Faint light of outer space

The sky in many places in the universe could be dark even at midday

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The reason we have such brightness when the sun is shining on the earth is that the atmosphere scatters light at us from different directions. If we did not have an atmosphere, everything in direct sunlight would be very well lit but we could not say the same about things in the shade. The sky overhead would be dark, and there would be stars, even more clearly than usually at night.

However, as we do have an atmosphere, we can see very little of the real blackness of outer space while we are on Earth. This is so even when we are above the atmosphere, because there is still scattering by interplanetary dust in the near solar system. Michael Zemcov, Poppy Immel, Chi Nguyen, Asantha Cooray, Carey M Lisse and Andrew R Poppe, from Rochester Institute of Technology, University of California, John Hopkins University and Jet Propulsion Laboratory, California describe in the journal, *Nature Communications*, the study of interstellar illumination conducted at a great distance from the earth. The study used instruments on Nasa's spacecraft, Deep Horizon, beyond the orbit of Jupiter, on its way to Pluto, precisely to escape the glare that persists at shorter distances.

The faint light that is there in the blackness of deep space, the so-called Cosmic Optical Background (abbreviated as COB), is the sum total of the radiation from all the light emitting objects in the universe, after taking away the contribution from the solar system and our own galaxy. Although there are a great many of such external objects, they are distributed at such large distances that their effect in the spaces between them is extremely faint. It is this extreme faintness that makes the light so difficult to isolate and detect.

An accurate measurement of this faint glow, however, is of great interest, to test our current theories about the nature of the universe. We have a certain estimate of the number of luminous objects, and their distances apart, which lead to a certain level of illumination. If what we measure turns out to be different, then we may need to change our ideas of where the light comes from.

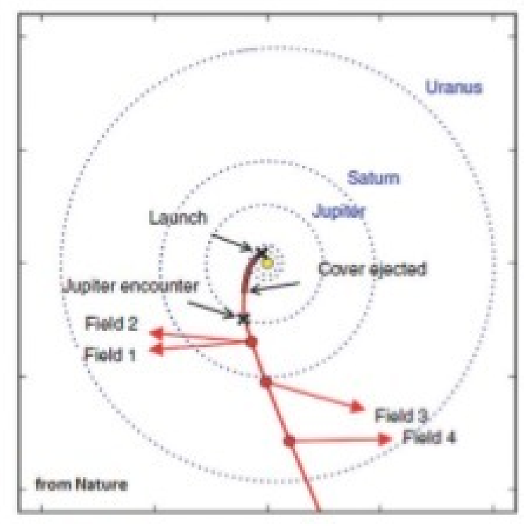
On the other hand, it is with the help of the faint background light that we make some of the estimates of the count of luminous objects in the heavens. If we have confidence in the amount of light from known objects, or the foreground light — in some direction — we could estimate the background light. We could then use this to work out the foreground light, from the total light coming in from another direction. The whole exercise, however, depends on measurement of the illumination itself, which is difficult in the level of glare in near-Earth locations.

The background illumination is believed to arise from different processes in the universe. These processes include the star formation process and, after the stars are formed, the nuclear fires in stars, where atoms of elements are generated by fusion of the nuclei of atoms of lighter elements. Another source of radiation is the matter near black holes, which accelerate to near the speed of light as they crash into the black holes. Yet another source is emission, as the nuclear fuel in the larger stars runs out and the stars collapse, because of their own gravity. And then there is the emission from events like the decay of elementary particles, or the effect of particle annihilation or acceleration.

Most of the early deep space missions sent out, the paper says, had rudimentary optical range cameras and did not make useful observation of the intensity of the COB. The probes, Pioneer 10 and Pioneer 11 (1972-73), however, had specialised equipment but the results were still uncertain as the foreground components to be subtracted were themselves uncertain. It was Nasa's New Horizons, the craft (launched in 2006) that flew by Pluto in 2015, which sent far superior data that the present researchers have analysed.

