Seeing the electron quiver

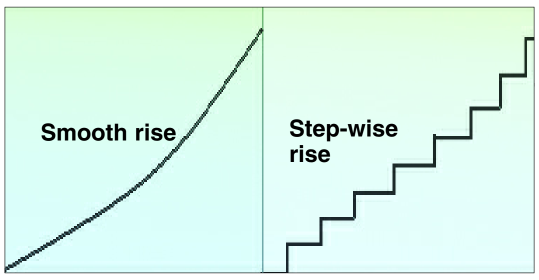
Simulating the condition of a 'free electron' has helped glimpse a quantum mechanics scepter, says s ananthanarayanan**.**

QUANTUM theory proposes that a free electron near the speed of light will exhibit a shiver at a fantastic rate. While there are no methods to check if this is true, Christian Roos and colleagues in the Austrian Academy of Sciences have used a calcium ion trapped in a field to behave just like the electron and have verified that the shiver does occur.

The beginning of the last century saw amazing changes in scientists' view of nature and gave rise to technology that was unimaginable till then. By the end of the 19th century, with the discovery of the steam engine, the petrol engine, the electric motor, radio waves, the microscope, Darwin's theory, the telescope and the nature of the heavens, it had begun to look like nature was being completely understood. But with the discovery of new phenomena, like radioactivity, the internals of the atom, the theory of relativity, classical physics was found to be quite off the mark when it came to the detailed working of atom-scale systems and the understanding of physics needed to be reassembled.

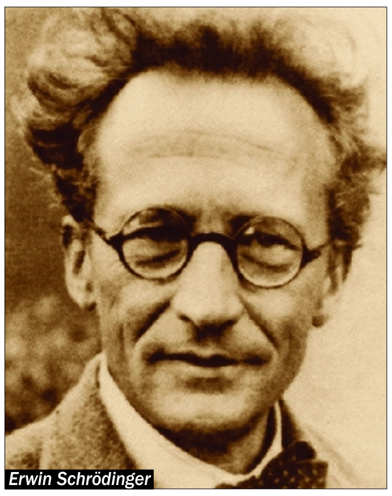
The main new concept developed was that energy was not transferred "continuously or smoothly", but in discreet packets, and in a *step fashion*. A light beam, then, was seen as not a continuous stream of waves, like ripples in a pond, but as a huge number of "packets" of waves. The packets were all of the same frequency and were so large in number that the effect was like a continuous wave, but in fact they were discrete, identical "quanta" which, individually, behaved like particles. An early success of the theory, in fact, was explaining the photoelectric effect using the idea that an electron was knocked out or not at all, depending on the energy of the particle of light.

In contrast, it was also found that particles, too, behaved like waves. In the case of a large, everyday particle like a pebble or a cricket ball, the waves are of too high a frequency for wave behaviour to be detected. But in the case of minute particles like electrons, wave properties are clearly manifest, although of very much shorter wavelength than X-rays or gamma rays. The early development of quantum mechanics, or the physics of minute dimensions, was around the wave phenomena, like diffraction and interference, shown by electron beams.



Schrödinger & Dirac

A new mathematical formulation of Newton's equations was developed to take the new ideas into account and produce the results that matched observation. A particle bouncing between the walls of a box, then, either oscillated at a certain rate or twice that rate or three times the rate, etc, never in between. In the case of an everyday particle and box of usual dimensions, we are already at the trillion trillion trillionth (or so) frequency and so the change to one higher frequency appears to be continuous. But at the dimensions of atoms and such like, each different frequency is a discernable energy step and the usual form of Newton's equations are inadequate.


Erwin Schrödinger


PAM Dirac

The first successful mathematical formula (1926), by Austrian physicist Erwin Schrödinger was of the form of Newton's equation of motion, but with properties built in to give solutions in discrete steps of energy. This was a fine "first cut" and it works most of the time where there are no relativistic effects. To take care of relativistic effects, like with an electron that moves near the speed of light, English physicist PAM Dirac wrote a new equation (1928) that applied to particles that had certain values of a quantum mechanics quality called "spin", related to the speed of rotation.

