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THE PARSEC-SCALE INFRARED EMISSION OF SEYFERT GALAXIES

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RESUMEN

Presentamos distribuciones espectrales de energía (SEDs) en el infrarrojo cercano y medio de 21 galaxias de tipo Seyfert, obtenidas a partir de datos con resolución espacial por debajo del segundo de arco. Nuestro objetivo es comparar las propiedades del toro molecular de las galaxias Seyfert 1 (Sy1) y Seyfert 2 (Sy2). Para ello hacemos uso de modelos de toro no homogéneos y de métodos Bayesianos para ajustar las SEDs infrarrojas. De acuerdo a nuestros ajustes, estos toros tendrían tamaños típicos de hasta 6 parsecs de radio. El modelo unificado de núcleos de galaxias activas (AGN) explica las diferencias entre tipos 1 y 2 basándose en la orientación del toro. Sin embargo, nosotros encontramos evidencias de que este modelo simple podría no ser válido, ya que los toros de las galaxias Sy2 de nuestra muestra son más anchos y contienen un mayor número de nubes que los de las Sy1. Así pues, la clasificación podría depender de las propiedades intrínsecas del toro, además de su orientación, en contradicción con el modelo unificado más simple.

ABSTRACT

We present near-to-mid-infrared spectral energy distributions (SEDs) for 21 Seyfert galaxies, using subarcsecond resolution imaging data. Our aim is to compare the properties of Seyfert 1 (Sy1) and Seyfert 2 (Sy2) tori using clumpy torus models and a Bayesian approach to fit the infrared (IR) nuclear SEDs. These dusty tori have physical sizes smaller than 6 pc radius, as derived from our fits. Active galactic nuclei (AGN) unification schemes account for a variety of observational differences in terms of viewing geometry. However, we find evidence that strong unification may not hold, and that the immediate dusty surroundings of Sy1 and Sy2 nuclei are intrinsically different. The Type 2 tori studied here are broader and have more clumps than those of Type 1. Thus, on the basis of the results presented here, the classification of a Seyfert galaxy may depend on the intrinsic properties of the torus rather than on its mere inclination, in contradiction with the simplest unification model.

Key Words: galaxies: active — galaxies: nuclei — galaxies: Seyfert — infrared: galaxies

Ground-based MIR high-angular resolution observations of 21 nearby active galaxies were carried out over the past years for a variety of science drivers. The observations were obtained with the instruments OSCIR, T-ReCS and Michelle on the Gemini telescopes. For details on the MIR observations we refer the reader to Ramos Almeida et al. (2009, 2011).

Using these MIR data and NIR data of similar resolution compiled from the literature, we constructed subarcsecond resolution nuclear SEDs in the wavelength range from ∼1 to 18 μmfor 21 Seyfert galaxies.

The clumpy dusty torus models of Nenkova et al. (2008a,b) hold that the dust surrounding the central engine of an AGN is distributed in clumps, instead of homogeneously filling the torus volume. The clumpy database now contains $\sim 5\times 10^6$ models, and the inherent degeneracy between the model parameters has to be taken into account when fitting the observables. To this end, we developed a Bayesian inference tool (BayesClumpy; Asensio Ramos & Ramos Almeida 2009). The results of the fitting process of the IR SEDs using BayesClumpy are the posterior distributions for the six free parameters that describe the models. In addition, we can translate the results into corresponding spectra (see Figure 1). The clumpy models successfully reproduce the individual Seyfert SEDs with compatible results among them and with torus outer radii smaller than 6 pc, in agreement with MIR direct imaging of nearby Seyferts (e.g. Packham et al. 2005) and interferometry (e.g. Tristram et al. 2007).

To take full advantage of the Bayesian approach, we normalized all the Sy1 SEDs at 8.74 μm and fitted them together using BayesClumpy, and we did the same for the Sy2. In Figure 1 we show the Sy1 (left panel) and Sy2 fits (right panel). Note that the maximum-a-posteriori (MAP) and median models predict a flat SED with the silicate feature in weak emission for the Sy1 galaxies, and steeper and

