Atomic forces on the dissection table

X-rays have helped virtually peel away the layers to reveal forces between atoms, says s ananthanarayan

A TEAM of French, Swedish and Japanese scientists, working at a facility on the outskirts of Paris, has made use of X-rays — not for imaging by throwing a shadow, as commonly understood, but as tuning forks to sound out the energy levels within a molecule — to form close-up pictures of the interactions that have been inaccessible to methods employed so far. The results of their work has been reported in the current on-line issue of *Nature*, in a paper by Catalin Miron, lead author, with Christophe Nicolas, Oksana Travnikova, Paul Morin, Yuping Sun, Faris Gel'mukhanov, Nobuhiro Kosugi and Victor Kimberg.

Forces at the atomic level are fundamentally different from those of ordinary experience because of the small dimensions. The particles are so light in relation to their electric charges that gravity becomes irrelevant and the interactions are purely electric or magnetic. And because of the small distances, quantum effects become important and movement is not continuous but in steps, between energy levels. Again, because of the dimensions, the time scales shrink and the separation of events is of the orders of pico-seconds. The whole action, naturally, is invisible and has to be understood only by inference, using probes like other atomic particles or light waves of suitable wavelength.

A traditional method has been by absorption and emission of light in the infra-red region, where the energy is of the order of the levels involved. Typically, infra-red light is shone through a sample of the material and the spectrum of the light that emerges is analysed. The atoms composing the molecules are held together by atomic forces and are in constant vibration or rotation, moving from one state to another by emission or absorption of energy. When infra-red light passes through the material, the specific wavelengths that correspond to energy differences between levels get absorbed and show up as dark lines in the spectrum. The spectra are analysed using special lenses and prisms, which allow infra-red radiation to pass through and detailed maps of the different vibration, rotation and combined energy levels of all kinds of molecules are created to understand the unseen world of how atoms combine and recombine.

The use of X-rays has been mainly to understand the spatial distribution of atoms in solids, typically in the form of crystals. X-rays have a wavelength that is comparable to the distances between atoms in crystals. When an X-ray beam is scattered by a crystal, X-ray photons deflected by adjacent atoms will arrive at various points on a screen through paths whose lengths differ on the scale of the X-ray wavelength. The pattern on the screen is thus of bright and dark spots and it helps work out how the atoms in the crystal are oriented. This method, in combination with a knowledge of the energy levels, chemical affinities and many other properties of materials, has provided a wealth of knowledge on the use and value for manufacture in medicine, agriculture and many other fields of life and industry.

Catalin Miron installs the Scienta R4000 on Pleiades, September 2007.

Limitation

These methods, however, are limited to the gross energy levels and spatial layout of static crystals and do not reveal first: many transitions that do not take place without additional requirements; and, second: the sequence of events that take place in the very short time-scale of atomic interactions. The group of scientists, working at the *Soleil* synchrotron light source at Saclay in Essonne, which is a district in the greater Paris region, has used the versatile capability of Soleil to probe and detect the short-lived, internal states of the nitrogen molecule. This nitrogen molecule consists of just two atoms, in combination by sharing their outer shell electrons to give stability and is a simple but illuminative instance of molecules in general.

The two atoms can have motion of vibration, where they bounce back and forth like a yo-yo, or of torsion, where they move in arcs, or of rotation, where they spin like a top, and so on. While the gross energy levels of these motions, averaged over time, have been observed, details like how the force increases or decreases with distance, or how the internal states of the atoms themselves affect their relation with other atoms have been out of reach.

Soleil

The Soleil synchrotron in Saclay is an accelerator of electrons, with the facility of sensitive control of speed and energy. When charged particles, like electrons, are accelerated or move in circles they radiate energy in the form of light whose wavelength depends on the acceleration. Soleil is thus able to throw out X-rays with a wavelength that can be controlled over a continuous range, which is a versatile experimental tool.

Using these controlled X-rays, the Saclay team evoked the property of atoms to throw out electrons when excited by radiation, usually Ultra Violet or X-ray. Collecting these emitted electrons with the help of the facilities that exist at Saclay the group was able to detect and time intermediate events within atomic interactions and plot a much more detailed picture of the energy levels at the inter-atomic scale.

