THE AUSTRALIAN NATIONAL UNIVERSITY

# SCIENCEWISE

Spring 2011

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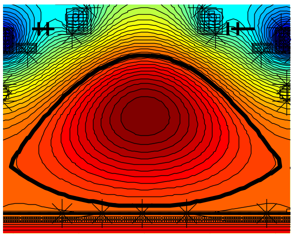

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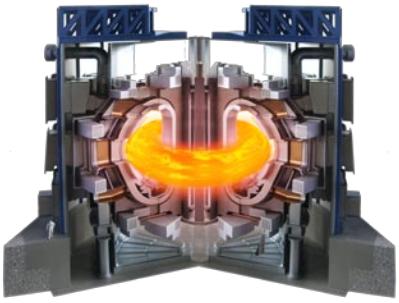

# Why does medicine have to taste bad?

Dr Tim Wetherell

When I was a very young boy, perhaps 8 or 9, I'd fallen ill and was prescribed two bottles of medicine to aid my recovery. One was a rich sweet tasting syrup that left to my own devices, I'd have happily drunk the whole bottle of in a sitting. The other tasted like ear wax and turpentine, utterly disgusting and totally unpalatable. When I complained that it should be made to taste like the sweet one I was told that in fact it was only the nasty stuff that would make me better - why then, I was also being prescribed the nice one remains a mystery to this day.

What brought this to mind was a couple of stories in the science news recently that really reenforced to me how we always sell the message of science and especially medical science with a heavy dose of puritanism. If you're enjoying it, it must be bad for you.

One such research project builds upon a long list of similar studies showing that people who consume a small amount of alcohol each day tend to live longer than those who abstain altogether. The second study looked at chocolate and found quite a remarkable reduction in heart disease amongst those who ate a couple of bars a week. All this work by credible university scientists.

Every time you hear such reports there's invariably a comment by some killjoy saying that you shouldn't do these things, that it's bad, blah, blah, blah.

Of course in a sense they're right. If you drink a lot of alcohol you'll risk many serious diseases and if you eat too much chocolate you'll get fat. But surely most adults are big enough and old enough to work that out for themselves. If my doctor tells me to take a paracetamol for a headache clearly she isn't instructing me to take the whole bottle.

Now imagine if someone developed a nasty little pill that tasted disgusting and had a couple of unpleasant side effects but reduced your chances of developing heart disease by 30%. We'd be encouraged to eat them like lollies. So why can't we drink some of Australia's wonderful red wine and eat chocolate?

I'm not saying let's all get drunk and get fat, but maybe just a little bit of what you enjoy doesn't always have to be a bad thing.

NTS

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Offsets its paper consumption with contributions to native tree planting programs.

Cover Image: Dr Cormac Corr with a plasma physics experiment used to develop advanced materials for fusion power.

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# Panning out

## What does evaporation data mean for Australia's climate?

As it's name suggests, an evaporation pan is a device scientists use to collect data on the rate of evaporation at a given location, usually in association with other weather monitoring instruments. Essentially, the pan records an upper limit on how much evaporation can occur at the site. You can think of this as the evaporative demand of the atmosphere. The pan measurements need to be multiplied by a factor (~0.7) to account for the fact that the pan is raised off the ground and intercepts additional sunlight. When that is done, the pan is a good measure of the evaporation and transpiration from the surrounding soil and plants if the soil were saturated. In practice, the moisture level in the soil is rarely that high so corrections factors have to be applied to calculations.

Looking at the data from such pans over the past 30 years, a strange pattern emerges. In spite of rising average temperatures, the rate of evaporation has been steadily declining, not just in Australia, but across the world from the US to Europe to China. One of the leading scientists in the field of evaporation is Dr Mike Roderick from ANU.

In 2011, Dr Roderick, together with other scientists around the country, have been successful in attracting over 20 million dollars in funding for a new ARC Centre of Excellence in Climate System Science. The centre will study potential changes to the climate of Australia with a special focus on water availability.

"A lot of people think that in a warming world, evaporation rates will increase and therefore soils will become dryer," Dr Roderick says, "but the reality is a lot more complicated than that. Evaporation depends on a number of factors, not just temperature. Humidity, wind speed and sunlight are just as important. For example Darwin is hotter than Alice Springs but the average pan evaporation in Darwin is lower because it's more humid."

Back in 2007, Dr Roderick's team were the first to effectively explain the falling evaporation rate anomaly. After an extensive study of vast quantities of data, they concluded that the reduced pan evaporation rates were the result of falling wind speeds - and coined the term, global stilling. Over the last 30 years the average wind speed has dropped by 0.01 $ms^{-1}$ each year resulting in average wind speeds 0.3 $ms^{-1}$ lower than they were 30 years ago. Given that the average wind speed is around 2 $ms^{-1}$, this represents a very significant change.

At the same time the average wind speed over the oceans is actually increasing by a similar amount. "The tricky thing with wind speeds is that the data over the ocean is collected by satellites, whilst that on the land comes from anemometer measurements. So you have to be careful in combining the two." Dr Roderick says.

Wind speed can't be measured directly by satellite so the data is based on the roughness of the ocean. A radar beam is bounced off a square of ocean eight by eight kilometres. If the sea is rough the back scatter will be greater and a rougher sea means a higher wind speed at the surface. The land measurements on the other hand are directly based on standard anemometers all set at two meters off the ground.

"In spite of the different measurement techniques, we are pretty sure that this is a real effect because recent research from land stations right on the coast in Canada shows that the average wind speed is rising when the wind blows from the sea and falling when it blows from the land."

There are a number of theories that aim to explain this phenomena one of the most popular being that increasing $CO_2$ levels are leading to increased plant size. This is not so much an increase in the size of a given species as a gradual change in vegetation types. Woody plants are starting to encroach more and more into what were traditionally grasslands and of course shrubs and trees are far taller than grass. The net result being that wind speeds near the ground are decreasing because of the increased drag and shielding effects of these plants.

