К о н ф е р е н ц и я «Физика плазмы в солнечной системе»
14 - 18 февраля 2011 г., ИКИ РАН

Исследование устойчивости турбулентного плазменного слоя по данным проекта КЛАСТЕР.

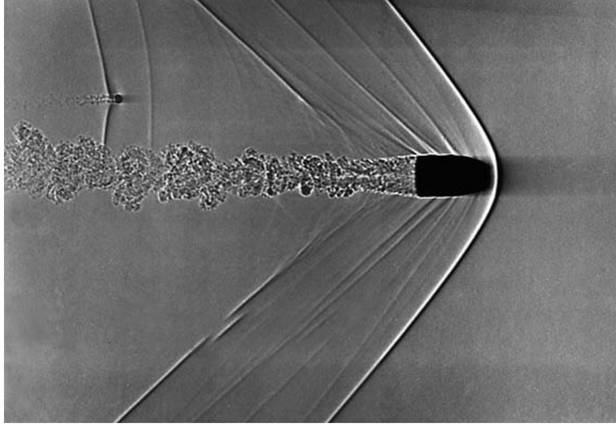
Степанова М.В. (1), Антонова Е.Е. (2,3) , Овчинников И.Л. (2)

(1) University of Santiago de Chile

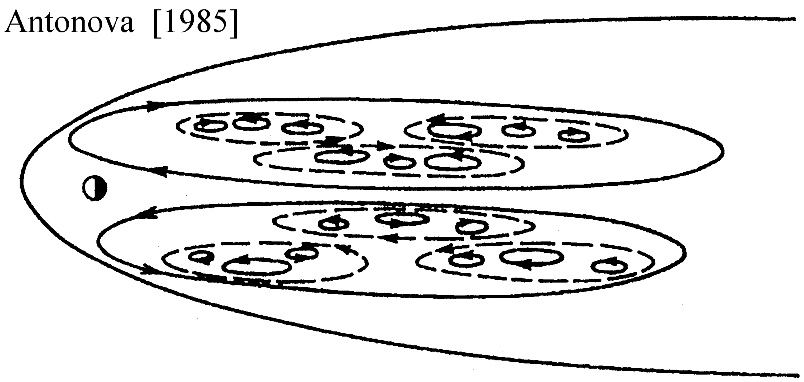
(2) НИИЯФ, МГУ

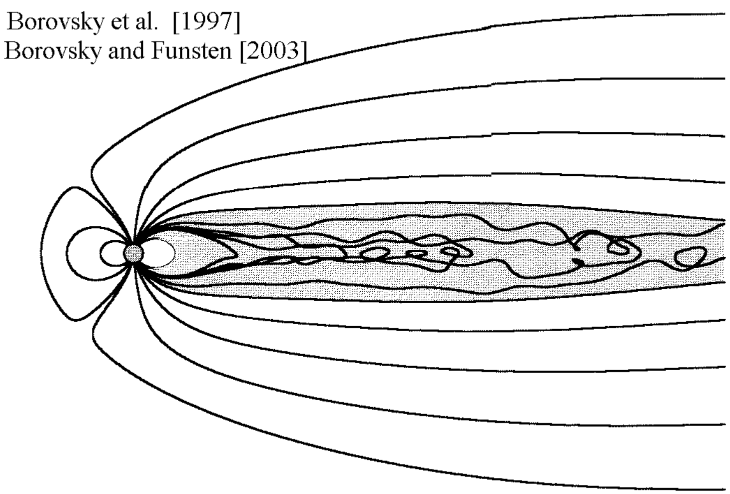
(3) ИКИ, РАН

If Re>>1 the turbulent wake is formed behind an obstacle.

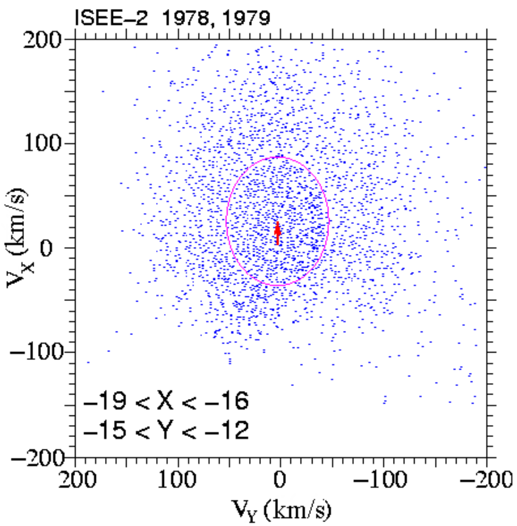


Magnetospheric tail can be considered as a turbulent wake behind an obstacle.
Very high values of Reynolds numbers (larger than 10^{10} Borovsky and Funsten, 2003).
Such turbulent wake should be formed even in case of laminar solar wind flow.

