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Statistical study of Alfvénic fluctuations in the Earth magnetosheath

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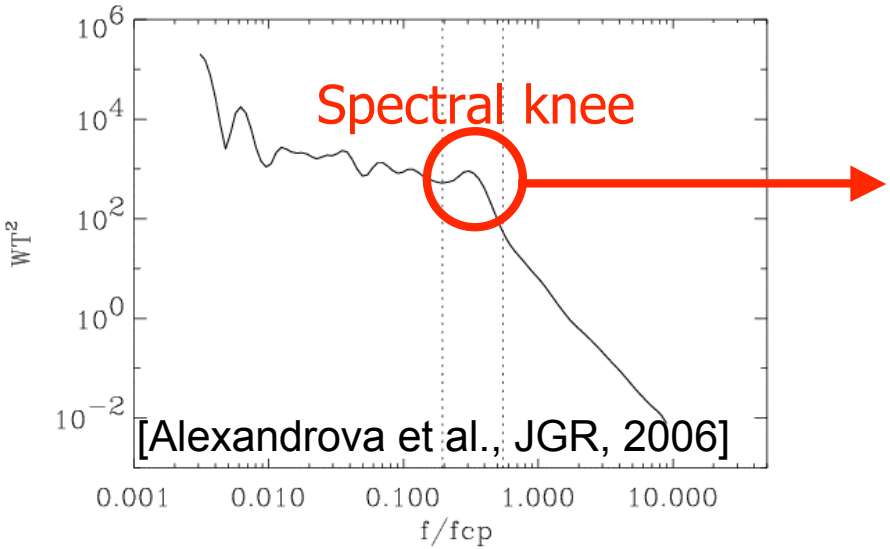
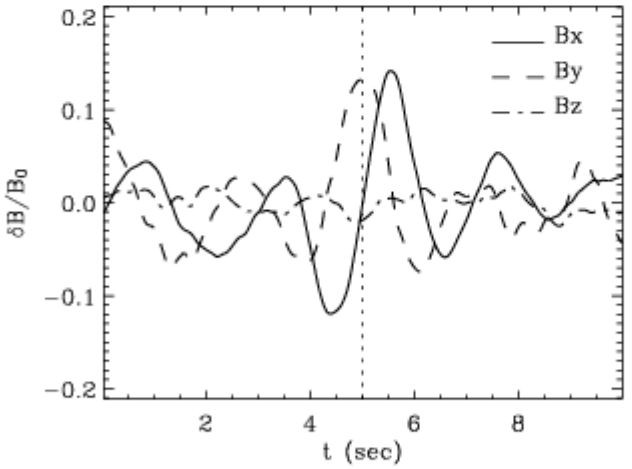
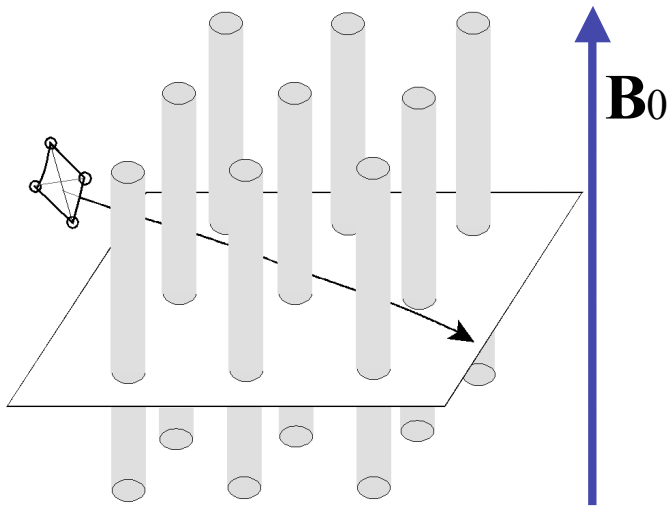
1. Motivation – observation of Alfvén vortices in the Earth magnetosheath







