CMB-France

Statistical separation of dust and CIB with Wavelet Phase Harmonics

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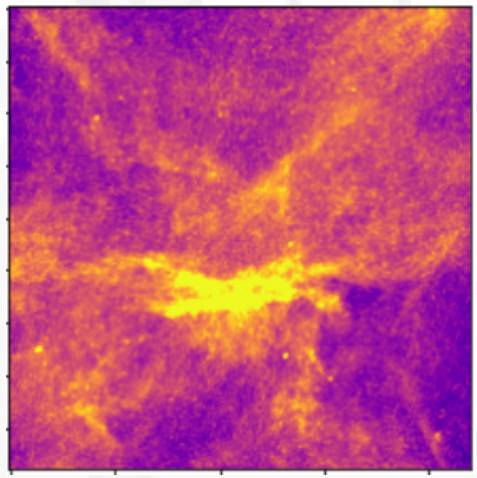
Context

Current models of CMB foregrounds based on Planck data suffer from the difficulty to separate dust and CIB

Cosmic Infrared Background (CIB) $\Longrightarrow$ cumulative infrared emission from all the galaxies throughout cosmic history

Dust and CIB :

- Same physical origin
  - Similar SED !



Herschel SPIRE observation at 500m

$\Longrightarrow$ Component separation using **new statistical tools**

(Mallat+ 2020, Allys+ 2020, Régaldo 2021)

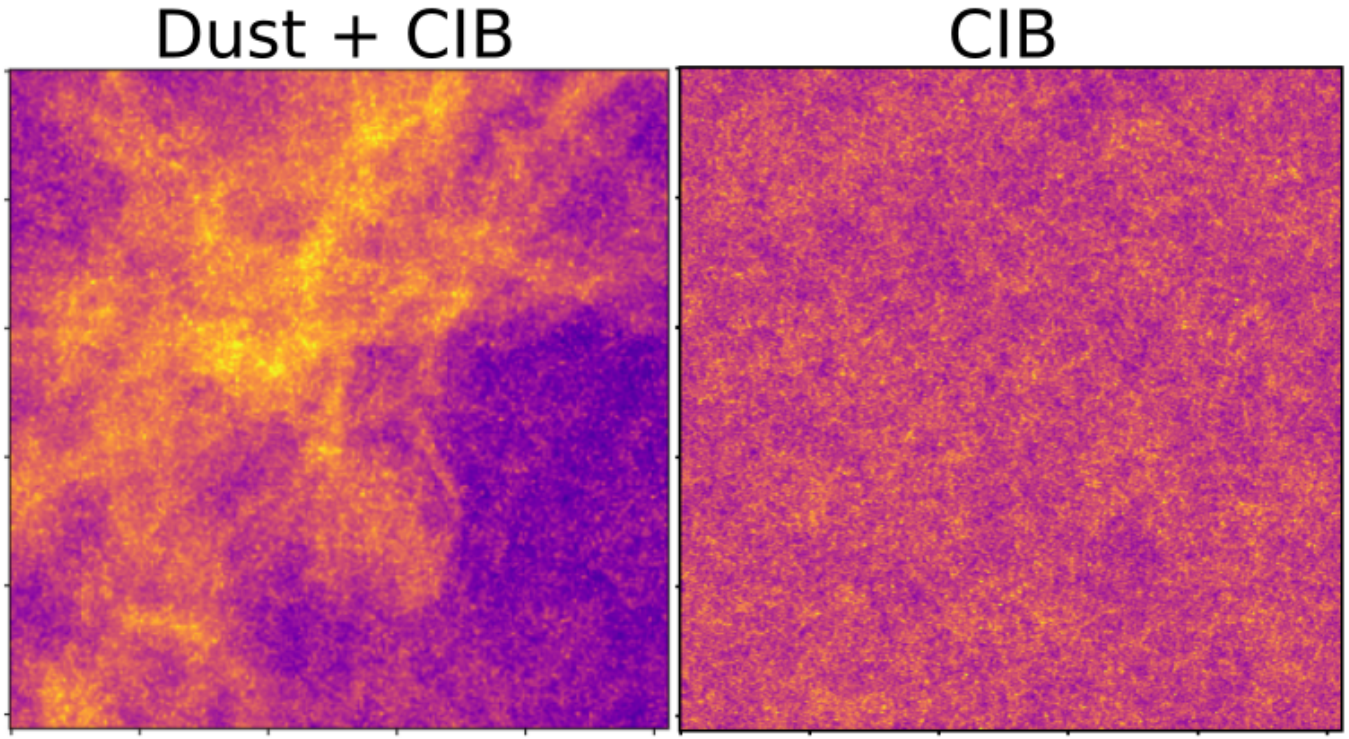
How to do it ?

CIB is statistically isotropic
$\Longrightarrow$ **We can compute its WPH statistics** on simulations or clean sky fields

Then, can we retrieve the **dust** and its **statistics** ?

Dust WPH statistics $\Longrightarrow$ generative model (Niall Jeffrey, 10 a.m.)

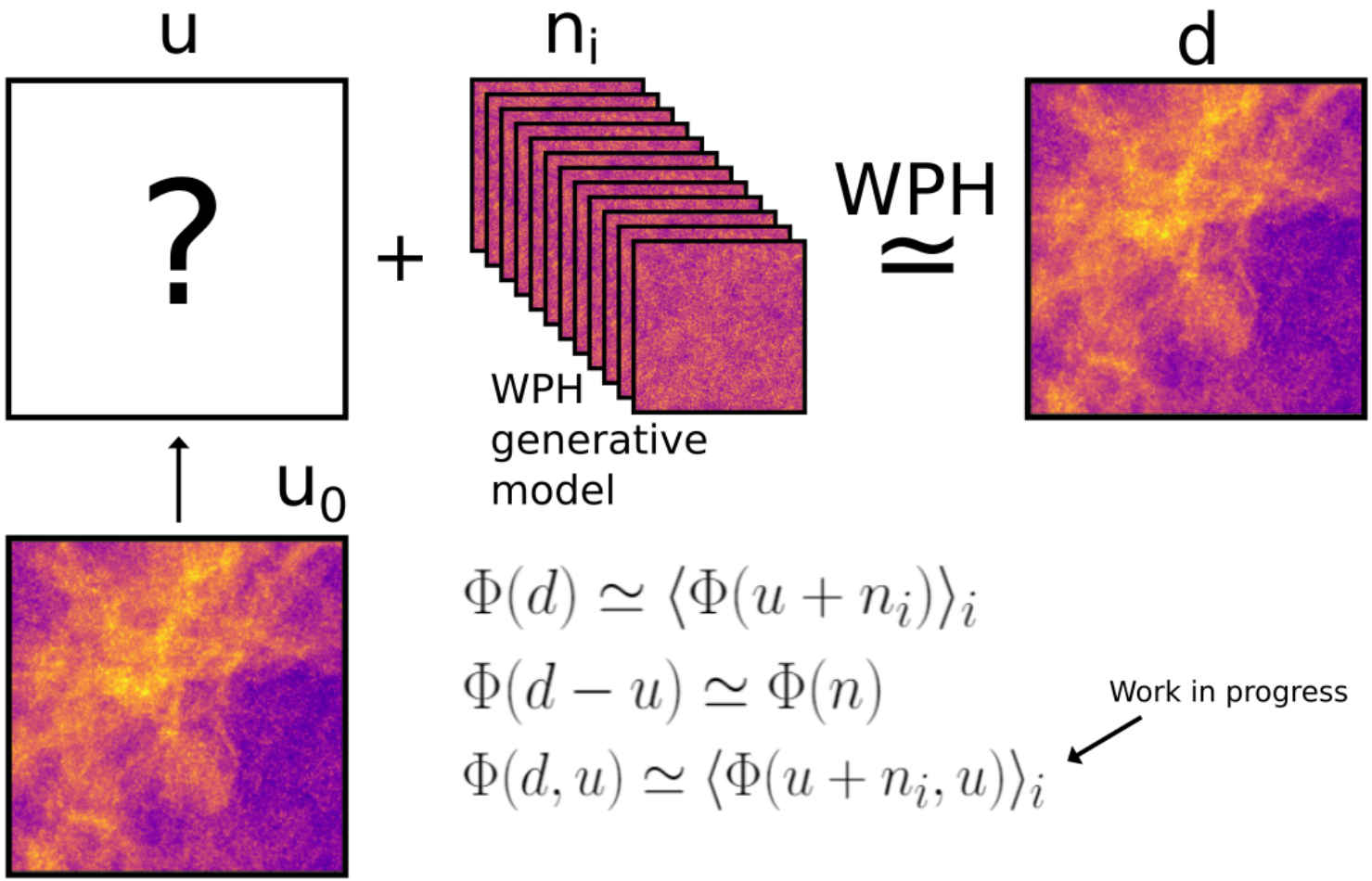
Component mixture



$\Longrightarrow$ Data : **1** component mixture map, **1** independent CIB map

How can we separate dust from CIB ?

