

PSM news

Jacques Delabrouille

Laboratoire APC, Paris, France

with

*A. Bonaldi, G. Castex, C. Hervias Caimapo, G. de Zotti,
A. Karakci, G. Martinez-Solaeche, J. B. Melin, M. Remazeilles,
and the PSM team*



Outline

- ➡ • Introduction
- Polarised diffuse foregrounds
 - ✓ Synchrotron
 - ✓ Thermal dust from observations
 - ✓ 3-D dust
- Summary

The PSM in a nutshell

- The "Planck Sky Model" is a parametric multicomponent model of sky emission originally developed for and by the Planck collaboration
- It is constituted of data and software, and is distributed as a single code that can be run to generate
 - a) A complete parametric model of multicomponent sky emission (maps of diffuse components, catalogues of point sources, emission law parameters, power spectra, number counts);
 - b) Observations of this model sky in a number of channels specified each by a frequency band, a (Gaussian) symmetric beam, and noise properties;
- The simulation uses HEALPix maps at a given $nside$, up to a given $lmax$, both user-defined;
- Everything is automated, including "on the fly" downloading of the data needed to run the code. One single command line produces all the output.

PSM implementation

- Components are modelled as sums of (parametric) emission laws.
- For diffuse components, we use maps:

$$I_{\text{comp}}(\vec{p}, \nu) = \sum_k I_k(\vec{p}, \nu_0) \left[\frac{f_k(\vec{p}, \nu)}{f_k(\vec{p}, \nu_0)} \right]$$

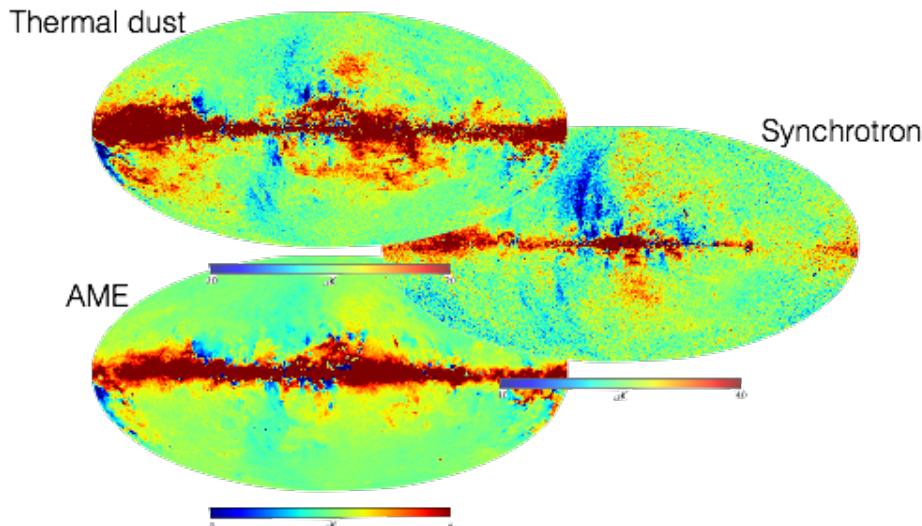
Template map at some
reference frequency Normalised
emission law

- For compact objects, we use catalogues, in which each object is modelled as a superposition of such emission laws, and may also be assigned a profile (galaxy clusters).
- Once generated, all the parameters and meta-parameters of a modelled sky are stored in specific subdirectories of the output directory. They can be "observed" and "re-observed" a posteriori with (simple) models of instruments for band-integration.

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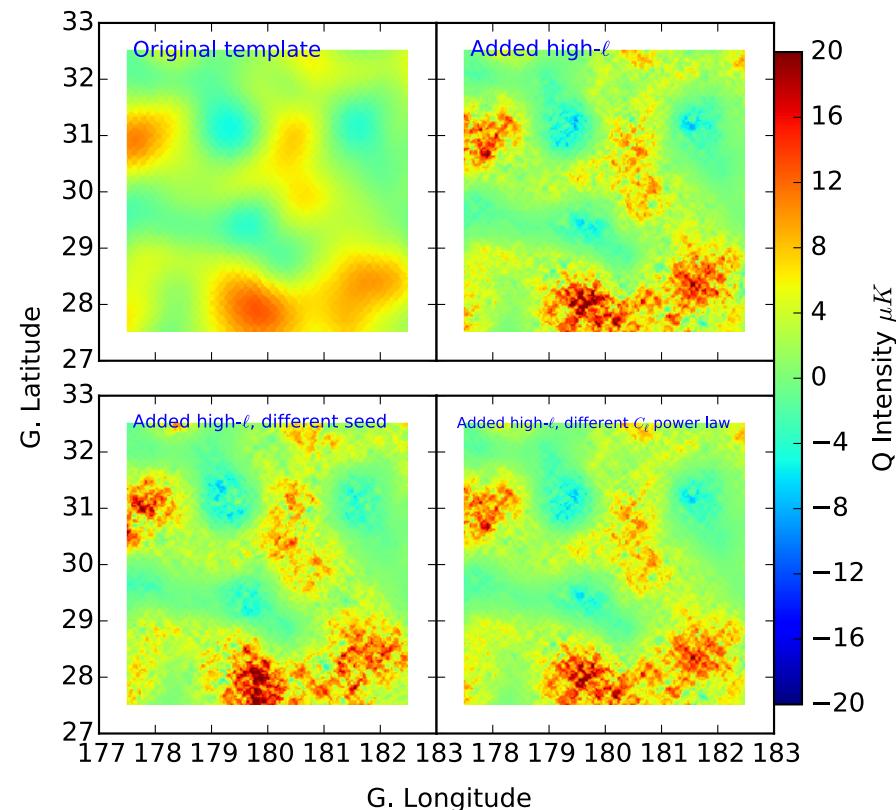
A new model of the microwave polarized sky for CMB experiments



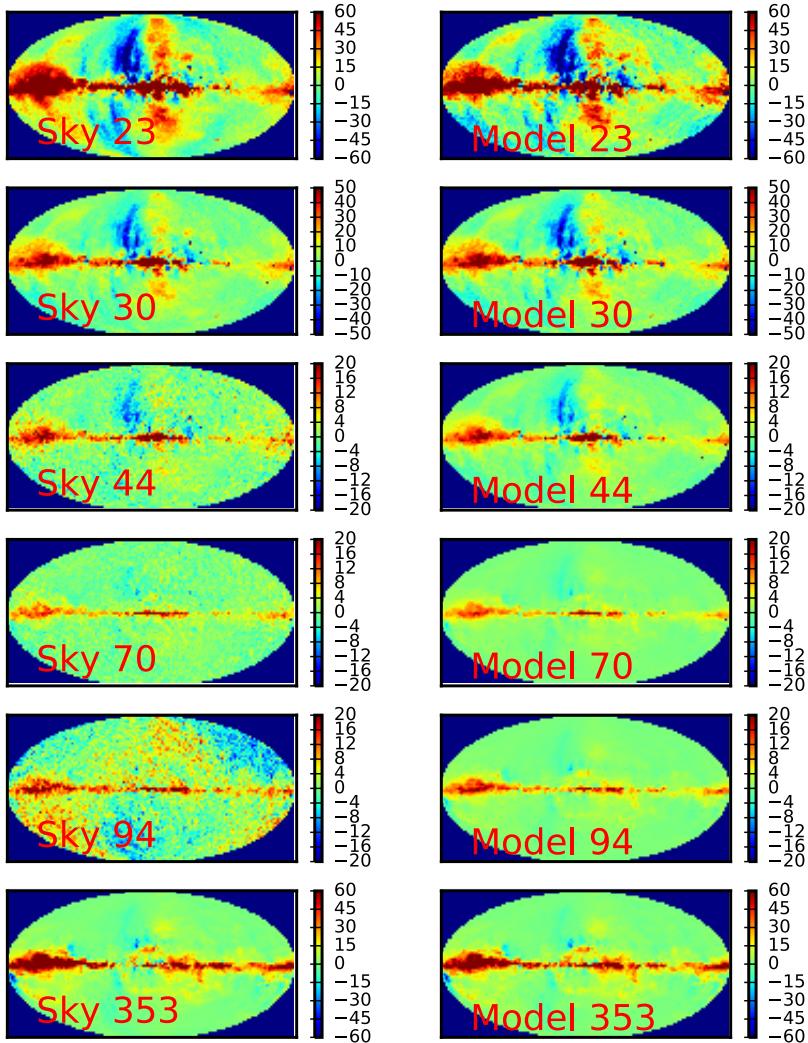
**Hervías-Caimapo, Bonaldi & Brown 2015,
submitted, Arxiv:1602.01313**

- Based on Planck 2015 data release (COMMANDER Galactic foregrounds templates).
- Includes synchrotron, thermal dust and 1% polarized AME template.

- New feature: high-multipole artificial features.
- Extrapolating the EE and BB power spectra. Below, example synchrotron



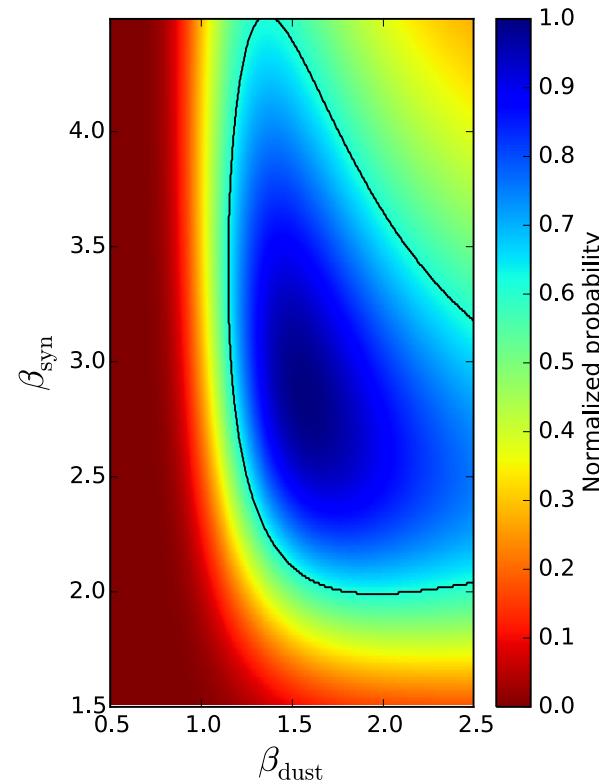
Agreement with observations: WMAP and Planck



Observations



Our model



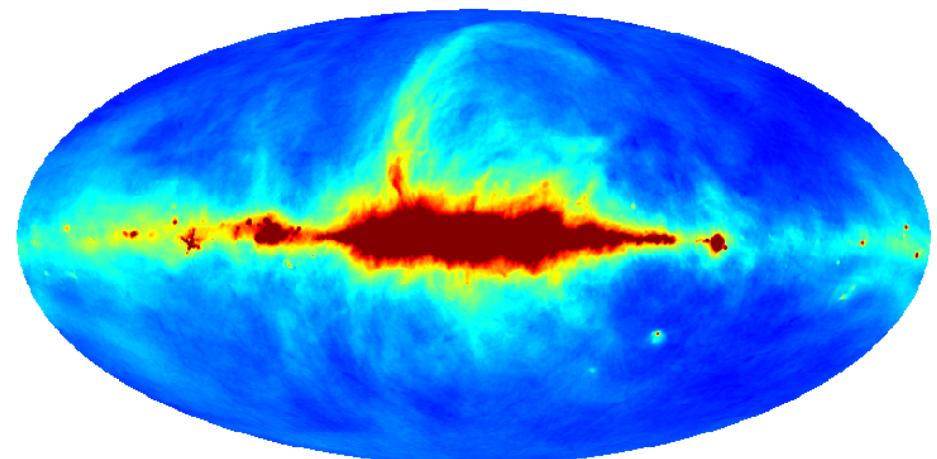
- We find good agreement with observations.
- A range of β_{dust} and β_{syn} can give a good fit to the data.
- **To do: Include model into PSM.**

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Synchrotron

- One of the major foregrounds for CMB observations.
- Strongly polarised (up to 75%).
- Synchrotron-dominated full-sky map at 408 MHz (Haslam et al. 1982), at 51' angular resolution.
- **New 408 MHz reference:** Map reprocessed to remove striping and point sources by Remazeilles et al. (2015). Angular resolution re-assessed to 56'.

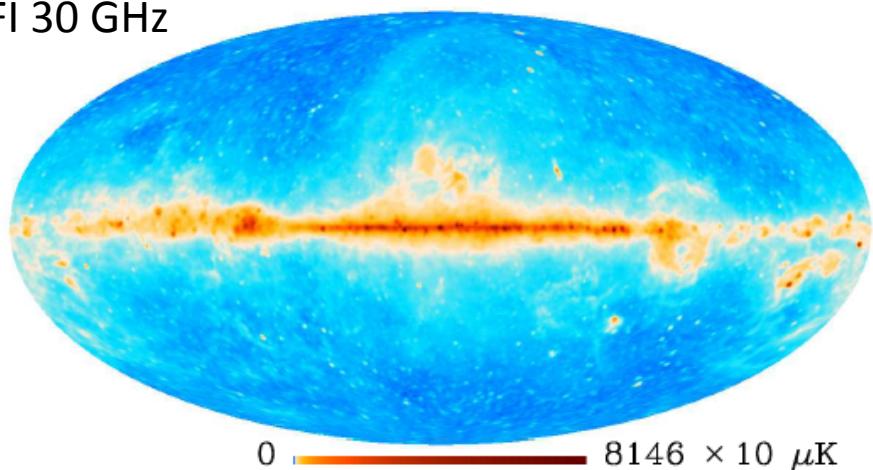


Remazeilles et al. 2015, MNRAS 451, 4311

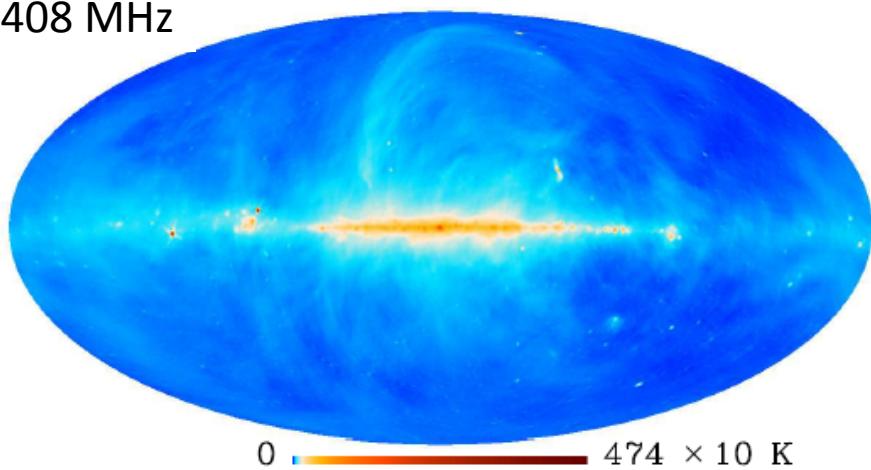
Frequency scaling of synchrotron

- There is evidence for fluctuations of the spectral index around a mean value of -3 (in K_{RJ} units).
- Evidence for steepening with increasing frequency
- However, there is at present no good measurement of the synchrotron scaling.
- Good-enough full-sky maps of synchrotron (only) at an other frequency than 408 MHz are not available!

LFI 30 GHz



408 MHz



HFI 545 GHz

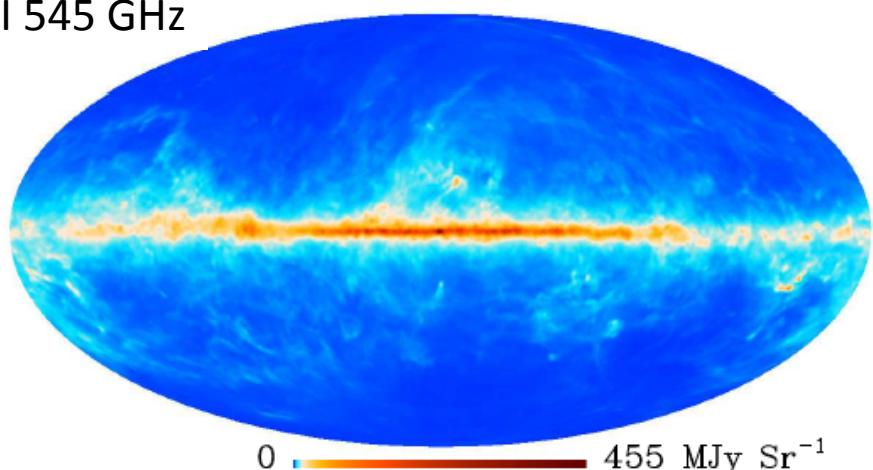
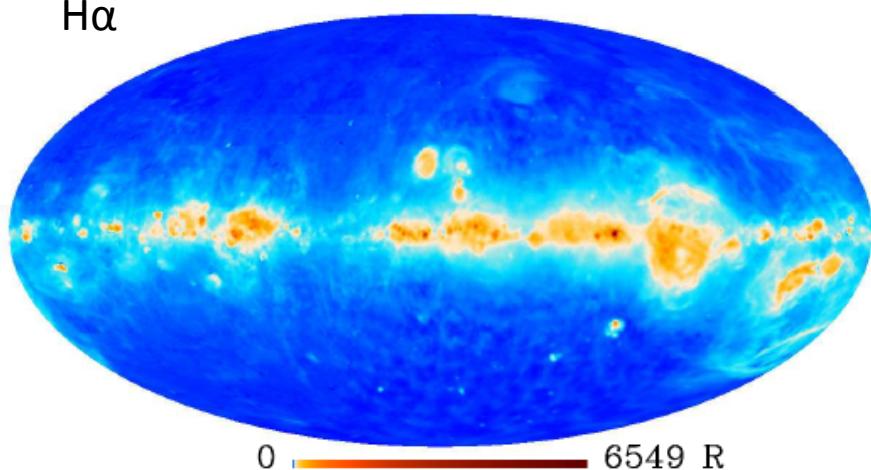
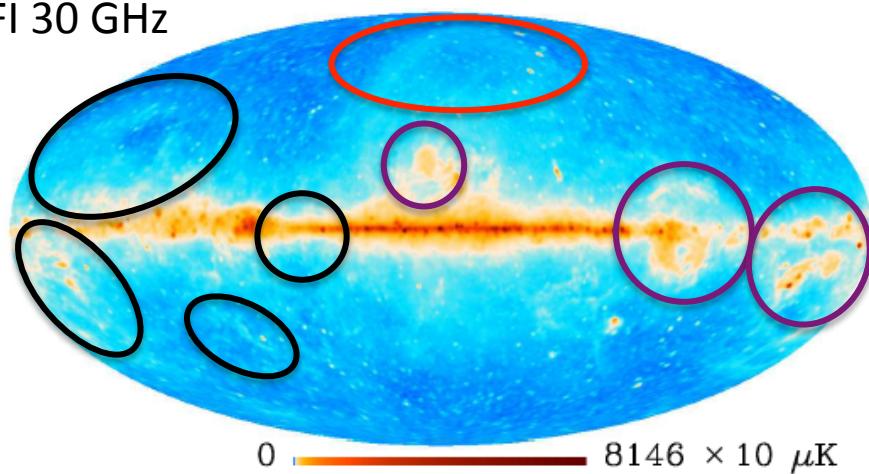
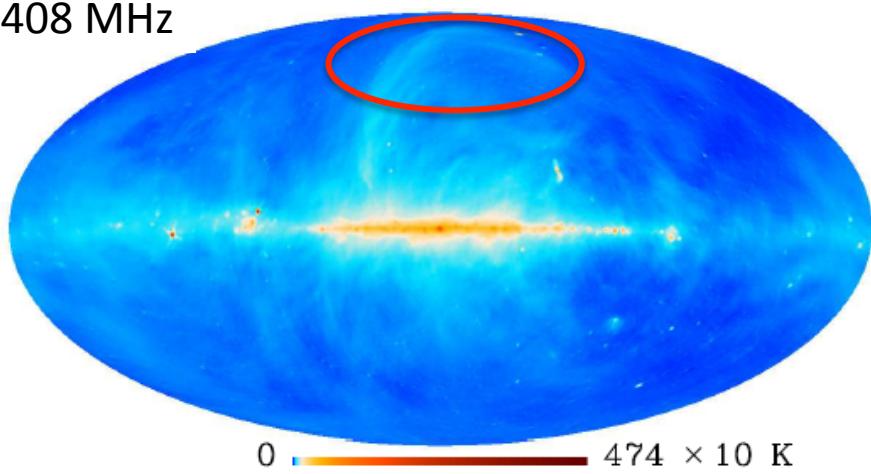
H α 

Fig. 1. (a) CMB-nulled map at 28.4 GHz, constructed using the ILC method (see text), where in this map, $\beta = -3$ emission is unchanged by construction; (b) 408 MHz map (Remazeilles et al. 2014), strongly dominated by synchrotron emission; (c) 545 GHz *Planck* map, strongly dominated by thermal dust emission; and (d) H α map (Dickinson et al. 2003). An asinh(I) colour scale is used for all images, where I is the intensity in the units indicated. The coordinate along the colour bar is linear in I near zero and becomes logarithmic ($\ln(2I)$) at high intensity. All maps are at 1° resolution.

