THE MAGNETIC FIELD OF MERCURY: INSIGHTS AFTER THE FIRST MESSENGER FLYBY. Brian J. Anderson[1], Mario H. Acuña[2], James A. Slavin[2], Haje Korth[1], Michael E. Purucker[2], Mehdi Benna[2], Catherine L. Johnson[3], David Schriver[4], Scott A. Boardsen[2], Sean C. Solomon[5], and the MESSENGER Team. [1]Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723 (brian.anderson@jhuapl.edu); [2]NASA Goddard Space Flight Center, Greenbelt MD, 20771; [3]Department of Earth and Ocean Sciences, University of British Columbia, Vancouver, Canada; [4]Institute of Geophysics and Planetary Physics, UCLA, Los Angeles, CA 90095; [5]Department of Terrestrial Magnetism, Carnegie Institution of Washington, Washington, DC 20015.

Introduction: The MESSENGER Magnetometer [1] will operate during the 14 January 2008 flyby of Mercury and will return the first data on Mercury's magnetic field since the Mariner 10 flyby in 1975 [2,3]. MESSENGER's closest approach (CA) will occur at 19:04:42 UTC. The Magnetometer will acquire data at 20 vector samples/s spanning 12 hours centered on CA, providing high-resolution (0.047 nT) observations of the field, magnetospheric boundaries (bow shock and magnetopause), and electromagnetic waves up to 10 Hz. Because the flyby trajectory complements the Mariner 10 trajectories in planetary body-fixed coordinates, the observations provide tighter constraints on the intrinsic field than previously possible.

Encounter Geometry: The MESSENGER mission design uses three flyby encounters of Mercury to decrease the spacecraft energy relative to Mercury to allow orbit insertion on 18 March 2011 using the spacecraft main engine [4]. The geometry of the first flyby as viewed above the planet's north pole (Figure 1) shows the spacecraft trajectory inbound from the dusk-side and outbound sunward in the morning. The transit through Mercury's magnetosphere takes approximately 40 minutes. MESSENGER will achieve a minimum altitude of 200 km at 38ºE planetary longitude and 4ºS planetary latitude, and a spacecraft velocity relative to Mercury of 7.0 km/s. The altitude is lower than Mariner 10 achieved, and the difference in MESSENGER's closest approach longitude from those of the Mariner 10 encounters will allow greater discrimination between the external and internal magnetic fields. In addition, the low altitude at the equator provides an opportunity to assess the presence of structure in the magnetic field due to crustal magnetization.

External Fields: The external magnetic fields, due to magnetopause and tail currents, make contributions at CA comparable to the intrinsic field and must be accounted as accurately as possible. The external contributions to the magnetic field at the encounter are derived both via magneto-hydrodynamic simulations [5] and empirical models scaled to Mercury [6]. The magnetopause and bow shock locations provide constraints on the imposed solar wind dynamic pressure at the time of the encounter, and the particle observations are used to cross-check the magnetosphere simulations. The external field correction is considered accurate to better than 30% or ~20 nT at CA.

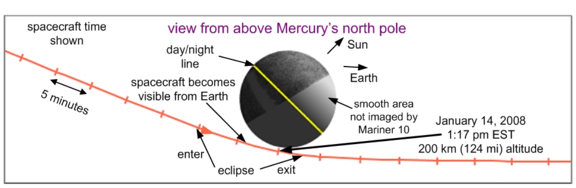

Figure 1. MESSENGER flyby geometry.

Intrinsic Field: The Mariner 10 results [2,3,6] provide a basis for predicting the field encountered by MESSENGER during the flyby. Figure 2 shows these predictions for an intrinsic dipole field, an external field, and the net magnetic field in nT and spherical body-centered coordinates: radial, r (positive outward), polar angle, θ (positive southward), and ϕ, azimuth (positive eastward). Only the portion of the flyby