"No one is really sure as yet if plant changes are the mechanism behind the reducing wind speeds," Dr Roderick says, "but what we are sure of is that plants respond directly to even modest changes in $CO_2$ levels and there's no doubt that those are rising."

But what does all this mean for Australia? "I think the message here is that climate science is complicated. You can't just say it's hotter so it will be drier." Dr Roderick explains. "Increasing temperatures and wind speeds over the oceans will almost certainly lead to increased evaporation. However where that moisture falls as precipitation will depend very much on the large-scale atmospheric currents which may themselves change. Decreasing evaporative demand, as shown by the decline in pan evaporation, and an increase in the efficiency of plant water use that is accompanied by high $CO_2$ may lead to less water being required by agriculture. Whether this will be outweighed by decreasing rainfall or indeed if rainfall will actually increase is of course one of the things what we'll be trying to figure out at the new Centre of Excellence."

Dr Michael Roderick with an evaporation pan at Canberra airport weather station

# Head banging to

## Can different bird species understand what each other

He spends half his time listening to heavy guitar riffs and the other half tuning in to the pleasant twitter of birdsong. Tegan Dolstra speaks to Trevor Murray, dreadlocked ANU PhD student and heavy metal fan, about the hot topics in bird communication.

Within the grounds of Canberra's Australian National Botanic Gardens, entire conversations are taking place, unintelligible to the human ear. A cacophony of bird song fills the air, from the delicate trill of the wren, to the raucous squawk of cockatoos.

The Research School of Biology's Trevor Murray is shedding some light on the remarkable way birds gather information by 'eavesdropping' on their neighbouring species' chitchat.

Understanding other species' 'languages' is sometimes more useful, safe and easy than listening to your own species or sourcing the information yourself.

"The birds all listen to each other," Trevor explains. "We've got this really cool system here in Canberra where we can look at the interactions between Superb fairy-wrens and White-browed scrubwrens, which both give alarm calls when predators fly overhead. As well as fleeing to cover when they hear their own alarm calls, they also respond to the other species' alarms."

Trevor wanted to find out just how easily scrubwrens and fairy-wrens listen in on each other.

"There's this intuitive idea that it's harder to understand other species: humans can understand one another pretty well, but we can't really understand what our dogs are saying. We expect it's the same for birds too," he says.

After many days playing recordings of alarm calls to birds and observing their response, Trevor found that they did indeed have more trouble understanding the other species. He also discovered an intriguing difference in the way fairy-wrens and scrubwrens react to alarms.

Photo : Andrew Kahn

# bird song

By Tegan Dolstra

## are saying?

“The really interesting thing is that the fairy-wrens responded differently to the scrubwrens. Whereas scrubwrens are just as likely to flee when they hear a fairy-wren alarm as when they hear their own alarm, fairy-wrens, on the other hand, are more likely to ignore a scrubwren alarm.”

Trevor thinks this difference in behaviour might be down to how familiar each species is with its neighbour’s call.

“If you meet someone with a heavy accent for the first time, you might not be able to understand what they’re saying,” he says. “Already being familiar with the accent will help.”

“Fairy-wrens generally give alarms more often than scrubwrens. My idea is that because scrubwrens are more likely to hear a fairy-wren alarm than vice versa, they are more familiar with it and can more easily understand what it means.”

Trevor also tested whether low volume or degradation of the alarm (due to the sound bouncing off undergrowth, for example) hampered the birds’ ability to understand their own alarms.

“We found that the quieter the alarm (the longer it’s travelled to get there), the less likely the birds are to respond,” he says. “On the other hand, degradation had no effect on alarm response.”

Trevor’s conclusion is that these alarms have evolved to be work over a short range.

“Over the normal distances these animals would be communicating - at most 10 or 20 metres - degradation doesn’t really come into play,” he says.

Growing up in Griffith, a country town in NSW, science was Trevor’s favourite school subject. For a Year 10 project he designed an animation of the molecular workings of DNA transcription.

Not realising how much he enjoyed biology, Trevor moved to Canberra to study video games programming. His interest in biology was reignited through a part-time tour guide job at the National Dinosaur Museum and he enrolled in a Bachelor of Science/Computer Science at the ANU.

Between listening to birds and heavy metal (his favourite band is Nile) and watching TV and movies, Trevor still spends most of his spare time playing computer games. He’s even found a way to combine his two passions at work, putting his computer skills to use helping his scientist colleagues with programming. I wonder if he’s also a fan of Twitter?

# Mimicking the brain

## Making Sense of High Temperature Plasma Confinement Data

Fusion power offers the promise of generating massive amounts of energy with essentially zero greenhouse gas emissions and few of the safety issues of conventional nuclear energy. But although huge progress has been made in the past 50 years, we are only just beginning to reach the elusive “burning plasma” condition, where output power of the confined products exceeds the input power required to heat the fuel.

The next step international fusion experiment ITER, is now under construction in France and is one of the world’s largest science experiments.  ITER plasma temperatures will be exceed 100 million degrees C, with a plasma volume comparable to an Olympic swimming pool. The construction of ITER is only possible because physicists are able to model the behaviour of plasmas sufficiently well to enable engineers to construct a machine on this scale with confidence. However, there is still much work to be done before we have a complete understanding of the theory underlying plasma confinement.

The behaviour of all fluids is notoriously difficult to model. Even a simple fluid such as water exhibits a myriad of twists and turns as it flows from a tap. Plasma circulating within the magnetic confinement of a fusion reactor is far more complex because it has massive temperature gradients and is composed of charged particles that repel and attract each other as they circulate.  This constantly moving charge also generates its own magnetic field which in turn, perturbs the flow of the plasma and disrupts the magnetic field used to confine it.

