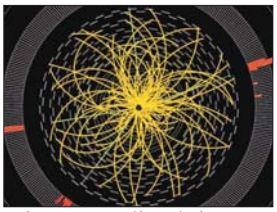
Higgs? Done. So what's the next Big Bang?

The God particle may have been found but so much of the universe remains unknown. jonathan brown **sets out the *really* big questions for our brightest minds to answer**



A computer-generated image showing proton collisions expected from the decay of a Higgs boson.

What is dark matter? Modern science suggests that "normal" matter – that is, everything on earth and all the stars and planets ever observed – constitute just five per cent of that space, with the rest made up of dark energy.

LAST week's announcement of the discovery of the Higgs boson — the so-called God particle — was hailed as one of the great breakthroughs of the 21st century, explaining some of the fundamental physics of the universe. Yet in many ways the achievement has only highlighted how much we still do not know. The coming years will see humankind embark on new missions that will seek to advance our understanding: both into the limitless depths of space and the subatomic world within. Here are four questions that still vex science.

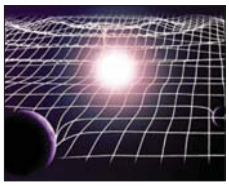
What is dark matter? Space is not empty and it is also growing. Meanwhile, modern science suggests that "normal" matter — that is, everything on earth and all the stars and planets ever observed — constitute just five per cent of that space. The rest is made up of dark energy (accounting for 70 per cent) and dark matter — of which very little is known. Invisible because it does not emit or absorb light, we suspect dark matter is there because scientists have detected its gravitational pull. But although it was first hypothesised in the 1930s, describing its make-up has become the subject of intense scientific debate. The leading theory being studied at the Cryogenic Dark Matter Search detector at the Soudan Mine in Minnesota is that it comprises massive sub-atomic particles formed during the Big Bang which have unique properties and are capable of passing through galaxies without causing any observable effects. The other mainstream theory is that it is in fact very large clumps of ordinary matter, ranging in size from black holes to neutron stars.

The debate moved forward last week when researchers in Germany said they had discovered filaments of what they believe to be dark matter connecting two galaxy clusters 2.7 billion light years away.

What are gravitational waves? These are the universe's most elusive waveforms, created by unfathomably huge events far out in the universe — the collision of neutron stars or the convergence of black holes.

Yet despite the cataclysms that spawned them, it has long been held that these "ripples on the face of time" happened so far away that they would be too weak ever to be recorded when they reached earth. But scientists at the Anglo-German Geo600 project near Hannover, among others, believe they could be on the brink of measuring their first gravitational waves. If or when they do, it is believed it will usher in a new era of astronomy.

At present, radio astronomy relies on other forms of electromagnetic radiation to peer into the universe. While these forms of energy are far stronger than gravitational waves, they are also much more easily corrupted by other matter. In contrast, gravitational waves pass through the universe as if it is transparent, allowing humans to glimpse back into the origins of the Big Bang — and possibly explaining how the cosmos was born. They could allow scientists to describe the creation of black holes and delve deep into phenomena such as supernovae.



What are gravitational waves? They are the universe's most elusive waveforms.

The instruments used in the hunt are highly sensitive and the search has so far been fruitless, but scientists are convinced the waves are out there — as predicted by Einstein in 1916 and strongly suggested by later observations. It is just a matter of finding them.

Can we travel faster than light? It is an immutable fact that nothing can travel faster than light — or least it was an immutable fact for most of the 20th century. Yet the possibility of travelling in excess of 186,282 miles per second has long intrigued scientists. To be able to do so would, of course, provide the key to true intergalactic travel. It might also open the door to time travel, potentially severing the link between cause and effect for the first time.

Hence the excitement which surrounded the claim in 2011 that neutrino particles had travelled 450 miles through the earth, from the Cern laboratory in Geneva to the Gran Sasso National Laboratory in Italy, in three milliseconds, some 60 nanoseconds faster than light.

