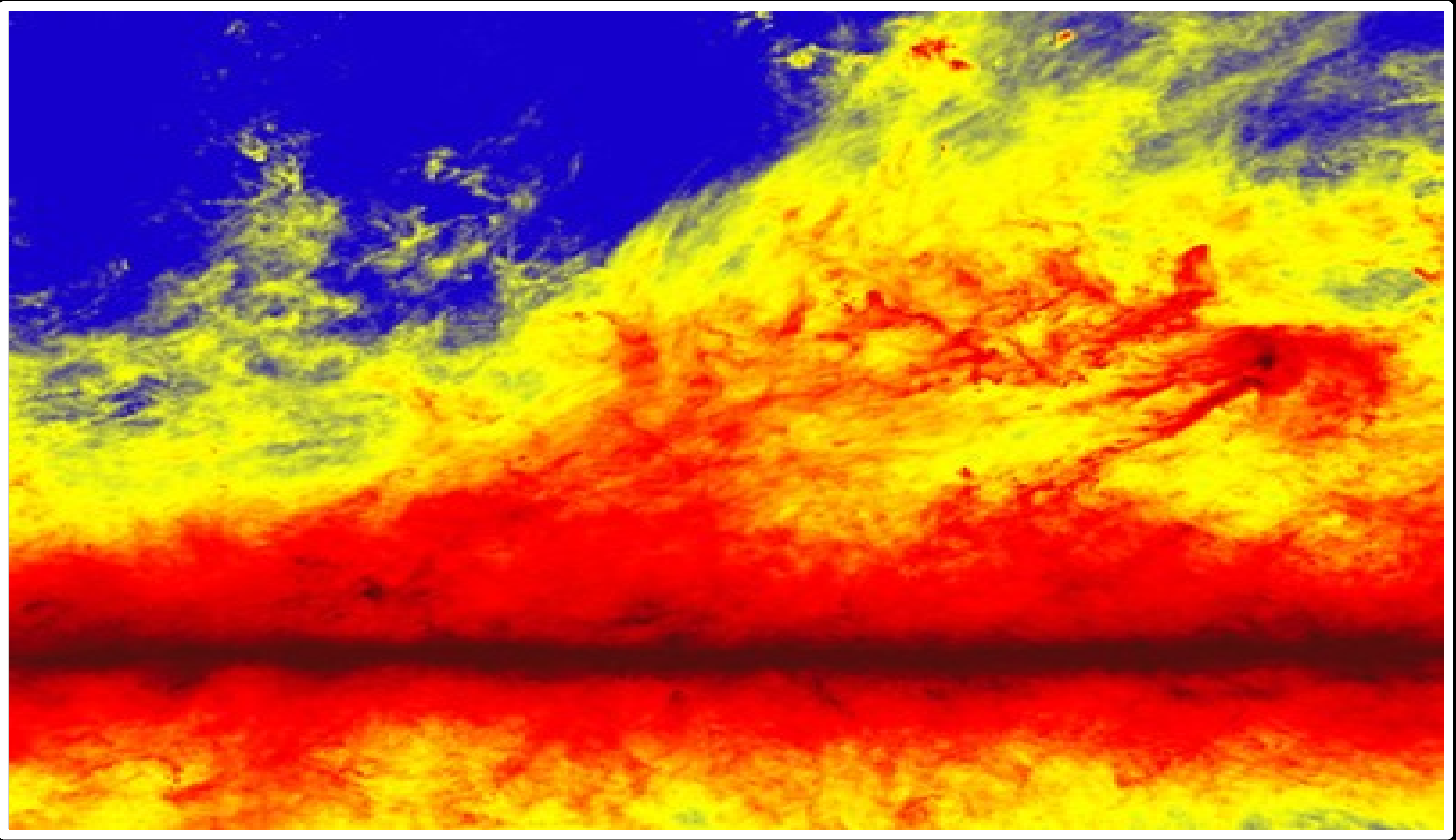
Characterization of CMB Foregrounds



Tuhin Ghosh (IUCAA)

