Star clusters: basic galactic building blocks
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Super star clusters in HII galaxies

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Abstract. We summarize our results based on observations with the NIRI camera on the *Gemini North* telescope of three HII galaxies (Mrk 36, UM 408 and UM 461), obtained to identify and determine the ages and masses of the elementary components (the star cluster population) of the starburst regions in compact HII galaxies. Our preliminary results indicate that the masses of the stellar clusters in these galaxies range from $\sim 10^4$ to $\sim 10^6$ $M_\odot$, with associated ages of a few Myr. The most massive star clusters fall in the so-called super star cluster category. The identification of these clusters suggests that the formation and evolution of massive star clusters is the dominant mode of star formation in these galaxies. Their spatial distribution and ages seem to indicate that star formation is simultaneous over these timescales in some of our objects. We also review our recent description of the spatial distribution of physical conditions in the HII galaxy UM 408 using the GMOS integral-field unit on *Gemini South*. The spatial distribution of the oxygen abundance does not show any significant variation or gradient across the galaxy on scales of hundreds of parsecs, within our observational uncertainties, confirming that this compact HII galaxy, like other previously studied dwarf irregular galaxies, is chemically homogeneous.

Keywords. galaxies: dwarf, galaxies: star clusters, galaxies: ISM, ISM: abundances

1. Introduction

HII galaxies are metal-poor galaxies characterized by their blue optical colors, small sizes ($\gtrsim 1$ kpc), and low luminosities ($M_B > -18$ mag), while undergoing vigorous star formation. Their observed colors and (HII-like) spectra indicate that they are young starbursts (Sargent & Searle 1970). The hypothesis of these objects being young galaxies forming their first generation of stars in the local Universe has been ruled out, since an underlying red stellar population has been detected in most observed galaxies in this class (e.g., Telles & Terlevich 1997; Cairós *et al.* 2003).

HII galaxies can be classified into two classes of objects (Telles *et al.* 1997), luminous galaxies with an irregular outer shape and evident signs of disturbance (Type I), and compact, regular, low-luminosity objects (Type II). The present star-formation activity in most Type I galaxies, can be explained as the consequence of a merger or fusion of objects, but this scenario does not explain the star-formation activity in compact and regular galaxies. In fact, HII galaxies are isolated objects, without an excess of companions when their clustering properties are compared with more massive galaxies (Telles & Madox 2000). The lack of external perturbers in the most compact and isolated galaxies indicates that an additional mechanism other than tidal interactions must be considered to explain their present star-formation activity. The internal mechanism which may trigger star formation in these galaxies without an obvious external agent is as yet unknown, but may be related to the overall physical conditions of the interstellar medium (ISM), particularly the gas surface densities, in conjunction with stochastic effects, allowing star formation to start.

Once star formation has been initiated, the collective effect of stellar winds and supernova ejecta from young massive stellar clusters or super star clusters (SSCs) sweep up the ISM, producing a dispersion of metals (Tenorio–Tagle 1996) on scales of ∼ 1 kpc and timescales of less than $\sim 10^7$ yr. This scenario has been invoked to explain the observed distribution of chemical abundances in HII galaxies (Lagos *et al.* 2009; and references therein).

The aim of this contribution is to show how high-resolution images and spectroscopy, obtained using 8m-class telescopes, can be used to study a sample of compact HII galaxies. We used near-infrared images (NIRI; Near-Infrared Imager) to resolve the star cluster population in the starburst regions and to study the clustered mode of star formation in compact galaxies. In addition, we took advantage of GMOS–IFU facilities to study the degree of chemical homogeneity in the ISM of a sample of compact HII galaxies. The spatial variations of the abundances should reflect the physical mechanisms involved in their recycling properties.