Alfvenic fluctuations $\delta B_\perp > \delta B_{||}$

- $\delta B_\perp \,||\, \delta V_\perp$
- $\omega=0$, $k \perp B_0$, section ~ 20 c/ω_{pi}
- the axis || $\mathbf{B}_0 \Rightarrow \mathbf{k}_{\text{min var}} \,||\, \mathbf{B}_0$
- $\delta n \sim 0$, $\delta B_{||} \sim 0$
- quasi-perpendicular propagation with $V \ll V_A$
- Observations (thanks to CLUSTER space resolution) at time scales from 2 to 10 seconds

2. The goal of statistical study

Establish the rules of appearance of Alfvén vortices in the Earth magnetosheath as a function of

- the position in the magnetosheath
- the local plasma parameters
  - Plasma β
  - Angle between the plasma flow and the mean field Θ_{BV}
  - Mean field amplitude B_0
  - Temperature anisotropy of the ions $T_{\perp}/T_{||}$
- the shock parameters
  - Angle between the shock normal and the IMF direction Θ_{BN}
  - Alfvenic Mach number $M_a = V/V_A$
  - Magnetosonic Mach number M_s
- the upstream solar wind parameters
  - Amplitude of B_{IMF}
  - Solar wind pressure ρV^2
  - Concentration of α–particles
  - Angle between the solar wind velocity and the IMF Θ_{BV}^{sw}

3. Data and tests

We use 2 months of CLUSTER data (01/02/2001-31/03/2001)

- 0.2 sec FGM data
- Onboard CIS/HIA moments
- Held in a multi-instrument, CLUSTER specialised database DD-CLUSTER, http://manunja.cesr.fr/DD_SEARCH
- In the solar wind, we use ACE data

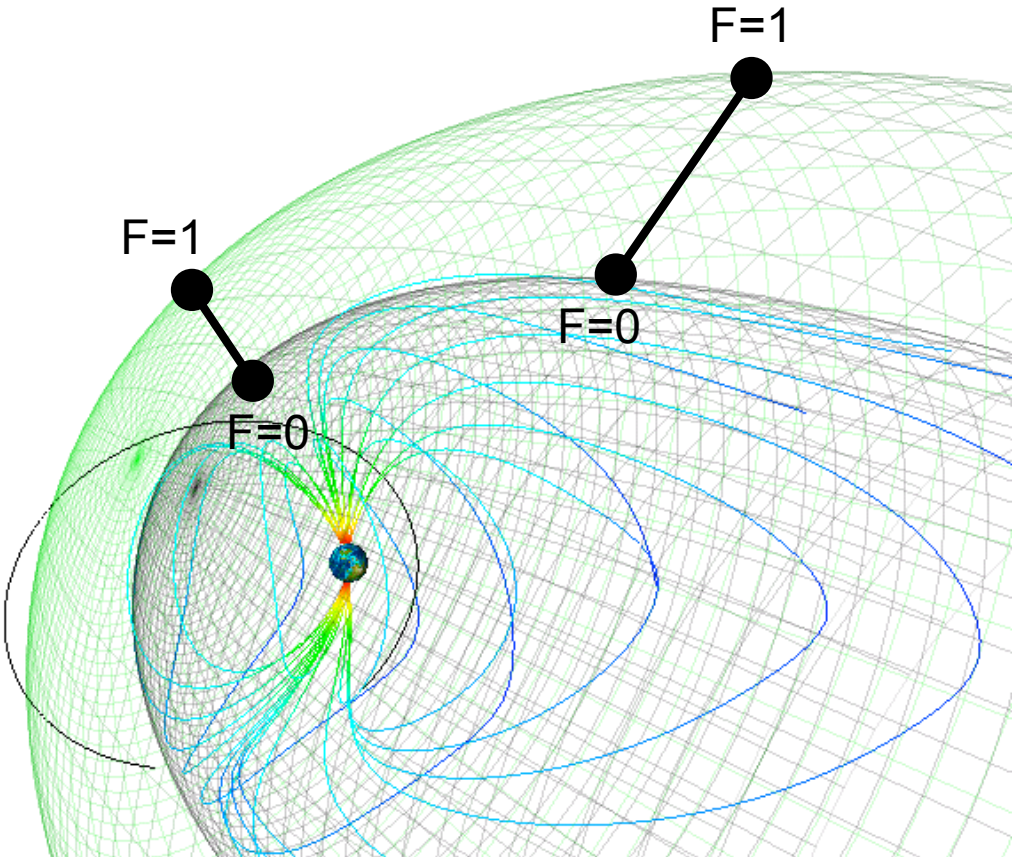
Test magnetosheath/solar wind :