17th of December, 2010

PFNG Meeting, HRI

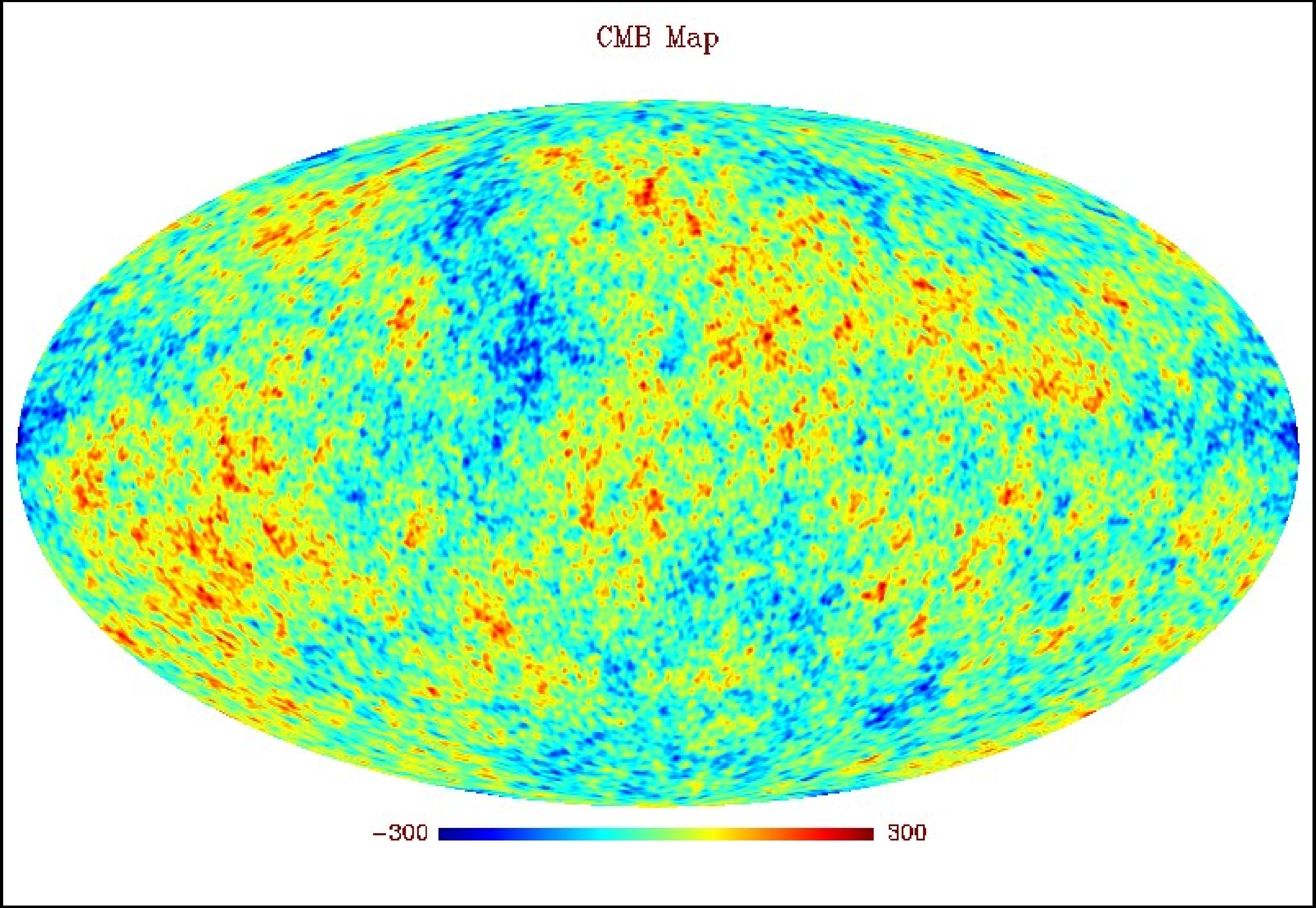
CMB Foregrounds

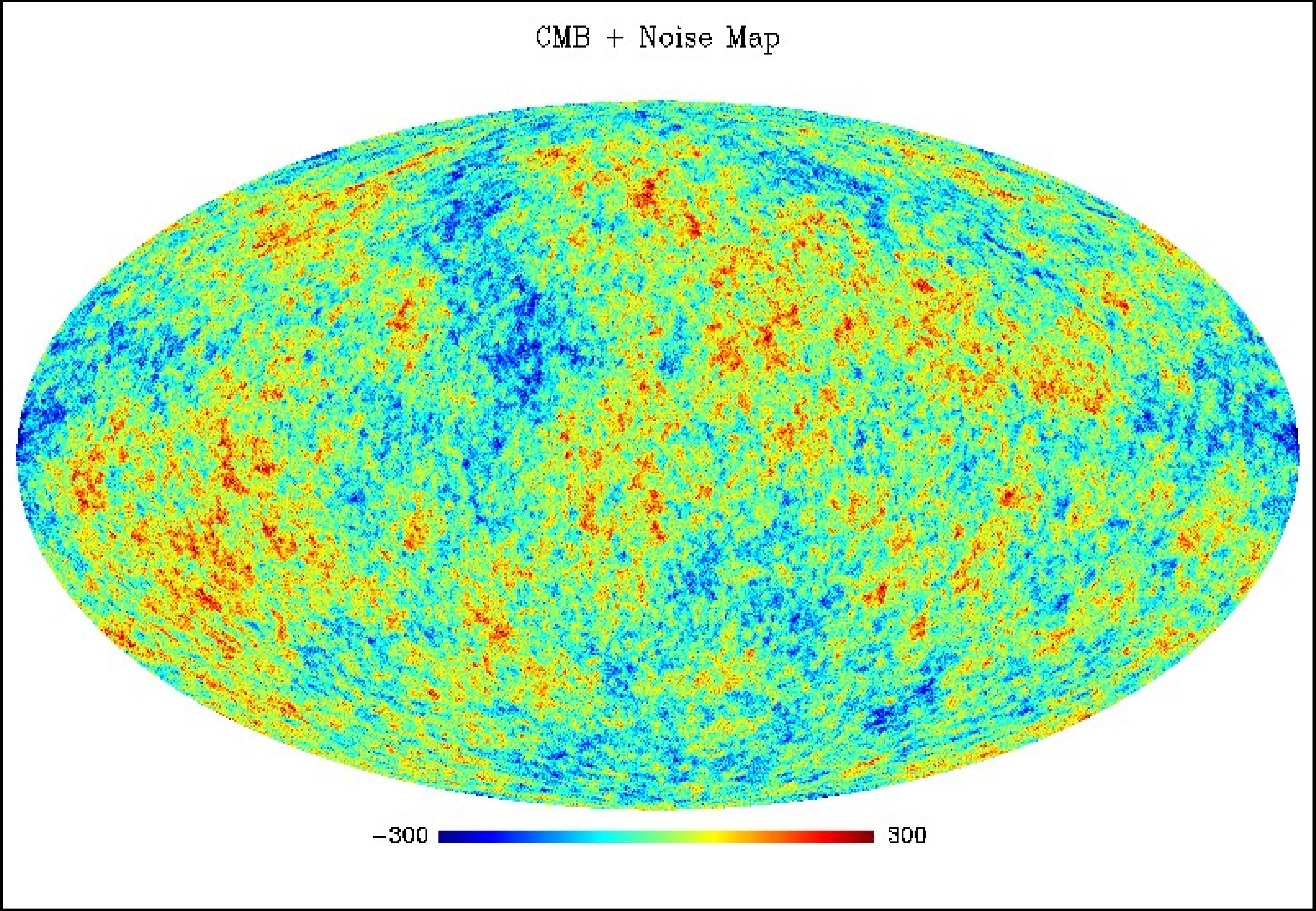
Can galactic foregrounds leaves **Non-Gaussian** signatures in the reconstructed CMB map ?

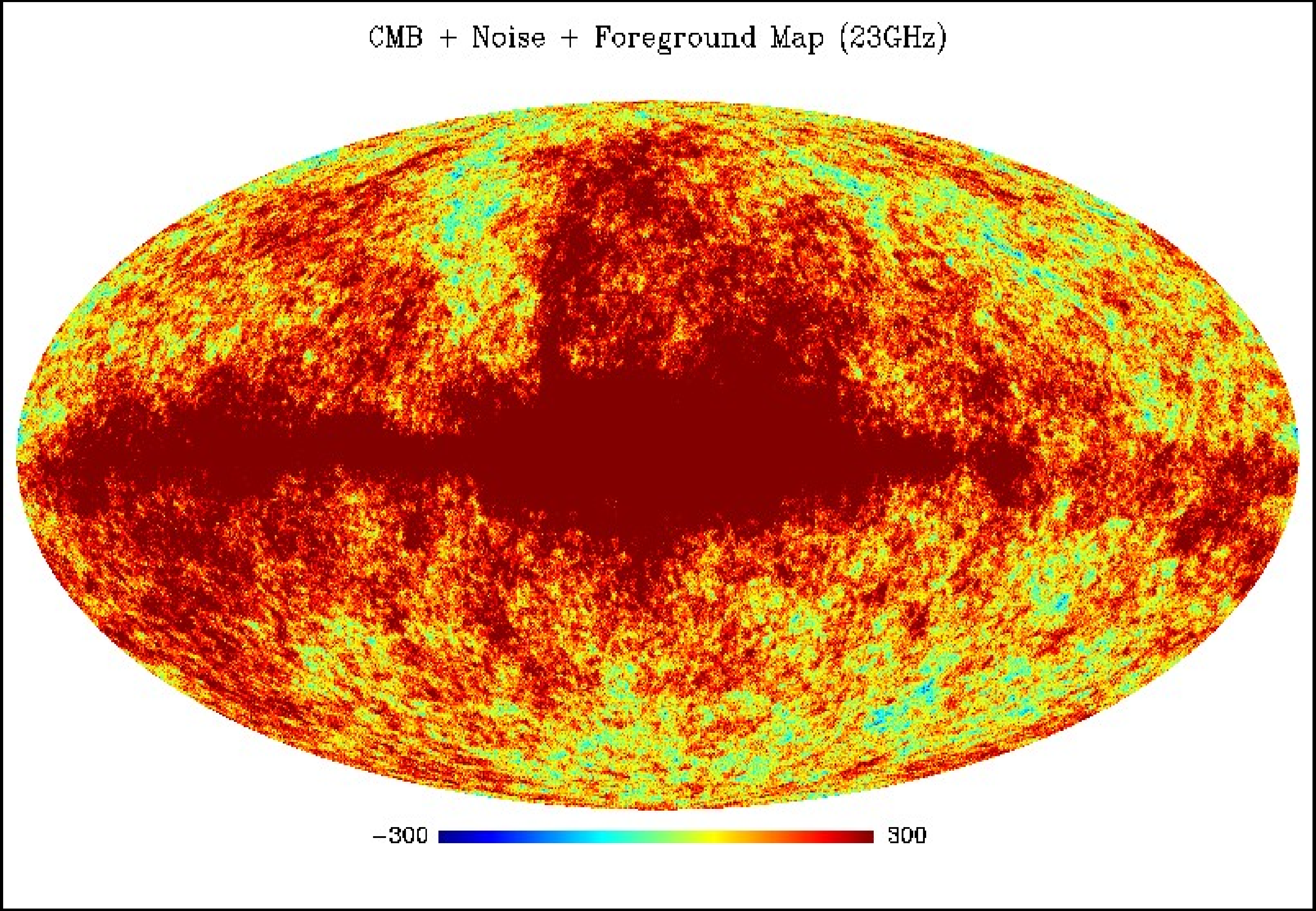
We need to understand the following properties of foregrounds:

1) Spectral characteristics of foregrounds

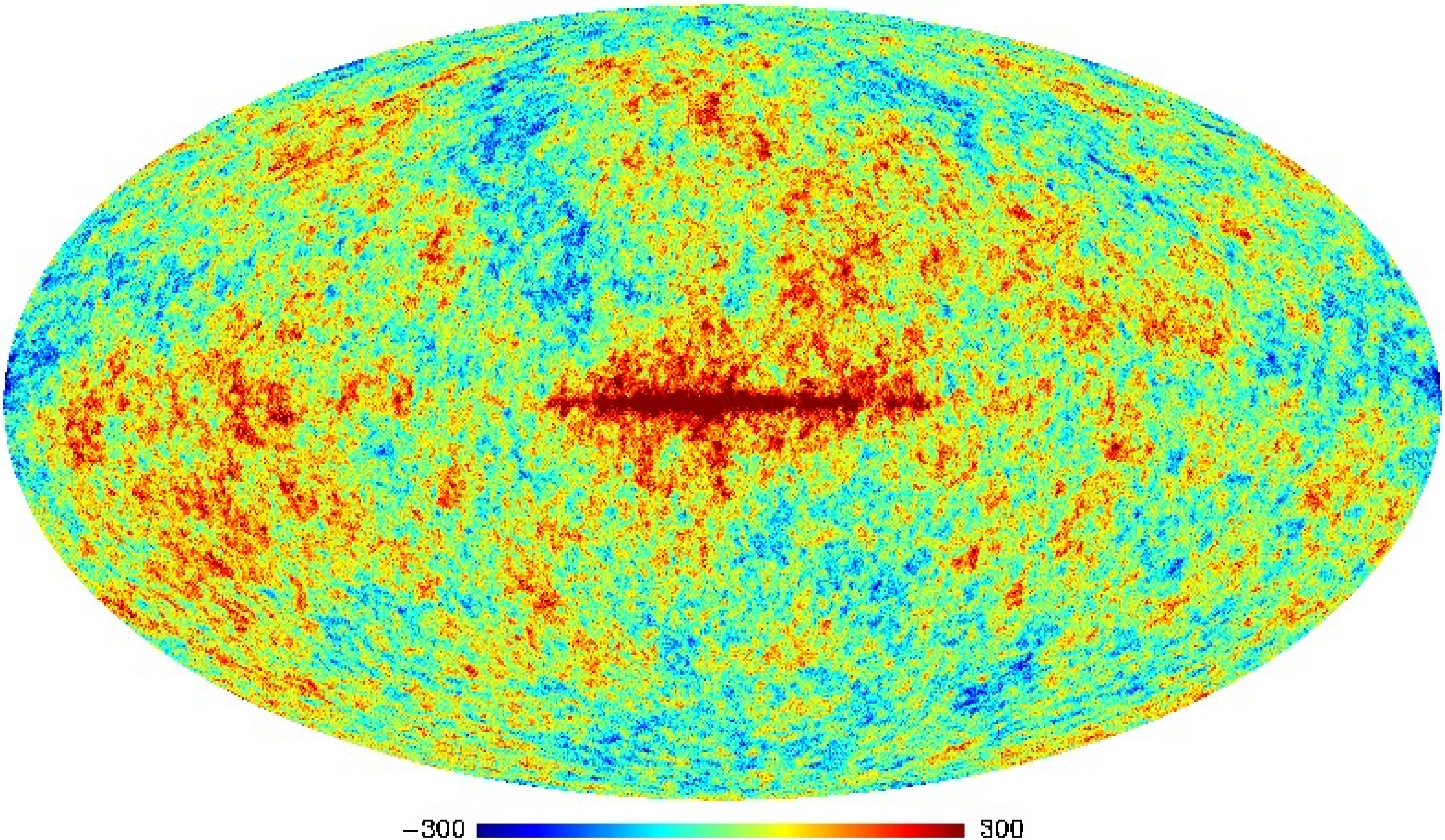
2) Foreground statistics >> non-gaussian signal


CMB Map
−300
300

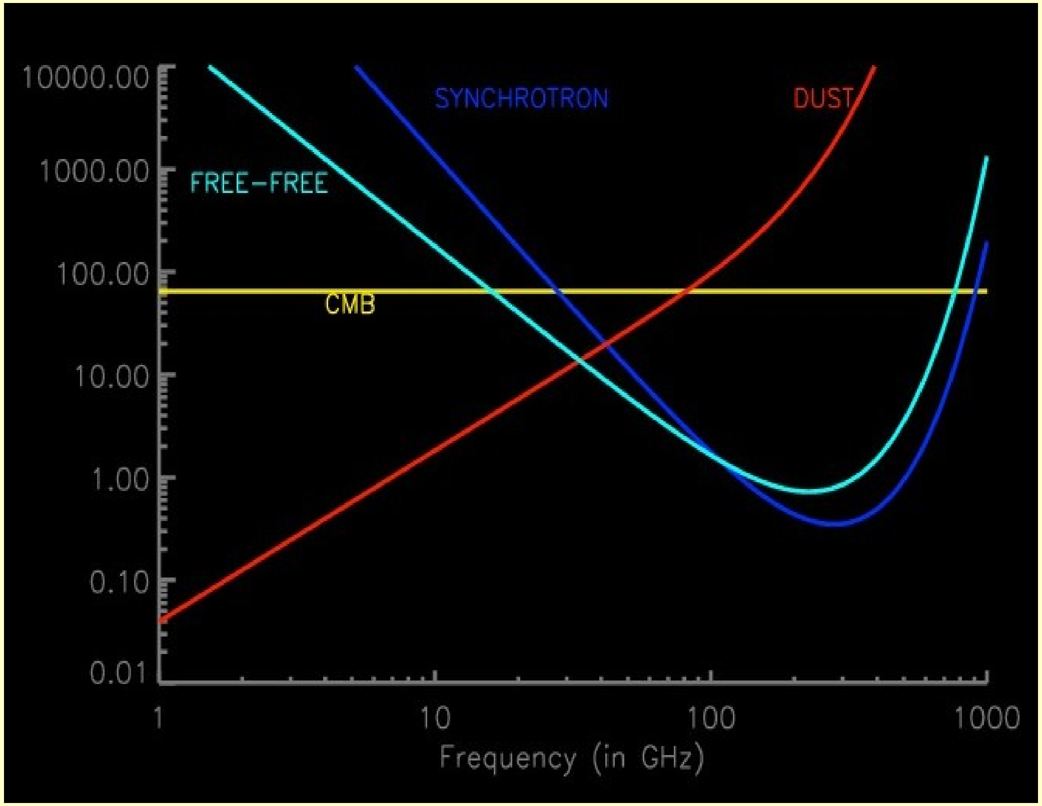

CMB + Noise Map
−300
300

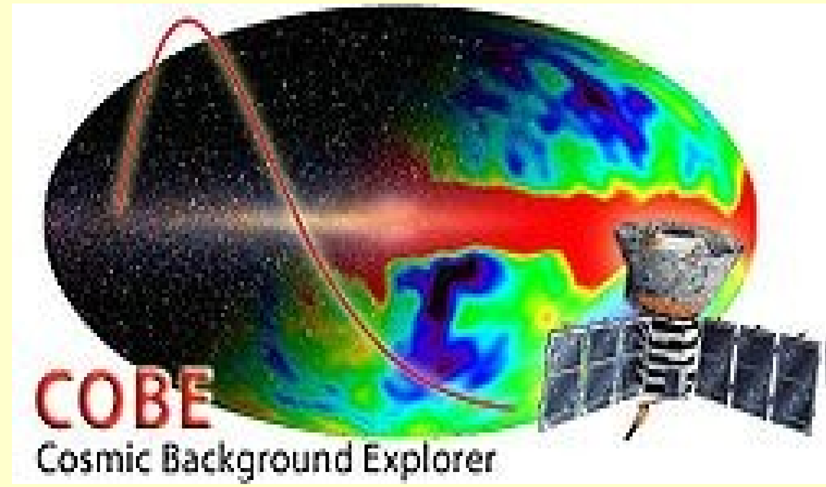

CMB + Noise + Foreground Map (23GHz)
−300
300

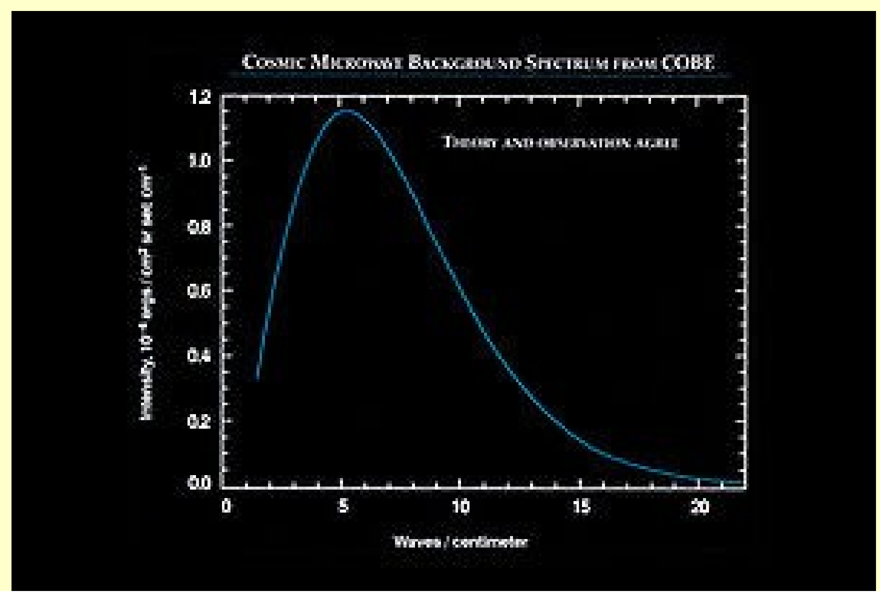
CMB + Noise + Foreground Map (41GHz)