This equation became a milestone in the development of the new physics and had the feature of permitting *negative energy states*. One way of understanding such a thing was to think that each particle had a corresponding "anti-particle", or a "hole" in the "energy sea", that would annihilate the particle if they came in contact. It was a major validation of the theory when the electron's antiparticle, the positron, was discovered a few years later.

Zitterbewegung

Schrödinger himself analysed Dirac's equation and proposed, in 1930, that due to the superposition of the positive and negative energy states, a free electron should exhibit rapid fluctuation in its position, a shiver called *Zitterbewegung*, or *trembling motion*, in German, at a frequency that corresponds to the particle's wave equivalent. In the case of the electron, this frequency is of the order of a thousand billion billion cycles a second and an amplitude of a thousandth of a nanometer, and is beyond the present capacity to observe.

The attempt to simulate the condition of the free electron is more complicated than the usual modelling methods using scaled down facsimiles or computer simulation. In this case, what is required is that the mathematical entity from which the position and movement of a quantum of the calcium ion can be derived should mirror, term for term, the same entity of a free, relativistic, mechanical particle that has two internal energy states – one positive, the other negative.

To reproduce this entity for a one-dimensional case, the Austria group irradiated the calcium ion with laser light so that the ion's motion in one dimension got coupled to the calcium ion's two internal energy states. When the ion is thus trapped with lasers of the right frequency, the equation describing its motion in the trap takes the same form as the free Dirac particle, but at a much lower speed. The behaviour of the Dirac particle is them mimicked in the behaviour of the ion, at rates that can be observed.

By varying the effective mass and speed of the ion, by choosing laser intensity and frequency, the group was able to simulate different conditions of effectively a negative and positive energy state superimposed, or purely negative energy states, etc. It was demonstrated that the quivering motion was indeed due to the interference of the positive and negative energy states and also that it disappeared in the high mass (non-relativistic) or the low mass (highly relativistic) case.

The experiment has been a demonstration of a highly counterintuitive and difficult to detect quantum mechanical effect in a real system. It also marks the beginning of technique of modelling quantum conditions that could be used to study different hitherto unsolved problems.

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Explaining the nature of reality

Biocentrism, writes rhishav n chowdhury**, holds that the universe is created by life and not the other way round**

DOESN'T life seem too perfect to be mere coincidence? Everything is perfect, as Goldilocks said, not too cold, not too hot; just right. Why is that so? Why is it that out of the hundreds and thousands of galaxies discovered till date, our planet seems to be the only habitable sphere? The further we peer into space, the more we realise that the nature of the universe cannot be understood by inspecting spiral galaxies or watching distant supernovas. It lies deeper; it involves our very selves. Is the reality of the universe we see possible without us? The only things we are aware of are our perceptions. In other words, consciousness is the matrix upon which the cosmos is comprehended; colour, temperature and the like exist only as perceptions in our head, not as absolute essences. In the broadest sense, we cannot be sure of an outside universe at all. Biocentrism is a radical new view of reality conceived by Robert Lanza in which life creates time, space and the cosmos itself.

For centuries, scientists built physical models based on a separate universe "out there", into which we have each individually arrived. These models presume the existence of one essential reality that prevails with or without us. But over the course of the last century, experiments in quantum physics regularly show the opposite: results do depend on whether someone is observing. For example, quantum theory tells us that an unobserved small object exists only in a blurry, unpredictable state, with no well-defined location or motion until the moment it is observed (Werner Heisenberg's uncertainty principle). The phantom, not yet formed condition is described as a wave function, a mathematical expression used to find the probability that a particle will appear in any given place, and when the property of a particle switches from possibility to reality the wave function as such collapses. What causes this collapse? Just by hitting it with a bit of light to take its picture, looking at it, or even the mere knowledge of the phenomenon is sufficient to convert possibility into reality.

