EPSC Abstracts
Vol. 11, EPSC2017-289-1, 2017
European Planetary Science Congress 2017

First 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. The ARTEMIS (Acceleration, Reconnection, Turbulence, and Electrodynamics of the Moon's Interaction with the Sun) spacecraft has recently observed outflowing molecular ions at lunar distances in the terrestrial magnetotail [1]. Backward particle tracing indicated that these ions should originate from the terrestrial inner magnetosphere. Here we have examined Cluster data acquired by the CIS-CODIF (Cluster Ion Spectrometry-Composition Distribution Function) ion mass spectrometer, obtained in the terrestrial magnetosphere. Events were selected for which the orbital conditions were favourable and the Cluster spacecraft were in the high-latitude inner magnetosphere a few hours before the ARTEMIS molecular ion detection, a time compatible with the transfer to lunar distances. 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 O^+ but also a group of 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. Although energetic heavy molecular ions have been detected in the storm time terrestrial magnetosphere in the past (e.g. [2], [3]), 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. Terrestrial heavy ions, transported to the Moon, suggest also that the Earth's atmosphere of billions of years ago may be preserved on the present-day lunar regolith [4]. Future missions, as the proposed ESCAPE mission, 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.

References

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