

Astrophysical Sciences & Technology
Ph.D. Dissertation Defense

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Dusty Donuts: Modeling the Reverberation Response of the Circumnuclear Torus Emission in Active Galactic Nuclei

Advisor: Andrew Robinson

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Abstract:

The obscuring circumnuclear torus of dusty molecular gas is one of the major components of AGN (active galactic nuclei), yet its size, composition, and structure are not well understood. These properties can be studied by analyzing the temporal variations of the infrared (IR) dust emission from the torus in response to variations in the AGN continuum luminosity; a technique known as reverberation mapping. In a recent international campaign 12 AGN were monitored using the Spitzer Space Telescope and several ground-based telescopes, providing a unique set of well-sampled mid-IR and optical light curves which are required in order to determine the approximate sizes of the tori in these AGN. To help extract structural information contained in the data a computer model, TORMAC, has been developed that simulates the reverberation response of the clumpy torus emission. Given an input optical light curve, the code computes the emission of a 3D ensemble of dust clouds as a function of time at selected IR wavelengths, taking into account light travel delays.

A large library of torus reverberation response simulations has been constructed, to investigate the effects of various geometrical and structural properties such as inclination, cloud distribution, disk half-opening angle, and radial depth. The effects of dust cloud orientation, cloud optical depth, anisotropy of the illuminating AGN radiation field, dust cloud shadowing, and cloud occultation are also explored in detail. TORMAC was also used to generate synthetic IR light curves for the Seyfert 1 galaxy, NGC 6418, using the observed optical light curve as the input, to investigate how the torus and dust cloud properties incorporated in the code affect the results obtained from reverberation mapping. This dissertation presents the most comprehensive investigation to date showing that radiative transfer effects within the torus and anisotropic illumination of the torus can strongly influence the torus IR response at different wavelengths, and should be accounted for when interpreting reverberation mapping data. TORMAC provides a powerful modeling tool that can generate simulated IR light curves for direct comparison to observations. As many types of astronomical sources are both variable and embedded in, or surrounded, by dust, TORMAC also has applications for dust reverberation studies well beyond the AGN observed in the Spitzer monitoring campaign.