Pathfinding with the Old Breed

An open cluster survey for Galactic Tracing

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Image courtesy of DSS2

“The heavens are now seen to resemble a luxuriant garden, which contains the greatest variety of productions, in different flourishing beds.”

- Sir William Herschel

Objectives and Motivation

Primary Objective

1. Observe open cluster with little use in galactic tracing
2. Determine cluster's population using methods from modern studies
3. Explore **relationships** between parameters and Galactic position.

Secondary Objective

1. Classify observed clusters according to the Trumpler scheme.
2. Nicely catalog stellar population of each observed cluster.

Motivation

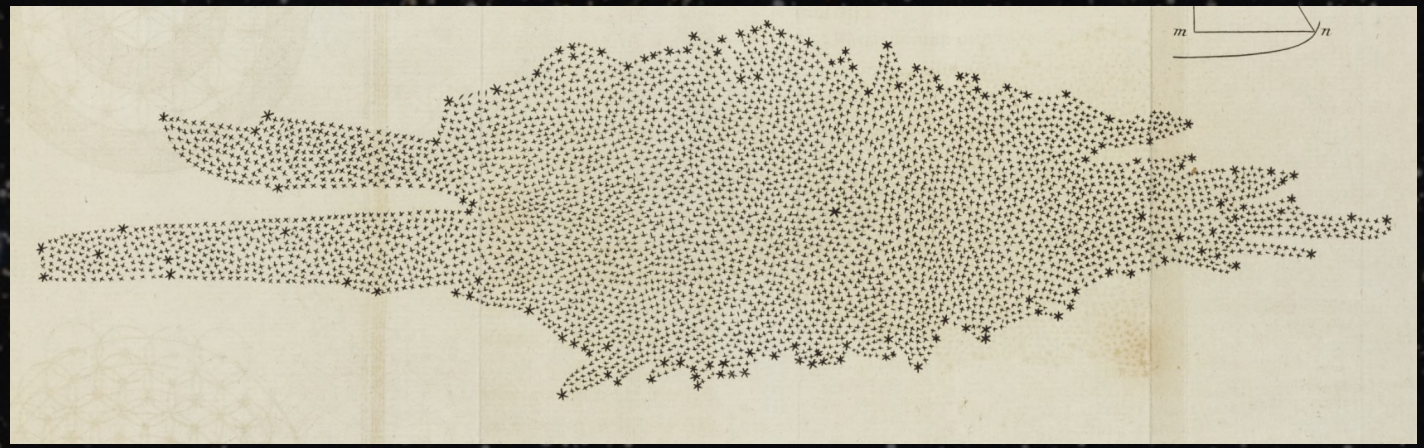
1. Lots of data, no one to analyze.
2. Large development in isochrone research in the last 2 decades
3. Aid Gaia's second data release (GDR2)
4. Resurgence of similar studies [Xiang, M., Rix, HW. (2022)]
5. I really like the idea of cataloguing stars

A Brief History on Galactic Tracing and Open Clusters

1785: *William Herschel* publishes ‘on the construction of the heavens’ detailing one of the first formal mappings of the milky way

1918 – 1930: *Harlow Shapley & Robert Trumpler* use classification schemes and cluster parameters to try relate milky way structure.

1960 – 90’s: *Van de Burgh, Becker and Fenkart* conduct first studies mapping the arms of the milky way using open clusters.

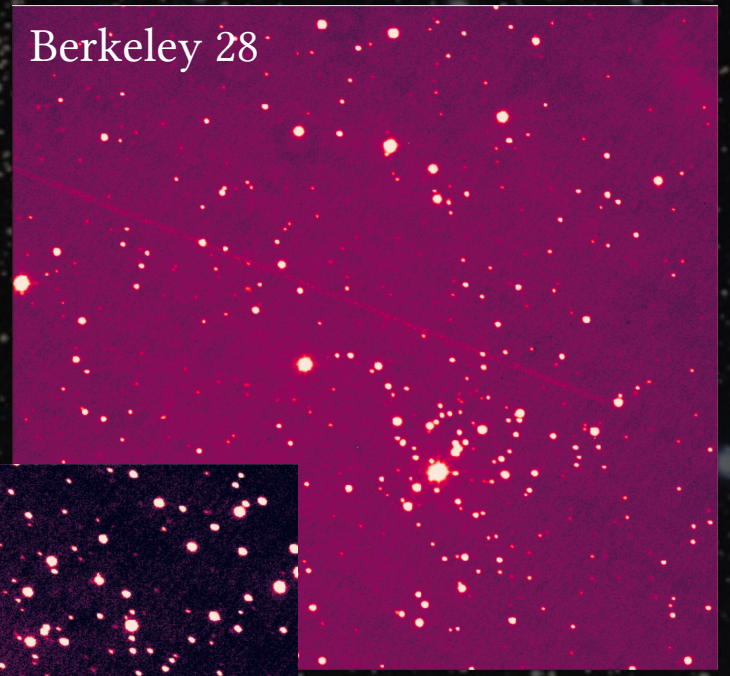


1980’s – 2010’s: ***Lynga and Janes et al.*** perform mass isochrone fitting and cataloging.

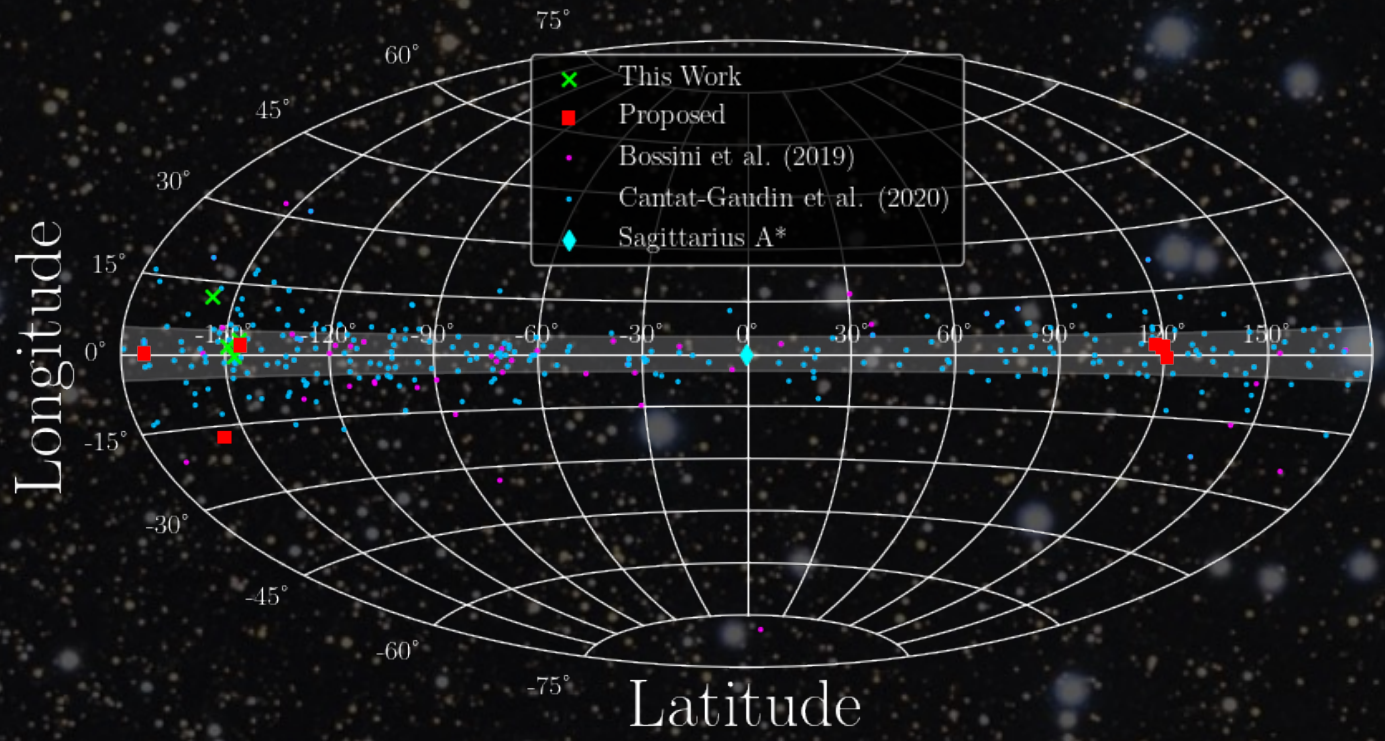
2010’s – Present: Dozens of machine learning and statistical studies looking at 1000’s of clusters

