FLARES ON RED DWARF STARS AS A RESULT OF THE DYNAMICAL RESPONSE OF THE CHROMOSPHERE TO THE HEATING

M.M. Katsova
Sternberg Astronomical Institute, Moscow State
University, Moscow, USSR
M.A. Livshits
Institute of Terrestrial Magnetism, Ionosphere and Radio
Wave Propagation of the Academy of Sciences,
Moscow, USSR

The impulsive hard X-ray, EUV and microwave radio bursts always start at or after the onset of a soft X-ray increase - the main phase of a solar flare - before the Hα flare maximum. This hard phase of a solar flare lasts ∿ 100 s and consists of several elementary bursts of 10 s duration. In this time electrons are accelerated up to energy 20-100 keV, then they are injected vertically downwards into denser chromospheric layers. The electron heating as well as the thermal conductivity heating leads to the appearance of the secondary process, in particular, to gasdynamical motions (Kostyuk and Pikel'ner, 1974).

The above mentioned electron event and corresponding secondary process are considered for a red dwarf atmosphere similarly to the solar case. The energy flux of a hard electron beam (> 15 keV) is supposed to be 10^{12} erg/cm^{2}s. The numerical solution of the one-dimensional system of gasdynamical equations was given by Katsova et al (1981) and by Livshits et al (1981). Radiative losses balance the energy input at each point taking into account the resonance line opacity. The adopted pressure at the coronae base was $P=0.3$ dyne/cm^2 in the initial model. Due to the initial heating, a region of higher pressure is formed, from which disturbances propagate upwards and downwards - see Figure 1. A shock wave is formed in front of the temperature jump propagating downwards. Between the temperature jump and this shock front a condensation with $\Delta z \approx 1$ km at the beginning and $\approx$ 10 km at the end of this process appears. The optical depth at λ4500 Å for this condensation (with $n \sim 10^{15}$ cm^{-3} and T=8500-9000K) is $\tau \sim 1$. On a star with $T_{eff}=3250$K , $R=0.3R_{\odot}$ and a flare area $S=3\times10^{18}$cm^2 the ratio of the flare B-filter-luminosity to the stellar bolometric luminosity is $L_{fl}/L \approx 0.7$; a smaller radius, $\approx 0.1R_{\odot}$, leads to $L_{fl}/L \simeq 6.3$. Grinin and Sobolev (1977), who were the first to suggest that the

P. B. Byrne and M. Rodonò (eds.), Activity in Red-Dwarf Stars, 617–619.

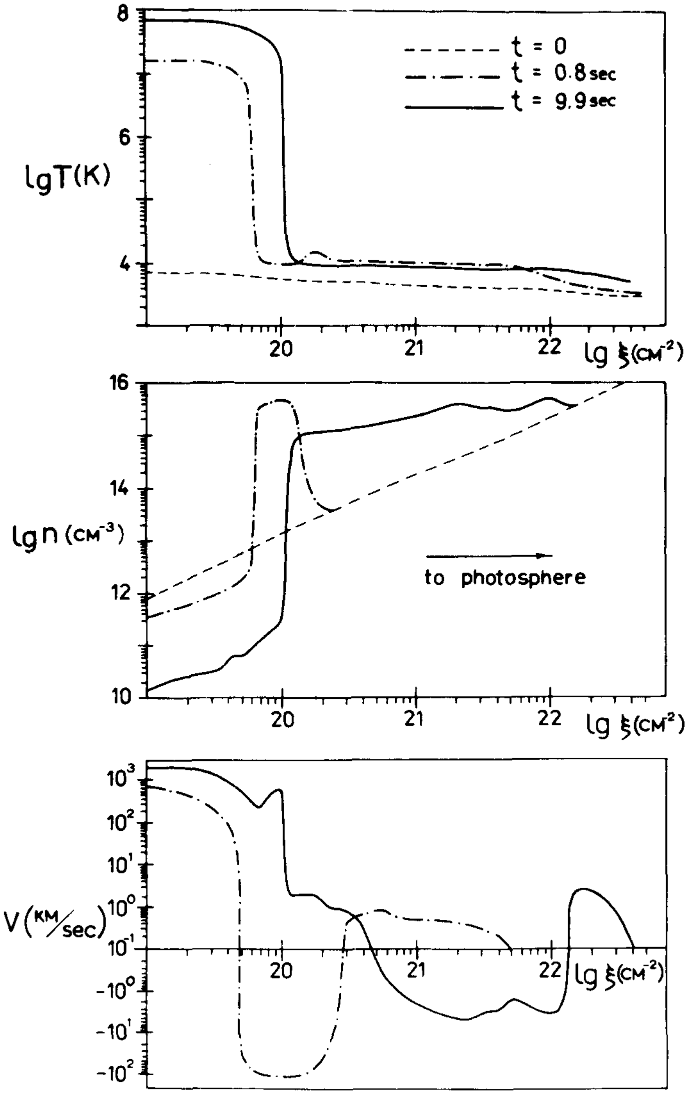

Figure 1. Distributions of the temperature, density and velocity calculated for the response of the red dwarf chromosphere to heating by a non-thermal electron beam with a power-law energy spectrum $vN{\sim}E^{-3}$. The positive velocities correspond to the gas flowing upwards. The dashed line shows the initial model.

optical flares on UV Cet-stars are located between the photosphere and the chromosphere, give U-B=-1 and B-V=0.5 for the low temperature emission source in the flare. The photometric parameters of this condensation are found to be in a good agreement with observations, in particular, with T_{fl}=8500K (Mochnacki and Zirin, 1980).

If the evaporated hot plasma is kept in closed magnetic loops near the stellar surface, the X-ray to optical luminosity ratio L_X/L_{opt} is equal to 0.02 for red dwarf flares. When the hot plasma flows from the star, this ratio will decrease. On the other hand, if the flare optical continuum is absent or is emitted from a small area (as in a solar white flare), L_X/L_{opt} will increase up to the solar value that is equal to several units.

We consider only the electron event without the second main phase of the solar flare, when the solar cosmic rays are sometimes accelerated. Such a second phase may be absent in red dwarf flares, and thus the gamma-radiation and nuclear line fluxes may be less than suggested by data on large solar flares.

REFERENCES

Grinin V.P. and Sobolev V.V.: 1977, Astrofizika, Vol. 13, p. 587.

Katsova M.M., Kosovichev A.G. and Livshits M.A.: 1981, Astrofizika, Vol. 17, p. 285.

Kostyuk N.D. and Pikel'ner S.B.: 1974, Astron. J. USSR, Vol. 51, p.1002.

Livshits M.A., Badalyan O.G., Kosovichev A.G. and Katsova M.M.: 1981, Solar Phys. Vol. 73, p. 269.

Mochnacki S.W. and Zirin H.: 1980, Astrophys. J. Letters, Vol. 239, p. 27.