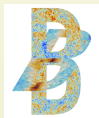


Galactic foregrounds and scattering transform

Erwan Allys, École Normale Supérieure - LRA
with F. Boulanger, F. Levrier, S. Mallat, S. Zhang, and other...

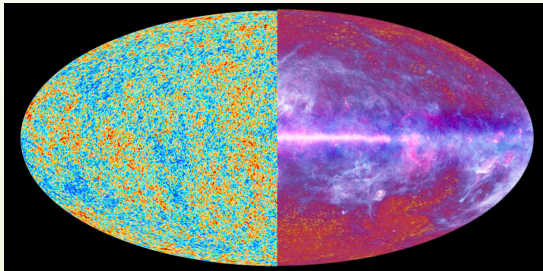
XIIIth School of Cosmology, IESC Cargèse
November 16th 2017



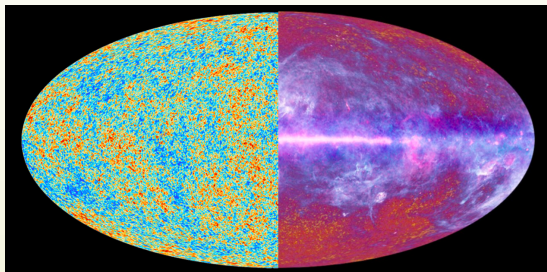
Outline

- 1 Galactic foregrounds and CMB polarization
- 2 Beyond Power-Spectrum
- 3 Scattering transform

- The microwave sky

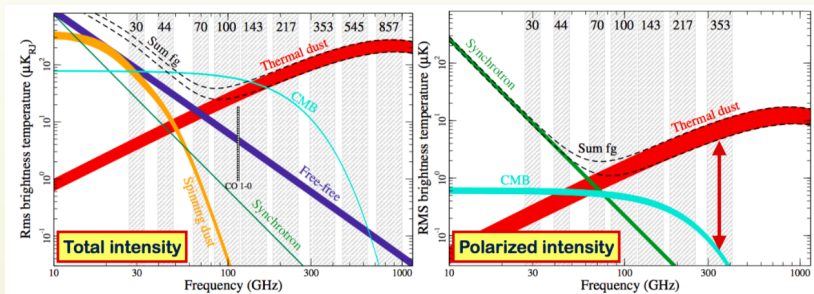


- The microwave sky

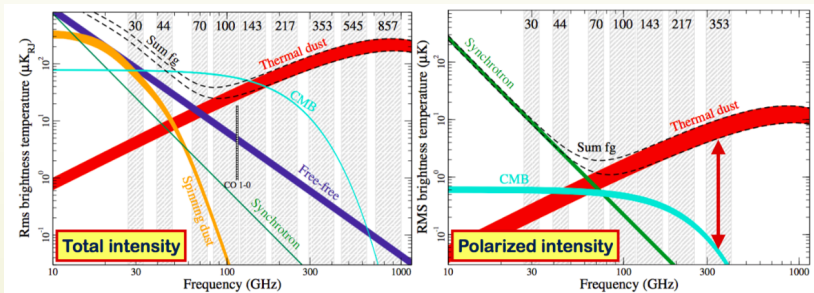


- ▶ CMB : Gaussian, isotropic, single-temperature blackbody spectrum
- ▶ Galactic foregrounds: highly non-Gaussian and anisotropic (multi-scale, with turbulence and intermittency)

- Polarization and B-modes

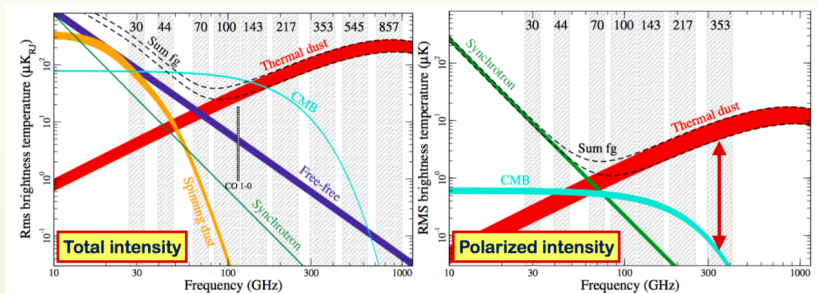


• Polarization and B-modes



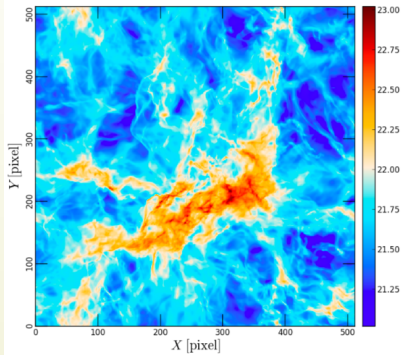
- ▶ Expected signal (much) lower than foregrounds
 ⇒ Need a very precise description of the foregrounds