Component separation method



Principle of the component separation algorithm
(adapted from Régaldo-Saint Blancard 2021)

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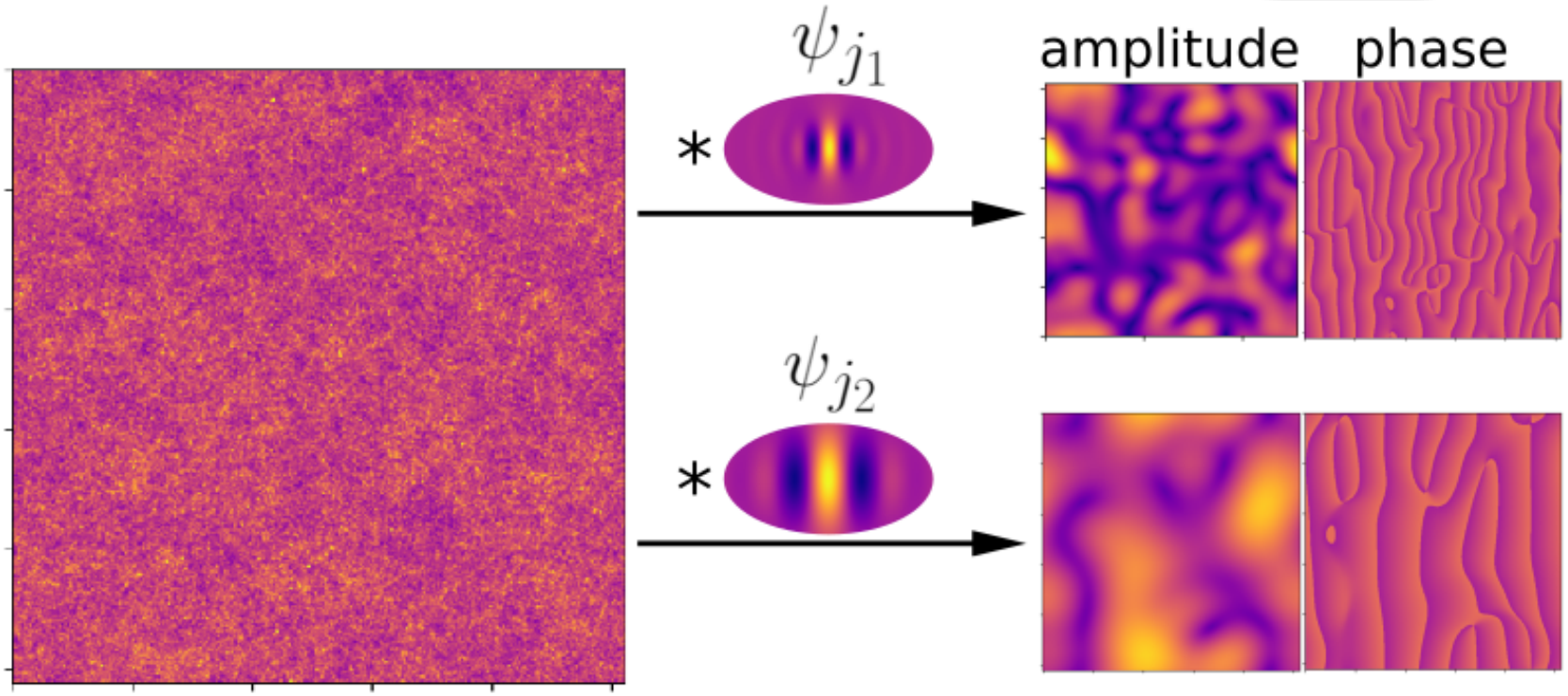
$\Longrightarrow$ Need for **efficient non-Gaussian statistics**

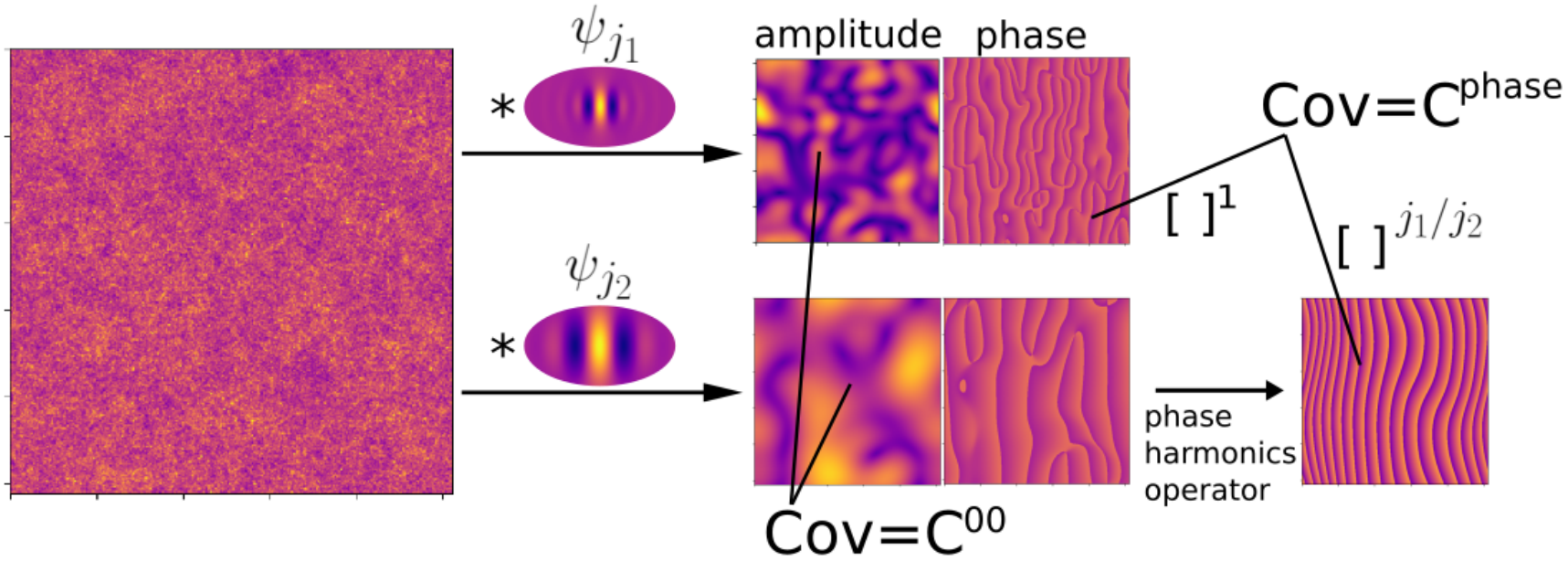
- Wavelet Phase Harmonics (WPH) statistics
  - Data science (Mallat+ 2020)
  - First application to astrophysics (Allys+ 2020, Régaldo 2021)
- How does it work ?
  - Without training phase
  - Physically interpretable
  - 2 steps :
    - **Multi-scale wavelets decomposition**
    - **Non-linearities $\longrightarrow$ Interactions between scales**

