The Interplay among Black Holes, Stars and ISM in Galactic Nuclei
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Emission processes in 3C 270

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Abstract. We identify the dominant emission processes in 3C 270 in the infrared to be non-thermal, and emission from its dusty disk does not contribute significantly to the total infrared output. This implies that such disks can be hard to find through their infrared emission, and that any circumnuclear torus, if at all present, is small and thin.

1. Introduction

Unification models for FR I radio galaxies lack the typical circumnuclear torus found in other models (Urry & Padovani, 1995). Such tori emit preferentially in the mid-infrared (van Bemmel & Dullemond, 2003). In the absence of observations of large, well-defined samples of FR I radio galaxies, a case study might shed light on the emission processes in the infrared. An ideal object for this purpose is 3C 270, in which a dusty disk has been detected in optical and UV HST images. The size of the disk is only somewhat larger than expected for a circumnuclear torus, but it could still emit significant amounts of infrared emission. Using radio to UV data, we have constructed and analyzed the SED of 3C 270, to determine the contribution of this disk. We adopt $F_\nu \propto \nu^\alpha$ and $H_0 = 65\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$.

2. Data collection and analysis

Using the NASA/IPAC Extragalactic Database a complete SED for 3C 270 has been constructed from radio to UV. From the archives more recent HST and ISO data have been obtained. Reduction was done where necessary, using the standard packages and analysis routines. Isolating the unresolved nuclear component at each wavelength, we constructed a core SED. Both the total flux and core SED are displayed in Fig. 1.

The total flux SED shows the typical components: synchrotron radio emission, an old stellar population in optical, but it is unclear what dominates the infrared. In a radio galaxy, there are three possibilities: non-thermal synchrotron emission, dust heated by the central source, or dust heated by star-formation in the host galaxy.

Using a Monte Carlo code, emission models have been generated for the dusty disk if it were heated solely by the AGN. The models are shown in Fig. 1. The infrared part of the SED is not fitted well, particularly in the mid-infrared, the region where a dusty torus would dominate. Additional heating by star-formation in the disk could not explain the lack of a good fit in the mid- and near-infrared, since the bulk temperature of the dust will not be high enough. Hence, the total flux SED is inconsistent with significant thermal dust emission in the infrared from either source.

The core SED reveals a double power-law shape, typical for jet-dominated synchrotron sources (Falcke et al., 2004). The power-laws only require the slope and offset as input, with $\alpha = 1$ at low frequencies and $\alpha = -2.5$ at high frequencies. With a mere four variables, 15 nuclear data points are well fitted. It is therefore most likely that the infrared emission is dominated by non-thermal synchrotron emission.

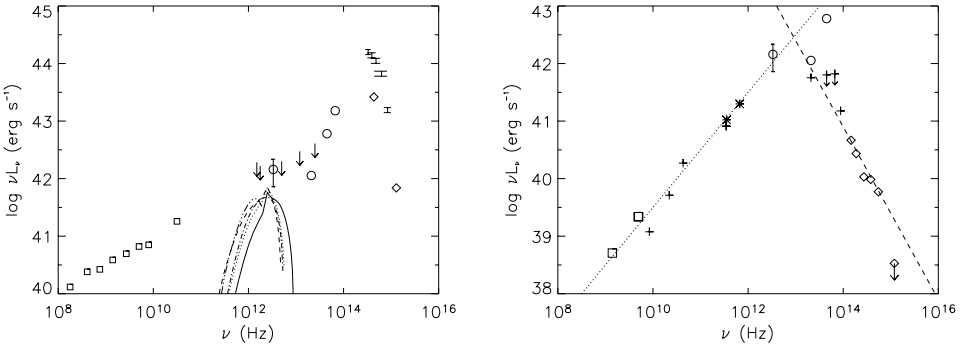

Figure 1. Total flux (left) and nuclear (right) SED for 3C270. Symbols are: squares: radio flux; arrows: IRAS & ISO upper limits; circles: ISO detections (N.B.**total** flux in both panels, source is unresolved at $\lambda > 10\,\mu$m); stars: SCUBA (Haas et al.,2004); plusses: Quillen et al. (2003); vertical bars: SDSS, diamonds: HST. In the left panel four radiative transfer models are over-plotted, varying in geometry, size and optical depth. None represent an adequate fit, and varying other parameters does not improve this. In the right panel the lines represent the double power-law jet-dominated synchrotron spectrum; dotted: $\alpha = 1$; dashed: $\alpha = -2.5$.

3. Discussion

We have demonstrated that synchrotron emission dominates the infrared emission in 3C 270. This has serious consequences for detecting dusty disks in radio galaxies at larger distances, where the spatial resolution doesn't allow for a detection at optical wavelengths. It also leaves the question open as to whether FR I radio galaxies have a circumnuclear torus at all.

Based on the models and accuracy of the power-law fit to the core flux, the dusty disk cannot contribute more than 50% of the total far-infrared flux, and much less at shorter wavelengths. If a circumnuclear torus is present in 3C 270, it must be small and thin, and will contribute even less than the large scale disk.

It remains to be seen if 3C 270 is representative of FR I radio galaxies as a group. However, it does stand in sharp contrast with the archetypal FR II radio galaxy Cygnus A, where thermal dust emission dominates the infrared from 1 up to at least 100 μm, and which is well fitted by a typical torus model (van Bemmel & Dullemond, 2003). The striking difference between these two sources may prove the infrared a poor regime to study differences between the radio classes, or even to test unification schemes.

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