Spatial resolution bias in the mid-infrared Starburst/AGN classification

O. Laurent [1], I.F. Mirabel [1,2], V. Charmandaris [3], P. Gallais [1],
M. Sauvage [1], L. Vigroux [1], C.J. Cesarsky [1]
[1] *CEA/DSM/DAPNIA Service d'Astrophysique, F-91191 Gif-sur-Yvette, France.*
[2] *Instituto de Astronomía y Física del Espacio. cc 67, suc 28. 1428 Buenos Aires, Argentina.*
[3] *Observatoire de Paris, DEMIRM, 61 Av. de l'Observatoire, F-75014 Paris, France.*

Abstract

We present the effects of limited spatial resolution to the observed mid-infrared (MIR) spectrum of an active galactic nucleus (AGN) surrounded by a disk with massive star forming regions. Using MIR observations of the face-on nearby Seyfert 1 galaxy NGC 6814, we vary the observing aperture and examine the evolution of the observed AGN/starburst fraction with our MIR diagnostic. We show that the spatial resolution of ISOCAM is sufficient to disentangle AGN from starburst features in nuclear regions of nearby galaxies (D < 50 Mpc). However, with the exception of a few ultra-luminous galaxies, dilution effects hide completely the AGN contribution in more distant galaxies.

1 Introduction

Based on ground-based MIR observations ([10], [2]) and more recently with ISO ([7], [4] and references therein), considerable progress has been made in defining the fraction of the AGN/starburst contribution to the MIR spectral energy distribution (SED) of luminous infrared galaxies. To further examine the AGN and starburst connection, we have developed a new MIR diagnostic diagram using ISOCAM observations from 5 to 16 μm, which allows us to quantify emission due to AGNs from that resulting from star formation activity (see [5] for details). Our diagram is based on the fact that MIR spectra of late type galaxies — assuming that the stellar contribution to active/star forming regions is negligible — can be decomposed in three components characteristic of emission from HII regions, photo-dissociation regions (PDRs) and AGNs. Each component presents an unique signature: 1) the hot continuum at short wavelengths (3-5 μm) is present in AGNs ([3], [2], [5]), 2) Unidentified Infrared Bands (UIBs) at 6.2, 7.7, 8.6, 11.3 and 12.7 μm are dominant in PDRs as well as in diffuse regions ([13], [11], [8]), and 3) a strong continuum due to emission from very small grains is detected in HII regions ([13], [1]). Due to the small physical size of the region which is heated directly by an AGN, a good spatial resolution is essential in order to probe the physics of the dust in nuclear regions hosting a weak AGN (i.e. where the MIR emission from the whole galaxy is largely higher than that from the AGN).

In order to examine how the spatial resolution of a telescope (in our case ISOCAM) may bias the detection of the MIR emission from an AGN and its surrounding star formation regions, we used NGC 6814, a nearby face-on Seyfert 1 galaxy located at 20 Mpc (H_0=75 km^{-1}Mpc^{-1})([12]), as a test case. The following section displays the effects of dilution in the MIR spectrum when we observe galaxies at increasingly larger distances. In Section 3, we show in detail how the integration beam affects the MIR SEDs as well as the evolution of the observed spectrum on our diagnostic diagram. Finally, we comment on the expected results from future instruments such as SIRTF and the NGST.

2 Contamination of an AGN from circum-nuclear starbursts.

The imaging capabilities of ISOCAM provide an angular resolution of 5"- 8" at 7-15 μm (250-400 pc at 10 Mpc). Even though in some extreme cases of ultra-luminous galaxies (e.g. IRAS 19254-7245 in [6] and IRAS 23060+0505 in [3]), the AGN contribution may completely dominate the total emission coming from a galaxy, the MIR emission in most galaxies of our sample containing an AGN is dominated by their disk emission. As a consequence, a good spatial resolution is necessary to separate galactic nuclei ($\sim$1 kpc in diameter) and to distinguish emission from an AGN. Moreover, intrinsic absorption particularly in Seyfert 2 galaxies can hide the AGN even in the MIR making its detection difficult. We present in Figure 1 images of NGC 6814 projected at different distances as well as their corresponding SEDs. Given a fixed aperture of 9" (3 pixels at 3"/pixel), we note the increase of UIBs associated with star forming regions in the galactic disk by observing distant galaxies. The AGN continuum is still detected at 50 Mpc, but it becomes negligible at 100 Mpc.

