AAO Final Project

Jui-Kuan Chan

December 21, 2023

Abstract

My term project is to plot the HR diagram of M6 open cluster. To achieve the goal, I do image reduction, stacking, flux measurement, standard star calibration, and error estimation. The whole code is available on the following website:https://github.com/zrk-dreamer/Advanced-Astronomical-Observation-/blob/main/AAO_project.ipynb

1 Procedure

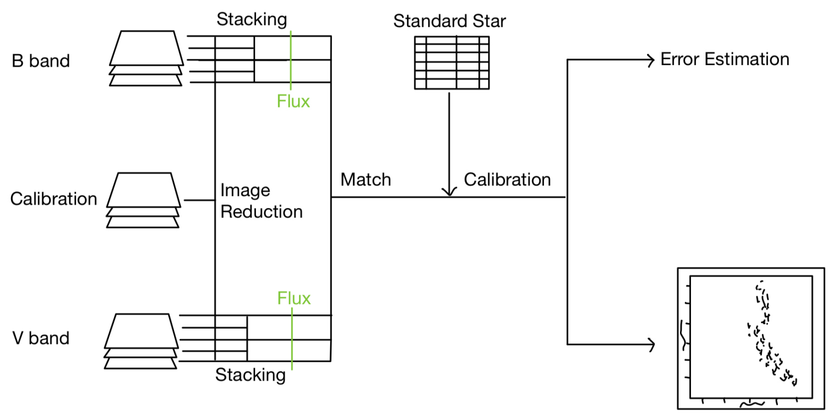
In this section, I will show the details of the procedures.

1.1 Image Reduction

I performed image reduction using the calibration frames shot under -15°C and the dark frames with the same exposure time to the light frames. (B: 4sec, 40sec, and 8min; V: 3sec, 30sec, 5min) After the reduction, I got six sets of reduced images with different bands and different exposure time.

1.2 Stacking

Before registration, to deal with artifacts (hot pixels or dead pixels) and to avoid their effect on the transformation, I first used Python package called ccdproc to clean the images (ccdproc.cosmicray_lacosmic). Then I use another package called astroalign to perform registration and transformation. After, stacking, I use mean method to stack the images. Finally, I got six



stacked images with different bands and different exposure time.

1.3 Flux Measurement

To remove background and perform aperture photometry, I used a package called SEP(Source Extraction and Photometry). First, I use sep.Background to get global backgrounds, and then I subtract backgrounds from the stacked images. Next I use sep.extract to find positions, semi-major axes, semi-minor axes, and theta (orientation) of potential object with 7σ for V band and 6σ for B band. Before the formal measurement of flux, I impose maximum limits on the peak values in the area of detected objects to prevent the saturation. With the information about the objects, I use sep.sum_ellipse to calculate the total flux and the associated error. Here, the radius of the aperture (ellipse) is Kron Radius.

1.4 WCS and Cross Match

Before going on, I first uploaded the six stacked image to Astrometry.net to do plate solving and to get new header that could be accepted by astropy.wcs.WCS. After getting WCS, I could map the position on the images to its corresponding equatorial system coordinate, which allowed me to match the objects detected in V band and in B band. In this case, the threshold is two arcsecond; that's to say, the object with only B band photometry or V band photometry would be discarded. After the cross match, there were

3303 remain objects.

1.5 Standard Star Calibration

I first generated a .txt file containing the position (RA, Dec) of those 3303 objects and upload to VizieR to get nearby standard stars (2 arcsecond), including the V mag, the B mag, and the associated error. Then, I perform matching between the standard star catalog and the objects I found; the threshold is one arcsecond. After matching, there were 437 remain objects (The other objects were not discarded in this case). With those remain objects, I use kmpfit from a package called Kapteyn to do fitting and try to figure out the extinction coefficient K, the zero point γ, and the color term β. However, during fitting, K and γ tend to show degeneracy ($-KX+\gamma = const.$, but the values of reduced χ^2 is insensitive to K and γ); hence I let $A = -KX + \gamma$, which becomes a new parameter in my fitting.

