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The first-ever image of black hole: An extraordinary achievement

INSIDE STORIES

EDITORIAL

Energy, Environment Day and the Doughnut

Nakul Parashar

Why wouldn't anyone be inquisitive to read if the science section of *The Economist* says – 'Baking the world's biggest bagel'. Yes, a conventional tokamak is a hollow torus with superconducting magnets wound around it, that reminds of a bagel or a doughnut. Now, what is a tokamak? It is one of the many types of magnetic devices used to produce thermonuclear fusion energy. Well, back to that biggest tokamak! The *Economist* article spoke about the Provence-based giant fusion reactor that is in the making. Expected to have started in 2016, the project is delayed. It is none else than the ITER, or the International Thermonuclear Experimental Reactor work on which is currently in progress at Provence, in south-east France, which involves 35 countries around the world. Dr Bernard Bigot, who's heading this project is quite positive that this internationally funded reactor would show the world the path to grid-scale fusion electricity. Hopefully, these endeavours reap fruits in time so that we do away with our dependence on fossil fuels. With a 2025 startup goal, wonderful and relevant, isn't it, especially when every year we celebrate the world environment day on 5 June?

So, what's happening this year on 5 June? The official site's home page says – nine out of ten people breathe polluted air. Quite startling, when another report claims that 92 per cent of the global population is breathing toxic air. Indeed, it's a global health problem. A WHO study says that seven million people globally die prematurely every year due to air pollution. Of these, four million deaths occur in Asia-pacific. This has, thus, affected the international economy as well – this toxic air has cost the globe about five trillion US dollars annually. Besides the loss of human lives, agricultural pundits predict a decline in staple crop yields by a whopping 26 percent by the year 2030.

In this connection, interestingly, China has been once known for the smog that enveloped its cities. It will be the global host of World Environment Day this year. We've all read and know how China has overcome its air pollution problem during the past few years. Joyce Msuya of UNEP (United Nations Environment Program) had acknowledged this fact, "The country has demonstrated tremendous leadership in tackling air pollution domestically." This fact can be duly supported by the fact that half of the world's electric vehicles today are owned by China. However, India's contribution to world environment day cannot be written off. India had led the initiative last year which was called as beat plastic pollution.

Tajassus, which means curiosity in Urdu is the name of the monthly newsletter in Urdu that we, at Vigyan Prasar launched last month. This came up as a part of our initiative to expand science communication, popularisation, and extension in Indian languages. We have thus, tried to bring together various agencies, both government and non-government to discuss the road ahead. Our first such endeavour with Bangla got started whence a widely attended conference in Kolkata came up in April. Attended by a number of scientists, teachers, students, and writers, this conference showcased a lot that has been done in Bangla, but disjointedly. We've, thus, planned to bring up a monthly newsletter in Bangla on lines of *Tajassus*. In fact, this journey doesn't stop here. We've done this in Tamil as well. A round of discussions to plan strategy related to Tamil with various stakeholders happened in Chennai recently.

The response so far has been very exciting, but the challenges are far bigger. Maintaining and yet moving ahead continually rather than continuously – we'll overcome them all of it with your support. Isn't it!

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The first-ever image of black hole: An extraordinary achievement

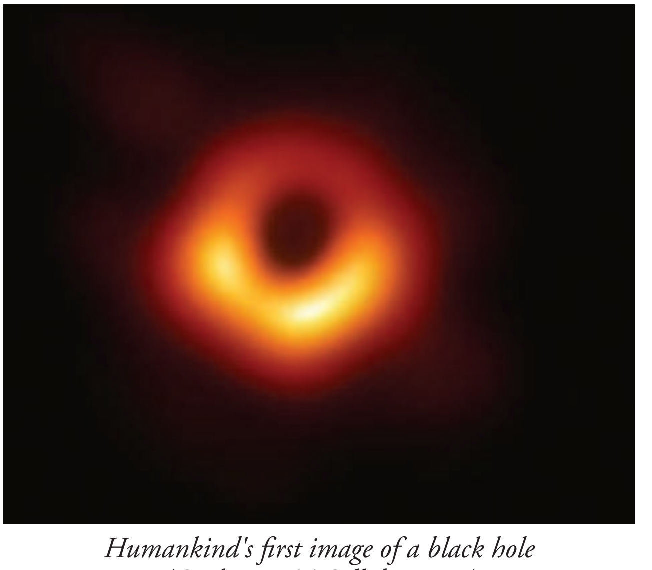
Dr. P. K. Mukherjee

Black holes are indeed weird astronomical objects. They are regions in space where gravitational pull is so powerful that even light cannot escape. The gravity of a black hole is extremely strong because matter has been squeezed into a tiny space. On 10 April 2019 scientists were able to finally unveil the first-ever image of a black hole. The path-breaking image was captured by the Event Horizon telescope (EHT), a network of eight radio telescopes, in an effort involving over 200 scientists.

The scientists were able to finally unveil the first-ever image of a black hole. The path-breaking image was captured by the Event Horizon telescope (EHT), a network of eight radio telescopes, in an effort involving over 200 scientists. The collaboration of scientists reveals what is called the "event horizon", the boundary at the edge of a black hole where the gravitational pull is so strong that no conventional laws of physics apply, and nothing can escape. The image released on 10 April 2019 shows the shadow, or silhouette, of the black hole at the centre of glowing plasma.

What is a black hole?

A black hole is generally defined as a region in space where gravitational pull is so powerful that even light cannot escape. The gravity of a black hole is so strong because matter has been squeezed into a tiny space. The idea of an object so massive that even light cannot escape the pull of its gravity was first mooted way back in 1783. It was Cambridge Professor John Michell who, in a paper for the *Philosophical Transactions of the Royal Society of London*, read on 27 November 1783, first proposed the idea that there were such things as black holes, which he called "dark stars". Having accepted Newton's corpuscular theory of light, according to which light consists of minuscule particles, he reasoned that such particles, when emanated by a star, would be slowed down by its gravitational pull, and thought that it might therefore be possible to determine the star's mass based on the reduction in speed. This insight led in turn to the recognition that a star's gravitational pull might be so strong that the escape velocity would exceed the speed of light. Michell calculated that this would be the case with a star more than 500 times the mass of the Sun. Since light would not be able to escape such a star, it would be



Humankind's first image of a black hole (Credit: EHT Collaboration)

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invisible. However, this insight of Michell went neglected for more than a century because physicists came to believe that light could not be deflected by gravity.

The enormous elliptical galaxy M87 at the heart of which lies the supermassive black hole pictured by EHT (Credit: ESO)

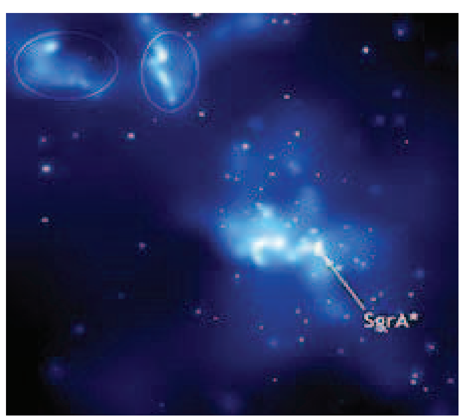
In 1915, Einstein formulated his general theory of relativity, describing gravity as a consequence of the warping of space-time. Massive objects create a sort of dent in the cosmic fabric. Einstein's general theory of relativity not only described the relationship between space, time, gravity and matter but also opened the door to the theoretical possibility of the existence of light-capturing bodies that was suggested by Michell. However, Einstein himself was reluctant to accept the existence of such weird objects, now called black holes. He concluded in a paper published in 1939 in the *Annals of Mathematics* that the idea was "not convincing" and the phenomena did not exist "in the real world."

However, the unveiling of the first-ever picture of a black hole by the EHT collaboration on 10 April 2019 not only confirmed Einstein's general theory of relativity but also provided an indisputable proof that the gravitational monsters dubbed as black holes are real.

The American physicist John Wheeler coined the term "black hole" in 1967 during a Conference in New York to describe the grim fate of a massive star after it runs out of fuel and collapses in on itself. As described by Wheeler, Einstein's general theory of relativity governs the nature of space-time in the presence of matter. He succinctly summed up his viewpoint by saying that "matter tells space-time how to curve, and the space-time tells matter how to move." To understand Wheeler's viewpoint in a clear manner, imagine a flat rubber sheet (space-time) suspended above the ground. Place a bowling ball in the middle of the sheet (matter) and the sheet will distort around the mass, bending half way to floor – this is matter telling space-time how to curve. Now, roll a marble (matter) around the loaded rubber sheet (space-time). The marble's trajectory will change being deflected by the warped sheet – this is space-time telling matter how to move. Thus, according to Wheeler, matter and space-time are inextricably linked, with gravity mediating their interaction.

What is meant by black-hole singularity and event horizon?

Black holes are indeed weird astronomical objects. As borne out by the work of several physicists including Karl Schwarzschild, S. Chandrasekhar, Roger Penrose and Stephen Hawking, who significantly contributed to the modern understanding of the nature of black holes, there is a point at the centre of a black hole called singularity. It is a one-dimensional point that contains enormous amounts of mass squeezed into an infinitesimal small space. According to Stephen Hawking, the formation of a black hole is rather like big bang at the beginning of time, only it would be an end of time for the body collapsing to form the black hole. At this singularity, density and space-time curvature become infinitely large and all laws of physics break down.



