A « Brief review » of ongoing S/WAVES studies at the Paris Observatory

M. Maksimovic, Lesia, Paris Observatory

<u>Type III associated Langmuir waves</u>

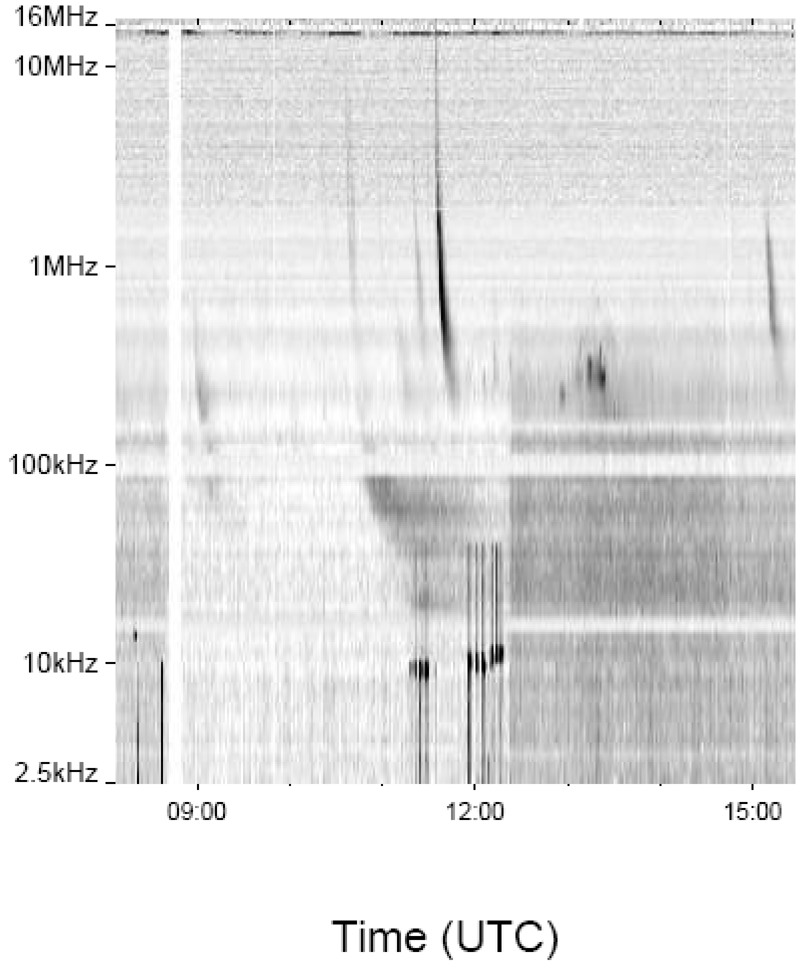
- **Langmuir Waves and simulations of their decay : Henri et al.**
- **Simulation on the spatial localization of Langmuir Waves : Zaslavsky et al.**

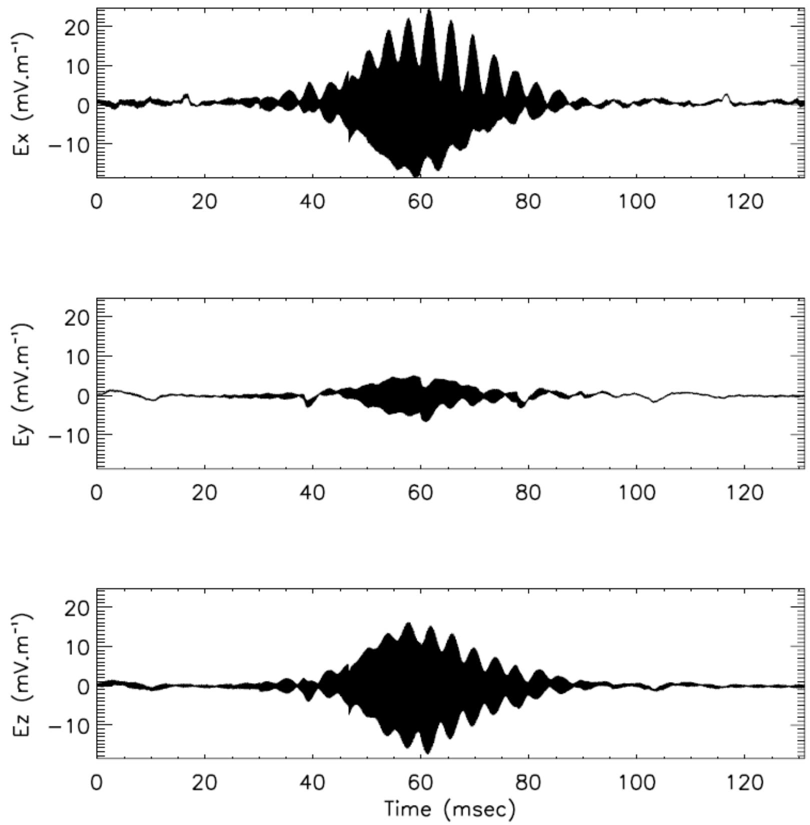
- **Magnetic holes in the solar wind: Briand et al.**
- **Nano-dust : Meyer-Vernet et al.**

