Differential imaging in heterogeneous media

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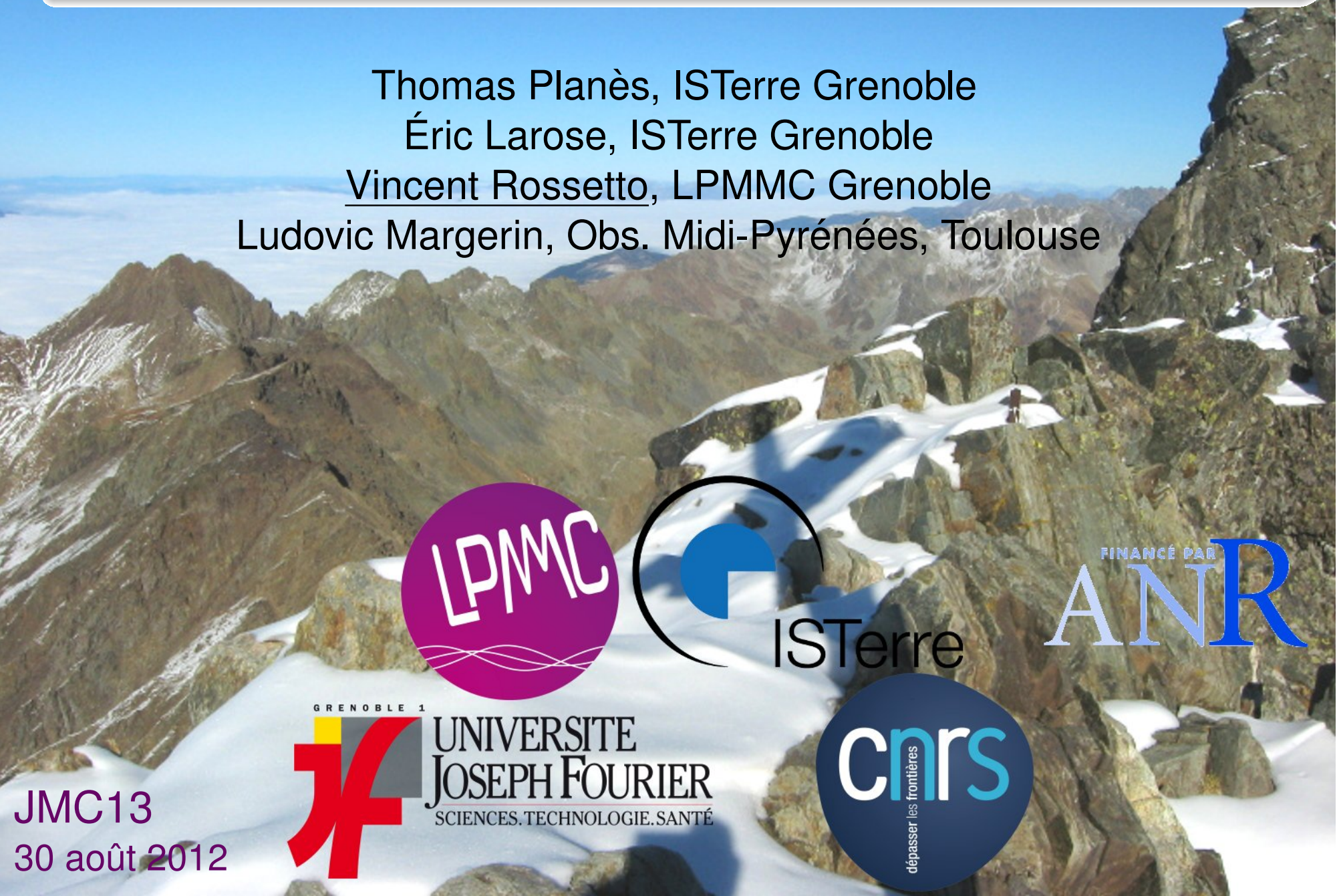

