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How do massive stars form? Finding targets for MIRADAS.

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Abstract

Observations from massive stars in H II regions can help to clarify theories of massive star formation because they show the degree of isolation under which massive stars can be formed. We present a new survey, called 'A-SMASHeR', consisting of massive stars associated to not yet characterized H II regions that are either more distant or more heavily embedded than the traditional samples. It will allow us to study in a homogeneus way many massive stars placed at different distances between l=30° and 180°, presenting different reddenings and metallicities. Besides, we will use it to constrain better the theories of stellar formation and design future observations with MIRADAS

1 Introduction

High mass stars ($M \geq 8\ M_{\odot}$) are crucial agents in the evolution of galaxies and have a disproportionate effect upon their environment. They provide most of the mechanical energy input into the interstellar medium through stellar winds and supernovae, and most of the UV ionizing radiation of galaxies. They also power the far-IR luminosities of galaxies through the heating of dust and are the primary source of CNO enrichment of the interstellar medium [1]. However, we still know very little about their formation, structure, evolution and death.

How do massive stars form? This is a fundamental question in astrophysics to clarify nowdays. At present, two main theories are invoked: (a) monolithic core accretion, basically a scaled-up version of classical low-mass formation theories, where very high opacities allow infalling material to overcome the radiation pressure ([2] and [3]) and (b) competitive accretion, where massive stars are formed in cluster cores, benefiting from the gravitational potential of the whole cluster to accrete more material ([4] and [5]). One of the key observations that may help to clarify theories of massive star formation is the degree of isolation under which massive stars can be formed [6].

H II regions are places of very recent massive star formation. They are made of plasma ionized by the far-ultraviolet radiation from the massive O-type and B-type stars living in their interior. They can be seen across the entire Galactic disk, because they are very bright at mid-infrared to radio wavelengths. We can use them to answer one of the main questions in the modern theory of star formation: to which degree OB stars can form in true isolation ([6] and [7]). Isolated OB stars are known to exist, but the present controversy is if they were formed in situ. OB stars within an H II region have recently formed within it, and are thus ideal targets to test this hypothesis. To characterize the whole population associated with the H II regions, we must use infrared detectors.

MIRADAS is a Mid-resolution InfRAreD Astronomical Spectrograph that will be installed on the GTC in 2019 [8]. It is a near-infrared multi-object echelle spectrograph operating at spectral resolution $R = 20\,000$ over the $(1 - 2.5)$ microns range that can obtain simultaneous spectra of up to 12 targets. *The massive stellar content of the Milky Way* is one of the MIRADAS science design reference cases because MIRADAS@GTC at $R = 20\,000$ is the ideal instrument to enable a proper abundance and radial velocity analysis of massive stars. Observing programmes with MIRADAS will provide insights on the details of the formation and stellar evolution of massive stars, the chemical composition of the inner Galaxy and the role of the different kinematical populations that populate the inner regions of the Milky Way.

2 Alicante Survey of MAssive Stars in H II Regions (A-SMASHeR)

Members of the MIRADAS science team are getting ready for the arrival of MIRADAS. We are looking for candidate massive stars to observe with MIRADAS by identifying the population of massive stars associated to the H II regions that have not been yet characterized [9]. This new survey of massive stars is formed by objects that are either more distant or more heavily embedded than the traditional samples. It will allow us to study in a homogeneus way many massive stars placed at different distances between l=30° and 180°, presenting different reddenings and metallicities. The more embedded population will signal the youngest sites of star formation. On the other hand, we are selecting a sample of H II regions with a wide variety of shapes and sizes. We want to study the formation of massive stars in small and isolated H II regions as well as in extended H II regions belonging to large areas of star formation. In some cases, we are choosing fields containing different small H II regions and we are very interested in studying if the massive populations of these regions are connected between them. We used LIRIS at the WHT to obtain images for a hundred different fields in the JHK_S bands and now we are getting spectra with EMIR at the GTC for those fields with apparently isolated stars.

