Statistical Noise Removal Method for the Mass Spectrum Analyzer onboard BepiColombo/Mio

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Résumé

Mercury is one of the two terrestrial planets in our Solar System possessing an intrinsic magnetic field. Being the closest planet to the Sun and having a weak magnetic field, the Hermean magnetic environment is rapidly changing and forms a tightly coupled system with the planet's core and surface. Its closeness to the Sun causes Mercury's surface to undergo extreme conditions, with continuous space weathering that can eject atoms from the surface to form a tenuous atmosphere called an exosphere (Potter & Morgan 1985). As these atoms become ionized, they drift along the magnetic field lines and populate the magnetosphere of Mercury. Part of these ions can re-impact the surface and eject surface atoms, forming a strong coupling between the magnetosphere, the exosphere, and the surface (Potter & Morgan 1990, Leblanc et al. 2003). More than fifty years after the Mariner 10 mission confirmed the presence of Mercury's magnetic field (Ness et al. 1974), the structure of Mercury's magnetosphere and its ionic composition remain poorly understood. The ESA/JAXA BepiColombo mission is currently cruising towards Mercury to study the Hermean environment, from the planet's surface up to its magnetosphere (Benkhoff et al. 2021). The Mass Spectrum Analyzer (MSA) (Delcourt et al. 2016) on board the ESA/JAXA BepiColombo mission collected some data during its cruise phase and during the different planetary swing-bys. The instrument measures the ions' energy, and the Time-Of-Flight (TOF) of the ions entering

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MSA TOF chamber. A striking feature observed in the data is a large band of detection counts present at similar energies than protons, when a large number of protons are detected by the instrument. This features was attributed to energy straggling, causing a delay in the ions' detection with respect to their theoretical TOF. As protons are the most abundant ionic species of the solar wind (SW), this straggler induced noise is nearly always present, and contaminates strongly the rest of the measurements. Using the data acquired by MSA in the SW, we derive a generic statistical fit of the noise induced by the proton stragglers, connecting the proton counts to the noise level. By applying our method to re-analyze some of the data collected by MSA during the Mercury swing-bys (MSB), we demonstrate that : 1) the stragglers play an important role in the determination of the spacecraft outgassing rate and confirm that the outgassing follows an exponential decrease; 2) the MSB3 data collected in Mercury's magnetosphere are heavily affected by the stragglers' noise. Using our noise subtraction method provides a refined constraint on the heavy ion populations during MSB3 and further strengthens the evidence ions detections from the O+, Na+, K+-groups. With our results, we try to infer the spatial distributions of the planetary ions during different Mercury flybys.