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Influence of rotation on the 'Iron Rain' in a Hadean magma ocean

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During its evolution, the Earth most likely experienced a 'Giant Impact' in which a Mars size body hit the early planet. Today it seems widely accepted that the origin of the Moon is a result of this Giant Impact. Another consequence of such an impact would be the formation of a 'Deep Magma Ocean', i.e. a layer of molten material, extending to a depth of about $1000km$. In this vigorously convecting environment the separation of iron and silicate takes place. Small iron droplets of a size about $1cm$ can form and fall, due to their higher density through the molten silicate to the bottom of the magma ocean. This scenario is called the 'Metal Rain Scenario'. It is the first step in the core forming processes of the earth.

We employed a 3D Cartesian numerical model with finite Prandtl number, in order to study the sinking of heavy particles in a vigorously convecting environment. Differently from most approaches we have included the effect of rotation on the flow dynamics. Due to the low viscosity of the magma ocean and a much faster rotation of the earth at the time after the giant impact the influence of rotation on the fluid flow of the magma ocean can not be easily neglected. Our numerical fluid model is based on a Finite Volume discretization, while the numerical model for the iron droplets based on an discrete element model for the simulation of granular Material. The particles influence the fluid flow through the chemical component of the fluid model, which is the volumetric ratio of the particle in each fluid cell. The particles themselves experience the force of the fluid through the fluids drag. Also gravitational and Coriolis forces act on the particles. In our simulations unlike to other approaches the particles are much smaller than the numerical fluid cells, thus saving computational effort.

In our present work we study the influence of strong rotation on the iron droplets with a rotation axes parallel to the gravitational acceleration like on the earth pole and with an rotation axes perpendicular to gravity like on the equator. Depending on the Rossby number of the system we find a different behavior of the particles. For the poles the particles fall nearly with Stokes' velocity to the bottom. Where as for the equatorial case the particles can stay suspended depending on the strength of the Coriolis force acting against gravity. We find three regimes depending on the strength of rotation for the equatorial case. At low rotation rates the particles fall to the bottom like at the poles. At higher rotation rates the particles stay suspended in the bottom 1/3 of the box and have an insulating effect on the hot thermal boundary layer. This leads to a layering of the temperature field. At high rotation rates the particles are completely suspended in a ribbon in the middle of the box. In this case there is no layering of the temperature field observable.

A parameter study can show at which fluid and particle parameters these three regimes do occur. Therefore it is possible to make predictions for the much higher parameters of the magma ocean. If on of these scenario was true for the magma ocean on the earth it leads to an interesting setup for the following core formation processes.