R&T DeepSee

SRoll : an algorithm based on data inversion and scattering transform to reduce systematic effects and foregrounds on satellite data.

Théo Foulquier
Jean-Marc Delouis

Context

Data from space observations have instrumental effects or foregrounds that degrade the signal of interest recovery.

This problem is common to **astrophysical and oceanographic** data as with CFOSAT, but the geophysical signal evolves over time on the scale of the measurement, unlike astrophysical processes.

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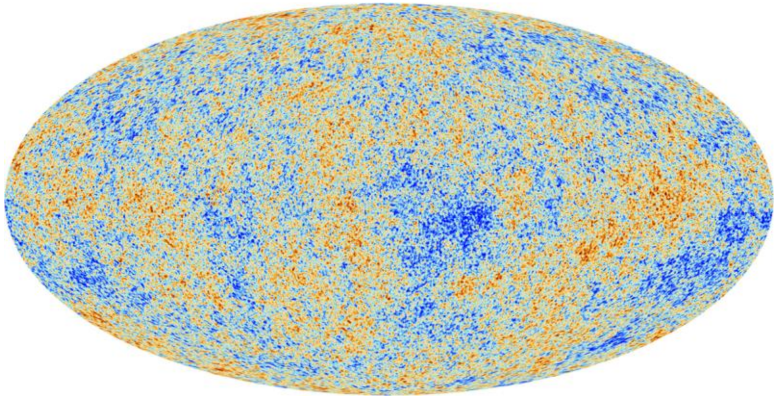
Planck - European Spatial Agency (2009-2013)



Cosmic **M**icrowave **B**ackground (CMB): 380,000 after the Big Bang

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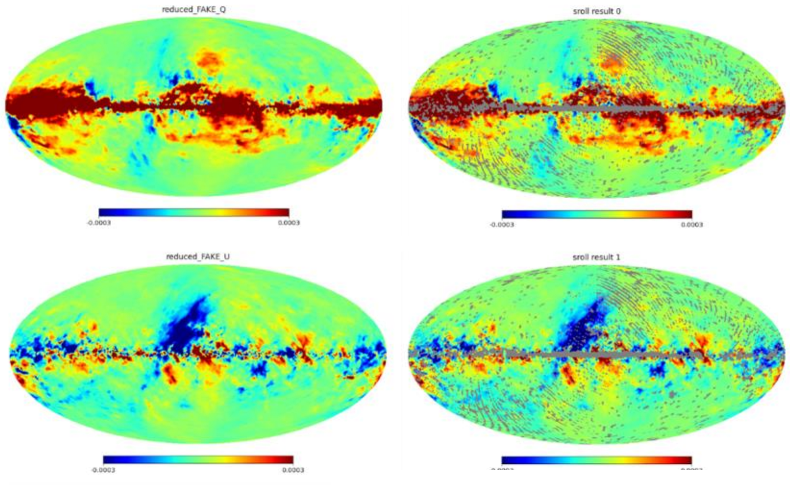

Use of SRoll to denoise Planck HFI data

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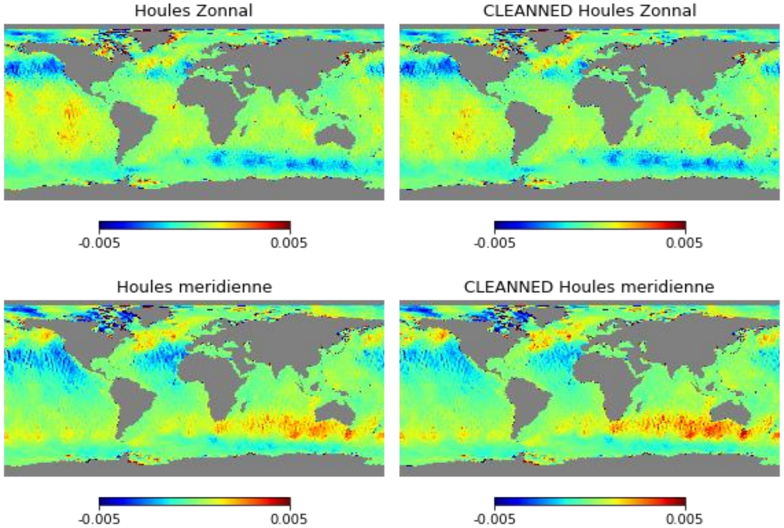
CFOSAT – CNES / CNSA



Context : SRoll ,an algorithm of denosing for planck HFI

The SRoll software developed initially for cosmology (Planck Project) simultaneously inverts this signal and the instrumental effects including noises.

Therefore, SRoll uses the all available dataset to minimise the variance of the measured calibration parameters.

2014

SRoll1 became the official Planck-HFI data processing pipeline.

