Variable “Be” Stars in the Perseus Constellation

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Abstract:

Over four nights between September 26th and October 23rd, the young star cluster “h Persei” was observed with a CCD camera attached to a Celestron telescope. The two stars, Oo 1278 and Oo 1282, are the primary focus of this research project. The apparent magnitudes for these two stars were plotted against time to create light curves to study the variability. Oo 1282 was found to be a variable star as its differential magnitude varies with time. Fourier Analysis found three frequencies for a multiperiodic trend of the differential magnitude for Oo 1282, but there was insufficient data to carry out the same analysis on Oo 1278. By analyzing the spectra obtained by the Dominion Astrophysical Observatory in Victoria B.C, the two stars in question can be classified as early B spectral-type stars. Furthermore, Oo 1282 can be classified as a mild Be star due to the H beta line in partial emission.

Introduction

The majority of the stars visible in the night sky are classified as variable stars. Variable stars are stars which change in brightness over time, with changes as small as a few parts in a million or larger by a factor in the thousands (Percy, 2007). This change in brightness can take anywhere from a second to many decades to occur. Studying variable stars allows more additional parameters, most importantly time scales, to be measured and utilized. These variations can be used to learn more about the internal composition, structure and physical processes in the star (Percy, 2007).

Professional and amateur astronomers all over the world study variable stars. They are popular because one does not need the biggest and best telescope to study them. A small telescope, a CCD camera and a computer are all that is needed to get real and accurate observations. The American Association of Variable Star Observers (AAVSO) is a non-profit organization of professional and amateur astronomers that boasts an archive of over 23 million variable star observations (AAVSO, 2013). AAVSO gives a chance for amateurs to provide real and useful contributions to the scientific community.

Purpose

This paper's purpose is to chronicle the observation and analysis of two stars, Oo 1278 and Oo 1282, in the young open star cluster "h Persei". This study contributes original research in this area of astronomy since these two stars were targets of only one other study, and as a result, very little is known about them. Through prior observations by Majewska *et al*. in 2008, the two stars in consideration have been classified as Be variable stars. Be type stars are B spectral type stars (temperature between 10,000 and 30,000 K) that show, or have shown, emission in one or more of the Balmer lines of hydrogen (Gray & Corbally, 2009). The distinguishing factor between B type and Be type stars is the Be type stars' rapid rotation. As the Be type star rotates rapidly, an airy disk of gas forms around its equatorial plane. This airy disk is where the emission lines arise (Percy, 2007). Be type stars vary in brightness and spectra, possibly with multiperiodic pulsation frequencies. These multiperiodic pulsation frequencies are to be found by observing and analyzing these two target stars, thus confirming the previous study's results. The spectra of the two stars will also be analyzed.

Equipment

The Observatory on top of the International Building at Thompson Rivers University is home to a 14-inch Celestron Telescope. Data of the stars in question was collected using a Santa Barbara Instruments Group ST-7XE CCD camera attached to the telescope. Figure 1 shows the Celestron Telescope with the CCD camera attached.

Figure 1: Celestron Telescope in Thompson Rivers University's Observatory

Data Acquisition

Images of the h Persei target stars were taken over four nights between September 26th and October 23rd, 2015. The CCD camera was cooled to -10°C before any images were taken, in order to reduce dark current and corresponding noise thermally generated in the camera itself. Dark current causes the pixels in the CCD camera to fill with unwanted electrons, even in the absence of light (SBIG, 2002). For each observing night, flat field images were taken of the dusk sky, before the stars were visible. Flat field images allow the correction of pixel non-uniformity, vignetting, dust spots and stray light variations on the final star images (SBIG, 2002). Nine flat field images were taken with an exposure of 10 to 20 seconds, binned 2x2 and with an average count of 25,000 pixels. For each night, a median flat field was found and normalized using IRAF (Image Reduction and Analysis Facility) software. As each night unfolded, it was time to image the target stars. Images of the target stars were taken using V filters (for visible light) and exposure times of sixty seconds. Due to the inability of this telescope to track the stars properly, it was set up to take twenty pictures in a row, then shift the telescope back to the stars' frame location, and then repeat the process. An image of the target stars is seen in Figure 2.

