Galactic Cold Cores

M. Juvela, I. Ristorcelli, On behalf of the Planck and Herschel projects on Cold Cores

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The project *Galactic Cold Cores* studies the initial phases of star formation using observations with the Planck and Herschel satellites. Because of the low temperature of pre-stellar cores, the sources need to be studied at sub-millimetre wavelengths.

The **Planck** satellite is performing a sensitive all-sky survey, including several bands in the sub-millimetre regime. Its resolution is comparable to IRAS but its sensitivity to the emission from cold dust far exceeds any previous survey. Planck helps to reveal the full population of pre-stellar cloud cores in the Galaxy and will provide statistics on their intrinsic properties. In the study of cold cores, **Herschel** is a perfect companion to Planck. Within our Herschel open time key programme *Galactic Cold Cores*, we are mapping a subset of Planck cores using the Herschel PACS and SPIRE instruments. Herschel will show whether the Planck targets are mostly isolated cores, fragmented filaments, or more complex clustered regions. By measuring the radial density and temperature profiles we provide data to test models of core fragmentation and collapse.

Planck has located cold dust in very different regions, ranging from quiescent, stable cores to regions of active star formation. The Herschel data have enabled us to study the variation of dust grain properties at small scales and the modelling of selected cores is in progress. However, the fields contain also many protostellar objects that remain unresolved even in the shortest wavelength Herschel observations. The internal structure of these more evolved sources can be studied only with the resolution provided by ALMA.

Background

The initial conditions in cold molecular clouds dictate many aspects of star formation, the stellar mass distribution, star formation efficiency, and evolution time scales. In particular, the initial mass function (IMF) may be largely determined during the pre-stellar core fragmentation. The first Herschel results have confirmed the similarity between the core mass spectra and the IMF (André et al. 2010). Both distributions are linked to general properties of interstellar turbulence (Padoan 1995) although local triggering also must play a role. Understanding the processes acting at the very earliest stages of star formation requires study of the cold pre-stellar cores.

Planck and Herschel studies

Planck and Herschel satellites were launched in May 2009. Planck is surveying the sky at nine frequencies between 857GHz and 30GHz. For Planck the main objective is accurate mapping of CMB fluctuations but its sub-millimetre bands mainly trace the distribution of Galactic dust clouds. The combination of high sensitivity and adequate resolution (down to below 5 arcmin) makes Planck an excellent tool for locating Galactic cold cloud cores. Simulations suggested that Planck will detect thousands of new cold cores. For many of these the core temperatures and the dust emissivity index can be determined using Planck data alone.

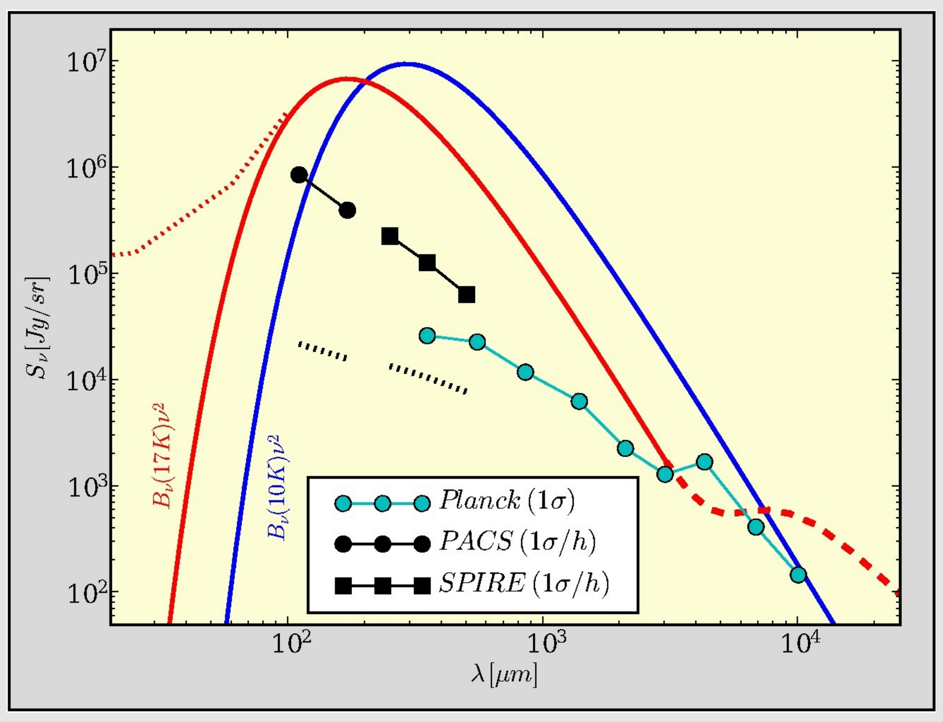

***Figure 1**: Surface brightness sensitivity of Planck all-sky survey and Herschel PACS and SPIRE mappings. Template dust spectra at two temperatures are also shown. The Herschel sensitivity is calculated for one hour observation, for full resolution (filled symbols) and for 5 arcmin resolution (dotted lines).*

