Understanding the emissivity variations

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Collaborators: Bernard, J.P., de Bernardis, P., Calzoletti, L., Faustini, F., Gromov, V., Martin, P., Masi, S., Mény, C., Molinari, S., Montier, L., Natoli, P., Noriega-Crespo, A., Paladini, R., Piacentini, F., Ristorcelli, I., Thompson, M. A., Traficante, A., Veneziani, M.,

BG emissivity

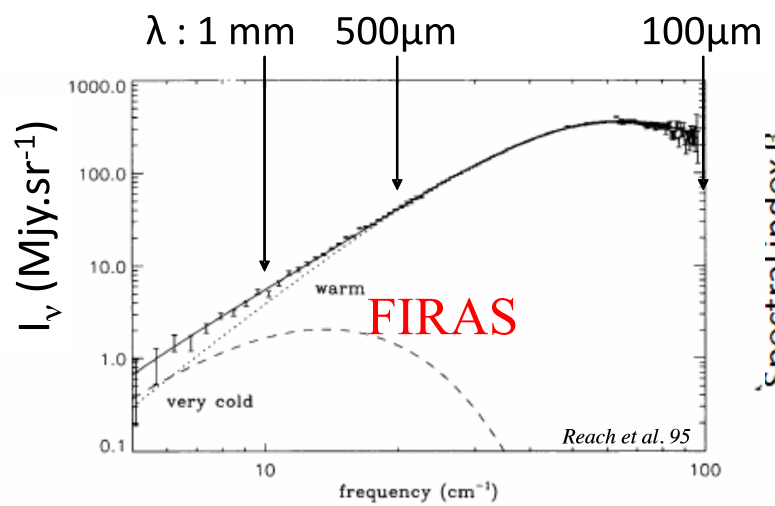
$$I_\nu(\lambda) = \underbrace{Q_{abs}(\lambda_0)\left(\frac{\lambda}{\lambda_0}\right)^{-\beta}}_{\text{emissivity} = \tau/N_H} B_\nu(T_{eq},\lambda) N_H$$

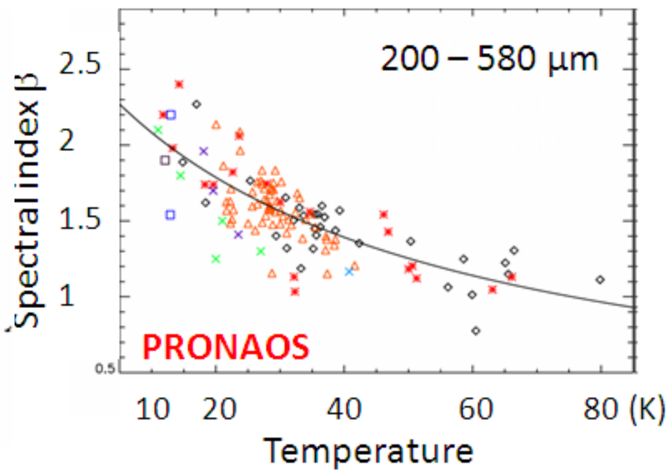
β : spectral index
Q_{abs} : *absorption efficiency*
$B_\nu(T,\lambda)$: *Planck function*
N_H : *column density*

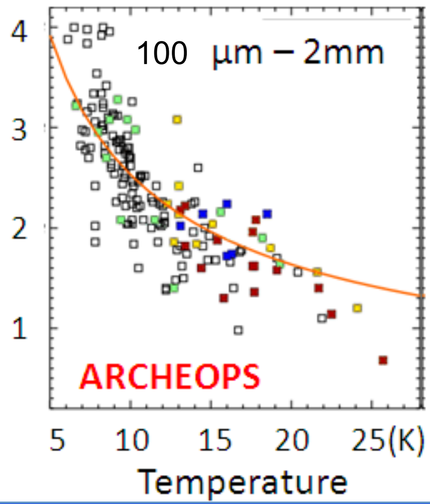
Conventionally admitted **: β = 2**

<u>But recent observations:</u>
FIRAS (COBE), PRONAOS (200-600 μm) et ARCHEOPS (550-3000 μm)

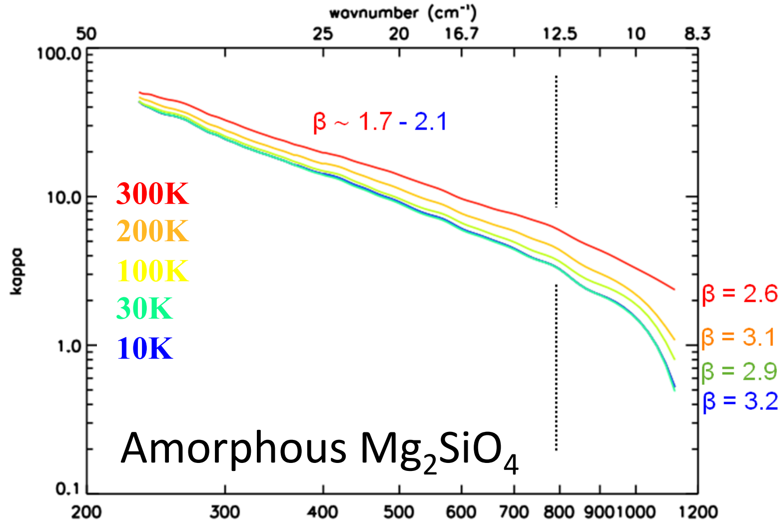
β ≠ 2 and varies with T and λ

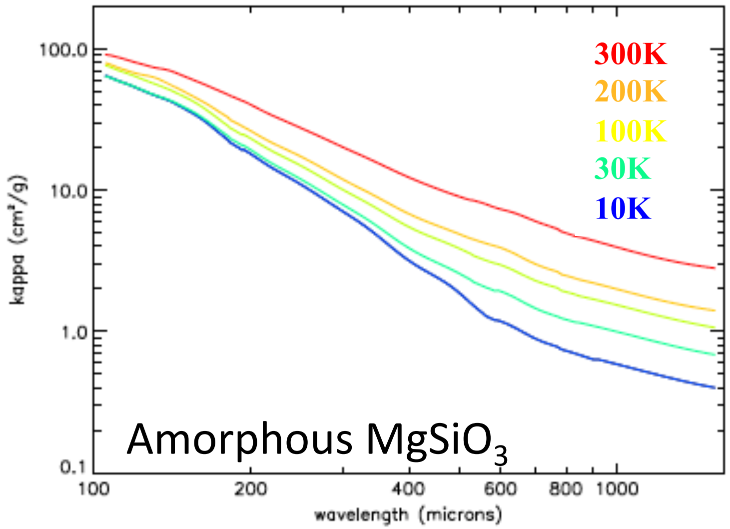






Laboratory Data: ESPOIRS Project





Coupeaud et al. A&A, 2011, submitted

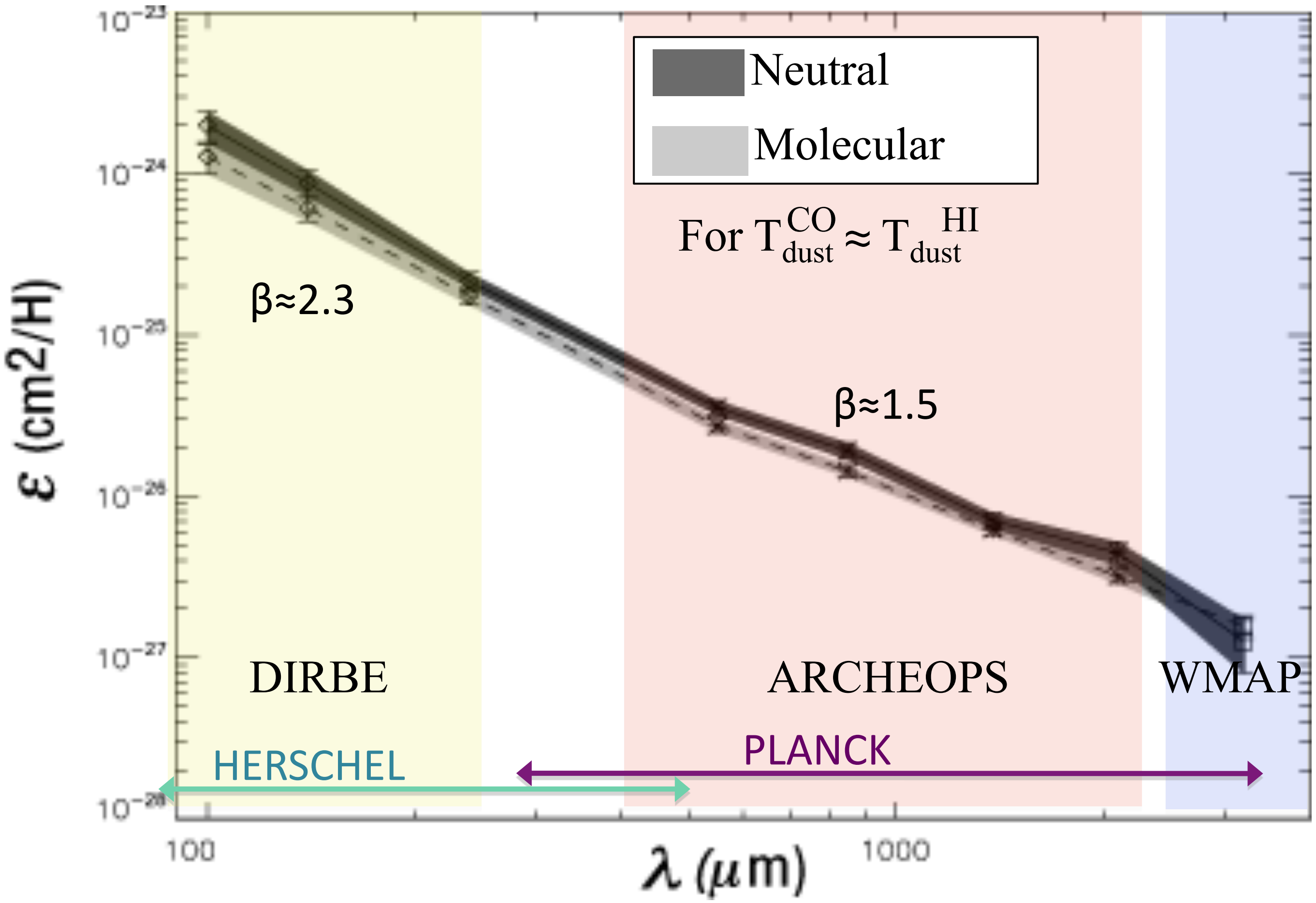
Most dust (98%) in ISM is amorphous (Kemper 2004)

