My observations of XX Cygni variable star

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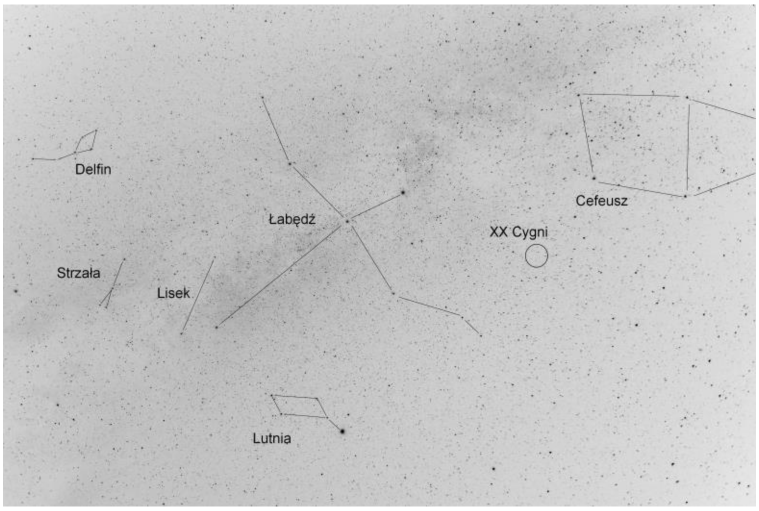
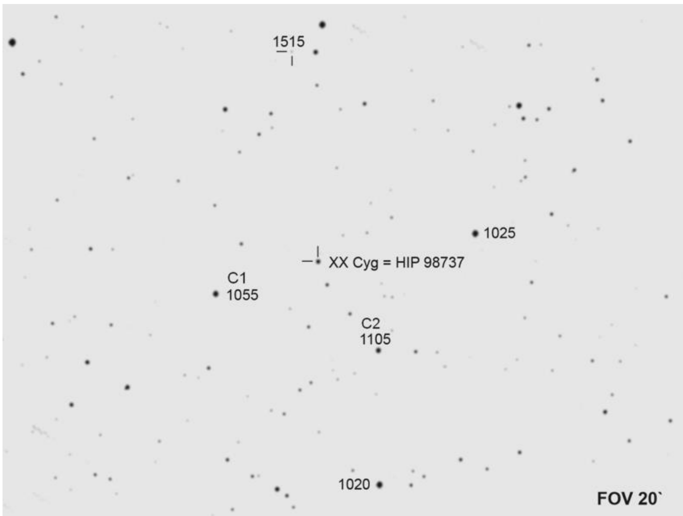
A bit of physic and history

Because of its short variable period, XX Cygni is counted amongst dwarf Cepheids – the so called delta Scuti stars, subtype: SX Phoenicis. Its location within the Hertzsprung-Russell diagram implies that it is a white hot star whose spectral type is A.
The star was discovered to be variable in 1904 by the Russian astronomer Lydia Ceraski. Based on her observations Ceraski found that the star's brigtness fluctuates between 11.36 mag and 12.20 mag. In 1912, Erich Korn published a monograph in which he focused on XX Cygni. The variability period he determined was 3 h 14 min 12 sec, i.e. 0.1348651 day.
Harlow Shapley was another astronomer interested in XX Cygni. He noticed that the star's period as well as its curve's shape differ from cycle to cycle. However, the average period appeared to him to be "sensibly constant".
Finally, in 2009, Richard Berry and his colleagues performed nearly 4,500 photometric measurements, and determined a new period.

The star's position on the celestial sphere

XX Cygni is positioned on the border between the Cygnus [Latin for "swan"] and Cepheus constellations. Its exact position is described by the following





coordinates:

Fig.2

Right ascension	**$RA_{2000} = 20^h\ 03^m\ 16^s$**
Declination	**$Dec_{2000} = +58^0\ 57'\ 17''$.**

Fig. 1

Observations and measurements

I have based my research on material gathered during two observation nights at the turn of July and august 2014. I have used a total of approximately 800 images.

Out of the three types of calibration frames used for developing CCD camera images, I have used only dark and flat frames.

Following my observations I performed a photometry, i.e. the measurement of XX Cygni's brightness. The photometry is always relative, therefore a star whose shine is non-variable. I have selected GSC 3948-2542 and GSC 3948-2105 (marked as C1 and C2 in figure no. 2).
I have used the Munipack automatic photometry software to measure the stars' brightness in particular images. I just needed to load the relevant images and calibration frames, wait, and obtain a ready-drawn curve. The software quotes time in HJD, i.e. JD time adjusted for the Earth's location on its orbit. I have used Excel to perform the necessary calculations and to present XX Cygni's relative brightness in magnitude scale.

