EPSC Abstracts
Vol. 5, EPSC2010-263, 2010
European Planetary Science Congress 2010

Observations of suprathermal electrons in Mercury's magnetosphere during the three MESSENGER flybys

George C. Ho (1), Stamatios M. Krimigis (1, 2), Richard D. Starr (3), Robert E. Gold (1), James A. Slavin (4), Daniel N. Baker (5), Brian J. Anderson (1), Ralph L. McNutt, Jr. (1), Larry R. Nittler (6), and Sean C. Solomon (6)
(1) The Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723, USA, (2) Academy of Athens, Office of Space Research and Technology, Soranou Efesiou 4, Athens 11527, Greece, (3) Physics Department, The Catholic University of America, Washington, DC 20064, USA, (4) Heliophysics Science Division, NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA, (5) Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, CO 80303, USA, (6) Department of Terrestrial Magnetism, Carnegie Institution of Washington, Washington, DC 20015, USA
(george.ho@jhuapl.edu / Fax: +1-228-7083)

MESSENGER Observations

In 2008 the MESSENGER spacecraft made the first direct observation of Mercury's magnetosphere in the more than 30 years since the Mariner 10 encounters. During MESSENGER's first flyby (M1) on 14 January 2008, the interplanetary magnetic field (IMF) was northward immediately prior to and following MESSENGER's equatorial passage through this small magnetosphere. The Energetic Particle Spectrometer (EPS), one of two sensors on the Energetic Particle and Plasma Spectrometer (EPPS) instrument that measures electrons from ~35 keV to 1 MeV and ions from ~35 keV to 2.75 MeV, saw no increases in particle intensity above instrumental background (~5 particles/cm^2-sr-s-keV at 45 keV) at any time during its magnetospheric passage. During MESSENGER's second flyby (M2) on 6 October 2008, there was a steady southward IMF, and intense reconnection was observed between the planet's magnetic field and the IMF. However, once again EPS saw no large bursts of energetic particles similar to those reported by Mariner 10 from its March 1974 encounter. On 29 September 2009, MESSENGER flew by Mercury for the third and final time (M3) before orbit insertion in March 2011. Although a spacecraft safing event stopped science measurements for the outbound portion of the flyby, all instruments recorded full observations until a few minutes before closest approach. The MESSENGER Magnetometer (MAG) documented several substorm-like signatures (tail loading), but again EPS measured no energetic ions or electrons above instrument background for the inbound portion of the flyby. MESSENGER's X-Ray Spectrometer (XRS) nonetheless inferred the presence of low-energy (~10 keV) electrons impinging on its detectors during each of the three flybys. Such suprathermal plasma electrons below the EPS energy threshold may have caused the bremsstrahlung and filter fluorescence seen by XRS. In Earth's magnetosphere, substorm events produce powerful particle acceleration bursts that seem to be absent in the Mercury conditions witnessed so far.

Mariner 10 Observations

The Mariner 10 (M10) spacecraft flew by Mercury three times in 1974 and 1975 and made measurements of Mercury's magnetosphere during its first and third (M10-I and M10-III, respectively) encounters. The M10 in-situ measurements not only showed that Mercury possesses an intrinsic magnetic field, but also revealed substorm-like energetic particle bursts [1] within the magnetosphere. However, ambiguities in the interpretation of the M10 energetic particle detector data were pointed out by Armstrong et al. [2]. In particular, there are difficulties extracting sufficient energy to accelerate highly repetitive bursts of high-energy (> 300 keV) electrons in Mercury's small magnetosphere. With the very limited set of in-situ data from M10, the identity of those measured particles remained uncertain.

Reconciliation of the M10 and MESSENGER Results

During M10-I, Mariner 10 reported four high-energy (>300 keV) particle events. In three of the four events, the time-intensity profiles had very sudden onsets, and intensity levels were at least three orders of magnitude above interplanetary background levels [1]. However, no such high-energy particles were detected by MESSENGER during any of the three flybys. There could be several factors that contribute to the different observations from M10 and MESSENGER. The energetic particle instrument on M10 was designed to measure high-energy electrons (> 170 keV) and ions (> 600 keV). Compared with the MESSENGER EPS, the geometric factor of the M10 instrument was large (14 cm^2-sr versus 10^{-3} cm^2-sr). Because of its large geometric factor, the M10 particle instrument was more susceptible to high-count-rate events. Armstrong et al. [2] pointed out ambiguities in the data set that suggested the M10 particle instrument was responding to pulse pile-up from low-energy (~35 keV) electrons during M10-I. In contrast, EPS is not susceptible to pile-up from high-count-rate events.

During all three MESSENGER flybys, the solar particle activity in the inner heliosphere was very low because of the extended period of minimal solar activity. During much of the cruise period from June 2007 up to M3, there were no solar energetic particle (SEP) events detected by EPS except for one on 31 December 2007. As a result, the number of low-energy suprathermal particles available in the inner heliosphere to interact with Mercury's magnetosphere and later be accelerated was also very low. This situation could limit the high-energy particle population in Mercury's magnetosphere. Not only has the extended period of low solar activity limited SEP seed particles for acceleration, but the IMF field has also been extremely weak. From the magnetic field measured by MAG during M2, Slavin et al. [3] calculated the cross-magnetospheric electron potential drop to be only about 30 kV. Although not all types of magnetospheric charged particle accelerations are limited by magnetospheric potential drop, this MAG result is consistent with the lack of particles with energies greater than 35 keV observed in the EPS data.

Slavin et al. [3] deduced that Mercury's magnetosphere is unusually responsive to IMF orientation. During the steady southward IMF at the time of M2, magnetic reconnection signatures (flux transfer events and plasmoids) were observed throughout Mercury's magnetosphere. However, no dipolarization was observed by MESSENGER during M2. In Earth's magnetosphere, dipolarization is closely related to particle acceleration during substorm activity [4]. We also note that the M10 data show a strong field dipolarization in close conjunction with the energetic electron events. The lack of high-energy particles at Mercury during reconnection may be important in understanding particle acceleration processes at Earth.

During M3, several substorm-like signatures were evident in the MAG data [5]. Although a spacecraft safing event stopped measurements for the outbound portion of the trajectory, no energetic particles were detected above instrument background level during the entire inbound pass up to a few minutes before closet approach.

Summary

In this paper, we summarize the energetic particle observations made by the EPS and XRS instruments during MESSENGER's three flybys of Mercury, revisit the observations reported by Mariner 10, and discuss possible acceleration processes that are effective at Earth but apparently inoperative at Mercury.

References

[1] Simpson, J.A., Eraker, J.H., Lamport, J.E., and Walpole, P.H., Electrons and protons accelerated in Mercury's magnetic field, Science 185, 160-166, 1974.

[2] Armstrong, T.P., Krimigis, S.M., and Lanzerotti, L.J., A reinterpretation of the reported energetic particle fluxes in the vicinity of Mercury, J. Geophys. Res. 80, 4015-4017, 1975.

[3] Slavin, J.A., et al., MESSENGER observations of magnetic reconnection in Mercury's magnetosphere, Science 324 (5927), 606-610, 2009.

[4] Baker, D.N., Pulkkinen, T.I., Angelopoulos, V., Baumjohann, W., and McPherron, R.L., Neutral line model of substorms: Past results and present view, J. Geophys. Res. 101, 12,975-13,010, 1996.

[5] Slavin, J.A., et al., MESSENGER observations of extreme loading and unloading of Mercury's magnetic tail, Science, in press, 2010.