Wavelet Phase Harmonics (WPH) : Decomposition



Step 1 : Multi-scale decomposition

$\longrightarrow$ local filtering over a range of scales and orientations



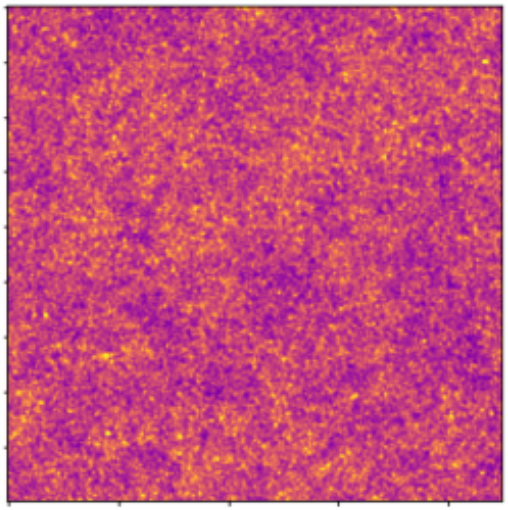
Step 2 : Characterize the interactions between scales
using a non-linear operator : $[z]^p = |z|e^{iarg(z)\times p}$

$$C_{j_1,j_2}^{p_1,p_2} = \mathrm{Cov}([\rho * \psi_{j_1}]^{p_1}(\vec{x}), [\rho * \psi_{j_2}]^{p_2}(\vec{x})) \Longrightarrow \left\{ S^{11}, S^{00}, C^{\mathrm{phase}}, C^{00} \ldots \right\}$$

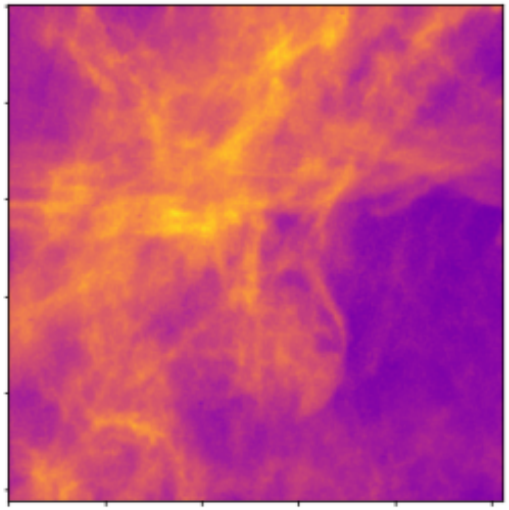
Data

CIB simulation:

Gkogkou,
Béthermin,
Lagache (LAM)



MJy/sr

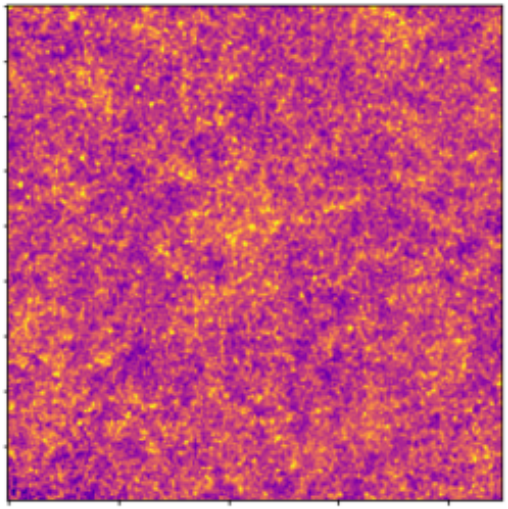


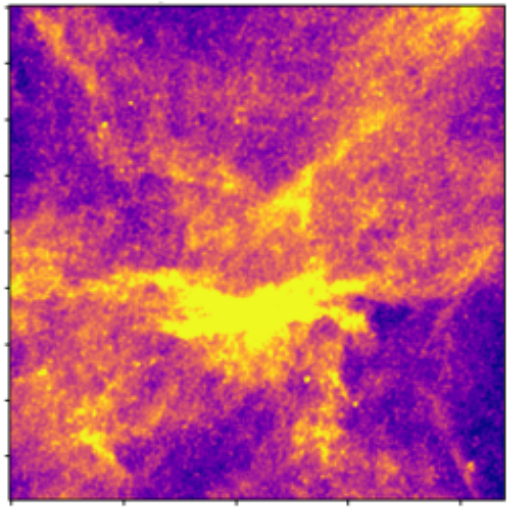
Galactic dust
map deduced
from HI
observations

