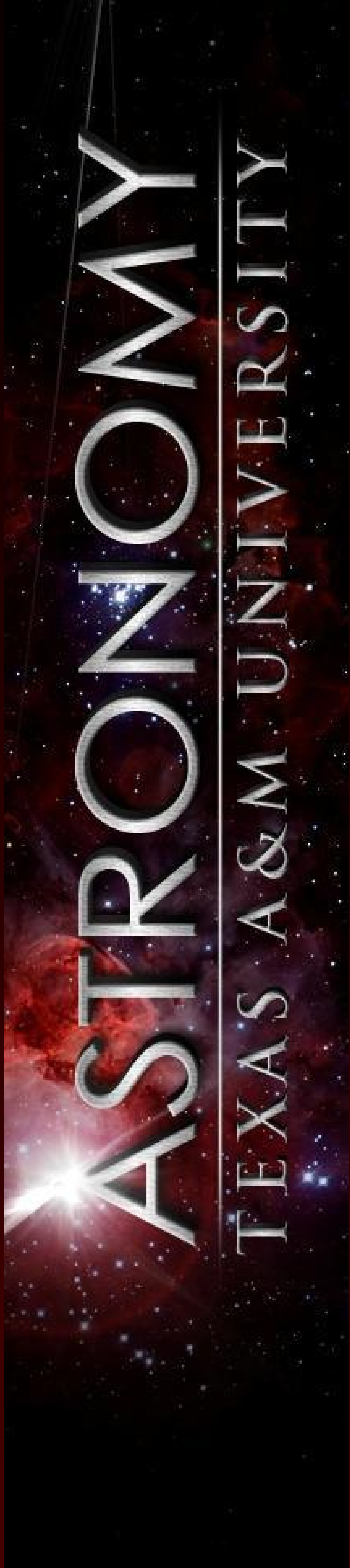
DuOCam: A Two-Channel Camera for Simultaneous Photometric Observations of Stellar Clusters

Emily M. Witt[1], Erin R. Maier[2], Darren L. DePoy[3], Luke M. Schmidt[3]

[1]St. Olaf College, [2] University of Iowa, [3] Texas A&M University Department of Physics and Astronomy



Abstract

We have designed the Dual Observation Camera (DuOCam), which is capable of simultaneous photometric observations at red and blue wavelengths. The instrument was designed for implementation on the 0.9 m, f/13.5 telescope at McDonald Observatory. Light collected by the telescope passes into DuOCam's optical assembly, where it is collimated, split into red and blue wavelengths and focused onto two independent charge-coupled devices (CCDs). In order to test the effectiveness of the camera, observations of both open and globular stellar clusters were carried out at McDonald Observatory. The resulting data was used to construct R vs. B-R color-magnitude diagrams for each cluster. Using isochrone fitting, the age, metallicity, and distance of each cluster will be determined.

Introduction

Color-magnitude diagrams are used to determine key attributes of stellar clusters, including age, metallicity, and distance, which can shed light on the evolution of stars and the formation of structure in our Galaxy (Figure 1). They are created by plotting the magnitude of stars in a cluster in a color band versus the difference in magnitude of that color band and another color band. When these values are plotted for a stellar cluster, a clear evolutionary track can be seen, the parameters of which are used to determine cluster attributes.