- magnetic field increases across the bow-shock $\Rightarrow$ $|B|_{Cluster}/|B|_{ACE}>1.3$
- when $B_0 \parallel X_{GSE}$ there is no significant changes in |B|, so we verify that the angle $\Theta_{BV}<20^o$ or $\Theta_{BV}>160^o$

Magnetosheath boundaries and fractional distance

$$F_{\mathrm{mipm}} = \frac{r - r_{\mathrm{MP}}(\vartheta_{\mathrm{mipm}} | \rho V^2, B_z)}{r_{\mathrm{BS}}(\vartheta_{\mathrm{mipm}}, \varphi_{\mathrm{mipm}} | M_{\mathrm{a}}, M_{\mathrm{s}}, \vartheta_{\mathrm{bv}}) - r_{\mathrm{MP}}(\vartheta_{\mathrm{mipm}} \mid \rho V^2, B_z)}.$$

- $\mathbf{r}_{mp}$ is the magnetopause position, that depends on ρV^2 and B_z [Shue et al,1998]
- $\mathbf{r}_{BS}$ is the bow shock position, that depends on the Mach numbers M_a and M_s; and on the angle Θ_{BV} in the solar wind [Verigin et al., 2001, 2003, 2006]
- For a position **r** inside the magnetosheath, the fractional distance F is between 0 (MP) and 1 (BS)



4. Data analysis

Definitions

- δB : magnetic fluctuations on time scale τ
- $\delta B_{||}$: longitudinal fluctuations
- $\delta B^2_{\perp}$: energy of transverse fluctuations
- A_B : anisotropy of magnetic fluctuations

