Galactic dust emission in the Planck perspective

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with

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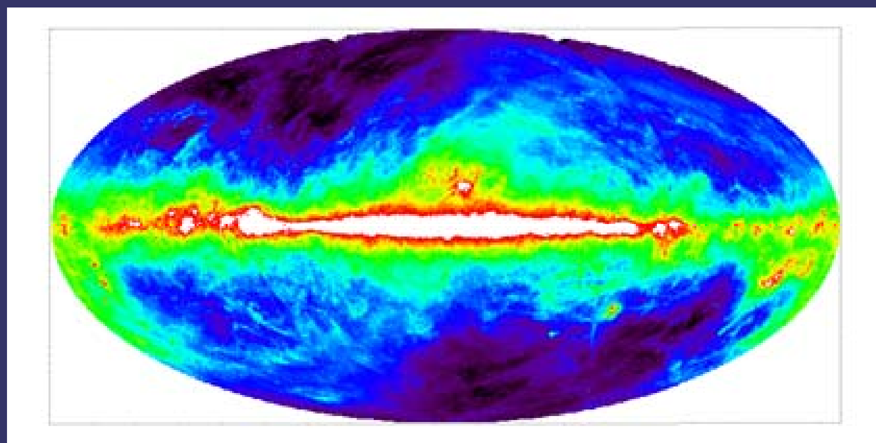
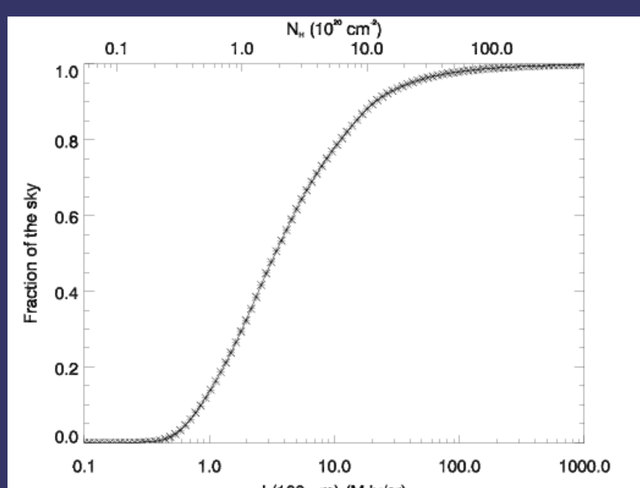
Plan

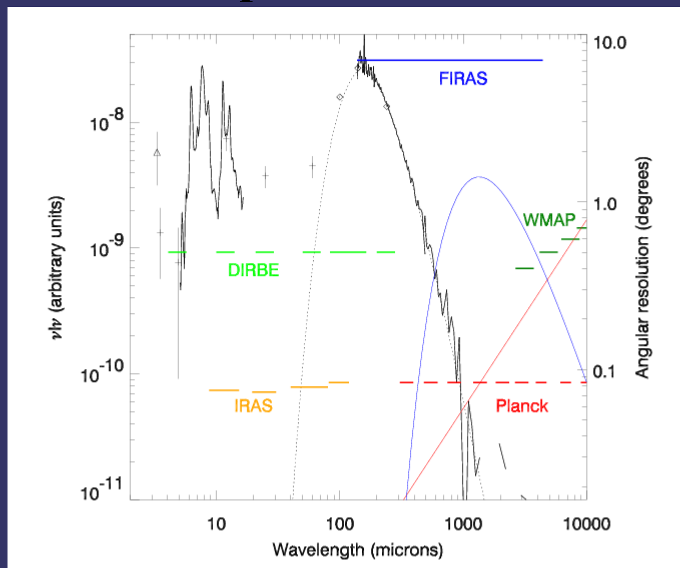
- Dust emission in the diffuse ISM
- Statistical properties of dust emission
- Simulation of dust maps
- Small-scale variations of dust emission and its impact on Planck data analysis
- Estimate of dust polarized emission in the diffuse ISM