New Horizons was equipped with Lorri, the Long-Range Reconnaissance Imager, a camera primarily meant to

It was daytime on the moon, but the sky was dark. If the earth had been there, it would have been visible, just like during the night



analyse geological features of Pluto. The high sensitivity and ability to resolve narrow angles, however, could eliminate much of the starlight foreground that had confused earlier measurements and the mission collected relatively undisturbed data about the diffuse astrophysical emission or COB. The authors of the paper bring out that over the cruise of the spacecraft — beyond the orbit of Jupiter, at 779 km from the sun, on its way to Pluto at 5.9 billion km — there was data about COB measured from a range of vantage points. Ninety days after the craft was launched, the Lorri camera recorded a series of measurements, with the camera shutter on or in total darkness. The shutter was removed about six months after the launch and a known open star cluster was imaged. The image that was acquired enabled the camera to calibrate, so corrections could be applied to faint measurements to be made later. Data was then recorded till July 2014, about a year before the encounter with Pluto.

The paper explains that the brightness of an image of the sky outside the atmosphere consists of several components. It arises because of interplanetary dust, with clearly visible stars; starlight from sources that cannot be made out, a component of "diffuse galactic light" and then the COB. With the help of the different sets of data acquired, the team could "correct for dark current in the detectors, mask bright stars from the images, assess the amplitude of residual starlight, sunlight from interplanetary dust and diffuse galactic light, and correct for galactic extinction," the paper says, to arrive at a statistical upper limit of the value of COB. The results show the effectiveness of the Lorri arrangement to make precise, low foreground measurements of the COB, the paper says. A future mission could hence be designed to yield a much more accurate upper limit of the COB, which could help us "complete our understanding of the history of stars and galaxies in the universe," the paper says, "While we have estimates of these processes and of how intense the COB should be, finding the COB to be different may reveal the presence of exotic forms of matter or of decay of particles other than those that fit into the Standard Model."

Is the universe infinite?

The fact that the night sky is dark helps us find an answer.

One reason why the light from all the stars that we see at night does not lead to more brightness is that the stars are so far away. As we know, the intensity of the light from the star falls off as fast as the square of the distance. The nearest star, Alpha Centauri, at 4.3 light years away, is 282,510 times more distant than the sun, which is only eight light minutes away. The fall in intensity of light, however, is a whole eight billion times, and Alpha Centauri is just a bright star in the southern hemisphere.

For all that, there are so many stars in the sky, certainly eight billion of them, that there may be a case to expect more light at night time, than what we see. And if the universe were infinite, it can be worked out that however so close a pair of stars may be when seen from the earth, there will always be one more star to peep in between them. And even if there were a gap between this star and the other two, there would be another star to fill the space, and so on. It can hence be worked out that if the universe were infinite, the whole sky would be lit with starlight and the illumination, in fact, would be infinite too.

But since the night sky, in fact, is dark, we know that the universe is finite.

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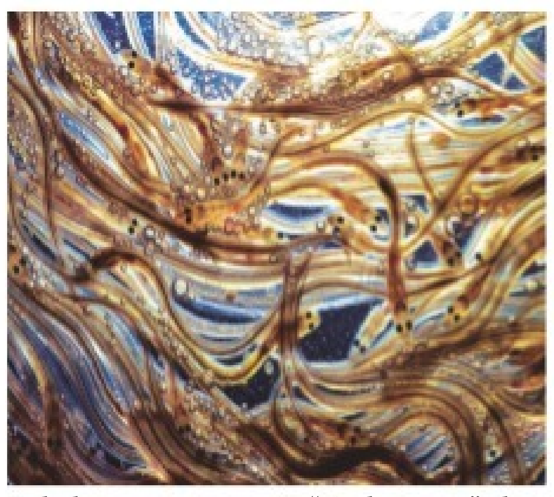
PLUS POINTS

Driven by sixth sense



Eels have a magnetic "sixth sense" that enables them to navigate 5,000 kilometres across the Atlantic from their birthplace in the Sargasso Sea, scientists have discovered.

It enables them to detect changes in the Earth's magnetic field, which allow them to hitch a ride in the Gulf Stream — a current that carries warm water from the Caribbean to Western Europe. And that reduces the amount of time it takes to make the journey, although it still lasts about 300 days.

The researchers used magnets to simulate conditions at different points on the journey, then noted how this influenced the young eels' swimming direction. Professor Lewis Naisbett-Jones, of North Carolina University, said, "We were not surprised to find that eels have a magnetic map, but we were surprised to discover how well they can detect subtle differences in magnetic fields.

