Planck, Herschel and ISM (+ radio)

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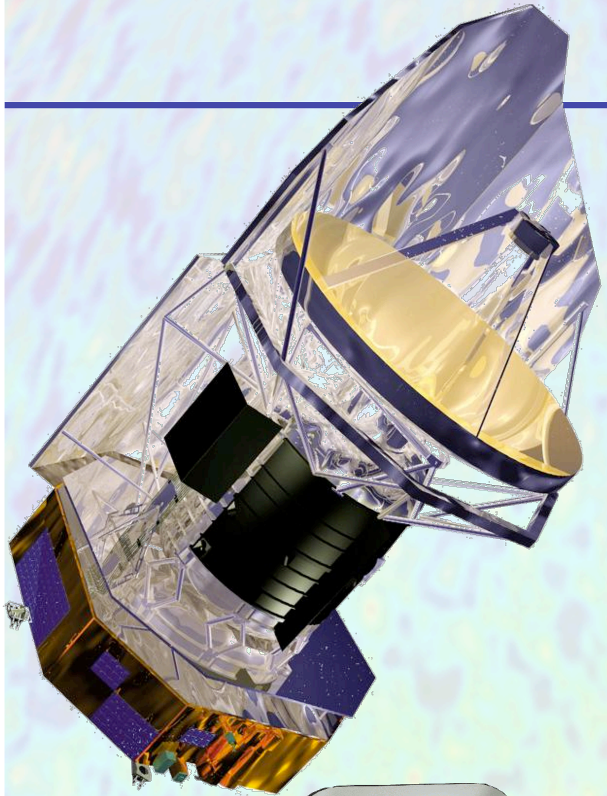
- Planck/Herschel
- Dust Emission (thermal & spinning)
- Dust emission complications vs component separation

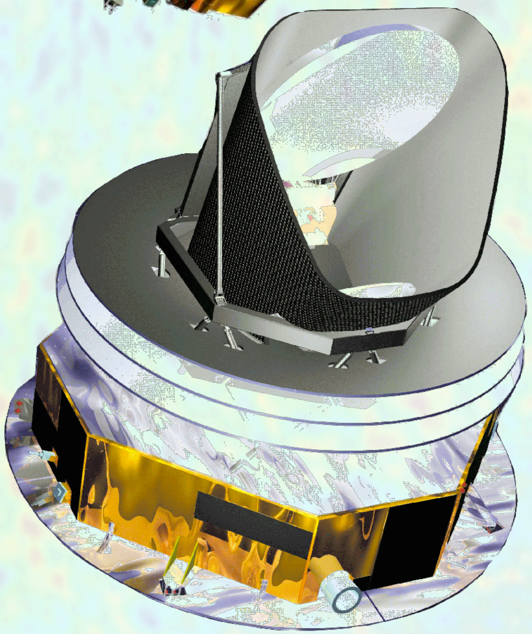
Planck & Herschel

★*Launched Mai 14th 2009*



Herschel :

PACS: 70, 100, 160 μm
SPIRE: 250, 350, 550 μm
Resolution: from 9-13” (PACS) 18”-36” (SPIRE)
Dedicated observations of some large regions of the sky (e.g. SAG3/SAG4, Hi-Gal, Heritage, …)
Component separation is a major concern for CIB studies



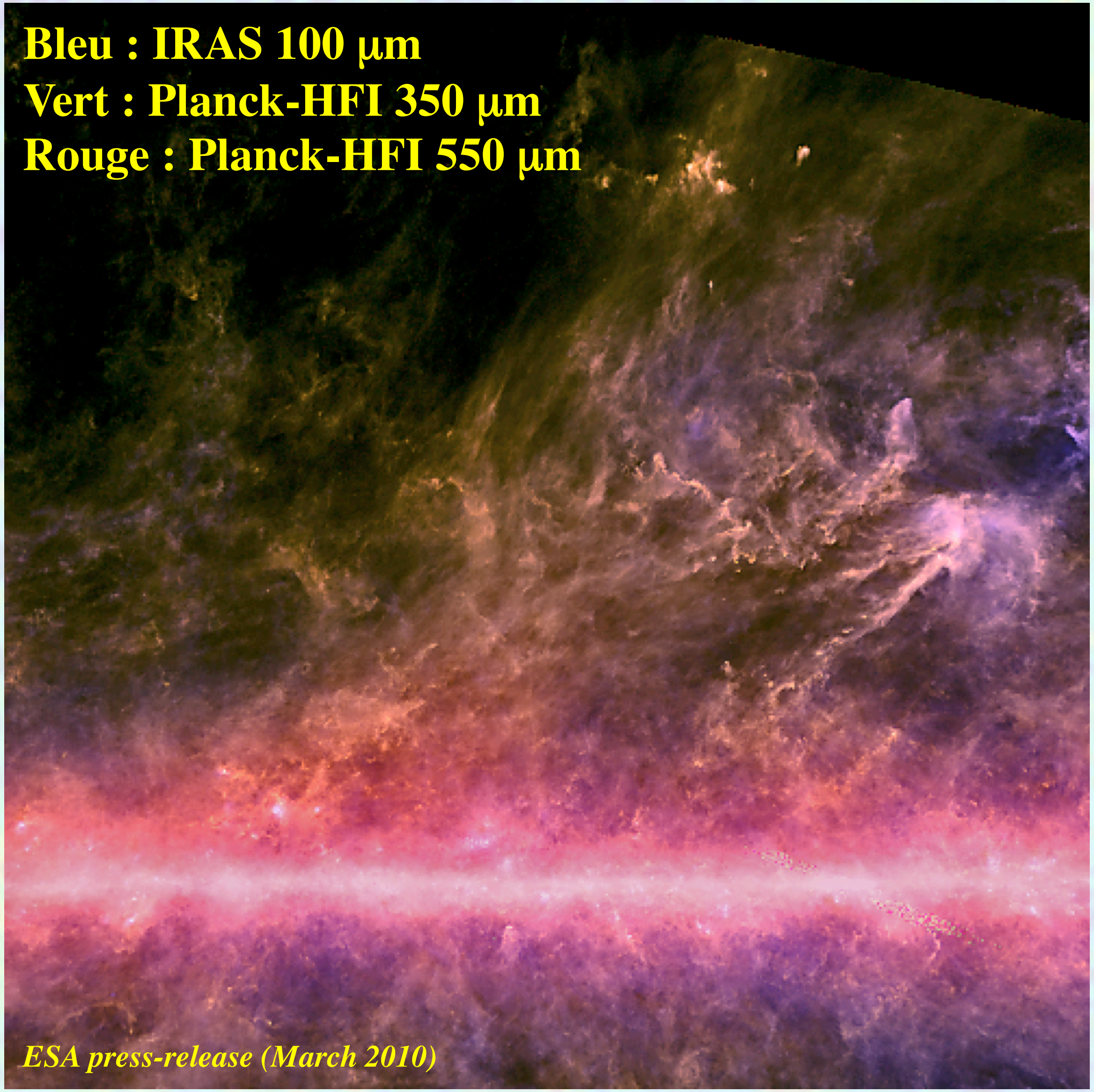
Planck :

HFI: 350, 550, 850, 1300, 2000, 3000 μm
LFI: 4285, 6818, 10000 μm
Resolution: from 5’ to 30’
All sky survey (already achieved 99%)
Component separation is a major concern for CMB studies

Already very good cross calibration on diffuse emission (+-15%)

Planck: First results

Planck data still under embargo …



- **Planck works perfectly**
- **1[er] sky survey completed**
- **All-sky determination of dust temperature at 5'**
- **Likely to lead to a complete reanalysis of IR (IRAS) data.**
- **Variations of dust submm emissivity with T and λ …**
- **Excellent results in polarization, will allow detailed study of dust and B structure (local and MW).**

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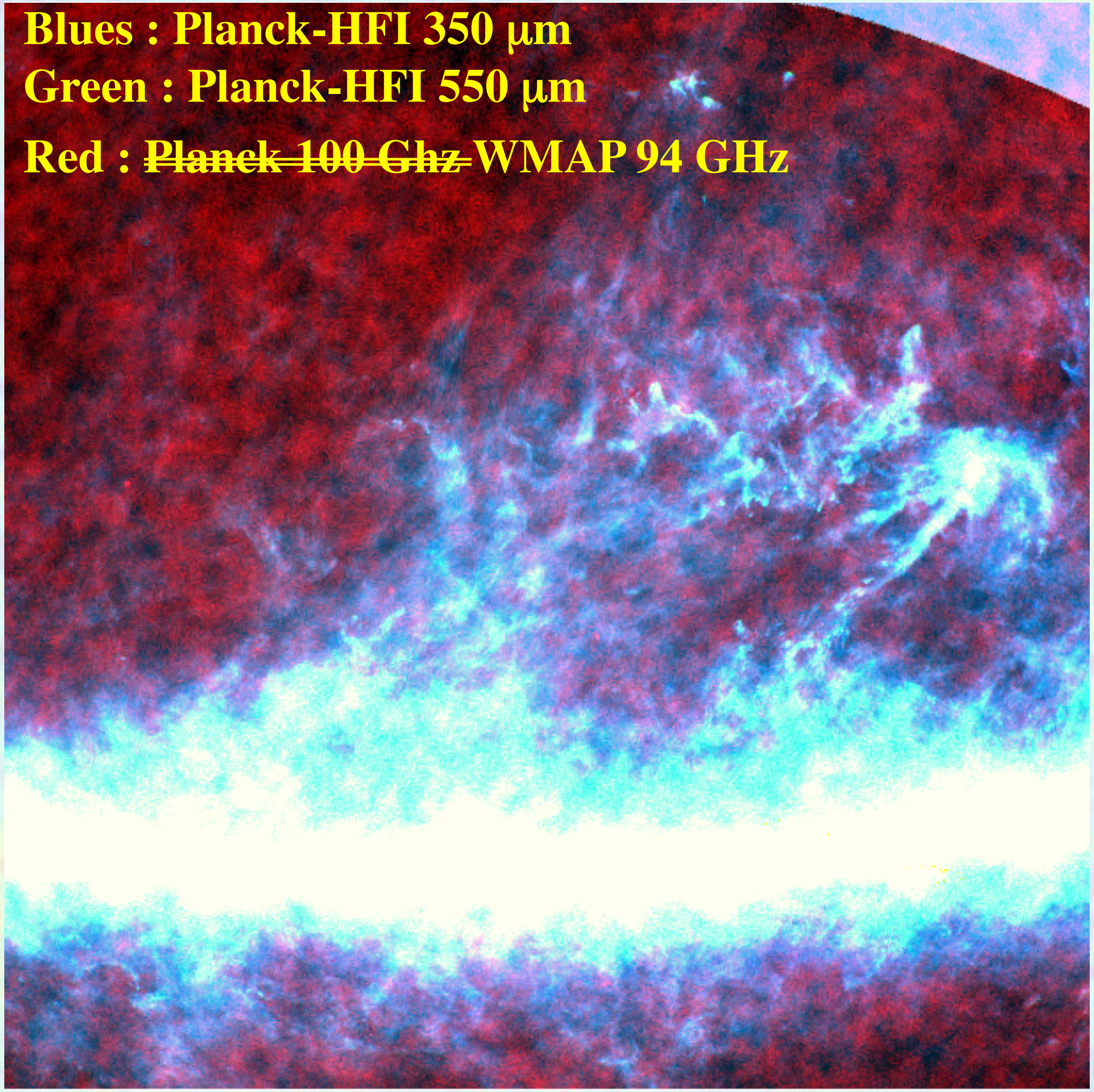

