DISCOVERY OF A FLARE STAR NEAR SIRIUS

D. P. SHARMA, T. M. K. MARAR, S. SEETHA, K. S. SHYLA,
K. KASTURIRANGAN, and U. R. RAO

ISRO Satellite Centre, Peenya, Bangalore, India

and

J. C. BHATTACHARYYA and M. J. ROZARIO

Indian Institute of Astrophysics, Bangalore, India

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Abstract. The discovery of a flare star (R.A. (1950) = $6^h43^m6\overset{s}{.}07$, Decl. (1950) = $-16°45'24''$) located about 6 arc min south of Sirius is reported. During photometric observations on the night of 13 January, 1982, using the 102 cm telescope at Kavalur, India, the star was seen to brighten by 2.55 mag. in *V* band over a duration of about 200 s. Observations on this object for a duration of about 10.5 hr spread over seven more nights indicate the star to be variable. The results of these observations are presented.

1. Introduction

We report here the discovery of a new flare star (R.A. (1950) = $6^h43^m6\overset{s}{.}07$, Decl. (1950) = $-16°45'24''$) located about 6 arc-min south of Sirius. This observation was primarily motivated by the recent discovery of two X-ray sources within only 9 arc-min south of Sirius (see Chlebowski *et al.*, 1981) with the attendant possibility of existence of other unexplored interesting objects in the Sirius neighbourhood. The new variable flare star might have gone undetected so far presumably due to its proximity to Sirius.

2. Observational Technique

High time-resolution photoelectric observations were carried out from the Kavalur Observatory of the Indian Institute of Astrophysics using the 102 cm telescope. A single channel photometer (Sharma *et al.*, 1981) was used for the observations. The photometer consisted of a dry-ice-cooled RCA 4832 photomultiplier tube and associated electronics. The latter had a counting capacity of 10^7 counts and a dead time of 10 μs. The integration time for counting the incoming pulses could be varied from 1 ms to several minutes, depending on the requirements of the observations.

The observational sequence included monitoring of the program star and one or two comparison stars. The sky background near the object was also measured in the conventional Johnson *U*, *B*, and *V* filter bands. The integration time used in the observations was usually 1 s. Several standard stars from the Landolt (1973) catalogue were also monitored for estimating the instrumental parameters and deriving standard magnitudes from the observations. A 24 arc sec diaphragm was used throughout the observations.

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3. Observations and Data Analysis

The reported observations commenced on 13 January, 1982 around 18^h16^m UT. Against a sky background of 2450 counts s^{-1}, the bulk of which was contributed by Sirius, the object under study could be observed at a significance level of 12σ. The flare activity commenced at about 18^h18^m and lasted for about 200 s. The brightening at the peak of the flare corresponded to $\Delta m_v = 2.55$. In Figure 1 we reproduce that portion of the light curve including the flare observations and the pre- and post-flare quiescent emission level of the object. A closer examination of the rising and declining parts of the light curve corresponding to the flare reveals the existence of miniflares or modulations superimposed on the main event. Such modulations appear to have a distinct recurring tendency with a period of about 16–18 s or its harmonic at about 8–9 s. The equivalent duration of the main flare computed in the conventional manner using the relation

$$T = \frac{(I_{0+f} - I_0)}{I_0}\, \mathrm{d}t\,,$$

is 8.28 min. Here I_0 is the quiescent flux and I_{0+f} is that recorded during the flare (including quiescent). Table I summarises some of the main characteristics of the flare.

TABLE I

Characteristics of the main flare

Date and time of flare maximum	13 January, 1982, $18^h19^m.7$ UT (JD 2444983.2638)
Standard deviation of random noise	0.0356 mag. (V)
Limiting V mag. for flare detection at 3σ level	13.2
V mag. of the star at flare maximum	8.9 ± 0.05
V mag. of the star just before and immediately after the flare	11.65 ± 0.05
Flare mag. Δm_v	2.55
Rise time	~ 138 s
Decay time	~ 84 s
Equivalent duration	8.28 min

The discovery of the giant flare motivated further monitoring of the star for 7 more nights. A journal of observations is given in Table II. Even though no similar large flare activity as seen on 13 January, 1982 was observed during the subsequent nights, smaller flare-type events were seen on 14 January and 1 March, 1982. These are shown in Figure 2. On 14 January, only one broad enhancement was observed, whereas on 1 March, 3 miniflares were detected. Properties of these events are given in Table III.

