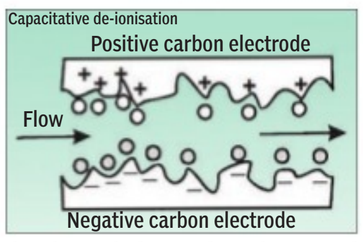
Scrubbing water clean

ITS CAPACITY AS A CLEANING AGENT IS WHAT MAKES IT A HOST TO CONTAMINANTS THAT ARE DIFFICULT TO REMOVE, WRITES **S ANANTHANARAYANAN**

Industry, pollution and the growing population together increasingly constitute both the demand for and scarcity of clean water. While river-fed sources are becoming less accessible, groundwater is also sinking deeper or getting contaminated.

Conserving and reusing the commodity has become vital and technology to turn bad water to good has become more important than ever. Marc Andelman, Massachusetts-based inventor, Professor Tony Cass from Imperial College, London, and Professor Sung Jae Kim from Seoul National University presented three new nano technology-based solutions for extracting potable water from inferior sources at the eighth India Nano Meet organised by the S&T Promotion Society, government of Karnataka, at Bengaluru on 8 March. The packed audience was of industrialists, start-ups and students and Professor T Pradeep of IIT, Chennai, who conducted the meeting, pressed for emerging technology to be picked up and used for the benefit of the country and the world.

Andelman's innovation is an improvement of the method called capacitative de-ionisation, or CDI, where a pair of oppositely charged surfaces, the electrodes, fish out contaminants, mainly salt, from water that is made to flow between the charged plates. The voltage used is low, and there is no current between the surfaces, but dissolved contaminants, which are split in the water medium into oppositely charged halves called *ions* drift to opposite ends till the ends collect full charge and their drifting stops. While the water that flows through gets purified when the charge is on, the surfaces can now be discharged to release a concentrate of contaminants for disposal. CDI, which extracts dissolved contaminants, is energy efficient compared to other methods like distillation or the now common *Reverse Osmosis*, which work the other way about, extracting water from a salt solution.



Andelman explained that the material of the electrodes had to be porous so that there was high surface area and greater capacity to collect charge for the same voltage applied. A limitation of the basic design, however, was that when charged ions of the contaminant piled up very near the electrodes, oppositely charged ions were also inserted into the region just beyond, a region called the *diffuse layer*, and this reduced the efficiency of the extraction of contaminants. A first improvement has hence been to insert an *ion exchange membrane* that would not impede the movement of the contaminant ions but act as a barrier to the counter-current of opposite charges. This did improve efficiency, but the membrane is expensive and takes space in the water channel.


Glucometer





Marc Andelman, Tony Cass, Sung Jae Kim and T Pradeep.

Andelman's innovation was to replace the membrane by directly coating the electrodes with a material that contained charged components that were drawn, half towards and half away from the charge on the electrodes. These separated charges create a layer that behaves like the *ion exchange charge barrier* in keeping down the counter-current of charges being released from the electrodes. This treatment, of creating a "polarised electrode", however, is a low-cost procedure and the electrodes themselves are nano-porous carbon, which could come from burnt coconut shells, Andelman said.

Measuring contamination

Professor Tony Cass, chemical biologist, explained that arsenic poisoning of ground water, which was notorious in Bangladesh, was in fact a problem the world over. And the great difficulty in its management was the complexity of detection and measurement. It was, hence, a challenge to monitor large numbers of water borings, particularly as arsenic levels could change within a very short period of time. "You cannot manage anything till you can measure it," Professor Cass said, citing a remark made about air pollution in London.

He said the current methods of measuring sugar levels in blood and urine of diabetics became an example to emulate in assessing arsenic levels. Testing for sugar used to be slow and cumbersome 30 years ago but it could now be done very easily, and fast, with a hand-held device by the patient. The secret of the advance was the discovery of an enzyme that reacted with glucose, and exclusively with glucose, to set free an electron, that formed a current that could be measured by a meter or a counter. A light pinprick to access the blood could then be automated to read out the glucose level, in a device that was now sold over the counter! And there is a strip of paper that can be dipped in urine and the colour shows the level of glucose.


Professor Sung Jae Kim takes inspiration from coastal mangroves that flourish in salt seawater to devise ways of desalination as a source of fresh water for human consumption or irrigation.

Professor Cass, with his colleagues Joanne Santini and Thomas Osborne, chanced upon a similar action of an enzyme that set electrons free while changing arsenic salts from one form to another. They have now devised a method to build a simple instrument, like the glucometer for diabetics, which measures low levels of arsenic in water with good accuracy. "The device is not so good at high concentrations," he says, "but fortunately the area of interest is low contamination."

