FINDING LIGHT CURVES

THE HIGH MASS X-RAY BINARY SYSTEM LPH 115

by

Tiffany Brown

A senior thesis submitted to the faculty of

Brigham Young University

in partial fulfillment of the requirements for the degree of

Bachelor of Science

Department of Physics and Astronomy

Brigham Young University

August 2008

BRIGHAM YOUNG UNIVERSITY

DEPARTMENT APPROVAL

of a senior thesis submitted by

Tiffany Brown

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

Date	Eric G. Hintz, Advisor
Date	Eric G. Hintz, Research Coordinator
Date	Ross Spencer, Chair

ABSTRACT

FINDING LIGHT CURVES

THE HIGH MASS X-RAY BINARY SYSTEM LPH 115

Tiffany Brown

Department of Physics and Astronomy

Senior Thesis

The high-mass x-ray binary system BD+53 2262 (LPH 115) was studied during spring and summer of 2007 and 2008 to determine its orbital period. No period had previously been documented for LPH 115 although it is thought to be a Be/X-Ray Binary which can have an orbital period from several weeks to years. Twenty nine nights of data were taken at the Orson Pratt Observatory on the 0.4 m David Derrick Telescope while twenty nights of data were obtained from the 0.81 m Tenagra Observatory Telescope. All the data was analyzed using classical differential photometry techniques. There was a slight upward trend for LPH 115 in 2007 while a point of minimum was seen in 2008. Also, only small amplitude short term variability was seen (about 0.05 magnitude amplitude). More data would make period determination for the long term variation possible. Some variation was also seen for comparison star 3 during a few nights in 2008.

ACKNOWLEDGMENTS

I would like to thank my advisor Dr. Hintz. His help and patience made all of this possible and his guidance and motivation helped me persevere. Also, I would like to thank Paul Iverson, Craig Swenson, and Natalie Porter for their IRAF scripts and willingness to help. If it weren't for them, I would still be staring at the computer blankly. I also have to thank everyone that observed on the telescope with me, keeping me awake during those endless nights. Finally, I would like to thank my parents and family for their never-ending motivation and support. They always believed in me.

Contents

List of Tables

List of Figures

Chapter 1

Introduction

1.1 Explanation of HMXB's and Goals

An X-ray binary is a system consisting of a compact object, such as a neutron star or black hole, and a companion star. There are two types of X-ray binary systems; low mass X-ray binaries (LMXB) and high mass X-ray binaries (HMXB). The difference between these classifications is that the second component is more massive than the compact object for HMXBs and less massive for LMXBs. This research consists of the former of the two therefore I will focus on HMXBs and their properties.

HMXBs are binary star systems in which one companion is a neutron star or black hole and the other is a massive O or Be spectral type star. Through various means, matter is transferred from the O or Be star to the neutron star or black hole. This process produces X-rays by converting gravitational energy to light as the gas in the accretion disk is transferred from one object to the other. An accretion disk is formed when mass flowing towards the compact object causes the angular momentum to move outward.

There are two classifications for HMXBs depending on the companion star. SG/X-ray binaries are shorter in period (a few days) and the companion is usually an O or B type supergiant. Be/X-ray binaries are longer in period (from a few weeks to a few years) and usually has a swiftly rotating Be type companion. This type of HMXB usually loses its mass through stellar winds and an equatorial bulge caused by its quick rotations. The mass loss is accreted to the compact object and produces X-rays as discussed previously.

BD+53 2262 (hereafter called LPH 115) is thought to be a Be/X-ray binary although its orbital period is uncertain. Figure 1.1 shows the star field with LPH 115

Figure 1.1: LPH 115 Star Field
(LPH 115 is in the Center)

at its center. For most of the HMXBs in the LPH catalogue (see section 1.2) orbital periods are unknown (only 47 out of 130 are known) (Lui et al. (2000) and Bosch et al. (2005)). The goal was to find these periods in order to more accurately understand the system and its components. Some of these could possibly be long periods ranging up to one or two years in length. Initially observing what it is doing has helped us know if LPH 115 has one of these long periods.

My goal was to find and verify the period of the HMXB system LPH 115. This was done by observing the target for several nights over the course of a number of months for two years. Once this was accomplished I analyzed the stars using standard IRAF techniques. I then plotted the light curves to find whether LPH 115 had a long orbital period.

1.2 Previous Observations and Documentation

During the spring and summer of 2007 and 2008, a set of data was taken at Brigham Young University on LPH 115 using the Orson Pratt Observatory on the

0.4 *m* David Derrick Telescope. Eleven nights of data were obtained in 2007 and eighteen nights in 2008. These observations were analyzed using classical differential photometry techniques in IRAF. Also during the spring of 2007, 20 nights of data were taken using the 32 in. telescope at the Tenagra Observatory in Arizona. This set of data was also analyzed in IRAF using the same techniques.

No optical period has previously been determined for LPH 115 although it is thought to be a Be/X-Ray Binary which can have an orbital period from several weeks to years. This system was especially unexamined and, therefore, there was a need of observing this system in order to find unknown periodic variations.

LPH 115 was among a number of HMXB's presented in a catalogue published by Lui et al. (2000). A paper by Sarty et al. (2007) called for amateur astronomers to assist in an AAVSO (American Association of Variable Star Observers) campaign to find the optical periods of several HMXB's listed in the LPH catalogue. LPH 115 was chosen for observation because it was one of the main targets for which they requested help.

Chapter 2

Observation and Analysis

2.1 Observations and Instrumentation

2.1.1 Observations

Eleven nights of photometric observations were obtained in 2007 at the Orson Pratt Observatory on the Brigham Young University campus. The night of May 12th had poor weather conditions making that night's data less accurate. During 2008, eighteen nights of data were taken at the OPO in order to better determine if any variability existed in LPH 115 compared to the previous year.

Twenty nights of data were taken from April through June 2007 using the Tenagra Observatory in Southern Arizona. All of these nights had problems with their calibration frames. This caused problems with data acquisition which will be discussed in section 2.2.

2.1.2 Instrumentation

Orson Pratt Observatory

The David Derrick Telescope (DDT) was used for obtaining the data at the Orson Pratt Observatory. It is located in the Erying Science Center at Brigham Young University.

The DDT is a reflecting telescope, meaning it uses mirrors instead of lenses to reflect and focus the incoming light. The aperture is 0.4 m in diameter. There are two types of foci on the DDT: Newtonian and Cassegrain. The Newtonian reflects the light from the primary mirror to a tilted secondary mirror sending the light out the side of the telescope. The Cassegrain focus bounces the light from the primary to a convex secondary mirror which then brings the light to a hole in the middle of the primary where it exits the telescope. These different focuses give the DDT two different focal ratios and thus focal lengths which affect the type of camera needed for data acquisition. The focal length is the length the light travels through the telescope to a detecter where all the light focuses. The focal ratio of the Newtonian is f/4 while the focal ratio of the Cassegrain is f/12.5. When the f-number of the focal ratio is multiplied by the aperture size it gives the focal length. For the Cassegrain focus it's f-number is 12.5 so the focal length is determined to be 5075 mm. The Newtonian focus has an f-number of 4 giving a focal length of 1624 mm. The focal length effects the plate scale which is basically a ratio that determines how large an image will appear on a detecter, whether that be a camera or an eyepiece. The plate scale can be calculated by dividing $206,265''$ by the focal length. For the Newtonian, the plate scale is $127''.01\ mm^{-1}$. The Cassegrain has a plate scale of $40''.64\ mm^{-1}$.

The plate scale has a large effect on what detector fits best with a telescope. A charged-coupled device (CCD) is the type of detector used today in optical astronomy. It is similar to the technology for a digital camera but is much more powerful and of higher quality. It basically consists of an array of photon counters that collects the photons, turns them into electrons, and stores them in the "wells." Figure 2.1 displays this idea of collecting light. The type of CCD camera that best fits with a particular telescope can be calculated using the plate scale. For the Utah Valley $1''\text{pixel}^{-1}$ is an ideal value. Multiplying the plate scale of the telescope by the pixel size of the CCD shows us if the combination of the two is a good choice. The CCD used in all OPO observations of LPH 115 is the ST-10 which has a pixel size of 6.8μpixels. This gives a value of $0''.276\ \text{pixel}^{-1}$ for the Cassegrain focus on the DDT and $0''.86\ \text{pixel}^{-1}$ on the Newtonian focus. The ST-10 is primarily used at the Newtonian focus since it's value is closest to $1''\text{pixel}^{-1}$.

