An Analysis of Data Relating to the Magnitude and Period of Variable Stars

Intro

Variable stars are stars whose apparent magnitude changes periodically. The range in brightness and time period can "range from a thousandth of a magnitude to as much as twenty magnitudes over periods of a fraction of a second to years, depending on the type of variable star" (1) This displays that although all stars appear to fluctuate slightly in luminosity over time, some do so with larger difference between the maximum and minimum apparent magnitude over a specific time period- these are variable stars. This phenomenon were first observed by Johannes Holwarda in the star Omicron Ceti (later named Mira) and was the first step in being able to link distance, apparent and absolute magnitude.

Variable stars is a general label for a vast selection of stars which all seem to pulsate but for different reasons. The main two types of variable stars are; intrinsic- where variation within the star is due to physical changes inside the star, and extrinsic-where the variation in luminosity is due to the geometrical alignment which normally involves one star eclipsing a secondary star or by the effect of stellar rotation.(2)

Intrinsically variable stars

Intrinsic stars can be further defined by whether they are pulsating or eruptive, with these two groups sub dividing again giving more than eight other groups. After looking at the data we received we narrowed down the stars we were going to research in depth down to three main ideas- Cepheid and RR Lyrae stars from the pulsating section of intrinsic and Eclipsing Binary from the extrinsic group.

Cepheid stars;

Cepheid stars are by far the most well-known type of variable star they pulsate with periods between roughly 1 and 70 days. (3) Most Cepheid stars are typically stars of type F or G and "have an average luminosity of around 300 to 40000 times the sun's magnitude" (4). In addition to their changing luminosities, their temperature fluctuates in line with their magnitude. Their variability is a result of the fact that when helium 1^+ ions are ionised to become helium 2^+ they become opaque. When a Cepheid is compressed, it becomes opaque as more of the helium in the stars envelope is ionised. Photons are absorbed or reflected by the helium 2^+ inside, heating the gas and increasing its pressure. The high-pressure gas expands, becoming transparent. The photons pass through the gas. The gas then cools, the pressure drops. As the pressure drops, the Cepheid is compressed by gravity. (4) There are two types of Cepheid, type 1 and type 2 this relates to their population (1 or 2) population 1 stars are metal rich and population 2 starts are metal poor.

RR Lyrae stars;

RR Lyrae stars are very similar to Cepheid stars because there pulsating apparent brightness is due to the star compressing and expanding causing a change in temperature due to the fluctuating ionisation of the helium gas. However RR Lyrae stars are typically a lot dimmer than Cepheid stars with an average luminosity around 80 times that of our sun (4). They have periods which are typically a fraction of a day ranging from around 3-29 hours (5). Because of their similarities to Cepheid stars they are often referred to as short-period Cepheid stars. RR Lyrae stars are often found in globular cluster and out of the 6000 known types of those stars around half are found in globular clusters.

Eclipsing Binary stars;

Eclipsing binary stars are part of a system involving two stars rotating around each other at such a distance that even the strongest telescopes can't resolve the two stars. If we view the pair of stars at a right angle of the plane of rotation no difference in luminosity can be noticed and so we it is impossible to know whether there are one or two stars present. But if we view the system parallel to the rotating plane the stars will periodically obscure each other resulting in a drop of luminosity relative to the brightness of the star that is eclipsed. If we see two drops in magnitude of different amounts then we know there must be two stars of different luminosity orbiting each other. As just over fifty percent of stars are binary, the range in luminosity can be from one or two times the Sun, to many hundreds of times more than the Sun. Also the period of eclipsing binaries has a massive range from 2.4 hours to 10^{11} days (6).

Target and Dataset

We were given 36 images of the same patch of stars over a period of around 6 hours. From this we wanted to determine which of the stars were variable and what type of variable star they were based upon our measurement of magnitude and period.

How it can be related to Distance

The relevance of the period of a variable star is that it can be used to determine cosmic distance, this is because they have well-defined absolute magnitudes which are assumed to not vary with age or distance. Cepheids period and absolute magnitude are linked using a period-luminosity curve so you can then calculate the absolute of any Cepheid by calculating there period. This then allows you to calculate distance to them using the equation $m-M=5\log(d-5)$ which gives you a standard candle which you can measure different stars around it from. If two Cepheids have the same period but is fainter than the other it must be further away. RR Lyraes similarly can be used as standard candles although as their intrinsic luminosity is lower than Classical Cepheids they cannot be detected at the great distances of Cepheids (8).

Methodology

From our data we first had to identify which one(s) we thought were variable and then choose a standard star to then compare it to. We then recorded the date and time that all the images and were taken and numbered them 1 – 36. The times we had then needed to be converted into seconds which we did by measuring how far away they were from the point 10:20pm on the 26/07/2010.

This information was entered into a table in excel. Next we measured the brightness in photon count(s) of the star we thought to be variable in all 36 images, which we chose by flicking through the images quickly and picking which one we thought by eye altered in brightness the most, and wrote down the photon count next to the corresponding time in the table *(given in the appendix).*

After this was done we measured the brightness of the control star. Following this the photon count was converted into apparent magnitude using the equation $-2.5*\log(F)$. We then plotted the light curve of time against both count and magnitude for both stars which gave the same shape on each of the graphs.

In order to calculate period we choose two points equal in amplitude and measured the time between them and converted it into hours which gave the period of our variable star. We then narrowed down the list of variable stars it could be using the period, shape of light curve and luminosity. This left us with three possible options; Cepheid variable star, RR Lyrae and an eclipsing binary star.

Classification of our star

Once we narrowed down the list of potential variable star types by comparing period, apparent magnitude and the shape of the light curve we produced we tried to decide which type we thought our star was most like.