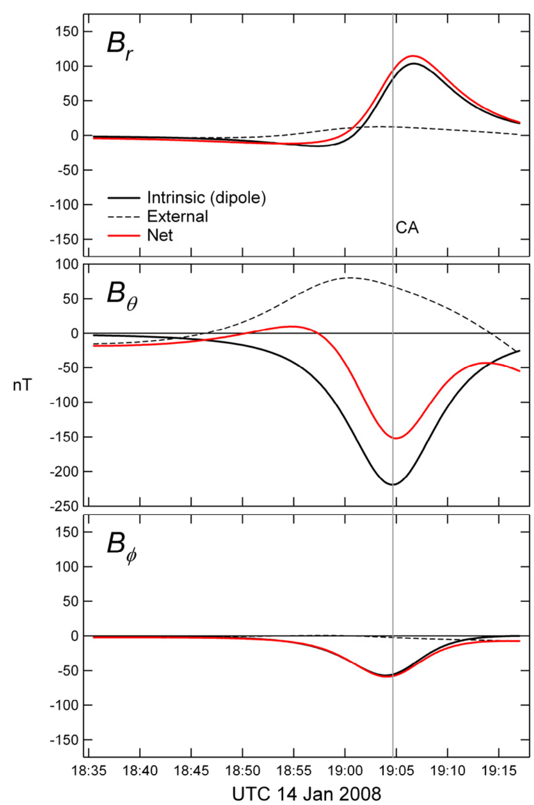

Figure 2. Magnetic field predictions for the first MESSENGER flyby. Intrinsic dipole derived from Mariner 10 observations (solid black), external field (dashed), and net field (red).

predicted to be within the magnetosphere is shown, approximately from 18:35 to 19:17 UTC. Solid black lines show a Mariner 10 dipole-only solution, $|g_1^0|$ = 291 nT/R_M^3, where R_M is Mercury's mean radius. Black dashed lines show the external field evaluated for nominal solar wind and interplanetary magnetic field conditions [6], and red lines show the net field. These estimates indicate that at CA the external field may be ~30% as large as the intrinsic field. Simulation and empirical model estimates for the magnetosphic current contributions are therefore key to accurate assessment of structure in Merucury's magnetic field. The MESSENGER results when combined with the Mariner 10 data will allow significant refinement of the relative contributions of the g_1^0 and g_2^0 (quadrupole) terms to the intrinsic field.

Crustal Signatures: The 200-km minimum altitude of the flyby provides an opportunity to assess crustal signatures [7]. Figure 3 shows the radial projection of the spacecraft position onto the Mercury surface together with features identified prior to the flyby showing that CA occurs near prominent features in radar images. The color geologic map is that compiled from Mariner 10 observations [8], and the radar image depicts radar brightness where darker shading denotes stronger radar returns [9,10]. The minimum altitude at CA, 200 km, corresponds to an arc length at the equator of 4.7º, so the southern hemisphere radar feature from 0 to 25°E spans a distance much greater than the altitude at CA. The Magnetometer data collected during the flyby may be sensitive to magnetic crustal signatures associated with the long-wavelength radar features.

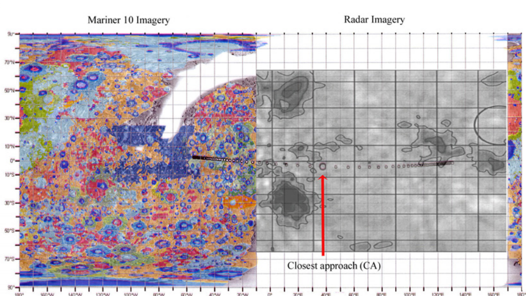

Figure 3.Radial projection of MESENGER sub-spacecraft location (black circles) for the first flyby overlaid on the Mariner 10 terrain map and a radar image mosaic for the remainder of the planet as available.

Magnetosphere: The structure and dynamics of Mercury's magnetosphere are unique in the solar system in several respects. Mercury alone has a magnetosphere but not an ionosphere [11]. In addition, the spatial and time scales of ion transport, fluid structures (boundaries), wave-particle interactions, and intrinsic wave modes of the magnetosphere are all comparable [12]. The Magnetometer observations are particularly well suited to observe signatures of magnetospheric processes since since they have high resolution, 0.047 nT, are free of magnetic contamination signals from the spacecraft above the instrument resolution, and cover frequencies up to 10 Hz [1]. The data from the first MESSENGER flyby provide new insight into the structures and waves in this unique system and will help constrain theories of the resulting net interaction.

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