ASTR 3070 Proposal Template

Autumn 2024

Summary: This proposal aims to observe the globular cluster Messier 13 (M13), also known as the Great Hercules Cluster and which is one of the brightest and best-known globular clusters in the northern hemisphere, using the Glenlea Remote Observatory (GRO) in two photometric bands which are choosen to be the G and the R filters from the SDSS (Sloan Digital Sky Survey) filters. The primary scientific goal of this observation is to construct a Hertzsprung-Russell (H-R) diagram of M13, which will be used to estimate its age and investigate its stellar population characteristics. Additional science goals include studying the cluster's structure and dynamics, as well as comparing its properties with other globular clusters.

Total Time Request: 4 hours

Science Justification

Globular clusters are of immense scientific interest due to their status as some of the oldest known objects in the universe, often exceeding 10 billion years in age (Nota & Charbonnel, 2016). These densely packed groups of ancient stars orbit the galactic core and serve as natural laboratories for studying stellar dynamics, evolution, and the chemical enrichment of galaxies. Their relatively simple stellar populations, compared to open clusters, make them ideal for testing theoretical models of stellar evolution and nucleosynthesis.

M13, also known as the Hercules Cluster, is particularly significant due to its brightness and accessibility in the northern hemisphere during the fall season. It is located approximately 22,200 light-years away in the constellation Hercules (NASA, 2024). According to the Digital Sky Survey (DSS) carried out by the Space Telescope Science Institute (STScI), M13 is located at a Right Ascension of 16 hours 42 minutes and 42.1882 seconds and a Declination of 36° 27' 17.161", as shown in the Finding Chart (figure 1). M13 contains several hundred thousand stars, making it an ideal candidate for detailed study. The relevance of M13 within the wider field of astronomy lies in its potential to provide insights into the early stages of galaxy formation and evolution. By constructing a Hertzsprung-Russell (HR) diagram of M13, we can determine the cluster's age and study its stellar population. This information is crucial for understanding the timeline of star formation and the chemical evolution of the Milky Way galaxy. Additionally, M13 is thought to contain multiple stellar populations, as mentioned by (Savino et al., 2018), which can shed light on the cluster's formation history and the processes that govern stellar evolution. The data obtained from studying M13 can also help refine theoretical models of stellar evolution, contributing to our broader understanding of these processes in globular clusters.

Constructing a Hertzsprung-Russell (HR) diagram of M13 is of particular scientific interest. The HR diagram is a fundamental tool in astrophysics, allowing us to plot the luminosity of stars against their effective temperature. By analyzing the HR diagram of M13, we aim to determine the age of the globular cluster. This will be achieved by fitting theoretical isochrones to the observed data, which will provide an estimate of the cluster's age. Determining the age of M13 is crucial for understanding the timeline of star formation and the chemical evolution of the Milky Way galaxy. It also helps in constructing the models of stellar evolution, as globular clusters like M13 contain stars that have evolved over billions of years. Furthermore, the HR diagram will allow us to study the distribution of stars in different evolutionary stages, providing insights into the cluster's stellar population and evolutionary history. This includes identifying the main sequence, red giant branch, horizontal branch, and asymptotic giant branch stars within the cluster. By examining these different populations, we can gain a better understanding of the processes that govern stellar evolution and the factors that influence the lifetimes of stars. The data obtained from this observation will also contribute to our understanding of the chemical composition and enrichment processes within the cluster. By comparing the observed properties of M13 with theoretical models, we can test and refine our understanding of stellar evolution and nucleosynthesis in globular clusters.

Globular clusters like M13 are also key to studying the dynamics of stellar interactions due to their high stellar densities. Ferraro & Lanzoni (2007) mentions that these interactions can lead to phenomena such as stellar collisions and the formation of exotic objects like blue stragglers, millisecond pulsars, and low-mass X-ray binaries. Understanding these interactions provides valuable insights into the end stages of stellar evolution and the dynamics of dense stellar systems. Moreover, globular clusters serve as important tracers of the formation and evolution of their host galaxies. The spatial distribution, kinematics, and chemical composition of globular clusters can reveal the history of galaxy mergers and interactions as demonstrated by Forbes et al. (2018). In the case of the Milky Way, studying globular clusters like M13 helps us understand the assembly history of our galaxy and the processes that have shaped its halo.

In summary, the scientific interest in M13 and its relevance within the wider field of astronomy stem from its age, stellar population, and potential to provide valuable insights into the early stages of galaxy formation and the evolution of the Milky Way. The data obtained from studying M13 will not only enhance our understanding of globular clusters but also contribute to broader astrophysical knowledge, including stellar dynamics, galaxy formation, and the chemical evolution of the universe.

