Simulations of polarised dust emission

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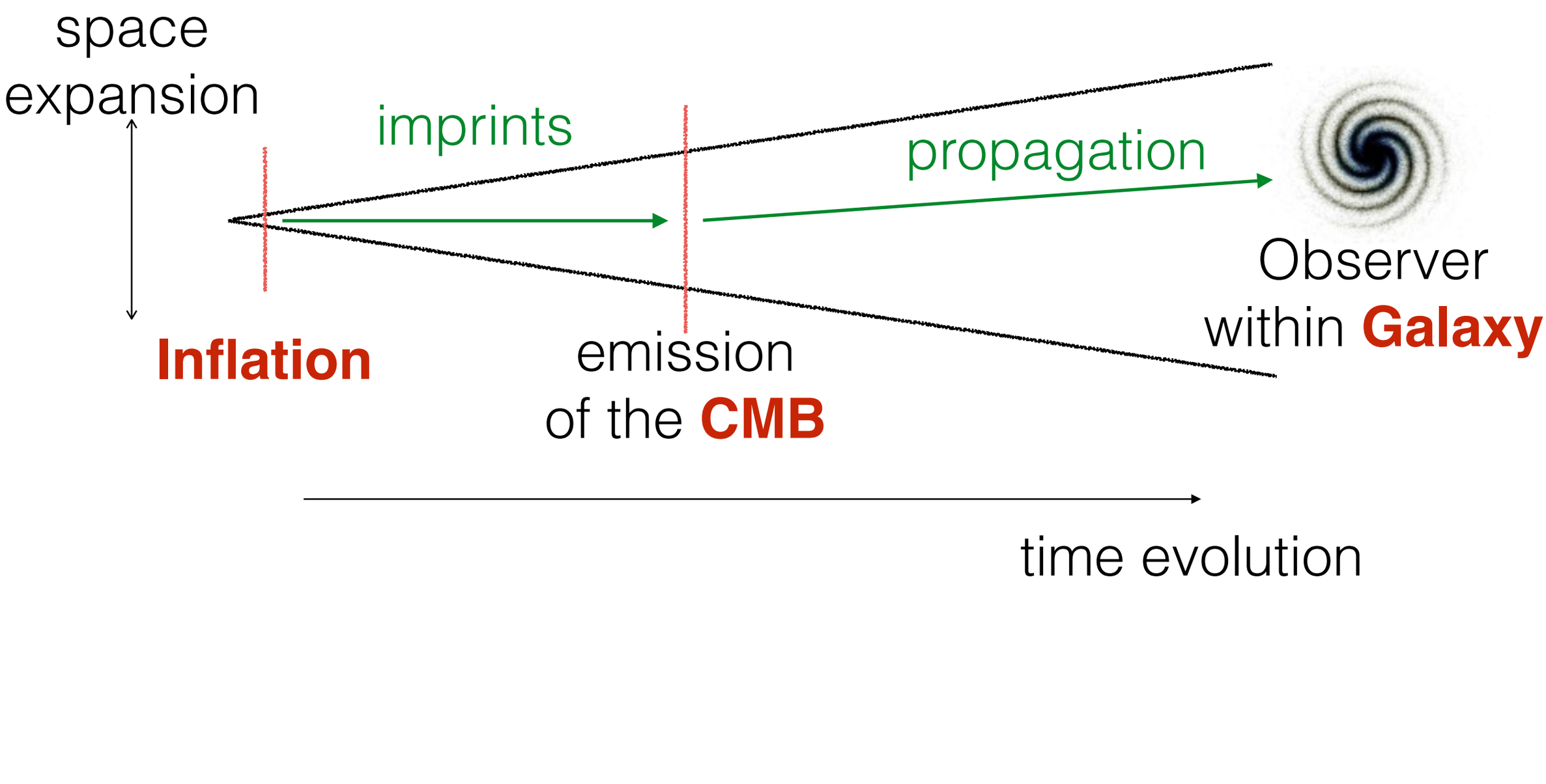
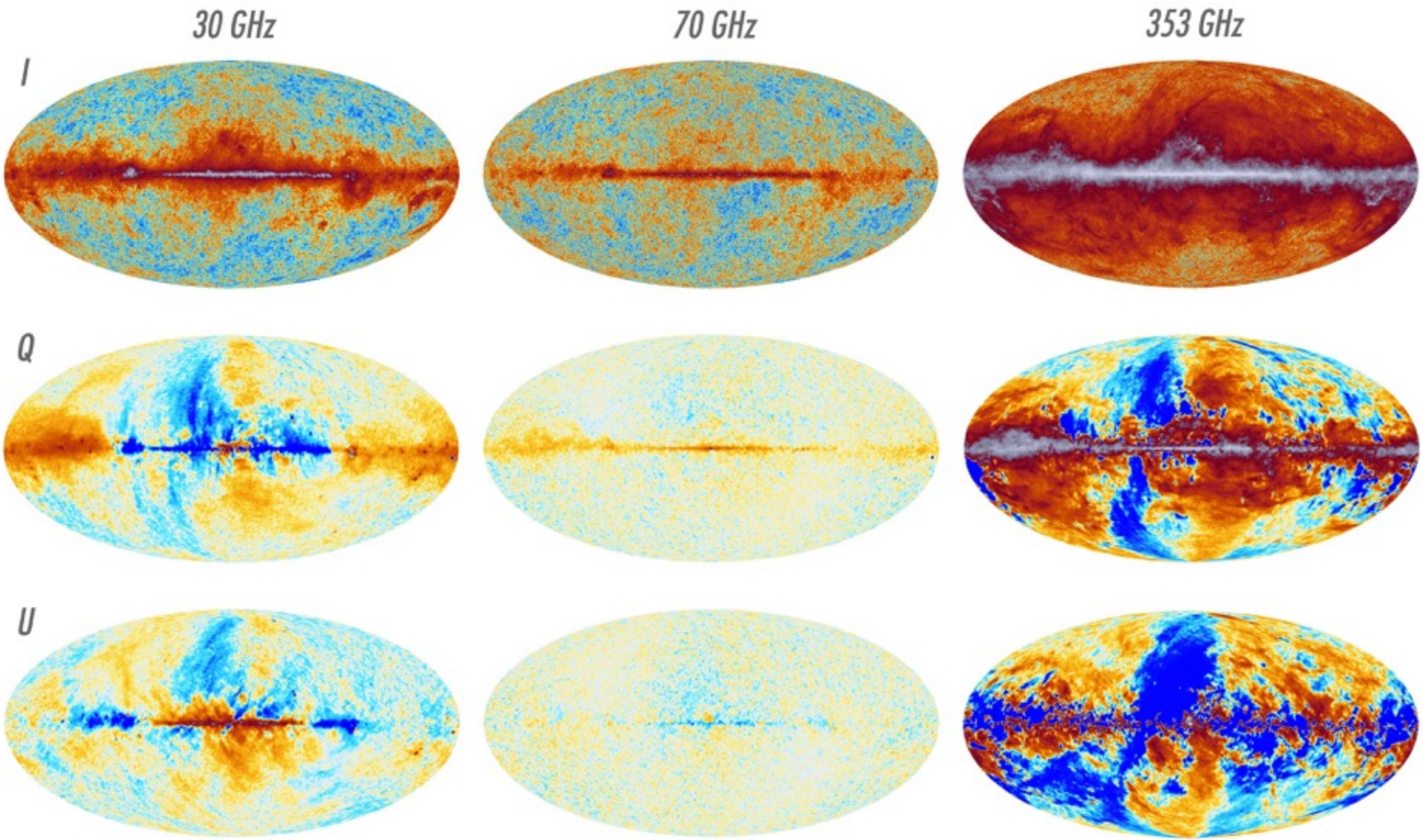
Collaborators: François Boulanger, Tuhin Ghosh, Andrea Bracco

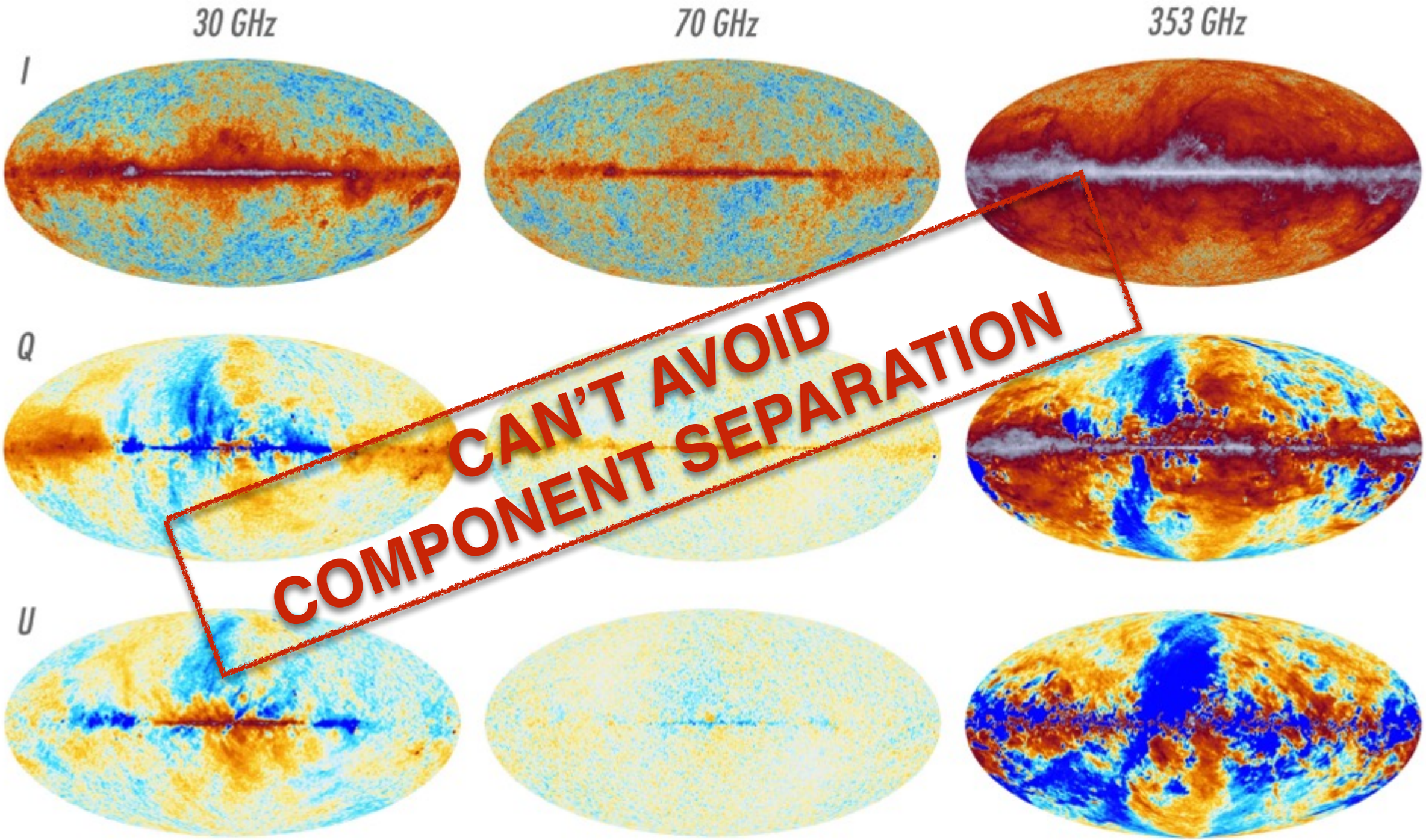
B-modes from space - 2015-12-11

Inflation through ISM





Planck polarised sky (2015)