LFI 30 GHz



408 MHz



HFI 545 GHz

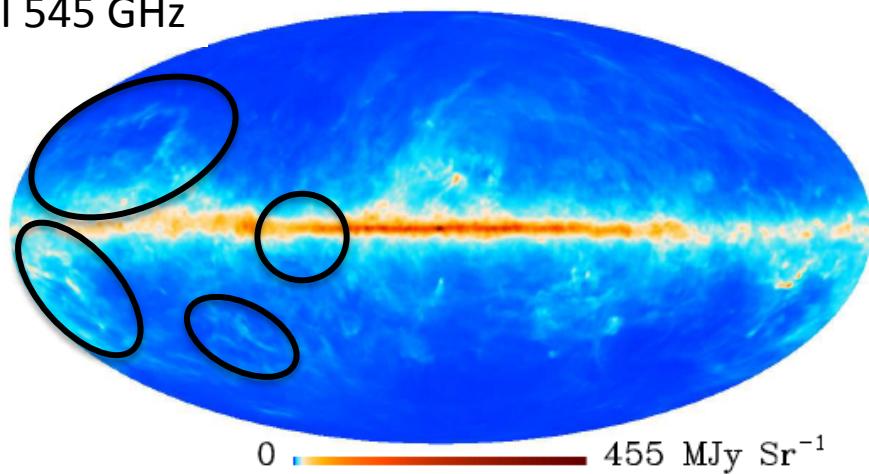
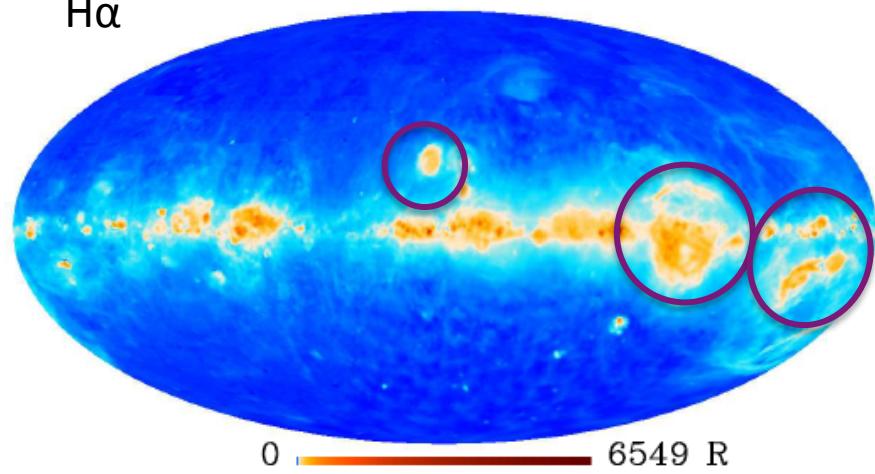
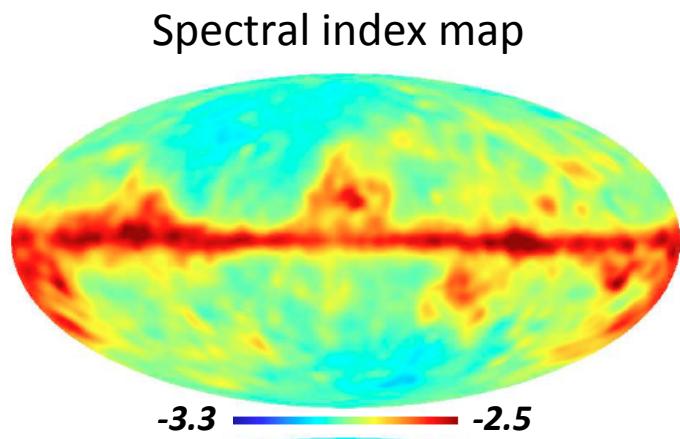
H α 

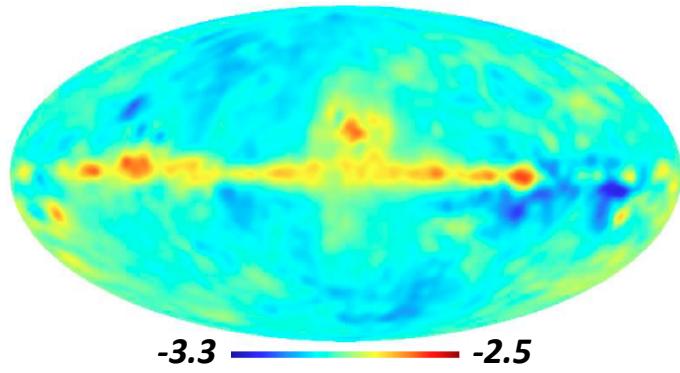
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Pre-launch Planck Sky Model

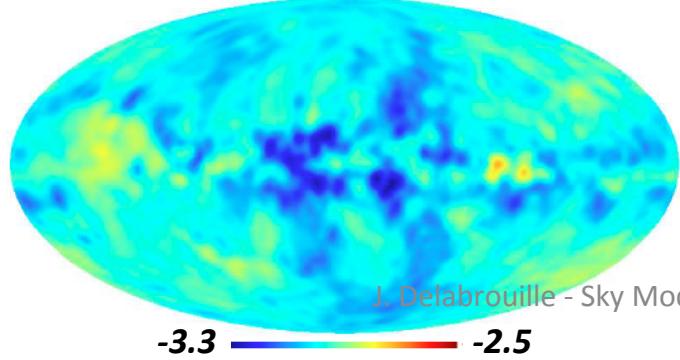
Assuming
no spinning dust
at 23 GHz



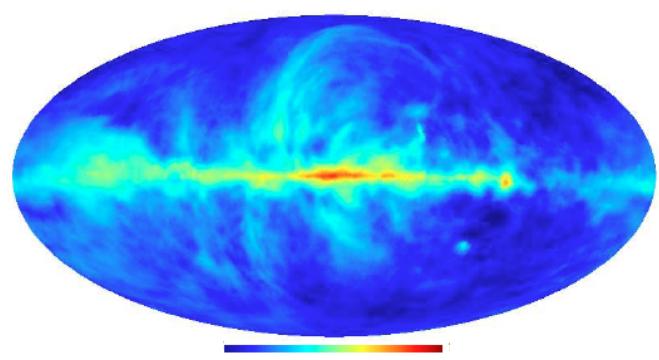
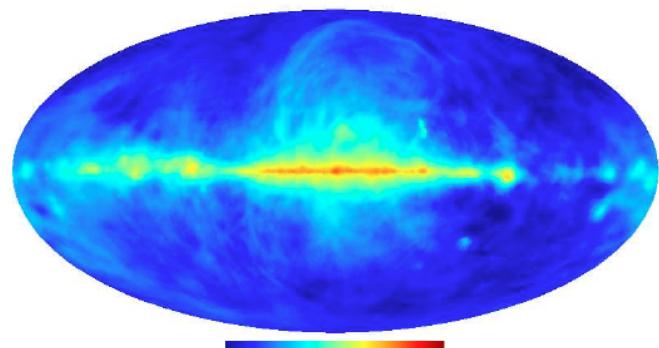
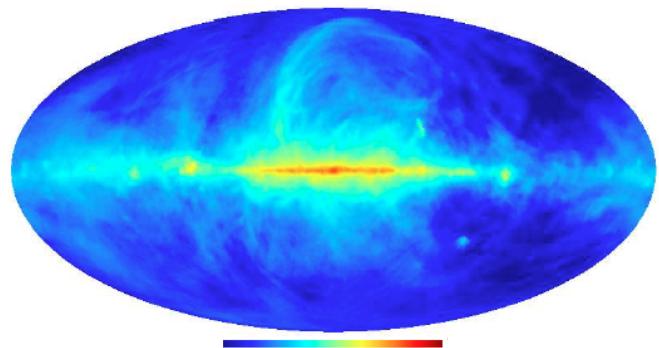
Spinning dust
proportionnal to
 $E(B_V)$



23 GHz intensity
from model of
polarisation
09 Mar. 2016



Synchrotron at 23 GHz



Frequency scaling of synchrotron

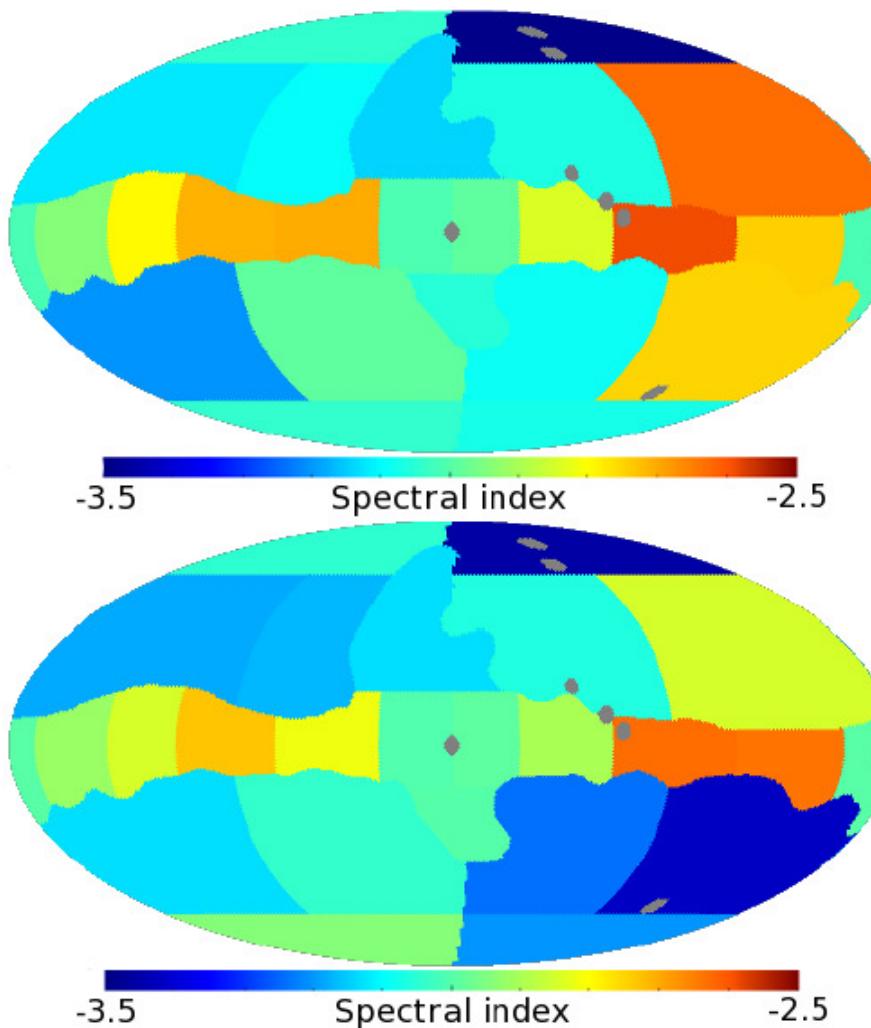
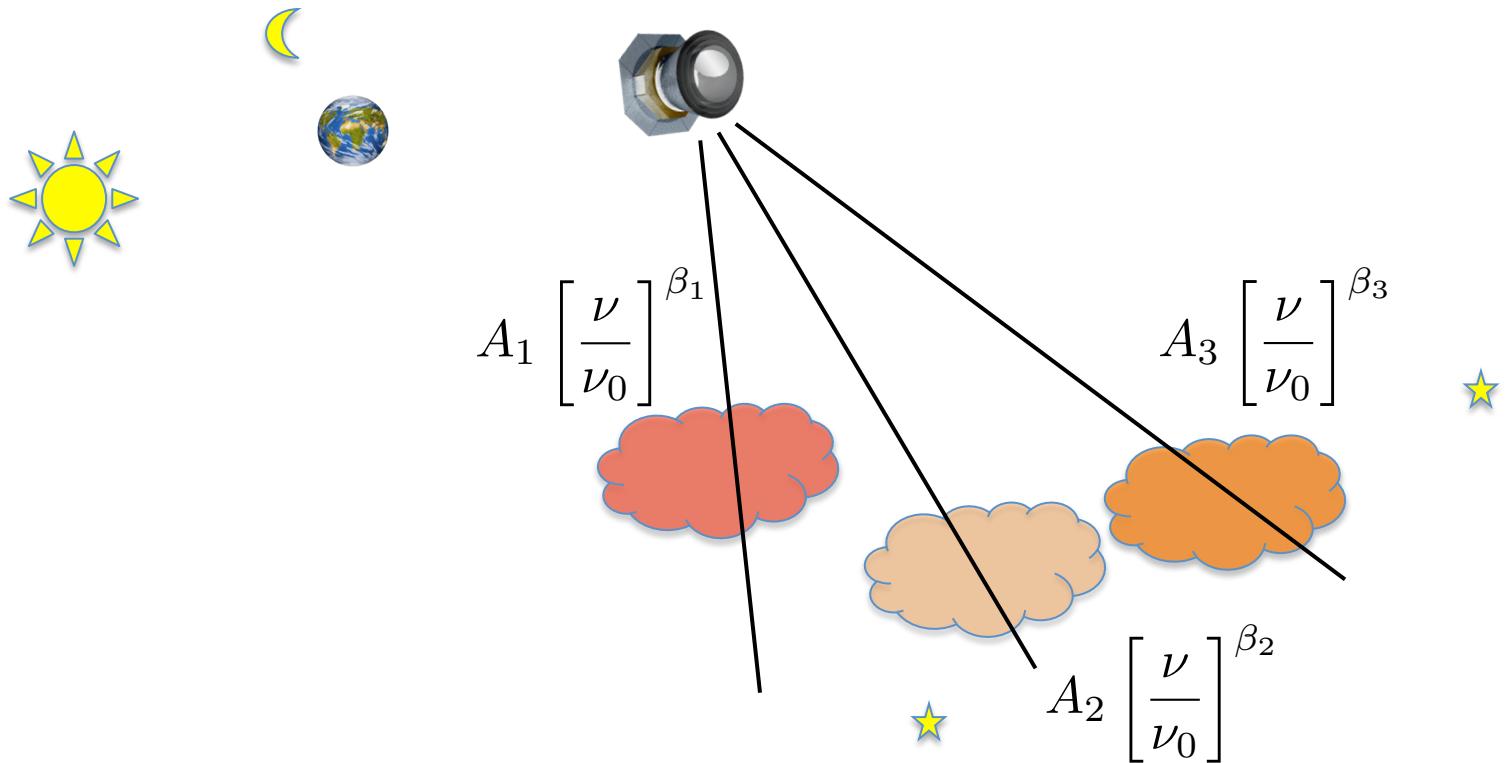


FIG. 6.— Synchrotron spectral index derived with the maximum likelihood (top panel) and T-T plot (bottom panel) methods from the 9 yr WMAP K- and Ka-band polarization sky maps.

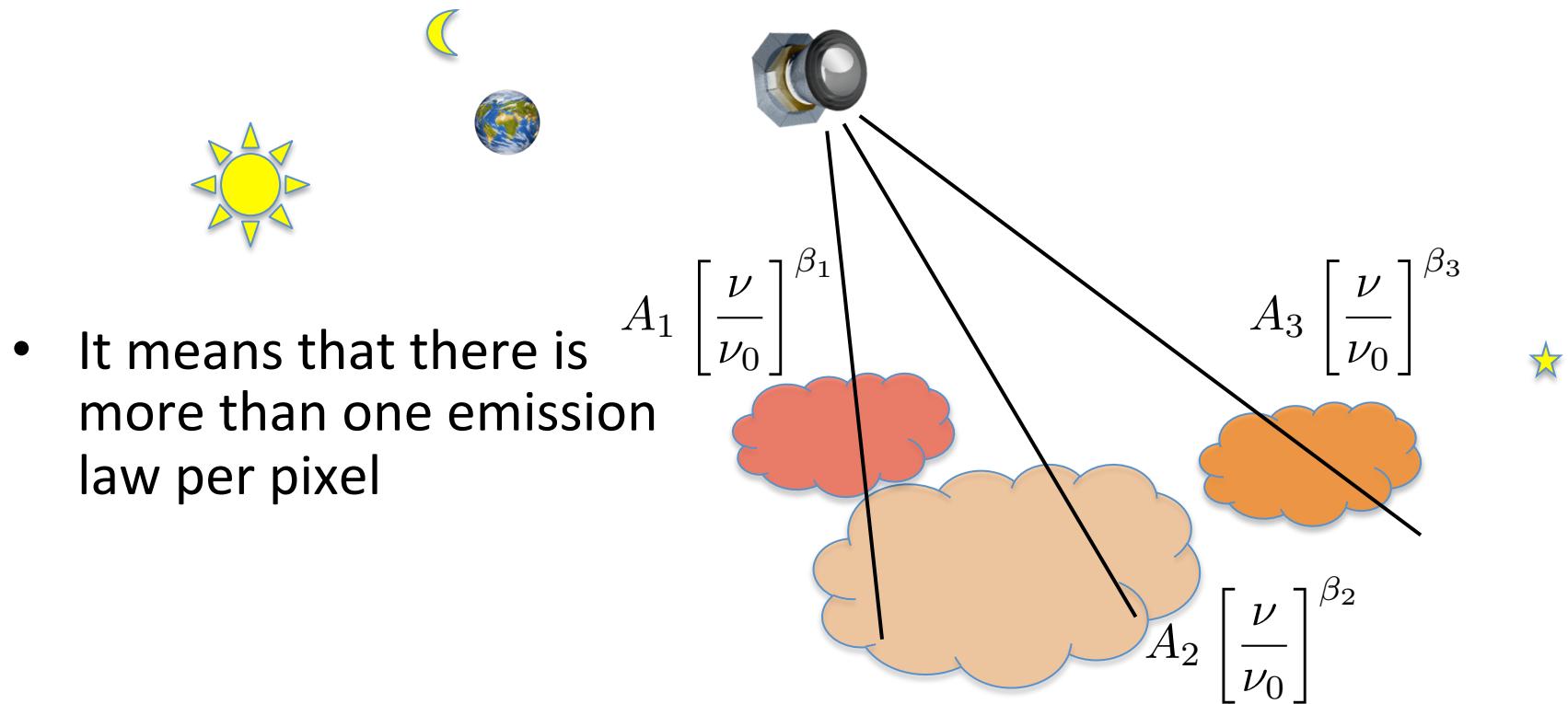
Frequency scaling of synchrotron

- There is evidence for fluctuations of the spectral index around a mean value of -3 (in K_{RJ} units)
- This must be due to different populations of electrons



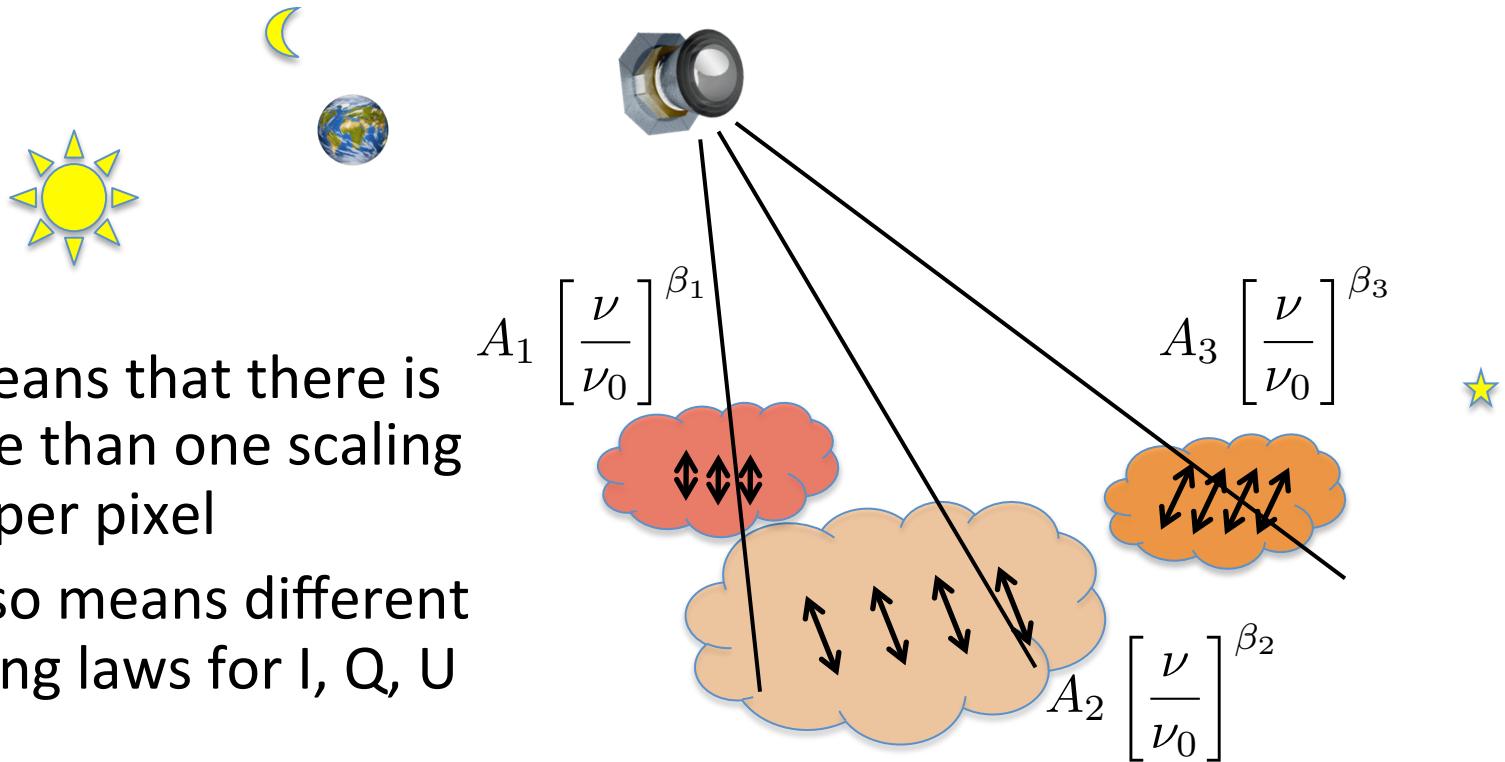
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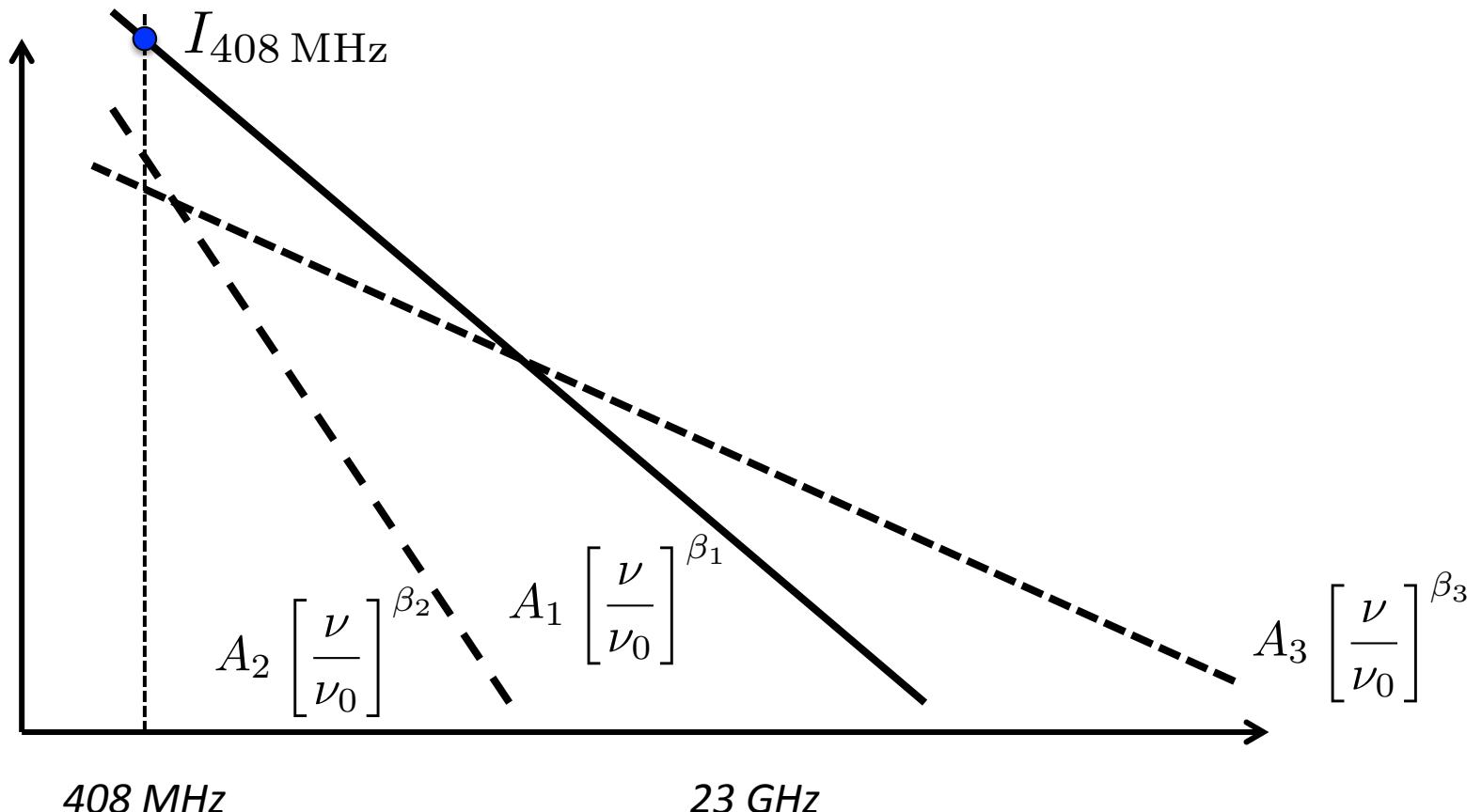
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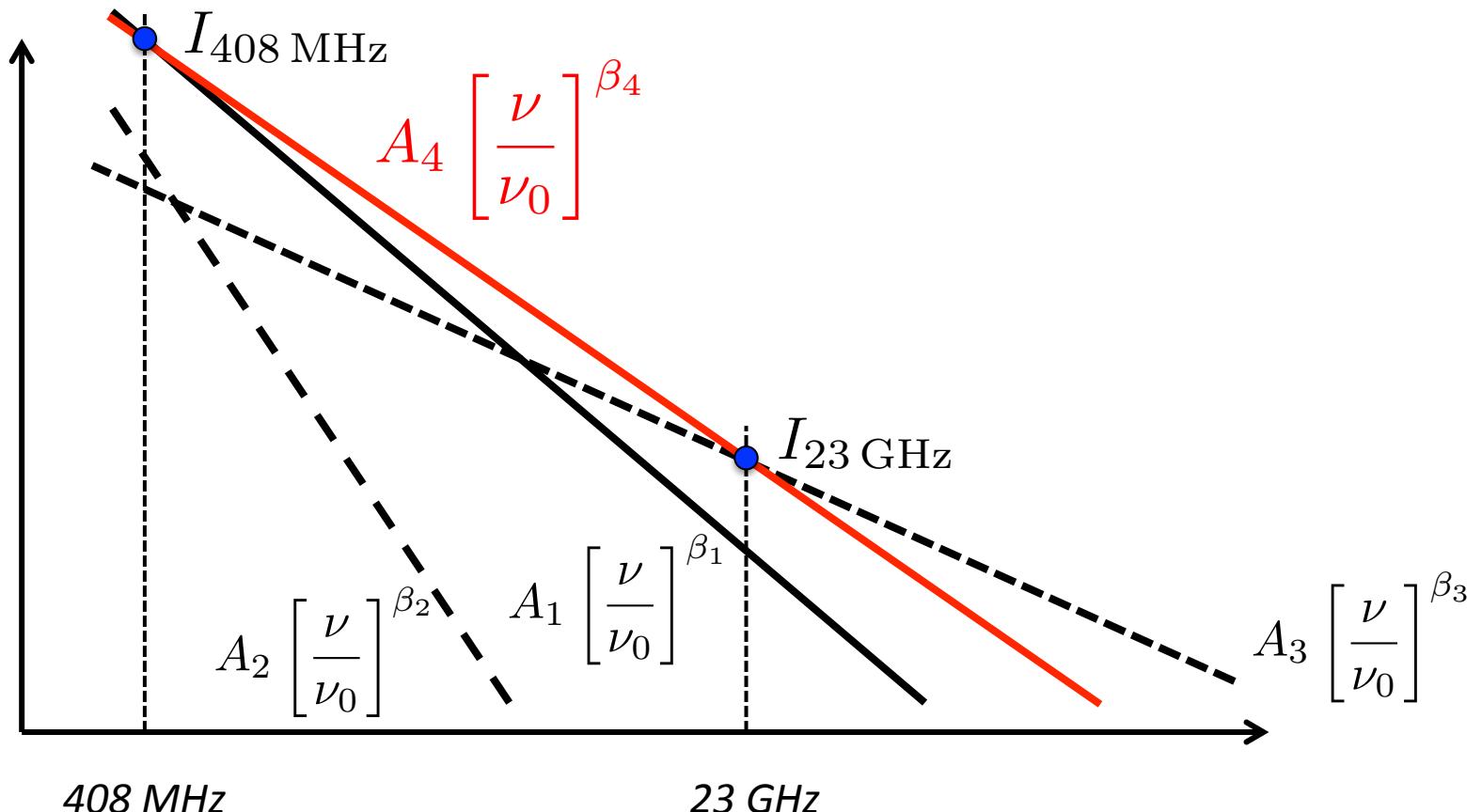
Frequency scaling of synchrotron

- A sum of power laws is not a power law...