$$\delta \mathbf{B} = \mathbf{B} - \langle \mathbf{B} \rangle_\tau$$

$$\delta B_{||} = \frac{\delta \mathbf{B} \cdot \mathbf{B}_0}{B_0}$$

$$\delta B_\perp^2 = \sum_{i=x,y,z} \delta B_i^2 - \delta B_{||}^2$$

Identification method

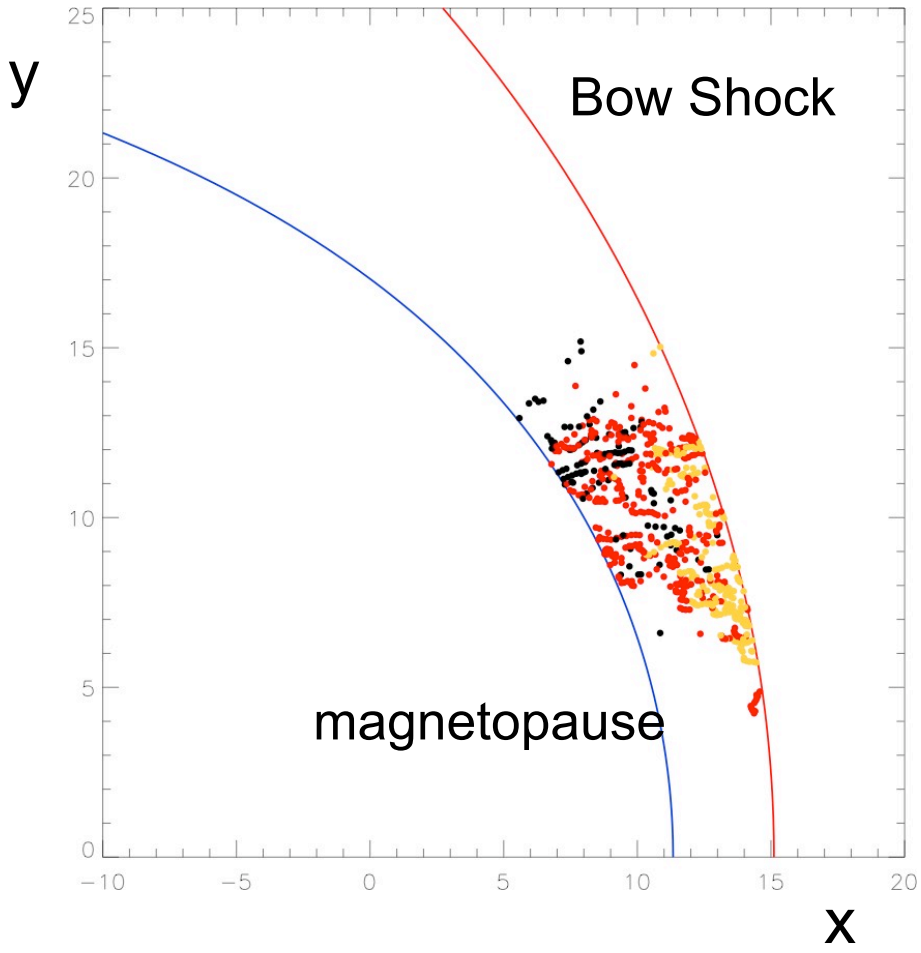
$$T \gg \tau$$

$$A_B = \frac{\langle \delta B_\perp^2 \rangle_T}{\langle \delta B_{||}^2 \rangle_T}$$

- test on the magnetic anisotropy : $A_B > 1$
- test on the minimum variance direction : $\Theta_{Bminv} < 30^o$

Preliminary results

We consider δB on time scale τ = 5 sec with T=300 sec



GIPM reference frame:

x - aberrated X_{gse}

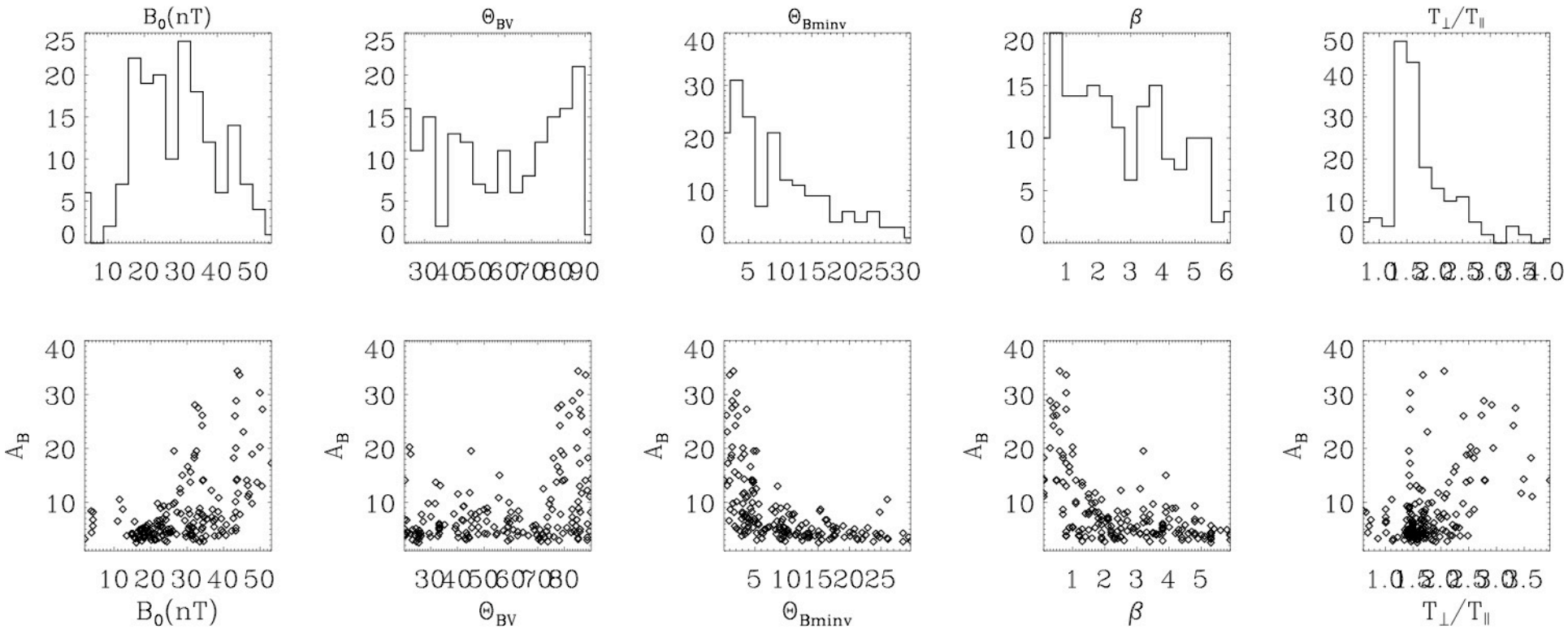
y - || or anti-|| to the projection of the IMF on $(YZ)_{gse}$ plane

• Red circles :
conditions are verified

