

# Photometry of the Open Cluster NGC 7142

Jon Voisey, University of Kansas

*Advisor: Dr. Barbra Anthony Twarog, University of Kansas*

We present the findings of our study of the old open cluster NGC 7142. While UBVI analysis is not yet complete, a new true distance modulus of 12.2 has been determined for the cluster using JHK photometry from 2MASS. Reddening estimates from the JHK photometry have also been used to estimate reddening for the UBVI bands. Additionally, we have attempted to locate new candidate variable stars. Although sparse data did not allow for complete light curves, several stars have been identified showing strong trends. Lastly we discuss the beginning steps towards further, but yet incomplete work.

## Introduction

NGC 7142 is an unusually old open cluster located in Cepheus. Previous age estimates have generally placed it between the clusters M67 and NGC 188 (van den Bergh & Herringa 1970). Distance estimates have thus far, been somewhat discrepant due to a large amount of variable foreground reddening that must be taken into account.

## Observations and Reduction

Observations were taken in during the summer 2005 REU program at San Diego State University, by Luis Vargas and Lindsey Mayer with the assistance of Dr. Sandquist. A total of 3 U-, 8 B-, 16 V-, and 7 I-filter images were taken using the 40" telescope at Mt. Laguna observatory on the nights of July 14<sup>th</sup> and 15<sup>th</sup>. The CCD used had a gain of 2.8 e<sup>-</sup>/ADU and a read noise of 6.5 e<sup>-</sup>. Bias and flat subtraction were performed by Luis and Lindsey. Point-spread function (PSF) photometry was performed within DAOPHOT II and ALLSTAR, also utilizing several routines written by Dr. Sandquist to expedite the process.

## Analysis

### *Reddening, Absorption, and JHK Distance Modulus*

The first task we wished to pursue was to produce a V vs. B-V color-magnitude diagram (CMD) for our UBVI data. To be useful for determining quantities such as distance and age, which are of primary interest in our study, the data must be corrected for extinction,  $A_V$ , and reddening,  $E(B-V)$ . Our uncorrected CMD for the UBVI data is shown in Fig. 1.

To approximate these values, we would first find reddening and extinction in the JHK bands using data from 2MASS, and then translating these values to the UBVI system using conversions provided by Rieke & Lebofsky (1985). In order to determine the reddening in the J-K, we would attempt to identify stars belonging to the "red giant clump" which, for clusters with metallicities between -1.0 and -0.3 [Fe/H], are shown to have a consistent average color in the JHK bands regardless of metallicity in that range (Carney et al. 2005). Thus, by comparing the expected J-K value, to our observed value we can determine the  $E(J-K)$  value.

The CMD from the 2MASS data was created using only stars for which the highest available grade of photometry (AAA) was available. In order to attempt to eliminate as many field stars as possible, we only kept stars that lied fairly close to the cluster's center. Once possible clump members were visually determined from the CMD, we performed an additional quality *membership* check comparing the radial velocities from WEBDA, of candidate stars to the average value of the cluster as a whole. Stars with obviously discrepant values were removed from consideration.

With red clump members identified, we obtained an average J-K for these stars of 0.791 from our observations. The  $(J-K)_0$  from Carney et al. gives a value of 0.596, thus giving  $E(J-K)$  of 0.224. To convert this value to ones usable for our UBVI data, we used conversions provided by Rieke & Lebofsky (1985). These transformations gave  $E(B-V) = 0.42$  and  $E(V-I) = 0.67$ . This value for the B-V reddening is in good agreement with the Crinklaw & Talbert (1991) value. This is considerably

greater than estimates of the reddening done by Johnson et al. (1961) of 0.18, and the value of 0.19 reported by Becker & Fenkart (1971).

Another conversion from the E(J-K) provided by Rieke & Lebofsky allowed us to determine the absorption in the K band to be 0.393. With this information in hand we could use the K magnitude of the clump members, to determine the distance true distance modulus. The absolute magnitude of the clump is  $M_K = -1.61$  (Carney) and our apparent magnitude was  $K = 10.5$ , leading to a true distance modulus of 12.1. Comparing this value to previous distance estimates from Crinklaw & Talbert (1991), as well as van den Bergh & Herringa (1970), we find out distance modulus to be in good agreement.

### *Search for Variable Stars*

The second task we approached in this study was a search for variable stars. Previous studies, specifically Crinklaw & Talbert (1991), have only uncovered one variable star although they were unable to determine the type. They speculated that it is likely to be an eclipsing binary. Additional observations appended to the Crinklaw & Talbert data was performed by Weinberger & Ziener further supported this conclusion.

Our search was conducted in much the same manner as the Crinklaw & Talbert search. Figure 2 displays the standard deviation for each V-filter observation versus the mean V magnitude. Stars with especially high standard deviations in relation to the mean for their magnitudes were considered candidates for more thorough analysis. A total of 49 such candidates were selected in this manner. Ultimately fourteen were eliminated from consideration, owing to the fact that they were only observed in a small number of frames which, presumably, was the cause of the high standard deviation, thus leaving 35 stars for which light curves were created.

Most of the light curves showed a consistent pattern in which there was a spread of roughly one magnitude on the first night. On the second night the scatter was much smaller, but the average value for the same star appeared to be about 0.4 – 0.5 magnitudes fainter. Of these 35 stars we kept, eight displayed notable trends or deviations from the normal configuration. While none of them displayed traits which positively identify the class of variable, it can be reasoned that each of these is variable of some sort.

