Modeling of accretion disks originating from disrupted rocky/icy planetary bodies around white dwarfs

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A growing number of debris disks have been detected around metal-polluted white dwarfs. They are thought to originate from tidally disrupted planetary bodies and are responsible for metal accretion onto host WDs. Observations have shown that (1) a large number of polluted WDs are inferred to have the accretion rate higher than that predicted by Poynting-Robertson flux, $\dot{M}_{\rm PR}$, and that (2) terrestrial rocky materials would be common polluting sources. Metzger et al. (2012) developed the first accretion disk model that formulates interaction between silicate particles and silicate vapor to propose that (1) and (2) could be reproduced by runaway silicate gas accretion. However, the effect of re-condensation of the silicate gas remained an unsolved issue.

In this study, we revisit this problem by one-dimensional advection/diffusion simulation that consistently incorporates silicate sublimation/condensation and back-reaction forces exerted on gas collectively by particles drifting due to gas drag. We find that because silicate vapor density in the region overlapping the solid particles follows the saturating vapor pressure, no runaway accretion occurs, and (1) cannot be reproduced by mono-compositional rocky disks. As outer planetesimal belts would leave larger mass up to the WD age, infalls of icy-rich bodies may frequently occur. They add volatile vapor (e.g., water vapor) to a silicate disk, which does not condense in the region overlapping the silicate particles. As a result, we demonstrate that volatile vapor enhances the silicate accretion through gas drag as steady accretion and this explains (1). Although the icy-rich composition appears inconsistent with (2), we find that the back-reaction of silicate particles on volatile vapor could produce the volatile accretion rate lower than the silicate accretion rate by an order of magnitude.