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The asymmetric bipolar nebula IRAS 16342–3814

Koji Murakawa

Max-Planck-Institut fuer radioastronomie, Auf dem Huegel 69, D-53121 Bonn, Germany

R. Sahai

IRAS 16342–3814, known as a water-fountain source because of the presence of a very high-velocity outflow seen in water maser emission, is a young, bipolar pre-planetary nebula (Sahai et al. 2005). We present H- and K_s-band polarimetric images of this object obtained using the VLT/NACO instrument. The pattern of polarization seen in the bipolar lobes and central waist, indicates a dusty structure which requires a three-dimensional model. We present results from a Monte-Carlo dust radiative transfer model constructed to fit the polarized light images and discuss a possible scenario of the three-dimensional morphology of IRAS 16342–3814.

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K. Murakawa [1] and R. Sahai [2]

(1) Max-Planck-Institut für Radioastronomie, Bonn, Germany, (2) Jet Propulsion Laboratory, California, USA

Planetary Nebula (PN) morphology represents a history of physical processes in the stellar/circumstellar environments. Several theoretical studies have been carried out to explain the PN morphologies (see review by Balick & Frank 2002). While details are still unknown, these mechanisms one way or another cause the equatorially enhanced mass loss in the AGB phase. In the subsequent post-AGB phase, the central star blows away the low density fast wind, which inflates the lobe in the polar direction more than in the equatorial direction. This generalized interacting stellar wind (GISW) model explains elliptic and bipolar structures (Kwok 1982; Balick 1987). On the other hand, Sahai & Trauger (1998) pointed out that the appearance of PNs are rather point-symmetry and proposed that high-speed collimated outflows or jets are responsible for such asymmetry. In these scenario, the binary interaction is thought to be one of the most promising mechanism to shape PNs with a narrow waist between the bipolar lobes because this can amplify the mass loss in the equatorial plane and make a disk-like structure. In addition, the binary interaction is also thought to form asymmetric structures such as jets, ansae and point-symmetric shapes such as a spiral and quadruple by precessing motion.

IRAS 16342–3814 is an oxygen-rich PPN, known as a water fountain source. In this object class, high-velocity H_2O maser jets (~ 100 kms^{-1}) are detected outside an OH maser region (Likkel & Morris 1988). Optical and NIR high-resolution images have shown a bipolar appearance with a narrow equatorial waist (Sahai et al. 1999; Dijkstra et al. 2002). In addition, an L'-band image shows a corkscrew-like feature in the bipolar lobes (Sahai et al. 2005). Because of these properties, a binary interacting model (e.g. Morris 1987) favored for this object.

To investigate the dust shell structure of IRAS 16342–3814, we obtained H and K_S-band polarimetric images using the VLT/NACO (383-D0197). We have demonstrated that this observing method is a powerful technique for this purpose (e.g. Murakawa et al. 2005; 2008a,b,c,d, 2010a,b). Figure shows the Stokes I (top) and degree of polarization (bottom) images in the H (left) and K_S (middle) bands. The asymmetric pattern in the Stokes I and degree of polarization distribution is seen. We have performed three-dimensional radiative transfer calculations to model the circumstellar dust shell of IRAS 16342–3814 using our own Monte Carlo STSH code (Murakawa et al. 2008b). The model geometry consists of an inner disk, a bipolar lobe, and an AGB shell. The disk and the AGB shell are axi-symmetry. On the other hand, the bipolar lobe has a water lily petal-shape with an inner cavity and a corkscrew-shaped jet structure in the cavity. The upper lobe is tilted towards the observer by 40 °. The right panel in Figure shows a sample result. A slightly lower polarization in the upper lobe than the bottom lobe is due to the effect of inclination angle. With a spiral-shaped jet structure, the asymmetric appearance in the lobe is reproduced. Further works may provide qualitative interpretations in the disk geometry, the grain sizes, and the density distribution of the jets and the lobe.

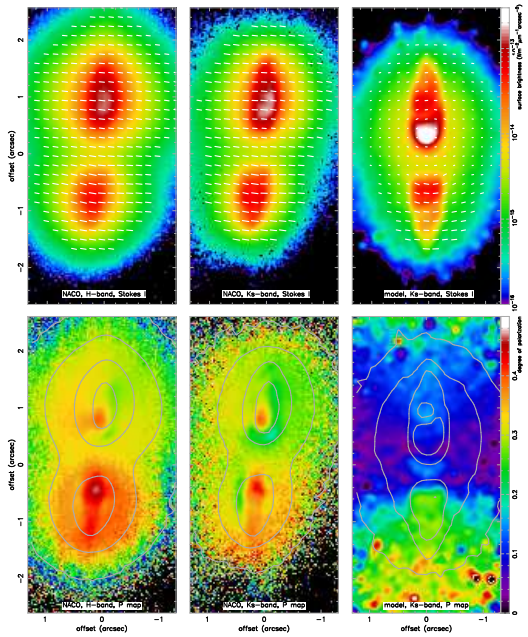

Figure: *top*: The Stokes I (total intensity) images with the polarization vector lines. *bottom*: the degree of polarization map overlaid with the intensity contour lines. *left & middle*: the VLT/NACO images in the H and K_S-bands, respectively. *right*: a model result of a 3D dust shell in the K_S-band.