1.6 Error Estimation

After obtaining the calibration formula, I could do the error propagation. The sources of error are A and β in the formula (includes the error from standard star) and flux measurement using SEP. As mentioned, the formula I used to do standard star is:

$$m_{\lambda_{std}} = m_{\lambda_{inst}} + A + \beta(m_{\lambda_{inst}} - m_{\lambda_{2,inst}}) \tag{1}$$

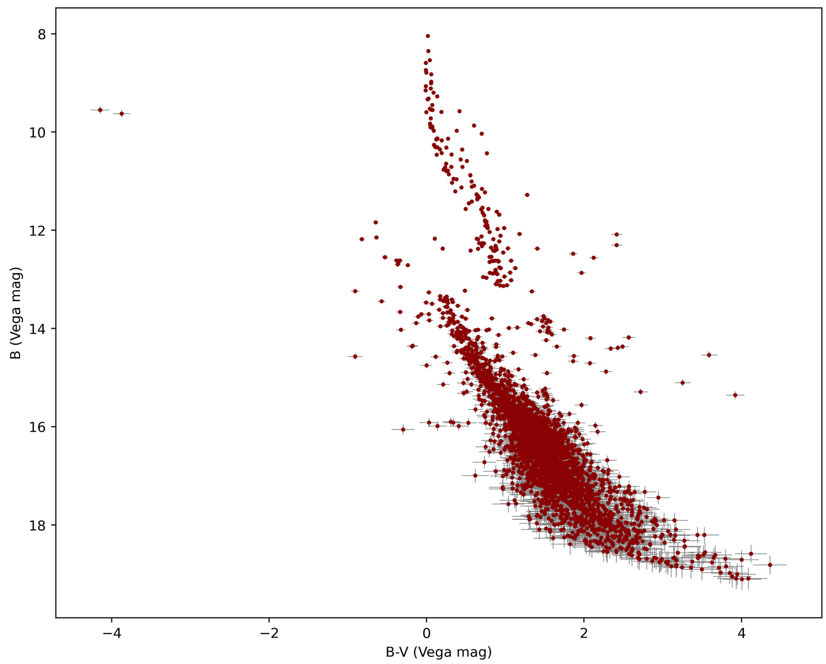
Then the associated error can be calculated via following formula:

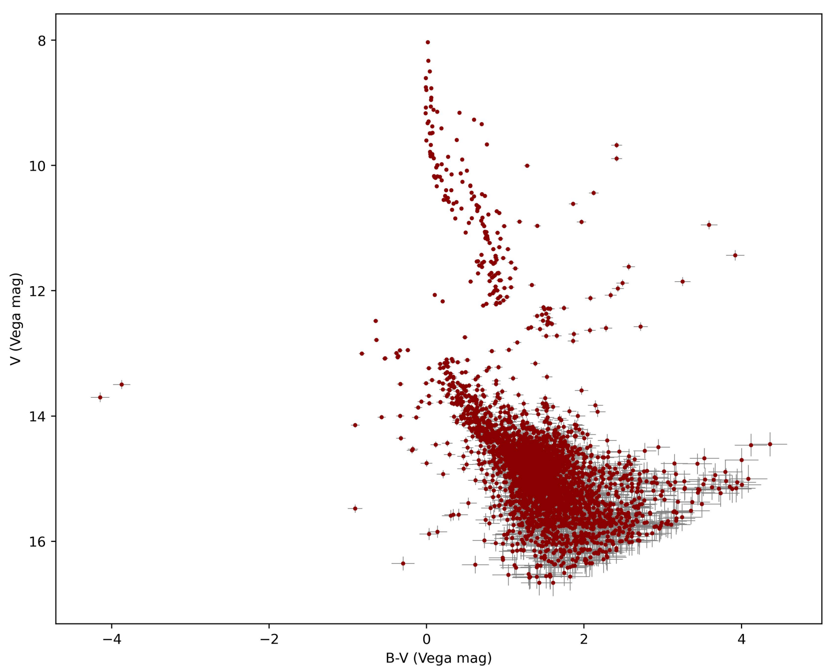
$$\sigma^2_{\lambda_{std}} = \sigma^2_{\lambda_{inst}} + \sigma^2_A + \beta^2(\sigma^2_{\lambda_{std}} + \sigma^2_{\lambda_{2,inst}}) + ((m_{\lambda_{inst}} - m_{\lambda_{2,inst}})\sigma_\beta)^2 \tag{2}$$

The result of error estimation will be show in the next section, along with the diagrams.

Case	A	β
To calculate V mag	21.69237 ± 0.00970	0.04299 ± 0.03199
To calculate B mag	21.66878 ± 0.00740	0.49828 ± 0.02793

2 Results


B (Vega mag)
B-V (Vega mag)


V (Vega mag)
B-V (Vega mag)