# The North American & Pelican Nebulae Observed with IRAC and MIPS

Sylvain Guieu[1], John Stauffer[1], Luisa Rebull[1], Lynne Hillenbrand[2], Alberto Noriega-Crespo[1], Sean Carey[1], John Carpenter[2], Deborah Padgett[2], Karl Stapefeldt[3], Stephen Strom[4]— 1 - Spitzer Science Center, 2 - Caltech, 3 - JPL, 4 - NOAO

**Abstract:** The nearby (∼600 pc) North America and Pelican Nebulae (NANeb) are regions of high mass star-formation beyond our local neighborhood located on the galactic plane and little-studied to date. However, both are well within the sensitivity regime provided by the Spitzer Space Telescope. We have conducted a large infrared imaging survey of these regions using the IRAC (3.6-8 $\mu$m) and MIPS (24-160 $\mu$m) instruments of the Spitzer Space Telescope. We have also obtained $BVI$ CCD imaging for the $\sim 2\times2^\circ$ central region. Based on their infrared colors and magnitudes, we have found more than 1700 sources with infrared excesses characteristic of young stellar objects (YSOs). We present here some of the main results; the detailed study will be soon published in 2 papers: Guieu et al. 2009 (for the IRAC observations) and Rebull et al. 2009 (for the MIPS observations).