CMB anisotropy signal is frequency independent

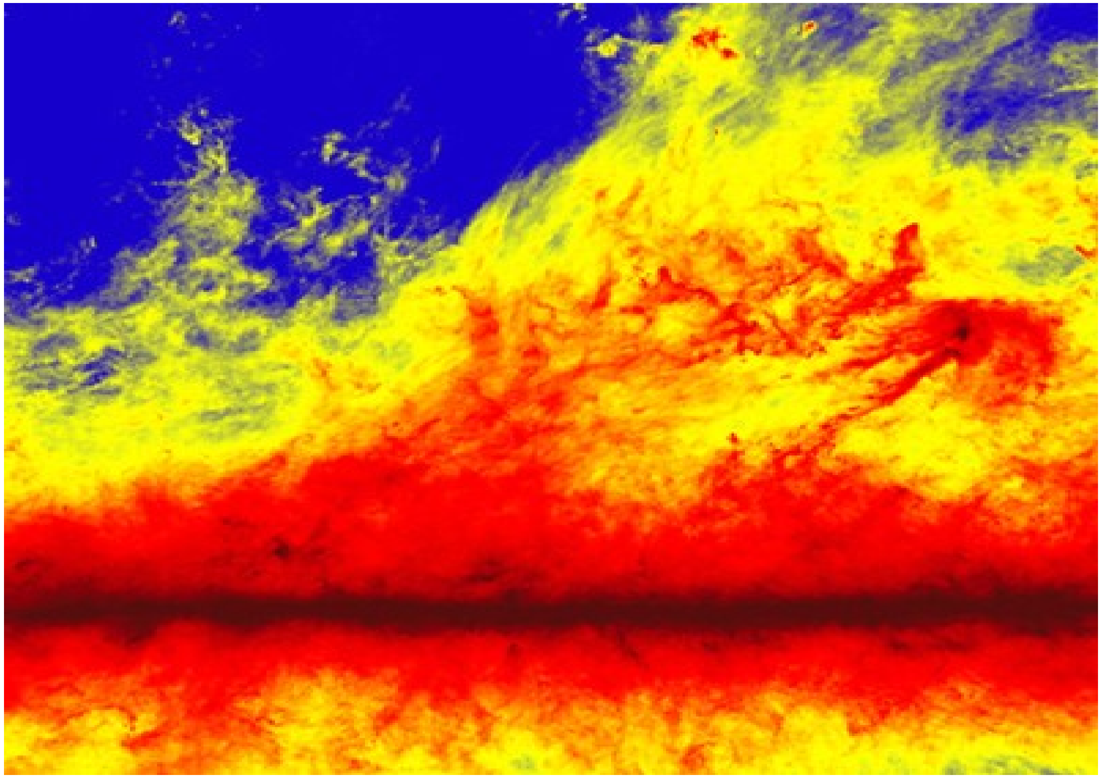






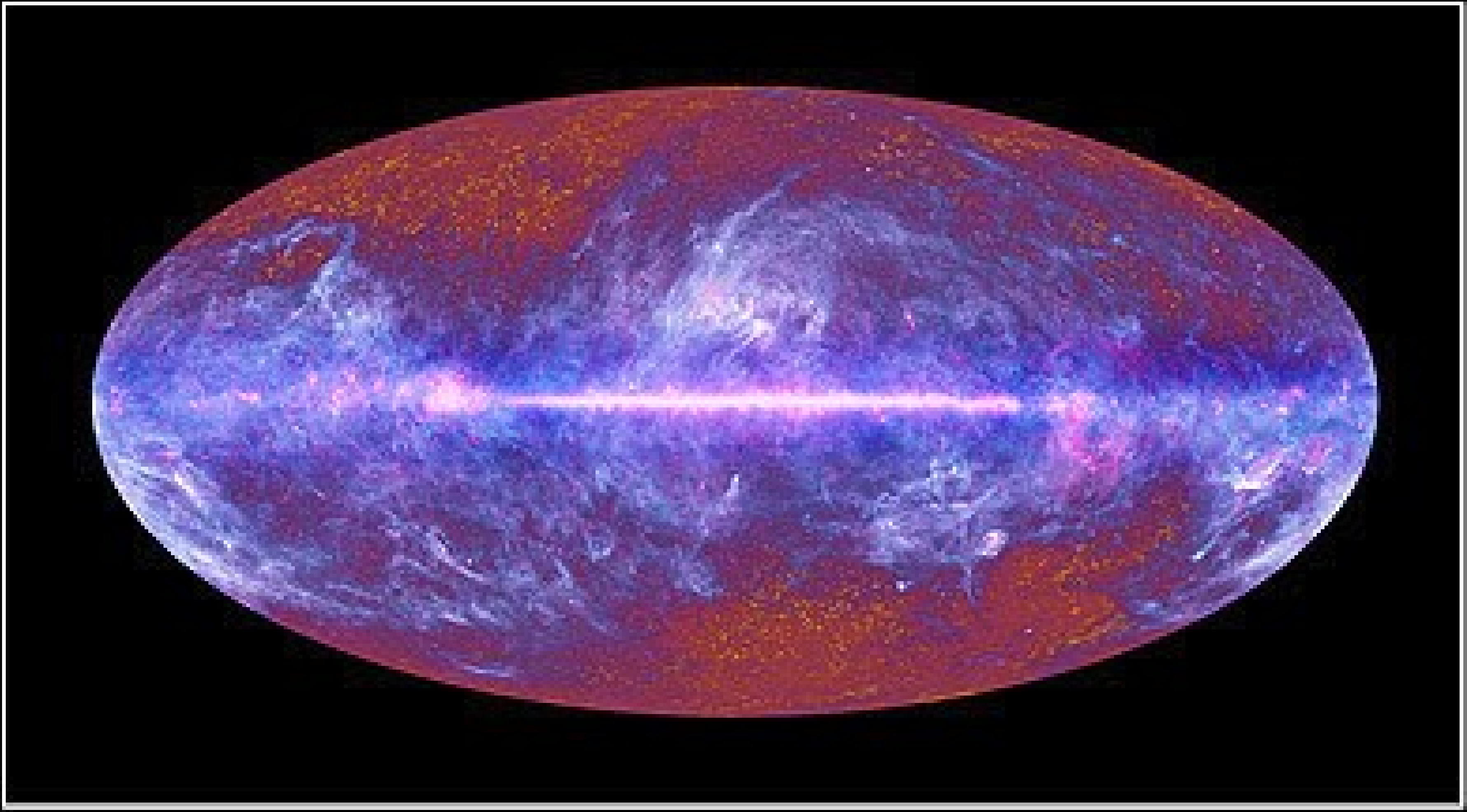
Thermodynamic temperature versus frequency

CMB Foregrounds



Non-Gaussian and Non-Stationary Signal

[1] T. Ghosh, S. Prunet, J.F. Cardoso and T. Souradeep



The Planck one-year all-sky survey

Spectral Characterization of CMB Foreground

Study of Galactic Physics using CMB

Cross-correlation Analysis:

We assume that different regions of the sky can be locally decomposed into four components which are dust, free-free, synchrotron and monopole term. The idea is to minimize the chi-square using one template for each of the component and calculate the fit coefficients. In simple terms,

$$\boxed{\chi^2 = \sum_{i,p} \frac{(T(\nu_i, p) - b_1(\nu_i)T_H - b_2(\nu_i)I_F - b_3(\nu_i)M_d)^2}{\sigma_i^2}}$$

The above relation is not in general true for various reasons which are **masking issues**, need to take into account **CMB**, **beam issues**.

