High Mass X-Ray Binary KRL2007B-367 and Adjacent Star Fey in the Optical

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A senior thesis submitted to the faculty of
Brigham Young University
in partial fulfillment of the requirements for the degree of

Bachelor of Science

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April 2016

ABSTRACT

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The High Mass X-Ray Binary KRL2007B-367 is observed in the Johnson B, V, R, and I filters from 2010 to 2012 and is analyzed in the optical for periodicity. Although there may be some hints of variability, KRL2007B-367 is for the most part stable. An uncatalogued star that is in the same field, referred to as star Fey, shows sporadic changes in magnitude. It is proposed that star Fey could possibly be the correct optical counterpart of the High Mass X-Ray Binary System. This is because star Fey shows much more variability in magnitude, and may show signs of periodicity. These are signs of evidence one would look for in a High Mass X-Ray Binary System. Even if this conclusion is incorrect, star Fey is still an object worth studying in the future since it shows interesting properties.

Keywords: KS 1947+ 300, High Mass X-Ray Binary System, Optical, KRL2007B-367

ACKNOWLEDGMENTS

I would like to acknowledge Eric Hintz for his help and guidance while this research was conducted.

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Chapter 1

Introduction

1.1 Properties of High Mass X-Ray Binary Systems

High mass x-ray binary systems (HMXB) are massive stars that have a companion neutron star or black hole. These systems are formed when one of the stars in a binary star system goes supernova and becomes either a neutron star or a black hole. After this occurs, the companion massive star that has not died will eventually exhaust all of its fuel in its core and begin to expand. As it expands, it will pass the bounds of its Roche Lobe, and its outer layers will begin to fall into its compact companion. As the massive star is being consumed, its lost material forms an accretion disc around the neutron star or black hole. As the gases swirl around the dead star, the accretion disc heats up to extremely high temperatures. After millions of years, the gas will eventually fall into the compact companion.

The impact of the gases with either the neutron star or the event horizon of the black hole is both violent and sporadic. It is so violent that highly energetic x-rays are emitted from the compact star. Thus HMXBs can be detected by the x-rays that emitted from the compact star. While the compact part is emitting violently in x-rays, the massive star is emitting in visible wavelenghts.

These massive stars are usually type O or type B stars. Thus HMXBs can be found by detecting the x-rays, and then finding its optical counterpart, which is just the massive companion star in visible wavelengths.

The visible light from the optical counterpart of a HMXB should have variablity in luminosity. This is because the point of impact of the accretion disc with the compact companion is sporadic and violent, thus causing great outbursts of light. There also should be periodicity observed as the massive star orbits its compact companion. Thus one can confirm the optical counterpart is correct by finding these traits in its visible light.

1.2 Description of KRL2007B-367

KRL2007B-367 ($\alpha_{2000} = 19^h49^m35.49^s, \delta_{2000} = +30^\circ12'31.8''$) is a HMXB that was discovered by Borozdin, K., Gilfanov, M., Sunyaev, R., et. al. (1990) in 1989. However, its optical part was not found until 1991, by Grankin, K.N., Shevchenko, V.S., Yakubov, S.D. (1991) and Goranskij, V.P., Esipov, V.F., Lyutyi, V.M., Shugarov, S.Y. (1991). Negueruela, I., Israel, G.L., Morco, A., Norton, A.J., Speziali, R. (2003) noted some interesting things about KRL2007B-367. They classified KRL2007B-367 as a B0Ve for the optical part and determined a distance of 10kpc. Although there was a large outburst in the x-ray during 2000-2001, Negueruela, I., Israel, G.L., Morco, A., Norton, A.J., Speziali, R. (2003) noted no luminosity change in the optical part. They concluded that this was probably due to a low inclination angle of the system. In 2004, Galloway, K.N., Morgan, E.H., Levine, A.M. (2004) took the x-ray data obtained by Negueruela, I., Israel, G.L., Morco, A., Norton, A.J., Speziali, R. (2003), and determined that KRL2007B-367 has an orbital period of 40.415 days.

Three years of data have been collected by the West Mountain Observatory of KRL2007B-367 in the optical. However, no change in magnitude has been seen. If KRL2007B-367 is the correct optical counterpart of the HMXB, there should be changes in its magnitude. There should also be signs of periodicity, which KRL2007B-367 shows no signs of. This is consistent with the study done by Negueruela, I., Israel, G.L., Morco, A., Norton, A.J., Speziali, R. (2003), where they also found no changes in magnitude in KRL2007B-367. They concluded that this was possibly because of a low inclination angle. However, another possible explantion is that KRL2007B-367 is not the correct optical counterpart of the HMXB.

1.3 Introduction of Star Fey

When no evidence was found that KRL2007B-367 is a HMXB, adjacent stars in the neighboring field were examined. One star did show great changes in luminosity on the order of 0.2-0.5 magnitudes over the course of the three years. It also showed occasional outbursts in luminosity on the order of one magnitude. This is expected of the optical counterpart of a HMXB. I propose that the wrong optical counterpart was chosen in 1991 to coincide with the HMXB discovered in 1989. I propose that this adjacent star is the correct optical counterpart. If KRL2007B-367 were a HMXB, it would show changes in luminosity to match x-ray outbursts. It might also show signs of periodicity as it orbits its neighboring neutron star or black hole. However, this is not the case.

The adjecent star that showed changes in luminosity is not cataloged. Since this star is not cataloged, it will be referred to as star Fey. The coordinates of star Fey are ($\alpha_{2000} = 19^h 49^m 38.84^s$, $\delta_{2000} = +30^\circ 12' 17.2''$).

This thesis proposes that star Fey is in fact the correct optical counterpart of the HMXB. After showing the methods of observation, an analysis of KRL2007B-367 and star Fey will then be done.

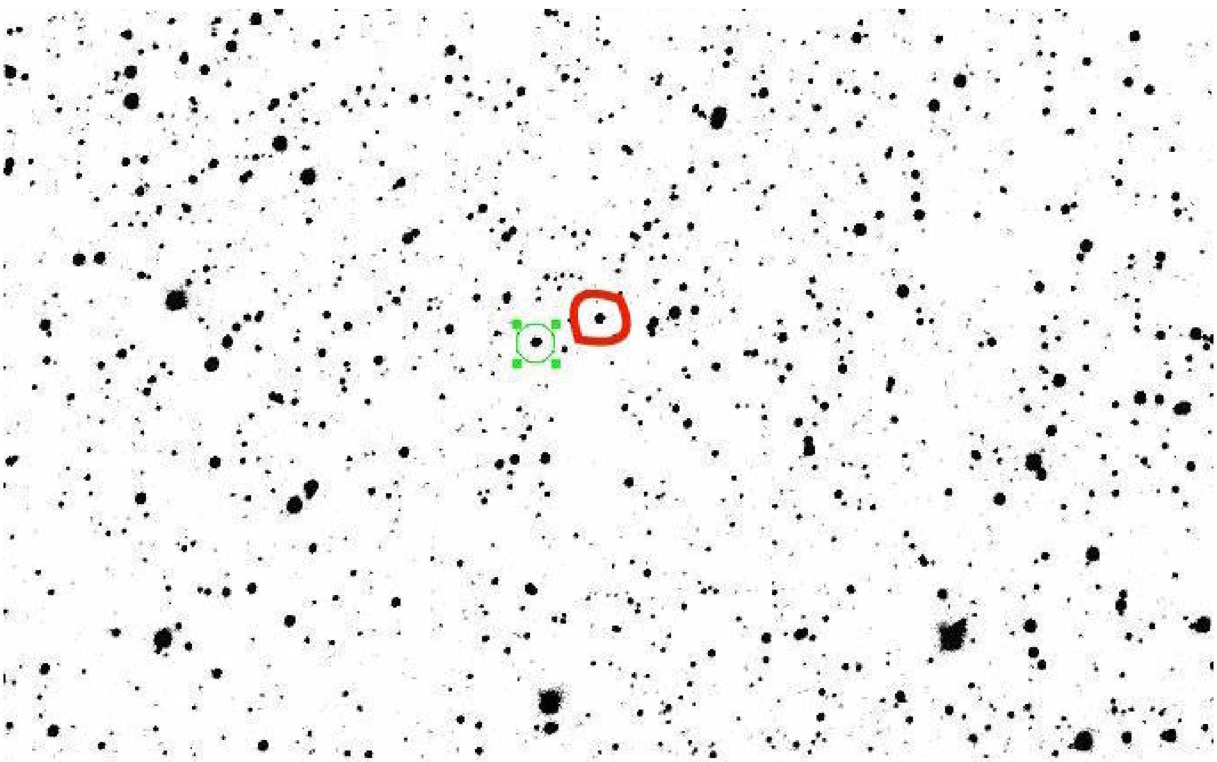

Figure 1.1 Optical Image of Star Fey and KRL2007B-367 the Johnson V filter. KRL2007B-367 is the star in the bold red circle and star Fey is the star in the thin green circle.

Chapter 2

Methods

2.1 Observations

Photometric data of KRL2007B-367 and Star Fey were taken on several nights from June 2010 to October 2012. The data was taken at the 0.91 meter telescope at the BYU West Mountain Observatory located at a latitude of 111:49:32W, a longitude of 40:05:15N, and an elevation of 2120 meters. The focus used was a Cassegrain with a focal ratio of f/5.5, giving a focal length of 5005 mm. The plate scale is 41 arcsec/mm. The CCD camera used to take the data was a PL09000, which is a 3K by 3K array, whose pixels are 12 microns. The data was taken in the Johnson B, V, R, and I filters. The frames were taken at an average exposure of 150 seconds.