Overturning Einstein's 1905 Special Theory of Relativity sent shockwaves through the scientific community, resulting in a retest and the conclusion that the neutrinos had, in fact, equalled, not surpassed, light. The quest continues.

Is there a theory of everything? Finding a theory that unifies all particles and forces in the universe would certainly be a tidy way of ordering our understanding. Scientists spent much of the 20th century bringing different theories together — most notably for particle physics in the Standard Model. For three decades the model has unified three of the four fundamental forces: the electromagnetic force; the strong force binding quarks together in atomic nuclei; and the weak force controlling radioactive decay.

Yet the Standard Model fails to incorporate gravity, something we have been familiar with since Newton's apple. Perhaps the best-publicised attempt to incorporate everything came from an unlikely source — freelance physicist and surfer/snowboarder Garrett Lisi, who unveiled his ideas in 2007. Lisi bases his "simple" theory on a baffling complex shape known as E8, plotting all known particles plus 20 notional ones on its 248 points. Although discovered in 1887, the eight-dimensional figure was only recently understood, requiring calculations that if written on paper would cover Manhattan. Lisi claims it could be the answer to everything.

The Independent, London

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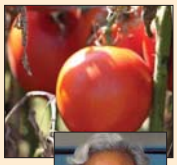
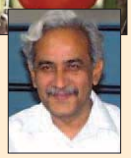
Tomato decoded

Gene analysis, writes jyotika sood, **shows how it got its size and flavour**

WANT tomatoes to be juicier, redder and more nutritious? Worry not. Research done over nine years by 300 scientists from 14 countries, including India, has finally made this possible. The scientists have sequenced the genomes of the domesticated tomato (*Solanum lycopersicum*) and its wild ancestor (*Solanum pimpinellifolium*). The discovery offers insight into how the tomato has diversified and adapted to new environments.





Akhilesh Kumar Tyagi

The scientists believed the tomato originated in Peru, from where it was brought to Mexico. Then around the 16th century, after its discovery in the USA, it was brought to Europe and then to Asia. The transfer from one habitat to another led to the slow evolution of its genes. The present traits in the domesticated tomato are the result of this slow evolution, called a genetic bottleneck.

Subsequently, most of the original genes were lost. However, some of the most important genes that control the most appealing traits of the tomato evolved gradually. For example, wild tomato was originally the size of a pea. But due to genetic bottleneck, it grew to the size we see today. Similarly, the flavour and fleshy part are the result of the same process. But the red colour has existed for millions of years.

The discovery is significant because tomato sequencing can serve as a model for other nightshade plants (plants in the *Solanum* genus), including many agriculturally important crops like potato, tobacco and eggplant. It also comprises some medicinal and ornamental plants like belladonna. The sequencing will help chose the most desirable traits and speed up efforts to improve tomato production. It will also better equip the crop to combat pests, pathogens, drought and disease that plague growers. Forty per cent of the tomato yield is destroyed every year due to these reasons in India alone. The country is the third largest grower of tomatoes.

The Indian scientists sequenced the euchromatic region of the tomato chromosome. The region constitutes some of the major genes that decide size, juiciness and flesh. "Our emphasis was on chromosome 5 of tomato," says Akhilesh Kumar Tyagi, director of National Institute of Plant Genome Research in Delhi. They also analysed specific genes related to ripening, nutrition and disease resistance. NK Singh of the National Research Centre of Plant Biotechnology of the Indian Agricultural Research Institute in Delhi says the research will help people by increasing and improving the quality of *lycopene*, an antioxidant. For farmers it will help boost solid content which is used for making tomato puree, he adds. The study was published in the May 31 issue of *Nature*.

Video-gamers turn protein designers

The human brain can do some things better than a supercomputer, says s ananthanarayanan

David Baker.

David Salesin.

Zoran Popovic.

THE digital computer has the speed and capacity to manipulate numbers that are unthinkable with only the use of human intelligence. With text or mathematical operations at speeds of thousands and millions every second, the computer has naturally become the instrument to extend our capability — electronic communication enables data transfer in megabits and gigabits and a computer set-up can handle not just the work of thousands of men and women but can do things that humans could not manage, no matter how many were employed.

