Galactic Emission Components

Francois Boulanger, Jean-Philippe Bernard (CESR), Marc-Antoine Miville-Deschênes and Nicolas Ponthieu

Institut d’Astrophysique Spatiale, Orsay

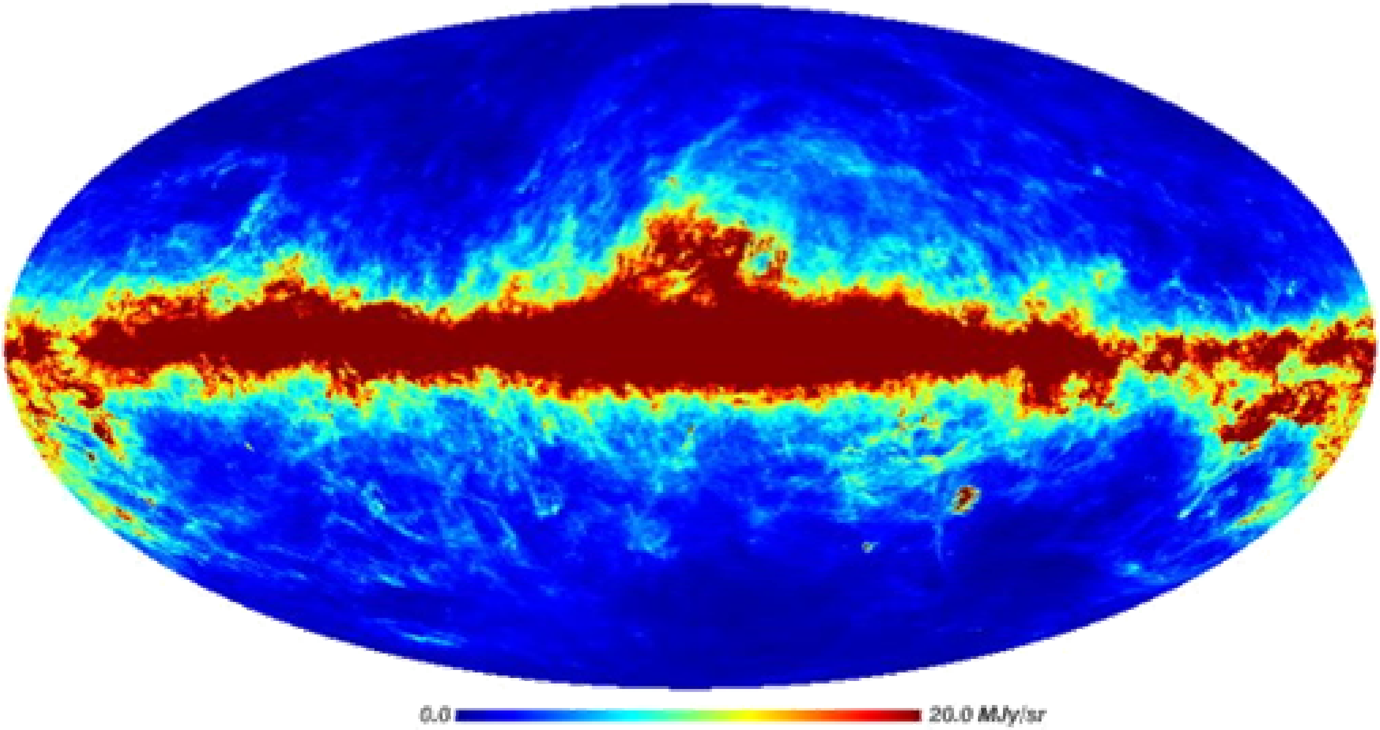
Outline

- Components (www.cesr.fr/~bernard/PSM, Bernard and Miville Deschenes)
  - Thermal Dust
  - Free-free
  - Synchrotron / spinning dust
- Non-Gaussianity
- Polarization

Submm/mm dust model

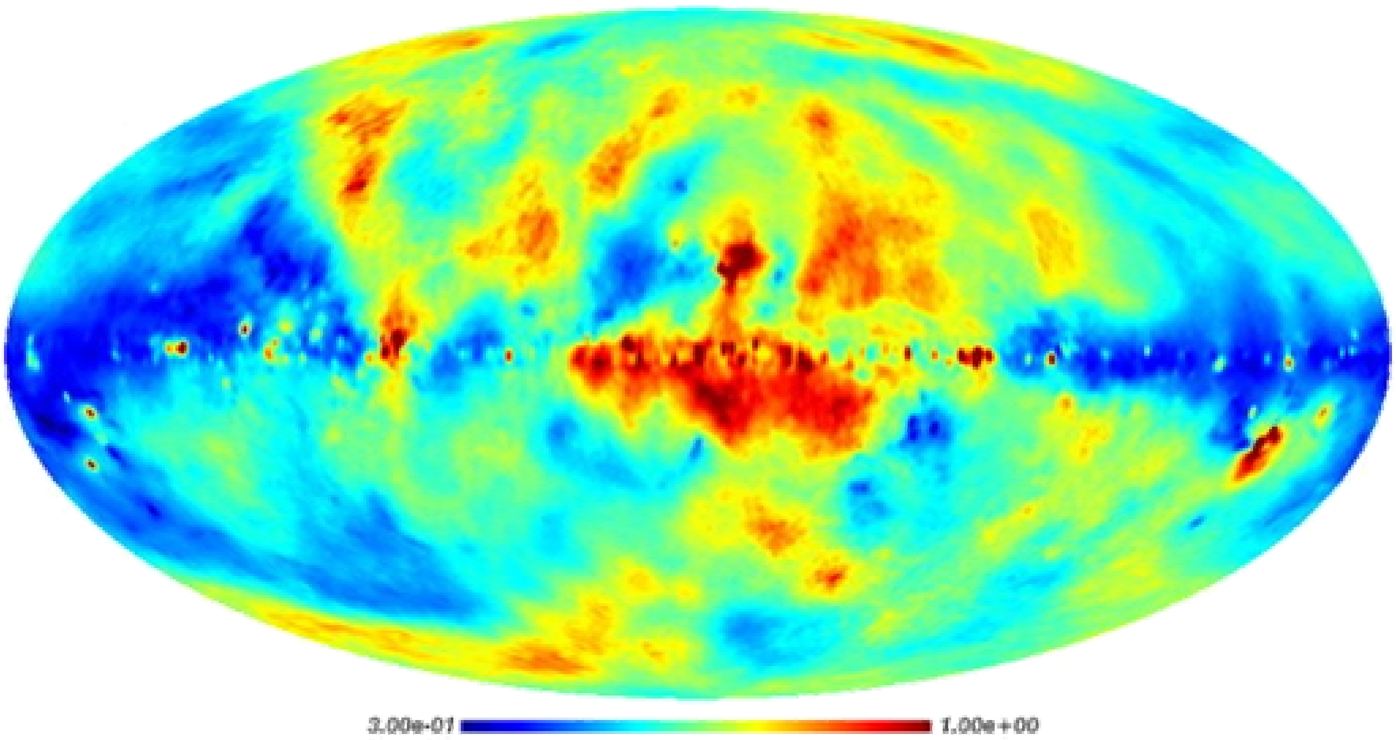
- Actual model (Finkbeiner, Davis, Schlegel, 1999) based on COBE/FIRAS data (7 deg.)
  - Two components ($<T_1>=9.6K$, $<T_2>=16.4K$).
  - The 2 components are linked : the ratio of emitted power of the 2 components is constant.
  - T_1 and T_2 are determined using the 100/240 micron ratio (DIRBE).

Dust 100 micron - Schlegel et al.



Angular resolution : 5 arcmin

Dust 240/100 ratio - Finkbeiner et al.

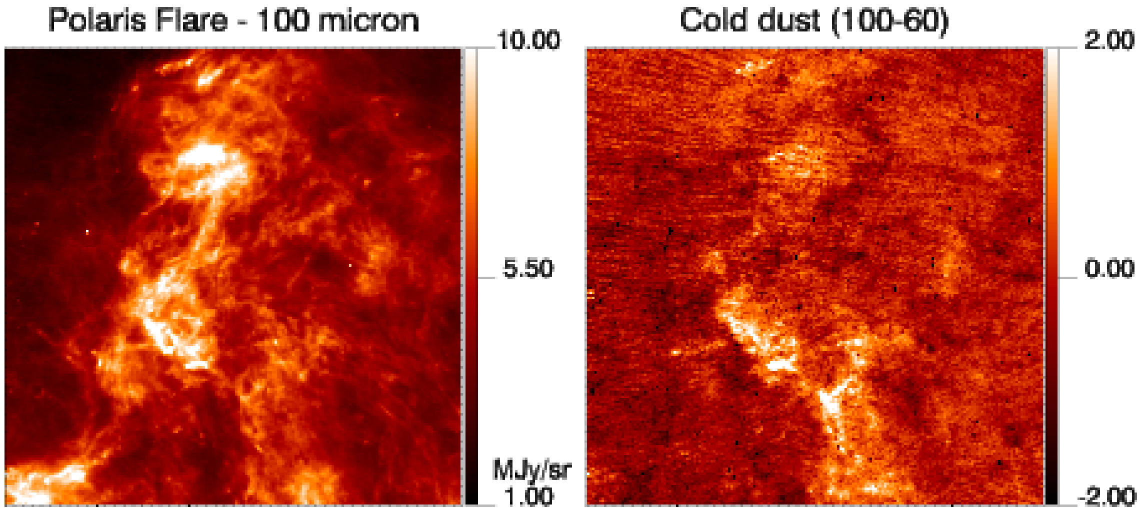


Angular resolution: 0.7 - 10 deg.