Australia’s contribution to the worldwide effort to develop fusion power centres on international collaborations, many of which harness the H1 National Plasma Fusion Research Facility at ANU. H-1 is a stellarator plasma confinement facility not designed to actually achieve fusion, but to conduct experiments on large scale confined plasmas. The relatively easy reconfigurability of the magnetic fields within H-1 makes it a particularly good tool for the development of diagnostic instruments to monitor the behaviour of confined plasma. However, Interpreting the gigabytes of data from the temperature, pressure and current sensors inside the plasma is a daunting task. Even more challenging is the globally consistent merging of this information into a cohesive picture that reflects the actual physics of a plasma confined in such extreme conditions.

Drs Matthew Hole and Greg von Nessi are part of the ANU Plasma Theory and Modelling group, who with collaborators (see photo) in the Plasma Research Laboratory are focussing on interpreting data from the many sensors on H-1 and compiling a picture of the underlying physics.

“The different diagnostics on H1 are a lot like our own five senses,” Dr von Nessi says. “Data comes in from sight, sound smell, and often something we’re experiencing influences more than one sense. In fact it’s the interaction between senses that often enables us to make sense of what’s in front of us. This is exactly the same situation with a confined plasma. We have hundreds of variables and only a few measurements we can make. But if we can make better use of the interdependency of those measurements, then we can generate a far clearer picture of what’s going on.”

*Drs Greg von Nessi, Matthew Hole, Boyd Blackwell and Professors John Howard and Bob Dewar with the H-1 stellarator*

The way our brains work is hugely sophisticated and complex but because we're part of the system we usually just take it for granted. But how do you go about building a rigorous mathematical model that in a sense, does the same thing?

Their model is compiled using a mathematical technique called Bayesian inference. The basic principle is that you begin with a scientific belief or expectation, add the observed data and then modify the extent of that belief to generate the next expectation. In effect as more and more data is added to the model the accurate predictions become reinforced and the inaccurate ones rejected. "It's a lot like the way we learn things," Dr von Nessi says, "We generate ideas based on experience then reinforce or reject them as more data comes in."

"We wanted to ground our approach to modelling the behaviour of plasmas in sound physical theory such as Maxwell's equations, but not to incorporate untested assumptions that might bias the outcome."

The beauty of this approach is that you don't have to deal directly with the hugely complex interdependencies within the data but those interdependencies are automatically incorporated into the model.

"By not building so many assumptions into the initial model, it's possible to compare what's going on in the data to various aspects of the physics" Dr Hole explains, "We can then use real data to give credence to, or reject proposed physical descriptions of the plasma."

The Bayesian inference techniques being developed for this project are currently being used to help understand the theory of force balance on the higher temperature Mega Ampere Spherical tokamak, at UKAEA Fusion in the UK. But the underlying mathematics can be applied to many different complex systems and may even find applications in areas as diverse as climate change and global financial markets.

# Something

## Nanotechnology largely eliminates reflection waste from solar cells

The average solar cell that you might see on the roof of a house has an efficiency of about 10 to 15%. That is, only about one in ten of the photons of sunlight striking it are converted into electrons of usable electricity. To a large extent this limitation is set by the inherent properties of the silicon that such cells are made of. In recent years scientists have been looking at ways of improving this situation by using other semiconductors to create cells and even sandwiches of several materials each able to absorb a part of the solar spectrum that the ones above can't.

One class of semiconductor frequently used in efficient solar cells is the III-Vs. Compounds like gallium arsenide GaAs, that have one atom from group three of the periodic table and one from group five. Using III-V cells, efficiencies of over 40% are possible when the cells are coupled with external optical concentrators.

However even III-V cells are limited by two fundamental physical processes. One is reflection from the surface. Semiconductors have very high refractive indices which means that incident light is reflected far more strongly than it would be from glass or plastic. As much as 30% of the sunlight can be lost in this way.

The second problem relates to the junction. Solar cells are made from junctions between an n-type semiconductor in which electrons are the predominant carrier of electricity and a different version of the same material in which holes carry the charge – so called p-type material. The physics of the p-n junction dictate that there are essentially no charge carriers at all in the junction region which can range from nanometres to microns in size. When a photon of sunlight hits the junction an electron and a hole are created which rapidly migrate to the n and p type material respectively thus creating a current in the external circuit.

The problem for a cell designer is that there are competing requirements in the size of this active junction. The wider the junction the more photons will be absorbed in it. But a wide junction also means a long journey for the electrons holes and a greatly increased chance that they will recombine with each other inside the junction yielding no external current.

However recent work at the Australia National University may be set to change the rules on how cells are made by making clever use of nanotechnology. Associate Professor Hoe Tan leads a group specialising in the growth of exotic structures in III-V semiconductors. "We've been adapting nanowire growth technology to produce solar cells." Professor Tan says, "Because the physical properties of nanowires should enable us to solve the twin problems of reflection and junction absorption."

Essentially the nanowire cell consists of countless ultra thin projections from the surface of a conventional semiconductor wafer almost like fur on animal skin. Each wire is several µm long but only a few 10's of nanometres wide. The core of the wire can be grown p type GaAs whilst the cladding n type so in effect each wire is a coaxial p-n junction.

The light trapping properties of the nanowire arrays reduces reflection to a tiny fraction of that from a solid chunk of GaAs with light reflected from one wire being absorbed by one of its neighbours. Likewise the microscopic coaxial junction leaves very little room for recombination loss since electrons or holes have to travel only a few 10's of nm to the contacts.

"Making nanowire junctions isn't the same as making conventional solar cells though," Professor Tan explains, "once we have the nano structure there are quite a few steps involved in creating the final cell."

The fine "fur" of nanowires is mechanically delicate so it has to be planarised – that is turned into a single solid mass by the addition of a polymer that fills the caps between the wires. The polymer is plasma etched back to expose the ends of the wires so that a transparent electrode can be applied to allow transmission of sunlight to the nanowires and draw off the electric current.