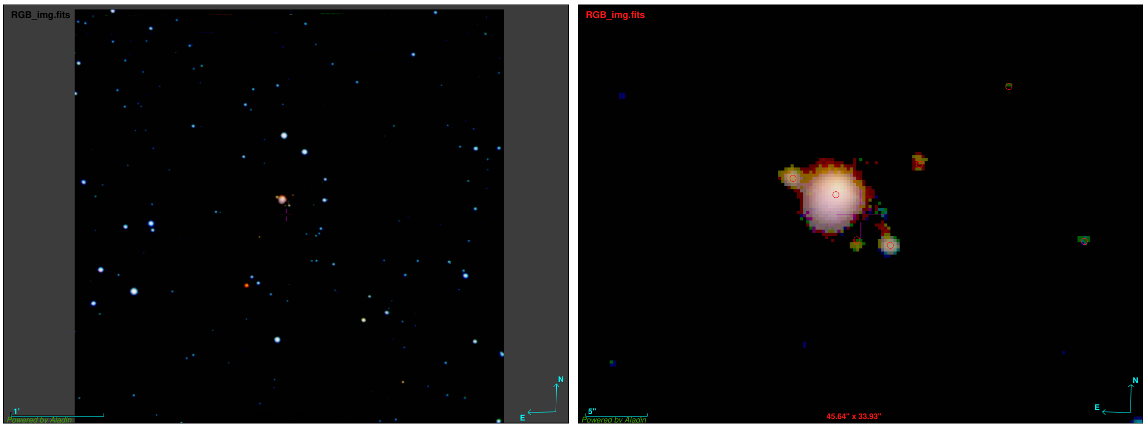

Figure 1: **Left:** Field observed with LIRIS for the H II region G124.640+02.536. The image is a 3 colour composite (JHK_S) and has asize $4.632' \times 4.369'$. We can see that the majority of the stars have blue colour. Only a few stars in the center are reddened stars. **Right:** Zoom for the center of the field where the reddened stars lie. It has a size $44.89'' \times 42.33''$.

We are building a new survey called "*Alicante Survey of MAssive Stars in H* II *Regions (A-SMASHeR)* " with a new sample of massive star forming regions that are either very distant, very reddened or both. It will represent a very significant contribution to the number of massive H II regions whose stellar population is characterized. Besides, it will allow us to constrain better the theories of stellar formation and will be very useful to design the future observations with MIRADAS

3 Results

From an initial study using images and JHK_S photometry, we could identify the massive star population associated to the H II regions. Initially, we have selected 18 candidate massive stars to be apparently isolated. Here, we present an example with the study of the H II region G124.640+02.536. In Fig. 1 we show the images in three colours taken with LIRIS. We can see the different colours of the stars in the field (Left). The redder stars are lying in the center (Right). We carry out the JHK_S photometry and build the $(J - K_S)$.vs.K_S diagram (see Figure 2). Stars located beyond $(J - K_S) \geq 2.5$ are clearly separated and correspond to the redder stars in Figure 1. In Fig. 3 we plot the position of these reddened stars in a WISE image and in a LIRIS image, respectively. We can observe that the brightest reddened star ($K_S = 11.82$; $(J - K_S) = 3.51$) is inside the H II region while the next in brightness but less reddened star ($K_S = 12.25$; $(J - K_S) = 2.92$) is outside the H II region at $1.5'$ in the SW direction. Therefore, we have a clear photometric candidate OB star ionizing the H II region whose nature will be confirmed using EMIR spectroscopy. With the spectral type we will estimate its intrinsic brightness and then we will use our LIRIS photometry to verify if any other massive stars could be present in the H II region by checking if they have the expected magnitude and colours.

