Did water come from comets?

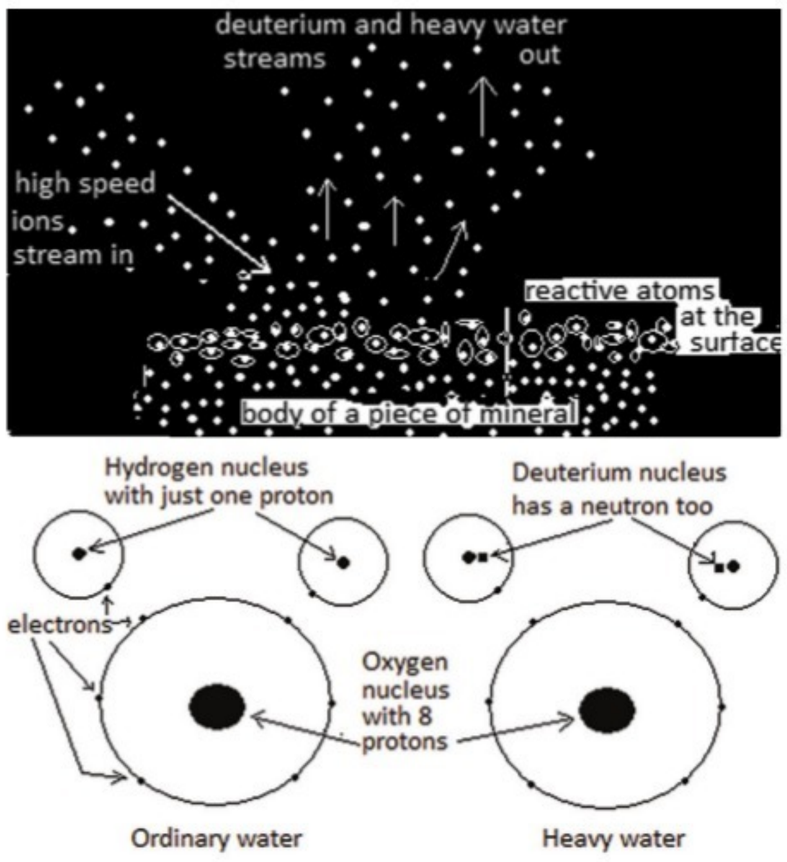
Separation of a 'heavy' component of the liquid is found to happen instantaneously on the surface of such celestial objects

S ANANTHANARAYANAN

One way to explain how Earth has so much water has been that the water came with comets. The content of water whose molecules have the "heavy" version of hydrogen atoms, however, was found to be much higher in the water vapour surrounding the comet, 67P, than what is found on Earth. This discovery persuaded a view that water on Earth may not have come from the 67P class of comets.

Yunxi Yao and Konstantinos P Giapis, researchers at the California Institute of Technology, Pasadena report in The Astrophysical Journal of The American Astronomical Society that processes on the surface of the comet could increase the content of the "heavy" form of hydrogen in water vapour when the comet approaches the sun. This could be the reason for the feature of the vapour cloud that surrounds 67P, and the class of comets to which it belongs could hence still be the real source of the water content of Earth.

Like many other elements, the nucleus of the hydrogen atom can have more than one stable form. The normal hydrogen atom has a nucleus with only one proton, which is positively charged, and an electron — a comparatively light particle that is negatively charged — is in orbit around the nucleus. Another form of hydrogen, called deuterium, occurs when a neutron — a neutral particle — is added to the nucleus. As the particle is neutral, the number of electrons remains the same as before. As it is on the number and distribution of electrons that chemical properties of an atom depend, the two forms of hydrogen are almost identical.



With two particles in the nucleus, however, the atom of deuterium has twice the mass of normal hydrogen. Deuterium occurs in traces as gas and is found in the form of "heavy water", or D_2O, whose molecules contain deuterium atoms in place of hydrogen. The heavy water molecule, which is about 10 per cent heavier than molecules of normal water, has a number special properties and applications.