- ***Direction Finding and Type III source sizes : Krupar et al.***

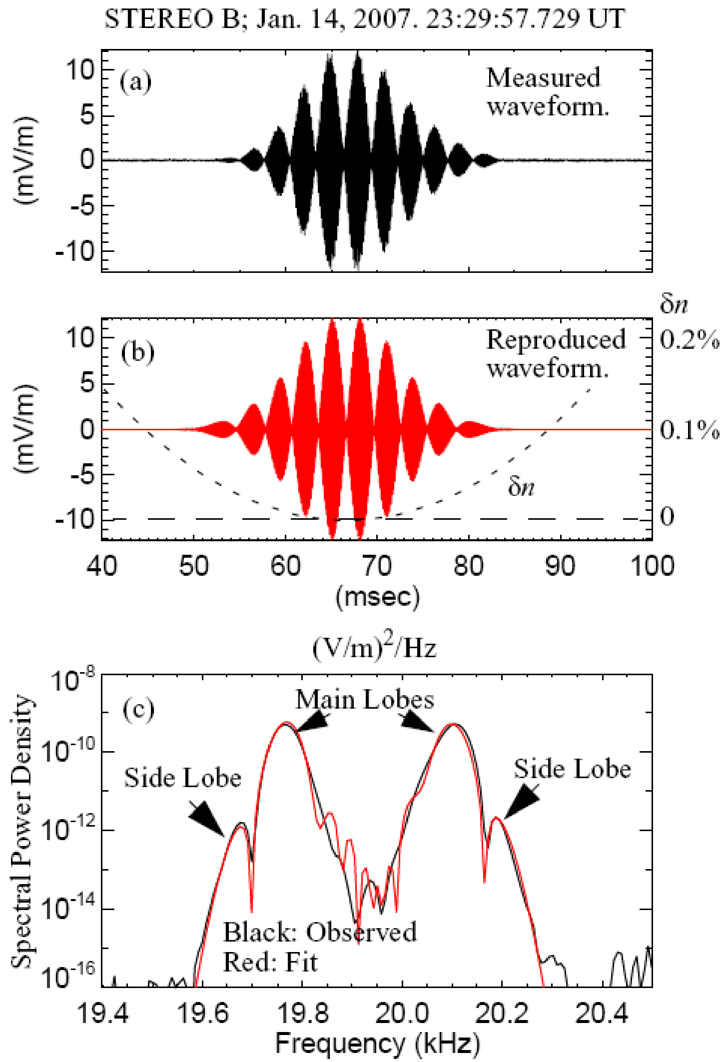
Type III associated Langmuir waves

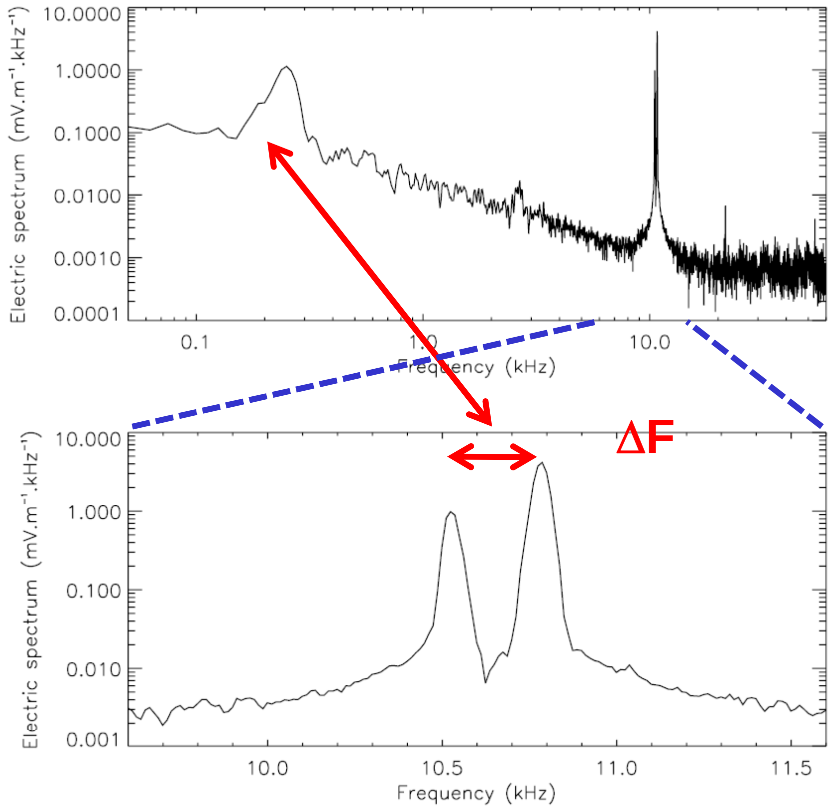
Duration of the TDS events (up to 130 msec instead of ~16msec on WIND) has geatly improved our knowledge of these waves





Various interpretations





Ergun et al. 2008, Malaspina et al. 2008
- Intense LW are localized eigenmodes trapped in a parabolic density fluctuation
- Eingenmodes structures used to explain the EM radaitions at the harmonic of Fp

Henri et al. 2008, 2009
- Direct evidence for three-wave coupling (Langmuir and Ion acoustic waves)
- Interpretations of the phase coupling and evaluation of the growth rate favor the LW parametric decay
- Is the observed Electric field strength enough for parametric decay ?

