Solar Flares and "Microflares"

H. S. Hudson

- "Extensive parameters" of flares tend to scale together
  → Energy distribution function $\frac{dN}{dW}$
- Distributions of flare parameters follow power law
  Early results of Kakinuma et al., Drake
  Stellar flare results (Kotetin & Kresnokahtsev ?)
- Implications of energy distribution law for coronal heating
- Numerical simulations
- Analyses of future data (GRO, Solar-A, Nobeyama, BIMA...)
- Interesting solar-cycle effect?

Statistical analyses of this type may be quite crude and unfortunately may conceal much interesting physics!

$$\frac{dN}{dW} = \text{Number of flares per unit total flare energy}$$

$$E = \int_{W_1}^{W_2} W \frac{dN}{dW}\, dW = \text{energy in entire distribution}$$

for $\frac{dN}{dW} \propto W^{-\alpha}$ find

$$\boxed{E \propto W_2^{-\alpha+2} - W_1^{-\alpha+2}} \qquad \alpha \neq 2$$

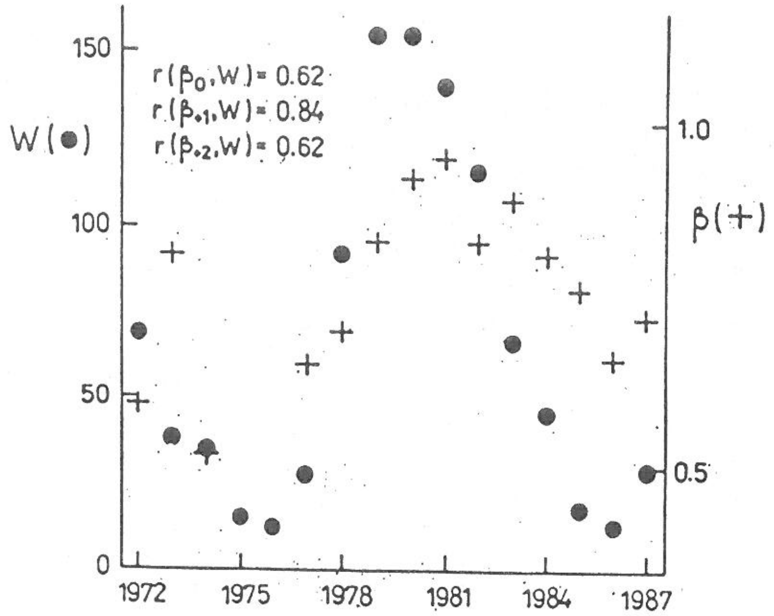
if $\alpha < 2$ $E = E(W_2)$ predominantly (events at the "microflare" end of the distribution do not contribute significantly)

For the Sun, $\alpha = 1.85$

E can be re-written as

$$E = \int_{W_1}^{W_2} W^2 \frac{dN}{dW}\, d\log W$$

so that $W^2 \frac{dN}{dW}$ represents the energy content per decade



Whose result is this?