The complete observational data on the object totalling to a duration of 10.54 hr have been examined to find the possibility of long term variations, if any, in the optical emission of the star. Extinction corrected V mag., $B - V$ values and air mass at the time of observation are plotted in Figure 3. It can be seen from the figure that the V-mag.

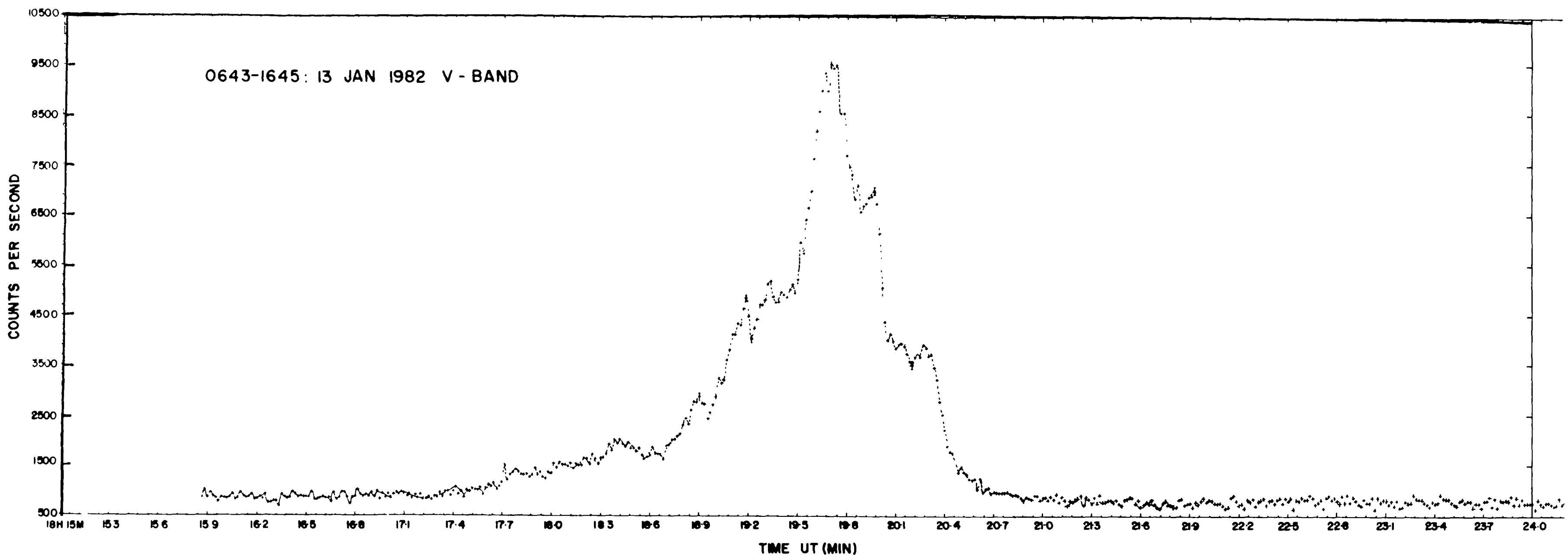


Fig. 1. The figure shows the stellar flux in V band during the flare. Time resolution of the observations is 1 s. The sky background has been subtracted.

