Dust temperature and Emissivity in the LMC from the Heritage SDP observations

Herschel content from : “Determining Dust Temperatures and Masses in the Herschel Era: The Importance of Observations Longward of 200 micron” by Gordon et al. (accepted yesterday)

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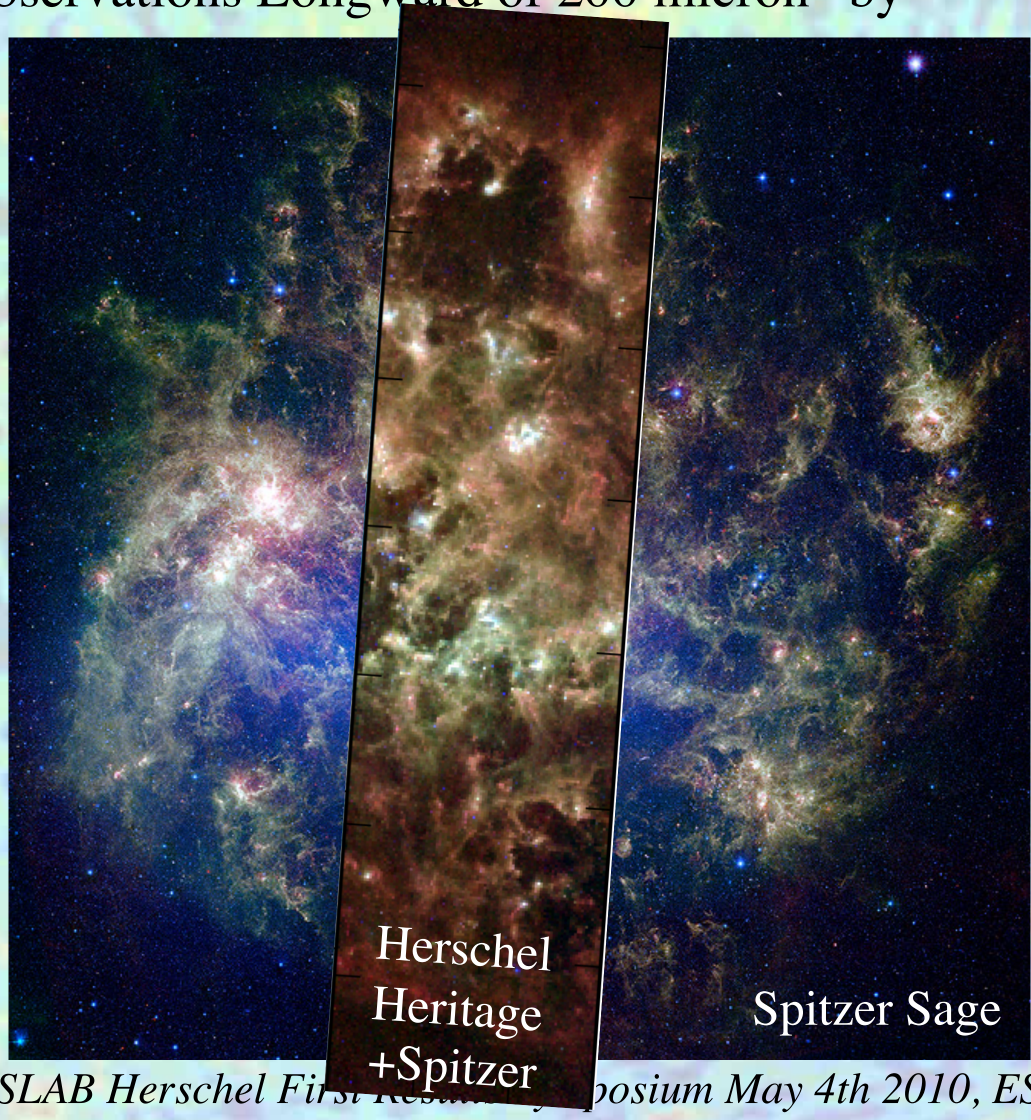
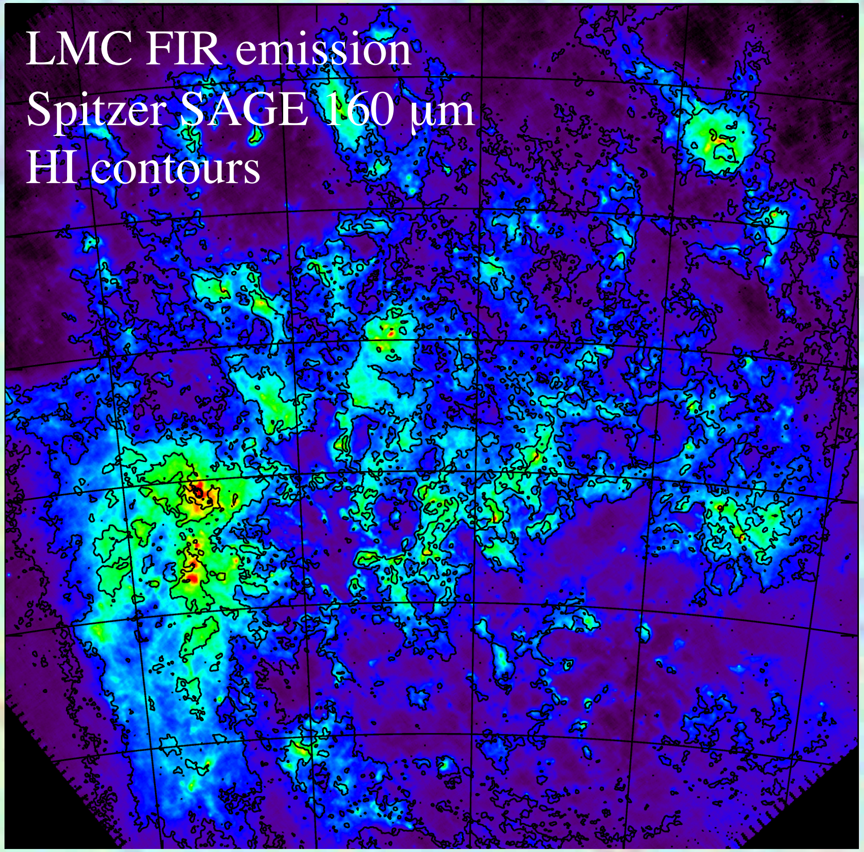
D=55 kpc
Z~1/3 solar
Seen face-on

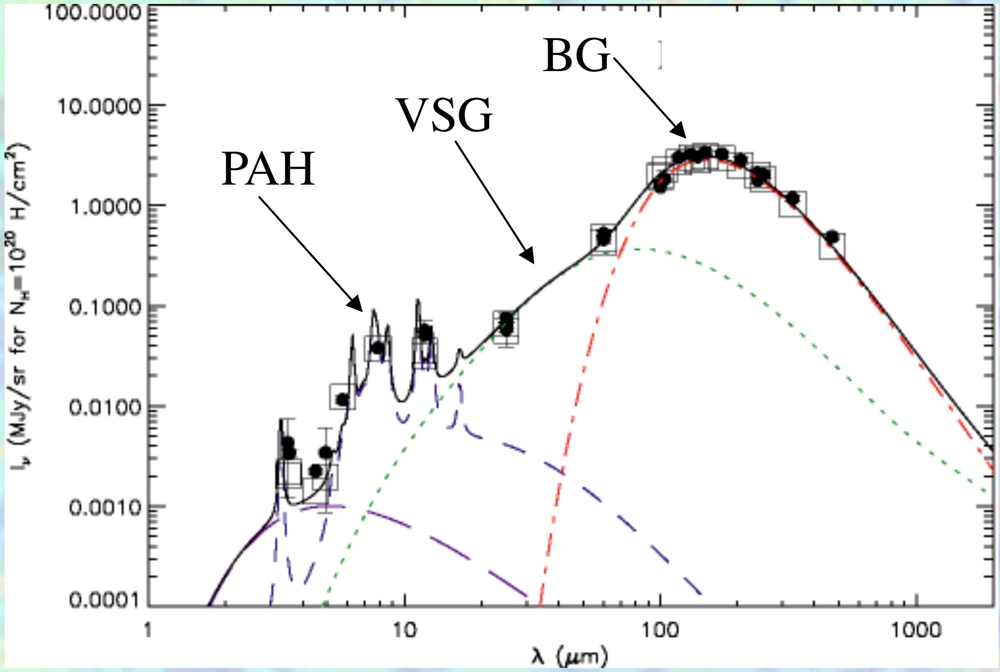


Dust temperature: a critical parameter

BG dominate dust mass and are a good tracer of the total ISM in MW and galaxies
They radiate at equilibrium with ISRF, so T_D reflects ISRF strength.
Other quantities of interest (dust mass, size, optical properties) need precise knowledge of T_D

Past studies have been limited by accuracy of T_D determination.
Use of IRAS 100 µm -> limited resolution, gain artifacts, contamination …
This is about to change with Herschel.