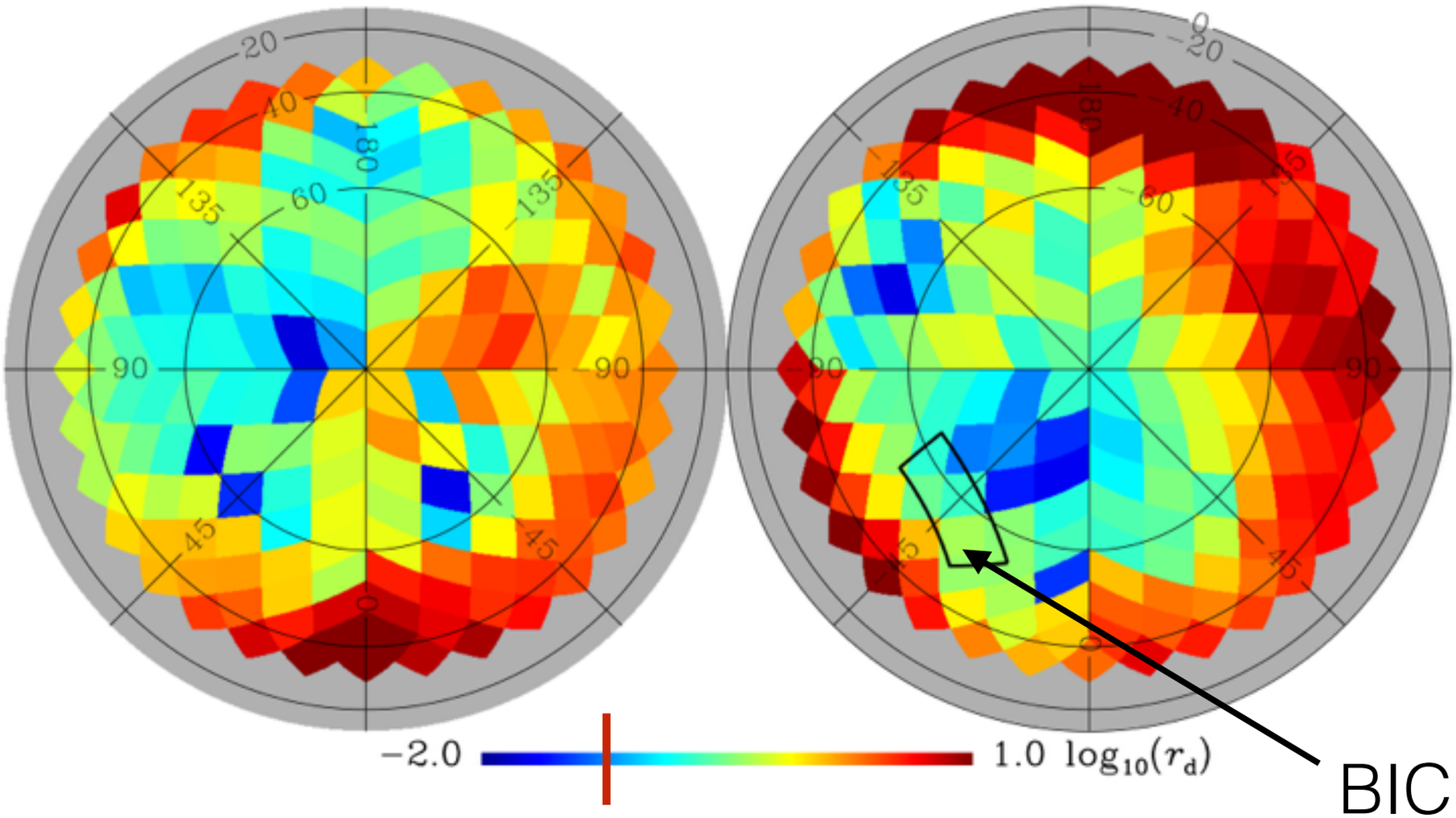


Planck **polarised sky (2015)**

Dust contamination

Toward North pole

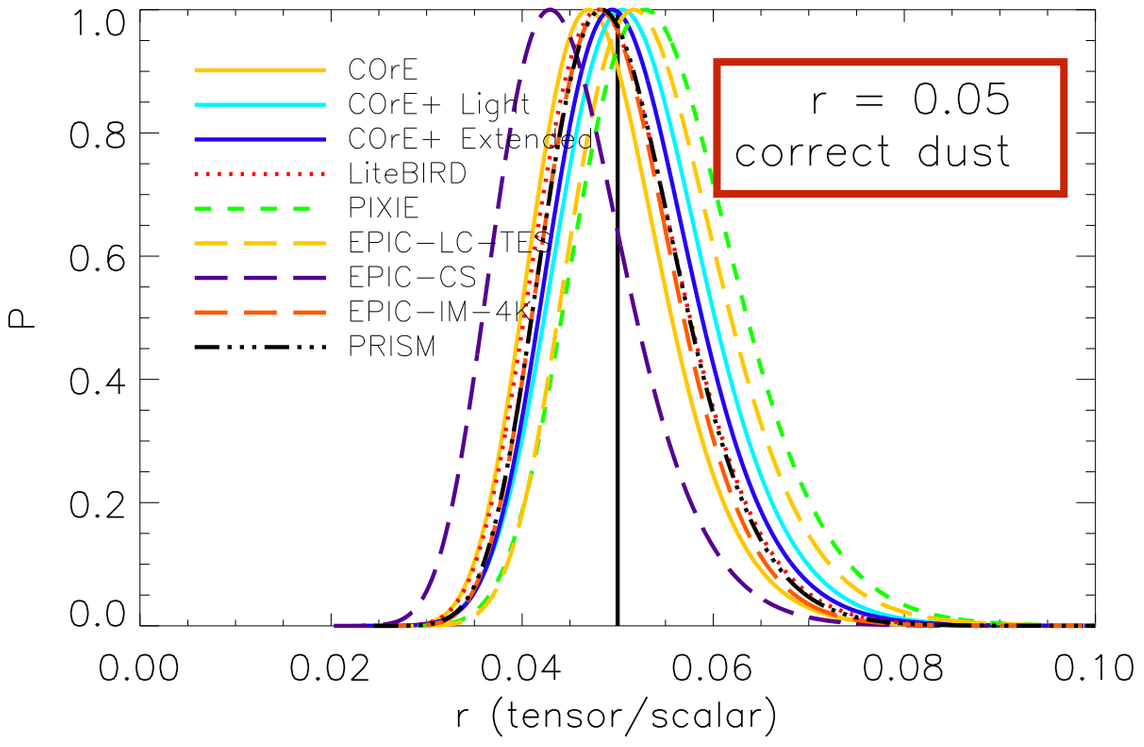
Toward South pole

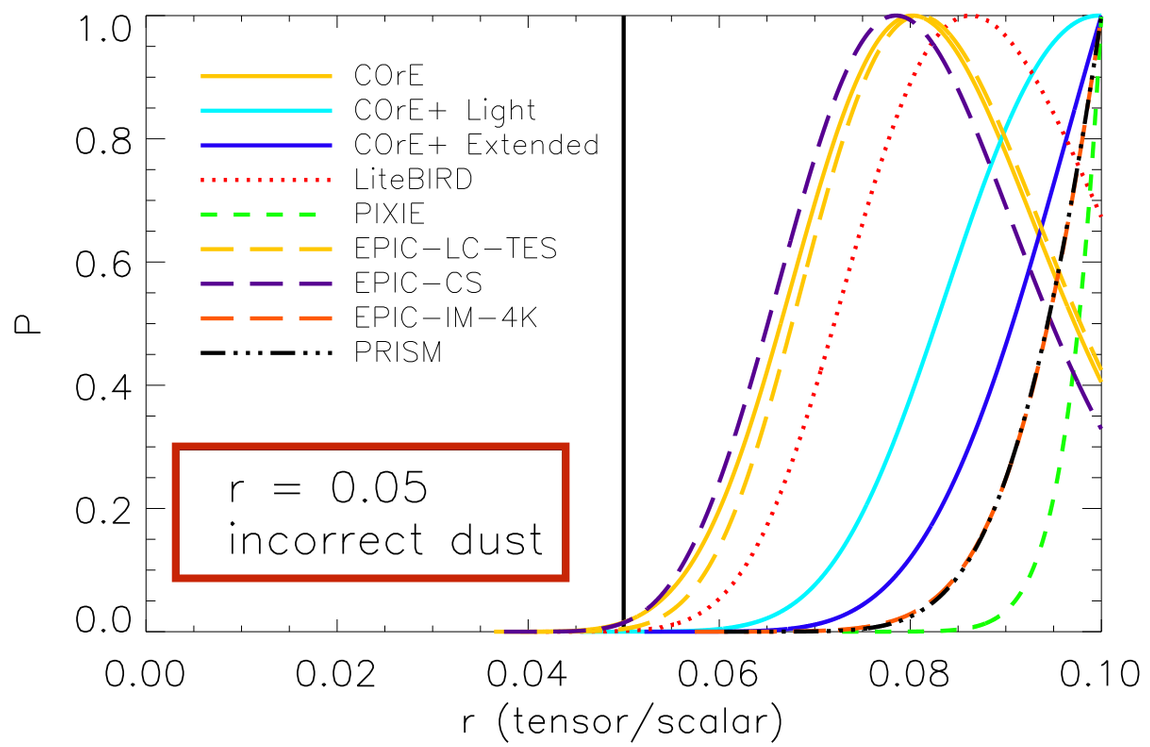


current limit

Planck collab. PIPXXX 2014

Fake CMB B-modes





Remazeilles, Dickinson, Eriksen & Wehus, 2015

Topical questions

- What experimental design for optimal cleaning?
- What level of B-modes can we actually reach?
- How to quantify the confidence in the cleaning?

