Earth's new neighbour

Our planet has found a follower that shares the same orbit around the sun, writes s ananthanarayanan

ANY object in stable orbit along with the earth is of interest as a natural place, apart from the moon, for spacecraft rendezvous, and the journal *Nature* carries a report of the discovery of just such an object, some 150 million km away.
It is commonplace that an object in space is captured by a more massive one and held prisoner as a satellite. Any object shooting past another will have its path bent toward the other object because of gravity. If the pass is close enough, the visitor's path may be turned all the way round and, if even closer, it could fall into orbit around the more massive object. A far less common occurrence is when a small object ventures into the region of two comparatively more massive bodies and gets trapped into moving only within a small region, defined by the two much bigger objects.

Lagrange points

The problem of the motion of two moving bodies that are attracted by gravity is quite easy to solve. They either change their motion somewhat as they near and move away from each other, or they collide or fall into mutual orbit. But the problem can get tiresome if there is a third object that affects and is also affected by the other two, and all the while the three objects are in motion! A simplified version of the problem is when the third object is quite small and its effect on the other two can be ignored. And in the case when the second object is orbiting the first one, there are three positions where the motion of the third object can be worked out without many tears.

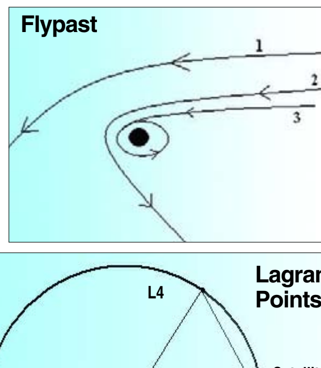
Let us take the case of earth, which orbits the sun. Now if there were a tiny object also in orbit around the sun, but closer to the sun, then it would orbit the sun faster. This happens because the inward pull by gravity is greater closer to the sun and the satellite needs to move round faster to avoid being pulled into the centre. But with a real, tiny object, in such an orbit the point just between the sun and the earth is one where the pull of the earth partly balances the pull because of the sun. At a particular distance, the two pulls would be just the same and the object would feel effectively no pull either way. Any movement away from this point, however, would create forces to push the object right back.

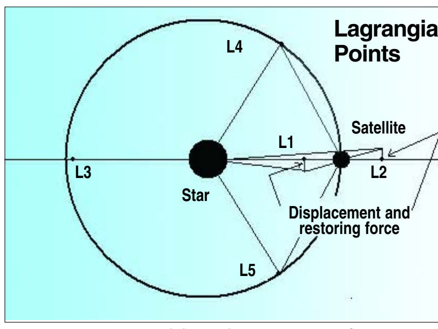
For instance, if the object starts moving to overtake earth, the sun would pull it radially down, but the earth would pull it back. And if the object were to slow, then the earth, again, would pull it forward, to speed up. Any movement towards or away from the sun, of course, would be punished by an increase or decrease in speed, pushing the object away or towards the sun, respectively. This point would thus be one where the average position would be stable, so long as the object strayed for short distances.

Another point where this would happen is in the sun-earth line, in an orbit outside earth's orbit. Here also, at the distance where the pull due to earth is equal to the pull because of the sun, any overtaking or falling behind earth would result in a braking or accelerating force, just right to keep the object in position. And there is yet another position, on the other side of the sun and a little closer to the sun than earth. At this point, where the force of gravity is that of the sun and earth combined, the speed of the orbit is still the same as that of earth because its centre is really the common centre of gravity of the sun and earth, which is a point within the body of the sun. But this point of equal speed of orbit is not stable like the other two.

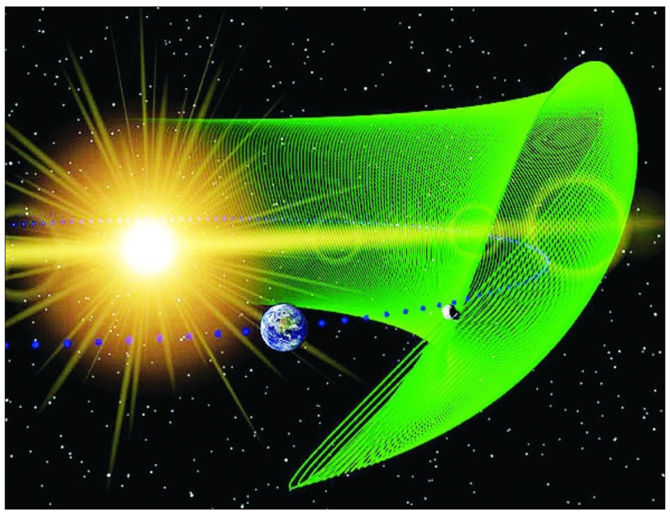
The first two points of stable orbit have been made use of to place artificial satellites, for communication and observation, without the need to expend large energy to keep them in place. The third one, which is unstable, is of no use and no object could possibly be found there.