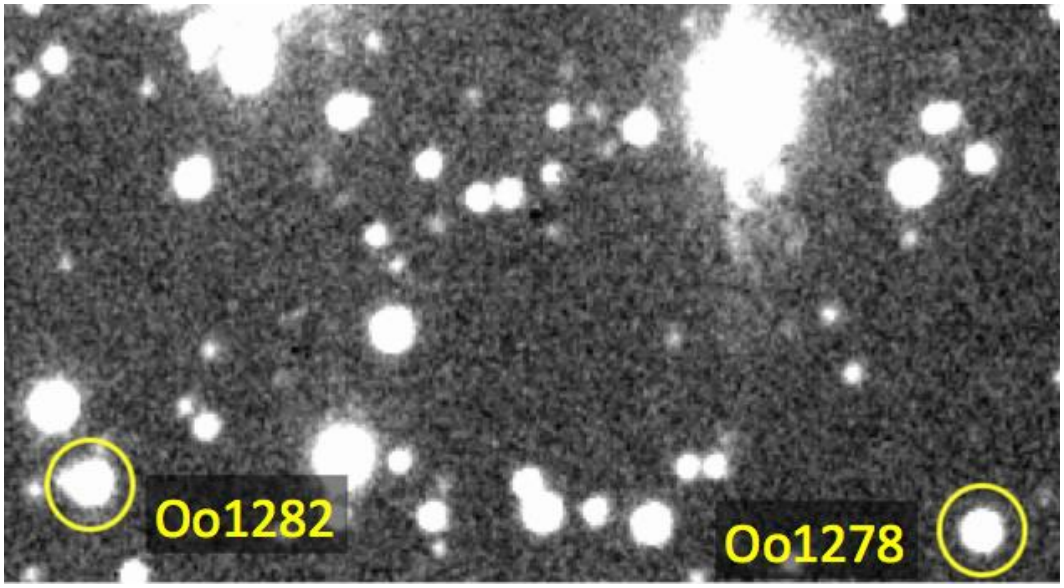

Figure 2: CCD image of the target stars Oo 1278 and Oo 1282

With the images taken, it was then time to start the reduction and analysis process. Each image had the normalized flat field for the specific night divided, thus removing any dust and spots from the image. The next step was to find the standard deviation of each image's background (night sky with no stars). The purpose of this is to find the noise created by the atmosphere and any moisture in the night sky. The standard deviation is found by selecting coordinates in the image to create a virtual rectangle encompassing a dark portion of the image and using the imstat task within IRAF. The virtual rectangle is seen in Figure 3.

