*Galaxy Evolution and Feedback across Different Environments*
*Proceedings IAU Symposium No. 359, 2020*
*T. Storchi-Bergmann, W. Forman, R. Overzier & R. Riffel, eds.*
doi:10.1017/S1743921320001635

# Modelling the silicate emission features in type 1 AGNs: Dusty torus and disk+outflow models

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**Abstract.** We investigated how the most common dusty torus models reproduce both the 10 and 18$\mu$m silicate emission features observed in the nuclear infrared (IR) *Spitzer* spectrum of type 1 active galactic nuclei (AGN). We use a sample of type 1 AGN for which the *Spitzer* spectrum is mostly dominated by the emission of the AGN (>80%), and the 10$\mu$m silicate emission feature is prominent ($1\sigma_{Si_{10\mu m}} > 0.28$). The models are the smooth dusty torus models from Fritz *et al.*, the clumpy dusty torus models from Nenkova *et al.* and Hoenig *et al.*, the two-phase media torus model from Stalevski *et al.*, and the disk+outflow model from Hoenig *et al.* These models differ by assuming either different geometry or dust composition. We found that in general, all models have difficulties reproducing the shape and peak of the silicate emission features, but the disk+outflow model is the best reproducing the AGN-dominated *Spitzer* spectrum.

**Keywords.** galaxies: active

## 1. Introduction

The emission of both 10 and 18 $\mu$m silicate features observed in the nuclear spectrum of type 1 AGN, obtained with the Infrared Spectrograph (IRS) on the *Spitzer* Space Telescope, is intimately linked to the physical properties of the dust in the nucleus of these galaxies, where is located the "putative" dusty torus that surrounds the central engine (super massive black hole, accretion disk and, broad line region) of the AGN. The dust in the torus absorbed the UV and optical emission produced by the accretion disk and re-emit it in the IR. In type 1 AGNs is possible to observe the emission from the dust directly heated by the AGN, while in type 2 AGNs, this emission is blocked by the outermost cold dust located along the line of sight. Therefore, to investigate how the most used dusty torus models in the literature reproduce the silicate emission features observed in type 1 AGNs, we selected a sample of local ($z < 0.1$) type 1 AGNs, for which the IRS/*Spitzer* spectrum, between $\sim 5 - 30$ $\mu$m, is mostly dominated (>80%) by the emission of the dust heated by the AGN, between them, we chose those in which the 10 $\mu$m silicate emission feature is prominent, i.e, those with the strongest 10 $\mu$m silicate strength ($1\sigma_{Si_{10\mu m}} > 0.28$, 10 objects). We used four dusty torus models, the smooth (Fritz *et al.* 2006) torus model, two clumpy (Nenkova *et al.* 2008a and Hönig *et al.* 2010) torus models, the two-phase media (Stalevski *et al.* 2016) torus model, and the disk plus outflow (Hönig & Kishimoto 2017) model, to investigate which of these models better reproduce the shape and peak of both silicate emission features since these models assume different geometries and/or dust composition (see Martínez-Paredes *et al.* 2020).

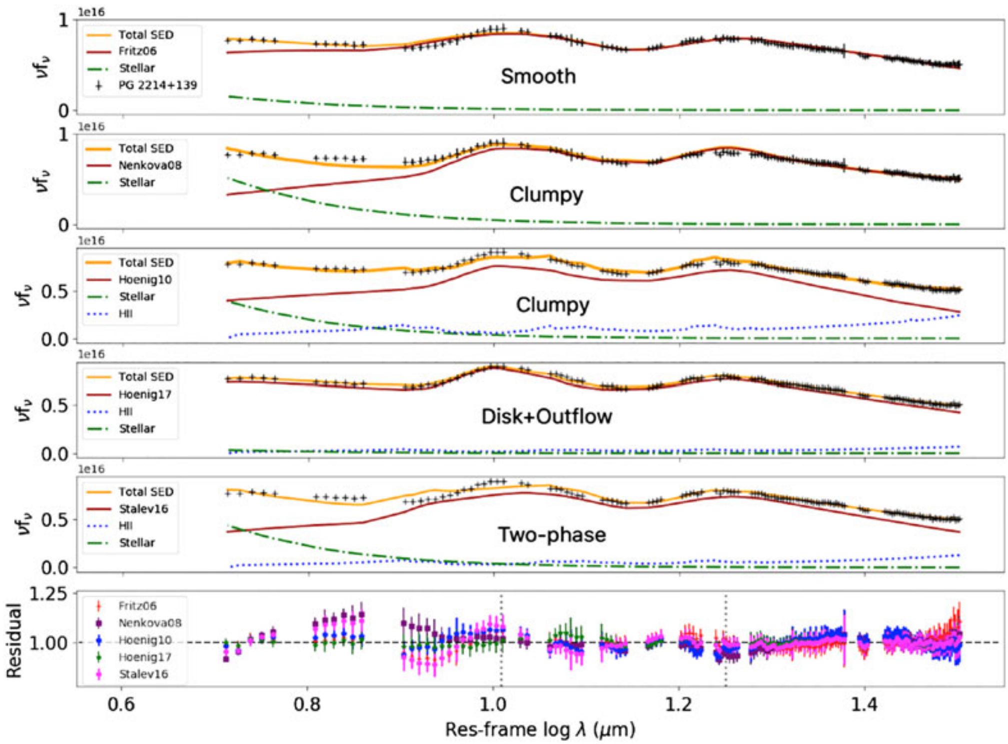


**Figure 1.** Modelling of the AGN-dominated IRS/*Spitzer* spectrum (in black) of the type 1 AGN PG 2214+139. From top to bottom is the modelling assuming the smooth dusty torus from Fritz *et al.* (2006), the clumpy dusty torus from Nenkova *et al.* (2008a,b), the clumpy dusty torus from Hönig *et al.* (2010), the disk+outflow model from Hönig & Kishimoto (2017), and the two-phase dusty torus model from Stalevski *et al.* (2016). The last panel shows the residuals. This figure is from Martínez-Paredes *et al.* (2020).

## 2. Results

We measured, for models and observations, both the 10 and 18 $\mu$m silicate strength ($Si_{\lambda_p} = ln f_{\lambda_p}(spectrum)/f_{\lambda_p}(continuum)$) at the wavelength where they peak, as well as the near- $(5.5 - 7.5\mu\text{m})$ and mid-IR $(7.5 - 14\mu\text{m})$ spectral indexes. Comparing the synthetic and observational values, we found that in general, the models predict the 10 and 18 $\mu$m silicate strength values observed in these objects. However, when we compare the 10 and 18 $\mu$m central wavelengths, we found that only the values observed in the objects (2) with the lowest bolometric luminosity ($L_{bol} < 10^{42}$erg s$^{-1}$ cm$^{-2}$) are poorly sampled by all models. In Figure 1 we show the fitting of the AGN-dominated IRS/*Spitzer* spectrum of the object PG 2214+139. In general, we found that clumpy models better reproduce the 10 and 18 $\mu$m silicate emission features than smooth models. However, on average, we noted that the disk+outflow model better reproduces the AGN-dominated IRS/*Spitzer* spectrum between $\sim 5 - 30\,\mu$m, specially for objects with the highest luminosity ($\sim 10^{44} - 10^{46}$ erg s$^{-1}$cm$^{-2}$).

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https://doi.org/10.1017/S1743921320001635 Published online by Cambridge University Press

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