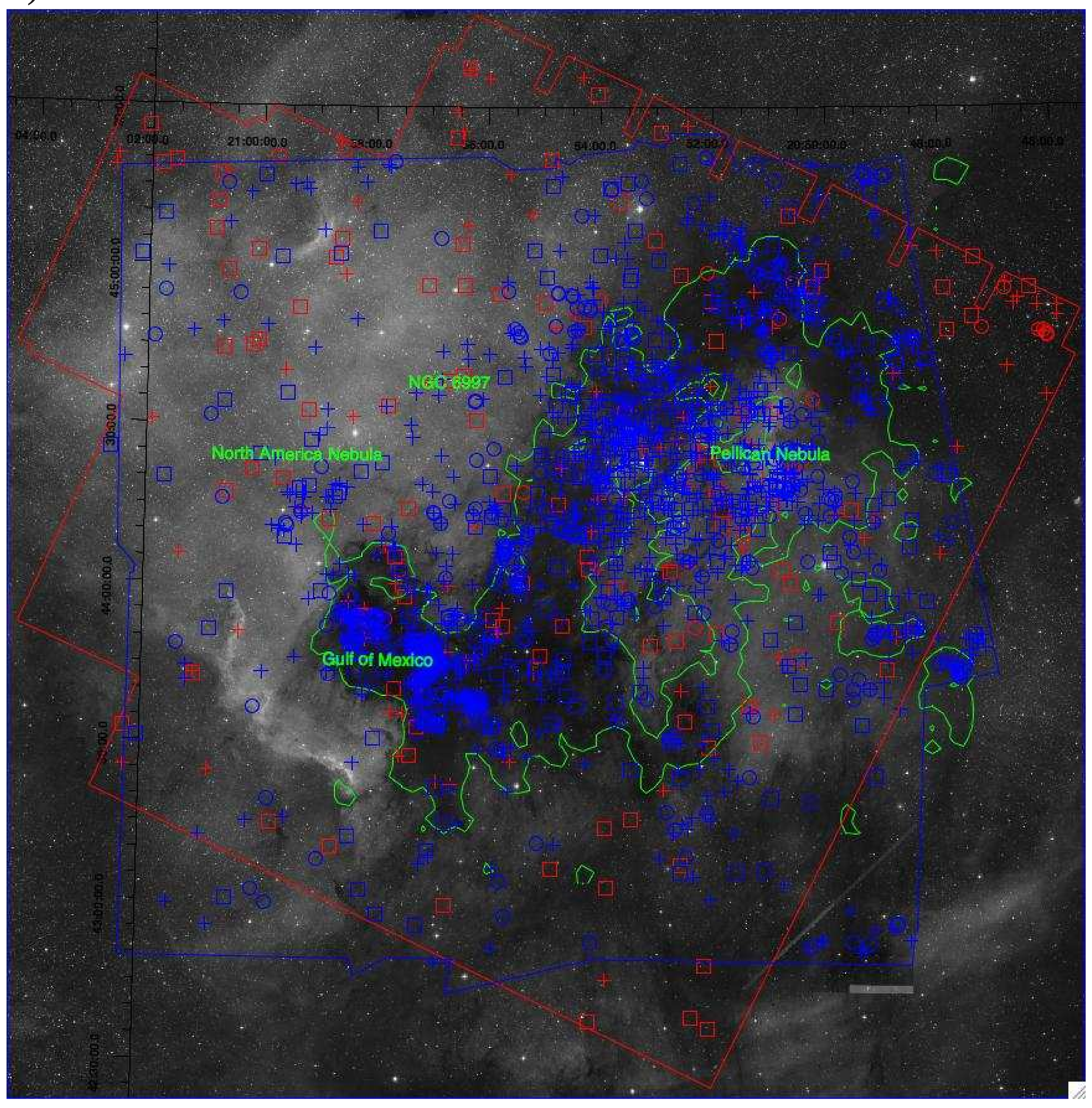


**Figure 1:** *Optical view of the NANeb. Blue (red) lines show the outline of the IRAC (MIPS) surveys. The green curve is the $A_v$=4 contour from Cambresy et al. (2002, AJ, 123, 2559). Blue symbols are YSOs selected from IRAC colors, and red symbols additional YSOs selected by $K_s$−[24]. Symbols denote the class of each object: square=Class III, cross=Class II, circle=Flat/Class I*

