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MESSENGER Epithermal Neutron Map of Mercury: Possible Low-Latitude Hydrogen Variation

Jack T. Wilson, David J. Lawrence and Patrick N. Peplowski.
The Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723, USA (Jack.Wilson@jhuapl.edu).

Abstract

Based on data from the MESSENGER spacecraft we present a spatially resolved map of the epithermal neutron flux in the northern hemisphere of Mercury. The decreasing epithermal neutron flux towards the north pole is consistent with the presence of hydrogen, in the form of water-ice in permanently shaded craters, as reported in previous work. Additionally, the new low-latitude map also shows significant variability away from the pole. Specifically, a correlation between epithermal flux and mean/maximum sub-surface temperature is seen. This may indicate longitudinal variation in hydrogen abundance in Mercury's low- and mid-latitudes.

1.Introduction

The MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) spacecraft [1] carried out an in-depth investigation of Mercury's surface composition during its 5-year mission. MESSENGER's X-Ray Spectrometer (XRS) and Gamma-Ray Spectrometer (GRS) provide element specific data. Data from these instruments have provided elemental abundances for H, K, Th, and U, as well as elemental ratios by weight of Na/Si, Mg/Si, Al/Si, S/Si, Cl/Si, Ca/Si, Ti/Si, Cr/Si, Mn/Si, and Fe/Si. However, several of these measurements are not spatially resolved and many that are suffer from incomplete coverage.

In addition to the XRS and GRS MESSENER contained a neutron spectrometer, unlike individual gamma ray lines neutron data are well sampled and spatially resolved. Neutrons are generated by nuclear spallation reactions when galactic cosmic rays interact with the surface materials of airless or nearly airless planetary bodies. These neutrons undergo moderation by the soil and atmosphere in a way that imprints compositional information into their energy spectra.

In planetary sciences neutron data are conventionally separated into three energy bands. Low-energy, thermal neutrons with energy < 0.5 eV are used to infer the macroscopic neutron absorption cross section, which contains information on the abundance of neutron absorbing elements. Epithermal neutrons, those with energies between 0.5 eV and 0.5 MeV, are primarily sensitive to the presence of hydrogen due to its strong neutron

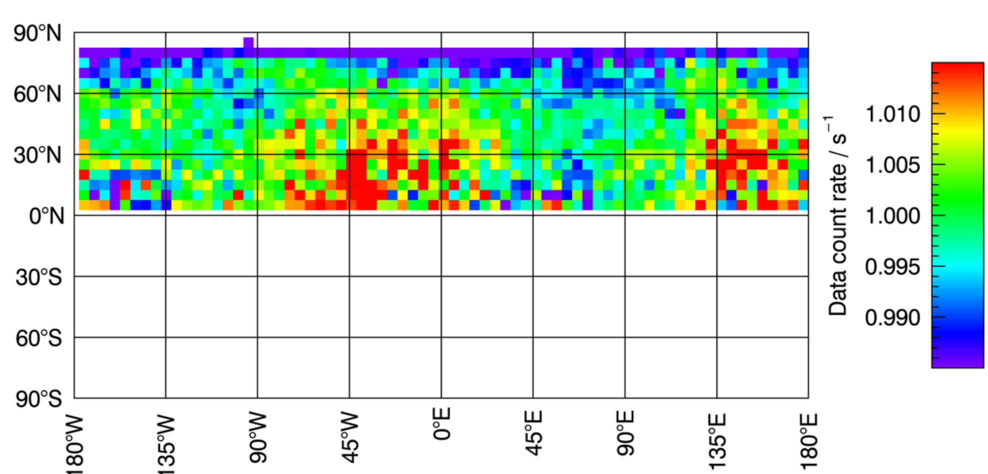

Figure 1: Northern hemisphere map of epithermal neutron count rate on Mercury relative to the mean count rate.

moderating ability, caused by the similarity in the neutron and proton mass. In the absence of hydrogen epithermal neutron flux is proportional to mean atomic mass of surface material. Fast neutron have energy > 0.5 MeV and are primarily sensitive to mean atomic mass.

Maps have been published of both the thermal [2] and fast [3] MESSENGER neutron data, but due to the large systematic errors no epithermal neutron map has yet been published. Here we will present a full-coverage map of epithermal-neutron variability in Mercury's northern hemisphere and discuss what this map implies for our knowledge of elemental composition variations across Mercury.

2.Data and Methods

All five years of MESSENGER epithermal data measured by the borated plastic sensor are used in this study. This large dataset provides sufficient statistical precision to produce a robust map of the thermal neutron flux.

The data reduction was similar to that described in [3] and references therein. That is, empirical corrections were made for variations in GCR flux, spacecraft attitude and solid angle subtended by the planet. Additionally, a correction was made for the Doppler-induced count rate variation based on the spacecraft velocity. This correction was unimportant for the fast neutron data but is important for the epithermal neutron data as the lower energy epithermal neutrons have a speed comparable to that of the spacecraft. As in [3] the efficacy of these corrections was verified by performing similar corrections on a mock data set to determine the size of residual systematic errors.

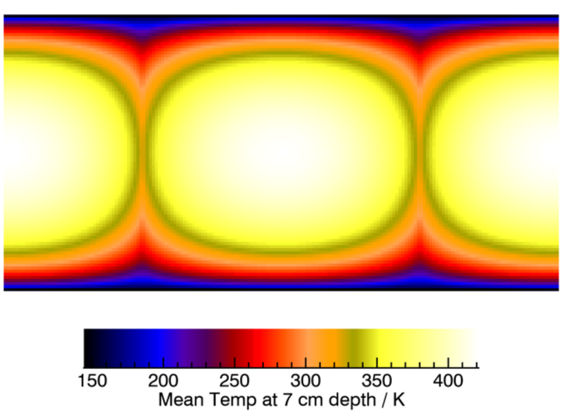

Figure 2: A global map of the mean temperature 7cm beneath Mercury's surface as modelled by [4].

3.Results and Discussion

Figure 1 shows the mapped, corrected epithermal neutron data. As expected the flux is low at the north pole implying an increased abundance of hydrogen and consistent with the presence of water ice in the permanently shaded craters. Significant additional variation is seen at equatorial to mid latitudes. Antipodal highs in epithermal flux are seen at ~30°W and ~150°E, which corresponds approximately to Mercury's hot poles as shown in Figure 2.

The low latitude modulation of epithermal flux is statistically significant and cannot be explained by any know systematic error. If the variation is interpreted as the result of hydrogen variation it implies that the Mercury's hot poles are depleted in hydrogen when compared to the cold poles. In the event that Mercury's volatiles were delivered recently one might expect to see such a correlation due to variation in the stability of hydrogen in the soil at different temperatures. We will further investigate possible physical explanations for this signature and look for confirmation of the hydrogen signal in other datasets including the GRS.

References

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