



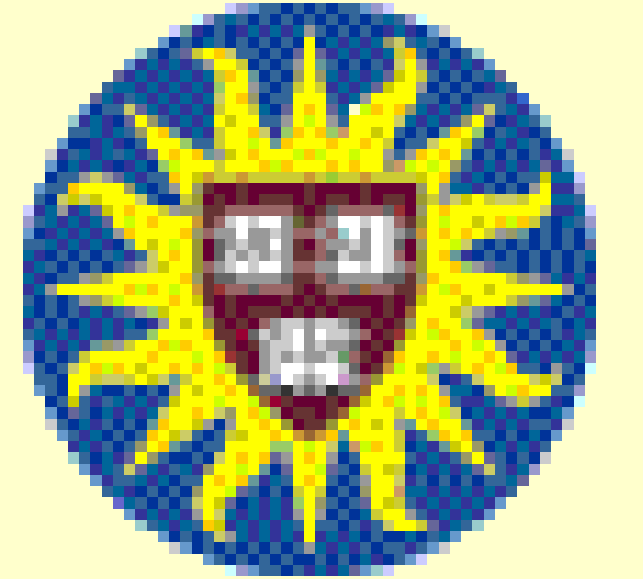
Spitzer/IRAC-MIPS Survey of NGC2244

Zoltan Balog, James Muzerolle

Steward Observatory, University of Arizona, 933 N. Cherry Av Tucson AZ, 85721 USA

S. Tom Megeath

Harvard-Smithsonian Center For Astrophysics, 60 Garden St. Cambridge, MA, 02138 USA



Introduction

We present initial results from a survey of NGC-2244 with the InfraRed Array Camera (IRAC) and the $24\ \mu\text{m}$ channel of the Multiband Imaging Photometer for Spitzer (MIPS) on board the Spitzer Space Telescope. This survey gives us a detailed look at star formation activity and disk survivability in a dense cluster environment with multiple O and B stars producing large amount of UV radiation.

NGC-2244 is one of the youngest nearby open clusters in our Galaxy containing several high-mass OB stars. It lies about 1.5 kpc from the Sun and has an age of about 2-3 Myr [9], [8]. It is in the phase of emerging from the spectacular H II region, the Rosette Nebula. The cluster has been studied in optical and X-ray wavelengths (e.g. [8], [6], [4], [3], [2], etc.).

Observations and data reduction

Our IRAC survey using HDR mode covers about half square degree centered on the main OB core in the "hole" of the Rosette Nebula where the molecular gas has been cleared out by the high mass stars. The frames were processed using the SSC BCD Pipeline, and mosaics were created using a custom IDL program. Source finding and aperture photometry were carried out using PhotVis version 1.09. We detected more than 10000 sources at $3.6\ \mu\text{m}$, 8000 at $4.5\ \mu\text{m}$ and over 2000 in the $5.8\ \mu\text{m}$ and $8.0\ \mu\text{m}$ images with photometric error less than 0.1 mag. There are 1076 sources which were detected in all 4 channels. The MIPS $24\ \mu\text{m}$ survey covers about 0.8 square degree including the region of the IRAC survey. We visually identified 500 $24\ \mu\text{m}$ sources, most of them are concentrated in the area where the known O stars are located. PSF fitting in the IRAF/DAOPHOT package was used to obtain photometry for the identified sources. 268 of the $24\ \mu\text{m}$ sources were also detected in the IRAC frames with acceptable uncertainty.