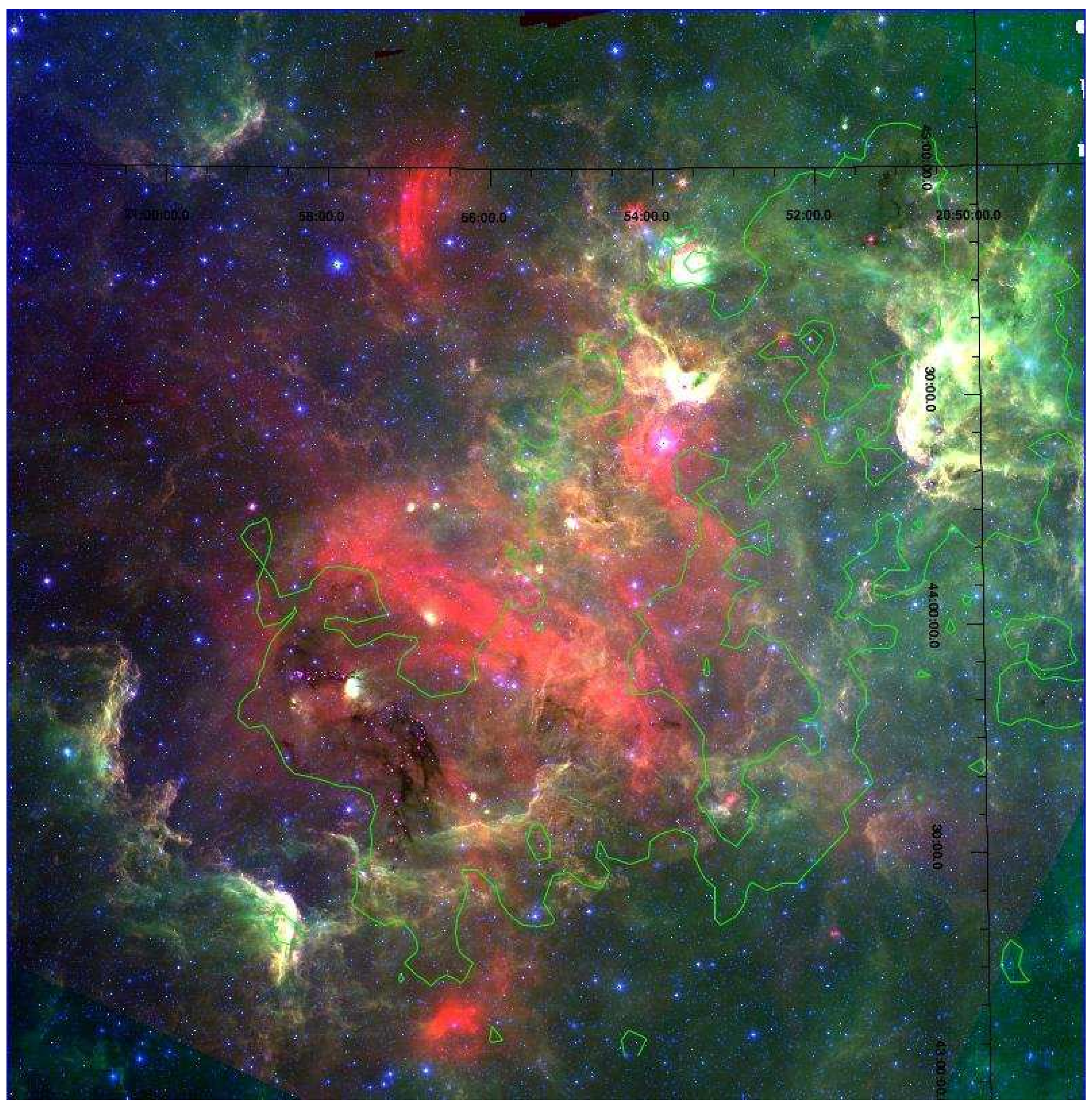

**Figure 2:** *Three-color mosaic of the central part of our observation with 4.5 (blue), 8.0 (green), 24$\mu$m (red).*

**Data:** We have obtained data for ∼9 deg$^2$ with IRAC and ∼10 deg$^2$ with MIPS. The boundaries of our survey are plotted on the optical view of the NANeb on Figure 1; a mosaic of the IRAC and 24$\mu$m images is plotted in Figure 2. We have extracted about 558 000 sources from IRAC 3.6$\mu$m images and 78 000 from the less sensitive 8$\mu$m images. We have initially selected YSOs using two independent methods, both using color selection to identify the IR-excess sources: (1) starting from the subset of our catalog consisting of objects detected in all four IRAC bands (63 000 sources; discussed further in Guieu et al. 2009); and (2) starting from the subset of our catalog consisting of objects detected in MIPS-24 and $K_s$. ( 2173 obj; discussed further in Rebull et al. 2009). Our 4-band IRAC sample is complete down to M4 or M1 stars according to the BCAH98 isochrones for 1 and 5 Myr, respectively, but it is also sensitive to later sources with IR excesses.

## Detection and Classification of YSOs

In order to create the most reliable catalog possible, we have required that objects identified as NANeb YSOs from IRAC data satisfy several criteria. Following Gutermuth et al. (2008, ApJ, 663, 1069), we used the IRAC colors and magnitudes to identify background galaxies and AGN contaminants. After removing the background contaminants, we have selected ∼1700 sources compatible with YSOs having IR excess (blue symbols in all figures here). By considering the 24 $\mu$m data, we have identified additional YSO candidates showing a $K_s$-[24] excess ($K_s$−[24]>2 & $K_s$ <15.5). Those additional objects are mostly Class III objects (red symbols in all graphics). Moreover, 27% of IRAC-YSOs have $K_s$ and 24 $\mu$m counterparts, all of them show $K_s$-[24] excess. We have classified the IRAC YSOs in the Class I / Flat / Class II / Class III system using their SED slope from 3.6 to 8.0 $\mu$m. The additional MIPS YSO candidates have been classified using the $K_s$-[24] color, according to Greene et al. (1994, ApJ, 434, 614). We found a similar Class I to Class II ratio as the Serpens cloud (compared to c2dd data, Harvey et al. 2007, ApJ, 663, 1149). The new young member population is highly clustered, found in 8 well-separated groups. The Class I objects are more clustered than the Class II or III stars.