"We were even more surprised when our simulation revealed that they use their map not so much to locate Europe, but to target a big conveyor belt — the Gulf Stream — that will take them there."

Pollution and our enthusiasm for eating eels have seen their numbers plummet by 95 per cent since the 1980s, and they are now critically endangered. It is hoped greater understanding of the animals could help conservation efforts. After their swimming the Atlantic, eels spend the next 15 years growing to maturity in the rivers and estuaries of Europe and North Africa.

Even though festivals of eel catching and eating have been held on rivers across Europe for centuries, their life history had long remained a mystery. It was only in 1922 that their spawning grounds were found, and the late 2000s when the adults' journey was mapped for the first time.

ben upton/the independent

Paths obstructed

Turtle breeding sites are already suffering from the impact of tourism and fishing, but scientists have just discovered that rare leatherback turtles nesting on the shores of Colombia in South America are also being threatened by logging in tropical forests.

Logging debris is hindering the movements of both the hatchlings and their mothers at one of the world's most important nesting sites, said researchers at the University of Exeter in Britain and the Donana Biological Station in Spain, who published their findings in the journal *Marine Ecology Progress Series*. To nest and breed successfully, females must be able to cross the sandy beaches to dig their nest to successfully incubate their eggs. In turn, hatchlings must be able to cross the sand unaccompanied to reach the water.

The team monitored 216 turtles, studying how their activity varied with the amount of debris. They found that females, which nested in areas with higher amounts of debris spent more time building their nest and tended to do so closer to the shoreline. This meant they were more vulnerable to flooding, which puts their eggs at risk. Some females were even wounded while negotiating the debris.

The debris also meant it took longer for hatchlings to reach the sea, increasing their chance of being eaten by predators. Professor Brendan Godley, the co-author and director of the Centre for Ecology and Conservation at the University of Exeter, said in a statement that leatherback turtles are already under immense pressure, not only from being caught in fishing nets but also from ingesting marine plastic litter. "It is now paramount that beach clean-up operations are built into logging activities to prevent further damage to this species," he said.

lin yangchen/the straits times

Meet Enceladus

Here's all you need to know about the 'tiny snowball' in our solar system that might hold alien life

ANDREW GRIFFIN

An image of icy Enceladus

Enceladus is, to many, just an icy snowball floating around in space. But it's just become a lot more important — it's perhaps the greatest hope for life in our own solar system.

The small moon of Saturn, which has a 502km diameter, has been revealed to have hydrothermal processes going on underneath its crust. That, in turn, means that it may have all the requirements for life — and that microbial life might be found there. What started out as an afterthought or side project for the Cassini mission to Saturn has turned out to be perhaps its crowning glory. Enceladus is made up of an icy surface shell and a rocky interior inside, with a warm ocean sandwiched between the two. It's in that ocean that any life is likely to live — apparently given fuel by the processes discovered in the new research.

It was first found by British astronomer William Herschel, in 1789. It got its name in 1847, from Herschel's astronomer son John. Since then, it languished mostly in obscurity — one of a full 53 moons around Saturn and not looking to be even one of the more interesting ones. But that all changed when the Cassini orbiter arrived at Saturn in 2005. It found plumes of water shooting out of cracks in Enceladus's surface, leading scientists to wonder whether it might be geologically alive after all. That led scientists to fly Cassini through the plumes, using all of the various sensing mechanisms on board to try and understand what the plumes were made of.

It found mostly water, or tiny ice particles, with traces of other things like methane, ammonia, carbon monoxide, carbon dioxide and various salts and simple organic molecules. Later it found silica nano-particles, suggesting that something was going on between the hot rocky interior and the alkaline water.

That led scientists to expect and hope that hydrogen might be found inside, making the world habitable. That's what the latest flyby — in 2015, when Cassini was shot through the plumes — was looking out for, and what it found.

"What we knew already from Cassini is that Enceladus has these fountains of water jetting out from its surface," said Lewis Dartnell, an astrobiologist from the University of Leicester. "That in itself was a hugely exciting and totally unexpected discovery — it tells us this tiny snowball of a world, smaller than the UK from side to side, is geologically active.

"It's warm on the inside, where there's a large body of liquid water. We knew there was an environment, which was potentially habitable, in Enceladus. But Cassini has essentially tasted what's in that water."

