NGC604 at the NIR: searching for the new stellar generation

Cecilia Fariña[1, 2, @], Guillermo Bosch[1, 2], and Rodolfo Barbá[3,4]

[1] Facultad de Ciencias Astronómicas y Geofísicas de La Plata – UNLP, [2] IALP CONICET (Argentina), [3] ICATE – CONICET (Argentina), [4] Depto. de Física, Universidad de La Serena (Chile) [@] ceciliaf@fcaglp.unlp.edu.ar

Abstract

We present a near infrared (NIR) photometric study focused on the location and characterization of the youngest massive stellar population of NGC 604, one of the most outstanding giant HII regions (GHIIR) in the Local Group.
We have identified, for the first time in NGC 604, massive young stellar objects (MYSOs) embedded within the GHIIR. We ascertained the location of these sources, which points to the places were star formation processes are taking place.

NGC 604 (a quick review)

NGC 604 in M33 (840 Kpc), together with 30 Dor the LMC, are the most outstanding massive star formation regions in the Local Group.
The giant HII region of NGC 604 is ionized by more than 200 OB stars immersed in complex environment with a puzzling geometry and dynamics. The main cluster is not centrally concentrated, but is spread in a projected area ~10000 pc^2 (Hunter+ 1996, Maíz-Apellaniz+ 2004).
Many WR/Of and RSG stars (or candidates) were identified within its stellar population (Conti+1981, Rosa+1982, Diaz+1987, Drissen+1993, Terlevich+1996, Bruhweiler+2003, Barbá+ 2009). The age of the main stellar population was estimated between 3-5 Myr.

Appropriate conditions (temperature and density) for massive star formation were found in studying molecular observations (CO, HCN) in the area of the nebular emission arc to the South-West of the region (Tosaki+ 2007, Miura+ 2010).

The Data

The images were obtained with the Gemini North telescope, using NIRI.
Filters:
- Broad-band: J, H, Ks
- Narrow-band: Brγ, Paβ, H2(2-1)

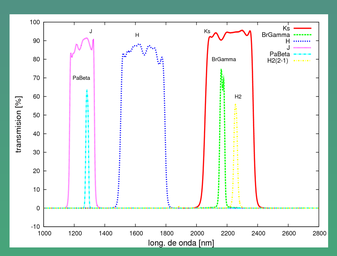


Plate scale: 0.117” px-1
Image field: 120 x 120 arc seconds2 (~ 490 x 490 pc2)
Seeing (measured in the broad-band images): ~ 0.35”

Data reduction and photometry

Data reduction was made using Python scripts (for 'vertical striping' and linearity corrections) and IRAF tasks at the Gemini package.
We performed PSF photometry with DAOPHOT (Stetson 1987) in IRAF, applying an iterative method to construct the PSF model in this crowded and background variable field.
We kept objects with a threshold of 5σ above the background noise.
The limiting magnitudes are: 22 for J and H, and 21.5 for K with mean errors of ~ 0.07 for J and H, and 0.17 for Ks (considering all the object with JHKs measured).

References

Barbá et al. 2009, Ap&SS, 324, 309
Bosch et al. 2002, MNRAS, 329, 481
Bruhweiler et al. 2003, AJ, 125, 3082
Churchwell & Goss 1999, ApJ, 514, 188
Conti & Massey 1981, AJ 249, 471
Díaz et al. 1996, ASPC, 98, 399
D'Odorico & Rosa 1981, ApJ, 248, 1015
Drissen et al. 1993, AJ, 105, 1400
Hunter et al. 1996, ApJ, 456, 714
Maíz Apellániz et al. 2004, AJ, 128, 1196
Miura et al. 2010 arXiv:1009.4082
Relaño & Kennicutt 2009, ApJ, 699,1125
Sabalisck et al. 1995, ApJ, 444, 200
Stetson 1987, PASP, 99, 191
Tenorio-Tagle et al. 2000, ApJ, 451, 720
Terlevich et al. 1996, MNRAS, 279, 1219
Tosaki et al. 2007, ApJ, 664, L27

I would like to thank the 'The Origin of Stellar Masses' SOC and CONSTELLATION, as well as SeCyT (UNLP) for the financial support to attend to this meeting.

