@ Authors

# *Current sheets with multi-component plasma in planetary magnetospheres*

**Victor Popov**[1,2], Vladimir Domrin[3], Helmi Malova[2,3], Elena Grigorenko[2], and Anatoly Petrukovich[2]

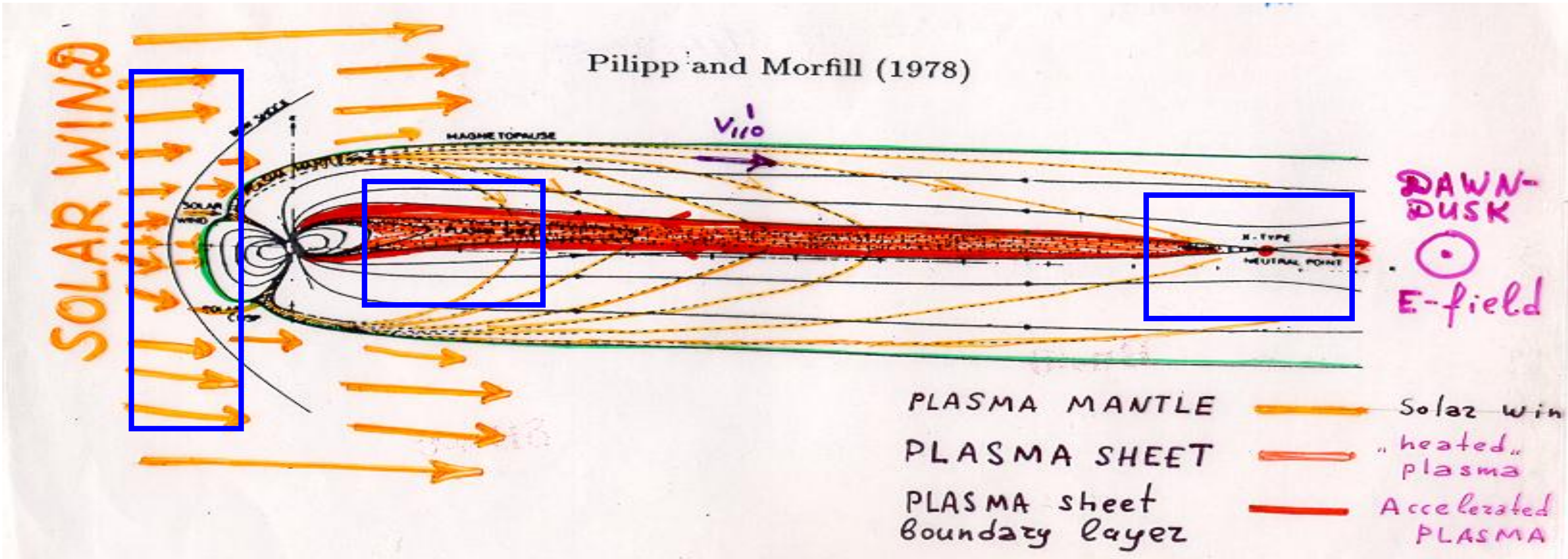
[1]M.V.Lomonosov Moscow State University; National Research University "Higher School of Economics", Moscow, Russian Federation (masterlu@mail.ru)

[2]Space Research Institute, Russian Academy of Sciences, Moscow, Russia

[3]Scobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University

The self-consistent hybrid model of a thin current sheet with a thickness about several proton gyroradii in a space plasma is proposed, taking into account multicomponent collisionless space plasma. Several plasma components are often presented in planetary magnetotails (Hermean, Martian, Terrestrial and other ones). Influence of heavy oxygen ions with different properties on current sheet structure is analyzed. It is shown that high relative concentrations of oxygen ions, as well as their relatively high temperatures and flow drift speeds lead to a significant thickening of the sheet and a formation of an additional embedding scale. For some real parameters the profiles of self-consistent current densities and magnetic field have symmetrical jumps of derivatives, i.e. sharp changes of gradients. The comparison is made with observations in the Martian magnetosphere. The qualitative agreement of simulation results with observational data is shown.

