ScienceWise

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ScienceWise

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ScienceWise offsets its paper consumption with contributions to native tree planting programs.

Back cover science quiz answers

(1) B
(2) A
(3) C
(4) D
(5) D
(6) C
(7) A
(8) D
(9) A
(10) B

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Cover Image: Eriita Jones

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The editor's corner

Dr Tim Wetherell

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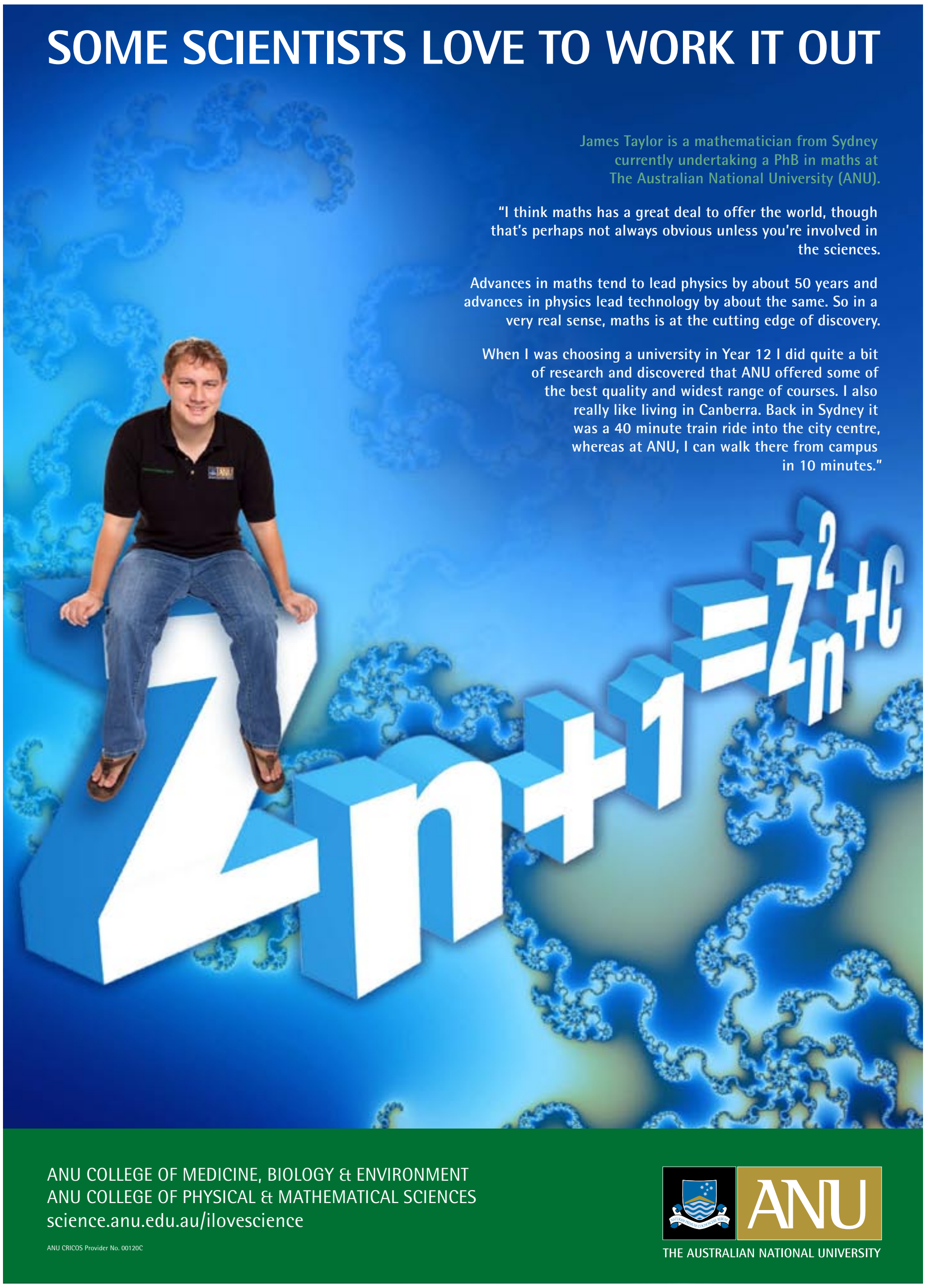

As you've probably gathered by now, a big part of what ScienceWise is about is helping educators to inspire youngsters to take an interest in science and to consider it as career.

As part of this, every edition comes with a free general science poster, covering all aspects of science from biology and medicine to physics and astronomy.

In addition to these free science posters, we're happy to be able to offer teachers another free set of posters profiling young scientists, their inspirations and what they personally see as the benefits of a science career. If you're interested in receiving a set of these posters simply email

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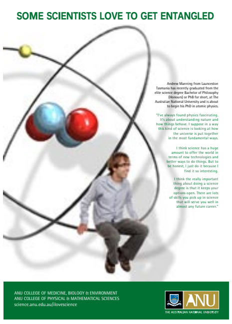


Do Martians live underground?

Finding life on Mars could be a case of knowing where to look

Volume 7 No. 4

All living things on Earth require liquid water at some point in their life cycle to survive. Since the other rocky planets in the Solar System formed from essentially the same raw materials as the Earth and physics and chemistry are the same there, it's a reasonable assumption that any extraterrestrial life may also have evolved around water.

Above: Eriita Jones

Below: The Martian surface as photographed by NASA's Spirit rover

This is the approach adopted by most scientists engaged in the search for extraterrestrial life and is well summed up by NASA's *follow the water* philosophy in their Martian life exploration. But will just any old water support life? This is a question that forms a central theme in the research of Eriita Jones, who is completing her PhD at the ANU Research School of Astronomy and Astrophysics. She's investigating how hot, how cold and how salty water can be and still support life and where exactly on a planet such water is likely to exist.

"We're interested in water on other planets such as Mars," Eriita says, "But we can learn a huge amount by looking at water here on Earth. And of course it's a lot easier to gather data on Earth than Mars." As part of this research Eriita has been working with Dr Charley Lineweaver on developing a computer model of water on the Earth from ice on the peak of Mount Everest to the depths of the oceans.

"Water behaves quite differently in different pressure and temperature regimes," Eriita explains" We know for example that if water is salty enough it can remain liquid at -20°C and still support life. We also see life in pressurised thermal vents at 120°C but that doesn't mean we should jump to the conclusion that 'water equals life'. When we looked at all the places on Earth where water can be found, there were some quite surprising results. We found that if you counted up the molecules of liquid water that aren't hospitable to life, only about 1 per cent of the liquid water on Earth is 'uninhabited', and that 1 per cent is incredibly spread out in the crust and upper mantle. However if you look at the volume of Earth with liquid water, 88% of that volume is uninhabited given current limits on life."

Dr Lineweaver adds "Even after roughly four billion years of evolution, life on Earth has not been able to figure out how to live in some water on this planet. The fundamental limits that we have identified may be more than just limits on terrestrial life – they may apply to any terrestrial-like life in the universe."

Having created a realistic model of the water on Earth and the life within it, the next step was to create a similar model for Mars. This also incorporated uncertainties in the parameters, but because the data is far more limited for Mars, the uncertainties are of course, larger.

Generally the temperature and atmospheric pressure on Mars is too low for liquid water to flow on the surface. What tends to happen is that exposed ice sublimes directly into water vapour. However, very occasionally conditions may be just right for some liquid water to exist. And of course once you get below the surface, it could be a very different story.

On Earth the temperature usually decreases initially as you go underground due to the lack of solar heating. However once you get a little deeper it begins to increase at the rate of about 25 degrees per kilometre down. From what we know of Mars, the situation is similar except that the temperature increase is a more modest 5° per km. So according to Eriita's and Charley's model, it's highly likely that liquid water will be found a few kilometres below the surface and that it may exist closer to the surface at least on a seasonal basis.

