Probing the protosolar disk using dust filtering induced by the gas giants in the early Solar System

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During the formation of the Solar System, Jupiter and Saturn played an important role in modulating and controlling the dust dynamics through the formation of gaps and dust traps in the protoplanetary disk. This is reflected in the distribution of chondrules and calcium-aluminum-rich inclusions (CAIs) in chondrite meteorites believed to have accreted in different disk regions. CAIs are almost exclusively present in chondrites accreted in the outer Solar System [1], and there are clear isotopic fingerprints showing that althougth inner Solar System chondrules were transported to the outer Solar System, no outer Solar System chondrules returned to the inner Solar System [2].

A dust trap can only stop particles above a certain size, while small particles are well coupled and flow through the trap together with the gas [3]. Using a large suite of two dimensional multifluid hydrodynamical simulations of the protosolar disk advanced for up to 45,000 Jupiter orbits that include gas, dust, and planets, we investigate the efficiency of the planet induced dust traps for different physical conditions and dust grain sizes. These models are compared to cosmochemical evidence with a systematic search for CAIs in slabs from the ordinary chondrite NWA 5697. Characterising the elemental abundance of polished sections with a 5 μm resolution using electron microscope scans, we identify 10 CAIs with a maximum linear size of 200 μm.

The combination of state-of-the-art numerical models and laboratory data give new insight into the architecture of the young Solar System. We will present constraints on the gas surface density of the protoplanetary disk at Jupiter's location. In addition, by comparing the size distribution and relative mass abundance of CAI fragments in ordinary chondrites to that in outer Solar System chondrites, we estimate the ratio of dust mass in the protosolar disk inside and outside of Jupiter's orbit. Furthermore, we find that models which have Jupiter and Saturn in a 3:2 resonance, as expected in the Nice II model [4], are difficult to reconcile with the obtained CAI size distribution in NWA 5697.

[1] Hezel et al (2008), MAPS, 43, 1879 [2] Olsen et al (2016), GCA, 191, 118 [3] Weber et al (2018), ApJ, 854, 153 [4] Levinson et al (2011) AJ, 142, 152