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USING THE VLT TO ANALYZE THE COMPACT PHOTOIONIZED REGIONS IN NGC 3109[1]

M. Peña,[2] M. G. Richer,[3] and G. Stasinska[4]

RESUMEN

Veinte nebulosas planetarias (NP) y numerosas regiones HII compactas fueron detectadas en la galaxia irregular NGC 3109, mediante imágenes “en-línea” y “fuera de línea” en [O III] 5007 obtenidas con el ESO VLT. Las NPs fueron seleccionadas como objetos estelares que no mostraran continuo estelar. Espectroscopía obtenida con el VLT FORS1 en modo multi-objeto ha permitido confirmar la naturaleza de NP para varias candidatas. Se ha obtenido también espectroscopía para varias regiones HII compactas. Los espectros son profundos de manera que muchos objetos muestran [O III] 4363 y se puede determinar la temperatura de las regiones, permitiendo analizar la composición química de NPs y regiones HII. Encontramos que las regiones HII muestran una composición química (O/H) muy homogénea (en promedio 12 + log O/H = 7.79±0.10), en tanto que las NPs muestran variaciones grandes de composición química y un aparente enriquecimiento en oxígeno.

ABSTRACT

From ESO VLT “on-band off-band” imaging of the dwarf irregular - late type spiral NGC 3109, we have detected 20 planetary nebula (PN) candidates and many compact HII regions all over the galaxy. PN candidates have been selected as stellar objects with no detectable (or very faint) stellar continuum. Further spectroscopy (with VLT FORS multi-object) in the 3700-6800 Å range has confirmed the PN nature of several candidates. Most of the PNe appear as low excitation nebulae. Spectra were also acquired for several HII regions. For many objects the [O III] 4363 line, sensitive to electron temperature, was detected, allowing a trustworthy determination of chemical abundances. Therefore a comparative analysis of chemical composition in both type of objects can be performed. We find that the HII regions present very similar O/H abundances (in average 12 + log O/H = 7.79±0.10), while O/H in PNe spreads in a larger range. Most of the PNe seem to be O-enriched.

Key Words: **GALAXIES: INDIVIDUAL (NGC 3109) — HII REGIONS — PLANETARY NEBULAE**

1. INTRODUCTION

NGC 3109 (DDO 236), Sextans A, Sextans B and Antlia are part of the Antlia-Sextans group: a small group of gas-rich dwarf irregular galaxies just beyond the Local Group at a distance of about 1400 kpc. They are metal poor objects. NGC 3109 is the dominant member of the group. It has been classified as a late type spiral SB(s)m by de Vaucouleurs et al. (1991). It seems to be similar to the SMC, in luminosity and chemical composition. The galaxy has an extension of about 17.4×3.5 arcmin, aligned almost E-W.

NGC 3109 is particularly suited for chemical evolution studies because, due to its distance, apparently it has not been affected by tidal effects from the large spirals of the Local Group (unlike the Magellanic Clouds), thus it has not lost a significant amount of gas due to tidal effects.

Our aim is to perform a deep analysis of the chemical composition in PNe and HII regions in NGC 3109, in order to test the chemical homogeneity of the galaxy and to probe the chemical enrichment and the star formation history of this galaxy.

On January 2006 we obtained spectrophotometric data for several photoionized regions using the Focal Reducer Spectrograph (FORS1) attached to the ESO VLT UT2 telescope at Paranal, Chile. The objects for spectroscopy were selected from a list of PN candidates and HII regions detected through [O III] 5007 on-band off-band pre-imaging acquired with the same instrument on Nov 29, 2005.

2. THE PN CANDIDATES

The [O III] on-band off-band images were subtracted in order to detect emission line objects. Numerous extended HII regions as well as compact

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[2] Instituto de Astronomía, Universidad Nacional Autónoma de México, Apdo. Postal 70264, 04510 México D. F., México (miriam@astroscu.unam.mx).

