Exploring Stellar Populations: A Detailed Observation of Open Cluster M52

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1 Introduction

1.1 H-R Diagram and Age of Star Clusters

H-R diagram (Hertzsprung-Russell diagram) is graph that displays the relationship between the brightness and temperature of stars by plotting the stellar luminosity (or absolute magnitude) on the vertical and stellar temperature (or spectral type) on the horizontal axis. The H-R diagram serves as a powerful tool to determine the age of star clusters by analyzing the location of stars, especially the main sequence turnoff point, which is a location on the HR diagram where stars start to leave the main sequence and evolve into red giants. The more massive stars burn through their fuel more quickly and thus evolve off the main sequence earlier. Therefore, the position of the main sequence turnoff indicates how long ago star formation began in the cluster. A high main sequence turnoff point, indicates a young age while a main sequence turnoff point at cooler, fainter stars indicates an older age.

1.2 Difference between H-R Diagram and Color-Magnitude Diagram

The basic difference between a color-magnitude diagram (CMD) and a Hertzsprung-Russell (H-R) diagram lies in what they plot. HR diagram plots luminosity (in solar luminosity) on the y-axis and surface temperature (hotter to cooler) or spectral class on the x-axis. On the other hand CMD plots absolute magnitude on the y-axis and the color of stars, typically expressed as the difference in magnitudes between two different wavelength bands, such as (B-V) or (V-I) on the x-axis.

1.3 CMD of Ope Star Clusters

The star clusters that we have chosen to observe are relatively younger and open star clusters. An open cluster is a group of stars that formed together from the same molecular cloud and are gravitationally bound, but loosely. The CMD of these clusters will show a prominent main sequence with a turnoff point near the top of the main sequence. The cluster will still have many blue (hot) stars because the more massive stars haven't yet evolved off the main sequence. A cluster's color magnitude diagram can use apparent (rather than absolute) magnitude on the y-axis as all the stars in a star cluster are almost at the same distance, their relative apparent magnitude appear same as their relative absolute magnitude.

2 Target List

Object ID	RA (J2000)	Dec (J2000)	Transit time (as of Sep 25)	Angular size (′)	m_g (mag)
M52	$23^h24^m48.0^s$	$+61°35'36''$	23:55	13'	7.3
M34	$02^h43^m42.8^s$	$+42°52'16.8''$	03:10	22.5'	5.5

Table 1: Data of the Targets

3 Observing Plan

3.1 Position of the Targets

I propose to observe M52 for my final project (and M34 as a backup target). The latitude of the observation site (Amherst College Observatory) is 42.3709°N. Considering altitude over 30° as suitable for observation, using the following formula we get the declination at HA 0° and 180°:

$$\sin(\delta) = \sin(A) \cdot \sin(\phi) + \cos(A) \cdot \cos(\phi) \cdot \cos(HA)$$

to be +79° and -18°. That's our optimal declination window. Please notice the following table for optimal RA window:

Time	RA at 7 pm	RA at Midnight	RA Window
Early October	21^h	2^h	$18^h - 2^h$
Early November	0^h	5^h	$20^h - 6^h$
Early December	3^h	8^h	$1^h - 8^h$

Table 2: RA of the Targets at Different Times

The declination and the RA of the targets (mentioned in table 1) that we have chose fit very well in the windows making them suitable for observation, which we can confirm from figure 1 and 2. Moreover, these targets transit at very different times (please see table 1) of the night.

3.2 Angular Size of the Targets

The telescope we will be using for observation is an 11-inch Schmidt-Cassegrain telescope with FOV about 40 arcminutes. The angular size of both of the targets (mentioned in table 1) are less than the FOV, which ensures that the entire cluster can be observed in a single exposure, making it suitable for wide-field imaging.