2.2 Photometry

The data taken during observation were reduced using aperture photometry and then differential photometry. Aperture photometry finds the brightness of KRL2007B-367 and surrounding reference stars on each frame, after taking into account darks, zeros, and flats. Darks are pictures taken by the telescope after putting its cap on. These take into account any noise or electronic feedback in the telescope. Zeros are pictures taken with the telescope off. This helps the CCD camera have a natural readout while taking data. Lastly, flats are pictures taken by the telescope pointed at the horizon right during twilight hours. These take into account the differing quantum efficiencies of the pixels in the CCD camera. Once darks, zeros, and flats are taken into account, aperture photometry then finds the apparent magnitudes of the stars in each frame. To do this, a fixed aperture of three full width half maximums was used in all the frames. This way the same amount of light was obtained, thus keeping the data consistent throughout.

Differential photometry then takes this data, and compares the data from each star with each other in order to find the correct magnitude of each star. In order to do this, the absolute magnitude of the star being observed must be given to the software so that it can correctly calculate the absolute magnitudes of the stars in each frame. Any frames that were off centered and did not have all the reference stars in the frame could not be used, and thus were removed from the data pool. The remaining frames were reduced using aperture photometry in IRAF, and differential photometry done using Varstar5.

Chapter 3

Results

3.1 Analysis of KRL2007B-367

KRL2007B-367 was observed in the Johnson B, V, R, and I filters. Their HJD times versus their differential magnitudes can be seen graphed out in Fig. 3.1, Fig. 3.2, Fig. 3.3, and Fig. 3.4 respectively. It can be noted that there is practically no change in the differential magnitudes in all filters. The difference between the maximum and minimum magnitudes measured over the whole three years is about a 0.05 magnitude difference. Since this is statistically insignificant, it is tempting to conclude that KRL2007B-367 is optically stable. Galloway, K.N., Morgan, E.H., Levine, A.M. (2004) determined an oribtal period of 40.415 days for the HMXB after analyzing the x-ray data taken by Negueruela, I., Israel, G.L., Morco, A., Norton, A.J., Speziali, R. (2003). Therefore, KRL2007B-367 was phased every 40.415 days to see if there was any periodicity in each filter. The plots do not show any strong evidence for periodicity in KRL2007B-367. These plots can be seen in Fig. 3.5, Fig. 3.6, Fig. 3.7, and Fig. 3.8. The only exception can be seen in Fig. 3.9. This is the same figure found in Fig. 3.6, except now it is zoomed up on the data. This plot may show signs of periodicity, however, no function could be fit to the data. It could be that the research that determiend a period of 40.415 days could be off by a factory of two. Thus KRL2007B-367 is shown phased at 20.2075 days and 80.83 days in Fig. 3.10, Fig. 3.11 respectively. It is concluded that KRL2007B-367 is most likely not the optical counterpart of the transient x-ray sources being emitted within that field, although it is not ruled out entirely due to the possibility of periodicity being present.

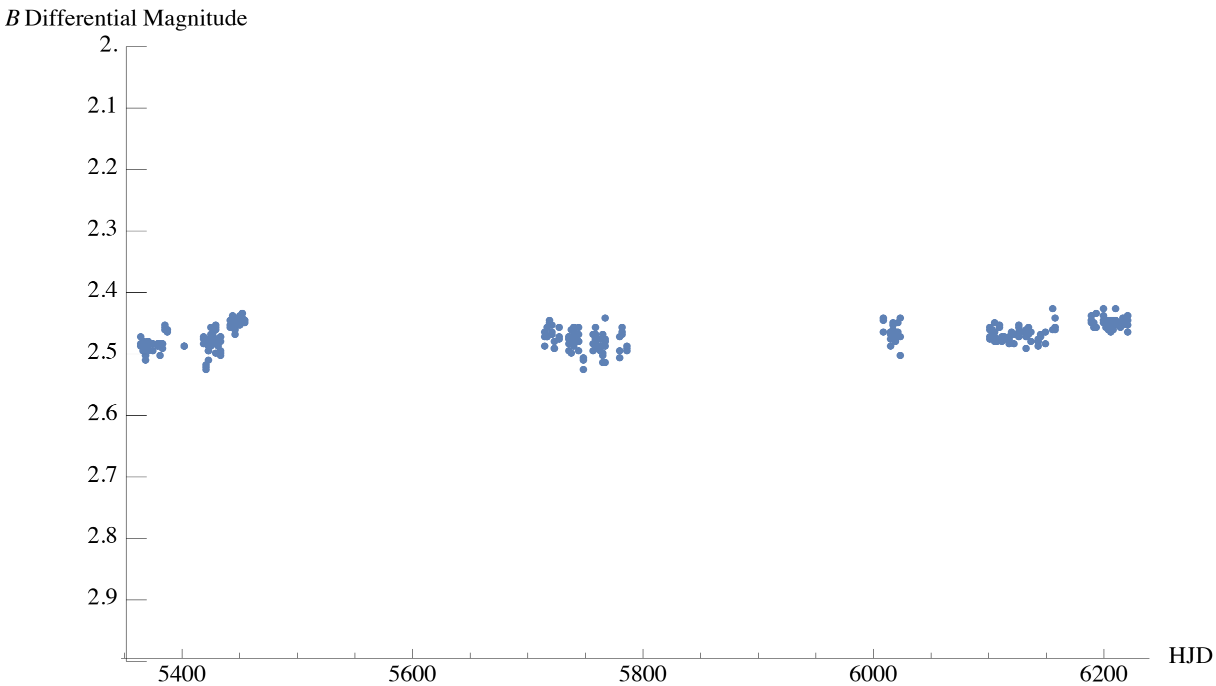

Figure 3.1 KRL2007B-367 in the Johnson B filter.

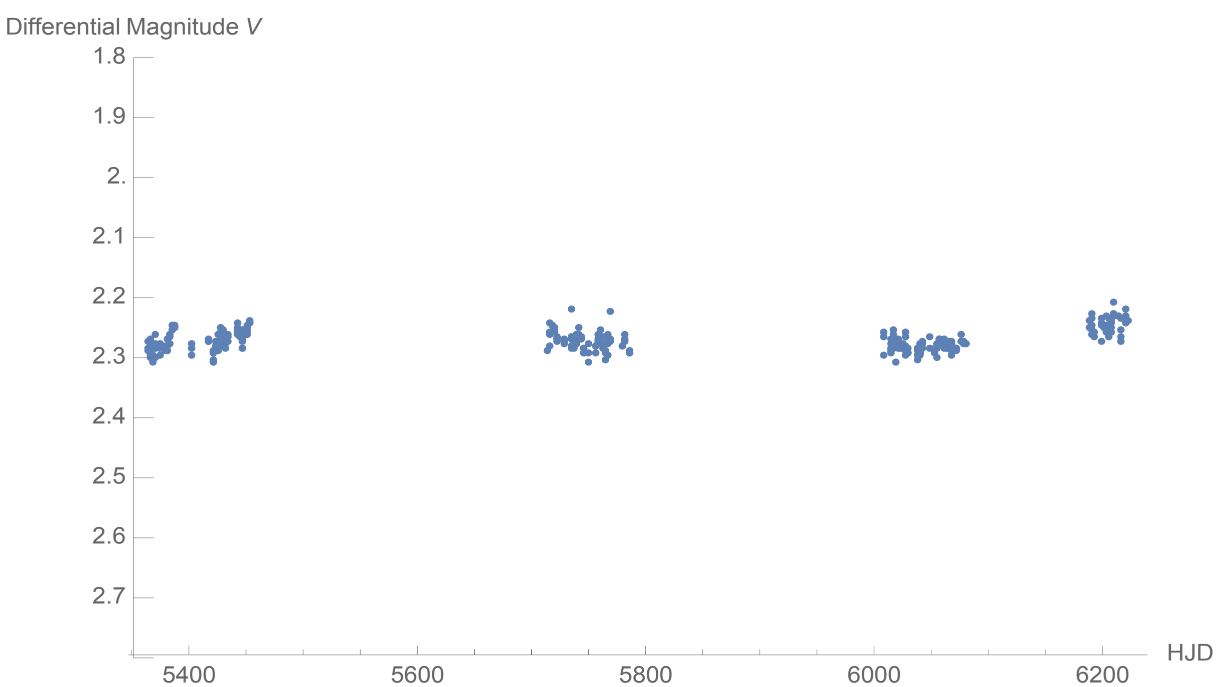

Figure 3.2 KRL2007B-367 in the Johnson V filter.