Results: Broad-band

The main results arose from the detailed analysis of the color-color and (CCD) color-magnitude (CMD) diagrams showed in Fig. 1 and Fig. 2, respectively.
In both diagrams, the loci of the main sequence (V) and giant (III) stars were included as a reference. The straight lines depict the reddening lines for a M0 III and a O7 V stars, at an Av~15 mag for CCD. In both plots can be clearly distinguished that there is an object set, denoted with red and green symbols, that lies far to the right of the O7 V reddening line.

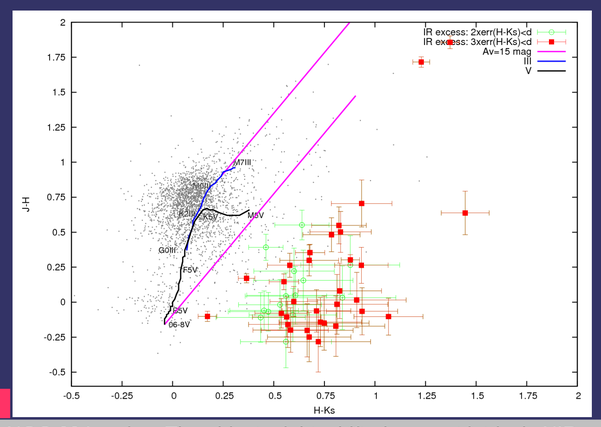


Figure 1

CCD for NGC 604 region. The objects right shifted present intrinsic NIR and meet the condition 3 x err(H-K) < d (red) and 2 x err(H-K) < d (green), where d is the distance to the reddening line. The errors bars for these sources are also plot.

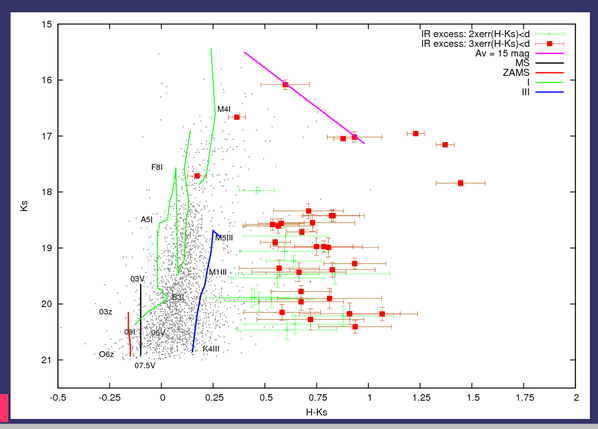


Figure 2

CMD for NGC 604 region. Same as Fig.1

These objects are shifted in the CCD and CMD due to their large intrinsic NIR excess (in fact, these objects meet the condition 3 x err(H-K) < d (red) and 2 x err(H-K) < d (green), where d is the distance to the reddening line). These objects are strong candidates to MYSOs, since in star-forming regions, the NIR excess in a source can be originated in the hot circumstellar material that is surrounding the source previous to (or just after) forming the proto-star.

Examining the location of these objects in the NGC 604 field (see Fig. 3), we found that they are mainly concentrated in the regions delineated by the 8.4 GHz radio continuum emission (Churchwell & Goss 1999). These regions form also part of a CO arc which temperature and density indicates that star formation processes can be currently taking place there, this was proposed initially by Tosaki+ 2007 and recently reinforced by Miura+ 2010 with more detailed CO observation together with HCN and 89 GHz radio continuum).

