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Structure of H_2 molecular knots in the Helix and Dumbbell Nebulae

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The recent development of a large field-of-view infrared camera have enabled deep imaging of large planetary nebulae (PNe), and the study of spatial distribution of near-infrared molecular hydrogen emission lines. We have observed the Helix and Dumbbell Nebulae, using the Subaru MOIRCS, which has a $4' \times 7'$ field of view. Molecular hydrogen in these two nebulae is highly collimated in knots. The shapes of knots change from the inner to the outer region. This suggests that PN wind shapes the knots, and that the difference in wind density affects the shapes of knots.

Molecular Hydrogen in the knotty Planetary Nebulae NGC 7293 (the Helix Nebula) and M27 (Dumbbell Nebula)

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Summary

Recent development of near-infrared wide field-of-view camera enabled studying spatial distribution of knotty structures in large planetary nebulae. We observed the Helix Nebula (NGC 7293) and the Dumbbell Nebula (M27), using 2.12 micron v=1-0, S(1) H_2 line. These planetary nebulae show highly collimated knots in molecular hydrogen throughout the nebulae, in contrast to optical images, where emission from 'diffuse' gas is more dominant.

Our MOIRCS image of the Helix Nebula clearly shows that the morphology of the knots changes from the inner edge to the outer ring. In general, the well resolved knots in the inner edge and inner ring show a "cometary" shape, i.e., an elliptical head including a bright crescent-shaped tip and a tail. In the outer ring, tails are not always obvious; some knots appear to have crescents only. Hydrodynamical effects might be involved to form these various shapes of knots.

Observations

Infrared images of the Helix and Dumbbell Nebulae were taken with the MOIRCS on the Subaru Telescope at Mauna Kea, Hawaii, USA on 2007 June 25 (UT) during the twilight. The field of view is 4x7 arcmin^2, with two 2028x2028 pixel HAWAII-2 arrays. Pixel scale is 0.117". The H2 filter has a central wavelength of 2.116 µm and a width of 0.021 µm (FWHM).

The data were taken under excellent seeing 0.3" arcsec in K-band for the Dumbbell and 0.4" for the Helix Nebula.

Distances to the Helix Dumbbell and Nebulae is 219 pc and 379 pc, respectivly (Harris et al. 2007) .

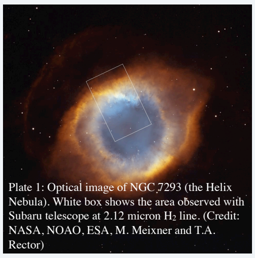


Plate 1: Optical image of NGC 7293 (the Helix Nebula). White box shows the area observed with Subaru telescope at 2.12 micron H_2 line. (Credit: NASA, NOAO, ESA, M. Meixner and T.A. Rector)

Shaping knots and tails

The interaction between the core and the wind can create both the heads and the tails (Pittard et al. 2005; Dyson et al. 2006). In this model, the crescent tip is a bow-shock (ignoring photo-ionization) and the ram pressure creates a narrowing tail for subsonic ambient winds and a widening tail for supersonic ambient winds.

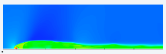


Fig 1: Model to reconstruct H_2 knots by Pittard et al (2005) and Dyson et al. (2006)

Helix Nebula

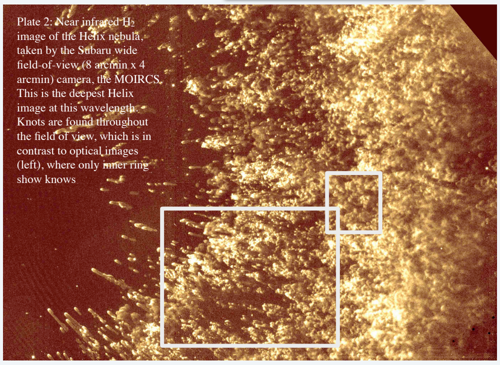


Plate 2: Near infrared H_2 image of the Helix nebula, taken by the Subaru wide field-of-view (8 arcmin x 4 arcmin) camera, the MOIRCS. This is the deepest Helix image at this wavelength. Knots are found throughout the field of view, which is in contrast to optical images (left), where only inner ring show knows

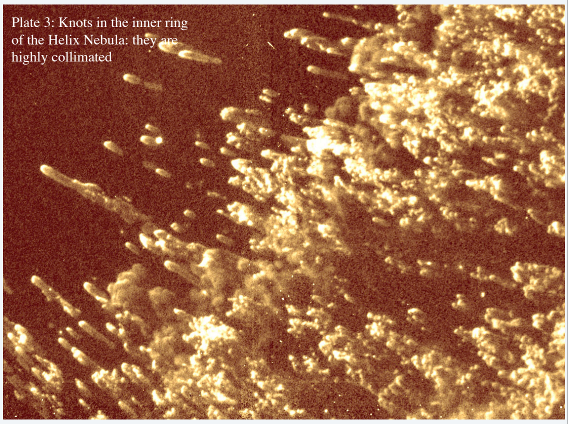
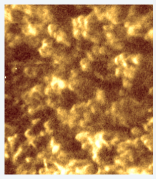


Plate 3: Knots in the inner ring of the Helix Nebula: they are highly collimated

Plate 4: Knots in the outer ring of the Helix Nebula: they are not pointing to one direction, and sometimes only crescents found without tails.



Dumbbell Nebula

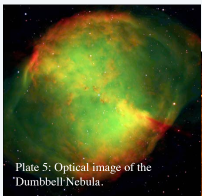


Plate 5: Optical image of the Dumbbell Nebula.

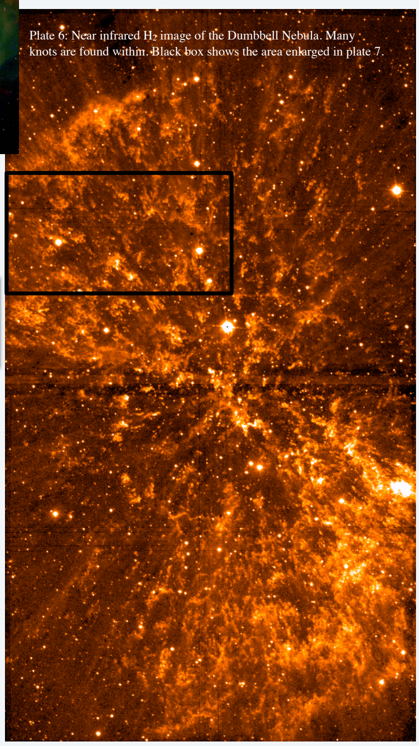


Plate 6: Near infrared H_2 image of the Dumbbell Nebula. Many knots are found within. Black box shows the area enlarged in plate 7.

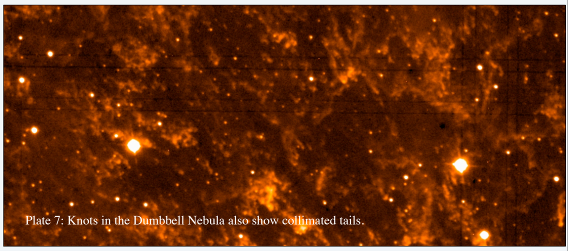


Plate 7: Knots in the Dumbbell Nebula also show collimated tails.