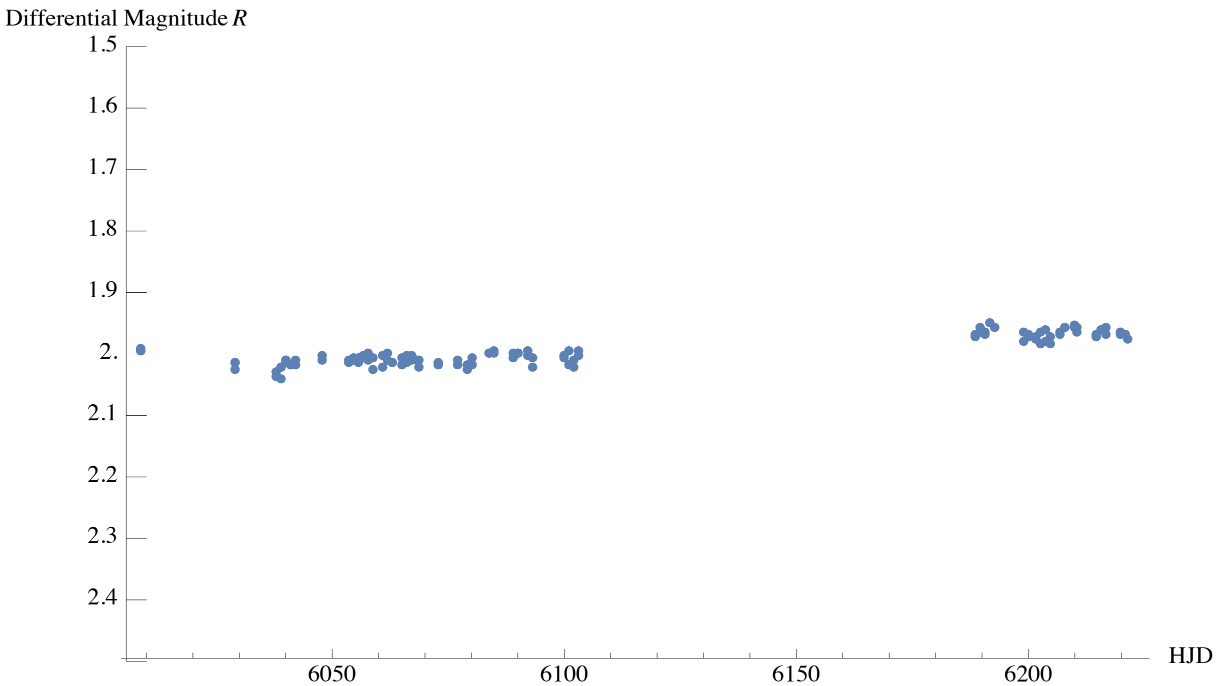

Figure 3.3 KRL2007B-367 in the Johnson R filter.

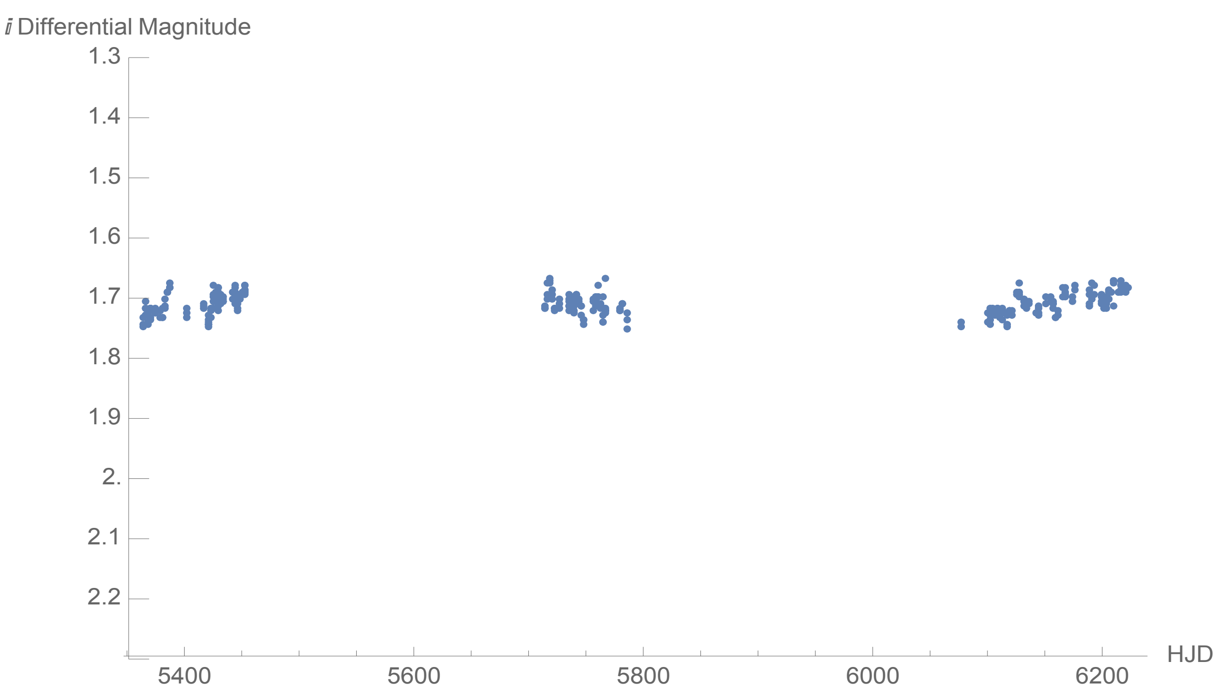

Figure 3.4 KRL2007B-367 in the Johnson I filter.

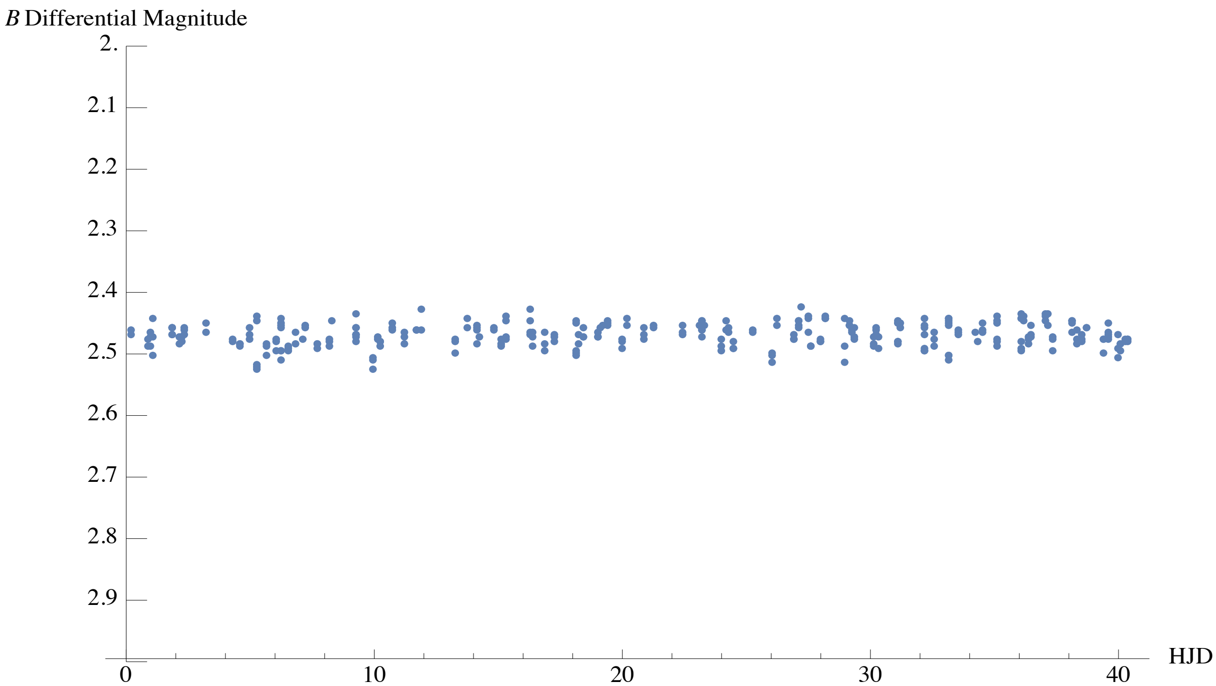

Figure 3.5 KRL2007B-367 in the Johnson B filter phased at 40.415 days.

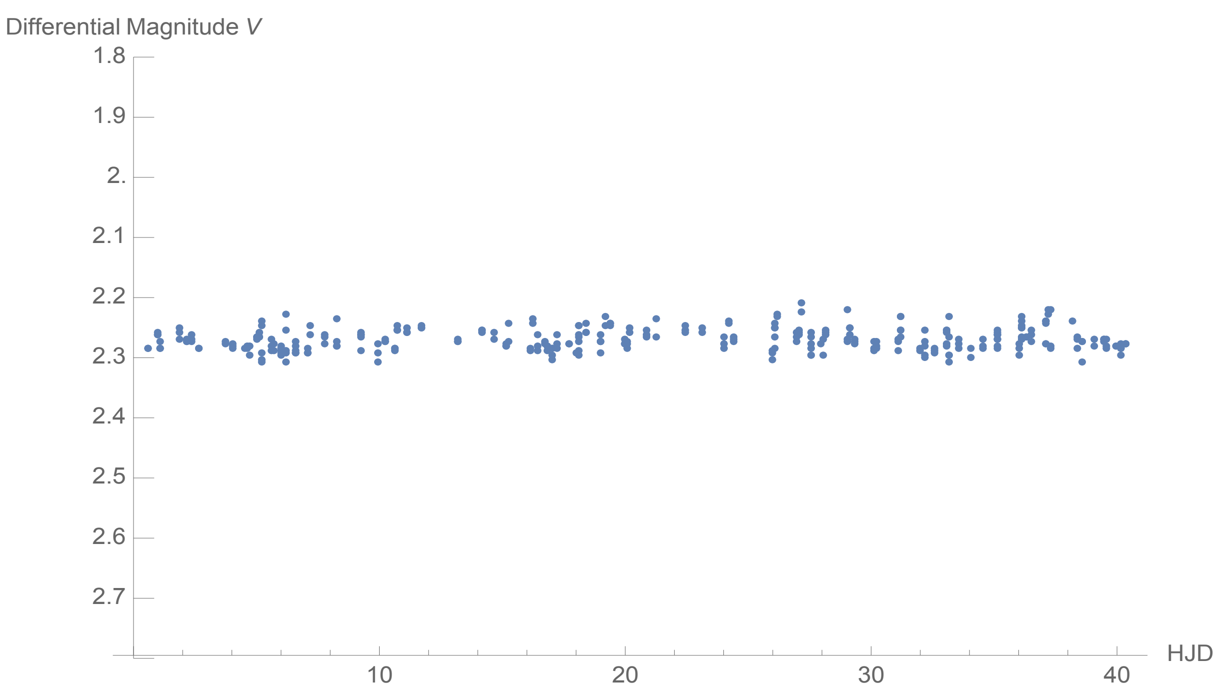

Figure 3.6 KRL2007B-367 in the Johnson V filter phased at 40.415 days.