If conditions in such shallow seasonally wet soil became very much less hospitable during the harsh Martian winter, that may not in itself exclude life. "Data from the Vostok ice core confirms the presence of dormant life even at -40°C," Eriita explains, "So it wouldn't be out of the question for a Martian microorganism to grow and multiply when liquid water was present then lie dormant in the ice when conditions were less favourable."

The value of such a model of temperature, pressure and the various phases of water in a Martian environment is that it may help in targeting the search for life there. For example if a spacecraft visited the Earth and sampled the crust and upper mantle randomly, it would have a significant chance of not detecting life. And compared to Mars, the Earth teams with life. So when targeting Mars missions to look for life, knowing the best place to look is especially important in achieving success. "Given the conditions on Mars, we think that there's a much better chance of life existing underground than on the surface" Eriita explains, "So two of the key questions we're hoping to answer here is; Where do you have to dig and how deep do you have to go on Mars to find liquid water and that potential for life?"

For more information see
To What Extent Does Terrestrial Life "Follow The Water"?
Eriita G. Jones, Charles H. Lineweaver
Astrobiology. April 2010, **10**(3): 349-361.

The no.1 lady detection agency

How crabs eavesdrop on their rival's courtship moves

By Tegan Dolstra

Males of a species often perform blatant exhibitions of power or skill to impress a female: think antler-locked clashes, the dance of a bird of paradise or arm-wrestling at the local pub. Male fiddler crabs, with their oversized claw and elaborate waving ritual, are no exception. PhD student Richard Milner has recently discovered a more subtle strategy employed by these clever crustaceans: by 'eavesdropping' on their rivals' courtship displays, these males gain a head start in the bid to charm the ladies.

The mudflats of the mangrove forests near Darwin are hectic, bustling places; hundreds of tiny fiddler crabs, less than two centimetres long, scuttle about, brawling over burrows, fighting over females and foraging for food. It is here within this exciting melee that Richard has witnessed the clever tactics applied by male fiddler crabs as they vie to out-compete their rivals for female attention.

When ready for a mate, female fiddler crabs abandon their burrows and set out across the flats looking for Mr Right. Male crabs have one oversized, brightly coloured claw which they wave in an eye-catching courtship display when they spot a female on the prowl. One of the key factors females consider when choosing a mate is wave rate: the faster the wave, the more attractive the male.

Due to the conspicuousness of this courtship display, wandering females often spot males before the males have spotted them; thus it would be advantageous for a male to begin waving before the female comes into his field of view. It might be expected, then, that males be evolutionarily attuned to any cue that potential mates are nearby.

With this in mind, Richard measured the wave rate of male fiddler crabs under different conditions to see whether they 'eavesdropped' on other males' courtship displays to detect the presence of females. "In other words," says Richard, "do males use other males as 'female-detectors'?"

Richard began by placing a small block of wood in front of an individual 'focal' male crab in a group of males. He then - using a very short length of string attached to a nail embedded in the sand - tethered a female crab behind the wooden barrier. In this set-up, the focal male could see all of his male neighbours (who were busy waving to the female) but could not see the female himself.

Richard observed that the focal male waved 12 times faster when the female was present than when she was absent. How

Richard Milner

was this male alerted to the presence of this potential mate? By peering at his peers. Richard also found that, remarkably, the eavesdropper modified his behaviour according to the reliability of the information he received: when the barrier was removed so he could see the female with his own eyes, he waved faster still.

Given the importance of waving in the intense competition for female attention, there is an obvious advantage for males in detecting and reacting to the presence of a female as early as possible. "Females are very drab looking and rather well camouflaged," says Richard. "Eavesdropping is so important because it allows the male to start courting the female even before he has seen her, which basically increases his chances of winning her over."

Information acquired by eavesdropping is used in an extraordinary variety of situations. Some bird species avoid danger by recognising cohabiting species' alarm calls in response to nearby predators, while female fighting fish gain inside knowledge on mate quality by spying on male-male confrontations, subsequently spending more time in the company of the victor.

Although the use of information acquired by eavesdropping on other males' advertisement calls to attract mates has been observed in some cricket and frog species, Richard's research

Are you feeling lucky punk? Male fiddler crabs have an enormous yellow claw that they use to court females and fight with other males

is the first evidence of such an approach in a species with a visual signalling system and has recently been published in *Biology Letters* with his supervisors and co-authors Associate Prof Pat Backwell and Prof Michael Jennions.

This publication marks the completion of Richard's 9th paper, an impressive accomplishment for any PhD student. It's hard to imagine where the 23-year-old finds the time alongside his passion for cricket and baking his own sourdough bread. The enthusiastic researcher is off to Darwin again later this year, as well as Broome and Zanzibar, to look at other fascinating fiddler crab habits. "One of the projects that I am quite excited about will be looking at fight choice," he says. "In fiddler crabs, males often form territorial coalitions with their neighbours. What I want to know is: do males, when choosing somebody to fight for their territory, take into account the size of that male's neighbour?"

Life is not all slaving in the 40°C heat of the mudflats; Richard was recently married at his family's property near Braidwood, which will also provide a lovely setting in which to write his PhD thesis. "I quite often go down to the farm to write," he says. "The house is about 180 years old and it has four or five big open fireplaces that are brilliant to sit down in front of and write, especially in winter." Richard plans to submit his thesis in July next year.