"We've been experimenting with several polymers some of which even enable us to peel off the nanowire cell layer right off the underlying wafer." Professor Tan says, "So in effect what we are creating is a flexible nanowire solar cell that you can wear."

# to reflect on

In their flexible or rigid forms these new cells are attracting lots of interest from those to whom efficiency really matters such as space engineers and designers of large scale solar concentrator power farms. “If you are building a concentrator system chances are you’re investing a lot of money, “Professor Tan says, “so generally you’re going to want to use the most efficient cells at the focal point of the concentrator even if they’re a bit more expensive than silicon cells. Additionally, III-V semiconductor materials are able to withstand much higher solar concentration ratio than silicon.”

*The nanowire solar cell grown on the lower wafer has vastly lower reflection loss than the conventional cell above*

# Pinching the

## Developing advanced materials to solve the energy crisis

The world is facing an energy crisis as increasing population and urbanisation consume fossil fuels at an exponential rate. Aside from their undesirable carbon footprint, fossil fuels like oil also look set to run out within this century. To make matters worse, recent events in Japan have deeply shaken public confidence in the nuclear industry and humanity's ability to deal with the highly toxic waste from conventional fission reactors.

However amidst this rather gloomy picture there is some positive news. International efforts to harness fusion power – the process of fusing two hydrogen-like nuclei to create helium – are well in progress. The world's first practical fusion power plant ITER is currently being built in Southern France by an international scientific consortium.

It is projected that ITER will generate 500 megawatts of power whilst requiring only 50 megawatts to create the plasma. Its fusion reactions will emit no greenhouse gasses and perhaps most importantly, will generate no long lived radioactive waste to pose a contamination threat to the environment. However, the technological challenge of designing and building such a device is daunting.

One particularly challenging aspect of designing a reactor like ITER is finding a suitable material for the walls of the reaction chamber. Although the pressure inside is low and the intensely hot plasma is kept out of physical contact with the wall by the magnetic containment field, energetic by-products of the fusion process irradiate the wall with great ferocity.

Such energetic particles smashing into materials like metals create two problems. Firstly the impacts degrade the wall material by both chemical reactions and by sputtering atoms out of the wall like a snooker ball hitting the pack. Secondly, these secondary atoms and ions that are sputtered out of the wall mix with the fusion plasma disrupting the flow and cooling it, both effects being detrimental to the efficiency of the reactor.

# plasma

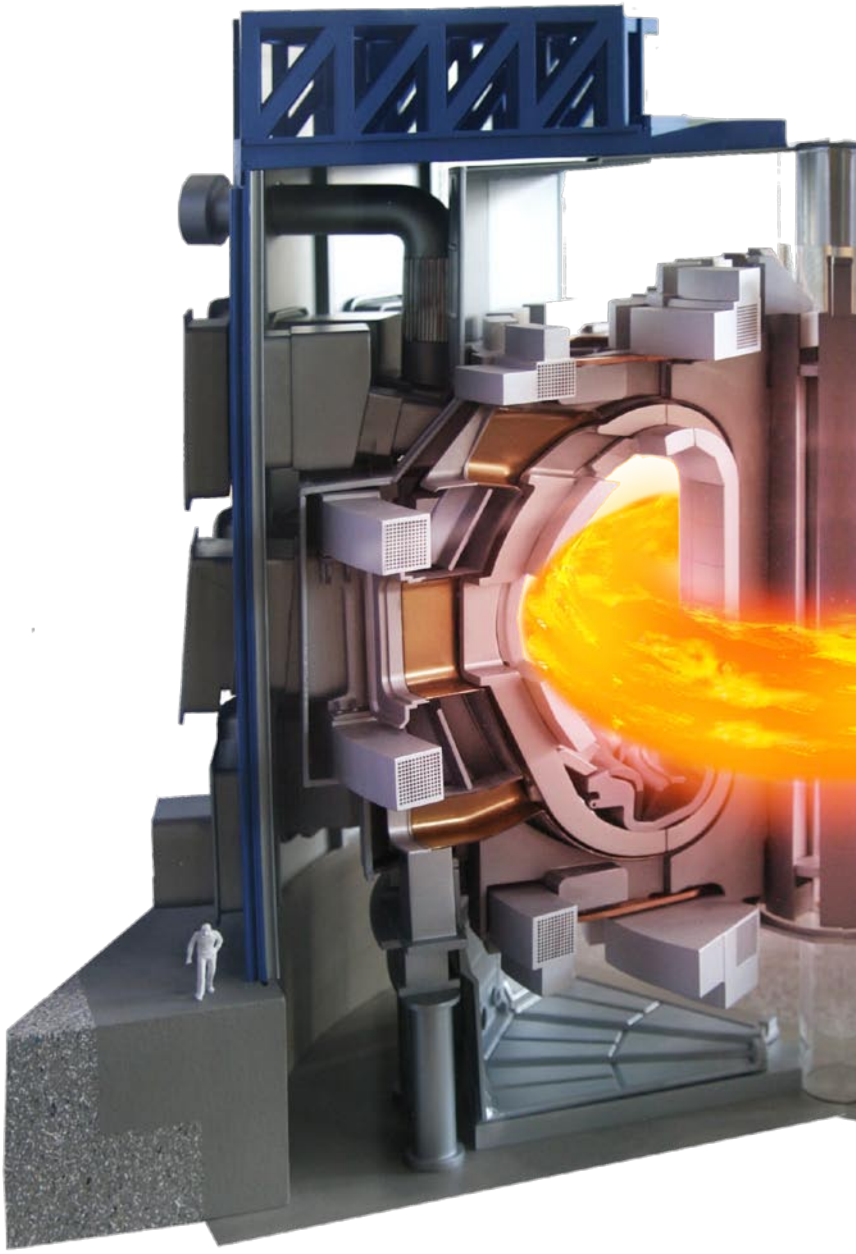
One scientist working on just this problem is Dr Cormac Corr who heads up the Plasma Surface Interaction group within the Plasma Research Laboratory at the Australian National University. “Really this boils down to a materials science problem,” Dr Corr explains, “ We need to develop new exotic materials that can better withstand these extreme environments.” Dr Corr’s research applies a helicon generated plasma system, initiated and designed by Dr. Boyd Blackwell in collaboration with colleagues from Oak Ridge National Laboratories, which can mimic the incredibly harsh conditions experienced inside a fusion reactor.

