

How I made a phased light curve...

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Bibliography:

“A new short period variable star in Cygnus”, M. A. Stark, J. M. Taylor,
IBVS 5247, 26 March 2002 (<http://www.konkoly.hu/cgi-bin/IBVS?5247>)

- Simbad Astronomical Database (<http://simbad.u-strasbg.fr/simbad/>)
- General Catalogue of Variable Stars (<http://www.sai.msu.su/gcvs/gcvs/>)
- project C-Munipack (<http://c-munipack.sourceforge.net/>)

- Stellarium.

Introduction

The subject of my project is periodicity variation of variable star – V2416 Cygni analyse. I have been observing it since August 2014 personally through Meade LX200-ACF Schmidt-Cassegrain telescope which has 3048 mm focal length, mirror of 300 mm diameter, Deep Sky Imager Pro III camera and through remote-controlled Teide2 telescope which is located on Tenerife.

Variable Star

A variable star is a star whose brightness as seen from Earth fluctuates. The variable stars are classified as either:

- Intrinsic variables, whose luminosity actually changes; for example, because the star periodically swells and shrinks.
- Extrinsic variables, whose apparent changes in brightness are due to changes in the amount of their light that can reach Earth; for example, because the star has an orbiting companion that sometimes eclipses it.

V2416Cygni variable star

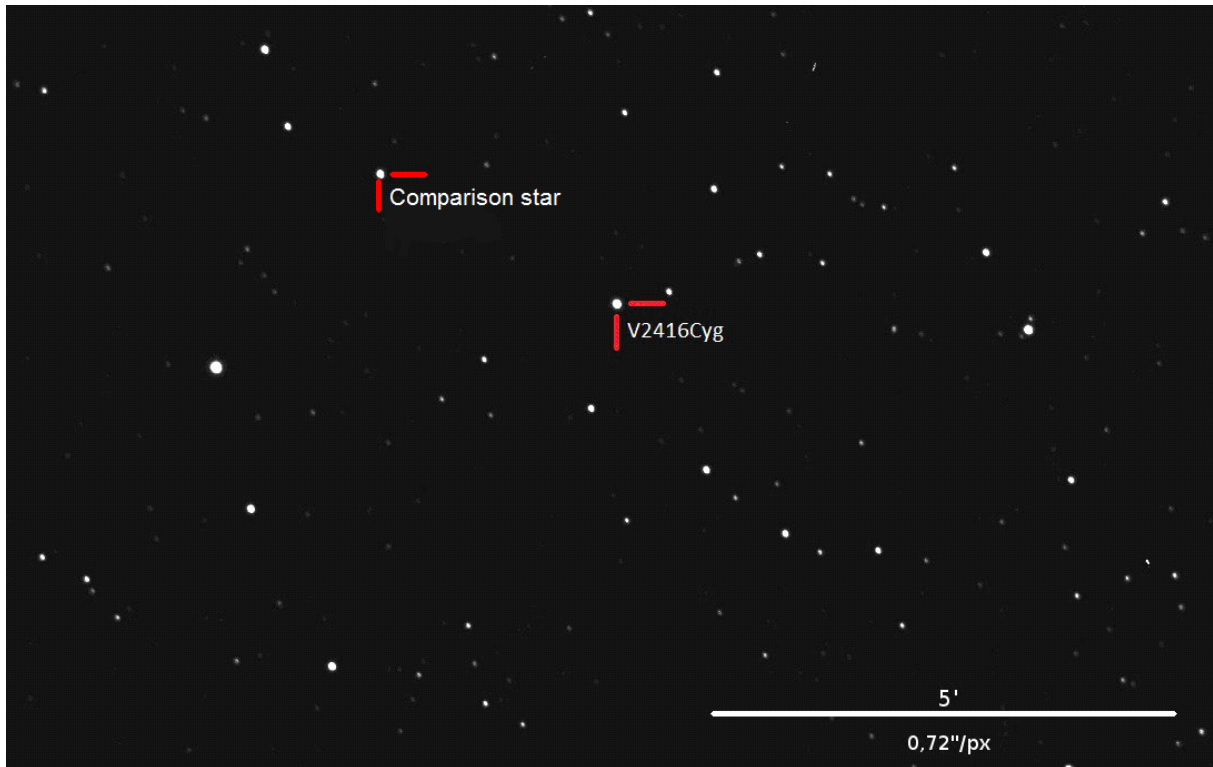
The star observed by me is located towards Cygnus constellation on the celestial sphere. For amateur this is a quite faint object – its brightness is 12,6 magnitudo and its coordinates are:

rectascension $RA_{2000} = 20^h 03^m 04.3^s$
declination $Dec_{2000} = 59^\circ 06' 54.6''$.