Laboratory measurements of dust analog materials show that the internal structure of the grain (amorphous vs crystalline) affects the emissivity shape

- Emissivity spectrum changes at long wavelengths (from FIR to submm)
- Emissivity spectrum flattens with temperature (decrease of β with T)

Evolution of dust properties from diffuse to dense medium

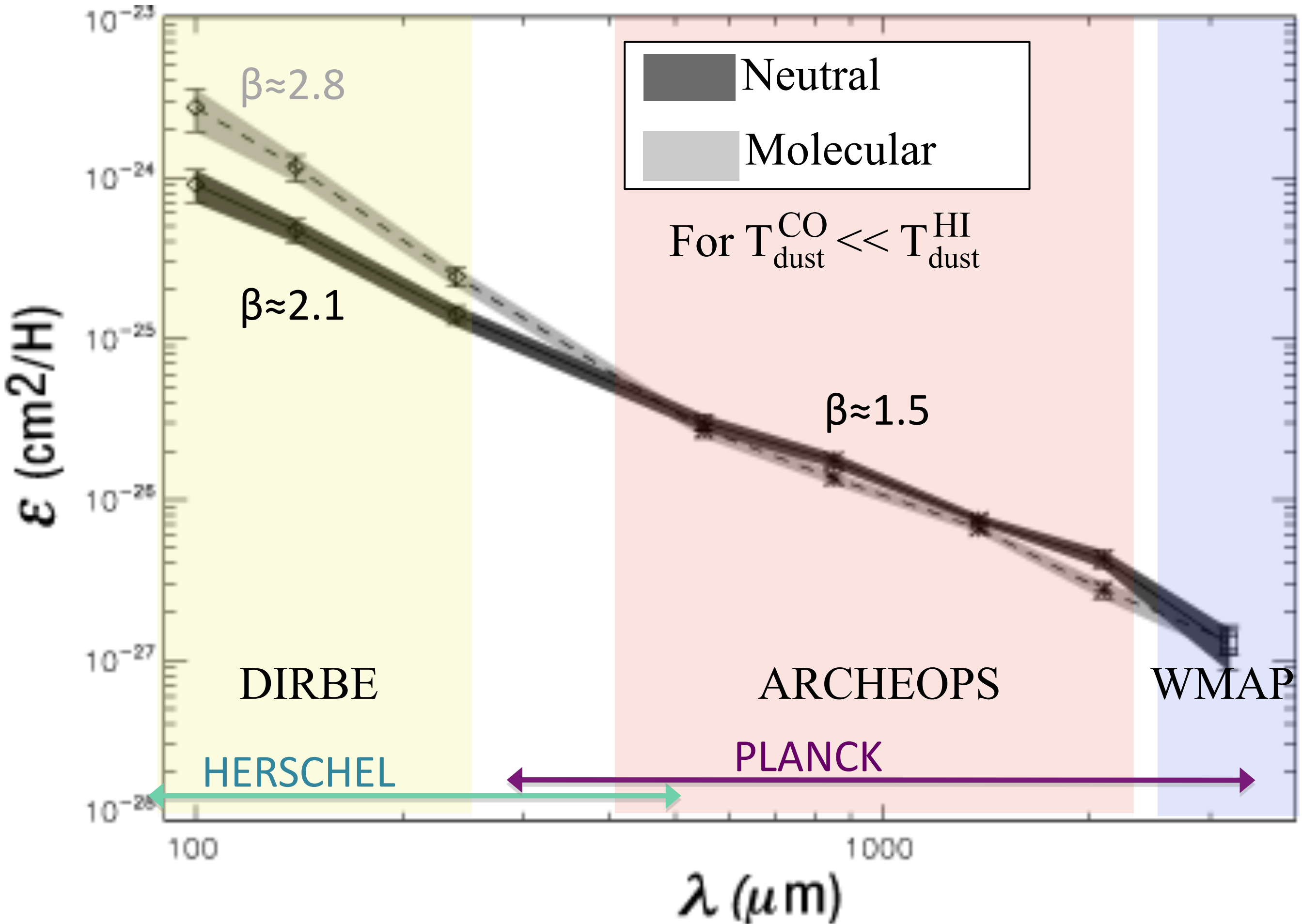
Paradis, Bernard & Mény, 2009a, A&A 506, 745



Emissivity SEDs in HI and CO are almost // and flatten in the submm (λ>550 μm)
=>We can assume that grains have evolved in a similar way in the 2 phases (with similar Xisrf)

Evolution of dust properties from diffuse to dense medium

Paradis, Bernard & Mény, 2009a, A&A 506, 745



=> Emissivity excess in dense environments
⇒ changes in dust properties in the cold molecular phase
=> Formation of dust aggregates

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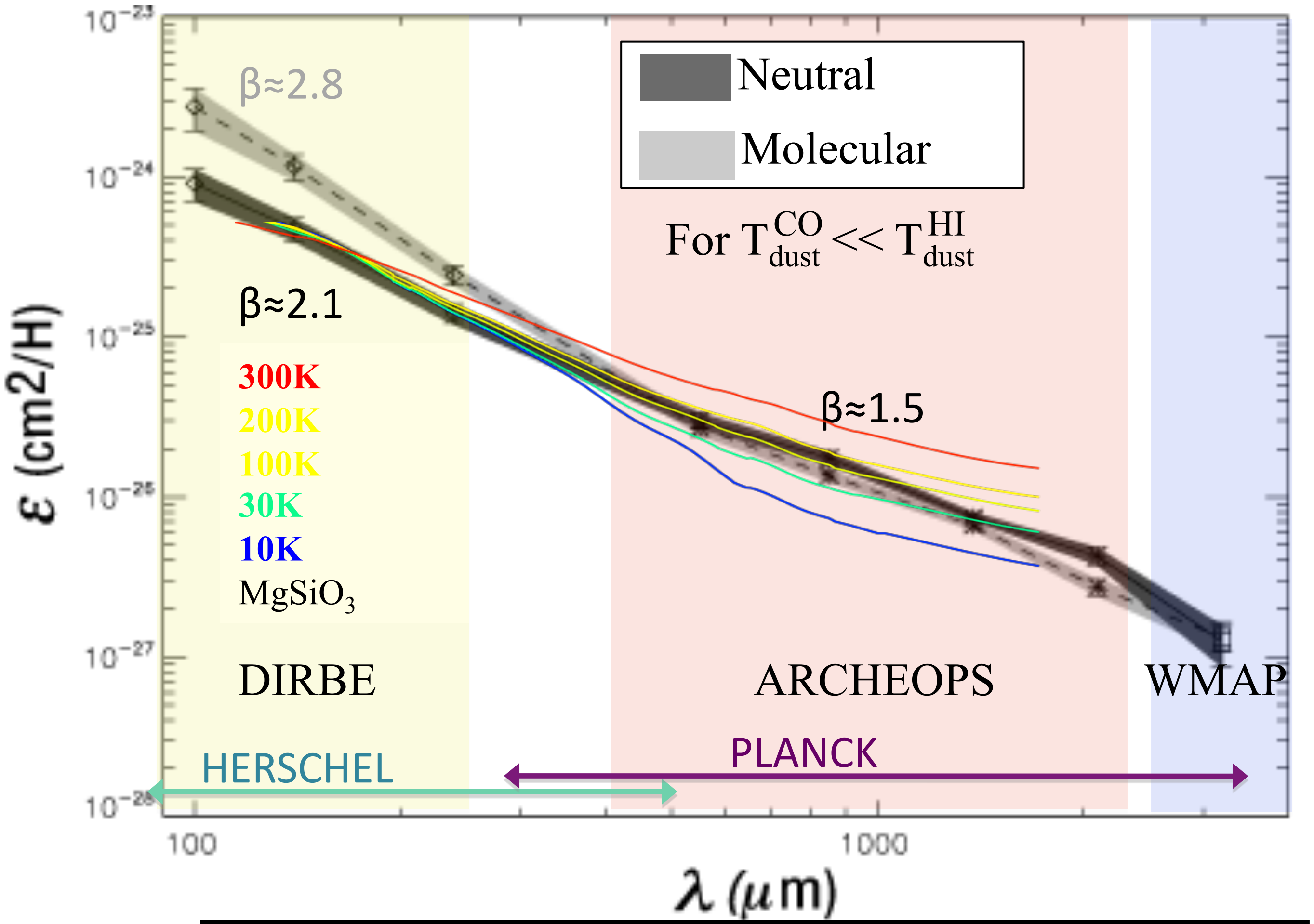