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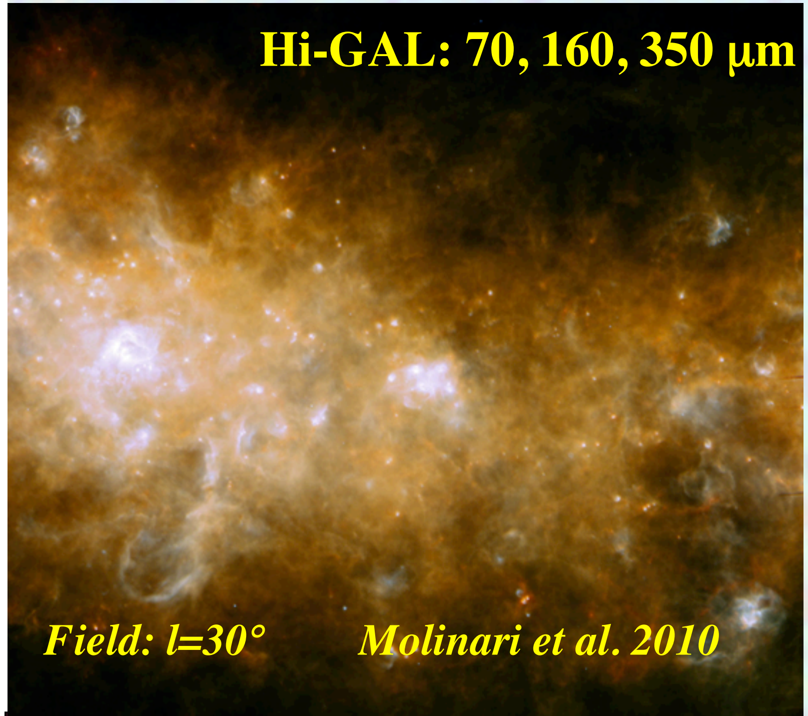
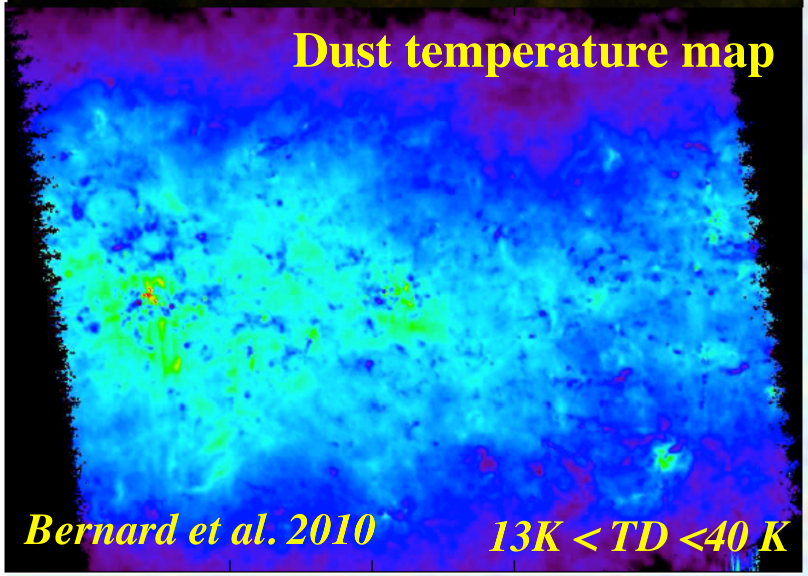
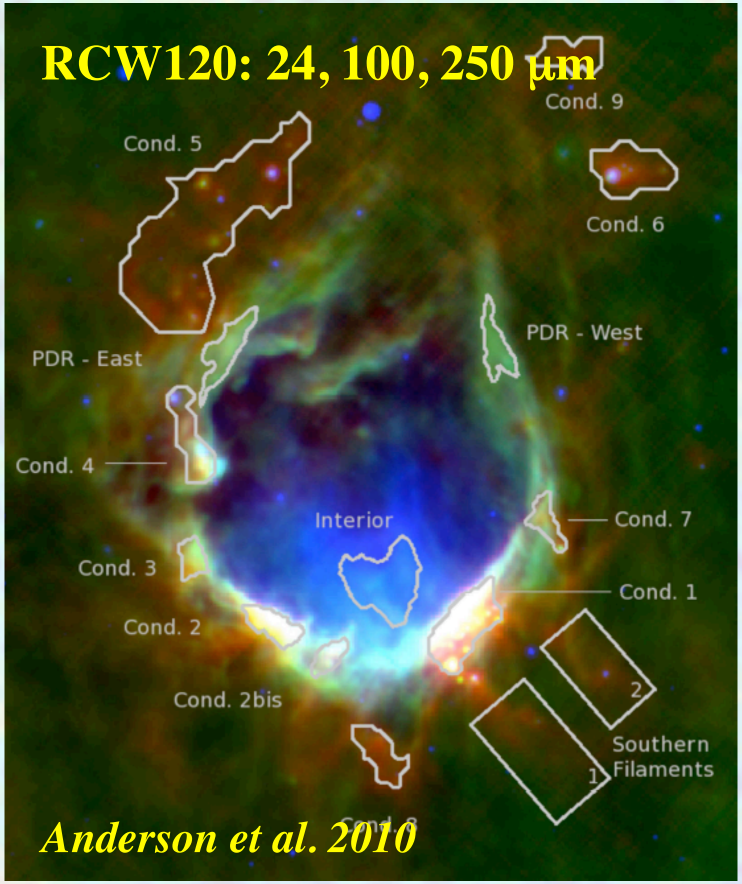
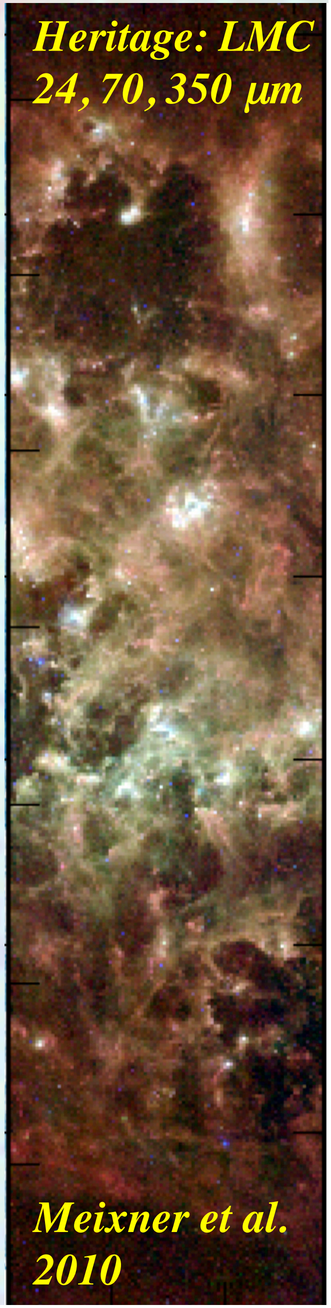
Herschel: First results





- Herschel is a fantastic machine to measure the emission by thermal dust emission
- In particular, the dust temperature
- Cold-cores
- Star formation regions
- distant galaxies, CIB