The supermassive black hole Sgr A at the centre of our Milky Way galaxy (Credit: Wikipedia)*

Roger Penrose proposed that the singularity is not an isolated or "naked" singularity but is surrounded by what is known as event horizon. So, according to Penrose, singularities produced by gravitational collapse are decently hidden from outside view by an event horizon. In other words, the event horizon prevents the singularity from being seen by the external observer. This led Penrose to propose a hypothesis which is known as the Cosmic Censorship Conjecture (CCC). This may be paraphrased as "God abhors a naked singularity." The CCC states that naked singularities do not occur in Nature. A lot of research is in progress to test its validity.

What is this "event horizon" of a black hole that shrouds the singularity inside it? A black hole's event horizon is its outermost boundary. This is the point at which the gravitational force precisely overcomes the ability of light to escape the black hole's pull. In fact, event horizon of a black hole is the literal point of no return – you cannot escape once you pass it.

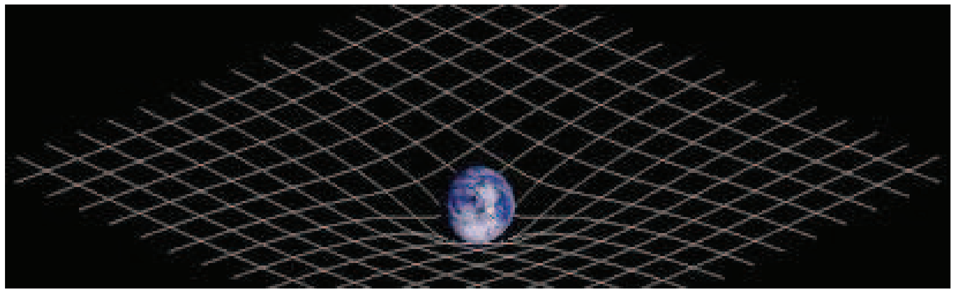
John Wheeler in his autobiography titled *Geons, Black Holes, and Quantum Foam: A life in Physics*, published in 1999, gave a beautiful description of black holes. Wrote Wheeler in his autobiography: "The black hole teaches us that space can be crumpled like a piece of paper into an infinitesimal dot, that time can be extinguished like a blown-out flame, and that laws of physics that were regarded as 'sacred' or immutable, are nothing but...." Thanks to astronomers and computer scientists working with the EHT, humanity was finally able to visualise these "infinitesimal dots." Although Einstein wasn't alive to see evidence of black holes –

the result of the real singularities about which he was doubtful – his general theory of relativity made their discovery possible. And, no doubt, he also would have marvelled at the glowing crescent surrounding a near-perfect dark disc – proof that even more outrageous theories can turn out to be true.

Detection of black holes

How could scientists hope to detect a black hole as, by its very definition, it does not emit any light? This definition, of course, comes within the realm of classical physics. If, however, we take recourse to Hawking process, involving quantum physics, then a black hole can radiate significant amounts of energy. But such a black hole must be much smaller in mass than the Sun. Leaving aside such radiating black holes proposed by Hawking, the question is: How can massive black holes (with masses at least three times the solar mass) be detected? The answer is through gravitation. For instance, black holes exert a powerful gravitational pull on nearby stars. This pull can be inferred by looking at the movement of stars. In some cases, stars are found to be orbiting an invisible partner, and if calculations show that the partner has a mass more than a certain mass, it is probably a black hole.

Astronomers have observed many binary star systems in which two stars orbit around each other due to the mutual force of attraction. If such a system happens to be near a black hole, part of the winds of charged particles (in the case of Sun, such a wind of charged particles is called solar wind) will be sucked into the black hole, leading to considerable acceleration of the winds. This will lead to the emission of X–ray shock waves, which can be detected using sensitive telescopes. A well-known example is the binary star system at the location of Cygnus-1, an X-ray source. This binary system consists of the star, known as HDE 226868 in the *Henry Draper Catalogue*, and an invisible companion. Detailed observations of this binary system show that the mass of the invisible companion must be at least 8 solar masses. This rules out it being a neutron star – hence it must be a black hole.



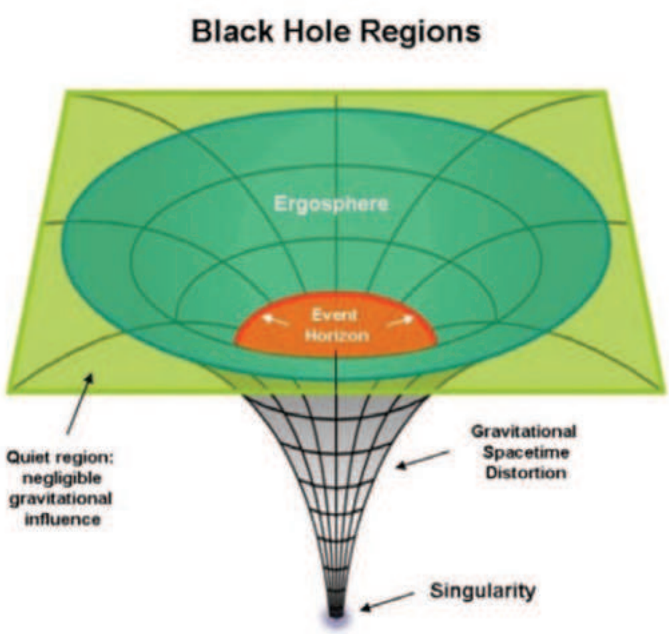
A ball on a rubber sheet showing warping of space-time

A black hole's intense gravity also tends to attract gas and dust, which forms an "accretion disc" around it. Friction in the disc heats up the material, causing it to release vast amounts of radiation (mostly in the form of X-rays), which telescopes can detect.

Another giveaway is the deflection of light from stars that lie beyond a black hole, by the black hole's gravity as seen from Earth. The process is called gravitational lensing and the measurements of the deflection of the light can again be used to infer the existence of the black hole.

How did EHT obtain the first-ever image of black hole?

In a major scientific breakthrough, the first-ever picture of a black hole was released on 10 April 2019, in a series of six papers published in a special issue of *The Astrophysical Journal Letters*. This was made possible, thanks to a global network of radio telescopes called the Event Horizon Telescope (EHT). No single telescope is powerful enough to image a black hole. So, in the largest experiment of its kind, Sheperd S. Doeleman of the Harvard-Smithsonian Centre for Astrophysics led a project to set up a network of eight linked telescopes. Together they form the EHT and may be thought of as an Earth-sized virtual telescope with unprecedented sensitivity and resolution comprising a worldwide array of dishes. Each is located high up at a variety of exotic sites, including volcanoes in Hawaii, mountains in Mexico, in Arizona, in the Spanish Sierra Nevada mountain, in the Atacama Desert of Chile, and in Antarctica. Two of the telescopes situated at Hawaii are named as James Clerk Maxwell telescope (JCMT) and the Submillimetre Array (SMA); while two of them situated in Chile are called Atacama Pathfinder Experiment (APEX) and Atacama Large Millimetre/submillimetre Array (ALMA). Single telescopes in Arizona, Mexico, Spain and Antarctica are respectively given the names Submillimetre Telescope (SMT), Large Millimetre Telescope (LMT). IRAM 30-metre Telescope and South Pole Telescope (SPT). The EHT uses a technique called very-long-baseline interferometry (VLBI) which allows it to achieve a resolution of 20 micro-arcseconds. Although the telescopes forming the EHT are not physically connected, they are able to synchronise their received data with atomic clocks – hydrogen masers – which precisely time their observations. These observations were collected during a 2017 global campaign. Each



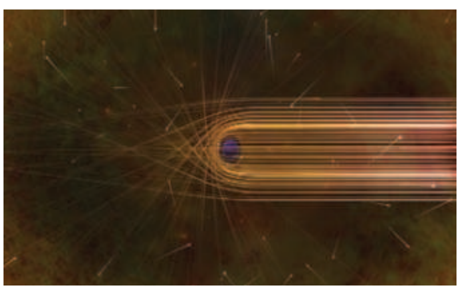
Anatomy of a black hole (Image source: http://www. astronomysource.com/category/cosmos/black holes/

Box: What's in a name!

There is no dispute that the term "black hole" was coined by the quantum physicist John Archibald Wheeler in 1967. Wheeler spent decades demonstrating that black holes really were consistent with Einstein's ideas propounded in his general theory of relativity. He also made great strides working out how black holes should behave. Wheeler coined the term "black hole" at a Conference held in New York to describe the grim fate of a massive star after it runs out of its fuel and collapses in on itself.

The concept of an object so massive that even light cannot escape the pull of its gravity was first mooted way back in 1783 by the Cambridge professor John Michell in a paper written by him in the *Philosophical Transactions of the Royal Society of London*. The French mathematician, the Marquis de Laplace, who had carried out extensive research on Newtonian gravity, in the year 1799 conceived of the notion of an object similar to that suggested by Michell. However, neither Michell nor Laplace used the term "black hole" to denote such a massive object. In scientific literature, use of the term "dead stars" for black holes could be found in some places. In erstwhile Soviet Union, black holes were called "frozen stars."

