DISTRIBUTION LAW OF INTEGRATED INTENSITY OF SOLAR OPTICAL FLARES

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Received 16 August 1982

ЗАКОН РАСПРЕДЕЛЕНИЯ ИНТЕГРАЛЬНОЙ ИНТЕНСИВНОСТИ СОЛНЕЧНЫХ ВСПЫШЕК В ОПТИЧЕСКОМ ДИАПАЗОНЕ

Исследуется распределение частоты появления солнечных вспышек в оптическом диапазоне по разным значениям интегральной интенсивности. Число вспышек уменьшается как $I_{(i)}^{-1\cdot9}$ для вспышек с интегральной интенсивностью $I_{(i)}$ большей чем 2 единицы. Этот степенной закон распределения сравнивается с законами установленными для других видов солнечной активности.

The occurrence frequency distribution of solar optical flares in different values of integrated intensity has been investigated. The number of flares diminishes as $I_{(i)}^{-1\cdot9}$for flares with integrated intensity, $I_{(i)}$, greater than 2 units. This power law distribution has been compared with that found in other kinds of solar activity.

1. Introduction

As the crux of devising an adequate instrumentation for measuring directly the energy yield of a solar flare process is still not resolved, several indirect techniques have been invoked for estimating the energy released due to such a pragmatic event in the solar atmosphere. In estimating the energy of a flare, several indices like 'flare index' (Sawyer, 1967) based on the measured area of the flaring region at the time of maximum brightness, luminosity and duration, and 'comprehensive flare index' (Dodson and Hedeman, 1977, 1975) based on the ionizing, Hα and radio emissions of flares have been introduced. With these devices in hand, it is conducive to establish an empirical relationship, giving the distribution of energy of solar flares. But so far as up-to-date literature is concerned, no such relationship has yet been formulated. Hence, in the present paper an attempt is made at obtaining an empirical relationship which connects the occurrence frequency distribution of solar optical flares with their integrated intensity values.

2. Results

Altogether 1438 data of Hα-flares have been taken from the group reports appearing in the Solar Geophysical Data bulletins issued by NOAA, U.S. Department of Commerce during the period from 1970 to 1977. The integrated intensities of these flares have been calculated by means of the expression (Sawyer, 1967)

$$I_{(i)} = 7{\cdot}6A_s^2 ,$$

where A_s is the measured area of a solar flare in square degrees.

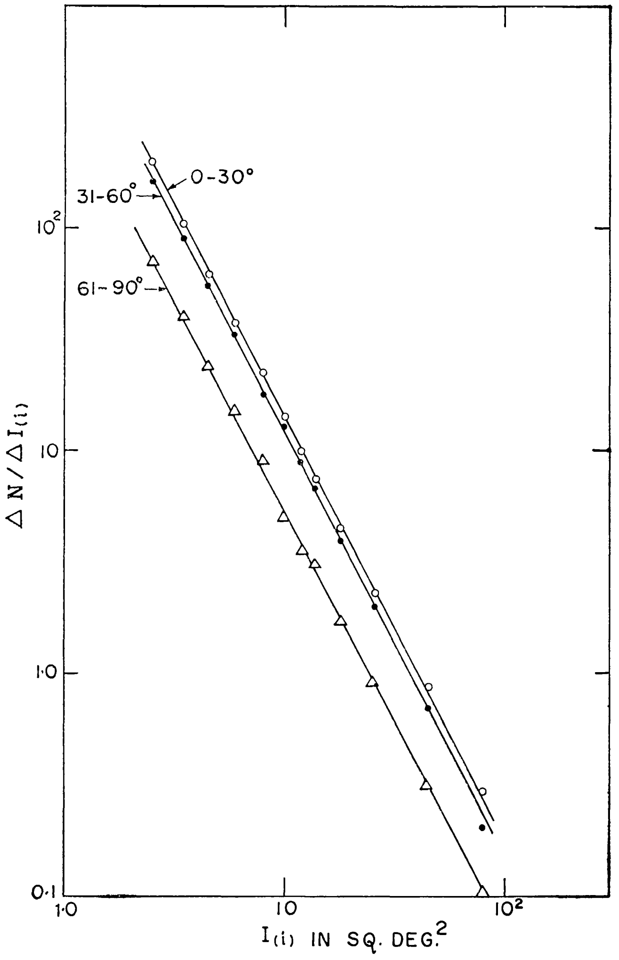

Fig. 1. Occurrence frequency distribution of integrated intensities $I_{(i)}$ drawn for the flares appearing in the ranges of longitudes 0—30°, 31—60° and 61—90°.