All-sky IRAS 100 micron emission



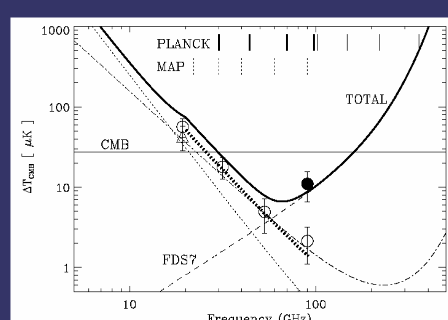


Dust emission spectrum



Anomalous microwave emission

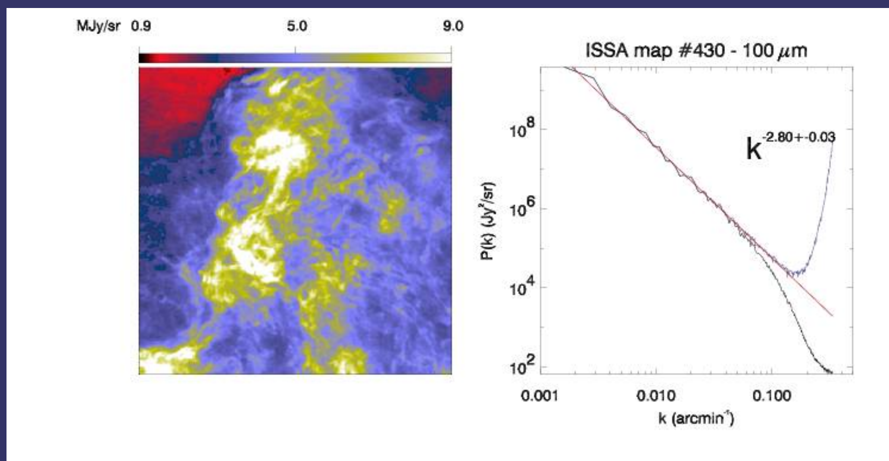
- Synchrotron-like spectrum but dust-like spatial structure
- Two explanations for now:
  - Spinning dust grains or small grains in their "cold state"
  - Synchrotron emission associated with dust emission, like the well-known radio-infrared correlation in galaxies.



Banday et al., 2003, astro-ph/0302181

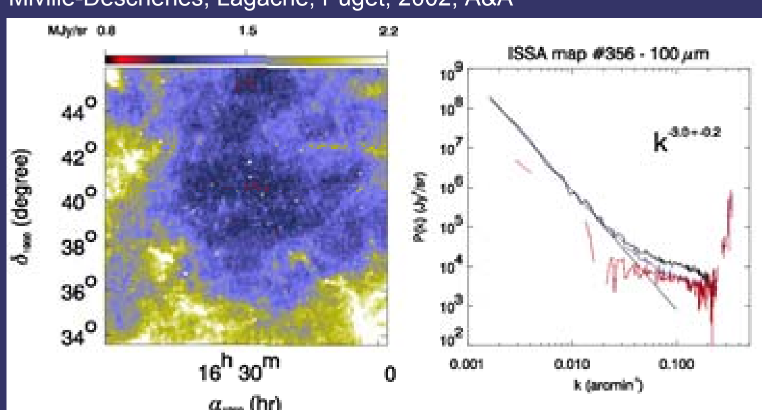
Spatial structure of dust emission : self-similar

– $P_{ism}(k) = P_0\, k^{-3}$ (Gautier et al, 1992)



Detection of Cosmic Infrared Background at small scales (60 and 100 microns)

Miville-Deschenes, Lagache, Puget, 2002, A&A



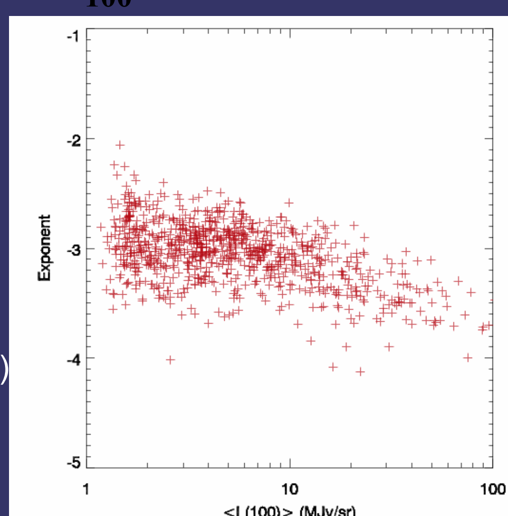
$$P(k) = B(k) * [P_{ism}(k) + P_{cib}(k) + P_{ps}(k)] + N(k)$$

Why study infrared stat. prop.?

