UNIVERSITY OF SOUTHERN QUEENSLAND

Finding Exoplanets Around Eclipsing Binaries: A Feasibility Study Using Mt Kent & Moore Observatories

Submitted by:
Jack Lang Soutter

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Abstract:

The project aims to test the feasibility of using Mt Kent and Moore Observatories to find exoplanets in orbit around eclipsing binary stars. For these stars the timing of eclipse variations caused by an orbiting planet is something suited to small telescopes as it relies on timing precision that can be readily obtained. In this project some test data for the eclipsing binaries V775 Centaurus and LT Herculis have been obtained using 0.5m aperture telescopes at Mt Kent (Queensland) and Moore (Kentucky), and the data reduced and analysed to produce light curves and times of eclipse minima, in a very limited search for new planets. Although no evidence for a planet was found from the limited dataset collected, interpretation of the results suggests that Mt Kent and Moore Observatories are capable of finding exoplanets around eclipsing binary stars, if these facilities are employed for a more extensive search of the many targets available using robotic observations to record eclipses at multiple epochs.

1. Introduction:

The search for exoplanets in orbit around distant stars has been a major focus of astronomy for many years, with more planets being discovered every month (websites like exoplanets.org and planetquest.jpl.nasa.gov provide great examples). But these searches have previously focused on single star systems or those in widely separated binary systems. In order to provide a more complete census of the planets in our Galaxy it is necessary to search for planets in orbit around close binary star systems. This paper will focus on eclipsing binaries, binaries whose orbital inclination to us make each star periodically eclipse each other. The reasoning for this is that the significant decrease in luminosity during the eclipses can provides us with a great deal of information that can be readily modelled, of particular interest is variations in eclipse periods which can indicate the existence of additional orbital bodies in the system – notably planets.

This paper will explore a methodology that complements more traditional planet search techniques, and allows for the discovery of even low-mass exoplanets around binary stars. The method investigated here is a variant of the Transit Timing Variation (TTV) technique that is specially designed for eclipsing binaries, which allows for small aperture telescopes to be used. This project will test the viability of using the Mt Kent Observatory in Queensland and Moore Observatory in Kentucky to find exoplanets in orbit around eclipsing binary stars.

1.1. Exoplanets and Planetary Categories:

The discovery of exoplanets has given astronomers a great insight into planetary formation and the evolution of planetary systems over time. One of the reason that exoplanets are of such interest to astronomers is that in observing them we are able to expand our knowledge about how planets are formed, evolve and even migrate after formation. We can also learn a great deal about the effects stars have on their orbiting planets and how planets may influence their host stars .

To date there are four categories of planets that have been observed, both in our Solar System and in other planetary systems. Below is a very brief outline of each type and how they are theorised to be formed:

1.1.1. Terrestrial Planets:

Terrestrial planets are simply defined as Earth-like, rocky planets and are usually of a smaller mass and radius then their gaseous cousins, but a higher density. These planets are formed closer to their host stars from the collision planetesimals and other bodies cotaining heavy elements. With our current models of planetary and stellar formation terrestrial planets can only form in the inner zones of the stellar planetary system (Bennett et al 2007).

1.1.2. Jovian Planets:

Jovian planets are the opposite to terrestrial planets, they are defined as large gaseous planets (similar in nature Jupiter, hence the name) with low densities but high masses. Much like terrestrial planets, Jovian planets are formed in their own distinct area of a planetary system. They are formed through the accumulation of gas, dust and icy particles/planetesimals, which can only occur at a significant distance from the host star (Bennett et al 2007). This is one of the reasons why we see a clear division and segregation between terrestrial and Jovian planets in our solar system.

1.1.3. Hot Jupiters and Super Earths:

Hot Jupiters and Super Earths are considered to be abnormalities in planetary systems but an abnormality that seems occurs frequently. Hot Jupiters are Jovian exoplanets that are found in close proximity to their host star, as close as 0.1 AU. As previously discussed Jovian planets should be able to form in such close orbits; this infers that either there is an error in our current model of planetary and stellar formation or some commonly occurring event has caused these outlying exoplanets to migrate into extremely close orbits.

Super Earths on the other hand are simply terrestrial planets that are significantly larger then was previously thought possible. These planets have all been found in close orbits to their host stars, but whether this is a characteristic of Super Earths, a feature caused by our limited search methods or simply a development that has not occurred locally is currently unknown.

1.2. Exoplanet Search Techniques:

At the writing of this paper there are 729 confirmed exoplanets around some 474 stellar systems (Planet Quest 2011). There are a large number of ways to detect exoplanets, these methods break down into indirect and direct techniques; the most popular indirect detection method is radial velocity with less common methods being astrometry, pulsar timing and gravitational microlensing. Of the direct detection methods currently used the most popular technique is transit detections with direct imaging and coronagraphy being significantly less popular due to large limitations they incur but they are still important tool in exoplanet searches.

1.2.1. Astrometry:

Finding exoplanets via astrometry requires taking very precise measurements of a star's position over long periods of time and analysing any change in its position in the sky (Carroll & Ostlie 2007). The reasoning behind this technique is that a stellar system does not orbit around the host star but around the centre of mass of the system, due to the massive nature of stars the centre of gravity is usually close to the centre of host star. This results in the star orbiting around a point close to itself (or frequently, inside itself) causing a 'wobbling' effect. By calculating the mass and spectral type of the star it is possible to ascertain the required mass and orbital radius a second celestial body that would be required to produce the variations in the host star's position. This particular technique is one of the oldest used in the field of exoplanet searches but at this time there has been no confirmed exoplanet discoveries using this method.

1.2.2. Radial Velocity:

This method uses the basic Doppler shift effect which states that waves appear to compress as the source of the waves approach the receiver while the waves appear to expand if the source is moving away from the receiver (Bennett et al 2007). The Doppler shift is usually used to describe the change in pitch of sound waves but same theory applies to electromagnetic waves. This results in the compressed waves from an approaching star having a smaller wavelengths therefore reaching the receiver as slightly shifted into the blue end of the spectrum (blueshifted) while the expanded waves from a receding source have larger wavelengths resulting in the light reaching the receiver as shifted further into the red end spectrum (redshifted).

If the target star has another celestial body(s) orbiting itself and the planetary disc is approximately parallel to our line of sight, the star will go through regular shifts in spectrum colour as its light changes from being blueshifted to redshifted (Cummings 2004). This is caused by the star orbiting the centre of mass of the system resulting in the previously mentioned 'wobbling' effect. This data can be used to calculate the orbital period of the star which is further used to calculate the minimum mass and nature of the planets in orbit around it. Unfortunately this method is only practical for finding massive exoplanets in close orbits to their host star.

1.2.3. Pulsar Timing:

Pulsars are the remnants of massive stars that have undergone supernovae and have become dense neutron stars. These stars release consistent, periodic bursts of electromagnetic radiation into space with periods accurate to fractions of nanoseconds. Because of this high level of precision it is easy to detect even the slightest change in the regularity of the pulses (Carroll & Ostlie 2007). The cause of any change in regularity between pulses is most likely caused (much like the radial velocity method) by the pulsar wobbling as a result of a

planetary system in orbit around it. This deviation in pulses allows for the calculation of the period and mass of the stellar and planetary bodies involved in the system. While this method is similar to the radial velocity technique it is far more accurate.
The major downside to this technique is that any planetary body in orbit around a pulsar will have suffered the effects of the preceding supernova. This means that the exoplanets in question will be vastly difference to any planetary body that we are familiar with. Unfortunately this renders these planets less useful in furthering our understanding of the birth and mechanics of planetary systems but none the less makes they are an interesting celestial body to study (The Planetary Society 2005).

1.2.4. Gravitational Microlensing:

It was long theorised by Einstein that gravity warps the fabric of space-time, this can result in light being affected by large masses as the photons are refracted by the curvature of space-time. The gravitational microlensing method of detecting exoplanets uses this basic theory by using unknown exoplanets as gravitational lenses which will refract the light around them in much the same way as a convex lens (The Planetary Society 2005). The microlensing technique requires searching for stars or other luminous celestial bodies that undergone a rapid intensification in brightness, a sudden change in position or experience a twinning effect. These are key signs that there is a dark body (most likely a previously unknown exoplanet) between the receiver and the source.

The reasoning behind these effects is that as the light is curved around the gravitational lens it appears to the receiver that the light source is in a different position to where it was previously located. The common twinning effect is cause by the same bending of light but with the light being refracted around both sides of the body resulting in the optical illusion of the light source appearing as two identical light sources some small distance apart (Bennett et al 2007).

This main advantage to this technique is that it can easily detect planets that are a great distance away from their host star but at the same time this method is difficult to use as the alignments are rare events and will only last for a few days or weeks and due to the distances between the host star and the exoplanets it is problematic to try and preform follow-up observations.

1.2.5. Direct Imaging:

Direct imaging is the simplest method of exoplanet detection in theory but one of the most difficult in practice. The basic theory is to simply to take an image of a planet in orbit around a star but in practice this proves to be near impossible due to the host star(s) being vastly brighter than any planet in orbit around it and the small angular distance between the exoplanet and its host star (Oppenheimer 2003). This conditions result in any possible planet in orbit around the target star being lost in the host stars glare. Because of this, direct imaging is mostly used to visually confirm the existence of already recorded exoplanets, even then there is only been a few circumstances where direct imaging has been used; these are usually only if the exoplanet in question is of a significant size in relation to the host star and if the exoplanet is far enough away from the star so that the glare does not block the light from the planet. Finally direct imaging can be used if the exoplanet in question has a high surface temperature so that the it strongly emits in the infrared section of the spectrum.

1.2.6. Coronagraphy:

This method of detection is very similar to direct imaging but includes the use of a coronagraph. A coronagraph is type of telescope that uses a disc to block out all but the coronasphere of the target star so that the majority of the star light is blocked allowing the viewing of orbiting exoplanets. Unfortunately this proves to be more difficult in practice as the star light will diffract around the blocking disc and causing diffraction patterns making it difficult to gain useful data without either correcting for the diffraction or controlling the diffraction so that the patterns do not directly interfere with position of the exoplanet is (Sivaramakrishnan & Oppenheimer 2006). Thankfully this isn't too hard to do and there has been proposals for different shaped discs so that the diffraction can be easily kept away from key areas of the CCD chips on the coronagraphs. Again this method is mostly used as a technique to visually confirm the existence of previously detected exoplanets.

1.2.7. Transit Detection:

Transit detection is the core of the transit time variation technique, the basic of the methodology that is used in this project. Transit detection is the most popular method for locating exoplanets currently being used today. The theory behind this technique is that as a planet passes in front of its host star there will be a noticeable drop in the stars luminosity, in the order of 1 – 0.01%, as the planet blocks a portion of the of the starlight. This also works as the planet pasts behind a star because the planet will be responsible for a small portion of the photon count recorded by the telescope as the planet's surface will reflect a percentage of the starlight that falls on it. This reflection results in the target star having a fractionally higher photon count then it would on its own so when the exoplanet passes behind the star the total luminosity will decrease (Gillion 2005).

The results from transit detection can give us very important information about the planetary radius, orbital radius and the rotational period of exoplanet. When this data is combined with secondary radial velocity data to confirm the rational period and the mass, the density of the target exoplanet can be ascertained. This allows for the planet to be classified as either a terrestrial or Jovian planet and allows an insight into the possible compositions of the target exoplanet.

One of the interesting abilities of transit detection is the ability to compare the change in absorption lines of the host stars spectrum in relation to the times where a planet is transiting its host star. There should be a constant and periodic change in the absorption lines that coincides with the transiting of the planet as a result of the atmosphere absorbing and re-emitting some of the starlight. This change in spectrum allows us to decipher the chemical composition of the exoplanet's atmosphere (Charbonneau et al 2002).

This technique is one of the simplest and effective methods available to us at this time. There are only two problems with this method: First the planetary disc must be close to parallel to our line of sight in order to detect to the exoplanet transiting the target star. Secondly the technique at this level is really only capable of detecting massive planets that have noticeable effects of the overall luminosity of the star when it transits.

1.3. Transit Timing Variations (TTV):

Transit timing variation is a technique based on studying and analysing the transit periods for any anomalies that occur, usually in the length of time between each individual transit. These delays or advancements are produced by gravitational interactions between the observed transiting planet and an unknown planet(s). With the use of modified Lagrange and gravity equations it is possible to calculate the mass and orbital radius of the secondary planet(s) (Holman J. et al 2005).

The major advantage of transit timing variation technique is that it is able to detect planets up to one-tenth the mass of Earth, something that other technique can not accurately and reliably achieve. The use of transit timing variations also presents itself as a way to circumvent one of that major problems that have existed in all forms of exoplanet hunting, in that the observation time needs to equal a multiple of the orbital period of the exoplanet in order to obtain accurate and useful data, this makes trying to find exoplanets far away from their host star both cost and time intensive. But with the TTV method the periods of planets with large orbital radii can be easily extrapolated from shorter period exoplanets in the same system (Nesvorny & Morbidelli 2008).

This problem of finding less massive exoplanets with large orbital periods has been a particular problem to astronomers as there has been a strong interest in trying to find other Earth like planets, not just in size and mass but also in an area of the stellar system referred to as the habitable zone. The habitable zone is an area in a stellar system where, if there was a terrestrial planet with water on it, it could hold the water in a liquid state without it boiling away or freezing.

1.4. Advantages of Transit Timing Variations:

There are many advantages the Transit Timing Variations (TTV) method has over it's earlier brethren. One of the major restriction of both Radial Velocity methods and Transit methods is that they are observing an event that is based around the orbital period of the exoplanet, this means that in cases of more distance exoplanets the amount of time that a star must be continuously observed rises from hours and days to months and years. Given the that stars are not observable for the entirety of the year, that telescope undergo maintenance and suffer faults as well as general bad weather it quickly becomes impractical for these methods to search for more distant exoplanets. Unlike both radial velocity methods and transit methods TTV is not restricted by close orbiting bodies as the method is searching for the perturbation effects of more distant bodies on that for a closer one rather then the direct pull or transit, this means that rather then having to have a base observation time anywhere between months and hundreds of years we only have base observation time of a few weeks.

1.5. Eclipsing Binaries:

Binaries are defined as stellar systems which contain two stars in close orbit of each other, therefore eclipsing binaries are defined as binary systems where the orbital plane of the two stars is parallel to the observer's line of sight. This means that as the stars orbit each other their combined magnitude will appear to periodically change as the stars move in-front/behind one another. Of all the stars in the night sky binary stars make up approximately half, with binaries whose orbital plane is parallel to us, eclipsing binaries, making up ~2.64% of those (Batalha et al 2011).

By definition all eclipsing binary stars must show variations in there light curves (see figure 1 for an example) but an interesting feature occurred that was previously unexpected; there were variations in the periods of the eclipses, not only that but this variations where occurring with a cyclical nature. For many years it was thought that this phenomenon was cause by one of two things: either magnetic activity occuring between the two stars or the gravitational effects of additional, darker bodies. In 2010 Lian and Qian published a paper on a survey they had preformed showing that these eclipse timing variations where still apparent in late type stars (with demonstrated little magnetic activity), this strengthening the concept that the majority (if not all) of observed eclipse timing variation is caused by additional objects in the system, most likely an exoplanet.