One of the methods used was "resonant photo-emission" or the peaking of electrons that are emitted by atoms as the wavelength of X-rays is varied. The way electron emission takes place is that an X-ray photon striking an electron in an atom knocks the electron out, with the energy of the original X-ray, less the binding energy of the electron. The sky-map of the emissions of electrons over the spectrum of incident X-rays would reveal in detail the original energy levels. When an electron is emitted from an atom, the atom is left with a "hole" or a missing electron in the shell from which it was emitted. An electron in a higher shell may now take its place, emitting the energy difference in the form of light of characteristic wavelength. Or it may result in another electron being emitted, a phenomenon known as the *Auger effect*.

The detection of these events, in conjunction with other indicators of molecular vibrations and rotation, has enabled the sighting of rare energy levels and allowed for plotting the core energy structure of molecules, which has so far been seen in its external manifestations.

The authors see the potential for advances in all fields that depend on the intrinsic properties of molecules. With the work at Saclay, "… a whole new field of possibilities opens up to other scientific disciplines in understanding the intimate behavior of matter", according to the Soleil synchrotron facility in a press release.

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The Soleil synchrotron light source at Saclay.

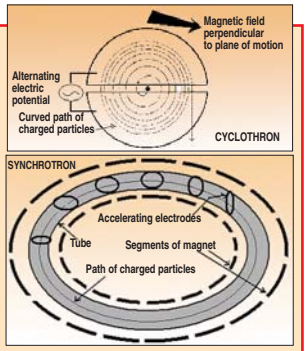
The synchrotron

CHARGED atomic particles can be accelerated by electric fields. At the same time, their path can be turned by applying a magnetic field. The combination of the two properties is used to repeatedly speed up charged particles, but by keeping them in a circular path so that the accelerator need not extend to hundreds or thousands of kilometres.

The *cylotron* was the first of these arrangements where a charged particle is released between a pair of semicircular disks that have a voltage difference. The charge particle rushes across the gap, from low to high voltage. But in the process, because of the magnetic field applied, it turns around to approach the gap again. Just then, the voltages applied to the discs are reversed — and the particle crosses, again with an increase in speed. With the higher speed it turns around in a larger circle. After millions of such transitions, the particle can be at very high speeds, comparable to that of light, but the diameter of the circular path keeps increasing. The size of the cyclotron facility is thus the limiting factor.

In the synchrotron, the path of the charged particles is a circular, evacuated tube. The large single magnet of the cyclotron is replaced by a large number of magnets over segments of the tube and the magnetic field is increased as the particles speed up. The frequency of the accelerating voltage is also increased in relation to the increase of speed and the arrangement can reach very high energies without the need for a wide area. In the synchrotron, the charged particles need to be introduced after having already reached a threshold speed, which may be through a cyclotron facility.

The charged particles then emit radiation of different wavelengths, which can be tapped in ranges, each range called a *beamline*. With the facility at Saclay being named Soleil, which means the sun in French, the beamlines have been named after stars and constellations. The beamline used in the current experiments was the *Pleiades*, which creates a beam between 10 and 100 microns in size, of soft X-rays.

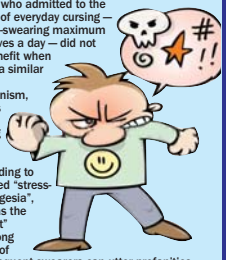


Swearing is good for you, but...

A study reveals that cursing can relieve pain ~ but only when practised in moderation, writes rob sharp

VICTIMS of paper cuts and stubbed toes don't need scientists to tell them about the pain-healing power of cursing but research suggests the more you swear the harder pain becomes to bear. A study by Keele University confirms that swearing can act as a form of relief, but those who have become habituated to cursing are less likely to feel the benefits.

Richard Stephens, of Keele's School of Psychology, said there was no "recommended daily swearing allowance", and it remains unclear whether certain swearwords are more effective analgesics than others. "We are just scratching the surface of how swearing can influence our emotions," he added. His findings, in America's *The Journal of Pain*, found that those who swear just a few times a day doubled the time they could withstand the "ice-water challenge" — how long they could hold their hands in a container full of ice-water. Those who admitted to the highest level of everyday cursing — up to a chain-swearing maximum of 60 expletives a day — did not show any benefit when undertaking a similar challenge.