Bio-inspiration

Professor Sung Jae Kim takes inspiration from coastal mangroves that flourish in salt seawater to devise ways of desalination as a source of fresh water for human consumption or irrigation. The current ways of largescale desalination are only distillation or reverse osmosis, both of which are power intensive. It is, hence, attractive to desalinate without the use of power, except sunlight, maybe, like nature.

The process of osmosis is that when solutions of different concentration are separated by a semi-permeable membrane, which lets through the solvent but not the solute, the solvent is driven to pass from the lower concentration to the higher side. This driving force, in fact, can support a higher column of greater concentration, which is what happens in a coastal freshwater well, which supports the pressure of salty sea water whose level is higher. In reverse osmosis, physical pressure that is greater than the pressure of osmosis is exerted on the side of higher concentration to drive the solvent, water in the case of brine, to the freshwater side.

The roots of coastal plants, which stand in salt water, are able to keep out the salt and take in fresh water, which then rises with the sap to the stem and leaves, using capillary forces. The work of Professor Sung Jae Kim and colleagues identifies the role of capillaries, or very narrow channels, in attaining the separation of higher and lower concentrations, or an "ion concentration polarisation", leading to an "ion depletion zone" near nano-porous materials that is selectively permeable. A device based on this effect has been found to achieve 90 per cent reduction of salinity without an external power source. The group has carried out theoretical analysis and has come to a conclusion of methods to commercialise the process.

Getting to the market

Professor T Pradeep spoke of the scale of the problem of water, which would soon dwarf other crises that humanity faces. A very low level of contamination, just one part in 10^{13}, which works out to "one person in 10,000 times the Indian population", he said, rendered water unfit for use. To purify water affordably and on a large scale was, hence, a priority. There was a case to create an institution to support research and to help ideas to be quickly commercialised, he said. But Andelman later observed that "there is zero R&D money in the USA for water tech, neither government nor corporate". and he funded his own research by running a side business!

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'INDIA HAS SOME OF THE BEST TALENT IN THE WORLD'

DELHI-BORN POSHAK GANDHI IS PART OF AN AMBITIOUS MISSION LAUNCHED BY THE JAPAN AEROSPACE EXPLORATION AGENCY AND HIS INTENTION IS TO FOCUS ON HOW BLACK HOLES ACCRETE MATTER FROM THEIR SURROUNDINGS AND GROW, WRITES **DEBAMEETA BHATTACHARYA**

Poshak Gandhi, a researcher at the UK-based University of Southampton, is part of the recently launched "Astro-H X-ray space telescope mission" that will explore the structure and evolution of the universe. The aim is to study hot and extremely dense objects such as black holes and clusters of galaxies. Since most of the largest, growing black holes are hidden behind thick interstellar gas and dust clouds, using X-ray observations is the only way researchers can directly study many of them and Astro-H promises to enable better observance than ever before.

The mission is led by the Japan Aerospace Exploration Agency (Jaxa) and includes the National Aeronautics and Space Administration and the European Space Agency. Astro-H was launched into low-earth orbit from the Tanegashima Space Centre in Japan by a Jaxa H-IIA rocket on 12 February and the mission will last for three years.

Dr Gandhi, who is an associate professor and Science and Technology Facilities Council Ernest Rutherford Fellow in the University of Southampton's Astronomy Group, has been a member of the Astro-H mission since 2010 and is participating in two "science task forces" focused on understanding how black holes accrete matter from their surroundings and grow and studying the interaction between black holes and the galaxies in which they live. Born in Delhi, he pursued a BSc (Physics) from St Stephen's College and then did his PhD from the Institute of Astronomy, University of Cambridge. Thereafter, he worked in Chile, Japan and the UK before taking up his current position at University of Southampton. Excerpts:

Astro-H comes across as an exhaustively ambitious mission, so what exactly is your involvement?

I am a science team member of the mission that is now renamed "Hitomi", and my focus is on black hole research. We are responsible for proposing some of the initial scientific observations, analysing observational data and interpreting the results, leading to new research that is published worldwide. I was invited to join the project because of my previous work on growing black holes. This is what my PhD was on and it fits in perfectly with the science focus of Hitomi.

What is Xray spectroscopy all about and how instrumental would it be in aiding the study of black holes?

The simplest analogy is to think of Hitomi as an X-ray prism. Just as a prism can split sunlight into its constituent colours, Hitomi will be able to split X-rays emitted from hot plasma (such as that found in the vicinities of black holes) into their constituent X-ray colours. This is X-ray spectroscopy. The study of these X-ray spectra reveals the elemental composition and motions of gas around black holes.

