Differential Photometry of M39

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I. INTRODUCTION

This lab seeks to determine the V and B magnitudes of four of the objects in M39, an open galactic cluster. M39 contains around 30 stars of various brightness and is about 9° from Deneb (α Cyg).

To determine the magnitudes of some of the objects in M39, we used differential photometry. This process uses the simplicity of comparing two objects taken in the same image, through the same filter, through the same optical path, and exposed for the same amount of time to determine

$$m_{tar} = m_{ref} + m_{diff} \tag{1}$$

The way an imaging program does this is by determining the instrumental magnitudes and then comparing them to the reference magnitudes.

$$m_{inst} = -2.5 \log_{10}(S - B) \tag{2}$$

where S is the sum of all the pixel values in a given aperture and B is the sum of all the pixel values of some background section, usually an annulus. The way AstroImageJ calculates these sums is dependent on more complex equations that parameterize the electron gain of the CCD and can do more image processing prior to integrating the pixel values. These extra parameters allow for determining the error of the instrumental magnitude.

After the instrumental magnitude of a reference star is found, we can determine the magnitude correction value by combining Equation 1 and Equation 2.

$$m_{corr} = m_{ref} - m_{inst} \tag{3}$$

and finally we can find the magnitude of any target star with

$$m_{tar} = m_{inst} + m_{corr} \tag{4}$$

II. DATA ACQUISITION AND SETUP

Observations were made on at the Zaffarano Hall observation deck in Ames, Iowa. The night was mostly clear and the ambient temperature was around 12 °C. The moon was full that night which caused higher than usual lunar presence. Observations were made using a Meade 8" reflector telescope with an SBIG ST-402ME CCD camera with internal V, B, and I filters.

Setting up the telescope was the same as previous observations made with the 8" Meade telescope at Zaffarano Hall. An obstacle we faced with alignment and slewing was the misalignment of our sight by a significant amount. To combat this, we shined a laser through the eyepiece to roughly show the target of the main mirror.

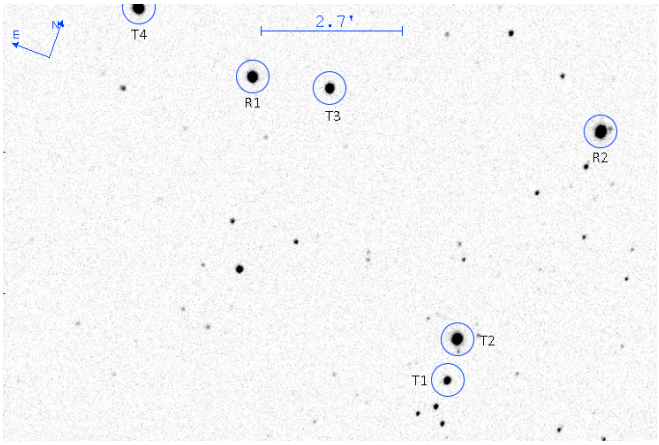

FIG. 1. Map showing the celestial direction, target stars, and reference stars. The names of the objects above are in Table II.

We took 15 frames of data at 13 s at two locations in the sky. Of those 15, 5 were with photometric V, 5 were with photometric B, and 5 were dark frames. The first target contained two M39 objects (BD+47 3452 and HD 205172), however this data was deleted by accident and was not used for analysis. The second target contained objects BD+47 3447, HD 205085, BD+47 3453, and BD+47 3458, all of which are recorded in Table III. Of these images, another issue we encountered was centering the images as the telescope shifted according to its tracking movements. Because of this, a few of the images do not contain a clear view of M39 BD+47 3458.

III. DATA ANALYSIS

Our data analysis involved preparing our science images and performing differential photometry on them. To prepare our images we created a median dark frame in AstroImageJ for our only exposure time, 13 s. We then subtracted this frame from each science image to filter out systematic noise from our CCD. These images were then grouped into two stacks, one for each photometric filter.

