Morphological and kinematical analysis of the planetary nebula Hu 1-2 and its irradiated bow-shocks

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Abstract. We present narrow-band optical and near-IR images, and high-resolution long-slit spectra of the planetary nebula Hu 1-2 that allow us to make a detailed description of its unusual morphology and internal kinematics. The data also reveal that the ansae of Hu 1-2 probably represent bow-shocks associated to high velocity outflows that are irradiated from the central star.

Keywords. planetary nebulae: individual (Hu 1-2), ISM: jets and outflows

1. Introduction

Hu 1-2 is a high-excitation elliptical planetary nebula with He and N overabundances, [N\textsc{ii}] enhanced microstructures in its inner regions and ansae outside the main shell (Sabbadin et al. 1987; Manchado et al. 1996). Sabbadin et al. (1987) analyzed the internal kinematics of the bright nebular regions and concluded that they trace an equatorial torus seen edge-on. Here we present a morphological and kinematical analysis of Hu 1-2 that includes both the bright and faint nebular regions and the ansae.

2. Observations and Results

In our analysis of Hu 1-2 we use: (a) H\textalpha{}, [N\textsc{ii}] and [O\textsc{iii}] images obtained with the Nordic Optical Telescope (NOT) with a seeing of 0.85\arcsec{}; (b) Br\gamma{}, H\textsc{\textalpha}{} and K\textsubscript{cont} images obtained with the Telescopio Nazionale Galileo (TNG) with a seeing of 0.65\arcsec{}; and (c) two high-resolution (8 km s\textsuperscript{−1}), long-slit spectra obtained with IACUB+NOT at position angles (PAs) of 50\degree{} and 140\degree{} with a seeing of 1\arcsec{}. Figure 1 shows the [N\textsc{ii}] image and [N\textsc{ii}] and [O\textsc{iii}] intensity contour plots of one of the ansae (the long-slit spectra are not shown here).

The images and spectra allow us to identify the following main structures in Hu 1-2:

1. a main elliptical/bipolar shell of size 14\arcsec{}×24\arcsec{} with the major axis oriented at PA \(\approx 320\degree\). It presents bipolar expansion with the polar axis almost perpendicular to the line of sight (<10\degree{} with respect to the plane of the sky).

2. four/five pairs of inner point-symmetric knots in the central nebular regions with separations between 2.5\arcsec{} and 4.6\arcsec{} and different orientations, but none of them along the minor axis of the main shell. Radial velocities of the knots are in the range ± 30–40 km s\textsuperscript{−1}.
Planetary nebula Hu 1-2

Figure 1. (left and middle) Grey-scale representations of the [N\text{II}] image of Hu 1-2. The main structures are labelled. (right) Intensity contour plots of the NW knot in [N\text{II}] (light contours) and [O\text{III}] (thick contours). The origin (0,0) is located at the position of the central star of Hu 1-2 as tentatively identified in the near-IR images (not shown here).

with a slight increase at larger distances from the center. The spatio-kinematical properties of these knots seem to suggest bipolar outflows along different directions.

(3) outer structures around the polar regions of the main shell. Towards the northwest a cap-like structure is observed at $\approx 14''$ from the center while towards the southeast several knots are observed at $\approx 18''$.

(4) the ansae located at $\approx 27.5''$ from the center along PA $320^\circ$ (labelled NW knot and SE knot in Fig. 1). They are detected in the three optical filters and also in H$_2$, suggesting shock-excitation. The radial velocity of the ansae is 60 km s$^{-1}$ (NW knot blueshifted, SE knot redshifted). If they move along the axis of the main shell, their expansion velocity is $>340$ km s$^{-1}$.

The ansae present clear bow-shock morphologies with extended wings. The [N\text{II}] emission is stronger at the tip of the bow-shock while the wings are stronger in H$\alpha$ and [O\text{III}]. The position of the intensity peak coincides in H$\alpha$, [N\text{II}] and H$_2$ but is shifted inwards by 0.5'' in [O\text{III}] (Fig. 1). These surface brightness distributions are reminiscent of those observed in the bow-shock-like structures of IC 4634 and NGC 7009, considered as prototypes of irradiated bow-shocks (Riera & Raga 2007; Guerrero et al. 2008; Raga et al. 2008). These results point out that the ansae of Hu 1-2 are bow-shocks associated to a high velocity bipolar outflow, that are irradiated from the central star of the nebula. A comprehensive analysis of these data will be presented elsewhere (Miranda et al. 2011, in preparation).

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References


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