Evolution of interstellar dust with Herschel

First results in the PDRs of NGC 7023

SPIRE ISM consortium

Scientific goals of the Key project

Evolution of interstellar dust

Survey of the properties of interstellar dust with different conditions
Av, Illumination, Density, History, Star forming activity

Contribution of all processes acting on the dust particles …
Fragmentation / Coagulation / Condensation / Evaporation / Photo-processing

… for very diffuse regions to sites of star formation of our Galaxy

Selected targets in nearby galactic regions,
with precise and well understood physical conditions and geometry,
in order to derive the dust and gas properties from the observations

Combination of Mapping and Spectroscopy (SPIRE and PACS)
Dust SED: Continuum
Physical conditions : mainly CI, CII, OI, high-level lines of CO

Strong emphasis on the spatial information within individual objects
Evolution of Interstellar Dust - NGC7023

Models after Spitzer, before Herschel/Planck:
- Silicate + Graphite + PAH (e.g., Draine & Li 2007)
- Silicate + Amorphous Carbon + PAH (e.g., Compiègne et al. 2010)
  with Silicate-cores / Carbonaceous mantles (e.g., Désert et al. 2010)
  with composite grains (e.g., Zubko et al. 2004)

Full emission spectrum of interstellar dust

\[ I(\lambda) = \tau \left( \frac{\lambda}{\lambda_0} \right)^{-\beta} B_{\lambda}(T) \]

Diffuse medium,
Compiègne et al. 2010
Main questions to be addressed with Herschel

Emission properties of Big Grains:
  Spectrum of the Big Grains?
  Variations of the emissivity index? Dependence with the temperature?
  Absolute emissivity? Dependence with the physical conditions?

Nature and structure of Big Grains:
  Separated populations of Carbonaceous and Silicate grains?
  Composite grains? Aggregates?

Evolution with:
  - the physical conditions?
  - the smaller dust components?

Structure of the ISM (diffuse clouds to dense cores) traced by the Big Grains emission (most of the dust mass)
### Sources and Observation Modes

<table>
<thead>
<tr>
<th>Source</th>
<th>Number</th>
<th>Observation Modes (SPIRE and PACS)</th>
</tr>
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<tbody>
<tr>
<td>Spica H II</td>
<td>4-8</td>
<td>Spectroscopy</td>
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<td>IVC G86.5+59.6</td>
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<td>Cirrus to Molecular Clouds</td>
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<td>Ûrsa Major</td>
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<td>Spectroscopy</td>
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<td>Polaris flare</td>
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<td>G300-17/Cham III</td>
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<td>Taurus filament</td>
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<td>PDRs</td>
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<td>NGC7023</td>
<td>1000</td>
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<td>Horsehead</td>
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<td>Hot PDRs with H\ II regions</td>
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<td>Sh2-104, Cygnus</td>
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<td>RCW120</td>
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(Large scale mapping of nearby molecular clouds in the Goult belt and HOBYS surveys, André et al., Motte et al.)

<table>
<thead>
<tr>
<th>Observation Modes</th>
<th>Time (h)</th>
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<tbody>
<tr>
<td>SPIRE mapping alone</td>
<td>4.5</td>
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<tr>
<td>SPIRE + PACS // mapping</td>
<td>22.5</td>
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<td>SPIRE Spectroscopy</td>
<td>85</td>
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<td>PACS Mapping alone</td>
<td>20.3</td>
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<td>PACS Spectroscopy</td>
<td>28</td>
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<tr>
<td>Total</td>
<td>163</td>
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</table>
Used Observations

SPIRE and PACS mapping in the Science Demonstration Phase (SDP):
- Cirrus/molecular cloud: Polaris (common field with the Gould belt KP) Miville-Deschênes et al., Men’shchikov et al., Ward-Thompson et al.
- Classical PDR: NGC 7023 Abergel et al., Hot PDRs: RCW120, SH2-104 Anderson et al., Rodon et al.

SPIRE/FTS (single pointings) spectroscopy in the SDP:
- SH2-104: Rodon et al.

