

March 23, 2004

Always remember to start your diary with the date and title.

The Light Curve of a Variable Star

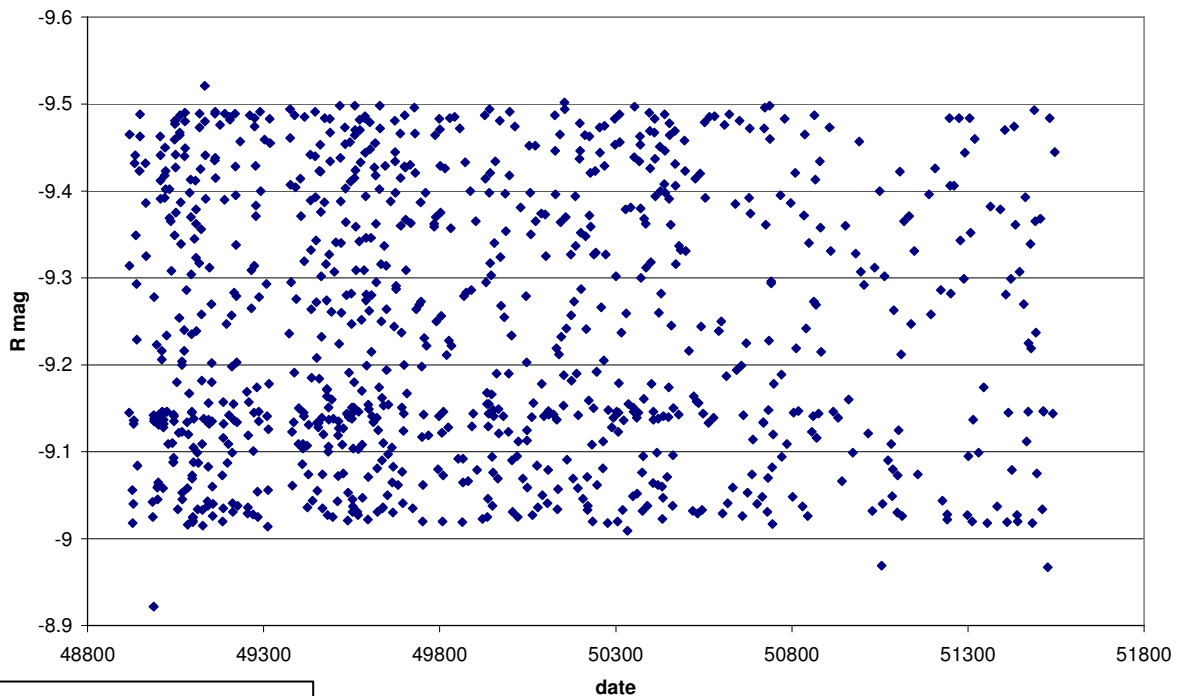
Aims

Fine. This is a good summary of the main aim of the exercise.

The aim of this exercise is to determine the period of a variable star from measurements made by the MACHO experiment over 7 years. I will use the estimated period to reconstruct the light curve and identify the type of star.

Data

Graph 1 shows the data plotted as magnitude against modified Julian date.



Numbering graphs is good practice. The axis labels on this one are a bit small.