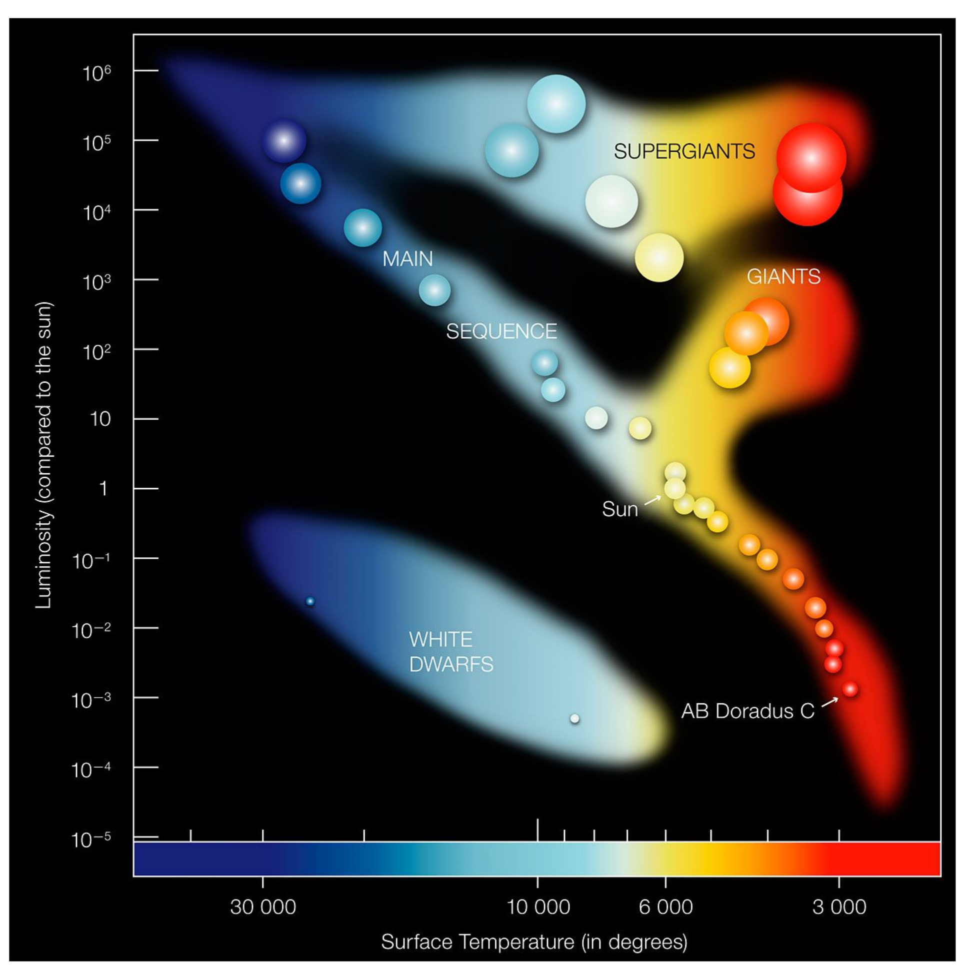


Figure 1: Example Hertzsprung-Russell Diagram. The axis can be converted to R vs. B-R to obtain a color-magnitude diagram. Source: European Southern Observatory.

In order to create these color-magnitude diagrams, DuOCam was designed for use on the 0.9 m telescope at McDonald Observatory in Ft. Davis, Texas. Using two CCDs, it simultaneously images stellar clusters in both the red and blue bands. In this way, the effectiveness of DuOCam can be tested on well documented clusters, and it can contribute information to existing knowledge on lesser known clusters.

Optics

In order to image the stellar cluster simultaneously in these two wavelengths, the light from the stars must be split. First, the light is collimated (made parallel), by use of a negative lens (-150 mm focal length) to prevent the introduction of aberrations by the dichroic. The light then encounters a blue dichroic, a specially treated piece of glass that transmits red light (~525 - 800 nm) and reflects blue light (~400 - 525 nm). This light is then refocused by positive lenses (+50 mm focal length) onto separate CCDs (Figure 2).

