Variations of the solar flare energy spectrum over solar cycles and solar-UV Cet stars analogy of energy release

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Solar flares are the process of rapid release of significant amount of energy. Similar flare processes were detected for red dwarfs stars (UV-Cet), see (Gershberg, 1998). The investigations carried out for the UV Cet type stars made it possible to suggest the similarity of the flare activity mechanism for the red dwarfstars and the Sun. Solar flares have the exponential energy spectrum with $\beta \sim 0.80$ (Hudson,1991). According to (Gershberg, 1998) β is age dependent parameter: the older the star claster the smaller the group value of β. It means that the flare activity process are not sensitive to the stelar interior structure variations including such an important parameter, as thickness of the convective zone.

Based on soft X-ray (1-8 Å) flux data for 1972-1995 the integral spectra of solar flare energy were computed. It has been shown that the spectral index β of the intergral energy spectrum (IES) has pover-law form and varies systematically with Wolf number (W) and 11-year cycle phase (Kasinsky and Sotnikova, 1996). The interval of β-variations ($0.47 < \beta < 1.0$), β is being approached to 1.0 in the phase of maximum of the solar cycle.

The energy spectrum of solar flares (IES) may be calculated for the short time interval, the year. The data were used on the X-ray emission energy flux within the range 1-8 Å (Solar Geophys.Data, PRF) to calculate the number of accumulated flares, that is approximated by the power-law function:

$$N(E_m) = \int_{E_m}^{\infty} n(E) dE \sim E_m^- \beta \tag{1}$$

where E_m is the threshold energy and β is the spectral index. In coordinates $\log E - \log N$ β was determined to be equal to the angular coefficient of a straight line: $\beta = -d \lg N / d \lg E$. Table 1 presents parameters of integral energy spectrum of flares for 20 years.

Table 1. Parameters of energy spectrum of X-ray solar flares

Year	$\lg E$	β	W	N
1974	31.9 - 2.111 $\lg N$	0.474	34	339
1977	30.4 - 1.608 $\lg N$	0.622	27	238
1978	31.4 - 1.525 $\lg N$	0.656	92	1215
1979	31.5 - 1.472 $\lg N$	0.679	155	1291
1980	30.9 - 1.148 $\lg N$	0.871	155	2161
1981	31.1 - 1.169 $\lg N$	0.855	140	3544
1982	31.4 - 1.302 $\lg N$	0.768	116	3693
1983	30.6 - 1.211 $\lg N$	0.826	67	2453
1984	31.3 - 1.243 $\lg N$	0.804	46	1191
1985	29.8 - 1.372 $\lg N$	0.729	18	1026
1986	30.4 - 1.630 $\lg N$	0.613	13	856
1987	30.1 - 1.345 $\lg N$	0.744	29	1259
1988	30.8 - 1.316 $\lg N$	0.760	100	1654
1989	31.7 - 1.299 $\lg N$	0.800	158	2513
1990	31.0 - 1.111 $\lg N$	0.900	142	2551
1991	31.7 - 1.250 $\lg N$	0.800	145	3229
1992	30.7 - 1.075 $\lg N$	1.000	90	2552
1993	30.3 - 1.333 $\lg N$	0.750	56	2161
1994	30.1 - 1.075 $\lg N$	0.700	30	1582
1995	30.4 - 1.620 $\lg N$	0.670	18	989

It follows from the Table 1 that β varies with cycle phase, that is with Wolf numbers W. As it is β shows the minimum values 0.5-0.6 at cycle minimum. With the cycle developed, β has a tendency for an increase up to 1.0. As follows from estimations (Kurochka, 1987) the largest energy of optical and UV emission of flare is several units per 10^{32} erg. As follows from the Table 1, the estimates of maximum flare energy in the X-ray range do not exceed 10^{32} erg.

The behaviour of β in the optical range is similar to that in X-rays: β for optical flares has a stable tendency for an increase to a maximum (1.04-1.11) being kept during 1-2 years after the maximum. On the whole, $\beta(optic)/\beta(X) > 1$. It may imply that the flare occurrence rate in the optical range is higher compared with that for the X-ray flares at cycle maximum. An investigation of solar flares IES during 2 cycles reveals.

1. The integral energy spectrum of the solar flares has the power law form. The β undergoes the variations associated with the cycle phase, correlating with the Wolf numbers.

2. The spectral index β increases from the epoch of minimum to the epoch of maximum of solar activity approacing 1.0, that means an increase in flare occurrence rate.

3. Cycle-like variations of β with the phase of an 11-year solar cycle can be a base for identifying the similar cyclic variability for red dwarf stars. The power-law character of the flare energy spectra for the Sun and stars provides the evidence in favour of the common energy mechanism for the solar-stellar flares.

References

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