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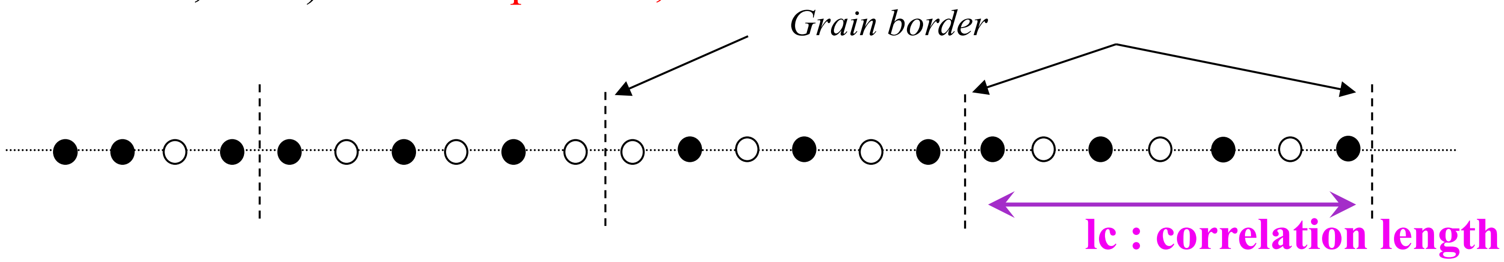
A model of amorphous dust: the TLS model

➢ 98% of amorphous dust in the ISM but no model takes into account this evidence!

➢ Double description of disorder in amorphous solids: TLS model *Mény et al., 2007*

• Disordered Charge Distribution (DCD): interaction between the electromagnetic wave and acoustic oscillations in the disordered charge of the amorphous material (Vinogradov, 1960; Schlomann, 1964) => T-independent, dominates the FIR



• Two Level System (TLS): interaction of the electromagnetic wave with a simple distribution of asymmetric double-well potential => T-dependent, dominate the submm/mm

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• Disordered Charge Distribution (DCD): interaction between the electromagnetic wave and acoustic oscillations in the disordered charge of the amorphous material (Vinogradov, 1960; Sc

Parameters of the TLS model:
- Dust temperature : Td
- Correlation length : lc
- intensity of the TLS processes with respect to the DCD part : A

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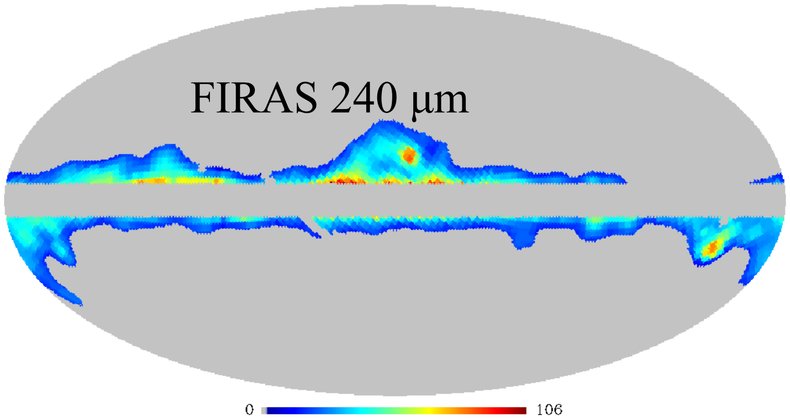
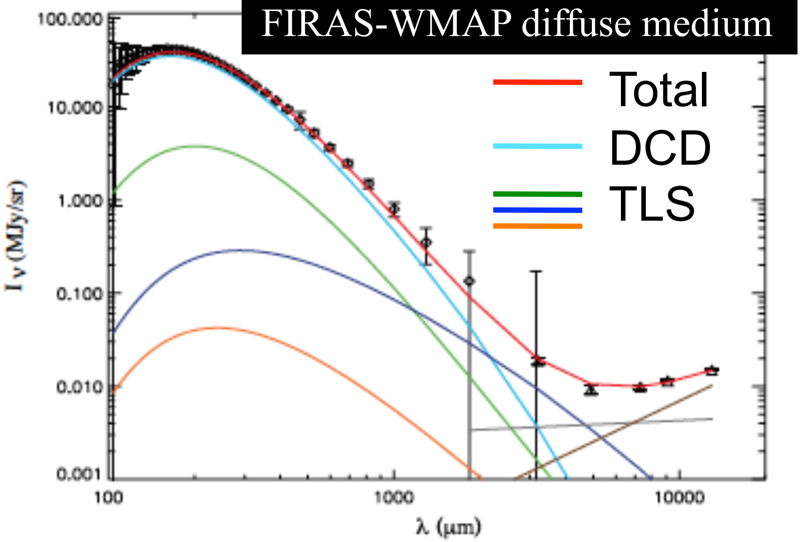
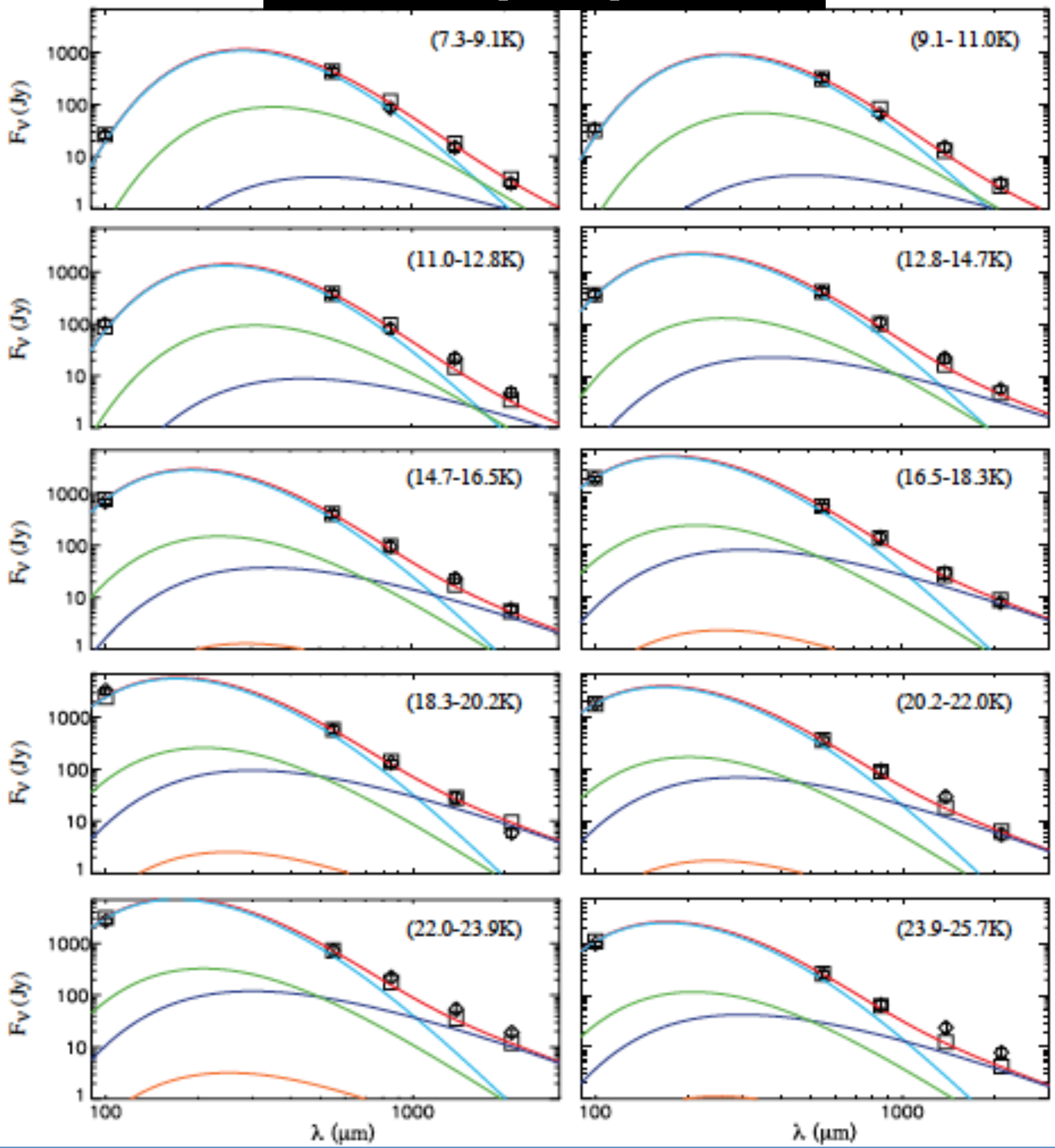
A model of amorphous dust: the TLS model