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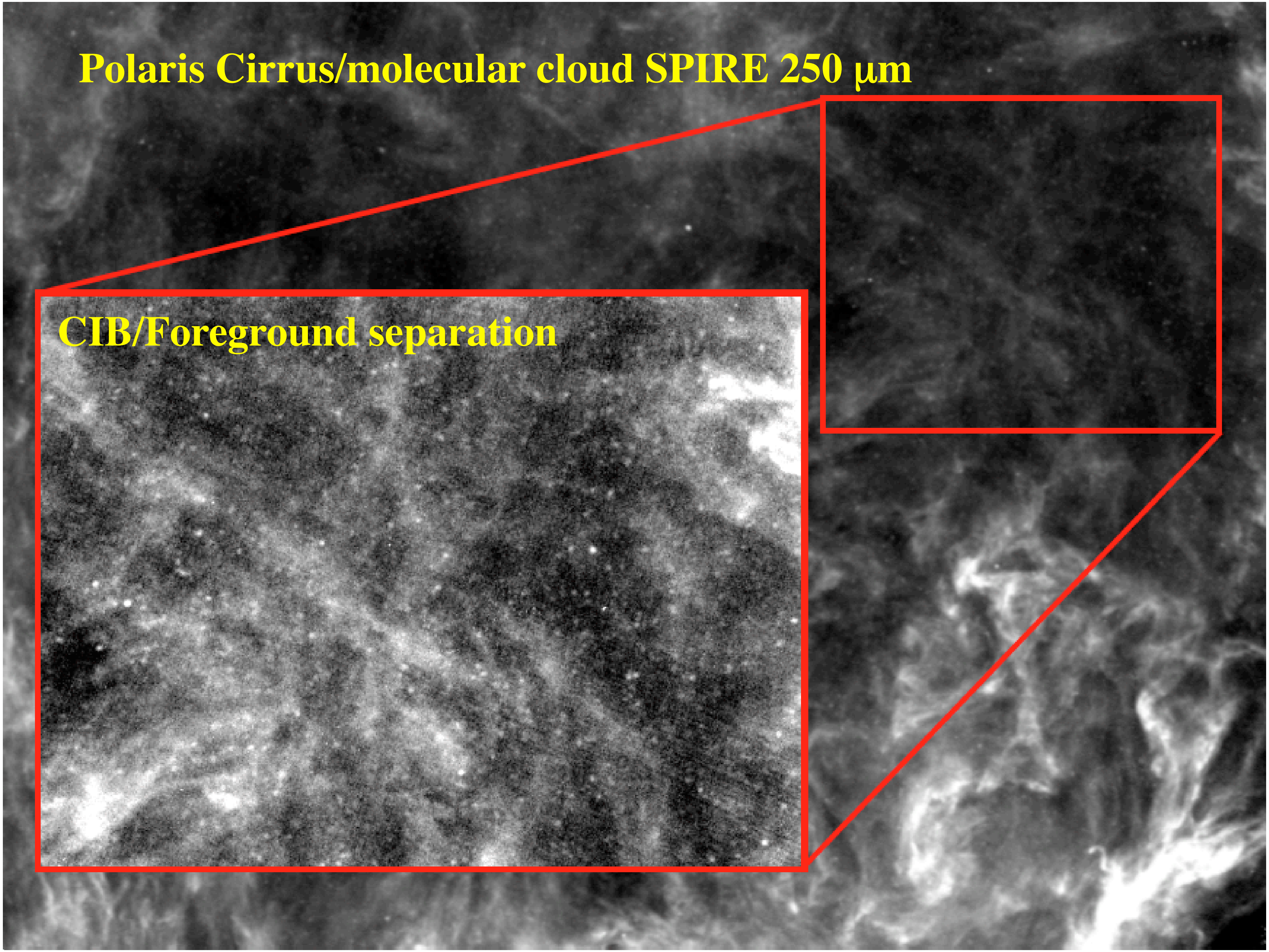
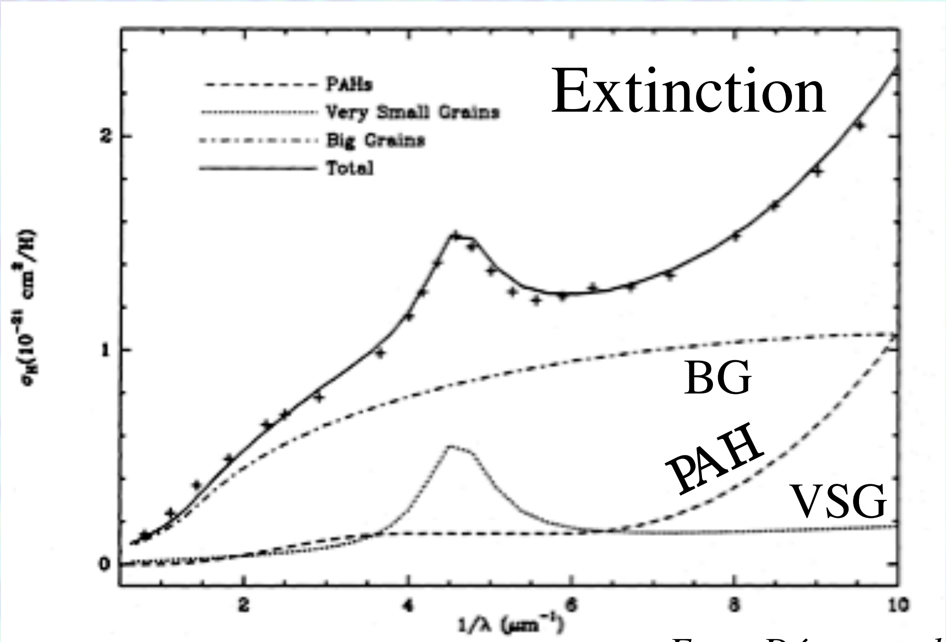
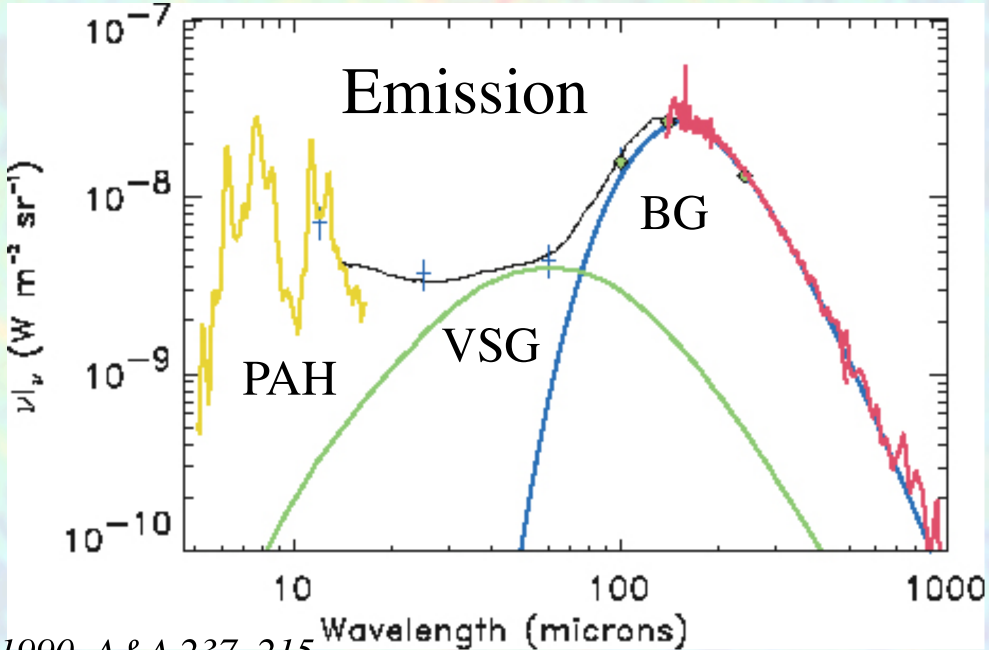

Polaris Cirrus/molecular cloud SPIRE 250 μm
CIB/Foreground separation

Extinction & Emission

Dust re-emits the energy absorbed in Vis-UV under the form of IR radiation





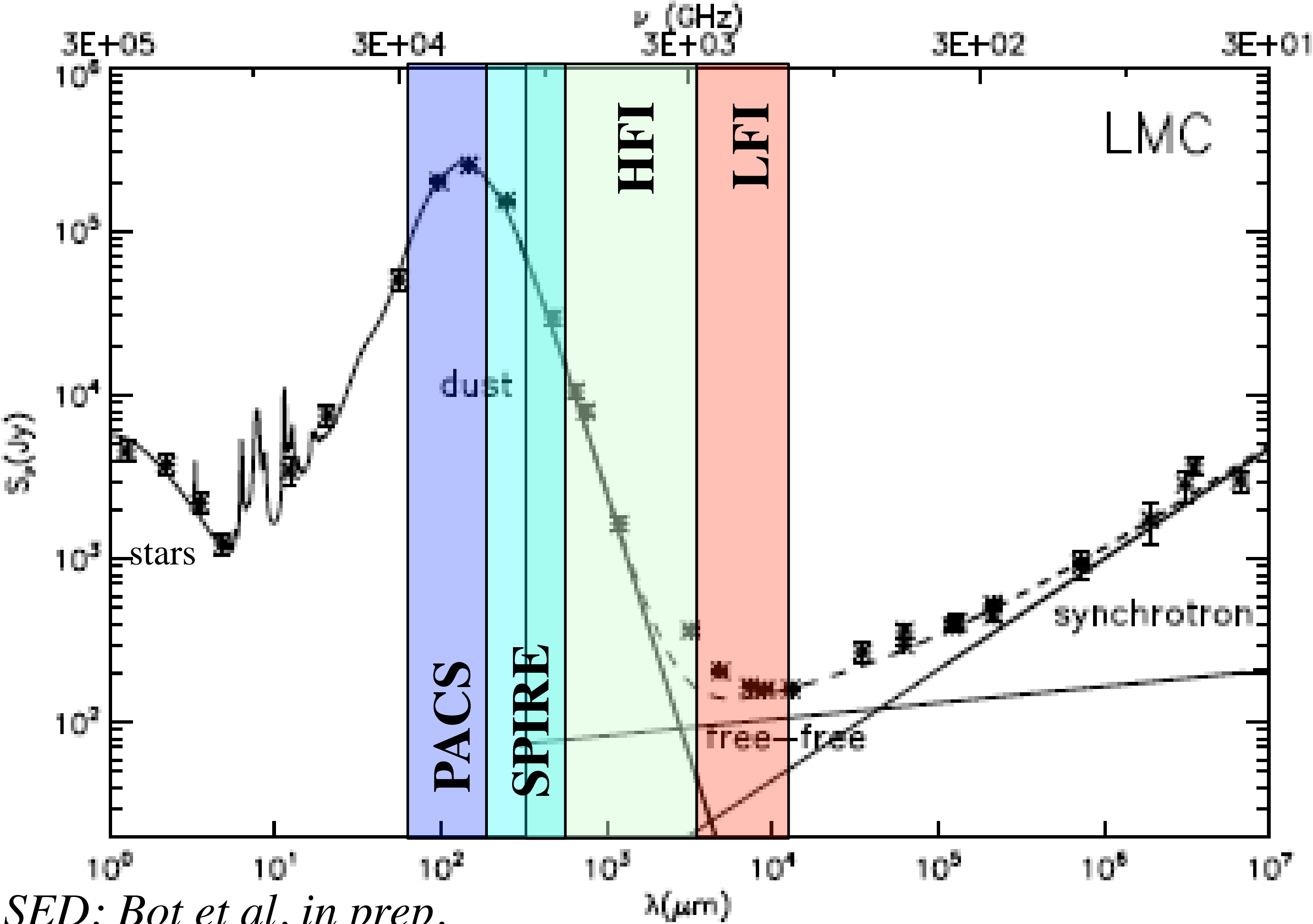
From Désert et al 1990, A&A 237, 215

Composition: From gas depletion, grains mostly made of C, Si, Fe, Mg …
Extinction curve implies existence of graphite (2200 A bump)
Absorption at 10, 20 μm implies existence of Silicates
NIR features indicates PAH (Polycyclic Aromatic Hydrocarbons)

Sizes: Extinction & emission require a large size distribution n(a) α $a^{-3.5}$ (MRN)
sizes must range from 0.005 μm < a< 0.1 μm

Herschel & Planck vs ISM SED

Herschel and Planck are most sensitive to thermal dust emission



SED: Bot et al. in prep.

Emission: General considerations

Dust emission on a given line of sight always depends on :

- Quantity of gas (N_H)

- Dust abundance (X_d)

- Emissivity of the dust (ε)

- Intensity of the ISRF

These 4 quantities are likely to change along the LOS and dust emission only gives access to the integrated product

$$I_\nu \propto \int_{LOS} \varepsilon \times N_H \times X_D \times ISRF$$

We will see that there is an important difference between emission by small dust and large dust particle's emission:

As small particles emit out of equilibrium, the apparent temperature (ie, the spectral shape) of their emission hardly depends on the intensity of the ISRF, while that of large grains will change with ISRF intensity.