2018

SRoll2* Post Planck consortium work that improves the handling of certain instrumental effects:

- *Reionization optical depth determination from Planck HFI data with ten percent accuracy (Astronomy & Astrophysics)*
- *Improved large scales interstellar dust foreground model and CMB solar dipole measurement (Astronomy & Astrophysics).*

2020

SRoll3 uses the dimensionality drop modelled by generative neural networks to extract instrumental systematics.

. *SRoll3: A neural network approach to reduce large-scale systematic effects in the Planck High Frequency Instrument maps. M. Lopez-Radcenco, J.-M. Delouis, and L. Vibert, Astronomy & Astrophysics (Accepted 02/2021))*

2021/22

SRoll4 uses dimensionality reduction for instrumental effects and for the signal. Also incorporates Scattering Transform approaches. Stabilisation of the code to make it a cross-cutting tool.

*SRoll2: an improved mapmaking approach to reduce large-scale systematic effects in the Planck High Frequency Instrument legacy maps.
J.-M. Delouis, L. Pagano , S. Mottet, J.-L. Puget and L. Vibert

SRoll : Global solution (0/3)

*
TOI = TIme ordered Information
HPR = HealPix Rings

Bins TOI into HPR → Calcul difference between HPRs → Clean data and project signal

SRoll : Global solution (1/3)

*
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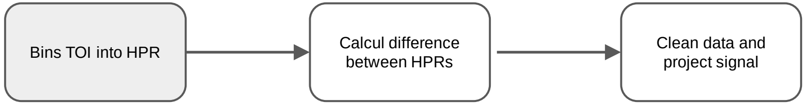
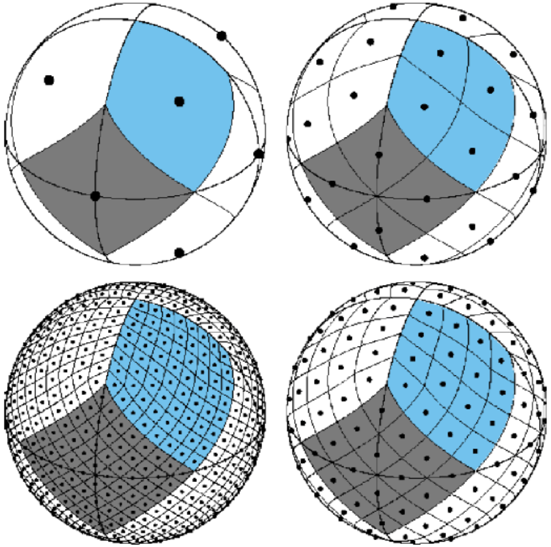
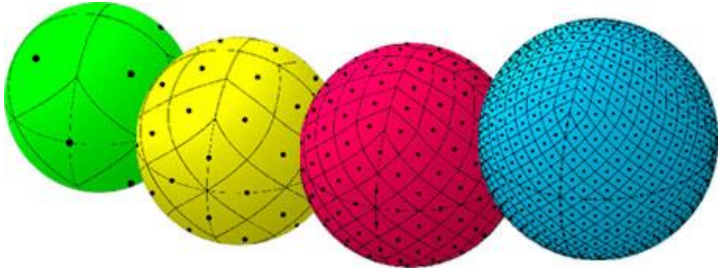


Bins the Time Ordered Information (TOI) into **HEALPIX** pixels per periods of stable satellite pointing to reduce the amount of data.





Healpix - **H**ierarchical **E**qual **A**rea iso**L**atitude **Pix**elation of a sphere

SRoll : Global solution (2/3)

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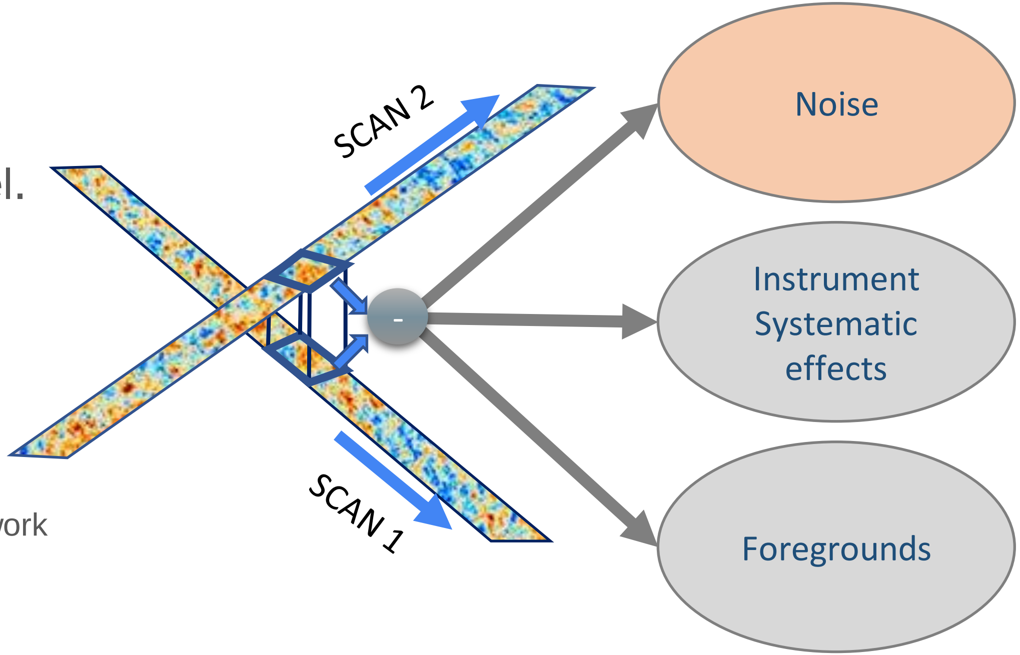
Bins TOI into HPR → Calcul difference between HPRs → Clean data and project signal

