The Ionization Mechanism of NGC 185: How to Fake a Seyfert Galaxy *

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ABSTRACT

NGC 185 is a dwarf spheroidal satellite of the Andromeda galaxy. From mid-1990s onward it was revealed that dwarf spheroidals often display a varied and in some cases complex star formation history. In an optical survey of bright nearby galaxies, NGC 185 was classified as a Seyfert galaxy based on its emission line ratios. However, although the emission lines in this object formally place it in the category of Seyferts it is probable that this galaxy does not contain a genuine active nucleus. NGC 185 was not detected in radio surveys either in 6 cm or 20 cm, or x-ray observations, which means that the Seyfert-like line ratios may be produced by stellar processes. In this work we try to identify the possible ionization mechanisms for this galaxy. We discussed the possibility of the line emissions being produced by planetary nebulae (PNe), using deep spectroscopy observations obtained with GMOS-N (Gemini Multi-Object Spectrograph - North), at Gemini. Although the flux of the PNe are high enough to explain the integrated spectrum, the line ratios are very far from the values for the Seyfert classification. We then proposed that a mixture of supernova remnants and PNe could be the source of the ionization, and we show that a composition of these two objects do mimic seyfert-like line ratios. We used chemical evolution models to predict the supernova rates and to support the idea that these supernova remnants should be present in the galaxy.

Key words:
Galaxies: abundances - evolution - Local Group - Individual (NGC 185); ISM: Planetary Nebulae - supernova remnants

1 INTRODUCTION

NGC 185 is a dwarf spheroidal (dSph) and together with NGC 205 and NGC 147, is one of the three brightest dwarf companions of M31. Unlike the other two however, NGC 185 has an important content of gas and dust (Marleau, Noriega-Crespo & Misselt 2010). At first, the dwarf ellipticals (dEs) and the dSphs have been regarded as simple, old stellar systems, with a stellar content resembling that of Galactic globular clusters. However, from mid-1990s onward, with the advent of Hubble Space Telescope, it was revealed that those simple galaxies often display a varied and in some cases complex star formation history (Mateo 1998). A dozen of luminous blue stars (Baade 1951) and other Population I features (dust clouds, HI gas, supernova remnants) were detected at the center of NGC 185. This has been an intriguing feature of this galaxy for several decades. This recent star formation is confined to its central 150 pc × 90 pc where the youngest (100 Myr old) population is found (Lee et al. 1993; Martínez-Delgado, Aparicio & Gallart 1999).

In an optical survey of bright nearby galaxies carried out by Ho et al. (1997, hereafter HO97), NGC 185 was classified...
as a Seyfert galaxy based on its emission line ratios. This is somewhat unexpected since active galactic nuclei (AGNs) are not commonly found in these small host galaxies. If true, this would be the only dSph with an active nucleus known today. The nucleus of NGC 185 is very ill defined, and the spectrum they obtained has low S/N. The emission lines of the galaxy are very weak and although their ratio formally place it in the category of Seyferts it is probable that this galaxy does not contain a genuine active nucleus. NGC 185 was not detected in radio surveys either in 6 cm or 20 cm (Ho & Ulvestad 2001, Heckman, Crane & Balick 1980), or x-ray observations (Brandt et al. 1997), which means that the Seyfert-like line ratios may be produced by stellar processes.

In this work we try to unveil the possible ionization mechanisms of NGC 185. In §2 we discuss its Seyfert classification using the integrated spectrum from HO97. In §3 we study the possibility that planetary nebulae are responsible for the galaxy's emission lines. To do this we used planetary nebulae's observations obtained by our group with Gemini. In §4 we propose another ionization mechanism for this galaxy, based on diagnostic diagrams. In §5 we support our theory using a chemical model of the galaxy and in §6 we present our conclusions.

2 THE SEYFERT CLASSIFICATION

HO97 classified NGC 185 as a Seyfert based on their spectrum of the central 2"x 4" of the galaxy. They acquired spectra covering the wavelength regions of 4230 - 5110 Å and 6210 - 6860 Å, with spectral resolutions of about 4 and 2.5 Å respectively.

