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VISIR-VLT images of the water maser: Emitting planetary nebula K3-35

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Abstract. K3-35 is an extremely young bipolar planetary nebula that contains a precessing bipolar jet and a small (radius 80 AU) water maser equatorial ring. We have obtained VISIR-VLT images of K3-35 in the PAH1 (λ=8.6 μm), [S IV] (λ=10.6 μm), and SiC (λ=11.85 μm) filters to analize the mid-IR morphology and the temperature structure of its dust emission. The images show the innermost nebular regions undetected at optical wavelegths and the precessing bipolar jets. The temperature map shows variations in the temperature in the equatorial zone and in regions associated to its jets.

Keywords. planetary nebulae: general, planetary nebulae: individual (PN K3-35), ISM: jets and outflows

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K3-35 is an extremely young PN with an optical bipolar morphology consisting of two lobes separated by a dark lane (Miranda *et al.* 2000). VLA radio observations of K3-35 have revealed a precessing bipolar jet and a small (radius 80 AU) disk traced by water masers (Miranda *et al.* 2001; Uscanga *et al.* 2008). Since water maser emission is expected to last only 100 yr after the strong AGB mass loss ceases (Lewis 1989; Gómez *et al.* 1990), water maser emitting PNe (H_2O-PNe) K3-35 can be considered among the youngest PNe identified yet. Observations of H_2O-PNe thus provide important insights on the formation processes of PNe. K3-35 is particularly remarkable because precessing jets and small sized disks are structural components believed to play a crucial role in the formation of PNe. We have obtained mid-IR images of K3-35 to explore the thermal emission of the dust using color and optical depth maps (Dayal *et al.* 1998), and to compare the mid-IR, optical, and radio morphologies to assess its multi-wavelength structure.

VISIR-VLT (Lagage *et al.* 2004) images of K3-35 in the N-band PAH1 (λ=8.6 μm, $\Delta\lambda$=0.42 μm), [S IV] (λ=10.6 μm, $\Delta\lambda$=0.16 μm), and SiC (λ=11.85 μm, $\Delta\lambda$=2.34 μm) filters were obtained (P85, 09/09/2010) with a 0.075″ pixel scale and 19.2″ FoV. The seeing during the observations was 0.4″. The data were deconvolved using a Richardson-Lucy algorithm. We also have used *HST* archive images in the [N II] and *R* filters (Prop. ID: 9101, PI: R. Sahai) and VLA radio continuum images at λ=3.6 cm (PI: Y. Gómez) adapted from Miranda *et al.* (2001).

The mid-IR emission of K3-35 is succesfully detected by VISIR. The core, bright in the *N*-band, is only minimally resolved with an extension of 0.38″×0.45″ along PA∼ 35°.

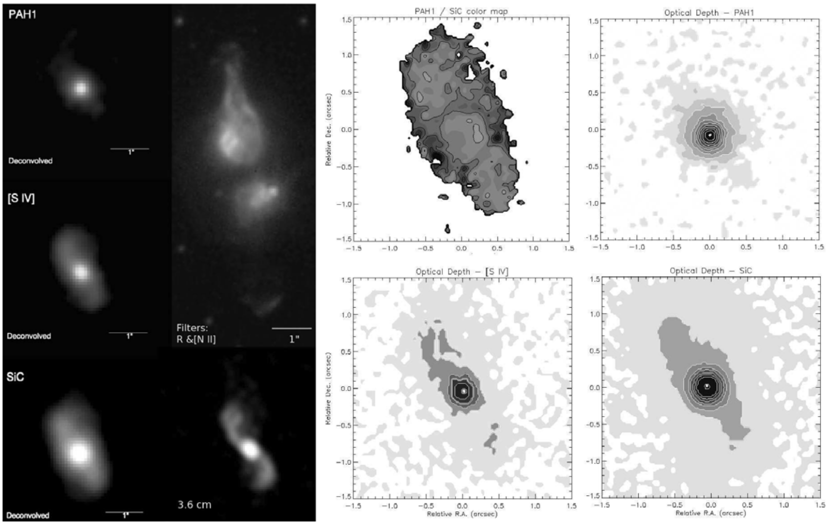

Figure 1. *(left)* Deconvolved VISIR-VLT, HST [N II] and R, and VLA 3.6 cm radio continuum images of K3-35. *(right)* K3-35 color and optical depth maps in the N-band.

The SiC and [S IV] images show a bright S-shaped structure with a size of 2.4″ oriented along PA$\sim 30°$, which corresponds to the precessing jets, whereas the PAH1 image show just the onset of these jets. The optical bipolar lobes are only marginally detected in the SiC image (Fig. 1). The comparison of optical, mid-IR and radio images shows that the dark lane observed at optical wavelengths corresponds to a peak in mid-IR and radio. The mid-IR and radio continuum morphologies are very similar to each other and clearly show the precessing jet that are only detected by the bright knots at their tips in optical images. From the 3.6 cm, SiC and [N II] images, we infer that dust emission dominates in the dark lane observed in the optical, while the jets emit mainly in radio continuum, but also in mid-IR. The comparison between the SiC and [N II] images sets a limit for the spatial extent of the dust emission up to the knots at the tips of the jets (Fig. 1).

The PAH1/SIC color map (Fig. 1) shows variations in the dust temperature in the range 230–1550 K with a mean temperature of 500 K. Warm dust at ∼500 K traces a ring-like structure around the core. The warmest dust is located in the outermost regions of the core along PA$\sim 120°$. Meanwhile, the innermost regions and the S-shaped precessing jets are cold, although warm dust may be present at the tips of the jets.

The optical depth maps (Fig. 1) reveal larger amounts of material at longer mid-IR wavelenghts. The emission peaks toward the center of K 3-35 in all filters, implying that the mid-IR emission is optically thin. It can be concluded that most mid-IR emission arises from a compact core enclosing the H_2O-maser-emitting magnetized torus (Miranda *et al.* 2001; Uscanga *et al.* 2008).

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