Marchal
Miville-Deschenes

Lockman hole:
Herschel SPIRE
observation
at 500 µm

Little dust

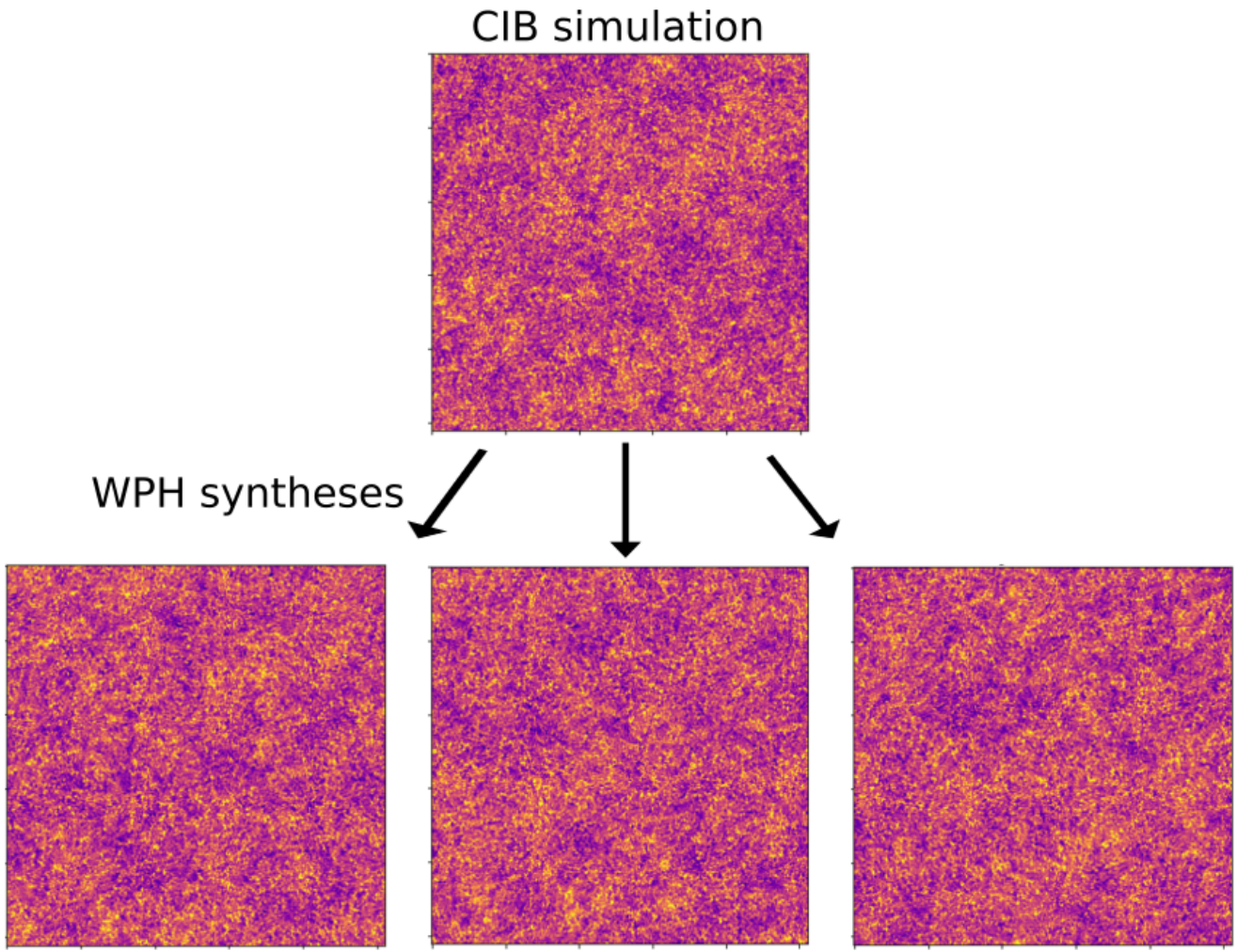




Spider:
Herschel SPIRE
observation
at 500 µm

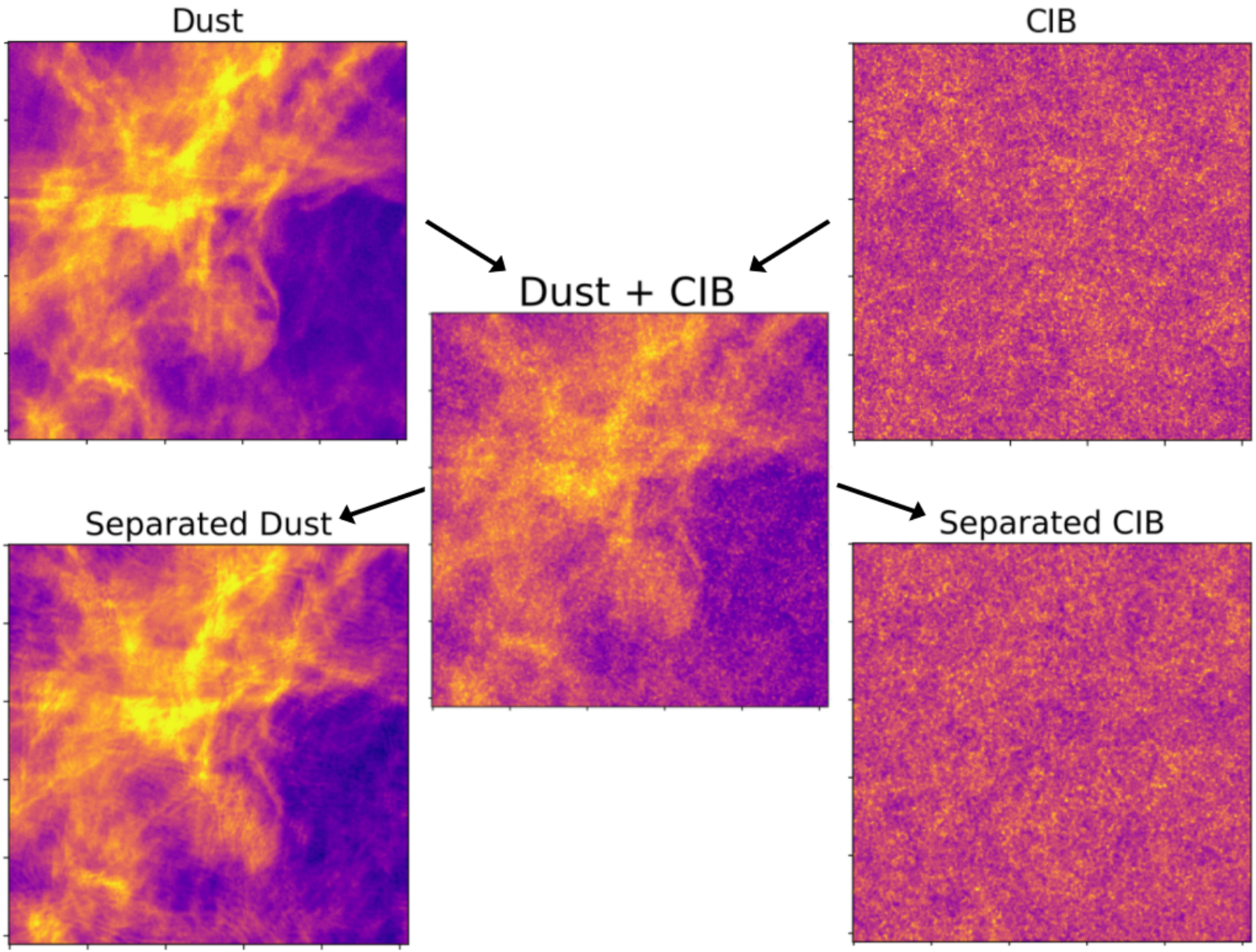
More dust

Generative model

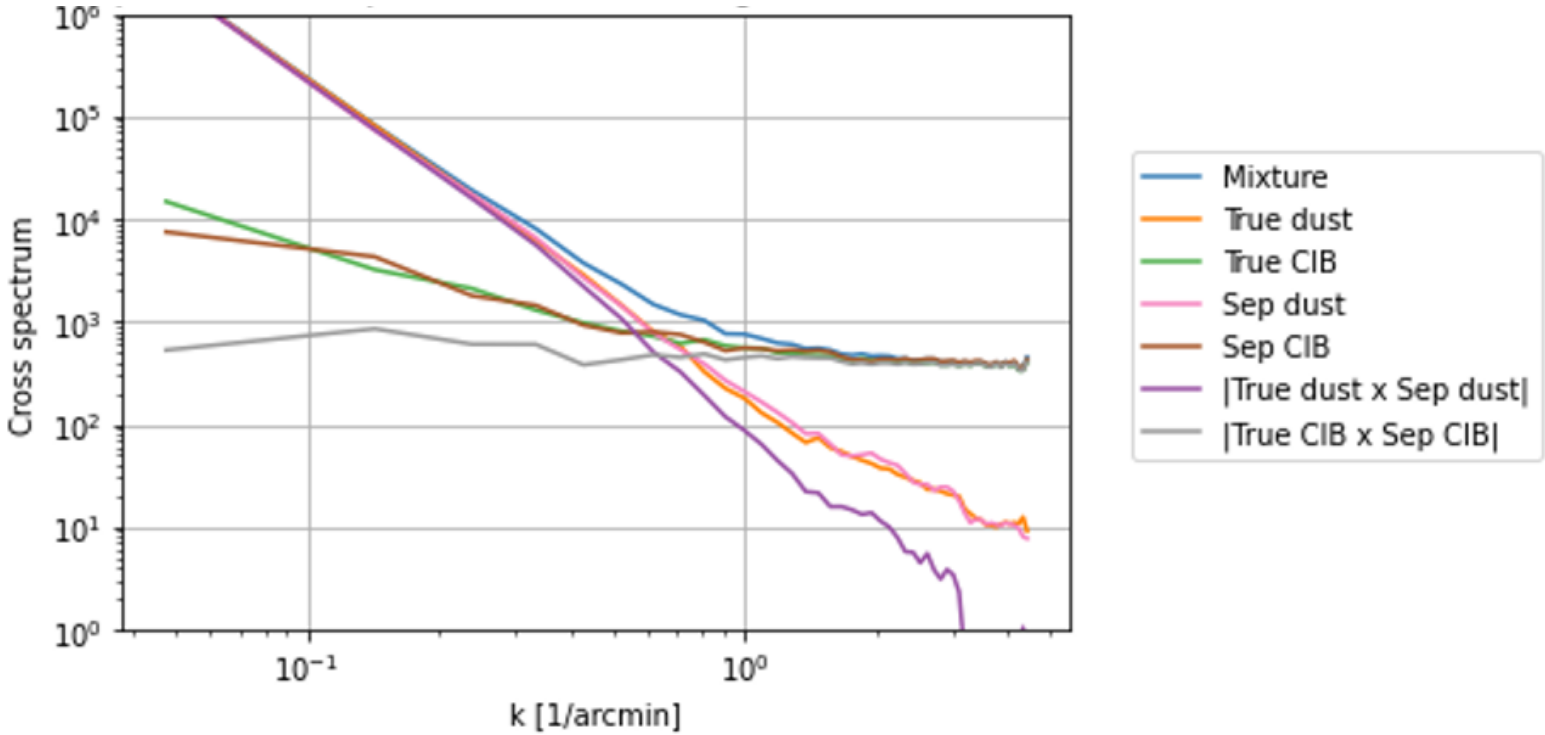


$\Longrightarrow$ **We generate new realizations of the CIB**

Results (work in progress)