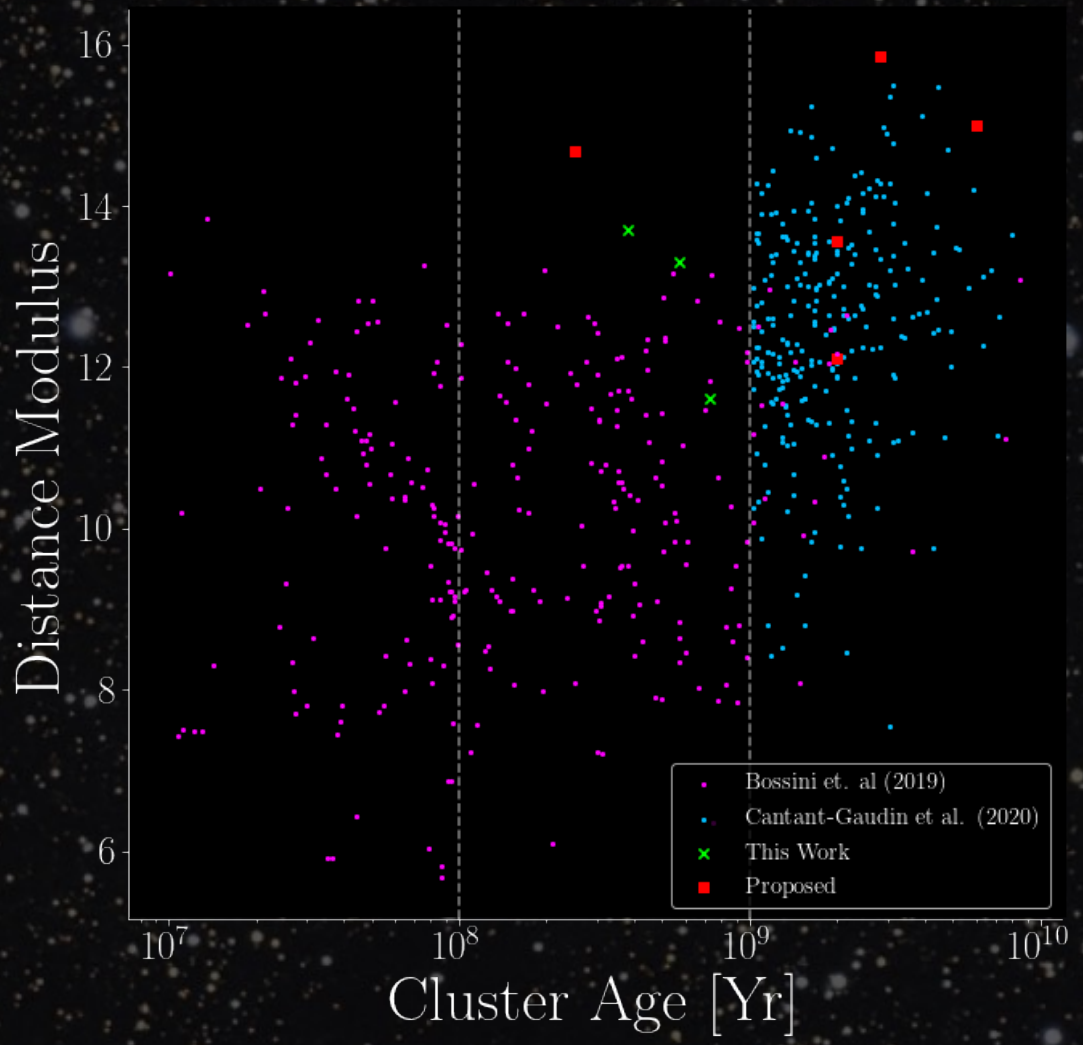
What are Open Cluster?

- Collective stellar populations of a few stars to ~ 1000
- Most are younger than globular cluster
  - Young: < 100 Myr
  - Old: > 1000 Myr
- Loose gravitational bound
- High metallic enrichment, comprised population I stars
- **Homogenous populations**, makes them ideal to use as stellar laboratories.



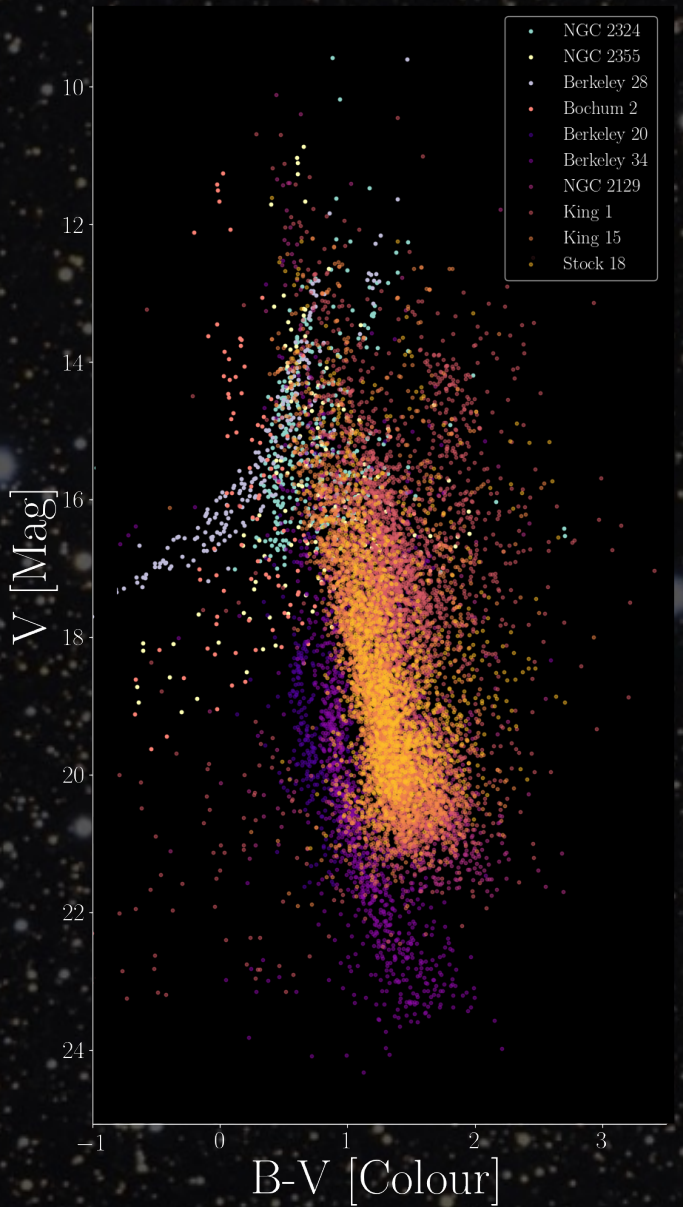
Target & Data Selection Strategy





Along with specific WEBDA studies

Determining Cluster Parameters



We've now have clusters of interest how do we learn about them?