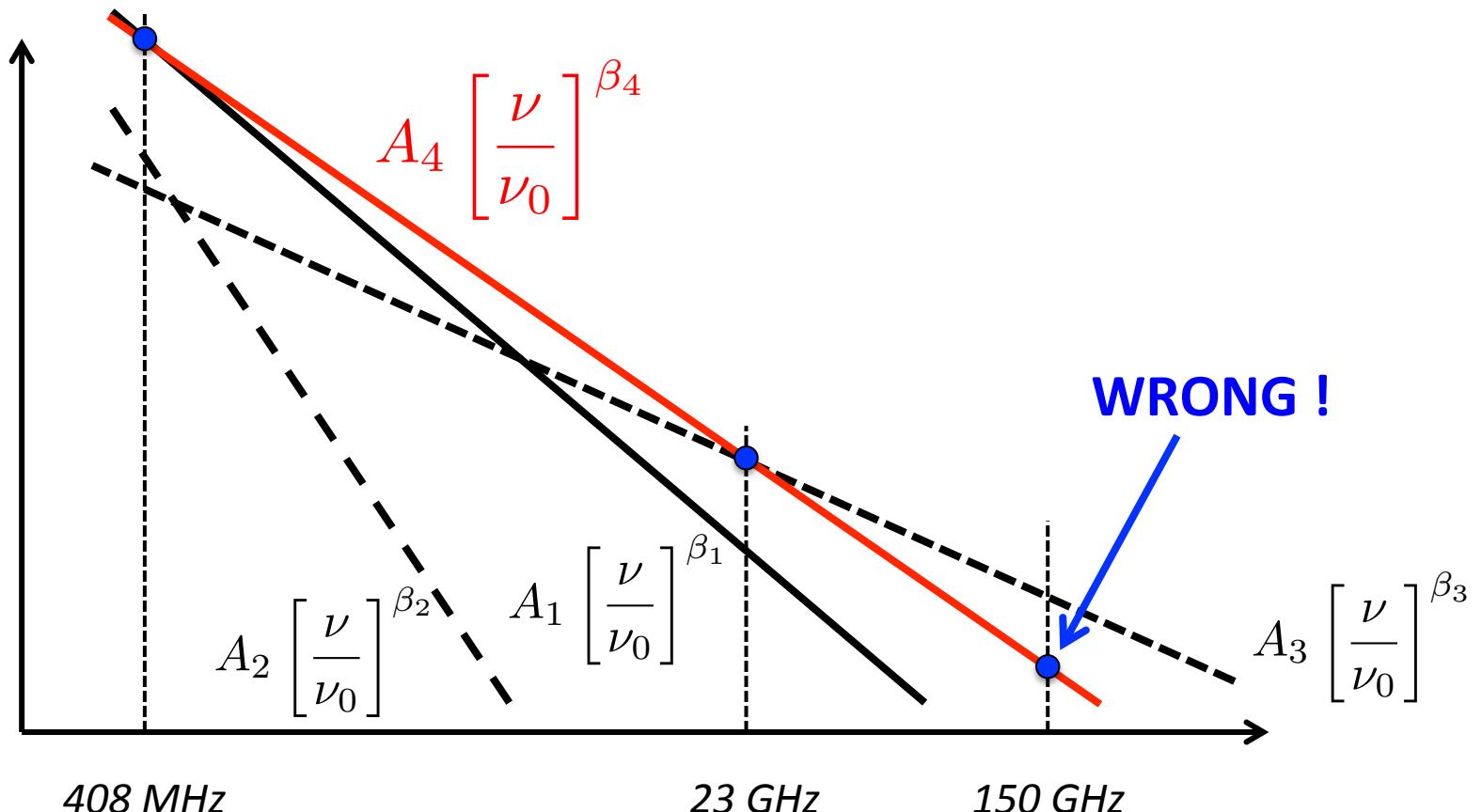
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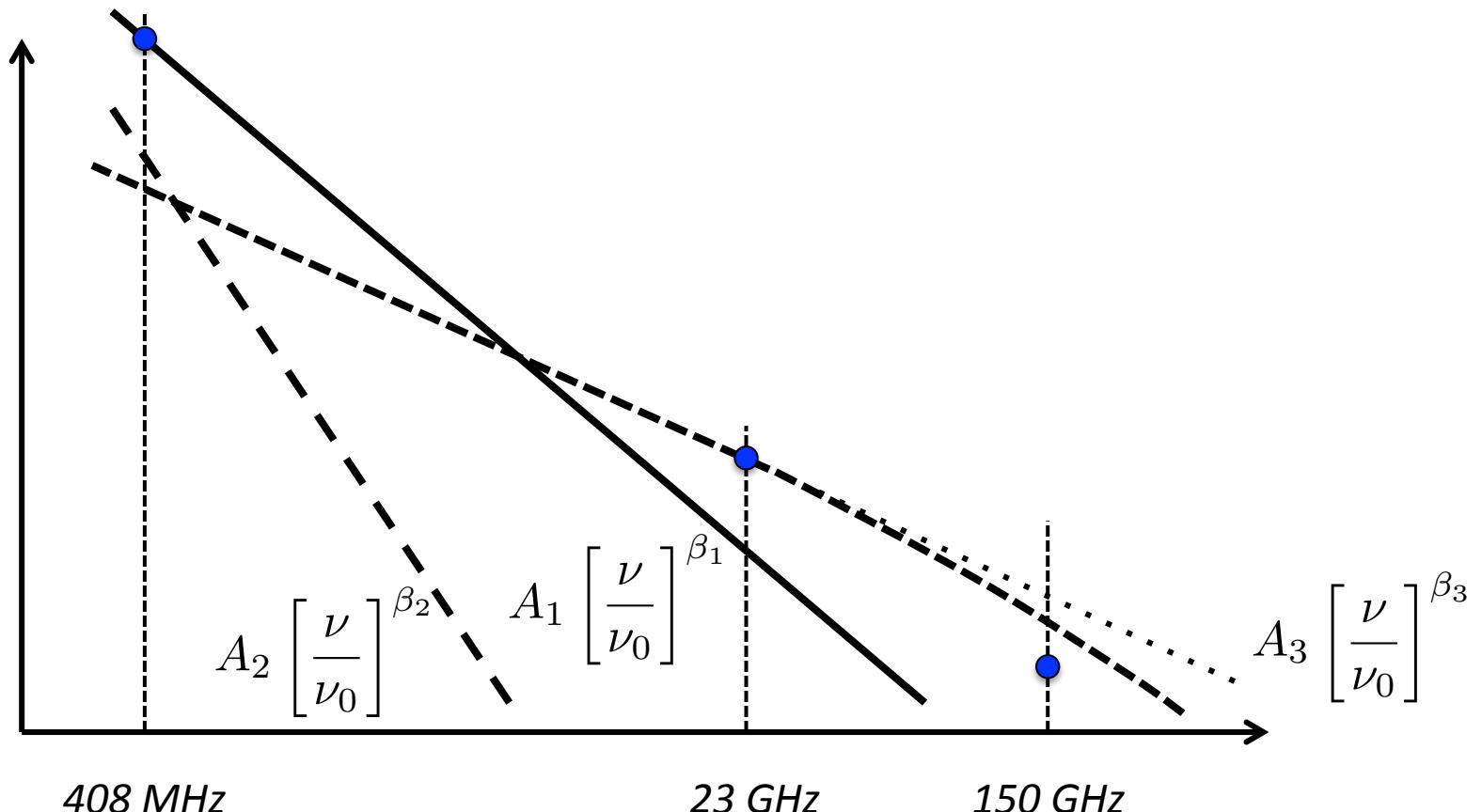
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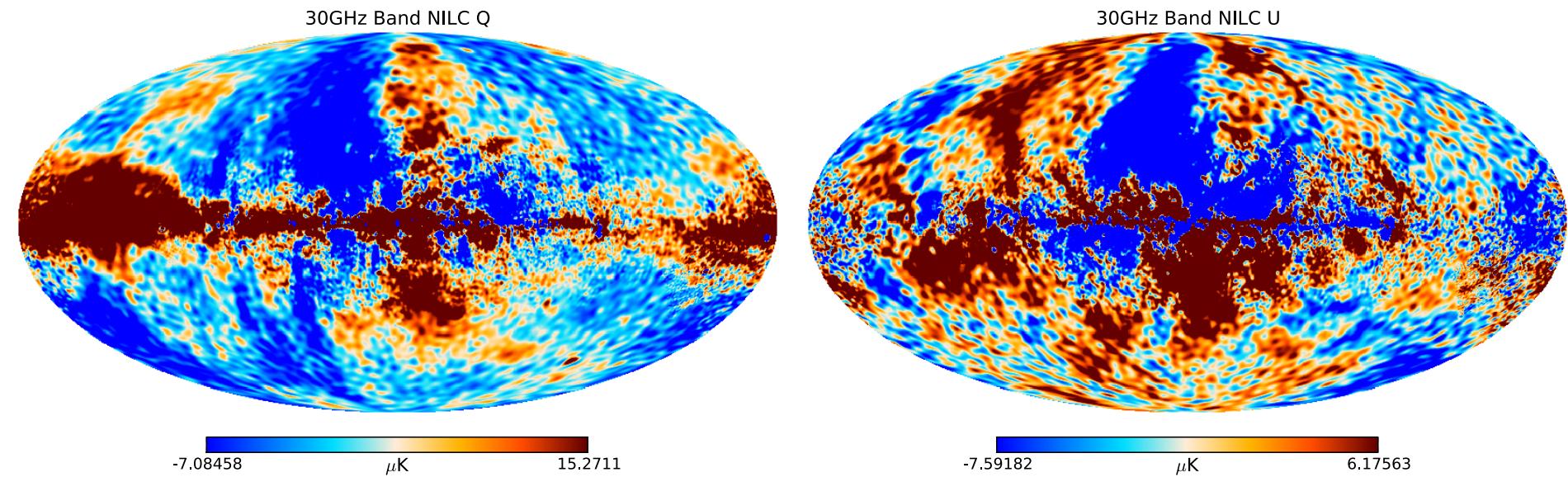
Frequency scaling of synchrotron

- There also is evidence for steepening of the synchrotron spectral index above 20 GHz ("aging" of CR electrons).



Polarisation at 30 GHz (LFI)

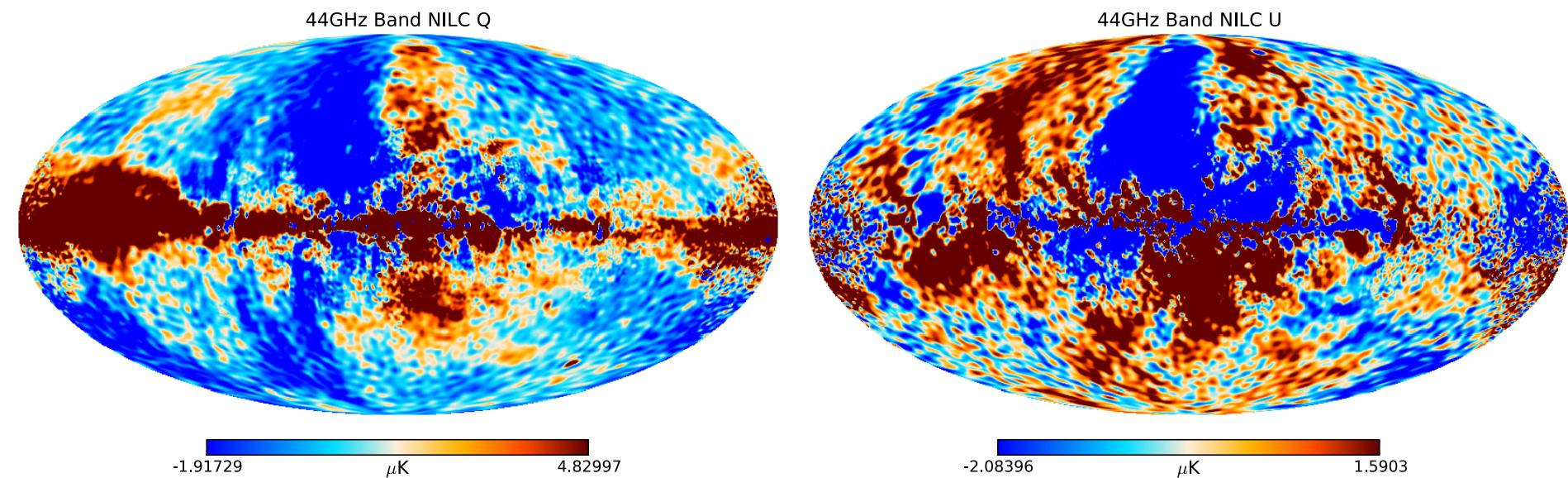
- Polarisation maps from Planck LFI (30, 44 GHz) and WMAP (<40 GHz) are dominated by synchrotron.
- 30 GHz polarisation maps obtained from Planck using GNILC



Signal-dominated at scales larger than 2-3 degrees

Polarisation at 44 GHz (LFI)

- Polarisation maps from Planck LFI (30, 44 GHz) and WMAP (<40 GHz) are dominated by synchrotron.
- 44 GHz polarisation maps obtained from Planck using GNILC



Polarised GNILC maps by Ata Karakci (ongoing work)

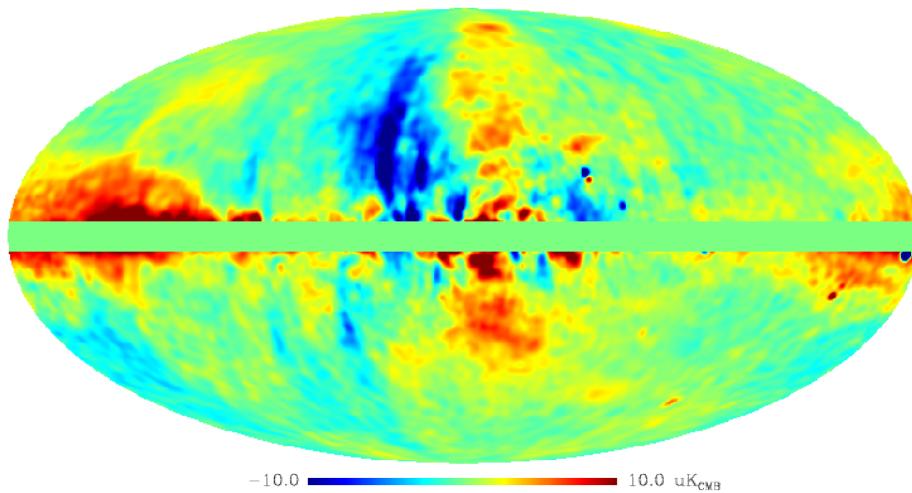
Spectral index for polarisation

- Polarisation maps from Planck LFI (30, 44 GHz) and WMAP (<40 GHz) are dominated by synchrotron.
- Best-fit spectral index of -3.275 for Q and -3.274 for U at galactic latitudes $> 10^\circ$ (very good agreement)

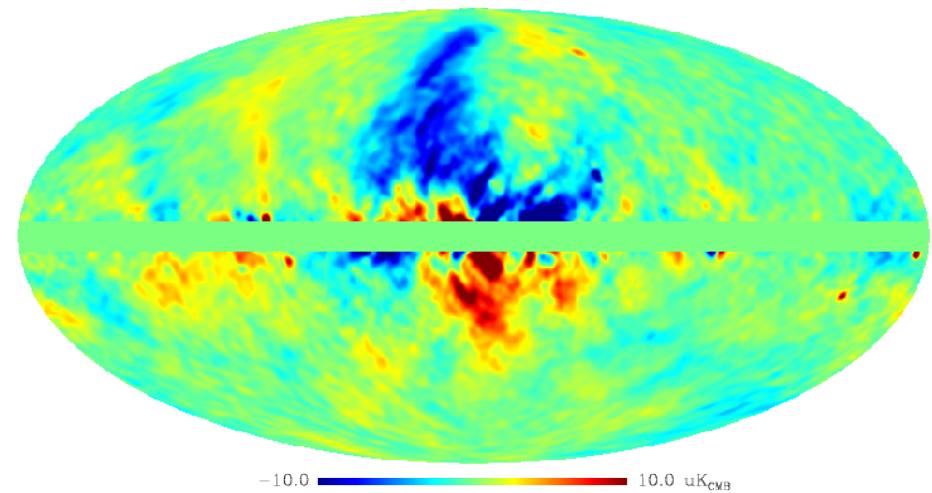
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Q Polarisation, 44 GHz extrapolated from 30 GHz