# Thin current sheets with anisotropic pressure



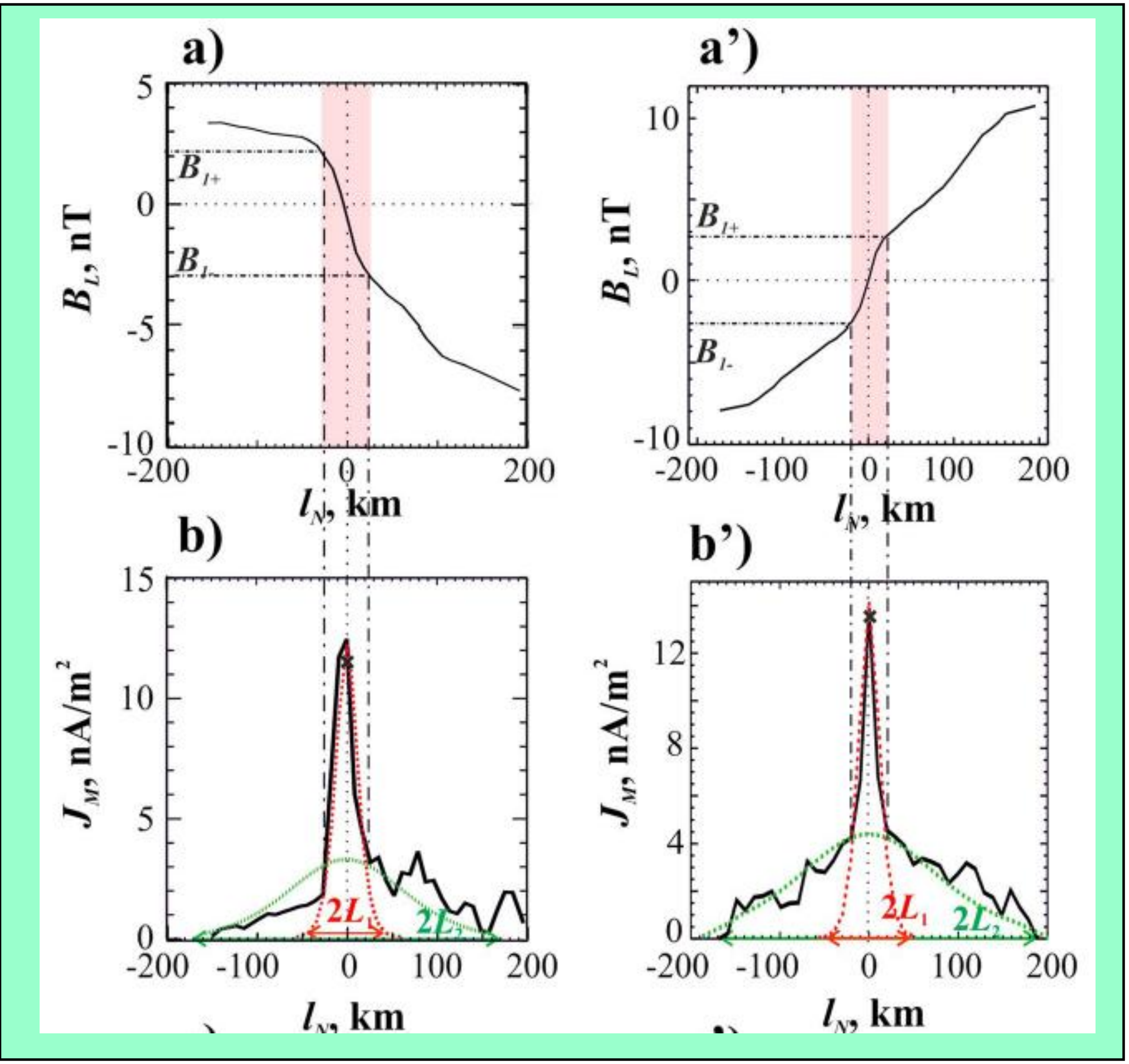

**Thin current sheets in planetary magnetospheres can be formed due to interaction of <u>ANISOTROPIC p</u>lasma streams from northern/southern plasma mantles**

**During substorms three essential plasma populations: $e^-$, $p^+$, $O^+$ are detected in lobes and plasma sheet of the Earth's magnetotail.**