Through fitting ***isochrones*** to ***colour magnitude diagrams*** (CMDs)

Isochrone → a curve that can be fitted to a Hertzsprung-Russell (H-R) diagram that details the evolution of stars with specific parameters (age, Fe/H, Av, distance)

CMDs → diagram variant of H-R diagram using magnitude (y-axis) and colour (x-axis)

Obstacles in Fitting Isochrones

The prominent problem in determining open cluster parameters

1. Are the detected stars members of the cluster?

Reason for problem: Open clusters have no discernable shape so that puts conventional spatial distribution profiling *out the window*

Possible Solutions to the Problem

1. Open Clusters do have a homogenous stellar population, we then turn to clustering on the CMD and metallicity distribution of targets!
2. Use of an astrometric study such as Gaia's second data release to determine population members!

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For this study we use Gaia's parallax data! Due to its accuracy and similar approach in [Joshi. Y.C et al. (2014)], [Stott. J, (2018)] and Gaia DR2

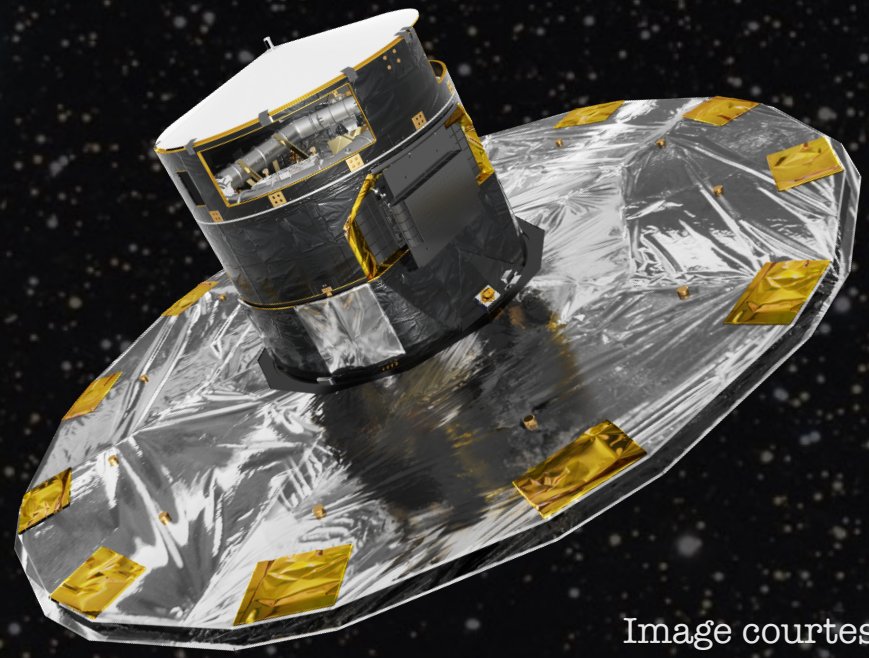
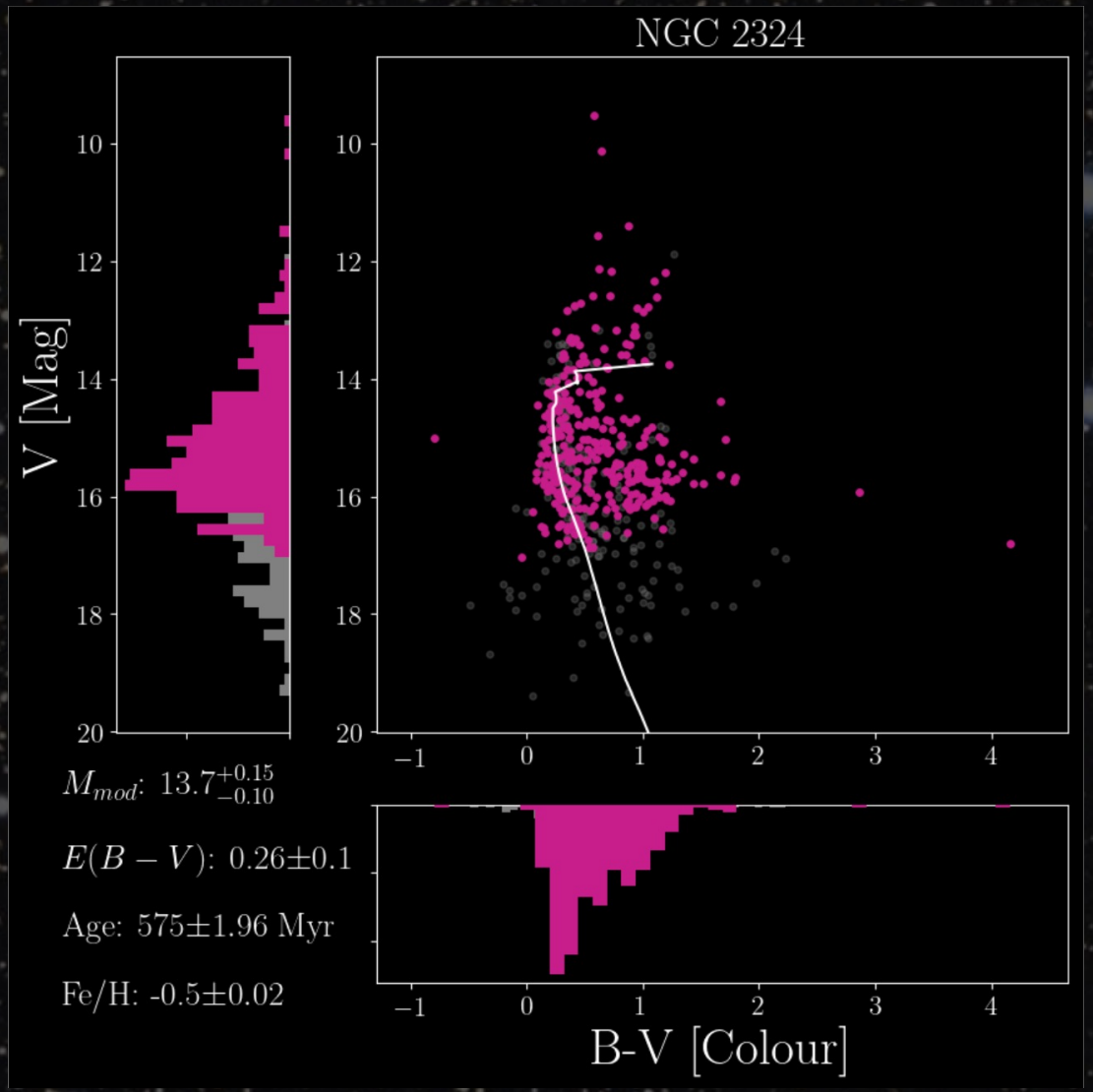
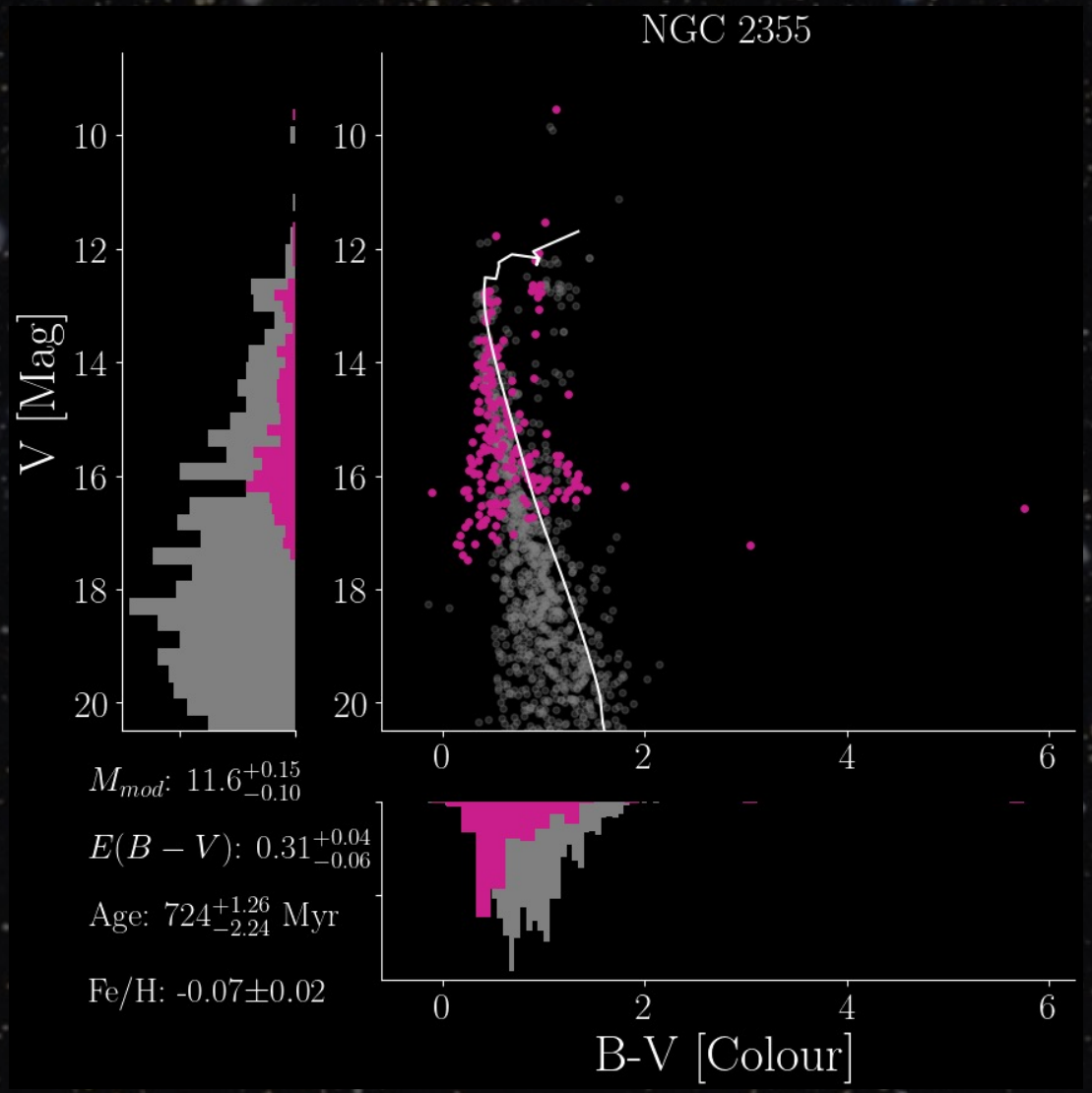


