# ScienceWise

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Volume 6 No. 3

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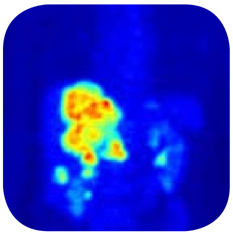

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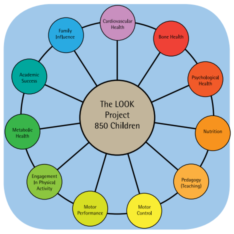


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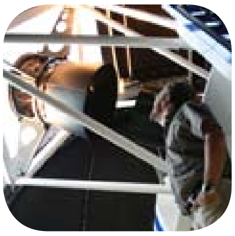

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Cover Image: Michael West with a space simulation chamber used to test the new HDLT

# The Editor's Corner

## *Moonstruck*

Dr Tim Wetherell

Studying the other planets of the solar system tends to make you think what an ideal place the Earth is for life to have evolved. Of course it's an anthropic argument; our home planet suits us since we evolved to live here and if it wasn't suitable we wouldn't be here to debate it! But when we look at the other planets in our own solar system the Earth does have a number of unique features that make it a great place for an experiment in applied biology on a grandiose scale.

Convection currents within the Earth's liquid iron core generate a global magnetic field that deflects the energetic charged particles of the solar wind away from ourselves and our atmosphere. Planets such as Mars and Venus that don't have such a global field are bombarded with radiation at far higher levels than the Earth. Of course life can evolve to survive in higher radiation environments but you can't avoid the essential physics. Radiation damages DNA and if the dose is high enough no amount of repair mechanisms can keep ahead.

The Earth has a mantle with just the right composition for tectonic plate movement. Although the collision and subduction process can be violent in places it provides a mechanism for releasing excess heat built up in the mantle. On planets such as Venus that don't appear to have this process heat builds up to the point where entire crust weakens and massive phases of vulcanism obliterate the entire surface of the planet every 500 million years. Bad news if you're an evolving organism!

The Earth also has a huge moon compared to the other terrestrial planets. This is far more important than many people realise because it generates big tides in the oceans. Many early marine organisms would have been left stranded on the beach by this tidal action and this may well have been a major factor in the evolution of air breathing animals.

I think the moon has also been really important in shaping the development of human thought. Having such a large bright and obvious thing progressing through its phases in the sky is a graphic demonstration of the nature of large bodies in space. Seeing regions of a spherical moon go from light to dark would have to have inspired the idea that the Earth too must be round and night and day were its phases.

When the first telescopes were turned to the moon the mountainous landscape must have been reminiscent of regions of the Earth. It wouldn't take a huge leap of imagination to see our own world as perhaps one of many in the vastness of space. Even today I think one of the coolest things you can see is a half moon through a really good quality telescope. It's truly amazing and something everyone should see it at least once in their lifetime!

# Space Engines of the Future

Tim Wetherell

## The Potential of Plasma Propulsion



Rocket propulsion is governed by Isaac Newton's third law of motion; that for every action there has to be an equal and opposite reaction. When mass is ejected from the back of a rocket engine nozzle, the rocket recoils forward. However, every kilogram of mass ejected by a rocket at a given point in its trajectory has to be lifted to that point by the rocket itself. A kilogram of propellant used in orbit will require as much as ten kilograms of propellant to get it there in the first place.

With space launch costs reaching tens of thousands of dollars per kilogram, it's important to get the most out of the least amount of fuel possible. Conservation of momentum tells us how best to achieve this. A kilogram of fuel expelled at a thousand metres per second will change the momentum of a spacecraft by ten times more than the same amount of fuel expelled at only a hundred meters per second. So the faster you make your exhaust, the more efficiently you use your fuel.

Whilst chemical rockets are the only practical method of launching vessels into space, once in space there are some innovative alternative propulsion systems. One way to achieve high exhaust velocities in space is to ionise your propellant using electrical energy and then accelerate these ions to high velocities before ejecting them out the back of the spacecraft. Such plasma based propulsion systems use propellant far more efficiently than conventional chemical rockets and have been used on recent space missions such as NASA's DAWN and the ESA's SMART-1.

A new plasma propulsion device is the Helicon Double Layer Thruster (HDLT) being developed by Professor Rod Boswell and Dr Christine Charles at ANU. As with all plasma thrusters, the principle is to eject charged particles, or plasma, at very high speeds. The innovation in the HDLT is the way the plasma is accelerated to these speeds.

The HDLT uses a phenomenon called an electric double layer, which is the electrostatic equivalent of a sheer drop. The plasma ions passing through the double layer experience a sudden and very forceful acceleration in the same way water does as it flows over a cliff. The same double layer physics are behind the awesome light show of the aurora. In this case, the charged particles of the solar wind enter the Earth's atmosphere at the poles.

"The HDLT is a beautiful piece of physics because it is so simple and has an almost infinite lifetime. It doesn't need any moving parts, any electrodes and is based purely on naturally occurring physical phenomena," Dr Charles explains.

