Dating M67
A Photometric Investigation of Stellar Evolution and Cluster dynamics

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ABSTRACT OF SCIENTIFIC JUSTIFICATION

We propose a photometric study of the open cluster M67 to determine its age and to examine its mass distribution for signs of dynamical evolution. Leveraging our calibration from M37, which has a similar brightness ∼6.2 and yielded a signal-to-noise ratio (S/N) of ∼200, we plan to observe M67 (magnitude ∼6.1) with the Trottier CDK700 telescope and the Light Speed Vision QHYCCD 461PH camera in B, V, and R filters. This high-resolution CMOS camera and our high-S/N data will enable us to construct detailed color–magnitude diagrams (CMDs) for isochrone fitting and to explore mass segregation. By improving our understanding of M67's stellar evolution and dynamical history, this project contributes to address fundamental questions about how star clusters evolve and how solar-type stars form and disperse in the Galaxy.

SCIENTIFIC JUSTIFICATION - BIG PICTURE AND QUESTIONS

Open clusters are vital for understanding stellar evolution because their stars form roughly at the same time and from the same material [4]. M67 is particularly special; as an old open cluster (3.5–4 Gyr) with a metallicity similar to the Sun, M67 is often considered a solar-composition benchmark for testing stellar evolution models [3]. Although well studied, open questions remain regarding M67's:

1. **Precise Age**: Making even small differences in age estimates significantly affect our understanding of stellar lifetimes and evolutionary stages refining models [3].
2. **Dynamical Evolution**: Whether more massive stars are centrally concentrated owing to primordial conditions or by later dynamical processes is still debated.
3. **Solar Birth Environment**: The solar-like composition of M67 offers a proxy for the environment in which the Sun may have formed, it can indirectly explains how solar-type stars form and evolve within similar environments in the Galaxy.

THEORY

1. **Isochrone Fitting and Estimation of Age and Distance:**

   The Color-Magnitude Diagram (CMD) of a star cluster, a plot of stellar color (e.g., B–V) versus magnitude (e.g., V), serves as a powerful tool for determining stellar parameters. The position of stars in the CMD provides direct evidence of their evolutionary state. Isochrones represent theoretical curves that show the expected color and magnitude of stars at various ages and metallicities. By comparing observed data from M67 with model isochrones (for example PARSEC), we can derive estimates for the cluster's age and distance. The distance modulus $(m - M)$ relates the observed apparent magnitude m and the intrinsic luminosity M of a star, and the age can be determined by fitting the cluster's CMD to theoretical isochrones.

2. **Cluster Dynamics:**

   The spatial distribution and proper motions of cluster members provide information about mass segregation, tidal interactions, and dynamical evolution using the CMD and N-body simulation codes like NBODY [5]. Mass segregation refers to the tendency of more massive stars to migrate toward the center of a star cluster due to gravitational interactions. By constructing a radial profile of stellar densities in M67 and comparing the distribution of stellar masses across different regions of the cluster, we can test for mass segregation. The concentration of massive stars at the core of the cluster would suggest mass segregation.

METHODS

Why M67? M67 is a rich open cluster located within 1 kpc of the Sun, in a low-reddening region with minimal dust, allowing accurate observation of its stars. Its high galactic latitude reduces background interference, making it easier to study [3]. Open clusters like M67 are ideal for understanding stellar formation and evolution, as their individual stars can be observed more clearly than in globular clusters [4]. Additionally:

- **Magnitude & S/N**: At ∼6.1 integrated brightness, M67 sits comfortably within the 5–6 magnitude range, ensuring Trottier's CCD camera will not saturate while allowing us to achieve a high S/N.

- **Scientific Payoff**: Its well-characterized nature and potential connection to Population I solar-age stars give M67 a high scientific return, validating or challenging current stellar evolution models.

- **Comparative Baseline**: Our class data on M37 (magnitude ∼6.2) showed that 510-second exposures can reach S/N ∼200, a benchmark we can use directly for M67.

TECHNICAL DATA

In order to find the desired signal to noise ratio, M67 can be compared to a star cluster that we have already worked with, M37. M37 has a magnitude of 6.2 and M67 has a magnitude of 6.1. From Fig.1 it can be seen that a magnitude of around 6 will result in a signal to noise ratio of around 200 for 510 seconds of exposure (specifically 51 shots of 10 seconds exposures), which will be plenty for this experiment. Real magnitude is calculated as

$$M_r = -2.5\log(F/t), \tag{1}$$

where F is the total flux through the object in ADUs and t is the exposure time of the picture. This is why the larger magnitude values have smaller signal to noise ratios, as a larger magnitude actually means a smaller total flux [1]. The reason it will be a good ratio is because M37 has such a similar magnitude to M67 and we already know that this ratio works for M37 because we have been doing analysis on it in class [1].Additionally require about ∼20 minutes to M67 is best viewable in the northern hemisphere at around 22:00 during the month of March [2], which means that we are very flexible for telescope time as basically any evening in March will work. Since we will need to use Phot B, Phot R and Phot V filters to get the largest amount of data the total telescope time will be 25.5 minutes.

REFERENCES

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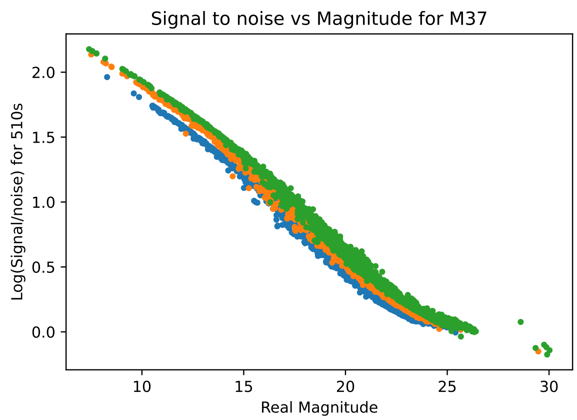

FIG. 1. A plot created using the data gathered in class for the M37 cluster. It shows what magnitude will result in what signal to noise ratio at 510 seconds of exposure. This is useful because M67 has a very similar magnitude to M37. B,V, and R bands are represented by different colors.

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