[1] Bennet et al., WMAP 1st Year Papers
[2] Hinshaw et al., WMAP 3rd Year Papers

Template Fitting

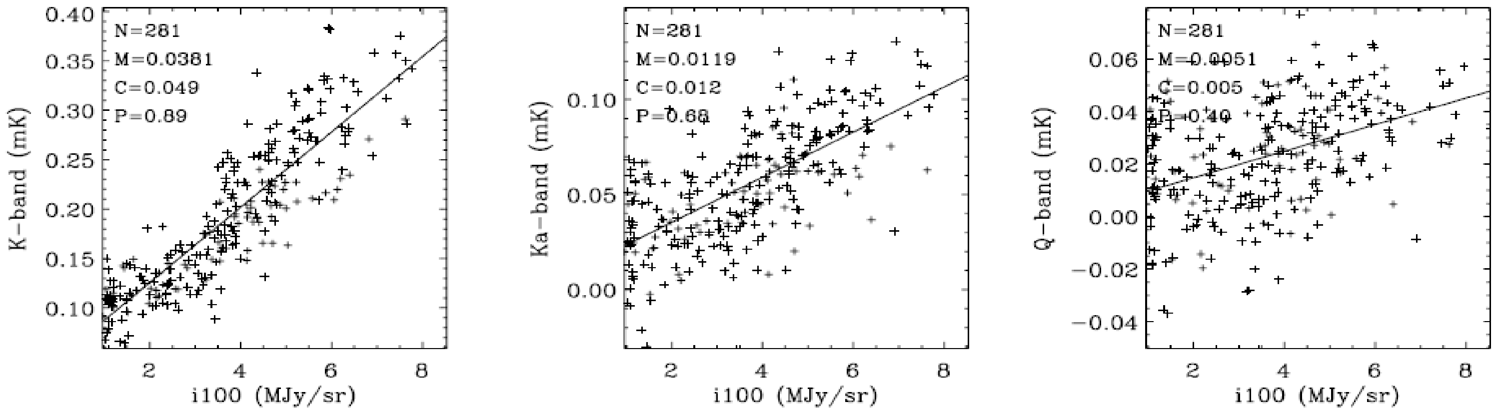
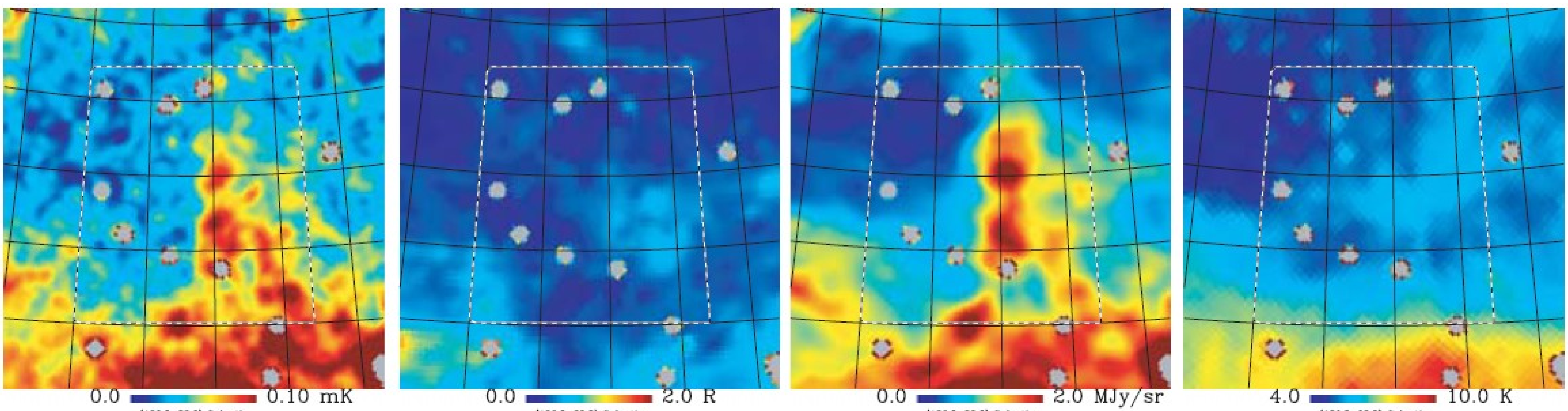


Figure 1. T–T plots for region 6 (middle row of Fig. 3) clearly showing the *WMAP* dust-correlated emission at K, Ka and Q bands against the 100-μm SFD98 map. The best-fitting line is plotted along with the number of pixels N, the y-intercept C, slope M and Pearson correlation coefficient P.

Cross-correlation Analysis

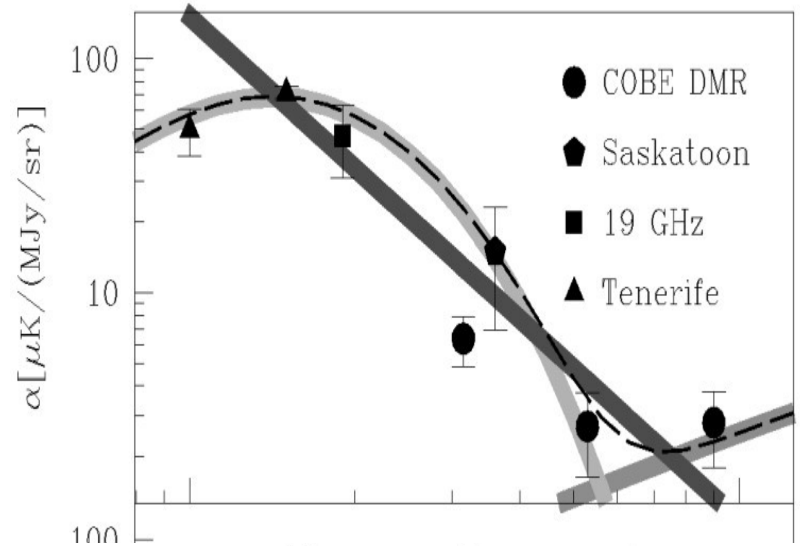
WMAP K Band | free-free | Dust | Synchrotron

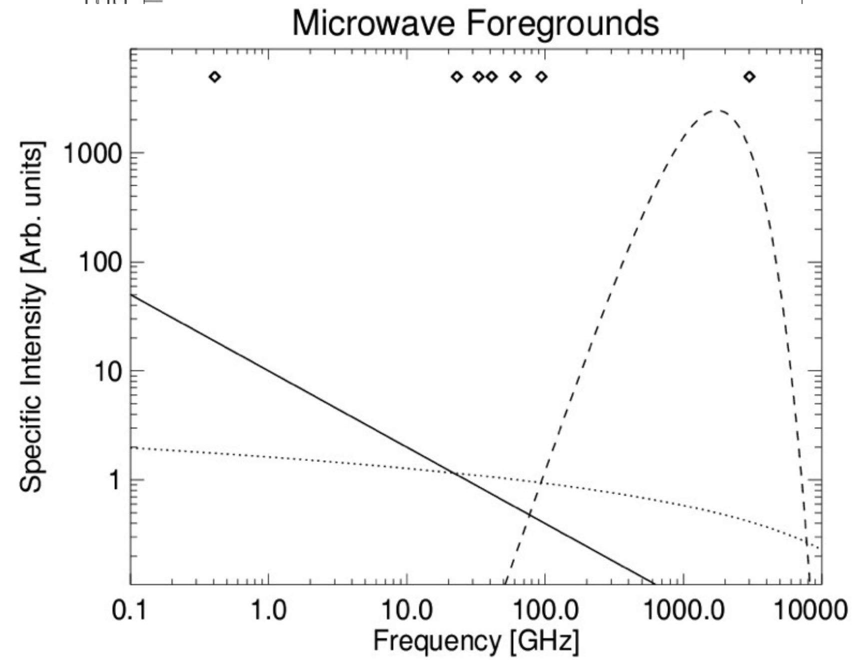


[1] Davies et al. , 2005, astro-ph/0511384

WMAP-1 Results

Band	Dust:FDS (rel to FDS)	Free-Free:Hα (μK/R)	Synchrotron:Haslam (μK/K)
23 GHz K	6.3	4.6	5.6
Ka	2.4	2.1	1.5
Q1	1.5	1.3	0.5
Q2	1.4	1.3	0.5
V1	0.9	0.5	-0.2
V2	0.9	0.4	-0.2
W1	1.2	0.1	-0.3
94 GHz W2	1.2	0.1	-0.4
W3	1.2	0.1	-0.3
W4	1.1	0.1	-0.3





First evidence of dust correlated spinning dust emission.