Hitomi will be able to do this far better than any previous mission. In essence, it will be able to distinguish "shades" of X-ray colour better than most previous missions. Imagine that you had blurry vision, and that with new glasses you could improve your eyesight by a factor of 30. This is what we can expect with Hitomi, and this is why it will be a huge step forward.

You've been working with space researchers from the Japan Aerospace Exploration Agency, Nasa and the ESA, so what has your experience been as a member of the Hitomi mission?

Japan has always been at the forefront of X-ray telescope technology and it was a very rewarding experience for me gaining expertise on X-ray astrophysics during my time in Japan, and I continue to do so as part of our ongoing collaboration. It was also very inspiring to see how the Hitomi team prevailed over the setbacks caused by the devastation of the tragic 2011 Japan earthquake and tsunami. The launch had to be delayed because of the setbacks, but the team worked incredibly hard to overcome these obstacles and finally launched the mission successfully.

Because Hitomi represents such a huge improvement in our capabilities, we can expect it to not only answer many longstanding questions but to also open up new frontiers and raise new questions. This requires the combined expertise of astronomers worldwide, and the Hitomi science team has been built up to comprise experts from more than 60 institutes across the globe. Personally, I find it very stimulating to be part of an active international collaboration where people can learn from each other and bring their combined expertise to bear on problems related to the nature of the universe.


Poshak Gandhi

Would you care to elaborate on your research on black holes? And what more do you intend to study by participating in the two science task forces that are part of this project?

Very briefly, one of my research themes is the growth of supermassive black holes in the cosmos. Following decades of research, we already know that most are hidden behind interstellar clouds of gas. These clouds probably provide the raw material that falls in and feeds the black holes to make them grow. But these clouds also often obscure our view, making black holes difficult to study directly.

Hitomi is an X-ray telescope, and X-rays can penetrate through, and reflect off, these clouds, giving us important information about what's hidden within. Further, previous X-ray missions have not had the capability to study in detail whether the clouds in the immediate vicinity of black holes are actually falling in, or not. These could be in stable orbits or may even be driven away because of the intense power of a black hole. Hitomi is our best bet so far for such studies, and this will be one of the questions I hope to address in my research.

What does it feel like being an Ernest Rutherford fellow and associate professor at the University of Southampton?

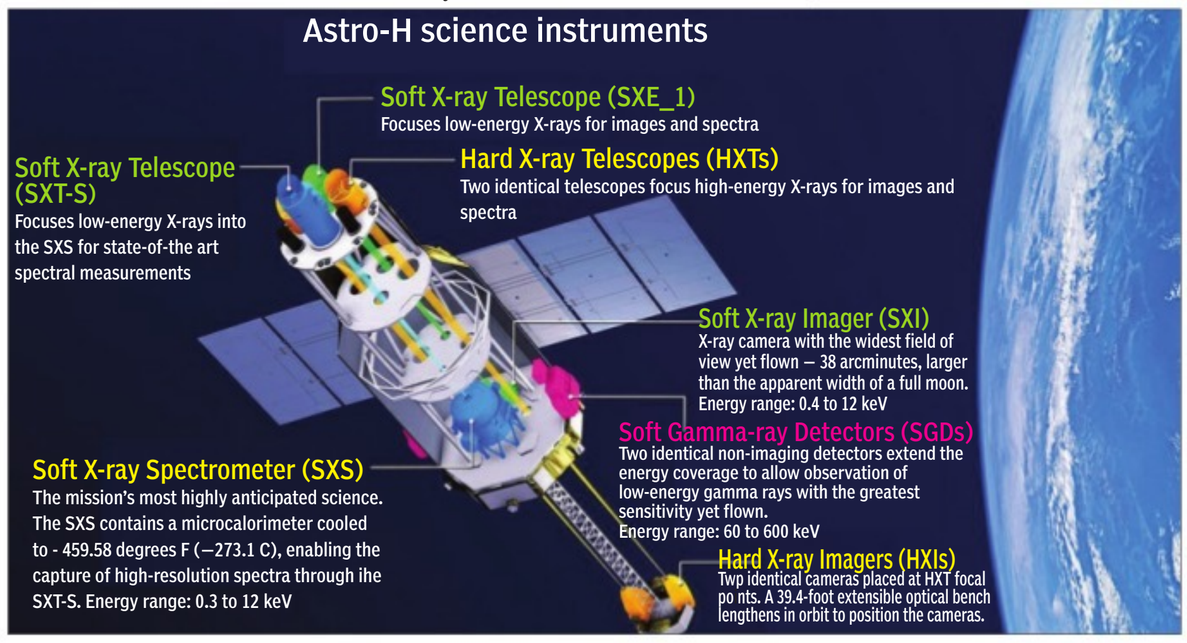
It is an incredible privilege. But what I've achieved is nothing extraordinary. With a passion for one's work, and a commitment to continue learning and becoming a better person every day, anything is possible.