FIRAS-WMAP diffuse medium

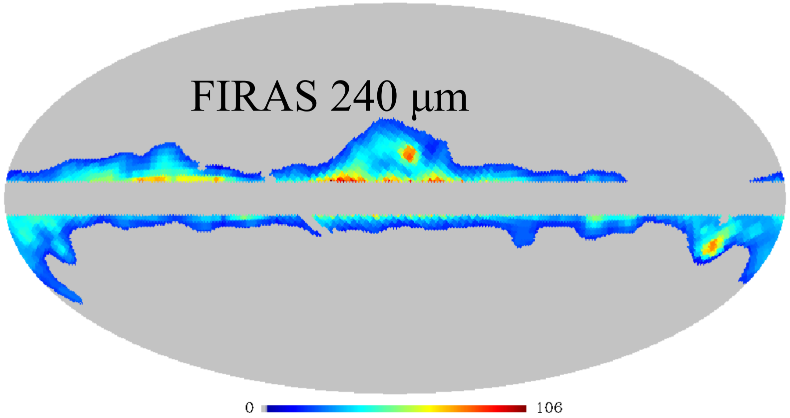


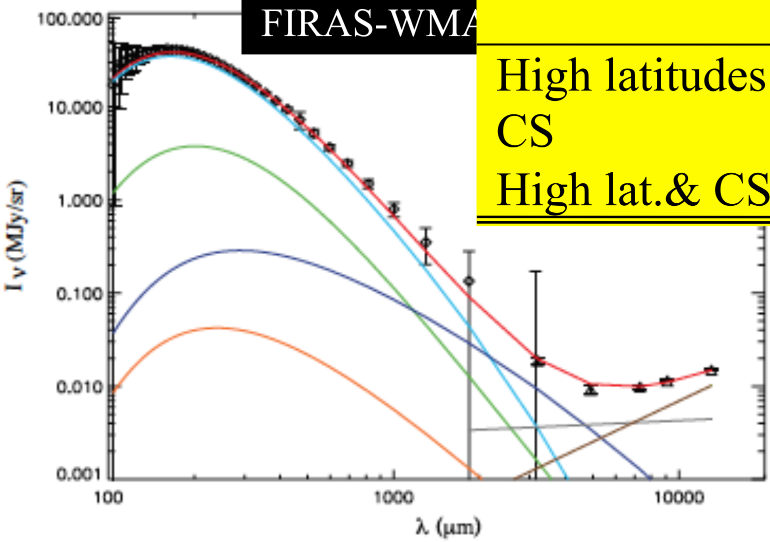
IRAS-Archeops compact sources

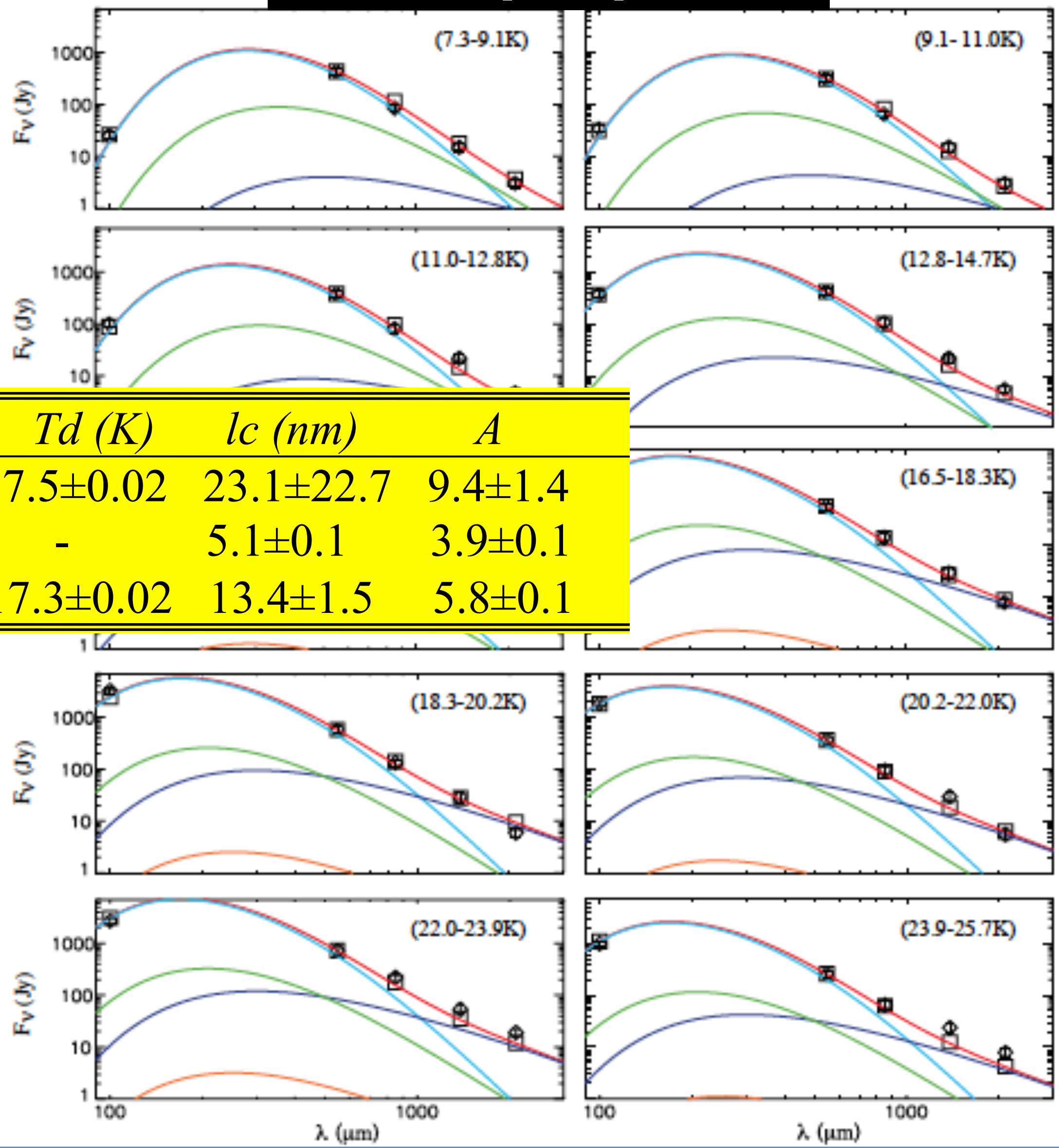


Paradis, Bernard, Mény, & Gromov, 2011c, A&A submitted

A model of amorphous dust: the TLS model







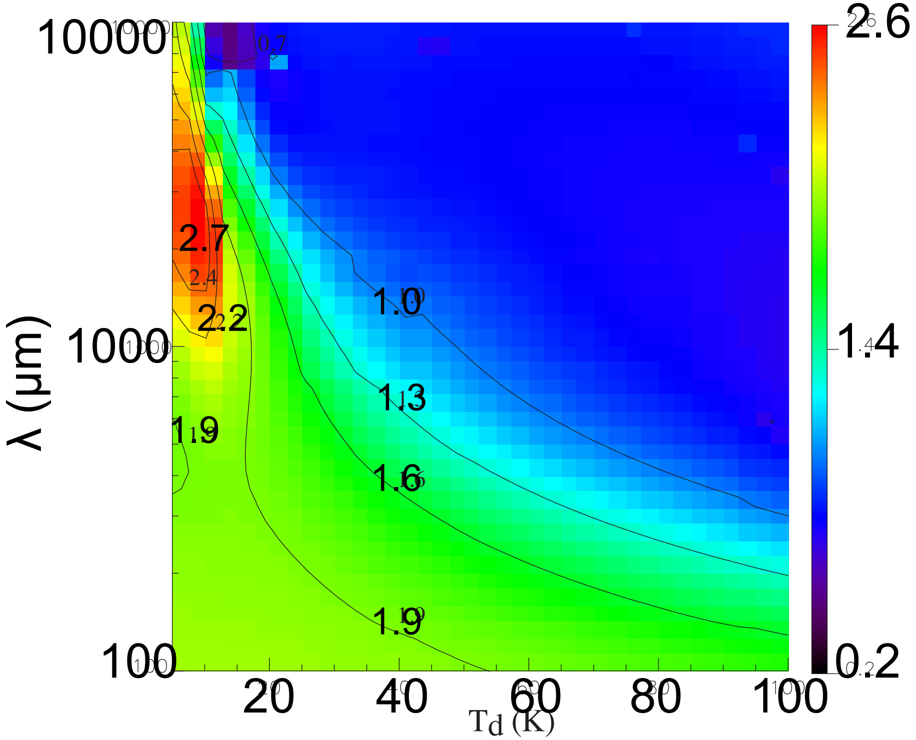
	Td (K)	*lc (nm)*	*A*
High latitudes	17.5±0.02	23.1±22.7	9.4±1.4
CS	-	5.1±0.1	3.9±0.1
High lat.& CS	17.3±0.02	13.4±1.5	5.8±0.1