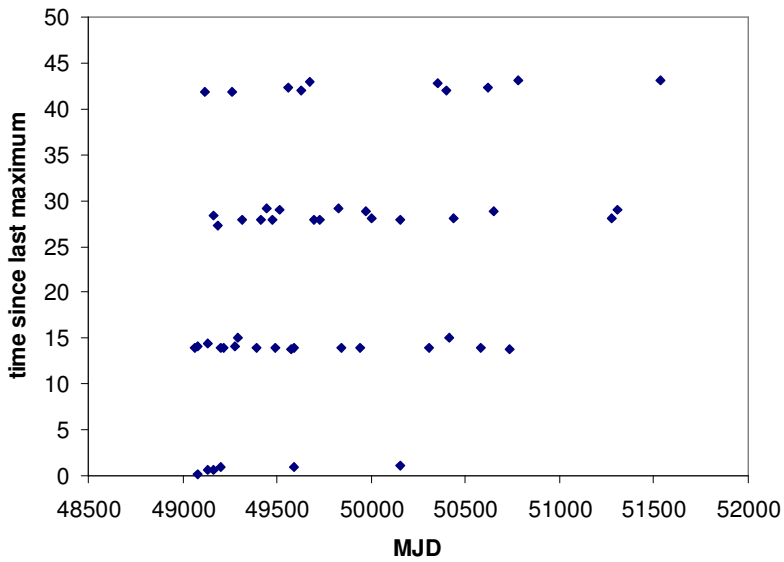
Graph 1: Basic data

The magnitude at minimum is about -9 and at maximum about -9.5.

Selecting all the data with magnitude between -9.48 and -9.5 and looking at the time separation gives the following plot:

Maybe these numbers should have errors. The minimum looks closer to -9.01.

This axis label should specify the units (days).



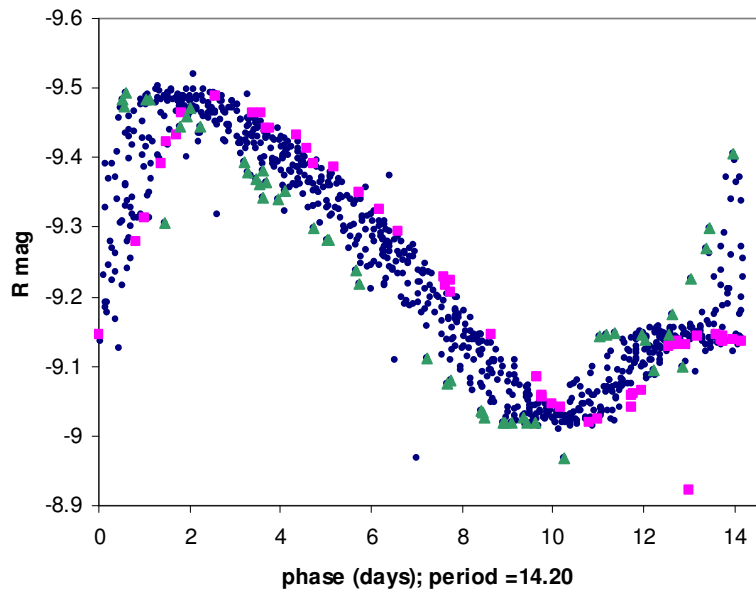
Graph 2: separation of maxima

This is good. The student has explained where the error estimate came from.

There are a few separations of ~1 day which probably come from the same maximum. Otherwise it is obvious that the period is about 14 days. Averaging all the intervals between 13 and 15 days gives 14.05 ± 0.07 days (standard error of 16 measurements).

Repeating this analysis for intervals around 128 days (9 periods) gives 14.20 ± 0.02 days (standard error of 6 measurements). The error is smaller, even though there are fewer measurements, because we divide by 9.

Try plotting this:

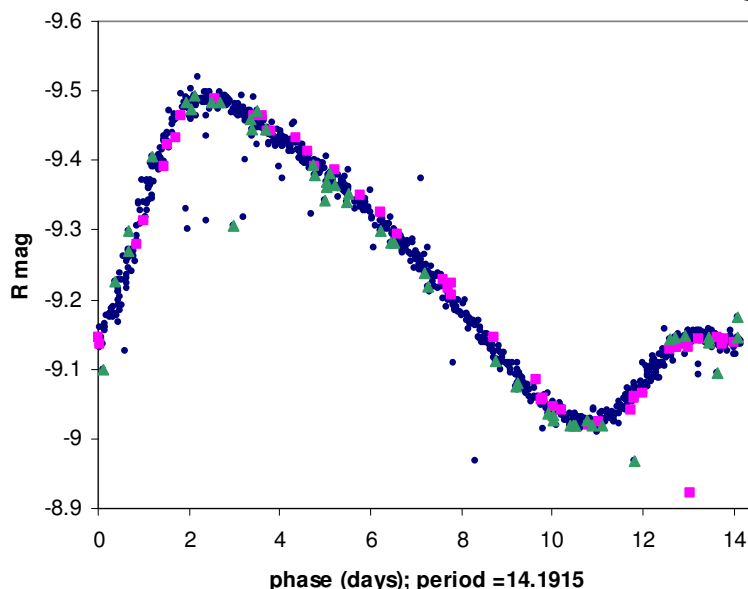


Graph 3: plot of first period estimate (14.20 days)

Alternatively, the student could have made a few more iterations at calculating the period before drawing graph 3.

The squares are the first 50 points and the triangles are the last 50. Obviously the period is a bit too long. In ~ 2500 days (176 periods) the curve has slipped by 1.5 ± 0.3 days (based on measuring a few pairs of squares and triangles). This suggests that the period should be reduced by 0.0085 ± 0.0017 days, to 14.1915 ± 0.0017 days.

Note that the ± 0.02 days on the 14.20 estimate no longer applies, because the trial period used was 14.20 days exactly, and the correction of 0.0085 ± 0.0017 is applied to this

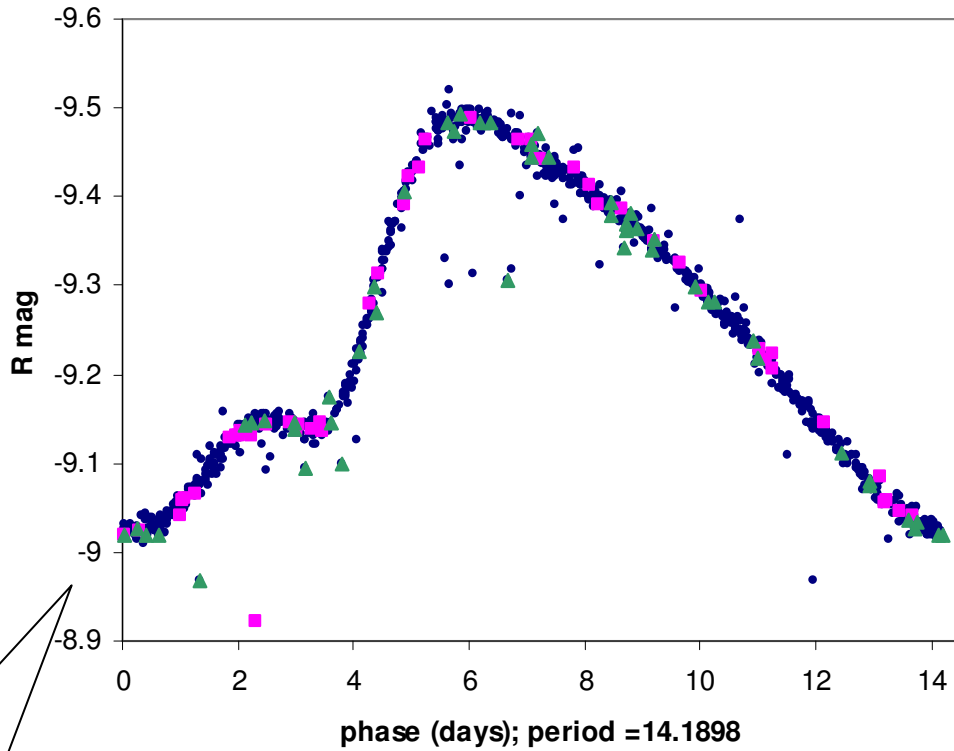


Graph 4: second estimate of period (14.1915 days).