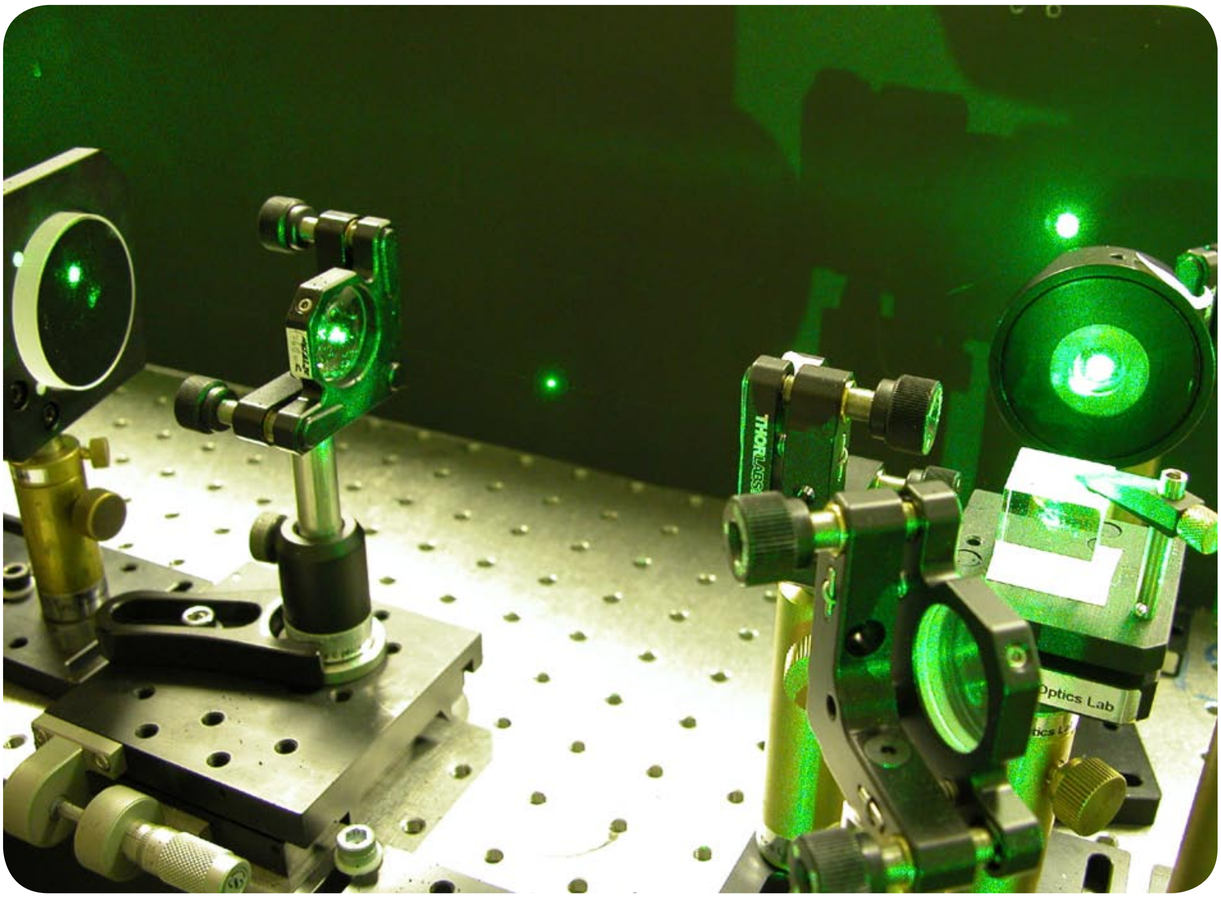
Tractor-beam one step closer

New optical vortex pipeline transports matter

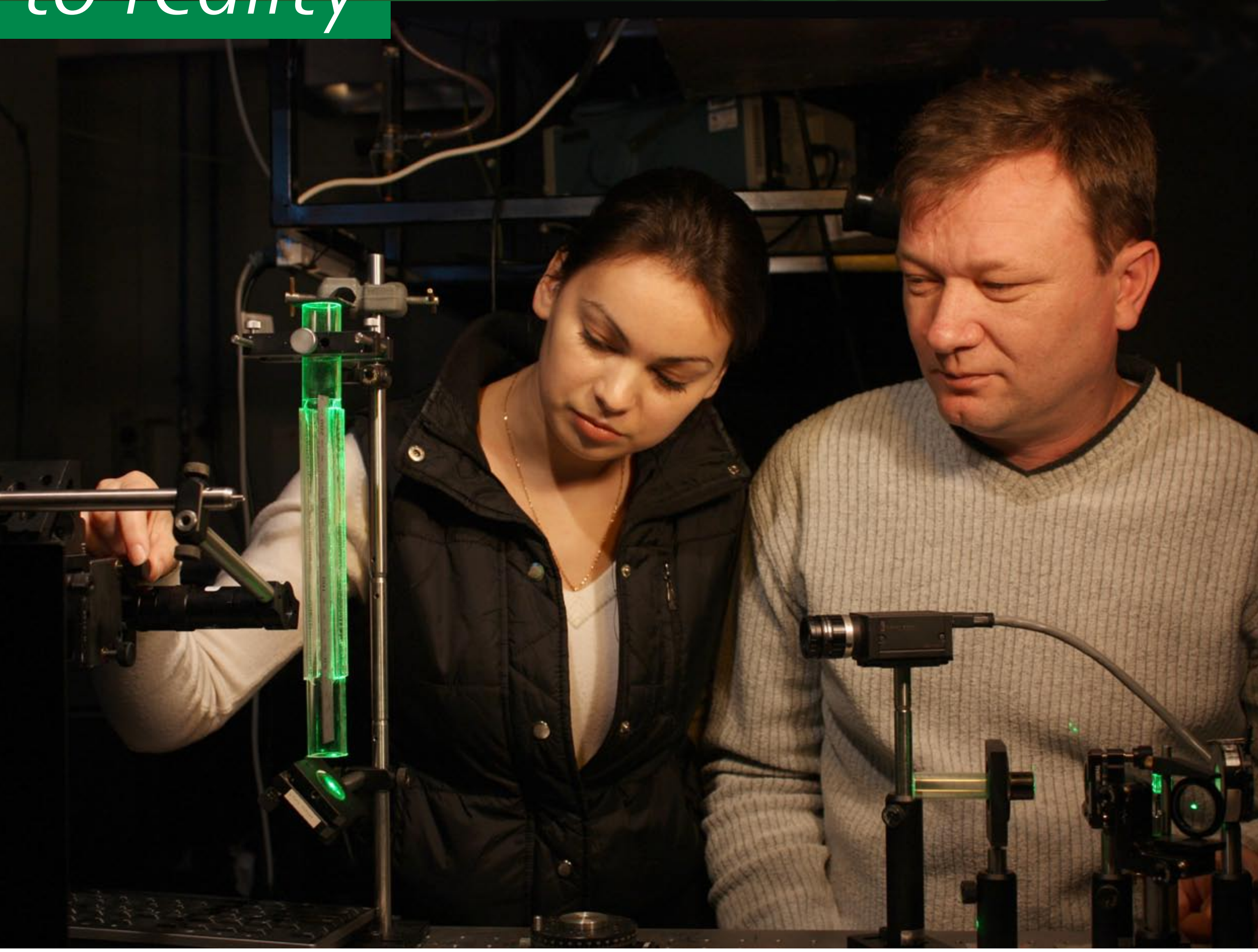
If you put your hand into a shaft of sunlight, you can easily feel its warming effect and anyone who's been foolish enough to put their finger into a powerful laser beam will be very aware of how much heat electromagnetic radiation can generate. Such radiative heating not only warms any object in the light path, it also warms any gas, such as air, that's in contact with that object. The air molecules move a little faster when warmed and the increased force of their impacts with the surface of the object imparts a tiny thrust to it. This is known as photophoretic force.

A Crooke's radiometer

It's a tiny force that you could never hope to feel on something as massive as your hand, but if the object is light enough, it can have a very noticeable effect. The famous Crooke's radiometer, a partially evacuated glass vessel with alternate silver and black vanes, operates on just this principle. When sunlight strikes the blackened sides of the



A particle of nanofoam trapped inside the laser vortex to reality



Drs Yana Izdebskaya, and Vladlen Shvedov make adjustments to a vertical version of the vortex transporter

vanes the air is heated slightly compared to the silver opposite side and the differential force makes the vanes spin round.