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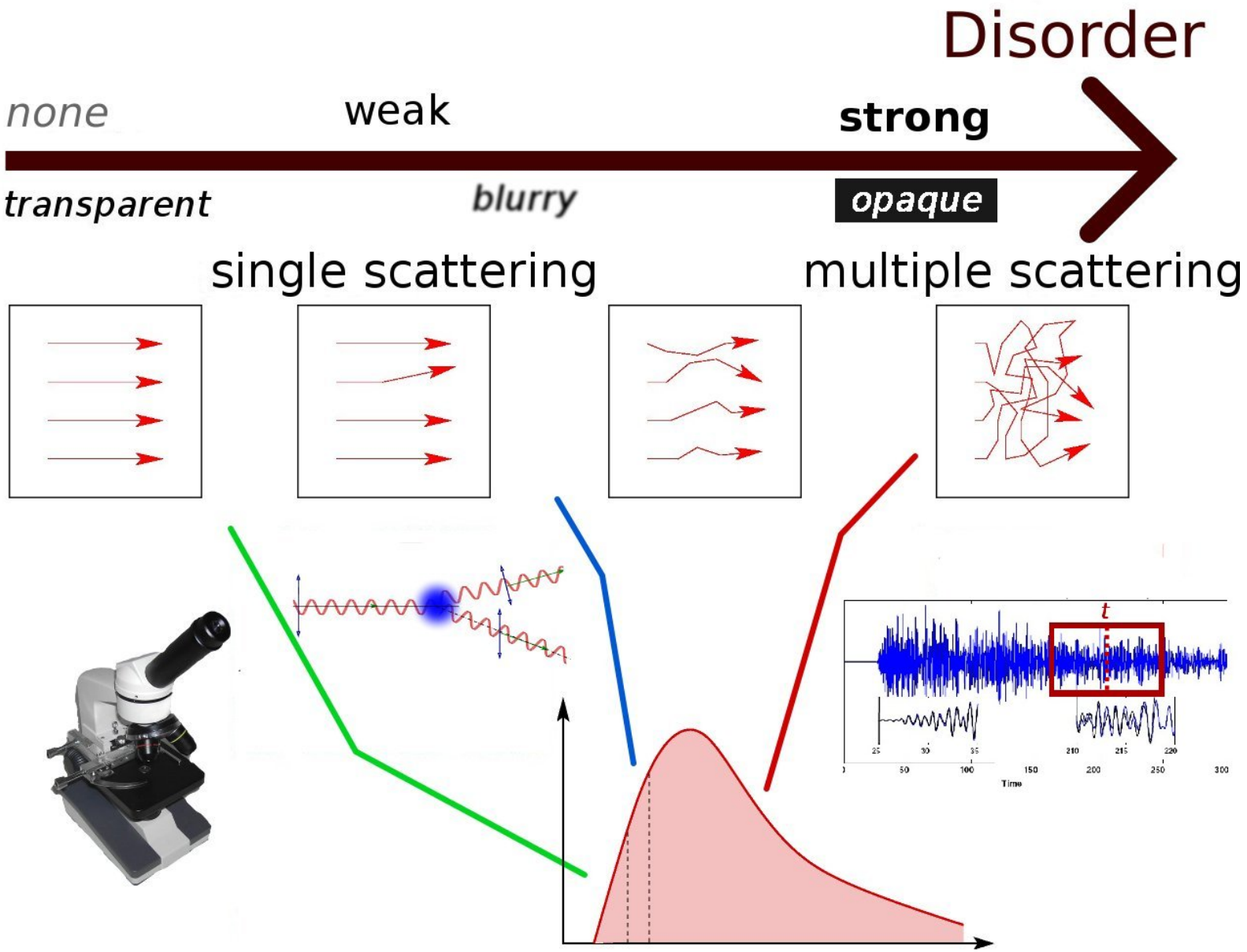
Classical imaging techniques