[3] Instituto de Astronomía, Universidad Nacional Autónoma de México, Apdo. Postal 877, 22800 Ensenada, B. C., México.

[4] LUTH, Observatoire de Meudon, France.

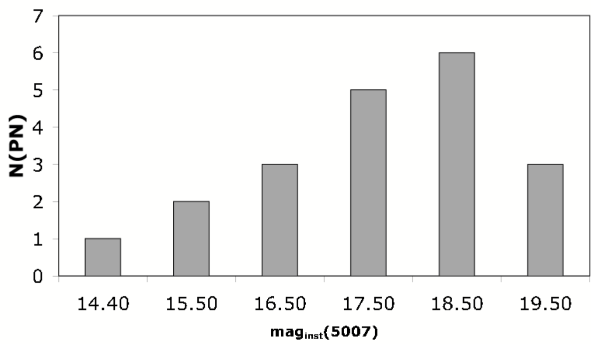

Fig. 1. The Planetary Nebula Luminosity Function constructed from the instrumental [O III] 5007 magnitudes. The shape of this PNLF is similar to the usual PNLF obtained for other galaxies.

emitting regions appear in the subtracted image. We have selected the PN candidates as those unresolved emitting objects, with no (or very faint) stellar emission in the off-band image. Compact objects with a noticeable star were classified as compact HII regions. This is because the central stars of PNe capable of producing a detectable [O III] 5007 emitting region should be about two magnitudes or more fainter than the corresponding stars capable of ionizing HII regions with detectable [O III] 5007 (e.g., Soffner et al. 1996). At the distance of NGC 3109, the ionizing stars of HII regions (of spectral type O8 V or earlier) should have a visual magnitude of about 21.4, thus PN central stars would have V$\geq$ 23.4 mag and they would not be detectable in our images. A full discussion of the criteria for distinguishing PNe from unresolved HII regions is presented in Peña, Richer, & Stasinska (2007).

A first inspection of our on-band off-band imaging searching for PNe produced the discovery of 13 PN candidates, reported by Peña et al. (2006). Since then we have re-inspected the images looking for faint [O III] emitting objects. From this we have found a number of very faint compact objects from which, according to our criteria for selecting PNe, other 7 objects have resulted to be PN candidates. Therefore, in total we have found 20 PN candidates in NGC 3109. Notice that most of the PN candidates reported by Richer & McCall (1992) are not in our list of PNe. They are classified as compact HII regions. We have measured the instrumental [O III] 5007 magnitudes of PNe which allows us to construct a rough Planetary Nebula Luminosity Function (PNLF, see Figure 1). Our PNLF's shape is similar to the usual PNLF (e.g. Ciardullo et al. 1989). In Figure 1 it is evident that the completeness of our PN sample extends about 3 magnitudes from the brightest PNe.

3. SPECTROPHOTOMETRIC DATA

FORS1, in multi-object mode (MOS), was used to obtain spectrophotometric data of the objects selected from the pre-imaging. The objects are distributed all over the galaxy. By using the grisms 600B+12 and 600V+94 the wavelength range from 3700 to 6900 Å was covered for most of the objects. The exposures times were about 1 - 1.5 hours for each spectral range. This was enough to detect with good signal-to-noise (better than 5) important lines for plasma diagnostic such as [O III] 4363 and [S II] 6716,6731. Thus electron temperatures and densities were determined for most of the objects.

Two calibrated spectra (one HII region and one PN) in the blue spectral range are shown in Figure 2. Notice the strong blue stellar continuum in the HII region, while the PN shows no stellar continuum and it has a much higher excitation ([O III]4959/H $\beta \geq$ 2).