2. Stellar populations in HII galaxies: near-infrared photometry

To study the stellar populations in HII galaxies, we obtained broad-band J (1.25μm), H (1.65μm), $K_{\rm p}$ (2.12μm) and narrow-band Brγ images of the galaxies Mrk 36, UM 408 and UM 461 using NIRI on *Gemini North*. In these high-resolution images we detected a myriad of compact regions that were associated with star clusters. We compared the near-infrared broad-band images with the Brγ emission images to identify the young cluster population. Brγ emission was found in our sample of galaxies, but the majority of the clusters do not show evidence of strong emission. The properties (ages and masses) of these clusters were calculated by comparing the observed colors with STARBURST99 (Leitherer *et al.* 1999) models. In Figure 1a we show the $K_{\rm p}$-band image of the compact galaxy UM 408. In this image, we identify with circles the detected stellar clusters. Our preliminary results indicate that the masses of these clusters range from $\sim 10^4$ to $\sim 10^6$ M$_\odot$, with associated ages of a few Myr. We note that the clusters are practically coeval, at least in UM 408, with ages of ∼ 5 Myr, suggesting that star formation was triggered simultaneously.

3. Spatial distribution of oxygen abundance: IFU spectroscopy

We started a program to study the spatial distribution of the physical conditions in compact HII galaxies. Thus far, we have analysed in detail the object UM 408 (Lagos *et al.* 2009). The observations were performed using GMOS–IFU on *Gemini South*, using the B600 and R600 gratings in one-slit mode, covering a total spectral range from ∼ 3021 to 7225 Å. We calculated oxygen abundances in the regions where [OIII]λ4363 was detected. In Figure 1b we show the smoothed spatial distribution of 12+log(O/H) in the GMOS–IFU field of view (see the area in the $K_{\rm p}$-band image of the galaxy). Each aperture or pixel in Figure 1b corresponds to 0.2 arcsec. The two giant regions formed by clusters 4+5 and 2+3, labelled A and B in Lagos *et al.* (2009), show a difference in oxygen abundance of only Δ(O/H) = 0.02 dex, indicating that these regions have identical chemical properties, within the errors. The bulk of the observed data points (black dots in Figure 1c) are lying in a region of $\pm 2\sigma$ ($\sigma = 0.1$ dex) with respect to the average value. Therefore, the new metals formed in the current star-formation episodes are not observed and reside probably in the hot gas phase ($T \sim 10^7$ K), while the metals from previous star-formation events