Following the release of the first-ever photograph of a black hole by the landmark EHT experiment, a language professor has given a Hawaiian name Powehi (pronounced as Poe-vay-hee) to the black hole. Powehi stands for "the adorned fathomless dark creation" or "embellished dark source of unending creation. ('Po' is a profound dark source of unending creation while 'wehi' is associated with embellishments.) Although the Hawaiian name Powehi has not been officially accepted, it is nevertheless justified because the (EHT) project included two Hawaiian telescopes, astronomers said.



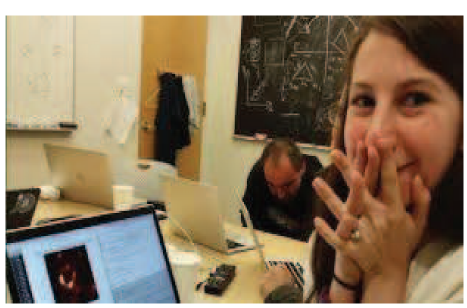
This artist's impression depicts path of light rays around a black hole (Credit: Nichole R. Fuller/NSF)

telescope of the EHT produced enormous amounts of data – roughly 30 terabytes per day – which was stored on high-performance helium-filled hard drives. The data collected was so massive that it couldn't be transmitted over the internet. Instead the hard drives had to be flown to four teams of scientists at the Max Planck Institute for Radio Astronomy and MIT Haystack Observatory. This raw data, which was in petabytes, was fed to highly specialised supercomputers, known as correlators. They were then painstakingly converted into an image using novel computational tools developed by the collaboration.

"We have taken the first picture of a black hole," said Doeleman, adding, "This is an extraordinary scientific feat accomplished by a team of more than 200 scientists."

The EHT trained its telescopes on two supermassive black holes – one situated at the heart of the galaxy M87 – and the second, Sagittarius A* (Sgr A*), sitting at the centre of our galaxy, the Milky Way. The galaxy M87 is part of a supercluster of galaxies situated in the constellation Virgo 3 million light years from Earth. The black hole situated at the centre of this galaxy has a mass of 62.5 billion solar masses. The other supermassive black hole Sgr A* has a mass of 4 billion suns and is situated 26,000 light years from Earth.

It may be remarked that the shadow, or silhouette, of a black hole is the closest we can come to an image of the black hole. As a black hole's size is proportional to its mass, the more massive a black hole, the larger its shadow. Although M87's black hole is about 2,000 times as far away as Sgr A*, it is also 1,000 times as massive as Sgr A*. The extra mass of M87 compensates for its greater distance. That is the reason why the scientists found it easier to image this black hole. The image released by EHT on 10 April 2019 was, therefore, of M87's black hole.



Katrine Bouman whose algorithm helped create the first-ever image of black hole

It may be remarked that all the vast amount of data the scientists generated through the EHT had to be sorted through to understand what exactly it stored. And it was an algorithm developed by Katherine Bouman that helped turn that messy data into something meaningful and visible. Bouman is now assistant professor at the Computing and Mathematical Sciences (CMS) department of Caltech. However, she was a graduate student in computer science and artificial intelligence at MIT at the time she started her work as part of a team that helped create the black hole's image. She is not an astronomer, nor did she have any role in collecting the raw data. Her expertise is in computer algorithm. She wrote a computer program called CHIRP (Continuous High-resolution Image Reconstruction using Patch priors) that led to the creation of a cohesive or useful picture of a black hole, taking care of the extra delays caused by atmospheric noise. Bouman used clever algebraic solution to cancel out these extra delays due to slowing down of radio waves caused by atmospheric noise. She realised that new measurement required data from three telescopes, not just two. If measurements from three telescopes were multiplied, the extra delays cancelled each other out. The increase in precision made up for the loss of information.

The way forward

EHT' future mission is to resolve some long-standing mysteries about black holes. These include how M87's black hole spews a bright jet of charged particles many thousands of light years in space. Also, there are plans to add more telescopes to EHT. In addition, the researchers plan to make observations using light having a slightly higher frequency. That can further sharpen the image. And even bigger plans are on the horizon – adding telescopes that orbit Earth. "World domination is not enough for us. We also want to go to space," quipped the EHT project director Doeleman. These extra eyes may be just what is needed to bring black holes into greater focus, Doeleman said. ■

A Peek into Planetary Magnetism

Dr. M.S.S. Murthy

Planetary magnetic field plays an important role in the planet's evolution, atmosphere, and eventually its habitability. Solar wind and cosmic rays from outer space rip through the planets' atmospheres. Magnetosphere of the Earth serves as a shield. It deflects these charged particles and protects the Earth from their harmful effects. Planet Mars probably was once a lot like Earth, with oceans of water and a thick atmosphere. But unlike Earth, Mars' magnetic field disappeared billions of years ago. Today, it has an extremely thin atmosphere and all the surface water has dried up.

It has long been known that Earth has a strong magnetic field. More than 2,000 years ago the Chinese had known that a type of rock (the loadstone), when suspended freely, had a strange property of aligning itself in a north-south direction. This observation led to the development of the compass as a direction finder, which has been an important tool for navigators.

It was in 1600 that the English physicist William Gilbert proposed that that the Earth behaved like a huge magnet and that was the reason why compass needles point north. However, its origin could not be explained by imagining a huge magnetised iron deposit at the centre of the Earth because no material can retain its magnetic field when heated to above a certain temperature known as the Curie temperature, which is about 770°C for iron and 360°C for nickel. The temperature at Earth'score was expected to be far above that. Palaeomagnetism – the study of magnetism embedded in ancient rocks – tells us that Earth's magnetic field has been in existence for billions of years. This cannot be attributed to some event that occurred that far back in the past, because it would have faded away long ago with a time constant of about 15,000 years, unless there is some intrinsic mechanism to continuously regenerate it.

So, whatis the source of Earth's magnetic field? How long ago was it formed? What about the other planets in the solar system – do they also have magnetic fields? These are some fascinating questions for which planetary scientists still do not have precise answers – but only approximate models. One of the most plausible models, known as the "magnetic dynamo theory" is based on some of the features of the internal structures of Earth and other planets. It is analogous to the dynamo which converts mechanical energy to electrical energy. It was first proposed by the Irish physicist Joseph Larmor in 1919 and further refined by the American physicist Walter Elsasser in the 1940s.

The Magnetic Dynamo

We all know how a bicycle dynamo works. A permanent magnet rotating inside a conducting coil generates electricity which lights up the bulb. Stronger the magnet and faster it rotates, more is the electric current generated. Conversely, a moving electric charge can also produce a magnetic field. For a planet's magnetic field, it essentially entails three criteria:

1) A large volume of electrically conducting fluid such as molten metal within the planet,
2) A rapid rotation to set the conducting material in continuous motion, and
3) A source of energy to drive convection motion in the conducting fluid.

Larger the volume of the electrically conducting fluid and faster the rotation of the planet, stronger is the generated magnetic field.

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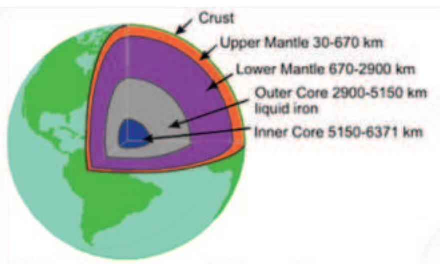
Magnetic Field of the Earth

Based on seismological and volcanic eruption studies the Earth is modelled as composed of several layers: a thin outer crust (mostly consisting of various types of rocks); a mantle rich in silicate; an outer core of liquid metal; and a solid inner core consisting mostly heavy metals like iron and nickel. Though the average temperature on the Earth's surface is a pleasant 15°C, both the temperature and pressure increase with depth. The temperature in the outer core is estimated to be about 4800°C, enough to melt the iron-nickel alloy. However, the inner core, despite its temperature being higher than that of the outer core, is in a solid state. The immense pressure exerted by the overlying layers on the inner core keeps this zone in a solid state.

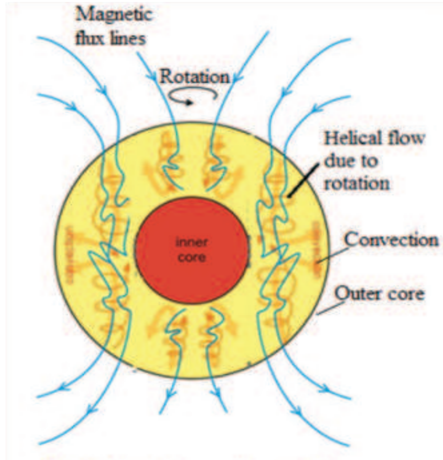
The outer core containing the molten metal rich in iron and nickel acts as the charge carrier. The spinning of the Earth about its axis once every 24 hours produces rapid movement of the conducting material. Plate tectonics cools planet's mantle, creating



Internal structure of the earth

a large temperature difference between the core and the mantle to produce convection currents in the metallic fluid. Maintaining the convection current requires that heat is generated continuously inside the inner core. Decay of long-lived radioactive elements such as thorium, uranium and potassium in the inner core is responsible for heat generation.

