AMBER+FINITO+UT Science Demonstration Proposal

Resolving the cores of nearby AGN

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Abstract:

We propose AMBER-FINITO visibility and closure-phase observations of the bright AGN NGC 1068, NGC 1365, and NGC 7469 in order to study the wavelength dependence of the size of their dust tori and to test AGN models. The torus region of NGC 1068 was already resolved by interferometric techniques in the K and H bands. Bispectrum speckle interferometry observations resolved an elongated structure with a K'-band size (FWHM Gaussian fit) of 18×39 mas (±4 mas) or 1.3×2.8 pc (Wittkowski et al. 1998, Weinberger et al. 1999, Weigelt et al. 2004). Furthermore, VLTI-VINCI observations revealed a substructure with a size of ≤5 mas or ≤0.4 pc, derived from the observed K-band visibility of 0.4 at 46 m baseline (Wittkowski et al. 2004). Our radiative transfer codes (Ohnaka et al. 2006, Hönig et al. 2006) will be used for a quantitative interpretation of the observations. Radiative transfer modeling will allow us to derive physical properties of the resolved structures and test AGN models.

Scientific Case:

The presence of a parsec-scale, molecular, dusty torus is a cornerstone of all AGN unification schemes. The torus provides the viewing-angle-dependent obscuration which is necessary to explain the apparent difference between type 1 and type 2 AGN. The torus seems to play a fundamental role in providing the fuel to feed the central accretion disk and the black hole. The dust in the torus absorbs the radiation from the central accretion disk and re-emits the absorbed energy in the NIR and MIR. Because of its small angular diameter, the dust torus cannot be resolved by direct imaging. The inner radius of the dust torus is set by the minimum distance from the central AGN at which dust can survive in the AGN's optical/UV radiation field. For standard dust models and a bolometric luminosity of 10^{46} erg/s, the actual size of this sublimation radius is of the order of 1 pc (Barvainis 1987, Kishimoto et al. 2007). Many important questions have not yet been answered: What is the geometry of the dust and gas distribution? Is the dust distributed homogeneously or is it arranged in clumps? What is the chemical composition of the torus? Is the torus the fuel reservoir which is important for feeding the accretion disk? How is mass transported through the torus towards the AGN?

Several authors have modeled the IR SED of AGN and have shown that, indeed, the nuclear IR emission can be explained by the reprocessing of the accretion disk radiation in the dust torus (e.g., Pier and

Krolik 1993, Granato and Danese 1994, Nenkova et al. 2002, Schartmann et al. 2005, Hönig et al. 2006). A few years ago, the only model constraints were the IR SED. However, without good size constraints, it is not possible to derive reliable model parameters.

During the last few years, it has become possible to resolve the nuclear IR structure of a few of the brightest AGN using interferometric methods. Bispectrum speckle interferometry of NGC 1068 in the K and H bands (see Fig. 1) allowed the resolution of its nuclear core with a K'-band size (FWHM Gaussian fit) of 18×39 mas (±4 mas) or 1.3×2.8 pc (Wittkowski et al. 1998, Weinberger et al. 1999, Weigelt et al. 2004). Furthermore, with VLTI/VINCI, a high K-band visibility of 0.4 was found at a baseline of 46 m (Wittkowski et al. 2004). Observations with the VLTI-MIDI instrument resolved NGC 1068 in the MIR (Jaffe et al. 2004). Similar results were also obtained for the Circinus galaxy (Tristram et al. 2007).

For the interpretation of AGN observations, two types of models were developed. The classical models use a homogeneous dust distribution (e.g., Pier & Krolik 1993, Granato & Danese 1994, Schartmann et al. 2005). More recently, clumpy tori (see Fig. 2) were studied (e.g., Nenkova et al. 2002, Hönig et al. 2006). Clumpy torus models require a dense distribution of distinct clouds which are on gravitationally bound orbits (e.g., Beckert & Duschl 2004). The thickness of the torus is a consequence of cloud-cloud interactions and is directly connected to the accretion of clouds towards the central accretion disk. NIR visibilities and closure phases are crucial observations to distinguish between both types of models.

