



Google Classroom and Open Clusters: An Authentic Science Research Project for High School Students



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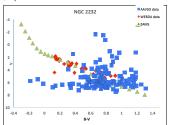
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Abstract

STEM education is about offering unique opportunities to our students. For the past three years, students from two high schools (Breck School in Golden Valley, Minnesota, and Carmel Catholic High School in Mundelein, Illinois) have collaborated on authentic astronomy research projects. This past year they surveyed archival data of open clusters to determine if a clear turnoff point could be unequivocally determined. Age and distance to each open cluster were calculated. Additionally, students requested time on several telescopes to obtain original data to compare to the archival data. Students from each school worked in collaborative teams, sharing and verifying results through regular online hangouts and chats. Work papers were stored in a shared drive and on a studentdesigned Google site to facilitate dissemination of documents between the two schools.

NGC 2232

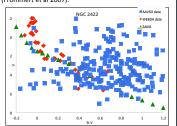
NGC 2232 is located in the Gould Belt. It contains approximately 20 stars of class A, B, and M stars. (Claria 1972).



RA 06 08 21 Dec -04 50 48 Reddening 0.03 Pub. distance: 359 pc Calc. distance: 258 ± 37 pc Published age: 53.3 Myr Calculated age: 69 ± 10 Myr

NGC 2422

NGC 2422, also known as M47, is located in the constellation Puppis and contains approximately 50 stars Two of the cluster members are orange K giants (Frommert et al 2007)



RA 07 36 35 Dec -14 29 00 Reddening 0.07 Pub. Distance: 490 pc Calc. distance: n/a Published age: 72.6 Myr

Results

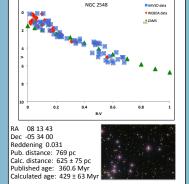
Data were shifted to match the ZAMS line. This shift (m-M) was then used to calculate distance using the distance modulus $(m-M=5 \log d -5)$. The magnitude of the best estimate turnoff point was used to calculate age (-3.477 logM + 33.304) (Meynet 1993). Through shared Google docs and virtual hangouts, team members compared their results. Errors were agreed upon to be 15%, which in some cases is quite conservative.

Methods

Following our initial conversations, team members from both schools narrowed their lists of open clusters to those with little reddening. We first used AstroImage to find the magnitude of representative cluster members. Later we searched available archival databases (i.e., WEBDA and AAVSO) for additional photometric values, namely B and V values. Through Google hangouts and Google sheets, team members compared their Color Magnitude Diagrams (CMDs). Team members then overlaid a Zero Age Main Sequence (ZAMS) graph. Applying a magnitude shift allowed us to separate cluster members from outliers. We discussed our personal methods of alignment and cluster membership. Where possible, the turnoff point was used to calculate cluster distance and age. This research has made use of the WEBDA database, operated at the Department of Theoretical Physics and Astrophysics of the Masaryk University and APASS, the AAVSO Photometric All-Sky Dataset.

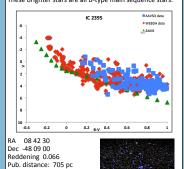
NGC 2548

NGC 2548 (M48) is in the Hydra constellation. Due to an error in recording the position of this cluster during its discovery in 1771, the cluster was missing from the star catalog and never counted.



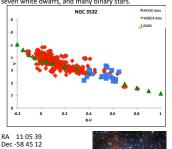
IC 2395

IC 2395 (also known as Cr 19) is in the constellation Vela is a small, scattered cluster of moderately bright stars. These brighter stars are all B-type main sequence stars.



NGC 3532

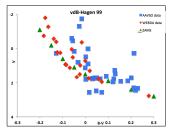
NGC 3532, also known as "the Wishing Well Cluster," is found in the Carina constellation. It contains approximately 150 stars and includes seven red giants even white dwarfs, and many binary stars.



Reddening 0.037 Pub. distance: 486 pc Calc. distance: 630 ± 92 pc Published age: 310 Myr Calculated age: 283 ± 42 My

vdB-Hagen 99

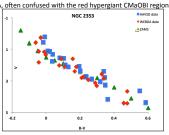
The vdB-Hagen 99 cluster is sparsely populated at distance of 507 pc and located near the Carina spiral arm structure of the Milky Way but is not a part of the spiral.



10 37 54 -05 34 00 Reddening 0.055 Pub. distance: 507 pc Calc. distance: 459 ± 69 pc Published age: 40.3 Myr Calculated age: 21 ± 3 Myr

NGC 2353

NGC 2353 lies along the celestial equator in the onstellation Monoceros. It contains several bright B and , often confused with the red hypergiant CMaOBI region.

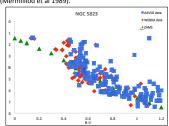


Dec -10 16 00 Reddening 0.072 Pub. distance: 1119 pc Calc. distance: 1148 ± 172 po Published age: 94.2 Myr Calculated age: 84 ± 12 Myr



NGC 5823

NGC 5823, located in the constellation Circinus, contains at least two red giants and could possibly contain more but the majority of the stars are on the main sequence (Mermilliod et al 1989)



15 05 30 Dec -55 36 12 Reddening 0.09 Pub. Distance: 1192 pc Calc. distance: 298 ± 45 pc



Conclusions and Future Work

It proved to be difficult to determine the exact turnoff point for many of our clusters.. A clearer method of determining cluster membership would allow for less subjectivity. A larger sample of clusters would allow for a better method of determining turnoff points, leading to greater accuracy in calculating age and distance.

Calc. distance: 758 ± 62 pc