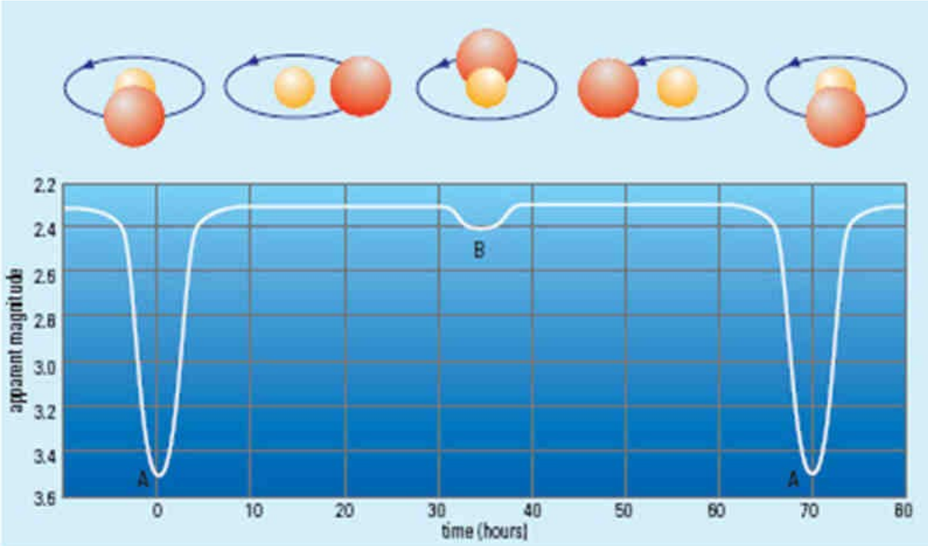

Figure 1: *A demonstration of the basic mechanics of an eclipsing binary and the typical light curve produced by the eclipses. Provided by www.variablestarssouth.org*

Unfortunately detecting dark objects around binary stars has historically proven difficult because methods such as radial velocity and transit detect are ill suited to the task. The main reasons being that the Doppler shift change caused exoplanets is significantly smaller than the Doppler shift changes caused by the binaries orbiting themselves, this results in any possible planetary data being drowned out by the larger shifts in the host stars. A similar problem occurs transit detections: A planet will only obscure up to around 1 percent of a stars' light, while a binary eclipse will block out several times this amount. This results in the much larger light curve dips of the stars' eclipses concealing the much smaller light curve dips of the exoplanet. All of this means that there needs to be another, more accurate way to detect exoplanets around eclipsing binaries, this is where the modified TTV method can be employed.

2. Methodology:

2.1. Finding Exoplanets Around Eclipsing Binaries.

As discussed above the current methods of radial velocity and transit detection are ill-suited for the detection of exoplanets around eclipsing binaries, this is where a variation on the Transit Timing Variation method can be used to great effect.

If you imagine a binary system as consisting of only two stars, the stars will orbit around each other with the barycentre residing somewhere between the two. But if you introduce a third body, such as an exoplanet, the two stars will still orbit around each other but the barycentre will now be moved away from them, resulting in the the two stars orbiting the barycentre as effectively one object. This results in a similar system to the one seen in figure 2. In this type of system the variation in eclipse periods is caused by the change in distance between the binary and the observer as the binary orbits the barycentre. The result is that when the eclipses occur they are closer to, or further away from, the observer than proceeding or subsequent eclipses as there is a longer/shorter distance for the light to traverse, therefore a shorter or longer period between eclipses (Tom Richards 2011). Commonly these variations in timing are plotted as “observed minus calculated” (or O-C) diagrams. O-C diagrams are a tool used to measure the time differences between luminosity variations in variable stars, they are most commonly used in the study of eclipsing binaries, Pulsars and Cepheid stars as a way to predict stars behaviour and monitor any changes, examples of the O-C diagrams can be see in figures 11 and 12.

By analysing this simplified planetary system we can calculate the mass and orbital radius of the exoplanet in question by using the equations in the following section. The only downside to this method is that unlike exoplanets transit TTV methodology, the base time can be much larger depending on the system.

2.2. The Mathematics.

As previously discussed, an eclipsing binary system with one or more orbiting exoplanets will result in all the involved bodies orbiting around the barycentre as the binaries orbit each other, an example of such as system can be seen below in figure 2. If the observer lies parallel to the plane of orbit (as depicted in the figure 2) there will be a significant variation in the distance between the eclipsing binaries and observer which changes over time. This change is distance will be detectable by a periodic variation in the timing of the eclipses. This variance will follow a sinusoidal pattern with the latest delay occurring when the binary is at position B and the earliest eclipses occurring when the binaries are at point D (Tom

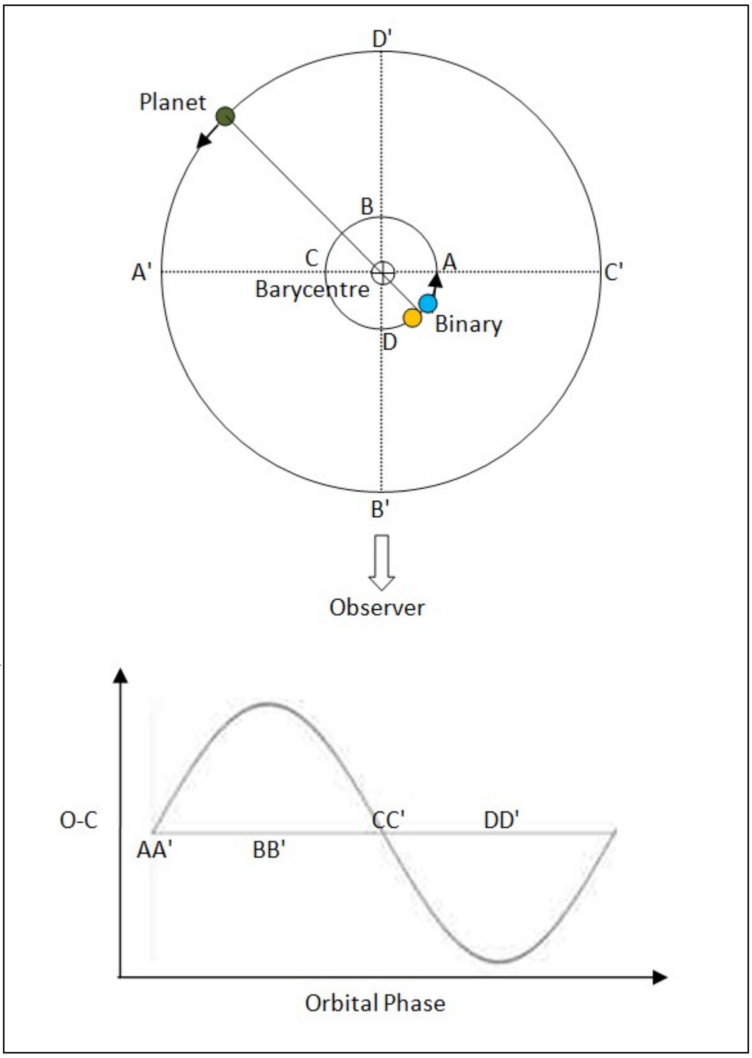

Figure 2: *The top image demonstrates a typical stellar system containing exoplanets in orbit around a binary star. The lower image shows the sinusoidal nature an binary's eclipses as it orbits the local barycentre. Provided by www.variablestarssouth.org .*

Richards 2011).

By plotting out this variation over time as an O-C diagram it possible to begin to learn a lot about the system. The amplitude of the sinusoidal pattern will correspond to the orbital radius of the binary from the barycentre in the direction of the observer (for example $\mathbf{A_b}$= 0 at positions A and C). This amplitude will be equal to $\mathbf{A_b/c}$, where $\mathbf{A_b}$ is the orbital radius of the binary from the barycentre and **c** is the speed of light.

By extension the amount of time delay between eclipses can be calculated as a ratio involved mass, speed and distance from the barycentre. The equation used for this time delay in the eclipses is:

$$t=\frac{A_p M_p}{c M_b}$$

Where $\mathbf{A_p}$ is the distance of the exoplanet from the barycentre in the direction of the observer ($\mathbf{A_p}$= 0 at A' and C'), $\mathbf{M_p}$ is the mass of the planet and $\mathbf{M_b}$ is the mass of the binary.

The next step is to calculate the period of the exoplanet, this is done by using Newton's modification of Kepler's Law. With is the period of exoplanet can be calculated by:

$$P^2=\frac{4\text{p}^2(A_b+A_p)^3}{G(M_b+M_p)}$$

Where **P** is the orbital period of the exoplanet, **G** is the gravitational constant and **p** is the orbital period of the binary. Through use of these simple equations and the data reduction software discussed in the following section it is possible to detect exoplanet in orbit around eclipsing binaries.

2.3. Software and Data Reduction

Most of this projects' data reduction and analysis was preformed by the AstroImageJ 2.0.0 software courtesy of Karen Collins. AstroImageJ is a modification of the ImageJ software released in 1997 by the National Institute of Health, the program was originally use as an open source imaging program to be used primarily for medical imaging but since then it has found popularity in other fields such as biology and astronomy. The AstroImageJ software modifies the original through a series of Java plugins and macros designed to allow for a number of astronomical operations to be preformed.

During the project the AstroImageJ software was used to preform data reduction on the images. This was accomplished by first averaging all of the dark images collected on a given night creating a master dark image, the same process is then completed with all of the bias images collected to create a master bias image. These master dark/bias images are used as way to remove any corruption from the data caused by instrument signature such as variation in pixel sensitivity, background noise and defective pixels or “hot pixels”. The master dark/bias images are then subtracted from all of the images collected on the night of observation. After this a master flat field image was created by once again averaging all of the collected flat fields. The master flat field is then divided from the observed data to remove an gradient error resulting from telescope and CCD impurities (dust particles, etc) as well as any gradient error caused by uneven sky illumination.

With all of the reduction completed all of the observed data was complied into a stack and a multi-aperture function was run over the images, targeting both the star in question and a number (4-5) stable comparison stars. This process analyses the flux of each selected star in the frame and compares it to the others. This is designed to assure the any variations in the flux of the target star are a result of the a stellar effect and not simply a observation error. Once all of the data has been collected, the relative flux of the target star is plotted versus the flux of the comparison stars, this creates the light curve plots seen in figures 4,5 and 7-10.

2.4. Observatories and Instruments

This project took photometric data on two eclipsing binaries; V775 Cen and LT Her. All of the V775 Cen data was taken using the Planewave CDK20 telescope at the MT Kent Observatory in Toowoomba, Australia. The telescope is a 0.508m Corrected Dall-Kirkham with a Apogee U16M CCD camera granting a 36.9'x36.9' field of view. A UBVRI filter wheel was used with all images taken using the V filter with an exposure time of 10 seconds.

Conversely all of the LT Her photometric data was taken using the Planewave CDK20N telescope at the Moore Observatory in Louisville, Kentucky. This telescope is identical to the one used at the Mt Kent observatory and runs on the same mount, camera, field of view and software. The data taken from the Moore Observatory used the R filter with 50 seconds exposure. These observations where made possible through the shared skies project; a endeavour between the University of Southern Queensland and the University of Louisville to develop two robotic observatories that can be used for both research and teaching.

Planewave CDK20 Statistics						
Optics	Aperture (cm)	Focal Length (cm)	Camera	Array	Pixel Size (microns)	Field
Corrected Dall-Kirkham	50	345.4	Apogee U16M	4096x4096	9	36.9' x 36.9'

Table 1: *The specifications of the Planewave CDK20 used by both the Mt Kent Observatory and the Moore Observatory to collect data on V775 Cen and LT Her.*

The data reduction was preformed using a variation of the ImageJ software called AstroImageJ. This software was developed by Karen Collins who assisted in the collection of the LT Her data, the program preforms data reduction parallel to the data input allowing for the creation of real time light curves.

3. Results:

Two eclipses of V775 Cen were observ ed on the 12th of May (secondary minima) and the 13th of May (primary minima) using the Mt Kent Observatory. The images of V775 Cen were taken in using a V filter with 10 second exposures over a period of 2-3 hours. The field of view can be seen in figure 3.

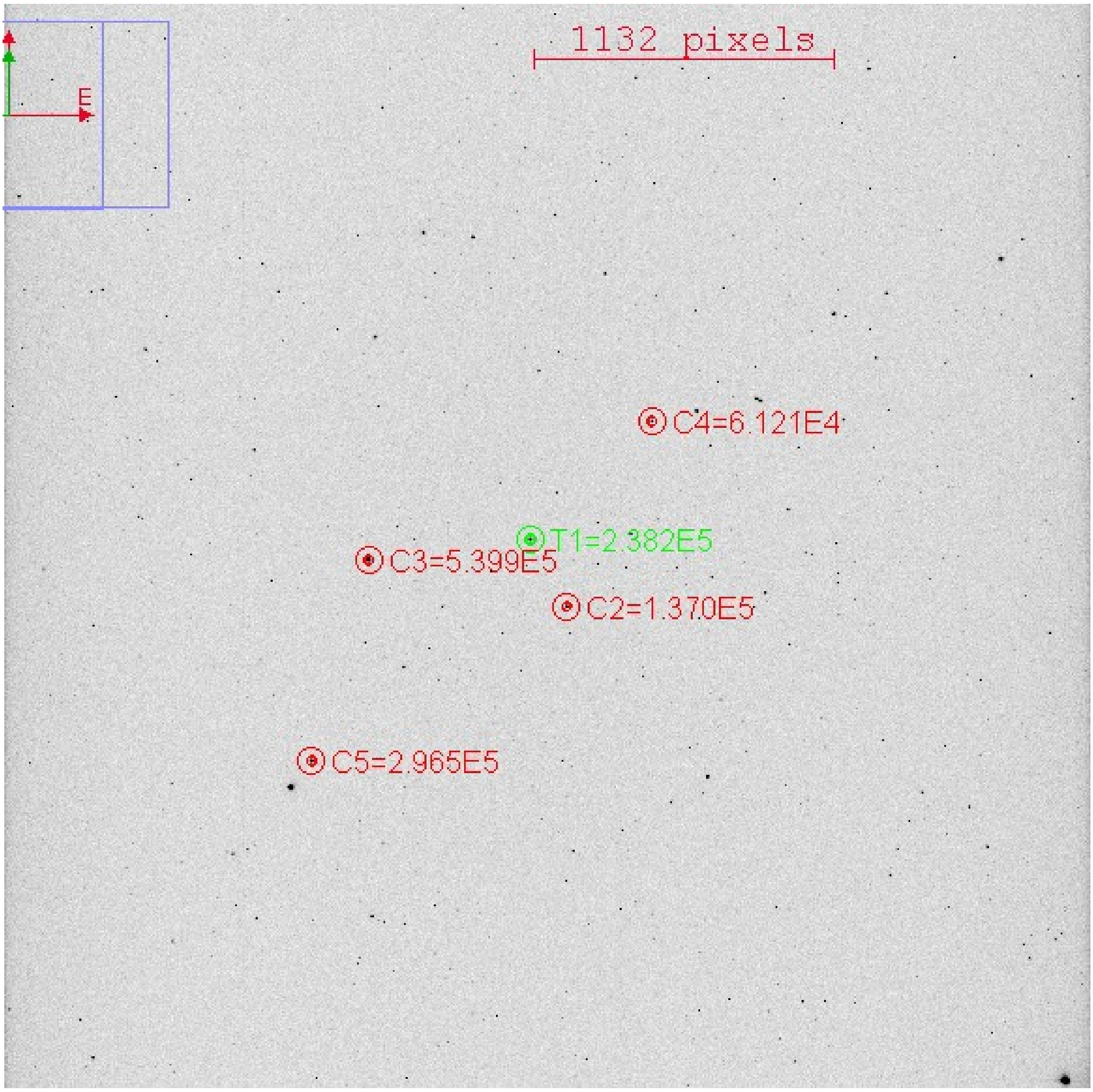

Figure 3: *A photo-negative image of the field of view. V775 Cen is centred in the image and circled in green with the 4 comparisons stars circled in red. All comparison stars were tested to make sure they are not variable stars.*

Four primary eclipses were observed for LT Her by John Kielkopf on the 17th, 18th and 30th of May as well as on the 9th of June. All images were taken using an R filter with 50 sec exposure times. The image field can be seen in figure 6. All target stars are highlighted by the green apertures with the check stars highlighted by the red apertures.

