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High-speed knots in the hourglass-shaped planetary nebula Hubble 12

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We present a detailed kinematical analysis of the young compact hourglass-shaped planetary nebula Hb 12. We performed optical imaging and longslit spectroscopy of Hb 12 using the Manchester echelle spectrometer with the 2.1-m San Pedro Martir telescope. We reveal, for the first time, the presence of end caps (or knots) aligned with the bipolar lobes of the planetary nebula shell in a deep [N II] 6584 image of Hb 12. We measured from our spectroscopy radial velocities of about 120 km s^{-1} for these knots.

We have derived the inclination angle of the hourglass shaped nebular shell to be 65° to the line of sight. It has been suggested that Hb 12's central star system is an eclipsing binary which would imply a binary inclination of at least 80°. However, if the central binary has been the major shaping influence on the nebula then both nebula and binary would be expected to share a common inclination angle.

Finally, we report the discovery of high-velocity knots with Hubble-type velocities, close to the core of Hb 12, observed in HA and oriented in the same direction as the end caps. Very different velocities and kinematical ages were calculated for the outer and inner knots showing that they may originate from different outburst events.

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Abstract

We present a kinematical analysis of the planetary nebula (PN) Hb 12, using optical imaging and longslit spectroscopy. We reveal the presence of knots aligned with the bipolar lobes of the PN shell in a deep [N II] λ6584 image for which we measured radial velocities of $\sim$ 120 $\mathrm{km\,s^{-1}}$. We have derived through SHAPE modelling the inclination angle of the shell to be 65°, which is inconsistent with an ecplising central star binary system (Hsia et al. 2006). Finally, we report the discovery of knots with Hubble-type velocities, close to the core of Hb 12, observed in Hα and oriented in the same direction as the end caps. Very different velocities and kinematical ages for the inner and outer knots suggest that they may originate from different outburst events.

Observations

We obtained deep narrowband Hα and [N II] λ6584 images and longslit spectroscopy of Hb 12 using the Manchester echelle spectrometer combined with the 2.1 m San Pedro Mártir telescope (MES-SPM). The [N II] image is shown in Fig. 1, the [N II] spectra of the outer knots in Fig. 2 and the Hα spectra of the nebular core in Fig. 3.

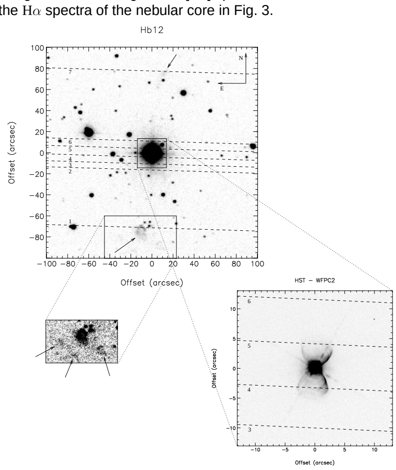

Figure 1: Deep MES-SPM [N II] λ6584 image of Hb 12. The inset to the lower-right is an HST/WFPC2 Hα enlargement of the core revealing the hourglass morphology of Hb 12 (HST archive / Sahai & Trauger 1998). The seven slit positions are marked with dashed lines. The arrows indicate the positions of the knots.

Inner and outer knots

- The [N II] spectra for slit positions 1 and 7 are shown in Fig. 2
- Radial velocities of -125 km s^{-1} and 116 km s^{-1} were measured for the south and north jets, respectively
- Fig. 3 shows the Hα spectra for slits 2 to 6 close to the bright PN core
- They reveal high-speed knots on each side of the core with velocities increasing with distance from the central star

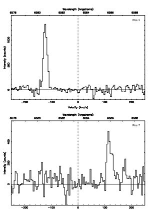

Figure 2: [N II] λ6584 spectra for slit positions 1 (top) and 7 (bottom) integrated over 10" in slit length. The velocities have been corrected for systemic motion.