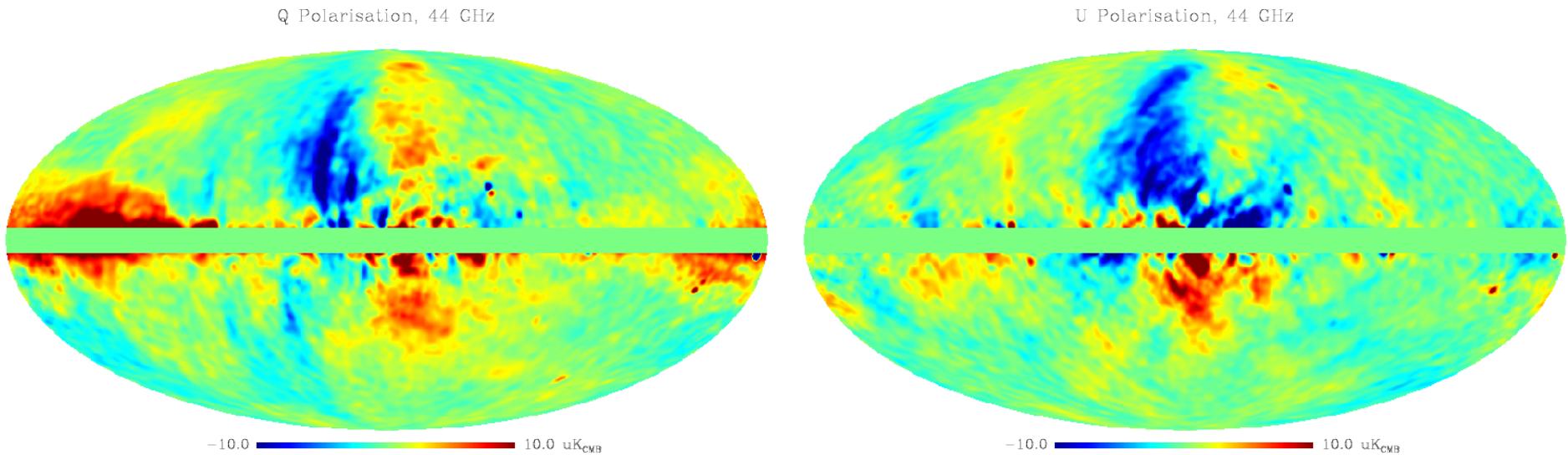


U Polarisation, 44 GHz extrapolated from 30 GHz

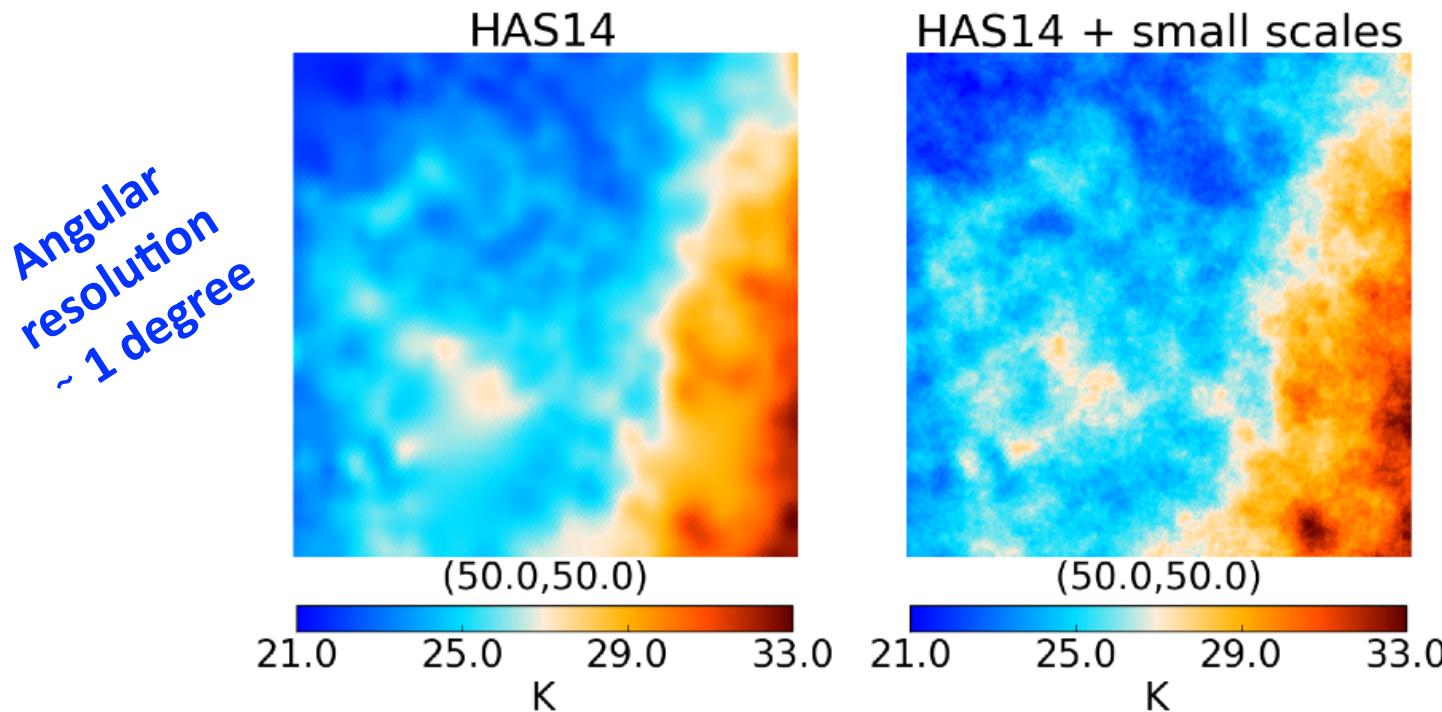


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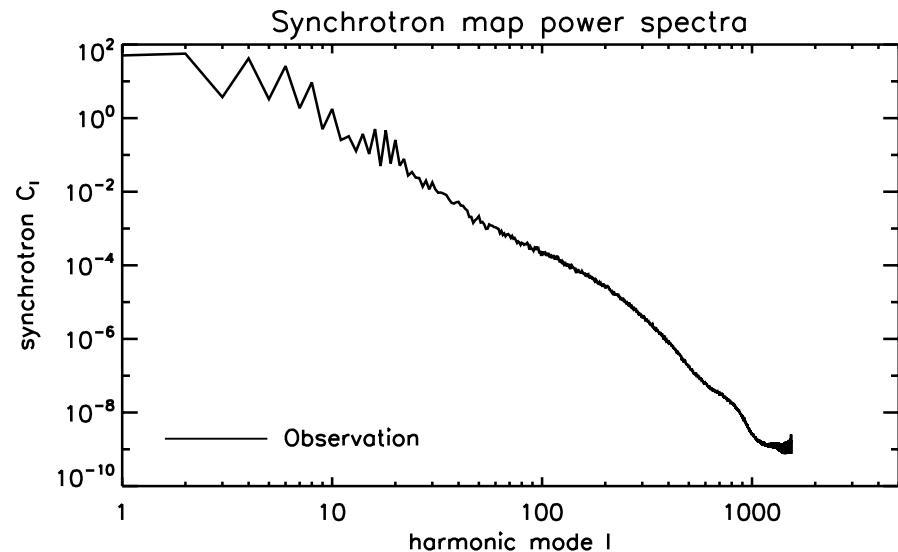
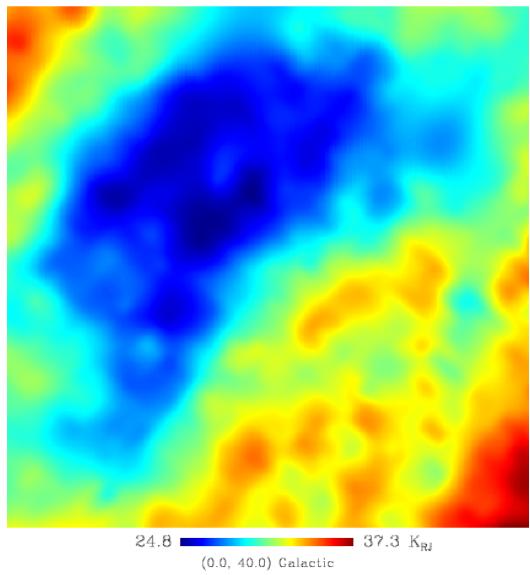
Synchrotron: small scales



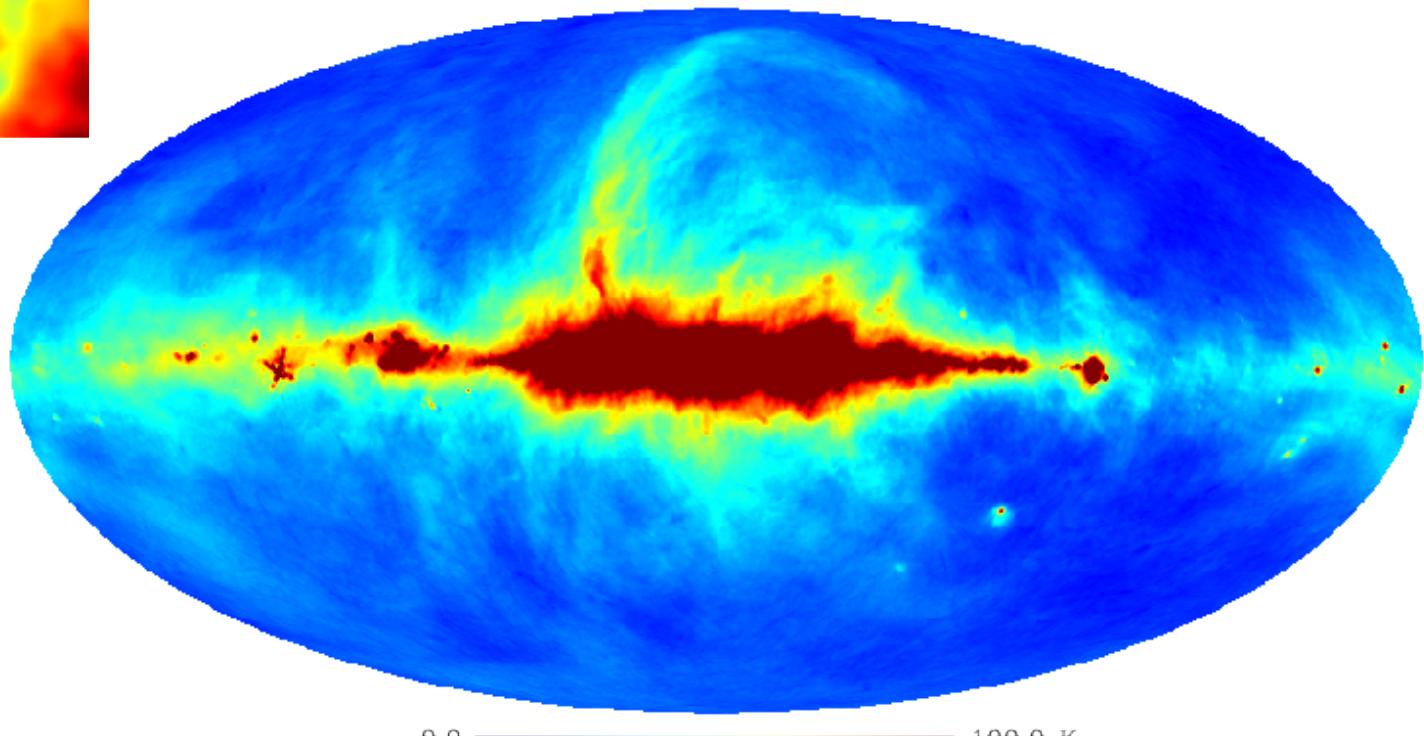
- **SMALL SCALES MISSING IN 408 MHz MAP**
- One single map with small scales added has been made available by Remazeilles et al. at $nside=2048$ (pixel size = $1.7'$). Small scales are generated as Gaussian fluctuations, following the prescription implemented in the pre-launch PSM.

Observation

observation



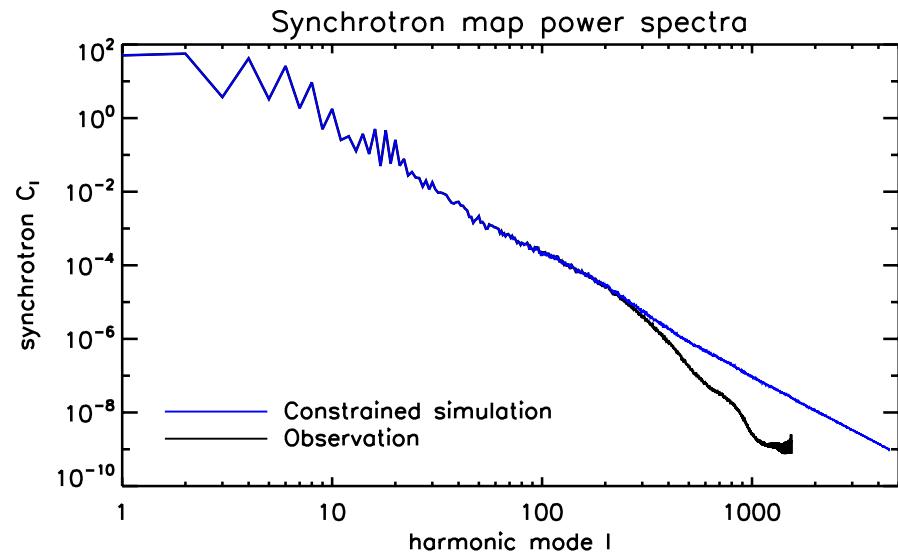
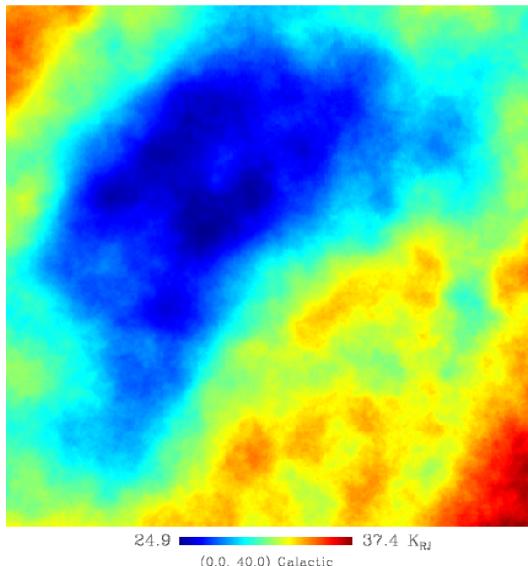
observation



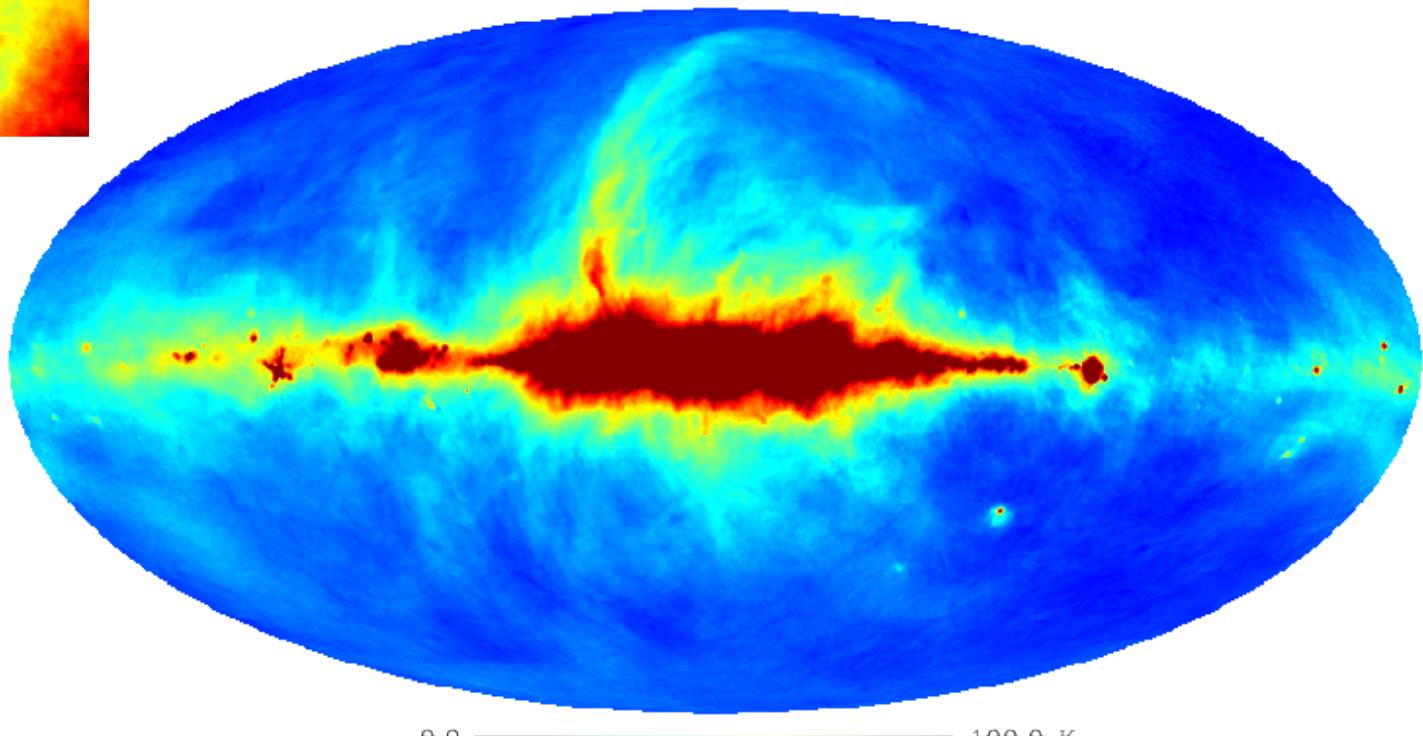
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Constrained

constrained simulation



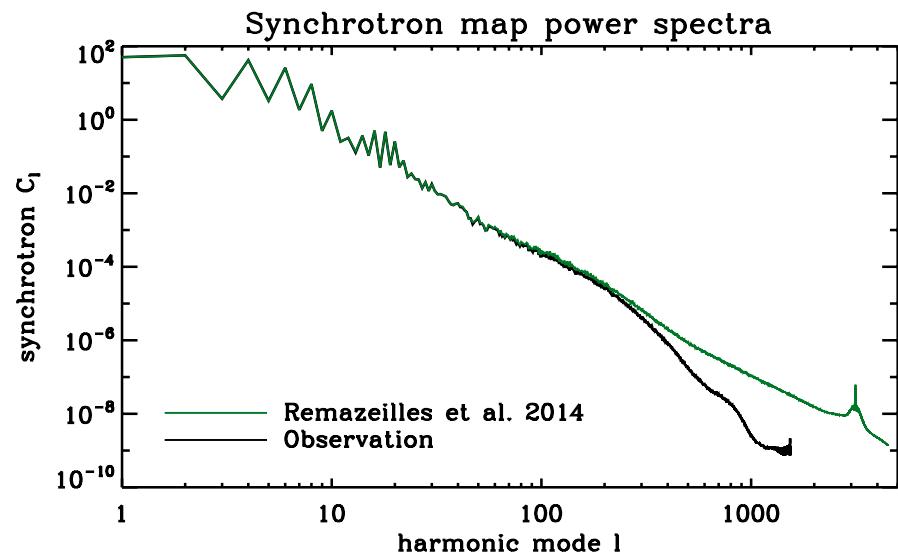
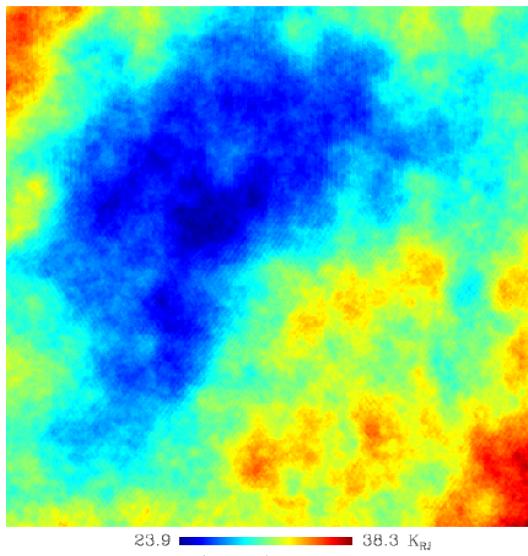
constrained simulation



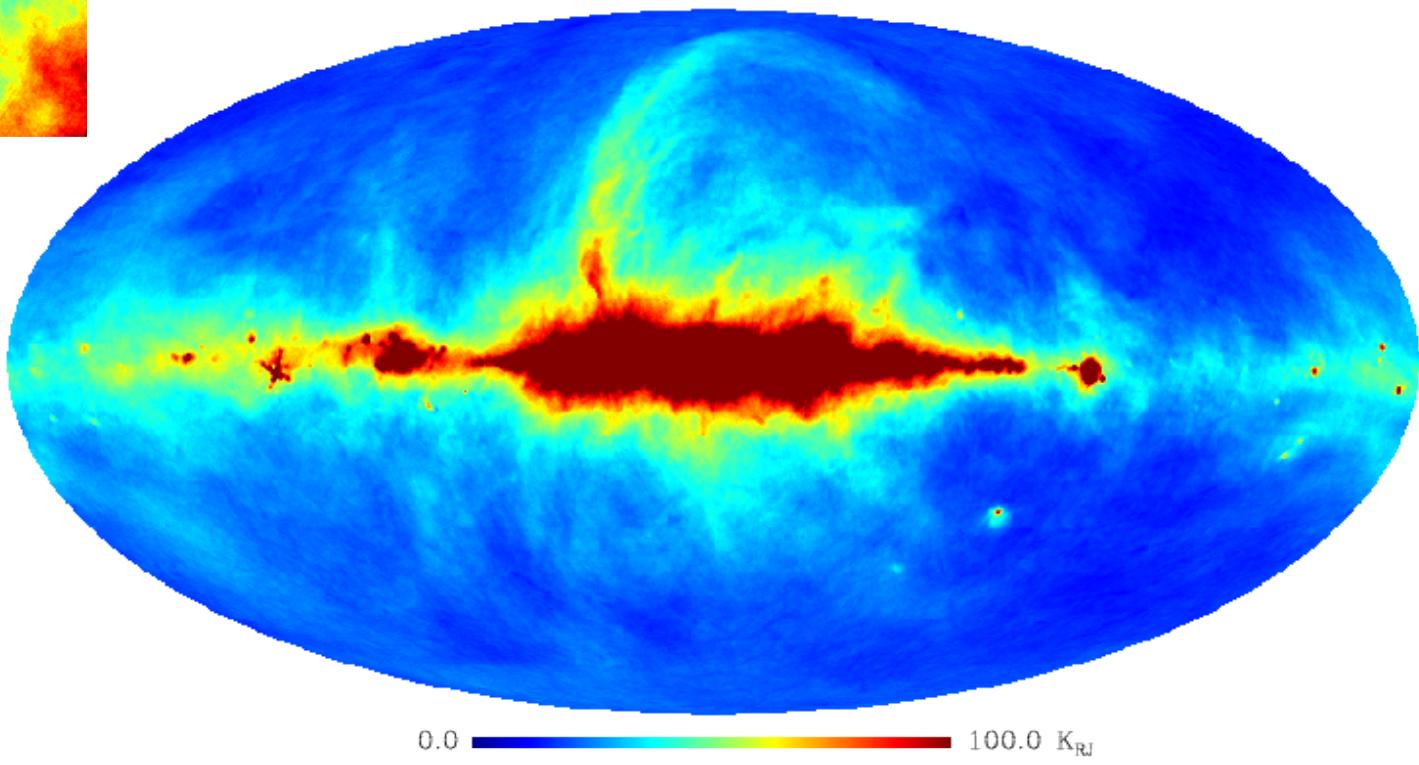
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Remazeilles 2014

Remazeilles with small scales



Remazeilles with small scales



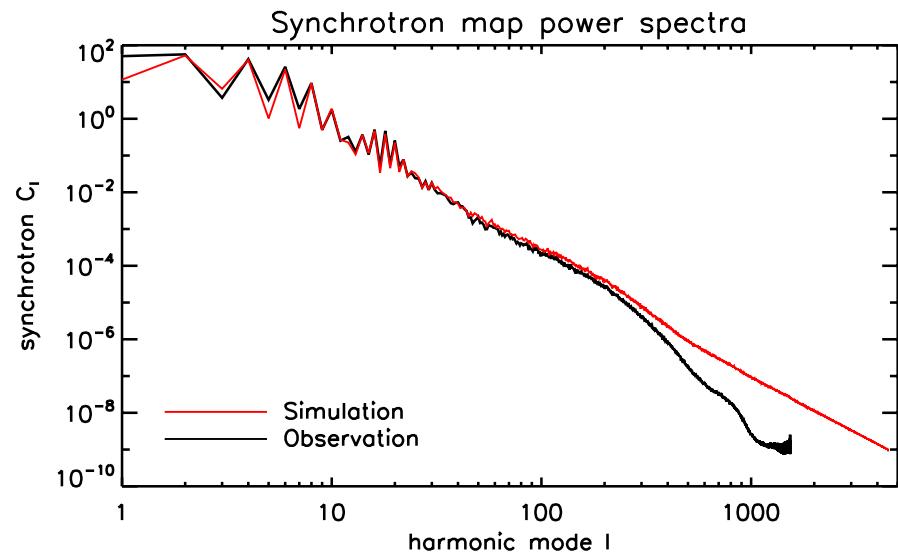
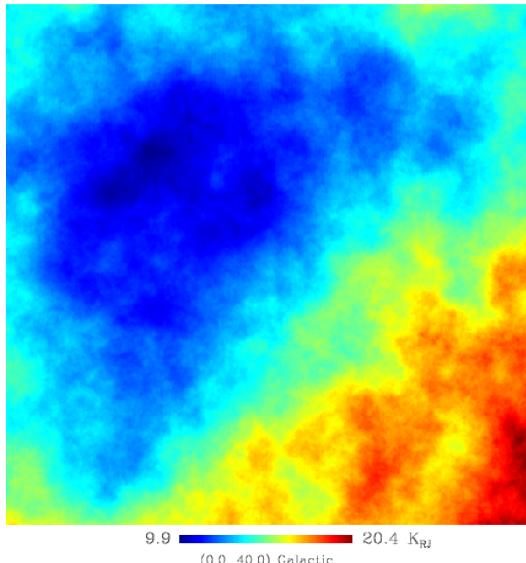
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Random high resolution synchrotron ?