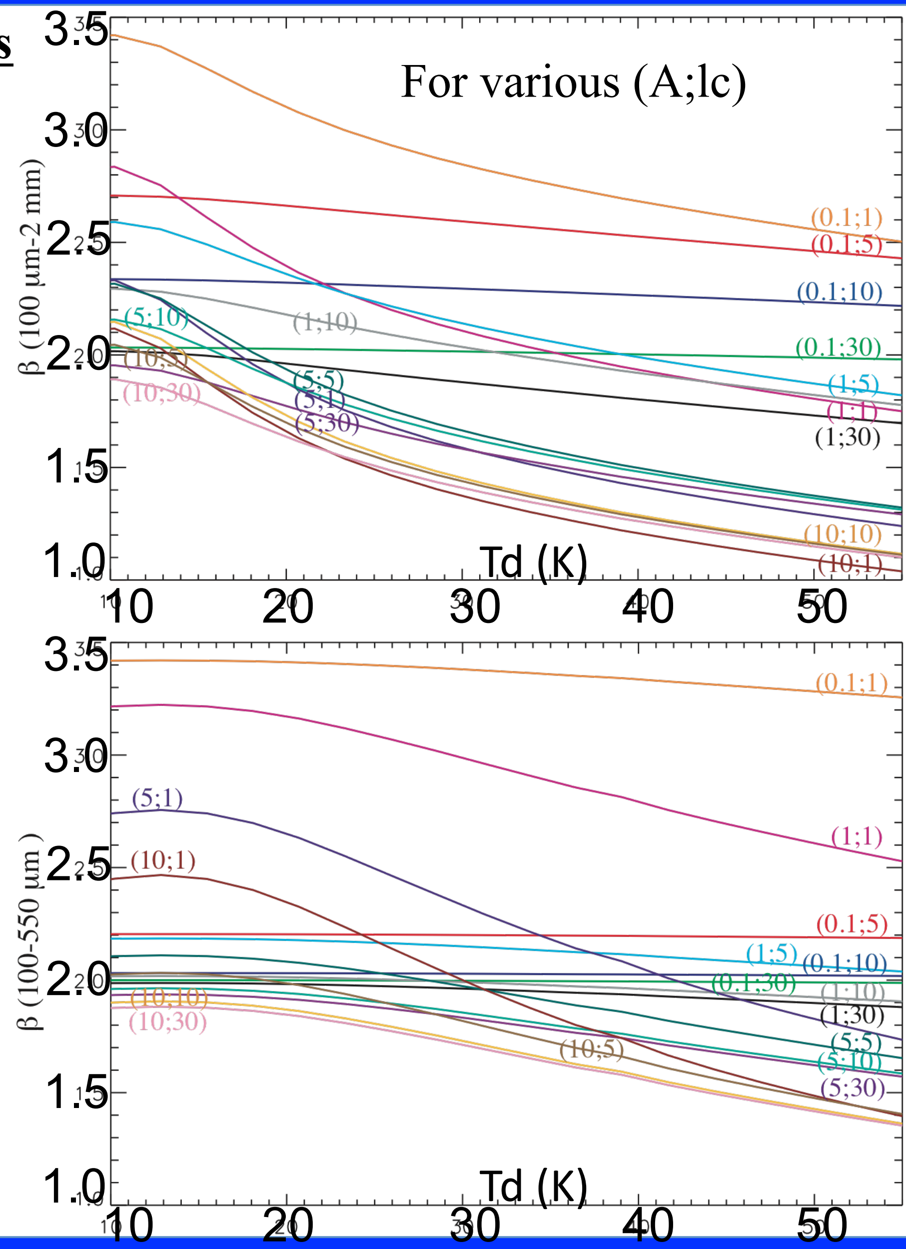
Paradis, Bernard, Mény, & Gromov, 2011c, A&A submitted

A model of amorphous dust: the TLS model

β predictions

with lc=13.4 nm and A=5.8





Important β variations with T and λ:

- T-β anti-correlation
- β ≈ 2.7 at 2mm and T=10 K
- β ≤ 1 in a large domain of T and λ

Paradis, Bernard, Mény, & Gromov, 2011c, A&A submitted

A model of amorphous dust: the TLS model

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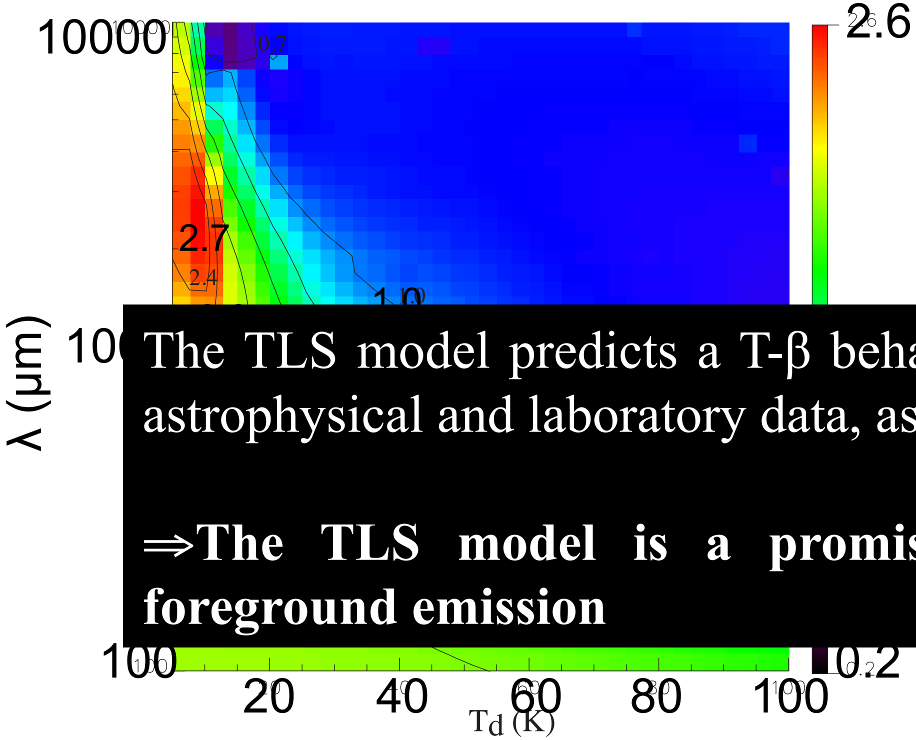

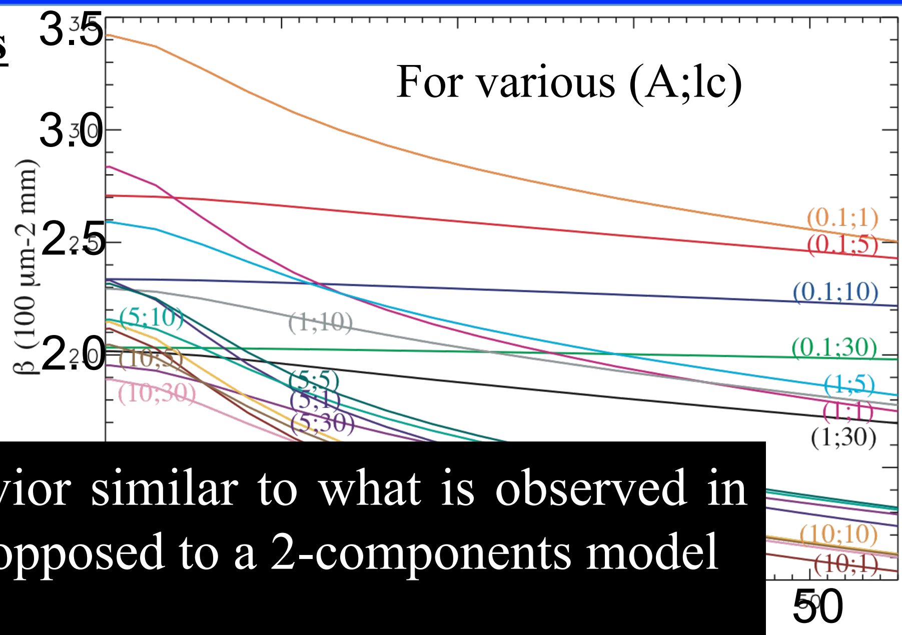

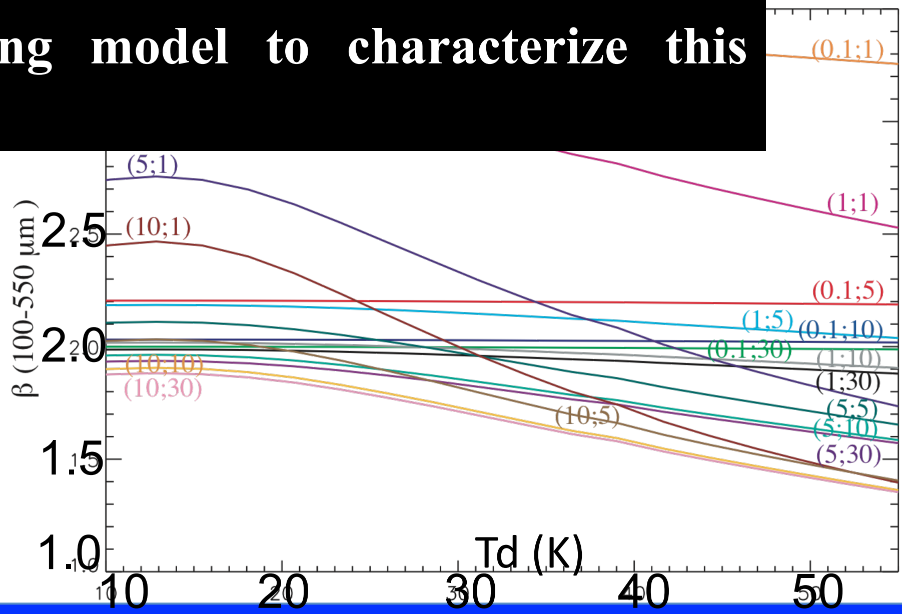

The TLS model predicts a T-β behavior similar to what is observed in astrophysical and laboratory data, as opposed to a 2-components model