With conventional plasma thrusters the continuous ejection of positively charged particles creates a problem. Negative charging of the spacecraft. If left unchecked this would both create havoc with the onboard electrical systems and also strongly reduce the number of particles leaving the thrusters which results is poor performance. To overcome these problems, most electric thrusters have an electron ejecting charge neutralising system that neutralises the ions leaving the spacecraft in the exhaust. These systems are prone to failure and conventional ion thrusters usual have two or three neutralisers onboard, which adds to the mass of the spacecraft. However, one of the special features of the HDLT is that due to the unique configuration of the double layer both electrons and ions are ejected from the exhaust, which ensures that the plasma leaving is neutral and that the spacecraft doesn't charge up.

Michael West

Making a successful space propulsion system is a difficult business. Space engineers don't have the luxury of flying one prototype thruster after another in orbit until they get the design just right. Such propulsion systems have to be designed using theory and computer simulations and then tested in labs on Earth. However, it's impossible to create a vacuum test chamber that's even remotely comparable with the vastness of space. And given that the magnetic field and ion exhausts of a plasma thruster extend over large distances, you can never be entirely sure that what you measure in the lab is going to be exactly what you get in space.

Michael West is undertaking his PhD testing the HDLT prototype in conditions that simulates the vacuum of space as closely as possible in a lab. "The main thing we're aiming for is to immerse the entire thruster in vacuum, not just the exhaust port. If in addition, we can make the chamber as big as practical, we're optimistic that we're getting pretty close to actual space conditions." He explains.

One of the most important parameters of any rocket engine is how much thrust it produces. With a chemical rocket this is relatively easy to measure because such engines produce a very large thrust for a very short time. You mount the engine on a jig, fire it up and measure how much force it exerts against a fixed mount. However with a plasma propulsion system it's not so easy because they produce a very small thrust for a very long time.

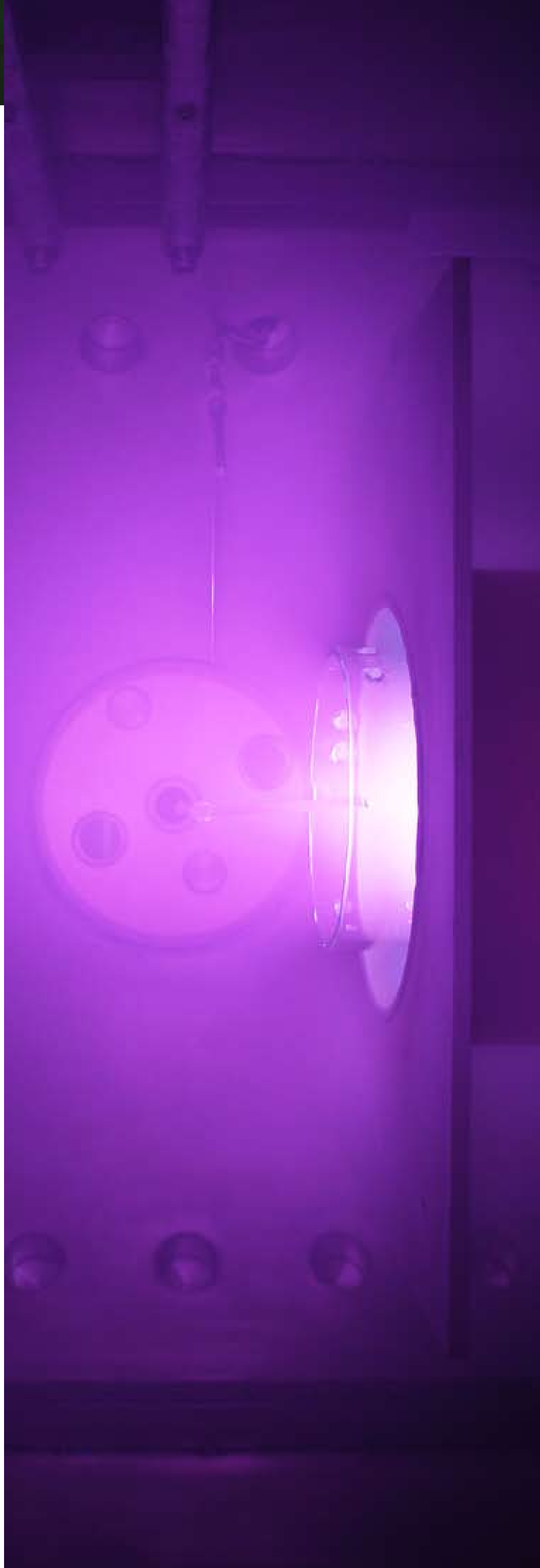
"It's a bit like paddling a canoe" Michael explains, "You can paddle like crazy until you're worn out, then coast along with the momentum you've built up, and that's like a chemical rocket. Or you can paddle gently all day, gradually increasing your momentum, which is more like electric propulsion."