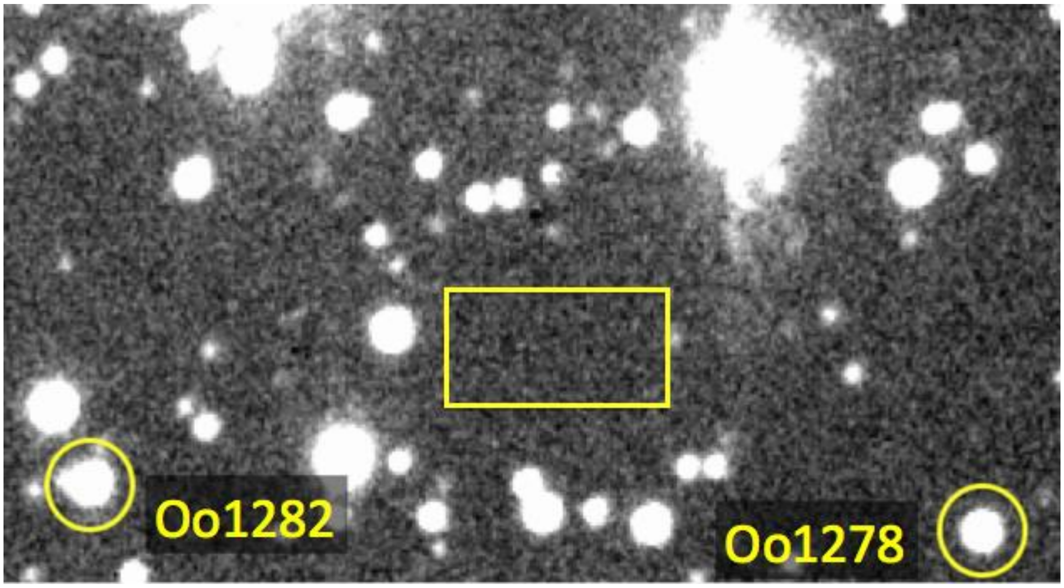

Figure 3: CCD image containing the target stars and the virtual rectangle for finding the standard deviation

Along with the standard deviation, the average full width half maximum (FWHM) of the stars in each image was found. The FWHM is found using the psfmeasure task in IRAF and is a parameter for photometry analysis within the daophot task. A radial plot of the star's brightness can be found for each star in an image using IRAF. The FWHM then corresponds to the width of the star's spectrum at half the maximum altitude. For each image, the FWHM was found for six stars and the average was taken. Figure 4 shows the stars for which the average FWHM was found.

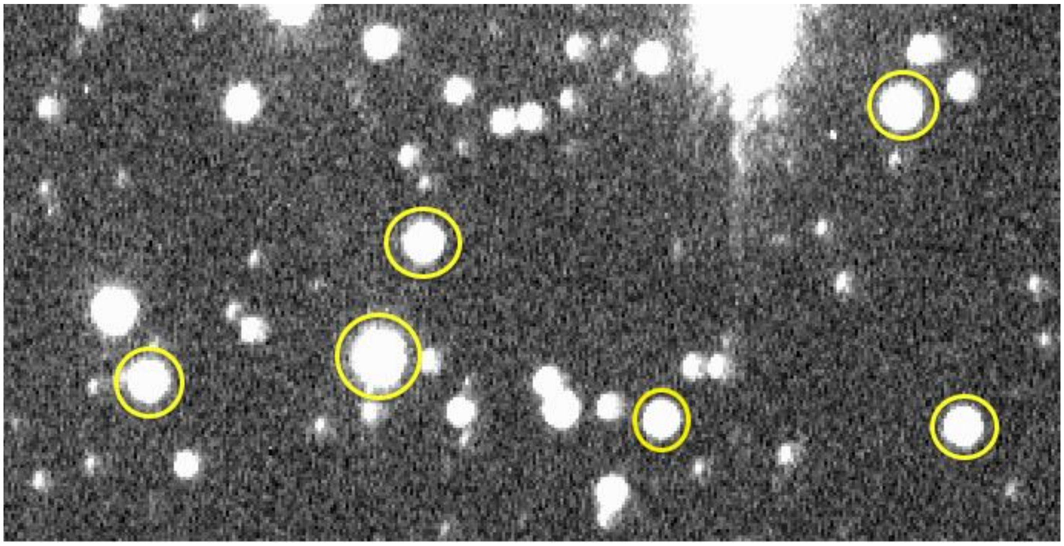

Figure 4: Stars used for calculating the average FWHM

Finding the standard deviation and average FWHM for each image is very time consuming. Therefore, ten to sixty images were aligned together by their corresponding stars using the imalign task within IRAF. IRAF scripts were utilized to find the standard deviation and average FWHM for ten to sixty images at a time. This greatly helped to speed up the data analysis. Each image was analyzed using the daophot task, employing the standard deviation and average FWHM as parameters. This task allowed for the determination of the apparent magnitudes of the target stars and all other stars in the images. A comparison, non-variable star was then needed to find the differential magnitudes of the target stars. By comparing different stars' apparent magnitudes, we found a non-variable star. This non-variable star then became the comparison star used to find the differential magnitudes. The comparison star used is seen in Figure 5.