The optical spectral region contains several emission lines whose intensity ratios can be used to discriminate different sources of ionization. Baldwin, Phillips & Terlevich (1981) suggested a series of two-dimensional, line-intensity ratio diagrams that have since become widely-used diagnostic tools to classify emission-line objects (the BPT diagrams). In these diagrams, nebulae photoionized by hot, young stars (HII regions) can be distinguished from those photoionized by a harder radiation field, such as that of an AGN. The separation between the two main ionization sources (young stars vs. AGNs) and between the two AGN excitation classes (Seyferts vs. Low Ionization Narrow Line Regions - LINERs) does not have sharp, rigorously defined boundaries. In practice, however, one must impose somewhat arbitrary, albeit empirically motivated criteria to establish an internally consistent system of classification. HO97 used the diagnostic diagrams recommended by Veilleux & Osterbrock (1987), which employ optical line-intensity ratios that are relatively insensitive to reddening and were contained in the spectral coverage of their survey. The classification criteria adopted by them is presented in Table 1.

The optical spectra of many emission-line nuclei are contaminated heavily, and often dominated, by the stellar component. As late-type giants dominate the integrated light of galaxy bulges, stellar absorption lines affect the strengths of most emission lines of interest. The magnitude of the effect obviously depends on the equivalent widths of the emission lines, but it is generally large in the centers of most “normal” galaxies, where the emission lines are quite weak. Consequently, quantitative studies of most emission-line nuclei depend sensitively on the accuracy with which the stellar absorption lines can be removed.

To correct for this effect, HO97 adopted a modified version of the technique of template subtraction: it subtracts from the spectrum of interest a suitably scaled template spectrum that best represents the continuum and absorption-line strength of the stellar component. The resulting end product should then be a continuum-subtracted, pure emission-line spectrum. The template models adopted by HO97 were constructed from a library of galaxy absorption-line spectra observed in their survey. For NGC 185 the template was constructed using one only galaxy, NGC 205, which they assume to have very similar stellar population, but has no emission lines.

2.1 Stellar Population Synthesis

Since the starlight subtraction is so crucially important to obtain correct emission-line fluxes, we decided to test HO97’s template subtraction by applying a stellar population synthesis method to their NGC 185 spectra. For this we used the code STARBURST 99 (Cid Fernandes et al. 2001, 2004, 2005, Mateus et al. 2006, Asari et al. 2007). STARBURST mixes computational techniques originally developed for semi empirical population synthesis with ingredients from evolutionary synthesis models. Basically the code fits an observed spectrum with a combination, in different proportions, of a number of simple stellar populations (SSPs). We used a base of 45 SSPs in this work. These SSPs are from Bruzual & Charlot (2003), and cover 15 ages from 1 Myr to 13 Gyr, and three metallicities: z=0.004, 0.020 (solar) and 0.050. It is important to keep in mind that the synthesis is based on the whole spectrum fitting, and the limited wavelength coverage of this spectrum means results have to be considered very carefully. Our aim here is not to describe in details the stellar population and metallicity of the galaxy, but to discover how much the stellar population absorption can interfere in the emission line measurements.

Figure 1 shows the synthesis results. In the top panel is the original HO97 spectrum (in black) and the synthetic spectra obtained by our stellar populations synthesis (in red). We also present the spectra of NGC 205 from HO97 for comparison (in blue). As it turns out, the synthetic spectra is very similar to the spectra of NGC 205, which means that HO97 line measurements were not affected by the template subtraction. The bottom panel shows the difference between the original and the synthetic spectrum (black line) and between the original and NGC 205 spectrum (blue line). It becomes clear that in both cases the Hα line increases significantly after the subtraction, showing how important it is to correctly measure the absorption lines. Hβ was not even detected in emission before the subtraction.

From the stellar population synthesis we can obtain the star formation history (SFH) of the galaxy. A description of the SFH in terms of 15 age bins is too detailed given the effects of noise, intrinsic degeneracies of the synthesis process, and limited spectral coverage of the data which is even further limited by the masks around the emission lines. A coarser but more robust description of the SFH requires
Table 1. Criteria for Spectral Classification

| Class             | \[OIII] \(\lambda5007/H\beta\) | \[OII] \(\lambda6300/H\alpha\) | \[NII] \(\lambda6584/H\alpha\) | \[SII] \(\lambda\lambda6716,6731/H\alpha\) |
|-------------------|-------------------------------|-------------------------------|-------------------------------|-----------------------------|
| HII nuclei        | Any                           | < 0.08                        | < 0.06                        | < 0.04                      |
| Seyfert nuclei    | \(\geq 3\)                    | \(\geq 0.08\)                 | \(\geq 0.06\)                 | \(\geq 0.04\)               |
| LINERs            | \(< 3\)                       | \(\geq 0.17\)                 | \(\geq 0.06\)                 | \(\geq 0.04\)               |
| Transition nuclei | \(< 3\)                       | \(\geq 0.08, < 0.17\)         | \(\geq 0.06\)                 | \(\geq 0.04\)               |

