PHOTOMETRIC SEARCH FOR VARIABLE STARS IN THE OPEN CLUSTER NGC 1528

by

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This thesis has been reviewed by the research advisor, research coordinator, and department chair and has been found to be satisfactory.

Date	Eric Hintz, Advisor
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ABSTRACT

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We report our search for variable stars in the open cluster NGC 1528. There were 40 stars that were included in this study. Through aperture photometry and analysis of light curves, we concluded that our data does not show variability for the chosen ensemble of stars. We are also unable to confirm that the suspected variable Star 21 is a variable star.

ACKNOWLEDGMENTS

I would like to thank my advisor Dr. Hintz for all of his help on data analysis and on this paper. I would also like to thank the BYU Orson Pratt Observatory and the Tenagra Observatory for the data acquisition of this project. I would like to thank the many students who helped me with my research. Lastly I would like to thank my husband Stephen for the enormous amount of time he spent helping me troubleshoot various problems with computer programs and helping me work on this paper.

Contents

List of Tables

List of Figures

Chapter 1

Introduction and Background

1.1 Background on Variable Stars

The amount of light that a star gives off may not be constant over time. Stars that do not give off a constant amount of light over time are known as variable stars. We can plot the intensity of the light that comes from a star with respect to time to see how the light changes and help us determine what kind of variable star we are studying. There are two main categories of variable stars, intrinsic and extrinsic and each of those has their own subcategories.

Intrinsic variable stars vary the amount of light that they give off because of some internal property of the star. There are four main types of intrinsic variables. Eruptive variable stars are stars that vary in brightness because of violent changes in its outer layers. Pulsating variable stars are stars that periodically expand and contract their surface layers. These stars can pulsate radially, which means that the star keeps its spherical shape, or nonradially, which means that the star does not maintain its spherical shape. Rotating variable stars are stars with nonuniform surface brightness or ellipsoidal shapes. Cataclysmic variables are stars that show outbursts in their surface layers, like novae, or in their interiors, like supernovae.

Extrinsic variable stars change in brightness because of the way we view the star. This often occurs in eclipsing binary systems. We can observe this when the two eclipsing stars are on the same line of sight. When one passes in front of the other the apparent brightness will change.

1.2 Open Clusters

Stars can become variable at certain stages of their evolutionary process. Open clusters are very useful in studying stellar evolution because all of the stars in them formed at about the same time all from the same cloud of gas.

We can make three general assumptions about stars in the same cluster. The first is that all of the stars are the same distance from us. This is significant because it makes it easier to compare the relative luminosities of the stars. The second assumption that we can make is that all of the stars are approximately the same age. We can assume this because stellar formation happens rather quickly compared to the overall age of the cluster. The third assumption that we can make is that the stars have about the same chemical composition.

These characteristics greatly limit the number of parameters that one has to consider when studying stellar evolution. One major difference that still exists between the stars is their masses. Since stars of different masses will evolve at different rates, we can use the clusters to help us understand this evolutionary process.

1.3 Previous Research

There are two suspected variable stars in NGC 1528 reported by Bruegman(2003). The first star has a V magnitude of 13.131 with an unconfirmed period. This star was too faint to be considered in this study. The second star has a V magnitude of 12.786 with a reported period of 0.859 days.

1.4 Magnitude Scale

We measure the brightness of a star by measuring its flux. Traditionally in astronomy, star brightness is reported on a magnitude scale. To convert from flux to magnitude we use the equation: magnitude = -2.5 * log(flux) + zeropoint. Because of the negative sign in the equation, stars with a larger numerical value magnitude are actually fainter than stars with a smaller value. It is even possible for stars to have a negative value for their magnitude depending on the zeropoint.

1.5 Plotting Differential Magnitude

When we plot the magnitude of a star versus time, we have to compare its brightness to the other stars in the ensemble. Unless we have a star with a standard known brightness in the region, we can not know the actual apparent magnitude of the star. Even without this knowledge, comparing the light curves of one star to another will help us gain valuable insight on the properties of the star. All of the light curves in this study will be plotted with a differential magnitude with respect to time.

Chapter 2

Observations and Data Reduction

2.1 Observations

2.1.1 BYU David Derrick Telescope

We observed NGC 1528 over 10 nights with the BYU 0.4 m David Derrick Telescope in the Orson Pratt Observatory for a total of 22.5 hours. Four different cameras were used in these observations. The filters used were the Johnson BVR filters. The right ascension (RA) of NGC 1528 is 04 hrs 07 min 48 sec and the declination (δ) is $+51^\circ\ 14'\ 00''$. A summary of data taken from this telescope can be found in Table 2.1. Information about the CCD specifications for each night of data can be found in Table 2.2.

2.1.2 Tenagra Telescope

NGC 1528 was also observed at the Tenagra 0.81 m telescope for a total of 19 nights. The total time that the cluster was observed with this telescope was about

Table 2.1. Summary of Data from BYU DDT

Year	Night	CCD	Filters	Time(hours)
2005	4-Feb	Ap47	V	2
	24-Feb	Ap8	BVR	4.25
2006	9-Feb	ST-1001	BVR	0.25
	24-Feb	ST-1001	V	3.25
	2-Mar	ST-1001	BVR	4
	23-Mar	ST-1001	BVR	2.25
2007	1-Feb	ST-10	BVR	1.75
	18-Feb	ST-10	BV	2.25
	28-Feb	ST-10	V	1
	23-Mar	ST-10	BV	1.5

Table 2.2. CCD Plate Scale and Field of View of BYU DDT

CCD	Focus	Plate Scale (″/mm)	Field of View (′)
Apogee 47	Newtonian	128.9	31.30x31.30
Apogee 8	Cassegrain	40.64	16.64x16.64
ST-1001	Cassegrain	40.64	16.64x16.64
ST-10	Newtonian	127.01	31.30x21.00

Table 2.3. Summary of Data from Tenagra

Year	Night	Filters	Time(hours)
2007	23-Jan	BV	0.25
	7-Feb	BVRI	1.75
	8-Feb	BVRI	2
	27-Feb	BV	2.25
	3-Mar	BV	2
	4-Mar	BV	2
	7-Mar	BV	2
	11-Mar	BV	2
	12-Mar	BVR	1.5
	15-Mar	BVR	0.25
	16-Mar	BV	0.75
	19-Mar	BVR	1.25
	20-Mar	BVR	1.25
	28-Mar	BVR	1
	31-Mar	BVR	1
	1-Apr	BVR	0.5
	4-Apr	BVR	0.5
	8-Apr	BVR	0.25
	9-Apr	BVR	0.25

22.75 hours. A summary of the nights of data can be found in Table 2.3. The Tenagra telescope uses a SITe based camera with a plate scale of 0.87 ″/pixel. The field of view is 14.8′on each side.

2.2 Data Reduction

2.2.1 Calibration

The cameras we use to take pictures of stars are called CCDs, short for charge-coupled device. An image taken with any electronic camera will have noise. In order to reduce the amount of noise that affects our object frames, the frames need to be calibrated. To do this, we take three different types of calibration frames and apply them to each object frame. These calibration frames are called zeros, darks, and flats.