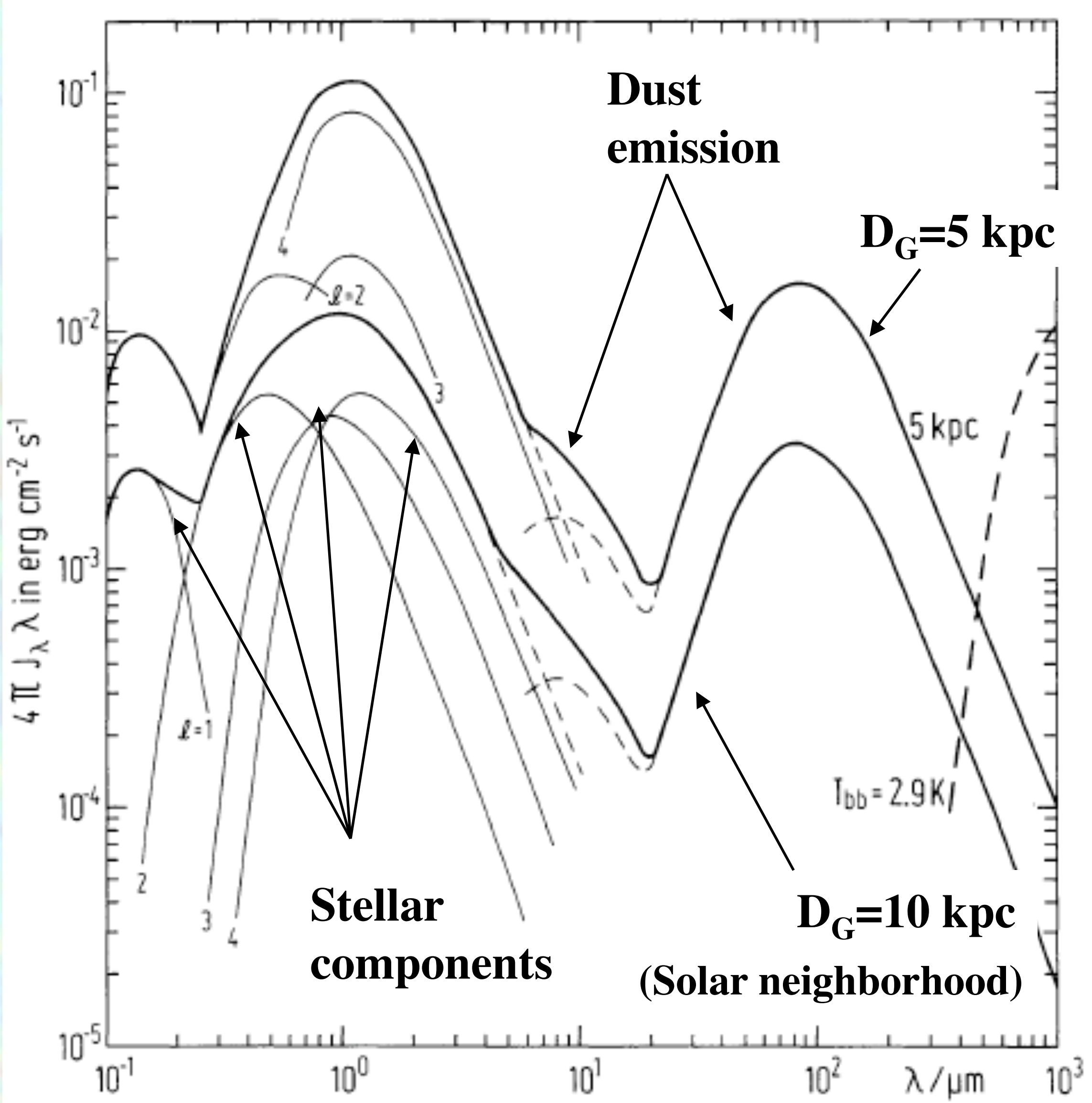
Emission: ISRF

Mathis, Mezger & Panagia 1983

Computed the Spectral Energy Distribution of the Interstellar Radiation Field (ISRF) as a function a distance from the galactic center

This estimate at 10 kpc still serves as the reference ISRF in the solar vicinity in many dust models.

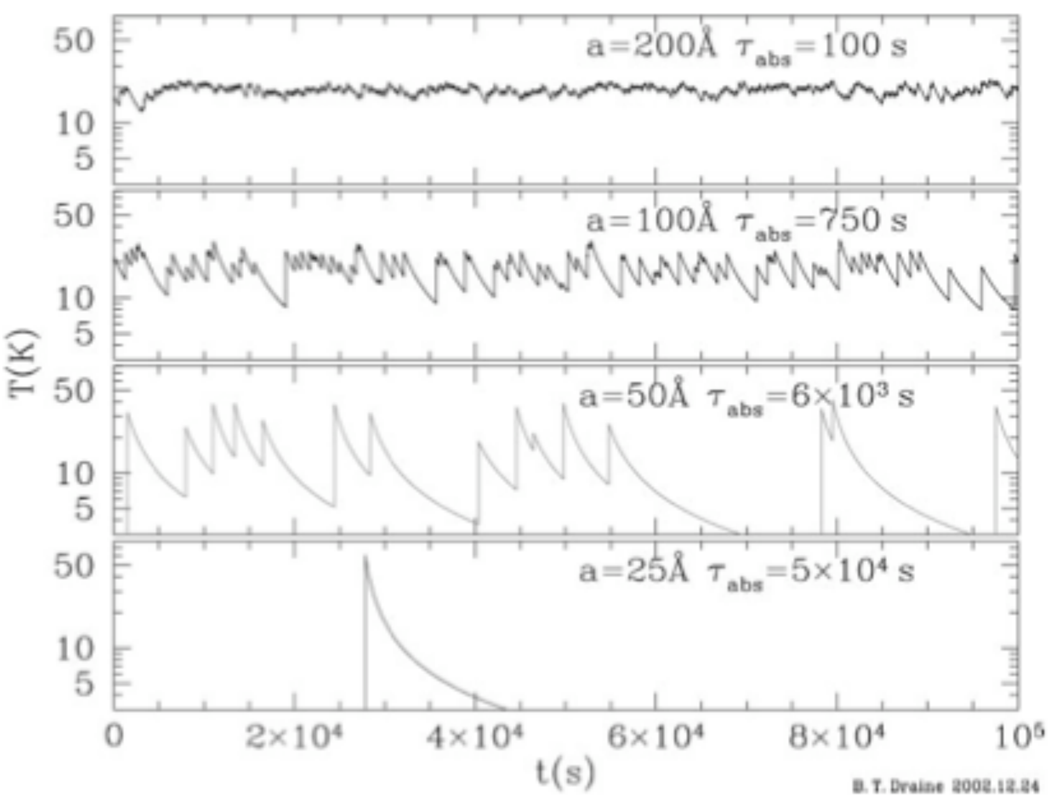
The local ISRF intensity defines $X_{ISRF}=1$



Emission: PAH & VSG

In the solar neighborhood ISRF (X_{ISRF}=1) a PAH with a=25 Å (Nc=700) will absorb one UV photon every 13 hrs or so. It will radiate the energy in about 1 s. Larger particles will absorb photons more often, but will actually be colder (because of higher C_v) and will radiate in the same time scale.

So, what we see is the collective emission of <u>transiently heated particles</u> emitting one at time and spending most of their time being "cold"



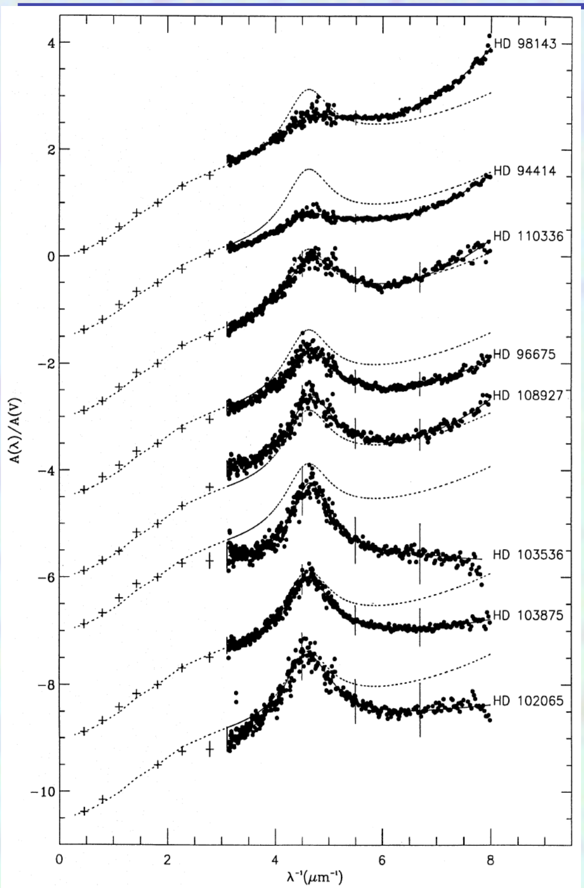
PAH

VSG

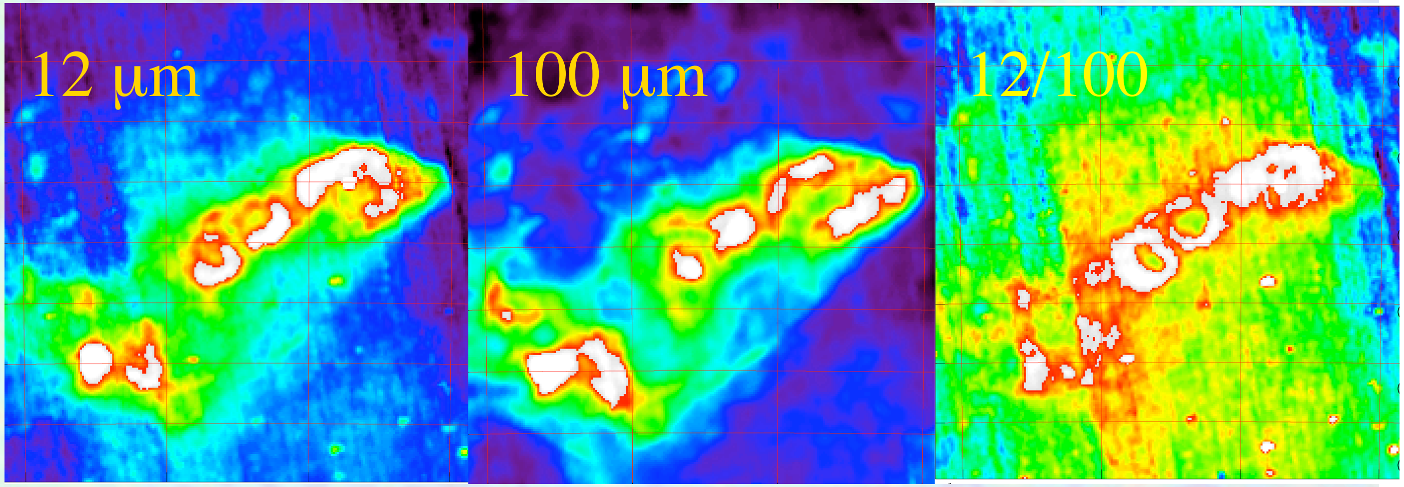
Evolution of the PAH and VSG vibrationnal temperature with time

From Draine Ann Rev. 2003, 41, 241

Spatial variations of small dust



• The Visible part of the extinction curve (dominated by BG) is fairly stable
• However, there are substantial spatial variations of the shape in the UV (Bump, FUV rise): PAH and VSG
• Emission indicates large variations of PAH abundances (by factors of up to 10) within dense, translucent and diffuse clouds.



It is therefore likely that the abundance of small dust particles varies (aggregation, destruction, etc …) while that of BG appear more stable:
BG are more reliable tracers of the ISM than small grains.