All of the data was processed by first creating master dark and master bias images by taking the average of multiple such images. A master flat field was created by subtracting the master darks and biases from all flat field images and then taking there average. All of the taken images where then processed by subtracting the darks and biases from the raw data and dividing the result by the master flat field. Once the basic image processing was completed, a multi-aperture and alignment function was run over the images to gain a reading and to plot the target star's relative flux over time. All of the data processing, photometry and plotting was preformed by the AstroImageJ 2.0.0. software, which was provided by Karen Collins.

After the light curves where produced, the exact minima were determined by using a software called Minima (version 2.5c) which calculates the minima by an average of 6 extrapolation methods; parabolic fit, curve overlay, bisector of chords, Kwee and van Woerden, Fourier fit and sliding integration. The results of this can be seen in Table 2.

	Observed time of eclipse (HJD)	Calculated time of eclipse (HJD)	O-C (d)	Error (d)
V775 Cen	2456060.07890	2456060.08200	-0.00310	±0.00010
	2456061.07450	2456061.07746	-0.00296	±0.00005
LT Her	-	2456065.60468	-	-
	2456066.68809	2456066.68871	-0.00062	±0.00003
	2456078.54780	2456078.61308	-0.06528	±0.00003
	-	2456088.36937	-	-

Table 2: *A table of all the data taken on each night. There was a timing error on the 17/05/12 and 09/06/12 which resulted in no light curve being recorded.*

All of the minima times have been uploaded in to the MT Suhora Astronomical Observatory data base of eclipsing binaries. The data collected by this project is still awaiting verification by the MT Suhora Astronomical Observatory but the O-C diagrams for the previously collected data can be seen in figures 11 and 12. The data for these diagrams is also displayed in tables 3 and 4 (Kreiner et al 2012).

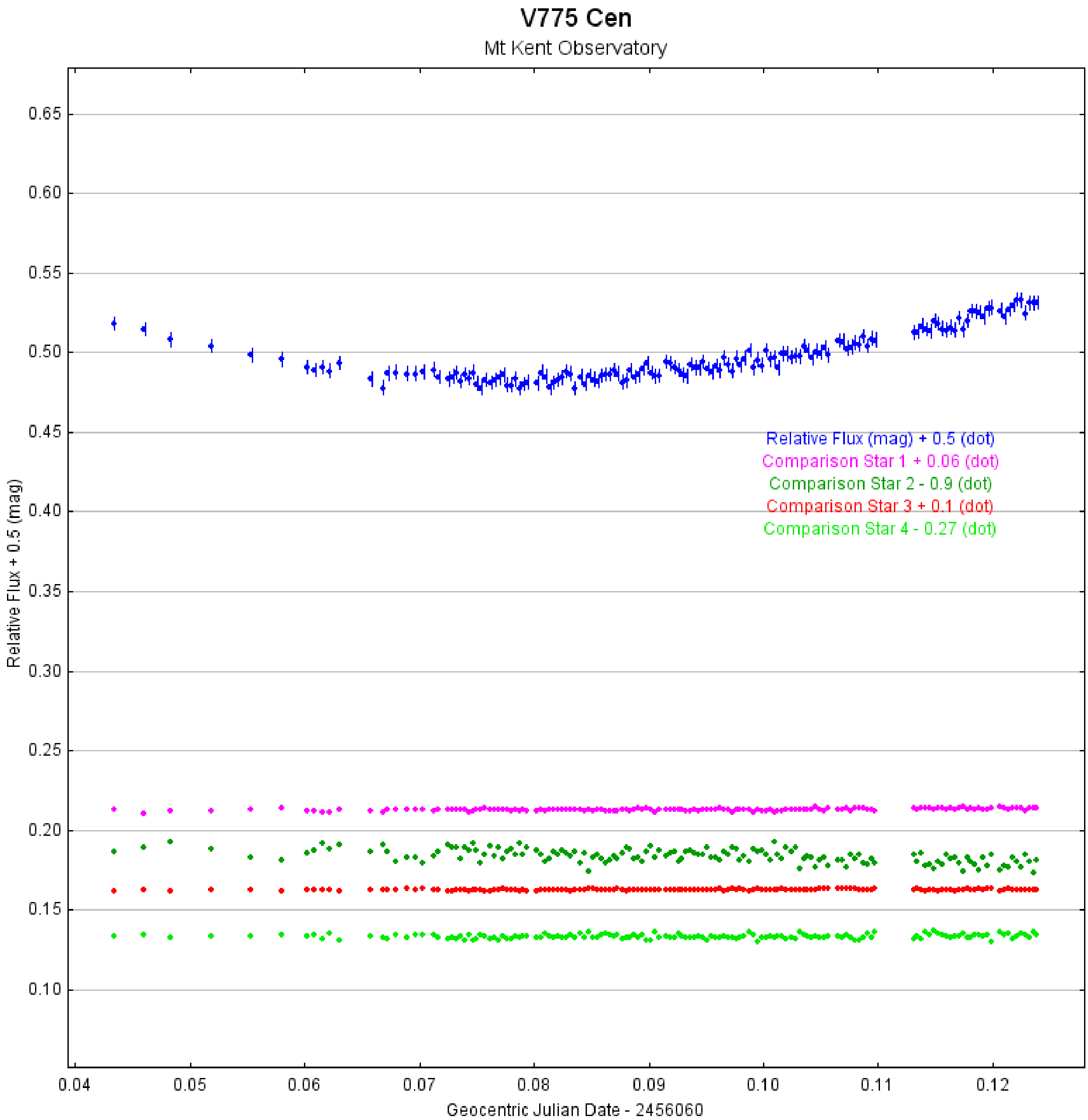

Figure 4: *Light curve of V775 Cen on the night of the 12th of May taken at the Mt Kent Observatory. The comparison stars are shown below for reference.*

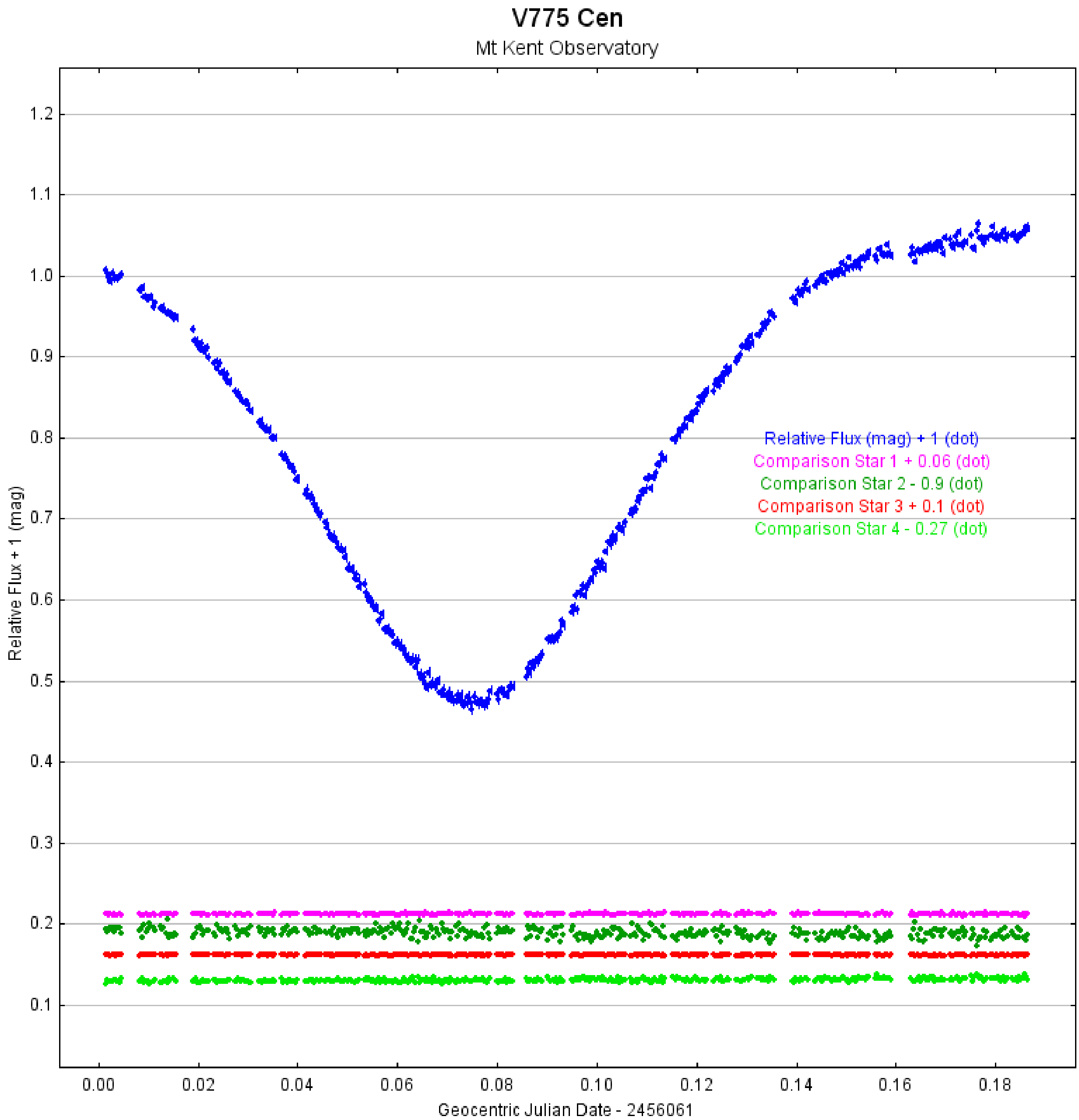

Figure 5: *Light curve of V775 Cen on the night of the 13th of May taken at the Mt Kent Observatory. The comparison stars are shown below for reference and stable luminosity.*

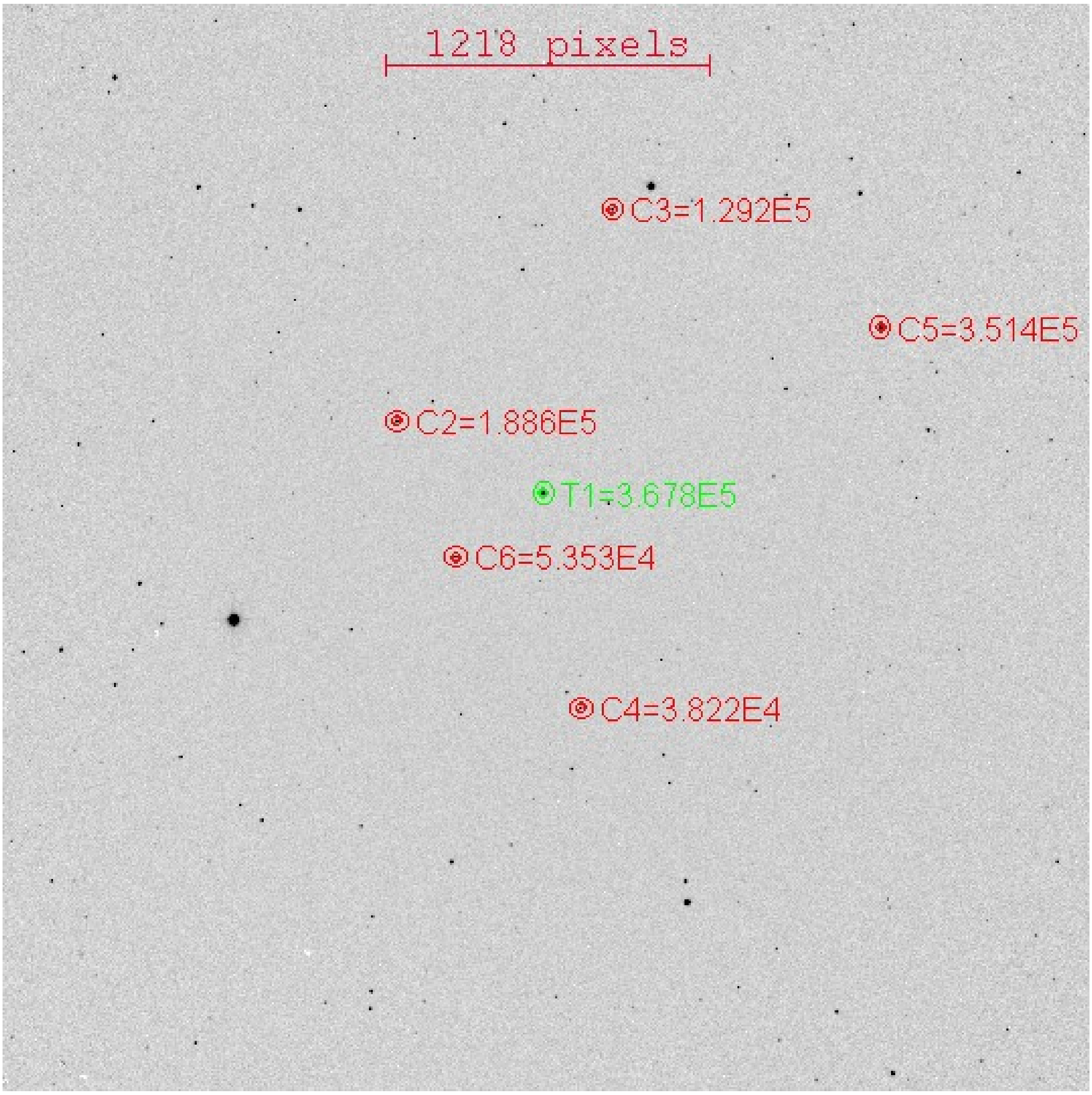

Figure 6: *A photo-negative image of the field of view. LT Her is centred in the image and circled in green with the 4 comparisons stars circled in red. All comparison stars were tested to make sure they are not variable stars.*

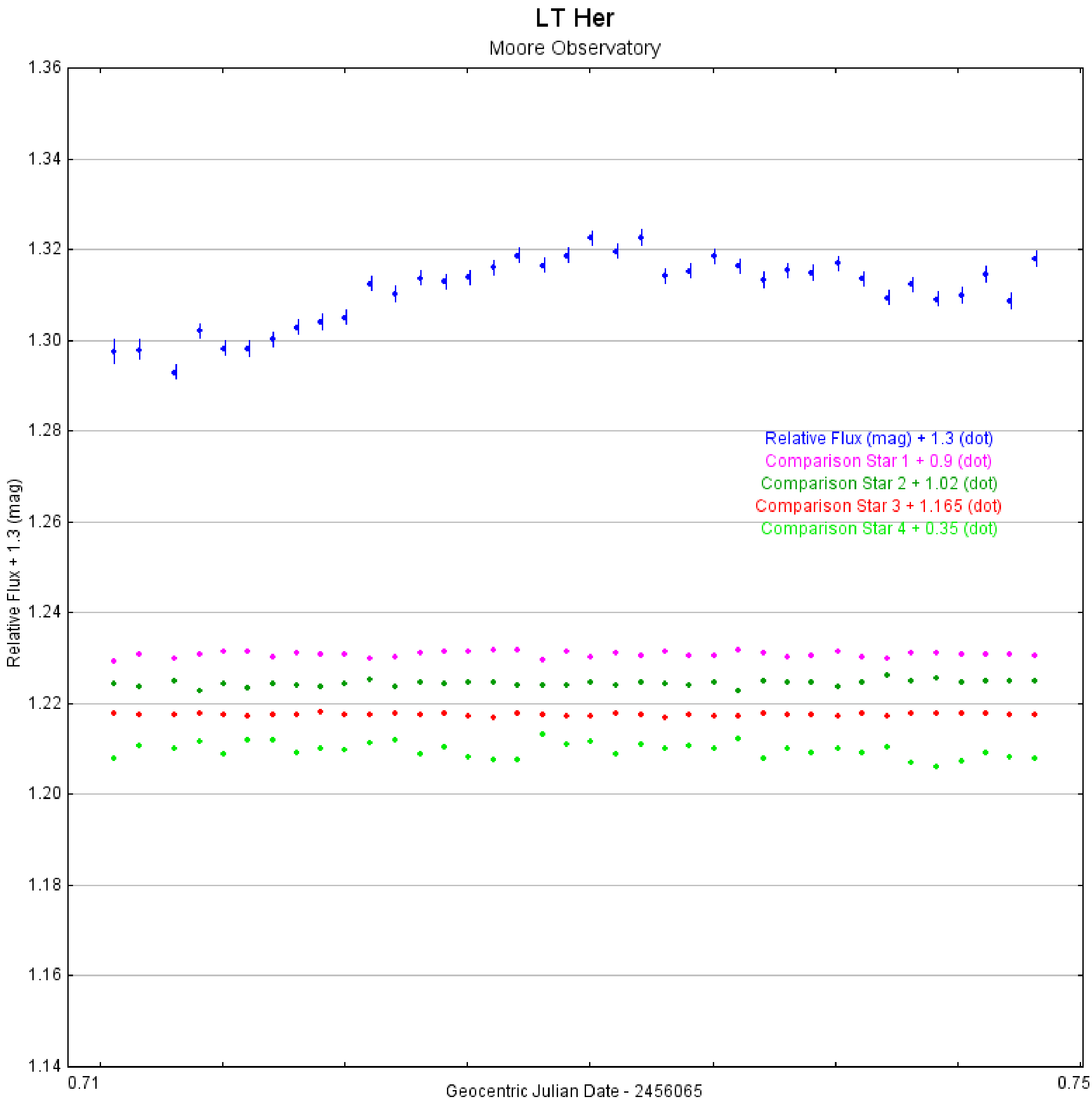

Figure 7: *A light curve for LT Her on the night of the 17th. Unfortunately due to a communication error the light curve only covers the last few minutes of the eclipse, this results relatively smooth light curve with some drop off occurring on left hand side.*