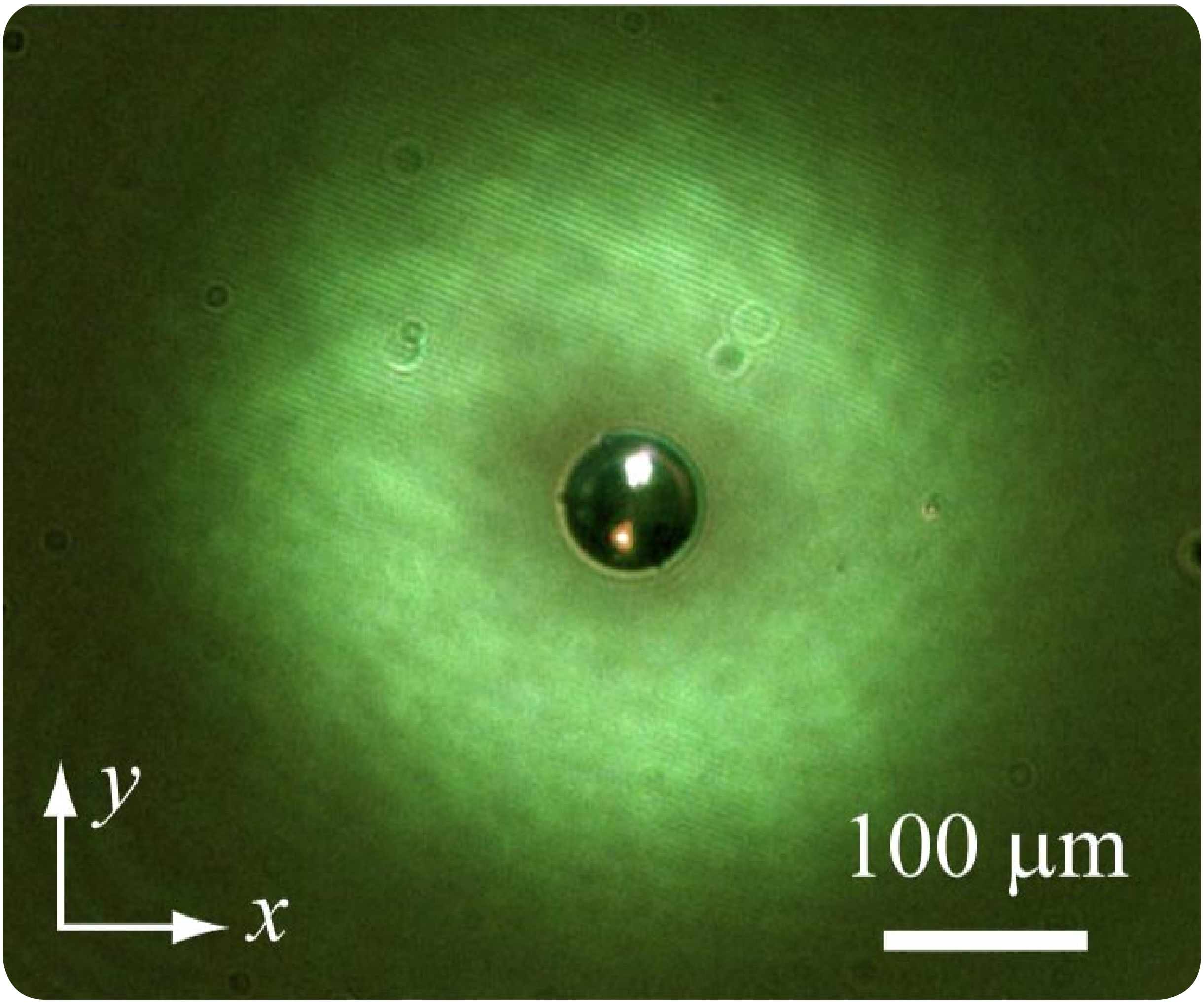
Although this phenomena has been known for over a century, it has recently found a new application in the world of nanotechnology. A group of scientists at the Australian National University have developed a system for the manipulation of small particles in air using a sophisticated optical vortex.

As its name suggests, an optical vortex is a beam of light that propagates as a very fast and tight spiral about a central axis. One of the properties of such vortices is that in the centre, the beams destructively interfere creating a dark core. If you were to project such a beam onto a piece of paper, you would see a ring of light with a dark centre.

If a very small particle is trapped in this dark core, interesting things begin to happen. As gravity, air currents and random motions of air molecules around the particle push it out of centre, one side becomes illuminated by the laser whilst the other lies in darkness. This creates a small photophoretic force that effectively pushes the particle back into the darkened core. The net result is that any particle in the vortex is pushed towards the dark core. In addition to the trapping effect, a portion of the energy from the beam and the resulting photophoretic force, pushes the particle along the hollow laser pipe.

If you replace the single vortex with two that are concentric but propagate in opposite directions, it becomes possible to move the particle back and forth along the pipeline by adjusting the brightness of either vortex.

The choice of particle to move is also important to some extent though the system will manipulate almost any fine particle in almost any gas. "Ideally you want a surface that absorbs as much radiation as possible, like the black side of the vanes in a Crook's radiometer," Professor Andrei Rode explains, "and you also need something light and with low thermal conductivity so the local heating stays local. We've done a lot of work in the past with carbon nanofoam, an agglomerate of carbon nano-



A microscopic glass sphere trapped in the dark core of an optical vortex

particles. This material has excellent properties in all these areas, so it was our first choice when setting up the experiment."

The initial results were quite spectacular. The nanofoam particles remained securely trapped within the vortex whilst they were transported the full length of the optical bench. The system allows the manipulation of these particles with a few microns accuracy whilst being transported over distances of a meter or more. That's the same precision as being able to throw a rock from Sydney and land it in a skip in Canberra.

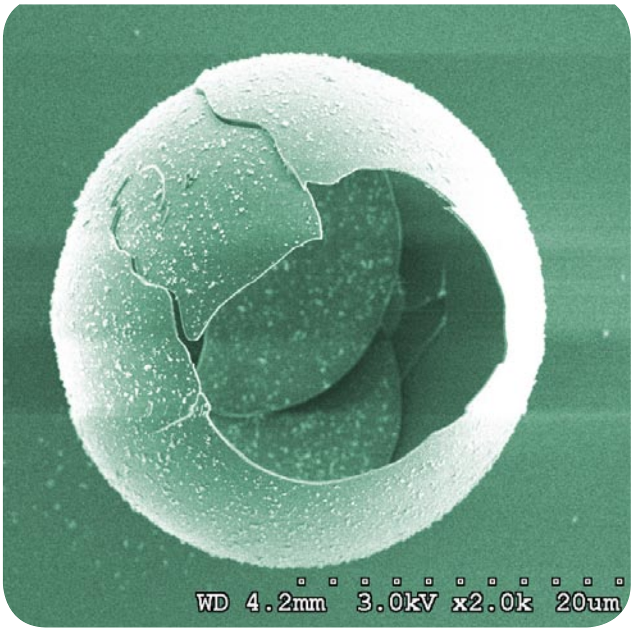
Although the nanofoam performed extremely well, working with alternative particles widens the potential applications and has other scientific benefits.

"The physical properties of nanofoam are ideal for this experiment but because it is irregularly shaped, it makes development of a good theoretical model quite difficult." Professor Rode says, "And we really need an exact mathematical treatment of this process if we're going to unlock its full potential."

To achieve this, the researchers decided to use another type of particle, a tiny hollow glass sphere about one tenth of a millimetre across. However because the technique relies on absorption of laser light and local heating of the air around the particle, to work really well, the transparent glass had to be first coated with a thin layer of graphite.

The size of the coated glass shell can be relatively easily measured using an electron microscope but working out its mass is a little more complicated as there are no effective balances for measuring the weight of things this small. So having completed a series of measurements on a given particle, the researchers broke it and measured the wall thickness again with an electron microscope. From this they were able to calculate the volume of glass and hence the mass.

There are a number of practical applications for this technology such as micro manipulation of objects, sampling of atmospheric aerosols, and low contamination, non touch handling of samples. But Professor Rode believes it's hard to predict all the potential applications for any new