The field of view is the amount of sky that can be viewed with the CCD/telescope combination. To find this, multiply the number of pixels by the size per pixel. For the ST-10 it has 2184×1472 pixels multiplied by $0''.276\ \text{pixel}^{-1}$ with the Cassegrain gives a field of view of 10.2' $\times$ 6.9'. The Newtonian focus with the ST-10 has a field

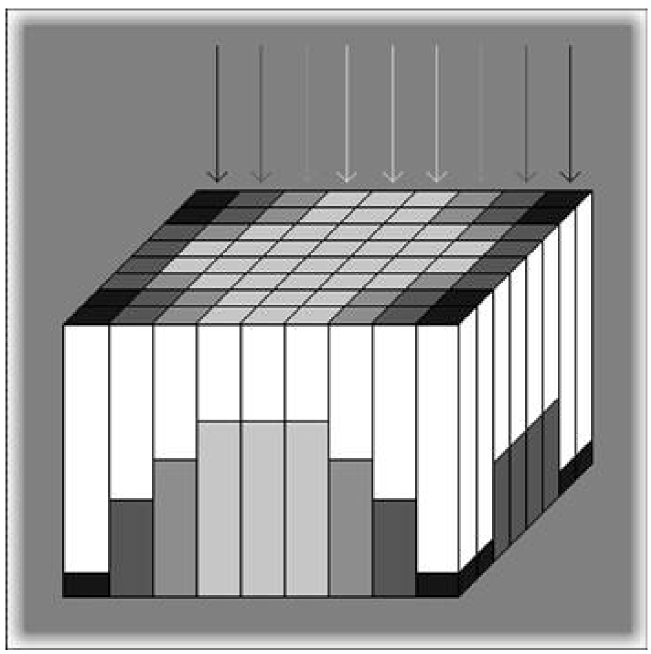

Figure 2.1: Array of “wells” in a CCD to count photons.

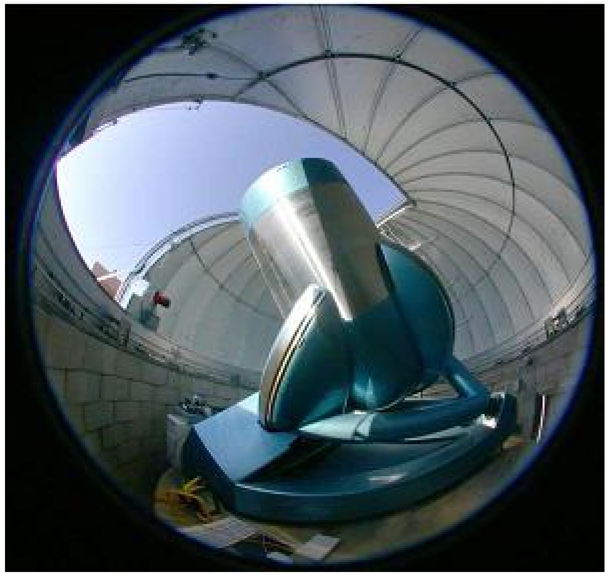

Figure 2.2: Tenagra Telescope
Tenagra Observatories (Ltd.)

of view of 31.3' × 21'. This is another reason the Newtonian focus was used with the ST-10. The standard Johnson *BVR* filters were used in obtaining the data.

Tenagra Observatory

The 32 in. (0.81 m) telescope at the Tenagra Observatory was used to acquire twenty nights of data on LPH 115. The Tenagra Observatory is a fully automated observatory located in the Sonoran Desert in Southern Arizona. It is at an altitude of 1312 m with excellent seeing almost year round. (The average night will have $2''$ FWHM seeing.)

The 32 in. telescope is combined with a SITe based CCD that is consistently cooled at $-40°$C. It has a plate scale value of $0.''87$ pixel^{-1} which gives a field of view of 14.8' × 14.8'. Again the standard Johnson *BVR* filters were used to obtain data(Tenagra Observatories (Ltd.)).

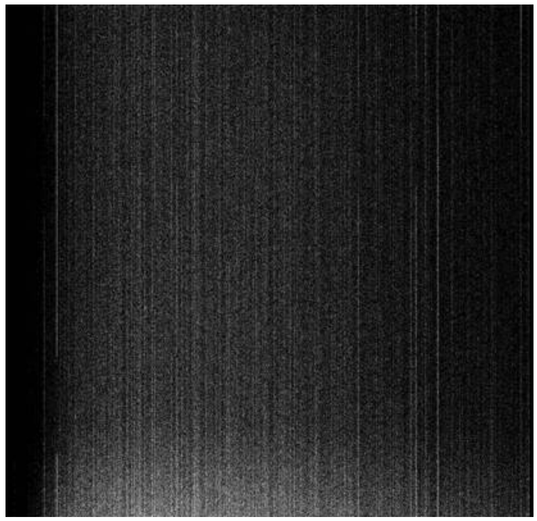

Figure 2.3: Bias (Zero) Frame

2.2 Analysis

2.2.1 Calibration Frames

CCD's are good detectors for telescopes but there are a few problems that have to be considered. To fix these problems, three types of calibration frames are used. Specific methods vary with observatory and astronomer but the basic idea is the same.

Bias Frame

The first type of calibration frame taken is the bias or zero frame. This type is needed since there are always extra electrons in the "wells" of the CCD even when no light is hitting the array. Each pixel can have a different amount leftover and each pixel can respond differently to those electrons. This extra noise will appear in the data if it is not subtracted out of each frame. A zero second exposure will detect these electrons and account for the noise.

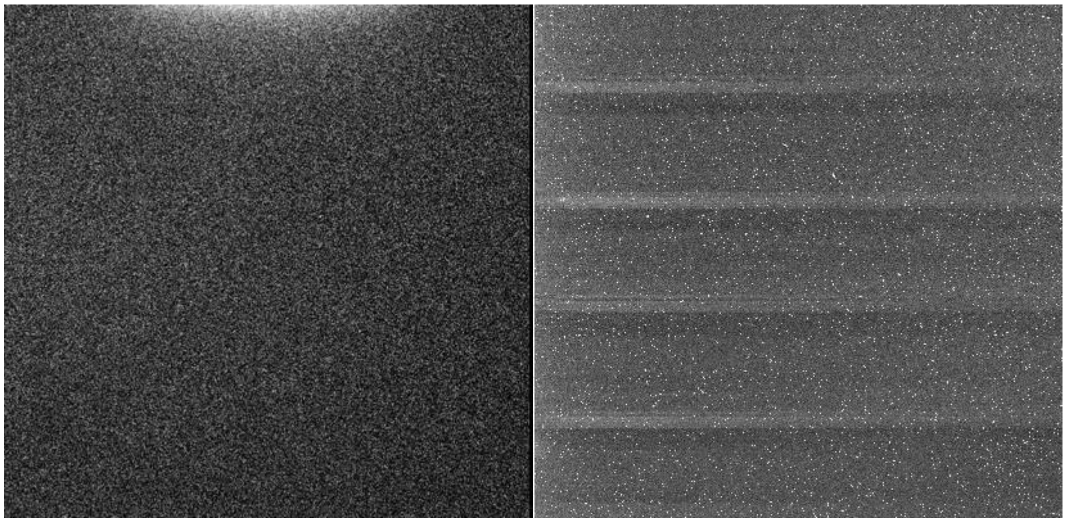

Figure 2.4: Normal dark frame (left) versus Tenagra dark frame (right)

Dark Frame

A dark frame is a calibration frame taken with the shutter closed so no photons can enter the CCD. Even with no light hitting the camera, there are still electronics connected to it that may cause extra electrons to enter the array. Each pixel can react differently to these electrons. Extremely low temperatures of the CCD can reduce the number of electrons affecting the array. This is the reason CCD's are cooled to low temperatures such as $-20°C$ at the Orson Pratt Observatory. The data obtained from the Tenagra Observatory had bands across the dark frames which showed in the image frames after being reduced. There was no means of correcting for these bands and therefore the images used from Tenagra were less reliable than those from the OPO. An example dark frame can be seen in figure 2.4 compared to a Tenagra dark frame.