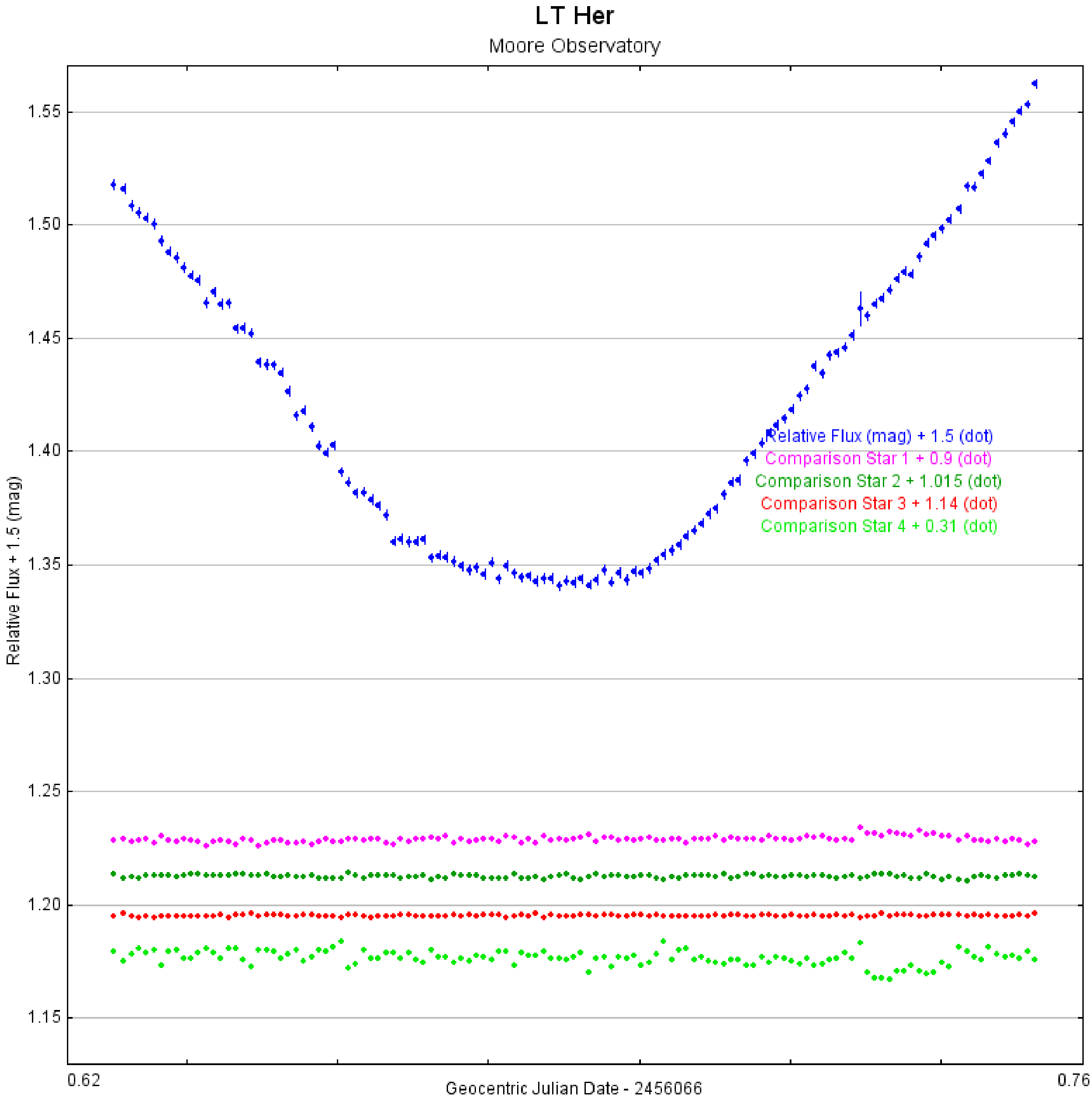

Figure 8: *LT Her on the night of the 18th of May. The figure shows a clear primary light curve with all check stars holding stable luminosity over the period of the eclipse.*

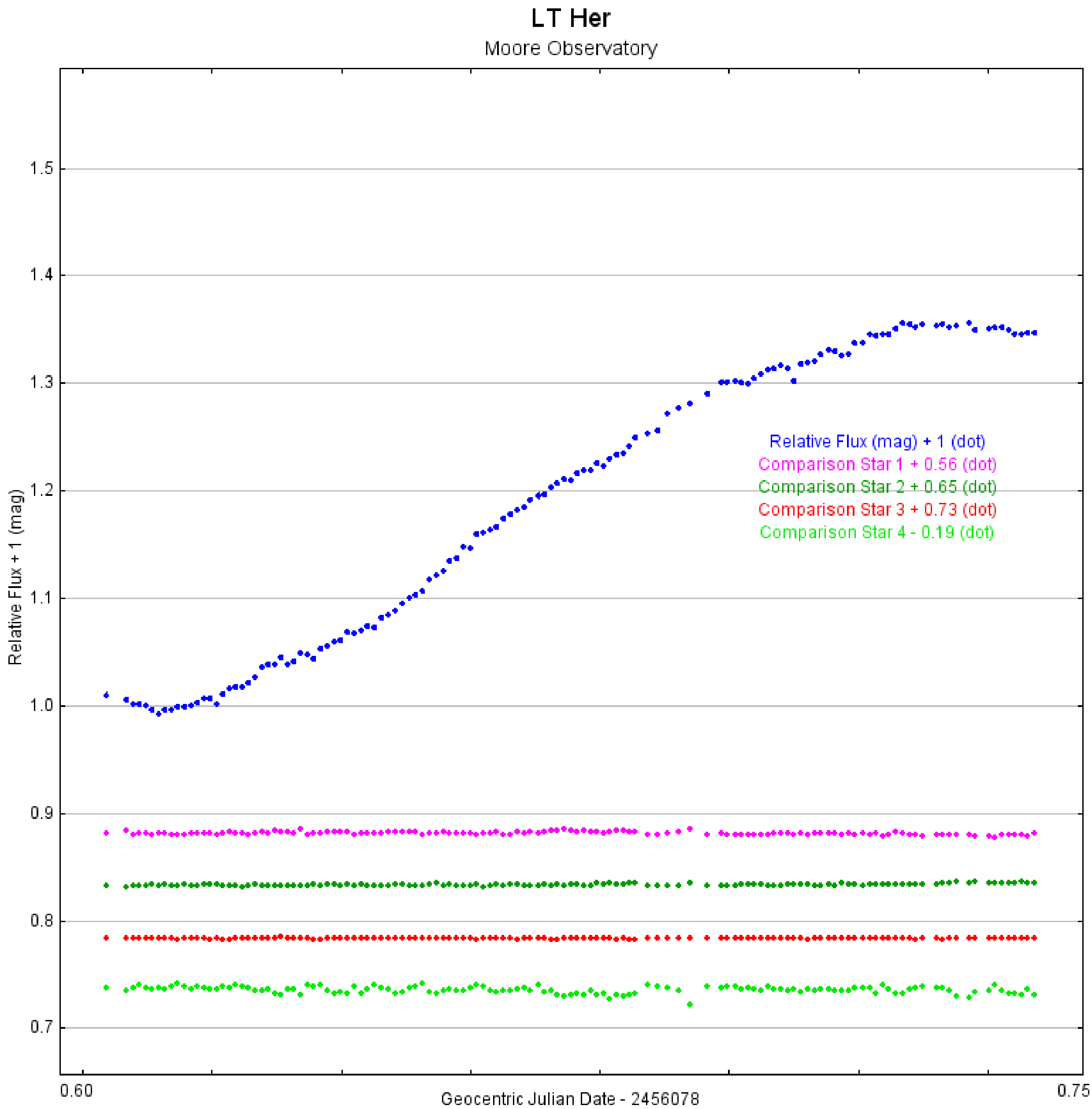

Figure 9: *A light curve taken of LT Her on the night of the 30th of May. The data taken on this night was only a part of the primary eclipse occurring that night, this curve shows that there was a eclipses that night but minima data taken from it is less accurate. All check stars hold a stable luminosity over the time of the eclipse*

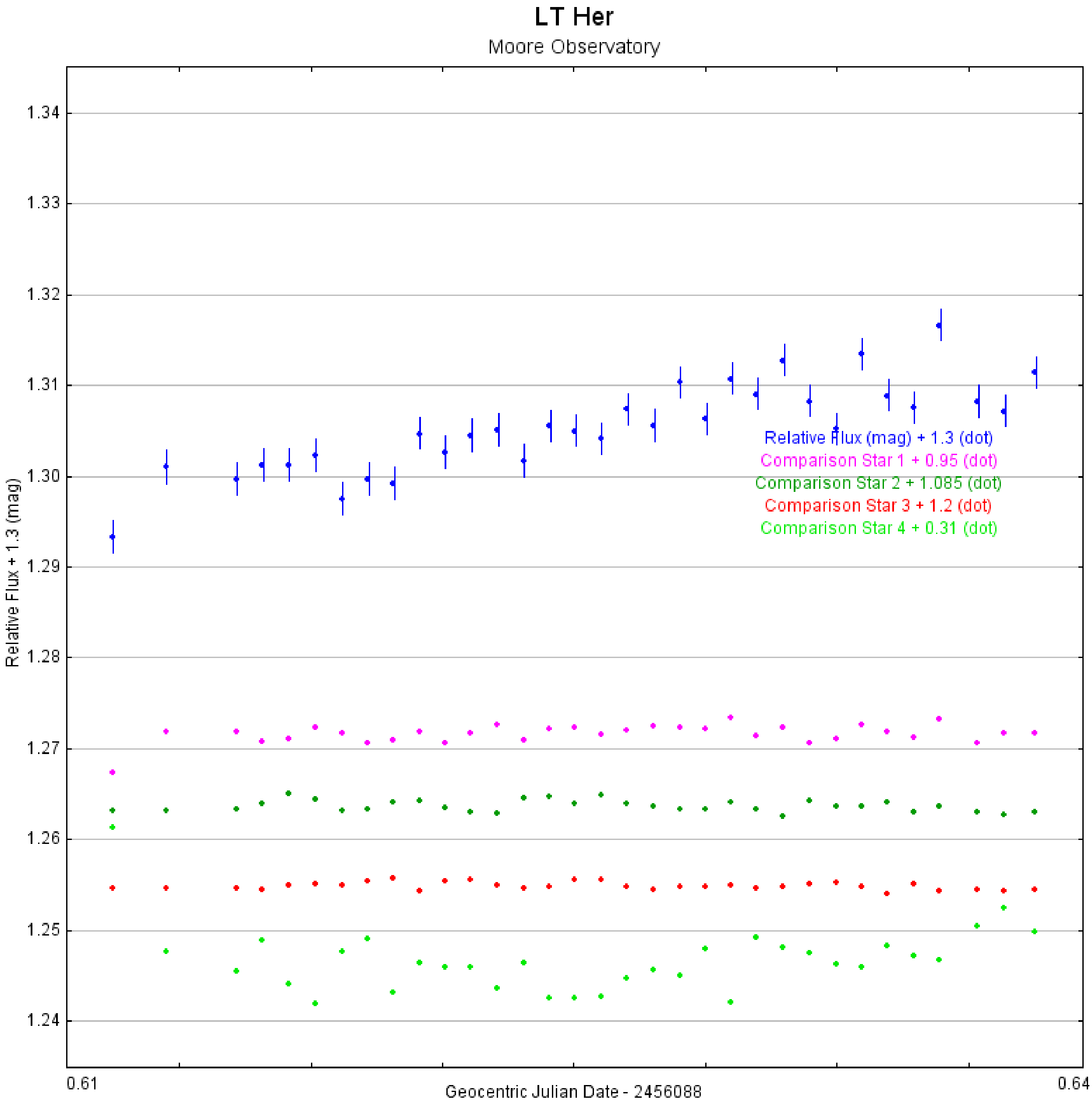

Figure 10: *Data taken for LT Her on the 9th of June. As can be seen in the graph this is no visible eclipse, there was a time zone calculation error which resulted in the data being taken later then planned. It is still possible to seen the tail end of the eclipse as the light curve slowly rises.*

V775 Cen Minima			
Time (HJD)	Error (d)	Eclipse Type	Detection
2416636.6790	-	pri	p
2418126.5670	-	pri	p
2418856.5820	-	pri	p
2419227.5540	-	pri	p
2420326.5480	-	pri	p
2424698.6290	-	pri	p
2425421.3450	-	pri	p
2427980.3450	-	pri	p
2428639.3600	-	pri	p
2428662.5750	-	pri	p
2428698.3970	-	pri	p
2428740.2500	-	pri	p
2429525.3060	-	pri	p
2432291.3610	-	pri	p
2432356.4110	-	pri	p
2432384.2890	-	pri	p
2433001.4830	-	pri	p
2438494.4470	-	pri	p
2438498.4500	-	pri	p
2438500.4400	-	pri	p
2438502.4380	-	pri	p
2438504.4380	-	pri	p
2438528.3350	-	pri	p
2438555.4590	-	pri	p
2438879.4030	-	pri	p
2438881.3760	-	pri	p
2439210.4860	-	pri	p
2439232.4170	-	pri	p
2439236.4580	-	pri	p
2439240.4120	-	pri	p
2440711.0190	-	pri	p
2440744.9000	-	pri	p
2441068.0000	-	pri	p
2441093.9660	-	pri	p
2441099.9410	-	pri	p
2441121.8490	-	pri	p
2441470.8760	-	pri	p
2441472.9020	-	pri	p
2451961.7670	-	pri	cc
2455294.5729	0.0002	pri	cc
2455305.5253	0.0009	sec	cc

Table 3: *Previously collected data on V775 Cen with the a large portion of the O-C data missing due to a clerical error. Provided by www.as.up.krakow.pl.*