Vlasov-Poisson simulations of Langmuir Decay Threshold in solar wind conditions

P. Henri, F. Califano, C. Briand

$$\frac{\partial f_\alpha}{\partial t} + v\frac{\partial f_\alpha}{\partial x} + q_\alpha E\frac{\partial f_\alpha}{\partial v} = 0 \qquad \text{Vlasov equation}$$

$$\frac{\partial E}{\partial x} = \int f_i - f_e \; dv \qquad \text{Poisson equation}$$

Kinetic code (1D-1V), electrostatic approximation.
(Numerical scheme: Mangeney & al., 2002)

Periodic boundaries.
Initial condition: localized Langmuir wavepacket with amplitude E.

From simulations of LED: (various # of wave-packets, various Tp/Te ratii …)

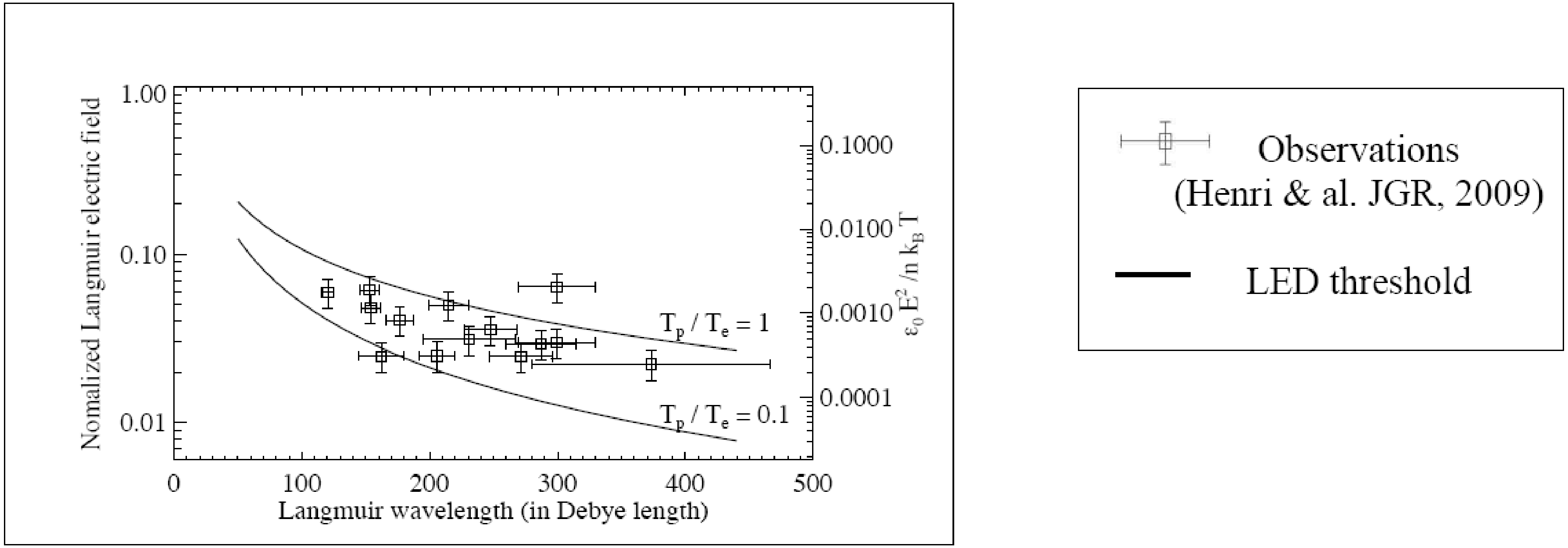
- Growth rate $\gamma_{LED} = \Gamma \; E_L^{\alpha} k_L^{\beta}$

	Γ	α	β
$T_p/T_e = 0.1$	0.026	1.11	0.59
$T_p/T_e = 1$	0.025	1.82	0.30

Assuming $\gamma_{LED}^{-1} \approx$ time intercation between wave packets (of scale Δ), The threshold electric field $E_{LED}^{threshold}$ is then

$$E_{LED}^{threshold} = \left(\frac{3 \; k_L^{1-\beta}}{\Delta \Gamma} \right)^{1/\alpha}$$

Localized wavepackets - $T_p \sim T_e$



Confirms interpretation of waveform observations in term of Langmuir electrostatic decay $L \rightarrow L' + S$

Spatial localization of Langmuir waves generated by an electron beam propagating in the Solar Wind

A.Zaslavsky, A.S. Volokitin, V.V. Krasnoselskikh, M. Maksimovic and S.D. Bale
Submitted to JGR

Simulation of the the propagation of the Langmuir waves in density fluctuations by solving the high-frequency Zakharov equation (includes **trapped eigen modes** as well as **freely propagating waves**) :

