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ADAPTIVE OPTICS OBSERVATIONS OF ACTIVE GALACTIC NUCLEI: ZOOMING INTO THE CENTRAL PARSEC REGION

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RESUMEN

Se presentan los primeros resultados del programa AGN de Heidelberg enfocado en resolver la región del parsec central de núcleos galácticos activos en el IR. Las regiones nucleares de núcleos activos prototipo se aprecian claramente en ondas del IR y a distancias del núcleo – de unos cuantos pc – donde aparentemente no están presentes las regiones circunnucleares de formación de estrellas. Dentro de esta perspectiva, los núcleos activos clásicos tales como Circinus y NGC 1097 revelan detalles sin precedentes de los canales del material que está siendo empujado hacia el núcleo, mientras que otros como Centauro A y NGC 1566 muestran un ambiente 'limpio' en el núcleo. Precisamente en el centro, se encuentra resuelta una región compacta central de escala de aproximadamente 2 pc en Circinus pero no en los otros casos, lo cual pone en entredicho la presencia universal del toro putativo de oscurecimiento.

ABSTRACT

First results from the AGN-Heidelberg program aimed at resolving the central pc region of the closest Active Galactic Nuclei in the IR are presented. The core region of prototype active nuclei are clearly unveiled at IR waves and at distances from the nucleus - few pc- where circumnuclear starforming regions appear not to be present. Within that perspective, classical active nuclei as Circinus and NGC 1097, reveal with unprecedented detail clear channels of material being driven to the core whereas others as Centaurus A and NGC 1566, show a 'clean' core environment. At the very center, a central compact region of about 2 pc scale is resolved in Circinus but not in the other cases challenging thus the universal presence of the putative obscuring torus.

Key Words: **GALAXIES: ACTIVE GALACTIC NUCLEI — INSTRUMENTATION: ADAPTIVE OPTICS**

1. INTRODUCTION

The Active Galactic Nuclei (AGN) paradigm relay on a massive black hole surrounded by an accretion disk with size of few astronomical units. Surrounding this core, there is the broad line region, still spatially unresolved with a predicted size of less than 1 pc. To account for the diversity of AGN, a further additional component is introduced: a central obscuring structure - a torus/warp-disk shape - which prevents photons from the central engine to escape in an isotropic manner. The presence of collimated nuclear cones of ionized gas constrains the size of this obscuring structure to be between 1 to a few tents of a pc. If due to dust, the peak emission of this structure should be in the IR and therefore observational confirmation of it has been hampered due to spatial resolution limitations in this range. Diffraction limited observations in 8-10m class telescopes and long-base-line interferometry allows us for the first time to resolve this structure in the IR for at least the closest AGN. This is the goal of the AGN-Heidelberg program. This paper presents sub-arcsec resolution observations in the near IR conducted with the VLT of the closest and brightest AGN accessible from the South Hemisphere. The observations allows us to set very stringent constrains on the size of the AGN core and hence, on that of the torus.

2. TARGET SAMPLE AND OBSERVATIONS

The sample of targets studied in this program includes those Southern objects having 10um flux larger than 300 mJy, a total of 18 targets. This brightness criteria was introduced to guaranty follow up observations with VLTI/MIDI interferometry at 10um for the most suitable cases. Broad-band J to M images for the sample are being collected with the Adaptive-Optics-assisted NACO IR camera/spectrograph at the VLT. The best spatial resolution is being achieved in the Ks-band, with typical FWHM: $0.07'' < FWHM < 0.16''$. At the distance of the targets presented here, this is equivalent to scales of 1 to 10 pc.

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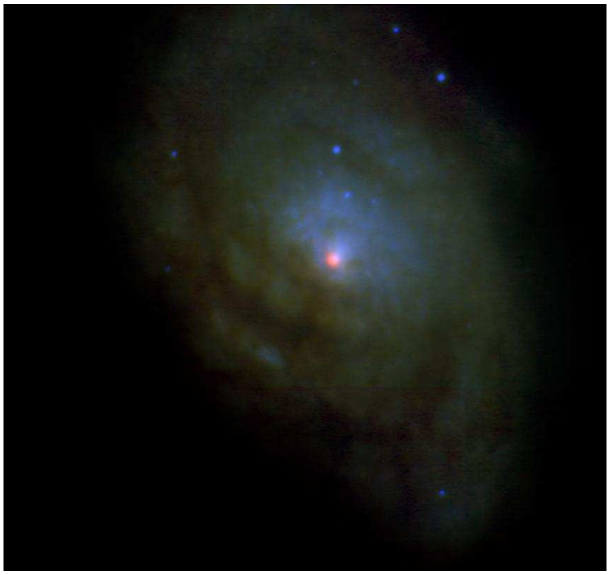


