

Skalierungsgesetze für die Manteldynamik in Exoplaneten

(Scaling Laws for Mantle Dynamics in Exoplanets)

Projekt bep00036

The last years of astronomical observation have opened the doors to a universe filled with extra-solar planets. Detection techniques still only offer the possibility to detect solely the largest of them above 5 Earth masses. But as observational technology is steadily improving we will gain the possibility to detect even smaller planets, even as small as Earth. The observations show that planets seem to exist in many possible sizes just as the planets of our own solar system do.

It is only a natural question to ask if planetary mass has an influence on some key habitability factors such as on plate tectonics, which might regulate the climate of the planet or on the magnetic field, which protects the planet's surface from hazardous solar and cosmic radiation, and reduces atmospheric escape – allowing us to test which exoplanets might be more likely habitable than others, and helping us to understand if plate tectonics and magnetic field generation on Earth are stable or critical, instable processes that could easily be perturbed.

Lately [Valencia et al. 2007, O'Neill and Lenardic 2007] studied the effect of planetary mass on the ability to break plates and hence initiate plate tectonics - but both derived results contradictory to the other. We think that one of the reasons why both studies are not acceptable in their current form is partly due to an oversimplification of the models. Both treated viscosity only temperature-dependent but neglected the effect pressure has on enlarging the viscosity in the deep mantle. More massive planets have therefore a stronger pressure-viscosity-coupling making convection at high pressures sluggish.

We observed [Stamenkovic et al., submitted] that a conductive lid (termed CMB-lid) forms above the core-mantle boundary and thus reduces the effective convective part of the mantle when including a pressure-dependent term into the viscosity laws. The pressure dependence changes the scaling laws for parameterized models and influences the scaling of stresses associated with breaking of plates and thus the initiation of plate tectonics.

All scaling laws that have been derived so far do not take into account the low-lid that evolves due to the pressure dependence of the viscosity, hence leading to wrong results when applied to planets of Earth-size or larger. To derive new, pressure-dependent scaling laws for convective parameters as velocity, plateness, effective mantle thickness and heat flow at the core-mantle boundary, several 2D and 3D convection simulations were needed and have been run in this HLRN project. In addition, first simulations have revealed that scaling laws for planets in the plate tectonics regime are different than assumed so far. New scaling laws for temperature- and pressure-dependent mantle convection have been derived for stagnant-lid planets and first conclusions have been drawn about the propensity of plate tectonics on super-Earths using the new scaling laws. Also, 2D simulations have been done to investigate the dependence of plate tectonics on various factors as the water content, surface temperature, age and mass of the planet [Noack and Breuer, 2011].

References:

Noack, L. & D. Breuer (2011): *Plate Tectonics on Earth-like Planets*. EPSC 2011, Nantes, 2011.

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