Zeros are taken for zero seconds and measure the residual noise on the CCD. Darks are taken for a certain amount of time with the shutter of the camera closed. They measure the noise built up on the CCD during the duration of each exposure. A flat is an image taken of the sky where there is a uniform amount of light. These calibration frames are taken because every pixel on the CCD responds differently to an even amount of light. All of these frames are divided out of each object frame to correct for this discrepancy from pixel to pixel.

2.2.2 Photometry

After each object frame has been calibrated, the next step is to measure the amount of light that each star gives off. This process is called photing. We do this by calculating a circle with a certain radius around each star and measuring the intensity in those circles. This circle is called an aperture. The light from the star can be mapped out with a Gaussian curve. If we try to account for all of the light from the star, then we will introduce too much noise from the background sky into our data. To correct for this, we first measure the full width - half max (FWHM) of the star and multiply it by a certain number to create an aperture size. Multiplying this number by 3 will probably give us all of the light from the star, but it also introduces a lot of noise. If we multiply the FWHM by about 1.5, we will get a reasonable aperture size with most of the stars light and not too much noise.

Before I actually began to phot, I had to choose stars in the cluster that I wanted to gather data on. I tried to choose stars that were not too crowded together and would appear in the field of view on each of the different cameras used. A picture of the labeled stars can be found in Figure 2.1.

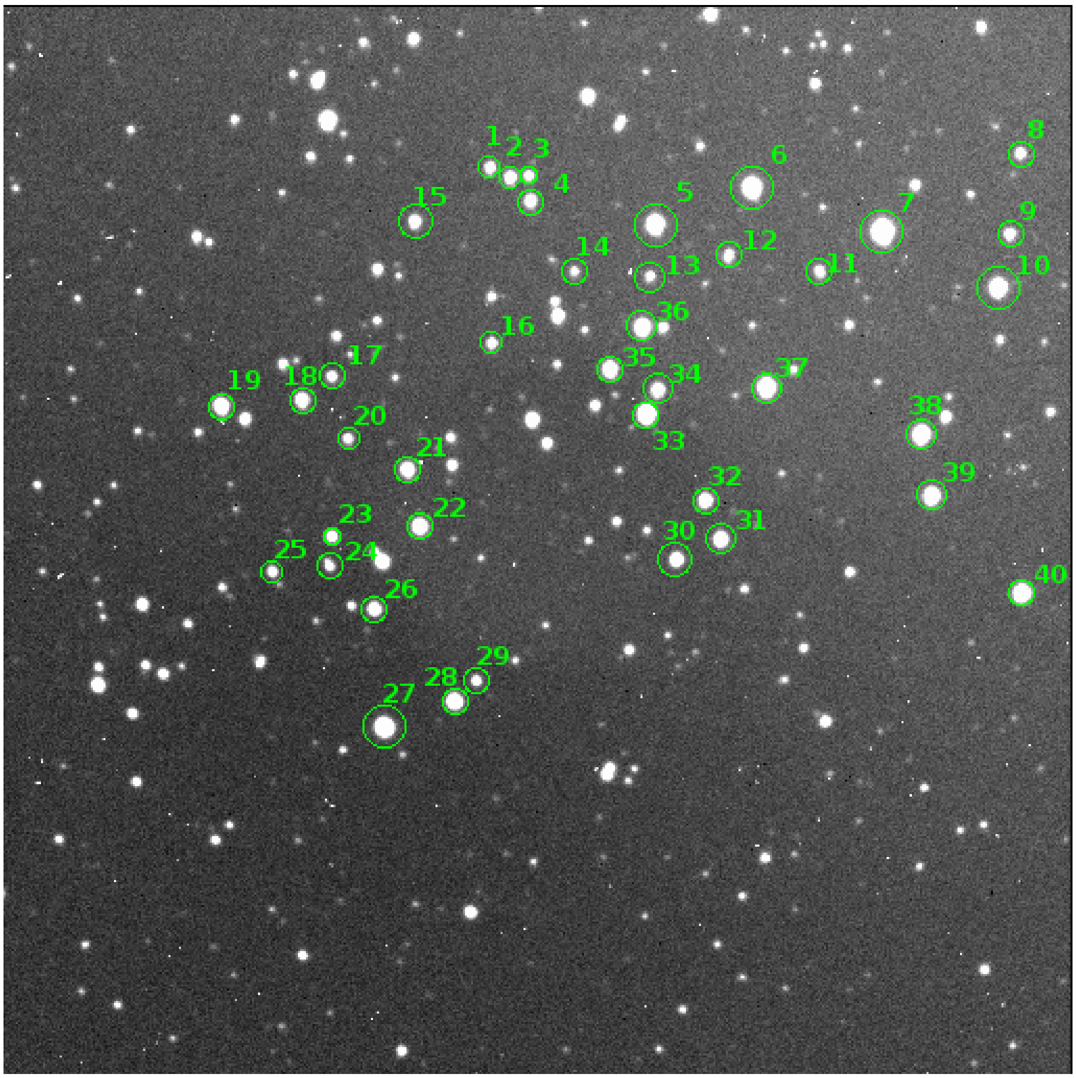

Figure 2.1: Star field with labeled stars

Chapter 3

Analysis

3.1 Varstar

When we look at light curves of stars, some curves will look like straight flat lines and some curves will vary. One reason that a star might not have a flat light curve is because it could be a variable star. A possible way to identify which stars are variable stars is to see which ones change the most from the average magnitude of the star over time. These stars might look like they have a higher error compared to the stars with straight flat lines.

Varstar5 is a program written by Dr. Eric Hintz that helps to numerically identify which stars have the most error. A star might have a higher error not only because it is a variable star but there could also be a lot of scatter because the star is faint. When we plot the light curves of the stars, we compare the varying stars to the most stable stars. To find the most stable stars, we can use Varstar5 to eliminate which stars have the most error. We are then left with an ensemble of stable stars to which we can plot the other light curves against.

After graphing the light curves, we visually inspected them to see which ones appeared to vary. In general, most of the nights of data showed plots of stars with little to no variability. We did, however, see some very strange variability on light curves plotted from data from the Tenagra telescope. After looking at light curves from several nights, we concluded that this variability was due to some bright stars left in the ensemble that had been saturated. We discovered this because some of the bright stars varied in phase with one another. This variation can be seen from stars 7 and 27 in Figure 3.1. We were able to fix this problem by running Varstar5 again but first eliminating the brightest stars from the ensemble and then removing the stars with the most error.