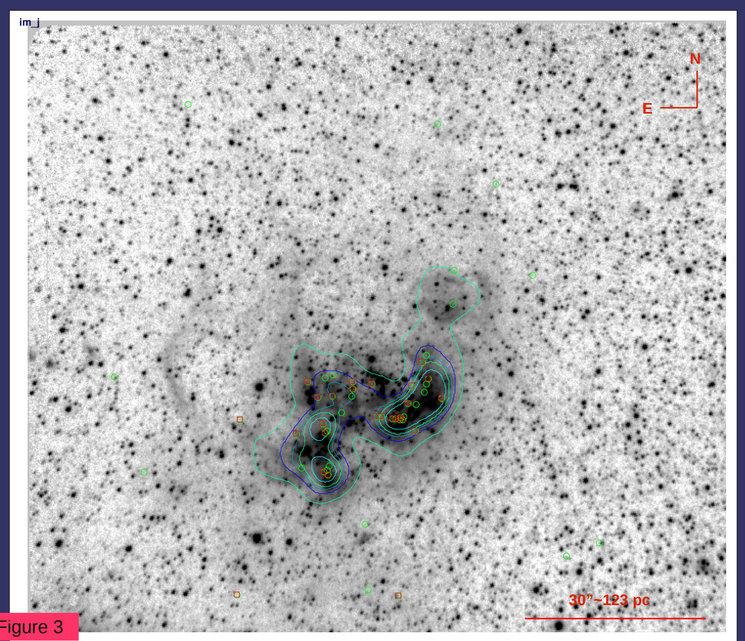
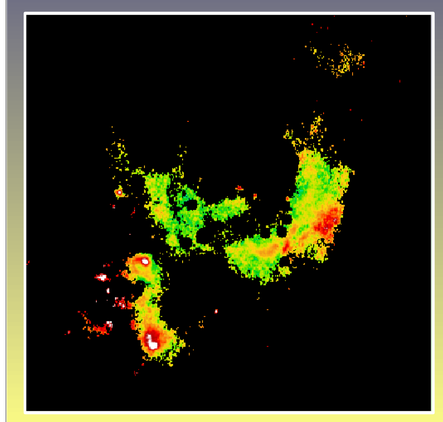


Figure 3

Image of our NGC604 field in J band with 8.4 GHz radio continuum contours overlaid (adapted from Churchwell & Goss 1999). Red circles are objects that show IR excess in our photometry.

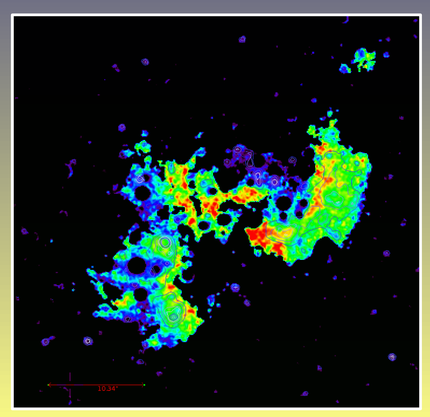
Results: Narrow-band



Extinction map *

Derived from the observed variations of the Brγ to Hα ratio (with the H image taken from Bosch+ 2002). The color scale used in the map shows regions with higher extinction in red/white.

* For morphological inspection only since narrow-band images are not flux calibrated yet. Bright stars were masked on both images.



Nebular structure map *

Red color indicates places with maximum Brγ/H2. H2 contours are superimposed showing that the molecular emission is shifted from recombination Brγ emission (which is higher towards the cloud's borders exposed to the ionizing stars).

Conclusions

We have performed a NIR study of NGC 604 star-forming region focused on its young and massive stellar population. By means of JHK photometry we have identified several objects which presents large intrinsic NIR excess. These embedded sources are strong candidates for massive young stellar objects (MYSOs) or proto-stars in the last stages of formation processes. With narrow-band NIR images we generated an image that exhibits the morphology of the nebular structure and combining our Paβ with the Hα we made an extinction map.
Continuing with this study new Ks spectroscopic observations are being taken in order to disentangle the real nature of these sources.
The massive stellar content of NGC 604 was the target of many previous studies mainly focused on the evolved population (OB, WR and RSG stars). This study provides an important piece of information by adding to the overall known picture new data that clearly denotes the presence and location of a new stellar generation in NGC 604.