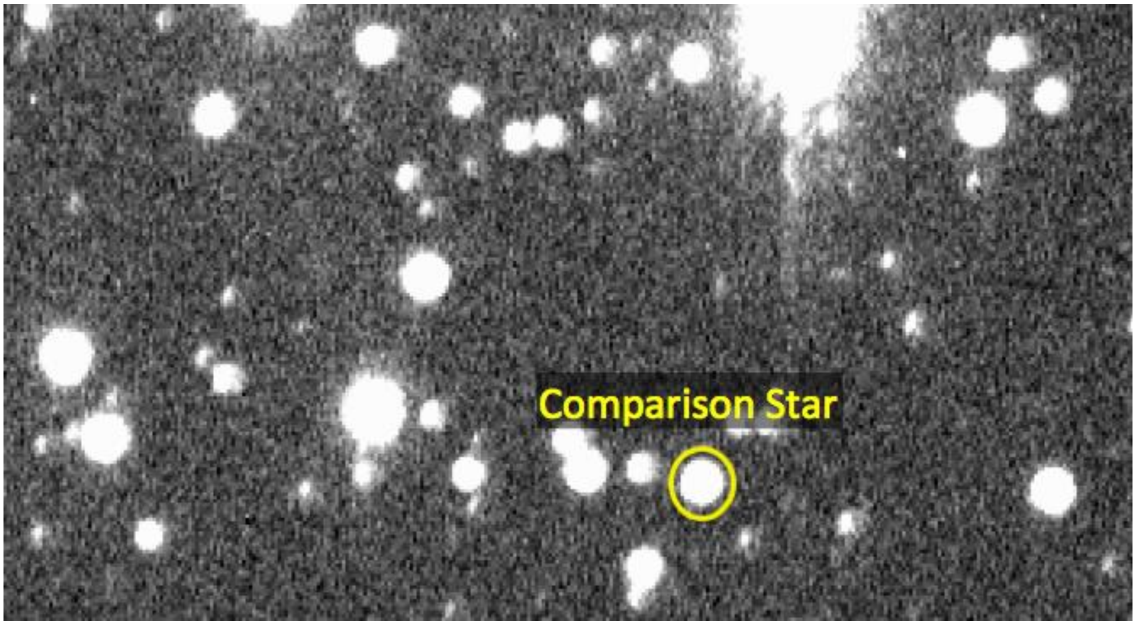

Figure 5: CCD image of the comparison star

We then found the differential magnitudes by taking the differences of apparent magnitudes between the target and comparison stars. The two stars' differential magnitudes were plotted against time to create light curves, in order to study the variability. The light curve for Oo 1282 can be seen Figure 6 and the light curve for Oo 1278 can be seen in Figure 7.

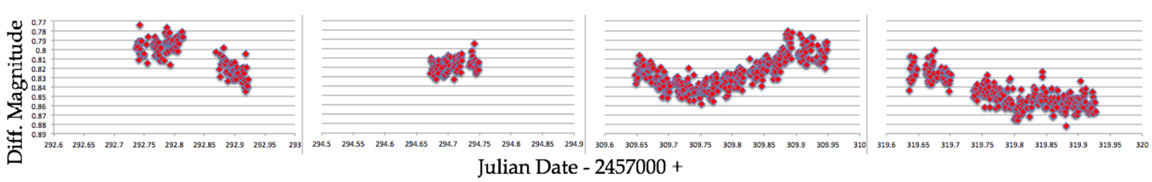

Figure 6: Light Curve for Oo 1282

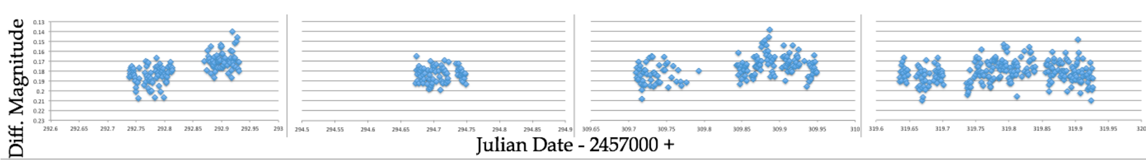

Figure 7: Light Curve for Oo 1278

The Julian Date was used for the x-axis on each light curve. This is standard astronomic procedure, as it cuts out the faults of the 12-month calendar and daylight savings time. As shown by these curves, Oo 1282 is clearly a visibly variable star, as its differential magnitude varies with time. However, there is insufficient data to verify Oo 1278 as a variable star.