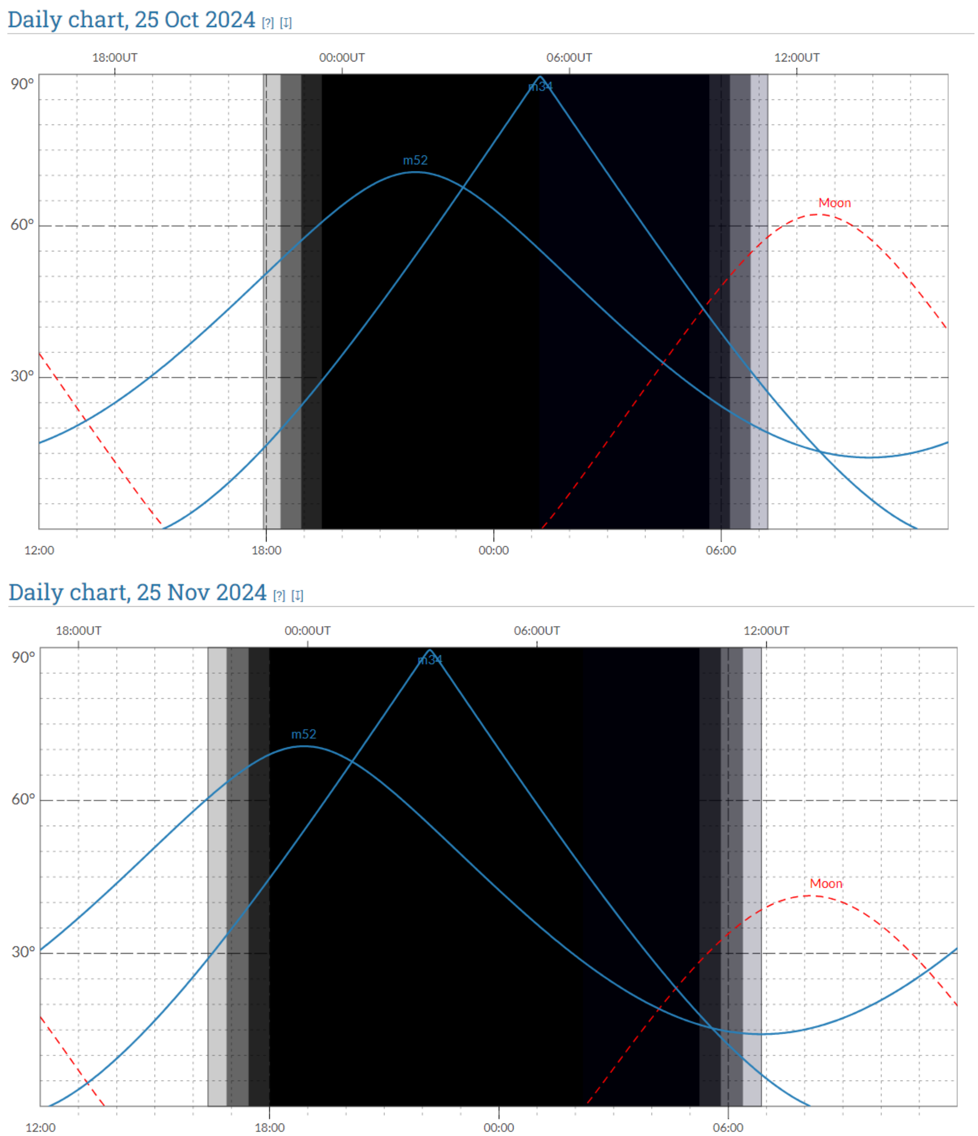

Figure 1: Trajectory of the Targets

3.3 Brightness of the Stars in the Clusters

ACO telescopes can detect 14-15th magnitude for clear filter in 60 seccons. Star cluster M52 has stars with magnitude ranging from 7.85 to 21.52. It has 280 stars with magnitude less than 14. Star cluster M34 has stars with magnitude ranging from 7.09 to 21.62. It has 144 stars with magnitude less than 14. So we can easily detect more than 50 stars with both the clusters.

```
print(f"Information about the stars in M52 cluster: \nNumber of stars: {len(m52['Gmag'])}")
m52['Gmag'] = pd.to_numeric(m52["Gmag"], errors='coerce')
print(f"Minimum G-band Magnitude: {np.min(m52['Gmag'])}")
print(f"Maximum G-band Magnitude: {np.max(m52['Gmag'])}")
m52_bright = m52[m52['Gmag']<14]
print(f"Number of bright stars (mag<14): {len(m52_bright)}")
```

```
Information about the stars in M52 cluster:
Number of stars: 14154
Minimum G-band Magnitude: 7.855377
Maximum G-band Magnitude: 21.515923
Number of bright stars (mag<14): 280
```

```
print(f"Information about the stars in M34 cluster: \nNumber of stars: {len(m34['Gmag'])}")
m34['Gmag'] = pd.to_numeric(m34["Gmag"], errors='coerce')
print(f"Minimum G-band Magnitude: {np.min(m34['Gmag'])}")
print(f"Maximum G-band Magnitude: {np.max(m34['Gmag'])}")
m34_bright = m34[m34['Gmag']<14]
print(f"Number of bright stars (mag<14): {len(m34_bright)}")
```

```
Information about the stars in M34 cluster:
Number of stars: 2644
Minimum G-band Magnitude: 7.094902
Maximum G-band Magnitude: 21.624807
Number of bright stars (mag<14): 144
```

Figure 2: Brightness of the Stars in the Clusters

3.4 Density of the Stars in the Cluster

The resolution of the telescope using the following formula:

$$\theta = 1.22\frac{\lambda}{D}$$

where The G-band in photometry generally refers to a wavelength range around $\lambda = 475nm$. That gives us a resolution of the telescope,

$$\theta = 1.22\frac{475 \times 10^{-9}m}{11 \text{ inch} \times 0.0254 \text{ m/inch}} \approx 2.09{\times}10^{-6} \text{ rad} = 2.09{\times}10^{-6}{\times}206265 \text{ arcsec} \approx 0.43 \text{ arcsec}$$

