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Short Communication

Modulation of the solar wind velocity and density by Mercury

I.F. Nikulin *

M.V. Lomonosov Moscow State University, Sternberg Astronomical Institute, Universitetski pr. 13, 119991 Moscow, Russia

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ABSTRACT

To study the variations in the solar wind velocity during inferior conjunctions of Mercury and Earth, we analyzed 54 events in the period 1995–2012 by the superimposed epoch method. We have found a noticeable increase in the velocity both before and after the conjunctions as well as decrease in the velocity within 3–4 days after them (Mercury's "shadow"). Variations of the solar wind density in 1997–2013 show a similar character, but their dispersion is substantially larger than for the velocity. The results obtained might be used to analyze variations and to improve a forecast of the solar wind velocity and density.

1. Introduction

Mercury is a small planet (0.055 terrestrial mass) closest to the Sun, which possesses the largest eccentricity (0.206) and orbital inclination to ecliptic (over 7°) among the eight planets of the Solar system (Allen, 1976). Mercury also has a global (but very weak) magnetic field and has almost no atmosphere. All these properties as well as its proximity to the Sun attract a special interest to the interaction of Mercury with the solar wind, the model of the respective ambient flow, and the possibility of survival of the hermean trace (or "shadow") in the interplanetary medium in the course of propagation of the solar wind (SW). The weak hermean magnetosphere as well as the absence of an appreciable atmosphere and ionosphere enable the enhanced solar wind to actually approach the planetary surface, as it takes place in the interaction of SW with Moon (Kabin et al., 2000; Fujimoto et al., 2007). It is the aim of the present paper to study the consequences of interaction of SW with Mercury by using the variation in the SW velocity in the Earth's neighborhood during inferior conjunctions, *i.e.*, at the distance of 1 AU from the Sun.

The solar wind is a quasi-steady radial supersonic outflow of the solar coronal plasma through the entire Solar system; its velocity being a few hundreds km/s, and the density, about a few particles in a cubic cm. SW affects the planets not only by a dynamic pressure of the corpuscular flux but also due to the "frozen-in" magnetic fields, which interact with the planetary magnetospheres depending on the magnetic field intensity and polarity.

SW velocity and density are very difficult parameters for a reliable forecast. Even in the clearest and most evident cases of the so-called post-flare coronal mass ejections, the amplitude and duration of the increase after a flare will depend on many parameters, such as a magnitude of the flare, its position on the solar disk, magnetic field structure in the active region and interplanetary space, direction of the outburst, and its solid angle. Therefore, establishment of an additional parameter affecting SW velocity may open new opportunities for the improved forecast and analysis of its variations.

2. Data and methods

To reveal the effect mentioned above, the mean daily velocities were analyzed by the superimposed epoch method for 54 periods of inferior conjunctions in 1995–2012. The superimposed epoch method (or the "synchronous detection") is based on the separation of the time interval under consideration into the equal subintervals of the specified duration T; and then the observational data in the same temporal points from the beginning of the above-mentioned subintervals are summed up or averaged. As a result, if the data vary with T or a comparable period, the corresponding effect is accumulated; while the data varying in time randomly or with the periods incomparable with T are smoothed out.

The instants of the superior conjunctions were refined by using the HORIZONS software (http://ssd.jpl.nasa.gov/horizons.cgi).

The mean daily velocities were derived from the mean hourly ones, which were measured by *ACE* satellite in L1 Lagrangian point (ACE, 2013), *i.e.* in the point of gravitational equilibrium between the Earth and the Sun, at the distance of approximately 1.4 million

* Tel.: +7 495 939 19 73.
E-mail address: ifn@sai.msu.ru

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kilometers from the Earth. A few particular examples of variations in the mean daily velocities during the inferior conjunctions of Mercury are given in Fig. 1.

At last, let us mention that differences in the space weather and in the relative positions of the planets and the Sun above ecliptic and with respect to the perihelion of hermean orbit were not taken into account yet in our analysis, although their role might be noticeable.

3. Results

Despite the restrictions outlined in the previous section, analysis of 54 oppositions (inferior conjunctions), presented in Fig. 2, shows a noticeable increase in the SW velocity within 4 days before the oppositions (~10%) and 8 days after them (~12%) along with a decrease in the velocity (~4%) within 3–4 days after the oppositions (which is the Mercury's shadow). Such a delay corresponds to the average SW velocity about 300–400 km/s, at which the radial SW passes the distance from the Mercury to the Earth.