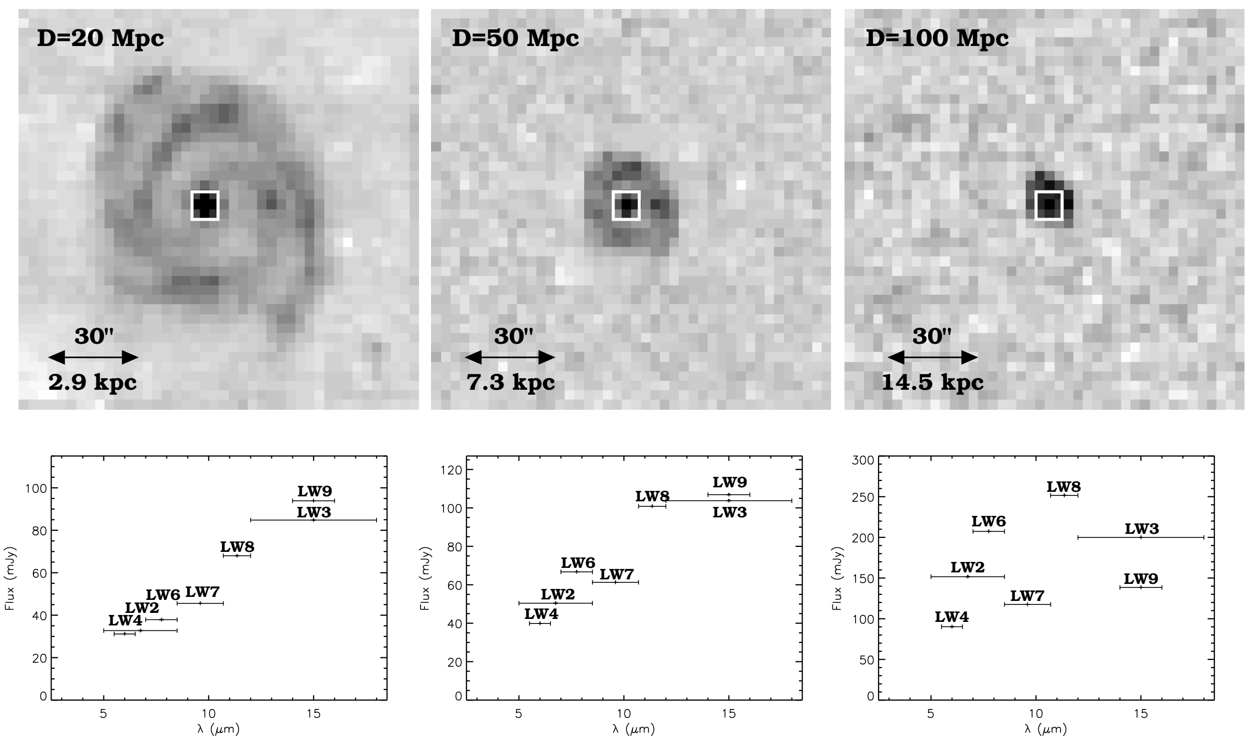

Figure 1: Effects of the spatial resolution in a MIR AGN spectrum. As an example, we use the Seyfert 1 galaxy NGC 6814 actually located at $\sim$20 Mpc (H_0=75 km^{-1}Mpc^{-1}). Left panel, we show an image of NGC 6814 in the 7-8.5μm band tracing mainly the UIB feature at 7.7μm. Middle panel, the galaxy is projected to a distance of 50 Mpc. Right panel, the projected distance is increased to 100 Mpc. For each distance, we calculate the flux inside a constant ISOCAM aperture given by 3$\times$3 pixels (i.e. 9"$\times$9", see SEDs underneath images). We have also applied an aperture correction to get spectra comparable to those in Figure 2.

3 MIR spectral classification: from an AGN to a galactic disk.

Our new MIR diagnostic diagram classification method is based on the UIB strength (LW2(5-8.5μm)/LW4(5.5-6.5μm)) and the slope of the MIR continuum (LW3(12-18μm)/LW2(5-8.5μm)) ([5]). In Figure 2, we present 8 SEDs corresponding to aperture diameters from 9"(nucleus) to 93"(whole galaxy) where we can observe the evolution from "pure" AGN spectrum to "pure" PDR spectrum (i.e. the AGN continuum is not detected). We can note the importance of the spatial resolution to find out MIR AGN features in our diagnostic diagram.