Fits systematics effects, 1/f noise and calibration using differences between measurements in the same HEALPIX pixel.



The algorithm :

- **Learns** the most suitable form to represent the difference between two measurements.
- **Synthesises** structures with small generative neural networks(SRoll3)
- **Finds the laws** constraining the structure, does not work on white noise.

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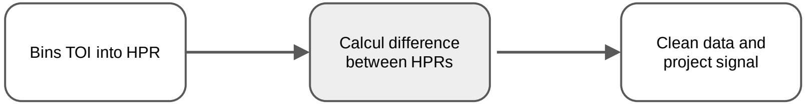

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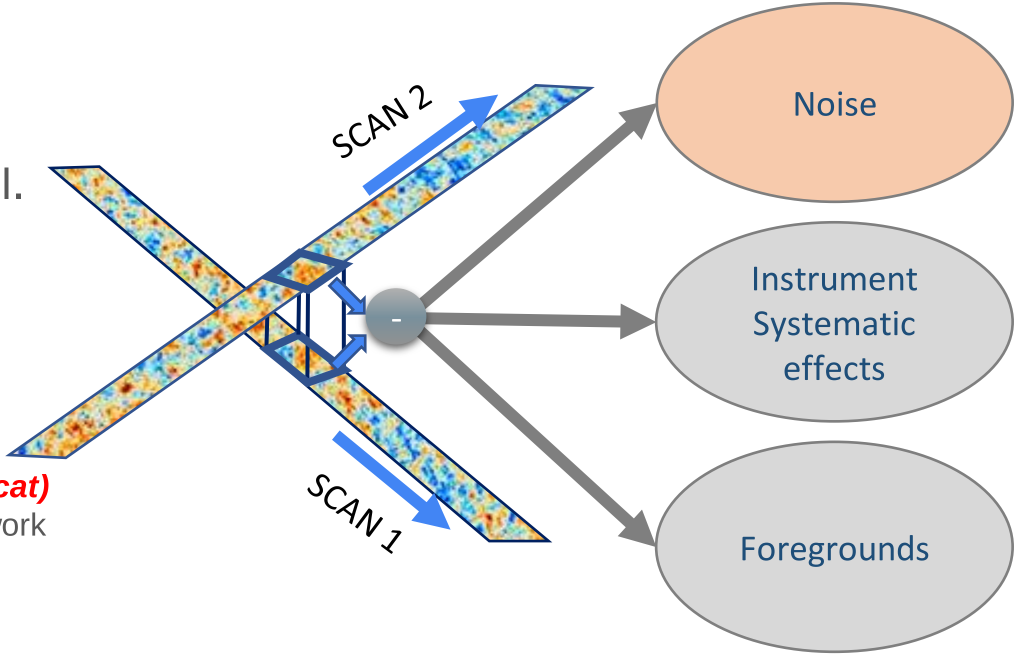

The algorithm :

- **Learns** the most suitable form to represent the difference between two measurements.
- **Synthesises** structures with small generative neural networks(SRoll3) ***=> use scattering transform (foscat)***
- **Finds the laws** constraining the structure, does not work on white noise.