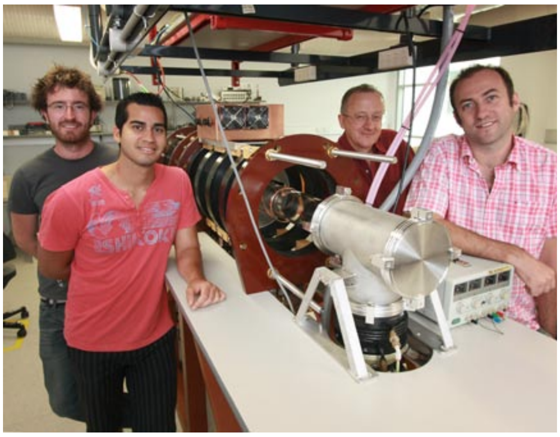
This prototype plasma system known as the Material Diagnostic Facility, MDF, generates a very high-density hydrogen plasma which is then accelerated towards the material test target. Looking something like a ray gun from a Flash Gordon movie, the MDF uses a series of magnetic coils to create a field gradient called a magnetic focus that acts like a lens on the plasma stream. Just as an electron microscope focuses electrons onto a sample, the magnetic field focuses the plasma beam into a single intense energetic spot. This mimics the very conditions that will exist at the internal walls of fusion reactors of the future.

“Essentially we’re trying to unfold the synergistic effect of plasma and ion bombardment at the plasma-wall interface. We want to do that in a controlled environment in which we can use advanced diagnostics to really understand the underlying science of what’s going on.” Dr Corr says.

The diagnostics on the MDF include optical spectroscopy and sophisticated ion probes that give scientists information on the types of particles sputtered out, their energy and how they are interacting with the plasma in the chamber. The MDF is a part of the Australian Plasma Fusion Research Facility, available to researchers through the Australian Institute of Nuclear Science (ANSTO) and Engineering or by collaboration with Plasma Research Laboratory staff.

As part of the recently announced collaborative agreement between ANU and ANSTO, researchers at the Institute of Materials are providing materials research expertise and developing a target chamber for MDF.

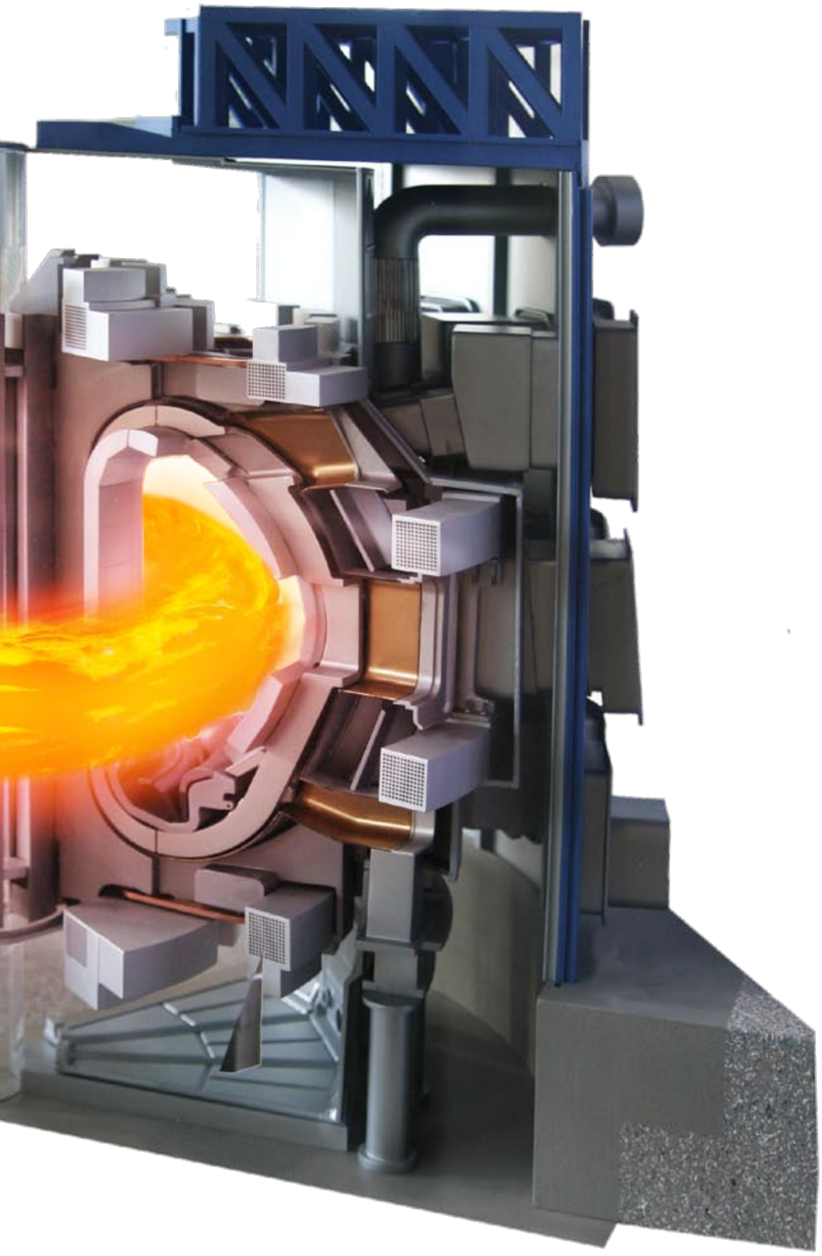




*Some members of the research team, Cameron Samuell, Juan Caneses, John Wach and Cormac Corr*

"Advanced materials is an area in which Australia can really make a significant contribution to the international fusion efforts," Dr Corr says, "Using the expertise here and at ANSTO  we have the capability to develop smarter, better materials for such harsh environments."  "It's difficult to predict the outcome of research, but we're hoping that we might be able to develop materials whose properties actually improve when irradiated perhaps even self organising or self repairing."