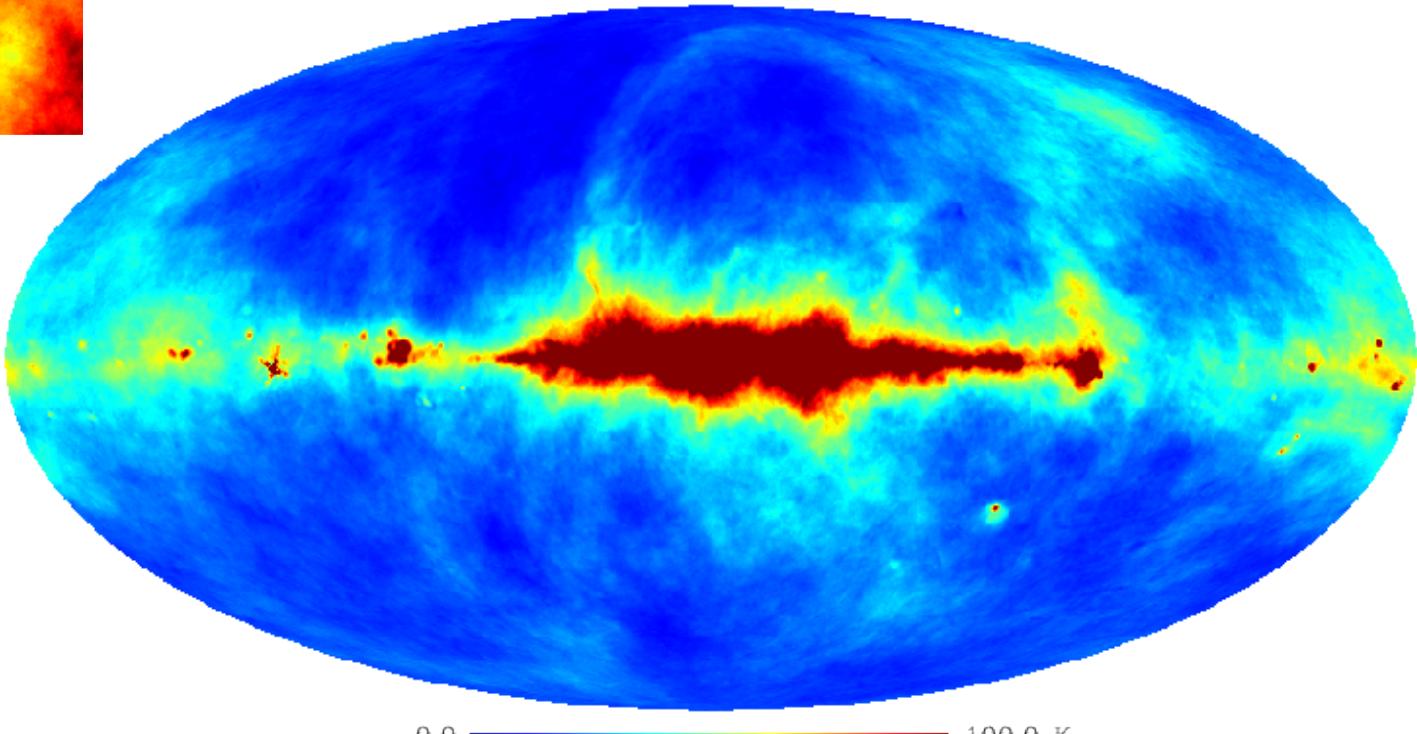
- ***NEW in PSM*** : We can now also generate a fully random synchrotron map with the same power spectrum (I^{-3}), with log-normal statistics in the map domain, modulated by the real synchrotron map for a similar "galactic" morphology.

Realisation 1

simulation



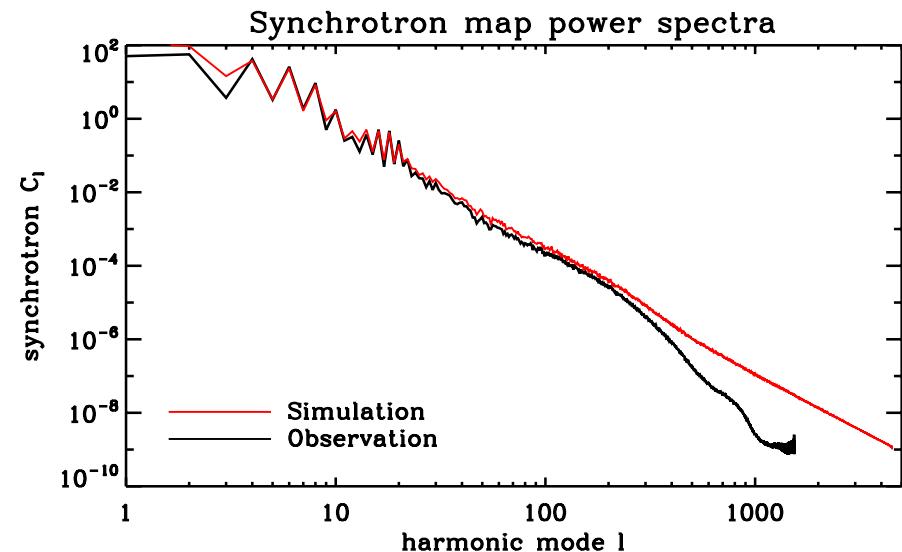
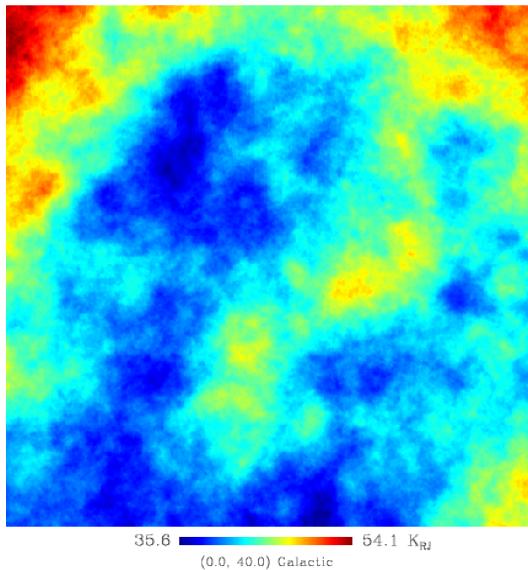
simulation



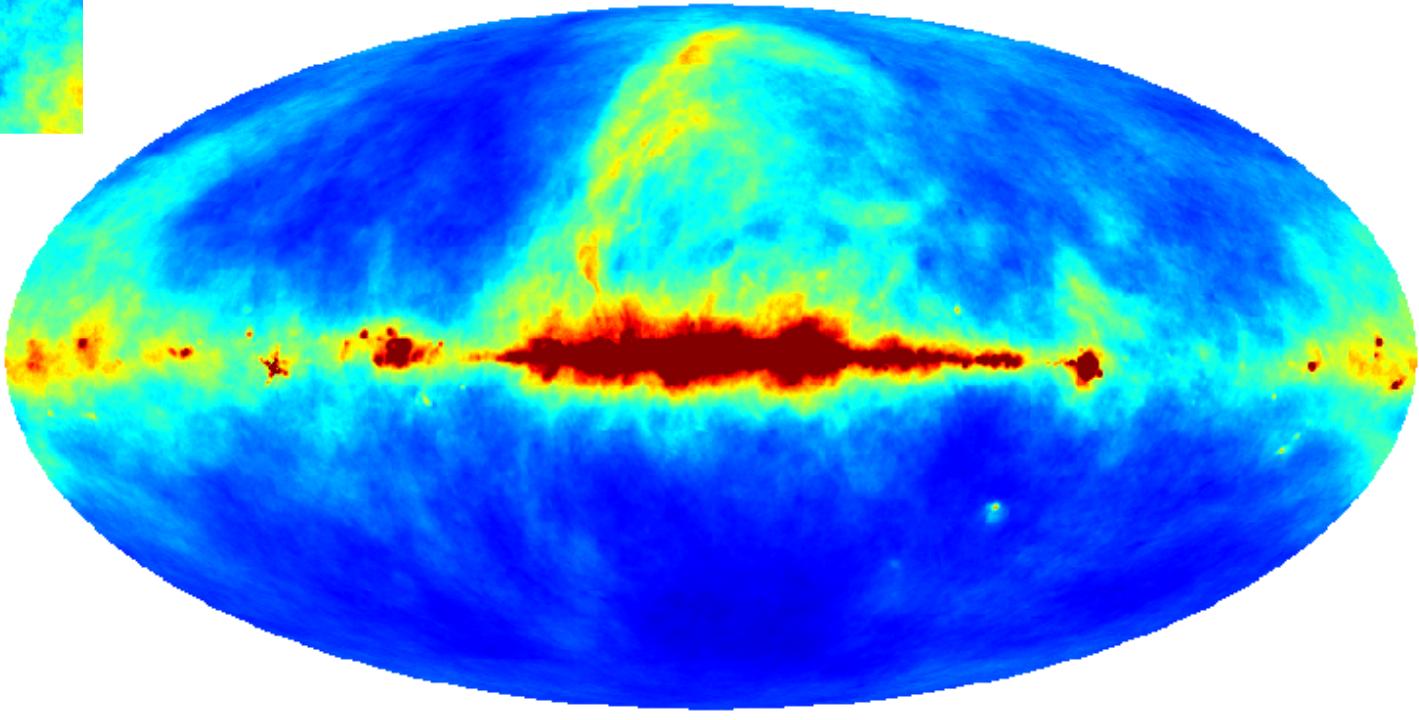
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Realisation 2

simulation



simulation

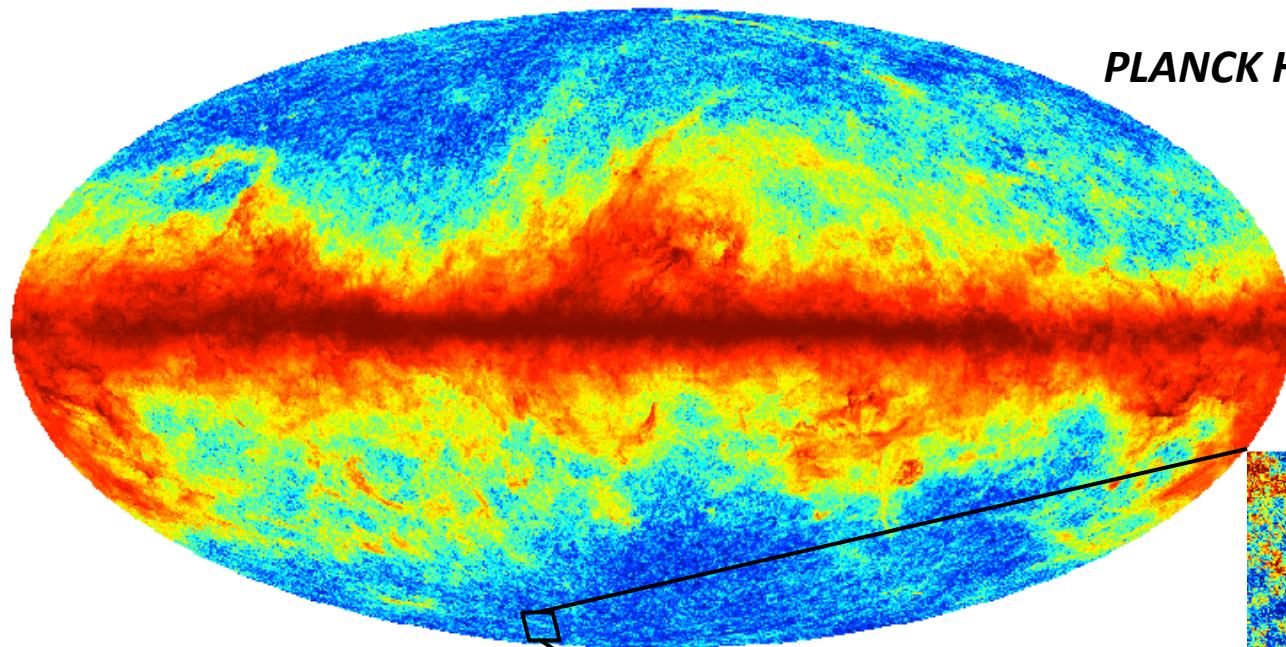


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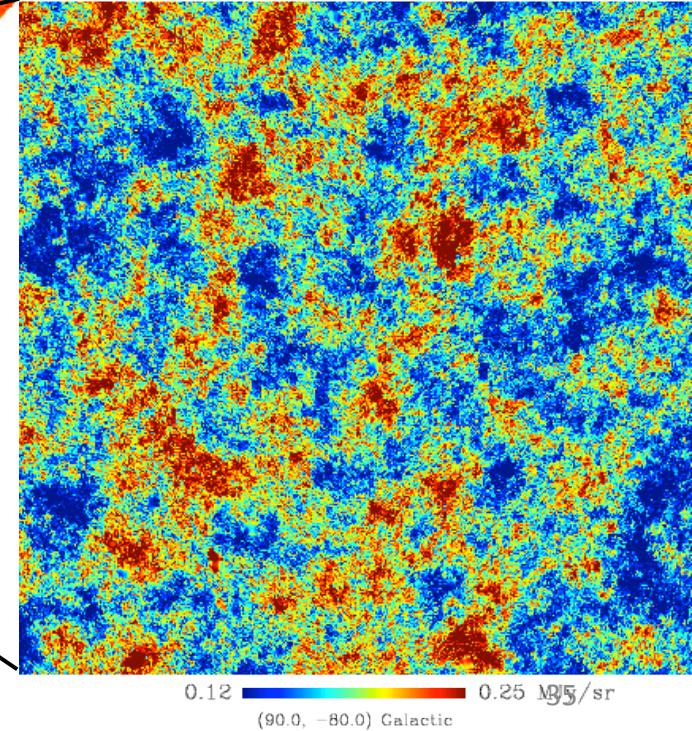
Improving dust maps



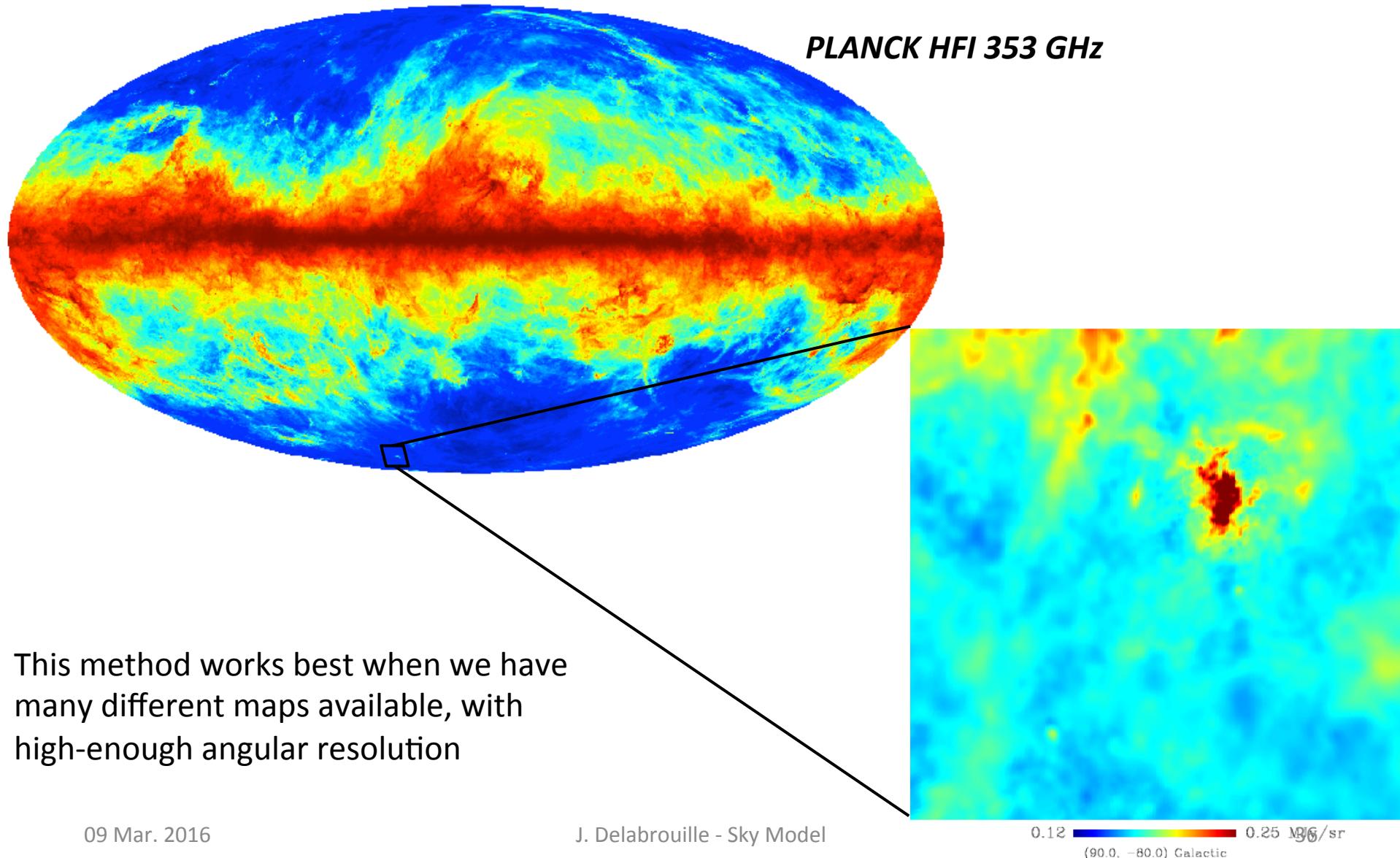
Dust maps are contaminated
by CIB, (by CMB) and by noise

Processing of multifrequency maps with GNILC

Remazeilles, Delabrouille & Cardoso 2011, MNRAS, 418, 467

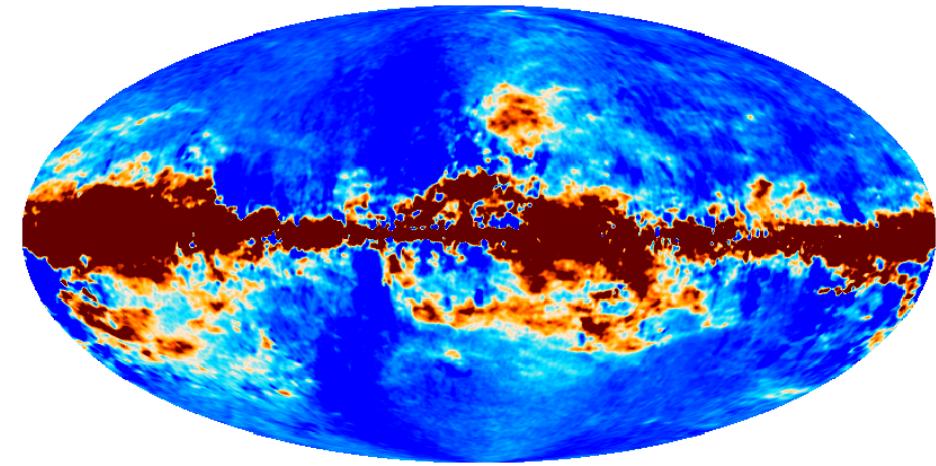


Improving dust maps

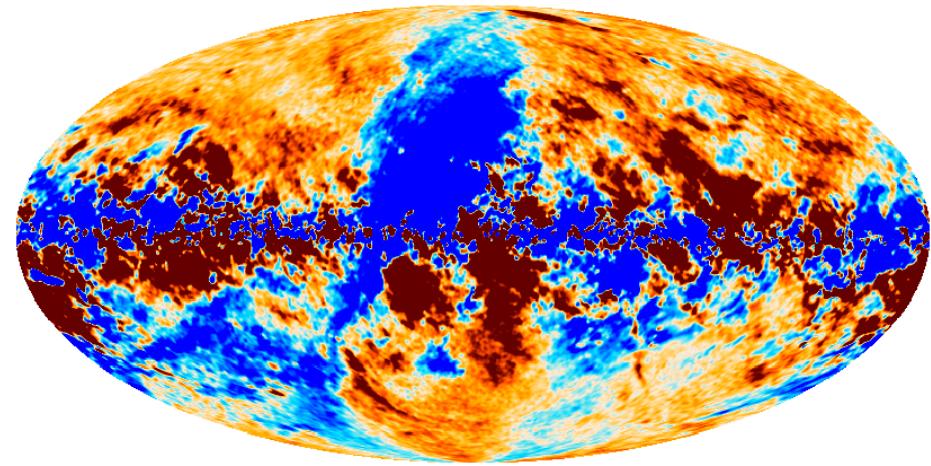


GNILC polarised dust (preliminary!)

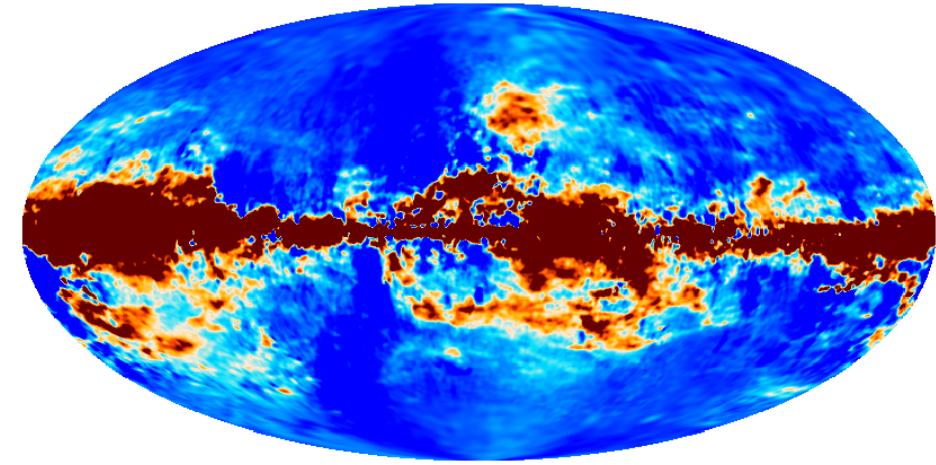
353GHz Band Data Q



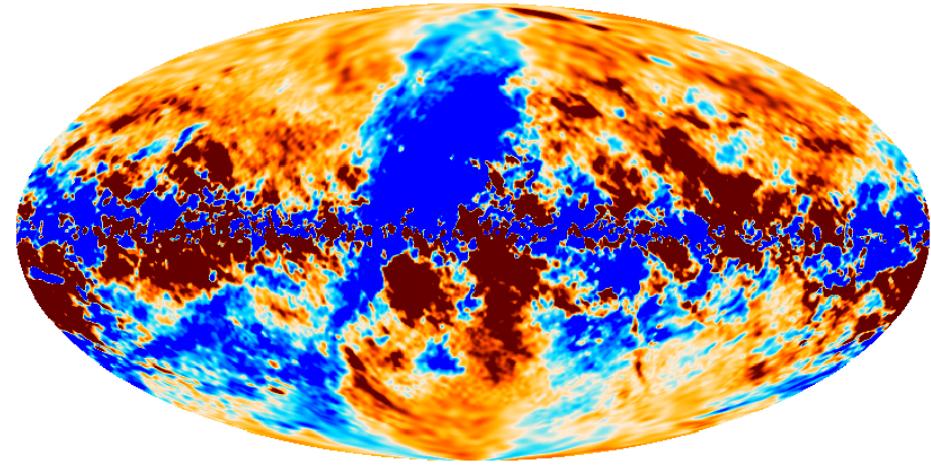
353GHz Band Data U



353GHz Band NILC Q

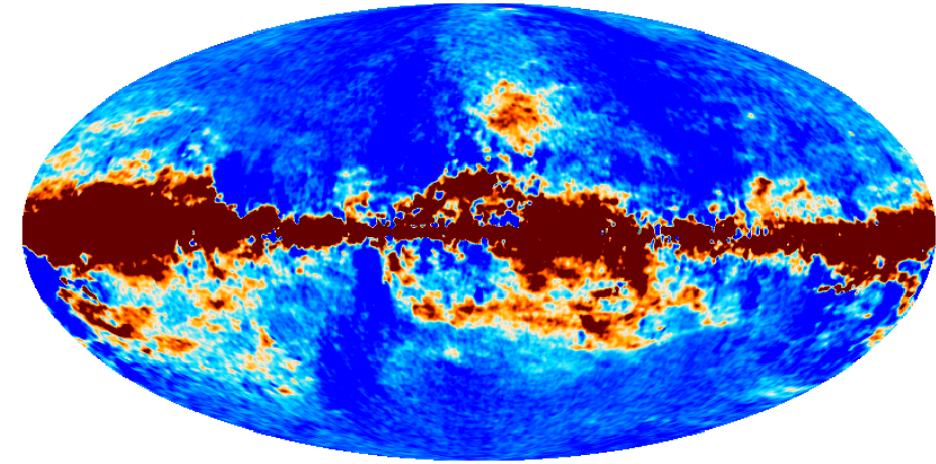


353GHz Band NILC U



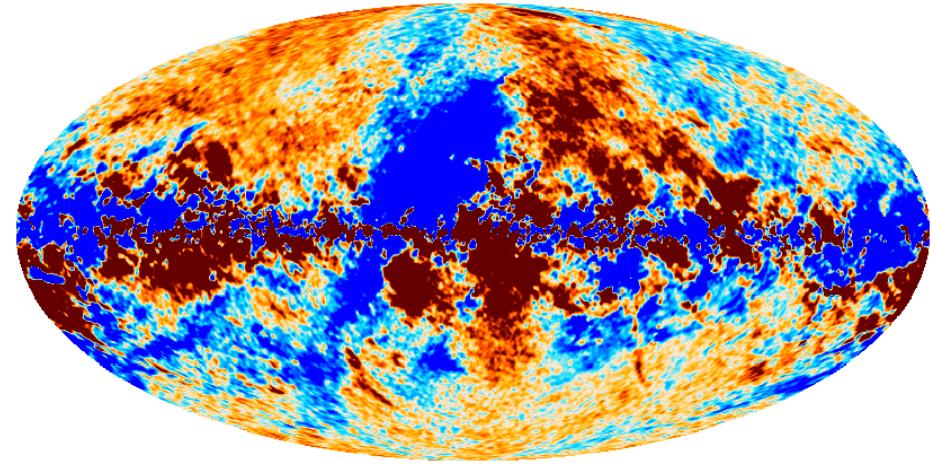
GNILC polarised dust (preliminary!)