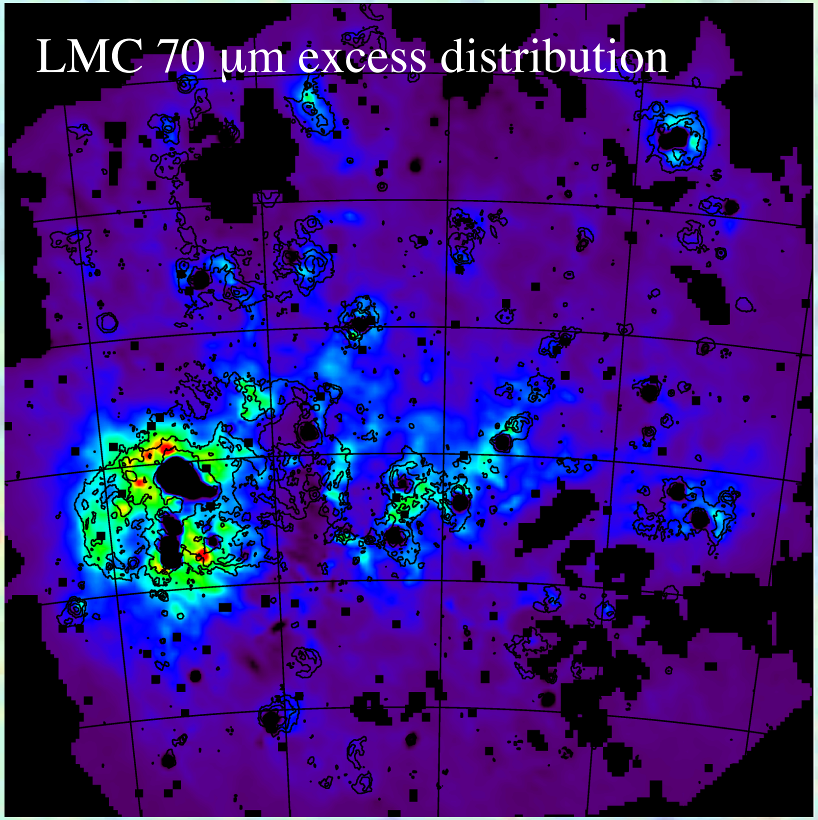


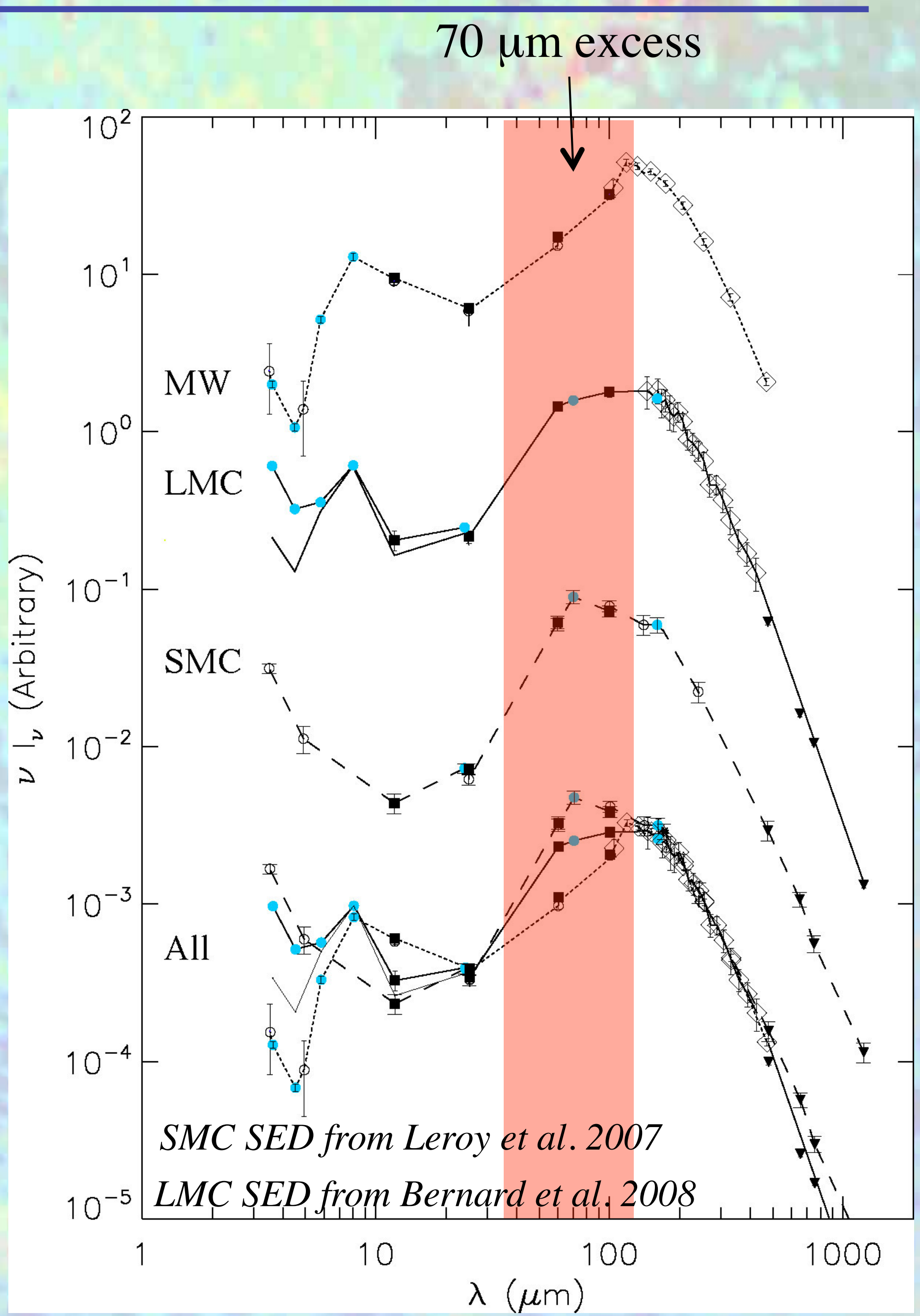


$$I_\lambda = \tau_\lambda B_\lambda(T) = \pi a^2 Q_{abs}(\lambda) N_{dust}\ B_\lambda(T_D)$$