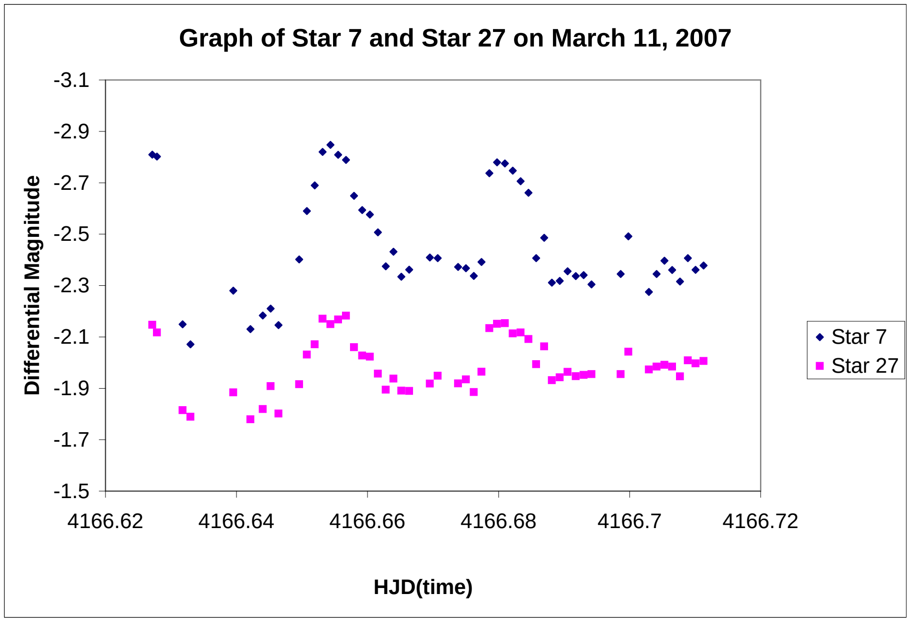

Figure 3.1: A Light Curve of Two Bright Saturated Stars From the Tenagra Telescope

3.2 Examining Star 21

3.2.1 Light Curves

Star 21 in Figure 2.1 corresponds to the star found in Bruegman(2003) that is presumed to be a variable with a period of 0.859 days. In order to examine this star, I picked twelve stars that appeared to have stable flat light curves every night to compare to star 21. Graphs of these stars can be found in Figure 3.2 and Figure 3.3. The light curve of Star 21 does not seem to change compared to the other stars in this graph. Similar plots from other nights of data appeared to show the same result.

To examine the possibility of long term variability, we plotted these same stars over several nights as seen in Figures 3.4, 3.5,and 3.6.

To examine Star 21 more closely, we plotted it along with its zero point over the same time scales as Figures 3.4, 3.5, and 3.6. These plots can be found in Figures