- Describe the density structure of the ISM
  - Dust traces all phases at once
  - Optically thin (but UV extinction)
- Interstellar turbulence
  - large maps
  - Understand projection effects
  - Comparison with numerical simulations
- Coupling with gas at diff. scale
  - passive scalar or not ?
  - relation with magnetic field
- Foreground (component separation)

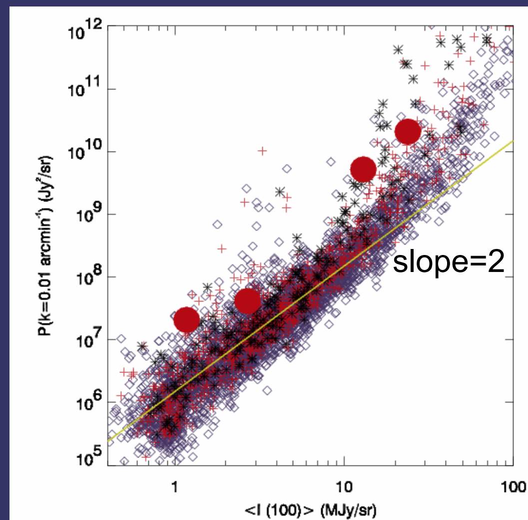
Spectral index vs $<I_{100}>$

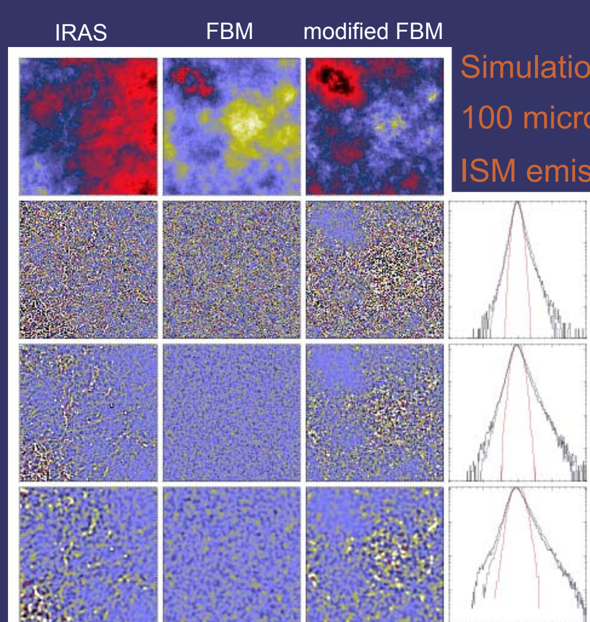
- β = -3.1 ± 0.3
- Decreases at large $<I_{100}>$: Galactic structure (?)
- Does not seems to agree with HI observations (~-3.6)
- Extinction / Dust temperature effect