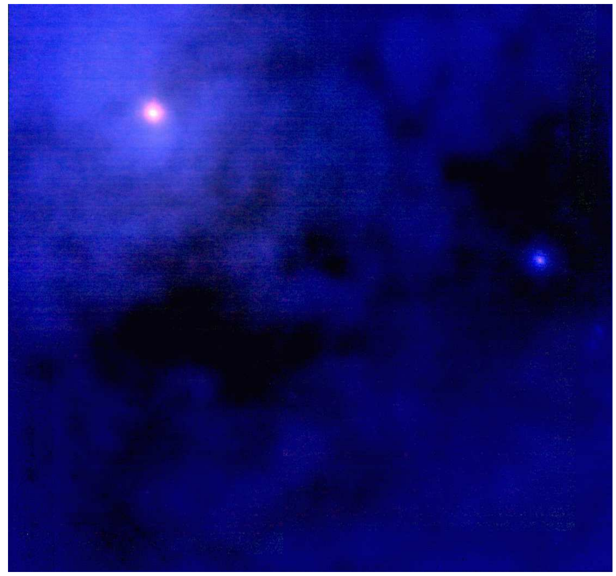


Fig. 1. Left: True colour image of Circinus, FoV = 27"x27", combining HST F814W (blue) and NACO J- (green) and Ks-bands (red). Some of the stars used for astrometry and spatial resolution estimate are visible. Right: NACO J+H+K image of Cena A, FoV=7"x14". The star on the right side was used for astrometry and spatial resolution estimate. North up, East left in both figures.

3. FIRST RESULTS: THE NEAREST AGN

A summary of the results obtained for for the four more relevant AGN studied: Circinus, Centaurus A, NGC 1097 and NGC 5506 are discussed bellow.

3.1. *Circinus*

Circinus is a SAb galaxy inclined by $\sim$ 65 deg. 1 arcsec $\sim$ 19 pc. Several dust lanes hide a large fraction of its East side, including its nucleus. It shows a well known, one side nuclear ionization cone extending on the kpc scale in the North-West direction. Circinus is the only case so far where we find a resolved central core from K- to M- bands with a size FWHM= 1.9 $\pm$ 0.6 pc. This size could be measured accurately due to the presence of several stars in the same field. A composite HST 8000 A and NACO J + K image is shown in Fig. 1. The core - red central point in the figure - is only contributing in the Ks-band, and it is shifted by 0.15 arcsecs (2.8 pc) Shout-East from the HST and NACO J-band peaks emission. It defines the vortex position of a rather collimate beam - bluish central emission in the figure pointing North-West - with extension $\sim$ 10 pc and seen both in continuum light below 1.6 μm and in $H\alpha$ line. This colimated beam is in the direction of Circinus ionization cone. The red core is also the center position of a [SiVII]2.48um ionization "double cone" discovered also in our NACO observations. The extinction in the inmediate surroundings of the core, derived from colour maps after comparing with those of normal ellipticals/spirals (e.g. Giovanardi & Hunt 1996), leads to Av=6 (screen dust layer) or Av=20 (gas mixed dust). Extensive analysis of these observations are presented in Prieto et al. (2004a).

3.2. *Centauros A*

Together with Circinus, these are the two nearest AGN in the Southern Hemisphere. Cen A is the nearest radio galaxy with a Seyfert type 2 nucleus, 1 arcsec is $\sim$16pc. Because of the prominent dust lanes covering Cen A, its nucleus is fully obscured at optical wavelengths but it was unveiled in the IR by HST (Marconi et al. 1999). VLT provides 3 times resolution better and a NACO Ks-band diffraction-limited image of Cen A sets a stringent upper limit for the size of its core to be FWHM<1 pc (Haering et al. 2003). A NACO J+H+K image of the central region (Fig. 1, right) shows a bright and isolated core source sitting on top of rather diffuse emission from the galaxy. The extinction measured from J-H colors at the surroundings of the core leads to values of Av$\sim$ 7 when comparing them with those of normal bulges, and ssuming a foreground dust layer.