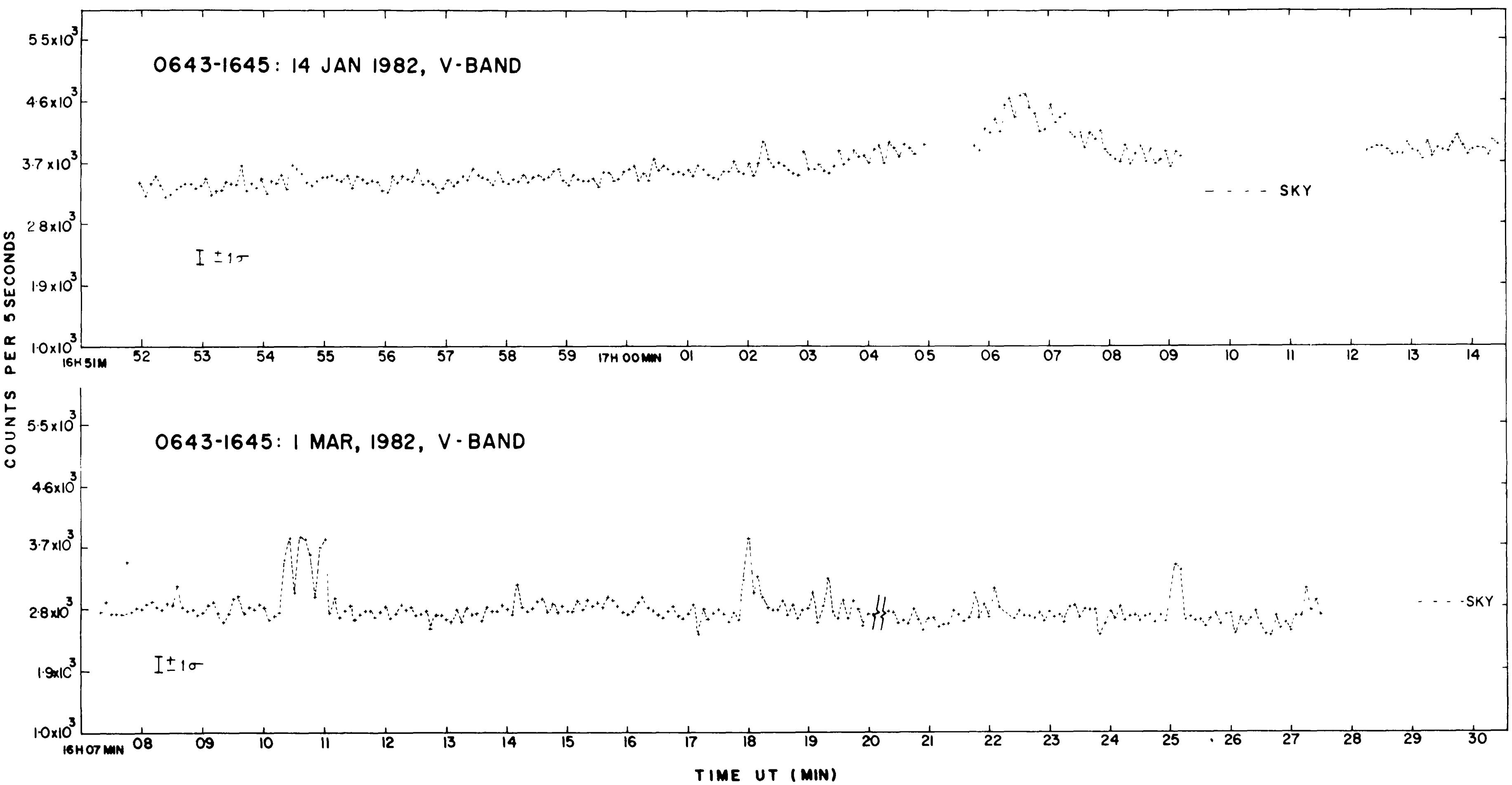


Fig. 2. Part of the data of 14 January and 1 March, 1982, showing the mini flares.

TABLE II

List of observations*

Date of observation	Duration of observation in each band (s)		Time resolution
13 Jan., 1982	*V* band	– 1421	1 s
	B band	– 318	
	U band	– 43	
	White light	– 123	
14 Jan., 1982	*V* band	– 6317	1 s
	B band	– 133	
	U band	– 111	
15 Jan., 1982	*V* band	– 3170	1 s
	B band	– 103	
	U band	– 73	
10 Feb., 1982	*V* band	– 3148	
	B band	– 259	
	U band	– 169	
1 March, 1982	*V* band	– 2385	1 s
	B band	– 82	
	U band	– 93	
	White light	– 1174	
2 March, 1982	*V* band	– 3537	1 s
	B band	– 93	
	U band	– 98	
	White light	– 45	
13 March, 1982	*V* band	– 47	1 s
	B band	– 51	
	U band	– 54	
	White light	– 6633	
14 March, 1982	*V* band	– 46	0.2 s for 502 s and 1 s for rest of the time
	B band	– 20	
	U band	– 19	
	White light	– 8061	

* Total observation time of source is 10.54 hr.