Bull. Astron. Inst. Czechosl. 35 (1984), 241—243.

The occurrences ΔN of solar flares in selected ranges of integrated intensity $\Delta I_{(i)}$ have been found in each of the ranges of longitudes 0–30°, 31–60° and 61–90°. For these three longitude ranges separately, the values of $\log(\Delta N/\Delta I_{(i)})$ have been plotted against $\log I_{(i)}$ as shown in Fig. 1, where $I_{(i)}$ represents the mid values of the corresponding ranges of integrated intensity. It appears from the figure that each of the lines can be fitted with the following empirical relation:

For $I_{(i)} \geqq 2$ sq. deg.^{2}

$$\frac{\Delta N}{\Delta I_{(i)}} \sim I_{(i)}^{-1.9} .$$

The aforesaid procedure was repeated after grouping the flares in the ranges of latitudes 0–12° and 13–24° in which most of the flares are found to lie. The results displayed in Fig. 2 reveal that the same empirical relationship as mentioned above is also followed in this case.

From the above considerations it is obvious that the above relationship, giving the intensity distribution of solar flares, is independent of the positions of the flares on the solar disk. However, there is an apparent dependence of this distribution on the heliocentric angles as it is evident from the vertical separation between the consecutive lines.

The above empirical relation has been compared with the occurrence frequency distribution of areas and also of durations of solar flares. This comparison is required only to justify the significance of the results obtained from Sawyer's expression which takes into consideration both of these two parameters in a combined way. The distributions of areas, as well as of durations of flares are shown in Fig. 3, the distributions being shown irrespective of the positions of the flares on the solar disk. It appears from the figure that for smaller values of the flare areas the frequency distribution falls slowly with area, but for larger values it drops sharply. As regards the frequency distribution of duration it can be concluded that the

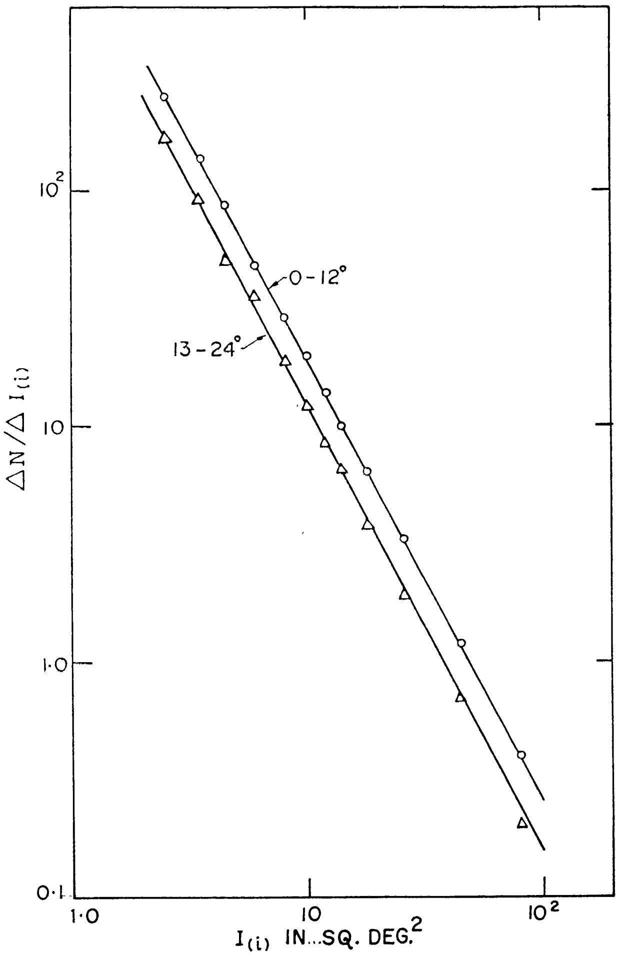

Fig. 2. Occurrence frequency distribution of integrated intensities $I_{(i)}$ plotted for the flares appearing in the ranges of latitudes 0–12° and 13–24°.