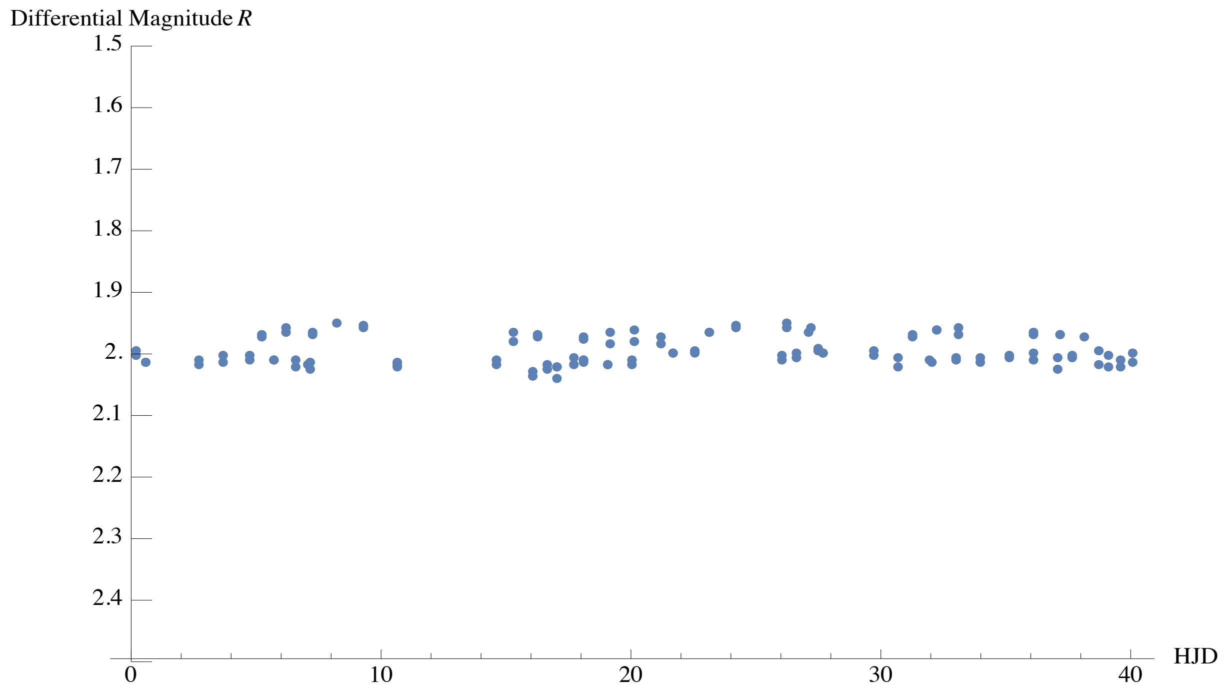

Figure 3.7 KRL2007B-367 in the Johnson R filter phased at 40.415 days.

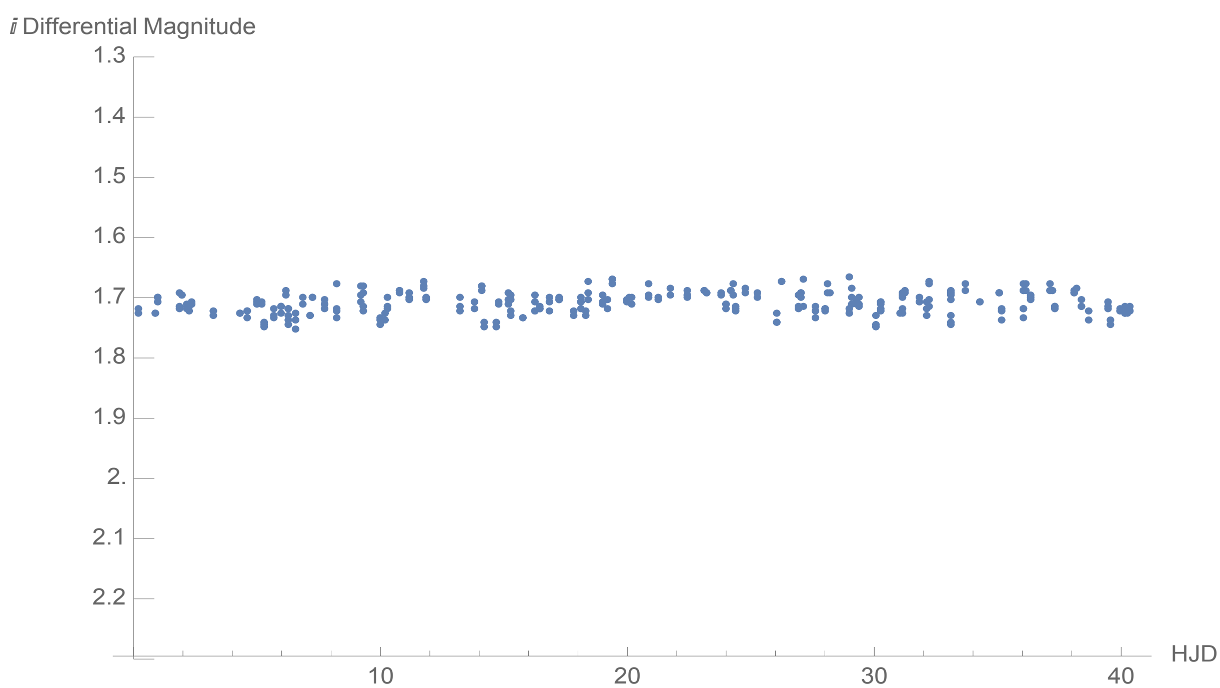

Figure 3.8 KRL2007B-367 in the Johnson I filter phased at 40.415 days.

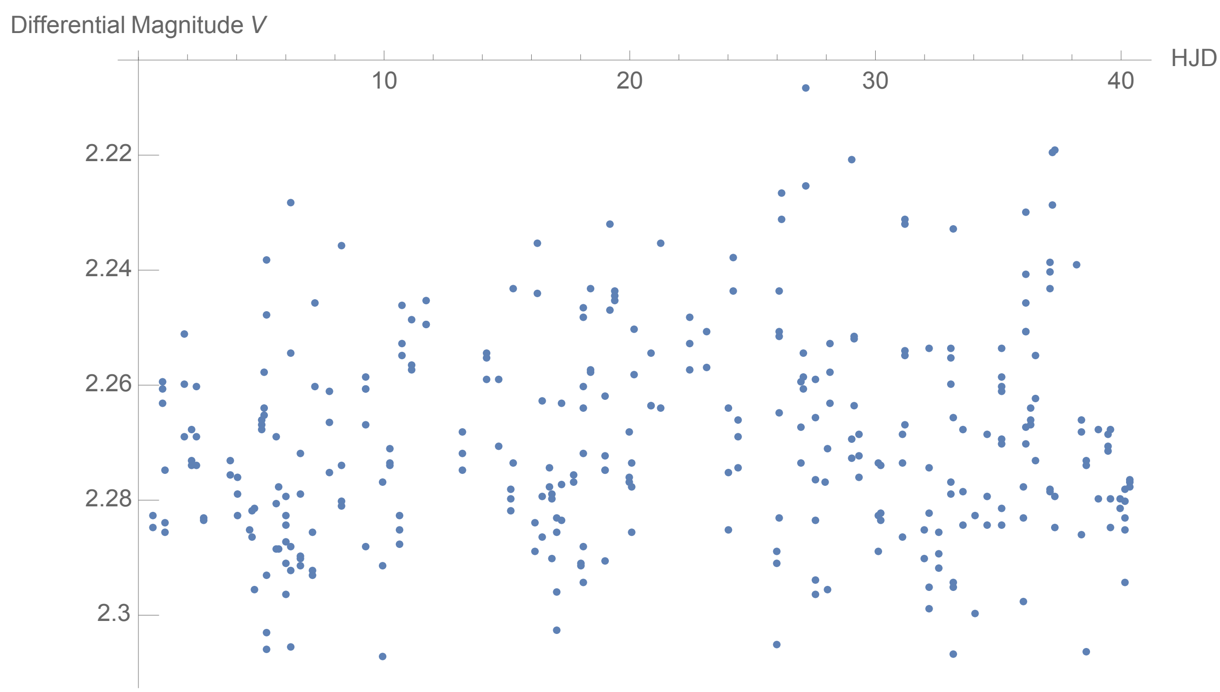

Figure 3.9 KRL2007B-367 in the Johnson V filter phased at 40.415 days. This plot zooms up on the data in order to show that there might be faint signs of periodicity in KRL2007B-367.