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- What level of B-modes can we actually reach?
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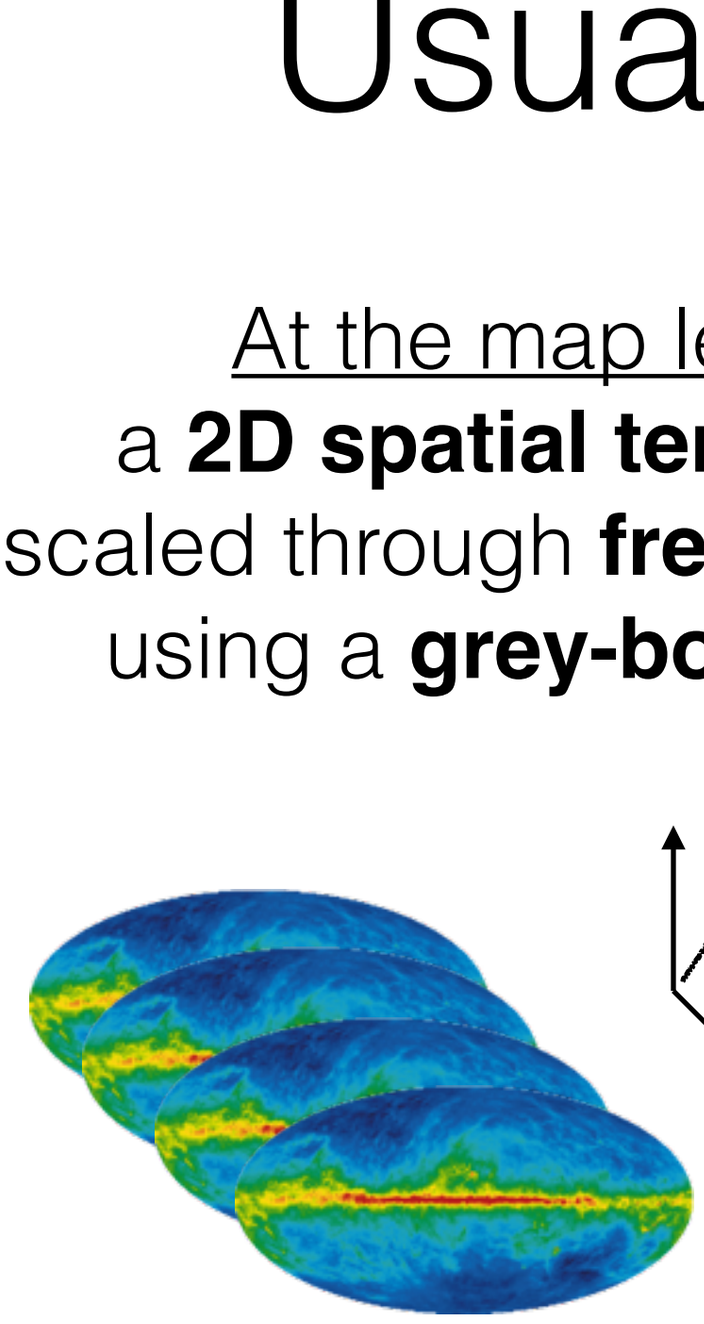
Need sky simulations to test component separation methods

Usual ISM dust model

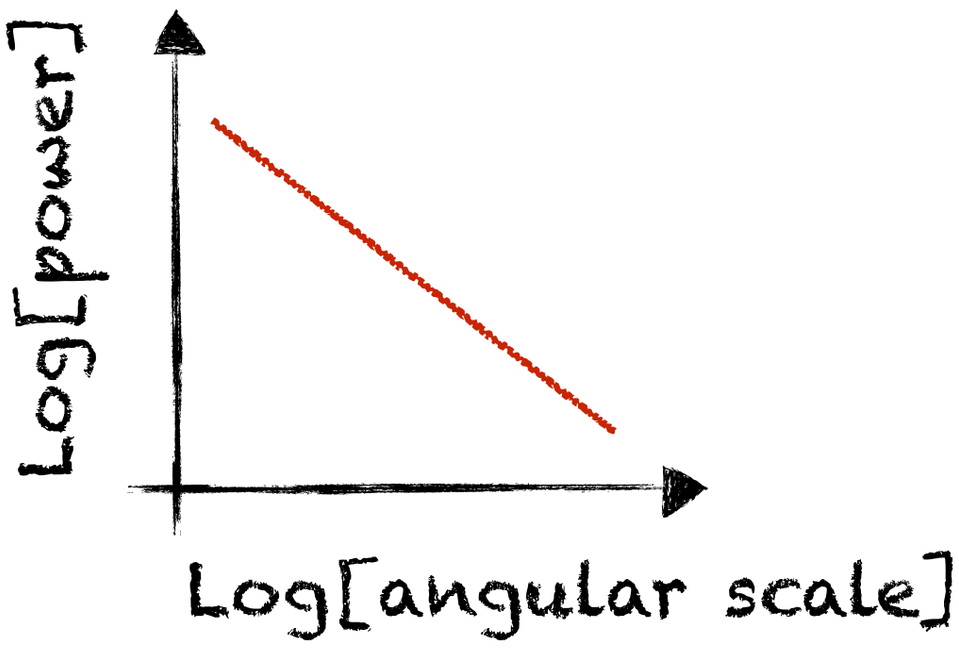
<u>At the map level</u>

a **2D spatial template**
scaled through **frequencies**
using a **grey-body** law



<u>At the power spectrum level</u>

a **power law**



Effective model

Actual ISM dust

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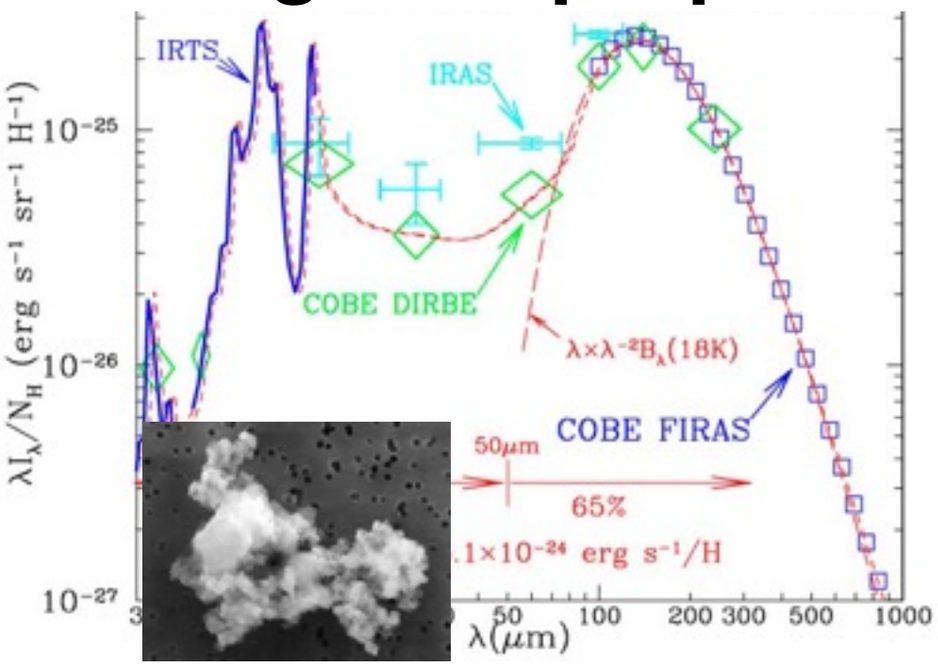
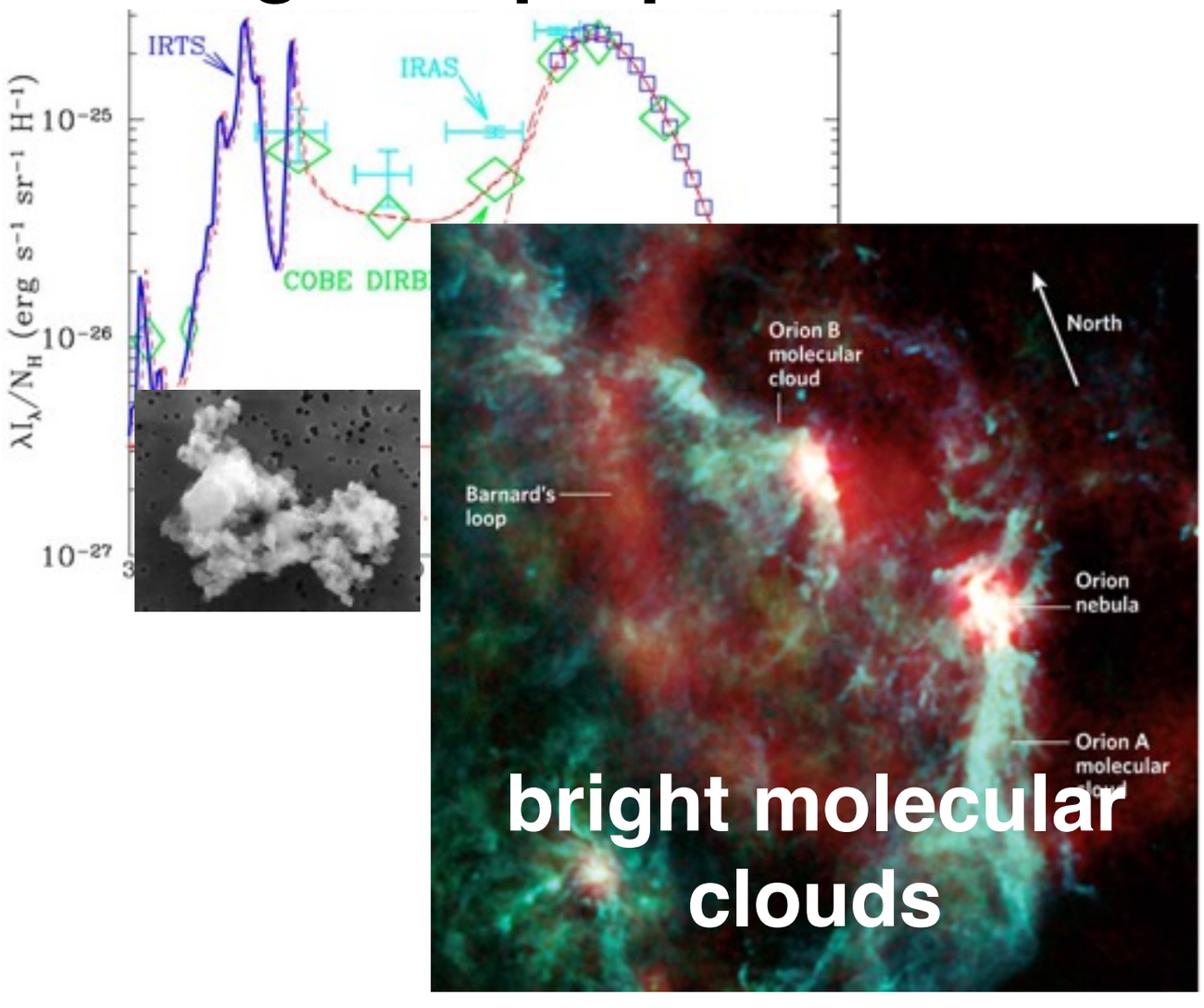
Actual ISM dust

