**ASTEROID SHIELDING FROM SOLAR WIND: CALCULATION OF THE PARAMETERS OF MAGNETOSPHERES.** L. V. Starukhina[1], T. B. McCord[2], [1]Astronomical Institute of Kharkov National University, Sumskaya 35, Kharkov, 61022, Ukraine, starukhina@astron.kharkov.ua, [2]Bear Fight Institute, Winthrop WA 98862, USA

**Introduction:** Reflectance spectra of some asteroids show reduced or lack of optical maturity due to space weathering, compared with, for example, the Moon. A prominent example is the spectra of asteroid 4 Vesta. The lack of the typical red spectral slope at visible and near infrared wavelengths combined with deep 1 and 2μm bands indicate the lack of nano-grains of reduced iron ($nFe^0$) in Vesta regolith. Such grains form in space weathering processes resulting from surface exposure to solar wind and meteoritic bombardment. The main mechanism of $nFe^0$-formation is still a subject of discussions. Though laboratory simulations of solar wind succeeded in iron reduction and optical maturation [1-3], some groups of researches demonstrated that micrometeoritic bombardment may be sufficient for maturation even in absence of solar wind [4-6].

However, for basaltic surfaces, there are spectral features that can be formed only in the presence of implanted protons, usually from the solar wind. These are OH absorption features near 3μm. The lack or reduced strength of such features for Vesta [7], compared with the Moon, might be explained by magnetic shielding [8], if Vesta has a magnetic field, which is not known yet. The Dawn space mission [9] is currently orbiting Vesta and is looking for evidence indicative of a magnetic field, although it carries no magnetometer. In the present study, the magnetic field required to protect asteroids from solar wind is calculated as a function of asteroid diameter and heliocentric distance.

**Calculation of shielding magnetospheres:** The magnetosphere of a celestial body is characterized by the dipole magnetic moment $M$, magnetic field at a distance $R$ from the dipole center being $B = 2M/R^3$. Size of a magnetosphere (Chapman-Ferraro radius $R_{ChF}$) is defined as the distance form the center of the magnetic dipole to subsolar point where magnetic pressure is balanced by solar wind dynamic pressure:

$$(B_{ChF})^2/8\pi = (2M/R_{ChF}{}^3)^2/8\pi = 2m_p n v^2, \qquad (1)$$

where $m_p$, $n$, and $v$ are proton mass, number density and velocity, respectively; factor 2 being due to reflection of protons from the boundary of a magnetosphere, and $B_{ChF}$ the value of magnetic field at the boundary. At a distance $r$ a.u. from the Sun, $n = n_1/r^2$, where $n_1$ is solar wind number density at the Earth orbit.

Magnetic shielding of an asteroid surface from solar wind protons is effective if Larmor gyroradius $r_L$ for protons at Chapman-Ferraro point $R_{ChF}$ is less than the distance $R_{ChF} - D/2$ from the boundary of the magnetosphere to the surface of an asteroid of a diameter $D$:

$$R_{ChF} - D/2 = r_L = m_p cv/qB_{ChF} = (cr/4q)(m_p/\pi n_1)^{1/2}, \qquad (2)$$

where $c$ is light velocity, and $q$ is proton charge. In the Main asteroid Belt, $r_L \approx 100$ km.

Substituting $R_{ChF}$ from (1) to (2), obtain the upper estimate for magnetic field on an asteroid surface that is sufficient for protection of the surface from solar wind protons:

$$B_s = 32v(\pi m_p n_1)^{1/2}(D/2 + r_L)^3/(rD^3) \qquad (3)$$

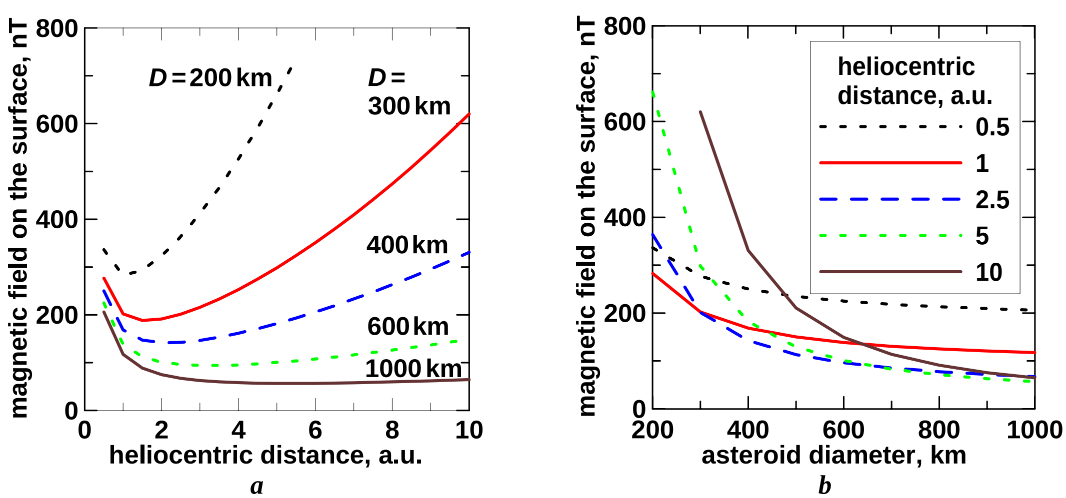
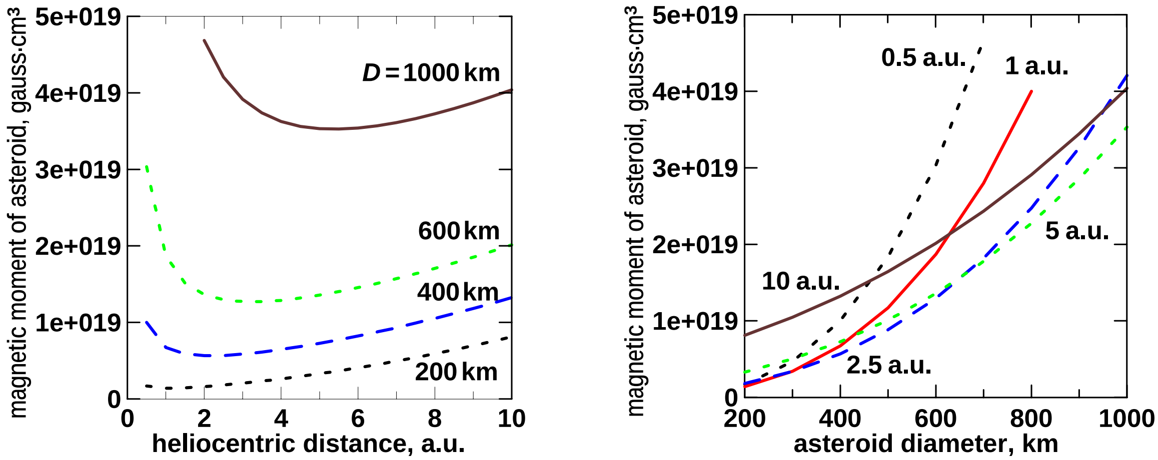



**Fig.1** Magnetic field on the surface of an airless body sufficient for its protection from solar wind vs. heliocentric distance (*a*), and diameter *D* of the body (*b*).




*a* *b*

**Fig.2** Magnetic moment of an airless body sufficient for its protection from solar wind vs. heliocentric distance (*a*), and diameter *D* of the body (*b*).

or, to emphasize the nonmonotonic dependence on heliocentric distance $r$:

$$B_s = 4v(\pi m_p n_1)^{1/2}[1 + (r/D)(c/2q)(m_p/\pi n_1)^{1/2}]^3/r. \quad (3')$$

At small heliocentric distances, where $r_L << D/2$, the value of the magnetic field on the surface is almost equal to the field at the boundary of the magnetosphere: $B_s \approx B_{ChF}$ which is determined by the dynamic pressure of solar wind and proportional to $1/r$, i.e., $B_s$ decreases with $r$. At larger $r$, where $r_L \sim D/2$, $B_s$ increases with $r$, together with $r_L$. (see Eq. (2)).

The dipole magnetic moment $M$ of the shielding magnetosphere can be calculated as

$$M = B_s D^3/16. \quad (4)$$

The results of calculations of $B_s$ and $M$ for various asteroid diameters and heliocentric distances are shown in Figs.1, 2. In particular, for Mercury ($r$ = 0.38, $D$ = 4880 km) $B_s$ = 242 nT and $M = 1.8 \cdot 10^{22}$ gauss·cm$^3$. This shows that magnetic moment of Mercury ($M = 8 \cdot 10^{25}$ gauss·cm$^3$) is sufficient for shielding of the surface (except polar cusps) from solar wind. For Vesta ($r$ = 2.36, $D$ = 530 km), $B_s$ = 108 nT and $M = 10^{19}$ gauss·cm$^3$; for Ceres ($r$ = 2.7, $D$ = 913 km), $B_s$ = 69 nT and $M = 3.3 \cdot 10^{19}$ gauss·cm$^3$.

**Conclusions:** To protect an asteroid from solar wind, rather moderate values of dipole magnetic moments and magnetic fields on the surfaces are required. For asteroids of diameters $D$ = 400-700 km the minimum of shielding magnetic moments is reached in the Main asteroid Belt.

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**References:** [1] Nash D. (1967) *J. Geophys. Res. 72*, 3089 – 3104. [2] Hapke B. W. (1973) *Moon 7*, 342–355. [3] Dukes C. A. et al. (1999) *J. Geophys. Res. 104*, 1865-1872. [4] Moroz L. V. et al. (1996) *Icarus 122*, 366-382. [5] Sasaki S. et al. (2002) *Adv. Space Res. 29*, 783-788. [6] Loeffler M. J. et al. (2008) *Icarus 196*, 285–292. [7] Rivkin A.S. et al., (2006) *Icarus 180*, 464–472. [8] Vernazza P. et al. (2006) *Astron. Astroph. 451*, L43-46. [9] Russell C. T. and Raymond C. A. (2011) *Space Sci. Rev*., doi: 10.1007/s11214-011-9836-2.