Mid-IR Imaging Atlas of Nearby Seyferts

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I. Introduction

The AGN unified model (Antonucci 1993; Urry & Padovani 1995) explains the observed differences between Type I and Type II galaxies (including Seyferts) as solely due to orientation. Type I objects are observed nearly pole on, allowing observations of both the inner broad emission line region (BLR) and the narrow-line region (NLR). Type II objects are observed nearly edge on where the BLR is obscured due to an optically and geometrically thick dusty torus. The torus dust grains absorb ultraviolet/optical photons from the central engine and reradiate them with a peak near mid-IR wavelengths (10-20 μm).

However, observations suggest that the thermal emission in Seyferts is complex and may not be adequately addressed by a simple Unified Model. Ramos-Almeida, C. et al. (2009, 2011) suggest that the classification of Seyfert as Type I or II depend more on the intrinsic properties of the torus rather than solely on its inclination towards us as would be the case in a strict unification theme. They show that Seyfert Type II likely contain tori with larger covering fractions than Seyfert Type I resulting in a higher chance of an obscured line-of-sight to the BLR characteristic of Type I. Another intriguing tentative result is that the covering factor decreases with increasing AGN luminosity (Alonso-Herrero et al. 2011), based on a combination of spectroscopy and SED fitting. In addition, ongoing observations using T-ReCS and MICHELLE have shown that the covering fraction of Seyfert II galaxies are also larger than that of Seyfert I's on larger scales with Type II Seyferts typically containing more dust in the form of extended mid-IR emission that Type I. This poster will highlight some of these observations of extended Type II Seyferts as well as the different mid-IR emission mechanisms in an ongoing survey of Seyferts observed as part the **CanariCam AGN Science team.**

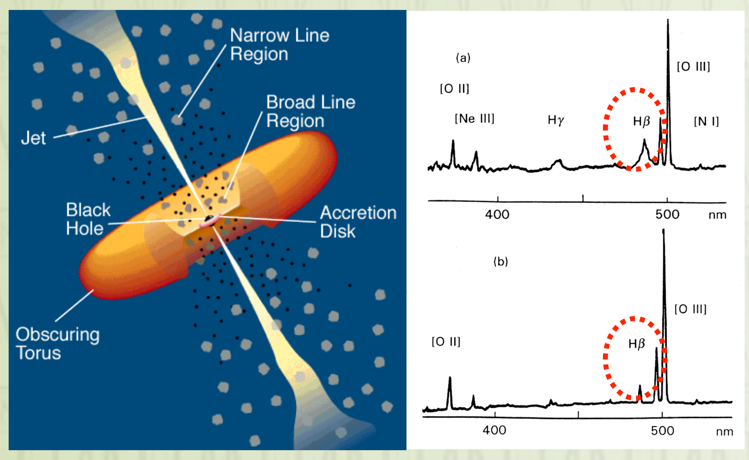

Figure 1. Simple AGN model from Urry and Padovani outlining basic structure. Spectra (a) shows narrow [OIII] and broad Hβ emission characteristic of the BLR in a Type I Seyfert. Spectra (b) shows only narrow Hβ and [OIII] characteristic of a Seyfert I (credit: Robson; Active Galactic Nuclei).

II. Torus

The mid-IR torus emission typically occurs on scales of a few parsecs or less (Radomski et al. 2008; Packham et al. 2005) and are usually unresolved even for nearby Seyferts. To separate unresolved torus emission from extended emission we use a PSF subtraction technique. In order to take account of the contamination of the extended emission, we subtract the PSF at several percentage levels of the peak emission in order to fit the best profile. Torus properties are then derived using clumpy torus models of Nenkova et al. (2008) (also see Levenson et al. 2009; Ramos-Almeida, C. et al. 2009, 2011).

