Types of Variable Stars

by

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Basically there are two types of variable stars. (Variable stars are those which do not appear to have a constant brightness.) These stars may be divided generally into the following categories: a)eclipsing binaries; and b)intrinsic variables. However, as we shall see, there are several sub-types in each of these large more general categories.

A. ECLIPSING BINARIES: Here, we have the case where two stars in the course of their mutual revolution, eclipse each other. However, this is not as straightforward as it seems, as there are several interesting possibilities.

Before embarking on these possibilities, let us first explain what is meant by a "light curve" since we shall be referring to this extensively throughout the course of this article. Simply stated, the light curve of a star is a graph, where the brightness of the star is plotted vertically while the time is plotted horizontally. The light curve of a non-varying star is a horizontal line (Fig.1) whereas the curve of a variable star may take one of many different forms, one of which is shown in figure 2.

This brings us, then, to our discussion of the various kinds of eclipsing binary stars.

Figure 1: a non-varying star

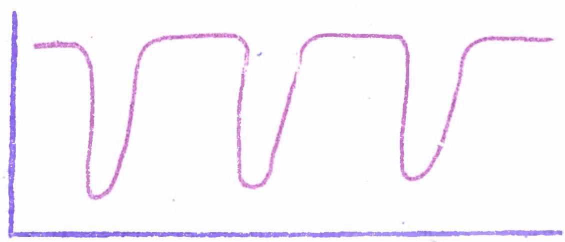

Figure 2: Algol type variable.

a.) Algol type variables. In this case, we have two spherical stars, of approximately the same size, which eclipse each other periodically. Here we have constant brightness for awhile, while both stars are visible, and then minimum light periods when one or the other is eclipsed. The resultant light curve is shown in Fig.2. (It should be noted here that the various types of variable stars are named after the first star of that type to be discovered. In this case, Algol was the first eclipsing binary to be known.)

It may be, however, that the two stars may not be of the same size or brightness, or that the eclipse may not be a total eclipse. Let us examine both of these possibilities.

Suppose that we have a large faint (by comparison to its companion) star, and a small brighter star. Then you will have periods of constant brightness, when both are visible, interspersed with deep minima, when the small star is behind the large one, and shallow minima, when the small star is masking a bit of the light from the larger one. (See fig.3)

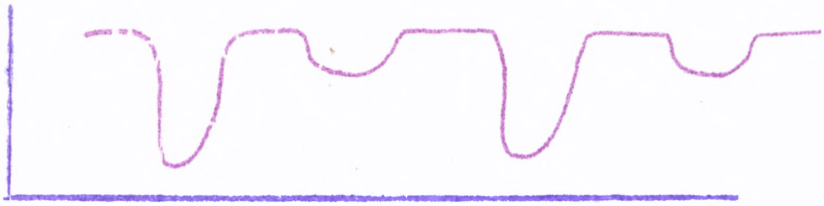

Fig.3 Stars of Unequal size and magnitude.

However, the light curve produced is nearly identical to that of a pair of stars which are only partially eclipsing (the only difference being perhaps in the depth of the minima). Here the spectral lines of the stars come to the rescue of the researcher, as in a total eclipse the spectral lines of the smaller star totally disappear, whereas, during a partial eclipse, the lines remain visible.

b.)Beta Lyrae Stars: Here we have "egg-shaped" stars, distended by their own mutual gravitation. Here, the light curve varies constantly.(See fig.4) There are no periods of constant brightness. Generally these stars are of spectral types O,B,and A, and have a period of revolution longer than ½ day. The constant variation is caused, not only by the eclipses,but also by the varying amount of elliptical surface presented by the star.

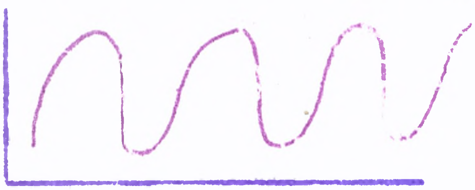

Fig.4-Beta Lyrae Stars

c.)W Ursae Majoris Stars: These stars are mainly of spectral types G,K,M and N, and a such are smaller than the sun. They are also very close, so that they are almost touching. The Law of Motion requires that they have a very short period, which is usually less than ½ day.

Fig.5-W UMa Stars.