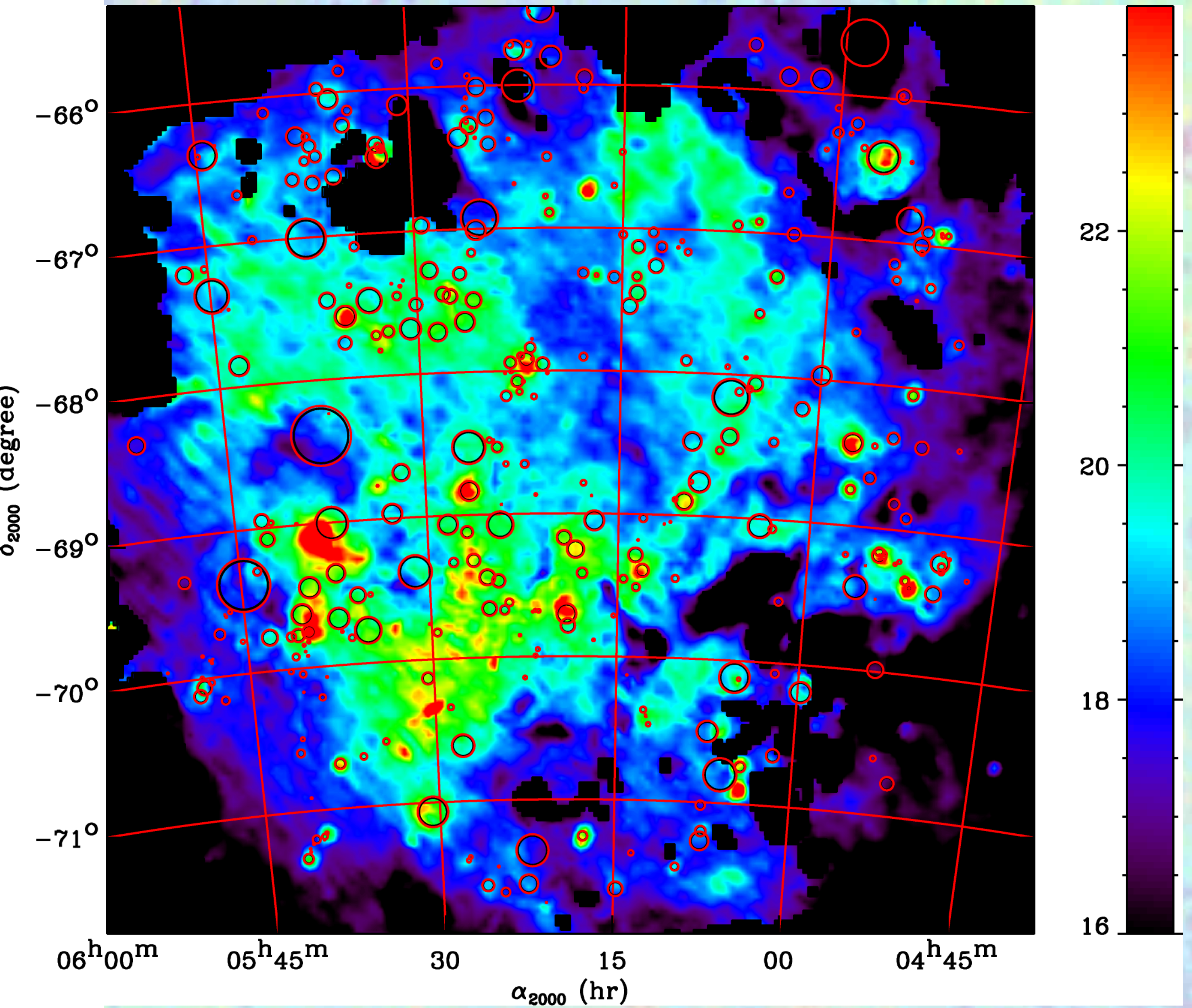
70 μm excess in LMC & SMC

- Large excess observed in MW, LMC, SMC
- Rising from MW to SMC (with decreasing Z)
- Found mainly in neutral gas
- In LMC, could be explained by modifying the grain size distribution (increase of grains with size intermediate between VSG and BG).
- Grain erosion processes in the diffuse medium ?
- Definitely a limitation in deriving T_D





Dust Temp. map



T map derived from I_{160}/I_{100} using β=2
HII regions contours

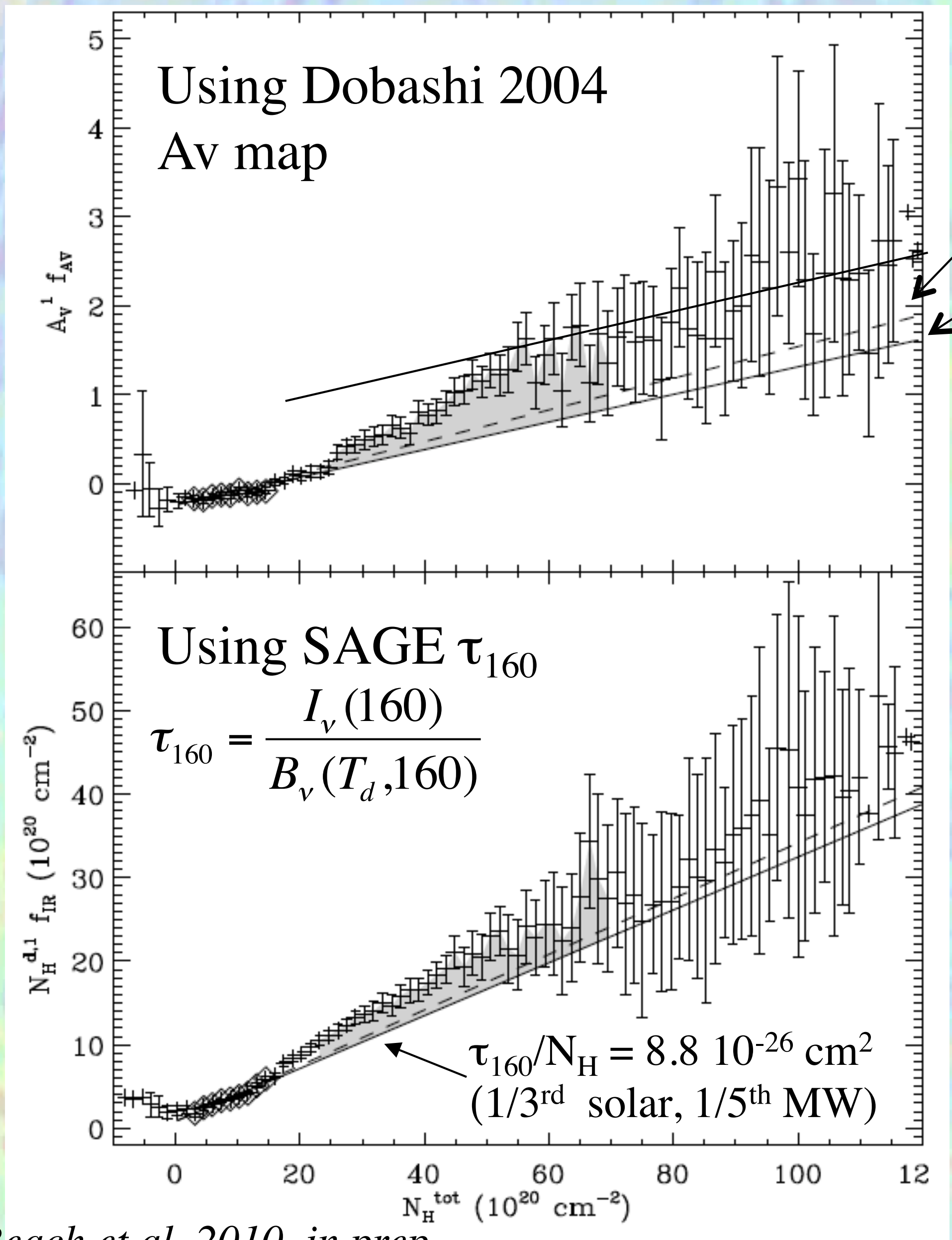
This is the first time the dust T distribution can be evidenced over LMC at 4' resolution.

Coherent variations of the dust temperature are clearly evidenced.

T map has defects (stripes) imposed by IRAS 100 μm map: Waiting for Herschel

Very important: It's our map of the radiation field

FIR optical depth excess

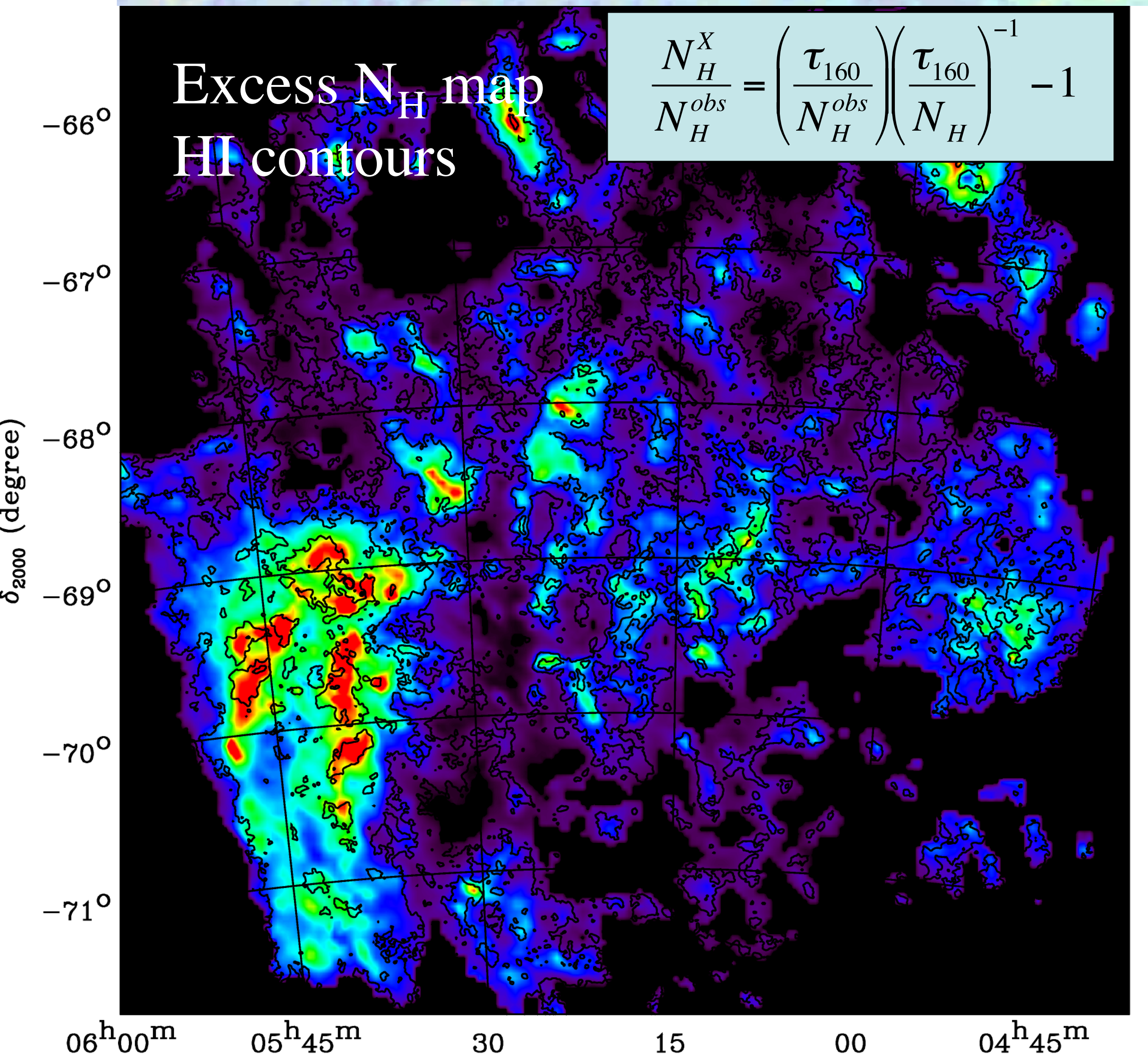


Reach et al. 2010, in prep

– τ_{160} shows departure from correlation with total N_H derived from HI and CO taken in low N_H regions.
- Transition is around N_H=2 10^{21} H/cm^2 (Av=0.3 mag in LMC)