217GHz Band Data Q



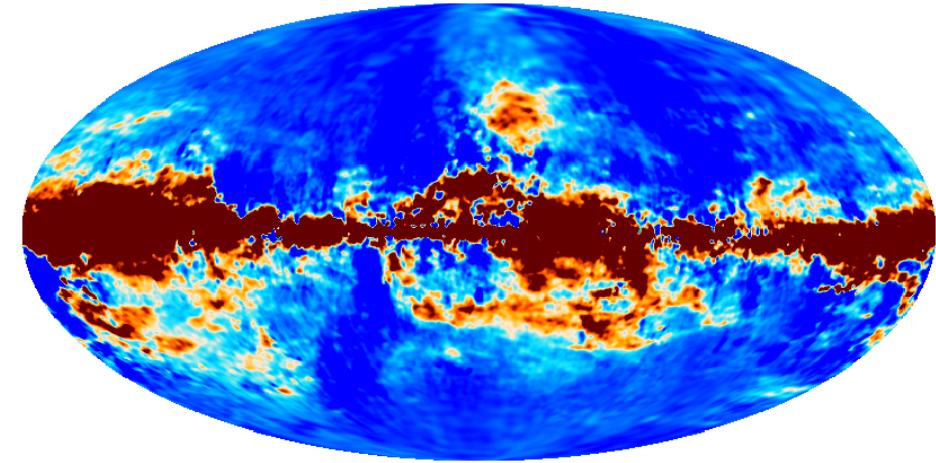
-2.73859 μK 27.5918

217GHz Band Data U



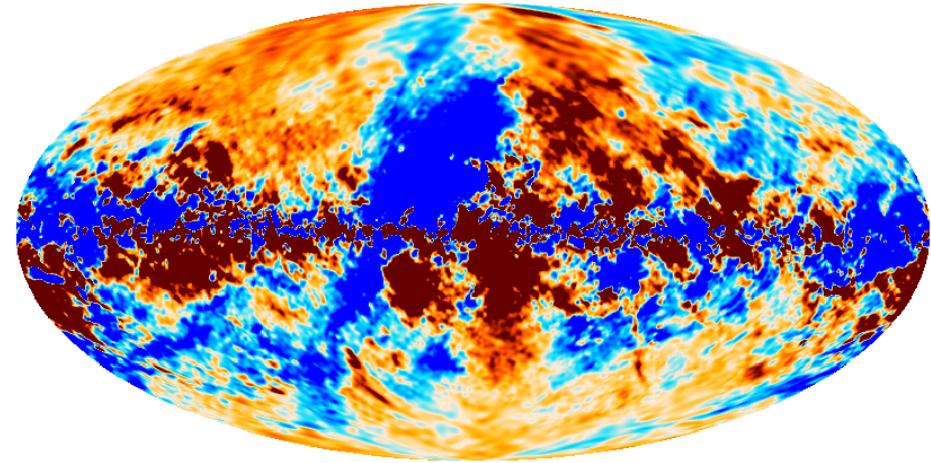
-8.91641 μK 6.82741

217GHz Band NILC Q



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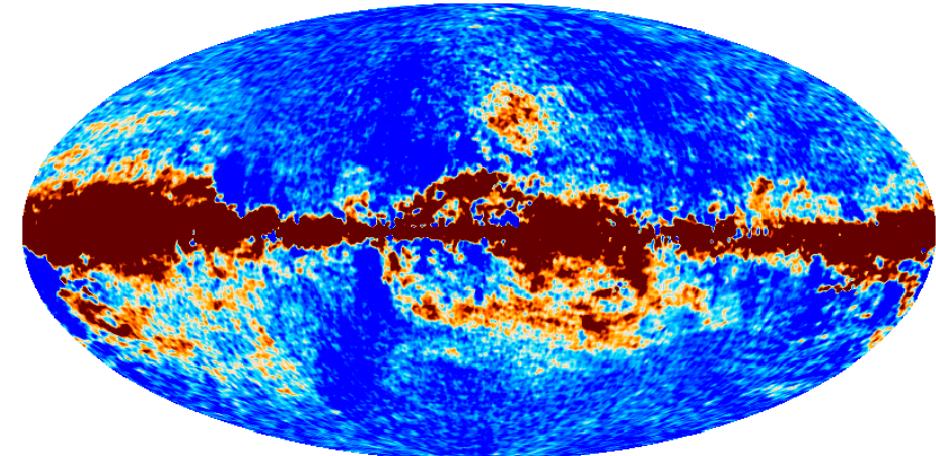
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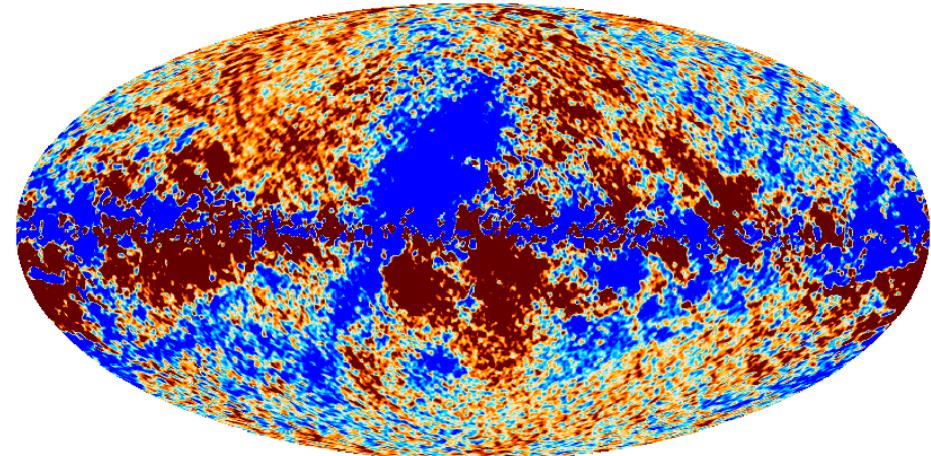
-8.91641 μK 6.82741

GNILC polarised dust (preliminary!)

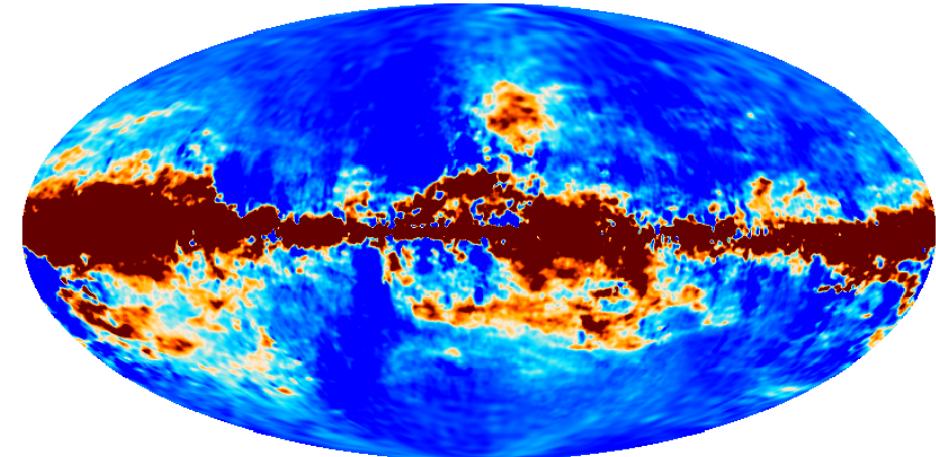
143GHz Band Data Q



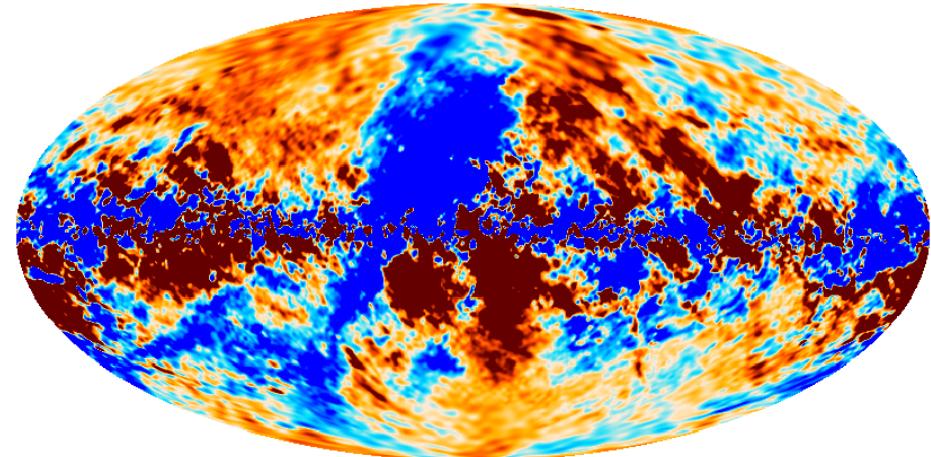
143GHz Band Data U



143GHz Band NILC Q



143GHz Band NILC U



Generating polarisation templates

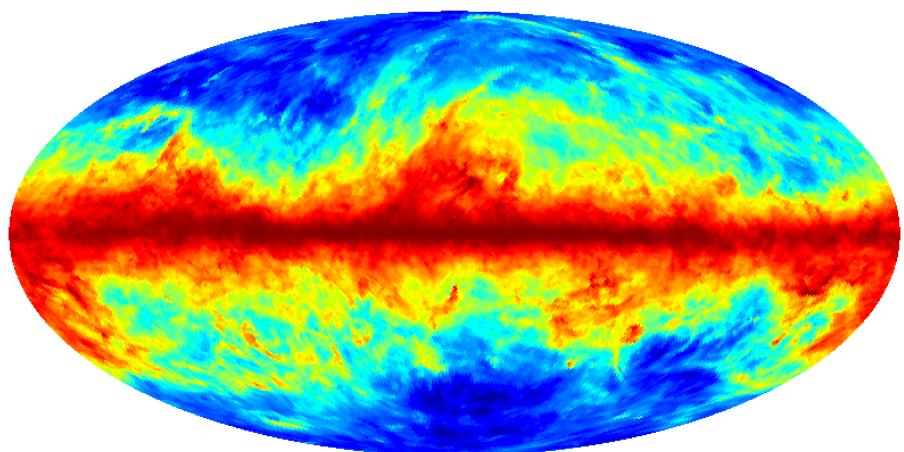
- Polarisation templates from real data are at poor angular resolution
- Use them to generate (low-resolution) maps of polarisation fraction and polarisation angle, and get smaller scale polarisation by applying that to high-resolution I templates.
- There is however a limitation to this...

Outline

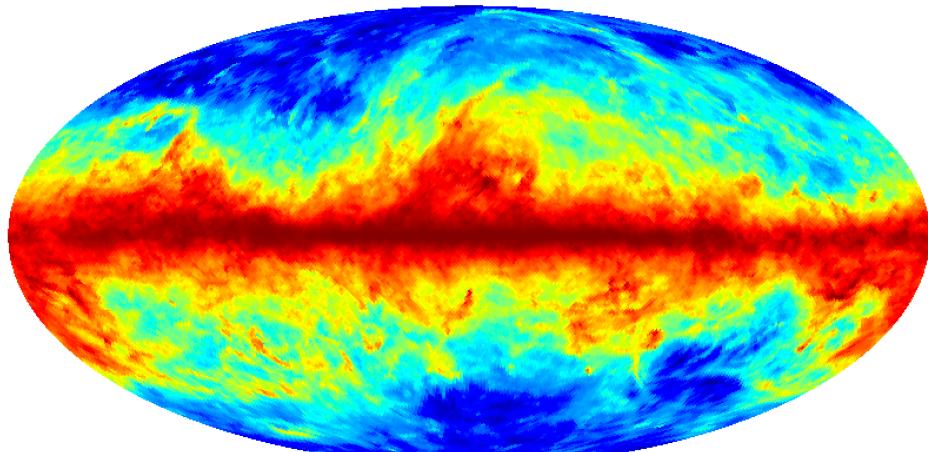
- Introduction
- Polarised diffuse foregrounds
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 - ✓ 3-D dust
 - ✓ Synchrotron
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Planck 2D maps (from GNILC of Mathieu Remazeilles)

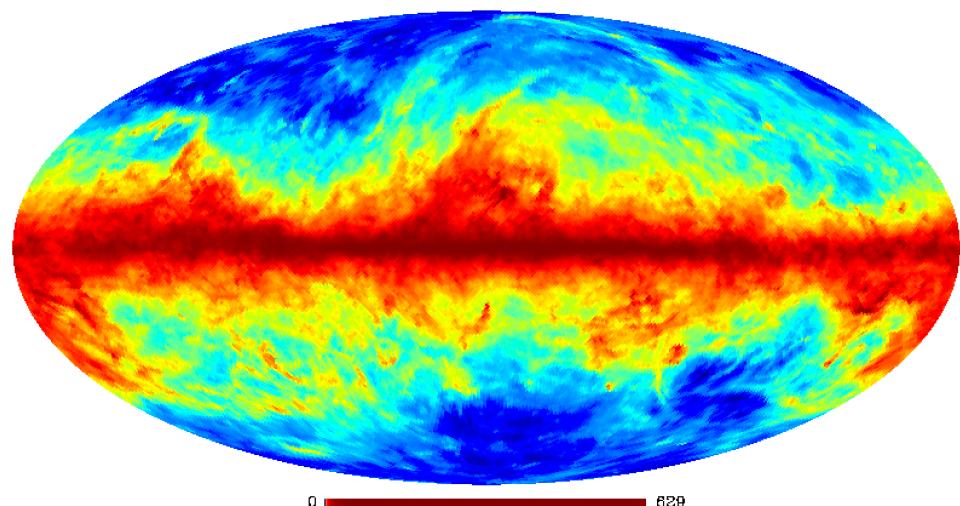
Planck 353 GHz



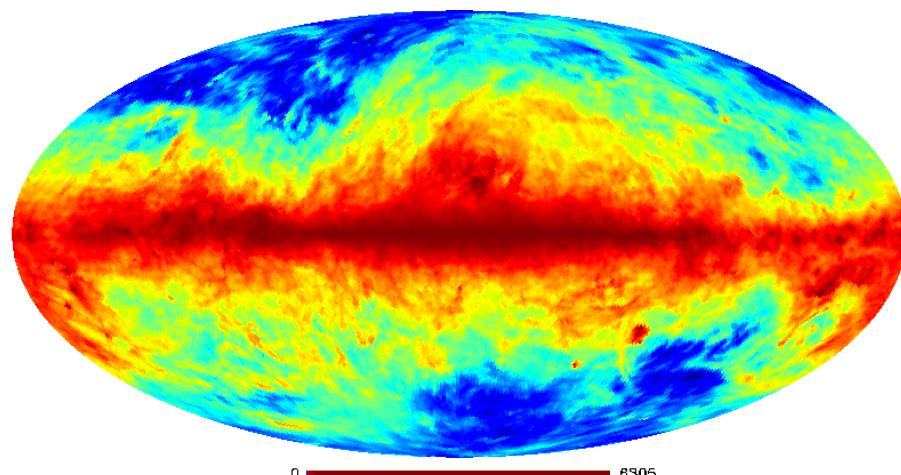
Planck 857 GHz



Planck 545 GHz



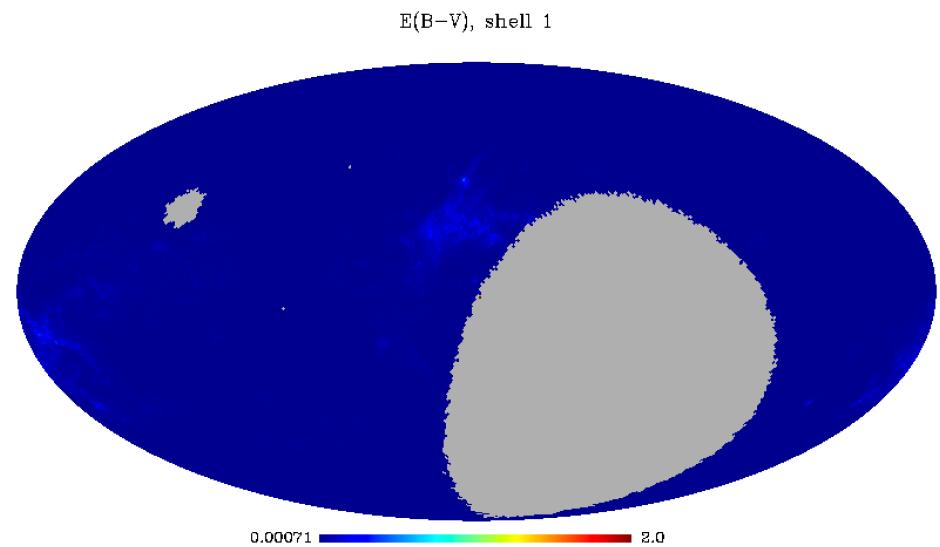
Planck 3000 GHz



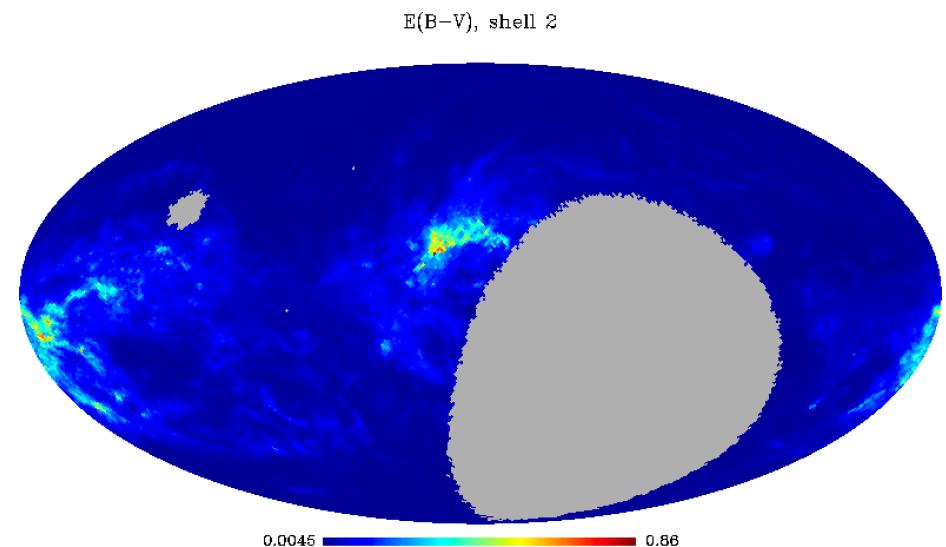
Project (Gines Martinez Solaeche) : make it 3D

Green et al. 3D maps

- Reconstruction based on the reddening of stars
- 3D maps (6 shells up to 19 kPc)

