Helping ice stay frozen

A covering of ice that lets heat leak out but not to get back in

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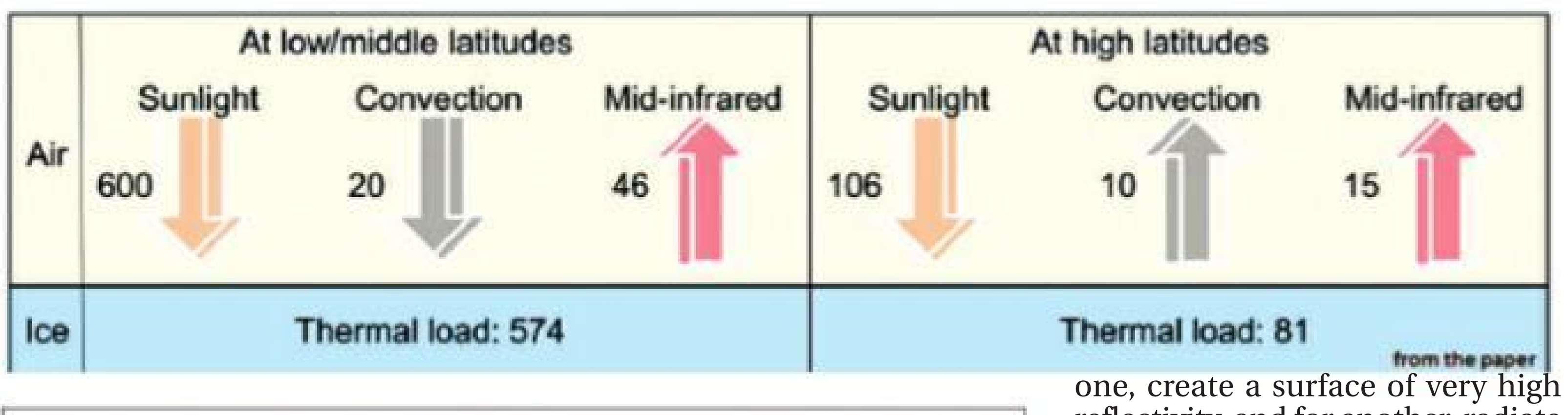
Ice is something that readily melts. As ice has a very large role in preserving food, much energy is expended in the production of ice. Melting of ice when exposed to sunlight is thus a factor that increases global energy consumption.

In the context of ecology, melting affects the ice cover at the poles, or on mountain tops. This ice is what regulates wind and rainfall, and importantly, locks away a huge quantity of water. This persistent store of ice is fast melting, leading to changes in climate and dangerous rise of the sea level because of the water released.

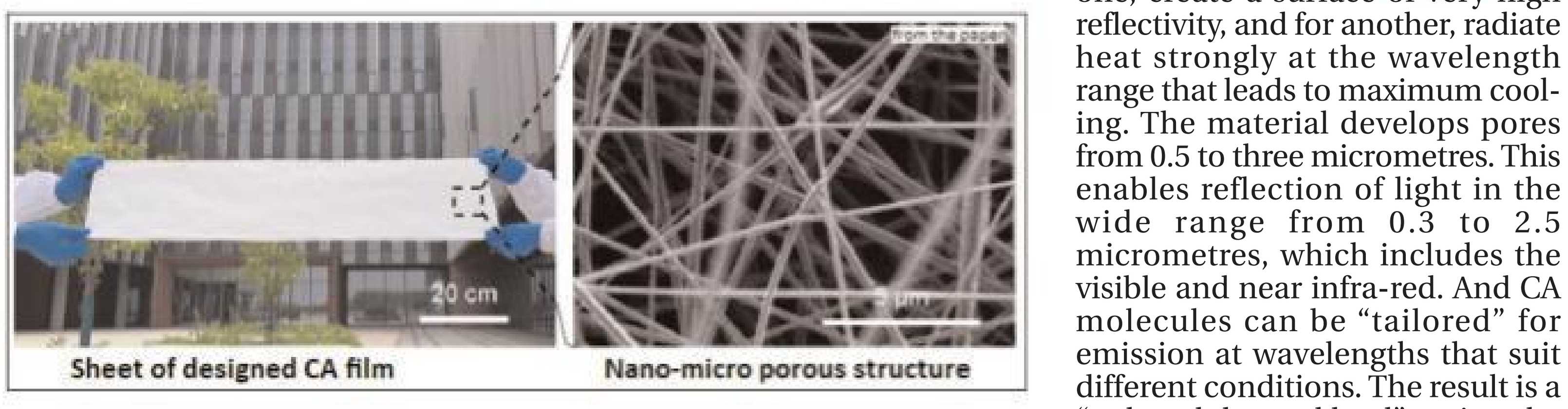
Jinlei Li, Yuan Liang, Wei Li, Ning Xu, Bin Zhu, Zhen Wu, Xueyang Wang, Shanhui Fan, Minghuai Wang and Zia Zhu, from Nanjing University, China, Stanford University and the Chinese Academy of Sciences, write in the journal, *Science Advances*, of an ecologically safe material that can retard melting by keeping away the energy of sunlight from small and large surfaces of ice, while allowing it to keep losing energy by radiation.