- Slopes reconcile when N_H is dominated by molecular: argues against dust abundance variations
- Similar transition seen in extinction: Argues against variations of the FIR dust optical properties (aggregation)

Dark molecular gas ?



$$\frac{N_H^X}{N_H^{obs}} = \left(\frac{\tau_{160}}{N_H^{obs}}\right)\left(\frac{\tau_{160}}{N_H}\right)^{-1} - 1$$

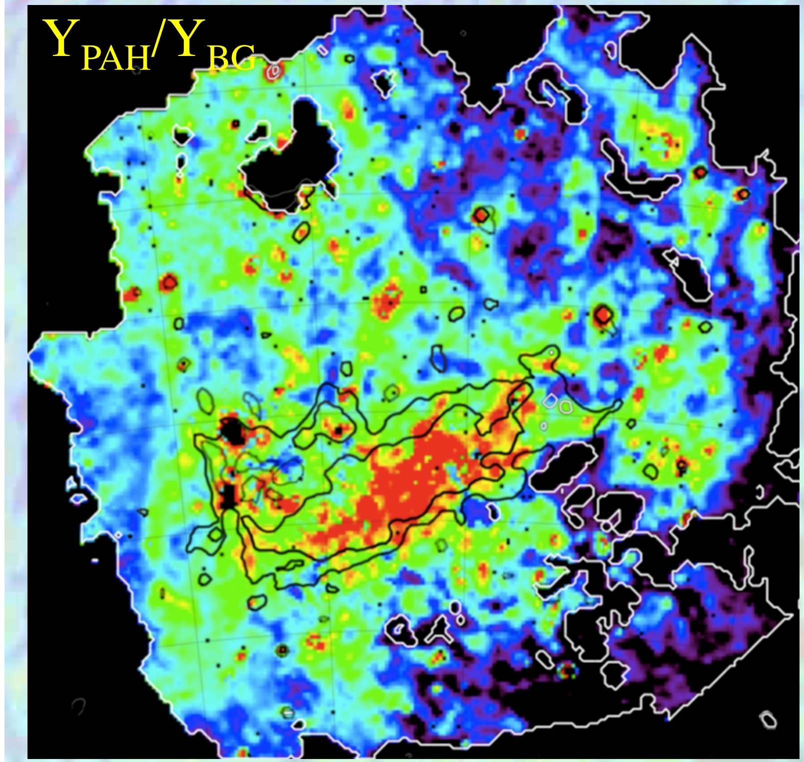
$$\left(\frac{\tau_{160}}{N_H}\right) = 8.8\,10^{-26}\,cm^2$$

$$N_H^{obs} = X_{HI}W_{HI} + 2X_{CO}W_{CO}$$

$$X_{CO} = 7\;10^{20}\;H_2/cm^2/(Kkm/s)$$

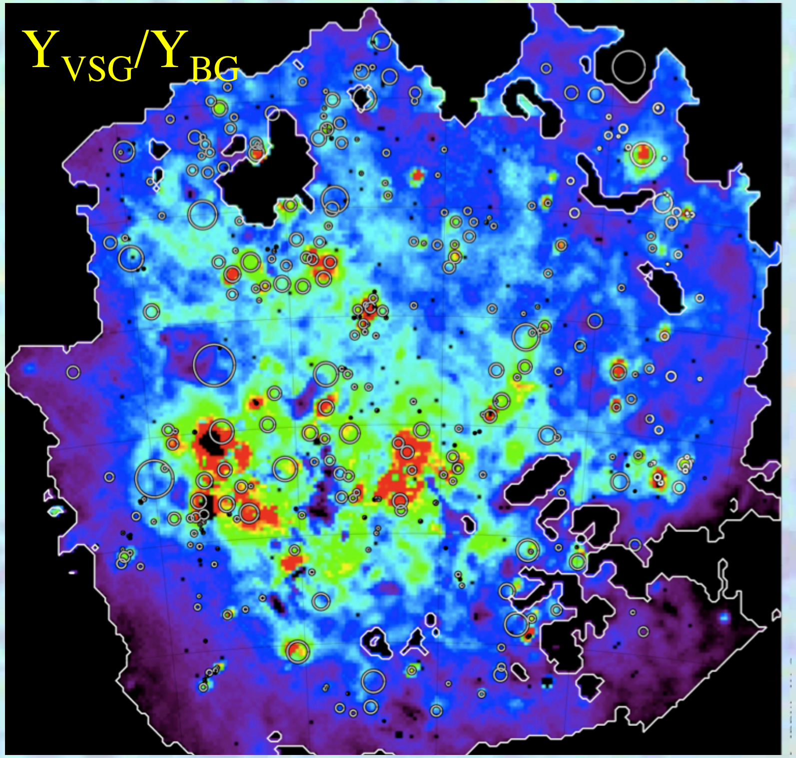
- Correlates with total N_H
- No obvious correlation with limited H_2 measurements (FUSE)
- No obvious correlation with limited HI self-absorption
- Could be either HI self absorption or H_2 phase without CO (dark molecular gas)
- Total mass = 2*HI mass (20 times CO) !
- Correlation with HI indicates good mixing (clumps ?)

Dust Composition variations



Paradis et al. 2009, AJ 138, 196 :Abundances derived from model inversion on each Line of Sight (taking radiation field intensity into account)

- PAH over-abundant in part of the stellar bar: remnant of past formation by old stellar population ?
- PAH over-abundant around some molecular clouds: PAH haloes similar to those observed in the MW ?
- Large fraction of ionized PAH required to explain SED of selected regions



- VSG over-abundant in part of the stellar bar: remnant of past formation by old stellar population ?
- VSG over-abundant around 30-Dor in the region of 70 µm excess
- VSG trace regions of star formation

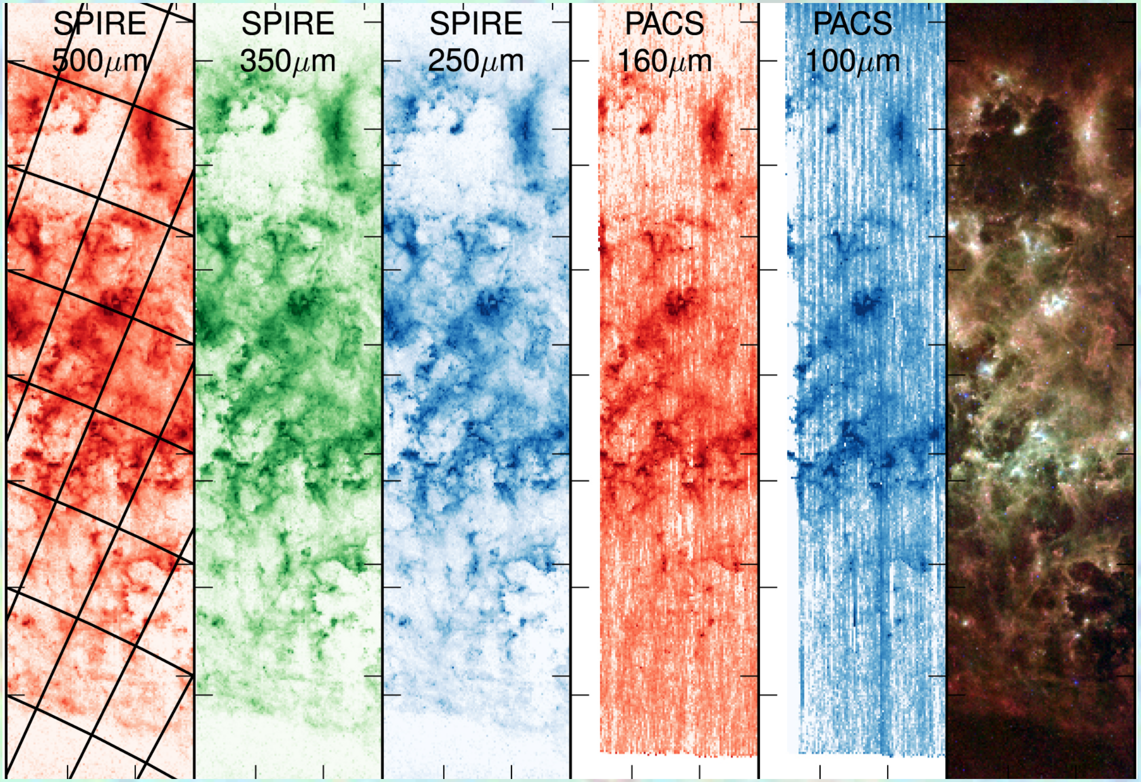
- VSG and PAH have very different spatial distributions