Emission: thermal dust (BG)

The grain emission spectrum is that of a grey body with a power-law emissivity :

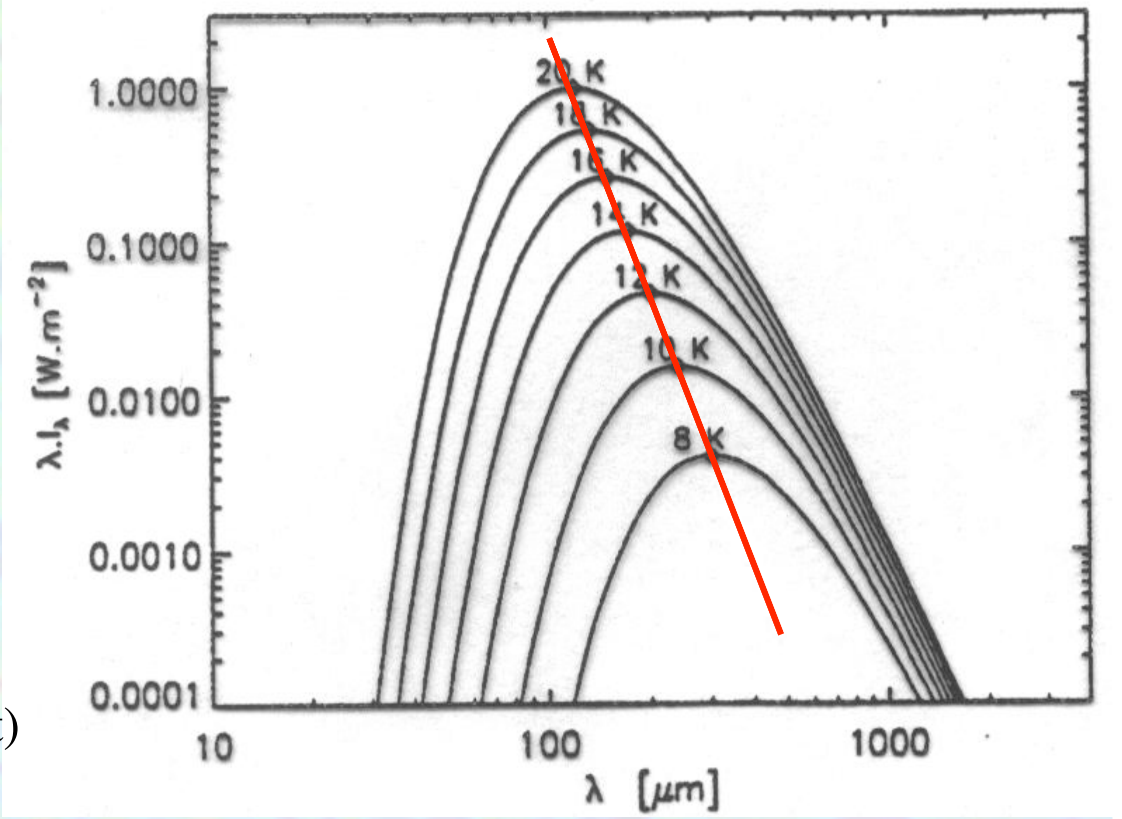
$$I_\nu = N_{grain} \pi a^2 Q_{abs}(\lambda_0) \left(\frac{\lambda}{\lambda_0}\right)^{-\beta} B_\nu(T_d) \qquad B_\nu(T) = \frac{2h\nu^3}{c^2} \frac{1}{\exp(h\nu/kT) - 1}$$

Maximum of emission at : $\lambda_{max} = 118\,\mu m \left(\frac{T_d}{17.5\,K}\right)^{-1} \frac{7}{\beta + 5}\mu m$ (Wien displacement law)

Rayleigh-Jeans limit (mm):
When $h\nu \ll kT_d$ (at very long
Wavelengths):
$B_\nu(T) = 2k/c^2\nu^2 \propto 1/\lambda^2$

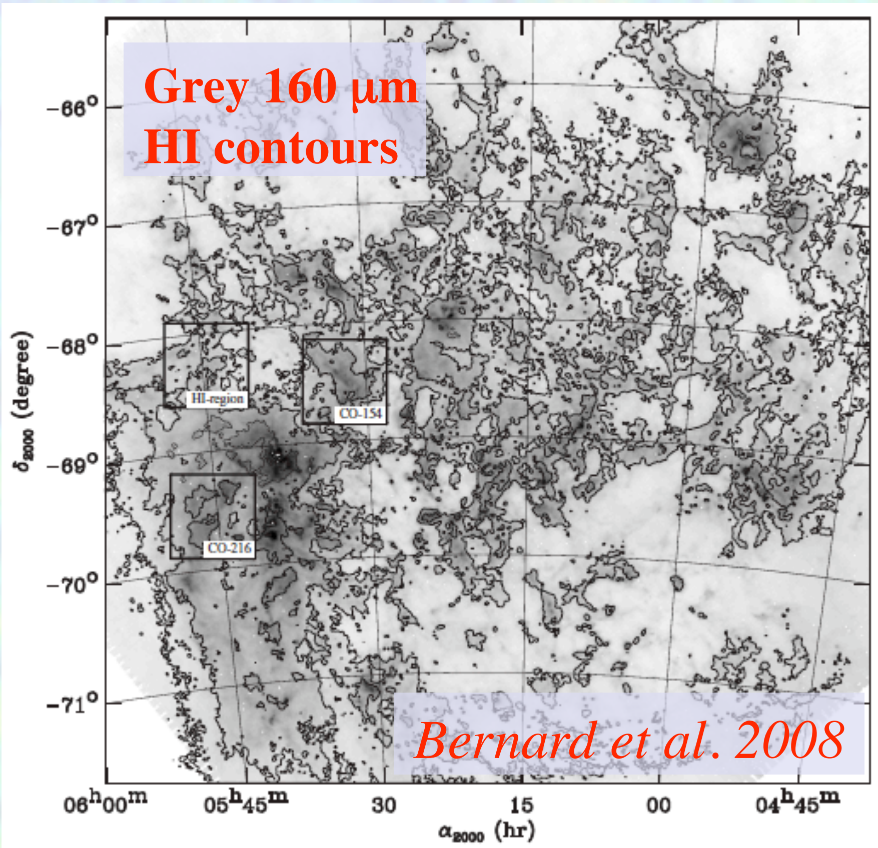
so, in the millimeter:
$I_\nu \propto T$ (good: N_H determination)
$I_\nu \propto 1/\lambda^{2+\beta}$ (bad: very steep !)

warm emission is blue, cold is red
(counter intuitive to most)
warm emission is always brighter than
cold emission (astronomers tend to forget)

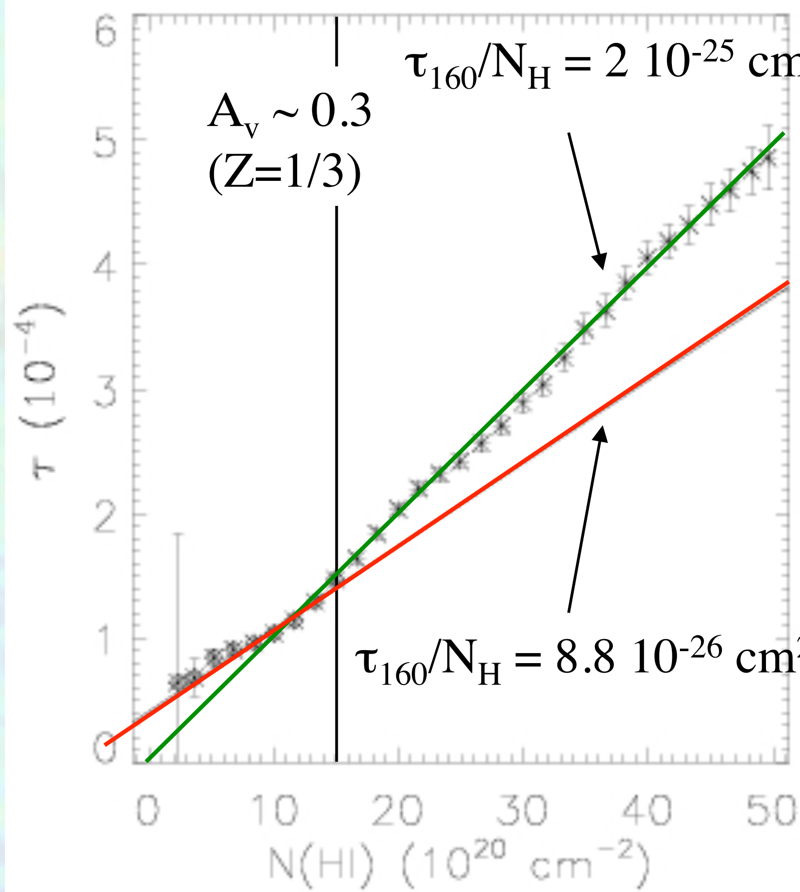


FIR optical depth vs gas

Very tight IR/HI correlation



τ_{160} vs N_H^{obs} correlation is not linear

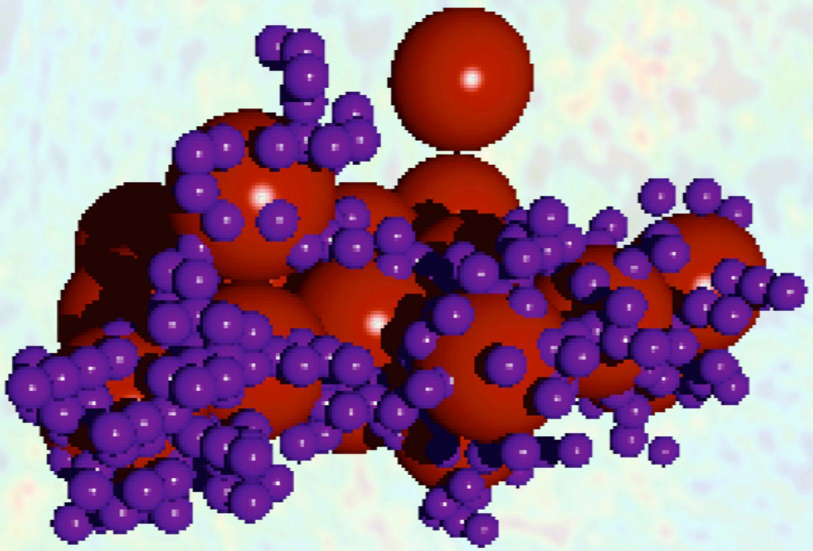


An additional gas component is needed to explain the observations (e.g. pure H_2 or thick HI), which is potentially as massive as HI itself

Similar conclusion in SMC (Leroy et al. 2007) and MW (Grenier et al. 2005)