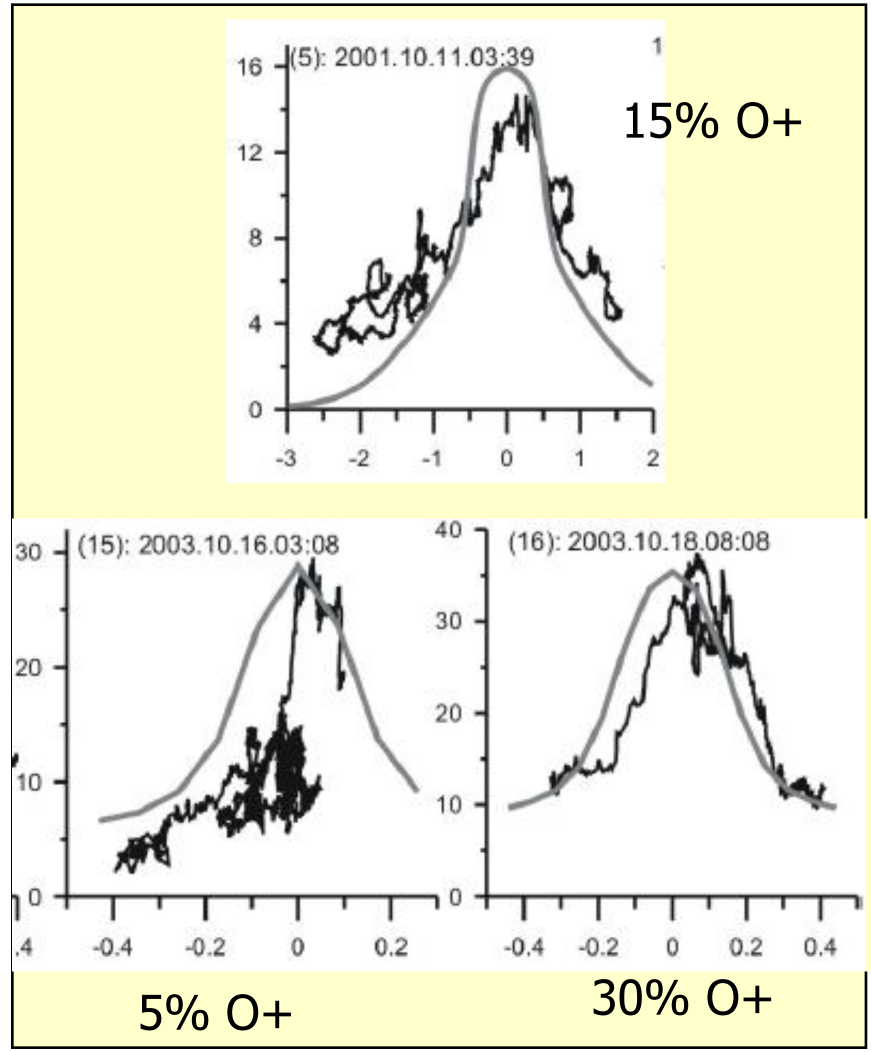
***ISEE 1-3, GEOS 1-2, Prognoz 8, Geotail, Cluster data are published in papers by*** **Shelley et al., JGR, 1972 ; Geiss et al., Space Sci. Rev., 1978 ; Dubinin et al.,1979; Chappell et al., JGR, 1987; Sharp et al., JGR, 1981, Vaisberg et al.,1981, Sauvaud, J.-A. and Kovragkin. JG R, 2004 and others.**

# Multiscale current sheets in planetary magnetospheres:

**Mars** (Maven data)
Grigorenko et al., JGR, 2017




**Earth** (Cluster data)
Artemyev et al., AnGeo, 2008



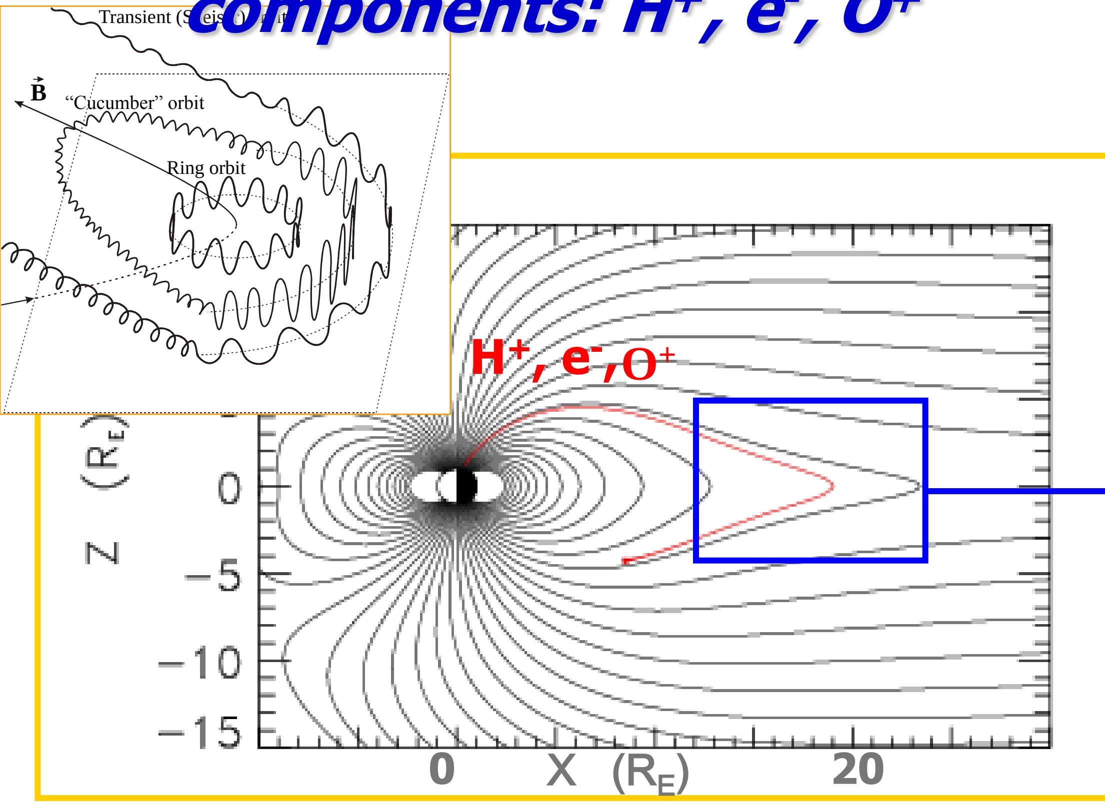
# *Some expectations about the possible role of $O^+$ ions in the structure and dynamics of thin current sheets in planetary magnetoitails:*

