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Does Leakage of Charge in Particle Collisions Kill the Concept of Deadzones?

Gerhard Wurm, Felix Jungmann, Hannah van Unen, Nils Voellings, Laurent Schoenau, and Jens Teiser
Faculty of Physics, University of Duisburg-Essen, Duisburg, Germany (gerhard.wurm@uni-due.de)

Protoplanetary disks are thought to harbor deadzones, regions in their interior, where the ionization fraction is too low to trigger MRI turbulence. This has quite severe consequences for accretion and planet formation.
So far, the dominant source considered for ionization is high energy radiation from external cosmic rays over stellar radiation to radioactive decay. Especially, external radiation might indeed be attenuated too much before reaching parts of the midplane in disks. Radiation might not be the only source of ionization though.

In recent years, we carried out a number of laboratory experiments on collisional charging (tribocharging) of grains related to planet formation. Being mm-size, in a range where fragmentation and bouncing dominate, these particles are large and, although charged, might not be relevant in the context of MRI themselves directly.

An underlying assumption though is that triboelectric charge generated in collisions among grains stays on the grains. In this case, grain charging and aggregation as part of early particle growth on one side and MRI building on gas ionization on the other side would be distinct processes. However, what we recently found in a number of different experiments, is that tribocharging of grains also charges the ambient gas.

In one set of microgravity experiments, we observed that the charge on two particles before and after a collision is not conserved. On the order of 20\% of the pre-charge on a grain is discharged into the environment. To mention a second experiment, the number of ions detected in a gas flow after passing a granular medium increases strongly if the particles undergo collisions, i.e. are charged. There are experiments with further evidence but these two clearly show that charge is leaking into the ambient atmosphere during collisions.

In detail, the charging depends on the collision frequencies and particle sizes, which are model dependent. We also caution that these are only first experiments in this direction, but, in any case, estimates suggest that ionization rates within the gas might regularly be way larger than e.g. provided by radiation at the surface of a disk. If this holds, the charge balance in the midplane of protoplanetary disks might be quite different than previously assumed. The obvious and severe consequence might simply be that there are just no deadzones.