Limitation of the FDS model

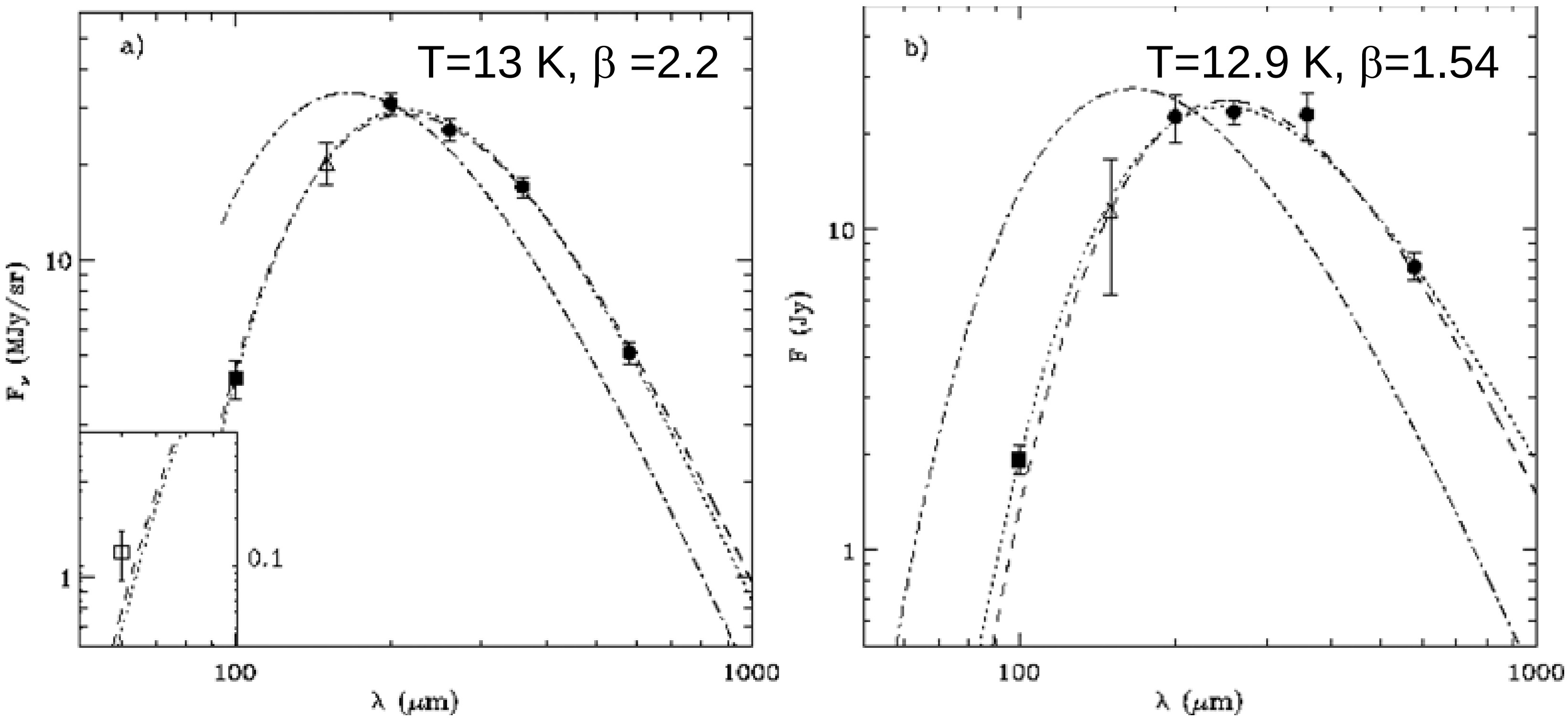
- No physical basis for 2 components linked together
- Spectral model is based on large scale properties of dust (7 deg)
- Grain temperature is determined at scales > 0.7 deg
- In the far-infrared, small-scale variations of dust properties are ubiquitous

Variations of dust properties at small scale in cirrus clouds



Several examples of fast dust evolution in cirrus clouds
with IRAS and ISO observations (Miville-Deschenes et al., 2003)

Cold dust at small scales in diffuse clouds

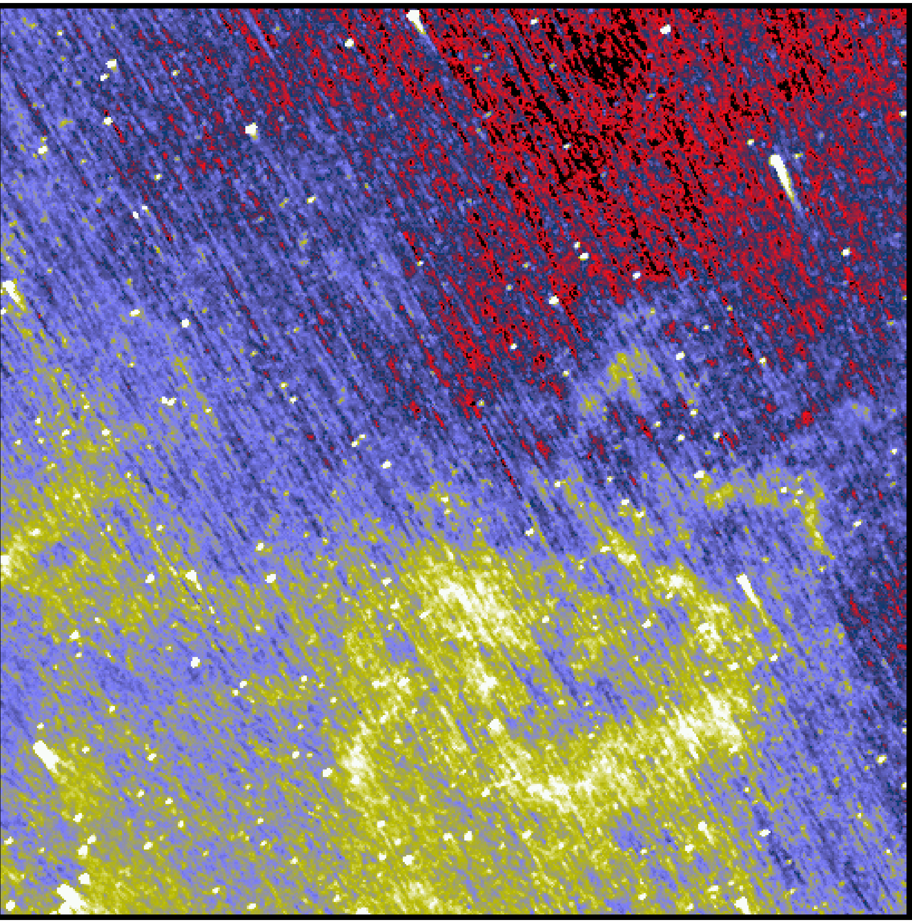


Pronoas observations (200-600 micron) of the Polaris cirrus cloud
Bernard et al., 1999

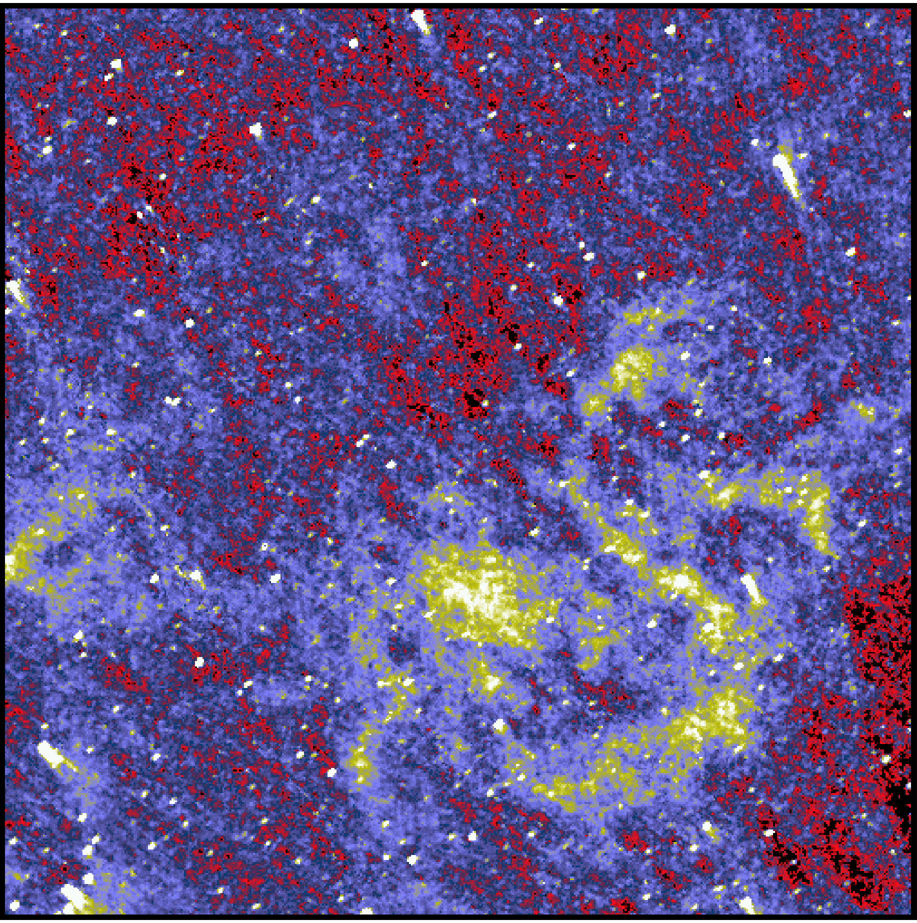
Reprocessing the IRAS data

- There is a clear need for a detailed work on spatial and spectral variations of dust emission
- IRAS data will be a very useful complement to Planck-HFI data to characterize dust emission (big grains and spinning dust)
  - Same angular resolution than HFI
- Reprocessing of the IRAS data (4 bands) has been done - Miville-Deschenes & Lagache, 2004
  - Destriping
  - Deglitching
  - Calibration (gain and offset) for point sources and diffuse emission

