Simultaneous detection of terrestrial ionospheric molecular ions in the Earth's inner magnetosphere and at the Moon

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ABSTRACT

Heavy molecular ions escaping from a planetary atmosphere can contribute to the long-term evolution of its composition. Here we have examined Cluster spacecraft data acquired by the CIS-CODIF (Cluster Ion Spectrometry-Composition Distribution Function) ion mass spectrometer, obtained in the terrestrial inner magnetosphere. Analysis shows that the CIS-CODIF instrument detected, in upwelling ion beams and in the ring current, a series of energetic ion species including not only atomic ions as O^+ but also molecular ions around ~30 amu. Given the 5-7 m/Δm mass resolution of the instrument, these could include N_2^+, NO^+, or O_2^+. The events were during active periods, with CME arrivals followed by a northward rotation of the IMF. For four of these events, for which the orbital conditions were favourable, the observations by Cluster preceded the observations of outflowing molecular ions by the ARTEMIS spacecraft, at lunar distances in the terrestrial magnetotail, reported by Poppe et al. [2016]. Although energetic heavy molecular ions have been detected in the storm time terrestrial magnetosphere in the past, these events constitute the first coordinated observation in the Earth's inner magnetosphere and at the Moon. They show that molecular ion escape, during active periods, is an additional escape mechanism (with respect to the atomic ion escape). Quantifying these mechanisms is important in order to understand the long-term (billion years scale) evolution of the atmospheric composition, and in particular the evolution of the N/O ratio, which is essential for habitability. Future missions should investigate in detail the mechanisms of atomic and molecular ion acceleration and escape, their link to the solar and magnetospheric activity, and their role in the magnetospheric dynamics and in the long-term evolution of the atmospheric composition.