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"Homothétiques" white light flares on a dMe star

Introduction:

Few peculiar features have been depicted in flare light curves so far, in spite of the many thousand flares observed. Among these peculiar cases, recursive flares with a periodicity of about 48 min were observed by Doyle et al. (1990), and a similar phenomenon was described by Andrews (1966). Periodic bursts were recorded by Houdebine (1990, 1991) during a flare on Wolf 424 AB and oscillations were observed by Rodonò (1974) during a flare on a star of the Hyades cluster. Haupt and Schlosser (1974) also pointed to the possibility of Homologue or sympathetic flares occurring on UV Ceti. These rare events are of particular interest since they provide valuable constraints for modeling the stellar flare phenomenon.

Most of the flares exhibit rapid and monotonous rise and decay (simple flare) or is made of several successive outbursts occurring randomly at first glance (complex flare) (e.g. Cristaldi and Rodonò, 1973). A lesser proportion display a slow rise and decay and are generally complex in character, but do not however exhibit any secular properties.

Here we report on a peculiar flare that occurred on the active binary GL 644 AB (=V1054 Oph) of spectral type dM4.5e. This large flare is made up of two main series of about 8 events of varying intensity. These series of flares or "flare bursts" do not show any striking periodicity, and the time delay between two successive events seems erratic. What makes this flare particular is the amazing similarity between the relative timing of the several events of the two series.

Observations:

The observations were collected at the European Southern Observatory in March 1990 with the 1m telescope and its standard photometric equipment (see Houdebine, 1990).

The complete flare light curve is given in Figure 1. Enlargements with a chronological numbering of the bursts are shown in Figure 2. Universal times and time delays since the first event in a given series are listed in Table 1. We plotted these delays, Δt_2 vs. Δt_1, in Figure 3.

Those figures show the most interesting common characteristics of these two series of flares:

- Event No 1 occurs during the rising phase at about 3/4 height of the maximum.
- The increase slows down after the first burst and until the maximum.
- A sharp decrease is observed after the 2^{nd} burst and is followed by the 3^{rd} burst.
- The gradient in the fall in luminosity diminishes after the 3^{rd} event.
- The observed bursts of the two series follow a strictly linear correlation which slope is about 1.45 (see fig. 3).

- No events step back from this correlation by more than 8% !

We therefore conclude that these two series are "homothétiques" in time - i.e. - one series of bursts leads to the other, following a translation and contraction in time.

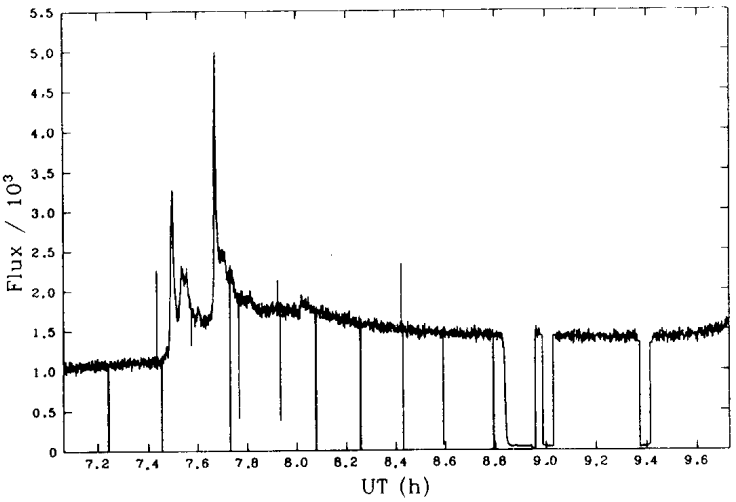

fig 1: Flare light curve in the U-band. The rise after 9.5 UT corresponds to dawn. Sharp cuts in the curve indicate when the star position in the diaphragm was checked.

As usual, it is of interest to compare such stellar events to their solar counterparts. Two similar classes of solar events immediately come to one's mind; the homologous flares and flares triggered by moving disturbances - i.e. - the sympathetic flares. However, the series of flares reported here do not check the requirements for homology as specified by Ellison et al. (1960). Indeed, the two complex flares do not evolve on the same time scale and greatly vary in shape and strength. We may add that no homologous white light flares of equivalent power have ever been observed on the Sun and that homology may sometimes involve disturbances that successively trigger various flare components.