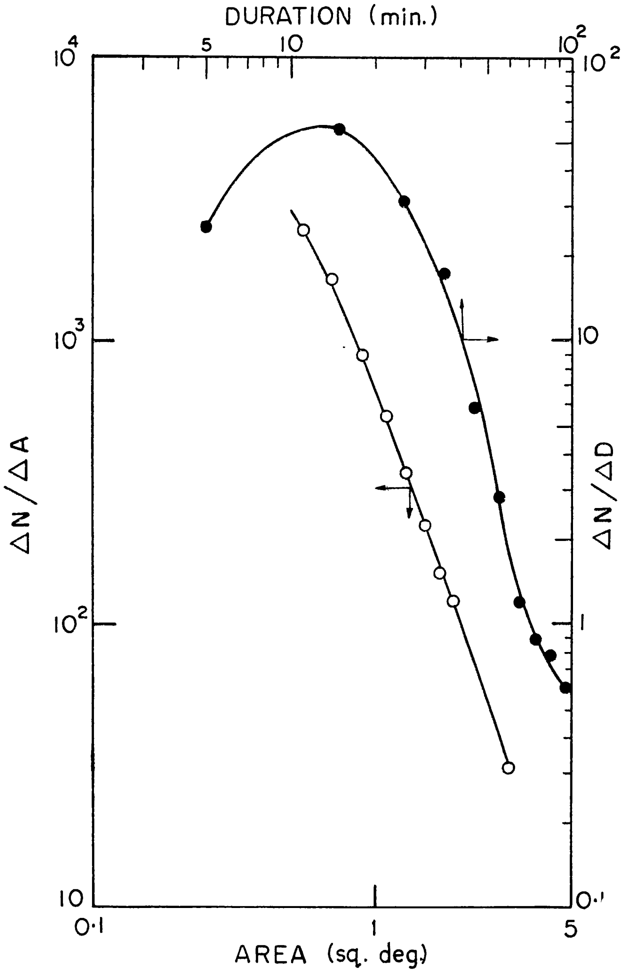

Fig. 3. Occurrence frequency distributions of areas and of durations of flares, plotted irrespective of the positions of the flares on the solar disk.

occurrence frequency is maximum for durations in the range of 10 – 20 min. and declines both in the lower and higher duration values.

3. Discussion

From the previous analyses it appears that the distribution of neither the areas nor the durations of solar flares obey any definite law, whereas, the distribution of integrated intensities of solar flares obeys a power law with an exponent nearly equal to 2. This deviation of the distribution of areas and also of durations from that of the integrated intensities clearly indicates that the empirical relationship, which expresses the distribution of flares in different integrated intensity values, is a unique one.

In an earlier paper by Das and Das Gupta (1982) a similar power law distribution with the same value of exponent as derived above was seen to hold true for the sunspot magnetic fluxes, the distribution being of the form

$$\frac{\Delta N}{\Delta \Phi} \sim \Phi^{-1.9} \quad (\text{for } \Phi \geqq 3 \times 10^{21} \text{ Maxwell}),$$

where ΔN is the number of sunspots between Φ and $\Phi + \Delta\Phi$. Drake (1971) found the following power law distribution of soft X-ray peak fluxes:

$$N = 82{\cdot}5 F_p^{-1.84 \pm 0.02}$$

for the peak flux range $2{\cdot}0 \leqq F_p \leqq 100{\cdot}0$ milliergs $(\text{cm}^2\,\text{sec})^{-1}$. The intensity distribution of microwave bursts also follows the same type of relation:

$$\frac{\Delta N}{\Delta I} \sim I^{-x}$$

where ΔN is the number of bursts in the intensity interval ΔI, I the mean intensity expressed in units of $10^{-22}\,\text{wm}^{-2}\,\text{Hz}^{-1}$, and x an arbitrary constant. The values of x are 1·5 and 3 at 10 cm wavelengths and 1·8 in the microwave range as found by Kundu (1980) and by Kakinuma et al. (1969), respectively. Rosner and Vaiana (1978) generalized the flaring behaviour for a variety of cosmic transient sources – the sun, flare stars and x-ray bursters which obey similar law giving the frequency of occurrences as a function of energy released.

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