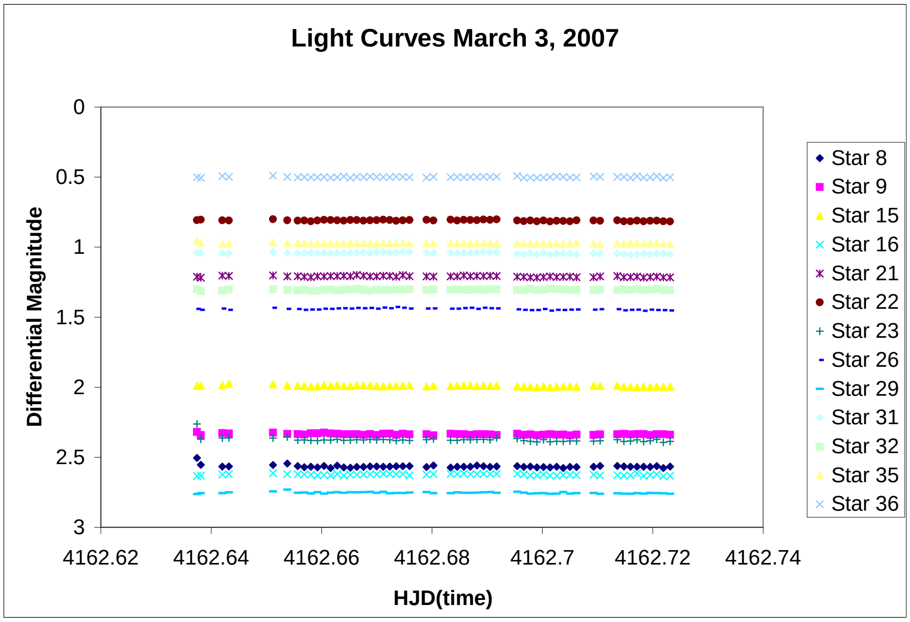

Figure 3.2: Light Curves for 13 Stars from BYU DDT

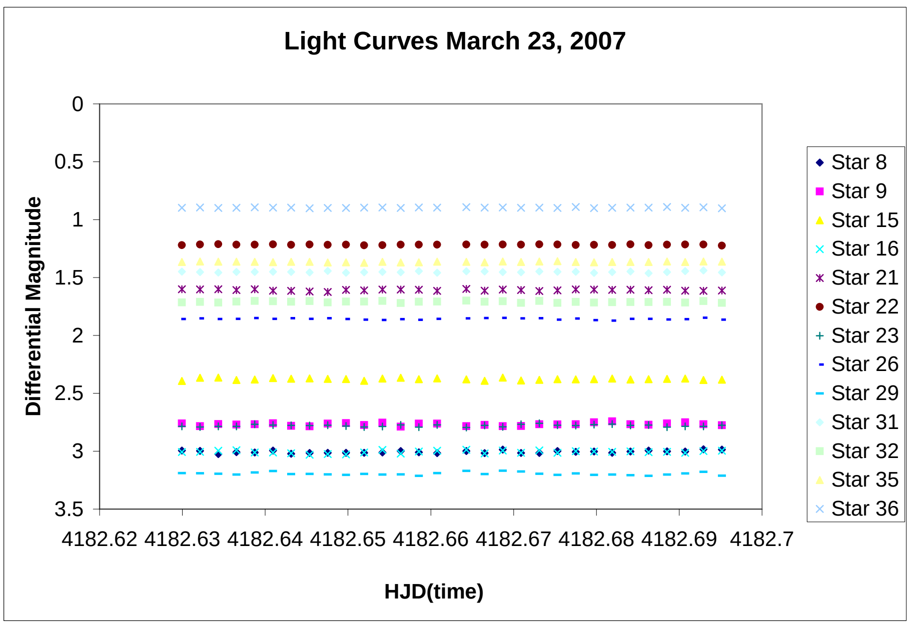

Figure 3.3: Light Curves for 13 Stars from Tenagra

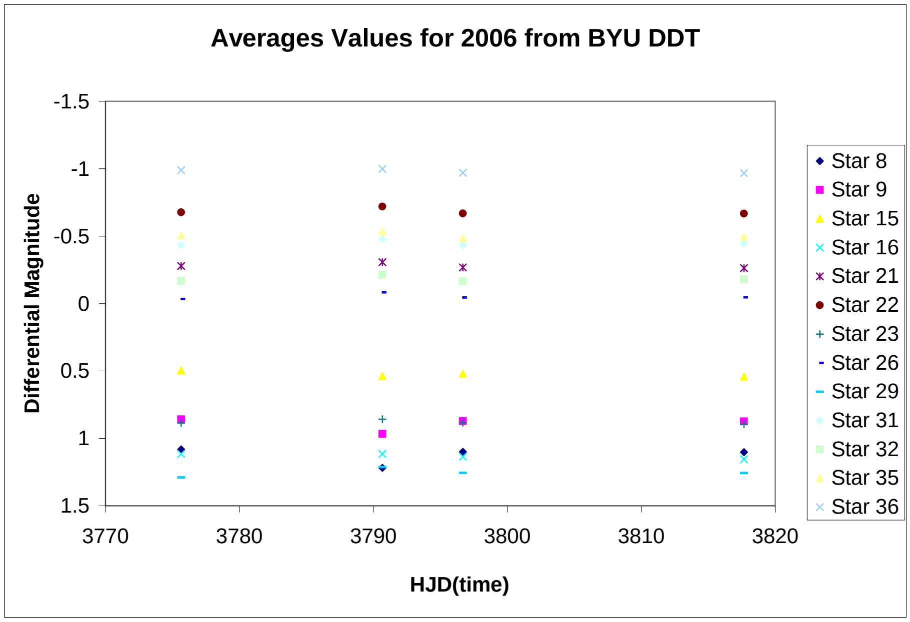

Figure 3.4: Graphs of Average Values for 13 Stars in 2006 from the BYU DDT

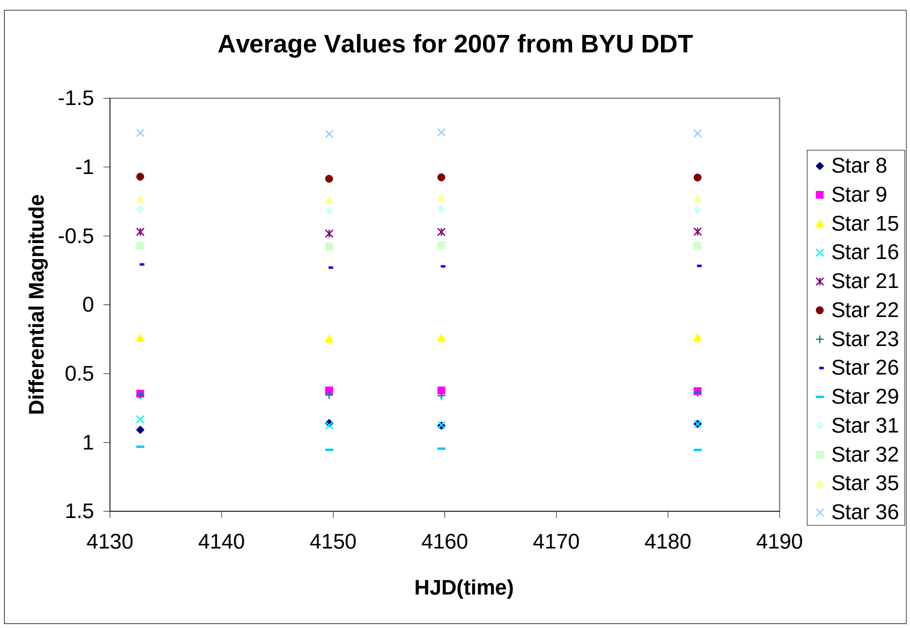

Figure 3.5: Graphs of Average Values for 13 Stars in 2007 from the BYU DDT

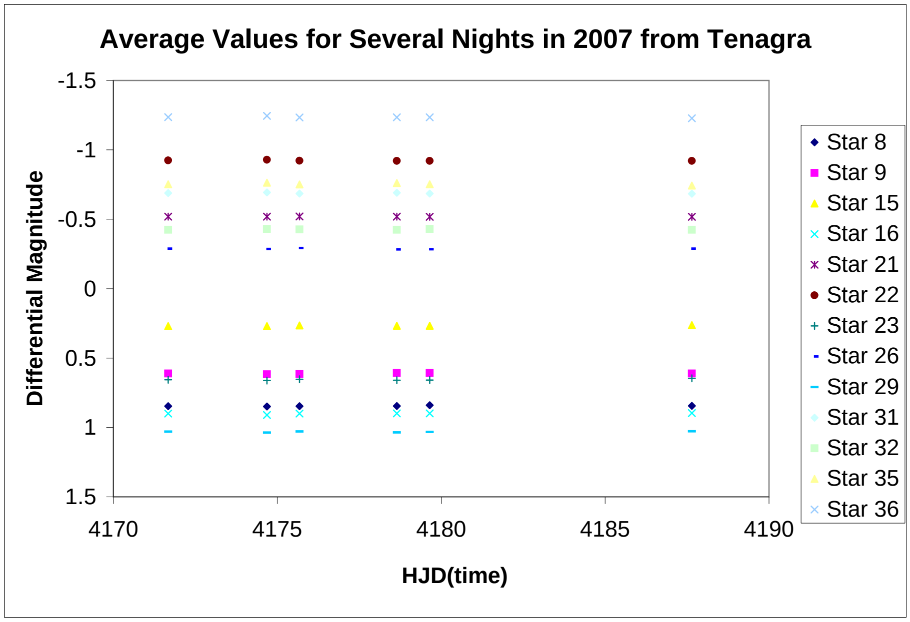

Figure 3.6: Graphs of Average Values for 13 Stars in 2007 from Tenagra

3.7, 3.8, and 3.9 respectively. I also included a graph of a stable star for 2007 from Tenagra to compare Star 21 to as seen in Figure 3.10.

We also compared Star 21 to Star 36 on several nights. We chose Star 36 because it was the brightest and seemingly most stable of the 12 stars that we compared Star 21 with. The following graphs show separate plots for each star plotted on the same y-axis scale. Some nights showed that Star 21 had much greater scatter than Star 36 but no significant trend lines. Other nights showed that Star 21 had no more significant amount of scatter than Star 36. Graphs of these light curves can be found in Figures 3.11, 3.12, 3.13, 3.14, 3.15, 3.16, 3.17, 3.18, 3.19, and 3.20. Some of the nights show some upwards or downwards trends. This could be because the star itself is changing or it could just be an artifact of the data. In the end, we could not find any conclusive variation for Star 21.

