AMBER+FINITO+UT Science Demonstration Proposal

Investigating the near-infrared cores of bright AGN

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Abstract:

We propose an AMBER observation of one of the closest and brightest Active Galactic Nuclei (AGN). AGN are one of the most energetic and mysterious phenomena in the universe. Their characterization by near-infrared (NIR) interferometry has always been a prime objective for the VLTI/AMBER instrument. At NIR wavelengths, AGN show a bright dominant core, which appears unresolved at the diffraction limit of 8 m class telescopes. For NGC 1068, the NIR core has been slightly resolved by speckle interferometry to ~ 30 mas ~ 2 pc (Wittkowski et al. 1998). NIR VLTI/VINCI interferometry (Wittkowski et al. 2004) has revealed an additional compact component of scale < 5 mas (0.4 pc) – the so far only NIR interferometric results on AGN obtained with the VLTI. This result has been interpreted as near-infrared emission or scattering from a region associated to the toroidal obscuration region or the inner region of the ionization cone of size ~ 2 pc with substructure at the $<$0.4 pc scale. The details of the NIR emission, however, remain unclear due to the limited observational information.

The proposed AMBER measurement promises to lead to a quantum leap in our understanding of the NIR cores of AGN by obtaining information at several spectral channels within the K band and by using three baselines simultaneously. This observation is technically very challenging, and should only be attempted if the atmospheric conditions are exceptionally good.

Scientific Case:

AGN are compact cores at the centers of galaxies with luminosities that may be larger than that of the host galaxy. They appear in different types, with broad and narrow lines or only narrow lines, and radio quiet or radio loud. In the standard unification scheme, these different types are mainly explained by different accretion rates and different viewing angles. In this scheme, AGN are understood to be composed of a super-massive black hole that is surrounded by a an accretion disk at small scales with surrounding gas clouds showing broad emission lines, the “Broad Line Region (BLR)”, and a dusty obscuration region, the “torus”, at larger scales that may or may not, depending on the viewing angle, obscure the direct view to the central source and the BLR. The dusty torus also leads to an ionization cone in perpendicular direction which harbors clouds showing narrow emission lines, the “Narrow Line Region (NLR)”. Inside this cone, a radio jet may be present as well. Fig. 1 (left) shows an illustration of this classical unification scheme (from Urry & Padovani 1995).

Observational evidence for this scheme was indirect and the exact size of the torus a matter of debate for decades. Recent mid-infrared interferometry using VLTI/MIDI on a number of nearby AGN (e.g.; Jaffe et al. 2004; Meisenheimer et al. 2007; Tristram et al. 2007) was successful to constrain the torus to a parsec-scale size.

While the dusty torus was usually thought of as a smooth-density doughnut-shaped torus (as in Fig. 1, left), most recent discussions and observational evidence suggest a clumpy structure of the toroidal obscuration region (TOR). Fig. 1 (right) shows an illustration by Elitzur (2007, 2008), where the BLR turns into the TOR at the point of the dust sublimation radius. Both regions consists of clouds (pure gas clouds in the BLR and dusty clouds in the TOR) with a higher density of clouds in the equatorial plane and a gradually lower cloud density in the perpendicular directions.

At near-infrared wavelengths, AGN show a bright dominant core. In the case of NGC 1068, Thatte et al. (1997) showed that 94% percent of the K-band light in the central 1 arcsec originates from a $\leq$30 mas diameter source. Likewise, for instance, VLT/NACO observations of Centaurus A by Häring Neumayer et al. (2007) show a strong unresolved K-band core with a spatial resolution of $\sim$60 mas. In the case of NGC 1068, the K-band core has been slightly resolved by speckle interferometry to an azimuthal average Gaussian FWHM of $\sim$30 mas $\sim$2 pc (Fig. 2 left), which was confirmed by Keck observations by Weinberger et al. (1999). Subsequent more detailed speckle interferometry by Weigelt et al. (2004) showed a K'-band FWHM diameter of the compact core of approximately 18×39 mas or 1.3×2.8 pc assuming a model of a single Gaussian component. K-band VLTI/VINCI long-baseline interferometry by Wittkowski et al. (2004) has revealed an additional compact component of spatial scale $<$5 mas (0.4 pc), see Fig. 2 (right). This result has been interpreted as K-band emission or scattering from a region associated to the toroidal obscuration region or the inner region of the ionization cone of size $\sim$2 pc, and showing substructure corresponding to the $<$0.4 pc scale. The details of the NIR emission, however, remain unclear due to the limited observational information. For instance, the exact size of the very compact VLTI/VINCI component could not be clarified. It might be of the order of a few mas (a few tenth of a parsec), or it might also be of much smaller scale. It is also not clear whether the K-band emission originates from the equatorial plane of the TOR, or rather from clouds located in the perpendicular region. It is also not clear if the K-band core is dominantly scattered or thermally emitted light.