According to a Canadian report, even before the Earth's magnetic field was first formed, weak magnetic field in the form of Sun's magnetic field was present. As the charge-carrying stream of molten iron circulates through this seed magnetic field, an electric current is generated around the outer core. The newly created electric field in turn induces a magnetic field, which reinforces the initial magnetic field. As long as there is sufficient fluid motion in the



Planet's rotation and convection current in the molten metal induce magnetic field Source: all-geo.org

core and supporting convection, the process would continue.

Earth's magnetic field, created by the dynamo effect about 3,000 kilometres below our feet, behaves like a dipole. Just as in a bar magnet, Earth's magnetic lines of force travel from the magnetic north pole to the magnetic south pole. The magnetic axis is tilted at 11 degrees from the spin axis of the Earth. Geophysicists at the University of California, Berkeley, USA have estimated the magnetic field at the inner core to be about 25 gauss. On the surface of the Earth the average field ranges from about 0.25 gauss to 0.65 gauss.

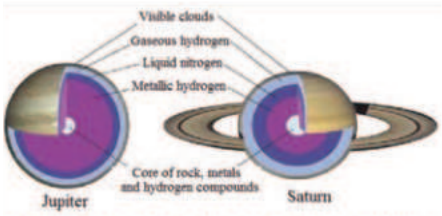
Magnetic Fields of Other Planets in the Solar System

Since the advent of space technology, several spacecraft have been launched to probe, among other features, the magnetic fields of the planets in the solar system. Among the rocky planets of the inner solar system, other than the Earth, only Mercury is known to have an intrinsic magnetic field, though weak. This has surprised many astronomers. Mercury has a high density, suggesting that its core may have a large proportion of iron and nickel. However, being the smallest planet in the solar system, it is expected to have cooled off long ago and the inner core may no longer be in a molten state. Furthermore, it spins very slowly (once every 58.8 Earth days). Hence, it was not expected to have an active magnetic field. However, the *Messenger* spacecraft launched by NASA in 2004 to probe the planet found that it has possessed a magnetic field for nearly four billion years. Though, at one time it was as strong as that of Earth, at present it is only about 1% of Earth's magnetic field. This means that, contrary to expectations, Mercury's core is at least partially liquid to account for its intrinsic magnetic field. But how the planet's outer core remained liquid and convecting despite its small size is still a mystery. Planetologists at the University of British Columbia in Vancouver, Canada suspect that Mercury's iron core may contain a little bit of non-metallic elements like sulphur that would lower its freezing point and prevent it from becoming completely solid.

The size of Venus is almost equal to that of the Earth. Hence, its interior may still be hot enough to have conducting molten metal. This has been confirmed by the *Magellan* spacecraft, which has recorded evidence of volcanic eruptions and flowing lava on the surface of Venus. Even then, space missions have not detected any intrinsic magnetic field of Venus. This is attributed to the slow spinning of the planet (once every 243 Earth days) and the absence of convection currents in the core because of lack of plate tectonics.

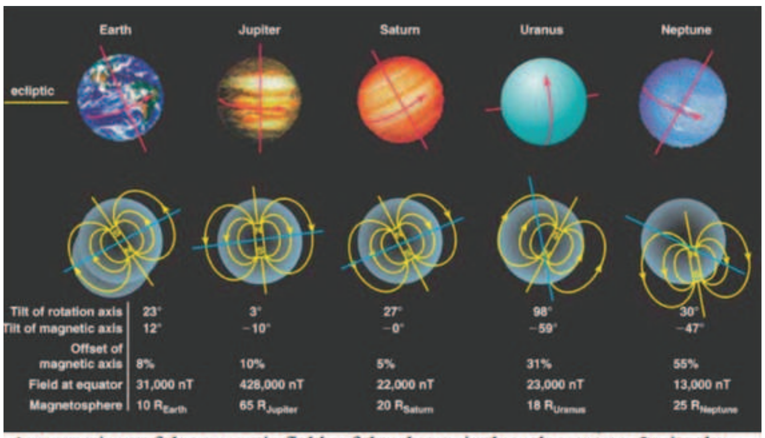
Mars also appears to have no intrinsic planetary magnetic field or has an extremely weak one. Since it is about half the diameter of the Earth and only one-tenth of its mass, the planet's internal heat must have disappeared long ago, rendering its metallic core mostly solid. Though it can spin fast (once every 24.6 Earth hours), charges in the solid metallic core cannot swirl around freely to produce magnetic field. Also, since its crust is too thick, there are no tectonic forces. However, the *Mars Global Surveyor* launched by NASA in1996 has revealed a 2,000 km×200 km region of strong, local magnetisation on the planet's surface. It is presumed to be the remnant magnetic field produced by an ancient dynamo that collapsed early in the planet's history.

The planets of the outer solar system–Jupiter, Saturn, Uranus and Neptune–have a different story to tell. They are made up of mostly hydrogen and some helium and trace quantities of methane. There is not much of metallic core as within the terrestrial planets. Surprisingly, however, the spacecraft *Voyager* sent to probe Jupiter recorded a huge intrinsic magnetic field–the strongest among the planets in the solar system. It



Metallic hydrogen in the interior of Jupiter and Saturn conducts electricity to produce the magnetic field

should be noted that materials which can conduct electricity have some electric charge free to move about. Though such materials are generally referred to as "metallic", they need not necessarily be shining solids like iron, copper, etc. Because of the huge mass of Jupiter, the extremely high gravitational compression at the interior of the planet produces what is known as "liquid metallic hydrogen", in which electrons are squeezed out of hydrogen atoms. They swirl around as the planet spins about its axis, producing magnetic field according to the dynamo theory. In Jupiter, 70% of its volume is filled with liquid metallic hydrogen and the planet spins very fast (once every 0.41 Earth days), accounting for its huge magnetic field. The same mechanism is proposed for Saturn's magnetic field, though it is not as huge as that of Jupiter because of its relatively smaller size.



A comparison of the magnetic fields of the planets in the solar system. Jupiter has the strongest. Note the abnormal declination of Uranus and Neptune. R refers to the radius of the planet. nT- nano tesla- a unit to measure the magnetic field. One tesla is equal to 10,0000 gauss. (Source: 2017 SlidePlayer.comInc)

The case of Uranus and Neptune is interesting in a different way. Though they spin fast enough to run a magnetic dynamo (once in 0.71 and 0.74 Earth days respectively), they are relatively smaller than the other gas giants and cannot produce metallic hydrogen in their interiors. Still, they have been found to have significant intrinsic magnetic fields. Planetologists believe that it is because of an 'ionic ocean' – a mixture of water, ammonia and methane n the outer core – which is electrically conducting.

What about the moons? There are 173 moons, including our own, orbiting some of the planets of the solar system. Though our Moon could have a metallic core like Earth, planetologists think that it is not large enough to retain heat for the core to be in a fluid state or maintain the convection currents needed for generating magnetic field. However, to their surprise, they found that the samples of Moon rock brought to Earth by the *Apollo* astronauts had remnant magnetic field, suggesting that Moon had its own intrinsic magnetic field in the past, which died down as the core solidified due to the loss of internal heat. To explain the possibility of convection current, scientists at the University of California, Santa Cruz, USA suggest that the tidal gravitational tug between the Earth and the Moon produced a differential motion between the Moon's mantle and the core that was once in a liquid state, generating the necessary convection currents. As the distance between the Earth and the Moon has been steadily increasing over time, the tidal tug has been decreasing, reducing the convection forces. This, along with the solidification of Moon's core as it gradually lost its heat, resulted in the waning of Moon's dynamo. It is estimated that Moon's magnetic field lasted for about 3.6 billion years.

The *Galileo* spacecraft, which orbited Jupiter from 1995 to 2003, found a weak magnetic field around its largest moon Ganymede, where none was expected. Although the exact mechanism is not clear, scientists believe that it is maintained by a saline ocean, with ions to carry electric charges, under the moon's icy crust. Ganymede is the only moon in the solar system that is currently known to have intrinsic magnetic field.

A comparison of the magnetic fields of the planets reveals several interesting features. The magnetic field strengths vary over a wide range, the strongest being that of Jupiter. For a perfect dipole, as in a bar magnet, the magnetic field is strongest at the poles and weakest at the middle, the ratio being 2. However, in the case of planetary magnetic fields, though the highest strength occurs at the poles, the ratio between the maximum and the minimum, as measured on the surface of the planet, ranges from 2 to 12, suggesting that the magnetic fields are not exact dipoles but more complex structures. While the tilt between the axis of rotation of the planet and the magnetic axis, known as declination, is about 10° for Earth and Jupiter, they almost coincide for Saturn. Uranus and Neptune stand out – having large declinations – 59° and 47° respectively. This large declination results in wild rotation of the magnetic field as the planet spins.