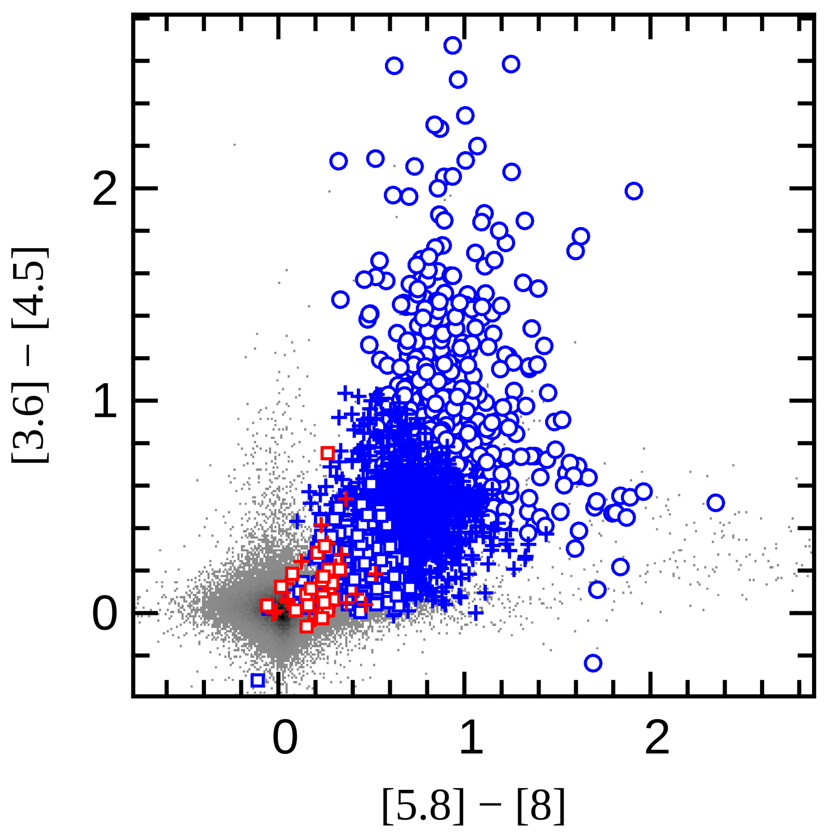


**Figure 3:** *[3.6]-[4.5] / [5.8]-[8] color-color diagram. The field star population is shown as a grey scale density representation. Other symbols are the same as Figure 1.*

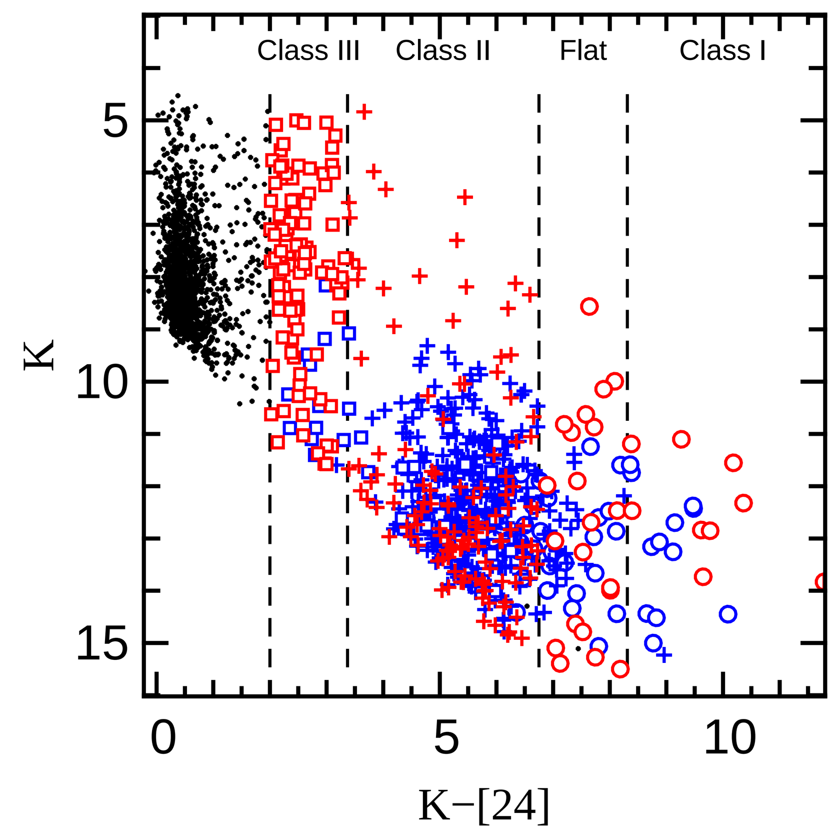


**Figure 4:** *$K_s$/$K_s$-[24] color magnitude diagram. Black crosses are all likely field stars (not YSO candidates); other symbols are the same as Figure 1.*

## Gulf of Mexico

The “Gulf of Mexico” is the densest and the most active portion of the NANeb. In particular, we find: (a) the ratio of the number of Class I + Flat to Class II sources is higher here than anywhere else in the NANeb; (b) the three densest embedded clusters of the NANeb are located here; and (c) many of the brightest 24 micron sources are here.

