Herschel far-infrared observations of the Carina Nebula complex
The embedded young stellar and protostellar population

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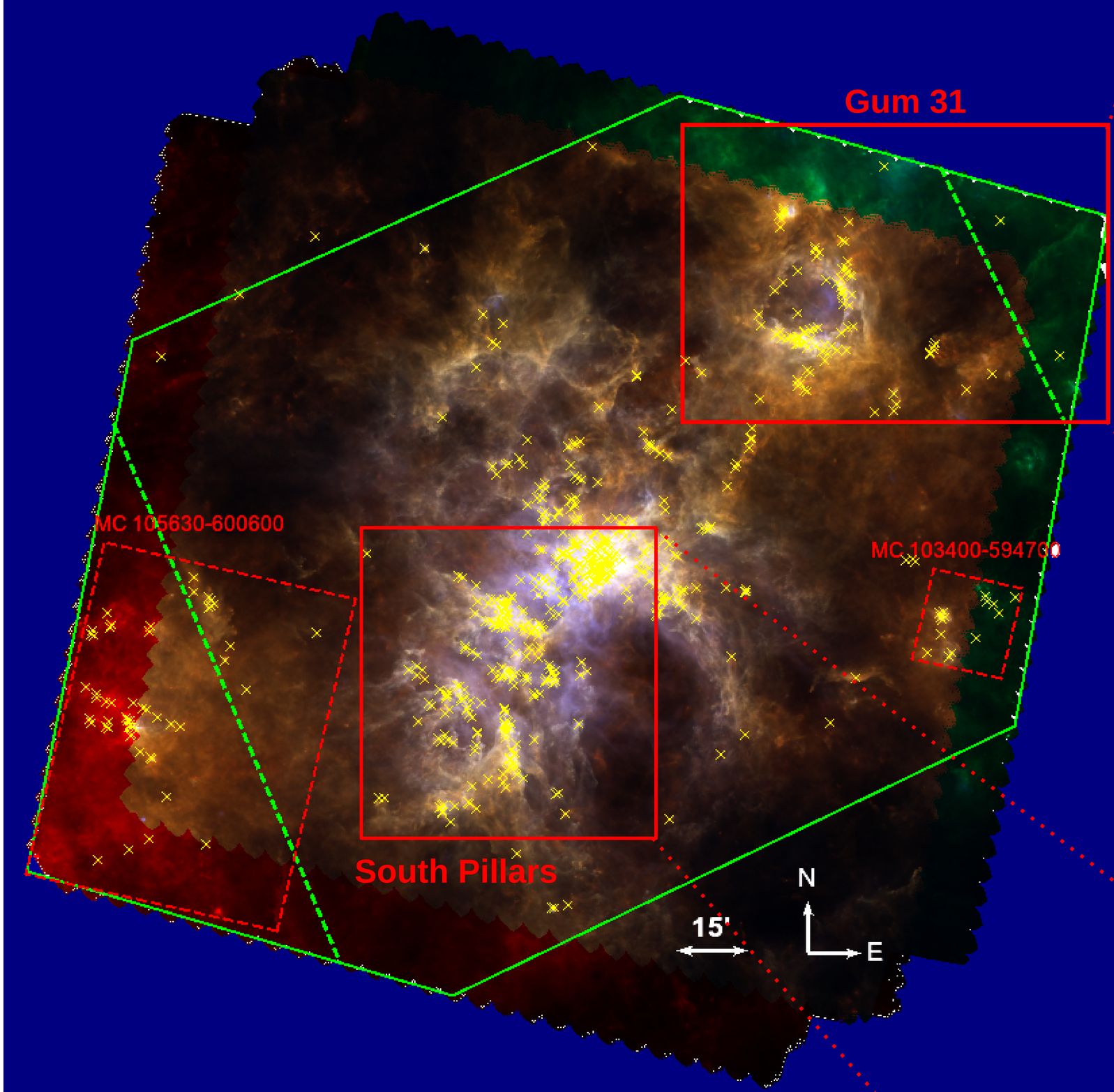

