

# 15 years in the induced magnetosphere of Mars: ion escape and all around

**Stas Barabash** and Mats Holmström  
Swedish Institute of Space Physics, Kiruna, Sweden (stas.barabash@irf.se)

## Abstract

This review talk presents the contribution of the Mars Express mission to the big picture of the solar wind interaction with the non-magnetized atmospheric planet Mars

## 1. The ion escape

Mars Express carries an ion, electron, and energetic neutral atom (ENA) instrument ASPERA-3 (Analyzer of Space Plasmas and Energetic Neutral Atom) carrying out measurements in the energy range few eV to few 10s keV relevant to study the solar wind - Mars interaction. The focus of the experiment was to establish the rate of the atmospheric erosion caused by the interaction with the solar wind. For 15 years of operation at Mars ASPERA-3 not only fully fulfilled the main objective but also provided us with a new picture of the induced magnetosphere, a “bubble” in the solar wind created by magnetic fields of currents induced in the Martian ionosphere.

The energy transfer from the solar wind to the planetary ions results in the ion escape. Mars Express established the average rate of the ion escape:

$$Q=(2.7\pm 0.4)\cdot 10^{24} \text{ s}^{-1}.$$

15 years of observations for more than one solar cycle allowed to determine the dependences of the escape rate on the solar wind and solar conditions by constraining of all other parameters. Using these dependences one could extrapolate the escape rate back in time and establish the total amount of the atmospheric loss for the last 4 Ga year  $\Delta p$

$$\Delta p < 10 \text{ mbar. Very little!}$$

The majority of the escaping ions are  $\text{O}^+$  and  $\text{O}_2^+$ ,  $\text{CO}_2^+$  is only 20% of these ion fluxes.

## 2. ..And all around

Mars Express revealed that the bubble of the induced magnetosphere is not empty from the solar wind electrons, protons, and  $\text{He}^{++}$ . Channeling along open field lines of the crustal magnetic anomalies or penetrating the thin magnetic barrier due to large gyroradius these particles deposit energy and matter to the atmosphere. Solar wind  $\alpha$ -particles contribute to the Martian helium balance. The magnetosheath electrons cause aurora-like phenomena.

The induced magnetosphere as seen by Mars Express is a dynamical object responding to the solar wind disturbance such as interplanetary shocks, co-rotation interaction regions, coronal mass injections. The disturbances result in increase of the escaping ion fluxes but also reducing the size of the induced magnetosphere shape. As a result the total escape rate does not change significantly. The magnetosphere dynamics is also manifested in oscillations of the magnetosheath plasma parameters with the characteristic period 50 s and 300 s as revealed by ENAs, electron and ion observations.

Mars Express also introduced a few new techniques to study induced magnetospheres. Measurements of the characteristic 10s eV photoelectrons allow tracing the open field lines of the crustal anomalies up to the Mars Express apocenter. Mars Express for the first time characterized ENAs generated in the Martian environment paving the way for the future global imaging missions to Mars.