Herschel SDP data

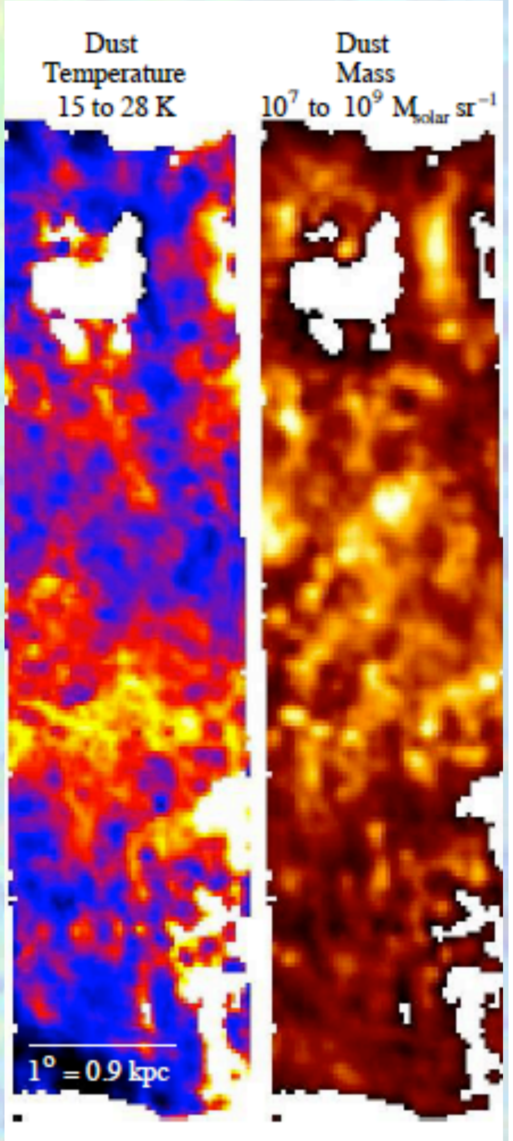
Heritage SDP data procesing: See Meixner talk

Additional processing for diffuse emission:

- MW foreground subtraction (HI +MW SED) using MW emissivity from Bernard et al. 2008
- Subtraction of NS gradient based on all data at end of stripe
- PACS data showing residual striping not used in the analysis
- Calibration of SPIRE data used beam area provided by M. Ferlet
- Data was smoothed to common resolution of IRAS (4.3’)



$\nu^{\beta} B_{\nu}(T_D)$ →



Herschel SDP data

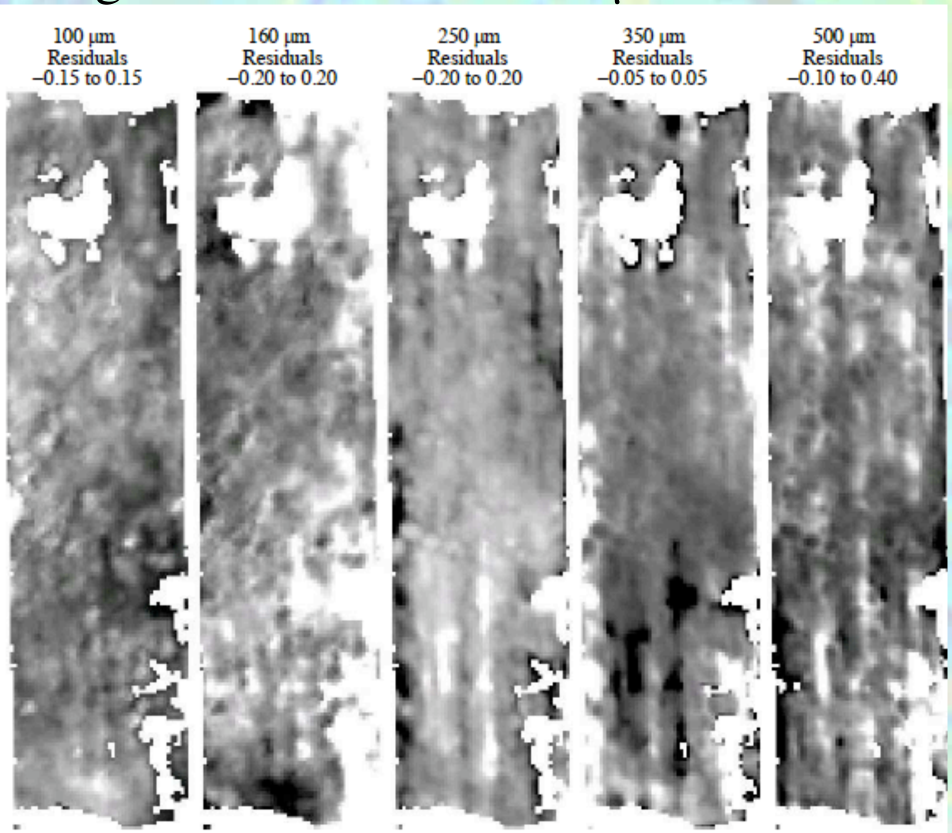
Greybody fitted to Spitzer 160 + SPIRE 250 and 350 μm. 15% error assumed for SPIRE

Best overall grey body fit to the data using a fixed β leads to β~1.5 (lowest residuals)

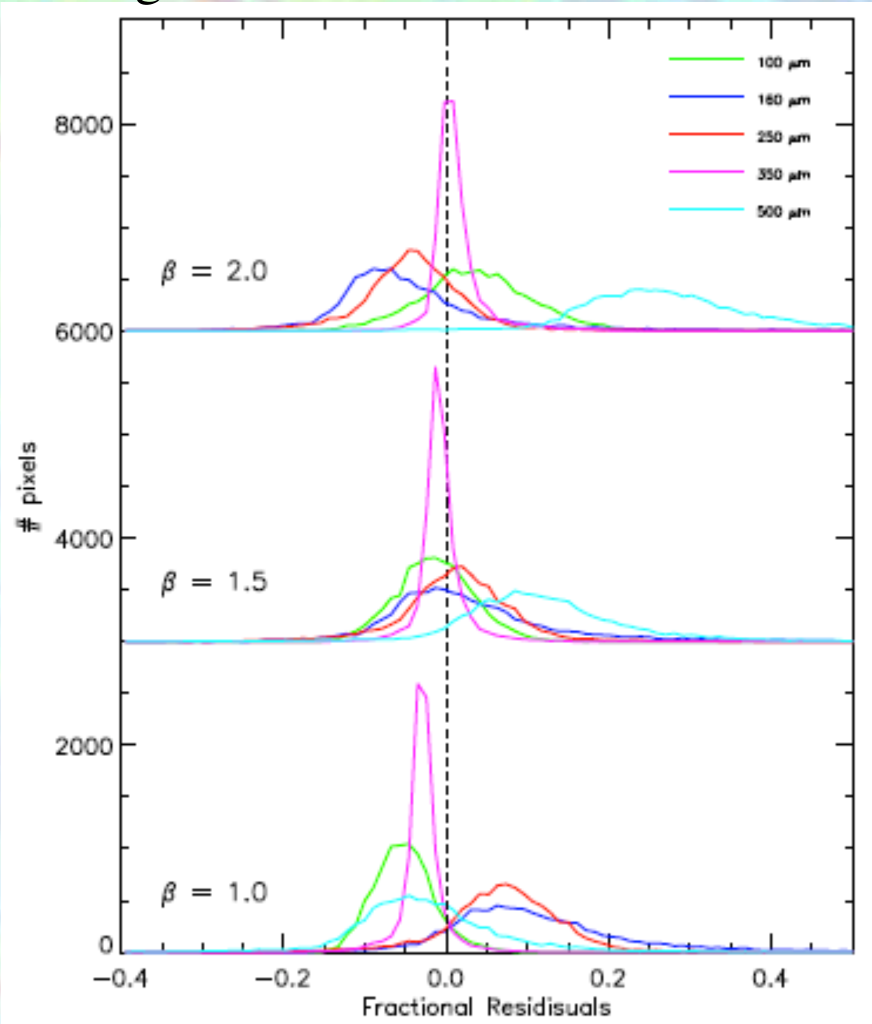
Residuals show:

- Real features at 100 and 160 μm
- Instrument artifacts in SPIRE bands
- Significant excess at 500 μm

Histograms of residuals:



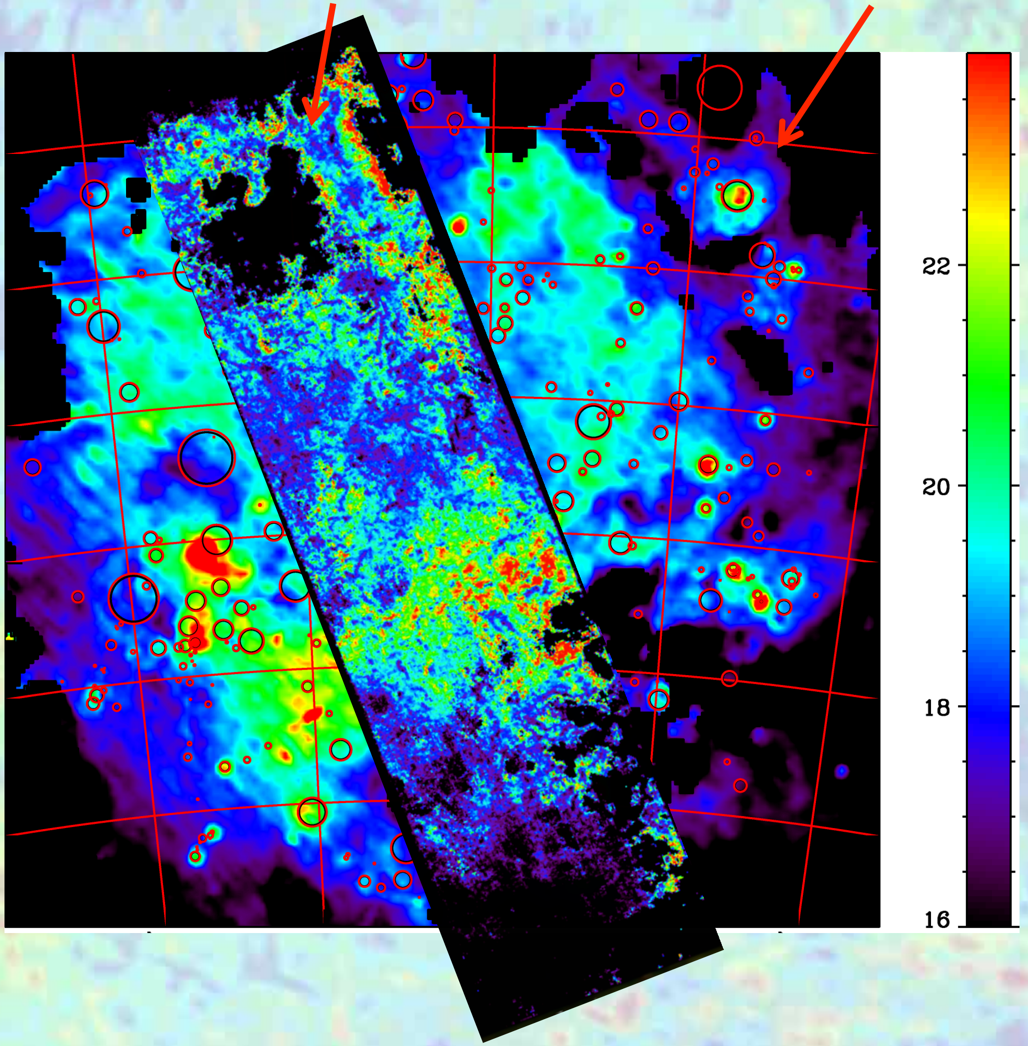
Spatial distribution of residuals (β=1.5)



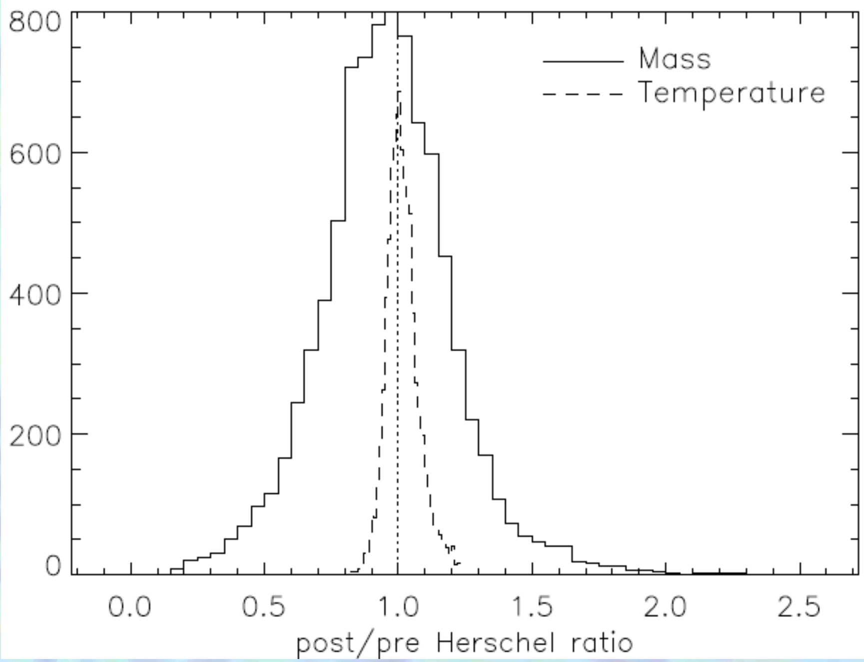
Dust Temperature map

Herschel :
IRIS 100 µm, MIPS160 µm
SPIRE250 µm, SPIRE350 µm
(38 arcsec)

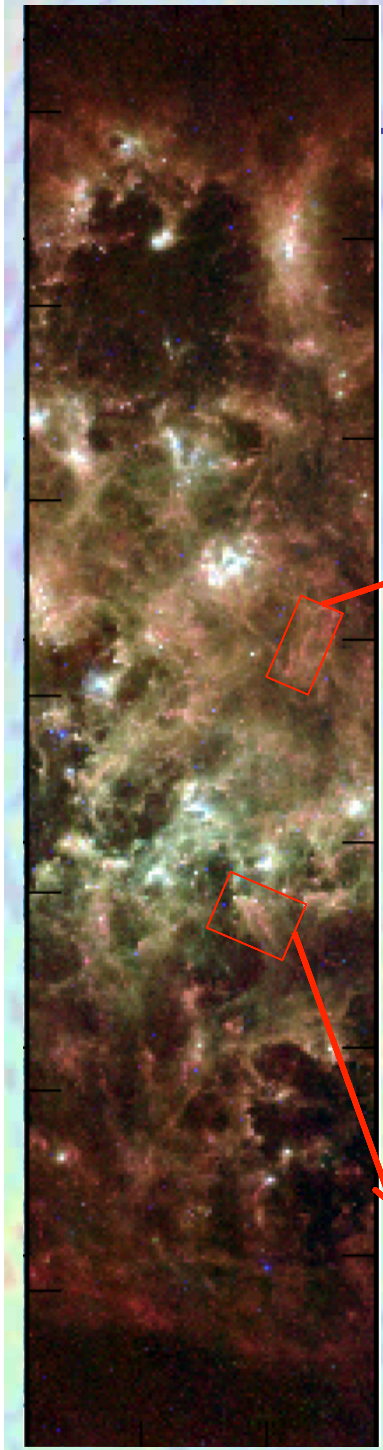
Spitzer :
IRIS 100 µm
MIPS160 µm
(4')

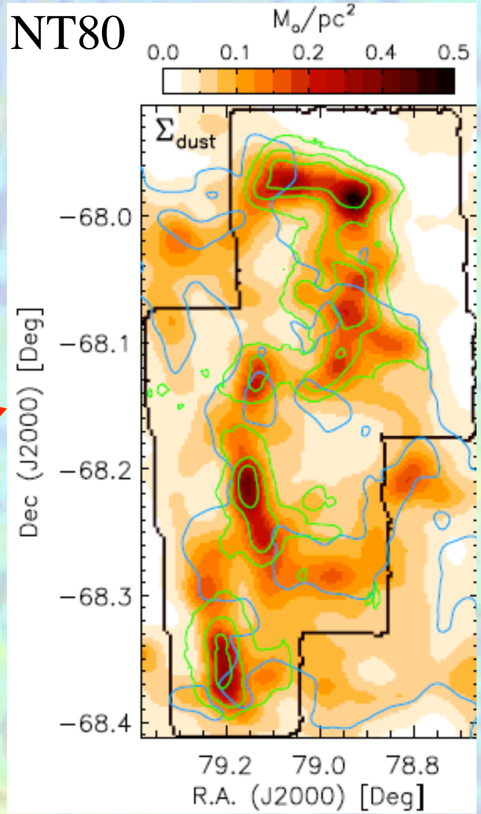


β	2	1.5	1
T_H/T_{post}	0.97	1.02	1.08
M_H/M_{post}	1.19	0.96	0.77
500 µm excess	+0.25	+0.10	-0.05



