Inferring the Solid Composition of Disrupting Minor Planets in White Dwarf Dusty Disks from Infrared Spectra

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Revealing the source materials of planets is important for understanding the interior of solid exoplanets that are ubiquitously found beyond our solar system. Between a quarter and half of white dwarfs have metals in their atmospheres (e.g. Zuckerman et al., 2010), and some of them exhibit an infrared excess from their circumstellar dusty discs (Rocchetto et al., 2015). These are thought to originate from minor planets that survive their host stars' post-main-sequence evolution and are subsequently disrupted around white dwarfs. Therefore, observations of metals in and around white dwarfs could provide a unique opportunity to probe the solid composition of minor planets.

If we can determine the mineral composition of dust particles in the disks around white dwarfs through their thermal emission spectra, we could infer the composition of disrupted minor planets. In fact, noticeable silicate features have already been detected in several disks, and Reach et al. (2009) constrained the candidate dust composition for the disk around G29-38 based on its observed infrared spectra. However, they did not investigate which particle sizes and disk geometries determine the observed spectra's profile. While Ballering et al. (2022) studied the dependence of spectra on such disk parameters, they fixed the dust composition at a hypothetical mineral, astronomical silicate.

In this study, we consistently investigate the impacts of dust mineral composition and disk parameters on spectra. We use a simple analytical two-layer model of passive disks (Chiang et al. 2001) to calculate the thermal emission spectra of the disk around G29-38. When comparing the calculated spectra to the observed ones, we focus on (1) the silicate feature at 10 μm and (2) the gentle excess peak at 5 μm. First, as Ballering et al. (2022), we calculate the spectra assuming dust composed of the hypothetical material, astronomical silicate. We find that the emission from particles on the disk surface at ~1000K governs the spectra profile. Furthermore, particles smaller than 5 μm produce (1) while larger particles than ~5 μm contribute to (2). We then recalculate the emission spectra using optical data of existing amorphous silicates, iron metal, and amorphous carbon (Dominik et al. 2021). We find that dust consisting solely of silicate cannot reproduce the shape of (2) even if changing disk parameters. On the other hand, the mixture of pyroxene silicate and amorphous carbon can well reproduce both (1) and (2). The best-fit composition allows a wide range of Mg/Fe ratios for pyroxenes but limits carbon fraction to 3－4wt%, implying that the disk originated from planets with C-type asteroid-like elemental composition. In this presentation, I will also discuss the results of the analysis of other white dwarf disks whose infrared spectra have been observed.