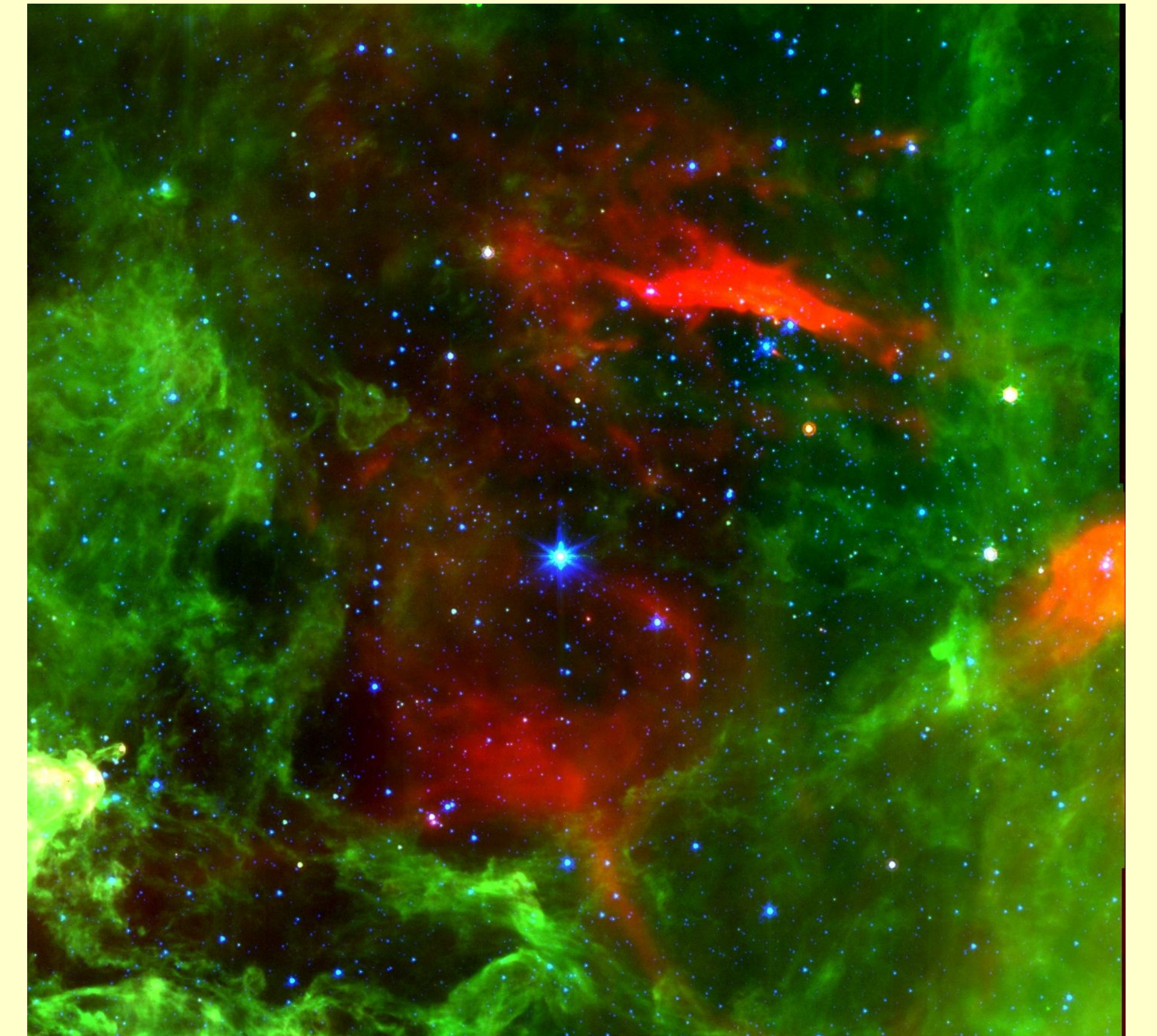


Figure 1. False color image of NGC-2244. Red: MIPS $24\ \mu\text{m}$, green IRAC $8\ \mu\text{m}$, blue: IRAC $3.6\ \mu\text{m}$