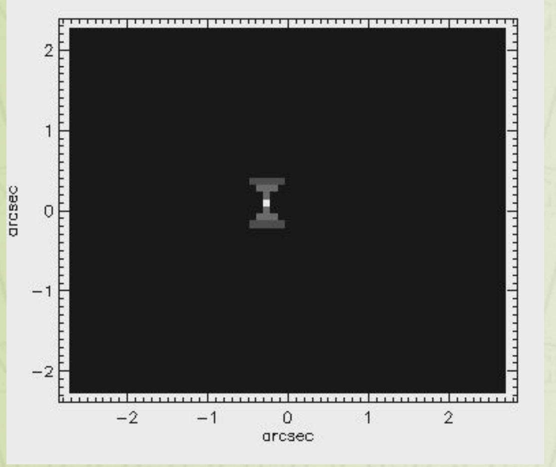

Figure 2. Simple model of unresolved torus and NLR to test PSF subtraction technique. One T-ReCS pixel (0.089") represents the torus and 15% of the peak emission.

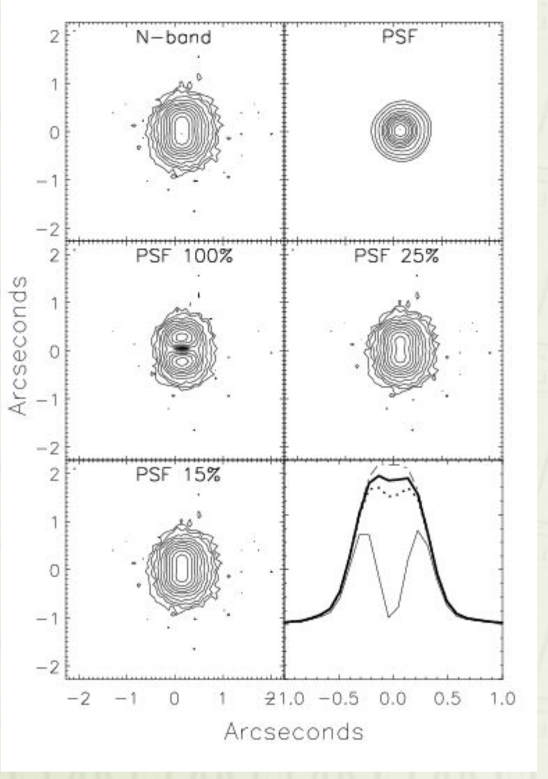

Figure 3. This image shows the simple model on the left convolved to the resolution at the telescope. The PSF is then subtracted at several levels (100%, 25%, and 15%) of the peak galaxy emission. The plot in the lower right shows a line cut in the direction of extended emission. The large dip represents the 100% PSF subtraction indicating that this is likely an over subtraction since the extended emission is unlikely to be zero at the center. Assuming a flat profile of the extended emission across the center is more accurate, the best fit is the dark line which represents 15% (±10%) of the peak emission. Thus this technique is better at recovering the unresolved emission due to a possible torus rather than just a simple subtraction of the PSF scaled to 100% of the peak.

III. Narrow Line Region Dust

Thermal emission in Seyferts from the central engine is not limited to the torus. Dust in the NLR can also play an important role, though is rarely the dominant emission mechanism (observations suggest typically 10-40%). Examples of such emission in Seyferts have been seen in NGC 4151 (Radomski et al. 2003) and Circinus (Packham et al. 2005). Further examples include the galaxies NGC 4388 and NGC 1386 seen below where the mid-IR NLR align with the NLR as detected in [OIII]. Observations have also shown that using the [OIII] luminosity as a proxy for the luminosity of the central AGN one can reliably predict whether an extended NLR is observable given typical dust grain properties and temperatures at the distance/resolution of the the source.