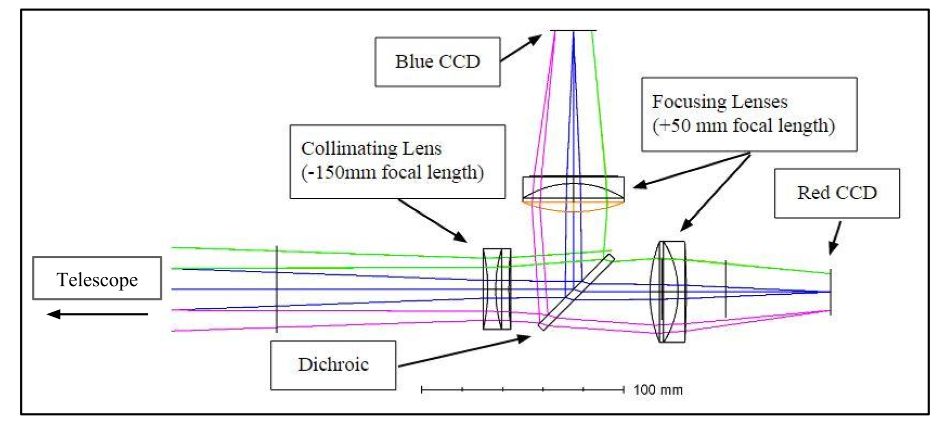
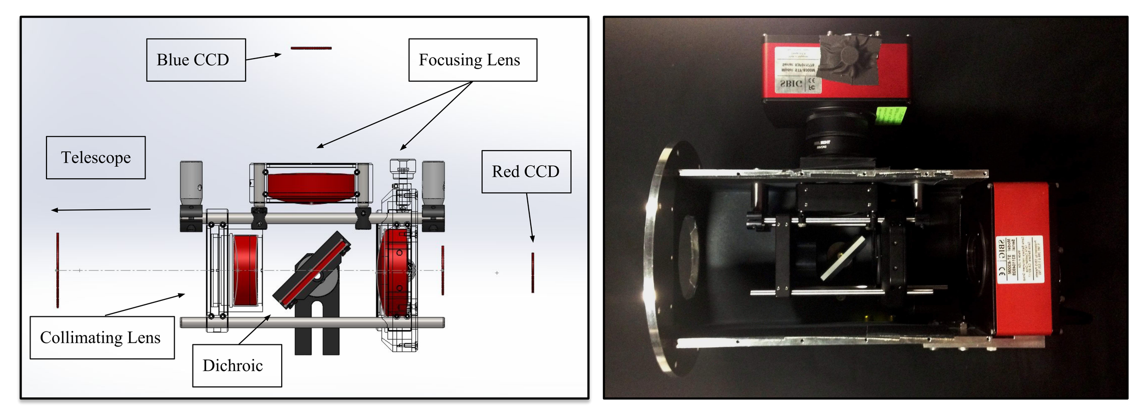


Figure 2: Optical system for DuOCam.

The lenses in this system (Figures 2 and 3a) were chosen in order to balance a maximal field of view with an optimal focus. The complete system (instrument and telescope), had an effective focal ratio of f/11 (nominal 9.87 m focal length). This combined with an SBIG ST-8300M and an SBIG STF-8300M CCD allowed a field of view of 6.26' x 4.71', with a plate scale of ~.38 "/pixel, binned 3x3. This is large enough to capture the majority of each of our stellar clusters in one image.