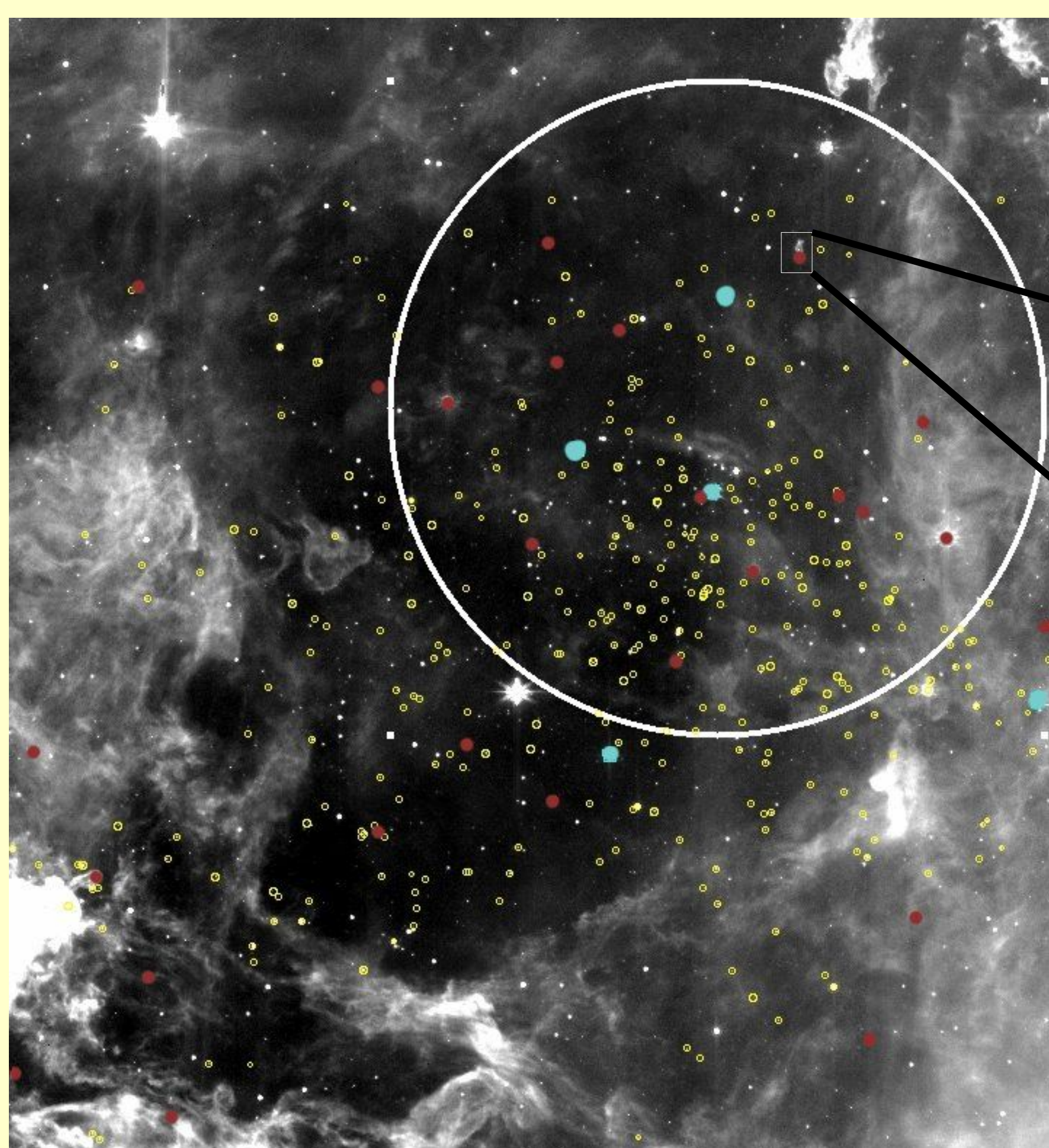


Figure 2 Position of class I (red) and class II (yellow) sources overlaid on the IRAC $8\ \mu\text{m}$ image of NGC-2244. O stars are plotted with large cyan dots for reference. The white circle represent the approximate inner boundary of the HII region

Extended structures

False color image of the NGC2244 region are shown in Fig. 1 (B: $3.6\ \mu\text{m}$, G: $8.0\ \mu\text{m}$, R: $24.0\ \mu\text{m}$). The prominent central cavity around the OB core extends to the south and east in the mid IR. It is filled with dust emitting at $24\ \mu\text{m}$. The $24\ \mu\text{m}$ emission is extremely strong in an elongated structure in the middle of the main OB core. Another interesting feature of this elongated $24\ \mu\text{m}$ structure is that it has bowshock-like geometry facing the nearest O and B stars. We suggest that the nearby O and B stars are responsible for the shape of this dust feature.

