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OPTICAL-IR ECHELLE SPECTROSCOPY OF NGC 6302

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RESUMEN

Espectroscopía echelle de [Si VI] 1.96 μm, [Mg VIII] 3.03 μm, y [Ar VI] 4.53 μm, usando el telescopio UKIRT+CGS4, muestra que los perfiles de las líneas en NGC 6302 son sencillos y no están resueltos aún con $R \sim 20\,000$; los anchos de las líneas son menores que 22 km s^{-1}. La estratificación espacial y en velocidad, como función del potencial de ionización, pone en evidencia la estructura de fotoionización. Pero una variedad de modelos con gradientes de densidad y temperatura reproducen el espectro igualmente bien. El análisis preliminar del echelograma de NGC 6302, entre 3000 y 10 000 Å, adquirido con $R \sim 80\,000$ usando el VLT+UVES, confirma la estratificación nebular, pero da resultados intrigantes en lo que se refiere a los perfiles de la líneas: [Ne V] 3426 Å es más ancha que [Ne IV] 4723 Å. Estas observaciones descartan la existencia de una cavidad vacía o una burbuja caliente, al menos a escalas de 1$''$ y 3 km s^{-1}. Nosotros no confirmamos las alas anchas en [Ne V] 3426 Å reportadas por Meaburn & Walsh (1980).

ABSTRACT

Echelle spectroscopy of [Si VI] 1.96 μm, [Mg VIII] 3.03 μm, and [Ar VI] 4.53 μm, using UKIRT+CGS4, shows the line profiles in PN NGC 6302 are singly peaked and unresolved even at $R \sim 20\,000$, with line widths less than 22 km s^{-1}. A photoionized structure is evidenced by spatial and velocity stratification as a function of ionization potential. But a variety of models, with density and T_e gradients, reproduce the spectrum equally well. Preliminary analysis of the 3000–10 000 Å echellogram of NGC 6302, acquired at $R \sim 80\,000$ using VLT+UVES, confirms the stratified nebular structure, but yields intriguing results concerning the line profiles: [Ne V] 3426 Å is broader than [Ne IV] 4723 Å. These observations rule out the existence of an evacuated cavity, or hot bubble, at least on 1$''$ and 3 km s^{-1} scales. We do not confirm the broad wings in [Ne V] 3426 Å reported by Meaburn & Walsh (1980).

Key Words: **DUST, EXTINCTION — INFRARED: ISM — ISM: LINES AND BANDS — PLANETARY NEBULAE: INDIVIDUAL (NGC 6302)**

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NGC 6302 is the highest excitation planetary nebula (PN) known, with emission from a broad range of ionization stages, up to [Si IX] 3.94 μm. Fast flows, as inferred from broad wings almost 1000 km s^{-1} in total width, have been detected in [Ne V] 3426 Å (accounting for ~1/3 of the line flux, Meaburn & Walsh 1980). But Ashley & Hyland (1988) indirectly showed that [Si VI] 1.96 μm is $<$ 30 km s^{-1}. Here we report on optical/IR echelle spectroscopy of the core of NGC 6302, aimed at understanding the physical conditions in the coronal region (traced by ionic species produced by radiation harder than ~100 eV).

We conducted infrared echelle spectroscopy of NGC 6302 with UKIRT and CGS4 at $R = 20\,000$ in Brγ and the coronal lines [Si VI] 1.968 μm, [Mg VIII] 3.028 μm and [Ar VI] 4.528 μm (Casassus, Roche, & Barlow 2000, hereinafter CRB). The infrared line profiles are unresolved, and $<$ 22 km s^{-1} FWHM for [Mg VIII] (see Table 3 in CRB). The spatial information for the two slit positions, along the bipolar axis and along the bipolar waist, both show centrally peaked flux distributions. In fact, a photoionized structure is evidenced by spatial and velocity stratification as a function of ionization potential (IP), consistent with a CLOUDY (Ferland 1996) model for a homogeneous nebula excited by a 250 000 K central star. In this picture, the velocity stratification stems from the coronal lines being confined to the core of an expanding nebula, with a velocity increasing with radius. Thus the IR echelle observations point at a filled-in nebula, at resolutions of 1.5$''$ and 10 km s^{-1}, and fail to detect any significant fast wind (see CRB for upper limits on the broad wings fluxes).