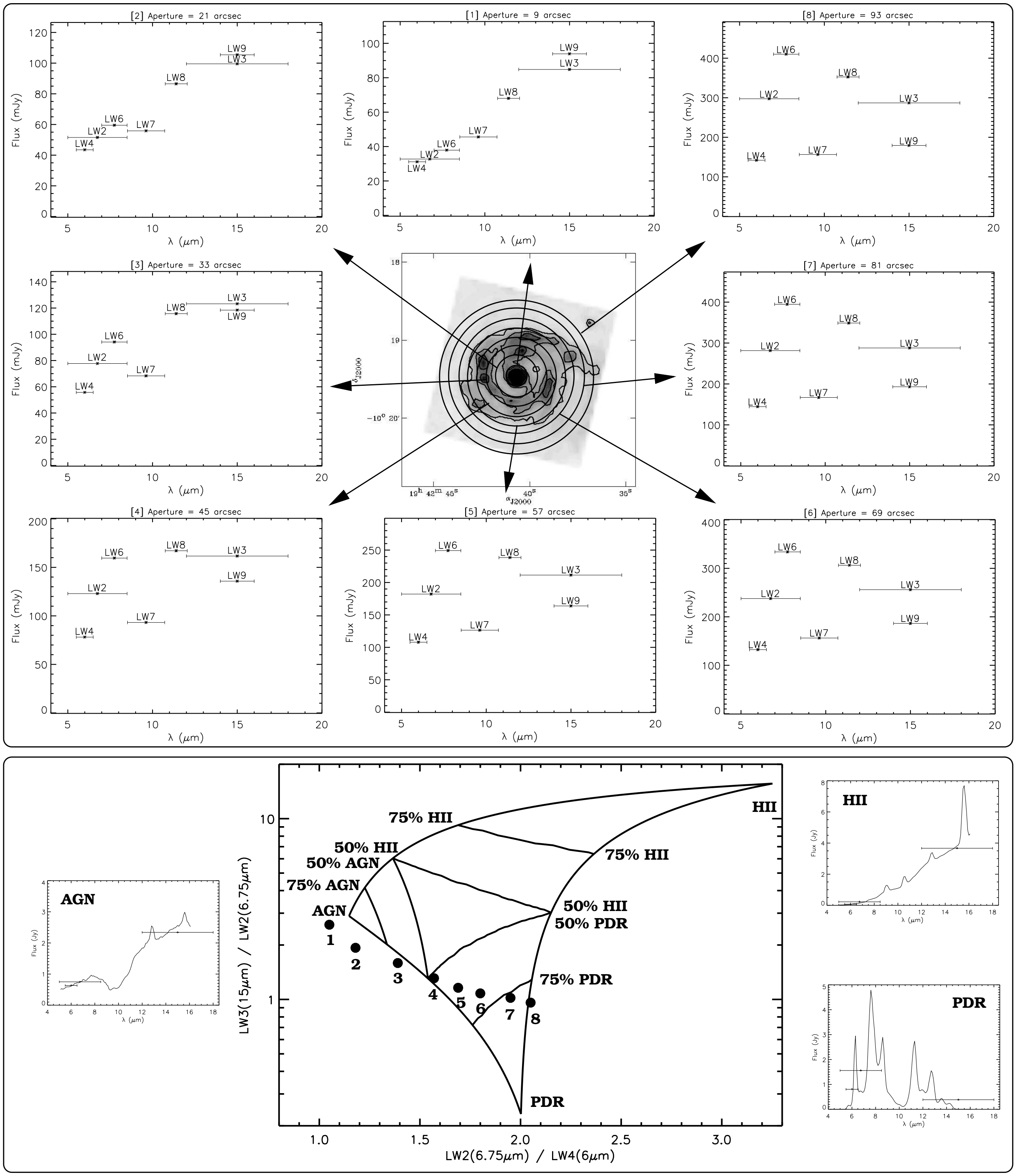

Figure 2: Top panel: variation of the MIR emission as a function of the size of the integrating aperture. We can follow (counter-clockwise) the evolution of the shape of the SED for each aperture radius from the AGN (Spectrum 1) to the total integrated galaxy (Spectrum 8). Note the absence of UIBs and the strong rising continuum at short wavelengths (5-8.5 μm) in the central region (Spectrum 1) typical of AGN emission. By increasing the aperture radius, the disk contribution dominated by UIBs contaminates the AGN emission. Bottom panel: application of our MIR diagram ([5]), for all SEDs. Each point corresponds to a spectrum marked from 1 to 8. The percentages indicate the fraction in the MIR (5-16 μm) of each template, in the observed spectra. The increasing disk contribution changes our classification from "AGN-like" to the "PDR-like", which is typical to galactic disks. The AGN dominates the MIR emission only for small apertures smaller than 45" in diameter (up to spectrum 4 with diameter = 4.3 kpc).

ISOCAM was the first instrument allowing us deep imaging covering the total wavelength range between 5 and 16 μm. Our diagnostic method can successfully detect the presence of an AGN in galaxies. However, it is limited to finding AGNs in nearby galaxies at distances less than 50 Mpc with the exception of some ultra-luminous galaxies powered principally by AGN. For galaxies at z>0.1, the redshift effect begins to play an important role since we look at through fixed broad band filters and as a consequence the shape of our diagnostic changes.

MIR observations IR-luminous galaxies at distances up to z=1, require new infrared instruments such as SIRTF and the NGST who will provide better spatial resolution to study the relationship between starburst and AGN emission. Moreover, due to their higher sensitivity, one could also compare our results with other MIR diagnostic based on ionic lines of high excitation levels which trace the presence of the AGN radiation field ([3]). These two methods are complementary since forbidden line emission due to an AGN in high resolution spectra can be easily identified in a spectrum (see the SWS spectrum of Circinus in [9]) even when a starburst is dominating the total MIR emission.

4 Conclusions

Studying the effects of spatial resolution in our MIR spectra we conclude that:

1) Our MIR diagnostic diagram based on the ISOCAM spatial resolution (∼8") can detect the presence of AGNs in late type galaxies only in the local Universe (D < 50 Mpc).

2) Some AGNs associated with ultra-luminous "monsters", which are encountered in merging systems and dominating the integrated MIR emission, can be detected at large distance such as IRAS 19254-7245 located at 250 Mpc.

3) Future instruments with higher spatial resolution will provide better estimates of the AGN/starburst fraction in more distant galaxies (D > 50 Mpc).

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