ROYAL ASTRONOMICAL SOCIETY OF NEW ZEALAND.

VARIABLE STAR SECTION.

CIRCULAR No. 138.

VISUAL OBSERVATIONS OF EX HYDRAE AT MINIMUM

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SUMMARY:- To assess the accuracy of visual observations a detailed study was made of EX Hydrae. Results in graphical form are presented showing that visual observations are in good agreement with predictions of eclipses of this binary star and also reveal an irregular flare like activity.

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INTRODUCTION:-

EX Hydrae (1950: R.A. 12h 49m 42s Dec. S. 28° 59!2) was tentatively assigned to U Gem class (1). Mumford has investigated this star (2) (3) which is also an eclipsing binary. Mumford has also reviewed data on Dwarf Novae (3) (4). Bateson has published a good chart for this variable (5).

Investigation of variations of EX Hydrae at minimum by visual methods was to determine whether such methods would be sufficiently accurate to show variations of small amplitude. It has long been contended that in the hands of experienced amateurs visual observing is capable of accuracy sufficient to permit the following of fluctuations of eclipsing binaries of U Gem type at minima under certain conditions.

Recent papers by Bateson and Kohler (6) and Bateson (7) support the accuracy of visual work by experienced observers.

EX Hydrae was chosen to test the accuracy of visual observing because its variations are small and its period is short and has been well determined photoelectrically. In addition it is well placed for observing from New Zealand and there is a good sequence of comparison stars close to the variable.

The observations here presented were carried out with the Zeiss 50 cm Cassegrain reflector (f.l. 6650mm) at the Auckland Observatory. Observing was carried out as for the standard visual flare star programmes but with estimates being made at one minute intervals.

OBSERVATIONS:- Observations were made as follows:-

1968 JUNE 27 GMAT	2037 to 2236	JD (H) 2,440,035.8606 to .9433
JULY 11	2050 to 2250	049.8684 to .9517
12	1909 to 1943	050.7981 to .8217
14	1816 to 2230	052.7611 to .9375
16	1947 to 2015	054.8241 to .8435
16	2041 to 2108	054.8616 to .8804
16	2130 to 2142	054.8956 to .9040

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Observations on June 27 and July 11, 12 and 14 were by Marino and Walker and on July 16 by Walker and Goodfellow. All observations were at one minute intervals.

The comparison sequence used for making the estimates was stars k, l, n and p of Chart No. 141 (5).

As photovisual magnitudes are not available equal steps were assumed for plotting results. This was considered sufficiently accurate for the purpose of the programme. Most observations were between stars l and p.

Results are given in graphical form (Figures 1 to 7). Figure 1 gives results for the interval JD (H) 2,440,035.8606 to .9433 from cycle phase 0.0 through a complete cycle to phase 0.25. Figure 2 gives a superimposed plot of the two parts of the curve on the same night from phase 0.9 to 0.3.

Figure 3 gives results for the interval JD(H) 2,440,049.8684 to .9517 from cycle phase 0.3 through one cycle to phase 0.55; Figure 4 for JD(H) 2,440,050.7981 to .8217 from 0.9 to 0.3; Figure 5 for JD(H) 2,440,052.7611 to .9375 for two and a half cycles from 0.7 to 0.3 and Figure 6 for part of a cycle from JD(H) 2,440,054.8241 to .9040 during the phase 0.95 to 0.25, 0.45 to 0.8 and 0.98 to 0.1. Figure 7 is the mean light curve for all nights, the lower curve omitting the major flare on July 14 GMAT.

COMMENTS ON OBSERVATIONS:

1. June 27 GMAT. JD(H) 2,440,035+

Minima were observed as shown in Table 1.

TABLE 1.

MINIMUM.	JD (H) 2,440,035+	DEPTH (approx).	DURATION.	PHASE.
A	.8613	0.8 mag.	start not observed	0.037
B	.8683	0.3	5 to 8 mins	0.139
C	.9009	0.4	5 to 10 mins	0.617
D	.9273	0.6	4 mins	1.000
E	.9384	0.3	5 mins	1.167

From Mumford's epoch and period, calculated major eclipses were predicted to occur at JD(H) 2,440,035.8588 and .9271. The calculated minima were not determined until after all observations were completed to avoid any possible anticipation of results.