As a first step in examining how to minimise the melting of ice in sunlight, the authors say, one needs to understand the energy flows that are involved. On the surface of ice, exposed only to sunlight, the principal inflow of energy, in the form of heat, is sunlight -- infra-red radiation in the wavelength range of 0.3 to 2.5 micrometres. While this heat flows in, the surface also radiates energy, heat energy, also in the infra-red, in the wavelength range 2.5 to 18 micrometres.



As shown in the diagram, the main input of heat is from sunlight, and there is more at lower latitudes, nearer the Equator, than at high latitudes, nearer the poles. In contrast, the heat that is radiated out is much less than what is received. A method of preventing ice from melting, hence, should minimise the Sun's heat that reaches the ice surface and, at the same time, allow the largest part of radiation from the ice to escape.

Several candidate solutions are now available. Most of those rely on "selective emissivity" or getting a surface to radiate heat within a narrow wavelength window. The reason the Earth does not chill to the icy coldness of outer space soon after sunset is that heat is trapped by the atmosphere, which keeps the Earth warm. The same property of the air around us captures radiation from an object and prevents it from cooling as fast as we would like it to. Except that there is a narrow range of wavelengths at which the atmosphere is transparent to infra-red radiation. And the part of the heat the object gives off, which lies in the window, passes through the atmosphere, without warming the surroundings, into outer space.



Sheet of designed CA film | Nano-micro porous structure

One such arrangement, reported in 2014, consisted of a combination of silica (silicon dioxide) and hafnium dioxide, with a polished silver backing, which captured incoming radiation and turned it around as radiation in the nine-12 micrometre wavelength range, which passes out, through the atmosphere. And a year later, silicon crystal architecture was adapted so that heat was sent out, as before, but visible light was allowed in, to allow solar cells to function, and to stay efficient, because they were kept cool.

And another year later, in 2016, a wearable fabric was developed that allowed body heat to pass through, but was opaque to light, so that it performed the "social" role of personal clothing. The fabric was a polyethylene, which is normally transparent. But the fibres were modified to have dimensions that were comparable to the wavelength of visible light. Visible light was hence scattered, but not infra-red radiation, which has a longer wavelength. A "wicking" treatment, that drew perspiration away from the inner surface, made the fabric comfortable to use for clothing.

While these were arrangements that required complex construction and were useful to cover smaller objects, a low-cost film which could be laid over larger structures was reported in 2019. The film was of a common silicone, a transparent, soft and pliable material that is found in contact lenses, as a lubricant, a water repellent coating, even in shampoos. The material was found to selectively emit at the wavelength where the atmosphere was transparent, and with a promise of passive cooling by 12 °C, under the night sky. And on the same lines, we now have super-reflective paints, with selective emission, to paint buildings and keep the interior cool during the day. There has been cooling to the extent of 40-100 Watts for every square metre, with temperature dropping as much as 13 °C, the *Science Advances* paper says.

Preventing the melting of ice, however, presents unique requirements, the paper says. For one, ice is at a lower temperature than other objects that need cooling. The rate of loss of heat hence needs to be greater, by some 70-110 W for every square metre. And then, there is a huge quantity of ice to be protected -- with widespread use, as in food preservation, and if used to help glaciers that are in danger of melting, hundreds of square kilometres would be required. "…It is critical that the radiative cooling materials be extremely abundant and scalable (to million metric tons) with minimised environmental impact," the paper says.

