WATER: PHYSICS & POLITICS
INTERACTION FREE MEASUREMENT
COLLAPSING THE MORAL WAVE FUNCTION
WIP REPORT
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Pliny, Natural History, XXII, 49

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## CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>President's Report</td>
<td>177</td>
</tr>
<tr>
<td>Editorial</td>
<td>178</td>
</tr>
<tr>
<td>Letters</td>
<td>179</td>
</tr>
<tr>
<td>Samplings</td>
<td>180</td>
</tr>
<tr>
<td>Physical and Human Factors Associated with the Politics of Water</td>
<td>183</td>
</tr>
<tr>
<td>News</td>
<td>186</td>
</tr>
<tr>
<td>Feedback</td>
<td>188</td>
</tr>
<tr>
<td>Physicist's Crossword</td>
<td>190</td>
</tr>
<tr>
<td>Conferences</td>
<td>191</td>
</tr>
<tr>
<td>Adam and Eve and the Collapse of the Moral Wave Function</td>
<td>192</td>
</tr>
<tr>
<td>FASTS</td>
<td>194</td>
</tr>
<tr>
<td>Schroedinger's Cat and Interaction-Free Measurement</td>
<td>195</td>
</tr>
<tr>
<td>Press Room</td>
<td>199</td>
</tr>
<tr>
<td>Book Reviews</td>
<td>200</td>
</tr>
<tr>
<td>Product News</td>
<td>205</td>
</tr>
</tbody>
</table>

**COVER:** Water is an important resource, especially in this dry country. See the article by Robert Robson. Photo by photokorn, Copyright Pixel Perfect Inc.

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The statements made and the opinions expressed in the *The Physicist* do not necessarily reflect the views of the Australian Institute of Physics or its Councils or Committees.
The delay in announcing this year’s ARC results raises important questions about the process for authorising and announcing such awards. The extended delay was caused by the Federal Election, which only occurs every 2-3 years, but in reality there is uncertainty every year. Such uncertainty is clearly unacceptable when the career decisions of many young researchers depend on the outcome. The fact that the ARC’s recommendations were likely known in September, around two months prior to the announcement, shows that there is considerable room for improvement. Perhaps it is time to argue that the announcement be made on a fixed date each year and to ask why Ministerial approval is required at all. Surely the announcement could be made by the ARC as a truly independent statutory body.

On a brighter note, the AIP Executive is currently examining the possibility of resurrecting the Australian Journal of Physics. Electronic access to journals has apparently led to a resurgence of interest in national publications as they no longer rely on the holdings of local libraries for their access and citation statistics. We have been approached by an international publisher with an interest in producing the Australian Journal of Physics and have requested a formal proposal from them. One possible concept at this stage is to broaden the role of the journal to focus more on the publication of domestic conference proceedings. However, we would welcome comment on this issue from the Australian physics community.

As noted in my annual letter to Members, the New Year will herald the imminent reign of a new President. My term as President comes to an end in February 2005, just as the Congress draws to a close. It has been a pleasure to serve the AIP membership over the past two years and it is an even greater pleasure to hand over to someone as committed as Prof. David Jamieson. I look forward to David’s Presidency and to serving with him on the Executive as Past President. The election of the new AIP Executive will take place at the 42nd Annual General Meeting (AGM) to be held in conjunction with the AIP Congress on Friday 4th February commencing at 12:20 pm.

Finally, I would like to take this opportunity to thank all those members who have served the AIP over the past year, including members of the AIP Executive and State Branch Committees and members of regular and ad-hoc AIP committees. Your contribution is crucial to the success of the AIP and is much appreciated. I have particularly enjoyed working with the present AIP Executive. It has been a great team.

Merry Christmas and Happy New Year.

Rob Elliott
EDITORIAL

Once again the year has sped by and the festive season is upon us. I hope that you all have an enjoyable Christmas and New Year. From this, you can assume that I am still hopeful that you will receive this issue before the end of the year. If this doesn’t happen, I hope that your festive season was happy and your New Year full of promise.