SRoll : Global solution (3/3)

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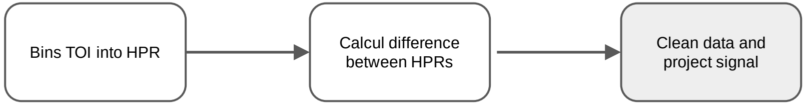
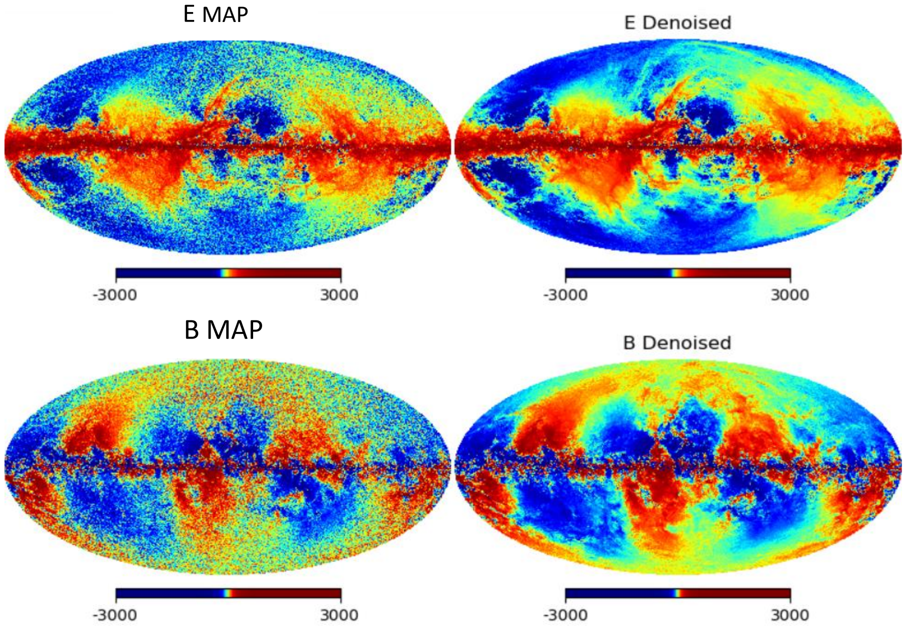


Clean the data using fitted parameters and projects the signal to make maps.



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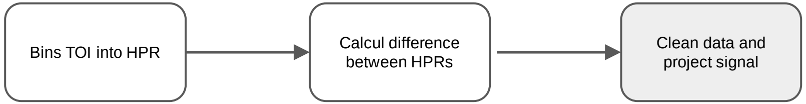

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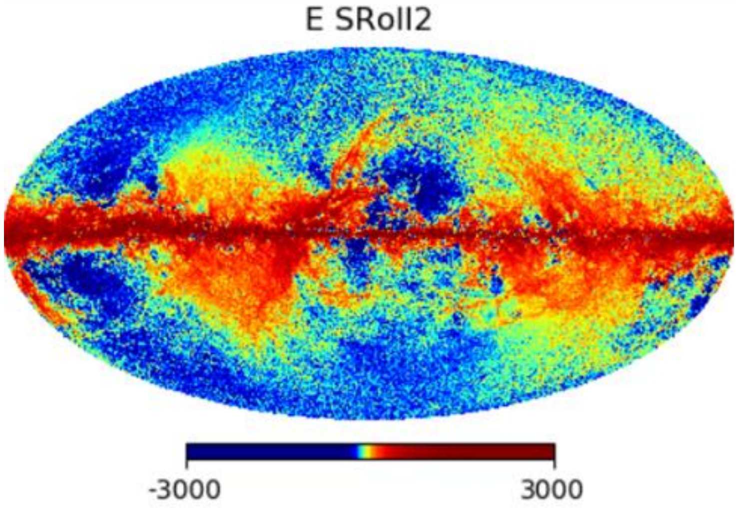