In addition to the dynamo in the inner crust, there are other sources which contribute to Earth's magnetism, though they are considered to be quite small. Some of these sources of magnetism are the minerals in Earth's mantle and crust, while the ionosphere and the magnetosphere also play a role. Since salt water is conductive, oceans can also make an additional contribution to the magnetic field.

Importance of Planetary Magnetic Field

Planetary magnetic field, originating from its interior, is not limited to its surface, but extends far into the space around it, though getting weaker with distance, creating what is known as the planet's magnetosphere. It has an important role in the planet's evolution, atmosphere, and eventually its habitability. In the case of Earth, its magnetosphere extends up to about 63,000 km (facing the Sun) to about 63,00,000 km (away from the Sun) from its surface. Apart from the Earth, Jupiter, Saturn, Uranus and Neptune have their own magnetospheres. Jupiter's is, by far the biggest.

It has been known that the Sun constantly emits energetic charged particles (mostly protons and electrons), known as solar wind, which stream towards the planets

(Continue on page 25)

The Five Generations of Computers

Soumadip Sen

Today's advanced computers aided with state-of-the-art technologies provide researchers with rich information and research data. It is because of computers, the concept of smart learning through smart and multimedia classes and e-books have become possible. Audio and video classes in schools help students to comprehend complex as well as basic concepts better with the help of computers. In higher education, computers help faculties and students to do their work in an efficient and smart way.

We all use computers, but not many of us may be aware of how computers have evolved over the years since the first general purpose programmable electronic computer – the Electronic Numerical Integrator and Computer (ENIAC) made its appearance in 1946. Not only have they become more complex and powerful, but at the same time their size has shrunk phenomenally. Here is the story of how computers have evolved and how their functions have changed.

First-generation computers

ENIAC was the first large-scale computer to run at electronic speed without being slowed by any mechanical parts. It used vacuum tubes which were fragile,very unreliable and required constant maintenance. They consumed large amounts of electric power and generated a lot of heat and hence required large cooling systems/AC to function properly. Since these computers used large components like vacuum tubes,they were quite large in dimension and occupied large rooms. They also weighed in tonnes; the ENIAC weighed 60 tonnes.

The storage capacity of first-generation computers was limited, and they could only store a small amount of information because they used magnetic drums for memory. The accuracy was not high and hence they were used only to perform straight-forward and simple numerical calculations. Programming capabilities too were limited, and instructions were given to the computers in machines language; punched cards were used to input data and instructions.

ENIAC had approximately 20,000 vacuum tubes, around 10,000 capacitors and

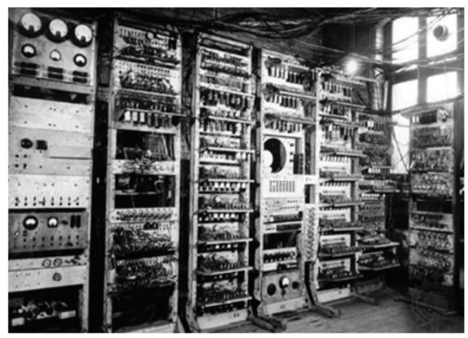


Figure 1. The Manchester Mark I, the first stored-program digital computer. (Source: Encyclopaedia Britannica and The Department of Computer Science, University of Manchester, Eng.)

nearly 70,000 resistors, giving it a gigantic look and required a large room to house it. Besides ENIAC, a few other first-generation computers were: EDVAC, Manchester Mark 1, UNIVAC, IBM-701, EDSAC, and IBM-650.

Second-generation computers

The second-generation computers, which came around 1956, were based on solid-state electronic devices called transistors that performed the same functions as the vacuum tubes but were much smaller, faster and more reliable. So, the second-generation

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Figure 2. IBM 1620 at Baylor University, Hankamer School of Business, Casey Computer Centre.(Credit: Google, Internet)

computers were much faster and more reliable in comparison to first-generation computers. Transistors were much more efficient in performance on account of their reduced size, lower power consumption, and less heat dissipation rate. Though they were still costly, they consumed much less electricity than vacuum tubes. The use of transistors drastically reduced the size of computers and added portability as an additional feature. They were faster than first-generation computers and replaced machine language with assembly-level language, thereby allowing programming instructions to replace long and difficult binary codes. Assembly language along with machine-independent language such as FORTRAN (FORmula TRANslation) and COBOL (COmmon Business Oriented Language) were introduced. Storage capacities were increased, and operating speeds enhanced in terms of microseconds. Apart from performing simple numerical calculations, the second-generation computers could perform scientific calculation like solving differential equations, etc. A few examples of second-generation computers are: Honeywell 400, IBM 1620, IBM 7094, CDC 1604, UNIVAC 1108, and CDC 3600.

Third-generation computers

Third-generation computers, which made appearance around 1964, came with the advanced and sophisticated technology of integrated circuits (IC). A single IC, popularly known as a 'chip' could replace several transistors, thus further reducing the size of computers. In fact, a single IC contained a large number of transistors, capacitors and resistors placed on a single silicon wafer using photo-lithographic process. As more and more electronic components were squeezed and accommodated on a single IC, there was a drastic reduction in the size of the computers. The reduction in size also helped improve the performance of the computers, making them faster, more reliable, and portable to a great extent. New technologies were used to enhance the storage capabilities.

Operating and computational speeds were now in terms of nanoseconds (billionths of a second), which were earlier measured in microseconds for the second-generation computers. Instead of punch cards, now mouse and keyboard were used for input. The use of operating system, time-sharing and multi-programming concepts for better resource management led to an outstanding enhancement in the performance and efficiency of these computers. They initiated the use of computers in industry, military, banks and research and development organisations. High-level languages were used for this generation of computers. A few examples of third-generation computers are:PDP-8/11, IBM 360/370, IBM 5150, and Honeywell-6000 series

Fourth-generation computers

Figure 3. Third generation computers. (Credit: Google, Internet)

Further advances in complex semiconductor and communication technologies saw the development of very-large-scale integrated (VLSI) circuits, which led to the fourth-generation computers. The first "personal computer" or PC developed by IBM, belonged to this generation. VLSI technology made it possible to create an integrated circuit (IC) which incorporated thousands of transistors or other electronic components on a single chip. It is due to this VLSI technology that microprocessors came into picture, which had a revolutionary effect on the efficiency, performance, reliability and portability of the fourth-generation computers.

Figure 4. Fourth generation computers. (Credit: Google, Internet)

There was a drastic reduction in the size of the computers and now they could be easily accommodated on a desk. There was an increase in operating speed, and with the advent of modern semiconductor technologies, storage capacity attained new heights with clear distinctions between primary and secondary storage. Due to its enhanced compactness and reliability, these computers were very much affordable and gave rise to the personal computer (PC) revolution.

Moreover, the continuous discoveries in computing and networking technologies added much more capabilities to this generation of computers. Distributed operating system, multi-processing and time-sharing concepts, use of high-level languages along with real-time networks made these computers popular among the masses. Besides IBM-PC, a few examples of fourth-generation computers are: STAR 1000 and PUP 11.

Fifth-generation computers

The Fifth Generation Computer Systems [Present and Future] (FGCS) was an initiative by Japan's Ministry of International Trade and Industry, begun in 1982, to create a computer using massively parallel computing/processing. The modern-day computers fall under this category. They use advanced technologies like very-very large-scale integration (VVLSI), ultra-large-scale integration (ULSI) and other state-of-the-art technologies. Performance has been enhanced with parallel processing using the technologies of task parallelism, concurrent computing with distributed inter-process communication facilities. Computers are no more just devices or a piece of machine but today they are a part of our life. They are used in educational institutions, research organisations, automobile industries, aerospace and space administration, engineering and medical domains, along with extensive use for individual and personal needs.

Modern computing is not limited to mere calculations or solving hard problems, but it has become an ever-expanding field of research for solving complex problems, predicting outcome with a goal to make the future much more exciting and reliable. With current and on-going innovations in soft computing, Artificial Intelligence, computational intelligence and machine learning, computing has attained new heights,going beyond the concepts of hard computing and predefined logical programming.

Computers have become an integral part of today's world. Now-a-days, it is not only an electronic device but a part of our day-to-day life. The scope of today's computers is beyond just performing complex calculations. The socio-economic structure has been massively impacted by computers. From education to research, from defence to astronomy, from banking to e-commerce, from agriculture to medical science, from railways to energy, from construction to governance – every sector depends on computers. Computers have improved the efficiency and productivity of work. Computer-aided diagnosis and treatment help doctors in better diagnosing the diseases quickly and efficiently.

Over the years, laptops, tablets and palmtops have replaced the desktops. With the reduction in size, it has become very easy to carry and use anywhere. The importance of computers can be judged by the number of people using them every day. They are not only used by professionals, but also by students, children and adults at home.

If we think deeply, then we will find that at every stage of its evolution, scientists and engineers have tried to enhance the capabilities of computers so that they can add speed and accuracy to our work and help us save time and money. Computers have contributed a lot in the education and research fields. With the evolution of internet as a backbone, computers not only provide important knowledge and information on every domain, but also help students to get across the world through educational forums, social networking platforms and research groups. Research and analysis are no more as difficult as it once was, and the credit goes to computers.