Fig.1 Herschel three color composite of the CNC maps at 70 µm (blue), 160 µm (green) and 250 µm (red). The yellow "x" mark the positions of our 642 Herschel point-like sources detected in at least two bands. The solid red boxes delineate the Gum 31 region and the South Pillars region, respectively. The two dashed red boxes delineate two clouds that are not part of the Carina Nebula. The green polygon marks the region of the Carina Nebula that is also covered by the Spitzer IRAC maps. The two green dashed lines within the polygon mark the borders of the region for which our Spitzer photometry was obtained. Because the field-of-views of PACS and SPIRE are shifted to each other, there are regions that are only covered by one instrument, i.e. the red region in the south-west is only part of our SPIRE maps, and the green region in the north-east is only part of our PACS maps, respectively.

The Carina Nebula

- The Great Nebula in Carina (NGC 3372) is the nearest (d = 2.3 kpc) very massive star forming region in our Galaxy. It contains at least 65 O-type stars, among them several of the most massive ($M \geq 100\ M_\odot$) and luminous stars known in our Galaxy. The feedback (ionizing radiation and winds) of the very massive stars strongly affects the surrounding clouds. The high-mass stars have created numerous pillars that may be the site of triggered star formation.

- Our Herschel PACS and SPIRE far-infrared maps (≈8.7 deg^2) cover the full area of the Carina Nebla complex (CNC) and reveal the population of deeply embedded young stellar objects (YSOs), most of which are not yet visible in the mid- or near-infrared.

- We study the properties of the 642 objects that are independently detected as point-like sources in at least two of the five Herschel bands. For those objects that can be identified with apparently single Spitzer counterparts, we use radiative transfer models to derive information about the basic stellar and circumstellar parameters (see Fig.4).

- We find that about 75% of the Herschel-detected YSOs are likely Class 0 protostars. The luminosities of the Herschel-detected YSOs with SED fits are restricted to values of $\leq 5400\ L_\odot$, their masses (estimated from the radiative transfer modeling) range from $\approx 1\ M_\odot$ to no more than $\approx 10\ M_\odot$. This is in a remarkable contrast to the population of the few Myr old optically visible stars, which contains a large number of objects clearly exceeding $20\ M_\odot$.

- Taking the observational limits into account and extrapolating the observed number of Herschel-detected protostars over the stellar initial mass function suggest that the star formation rate of the CNC is $\sim 0.017\ M_\odot$/year.

- The spatial distribution of the Herschel YSO candidates is highly inhomogeneous and does not follow the distribution of cloud mass (Fig.1 and Fig.3). Rather, most Herschel YSO candidates are found at the irradiated edges of clouds and pillars.

- The currently ongoing star formation process forms only low-mass and intermediate-mass stars, but no massive ($M > \sim 20\ M_\odot$) stars. This result is in contrast to previous expectations that irradiated pillars should be prime candidates for triggered massive star formation (see Smith et al. 2000, ApJ 532, 145; Walborn et al. 1999, AJ, 117, 225). The characteristic spatial configuration of the YSOs provides support to the picture that the formation of this latest stellar generation is triggered by the advancing ionization fronts.

For further information consult these recent publications on our Carina multi-wavelength project:

Herschel far-infrared observations of the Carina Nebula complex: I. Introduction and global cloud structure, Th. Preibisch, V. Roccatagliata, B. Gaczkowski, T. Ratzka, Astronomy & Astrophysics, 541, A132 (2012)

Herschel far-infrared observations of the Carina Nebula complex: II. The embedded young stellar and protostellar population, B. Gaczkowski, Th. Preibisch, T. Ratzka, V. Roccatagliata, H. Ohlendorf, H. Zinnecker, A&A, 549, A67 (2013)

Herschel far-infrared observations of the Carina Nebula complex: III. Detailed cloud structure and feedback effects, V. Roccatagliata, T. Preibisch, B. Gaczkowski, T. Ratzka, A&A, 554, A6 (2013)