In the frictionless environment of space, a milliNewton of thrust applied for several months will slowly accelerate a 1000 kg space ship to huge speeds. But on Earth it's very hard to measure this tiny thrust by just monitoring the force on the back of the thruster assembly. To get around this, Michael developed a simple but effective thrust measuring instrument. A silicon wafer is attached to the end of a rod, which is suspended on a pair of knife edges. This creates a pendulum-like structure. When the plasma exhaust from the thruster hits the wafer it displaces it from vertical – the larger the thrust, the greater the displacement. In order to measure the very small displacements, Michael uses a laser bounced of the back side of the wafer and directed to a CCD sensor some distance away. Using this device, he is able to measure thrusts of a few microNewtons – about the force an ant's foot exerts on the ground.

The team are now using the thrust measurement system and simulation chamber to explore the possibility of operating the thruster in a super-bright high density mode, which generates about seven times the ion flux of normal operations. The group have collaborated with the European Space Agency during initial development and testing of the first HDLT prototype.

Michael explains, "Highly efficient electric propulsion systems like the HDLT are exactly what you need for manned flights to Mars. The idea is that a series of unmanned cargo craft use plasma propulsion to take a long, slow but super-efficient route to Mars. Because of the efficiency of the thruster the mass of cargo would be far higher than conventional rockets could carry. Once the supplies are all in place at Mars, you can send the astronauts on a conventionally powered express trip."

When asked how he first became interested in space, Michael explains. "When I was in year nine I had a really enthusiastic science teacher, a real mad professor type!" He encouraged a group of students to enter a NASA sponsored competition to design an experiment for the Space Shuttle. Michael and a group of friends entered and won the competition. The prize was an expenses paid trip to see a Space Shuttle launch and a behind the scenes tour of NASA. "From that point on I was hooked," he says, "I had to become a space scientist." Proof positive that inspirational teachers make a huge difference to the lives of their students.



The exhaust of the HDLT in a space simulation chamber

# Are We Alone in the Universe?

## Using the Earth to Help Find Water and Life on Mars

Lauren McBain-Binette



Are we alone in the Universe? That is a question that has been asked again and again, ever since ancient astronomers first looked up into the night sky and realised that there were other planets and worlds out there.

It is also a question that Eriita Jones, of the ANU Research School of Astronomy and Astrophysics, asks herself daily. This past year, Eriita completed her PhB with an honours project on water and the potential for life on Mars. She is now continuing her innovative research in her PhD under Charles Lineweaver.

But Eriita doesn't spend her days looking at data from Mars, hoping to see some sign of aliens or what she amiably calls 'Martian rabbits' – her technique is much more realistic. She looks for micro-organisms, and uses life here on Earth to direct her search.

"We're studying the Earth and looking for the environments that life inhabits, and what kind of conditions life likes. You can find life on Earth living at extreme temperatures and pressures, deep under the ground where it's very cold and where there is no sunlight. Those are the types of environments that we might be able to find on other planets... and if we find

Eriita Jones, PhD student at the Research School of Astronomy and Astrophysics, researches the possibilities of water and life on Mars.

those conditions on other planets then that's our best guess as to where we should start looking (for life)."

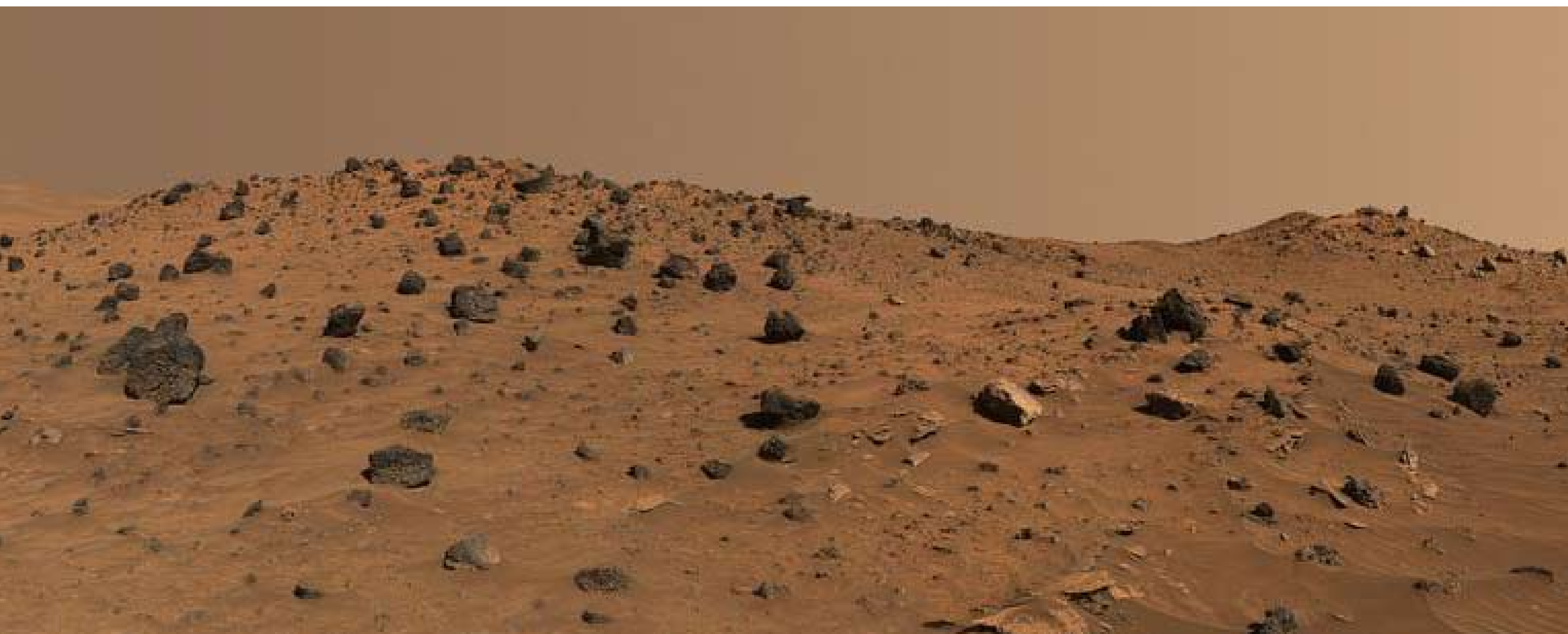
When asked what makes her research unique, Eriita explained that a lot of researchers "focus on Mars itself, and forget that we have all the examples that we're trying to understand right here on Earth". In fact, there are places in Australia where people are doing what Eriita calls "Mars analogue research". Eriita is particularly interested in the analogue research being done in Australian deserts. She looks at the surface of the Earth to find features that tell her that there is water under the surface. Learning more about these surface features on Earth, specifically gullies, helps her locate similar features on Mars and with any luck, that will lead to the ability to find water below the Martian surface as well.