The primary minima "A" and "D" are both very definite although from Mumford's data the depth is only 0.6 magnitude. The beginning of the observing period coincided with the first eclipse "A" and the time of mid-eclipse and its depth and duration are thus uncertain. No accurate estimate of the period between eclipses is possible. Eclipse "D" is well defined both in depth and duration, both of which were found to be identical to previous published values. This minimum was observed within 15 seconds of the predicted time, and a higher accuracy than this would be impossible to achieve using visual techniques.

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The largest minor minimum was observed at 0.617, considerably later than expected.

The general shape and duration of curves for minima at "B" and " "E" are the same but "B" is generally brighter than "E" (fig. 2).

It was apparent while observing that the star is subject to minor fluctuations. This is shown also in the observations where there is flickering about the mean value. While some of the flicker would be due to atmospheric disturbance and observational error, the close proximity of the comparison stars would reduce these errors to a minimum.

No observation was recorded of the eclipse at 0.5P(0.8929d) and in fact a brightening was observed from 0.8912d to 0.8933d.

2. July 11 GMAT. JD(H) 2,440,049*

A primary minimum was predicted at 0.9151d. (Fig. 3). When Figures 1 and 3 are superimposed there is little direct correlation between the two sets of readings. It is apparent that the system was in a very active state on this night and that irregular fluctuations completely obscured the eclipse.

The shape of the curve, when it exhibited rapid brightenings, particularly at 0.8822d and 0.9413d, is strikingly similar to the flare observed by Goodfellow and confirmed photometrically from Japan for the flare star YZ CMi (7).

In addition to rapid brightenings, fadings were found to occur usually immediately before and/or after the flaring. This is particularly noticeable from 0.8774 to 0.9059d when four maxima occured followed by four minima, none of which coincided with predicted eclipses, and from 0.9322d and .9489d when two maxima alternated with two minima.

3. July 12 GMAT. JD(H) 2,440,050+

A primary minimum was predicted at 0.8021d and observations were made over a short period to cover the minimum (Fig. 4).

Again as on the previous night the eclipse suffered interference from a minor flare which reached a maximum approximately 1½ minutes before the predicted eclipse and had the effect of making the eclipse appear to occur late. Observation was further complicated by a fading immediately following the flare.

Although observation was restricted to a short period it was apparent that the system was in an active state similar to the previous evening.

4. July 14 GMAT. JD(H) 2,440,052+

Primary minima were predicted at 0.7809d, 0.8491d and 0.9173d.

Observing conditions on this evening were excellent and the quality of the observations would be better than on other evenings of the programme.

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In particular the change of brightness at eclipse times was very distinct. Advantage was taken of the conditions to observe for a full two and a half cycles (4hrs 14 mins). Refer to Figure 5.

Irregular fluctuations were not as dominant as on the previous evenings, particularly from the second half of the first cycle to the end of the observing period.

A major flare was observed from 0.8201d to 0.8306d being approximately 1½ to 2 magnitudes above the mean cycle brightness at its maximum. It occurred immediately following the secondary eclipse and rose slowly at first then quickly to maximum brightness in less than two minutes. It dropped slightly within a further two minutes and then slowly dropped back to normal over an interval of ten minutes.

As with flares observed on July 11 GMAT there is a striking similarity with flares observed previously with UV Ceti type stars. The major flare was observed by Walker and confirmed by Marino shortly after maximum.

A further feature of this particular cycle which was not observed on other cycles was a long period of steady brightness from 0.8021d to 0.8167 immediately preceding the major flare. The brightness was approximately 0.4 magnitude greater than usual for this part of the cycle.

5. July 16 GMAT. JD(H) 2,440,054+

Primary minima were predicted at 0.8279d and 0.8961d. Observations were restricted due to other commitments with the telescope to periods adjacent to each eclipse. Refer to Figure 6. All eclipses were observed, primary eclipses being later than the predicted times.

COMPARISON OF CYCLES--MEAN LIGHT CURVE.

A number of common features emerge from the light curves of theindividual cycles.

1. On all nights there was some, and often considerable flare-like activity superimposed on the basic cycle. This activity exhibited some of the visual characteristics of the UV Ceti type flares but may not arise from the same causes. These flares associated with EX Hydrae appear to be preceded or followed in many cases by sudden fading in brightness. The flare activity varies in extent, both in range and frequency, on different nights. In general, the shorter the period between disturbances the smaller is the amplitude.

2. In all cases an increase of brightness was observed prior to the primary eclipse. The rise was irregular and varied from cycle to cycle. In some cases a degree of fading was observed prior to the rise.