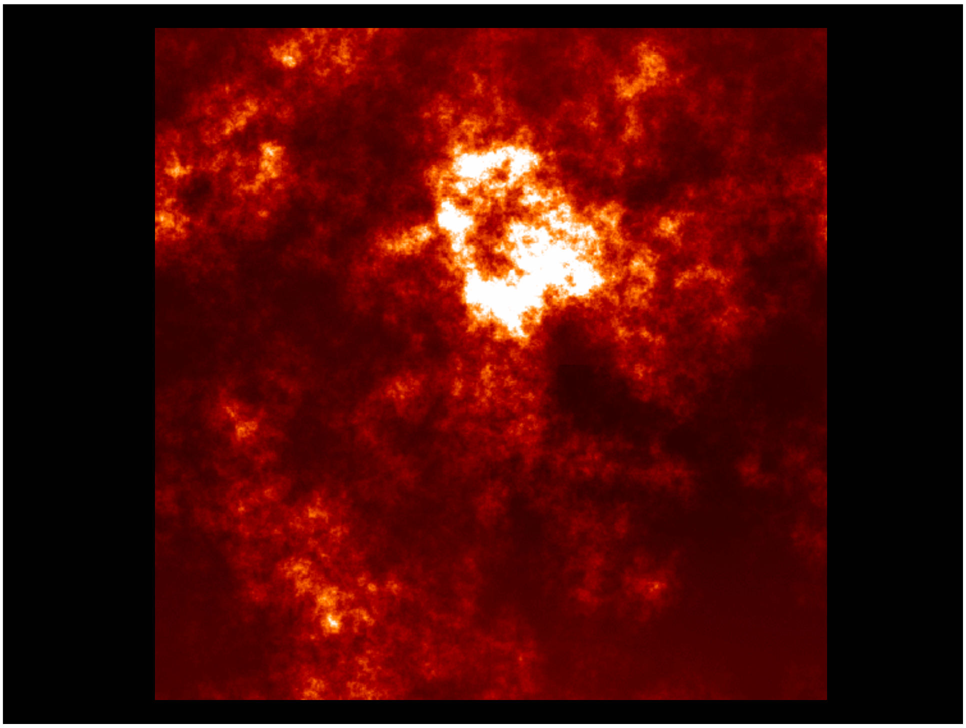
Normalisation vs $<I_{100}>$

- $P_0 \sim <I_{100}>^2$
- Multiplicative effect : density and/or ISRF variation



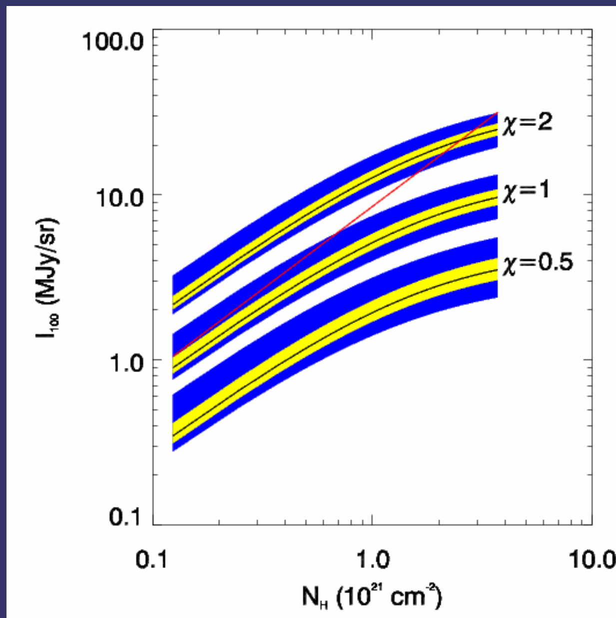


Simulation of 100 micron ISM emission.