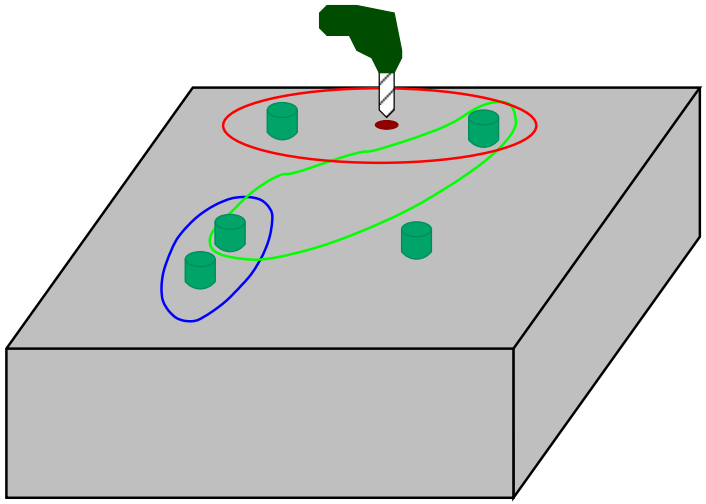


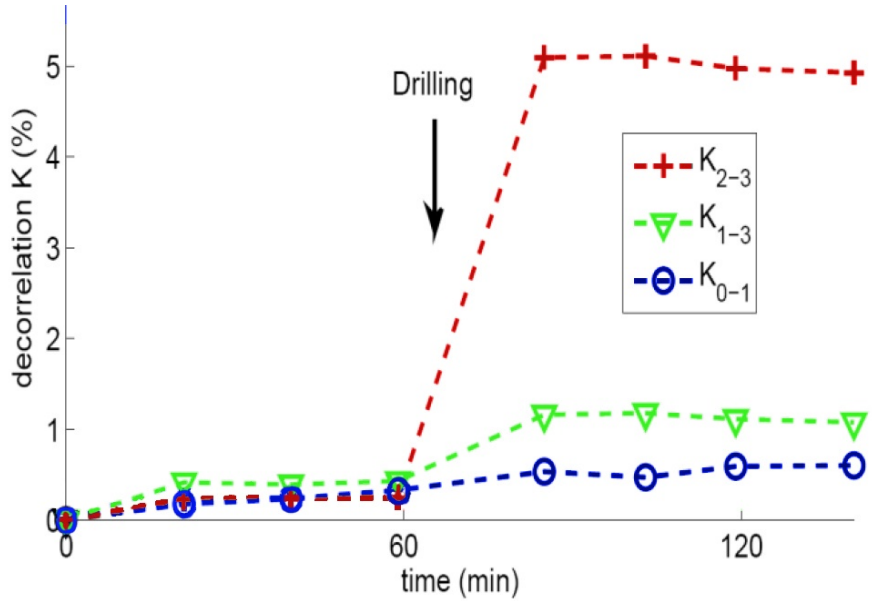
Sensitivity to small changes

Sensitivity depends on location

Setup

- Five transducers (operated as source or receiver)
- Correlations are computed from the **codas** of the signals at time t and time 0.
- A little hole ($\varnothing$ 3 mm, depth 4 cm) is drilled during the experiment.