- Polarization and B-modes

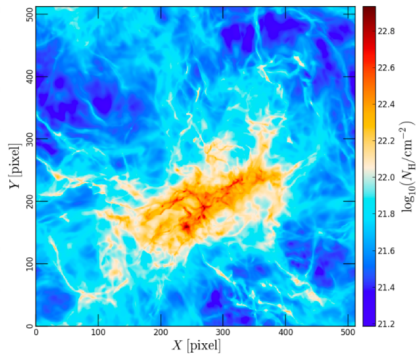


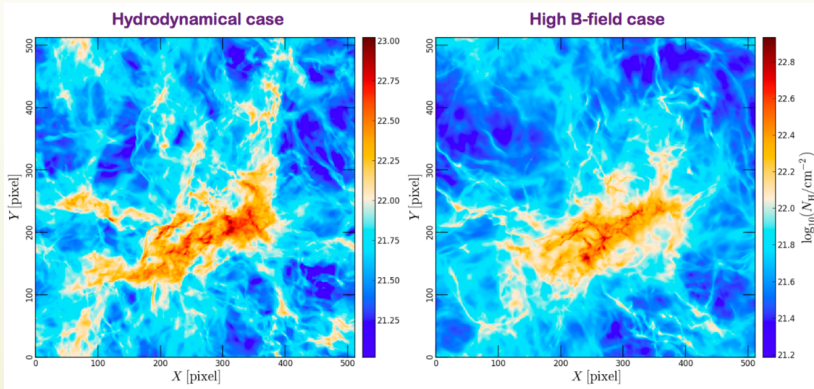
- ▶ Expected signal (much) lower than foregrounds
 \Rightarrow Need a very precise description of the foregrounds
- ▶ Foreground from magnetized and turbulent ISM
 \Rightarrow The description has to be statistical

Hydrodynamical case

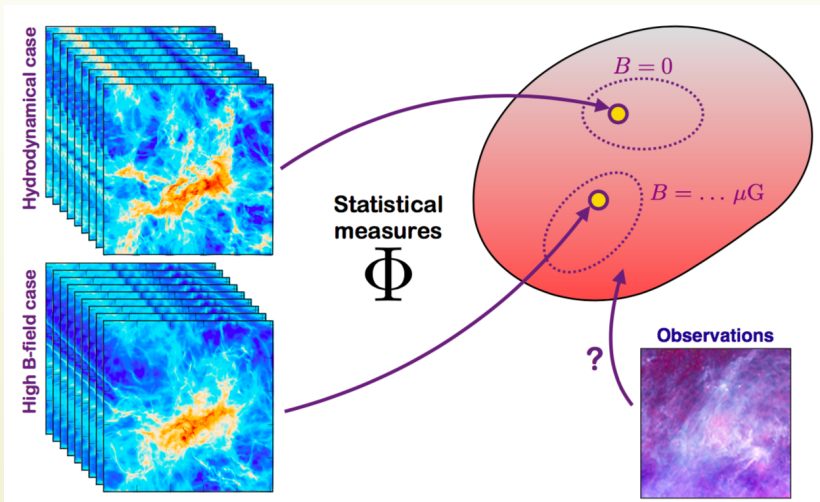


High B-field case





- Goal: Achieve a satisfactory statistical description of the Galactic magnetized and turbulent ISM



- Satisfactory statistical description Φ
 - ▶ Extract information from observations
 - ▶ Link between micro-physics and statistical properties
 - ▶ Allow syntheses without expensive numerical simulations

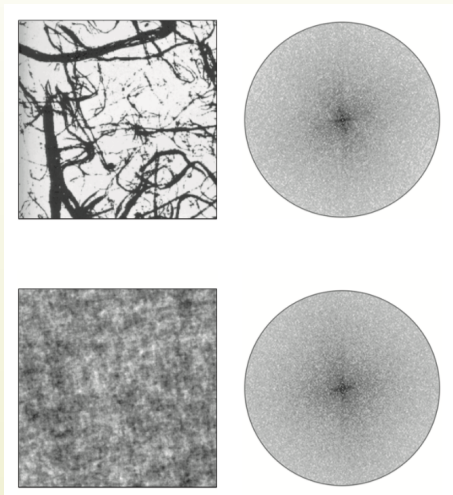
- **Satisfactory statistical description Φ**
 - ▶ Extract information from observations
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- **Interest with respect to pure machine learning**
 - ▶ Optimization \Rightarrow Computer-time and data-bank
 - ▶ Not a black-box \Rightarrow link with micro-physics
 - ▶ Sparsity