The theory of how these points of equal orbit should exist was first worked out by French mathematician Joseph Louis Lagrange. He predicted another two points where the same property should hold — points on earth's orbit, 60? ahead or behind our planet, so that the sun, earth and the points form an equilateral (equal-sided) triangle. At these points, even displacements outside the plane of the orbit of the first two objects result in restoring forces.





Lagrange said that as these were points of stability lying in orbit around the sun, the orbit of Jupiter, the largest planet, should have collected a good number of objects at these stable points, which are now called *Lagrangian points*, of its orbit. And surely such was the case; Jupiter's Lagrangian points are crowded with asteroids that have been captured. These bodies are called *Trojan* asteroids as a convention because the asteroids of Jupiter, as they were discovered, were named after personages of the *Trojan war*.



The so-called Trojan asteroid, known as 2010 TK7.

Earth's Trojan

Astronomers have long wondered if earth has any asteroid captured in the Lagrangian points in its orbit — that is, the points that lie 60? before and after our planet. Objects at these points are naturally difficult to observe, as the points lie on the sunward side and objects would be obscured by the glare. But things changed with the launch of the National Aeronautics and Space Administration's *Wide-Field Infrared Survey Explorer*, a 16-inch IR telescope placed in orbit around earth in Dece,ber 2009. The sun's glare from the open sky is mostly from scattered light, which is in shorter wavelengths. Infrared light is of longer wavelength and does not scatter. It is, hence, possible to detect infrared light from distant objects from a spot in space like where Wise is placed, provided that the IR camera itself were kept cool enough not to generate conflicting IR radiation. The Wise camera thus needed a store of liquid hydrogen to let it work and it worked till October- February 2010, when its liquid hydrogen store gave out. But it was kept going for another four months as a *Neowise*, for *Near Earth Objects*.

In the 10 months that Wise was active, it detected a stupendous number of asteroids and Neos. Its equipment was 1,000 times and 500,000 times more sensitive than the earlier Infrared Astronomical and Cosmic Background Explorer Satellites, at the frequencies where Wise was working. By October 2010, Wise discovered more than 33,500 new asteroids and comets and observed nearly 154,000 solar system objects. Among these was *2010 TK7,* the first earth Trojan asteroid.

Martin Connors, Paul Wiegert and Christian Veillet, working in Canada, the University of California, Los Angeles, and at the Canada-France-Hawaii Telescope in Kamuela, Hawaii, respectively, report in *Nature* how the Trojan was confirmed from data sent down by Wise. While *2010 TK7* was first identified from data, confirmation was through observations at the Hawaii telescope facility, which was best possible in April 2011. Unlike satellites or comets that follow symmetric, elliptic orbits, Trojans typically hover around the stable point in a *tadpole-shaped* trajectory. But along with "tadpole" motion, *2010 TK 7* also shows considerable chaotic movements, which make it impossible to chart its future motion over any substantial time.

Earth Trojans are of interest because their positions are fixed with respect to earth and are thus eminently suitable for extraterrestrial spacecraft operations. *2010 TK7* is thus an important neighbour we have come to know. Its orientation and size have been worked out but other details such as composition are not yet available.

The writer can be contacted at simple-science@gmail.com

Competition calling

IIT, Kharagpur, needs designs from you in its diamond jubilee year

Since, in the long run, every planetary civilisation will be endangered by impacts from space, every surviving civilisation is obliged to become spacefaring — not because of exploratory or romantic zeal, but for the most practical reason imaginable: staying alive... If our long-term survival is at stake, we have a basic responsibility to our species to venture to other worlds.
— Carl Sagan

WITH the month just begun, IIT, Kharagpur, is all set to buzz with activity in this its diamond jubilee year. And what better attempt to highlight the occasion than with a first space-engineering competition in India being organised on 28-29 August — the National Students' Space Challenge.

This competition is the brainchild of Space Technology Students' Society, a student-run organization comprising space enthusiasts from IIT, Kharagpur, who aim to broaden the scope for actively pursuing space science as a career in India. These students, whose engineering disciplines are diverse – from mechanical engineering to geological sciences and biotechnology — have been working actively for the past four years to promote awareness related to space technologies and astronomy among their community. The society has been instrumental in organising lectures, competitions, astronomy sessions and workshops not only at IIT, Kharagpur, but all across the country.

The society functions under the patronage of the Kalpana Chawla Space Technology Cell, the contact-point of the Indian Space Research Organisation, at IIT, Kharagpur, and hence, receives indirect patronage from the national space agency.