Introducing an additional particle into the nucleus of the hydrogen atom, however, takes energy, and deuterium atoms arose only at the violent time of the Big Bang. Their incidence in the universe is hence rare, to the extent of just 26 parts per million. Except that in many astronomical bodies, because of different concentrating processes, the content is a lot higher. In giant gas planets, like Jupiter, it is the same 0.000026 per cent as the rest of the universe, but in Earth's oceans, it is six times as much, at 156 parts per million. This is very close to the content in certain groups of comets, and it has been the view that it is comets that brought much of the water that we find on Earth.

The implicated comets, in fact, are the Jupiter-family comets, or comets, which the gravitational forces of Jupiter have drawn into closer orbits around the sun. The source of most comets is in the Oort Belt, or the distant cloud of icy remnants of the formation of the solar system. But in these comets, the ratio of deuterium to hydrogen was twice that on Earth. It was only in the case of the Jupiter-family comets that the ratio matched and they were considered an important source of terrestrial water.

The problem arose with the detailed study carried out by Rosetta mission, of 2014, which sent Philae, an observation station, down to the surface of 67P — a four km-wide Jupiter-family comet. The study showed that the content of heavy water in the vapour around the comet was more than three times higher than what was found on Earth. This disturbed the notion that water came to Earth from this class of comets.

The team of researchers from Caltech, Pasadena have been working on the interaction of high speed ions, or bits of molecules that carry a charge, and the atoms at the surface of materials. Given the high energy of the projectiles and the high charges in the region very close to surface atoms, molecules can be split and reassembled in ways that are normally not possible or possible only very slowly. As the coma — or the gas cloud that forms around a comet as it nears the sun — is rich in water vapour, the impact of water ions, which get accelerated by radiation from the sun, on the surface of comets, is of interest. And during this study, the researchers found that water ions impinging on the surface tend to pick up atoms of deuterium, and transform into heavy water.

Heavy water has industrial use, particularly in nuclear reactors, where it helps slow down high energy neutrons and promote the nuclear fission chain reaction. This calls for 99.99 per cent pure heavy water and the extraction, from ordinary, fresh water takes elaborate and energy-intensive processing. What the Caltech researchers have published, in contrast, is a painless method where water ions are speeded up and thrown against a deuterium-rich surface, to transform to heavy water.

That such a process is possible has implications in understanding the discovery of high deuterium content in the coma of the comet, 67P. The researchers observe that the surface of the comet consists of minerals that are rich in deuterium and the energy of the ionised water molecules would bring about the hydrogen-deuterium exchange. There would hence be transfer of deuterium content from the surface of the comet to the water vapour in the coma, and hence the detection of high levels of heavy water.

The journal paper works it out that the deuterium to hydrogen ratio should increase as the comet approaches the sun. The actual relationship of how this ratio changes with distance was one of the objectives of the Rosetta mission but has not been reported, the paper says.

But the paper has shown that the high ratio on 67P is because of this water ion-surface interaction. It would hence be hasty to conclude, from the higher ratio on 67P, compared to the level on the waters of Earth, that Jupiter-family comets were not the source of water on the earth. The evidence of the water on these comets being comparable, in deuterium/hydrogen ratio, to sea water is still valid.

The writer can be contacted at response@simplescience.in

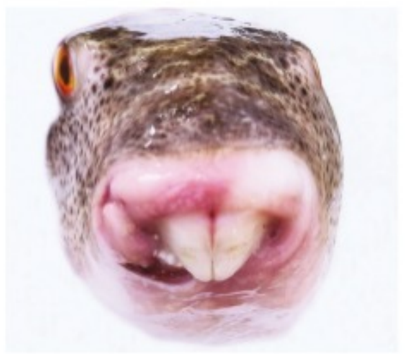
From the heavens

All the metallic iron on the Earth got converted to oxides and ore long before humans evolved. As early civilisations did not have coal fires, the first metals extracted from ores were copper, silver and gold, which can be worked with wood fires. Copper was alloyed with tin and formed the basis of the Bronze Age, which started in 3300 BCE. Smelting of iron became possible only after 1200 BC.

Discovery of iron artefacts in pre-Iron Age archaeological sites was hence mysterious. The sites, in fact, predate even the Bronze Age. Analyses of these artefacts have revealed that they were fashioned out of meteorites, which fell on Earth, where the high temperature of entry would have allowed skeins of metal to form. The samples were found to be rich in nickel, cobalt, phosphorus and germanium, which marked them as being of a meteoric origin. The iron beads appear along with gold and gemstones, suggesting they had value. This must have been so, as any iron would be rare and may have been seen to have "fallen from the heavens".