FIR Excess

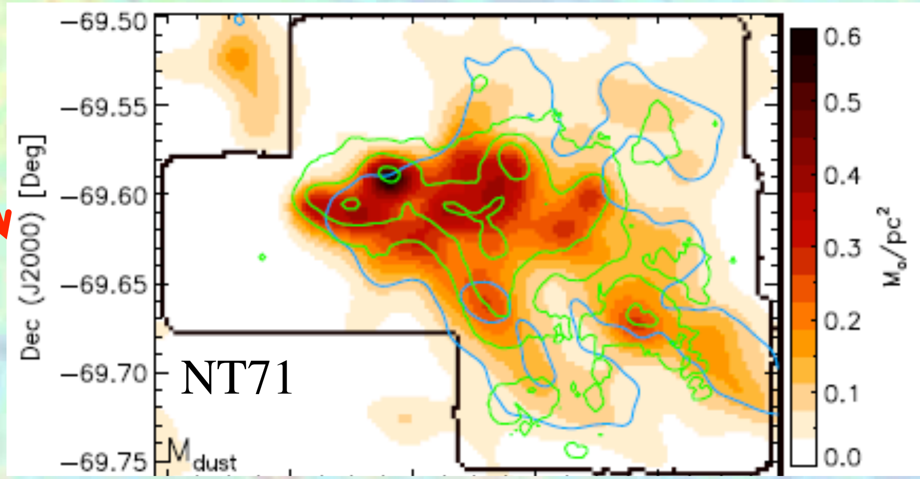




FIR excess was analyzed in a paper of the A&A special issue by Duval et al. They examined 2 molecular regions in NT80 and NT71

Confirms the existence of a strong FIR excess with respect to HI and CO

Study favors H_2 without CO

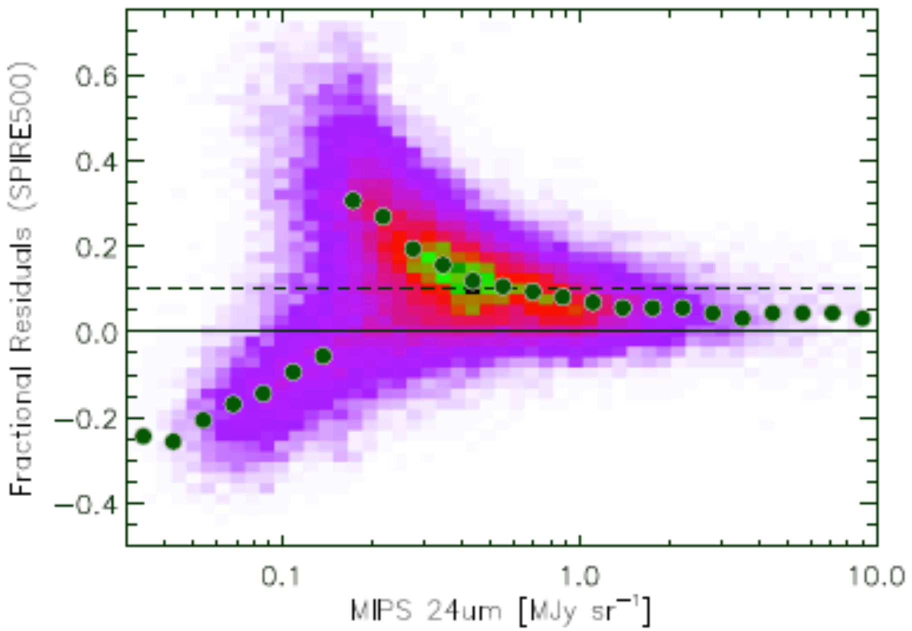


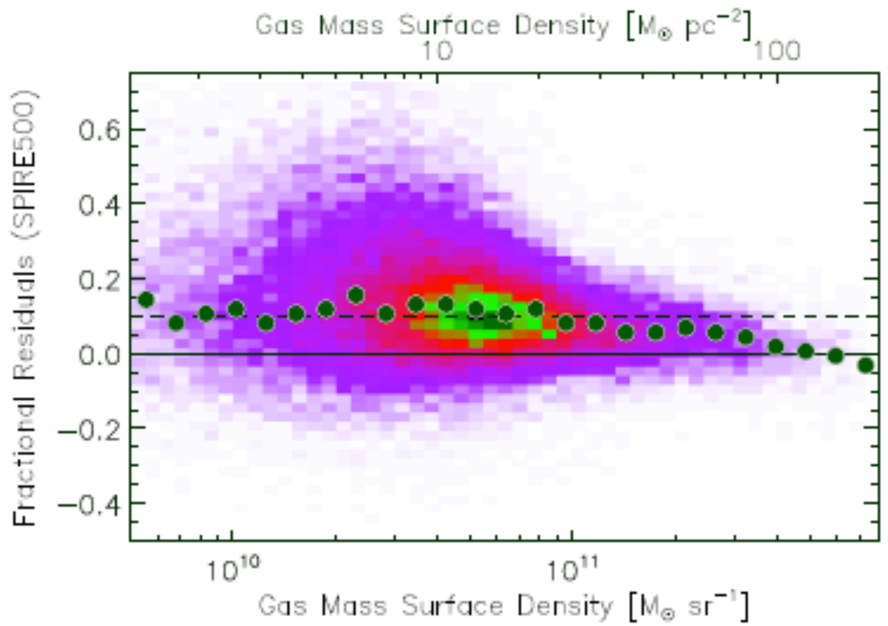
For more details, see Duval's poster

500 μm excess ?

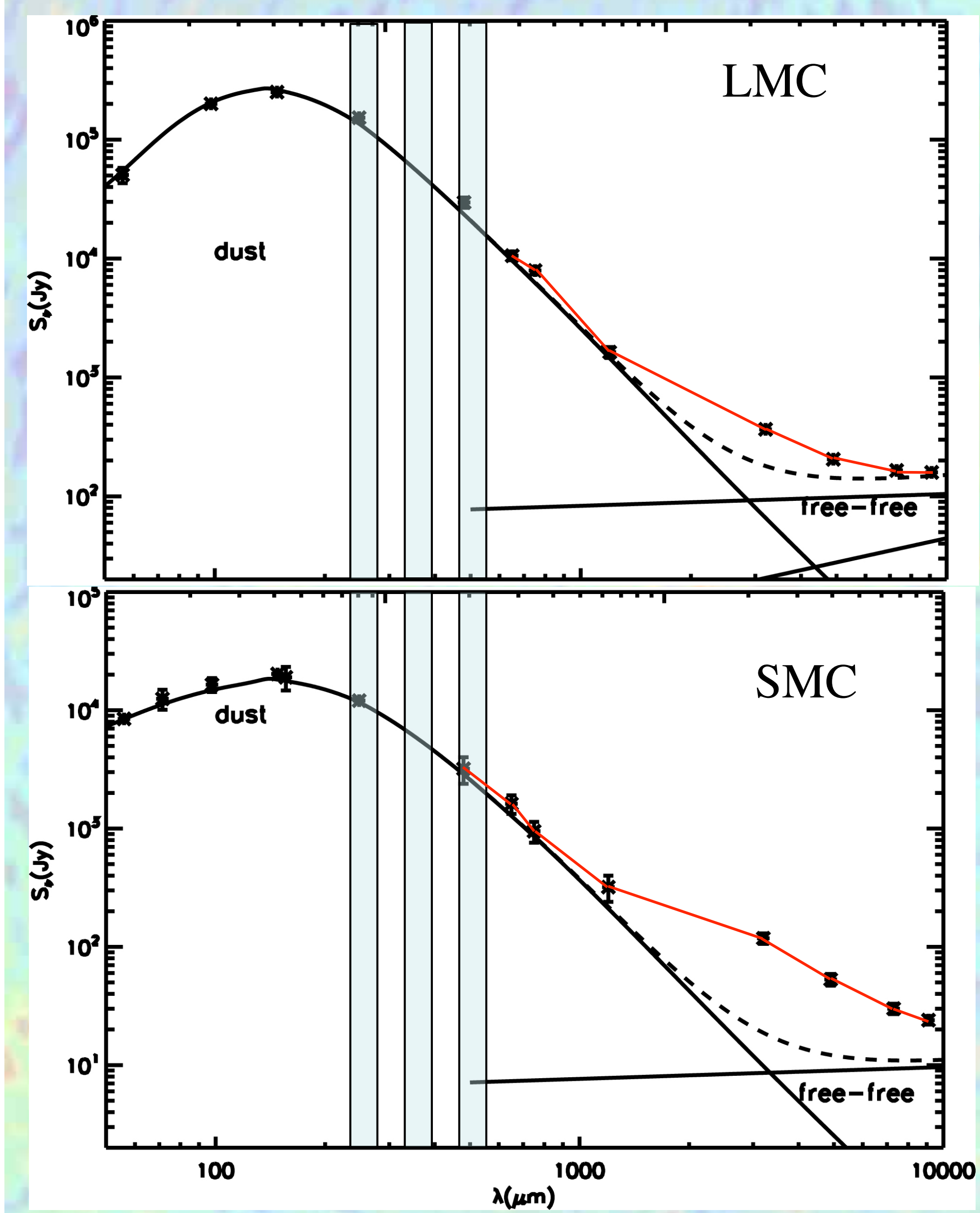
500 μm excess emission appears:
- Not localized in higher column density regions which probably excludes very cold dust
- Weakly anti-correlated with MIPS 24 μm

Could be due to an absolute calibration effect, or an actual flattening of the dust SED at long λ.





Long wavelengths ?