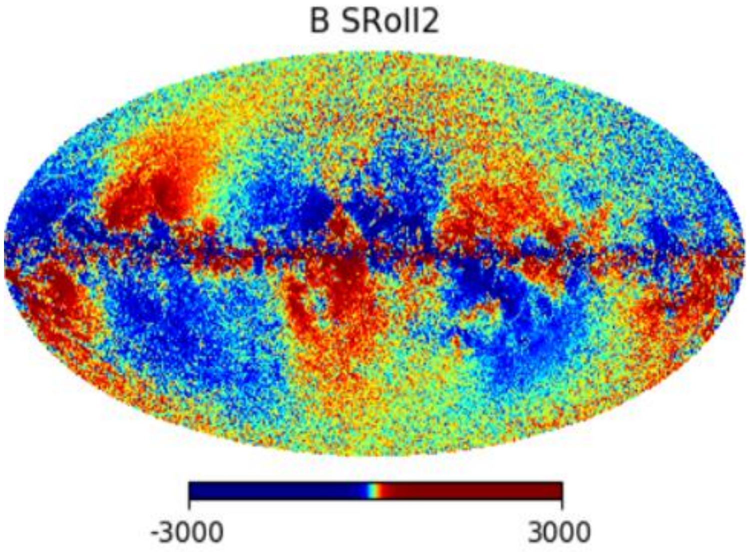

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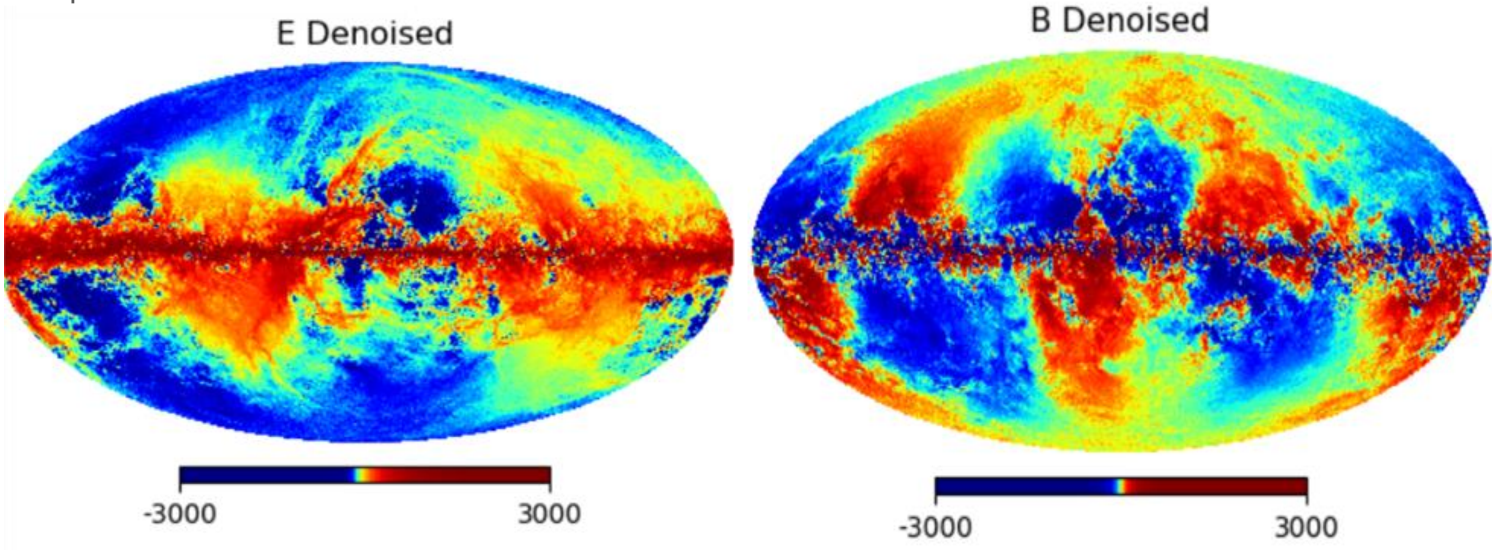


SRoll : Calibration

- Relative calibration instead of global calibration
  - Calibration between detectors M1,M2 (Determine Δg = gain error)

$$gM = Ax + N + n$$
$$\Delta gM = A(\Delta gX + \Delta X) + \Delta N + \tilde{n}$$

g = gain
A = data
N = noise

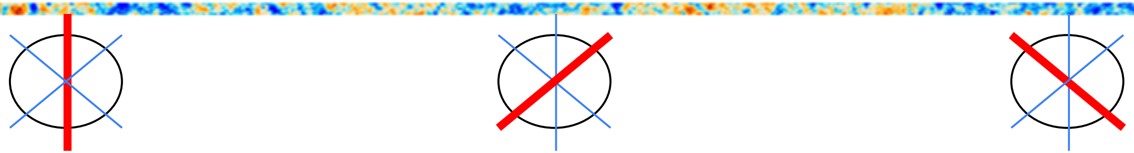
Where $x = X + \Delta X$

For **SWIM** :

x = wave spectrum
X = WW3
ΔX = difference between the model and the signal to be determined

