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Cometary nitrogenous salts tell about the Solar System's history

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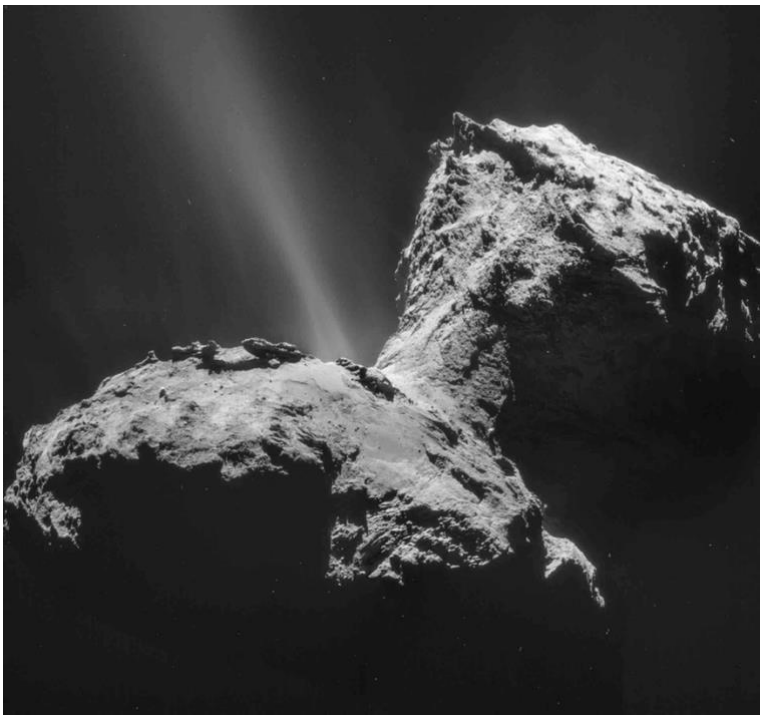
Ancient comets are great history-tellers of the Solar system. Our discovery of nitrogenous salts within comets provides hints for how comets might have brought nitrogen onto different planets, including Earth where nitrogen is crucial to creating and preserving life.



The surface of comet 67P/Churyumov-Gerasimenko photographed by the Rosetta spacecraft
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How did planets arise? How did the Earth become a unique planet with a habitable surface? A way to address these long-standing questions is to explore the "small bodies" of the Solar System. In addition to the planets and the satellites circuiting around them, our Solar System consists of many smaller bodies, which are the remnants of the planets' formation and thus provide hints for the Solar System's evolution.

These small bodies include asteroids and comets, both of which circuit around the Sun. Asteroids are mainly made of rocks with no or little amount of volatile compounds. Comets contain much more volatile compounds stored in the form of ices that were frozen more than four billion years ago during the earliest stages of planets' formation. Collisions of comets and asteroids with the Earth may have brought to the planet the volatile elements such as hydrogen, carbon and nitrogen, essential for the emergence of life.

Comets are one of the most ancient objects around the Sun. Scientists have thus hypothesized that comets and the Sun were formed from the same original material, and if so, their nitrogen contents—

measured as the ratio between nitrogen and carbon atoms—must be comparable. However, previous studies could not confirm the amount of nitrogen within comets to be similar to that of the Sun, and this hypothesis remains to be tested.

Recently, the European Space Agency's spacecraft Rosetta performed an in-depth analysis of a comet named 67P/Churyumov-Gerasimenko (comet 67P) and obtained a new insight. While orbiting the comet, Rosetta measured the sunlight, a mix of different wavelength radiations, reflected and absorbed by the cometary surface. This allowed identifying some substances composing the comet, based on their unique light absorption patterns. The first set of studies uncovered that the cometary surface contains carbon compounds and opaque minerals but also it includes an unknown compound whose light absorption pattern could not be interpreted.

In this study, we aimed to gain the missing piece and a more comprehensive picture of comet 67P's chemical composition. We created artificial comets whose light absorption patterns should fit those of the natural comet, which would help identify unknown components of comet 67P. To create the artificial comets, we first made fine particles of possible comet materials—water ice and dust (opaque minerals, carboxylic acids, ammonium salts etc.)—then placed them together under vacuum and low temperature. Under these cometary-like conditions, the ice sublimated, leaving a porous layer of dust, with a texture similar to that of cometary dust. By comparing the sunlight absorption patterns between the artificial comets and comet 67P, we found that the patterns of artificial comets containing ammonium salts almost perfectly fit those of the natural comet. This highlights that the comet 67P contains nitrogen in a form undetected from previous observations: ammonium salts.

Our data demonstrated that ammonium salts are present all over the cometary surface, together with carbon compounds and other minerals. These nitrogenous salts could be the dominant reservoir of nitrogen on the comet, allowing to significantly increase its nitrogen concentration and to possibly make it comparable with the Sun's. Ammonium salts are likely present on other comets as well. Indeed, several comets passing close to the Sun are known to release ammonia gas that is possibly generated from these salts. Ammonium salts, therefore, seem to be the long-sought nitrogen reservoir in comets, and probably some asteroids.

Our discovery of ammonium salts on a comet provides new insight into the nitrogen evolution in the Solar System. The presence of these cometary nitrogenous salts supports that both the Sun and comets might have been formed from the same origin, emphasizing the significance of comets research in understanding the Solar System's history. While it remains unclear how nitrogen was distributed among the planets and where the Earth's nitrogen is derived from, this study can suggest that certain comets, and maybe asteroids, might have brought nitrogen onto the Earth in the form of ammonium salts. These water-soluble salts may have even triggered the emergence of life on Earth by enhancing the formation of key life materials, such as amino acids and nucleobases. This study, in turn, is a milestone in deciphering a mystery about the origin of the Solar System.