The spectral energy distribution of the central parsec-scaled region of AGN

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Abstract. Genuine spectral energy distributions (SEDs) of the central few parsec of the nearest and brightest active galaxies in the Southern Hemisphere are presented. They are compiled from very high spatial resolution observations in the radio (VLBA), the infrared (using adaptive optics and interferometry) and the optical (HST). The SEDs are characterized by two main emission bumps peaking in the X-rays and in the infrared respectively, as it is known from optically obscured galactic nuclei. Yet, the SED shape of the IR largely departs from the one derived from large aperture data. It reveals two new features: (1) a very sharp decay at wavelengths shortward of 2 µm, plausibly a consequence of the heavy extinction towards the core region and (2) a flattening in the 10-20 µm range as well as a downturn toward longer wavelengths. Accordingly, the true bolometric luminosity of these core regions turns out to be about an order of magnitude lower than previously estimated on the basis of IRAS/ISO data. These findings indicate that large aperture IR data are largely dominated by the contribution of the host galaxy. They warn against over-interpretations of IR/X-ray and IR/optical correlations based on large aperture IR data which are used to differentiate AGN from normal galaxy populations.

The new derived IR bolometric luminosities still exceed the output energy measured in the high energies by factors from 3 to 60. With the expectation that both luminosities should be comparable within an order of magnitude, the reduced factors between both suggests that the derived IR luminosities are getting closer to the genuine power output of the core.

Due to the apparent SED emission turnover in the mid-IR region, an extrapolation of the VLBA core emission towards shorter wavelengths closely meets the IR data. In Cen A, NGC 1068 and NGC 5506, this extrapolation fits a power-law with an exponent of about 1/3. This indicates that the IR emission may not be as dust dominated as previously thought but that it includes an important non-thermal component.

1. The spectral energy distributions of the nearest active galactic nuclei

High spatial resolution spectral energy distributions (SEDs) of the nearest and brightest nuclei of galaxies accessible from the Southern Hemisphere are presented. The selection is driven by the requirement to obtain, in the wavelength range of 1 to 5 µm, adaptive optics observations of the nuclei with spatial resolution scales comparable to those obtained with radio interferometry and HST. The galaxies analyzed so far include the best known southern AGN (e.g. Cen-
Figure 1. SEDs of the central parsec-scaled region of four representative AGN in our study: filled points represent the highest available spatial resolution data for these cores; the thin V-shape line in the mid-IR region corresponds to the spectrum of the unresolved source measured with VLTI/MIDI (W. Jaffe et al. these proceedings); crosses refer to large aperture data mainly from IRAS and ISO. Further information is provided in Prieto, Reunanen et al. (2007, in preparation).

taurus A, NGC 1068, Circinus, NGC 1097 and NGC 7582). The compiled SEDs make use of observations with the highest spatial resolution achievable with current instrumentation: (1) VLBA interferometry in the radio, (2) VLT NACO adaptive optics observation in the near infrared, (3) VLT VISIR diffraction limited observations and (4) VLTI interferometry, both in the mid-IR, as well as (5) HST observations in the optical. The spatial resolutions achieved in the IR have a FWHM ≲ 0.1 arcsec, equivalent to those achieved with HST in the optical and comparable to those in the radio. These unprecedented spatial resolutions in the IR allow us to pinpoint the true nucleus in each galaxy and extract its luminosity within aperture diameters of less than 1 to 10 pc at the distance of those targets.

Here we present SEDs that best illustrate the main result of this project, namely the new SED shape of these galaxy cores. The SEDs correspond to those
of Cen A, Circinus, NGC 1068 and NGC 7582. The first two galaxies are, with a distance of $\sim 4$ Mpc, the two nearest AGN in the Southern Hemisphere, while the latter are 4 and 7 times further away respectively.

In fig. 1 the filled points correspond to the data with the highest available resolution. The high energy range is covered by XMM, BeppoSax and COMPTEL data when available. For sake of clarity, fig. 1 shows only frequencies up to 10 keV. The optical is covered by HST. All these nuclei are heavily obscured, they are not detected in the optical and thus the optical data are upper limits. They are all, however, unveiled in the IR. They are unresolved at least from 2 $\mu$m on, except in the case of Circinus (Prieto et al. 2004) where a resolved source of 2 pc size is found. Fluxes from these nuclei in the 1-5 $\mu$m range from VLT/NACO adaptive optics data, in the 8 - 12 $\mu$m range from VLTI/MIDI interferometry data (when available), and in the 10 - 20 $\mu$m range from VLT/VISIR diffraction-limited data are included in the SEDs. The radio range is covered with VLBA/VLBI observations which are available for the core of Cen A and NGC 1068. No equivalent data exist for NGC 7582 and Circinus. In these two cases, the available radio data are from very large beams including both the core and lobes of the galaxy. As a reference for the true core emission, these large beam data are included as well in fig. 1. For all cases, the figure also includes mid-IR fluxes from large aperture IRAS and ISO data, which are marked by crosses.

2. Results: the new SED shape of AGN

Comparing the large aperture data (crosses, fig. 1) with the new high spatial resolution SEDs (filled points), two main differences become obvious: (1) the shape of the new SED in the IR clearly departs from that followed by the large aperture data, namely the new SED shows a flat distribution at 2-10 $\mu$m with indications for a fall off turnover towards lower frequencies; (2) the large aperture data are shifted up in power by more than an order of magnitude, the inferred bolometric luminosities are thus a factor of 2 to 10 larger than those estimated by the new high resolution data. These two findings indicate that the mid- to far-IR luminosity in AGN is dominated by the host galaxy contribution and thus IR luminosities derived from large aperture data cannot be taken as indicators of AGN activity or tracers of AGN populations.

2.1. The contribution of non-thermal emission to the IR in AGN

In some galaxies, the SED shape in the IR is such that a simple extrapolation of the VLBI core emission towards higher frequencies closely meets the IR. Subjected to the confirmation by millimetric data of comparable resolution, such extrapolation indicates that the IR emission may not be as much dust dominated as previously thought but some other non-thermal components may be equally important. The best example is the nucleus of Cen A: the VLBI to IR to optical data fit a synchrotron spectrum with a spectral index close to 0.3, similar to the case found in the Galactic Center source $Sgr\,A^*$, and corresponding to the index produced by a monoenergetic electron distribution. Accordingly, the SED of Cen A was modeled with a synchrotron spectrum produced by a quasi monoenergetic electron distribution. Such models have been suggested for $Sgr\,A^*$.
Figure 2. SED of the Cen A core dereddened by $A_V = 19$ mag, this being estimated from the silicate feature in the VLTI correlated flux spectrum. The continuous line is a synchrotron plus SSC model accounting for the radio and IR to the 0.1 MeV regime; the contribution of a weak accretion disk at optical wavelengths, and the “comptonization” stage of the accretion disk photons in a hot corona are also included. Radio points above the model are large aperture VLA data; millimetric data are also large aperture data and provided for comparative purposes only, high energies data include two emission states of Cen A. Details of the model are in Beckert et al. (2007, in preparation).
(Beckert & Duschl 1997, and references therein). The synchrotron model (fig. 2) successfully accounts for the observed $\gamma$-ray emission which dominates the high energy SED of Cen A, due to inverse Compton scattering of the radio synchrotron electrons. Because of the apparent naked nature of the Cen A nucleus, the contribution of a weak accretion disc to account for the dereddened nuclear optical emission is shown in fig. 2 however this component is not constrained with the available data. Details of the model will be presented in Beckert et al. 2007, in preparation.

References

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