dust grains properties



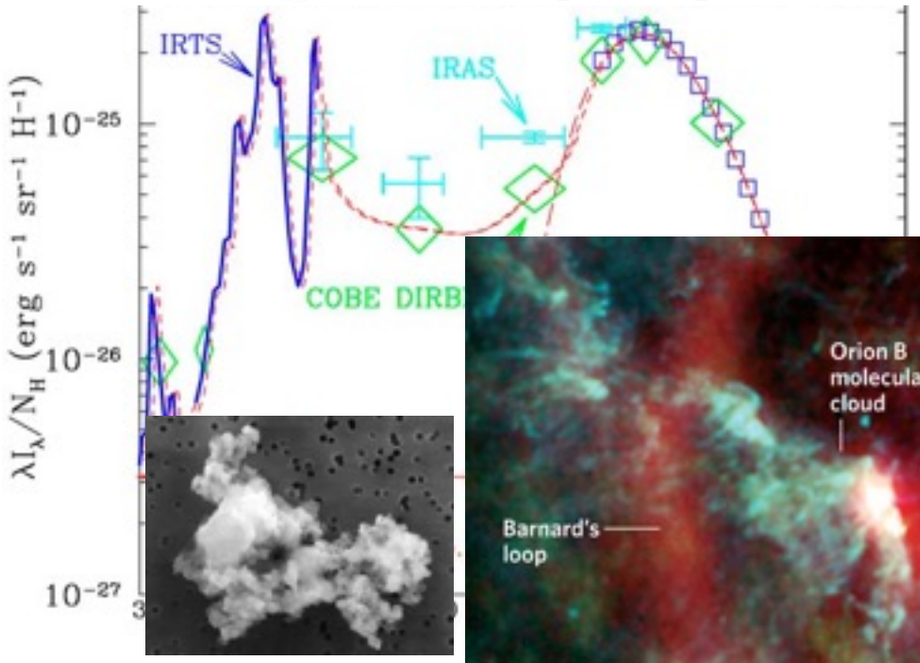
Actual ISM dust

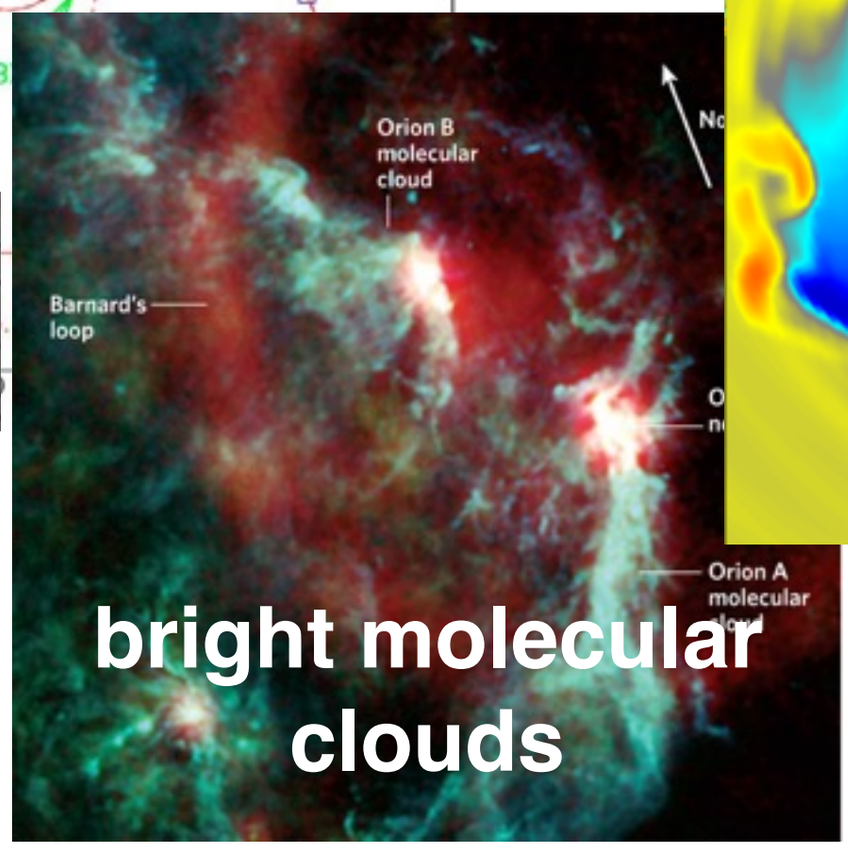
dust grains properties



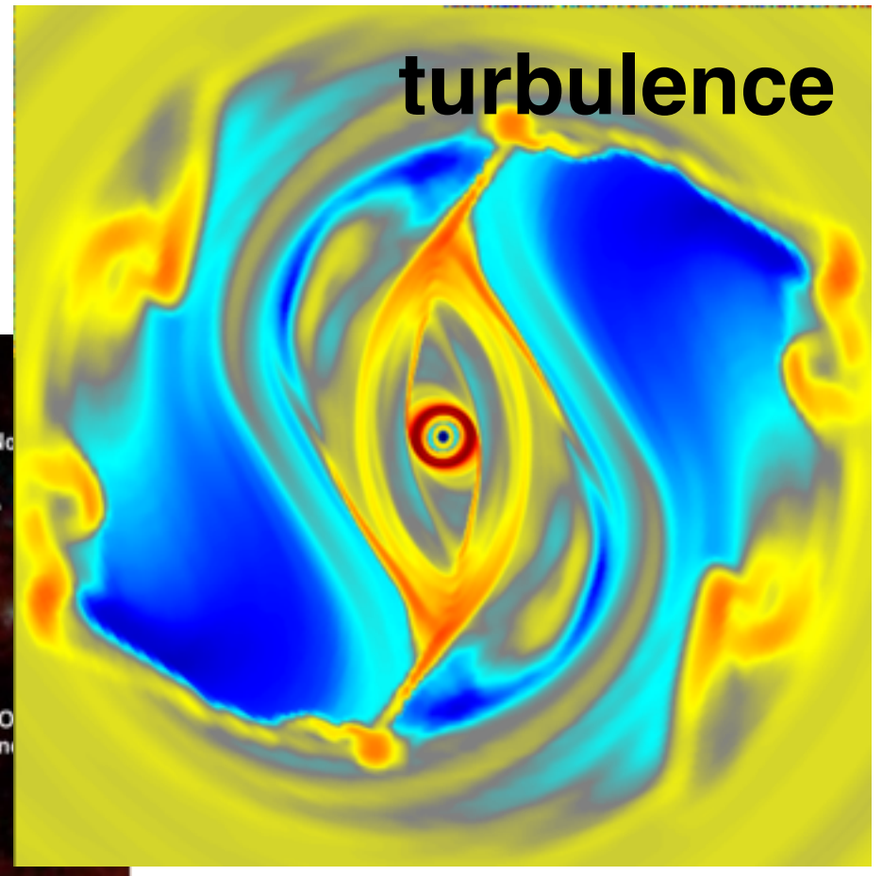
Actual ISM dust

dust grains properties





bright molecular clouds



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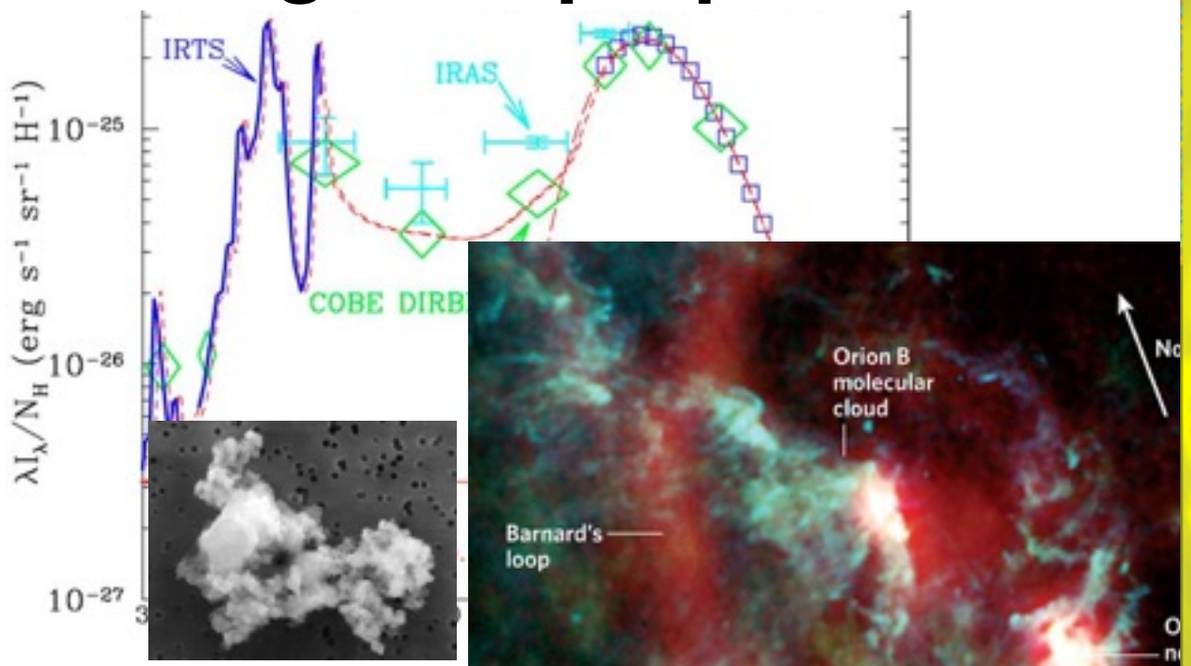
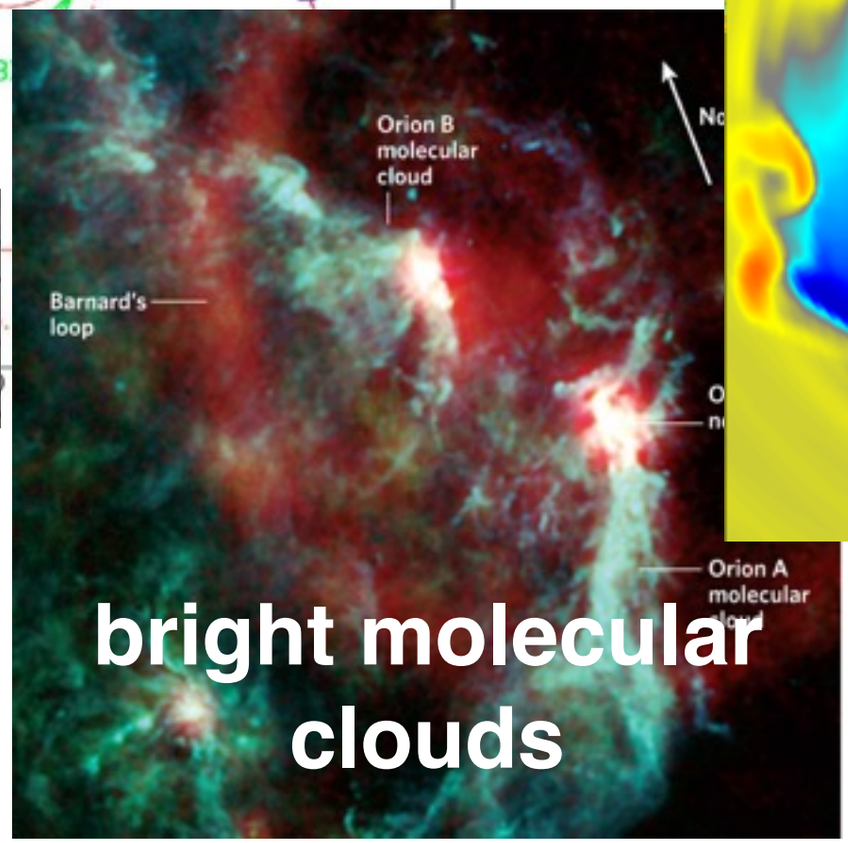
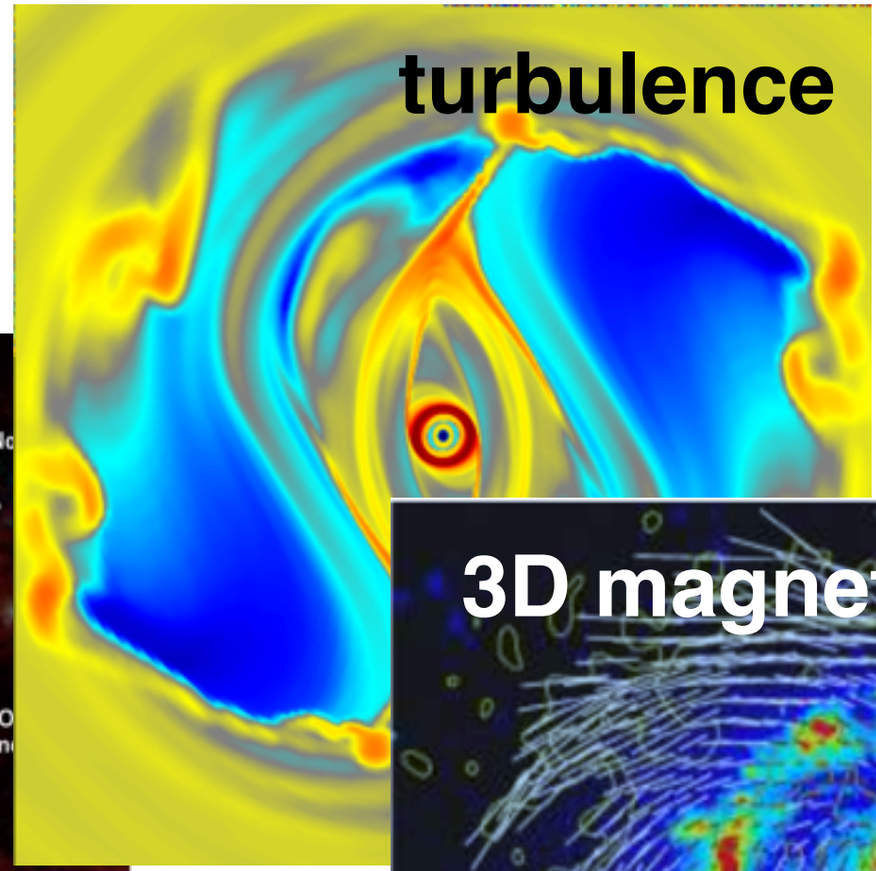
Actual ISM dust