• Black circles :
conditions are not verified

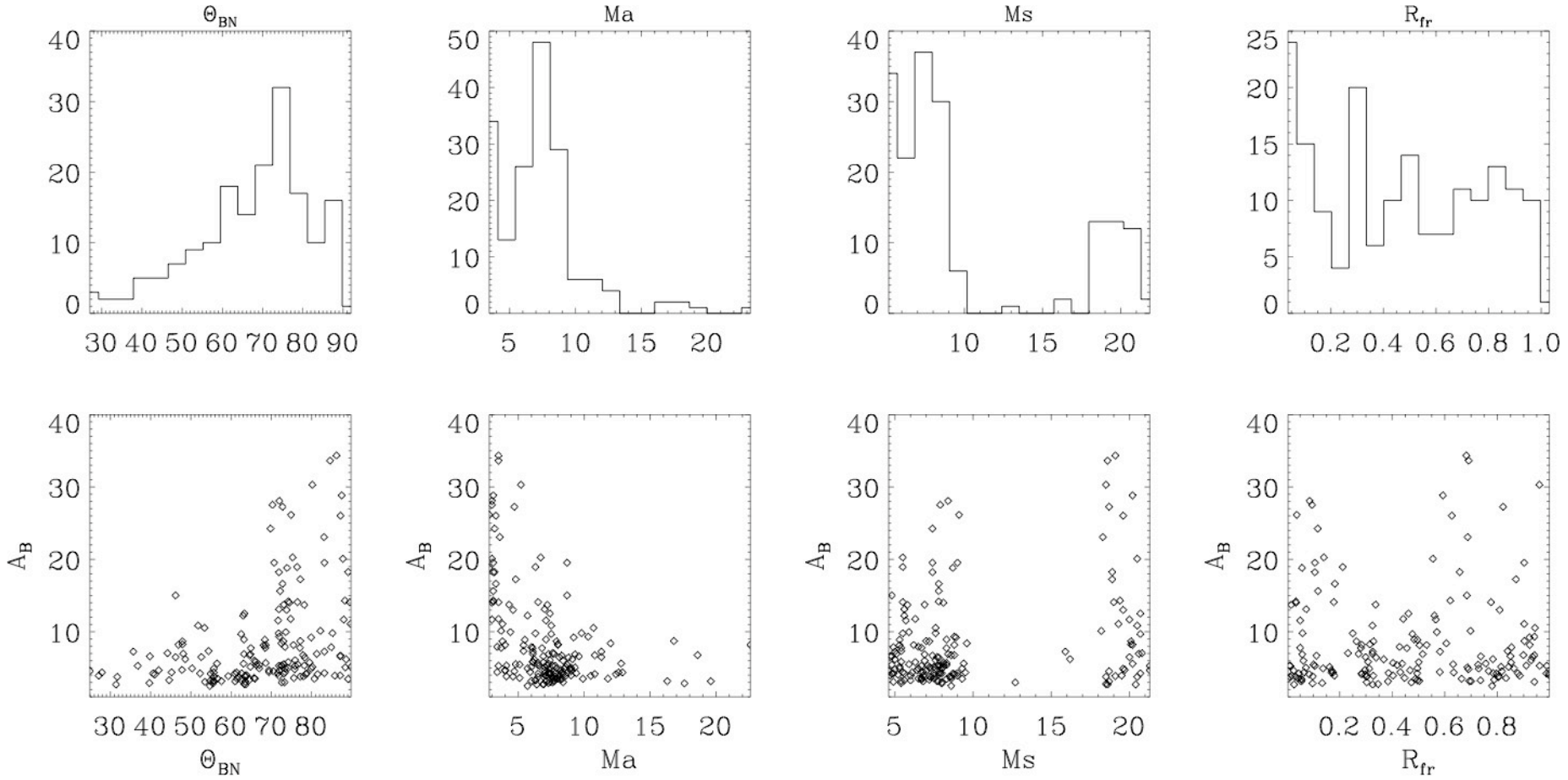
• Yellow circles :
Cluster is in the solar wind, but the model indicates the magnetosheath