This is much better, but the triangles are still behind the squares. Adjusting by hand, I find that it is impossible to distinguish between the curves for 14.1895 days and 14.1900 days, but 14.1890 and 14.1905 days are definitely worse. I therefore estimate a period of 14.18975 ± 0.00025 days. The minimum occurs at about 10.75 days, so adding this to the zero time gives Graph 5.

Again, this is good, because the student has clearly explained how the final error was estimated.

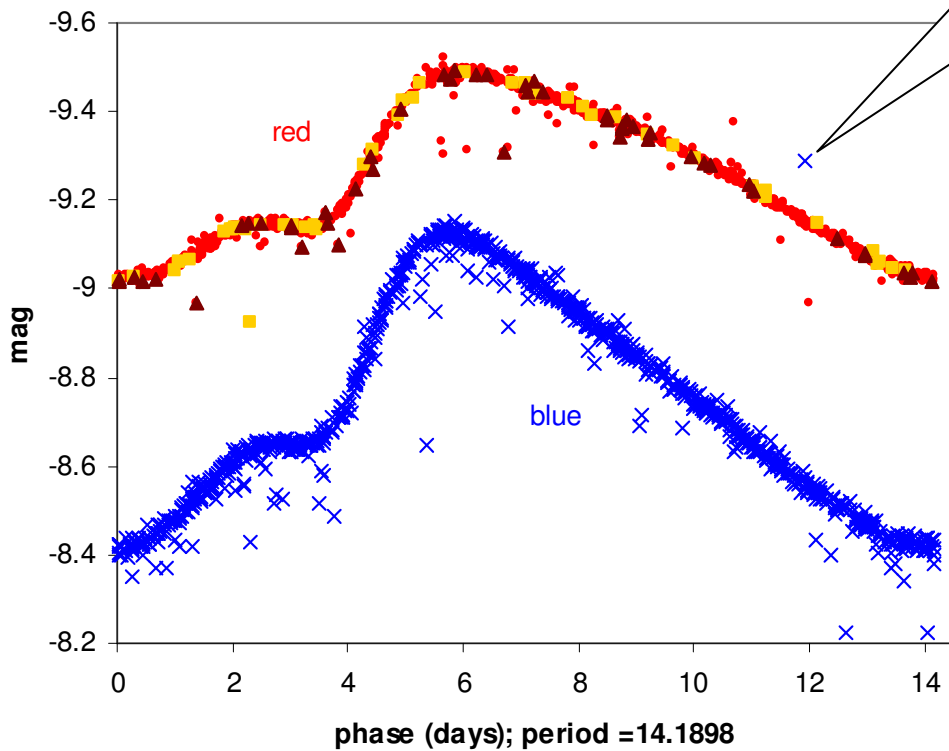
The same period and zero give a good curve for blue magnitude (graph 6). The amplitude of the red curve is 0.468 ± 0.007 magnitudes; the blue curve amplitude is 0.720 ± 0.007 magnitudes (errors based on the thickness of the curve). The amplitude is clearly greater in blue light.



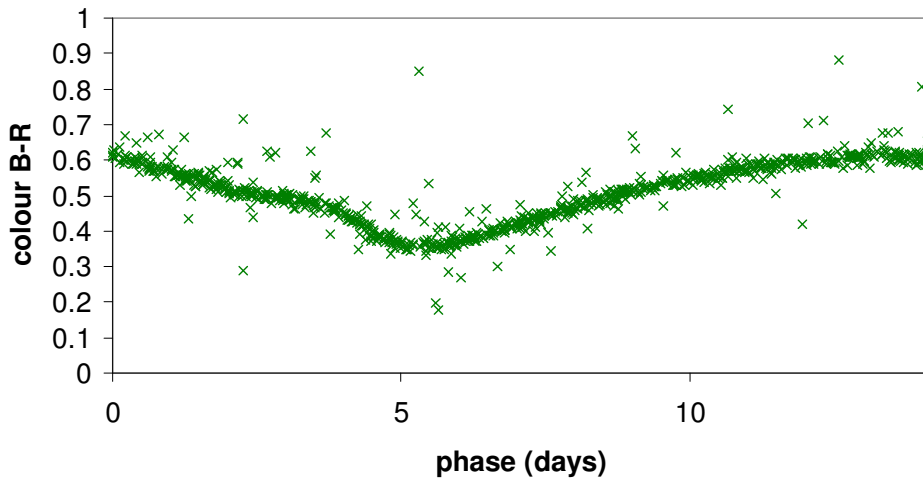
At this point the student should really have inserted error bars (the spreadsheet does give the errors in magnitude).

