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MAVEN 及び Mars Express の観測に基づく太陽活動イベント時における火星のイオン散逸に関する統計的研究

#亀井 りま [1), 関 華奈子 [1), 桂華 邦裕 [1), Ramstad R.[2), Brian D. A.[2), Hara T.[3), McFadden J. P.[3), Hanley K. G.[3), Fowler C.[4), Halekas J. S.[5), DiBraccio G. A.[6), Curry S. M.[2)
([1 東大理・地球惑星科学専攻, ([2 コロラド大学ボルダー校 大気宇宙物理学研究所, ([3 カリフォルニア大学バークレー校 宇宙科学研究所, ([4 ウェストバージニア大学物理学・天文学部, ([5 アイオワ大学物理学・天文学部, ([6NASA ゴダード宇宙飛行センター

Statistical study of ion escape from Mars during ICME and CIR events based on MAVEN and Mars Express observations

#R. Kamei[1), K. Seki[1), K. Keika[1), R. Ramstad[2), D. A. Brian[2), T. Hara[3), J. P. McFadden[3), K. G. Hanley[3), C. Fowler[4), J. S. Halekas[5), G. A. DiBraccio[6), S. M. Curry[2)
([1Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo, ([2Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, CO, USA, ([3Space Sciences Laboratory, University of California, Berkeley, CA, USA, ([4Department of Physics and Astronomy, West Virginia University, Morgantown, WV, USA, ([5Department of Physics and Astronomy, University of Iowa, Iowa City, Iowa, USA, ([6NASA Goddard Space Flight Center, Greenbelt, MD, USA

It is important to clarify responses of each atmospheric escape mechanism to solar activities for understanding of the planetary atmospheric evolution. This is especially significant for Mars, which lacks an intrinsic magnetic field, allowing direct interaction between the solar wind and its atmosphere. While various mechanisms can contribute to the atmospheric escape, we here focus on the ion escape driven by solar activity events, such as Interplanetary Coronal Mass Ejections (ICMEs) and Corotating Interaction Regions (CIRs). ICMEs occur when large amounts of plasma are ejected into interplanetary space following solar flares, while CIRs are formed when fast solar wind overtakes slower one, creating interaction regions, Both ICMEs and CIRs often facilitate high solar wind dynamic pressure condition and disturb the Martian induces magnetosphere and influence atmospheric escape. MAVEN observations and their comparison with global MHD simulation results show that atmospheric escape rates increased significantly during an ICME event in March 2015 [1]. On the other hand, Ramstad and Barabash (2021) pointed out that the ion escape rate from Mars does not have clear dependence on the solar wind dynamic pressure based on statistical analysis [2]. These contradictory observations indicate the need for careful investigation of effects of ICMEs and CIRs on the ion loss from Mars. Observationally there are two major escape channels for ions from Mars: polar plumes accelerated by the convective electric field of the solar wind and the tailward escape, a bulk ion outflow through Martian magnetotail [2]. Statistical studies of the polar plumes [3] and tailward escape [4] both indicate that the spatial distributions of the ion escape flux are highly localized in terms of the MSE coordinates determined by the direction of the solar wind electric field. In this study, we aim to evaluate the impact of solar wind on the ion escape from Mars during ICMEs and CIRs by carefully investigating the localization effects of the both ion escape channels.

Utilizing simultaneous observations by Mars Express and MAVEN from 2015 to 2019, we identified ICMES and CIRS. First, the data satisfying the following criteria were selected: (1) the maximum daily solar wind density exceeded 15 cm^{-3}, and (2) the difference in velocity over two days was greater than 100 km/s. Among the selected data, events where density and velocity increased simultaneously were classified as CMEs, while those where velocity increased following a density rise were classified as CIRs. We also used the ENLIL simulation model to identify events where both CIR and CME occurred simultaneously. As a result, we found 7 CMEs, 120 CIRs, and 8 events where both CIR and CME arrived simultaneously over the five-year period. We used the Supra-Thermal And Thermal Ion Composition (STAIC) onboard MAVEN to investigate spatial distributions of escaping ions. Distributions of O^+ and ${O_2}^+$ fluxes are separately examined both in the Mars-Solar-Orbital (MSO) coordinates and the Mars-Solar-Electric field (MSE) coordinates to differentiate the effects of the crustal magnetic field and acceleration by solar wind electric field. Based on the statistical results focusing only during the solar event intervals (ICME and CIRs), effects of ICMEs and CIRs on the ion loss from Mars are discussed.

References

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