Integrated LMC & SMC SEDs from Israel et al. 2010 and Bot et al. 2010 in prep

FIR Data: Dirbe, Top-Hat, WMAP +radio
Model: Draine & Li 2007

Large excess seen in the millimeter. Could this be linked with the small excess detected at 500 μm ?

Current explanations include
- spinning dust (specially tuned model)
- optical properties from amorphous dust

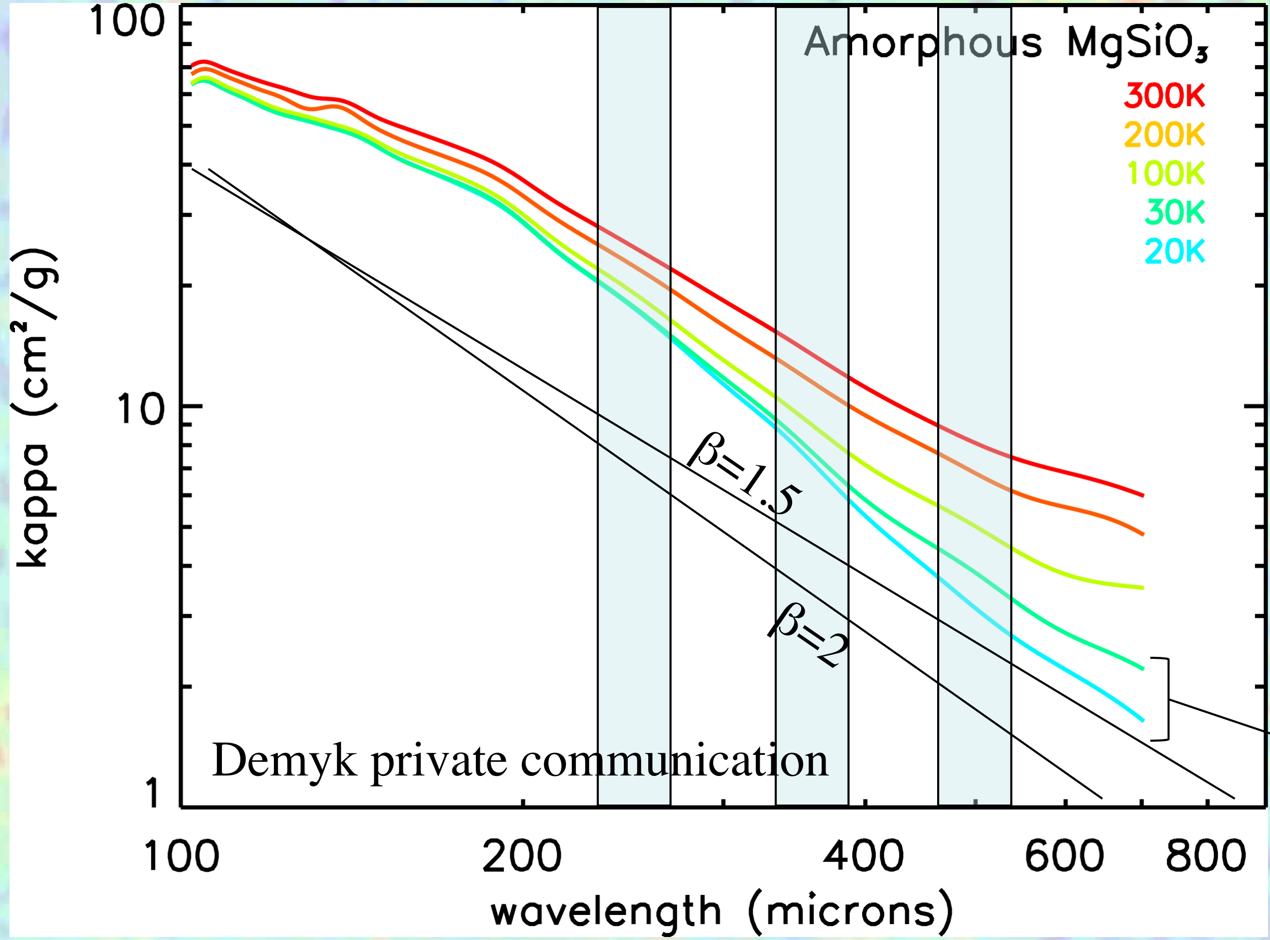
The Planck data will be crucial to elucidate origin of excess

Long wavelengths ?

Laboratory data on amorphous analogs show that β varies with both temperature and wavelengths

Flattening (lower β) at higher dust temperature and longer wavelength

Expected from theory of amorphous material (Meny et al. 2004)

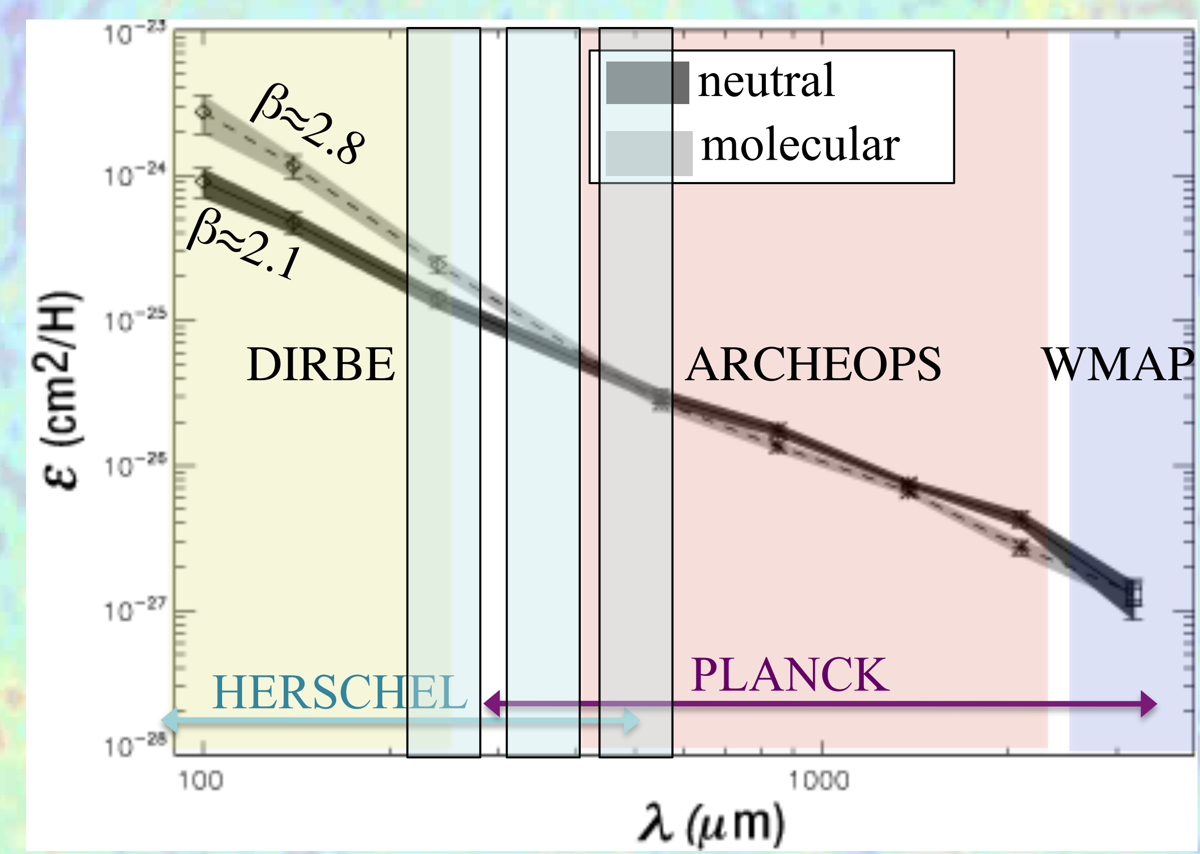


Range of LMC temperatures

Dust emissivity variations

Results by Paradis et al. 2009 (DIRBE+WMAP+Archeops) in the MW:

- Break in emissivity at λ~500 μm (could be due to amorphous nature of dust)
- Increased emissivity in λ-range of Herschel in cold molecular clouds (probably due to dust aggregation)



Flattening will be difficult to see with Herschel only (Planck needed)
Increased emissivity should be detectable towards cold MCs.
Question is what is the spectral shape of this excess.

Conclusions

Analysis of diffuse emission in the LMC with IRAS + Spitzer was limited by angular resolution (4’) and quality of 100 μm data and contaminations (e.g. 70 μm excess)

Herschel brings the data that will allow us to greatly improve the analysis
In particular, it will allow dust temperature determination at higher angular resolution and further away from known contaminations.

Preliminary results for the LMC favor β=1.5 which minimizes residuals, but the actual SED could be more complicated than a single grey body

LMC results are otherwise consistent with previous findings so far …

The FIR excess emission in the LMC is confirmed and an H_2 phase without CO remains the most likely explanation. Precise mass determination will have to wait for the full Heritage dataset

Combination with longer λ data (Planck) will be critical.