It would also have been good to comment on the small number of obviously bad points.

Graph 5: best estimate: 14.1898 days

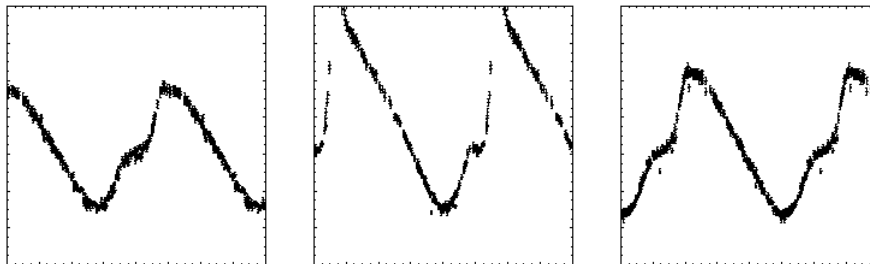


Graph 6: Red (top) and blue (bottom) light curves



Graph 7: B-R colour

The colour plot (graph 7) shows that the colour index is smallest at or just before the star is at its brightest. This means that the star's surface temperature changes through its cycle and is hottest at or near its brightest point. This is reasonable since blackbody radiation is proportional to T^4 .



These graphs don't have axis scales! This is not easy for the student to fix, because that's how they come off the web site, but some comment would be good.

Graph 8: MACHO light curves from the interactive PL plot

Comparison with curves 13-15 of Payne-Gaposhkin (periods 10.89, 14.71 and 15.11 days) and with plots from the correct region ($\log P \approx 1.15$) of the MACHO web site (see graph 8) shows that the light curve obtained is typical of a Cepheid of this period. The diagnostic features are

- "sawtooth" shape (fast rise, slow decline)
- small secondary bump on the rising part of the curve.

It can be seen from Payne-Gaposhkin that the position of the secondary bump varies smoothly according to the period of the Cepheid. A bump on the rising part seems to be typical of periods between 10.89 and 17.07

days, whereas Cepheids with periods between 5.37 and 10.14 days, and the long-period Cepheid SV Vulpeculae, have bumps on the falling part.

Comparison with accepted values is a good thing. The student should give a reference URL for this database.

The MACHO Variable Star database gives the following parameters for star 82.8408.22:

- period 14.1895 days
- amplitude in red 0.463 magnitudes
- amplitude in blue 0.711 magnitudes
- apparent magnitudes 15.545 (V) and 14.78 (R).

No errors are quoted. These are in good agreement with my values: the period and the red amplitude are within one error bar and the blue amplitude is just outside one error bar. The quantity $W = R - 4(V-R)$ plotted on the interactive PL plot comes out to 11.72, which is consistent with the period. The MACHO database appears to class this star as an eclipsing binary, but this is clearly not right: the web page does warn that the classification is only approximate.

This is a good lab diary. The student might have been docked half a mark for the various minor criticisms, particularly missing out the error bars on graphs 5, 6 and 7, and not making any comment about the outliers. But the measurements seem to be good, the errors on the measurements have been carefully explained, and the comparison with the MACHO database demonstrates that the results achieved are reasonable. A lot of the calculations have been done on an Excel spreadsheet, and it would probably be wise for the student to print this out and attach it to the lab diary – otherwise any mistakes made in the spreadsheet calculations would be difficult to track down later.