Figure 1. Top panel: spectrum of NGC 185 from HO97 - black line. Superimposed it is shown the spectra of NGC 205, also from HO97, which was used by the authors as a stellar population template - blue line. In red is shown the result of the stellar population synthesis of NGC 185 done with STARLIGHT. Bottom panel: subtraction of the stellar population of NGC 185 using the NGC 205 template (blue line) and using the synthetic spectra from STARLIGHT (black line).

Further binning of the age distribution. Because of that we binned the results in 5 age bins: \(\log(\text{age}) < 8.3\) dex, \(8.3 \leq \log(\text{age}) < 8.7\) dex, \(8.7 \leq \log(\text{age}) < 9.3\) dex, \(9.3 \leq \log(\text{age}) < 9.7\) dex and \(\log(\text{age}) \geq 9.7\) dex. This result is shown in Figure 2. The plot shows the flux fraction \(x_j\) - the fraction of light that comes from the stellar population in that bin - as a function of age. The symbols represent the fraction for each metallicity, and the black solid line represents the sum for all three metallicities.

From the synthesis we obtained a light-weighted mean age of 0.8 Gyr. However, about 30% of the light comes from a population younger than 500 Myr. We also obtained a light-weighted mean metallicity of 0.021 and \(A_V = 0.80\). The metallicities obtained for each stellar population are somewhat puzzling, since it seems that the younger population is less metallic than the older population. This trend however was observed before (Coelho, Mendes de Oliveira & Cid Fernandes 2009) and it is probably an artifact from the method.

Figure 2. Star formation history of NGC 185 obtained from the stellar population synthesis. The plot shows the population vector in flux fraction \(x_j\) as a function of the 5 age bins. The symbols represent the fraction for each metallicity, and the black solid line represent the sum for all three metallicities.

2.2 Emission Line Measurements and Spectral Classification

After the stellar population subtraction, the emission lines can be measured. We measured the emission lines of NGC 185 after subtracting the stellar population in two ways: using NGC 205 and the synthetic spectra. The first of these measurements were already done by HO97, but considering that we are comparing results from different subtractions, we decided to do them again to avoid any bias from the method. In any case, the values we measured with the NGC 205 template subtraction agree very well with those obtained by HO97. Results for the lines used in the classification are presented in Table 2. According to the classification scheme presented in Table 1, the ratios obtained by the subtraction of NGC 205 place NGC 185 in the Seyfert category. However, a more careful analysis show that the \([OIII] \lambda5007/H\beta\) is in the borderline of the Seyfert classification while \([OII] \lambda6300/H\alpha\) is actually in the LINER regime. This becomes clearer when the stellar population subtraction is done with the stellar population synthesis. Although visually there is not much difference from the spectra of NGC 205 and the synthetic spectra, small differences can produce significant changes in the line ratios. This happens because the absorption lines from the stellar population will affect more the hydrogen lines than the other lines. If these absorption lines are underestimated, the ratios used for the spectral classification will be higher than they should be. Using the synthetic spectra to subtract the stellar population NGC 185 classification changes to LINER.

Since stellar population subtraction can drastically influence the line ratios, we wanted to determine an up-
per limit to the hydrogen absorption line fluxes. As mentioned previously, younger stellar populations were detected in NGC 185. Our synthesis also confirms the presence of this population even though the fraction obtained cannot be fully trusted. The balmer absorption lines are stronger in stellar populations of about 200 Myr. To test what is the maximum effect of these lines in the emission lines measured, we also used a 200 Myr stellar population as a template for the starlight of NGC 185, and subtracted it from the spectra. Results for this subtraction are also shown in Table 2. For this subtraction the classification becomes very uncertain. The ratio [OIII]λ5007/Hβ is in the borderline of Seyfert classification, while the [OIII]λ6300/Hα ratio now points at a Transition Object. The [NII]λ6300/Hα and [SII]λ6300/Hα ratios point to opposite classifications: The first is in the range of HII nuclei while the second would agree with any other active nuclei classification.

