Large-scale planetesimal formation and water transport in evolving protoplanetary disks with a dead-zone

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When, where and how planetesimals form in a protoplanetary disk are highly debated questions. While streaming instability (SI) is largely considered the most promising mechanism for forming planetesimals, the conditions for its onset are very stringent. Recent works have shown that SI can be effective close to the H_2O snow line of a fully turbulent disk. However, it is thought that the planet-forming region is mostly laminar because of non-ideal MHD processes that form dead zones (DZ). Here we investigate planetesimal formation using a 1D time-evolving stratified protoplanetary disk model that includes a DZ, transport of multiple dust species (Si, Fe, CAIs, H_2O, CO), condensation/vaporization and growth/fragmentation, as well as prescriptions for planetesimal formation.

In the presence of a DZ, accretion of planetesimals develops over a wide region from the H_2O snow line, up to the CO ice line, with most planetesimals forming close to the snow line. The surface density ratio of pebbles to planetesimals is less than 1 in this region, but reaches unity close to the CO ice line. This generates a viable pathway to slow down pebble accretion ~~processes~~ for giant-planet formation. Around 1 Myr after time zero, the snow line moves outward because of mass-loading in the DZ, leaving water-rich planetesimals inside the snow-line next to water-poor ones. Water vapor abundance increases by a factor 10-100 below the snow-line in about 1 Myrs due to the efficient influx of pebbles from the outer Solar System. Between 1 and 10 Myrs, water nominally disappears, leaving a dry inner Solar System. If the fragmentation velocity of silicate-rich dust is increased to 10 ms^{-2}, then up to 100$M_\oplus$ of planetesimals can form at the inner edge of the DZ. These results show that a DZ allows the general formation of planetesimals across wide regions. Regions close to the snow line or the inner edge of the DZ are favoured, and planetesimal composition at a given radius is dominated by material coming from much larger distances. These observations suggest that giant planets may form at about 20 AU, where pebble accretion is more efficient.