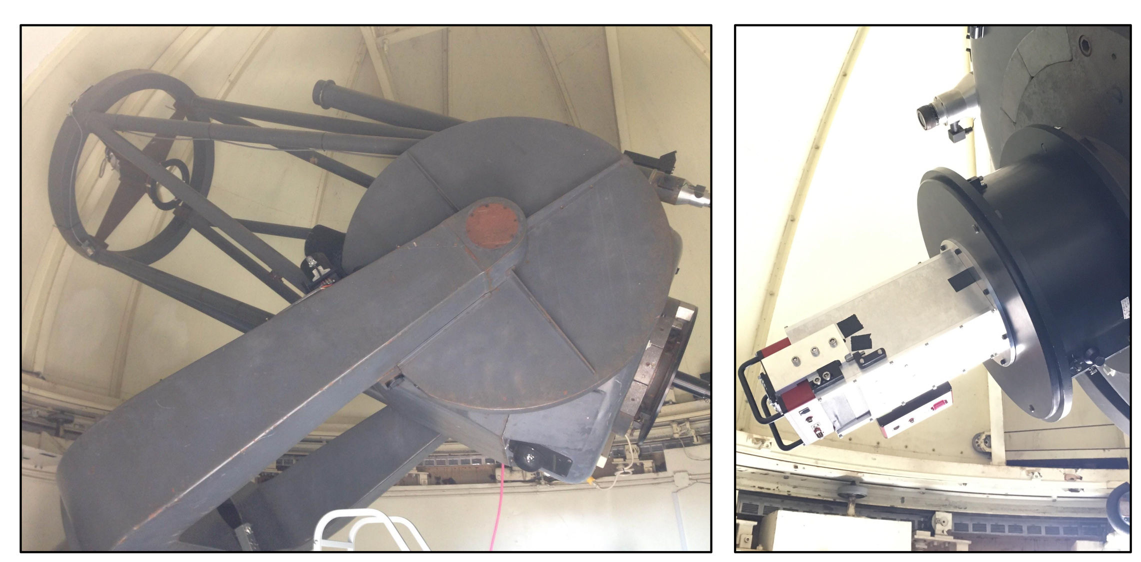


(a) (b)

Figure 3: **(a)** SolidWorks model of the optical system with lens mounts. **(b)** Assembled optical system in mounting box with CCDs.

The effectiveness of the design was hindered by the use of a mounting box inherited from a previous project (Figure 3b). Space restrictions imposed by the box limited our ability to focus the optical system. Furthermore, the size of the optics (limited by the mounting box and by commercial availability) resulted in some vignetting in the corners of each image. Despite these limitations, the system is still able to achieve a nominal resolution slightly better than 2'', the approximate seeing at McDonald Observatory.

Observations



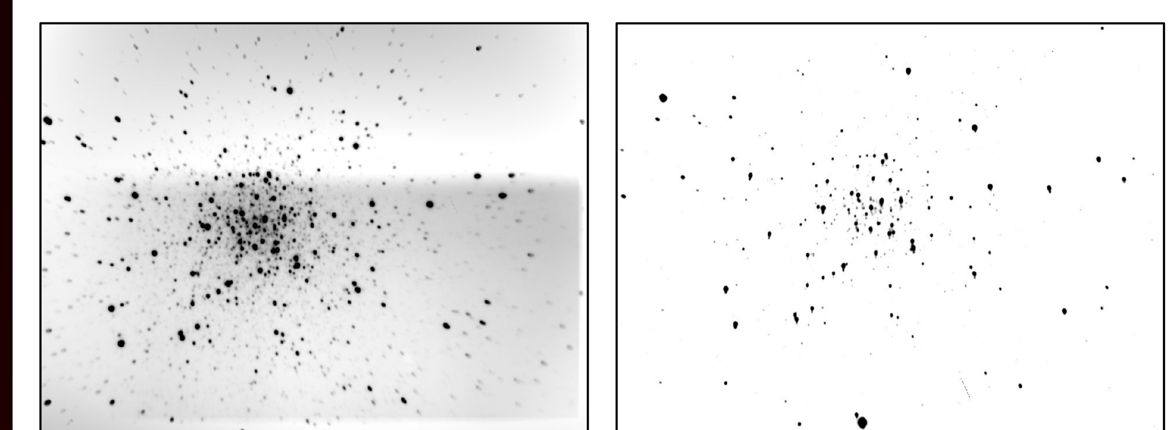
(a) (b)

Figure 4: **(a)** The 0.9 m telescope at McDonald Observatory. **(b)** DuOCam installed on the 0.9 m telescope.

Observations occurred on four nights from July 21 to July 24 using the 0.9 m telescope at McDonald Observatory (Figure 4). The first night was devoted to focusing both CCDs. Data taking of previously selected stellar clusters (Table 1) began on the second night, using the OBSCCD_M software designed by Don Carona, which allows simultaneous data collection from multiple CCDs. Exposures of various lengths (10s, 30s, 60s, 90s, and 120s) were taken. The 60s exposures proved the most effective, balancing the need for a long exposure to capture dimmer stars with the telescope's limited tracking ability.