We propose AMBER visibility and phase-closure measurements of the bright AGN NGC 1068, NGC 1365, and NGC 7469 to study the wavelength dependence of the shape of the circumnuclear dust structures in order to test AGN models. If the atmospheric conditions are exceptionally good, fringe tracking (FT) and emission line observations with medium spectral resolution are possible to study the gas. Radiative transfer modeling (see Fig. 2) of the SEDs, AMBER visibilities and closure phases, as well as MIDI visibilities (available for all 3 AGN) will allow a quantitative interpretation of the data. Various codes were developed in our group for this goal (e.g., Ohnaka et al. 2006, Hönig et al. 2006: clumpy torus model) and were applied to a large number of VLTI observations of young and evolved stars (e.g., Preibisch et al. 2006, Kraus et al. 2008, Ohnaka et al. 2006) as well as AGN (see Fig. 2; Hönig et al. 2006). The modeling of the proposed observations will allow us to derive physical parameters of the resolved structures. The comparison of the model predictions with the observations will constrain the geometries and, more specifically, will show whether classical models of a torus with the inner wall traced by the sublimation radius of dust are correct or require modification.

References:
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Calibration strategy:

We need standard calibration data (target-cal pairs; goal: visibility error $\leq$20%). We propose LR group tracking (GT) observations, which should be feasible in nights of very good seeing and long coherence

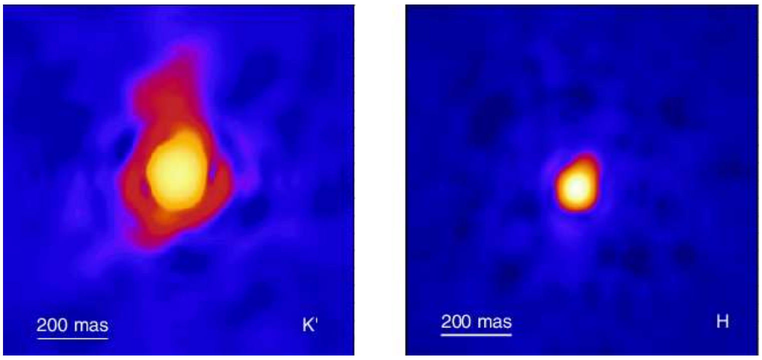

Figure 1: K'- and H-band bispectrum speckle interferometry of NGC 1068. The central (yellow) elongation is caused by the resolved elongated core. Its size (Gaussian fit) of 18×39 mas (1.3×2.8 pc) was derived from the 2-D visibilities (see Weigelt et al. 2004 for more details).

time. Previous AMBER-FINTO observations have shown that group tracking can improve the calibrated visibilities in the LR mode. LR fringe tracking (FT) is extremely difficult to achieve due to the faint target magnitude. If AMBER AGN fringes are found for the first time, a large amount of data (approx. 1 h per target and hour angle) should be recorded in order to obtain accurate visibilities and closure phases. The AGN cores are bright enough for guiding and wavefront sensing (brighter off-axis stars within 15 arcsec are not available). Based on our earlier experience, the observations should only be tried if seeing is better than 0.8 arcsec and the coherence time is longer than 3 ms.

Targets and number of visibility measurements

Target	RA	DEC	V mag	H mag	K mag	Size (mas)	Vis.	Mode	# of Vis.
NGC 1068	02 42 41	-00 00 48	11	10.4	8.2	5	0.4/0.4/0.4	LR-GT (MR 2.1)	3
NGC 1365	03 33 36	-36 08 28	12	10.4	9.4	1	0.9/0.9/0.9	LR-GT (MR 2.1)	3
NGC 7469	23 03 16	+08 52 26	13	10.7	9.8	1	0.9/0.9/0.9	LR-GT (MR 2.1)	3

NGC 1068 is the brightest target, but previous AMBER attempts have shown that precise AO wavefront sensing is very difficult due to the underlying galaxy. Wavefront sensing on the more compact cores of NGC 1365 and NGC 7469 is probably easier, but both targets are fainter than NGC 1068 in the K band. Therefore, it is important to try both types of objects. If fringes are found, we propose to record data even if GT is not successful.

If the atmospheric conditions are exceptionally good, fringe tracking (FT) might work in addition to group tracking (GT). In this case, medium-resolution observations (MR 2.1 FT), in addition to LR observations, should be carried out. This would allow us to obtain, for the first time, data from which both continuum and emission line diameters can be derived.

Time Justification:

It is very likely that the observation of each AGN-calibrator pair will require approximately 2.5 h observing time (to observe 3 visibilities and 1 closure phase at 1 hour angle) since searching for fringes will be time-consuming ($\sim$ 1 h) and large amounts of data are required due to the faint magnitude of the targets (1.5 h per AGN-cal pair). We propose to invest up to about 1 h per AGN for the fringe search using nearby calibrators to determine the OPD off-set. Therefore, for 3 targets, 7.5 h observing time is required.