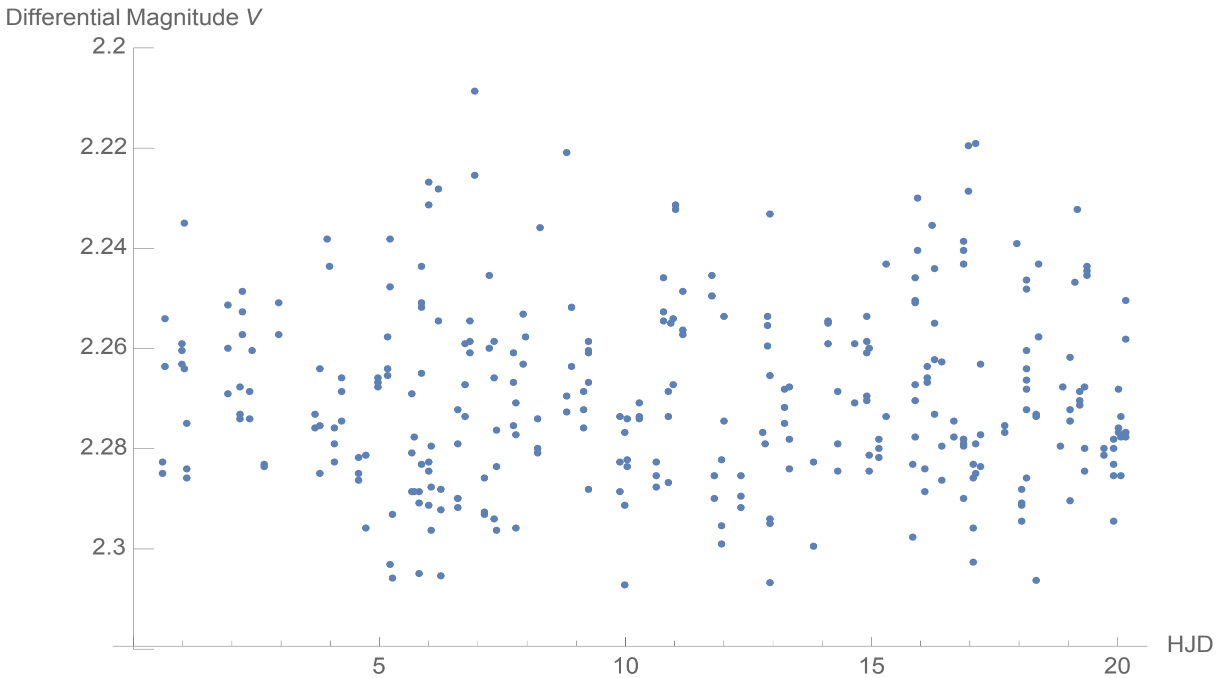

Figure 3.10 KRL2007B-367 in the Johnson V filter phased at 20.2075 days.

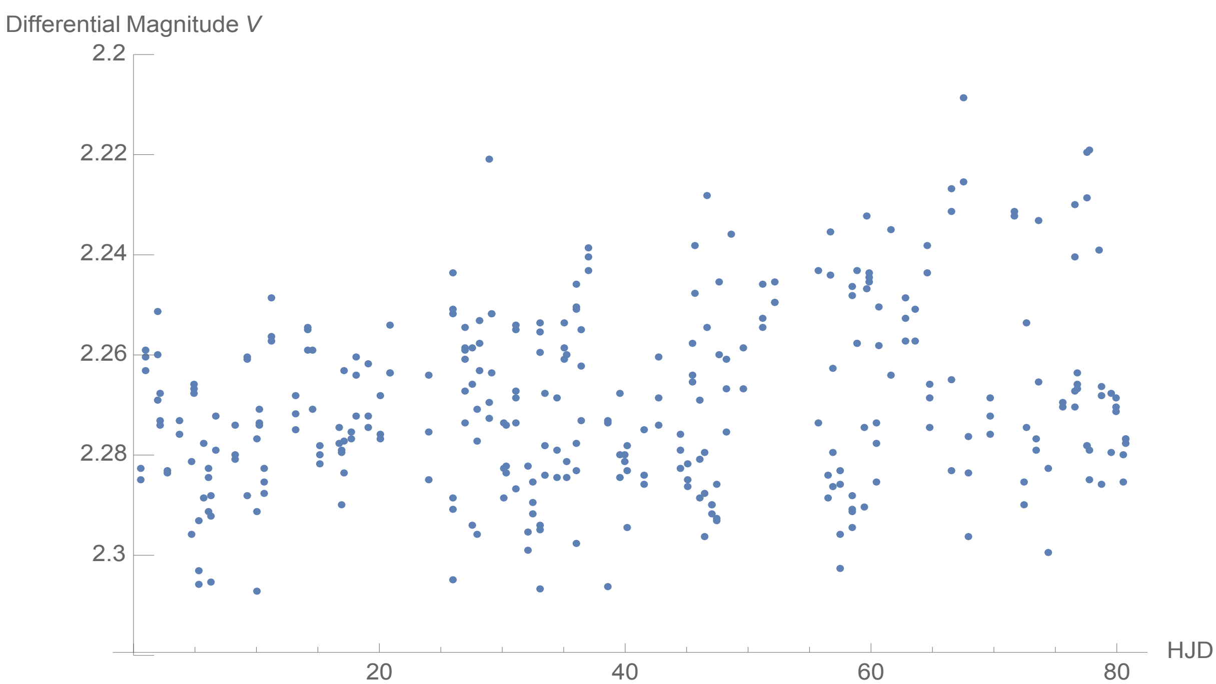

Figure 3.11 KRL2007B-367 in the Johnson V filter phased at 80.83 days.

3.2 Analysis of Star Fey

Stars neighboring KRL2007B-367 were then observed to find variations in luminosity, which would be observed if it is the counterpart of the transient x-ray sources. After analyzing different stars surrounding KRL2007B-367, star Fey showed some interesting results. The plots of star Fe of HJD times versus differential magnitudes in the Johnson B, V, R, and I filters can be seen in Fig. 3.12, Fig. 3.13, Fig. 3.14, and Fig. 3.15. Each filter was also phased at 40.415 days in order to see if there was any periodicity in the optical for this star. These plots are shown in Fig. 3.16, Fig. 3.17, Fig. 3.18, and Fig. 3.19. It can be noted that the changes in differential magnitude for star Fey are much greater than that of KRL2007B-367. The changes in magnitude for star Fey are on the order of 0.2-0.5 magnitudes. It can also be seen that there are occasional outbursts in the optical, which can be expected if it is the optical counterpart of the x-ray sources. This would be because of flares from the accretion disc. The changes in magnitude for the flares are on the order of one magnitude. Other evidence that star Fey could be the correct optical counterpart of the HMXB are the dips in luminosity. This could be dust found in the HMXB, which one would expect to find from the remnants of the black hole having gone supernova. One possibility is that the research done to determine the period of 40.415 days could be off by a factory of two. Thus star Fey is shown phased at 20.2075 days and 80.83 days in Fig. 3.20, Fig. 3.21 respectively.

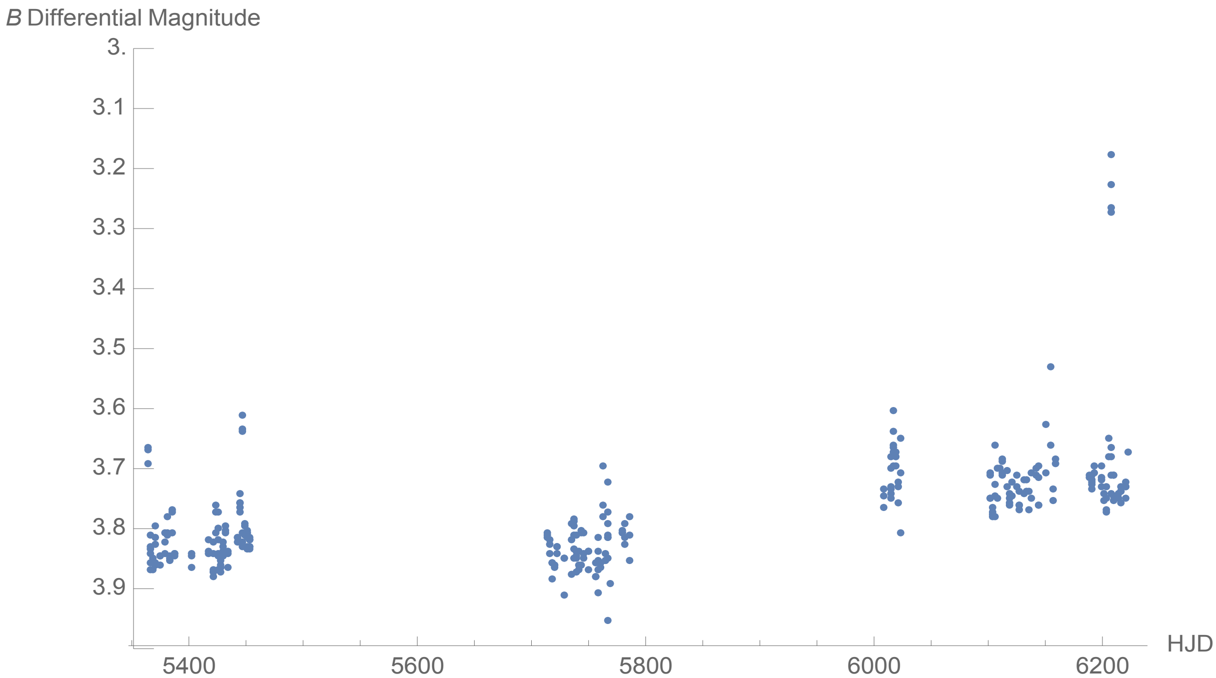

Figure 3.12 Star Fey in the Johnson B filter.