The material developed by the authors is based on eco-friendly, cellulose acetate, or CA, which is sourced abundantly from vegetable matter. The CA is worked into a layered film, where the molecules, for one, create a surface of very high reflectivity, and for another, radiate heat strongly at the wavelength range that leads to maximum cooling. The material develops pores from 0.5 to three micrometres. This enables reflection of light in the wide range from 0.3 to 2.5 micrometres, which includes the visible and near infra-red. And CA molecules can be "tailored" for emission at wavelengths that suit different conditions. The result is a "reduced thermal load" on ice, the paper says, and the material is non-polluting, as it can be digested by micro-organisms in nature.

Trials were conducted with common food materials, like ice cream, wrapped in the CA-based film and in the usual way with paper, aluminium foil, polyethylene terephthalate or polyethene. It was found that the heat load with usual materials was some 150-300 W for every square metre, against a net "heat loss" in the case of the CA-based film. Ice cream wrapped in the film stays 98 per cent intact after 80 minutes in the Sun, against only 50 per cent with usual wrapping, the paper says.

For preservation of ice in bulk, as in icebergs, trails showed that even with a load of 700 W for every square metre, which is nearly twice than what is found in higher latitudes, the CA-based film could keep the ice temperature at seven °C below the ambient. In a trial, samples of ice were exposed to natural sunlight for five consecutive days. Ice covered with CA-based film stayed unchanged, while bare ice shrank and disappeared, the paper says. The CA-based material, which can be spread as a powder over ice, is equally effective over snow, the paper says.

The development is exciting, as a solution both to conserving huge energy that is consumed to manufacture ice, as well as to help stave the melting of glaciers, in the face of global warming.

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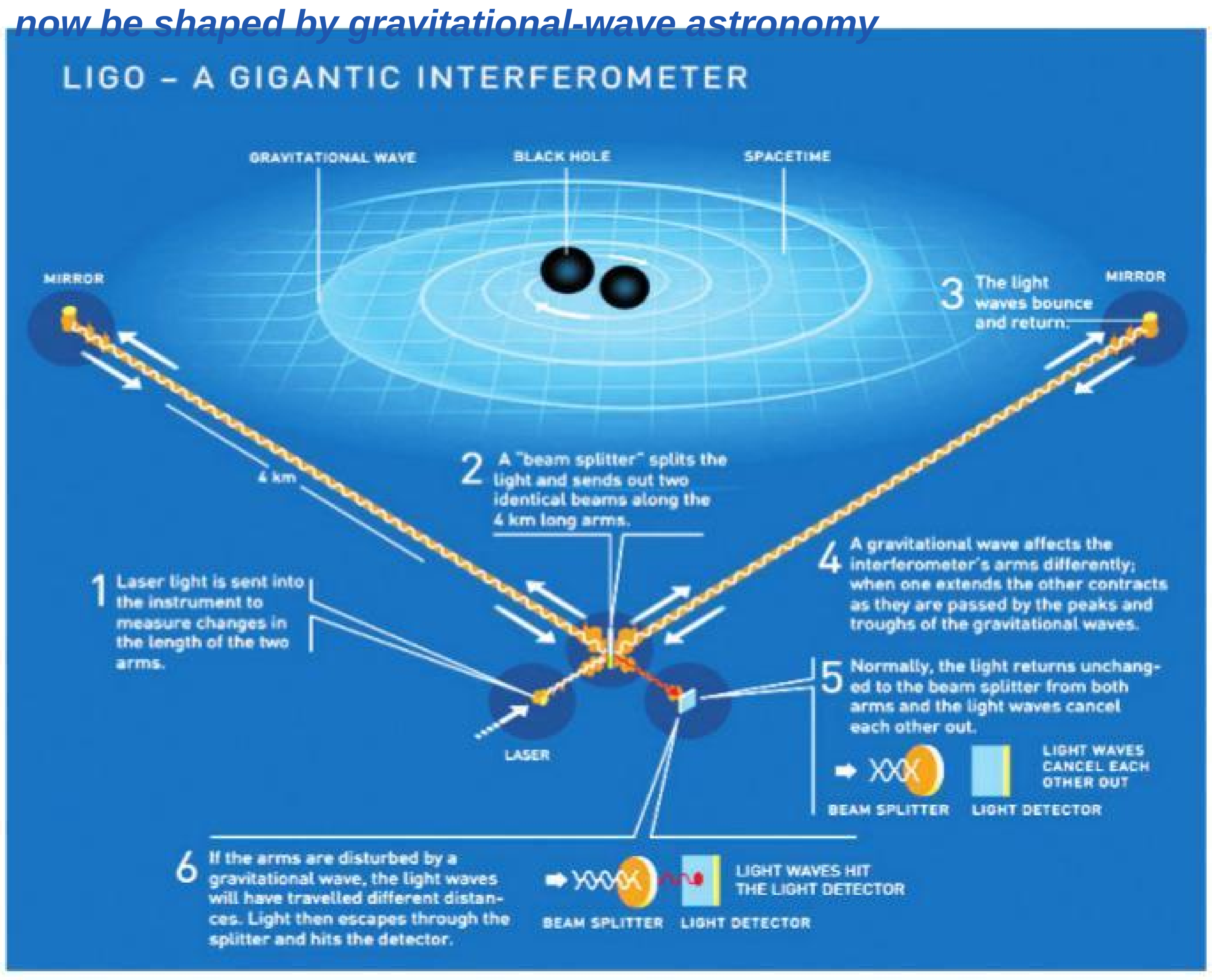
Secrets of the cosmos