Reprocessing IRAS : 12 μm

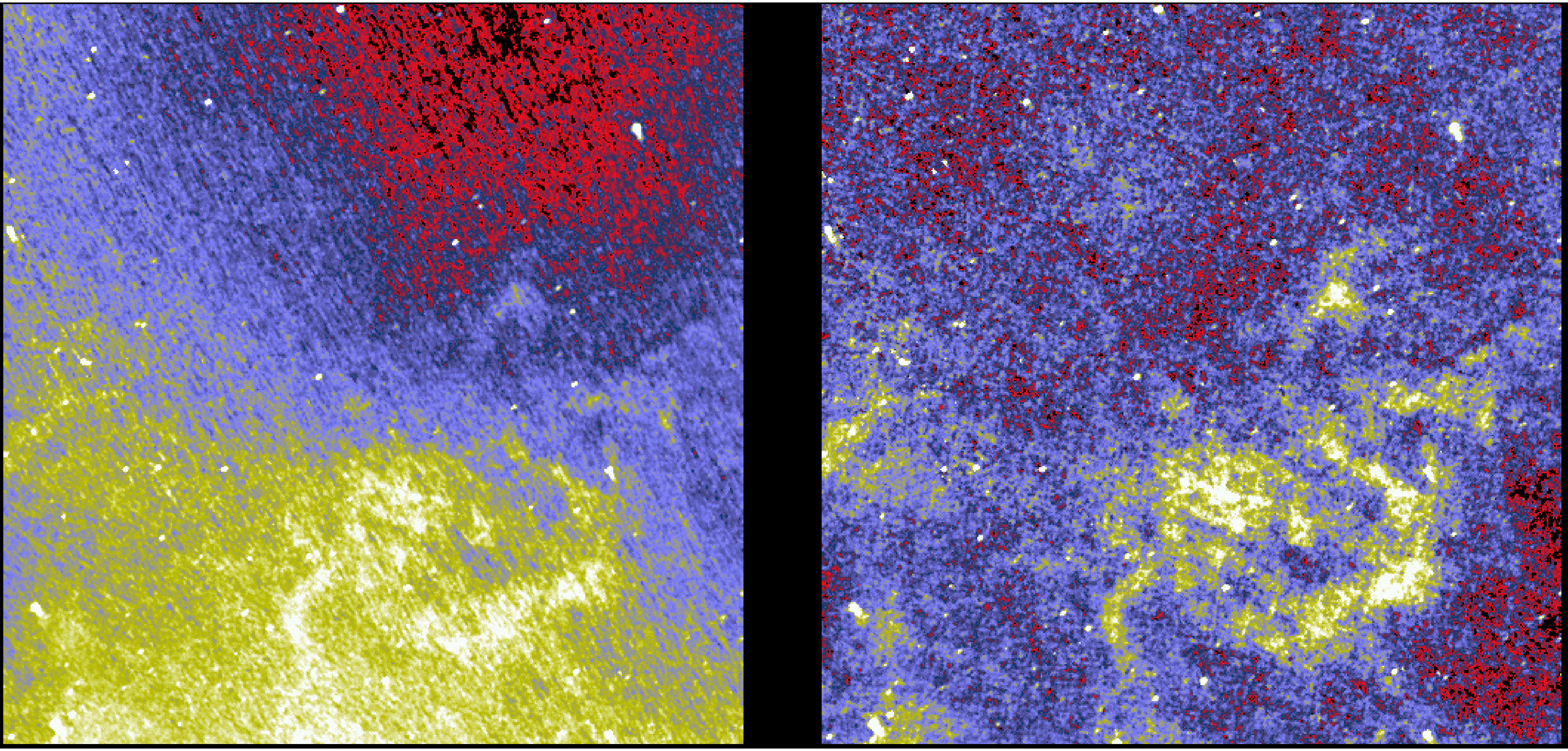


Before



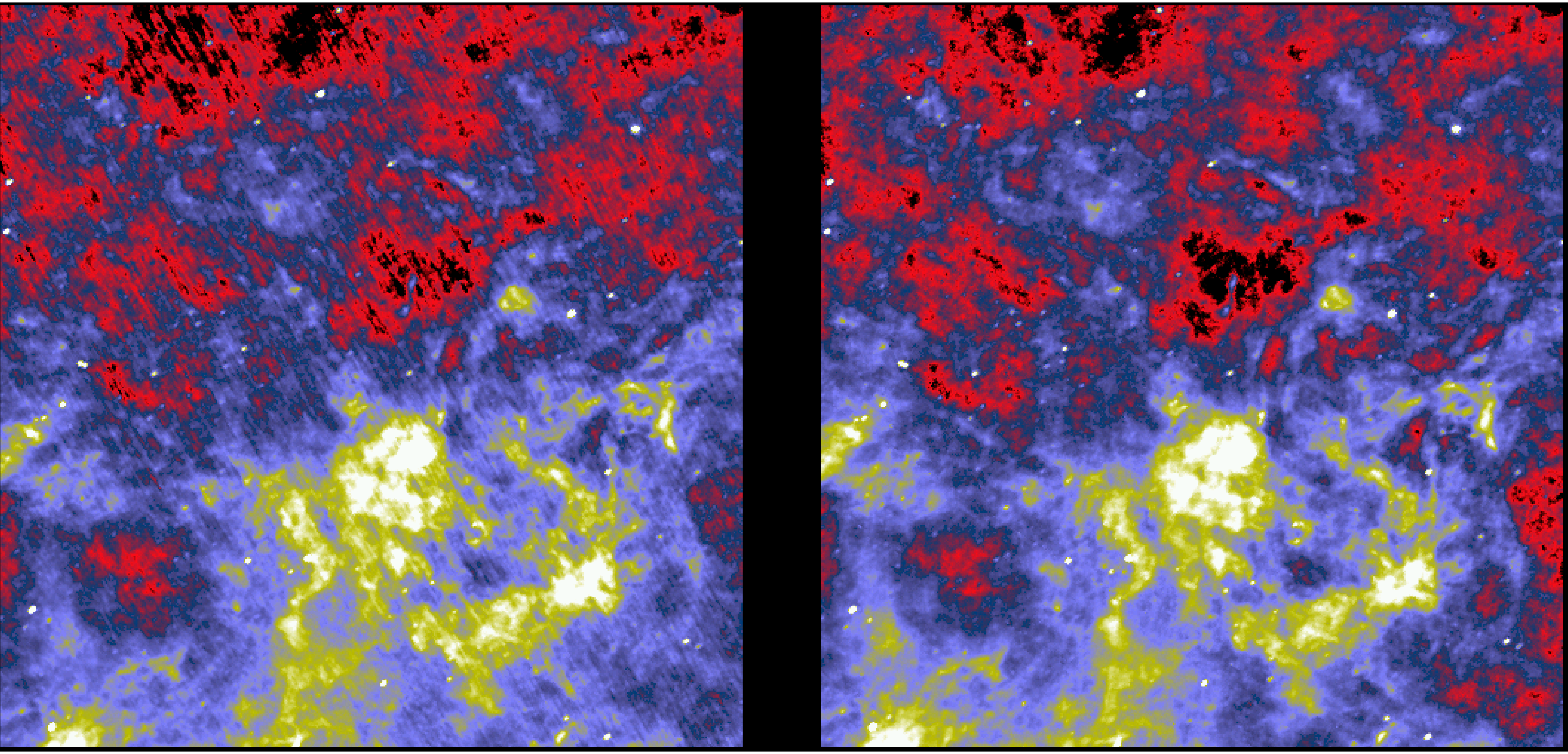
After

Reprocessing IRAS : 25 μm



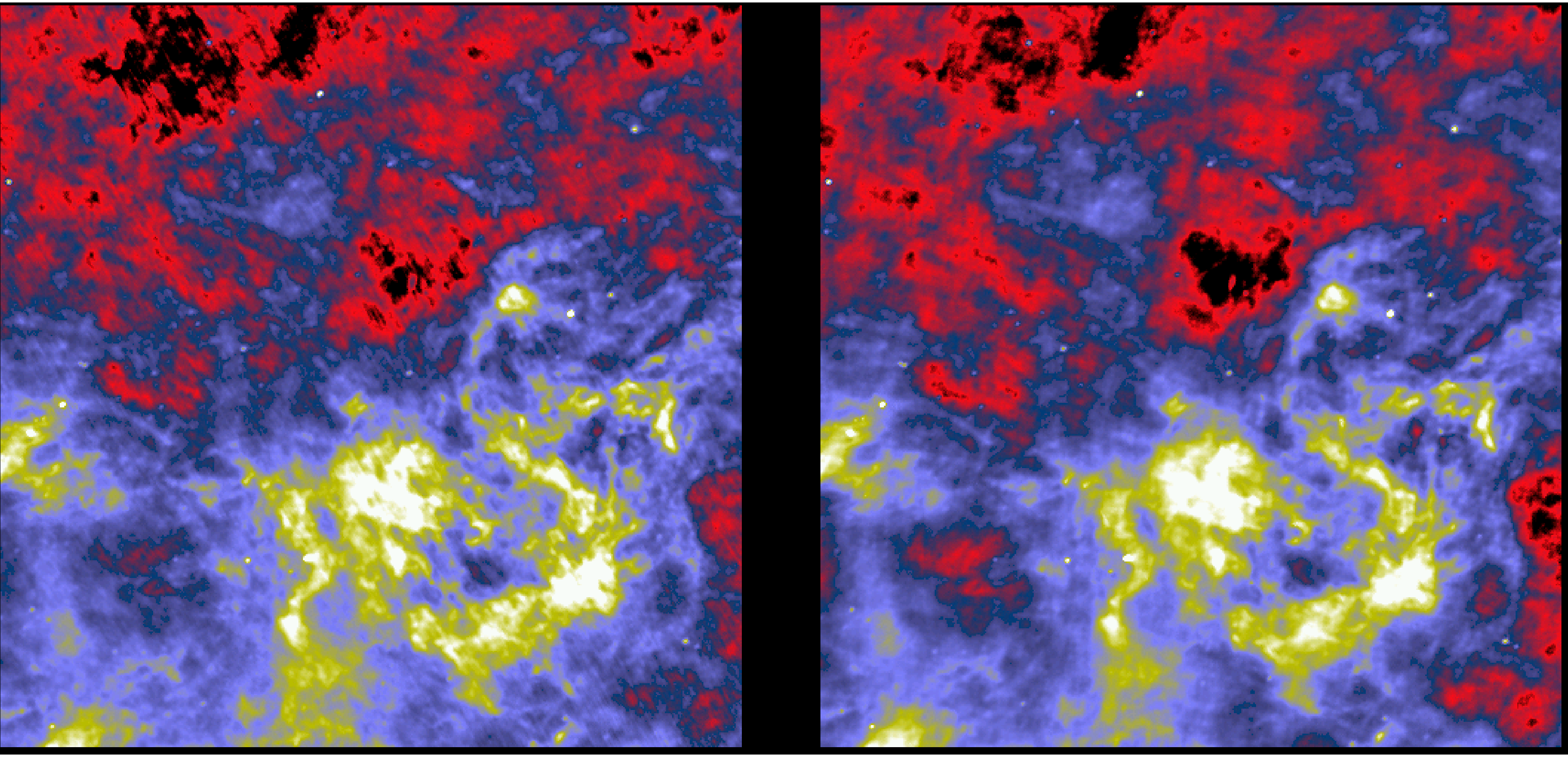
Before After

Reprocessing IRAS : 60 μm



Before   After

Reprocessing IRAS : 100 μm



Before

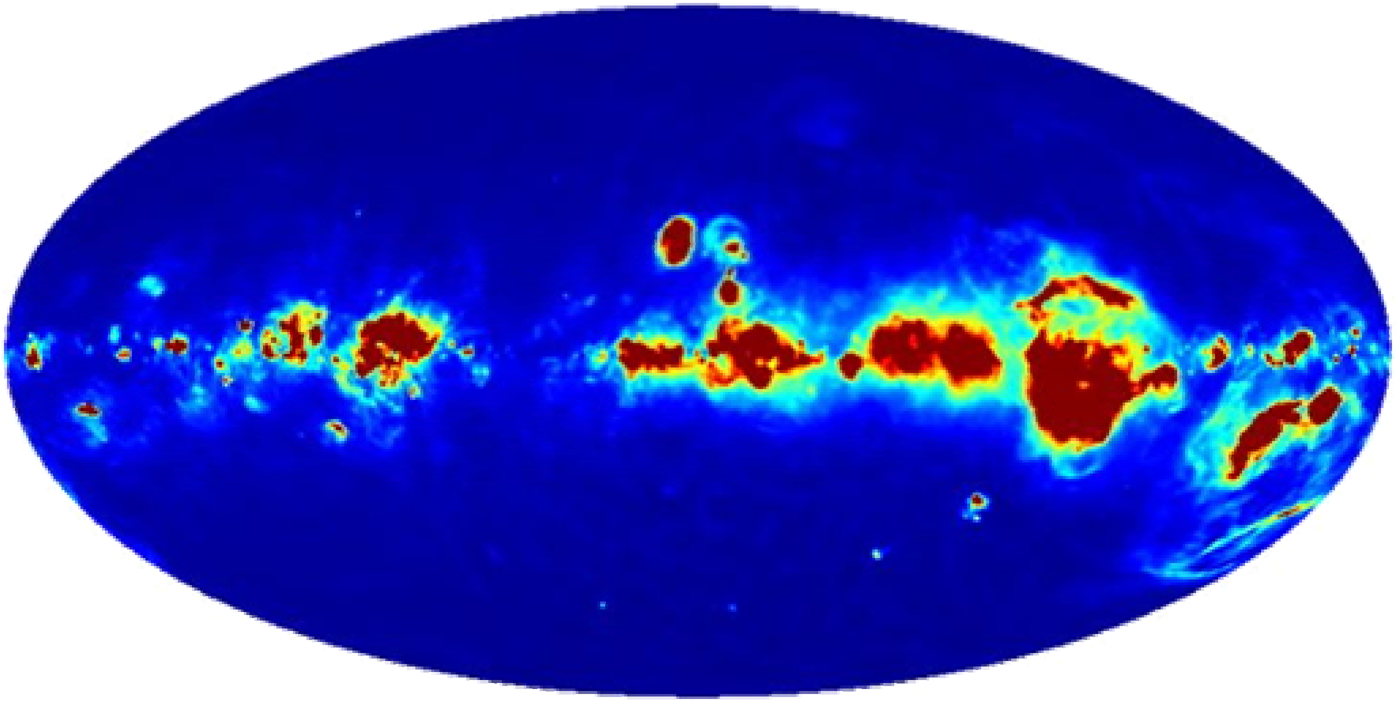
After

Free-free emission

(Dickinson, Davies, Davis, 2003)

