Present AGN and starburst models aiming to account for the observed infrared SEDs consider a physical description of the dust and a solution of the radiative transfer problem. Mid infrared spectra obtained at different spatial scales (SST-IRS, ISO and Timmi2) are presented. They show that PAH bands are detected in starburst regions but significantly reduced near the centre of AGN. This is explained by examining the heating mechanism of PAHs after hard (FUV, X-ray) photon interactions. Most economic radiative transfer models of starbursts and AGN are presented where only key parameters such as luminosity, dust mass or size of the nucleus are varied. For both activity types synthetic spectra are made available. The successful application of the starburst model is demonstrated by fitting broad band data and detailed Spitzer IRS spectra of NGC7714. The AGN model is applied to ISOCAM and ISOPHOT broad band data of a sample of 68 radio galaxies and quasars of the 3CR catalogue. Radiative transfer models of galaxies with Hidden Broad Line Regions (HBLR) are presented. Their SED enable us to separate the contributions from the dusty disc of the AGN and the starbursts. We find that the combination of AGN heated discs and starbursts provide good fits to the data. The composite model is consistent with the unified scheme and the idea that the inferred emission of AGN is dominated by a dusty disc in the mid-infrared and starbursts in the far-infrared. According to the unified scheme, AGN are surrounded by a dust-torus, and the observed diversity of AGN properties results from the different orientations relative to our line of sight. The strong resonance of silicate dust at 10 \( \mu m \) is therefore, as expected, seen in absorption towards many type-2 AGN. In type-1 AGN, it should be seen in emission because the hot inner surface of the dust torus becomes visible. However, this has not been observed so far, thus challenging the unification scheme or leading to exotic modifications of the dust-torus model. Here the recent discovery of the 10 \( \mu m \) silicate feature in emission in luminous quasar spectra observed with the SST/IRS is reported.

1 Introduction

Nuclei of luminous infrared galaxies are generally dust enshrouded and not transparent. Therefore radiative transfer calculations have to be carried out for an optically thick dusty medium.
This has been done in various approximations of the physics in starburst and AGN dominated galaxies. In the following I summarize some of our recent findings on the dust interaction with hard radiation, the application of the models to recent Spitzer data and report on the discovery of the silicate emission in type 1 AGN.

Seyfert galaxies

![Figure 1: Mid-infrared flux densities in Jy of Seyfert galaxies (Siebenmorgen et al. 2004 [2]): histograms and dashed lines are large beam (14" – 20") ISO observations, thick lines are narrow slit (3") data with TIMMI2. Note that PAH bands are visible in the large beam spectra but absent in the high spatial resolution data of the same galaxy.]

2 The Dust Model

Any dust model should be based on fitting interstellar extinction curves, abundance constrains and dust features. We use large carbon and silicate grains with radii, \( a \), between 300 and 2400 Å with a size distribution \( n(a) \propto a^{-3.5} \); very small graphites \( (a = 10\, \text{Å}) \); and two kinds of PAHs (30 C and 20 H atoms; 252 C and 48 H atoms). The PAH abundance is such that for \( 10^5 \) protons in the gas phase one finds one carbon atom in each PAH population. The infrared absorption coefficient, \( \kappa_\lambda \), of astronomical PAH is derived by Siebenmorgen et al. (2001) [1].

The MIR emission bands give important insight on the activity type of a galaxy: starburst or AGN. Active galaxies with Seyfert nuclei often show strong PAH emission bands when observed
at large scales, say with the spatial resolution of ISO/SST ($\geq 10''$). However, mid infrared spectra of the same galaxy are PAH free when observed at high spatial resolution and where the slit is centered close to the nucleus. A few examples of this finding are presented in Fig. 1.

This observational fact and a study of the survival of PAHs in starburst and AGN environments with energetic photons of, at least, a few up to hundreds of $eV$ is presented by Siebenmorgen et al. (2004) [2]. It is found that small grains evaporate after interaction with hard photons; in particular with photons of more than $50eV$, which can only be emitted by X-ray sources. A simple explanation is given by studying the quantum statistical behaviour of PAHs. This destruction process is considered in the radiative transfer models described below.

3 Radiative transfer models

The radiative transfer in a dust cloud around a starburst is computed following Siebenmorgen et al. (2001) [1], around an AGN after Siebenmorgen et al. (2004b) [3]. The major difference between both radiative transfer models is that AGN are heated by a central source emitting hard photons whereas starburst galaxies are heated by stars which are distributed over a large volume.