PLUS POINTS

Same as our teeth



Human teeth evolved from the same genes that make the bizarre beaked teeth of the puffer fish, according to new research by an international team of scientists.

The study, led by Gareth Fraser from the University of Sheffield's department of animal and plant sciences, has revealed that the puffer fish has a remarkably similar tooth-making programme to other vertebrates, including humans.

Published today recently in the journal *PNAS*, the research has found that all vertebrates have some form of dental regeneration potential. However the puffer fish use the same stem cells for tooth regeneration as humans do but only replace some teeth with elongated bands that form their characteristic beak.

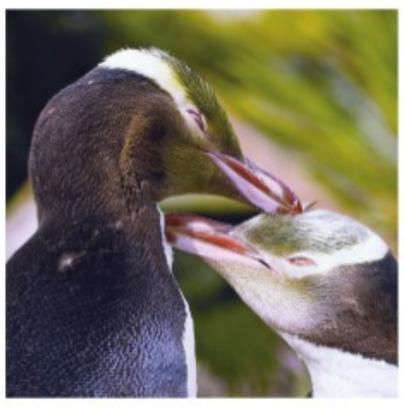
The study's authors, who include researchers from the Natural History Museum London and the University of Tokyo, believe the research can now be used to address questions of tooth loss in humans.

"Our study questioned how puffer fish make a beak and now we've discovered the stem cells responsible and the genes that govern this process of continuous regeneration. These are also involved in general vertebrate tooth regeneration, including in humans," Fraser said, "The fact that all vertebrates regenerate their teeth in the same way with a set of conserved stem cells means that we can use these studies in more obscure fishes to provide clues to how we can address questions of tooth loss in humans."

The unique puffer fish beak is one of the most extraordinary forms of evolutionary novelty. This bizarre structure has evolved through the modification of dental replacement.

The beak is composed of four elongated "tooth bands", which are replaced again and again. However, instead of losing teeth when they are replaced, the puffer fish fuses multiple generations of teeth together, which gives rise to the beak, enabling them to crush incredibly hard prey.

Could become extinct



The iconic yellow-eyed penguin could disappear from New Zealand's Otago Peninsula by 2060, latest research warns.

In a newly published study in the international journal PeerJ, scientists have modelled factors driving the mainland yellow-eyed penguin population decline and are calling for action to reduce regional threats.

According to the researchers' prediction models, breeding success of the penguins will continue to decline to extinction by 2060 largely due to rising ocean temperatures. The yellow-eyed penguin is classified as endangered by the International Union for Conservation of Nature.

The lead study author, Thomas Mattern of the University of Otago, said his team's predictions are conservative estimates and do not include additional adult die-off events such as the one seen in 2013 in which more than 60 penguins died. "Any further losses of yellow-eyed penguins will bring forward the date of their local extinction," Mattern said in a statement from the university.

Increasing sea surface temperatures in part explain the negative trend in penguin numbers. "The problem is that we lack data to examine the extent of human impacts, ranging from fisheries interactions and introduced predators to human disturbance, all of which contribute to the penguins' demise," said Mattern.

"However, considering that climate change explains only around a third of the variation in penguin numbers, clearly those other factors play a significant role. Unlike climate change, these factors could be managed on a regional scale," he added.

Yellow-eyed penguins continue to drown as unintentional by-catch in nets set in penguin foraging areas, suffer from degradation of their marine habitat because of human activities, and die from unidentified toxins.

The straits times/ann

Radical new idea

Using the same farming technology as the one being mooted by Nasa for future astronauts on Mars, two professors teaching finance and entrepreneurship in Kathmandu are aiming to eliminate drudgery from agriculture

BIBEK SUBEDI

Strange things are happening on the rooftop of a family house in Kathmandu's Kalanki. Lush green plants are sprouting out of plastic barrels wrapped in aluminium foil. The sight of the plants' dark green hues in contrast to the metallic sheen from the aluminium foil is both beautiful and alien. Could this be the future of farming?