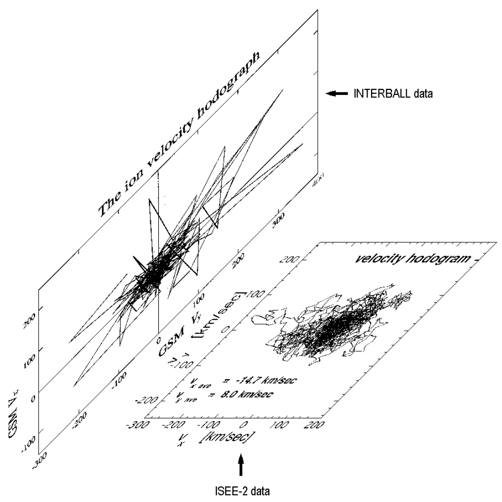




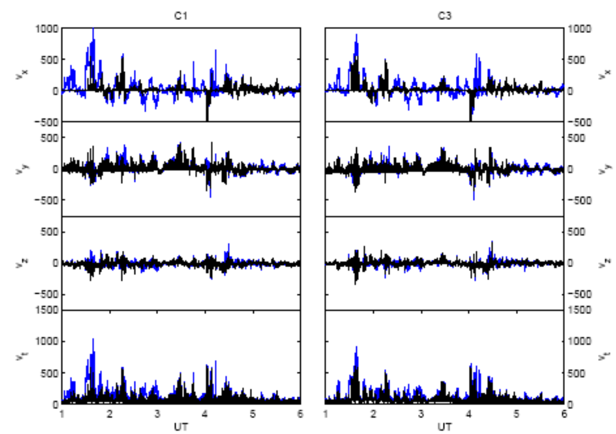
Velocity and magnetic field fluctuations are studied by Angelopoulos et al. (1992, 1993, 1996, 1999); Borovsky et al. (1997, 1998), Antonova et al. (2000, 2002); Ovchinnikov et al. (2002), Neagu et al. (2001, 2002); Troshichev et al. (2001, 2002); Petrukovich and Yermolaev (2002); Borovsky and Funsten (2003a,b); Voros et al. (2003); Volwerk et al. (2004); Goldstein (2005); Weygand et al. (2005); Stepanova et al. (2005, 2009) etc.



ISEE-2 results (Angelopoulos et al., 1993)

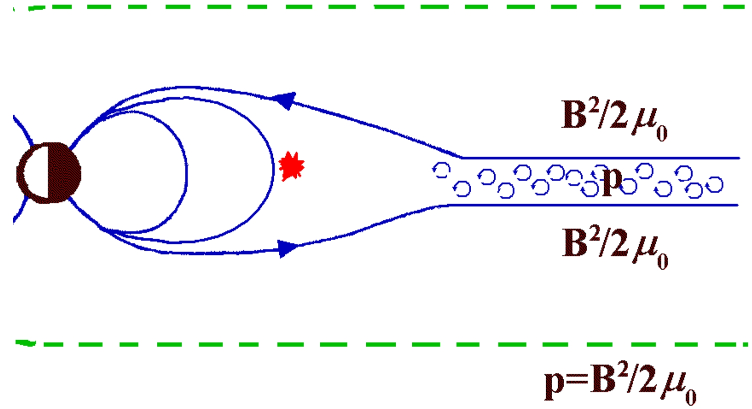


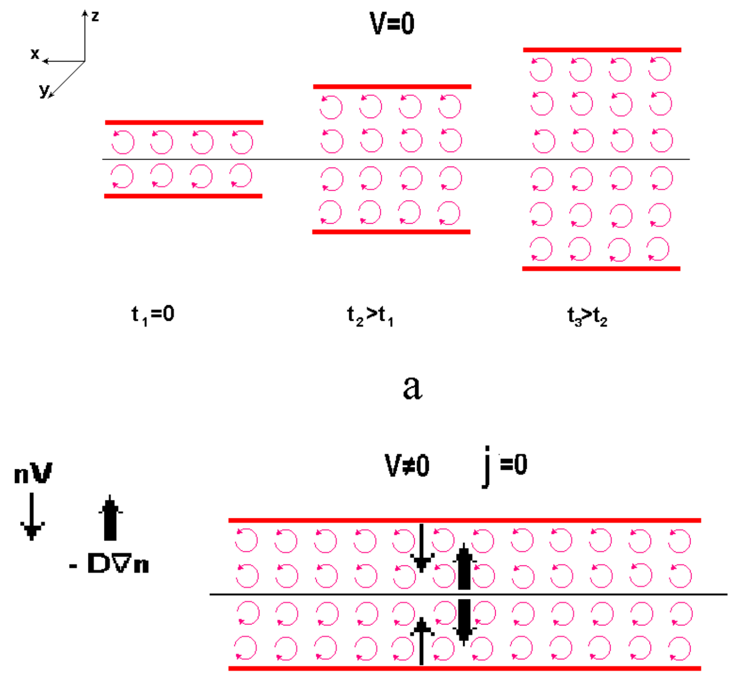
Interball/Tail probe results (Antonova et al., 2000, 2002)



