SYNCHROTRON OR PLASMA EMISSION IN SOLAR MICROWAVE FLARES?

(Research Note)

A. O. BENZ

Institute of Astronomy, ETH, Zürich, Switzerland

(Received 28 June, 1984)

Abstract. The spectral indices of microwave and hard X-ray emissions of a solar flare are found to correlate. Their observed values are in agreement with the expected relation from synchrotron and bremsstrahlung theory. These results are considered as strong evidence for the synchrotron mechanism in the microwave flare, contrary to recent alternative suggestions.

1. Introduction

Is the microwave flare emission really synchrotron radiation? While elaborate, quantitative models based on this assumption are being developed (e.g. Mätzler, 1978; Klein and Trottet, 1984; Takakura, 1984), doubts have been raised by Kaplan et al. (quoted in Zaitsev and Stepanov, 1983) who claim to have observed a threshold number of energetic electrons (obtained from X-ray observations) for impulsive microwave emission. Alternative plasma models have been suggested by Smith and Spicer (1979) and Zaitsev and Stepanov (1983) proposing emission by Langmuir waves and, respectively, by upper-hybrid waves in the primary energy release region.

Benz (1977) has pointed out that a comparison of the high frequency microwave spectral index (measured simultaneously) yields a strong argument for the synchrotron process. The argument is repeated with better data, and some quantitative errors are corrected.

2. Observations

In Figure 1 the spectral indices during a well-observed flare are shown. The instantaneous best-fit power-law index, $\gamma$, of the hard X-ray spectrum $I$ as a function of the photon energy $\varepsilon$ and time $t$,

$$I(\varepsilon, t) \approx I_0(t)e^{-\gamma(t)},$$

has been determined by Hoyng et al. (1976). The microwave flux at 5.0, 8.8, 15.4, and 35 GHz has been measured at Sagamore Hill. Castelli and Guidice (1976) have computed the microwave power-law index, $\alpha$, of the high frequency slope:

$$\alpha(t) = -\frac{\frac{d}{d \log \nu} \log I_\mu(\nu, t)}{\log(v_2/v_1)} \approx \log \frac{I_\mu(\nu_1, t)}{I_\mu(\nu_2, t)}.$$
Fig. 1. Spectral index $\gamma$ of hard X-ray emission (best fit 28–440 keV) and spectral index $\alpha$ of microwave emission (frequency of peak flux (10.6 GHz)–35 GHz) during the flare of August 7, 1972. The microwave index is multiplied by two (as suggested by theory) and shifted for comparison. The hard X-ray data were observed by TD-1A, (courtesy of Dr P. Hoyng) the microwaves were measured at Sagamore Hill (Castelli and Guidice, 1976).

The $\alpha$ curve is shifted in Figure 1 to allow a direct comparison with $\gamma$. The two curves clearly correlate. Calibration errors of the microwave data shift the $\alpha$ curve by a constant amount, which can be more than unity. This seems to be responsible for the larger $\alpha$'s obtained by Benz (1977) from Slough data for the same event. For this reason we do not consider here the absolute value of $\alpha$.

A similar correlation was also found for another big flare on August 4, 1972.

3. Interpretation

In the following a power-law distribution of electron energy,

$$f(E) = f_0 E^{-\delta}, \quad (3)$$

is assumed. The argument would stand very similarly for a Maxwellian. If the particles hit a thick target, their bremsstrahlung spectral index relates to their distribution at the target site by

$$\gamma = \delta + \frac{1}{2} \quad (4)$$