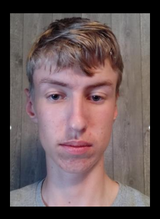
The age of NGC 6939 using an isochrone fitting on a color-magnitude diagram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Introduction

Observation were done of open cluster, a group of 20 to 1000 stars which were formed from the same gas cloud, NGC 6939 (see fig. 1). Therefore their age is approximately the same.

In this research the age of the cluster was determined and thus the age of hundreds of stars.

Fig. 1: Open cluster NGC 6939
Exposure time is 15x60 in B, 9x60 in R and 14x60 in V. Pixel scale is 0.431 arcsec/px. Diameter of 20” with f/8.1.

Method

The positions of the stars were found in the V filter using a local density maximum algorithm. Their position were used to measure the flux in the B and V filter using aperture photometry.

The flux was converted into magnitudes using $m = c_0 - 2.5\log(f)$. c_0 is determined by using reference stars from the Simbad catalogue. Those magnitudes were used to form a color-magnitude-diagram (CM-diagram).

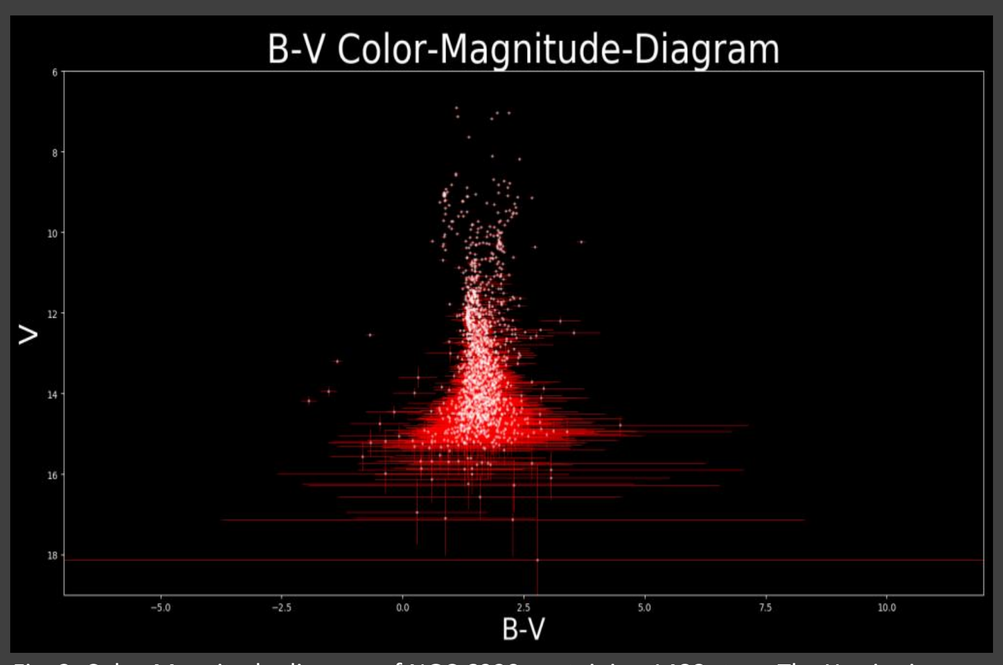

Fig. 2. Color-Magnitude diagram of NGC 6939 containing 1488 stars. The Y-axis gives the magnitude in the V filter. The X-axis gives the magnitude of the subtraction of the B and V filters (B-V).

Conclusion

While the reduced chi-squared was the lowest for a logAge of 9.1, the chi-squared test is not truly applicable, since the isochrone is a function of the star mass, a variable that we did not have data on for the cluster. Because of this, the result for the logAge should be interpreted as “between 9.0 and 9.4” based on the eye test, rather than as 9.1 based on the chi-squared test.

The cluster age is therefore estimated to be between 1.0 and 2.5 billion years old.

Isochrone fitting

A cluster’s age can be determined by using isochrones, which are lines in a CM-diagram on which stars with the same age with varying masses would be located. Specifically the location on the diagram where the isochrone bends away from the main sequence, called the turnoff point, is crucial.