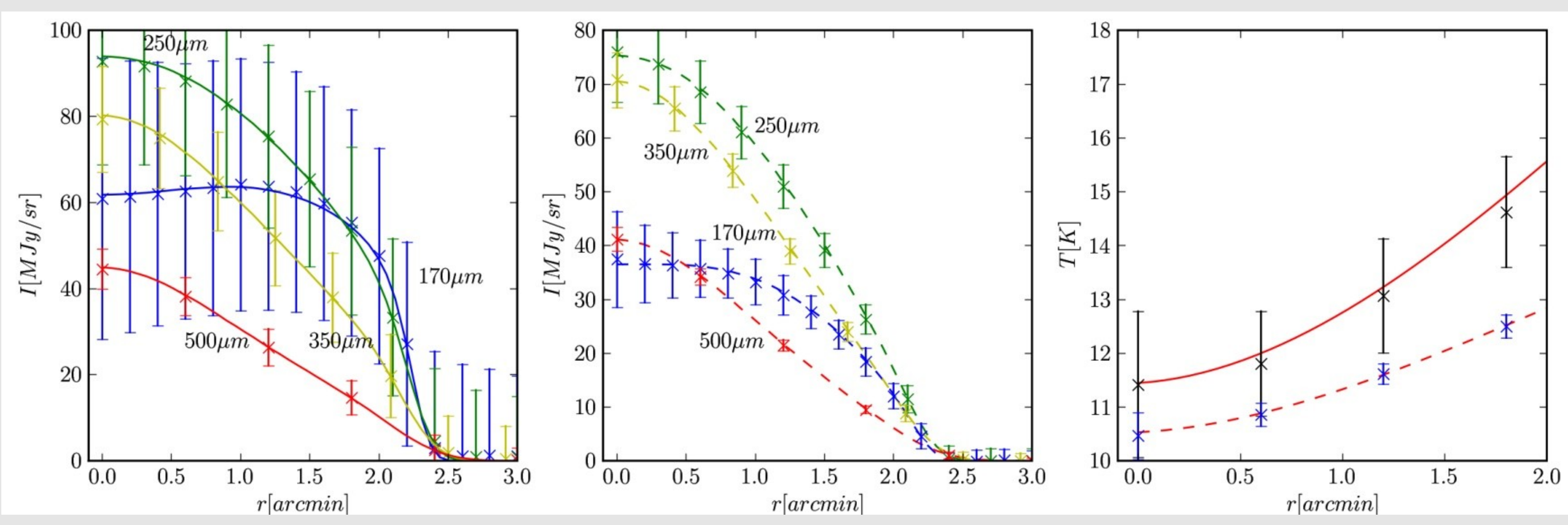

***Figure 2**: Simulated Herschel observations of a $4M_o$ cloud at the distance of 250 pc. The radial surface brightness profiles are affected by background fluctuations (left). After using PACS 100µm measurement to subtract the warm component, the profiles of the cold core itself can be recovered with higher accuracy (centre). This is reflected in recovered temperature profiles (right), the dashed line showing the profile after subtraction of the warm component.*

In the Herschel open time programme *Galactic Cold Cores* we will map ~150 fields with the Herschel PACS and SPIRE instruments at 100, 160, 250, 350, and 500µm. The wavelength coverage ensures that we can trace independently both the warm and the cold dust component. The multiwavelength data help to overcome some of the confusion caused by the warmer dust clouds around the cold cores.