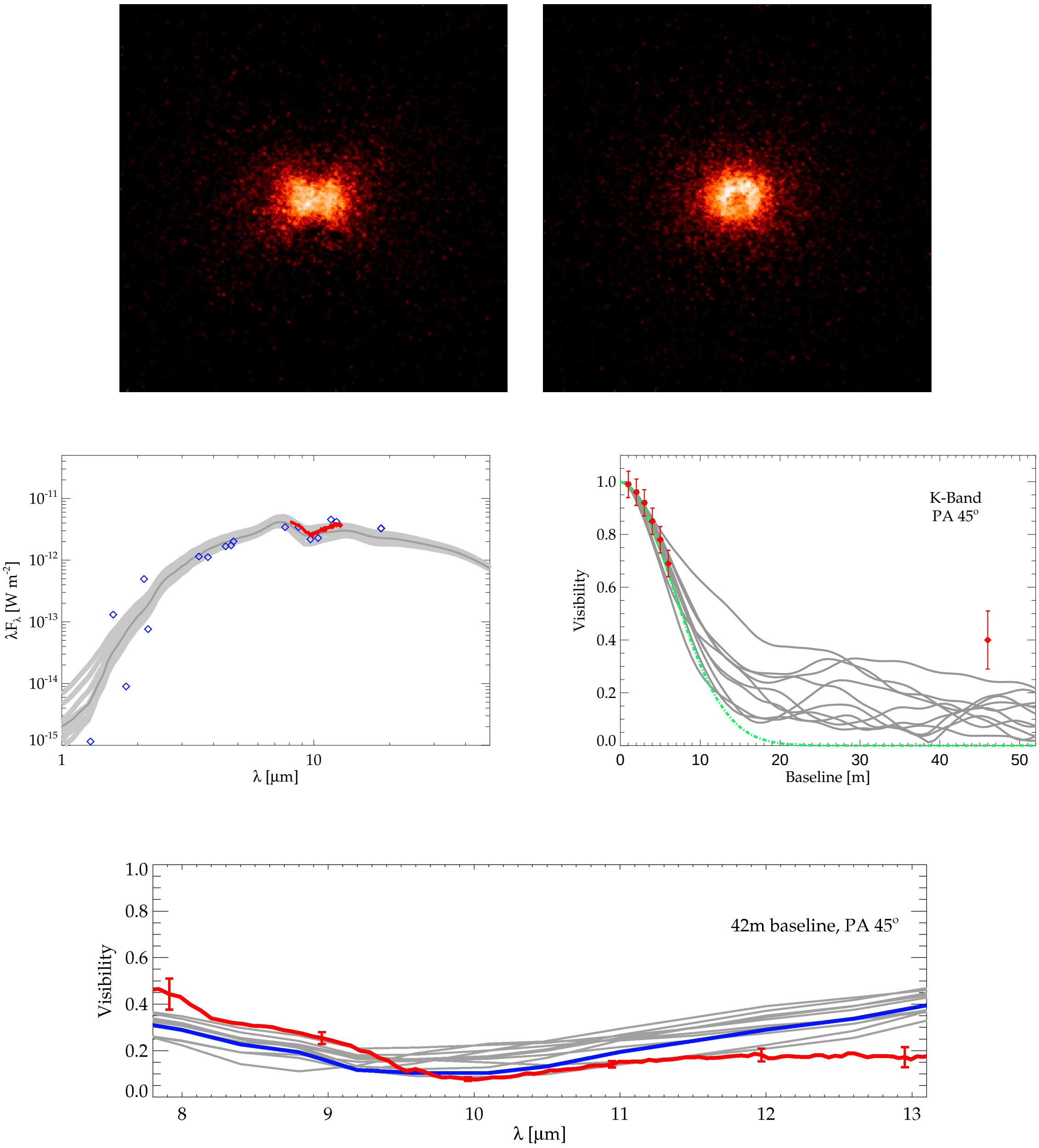

Figure 2: Radiative transfer modeling of NGC 1068 (see Hönig et al. 2006 for more details). Top: clumpy torus model images (left: edge-on view; right: inclination 45°). Middle left: small-aperture SED. Middle right: speckle, VINCI, and model NIR visibilities. Bottom: MIDI (baseline 42 m) and model visibilities.