dust grains properties

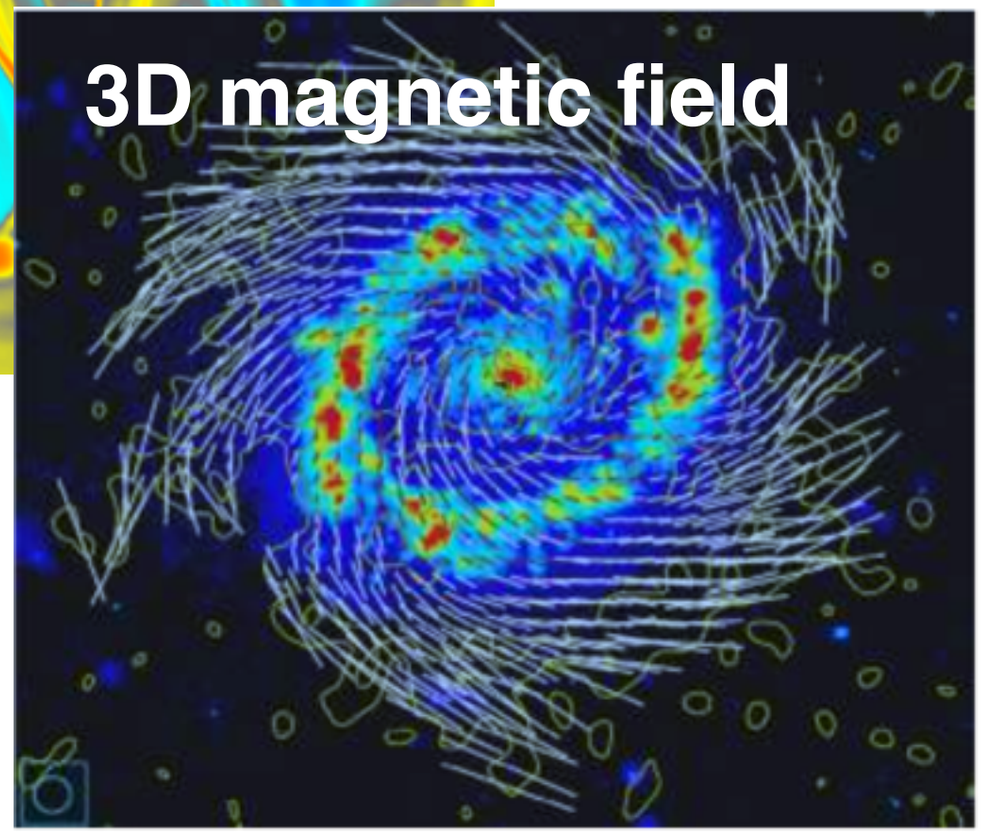




bright molecular clouds



turbulence



3D magnetic field

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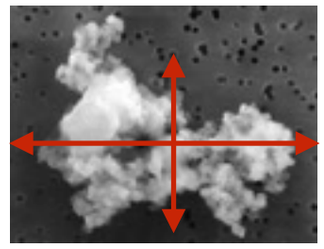
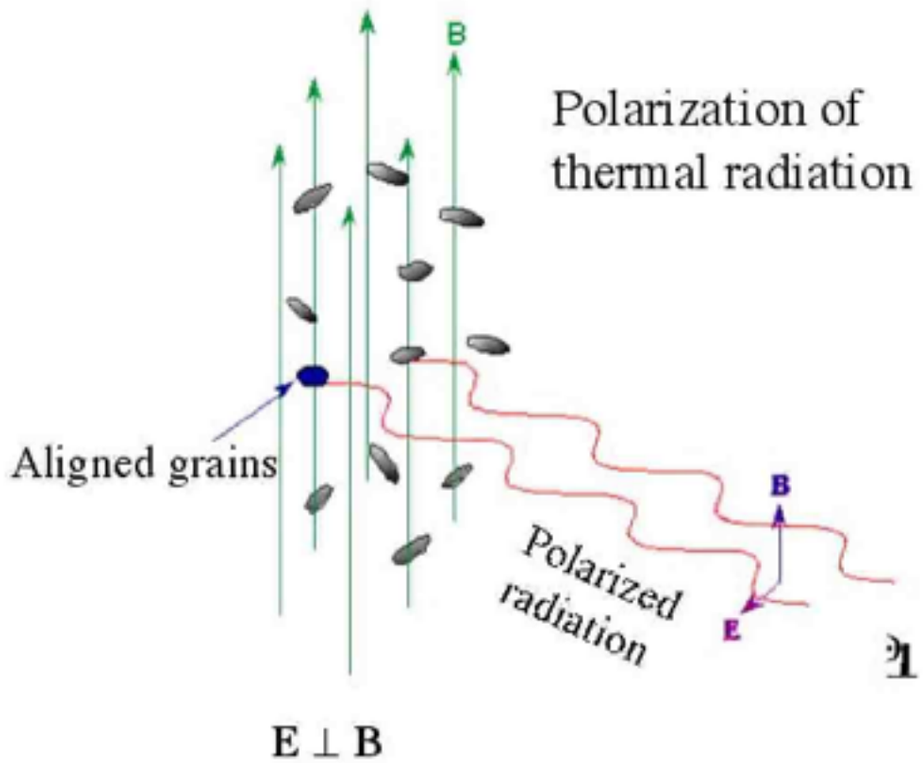
Toward realistic dust simulations

Why is dust emission polarised?

- Dust grains are heated by star light
- They radiate thermal emission (microwave domain)
- grains are **not spherical** and **aligned** with the ambient galactic **magnetic field**



One dust grain produced in laboratory



STEP 1: Galactic magnetic field

$$\vec{B}_{\rm gal}(\vec{r}) = \vec{B}_0(\vec{r}) + f_m \vec{B}_{\rm turb}(\vec{r})$$

random

with

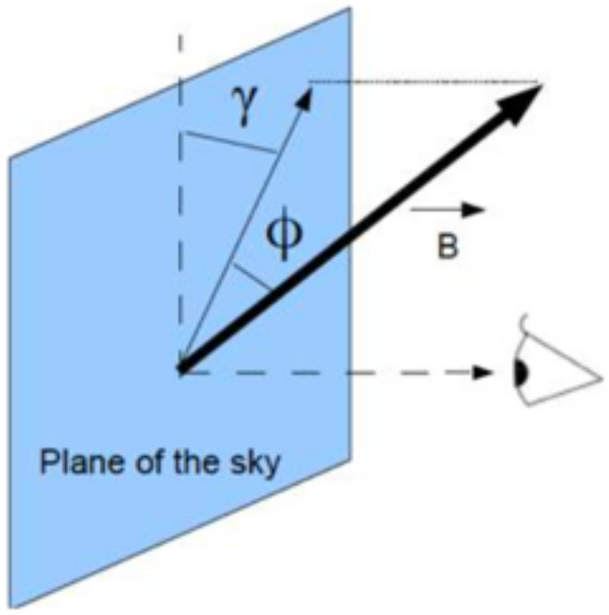
$$\left\langle \vec{B}_{\rm turb}(\vec{r}) \right\rangle = \vec{0}, \quad C_\ell^{\rm turb} \propto \ell^{\alpha}$$