Figures

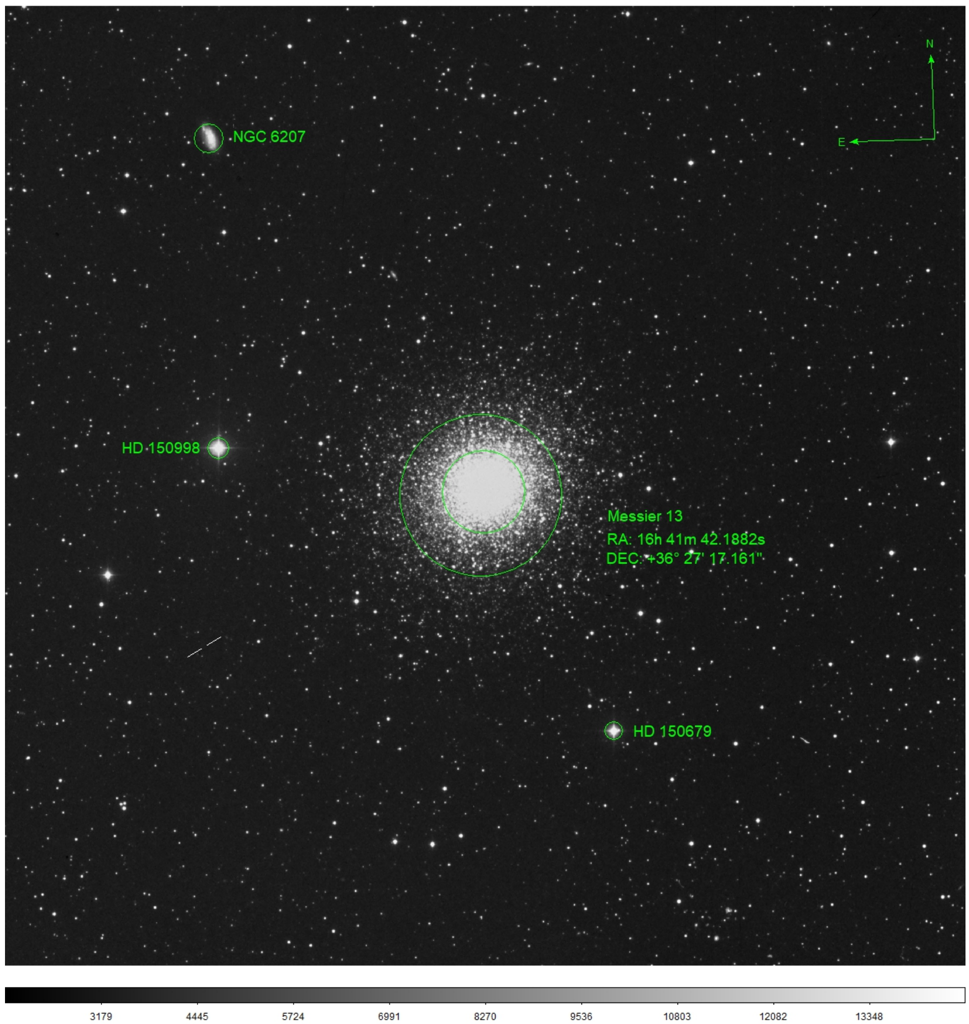

Figure 1: M13 Finding Chart

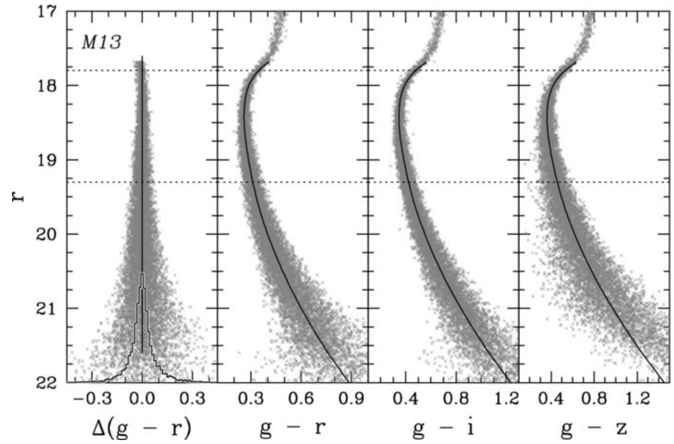

Figure 2: CMD using the SDSS filters obtained from An et al. (2009).

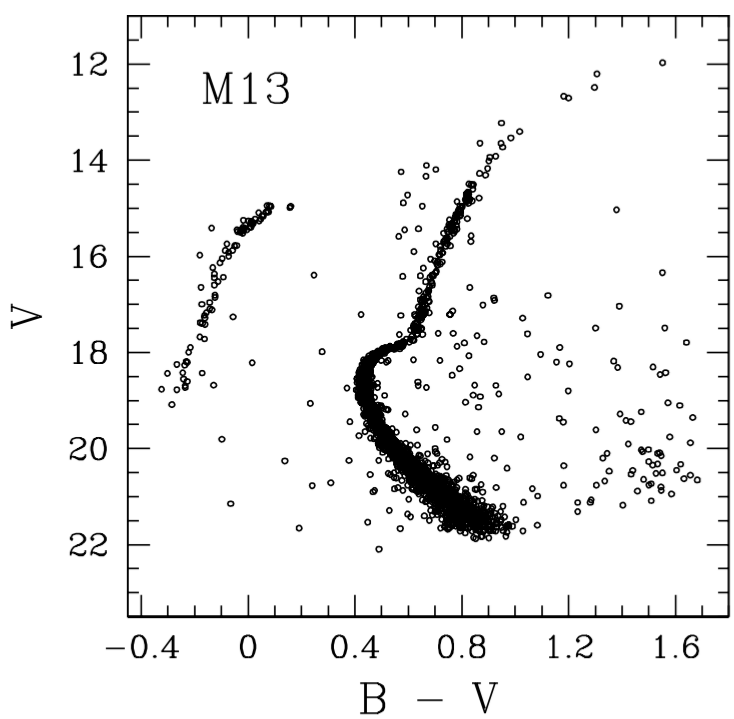

Figure 3: CMD using the Johnson's Cousins filters obtained from Rey et al. (2001)

