

Dissecting the complex bipolar planetary nebula Hb 5

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HB 5 is a bipolar planetary nebula with point-symmetric structures in its opposite lobes and a complex core dominated by filamentary loops. We present a comprehensive set of spatially-resolved, high-spectral-resolution, long-slit spectra to investigate its kinematics in detail. The kinematic information is combined with *HST* imagery to construct a 3D model of the nebula using the code SHAPE.



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ABSTRACT

Hb 5 is a bipolar planetary nebula with point-symmetric structures in its opposite lobes and a complex nebular nucleus dominated by rosette-type filamentary loops. We present a comprehensive set of spatially resolved, high spectral resolution, long-slit spectra to investigate its kinematics in detail. The kinematic information is combined with HST imagery to construct a detailed 3D model of the nebula using the code SHAPE. It is pointed out that rosette-type nebular nuclei may develop into poly-polar nebulae.

1- Aim

In order to gain a better understanding of this complex nebula, we have produced the first detailed 3D morpho-kinematic model by combining the information contained in the superb HST images with a thorough long-slit, high spectral resolution mapping of the nebula along its two main axes. The 3D morpho-kinematic model has been produced with the program SHAPE.



Figure 1. HST WFPC2 image of Hb 5 (B. Balick). The size of the image is about $60'' \times 60''$. North is at P.A. = 42° . The image is a composite containing (R) H α , (G) [N II] and (B)[O III]

2- Observations

High-resolution spectroscopic observations of Hb 5 were carried out using the MES-SPM spectrograph attached to the 2.1 m telescope at the Observatorio Astronómico Nacional, San Pedro Mártir (SPM), México. Figure 2 shows the location of the slits over an SPM image of the nebula. WFPC 2 images of Hb 5 have been obtained from HST archive.

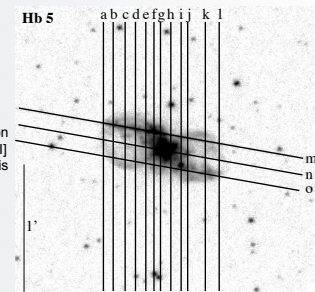


Figure 2. Location of each slit position is indicate and labeled on a H α + [NII] image from San Pedro Mártir. North is up, east left.

3- Kinematics + model

We have used the code SHAPE (Steffen, W., & López, J. A., 2006) to model the 3-D morpho-kinematic structure of Hb 5. The observed and synthetic P-V arrays derived from the model are shown in Figure 3 next to each other for each slit position. Figure 4 compares the result of the 3D model of Hb 5 with the HST image and the P-V array from the long symmetry axis of the nebula.

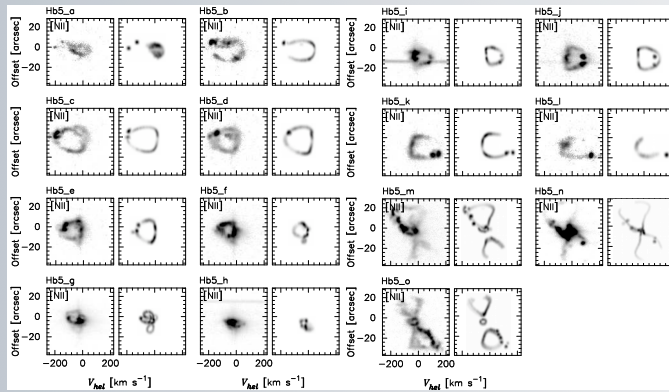


Figure 3. Mosaic of bi-dimensional position-velocity (P-V) arrays labeled according to slit positions shown in Figure 2. For each slit position we show a couple of P-V arrays, the observed [N II] P-V array is on the left panel and the corresponding synthetic P-V array derived from the model is on the right panel.

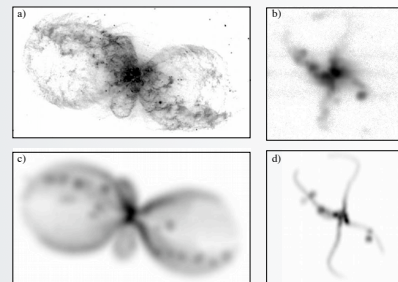


Figure 4. Top panels, frames a) and b), show the HST image of Hb5 and the observed [NII] P-V array from slit n. Lower panels, c) and d) are the synthetic image and synthetic [NII] P-V array from slit n, modeled with SHAPE.

4- Results

Modeling the line profiles required the use of different velocity laws for each of the main components of Hb 5 indicating a complex mass ejection history. The point-symmetric outflow that runs along the lobes has its own kinematic signature and its interaction with the lobes has had a shaping effect on them. The P-S outflow is just reaching the tip of the lobes, which are open. The filamentary loops that surround the nucleus show lobe-like expansion patterns that suggest that Hb 5 may acquire a poly-polar morphology in the future, similar to the case of NGC 2440 (López et al. 1998).

5- References

1. Steffen, W., López, J. A., 2006, RMxAA, 42, 99
2. López, J. A., Meaburn, J. Bryce, M., Holloway, A. J., 1998, ApJ., 493, 803