While Galileo Galilei birthed electromagnetic astronomy, our understanding of the universe will now be shaped by gravitational-wave astronomy



BIKASH SINHA

Around 400 years ago, Galileo Galilei built a telescope. A professor in Italy's Padua at the time, he started to survey the sky by peering through his telescope. It was powerful enough to detect the four largest moons of Jupiter and thus, electromagnetic astronomy was established on a firm foundation.

With his initial observations, Galileo was slowly but surely demolishing the opaque veil of religious mythology wrapped around our Solar System by the all-powerful cardinals of the Vatican at Rome. The Earth was considered to be at the centre of the Solar System and the Vatican firmly stood by that dogma. For a true scientist, truth is above everything else, and Galileo declared, "In the question of science, the authority of a thousand is not worth the humble reasoning of a single individual."

Galileo went to establish the most revolutionary idea for the time -- the Sun, and not the Earth, was at the centre of the Solar System. With one stroke, he established a new order of the world in the sky and Earth became helio (Sun)-centric. Famous playwright Bertolt Brecht later wrote, "January ten/ Sixteen ten/ Galileo Galilei/ Abolishes heaven."

In the 400 years since Galileo, the greatest discovery in electromagnetic astronomy is by British physicist Roger Penrose, who got the Nobel Prize in Physics last year. Our present universe is expanding and therefore, cooling with expansion. The question asked by Penrose was echoed by others down the centuries, "Do we have only one unique universe?"

Penrose's thesis went thus. With expansion, the universe cools down and in time, the universe will be extremely cold, an icy graveyard of galaxies. The temperature of the universe will be very close to absolute zero (-273 °C), the lowest conceivable temperature in science. The irony is that the billions of black holes in the universe would still have the "Hawking temperature", which is somewhat warmer than the surrounding universe.

So, what happens then? The black holes would start bursting or popping and it will become the Big Bang for the next universe. Penrose's prediction is that this aeon comes to an end and another universe is born from that Big Bang. And in the process, the cycle goes on, from one aeon to another. Clearly then, in this framework, time has no beginning or end and thus, neither does space.

It is an eternal drama of creation and destruction. The amazing consequence of this idea is that Penrose and his collaborators see the evidence of the last universe's signatures in our universe. This must be one of the most extraordinary discoveries since Galileo's helio-centric Solar System.

It brings one to Albert Einstein's gravitational waves and gravitational-wave astronomy, a complete departure from electromagnetic astronomy. Gravitational waves, as predicted by Einstein in the General Theory of Relativity, originate from the space-time manifold. The one near a black hole, for example, is already curved, and thus, when two black holes collide, the space-time manifold sends out gravitational waves.

For about 50 years, scientists have been trying to detect gravitational waves without much success. It is a complicated endeavour as gravitational waves have very large wavelengths, which makes it quite difficult to measure their arrival on Earth. That said, Reiner Weiss, Barry Barish and Kip Thorne took up the challenge and convinced themselves that gravitational waves could be observed. They developed a curious device called interferometers in collaboration with around 1,200 scientists across the world. What a departure indeed from Galileo's one-man army!

The L-shaped interferometer is a marvel -- technology of this kind had to be invented and without doubt, the shining leader was Weiss from Massachusetts Institute of Technology in the United States. The long arm of the detector called Ligo, an acronym for laser interferometer gravitational-wave observatory, is unique, measuring approximately four kilometres in length and full of hanging mirrors.

Everyone in the game expected that gravitational waves would be detected from the coalescence of neutron star binaries. Neutron stars are known from the 1960s after their discovery by Tony Hewish, Jocelyn Bell and Martin Ryle.