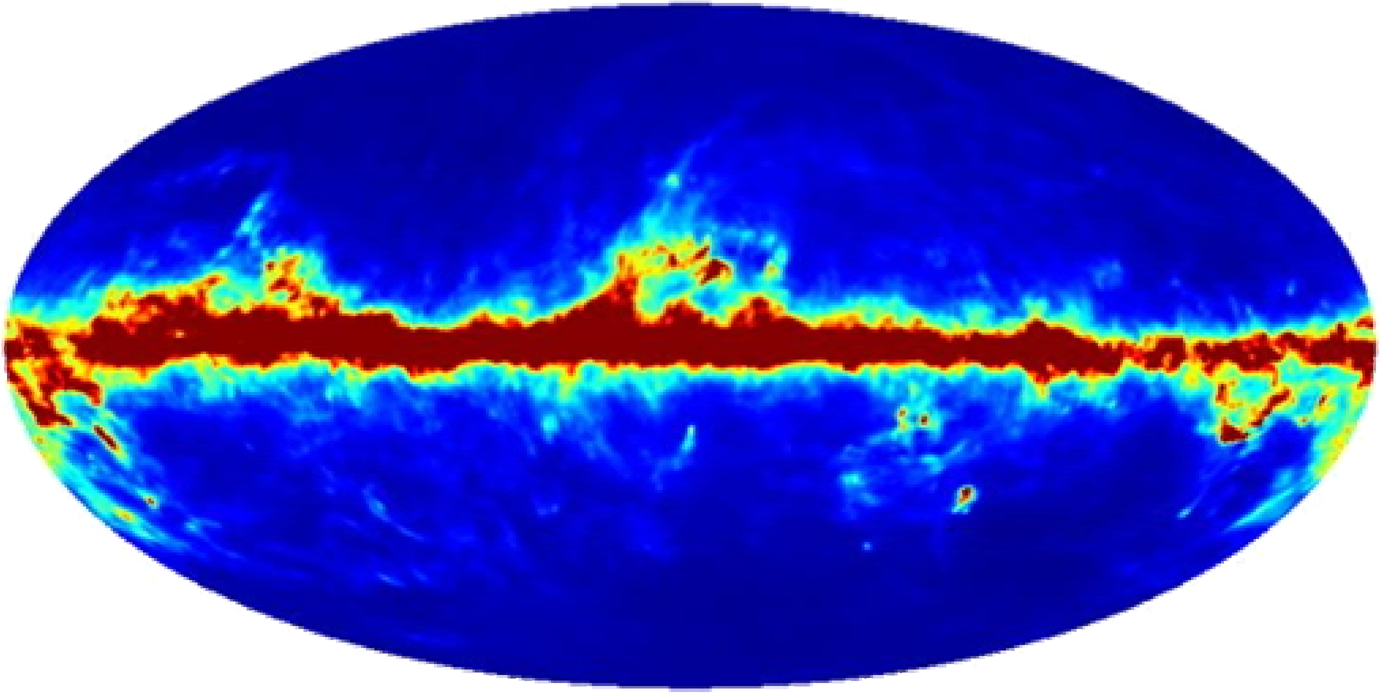
- Electron-ion scattering ; relatively well known physics
- $T_{ff} \sim a(\nu , T_e) \, \nu^{-2.1} \, T_e^{-0.35}$ (EM)
- $T_{ff} \sim a(\nu , T_e) \, \nu^{-2.1} \, T_e^{0.667} \, I_{H\alpha}$
- Hα survey is used as a template for free-free emission, except in region of high dust column
- For τ<1 the H α map can be corrected for the effect of extinction
  - Hypothesis on dust/gas mixing

Hα - Dickinson et al.



Combination of WHAM and SHASSA
Angular resolution : 1 deg

Extinction map - Schlegel et al.



True resolution of extinction map is >0.7 deg (based on DIRBE dust temperature)

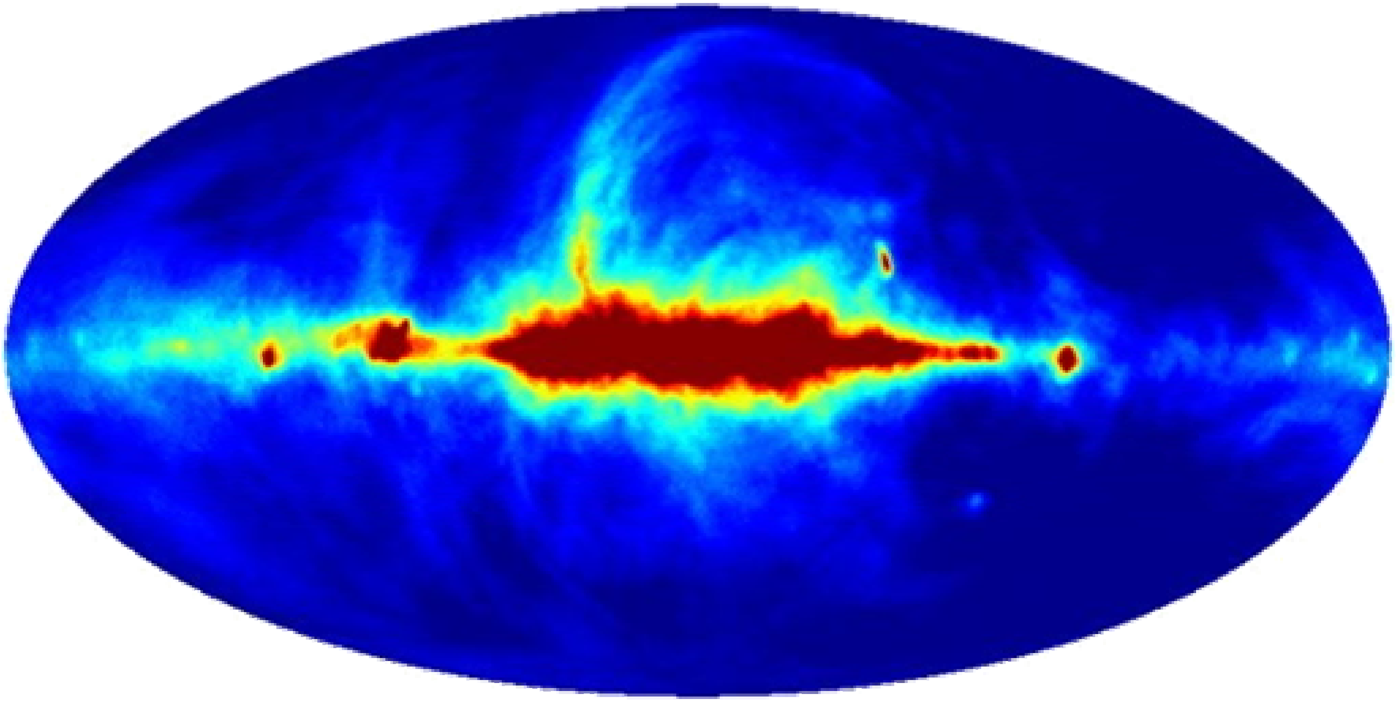
Free-free template : limitations

- Spatial variations of T_e
- Variations of the dust/gas mixing ratio
- Galactic plane : Hα extinction is too large to estimate free-free
  - HIPASS/HIJASS survey (radio recomb. lines)
- Calibration of Hα is uncertain to ~10%
- Geocoronal emission
- Angular resolution : 1 deg

Synchrotron

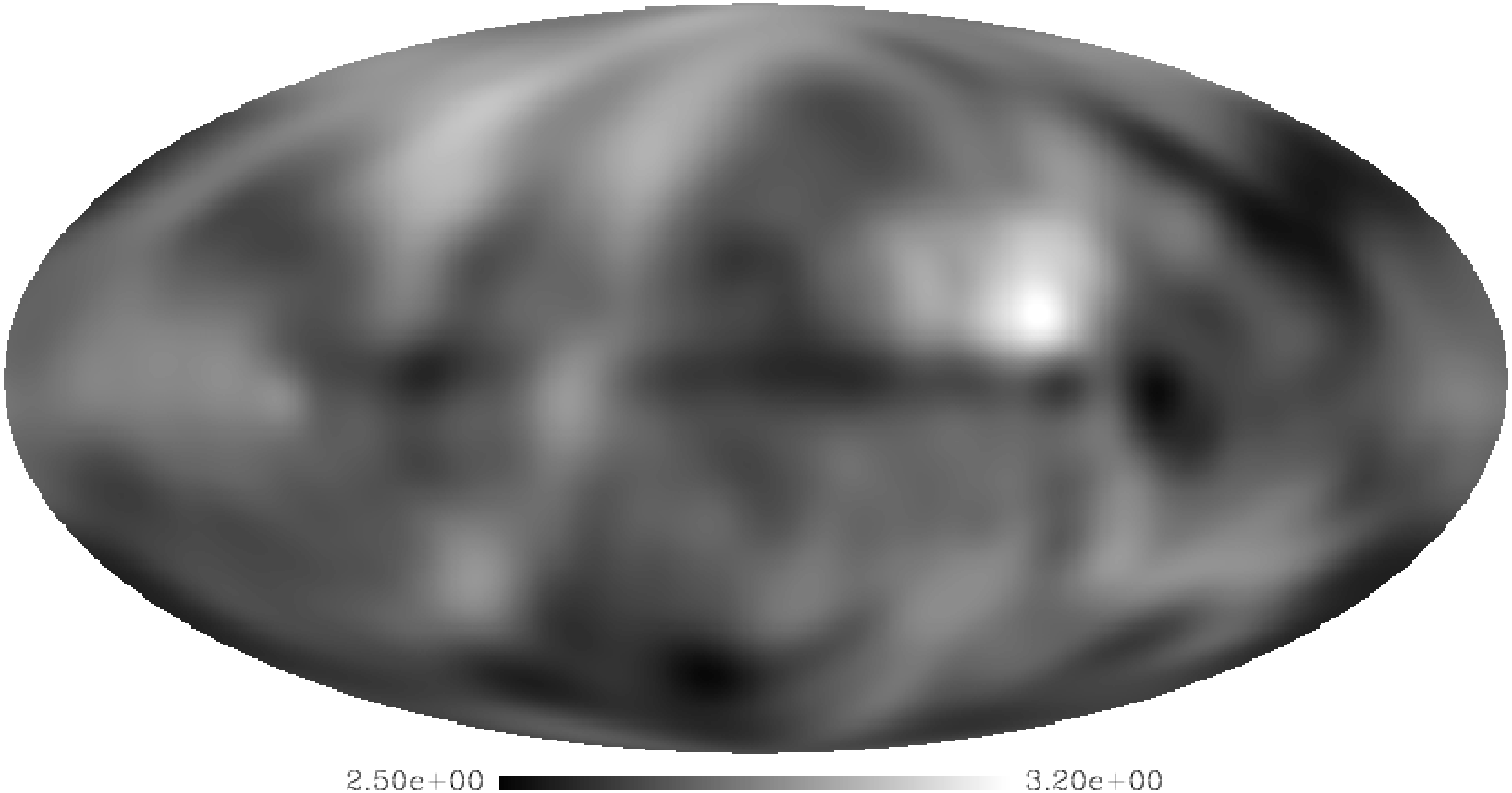
- Relativistic CR electrons spiraling around the Galactic magnetic field lines
- Emission depends on magnetic field strength and CR energy distribution (both not well known)
- $T_{sync} \sim \nu^{-\beta}$
- Spectral index (β) depends on energy spectrum of relativistic electrons $\rightarrow$ "Dust correlated" high frequency synchrotron excess?
  - Spatial variations of the index correlated with energy input in star forming regions?
  - IR-Synchrotron correlation in galaxies observed down to massive star forming region at ~1 kpc scale