Examples are a modern airport or the transactions of banks with ATMs across the world. In science and technology, computers manage the collection of thousands of items of data every second and computations on that data which could not have been done manually in a century! But for all their capabilities, computers have limitations in using methods that cannot be reduced to straightforward computing. In some such areas, human resources are being used to "go the last mile". A case in point is the use of online gamers to solve problems of protein structure!

Commerce and technology now generate and use extensive data that need several disciplines, statistics, mathematics, communication, networks and distributed computing for manipulating and handling. Routine data is stored and "mined" to reveal opportunities or ways to optimise services. Volumes of wind and rainfall data to support aviation and sea navigation are legendary. In other areas, complex equations are "solved" by evaluation with successively more accurate "test" solutions. And there are "simulations", where computers are used to mimic how the world evolved over millions of years, or other processes with huge numbers of iterations.

Along with the capacity to handle massive data, computer scientists have looked at building intelligence into computers by trying to create computers on the lines of what is understood of the human brain. *Neural networks* are arrangements where connections in a network become "strengthened" when used more often to mimic the way "learning" takes place in the brain. Ingenious algorithms or computation tricks now support video games, robotic devices, business implementations, medical support systems — the world of *Artificial intelligence*. IBM's *Deep Blue* was the computer system that was programmed to play chess. The method, described as "brute force", was to consider all possible moves of both players for several successive moves and then to evaluate the quality of the position reached, based on a measuring tool devised with the help of expert chess players.

Needless to say, the number of possible moves, with as many as 32 pieces in 64 squares, can run into large numbers and working even two moves ahead, if all possible moves are considered, would run into millions of positions. Algorithms were devised to avoid computing worthless lines of play and support was taken from a database of thousands of past games. The system consisted of 30 computers, each running a 120-MHz processor supplemented with 480 special purpose "chess chips". The function for evaluation of moves was split into 8,000 parts and the openings were judged using 4,000 positions and 700,000 grandmaster games.

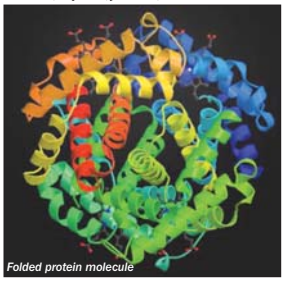
For all the computing power used, in 1996 *Deep Blue* could win only one out of six games against grandmaster Garry Kasparov. *Deep Blue* was then heavily upgraded (unofficially named *Deeper Blue*) and in the next trial in 1997 it won a deciding game against Kasparov, thanks to an error by the grandmaster. While IBM did not respond to Kasparov's protest that the computer had surely been supported by help from real chess players, what the trials showed was that playing chess is a lot more than computation.

Deep Blue had the capacity to view the game between eight and 20 moves ahead and was certainly miles ahead of anything Kasparov could do. And yet it could barely steal a win, and that with questions raised about how fairly it had been done. The emphasis in Artificial Intelligence is hence not just to rely on computation but to develop ways of "pattern recognition". Human ability is clearly the winner here, with the ability to make out faces, tell twins apart and even make out the emotional state of another, with a glance. Even in computation problems, there are uses of pattern recognition that cut through the need for mechanical computing. The simple game of Sudoku, for instance, needs massive computing power to solve by trial and error, but it falls to ordinary newspaper readers during the bus ride between home and office!

Protein structure

A huge computation problem presents itself in working out of the structure of protein molecules. The components of the molecule, which is a chain of amino acids, are dictated by the coding of DNA — but that is the bare composition, not how these components will orient themselves in space. The actual protein molecule, in practice, *folds* itself, under the forces of attraction and repulsion, among its constituent parts into a complex 3D shape, such that the total energy of the arrangement is the minimum. It moves into the minimum energy shape because that is the most stable shape — any other form would tend, sooner or later, to slip into this lower energy condition. It is in this shape that the protein molecule then actually exists and functions, presenting exceedingly specific interfaces to bond with specific molecules in the environment, to form tissue, speed up other reactions, etc.