CLUSTER results (Volwerk et al., 2004)

The interaction of large an medium-scale harmonics gives the possibility to explain the existence of the pressure balance across the plasma sheet/tail lobes supported by many measurements (Michalov et al. [1968], Stiles [1978], Spence et al. [1989], Tsyganenko [1990], Baumjohann et al. [1990], Kistler et al. [1993], Petrukovich [1999], Tsyganenko and Mukai [2003]) in spite of the observed turbulence.



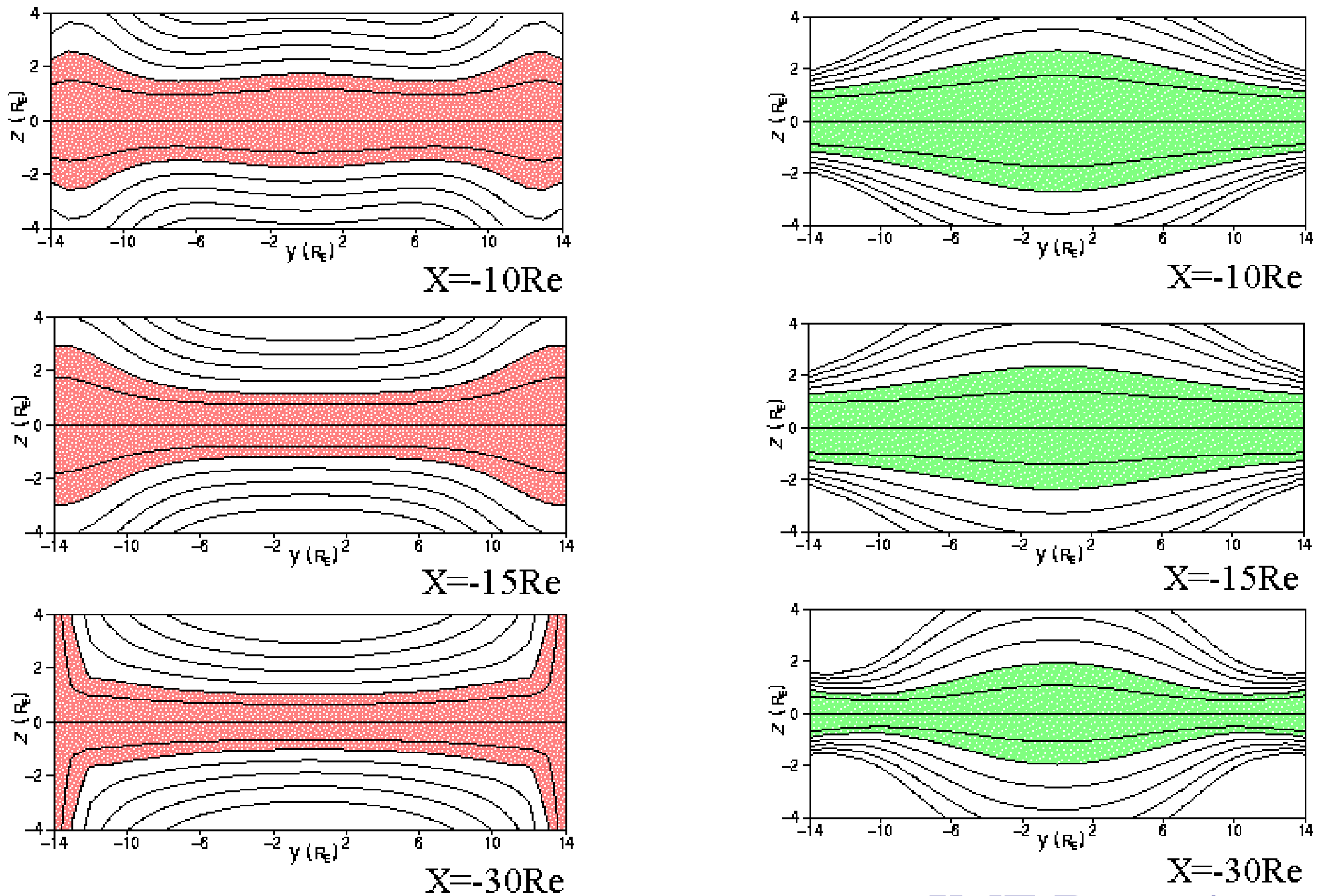


а

б

Antonova and Ovchinnikov [1996, 1999, 2003] model

$$\mathbf{S} = n\,\langle \mathbf{V} \rangle - D\nabla n\ ,$$



IMF Bz<-4 нТ

IMF Bz>+4

The regular plasma transport related to the regular dawn-dusk electric field across the plasma sheet is compensated by the eddy diffusion turbulent transport.