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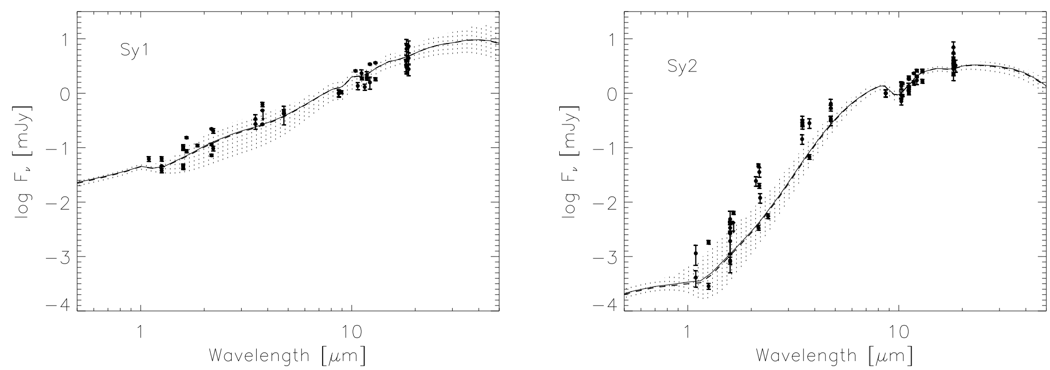

Fig. 1. Individual Sy1 (left) and Sy2 SEDs (right) normalized at 8.74 μm and fitted with the clumpy torus models. Solid and dashed lines correspond to the MAP and median models, respectively. Shaded regions indicate the range of models compatible with the 68% confidence interval for each parameter around the median.

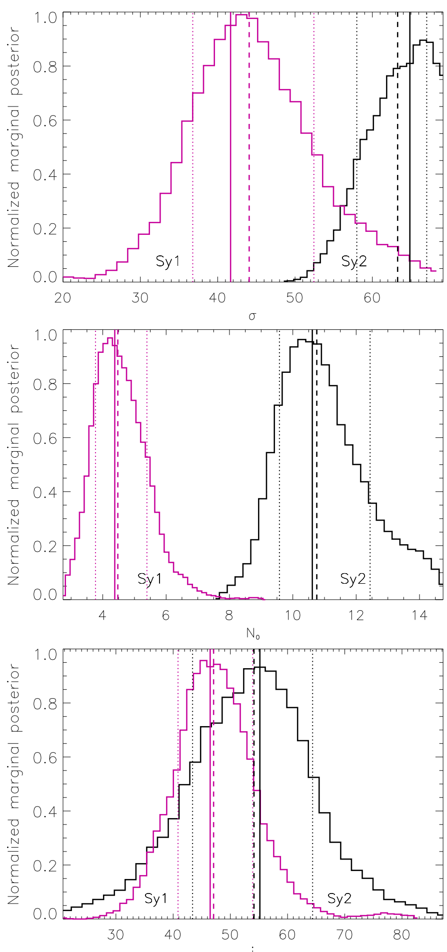

Fig. 2. Posteriors resulting from the fits of the joint Sy1 and Sy2 SEDs. Solid and dashed lines represent the mode and the median of each distribution and dotted lines indicate the 68% confidence level for each parameter around the median.

with the silicate band in shallow absorption for Sy2. The comparison between the Sy1 and Sy2 posterior distributions for three of the free model parameters is shown in Figure 2. From a visual inspection it is clear that the joint posteriors of the number of clumps (N_0) and the width of the clump distribution (σ) are completely different between Sy1 and Sy2. There is no overlap between the 1-sigma intervals.

Sy1 tori are narrower and have fewer clouds (median values $\sigma = 44°\pm^{8°}_{7°}$ and $N_0 = 4 \pm 1$) than those of Sy2 ($\sigma = 63°\pm^{4°}_{5°}$ and $N_0 = 11\pm^{2}_{1}$). Interestingly, we find high as well as low values of the inclination angle of the torus (i) for Sy1 and Sy2, which translates into similar median values of the joint Sy1 and Sy2 posteriors ($47°\pm^{7°}_{6°}$ for Sy1 and $54°\pm^{10°}_{11°}$ for Sy2). *This is telling us that, in the clumpy torus scenario, the classification of a Seyfert galaxy as a Type 1 or 2 may depend on the intrinsic properties of the torus rather than in mere inclination.*

In order to confirm this challenging result, a larger an homogeneous sample of Sy1 and Sy2 galaxies observed in the NIR and MIR at subarcsecond resolution is required. We plan to do this using the MIR instrument CanariCam on the 10m GTC and the NIR camera NIRI on the 8m Gemini North. These observations will lead to the definitive characterization of the AGN unifying torus.

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