Pixel scale = 0.64"/pixel. So the bright stars should also be far enough apart to avoid them falling onto the same pixel on the camera. We can calculate the angular separation between each pair of the stars from their RA and Dec, compare that separation with the pixel scale and estimate the number of stars we can observe in each cluster.

Applying this method to the bright stars (mag¡14) only we get that all of the bright stars are resolvable (as shown in figure 3.

```python
def distance(x1, y1, x2, y2):
    return np.sqrt((x2 - x1)**2 + (y2 - y1)**2)
```

```python
def countResolvedPairs(ra, dec, px_scale):
    '''Count the number of star pairs with distance greater than the pixel scale'''
    ra_arcsec = ra * 3600
    dec_arcsec = dec * 3600
    count = 0
    num_stars = len(ra_arcsec)
    for i in range(num_stars-1):
        flag = True;
        for j in range(i + 1, num_stars):
            dis = distance(ra_arcsec[i], dec_arcsec[i], ra_arcsec[j], dec_arcsec[j])
            if dis < px_scale:
                flag = False
                break
        if flag:
            count += 1
    return count
```

```python
pixel_scale = 0.64
print(f"# of Bright and Resolved stars in M52 = {countResolvedPairs(m52_bright['RA'], m52_bright['Dec'], pixel_scale)}")
print(f"# of Bright and Resolved stars in M34 = {countResolvedPairs(m34_bright['RA'], m34_bright['Dec'], pixel_scale)}")
```

```
# of Bright and Resolved stars in M52 = 279
# of Bright and Resolved stars in M34 = 143
```

Figure 3: Number of Resolved Stars

4 Conclusion

M52 and M34 are both ideal targets for this project because their location in the sky, angular size, and range of magnitudes fit the capabilities of the Amherst College Observatory telescope. The magnitude and the separation of the stars of the open clusters ensures that enough individual stars can be resolved, observed and analyzed, and their sizes allows the entire clusters to fit within the field of view, making them a highly efficient and scientifically valuable target for your observations.