$$D = \frac{V_{\mathrm{rms}}{}^{2}\,\tau_{\mathrm{auto}}}{2}$$

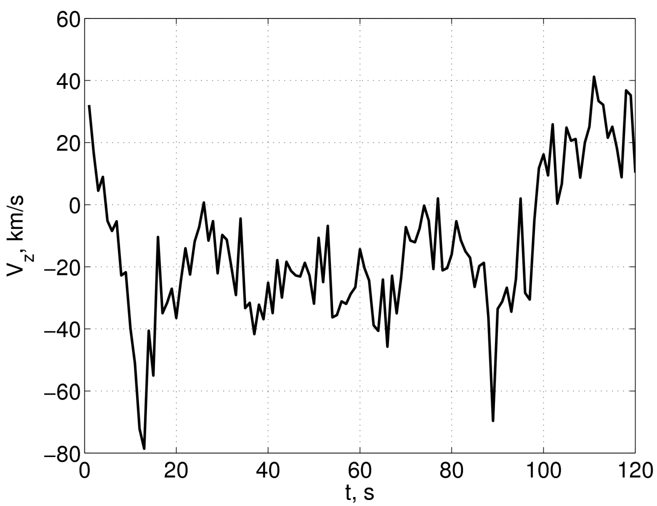
$$A_{\alpha\beta}(\tau) = \frac{\sum \left(V_\alpha(i) - \langle V_\alpha \rangle\right)\left(V_\beta(i+\tau) - \langle V_\beta \rangle\right)}{\sqrt{\sum \left(V_\alpha(i) - \langle V_\alpha \rangle\right)^2}\sqrt{\sum \left(V_\beta(i) - \langle V_\beta \rangle\right)^2}},$$

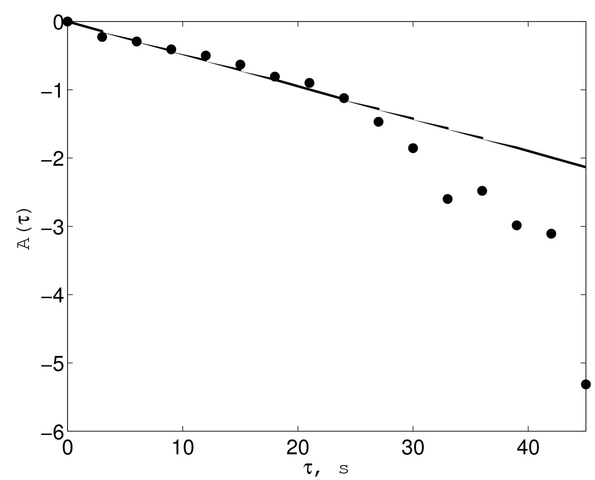
$$\langle V_\alpha \rangle = \frac{1}{N}\sum_{i=1}^{N} V_\alpha(i).$$

$$A_{\alpha\beta}(\tau) = \exp(-\tau/\tau_{\alpha\beta})$$

$$V^2_{rms,\alpha\beta} = \frac{1}{N}\sum (V_\alpha(i) - \langle V_\alpha \rangle)(V_\beta(i) - \langle V_\beta \rangle),$$

Borovsky, J.E. (1997, and much more)
Antonova and Ovchinnikov (1997)
Stepanova et al. (2008, 2009)