In 2015, the first gravitational waves were detected by Ligo with the cryptic numbers GW150914 and GW151226. It happened not from coalescing neutron star binaries but from the coalescence of a pair of black holes. The results, both from the Hanford Observatory in Seattle and the Livingstone Observatory in Louisiana, confirmed the dramatic existence of gravitational waves. Much later, on 17 August 2017, gravitational waves from two neutron stars were detected. These massive black holes inhabit the cosmos some 1.3 billion light years away from Earth.

Gravitational-wave astronomy is quite different from electromagnetic astronomy. One of the simplest reasons is that gravitational waves hardly interact with anything, except under some very special circumstances, such as the exponential expansion of the universe. Thus, gravitational waves are excellent witnesses to major happenings in the universe.

In the words of Thorne, professor at the California Institute of Technology, U S, who got the 2017 Nobel Prize in Physics for discovering gravitational waves, "When we contemplate the enormous revolution in our understanding of the universe that has come from electromagnetic astronomy over the four centuries since Galileo, we are led to wonder what revolution will come from gravitational astronomy and from its multi-messenger partnership, over the coming four centuries."

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PLUS POINTS

Good till 60

The human brain's processing speed remains high until the age of 60, according to a new study that challenges previous assumptions that mental speed peaks at 20.

As humans age, it takes us longer to react to changes in our environment, or stimuli. Previous research has shown that this slowing of response time starts from the age of about 20, gradually continuing to increase as people get older. In societies across the world, older people are often assumed to be slower thinkers than younger people, and this notion also has significant consequences in work life.

The new research, published in the journal *Nature Human Behaviour* last Thursday, tested this theory by analysing more than a million participants across a wide age range who had taken part in an online experiment that measured their reaction times to a cognitive task. Participants had to categorise a selection of words and images that flashed up on a screen by pushing the correct key in response.

Although the response times do seem to slow down after age 20, scientists from Heidelberg University in Germany said it could be due to increases in decision caution and to slower non-decisional processes, such as the time taken to press the key. Researchers said that response times are not pure measures of mental speed but instead represent the sum of multiple processes. They used Machine Learning to extract more information and find out why someone responded slowly to a question -- whether it was attributable to slow motor responses or slow cognitive response.

"Only after about age 60 do drift rates start to show an accelerating negative age-related decline, with the lowest mean values found for the oldest participants," the scientists said.

The Independent

Purifying water

Researchers at the Indian Institute of Science Education and Research-Bhopal have developed organic polymers, which can remove highly polar organic micropollutants from water to render it safe for consumption.

These polymers have already been tested for polar organic micropollutants removal at a laboratory scale. Large-scale fabrication of these materials in collaboration with industrial partners will open a promising avenue for real-time scavenging of toxic polar organic micropollutants from water. Called hyper-crosslinked porous organic polymers, or HPOPs, a teaspoon of the powder of these polymers will cover an internal surface area close to 10 tennis courts.

The research was led by Abhijit Patra, associate professor, department of chemistry, IISER-Bhopal, at the Functional Materials Laboratory of the Institute. Other members of the team comprised Arkaprabha Giri, PhD student, department of chemistry; Subha Biswas, former student, department of chemistry, currently pursuing PhD at Indian Institute of Science-Bangalore; Mohammed Waseem Hussain, former PhD student, department of chemistry, currently pursuing post-doctoral research at Hanyang University, South Korea, and Tapas Kumar Dutta, PhD student, department of chemistry, IISER-Bhopal.

This project was funded by the department of science and technology, Government of India, under the "Centre for Sustainable Treatment, Reuse and Management for Efficient, Affordable and Synergistic solutions for Water" Initiative. The findings have been published in the journal of the American Chemical Society, *ACS Applied Materials and Interfaces*.

The researchers showed, for the first time, the evolution process of two dimensional nanosheets of solvent knitted HPOP from nanospheres to nanoribbons to 2D nanosheets through electron microscopy. The adsorption rate for toxic cationic dye, methylene blue (carcinogenic, teratogenic, mutagenic) by solvent knitted HPOP is one of the highest among the well-known adsorbent materials reported. The 2D sheet-like HPOP could sequester a broad-spectrum of polar organic micropollutants, including antibiotics, endocrine disruptors, steroid-based drugs, ionic dyes, plastic precursors, pesticides, and herbicides within 30 seconds only.