Haslam 408 MHz synchrotron map



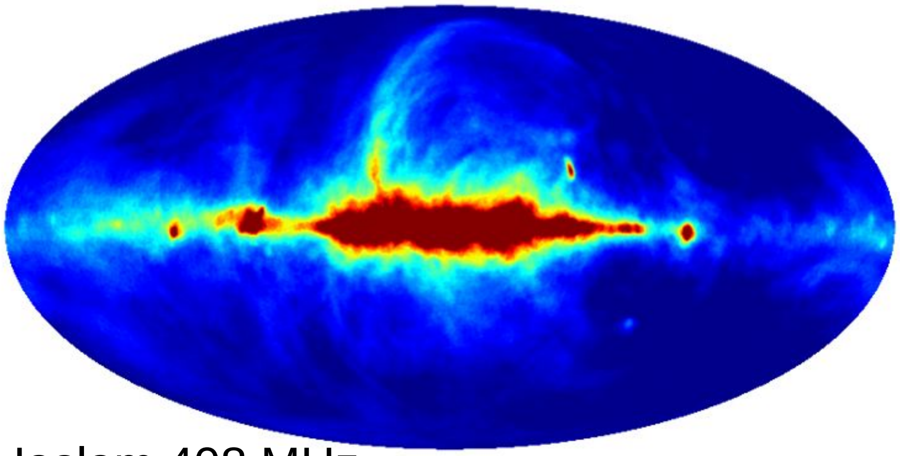
Corrected for free-free emission (non-negligible in Orion)
Angular resolution : 0.85 deg

Synchrotron index (408 MHz - 1.4/2.3 GHz)

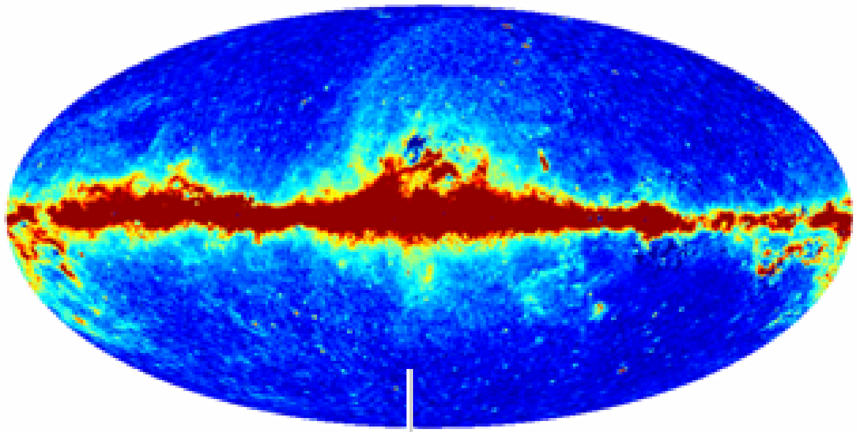


Giardino et al., 2002

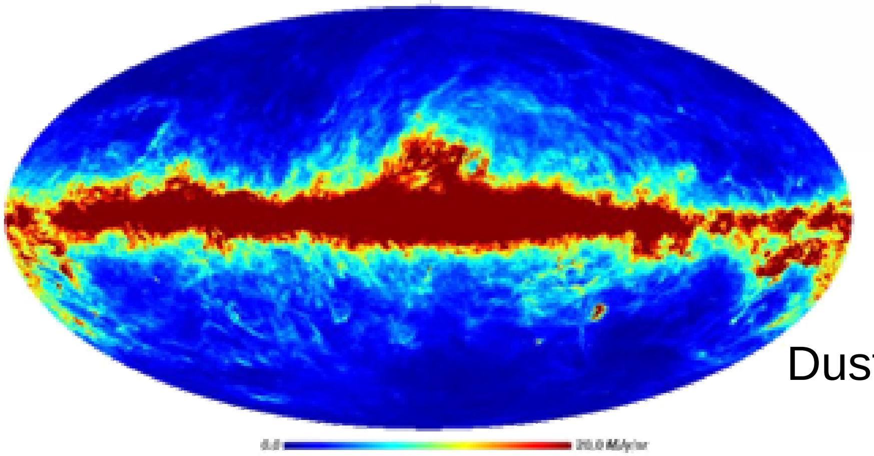
WMAP synchrotron map



Haslam 408 MHz

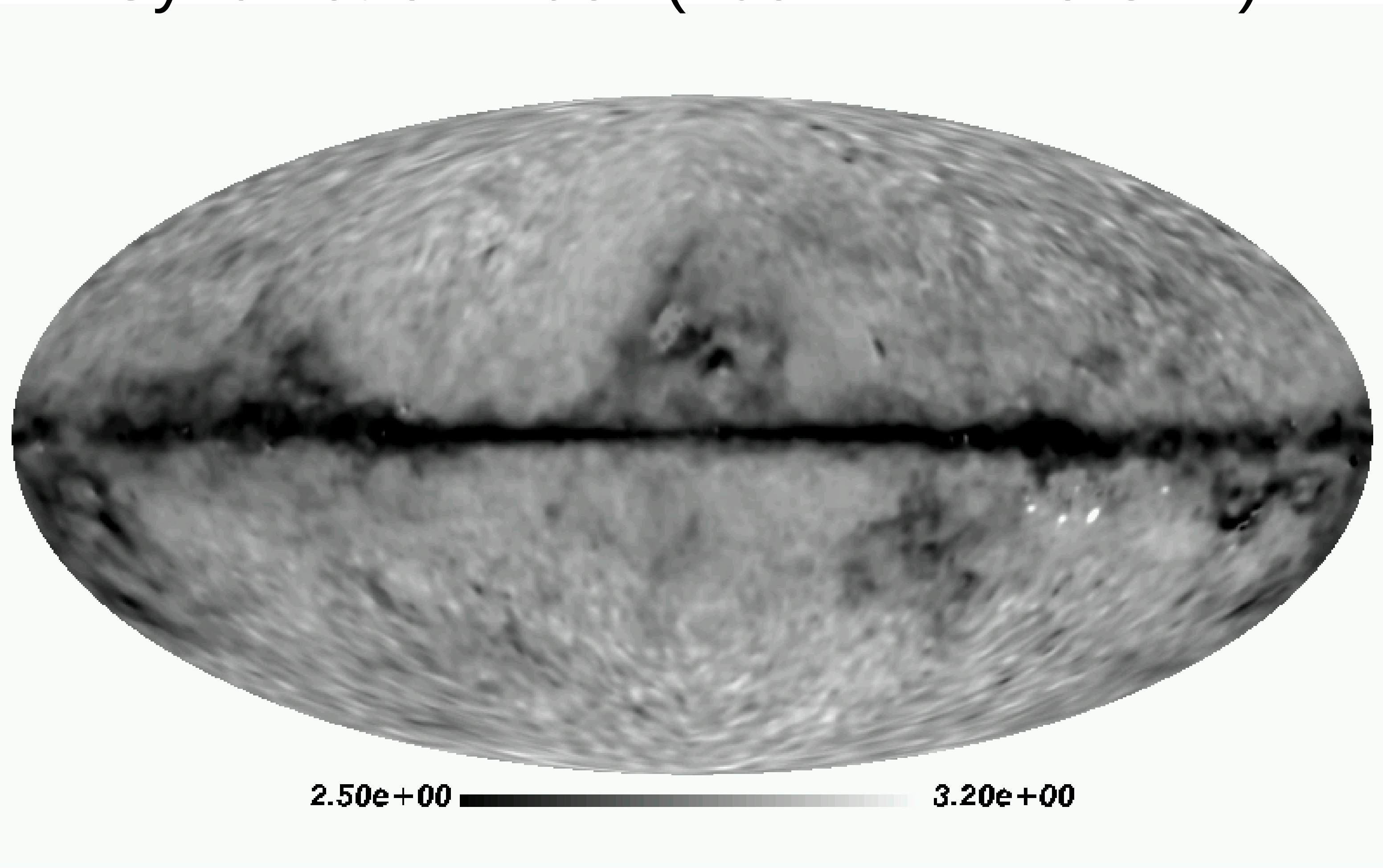


WMAP synchrotron



Dust 100 micron

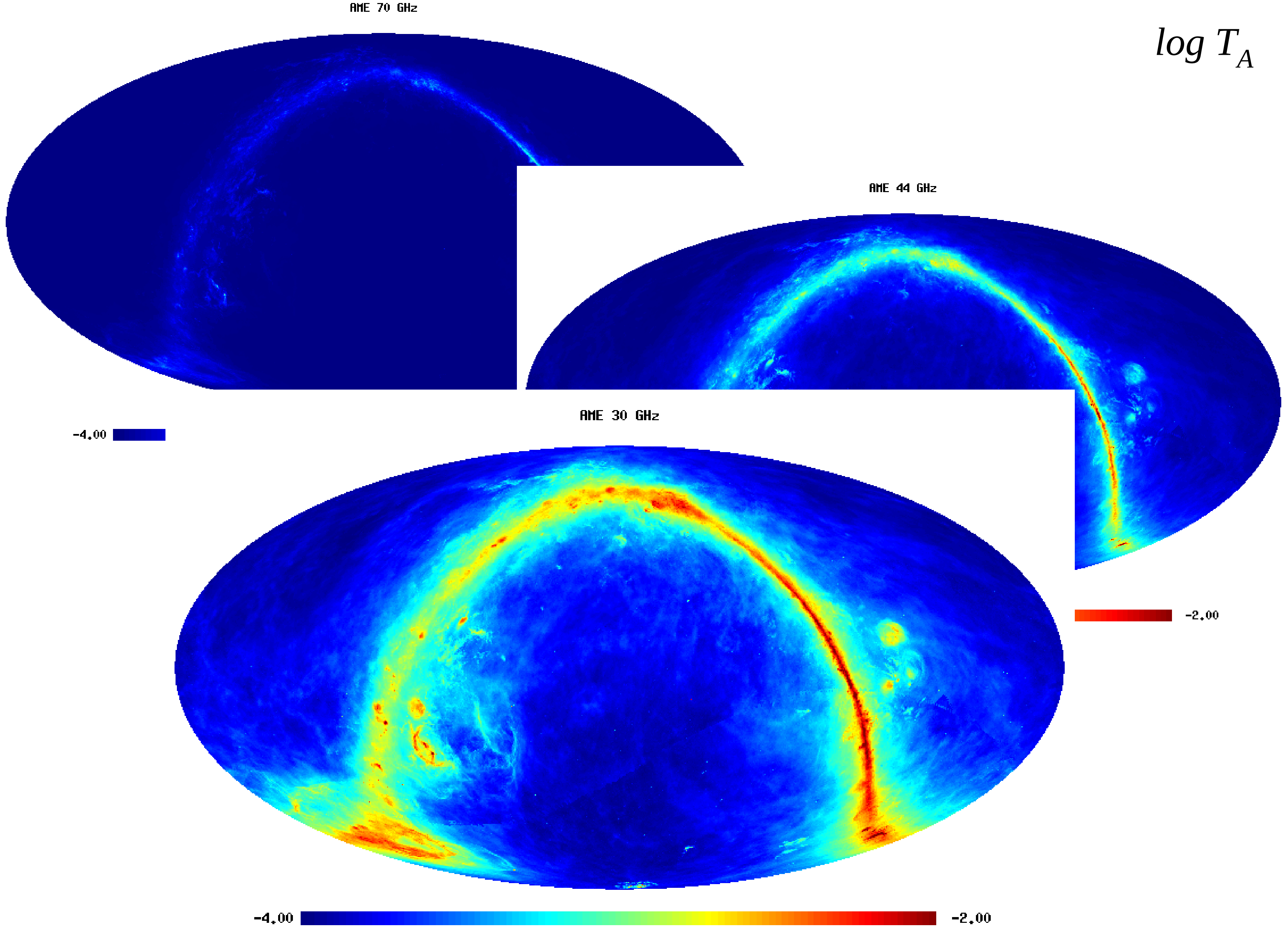
Synchrotron index (408 MHz - 23 GHz)