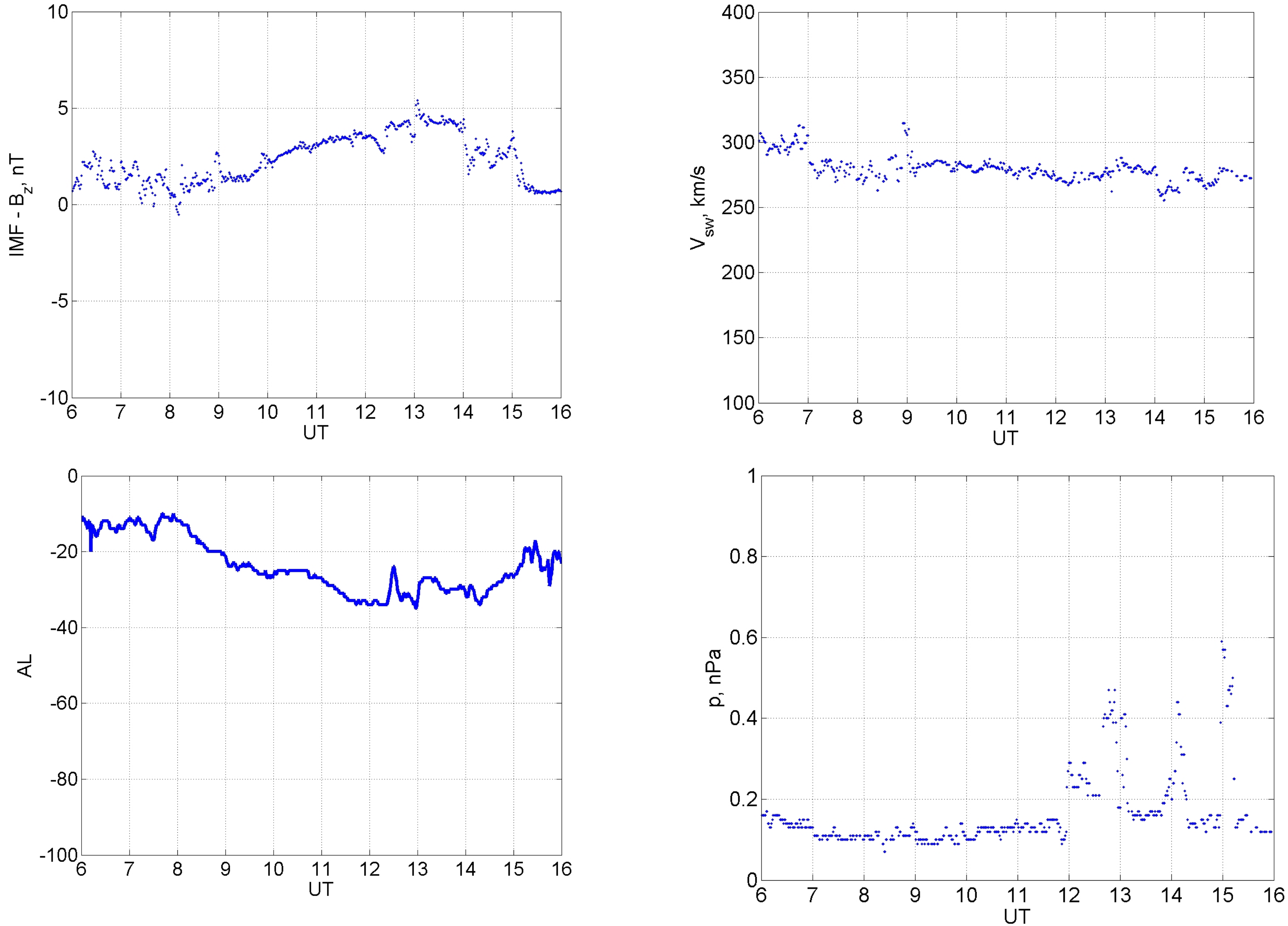
September 12, 2004 event: Cluster satellite mission