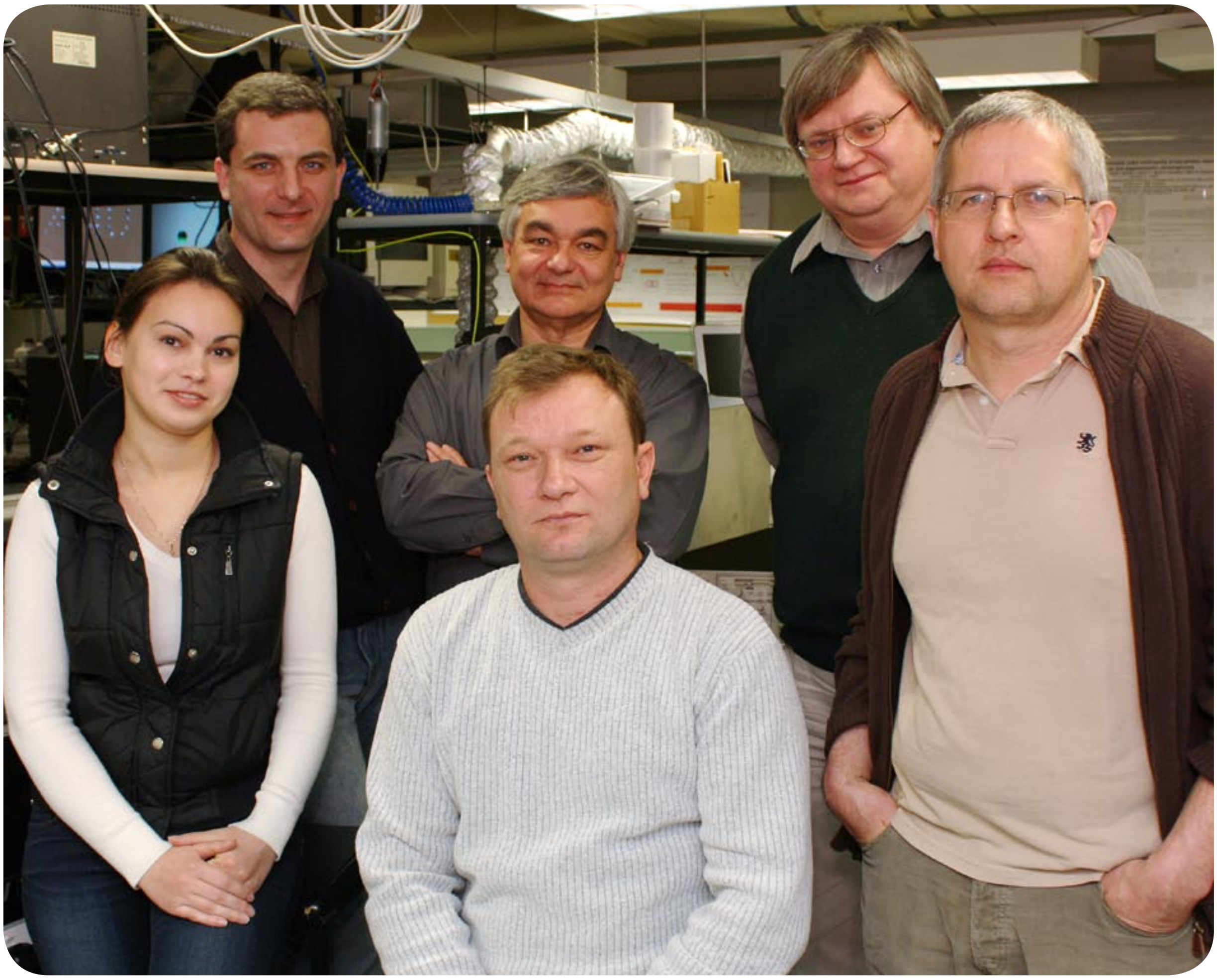


The mass of the tiny glass spheres is calculated by breaking them and measuring the wall thickness with an electron microscope

technology. He tells a story about the Lebedev Physics Institute of the Russian Academy of Sciences, where he completed his PhD.

"There was a framed page from a PhD thesis in the library at Lebedev Physical Institute in Moscow, that of Nikoly Basov. Basov's thesis was on a very early form of laser and a very eminent scientist, Giuzburd who was one of the examiners had written, 'this work is very interesting but I see no practical application for it.' Of course everyone knows how important lasers are today and Basov ultimately received the Nobel prize for his work, but this shows how difficult it can be to envisage what any new technology will bring to the world."

This work is supported by a grant from the National Health and Medical Research Council



Members of the scientific team: Yana Izdebskaya, Anton Desyatnikov, Vladlen Shvedov, Andrei Rode, Yuri Kivshar and Wieslaw Krolikowski

A big impact on climate

Examining a new asteroid crater found in the Timor Sea

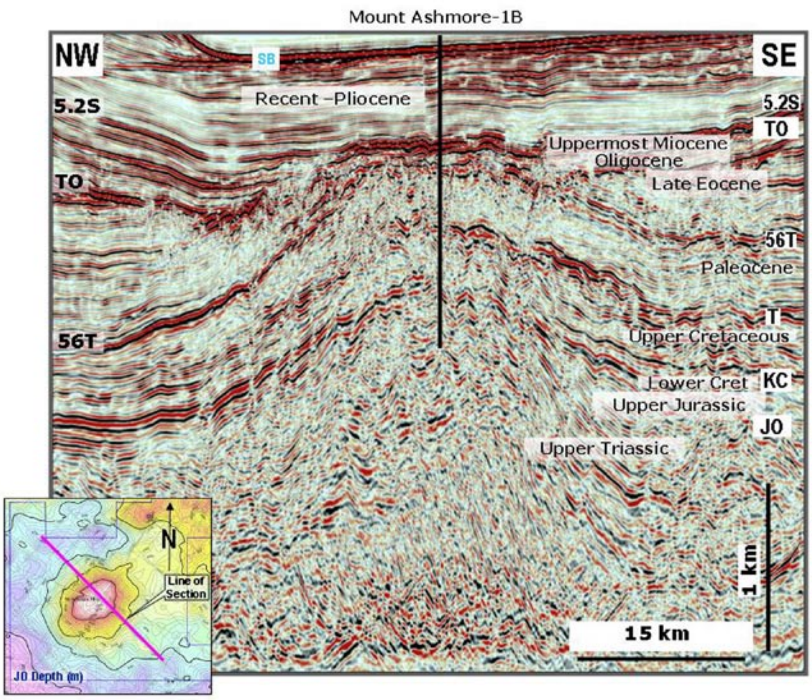
As new land-based oil deposits become increasingly scarce, oil companies have turned to the seabed in search of new reserves. The drilling and seismic surveying often find oil, but occasionally they turn up something far more interesting, at least from a scientific perspective.

This was exactly what happened when oil company geologist Dariusz Jablonski of Finder Exploration was conducting seismic surveys in areas straddling the Ashmore Platform and Browse Basin north of Australia. His results led him to suspect the existence of a large impact feature so Dariusz contacted Dr Andrew Glikson at ANU who is a specialist in the study of extraterrestrial impacts. Dr Glikson was asked to study cuttings from the Mount Ashmore-1B well and investigate whether there was indeed evidence for an ancient impact structure.

But how exactly does a scientist go about determining if a 35 million years old structure deep below both rock and sea is indeed impact related?

'It's a process of elimination," Dr Glikson explains, "Essentially we look at all plausible explanations and eliminate them one by one. But the process can be difficult depending on the type of rocks in that particular area."

When an impact occurs in Igneous or Metamorphic Rocks it's usually possible to see tell-tale crystallographic fracture planes under the microscope. These particular structures known as planar deformation features (PDFs) only form due to high velocity shock imparted by an impact but can't form due to volcanic explosition, which makes them a "fingerprint" for impacts. However in the sedimentary rocks that are commonly found under the sea the high concentration of volaltiles – mainly water and carbon dioxide - makes it much less likely that PDFs will form, so scientists have to look for other clues.



Seismic section through the Mount Ashmore Dome

Dr Andrew Glikson

Two candidates for non-impact explanations of dome structures are volcanism and salt domes. Salt domes are created when restricted marine basins have a cyclical evaporation causing salt and gypsum to be deposited over many centuries. As time progresses these salt deposits can become covered in layers of sediment. However because the salt is less dense than the sedimentary rock that forms over it, it has a tendency to rise up through the rocks above like a bubble.

"The Mount Ashmore feature extends far too deep into the crust to be a salt Dome and has a basement rise underneath it, "Dr Glikson says, "In the seismic profiles we can see a number of features deep below that are not consistent with such an explanation. We also see no indication of igneous material in the drill core, which makes a volcanic explanation unlikely. So what we're left with is an impact explanation."

"At the time of the impact the ocean would have been a few hundred metres deep" Dr Glikson adds, "But when you're talking about large impacts, the presence of a relatively small amount of water is not a major factor in attenuating the impact."

Only very low angle impacts which plunge into deep water may be slowed

The asteroid that created the Mount Ashmore impact feature may have looked something like this as it struck the Earth about 35 million years ago.