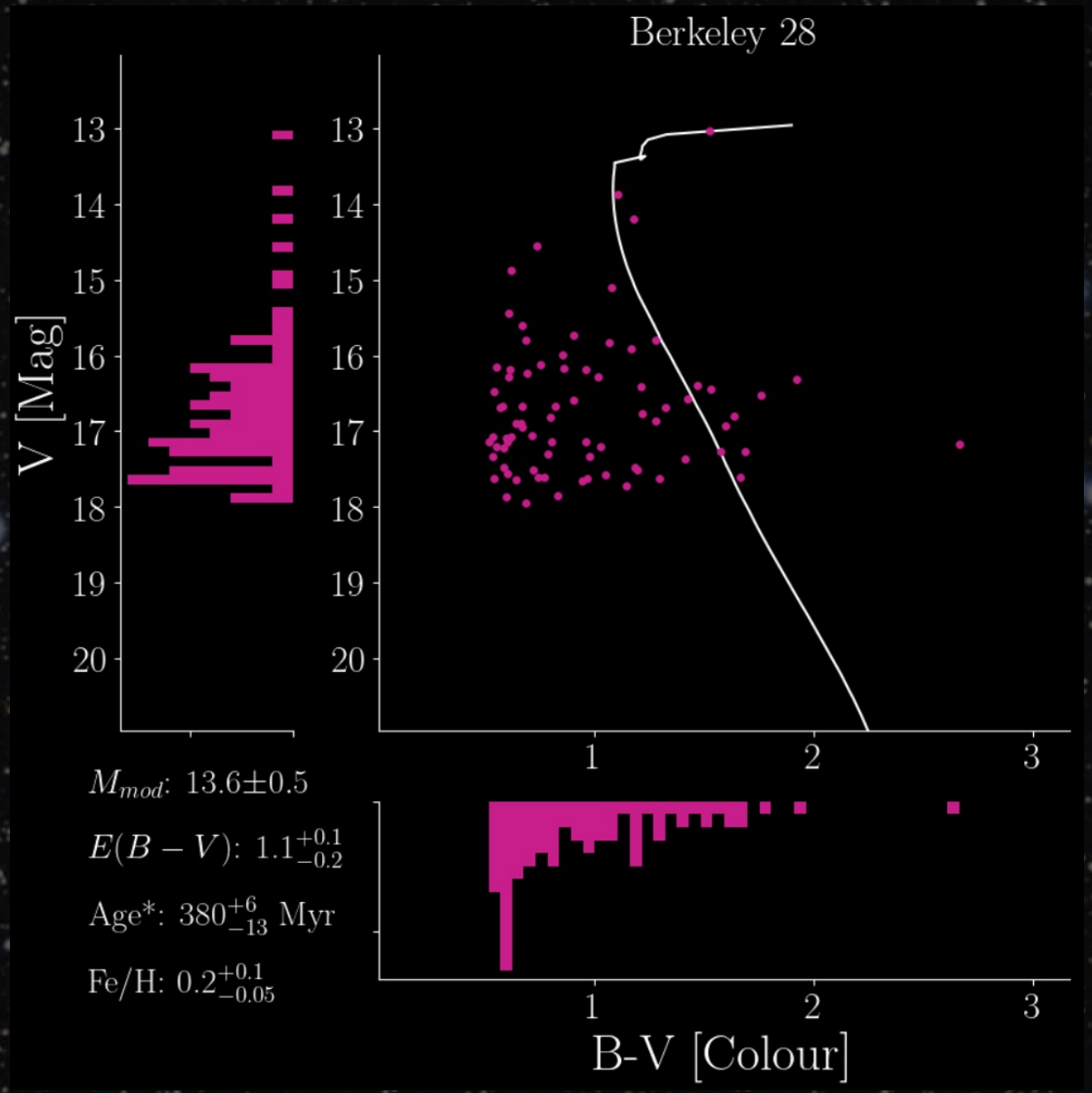
Image courtesy of ESA

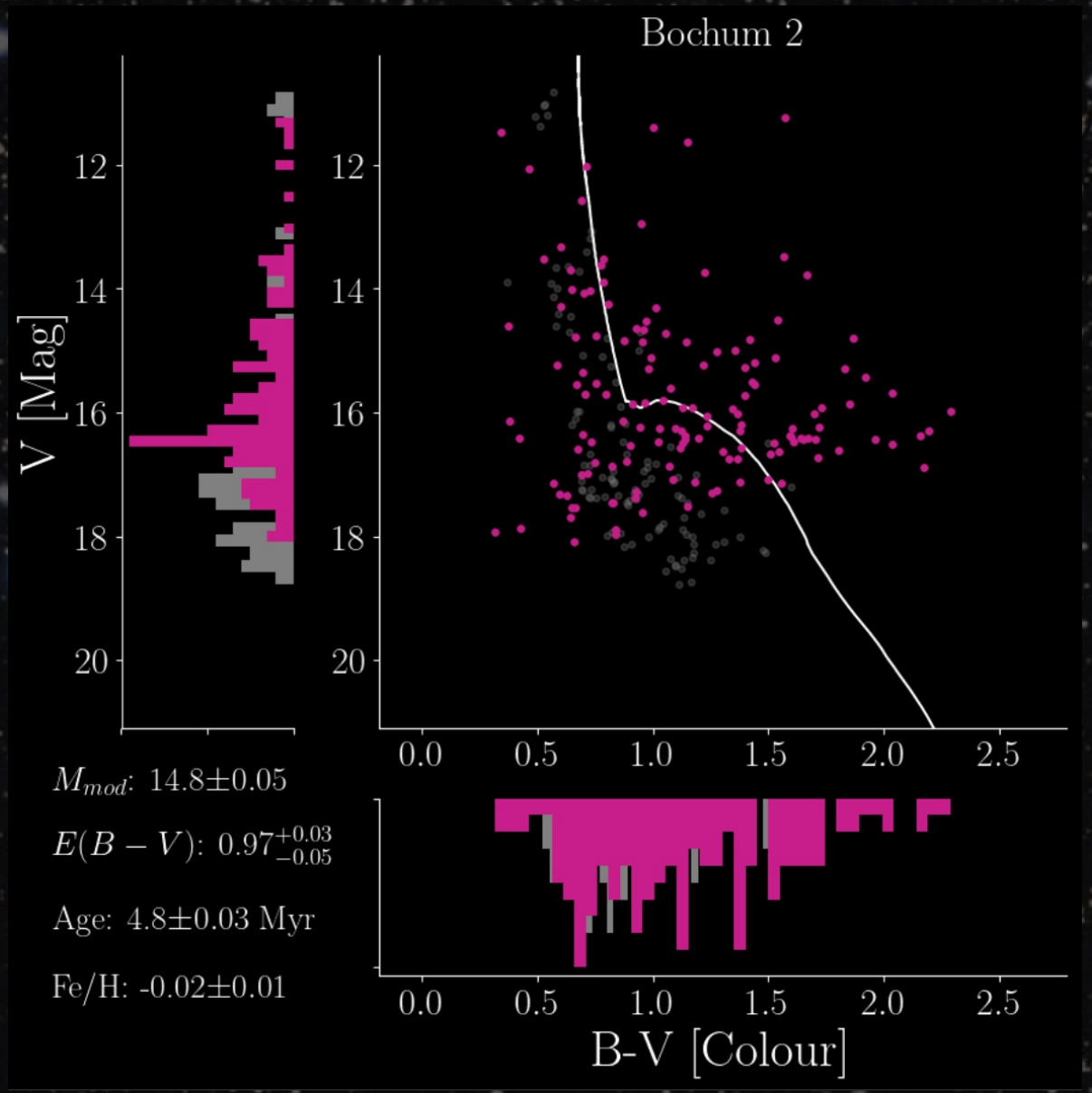
Observational Results

Using MIST Isochrones






Berkeley 28
V [Mag]
B-V [Colour]
M_{mod}: 13.6±0.5
$E(B-V)$: $1.1^{+0.1}_{-0.2}$