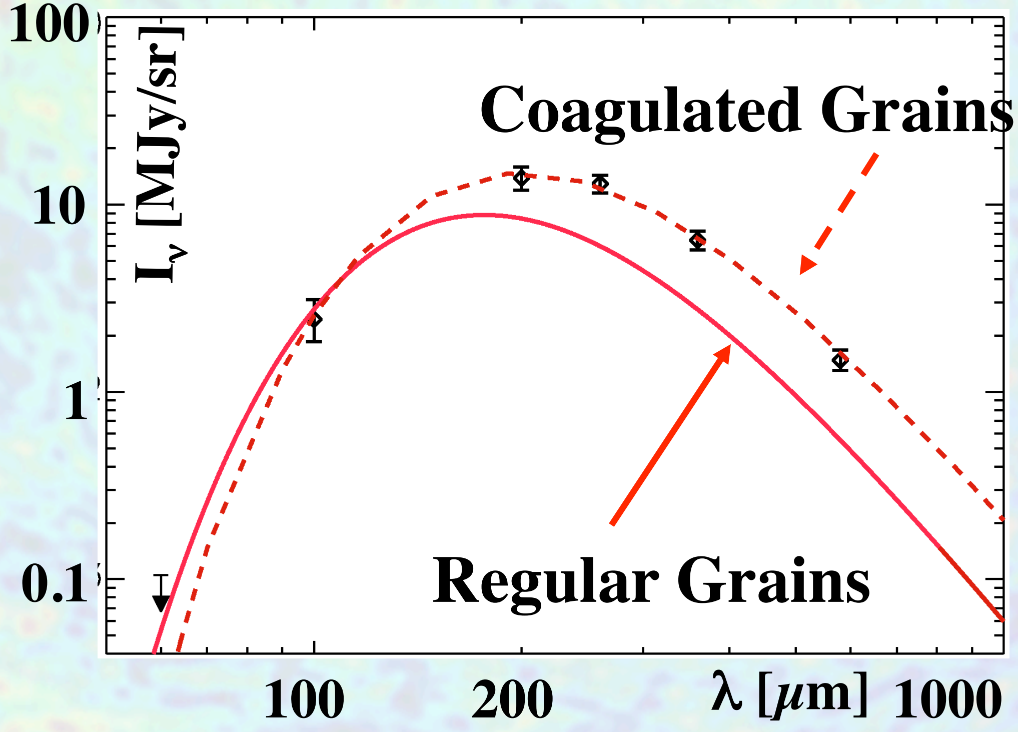
Dust Aggregates

- Dust aggregation was evidenced in the Pronaos data (Polaris, Taurus)
- Coagulation des gros et des petits grains
- fractal dimension ~2, N_{grains}>20
- 80-100% of small grains included in the aggregates (60 µm deficient)



Bernard et al. 1999, A&A 347, 640
Stepnik et al. 2003, A&A 398, 551

DDA Model



Dust in space is Amorphous (sorry)

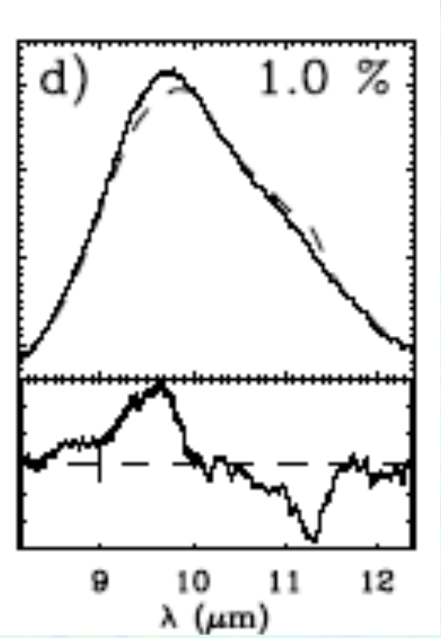
Kemper et al. 2004 :

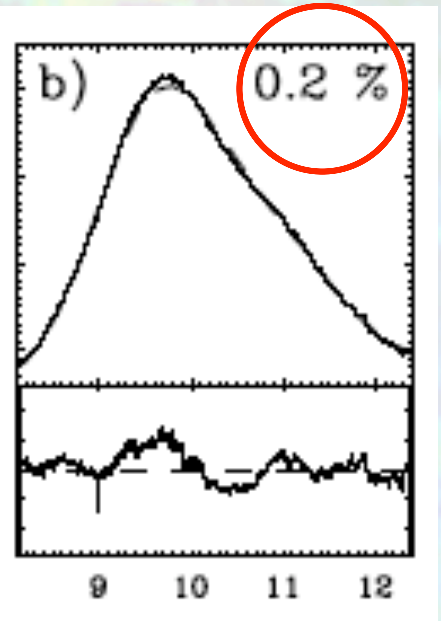
• Using absorption toward SgrA* observed by ISO

• Managed to separate the ISM absorption from source emission in the silicate feature

• Showed that the vast majority of the silicate dust in the diffuse ISM is amorphous

• The derived degree of crystallinity is only 0.2% !!





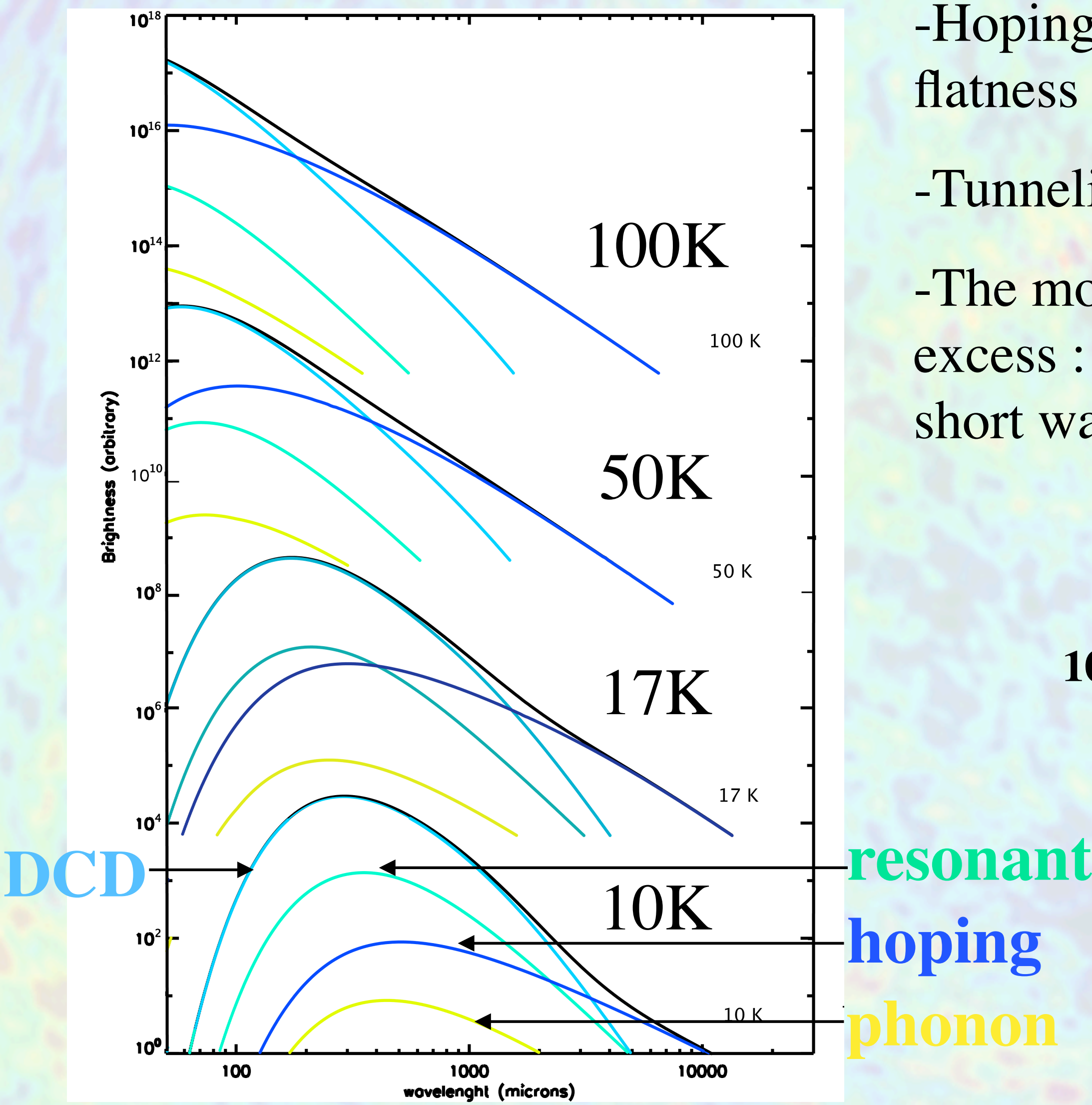
Kemper et al. 2004

Amorphous silicate

Crystalline silicate

“Two Level System” Predictions

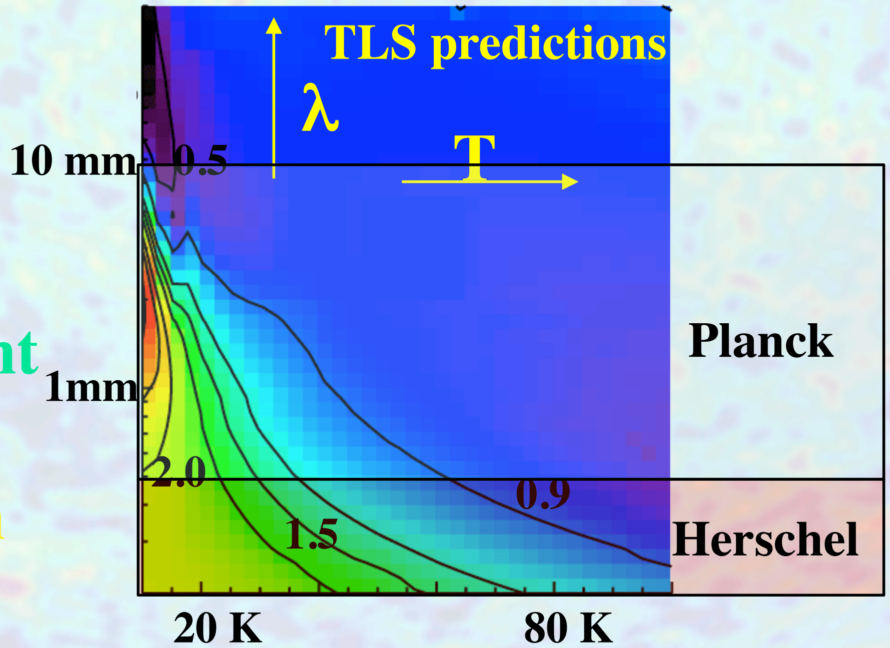
Spectral Shape evolution with temperature for amorphous grains



-Hoping effect explains the mm excess and the flatness of the spectrum at highest T

