Detecting water ice and vapor in debris disks around white dwarfs with future PRIMA observations

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Observations of atmospheres of polluted white dwarfs provide valuable insights into the elemental composition of accreted exoplanets and exo-asteroids. However, they poorly constrain the abundance of ice-forming volatile elements due to the properties of white dwarf atmospheres (e.g., Williams et al. 2024, A&A, 691, A352). Instead of focusing solely on atmospheric observations, we propose to observe circumstellar water ice and vapor disks formed by the tidal disruption of icy bodies using the future PRobe Far-Infrared Mission for Astrophysics (PRIMA) far-infrared enhanced survey spectrometer. Water vapor may experience suppression of accretion due to angular momentum exchange with dust. Diffusing outward beyond the disk's ice sublimation line, it could re-condense into ice particles, serving as a potential mass reservoir of circumstellar ice (Okuya et al. 2023, MNRAS, 519, 1657). PRIMA has the potential to measure volatile abundances in such colder circumstellar regions inaccessible by shorter-wavelength observations.
We calculate the flux density of the emission from rocky dust and water ice using the radiative equilibrium model for passive disks (Chiang et al. 2001, ApJ, 547, 1077) and the integrated line flux of water vapor using the non-LTE 1D radiative transfer code RADEX (Van der Tak et al. 2007, A&A, 468, 627). We employ disk parameter ranges inferred from previous observations and disk evolution simulations. As a result, we find the 44-μm water ice feature promising for observing icy disks. For white dwarfs within 60 pc, 1-h PRIMA observations could detect water ice with a mass above 10^{20} g, representing a potential lower limit of circumstellar disk mass. Water vapor rotational lines also abundantly emerge within the PRIMA wavelength coverage, and 5-h observations for white dwarfs within 20 pc could detect water vapor with a total disk mass of $\gtrsim 10^{20}$ g, depending on the H_2/H_2O ratio. A total of 19 metal-polluted white dwarfs within 20 pc and 210 within 60 pc could be optimal targets for water vapor and ice observations, respectively. This presentation is based on Okuya & Nomura (2025, JATIS, 11, 031607).