3. In most cases a further rise and fall was observed immediately after primary eclipse. The position of the fading, when occuring, was different for each cycle. Considerable activity was observed in the region of primary eclipse.

4. Minima deeper than those of the main eclipse were observed at irregular times. These were apparent particularly prior to and following the primary eclipse.

5. The secondary eclipse was in many cases distorted by similar activity.

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The mean light curve (Figure 7) exhibits most of these features In addition it indicates:-

(a) A general rise in brightness from the primary to the secondary eclipse.

(b) A fall of brightness following the secondary eclipse and a recovery just prior to the primary eclipse.

(c) The flare-like activity flattens out when a number of cycles are averaged, suggesting that this phenomenon is irregular and not linked to the basic period of the system.

Table 2 gives values derived from the mean light curve comparable to minima A to E of Table 1.

TABLE 2.

MINIMUM.	DEPTH.	DURATION.	PHASE.
A (D)	0.6 mag	13 mins	.007
B (E)	uncertain	4	.111
C	0.4	8	.574

The position on the cycle, 0.574P, of the minor eclipse does not agree with that in Table 1 (0.617P). Further examination of the light curve for that evening indicates that a flare, which coincided with the secondary eclipse obscured it and the following fading was wrongly interpreted as the minor eclipse. This indication is further strengthened by detailed inspection of the secondary eclipses of other cycles.

Whilst the mean curve is of value in determining the position of the main eclipses and the general base shape of the cycle it is necessary to go to the individual curves to determine depths, durations, etc. of eclipses and to compare detail not related to the base cycle.

SUMMARY.

The programme had two basic aims:-

a. To establish whether visual techniques could be successfully used to observe short period fluctuations of the order of 0.5 magnitude.

b. To obtain experience in the observation of certain types of short period eclipsing binary stars in which factors other than the reciprocal eclipses of the two components are expected to be present.

VISUAL TECHNIQUES:

Results show that considerable information can be obtained providing certain precautions are taken and a stndardised observing technique is used.

Variations of 0.1 magnitude are detectable if the following procedures are adopted:

(a) All the procedures outlined in "Observation of Variable Stars" by F.M. Bateson (8) must be used.

(b) The presence of the Moon near the variable appreciably flattens the observed activity, thus observation should be avoided during these periods.

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(c). The observer must be comfortably positioned while making his observations.

(d). The observers at each observing session should alternate as observer and recorder. Two observers are therefore desirable. Techniques recommended for Flare Star programmes should be followed.

(e). The length of observing period for each observer must be reduced towards the end of an observing session to maintain accuracy. Readings show a definite tendency to become brighter as fatigue sets in.

(f). A good selection of comparison stars must be available close to the variable for best results. With comparison stars 0.3 or 0.4 apart it is very easy for a competent observer to consistently reach an accuracy better than o.1 of a magnitude.

(g) All observations should be made between comparison stars and extrapolation must be avoided.

FEATURES OBSERVED:

The observation of this class of star appears to require an approach which differs substantially from that required for eclipsing binaries of the Algol class.

In addition to eclipse effects numerous 'flare-like' disturbances were observed and in many cases the fading following these were similar in depth and duration to either one or other of the major eclipses. If this activity is common to all stars of this class then considerable difficulty could be experienced in determining periods in the normal manner. The best method may be curve fitting general trends rather than matching peaks and hollows.

One point of note is that during the period of observation the star was normally brighter than the 13.72 given by Mumford.

ACKNOWLEDGEMENTS:

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(7) BATESON, F.M. 1968 Circ. 135, VSS, RASNZ.
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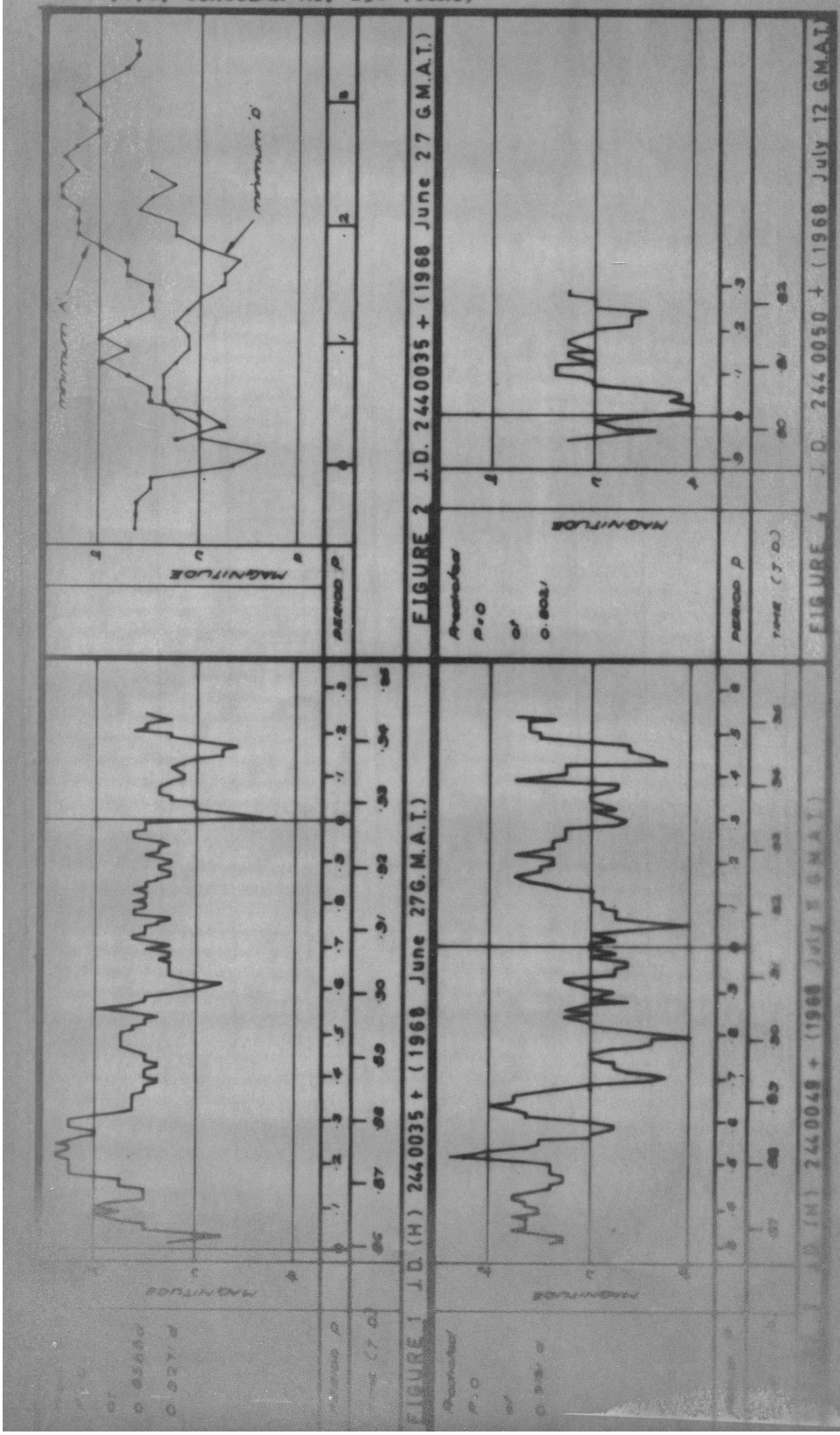
MAGNITUDE
PERIOD P
minimum A
minimum B
FIGURE 1 J.D. (H) 2440035 + (1968 June 27 G.M.A.T.)
FIGURE 2 J.D. 2440035 + (1968 June 27 G.M.A.T.)
FIGURE 4 J.D. 2440050 + (1968 July 12 G.M.A.T.)