Discovering young stars in the Gum 31 region with infrared observations, H. Ohlendorf, T. Preibisch, B. Gaczkowski, T. Ratzka, J. Ngoumou, V. Roccatagliata, R. Grellmann, A&A, 552, A14 (2013)

Jet-driving protostars identified from infrared observations of the Carina Nebula complex, H. Ohlendorf, T. Preibisch, B. Gaczkowski, T. Ratzka, R. Grellmann, A. McLeod, A&A, 540, A81 (2012)

Detection of a large massive circumstellar disk around a high-mass young stellar object in the Carina Nebula, Th. Preibisch, T. Ratzka, T. Gehring, H. Ohlendorf, H. Zinnecker et al., A&A, 530, A40 (2011)

More information and pre-prints are available at: http://www.usm.uni-muenchen.de/people/preibisch/carina_project.html

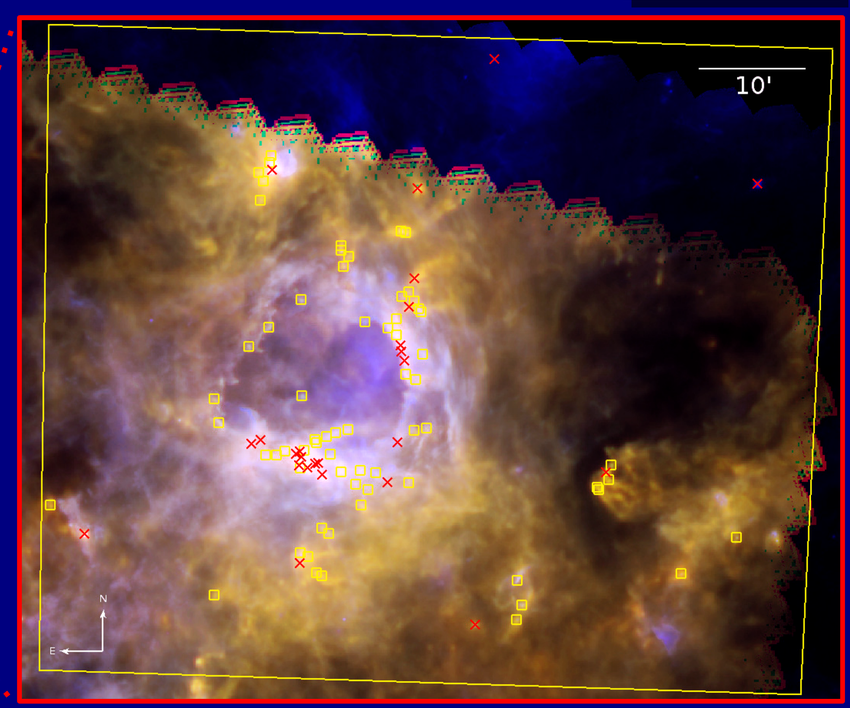

Fig.2 Herschel RGB image (red: 500 µm, green: 250 µm, blue: 70 µm) with positions of all Herschel point-like sources detected in at least two bands overlaid. Red crosses show the position of protostellar, yellow boxes those of prestellar cores. The large yellow rectangle marks the borders of the analysed region.

The Gum 31 region

- Around the bubble-shaped HII region Gum 31 (containing the young stellar cluster NGC 3324; see Fig.2) in the north-western part of the CNC we identified 752 candidate YSOs (above our completeness limit of about 1 $M_\odot$) from Spitzer, WISE, and Herschel data and analyzed their spectral energy distributions

- Their location in the rim of the bubble is suggestive of their being triggered by a 'collect and collapse' scenario, which agrees well with the observed parameters of the region which we obtained from density and temperature maps from our Herschel data

