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Stereoscopic Observations of Hard X-Ray Sources in Solar Flares Made with GRO and Other Spacecraft

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ABSTRACT

Since the launch of the Gamma Ray Observatory (GRO) in April 1991, the BATSE instrument on GRO has recorded a large number of solar flares. Some of these flares have also been observed by the Gamma-Ray Burst Detector on the Pioneer Venus Orbiter (PVO) and/or by the Solar X-Ray/Cosmic Gamma-Ray Burst Experiment on the Ulysses spacecraft. A preliminary list of common flares observed during the period May-June 1991 is presented and the possible joint studies are indicated.

1. MOTIVATION

Energetic solar flares accelerate electrons and ions over a wide range of energies. The electrons carry a large part of the energy released during the impulsive phase of a flare. They also play an important role in the transport of energy from the acceleration region to various parts of the flare. Determination of the spectral and spatial distribution of the energetic electrons at the sun is, therfore, a very important part of the current solar flare research.

As the energetic electrons accelerated in a flare interact with the ambient ions, they produce hard X-rays through bremsstrahlung. Hence the characteristics of the energetic electron distribution can be deduced from suitable observations of the hard X-ray emission. If the electrons propagate in a relatively well collimated beam, as assumed in some models of the hard X-ray source (cf. discussion in McTiernan and Petrosian, 1990a,b), the X-ray emission is expected to be anisotropic, the degree of anisotropy increasing with photon energy. The anisotropy may also vary with time during a flare and from one flare to another. It is therefore important that the observations of the hard X-ray spectrum with instruments aboard a single spacecraft which provides one view angle with respect to the flare be supplemented, whenever possible, with similar instruments aboard another spacecraft which provides a different view angle. In case of flares where the view from one of the spacecraft is partially occulted by the photosphere, important information about the height structure of the hard X-ray source can be obtained. Such stereoscopic observations of hard X-ray sources in solar flare were suggested earlier (cf Kane, 1980; Hurley, 1986) and have been used in the past to study the directivity and height structure of hard X-ray sources in solar flares (cf Kane et al, 1982, 1988). Multi spacecraft observations have also been used for confirming rapid intensity variations during a flare (Hurley et al, 1983). The past stereoscopic observations of flares had a limited range of

view angles and only a few partially occulted flares were observed. Therefore, analysis of new stereoscopic observations is essential. It is expected to provide important information for verifying theoretical models of solar flares.

TABLE 1
PRELIMINARY LIST OF COMMON SOLAR FLARES
(Flares observed by BATSE and Ulysses and/or PVO)

Date (1991)	Hard X-Ray Max (UT)	Soft X-Ray Class (GOES)	Hα-Flare Imp.	Region	Location
30 May	0938	M 8.2	1F	6654	N07 E30
1 June*	1503	X 12		6659	N25 E>90
4 June	0339	X 12	3B	6659	N30 E70
6 June	0107	X 12	4B	6659	N33 E44
26 June**	2014	C 2.9			
28 June**	1430				
30 June***	0257	M 5.0	1N	6693	S06 W19

* Flare located behind the East limb of the Sun
** Flare probably located behind the East limb of the Sun
*** Flare identification uncertain

2. AVAILABLE OBSERVATIONS

The high sensitivity and large dynamic range of the BATSE instrument on GRO make BATSE a very desirable near-Earth component of a multi-spacecraft network for stereoscopic observations of the hard X-ray sources in solar flares. At present, hard X-ray spectrometers aboard two interplanetary spacecraft, Ulysses and PVO, are providing relatively good data coverage for solar flares. These two instruments have been described in the literature (Hurley et al, 1991; Kane et al, 1982). The BATSE, PVO, and Ulysses instruments cover the photon energy ranges 30-1900 keV, 100-2000 keV, and 15-150 keV respectively. Although the three energy ranges are not identical, there is enough overlap between them to permit scientifically important correlated studies.

After the launch of GRO, the first two-month period in which the solar flare activity was high was May-June 1991. During that period both Ulysses and PVO were located behind the East limb of the Sun. At present the Ulysses and PVO data sets for this period are incomplete. Additional data may be available in the near future. We have examined the available data for flares observed by Ulysses and/or PVO. The list of these flares was then compared with the list of flares observed by BATSE (Dennis and Schwartz, 1991) and the flares common to BATSE and Ulysses and/or PVO were identified.

A preliminary list of the "common" flares is presented in Table 1. Relevant information regarding the associated Hα-flares and soft X-ray bursts (GOES) is also given. The list includes (1) flares in full view of two or more spacecraft and (2) flares for which the view of one or more spacecraft was partially occulted by the photosphere.

Further analysis of these common flares requires the following: (a) confirmation of the identification of the associated Hα-flare flares and determination of the view angle for each instrument, (b) verification of the response characteristics of the three instruments to solar flare X-ray spectra, especially for large solar flares, and (c) comparison of the photon energy spectra observed by each instrument. Work on these aspects of the data analysis is in progress. Some early results are expected during the next few months.

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