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THE MID-IR EMISSION OF SEYFERT GALAXIES: RELEVANCE FOR CANARICAM

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RESUMEN

Se presentan nuevos resultados sobre la emisión en el IR medio de galaxias tipo Seyfert. Las observaciones fueron realizadas usando el instrumento TIMMI-2 en el telescopio 3.6 m de la ESO. Hemos obtenido imágenes en el límite de difracción. En algunos casos la emisión se puede resolver y varía con la longitud de onda. Se discute brevemente la relevancia para CanariCam de estos estudios.

ABSTRACT

New results on the mid-IR emission of Seyfert galaxies are presented. The observations were performed using the TIMMI-2 instrument at the 3.6 m ESO telescope. We have obtained diffraction-limited images. In some cases the emission can be resolved and varies with wavelength. The relevance for these studies for CANARICAM is briefly discussed.

Key Words: **GALAXIES : ACTIVE — INFRARED : GALAXIES**

1. INTRODUCTION

The origin of the mid-IR emission in AGN is still a matter of debate. The commonly accepted unification model of Seyfert galaxies postulates the existence of a thick dusty torus surrounding the active nucleus and the broad line region. According to this model, Seyfert classification depends only on the line of sight with respect to the torus axis (Antonucci 1993). The energy absorbed by the obscuring structure must be reradiated mostly in the mid-IR range, peaking around 10 μm. Another controversial question is the size of this structure (Fadda et al. 1998). Pier & Krolik (1992) proposed an optically thick and compact (radius $\lesssim$ few pc) torus as the obscuring structure. Later on, Granato & Danese (1994) proposed a different model with a moderately thick and extended (tens to hundreds pc) torus. Efstathiou, Hough, & Young (1995) also proposed a tapered disk with a similar radial scale as the most successful model to explain the IR radiation of AGN.

Within this scenario, the nuclear ionizing radiation is expected to escape in oppositely directed cones along the torus axis. Indeed, conical structures have been observed in high excitation emission line images of some Seyfert galaxies, mainly type 2. For example, well defined ionization cones have been detected in the Seyfert 2 galaxies NGC 1068, NGC 5252, and NGC 4388. One may ask whether the ionization cones could also be present in different wavelength ranges. In the mid-IR extended emission has been detected in NGC 1068 using high spatial resolution imaging (Bock et al. 2000; Braatz et al. 1993; Cameron et al. 1993). The mid-IR morphology of NGC 1068 shows, in addition to a bright unresolved nuclear peak, extended emission up 2–3 arcsec, coincident with the conical [O III] emission and aligned along the radio jet. The origin of this emission is probably due to dust heated by the collimated nuclear radiation field.

Extended mid-IR emission has been detected in other Seyfert 2s (e.g., Circinus, NGC 3281) by Krabbe, Böker, & Maiolino (2001), who also found a good correlation between the nuclear N-band and the X-ray luminosity, the correlation being different for starbursts.

There are a number of arguments supporting the idea that the ionization cones are not completely dust-free. Rowan-Robinson (1995) suggested that the NLR clouds contains dust. Efstathiou et al. (1995) included an extra component corresponding to optically thin dust located in the cones in order to account for the observed flatness of the emission around 3–5 μm in NGC 1068. Netzer & Laor (1993) proposed a model in which the dust is embedded in the NLR would naturally explain certain features such as the gap between the BLR and the NLR, the size of the BLR, and the low filling factor of the NLR.

The major reason for observing the nuclear regions of active galaxies in the mid-IR is because the reprocessing of the UV/X-ray nuclear radiation is

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reradiated in that range. According to the models the details of the mid-IR emission depends on the size of the structure. Mid-IR spectroscopy may elucidate the composition and chemistry of the intervening material. There are other reasons that make the mid-IR very attractive. In this wavelength range, extinction is greatly reduced, there is great light penetration, and the morphology might be better determined. The morphology is related to nuclear fueling mechanisms.