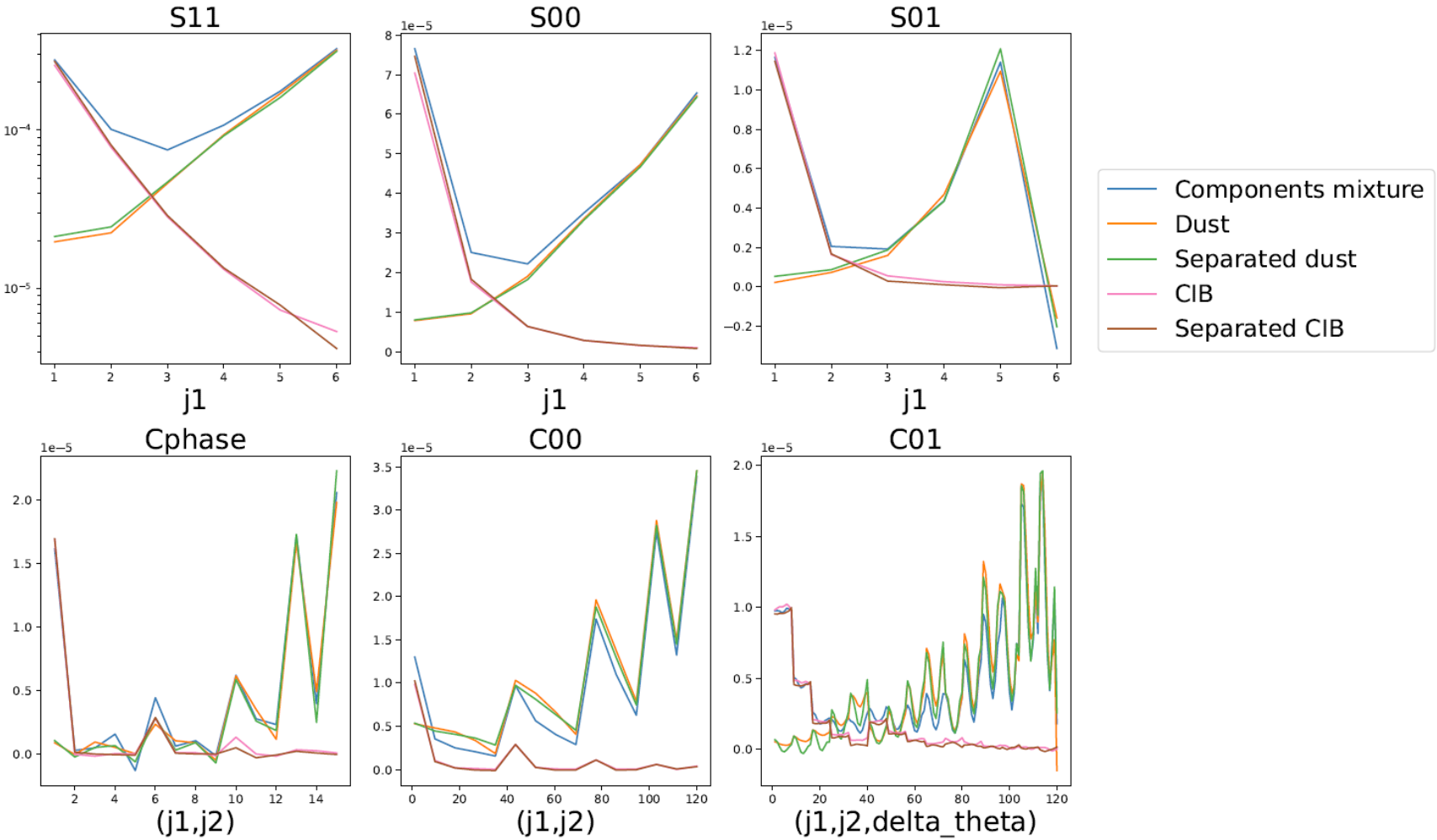
Result analysis



Power and cross spectra

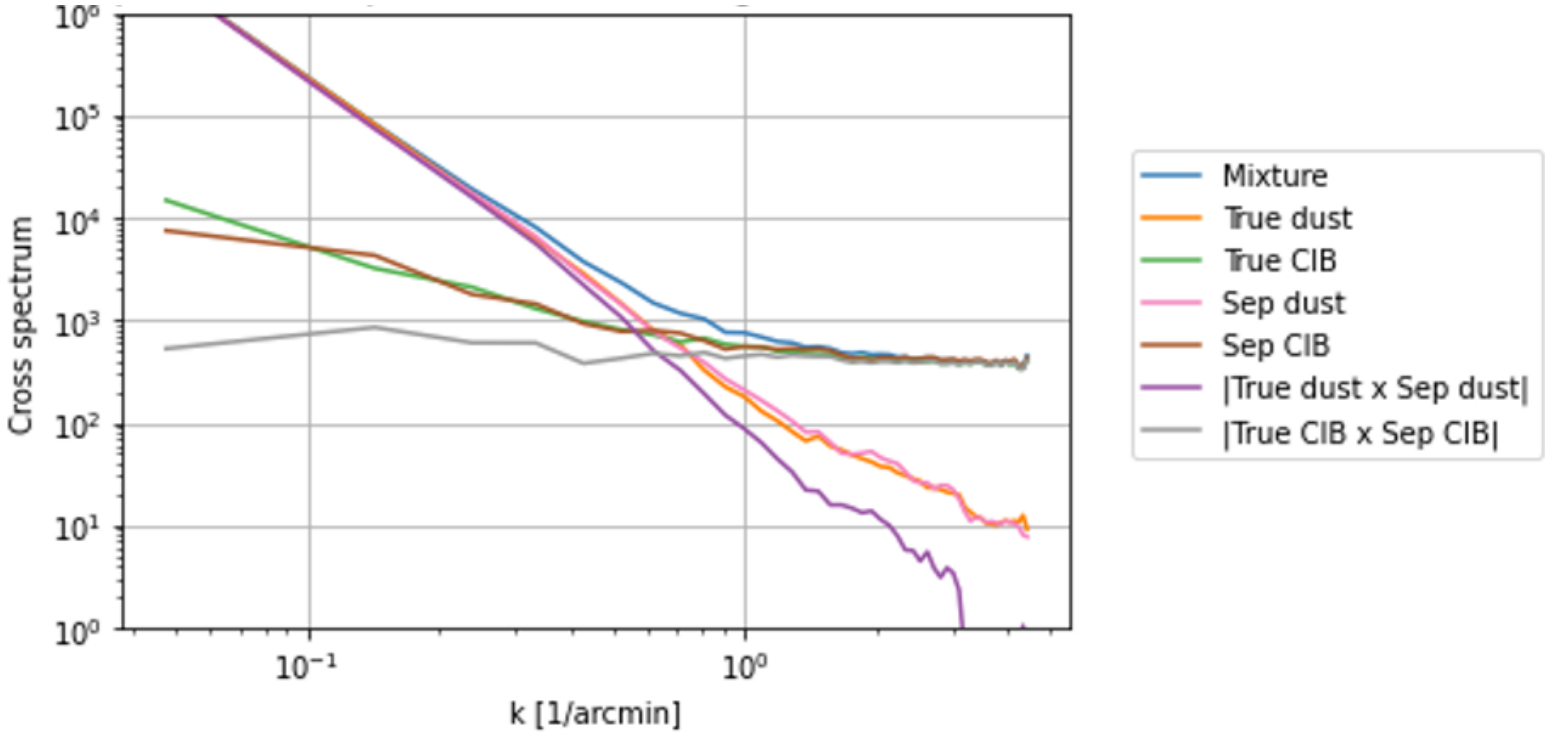
We are able to separate the power spectra