Name	Type	Size	Magnitude	Transit Height	Transit Time
NGC 6649	Open	6.0'	8.9	49°	00:30
M29 (NGC 6913)	Open	7.0'	6.6	82°	02:15
IC 1369	Open	4.0'	6.8	73°	03:00
NGC 6934	Globular	5.9'	7.3	67°	02:30
NGC 6229	Globular	4.5'	9.4	78°	23:00
M56 (NGC 6779)	Globular	7.1'	8.3	89°	01:00

Table 1: Stellar clusters selected for observation. Clusters chosen had to be high enough in the sky from July 21 to 24 to minimize atmospheric interference, be bright enough for the camera to detect them in a relatively short exposure time, and be small enough for the CCDs to detect the majority of stars in the cluster. Source: Arnold Barmettler, www.calsky.com



(a) (b)

Figure 5: Dark field subtracted, bias corrected, and stacked images of M56 in **(a)** the red band and **(b)** the blue band. Images have been color inverted for ease of viewing.

Analysis

In order to increase the signal-to-noise ratio, dark frame subtraction and bias frame correction were performed on the raw data and the images were stacked (Figure 5). The location of the stars in the red and blue images were then mapped to each other. The magnitude of each star in both the red and blue band was extracted and a color magnitude-diagram was created. (Figure 6).

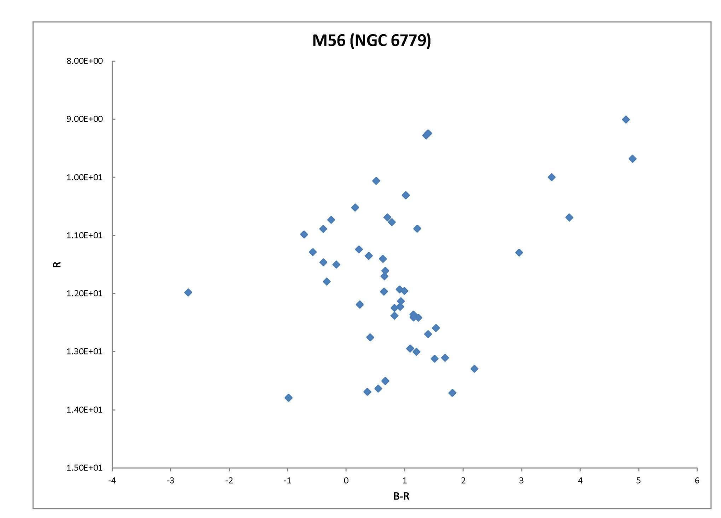


Figure 6: Color magnitude diagram for M56 (NGC 6779). Note the main sequence turning off into the red giant branch.

Conclusions

DuOCam effectively images star clusters at red and blue wavelengths simultaneously. Color-magnitude diagrams can be produced from its data that can be used to deduce the age and distance of the cluster. However, DuOCam's imaging capabilities would be improved were the CCDs able to be focused more finely. Additionally, the data would be improved by observing at a time closer to new moon, as the near-full moon significantly affected our data. Should a similar project be undertaken in the future, we recommend the mounting box be redesigned to allow more freedom of movement of the optics, so that the system can be more effectively focused. Overall, DuOCam performed within expectations, allowing the creation of a color-magnitude diagram, though steps could be taken to improve its performance and allow for more accurate measurements of the stars in stellar clusters.

References

(2007, June 19). Hertzsprung-Russell diagram. *European southern observatory.* Retrieved from https://www.eso.org/public/images/eso0728c/.

Barmettler, A. (2016, June 18). CalSky [computer software]. Available from https://www.calsky.com/

Carroll, B. W., & Ostlie, D. A. (1996). An introduction to modern astrophysics. Reading, MA: Addison-Wesley.

Texas A&M University Department of Physics and Astronomy is an institutional member of:

Acknowledgments

Texas A&M University thanks Charles R. '62 and Judith G. Munnerlyn, George P. '40 and Cynthia Woods Mitchell, and their families for support of astronomical instrumentation activities in the Department of Physics and Astronomy. This work was supported by NSF grant AST-1263034, "REU Site: Astronomical Research and Instrumentation at Texas A&M University."