⇒**The TLS model is a promising model to characterize this foreground emission**

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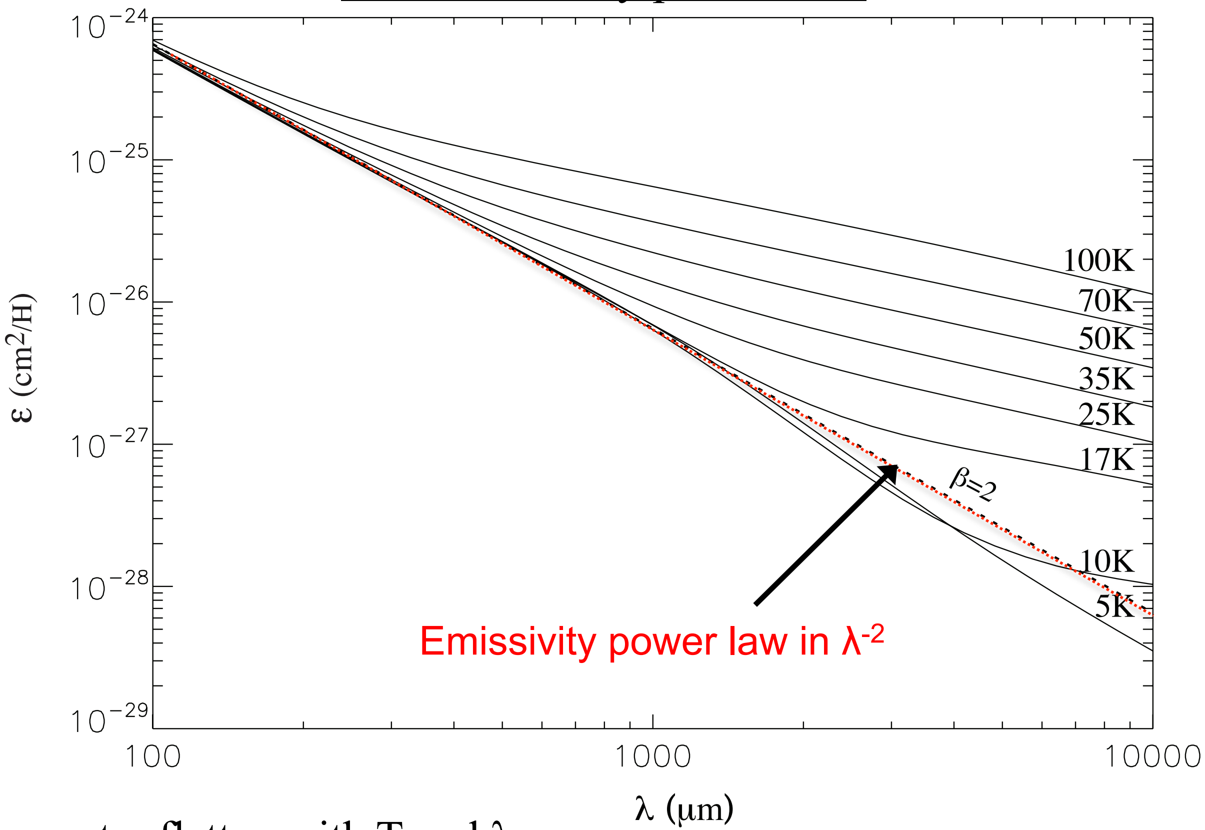
Paradis, Bernard, Mény, & Gromov, 2011c, A&A submitted

A model of amorphous dust: the TLS model

Dust emissivity predictions



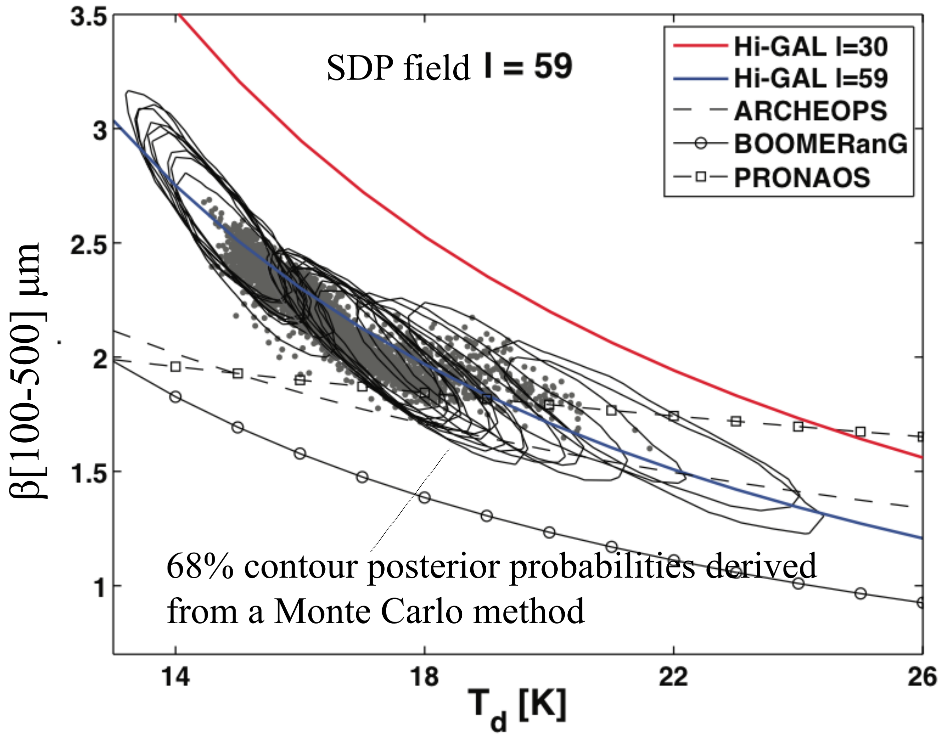
Emissivity spectra flatten with T and λ

=> Therefore, when assuming no dependency of the emissivity spectrum with λ nor T, one can significantly bias the mass estimate, especially when derived from submm/mm data and extrapolated to shorter wavelengths.

Paradis, Bernard, Mény, & Gromov, 2011c, A&A submitted

Dust properties along the Galactic Plane (GP)

Herschel Hi-GAL (PI S. Molinari)



Paradis, Veneziani and the Hi-GAL team, 2010, A&A, 520, 8

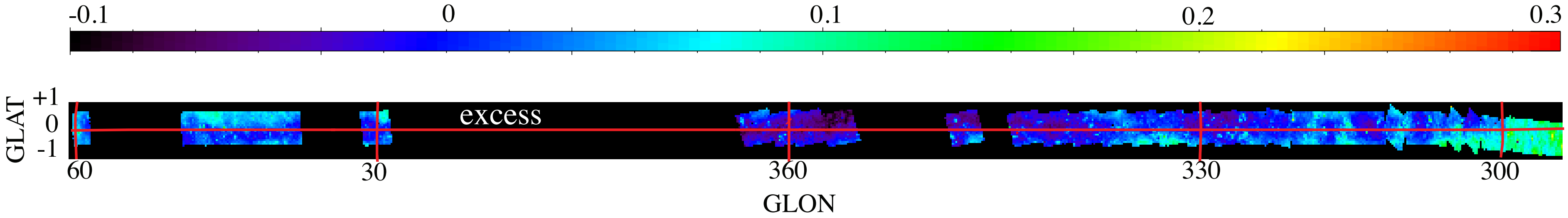
⇒ Results have been checked using 2 independent methods

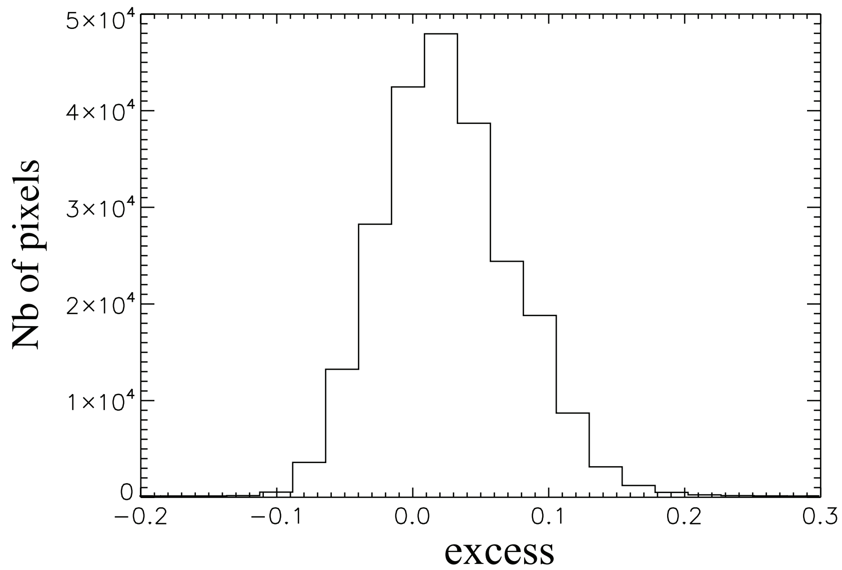
⇒T-β anti-correlation in the inner GP, already highlighted in external regions and in the solar neighborhood (Dupac et al. 2003, Désert et al., 2008, Veneziani et al., 2010)