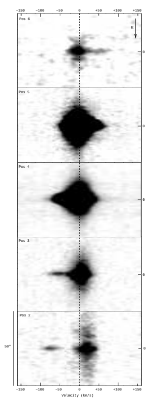

Figure 3: Position-velocity arrays for slits 2 to 6. West is up and east is down, each frame measures 50" in height.

SHAPE model and shell inclination

- We created a synthetic hourglass model of the shell using the SHAPE code (Steffen & López 2006) based on HST imagery
- Axi-symmetric shell with a Hubble velocity law (column a)
- The model was convolved to the SPM image seeing of 2" (column b)
- Synthetic longslit p-v arrays extracted along slits matching positions 4 and 5 and convolved to the MES resolution
- Those are compared to the observed [N II] p-v arrays for various inclination angles (columns c and d)
- A best fitting inclination of 65° was found

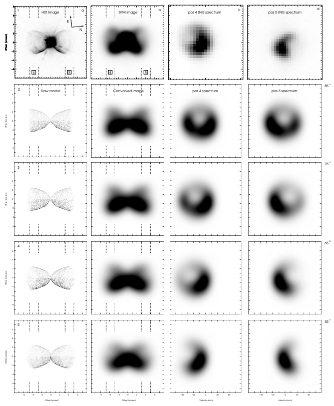

Figure 4: Row 1: optical data. (a) HST Hα image of the hourglass shell of Hb 12. (b) [N II] λ6584 SPM image of Hb 12. (c) Position 4 [N II] λ6584 p-v array. (d) Position 5 [N II] λ6584 p-v array. Rows 2–5: Column (a): Raw SHAPE particle model. Column (b): raw model convolved with 2" seeing. Column (c): position 4 synthetic p-v array. Column (d): position 5 synthetic p-v array. Inclination angles are 85°, 75°, 65° and 55° for rows 2, 3, 4 and 5, respectively. The dashed lines in columns (a) and (b) mark the positions of slits 4 and 5.

Knot velocities

Slit position	Radial velocity (km s^{-1})	Deprojected velocity (km s^{-1})	Distance from centre (arcsec)	Deprojected distance ($\times10^{15}$m)	Kinematical age (years)
1	-125 ± 3	-296 ± 7	72.3 ± 0.3	26.69 ± 0.09	2860 ± 60
2	-75 ± 4	-178 ± 10	16.1 ± 0.3	5.95 ± 0.09	1060 ± 60
3	-48 ± 4	-114 ± 10	10.0 ± 0.3	3.70 ± 0.09	1030 ± 90
4	-21 ± 6	-50 ± 14	3.7 ± 0.3	1.37 ± 0.09	870 ± 230
5	$+28 \pm 6$	$+66 \pm 14$	4.2 ± 0.3	1.56 ± 0.09	750 ± 100
6	$+58 \pm 4$	$+137 \pm 10$	11.5 ± 0.3	4.25 ± 0.09	980 ± 70
7	$+116 \pm 5$	$+275 \pm 13$	76.3 ± 0.3	28.16 ± 0.09	3250 ± 90

Deprojected quantities and kinematical ages were calculated assuming and inclination of 65° and a distance to the nebula of 2.24 kpc.

Conclusions

- High-velocity knots were discovered in Hb 12
  - Outer knots were observed in the wide-field image of Hb 12
  - Bipolar outflows with Hubble velocities were detected close to the PN core
  - This is strong evidence for jet-like activity
  - Large differences in velocities and kinematical ages between inner and outer knots suggest that they originated from separate events.
- We found that the shell inclination of 65° best matched the observations
  - This is much lower than the inclination of an eclipsing binary (> 80°) thought to be at the centre oh Hb 12 (Hsia et al. 2006; De Marco et al. 2008).
  - This result would go against current ideas of PN shaping where binary system and shell share a common inclination.
  - Is there really an eclipsing binary at the centre of Hb 12?

References

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