[1] Bennet et al., WMAP 1st Year Papers
[2] Oliveira de Costa et al., ApJ, 527 (1999)

Cross Correlation Analysis in case of correlated errorbars:

Let **d** be the data vector and **t** is the template vector. Then chi-square is given by,

$$\chi^2 = (\mathbf{d} - \alpha\mathbf{t})^{\mathbf{T}} \mathbf{M}_{\mathbf{SN}}^{-1} (\mathbf{d} - \alpha\mathbf{t})$$

General Expression

Using cholesky decomposition, we get

$$\chi^2 = (\mathbf{d} - \alpha\mathbf{t})^{\mathbf{T}} (\mathbf{L}\mathbf{L}^{\mathbf{T}})^{-\mathbf{1}} (\mathbf{d} - \alpha\mathbf{t})$$

In case of diagonal approximation, it reduces to simple chi-square,

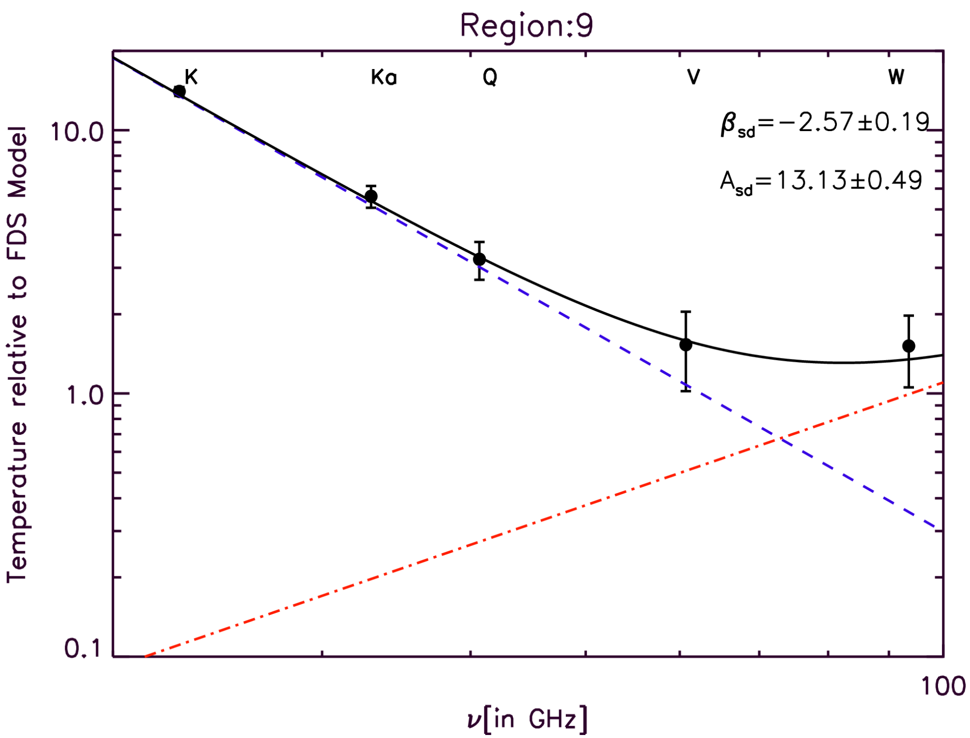
$$\chi^2 = \left(\frac{\mathbf{d} - \alpha\mathbf{t}}{\sigma}\right)^2$$

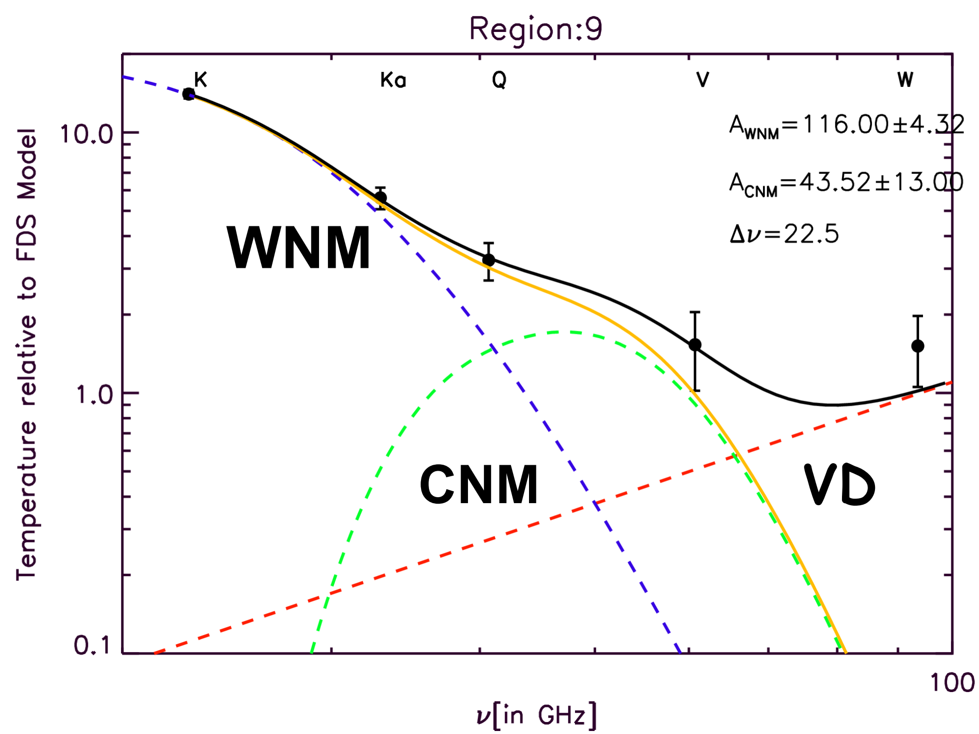
Minimization of chi-square gives,

$$\alpha = \frac{t^T M_{SN}^{-1} d}{t^T M_{SN}^{-1} t}$$

[1] Davies et al. , 2005, astro-ph/0511384

Constraint the dust correlated spinning dust emission





WNM : Warm Neutral Medium
CNM : Cold Neutral Medium

Even with WMAP data, we put constraint on the spinning dust models and get the idea of ratio of different spinning dust components.

