Merger and absorption: the intricacies of the evolution of large planets

An international group of researchers, which included a scientist from Siberian Federal University, explained some of the features of the origin of large planets. With the help of computer modelling, the experts have proved that in the process of the formation of planetary embryos there is an intense loss of light chemical elements, while heavy elements take an active part in giving the final appearance of planets. The results of the study [are published in Icarus journal](#).

According to the modern concepts, the planets of the solar system emerged from a gas and dust cloud that existed in the circumsolar disk. In the beginning, the so-called "embryos" of planets, growing planetary "embryos", formed. Then the largest of them attracted and absorbed their smaller "siblings". The winners of this peculiar evolutionary race were expected to gradually acquire the final form. This was, in particular, the childhood of the Earth. One of the questions thrilling the researchers is the reason for the predominance of heavy chemical elements (iron and magnesium) in the composition of our planet.

> *“The loss of light elements, which occurs at the stage of formation of “embryos”, leads to the predominance of heavy elements, which is observed, in particular, on the Earth. The fact is that planetary embryos ranging in size from several hundred to several thousand kilometres can form oceans of hot magma due to mutual collisions, gravitational energy, and heating from short-lived radioactive elements. In this case, volatile elements are released from the magma ocean and form vapor atmospheres. However, in the process of magma solidification after the cooling of the protoplanetary disk, the vapour atmosphere begins to catastrophically evaporate and can be completely lost due to the hydrodynamic outflow of the atmosphere into the surrounding space under the absorbed intense ultraviolet radiation from the Sun. At the same time, the fleeing hydrogen atoms formed during the dissociation of water and hydrogen molecules will also pull out more massive elements such as inert gases (neon and argon) and even elements forming the solid crust (potassium, sodium, silicon, magnesium,)”* said **Nikolay Yerkaev**, a co-author of the study, professor of the Department of Applied Mechanics, Siberian Federal University, and a chief researcher of the Institute of Computational Modeling of the SB RAS.

The researcher explained that the new work employed a mathematical model developed by the team earlier, which helps calculate the outflow of the upper atmosphere taking into account the removal of more massive atoms due to friction with the escaping hydrogen atoms.

> *“We have considered three scenarios for the evolution of UV radiation from a young star (for the calm, temperate and active Sun), carried out a computer simulation of the escaping of the atmosphere, studied changes in its composition from various planetary embryos with the mass equal to the mass of the Moon, Mars, and also those making up half and one and a half of the mass of Mars at various orbital distances in the interval between the orbits of Venus and Mars. It turned out that vapour atmospheres and the trace elements in them will be quickly and completely lost if the mass of the protoplanet is less than the mass of Mars and which orbital distance of which is less than 1.5 au from the Sun. For example, the Earth's orbit corresponds*

> *to 1 au,"* noted **Nikolay Yerkaev**.

Based on this pattern, the scientists concluded that for "embryos" with a mass less than the Moon's, the gravity is too weak to create a dense atmosphere at the surface temperatures corresponding to the magma ocean, and all elements evaporating from the surface will immediately evaporate into space.

For more massive "embryos" (1 to 1.5 masses of Mars), almost all of the considered vapour atmospheres can be lost in about 12 million years, which is within the time frame for the formation of the first solid Martian crust (after 20 million years). And, finally, for all the considered planetary masses and orbits, the intensity of "leakage" of argon and neon is so high that there will be no separation of their isotopes in the atmosphere.

> *"Our team concluded that the studied planetary embryos, even in the absence of isotope separation, would be highly depleted in inert gases and moderately volatile elements. Thus, the hydrodynamic outflow of atmospheres can significantly affect the final composition of the planets that absorb such planetary embryos in the course of their evolution. This can apply to both volatile components and the ratio of iron and magnesium in the composition of the planet. For example, the considered mechanism may be one of the reasons for the high values of iron and magnesium and low values of silicon observed on the Earth at the present time,"* the Krasnoyarsk scientist summed up.

This study was initiated by the staff of the Space Research Institute and the University of Graz (Graz, Austria), as well as the Versailles Saint-Quentin-en-Yvelines University (Versailles, France).

23 september 2020

Web page address: https://news.sfu-kras.ru/node/23610