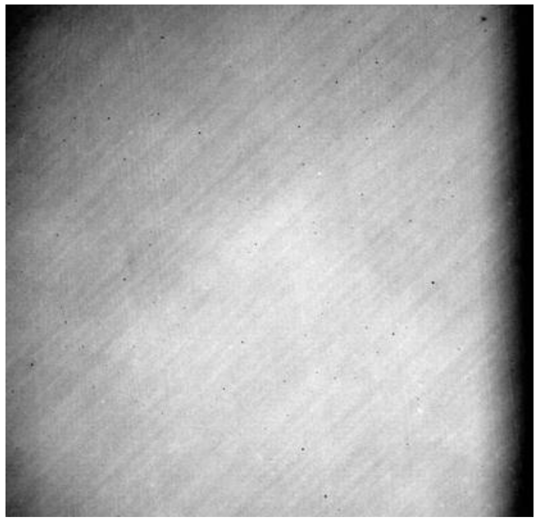

Figure 2.5: Flat Frame

Flat Frame

Each pixel in the CCD array can react differently to incoming light. To correct for this a flat image is subtracted from each frame. The idea is to take a frame with equal brightness across the entire array. There are a number of methods to accomplish this, but the one primarily used with the DDT is to aim the telescope at a piece of sky with fairly consistent brightness and image it. This is best done at dusk or dawn when the sun is not in the sky but there are no stars out either. Flat frames are the trickiest calibration frames to obtain, but the ones most needed to subtract from the object frames.

2.2.2 IRAF

To subtract the calibration frames from the object frames, a computer program must be used. The program primarily used at BYU is the Image Reduction and Analysis Facility (IRAF). It is an image processing progam for Linux/Unix that was created from a government contract with National Optical Astronomy Observatories (NOAO). This program takes the the bias images and averages them. The average is then subtracted from the dark frames. An average can then be taken of the dark frames which will be subtracted from the flat frames. After these are subtracted from the flat frames, the flat frames can be averaged as well. This final average is subtracted from the object frames for that night. The object frames can then be processed.

Each object frame has to go through a process called *photing* which basically counts the number of photons that hit each pixel for specific stars in your frame. Once each object frame has been processed using the *phot* package in IRAF, the data can be sent through a program entitled varstar5. The basic idea of this program is that it calculates differential magnitudes for specific stars in your field.(Mennickent (1994))

Once varstar5 was run for the LPH 115 observations, the resulting data files were used to obtain apparent magnitudes. This was achieved by initially setting the first frame on the night of May 7, 2007 taken at the DDT as an arbitrary zeropoint for all other nights. After this, an average difference from the zeropoint was found for each frame on every night. LPH 115 was excluded from this average since it was thought to be varying. This average was then subtracted from each frame to produce an apparent magnitude for all the stars.

Only five comparison stars where used for photometric analysis. These stars were chosen using the suggestions given in the paper by Sarty et al. (2007). They were used initially assuming consistency in brightness to compare to the variations in LPH 115. Table 2.1 shows the coordinates of LPH 115 and the five comparison stars.

For graphing and analyzing purposes, a constant of two magnitudes were subtracted from star six for all frames since its magnitude was significantly lower than the other five stars.

Table 2.1: Comparison Stars

Star	Reference	RA	Dec
1	BD+53 2262 (LPH 115)	19 32 52.31	+53 52 45.5
2	HD 184658	19 32 44.53	+53 49 39.5
3	GSC 03921-01933	19 32 09.51	+53 53 34.9
4	GSC 03934-00892	19 33 32.14	+53 58 19.9
5	unknown	19 32 57.72	+53 53 38.6
6	unknown	19 32 45	+53 55 06

After the apparent magnitudes of the five comparison stars and LPH 115 were obtained, light curves were plotted for the system in each filter. A light curve is simply a graph of magnitude versus the Heliocentric Julian Date (HJD).

Chapter 3

Results

3.1 Results

A number of observation were taken during 2007 and 2008 in the B, V, and R filters. Table 3.1 states how many nights of data were obtained at each observatory.

Table 3.1: Number of Nights of Data Taken

Year	Observatory	B	V	R
2007	Orson Pratt Observatory	1	11	5
2007	Tenagra Observatory	16	11	0
2008	Orson Pratt Observatory	2	18	2

3.1.1 R Filter

Comparison star number three on the first night in 2007 appears comparatively deep while the others are shallow (see fig. 3.6). This could be a sign of variability or instability in the star. As for LPH 115, there was no large amplitude variation noted although with only seven nights of data there could still be long term variation which wasn't seen here. Figure 3.1 shows the light curves for LPH 115 along with all the comparison stars, showing it's stability. The next two figures (fig. 3.2 and fig. 3.3) divide those light curves into 2007 and 2008. A closer look at only LPH 115 (see fig. 3.5) reveals only small amplitude variation (less than 0.1 magnitude) which is most likely just extra noise that was left over in the frames.

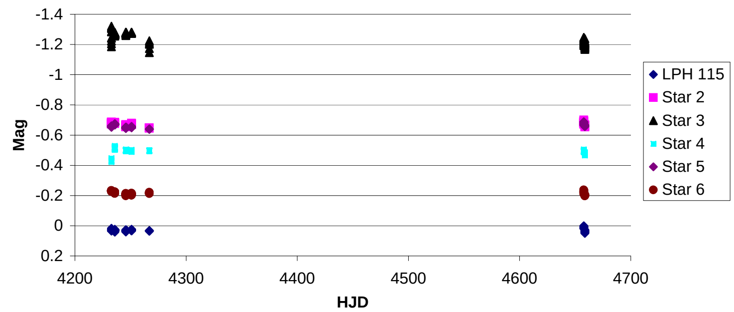

Figure 3.1: R filter light curves for all stars throughout 2007 and 2008

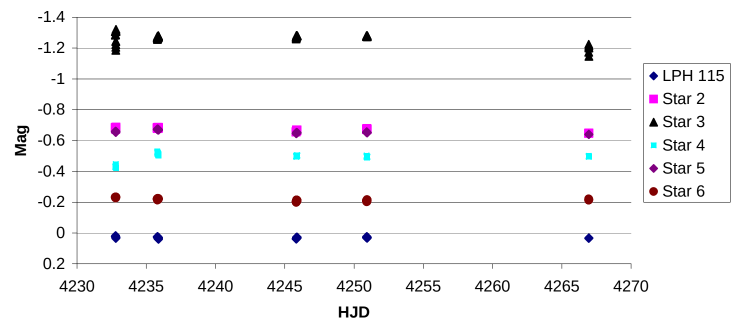

Figure 3.2: R filter light curve for just 2007

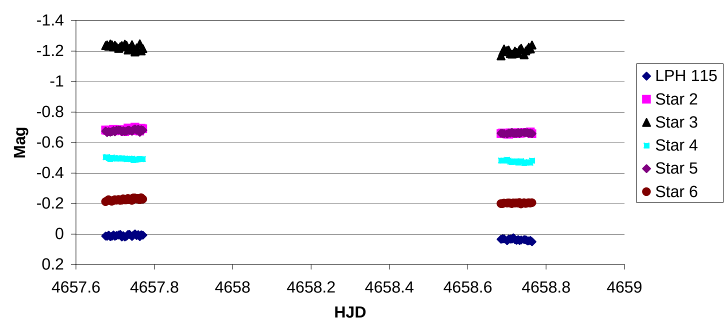

Figure 3.3: R filter light curve for just 2008

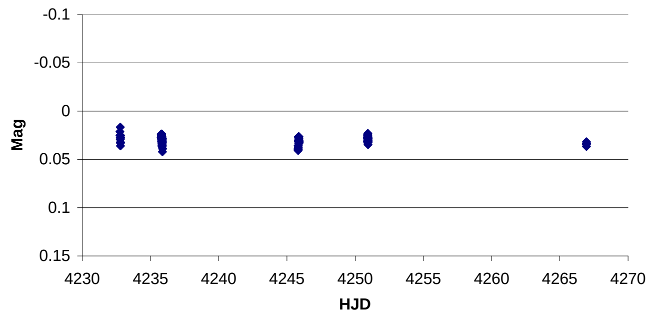

Figure 3.4: R filter light curve for LPH 115 in 2007

3.1.2 *B* Filter

Observations in the *B* filter were only obtained for one night at the OPO in 2007. Again, very small variations are present (amplitude about 0.01 magnitude) but mostly likely as a result of extra noise in the data. In 2008 two more nights were added from the OPO. Sixteen more nights from the Tenagra Observatory were added to contribute to the baseline data in the *B* filter. This data was not extremely accurate due to the banding patterns in the calibration frames. Overall, no long term variation could be seen in LPH 115 (see fig. 3.8). Star three stayed fairly stable in the *B* filter except at the end of the night on July 10, 2008 (see fig. 3.9). Figure 3.7 shows light curves for LPH 115 with its comparison stars.