+ SPIRE/FTS (single pointings) in the Performance Verification Phase:
  - Orion Bar: Habart et al., Naylor et al, Dartois et al.
  - DR21, Rosette: White et al.
  - Compact HII regions: G29.96-0.0, G32.80+0.19 Kirk et al., Dartois et al.
  - Pre-stellar core B133: Ward-Thompson et al.

Less than 10% of the total observing time
No PACS spectroscopy
No full sampling SPIRE/FTS observation
Mapping of NGC 7023
Observations & Data processing

SPIRE:
- 2 perpendicular 8’ X 8’ maps (nominal scan speed, R=4), total time= 1765 s
- Level-2 naive maps delivered by the HSC (standard corrections)
- Overall absolute flux accuracy: 15 %

PACS:
- 2 perpendicular 10’ X 10’ maps (medium scan speed), total time= 5166 s
- HIPE 2.3.1: Simple projection with second level deglitching
  - High pass filtering to remove the 1/f noise
  - Artefacts around bright structures
- Preliminary
- Overall absolute flux accuracy: 10% and 20% in the blue and red bands, resp.
NGC 7023

3 PDRs viewed approximately edge-on

HD 200775

\(^{13}\text{CO} (3-2)\) emission

Gerin et al. 1998

Evolution of Interstellar Dust - NGC7023

A. Abergel

ESLAB 2010
NGC 7023: Spitzer + Herschel
Evolution of Interstellar Dust - NGC7023

A. Abergel
ESLAB 2010

Angular resolution of SPIRE at 500 µm assuming gaussian beams Preliminary

NGC 7023: Spitzer + Herschel

IRAC, 3.6 mic | IRAC, 5.8 mic | IRAC, 8 mic
MIPS, 24 mic | PACS 70 mic | PACS 160 mic
SPIRE 250 mic | SPIRE 350 mic | SPIRE 500 mic
NGC 7023: SED at the peak 250 µm positions

Solid lines: \( \beta = 2, T = 30.0, 33.5, 23.3 \) K.
Dashed lines: Free values of \( \beta = 2.3, 2.6 & 2.1 \) with \( T = 27.1, 27.2 \) K, 22.1 K

Taking into account the overall uncertainties: compatible with \( \beta = 2 \)
RCW 120 hot PDR

From Anderson et al. (submitted to A&A):
- Peak positions: spectra compatible with $\beta = 2$
- Indication of increasing value of $\beta$ with decreasing temperature (T around 10 K)

