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Radio nuclei of z~0.2 X-ray AGN and prospects for future NIR interferometry with LINC-NIRVANA at the LBT

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Several studies of radio and X-ray detected AGN have resulted in an apparent correlation between the radio and X-ray luminosities, indicating a common physical background of both phenomena. In order to be able to distinguish between extended, jet- or starburst-related radio emission and core radio emission, high angular resolution is inevitable.

We studied 13 z~0.2 X-ray AGN with MERLIN/EVN at 18cm and find that the radio emission is mostly unresolved and cannot predominantly arise from star formation. This suggests that the radio emission in these sources is closely connected to processes that occur in the vicinity of the central massive black hole, also where the X-ray emission is believed to originate in.

Future observations at high angular resolutions at other radio frequencies and especially in the near-infrared (e.g., LINC-NIRVANA at the LBT will provide 9mas angular resolution at 1µm) can provide further important spectral information about the structure and energetics in these sources.

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[1] Speaker

1. Introduction

The relationship[1,2] between Seyfert activity and circumnuclear star formation is still an unsolved question in active galactic nuclei (AGN) research. The spatial distribution of radio emission gives information about its origin and contribution: diffuse emission indicates star formation, while extended but collimated emission arises from a jet and compact nuclear emission from processes close to a supermassive black hole. Therefore, high angular resolution observations are necessary to disentangle the associated energetics into nuclear and stellar components. The relations between the emission processes at different wavelengths are also not fully understood. Seyfert 1 galaxies for example reveal quite flat near-infrared (NIR)-to-X-ray spectral energy distributions (SED). Most of the X-ray emission is believed to originate from a hot corona close to an accretion disk, while only a small fraction can be accounted by star formation. In the radio regime, extended emission is most likely synchrotron radiation from radio jets or supernovae. In contrast to the steep spectral slope of a radio jet, the core radio emission usually shows a flat, self-absorbed spectrum.[3] One possible explanation is the inverse Compton-up-scattering of radio photons in relativistic electron plasma at the base of a jet. Since no correlation is found between radio-loudness and X-ray luminosity, this cannot be the only explanation. Moreover, there seems to be a tight correlation between X-ray and radio flux, in both, AGN and in star forming galaxies. The correlations indicate that the emission processes are linked. This would support the hypothesis of a hot and optically thin emitting region as additional or even dominant emission process for radio core emission. Optically thin bremsstrahlung from a slow, dense disk wind could contribute significantly to the observed emission level and explain the flat spectrum point source.[4] In this case, the correlation between X-ray and radio emission would be due to a common disk origin.

For the determination of the different physical phenomena in the nuclear regions of AGN wide spectral range data, especially in the visible/NIR wavelength regime, becomes as essential as high angular resolution.[5]

2. Radio Observations

We present MERLIN/EVN phase-referenced 18 cm observations of 13 z~0.2 ROSAT/SDSS based X-raying AGN (5 NLS1s, 4 Sy1s, 2 LINERs, 1 BL Lac, and 1 passive galaxy).[1] The angular resolutions are 200 mas (MERLIN) and 15 mas (EVN) and accordingly the restoring beams correspond to physical scales of 500pc and 40pc. The detection rate is high and the radio emission is predominantly unresolved. An example for our maps is shown in figure 1. We find that the star forming and the supernovae rates, calculated from the radio flux which is a tracer for supernovae, are unrealistically high for many targets with respect to the small volume (40pc). As a measure for star formation we also estimated the far-infrared (FIR) luminosities from well-known X-ray/FIR and radio/FIR correlations of normal star forming galaxies. Compared with typical FIR luminosities from inactive galaxies all targets are FIR under luminous, for given X-ray and radio luminosity. Furthermore, we derived the radio brightness temperatures that are about 10^7 K, i.e. too high for star formation to play an important role.