$\vec{B}_0(\vec{r})$ Model for mean magnetic field

f_m Relative strength of turbulent field

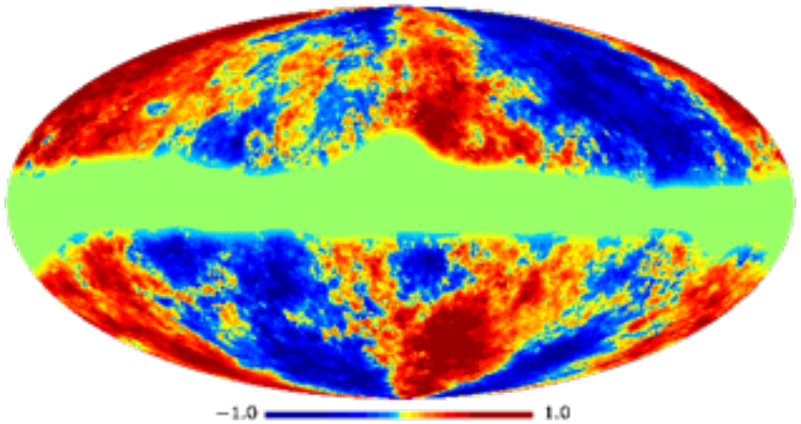
α 3D power index of the turbulent field

STEP 2: Stokes parameters

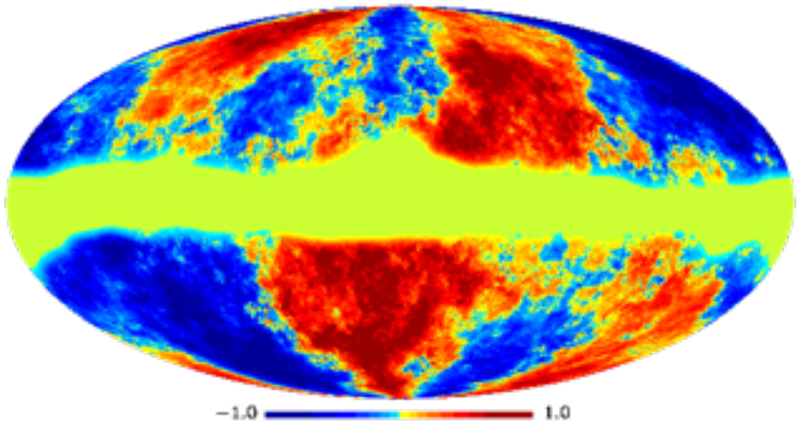


One **random** realisation of the magnetic field

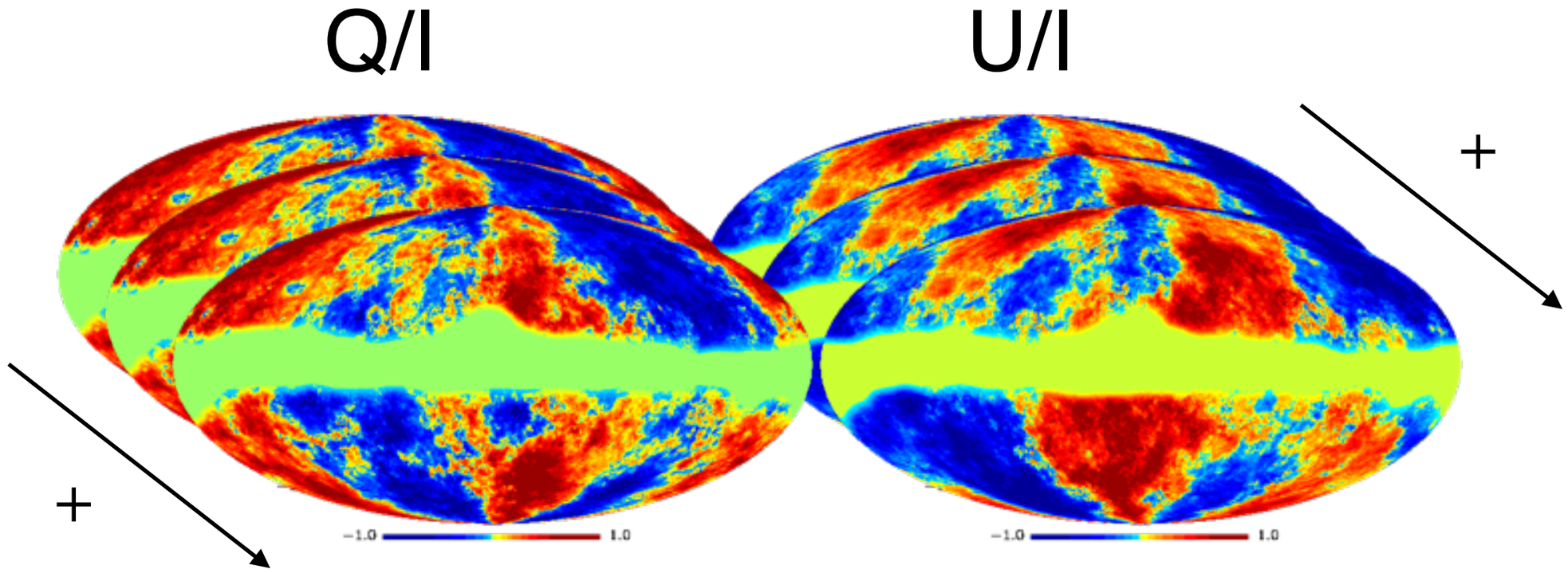
Q/I



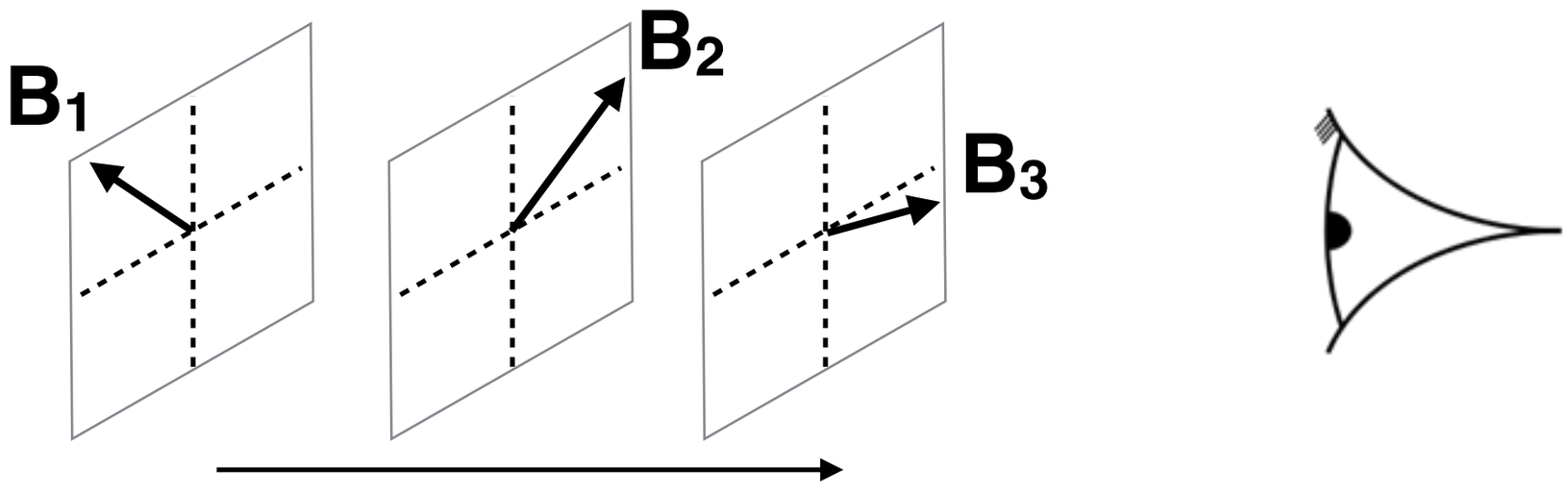
U/I



STEP 3: depolarisation

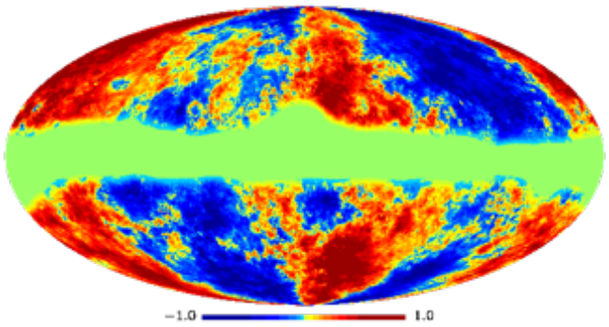


Stack **N layers** of Q/I,U/I

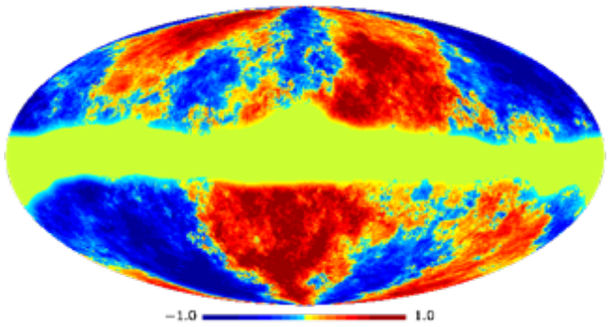


STEP 4: dust Stokes parameters

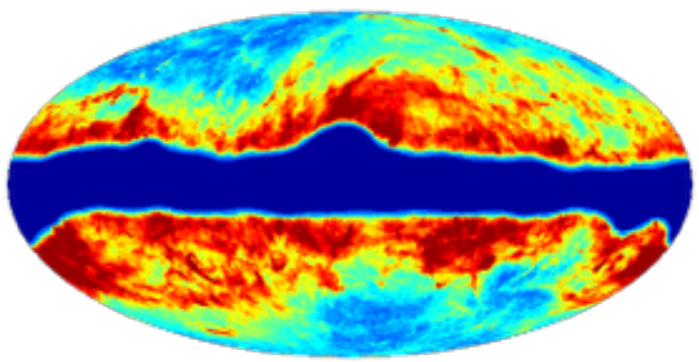
Q/I



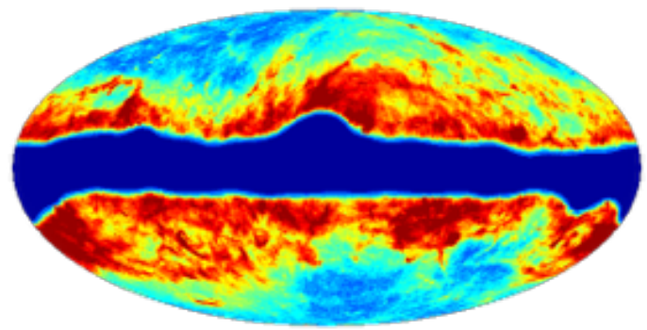
U/I



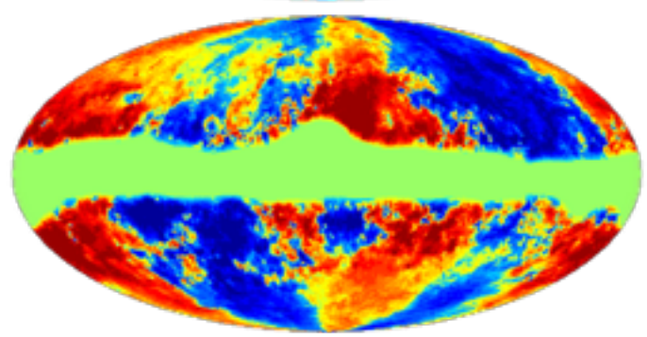
multiply by
an **external intensity map I**



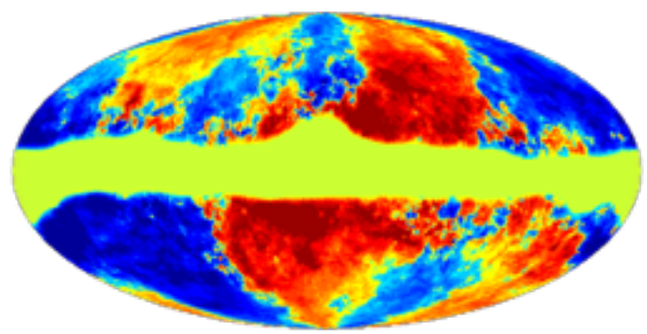
I



Q



U



Is it realistic enough?