IMPORTANT PRINCIPLE: From the above, it should be evident that stars of equal size and magnitude give equal minima on the light curves. Stars with inequalities give unequal minima. However, the minima are evenly spaced.

d.Peculiar Eclipsing Binaries:

d1)W Serpentis Type; Here we have an eclipsing binary which is embedded in very dark nebulosity. The dark gasses blowing around the stars cause irregularities in the light curves as they mask certain parts of the star system. See fig.6

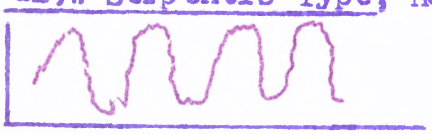

Fig.6-W Ser Light curve

d2) UX Ursa Majoris Type- In this type of binary system we have a gas jet flowing from one star to the other.This jet is illuminated and causes a dip in the curve at various places. The reason for the gas jet is that the stars are so close that they are almost touching. By necessity, their period of revolution is extremely short, just a few hours.

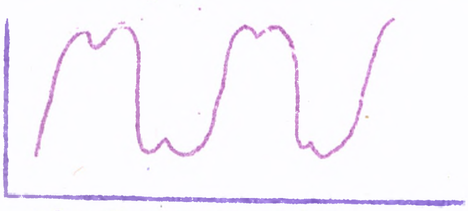

Fig. 7-UX UMa light curve.

B. INTRINSIC VARIABLES.-- In this case the star itself is truly variable and the magnitude changes come from within the star, not just from mutual hiding, as in the case of eclipsing binaries. Again, there are several sub-types of intrinsic variable stars.

I. RR LYRAE Stars: These stars are extremely regular stars (being similar to the famous Cepheids). Generally speaking, they have a period which is less than one day long. There are 3 sub-types of RR Lyrae stars..

RR Lyrae-a). These stars have rather large amplitudes (3 to5 magnitudes) and have periods around ½ day. The light curve (Fig.8) is characterized by a rapid rise to maximum and a slower decline. The minimum is nearly flat and takes up almost ½ of the period.

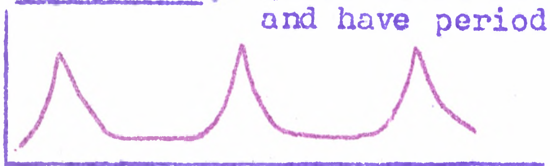

Fig. 8-RR Lyrae-a curve.

RR Lyrae-b). Remember that we are still speaking of RR Lyrae stars, so that the light curve (Fig.9) is very similar to that of the "a" type. The difference is shown in smaller amplitudes and slower rises to maximum.

Fig.9-RR Lyrae-b curve.

RR Lyrae-c). These stars have a light curve which is a sine curve. (Fig.10) That is, there is a gradual rise to maximum, followed by an identical fall to mimimum.

Fig.10-RR Lyrae-c curve.

II. CLASSICAL CEPHEIDS: These stars are the "yard-sticks" of the universe, as they are used to measure the distances of distant star clusters and galaxies. This is possible through the Period Luminosity Law. This Law says, in general terms, that all Cepheids of the same period have the same luminosity. We know, for example, that a star with a period of 1 day has an absolute magnitude (luminosity) of -3. Then once its absolute magnitude and its apparent magnitude are known then it is an easy matter to calculate its distance. This is true even for Cepheids in outer galaxies, so, if you know the distance to the Cepheid you know the distance to the galaxy.

However, there are two sub-types of Cepheids.

Delta Cephei stars (Population I stars). These are found generally along the galactic plane. The light curve is characterized by a rapid rise to maximum, a slower descent, with a hump on the descending side of the curve (Fig. 11). Each rise and descent is exactly the same as the rise and descent immediately before and after it. The curve, therefore, is extremely regular.

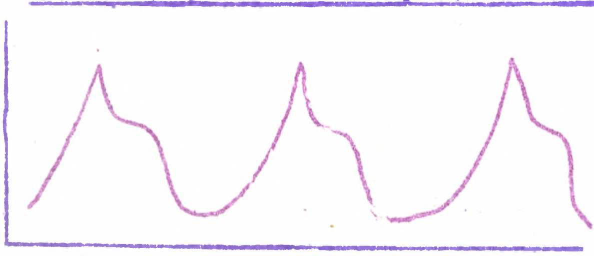

Fig.11- Delta Ceph curve.

