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Condensation of planets and formation of atmospheres from protolunar disks after giant impacts

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Giant and large-scale impacts are ubiquitous features of early solar systems. They dominate the end of the accretion stage, where the number of bodies decreases but their size increases. The last major accretion event in Earth's history was the Moon-forming giant impact. Depending on the impact parameters, its outcome was the formation of a traditional protolunar disk or a synestia. Eventually, the protolunar disk/synestia evolved to condense a large central hot body: the Earth, and a smaller satellite: the Moon.

Here, we study the behavior of a multi-component silicate fluid with bulk silicate Earth composition [1] at conditions typical for the giant impact. For this, we employ molecular dynamics simulations based on ab initio calculations. From the pressure-density variation and the Maxwell construction, we determine the limits of stability of the molten silicate and the position of the critical point. We find that the Earth's protolunar disk reached the supercritical state of the silicate mantle [2].

Then we follow the chemical evolution of the disk during its cooling. Liquids and gases separate according to the liquid-vapor dome. As the liquid rains towards the centre, the leftover gas forms a hot dense atmosphere. We characterize the composition of the atmosphere and find that it is extremely rich in molecules. Oxidized phases like SiO, O, O2, MgO, and cations like Na and Mg dominate the gas phase. But a plethora of other phases are present in the system, with lifetimes that allow them to play a role in the chemical and isotopic exchanges.

Many of the gas molecules that we find in our simulations are not present in databases like JANAF. This suggests that a huge field of investigation lies bare ahead of us.

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References:

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