THE ROLE OF HIGH RESOLUTION OBSERVATIONS IN DETERMINING ENERGY RELEASE AND TRANSPORT PROCESSES

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With present observations from the Solar Maximum Mission and Hinotori, we are seeing a very selective sample of spatially large flares in the soft part (10 to 50 keV) of the hard X-ray spectrum. The spatial resolution is at best 5600 km with a corresponding time resolution of 4.5 s for adequate count statistics. This resolution gives rise to the following problems: We cannot resolve the minor radii of the loops involved or tell where and how the energy release occurs. The manner in which loops interact and the relationship between the soft and hard ($\gtrsim$100 keV) parts of hard X-rays remains elusive. We cannot see how energy propagates in most cases.

Thus it is desirable to determine the minimum increase in spatial and temporal resolution required to solve these problems. Spatially we need to resolve the minor radius of a small loop which is about 800 km or 1 arc s. Upper limits to observed speeds of conduction fronts and shocks are ~2000 km s^{-1} with theoretical limits running about a factor of 2 higher. Thus, a compatible minimum time resolution is in the range of 0.2 to 0.4 s. With these spatial and temporal resolutions, sufficient count statistics are required to go up to ~120 keV with a sufficient number of energy bands to obtain spectra.

Before noting some of the results to be expected with these resolutions, we briefly consider some recent results on energy transport which are described in detail in Smith (1985a). For the past several years starting with Brown, Melrose, and Spicer (1979) and Smith and Lilliequist (1979) there has been some question as to what extent a thermal hard X-ray source could be more efficient than a nonthermal thick-target source. The laser fusion community has devoted a considerable amount of effort to the problem of heat transport in steep temperature gradients (e.g., Campbell, 1984). The results of these studies have shown that the Spitzer-Harm conductivity has a very narrow range of applicability. In terms of the mean free path of the bulk thermal electrons

$$\lambda_s = \frac{K^2 T_e^2}{Z\pi e^4 n_e \ln\Lambda} \quad , \tag{1}$$

and the temperature scale height L, the condition for the applicability of Spitzer-Harm conductivity, is

$$\lambda_s/L < 10^{-3} \quad . \tag{2}$$

Here T_e and n_e are the electron temperature and density, respectively, Z is the ionic charge and $\ln\Lambda$ is the Coulomb logarithm. When condition (2) is violated, which can be determined using

$$\lambda_s/L = 6.31 \times 10^9 \, |q_{SH}| \, T_e^{-3/2} \, n_e^{-1} \quad , \tag{3}$$

where q_{SH} is the Spitzer-Harm conductivity, the actual conductivity q should be calculated from the following table for hydrogen (Z = 1):

TABLE 1. HEAT FLUXES FOR DIFFERENT λ_s/L

λ_s/L	q/q_{SH}	q/q_{FS}
0.0010	0.9998	0.0030
0.0032	0.9706	0.0094
0.010	0.8351	0.0251
0.032	0.5849	0.0564
0.10	0.3792	0.1142
0.32	0.2251	0.2169
1.00	0.1235	0.3718

Here $q_{FS} = n_e m_e v_e^3$ (v_e = electron thermal velocity) is the free streaming heat flux.

The physics in the reductions to q_{SH} in Table 1 is the following: Spitzer-Harm conductivity neglects the presence of fast tail electrons with mean free paths $\lambda_f >> L$. Thus it overestimates the heat flux because it does not take into account the fact that these electrons cannot contribute to the local transport of heat. They do contribute to the global heat transport by depositing heat far beyond the temperature gradient. For most astrophysical applications where local values of the transport coefficients are important, it is sufficient to use Equation (3) and Table 1.

The effect of employing these results in thermal models for hard X-ray sources is the following (Smith, 1985a): The conduction fronts formed now travel at $\sim 5c_s$, where c_s is the ion-acoustic speed and for energy inputs up to 6.4 x 10^3 erg cm^{-3} s^{-1} (equivalent to the conversion of a 400 G field every second into heat) the maximum T_e reached is 10^8 K. Thus a thermal hard X-ray source can only be effective in the soft part of the hard X-ray spectrum. The hard part of the spectrum must be due to accelerated electrons. A possible acceleration scenario is given in Smith (1985b). By separately following the hard and soft parts of the hard X-ray spectrum we shall be able to test these theoretical results and thus determine the mode of energy propagation. This exercise will probably be most unambiguous for limb flares and theoretical support of this nature will be useful.

With the above desired resolutions we shall be able to determine where the energy release occurs and, with comparable optical and UV data to ascertain the preflare energy storage, to determine whether coronal storage is sufficient or energy must be transported from the photosphere. The role of the interaction of loops in this release and in particular acceleration should also become clear.

Acknowledgment. This work was supported by NASA contract NASW-3603 and NSF grant ATM-8314511.

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