In any of the three tests however, NGC 185 clearly has emission lines that cannot be explained simply by an HII region, which would not produce the line ratios observed. Although the line ratios indicate some type of activity, it is very unlikely that the emission lines are powered by an AGN, since it was not detected in many different surveys. We cannot exclude the possibility of a heavily obscured AGN, although the existence of a supermassive black hole should be much more common in massive bright galaxies. For galaxies with absolute magnitude MB fainter than -18, this central massive object would be most likely a compact stellar nucleus (Ferrarese et al. 2006). This is further supported by semi-analytical models which follow the formation and evolution of black holes seeds formed at high redshift in the context of hierarchical cosmologies: low mass objects are more likely to eject their nuclear supermassive black hole following a major merger as a result of gravitational recoil (Volonterey et al. 2007). To explain these line ratios we investigate other emission line mechanisms that could be present in this galaxy.

3 CAN PLANETARY NEBULAE FAKE A SEYFERT GALAXY?

NGC 185 has bright Planetary Nebulae (PNe) which were already identified in the Local Group Census and previous studies (Corradi et al. 2003 and references therein). Our group obtained deep spectroscopic observations of the central region of NGC 185, aiming to study the Hα emitting population (Gonçalves et al. 2011).

GMOS-N pre-imaging exposures of a field of view of 5.5′x 5.5′ at the central region of NGC 185 were taken in order to identify the PNe and other emission-line objects for the multi-object spectroscopy. The two narrow-band frames were used to build a Hα continuum-subtracted image, where we re-identified the 5 brightest PNe from Richer & McCall (1995), Corradi et al. (2003), Richer & McCall (2008), together with other, much fainter, compact and diffuse emission-line objects. In total the selected objects for spectroscopy were 15, including the previously known PNe and new emission-line objects among them: PN, supernova remnant (SNR), and symbiotic system, and one diffuse object that is part of the arc-like central nebula, described as interstellar medium (ISM) emitting in Hα by Martínez-Delgado et al. (1999) and by Corradi et al. (2003). For details on the reduction process and the line measurements please refer to Gonçalves et al. (2011).

Could the emission line of these objects be responsible for the emission lines observed in the integrated spectrum of NGC 185 by HO97? Values of the line fluxes of interest are presented in Table 3, together with the fluxes measured by HO97. Four out of the 15 objects were stars and one is part of the diffuse nebula (ISM), so they had no forbidden emission lines measured. We also do not present the fluxes for a Symbiotic star we found, since it only has permitted lines observed. Off course, HO97 spectrum could not contain all these objects. In fact, Figure 3 shows our objects in an image of NGC 185 and the slit of HO97 over it. Given the errors in the positions, caused by pointing inaccuracies (for example, GMOS pointing errors can be as high as 2′′), it is probable that HO97 spectrum might have one or two objects only. However, this would be enough to explain at least the Hβ flux they measured.

The spectral classification is based on line ratios, and, although the PNe line intensities could be high enough to justify the integrated emission observed in the galaxy, for most of them the line ratios would not explain the Seyfert classification, and are very far from explaining the actual ratios measured by HO97. Table 4 shows the line ratios used for the classification for each object in our sample. Comparing these values with Table 1, it is clear that the values for most objects are very far from what is expected for an active galaxy (Seyfert or LINER). For the PNe, while the [OIII] line is very strong, the low ionization lines are too weak, specially [OII] and [SII]. Besides the PNe, we detected a resolved emission line object close to the center of NGC 185, which has a fwhm two times broader than the point spread function. This object (SNR-1 in Tables 3 and 4) was identified in Gonçalves et al. (2011) as an old supernova remnant, and probably corresponds to the object found by Gallagher et al. (1984). Its emission lines alone also cannot explain the Seyfert classification of NGC 185, since it has no [OIII] emission. However, if we consider in Figure 3 that both PN2 and SNR-1 contribute to HO97’s slit, we might have a different scenario. If we average these objects’ line ratios, weighted by their Hβ fluxes, we find values of [OIII]λ5007/Hβ = 9.89, [NII]λ6584/Hα = 0.13 and [SII]λ6716,6731/Hα = 0.04. These ratios are in agreement with the Seyfert regime. Although [OII] is still a problem here and the values are very different from what was obtained by HO97, this gives us a hint of what might be responsible

