Formation, evolution, and survival of massive star clusters
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The Spectral Energy Distribution of the Earliest Phases of Massive Star Formation

Randolf Klein[1], Jennifer Cooper[1], Leslie Looney[2], Thomas Henning[3], Sukanya Chakrabarti[4] and Sachin Shenoy[1]

[1]SOFIA-USRA, NASA Ames Research Center, MS 232-12, PO box 1, Moffet Field, CA 94035
email: rklein@sofia.usra.edu

[2]University of Illinois, Dept. of Astronomy, MC-221, 1002 W. Green St., Urbana, IL 61801

[3]Max-Planck-Institut für Astronomie Königstuhl 17, D-69117 Heidelberg

[4]School of Physics and Astronomy, Rochester Institute of Technology
84 Lomb Memorial Dr., Rochester, NY 14623

Abstract. We have selected cold and massive ($M > 100 M_{\odot}$) cores as candidates for early phases of star formation from millimeter continuum surveys without associations at short wavelengths. We compared the millimeter continuum peak positions with IR and radio catalogs and excluded cores that had sources associated with the cores' peaks. We compiled a list of 173 cores in over 117 regions that are candidates for very early phases of Massive Star Formation (MSF). Now with the Spitzer and Herschel archives, these cores can be characterized further. We are compiling this data set to construct the complete spectral energy distribution (SED) in the mid- and far-infrared with good spatial resolution and broad spectral coverage. This allow us to disentangle the complex regions and model the SED of the deeply embedded protostars/clusters. We present a status report of our efforts: a preview of the IR properties of all cores and their embedded source inferred from a grey body fit to the compiled SEDs.

Keywords. stars: formation, infrared: ISM, ISM: clouds

For our millimeter survey (Klein et al. 2005), we defined the following criteria for cloud cores to be in an early stage of massive star formation (MSF):

(a) No radio, IRAS, MIR, NIR sources should be within 10″ of the core's peak. As a basis for these constraints the NVSS, IRAS, MSX, and 2MASS databases were used.

(b) A minimum core mass of $100\,M_{\odot}$. The star formation efficiency can reach values of 50% (Hillenbrand & Hartmann 1998). Thus, to build a $8\,M_{\odot}$ star and its low-mass companions, one needs at least a $130\,M_{\odot}$ core (Miller & Scalo 1979).

Similarly, Sridharan et al. (2005) selected successfully high-massive starless core candidates from their millimeter continuum survey by the lack of mid-infrared (MIR) emission. Using the above criteria, we compiled a source list from the following millimeter surveys in order to get a comprehensive set of cloud cores in an early stage of MSF: Hunter et al. 2000; Sridharan et al. 2002; Faúndez et al. 2004; Klein et al. 2005; Beltrán et al. 2006.

The source list collected from the above surveys is a comprehensive set of massive millimeter cores. This selection results in a list of 173 millimeter cores across the Galaxy allowing a global study of the earliest stage of MSF and their evolution.

We collected for all cores the data available from Herschel (SPIRE and PACS photometry), which provided the data around the peak of the SED. This in turn, allowed to fit a grey-body to the emission by the cold dust in these envelops (using the Herschel and sub-millimeter data points). For the grey-body fits the Rayleigh-Jeans tail has been multiplied by ν^{β} with β being the spectral index of the dust emissivity. For 132 cores, the fits were successful. The top pannel of Fig. 1 shows the distribution of the fit parameters.

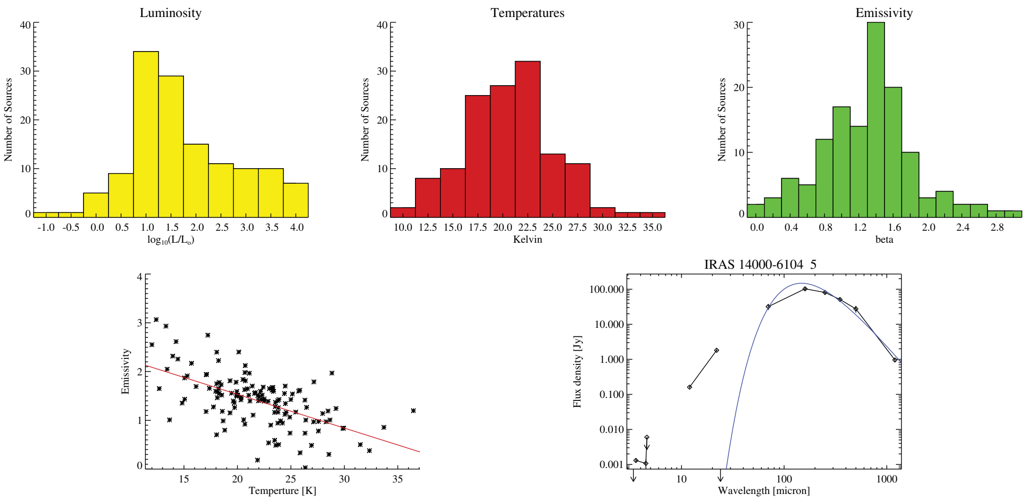

Figure 1. Top: grey-body fit parameter distributions; bottom left: Correlation of dust temperature and emissivity; bottom right: typical SED

Figure 1 shows on the bottom left how the fitted temperature and dust emissivity are related. The data points are scattered, but there is a correlation between the fitted cold dust temperature and the dust emissivity. The red line is a linear fit: $\beta = -0.07T[K]+2.9$.

On the bottom right is the SED of a typical source, i.e. all fit parameters are close to average. The parameters for this source: $L = 41\,L_{\odot}$, $T = 22\,\mathrm{K}$, $\beta = 1.5$. The blue line is the grey-body fit. Only the far-infrared part is fitted.

The Herschel data allowed us a first characterization of the dusty envelopes of the massive protostar candidates with a grey-body fit. While a few sources are quite faint for massive star-forming cores (but maybe they aren't, yet), most cores emit $100\,L_{\odot}$. The fitted cold dust temperature and the dust emissivity are correlated. If temperature is an indication of age (core is heating up with progressing star formation), the change in emissivity could be dust evolution.

The next step will be to model the full SED from the NIR to mm-wavelengths, e.g. with the Robitaille et al. (2006) models, but early tests show that the model library does not contain good fits for the coldest sources. We will also employ the semi-analytic SED models of Chakrabarti & McKee (2005).

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