An important characteristic of the coronal region in NGC 6302 is that it is dusty: Fe, Al, Ti and Ca are strongly depleted, even when inferred from coronal lines (e.g., [Al VI] 3.66μm, see CRB and references therein). Binette & Casassus (1999) investigated the

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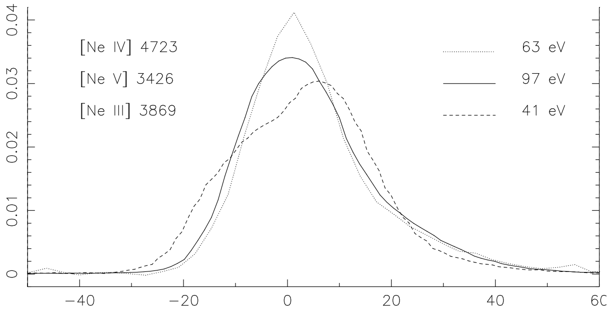

Fig. 1. Normalized line profiles from the collapsed slit along the bipolar axis, as a function of velocity in km s^{-1}.

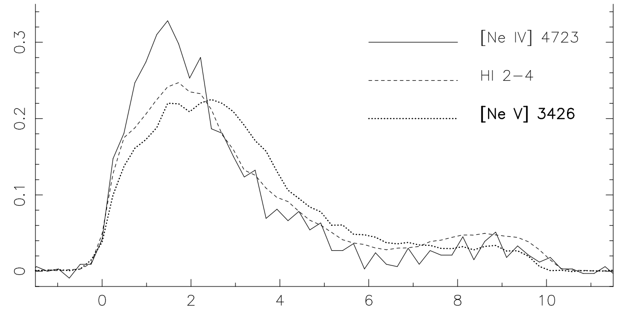

Fig. 2. Normalized traces along the bipolar axis as a function of offset along the slit, in arcsec. Note the enhanced extinction due to the dust lane at offsets 4″–8″.

non-uniqueness of nebular models for NGC 6302, for plane parallel and spherical geometries. The inclusion of dust grains in the nebular models bears strong consequences on the density and temperature profiles, and a variety of models reproduce NGC 6302's spectrum. Particularly interesting is the broad range of electronic temperatures, varying from 70 000 K to 20 000 K as a function of depth. Apart from representing an interesting test-bed for nebular models, the physical conditions in NGC 6302's core are crucial for understanding its shaping and excitation mechanisms, but are still poorly constrained.

The 3000–10 000 Å echellogram of the core of NGC 6302, acquired with VLT+UVES at $R >$ 80 000 for two slit positions, along the bipolar axis (across the brightest point to the radio core and 3″ past), and along the dust lane across the radio core (Gómez, Rodríguez, & Moran 1993), each 10″ long, brings additional information. Figure 1 shows selected line profiles for the collapsed slit (along the bipolar axis). The structure in the [Ne III] 3869 Å profile is repeated for [Ne III] 3968 Å, and is probably due to variations in the physical conditions along the slit and in velocity space, while its width is consistent with stratification in IP. However, [Ne V] seems broader than [Ne IV]. The asymmetry in [Ne V] and [Ne IV] is repeated in other line profiles, but not in He II lines, which suggests the red tail is a feature reflecting varying physical conditions, and not the actual ionic distributions. It is noteworthy that [Ne V] lacks any broad wings—thus we do not confirm the measurement by MW80 (this holds for the two slit positions).

Why is [Ne V] broader than [Ne IV]? The spatial information along the slit, shown in Figure 2, indicates [Ne IV] is not as extended as [Ne V], consistent with a photoionized nebula: [Ne V] seems to be slightly more centrally distributed than [Ne IV]. For an expanding nebula, [Ne IV] should be broader. It is possible to speculate that the velocity field is decelerated across the Ne V and Ne IV regions, or that T_e increases significantly closer to the central star. Resolving this question is postponed to a more thorough analysis of the echellogram.

The line profiles observed so far in NGC 6302 have brought intriguing information. It has been argued that the bipolar shape is the result of interaction between a fast stellar wind and the surrounding AGB ejecta. In the case of NGC 6302, there is no sign of the corresponding evacuated cavity (or hot bubble), as shown in the IR echelle frames in CRB. The echellogram frames, with the slit oriented along the dust lane, also show centrally peaked brightness distributions in velocity-offset space, for the highest excitation species. These observations argue against a fast stellar wind playing an important role in shaping bipolar PNe—although the information on the Ne line widths lacks a solid interpretation.

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