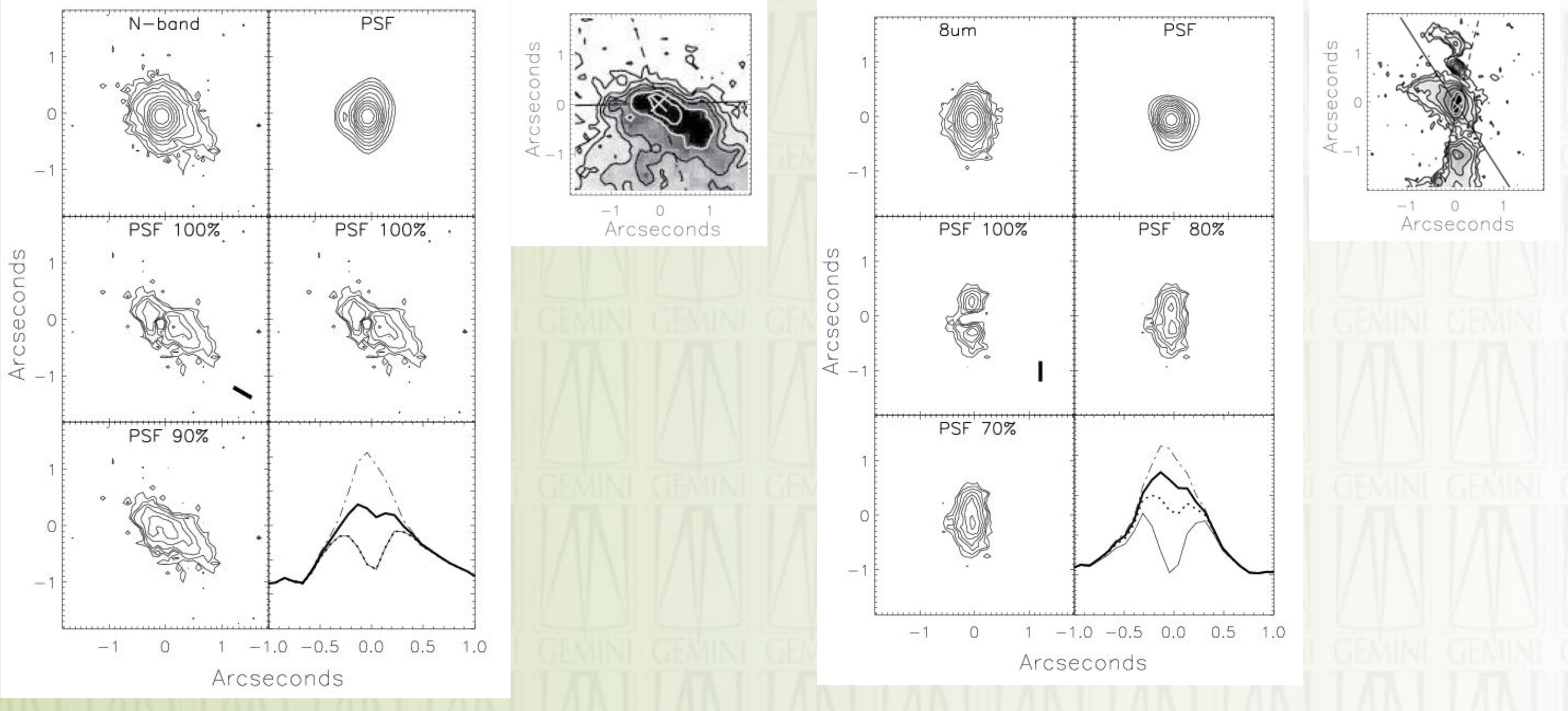

Figure 4. Images show PSF subtracted images of nearby Seyferts NGC 4388 (left) and NGC 1386 (right) with extended mid-IR NLR's. Best fits of the unresolved emission likely due to the torus is 90% of the peak and 70% of the peak emission respectively. The extensions in the mid-IR are in the same direction as that of the [OIII] seen by HST (Schmitt et al. 2003). Theses regions are consistent with heating of dust from a central luminous region based on the [OIII] luminosity of the AGN and typical dust grain emission properties.