I have obtained the following curves:

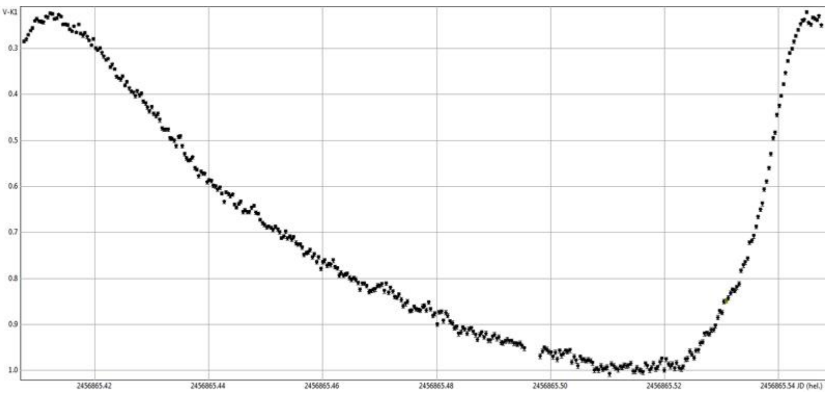


Fig. 3 2014-07-26/27

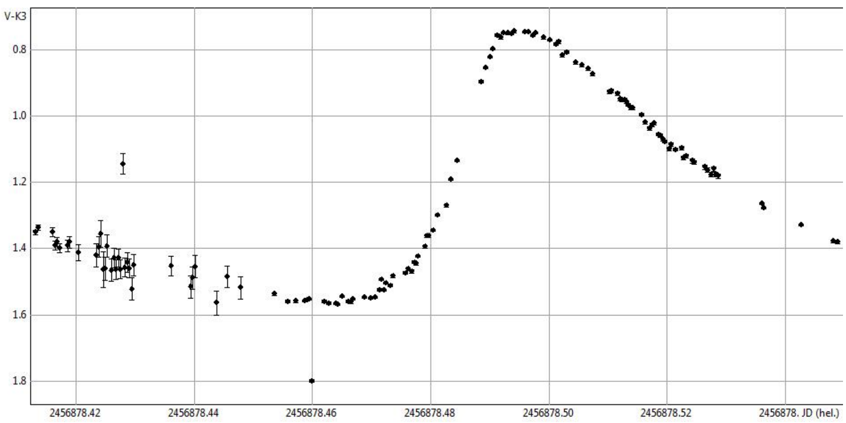


Fig. 4 2014-08-08/09

The stars' brightness vs time plot

I started with determining the maximum brightness point for each curve, i.e. my T_{obs}. To do so, I used the Kordylewski method which involves overlapping the curve with its reverse picture. In Kordylewski's times carbon paper was used for this purpose, now however, I have used Gimp graphic software.

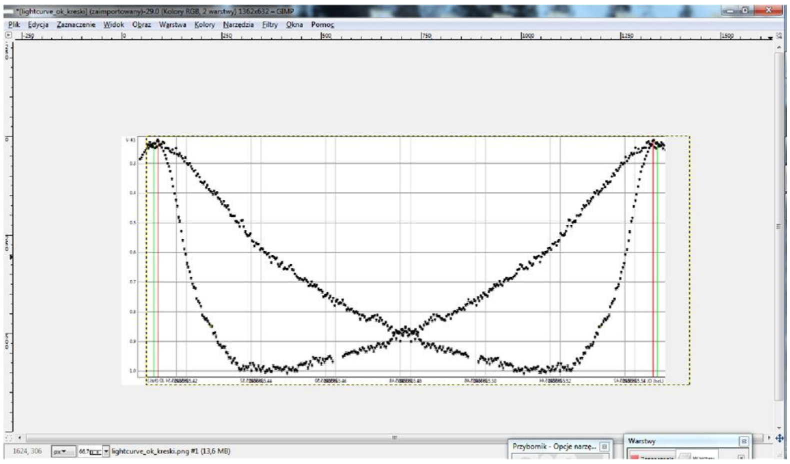


Fig. 5

I have then measured the distance between the lines I had drawn before (from the point which to me reflected the maximum), bisected it, and added or subtracted from the value of abscissa for the point concerned. I have obtained the following results:

T_{Obs1} = 2456865.41054
T_{Obs2} = 2456865.54603
T_{Obs3} = 2456878.49275

In addition, I was able to determine a makeshift variability period as:

$P = T_{Obs2} - T_{Obs1} =$ **0.1355^d +/- 0.0001 = 3^h 15^m 07^s +/- 10 s**

The shape of the curve is strongly asymmetric, the star fading slowly and shining up rapidly.

The O minus C method (Observatum minus Calculatum)

The O – C method is a powerful tool to study periodic phenomena. In order to analyse periodic phenomena, we can determine an *ephemerid*, i.e. the expected moment of appearance of a variable star's brightness point for instance. Usually, the moment when the point is observed – i.e. the ***Obsevatum*** value – differs from the calculated point – i.e. ***Calculatum***. The analysis of departures, i.e. computed "O-C" differences makes it possible to draw conclusions both as to the object concerned, and as to our knowledge about the object concerned. Let me explain it with four examples, using the variability period P (expressed in days) and the starting period T_0 (expressed in HJD). The number of cycles, i.e. epochs (E, which is always an integer) is going to be my auxiliary value. The *ephemerid* for a given phenomenon, e.g. for the appearance of a variable star's brightness point, is calculated as follows:

$T_{Cal} = T_0 + E \times P$, where T_{Cal} is our Calculatum.