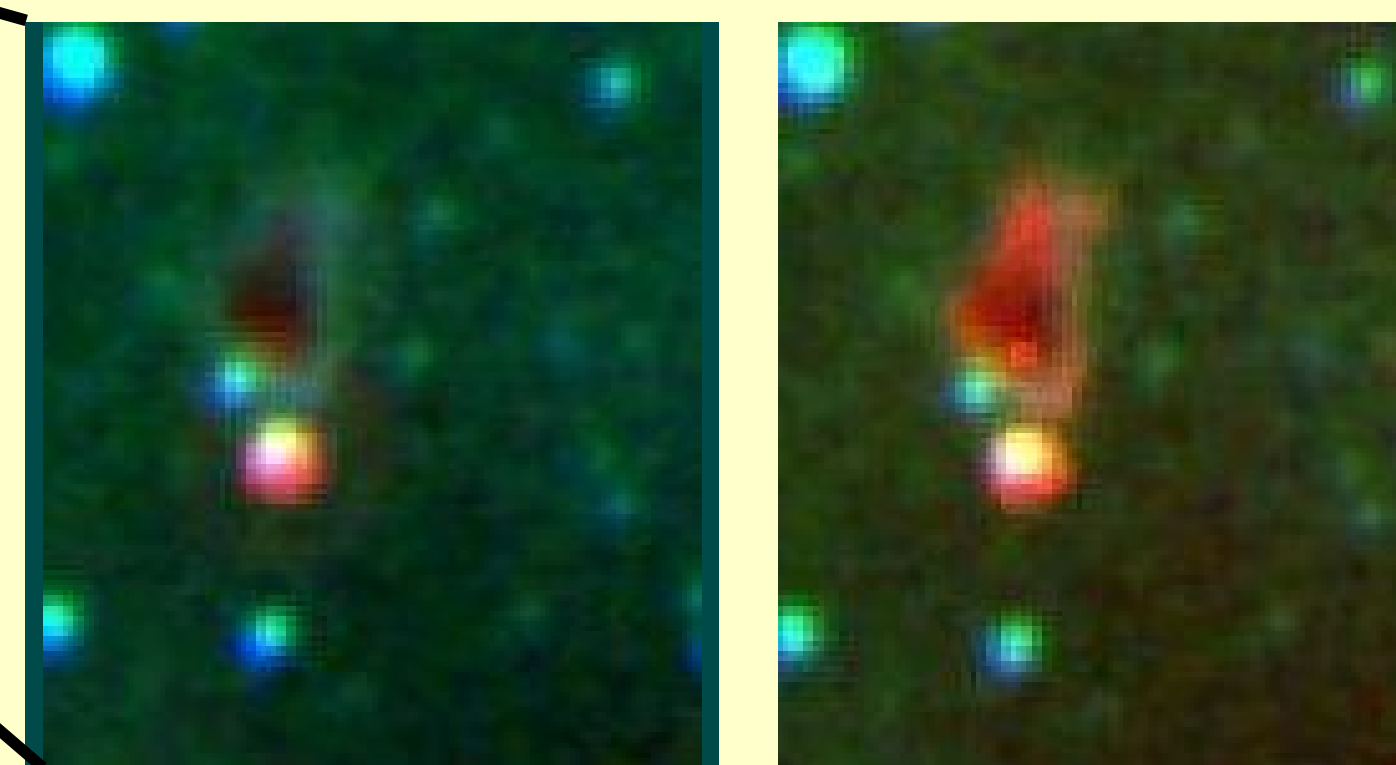


Figure 3 False color images of a globule next to a class I source. Left: R: $24\ \mu\text{m}$ G:DSS red B:DSS blue; Right: R: $8\ \mu\text{m}$ G:DSS red B:DSS blue

Fig. 2 shows the $8\ \mu\text{m}$ IRAC image with class I, class II sources and O stars overlaid (see later in the text). It is apparent that the inner rim of the H II region as seen in the optical (white circle) doesn't coincide with the extended PAH emission detected in the $8\ \mu\text{m}$ IRAC image.

Another interesting object on the images is a small patch of $8\ \mu\text{m}$ images extending north from a class I source (Fig 3.). It looks like a small globule in the optical images. A very weak $24\ \mu\text{m}$ emission can be detected which is associated with this $8\ \mu\text{m}$ feature