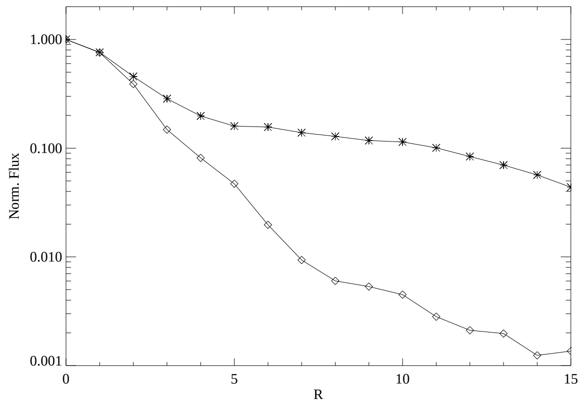

Fig. 1. Normalized radial profile of NGC 7582 compared to a point source. The unresolved nucleus of NGC 7582 (size $\leq$ 50 pc) can be c learly distinguished.

1.1. *NGC 7582*

2. THE OBSERVATIONS

We have obtained mid-IR images of a sample of Seyfert 2 galaxies known to exhibits ionization cones in the [O III] line. The observations were performed using the TIMMI-2 instrument (Reimann et al. 2000) at the 3.6 m ESO telescope on 2001 October. TIMMI-2 provides a plate scale 0.2arcsec/pixel, with a total field of view of 64×48 arcsec. Observations were performed using the chopping plus nodding technique. We have obtained diffraction-limited images ($\sim$ 0.5arcsec) using the filters N1, 11.9, 12.9, and [Ne II]. In addition, we have obtained N-band spectroscopy with a resolution $R \simeq 120$ and dispersion 0.02 μm/pixel. Here we report preliminary results about one of the observed galaxies, NGC 7582.

NGC 7582 is one the brightest narrow line X-ray luminous galaxies (NLXGs). Its X-ray luminosity corresponds to a type 1 Seyfert galaxy, whereas in the optical the recombination line widths are ≤ 200 km s^{-1}. *ASCA* observations (Xue et al. 1998) have revealed high variability on a timescale of few hours in the hard X-ray range (2–10 keV), whereas the soft X-ray (0.5–2 keV) remained constant. The

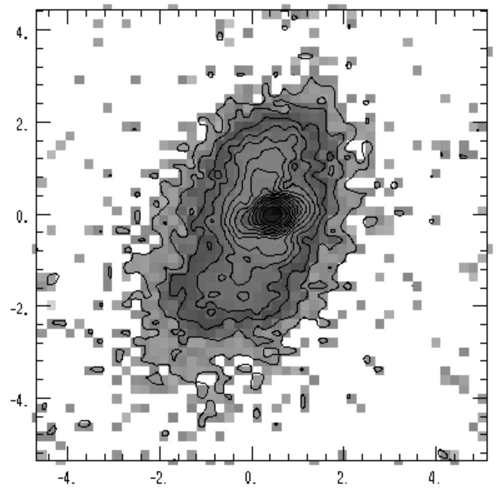

Fig. 2. Map of NGC 7582 through the N1 filter. A spiral structure oriented N–S is clearly seen. A perpendicular nuclear bar is also present.

inferred column density varies suggesting a patchy torus structure. Aretxaga et al. (1999) observed the development of broad Hα component during three months in 1998, which is also consistent with previous hypothesis. The existence of a hidden active nucleus is also suggested by the detection of an ionization cone in [O III] images (Storchi-Bergmann & Bonatto 1991). NGC 7582 also shows strong circumnuclear star formation (Morris et al. 1985). The far-IR emission is explained as a composite between AGN and starburst component, plus cold dust in the disk (Radovich et al. 1999).

In the mid-IR the morphology of NGC 7582 consists of a compact unresolved nuclear component (see Figure 1), plus an extended structure elongated from SE to NW resembling the beginning of two spiral arms (See Figures 2 and 3. This spiral structure contrasts with the morphology observed in the optical images (Malkan, Gorjian, & Tam 1998), in which a strong obscuration is seen on the E side. An inner bar (extending 2 arcsec), oriented almost E–W, can be clearly distinguished in the N1 band image(see Figure 2), but not in the other filters (see Figure 3). The diffuse emission observed in the [Ne III] line (see Figure 4) is similar to the conical morphology observed in the [O III] maps presented by (Storchi-Bergmann & Bonatto 1991).

