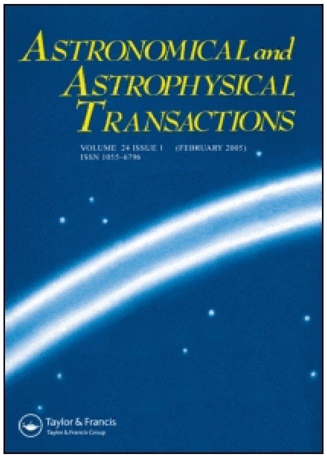

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V. V. Kasinsky [a]; R. T. Sotnikov [a]
[a] Irkutsk Institute of Transport and Irkutsk University, Irkutsk, Russia

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SOLAR FLARE ENERGY SPECTRUM OVER THE 11-YEAR CYCLE, AND THE SIMILARITY BETWEEN SOLAR AND STELLAR FLARES

V. V. KASINSKY and R. T. SOTNIKOVA

Irkutsk Institute of Transport and Irkutsk University, 664000, Irkutsk, Russia

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Energy distribution in solar flares and in UV Ceti stellar flares are similar and can be approximated by a power law. The value of the flare energy spectrum power law exponent is $0.47 < \beta < 0.93$. It changes cyclically and correlates with Zurich Wolf numbers.

KEY WORDS 11-year cycle, Wolf numbers, solar flares, UV Ceti flares

It is known that the physical origin of flares on UV Ceti stars is similar to solar activity (Gershberg, 1978). A general theory for flare activity of UV Ceti stars and the Sun is still not available. An attempt to construct an integral energy spectrum (IES) of solar flares in the X-ray range was made by the authors (Kasinsky, Sotnikova, 1989). Preliminary estimats showed that both the flare energy and the exponent of the power spectrum varied in a cyclic fashion with time. The goal of this paper is to identify such a dependence on the level of solar activity (Wolf number) in terms of the analogy between stellar and solar flares. The flare IES was constructed for every year (1972–1993) using data reported in PRAF of SOLAR GEOPHYSICAL DATA, publ.NOAA–USAF Space Envir. Center, Boulder, Colo., US Dept. Comm., 1972–1993 and was represented in a power-law form (E is total energy in the range 1–8Å, and $N(E_m)$ is the number of flares with energies higher than a fixed one):

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

An average regression for 1972–1993 was obtained from 36949 flares. The regression level was used to determine, in coordinates $\log E$–$\log N$, the spectral index equal to the angular coefficient of the straight line: $\beta = -d \log N / d \log E$. The exponent of the spectrum was found to be smaller compared to optical flares ($\beta = 0.80$). Physically, this means that X-ray flares are uncommon and relatively powerful, and, compared to optical flares, their occurence rate is higher. According to data

Table 1.

Year	*Spectrum* β	*Wolf number*	*Number of flares*	*Year*	*Spectrum* β	*Wolf number*	*Number of flares*
1972	0.72	69	2723	1984	0.80	46	1191
1973	0.76	38	318	1985	0.73	18	1026
1974	0.47	34	339	1986	0.61	13	856
1975/76		15/12	–	1987	0.74	29	1259
1977	0.62	27	238	1988	0.76	100	1654
1978	0.66	92	1215	1989	0.77	158	2513
1979	0.68	155	1291	1990	0.90	142	2551
1980	0.87	155	2161	1991	0.80	145	3229
1981	0.86	140	3544	1992	0.93	90	2552
1982	0.77	116	3693	1993	0.75	56	2161
1983	0.83	67	2453				

covering a 22-year time interval, the highest energy of an X-ray flare never exceeded 10^{31} erg. As apparent from the Table 1, the exponent undergoes variations and follows Wolf numbers (W). The exponent value is the smallest (0.47–0.61) in the cycle minimum and is the highest (0.92) in 1992. Therefore, rare but powerful flares contribute to the total emission power of flares in the cycle minimum. By the cycle maximum, the role of weak and frequent flares increases. Curiously, there is a one year delay of β with respect to variations of W. Such a delay requires that the flare production mechanism has a link with hydrodynamic storage times ($\sim$ 1 year).

Thus, the Sun behaves as a UV Ceti star whose exponent of flares IES depends on Wolf number, i.e. on cycle phase. The interval of β variations ($0.47 < \beta < 0.93$) is characteristic of UV Ceti stars with powerful but rare flares. The main conclusions are as follows.

1. The energy spectrum of solar flares is a power law (1), with a variable exponent which increases from epoch of minimum to epoch of maximum (see Table 1).

2. A positive correlation of β with Wolf number (W) and with the phase of the solar 11-year cycle, and the cyclic variation of the IES exponent from epoch of minimum to epoch of maximum may serve as fundamental dependences for revealing similar flare activity on red dwarf (UV Ceti) stars.

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