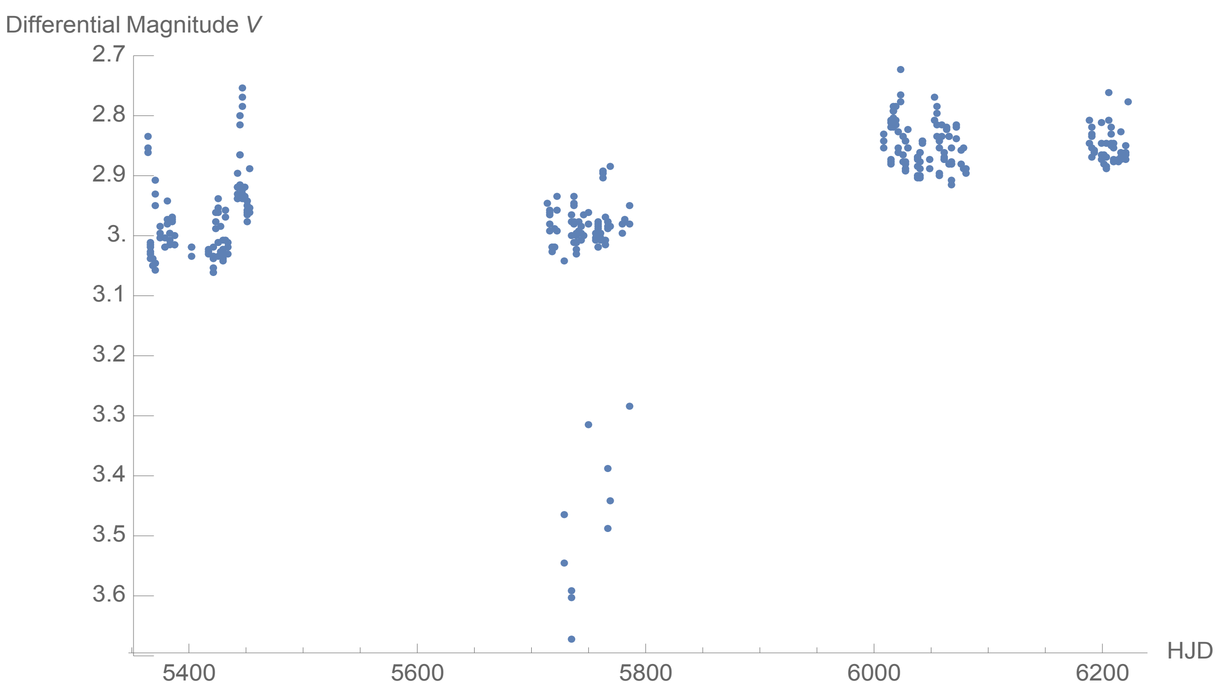

Figure 3.13 Star Fey in the Johnson V filter.

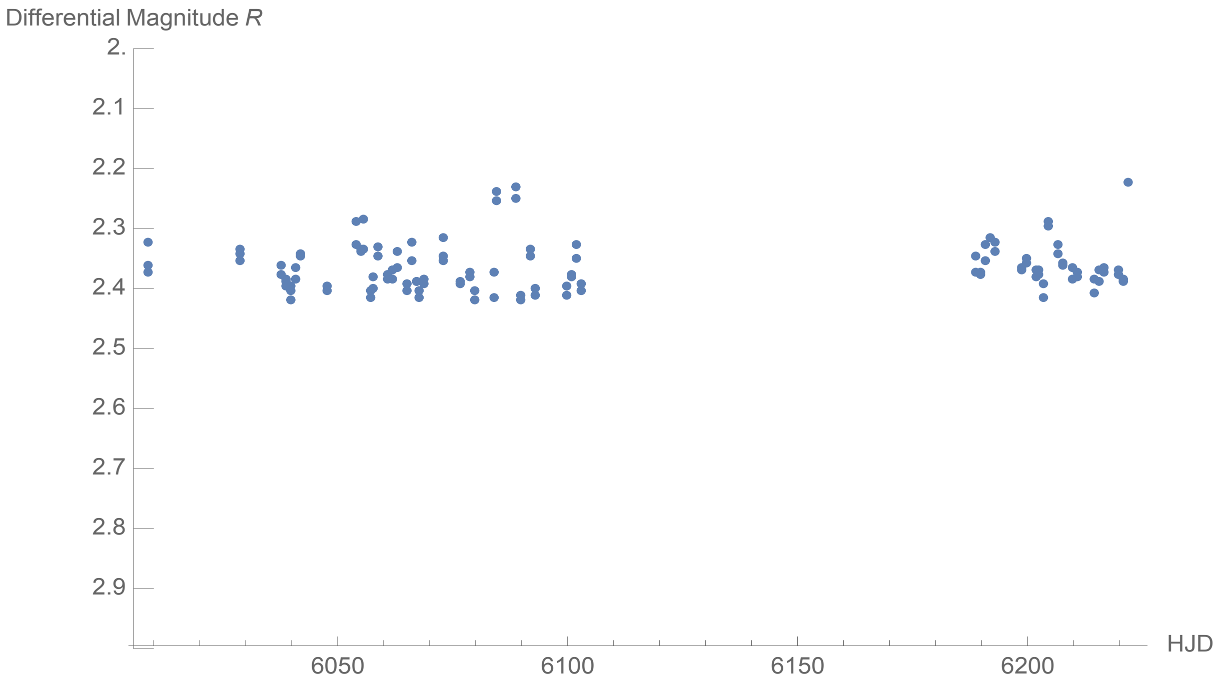

Figure 3.14 Star Fey in the Johnson R filter.

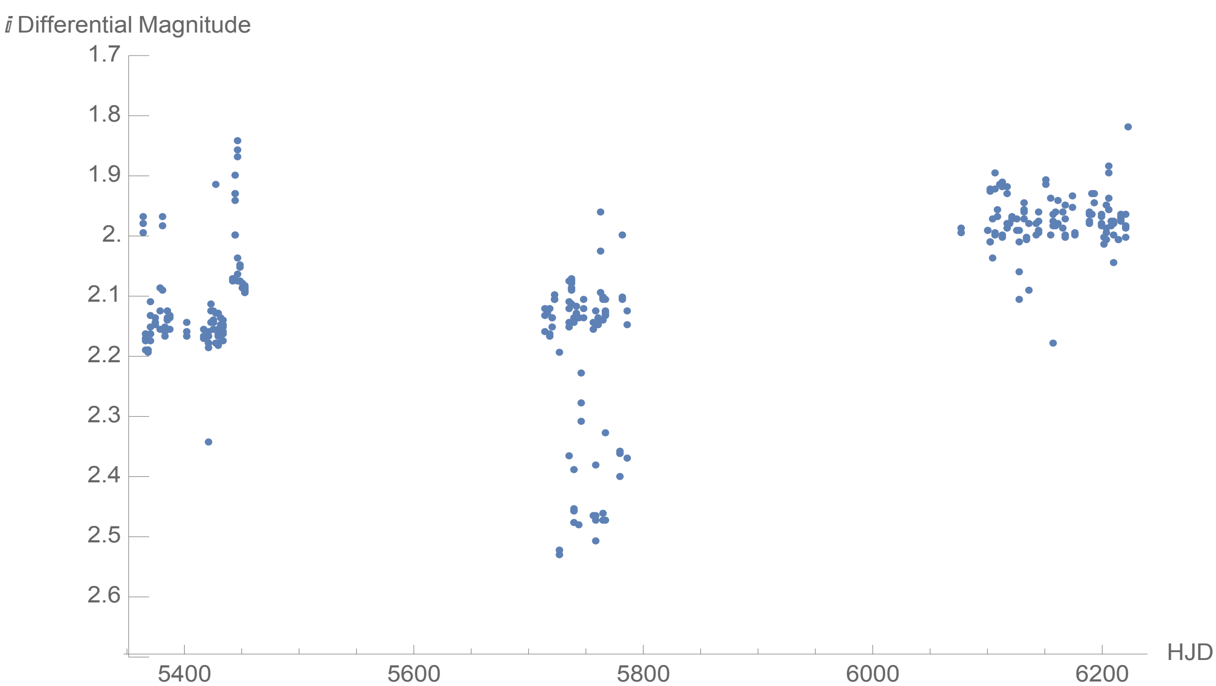

Figure 3.15 Star Fey in the Johnson I filter.