NSSC 2011 comprises four technical competitions, along with guest lectures by eminent scientists and exhibitions on the history and achievements of Isro. The competitions have been carefully crafted to bring out the space engineer in participants. One competition, called LiftOff, requires students to design a rocket powered by pressurised water and demonstrate accurate control in its flight. Another called MoonLab requires a team of students to present a proposal for building a human settlement on the moon. The other two, MoonBots and Submerge, are robotic competitions that require students to build a lunar rover and an underwater rover, respectively.

Details of the competitions can be obtained from the official website: http://nssc.spats.in.

Evolution via evaluation

Great advances notwithstanding, contemporary genetic research has triggered not a few controversies, says tapan kumar maitra

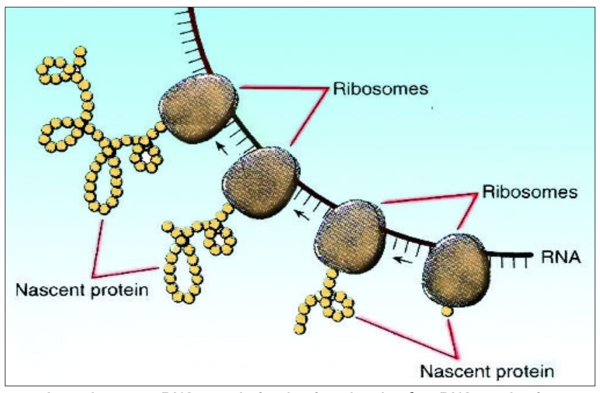
WITH the exception of some viruses, the genetic material of all cellular organisms is double-stranded DNA — a double helical molecule shaped like a twisted ladder. The backbones of the helices are repeating units of sugars (deoxyribose) and phosphate groups. The rungs of the ladder are base pairs, with one base extending from each backbone. Only four bases normally occur in DNA: adenine, thymine, guanine, and cytosine, abbreviated A, T, G and C respectively. There is no restriction on the order of bases on one strand. However, a relationship called complementarity exists between bases forming a rung. If one base of the pair is adenine, the other must be thymine; if one base is guanine, the other must be cytosine. James Watson and Francis Crick deduced this structure in 1953, ushering in the era of molecular genetics.

The complementary nature of the base pairs of DNA made the mode of replication obvious to Watson and Crick: The double helix would "unzip," and each strand would act as a template for a new strand, resulting in two double helices exactly like the first. Mutation, a change in one of the bases, could result from either an error in base pairing during replication or some damage to the DNA that was not repaired by the time of the next replication cycle.

Information is encoded in DNA in the sequence of bases on one strand of the double helix. During gene expression, that information is transcribed into RNA, the other form of nucleic acid, which actually takes part in protein synthesis. RNA differs from DNA in several respects: it has the sugar ribose in place of deoxyribose; it has the base uracil (U) in place of thymine (T) and it usually occurs in a single-stranded form. RNA is transcribed from DNA by the enzyme RNA polymerase, using DNA-RNA rules of complementarity. Three nucleotide bases form a codon that specifies one of the 20 naturally occurring amino acids used in protein synthesis. The sequence of bases making up the codons is referred to as the genetic code.

The process of translation, the decoding of nucleotide sequences into amino acid sequences, takes place at the ribosome, a structure found in all cells that are made up of RNA and proteins. As the RNA moves along the ribosome one codon at a time, one amino acid attaches to the growing protein for each codon.

The major control mechanisms of gene expression usually act at the transcriptional level. For transcription to take place the RNA polymerase enzyme must be able to pass along the DNA; if this movement is prevented, transcription stops. Various proteins can bind to the DNA, thus preventing the RNA polymerase from continuing, providing a mechanism to control transcription. One particular mechanism, known as the operon model, provides the basis for a wide range of control mechanisms in prokaryotes and viruses. Eukaryotes generally contain no operons; although we know quite a bit about some control systems for eukaryotic gene expression, the general rules are not as simple.



In prokaryotes RNA translation begins shortly after RNA synthesis.

In recent years, there has been an explosion of information resulting from recombinant DNA techniques. This revolution began with the discovery of restriction endonucleases, enzymes that cut DNA at specific sequences. Many of these enzymes leave single-stranded ends on the cut DNA. If a restriction enzyme acts on both aplasmid, a small, circular extra-chromosomal unit found in some bacteria, and another piece of DNA (called foreign DNA), the two would be left with identical single-stranded free ends. If the cut plasmid and cut foreign DNA are mixed together, the free ends can re-form double helices and the plasmid can take in a single piece of foreign DNA. Final repair processes create a completely closed circle of DNA. The hybrid plasmid is then reinserted into the bacterium. When the bacterium grows, it replicates the plasmid DNA, producing many copies of the foreign DNA. From that point, the foreign DNA can be isolated and sequenced, allowing researchers to determine the exact order of bases.