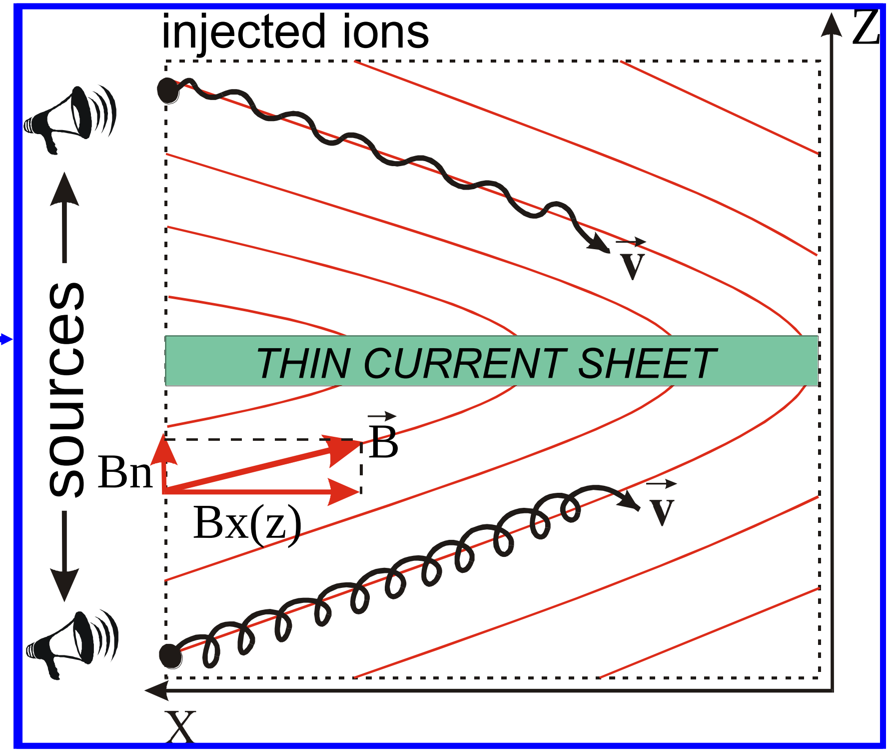
- **$O^+$ ions may play a role in substorm triggering ?**

  *(e.g., Baker et al., 1982 ; Cladis and Francis, 1992)*

- **$O^+$ ions may increase characteristic thickness of TCS ??!!**

# Multicomponent quasiadiabatic 1D current sheet model is constructed where plasma consists from three components: $H^+$, $e^-$, $O^+$