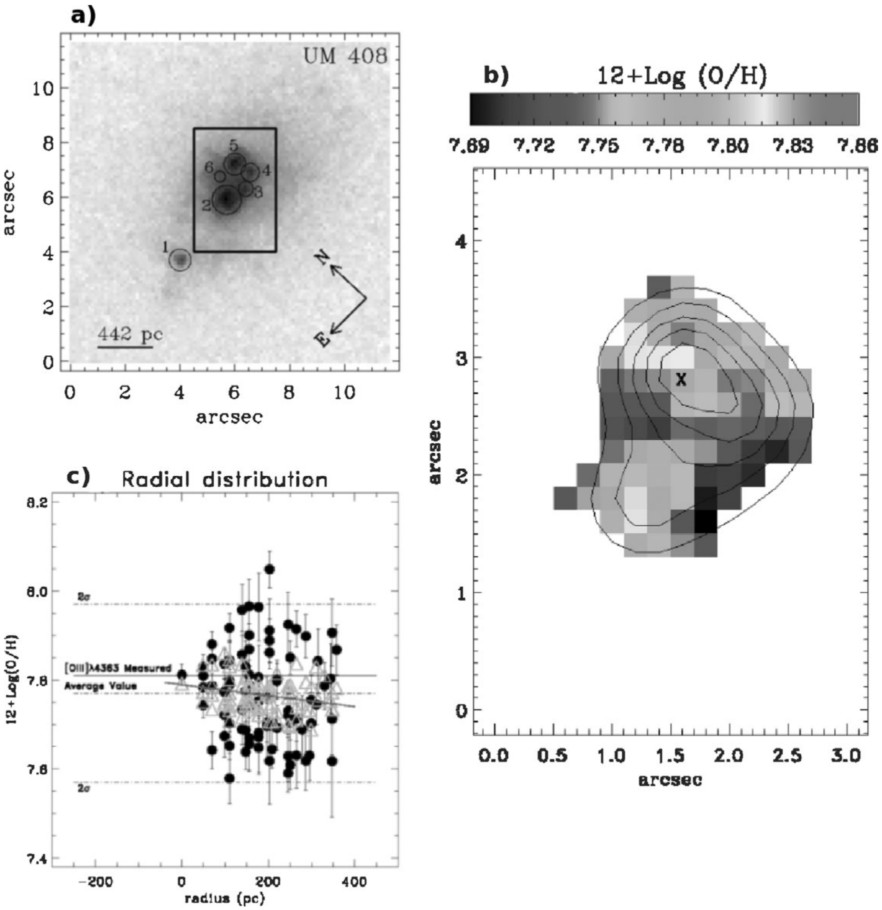

Figure 1. Correlation between the spatial distribution of oxygen abundances $[12+\log(\mathrm{O/H})]$ and the position of the stellar clusters in the galaxy UM 408. *(a)* K_{p}-band image of the galaxy UM 408. The rectangle indicates the field of view of $3'' \times 4.4''$ used for the GMOS–IFU observation. *(b)* Smoothed spatial distribution. The isocontours display the Hα emission. The maximum Hα emission is found associated with region A and is indicated in the map by a cross. Hα contours are overplotted on the map. *(c)* Radial distribution. The central dotted line represents the $12+\log(\mathrm{O/H})$ average value of 7.77, and the solid line the integrated value of $12+\log(\mathrm{O/H}) = 7.81$ in the region where the [O III]λ4363 emission lines were measured. The 2σ dispersion is represented by the dotted lines. The difference between the maximum and minimum values in the original data set (black dots) is 0.47 dex. Light blue triangles represents the smoothed $12+\log(\mathrm{O/H})$ radial distribution. A least-squares fit using the original data set is indicated by the red line. For more details, see Lagos *et al.* (2009).

are well mixed and homogeneously distributed throughout the whole extent of the galaxy. The absence of chemical overabundances in the ISM of UM 408 and in the dwarf galaxies studied in the literature leads to the conclusion that the population of young clusters are not producing localized overabundances. This agrees with theoretical estimates (e.g., Wofford 2009). On the other hand, we observed that there is a very marginal gradient of decreasing abundance from the center outwards, indicating that the highest abundance values are found near the peak of Hα emission.

4. Conclusions

To our knowledge, this is the first time that the elementary structures within the starburst regions in the HII galaxies Mrk 36 and UM 408 are resolved. The identification of these regions reveals that the formation and evolution of massive star clusters appears to be the dominant mode of star formation in these HII galaxies.

As far as the spatial distribution of the oxygen abundance is concerned, we did not detect localized overabundances associated with the positions of the star clusters in UM 408, within our observational uncertainties. However, a marginal gradient of decreasing abundance from the center outwards indicates that the highest abundance values are found near the position of the detected star clusters in this galaxy.

All results presented in this contribution are suggestive that compact HII galaxies are unevolved, low-metallicity dwarf galaxies possibly undergoing a simultaneous episode of star formation over their entire optically observed extent. They are a genuine example of the simplest starbursts occurring on galactic scales, possibly mimicking the properties one expects for young galaxies at high redshift.

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References

Cairós, L. M., Caon, N., Papaderos, P., Noeske, K., Vílchez, J. M., Lorenzo, B. G., & Muñoz–Tuñón, C. 2003, *ApJ*, 593, 312

Lagos, P., Telles, E., Muñoz–Tuñón, C., Carrasco, E. R., Cuisinier, F., & Tenorio–Tagle, G. 2009, *AJ*, 137, 5068

Leitherer, C., *et al.* 1999, *ApJS*, 123, 3

Sargent, W. L. W. & Searle, L. 1970, *ApJ*, 162, 155

Telles, E. & Terlevich R. 1997, *MNRAS*, 286, 183

Telles, E., Melnick, J., & Terlevich, R. 1997, *MNRAS*, 288, 78

Telles, E. & Maddox, S. 2000, *MNRAS*, 311, 307

Tenorio–Tagle, G. 1996, *AJ*, 111, 1641

Wofford, A. 2009, *MNRAS*, 395, 1043