Revealing the full young stellar population in the Carina Nebula, the nearest laboratory of massive star feedback, with VISTA

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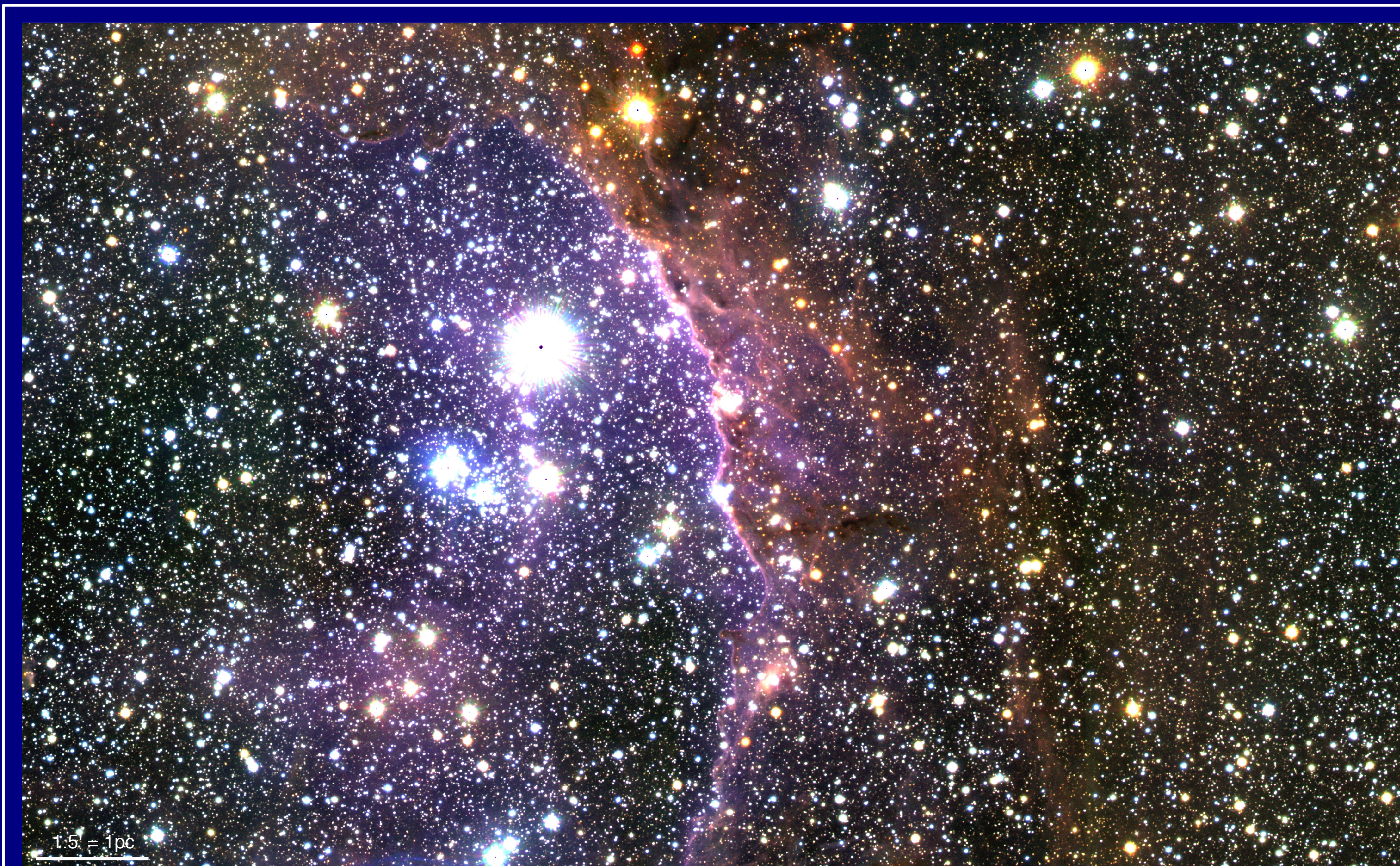

Figure 1: A part of Gum 31 including NGC 3324 from our recent VISTA/VIRCAM data as a combined RGB image. Red: K_s-band (2.15 µm), Green: *H*-band (1.65 µm), and Blue: *J*-band (1.25 µm).

Introduction

The Carina Nebula (NGC 3372) represents one of the most massive star forming regions in our Galaxy. With a distance of ~2.3 kpc, Carina has the most extreme stellar population within a few kpc of the sun (at least 65 O-type stars and four WR-stars). Several of the most massive ($M \geq 40\ M_☉$) and luminous stars, known in our Galaxy, can be found there, including the famous luminous, variable star η Carinae. It is our best connection between the nearby and in detail studied star forming regions like Orion and the even larger and extremer, but more distant regions like 30 Doradus in the LMC.