The mechanism, the scientists say, is simple; swearing elicits an emotional response leading to what is termed "stress-induced analgesia", also known as the "fight or flight" response, along with a surge of adrenalin. Frequent swearers can utter profanities without feeling an emotional response, and thus do not get the same pain-relieving effects. So it seems that swearing lightly in one's daily routine can help in the occasional, stressful situation. "Swearing seems to activate parts of the brain that are more associated with emotions," Stephens said. "But in the context of pain, swearing appears to serve as a simple form of emotional self-management. Whether swearing has beneficial effects in other contexts is something we would like to explore further."

A history of swearing

- The original meaning of the adjective "profane" derives from the Latin meaning "in front of" and "outside the temple". It refers to items not belonging to the church. For example, "The fort is the oldest profane building in the town, but the local monastery is older."
- A 2000 report co-commissioned by the Advertising Standards Authority and the BBC ranked swearwords on their severity. The most severe words related to racial abuse. The mildest were "baby words" such as "poo, wee and bum" and rhyming slang "berk".
- Regarding broadcast swearwords, 52 per cent of respondents to the Asa survey said that the "c" word should never feature in television programmes, whereas just seven per cent had a problem with the word "bloody".
- Every language, dialect or patois, whether living or dead, has its own share of forbidden speech. Additionally, young children will memorise the "illicit inventory" long before they can grasp its sense, believes John McWhorter, a scholar of linguistics at the Manhattan Institute.
- About 80-90 words each day — between 0.5-0.7 per cent of all words — are swearwords, according to analyses of recorded conversations.
- A 2006 survey found that 36 per cent of 308 British senior managers and directors accepted swearing as a part of workplace culture. "If swearing is discriminatory it is a complete no-no," said employment lawyer Brian Palmer. "Employers have a duty of care towards their employees so they have a reasonable working environment."

The Independent, London

Back to basics

aparna pallavi **reports on how innovative Vidarbha farmers are making biogas plants viable**

WHEN Vijay Ingle of Chittalwadi village in Akola district decided to install a biogas plant at his dairy last year, everyone was sceptical. It had failed to take off in the Vidarbha region despite the government promoting biogas as the cleanest and cheapest fuel for over three decades and offering subsidies for setting up the plant. Besides, no one had heard of a biogas plant installed 400 metres from the house; it is usually set up in the backyard, close to the kitchen. In neighbouring Tandulwadi village of Buldhana district, farmer Shyamrao Deshmukh had faced similar scepticism four years ago. As his joint family grew and multiplied, they had to relocate their cowshed to the village outskirts, around half a kilometre away. To cut down growing LPG expenses, Deshmukh decided to set up a biogas plant in the cowshed. He, too, found himself surrounded by people asking him to give up the project.

The two farmers, however, stuck to their resolve and made the plants work. The success turned critics into believers. Today, Chittalwadi has 15 working biogas plants. Tandulwadi has four. Several others also plan to install biogas plants and have applied for subsidies.

So far, officials had cited a cow dung scarcity in Vidarbha as the reason biogas was not drawing a crowd, despite subsidies. But farmers setting up biogas plants in these villages do not own large numbers of cattle, disproving the official theory. They have found innovative solutions to the challenges that prevented them from accessing biogas.

While struggling to overcome problems involving distance, Deshmukh approached the Dr Punjabrao Deshmukh Krishi Vidyapeeth, an agriculture university in Akola that offers extension services. He was advised to install telescoping PVC piping to build pressure in the gas tank and put the pipeline below ground with a gentle gradient for an unhindered flow of gas to the kitchen. He was also told to install equipment for removing moisture from the pipeline. Deshmukh realised that to install the pipeline he would have to shell out more than the cost of the entire plant. He would also have to lower his kitchen floor by around 60 cm. About to give up, he decided to try out his original plan. After all, he'd already constructed a two-cubic metre digester tank at Rs 9,000. Instead of PVC piping, he installed a rubber pipe used for drip irrigation. Instead of laying it underground, he took the pipe to his house by securing it to tree branches overhead. It cost him Rs 1,000. To trap moisture, he twisted the pipe into a loop at the source and secured it in that position; being heavier than gas, moisture settles within the loop and flows back into the digester. "It has been four years but moisture, which the university official had warned would be the problem, has not troubled me," Deshmukh says. The plant provides enough gas to cook for his family of six all year round.