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- Power-Spectrum does not encode interactions between scales

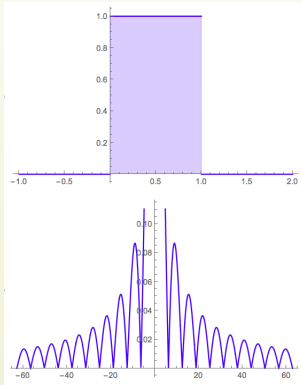


- What would be a good representation ?
 - ▶ Go beyond Power-Spectrum
 - ▶ Lipschitz continuous to deformations
 - ▶ Don't put too much information in the phases

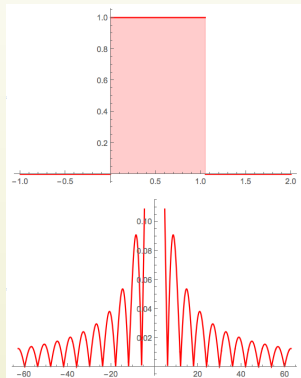
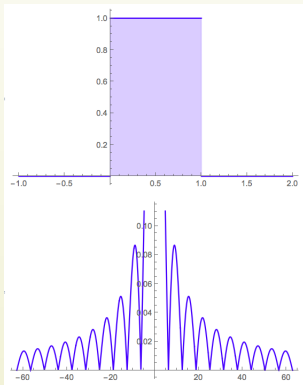
- **What would be a good representation ?**
 - ▶ Go beyond Power-Spectrum
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- **Inconvenience of Fourier transform**
 - ▶ Non-localized
 - ▶ A lot of information in phases
 - ▶ High-frequency instabilities

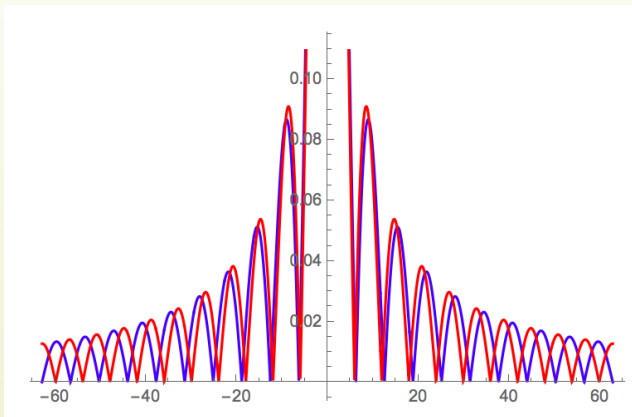
- Fourier transforms and high-frequencies



- Fourier transforms and high-frequencies



- Fourier transforms and high-frequencies



- **How to go beyond Power-Spectrum ?**
 - ▶ Wavelet transform ?

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- ▶ Not sufficient... reduces more-or-less to smart Power-Spectrum
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 - ▶ Describe the shape of the signal
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 - ▶ Examples in speech or in vision
- **⇒ Successive Wavelet transforms**

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- Scattering transform of a signal x
 - ▶ Decomposed in layers of indices m
 - ▶ $m = 0$: Average of the signal

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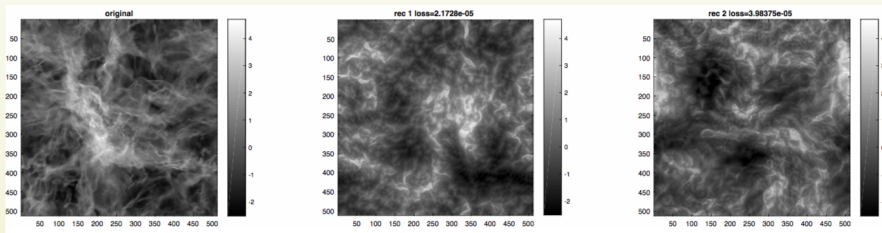
● Scattering transform of a signal x

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- ▶ ...

● Properties

- ▶ Good behavior under deformations, energy conservation, ...
- ▶ Most of the information contained in $m \leq 2$
- ▶ Order m contains moments up to order 2^m
- ▶ No significant information loss by L_1 norm

- Example of syntheses



Conclusion

- Galactic foregrounds with magnetized turbulent ISM require an advanced statistical description. Necessity to go beyond Power Spectrum
- Interaction with data scientists: scattering transform
- Link with micro-physics ? Extraction of information from observations ? Cheap realizations from statistical syntheses ?
- Work in progress

Thanks for your attention !