TABLE III

Details of small flares

Date and time of flare (UT)		Duration* (s)	Peak intensity in Δm_v
14 January	1706	132	0.19
1 March	1610	48	0.37
1 March	1618	34	0.36
1 March	1625	19	0.26

* Duration is defined as time during which counts rise above average level of quiescent intensity.

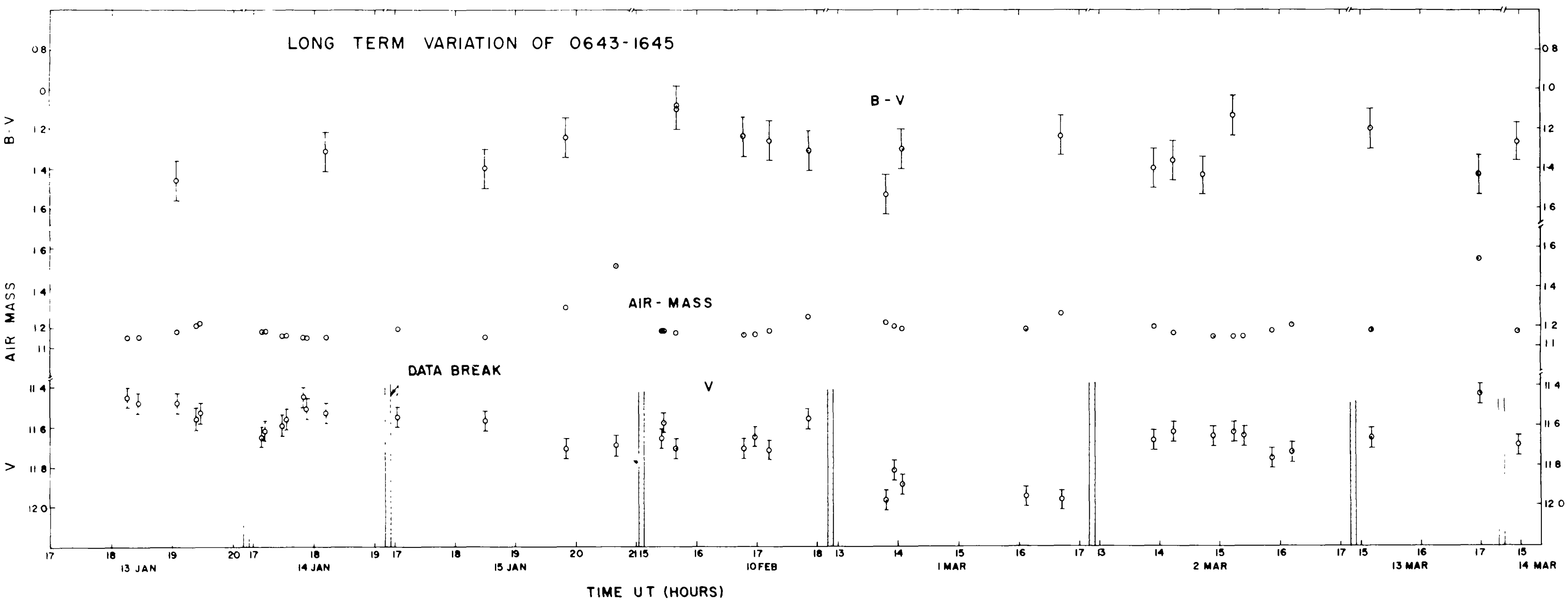


Fig. 3. Figure shows long term variations of the star in V band. Flare part has not been included.

varies from 11.4 ± 0.05 to 11.97 ± 0.05, the maximum amplitude of variation over a span of 60 days being 0.6 ± 0.05 mag. The average values of apparent V mag. and colour $B - V$ are 11.65 ± 0.05 and + 1.31 ± 0.1, respectively.

4. Discussion

A finding chart for the star reproduced from Papadopoulos (1979) is given in Figure 4. The co-ordinates of the star as derived from this atlas are:

$$\text{R.A. (1950)} = 6^{\text{h}}43^{\text{m}}6\overset{\text{s}}{.}07\,,$$

$$\text{Decl. (1950)} = -16°45'24''.1\,.$$

From the colour index of $B - V = +1.31 \pm 0.1$, the star appears to belong to a spectral class between K5 and M0. Considering that several flare stars in the Orion Nebula and NGC 2264 are of spectral type K0 to M, and those in Taurus dark clouds and pleiades of spectral type K5 to M5 (Haro, 1968; Shakhovskaya, 1971), the present deduction regarding spectral classification of the object with our own limited observations appear to be plausible. However this needs further confirmation through detailed spectroscopic studies.