**The ion motion is quasi-adiabatic, but electrons are magnetized within current sheet**

$$I_z \equiv \frac{1}{2\pi}\oint m v_z dz \approx const$$

**The approximate INTEGRAL of motion for non-adiabatic trajectories makes the system of equations integrable:**

**QUASIADIABATIC APPROACH when** $\Delta I_z \ll I_z$

# General equations of model

$$f = const, \qquad \frac{dB}{dz} = \frac{4\pi}{c}\left\{\int_{V^3} v_y f(\vec{v}) d^3 v + J_{e\perp}\right\}$$

$$B(z = L) = B_0, \ \varphi(z = L) = 0$$

***Vlasov-Maxwell system of Eqs.***

$$I_z = \frac{2mc}{e}\mu; \qquad \mu = \frac{mv_\perp^2}{B_0}$$

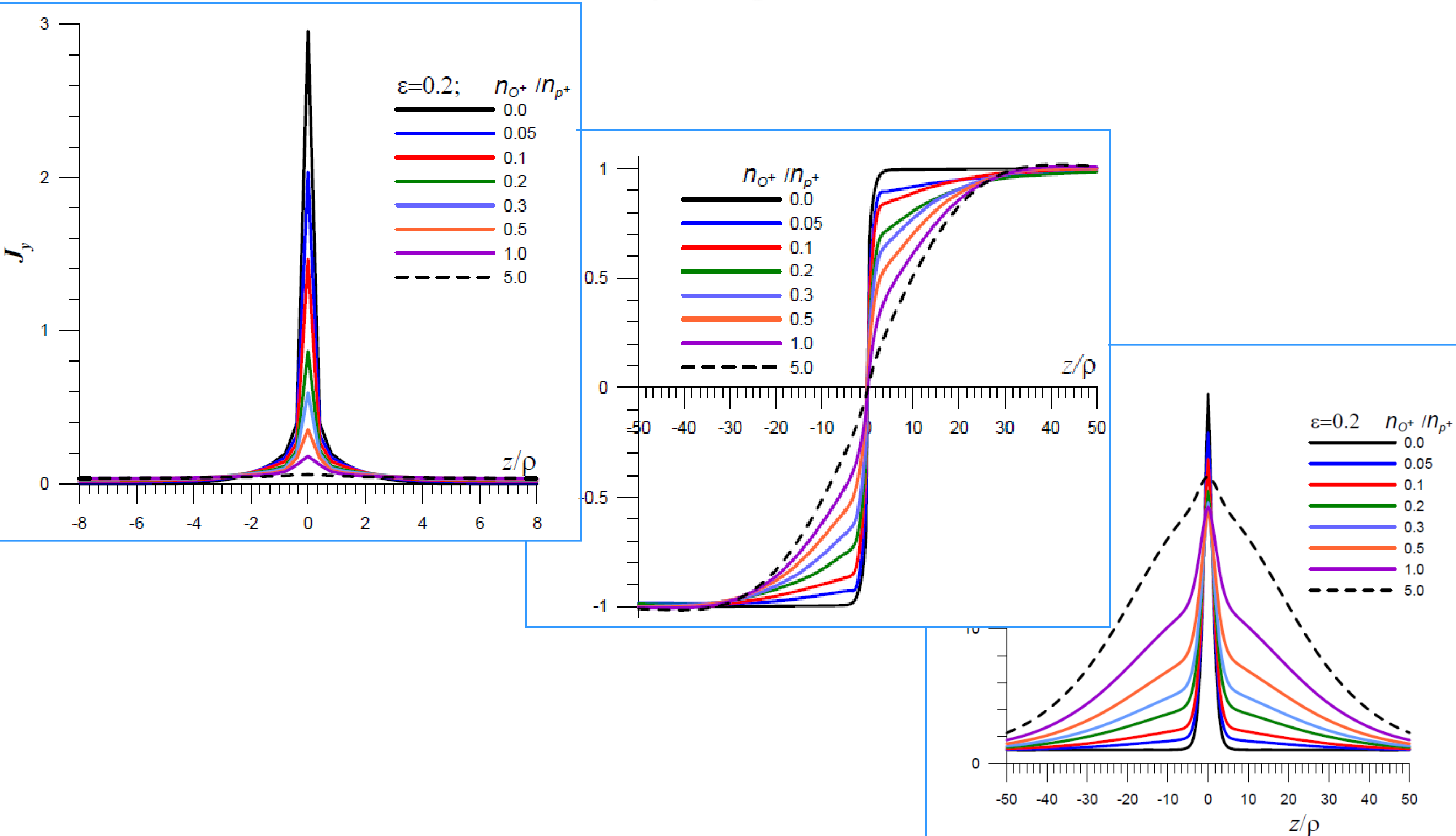
$$\Rightarrow \quad f_{p+,O+} \equiv f(v_{II}, v_\perp) \to f(v_0, I_z)$$