3.1.3 *V* Filter

Star three showed signs of variability on a few nights in 2008 (see fig. 3.18). There was also a general downward trend for star three in 2008 overall (see fig. 3.17). More study of this star is needed to solidify this evidence and determine a period.

For LPH 115 there is virtually no variation for the duration of each individual night except for a few in 2008 where some very short amplitude variation can be seen (about 0.05 magnitude amplitude) (see fig. 3.16). There are three nights in 2007 where two of the comparison stars jump in magnitude (in phase with each other)

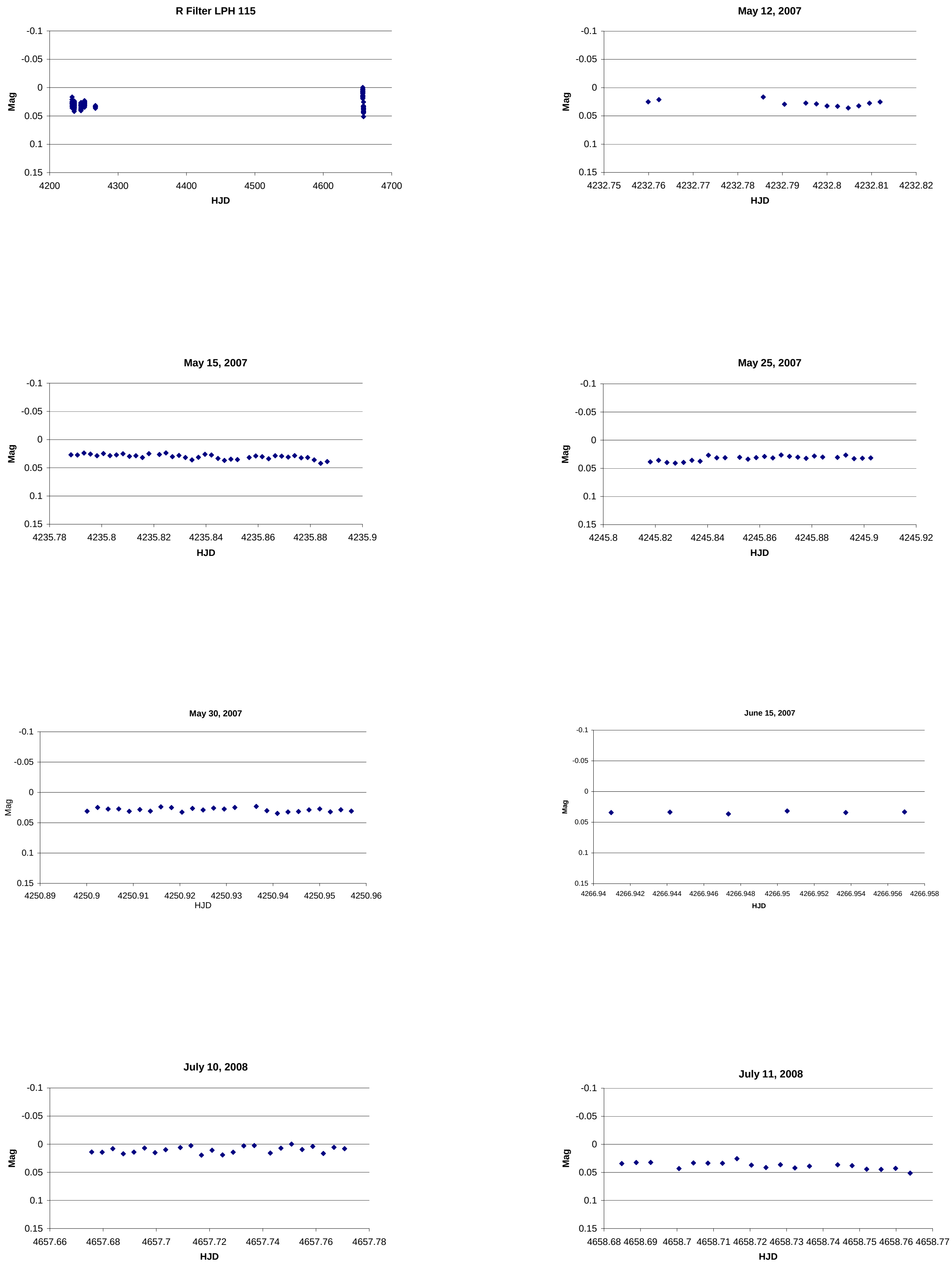

Figure 3.5: R filter light curves for LPH 115 (top left is all nights)

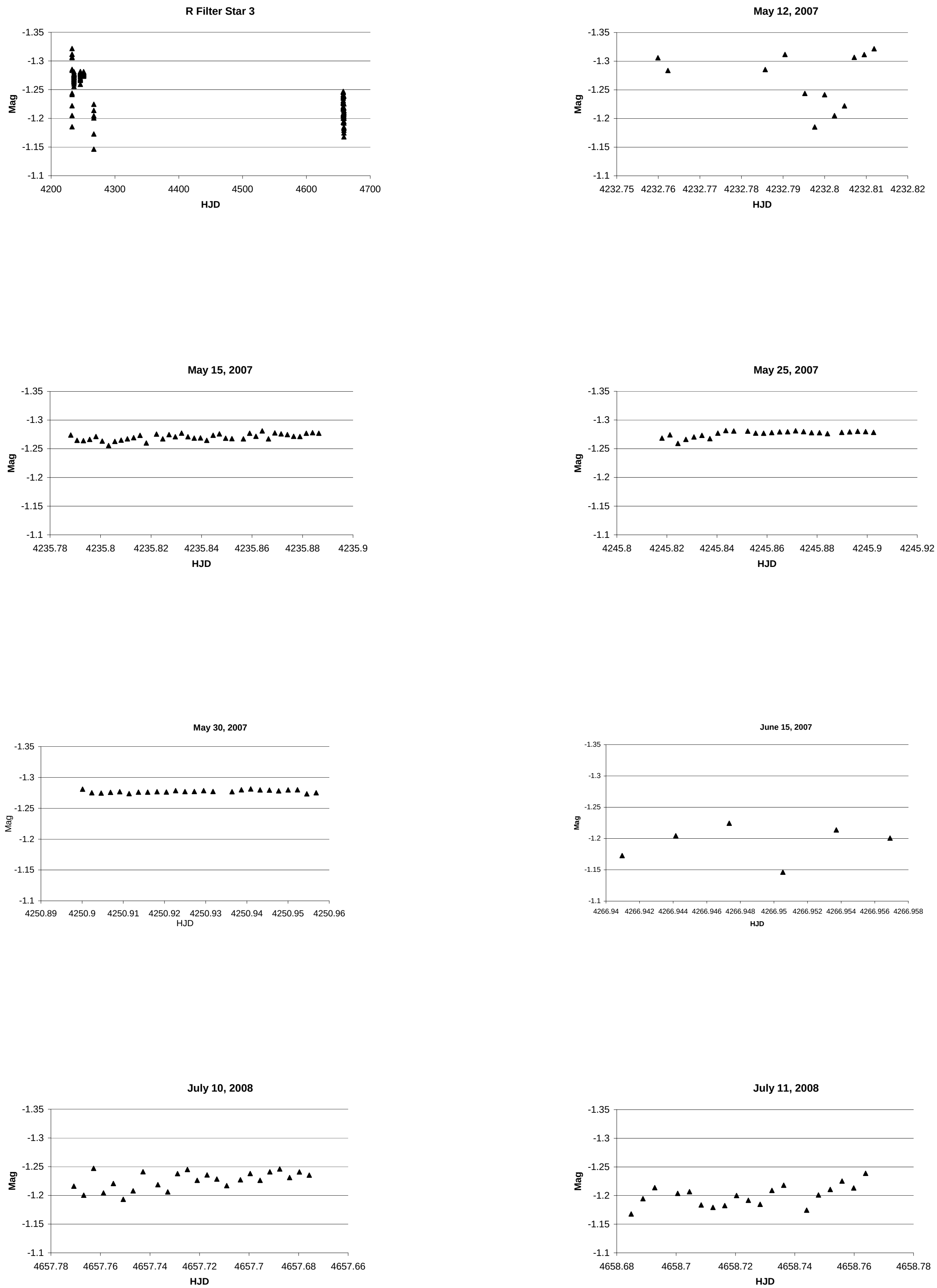

Figure 3.6: R filter light curves for star 3 (top left is all nights)