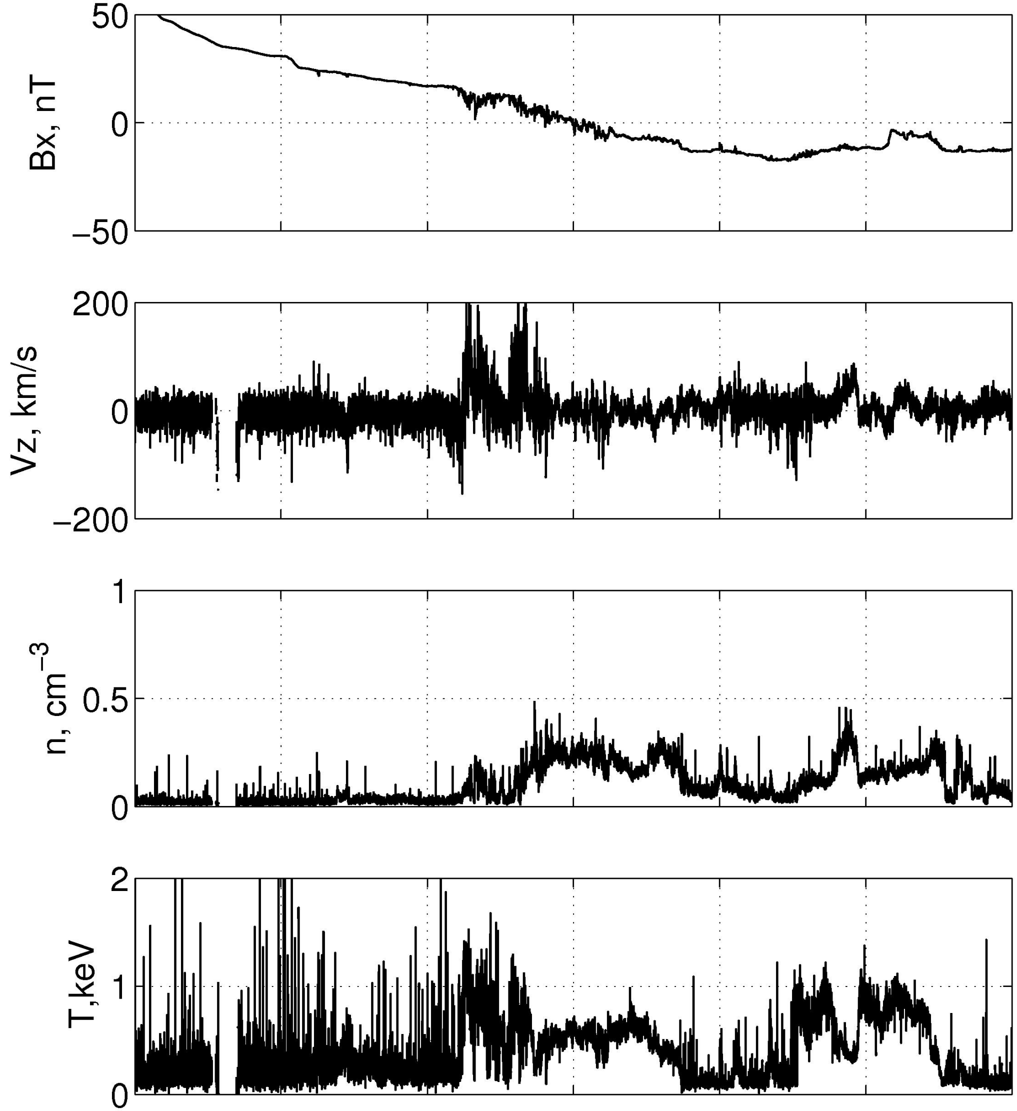
FGM – fluxgate magnetometer, three components of geomagnetic field

CIS - Cluster Ion Spectroscopy experiment, three components of bulk velocity, number density and temperature.

Main goal: Study of quiet time plasma sheet turbulence, in particular the variation of the eddy diffusion coefficients across the plasma sheet and the influence of the dawn-dusk electric field

September 12, 2004. Really quiet time event. OMNI 1 minute resolution.