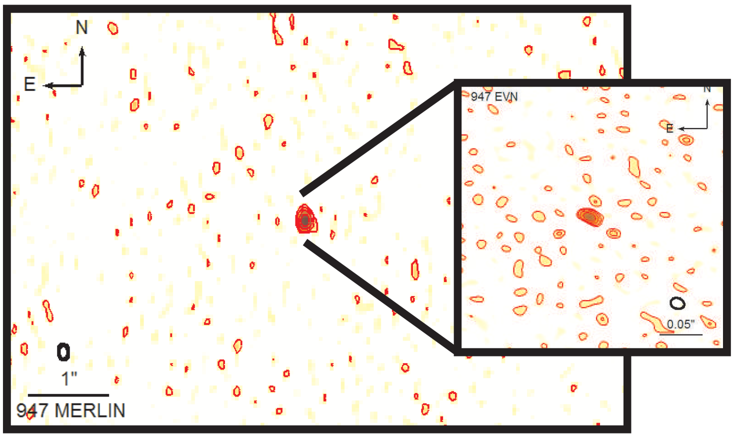

Figure 1: Example 18cm MERLIN map of one source with EVN data as inset. The contours shown are multiples of the rms in the images (2, 4, 8, 16 ...). The beam sizes and orientations are indicated by the ellipses. This target is clearly unresolved.

These results and the compactness of the emission indicate that the radio emission in these sources is closely connected to processes that occur in the vicinity of the central massive black hole, also where the X-ray emission is believed to originate in.

In order to obtain more spectral information and to improve the models of nuclear structures, dynamics and emission processes not only further observations at other radio frequencies but also AO-assisted NIR follow-up studies are important.

3. LINC-NIRVANA: NIR Fizeau interferometry with the LBT

High angular resolution and wide spectral range data are the keys to differentiating and interrelating physical phenomena in the nuclear regions of AGN, in particular, mixing effects of non-thermal, stellar emission, and dust extinction. This becomes important especially in the visible/NIR wavelength domain.

The NIR is a sensitive tracer of the mass dominating (older) stellar populations and of the distribution and contribution of (hot) dust. As it is less affected by extinction the NIR is suitable for inspecting circumnuclear regions of the targets that are expected to be extincted. With the NIR colors and spectra, which give information about the stellar content of the host and the importance of the presence of dust, star formation, nuclear activity, dynamics and structure as well as interactions and merging processes of galaxies can be studied in detail out to high redshifts.

The Large Binocular Telescope[6] (LBT) (figure 2), located on Mt. Graham (Arizona, US), is one of the first extremely large telescopes (ELTs). Its two 8.4m diameter primary mirrors have a common mount with a center-to-center distance of 14.4m and the 110 m² collecting area samples virtually all baselines from 0 to 22.8 m.

LINC-NIRVANA[6] is a wide field imaging interferometer for the LBT. It will combine the radiation from the two 8.4 m primary mirrors of the LBT in so-called Fizeau mode. This configuration preserves phase information, and allows true imagery over a wide field of view (FOV).

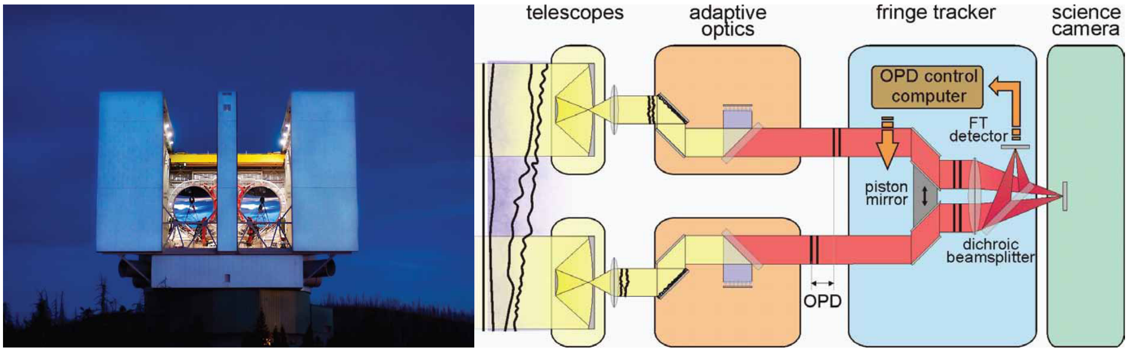

Figure 2: Left: Large Binocular Telescope (courtesy of David Steele, LBT). **Right:** Working principle of LINC-NIRVANA[7]. The incoming wavefronts have been distorted by the turbulent atmosphere and have first to be corrected by an adaptive optics (AO) system for each eye individually. Optical path differences (OPD), residual to the AO-corrected wavefronts and due to internal flexure and vibrations, have to be assessed by measuring a point source within the FOV and corrected for by a moving piston mirror. The piston control subsystem is called Fringe-and-Flexure Tracker. The fully corrected wavefronts are then coherently combined in the focal plane of LINC-NIRVANA