***distribution function $f_{p,O}$ may be re-written as function of integrals of motion $\{v_0, I_z\}$***

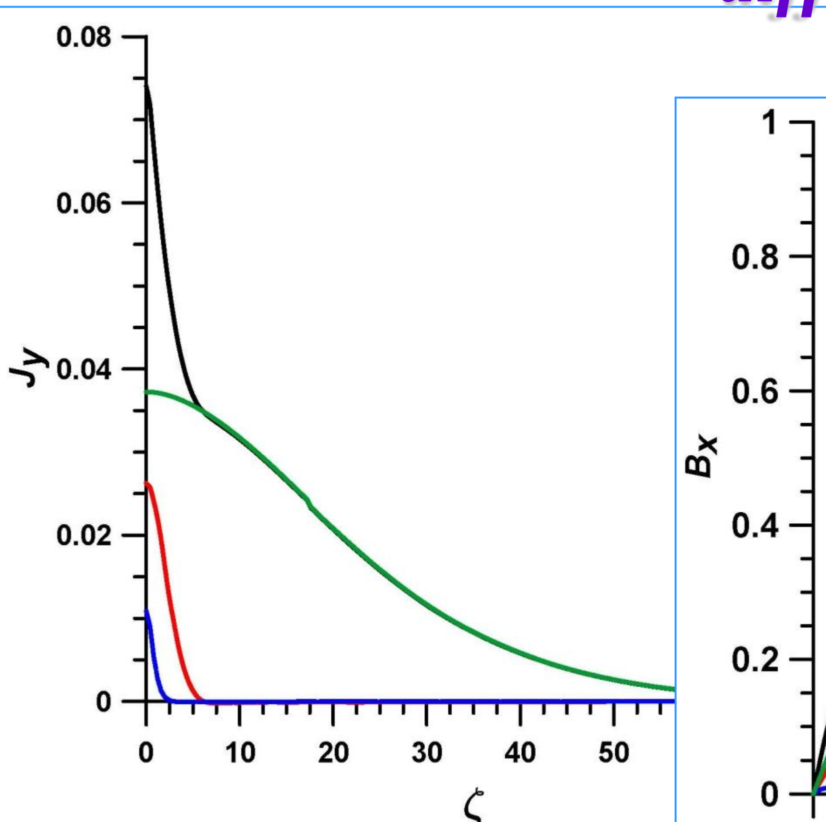
***Liouville theorem***

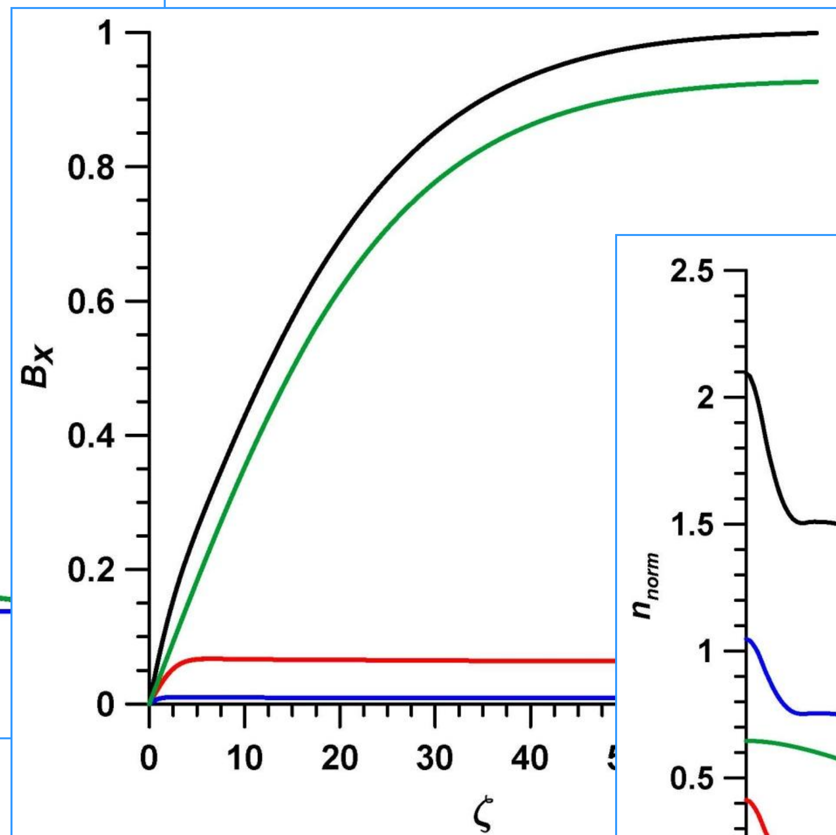
$$J_{e\perp} = -en_e c\frac{\left[\vec{E},\vec{B}\right]}{B^2} + \frac{c}{B^2}\left[\vec{B},\vec{\nabla}_\perp \tilde{p}_{\perp e}\right] + \frac{c}{B^4}\left(\tilde{p}_{IIe} - \tilde{p}_{\perp e}\right)\left[\vec{B},\left(\vec{B}\vec{\nabla}\right)\vec{B}\right]$$