Our variable star showed a similar light curve to one of a Cepheid variable *(see figure 1)* leading us to believe that it is some type of pulsating star, with the shape of the Cepheid variable coming the closest to the graph we created. However, Cepheid variables tend to have periods of 1-70 days and ours was only around four hours.

When looking at the period of our star the type which came closest to having the same time between pulses was the RR Lyrae star which typically has a period around 3-29 hours(5) and when we compared the two graphs they fit relatively well together*(see figure 2)*. However RR Lyrae stars are often found in globular clusters and we were unable to tell whether our star was a part of a cluster so we did not have this piece of evidence to confirm our hypothesis.

Finally we looked at the possibility of it being of an eclipsing binary star because the troughs in our graph differ slightly in photon count, with the first being slightly brighter than the second. This is consistent with the light curve of an eclipsing binary *(see figure 3)*, however we felt that there should be a more prominent straight line at the top of our graph before the troughs. The period of eclipsing stars can vary by a huge amount so the fact that our period was 4.27 hours was unable to confirm or disprove our prediction.

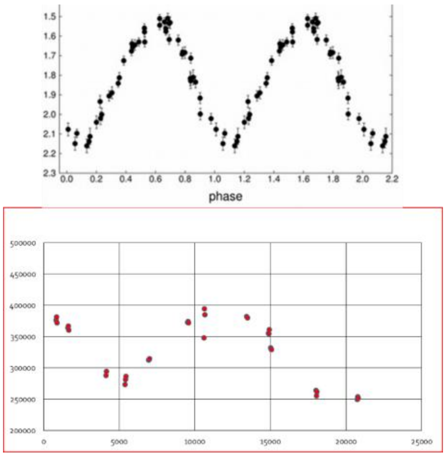

Figure 1:Cepheid Variable Star

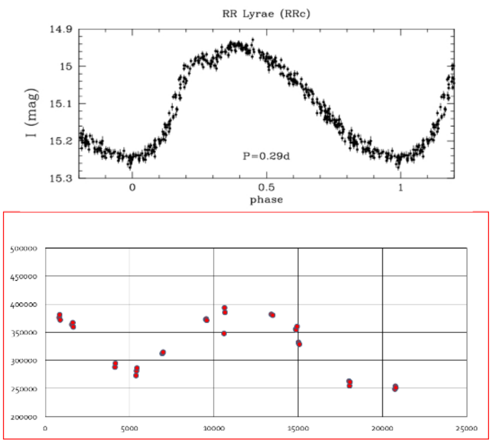

Figure 2: RR Lyrae

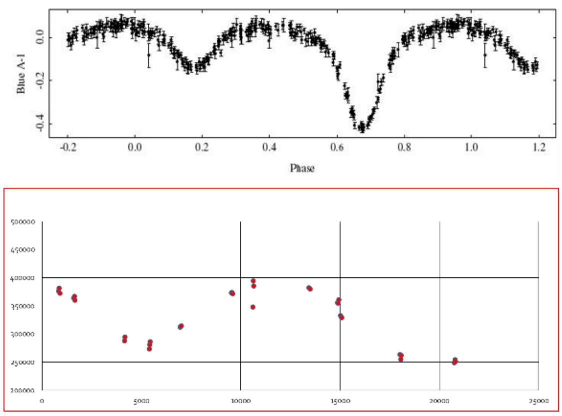

Figure 3:Eclipsing Binary Star

Looking at all the arguments for our final three stars, we decided that our data was most like a RR Lyrae star because both the shape of the light curve and time period were consistent with that of a RR Lyrae star. In order to test our final hypothesis we took the coordinates of our star and put them into SIMBAD. Two different organisations had data on our star and both agreed that it was an eclipsing binary (6). This being said, both of the organisations disagreed with the exact time period and luminosity of the star and the data was deemed “obsolete” (7).

Conclusion

When we started our project, we used our data to produce a table showing how the apparent magnitude varies as the time in seconds from the point 22:20 on the day 26/07/2012 increases. We then used this data to create a light curve on Edexcel which we used to calculate the period of the variable star by measuring the time between two troughs. This gave us a time period of our star at about 4.27 hours. We then used this along with the light curve to compare against the different types of variable star. It should be noted that we encountered anomalous results. As we were going through the different images we were given, some of the pictures had lines of white specks which we identified as background noise detected by the telescope, this made it difficult to accurately detect the apparent magnitude of the star at some times. We narrowed down the types of variable star it could be to a Cepheid, RR Lyrae and an eclipsing binary star. After comparing the three types of variable star we came to the conclusion that it was an RR Lyrae star because the graphs whilst not the closest were quite similar and it was the only type with a feasible period. However when we used SIMBAD to check our conclusion we discovered that it was an eclipsing binary star. This being said the name of the star we were given and the coordinates did not seem to match up which could have been an error within the data we were given. Taking all of this into account we feel that the data we were given wasn't valid enough to give a valid conclusion, but the method we used could be repeated with different data to confirm the exact type of variable star.

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Appendix

Seconds from 10:20pm 26/07/2010	Photon count
508	289896.4
831	376291.7
862	381597.8
894	371926.8
1595	363963.6
1626	366997.8
1658	360056.1
4140	287879.8
4171	294559.5
5388	273390.4
5419	281245.8
5451	286328.2
6940	312372.9
6974	312984.5
7005	314656.8
9528	373040.7
9559	373856
9591	371824.8
10596	347837.2
10628	394158
10660	385191.2
13421	382350.3
13454	482102.4
13487	380188.1
14865	355326
14896	354571.5
14928	360987.3
15023	332283.3
15055	329809.1
15087	329160.6
18018	263559.8
18050	255113.7
18083	261719.9
20750	249177.8

20782	253892.8
20814	251333.3