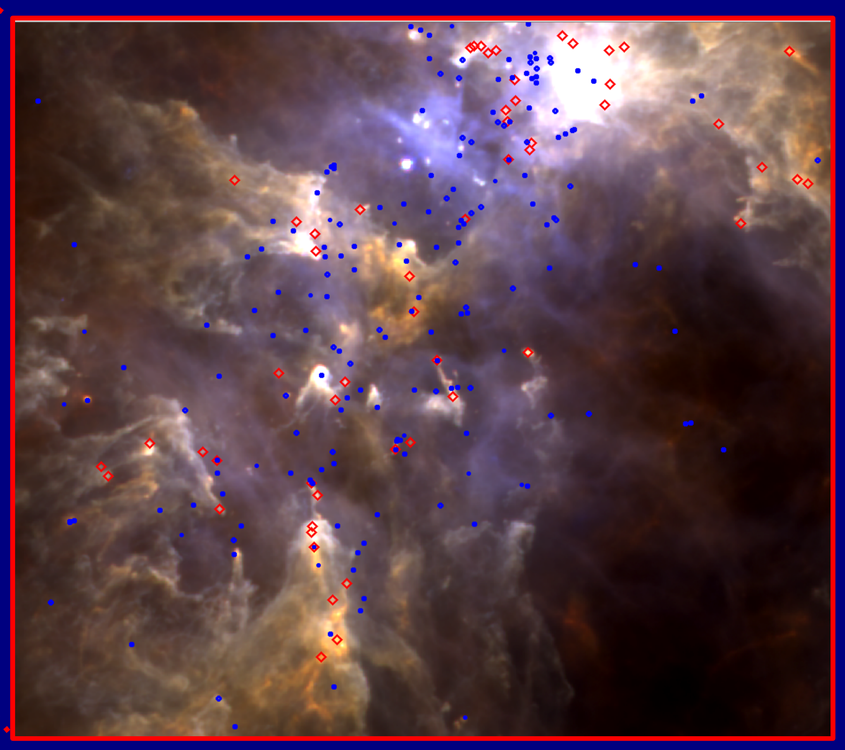

Fig.3 Same color composite image as in Fig.1 of the South Pillars region. Positions of the YSO candidates are again marked with red diamonds. The blue circles represent the class 0 and class I YSOs from the PCYC catalog by Povich et al. (2011). Note that the region around Eta Car lacks Spitzer YSOs because of the nebulosity caused by itself

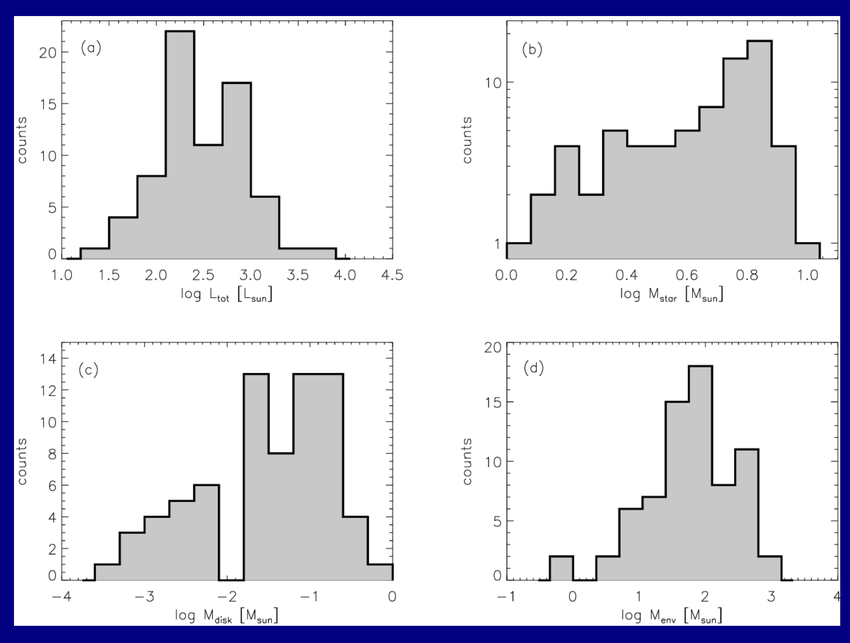

Fig.4 Histograms of the four model parameters obtained from the SED analysis: total luminosity a), central stellar mass b), circumstellar disk mas c), and envelope mass d).