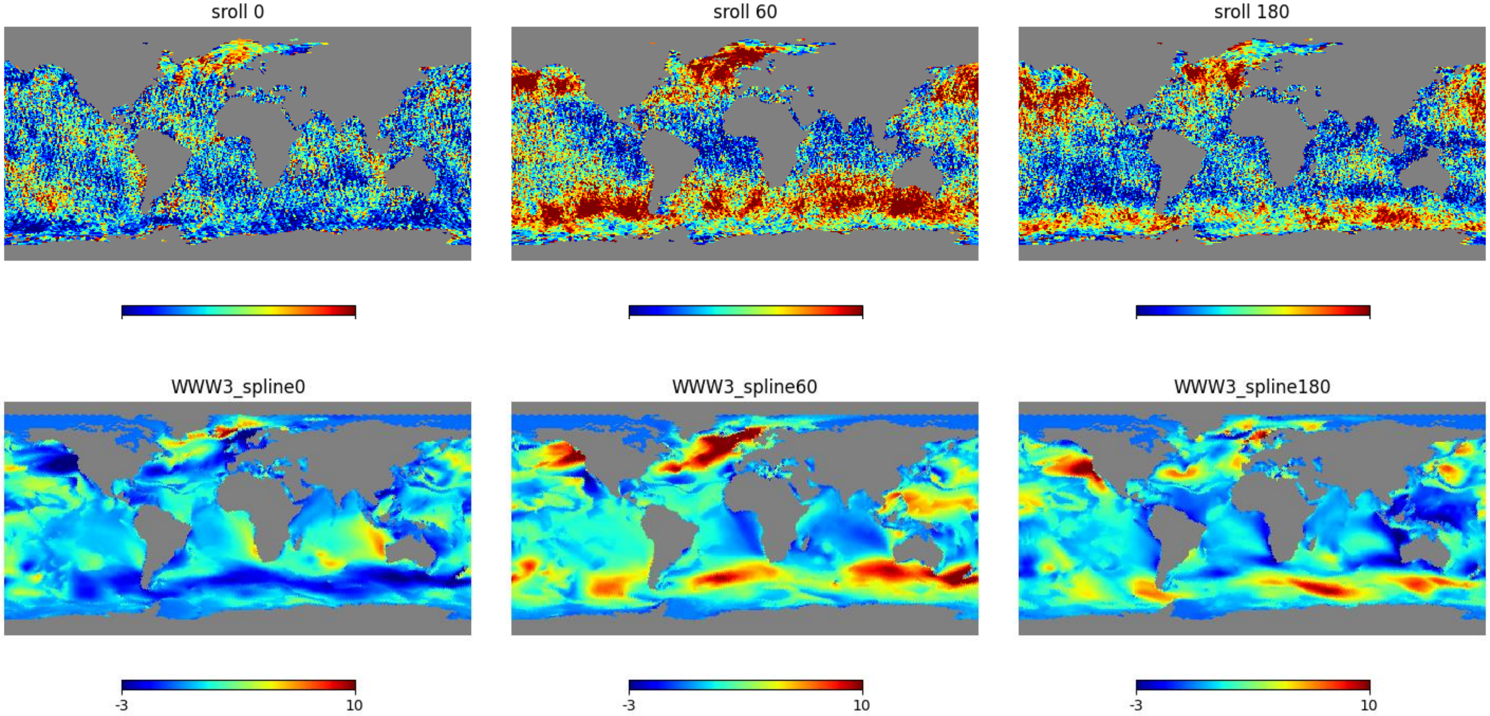
This SROLL data model has the advantage that after a certain number of iterations there is no more residual of the model (here WW3) so it is very efficient for relative calibration.

First results with CFOSAT data :



SRoll output

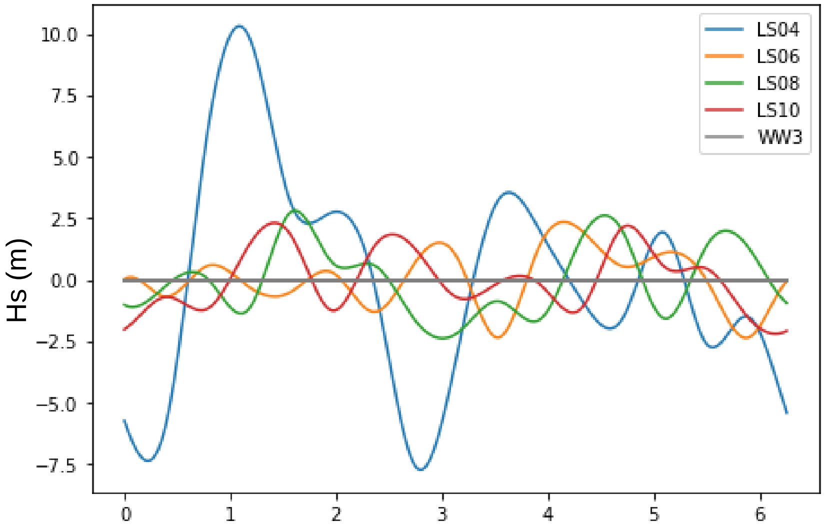
WW3 model



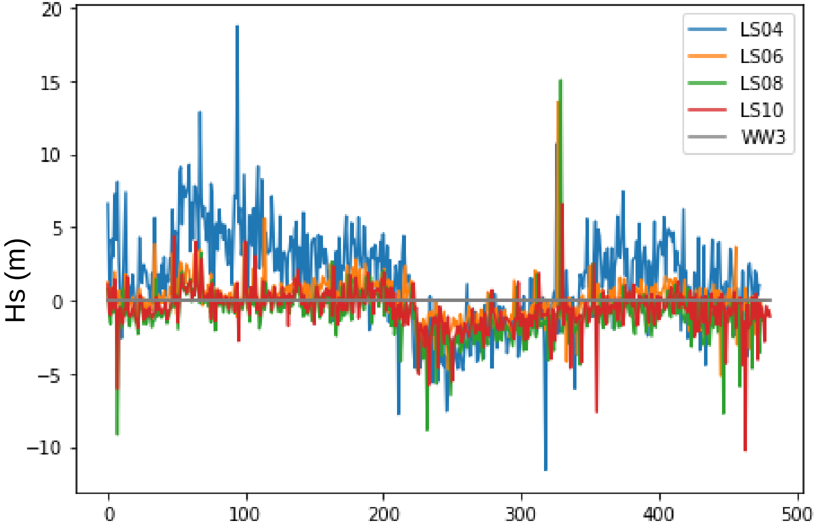
N values retrieved by SRoll (one month of data)