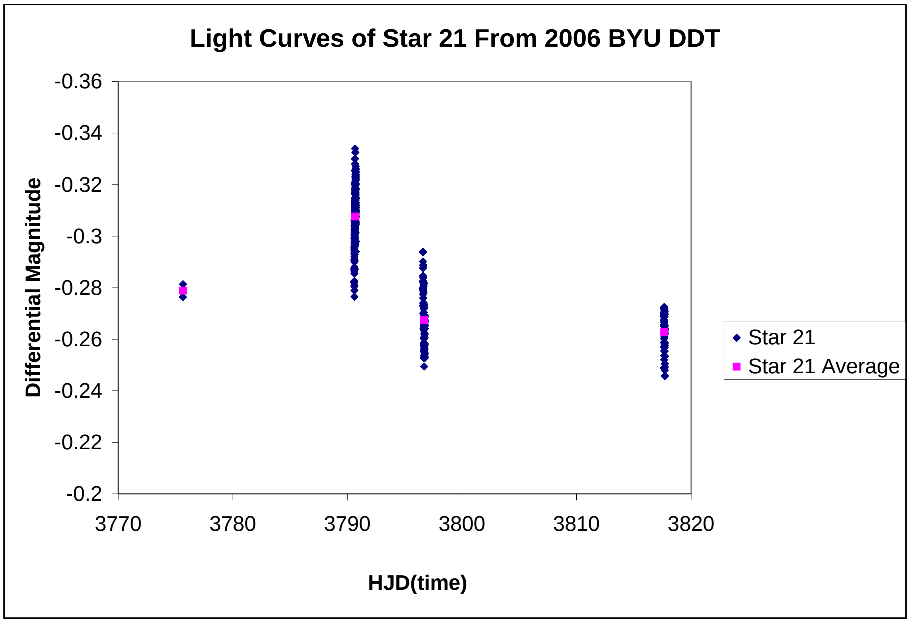

Figure 3.7: Graph of Star 21 and Average Values during 2006 from BYU DDT

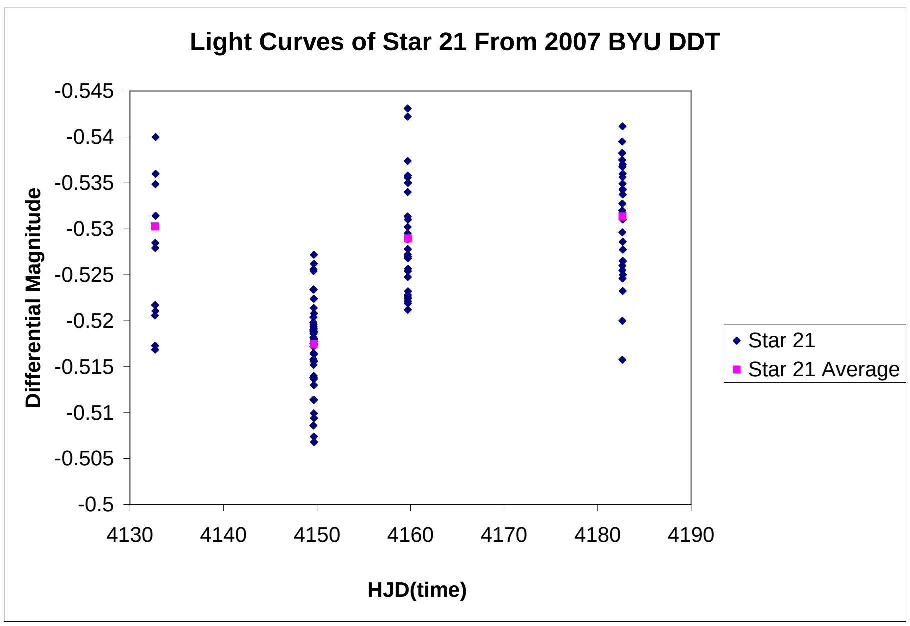

Figure 3.8: Graph of Star 21 and Average Values during 2007 from BYU DDT

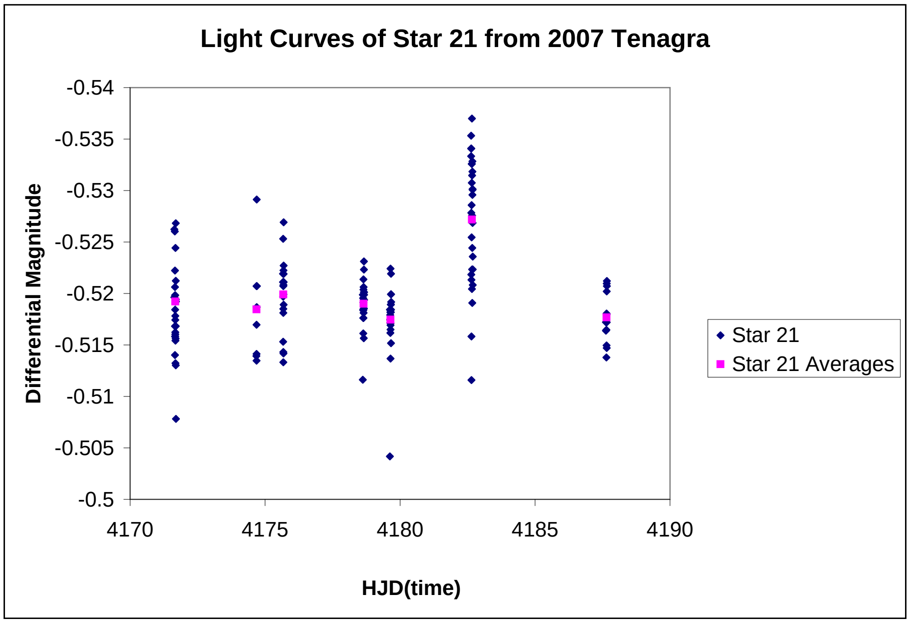

Figure 3.9: Graph of Star 21 and Average Values during 2007 from Tenagra

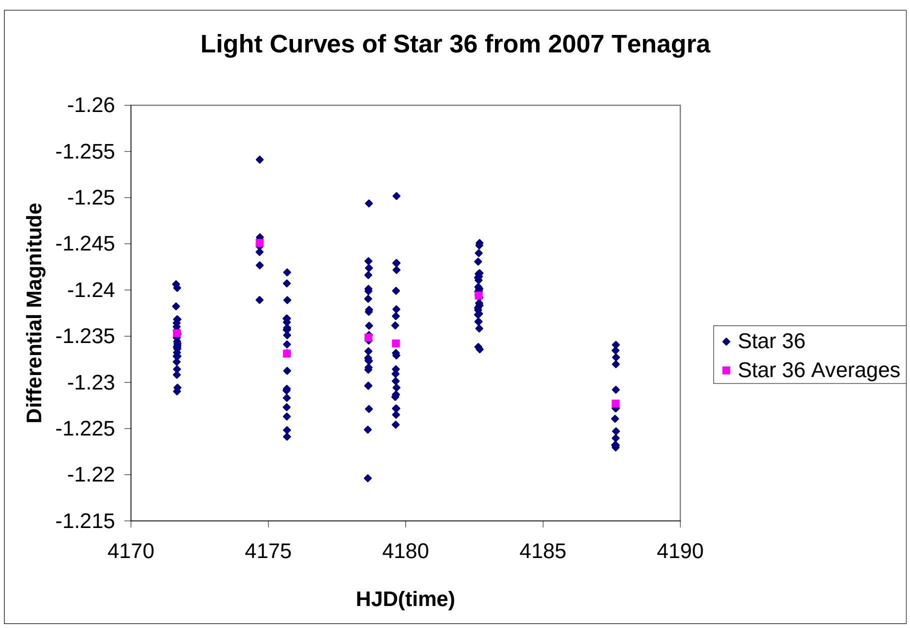

Figure 3.10: Graph of Star 36 and Average Values during 2007 from Tenagra

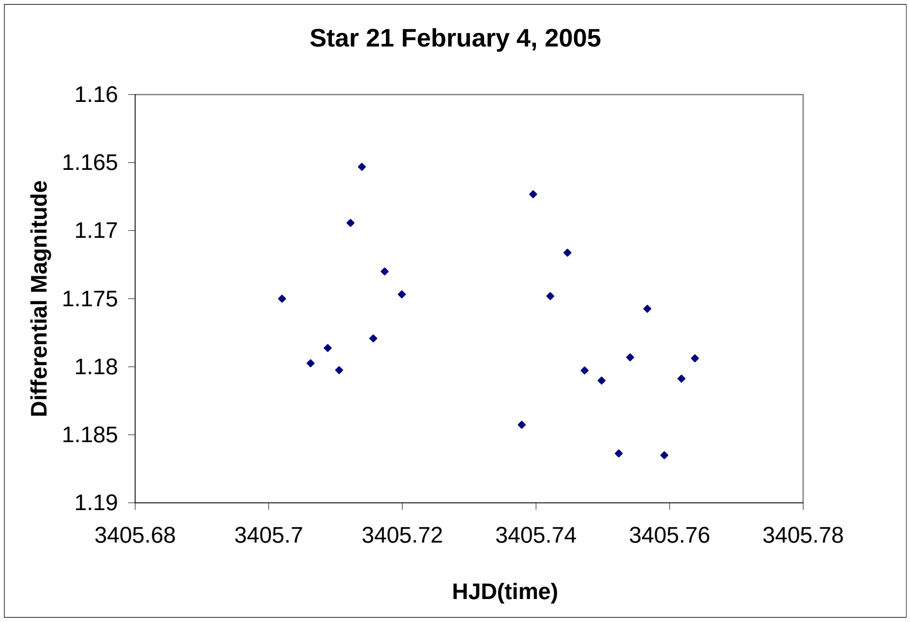

Figure 3.11: Light Curve for Star 21 on February 4, 2005

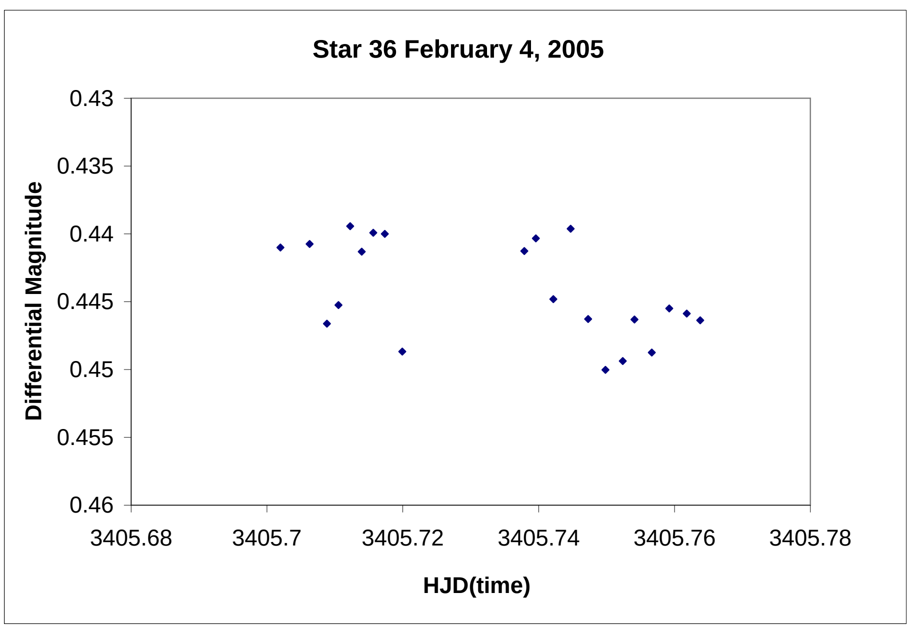

Figure 3.12: Light Curve for Star 36 on February 4, 2005

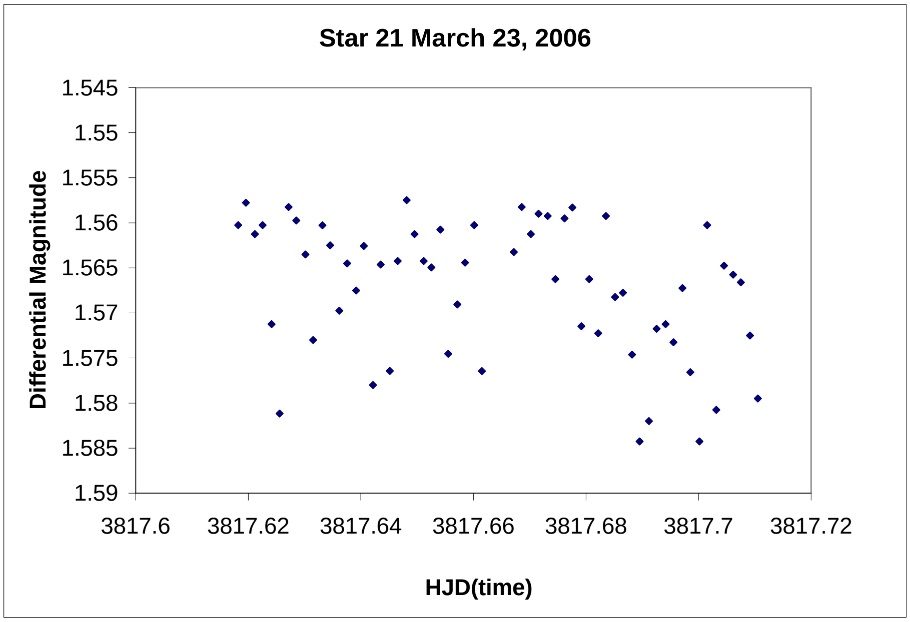

Figure 3.13: Light Curve for Star 21 on March 23, 2006

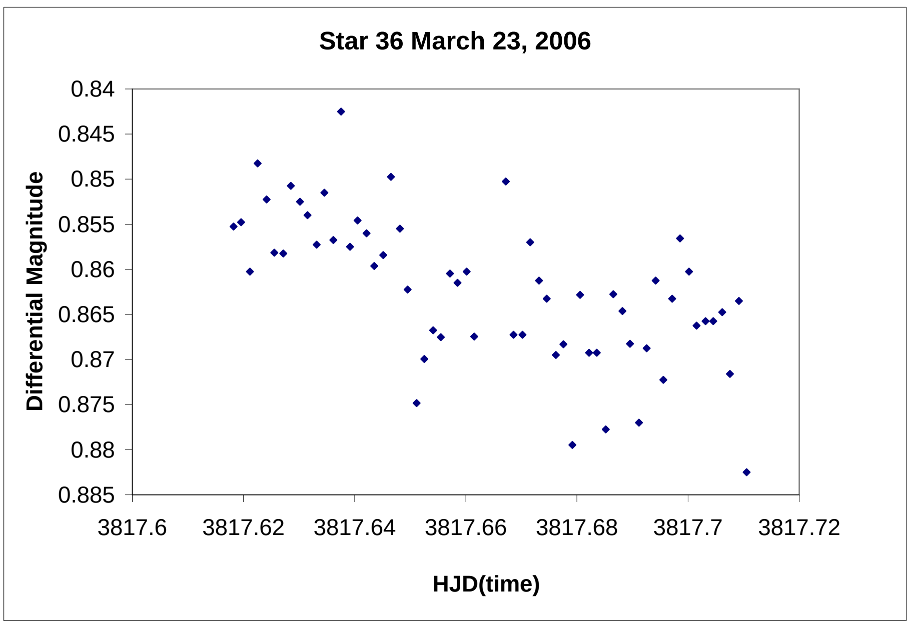