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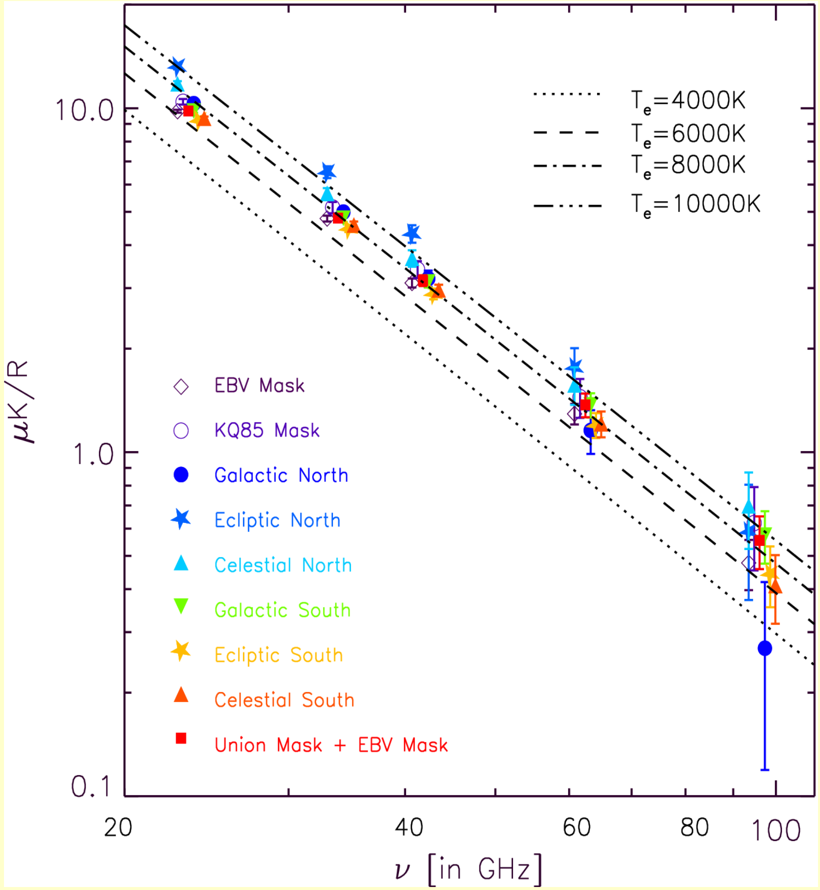
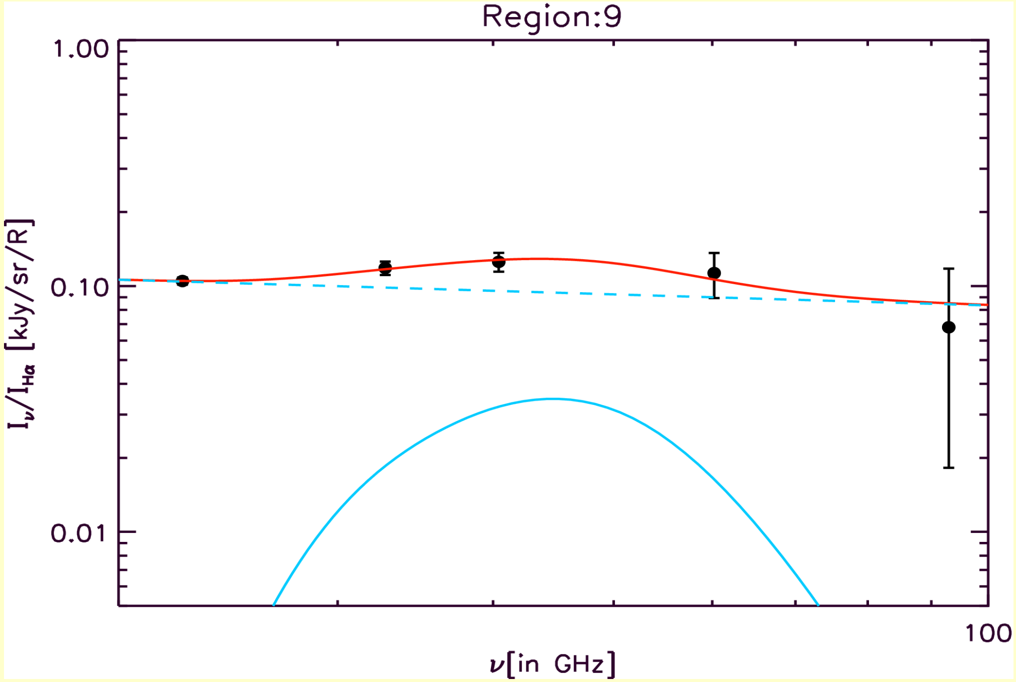
[1] Ali Hamoud et al. , 2008, astro-ph/0812.2904
[2] Draine and Lazarian, 1998 papers
[3] Ysard et al. 2009, astro-ph/0906.3360

Free-free fit coefficients

Can be used to study the free-free electron temperature.

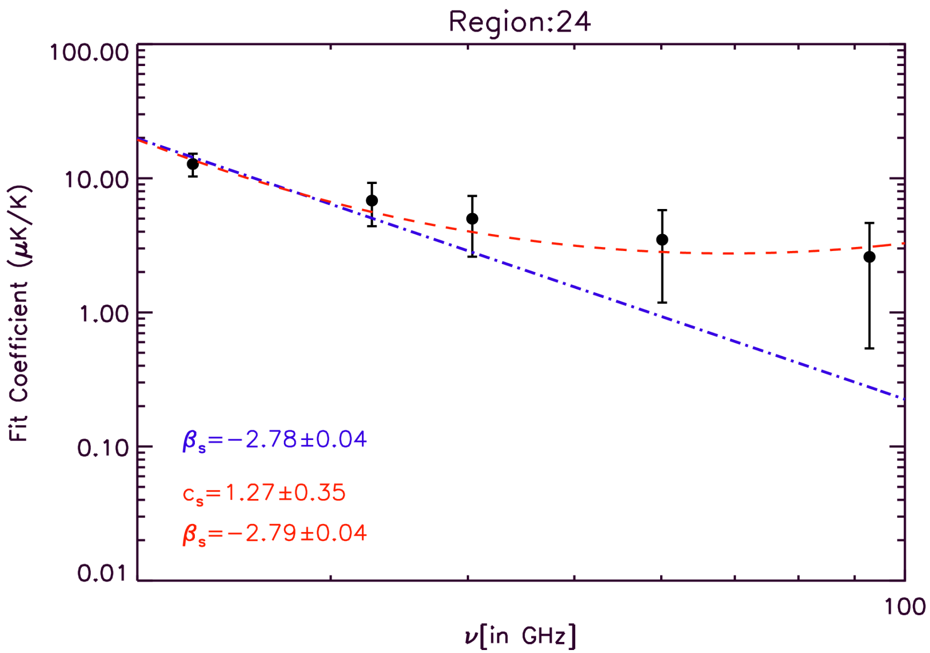


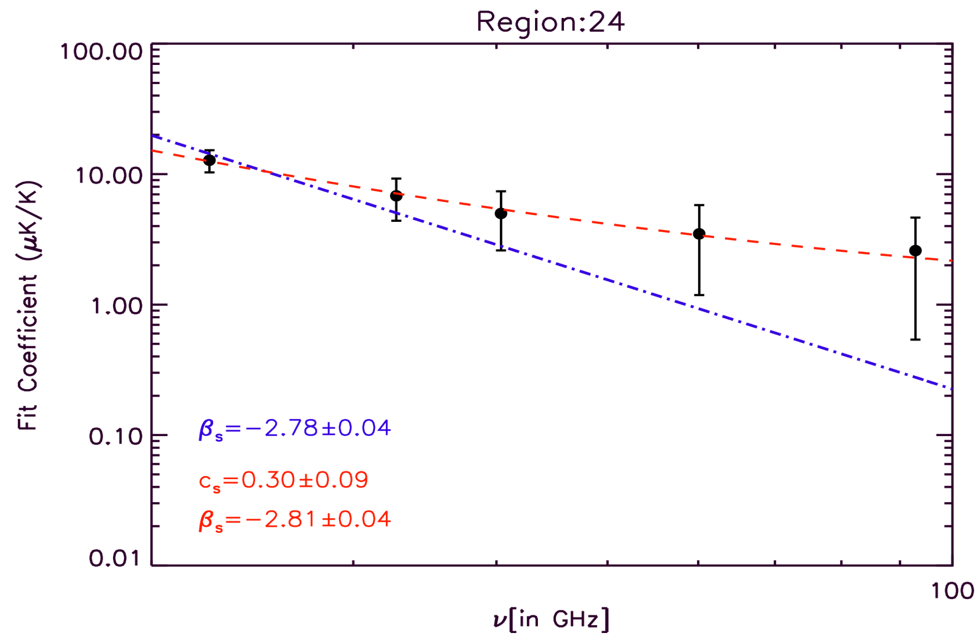


Important to find the regions of Ha correlated spinning dust emission (WIM). Important to find the ratio between free-free intensity and spinning dust at peak frequency.

[1] Dickinson et al. , 2003, astro-ph/0302024

Synchrotron Fit Coefficients





$$A_s \times \left(\frac{\nu}{23.}\right)^{\beta_s} \qquad \nu < \nu_K$$

$$A_s \times \left(\frac{\nu}{23.}\right)^{\beta_s + c_s ln(\frac{\nu}{\nu_K})} \qquad \nu < \nu_K$$

Gold et. al. Model of Synchrotron

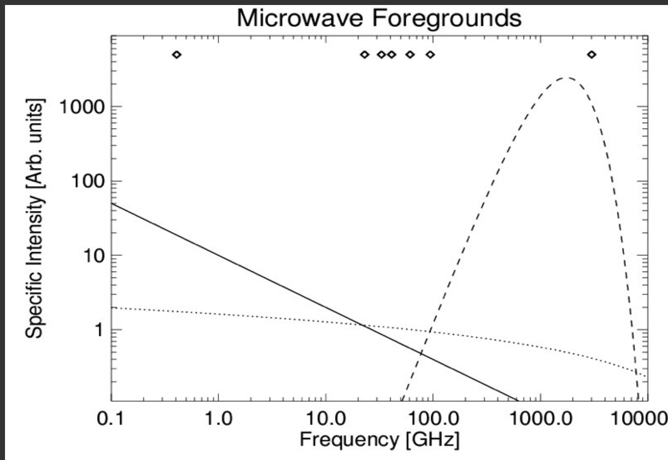
$$F(\nu) = A_s \times \left(\frac{\nu}{23.}\right)^{\beta_s + c_s ln(\frac{\nu}{\nu_K})}$$