W Virginis Stars (Population 2) These stars, a type of cepheid, are found in the galactic halo. There is a pronounced hump on the descending branch of the curve, which varies perceptibly from one maximum to the next. See fig.12) However, the time between maxima is constant, and the Period-Luminosity Law still holds for these stars.

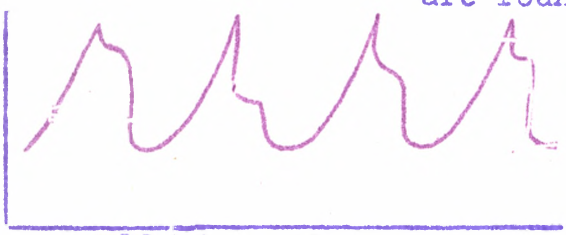

Fig.12- W Vir curve

III. BETA CANIS MAJORIS VARIABLES: These stars, named after the second brightest star in Canis Major, have a very small amplitude, rarely exceeding 0.1 magnitudes. (Fig.13) The fluctuations die out after varying regularly and do not resume for a year or two. Most of these stars are hot white stars of spectral types A and B.

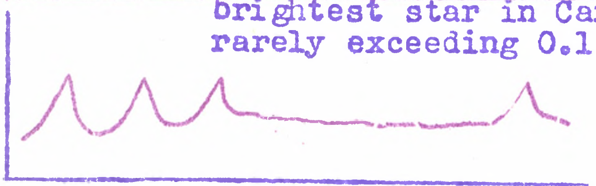

Fig.13-Beta CMa curve.

IV: DELTA SCUTI VARIABLES.: Delta Scuti stars are visually indistinguishable from RR Lyrae stars. However, when examined with a spectrograph, the radial velocity curve, showing the rising and falling of the surface, is out of step with the light curve. (See Fig.14) These stars are usually of spectral type F.

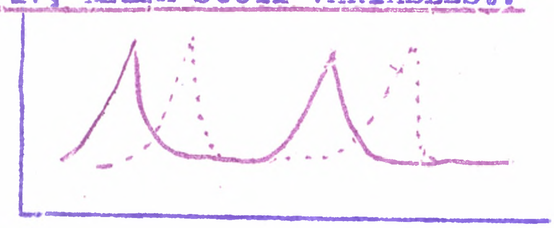

Fig.14- Delta Sct. curve with dashed radial vel. curve.

V: LONG PERIOD VARIABLES.: These variables are by far the most common type. They are easily studied by amateur astronomers, and, as such, are not studied extensively by professionals. These are sometimes called "Mira" type stars as they were named after Omicron Ceti, their prototype, which was called Mira by the Arabs.

The light curve does not really have an absolutely regular maximum, or period, but seems to vary around a mean. Thus, a maximum may be a few days late, a few days early, and brighter one time than the next. (See fig.15). Some variables have periods as short as 10 days, while others are as long as 400 days. Magnitude ranges may be as large as 14 magnitudes or as small as a few tenths of a magnitude.

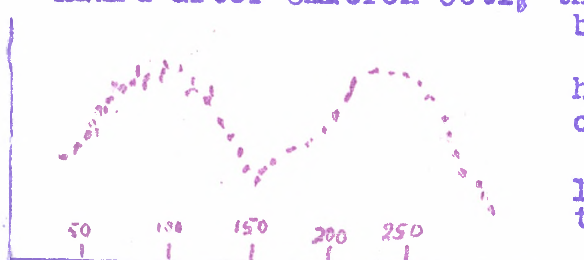

Fig.15-Long Period Var. curve.

VI: SEMI-REGULAR VARIABLES.- Semi-Regular Stars are those which have a regular curve for awhile (more like long-period) and then go totally irregular for awhile, with unpredictable ups and downs. There are four types of semi-regular variables.

Semi-regular-a: These are giants of spectral types K, M and R. They are much like Long-Period variables, and are differentiated from them by smaller changes in magnitude.

Semi-regular-b: They are generally recognizable in that they often have a very distinct regular period with interruptions of constant brightness or irregular brightness. An example is the Variable U Bootis.

Semi-regular-c: Again we have giant stars. The light changes are only one or 1.5 magnitudes. An example of a semi-regular-c type is Betelguese.