An iterative fitting process was performed with 3 parameters: distance, reddening and age. Those were alternately varied with the others set as constants, and the value with the lowest reduced chi-square was returned. This value was then used to determine the optimal value for the next parameter. This process was continued for several cycles until all 3 parameters converged to certain values.

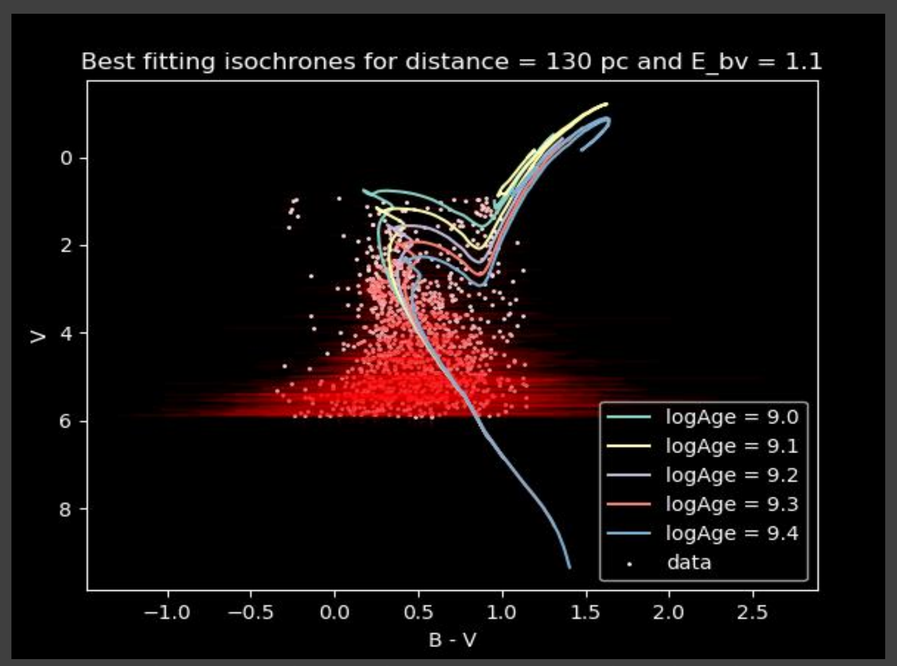

Fig. 3: CM-diagram with error bars in opaque red, and isochrones ranging from logAge 9.0 to 9.4 with reddening 1.1 and distance 130 parsec. Only the stars and the parts of the isochrone around the turnoff point are shown.

Results

Optimal values and uncertainty ranges are shown in the table below. For distance and reddening, lower and upper uncertainty bounds were defined as the values on either side of the optimal value for which reduced chi-square was at least 1 higher. This method was not suited and wildly inaccurate for the age however, so the bounds on that were determined with the eye.

Parameter	Optimal value	Lower bound	Upper bound
distance (parsec)	130	60	300
reddening	1.1	0.7	1.4
logAge	9.1	9.0	9.4

Discussion

Due to some stars emitting less light in the B wavelength compared to V, the signal-to-noise ratio was lower. This resulted in larger errors.

A consequence of this was that the weight of the less bright stars in the fitting process was very low compared to the brightest stars. This is not necessarily a problem, but it does mean that the fitting was mostly based on a very limited number of stars, which adds to the uncertainty of the eventual result.

Finally, the eye test used to determine the bounds for the final result might seem somewhat arbitrary. However, the uncertainty caused by this was much lower than the error from statistical methods which could have been used, and it is beyond doubt that ages outside of the chosen bounds result in isochrones that are certainly not correct.

Sources

1. 1. G. Andreuzzi, A. Bragaglia, M. Tosi and G. Marconi, photometry of the intermediate-age open cluster NGC 6939. Monthly Notices of the Astronomical Society 348, 297–306 (2004)
2. De Angeli, et al., Galactic globular cluster relative ages, The Astronomical Journal 130, 116–125 (2005).
3. Cannon, R. D., & Lloyd, C. (1969). The main sequence gap and red giant clump of NGC 6939. Monthly Notices of the Royal Astronomical Society, 144(4), 449-458.