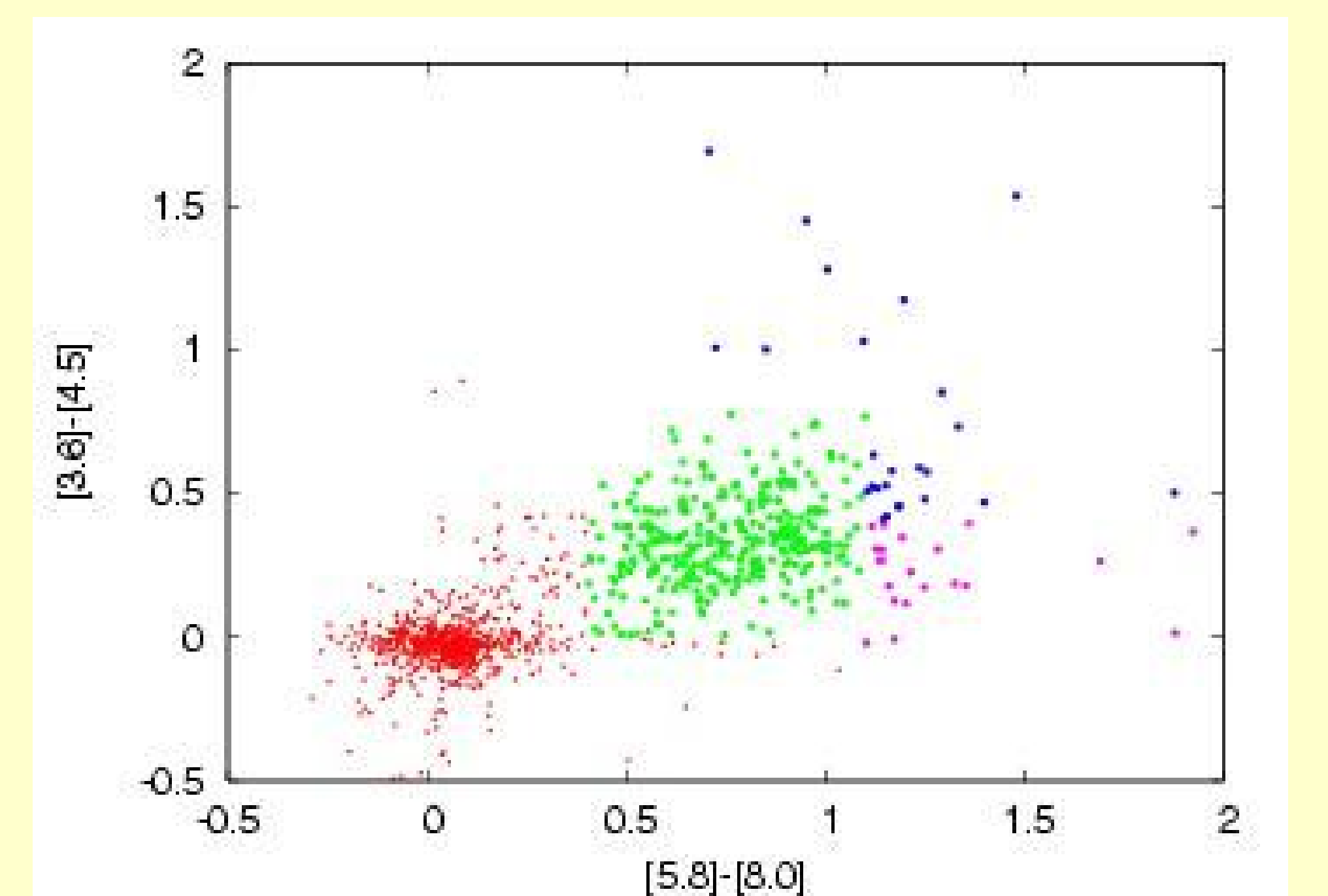


Figure 4 The selection of class I and class II sources using the combined four channel photometry from IRAC. Red dots: normal stellar photospheres, green dots: class II sources, blue dots: class I sources, magenta dots: class III sources