At the moment there are four explanations why the universe seems tailormade for life. One is simply incredible coincidence, another is to say God created it, which explains nothing, even if true. The third explanation invokes a concept called the *anthropic principle* which holds that we must find the right conditions for life in our universe because if such life did not exist, we would not be here to find those conditions. Recently, the anthropic principle was fused with the *multiverse theory*, which suggests that our universe is just one in a vast multitude of universes. Through sheer numbers, then, it would not be surprising that one of these universes would have the right qualities for life. However, so far there is no direct evidence whatsoever for other universes. The final option is biocentrism, which holds that the universe is created by life and not the other way round.

Even the most fundamental elements of reality — space and time — strongly support a biocentric basis for the cosmos. According to biocentrism, time does not exist independently of the life that notices it. Time can be seen from two perspectives, in the first the past exists only as ideas in the mind, which themselves are neuroelectrical events occurring strictly in the present; in the second, time is described in terms of change. Change, though, is not the same as time. To measure anything's position precisely at any given instant is to lock on one static frame of its motion, as in the frame of a film. Conversely, as soon as you observe a movement you cannot isolate a frame because motion is the summation of many frames. All this makes perfect sense from a biocentric perspective, everything we perceive is actively and repeatedly being reconstructed inside our heads in an organised whirl of information. Time in this sense can be defined as the summation of spatial states occurring in the mind. This begs the question: what is, in fact, real? If the next mental image is different from the previous, then it is different, period. We can relate that change with the word "time", but that does not mean there is an actual invisible matrix in which changes occur. That is just our way of making sense of things. For example, we watch our loved ones age and die and assume that an external entity called time is responsible for the crime. The same peculiar intangibility can be applied to space as well. Like time, space is neither fundamentally real in our view. Rather, it is a mode of interpretation and understanding, part of an animal's mental wiring that moulds sensations into multidimensional objects. Most of us regard space as a sort of vast container that has no wall. This notion has several loopholes, however. First, distances between objects change, depending on conditions like gravity and velocity, as described by Einstein's relativity, so there is no absolute distance between something and anything else. Second, as described by quantum mechanics, space is not actually empty put filled with particles and fields. Last, quantum theory even casts doubts on the notion that distant objects are truly separated, since entangled particles can act in unison even if separated by the width of a galaxy.

In daily life, space and time are inconsequential illusions. The problem, though, is that by treating these as a fundamental and independent concept, science picks a flawed investigation into the nature of reality. The belief is that answers can be built from one side of nature, the physical, without the other side, the living. Biocentrism could unlock the cages in which science has confined itself, allowing the observer into the equation to open new approaches to understanding cognition — from unravelling the nature of consciousness to developing thinking machines that experience the world in a similar way as we do. Accepting space and time as forms of animal perception, rather than external physical objects, allows a novel way of understanding everything from the micro-world to forces, constants and laws that shape our universe, and providing stronger bases for solving problems related to quantum physics and the Big Bang.

Above all, until we recognise the essential role of biology in understanding the nature of reality, attempts to find a truly unifying theory that explains the universe will remain like a ship sailing in an endless ocean, never reaching a port of destination.


Time (and space) does not exist independently of the life that notices it.

The writer is a freelance contributor

Survival strategies

tapan kumar maitra **explains the complex metabolic processes of bacteria**

A CONSTANT exchange of compounds with the surrounding environment is inherent in all organisms. To carry out the processes of nutrition and reproduction certain conditions are necessary: the presence of food material from which microbes synthesise the component parts of their cell and by oxidation of different substances receive the required energy.