The best conditions to observe it are in summer, when the star is located close to zenith. It's period, in other words, time between two next maxima or minima was publicated in 2002 based on July 1998 observations and was

$$P = 0.05589^d \pm 0.00001$$

that's about 80 minutes and 30 seconds. Fidelity of this product is about one second. That's how V2416 star region looks like through Teide2 view:



The same region in Simbad2 base enriched by CGVS data.

Location: 20:03:04.20 +59:06:55.4 Frame: ICRS

★ DSS ★ SDSS ★ 2MASS ★ WISE ★ GALEX ★ PLANCK ★ AKARI ★ XMM ★ Fermi ★ Simbad ★ NED +

DSS colored-1

V* V2416 Cyg (13.4,PulsV*delSct)

6.442' x 5.108'

1'

6.442' x 5.108'

epoch - size - opac. - zoom -

Frame: ICRS

+180 +90 -90 -180

20:03:22.06 +59:06:50.0 6.442' x 5.108'

grid wink north multiview match V* V2416 Cyg (13.4,PulsV*delSct) [by Simbad] Search

I checked out, that star which I chosen to comparison star isn't listed as variable star at CGVS catalogue, so we can have hope, that it shines stable light.

Observations list

Plus in table means, that all photos were elaborated and used to make light curve.

Minus in table means, that all photos were elaborated but were rejected. The main causes were:

- wind, which caused, that stars looked like lines, not points
- mount tracking, which caused, that photos due to Earth rotation didn't show the same field, so the Munipack program couldn't match them and make a light curve.

Notation like 3/2 means in number of photos and +/- means, that the number in nominator shows, how many photos were elaborated and used to make a light curve and the number in denominator shows, how many photos were elaborated but rejected.

Question mark means, that the photos hasn't been elaborated yet.

Date	Number of photos	Telescope	
12.08.2014	513	Meade LX200ACF	-
17.08.2014	5	Slooh	+
17.08.2014	932	Meade LX200ACF	-
23.08.2014	3/2	Slooh	+/-
24.08.2014	4/1	Slooh	+/-
25.08.2014	5	Slooh	+
26.08.2014	5	Slooh	+
30.08.2014	5	Slooh	+
4.09.2014	4/1	Slooh	+/-
5.09.2014	5	Slooh	+
7.09.2014	3/2	Slooh	+/-
8.09.2014	5	Slooh	+
9.09.2014	2/3	Slooh	+/-
10.09.2014	5	Slooh	+
11.09.2014	5	Slooh	+
12.09.2014	5	Slooh	+
13.09.2014	5	Slooh	+
18.09.2014	5	Slooh	+
20.09.2014	5	Slooh	+
22.09.2014	3/2	Slooh	+/-
23.09.2014	3/2	Slooh	+/-
25.09.2014	4/1	Slooh	+/-
13.12.2014	419	Meade LX200ACF	?

Remote-controlled observations method

The photo below shows the Slooh web page interface. We can see five free slots, which let us make a photos. We can reserve them at a available hour. We can also check the weather, where the telescope is located.

The screenshot displays the Slooh web page interface for the Canary Islands LaunchPad. The page is titled "Canary Islands LaunchPad" and features a navigation bar with "Clubhouse", "Observatories", "What's Up", "Activities", "Community", and "Shows". The main content area is divided into several sections:

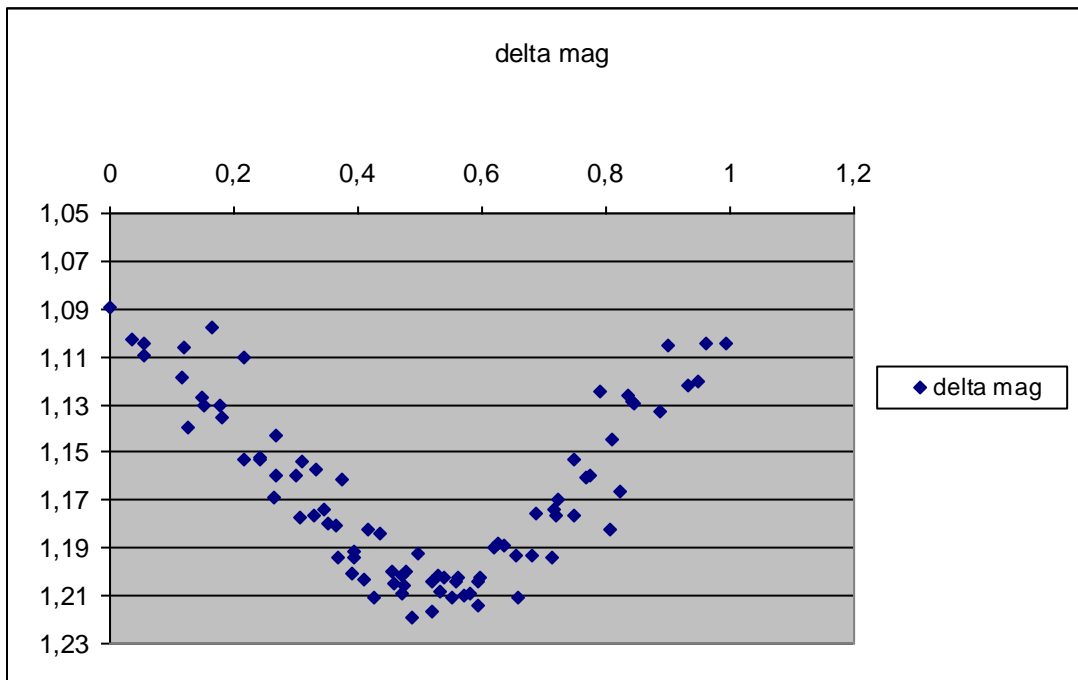
- Canary Islands Dome 2:** Shows the observatory's status, including "Weather Conditions", "Observatory Time 15:51:52 UTC", and "Domes" (C11, C12, CL). A "MISSIONS OFFLINE" warning is present.
- RESERVATIONS:** Displays "5 Available" slots and "You have no reservations." with five "Empty Slot" icons.
- UPCOMING MISSIONS:** Shows a mission for "Jupiter" at 19:57 UTC.
- PICTURES:** Displays a gallery of images, including "Saturn", "Whale Galaxy", and "M22".
- Live Updates:** Provides information about tracking near-earth asteroids and comets.

The bottom of the page shows upcoming missions for "Chile" and "Canary Islands Dome 1", both featuring "Waxing Gibbous Moon" observations.

This picture shows us folder with photos, which were made by telescope. Slooh telescope offers us photos in four filters: luminance, red, green and blue and wide and narrow field of view.

Making the phased light curve

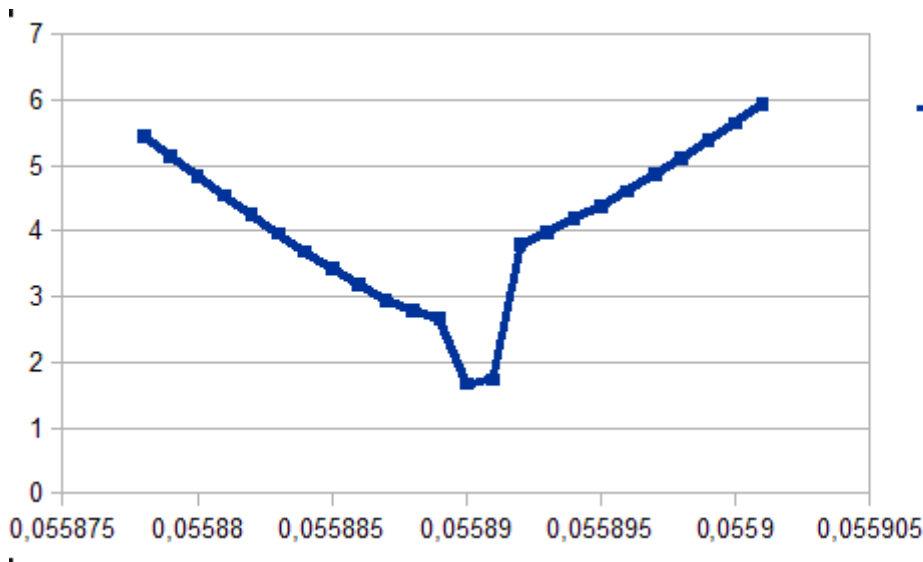
The primary thing when you examine variable stars is making a graph, which shows variations of star brightness during one cycle. After I had made photos through Slooh telescope with luminance filter, I used Munipack program to measure the star brightness in terms of comparison star in particular moment. Then I elaborated data, which I got from Munipack in Microsoft Excel. Every photo is a different star brightness and it's period. I choosen a nearest maximum moment as T_0 and I subtracted date of that moment expressed in JD from the date of photo making and divided the product by period. From this operations I got phase, which defines in what moment of variation cycle the star is. After all these operations I made a phased light curve of a variable star.