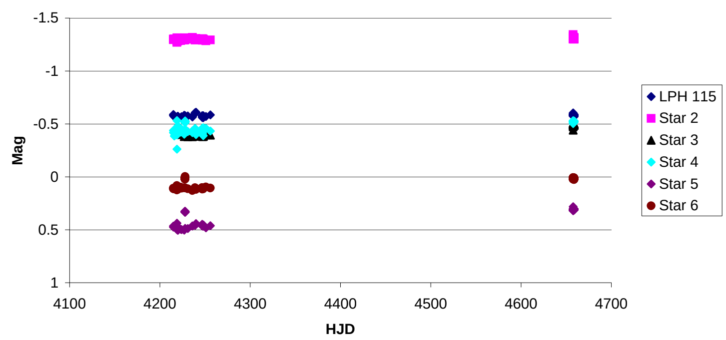

Figure 3.7: B filter light curves for all stars throughout 2007 and 2008

thus altering the data for the other stars including LPH 115. This is possibly caused by the variation in star three. In figures 3.11 and 3.14 the three points of skewed data can be seen. If these skewed nights are not included in the overall data set, then LPH 115 shows no large amplitude variations over the course of 2007 and 2008. A closer look at 2007 by itself shows a general upward trend (see fig. 3.14). In 2008 a definite variation can be seen (about 0.1 magnitude amplitude) with a distinct dip downward in the middle of the data set (see fig. 3.15). Long term variability is definately present in LPH 115, but there is not enough data for period determination.

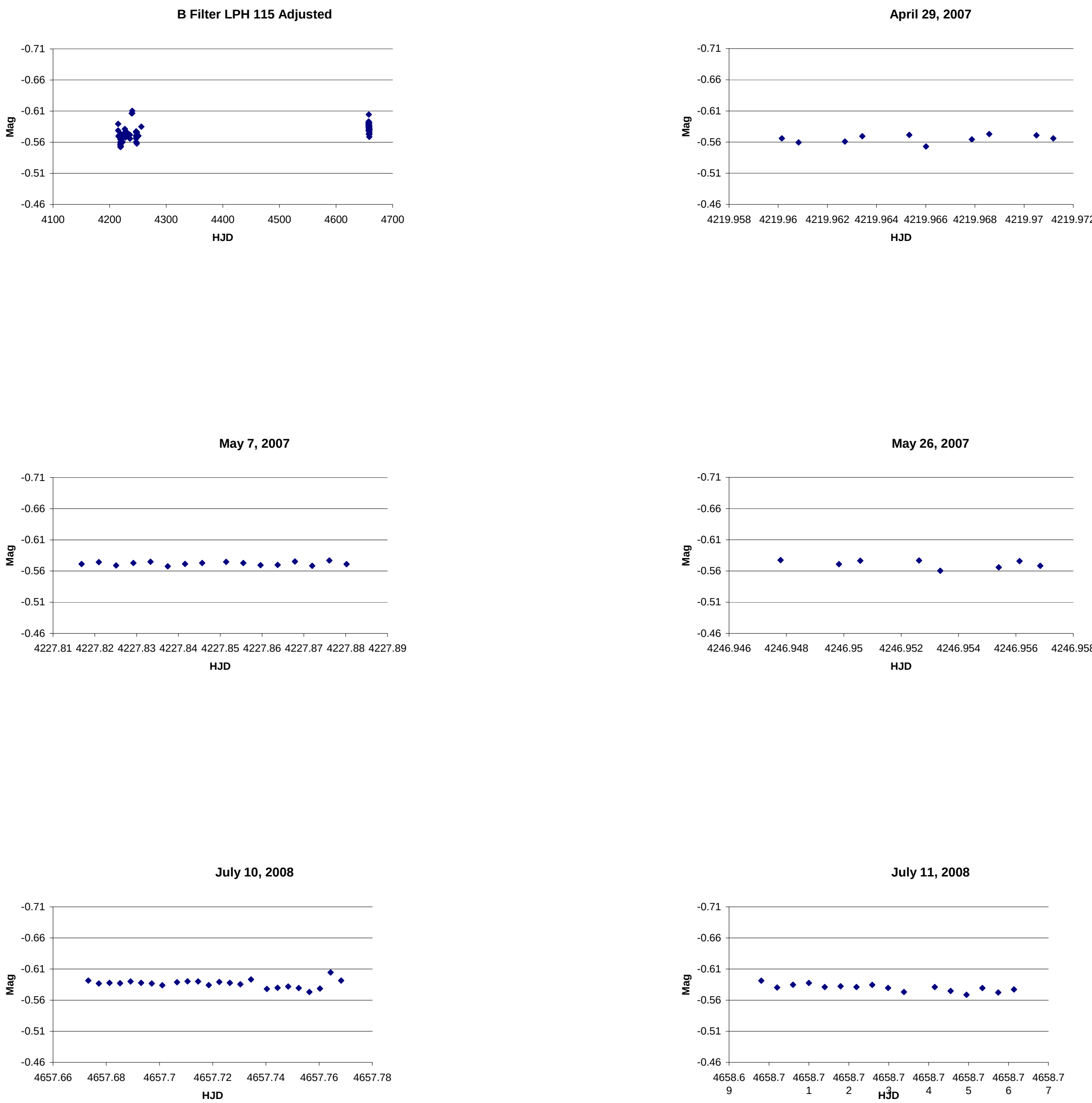

Figure 3.8: A few B filter light curves for LPH 115 (top left is all nights)
April 29, 2008 and May 26, 2007 are from Tenagra. The small fluctuations in those nights are probably from banding patterns in the calibration frames.

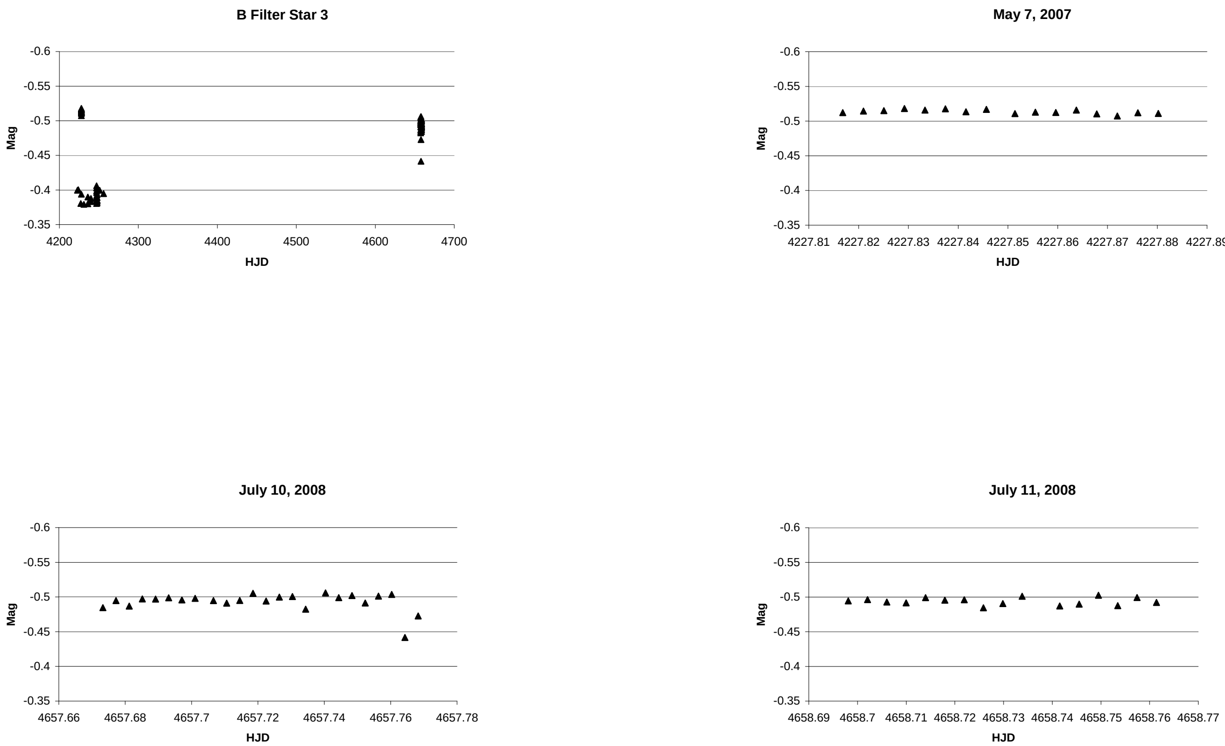

Figure 3.9: B filter light curves for star 3 (top left is all nights)