Result analysis



We are able to get the good WPH statistics

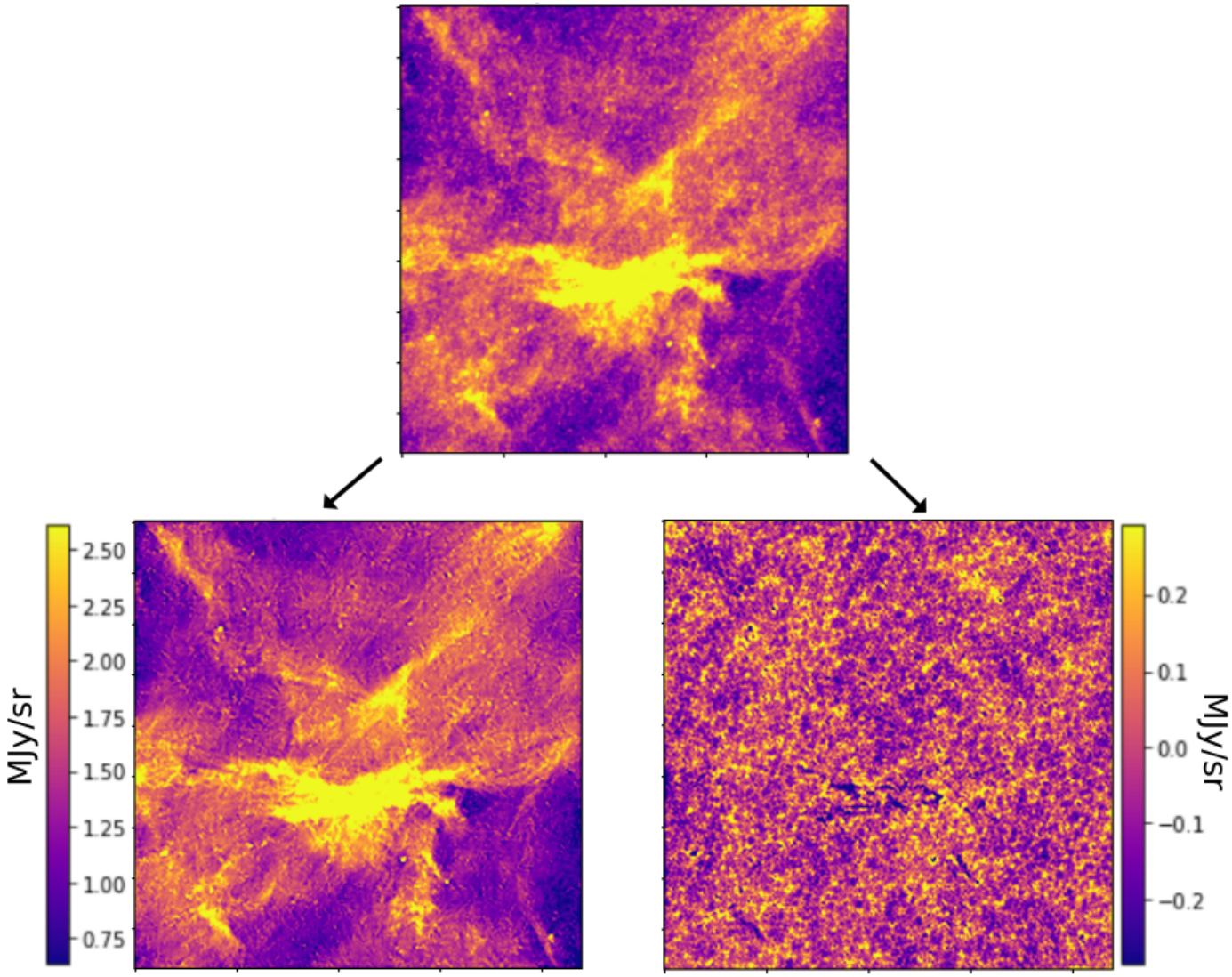
Result analysis



Power and cross spectra

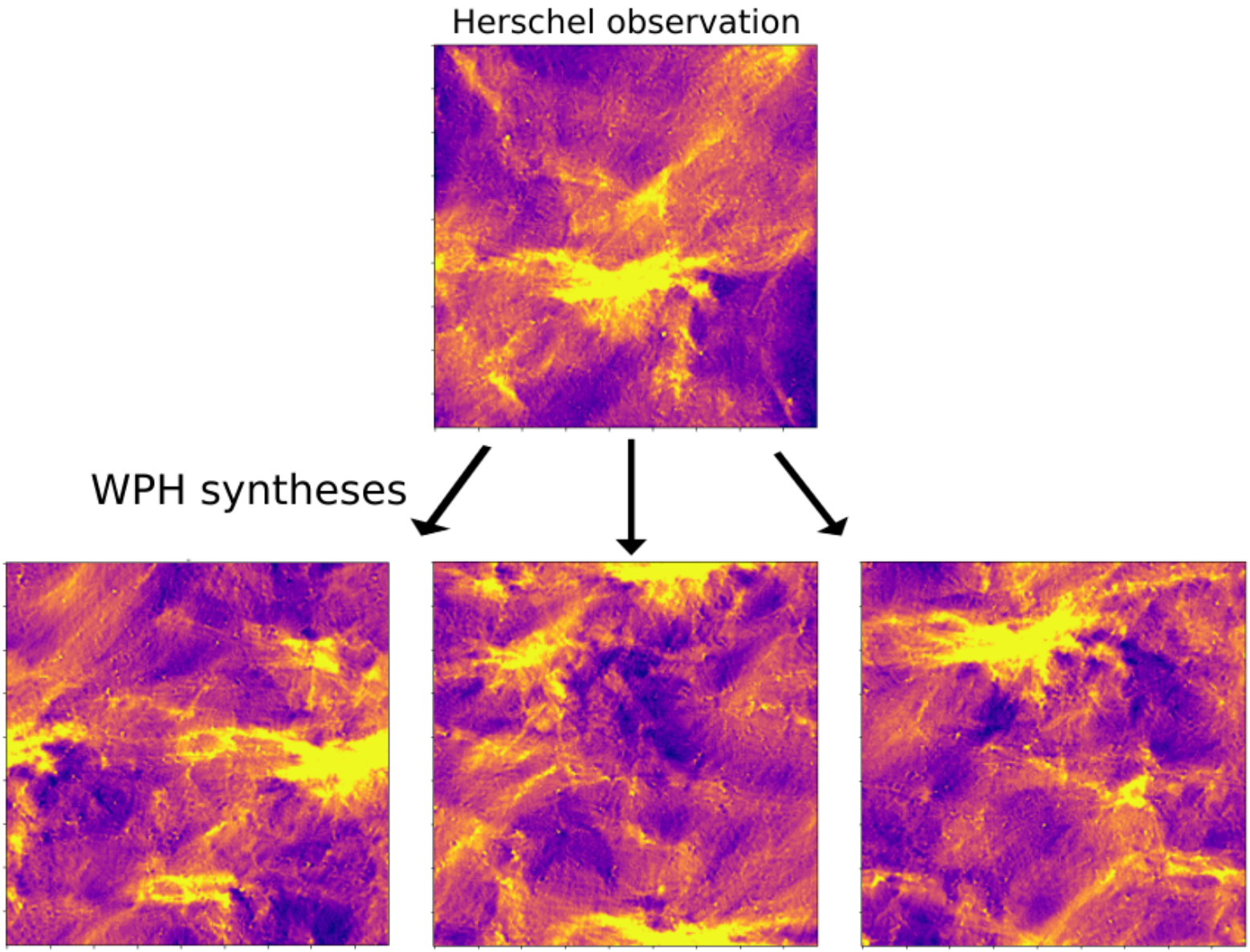
So far $\Longrightarrow$ statistical separation

