PROSPECTS FOR HARD X-RAY SOLAR FLARE POLARIMETRY WITH HESSI

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ABSTRACT

Designed primarily as a hard X-ray imager and spectrometer, HESSI is also capable of measuring the polarization of hard X-rays (20–100 keV) from solar flares. These studies will provide the capability to probe the geometry of the acceleration process. Although not originally designed to study hard X-ray polarization of solar flares, it was realized during the development of HESSI that the essential ingredients for measuring the polarization, namely, an array of detectors in a rotating spacecraft, were already present. All that was needed was the addition of a strategically placed cylinder of Be in the cryostat to Compton scatter the hard X-rays (20–100 keV) into the rear segments of the adjacent Ge detectors, since the direction of the scattering depends on the polarization of the incoming photon. Monte Carlo simulations indicate that a 20–100 keV polarization sensitivity of less than a few percent can be achieved for X-class flares, by comparing the counting rates of these rear segments.

HESSI AS A POLARIMETER

The capability for doing polarimetry arises from the inclusion of a small unobstructed Be scattering element (3 cm in diameter by 3.5 cm long) that is located within the detector cryostat, near the center of the Ge detector array (Figure 1). Directly in front of the cryostat is a graded-Z shield that is designed to absorb a large fraction of the flux below 100 keV, flux that tends to dominate the flare event. Openings in this shield provide an unattenuated path for low energy photons from the Sun to reach the front surface of the cryostat directly in front of each Ge detector and directly in front of the Be scattering block. Thinned windows in the cryostat are designed to maximize the transmission of low energy solar photons to each Ge detector and to the Be scattering block. The Ge detectors are segmented, with both a front and rear active volume. Low energy photons (below about 100 keV) can reach a rear segment of a Ge detector only indirectly, by scattering. Some fraction of the photons which reach the Be block are Compton scattered into the rear segments of adjacent Ge detectors, four of which have an unobstructed view of the Be block. The angular distribution of the scattered photons (in which is embedded the polarization signature) is sampled by the adjacent Ge detectors. The spacecraft rotation serves to increase the angular sampling frequency and to reduce the effects of any systematic variations in the intrinsic detection efficiencies.

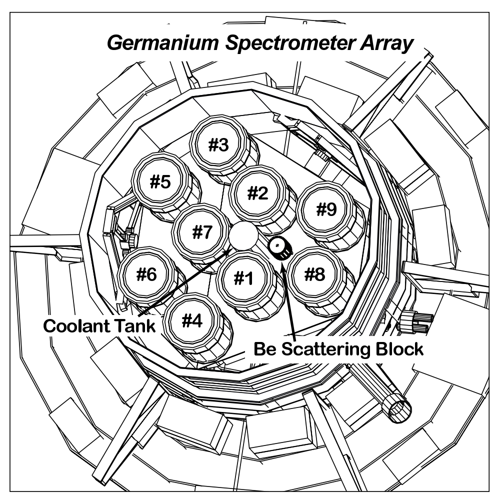

Fig.1. A view of the spectrometer array from the HESSI mass model, showing the location of the Be scattering block.

For performing polarimetry response simulations, we have used a modified version of GEANT3 along with a HESSI mass model that includes not only the HESSI scientific instrumentation, but also the spacecraft support structure. In our analysis of the simulation data, we use events only from the four Ge detectors closest to the Be. We have found that the Ge detectors that are further from the Be do not provide a polarization signature with sufficient signal-to-noise to be useful in polarization studies.

We characterize the polarization response of HESSI using two parameters: 1) the effective area, which represents the effective area for events satisfying the necessary criteria (single energy deposit in rear segments of the selected Ge detectors); and 2) the polarization modulation factor, a quantity ranging between 0 and 1, that is a measure of the quality of the polarization signature (e.g., McConnell *et al*. 1999). Of particular importance here is the significant impact of spacecraft scattered photons, which is most easily seen in terms of the effective area (Figure 2). Above about 50 keV, scattered photons become important. At energies near 100 keV and above, scattering completely dominates the response. The effects of scattering are also seen in the plot of modulation factor versus energy (Figure 3). Since the scattered component carries with it no polarization signature, the modulation factor decreases at energies above ~30 keV, where scattering becomes important.

It is difficult to define a 'typical' solar flare to use as a baseline for estimating polarization sensitivities. The X-ray classification depends only on the peak X-ray flux. The polarization sensitivity for a given class of flare will also depend on the specific spectral shape and on the duration of the event. We have used durations ranging from 20 seconds up to 1000 seconds, with an average spectrum corresponding to that given by Chanan, Emslie & Novick (1988) for an X2 class flare. The background is estimated using data from the Ge detector of the Wind/TGRS experiment. We have found that HESSI will have sufficient polarization sensitivity to measure the polarization of X-class flares down to a level below 10% and, in some cases, below 1%. This level of sensitivity will be useful in constraining various models that have been published in the literature, some of which predict polarization levels as high as 20 or 30% (e.g., Leach & Petrosian 1983). Our sensitivity estimates have not yet considered the effects of albedo flux scattered from the Earth's atmosphere. Although the level of the albedo flux may be significant, its modulation by the spacecraft rotation (with a different modulation pattern than that of the polarization signal) will help us to distinguish the albedo component from the direct source flux.

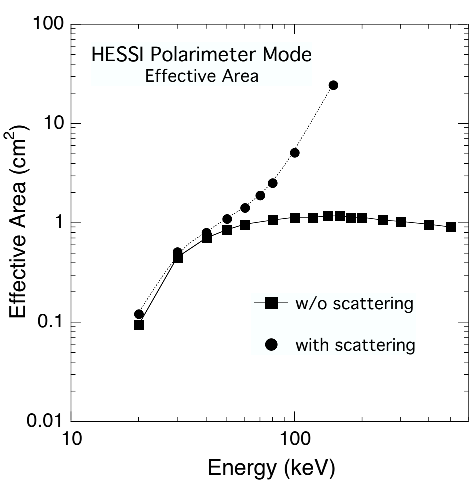

Fig. 2. Effective area of the polarization mode both with and without scattering.

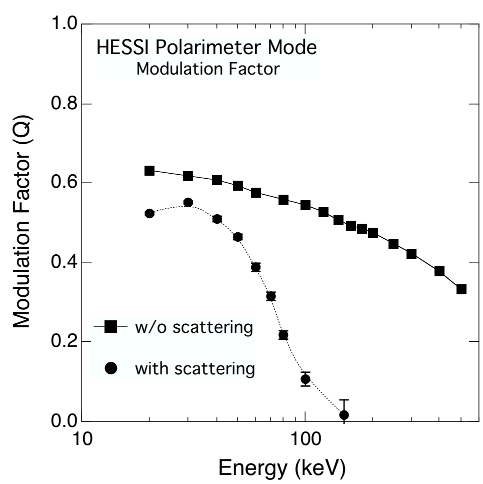

Fig. 3. Modulation factor of the polarization mode both with and without scattering.

ACKNOWLEDGEMENT

This work is currently supported by NASA grant NAG5-10203.

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