The newly discovered impact feature lies near the Ashmore Reef in the Timor Sea north west of Australia

Looking at the Earth from the South Pole, the broken land connection between Antarctica and South America can clearly be seen, forming the Drake Passage. Thanks to this passage continuous ocean current circulation around the Antarctic continent became possible about 34 million years ago

down. When a large mass of a hard material like silicate rock or iron hits the Earth the tremendous kinetic energy is converted into thermal energy at the end of its trajectory. This releases a vast amount of heat in a very small time, melting the rocks and vaporising the solid mass into a series of hot gasses such as CO_2, water and silicate vapour. The process involves a rapid and enormous increase in volume, perhaps analogous to an underground nuclear detonation.

You can see clear evidence of this impact explosion mechanism for yourself if you look at the moon through a small telescope. The many thousands of asteroids and comets that have hit the moon over the last 4 billion years came in at every possible angle. If you imagine throwing stones into mud, the ones that hit at a grazing angle leave long elliptical indentations and it's actually quite difficult to create a circular carter. However when you look at the moon, all the craters and basins are essentially perfect circles.

The explanation of this is that when an asteroid hits a planetary sized body, the initial crater (which may be elongated) is wiped out a few milliseconds later by the explosive release of kinetic energy. This explosion creates an essentially spherical impact feature. So all the craters on the moon are perfectly round despite the variety of impact angles.

There is a rule of thumb that says that the diameter of a particular crater sill will be about 10 to 20 times larger than the impactor that caused it. "The minimum size of the Mount Ashmore dome, which represents elastic rebound doming of the Earth's crust triggered by the impact, is 50 kilometers at the base, but the full size of the impact crater - not yet defined - may be significantly larger" Dr Glikson says. "This would suggest that the asteroid that created the structure was at least 5 kilometers across."

The impact of such a large asteroid throws up vast amounts of dust and fine particulate matter into the upper atmosphere. This reflects sunlight resulting in a significant, though temporary cooling of the planet. Although a single massive impact could create this effect, a series of smaller ones close together in time may have a bigger and more prolonged effect. Despite the fact that asteroid impacts are very infrequent, clusters of asteroid impacts have occurred several times through the history of Earth.

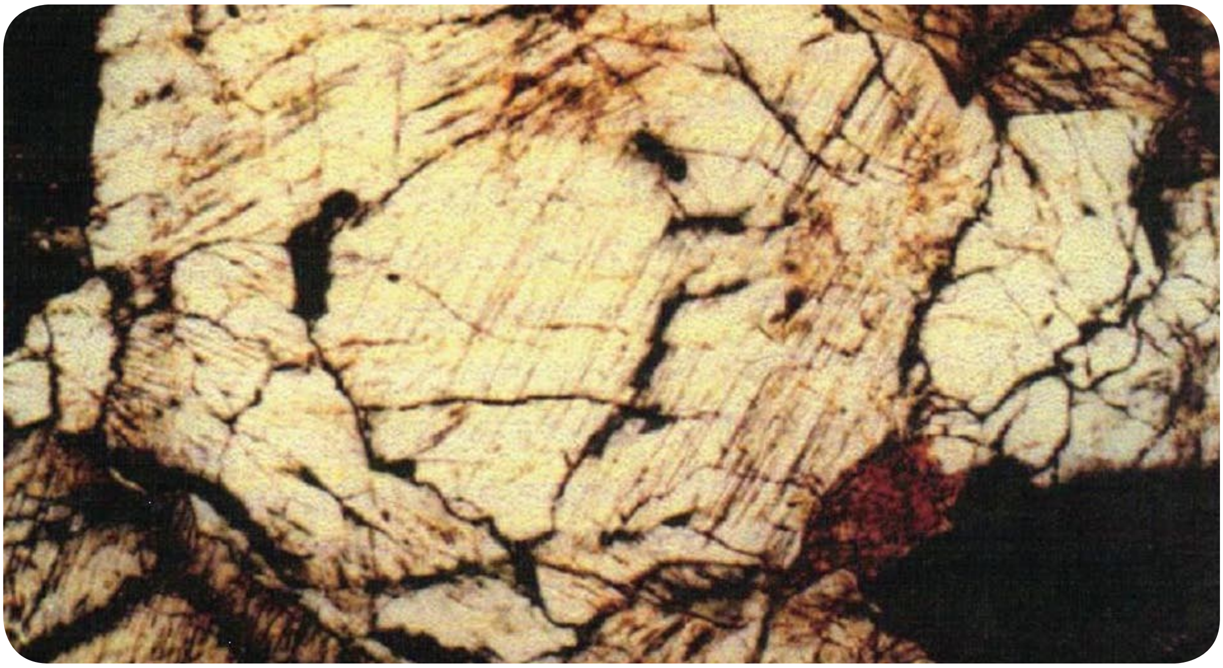
Relatively small objects like asteroids that orbit the Sun are very strongly influenced by the gravity of massive planets, in particular Jupiter. Astronomers believe that perturbations caused by Jupiter's gravity either prevented a planet forming from the debris between Mars and Jupiter or even tore it apart. This perturbation coupled with gravitational attraction between different asteroids means that many of them orbit in loose clumps. The implications for the Earth being, that if one member of such a clump hits the Earth many of the others may also do so within a few orbits, creating an impact cluster. Scientists know that there have been a few such clusters of impacts throughout the history of the Earth. There are a number of impact features around the world that, like the Mount Ashmore dome, are about 35 million years old suggesting the newly discovered dome is part of this impact cluster.

"Around the same time as the Mount Ashmore impact, a 100 kilometer wide asteroid impact structure formed in Siberia, and another measuring 85 km in diameter in Chesapeake Bay, off Virginia, in the United States. Likewise a large field of tektites – molten rock fragments splashed by impact – fell over northeast America. This defined a major impact cluster across the planet," Dr Glikson says.

This impact cluster would have contributed significantly to a global cooling in so far as it may have triggered the opening of the Drake Passage between Antarctica and South America. The opening of the Drake Passage allowed continuous circulation of the circum-Antarctic ocean current, isolating the Antarctic continent from warm mid-latitude currents and allowing the onset of its large ice sheet, which acts as a 'thermostat' for the Earth's climate." Dr Glikson explains.

The opening of the Drake Passage and the impact may have occurred around the same time purely by coincidence. However it's also possible that the disturbance of the crust caused by such massive impacts may have nudged the existing tectonic movements into action. A bit like kicking a boulder on a hill. The kick isn't enough to move the boulder far but it can give it the tiny extra impetus it needs to start and gravity will do the rest.

"We really don't know for certain if there's any causal relationship between the impact cluster and the opening of the Drake Passage," Dr Glikson says, "But what we do know with certainty is that impact clusters have had and may continue to have, profound implications for life on planet Earth."



Planar deformation features (PDFs) as seen in this microscope image, are a strong geological fingerprint for impacts in igneous and metamorphic rocks. However, when the impact occurs in sedimentary rocks (as is the case with the Mount Ashmore Dome) differences in the physical and chemical properties of these rocks mean PDFs are rarely seen.

Silver lining

How chemistry may be the key to clean transport

For centuries photographers have taken advantage of the fact some silver compounds degenerate when exposed to light, making it possible to record images on suitably prepared film and paper. But just as most people have now ditched film in favour of digital photography, the photochemistry of silver may be about to take on a new and quite unexpected role - the generation of oxygen and hydrogen from water.