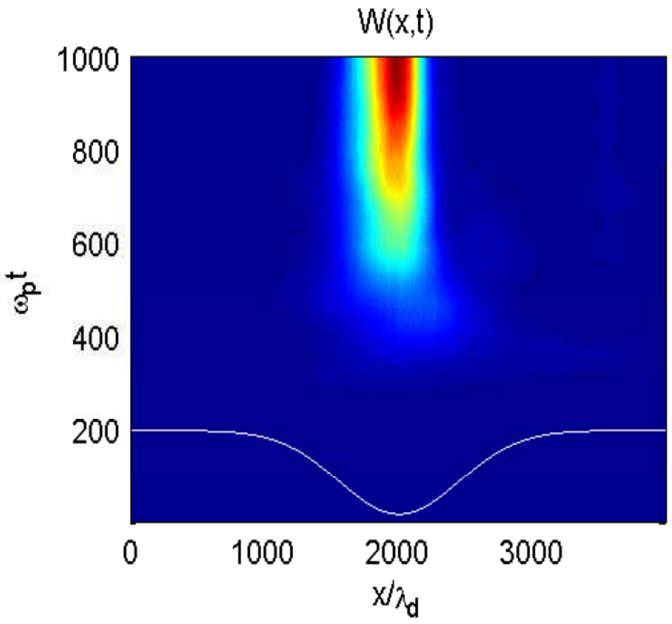
$$i\frac{\partial}{\partial t}E + \frac{3}{2}\omega_p\lambda_d^2\nabla^2 E - \omega_p\frac{\delta n}{n_0}E = 0$$

Generalized this equation to include the effect on the waves of an external charge density -e.n$_b$ (x,t), where n$_b$ (x,t) is the density of the energetic electrons :

$$\nabla\left(i\frac{\partial}{\partial t}E + \frac{3\omega_p}{2}\lambda_d^2\frac{\partial^2}{\partial x^2}E - \omega_p\frac{\delta n}{2n_0}E\right) = -2\pi e n_b\left(x,t\right)\omega_p e^{i\omega_p t}$$

A **numerical code** has been made to solve this equation. The code has been tested to reproduce accurately the propagation effects of the langmuir waves in the absence of resonant particles and the beam instability in an homogeneous plasma

Results of simulation :destabilization of waves in the presence of a gaussian density cavity



We consider **beam-plasma instability** in the typical case of a type III solar radio burst at 1 A.U. :

- The average beam velocity is c/10

- We start from a thermal noise level for the electric field

- The cavity has a size of around 1000 debye lengths (10 km)

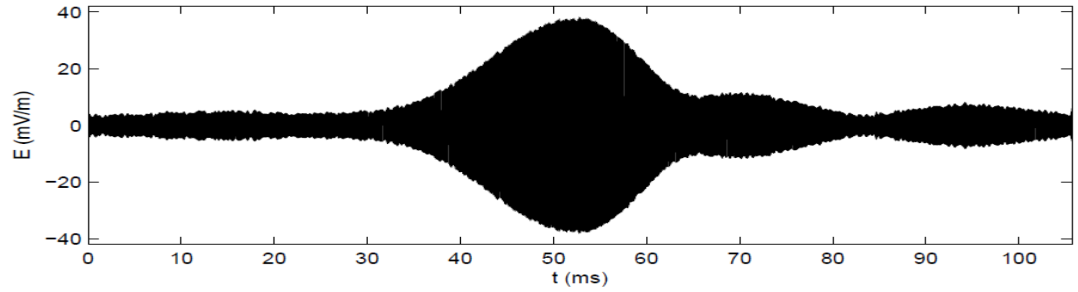
- The cavity depth is of 3% of the average solar wind density

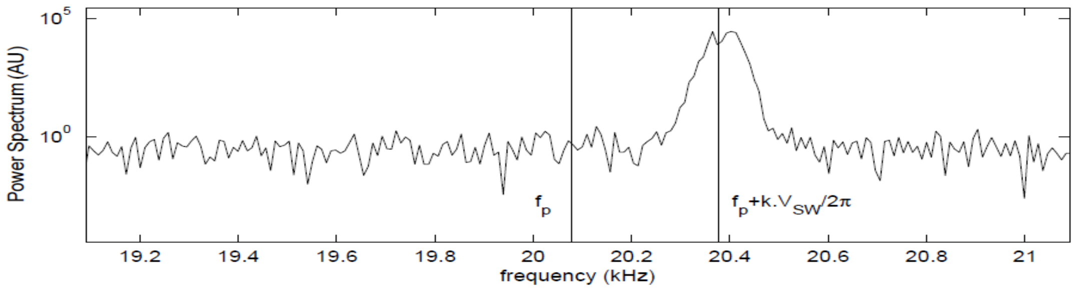
➡ The linear stage is similar to the case where no density fluctuation is present (same growth rate and destabilized spectrum)

➡ In the non-linear stage, the electrostatic energy gets focalized in the density depletion.

Wave form reproduction

For the simulation presented, we can simulate the wave form that would be observed by S/WAVES (TDS) (solar wind velocity of 300 km/s) :





Results comparable to the observations realized during a type III solar radio burst.

It seems however that the discrete eigenmode structure of the trapped waves does not have time to be established over the typical time scale of stability of the considered density holes.