The radiative transfer in starburst nuclei is solved by a scheme first described by Krügel & Tutukov (1978) [4] for the Galactic Centre and generalized by Krügel & Siebenmorgen (1994) [5] for starbursts. In the starburst models two populations of stars are considered OB stars have a uniform luminosity of $20000L_\odot$ and a stellar temperature $T_\ast = 25000K$ and KM stars with stellar temperature $T_\ast = 4000K$. The stellar density of OB stars changes with galactic radius $r$ from the center like $\propto 1/r$. An important feature of the starburst model is that each OB star is surrounded by a dust shell, for which we apply a constant dust density, $n^{OB}(H)$. The inner radius of this circumstellar dust shell is given by the photo-destruction or evaporation radius of the grains. The outer radius of such hot spots is determined by the condition of equal heating of the dust from the star and from the radiation field in the galactic nucleus. Therefore most of the UV light of a particular OB star is absorbed by the circumstellar dust shell and then re-emitted at infrared wavelength into the galactic nucleus. Hence for starburst galaxies the radiative transfer has to be solved for two different scales: first, on galactic scale of the nucleus and second, for each of the dust embedded OB stars. Both transfer problems are linked to each other via the boundary conditions (for example the outer radius of the circumstellar shell) and an iterative scheme is applied to find a self consistent solution. Starburst models presented by other groups often simplify matters and consider the first problem for an ensemble of OB stars or molecular clouds assuming an optically thin medium surrounding it. A grid of our starburst model spectra is available where four basic parameters are varied: the luminosity of the OB and KM stars, the size of the nucleus, the total extinction of the nucleus (as measured from surface to center), and the dust density of the circumstellar shells surrounding the OB stars. In Fig. 2 we present one example of such model fits to the SED of NGC7714. The fits successfully reproduce the detailed Spitzer IRS spectrum (Charmandaris, priv. com.) of the dust emission. Gas features are not treated. Slight fine tuning of the PAH abundance will result in an even better fit.
Figure 2: Spectral energy distribution of the starburst galaxy NGC7714. Spitzer IRS (Charmandaris, priv. com.) and NED data are in green, other curves are starburst models with luminosity between $10^{10.9-11}L_{\odot}$ (by assuming a distance of 40Mpc), visual extinction $A_V = 2.5$mag and a dust density surrounding the OB stars of $n$(H): $10^3$, $2.5 \times 10^3$ cm$^{-3}$. The size of the nucleus is not varied and fixed to 3kpc.

Figure 3: Spectral energy distribution of the hidden broad line region galaxy 3C321. Two radiative transfer models are compared: i) a three parameter fit (dashed line) using the AGN model by Siebenmorgen et al. (2004b) [3] and ii) a combination of a tapered torus model with starburst activity by Efstathiou & Siebenmorgen (2005) [6]. Both models are consistent with the observations. However, the later is in better agreement with the unification model and provides correction for the anisotropic torus emission.
Figure 4: Spectra and models of the quasars 3C249.1 and 3C351, obtained with the Infrared Spectrograph (IRS) of the Spitzer Space Telescope (Siebenmorgen et al. (2005) [7]). AGN-typical high-excitation emission lines like $[\text{Ne V}] \lambda=14.3\mu\text{m}, \lambda=24.3\mu\text{m}$ are marked with vertical dotted lines. The broad bump in the wavelength range $9 - 13 \mu\text{m}$, indicated by horizontal dotted lines, is the detected silicate emission. The models consist of a central heating source with an X-ray-to-infrared power-law spectrum, two dust components and a black body. The warm (140 – 200K) dust component is located 30 – 100pc from the central heating source, while the cold (30 – 70K) dust is more than 600pc and up to a few kpc further out.
4 AGN and starburst composite spectra

Most active galaxies are known to be composite objects where a Seyfert nucleus is surrounded by a ring of star formation. Efstathiou & Siebenmorgen (2005) [6] fit ISO data of galaxies with hidden broad line regions. In their models a combination of a tapered AGN torus with starburst activity is treated using six free parameters. One example of the model fit is given for 3C321 in Fig. 3. We compare the fit with a pure and simplified AGN model by Siebenmorgen et al. (2004b) [3] where only 3 parameters: luminosity, effective size and extinction of the nucleus are varied to compute the SED. (A full grid of such models is available by request.) As shown in Fig. 3, both models are consistent with the data. However, the model by Efstathiou & Siebenmorgen enables to separate the contribution from the dusty disc of the AGN and the dusty starbursts. We find that tapered discs dominate the emission in the mid infrared part of the spectrum and the starbursts in the far infrared. The AGN models by Efstathiou & Siebenmorgen have a two dimensional structure therefore they provide a correction factor of the AGN luminosity for anisotropic emission and are more consistent with the unified scheme.

5 AGN unification and the MIR emission of quasars

According to the unified scheme, AGN are surrounded by a dust-torus, and the observed diversity of AGN properties results from the different orientations relative to our line of sight. The strong resonance of silicate dust at 10\(\mu\)m is therefore, as expected, seen in absorption towards many type-2 AGN. In type-1 AGN, it should be seen in emission because the hot inner surface of the dust torus becomes visible. However, this has not been observed so far, thus challenging the unification scheme or leading to exotic modifications of the dust-torus model. In Fig. 4 we present our recent discovery of the 10\(\mu\)m silicate feature in emission in luminous quasar spectra observed with the Infrared Spectrograph of the Spitzer Space Telescope is presented (Siebenmorgen et al. (2005) [7]).

The Spitzer observations, as well as the photometric data at other infrared wavelengths, can be reproduced by a model consisting of three components: cold (30 – 70K) and warm (140 – 200K) dust and a hot blackbody. The primary heating source has a power-law spectrum, \(F_\nu \propto \nu^{-0.7}\), in the wavelength range 1\(\AA\) – 15 \(\mu\)m. The emission of the dust is treated to be optically thin which is a reasonable assumption for a face-on viewed quasar. Of course, this approach needs further refinement by a self-consistent axial-symmetric radiative transfer model of the quasar emission, on which we are working.

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