Modelling Spinning Dust Component

- emission from very small, rapidly **spinning dust** grains:
  - Draine & Lazarian 1998 gave predictions on emissivity under different conditions of the ISM
  - column densities of molecular, neutral and ionized material can be derived from existing surveys

  $\Rightarrow$ a ***tentative*** template for anomalous microwave emission

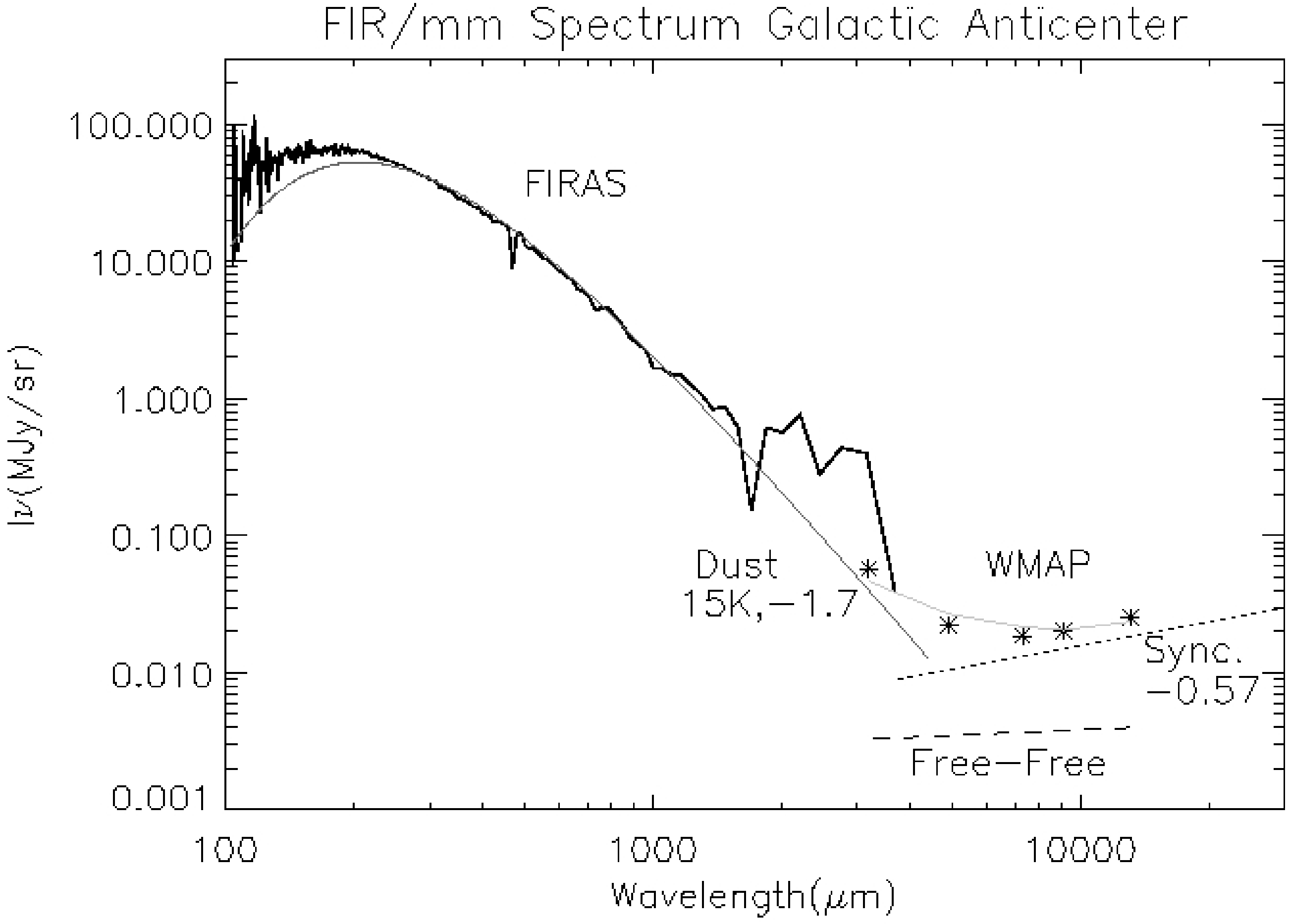


AME 70 GHz
log T_A
AME 44 GHz
-4.00
AME 30 GHz
-2.00
-4.00
-2.00

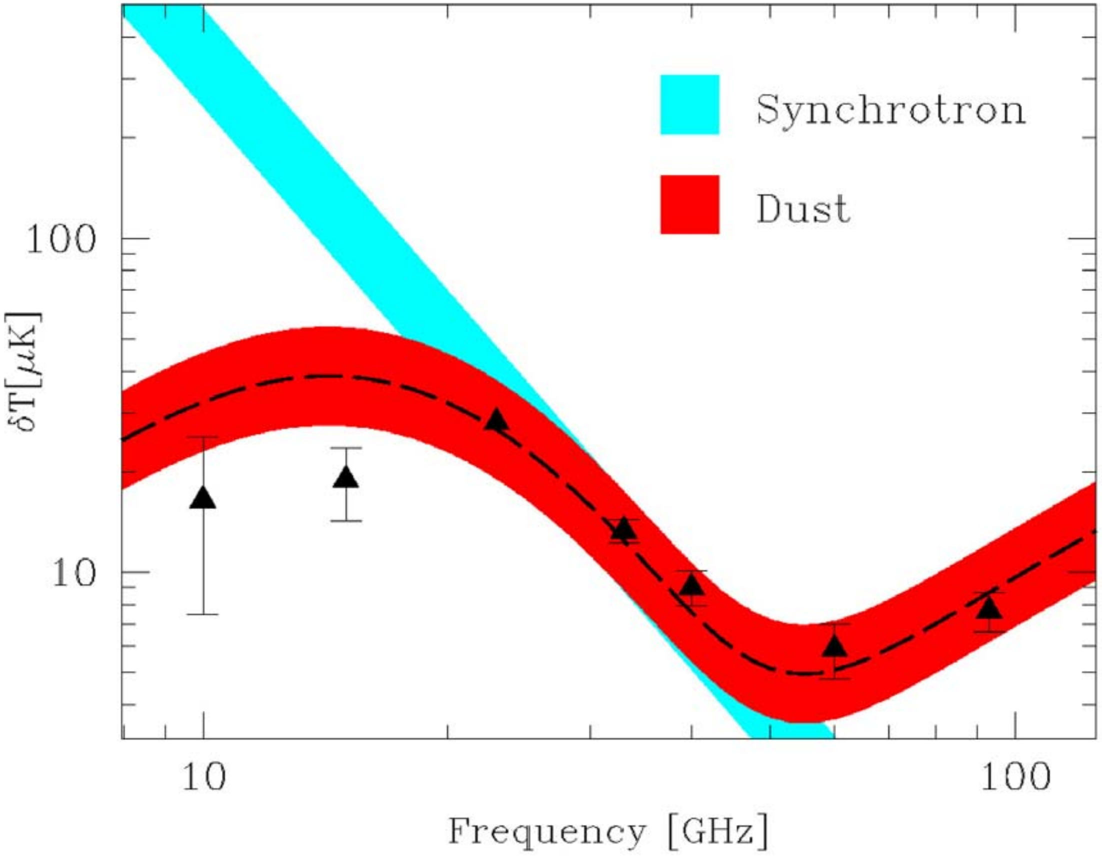
Foreground X:
Synchrotron or Spinning dust ?

- Dust Correlated microwave component discovered in the COBE-DMR data
- WHAM data: not Free-Free
- Dipolar emission from small spinning dust grains (Draine and Lazarian Model) $\rightarrow$ Unlike dust thermal emission it is not powered by stellar photons absorption
- No evidence for correlation with a specific interstellar component/environment
- WMAP team interprets this as a change in the synchrotron spectrum from high-latitude to Galactic plane regions