It is a unique target and our richest nearby laboratory for detailed studies of violent massive star formation and its resulting feedback effects like cloud dispersal and triggered star formation.

In the past years our group has worked with a lot of data of the Carina Nebula ranging from sub-mm (LABOCA) over FIR (*Herschel* PACS/SPIRE), MIR (*Spitzer* IRAC), NIR (HAWK-I), and the X-ray CCCP survey with *Chandra*. The most recent data is the NIR survey performed with VISTA to extend the HAWK-I survey to the outermost edges of the Carina Nebula and to have a full deep NIR coverage of the Chandra CCCP field.

An overview over all mentioned surveys including their FOVs is given in figure 2

The improvement in resolution

Not only the sensitivity of the VISTA survey is much better but also the spatial resolution (0.339" per pixel) is a major improvement (see fig. 3). Therefore objects which stay unresolved in 2MASS can now be seen such as close binaries and other very close objects. So also the smallest clusters can be found and studied in detail.

Figure 3: Comparison between the VISTA image (left) and the 2MASS image (right) for the cluster G286.21+0.17 (H. Ohlendorf et al. (A&A 552, A14 (2013)). Both are RGB images (colors as in figure 1.)

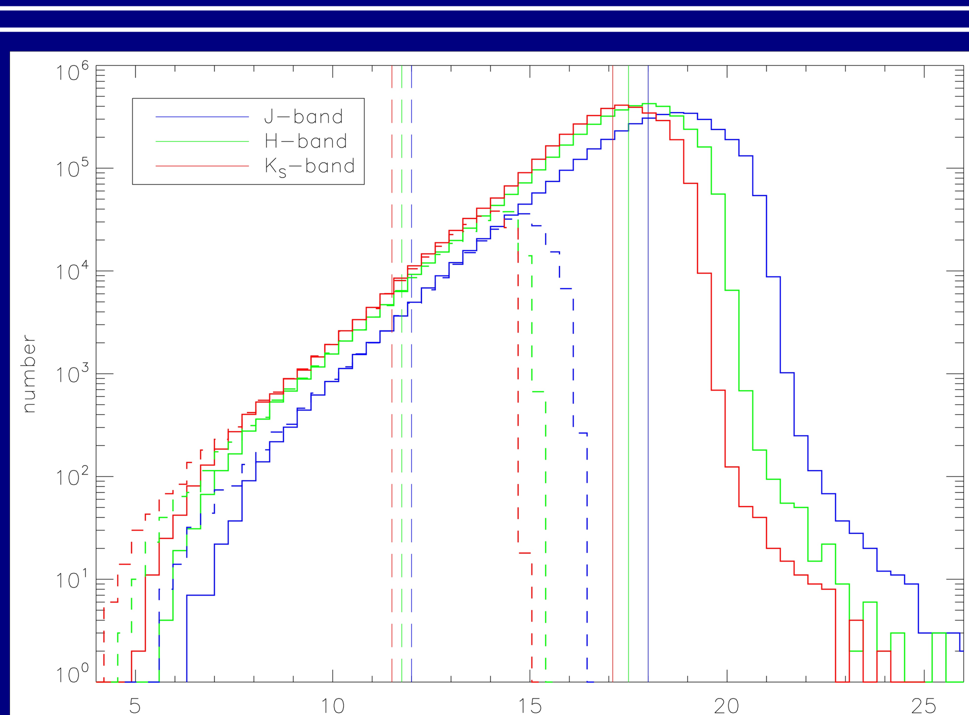

Figure 4: The magnitude histogram for the three infrared bands. The dashed histograms show the 2MASS catalog.

The long dashed lines show the non-linear limits of the detector. For objects brighter than these limits the 2MASS magnitudes were adopted to assure photometric consistency.

The solid lines represent the typical completeness limit as it was derived from this histogram.

For bright sources there were detection problems in VISTA, so these are missing detections (at least for 2 band detections). This results in the missing sources in the VISTA catalog.

The VISTA/VIRCAM data

Our recent near-infrared survey of the whole Carina Nebula acquired with the VISTA/VIRCAM telescope (PI: T. Preibisch) can reveal, in combination with the CCCP Chandra X-ray data, the full young stellar content of the Carina Nebula.

The VISTA FOV has a size of 6.67 deg^2 (2.30 deg x 2.94 deg). We managed to get a full calibrated NIR catalog with almost ~4 million detected objects in the *J*, *H*, and K_s-band (1.25 µm, 1.65 µm, and 2.15 µm). 3193245 sources were detected in all three filters. The typical completeness limits are *J* = 18.0 mag, *H* = 17.5 mag, and K_s= 17.1 mag (see fig. 4).