Figure 5. Fifth generation computers. (Credit: Google, Internet)

Today's advanced computers aided with state-of-the-art technologies provide researchers with rich information and research data. It is because of computers, the concept of smart learning through smart and multimedia classes and e-books have become possible. Audio and video classes in schools help students to comprehend complex as well as basic concepts better with the help of computers. In higher education, computers help faculties and students to do their work in an efficient and smart way.

Business has also gained a lot from computers. Apart from being small or big, almost all small and medium enterprises and businesses organisations maintain their books of accounts in computers. Computer-backed business strategies like marketing campaign, email campaign, social media promotions, etc., help businesses to prosper and flourish. Today's entertainment industry depends totally on computers.

It can be said that computer has been one of the best gifts of science and technology to mankind. It is beyond any doubt that, computers have made significant contribution and is still continuing to contribute largely towards human life and progress. It is also true that with advantages there comes associated disadvantages too. There are people who devote their time towards exploring the negative side of this 'gift' and try to disrupt life through hacking or other means. But this number is negligible when compared with the advantages and contribution of computers in our life. ■

A Peek into Planetary Magnetism

(Continued from page 28)

in large numbers. In addition, cosmic rays from outer space also pervade the interstellar space. These particles rip through the planets' atmospheres and destroy all the gases there. When once the atmosphere is gone, planet's water, if any, also evaporates. Furthermore, they interact with the life forms present, if any, deliver large radiation doses and cause harmful mutations and diseases. Fortunately, Earth's magnetosphere serves as a shield. It deflects these charged particles and protects the Earth from their harmful effects.

Mars is a good example of what solar wind can do. It was probably once a lot like Earth, with oceans of water and a thick atmosphere. But unlike Earth, Mars' magnetic field disappeared billions of years ago. Today, it has an extremely thin atmosphere and all the surface water has dried up. Instruments aboard the *Curiosity Mars Rover* during its 253-day deep-space cruise from Earth to the Red Planet revealed that the radiation dose received by an astronaut would be about 0.66 sievert. Since the average daily radiation dose on Earth is estimated to be about 0.00001 sievert, the astronaut's dose would be about 264 times higher than he would have received for that period on Earth.

Today, when humans are eagerly looking for habitable planets or their moons, the magnetosphere becomes an important factor, without which, habitation would be impossible. Since Mars is one of the favoured planets, NASA announced in its Planetary Science Vision 2050 Workshop, plans to launch an artificial magnetosphere with dipole field level of 10,000 to 20,000 gauss around Mars to shield it from solar wind and cosmic radiation. This would, in a couple of generations' time, restore Mars' atmosphere, improve its temperature, create fresh surface water resources and make it habitable for human beings!

Recent Developments in Science and Technology

Biman Basu

One of the biggest questions in science has been how life arose from the chemical soup that existed on early Earth. One theory is that RNA, a close relative of DNA, was the first genetic molecule to arise around four billion years ago, but in a primitive form that later evolved into the RNA and DNA molecules that we find in living organisms today. The prevailing scientific view – commonly known as the "RNA World" hypothesis – is that early life forms were based purely on RNA, and only later evolved to make and use DNA.

Indian muon telescope detects extreme thundercloud voltage

Lightning during thunderstorms is a common phenomenon. Cloud-to-ground lightning bolts are also quite common – about 100 strike Earth's surface every single second – and their power is extraordinary. Till now it was difficult to experimentally determine the voltage that develops within thunderclouds. Over the past several decades, researchers have flown airplanes and balloons into the centres of thunderstorms to study their electrical structure, but they could only probe a small region and not the entire cloud.

Now, in a new effort, researchers have developed a way to capture one critical measurement of an entire storm – its electric potential. A team of scientists from several institutions in India and Japan has found that it is possible to use a muon detector to measure electric potential in thunderstorms and their finding is an astounding 1.3 billion volts (GV), which is 10 times greater than the largest value ever reported (*Physical Review Letters*, 15 March 2019 | DOI: 10.1103/PhysRevLett.122.105101).

Muons are elementary particles similar to the electron, with an electric charge of -1 and a spin of ½, but with a much greater mass. Muons are formed when cosmic ray particles slam into the atmosphere and break apart into millions of bits of debris – they constantly rain down from above. Scientists have built muon detectors to study them. One such facility is the GRAPES-3 (*G*amma *R*ay *A*stronomy *P*eV *E*nergie*S* phase-3), located at Ooty in southern India. It has 400 muon detectors located on the ground, covering approximately 25,000 square metres. Together, they normally detect millions of muons every minute.

The new method of measuring thundercloud voltage was devised by Sunil Gupta of Tata Institute of Fundamental Research in Mumbai and colleagues and is based on probing the effect of thunderstorms on particle detections by the GRAPES-3 Muon Telescope (G3MT) – a muon telescope which is part of the GRAPES-3 cosmic-ray detection facility. Researchers at several other muon telescopes around the

New studies have shown that thunderclouds may harbour voltages of the order of 1.3 billion volts.

world had previously observed a correlation between thunderstorms and changes in the measured numbers of muons detected. Now Gupta's team has taken the next step and developed a quantitative method. He says, "We realised that GRAPES-3 is an ideal tool for measuring thunderstorm potentials, in particular for the biggest storms".

According to Gupta, the majority of the muons detected by G3MT are positively-charged anti-muons, which usually lose energy as they pass through a thundercloud.

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With reduced energies, these muons are less likely to be picked up by the detector, which only measures particles with energies above a certain threshold. So, the storm registers as a reduction in detected muon flux that can be as large as a couple of per cent. With over one million muons reaching G3MT every minute, the system can measure muon-flux changes with 0.1% precision. The telescope can also distinguish among 169 discrete directions in the sky.

Sunil Gupta of TIFR, who devised the method to use muons to measure thunderclouds.

From measurements of muon flux, Gupta and his colleagues could estimate the thunderstorm potential using computer simulations based on a simplified description of the thunderstorm, which they treat as a giant capacitor made of two parallel plates kept two kilometres apart generating an upward-pointing electric field.

Between 2011 and 2014, the researchers had gathered data on 184 thunderstorms, short listing seven largest events, out of which six had a complex temporal profile, which made it hard to compute the potential. So, the researchers focussed on the seventh storm, which occurred on 1 December 2014, and derived a peak, record-breaking electric potential of 1.3 GV.

The new finding may help researchers solve another atmospheric puzzle, says Gupta. Since 1994, satellite measurements have revealed gamma-ray flashes coming from altitudes of tens of kilometres. Researchers speculate that these flashes could be produced by electrons accelerated by thunderstorms, but previous measurements had not found sufficiently large thunderstorm potentials. However, the newly observed potentials in the gigavolt range are much closer to the values required to produce the observed gamma rays.

The GRAPES-3 experiment is a special telescope-array established in Ooty to detect muons from cosmic ray showers.

Some humans can perceive magnetic field

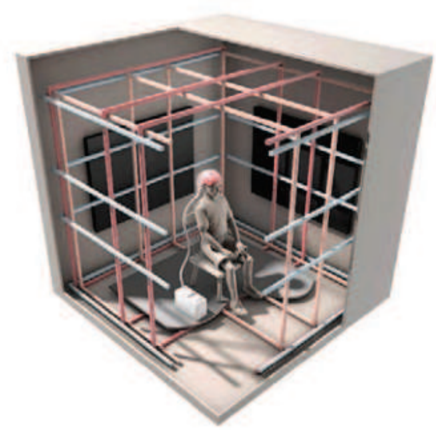
The ability to sense the Earth's magnetic field – a trait known as magnetoreception – is well documented among many animals. A variety of species – bacteria, snails, frogs, lobsters – seem to detect Earth's magnetic field, and some animals, such as migratory birds, sea turtles, migratory eels and other fish species rely on it for navigation. In all these cases, the animals use the geomagnetic field as components of their homing and navigation abilities, along with other cues like sight, smell and hearing.

Over the past 50 years or so, scientists have shown that hundreds of organisms in nearly all branches of the bacterial, protist and animal kingdoms have the ability to detect and respond to this geomagnetic field, but so far, there has been little evidence for any such magnetic sense in humans. However, a new study by geophysicist Joseph Kirschvink of California Institute of Technology and neuroscientist Shin Shimojo of the University of Tokyo suggests that some people do indeed perceive magnetic fields, though at this point it is not possible to say if it affects human behaviour in any way (*eNeuro*, 18 March 2019 | ENEURO.0483-18.2019 DOI: 10.1523/ENEURO.0483-18.2019).

Earlier studies on the subject had focussed mainly on behavioural changes, but according to Kirschvink and Shimojo, if human beings do possess a magnetic sense, daily experience suggests that it would be very weak or deeply subconscious. Such faint impressions could easily be misinterpreted – or just plain missed – when trying to make decisions, they said.