The interpretation as series of sympathetic flares is far more attractive since a simple change by a factor of 1.45 in the speed of a flare born disturbance is required to explain the observations. In such a case, the disturbance speed should be less than 3700 km/s, and the first event must occur at the same location on the star. This subsequently implies that at least the first events are homologous and points to *the amazing rapidity (about 10 minutes) of an active region to recover its ability of producing large flares* ! Nevertheless, if one compares the strength of events 4 to 7 in the two series, one sees that all active region magnetic patterns did not restore during this 10 min laps of time.

Our early interpretation is that we observed a *combination of homologous and sympathetic flares*. This further highlights that all complex stellar flares may be in fact a combination of sympathetic flares, and that the Poisson distribution found for the relative timing of stellar flares (e.g., Lacy et al., 1976) originates from the combination of the varying disturbance speeds and active region flare occurrence.

Many other consequences may be inferred from the investigation of this flare, some of which have

already been discussed by Houdebine (1990). A more complete study will appear in a forthcoming publication.

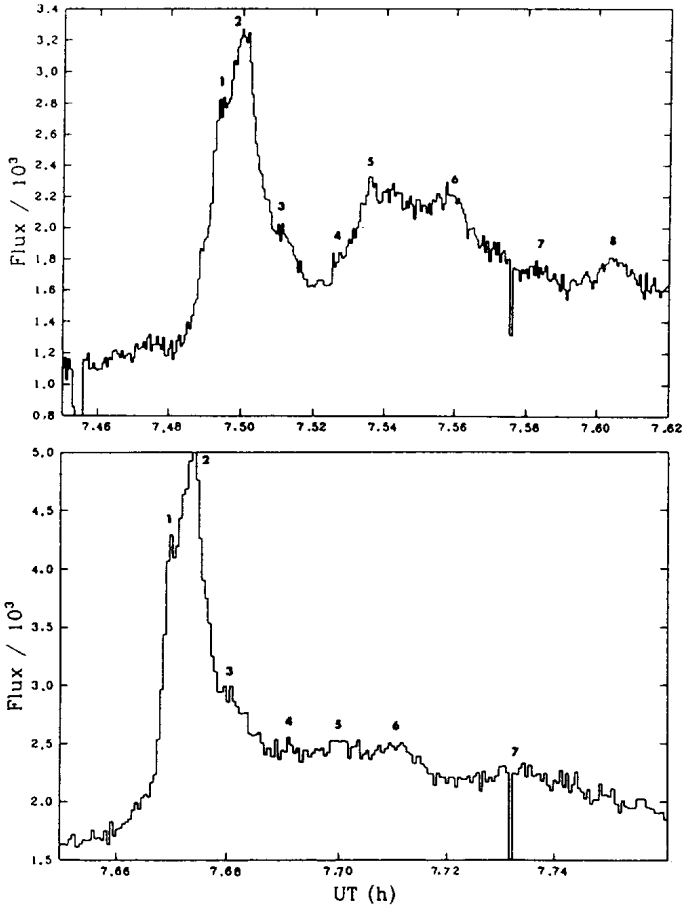

fig 2: Enlargements of the two main series of flares. The ordinate axis gives the photon counting rate.

Table 1: Universal time for the flare events numbered in figure 2, and time delays with respect to the first in a series. The last column shows the ratio of these time delays.

No.	UT $h:min:s$	Δt_1 (min)	UT $h:min:s$	Δt_2 (min)	$\Delta t_1/\Delta t_2$
1	07:29:40	0	07:40:12	0	-
2	07:29:59	0.00552	07:40:26	0.00414	1.333
3	07:30:41	0.01698	07:40:51	0.01193	1.423
4	07:31:37	0.03266	07:41:28	0.02116	1.543
5	07:32:41	0.04140	07:42:04	0.03025	1.369
6	07:33:31	0.06417	07:42:38	0.04083	1.572
7	07:35:02	0.08947	07:43:55	0.06222	1.438
8	07:36:15	0.10994	-	-	-

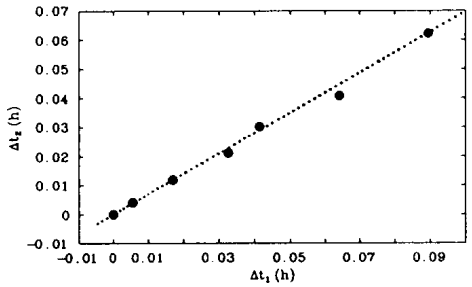

fig 3: Δt_1 vs. Δt_2.

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