The medical profession and the pharmaceutical industry thus have great use to know the details, at least in portions, of protein structure. Some information comes from analysis using X-Ray scattering or experiments with chemical reagents, but the information is partial and is often of little use. The interest is therefore in starting from the bare, straight-line chemical description and then working out how the molecule should fold. With huge numbers of components — a small protein has 100 amino acids, most proteins have thousands — the problem is clearly one for computers. With the help of some basic known patterns of folding, the technique is again to try out a series of new shapes, evaluate the energy for each one and then proclaim the shape with the lowest energy. The trouble is that with thousands of components, protein structures are exceedingly complex and hundreds of computers together are not able to cope with the task this presents. And then, there are false results of local pockets of low energy, which are not the correct, least energy configuration. It is in this condition that the industry has found that pattern recognition capacity of the human brain practically does much better than computers. Scientists at the University of Washington modified the basic software used by computers to solve protein structures into an online computer game, where hundreds of players are challenged to fold proteins into the best shapes they could imagine.



Folded protein molecule

The basic programme, which used various algorithms to predict a bare outline structure of molecules, was called *Rosetta* and could turn out a large number of candidate structures. To make the best use of personal computers in the community, *Rosetta* was developed as a distributed computing programme, where people could download and watch the progress of pattern development as a screensaver. This was when many persons noticed that they could readily think of patterns superior to what they saw on the screen.

David Baker, the researcher in Washington University who had launched *Rosetta*, recognised the value of such human puzzle solvers and took the help of fellow computer scientist David Salesin and Zoran Popovic, a game designer, to create *Foldit*, an online computer game where any number of players could compete to create the most energy efficient variations of basic *Rosetta*-generated structures that were presented.

The technique, which has come to be called *crowdsourcing*, has shown excellent results, with major advances in protein structure discovery, including the structures of Simian HIV virus, providing insights for the design of retroviral drugs. "Players working collaboratively develop a rich assortment of new strategies and algorithms; unlike computational approaches, they explore not only the conformational space but also the space of possible search strategies," says a paper published by the University of Washington team.

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Unfavourable winds

mohd sajid idris reports on how turbines can increase local temperatures

OVER the years, wind turbines have been favoured as one of the most promising renewable sources of energy. But it may come at a cost because this pollution-free, environment-friendly source of energy can cause an increase in local temperatures.

Researchers from the University at Albany in the USA, led by Liming Zhou, analysed land surface temperature data of west-central Texas between 2003 and 2011 using instruments on board the National Aeronautical and Space Administration's Aqua and Terra satellites. The Texas region in the USA has four of the world's largest wind farms. The number of wind turbines increased from 111 in 2003 to 2,358 in 2011. The area does not have any other development activities that can contribute to temperature rise.

The analysis of data showed an upward trend in temperatures during the nine years, consistent with the increasing number of operational wind turbines. The land surface temperature increased at a rate of 0.72° Celsius per decade during the study period relative to nearby regions without wind farms. The reason behind this, researchers suggest, is that the turbines act as fans that pull the warmer air higher in the atmosphere to the surface and cooler air from the surface higher up at night. This pushes up the overall temperature. Under normal circumstances, at night when the sun goes down and the earth cools the air closer to the ground becomes colder. The study was published in the 29 April issue of *Nature Climate Change*.

"The research is a first step in exploring the potential of using satellite data to quantify the possible impacts of wind farms on weather and climate," says Zhou. "We are now expanding this approach to other wind farms too."

Somnath Baidya Roy, co-author of the study, notes that the study is important as understanding the impacts of wind farms will help in developing efficient adaptation and management strategies to ensure long-term sustainability of wind power.

Vinay Shankar Prasad Sinha, associate professor of remote sensing at Banasthali University in Rajasthan, points out that the impact of wind turbines on local temperatures may vary with geographical locations and this needs to be studied further.

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