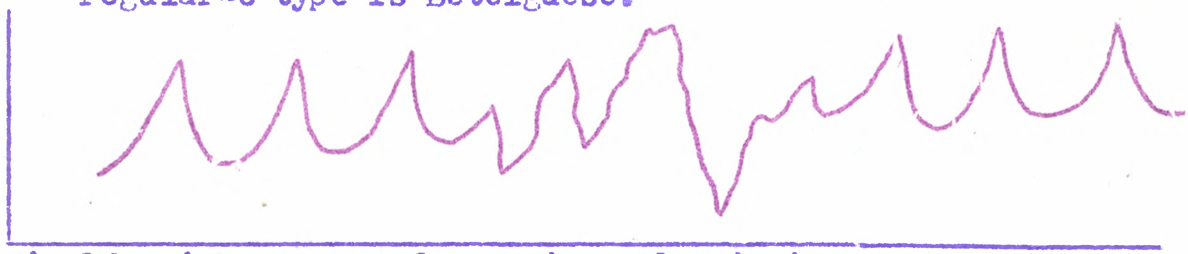

Fig.16- Light Curve of a semi-regular-b star.

Semi-regular-d: These are giants of types F, G and K. They have alternate deep and shallow minima like RV Tauri stars (whose description follows). The difference is that they have emission lines of Hydrogen in their spectrae while RV Tauri types do not.

VII: RV TAURI STARS: This type of star is both rare and luminous. It has alternate deep and shallow minima. They are largely of spectral types F, G and K. Figure 17 shows a stylized curve, while figure 18 shows an actual curve of R Sct, which is an RV Tauri type. This curve was made from observations by the author over a period of 2 years.

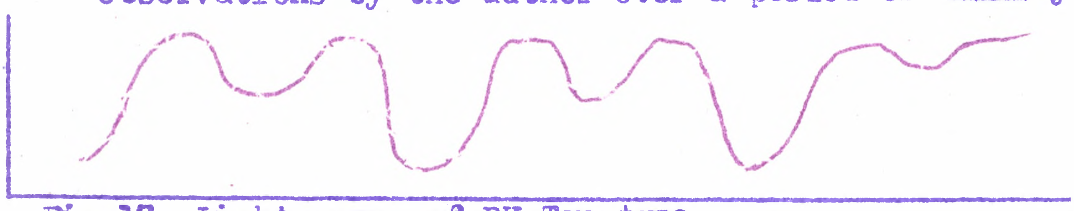

Fig.17- Light curve of RV Tau-type

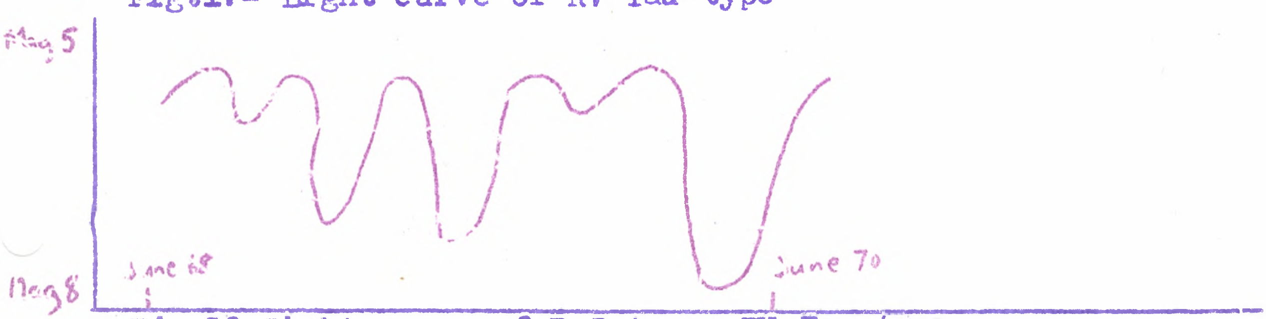

Fig.18-Light Curve of R Sct, an RV Tau-type.

VIII: IRREGULAR VARIABLES.. Irregular variables have no period but vary several magnitudes at inconstant periods. Figure 19 shows the light curve of RX Leporis, an irregular variable observed by the author. The curve is based on actual observations.