This year has seen only small changes in the format of The Physicist to allow it to settle a bit. However, 2005 is likely to see some more noticeable changes. Because of this, in the last issue I requested some specific feedback as well as general comments. I am delighted that I have already received some responses to the call for feedback that I made in this column last issue. I hope that more are still to come. All the respondents so far have said that they read the Editorial – of course, as the call for feedback was made there, this is a somewhat self-selected sample. In an effort to broaden the response base, I’ve started a new section that I have called, with great originality, Feedback.

On a sad note, Conrad Burden, the man behind the crossword, has found that the constraints upon his time mean that he will no longer be able to provide the Physicist’s Crossword. I’d like to take this opportunity to thank Conrad for the work he has put in to providing a puzzle for each issue for the last three years - I know that they will be missed by many readers as well as the editor.

This means there is a vacancy in the crossword producing department, so if you are a crossword buff itching to become a maker rather than a solver of puzzles, perhaps you might like to take up the mantle of crossword guru. Something to think about over the holiday season!

On a blatantly importunate note, if you are not a crossword enthusiast, you may yet like to submit something else; you might be a budding cartoonist or caricaturist; or an essayist. The Physicist is your magazine, so help to make it what you want it to be!

In this issue: Sometimes themes emerge even when you are not trying. This issue contains an article by David Miller about Schrödinger’s poor cat – how to collapse, or not, the wave-function using interaction-free measurement. This article refers to an earlier paper by Neville Fletcher, who, for this issue has written an somewhat more light-hearted article on the collapse of the moral wave-function.

Considering how important water is in this dry continent and how conscious we are of it after the drought, the article by Robert Robson about the physics involved and the way that must affect the politics of water is timely and thought-provoking.

There is also a report on the Women in Physics lecture tour, a short student report, the Feedback section mentioned above and the book reviews – this week with a longer essay style review of one of the books.

Hope for the future

Dear Ms Horrigan,

From time to time in the education of young physicists, outstanding students pass through our care, and reassure us that our efforts are not in vain.

In the past month two final-year students, Kong Guan Tan and Anthony Skews, undertook a standard (though fairly sophisticated) laboratory experiment in the undergraduate nuclear lab. The normal experiment involves identifying the alpha particle groups that are emitted from the nucleus carbon-12 when a target of boron is bombarded with protons from a small accelerator. These students realized that when the $^{12}$C nucleus breaks up, the recoiling $^8$Be residual, being unstable, would disintegrate into two alpha particles, which should also be detected. After careful calculations, involving concepts beyond the norm, they set about modifying the experimental procedures to find evidence for this.

I think it would be reassuring to many AIP members, particularly those involved in university teaching, to know of such insight in the upcoming generation of physicists. It would also provide a real encouragement to the students as they consider their future options. I therefore asked the students to prepare a short article on their work, which is enclosed, and would like to request you to consider publishing it as a small item in "The Physicist".

Sincerely

M. N. Thompson  D.Sc.  FAIP
Reader and Associate Professor
School of Physics, University of Melbourne

Investigation of the $^{11}$B($p,\alpha$) Reaction

KONG GUAN TAN and ANTHONY SKEWS
School of Physics, The University of Melbourne

Final-year undergraduate physics students at the University of Melbourne can study the 16.106-MeV state of $^{12}$C using the reaction $^{11}$B($p,\alpha$)$^8$Be and a low-energy (200 keV) linear proton accelerator and an evaporated target of $^{11}$B. Decay of $^{12}$C is via a-emission to the ground-state of $^8$Be ($\alpha_0$) and the first excited state (2.9 MeV) of $^8$Be ($\alpha_1$), and by 3-body $\alpha$-disintegration. The relative probability of each mode may be observed and depends on the energy of the incident protons.

The Si solid-state detector system was calibrated by recording the a-spectrum from a $^{226}$Ra source with a MCA. The detector was then placed in the accelerator target chamber so as to observe $\alpha$-particles produced in the reaction. The recorded a-spectra for proton energies between 140 and 175 keV showed evidence of the three modes of decay of $^{12}$C. Even over short running times the spectra reveal an insight into the energy and widths of the intermediate $^{12}$C and $^8$Be nuclear states. We used kinematics to calculate that the energies of the emitted $\alpha$-particles from $^{12}$C would be 5.84 MeV ($\alpha_0$) and 3.88 MeV ($\alpha_1$). These groups together with evidence of the 3-body breakup can be seen in the figure.