Technical Justification

For this observation, we will use the Glenlea Remote Observatory's telescope equipped with the G and R filters from the Sloan Digital Sky Survey (SDSS). The choice of these filters is based on their ability to provide high-quality photometric data in the visible spectrum, which is essential for constructing an accurate Hertzsprung-Russell (HR) diagram of M13. The G filter (centered around 477 nm) and the R filter (centered around 623 nm) will allow us to capture the necessary photometric bands to analyze the cluster's stellar population and estimate its age. The telescope's aperture of 35.59 cm, focal length of 256.3 cm and plate scale of 0.72" per pixel are well-suited for observing globular clusters, providing the necessary resolution and sensitivity to detect stars across a wide range of magnitudes. GRO's telescope with attached to the ATIK 110000 camera which uses a Kodak KAI 11002 CCD sensor, which according to AtikLLC (2020), has a 4007 by 2671 square pixels which are 9 microns in size, and the sensor with a quantum efficiency of about 0.5. It has a gain of 0.92 e^- per ADU, a full well of 60000 e^- and a dark noise of 0.03 e^- per second per pixel. The GRO's imaging capabilities, combined with the selected filters, will enable us to obtain precise photometric measurements of M13's stars, which are crucial for constructing the HR diagram and achieving our scientific goals.

The observation of M13 is planned to be conducted under optimal observing conditions to ensure the highest quality data. Observations will be scheduled during a new moon or when the moon is below the horizon to minimize the impact of moonlight on the photometric measurements. This is particularly important for detecting faint stars in the cluster. While the observation is not strictly constrained by seeing conditions, it is preferable to conduct the observations during periods of good seeing to maximize the resolution and quality of the data. This will help in accurately measuring the positions and magnitudes of stars in the cluster. For the chosen Glenlea site, the seeing condition is about 3 arcsecounds. M13 is best observed during the months of May to September when it is high in the sky during the night. Since the construction scedual for the GRO forces us to observe M13 during November, Observations will be scheduled to ensure that M13 is at least 30 degrees above the horizon to minimize atmospheric extinction and distortion. Observations will also be planned for nights with clear skies and low humidity to reduce the impact of atmospheric absorption and scattering on the photometric data.

The total integration time required for this observation is estimated to be 4 hours. This time is divided equally between the G and R filters, with 2 hour of exposure time for each filter. The integration time has been calculated based on the SNR, photometric precision, background noise and weather conditions. We require a total integration time that allows for sufficient photon collection. Based on the expected magnitudes of the stars that have their mass just below to the main sequence turnoff mass for M13, which according to both figures 3 and 2, taken from Rey et al. (2001) and An et al. (2009) respectively, is about 20, and the sensitivity of the GRO's telescope and choosen filters, 2 hour of exposure time per filter is necessary to achieve an SNR of at least 15. The integration time has been optimized to minimize the impact of background noise, including sky brightness, which for the GRO site is about 20.87, and readout noise from the detector, which is about 13 e^- per pixel. By spreading the total integration time over multiple exposures, we can effectively reduce the noise and improve the overall quality of the data.

The data obtained through this proposal will be used to construct a detailed Hertzsprung-Russell (HR) diagram of the globular cluster M13. This diagram will be analyzed to estimate the cluster's age and investigate its stellar population characteristics. By fitting theoretical isochrones to the observed data, we aim to determine the age of M13 and study the distribution of stars in various evolutionary stages. A key aspect of this analysis involves identifying the main sequence turnoff mass, which is the point where stars begin to leave the main sequence and evolve into red giants. The mass of stars at this turnoff point is directly related to the cluster's age, as more massive stars evolve faster. Since all the stars in the cluster are about the same distance away from us, we substitute mass with magnitude. Therefore, our primary goal is to find the magnitude of stars at the main sequence turnoff point, as these would be the oldest stars in the cluster according to stellar evolution models. By accurately determining the main sequence turnoff point stars, we can refine our age estimates for M13. The procedure of obtaining the age of M13 by taking photometric observation is described in more detail in the paper by Grundahl et al. (1998)

This analysis will provide valuable insights into the processes that govern stellar evolution and the formation history of globular clusters. Additionally, the data will be compared with ancillary data, such as Gaia mission data, to refine our understanding of M13's properties and contribute to the broader field of astrophysics. The HR diagram of M13 shows distinct groups of stars, with a broad swath extending diagonally from the bottom right representing the cluster's main sequence, and a sharp turn toward the upper right indicating the red giant branch

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