To test whether the human brain is capable of magnetoreception in a reliable, believable manner, Kirschvink and Shimojo set up an elaborate experiment involving a chamber specially designed to filter out any extraneous interference that might influence the results. The isolated chamber, within which participants had their brainwaves monitored by electroencephalogram (EEG), was housed inside a Faraday Cage, which shielded all interior contents from external electromagnetic fields. Three sets of square coils, called Merritt coils, arranged in mutually perpendicular axes allowed the researchers to control the ambient magnetic fields around a participant's head. A wooden chair and isolated floor prevented any unwanted interference with the magnetic coils. A battery-powered EEG was placed next to the participant, which was connected to a computer in another room with an optical fibre cable. The study's participants sat alone in darkness and quiet for an hour, wearing EEG caps that allowed the scientists to eavesdrop on their brains as they manipulated the magnetic field in the cube.

The researchers used electro-encephalography to record adult participants' brain activity during magnetic field manipulations. Carefully controlled experiments revealed a decrease in alpha-wave activity in the brain – an established response to sensory input – in some participants. The researchers observed a significant decrease in the alpha wave amplitude when they pooled the data from 26 subjects for analysis. In some people, the amplitude of their brain's



A schematic of the experimental chamber shows how a volunteer would sit and experience an applied magnetic field. The participant wears an EEG cap to monitor the brain's response.

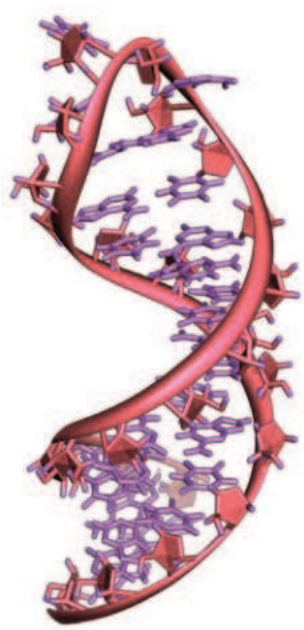
rhythm dropped by up to 60 per cent over hundreds of milliseconds before returning to normal. The researchers replicated this effect in participants who responded strongly and confirmed that these responses were tuned to the magnetic field of the Northern Hemisphere, where the study was conducted.

Kirschvink and his colleagues say they have already replicated the field-sensing effects through similar tests with volunteers in Japan and will report them in a future paper. According to the researchers, future studies of magnetoreception in diverse human populations may provide new clues into the evolution and individual variation of this ancient sensory system.

Building blocks of DNA and RNA may pre-date life on Earth

One of the biggest questions in science has been how life arose from the chemical soup that existed on early Earth. One theory is that RNA, a close relative of DNA, was the first genetic molecule to arise around four billion years ago, but in a primitive form that later evolved into the RNA and DNA molecules that we find in living organisms today. The prevailing scientific view – commonly known as the "RNA World" hypothesis – is that early life forms were based purely on RNA, and only later evolved to make and use DNA.

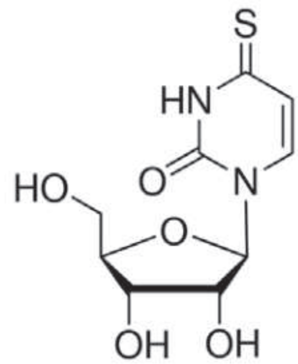
Now scientists for the first time have found strong evidence that RNA and DNA could have arisen from the same set of precursor molecules even before life evolved on Earth about four billion years ago. According to Ramanarayanan Krishnamurthy, associate professor of chemistry at Scripps Research (earlier known as the Scripps Research Institute) and co-principal investigator, "these new findings suggest that it may not be reasonable for chemists to be so heavily guided by the RNA World hypothesis in investigating the origins of life on Earth". Krishnamurthy and his lab worked on the study with the lab of John Sutherland, of the UK Medical Research Council's Laboratory of Molecular Biology at Cambridge, as part of the New York-based Simons Foundation's Collaboration on the Origins of Life (*Nature Chemistry*, 1 April 2019 | DOI: 10.1038/s41557-019-0225-x)



Scientists for the first time have found strong evidence that RNA and DNA could have arisen from the same set of precursor molecules even before life evolved on Earth about four billion years ago.

Structurally, DNA and RNA are nearly identical; however, there are three fundamental differences that account for the very different functions of the two molecules. RNA has a ribose sugar instead of a deoxyribose sugar as in DNA. Moreover, RNA nucleotides have a uracil base instead of thymine. Despite many efforts, chemists have never been able to show how the one could have been converted to the other on the early Earth, except with the help of enzymes produced by early organisms. It was mainly because of this reason that researchers in this field have been inclined to think that the simpler, more versatile one, RNA, was the basis for the first life forms – or at least for an early stage of life before the emergence of DNA. According to the researchers, RNA can store genetic information as DNA can, is able to catalyse biochemical reactions as protein enzymes can, and otherwise probably could have performed the basic biological tasks that would have been necessary in the first life forms. However, despite the widespread belief in the "RNA World" hypothesis, the present researchers have accumulated evidence that RNA and DNA may have arisen more or less all at once in the first life forms.

In an earlier study published in 2017, Krishnamurthy and colleagues at Scripps Research identified a sulphur-containing compound called thiouridine that was probably present on the pre-biotic Earth and could have performed the crucial task of linking RNA building blocks into larger, chain-like RNA strands – and could have done the same for the building blocks of DNA and proteins.



Thiouridine molecule

In the new study, the researchers combined insights from that investigation with recent findings from Sutherland and his lab on thiouridine. They say the latter was likely present on Earth before life arose and could have been a chemical precursor of the nucleoside building blocks of early RNAs. The team showed that in a few chemical-reaction steps, which plausibly could have occurred in a pre-biotic world, they could convert this precursor of an RNA building-block into a DNA building-block known as deoxyadenosine, which is the DNA nucleoside A, which pairs with deoxythymidine in double-stranded DNA. Alternatively, they could convert thiouridine into deoxyribose, which is very closely related to deoxyadenosine and may also have been a precursor of early DNA building blocks.

According to the researchers, the finding should make it easier for scientists to accept the possibility that DNA and RNA arose together and were included in the first life forms. Some researchers including Sutherland have suggested that RNA and DNA might even have been mixed together to make the first genes. No such organism is known to occur naturally now, but a recent paper by Scripps Research's Peter Schultz and colleagues described an engineered bacterium that can survive with genes made of an RNA/DNA mix.

Krishnamurthy suspects that, however life may have arisen, RNA and DNA with their respective strengths and shortcomings would swiftly have sorted themselves into the rather strict division of labour seen in all cells today: DNA for the stable long-term storage of genetic information, and RNA for its own special set of tasks including the short-term storage and transport of genetic information and the making of proteins. "There is the beginning of a realisation in the field that RNA and DNA could have been mixed together initially but later separated according to the things they do best," he says. ■

Science communication, popularisation, and outreach in Bengali – The road ahead

In its endeavour to enhance its outreach activities in Indian languages, Vigyan Prasar has chosen Bengali, Tamil, and Marathi in its first phase of the Project Outreach in Indian Languages. The project started with West Bengal.

Officials of Vigyan Prasar met with several organisations in West Bengal during the last few months. It was observed that many S&T institutes and NGOs in West Bengal are doing science communication and popularisation activities. It was felt, at times, there is overlapping in terms of resource utilisation and reaching the target audience. Being a national institute mandated with large-scale science communication, popularisation, and extension, Vigyan Prasar can help in streamlining some of the activities. With this objective in mind, Vigyan Prasar started short-, mid-, and long-term strategies and action plans in this direction.

Creation of print and digital popular science content in Bengali, coordination with other S&T organisations to create a pool of resources and content, coordination with NGOs and science clubs for outreach activities to popularise science to the unreached and encouraging schools and community participation are some of the objectives. To discuss and brainstorm on these issues, a two-day conference was organised by Vigyan Prasar during 26–27 April 2019 at CGCRI, Kolkata. The conference was supported by Central Glass and Ceramic Research Institute (CGCRI) and Indian Science News Association (ISNA), which publishes the monthly journal *Science and Culture*.

Vigyan Prasar invited representatives of various organisations involved in science communication, popularisation and extension in Bengali to came together and to explore areas/projects to work together. 160 experts from different institutions participated in the conference.

Inauguration session (from Left): Dr. Nakul Parashar, Professor Maitree Bhattacharyya, Dr. Debopriya Dutta, Professor Sibaji Raha, Shri Jayant Sahasrabuddhe, Professor Bimal Roy, Professor Uday Bandopadhyay, Shri A.D. Choudhary, Dr. B.B. Jha, Dr. Amit Krishna De

A 'call for paper' was circulated and experts were invited to write concept paper/article in Bengali with the theme 'Science communication, popularisation, and outreach in Bengali – The road ahead'. Vigyan Prasar has received 30 abstracts. Full papers will be invited from the authors and will be published.