Working in the NIR (1-2.4µm), LINC-NIRVANA will provide 9mas (at 1.2µm) angular resolution and a FOV of at least 2 arcminutes, when coupled with its advanced multi-conjugated adaptive optics system (MCAO).The working principle of LINC-NIRVANA's wavefront correction system is described in figure 2. Part of the sample presented in Sec. 2 is suitable for adaptive optics assisted observations, i.e. with nearby natural guide stars, and presents prime targets for LINC-NIRVANA.

With its large light collecting area and high angular resolution, LINC-NIRVANA will allow us to resolve the nuclear region of AGN on scales of 30pc (at z=0.2), which correspond to the EVN scales (figure 3). This is essential for disentangling the AGN from the circumnuclear star-forming component and assessing the importance of dust reddening in order to derive the nuclear SED by combination with high angular resolution data at other wavelengths. While at a redshift of z=0.2 only the circumnuclear structures become apparent, the torus structures can be studied for closer AGN (figure 4).

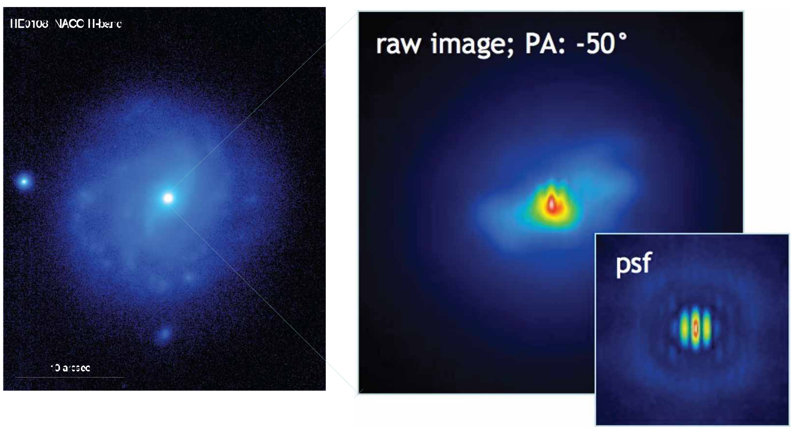

Figure 3: Left: Example of an AO-assisted NIR observation of an AGN (Fischer et al. in prep.). Right: Simulation of an LINC-NIRVANA observation of the nuclear region. The LBT PSF is indicated. The fringe pattern is also visible in the galaxy image, too. The Fizeau type setup provides a large FOV and therefore direct imaging capabilities[8]

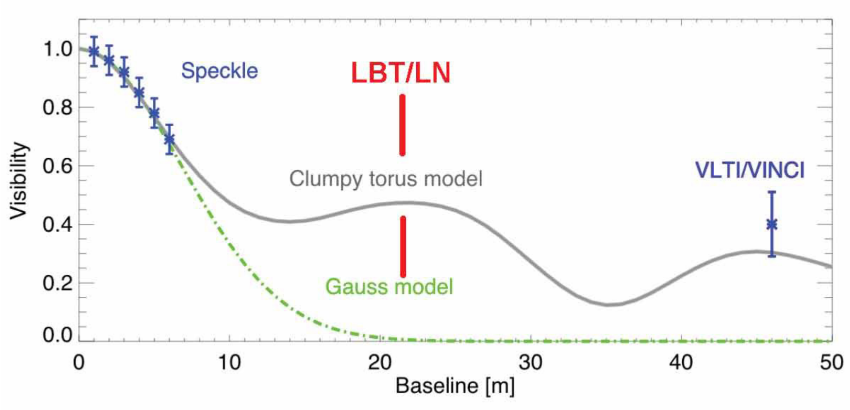

Figure 4: LBT interferometry fills the short spacing gap between speckle and long baseline interferometry, allowing for discrimination of different AGN torus models[8]

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