Magnetic holes in the solar wind: STEREO (/CLUSTER)

C. Briand(1), J. Soucek (2), A. Mangeney (1), F. Califano(3)

(1) LESIA, Observatoire de Paris, CNRS, P6, P7, France

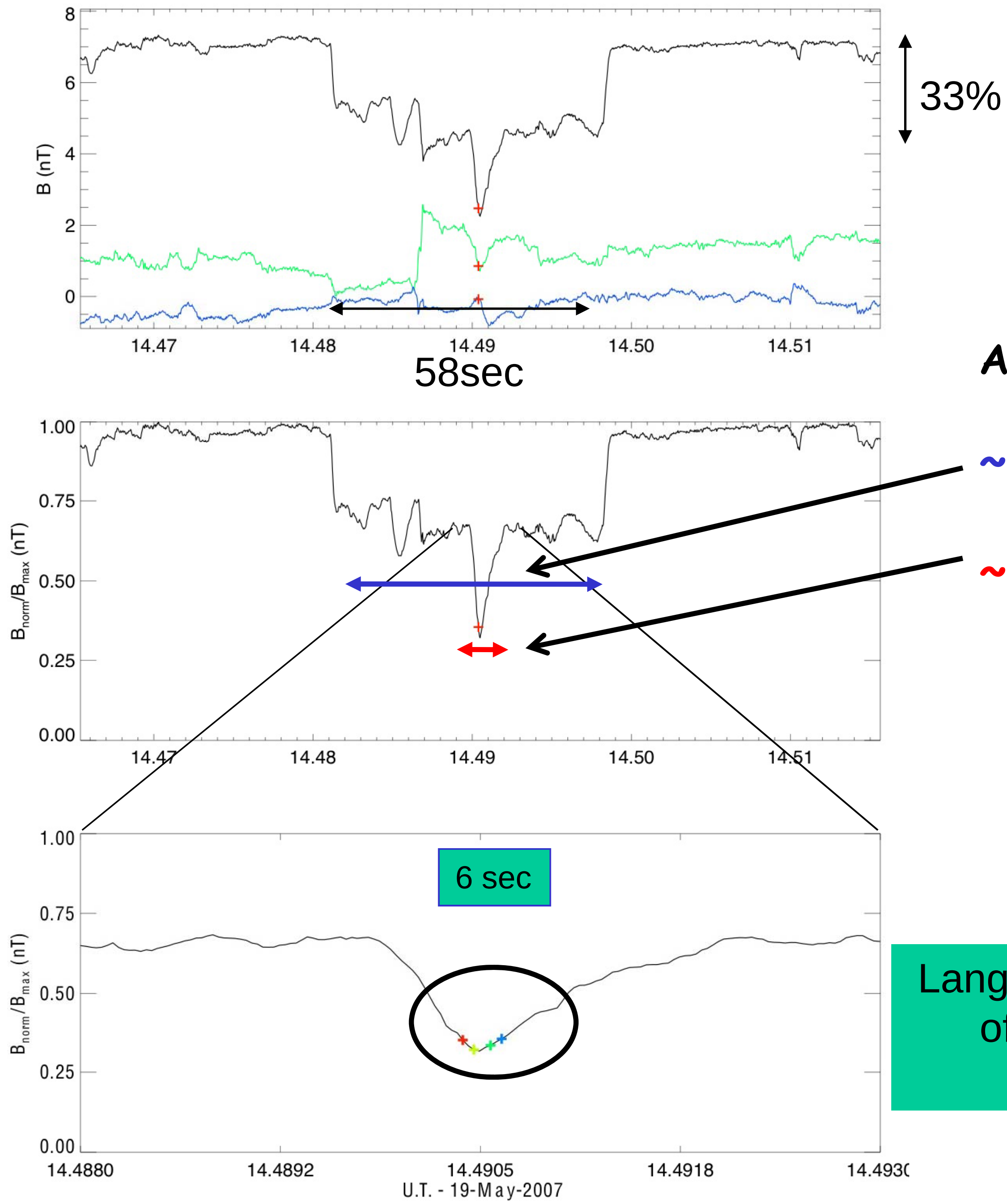
(2) Institut of Atmospheric Physics, Prague, Czech Rep.

(3) Université de Pise, Italie

- Magnetic holes or "kinetic holes" are pressure balanced structures advected by the solar wind.