- Alfvenic fluctuations at scale τ=5 sec as a function of the local plasma parameters (B_0, Θ_{BV}, Θ_{Bminv}, β, $T_\perp/T_{||}$)



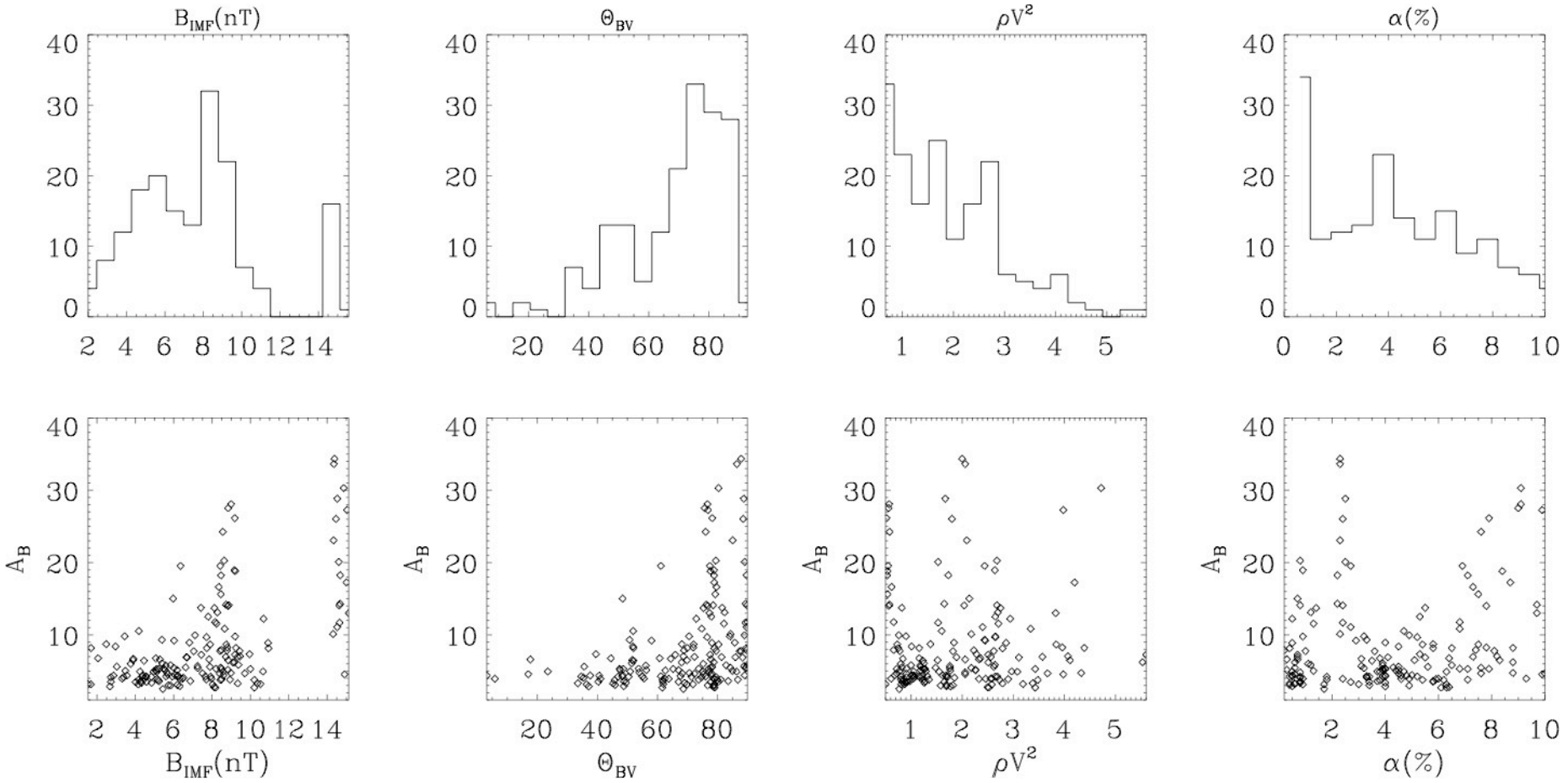
– A_B seems to increase with B_0, with Θ_{BV} and with $T_\perp/T_{||}$
– A_B seems to decreases with Θ_{Bminv} and with β

- Alfvénic fluctuations (τ=5 sec) as a function of the the shock parameters (Θ_{BN}, M_a, M_s) and the fractional distance R_{fr}



  - The conditions are verified especially for Q-$\perp$ bow-shocks, increase with Θ_{BN} ; decrease with M_a (~ upstream β)
  - No dependence on the distance from the shock (on R_{fr})

- Alfvénic fluctuations (τ=5 sec) as a function of the upstream solar wind parameters (B_{IMF}, Θ_{BV}, ρV^2, α-particules)



  - No clear dependencies on SW-pressure and α-particles abundance
  - Dependence on IMF : A_B seems to increases with Θ_{BV} and with B_{IMF}

Conclusions

- At time scale τ = 5 sec (i.e. f=0.2 Hz, just below f_{ci}) the magnetic fluctuations becomes more Alfvenic when
  - B_0 increases (in the sw and in the magnetosheath) & β decreases
  - Angle between B_0 and the min variance direction Θ_{Bminv} decreases
  - Angle Θ_{BV} increases (in the sw and in the magnetosheath)

- The anisotropic Alfvenic fluctuations appear preferentially downstream of Q$\perp$ bow-shocks (Θ_{BN} is correlated with Θ_{BV} in the solar wind)
- These fluctuations are independent on the position in the magnetosheath

Perspectives

- Analysis of other time periods
- Analysis of different time scales (up to 1 second)
- Spectral shape test (?)