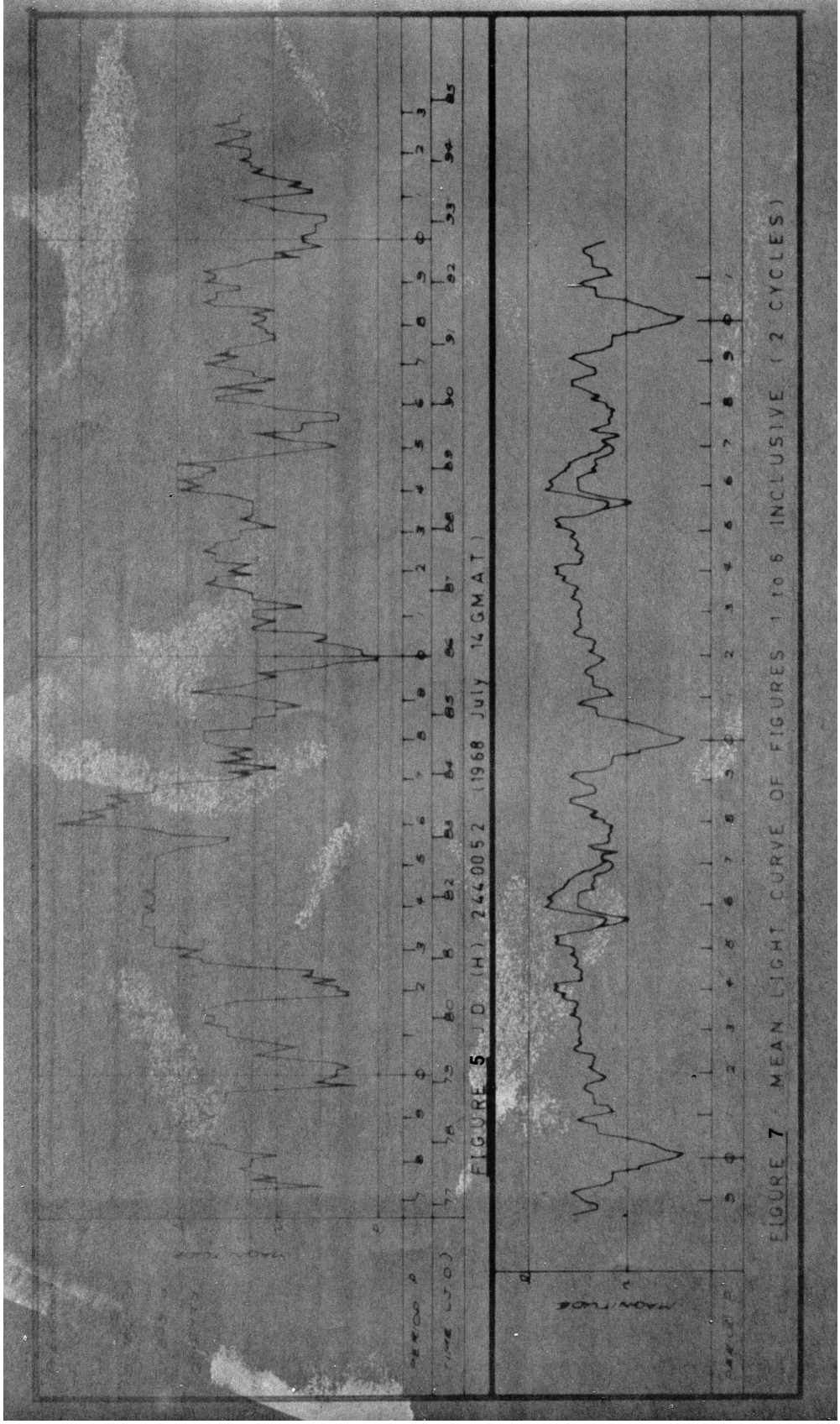
FIGURE 5 J.D. (H) 2440052 (1968 July 14 G.M.A.T.)
FIGURE 7 MEAN LIGHT CURVE OF FIGURES 1 to 6 INCLUSIVE (2 CYCLES)

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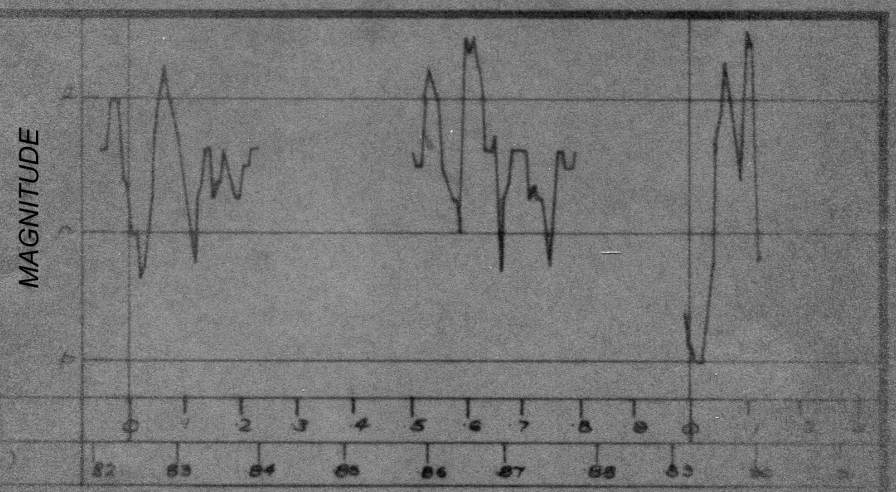

FIGURE 6 J.D. (H) 2440054 + (1968 July 16 G.M.A.T.)