We have measured all the emission lines in the spectra of PNe and HII regions and have determined their physical conditions. This allows us to estimate the ionic and total abundances. Preliminary results for the oxygen abundances indicate that HII regions present, on average, a value 12+log O/H= 7.79$\pm$0.10 with a very small dispersion. This constitutes evidence that the present interstellar medium is homogeneous in NGC 3109. On the other side, PNe present a wider range in 12+log O/H from 7.8 to 8.2, with an average of 8.0. Similar results have been reported by Leisy et al. (2005). Thus, PNe are more O-rich than HII regions, which could be interpreted as a probable contamination of oxygen in the stellar atmosphere by products from the stellar nucleosynthesis, previous to the PN ejection.

This is contrary to expectations in the sense that usual evolution models predict no O dredge up for the progenitors of PNe (medium to low mass stars). In most of the observed galaxies, bright PNe and HII regions show similar O/H ratios. However, recently there have been some indications that in low metallicity conditions, PN progenitors do dredge up some oxygen. It seems to be the case of the only PN known in Sextans A, which presents an O/H larger than the value in HII regions by 0.2 dex (Magrini et al. 2005; Kniazev et al. 2005). Also some recent theoretical works support the possibility of O enrichment as results of dredge up in low metallicity PN progenitors (Marigo 2001; Herwig 2004). Our results for the PNe in NGC 3109 would be another evidence of such a phenomenon.

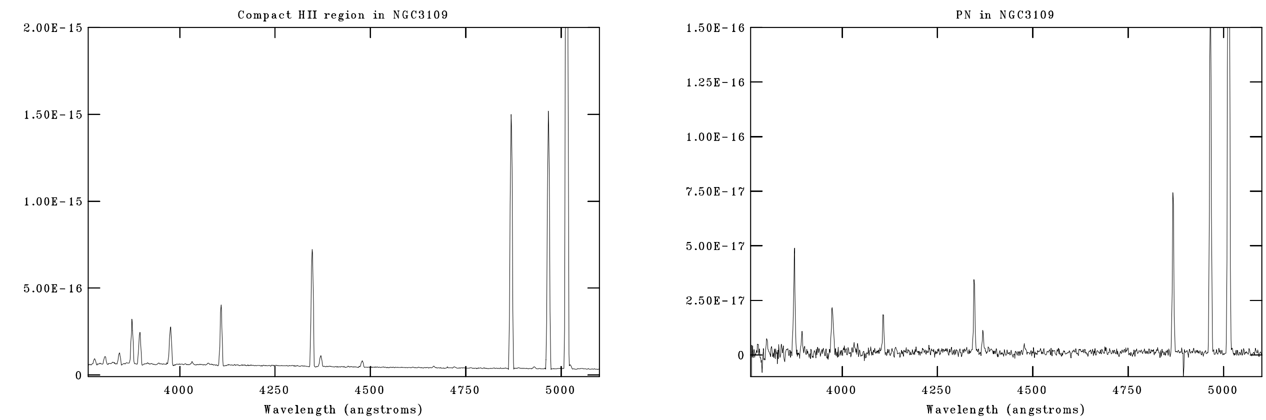

Fig. 2. The blue spectra of a compact HII region (left) and a planetary nebula (right) in NGC 3109 are shown. In both cases we detect [O III] 4363, useful for temperature determination. The compact HII region shows an important stellar continuum while the PN presents no continuum and a much higher excitation.

4. CONCLUSIONS

We are analyzing [O III] 5007 on-band off-band imaging and spectroscopy of PNe and HII regions in NGC 3109. From the imaging we have discovered 20 PN candidates, several of which have been spectroscopically confirmed.

Our spectrophotometric data allow to determine physical conditions and chemical composition for several PNe and HII regions. Preliminary results show that HII regions present an average value 12 + log O/H = 7.79 ± 0.10 with a very small dispersion, while PNe present a wide range of values from 7.8 to 8.2.

Apparently PNe are O-enriched in NGC 3109. This result would confirm that low-metallicity PN progenitors can dredge up oxygen to their atmospheres previous to the PN ejection.

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