Once the phenomenon is observed, we determine the T_{Obs} point, i.e. our *Observatum*. The remainder of

$T_{Obs} - T_{Cal}$

is the value **O – C** that we have just wanted to determine.

Now it is sufficient to trace the behavior of the O-C value along the E (epoch) function, and we can draw astrophysical conclusions. There are four fundamentally different behaviors:

a) Where with the increase of the epoch the O-C values oscillate around zero, our period (P) has been determined correctly, and it can be said to be stable
b) Where with the increase of the epoch the O-C value increases (or decreases) in a linear way, our period (P) as used for computations is too short (or too long)
c) Where with the increase of the epoch the O-C graph becomes a paraboloid with its peak turned upwards (or downwards), the star's variability period (P) extends (or decreases)

d) Where with the increase of the epoch the O-C graph becomes a sinusoid, the star's value of the variability period is cyclical, which is the most interesting case.

Computing the O-C value (Observa~~n~~tum minus Calculatum)

The respective maximum brightness points are:

TObs1 = 2456865.41054

TObs2 = 2456865.54603

TObs3 = 2456878.49275

The subsequent step has involved computation of the C value. To calculate the value, I have used the Berry at al. ephemeris formula:
T_{Cal} = 2430671.1027 + 0.134 865 075 x E + 2.53 x $^{10-13}$ x E^2
where:
E - – epoch, i.e. the period's number.
I have obtained the following points for the data analyzed at the relevant observation dates:
T_{Cal1} = 2456865.40695 + 0.00954 = **2456865.41649** where E = 194 226
T_{Cal2} = 2456865.54182 + 0,00954 = **2456865.55136** where E = 194 227
T_{Cal3} = 2456878.48886 + 0.00954 = **2456878.49840** where E = 194 323

Once I subtracted the observed points from the computed points, I arrived at the following three O-C values:

$O\text{-}C_1$ = - 0,00595
$O\text{-}C_2$ = - 0,00533
$O\text{-}C_3$ = - 0,00565
I have plotted the results on the graph developed by Berry and his colleagues. The blue points are the historic data, the white points are Berry's observations, and the red points are mine.

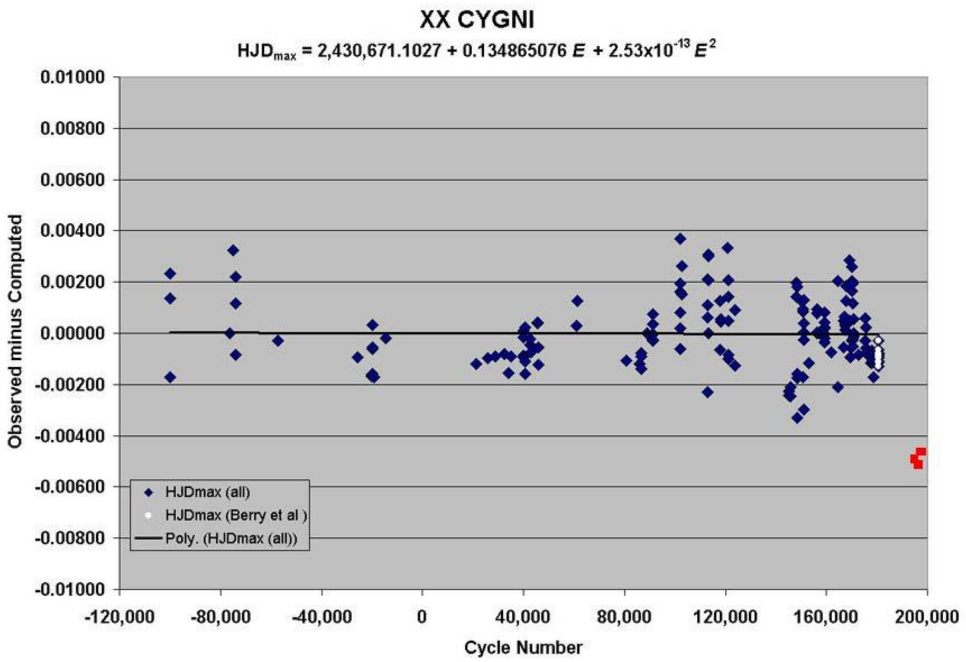


Fig.6

Summary

While using photometric observations of the XX Cygni pulsating variable star, I developed 2 brightness variability curve graphs. I determined the observed points for three brightness points, and subsequently I determined three O-C values using the *ephemeris* published in the related literature. As can be inferred from the graph, the *ephemeris* concerned correctly describes the changes of the variability period of the star concerned. There might be just one adjustment regarding the very value of the variability period (P). As can be inferred from the graph, the gradient is 0.004 day for 300 000 cycles, which results in the following period adjustment:

delta P = - 0.0000000013^{d} therefore the new suggested period is:

P = 0.134865063^{d}.

Bibliography:

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