What mysteries of the universe would you as an astronomer love to solve?

This is a difficult question because there are so many! Personally, I would love to understand the physics of black holes; whether they all are the same, no matter their sizes, how they are able to generate the incredible power they do, and what their extreme physics tell us about the nature of space. But I also hope that during my lifetime we are able to find definitive proof of life (in any form) outside the earth, should it exist.

You seen observatories across the world, which one would you say has the best space research set-up?

In my experience, the key resource is actually good people. Although equipment and research facilities can always be upgraded, it is much harder to find the right person with the combination of skill, sensitivity, insight and energy who can forge a new path forward in research. The best observatories and institutes are always the ones that can attract such people, and they draw future generations of great researchers. India has some of the best talent in the world and also excellent potential in this regard.



PLUS POINTS

Life on Mars?

The UK is set to join the European Space Agency in a mission to discover whether life exists on Mars. This is the country's first attempt to visit the Red Planet since the failed 2003 *Beagle 2* mission, which lost contact with ground staff and was only spotted more than a decade later when Nasa cameras picked out its shape on the surface of Mars in 2015.

In a joint project between the ESA and Russian space agency Roscosmos, the *Exomars 2016* orbiter and probe are set to leave earth on 14 March from Kazakhstan and are intended to arrive on the Red Planet in October 2016, if all goes to plan.

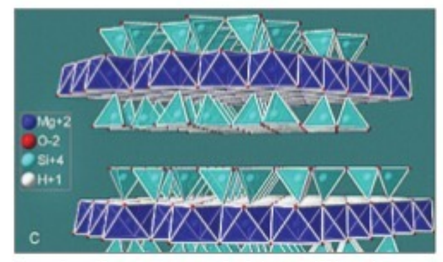
A trace gas orbiter and a landing module known as Schiaparelli will be launched on a rocket and fly to Mars as one, with Schiaparelli being fired from the orbiter towards the red planet three days before reaching the planet's atmosphere.

It will then travel towards the planet at 12,000 kmph, using a parachute to slow itself down before its thruster allows it to brake and allow it to land on the surface of Mars. The mission will then carry out tests on the surface of the planet to attempt to trace the origin of important gases, which scientists believe could indicate the presence of life.

HARRIET SINCLAIR/THE INDEPENDENT

Talc & cancer?

Jurors in Missouri recently concluded that Johnson & Johnson bore some responsibility in the death of Jackie Fox, who died of ovarian cancer. Her family was awarded $72 million in a case against the pharmaceutical behemoth because, the jurors said, Johnson & Johnson failed to disclose that its talc-based feminine hygiene powder carried an ovarian-cancer risk.



Yet, according to the company, the jurors' decision was not rooted in evidence. "The recent jury outcome goes against decades of sound science proving the safety of talc as a cosmetic ingredient in multiple products," Johnson & Johnson said in a statement.

The truth, it appears, lies somewhere in between. Epidemiologic studies have produced mixed results, though many have found a slight increase in risk for ovarian cancer — roughly 30 per cent — among women who use talcum powder in their genital areas. But as far as experimental evidence showing talc can cause cancer, "those studies are definitely needed," said Katie Terry, an epidemiologist at Harvard Medical School who conducted a recent study looking at talc use and ovarian cancer risk.

KERRY GRENS/THE SCIENTIST

Mysterious signal

Scientists have heard a long, repeated sound from deep in space — and nobody is sure where it is coming from. Astronomers found 10 millisecond-long "fast radio bursts", the latest example of a mysterious radio wave coming from outside of our galaxy. Scientists had previously thought that the bursts were singular events. But a new study finds that at least some of the sources send out repeated messages. The finding adds to other strange discoveries about the fast radio bursts that seem to indicate that there may be something unusual causing them.


Arecibo Observatory in Puerto Rico, which simultaneously observes the same targets, simulating a telescope more than 6,800 miles in diameter.

Scientists said last year that some of the messages appear to be coming in a pattern — one that could even be created by alien technology.

The new research sheds little new light on what exactly is causing the messages. But it does offer perplexing questions about what sort of source could be emitting them.

ANDREW GRIFFIN/THE INDEPENDENT