-Tunneling effect assisted by phonon negligible

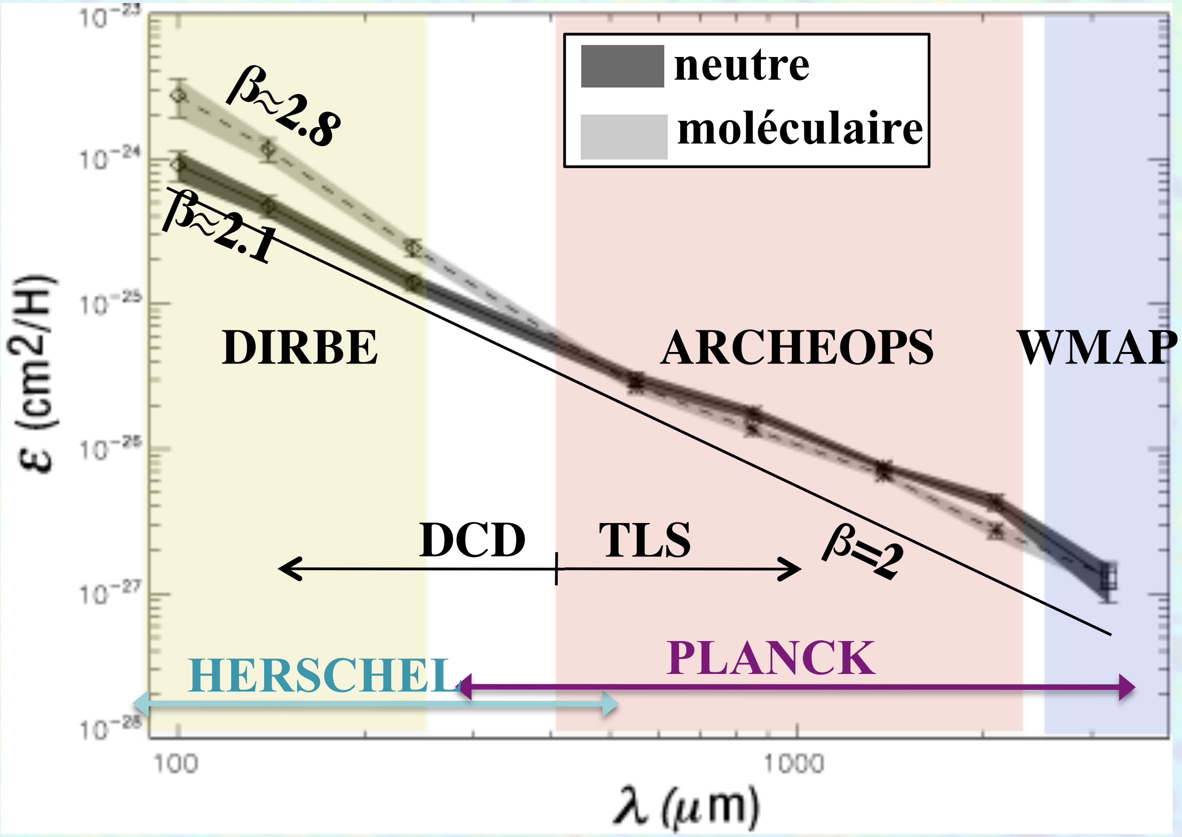
-The model predicts the evolution of the mm excess : Increases with T and moves up towards short wavelengths



Evidences for aggregation/TLS

Statistical study of molecular clouds colder than their neutral surrounding *Paradis et al. 2009, A&A 506, 745*

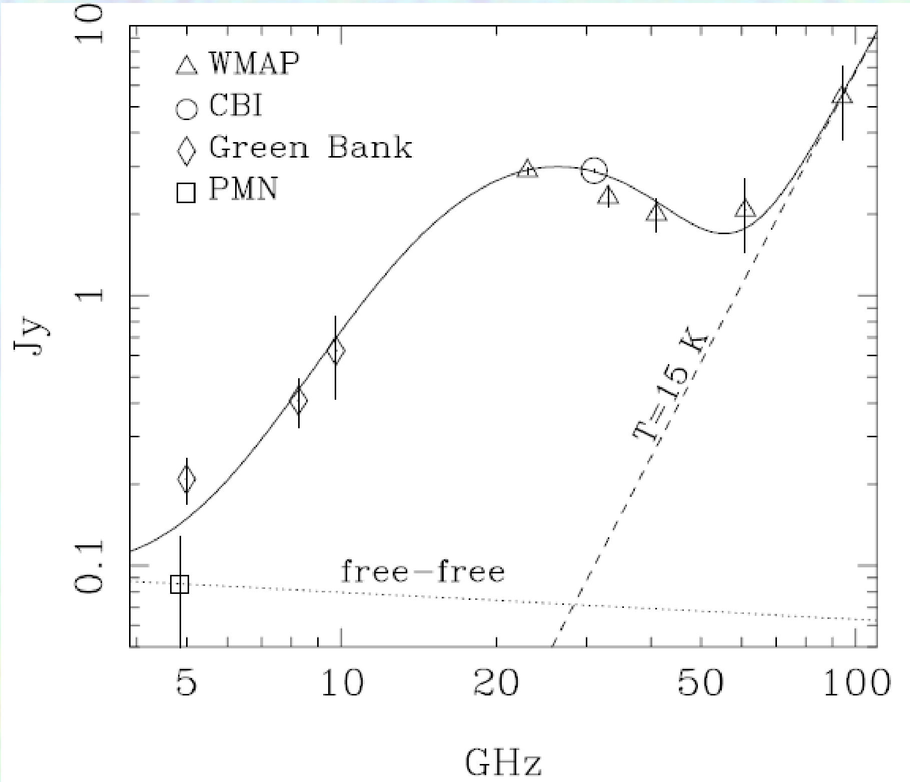
- First direct measurement of $\tau(\lambda)=I_\nu/B_\nu(T_D)$, through T_D determination
- Flattening of $\tau(\lambda)$ à λ>500 µm : TLS in amorphous materials
- τ increase at λ<500 µm (factor 3) : Aggregation
- Possible interaction between aggregation (λ<500 µm) and TLS (λ>500 µm) …



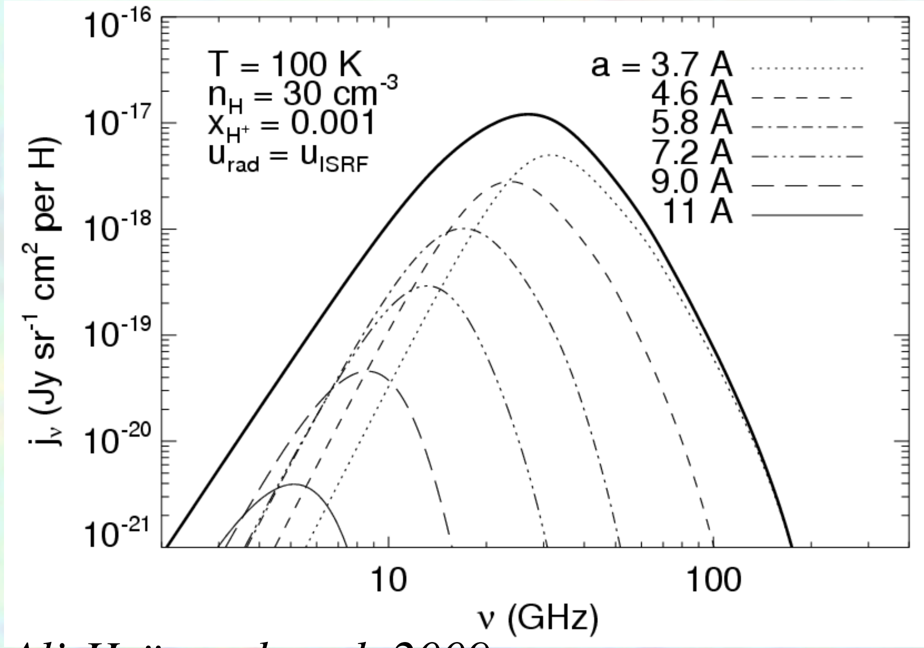
This is complications for component separation
May not appear everywhere (will see with Planck/Herschel)

Anomalous Emission (Spinning Dust)

A strong excess is observed around 20 GHz which cannot be explained by thermal dust emission, free-free or synchrotron



Casassus et al., 2006, ApJ, 639, 951



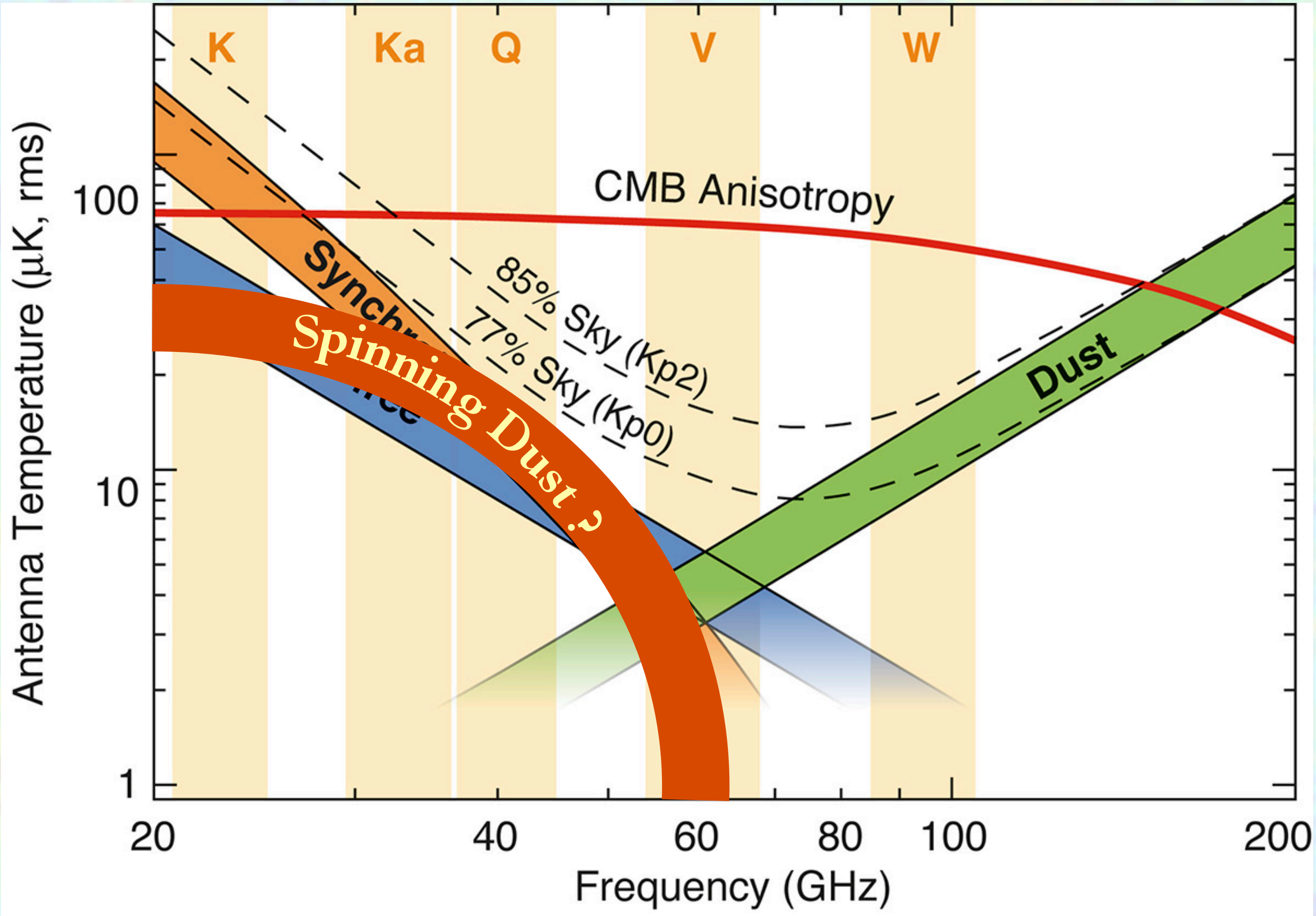
Ali-Haïmoud et al. 2009

Small grains rotate faster than large grains: They dominate spinning dust emission