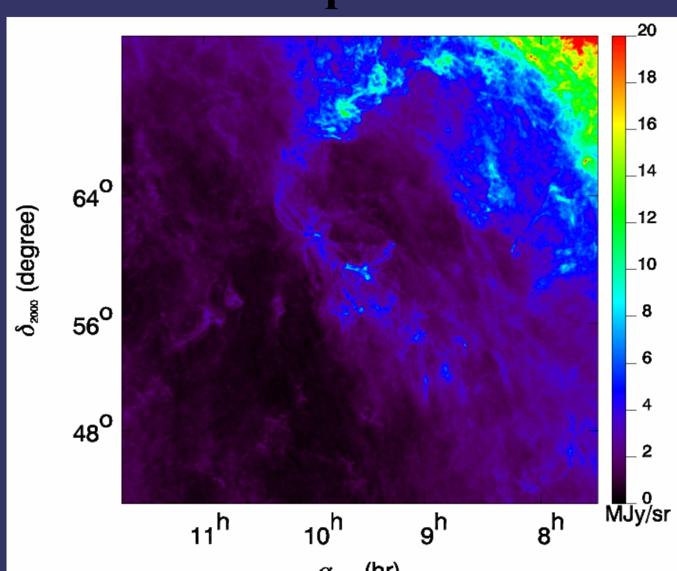


Variations of the statistical properties

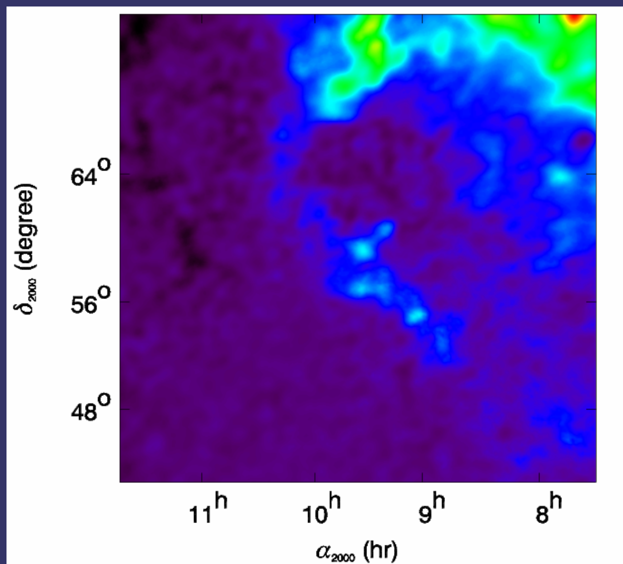
- Significant scatter of spectral index and normalisation
- 100 micron emission depends on:
  - Dust (gas) column density
  - VSG abundance (10-30 %)
  - Dust temperature
    - ISRF
    - Extinction curve (PAH and VSG abundance)
  - Dust emissivity (fractal agregates)



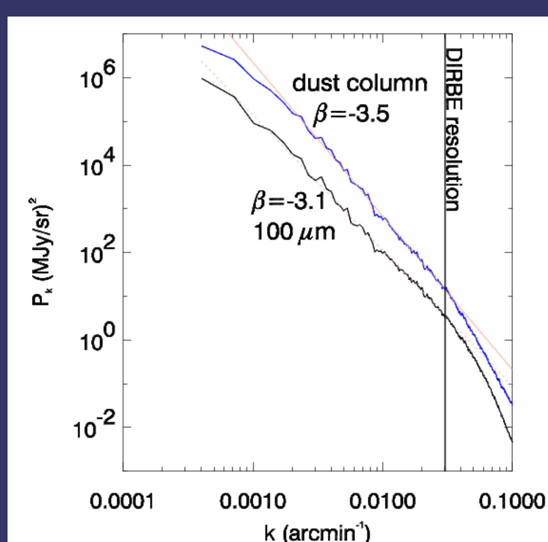
North Celestial Loop – 100 microns



100 microns temperature correction



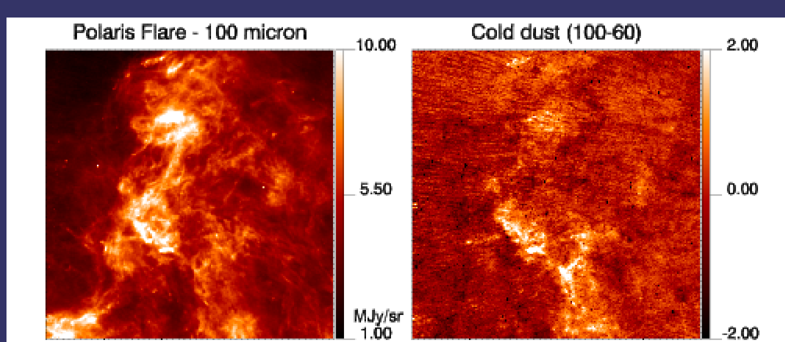
Power spectrum of 100 microns emission corrected for dust temperature