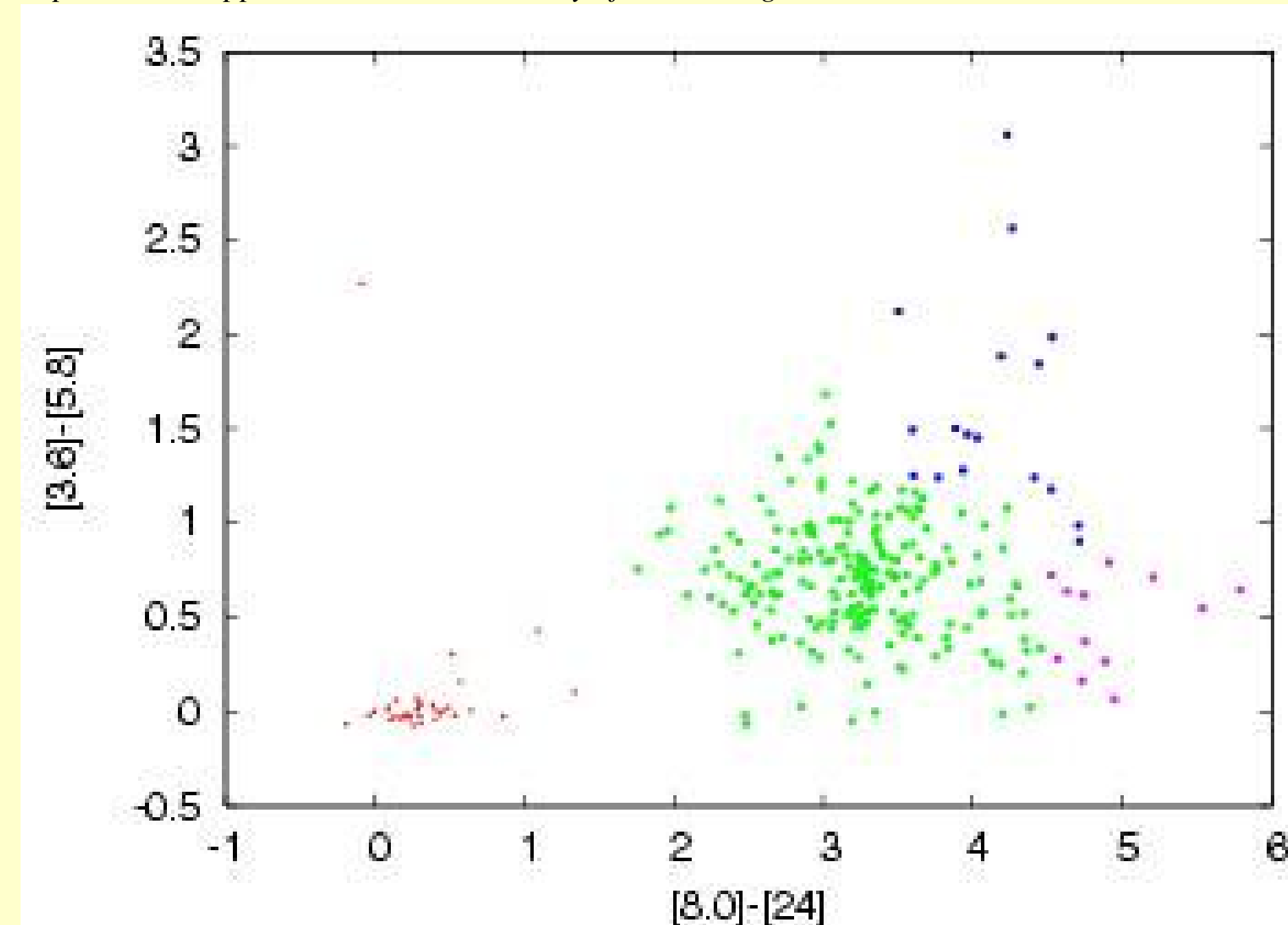


Figure 5 The selection of class I and class II sources using the combined photometry from IRAC and MIPS. Red dots: normal stellar photospheres, green dots: class II sources, blue dots: class I sources, magenta dots: sources which don't fit into any previous category.