General Model of Synchrotron

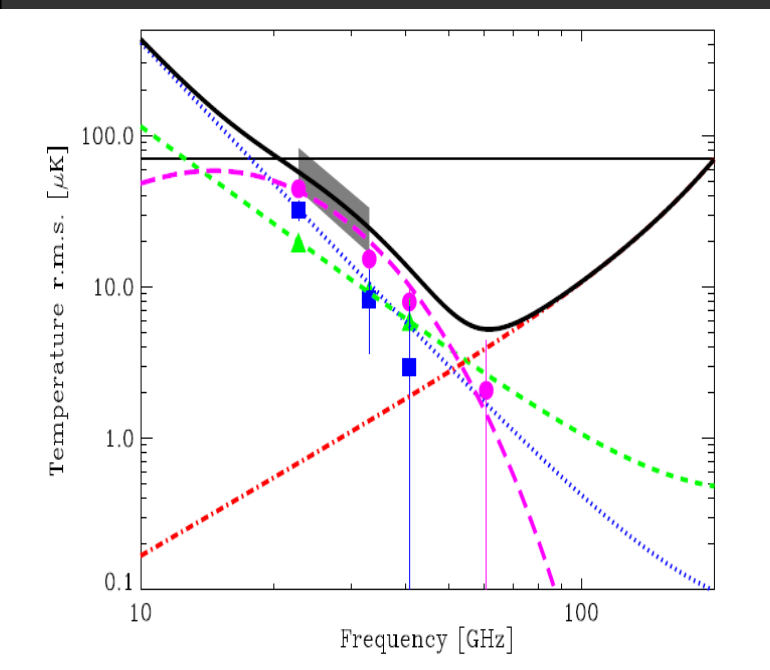
Can distinguish between different models of synchrotron by measuring chi-square value.

[1] Gold et al. , 2010, WMAP 7yr paper

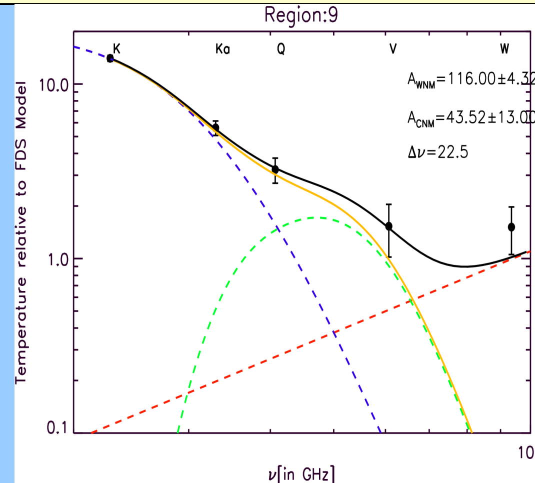
Modelling of Galactic Foregrounds



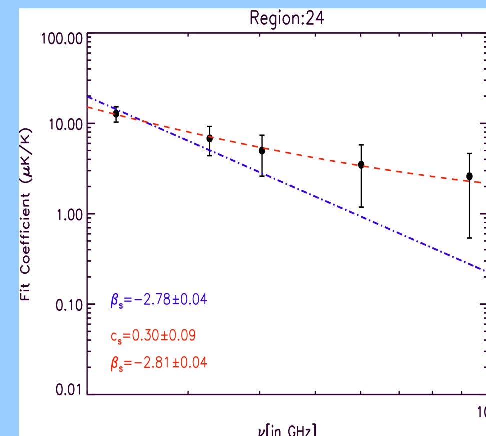
Early 2000

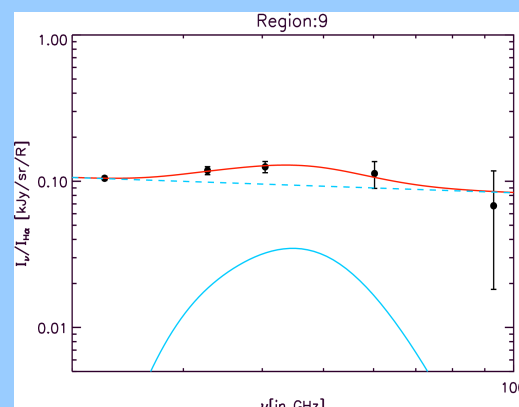


2006 Models



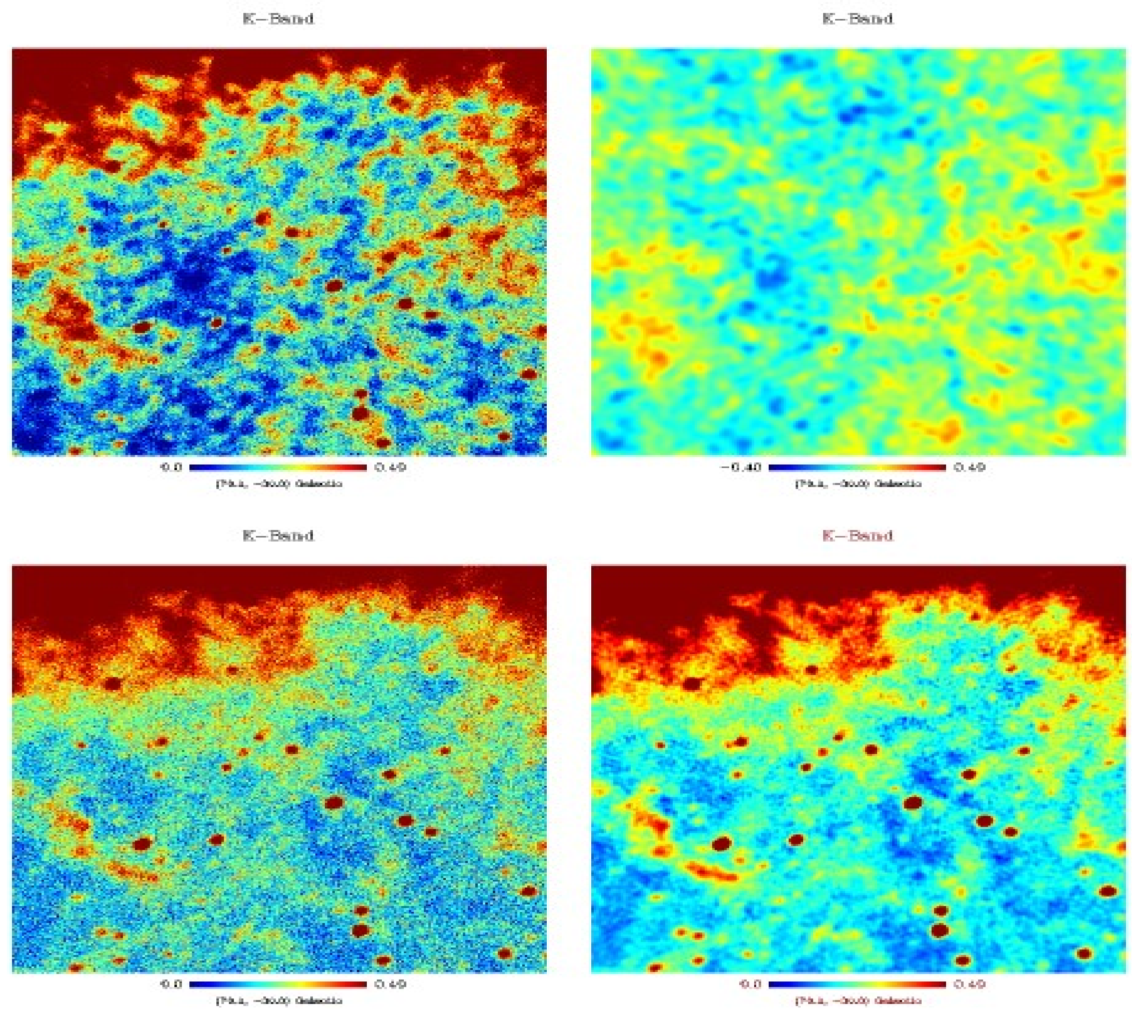
Data supports general curvature synchrotron model





Current Understanding (2010)

Towards Getting Foreground Maps at WMAP Frequency Bands



[1] T. Ghosh, J. Delabrouille, M. Remazeilles, J.F. Cardoso and T. Souradeep, astro-ph/1006.0916

Summary

1) Using current WMAP data, we can improve our understanding about the various galactic components.

2) Foregrounds are non-gaussian and non-stationary signal and in needlet space follows the Student t-distribution function.