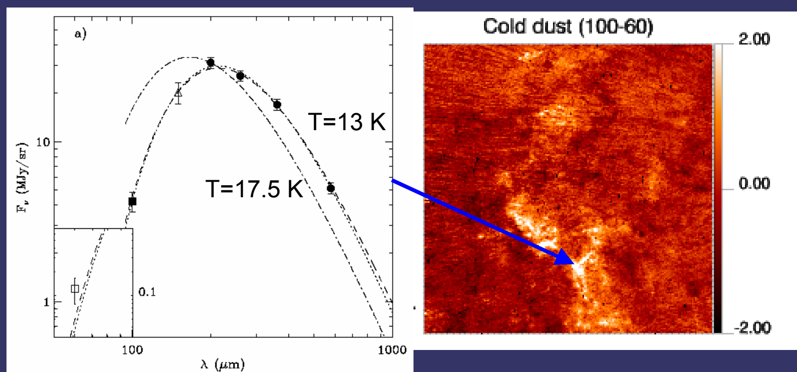
Importance of dust coagulation

- From ISOCAM we know that coagulation starts at Av~1. (Miville-Deschenes et al. 2002, A&A, 381, 209)
- A recent analysis of several high-latitude clouds (using dust emission/absorption model and radiative) shows that PAHs get depleted at n~600 cm^{-3}.
- Impact on extinction curve ? on dust temperature ? on the I100/N_H relation ?

Dust coagulation



Dust coagulation



PRONAOS observations of a diffuse cloud (Av<1)

Bernard et al., 1999, A&A

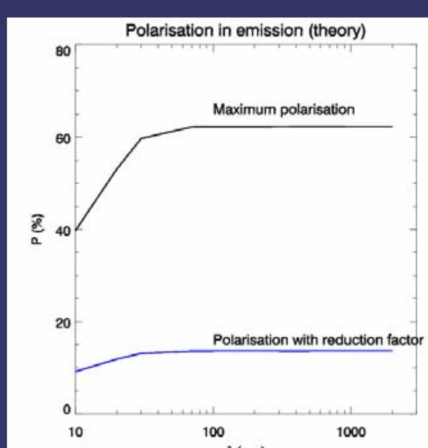
Planck specific issues related to the separation of dust emission

- Model of Schlegel/Finkbeiner for the dust emission has been fitted at the FIRAS resolution (7 deg) and is provided at a resolution of only 1.3 deg.
- Schlegel/Finkbeiner model seems fine for WMAP but Planck needs a higher-resolution description. A model using well calibrated IRAS data (must estimate the VSG contribution to the 100 micron band) and the Planck 350 micron band is probably the key.
- If the mm excess is due to small dust grain, large spatial variations should be expected even in cirrus clouds (ISOCAM and IRAS results)
- Dust emission variations are more important at small scales. This is where the physical evolution takes place (SIRTF, Herschel, JWST). Impact on high-l CMB emission (power spectrum and non-Gaussianity) must be understood.

Can we simulate polarized dust emission maps ?

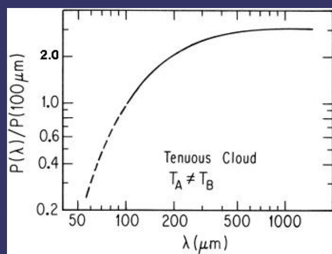
- At least, can we estimate what would be the polarization degree of dust at high latitude in the FIR ?
- Very important for component separation
- Polarized emission depends on
  - dielectric parameters of grain, shape
  - relative fraction of silicate and graphite grains
  - alignment efficiency
  - angle between the magnetic field and the line-of-sight (and its variation along the l.o.s.)