⇒ Different T-β trend with respect to previous observations based on BOOMERanG, Archeops and Pronaos, probably because of different dust properties in the GP

Dust properties along the Galactic Plane (GP)

IRAS+Hershel => 4’ resolution

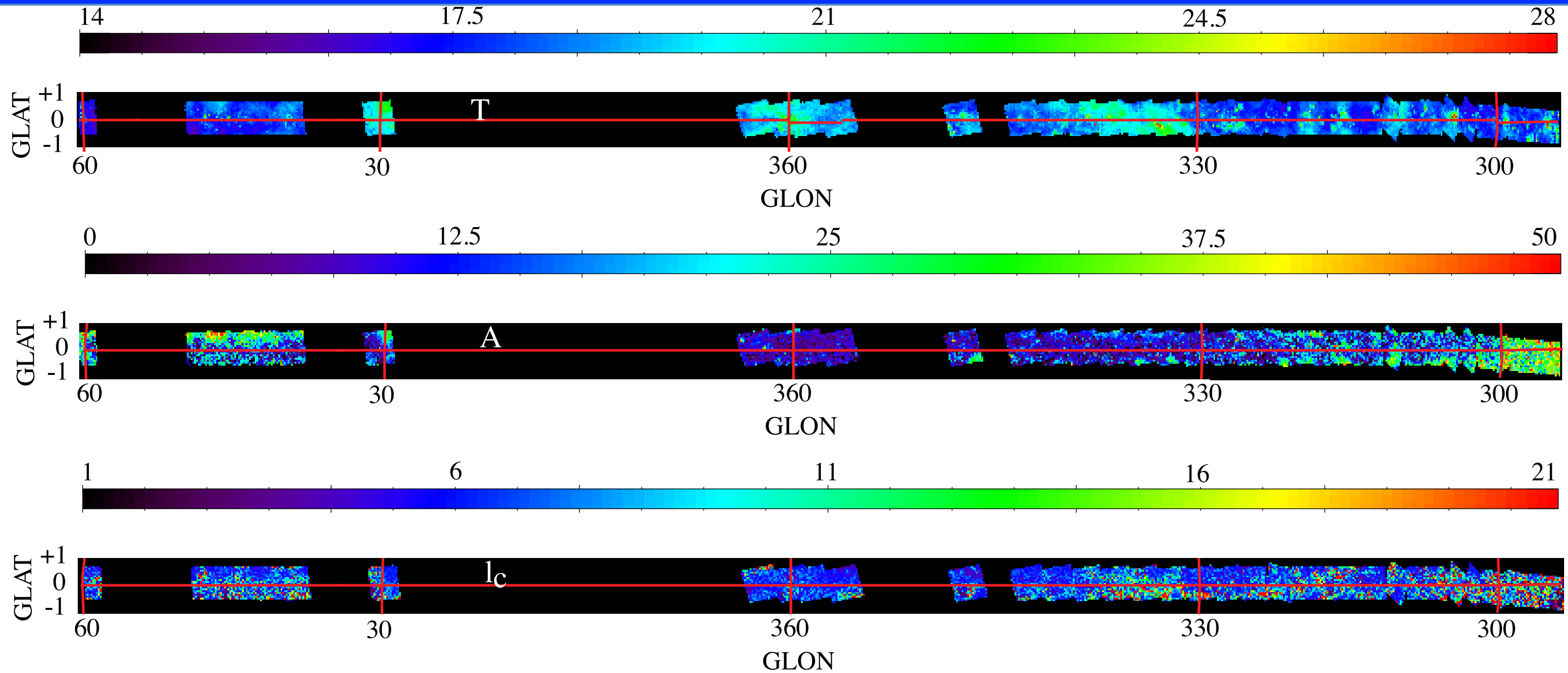




- 500 µm emissivity excess in the outer parts of the GP, as compared to a power law in λ^{-2}, that can represent 15-20% of the emissivity
- median value of the excess along the GP : 2%
- no excess in the Galactic Center
- most likely related to the flattening of the spectra observed in the submm/mm (Reach et al., 1995; Finkbeiner et al., 1999; Paradis et al., 2009, Planck Collaboration, 2011u)

Paradis, et al., 2011d, A&A in preparation

Dust properties along the Galactic Plane (GP)



	Td (K)	*lc (nm)*	*A*
All GP	18.5±1.4	7.1±5.9	14.6±11.0
External GP	18.0±1.3	7.5±6.6	19.7±11.5
Inner GP	19.5±1.3	6.8±4.6	9.9±6.5
FIRAS high lat.	17.5±0.02	23.1±22.7	9.4±1.4
Arch. CS	-	5.1±0.1	3.9±0.1
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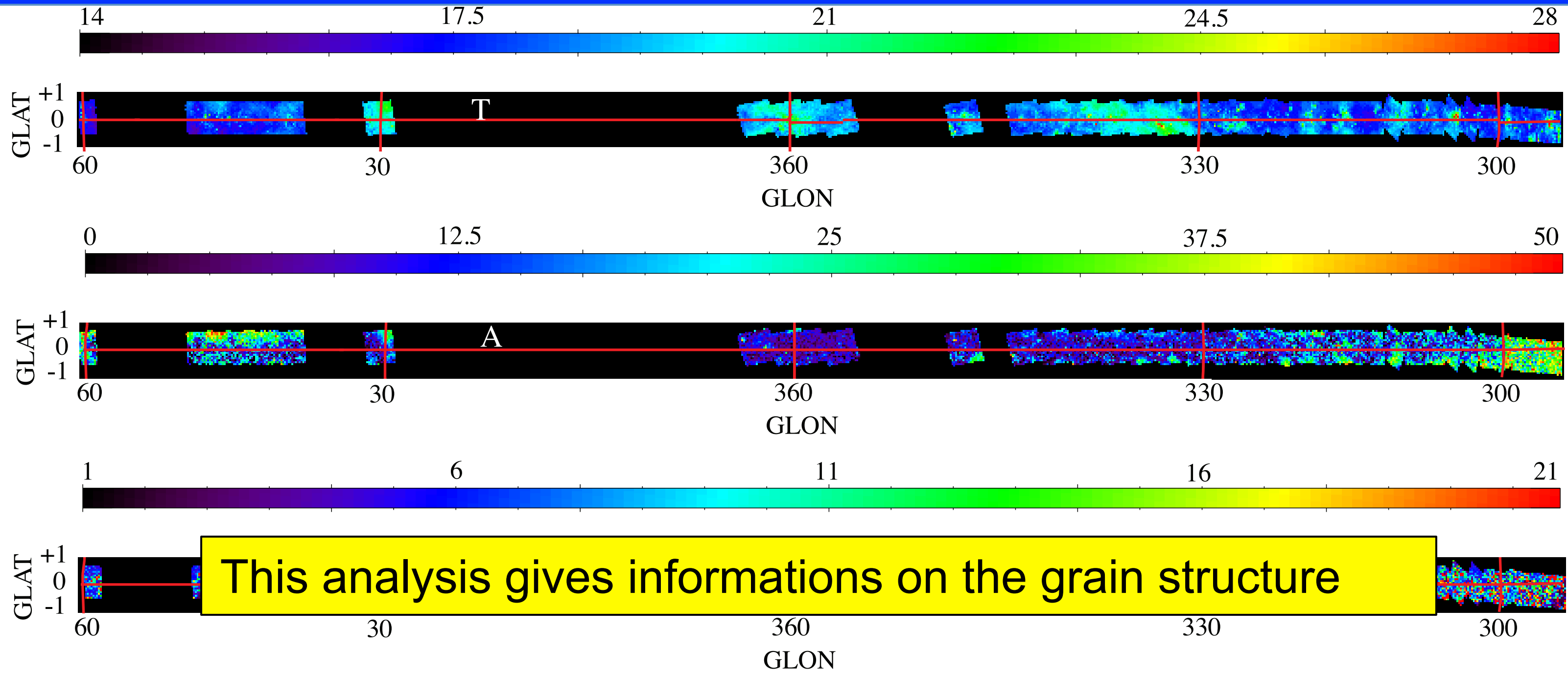
Paradis, et al., 2011d, A&A in preparation

- Inner parts warmer than outer parts
- Increase of *A* from the inner to the outer GP
 => changes in dust properties
- *lc* ≈ constant along the GP

- *A* larger in the GP compared to high latitudes and CS
 => Following the TLS model, grains in the GP could be characterized by a degree of amorphization more important in the GP, and the degree or amorphization increases in outer parts.

