Cold Cores with Planck & Herschel

Mika Juvela

On behalf of the Planck and Herschel projects on cold cores
Sub-millimetre dust emission probes the hidden dense and very cold regions of molecular clouds.

Tracer of the earliest phases of star formation.

What creates the pre-stellar cores, what governs their evolution to protostars and proto-brown dwarfs?

Origin of the global stellar initial mass function (IMF).

Part of the life cycle of dust.

We need large samples of cold and compact Galactic dust clouds ...
Cold Cores & Planck

The Planck satellite is mapping the sky at 9 frequencies between 857GHz and 30 GHz

- 350, 550, 850, 1380, 2100, ..., 10000 µm
- better than 5' resolution in the sub-mm

This enables the detection of cold cores!

Planck is also the first mission that is capable of a full survey

- all-sky
- coverage of sub-millimetre wavelengths
- sufficient resolution
- excellent sensitivity
The analysis of Planck data has resulted in the Cold Clumps Catalog of Planck Objects – C3PO
Planck Early Results - Planck 2011s
(cf talk by L. Montier)

ESA and the HFI Consortium, IRAS
http://www.esa.int/esaMI/Planck/SEMMN9CKP6G_1.html
We want to *understand* star formation

- what forms the gravitationally bound cores
- how do the cores evolve
- what is the connection with the surrounding cloud
- what is the morphology of the regions
- what is the structure of the cores themselves
- how do dust properties vary in the cores
- how does the star formation affect the cores

... we need higher spatial *resolution* and better coverage of the *far-infrared* wavelengths
Cold Cores & Herschel

- OT KP *Galactic Cold Cores*
- PACS and SPIRE maps of cores detected by Planck
- A representative **cross-section** of the Galactic cold core population
  - temperature, mass, density, size, location (high/low latitudes, inner/outer Galaxy), environment (clustered vs. isolated sources, magnetic fields), dust properties (emissivity index, signs of anomalous microwave emission, polarization)
- 151 hours ~ 100 fields
Cold Cores

on Planck\textsuperscript{1, 2} and Herschel \textsuperscript{1}

on behalf of the Planck collaboration

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\textbf{Planck}


Abergel, \textbf{Bernard}, Boulanger, Cambresy, Davies, Dickinson, Fischera, Macias-Perez, \textbf{Marton}, Meny, Miville-Deschenes, Nartallo, \textbf{Pagani}, Puget, Reach

\textbf{Herschel}

Andre, Kiss, Klaas, \textbf{Krause}, Molinari, Motte, Schneider, \textbf{Toth}, Ward-Thompson, \textbf{Zavagno}

\textbf{External}

\textbf{Doi, Ueno, Kitamura, Nikeda, Kawamura, Onishi}

\textit{With acknowledgement to ESA\textsuperscript{1} and the Planck HFI & LFI consortia\textsuperscript{2}}
15 fields observed and 44 waiting scheduling, the remaining targets will be selected by mid February

in the following some results on three fields **PCC288, PCC550, PCC249**

- These three observed during Herschel Science Demonstration Phase (SDP); PCC550 also included in ECC/ERCSC
- for further examples, see the poster by P17 (ask I. Ristorcelli)
PCC288 in IRAS

Mika Juvela - Paris 12.1.2011
PCC288 is
- a cold clump...
- but also a star forming cloud with class 0/I protostars
The Herschel SDP fields

**PCC288** at 800 pc
- ~14K clump in Cepheus with ~140 Msun
- Several compact objects with FIR/submm colour temperatures above 20K
- One Fu Ori type protostar with a molecular outflow
- Between a young stellar group and a molecular cloud – triggered SF?

(Juvela et al. 2010, 2011)

**PCC550** at 225 pc
- Piece of a long filament in Musca
- Two ~11K cores, both about 10 Msun
- Quiescent with density profiles similar to stable Bonnor-Ebert spheres

**PCC249** at 900 pc
- Very active star forming region
- Average temperature high, the Planck detections correspond to ~100 Msun regions at ~17K
- Colder smaller clumps (~13K) between the hot cores – possibly prestellar?
The Colour Temperatures

- In the Herschel maps – 100, 160, 250, 350, and 500µm - the zero levels were adjusted using Planck and IRAS data.
- Temperature maps (β=2) confirm the Planck detections.
  - For example, in PCC288 the protostars raise the temperature only locally, in Planck beam the cold clump dominates.
The Column Densities

- The Planck detections also correspond to peaks in column density

- The analysis of Herschel maps gives $N(H) \sim 10^{22}\text{cm}^{-2}$ in PCC550, a factor of a few higher in the other fields
Planck Early Results Planck2011r
See the poster P17 (ask I. Ristorcelli)
**The Dust Spectral Index**

- Mapping artifacts may affect the $\beta(T)$ relation at large scales.
- The features at smaller scales provide stronger evidence of variations of the **apparent** $\beta$.
  - $\beta$ decreases to $\sim 1$ close to internal sources.
  - $\beta$ increases (by 0.3?) in the cores.

$I_\nu \sim B(T) \nu^\beta$

$\beta$ vs. $T$ ?

Juvela - Paris 12.1.2011
• It is well known that line-of-sight temperature variations decrease the observed $\beta$ (e.g. Schwartz 1982, Malinen et al. 2011)

• The **magnitude** of the effect was studied in PCC288 with the help of a 3D radiative transfer model
  
  • Density distribution based on the column density map
  
  • Included three internal heating sources
high column density far from sources → \( \beta \) is underestimated → the real \( \beta(T) \) relation may be steeper than observed

\( \beta \) strongly underestimated near the sources → low \( \beta \) values can be explained without a change in grain properties
Similar conclusion was reached by Malinen et al. (2011)
- High resolution models based on AMR MHD calculations
- Externally heated cloud vs. a cloud with some tens of internal heating sources (~1-100 L_☉)
Conclusions

• The Cold Cores project **complements** other Herschel programmes by picking sources from all over the sky, including high latitudes and areas outside currently active SF

• The study of the first fields has **confirmed** the Planck detections and has demonstrated the variety of the cold core / clump population

• Clear variations are detected in the apparent – and the intrinsic – **dust properties**. The effects need to be considered when estimating the source properties

• The Herschel survey will be completed within about one year. The results will be used to characterize the initial stages of the **Galactic star formation - on a global scale**