In 2000, scientists announced the complete sequencing of the human genome. That sequence can tell us much about how a gene works. In addition, the foreign genes can function within the bacterium, resulting in bacteria expressing the foreign genes and producing their protein products. Thus we have, for example, E. coli bacteria that produce human growth hormone.

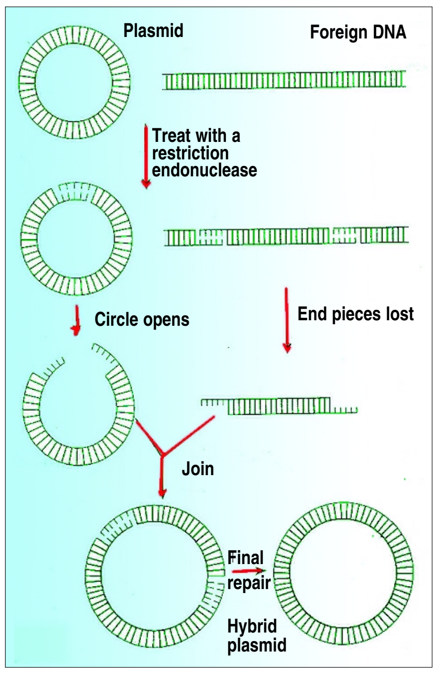
This technology has tremendous implications in medicine, agriculture and industry. It has provided the opportunity to locate and study disease-causing genes, such as the genes for cystic fibrosis and muscular dystrophy, as well as suggesting potential treatments. Crop plants and farm animals are being modified for better productivity by improving growth and disease resistance. Industries that apply the concepts of genetic engineering are flourishing.

One area of great interest to geneticists is cancer research. We have discovered that a single gene that has lost its normal control mechanisms (an oncogene) can cause changes that lead to cancer. These oncogenes exist normally in non-cancerous cells, where they are called proto-oncogenes and are also carried, by viruses, where they are called viral oncogenes. Cancer-causing viruses are especially interesting because most of them are of the RNA type. Aids is caused by one of these RNA viruses, which attacks one of the cells in the immune system. Cancer can also occur when genes that normally prevent cancer, called anti-oncogenes, lose function. Discovering the mechanism by which our immune system can produce millions of different protective proteins (antibodies) has been another success of modern molecular genetics.

From a genetic standpoint, evolution is the change in allelic frequencies in a population over time. Charles Darwin described evolution as the result of natural selection. In the 1920s and 1930s, geneticists, primarily Sewall Wright, RA Fisher and JBS Haldane, provided algebraic models to describe evolutionary processes. The marriage of Darwinian theory and population genetics has been termed neo-Darwinism.

In 1908, GH Hardy and W Weinberg discovered that a simple genetic equilibrium occurs in a population if the population is large, has random mating and has negligible effects of mutation, migration and natural selection. This equilibrium gives population geneticists a baseline for comparing populations to see if any evolutionary processes are occurring. We can formulate a statement to describe the equilibrium condition: If the assumptions are met, the population will not experience changes in allelic frequencies and these allelic frequencies will accurately predict the frequencies of genotypes (allelic combinations in individuals, eg AA, Aa or aa) in the population.

Recently, several areas of evolutionary genetics have become controversial. Electrophoresis — a method for separating proteins and other molecules — and subsequent DNA sequencing has revealed that much more polymorphism (variation) exists within natural populations than older mathematical models could account for. One of the more interesting explanations for this variability is that it is neutral. That is, natural selection, the guiding force of evolution, does not act differentially on many, if not most, of the genetic differences found so commonly in nature. At first, this theory was quite controversial, attracting few followers. Now it seems to be the view the majority accepts to explain the abundance of molecular variation found in natural populations.



Hybrid DNA molecules can be constructed from a plasmid and a piece of foreign DNA.

Another controversial theory concerns the rate of evolutionary change. It is suggested that most evolutionary change is not gradual, as the fossil record seems to indicate, but occurs in short, rapid bursts, followed by long periods of very little change. This theory is called punctuated equilibrium.

A final area of evolutionary biology that has generated much controversy is the theory of sociobiology. Sociobiologists suggest that social behaviour is under genetic control and is acted upon by natural selection, as is any morphological or physiological trait. This idea is controversial mainly as it applies to human beings; it calls altruism into question and suggests that to some extent we are genetically programmed to act in certain ways. Many thinkers still criticise the theory, as they feel it justifies racism and sexism.

The writer is associate professor in botany, Anandamohan College, Kolkata