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Explosive Energetic Electron Events at Mercury

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Introduction

On March 18, 2011, the MESSENGER spacecraft entered into orbit about Mercury and began the primary phase of its mission. Prior to orbit insertion the spacecraft completed three flybys of the planet in 2008 and 2009. During the three flybys, the Energetic Particle Spectrometer (EPS), one of the two sensors on the Energetic Particle and Plasma Spectrometer (EPPS) instrument [1] that measures electrons from ~25 keV to 1 MeV and ions from ~25 keV to ~2.75 MeV, saw no increases in particle intensity above instrumental background at any time during its near-equatorial magnetospheric passages. On the basis of fluorescent X-ray events seen by MESSENGER's X-Ray Spectrometer (XRS) during the flybys, suprathermal plasma electrons were inferred to be present inside Mercury's magnetosphere but below the EPS detection threshold [2]. By contrast, the detection of high-energy particle events within Mercury's magnetosphere was reported by Mariner 10 (M10) during its encounters in 1974 and 1975 (M10-I and M10-III, respectively). In particular, during M10-I, Mariner 10 reported four high-energy (>300 keV) particle events that included protons at energies > 550 keV.

There are notable differences in the energetic particle instruments for M10 and MESSENGER. The instrument on M10 was designed to measure high-energy electrons (> 170 keV) and ions (> 550 keV). The geometric factor of the M10 instrument was 14 cm^2-sr, which is four orders of magnitude larger than that for EPS (10^{-3} cm^2-sr). This difference may imply that the M10 particle instrument was more susceptible to false detection of high-energy events due to pile-up of low-energy high-count-rate signals within a single energy-deposition accumulation. Ambiguities in the interpretation of the M10 energetic particle detector data were noted by Armstrong et al. [4], who suggested that the M10 particle instrument was responding to pulse pile-up from lower-energy (~170 keV) electrons during M10-I. In particular, these workers argued that there are difficulties extracting sufficient energy to accelerate highly repetitive bursts of high-energy (> 550 keV) protons in Mercury's small magnetosphere. With the very limited set of in-situ data from M10, the identity of those measured particles remained uncertain.

Observations in Mercury Orbit

Shortly after MESSENGER began making science measurements in orbit, EPS measured recurring, intense bursts of energetic electrons. Figure 1 shows the energy spectrogram of several of these events from day of year (DOY) 85 to 91. The first burst occurred on DOY 86, and subsequent bursts are seen in each 12-hour orbit over the following days. During these bursts, the measured electron intensity at energies less than 100 keV increased by one to three orders of magnitude above background with onset times of a few seconds.

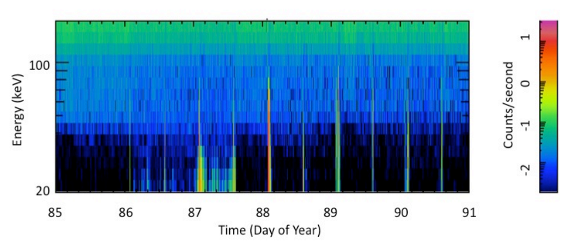

Figure 1. Energy spectrogram for the electron bursts observed by EPS during DOY 85 to 91.

The bursts last from a few seconds to several minutes and typically come in groups spread over as long as several hours. Figure 2 shows a close-up profile of intensity versus time for one of this group of bursts on DOY 87.

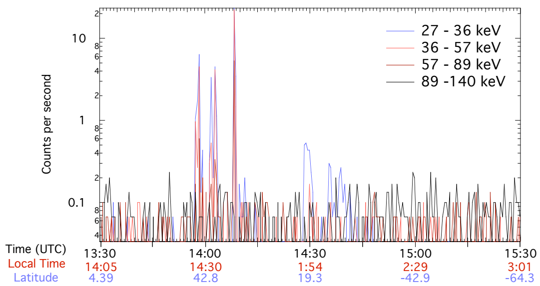

Figure 2. Profile of intensity versus time for the electron bursts observed on DOY 87. The time span of this plot is two hours, from 1330 to 1530 UTC. We also show both the Mercury solar orbital (MSO) local time and MSO latitude along the abscissa. The electron bursts on this day came in two separate groups, with the first group detected around 1400 UTC and the second smaller group around 1430 UTC.

The main group of electron bursts on this day occurred around local afternoon at high latitude, and the second, smaller group was detected just after local midnight. Most of the events that have been observed by EPS are on the night side of the planet at high latitude, with a broad distribution from 30° to 80° north of the MSO equator. These electron events typically are aligned with the local magnetic field (not shown).

Correlative Detections

There were times when electron events were also seen by other instruments on MESSENGER. In particular, XRS detected electron-induced fluorescence and bremsstrahlung in its detector near the times that EPS detected the electron bursts shown here. Following the analysis completed for the flyby data [2], we used the electron spectra measured by EPS for several bursts that were also detected by XRS to model the XRS response. We obtained excellent agreement between modeled and observed X-ray spectra. We conclude that these bursts consist of low-energy (~tens to hundreds of keV) electrons.

Summary and Conclusions

So far there is no evidence to suggest that there are large fluxes of high-energy (>300 keV) electrons or protons in Mercury's magnetosphere, contrary to the report by Mariner 10 [3]. The field-aligned distribution and general location of these electron events lead us to believe that they are associated with some type of particle acceleration in the tail region of Mercury's magnetosphere. The recurrent and burst-like nature of these events suggest that there is an efficient acceleration mechanism operating at Mercury's magnetosphere on a regular basis that is able to produce low-energy electrons with energies up to hundreds of keV on timescales of seconds.

Acknowledgements

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