"We are attempting to build an automated plant growing machine," says Caesar Rana, co-creator of the experiment. "The machine will provide the plants with everything they need to thrive so that farmers only have to worry about sowing seeds and reaping harvests." In essence, Rana and his partner Prakash Dahal want to create a system that will automatically handle much of backbreaking farm work like watering, fertilising, weeding, tilling and even pest control. A tall order by any standard but Rana and Dahal are determined to realise their vision of eliminating the drudgery from agriculture.

Their machine is based on a radical new idea called aeroponics, which is the same technology being mooted by Nasa for future astronauts during the potential colonisation of Mars. Instead of soil and traditional fertilisers, aeroponics uses a fine mist of carefully prepared nutrients to sustain and nurture plants using no soil and little water.

"Our system uses one percent of the water necessary in traditional farming and only 10 percent of the water needed for comparable hydroponics systems," Dahal says, adding, "Our plants also grow 30 percent faster and are more disease resistant than those grown in hydroponics or soil." Hydroponics is a method of growing plants that uses water and soil-less media like coco peat or expanded clay pebbles. It is nothing short of incredible that two professors teaching finance and entrepreneurship were able to create what they did with no prior experience in agriculture, biology, chemistry or engineering. Their machine, which went online on Nepali New Year's day, can grow 380 plants on less than 40 litres of water a week and runs on a fraction of the power requirements of an average 14 inch laptop.

"We have learnt more in the last few months than we have in the many years before that," Dahal reminisces. "From plant nutrition and mist generation to more practical concerns like drilling large holes into the sides of plastic drums, the range of topics we have had to research was mind boggling," he adds.

The creators of the aeroponics system admittedly imported only the mist nozzles and the high pressure pump from a supplier in China and put together the remainder of the machine using only materials that are readily available in Nepal. "We wanted our system to be as affordable as possible so that more people in Nepal could start using it. As such, we tried to use locally available materials and components for the construction of the machine as much as it was practical," they explain.

When asked if their machine-grown produce can be called organic, Rana replies, "Yes, we are 100 percent organic because in addition to only using organic seeds and fertilisers, we also source the highest quality nutrients to make our nutrient solution. The nutrients in our solutions are essentially simple inorganic salts and chelates that can even be ingested by humans harmlessly at the concentrations that we employ." In addition, growing in a perfect blend of essential nutrients, the plants in aeroponic systems are naturally more resistant to diseases and pests. "Due to the absence of soil, the life cycles of many pests and parasites cannot be complete in an aeroponic system, further reducing the need for any type of pesticides or chemicals," he adds.

Dahal believes that there are several possible ways for them to grow as a business once their grand experiment comes to an end. "The obvious way to grow would be to establish big farms to cater to the fresh vegetables demand in Kathmandu. But we also want to take this technology to growers at the household levels who can set up something similar to our Kalanki experiment on their rooftops or kitchen gardens. Home gardeners will be able to produce nearly all the vegetables they will need using a system that is slightly smaller than our experiment." Now, once saplings are inserted into the duo's aeroponic system, home growers only need to spend a few minutes to measure and adjust the pH levels and the concentration in their nutrient solution once every few days to ensure a rich harvest.

Rana says, "In addition to saving you time and work, the system will also save you money because you use a fraction of the water compared to a traditional garden and the cost of the nutrients will be lower than the costs of the fertilisers and soil conditioners necessary for soil-based farming."

Aeroponics systems are also more suitable for rooftop installations because of their comparatively lighter weight. "Our experimental system weighs a total of 250 kg, including the weight of the greenhouse and the nutrient solution. A comparable hydroponics system would weigh nearly two tonnes and a soil based method would be even heavier," they explain.

Rana maintains that the benefits of aeroponics over other methods of farming are so significant that many experts across the world are calling it the future of agriculture. "It eliminates tedious chores, increases productivity by up to 20 times, reduces the need for harmful pesticides and demands much less water. To put that in perspective, a 10-*ropani* (about 5,000 square metres) aeroponic greenhouse with extended lighting and climate control will have the same productivity as 200 *ropanies* of fertile and irrigated fields," he says, adding, "If we are able to develop this technology in Nepal, we will be in the forefront of agricultural innovation and productivity by global standards."

The kathmandu post/ann