Why water? Well, Eriita explained that "the really special ingredient for life seems to be liquid water... the stuff that we're made out of – carbon, hydrogen, oxygen, nitrogen – are the main ingredients of all life and they are everywhere. But so far as we know the only large amounts of water are on Earth, and we're trying to find large amounts of it in other places too". If she can find water on Mars, it is a good sign there could be life there too, she said.

Amidst all the exciting ideas of water and life on Mars, Eriita was quick to admit that the daily life of a researcher in this area holds much less excitement and drama. She said most of her day is spent on her computer, going through data from the Mars global surveyor mission, making codes to manipulate data, making plots to display the data and, as she put it, "constantly reading because everyone else in the world is constantly publishing!" Despite the hard work, Eriita displays a zeal for her research that is unmistakable, and surely an asset in her personal quest... finding that elusive "martian rabbit".


According to Eritta Jones, surface features on Mars - such as this gully - are key to finding water on Mars.

It sure isn't Ireland's emerald pastures, but many scientists believe that water may still exist beneath Mars' barren surface.
Image: NASA/JPL/Cornell



# Antimatter Matters

Tim Wetherell

## Exploring the Potential of the Australian Positron Beam Line Facility



Most of the fundamental particles of physics have an associated antiparticle with the same mass but opposite electric charge. In the case of electrons, their antiparticle is the positron, which carries a positive charge. A group of scientists at the ARC Centre for Antimatter-Matter Studies (a collaboration of Australian universities and research institutions) have recently completed a dual beamline facility at ANU for the study of positrons. The scientist leading the development of the Australian Positron Beamline Facility is Dr James Sullivan.

"This facility will provide us with a new tool to study the basic processes underlying positron physics. How they scatter off, and interact with, atoms and molecules of matter and how they ultimately annihilate by combining with their antiparticle." Dr Sullivan explains. "Essentially, we are interested in understanding the detail of the quantum mechanical processes that underpin such interactions."

There is a great potential to expand our knowledge of science using positrons but they also have a number of very practical applications. One is Positron Emission Tomography or PET - a medical imaging technique in which a small quantity of positron emitting radioactive isotope is bound to a biological molecule, such as glucose, and injected into the patient. When the emitted positrons annihilate a pair of gamma rays are emitted. By monitoring the position and direction of the gamma rays, it's possible to determine the location of the isotope/molecule complex within the body. PET scans are particularly useful in detecting local changes in biochemistry which often occur before the structural tissue changes that appear on other scans.