Age*: 380^{+6}_{-13} Myr
Fe/H: $0.2^{+0.1}_{-0.05}$


Bochum 2
V [Mag]
B-V [Colour]
M_{mod}: 14.8±0.05
$E(B-V)$: $0.97^{+0.03}_{-0.05}$
Age: 4.8±0.03 Myr
Fe/H: -0.02±0.01

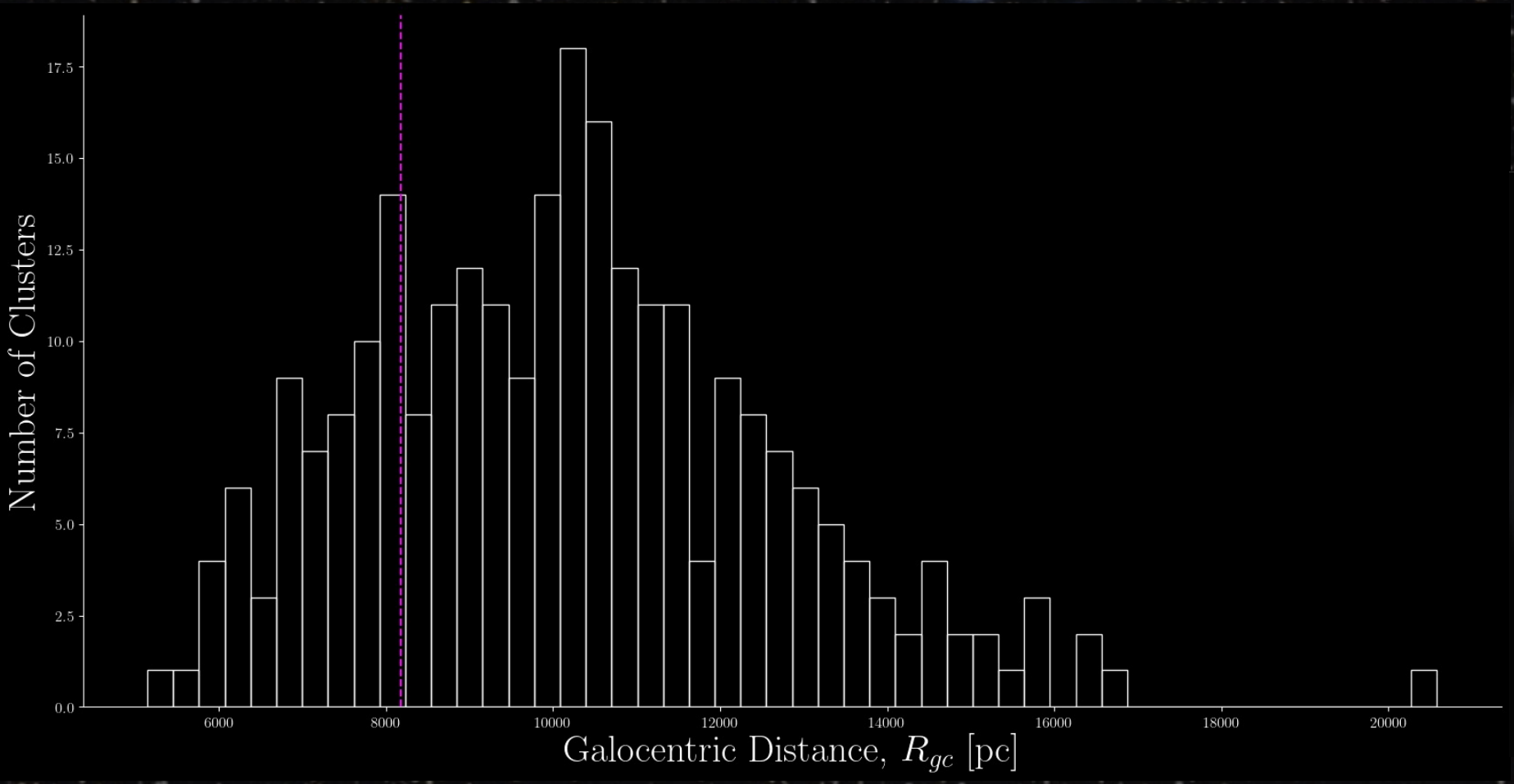
How do these compare to other values?