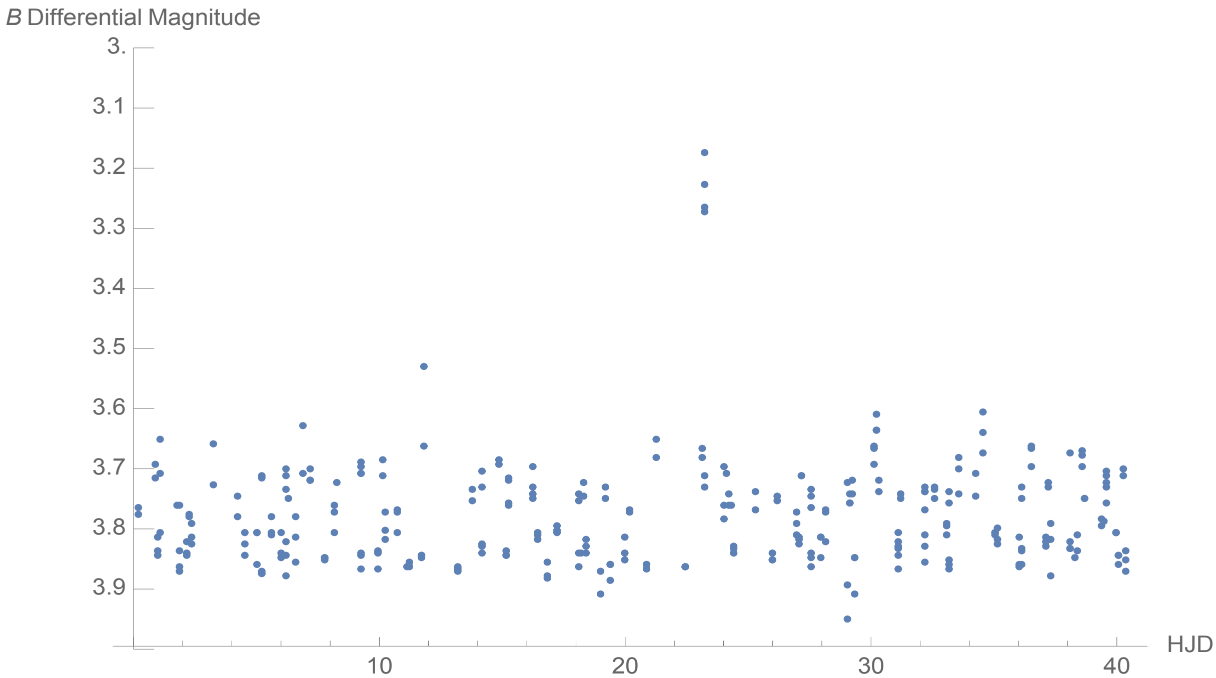

Figure 3.16 Star Fey in the Johnson B filter phased at 40.415 days.

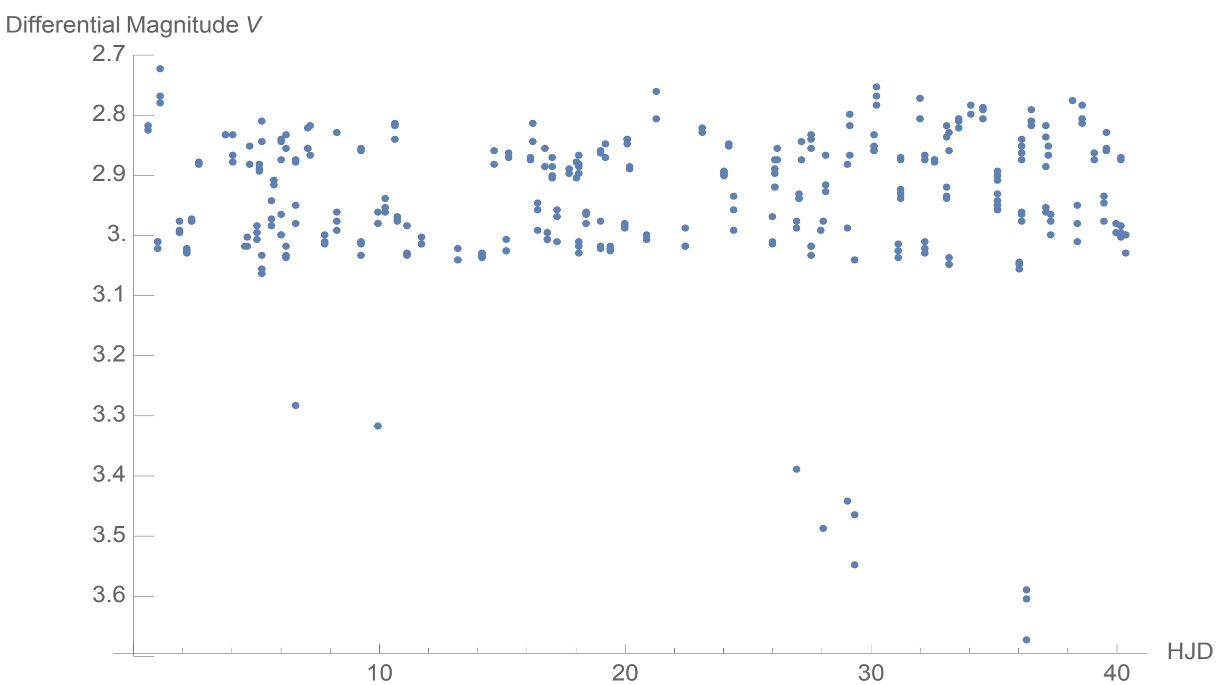

Figure 3.17 Star Fey in the Johnson V filter phased at 40.415 days.

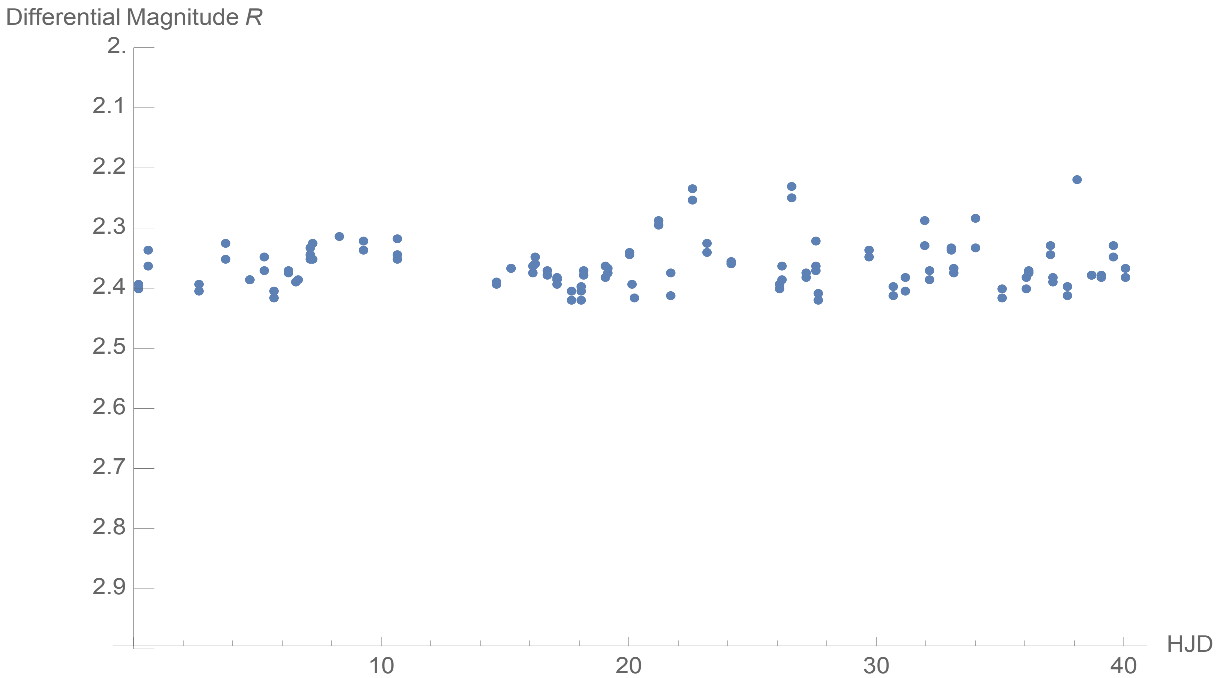

Figure 3.18 Star Fey in the Johnson R filter phased at 40.415 days.