LT Her Minima			
Time (HJD)	Error (d)	Eclipse Type	Detection
2430893.2180	-	pri	v
2430919.2280	-	pri	v
2431021.1360	-	pri	v
2431242.2610	-	pri	v
2440755.7594	-	pri	e
2441864.7403	-	pri	e
2445820.4560	-	pri	v
2447266.5049	-	pri	eB
2447266.5091	-	pri	eV
2447653.5136	-	pri	eB
2447653.5150	-	pri	eV
2448014.4990	-	pri	pg
2448762.4734	0.0007	pri	e
2449060.5783	0.0010	pri	eB
2449060.5842	0.0009	pri	eV
2449472.5069	0.0022	pri	eB
2449472.5105	0.0014	pri	eV
2449859.5156	0.0020	pri	eB
2451287.7312	0.0009	sec	cc
2451308.8692	0.0007	pri	cc
2451386.3533	0.0016	sec	cc
2451386.9077	0.0026	pri	cc
2451703.4593	0.0100	pri	cc
2452426.5059	0.0011	pri	cc
2453408.6264	0.0048	pri	cc
2453589.6659	0.0006	pri	cc
2453774.4927	0.0027	sec	cc
2453775.0367	0.0008	pri	cc
2454218.4095	0.0021	pri	cc
2454235.7502	0.0005	pri	cc
2454244.4224	0.0008	pri	cc
2454261.7725	0.0003	pri	cc
2454296.4520	0.0008	pri	cc
2454555.5385	0.0003	pri	cc
2454596.7338	0.0008	pri	cc
2454608.1716	-	sec	cc
2454941.4588	0.0009	pri	cc
2454945.7946	0.0001	pri	cc
2454945.7970	0.0002	pri	cc
2455340.3867	0.0011	pri	cc
2455345.8105	0.0004	pri	cc
2455353.3967	0.0025	pri	cc
2455707.8793	0.0004	pri	cc
2455752.3184	0.0001	pri	cc
2455778.3450	0.0001	pri	cc

Table 4: *Previously collected data on LT Her. Provided by www.as.up.krakow.pl.*

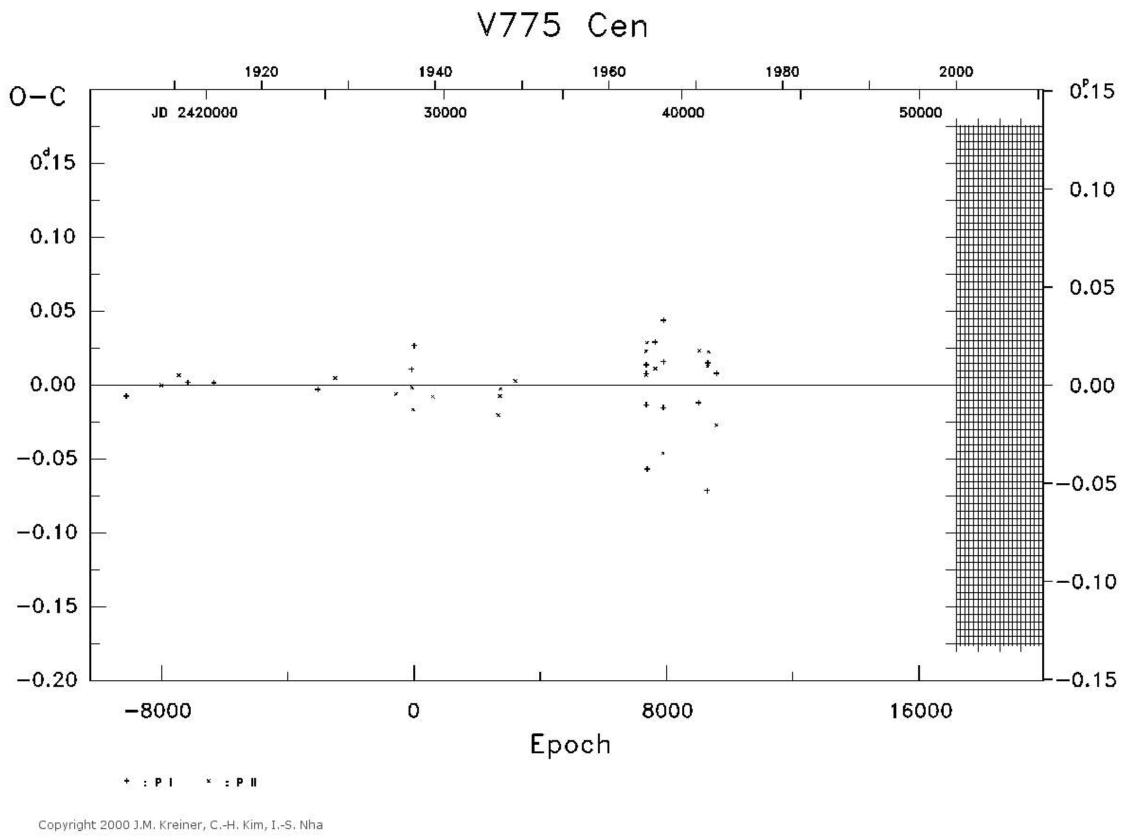

Figure 10: *An O-C diagram of data taken of V775 Cen since 1904. The data that was taken has been uploaded on this database but is still waiting verification before it will be added. Provided by www.as.up.krakow.pl.*

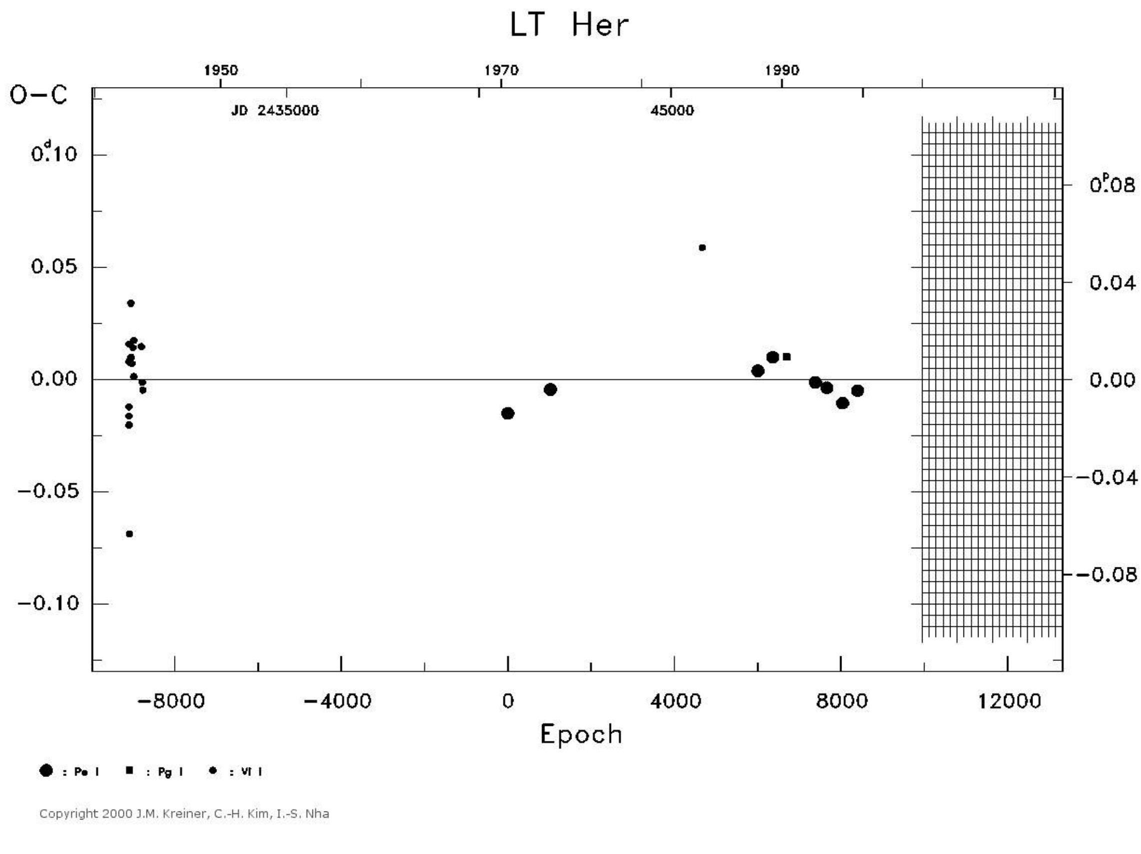

Figure 10: *An O-C diagram of data taken of LT Her since 1904. The data that was taken has been uploaded on this database but is still waiting verification before it will be added. Provided by www.as.up.krakow.pl.*

4. Discussion:

4.1. Light Curves and Minima:

The light curves of V775 Cen shown in figure 4 and figure 5 are typical of a binary system where one star is significantly brighter then it's companion, with the primary eclipse having a much larger impact on the luminosity as the cooler star blocks light from the brighter partner. The light curve from the 13th of May shows a clear primary eclipse with little to no noise or error and a deep decrease in magnitude. While the light curve taken from the 12th of May displays a much shallower light curve characteristic of a secondary eclipse. Due to the deeper drop in magnitude on the night of the 13th, the Minima software was able to determine a much more accurate minima time then on the shallower, secondary minima. For this reason primary minima are the most commonly used data points in eclipsing binaries research, with many telescopes and software unable to detect the very small decreases. One of the many interesting and promising results to come out the data taken at the MT Kent Observatory was the CDK20's ability to accurately detected the secondary minima on V775 Cen and for the exact minima time to be determined with only an error of ±0.0001.

Some of the light curves produced from the LT Her data are not currently usable to obtain minima times as there was a time zone miscalculation on the nights of the 17th of May and 9th of June. The miscalculation resulted in LT Her being observed 2 hours later then originally intended, there is still evidence of the eclipses occurring in the slow rise and levelling off of the luminosity but the data is not usable for the project. There was also a calculation error for the timing on the night of the 30th of May which resulted in approximately half of the eclipse being observed, this can be clearly seen in figure 9.

Despite the incomplete light curve on the 30th it was still possible to use the Minima software to obtain an exact minima, but I am unsure as to the exact accuracy of this measurement due to the heavy extrapolation involved.

4.2. Viability of the MT Kent Observatory and Future Research:

The confirmation of exoplanets via the eclipsing time variation methodology was always beyond the scope of this project due to the large amount of observation time required. However this was not the main focus. The most important aspect of the results was that the project successfully demonstrated the viability of the MT Kent and Moore Observatories to detect exoplanets around of eclipsing binaries using a variation of the TTV technique. All eclipses, primary and secondary, were easily detected with their corresponding light curves containing little error. The exact time of each minima is easily and accurately determined, this allows for the most important aspect of TTV exoplanet searches to be to obtained; precise observed minus calculated (O-C) data.

MT Kent has shown itself capable of preforming observations and analysis of eclipsing binaries and it's potential as a remote/robotic exoplanet observatory. The author is currently planning on continuing the study of eclipsing binaries out of the MT Kent and Moore Observatories in order to observe more epochs and to possibly confirm an exoplanet orbiting an eclipsing binary. There has also been talks with Daniel Bayliss, in light of this projects clear light curves, to use the MT Kent Observatory to preform the confirmation of exoplanet transits from the HATSouth project, as well as possible Transit Timing Variations calculations.

4.3. Observation Conditions and Potential Errors:

On both nights used to take the V775 Cen data the sky was clear with the exception of some potential light, scattered cloud on the night of the 12th of May from 21:00 until 23:00. From the plot in figure 4 it would appear that if there was any cloud that it had little to no effect on the CDK20's visibility. The night of the 13th was clear of all cloud but it was noticed that the dome had begun to obscure the eastern edge of the field of view of the scope at 01:06, this was quickly rectified and the data taken around this time did not appear to contain any corruption or irregularities caused by this event. The wind speed was and sky temperature were low on both nights of observations.

The weather conditions in Louisville on the four nights that the data on LT Her was obtained were clear with no cloud cover being recorded and no errors occurring with the telescope or any of the software. The wind speed and sky temperature at the Moore Observatory were also low on all nights

Both observatories' servers are synced with the online Greenwich time in order to assure precise timing, this timing was checked every night before and after each observation session. The CDK20s in both locations are precisely focused and aligned with a drift measurement of less then 3 pixels per minute.

5. Summary:

The project aimed to test the MT Kent and Moore Observatories' ability to detect exoplanets around eclipsing binaries. This was done by using both of the observatories' CDK20 telescopes to analyse the timing of the binaries eclipses to test for variations in the events which would be caused by orbiting exoplanets. Data was taken on two stars over several nights from both the MT Kent and Moore Observatories, which detected significant decreases in magnitude. In conclusion it was found that both observatories are well equipped to preform this kind of research and there are plans to continue this research in to the future.

Acknowledgements:

I would like to thank Brad Carter and Rhodes Hart for all their hard work and assistance with the MT Kent Observatories as well as John Kielkopf and Karen Collins for all their hard work both with the Moore Observatory and the AstroImageJ software.

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Appendix A

Date: 12/5/12
Target: V775Cen
Camera temperature: -10C
Filter set: 1=U, 2=B, 3=V, 4=R, 5=I, 6=blank

Finding target
20:20 V775Cen0001.fits 10s V
Had to focus
V775Cen0002.fits " " Plate solved and referenced

Moved to target (Scope is on west side of mount, high altitude)
V775Cen0003.fits " " Target identified in field centre at (2033,2058). 14081 counts

Note: Had to flip Y to match ref frame from Czech site
V775Cen0004.fits 20s V Some elongation in X

21:24 T=17C DP=6C 50%RH 1016.7hPa Wind speed=0km/hr
V775Cen0005.fits 20s V
V775Cen0006.fits
V775Cen0007.fits 60s V 5 pixel streaks in X
V775Cen0008.fits " " 3 pixel streaks in X:different!(Az166, Alt65)

Reposition so scope on East of mount
V775Cen0010-11.fits 10s V Finding target
V775Cen0012.fits " " on target 25000 counts
V775Cen0013.fits 20s V

23:02 T=17C DP=6C 48%RH 1016.0hPa Wind speed=0km/hr
V775Cen0014.fits 10s V 15000 counts
V775Cen0015.fits " " ST -31.9
V775Cen0016-18.fits " " ST -31.7 19000-14000
V775Cen0021.fits " " ST -31.5 19000
V775Cen0024.fits " " ST -31.2
V775Cen0034-62.fits " " first of 10 frame multi exposure ST -32.0 possible light/scattered cloud cover moving across on the radar

V775Cen0063-116.fits 10s V Moon Rising ST -32.2
V775Cen00117.fits " " ST -32.8
V775Cen00164-173.fits 10s V Dark
V775Cen00174.fits 2s V Flat
V775Cen00175-185.fits 3s V Flat
V775Cen00186-195.fits 3s V Dark

Date: 13/05/2012
Target: V775 Cen
Camera temperature: -10C
Filter set: 1=U, 2=B, 3=V, 4=R, 5=I, 6=blank

V775Cen0001-5.fits 10s V Used to solve telescope and find target telescope on east side of mount

21:57 T=9C DP=0C RH 55% 1019.0hpa wind 3km/hr Av 6km/hr
ST -35.9C

22:03
V775Cen0006-15.fits 10s V Counts 22000-17600
22:13
V775Cen0016-25.fits " " Counts 18000-18000 ST -38.5
22:18
V775Cen0026-35.fits " "
22:27
V775Cen0036-45.fits " " ST -37.3
V775Cen0046-425.fits " "
23:03 ST -37.1