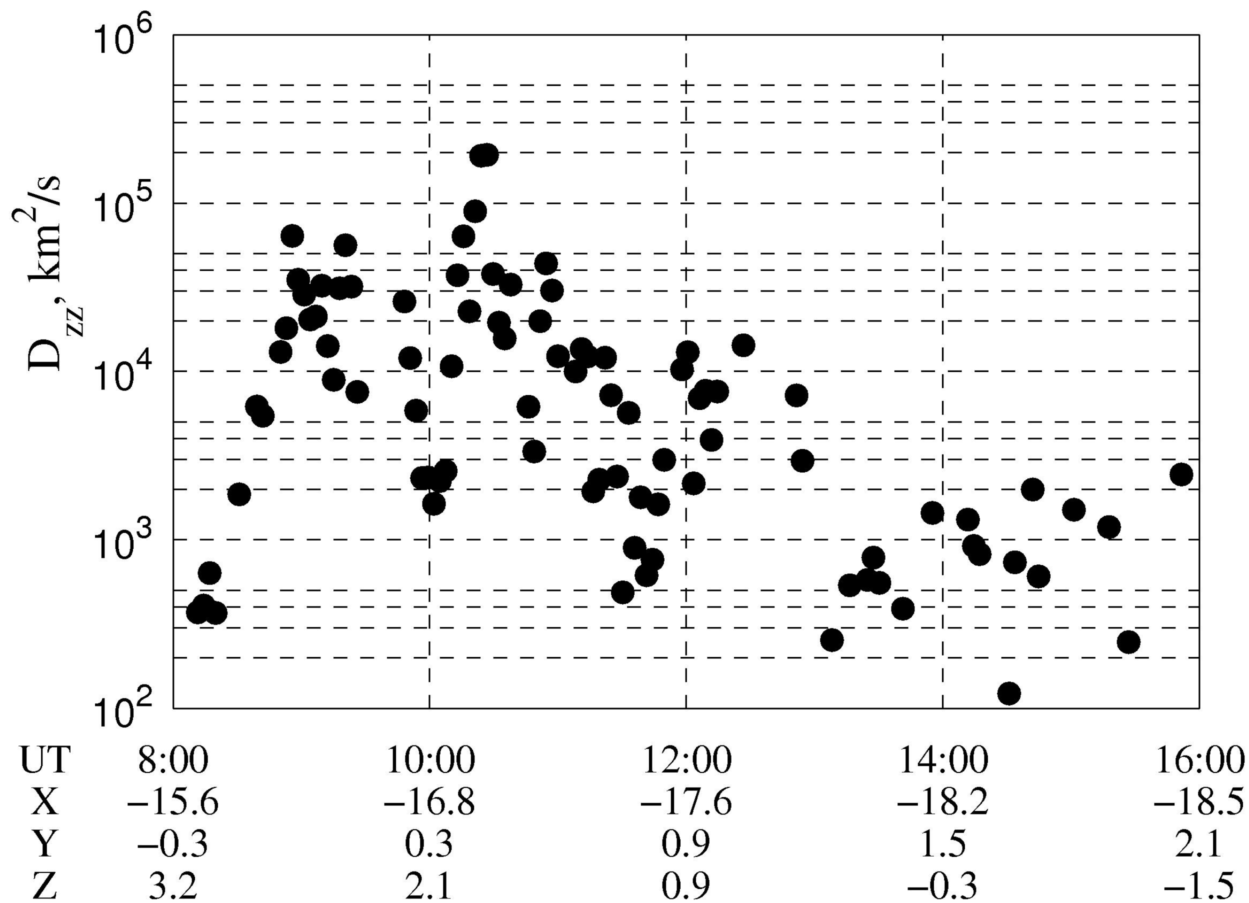


UT	0:00	4:00	8:00	12:00	16:00	20:00	24:00
X	−7.6	−12.4	−15.6	−17.6	−18.5	−18.5	−17.7
Y	−2.4	−1.4	−0.3	0.9	2.1	3.1	4.0
Z	6.7	5.3	3.2	0.9	−1.5	−3.9	−6.1

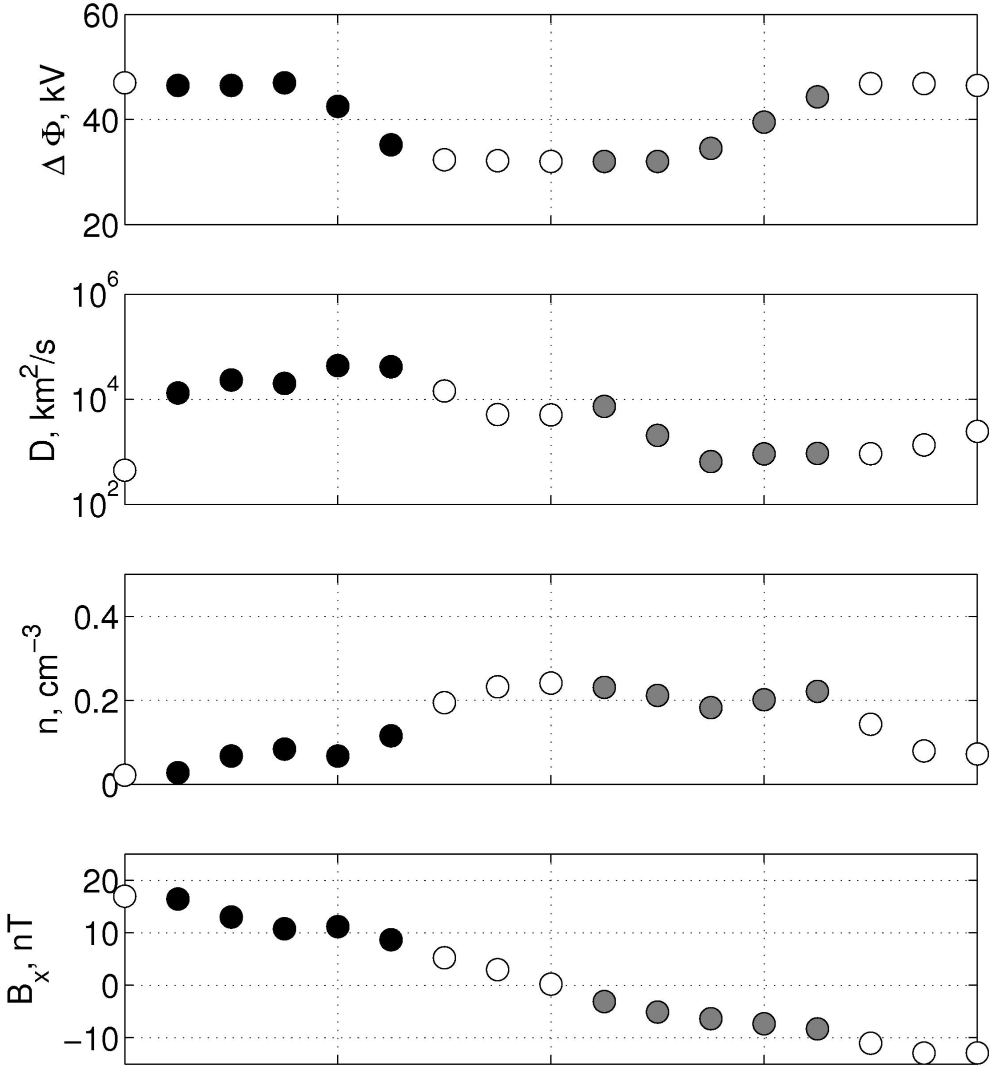
Quiet time event, September 12, 2004 Doy 256

