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Planetary Nebula detection using photometry in the galaxy NGC 6744

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Abstract. We investigated the preliminary selection of planetary nebulae (PNe) candidates in the barred spiral galaxy NGC 6744 using differential photometry techniques from observations obtained in the SOAR telescope. We performed PN detection using broadband and narrowband filters centered on the wavelengths of the most intense emission lines. By combining images with the [OIII] filter with the V filter, dozens of PNs were detected in the galaxy disk, confirming the feasibility of the technique.

Resumo. Investigamos a seleção preliminar de candidatas a nebulosas planetárias (NPs) na galáxia espiral barrada NGC 6744 utilizando técnicas de fotometria diferencial. Realizamos a detecção de NPs utilizando filtros de banda larga e banda estreita centrados nos comprimentos de onda das linhas de emissão mais intensas. Através de uma composição das imagens com o filtro [OIII], comparadas com o filtro V, pôde-se detectar dezenas de NPs no disco da galáxia, confirmando a viabilidade da técnica.

Keywords. Galaxies: photometry – Galaxies: ISM – Galaxies: spiral – planetary nebulae: general – HII regions

1. Introduction

Planetary nebulae (PNe) are the final evolutionary stages of low to intermediate-mass stars (approximately 1–8 M⊙), consisting of an expanding ionized shell of gas surrounding a soon-to-be white dwarf core. These objects result from the ejection of the outer layers of the progenitor star after it exhausts its nuclear fuel, marking the end of an asymptotic giant branch (AGB) phase. The central stars of planetary nebulae are among the brightest stellar remnants in a galaxy, with luminosities exceeding 6000 $L_{\odot}$. Due to the physics of photoionization, up to 10% of the stellar flux can be reprocessed into a single emission line, such as the [O III] emission at 5007 Å, transforming these objects into remarkably bright monochromatic sources Ciardullo et al. (1989). Because all stars with main-sequence masses between 1 and 8 M⊙ evolve into PNe, they are abundant in stellar populations with ages between 10^8 and 10^{10} years.

These characteristics make planetary nebulae powerful tools for studying various astrophysical phenomena. PNe serve as tracers for the internal kinematics of spiral, elliptical, and interacting galaxies, as well as for understanding the chemical evolution of the Local Group Herrmann & Ciardullo (2009). Furthermore, PNe are essential for probing the stellar populations of early-type systems, calibrating the extragalactic distance scale via their planetary nebula luminosity function (PNLF) Ciardullo et al. (2002), and studying the dynamical evolution of galaxy clusters. Their unique properties also allow for detailed investigations into mass distributions within spiral disks based on their kinematics.

In this work, we describe an [O III] λ 5007 and Hα survey for PNe in the nearby, face-on spiral galaxy NGC 6744. We present the details of our observing runs and image reduction and explain how we identified our PNe candidates and measured their magnitudes. We discuss the discrimination of possible contaminants, including how we used photometry and follow-up spectroscopy to eliminate H II regions. The ultimate objective is to derive the PNLF distance of NGC 6744.

2. Methodology

The spiral galaxy NGC 6744, classified as SAB(r)bc Crowther (2013), is selected for this study due to its well-defined morphology and proximity. Its coordinates are RA 19h 09m 46s and DEC −63°51' 26" Gaia Collaboration (2020), with magnitudes of 8.25 in the V-band and 8.08 in the R-band Lauberts & Valentijn (1989). The galaxy has a calculated distance of 8.95 Mpc Kourkchi et al. (2020), providing a suitable target for the identification and analysis of PNe.

Observations were carried out using the SOAR telescope equipped with the Goodman spectrograph in two separate fields, each covering 7.2 arcminutes. Filters in the V, R, O III, and Hα bands were utilized for imaging. The O III filter, was used in 6 exposures of 2400 seconds for each field. The observations achieved a spatial resolution of 6.69 pixels full width at half maximum (FWHM), equivalent to 1 arcsecond.

Image reduction and analysis were performed using the IRAF and DS9 software packages. Astrometric calibration and alignment of the images were conducted with a custom IDL-based software, utilizing hundreds of field stars to ensure precise registration. To enhance regions with significant line emission, subtraction techniques were applied between broadband (V, R) and narrowband ([O III] and Hα) images. This method allows for the isolation of emission-line regions, facilitating the distinction between H II regions and PNe.

The comparative analysis of the [O III] and Hα filters was key to differentiating between ionized gas regions primarily driven by massive stars (H IIregions) and low-mass stellar remnants like PNe. Photometry was conducted using the StarFinder software Diolaiti et al. (2000), employing point spread function (PSF) fitting to extract fluxes and perform accurate photometric measurements.