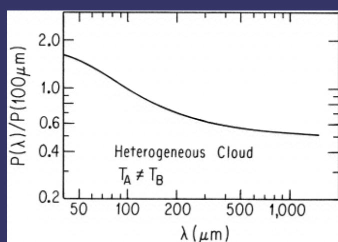
Estimate of polarization degree in FIR

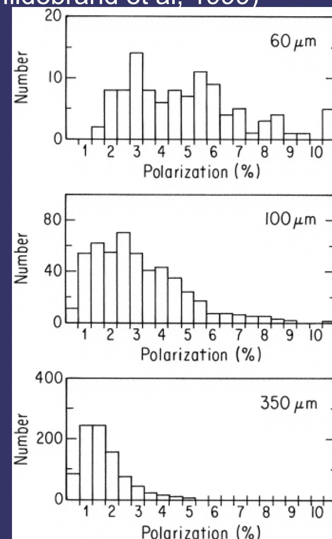


- Theory predicts constant polarisation degree (~10-15%) in the FIR/submm for aligned silicates
- Temperature difference between silicates and (non-aligned carbon grains) will introduce wavelength dependance

Observations of polarization emission in the FIR of molecular clouds (Hildebrand et al, 1999)

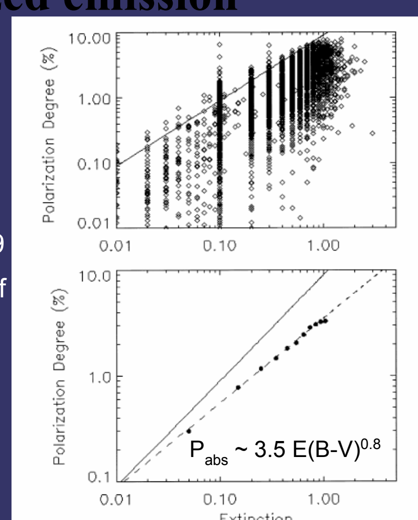






Simulate FIR polarized emission

- $P_{em}(\lambda) = P_{abs}(\lambda)/\tau(\lambda)$
- Use grain optical properties to estimate P_{em}(FIR) from P_{abs}(V) and E(B-V)
- First step: use SFD98 and FDS99 to estimate the power spectrum of dust polarization emission in the Planck bands
- 3D structure of Galactic magnetic field (depolarisation)



Fosalba et al, 2002

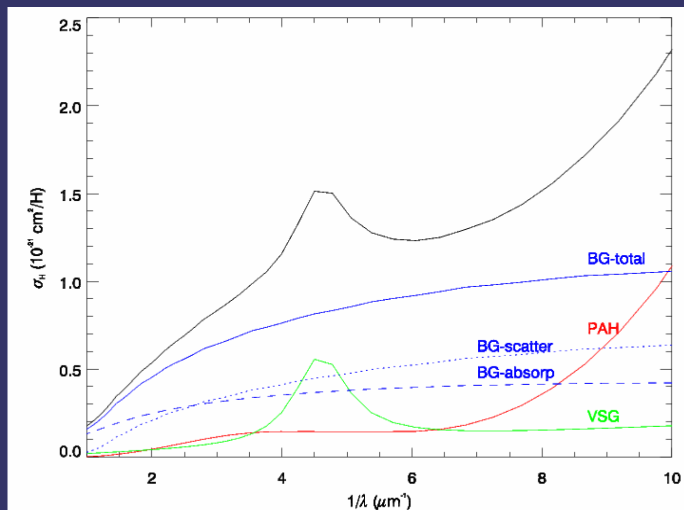
Conclusion

- Small-scale variations of dust properties (abundance, temperature, emissivity) are observed even in the diffuse ISM.
  - Planck will bring an important contribution to our understanding of dust
  - To achieve its sensitivity goal Planck needs surface : diffuse ISM must be much more understood than for WMAP.
- Analysis of dust statistical properties can help us to describe the 3D density structure of matter provided if we take into account extinction (dust temperature) variations.
  - Important for interstellar turbulence and gas/grain relation.
  - Important for component separation
- How do we simulate realistic dust emission maps in the Planck bands ?
  - what is the spectrum of dust emission and its polarization properties ?
  - what is the structure at small scale ?

And before Planck...