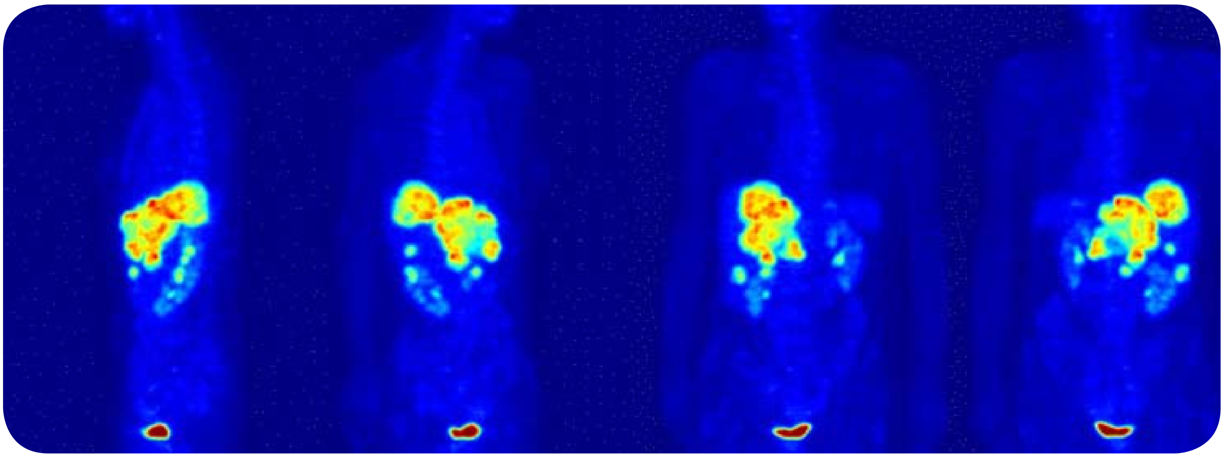
"Despite the usefulness of PET scans, the basic physics of the positron electron annihilation process is not well understood," Dr Sullivan says, "perhaps if we can get a better handle on the physics, there may be opportunities to improve the resolution of scans and or reduce the necessary dose of radioactive marker."

Science often works like this. A thorough understanding of what's going on at the fundamental level often enables technological breakthroughs that can't be achieved by simply refining the engineering.

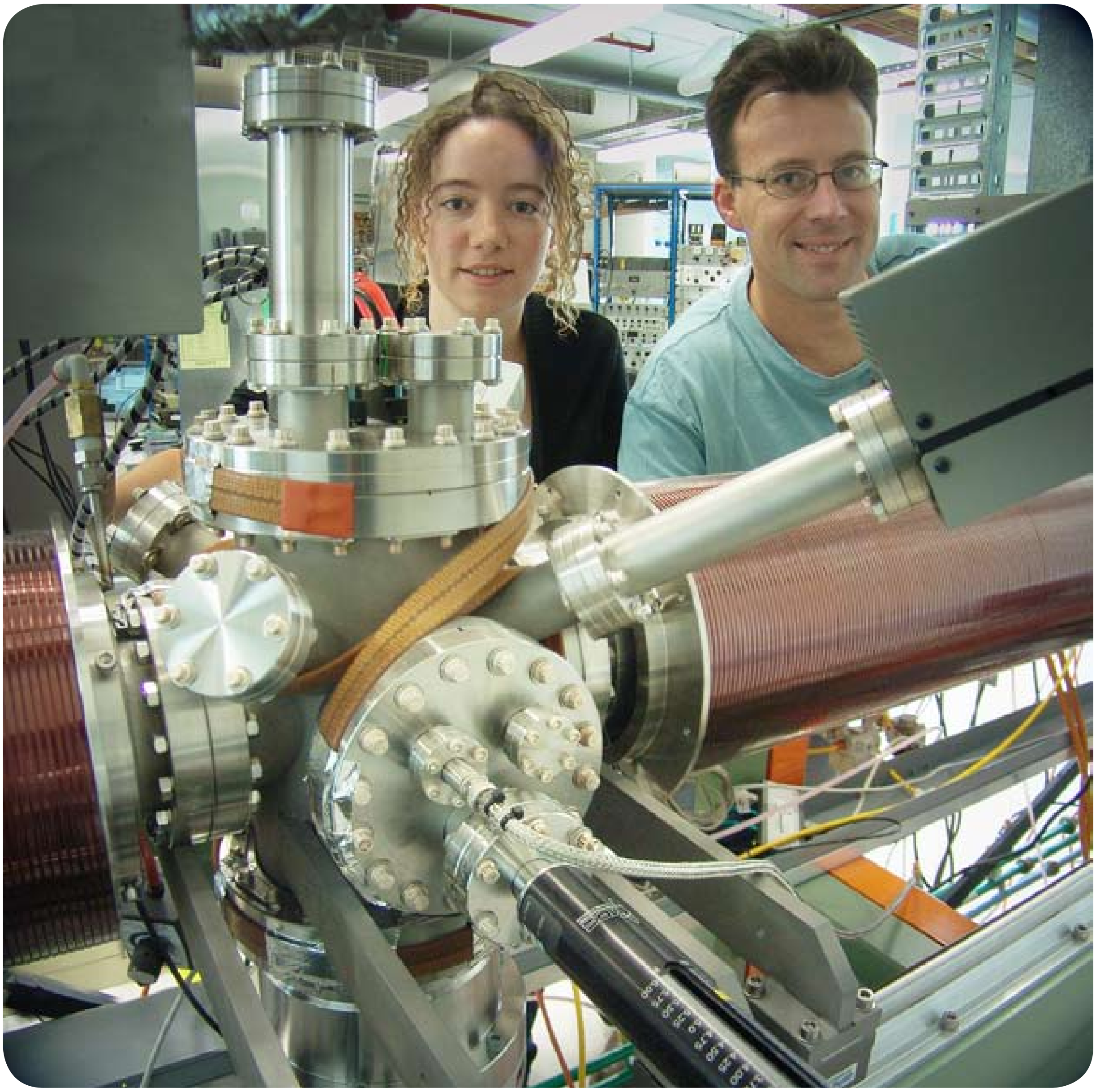
The second beamline of the facility is devoted to materials science. When positrons enter matter they commonly join with an electron to form a short-lived exotic atom called positronium. In vacuum, orthopositronium has a lifetime of 140ns but in solids this can be reduced to a few hundred picoseconds. However, orthopositronium is attracted to voids in solid material and because these act like tiny vacuums its lifetime is extended where voids are present. In effect this means that by injecting a very short pulse of positrons into a material and measuring the timing of the gamma ray annihilation signatures, scientists can determine the size and density of imperfections in the material. This is especially useful for example, in high grade silicon used in microelectronics and in detecting early signs of fatigue in metals.