N values retrieved by SRoll (one month of data)

The data used are the ODL L2



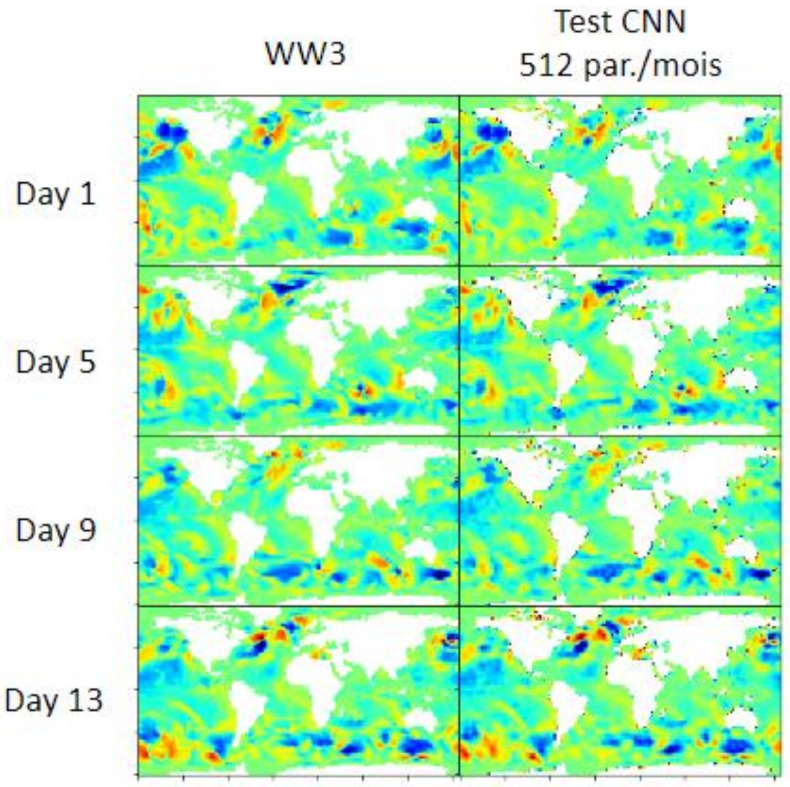
Along track azimuth angle [rad]



#orbit

SRoll : Use of IA

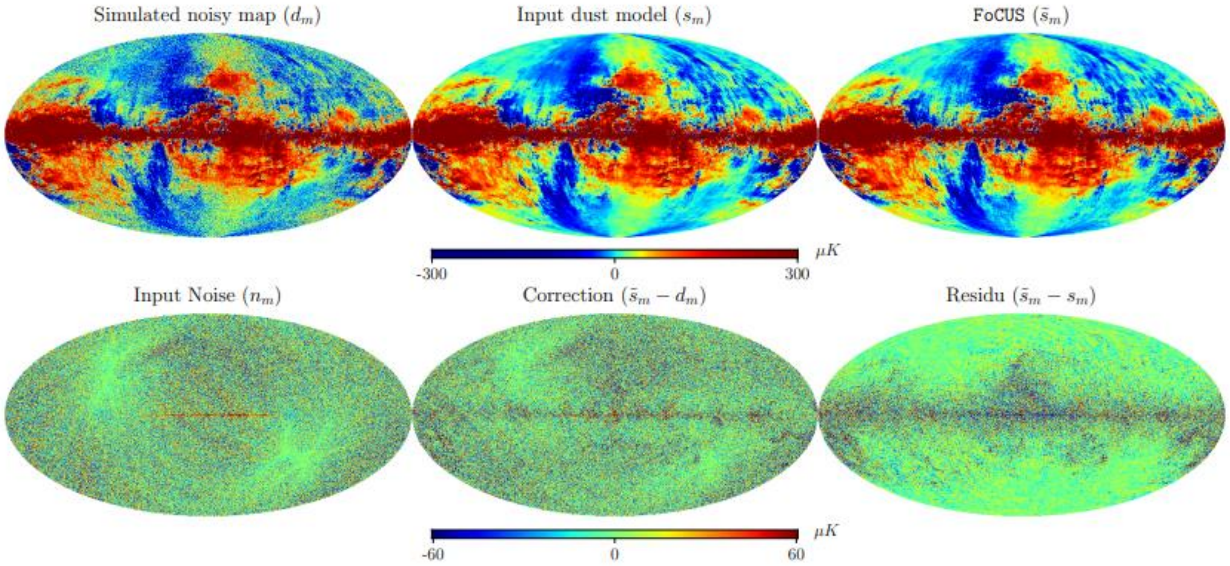
- 3 versions:
  - 1) Use Sroll without NN to find difference between the model and the signal to be determined with precalculated templates or spline base
  - 2) Neural networks not very satisfying because need to know the solution to be able to invert.
  - 3) Implementation of scattering transform