3.3. *NCC 1097*

This is one of the few nearest Seyfert 1 objects in the South: 1 arcsec $\sim$ 70 pc. The galaxy is a SBb

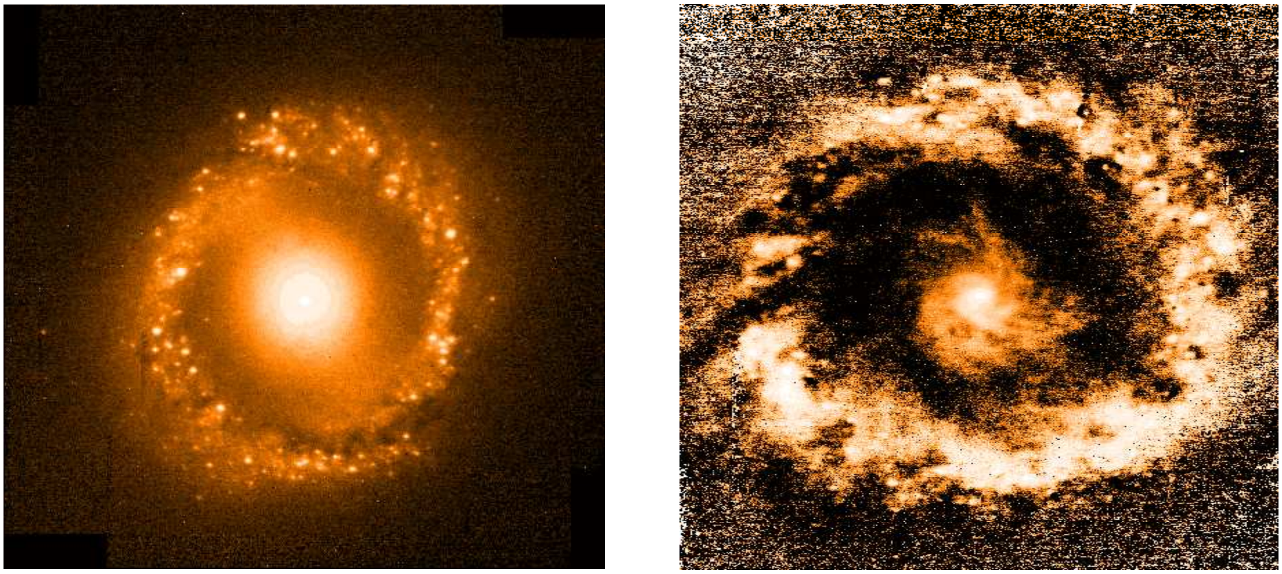


Fig. 2. Right: NGC1097 NACO Ks-band of the central 27x27 arcsec region; Right: NACO J-K image disclosing witin the central 300 pc radius a fine spiral network of dust and gas spiraling toward the center. North is up, East to the left in both figures.

with a prominent circumnuclear ring at radius of 1.3 kpc enclosing a nuclear bar. Fig 2 shows a NACO Ks-band image showing all those features. At the resolution of this image, FWHM$\sim 0.14'' \times 0.19''$, the core of NGC1097 is unresolved which sets an upper limit to its size of $\sim$ 11 pc. The best detailed view of the core region is however seen in the NACO J-K image (Fig. 2, right). It shows a complex network of filaments of dust and gas spiraling down towards the core. Some of the longest filaments seem to connect with the circumnuclear star forming ring. Presumably, material from the star forming regions is loosing angular momentum and falling straight to center to feed the AGN. The extinction derived from colour maps, after comparing with those of normal bulges lead to rather moderate values: Av=1.4 - 4, depending of whether a screen case or gas mixed with stars case are respectively considered (Prieto et al. 2004b).