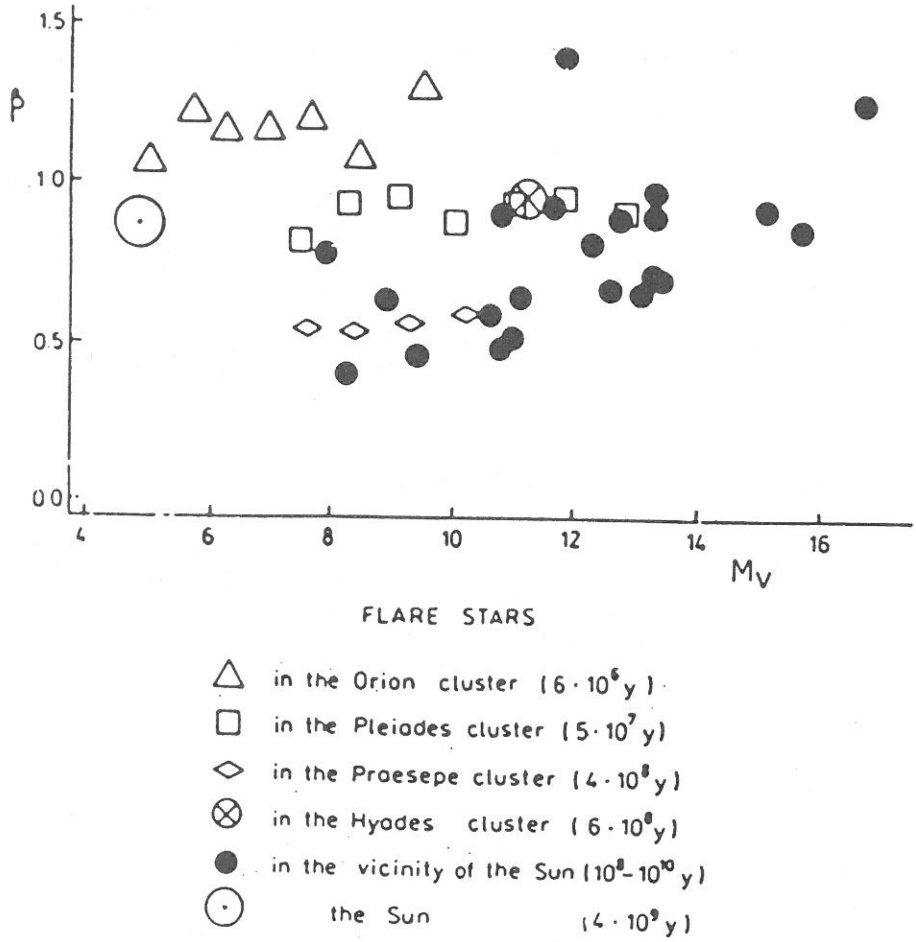


Fig. 3. Spectral indices of energy spectra of flares on red dwarf stars in the solar vicinity and in clusters.

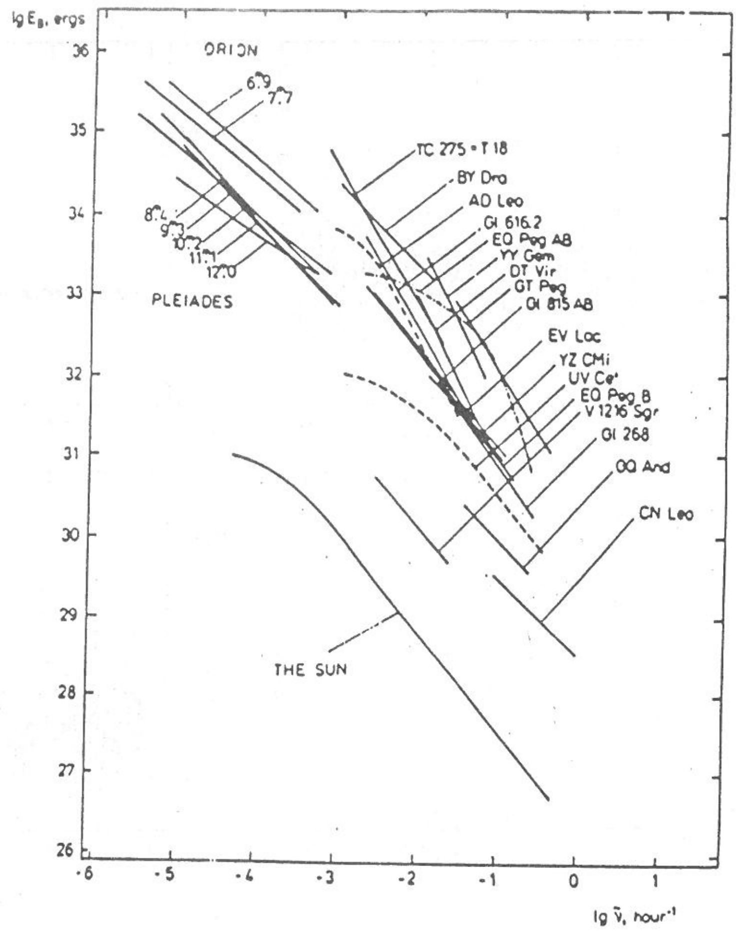


Fig 2. Energy spectra of flares on red dwarf stars and the Sun. Total energy in the B-band flare radiation, E, is plotted versus frequency $\tilde{\nu}$ of flares with energy exceeding E.