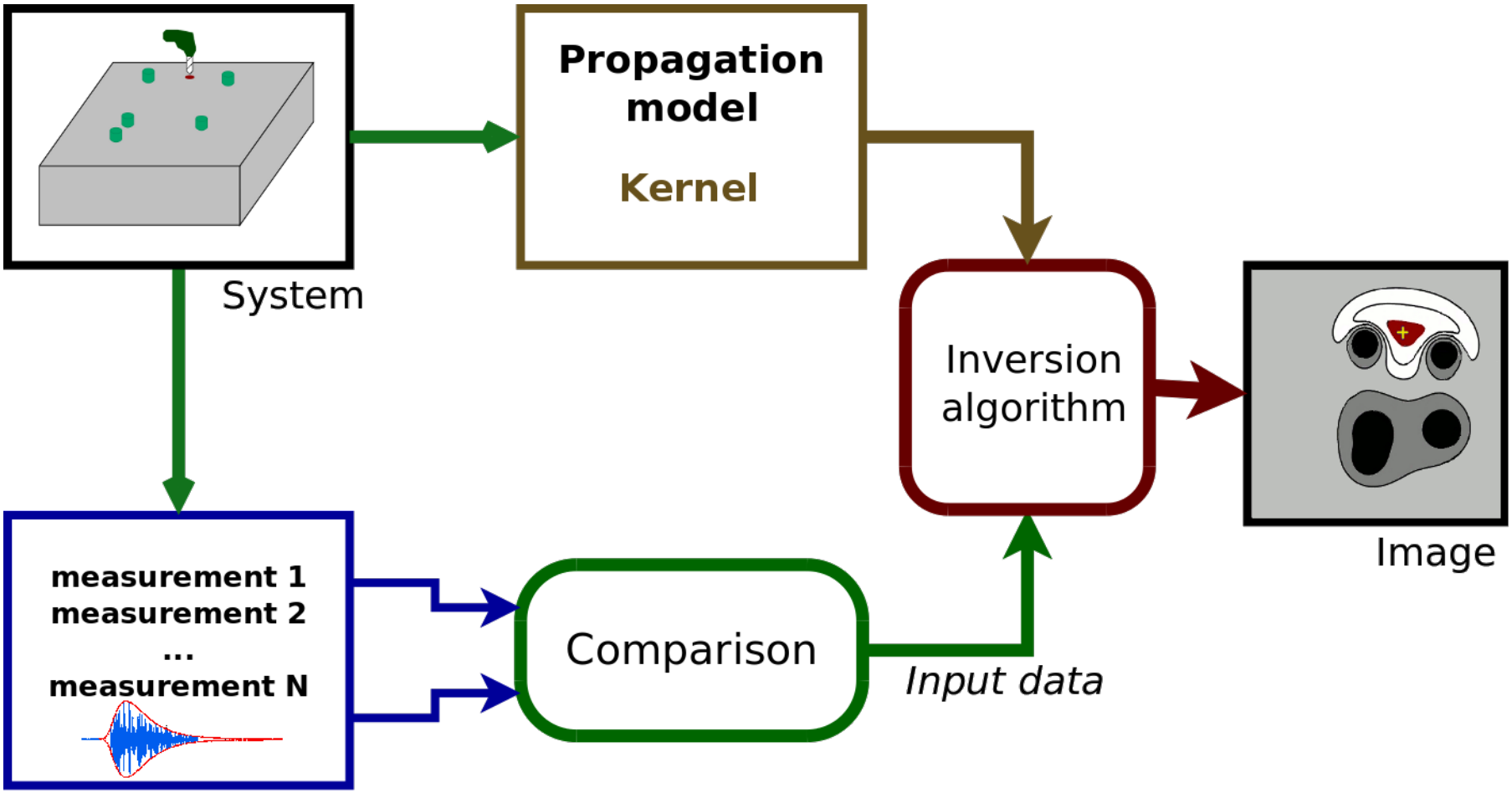




Imaging small changes : differential imaging

Principle of differential imaging

In strong disorder, small details cannot be distinguished from their surroundings $\Rightarrow$ make an image of the *changes*



Broadness of differential imaging

Comparisons

- Travel time change (velocity change)
- Correlations (scattering change)
- Intensity ratio (absorption change)

Total variation
Displacement of edges

Propagation models

- Pure diffusion / radiative transfer / ...
- Boundary conditions

Inversion algorithms

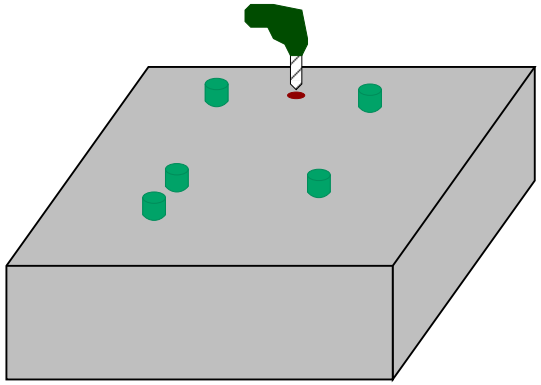
- χ^2 optimization, local χ^2
- Error minimization (Tarantola-Valette)
- Compressive sensing algorithms (OM, PPPA,...)