It is also interesting to note the unusually slow build-up of the flare compared to its decay. Moffett (1974) reports similar features in the case of flare observations on some of the UV Ceti flare stars.

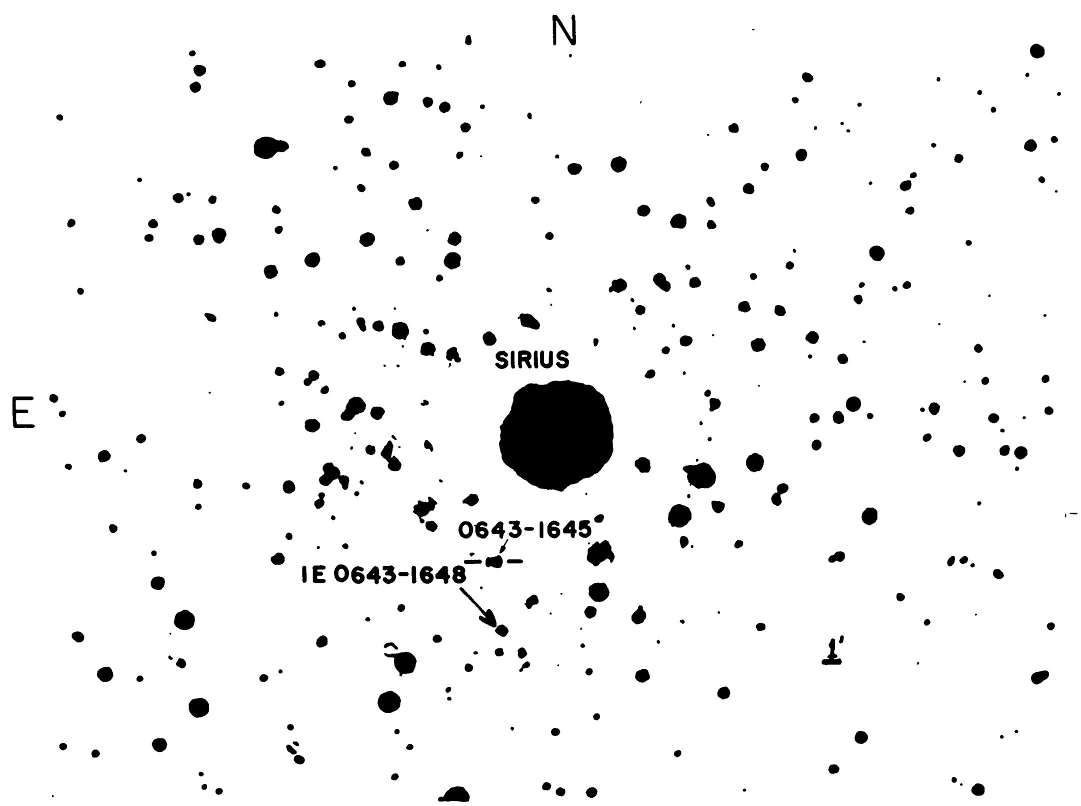


Fig. 4. Finding chart for the new star reproduced from Papadopoulos (1979).

The observed long term variations in the quiescent flux can be attributed to the binary nature of the object. Detailed spectroscopic and photometric observations are needed to confirm the above conjecture.

The observed modulation or pulsation period of about 16–18 s or its harmonic at 8–9 s during the flare can be interpreted as due to the rotation of a collapsed object like a white dwarf or due to a differential rotation of an accretion disc around it, while the flare activity was in progress, the modulation being caused by a partial obscuration of the flaring region during the rotation. Similar pulsation periods have been observed in a number of white dwarf systems like AE Aqr, DQ Her, V 603 Aq1, etc. The flare in the present case could have been produced by a sudden enhancement of accretion on to the disc surrounding the collapsed object or its surface itself. The absence of strong X-ray emission from the object at the time of Einstein observations indicates that the rotating object is probably a white dwarf and not a neutron star. This, however, needs further observations for its confirmation.

The periodic modulations in the flare light curve has been further investigated by deriving an average light curve of the flare data using the moving point averaging technique. This curve was subtracted point by point from the original flare curve and the deviations so obtained were plotted as a function of time as shown in Figure 5a. The peak to peak amplitude of the deviations occurring at intervals of 8–9 s from Figure 5a is plotted against the average intensity of the flare corresponding to that instant of time in Figure 5b. Figure 5b clearly indicates a linear relationship between the deviations and the average stellar flux, once again proving that the deviations are not statistical in nature, and that they may be explained in terms of the rotation of an underlying object.

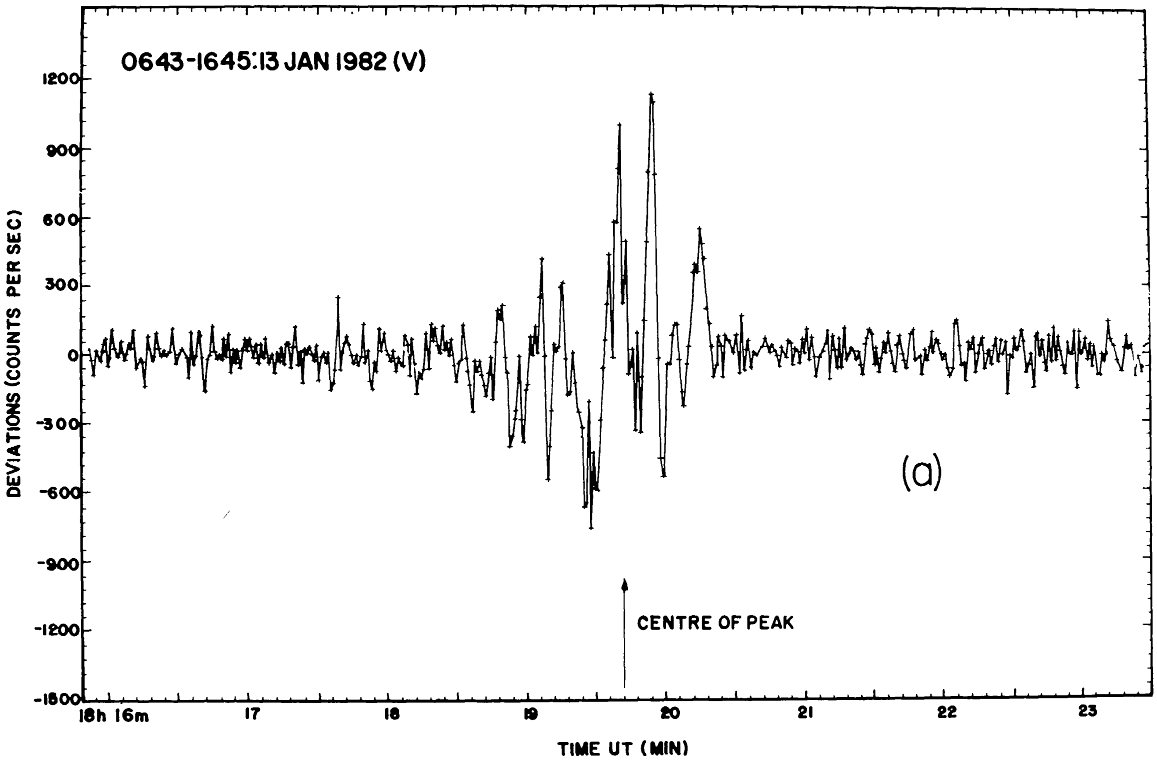
The observed V mag. of the star in its quiescent and flare states could be used to estimate the energetics involved in the flare. Using the relation

$$\log f_\lambda(V) = -0.4 m_v - 8.43 ,$$

(Allen, 1976), where $f_\lambda(V)$ is the flux in erg cm^{-2} Å^{-1} s^{-1} outside Earth's atmosphere, and assuming a bandwidth of 900 Å for V-band, we estimate the peak output during the flare as 1.0×10^{29} D^2 erg s^{-1} where D is the distance to the star in pc. The total output of energy during this flare (with 100 s FWHM) will then be 1.0×10^{31} D^2 ergs. If we assume that the star is on the Main Sequence, the $B - V$ color of $+1.31$ may be used to estimate a distance of 50 pc to the star. This gives a total energy output during the flare, of 2.5×10^{34} ergs. Assuming equal amounts of energy release in U, B, and V bands, we find that the total output in the optical region amounts to $\sim 10^{35}$ ergs, which places this flare among some of the largest stellar flares reported in literature (Ambartsumian and Mirzoyan, 1975).