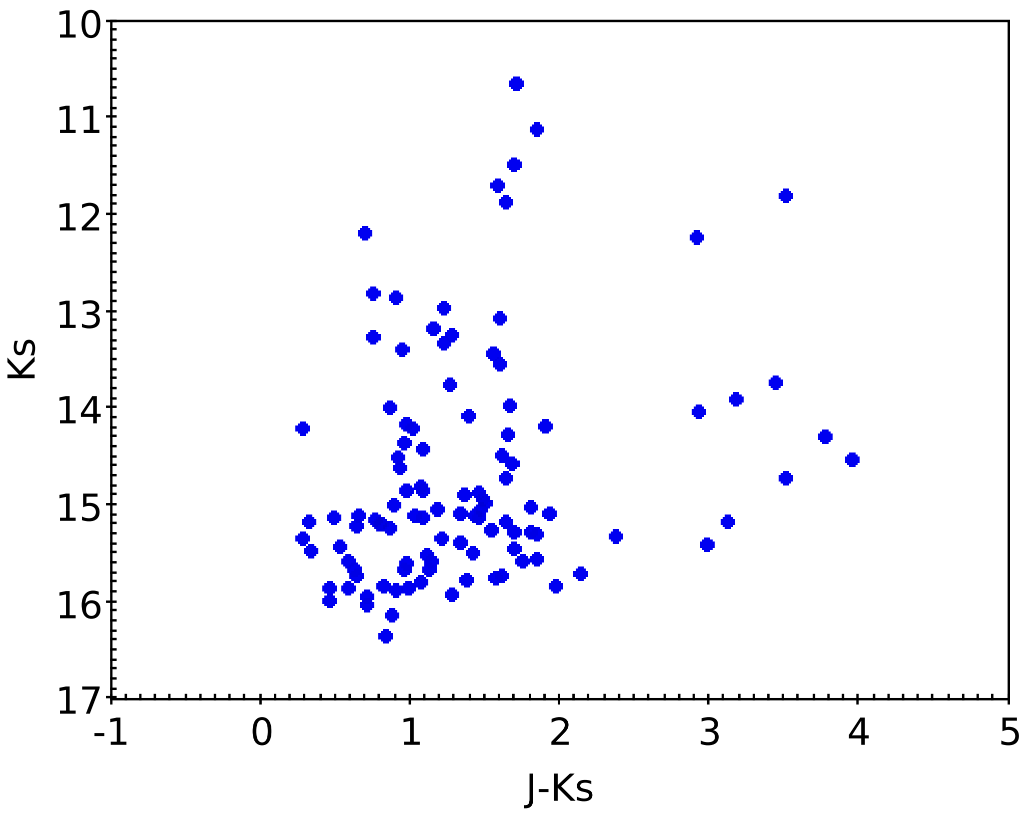

Figure 2: $(J - K_S)$.vs.K_S diagram for the stars in the field from our LIRIS photometry. The group of the stars lying beyond $(J - K_S) \geq 2.5$ correspond to the heavily reddened stars in the field.

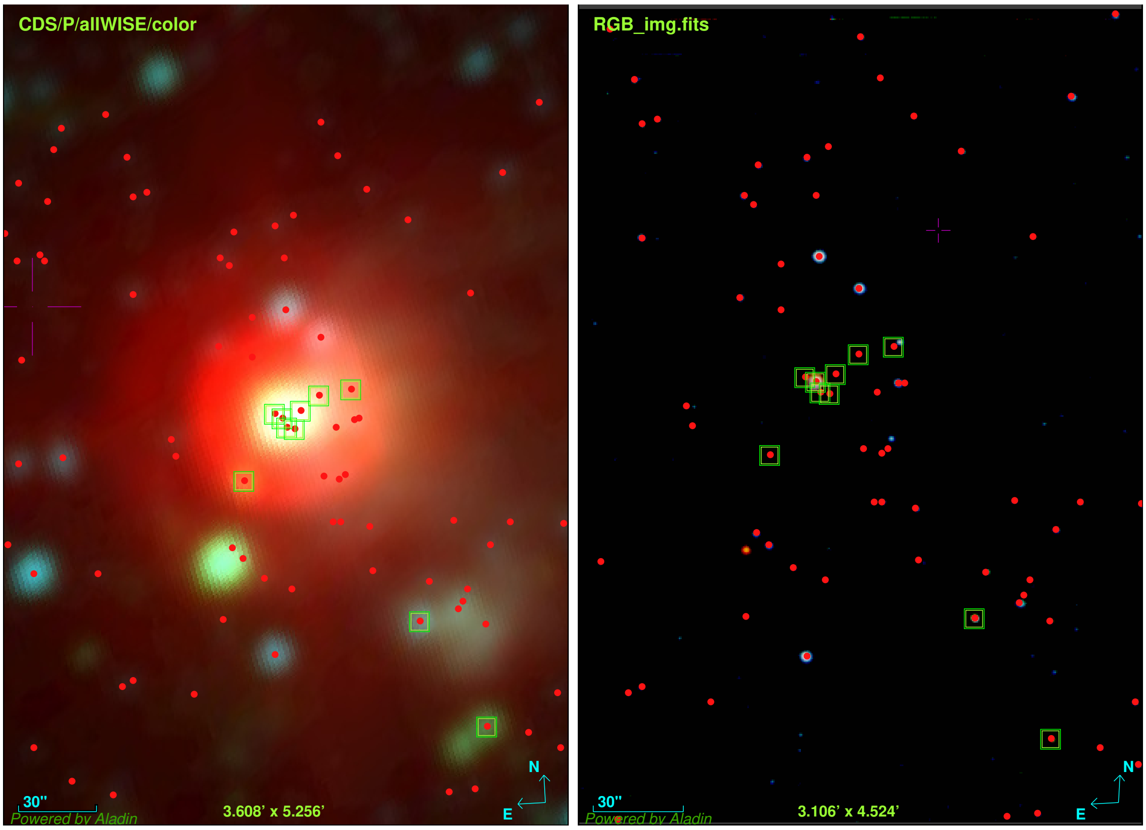

Figure 3: **Left:** WISE image for the H II region G124.640+02.536. Stars lying beyond $(J - K_S) \geq 2.5$ in Figure 2 are marked as green open squares **Right:** Zoom in of the LIRIS image for the H II region G124.640+02.536 shown before. Stars lying beyond $(J - K_S) \geq 2.5$ in Figure 2 are marked as green open squares

Acknowledgments

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