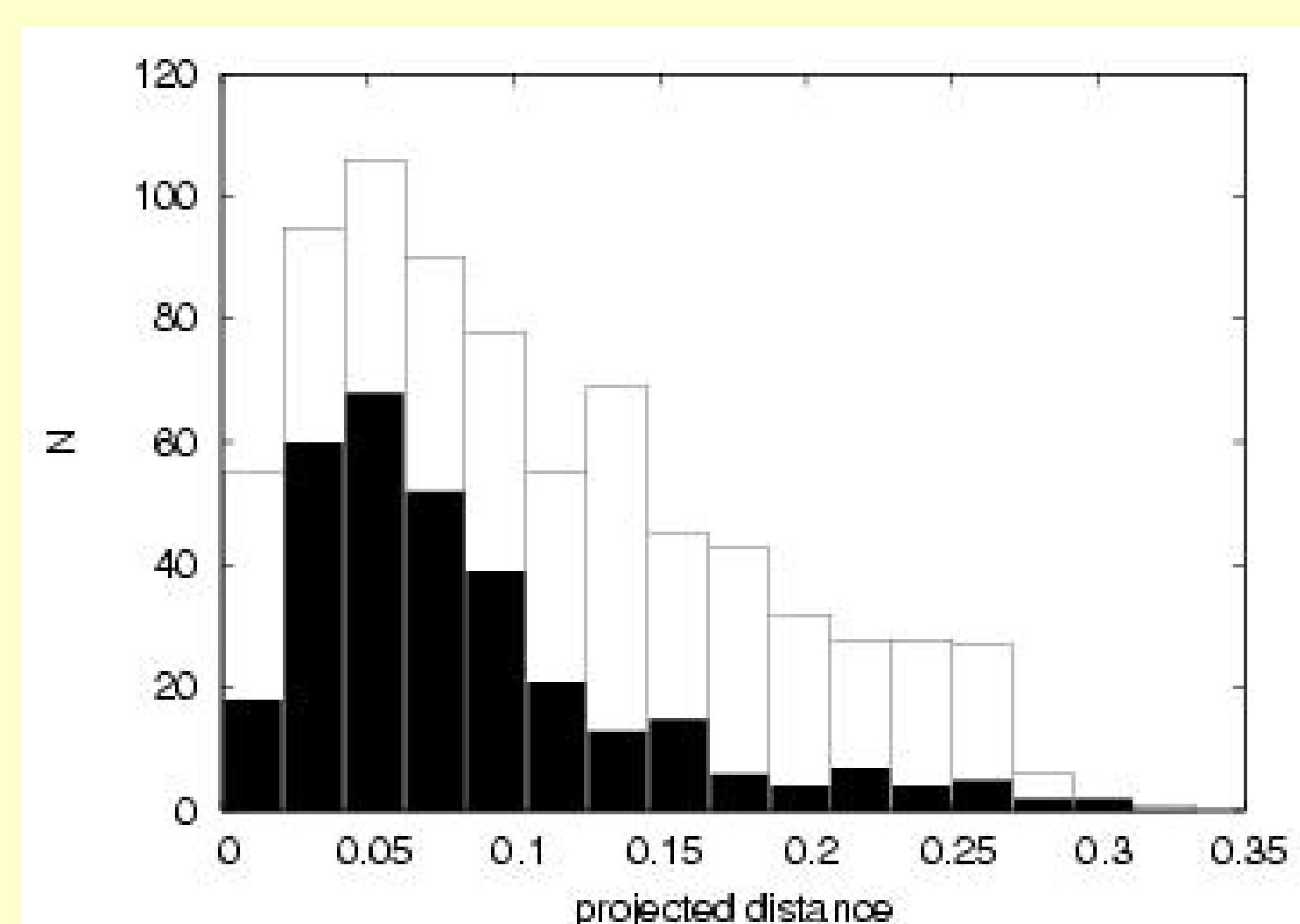


Figure 6 The projected distance from the nearest O star. Filled histogram: IRAC class II sources; hollow histogram: "normal" stars

Identification of IR excess sources

We identify 316 class II sources in the IRAC two color ($[3.6]-[4.5]$ vs $[5.8]-[8.0]$) diagram using the method described by [1] (Fig. 5). We double checked our identifications using other color-color and color-magnitude diagrams like J-H vs K-[24] or J-H vs H-K using 2MASS data. In each diagram the class II sources occupy the regimes predicted by model calculations or by observations of other class II sources. We also used the $[8]-[24]$ vs $[3.6]-[5.8]$ color-color diagram and the color criteria defined by [7] for identifying stars with IR excess (Fig 5.). We found 17 class I and 204 class II sources out of 268 $24\ \mu\text{m}$ sources detected in the region common in IRAC and MIPS observations.

Spatial distribution and statistics of the IR excess sources

The class II stars are located mainly in the OB core. The center of the concentration is at RA=6:31:58.4 DEC=4:54:39.52 which is in very good agreement with the coordinate of the center of the IR cluster derived from 2MASS data by [5]. The ratio of class I/class II sources is about 3% and 8% in the pure IRAC and the IRAC-MIPS combined sample respectively, which is much smaller than the similar ratio in other young star forming region like Taurus and Ophiuchus [3]. This might indicate that the star formation activity in the immediate vicinity of NGC-2244 is coming to an end perhaps as a result of the high radiation environment destroying the surrounding molecular material.

The class I sources are located mostly around the rims of the surrounding nebula (Fig 2.) which might indicate self-propagating star formation triggered by the expanding shell driven by OB stars in the core of the cluster. Surprisingly some class I sources situated close to one of the O stars suggesting that small scale circumstellar envelopes can survive in dens high-UV environment where the globule material is destroyed quickly. We note however, that some of these class I sources might be misidentified reddened class II sources. Further examination is necessary to solve this question.