**But given that antimatter and matter annihilate on contact, how do you create a positron beamline in the first place?**

The positrons in the Australian Positron Beamline Facility are generated as a radioactive decay product of an isotope of sodium 22Na. The positrons emitted by the sodium source emerge at every angle and with a range of energies up to about 500keV. This energy spread creates a problem because the resolution of most measurements that can be made with positrons depends on the energy variation within the initial



Positron Emission Tomography image of the human body. Image: Jens Langner, Forschungszentrum Dresden-Rossendorf



Dr James Sullivan and PhD student Violaine Vizcaino with the Australian Positron Beamline Facility

beam. Scientists get around this using what's known as a moderator.

A common choice of moderator is tungsten. When the positrons enter the tungsten they very rapidly thermalise, that is dissipate any excess energy and slow down to the same speed as the electrons in the material. However, the work function of materials like Tungsten is negative for positrons so they tend to be very quickly ejected again. Of course quite a large number recombine and annihilate within the moderator, but those that don't, emerge with a much narrower range of energies than when the beam entered.

In the Australian Positron Beamline Facility, the chosen moderator is frozen neon gas rather than tungsten because the rate of annihilation is far lower in neon than in tungsten. To capture as many of the positrons as possible the neon is frozen directly to the radioactive source casing. The moderated low energy positrons that emerge from the neon are channelled into a positron trap using electric and magnetic fields. The trap further reduces the energy of the positrons and concentrates them in space. The scientists then use these trapped positrons as a reservoir from which to make a positron beam.

For experiments on the first beamline where low energy spread is required the positrons are accelerated from the trap using electric fields and directed through a gas of the target atom or molecule. In the second beamline devoted to lifetime experiments, the positrons are compressed into a series of very short (<1 ns) and compact pulses and implanted into the material to be studied.

# How Do I feel About Myself?

## *Exploring the Relationship Between Body Image and Body Mass in Kids*



A large number of Australians are becoming overweight, a situation that will inevitably lead to poorer health and increased burden on Medicare. Of particular concern to many doctors is the increasing proportion of young children with weight problems. However aside from the physical effects of being overweight, the condition also has a significant impact on a child's psychological wellbeing.

Professor Don Byrne from the ANU Department of Psychology is part of a team of scientists engaged in one of the largest and most comprehensive studies of the health and wellbeing of Australian children to date. The "Lifestyle Of Our Kids" project, known as LOOK, has been underway since 2005 and involves around 850 children in the Canberra region. Beginning at 8 years old, the kids have been regularly assessed by health professionals and had their body mass, cardiovascular fitness and many other health parameters measured. In parallel with this, the kids have also been undertaking a series of psychological questionnaires designed by Professor Byrne to determine their psychological wellbeing, self esteem and body image.

"One of the things we are especially interested to know is how a person's sense of body image develops?" Professor Byrne explains. "There have been quite a number of studies of body image in children with disabilities and physical problems, but surprisingly few on normal, average children."

To be fully effective the study needs to follow these kids right through to adolescence, but even in the four years it has been currently running, it's beginning to turn up some interesting results. Perhaps not surprisingly there is a fairly strong correlation between increasing body mass and decreasing body image. "Clearly the kids have taken on board the strong messages in the media about the health implications of being overweight," Says Professor Byrne, "But the surprising thing is that for the most part, while kids may feel bad about the way they look, they don't seem very motivated to do anything about it, such as engage in more exercise or eat more healthy food."

Professor Byrne feels that this is a key area for further study. "If we can better understand how kid's perception of health risks leads to the development of poor body image, perhaps we can develop better strategies to help them take responsibility for their own health."

Professor Don Byrne

Another interesting finding of the study is that girls generally have a poorer body image than boys with equivalent body mass and generally this declines further as the girls grow older.