Example on Herschel SPIRE observation



Herschel SPIRE observation at 500μm of "Spider" region

Example on Herschel SPIRE observation



Perspectives

Results

$\Longrightarrow$ Separation of two non-Gaussian fields using only 2 maps

On-going work

Cross-WPH statistics to characterize
correlations between two or more fields

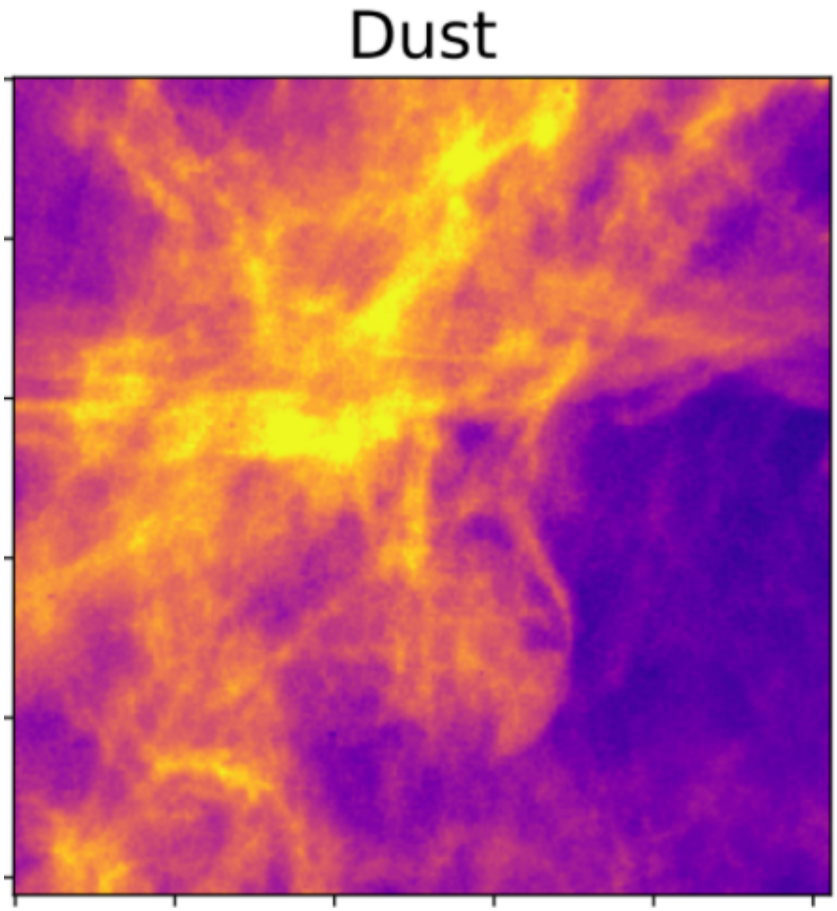
$\Longrightarrow$ Get a more deterministic dust/CIB separation

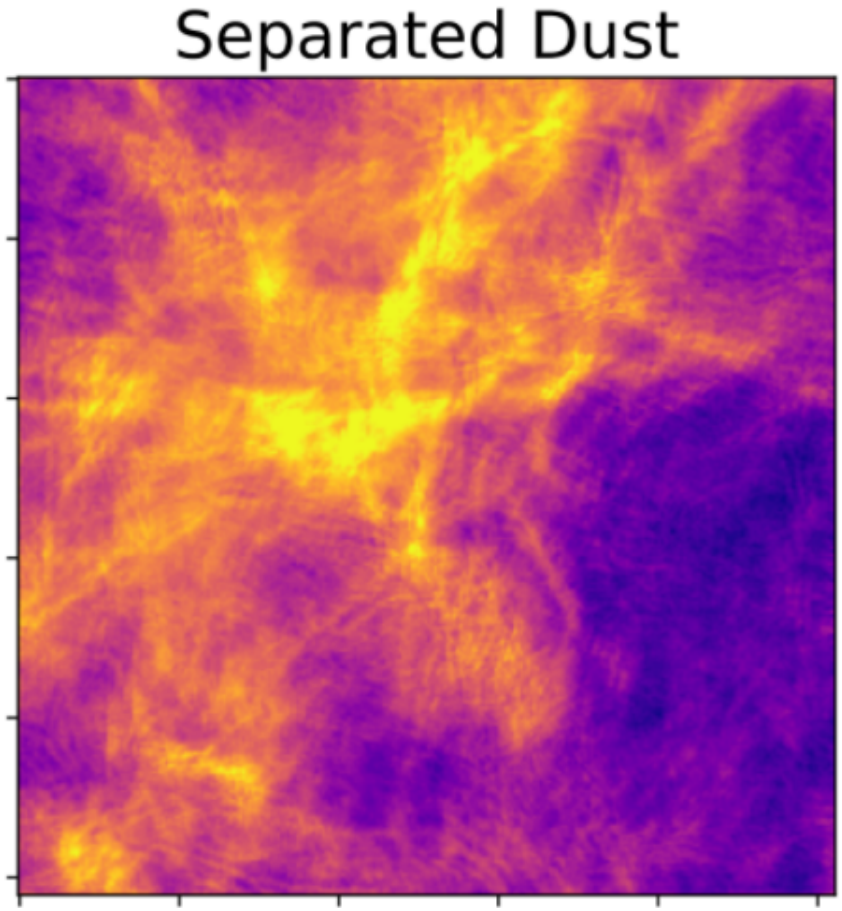
$\Longrightarrow$ Develop a multi-frequency model of dust and CIB emission for syntheses and separation

The End

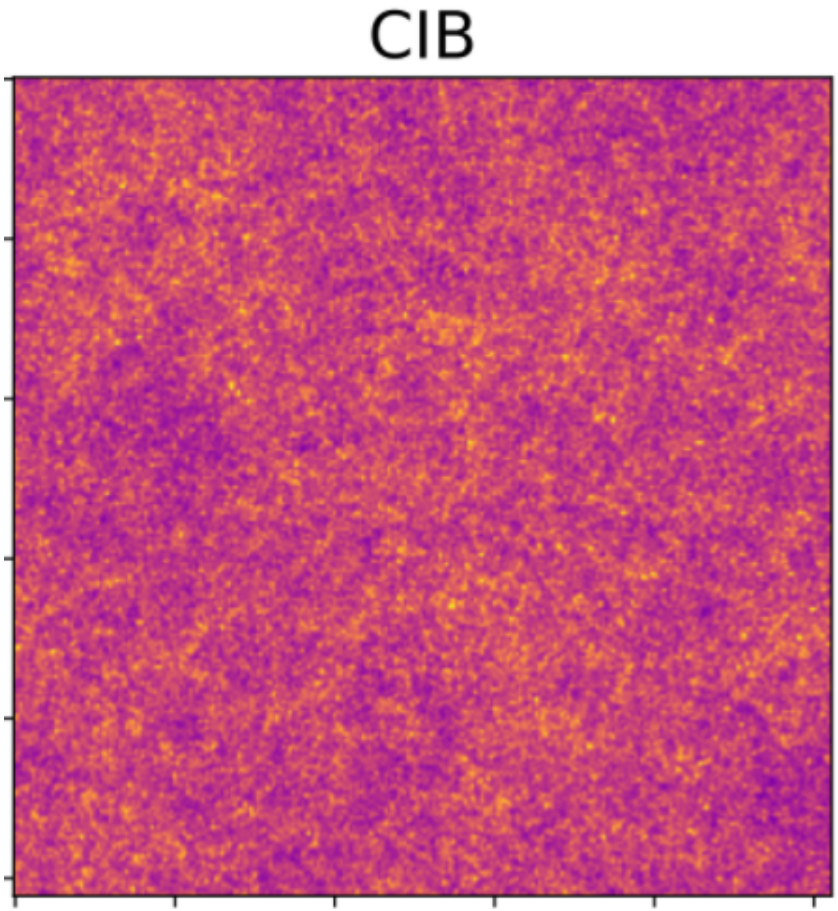
Thank you for listening !