### *Unfinished Business*

With a reddening estimate in hand, we could now resume work on the UBVI data. Our first task was to work out a correspondence between the stars on the 2MASS list and that of ours. A coordinate transformation was worked out by Barbara Twarog, which was then applied to the 2MASS list and then checked by hand against one another. This will easily allow us to identify the stars which we believed were members of the red giant clump in our B, B-V CMD since it appeared easier to identify in the JHK bands.

Another course we began but have not yet finished was to determine the cluster center. Knowing the cluster center will allow us to conduct later analysis of star types as a function of distance from the cluster center; in particular, blue stragglers. In order to do this, we first made histograms along the x axis, using bins widths of 100 pixels and then plotting using Excel. A 2<sup>nd</sup>-order polynomial was then fitted to the histogram and a simple derivative was taken in order to find the maximum for the curve. This was then repeated for the y axis. The value at which we arrived using this method produced a cluster center at  $x = 1153.1$ ,  $y = 960.8$ . Using conversions worked out by Dr. Twarog, this was then converted to RA/Dec. and compared to the cluster center given in SIMBAD, which agreed closely.

However, the trouble in this task has remained in trying to determine precisely how Excel is fitting the curve to the histograms which is key to understanding the errors involved. When plotting the histograms using different bin sizes and cutting out the faintest stars or brightest stars, the determined cluster center shifted significantly. Using the four methods mentioned produced a standard

deviation of 115.1 in the x, and 39.4 in the y. Given the extremely large standard deviations for what should produce similar centers, the methodology is suspect.

## Conclusions

The distance modulus at which we arrived primarily seems to be in good agreement with the previous studies from both Crinklaw & Talbert, as well as van den Bergh & Herringa. Our estimate for the reddening in the B-V color of 0.425 is in rough agreement with the Crinklaw & Talbert value. We have also identified eight new variable stars in NGC 7142.

This leaves us still with several tasks. The first is to calibrate the photometry and then correct for reddening the color correction to be able to produce a CMD for the UBVI data. With this, we will be able to make additional estimates for the distance modulus as well as the age of NGC 7142. Although it won't fall to us in this project, the variable stars identified need to undergo additional observations to verify their type.

## Acknowledgements

I would like to thank Dr. Barbra Anthony Twarog for her guidance and leadership on this project. Additionally I would like to thank Dr. Eric Sandquist for his repeated assistance and for contributing Fortran scripts which considerably shortened our work. I would also like to thank the National Science Foundation as well as San Diego State University for sponsoring this REU program. Lastly I would like to thank Dr. Bruce Twarog for recommending I apply for this program, despite being only three days before the application was due.

## References:

- Becker, W., & Fenkart, R. 1971, A&AS, 4, 241  
Carney, B. W., et al. 2005, ApJ, 129, 656  
Crinklaw, G., & Talbert, F. D. 1991, PASP, 103, 536  
Johnson, H. L., Hoag, A. A., Iriarte, R., Mitchell, R. I., & Hallam, K. L. 1961, Lowell Obs. Bull., 5, 133  
Seeberger, R., & Winberger, R., 1991, IBVS, 3657  
Van Den Bergh, S. & Herringa, R., 1970, A&A, 9, 209

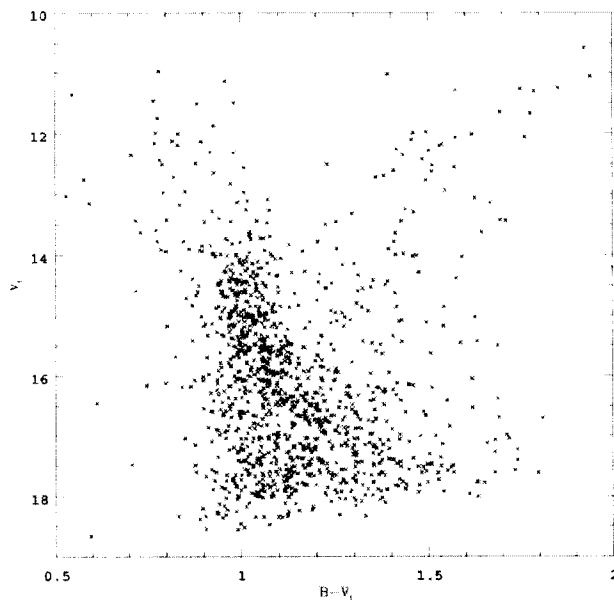


Fig. 1: Uncalibrated CMD from UBVI data

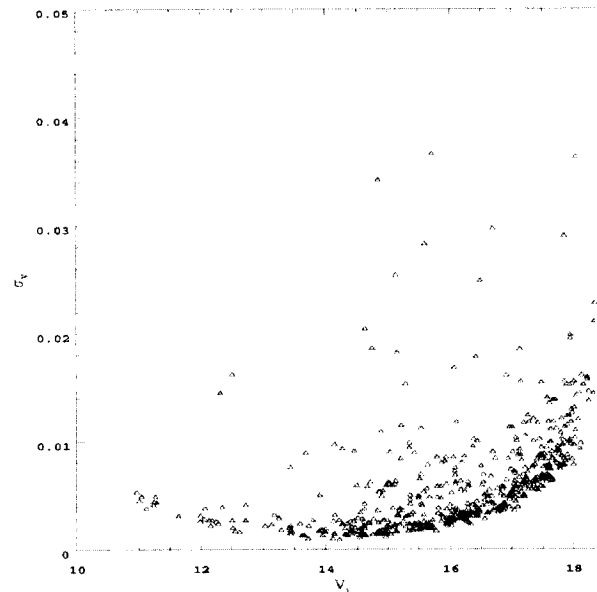


Fig. 2: Standard deviation of V magnitude vs. mean V magnitude for stars in survey.