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Energetic electron detection in Mercury's magnetosphere with the MESSENGER Gamma-Ray Spectrometer

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1. Introduction

The MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) spacecraft entered a ~12-hr orbit around Mercury on 18 March 2011. Following instrument turn-on, several instruments in the payload began detecting energetic electrons with energies from < ~30 keV to > ~300 keV. In addition to direct measurements with the Energetic Particle Spectrometer (EPS) component of the Energetic Particle and Plasma Spectrometer (EPPS) [1], bursts of hard X-rays have been measured in the sensors of the Gamma-Ray and Neutron Spectrometer (GRNS) [2] and soft X-rays in the X-ray Spectrometer (XRS) [3], consistent with bremsstrahlung from *in situ* electrons [4]. Accumulated evidence to date corroborates the XRS data from the MESSENGER flybys, as well as the inference of bursts of energetic electrons identified during the first Mercury flyby of Mariner 10 [5-7].

2. GRNS Observations

High-count-rate events in the Gamma-Ray Spectrometer (GRS) and Neutron Spectrometer (NS) detectors on GRNS have been seen typically once per orbit but with large variations in magnitude. From instrument turn-on (24 March 2011) through the end of April 2011, 56 high-count events were observed in the boron-loaded plastic scintillator (BC454) of the NS detector and 39 events in the high-purity germanium detector (HpGe) of the GRS, with 8 of the latter events markedly more intense than others.

Raw count rates from the middle of 9 April (day of year, DOY, 99) though the middle of 12 April (DOY 102) are shown in Fig. 1. Every 12 hours the count rate increased from background (~250 counts s^{-1}) to a peak count rate near periapsis of ~330 counts s^{-1}) due to the proximity of Mercury. The non-periodic sharp peaks are associated with energetic-electron events.

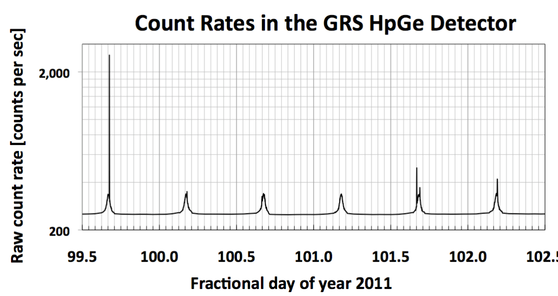

Figure 1: HpGe detector count rates, DOY 99–102.

The event on 9 April, during which the count rate peaked at 2,554 counts per second, is the largest seen to date. Other events are easily discerned and are more typical of amplitudes seen to date. Some, e.g., on DOY 101, occur both before and after periapsis, the event on approach being one of the more intense.

2.1. Sensor Characteristics

Except for the forward direction, the HpGe sensor in the GRS is surrounded with an anti-coincidence shield of BC454. In typical events, the BC454 in the NS and the GRS and the HpGe in the GRS all register, but the HpGe has a substantially higher energy resolution. Accumulation times vary: 60 s for GRS (including the shield), 20 s for NS, and 60 s for EPS. For the largest events, the NS triggers a burst mode, providing data but not energy spectra at a 1-s interval. This information provides insight into the temporal structure of the events, which varied on short timescales during the Mariner 10 flyby [5].

2.2. The Event of 9 April 2011

NS count rates from the burst mode for the 9 April event are shown in Fig. 2. Counts were above nominal levels for approximately 90 s, consistent with the two spectra observed in the HpGe data. Although the count rates are elevated in general, there is also structure at the 1-s time scale.

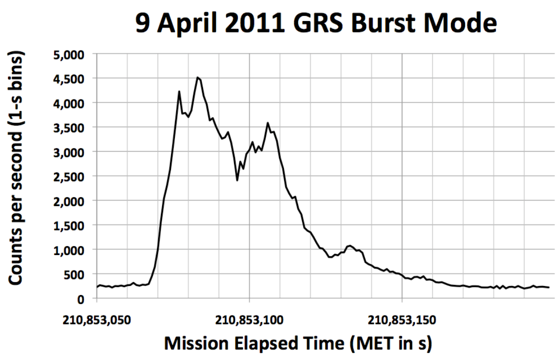

Figure 2: Count rates in the NS burst mode. Minor tick gridlines are at 10-s intervals along the time axis.

Counts per channel versus energy are shown in Fig. 3 for the two high-count HpGe spectra as well as those prior to and following the 9 April event. All spectra exhibit gold Kα and Kβ fluorescence lines and K-edge cutoff from the gold in the HpGe thermal isolation system. The annihilation line at 511 keV, the electronics pulser data at just under 10 MeV, and the low-level discriminator (electronics) cutoff at ~22 keV are also common features.

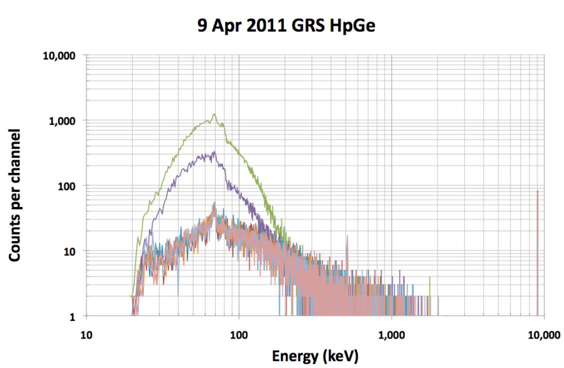

Figure 3: Energy spectra (photon counts per channel as functions of energy) for the 9 April event.

3. Discussion

The spectra during the event, sampled across the rapid variations shown in Fig. 2 are qualitatively very similar, suggesting no adverse time aliasing. Both are consistent with hard X-rays produced by thick-target bremsstrahlung in the GRS. The spectral shape on the low-energy side of the gold-line complex is consistent with absorption expected for the germanium dead-layer in the detector. The high-energy portion, extending from ~80 keV to at least 200 keV, is consistent with a thermal electron distribution with a temperature of ~30 keV and shows no evidence of a suprathermal component. Such a population might be expected for a quasi-steady plasma sheet distribution. Most events to date have been observed at moderate latitudes, away from the location at which such a structure is expected, and the sharp definition of the events is not consistent with an extended sheet structure.

Acknowledgements

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