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Compositional variations in the distribution of plasma ions in Mercury's magnetosphere: The first Mercury year of MESSENGER observations

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MESSENGER's Fast Imaging Plasma Spectrometer (FIPS) has observed planetary ions on nearly every orbit about Mercury since orbit insertion on March 18, 2011. On average, the ratio of the flux of Na-group ions (mass per charge m/q = 21-30) to that of alpha particles (He^{2+}) has been 26%, and the corresponding ratios for O-group ions (m/q = 14-20) and $He^{+}$are 9% and 7%, respectively. Other species, such as S and Ca, are present at times, but only in trace amounts ($< 1\%$). Though variability has been substantial, three dominant magnetospheric plasma features were regularly observed in measurements collected during MESSENGER's first Mercury year in orbit. On the dayside, a large plasma population has been seen at high northern latitudes, in the region of the magnetospheric cusp. On the nightside, plasma has regularly been observed near the equator, in the central plasma sheet. The third regular feature has been an increase in plasma flux near the magnetopause. In this work, we examine the composition of these plasma populations in detail, as well as spatial variability within these regions. We find that the Na-group has the highest flux among planetary ions in all regions. Its flux is the highest in the magnetospheric cusp, by a factor of 10, consistent with polar enhancements of observed neutral species. The fluxes of O-group ions and He^{+}, although lower, also peak in the magnetospheric cusp, indicating that planetary ions are produced and/or trapped in that location. In the plasma sheet, the fluxes of $He^{2+}$and He^{+} are enhanced on the post-midnight side, in agreement with the pattern of diamagnetic depressions documented by MESSENGER's Magnetometer. However, Na-group and O-group ions show the opposite pattern: enhancement on the pre-midnight side. This difference suggests a cause other than increased solar wind flux and may indicate that an alternate source or transport process is involved. The increased planetary ion flux observed around the magnetopause suggests a high-magnetic-latitude source or the entry and subsequent trapping of planetary ions from the magnetosheath. The regional patterns highlighted by this initial survey confirm that differences in planetary ion composition across Mercury's magnetosphere offer new clues to the processes of ion formation and transport at the innermost planet.