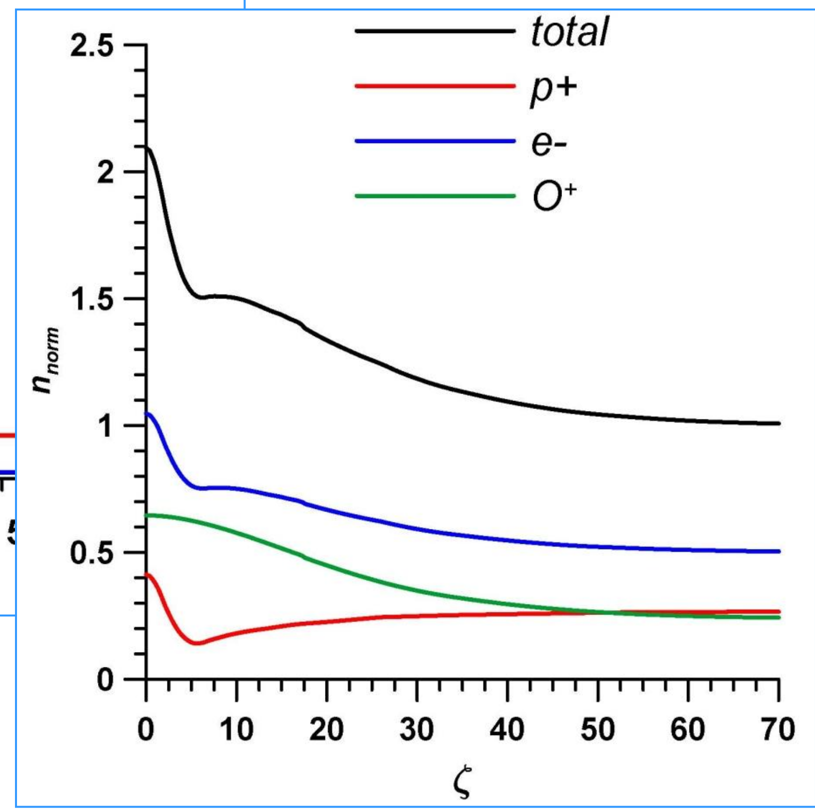
# *Self-consistent multi-scale profiles of current density, magnetic field and plasma density dependent from the concentration of heavy ions in planetary magnetotails*



# *Self-consistent profiles of embedded current sheets taking into account the partial contributions of different plasma components*