| Object | Hβ | [OII]λ5007 | [OII]λ6584 | [SII]λ6716,6731 |
|--------|-----|-----------|------------|-----------------|
| PN1    | 0.46| 653       | 3.34       | 4.18            |
| PN2    | 1.09| 907       | 272        | 8.7             |
| PN3    | 0.72| 1420      | 273        | 104.5           |
| PN4    | 3.33| 1075      | 327        | 26.0            |
| PN5    | 0.19| 1919      | 529        | -               |
| PN6    | 0.05| -         | 295        | -               |
| PN7    | 0.35| 2810      | 395        | 59.1            |
| SNR-1  | 0.04| -         | 396        | 119.6           |
| PN8    | 0.07| 1030      | 533        | 421             |
| Total  | 7.50| 1058      | 3,535      | 38.0            |
| HO97   | 0.24| 326       | 9.57       | 435             |
Table 2. Emission-line intensity ratios used for spectral classification.

| Subtraction       | Hα/Hβ | [OIII]λ5007/Hβ | [OI]λ6300/Hα | [NI]λ6584/Hα | [SII]λλ6716,6731/Hα |
|-------------------|-------|----------------|---------------|---------------|---------------------|
| NGC 205           | 3.92  | 3.14           | 0.20          | 0.59          | 1.39                |
| Synthetic Spectra | 4.72  | 2.53           | 0.25          | 0.54          | 1.31                |
| 200 Myr population| 5.63  | 3.14           | 0.15          | 0.51          | 1.11                |

Figure 3. A zoom of the DSS2 image of NGC 185, with $2 \times 2$ arcmin$^2$, and the location of the objects inside it that we studied spectroscopically. North is up and east points to the left. The original version of this figure with all the objects we detected can be found in Gonçalves et al. (2011).

Table 4. Extinction corrected line ratios used in the spectral classification.

| Object | [OII]λ3727/Hβ | [OI]λ6300/Hα | [NI]λ6584/Hα | [SII]λλ6716,6731/Hα |
|--------|---------------|--------------|---------------|---------------------|
| PN1    | 6.34          | 0.099        | 0.11          | 0.015 |
| PN2    | 9.07          | -            | 0.03          | -                 |
| PN3    | 14.20         | 0.037        | 0.38          | 0.067 |
| PN4    | 10.57         | 0.013        | 0.08          | 0.010 |
| PN5    | 17.86         | -            | -             | -                 |
| PN6    | -             | -            | 0.20          | -                 |
| PN7    | 26.25         | -            | -             | -                 |
| SNR-1  | -             | -            | 0.33          | 0.533 |
| PN8    | 9.57          | -            | 0.78          | 0.358 |

for the emission lines observed in the integrated spectra of HO97.

4 A SCENARIO WITH SUPERNOVA REMNANTS

Marleau et al. (2010) took IRS (Infrared Spectrograph, on board of the Spitzer Space Telescope) spectra of NGC 185, and that shows strong polycyclic aromatic hydrocarbon (PAH) emission, deep silicate absorption features and H$_2$ pure rotational line ratios consistent with having the dust and molecular gas inside the dust cloud being impinged by the far-ultraviolet radiation field of a relatively young stellar population. This young stellar population was never really detected, possibly due to the large extinction caused by the large amount of dust in this galaxy. Despite the fact that the current rate of star formation they measured is quite low ($10^{-10}$ M$_\odot$/yr), this suggests that the star formation history of NGC 185 is complex.

Although it is very likely that a young stellar population is buried in this galaxy and somehow contributing to the ionization process, it is very unlikely that this would explain the high intensity of the low ionization emission lines.

Like mentioned in the previous section, Gallagher et al. (1984), took an integrated spectra of NGC 185, and they suggest that the emission lines could be explained by a supernova remnant. They argue that the high intensities of [NI] and [SII] are characteristic of shock-heated gas. The expected supernova (SN) rate in spheroidal galaxies is lower than in normal spiral galaxies. However, since this galaxy contains traces of young stars, the rate might be higher.

The spectral identification of supernova remnants (SNRs) was pioneered in a series of papers by Mathewson and Clarke (1972, 1973a, 1973b, 1973c) where narrow-band optical interference filters, centered on H$_\alpha$ and the [SII]λλ6716,6731 were used to differentiate between primordial hydrogen and a heavy metal contaminated ejecta of a SNR. In this technique the strength of [SII] lines should be about the same as the H$_\alpha$ line, probably due to shock fronts in the expanding SNR shell. The [SII] lines should be at least an order of magnitude weaker than the H$_\alpha$ line in HII regions as compared to SNRs.

