Galactic dust emission in the Planck perspective

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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

\[ P_{\text{ism}}(k) = P_0 \, k^{-3} \] (Gautier et al., 1992)

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

\[ P(k) = B(k) \ast [P_{\text{ism}}(k) + P_{\text{cib}}(k) + P_{\text{ps}}(k)] + N(k) \]

Miville-Deschenes, Lagache, Puget, 2002, A&A
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 $<I_{100}>$

- $\beta = -3.1 \pm 0.3$
- Decreases at large $<I_{100}>$ : Galactic structure (?)
- Does not seems to agree with HI observations ($\sim 3.6$)
- Extinction / Dust temperature effect
Normalisation vs $\langle I_{100} \rangle$

- $P_0 \sim \langle I_{100} \rangle^2$
- 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 aggregates)
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 $A_V \sim 1$. (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 $n \sim 600 \text{ cm}^{-3}$.

- Impact on extinction curve? on dust temperature? on the $I_{100}/N_H$ relation?

Dust coagulation
Dust coagulation

PRONAOS observations of a diffuse cloud \((A_v<1)\)
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
Simulate FIR polarized emission

- $P_{\text{em}}(\lambda) = \frac{P_{\text{abs}}(\lambda)}{\tau(\lambda)}$
- Use grain optical properties to estimate $P_{\text{em}}(\text{FIR})$ from $P_{\text{abs}}(V)$ 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)
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 diffuse ISM (SIRTF, ELISA).
- Study the nature of the mm excess emission (relation with small grains?)
- Study dust polarized emission properties
- Make realistic simulations of dust emission to test component separation methods
- Work on well calibrated/destriped IRAS maps at all wavelengths
extinction curve

- 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

analyse/simulate polarized emission
Projection effects on power spectrum


- 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