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Physical conditions of the acceleration region of a solar flare with an unusually narrow gyrosynchrotron spectrum

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During the rising phase of the August 30, 2002 X1.5 flare a short pulse with a total duration of 8 seconds was observed. Its background-subtracted radio spectrum ranges only from 5 to 12 GHz with a maximum flux density of approximately 900 s.f.u. at 7 GHz and a steep optically thin spectral index $\alpha \simeq 8$. Maximum degree of polarization at 7 GHz is around 5%. The hard X-ray pulse emission above the background in the range of 30–150 keV observed by *RHESSI* is coincident in time with the microwave observation. Hard X-ray images reveal very compact ($\sim 10''$) footpoint sources. Below 30 keV, a thermal source is observed.

In order to explain the microwave spectrum we analyzed different alternatives. A thermal source would need extremely high temperature to produce the photons of 150 keV observed with *RHESSI*. Harmonic or maser emission generate spectra which are narrower than ours, and are strongly polarized. We used instead a distribution of accelerated electrons represented by a double power law, with $\delta_{E\,<\,250\text{ keV}} = 5.3$ and $\delta_{E\,\geqslant\,250\text{ keV}} = 13$, a 35 keV low energy cutoff, and computed the gyrosynchrotron and thick target *bremsstrahlung* fluxes of a homogeneous source. A thermal source with $EM = 10^{48}$ cm^{-3} and $T = 3.2\,10^7$ K was added to fit the X-ray spectrum below 35 keV.

From our fitting we determine a rate of $\dot{N} = 7.5\ 10^{34}\ \mathrm{s}^{-1}$ accelerated electrons. The power deposition of the nonthermal electrons is $5.5\ 10^{28} \leqslant Q \leqslant 5.5\ 10^{29}$ ergs s^{-1}, depending on the plasma density assumed: $10^{10} \leqslant n \leqslant 10^{11}\ \mathrm{cm}^{-3}$. The ratio $\dot{N}/Q$ can be related to the accelerating DC electric field. Using the relation established by Holman *et al.* (1989), we may deduce that $17 \leqslant E_d/E \leqslant 24$ here with E the electric field, and E_d the Dreicer field. The critical energy above which the electrons runaway can also be determined, yielding $24 \leqslant W_c \leqslant 33$ keV. Finally, the total number of current sheets is $7.5\ 10^4 \leqslant s \leqslant 10^5$.

This uncommon event, short in time and intense in flux, is explained by means of a beam of accelerated electrons with energies mainly between 35 and 250 keV, because the electron index above the break energy is so high that it acts as a high-energy cutoff. Assuming that a DC field accelerated the electrons, we concluded that the electric field should be sub-Dreicer. The critical energy obtained, around 30 keV, is compatible with the 35 keV low-energy cutoff of our model. The large number of current sheets needed to accelerate the electrons could be overestimated if the current sheet density is higher or if the resistivity is non classical.

Reference

Holman, G. D., Kundu, M. R., & Kane, S. R. 1989, *ApJ*, 345, 1050