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"Correlative Studies of Solar Flares"

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Harold Zirin, P.I.
Big Bear Solar Observatory
California Institute of Technology

In October 1992, post-doc Haimin Wang was awarded a Compton GRO Fellowship by NASA to study the flares observed simultaneously by BATSE, OVRO, Yohkoh, and BBSO. During the past four years, a number of flares have been analyzed in detail. Substantial information on the physics of flares came out of these studies. The results have been published in eight papers listed in the end of this section.

(1) Based on the comparison of BATSE hard X-ray spectra and OVRO microwave brightness temperature spectra for four flares, we confirmed that microwave and hard X-ray emissions are likely to be from the same group of accelerated electrons within magnetic loops (but the emission in the two regimes may be weighted differently in the loop---see item (4) below). For some events, we can identify both thermal and non-thermal components in the distribution function. These components are apparent in both hard X-rays and microwaves, and their parameters agree in the two wavelength regimes.

(2) With the exceptional energy resolution of the BATSE SD data, we found that thermal components are more common in hard X-ray spectra than previously believed (at least based on our admittedly small sample), with 2 out of 5 flares showing a clear thermal component. For the 1992 June 25 flare, we derived a thermal component with a record high temperature (8.4×10^7 K) from the BATSE SD observations. We believe this is the hottest thermal component yet observed. The thermal component dominates even at the very early stage of the flare. There is a non-thermal tail as well, but it is much weaker relative to the thermal component than that of other events we have studied.

(3) We found that microwave source positions change with frequency. At lower frequencies, the source is near the top of the Yohkoh soft X-ray

loops. As frequency increases, the source centroid moves toward the footpoint of the loop that has the higher magnetic field strength. The shift of the source is apparently due to the change of magnetic fields along the loop, with the high-frequency source associated with the stronger magnetic fields at the footpoint.

(4) We discovered an important asymmetry in the microwave and hard X-ray sources. We found that the hard X-ray source seen with the Yohkoh HXT instrument is preferentially at the weaker-field end of the magnetic loop. Recently, Sakao (1994 Ph.D. Thesis, University of Tokyo) studied a number of flares seen with HXT, but without microwave data, and found that hard X-ray emissions at the weaker-field end of magnetic loops are stronger and have a harder spectrum than the stronger-field end, in agreement with our finding. Evidently these strong fields, which favor the gyrosynchrotron microwave emission, turn the electrons back before they penetrate to high enough density for effective bremsstrahlung. Our conclusion is that both thermal and non-thermal electrons are present throughout the loop, but different emission mechanisms act to make the sources appear spatially separated.

(5) We found evidence of interacting magnetic loops, where low-frequency microwave emissions and weak soft X-ray emission are associated with a large loop connecting the main leading and following spots of the active region; high- frequency microwaves, strong soft X-ray emissions, D3, and Hα emissions are concentrated in a compact loop, where new magnetic flux emerges.

(6) For the 1992 January 13 flare, we determined that the main Hα flare ribbons are over the limb. This permits us to measure the position of the solar microwave limb from the height of high-frequency microwave sources. We found that it is about 10" higher than the optical limb. Based on these observations, we used partial occultation of the emissions by the limb to explain the unusual behavior in the time evolution of hard X-ray flux and photon index observed by the BATSE/LAD.

Related Publications

"Microwave, Hα and Hard X-ray Observations of the 1992 June 26 C7.3 Solar Flare," H. Wang, 1993, Proceedings of Second China-Japan Solar Physics Workshop, p33.

"Microwave Spectra Imaging, Hα and Hard X-ray Observations of a Solar

Limb Flare," H. Wang, D.E. Gary, J. Lim and R.A. Schwartz, 1994: *Ap. J.* **433**, 379.

"Coordinated OVRO, BBSO, BATSE and YOHKOH observations of the 1992 June 25 M1.4 Flare," H. Wang, D.E. Gary, H. Zirin, R.A. Schwartz, T. Sakao, T. Kosugi and K. Shibata, 1995: *Ap. J.* **453**, 505.

"Generation of Secondary Emissions During the 1991 March 22 Disk Solar Flare," L. G. Kocharov, J. Lee, H. Wang, H. Zirin, G.A. Kovaltsov and I.G. Usoskin, 1995: *Solar Physics* **158**, 95.

"The Microwave and Hα Sources of the 1992 January 13 Flare," H. Wang, D.E. Gary, H. Zirin, T. Kosugi, R. A. Schwartz and G. Linford, 1995: *Ap. J. Letters* **444**, L115.

"Multi-Wavelength Flare Observations," H. Wang, 1995, Invited Paper of the Third China-Japan Solar Physics Workshop, Beijing, China.

"OVRO, BBSO, BATSE and Yohkoh Observations of a Solar Flare," H. Wang, D. Gary, H. Zirin, N. Nitta and R.A. Schwartz, 1996: *Ap. J.* **453**, 505.

"Solar Microwave and Soft X-ray Observations of Thermal Bremsstrahlung from a Post-Flare Loop," D. Gary, H. Wang, Nitta, N. and Kosugi, T. 1996: *Ap. J.* **456**, 403.