In comparison with the numerical evolution models of Baraffe our catalog is complete for stars with masses of $M \geq 0.1\ M_☉$.

The detection limits are *J* = 21.7 mag, *H* = 20.4 mag, and K_s= 19.8 mag. This means that stars with masses of $M \geq 0.02 M_☉$ are still detectable.

This results in a gain in depth of ~2.5 mag compared to the 2MASS catalog and a spatial extension compared to similar data of the central region from the HAWK-I survey (~0.36 deg^2).

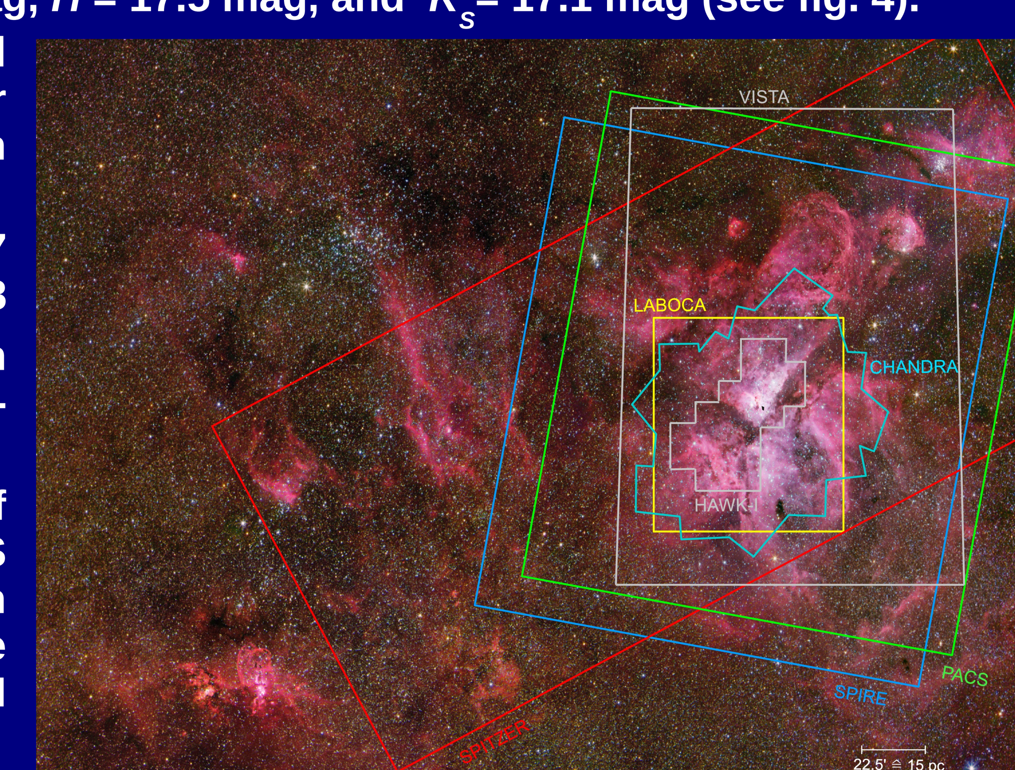

Figure 2: The different surveys of the Carina Nebula

The infrared excess selection

To determine the young stellar objects in combination with X-ray data, we selected the IR-excess sources from our catalog. To avoid the high background contamination in the relatively small wavelength range of the NIR sample, we extended the catalog with the *Spitzer* IRAC 2 (4.5 µm) data. We chose this band because it contains the most detections and no contamination due to PAH features.

The selected sample for all sources with SNR > 10 had a size of 181853. We then selected the IR-excess sources very conservative, with *J-H* > 0.7 mag and K_s- [4.5] > 0.45 mag, to assure not to take any objects from the main sequence (see fig. 5). The slope of the reddening band was derived empirically based on this color color plot . In total there are ~10000 selected IR-excess sources.

