Probing the small dust properties in the diffuse galactic plane using the Spitzer – Herschel synergy

Studying the dust evolution

• Dust has a great impact on ISM physics and chemistry
  • This impact depends on their properties
  • Dust properties evolves depending on the physical properties of the ISM

Dust evolution physical processes characterization
  → dust impact on the ISM all-over the ISM cycle
  → build physical scenario for SED interpretations
**Aims - Goals**

Full (mid-IR - submm) SED fitting using a dust model:

- (Demonstration of) the Spitzer–Herschel synergy to study the dust evolution

- Why does PACS 70 looks like shorter wavelengths?
  - What lights up PACS observed emission?
  - What is the contribution of very small stochastically heated grains (VSGs) to the PACS observed emission?

- What does the IRAC 8 µm trace?
The data: Hi-Gal / MIPSGAL / GLIMPSE

• Spitzer: GLIMPSE and MIPSGAL (8 & 24 µm)
  – These are zodi-subtracted
  – IRAC 8µm is point sources subtracted

• PACS 70 is the ROMAGAL map X-calibrated on MIPS70 (zodi corrected)

• PACS 160, SPIRE 250 & SPIRE 350
  – ROMAGAL maps & official calibration
  – Offset correction (Planck, private comm.)

• All data brought in the SPIRE350 resolution and grid
  – Resolution matching using a Gaussian of appropriate width
Hi-Gal SDP field $l=59^\circ$

SPIRE 350
SPIRE 250
PACS 160
PACS 70
MIPS 24
IRAC 8

$l$ (degree)

$b$ (degree)

I (degree)
DUSTEM model (I)

• DUSTEM provides dust extinction and emission (and soon a spinning dust component, the polarization, $\beta(T)$ and $\beta(\lambda)$)

• $dP/dT$ computation based on Désert, Boulanger & Shore (1986)

• DUSTEM is a versatile & user friendly model:
  ✓ Arbitrary number of dust population
  ✓ All dust properties defined through input files
  ✓ Tabulated (arbitrary) size distribution allowed
  ✓ Includes a Interactive Data Language (IDL) wrapper for the SED fitting
    → new dust properties easily implemented

• Publicly available online in couple of weeks, after the paper submission (Compiègne, Verstraete et al., 2010 : watch astro-ph !)
• Reference SED: Diffuse High Galactic Latitude SED for \(|b| > 15^\circ\) and \(I_{\text{HI}} < 300 \text{ K Km s}^{-1}\)
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• DUSTEM $\rightarrow$ reference dust properties from the reference SED

3 grain types:
- PAHs
- Amorphous carbon
- Astro-Silicates

- Also satisfies the measured extinction, albedo and abundances
The SED fitting procedure (I)

- DUSTEM populations merged:
  - PAHs
    - SamC + SaSil = VSGs
  - LamC + LaSil = BGs

- Fitting of the photometric point by adjusting:
  - $Y_{PAH}$ and $Y_{VSG}$: abundance relative to BGs
  - $N_H$: Column density
  - $G_0$: scaling factor of the radiation filed

- BG properties are constants (e.g. emissivity and abundance)

- Effect of extinction on the line of sight is accounted for (important at 8 µm)
  assuming $I_\lambda = I_{0,\lambda} \frac{1-e^{-\tau_\lambda}}{\tau_\lambda}$
The SED fitting procedure (II)

- Thermal equilibrium grains spectrum shape = $\text{fct}(G_0)$
- PACS160, SPIRE250 and 350 → $N_H$ & $G_0$
  IRAC 8, MIPS24 → $Y_{PAH}$
  MIPS24, PACS70 → $Y_{VSG}$
- For higher $G_0$, smaller species at thermal equilibrium
  → degeneracy between $N_H$ and $Y_{VSG}$ then $Y_{PAH}$
Fitting products

- $Y_{\text{VSG}}$
- $N_H$
- SPIRE 350
- $Y_{\text{PAH}}$
- $G_0$
- PACS 70
Fitting products

\[ Y_{VSG} \quad N_H \quad \text{SPIRE 350} \]

\[ Y_{PAH} \quad G_0 \quad \text{PACS 70} \]
**Fitting produced quantities**

\( Y_{PAH} \) and \( Y_{VSG} \): PAH and VSG abundances relative to BG. 1 is the value for DHGL medium (\(|b| > 15^\circ|\)"

\( G_0 \): Scaling factor of the Mathis, Mezger, Panagia, (1983) radiation field intensity

\( N_H \): column density in unit of \(10^{20} \text{ H cm}^{-2}\)
First conclusions

- $Y_{PAH}$, $Y_{VSG}$, $N_H$ and $G_0$ have consistent values and behavior
- $Y_{PAH}$ and $Y_{VSG}$ decrease toward dense filamentary structures
- Lack of correlation of $Y_{PAH}$ and $Y_{VSG}$ especially at large spatial scales.
What lights up PACS 70 µm?

In this field, PACS 70 is enlightened by VSGs (stochastically heated) and Wien part of the BGs spectrum

→ Very sensitive to $G_0$
  → Looks like shorter wavelengths

→ VSG contribution can vary depending on $Y_{VSG}$ and $G_0$
PACS 70 VSG contribution (I)

- From the modeled PACS images resulting from the fit:

  \[ \rightarrow \text{PACS 70 VSG relative contributions: 56\% and 9\%} \]

  \[ \rightarrow \text{PACS 100: 23\% and 3\%} \]

  \[ \rightarrow \text{PACS 160: 9\% and 1\%} \]
At a given $G_0$, the contribution scales linearly with $Y_{VSG}$.

At a given $Y_{VSG}$, VSG contribution decreases with $G_0$ increasing.

$Y_{VSG} = 1$

Asymptotic for $G_0 > 100$ cause VSGs starts being at thermal equilibrium and behave like BGs.
What does the IRAC 8 µm trace?

• IRAC8 does not trace $Y_{\text{PAH}}$

Stochastically heated particles:

$I_{\text{PAH},\lambda} \propto G_0 \times N_H \times Y_{\text{PAH}}$

• Now by constraining $N_H$ and $G_0$ with BGs emission - we can actually constrain $Y_{\text{PAH}}$

• Extinction in IRAC8 map regarding $G_0 \times N_H \times Y_{\text{PAH}}$
Summary

• PACS70 looks like shorter wavelengths cause it’s enlighten by Wien part of BG emission (at $G_0<100$) and by VSGs
  → Very sensitive to $G_0$ (regarding longer wavelengths)

• VSG contribution can be very important in PACS70 (up to 56% in our field)
  → Dust model is needed to account for it depending on $Y_{VSG}$ and $G_0$ (a grey body does not do a good job)

• “Spitzer – Herschel” synergy + dust model fitting is very promising to quantify dust properties evolution on the entire galactic plan
  → Very near future :
    ✓ Correlation with BGs emissivity evolution (implemented in the fitting process)
    ✓ Correlation with gas physical properties (CO and HI cubes available)
    ✓ Can do that systematically and homogeneously overall the galactic plane