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Laboratory simulation of very strong magnetosphere's compression by giant Solar flare's plasma, supplying a SEP's trapping and other world – wide effects

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The problems of required conditions and possible consequences of the super - compression (up to $R_m \sim 3R_E$) of the Earth's magnetosphere by giant CME are investigated by the methods of laboratory and computer simulations. A useful relation between an expected magnetopause location R_m^* and the kinetic plasma energy E_0 of spherical plasma cloud (exploded at distance R_0) was obtained $R_m^*/R_0 \approx 0,75/æ^{1/6}$ and tested by MHD – model of Nikitin & Ponomarenko (1994) with the using their main energetic criterion of the problem $æ = 3E_0R_0^3/\mu^2$ (for magnetic moment μ of point obstacle in vacuum). This relation could describe rather well an observed compression ($R_m \sim 5-6R_E$ for CME with energy $10^{32}\,ergs$ and effective value $E_0 \sim 10^{33} ergs$, into 4π) and predicts $R_m^* \leqslant 3R_E$ in a probable case of Mega Flare with the total energy release $\sim 10^{34}\,ergs$ and possible $E_0 \sim 5 \cdot 10^{34}\,ergs$ according to Kane *et al.* (1995) and Tsurutani *et al.* (2003). Some most important features of the formation such Artificial Magnetosphere (AM) structure and its possible influence onto various geospheres media (or technosphere areas) could be successfully studied in the simulative experiments at KI-1 facility of ILP with Laser Plasmas (LP) of E_0 up to kJ and dipole $\mu \sim 10^7\,G \cdot cm^3$ as was shown by Ponomarenko *et al.* (2001) and Zakharov (2003). But the main problem of such planned AMEX experiment (at $æ \sim 50$ for $R_0 = 75\,cm$) is the influence of finite value of ion magnetization $\varepsilon_m = R_L/R_m^*$ based on the ion Larmor radius $R_L = mcV_0/ezB_d$, where $V_0 \sim 100\,km/s$ is the expansion velocity of LP and B_d is the initial dipole field at the point R_m^*. Of coarse, $\varepsilon_m \ll 1$ in a real space conditions (excluding cases of Mercury or asteroids, explored by Omidi *et al.* (2004)) while in the laboratory to fulfill both need constrains $æ \gg 1$ and $\varepsilon_m \ll 1$ we should use a thermonuclear plasma and devices. To overcome this problem we did a 3D/PIC – calculations by hybrid model of Kyushu University, described by Muranaka *et al.* (2001), to find out a critical value of ε_m^* ($\approx 0,2-0,3$), which need for MHD – like interaction of exploding plasmas with magnetic dipole.

We have used the MHD – model of plasma dynamics based on the approach of Raizer (1963) for deceleration of diamagnetic plasma boundary in vacuum magnetic field B_d that includes two (both local) relations: for pressure balance $2nm\,(W-V)^2\cos^2\chi = kB_d^2/8\pi$ at plasma boundary R and for decrease of its energy $2W\dot{W} + kB_d^2\cos\chi VR^2/0,6M = 0$ (for $V = dR/dt$ and W – velocity of plasma ions). The latter one, according to Nikitin & Ponomarenko (1994), could be obtained via usual expression for total plasma energy $E(t) = E_0 - A(t)$, where $A(t) = (1/8\pi)\int_s\int_t kB_d^2\cos\chi\vec{V}\cdot d\vec{S}\,dt$ is its work against B_d. Here χ is the angle between R and local normal to boundary, while a constant $k \sim 1 \div 2$ characterizes a field amplification near the boundary.

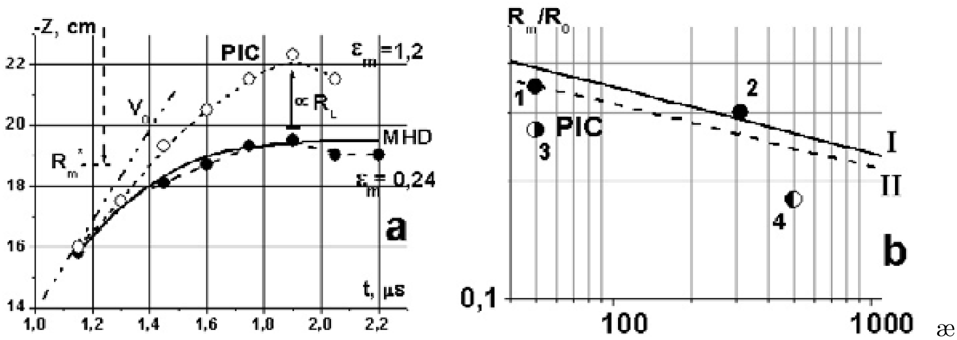

Figure 1. Dynamics **(a)** of plasma deceleration near magnetopause and dependence **(b)** of its size R_m on the energetic criterion æ : at **(a)** dipole stands at $Z = -30\,cm$ and for the same æ = 50 the data of MHD – model and PIC – calculations (for various values of ion magnetization ε_m) are presented; at **(b)** the dimensionless relation between the R_m – size and æ is shown based on approximation $R_m^*/R_0 \approx 0,75/æ^{1/6}$ (I), MHD – model (II) and PIC – calculations (1 – 4) for $\varepsilon_m = 0,24$ (AMEX), $\sim 0,1$, ~ 1, and $1,2$ (KEVL) correspondingly.

A lot of runs were done with MHD and PIC models under conditions close to planned AMEX and recently done KEVL experiment at KI-1, in which we have used a plastic target, LP with $E_0 \sim 15 - 20\,J$ (for $\langle m/z \rangle \approx 2,5\ a.m.u.$) and $\mu \sim 10^5 G \cdot cm^3$, supplying æ ~ 500 at $\varepsilon_m \sim 1$ (for $R_0 = 25\,cm$). As a result, a well pronounced effect of R_L was revealed both in laboratory (KEVL) and PIC - simulations (presented at figure 1a for KEVL-like upper case with $E_0 = 10\,J$ and $\mu = 4 \cdot 10^5 G \cdot cm^3$), that leads to more deep penetration of plasma into dipole field (at distance up to $-22\,cm$, instead of expected R_m^* at $-19,5\,cm$). So for the physical conditions of AMEX, corresponding to parameters of figure 1a, it was shown that the value $\varepsilon_m = 0,24$ is enough small to supply MHD - like interaction of plasma with the dipole and a similar relation between the real R_m and expected R_m^* values (depending upon ε_m – criterion) were obtained in a wide range of æ, as is shown at figure 1b (with the PIC data -4, corresponding to KEVL experiment).

As result, the conclusion could be done that in the MHD-range of planned AMEX experiment we could simulate such expected AM – phenomena, as enormous SSC – effect relevant to the possible processes of SEP's penetration and trapping according to Kress *et al.* (2005), Van Allen belt's pertubations or generation of huge telluric currents, possibly connected with the ideas of Sobolev *et al.* (2003) about induced seismicity.

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