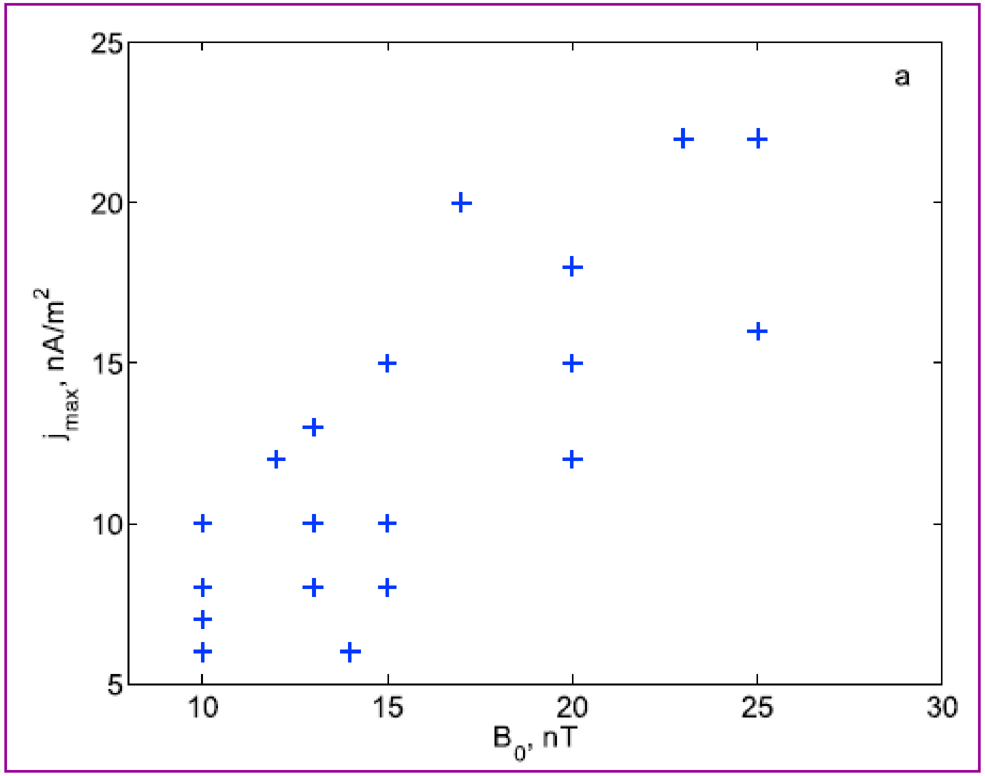



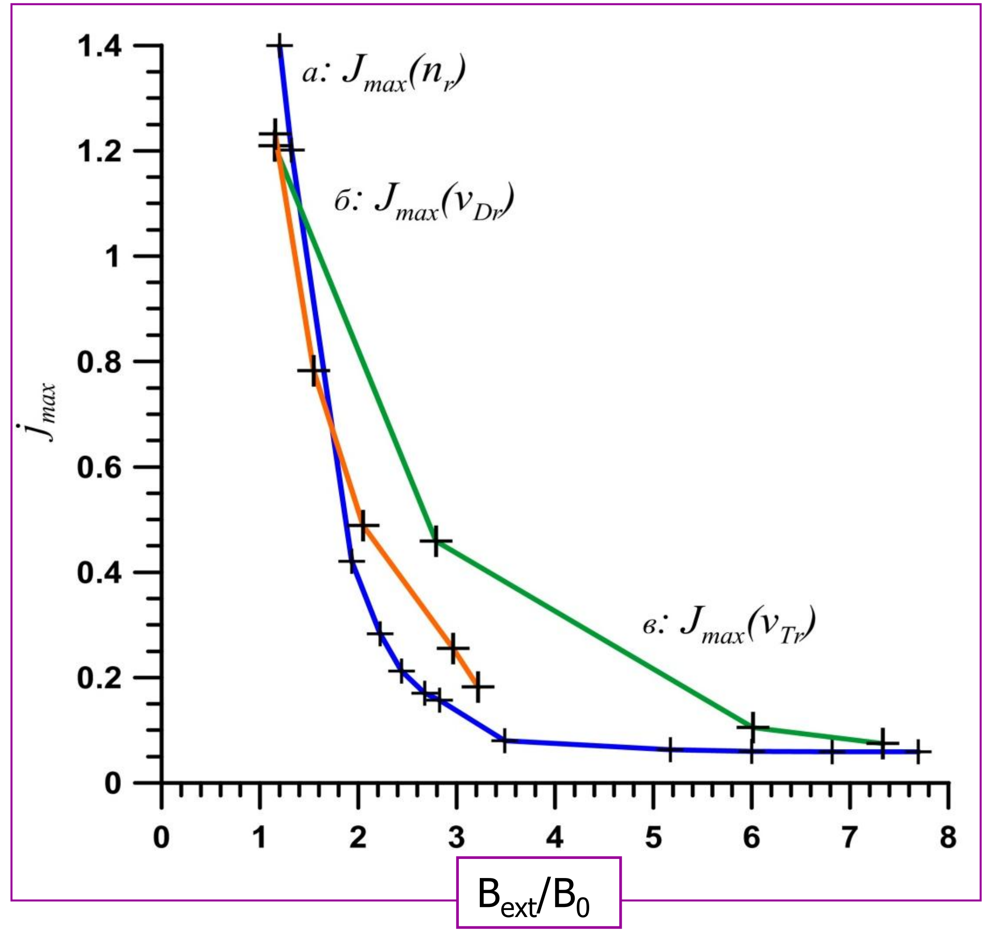

$$n_{O^+} / n_{H^+} = 0.9, \quad T_{O^+} / T_{H^+} = 1$$

$$\zeta = z / \rho_L$$

# *Dependence of the maximum current density on the embedding parameter* $J_{max}\left(B_{ext}/B_0\right)$




Petrukovich et al., JGR, 2011




Model results

# Conclusions

The effect of oxygen ions $O^+$ on the structure of the current layer in the tail of the magnetosphere can have the following manifestations:

- Increase of current sheet thickness;
- Decrease of maximum current density that is proportional to the density of $O^+$ ions in multi-component plasma;
- Formation of multiscale embedded current density and magnetic field profiles depending on the embedding coefficient Bext/B0.