Fesen, Blair & Kirshner (1985) obtained optical spectra of galactic supernova remnants and found that [OI]λ6300, [OII]λ3727 and [OIII]λλ4959, 5007 are often all simultaneously strong in SNRs and this can be used to differentiate SNRs from HII regions in cases where [SII]/H$_\alpha$ is borderline.

In our optical survey Gonçalves et al. (2011) we detected the presence of an old SNR close to the center of NGC 185, but if more were present in the very central region, the detection in the optical would be very difficult due to the large extinction. However, the shock wave of this SN would produce emission lines that could be detected in an integrated spectrum of the central region. We can test if SNRs would be able to produce the line ratios we see in the integrated spectrum of the galaxy. To do that we used Fesen et al. observations of galactic SNRs, and compared their line ratios with what we measure for NGC 185. The results are shown in Figure 4. In this figure, the filled black circles are obtained from the integrated spectra of HO97, and the ratios we are trying to explain. Each of these points represent a different stellar population subtraction. Filled black squares are the ratios corresponding to the PNe.
we observed, and the blue filled square is obtained averaging all their line fluxes and then calculating the ratios. For all three diagrams, it is clear that no combination of PNe could explain the integrated line ratios. The open black squares represent line ratios for the galactic SNRs from Fesen et al. (1985). Their low ionization lines are much stronger than the ones from PNe, and some of these objects come very close to the ratios we are trying to explain. One of them in particular explains all the lines in the three diagrams. If a SNR with lines similar to this one would fall inside the slit, this would be enough to explain NGC 185 lines. The blue open square in the diagrams represents the average ratios for the SNRs.

If SNRs and PNe are present in NGC 185, it is possible, and even likely, that, in an integrated spectrum of the central region, both objects would fall inside the slit. What would be the result of this combination? To test that we took the average values for the PNe and for the SNRs, and calculated another average, weighted by their median Hβ flux (which are of the same order of magnitude). The result is the filled red circle presented in Figure 3. This average has ratios very similar to the ones for the integrated spectra of NGC 185. We then believe that the emission lines of NGC 185 are produced by a combination of PNe and SNRs, and that this combination fakes a Seyfert galaxy in a BPT diagram.

5 PREDICTED SN RATES FROM CHEMICAL EVOLUTION MODELS

Although young SNRs were not detected in the nuclear region of NGC 185, we can investigate if they are expected to be present in this galaxy. Since the star formation history inferred in this work and others (Mateo 1998; Martínez-Delgado et al. 1999; Dolphin et al. 2005) indicates a very recent star formation episode in NGC 185, it is reasonable to think that SNe should have exploded recently in the galaxy. The rate at which SNe occur, however, is crucial to determine whether or not they could be responsible for the emission lines observed. A very low rate would probably mean that the contribution of the SNRs for the emission lines is negligible whereas a high rate would be a strong indication that SNRs are indeed present in NGC 185, even if they are not observed.

The SNe rate of a galaxy can be predicted by detailed chemical evolution models. After a maximum mass, a star formation history (SFH), an initial mass function (IMF), and a star formation rate are chosen as inputs of the model, the code solves the basic equations of chemical evolution (Tinsley 1980, Matteucci 1996) and calculates the evolution in time of the mass fraction of several chemical species in the gas of the galaxy by taking into account the contribution of stars from 1 to 100 solar masses and their lifetimes. The contribution of the stars to the abundance of the chemical elements (stellar yields) and to the energy (in the form of stellar winds and supernovae type Ia and type II) of the interstellar medium are considered. The stellar yields play an important role in the abundances of chemical elements whereas the stellar winds and the SNe explosion, together with the dark matter content, define the occurrence of galactic winds (Bradamante, Matteucci, D’Ercole, 1998). Normally, the star formation history adopted in the models are the ones derived from observations and the star formation rate, IMF, and efficiency of galactic winds are constrained strongly by the abundance ratios, the stellar metallicity distribution, and the age-metallicity relation observed. Once the main parameters of the model are adjusted to fit the data, the SNe rate comes naturally, given the stellar lifetimes, as an output of the code.