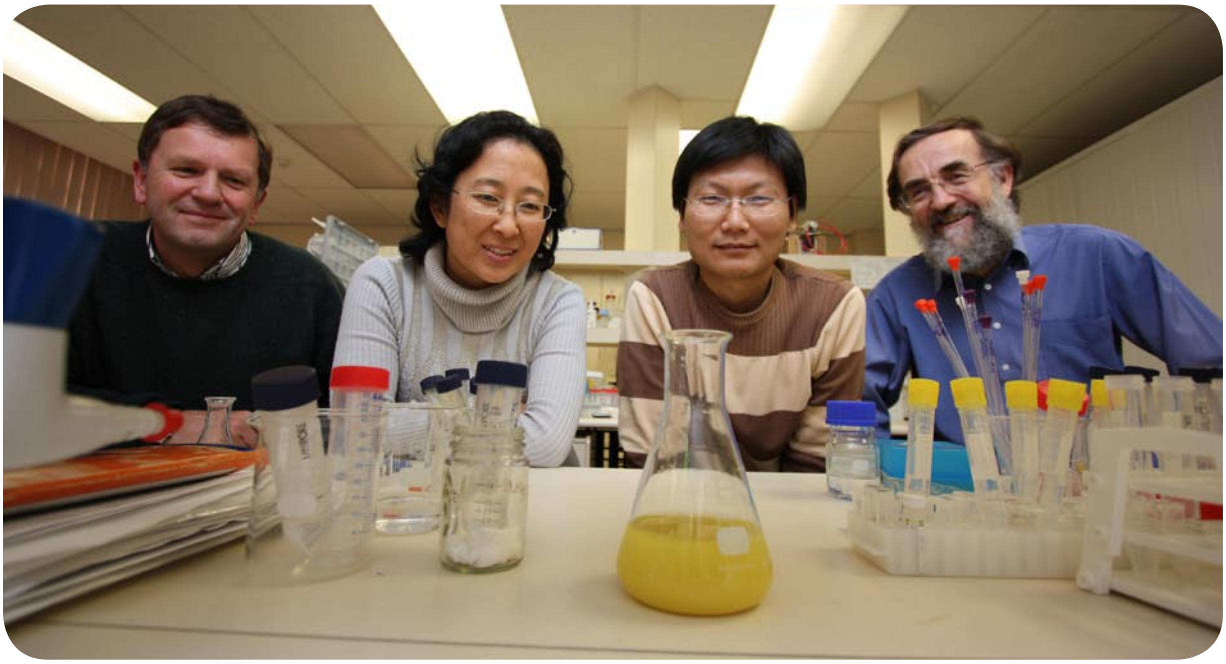
Hydrogen and oxygen are the dream fuels of the environmentally conscious engineer. They can combine in a fuel cell to produce electricity and the exhaust is pure clean water. The difficulty at present is that the only practical ways to create hydrogen gas are from coal or from the electrolysis of water, which requires vast amounts of electrical energy. If you generate this electrical electricity by burning coal, then you're no better off in environmental terms than you were extracting the hydrogen directly from the coal. But a new and exciting option for cleanly splitting water may be just around the corner.

Dr Zhiguo Yi is a scientist currently working with Professor Ray Withers at the Research School of Chemistry at ANU. One day he was thinking about the silver halide chemicals that are used in traditional photography and the way they break down in sunlight and he began to wonder if he could tailor this process to create a chemistry based system for splitting water molecules. Having considered a number of silver compounds to base this work on, the one he finally chose to work with was Silver orthophosphate.

"It's well known that silver halides used in photography are not stable under illumination, Dr Yi says, "and the silver orthophosphate that we use in our work has similar chemistry."

Silver orthophosphate (Ag_3PO_4) is a semiconductor and one of the properties of all semiconductors is that they have a band gap. What this means is that there is a range of energy values that any free electrons wandering around the crystal are not allowed to have. If the energy of photons of light hitting the semiconductor is too small to ionise an electron from an atomic orbital right across this forbidden gap, nothing happens. The photon will pass right through making the material transparent to that wavelength of light. However once the energy of the photon becomes enough to catapult a valence electron right across the energy gap, the light is strongly absorbed.

One of the things about Silver orthophosphate that makes it so suitable for harnessing sunlight is that it's forbidden energy gap (2.36eV) corresponds almost perfectly with the wavelengths of sunlight making the process highly efficient. When sunlight hits the crystal the strong absorption process creates many free electrons within the lattice and vacant holes where the electrons came from.



Some of the scientists involved in the research with a Silver orthophosphate solution, L to R: Hilary Stuart-Williams, Yun Liu, Zhiguo Yi and Ray Withers

Zhiguo photographs the vigorous stream of oxygen bubbles rising from a silver orthophosphate solution when a bright light spot shines on it

Electrons and holes are the domain of electronic engineers, enabling them to create many devices from transistors to lasers. But chemists get excited about free electrons for different reasons. Electron exchange is the basis of chemical reactions.

When powdered silver orthophosphate is placed on a conductive electrode under water interesting things begin to happen. Sunlight falling on the powder creates free electrons and this drives a reaction that very efficiently oxidises the water.

$$4Ag_3PO_4 + 6H_2O + 12h^+ + 12e^- \longrightarrow 12Ag + 4H_3PO_4 + 3O_2$$

"The reaction is so vigorous you can see a plume of oxygen bubbles pouring from the anode." Professor Withers says.

Of course once you've taken the oxygen out, your silver orthophosphate has become metallic silver and phosphoric acid and the reaction stops when the silver orthophosphate is consumed. So to keep the process going, it's necessary to electrolyse the solution to regenerate the silver orthophosphate, a process that also liberates hydrogen gas that can then be stored.

As the driving voltage to electrolytically release the hydrogen from this solution is much lower than that for water electrolysis, the new process would greatly reduce the costs of producing hydrogen and oxygen fuel gases by electrolysis, but the group want to take it a step further. They're investigating ways to adapt the chemistry so that it can generate both oxygen and hydrogen gas whilst at the same time regenerating the silver orthophosphate electrodes. And all with no net input of energy other than sunlight.

"It's a really simple artificial photosynthesis," Professor Withers explains, "At the moment it's a very economic way to generate oxygen gas from water and more than halves the electrical energy required to then electrolyse the hydrogen out. But what we're really working towards is a simple all-chemistry process that will convert sunlight and water directly into hydrogen and oxygen for fuel cells."

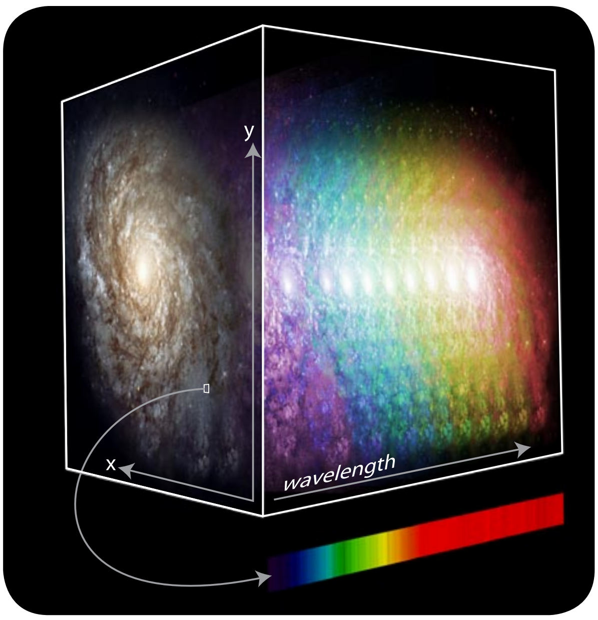
There are many problems to be solved before hydrogen fuel could become a practical and economically viable alternative to petrol, but this work may represent a very significant step on that road.

The astronomy opportunity of

The Giant Magellan Telescope holds great promise for young Australian astronomers

You might not immediately think of Australia as a country of astronomers, but when you look at the quality and quantity of our scientific publications on a per capita basis, we are one of the highest ranking nations in the world in this area. But until recently there has been a disturbing downward trend in the facilities available to Australian astronomers. It's not that our telescopes are becoming fewer or smaller, it's that the rest of the world is building bigger and better instruments. However, a recent government decision to fund Australian partnership in the Giant Magellan Telescope will guarantee our astronomers a 10% share in what will be by far the largest and most powerful telescope the world has ever seen.