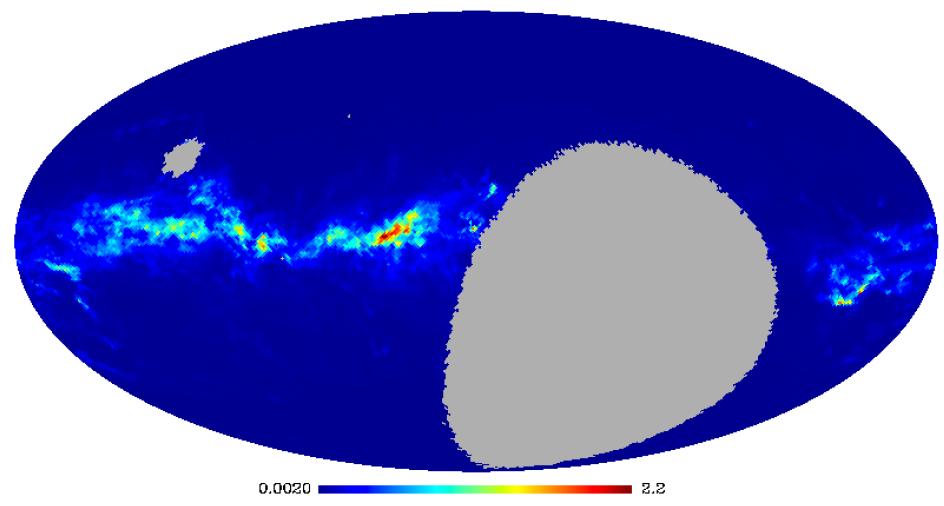


a) 0.0-4.0 kpc

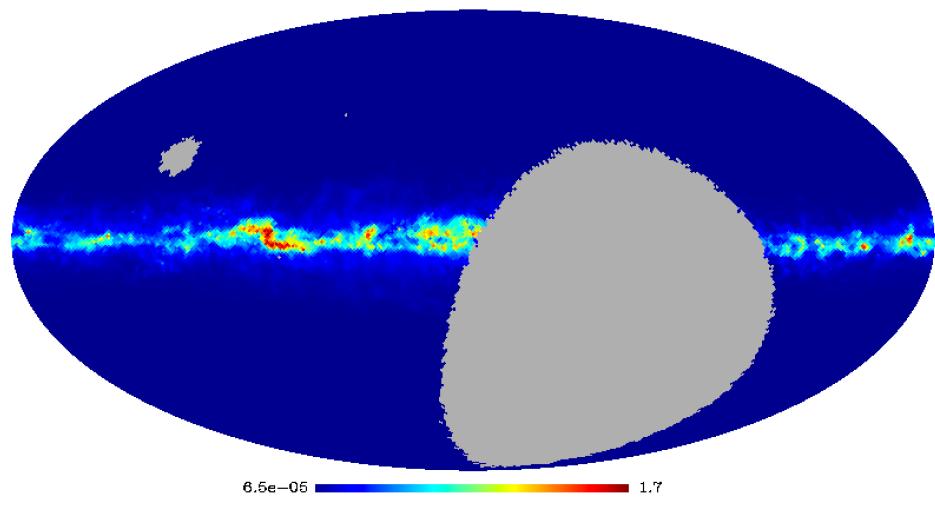


b) 4.0-7.0 kpc

E(B-V), shell 3

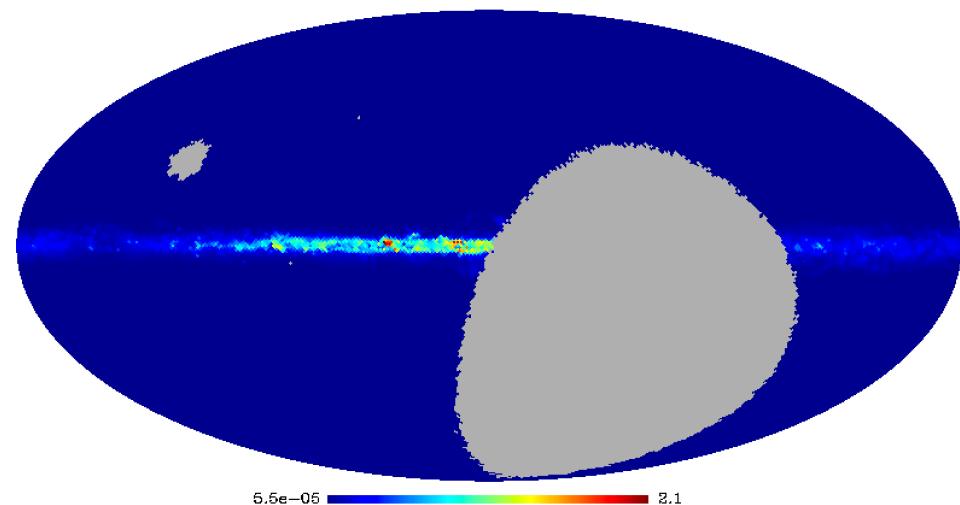


E(B-V), shell 4



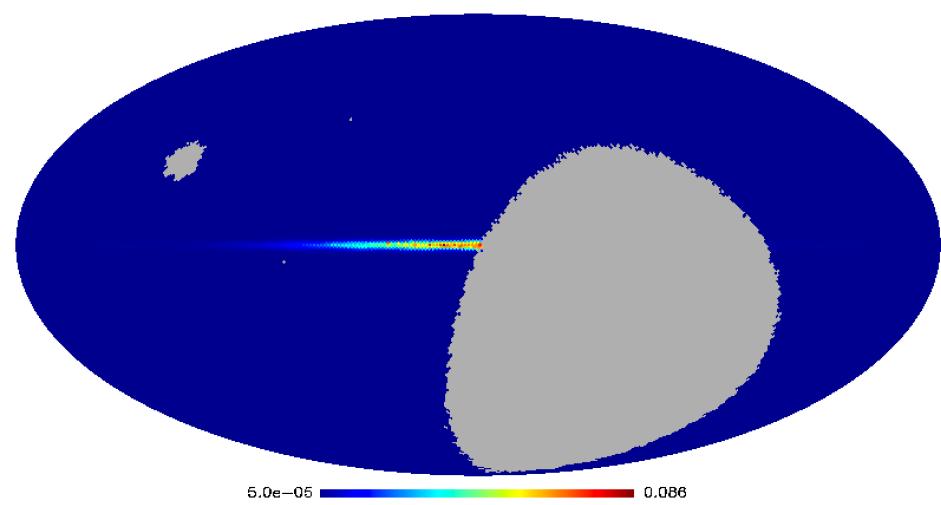
c) 7.0-10.0 Mpc

E(B-V), shell 5



d) 10.0-13.0 Mpc

E(B-V), shell 6

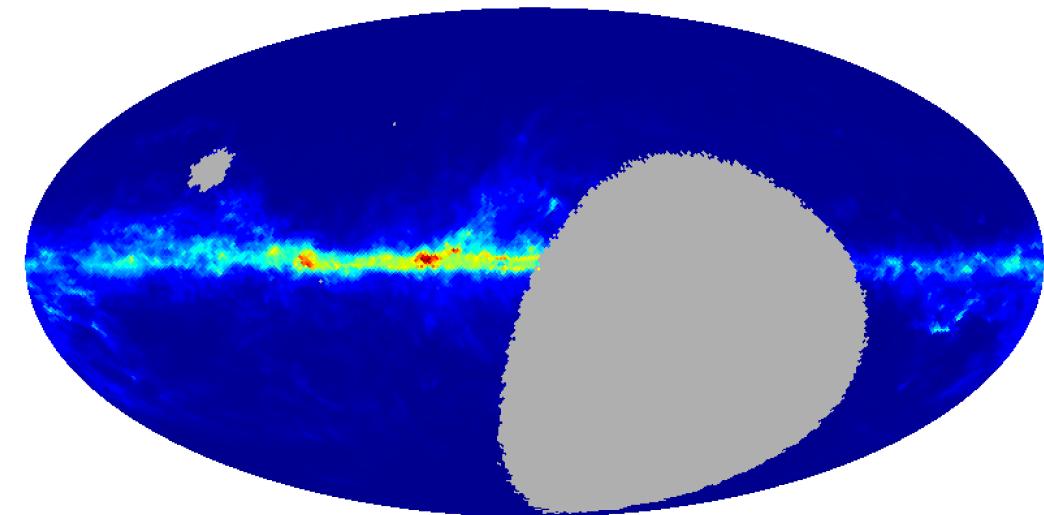


e) 13.0-16.0 Mpc

f) 16.0-19.0 Mpc

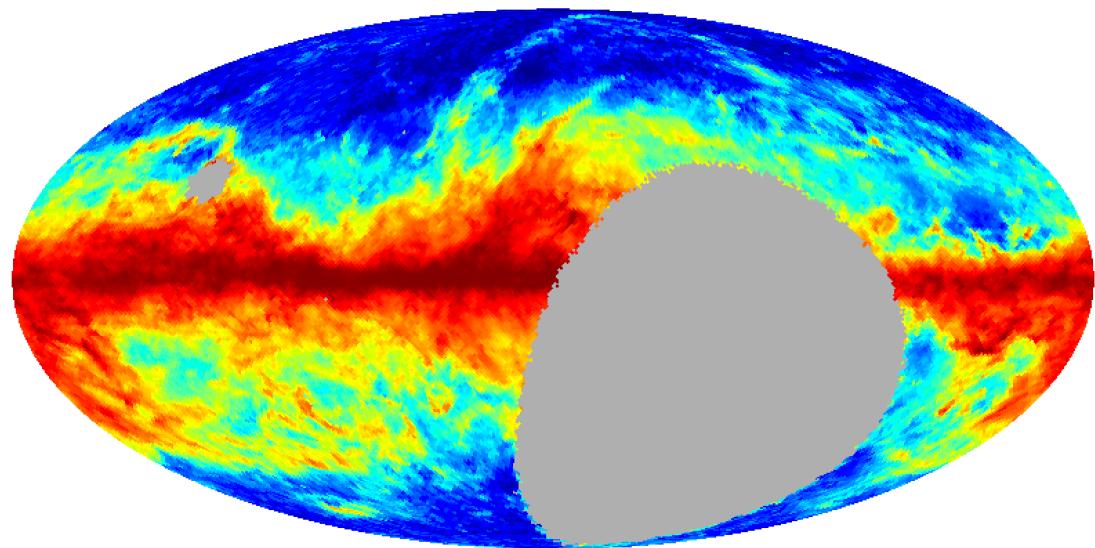
Sum of all shells:

$E(B-V)$



0.0098 ————— 4.1

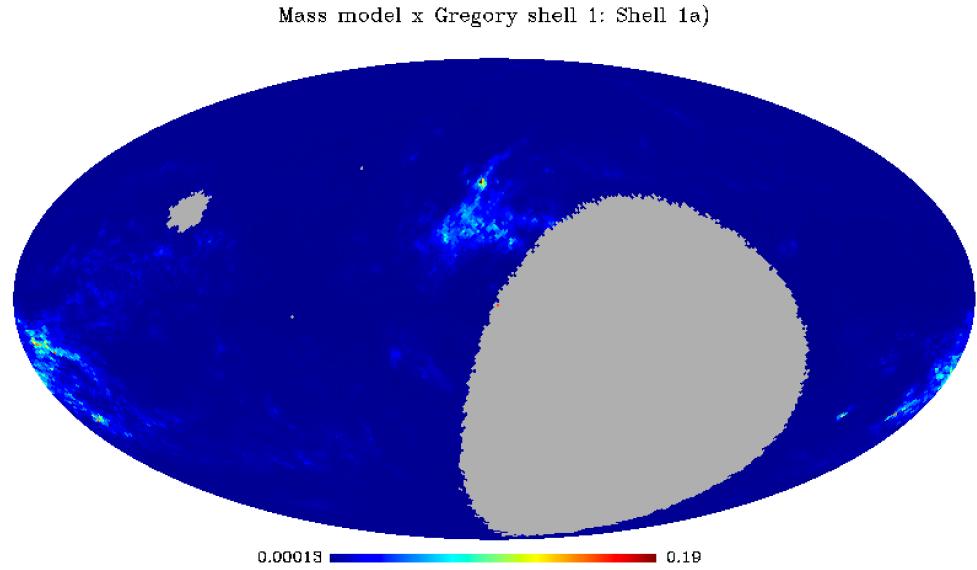
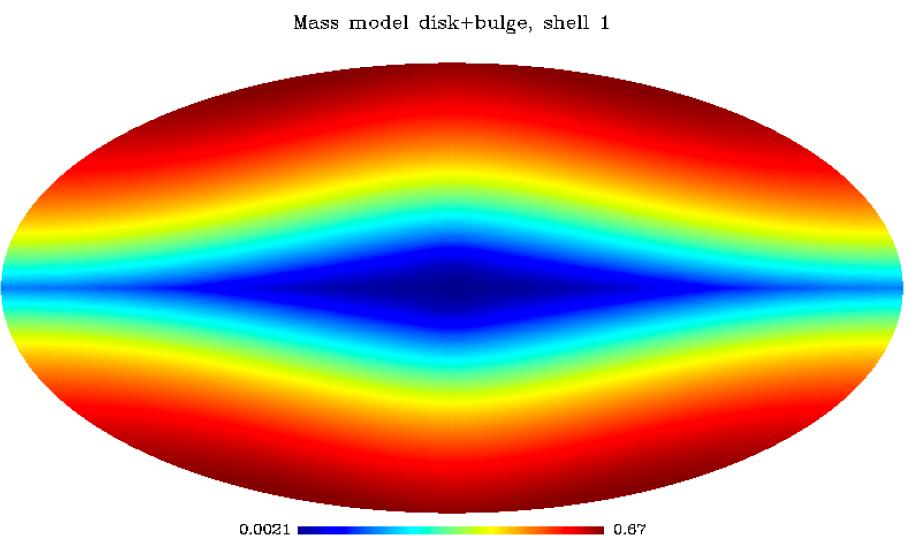
$E(B-V)$



0.0098 ————— 4.1

Cut first shell in 3 sub-shells

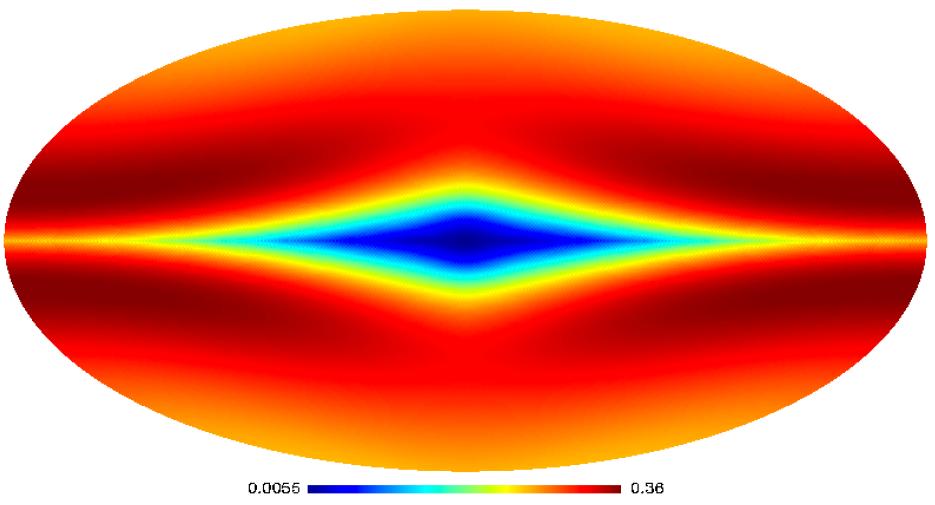
- up to **0.5 kpc** and from **0.5 to 1.5 kpc**
- A simple mass model of the galaxy is used: **Disk + Bulge**



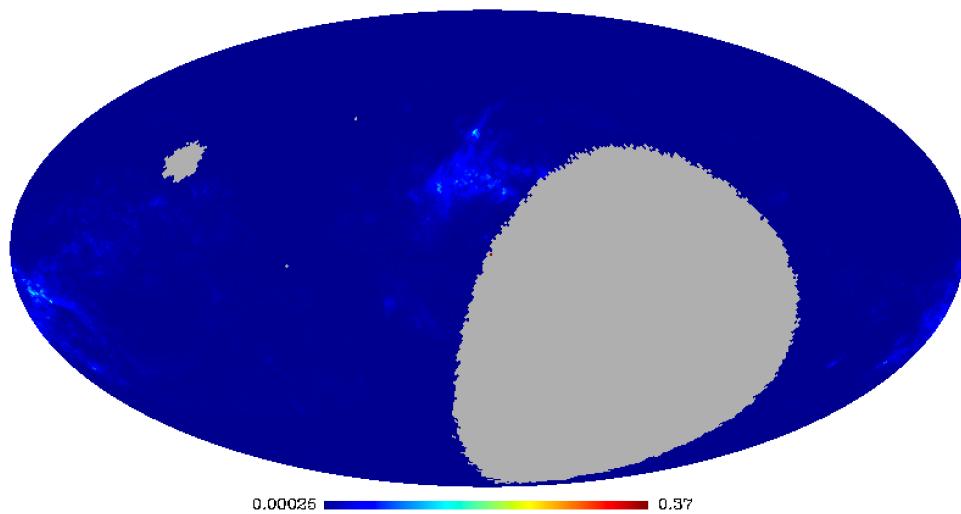
percentage of total first shell
in the first subshell
(from 0 to 0.67)

0.0-0.5 Mpc

Mass model disk+bulge, shell 2

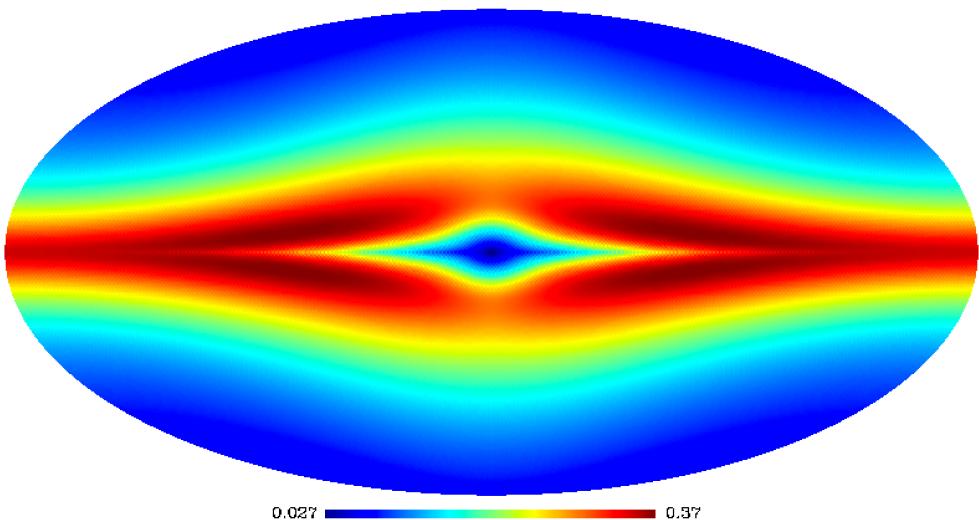


Mass model x Gregory shell 1: Shell 1b

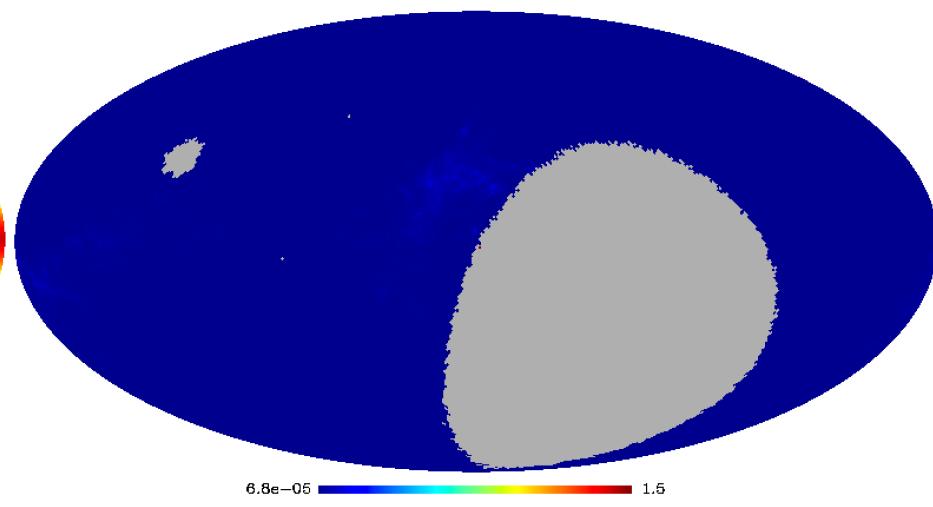


0.5-1.5 kpc

Mass model disk+bulge, shell 3



Mass model x Gregory shell 1: Shell 1c

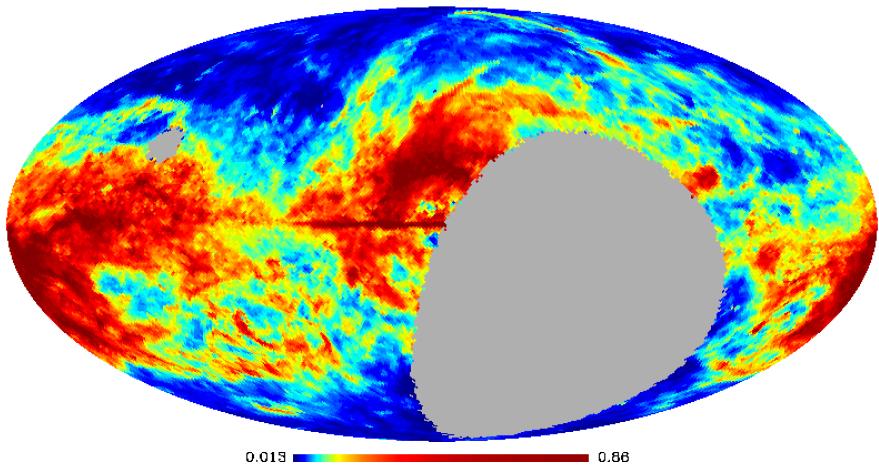


1.5-4.0 kpc

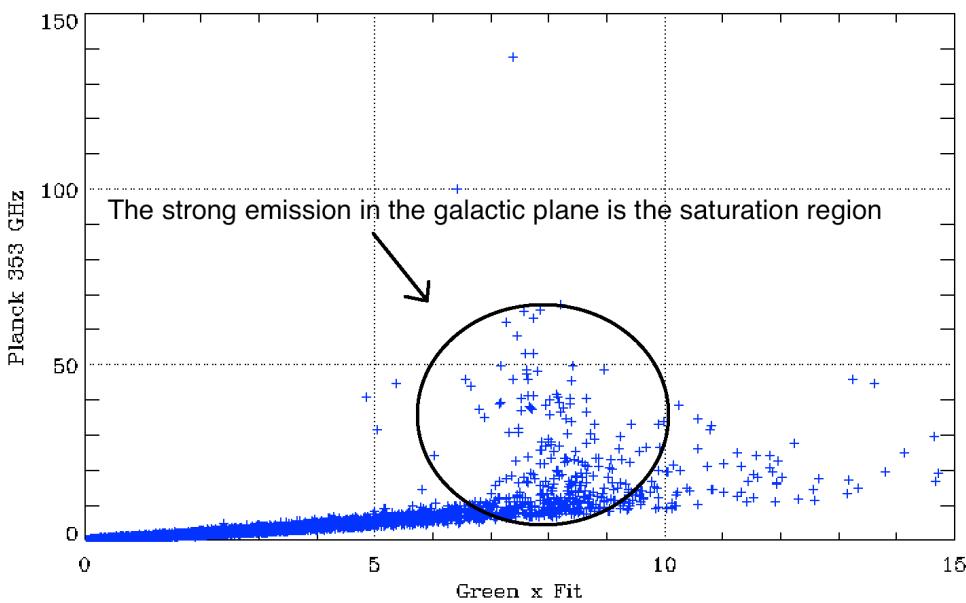
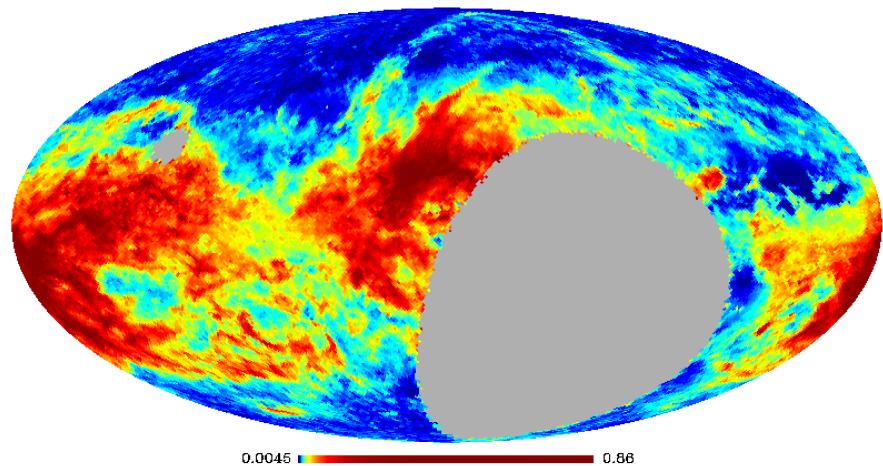
Green extinction vs Planck

- The **mass fraction** of dust in each shell is computed and multiplied by either Planck or Gregory Green's total maps

Planck 353 GHz, shell 4



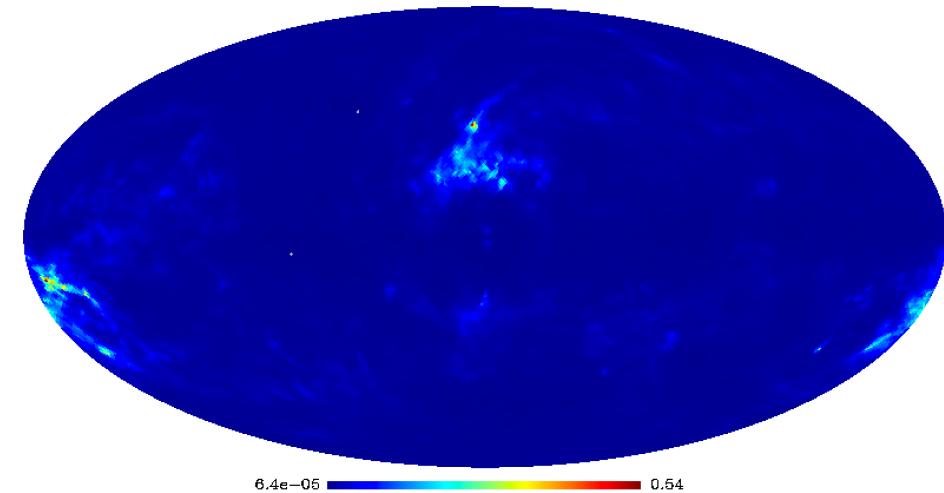
Green GHz, shell 4



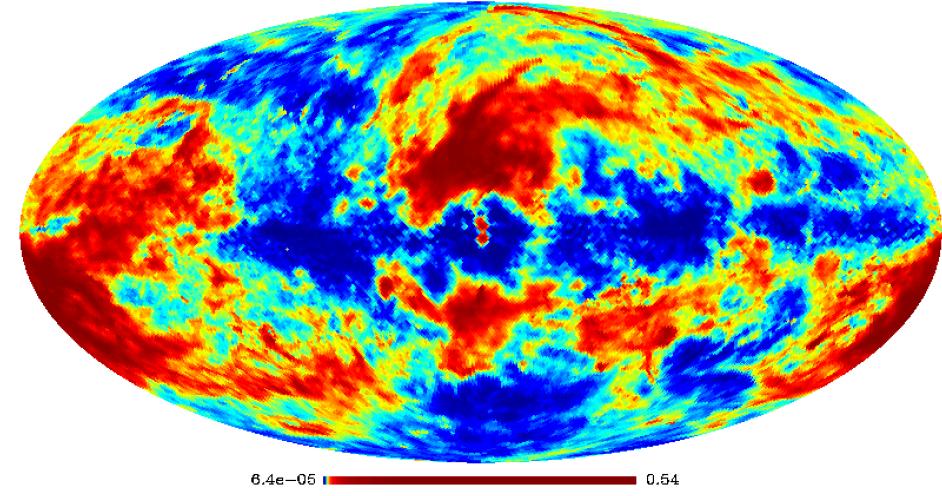
Full sky extinction maps

- The hole is filled using Planck + **symmetry** in the maps.

