Thirty Years Photometry of Flare Stars at the Stephanion Observatory

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Abstract

The research on the flare stars of the solar neighborhood which was developed during the 30 years at the Stephanion Observatory is reviewed in this report. A very rich and homogeneous observational material concerning the flare activity and the quiet- state luminosity of the flare stars under investigation has been obtained so far. The analysis of this material as an homogeneous data set, as well as a contribution to a multitude of international multiwavelength spectrophotometric, radio and EUV observational campaigns contributed significantly to the today notions on the stellar magnetic activity which results to the flare phenomenon.

Introduction

In June 1971 a 30-inch Cassegrain reflector with asymmetric mount (focal ratio f/3 for the primary hyperbolic mirror and f/13.5 for the Cassegrain focus) constructed by the USA firm Astro Mechanics was install in the grounds of the Stephanion Observatory. The new telescope was equipped with the following auxiliary equipment: (1) one Johnson dual channel photoelectric photometer with offset guide unit, constructed by Astro Mechanics, which is cooled with dry ice and is suitable for carrying out photoelectric observations in the U, B, V, R, I colours of the international U, B, V system and (2) one Meinel plane grating spectrograph with flat-field folded Schmidt camera f/2 focal ratio constructed also by Astro Mechanics. This telescope, which belongs to the Department of Geodetic Astronomy, Aristotle University of Thessaloniki and is of the light-collector type, turned out to be very suitable for photoelectric observations of variable stars. The observations with the new telescope started in July 1971 and are continued regularly until now. ¿From the very beginning, stellar activity was the field of intensive research conducted with the help of this new telescope. In particular extensive programs of photoelectric observations of particular types of variable stars were set up and followed until today, whereas minor programs on different types of variables, i.e. Mira or Nova [6], etc. were occasionally undertaken . The main types of variable stars under extensive investigation were: a) the flare stars of the solar neighborhood, b) the variables of the RS CVn type and c) the galactic cepheids [15]. In the following the main research programs and their results referring to the flare stars of the solar neighborhood will be summarized

1 The observations

In the beginning of the 70s the interest on the flare activity of the red dwarf stars of the solar vicinity has been culminated. In order to achieve the maximum coverage of the stellar activity of these interesting objects by compatible photometric observations, special specifications were set for by the Commission 27 for the Variable Stars of the IAU [4]. According to these specifications a systematic monitoring of the luminosity of selected flare stars of the solar neighborhood started at the Stephanion Observatory with the help of the new 30-inch Cassegrain reflector. This monitoring is being carried out mainly in the B color of the international U, B, V system. During most of the observing nights, however, additional observations are being made in the U, B, V colors of the same system. These observations allow us to study the behavior of the colors of the stars under investigation. The following flare stars of the solar neighborhood have been observed so far : EV Lac, BY Dra, AD Leo, UV Cet, YZ CMi, DT Vir, DO Cep, BD +16sup 0 2708, BD +55sup 0 1823 and Gl 182. The first result of these observations is the detection of stellar flares and the determination of the corresponding light curves. In this way many hundreds of flares of the stars under investigation have been detected and studied so far. In addition to the flare patrol, it has been possible, through a proper arrangement of the observational procedure, to use the same observations for the determination of the quiet- state luminosity of the stars under observation during the monitoring period. The quiet-state luminosity thus determined refers to the B color or to the U, B, V colors of the international U, B, V system, depending on whether the monitoring is being carried out in the B or in the U, B, V colours. In this way very rich observational material concerning the flare activity and the quiet- state luminosity of the flare stars under investigation have been obtained so far [16]. This material is of special value for three reasons : (1)it covers a fairly long period of time (1971 until now), (2)it is of high accuracy, and (3)it is very homogeneous, because it has been obtained by the same team of observers, using the same methods for the execution and the reduction of the observations and the same instruments. With the help of this observational material a number of investigations concerning the phenomenon of flare activity could be carried out. In the following some of the main results of these investigations are being summarized.

2 Long- and short-term variations of the flare activity and the quiet-state luminosity

A great percentage of the observational material obtained at the Stephanion Observatory refers to the flare star EV Lac. This star shows the well known BY Dra syndrome, i. e. a short-term variation of the quiet-state luminosity with a period of 4.375 days and an amplitude $\Delta V = 0.08$ mag. This variation is being interpreted by most of the authors as indicating the existence of starspot(s) on the surface of the star, which are rotating with the same period. Evidence for rotational light modulation by transient starspot formation was found by analyzing the quiet state luminosity variations together with the flare frequency distribution over the phase for the flare stars EV Lac, BY Dra and DO Cep [7, 8, 9]. With the help of the observational material obtained at the Stephanion Observatory it can be shown that, besides this short term variation of the quiet state luminosity, there is also a long-term fluctuation of the mean annual values B of the quiet-state luminosity of the star with an amplitude of 0.3 mag and a period of about 5 years. Similar fluctuations show also the mean annual values of the flare frequency P(1) and the integrated flare intensity P(2) of the star. Moreover very strong negative correlations exist between the values of B corresponding to a given year and the values of P(1) and P(2) corresponding to the previous year, in the sense that years with enhanced flare activity are followed by years with lower quiet-state luminosity [17]. This and other similar results could be interpreted as indicating that years with enhanced flare activity are followed by years with larger starspot coverage on the stellar surface. This conclusion, if confirmed by additional observations, could be of importance for a better understanding of the physical processes underlying the phenomenon of stellar activity [18].

3 Very short-term variations of the quiet-state luminosity

With the help of the observational material obtained at the Stephanion Observatory the existence of another type of variations of the quiet-state luminosity of the star EV Lac, the very short-term variations could be shown [20]. In fact, during most of the nights the luminosity of the star remains constant (standard deviation less than 0.04 mag during 2 hours or more). In some other nights the luminosity of the star shows a fairly sinusoidal variation with a period between 0.5-2.0 hours and an amplitude between 0.1 and 0.2 mag. In some other nights, on the contrary, the stars luminosity shows very irregular variations with a duration of at least few hours and an amplitude of 0.4 mag or even more.

4 Dependence of the flare activity on the phase of the short-term periodic light variation of BY Dra

BY Dra is another flare star, besides EV Lac, for which numerous observations were obtained at the Stephanion Observatory. This observational material, together with additional material obtained at the Byurakan, Konkoly and Matra Observatories were used for a systematic study of the flare activity of this star during the period 1971-92 [19]. The following conclusions could be drawn : a) the flare activity of BY Dra shows also a long-term fluctuation with a very pronounced maximum during the years 1973-75 and a new enhancement of the activity from 1987 onwards, b) there is a clear tendency for the flares of BY Dra to appear during certain part of the period of the short-term periodic light variation of the star (P = 3.8285 days). This could be interpreted as indicating a pronounced tendency of the flares on BY Dra to be originated within the part of the stellar surface covered by the magnetic field (B = 2.800 Gauss, f = 60%).

5 Co-ordinated simultaneous multiwavelength observations of flare stars

It is obvious that the physical processes connected with the phenomenon of flare activity [15], and more generally of stellar activity, would be better studied, if we could have at our disposal simultaneous observations of these stars in various spectral regions. For these reasons an effort is being made in recent years to organize co-ordinated multiwavelength observations of selected flare stars. In these campaigns, besides the optical observations, an effort is being made in order to secure also simultaneous observations in as many other spectral regions as possible, such as the X-rays and the ultraviolet spectral regions, using artificial Earth satellites, the region of radio waves, using radio telescopes, etc. Because of the fairly great number of clear nights and its long tradition in similar observing programs the Stephanion Observatory is a very welcome partner in most of these campaigns. In the following some of the programs of coordinated simultaneous multiwavelength observations of flare stars in which the Stephanion Observatory has been actively involved will be summarized :

1. Simultaneous optical and radio observations of the flare star UV Cet in October 1972. In the framework of this joint program between the Stephanion Observatory and the Jodrell Bank Radioastronomy Observatory in the United Kingdom a very large flare was observed on October 11, 1972 on the flare star UV Cet both in the optical region at the Stephanion Observatory (Δm greater than 4.5 mag) and in the radio waves (408 MHz) at Jodrell Bank. The maximum of the optical flare precedes that of the radio flux by approximately 8 minutes. These results have been of fundamental importance for a better understanding of the mechanism of the origin of radio flares [13].

2. Simultaneous optical, radio and X-ray (EXOSAT) observations of the flare star BY Dra in September 1984 [10].

3. Simultaneous optical, radio and X-ray (EXOSAT) observations of the flare star UV Cet in December 1985 [11].

4. Simultaneous optical, ultraviolet (IUE), and microwave (VLA) observations of the flare star Gl 182 in October 1983 [14].

5. Co-operative optical and radio observations of the flare star EV Lac in August 1990 [12].

6. Co-ordinated optical observations of the flare star EV Lac in September 1991 [3].

7. Co-ordinated optical and radio observations of the flare star EV Lac in September 1992 [1].

8. Co-ordinated observations of the red dwarf flare star EV Lac in 1993 [2].

9. Co-ordinated Multiwavelength Simultaneous high resolution photometry for observing rapid optical oscillation on red dwarfs. [21]. In which high frequency oscillations of a period of 26s and 13s, near the maximum phase of strong flares were detected (see Fig. 2 and Fig. 3). The phenomenon is being further investigated.

6 Concluding Remarks

From the above discussion, the important contribution of the observational programs, which have been carried out so far and are continued at the Stephanion Observatory, to the research in the field of the flare stars and the stellar activity in general becomes evident. These programs are continued and together with farther research activities in the field of the stellar activity make the Stephanion Observatory one of the significant astrophysical observatories all over the world in the field of stellar activity.

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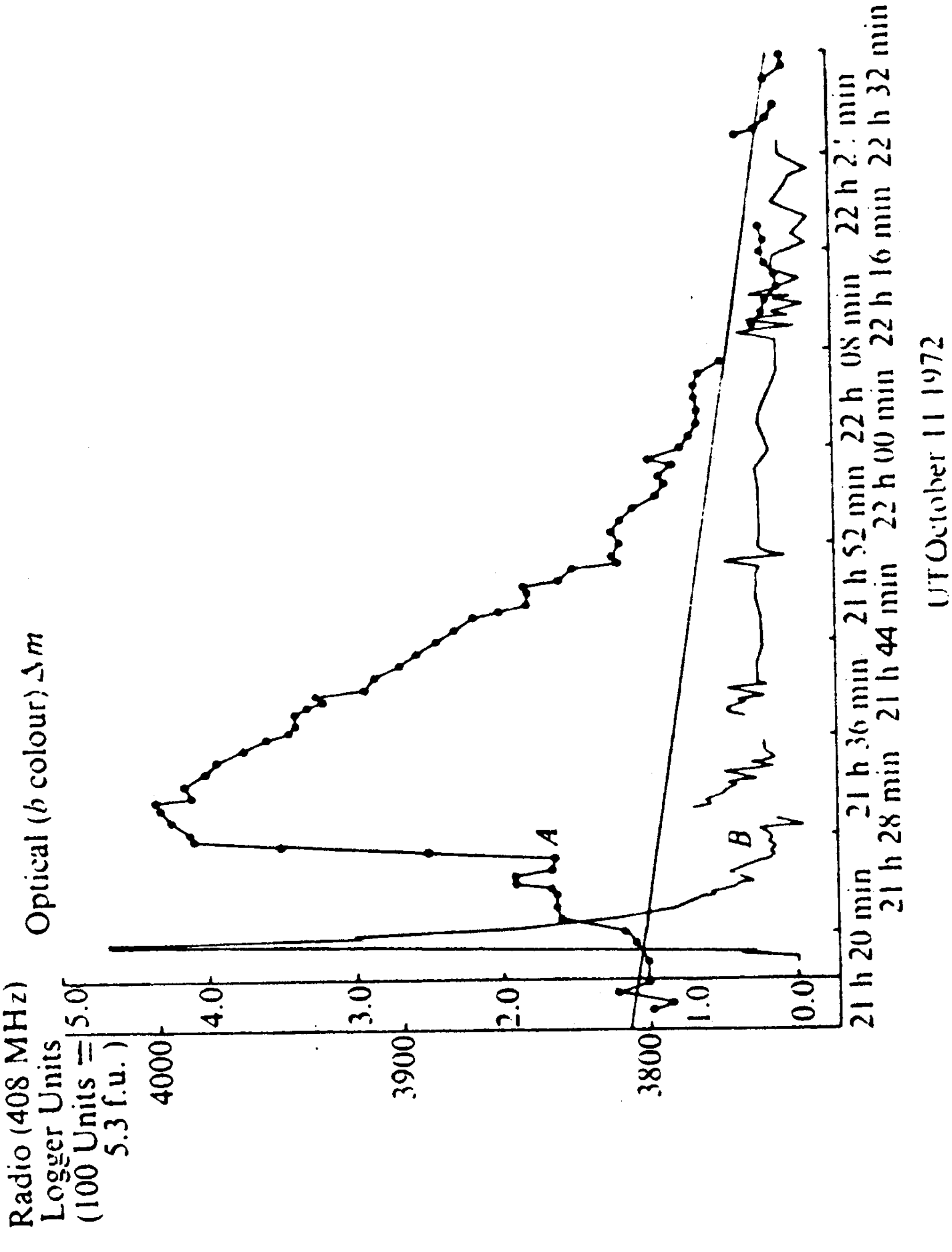

Figure 1: The radio(A,408MHz) and photoelectric (B,b colour) of the flare on UV Cet on October 11,1972.

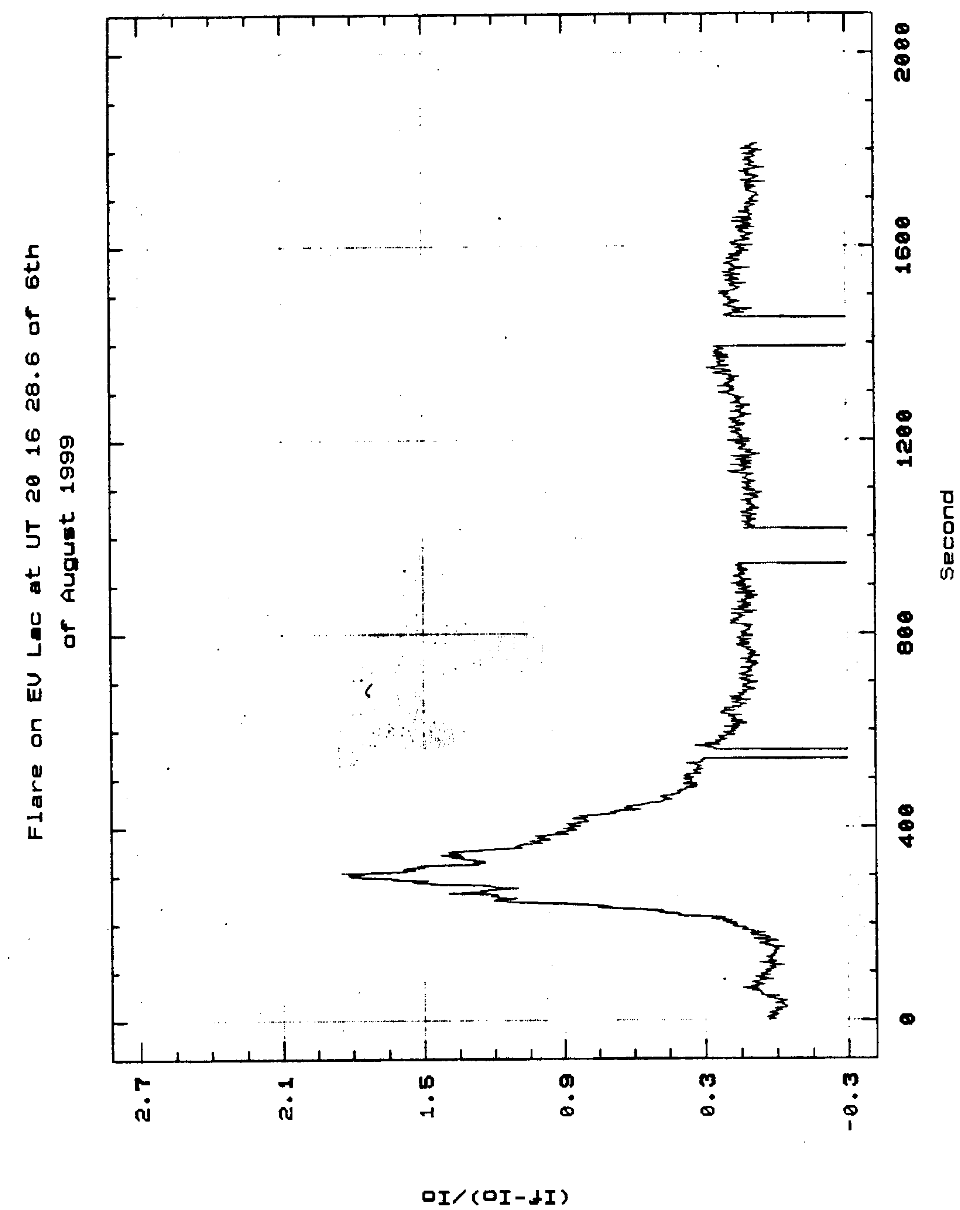

Figure 2: B-light curve of the flare of 6th of August 1999 on EV Lac.

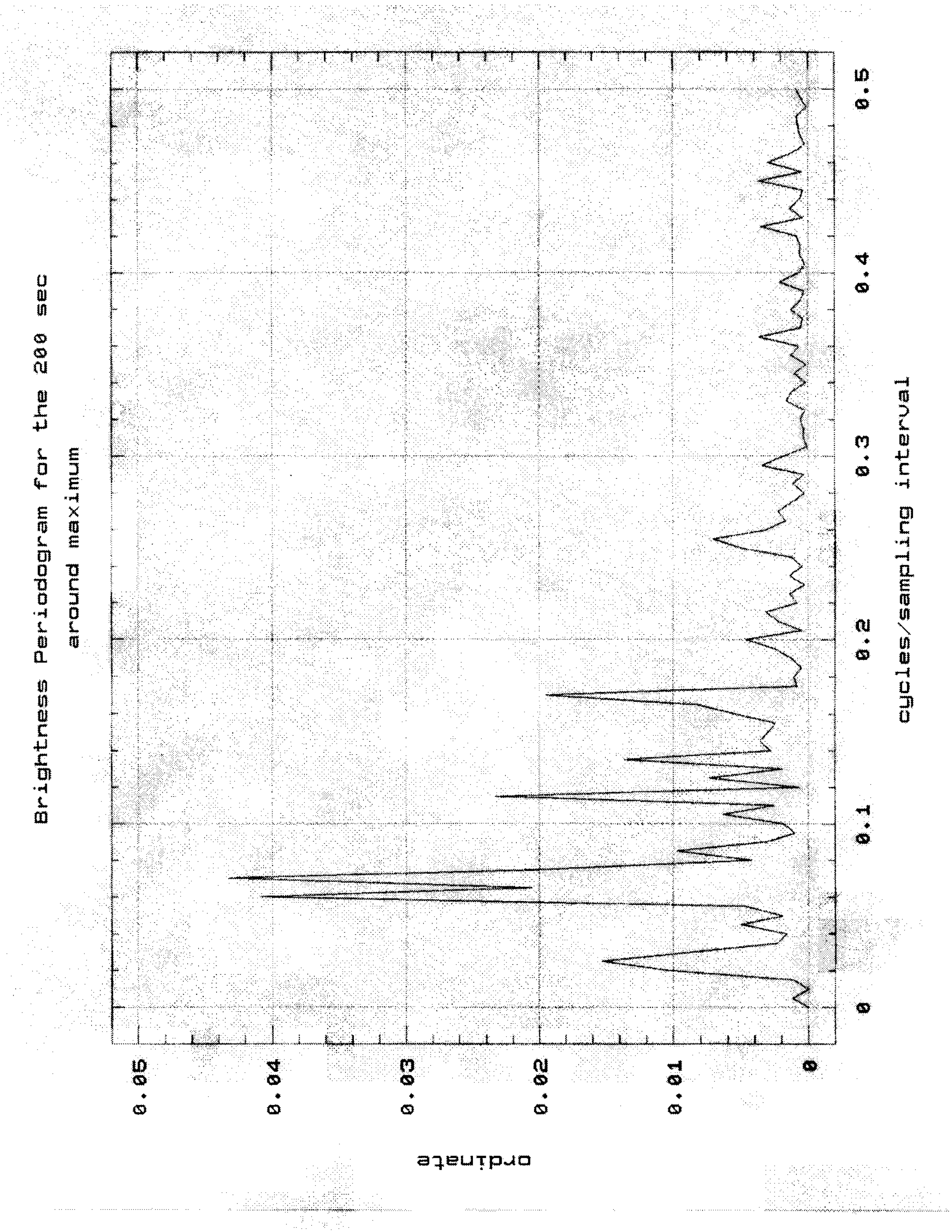

Figure 3: The periodogram for the 200 sec of the lightcurve of the flare of 6th of August 1999 on EV Lac.