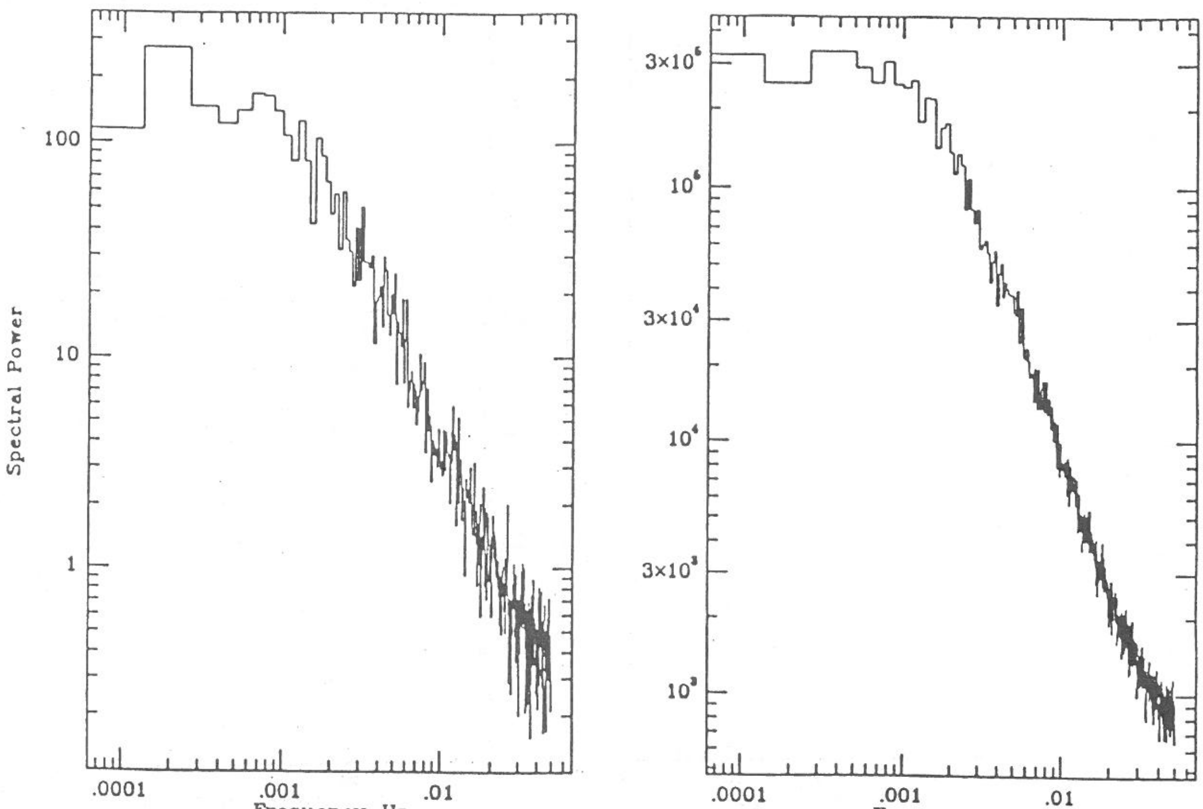


FIGURE 3

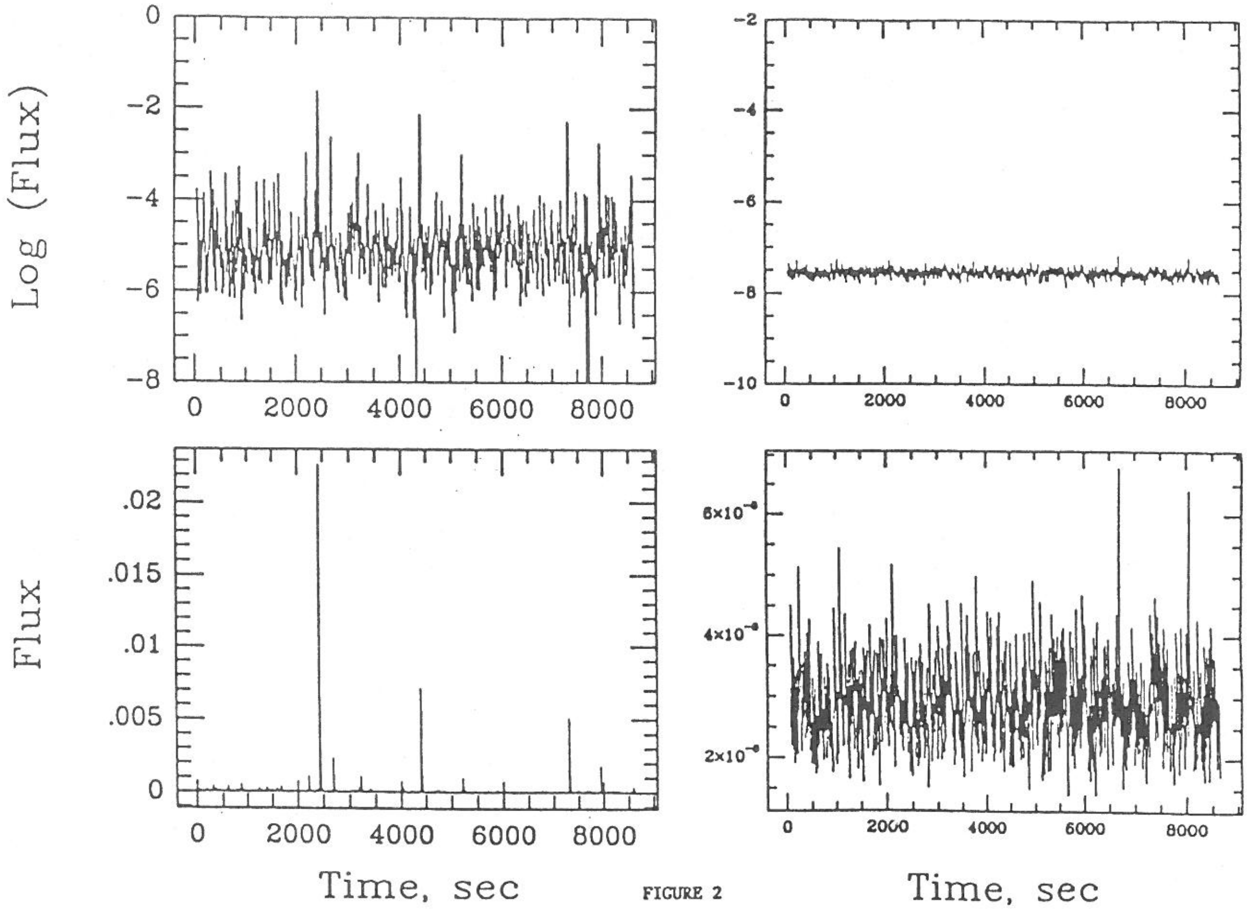


FIGURE 2

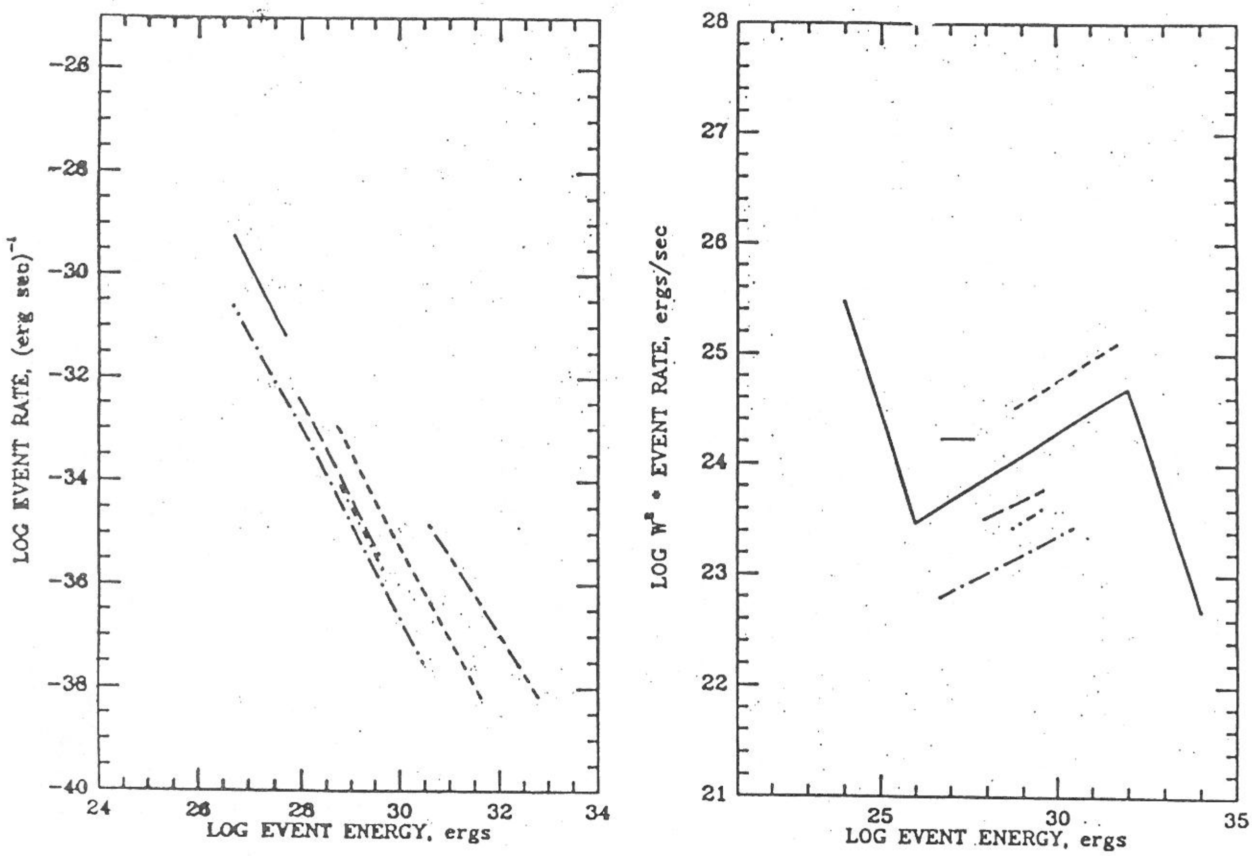


Figure 1

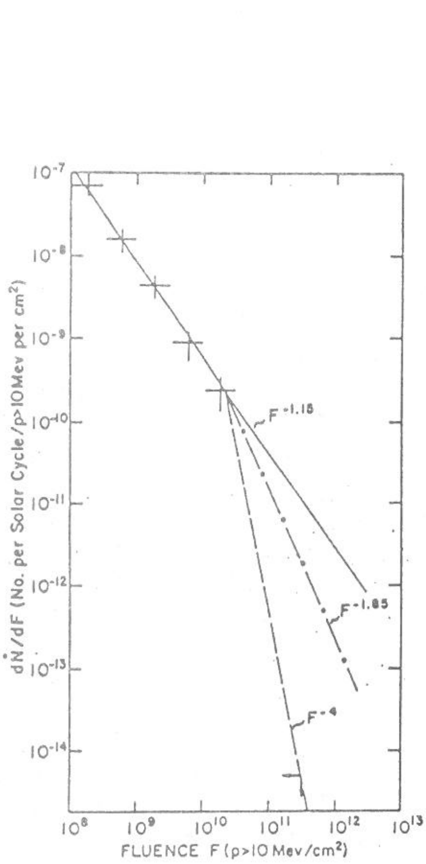


Fig. 3. Size-frequency distribution of the flare proton fluences (>10MeV) for all flares in solar cycles 19 and 20, as given by the data points. A power-law distribution of the form $F^{-1.15}$, as shown by the solid line, gives a good fit to these data up to $F \sim 2 \times 10^{10}$ p/cm². Given this distribution, the absence of events with fluences $>2 \times 10^{10}$ p/cm² clearly requires a break or steepening in the distribution. The dashed line shows an extrapolation at the slope -4 above the break energy, as required by the upper limits described in the text. The dash-dot line has a slope -1.85 to match the distribution of total flare energy (Hudson, 1978), and also falls well above the limit.