To verify this effect and to reveal its probable dependence on the solar cycle phase, we have performed the same processing separately for three data sets: from the minimum to the maximum of the 23rd cycle, for the period of its decay, and for the minimum and the onset of the new 24th cycle (Fig. 3). The above-mentioned characteristic features of the velocity variations were found to survive in all three periods, although the ratio of velocities before and after the oppositions as well as their temporal localization with respect to the conjunctions slightly varied.

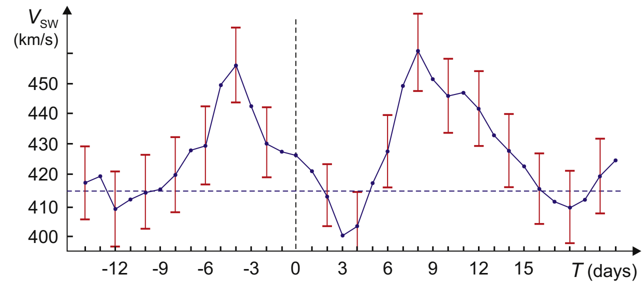

Fig. 2. Mean variation of velocity of the solar wind during the inferior conjunction with Mercury. Vertical dashed line is the instant of conjunction, horizontal dashed line is the average velocity of the solar wind in the interval under consideration (1995–2012); and vertical bars show the standard deviations σ of the mean values.

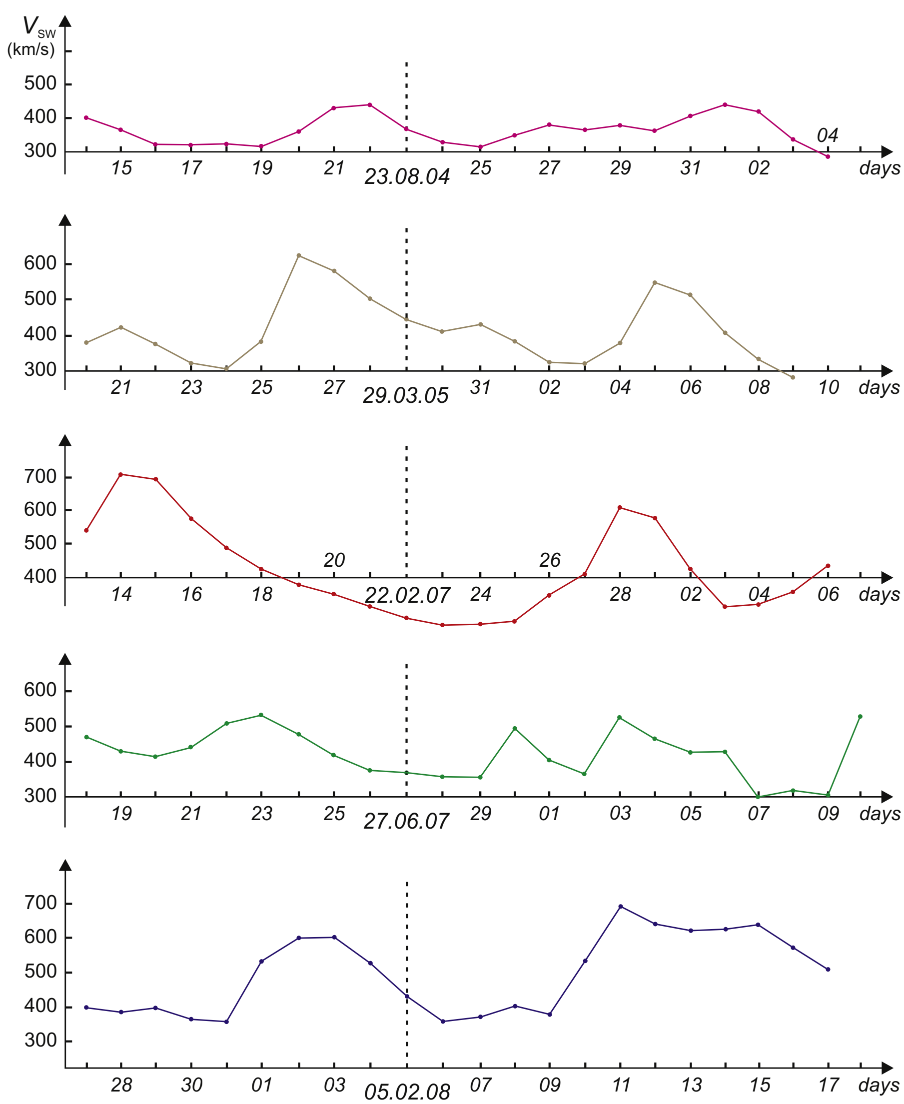

Fig. 1. Examples of variations in the SW velocity around the individual inferior conjunctions, which are marked by the vertical dashed lines in plots. The corresponding dates are given under each plot.

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