- Understand the properties of dust emission at small scales in the diffus ISM (SIRTF, ELISA).
- Study the nature of the mm excess emission (relation with small grains ?)
- Study dust polarized emission properties
- Make realisitic simulations of dust emission to test component separation methods
- Work on well calibrated/destriped IRAS maps at all wavelengths

extinction curve



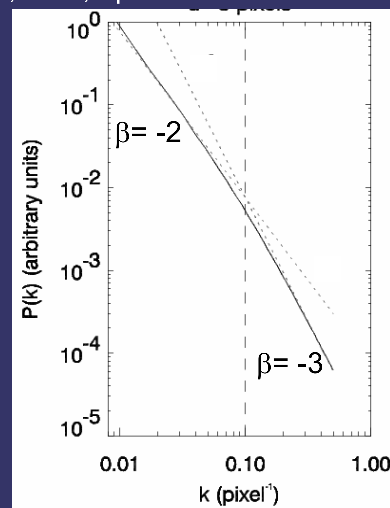
analyse/simulate polarized emission

- Depends on variation of dust temperature on the line of sight (ISRF, PAH/VSG abundance (coagulation), gas column density)
- Depends on relative abundance of silicate and carbon grains (difficult to determine from dust emission)
- Depends on the Galactic magnetic field structure

Projection effects on power spectrum

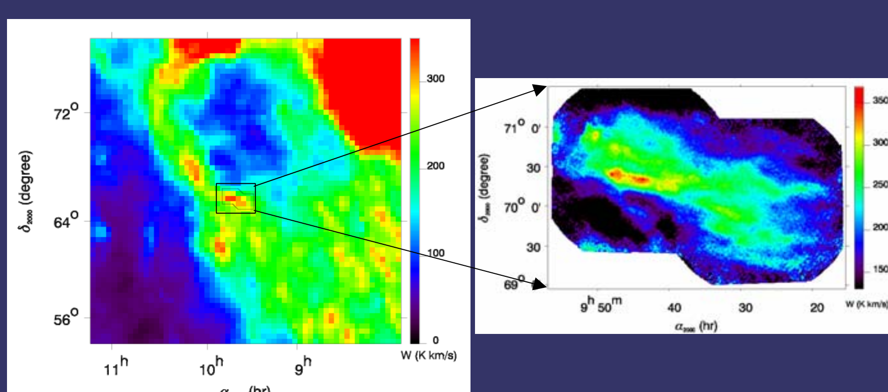
Miville-Deschenes, Levrier and Falgarone, 2003, ApJ

- For optically thin clouds
- Column density -> 3D density
- Centroid velocity -> 3D velocity
- depth > 2D scale : $\beta_{2d} = \beta_{3d}$
- depth < 2D scale : $\beta_{2d} = \beta_{3d} - 1$



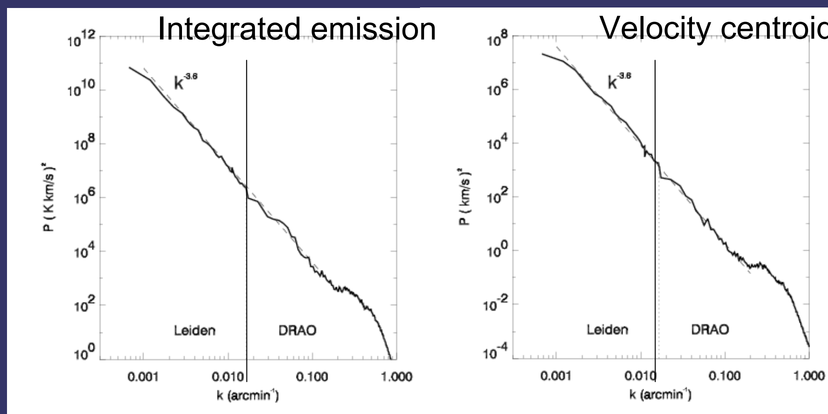
North Celestial Loop – 21 cm

(l=140, b=40)



Power spectrum of the high latitude HI

Miville-Deschenes, et al., 2003, A&A



Result : spectral index = -3.6±0.2

Compatible with Kolmogorov (-3.66)

From 0.1 to 30 pc