Fig 6. shows the number of class II sources and normal stars vs the projected distance to the nearest O star. The shape of the two histogram is very similar. The distribution of non-disk stars levels off around 15 arcmin. This suggest that the stars outside this radius are probably non-members and belong to the foreground or background population. By subtracting the non-member stars from the sources detected in the cluster area and dividing the number of excess sources with the total number of sources in each bin we get a rough estimate of the disk fraction in NGC2244 as a function of distance from the nearest O star (Fig 7). After rejecting the two obvious outlying value (probably the result of low number statistic), the average disk fraction throughout the whole cluster is about $41\% \pm 4\%$. The small variation indicates that the disk fraction is not strongly correlated with the distance from the O stars implying that photo evaporation is less efficient in NGC2244 than theory currently predicts

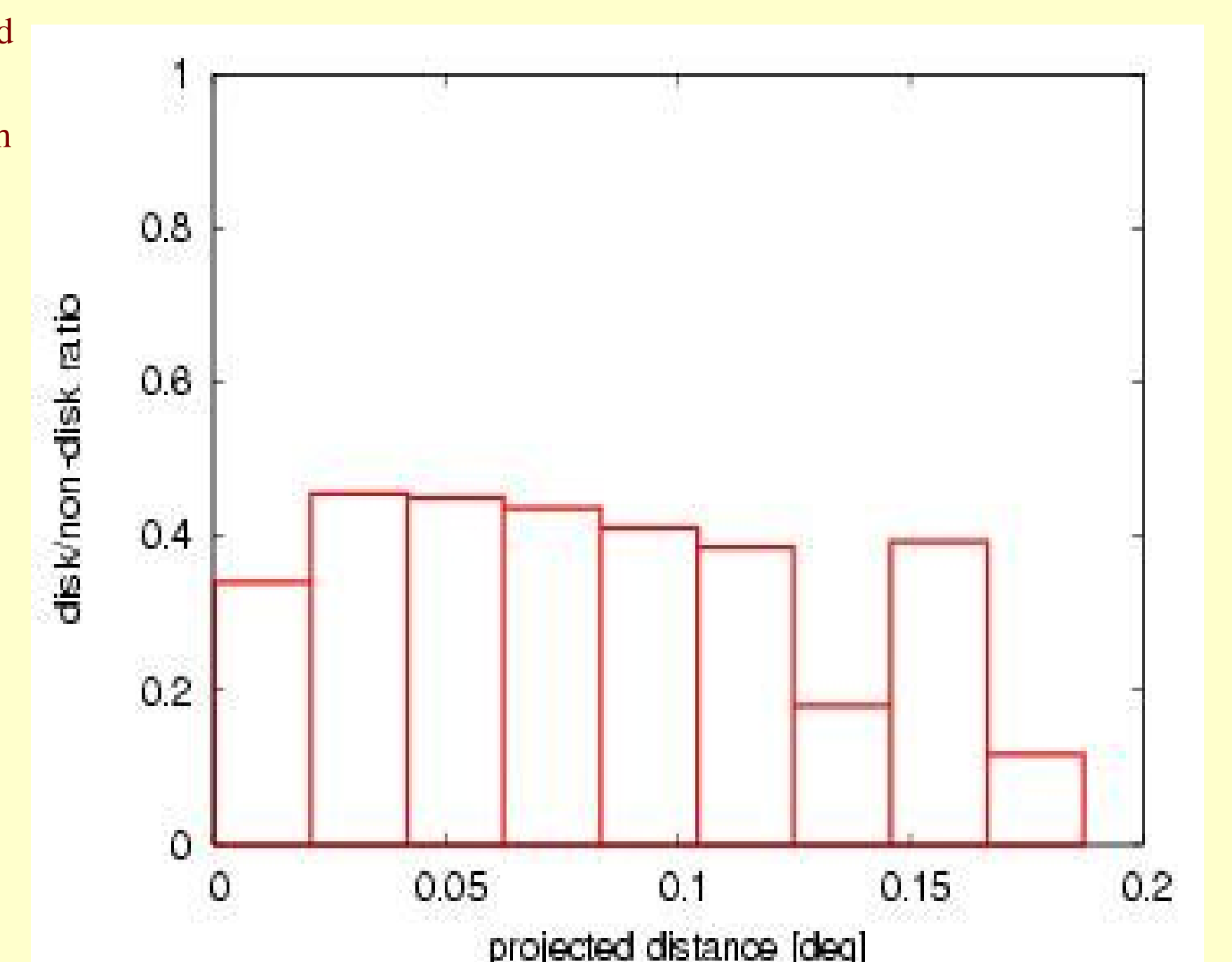


Figure 7 Disk ratio vs projected distance to the nearest O star

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