With seven giant 8 metre mirrors the effective aperture of GMT will be a staggering 22 metres enabling it to collect almost ten times the light of current generation super-telescopes. The large aperture coupled with advanced adaptive optics will also enable the GMT to achieve very high-resolution images of the cosmos. But straight imaging of the universe is only a small part of the science mission of the GMT. The vast majority of its time will be spent directing the light it collects into an array of specially designed instruments. One of these, the GMT Integral Field Spectrograph (GMTIFS), is being designed at the ANU Research School of Astronomy and Astrophysics.



An integral field spectrograph records the spectrum of an object at every pixel of the image plane creating what astronomers refer to as a data cube

Spectroscopy (splitting light into its component colours) has been of fundamental importance to astronomy for more than a century. It enables astronomers to determine the chemical composition of stars and nebulae by studying the sharp emission and absorption lines present in starlight. Because motion Doppler shifts the frequency of these lines – in the way the pitch of a moving siren can be heard to change – they can also be used to measure the velocities of stars and rotation of galaxies.

In its simplest form a spectrograph places a slit at the focal plane of the telescope and disperses the light using either a prism or more commonly a diffraction grating. The problem with this design is that if you're interested in something extended like a galaxy, it only enables you to measure the spectrum of one section through it – defined by the slit. What's much more useful it to be able to measure the spectrum of every part of the galaxy. With a traditional spectrograph, this can be done by moving the slit across the object and combining the data. But this approach is very slow, laborious and wastes a lot of precious telescope time.

An Integral Field Spectrograph takes the concept of spectroscopy one step further, enabling astronomers to record the spectrum of each point in the galaxy simultaneously. This makes it a much more useful and powerful instrument.

Professor Peter McGregor is leading the design team for the GMTIFS. "What we're aiming to do is build a dedicated instrument that will take full advantage of the incredible light grasp and resolution of the GMT." He says. One of the key things with the GMTIFS is that it will sit after the adaptive optics module that corrects for the constant distortions created by the Earth's atmosphere. This means that it will be able to take full advantage of the GMT's enormous spatial resolution when generating its spectroscopic maps of objects. "With adaptive optics and IFS working together, we'll be able to do science that simply can't be done with current generation telescopes." Professor McGregor says.

One area of particular interest to Professor McGregor is the formation of galaxies. Because light travels at finite speed and the universe is very big, when we look at the most distant galaxies we are in effect looking back in time. Expansion of the universe means that generally, the further away a galaxy is the older it is, but of course larger distance also means a dimmer galaxy with less light to work with. Current studies using present generation large telescopes such as Gemini, have shown that in the very early universe galaxies were lumpy and irregular.

"From the work we've been able to do with existing telescopes, it would seem that galaxies evolve from these clumpy structures

Professor Peter McGregor in the massive instrument assembly hall of the Advanced Instrumentation and Technology Centre at Mt Stromlo

to the spirals and ellipticals we see in more modern galaxies. But because the early galaxies are so small and faint we've only been able to study a couple of the brightest ones and whether these are really typical of the whole population is very much debatable," Professor McGregor explains. "Using the GMTIFS we should be able to not only see the structure of early galaxies, but also measure the motions of the different parts of them and get a much better idea of how they evolve."

Closer to home, the GMTIFS will enable astronomers to see nearby galaxies in such detail that the motions of individual stars can be mapped. This will enable them to study how the giant black holes that lie at the core of most galaxies influence the motion of the stars that lie within their spheres of influence. "Our current thinking is that the presence of super massive black holes at the centre of most galaxies, including our own Milky Way, has a profound influence on the way the galaxy evolves and behaves. So having access to this kind of data will really help us to understand this process." Professor McGregor says.

The GMT and its Integral Field Spectrograph should also enable astronomers to make great advances in the study of the formation and nature of planets orbiting other stars. "Using the GMT we should be able to not only directly image nearby planetary systems, but to do spectroscopy on individual planets in such systems." Professor McGregor says. "And that could be the critical step in detecting life outside the solar system."

However in spite of his enthusiasm for the GMT and its instruments, Professor McGregor isn't expecting a lot of personal benefit from the project. "Realistically first light will be around 2020," He says, "And by then I'll have more or less retired. But what this instrument and Australia's partnership in it really mean is that the next generation of Australian astronomers, kids that are in high school and college now, will have a wealth of opportunities at their disposal. This is a really great time for young scientists in Australia to get involved in astronomy."

GMTIFS is supported in part by a grant from the US National Science Foundation

Artist's concept of the Giant Magellan Telescope next to the Sydney Opera House

How science wise are you? *Try our quiz and see.*

All the answers can be found both in the stories in this edition of ScienceWise and listed on the inside cover. The magazine is also available on line at http://sciencewise.anu.edu.au

(1) How much hotter does the Earth get as you drill down into it?
- [ ] (A) approximately 5° per km down
- [ ] (B) approximately 25° per km down
- [ ] (C) approximately 75° per km down
- [ ] (D) It doesn't, it stays the same temperature

(2) How does a male fiddler crab attract the attention of a female?
- [ ] (A) By waving at her
- [ ] (B) By pouncing on her
- [ ] (C) By building an elaborate burrow
- [ ] (D) By whistling at her

(3) What is a Crooke's radiometer?
- [ ] (A) A device by which criminals detect back to base alarm systems
- [ ] (B) A device that measures the strength of radio signals
- [ ] (C) A device that measures the strength of light using rotating vanes
- [ ] (D) A device that measures radioactivity using a supercooled gel

(4) What is nanofoam?
- [ ] (A) A foam rubber with incredibly small cells
- [ ] (B) A scum that forms on the surface of liquids used in semiconductor manufacturing
- [ ] (C) A very porous filter used for water purification
- [ ] (D) A very low density form of carbon

(5) What are planar deformation features?
- [ ] (A) Large flat geological structures caused by asteroid impacts
- [ ] (B) Stretch marks in the Earth around tectonic plates
- [ ] (C) Flattened areas on a meteorite caused by its impact on terrestrial rocks
- [ ] (D) Microscopic crystallographic fracture planes caused by large impacts in rock

(6) Why are the craters on the moon almost all round?
- [ ] (A) Because the moon's gravity pulls any impacting body's trajectory vertically downwards
- [ ] (B) Because most asteroids and comets that create them are round
- [ ] (C) Because impacts end in an explosive release of kinetic energy regardless of their angle of incidence
- [ ] (D) Because the moon is made of cheese and cheese always has round bubbles in it

(7) What is an integral field spectrograph?
- [ ] (A) A device that is able to record the spectrum of something like a galaxy at many points across the image
- [ ] (B) A spectrograph with a built in field
- [ ] (C) A portable spectrograph for use in the field
- [ ] (D) A device for measuring the spectrum of powder samples

(8) What will the effective aperture of the Giant Magellan Telescope be?
- [ ] (A) approximately 2 metres
- [ ] (B) approximately 6 metres
- [ ] (C) approximately 12 metres
- [ ] (D) approximately 22 metres

(9) Which precious metal forms many compounds that chemically change when illuminated?
- [ ] (A) Silver
- [ ] (B) Gold
- [ ] (C) Platinum
- [ ] (D) Bronze

(10) What role does the giant black hole at the centre of most galaxies play?
- [ ] (A) It swallows up all the stars in that galaxy
- [ ] (B) Its gravity influences the motions of stars and shape of the galaxy
- [ ] (C) Its Hawking radiation makes the central portion of the galaxy uninhabitable
- [ ] (D) It perturbs the path of asteroids creating a safe habitable zone