This graph contains 86 points, where every point represent different photo.

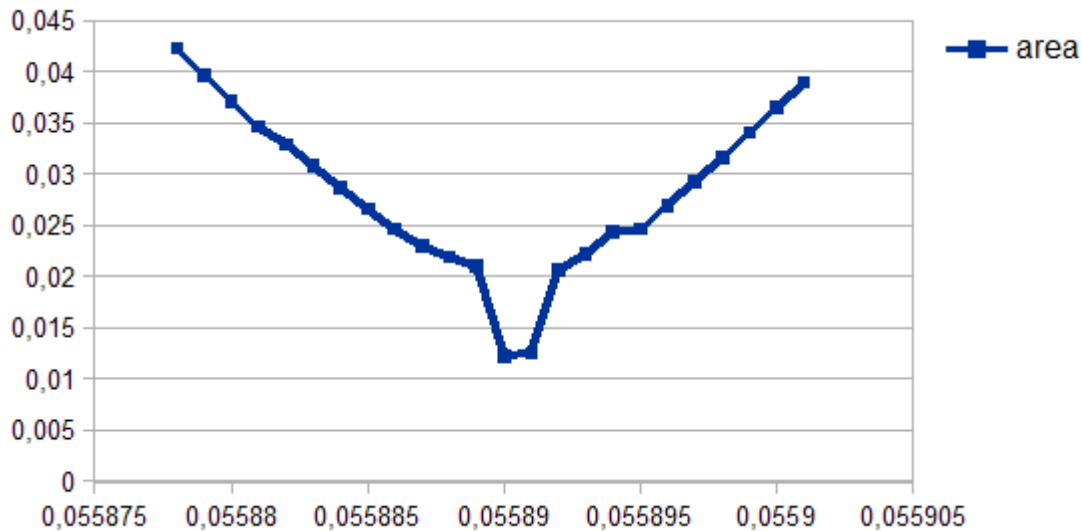
Period verification

After 17 years from the period calculation there is a need to check, if it hasn't change. There are professional methods, which allows to examine periodicity of physical processes, like harmonic analysis, but their mathematical basics are unknown to me, so I made my own, simplified methods to designate the most probability period. I made that by using two methods: the method of the shortest string and the method of the least triangles area. The first one bases on making a hypothetical string connecting all the points on the light curve graph for few choosen periods. In my project I choosen trial periods from 0,055878 day to 0,055901 day, which I was changing by 0,000001 day. After that you have to check for which period the string is the shortest.



At the upper graph the shortest string is for period 0,055890 day.

The next method is the method of the least triangles area. It is based on calculating area of triangles, whose vertices are next points at the phased light curve graph. It is need to be done for few periods as the same as in the shortest string method and check, for witch period the total of triangle areas are the least.



At this graph the least total of triangle areas is for period 0,055890 day.
 The compatibility of two products given by two different methods makes me sure, that the correct period, which I get from my observations is