Model vs Data

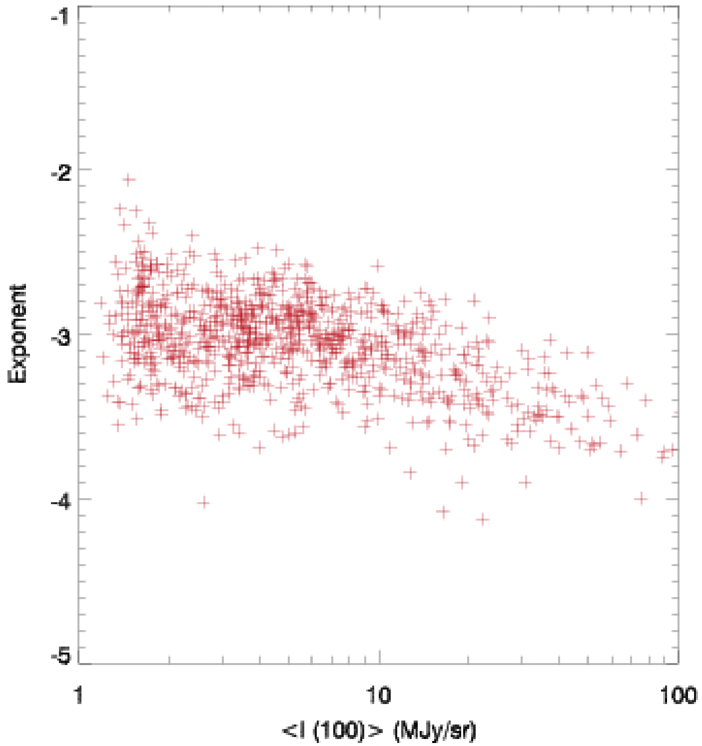


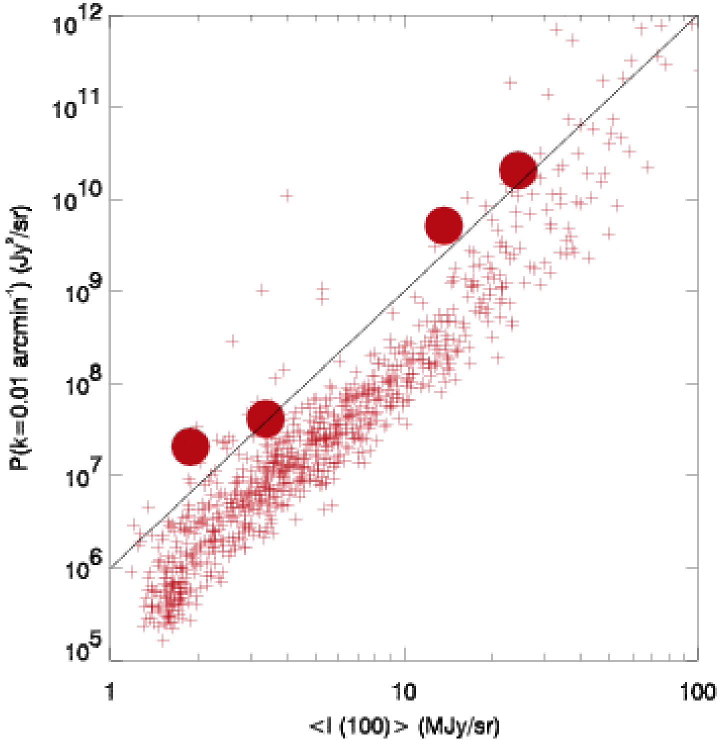
Spinning Dust vs Synchrotron



De Oliveira-Costa et al. 2004

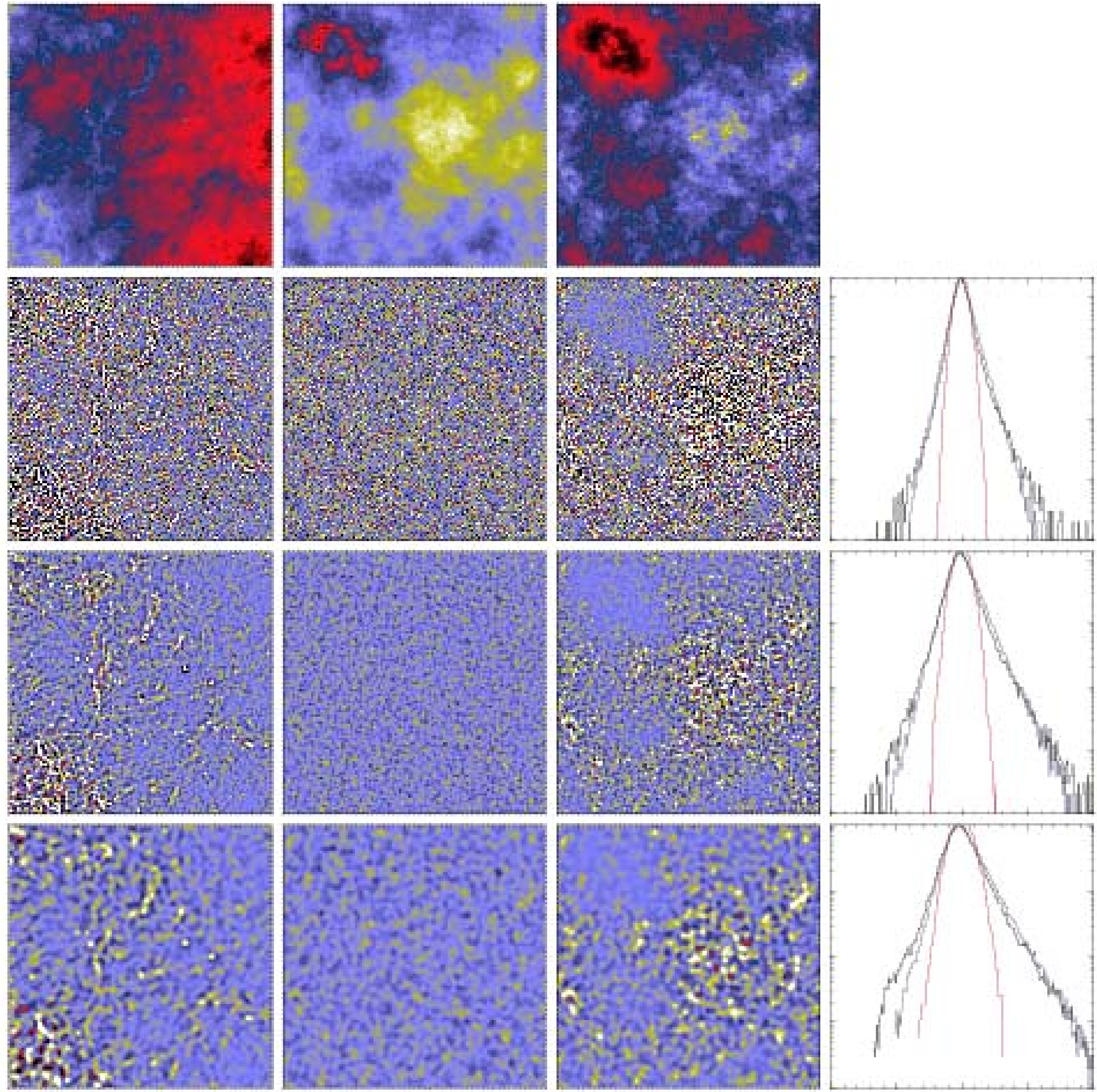
Power spectrum of dust emission



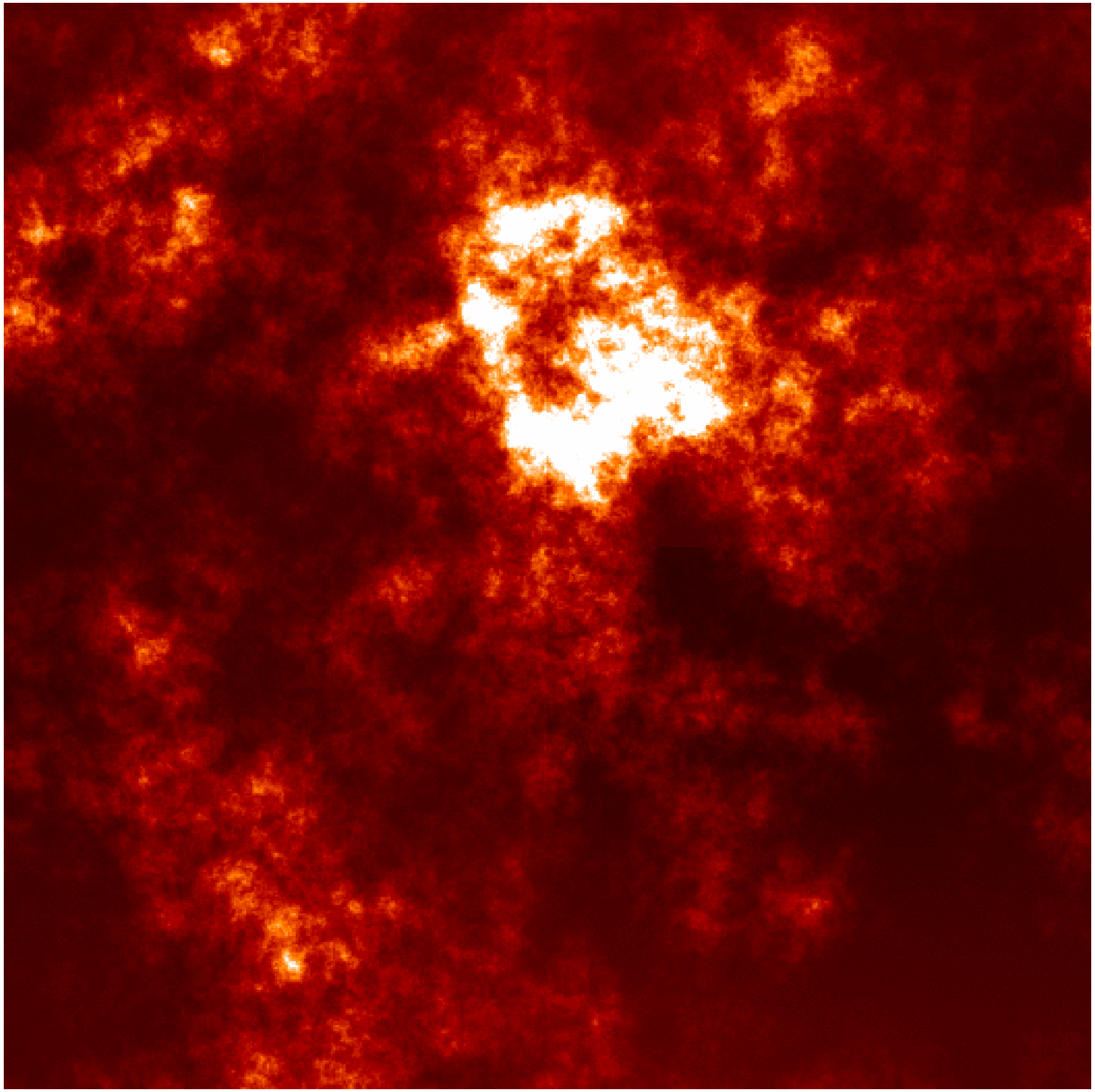


Miville-Deschenes & Lagache, 2004

Non-Gaussianity of dust emission



Simulation of dust emission



Polarized foregrounds

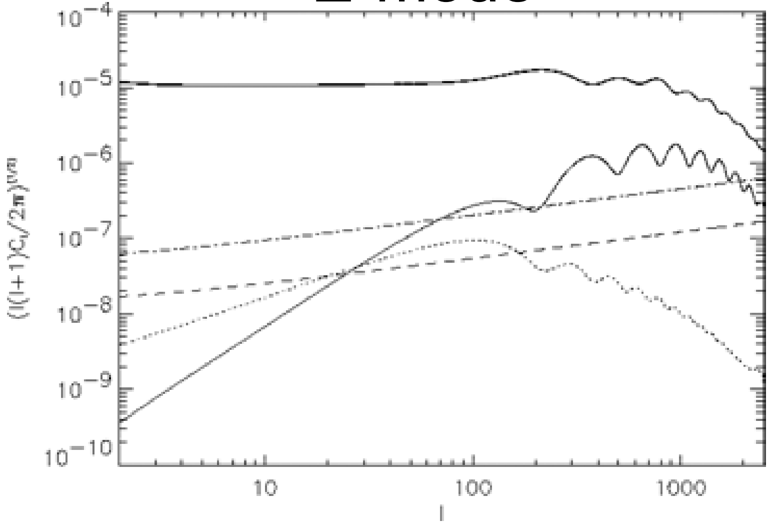
- Synchrotron is highly polarized but few measurements outside the Galactic plane $\rightarrow$ expecting release of WMAP data
- Spinning dust : we do not expect a high polarization level $\rightarrow$ a good way to differentiate spinning dust from synchrotron emission with WMAP
- Thermal dust : Archeops implies a large intrinsic polarization ~10% on large angular scales (reduced to an observed value of ~5% in the Galactic plane by line of sight averaging)
- Expected to be higher for high Galactic features where the turbulent component of the field is coherent