The proposed AMBER/VLTI observations would represent an important leap to address these questions. By obtaining three visibility measurements simultaneously with different projected baseline lengths, and at several spectral channels within the K band, the size of a compact core will be constrained much stronger than with the previous single VINCI point. Also, the nature of the NIR emission will be clarified by using visibility spectra. NGC 1068 is not part of our target list, because it is a GTO target. However, other bright AGN are equally suited for our scientific purpose. GTO targets will be proposed separately (Weigelt et al.).

This observation is technically very challenging because of the faintness of the sources, and should only be attempted if the atmospheric conditions are exceptionally good. Additional remarks on the observational strategy and the sources follow below.

Calibration strategy:

So far no AMBER observations of any AGN could be obtained, although this has always been a prime science driver for AMBER. Thus, the pure detection of AMBER fringes on any AGN would already represent a dramatic success toward opening the field of NIR interferometry of AGN. Some absolute calibration of the visibility should be attempted, but a certain accuracy is not required at this point.

Targets and number of visibility measurements

Target	**RA**	**DEC**	**V** mag	**H** mag	**K** mag	**Size** (mas)	**Vis.**	**Mode**	**# of** Vis.
NGC 7582	23 18 23	-42 22 14	10	11	10	5 mas	0.5/0.5/0.5	LR (GT)	1 *OR*
NGC 424	01 11 28	-38 05 01	12	11	10	5 mas	0.5/0.5/0.5	LR (GT)	1 *OR*
IRAS05189-2524	05 21 01	-25 21 45	13	12	11	5 mas	0.5/0.5/0.5	LR (GT)	1 *OR*

We propose three of the brightest AGN, excluding P82 and P83 GTO targets, at different positions on sky, so that the most appropriate can be chosen depending on the ambient conditions and the time of observation during the night.

The V magnitudes are red colors of the extended source. At least in the case of IRAS 05189-2524, the MACAO loop could already be closed on the galaxy itself (for MIDI observations). Coudé guide stars within the required 15 arcsec were not found for these sources.

The H and K magnitudes are the expected magnitudes within the field of view (FOV) of ~ 60 mas. NGC 1068 has a K brightness within the AMBER FOV of about 9th magnitude (Wittkowski et al. 2004), and the next-brightest targets selected here are expected to be roughly one magnitude fainter, based on a comparison of magnitudes using small beam sizes (Gezari 1999). This is consistent with estimates by Peng et al. (2006) based on a decomposition technique of 2Mass data ($K_{\rm AGN}$=10.1/10.3 for NGC 7582/NGC 424). AGN cores are roughly 1 magnitude fainter in H than in K (Gezari 1999; Weigelt et al. 2004).

The given size of 5 mas corresponds to the Gaussian FWHM found for NGC 1068 by Wittkowski et al. (2004) if a single Gaussian component is assumed (but in fact a multi-component structure is the preferred interpretation). The visibility corresponds to the visibility found for NGC 1068. Similar values are expected for the targets chosen here.

The NIR magnitudes are about 3 magnitudes below the advertised limits. However, if the observations are only attempted under excellent conditions, we can expect to gain at least 1 magnitude. At least another magnitude can be gained accepting that most scans can possibly not be analyzed by the standard pipeline reduction, but need special treatment. Finally, the pure detection of fringes on an AGN would already be a large step toward opening the AMBER instrument for AGN research, and a good calibration of the data is not our goal at this point.

We suggest to use the 2Mass coordinates of the bright IR core, which are precise to <0.8 arcsec. We found bright (K, H <6) stars in the 2Mass catalog within a distance of <0.4 deg (HD 2194924 for NGC 7582; HD 7235 for NGC 424; HD 35055 for IRAS 05189). Possibly, the OPD offset can be measured for these stars and be used for the AGN to record the fringes blindly.

Time Justification:

We propose one observation of any of the three suggested AGN, which shall be selected based on the time of observation during the night. This observation is extremely difficult due to the faintness of the sources. It shall only be attempted if the conditions are exceptionally good (seeing < 0.6 arcsec, τ_0 >4ms). Even under such good conditions, we suggest to spend a maximum of twice the average time for one observation (i.e. $\sim$1h) and to give up if the fringe acquisition is not successful within this time. It would be a tremendous success for the VLTI if an AMBER observation of an AGN succeeds for the first time. If this observation is not successful, this observing time can also be seen as an important first step toward a better understanding why in detail the anticipated observations of bright AGN are not yet feasible.