- Origin is still puzzling: *generated near the Sun and then advected or formed locally in the interplanetary space?*

- Langmuir-like waves ⇔ generated by electron beams from the thermal electron population + mag moment conservation inside the holes.[MacDowall et al., 1996]



Minimum variance analysis

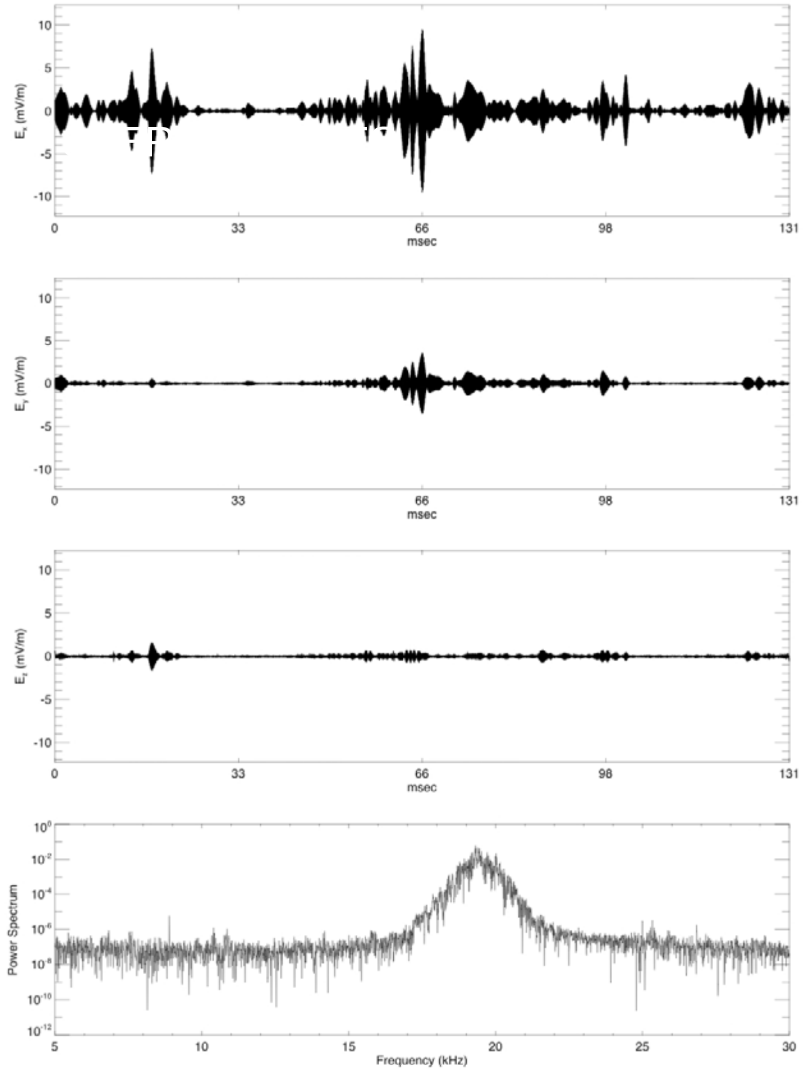
Assuming convection @ Vbulk

~ 50 ρ prot.

~ 5 ρ prot.

Langmuir waves located at the edge of the hole or **inside deepest** depressions

Corresponding Langmuir waves



X : Along B

$Y = B \wedge V_{sw}$

$Z = Y \wedge B$

For the first time:
waveforms in the solar wind

- Propagation // B or slightly oblique
- Bursty aspect (large spectrum, low velocity beam)
- No low frequency waves (172 events)

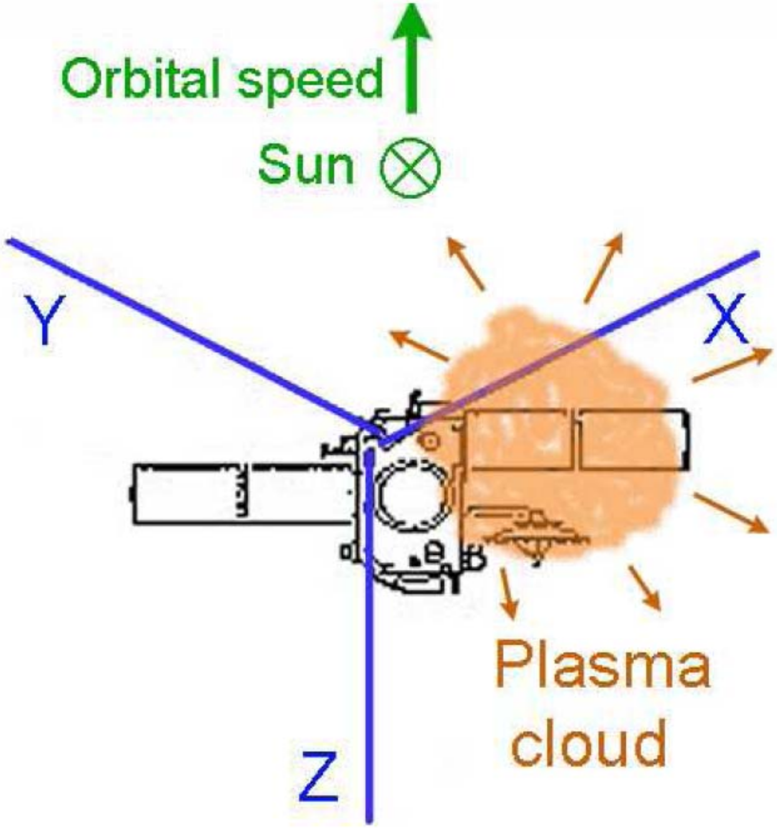
Next steps :