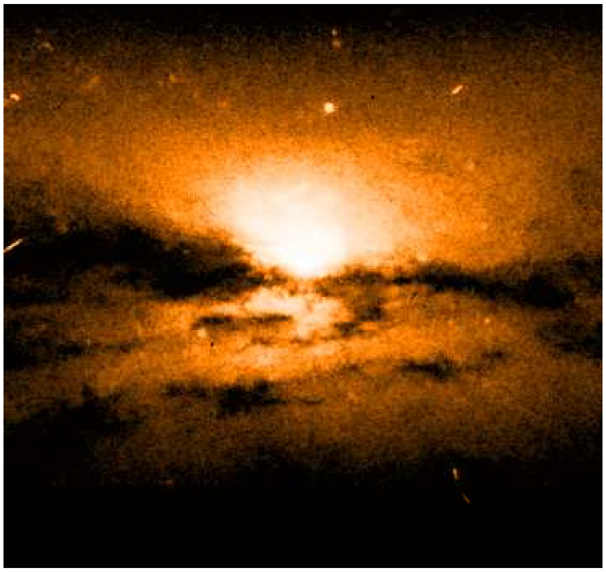
3.4. *NGC 5506*

This is a disky, edge on (i =70deg) galaxy covered by a thick dust lane all across its disk. Ussually refered as a Seyfert type 2, the detection of broad both Paβ and permitted OI 1.1287um line (Nagar et al. 2002) upgrades it into the type 1 class. Fig. 3 (left panel) shows a HST 6000A broad-band image of the central 35x35 arcsec showing the dust lanes and the potential position of its nucleus. NACO J- to L- band images unveal a very bright core but do not recover much from the host galaxy. The L- and M-bands are limited in sensitivity but the Ks image is deep to surface brightness $S_B(K) \sim <16$. The Ks-band image is diffraction-limited (Fig. 4, right panel), which sets un upper limit to the size of the core of FWHM<10 pc. J-K colors measured around the core leads to Av$\sim >$ 10 when compared to those of normal ellipticals/spirals, for which we assume J-K=0.95. An screen dust case is assumed.

4. CONCLUSIONS: WHERE IS THE TORUS?

Considering the upper limit size of the core for the four galaxies described, any torus in these objects has to be less than 10 pc in N1097 and N5506 and definitively less than 1 pc in Cen A. In Cen A, HST measures a polarised (P= 11%) K-band nucleus from a core size less than 1 pc (Capetti et al. 2000). If the polarization is due to scattered light from an obscured nucleus, the size of the obscuring structure should be strictly less than 1 pc. Of course, much cooler material, not traced by these near-IR observations, may extend to larger radius. Indeed, that may well be the case considering the HI absorption spectrum seen in the direction of Cen A nucleus (Sarma et al. 2002).

Circinus is the only case where a central resolved structure is measured, with a core size of FWHM$\sim$ 2pc. The J-to-N SED of this core is compatible with dust temperature of about 300 K (Prieto et al. 2004a). Coincidentally, these are about the size



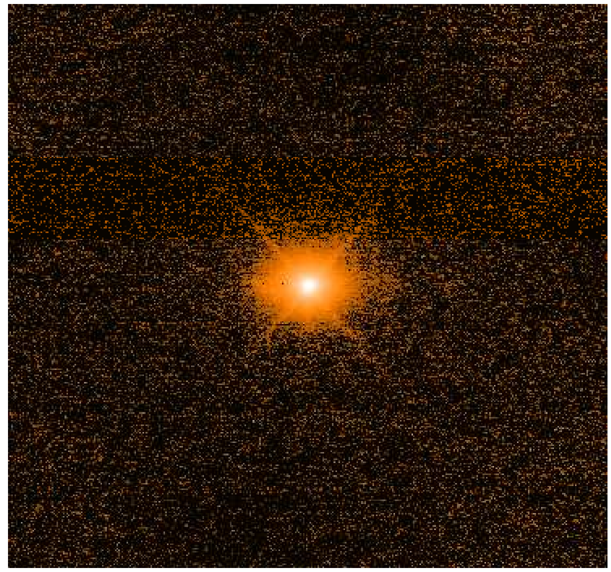


Fig. 3. NGC 5506 images of the central 35x45" by HST F606W (left) and NACO in Ks-band, 20x20" (right). Resolution of the NACO image is 57 mas. North is up, East, left.

and temperature measured in N1068 from the VLTI 10um spectrum (Jaffe et al. 2004).

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