We have also obtained a spectrum in the N band. PAH features at 7.6, 8.3, and 11.3 μm are clearly detected in the integrated spectrum (see Figure 5). In addition, there are a number of features whose identification cannot be firmly established yet. The most prominent feature appears at 9.5 μm and could

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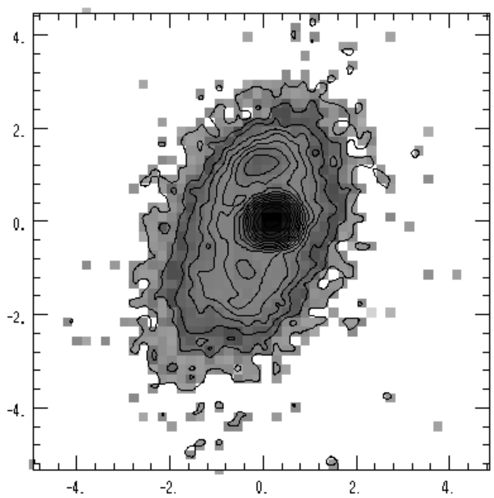

Fig. 3. Map of NGC 7582 through the 12.9 μm filter. The N–S spiral structure can be seen although the nucleus appears shift to the west with respect to the origin of the arms.

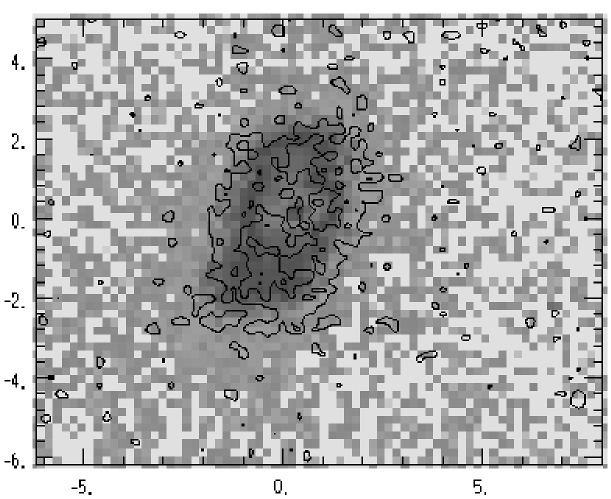

Fig. 4. Map of NGC 7582 through the [Ne II] filter. The emission appears diffuse and a central peak is not seen.

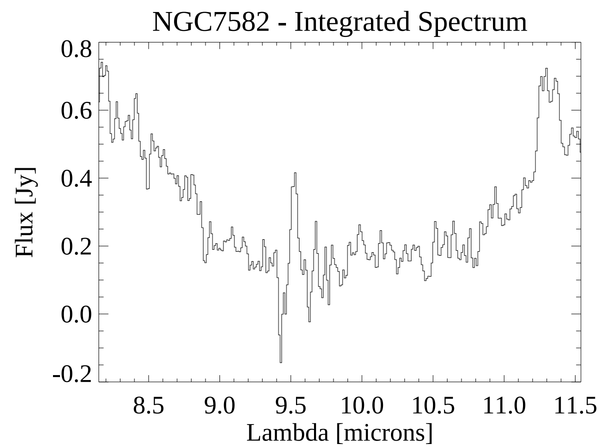

Fig. 5. Integrated spectrum corresponding to the central 4 arcsec. The slit orientation was N–S.

be associated with the molecular line H_2 S(3), the high excitation [S IV] could be also detected.

3. EXPECTED IMPROVEMENTS FROM CANARICAM

What can be gained using CANARICAM with respect to the current observations? The first thing to be gained is better spatial resolution; the diffraction limit for CANARICAM is about 0.2 arcsec, which is a factor 2.5 better than from TIMMI-2. The other thing will better sensitivity: for a 1 hr integration time in the N band, and $S/N = 5$ CANARICAM should reach 0.16 mJy (see http://www.iac.es/galeria/mrk/C-Cam/), whereas with TIMMI-2 we achieved 40 mJy. The increase in S/N together with the larger spatial resolution should make it possible to study spectroscopically the extended emission around AGN. In addition there is a coronagraphic mode which is ideal for measuring faint extended emission close to a very bright central source. It will be essential to have a filter set able to discriminate unambiguously between spectral features and continuum. Furthermore, there should be a quick and reliable data reduction in real time, which enables the astronomer to assess the quality of the data being obtained.

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