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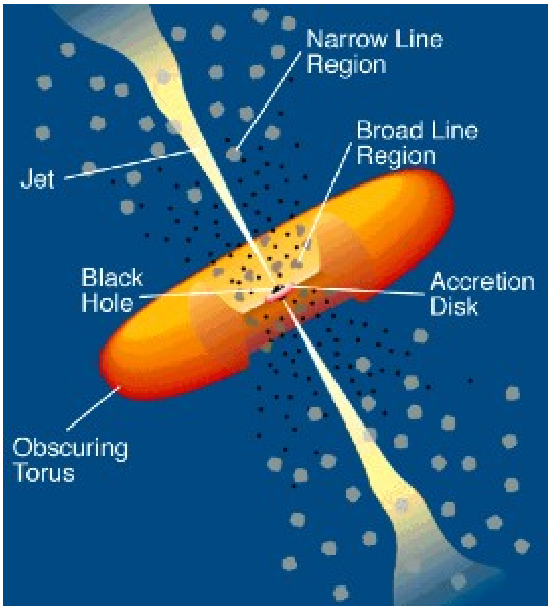
Figures:



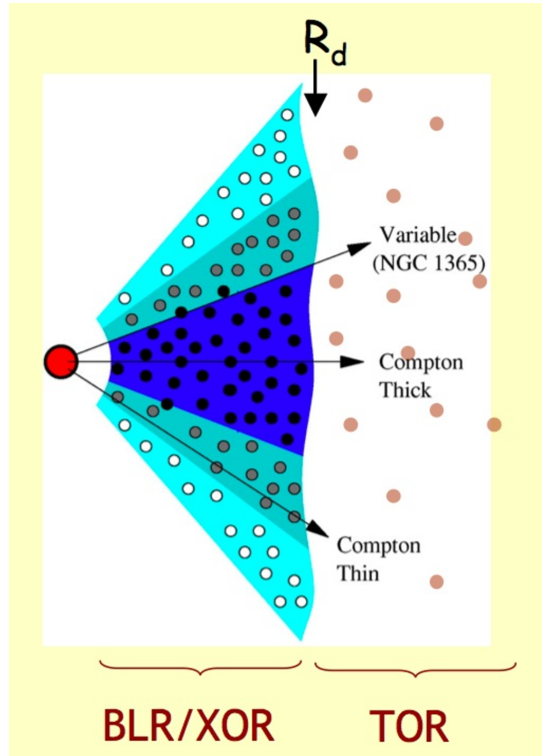
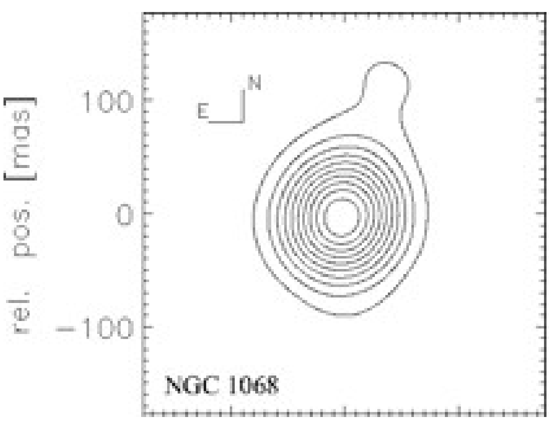


Fig. 1:
Left: Illustration of the standard unification scheme of AGN from Urry & Padovani (1995).
Right: Scheme of the clumpy structure in the broad line region (BLR) and the toroidal obscuration region (TOR) from Elitzur (2007). The dust sublimation radius R_d marks the transition between BLR and TOR.



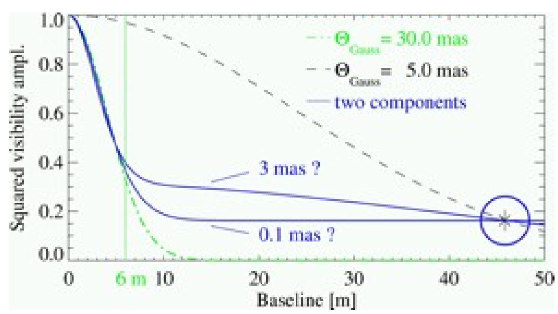


Fig. 2:
Left: Speckle interferometry of NGC 1068 obtained at the Russian 6 m telescope showing that the dominant NIR core is slightly resolved with a size of $\sim$ 30 mas $\sim$ 2 pc (Wittkowski et al. 1998). More detailed speckle interferometry of NGC 1068 is described in Weigelt et al. (2004).
Right: VLTI/VINCI observation of NGC 1068 revealing an additional structure of scale $<$ 5 mas $<$ 0.5 pc (Wittkowski et al. 2004).