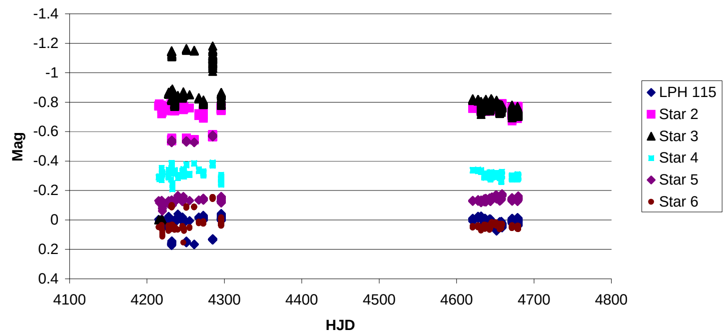

Figure 3.10: V filter light curves for all stars throughout 2007 and 2008

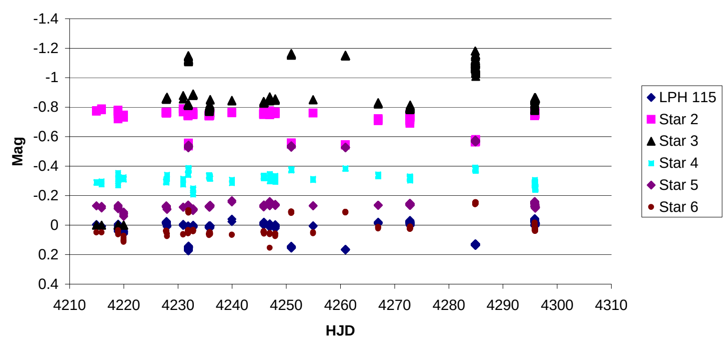

Figure 3.11: V filter light curve for just 2007

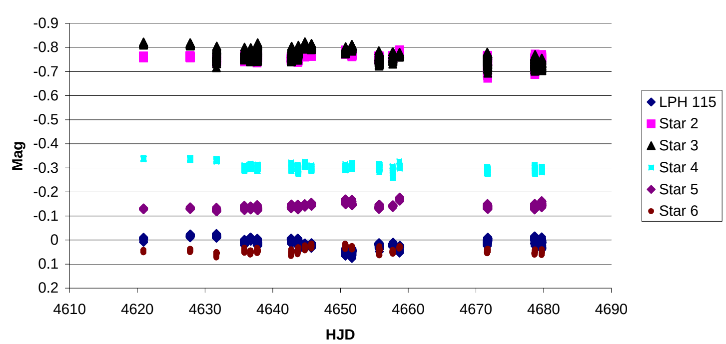

Figure 3.12: V filter light curve for just 2008

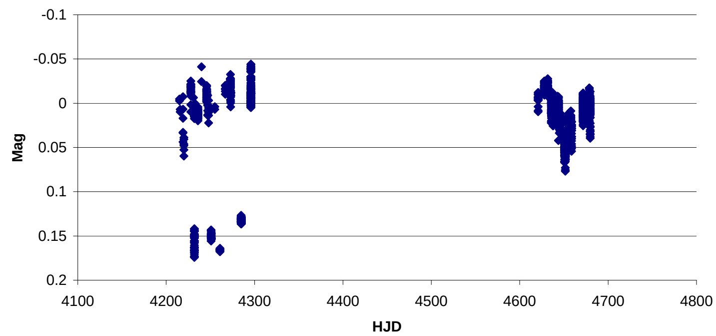

Figure 3.13: V filter light curves for LPH 115 throughout 2007 and 2008

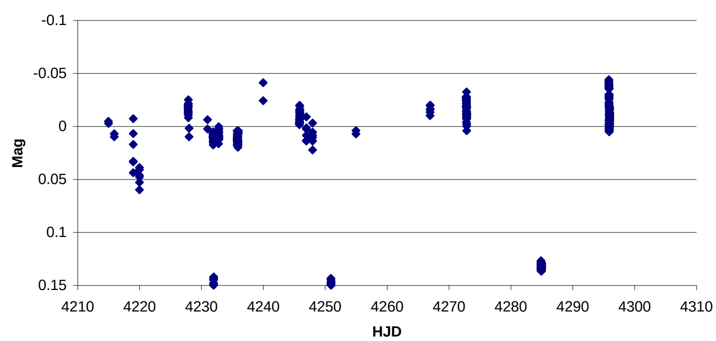

Figure 3.14: V filter light curve of LPH 115 in 2007 (The three points at the bottom are the skewed nights of data)