See also Rodon et al. (poster) for Sh2-104

<table>
<thead>
<tr>
<th>Name</th>
<th>$T (K)$ $\beta = 2$</th>
<th>$T (K)$ $\beta$ free</th>
<th>$\beta$</th>
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<tbody>
<tr>
<td>Interior</td>
<td>30.4 ± 0.9</td>
<td>28.9 ± 2.0</td>
<td>2.4 ± 0.2</td>
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<tr>
<td>PDR - West</td>
<td>27.1 ± 0.6</td>
<td>20.5 ± 1.0</td>
<td>2.9 ± 0.2</td>
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<tr>
<td>PDR - East</td>
<td>23.1 ± 0.7</td>
<td>22.9 ± 2.1</td>
<td>2.1 ± 0.2</td>
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<tr>
<td>Cond. 1</td>
<td>20.1 ± 0.3</td>
<td>21.6 ± 1.1</td>
<td>1.7 ± 0.2</td>
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<tr>
<td>Cond. 2</td>
<td>22.2 ± 0.4</td>
<td>22.1 ± 1.2</td>
<td>2.1 ± 0.2</td>
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<tr>
<td>Cond. 3</td>
<td>21.5 ± 0.3</td>
<td>22.2 ± 1.2</td>
<td>2.0 ± 0.2</td>
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<tr>
<td>Cond. 4</td>
<td>21.0 ± 0.4</td>
<td>23.0 ± 1.2</td>
<td>1.8 ± 0.2</td>
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<tr>
<td>Cond. 5 (IRDC)</td>
<td>12.6 ± 0.5</td>
<td>9.2 ± 0.9</td>
<td>3.2 ± 0.4</td>
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<td>Cond. 6 (IRDC)</td>
<td>13.1 ± 0.5</td>
<td>10.5 ± 1.2</td>
<td>2.8 ± 0.4</td>
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<td>Cond. 7</td>
<td>21.8 ± 0.4</td>
<td>22.7 ± 1.2</td>
<td>1.9 ± 0.2</td>
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<td>Cond. 8</td>
<td>14.3 ± 0.6</td>
<td>9.9 ± 1.0</td>
<td>3.3 ± 0.4</td>
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<td>Cond. 9 (IRDC)</td>
<td>12.8 ± 0.5</td>
<td>10.2 ± 1.1</td>
<td>2.9 ± 0.4</td>
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<td>Cond. 10</td>
<td>23.5 ± 0.7</td>
<td>25.9 ± 2.8</td>
<td>1.9 ± 0.2</td>
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<tr>
<td>Southern Filaments 1</td>
<td>14.6 ± 0.7</td>
<td>10.7 ± 1.3</td>
<td>3.0 ± 0.4</td>
</tr>
<tr>
<td>Southern Filaments 2</td>
<td>13.5 ± 0.6</td>
<td>9.6 ± 1.0</td>
<td>3.2 ± 0.4</td>
</tr>
</tbody>
</table>
NGC 7023: Spitzer + Herschel

Angular resolution of SPIRE at 500 µm assuming gaussian beams Preliminary
Brightness profiles across the East PDR

SPIRE 250 µm

Distance from PDR edge (parsecs)

Normalized profiles

Angular distance from star (arcmin)
Modelling of the East PDR: 1. Density profile

\[ n(z) = n_0 \times \left( \frac{z}{z_0} \right)^\alpha \]

3 parameters: \( n_0, z_0, \alpha \)
Modelling of the East PDR: 2. Dust Model

“DUSTEM” Compiegne et al. 2010 : Silicate + Amorphous Carbon + PAH, with dust properties and abundances corresponding to the diffuse ISM and $G_0 = 250$ (from the distance star-illuminated edge):

![Graph showing dust emissions in the infrared spectrum with labels for BGs, VSGs, and PAH]
Modelling of the East PDR: 3. Radiative Transfer

Plan-parallel model (Compiègne et al. 2008):

\[ F^{tot}(z, \lambda) = F_t(z, \lambda) + F_b(z, z_{max}, \lambda) + F_{dust}(z, \lambda) \]

\[ = F(z, \lambda) + F_{dust}(z, \lambda) \]
Modelling of the East PDR: 4. Results

3 parameters of the density profile: $n_0 = 3 \times 10^4$ cm$^{-3}$, $z_0 = 0.18$ pc, $\alpha = 2.8$
Length of the PDR along the line of sight = 0.65 pc

PAHs and VSGs emissions over-estimated by a factor 2
Decrease of the relative abundances
Or the absolute emissivity of the Big Grains is increased
- The 70 µm emission is comparable to smaller wavelengths maps, since it is more sensitive to the radiation field than the longer wavelength emission (as the PAHs and the VSGs emissions)
- The 160 µm emission is comparable to longer wavelengths maps
First Conclusions

SPIRE and PACS data allow us to use the Big Grain emission are a tracer of the interstellar matter.

At the peak positions of the PDRs, the SED of Big Grains measured with SPIRE and PACS can be adjusted with a modified black-body with $\beta = 2$.

Improvement in the data processing still necessary to conclude firmly for a dependence of $\beta$ with the temperature.

Dust and radiative transfer models allow us to derive, from SPIRE and PACS, data quantitative informations on the dust properties.

Next step: Combination with spectroscopic observations.

See presentations/posters in SPIRE spectroscopy by Dartois et al., Habart et al., White et al., Rodon et al., Ward-Thompson et al.

Acknowledgements: ESA, SPIRE & PACS teams.