Speaking on occasion, Dr. Nakul Parashar, Director, Vigyan Prasar welcomed the distinguished guests and briefed about the objectives of the conference. During the inaugural session, Dr. Debapriya Dutta, Advisor, and Scientist-G, Department of Science and Technology, Government of India, explained the role of Department of Science and Technology in research and development as well as popularisation and communication of science and technology to society. Dr. Dutta mentioned about various programs and initiatives of DST. He chaired the panel discussion on 'The Road Ahead' held on 27 April and answered questions from the media and audience regarding the initiatives of Vigyan Prasar and DST in its outreach activities in Indian languages, Bengali in particular. Dr. Uday Bandopadhyay, Director, Bose Institute stressed the need for science communication in mother tongue and informed that Bose Institute is committed towards science and technology outreach through various activities and programs. Professor Sibaji Raha, Former Director of Bose Institute, praised the efforts of Vigyan Prasar in coordinating and consolidating science communication in Bengali. Professor Bimal Roy, Former Director of Indian Statistical Institute, Kolkata explained the need for science communication. Shri Jayant Sahasrabuddhe, Organising Secretary, Vigyan Bharati said that only about 10% of the Indian population understands English. Hence it is important to create content and organise outreach activities in Indian languages. Dr. B.B. Jha, Acting Director of CGCRI, said that all CSIR institutions, including CGCRI, are committed to science and technology outreach activities. CGCRI will support Vigyan Prasar in its future endeavours in Science communication, popularisation and outreach in Bengali. Professor Maitree Bhattacharya, Director of Jagadis Bose National Science Talent Search (JBNSTS), stressed the need of empowering women in the society through science and technology interventions. She also said that JBNSTS would partner with Vigyan Prasar in popularising science in West Bengal and North-Eastern states. Shri A.D. Choudhary, DG, National Council of Science Museums (NCSM) explained the role of NCSM in communicating and popularising science and technology through science centres and mobile exhibitions. Dr. Amit Krishna De, Executive Secretary, Indian Science Congress Association (ISCA) explained the role of ISCA in spreading awareness and appreciation towards science and technology among masses.

Panel discussion (from left): Dr . Nakul Parashar, Dr. Rintu Nath, Dr. Jisnu Basu, Professor Partha Ghosh, Professor Soumitro Banerjee, Dr. Debopriya Dutta, Professor Matangini Chattopadhyay, Professor Dhrubojyoti Chattopadhyay, Dr. Samarendra Kumar

Apart from the inaugural session, the conference had three sessions and a panel discussion.

The first session was on the role of scientific institutions in science communication and outreach activities. Dr. Amit Krishna De chaired the session. In session 1, Dr. Debapriya Dutta represented DST; Professor Samir Kumar Pal represented S.N. Bose National Centre for Basic Sciences; Dr. Sitendu Mandal represented CGCRI; Dr. Subhabrata Chaudhuri represented NCSM; Professor Sanjay Kumar Ghosh represented Bose Institute, Dr. Rintu Nath represented Vigyan Prasar.

The second session was the continuation of the first session. Dr Manoj Chakrabarti from National Institute of Cholera and Enteric Diseases (NICED) chaired the session. In session 2, Shri Sourav Sen represented Science Channel of Vigyan Prasar and DST; Professor Soumitro Banerjee represented Indian Institutes of Science Education and Research (IISER), Kolkata; Professor Ananga Chandra represented ISCA-Kolkata chapter; Dr. Abhijit Kar represented JBNSTS; Professor Sabyasachi Chatterjee represented Kalyani University; Dr. Kinkini Dasgupta Misra mentioned digital initiatives of Vigyan Prasar; Dr. Archita Bhatta mentioned Indian Science and Technology Innovation (ISTI) portal of Vigyan Prasar.

The third session was on the role of print and electronic media in science communication and outreach. The session was chaired by Professor Shyamal Chakrabarty, Department of Chemistry, Calcutta University; and co-chaired by Professor Siddhartha Narayan Joardar, West Bengal University of Animal & Fishery Sciences. In this session, Professor Pallab Banerji represented IIT Kharagpur and Vivekananda Vigyan Mission; Professor Manas Chakraborty represented Indian Science News Association(ISNA); Shri Abhijit Bardhan represented Science Communicators' Forum-Kolkata; Professor Surojit Chakrabarti and Professor Bhupati Chakrabarti represented Indian Association of Physics Teachers (IAPT); Professor Subhadas Mollick represented Bichitra Pathshala; Professor Pradip Mahapatra represented Paschim Banga Vigyan Mancha; Professor Tapan Saha represented Bongiyo Bigyan Parishad; Shri Dhananjay Ghosal represented Science Press; and Shri Pathik Guha represented a print media establishment.

Day 2 started with a panel discussion on 'The way ahead.' Dr. Debapriya Dutta chaired the session. The panellists were Professor Soumitro Banerjee, IISER-K; Dr. Samarendra Kumar, Director, HQ, NCSM; Professor Partha Ghosh, Honorary Scientist, National Academy of Sciences; Professor Matangini Chattopadhyay, Professor, School of Education Technology, Jadavpur University; Professor Dhrubojyoti Chattopadhyay, VC, Amity University, Kolkata; Dr. Jisnu Basu, Saha Institute of Nuclear Physics; and Dr. Rintu Nath, Scientist-F, Vigyan Prasar.

In the valedictory session, Vigyan Prasar felicitated three distinguished science writers Professor Palash Baran Pal, Professor Satyabachi Sar, and Shri Ashish Lahiri.

Dr. Nakul Parashar, Director, Vigyan Prasar consolidated the deliberations during the two-day conference and outlined a roadmap. He reiterated that the conference was aimed at networking and evolving a roadmap of actionable items to enhance the outreach of science communication, education, popularisation in Bengali. He invited participation from all the institutions in this endeavour. ■

Third session of the conference - 'The role of print and electronic media' in progress

"Wishpers of Wind"

New Radio Serial : A joint venture of Vigyan Prasar & All India Radio

A joint venture of Vigyan Prasar and All India Radio (Prasar Bharti), a 52-episode radio serial on Climate Change and Global Warming was launched on 31 March 2019. Initially, the serial is being broadcast in Hindi and English, but subsequently it will be broadcast in 19 Indian languages.

Climate change is now a reality. The fact has been supported by a plethora of literature published in the last decade. Some of the observable effects on the environment are already visible. The scientific community across the globe is confident that the global temperature will continue to rise for decades to come, mainly due to the emission of greenhouse gasesproduced as a result of human activities. It is also predicted by IPCC that an increase in global mean temperature of less than 1 to 3 degrees Celsius above 1990 levels will have beneficial impact in some regions and harmful ones in others, but "taken as a whole, the range of published evidence indicates that the net damage costs of climate change are likely to be significant and to increase over time".

Recognising a major threat because of projected changes in climate at the global level, India has engaged quite actively at international and regional fora. The country is providing leadership to other developing countries as well as espousing their cause at multinational negotiations including the United Nations Framework Convention on Climate Change (UNFCCC), with the objective of establishing an effective, cooperative and equitable global approach to deal with the consequences of climate change.

India's National Action Plan on Climate Change (NAPCC) consists of eight national missions. They represent multipronged, long-term and integrated strategies for achieving key goals in the context of climate change. The NAPCC hinges on the development and use of new and sustainable technologies.

Considering the current relevance of the theme, which is aligned with the national agenda and its objectives of science communication and popularisation, Vigyan Prasar, an autonomous organisation under the Department of Science and Technology (DST), and All India Radio, Delhi, have developed a package of 52 episodes on the multidimensional aspects of climate change and global warming. The 52-episode series is named *Badalti Fizae* in Hindi and *Whispers of Wind* in English.

The radio serial consisting of stand-alone thematic episodes will be broadcast nationally – in 19 Indian languages from 121 stations of All India Radio (14 FM and 107 Medium Wave Stations). The broadcast of the serial has begun in Hindi and English from 31 March 2019. (FM Gold 100.1MHz at 2.30 pm in Hindi and Rajdhani Channel MW 666 kHz at 9.30 pm in English).

Each episode is of 27 minutes duration and will focus on a particular aspect relating to climate change. The basic objective is to create awareness about the challenges of climate change and promote understanding of climate change science, adaptation, mitigation, energy efficiency, and natural resource conservation. The episodes also include success stories and Do's and Don'ts to motivate people for local action.

The radio serial will further India's objective of engaging and ensuring participation of people in mitigation and adaption measure to ensure success of the national missions. To ensure the interactivity and two-way communications, there will be eight to ten interactive episodes based on the questions, queries and letters/e-mails of the listeners. Additional material, developed for the serial on the theme, will be given to selected listiners.

Prominent subject experts, technologists and planners will highlight the science and scientific thinking facets of climate change in a simple and understandable manner in the interactive episodes of the series. The serials in 19 languages will promote the appropriate mechanisms that India is developing to deal with the challenge of climate change on several fronts simultaneously.

Thrust areas covered in the serial:

a) Understanding the science of climate change and global warming
b) The natural and anthropogenic factors responsible for climate change
c) The impact of climate change
d) Preparedness of the global community to address the challenges of climate change
e) Norms, conventions, and institutions to cope with climate change
f) India and climate change
g) Institutional framework in India
h) Mitigation and adaptation

The target groups include common citizens, civil society awareness facilitators, and managers.

For the exact schedule of the broadcast day/time/frequency, etc., one may contact nearby AIR Station. Before the launch of the serial, a press meet was also organised at the Constitutional Club in New Delhi on 29 March 2019.

(Report by B.K. Tyagi
Scientist-F, Vigyan Prasar)