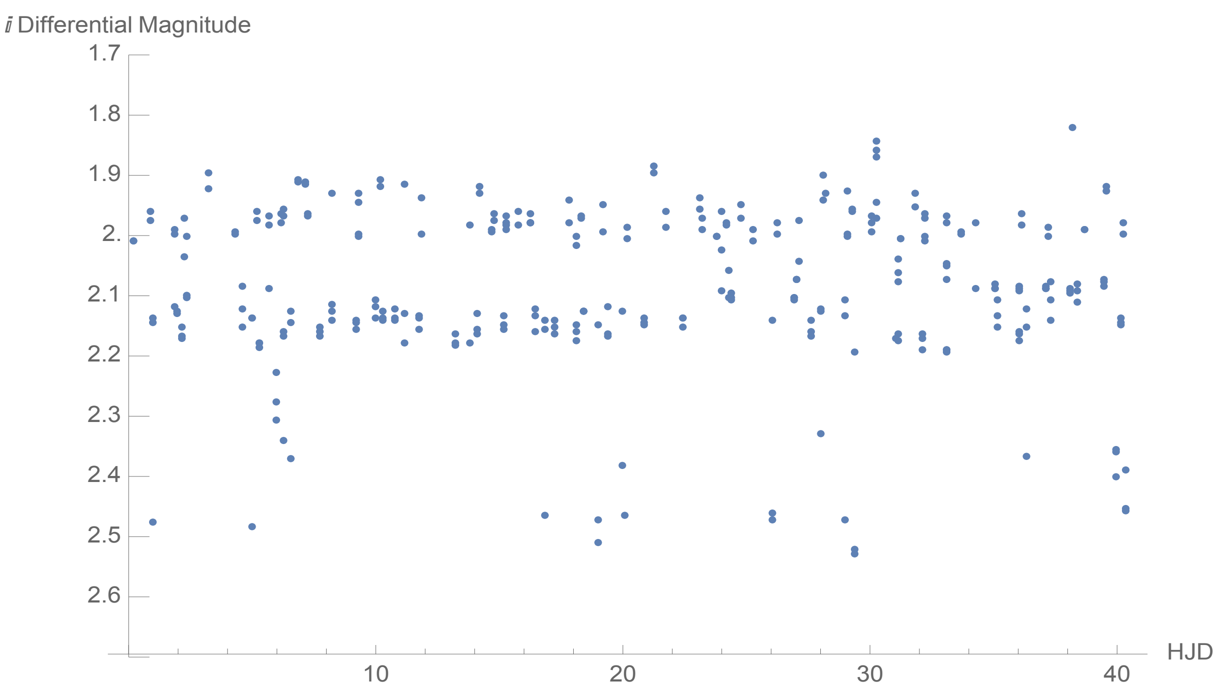

Figure 3.19 Star Fey in the Johnson I filter phased at 40.415 days.

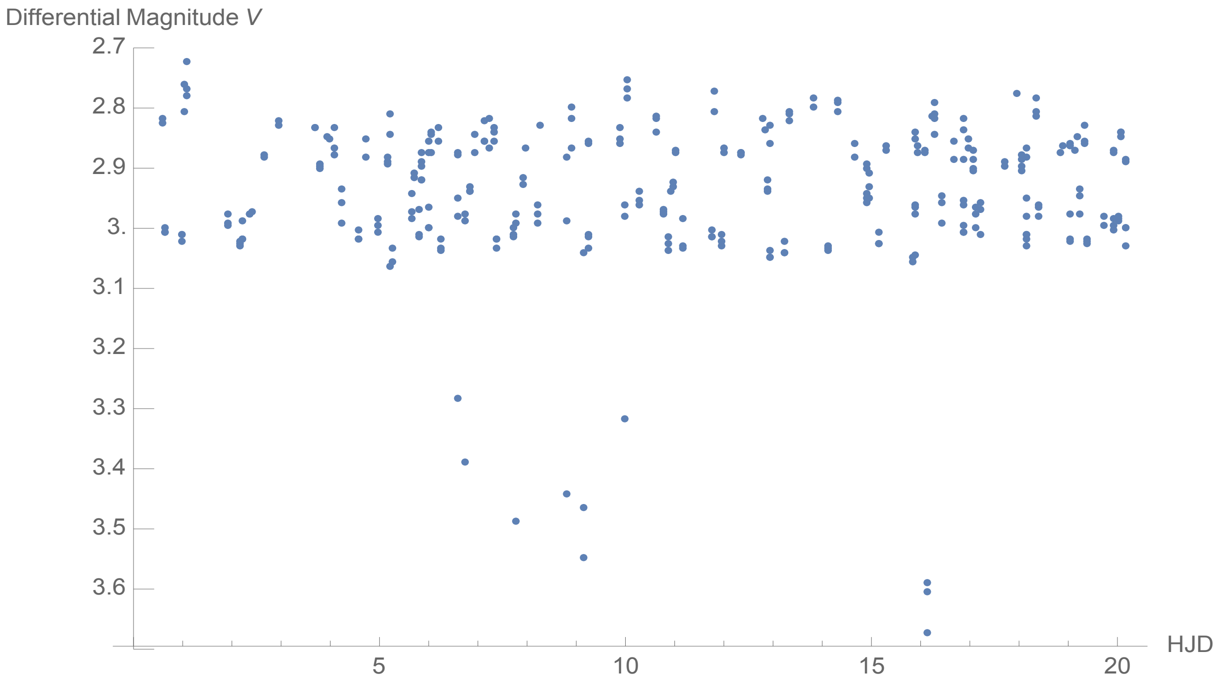

Figure 3.20 Star Fey in the Johnson V filter phased at 20.2075 days.

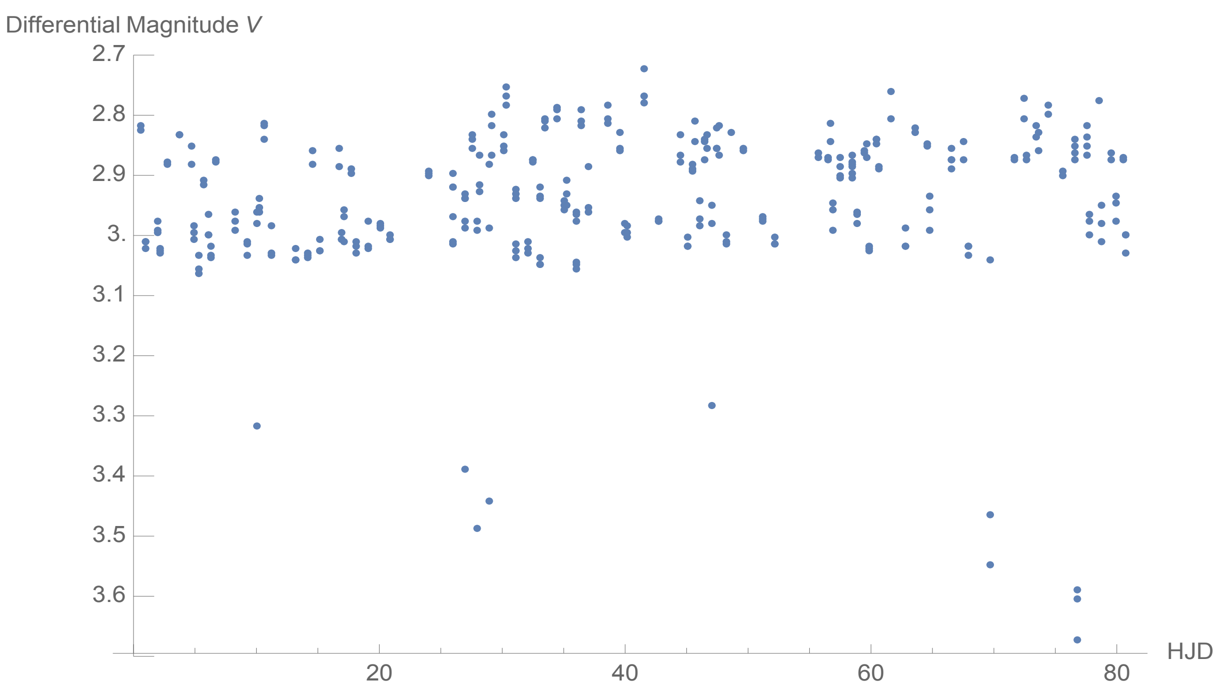

Figure 3.21 Star Fey in the Johnson V filter phased at 80.83 days.

Table 3.1. The brightest and dimmest magnitude and difference in magnitude observed for KRL2007B-367 in the Johnson B, V, R, and I filters.

Johnson Filter	Brightest mag	Dimmest mag	Difference mag
B	2.42437	2.52644	0.102067
V	2.2084	2.3072	0.098791
R	1.94797	2.03976	0.091787
I	1.66688	1.75155	0.084665

Table 3.2. The brightest and dimmest magnitude and difference in magnitude observed for Star Fey in the Johnson B, V, R, and I filters.

Johnson Filter	Brightest mag	Dimmest mag	Difference mag
B	4.67414	3.17506	1.49908
V	2.72368	3.67191	0.948237
R	2.22119	2.41933	0.198148
I	1.82045	2.52988	0.709431

3.3 Conclusion

After plotting three years of data of KRL2007B-367 in four different filters versus their differential magnitudes, it can be concluded that KRL2007B-367 is a stable star, with no changes in luminosity in the optical wavelenghts. This would explain why Negueruela, I., Israel, G.L., Morco, A., Norton, A.J., Speziali, R. (2003) did not see any changes in the optical part that matched the x-ray sources. This means that it is most likely not the optical counterpart of the x ray sources coming from that field. However, it is not ruled out completely since there may be subtle hints of periodicty. After examining star Fey under the same conditions, variability in the optical is clear, although no period could be determined for star Fey. It is concluded that star Fey could be the correct optical counterpart of the transient x-ray sources found by Borozdin, K., Gilfanov, M., Sunyaev, R., et. al. (1990), and that KRL2007B-367 is not the optical counterpart. In order to confirm this result, the optical variability of star Fey needs to be compared with x-ray data in order to see if their periodicity's are in phase with each other. If a period of 40.415 days could be determined for the optical changes of star Fey, that would also confirm that it is the optical counterpart of the x-ray sources taken by Negueruela, I., Israel, G.L., Morco, A., Norton, A.J., Speziali, R. (2003). If this conclusion is incorrect, at the very least star Fey is an object that needs to be studied in the future since it is definitely a variable object.

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