It's what it tasted there that has got scientists so excited — molecular hydrogen, suggesting that the moon has fuel for life. With that, it completes the three things — alongside water and organic molecules — that are required to support living things.

But it's just the latest surprise from the little moon, which was never intended to be a significant object of study for the Cassini mission. "When Cassini got there it was not a major target of the mission," says Caitriona Jackman from the University of Southampton. "It was thought just to be a rocky or icy moon. It was at the beginning of the mission in 2005 when it had a flyby and realised there was more than meets the eyes."

Gradually, the truth about the moon was revealed — strange magnetic effects were pinned down to "tiger stripes" on the crust, and water vapour and other organic material was shooting out of its vents.

"Enceladus has been the biggest bonus ever," says Professor Jackman, who worked on the Cassini mission. "It was an incredible discovery to even know that it was interesting. It wasn't a highlight or a major target, but it turns out to be one of the most interesting of Saturn's moons."

the independent

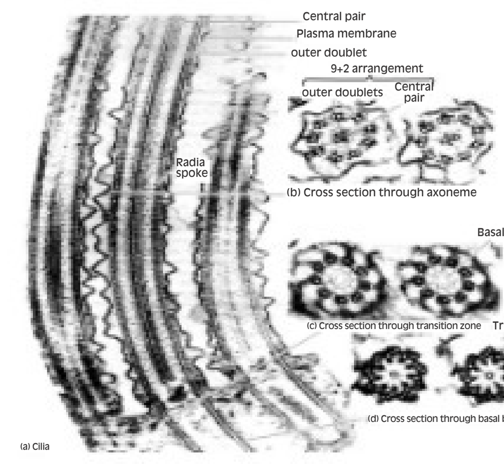
Of pairs, connections and spokes

An explanation of how cilia and flagella are structured in eukaryotes

TAPAN KUMAR MAITRA

Cilia and flagella have a common structure consisting of an axoneme, or main cylinder of tubules, about 0.25µm in diameter. The axoneme is connected to a basal body and surrounded by an extension of the cell membrane. Between the axoneme and the basal body is a transition zone in which the arrangement of microtubules in the basal body takes on the pattern characteristic of the axoneme. The basal body is identical in appearance to the centriole. A basal body consists of nine sets of tubular structures arranged around its circumference. Each set is called a triplet because it consists of three tubules that share common walls — one complete microtubule and two incomplete tubules. As a cilium or flagellum forms, a centriole migrates to the cell surface and makes contact with the plasma membrane. The centriole then acts as a nucleation site, initiating polymerisation of the nine outer doublets of the axoneme. After the process of tubule assembly has begun, the centriole is then referred to as a basal body.

The axoneme has a characteristic "9 + 2" pattern, with nine outer doublets of tubules and two additional microtubules in the centre, often called the central pair. The nine outer doublets of the axoneme are thought to be responsible for the sliding of adjacent doublets. The inter-doublet links (nexin connections) join adjacent doublets and the radial spokes project inward, terminating near projections that extend outward from the central pair of MTs. Each outer doublet of the axoneme therefore consists of one complete MT, called the A tubule, and one incomplete MT, the B tubule. The A tubule has 13 proto-filaments, whereas the B tubule has only 10 or 11. The tubules of the central pair are both complete, with 13 proto-filaments each. All of these structures contain tubulin, together with a



second protein called tektin. Tektin is related to intermediate filament proteins and is a necessary component of the axoneme. The A and B tubules share a wall that appears to contain tektin as a major component.

In addition to microtubules, axonemes contain several other key structures. The most important of these are the sets of side arms that project out from each of the A tubules of the nine outer doublets. Each sidearm reaches out clockwise toward the B tubules of the adjacent doublet. These arms consist of axonemal dynein, which is responsible for sliding MTs within the axoneme past one another to bend the axoneme. The dynein arms occur in pairs, one inner arm and one outer arm, spaced along the MT at regular intervals. At less frequent intervals, adjacent doublets are joined by inter-doublet links. These links are thought to limit the extent to which doublets can move with respect to each other as the axoneme bends. At regular intervals, radial spokes project inward from each of the nine MT doublets, terminating near a set of projections that extend outward from the central pair of microtubules. These spokes are thought to be important in translating the sliding motion of adjacent doublets into the bending motion that characterises the beating of these appendages.

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