Sintering-induced dust ring formation in protoplanetary disks

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The latest ALMA observation of HL Tau revealed spectacular concentric dust rings in its circumstellar disk. We propose the hypothesis that the multiple rings resulted from the sintering of icy aggregates in the disk. Sintering is the process that fuses particles consisting of an aggregate at temperatures slightly below the melting temperature of the particles. Sintering makes aggregates harder but less sticky (Sirono 1999; Sirono & Ueno 2008), thereby suppressing their growth through coagulation. In a protoplanetary disk, icy aggregates are thought to contain various volatiles such as CO and CH_4, each of which may cause the sintering of the aggregates in the vicinity of its snow line (Sirono 2011). We construct a simple model that takes into accout sintering, coagulation, and radial drift (Adachi et el. 1976; Weidenschilling 1977) of composite ice aggregates in a protoplanetary disk. We find that the aggregates pile up in the sintering zones near the snow lines because smaller aggregates drift toward the central star more slowly. At millimeter wavelengths, the sintering zones are seen as bright, optically thick rings with a spectral slope of 2, whereas the non-sintering zones are seen as as dark, optically thin rings of a spectral slope of 2.3-2.5. The observational features of the sintering and non-sintering zones are consistent with those of the major bright and dark rings found in the HL Tau disk, respectively. We also apply our model to the protoplanetary disk of TW Hya, for which latest ALMA observations suggest the presence of a pileup of dust near the CO snow line (Nomura et al. 2016).

Keywords: HL Tau, TW Hya, sintering, ALMA

