ON THE THERMAL STRUCTURE OF THE FLARE-PRODUCED PLASMA

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Summary. Recent flare studies have shown that soft X-ray data are not compatible with simple isothermal models of the source (Herring and Craig, 1973; Craig, 1973; Neupert *et al.*, 1973). With this in mind, the emitting flare plasma has been represented by the temperature-emission measure distribution function,

$$\zeta(T)\,\mathrm{d}T = \left(\sum_{i=1}^{n} A_i T^{-\alpha_i}\right)\mathrm{d}T \quad \text{for} \quad T \geqslant T_0, \tag{1}$$

where $\zeta(T)$ is the differential emission measure (cm^{-3} per 10^6 K), T is the electron temperature in units of 10^6 K, T_0 is a low temperature cut-off for the distribution, α_i are real positive numbers, and A_i are positive coefficients determined from data (for appropriate values of T_0 and α_i) by a least squares fitting procedure. Such a distribution is suggested by results obtained by the present author using simple delta-function representations for $\zeta(T)$ (with $n \leqslant 4$); these discreet multi-temperature models usually indicate that the emission measure decreases with increasing temperature. Also, as discussed by Brown (1974), a power law distribution for $\zeta(T)$ is consistent with the observed bremsstrahlung emission in the hard X-ray (> 10 keV) domain. In attempting to find a suitable form for the differential emission measure, a simple empirical function of the type assumed by Chambe (1971) for active regions was also tried, but the fit, as evidenced by the χ^2 test was unsatisfactory.

The present analysis indicates that the flare regions above about 3×10^6 K may be described adequately (as defined by the χ^2 test), though not uniquely, by a single power law for $\zeta(T)$; viz. $\zeta(T) = AT^{-\alpha}$ for $T > 3 \times 10^6$ K. Other terms in the expansion for $\zeta(T)$ may be neglected above this temperature. Figure 1 shows the differential emission measure for three points in a flare previously discussed by Craig (1973). Note the tendency for α to increase as the spectrum softens during the decay phase of the flare.

In considering the decay of the high temperature flare regions, it has been assumed that the dominant energy loss mechanisms are radiation and conduction. It is further assumed that the hot region has an approximately cylindrical structure, and that, at any instant, constant pressure prevails throughout the source. Thus $N_e(z)\,T(z) = P$ is constant, where $N_e(z)$ (cm^{-3}) is the electron density at some position z (cm) in the source, and $T(z)$ (10^6 K) is the associated local temperature (cf. Brown, 1974). Under the above conditions, the ratio of the conductive energy flux to the radiative energy loss, for unit volume of plasma, at each point in the tube is given by

$$R(T) = \left|\frac{\nabla \cdot \mathbf{F}_{\mathrm{cond}}}{\nabla \cdot \mathbf{F}_{\mathrm{rad}}}\right| = 9.2 \times 10^{14}\,\frac{S^2 P^2}{A^2 f(T)}\,(\alpha + \tfrac{1}{2})\,T^{2\alpha - 1/2}, \tag{2}$$

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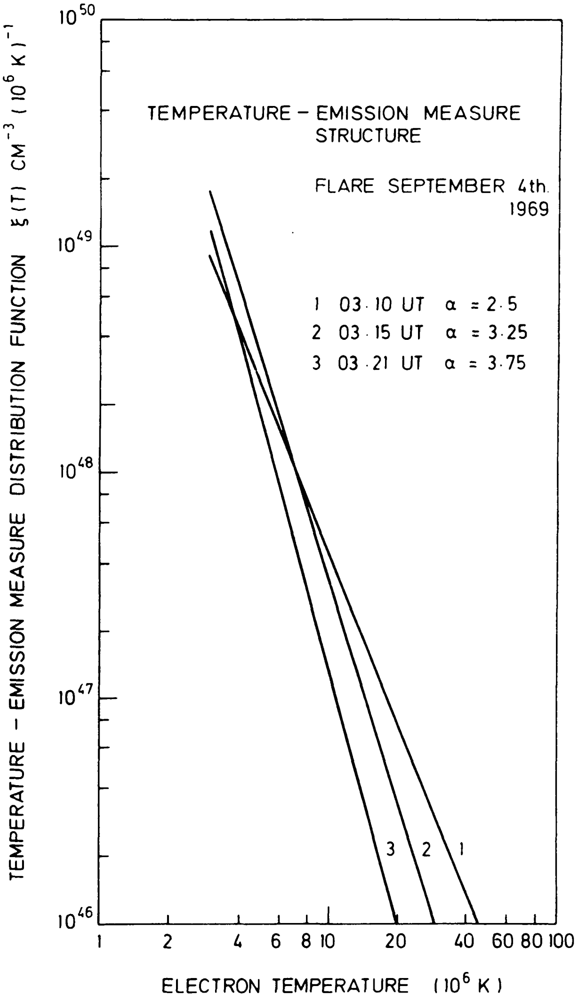

Fig. 1. The temperature structure at three instants during the decay phase of a flare on 1969, September 4.

where **F** represents the appropriate energy flux vector, $f(T)$ is the radiative energy loss function calculated by Tucker and Koren (1971), and $S(\text{cm}^2)$ is the cross-sectional area of the filament.

Inserting typical values for the parameters in the above equation ($\alpha=3$, $A=10^{51}$, $f(T)=10^{-23}$, $S=10^{17}$ and $P=10^{12}$) yields $R(T=10)\simeq 1$, which implies that conductive effects will dominate strongly for those regions of the plasma above 10^7 K. This preliminary analysis suggests that both radiative and conductive mechanisms are required to explain the decay of the multithermal plasma. However, bearing in mind that conduction is an energy redistribution process, radiation provides the dominant energy loss mechanism over the temperature structure ($>3\times10^6$ K) as a whole.

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