Of course fusion power is by no means the only application for such materials. Spacecraft and satellites are constantly bombarded by the energetic particles in the solar wind and frequently suffer damage as a result. Such better radiation resistant materials may also lead to longer, better and more ambitious space missions.



*Fusion reactors such as the European ITER, promise vast quantities of electrical energy with zero greenhouse gas emission and no long lived radioactive by products. The sheer size of ITER can be gauged from the man standing in the bottom section of the reactor.*

# A star is born

## Newly discovered red dwarf may yield clues to planet formation

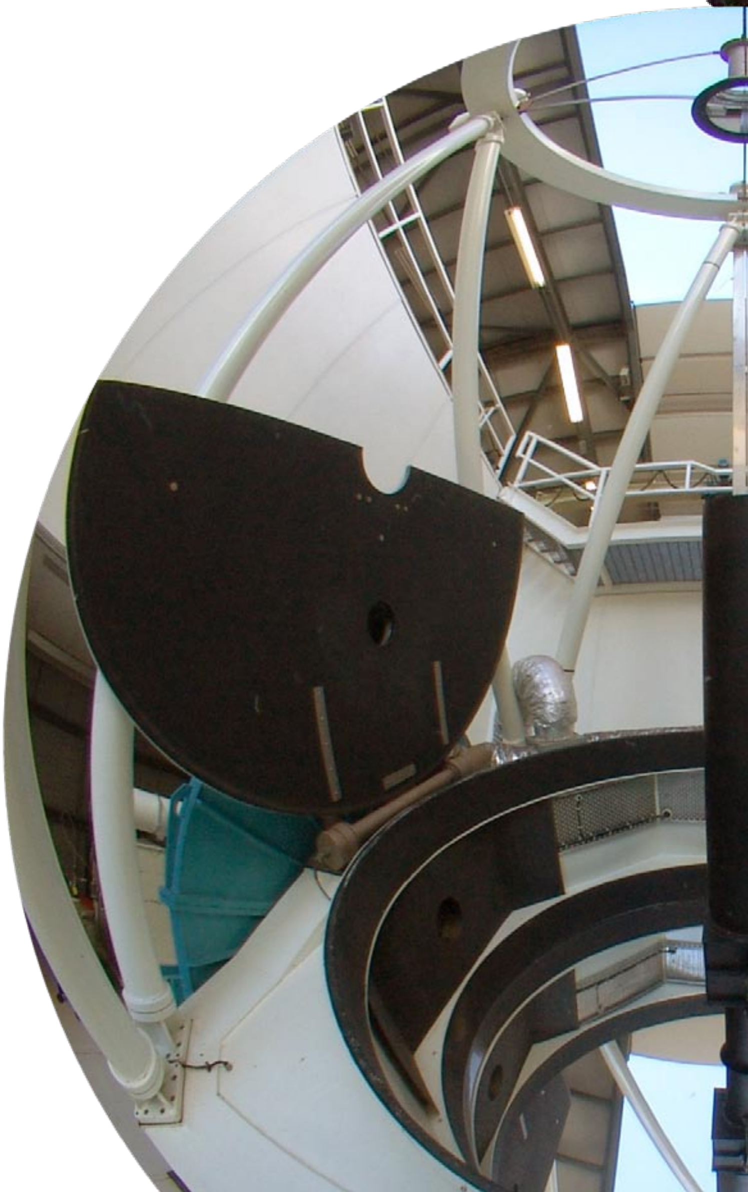
On casually glancing into the night sky, you couldn't help but notice that some stars are very much brighter than others. Sometimes this is because faint stars are much further away than bright ones but to a very large extent it's because stars really do vary greatly in their intrinsic brightness.

When it comes to stellar brightness, mass and age are the most important factors. All stars form from a gravitational accumulation of diffuse dust and gasses, principally hydrogen, that occupy regions of interstellar space. How much material is available will ultimately dictate not only the star's brightness but its ultimate fate.