In this work, we adopted the chemical evolution code of Lanfranchi & Matteucci (2003, 2004), developed to fit several observed data of dwarf irregular and dwarf spheroidal galaxies. The most important parameters in the models are the SFH, the SF efficiency and the galactic wind efficiency. Dwarf Irregular galaxies are normally characterized by several short bursts of star formation with high rates and low galactic wind efficiencies (Yin et al. 2010, Yin, Matteucci & Vladilo 2011) whereas the dwarf spheroidals exhibit a few long (few Gyr) episodes of SF with low rates and very efficient winds (Lanfranchi & Matteucci 2004). The star formation histories adopted for the NCG 185 models are generally the same as the one inferred in this work (Figure 2: three episodes of activity separated by long intervals. The first episode is the most intense and starts at the beginning of the formation of the galaxy lasting a few Gyr (from 3 to 4), the second one occurs between 10 to 13 Gyr with a lower rate compared to the first, and the last one, in the last few hundred Myr, has the lowest efficiency (Figure 5). The two curves in the figure represent two models with slightly different SFH (solid line - model 1, dotted line - model 2). The others parameters (IMF, total mass, infall timescale) are essentially the same in both models and identical to the ones adopted in the dwarf models from Lanfranchi & Matteucci (2003, 2004). The predictions of the models were compared to the chemical properties of NGC 185, specially the abundance ratios (determined for three PNe), the age-metallicity relation, and the total present day mass. The IMF follows the prescriptions suggested by Salpeter (1955), the stellar yields are the same as in Lanfranchi & Matteucci (2010),
and the efficiency of the galactic wind is low ($w_i = 0.4 - 0.6$). For more details of the code we refer the reader to Lanfranchi & Matteucci (2003, 2010).

The exact time of occurrence of the SF episodes and their duration is not certain, as mentioned before. Because of that, we varied slightly the SFH given in section 2, trying to find the best fit to the observed data. The two best models are models 1 and 2 in Figure 5. The most important feature of both SFHs is the occurrence of three episodes of activity with a long quiescent interval (a few Gyrs) between the first two episodes and a shorter interval between the second and the last episode. During the first SF episode the metallicity of the galaxy increases fast reaching [Fe/H] = -0.6 dex in $\sim 2.5$ Gyr and then decreases slowly in the inter-burst period due to the inactivity and to the galactic wind. The metallicity starts increasing again with the second and third episodes of SF, reaching [O/H] = -0.6 dex at an age of $\sim 12$ Gyr. The age-metallicity relation predicted by both models is in agreement with the data, as one can notice in Figure 6 (upper panel). The lines are the same as in Figure 5, and the large squares represent the observed values of [Fe/H] in stars (thick line - Butler & Martinez-Delgado 2005) and [O/H] in PNe (thin line - Gonçalves et al. (2011)). In order to make a proper comparison with the data it is shown the predictions of the models for [Fe/H] (thick line) and [O/H] (thin line).

Besides the age-metallicity relation, the predictions of the models are compared to the observed (S/O) ratios. Nitrogen and helium were not considered because their abundances in PNe may not represent the abundance of the interstellar medium at the epoch of the formation of the star responsible for the PNe (see Chiappini et al. 2009). The evolutionary tracks of the models reproduce very well the (S/O) ratios observed in all three PNe (Figure 6 - middle panel). The loop in the track is caused by the galactic wind that reduces considerably (O/H) increasing (S/O) at the same time. Small changes in the SFH and SF efficiency do not change considerably the results as one can see by the lines of the two different models in the Figure 6. The galactic wind plays an important role also in the final luminous mass of the galaxy. A galactic wind with a low rate of gas removal does not change much the mass of the galaxy, since only a small fraction of gas is lost. Our choice of wind efficiency allows us to reproduce the age-metallicity relation, the (S/O) ratio, and also the present day total mass of the galaxy (Figure 6 - lower panel). Battinelli & Demmers (2004) inferred a total mass of $1.3 \times 10^8 M_\odot$ (small square in the lower panel of Figure 5) whereas the models predict values between 0.7 - 1.5 $\times 10^8 M_\odot$ (models 1 and 2, respectively).

After adjusting the main parameters of the models to reproduce the observational constraints, it is possible to infer the SNe (types Ia and II) rate and the number of SNe that might have exploded recently. The predictions of models 1 and 2 for SNII (up panel) and SNIa (lower panel) rates in number of explosions per century are shown in Figure 6. Even though the absolute number is low in both cases ($0.88-0.94 \times 10^{-4}$ century$^{-1}$ for SNII and $0.11-0.18 \times 10^{-4}$ century$^{-1}$ for SNIa).
century$^{-1}$ for SNIa) one should consider that SNI could have exploded during all the period of the last SF episode, being distributed in time according to the stellar lifetimes, and that SNIa occurred over an even longer period due to the typical lifetimes of their progenitors. In that sense, we can estimate the number of SNe explosion of both types by considering the time intervals within which the rates of explosions are not negligible. The SNe II rate is very low in the period between $\sim$ 1.5 to 0.4 Gyr ago until a SF episode took place. With the formation of new stars, new SNII starts exploding again increasing the SNe II rate, that remains high until now. The rate of SNIa, on the other hand, although lower, remains considerable for the last $\sim$ 3 Gyr. Taking that into consideration, we can estimate that around 80 SNe II and 15 SNIa exploded in the last 100 Myr.