Dust properties along the Galactic Plane (GP)



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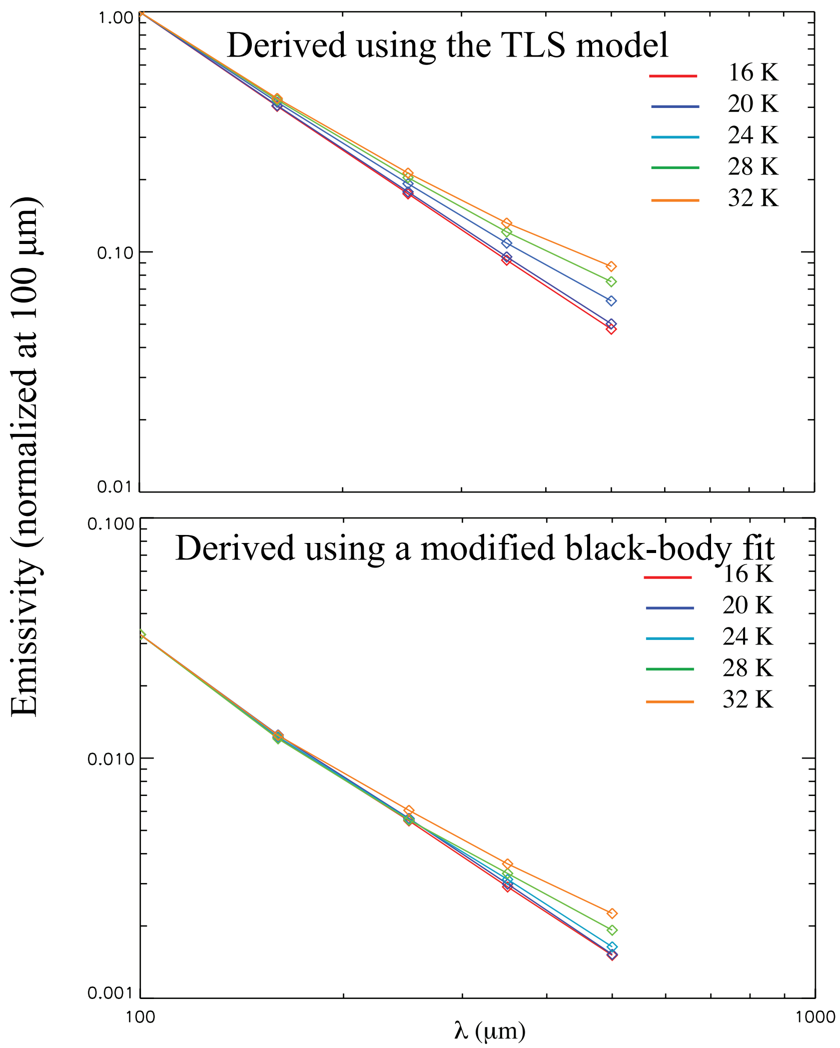
Dust properties along the Galactic Plane (GP)



Using the TLS model and a modified black-body fit we have plotted the emissivity spectra in 5 bins in temperature

⇒ same trend with both models:

flattening of the spectra with the increasing dust temperature

Paradis, et al., 2011d, A&A in preparation

Dust properties along the Galactic Plane (GP)

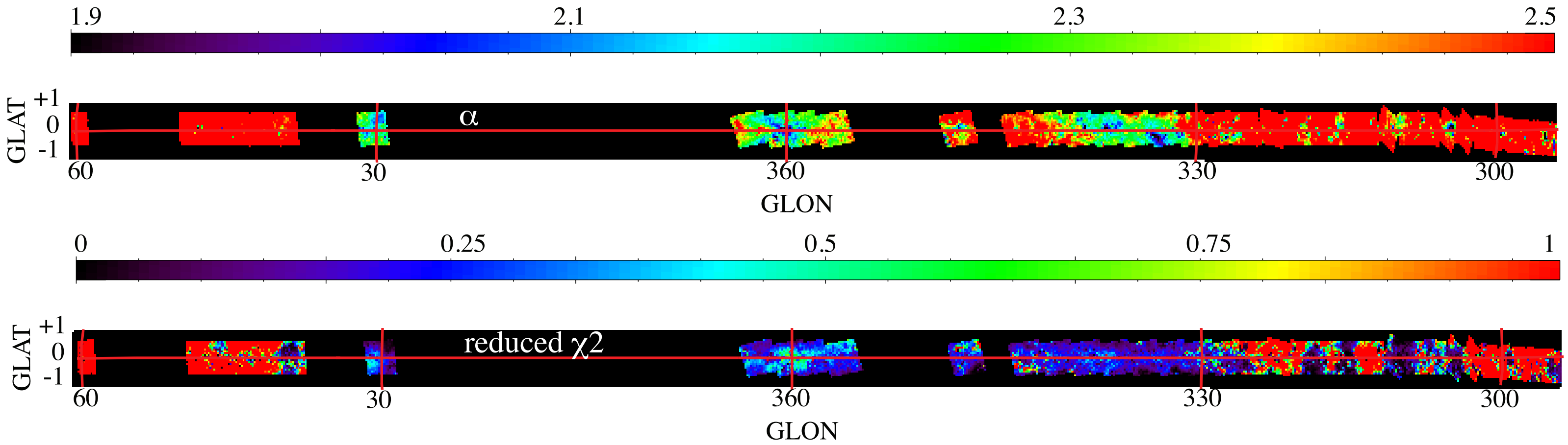
__Composite radiation field components along the LOS__

- *Local SED combination (Dale et al., 2001)*
- Model: *DustEM (Compiègne et al., 2011)*

$$I_\nu^{tot} = \frac{\sum_i \sum_j I_\nu^{\mathrm{mod}}\left(X_{RF,i}, RF\right) X_{RF,i}^{-\alpha_j}}{\sum_i \sum_j X_{RF,i}^{-\alpha_j}}$$

$$1 < \alpha < 2.5$$

$$0.3 < X_{ISRF} < 10^5$$

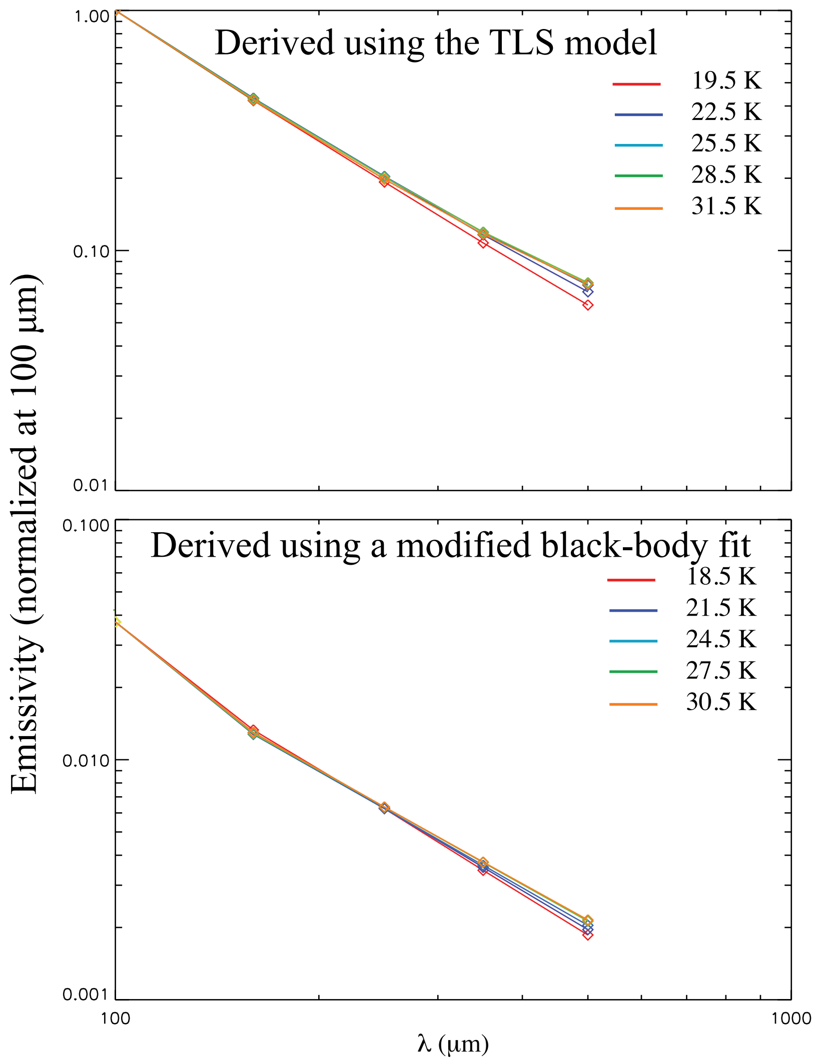


➔**Each pixel of the map has now an emission that incorporates a temperature-mixing along the LOS**

- The SEDs of the most diffuse part of the GP (outer parts essentially) are not well reproduced by the Dale et al. (2001) model (a temperature mixture is probably less important than in the inner arms of the Galaxy)
- We have selected only pixels with good $\chi 2$

Paradis, et al., 2011d, A&A in preparation

Dust properties along the Galactic Plane (GP)



We then fit the simulated data which incorporate a T-mixing, with the usual models (single T)

➔we do not see any significant variations of the emissivity with T, whatever the model used

➔ the temperature mixing is not likely to be responsible of the observed emissivity trend with temperature

Paradis, et al., 2011d, A&A in preparation

Conclusions

✓Understanding emission of the BG dust component and especially its variation with λ and T is an important aspect of component separation.

✓Comparison between the TLS model and astrophysical/laboratory data allow us now to deduce informations on the amorphous state of the grain itself

✓ Extrapolating emissivity spectrum from the submm/mm to the FIR with β=2 and without any dependency with T can induce important errors on the emissivity and therefore on mass estimates

✓ Dust properties seem to vary with environment : diffuse / dense medium, high latitudes / along the Galactic Plane, in the inner parts / outer parts of the GP …