23:19 ST -35.0C

23.49 T=8C DP=0C RH 60% 1 019.0hPa Wind 3km/hr Av 3km/hr
ST -35.8C
00:00 ST -37.2C
00:07 T=*C DP=0C RH 59% 1018.8hPa wind 5km/hr Av 6km/hr
ST -35.4C
00:28 ST -36.7C
00:42 ST -36.3C
01:00 ST -35.6C
01:06 Noticed scope ~1/3 obscured by dome. Moon just rising.
01:30 T=7C DP=1C RH 62% 1018.8hPa wind 5km/hr Av 5km/hr
ST -35.9C
01:50 ST -35.6C
02:01 ST -36.2C

Appendix B

V775Cen on the night of 12/5/2012			
Julian Date: +2400000	Flux of Target Star	Flux of Comparison Star 1	Flux of Comparison Star 2
56060.043426	0.316047	0.153097	1.086799
56060.046065	0.315140	0.150852	1.089713
56060.048333	0.313195	0.152131	1.093471
56060.051933	0.312048	0.152212	1.088532
56060.055405	0.310420	0.153385	1.083529
56060.058067	0.309646	0.154158	1.081521
56060.060243	0.308201	0.152556	1.085969
56060.060938	0.307753	0.152252	1.087369
56060.061632	0.308211	0.152056	1.092216
56060.062222	0.307600	0.151384	1.088338
56060.063102	0.308960	0.153673	1.091389
56060.065833	0.306138	0.152293	1.087012
56060.066887	0.304565	0.151847	1.091458
56060.067315	0.307162	0.153082	1.086968
56060.067975	0.307314	0.153566	1.080800
56060.068958	0.307055	0.152984	1.082997
56060.069722	0.307092	0.153084	1.083646
56060.070394	0.307412	0.153245	1.080227
56060.071308	0.307838	0.152641	1.084524
56060.071736	0.306485	0.153593	1.086527
56060.072593	0.306173	0.153355	1.091325
56060.072951	0.306590	0.152972	1.089322
56060.073299	0.307248	0.153415	1.089276
56060.073657	0.305791	0.153548	1.082781
56060.074016	0.307016	0.153180	1.089732
56060.074375	0.306308	0.151989	1.087549
56060.074722	0.307328	0.152452	1.092290
56060.075081	0.305319	0.153432	1.087874
56060.075440	0.304630	0.153561	1.080254
56060.075799	0.306004	0.153968	1.084750
56060.076285	0.305543	0.153299	1.090715
56060.076644	0.306035	0.153835	1.084019
56060.077002	0.306428	0.153439	1.089262
56060.077361	0.306895	0.153367	1.082296
56060.077708	0.305089	0.153538	1.087156
56060.078067	0.305121	0.152535	1.088859
56060.078426	0.306145	0.153004	1.084739
56060.078785	0.304460	0.152571	1.092613
56060.079132	0.305254	0.153030	1.085263
56060.079491	0.305598	0.152297	1.089759

56060.080347	0.305431	0.152920	1.087940
56060.080706	0.307334	0.153657	1.085049
56060.081065	0.306568	0.152740	1.080718
56060.081412	0.304662	0.153743	1.082412
56060.081771	0.305490	0.153599	1.086940
56060.082130	0.306018	0.153215	1.085437
56060.082488	0.306425	0.153090	1.087791
56060.082836	0.307465	0.153477	1.086264
56060.083194	0.307117	0.153283	1.084047
56060.083553	0.304547	0.153064	1.086777
56060.084155	0.306568	0.153320	1.079993
56060.084502	0.305325	0.152815	1.086321
56060.084861	0.306781	0.153689	1.074603
56060.085220	0.306059	0.152806	1.083551
56060.085579	0.305732	0.153317	1.085556
56060.085926	0.306770	0.153279	1.082326
56060.086285	0.306962	0.152576	1.079873
56060.086644	0.307028	0.152840	1.081163
56060.087002	0.307742	0.152953	1.084148
56060.087350	0.307049	0.152782	1.082475
56060.087743	0.305552	0.153186	1.086116
56060.088102	0.305905	0.153000	1.089377
56060.088461	0.307676	0.152836	1.088544
56060.088819	0.306518	0.153087	1.082215
56060.089167	0.306907	0.154035	1.083063
56060.089525	0.307974	0.153666	1.080478
56060.089884	0.308989	0.154160	1.087214
56060.090243	0.307200	0.153291	1.090563
56060.090590	0.306624	0.151786	1.083202
56060.090949	0.306726	0.153300	1.087392
56060.091574	0.309260	0.153096	1.083993
56060.091933	0.308885	0.153554	1.085657
56060.092280	0.308230	0.153439	1.087137
56060.092639	0.307709	0.153015	1.080747
56060.092998	0.306941	0.153638	1.082178
56060.093356	0.306676	0.152529	1.086788
56060.093704	0.308764	0.152359	1.087575
56060.094063	0.308177	0.153103	1.086219
56060.094421	0.308178	0.152821	1.084989
56060.094780	0.309256	0.153275	1.084688
56060.095174	0.307958	0.153772	1.089250
56060.095532	0.307400	0.153048	1.083670
56060.095891	0.308538	0.153732	1.083233
56060.096250	0.307677	0.154310	1.081173
56060.096609	0.309926	0.153150	1.086855

56060.096956	0.308664	0.153175	1.084848
56060.097315	0.307576	0.152018	1.089153
56060.097674	0.309852	0.153341	1.088683
56060.098032	0.308680	0.153393	1.081852
56060.098391	0.309830	0.153433	1.084132
56060.098843	0.311228	0.153364	1.080999
56060.099201	0.308125	0.151846	1.088522
56060.099560	0.309573	0.153845	1.087294
56060.099919	0.308561	0.152895	1.087555
56060.100278	0.311259	0.152788	1.085203
56060.100625	0.309690	0.153785	1.081834
56060.100984	0.309893	0.151586	1.093428
56060.101343	0.308164	0.152414	1.085313
56060.101701	0.310675	0.152585	1.082253
56060.102060	0.310643	0.153182	1.089302
56060.102500	0.310020	0.153115	1.086651
56060.102859	0.310334	0.153114	1.089176
56060.103218	0.310168	0.153743	1.075910
56060.103576	0.312016	0.153690	1.082316
56060.103924	0.311176	0.153193	1.083820
56060.104282	0.309886	0.153620	1.083509
56060.104641	0.311082	0.154811	1.076805
56060.105000	0.310823	0.153794	1.081444
56060.105359	0.311768	0.152890	1.083309
56060.105706	0.310424	0.154132	1.078028
56060.106609	0.313061	0.153274	1.081435
56060.106968	0.312880	0.153701	1.081737
56060.107326	0.311588	0.154094	1.076744
56060.107674	0.311855	0.152732	1.085057
56060.108032	0.312619	0.153910	1.082330
56060.108391	0.312347	0.154068	1.085230
56060.108750	0.313785	0.154446	1.079590
56060.109109	0.312050	0.153384	1.078699
56060.109468	0.313390	0.153569	1.082898
56060.109815	0.313174	0.152193	1.079639
56060.113137	0.314521	0.153988	1.084731
56060.113495	0.314681	0.153450	1.080671
56060.113854	0.315712	0.154037	1.085578
56060.114201	0.315065	0.154022	1.078057
56060.114560	0.314761	0.153939	1.078933
56060.114919	0.316700	0.153351	1.076181
56060.115278	0.316113	0.154274	1.080724
56060.115637	0.315189	0.153945	1.078751
56060.115984	0.314907	0.153160	1.084752
56060.116343	0.315432	0.154270	1.082440

56060.116736	0.314935	0.153802	1.083351
56060.117095	0.317208	0.154294	1.080258
56060.117454	0.315016	0.154767	1.074787
56060.117801	0.316686	0.153508	1.082991
56060.118160	0.318476	0.154630	1.080352
56060.118519	0.318332	0.153560	1.079148
56060.118877	0.318156	0.154684	1.075279
56060.119236	0.317307	0.153400	1.083190
56060.119595	0.318886	0.153384	1.078204
56060.119942	0.319067	0.154320	1.085485
56060.120718	0.318535	0.154895	1.075750
56060.121076	0.317338	0.154106	1.078437
56060.121435	0.318683	0.153250	1.077387
56060.121794	0.319436	0.154570	1.083442
56060.122141	0.320542	0.154232	1.080534
56060.122500	0.320416	0.154281	1.077146
56060.122859	0.317999	0.152754	1.085412
56060.123218	0.319936	0.154592	1.080726
56060.123576	0.319941	0.154211	1.073919
56060.123924	0.319955	0.153948	1.081432

V775Cen on the night of 13/5/2012			
Julian Date: +2400000	Flux of Target Star	Flux of Comparison Star 1	Flux of Comparison Star 2
56061.001516	0.322520	0.154082	1.095276
56061.001875	0.321550	0.152878	1.091341
56061.002234	0.319974	0.152389	1.092466
56061.002581	0.318586	0.153164	1.096591
56061.002940	0.321628	0.152744	1.095447
56061.003299	0.319394	0.152813	1.091288
56061.003646	0.319519	0.152060	1.096570
56061.004005	0.319847	0.152284	1.095840
56061.004363	0.320387	0.153909	1.095603
56061.004722	0.321155	0.152728	1.088727
56061.008287	0.315463	0.154385	1.092643
56061.008646	0.315535	0.152417	1.094153
56061.009005	0.316401	0.152103	1.083586
56061.009363	0.313001	0.152663	1.100409
56061.009711	0.312710	0.153288	1.091454
56061.010069	0.312203	0.152301	1.095051
56061.010428	0.312901	0.152527	1.101716
56061.010775	0.312427	0.152742	1.098151
56061.011134	0.309638	0.152983	1.095823
56061.011493	0.310768	0.152562	1.092136
56061.012593	0.309110	0.152481	1.098787
56061.012940	0.309379	0.153148	1.094628
56061.013299	0.307873	0.153261	1.095766
56061.013657	0.307302	0.153587	1.089257
56061.014005	0.307750	0.151265	1.107513
56061.014363	0.307311	0.153544	1.084716
56061.014722	0.306629	0.153888	1.086953
56061.015081	0.305402	0.152706	1.086504
56061.015428	0.306340	0.153449	1.089793
56061.015787	0.305564	0.154045	1.088251
56061.019039	0.301722	0.154470	1.083770
56061.019398	0.297878	0.153586	1.088415
56061.019745	0.297816	0.153057	1.088880
56061.020104	0.296621	0.152828	1.097004
56061.020463	0.294967	0.152838	1.098324
56061.020810	0.296720	0.152043	1.094784
56061.021169	0.295147	0.153203	1.086798
56061.021528	0.294177	0.153667	1.091853
56061.021875	0.295399	0.152505	1.093081
56061.022234	0.292222	0.152700	1.092379
56061.023356	0.290292	0.153350	1.088778
56061.023715	0.290587	0.154026	1.084994

56061.024063	0.288276	0.151977	1.100073
56061.024421	0.290479	0.153280	1.094242
56061.024780	0.287285	0.153135	1.094594
56061.025139	0.287620	0.152904	1.091808
56061.025486	0.285112	0.153735	1.094523
56061.025845	0.286617	0.152457	1.095267
56061.026204	0.283997	0.152739	1.090047
56061.026563	0.284552	0.154441	1.081691
56061.027569	0.281145	0.152148	1.097520
56061.027928	0.280867	0.152817	1.095325
56061.028287	0.279940	0.154265	1.085134
56061.028634	0.278940	0.153426	1.090783
56061.028993	0.277952	0.152329	1.092646
56061.029352	0.277656	0.152247	1.091694
56061.029711	0.277654	0.152706	1.092711
56061.030058	0.276963	0.153581	1.087061
56061.030417	0.275387	0.153020	1.096201
56061.030775	0.275118	0.152710	1.097409
56061.032384	0.271397	0.152798	1.095425
56061.032731	0.272056	0.153584	1.090268
56061.033090	0.270132	0.153689	1.093897
56061.033449	0.269438	0.153398	1.085732
56061.033808	0.269692	0.154062	1.090093
56061.034155	0.268886	0.153832	1.093647
56061.034514	0.269336	0.152836	1.091351
56061.034873	0.266590	0.153315	1.092890
56061.035220	0.266782	0.151776	1.094683
56061.035579	0.266841	0.154571	1.087207
56061.036898	0.261459	0.152398	1.086948
56061.037257	0.261040	0.153800	1.094308
56061.037604	0.260556	0.152972	1.092176
56061.037963	0.259948	0.153714	1.098286
56061.038322	0.259147	0.153421	1.087983
56061.038669	0.258030	0.152658	1.091432
56061.039028	0.257766	0.153718	1.091099
56061.039387	0.256849	0.154082	1.094705
56061.039745	0.254360	0.153307	1.094739
56061.040104	0.254487	0.153495	1.091248
56061.041597	0.249976	0.153081	1.094550
56061.041944	0.251501	0.154264	1.092299
56061.042303	0.249268	0.153403	1.093344
56061.042662	0.249730	0.153999	1.087532
56061.043021	0.248976	0.152861	1.089748
56061.043368	0.247248	0.153273	1.097103
56061.043727	0.246586	0.152939	1.096016

56061.044086	0.245430	0.153099	1.089788
56061.044444	0.244064	0.153486	1.093533
56061.044792	0.244621	0.152250	1.091595
56061.045706	0.242163	0.153819	1.091654
56061.046065	0.240937	0.152926	1.089422
56061.046412	0.239011	0.152608	1.091192
56061.046771	0.238164	0.153893	1.091376
56061.047130	0.238550	0.153666	1.088356
56061.047488	0.237473	0.152611	1.095656
56061.047836	0.237040	0.153084	1.088182
56061.048194	0.235495	0.153346	1.083630
56061.048553	0.235113	0.152793	1.092361
56061.048912	0.234635	0.152902	1.093316
56061.049375	0.234679	0.153998	1.087225
56061.049734	0.232727	0.152858	1.093440
56061.050093	0.229938	0.153101	1.093230
56061.050440	0.230245	0.152652	1.090990
56061.050799	0.229606	0.153893	1.088506
56061.051157	0.229711	0.152797	1.094162
56061.051516	0.227365	0.153919	1.094587
56061.051863	0.228266	0.152923	1.094041
56061.052222	0.227005	0.152066	1.095296
56061.052581	0.225225	0.152459	1.090166
56061.053461	0.225925	0.153992	1.091460
56061.053808	0.223636	0.152234	1.086072
56061.054167	0.222594	0.152808	1.093028
56061.054525	0.221597	0.153233	1.086704
56061.054873	0.221407	0.153839	1.088829
56061.055231	0.220015	0.152387	1.092419
56061.055590	0.219961	0.153433	1.093629
56061.055949	0.219458	0.152505	1.101113
56061.056296	0.216484	0.152674	1.089624
56061.056655	0.216992	0.153155	1.095469
56061.057049	0.218292	0.153029	1.091267
56061.057407	0.214493	0.152890	1.084216
56061.057755	0.214345	0.153620	1.095232
56061.058113	0.214835	0.153271	1.093941
56061.058472	0.213763	0.152917	1.095389
56061.058819	0.213314	0.154373	1.089806
56061.059178	0.213262	0.153269	1.101129
56061.059537	0.211076	0.152796	1.095825
56061.059896	0.211500	0.151599	1.095241
56061.060243	0.210819	0.152516	1.098580
56061.060660	0.210858	0.151429	1.100705
56061.061019	0.209712	0.153803	1.093466

