Near-Infrared Reverberation by Dusty Clumpy Tori in Active Galactic Nuclei

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According to recent models, the accretion disk and black hole in active galactic nuclei are surrounded by a clumpy torus. We investigate the NIR flux variation of the torus in response to a UV flash for various geometries. Anisotropic illumination by the disk and the torus self-occultation contrast our study with earlier works. Both the waning effect of each clump and the torus self-occultation selectively reduce the emission from the region with a short delay. Therefore, the NIR delay depends on the viewing angle (where a more inclined angle leads to a longer delay) and the time response shows an asymmetric profile with a negative skewness, opposing to the results for optically thin tori. The range of the computed delay coincides with the observed one, suggesting that the viewing angle is primarily responsible for the scatter of the observed delay. We also propose that the red NIR-to-optical color of type-1.8/1.9 objects is caused by not only the dust extinction but also the intrinsically red color. Compared with the modest torus thickness, both a thick and a thin tori display the weaker NIR emission. A selection bias is thus expected such that NIR-selected AGNs tend to possess moderately thick tori. A thicker torus shows a narrower and more heavily skewed time profile, while a thin torus produces a rapid response. A super-Eddington accretion rate leads to a much weaker NIR emission due to the disk self-occultation and the disk truncation by the self-gravity. A long delay is expected from an optically thin and/or a largely misaligned torus. A very weak NIR emission, such as in hot-dust-poor active nuclei, can arise from a geometrically thin torus, a super-Eddington accretion rate or a slightly misaligned torus.

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