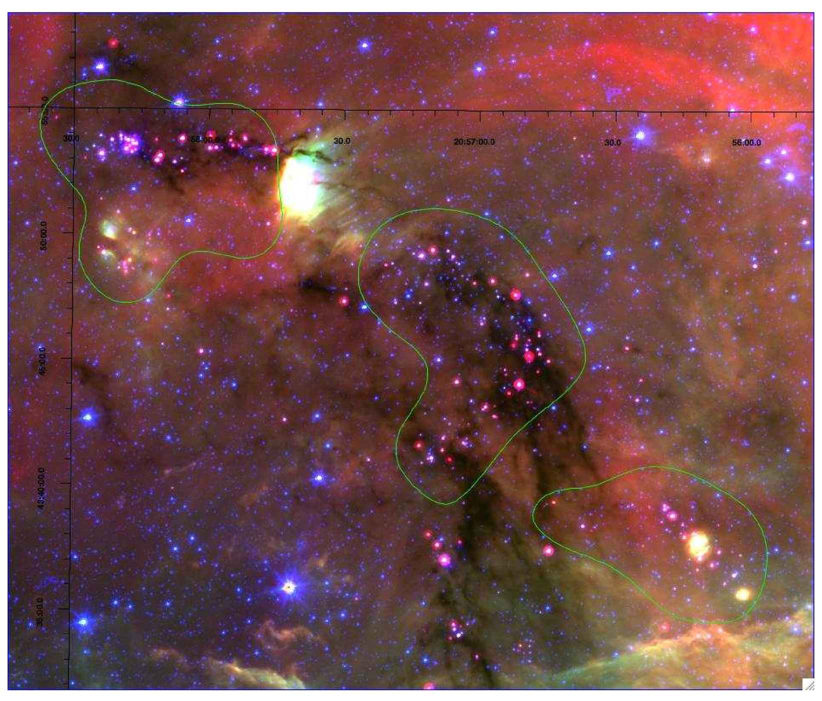

**Figure 5:** *4.5 (blue) + 8 (green) + 24$\mu$m (red) zoomed-in image of the Gulf of Mexico. The green curves show the boundaries of the 3 clusters defined from YSO density contours.*

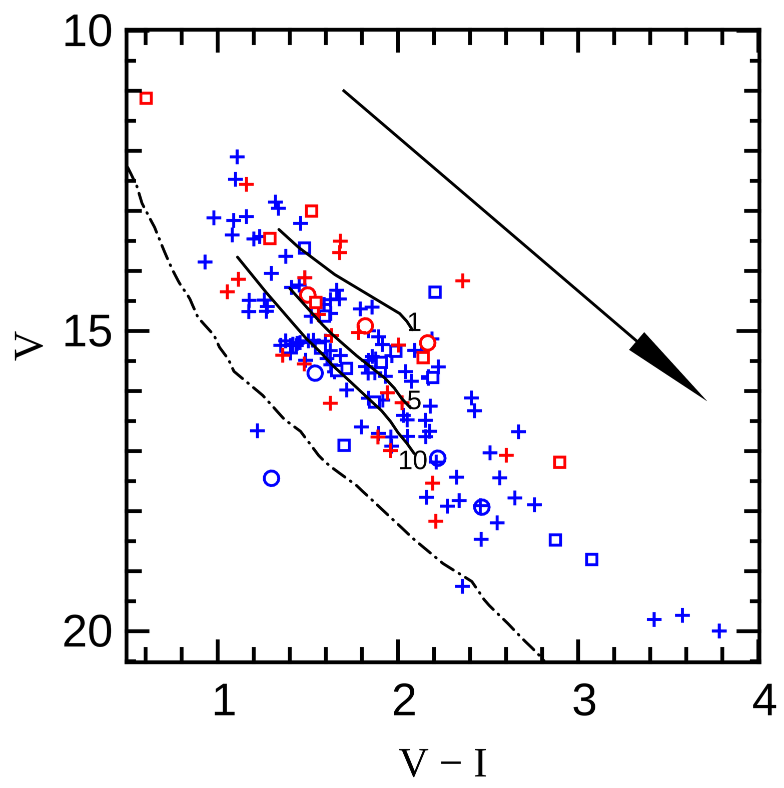


**Figure 6:** *$V$/$V-I$ diagram for YSOs with optical counterpart. The symbols are the same as Figure 1. The solid line are the BCAH98 isochrone models of 1, 5 and 10 Myr. The dashed line is the observed Pleiades isochrone from Stauffer et al. (2007, ApJS 172-663). A reddening vector of Av=5 is plotted.*

## Age estimation

We have compared the optical data for the YSOs to models. Figure 6 shows the de-reddened V / V-I diagram (sources have been de-reddened to the locus of TTs in J-H/H-K diagram).

Our age estimates are uncertain for all of the normally expected reasons (e.g. uncertainties in the isochrones; imprecision of the reddening corrections; spots and UV excesses; binarity ...). However, it is apparent in Figure 6 that most of our YSO candidates are younger than 10 Myr according to the isochrone tracks. The median age is slightly younger than 5 Myr.