New implementation : Scattering transform

Therefore, we present a new version of SRoll based on **Scattering Transforms** (ST) to model the signal dynamics.

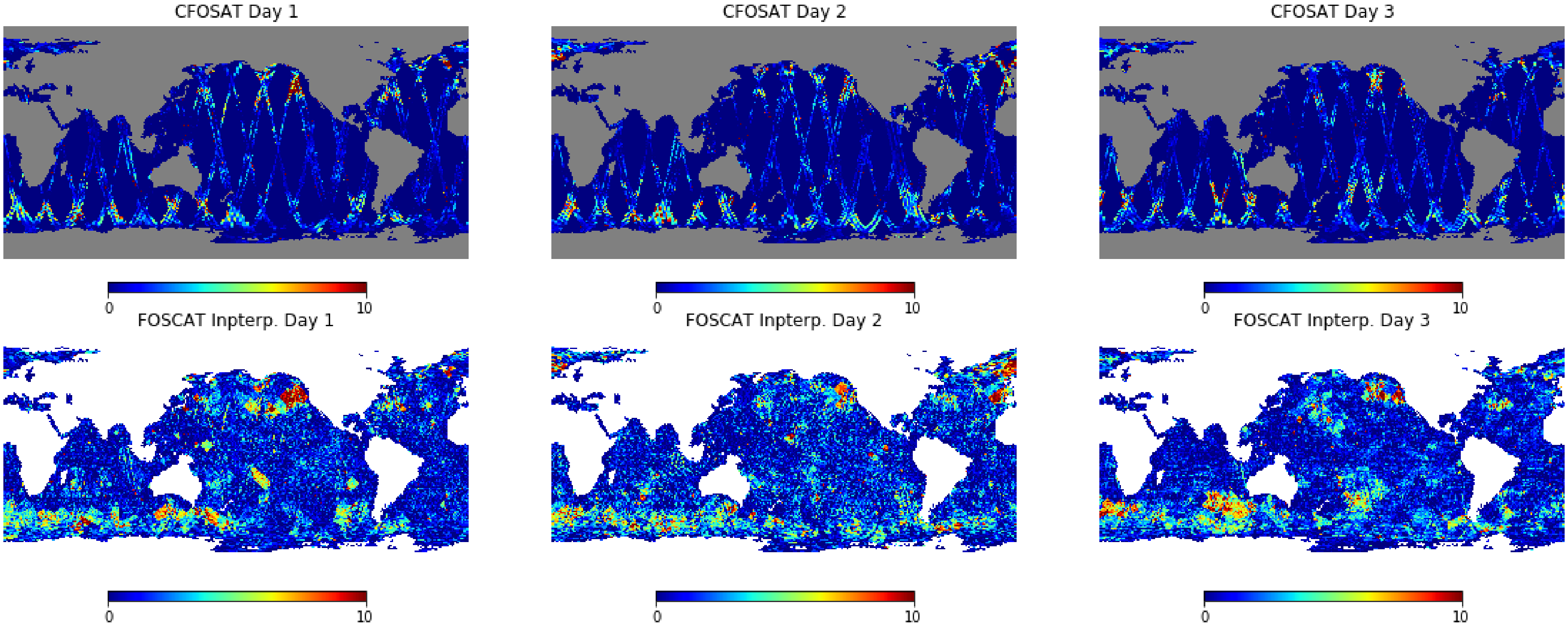
- STs have been used successfully on interstellar medium thanks to the intermittent structure of its turbulent processes. By using these statistical constraints measured on the data itself there is no learning phase as with usual neural networks.



https://pypi.org/project/foscat/

Non-Gaussian modelling and statistical denoising of Planck dust polarization full-sky maps using scattering transforms : J.-M. Delouis, E. Allys , E. Gauvrit, and F. Boulanger.

Results cross stat



Conclusion

This work presents the encouraging results obtained with this type of method on one month of CFOSAT data to correct the calibration of the SWIM instrument.Already prove it efficiency with comsologic data.

Possibility to work on other domain/projects : SKA,SWOT,LITEBIRD..

Thanks for your attention.