The earliest phases of star formation: From low- to high-mass objects
Proposal for a Herschel-PACS GT Key Project

O. Krause, Th. Henning, H. Beuther, S. Birkinmmann, M. Hennemann, R. Launhardt, D. Lemeke, H. Linz, M. Nielbock, J. Steinacker (all MPIA Heidelberg), R. Klein (MPE Garching), B. Stecklum (TLS Tautenburg), and P. André (CEA Saclay)

It is generally agreed that present-day Galactic star formation starts in the coldest and densest cores of molecular clouds. However, our knowledge about the very early stages of star formation is still quite limited. Such objects emit most of their luminosity at far-infrared wavelengths (roughly 60 - 400 μm), thus not (or not easily) observable from the ground. Hence, up to now our view in this wavelength range remains fuzzy at best, since all available information generally comes from small aperture satellite and airborne missions which severely lack spatial resolution. This is a major drawback for detailed studies of young low-mass cores, and it has severely hampered almost any progress in identifying and thoroughly characterising young and cold high-mass cores which are, on average, far more distant. Still, detailed knowledge about these early pre- and proto-stellar stages is indispensable if we want to answer fundamental questions about the physics of the early collapse phase, the core fragmentation and the principle ways to finally form stars of all masses. With the advent of the Herschel satellite, we will have the unique opportunity to deeply scrutinise such cold cradles of stars with unprecedented sensitivity and angular resolution. We therefore propose to use the PACS and SPIRE instruments to perform deep and directed multi-wavelength mapping of individual objects and confined regions. We have compiled a unique sample of low- and high-mass targets that we identified, based on careful preparatory studies (including ISO and Spitzer observations), as very promising sources for the study of initial conditions of star formation. The Herschel data will allow us to reconstruct the (3D) density and temperature structure, to assess the energy budget of the cores and to unveil potential substructures. Furthermore, Herschel observations will render it possible for the first time to perform an advanced modelling of such cold cores that is meaningful and not plagued by simplifications and parameter ambiguities.

Proposal Overview and Science Goals

The proposal includes two different target groups that require slightly different observing strategies: 1) isolated low-mass prestellar cores and protostars in regions of exceptionally low cirrus noise and 2) candidates of high-mass prestellar and protostellar envelopes. This will be achieved by deep pointed observations of selected targets in contrast to (shallow) blind surveys of large areas.

The targeted low mass cores will be observed with PACS and SPIRE and the data will be combined with existing ground-based submm maps. From the spatially resolved flux ratios we will measure the dust temperature distribution with an accuracy of ΔT < 1K and derive density profiles and the mass distribution. This will yield constraints on external heating (energy input from the ISRF), internal heating and the dust properties. By means of radiative transfer modelling the data will allow a precise quantification of the initial conditions of isolated star formation.

The sample of high-mass SFR were selected from MPIA surveys of well studied sources, that have an extensive set of existing multi-wavelength data. The samples were build up using different selection techniques, with the common goal of identifying candidates for massive star forming regions in an early evolutionary state: by using the ISOPHOT Serendipity Survey (ISOSS) only by selecting high-mass stainless cores (HMMCs) and infrared dark clouds (IRDCs). The proposed observing strategies with PACS and SPIRE for the selected low- and high-mass SFRs are summarised in the table below.

Target Selection

For the low-mass case we selected 20 targets of isolated prestellar and protostellar cores in regions of exceptionally low cirrus confusion noise (< 1 mJy/beam at 110 μm). Only known and well-studied sources were considered. Their distances range between 140 and 300 pc, yielding a linear resolution of about 1000 (910 μm) to 7000 AU (9350 μm).

Observing Strategy and Target Lists

- IRAC colors + 450 μm
- NIR colors + Hα
- IRAS 100 μm & 170 μm
- MSX 8 μm & 170 μm
- PACS 70 μm & 160 μm
- SPIRE 250 μm & 350 μm
- SPIRE 500 μm & 600 μm
- SPIRE 900 μm & 1000 μm

The flight model of the PACS bolometer camera manufactured by CEA. Below the layout of the two arrays that allow for simultaneous imaging in two of the three photometric bands of PACS is shown.

Target lists for the low- (bottom left) and high-mass SFRs (bottom right). For the low-mass case the list is not fully finalized, but all candidate regions are displayed. For the high-mass SFRs only a partial listing of the targeted IRDCs is shown, due to the larger number of sources.

References

Birkinmmann et al. 2007, accepted for publication in A&A