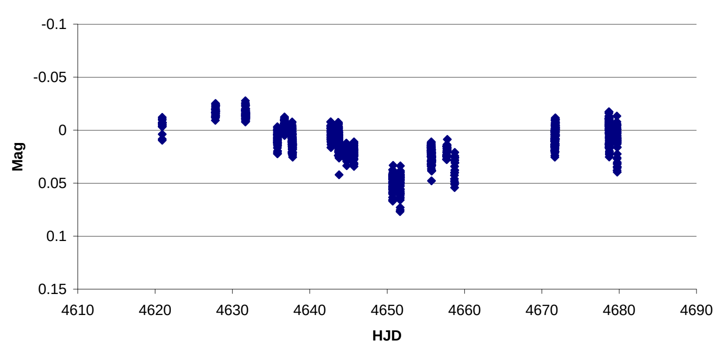

Figure 3.15: V filter light curve for LPH 115 in 2008

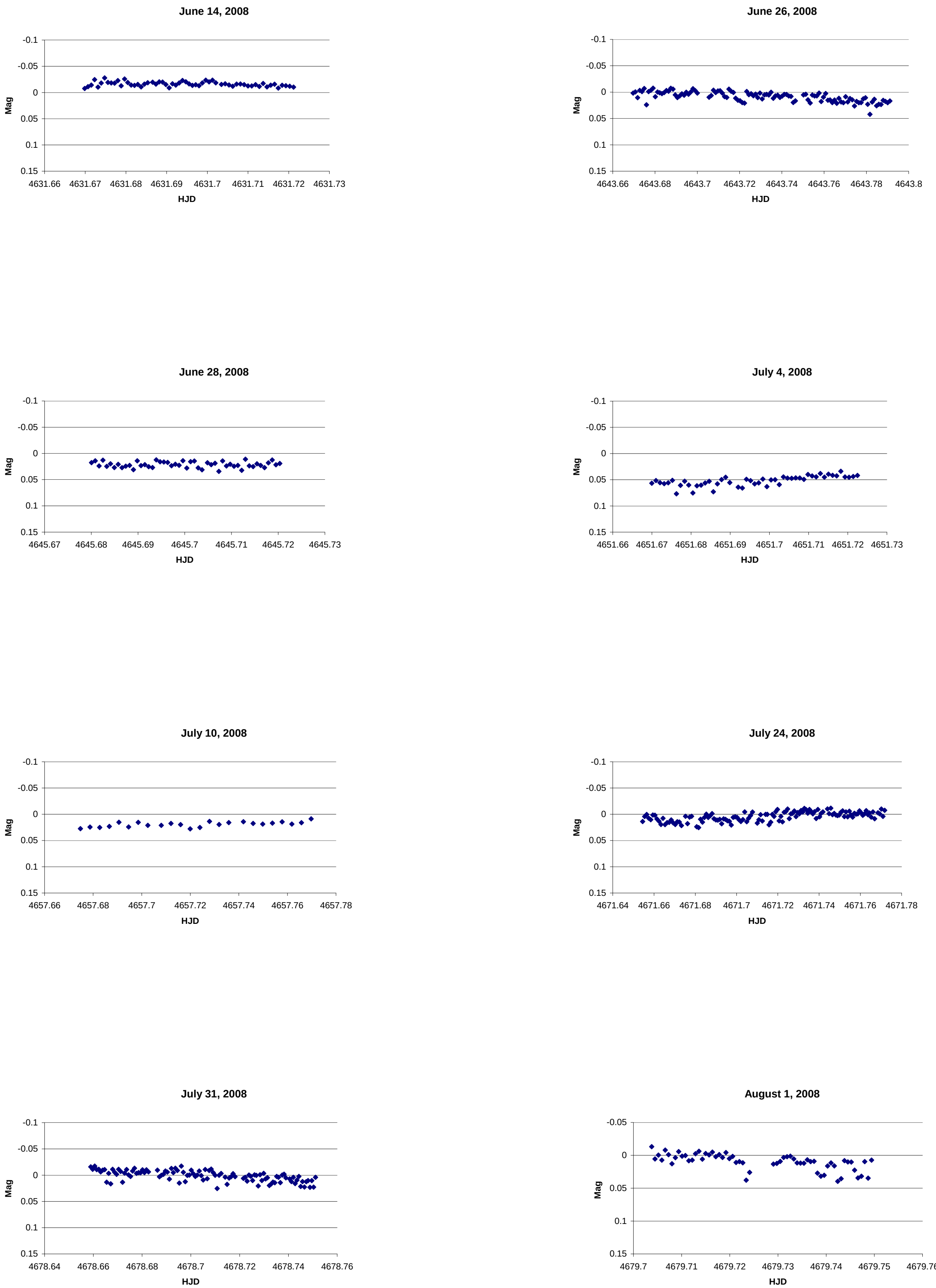

Figure 3.16: A few V filter light curves for LPH 115

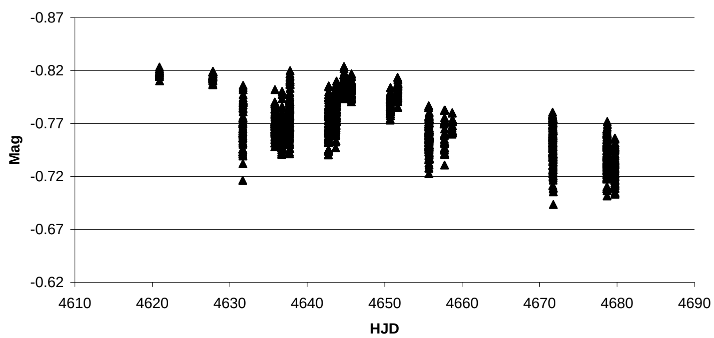

Figure 3.17: V filter light curves for comparison star 3 in 2008

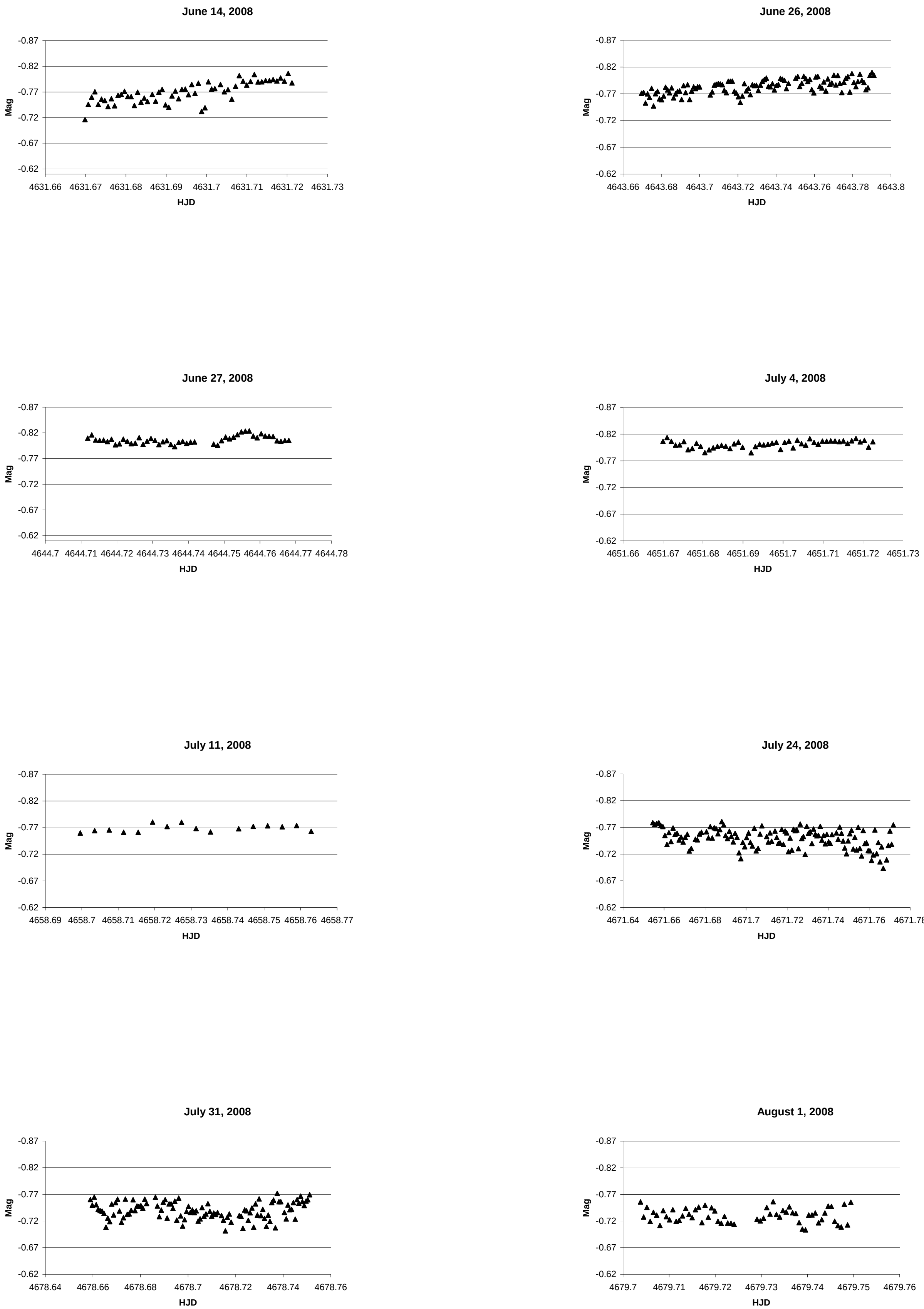

Figure 3.18: A few V filter light curves for comparison star 3

Chapter 4

Conclusions

4.1 Conclusions

From observations taken on the HMXB system LPH 115 the B, V, and R filters where found to be varying on a small amplitude scale (0.1 magnitude or less). Star 3 was found on a number of nights to be varying on a short term scale. Long term variation in LPH 115 is definitely present but there was not enough data to deduce a period since the time frame would not allow it. Adding the acquired data to the AAVSO campaign data will significantly increase the baseline of data on LPH 115. In 2007 there was a slight upward trend while a point of minimum occurred in 2008. It is probable that another minimum could appear in 2009 (possibly during the beginning of June) if it stays consistent. Continued observation of LPH 115 will provide ability for period determination.

References

Sarty, G. E. and Kiss, L. L. and Johnston, H. M. and Huziak, R. and Wu, K., ArXiv Astrophysics e-prints, 2007, astro-ph/0702248, 1

Liu, Q. Z. and van Paradijs, J. and van den Heuvel, E. P. J., A&AS, 2000, 147, 25-49

Bosch-Ramon, V. and Paredes, J. M. and Ribó, M. and Miller, J. M. and Reig, P. and Martí, J., ApJ, 2005, 628, 388-394

Tenagra Observatories, Ltd., (http://www.tenagraobservatories.com/)

SIMBAD database 2008, (http://simbad.u-strasbg.fr/simbad/sim-fid)

Merrill, P. W. and Burwell, C. G., ApJ, 1950, 112, 72

Mennickent, R. E. and Vogt, N. and Sterken, C., A&AS, 1994, 108, 237-250

Appendix A

Scripts

A few of the scripts used in image reduction and processing in IRAF are listed here.