56061.061377	0.209712	0.153398	1.087622
56061.061725	0.208605	0.154696	1.088697
56061.062083	0.207845	0.151313	1.094802
56061.062442	0.207034	0.153089	1.101107
56061.062789	0.207026	0.154037	1.082204
56061.063148	0.207497	0.152748	1.083168
56061.063507	0.207210	0.153443	1.090482
56061.063866	0.205495	0.153690	1.095429
56061.064248	0.207290	0.153436	1.078375
56061.064606	0.203853	0.151182	1.105669
56061.064965	0.202873	0.153957	1.091339
56061.065324	0.203307	0.152623	1.091571
56061.065671	0.201491	0.155254	1.084559
56061.066030	0.200770	0.152970	1.084947
56061.066389	0.204166	0.154379	1.090025
56061.066736	0.201370	0.151696	1.097270
56061.067095	0.201971	0.153735	1.093775
56061.067454	0.201203	0.152542	1.084028
56061.067963	0.201483	0.152634	1.094175
56061.068310	0.202465	0.154133	1.090059
56061.068669	0.199556	0.153328	1.087469
56061.069028	0.199555	0.153114	1.101152
56061.069375	0.200323	0.153319	1.093863
56061.069734	0.198903	0.153065	1.090995
56061.070093	0.198668	0.152793	1.092008
56061.070451	0.199801	0.155559	1.091044
56061.070799	0.198834	0.153438	1.082112
56061.071157	0.197716	0.153144	1.090466
56061.071806	0.197904	0.153723	1.097366
56061.072164	0.199068	0.153749	1.086064
56061.072512	0.197814	0.151333	1.100716
56061.072870	0.198983	0.153387	1.092293
56061.073229	0.196908	0.151344	1.094467
56061.073588	0.197345	0.153240	1.093302
56061.073935	0.197258	0.153910	1.082144
56061.074294	0.198747	0.153427	1.091143
56061.074653	0.197541	0.154769	1.085854
56061.075000	0.195933	0.153160	1.091312
56061.075567	0.198765	0.152694	1.090164
56061.075926	0.197580	0.152805	1.089609
56061.076285	0.197153	0.153592	1.086652
56061.076632	0.197585	0.153836	1.085678
56061.076991	0.197556	0.153706	1.087945
56061.077350	0.196812	0.153921	1.084455
56061.077697	0.197361	0.153142	1.096629

56061.078056	0.197091	0.152613	1.099954
56061.078414	0.198123	0.153532	1.090061
56061.078773	0.200133	0.153958	1.082507
56061.080035	0.199272	0.153388	1.089893
56061.080394	0.198087	0.153547	1.096646
56061.080752	0.200171	0.153605	1.090520
56061.081111	0.199714	0.153059	1.091574
56061.081458	0.199577	0.151854	1.094411
56061.081817	0.199187	0.151969	1.090934
56061.082176	0.199114	0.153102	1.096104
56061.082535	0.200872	0.152177	1.091770
56061.082882	0.201061	0.153082	1.091326
56061.083241	0.201041	0.153178	1.093004
56061.085926	0.203344	0.153355	1.082539
56061.086285	0.205013	0.152428	1.097731
56061.086644	0.204139	0.153351	1.094948
56061.086991	0.206340	0.153916	1.085612
56061.087350	0.205597	0.152186	1.097160
56061.087708	0.206894	0.152220	1.095071
56061.088056	0.206760	0.152689	1.093813
56061.088414	0.207348	0.153508	1.084903
56061.088773	0.208149	0.152683	1.090425
56061.089132	0.208602	0.152302	1.093681
56061.090243	0.212022	0.154181	1.080902
56061.090602	0.211988	0.154100	1.088857
56061.090961	0.212416	0.153592	1.090908
56061.091319	0.211974	0.154041	1.086517
56061.091667	0.212349	0.152581	1.096868
56061.092025	0.212268	0.153113	1.087616
56061.092384	0.213327	0.153544	1.097062
56061.092743	0.214024	0.153429	1.079170
56061.093090	0.216456	0.152786	1.097206
56061.093449	0.215425	0.154288	1.087567
56061.095139	0.218803	0.152448	1.092160
56061.095486	0.220003	0.151647	1.097163
56061.095845	0.223117	0.152519	1.085499
56061.096204	0.219299	0.152877	1.087429
56061.096563	0.223637	0.153861	1.080464
56061.096910	0.223802	0.154204	1.089005
56061.097269	0.225453	0.152295	1.088273
56061.097627	0.223125	0.152801	1.081777
56061.097986	0.225230	0.153395	1.088330
56061.098333	0.225978	0.153678	1.084268
56061.098750	0.226641	0.154663	1.085888
56061.099109	0.227221	0.154357	1.079656

56061.099468	0.229443	0.153433	1.084041
56061.099815	0.228766	0.153634	1.085323
56061.100174	0.231606	0.152761	1.090175
56061.100532	0.230041	0.152823	1.088354
56061.100880	0.231352	0.154110	1.084643
56061.101238	0.231327	0.152941	1.083531
56061.101597	0.229998	0.152444	1.092116
56061.101956	0.234477	0.154507	1.086916
56061.102500	0.236910	0.153432	1.090889
56061.102859	0.236001	0.152621	1.086804
56061.103218	0.238638	0.152035	1.095847
56061.103576	0.237389	0.152516	1.095334
56061.103924	0.238378	0.152136	1.096540
56061.104282	0.240861	0.153059	1.081798
56061.104641	0.241176	0.154030	1.094198
56061.104988	0.240798	0.153421	1.085243
56061.105347	0.239794	0.153910	1.091545
56061.105706	0.242170	0.153896	1.087994
56061.106979	0.244789	0.154218	1.085698
56061.107326	0.245659	0.153186	1.101114
56061.107685	0.245946	0.154044	1.090066
56061.108044	0.245831	0.153805	1.086604
56061.108403	0.248333	0.154093	1.097790
56061.108750	0.249482	0.151521	1.093995
56061.109109	0.250839	0.152463	1.090236
56061.109468	0.250718	0.154033	1.080456
56061.109826	0.251558	0.152795	1.087840
56061.110185	0.254794	0.153448	1.087774
56061.110579	0.254972	0.154659	1.085748
56061.110938	0.251818	0.152036	1.101208
56061.111296	0.255136	0.153265	1.100137
56061.111655	0.255194	0.151467	1.092283
56061.112002	0.256178	0.151625	1.094036
56061.112361	0.258781	0.153691	1.093160
56061.112720	0.259183	0.153162	1.090321
56061.113079	0.261524	0.152872	1.085169
56061.113426	0.260574	0.153290	1.097792
56061.113785	0.260305	0.154623	1.084695
56061.115486	0.266102	0.152761	1.084982
56061.115845	0.265922	0.153805	1.082905
56061.116192	0.267281	0.154118	1.080002
56061.116551	0.267602	0.153208	1.087450
56061.116910	0.269163	0.152551	1.089953
56061.117269	0.269456	0.152783	1.090012
56061.117627	0.270734	0.152233	1.088902

56061.117975	0.270157	0.153420	1.090640
56061.118333	0.272595	0.152817	1.085506
56061.118692	0.273290	0.154279	1.090769
56061.119132	0.272455	0.152360	1.095362
56061.119479	0.274640	0.153452	1.085472
56061.119838	0.274896	0.152617	1.086363
56061.120197	0.275139	0.153290	1.087564
56061.120556	0.276986	0.153439	1.089780
56061.120903	0.279230	0.153986	1.090188
56061.121262	0.277986	0.153509	1.088420
56061.121620	0.279374	0.154201	1.087879
56061.121979	0.280537	0.153037	1.093330
56061.122326	0.281541	0.153022	1.091574
56061.123542	0.281322	0.152711	1.093013
56061.123900	0.283540	0.152840	1.093932
56061.124259	0.284684	0.153246	1.086307
56061.124606	0.283163	0.153193	1.092112
56061.124965	0.285721	0.154747	1.078556
56061.125324	0.285010	0.151816	1.098376
56061.125683	0.287066	0.153222	1.089750
56061.126030	0.288706	0.153396	1.090659
56061.126389	0.287088	0.152426	1.087968
56061.126748	0.288280	0.152619	1.090363
56061.128113	0.290895	0.151880	1.096445
56061.128472	0.292273	0.153297	1.089505
56061.128831	0.293208	0.154063	1.092481
56061.129178	0.295719	0.154542	1.087035
56061.129537	0.295994	0.154533	1.084860
56061.129896	0.295776	0.152373	1.092773
56061.130255	0.297822	0.153338	1.086411
56061.130602	0.295253	0.154982	1.081954
56061.130961	0.299275	0.154329	1.079789
56061.131319	0.296761	0.153252	1.085008
56061.132477	0.299667	0.152875	1.083267
56061.132824	0.300073	0.152838	1.087574
56061.133183	0.301005	0.154337	1.089100
56061.133542	0.303842	0.152156	1.090970
56061.133900	0.302735	0.152141	1.090156
56061.134248	0.303857	0.153727	1.082356
56061.134606	0.304817	0.153964	1.089364
56061.134965	0.307293	0.155103	1.076449
56061.135324	0.306524	0.154423	1.082715
56061.135671	0.306114	0.153983	1.086646
56061.139340	0.312461	0.153448	1.089935
56061.139699	0.312492	0.152589	1.096339

56061.140058	0.311008	0.152474	1.088221
56061.140405	0.315667	0.154571	1.086083
56061.140764	0.313825	0.153116	1.094234
56061.141123	0.313813	0.151507	1.090591
56061.141481	0.315280	0.153686	1.088741
56061.141829	0.317657	0.152834	1.089417
56061.142188	0.318382	0.153737	1.081040
56061.142546	0.315636	0.152884	1.089752
56061.144039	0.317078	0.153391	1.089828
56061.144387	0.318405	0.153446	1.081919
56061.144745	0.318577	0.155308	1.079772
56061.145104	0.318886	0.153577	1.084659
56061.145463	0.320431	0.153156	1.091890
56061.145810	0.318369	0.153100	1.080990
56061.146169	0.318665	0.153720	1.083011
56061.146528	0.321363	0.153530	1.084891
56061.146887	0.321457	0.153011	1.087386
56061.147234	0.320041	0.154165	1.090982
56061.147928	0.322150	0.153068	1.087070
56061.148287	0.320999	0.153224	1.091513
56061.148646	0.321800	0.153339	1.087366
56061.149005	0.323042	0.152995	1.090892
56061.149352	0.325218	0.152874	1.090036
56061.149711	0.321486	0.153138	1.083816
56061.150069	0.324041	0.152652	1.090271
56061.150428	0.322887	0.153360	1.092738
56061.150775	0.327064	0.153517	1.095387
56061.151134	0.323929	0.153721	1.086044
56061.151528	0.323863	0.153526	1.085994
56061.151887	0.324259	0.153769	1.085438
56061.152234	0.325754	0.152832	1.095750
56061.152593	0.325904	0.152942	1.083085
56061.152951	0.323552	0.152330	1.090233
56061.153310	0.327330	0.151936	1.086240
56061.153657	0.326865	0.152334	1.086994
56061.154016	0.327395	0.154425	1.084059
56061.154375	0.327537	0.153737	1.082610
56061.154734	0.329245	0.152396	1.085366
56061.155972	0.327675	0.152302	1.090542
56061.156319	0.326259	0.153073	1.079430
56061.156678	0.330354	0.153994	1.086040
56061.157037	0.330693	0.154105	1.080487
56061.157396	0.328236	0.155142	1.082198
56061.157755	0.328526	0.154378	1.081211
56061.158102	0.328574	0.152626	1.088202

56061.158461	0.332193	0.153840	1.084039
56061.158819	0.328744	0.152502	1.091849
56061.159178	0.327666	0.154403	1.085785
56061.163032	0.328198	0.152266	1.085728
56061.163391	0.331020	0.155127	1.083065
56061.163750	0.328707	0.152735	1.094125
56061.164109	0.325970	0.151794	1.103164
56061.164456	0.329974	0.152491	1.087595
56061.164815	0.329435	0.154174	1.080699
56061.165174	0.329524	0.154063	1.093761
56061.165532	0.330317	0.153809	1.078406
56061.165891	0.331044	0.153187	1.081253
56061.166238	0.329847	0.154070	1.089111
56061.166829	0.332103	0.154345	1.088922
56061.167188	0.330383	0.152174	1.090286
56061.167546	0.330883	0.153063	1.086156
56061.167905	0.332241	0.153111	1.094216
56061.168252	0.330427	0.153161	1.093739
56061.168611	0.332858	0.153206	1.092209
56061.168970	0.332853	0.152143	1.092765
56061.169329	0.330935	0.154674	1.085578
56061.169676	0.329066	0.152786	1.091940
56061.170035	0.334531	0.152300	1.095156
56061.170972	0.334159	0.152727	1.089998
56061.171331	0.332160	0.152538	1.091019
56061.171678	0.331063	0.154676	1.085614
56061.172037	0.335257	0.152708	1.088553
56061.172396	0.332449	0.151031	1.090254
56061.172755	0.336655	0.153030	1.082774
56061.173102	0.332034	0.153418	1.091623
56061.173461	0.331327	0.150495	1.096595
56061.173819	0.332897	0.153252	1.085740
56061.174178	0.333087	0.151811	1.090215
56061.175197	0.335704	0.153422	1.081511
56061.175556	0.331163	0.152823	1.094345
56061.175914	0.330438	0.152251	1.087017
56061.176273	0.337245	0.154023	1.074235
56061.176620	0.340161	0.152900	1.081364
56061.176979	0.334787	0.153723	1.084458
56061.177338	0.333995	0.153114	1.083736
56061.177697	0.332321	0.151861	1.093575
56061.178044	0.334467	0.154488	1.084581
56061.178403	0.334483	0.152048	1.091802
56061.179282	0.335564	0.154319	1.080425
56061.179641	0.338960	0.153712	1.084449

56061.180000	0.334732	0.154212	1.086971
56061.180347	0.336047	0.153460	1.085238
56061.180706	0.334177	0.151542	1.088150
56061.181065	0.335770	0.153127	1.093089
56061.181424	0.336305	0.153023	1.084220
56061.181771	0.337282	0.153394	1.081694
56061.182130	0.334133	0.153008	1.095423
56061.182488	0.335844	0.153351	1.085707
56061.183472	0.335914	0.151926	1.091801
56061.183819	0.336278	0.153982	1.087638
56061.184178	0.334100	0.153189	1.084183
56061.184537	0.334223	0.152922	1.096636
56061.184896	0.335754	0.152463	1.083427
56061.185243	0.336264	0.151249	1.093562
56061.185602	0.337074	0.154217	1.084224
56061.185961	0.337031	0.150681	1.083964
56061.186308	0.338778	0.153785	1.080903
56061.186667	0.338214	0.153067	1.088272

LTHer on the night of 17/5/2012			
Julian Date: +2400000	Flux of Target Star	Flux of Comparison Star 1	Flux of Comparison Star 2
56065.710590	0.483404	0.329527	0.204568
56065.711644	0.483590	0.330888	0.203855
56065.713090	0.481410	0.329921	0.204883
56065.714086	0.485428	0.330847	0.202802
56065.715093	0.483724	0.331676	0.204344
56065.716088	0.483660	0.331532	0.203489
56065.717083	0.484624	0.330212	0.204455
56065.718090	0.485798	0.331116	0.204012
56065.719074	0.486349	0.330786	0.203920
56065.720046	0.486806	0.330782	0.204489
56065.721076	0.490136	0.329938	0.205261
56065.722083	0.489074	0.330297	0.203708
56065.723113	0.490707	0.331314	0.204745
56065.724097	0.490304	0.331455	0.204477
56065.725093	0.490760	0.331659	0.204694
56065.726076	0.491716	0.331936	0.204685
56065.727106	0.492950	0.331761	0.204030
56065.728125	0.491975	0.329622	0.204129
56065.729097	0.492952	0.331421	0.203987
56065.730069	0.494695	0.330260	0.204603
56065.731100	0.493365	0.331364	0.204069
56065.732106	0.494710	0.330770	0.204605
56065.733102	0.490872	0.331628	0.204396
56065.734086	0.491382	0.330626	0.204162
56065.735104	0.492826	0.330659	0.204725
56065.736111	0.491852	0.331963	0.202819
56065.737106	0.490492	0.331124	0.205069
56065.738079	0.491448	0.330415	0.204843
56065.739097	0.491235	0.330636	0.204799
56065.740139	0.492147	0.331530	0.203857
56065.741146	0.490604	0.330432	0.204722
56065.742176	0.488747	0.329909	0.206321
56065.743171	0.490051	0.331360	0.204921
56065.744201	0.488606	0.331181	0.205552
56065.745197	0.488987	0.330794	0.204637
56065.746169	0.491053	0.330993	0.204924
56065.747187	0.488424	0.330978	0.205119
56065.748218	0.492595	0.330548	0.204894