6 SUMMARY AND CONCLUSIONS

In this paper we investigate the spectral classification of the dwarf spheroidal galaxy NGC 185 as a Seyfert galaxy. This classification was defined by HO97 based on the integrated optical spectrum of the central 2"x4" of the galaxy. The emission line ratios measured by them places this galaxy on the Seyfert category. However, NGC 185 was not detected in radio surveys either in 6 cm or 20 cm, or x-ray observations. Although the possibility of a heavily obscured AGN cannot be excluded by our data, the existence of a supermassive black hole in the center of a small, low-luminosity galaxy as NGC 185 is very unlikely. In the absence of an active nucleus, the Seyfert-like line ratios have to be produced by some other process, probably stellar.

Since the emission line measurements are very dependent on the stellar population subtraction, we performed stellar population synthesis on the integrated spectrum from HO97 to test how much the emission line ratios measured were dependent on the methods used. Although the ratios change depending on the method used for the stellar population subtraction, these changes are too small to justify the misclassification. This means that the emission lines measured are indeed there and are not an artifact of the method.

It is known that NGC 185 has bright PNe, and our group recently performed a deep spectroscopy observation of this galaxy searching for the Hα emitting population. Although the fluxes of individual objects are high enough to explain the emission lines observed in the integrated spectra, the line ratios of the PNe are very far from what was measured for NGC 185. [OII]λλ4959, 5007/ Hα is too high and the low ionization lines are too low for these objects. The emission lines of these objects might be contributing to the integrated spectrum, but something else is needed to explain the low ionization lines.

Besides the PNe, we found two other Hα emitters: a SNR and a symbiotic star. SNRs are known to have very strong low ionization lines like [OI], [NII] and [SII] lines. The one we detected is an old object, since its [SII] and [NII] are low compared with average SNRs, and no [OI] was detected. If we consider the two objects closer to the center (SNR-1 and PN2) and calculate their average line ratios, the results would place NGC 185 in the Seyfert category. The [OII] is however, the hardest to explain.

Young SNRs usually have strong [OII] emission. We then consider the possibility that there is a young SNR in the central part of NGC 185, which was not detected due to the extinction caused by the large amount of dust in this region. It was already suggested that a young stellar population is present in the central part of the galaxy, which was confirmed by our stellar population synthesis: our results suggest that 30% of the light might be coming from a population younger than 500 Myr. The same young population originate a considerable number of SNe explosions in the last 100 Myr, as predicted by chemical evolution models that adopted the SFH derived by the stellar population synthesis. These models reproduce the observed (S/O) ratios, the total present-day mass, and the age-metallicity relation. The models pointed that $\sim$ 90 SNe exploded recently, indicating a large probability that at least a few young SNR should be present in the galaxy. To demonstrate how a young SNR could explain the line ratios observed in the galaxy we used a sample of galactic SNRs from [Feen et al. (1983)]. The combination of the average line fluxes of these objects with the average line fluxes of the PNe we found gives line ratios that are exactly in the range of the ratios measured for the integrated spectrum of NGC 185. We then conclude that the emission lines observed in the integrated spectrum of HO97 are probably result of either one SNR or the combination of a PN and a SNR inside their slit. As stated previously, we cannot exclude the possibility of an obscured AGN, but we believe it is very unlikely that NGC 185 is a Seyfert galaxy.

ACKNOWLEDGMENTS

L.P.M. thanks the financial support by the Brazilian agency FAPESP (2011/00171-4). L.P.M. also thanks L’Oreal Brasil and ABC for financial support. D.R.G. kindly acknowledges the UCL Astrophysics Group for their hospitality. LM is supported through the ASI/INAF grant “HeViCS: The Herschel Virgo Cluster Survey” 1/009/10/0. The work of CQ is supported by the INCT-A (PDJ 154908/2010-0).
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