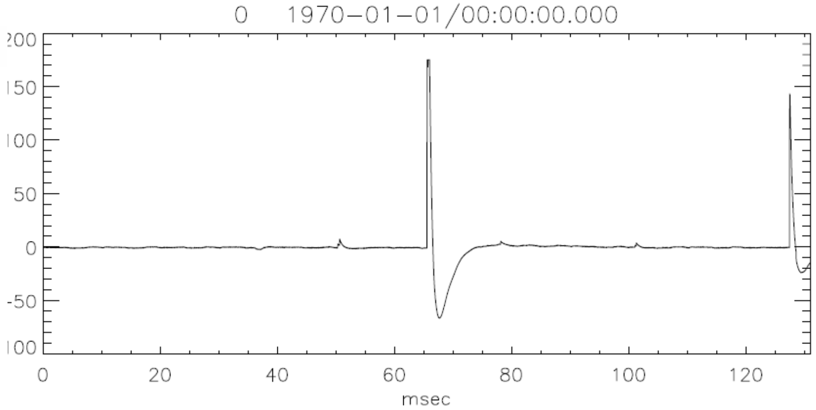
-Statistical analysis (CLUSTER/STEREO/WIND) Conditions of occurrence of the LW

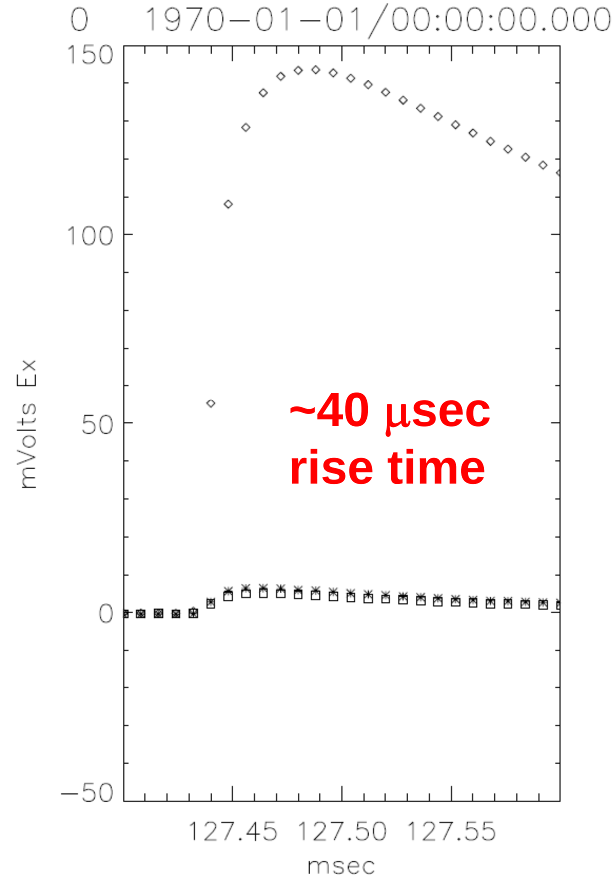
-Kinetic simulations Formation of the LW / Holes