Bacteria can be subdivided into autotrophic and heterotrophic, according to their type of nutrition. Autotrophic chemosynthetic and photosynthetic micro-organisms are able to produce organic substances from inorganic compounds. They do not require organic carbon compounds and synthesise the component parts of their cell by absorbing carbon dioxide, water and simple nitrogen compounds — ammonia and its salts, the salts of nitric acid. Nitrifying bacteria and many sulphur bacteria belong to the autotrophic microbes. They synthesise complex substances at the expense of the energy they receive on oxidation of ammonia to nitrites and oxidation of sulphur, sulphides, thiosulphates to sulphuric acid.

Of interest are lithotrophic bacteria that receive energy from the oxidation of inorganic substances — hydrogen, carbon monoxide, methane, ammonia, compounds of iron, manganese, sulphur, etc. These play an important role in the substance cycle in nature. Some species of micro-organisms like anaerobic, purple and green sulphur bacteria contain chlorophyll and utilise radiant energy for photosynthesis.

It was established long back that during synthesis cellular organic substances utilise carbon dioxide as the sole source of carbon and are unable to absorb more complex carbon compounds. For this reason such organisms are not pathogenic for man and animals. Certain autotrophic bacteria possess the property of utilising polyethylene, nylon, diesel fuel, boric acid, phenol and other inorganic substances.


Heterotrophic bacteria requires organic carbon, nitrogen compounds, inorganic substances, trace elements and vitamins.

Heterotrophic bacteria require organic carbon (carbohydrates, keto-, amino-, oxy- and fatty acids), various nitrogen compounds (nitrates, ammonia), inorganic substances, trace elements and vitamins. Micro-organisms which may change from one type of nutrition to another are called mixotrophs — hydrogenous bacteria. Heterotrophic bacteria are subdivided into saprophytes and parasites.

Saprophytes live at the expense of organic substances found in the surrounding environment. These include most species of bacteria inhabiting our planet.

Parasites make up a comparatively small amount of species of microbes which in the process of evolution have adapted themselves to a parasitic mode of life. Some scientists call them paratrophs since they feed at the expense of organic compounds of animals and man. However, this kind of subdivision of heterotrophic microbes into saprophytes and parasites is not absolute since such a distinction into subgroups can hardly be established.

Certain species of microbes, pathogenic for man, can exist in the environment as saprophytes and vice versa. Some of these, under unfavourable conditions, can cause different diseases in humans and animals.

Some microbes that were earlier considered typical heterotrophs grow well on synthetic media containing ammonium sulphate supplemented by vitamins. Many pathogenic micro-organisms cultivated on media containing blood, serum, etc can be grown on synthetic media.

The majority of bacteria develop only on complex media containing peptone — a product of enzymatic breakdown of meat and other protein substrates —, meat extract and products of a similar biological origin, which contain all the organogenes in the form of highly molecular compounds necessary for the nutrition of microbes.

Nitrogen and its compounds are of great importance in the nutrition of microbes. The sources of carbon for microbes may be different carbohydrates, polyatomic alcohols organic acids and their salts.

B Knight has divided bacteria into four groups according to their ability to synthesise complex compounds. These are:

- Bacteria obtaining carbon from carbon dioxide, and nitrogen from inorganic compounds which include autotrophs capable of photosynthesis. Such organisms utilise radiant energy (light). Autotrophs capable of chemosynthesis obtain energy by the simple processes of oxidation of inorganic compounds (nitrifying bacteria, sulphur bacteria and some iron bacteria;
- Bacteria deriving carbon and obtaining energy from organic carbon compounds and nitrogen from its inorganic compounds — the majority of saprophytes;
- Bacteria obtaining carbon and energy from organic carbon compounds and nitrogen from amino acids — colibacilli and other commensals; and
- Bacteria absorbing carbon and obtaining energy from organic compounds and nitrogen form a complex of many amino acids, requiring one or more vitamins — pathogenic bacteria.

The main difference between heterotrophic and autotrophic organisms is they require organic compounds containing an asymmetric carbon atom. However, recently it has been proved that separate species of heterotrophic bacteria, protozoa, yeasts and also animals absorb carbon dioxide and ammonia, synthesising complex carbohydrates and amino acids from them.

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