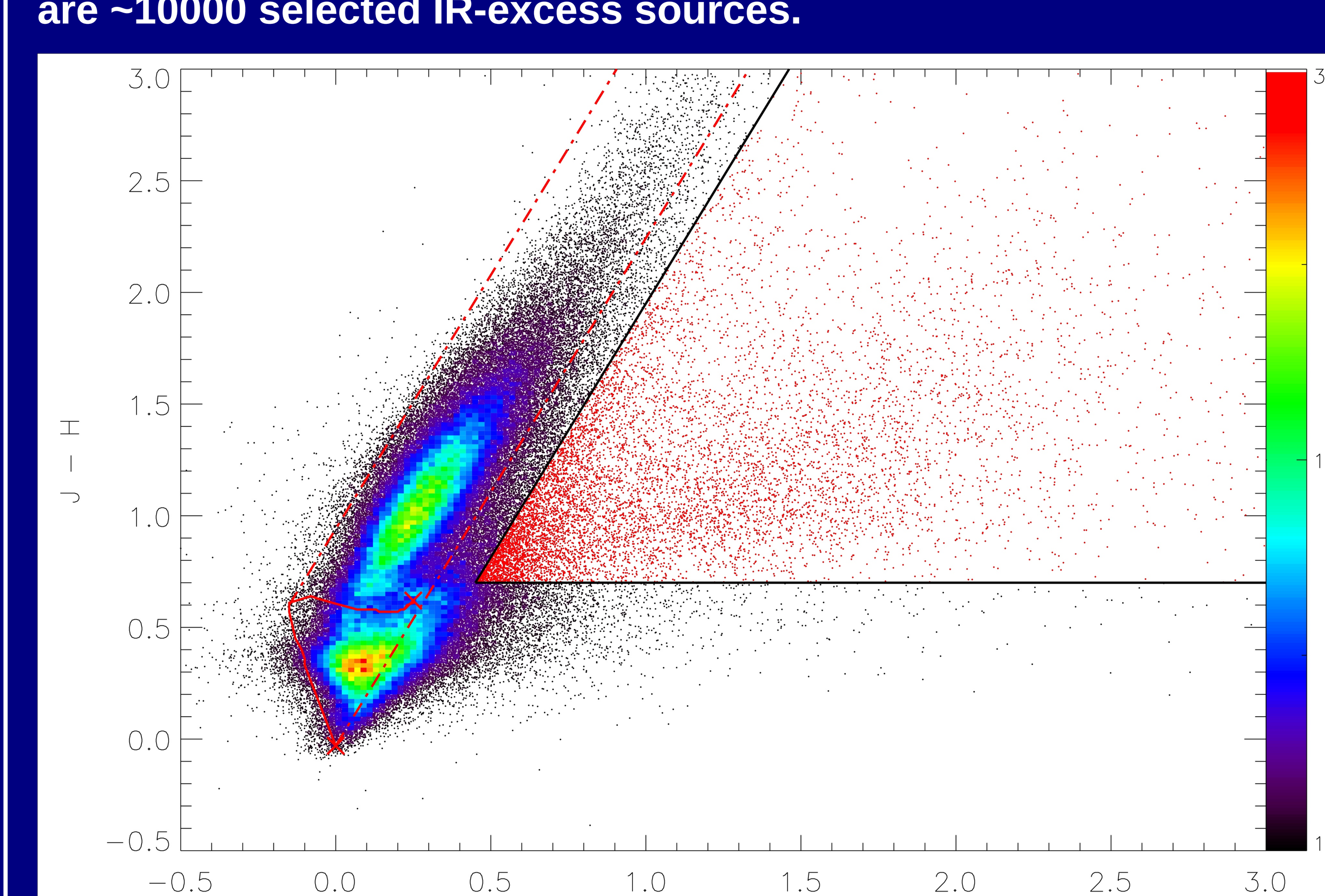

Figure 5: The infrared selection based on the two colors *J-H* and K_s- [4.5].

The color limits are *J-H* > 0.7 mag and K_s-[4.5] > 0.45 mag. The slope of the reddening band was derived empirically.

The color bar indicates the number of sources per bin. There were ~10000 IR-excess sources selected (red points). The red dashed lines indicate the reddening band of the main sequence (red solid line).

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

The mysterious Sickle Object in the Carina Nebula: A stellar wind induced bow shock grazing a clump?, J. Ngoumou, T. Preibisch, T. Ratzka, A. Burkert, Astronomy & Astrophysics, 554, A6 (2013)

Herschel far-infrared observations of the Carina Nebula complex: II. The embedded young stellar and protostellar population, B. Gaczkowski, T. 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)

The Clump Mass Function of the Dense Clouds in the Carina Nebula Complex, S. Pekruhl, T. Preibisch, F. Schuller, K. Menten, Astronomy & Astrophysics, 550, A29 (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)

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

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

Deep wide-field near-infrared survey of the Carina Nebula, T. Preibisch, T. Ratzka, B. Kudera, H. Ohlendorf, R. R. King, S. Hodgkin, M. Irwin, J. R. Lewis, M. J. McCaughrean, H. Zinnecker, A&A, 530, A34 (2011)

Near-Infrared properties of the X-ray emitting young stellar objects in the Carina Nebula, (part of the Chandra Carina Complex Project, see the NEWS & VIEWS article in Nature), T. Preibisch, S. Hodgkin, M. Irwin, J.R. Lewis, R.R. King, M.J. McCaughrean, H. Zinnecker, L. Townsley, P. Broos, Astrophysical Journal Supplements, 194, 10 (2011)

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