Figure 3.14: Light Curve for Star 36 on March 23, 2006

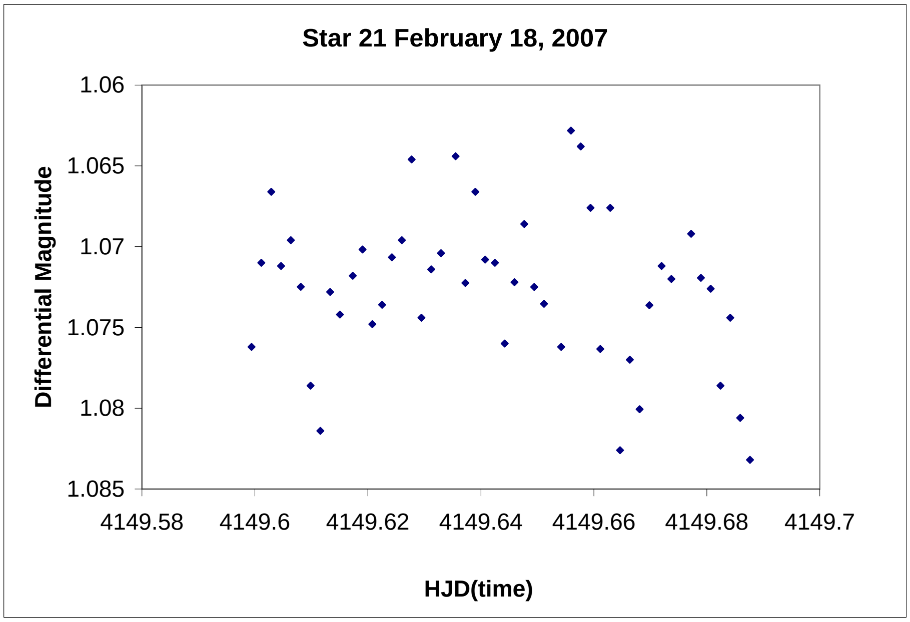

Figure 3.15: Light Curve for Star 21 on February 18, 2007

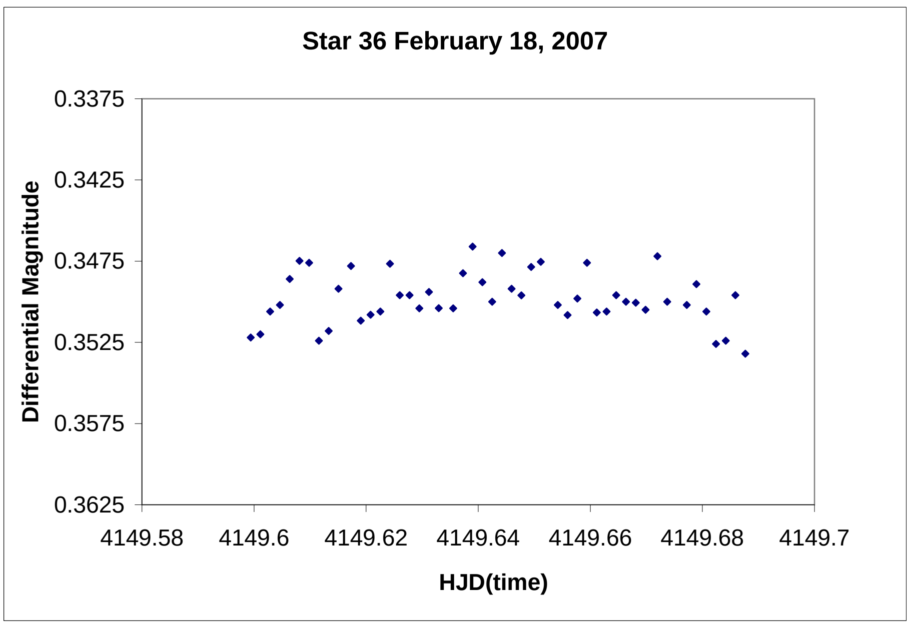

Figure 3.16: Light Curve for Star 36 on February 18, 2007

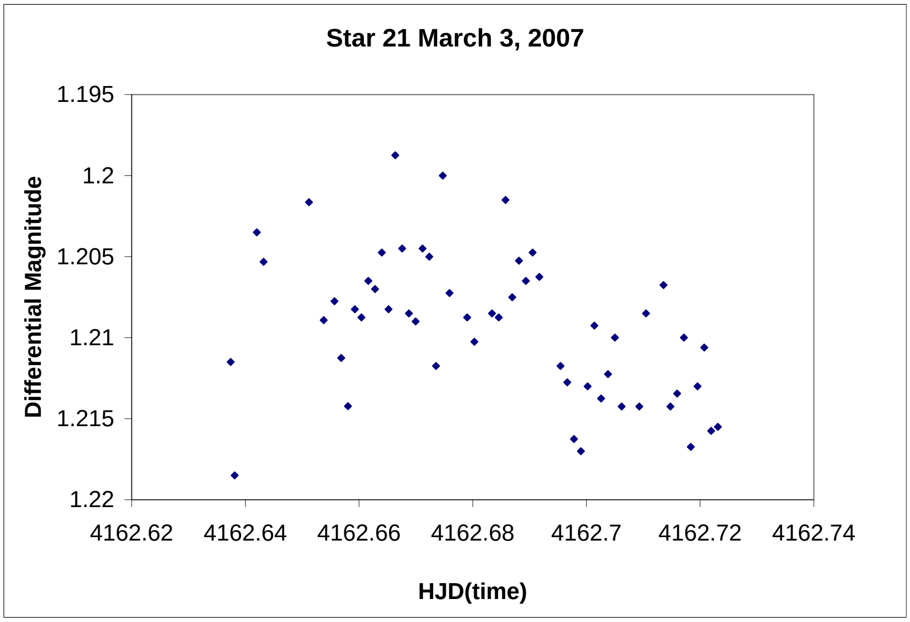

Figure 3.17: Light Curve for Star 21 on March 3, 2007

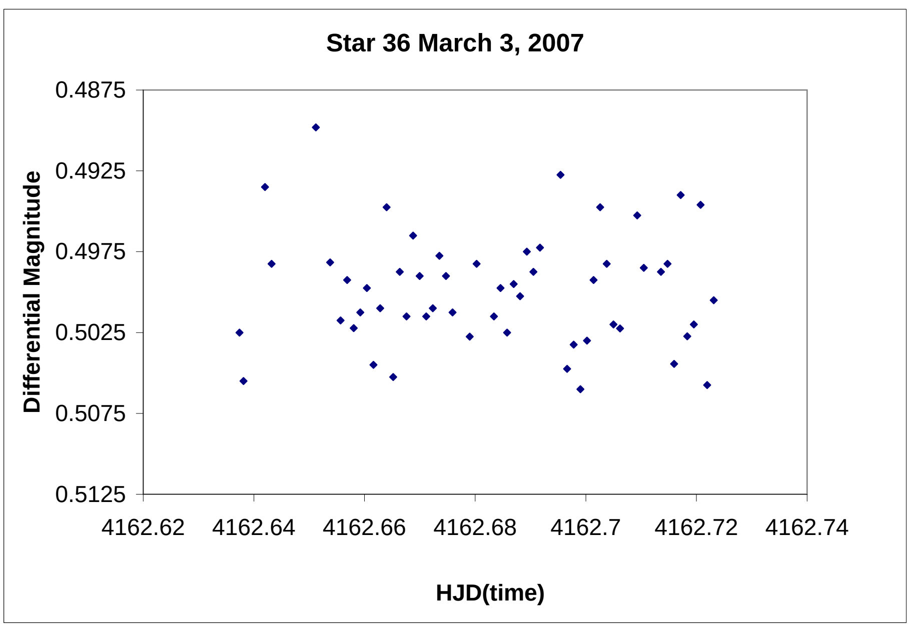

Figure 3.18: Light Curve for Star 36 on March 3, 2007

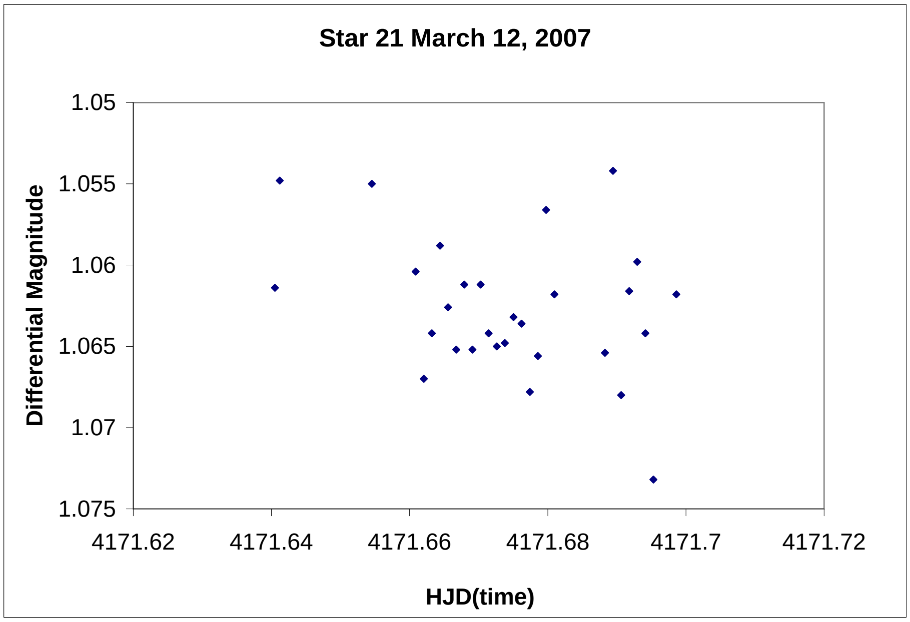

Figure 3.19: Light Curve for Star 21 on March 12, 2007

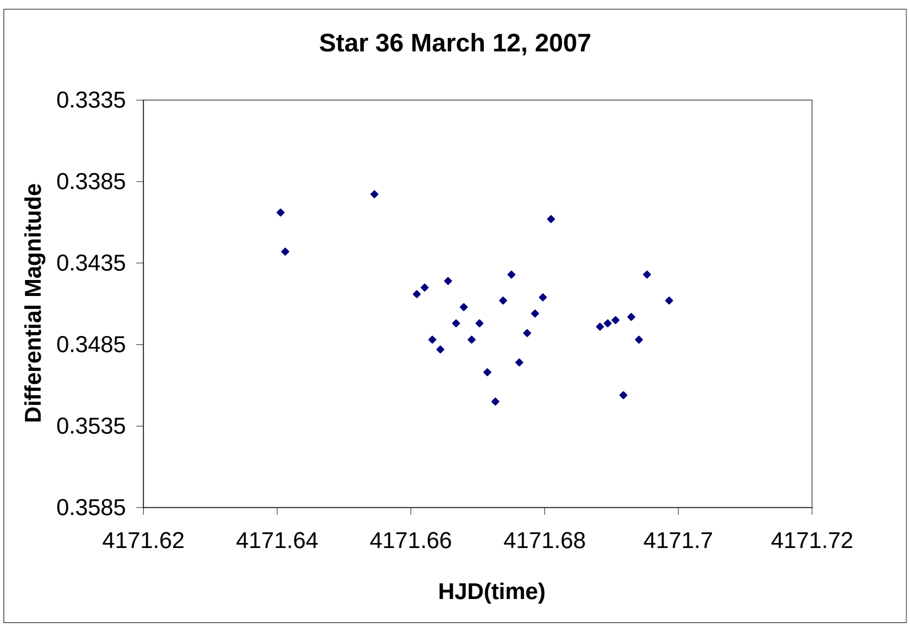

Figure 3.20: Light Curve for Star 36 on March 12, 2007

3.2.2 Period Analysis

Period04 is a program that uses Fourier analysis to calculate the frequencies of a star which you can use to find its period. I used data from seven days in March 2007. After experimenting with different combinations of days, it seemed that there were no significant periods from the data. The highest amplitude variation that Period04 was able to find was 0.005 which is not significant because it is smaller than the error.

Chapter 4

Conclusions

We were unable to identify any new variable stars in NGC 1528 out of the 40 stars that were studied. This result was unexpected because it is very rare to have such a large ensemble of stars that all have flat light curves.

After realizing this, we then concentrated on examining the suspected variable Star 21. The light curves did not show variability on any of the time scales that we plotted it on. One reason could be that the zero-points may not have been exactly correct so it would have been harder to pick out any long term variability.

When we looked at individual light curves for Star 21 and compared them to the stable Star 31, some nights showed a significant amount of error but some did not. It may be possible that Star 21 is a variable but these data sets could not confirm it. When we tried to use Period04 as a statistical method of searching for variability, we also got no result seeing as how the amplitudes were very much smaller than the errors. This could just be because of a zero point problem or it could be that this data did not show a significant enough change in amplitude.

References

Bruegman, O., The Observatory, 2003, 109, 95

General Catalogue of Variable Stars 2004,
(ftp://cdsarc.u-strasbg.fr/pub/cats/II/250/vartype.txt)