We used AstroImageJ to process each stack for the differential photometry. For use in the differential photometry algorithm we use the CCD reported electronic gain of 1.49 e/ADU. AstroImageJ processes the stack of images

TABLE I. Reference Stars

Object	Name	V Mag	B Mag
R1	BD+47 3454	8.917	9.028
R2	HD 205073	7.845	7.870

TABLE II. Photometry Results

Object	Name	V Mag	B Mag
T1	BD+47 3447	10.189(19)	10.394(56)
T2	HD 205085	7.9696(75)	8.0264(16)
T3	BD+47 3453	9.540(10)	9.669(24)
T4	BD+47 3458	NA	NA

in a way that allows for quick calculations. An aperture can be placed on each star of interest in an image and AstroImageJ allows placing target stars and reference stars, where the reference stars have predetermined magnitudes.

After placing the apertures for one image in the stack we move forward in the stack and by choosing the same initial aperture AstroImageJ will place the remaining apertures automatically. The reference magnitudes are shown in Table I. After each aperture has been placed on each image in the stack and the reference star magnitudes have been set, AstroImageJ will do the photometry and creates a measurement table with the results. The full results are shown in **??**. This table shows results for target and reference stars shown in Figure 1.

IV. RESULTS

The table of the results from AstroImageJ are in section B and the results calculated using **??** and **??** are in Table II.

V. CONCLUSIONS

ACKNOWLEDGMENTS

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Appendix A: Observation Log

TABLE III. Observed 06 September 2017 by Miles Lucas and John Brandon

Time	File	N Frames	Object	Filter	Exposure	Camera Temp.	Notes
21:39	M39_2_V_13s_	5	M39 Objects x1, x4, x7, and x9; stars E, D	V	13 s	5.33 °C	
21:41	M39_2_V_13s_dark_	5	M39 Objects x1, x4, x7, and x9; stars E, D	V	13 s	5.33 °C	Dark frames
21:43	M39_2_B_13s_	5	M39 Objects x1, x4, x7, and x9; stars E, D	B	13 s	5.33 °C	

Appendix B: Photometry Results

TABLE IV. Full results from AstroImageJ multi-aperture differential photometry for the photometric V filtered images

Slice	T1 Mag	T1 Err	T2 Mag	T2 Err	T3 Mag	T3 Err	T4 Mag	T4 Err	R1 Mag	R1 Err	R2 Mag	R2 Err
1	10.18609	0.176984	7.960098	0.037337	9.537899	0.10435	8.716391	0.055953	8.917	0.061367	7.845	0.025834
2	10.193105	0.187644	7.973817	0.04062	9.537579	0.111398	8.786726	0.06126	8.917	0.0653	7.845	0.02774
3	10.195668	0.191079	7.968483	0.041178	9.529998	0.112293	9.008232	0.071347	8.917	0.066747	7.845	0.028051
4	10.220418	0.200807	7.963982	0.042037	9.557328	0.116375	9.249187	0.086958	8.917	0.06898	7.845	0.028695
5	10.169891	0.14342	7.978648	0.03339	9.537594	0.086798	10.330707	0.155808	8.917	0.051375	7.845	0.022805

TABLE V. Full results from AstroImageJ multi-aperture differential photometry for the photometric B filtered images

Slice	T1 Mag	T1 Err	T2 Mag	T2 Err	T3 Mag	T3 Err	R1 Mag	R1 Err	R2 Mag	R2 Err
1	10.374302	0.058418	8.028253	0.019926	9.661362	0.038906	9.028	0.025439	7.87	0.014405
2	10.398856	0.072556	8.024075	0.023852	9.66782	0.047418	9.028	0.030662	7.87	0.017282
3	10.467363	0.175167	8.026245	0.033794	9.702747	0.094185	9.028	0.053192	7.87	0.023198
4	10.423689	0.190297	8.026522	0.036299	9.665717	0.103558	9.028	0.058534	7.87	0.024633
5	10.470166	0.211676	8.025427	0.038635	9.701385	0.114719	9.028	0.062982	7.87	0.02621