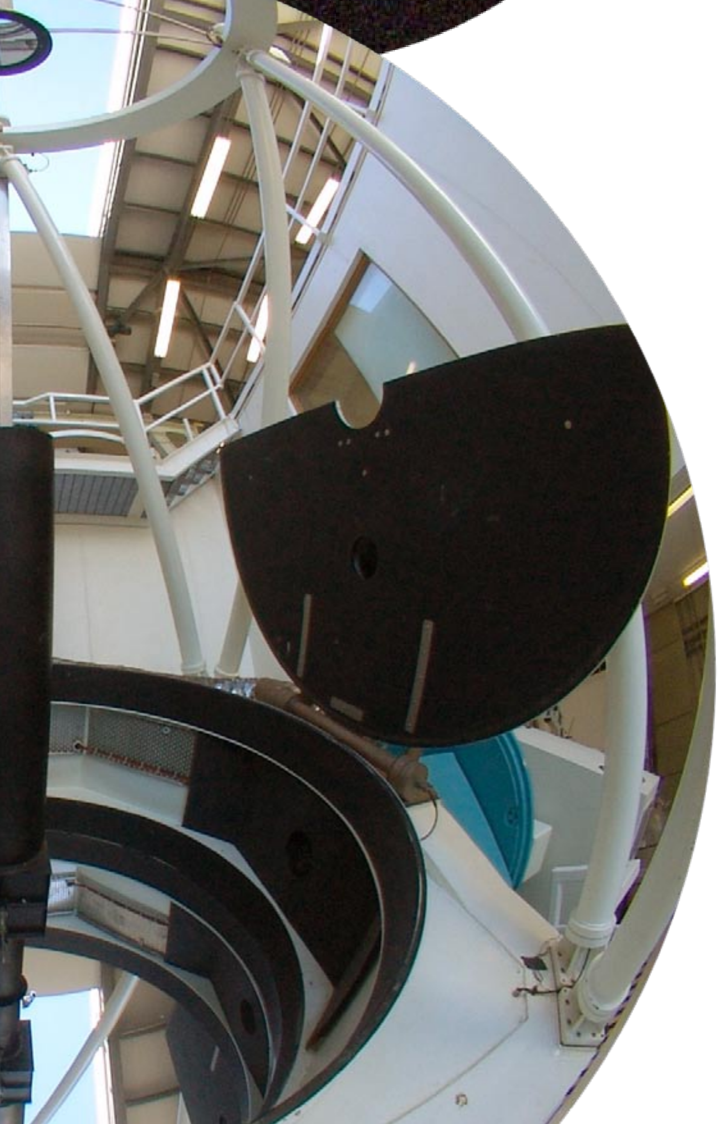
You might imagine that a very big star would live a very long time because it has large reserves of hydrogen fuel to drive the nuclear fusion reactions in its core. But surprisingly, the direct opposite is true. Massive stars burn very bright but for a very short time whilst small stars such as red dwarves, burn for a very, very long time indeed – tens of billions of years.

Red dwarves are particularly interesting to astronomers because they comprise the vast majority of the stars in the universe. However their low intrinsic brightness makes all but the closest ones quite challenging to study. For that reason there was great excitement in the astronomy community when an international team, including Simon Murphy, a final-year PhD student from the ANU Research School of Astronomy and Astrophysics, discovered a red dwarf that is not only close to Earth, but is also very young in stellar terms. Known as AP Columbae, this star is a mere 40 million years old.

“This is a really exciting opportunity not only to study a red dwarf at close quarters, but to study one around which young planets will most likely be forming.” Simon says, “And because the system is so young, the planets should still be very hot and therefore bright which really increases our chances of directly imaging them.”



> **“just like human toddlers, young stars are prone to tantrums”**



But how exactly does one go about ascertaining the age of a star? “One of the key indicators is lithium,” Simon explains, “Lithium is destroyed quite quickly in red dwarf stars so when we see a strong lithium signature in the spectrum we can be pretty sure the star is less than100 million years old.

Another clue comes from the pressures in the stellar atmosphere. Very young stars are still in the process of gravitational collapse. They haven’t reached an equilibrium point where the pressure of radiation from the core balances the contraction caused by their own massive weight. The spectral signature of elements such as sodium is highly sensitive to pressure so the nature of the sodium lines can yield clues to the pressure gradient in the star and hence it’s age.

A careful study of the spectrum of AP Columbae using the newly commissioned WIFeS spectrometer, designed and built at ANU and fitted to the 2.3m telescope at Siding Spring, NSW enabled Simon to tie down the star’s age - 40 million years. “Early in their lives these stars are prone to violent flares and eruptions. This one’s not quite a baby, more of a toddler. And just like human toddlers, young stars are prone to tantrums,” Simon says.

Quite apart from the flares, the planetary system would be far too young and hot for life to have evolved there, but it should give astronomers vital clues into what kind of planets might be expected in orbit around the universe’s most common star type. And by sheer weight of probability, a red dwarf system may well house our nearest living neighbours in the universe.

*Above: AP Columbae*

*Below: Fisheye view of the 2.3m telescope at Siding Spring used for the spectroscopic age determination ov AP Columbae*

# Heavy

## Scientists discover radically new form of aluminium

Many common materials behave in extraordinary ways when subjected to extreme temperatures and pressures. For example the common barbeque gas propane becomes liquid when pressurised in gas bottles. Under the far more extreme pressures found at the centres of stars, gaseous hydrogen adopts a metallic state.

Theoretical physicists have for many years predicted that if subjected to sufficient pressure the common metal aluminium can change its crystal structure from the normal face centred cubic to a denser body centred cubic BCC form.  Crystal structure matters a lot when it comes to chemical and physical properties, graphite, and diamond are both forms of pure carbon, yet their properties could hardly be more different. Theorists predict that aluminium with a BCC structure would be 41% denser than the FCC metal and may have vastly different chemical and physical properties.

Generally when physicists want to study what happens to materials under extreme pressures they use a device known as a diamond anvil. This is a specially shaped pair of diamond points that can be set in the jaws of a large hydraulic press which generally also has facility to heat the compressed material too. However diamond - the strongest material available - yields below the pressure and temperature required to transform aluminium. As a result no one has ever created BCC aluminium until now.

A international team including scientists at the Australian National University have just released a paper in Nature Communications in which they have created BCC aluminium by an unusual method they describe as a top down temperature and pressure approach. Instead of a mechanical squeezing device, they used an ultrafast pulse laser to create a plasma.

When using lasers to heat matter the pulse length is of critical importance.  A given amount of energy spread over a long pulse, heats the electrons and ions of the crystal relatively slowly allowing the heat to be transported from the focus by electrons and vibrations of the lattice known as phonons. As a result, an area far larger than the focal spot gets heated. However if the energy is concentrated into a short enough pulse – a few femtoseconds – the heat conduction mechanisms can’t remove it from the focus in time and the result is a massive heating of a tiny area deep within the crystal.