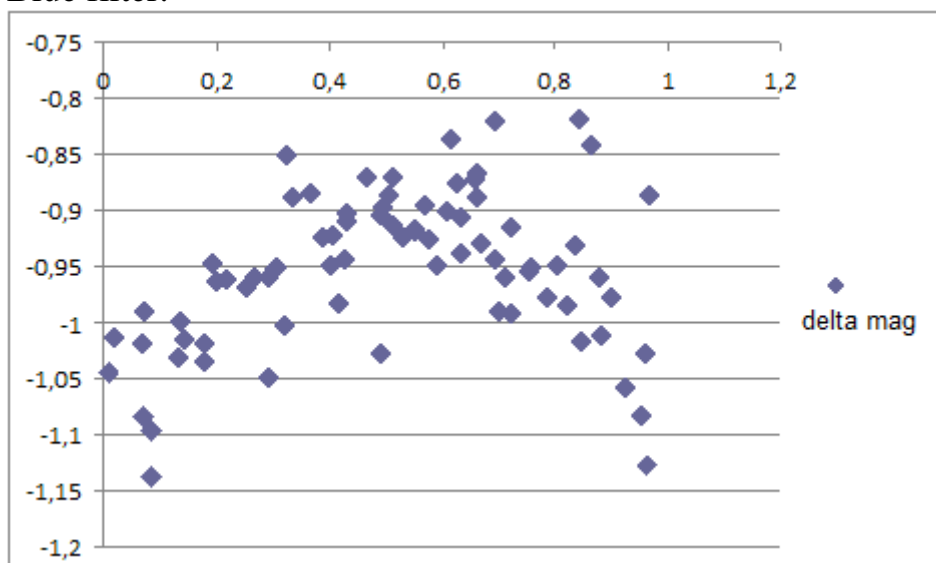
$$P = 0.055890d \pm 0.000001$$

what means fidelity about 0.1 second.

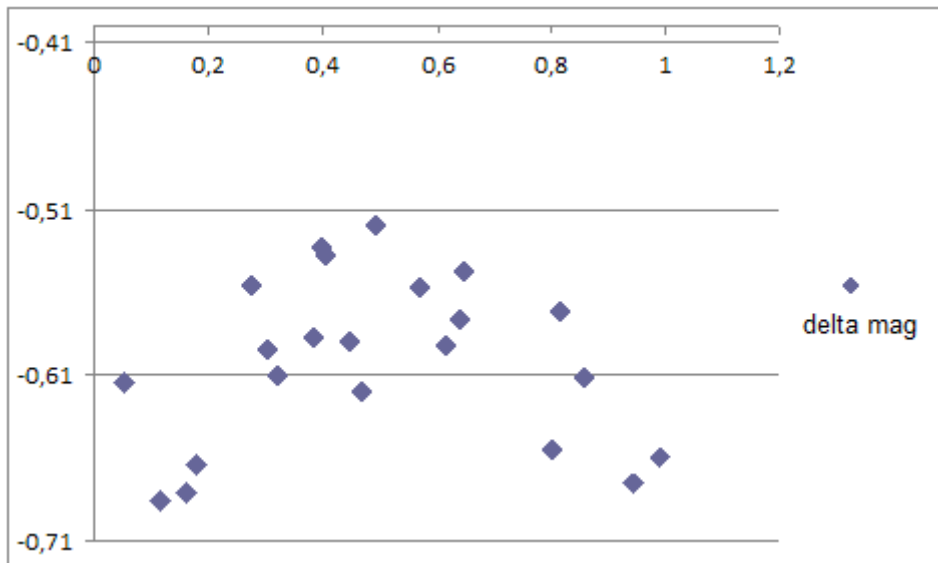
Colour

Slooh telescope also made a photos with RGB filters. I have also measured star brightness by Munipack program at these photos and made a light curve. I did it with red and blue filters.

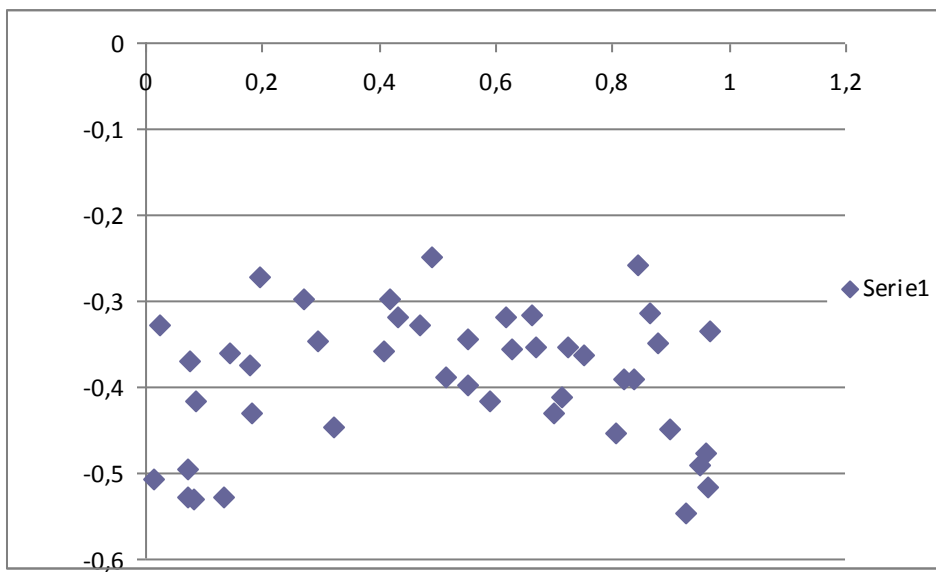
Blue filter.



