Physicists obtain data on particle self-organization in ultracold dusty plasma

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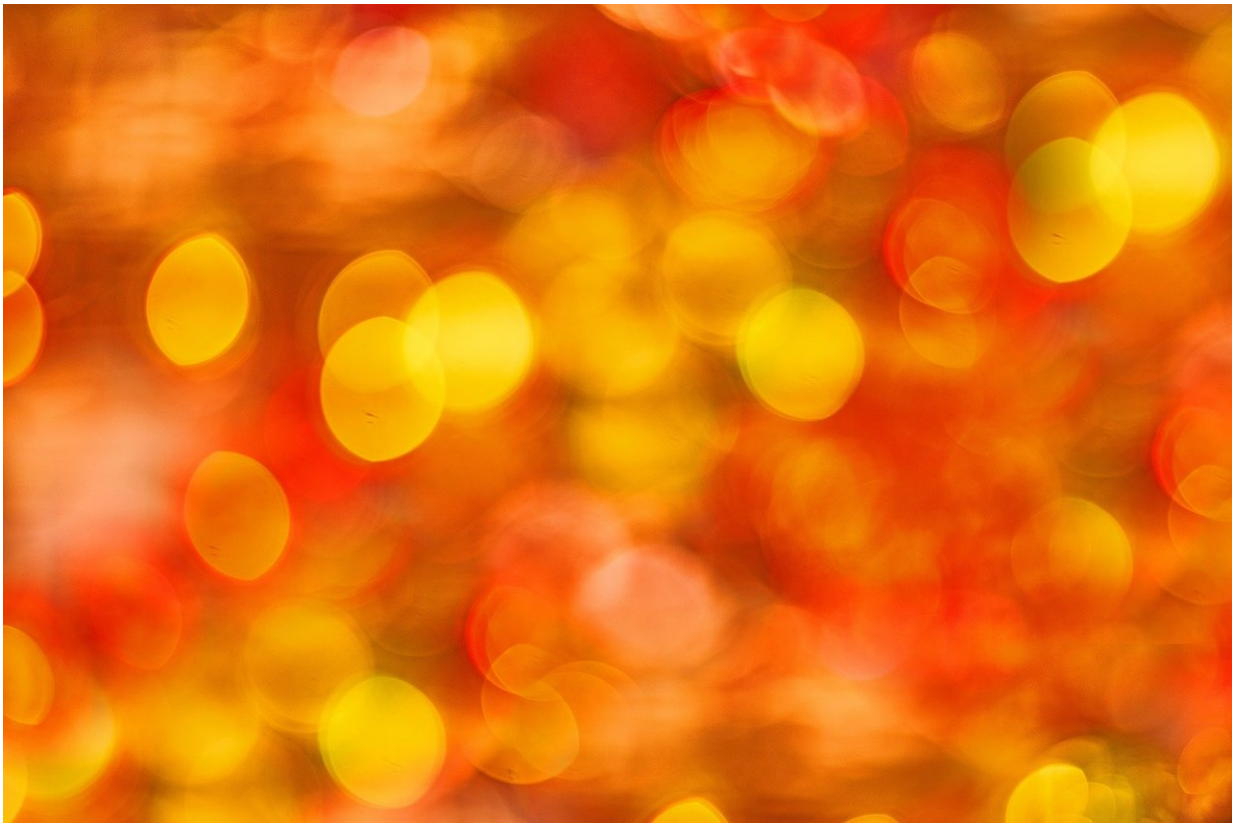

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Physicists recently investigated the behavior of particles in a dusty plasma at a temperature below 2 degrees K. The experiment showed that at extremely low temperatures, nanoclusters can form in the plasma, and

the synthesis of polymer fibers takes place. The results of the experiment can be used to create new materials with desired and controlled properties. The results of this study are published in *Scientific Reports*.

Scientists from the Joint Institute for High Temperatures, Russian Academy of Sciences together with colleagues from the Branch of Talrose Institute for Energy Problems of Chemical Physics, RAS and Moscow Institute of Physics and Technology studied a multimodal dusty plasma formed in a positive column of the direct current glow discharge at ultralow temperatures (at superfluid helium temperatures).

According to Oleg Petrov, director of the Institute for High Temperatures RAS and one of the authors of the article, the scientists managed for the first time to observe dusty plasma in a gas discharge cooled by superfluid helium at a temperature of 1.6 to 2 degrees K. Until now, dusty plasma and even gas discharges have not been studied at temperatures lower than 4.2 degrees K, which is the temperature of liquid helium.

In the course of the experiment, ion sputtering of polymers from a special insert resulted in self-organization phenomena, namely, the formation of nanoclusters with sizes less than 100 nm and polymer fibers with a length of up to 5 mm and a diameter of about 10 microns. Obtained at extreme temperatures, the fibers do not collapse when studied later in normal conditions.

"At ultralow temperatures, it becomes possible to precisely control the composition of the sprayed material, since under these conditions any impurities "freeze" and precipitate," Oleg Petrov says. "As a result, when spraying a substance in the gaseous helium, it is possible to obtain super-pure materials, which might be the way to obtain fibers with new desired properties—for example, new types of polymers that cannot be obtained

by ordinary chemical synthesis. Such materials may be radically different from existing ones."

Phenomena of self-organization are widespread in nature, and are observed in various systems of complexity and scale, including physical nano-scale events, astronomy, and in biological, social and economic processes. Such phenomena are characteristic of the so-called open (non-equilibrium) systems, which include, among others, dusty plasma formed by charged particles of micron size, retained in the plasma of a gas electric discharge. The intense scattering of laser radiation by particles allows to study the systems formed by charged particles, tracking their coordinates and speeds in real time. Dusty plasma is a convenient tool for studying various phenomena, for example, three-dimensional and two-dimensional phase transitions, as well as the formation of non-linear waves.

Compared with alternative systems,dusty plasma provides a unique opportunity to vary the temperature of the plasma-forming gas—gaseous helium—which helps to study the effect of gas temperature changes on properties of plasma and the processes that occur in it. The question of the lower limit of temperatures at which experimental studies of dusty plasma can be carried out remained open until recently.

The reason for this lack of knowledge of the gas discharge plasma at temperatures below 4.2 degrees K is related to the fact that the problem is not only to cooling the tube to temperatures below that of liquid helium, but also the power limit in the discharge which leads to heating of gaseous helium.

The experiment, the results of which were published in *Scientific Reports*, was carried out with an optical cryostat on a platform intended to study plasma-dust structures at helium temperatures. At present, scientists of the JIHT RAS plan to continue the experiments and study

the phenomena of self-organization in dusty plasmas at ultralow temperatures using various dispersed materials.

More information: Roman E. Boltnev et al, Formation of solid helical filaments at temperatures of superfluid helium as self-organization phenomena in ultracold dusty plasma, *Scientific Reports* (2019). DOI: 10.1038/s41598-019-40111-w

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