The Moon formation after the giant impact

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Giant and large-scale impacts dominate the end of the accretion stage in early solar systems. As the accretion advances, the size of the leftover planetesimals increases and, therefore, the impacts between them become increasingly energetic. Here **we use atomistic simulations based on *ab initio* molecular dynamics and machine learning** to study the behavior under shock of a series of silicates, representative of various rocky worlds, like the bulk silicate Earth (BSE) and several chondritic compositions. We calculate the entropy production during shock and relate it to the accretion history of the rocky planets. We show that many impacts have been sufficiently energetic to produce at least partial vaporization. This has tremendous effects to the transport of volatiles towards the inner part of the solar system.

In the specific case of our planet, the last major accretion event was the Moon-forming giant impact. The outcome of this impact was the formation of a large supercritical protolunar disk. The atomic structure of the silicate fluid varies with the radius within the disk due to strong pressure and temperature gradients. Fluffy short-lived chemical species dominate the outer parts of the disk, and long-lasting dense polymers abound in the deeper parts. At the beginning of its separation in the center of the disk, the Earth, and most rocky planets, will traverse a temporary state that lacks a surface defined by a magma ocean-atmosphere boundary. During further cooling, liquids and gases separate according to the liquid-vapor stability dome. The liquid droplets rain toward the center, contributing to the planet's growth, which takes place in a state of a magma ocean (MO). The leftover gas forms the hot dense disk atmosphere.

We compute the chemical structure and the properties of the disk (Figure 1) and the composition of the disk atmosphere. We find the atmosphere to be extremely rich in molecular species, dominated by oxidized phases like SiO, O, O2, MgO, and cations like Na and Mg. 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 thermodynamic databases suggesting that a huge field of investigation lies bare ahead of us.

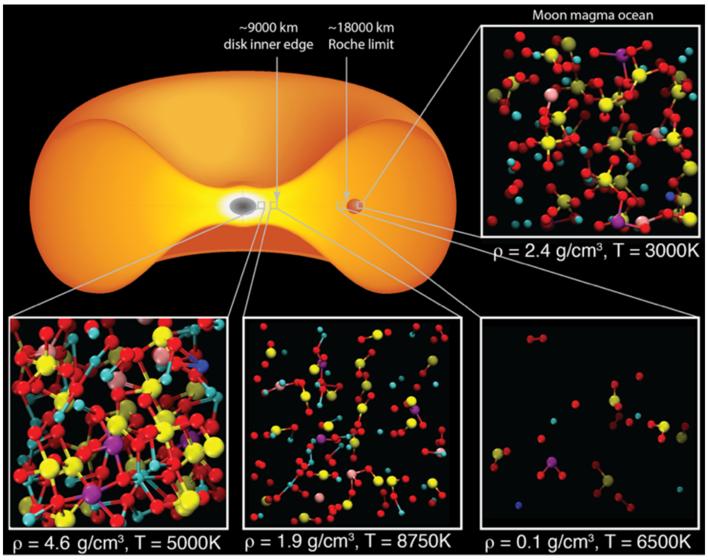

Figure 1. The chemical structure in the pyrolytic fluid changes with the widely-varying pressures and temperatures in the disk after a giant impact.

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References

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