Red filter.



Then I subtracted star brightness in blue filter from star brightness in red filter and made a new graph.



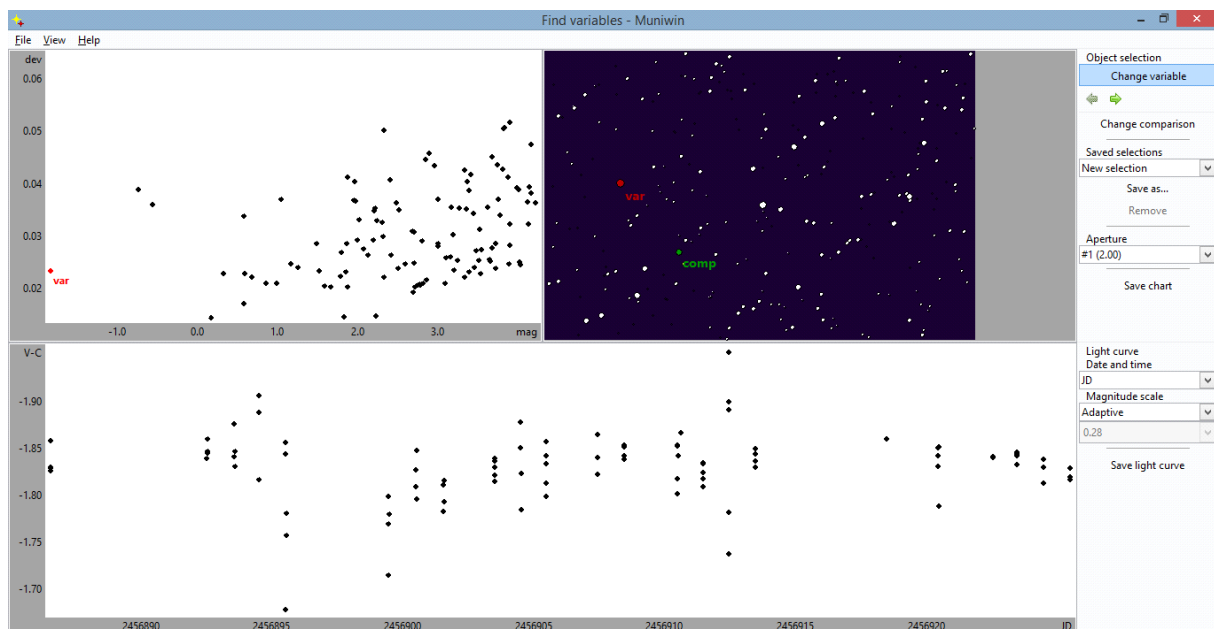
You can see, that in maxima the star colour is different than in minimum – when the star becomes more brightness it also becomes more blue.

Conclusion

Analysing the light curve graph we can say that it is an intrinsic variable star, because the variations are smooth. The brightness amplitude is about 0.22 magnitudes. The period is still the same - **0,055890 day**, or 80 minutes and 28,9 seconds. It is not more than 8 hours and not less than 30 minutes, the brightness amplitude is not more than 1 magnitude, so it is a delta Scuti variable star. At the colour difference graph we can see, that in its maximum star sends to us more blue light than in its minimum. It means, that the star in its maximum increases its temperature in cause of its size decrease, so the star in the same amount of time increases its size and decreases.

Plans for the future

In the future I'm going to analyze about 2000 photos from Meade telescope. It needs to be done manually. It will allow me to examine period more precisely and curve looks for its eventually asymmetric. When I was analyzing the V2416 variation I saw a new interesting object. Munipack program reveals, that it has also brightness variation. In the variable stars catalogue in this area only V2416 Cygni is marked as variable star and that's why the star has been interesting for me.



Here you can see, that the star has a brightness variation about 0.2 magnitudes.

It's coordinates are:

rectascension $\mathbf{RA}_{2000} = 20^{\mathbf{h}} 03^{\mathbf{m}} 37.2^{\mathbf{s}}$

declination $\mathbf{Dec}_{2000} = 59^{\circ} 07' 35.8''$.

Localization of the star suspected of brightness variation:

