FLARE STARS AND THE FAST ELECTRON HYPOTHESIS

G. A. GURZADYAN
Garny Space Astronomy Laboratory, Erevan, Armenian SSR, U.S.S.R.

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Abstract. An extensive analysis is made of the theory of flare stars based on the ‘fast electron hypothesis’, in the light of the latest observational evidence. It is shown that an adequate agreement of theory with the observations obtains regarding the internal regular features in the flare amplitude data in $UBV$ rays, as well as the changes of the colour characteristics of stars during the flares; in the latter case the analysis is made not only in respect of the UV Cet-type stars, but flare stars as well, forming a part of the Orion association. Problems bearing on the ‘negative flare’ and the screening effect are dealt with. New properties of the light curves of flares are revealed, based on the above theory.

Particular emphasis is laid on the X-ray radiation from flare stars. It is shown that the observed spectrum of X-ray radiation of flare stars differs sharply from that of X-ray radiation both of the stellar corona and solar X-ray flares. At the same time, the observed X-ray spectrum of flares is in complete harmony with the previously calculated theoretical spectrum corresponding to nonthermal bremsstrahlung with the energy of monoenergetic fast electrons $1.5 \text{ MeV}$. The durations of X-ray flares should be essentially shorter than that of the optical flares. The very high momentary intensities of the X-ray brightness with the exceedingly small duration at the curve maximum is predicted. It is shown that the gamma-ray bursts recorded so far have no relation whatever to flare stars.

1. Introduction

Twelve years ago the first contours of the ‘fast electron hypothesis’ were outlined – a theory designed to account for the flare phenomenon in cold dwarf stars (Gurzadyan, 1965), based on the concept of its nonthermal origin (Ambarzumian, 1954).

Subsequently the development of the theory assumed a complex nature, which meant overstepping the framework of a qualitative description of the picture and an attempt to include the observation aspects of the phenomenon in the theory. Thus the theory was pushed as far as making deductions on the energetic and spectral characteristics of the flare, revealing the inner regular features in the flare amplitudes in various wavelength ranges and in different types of stars, establishing clear-cut rules according to which the colorimetric characteristics of stars in time of the flare should change, deciphering the excitation mechanism of emission lines, dealing with problems concerning the very dynamics of the flare and the peculiar behaviour of light curves during the whole duration of the flare and so on. Prominence was assigned in the theory to flare stars and unstable stars with emission lines, to be found in stellar associations and young clusters, as well as to problems relating to the cosmogonic significance of the flare in time of the formation and evolution of the star. The fast electron hypothesis made it possible to advance actually the first quantitative theory of the T Tauri-type stars and other similar objects. Finally, the theory predicted a series of phenomena and regular features, of which the possibility of the appearance
of X-ray emission in time of the flare of the star should be singled out for mention. All of those facts and many more were generalized, systematized and compared with the observational evidence available at that time in the author’s monograph (Gurzadyan, 1973).

However, many fresh and extremely interesting observational facts concerning the matter under study have transpired in recent years. Distinctive among those data are: highly precise three-colour electrophotometric observations of Cristaldi and Rodono (1975), and Osawa et al. (1973), made on quite a large number of the UC Cet type stars with a very high time-resolution; a broad range of electrophotometric observations of the UV Cet flare by Kunkel (1973), Moffett (1975) and others; three-colour photographic observations of faint flare stars in the Orion association by Andrews (1972), Gasparian (1975), and others.

However, special mention should be made of the discovery of X-ray emission from flare stars by Heise et al. (1975) in 1974; we believe that this marked a new and important stage not only in understanding the nature of the flares, but it encompasses also a broader range of problems concerning the physics of stellar atmospheres, the internal structure of stars and the sources of innerstellar energy.

In this connection the following question is posed: to what extent are the new observation facts in agreement with the fast electron hypothesis? In other words, are we justified in asserting that this hypothesis has been confirmed experimentally in the light of new observational evidence and got in this way closer to an understanding of the nature of flare stars? It is with this problem that we shall be concerned in the present paper.

2. Fast Electron Hypothesis

The essence of fast electron hypothesis reduces to this (Gurzadyan, 1965, 1973):

The observed peculiarities of flares in flare stars can be accountable if we assume that all of the additional radiation emitted by the star during the flare in the optical range is produced by virtue of the secondary processes and is of nonthermal origin. More specifically, this means that:

(i) The emission energy of the flare is derived wholly at the expense of the energy of relativistic electrons, and only a small part ($\sim 10^{-4}$) of the total kinetic energy of the electron turns into the optical emission of the flare.

(ii) The very phenomenon of the flare – the fact and strong increase of the brightness of the star – results in a fast and intensive generation of relativistic electrons over the photosphere of the star.

(iii) The inverse Compton effect is an elementary process of the optical flare–inelastic collisions of infrared photons of the ordinary photospheric radiation of the star with relativistic electrons, in consequence of which the infrared photons transform or drift to the region of photons with greater energy. However, the more powerful optical flares partly and the X-ray flares fully are induced by nonthermal bremsstrahlung.

Furthermore, electrons, the energy of which exceeds but very little the intrinsic