Fourier Analysis

Using the differential magnitudes for Oo 1282, a Fourier analysis was completed for the star using a program called Period 04. In this program, the differential magnitude and time info is loaded in as an imported time string. The first Fourier calculation is then carried out for the original data from 0 to the Nyquist frequency, the upper frequency of the current data set calculated by Period 04. This first Fourier calculation finds the first frequency of the Fourier series. This procedure is repeated two more times, with the calculation now based on the residuals of the original data. As more frequencies are added to the data's fitting formula, the residual's value gets closer to the value of 0. The Fourier analysis found three frequencies for Oo 1282 for a multiperiodic trend of the differential magnitude. The three frequency values were 1.563, 0.235, and 4.102. A plot of the Fourier analysis on Oo 1282 is seen in Figure 8.

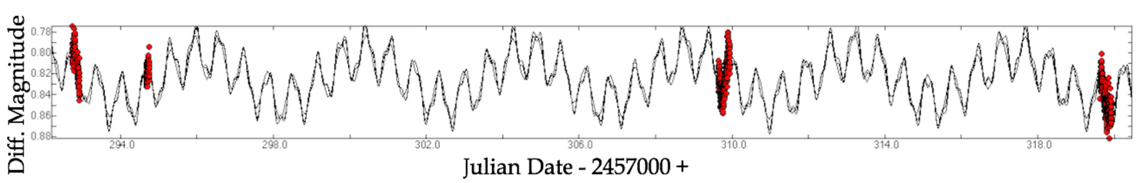

Figure 8: Fourier analysis for Oo 1282

This Fourier analysis, however, is not yet complete. Artificial data was then created using a sine wave with the superposition of the three calculated frequencies to test the validity of the Fourier analysis for fourteen days and nights. Using the same steps listed above, the same frequencies were found using Period 04 for the artificial data. By decreasing the amount of artificial data into Period 04, it was found that once there was only the equivalent of four nights of data, different frequencies were found. This points towards a possible conclusion: a minimum of five nights is needed to find the actual multiperiodic trend. No Fourier analysis was done on Oo 1278, due to the insufficient amount of data.

Spectra Analysis

Spectra for the two stars were obtained by David Balam at the Dominion Astrophysical Observatory in Victoria, B.C with the Plaskett 1.8 m telescope. The spectral data plots of each star were produced by Joanne Rosvick and can be seen in Figures 9 and 10.