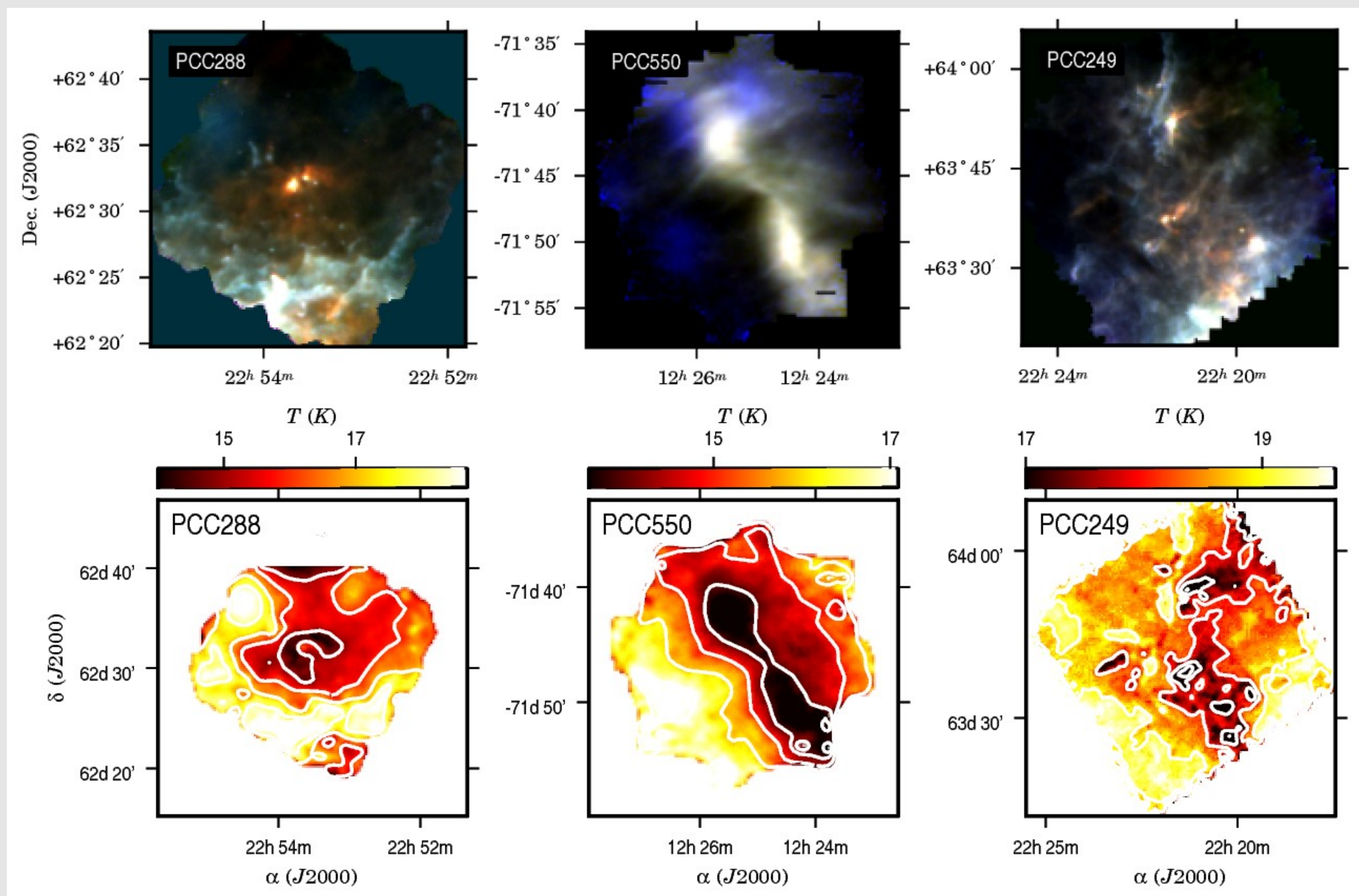

***Figure3**: Herschel images of three fields where Planck located significant amount of emission from cold dust (upper frames). The figures combine different wavelengths, red colour corresponding to lower temperature. The analysis of colour temperature (lower frames) confirmed the Planck detections of compact and cold dust cores.*

The first results of the Planck study of cold cores will be made public in January 2011, including an Early Cold Cores Catalogue. The analysis of the first Herschel data has revealed that Planck has located cold dust in very different environments (see Fig. 3). The sources range from quiescent cores in apparent hydrostatic equilibrium to very active star forming regions where cold and possibly pre-stellar clumps can still be found. The study of dust properties has confirmed the assumption of evolving dust properties: both dust opacity and the spectral index increase towards the coldest and densest regions (Juvela et al. 2010; Juvela et al. submitted).

Outlook

Planck and Herschel are providing an unprecedented view of cold dust in the Galaxy. The results will be used to address several key questions about initial stages of star formation. Planck will provide the first statistics of pre-stellar cores at high latitudes and may lead to the detection of rare but very nearby, low-mass compact clouds. Herschel enables detailed studies into the structure of individual cores and the dust physics. With statistical studies, we will examine correlations between the properties of the cores and their environment and determine the role of external triggering in global star formation. The located embedded sources are prime targets for future ALMA observations.

References

André al. 2010, A&A 518, L102
Juvela et al. 2010, A&A 518, L93
Padoan 1995, MNRAS 277, 377