Nanoparticles Observed by S/WAVES

N. Meyer-Vernet, M. Maksimovic,
K. Issautier, A. Zaslavsky, G. Lechat …



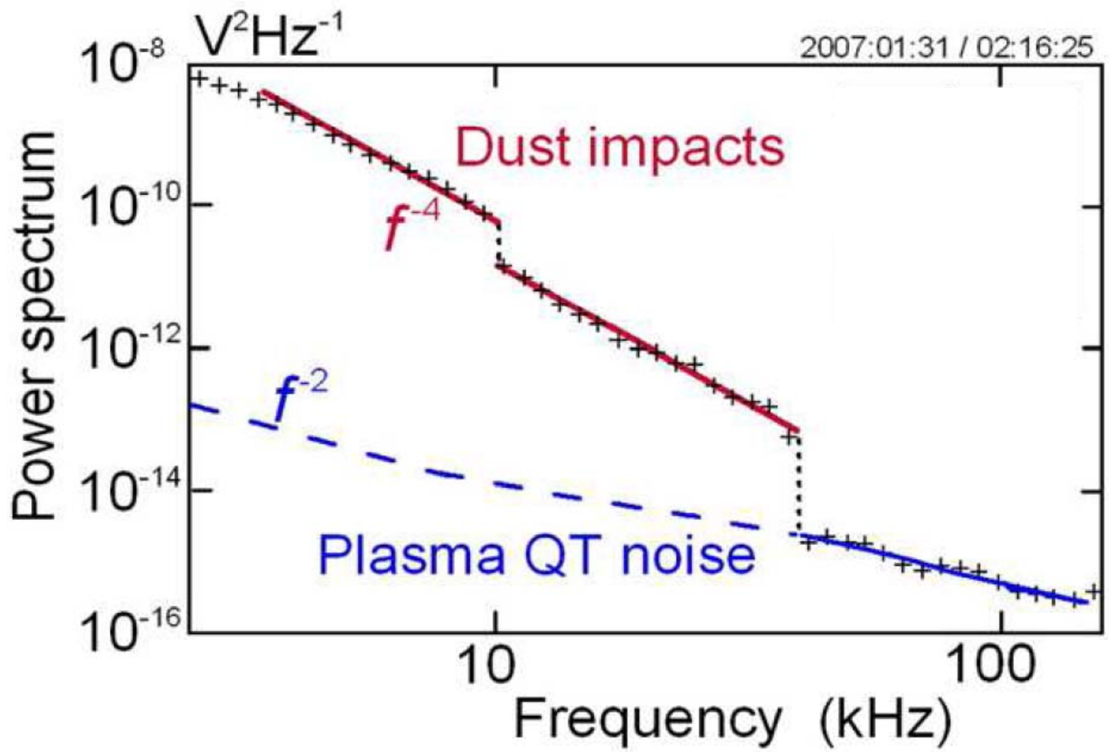




Released charge : $Q \simeq 0.7 m^{1.02} v^{3.48}$

Induced voltage pulse on S/C of capacitance C : $\delta V \sim -Q/C$

Accelerated by the -VXB field

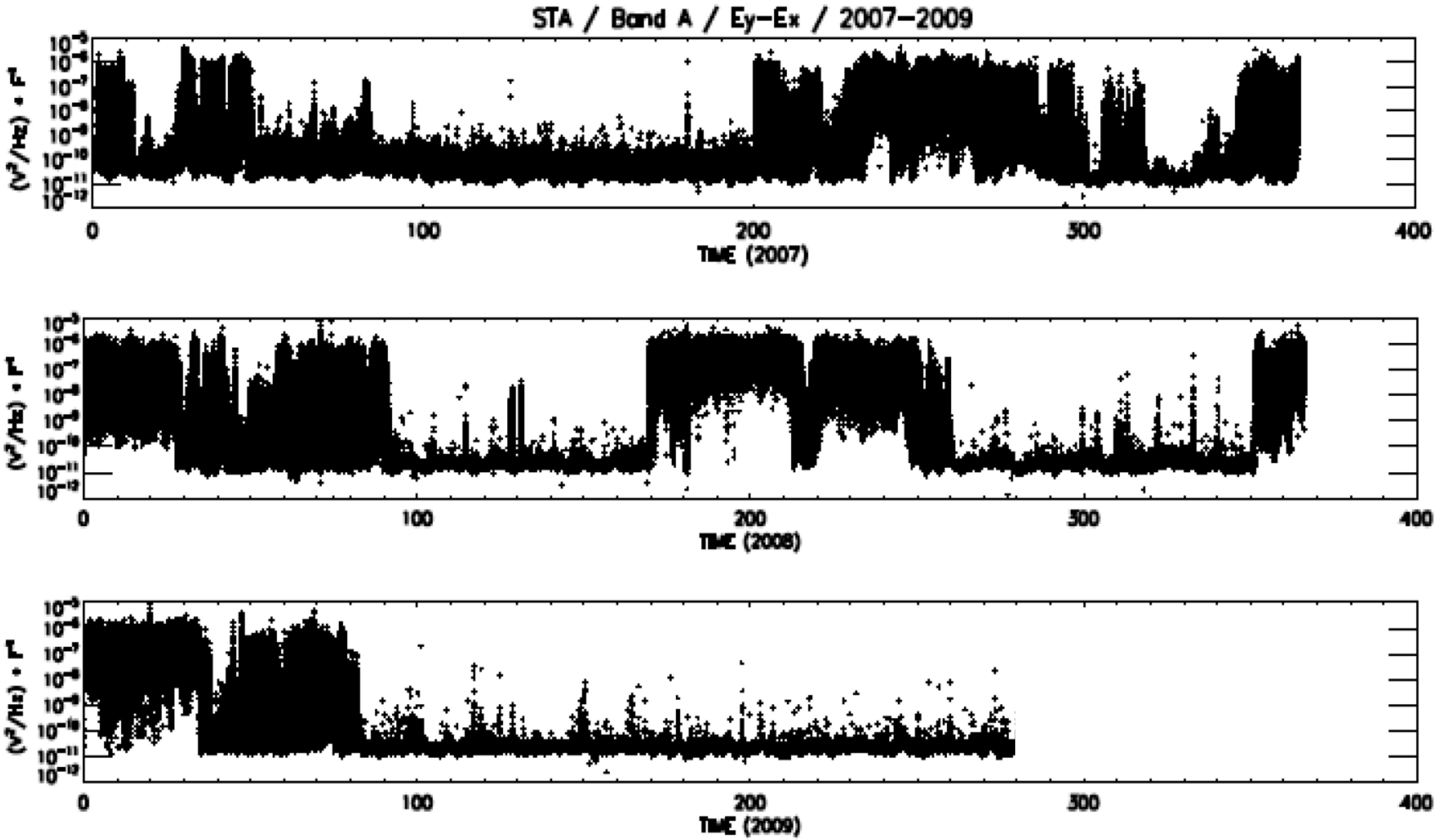


In the spectral domain :

For pulses of rate N, max. amplitude δV, and rise time τ (~40 μs), the theoretical power spectrum is

$$V_f^2 \simeq 2 < N \delta V^2 \omega^{-2} (1 + \omega^2 \tau^2)^{-1} >$$

$$\sum_{\text{Band A}} V^2 \times f^4$$



$$\sum_{\text{Band A}} V^2 \times f^4$$