Target	Distance [Mod]	Log Age [yr]	Fe/H	Population*	WEBDA Study
NGC 2324	13.7/13.3/13.1	8.8/8.6/8.7	-0.5/-0.5/-	251/187/242	Frandsen S., Arentoft T. (1998)
NGC 2355	11.6/12.1/11.4	11.6/11.8/9.0	-0.07/-0.07/-	209/266/261	Kaluzny J., Mazur B. (1991)
Berkeley 28	13.6/14.4 /13.4	8.6/7.8/8.5	0.2/-/-	79/77/53	Mohan V. et al. (1988)
Bochum 2	14.8/14.7/-	6.7/6.6/-	-0.02/-/-	108/87/-	Turbide L., Moffat A.F.J. (1993)

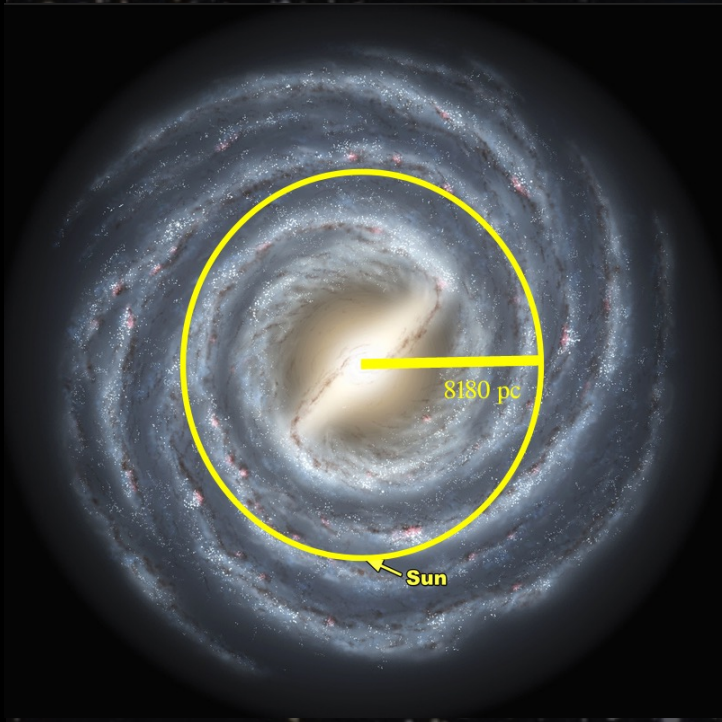
Cantant-Gaudin et al. (2020)

