Near-infrared interferometry of AGN

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Abstract. Interferometry in the infrared is able to resolve the sub-parsec-scale dust environment surrounding the accretion disk of AGN. The first diffraction-limited $K$-band ($\approx 1\mu m$) image of NGC 1068 with 74 mas resolution and the first $H$-band (1.65 \mu m) image with 57 mas resolution were reconstructed from speckle interferograms obtained with the SAO 6m telescope. The resolved structure consists of a compact core and an extended northern and south-eastern component. The compact core has a north-western, tail-shaped extension. The $K$-band FWHM diameter of this compact core is approximately 18 $\times$ 39 mas (1.3 $\times$ 2.8 pc), and the position angle (PA) of the north-western extension is $-16^\circ$. The PA of $-16^\circ$ is similar to that of the western wall of the ionization cone. This suggests that the $H$- and $K$-band emission from the compact core is both thermal emission and scattered light from dust near the western wall of a low-density, conical outflow cavity or from the innermost region of a parsec-scale dusty torus. The first $K$-band long-baseline interferometry of the nucleus of NGC 1068 with resolution $3/4 \times 10$ mas was obtained with the ESO VLTI. A squared visibility amplitude of 16 $\pm$ 4 $\%$ was measured at a baseline of 54 m. Taking into account $K$-band speckle interferometry observations, the VLTI observations suggest a multi-component structure, where part of the flux originates from scales clearly smaller than $\sim 5$ mas or 0.4 pc. In addition to NGC 1068, the Seyfert galaxies NGC 4466 and NGC 4102 were investigated using bispectrum speckle interferometry.

Bispectrum speckle interferometry of the Seyfert 2 galaxy NGC 1068

Diffraction-limited $K$, $K'$, and $H$-band images with 76, 74, and 57 mas resolution, respectively, were reconstructed from speckle interferograms obtained with the SAO 6m telescope using bispectrum speckle interferometry (Wittkowski et al. 1998; Weigelt et al. 2004). The resolved structure consists of a compact core and an extended northern and south-eastern component. The compact core has a north-western, tail-shaped extension. The $K'$-band FWHM diameter of this resolved compact core is $\sim 18 \times 39$ mas or 1.3 $\times$ 2.8 pc. The position angle of the north-western extension is $-36^\circ$. Two extended northern components (PA $-16^\circ$) have an elongated structure with a length of about 400 mas or 29 pc.

Figure 1: Left, top and bottom: Diffraction-limited $K$-band image of NGC 1068 reconstructed by bispectrum speckle interferometry. The image shows the compact core with its tail-shaped, north-western extension at a PA of $-16^\circ$ as well as the northern and south-eastern extended components. North is up, and east is to the left. Middle, top and bottom: Diffraction-limited $H$-band image. Right: MERLIN 5 GHz contour map (Gallimore et al. 1996) superposed on our $K$-band image. The center of the radio component coincides with the center of the $K$ peak.

The PA of $-16^\circ$ of the compact 18 $\times$ 39 mas core is very similar to that of the western wall (PA $-15^\circ$) of the ionization cone. This suggests that the $H$- and $K$-band emission from the compact core is thermal emission and scattered light from dust near the western wall of a conical outflow cavity or from the innermost region of a parsec-scale dusty torus (the dust sublimation radius of NGC 1068 is approximately 0.1 $-$ 1 pc). The northern extended 400 mas structure lies near the western wall of the ionization cone and coincides with the inner radio jet.

The $K$-band emission from the compact 18 $\times$ 39 mas core can be interpreted as scattered and direct thermal radiation of hot dust near its sublimation temperature. Various models have been published for NGC 1068 (e.g., Fink & Krolik 1992; Granato & Danese 1994; Nenkova et al. 2002). All these models try to fit the SED of Rieke & Low (1975) with a $K$-band flux of 0.3 $\pm$ 0.1 Jy. Torus models which can explain the observed infrared SED by emission exclusively from the torus were presented by Granato et al. (1997). Due to the proposed clumpiness of the torus (Krolik & Begelman 1988; Nenkova et al. 2002; Vollmer et al. 2004) there is a possibility that a fraction of the NIR flux of the central source is scattered and direct thermal radiation of hot dust near the western wall of a low-density, conical outflow cavity or from the innermost region of a parsec-scale dusty torus. The $K$-band long-baseline interferometry observations (Wittkowski et al. 1998; Weinberger et al. 1999; Weigelt et al. 2004), these observations suggest a multi-component structure for the intensity distribution, where one part of the flux originates from scales clearly smaller than $\sim 5$ mas or 0.4 pc and another part from larger scales.

The $K$-band emission from the small (less than 5 mas) scales might arise from the substructure of the dusty torus or directly from the central accretion flow viewed through only moderate extinction.

Clumpy torus model

To explain the torus substructure in NGC 1068 mentioned above, the existence of cold and dusty clouds in a geometrically thick torus with only a few clouds along the line of sight is required. We have applied the radiative transfer treatment in a clumpy medium (Nenkova et al. 2002) to our dynamical model of clumps in the torus of NGC 1068 (Beckert & Duschl 2004). The resulting model image (Fig. 3) allows a comparison with the structures (size, shape, and flux) seen in Fig. 1.

References