The LOOK project is not limited to just observing the kids, it also has an intervention element. A randomly selected half of the children are being given a structured physical exercise program by fully trained fitness professionals provided by the Bluearth Foundation – a not-for-profit organization focused on improving health through participation in physical activity.

It's too early to draw any final conclusions, but the data so far indicate that kids who participate in the Bluearth fitness program experience a significant positive effect on their body image. They also experience less negative moods and depression. Interestingly though, to date, there hasn't been such a large difference in the body mass data between the two groups. There may however be an improvement in the physical fitness data from the intervention group as the study progresses but the data analysis is at too early a stage to be sure.


"We want to find out whether early exposure to structured physical exercise establishes health facilitating behaviours more broadly in young people," says Byrne. "Do they, for example, develop a healthier attitude towards diet, smoking, and use of alcohol and other drugs? Would we have a healthier population in the long run?"

The first five years of the psychological element of this study have been funded by an Australian Research Council grant, but that funding runs out next year. 'This is one of the world's most useful and important data banks in the area of child health," Professor Byrne says, "and it's vital that we don't loose the opportunity to monitor these kids as they make the transition to adolescence and high school."

The LOOK project investigates a multitude of factors influencing child wellbeing such as physical activities, nutrition, health and their relation to self esteem.

# The Evil Twin

Tim Wetherell

## How Modelling the Atmosphere of Venus Helps Us Understand the Earth



One of the difficulties in modelling the climate of the Earth under various greenhouse scenarios is that scientists only have one set of parameters against which to compare such models, that is, the climate history of our own planet. When making future predictions it's hard to be 100% sure that you haven't simply tweaked your model to fit the past without the underlying science being good enough to give a degree of certainty to the future scenarios it predicts. One way this can be overcome is by looking at the atmospheres of other planets such as Mars and Venus where the parameters are different but the science is exactly the same. Venus is an especially interesting and alarming case as its dense $CO_2$ atmosphere has led to a runaway greenhouse effect heating the surface to temperatures that would easily melt lead.

Dr Frank Mills

Dr Frank Mills is an atmospheric and climate scientist with a joint appointment in The Fenner School of Environment and Society and The Research School of Physics and Engineering at the ANU. A primary interest is numerical modelling of the chemical processes within the atmosphere of Venus. "Many of us are strongly interested in creating better models of the Earth's atmosphere and because the physics and chemistry are the same on Venus but the density and composition of the atmosphere are vastly different, it gives us an opportunity to test our models in two very different cases. If a model of planetary atmospheres holds good to observations when you plug in the pressures, densities and chemical compositions of two planets, then it gives you confidence that you've got the underlying science right." Dr Mills explains.

The Anglo Australian Telescope

Of course the problem with Venus is that it's not nearly so easy to gather atmospheric and climate data as it is on the Earth. The data that Dr Mills feeds into his models come from two sources. The first is from spacecraft such as the European Space Agency's Venus Express for which Dr Mills is a member of the scientific team.

The other way to gather Venus data is using large Earth based telescopes such as the 4m Anglo Australian Telescope in NSW. An important portion of the Earth based data for this research program has come from collaborations with Dr Jeremy Bailey of the University of New South Wales. Although it may seem strange to observe a bright planet with a 4 metre diameter telescope designed for very faint objects, the AAT has an advanced suite of spectroscopic instrumentation that make it one of the best telescopes in the world for gathering such data.

One of the difficulties with making measurements of molecular absorption lines in the atmosphere of Venus using terrestrial telescopes is that the Earth's atmosphere contains nearly all the same molecules as those on Venus so the two spectra overlap. To get around this scientists make atmospheric measurements on Venus when the relative velocity between the two planets is large enough to Doppler shift the spectral lines from Venus away from the terrestrial lines. This makes it possible to distinguish the Venus spectrum from that of the Earth's own atmosphere.

Within the atmospheres of planets, chemistry, thermodynamics and convection combine with solar radiation and surface interactions to create a highly complex and dynamic system. The high densities and temperatures on Venus coupled with the intense solar radiation make it a particularly interesting system to study. One intriguing aspect of the photochemistry of Venus is the creation and destruction of free oxygen.

In Venus' upper atmosphere ultraviolet light from the sun splits carbon dioxide molecules into carbon monoxide and atomic oxygen (O). The direct recombination reaction to produce carbon dioxide from carbon monoxide and atomic oxygen is very slow so the majority of this atomic oxygen forms $O_2$. The 2O to $O_2$ reaction emits a characteristic light which forms an airglow that is visible on the dark side of Venus. By measuring the intensity of this glow scientists can estimate the rate of molecular oxygen production. "We know the rate of oxygen generation on Venus is quite high from the airglow data," Dr Mills explains, "but when we look at the bright side of Venus using absorption spectroscopy we see very little molecular oxygen. So some process has to be consuming it at a very fast rate. Our current models can't really plausibly explain this so it's an area of great interest to planetary scientists."