Conclusions

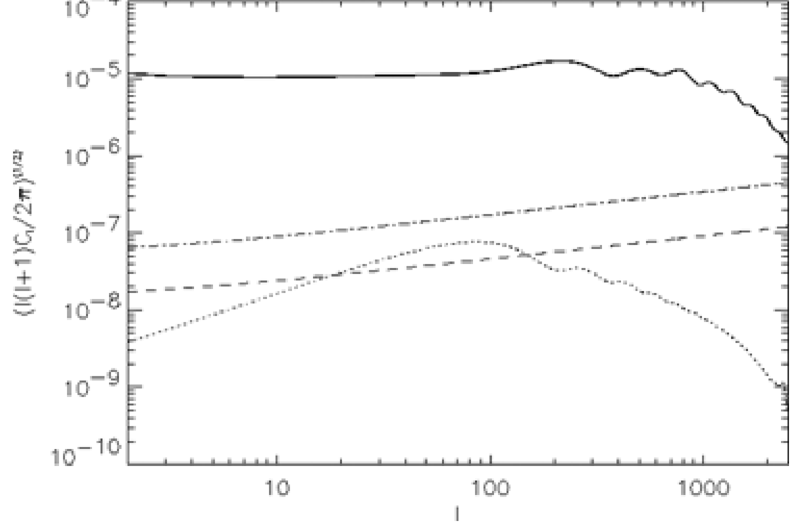
- A model of the main Galactic components is available - but polarization is still missing -
  - WEB site: www.cesr.fr/~bernard/PSM
- Synchrotron spectral index vs spinning dust grain needs to be addressed:
  - polarization test with WMAP
  - CMB contamination
- Strong small-scale variations are observed in the dust emission: higher resolution model is needed
- Foregrounds are highly non-Gaussian
  - To be quantified and included in models
- Polarized foregrounds are critically unknown
  - Use MHD simulations of the Galactic ISM

Dust polarized emission

E-mode

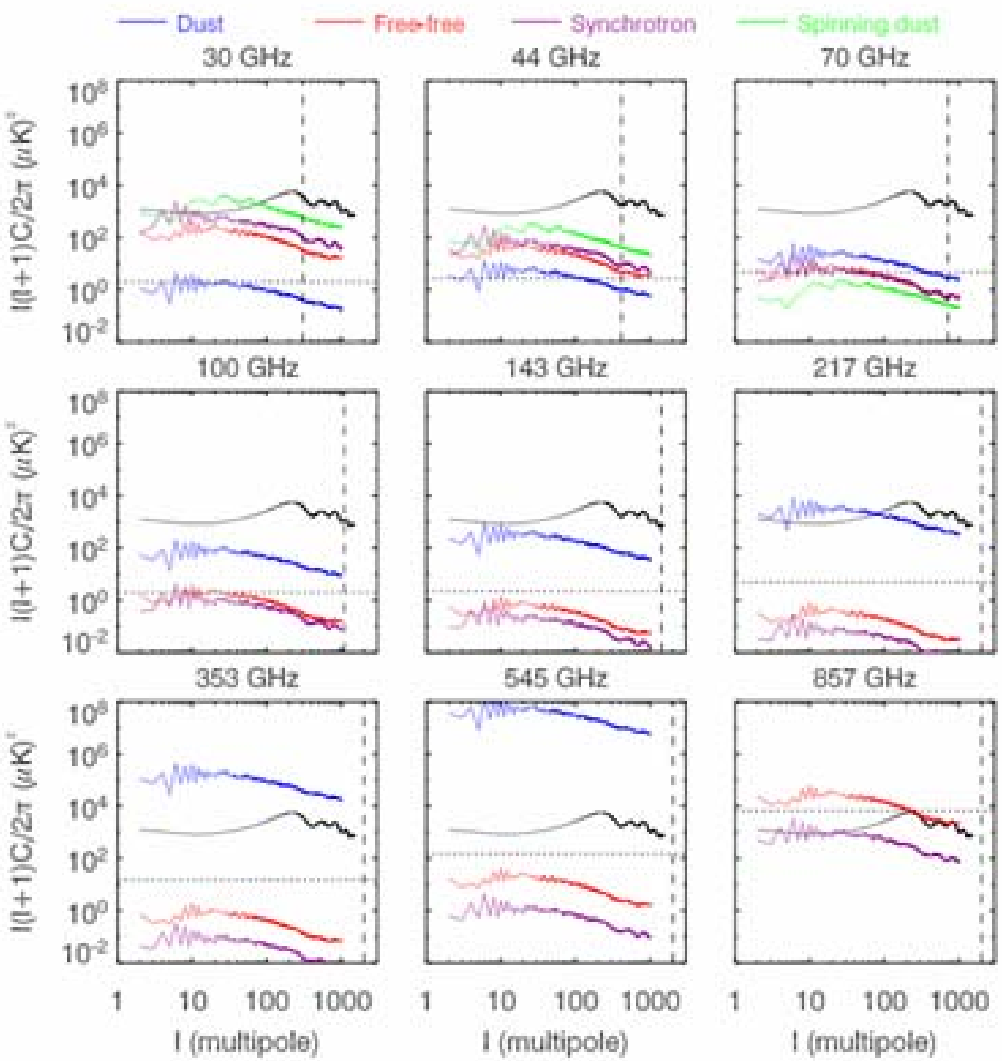


B-mode



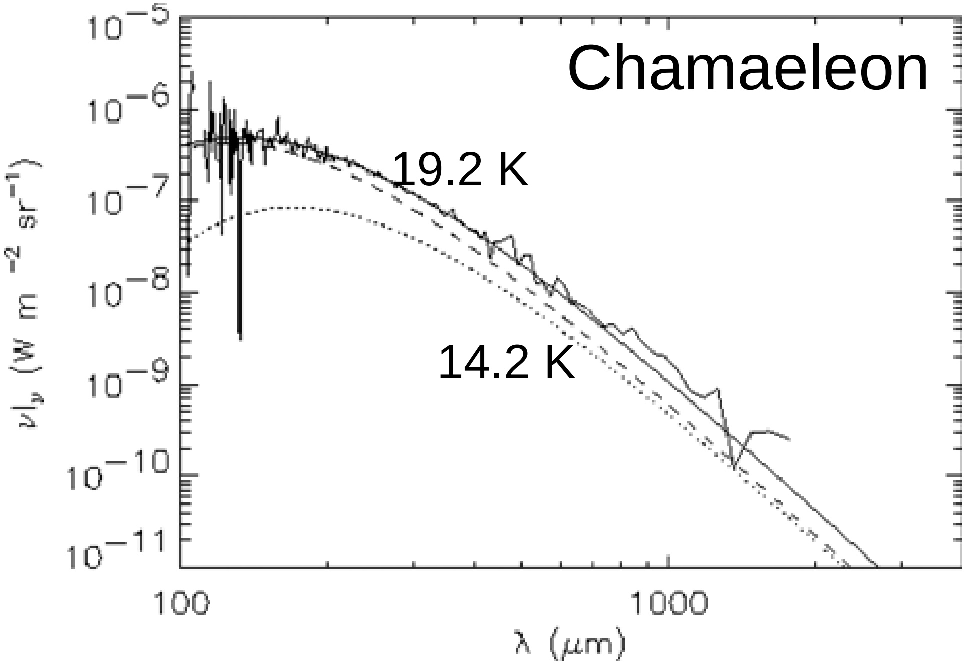
Simulation of the dust polarized emission using the 21 cm Leiden data as an indicator of density structure and magnetic field orientation.
Prunet et al., 1998

Power spectra of foregrounds in Planck bands



Interstellar dust in the submm/mm

- Emission from big dust grains at thermal equilibrium.
- Two dust components
- Colder dust component mainly in molecular clouds



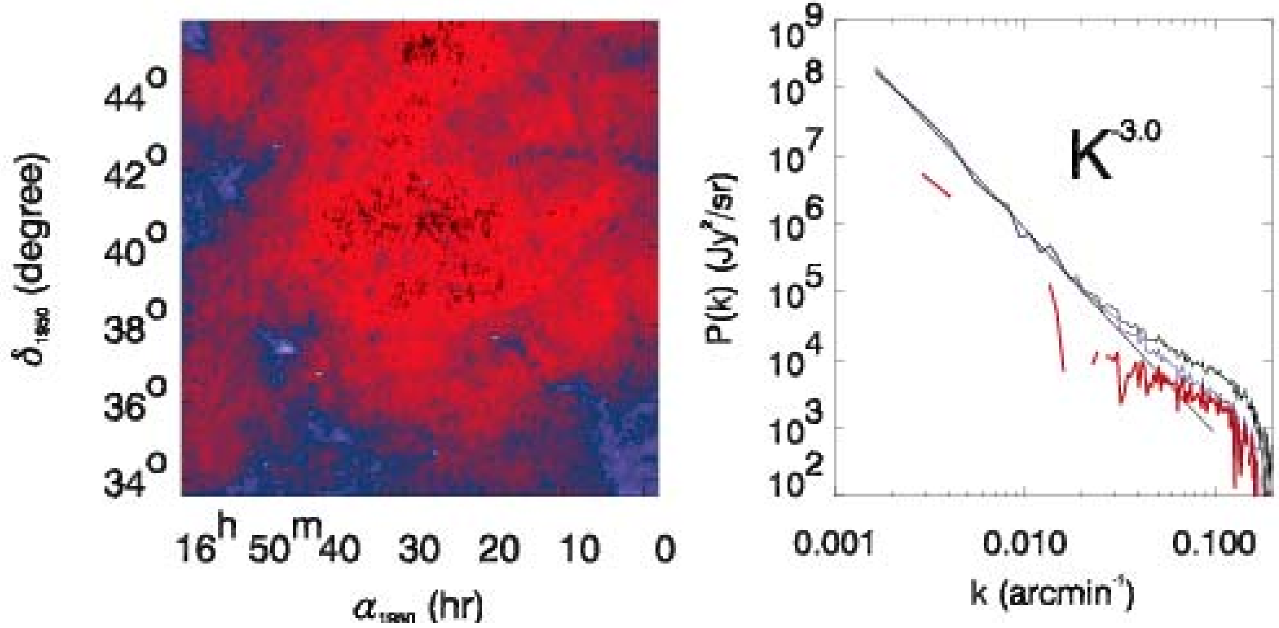
Lagache et al., 1998

A model of diffuse emission for Planck

M.-A. Miville-Deschenes and J.-P. Bernard

- Provide a model of diffuse emission for WG2 (Component Separation)
- The model should follow our understanding of foreground properties
- It should include total intensity and polarization
- Provide simulation at all ν in the Planck range
- Possibility of including toy models ; simulations of foreground maps based on their statistical properties. Useful for error estimate and testing of component separation methods

Detection of the Cosmic Infrared Background fluctuations at 60 and 100 microns with IRAS



Miville-Deschenes et al., 2003

The CIB will also be a very significant foreground for Planck at small scales - see talk by J.-L. Puget

Power spectrum of synchrotron emission

- Based on an extrapolation of the power spectrum of polarized emission at 2.4 GHz (Galactic plane) and the 408 MHz all-sky map (Giardino et al., 2002)