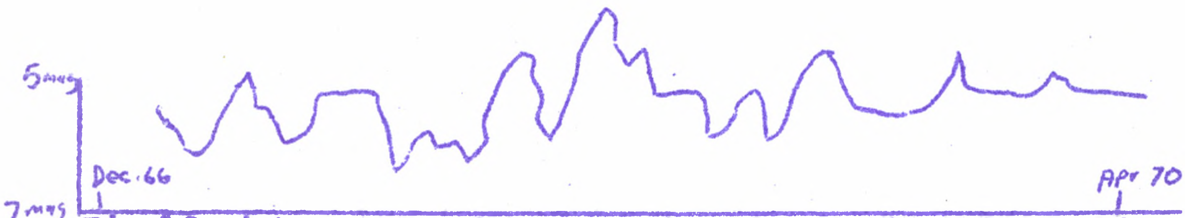

Fig.19 Light curve of RX Leporis- observations by K.Chilton

IX: ERUPTIVE VARIABLES: Eruptive variables are those that remain constant for certain periods and then burst out into greater brilliance. The rise in magnitudes is quite sudden and quite quick. If the observer is not aware, he might think that he has discovered a nova!

There are two main kinds of Eruptive variable.

U Geminorum Type: One type of eruptive variable is the U Gem type. However, there are two kinds of U Gem stars. One has a long maximum (fig.20) before returning to normal, while the other has a short ~~maximum~~ before descending. see fig.21.

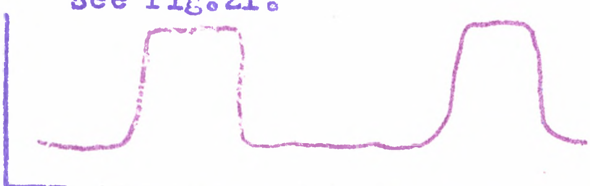
Fig.20- U Gem type-Long max.

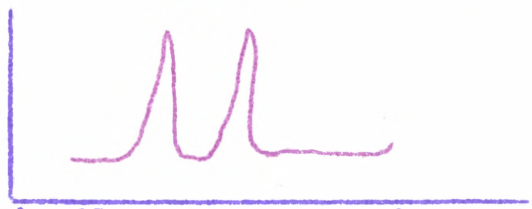
Fig.21- U Gem type- short max.

Z Caemelopardelis type; Z Cam stars are quite like U Gem stars except that there is usually a distinct plateau on the descending branch of the curve. (See fig.22)

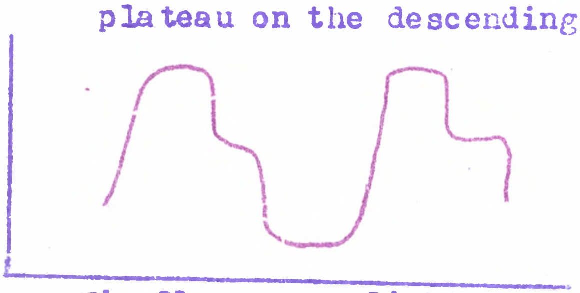
Fig.21- Z Cam light curve.

X: NEBULAR VARIABLES: Like the W Serpentis type of eclipsing binary nebular variables are embedded in, or associated with, nebulae. The passing gasses cause some fluctuations in the light curve, but it must be remembered that they are still varying of their own accord. There are three sub-types.

RW Aurigae types; It is likely that this type is an exceptional

Cepheid with a long period. They are reasonably periodic with fluctuations at maximum and minimum, no doubt caused by the nebulosity.

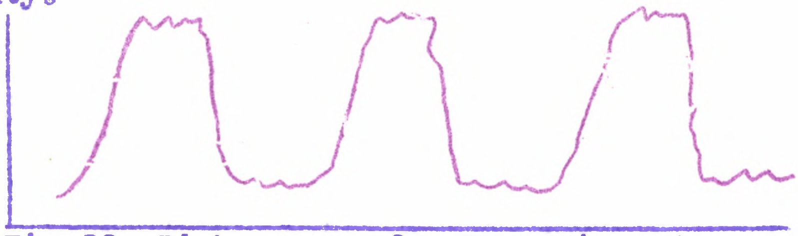

Fig. 22- Light curve for RW Aurigae types

T Orionis type: These stars are still in the process of forming under gravitational contraction. (All known examples are embedded in the Great Nebula in Orion.) The light curve is quite irregular, but in this case, the main source of irregularity is the opacity of the surrounding gas, while there is some pulsation due to contraction.

T Tauri type: This kind of star may not be true variable. Not enough observational data has been gathered to make a statement one way or the other. The light curve is marked by small sinusoidal changes.

