ON SOLAR WIND INTERACTION WITH ASTEROIDAL OBJECTS, W.-H. Ip\(^1\)\(^2\) and F. Herbert\(^2\), ¹Max-Planck Institut fur Aeronomie, D-3411, Katlenburg-Lindau, Federal Republic of Germany, ²Lunar and Planetary Laboratory, The University of Arizona, Tucson, AZ 85721.

Solar wind or magnetospheric interactions of planetary bodies vary from the strong kind of interactions like the Earth, Jupiter and Saturn which cause extensive perturbations to the solar wind - as a result of their large intrinsic magnetic fields - to the weak type like that of Mercury. Another class includes planets and satellites with atmospheres but very little or no intrinsic magnetic field (i.e., Venus, Mars, Io and Titan). Depending on their corresponding ionospheric conductivities their MHD interactions can be identified as being strong or not. For the case of a strong interaction, the interplanetary magnetic field is compressed ahead of the ionosphere to level substantially larger than the ambient solar wind field strength. Venus is the best example.

In the case of asteroids, the general impression is that their solar wind interaction should be similar to that of the moon or a planetary satellite without an atmosphere (i.e., Ganymede). More specifically, if intrinsic permanent magnetic fields are assumed to be absent or negligible, and the interior conductivities are low, the solar wind can directly impinge onto the surface, thus creating a plasma cavity downstream. At the same time the interplanetary magnetic field is not significantly perturbed except for the effect of the diamagnetic current (see Figure 1).

However, from ground-based observations different classes of asteroids with a variety of spectroscopic signatures have been found (1). If the surface mineral property is indicative of the internal composition, the asteroids may be metal-rich. As the possibility that some of them are in fact partially, if not completely, composed of nickel-iron akin to the iron meteorites cannot be readily ruled out at this point, the effective conductivities of some of these M-type (or other) asteroids may be considerably larger than that of the rocky material. Moreover, C-type asteroids resemble carbonaceous chondritic meteorites (1), some of which have electrical conductivities in the range 10\(^{-5}\) to 10\(^{-3}\) mho/m (2). In this event a large electrical current could be induced across the asteroid due to the convection electric field (\(E = v \times B\)) of the solar wind. The magnetic field generated by this unpolar induction current system would then turn perturb the ambient field changing the magnetic field configuration in the near vicinity of the asteroid in question. An average conductivity of \(\sigma = 10^{-5}\) mho/m would be sufficient to cause pileup of the interplanetary field ahead of the asteroid to the point that the solar wind interaction can be considered as being strong (i.e., formation of bow shock, magnetosheath and magnetotail, etc. (3,4,5)).

Even though the conductivity of metallic material (\(\sigma_{\text{Fe}} = 10^8\) mho/m) can be much larger than the critical value of \(10^{-5}\) mho/m, the actual induced current is self-limiting to a certain value. This is because diversion of the solar wind plasma around an induced magnetosphere would in turn reduce the unpolar dynamo action of the solar wind. The total current hence would be adjusted in such a way that the solar wind flow could be accommodated (6). In any event, two different conditions can be used to estimate the total current (1) flowing through the conducting bodies. Firstly, if it is argued that the induced field \(B_1\) at the asteroid must be comparable to the interplanetary magnetic field \(B_\odot\) (i.e., \(B_1 \approx B_\odot\)) from the relation: \(1 = B_\odot R^2/B_1 = 400\) A if \(R = 100\) km and \(B_\odot = 5\) nT (and \(u = 4 \times 10^7\) km/s). Secondly, if the upper limit of the magnetic pressure \(P_m\), the induced field at the surface is on the order of the solar wind dynamic pressure (i.e., \(B_1^2/8\pi = 2p_m V_w^2\)) we find \(B_1 = 260\) nT if \(p_m = 1\) cm\(^2\) and \(V_w = 400\) km/s; also the total current \(I = 5 \times 10^7\) A if \(B_1 = 260\) nT.

The configuration of the asteroidal magnetosphere induced by the solar wind interaction process is sketched in Figure 2. As its physical dimension is not expected to be much larger than the size of the asteroidal objects, only close approach by space probes at close ranges (a fraction of one radius upstream of the asteroid or up to a few radii downstream) would reveal its presence. This consideration thus highlights the possible usefulness of remote sounding of the interiors of different kinds of asteroids by magnetometer (e.g., 7) and particle detectors (e.g., the electron reflection technique (8)) in an asteroid fly-by mission.

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Fig. 1. Solar wind interaction of an asteroid with low electrical conductivity. As a result of direct impinging of the solar wind onto the dayside surface a plasma void is formed within the region defined by the (...) lines, and the interplanetary magnetic field is slightly perturbed in the asteroidal wake defined by the (---) lines. Details of the process could change as a function of the asteroidal size.

Fig. 2. Solar wind interaction with a highly conducting asteroid. Unipolar dynamo action by the solar wind would generate a current system flowing across the asteroidal body. The magnetic fields so induced lead to the pile up of the interplanetary magnetic field ahead of the asteroid and the formation of a magnetotail downstream in the wake region. Direct sweeping of the solar wind may be avoided if a bow shock forms upstream. Thus history of solar wind sputtering of the surface regolith may vary as a function of the conductivities. Also note that this MHD picture could breakdown if ion gyration effect is important.