IV. Star Formation

Star formation on circumnuclear scales can dominate the thermal emission of Seyferts and even completely obscure the torus emission in some cases. Below are two example from our survey NGC 7582 and NGC 4945. Multi-wavelength observations confirm the star formation component of the extended mid-IR emission. In addition, the extent of such emission is far beyond that possible for central heating due to the AGN as one might expect in a dusty NLR. In NGC 7582 the unresolved source still dominates the total emission while in NGC 4945 the unresolved torus represents no more than 10% (±10%) of the peak emission of the galaxy and is likely completely obscured by the central star formation.

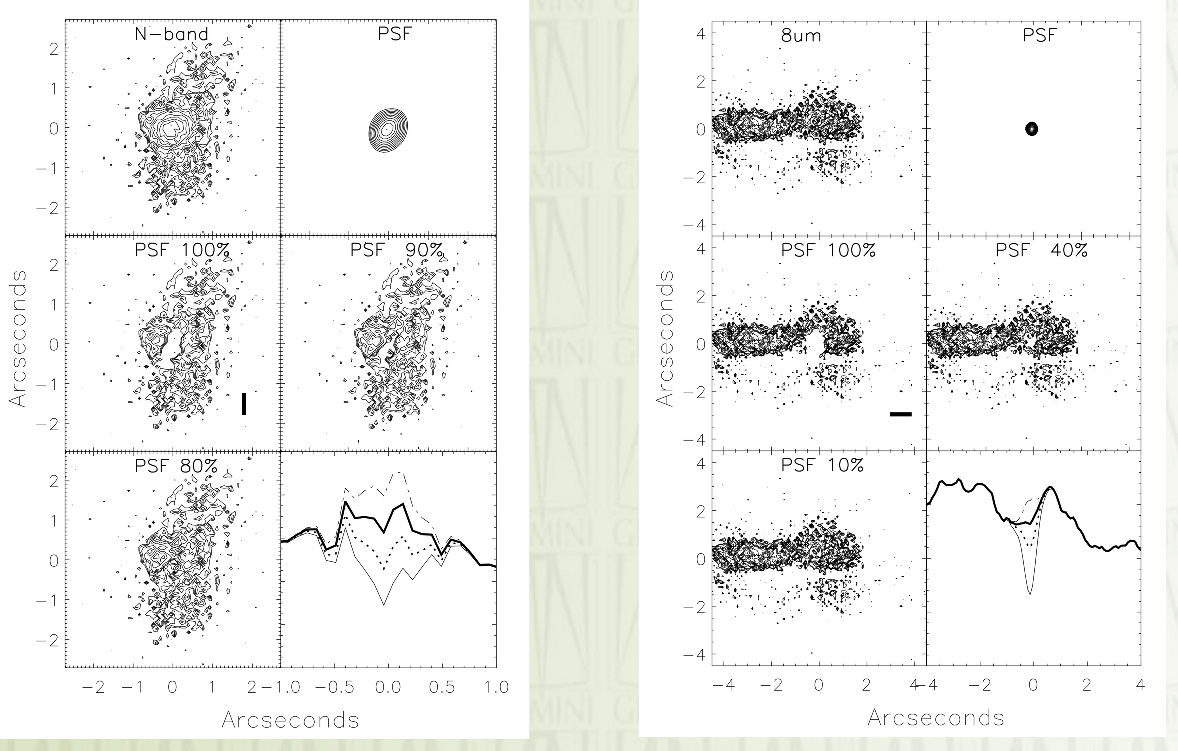

Figure 5. T-ReCS observations of NGC 7582 (left) and NGC 4945 (right) showing the galaxy and PSF followed by several PSF subtraction intervals at different peaks.

V. Summary

The thermal emission associated with Seyferts is complex with multiple emission mechanisms including emission from the central torus, dusty NLR, and central star formation regions. Ongoing observations using T-ReCS and MICHELLE as part of the **CanariCam AGN Science team** are beginning to build a large enough survey for a statistically significant sample of Seyferts showing possible differences in the circumnuclear environment and torus structure between Type I and II Seyferts. Future observations using the mid-IR camera/spectrometer CanariCam on the GTC will be used to complete this survey.

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