

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

Luis F. Miranda<sup>1,2</sup>, Mónica Blanco<sup>3</sup>, Martín A. Guerrero<sup>3</sup> and Angels Riera<sup>4</sup>

<sup>1</sup> Departamento de Física Aplicada, Universidade de Vigo, Vigo, Spain (present address)  
email: lfm@iaa.es

<sup>2</sup> Consejo Superior de Investigaciones Científicas, Madrid, Spain

<sup>3</sup> Instituto de Astrofísica de Andalucía – CSIC, Granada, Spain  
email: mblanco@iaa.es, mar@iaa.es

<sup>4</sup> Departament de Física i Enginyeria Nuclear, Universitat Politècnica de Catalunya,  
Barcelona, Spain  
email: angels.riera@upc.edu

**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

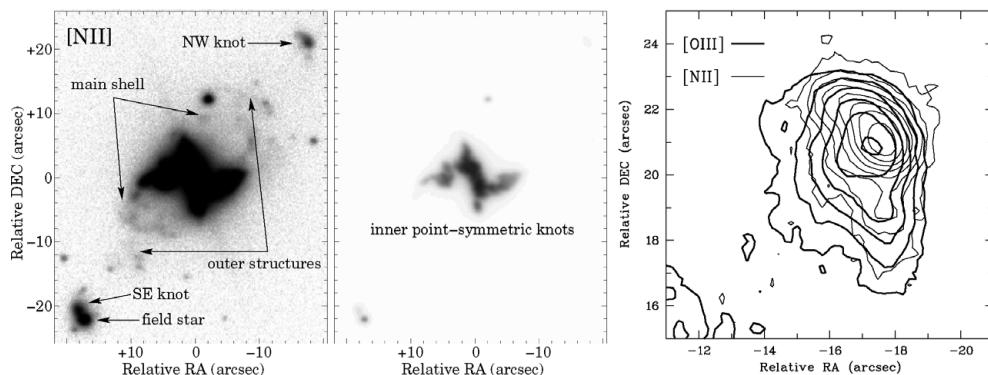
Hu 1-2 is a high-excitation elliptical planetary nebula with He and N overabundances, [N II] enhanced microstructures in its inner regions and ansae outside the main shell (Sabbadin *et al.* 1987; Manchado *et al.* 1996). Sabbadin *et al.* (1987) analyzed the internal kinematics of the bright nebular 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 $\alpha$ , [N II] and [O III] images obtained with the Nordic Optical Telescope (NOT) with a seeing of 0.85''; (b) Br $\gamma$ , H $_2$  and K<sub>cont</sub> images obtained with the Telescopio Nazionale Galileo (TNG) with a seeing of 0.65''; and (c) two high-resolution (8 km s $^{-1}$ ), long-slit spectra obtained with IACUB+NOT at position angles (PAs) of 50° and 140° with a seeing of 1''. Figure 1 shows the [N II] image and [N II] and [O 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'' $\times$ 24'' with the major axis oriented at PA  $\simeq$  320°. It presents bipolar expansion with the polar axis almost perpendicular to the line of sight (<10° 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'' and 4.6'' and different orientations, but none of them along the minor axis of the main shell. Radial velocities of the knots are in the range  $\pm$  30–40 km s $^{-1}$



**Figure 1.** (left and middle) Grey-scale representations of the [N II] image of Hu 1-2. The main structures are labelled. (right) Intensity contour plots of the NW knot in [N II] (light contours) and [O 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  $\simeq 14''$  from the center while towards the southeast several knots are observed at  $\simeq 18''$ .

(4) *the ansae* located at  $\simeq 27.5''$  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<sub>2</sub>, suggesting shock-excitation. The radial velocity of the ansae is  $60 \text{ km s}^{-1}$  (NW knot blueshifted, SE knot redshifted). If they move along the axis of the main shell, their expansion velocity is  $> 340 \text{ km s}^{-1}$ .

The ansae present clear bow-shock morphologies with extended wings. The [N II] emission is stronger at the tip of the bow-shock while the wings are stronger in H $\alpha$  and [O III]. The position of the intensity peak coincides in H $\alpha$ , [N II] and H<sub>2</sub> but is shifted inwards by  $0.5''$  in [O 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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