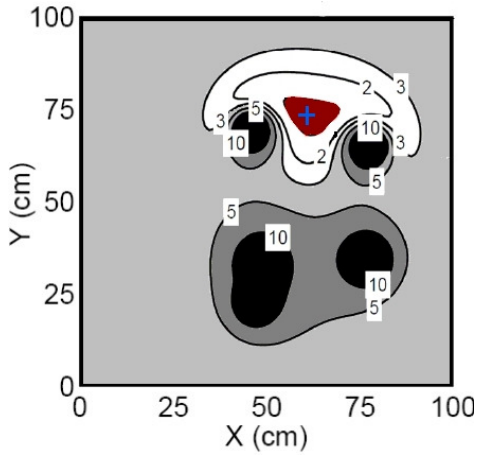
Examples of differential images

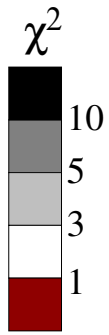
Holes in a concrete block

Diffusion - χ^2 inversion

- Diffusion model with reflecting boundary conditions
- χ^2 algorithm : for each $\boldsymbol{x}$
  - Suppose there is a *unique* change in $\boldsymbol{x}$
  - Compute expected correlation losses
  - Compute the mismatch between model and data







- É. Larose, T. Planès, VR and L. Margerin, *Appl. Phys. Lett.* (2010)
- VR, L. Margerin, T. Planès and É. Larose, *J. Appl. Phys.* (*2011*)

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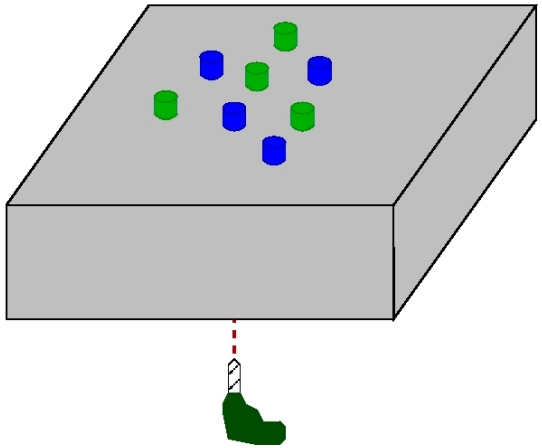

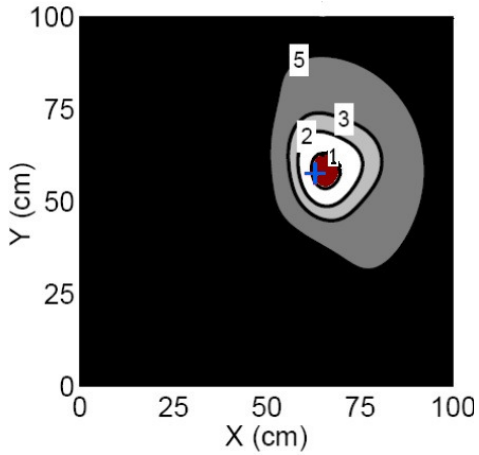

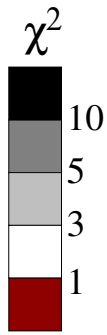

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Examples of differential images