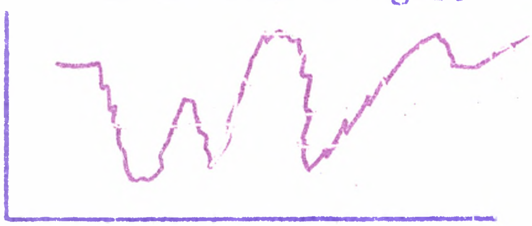

Fig. 23- T Ori light curve

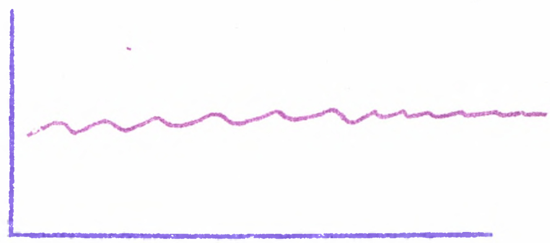

Fig. 24- T Tau light curve.

XI.* R CORONA BOREALIS TYPE- R Cor Bor stars are the opposite of eruptive variables. They remain at constant brightness and then fade very quickly. The unwary observer may believe that the star has "gone out," but after awhile, the star returns just as quickly to normal.

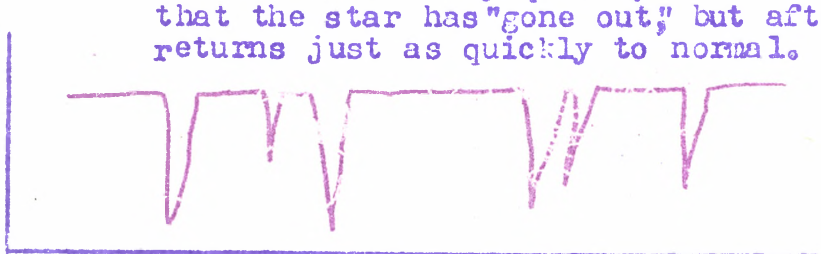

Fig. 25- Light Curve for R CrB type stars.

XII* UV CETI STARS (Flare stars)-- Flare stars are very small red dwarfs, reaching the ends of their lives as stars. They are, nontheless, suns, and as such are likely to have the equivalent of solar flares. (Probably all stars do.) However, in this case, that star is quite dim, and the flare is very bright, so that a sudden brightening will occur for 5 or 6 minutes, and the star will then fade back to obscurity. This happens at very infrequent and irregular intervals, and so is one of the most frustrating types of observations to make.

XIII: Novae -- Novae are the stars which perhaps catch man's imagination like no other type. The thought of the sun blowing up is one of man's hidden terrors, hidden in the very back of his subconscious.

Two or three novae are discovered every year by patient observers who are very familiar with every square degree of the sky. In a nova, there is a sudden brightening of 8 to 10 or more magnitudes. The star throws off a sphere of gas in all directions and then fades to relative obscurity.

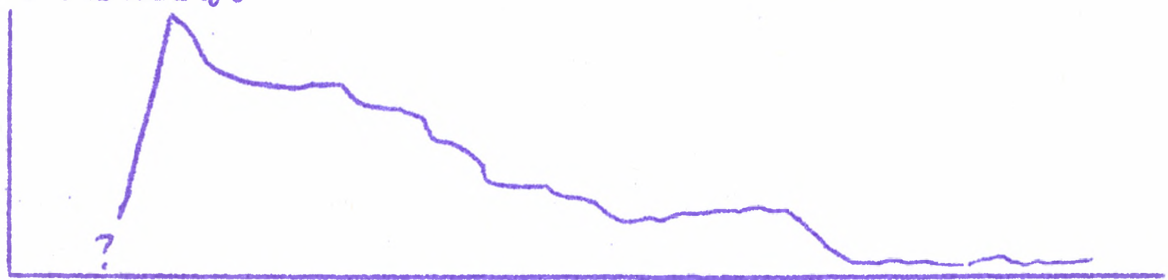

Fig. 23;- Light curve of Nova Delphini-1939-

XIV: SUPERNOVAE- A supernova is greater than a nova in that in the former case, the star is nearly totally annhilated. Such an occurrence took place at the formation of the Crab Nebula-(M 1) and was recorded by Chinese astronomers in 1054.

References:

VARIABLE STARS- J.S.Glasby

OBSERVING VARIABLE STARS WITH BINOCULARS* K.E.Chilton

A.A.V.S.O. MANUAL FOR OBSERVING VARIABLE STARS.

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