One-point statistics of the model

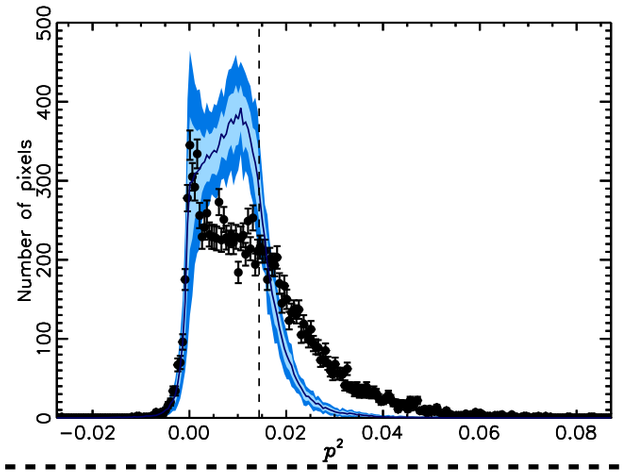
Polarisation fraction
$(Q^2+U^2)/I^2$

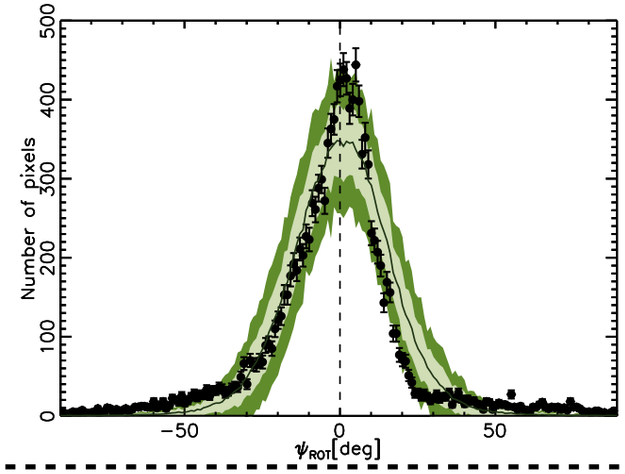
Polarisation angle
(direction of the pola)

N_{layers} 1

f_m 0.4

α -1.5

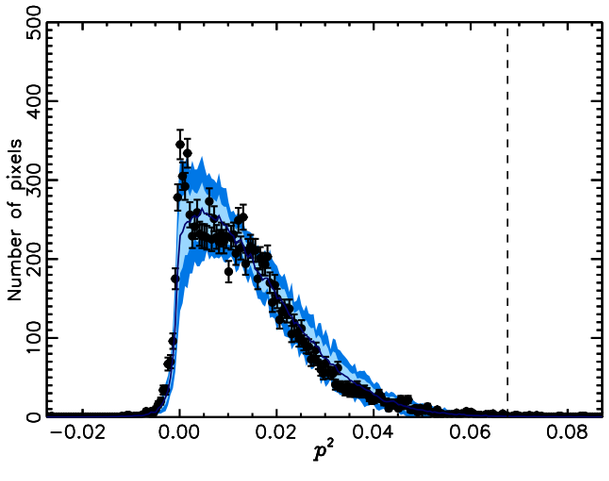


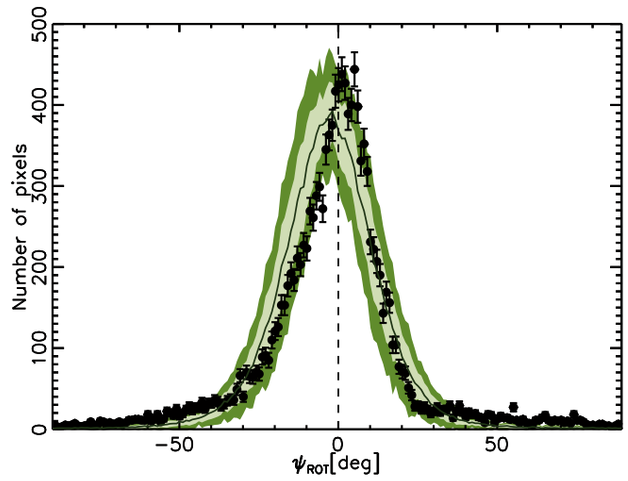


N_{layers} 7

f_m 0.9

α -1.5





data sims

figures from Bracco Ph.D thesis

Is it realistic enough **for cosmology**?

Two-point statistics of the model

Simulations

N_{lay} f_m α

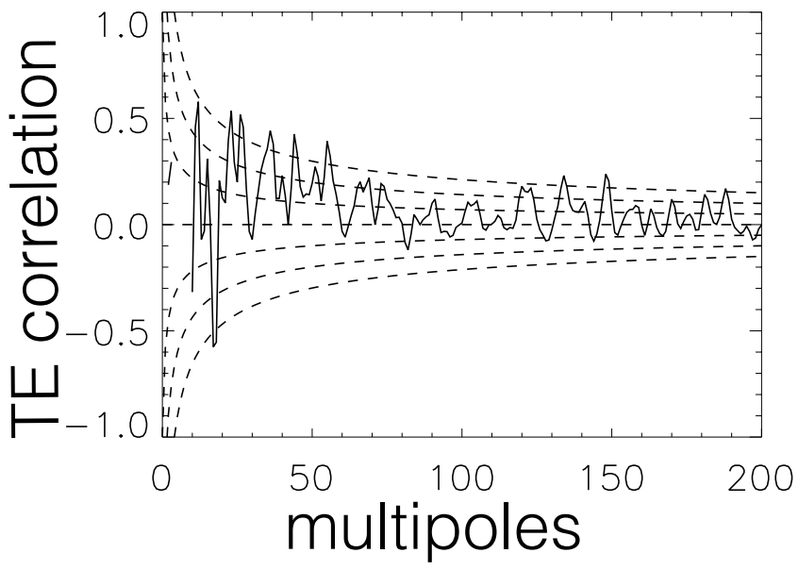
7 0.8 -2.6

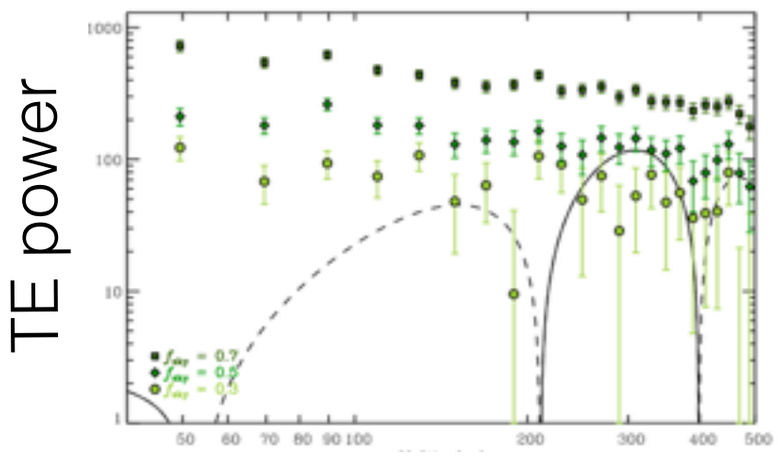
Data

Planck collab.

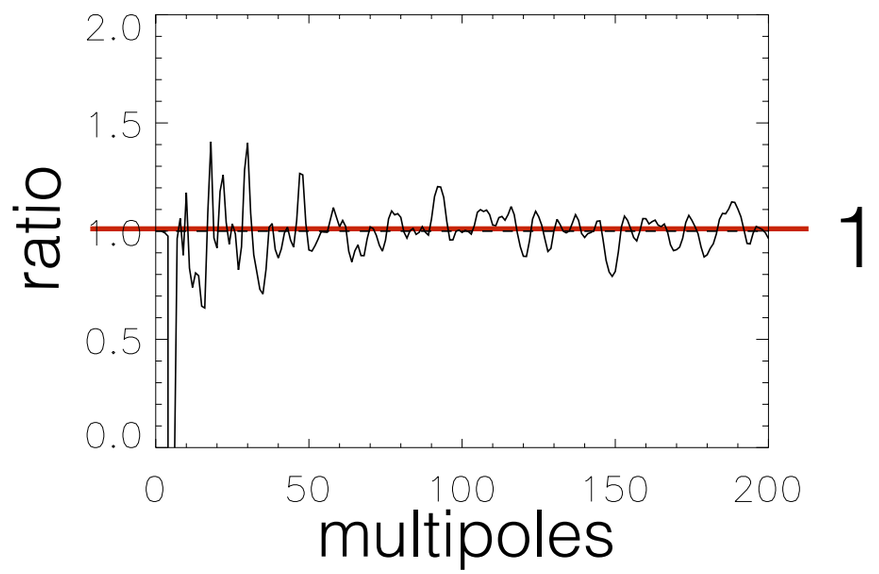
PIPXXX 2014

TE correlation

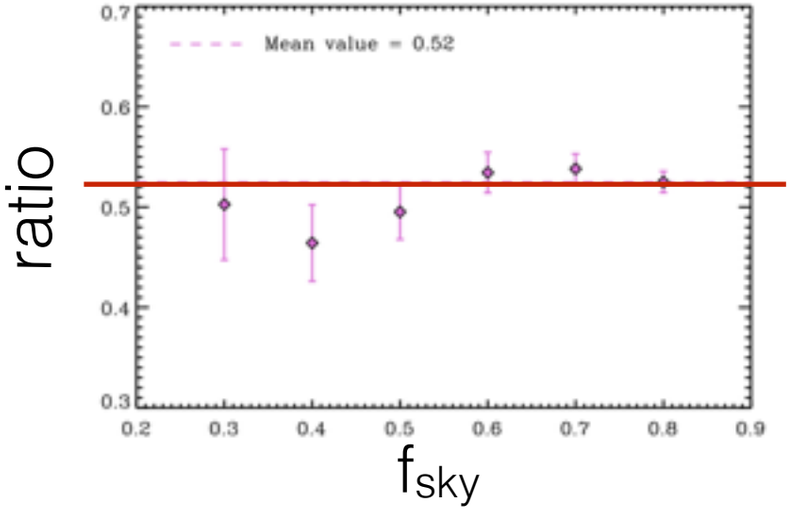




BB/EE ratio



1



0.52

STEP 5: introduce correct statistics

$(I,Q,U)_A$ such that:

$$\begin{pmatrix} A_\ell^{TT} & 0 & 0 \\ 0 & A_\ell^{EE} & 0 \\ 0 & 0 & A_\ell^{BB} \end{pmatrix}$$

linear transform at the a_{lm} level

$(I,Q,U)_B$ such that:

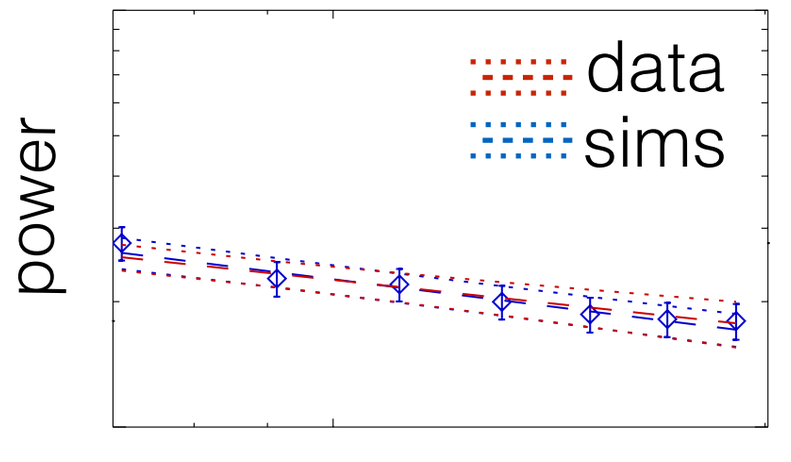
$$\begin{pmatrix} B_\ell^{TT} & B_\ell^{TE} & 0 \\ B_\ell^{TE} & B_\ell^{EE} & 0 \\ 0 & 0 & B_\ell^{BB} \end{pmatrix}$$

$$\begin{cases} b_{\ell m}^T &= t a_{\ell m}^T \\ b_{\ell m}^E &= p_0 (a_{\ell m}^E + \gamma a_{\ell m}^T) \\ b_{\ell m}^B &= p_0 f a_{\ell m}^B \end{cases}$$

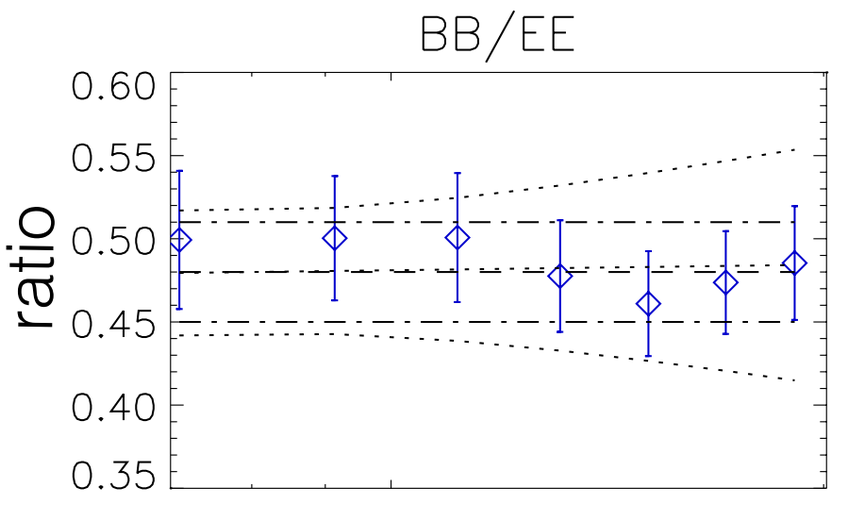
In particular: include **E-B asymmetry** and **TE correlation**

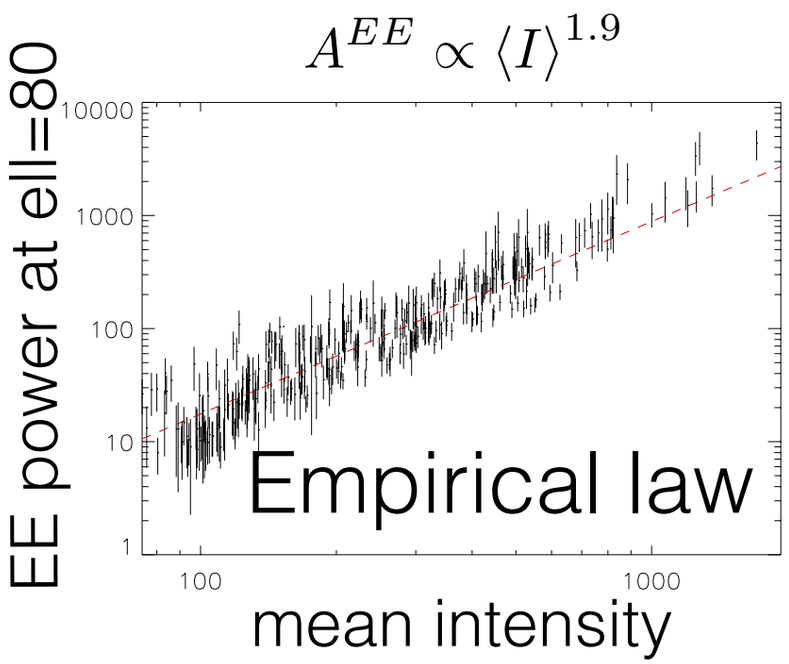
Properties of the simulations

BB power spectrum



E-B asymmetry



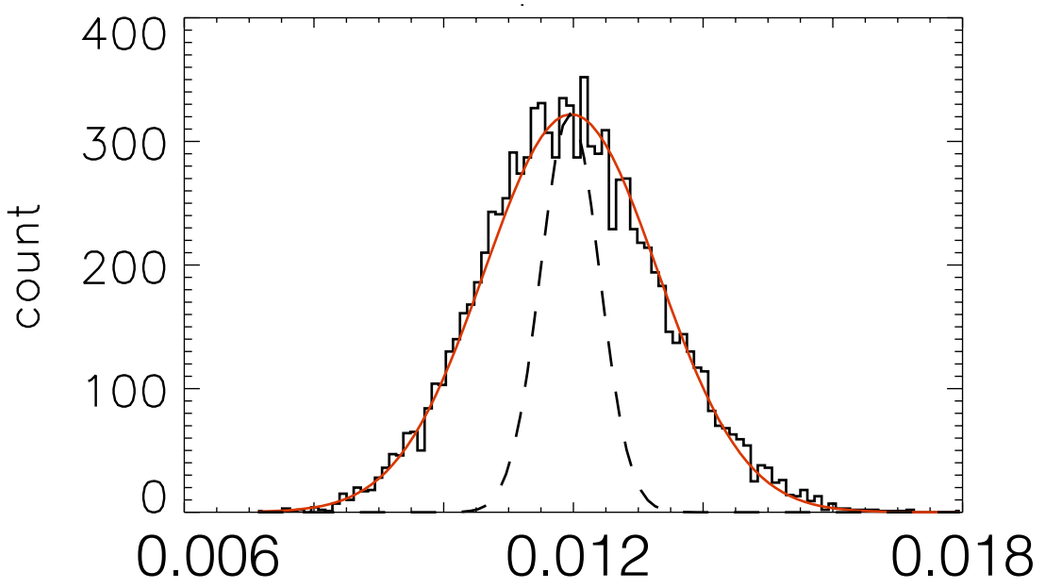


The simulations are able to **reproduce the data** also at the power spectrum level

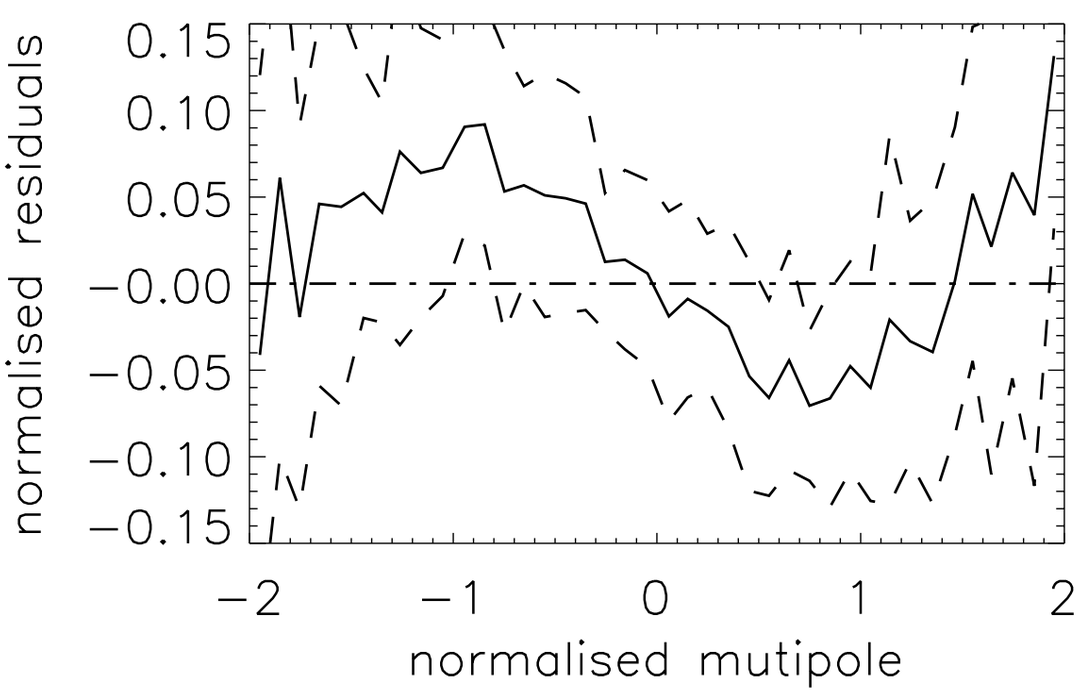
Vansyngel, Boulanger & Ghosh (in prep.)

PDF of power spectra

PDF of power at multipole ~110



Residuals of Gaussian fit



Distribution **close** to Gaussian

Toward full simulations of the microwave sky

- Improve complexity of one frequency:
  - ✦ introduce TE correlation at particular scales (filaments)
  - ✦ different intensity map for each layers
  - ✦ turbulence power spectrum
    (several injection scales, anisotropic, …)
  - ✦ …

- Introduce frequency dependence
  - ✦ intensity and angle decorrelation

- Simulate polarised synchrotron emission

Conclusion

- Too much foreground to avoid process of component separation

- Need realistic simulations to test limits of component separation methods

- New method to simulate dust polarisation:
  - ✦ draw many realisations rapidly
  - ✦ one frequency
  - ✦ reproduce observed 1-point statistics
  - ✦ reproduce observed 2-point statistics