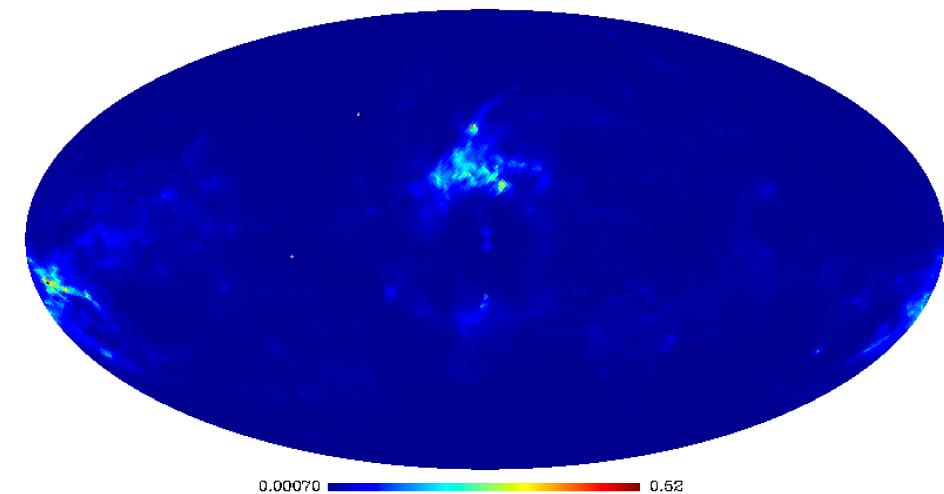
shell 1: 0.0 - 0.5 kpc



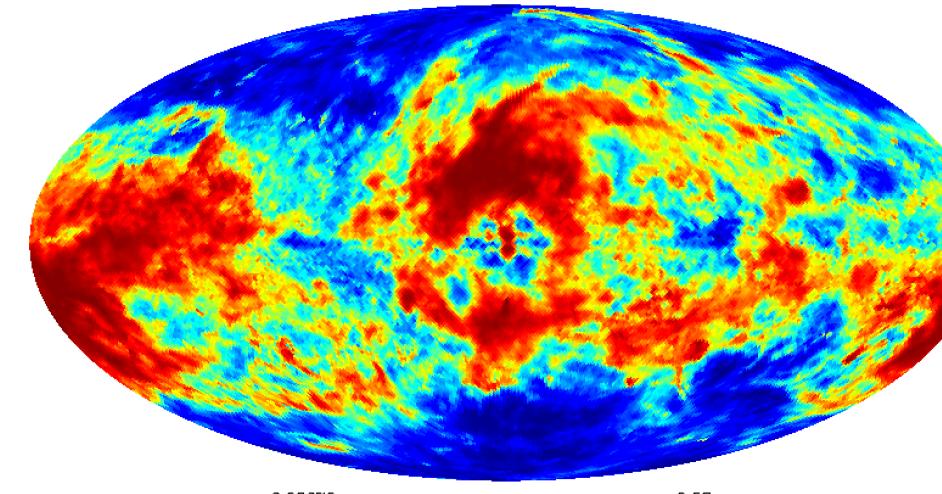
shell 1: 0.0 - 0.5 kpc



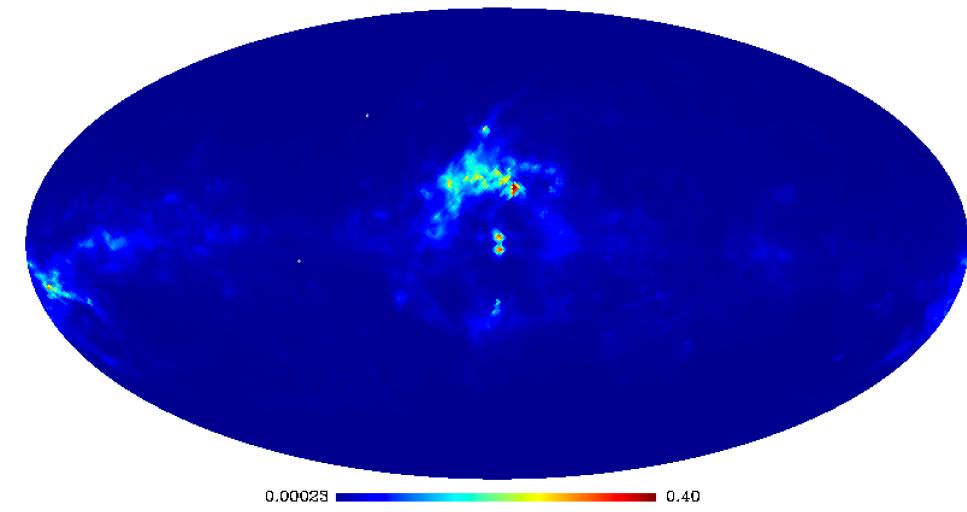
shell 2: 0.5 - 1.5 kpc



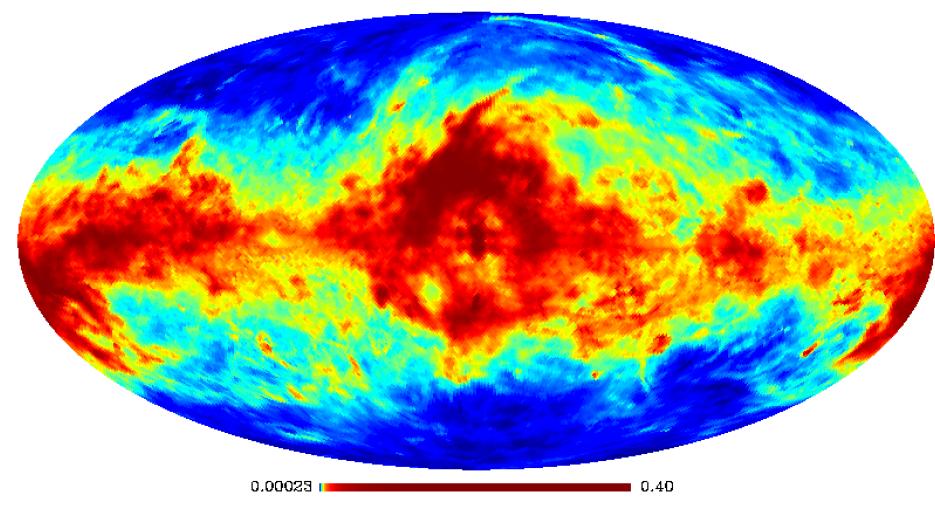
shell 2: 0.5 - 1.5 kpc



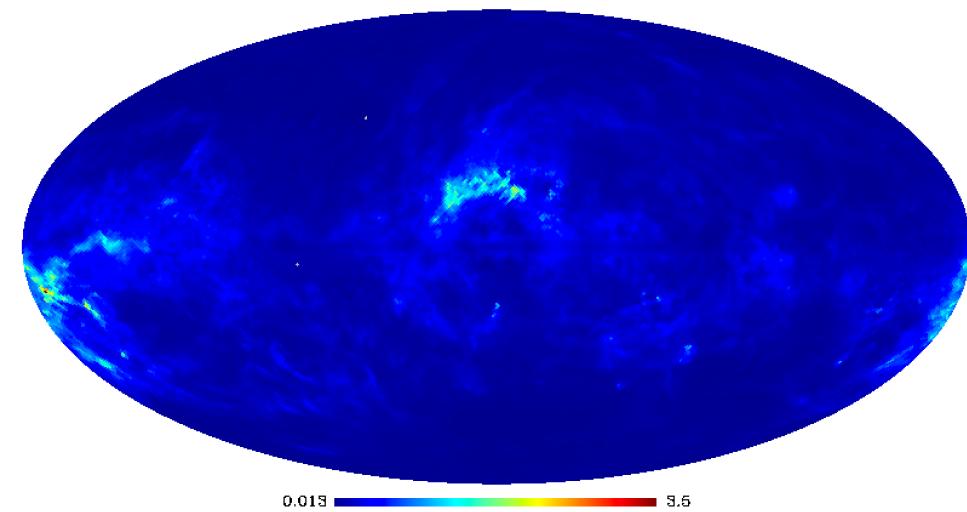
shell 3: 1.5 – 4.0 kpc



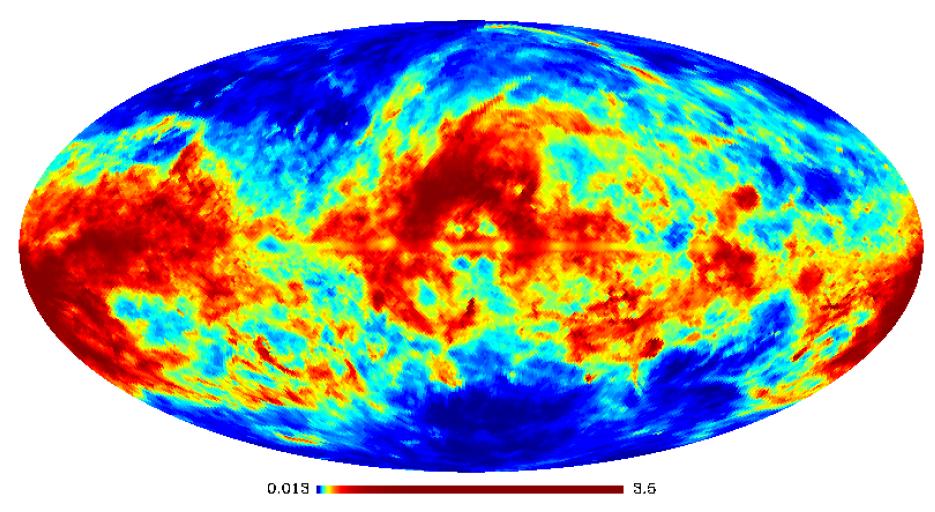
shell 3: 1.5 – 4.0 kpc



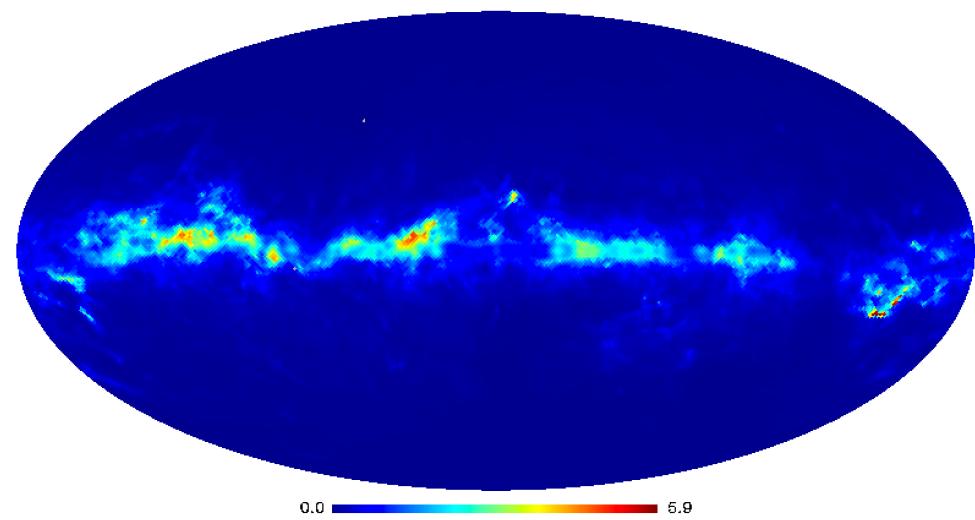
shell 4: 4.0 – 7.0 kpc



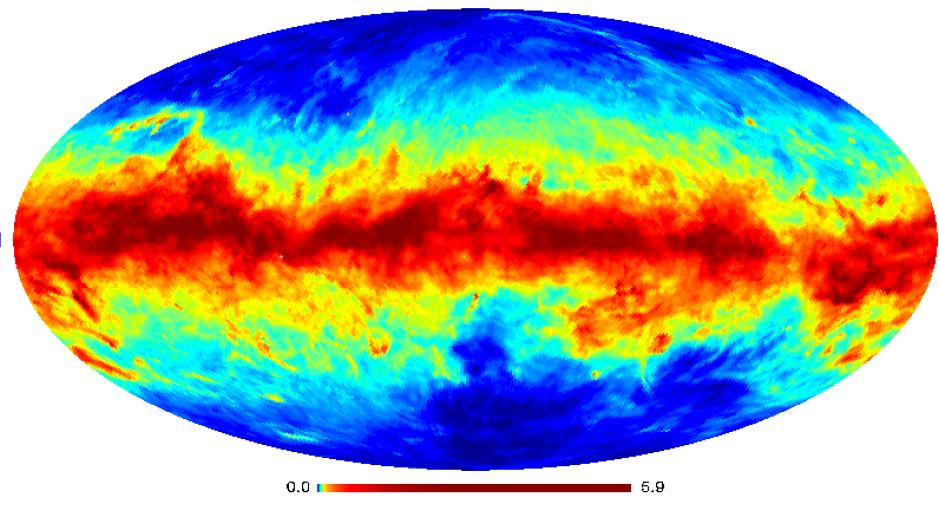
shell 4: 4.0 – 7.0 kpc



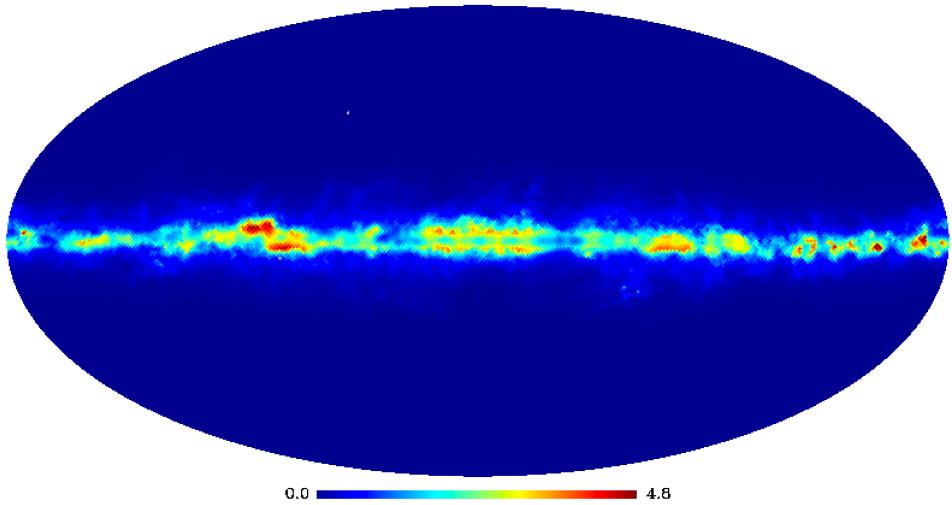
shell 6: 7.0 – 10.0 kpc



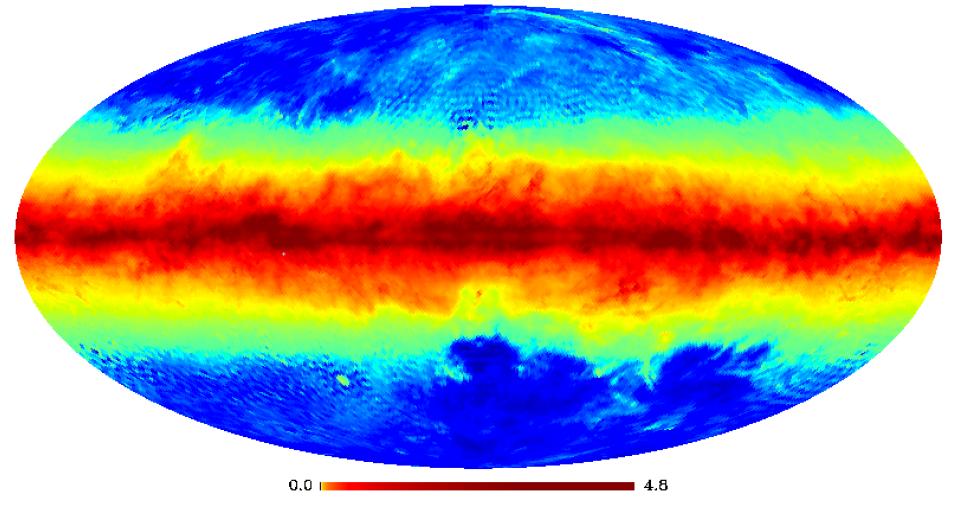
shell 6: 7.0 – 10.0 kpc



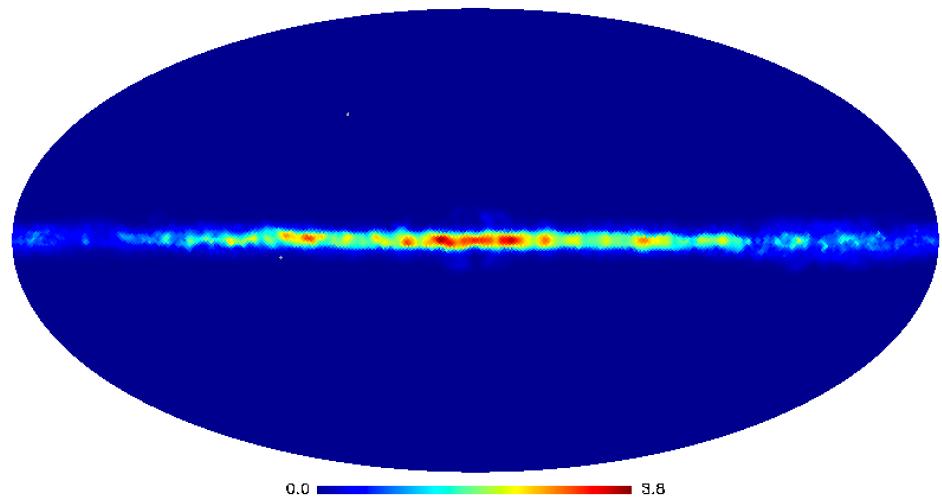
shell 6: 10.0 – 13.0 kpc



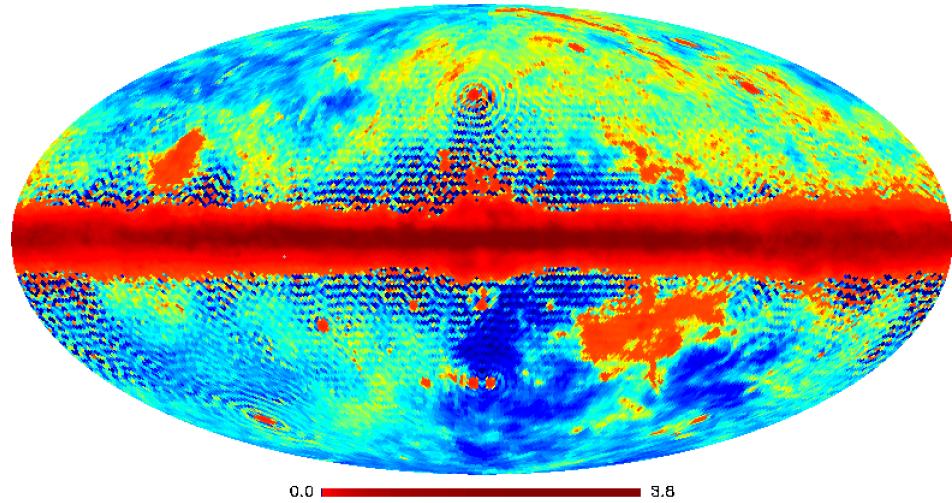
shell 6: 10.0 – 13.0 kpc



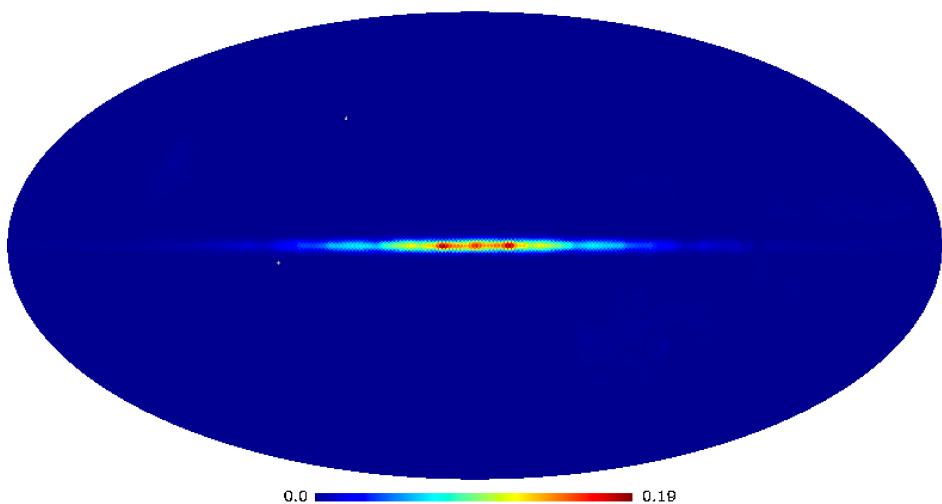
shell 8: 13.0 – 16.0 kpc



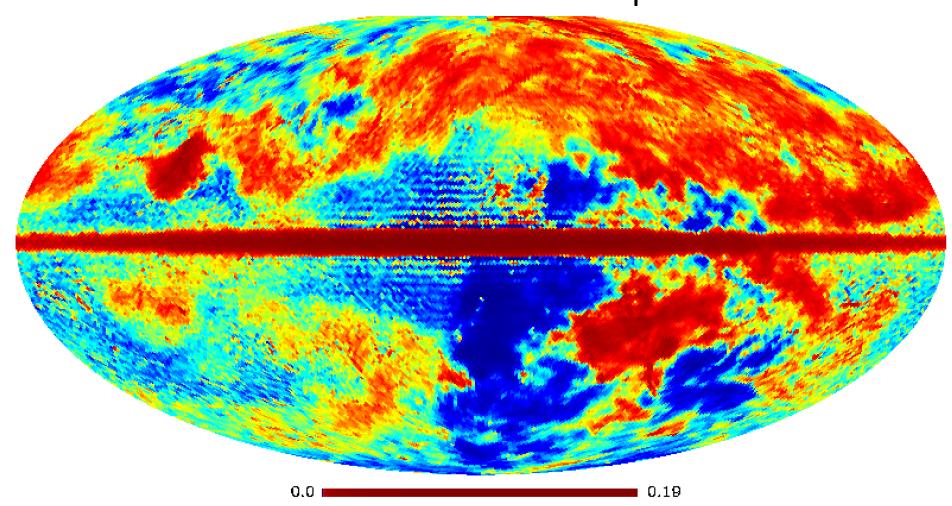
shell 8: 13.0 – 16.0 kpc



shell 8: 16.0 – 19.0 kpc



shell 8: 16.0 – 19.0 kpc



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Summary

- The PSM is in a quick development phase for generating simulations for COrE (and other experiments: CMB-S4, LiteBIRD, etc ...).
- A tool for the CMB community, but person-power limited
- NEW features since "pre-launch" model
 - New templates for galactic temperature and polarisation
 - Several emission laws for synchrotron and dust
 - Polarised spinning dust
 - New random galactic emission + development of 3D galaxy
 - New CMB x CIB x Lensing (x SZ), dust contamination in clusters
- Send-in your wish-list, give a hand if you can, and stay tuned !