Debris Disks Caused by Giant Impacts and their Time Evolution

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Warm Debris Disks (WDDs) are located in the terrestrial planet forming regions around their hosts stars, and can be observed from the infrared excess luminosity of main-sequence stars. The lifetimes of the dust grains in WDDs is much smaller than the stellar ages, therefore to maintain the WDDs a supply of dust grains is necessary. The dust in WDDs is supplied by the fragments ejected from collisions between planets (called giant impacts), which are expected to occur in the final stages of terrestrial planet formation, and explain the observed infrared excesses. Those fragments collide with each other, resulting in still smaller fragments. The successive collisions among the fragments grind them down until micron-sized or smaller fragments are blown out by stellar radiation pressure. This collisional cascade, associated with the re-accretion of some fragments by the surviving planets, decreases the total mass of fragments in the disk.
The evolution of giant impact debris disks is governed by the collisional cascade, whose timescale is much longer than several thousand years. The succession of giant impacts and collisional cascades roughly explains the relation of WDDs' infrared excesses to the ages of host stars. However, some WDDs show the brightness evolution in much shorter timescales.
Giant Impacts are highly energetic events, which result in the production of both big rocky debris and rocky vapor. The amount of vapor generated from a single giant impact represents about 10% of the total ejecta mass. This vapor expands and cools down, finally condensing into small rocks ranging from mm-cm in size (herein called vapor condensates). The orbits of the vapor condensates evolve much like that of the bigger fragments, and they also undergo the collisional cascade. Given their size, the collisional cascade timescale of the vapor condensates is much shorter than the larger rocks, and can explain the short term variations in some WDDs.
We investigate the orbital and mass evolution of the ejecta originated from a giant impact between protoplanets via N-body simulations with collisional cascade. We use the super particle approximation to treat the fragments, and assume that they do not have gravitational interaction with each other. We investigate the mass evolution of the vapor condensates originated from such giant impact (mm-cm size), as well as that of non-vaporized bigger fragments. The collisional cascade of the vapor condensates is as short as the timescales of the short-term variations of the WDDs. On the other hand, non-vaporized bodies evolve in a much longer timescale. By combining the fractional luminosity evolution of the vapor condensates with that of non-vaporized fragments, we observe the formation of peaks in the fractional luminosity of the disk at different epochs, compatible with the variations observed from WDDs fractional luminosities.

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