Resume:

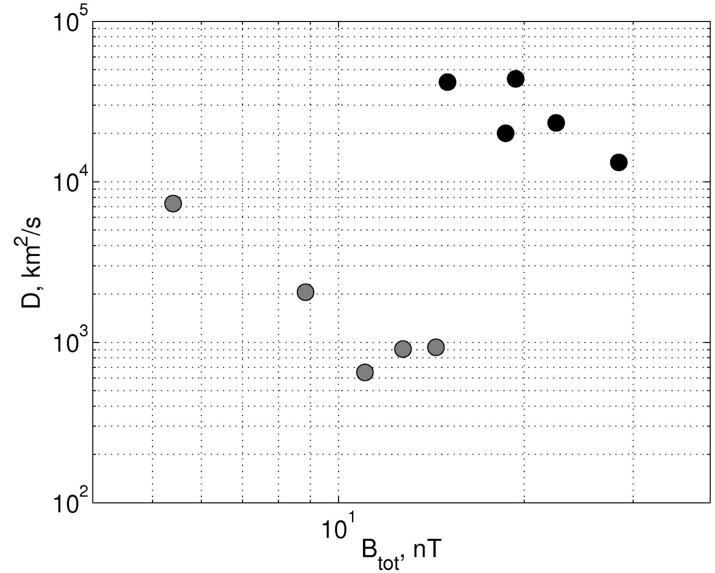
1. Dst>-20 nT
2. AL>-30 nT
3. Bz>0 nT
4. Vsw<280 km/s



D_{zz}, km^2/s
10^6
10^5
10^4
10^3
10^2
UT 8:00 10:00 12:00 14:00 16:00
X −15.6 −16.8 −17.6 −18.2 −18.5
Y −0.3 0.3 0.9 1.5 2.1
Z 3.2 2.1 0.9 −0.3 −1.5



UT	8:00	10:00	12:00	14:00	16:00
X	−15.6	−16.8	−17.6	−18.2	−18.5
Y	−0.3	0.3	0.9	1.5	2.1
Z	3.2	2.1	0.9	−0.3	−1.5



$$D(B) = (4.5 \pm 0.8) \cdot 10^6 \cdot B^{(-1.7 \pm 0.7)}$$

$$D(B) = (0.33 \pm 0.03) \cdot 10^6 \cdot B^{(-2.3 \pm 0.5)}$$

$$V = \Delta\Phi / (L_{tail} B_L) \longrightarrow 10 \text{ km/s}$$

$$L = D/V \longrightarrow 1.5 \text{ R}_E.$$

$$\mathbf{S} = n \langle \mathbf{V} \rangle - D \nabla n \, ,$$

Заключение

- Турбулентность в центральном плазменном слое существует даже при спокойных геоманитных условиях
- Основные параметры этой турбулентности, включая коэффициент квазидиффузии, находятся в хорошем согласии с предсказаниями теории турбулентного плазменного слоя (Antonova, Ovchinnikov, 1996, 1999, 2003)