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Atmospheric escape from Mars during the impact of solar wind pressure pulses

N. J. T. Edberg (1,2), H. Nilsson (3), A. O. Williams (2), M. Lester (2), S. E. Milan (2), S. W. H. Cowley (2), M. Fränz (4), S. Barabash (3) and Y. Futaana (3)
(1) Dept. of Physics and Astronomy, University of Leicester, UK, (2) Swedish Institute of Space Physics, Uppsala, Sweden, (3) Swedish Institute of Space Physics, Kiruna, Sweden, (4) MPI for Solar System Research, Katlenburg-Lindau, Germany (ne@irfu.se)

Abstract

During the solar minimum of 2007-08 we have observed 41 high-pressure events in the solar wind, which are predominantly identified as corotating interaction regions (CIRs) and some as coronal mass ejections (CMEs). These pressure pulses propagate outward in the solar system and eventually impact on planetary atmospheres. By studying the fluxes of heavy ions in the antisunward direction around Mars we can show that when these 41 pressure pulses impact on Mars, the atmospheric escape rate increases by a factor of 2.5, on average. This means that 30% of the total amount of outflowing plasma from Mars escape during the impact of CIRs and CMEs.

1. Introduction

As the tilted Sun rotates it periodically emits plasma from either the Sun's equatorial regions or the high-latitude regions, as seen from one specific location in space. The plasma from the high latitude regions is generally streaming faster than the equatorial plasma such that the faster plasma will inevitably catch up with slower flowing plasma. At the interaction region between these two streams is the plasma density and temperature as well as the interplanetary magnetic field generally increased such that the total pressure is increased. This so called co-rotating interaction region (CIR) propagates outward in the solar system and acts as solar wind pressure pulse. It will eventually impact on any obstacle present in the solar systems, such as the planet Mars [1].

2. Observations

We have used data from the Advanced Composition Explorer (ACE) upstream of Earth to identify such events in the solar wind during the solar minimum of 2007-08 and found 41 events. 5 of these events are coronal mass ejections rather than CIRs but as they are all propagating toward Mars, we still include them in our study. By measuring their propagation speed and taking into account the relative positions of Earth and Mars, we can predict when these events will impact on Mars in order to determine what effect they have on the planet. The prediction is also verified through a by-eye search in the electron measurements from the ASPERA-3/ELS instrument on the Mars Express spacecraft. These events can also be predicted to arrive at Venus as is being done in a related study [2].

Since we know when these pressure pulses are impacting on Mars, we can use the ion measurements from the ASPERA-3/IMA instrument to study what happens to the heavy planetary ions during such impacts, in terms of their escape rate. The 41 observed events each pass by Mars during a period of 36 hours, on average, such that we have a large number of data points. By comparing the escape fluxes during the impact of CIRs with the escape fluxes during quiet solar wind conditions, as is shown in Fig. 1, we find that the escape rate increases by a factor of ~2.5, on average. This means that 30% of the total outflowing plasma escape during the impact of solar wind pressure pulses.

3. Figures

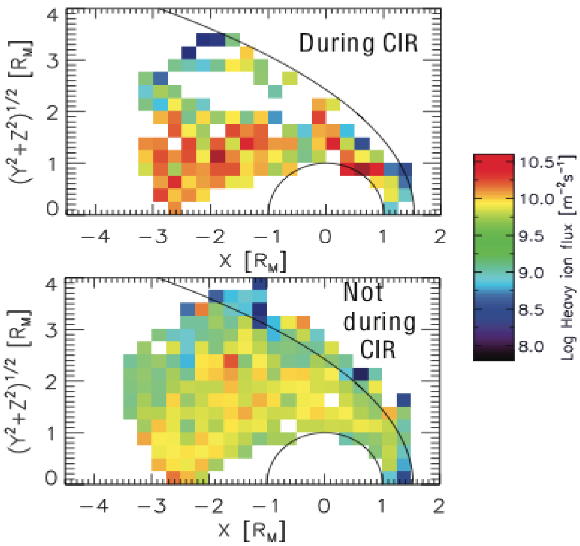

Figure 1: Heavy ion fluxes observed around Mars during (top) the impact of CIRs and (bottom) during quiet solar wind conditions. Reproduced after [1].

4. Summary and Conclusions

In this paper we have shown that the impact of solar wind pressure pulses, like CIRs or CMEs, have a significant effect on the evolution of Mars' atmosphere. We find that the escape rate of heavy planetary ions increase by a factor of ~2.5 when the planet is impacted by a solar wind pressure pulse.

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References

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