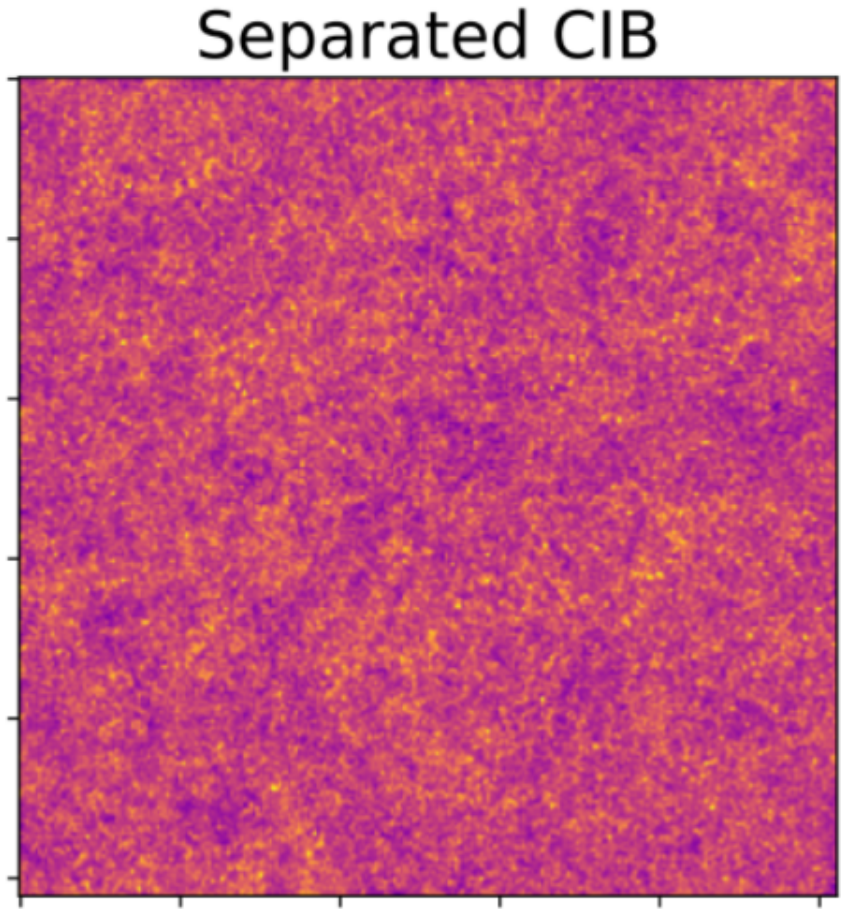
Result for dust





Result for CIB





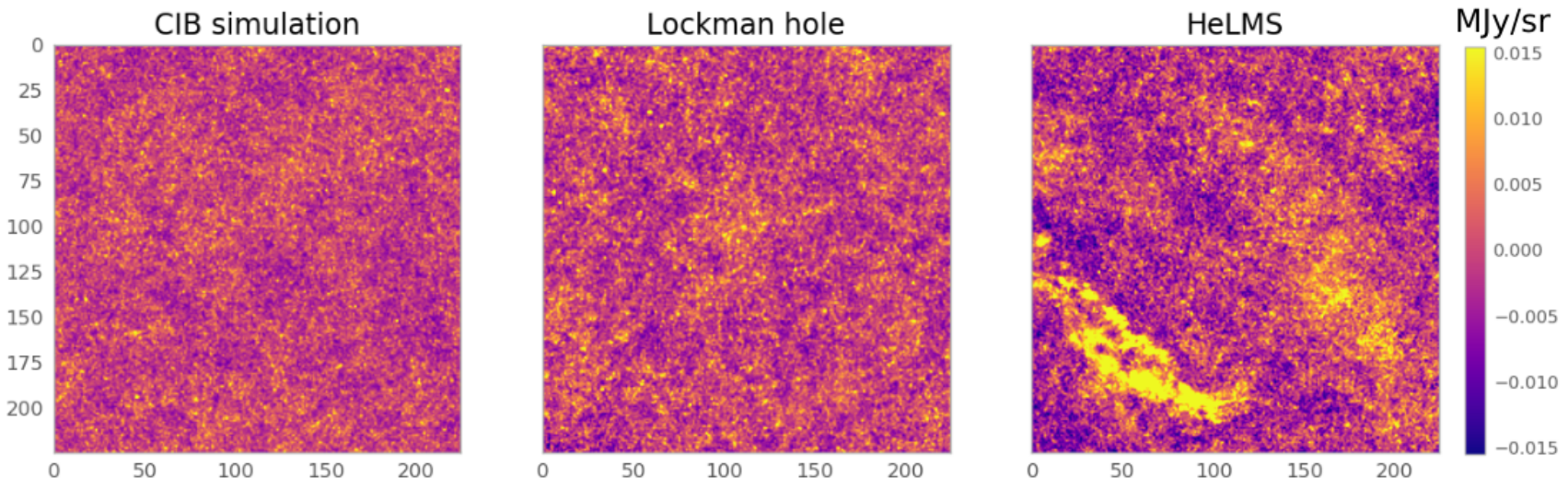
The WPH statistics as a generative model

- Validated using large scale structure simulations (Allys+ 2020)
- Reproduce the usual statistics in cosmology
- Necessary for our component separation

- Principle :
  - Start from a white noise
  - Gradient descent in pixel space

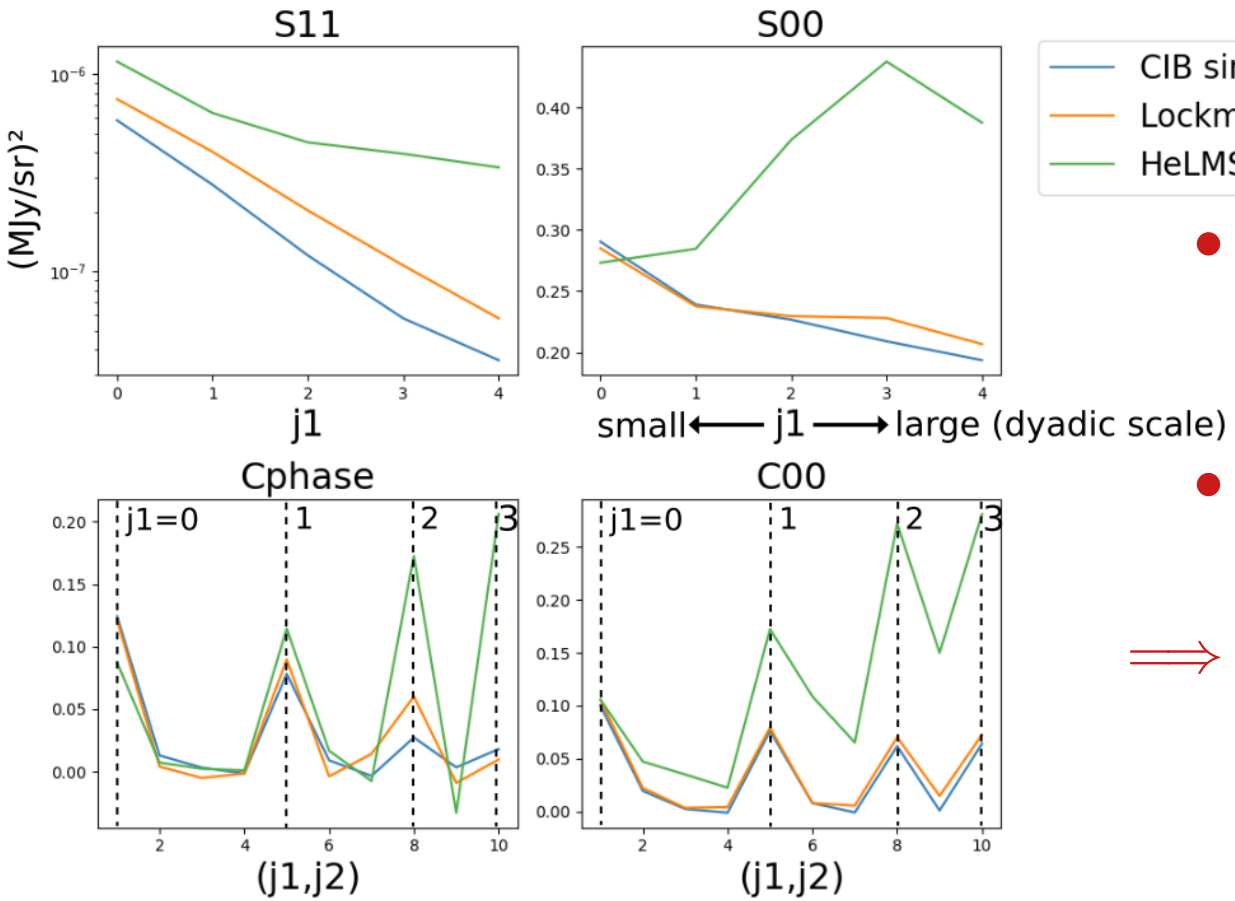
  $\longrightarrow$ reproduce the WPH statistics

Statistical characterization



- Difference between CIB simulation and Lockman hole ?
- How does dust contamination impact the WPH statistics ?

Statistical characterization



- CIB / Lockman hole $\longrightarrow$ same non-Gaussian statistics
- Dust signature on HeLMS

$\Longrightarrow$ Validation of the CIB model

Comparison of the **normalized** WPH moments