LTHer on the night of 18/5/2012			
Julian Date: +2400000	Flux of Target Star	Flux of Comparison Star 1	Flux of Comparison Star 2
56066.630382	0.420149	0.328576	0.198552
56066.631759	0.419440	0.329054	0.197171
56066.632789	0.416510	0.328282	0.197569
56066.633796	0.415337	0.328581	0.196957
56066.634780	0.414452	0.329132	0.198144
56066.635764	0.413463	0.327598	0.198382
56066.636748	0.410638	0.330291	0.198067
56066.637755	0.408827	0.328614	0.198192
56066.638750	0.407773	0.328319	0.197639
56066.639734	0.406229	0.329632	0.198178
56066.640718	0.404904	0.328502	0.198682
56066.641701	0.404065	0.327945	0.199037
56066.642708	0.400418	0.326471	0.198208
56066.643704	0.402182	0.327905	0.198514
56066.644699	0.400205	0.328541	0.198307
56066.645671	0.400315	0.328132	0.198098
56066.646667	0.396254	0.327107	0.198902
56066.647662	0.396298	0.329080	0.198604
56066.648692	0.395532	0.328634	0.198353
56066.649687	0.390883	0.326374	0.198328
56066.650683	0.390491	0.327287	0.198670
56066.651667	0.390412	0.328435	0.197492
56066.652650	0.389197	0.328802	0.197875
56066.653634	0.386287	0.327236	0.198088
56066.654630	0.382447	0.327774	0.197886
56066.655625	0.383280	0.328203	0.197634
56066.656644	0.380688	0.326576	0.198146
56066.657616	0.377836	0.328041	0.197248
56066.658623	0.376761	0.329277	0.196866
56066.659606	0.377917	0.328220	0.196967
56066.660579	0.373792	0.328011	0.197213
56066.661563	0.372264	0.329263	0.199338
56066.662569	0.370637	0.329372	0.198110
56066.663576	0.370783	0.328616	0.196809
56066.664549	0.369623	0.329074	0.198435
56066.665544	0.368716	0.329651	0.198293
56066.666539	0.367349	0.327417	0.198357
56066.667535	0.363439	0.326851	0.198490
56066.668530	0.363779	0.329238	0.197158
56066.669537	0.363345	0.327933	0.197387
56066.670532	0.363429	0.329115	0.197916
56066.671528	0.363684	0.329612	0.198199

56066.672535	0.360993	0.329927	0.196302
56066.673507	0.361351	0.329623	0.197761
56066.674502	0.361071	0.330287	0.196755
56066.675498	0.360476	0.327405	0.198781
56066.676505	0.359762	0.329364	0.198074
56066.677500	0.359231	0.328393	0.198143
56066.678484	0.359559	0.328501	0.198195
56066.679491	0.358594	0.329420	0.197261
56066.680498	0.360346	0.329232	0.197103
56066.681470	0.357932	0.328406	0.197165
56066.682465	0.359813	0.330305	0.196948
56066.683461	0.358723	0.329991	0.198751
56066.684444	0.358145	0.327650	0.197195
56066.685451	0.358322	0.329085	0.197171
56066.686435	0.357592	0.327548	0.197604
56066.687442	0.358012	0.330372	0.196568
56066.688426	0.358024	0.329012	0.197818
56066.689433	0.356934	0.329358	0.198066
56066.690440	0.357641	0.328643	0.199088
56066.691412	0.357417	0.329462	0.197213
56066.692396	0.357952	0.329705	0.196311
56066.693437	0.357082	0.331010	0.197620
56066.694421	0.357809	0.328390	0.198872
56066.695417	0.359261	0.329842	0.197456
56066.696400	0.357468	0.330057	0.198056
56066.697419	0.358798	0.328923	0.198178
56066.698426	0.357795	0.329357	0.197873
56066.699410	0.359020	0.328701	0.197346
56066.700405	0.358753	0.329068	0.198022
56066.701389	0.359465	0.329691	0.198178
56066.702384	0.360600	0.328791	0.196986
56066.703380	0.361507	0.328593	0.196078
56066.704375	0.362125	0.329358	0.197908
56066.705370	0.362972	0.329118	0.197076
56066.706354	0.364268	0.327671	0.198443
56066.707338	0.365113	0.329279	0.198125
56066.708333	0.366115	0.329576	0.198033
56066.709306	0.367519	0.329383	0.198026
56066.710278	0.368343	0.330747	0.197389
56066.711308	0.370387	0.328771	0.198745
56066.712280	0.372248	0.329683	0.197114
56066.713264	0.372587	0.329394	0.197518
56066.714271	0.375499	0.329340	0.198901
56066.715278	0.376652	0.329336	0.198839
56066.716285	0.378242	0.328958	0.197673

56066.717280	0.379824	0.330885	0.197991
56066.718264	0.381000	0.329588	0.197794
56066.719271	0.382063	0.329319	0.197480
56066.720289	0.383439	0.328842	0.198248
56066.721285	0.385501	0.329213	0.198357
56066.722303	0.386610	0.330565	0.197758
56066.723275	0.390257	0.329835	0.198311
56066.724282	0.389116	0.330360	0.198325
56066.725255	0.392012	0.329355	0.197722
56066.726308	0.392422	0.328960	0.196929
56066.727303	0.393280	0.329188	0.197616
56066.728356	0.395201	0.328944	0.198112
56066.729340	0.399416	0.334083	0.197145
56066.730312	0.398335	0.331926	0.197619
56066.731296	0.400205	0.331606	0.198876
56066.732269	0.401166	0.330616	0.198635
56066.733252	0.402540	0.332462	0.198601
56066.734236	0.404384	0.331612	0.197536
56066.735208	0.405597	0.331100	0.197922
56066.736181	0.405040	0.330416	0.197229
56066.737199	0.408037	0.332960	0.197247
56066.738171	0.410203	0.330990	0.198624
56066.739155	0.411505	0.331770	0.197343
56066.740139	0.412710	0.330605	0.196492
56066.741169	0.414226	0.330856	0.197763
56066.742431	0.416033	0.328873	0.196610
56066.743461	0.419792	0.330543	0.195859
56066.744444	0.419743	0.328732	0.197872
56066.745417	0.421999	0.328864	0.198249
56066.746424	0.424207	0.327994	0.197706
56066.747465	0.427326	0.329231	0.197280
56066.748495	0.428871	0.328082	0.198419
56066.749514	0.430977	0.329255	0.198411
56066.750509	0.432805	0.328502	0.198564
56066.751528	0.434017	0.327076	0.198096
56066.752558	0.437684	0.328249	0.197847

LTHer on the night of 30/5/2012			
Julian Date: +2400000	Flux of Target Star	Flux of Comparison Star 1	Flux of Comparison Star 2
56078.603738	0.354996	0.321797	0.182807
56078.606968	0.353428	0.324479	0.182307
56078.607963	0.352215	0.320763	0.183559
56078.608947	0.352223	0.321215	0.183118
56078.609919	0.351664	0.322074	0.183156
56078.610937	0.350421	0.321044	0.184231
56078.611910	0.349391	0.321170	0.183458
56078.612894	0.350482	0.321693	0.183848
56078.613877	0.350352	0.321092	0.183000
56078.614873	0.351269	0.321051	0.183454
56078.615926	0.351190	0.320788	0.184158
56078.616898	0.351789	0.321985	0.182919
56078.617905	0.352452	0.321964	0.183626
56078.618877	0.353789	0.321602	0.184539
56078.619896	0.353938	0.321684	0.184248
56078.620868	0.352021	0.320802	0.184166
56078.621840	0.355402	0.322060	0.183487
56078.622812	0.356750	0.322971	0.182725
56078.623843	0.357556	0.322025	0.182680
56078.624838	0.357342	0.321569	0.181820
56078.625810	0.358819	0.321029	0.183661
56078.626817	0.360423	0.321396	0.183874
56078.627812	0.363631	0.323090	0.182795
56078.628808	0.364413	0.321765	0.183233
56078.629826	0.364212	0.324179	0.182817
56078.630856	0.366414	0.323696	0.182618
56078.631852	0.364324	0.322672	0.183004
56078.632847	0.365091	0.321368	0.183694
56078.633831	0.368045	0.325113	0.183039
56078.634861	0.367385	0.321144	0.183605
56078.635880	0.366289	0.321232	0.183825
56078.636910	0.369190	0.322037	0.183129
56078.637963	0.370359	0.323189	0.183824
56078.638993	0.371317	0.323152	0.184501
56078.640058	0.371903	0.322808	0.183325
56078.641100	0.374484	0.322872	0.184039
56078.642118	0.374274	0.321095	0.182869
56078.643183	0.375058	0.322234	0.183783
56078.644236	0.376458	0.321965	0.183243
56078.645336	0.376157	0.321411	0.182408
56078.646366	0.379135	0.322131	0.183457
56078.647419	0.380068	0.322619	0.183563

56078.648461	0.381537	0.323159	0.183937
56078.649525	0.384011	0.323458	0.183722
56078.650671	0.385972	0.322501	0.182994
56078.651667	0.386812	0.322535	0.182975
56078.652720	0.387904	0.321088	0.183259
56078.653715	0.391854	0.322317	0.184840
56078.654792	0.393402	0.321844	0.185357
56078.655868	0.394709	0.323777	0.182817
56078.656887	0.398261	0.321588	0.184449
56078.657951	0.399257	0.322429	0.183352
56078.658935	0.402919	0.322254	0.183464
56078.660035	0.402724	0.321651	0.182876
56078.661088	0.407436	0.320484	0.183777
56078.662095	0.407887	0.321921	0.181840
56078.663148	0.408728	0.321683	0.183396
56078.664144	0.410020	0.322637	0.183762
56078.665243	0.413063	0.320785	0.183624
56078.666296	0.414494	0.320356	0.184563
56078.667338	0.415833	0.322560	0.183711
56078.668391	0.417176	0.321986	0.183398
56078.669421	0.419659	0.323154	0.182975
56078.670567	0.421028	0.321725	0.182782
56078.671562	0.421442	0.323096	0.183921
56078.672558	0.423888	0.324017	0.182874
56078.673565	0.425396	0.324539	0.183965
56078.674606	0.427047	0.325577	0.183401
56078.675613	0.426917	0.324050	0.184330
56078.676620	0.429347	0.323507	0.183814
56078.677616	0.430574	0.324783	0.183201
56078.678646	0.430111	0.322950	0.183557
56078.679664	0.432844	0.322798	0.185105
56078.680660	0.432100	0.322386	0.184586
56078.681667	0.434718	0.323301	0.185536
56078.682708	0.436252	0.323848	0.184806
56078.683692	0.436576	0.324000	0.184578
56078.684664	0.439256	0.322540	0.185435
56078.684664	0.439257	0.322540	0.185435
56078.685637	0.442590	0.322682	0.185459
56078.687465	0.444215	0.320638	0.183536
56078.689097	0.445257	0.320504	0.183426
56078.690567	0.451578	0.321653	0.182524
56078.692326	0.454203	0.323332	0.183232
56078.694074	0.455826	0.325980	0.185360
56078.696794	0.459578	0.319882	0.183538
56078.698981	0.464234	0.321452	0.183229

56078.699873	0.464197	0.320902	0.183262
56078.701030	0.464378	0.320662	0.183410
56078.702002	0.463808	0.320597	0.184432
56078.702998	0.463337	0.320545	0.184451
56078.704005	0.465521	0.320899	0.183873
56078.705035	0.467192	0.320857	0.184509
56078.706053	0.469345	0.321095	0.183193
56078.707095	0.469430	0.321176	0.183607
56078.708102	0.470967	0.322221	0.182887
56078.709097	0.469358	0.321751	0.184740
56078.710139	0.464436	0.320571	0.184055
56078.711181	0.471339	0.321896	0.184660
56078.712234	0.471914	0.321022	0.183930
56078.713310	0.472627	0.321624	0.183490
56078.714340	0.475236	0.321891	0.183612
56078.715451	0.476848	0.321692	0.183959
56078.716539	0.476599	0.322306	0.183445
56078.717523	0.474551	0.320945	0.185603
56078.718600	0.475303	0.321185	0.184554
56078.719595	0.479762	0.320490	0.184285
56078.720741	0.479746	0.321994	0.183550
56078.721829	0.483233	0.320049	0.184453
56078.722859	0.482911	0.322087	0.184772
56078.723877	0.483686	0.319600	0.183952
56078.724850	0.483538	0.320229	0.184888
56078.725961	0.485983	0.322807	0.183955
56078.727037	0.487976	0.322262	0.184750
56078.728044	0.487718	0.320192	0.184787
56078.729016	0.486760	0.320566	0.184989
56078.729988	0.487871	0.319717	0.184128
56078.732118	0.486950	0.321049	0.184178
56078.733090	0.487922	0.320529	0.185474
56078.734167	0.486251	0.320228	0.185034
56078.735185	0.487185	0.320720	0.187154
56078.737211	0.488190	0.321060	0.186305
56078.738183	0.485404	0.319076	0.186385
56078.740255	0.485692	0.319419	0.185319
56078.741227	0.486289	0.317695	0.185333
56078.742292	0.486460	0.321002	0.185514
56078.743322	0.485408	0.320753	0.186330
56078.744294	0.483699	0.320429	0.186032
56078.745336	0.483571	0.320549	0.187331
56078.746331	0.484112	0.318618	0.185931
56078.747407	0.484232	0.321338	0.185699

LTHer on the night of 9/6/2012			
Julian Date: +2400000	Flux of Target Star	Flux of Comparison Star 1	Flux of Comparison Star 2
56088.607477	0.508345	0.317383	0.178191
56088.609514	0.511987	0.321902	0.178266
56088.612199	0.511382	0.322009	0.178408
56088.613183	0.512090	0.320904	0.179035
56088.614178	0.512097	0.321144	0.180034
56088.615185	0.512577	0.322413	0.179514
56088.616215	0.510367	0.321714	0.178264
56088.617188	0.511341	0.320625	0.178404
56088.618160	0.511149	0.320941	0.179180
56088.619144	0.513735	0.321931	0.179405
56088.620127	0.512737	0.320758	0.178619
56088.621100	0.513640	0.321706	0.178108
56088.622130	0.513923	0.322773	0.177879
56088.623125	0.512316	0.320936	0.179589
56088.624097	0.514122	0.322321	0.179818
56088.625081	0.513872	0.322330	0.179082
56088.626053	0.513458	0.321630	0.179886
56088.627049	0.514994	0.322085	0.178979
56088.628056	0.514145	0.322495	0.178688
56088.629051	0.516390	0.322352	0.178335
56088.630035	0.514508	0.322291	0.178349
56088.631007	0.516586	0.323442	0.179170
56088.631979	0.515771	0.321436	0.178399
56088.632998	0.517567	0.322354	0.177583
56088.633993	0.515408	0.320749	0.179347
56088.635000	0.513980	0.321163	0.178724
56088.635972	0.517895	0.322639	0.178700
56088.636944	0.515700	0.321859	0.179219
56088.637951	0.515086	0.321389	0.178111
56088.638947	0.519400	0.323368	0.178705
56088.640370	0.515394	0.320763	0.178129
56088.641400	0.514896	0.321753	0.177793
56088.642581	0.516914	0.321816	0.18