Venus is sometimes termed the Earth's twin due to its almost identical size, its similar proximity to the sun, and the likely (but not yet proven) similarities in its initial composition. The Earth's first stable atmosphere was dominated by carbon dioxide, much like Venus today except not nearly so dense. Over the course of billions of years, the evolution of life on Earth transformed the atmosphere by releasing free oxygen and binding the $CO_2$ in biomass and sedimentary rocks. "In a sense you can think of the early Earth as being quite Venus-like." Says Dr Mills, "It would be unfortunate if the Earth turned back to that state!"

Understanding how to prevent that happening has been a primary objective of climate scientists. A very important step in doing so has been to develop models of atmospheric processes so thorough and reliable that no one can question the need to take heed of their future predictions.

Artist's impression of Venus Express in orbit around Venus. Image: European Space Agency

# SkyMapper

Tim Wetherell

## State-of-the-art Facility Begins Survey of the Southern Sky



Mount Stromlo Observatory had just refitted the historic Great Melbourne Telescope as an automated sky survey instrument when the 2003 Canberra bushfires swept through the area. These devastating fires destroyed the Great Melbourne Telescope along with many other instruments. Although a research setback, this also presented an opportunity to design a state-of-the-art replacement survey telescope - SkyMapper. Growing light pollution in Canberra and improvements in communications technologies led to the decision to site SkyMapper under the pristine skies of Siding Spring Observatory near Coonabarabran.

Skymapper represents the state of the art both in terms of the 1.35m diameter f4.79 modified Cassegrain optics and the 268 megapixel detector designed and built at The Australian National University. The instrument also has the advantage of being designed as a stand alone automated survey instrument from the outset. So the design isn't compromised by requirements to perform other kinds of astronomy.

The aspheric mirrors, and a sophisticated mirror alignment system give the telescope a wide field of view free of distortions, such as coma and spherical aberration that would normally render such a fast optical system useless. "Normally when a telescope looks at the sky, it looks at a narrow patch which is about a hundredth the size of a full moon," Project leader Professor Brian Schmidt explains. "SkyMapper will look at a piece of sky 40 times larger than the full moon. In addition, there will be huge digital cameras behind them that are 100 times more sensitive than normal cameras."

Data will be transmitted at a rate of 100 Megabytes a second to The ANU supercomputer facility for processing. The telescope will be fully automated, with the astronomers working from the Mount Stromlo Observatory.

SkyMapper's main task will be to conduct the first ever systematic survey of the entire southern sky to produce a detailed digital map.

Since SkyMapper will be sensitive enough to pick up some of the most distant and faintest objects, the chart will have a deep time dimension. Because of the time it takes light waves to reach Earth, the Southern Sky Survey will enable astronomers to look back to the time soon after the Big Bang when the first stars' nuclear fusion reactions set the primeval universe ablaze. This was the time when stars were beginning to manufacture the heavy elements from hydrogen, including iron and the element that billions of years later would form the basis of life on Earth.

As well as information on brightness, position and shape of celestial objects, SkyMapper's survey will also record the spectral types of stars. To achieve this, a series of six glass filters each about 300mm square will be automatically inserted in sequence during each exposure. The filters isolate various wavelength bands from ultra-violet to the near infra-red. Of course design of this system is more complex than it at first sounds because each filter must have superb uniformity in order for images recorded at different times and orientations to be meaningfully compared. "This wavelength discrimination facility will enable scientists to pinpoint stars with low concentrations of heavy elements," says ANU astronomer Stefan Keller. "Successive generations of stars return heavy elements to the interstellar gas and this is incorporated in future stars, SkyMapper will search for stars with the lowest proportion of heavy elements to find the oldest stars. These will give us insight into the way the universe was first lit up by stars and how galaxies form. This is the real niche of SkyMapper. These stars are very rare – about 100 in a billion."

Another project will centre on objects almost on our doorstep – lumps of rock heavier than Pluto and variously catalogued as planetoids, trans-Neptunian objects and dwarf planets.

"Most observations of our solar system so far have focused on the orbital plane of the planets," says Stefan Keller. "Skymapper will look far beyond that and has the potential to detect the biggest planetoids."

A manageable distilled version of the Southern Sky Survey will provide a publicly available set of images of all the stars, galaxies, and nebulae in our celestial hemisphere, as well as a database containing the accurate colour, position, brightness, variability, and shape of every one of the billions of objects in the southern sky.


Unpacking the primary mirror on site

Dr. Stefan Keller of the Research School of Astronomy and Astrophysics inside the Skymapper dome

The SkyMapper survey will be used by astronomers across Australia and around the world to undertake a multitude of projects including:

• Uncovering the most distant objects known in the universe – the first quasars that we think formed when the universe was 3% of its current age.

• Discovering large dwarf planets like Pluto in the outer solar system.

• Obtaining a comprehensive map census of the stars in our Galaxy, providing the temperature, composition, and size of more than a billion objects.

• Providing our best map of the invisible material (known as dark matter) which makes up the majority of our galaxy using samples of very rare stars uncovered in the survey.

• Pinpointing the first stars that formed in our galaxy 13 billion years ago by their chemical composition.

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