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Convection and plate tectonics on extrasolar planets

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The number of potential Earth-like exoplanets is still very limited compared to the overall number of detected exoplanets. But the different methods keep improving, giving hope for this number to increase significantly in the coming years. Based on the relationship between mass and radius, two of the easiest parameters that can be known for exoplanets, four categories of planets have been identified: (i) the gas giants including hot Jupiters, (ii) the icy giants that can be like their solar system cousins Uranus and Neptune or that can have lost their H2-He atmosphere and have become the so-called ocean planets, (iii) the Earth-like planets with a fraction of silicates and iron similar to that of the Earth, and (iv) the Mercury like planet that have a much larger fraction of iron. The hunt for exoplanets is very much focused on Earth-like planets because of the desire to find alien forms of life and the science goal to understand how life started and developed on Earth. One science question is whether heat transfer by subsolidus convection can lead to plate tectonics, a process that allows material to be recycled in the interior on timescales of hundreds of millions of years. Earth-like exoplanets may have conditions quite different from Earth. For example, COROT-7b is so close to its star that it is likely locked in synchronous orbit with one very hot hemisphere and one very cold hemisphere. It is also worth noting that among the three Earth-like planets of the solar system (Earth, Venus and Mars), only Earth is subject to plate tectonics at present time. Venus may have experienced plate tectonics before the resurfacing event that erased any clue that such a process existed. This study investigates some of the parameters that can influence the transition from stagnant-lid convection to mobile-lid convection.
Numerical simulations of convective heat transfer have been performed in 3D spherical geometry in order to determine the stress field generated by convection processes in the cold thermal boundary layer that lies under the stagnant lid. Different boundary conditions have been investigated such as the surface temperature, the core temperature, the viscosity of the mantle, and the amount of internal heating. A total of 18 numerical simulations have been carried out from which scaling laws describing the shear stresses affecting the stagnant lid have been have been deduced. Their application to Earth-like exoplanets will be discussed. Different viscous laws have also been investigated. Preliminary results suggest that non-Newtonian deformation favors the transition from stagnant lid to mobile lid. Finally, application to large icy moons and icy giants is being investigated.

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