5. Conclusions

(a) We report the discovery of an unusual flare of 2.55 mag. in V band over a duration of 200 s from an object with quiescent V mag. of 11.65 ± 0.05 and co-ordinates



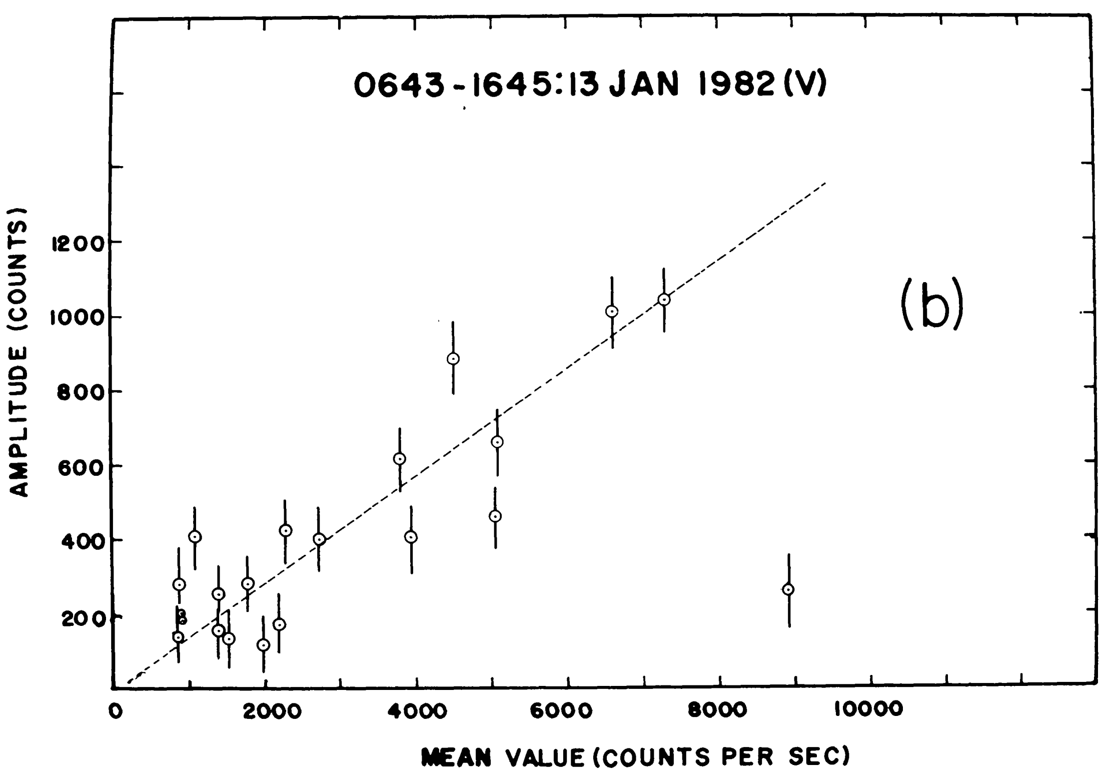


Fig. 5a–b. Part (a) shows the deviations obtained by subtracting the average curve from the observed curve (see text). Part (b) shows a plot of peak to peak amplitude of deviations vs mean value of the stellar flux at the instant.

$\alpha(1950) = 6^h43^m6^s07$, $\delta(1950) = -16°45'24''$. This flare appears to represent an energy output of about 10^{35} ergs based on our distance estimate.

(b) The object appears to have additionally a slow variational component with a maximum amplitude of 0.6 mag.

(c) Based on the present observations we place the object in the spectral class between K5 and M0. However detailed spectroscopic investigations are necessary for a more definitive spectral classification of the object.

(d) The present data are inadequate to draw conclusions as to the origin of the long term variations. Further observations are necessary to confirm the slow variation observed by us.

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