A.1 tiffrfits.cl

A cl script for rfits-ing calibration frames from Tenagra by Tiffany Brown

rfits B*.fit ”” zero

rfits D*.fit ”” dark

rfits Flat*B*.fit ”” flatb rfits Flat*R*.fit ”” flatr rfits Flat*V*.fit ”” flatv

A.2 tcalhead.cl

Here is a script for updating the headers.

tcalhead.cl by Paul Iverson, edited by Alie Porter

hedit flatv*.fits SUBSET ”V” ver-

hedit flatb*.fits SUBSET ”B” ver-

hedit flatr*.fits SUBSET ”R” ver-

hedit zero*.fits IMAGETYP zero ver-

hedit dark*.fits IMAGETYP dark ver-

hedit flat*.fits IMAGETYP flat ver-

hedit zero*.fits OBJECT Zero ver-

hedit dark*.fits OBJECT Dark ver-

hedit flatv*.fits OBJECT ”Flat V” ver-

hedit flatb*.fits OBJECT ”Flat B” ver-

hedit flatr*.fits OBJECT ”Flat R” ver-

hedit flatv*.fits FILTER ”V” ver-

```
hedit flatb*.fits FILTER "B" ver-
hedit flatr*.fits FILTER "R" ver-
```

A.3 tdateobhead.cl

Here is a script to finish updating the headers.

tdateobhead.cl modified slightly from Joner's ten1headfix.cl by Paul Iverson

```
hedit lph*.fits OBSERVAT "ten" add+ ver-
hedit lphv*.fits SUBSET "V" add+ ver-
hedit lphb*.fits SUBSET "B" add+ ver-
hedit lphr*.fits SUBSET "R" add+ ver-
hedit lph*.fits IMAGETYP object ver-

hedit lph*.fits OBSERVER "BYU-Tiffany Brown" addonly- ver-

hedit lph*.fits RA "19:32:52.31" add+ ver-
hedit lph*.fits RA "19:32:52.31" add+ ver-
hedit lph*.fits DEC "53:52:45.5" add+ ver-
hedit lph*.fits DEC "+53:52:45.5" add+ ver-

hedit lph*.fits EPOCH '2000.0' add+ ver-
hselect lph*.fits $I,DATE-OBS yes > datalist1
!sed "s/[0-9-]*[T]//g" datalist1 > datalist2
list = "datalist2"
while (fscan (list, s1, s2) != EOF)
hedit (s1, "UT", s2, add+, ver-)
del datalist1
del datalist2
```

```
!echo ”st = mst(@’DATE-OBS’, UT, obsdb (observat, l̈ongitude)̈)” > st.cmds
asthedit lph*.fits st.cmds table=“” verbose+
del st.cmds

setairmass lph*.fits
setjd lph*.fits
```

A.4 tproc.cl

Here is a script for reducing the calibration frames.

tproc.cl by Paul Iverson, edited by Tiffany Brown

```
zerocombine zero*.fits

ccdproc.ccdtype = ”dark”
ccdproc.zero = ”Zero.fits”

beep beep
disp Zero.fits

ccdproc dark*.fits zerocor+ darkcor- flatcor-
darkcombine dark*.fits

ccdproc.ccdtype = ”flat”
ccdproc.zero = ”Zero.fits”
ccdproc.dark = ”Dark.fits”

beep beep
disp Dark.fits
```

```
ccdproc flat*.fits zerocor+ darkcor+ flatcor-
flatcombine flat*.fits subsets+

ccdproc.ccdtype = "object"
ccdproc.zero = "Zero.fits"
ccdproc.dark = "Dark.fits"
ccdproc.flat = "Flat*.fits"

beep beep
disp FlatV.fits
disp FlatB.fits
disp FlatR.fits

ccdproc lph*.fits zerocor+ darkcor+ flatcor+

beep beep
disp lphv*01.fits
disp lphb*01.fits
disp lphr*01.fits
```

A.5 anightphot4.cl

Here is a script for *photing* the frames. NIGHTPHOT – IRAF script designed to make photing a million files a lot easier without having to do each frame individually.

```
$procedure anightphot4 (images, center_file)

string images prompt="Root name of images to phot"
string center_file prompt="File of approximate centers (ds9.reg)"
```

```
struct *list, *list2

begin
Local variables
string imagelist
string img
string imgroot
string coordfile, tmp5
int i, end1, end2, tmp1, tmp2, tmp3, tmp4, tmp6
real temp, FWHM, temp3, intfwhm, inthwhm #temp2

Make sure the noao and apphot or daophot packages are loaded
if (! defpac (”digiphot”)) {
print (”You have not loaded the apphot or daophot package.”)
print (”One of these packages must be loaded before continuing.”)
bye
}

Create a text file list of images to phot.
imagelist = mktemp (”tmp$night”)
imgroot = images
sections (imgroot//”*”, > imagelist)

Open the list of images and scan through it.
list = imagelist
coordfile = center_file
#print (”What is your starting FWHM value from IMEXAM”)
#scanf (”%f”, intfwhm)
```

```
while (fscan (list, img) != EOF)

# Display the current image frame in frame 1. This allows the
# frame to appear fresh without markings, etc.
display (img, 1)

# Call the tvmark command to allow the user to see if his/her stars
# are correctly centered.
tvmark (1, coords=coordfile)

# Ask the user to input whether to continue or not.
end1 = 0
while (end1 == 0){
print ("Are your stars marked and labeled correctly? (0 if no, 1 if yes)")
scanf ("%d",tmp3)
if (tmp3 != 0 && tmp3 != 1)
print ("You entered an incorrect response!")
if (tmp3 == 0){
while (tmp3 == 0) {
display (img, 1)
print ("Please re-mark the stars and save as "ds9.reg"")
print ("Once you are done please enter 1 to continue.")
scanf ("
if (tmp4 != 1)
print ("You entered an incorrect response!")
if (tmp4 == 1)
tmp3 = 1
}
}
```

```
if (tmp3 == 1){
coordfile = "ds9.reg"
end1 = 1
}
}

# PSFMeasure Command
# psfmeasure(img,imagecu="ds9.reg")#Tells psf to use the reg file as input
# print ("Input the FWHM values determined by PSFMeasure")
# scanf ("%f", intfwhm)
# hedit (img, fields="FWHM", value=intfwhm)
imgets (img,param="FWHM") # New line
intfwhm = real(imgets.value)# New line
temp = intfwhm # New line
#temp2 = 4*real(s1) Removed line
temp3 = 3*intfwhm

# Get rid of the ".imh" extension
i = strlen (img)
if (substr (img, i-3, i) == ".imh")
img = substr (img, 1, i-4)

# Call the phot command
photpars.apertur = temp
fitskypars.annulus = temp3
phot (img, "", coords=coordfile, output="default", verify=no, update=yes,
verbose=yes)

# Ask the user to input whether they want to keep this ".mag.1" file.
```

```
end2 = 0
while (end2 == 0){
print ("Are you satisfied with your results for this frame (no errors)?")
print ("Enter 1 to continue, 0 to re-phot")
scanf ("%d", tmp1)
if (tmp1 != 0 && tmp1 != 1)
print ("You entered an incorrect response!")
if (tmp1 == 0){
delete img//".mag.1"
while (tmp1 == 0){
display (img, 1)
print ("Please re-mark the stars and save as "ds9.reg"")
print ("Once you are done please enter 1 to continue.")
print ("This will re-phot the image frame with the new coordinates")
scanf ("%d", tmp2)
if (tmp2 != 1)
print ("You entered an incorrect response!")
if (tmp2 == 1){
coordfile = "ds9.reg"
phot (img, "", coords=coordfile, output="default", verify=no, update=yes,
verbose=yes)
print ("Are you satisfied with your results for this frame (no errors)?")
print ("Enter 1 to continue, 0 to re-phot")
scanf ("%d", tmp6)
if (tmp6 != 0 && tmp6 != 1)
print ("You entered an incorrect response!")
if(tmp6 == 1)
tmp1 = 1
if(tmp6 == 0)
```

```
tmp1 = 0
delete img//”.mag.1”
}
}
}
if (tmp1 == 1)
end2 = 1
}

# Delete the coordinate file
delete ”ds9.reg”

# Text dump the coordinates from the above image’s mag file
# into a new coordinate file
txdump (img//”.mag.1”, ”xcenter,ycenter”, ”yes”, headers=no,
parameters=yes, > coordfile)
}

# Create the text file for Varstar.
print (”Nightphot will now create the text file needed for Varstar4 or Varstar5”)
print (”What would you like to name the file? (e.g. starB.lst)”)
scanf (”%20s”, tmp5)
txdump (imgroot//”*.mag.1”, ”id,mag,otime,xairmass,ifilter”, ”yes”,
headers=no, parameters=yes, > tmp5)

# Clean up
delete (imagelist, ver-, $>&$ ”dev$null”)
end
```

Index