Weak and Extended H$_2$ Emission in NGC 6369

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Abstract. NGC 6369 is a double-shell PN with a filamentary outer shell or envelope and faint bipolar extensions. We have used ground- and space-based narrowband optical and near-IR images, broadband mid-IR images, optical long-slit echelle spectra, and mid-IR spectra to investigate its physical structure. The observations confirm a bipolar structure for the inner shell of NGC 6369, but they also reveal evidence for H$_2$ and strong polycyclic aromatic hydrocarbons (PAHs) emission from a photo-dissociation region (PDR) with molecular inclusions located outside the bright inner shell.

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1. Introduction

There is a growing number of PNe in the literature showing knots or blobs of emission well separated from their main nebular shells that do not form a halo. In some cases, the kinematics of these knots imply high-velocity collimated outflows, e.g., Fleming 1 (Boffin & Miszalski 2011; Palmer et al. 1996) or MyCn 18 (Redman et al. 2000), while in some others, as for IC 4634 (Guerrero et al. 2008), the velocity of the knots is close to the systemic velocity, may be due to motions close to the plane of the sky.

2. Observational Results

[O III], H$_\alpha$, and [N II] narrowband images of NGC 6369 were obtained with ALFOSC at the 2.56m NOT, and near-IR H$_2$ (1,0) S(1), Br$_\gamma$, and continuum $K$ narrowband images were obtained with LIRIS at the WHT (Figure 1 - left). An inspection of the optical and near-IR images of NGC 6369 shows a bright inner shell, two extensions, and an envelope. The western extension is reminiscent of a lobe or a large “ansa”, whilst the eastern one displays a complex morphology that can be described as a bifurcated structure best seen in the H$_\alpha$ and [N II] images. The envelope, barely detected in [O III] and only a little brighter in H$_\alpha$, has bright [N II] emission composed of an ensemble of knots, blobs, and filaments. The region interior to the bright inner shell, which shows anomalously low excitation emission, is revealed to be filled with H$_2$ emission. We found evidence that the [N II] knots and filaments are associated with H$_2$ emission, i.e., they include significant amounts of neutral material.

Spitzer IRAC images were retrieved from the NASA/IPAC Infrared Science Archive (IRSA) obtained as part of Program 20119 (The Darkest Cloud, An IRAC/MIPS Survey

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The eastern and western extensions, as well as the outer envelope, show a higher relative contribution of 8.0 µm emission.

Long-slit high-dispersion spectroscopy of NGC 6369 has been acquired using MES on the 2.1m OAN-SPM telescope. The spectral range includes the Hα and [N II] λ6583 lines. Five long-slit spectra were obtained to map the kinematics at different regions of the nebula with spectral resolution of ≈12 km s⁻¹. The position-velocity maps reveal that the envelope is not completely inert.

An ISO spectrum of NGC 6369 in the mid-IR spectral range is showing in Figure 1-right. The ISO spectral range is dominated by emission lines, with Brγ being the most intense and the 3.3 µm PAH band being relatively weak or negligible. The data also show convincingly that the emission in the IRAC 3.6 and 4.5 µm bands is largely dominated by H I lines, with the Brα λ4.052 µm line in the 4.5 µm IRAC band being the brightest line. The evidence for the H₂ 1–0 Q(3) λ2.424 µm and H₂ 1–0 Q(7) λ2.500 µm lines is consistent with the detection of H₂ emission in our WHT LIRIS images and at 17.036 µm (Pottasch & Bernard-Salas 2008).

3. Discussion

The inner optical shell in NGC 6369 is the brightest feature in optical, near-IR and mid-IR images, whereas the outer envelope and east and west extensions are fainter but still noticeable. We report the detection of irregular knots and blobs of diffuse emission in low-excitation and molecular line emission that are located up to 80" from the central star, well outside the main nebular shells.

These external condensations and filaments associated to the bipolar extensions may probe earlier, point-symmetric ejections, but they can also arise from shocks associated with the east-west bipolar flow that excite the material surrounding the nebula.

References

Boffin H., & Miszalski B., 2011, IAUSS283, in press
Guerrero M. A., et al., 2008, ApJ, 683, 272
Palmer J. W., López J. A., Meaburn J., & Lloyd H. M., 1996, A&A, 307, 225
Pottasch S.R., & Bernard-Salas J., 2008, A&A, 490, 715
Redman M. P., O’Connor J. A., Holloway A. J., Bryce M., & Meaburn J., 2000, MNRAS, 312, L23