3. Results

The subtraction of narrowband ([O III] and Hα) and broadband (V and R) images allowed the identification of point-like emission sources within NGC 6744. This technique effectively enhanced the contrast of regions with significant line emission, isolating potential PNe candidates and other emission-line objects.

Through a detailed manual comparison of the emission sources detected in the [O III] and Hα filters, it was possible to distinguish PNe candidates from H II regions. Sources showing strong O III emission with little or no corresponding Hα emission were classified as PNe candidates, while regions with prominent Hα emission were discarded.

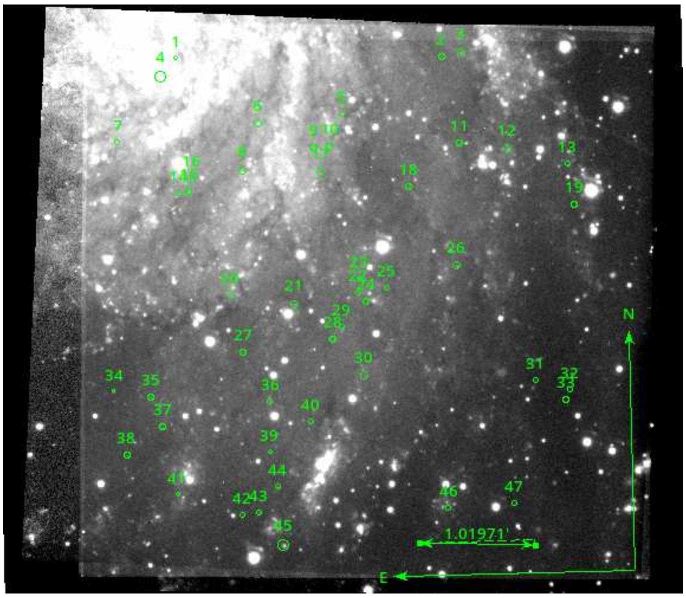

Figure 1. Field 1 and the 47 detected PNe candidates.

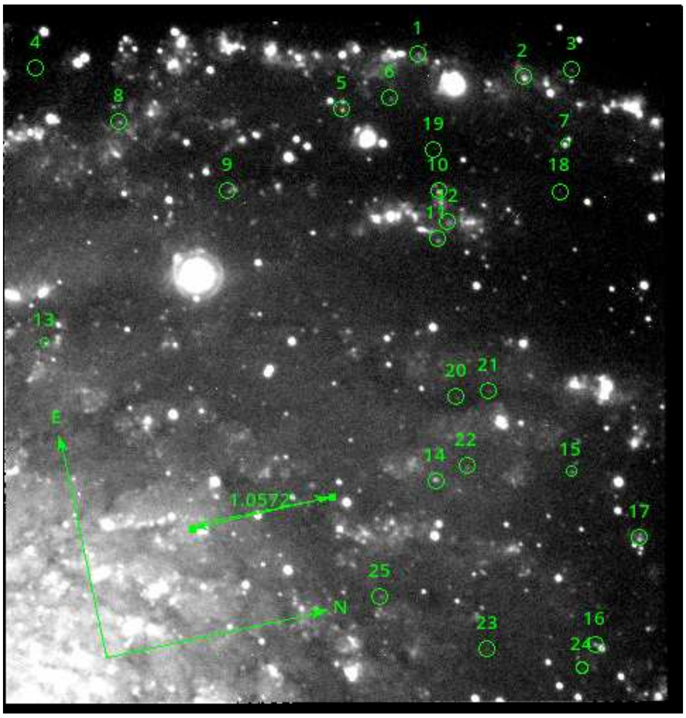

Figure 2. Field 2 and the detected 25 PNe candidates.

In Figures 1 and 2 we can see the candidates that are identified. A total of 72 PNe candidates were identified across the two observed fields. These candidates exhibit a typical angular diameter of 2.1 arcseconds, consistent with the expected size of PNe at the distance of 8.95 Mpc for NGC 6744 and the spatial resolution achieved (1" per pixel).

4. Conclusions

As we can see, the analysis demonstrated that the applied methodology was effective in finding objects with [O III] emission, even within a complex galactic background field such as NGC 6744. The combination of image subtraction techniques and manual analysis successfully isolated more than 60 PNe candidates, highlighting the potential of these methods for the identification of nebular objects. However, confirmation of these candidates will require follow-up spectroscopic observations to ensure their classification.

The next phase of this study involves the construction of the PNLF, which will allow for more refined distance measurements and further investigation of the distribution and properties of PNe within NGC 6744.

These results validate differential photometry as a tool for the initial identification of PNe in spiral galaxies. They also underscore its contribution to the development and refinement of extragalactic mapping techniques for detecting and characterizing nebular objects.

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