



From Dust Till Dawn – How Dust Aggregates grow to Planetesimals with Tribocharging

Florence Chioma Onyeagusi, Jens Teiser, and Gerhard Wurm

University of Duisburg-Essen, Duisburg, Germany (florence.onyeagusi@uni-due.de)

In planet formation, the evolution of particles from dust to km-sized planetesimals goes through different stages of growth processes [1]. Starting with micron dust, hit-and-stick collisions create rather fluffy aggregates. With further collisions, these aggregates become more compact until the kinetic energy cannot dissipate into deformation anymore. At about mm-size, the dust aggregates reach the so-called bouncing barrier, where further growth is halted [2]. However, for subsequent growth mechanisms (e.g. hydrodynamic trapping through streaming instability) to set in, cm- to dm-sized pebbles are needed [3]. There are several approaches and explanations how one could overcome the bouncing barrier. One of them is collisional charging. Through tribocharging, there will be a transfer of electric charges between particles with each impact, leaving surface charges at the point of contact [4,5]. In previous experiments, these surface charges have already proven to be the cause of stable cluster formation for solid, monolithic grains [6]. Now, for the very first time, we also observed clustering of charged dust aggregates.

We conducted microgravity experiments at the Drop Tower in Bremen with mm and sub-mm aggregates made from μm dust. The sample is placed in an experiment cell under vacuum conditions. During the 9 seconds of microgravity, the cell can be shaken to distribute the sample and induce inter-particle collisions. The video data show that the particles move rather randomly through the volume of the cell. For the sub-mm aggregates, clusters already form during the shaking phase. For the mm particles, the clustering only begins as soon as the shaking stops and the granular gas has somewhat cooled down. Both samples form cm-sized clusters, the smaller particles more efficiently than the larger ones. The clusters are stable when colliding with the wall but can be eroded by particle impacts at certain velocities. When an electric field is applied to the chamber walls, single particles and small clusters are accelerated to the walls, indicating that they are electrically charged.

Our findings show that electric charges are capable of bridging the bouncing barrier. Sub-mm and mm particles that are made up of μm grains will stick together after impacts below a certain velocity, forming cm-clusters that are mostly stable against further impacts. This paves the way for pebbles to grow to a size range where further growth processes set in, eventually leading to km-sized planetesimals that can accrete more mass gravitationally.

References:

- [1] G. Wurm, J. Teiser, 2021, Nature Reviews Physics, Vol. 3, No. 6, Springer Science and Business Media LLC, p. 405-421

- [2] A. Zsom, C. W. Ormel, C. Güttler, J. Blum, C. P. Dullemond, 2010, *Astronomy & Astrophysics*, 513, A57
- [3] A. Johansen, H. Klahr, T. Henning, 2006, *The Astrophysical Journal*, Vol. 636, No. 2, American Astronomical Society, p. 1121-1134
- [4] D. J. Lacks, T. Shinbrot, 2019, *Nature Reviews Chemistry*, Vol. 3, No. 8, Springer Science and Business Media LLC, p. 465-476
- [5] T. Steinpilz, F. Jungmann, K. Joeris, J. Teiser, G. Wurm, Gerhard, 2020, *New Journal of Physics*, Vol. 22, No. 9, IOP Publishing, p. 093025
- [6] J. Teiser, M. Kruss, F. Jungmann, G. Wurm, 2021, *The Astrophysical Journal*, 908, L22