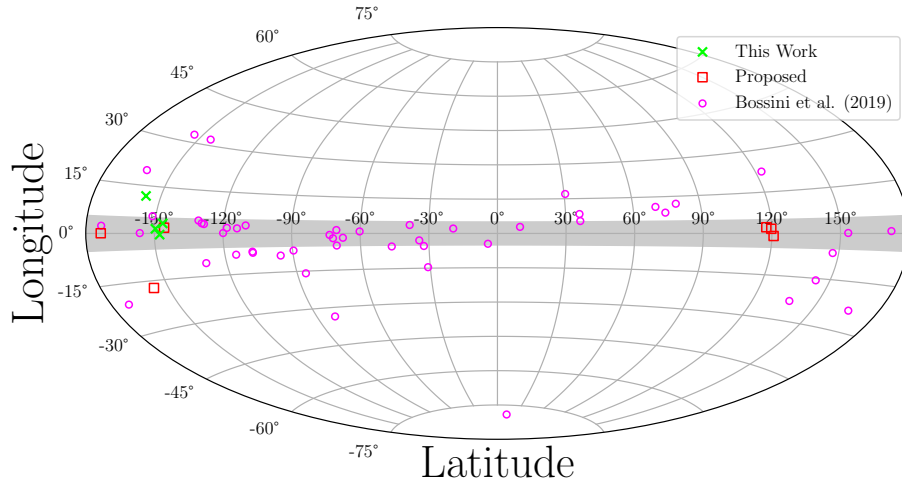


Figure 1. Aitoff projection of targets in terms of galactic co-ordinates, longitude (l) and latitude (b). Targets observed at CAHA are observed in X, the original proposal targets shown in X and studies by [Bossini et al. \(2019\)](#) and

3. SUPPLEMENTARY DATA

This study compiles X clusters to aid the observational data. When searching for studies to compliment this work use Gaia's second data release (DR2) was set given preference. The reason for the use of supplementary data was to provide a more varying survey of the galactic disk. The first data set implmented was 269 clusters analysed and catalogued by [Bossini et al. \(2019\)](#). This dataset contains large sample of clusters analysed from Gaia DR2, with each of the clusters containg a high degree homogenity among the stelllar population. The cluster populations were determined using Bayesian

methods of statistics along with DR2 astrometric data. In doing this the probability of each star being a member of each clusters was approximately X. The parameters of each cluster was found using PARSEC isochrones ([Bressan et al. 2012](#)). This data set worked well to fill out a sample size in the galactic disk as seen in fig. 1. Although this survey contained a good amount of clusters with varying age it lacked some the ancient clusters of the milkey way. To supplement this gap the Swift UVOT near-infrared isochrone study using Gaia DR2 ([Siegel et al. 2019](#)) was added to the pool of clusters for analysis.

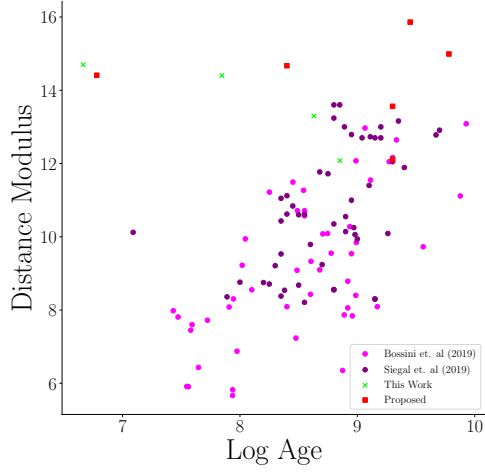
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Table 2. Results of Trumpler classification on observed targets.

Target	ΔV_{mag}	ΔB_{mag}	σ_s	Population n	
(1)	(2)	(3)	(4)	(5)	(6)
Berkeley 28					m
Bochum 2					
NGC2324	12	12	12	333	r
NGC2324					r

NOTE—Where n denotes the amounts the stellar population in a given cluster. For example Pleiades is a I3rn cluster and Hyades is a II3m cluster. Where the 'n' flag on a classification relates if the cluster shows nebosity.

**Figure 2.** Distance against the log age of both observed targets, proposed targets and supplementary targets.

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APPENDIX