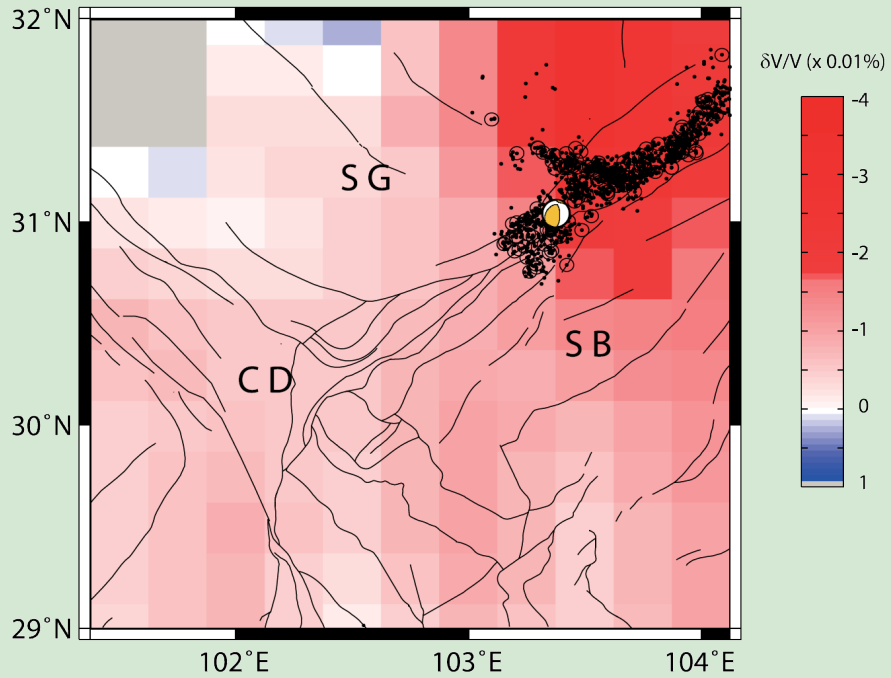
Wenchuan earthquake (May 12th, 2008)

Travel time change - Tarantola-Valette algorithm

- Ballistic wave propagation
- Tarantola-Valette error minimization algorithm

Travel time change

- Continuous measure of ambient noise
- Reconstruction of Green's function (stacking)
- Maximize correlations by time stretching



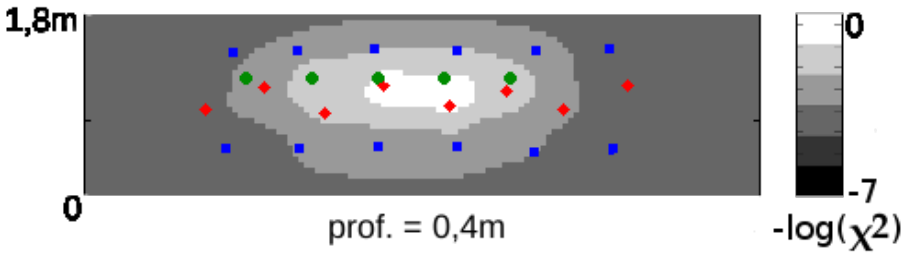
Cheng, Froment, Liu & Campillo, *Geophys. Res. Lett.* **37** 2010

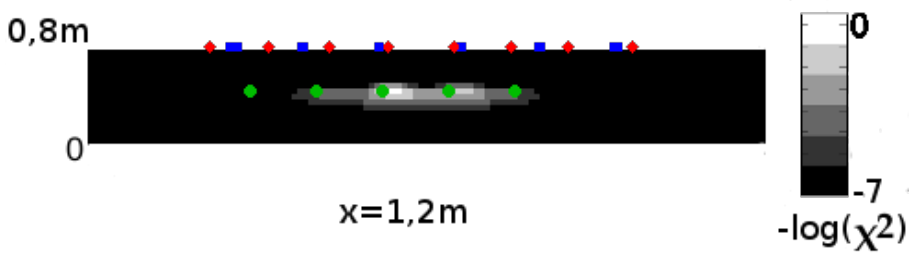
Examples of differential imaging

Simulation of 5 aligned changes

Compressive sensing algorithm (PPPA)