The Old Breed's Distribution

Distribution of Observed, Proposed and Cantat-Gaudin et. al

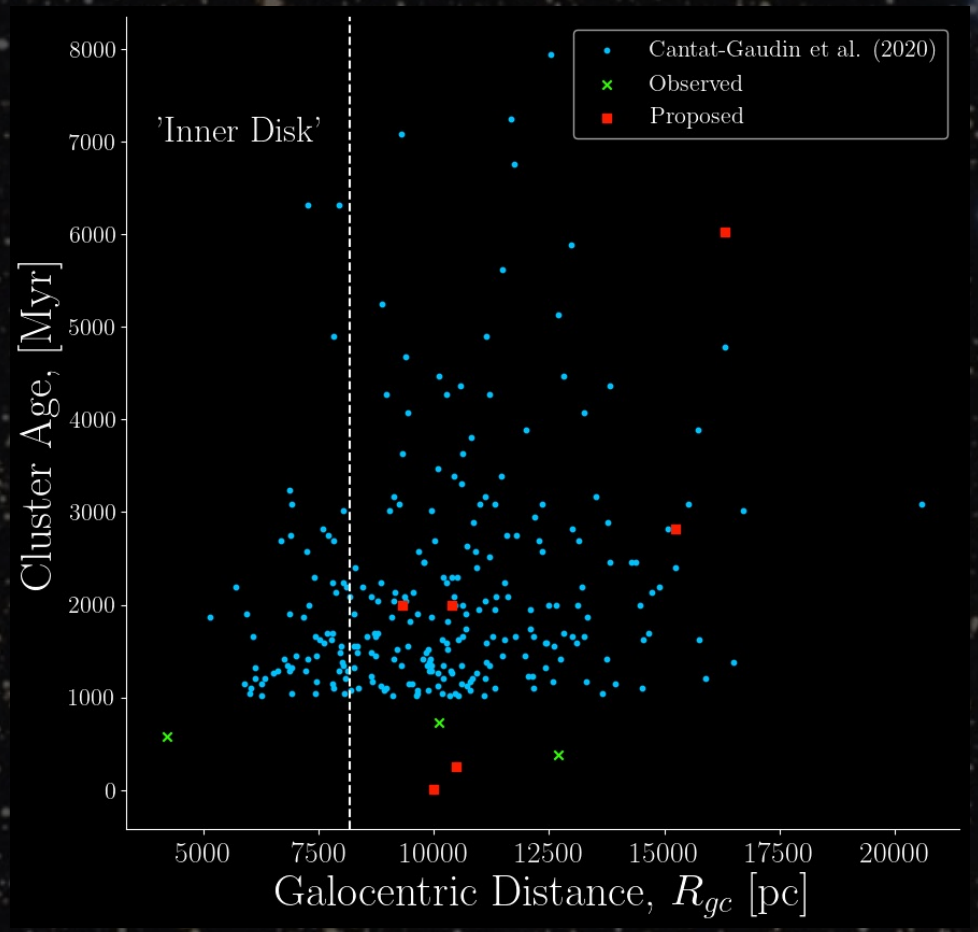


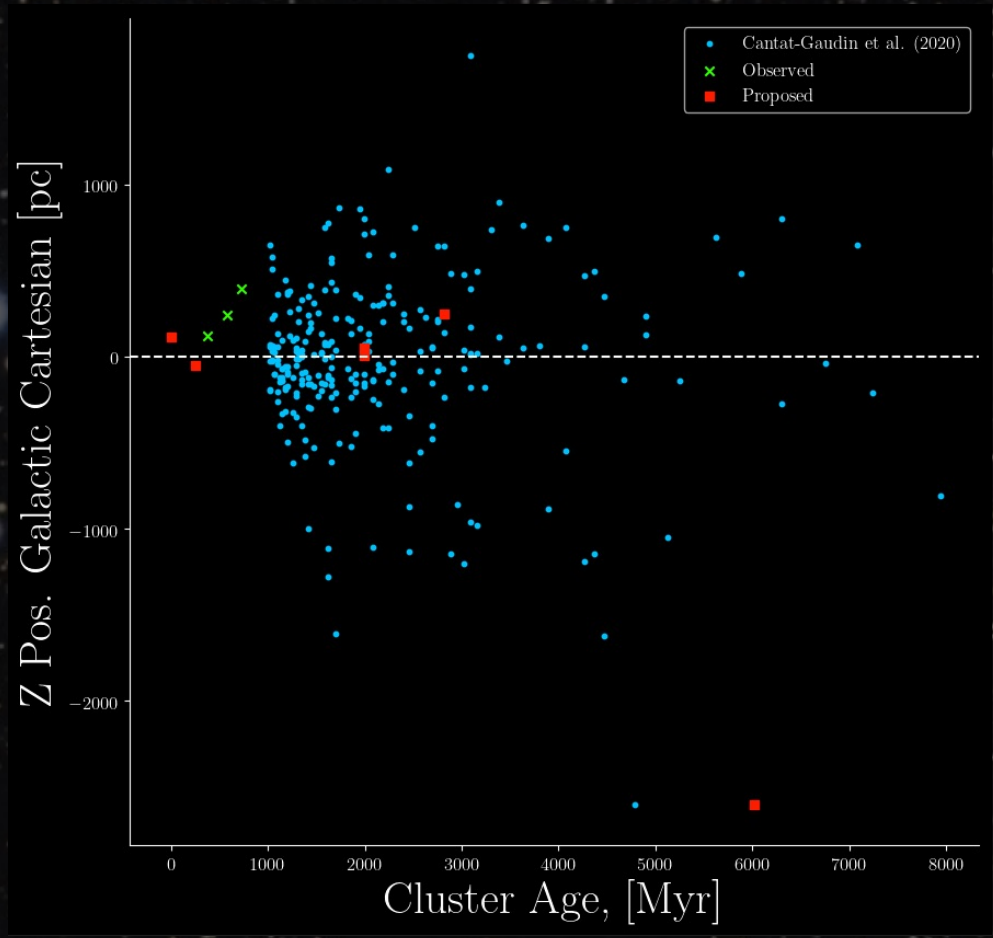
- Underabundance of open clusters in the inner disk.
- Relationship between open clusters age and galactic position?

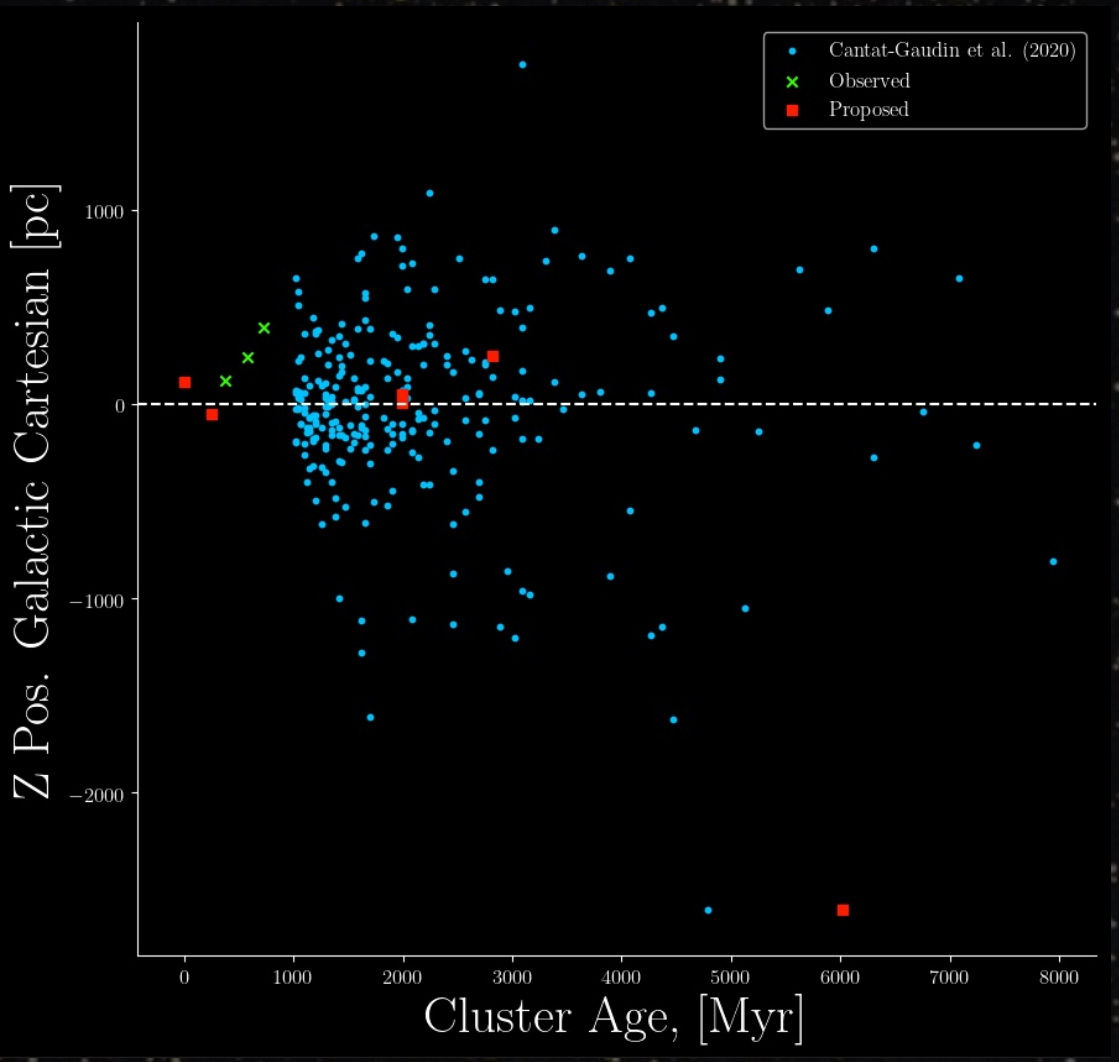


~8180 pc for Suns R_{gc} [Gravity Collab. , 2019]

How these values add to mapping the Milky Way







- My thought, correlation between age and location is non-existent
- Contradicts initial predications by Oort [1950] and Spitzer [1958]
- Oort assumed uniform star formation throughout the galactic disk. Lack of old open clusters was due to extrapolation from younger clusters.
- Spitzer: Interactions with massive clouds at the core were the cause. Janes et al. [1988], cluster formation is too efficient for this to be the case.

Reasons for this?

- Two of the oldest known clusters are within 200 pc from the plane, Be 17 (10 Gyr) and Cr 261 (8 Gyr)
  - Presence of old clusters like this among others don't help the case for disruptive tidal forces
  - This is furthered by the presence of WEBDA clusters within the 'inner disk'.

- It's also not surprising to find so many old clusters are found away from the galactic plane from an observational point of view.