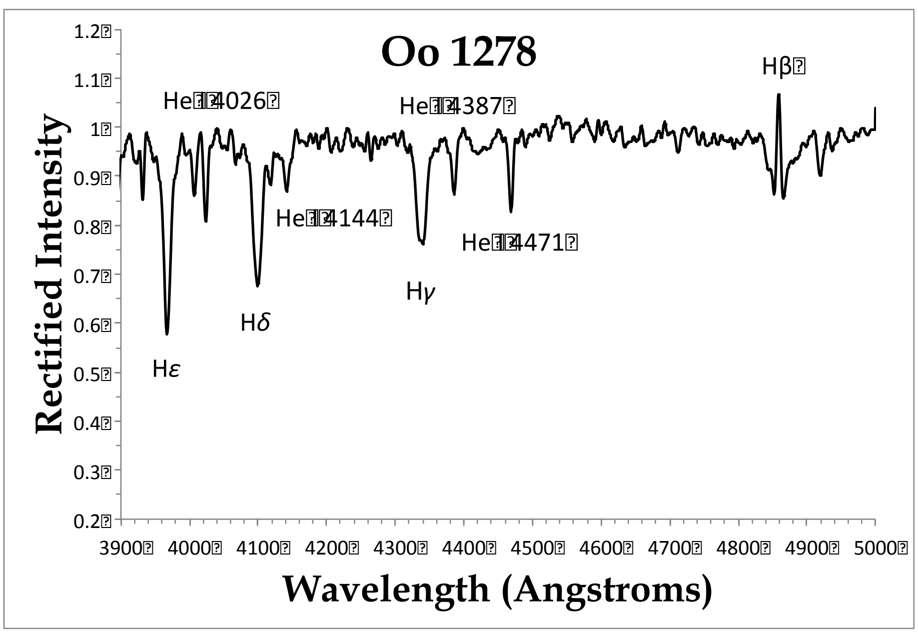

Figure 9: Spectra for Oo 1278

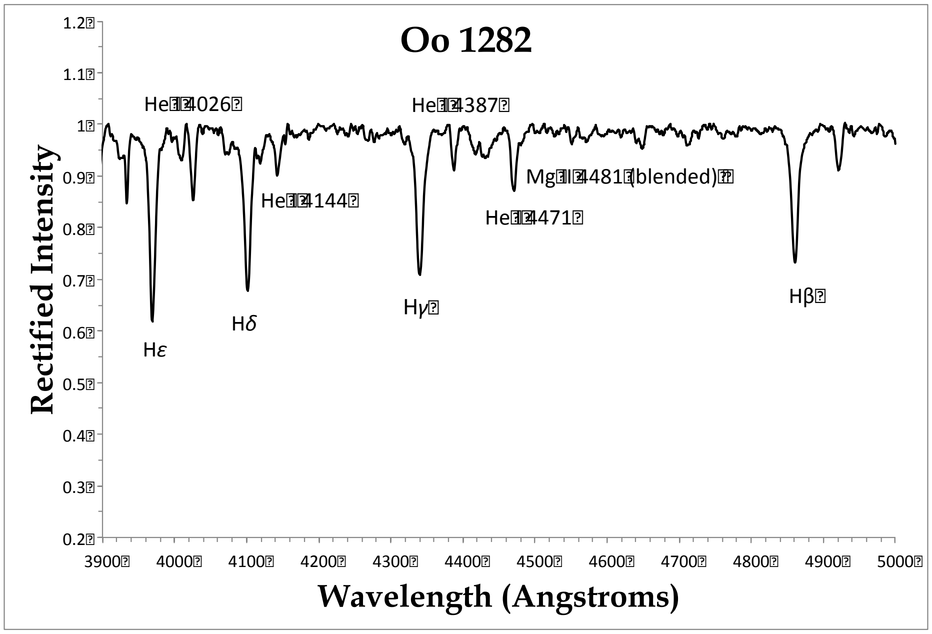

Figure 10: Spectra for Oo 1282

The two stars in question are both early B spectral type stars, marked by the presence and strength of neutral helium absorption lines. Oo 1278's spectrum has stronger helium lines indicating an atmospheric temperature around 20000 K while Oo 1282's spectrum has a lower temperature of 16500 K. Oo 1278 can be further classified as a mild Be star, due to the H beta line in partial emission. Both of these spectra are incomplete because the Wavelengths only go from 3900 to 5000 Angstroms. At 6560 Angstroms, there is an H alpha line that is not present in either of these. It is then possible that Oo 1282 is a Be type star with H alpha in emission. Future research is required in order to support these predictions and hypotheses.

Future Research

Students in the future may be able to continue this research by taking more images of the two target stars. By following the steps already taken, the students can find differential magnitudes and plot this data against time. A complete Fourier analysis can be made with more data. The Fourier analysis will then produce the multiperiodic frequencies of the target stars.

Conclusion

By analyzing the plots produced, Oo 1282 is identifiable as a variable star, as its differential magnitude varies with time. By analyzing the spectra from the Dominion Astrophysical Observatory, Oo 1278 was found to be a mild Be type star, while Oo 1282 is an early B type star.

References

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