- Input data : 50 numbers
- Unknows : 80,000 voxels





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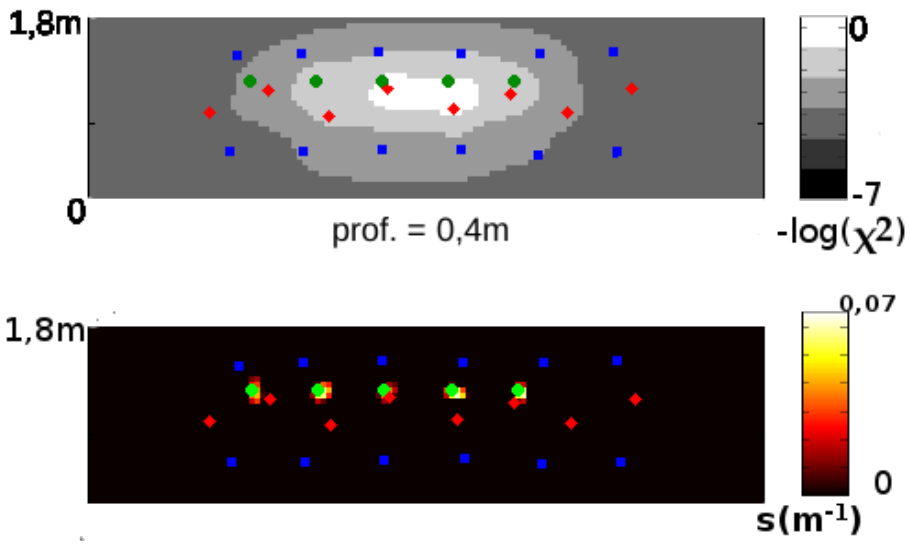

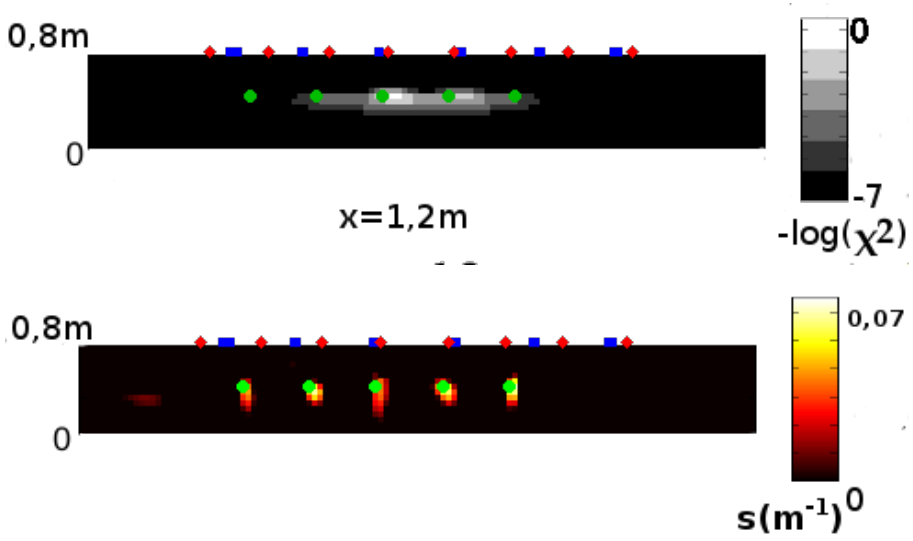

- PPPA algorithm can locate up to $\sim N/2$ changes from N input measurements

Outlook

Improvements in progress

- Radiative transfer in 3D (Paaschens formula)
- Extract more information from the coda
- Extended scattering changes

Future improvements

- Improve pre-processing
- Identify the best algorithm for a given problem
- Monitor edge displacement

Applications

- Study damaging or ageing of materials
- Monitoring of concrete structures (bridges, dams...)
- Observational or preventive seismology, volcanology