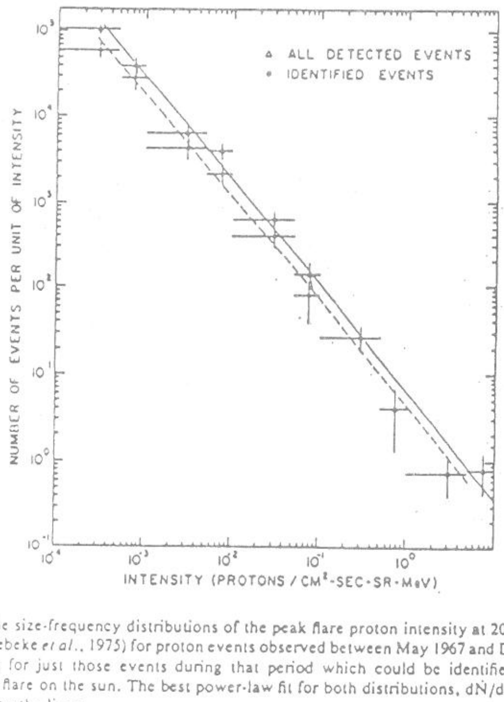


Fig. 1. The size-frequency distributions of the peak flare proton intensity at 20–80 MeV (van Hollebeke *et al.*, 1975) for proton events observed between May 1967 and December 1972, and for just those events during that period which could be identified with a particular flare on the sun. The best power-law fit for both distributions, $d\dot{N}/dI \propto I^{-1.15}$, is shown by the lines.

PARTICLE ACCELERATION IN SOLAR FLARES

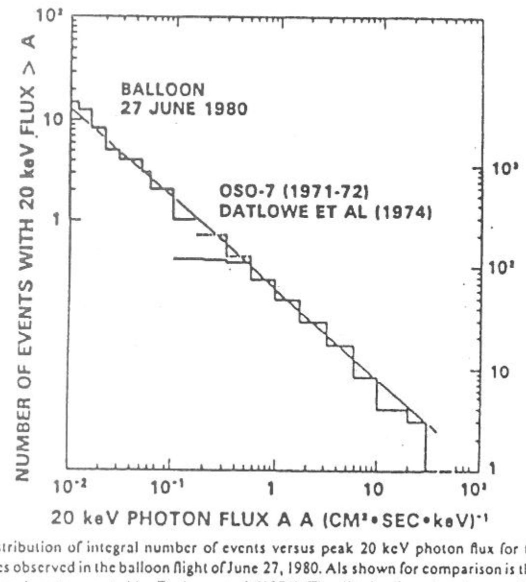


Fig. 1. The distribution of integral number of events versus peak 20 keV photon flux for the solar hard X-ray microflares observed in the balloon flight of June 27, 1980. Also shown for comparison is the distribution of solar flare X-ray bursts reported by Datlowe *et al.* (1974). The distributions have been arbitrarily moved vertically to show that their slopes are approximately the same (from Lin *et al.*, 1983).

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The distribution function of flare occurrence (the ``log(N)/log(S) function'') has a flat power--law form over the range of total flare energies observed, both for solar and for stellar flares. For parameters that appear to scale with the total energy of the flare, the differential power--law index typically is in the range 1.7--1.8. Smaller events following such a distribution, and hence presumably having a related physical origin, cannot explain the steady heat input required for ambient coronal heating. Similarly late--phase energy release in extended solar flares probably cannot be attributed to microflares, unless their physical properties differ from those of the main population of flares. If elementary non--thermal processes (microflares) do explain these forms of gradual energy release, a separate population with a steeper distribution function must exist. There is at present no observational evidence for the existence of such a separate distribution.