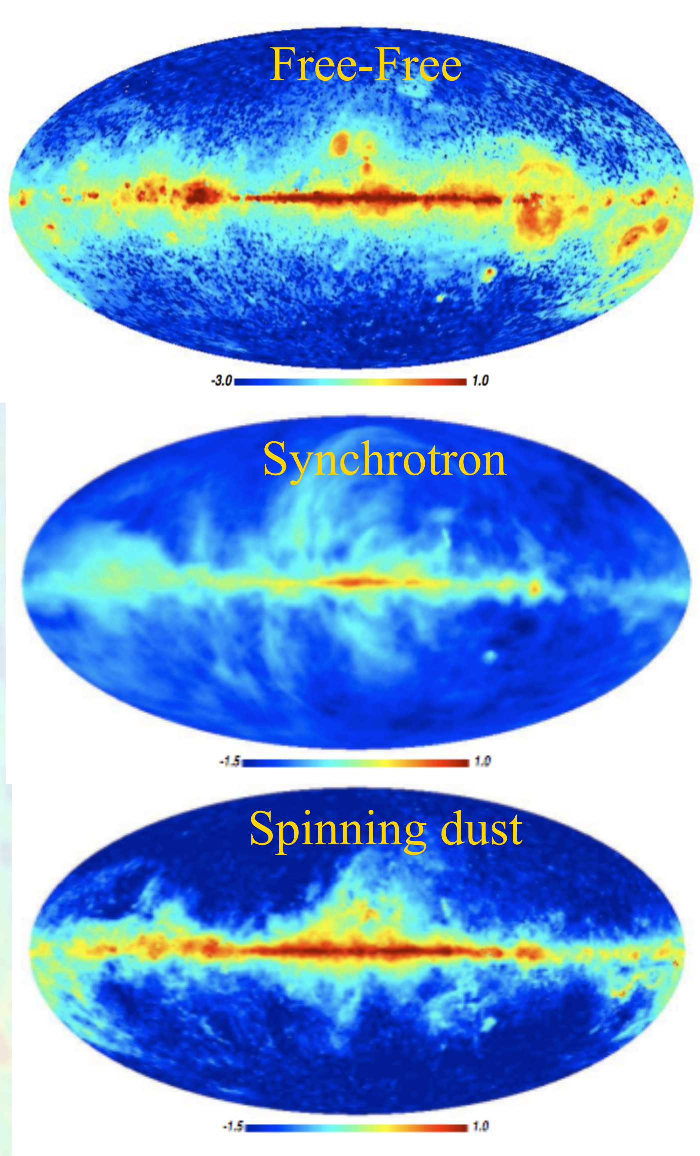
J=I x ω **J=cste**

Anomalous Emission & CMB

Spinning dust is an additional foreground in front of the CMB
It is likely due to PAH: spatial variations is a problem
Similarity in shape with Synchrotron is a problem
Unlike synchrotron, spinning dust is expected unpolarized



Anomalous Emission & CMB



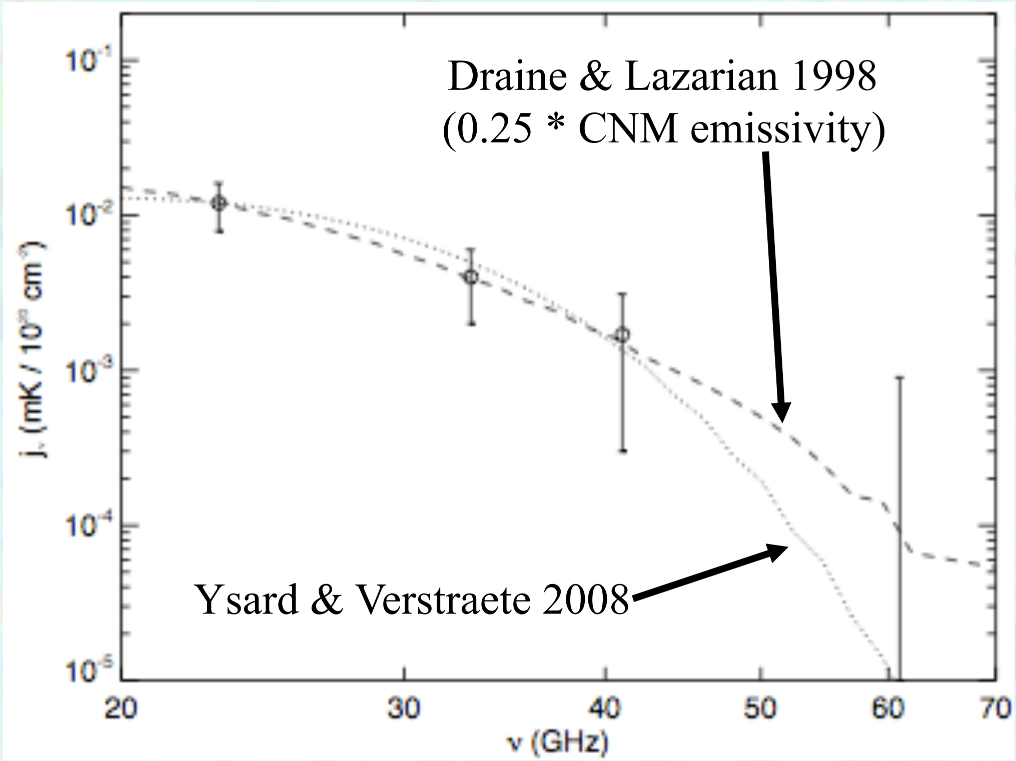
Mivilles-Deschenes et al 2008

Results of the polarization approach

It confirms that

- A significant fraction of the 20 GHz emission is not Synchrotron, in particular in the MW plane
- The spectral shape and spatial distribution is consistent with spinning dust models

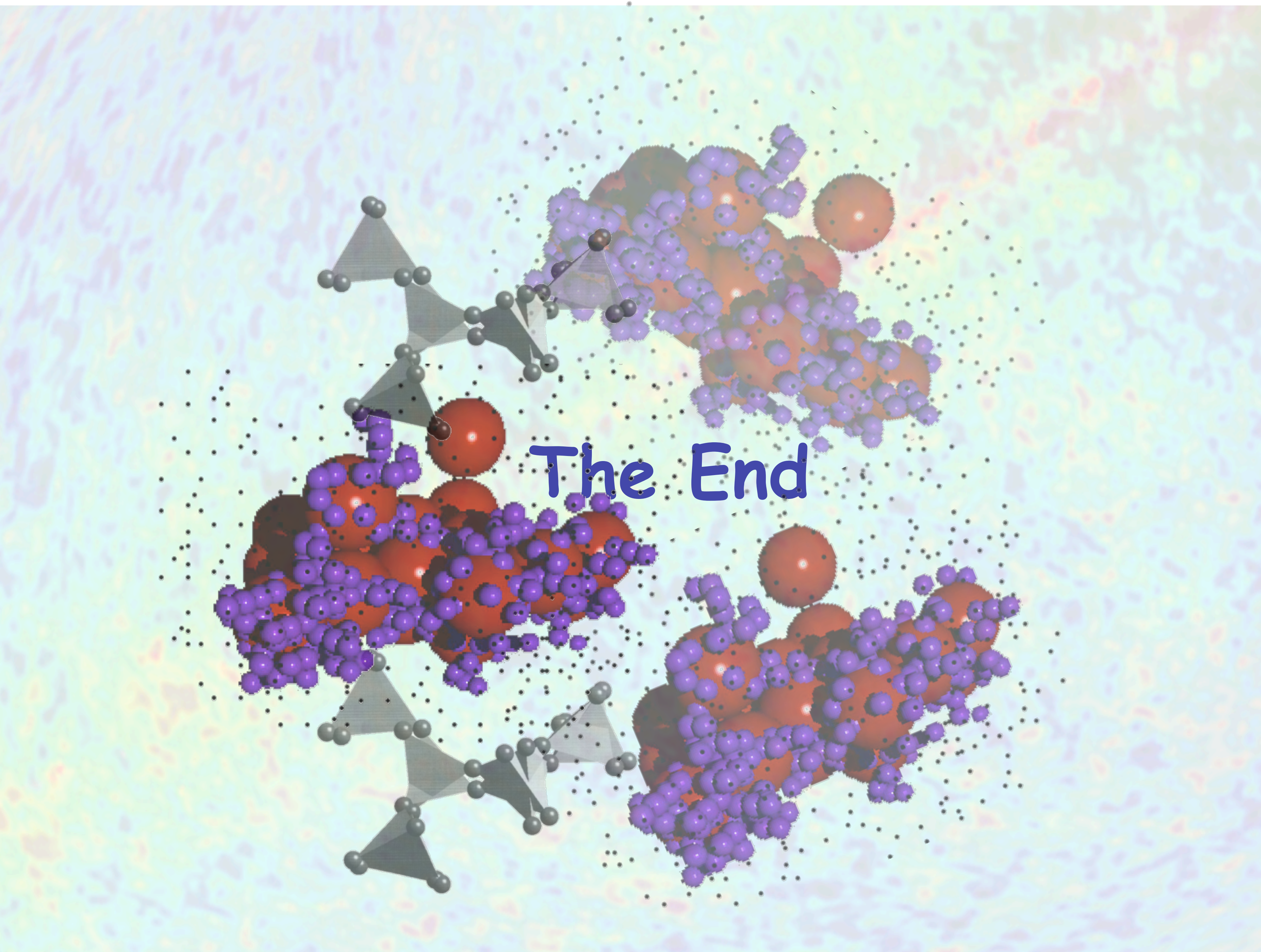
Derived spectrum of anomalous emission



Summary

° Thermal dust emission is the galactic foreground for CIB studies
° Thermal & spinning dust emission are major foregrounds for CMB studies
° Thermal dust emission is in principle easy to extrapolate to CIB/CMB λ
° However, there are complications to be taken into account:
- Dust aggregation in molecular regions (increases emissivity)
- Modification of long-λ emissivity due to amorphous nature (TLS: $\beta(T,\lambda)$)
° Spinning small dust is a real problem, because of spatial variations !
° Planck and Herschel will uniquely contribute to
- Understand dust physics
- Qualify separation methods

° Polarization (of importance only for CMB):
- Thermal dust emission weakly polarized
(May not be so much of a problem if nothing prevents accurate λ extrapolation)
- Spinning dust vs Synchrotron separation more of a problem.


The End