Resolving the dusty cores of nearby AGN with mid-infrared interferometry

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Goal:

Resolve the central mid-infrared emission in nearby Active Galactic Nuclei (AGN) and provide direct observational evidence for the presence of a geometrically thick dust distribution, the long postulated "dusty torus".

Method:

Mid-infrared interferometry with MIDI (Mid-InfrareD Instrument) at the VLTI (Very Large Telescope Interferometer, figure 1) on Cerro Paranal, Chile operated by ESO, the European Southern Observatory.

- Produces spectrally dispersed fringes from 8 to 13 µm (N band).
- Allows for resolutions down to 7 milliarcseconds.

Figure 1: The VLTI with the four 8.2m telescopes and two of the 1.8m auxiliary telescopes.

Name	Type	$F_{11.9\mu m}$ [Jy]	Publication of MIDI results
NGC 1068	Sy 2	12.50	Raban et al. (2008)
Circinus	Sy 2	9.70	Tristram et al. (2007)
Centaurus A	FR I	1.22	Meisenheimer et al. (2007)
MCG-05-23-016	Sy 1.9	0.65	Tristram et al. (2008)
Mrk 1239	Sy 1	0.64	Tristram et al. (2008)
NGC 3783	Sy 1	0.59	Beckert et al. (2008)
NGC 1365	Sy 1.8	0.61	Tristram et al. (2008)
NGC 4151	Sy 1	1.20	resolved (paper in prep.)
3C 273	Quasar	0.35	Tristram et al. (2008)
IC 4329A	Sy 1	0.35	Tristram et al. (2008)

Table 1: List of selected AGN observed with MIDI at the VLTI. The fluxes are from Raban et al. (2008) and were obtained with TIMMI2, except for the fluxes of NGC 1068 and NGC 4151 where the values were derived from Mason at al. (2006) or Roche et al. (1991), respectively.

Results:

- An interferometric signal was detected in most of the AGN targeted by MIDI (see table 1).
- The nuclear mid-infrared emission in the two Seyfert 2 galaxies NGC1068 and Circinus is well resolved. For both galaxies the data was modelled by two elliptical Gaussian black body emitters:
  - ⇨ Circinus contains a small (0.4 pc) and warm (T = 330 K) dust disk perpendicular to the ionisation cone, matching an H_2O maser disk in orientation and size and embedded in a larger (2.0 pc), slightly cooler (T = 300 K), geometrically thick dust torus (see figure 2).
  - ⇨ In NGC 1068 the emission comes from an extended (3.5 pc), warm (T ~ 300 K) and geometrically thick torus plus a hot (T ~ 800 K) component, 1.4 × 0.5 pc in size, the hot inner funnel of the torus, which also aligns with a H_2O maser disk (see figure 3).
  - ⇨ In both cases a clumpy or filamentary structure is needed to explain "wiggles" in the interferometric measurements.
- The mid-infrared emission in the nucleus of the radio galaxy Centaurus A comes in about equal part from a thin dust disk and an unresolved core which fits to the synchrotron spectrum of the foot of the jet (see figure 4).
- Some of the fainter sources are partially resolved (e.g. NGC 1365, NGC 4151), others (e.g. Mrk 1239) essentially remain unresolved for the baselines sampled.

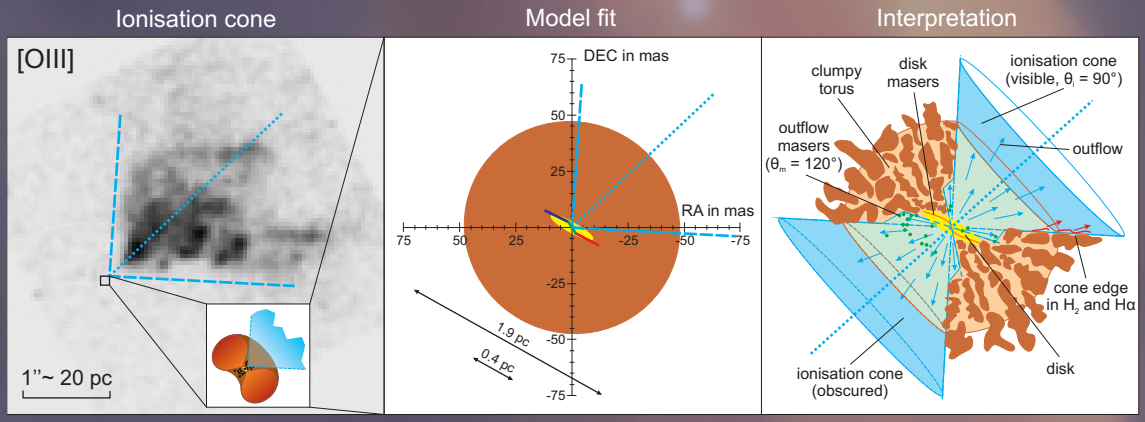

Figure 2: The dusty torus in the Circinus galaxy. The ionisation cone from Wilson et al. (2000) is compared to the model fit of the interferometric observations and the interpretation in terms of a dust disk and a geometrically thick, filamentary dust distribution. The rotating maser disk (blue part approaching, red part receding) and the outflow masers from Greenhill et al. (2003) are also plotted.

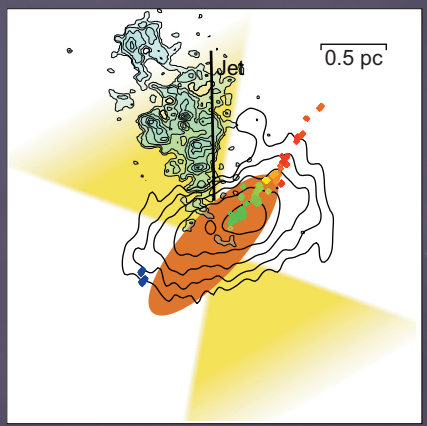

Figure 3: Structures in the nucleus of NGC 1068: hot dust component (orange), free free emission (black contours), maser disk (dots), ionisation cone (green contours) and outflow (yellow). From Raban et al. (2008)

Conclusions:

- ⇨ Geometrically thick dust distributions exist in Seyfert 2 galaxies and seem to be clumpy.
- ⇨ The radio galaxy Centaurus A, however, shows no evidence for such a torus.
- ⇨ The study of several more AGN is underway. Continuing investigation of already studied sources.
- ⇨ Need proper hydrodynamic modelling to fully understand the tori (talk by Marc Schartmann).

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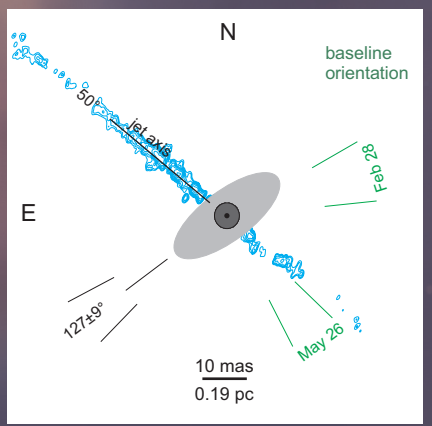

Figure 4: Centaurus A. Sketch of the dust disk (light grey) and the unresolved mid-infrared emission (dark grey) which is identified with the VLBI core (black dot) at the foot of the jet. From Meisenheimer et al. (2007).