Final Thoughts

- The underabundance of the Old Breed in the disk is probably due to a nuanced relationship between cluster properties, internal dynamics and overall galactic environment
- Answer lies with…
  - Astrometric data for old clusters looking at orbital motion
    - [Carraro and Chiosi, 1994]
  - Mass cataloging of cluster parameters, reddening & metallicity
    - [Cantant-Gaudin et al. 2020]
  - Spectroscopic surveys in tandem with Open Cluster classification
    - [Jackson et al. 2022]

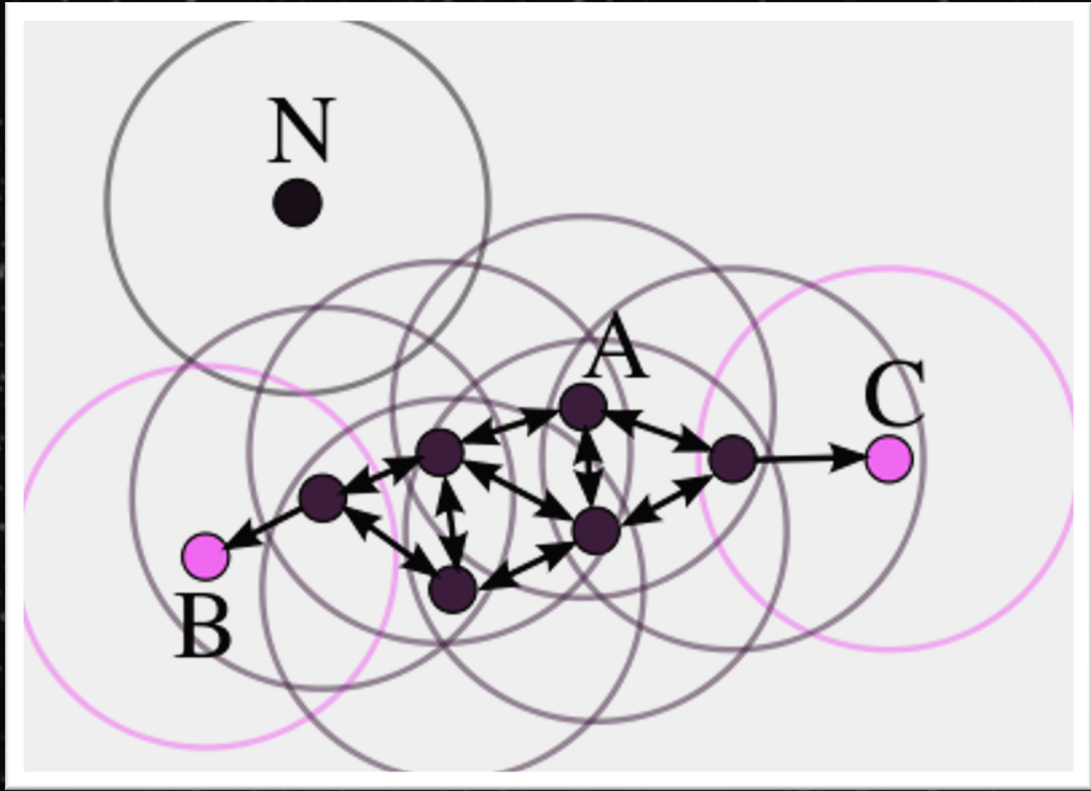
The End…

Questions? Feedback?

Slides to Aid Potential Questions

How does the Gaia data filter population

Using parallax and HDBSCAN



DBSCAN is an algorithm coined by Ester et al. (1996)

Identifies clusters and areas of high density based on two things!

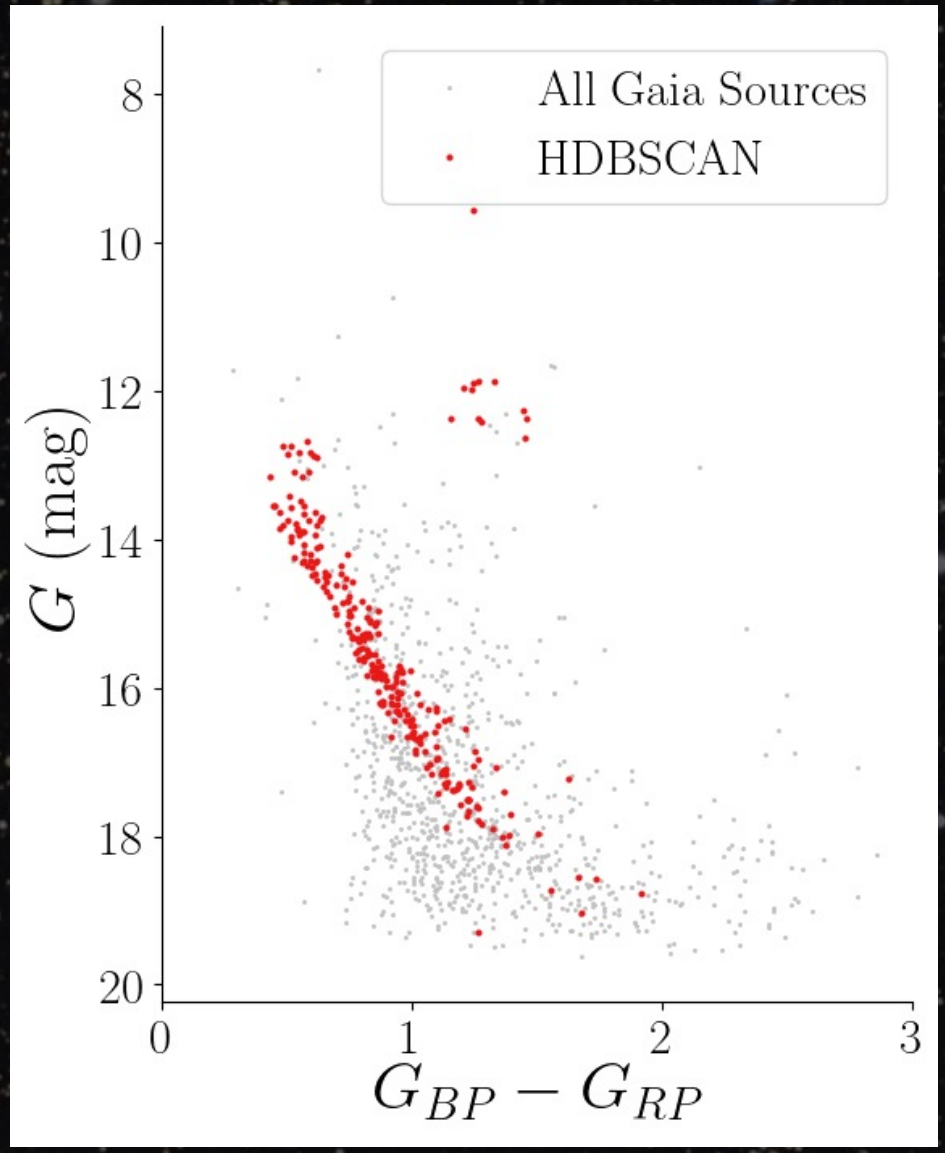
1. Linking length!
2. Minimum neighborhood points

How does the Gaia data filter population

HDBSCAN depends only on the cluster size. It removes the need for a linking length.

It creates a minimum spanning tree by pruning off the nodes that do not meet the minimum number of stars in a cluster cluster, and reanalysing the nodes that do.

Designed by Kounkel C. et al. (2019)



Metallicity relationship