This heating turns the material of the crystal into plasma which expands with colossal force, compressing the atoms of the crystal around it. By using a sapphire, which is an oxide of aluminium, the team were able to generate conditions of such extreme pressure and temperature that tiny shells of BCC aluminium were formed within the crystal. “It’s not just the speed of heating that’s important here, the material also quenches or cools very rapidly, freezing in a new phase.” Professor Rode explains. “the pressures involved are enormous, over 50 million atmospheres.”

At present the new metal only exists in tiny crystals, about 20 nanometres across within the compressed sapphire. however, new materials are always exciting to scientists and engineers because they offer the potential for better devices that can do things that were previously impossible. And the ultra fast pulse laser method offers a relatively simple way to do just that.

There’s also a lot of excitement about work like this from a pure physics point of view. Generally scientists don’t have  access to conditions like the centre of planets and stars in the laboratory. Moreover having the ability to create such ultra high pressures relatively easily using fairly small scale equipment offers the exciting potential of opening up this field of study.

“Knowing how materials behave under extreme pressures and especially having them available in the lab to study is a really helpful step in better understanding extreme physics such as that at the centre of the Earth as it was forming.” Professor Rode says.

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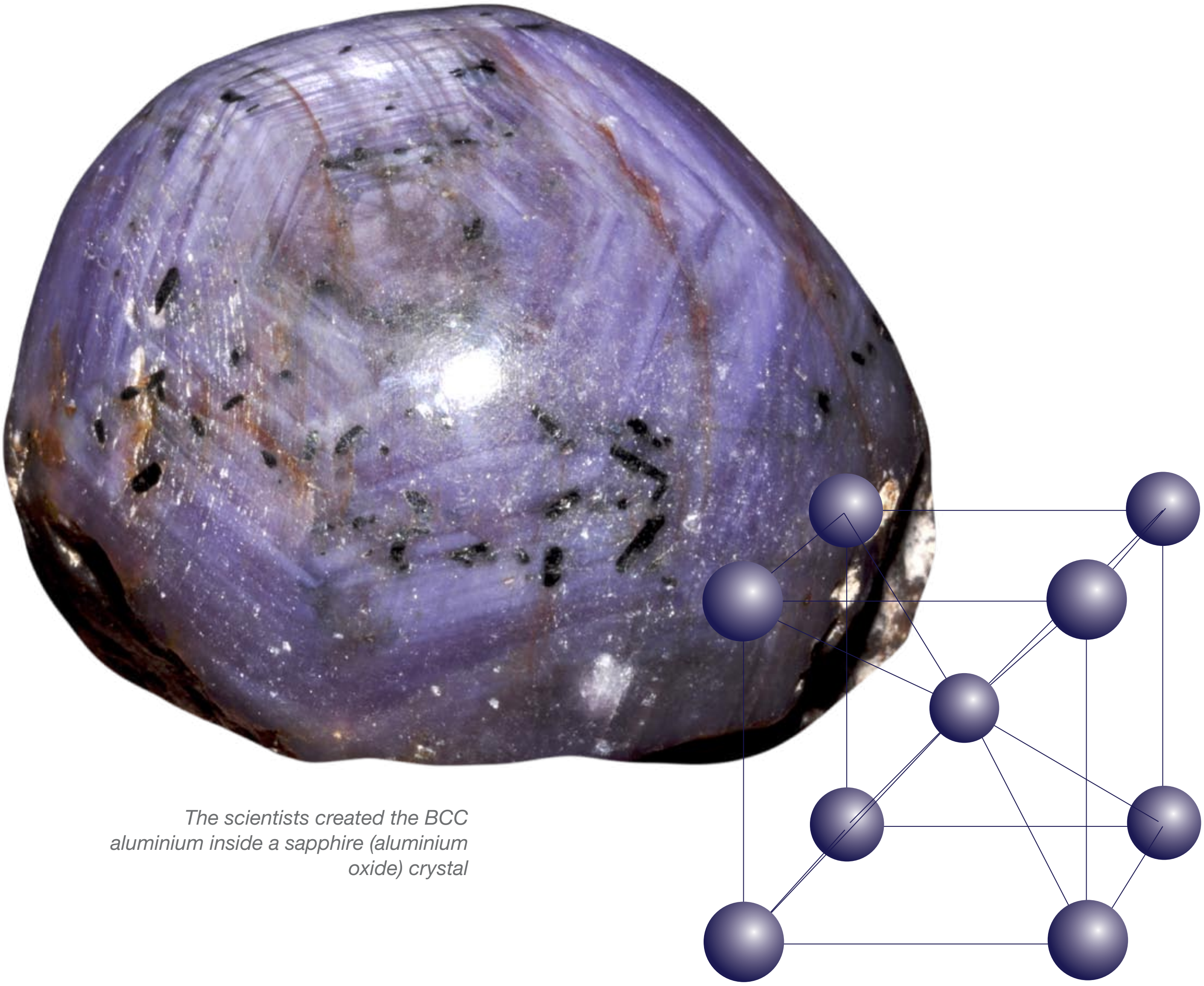
# metal



*The scientists created the BCC aluminium inside a sapphire (aluminium oxide) crystal*

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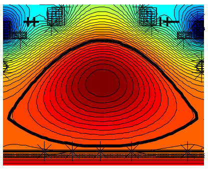
# SCIENCEWISE

ANSWERS

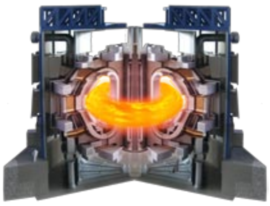
**If the world's getting warmer, why are evaporation rates falling?**

Can different species of bird understand each other?



**Can maths be designed to mimic the brain's ability to solve complex problems?**

Can nanotechnology eliminate reflection loss from solar cells?



How do you test the materials fusion reactors are made of?

**How can you tell how old a star is?**

**Can a laser squeeze matter harder than a hydraulic press?**