Ingle had also approached the university for guidance but to no avail. Then he approached an agriculture input dealer who suggested he use rubber tubes as in LPG cylinders. "My brothers and I had spent Rs 1.75 lakh for constructing four six-cubic metre digester tanks," he says. "Installing that kind of a pipe would have cost us another Rs 1.4 lakh, which was impossible." Like Deshmukh, Ingle used a drip irrigation pipe, running overhead. But he bifurcated it at the source with a T-section. One branch carries the gas to the house while the other heads vertically downwards to a nozzle. "I open it once a week to drain out moisture," he says.

Apart from providing enough gas for cooking and heating bath water for 22 people, Ingle's plant also provides enough gas for extra cooking for about 100 people three to four times a year during festivals, processing of 100 litres of milk products in the dairy every day and lighting the cattle shed. "We are still left with surplus gas and plan to install a generator to supply power to the house," he says. His joint family now saves Rs 80,000 per year on LPG cylinders.

Most of the 15 farmers in Chittalwadi who used Ingle's innovation own not more than three to four heads of cattle. "Initially, we were reluctant as the conventional biogas plant design requires a large amount of dung," says Sindhutai Tayade, who owns four heads of cattle. "But when we found that Ingle's plant works just by using dung from 10 to 12 animals, that too on alternate days, we thought it could work for us too."

Milind Ingle, another farmer from Chittalwadi, was surprised to find that dung from his three cows was more than enough for his family of three. "We have surplus gas left after meeting our cooking and bath water needs," says Harsha Ingle, Milind's mother. She now plans to give gas connection from the plant to his farm helpers.

The innovations are fast spreading to nearby villages where people are rediscovering biogas. Manohar Kokate of Shirla village in Akola says some 50 biogas plants were installed in the village in the 1980s when the government introduced biogas under a national project. Most closed down within a decade after cattle numbers dwindled in the arid region. Now, with the government introducing the smaller Deenbandhu model of biogas plant and innovations by several farmers, people want biogas again, he adds.

Uday Kathode, Agriculture Development Officer of Akola, says three years of severe drought in the region has caused a fuel wood crunch and raised awareness regarding the importance of biogas. In Akola, for instance, 135 new biogas units were installed last year, and most are functioning now, he says. Since the drought has brought down livestock numbers, to keep up the interest, Kathode suggests the government promote small dairy endeavours in the region so that more farmers can use the dung to generate biogas.

But more than dairy farms, farmers feel that guidance for installation of biogas plants and associated innovations are a more pressing need. One area of improvement is transporting gas from a distance. In most villages, with families multiplying, cattle sheds are located away from the homestead. SR Gadge, who heads the Department of Unconventional Energy at the agriculture university, says the Deenbandhu model works on gas pressure and no special technology is required to transport gas to a distant kitchen. But farmers disagree.

For Harsha Ingle, dung from three cows generates enough gas for two families.

The gas pressure is influenced by distance, topography, as well as the number of twists and turns in the pipeline, says Vijay Ingle. "What works for one may not work for others. It took me two months to work out how often I need to feed dung to the plant to maintain uniform gas pressure. Also, there is no guidance on the kind of pipes to use. Metal and PVC pipes are expensive and need to be laid underground. Even though I am using a drip irrigation pipe, it could be risky," he adds.

The government, he says, should raise the subsidy bar. The current subsidy of Rs 8,000 is for a two cubic-metre plant, which generates just enough gas for cooking. To meet all domestic fuel needs of a family of five to seven members, one needs a six cubic-metre tank. With fuel wood becoming scarce and LPG cylinders expensive, the number of farmers opting for biogas is rising in Vidarbha. All they need is a little help in the right places to tap this perennial and cost-effective source of energy.

Sindhutai Tayade adds cow dung slurry to her plant through the feeder; Vijay Ingle stirs the slurry in a biogas digester tank.

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