This is the usual extent of the experiment. However, it occurred to us that since in each of the two-body breakup cases the recoiling $^8$Be rapidly decays into two alphas, we might be able to detect these and should see evidence of this in the spectrum. Conservation of energy-momentum requires that the recoiling $^8$Be nuclei have energies of 2.92 and 1.94 MeV respectively. We calculated each $\alpha$-pair's travel time to the detector and their angular separation, and concluded that both particles would be detected simultaneously. These predictions are borne out by observation and the groups can be seen in the figure. The sharp group marked $^8$Be$_{0}$ results from the recoiling $^8$Be$_{GS}$, and the broad group ($^8$Be$_{1}$) results from the breakup of the recoiling nucleus in its very short-lived excited state.

It is impressive that the richness and complexity of nuclear reactions may be investigated using truly 'table-top' equipment. The availability of sophisticated equipment in undergraduate labs is important. However more critical is the time and the encouragement to venture beyond the proscribed limits.
Supernova Debris

Supernova debris on earth, in the form of deposits of iron-60, a radioactive isotope of iron occurring on our planet at much smaller levels, has been studied by German physicists. The same team of scientists reported first signs of the deposits five years ago. Back then they analyzed three layers of South Pacific sediment, each over 2 million years thick in geologic time.

The new measurements, acquired at a site some 3000 km away, are much more robust: 28 layers (rather than 3), from deeper depths (4830 m rather than 1300 m), with a better dating method (beryllium-10 dating) and a more accurate estimate of the layers' age (in some cases to within a few 100,000 years). On the basis of their measurement, the researchers deduce that the samples represent the remains of a star that exploded 2.8 million years ago (with an uncertainty of 0.3 million years) at a distance from Earth of some tens of parsecs.

What, if any, were the implications of this splash of foreign matter at the time? Gunther Korschinek at the Technische Universität Muenchen says that, depending on exactly how far away the supernova was, it might have caused an increase in cosmic ray flux for about 300,000 years. (Knie et al., Physical Review Letters, 22 October 2004)

Physics News Update

A train that runs on feathers

What do trains, red blood cells and snowboarding have in common? More than you might think according to scientists who hope to develop a new type of train track based on lessons they have learned from the flow of blood through the body and experiments with a snowboarder. Sheldon Weinbaum and colleagues at the City College of New York claim that a track made of goose feathers is capable of supporting the weight of a moving train (Phys. Rev. Lett. 93 194501).

The lift force experienced by red cells as they move through capillaries is similar to that experienced by a snowboarder, even though blood cells and human beings differ in mass by a factor of 1015. For a snowboarder, friction drag is reduced by a micron-thick fluid film that becomes trapped in the layers of snow beneath the snowboard.

Similarly, the drag on a red cell is reduced because a thin film of fluid is trapped between the cell and the endothelial surface layers in the blood vessel. However, the New York team found that soft porous materials - such as the inside of a blood vessel or soft snow - can generate lift forces that are a million times greater than the predictions of classical lubrication theory.

To measure the pressures that develop during snowboarding, Weinbaum and colleagues used a piston cylinder apparatus that was capable of reproducing the dynamic forces experienced by a moving snowboard. They calculated that the air trapped in the snow can easily support the weight of a 70-kg snowboarder. They also found that the pore pressure underneath a snowboard with a surface area of 5000 square centimetres is about 1.4 kilopascals.

Extrapolating these results to the case of a 50-ton high-speed train, Weinbaum and co-workers estimated that 9.8 kilopascals of pore pressure would be needed to support a train that was 25 m long and 2 m wide. According to the scientists, a porous material with a permeability of 10-8 m2 or smaller - such as goose down - could be used as a track that was capable of supporting the weight of the moving train. Although goose down is too expensive for practical applications, the team points out that there are many synthetic fibres with comparable mechanical properties.

The researchers say their findings could be used to develop a new type of train track. (Weinbaum et al., Applied Physics Letters, 30 September 2004)

A Natural Nuclear Reactor In Gabon

Uranium-235 undergoes self-sustaining fission in commercial reactors and, since uranium lies in the Earth in great quantities, Paul Kuroda predicted that naturally operating reactors are possible under special conditions. These conditions could have existed in the past when the ratio of uranium-235 to uranium-238 was much higher (U-235 has a shorter half-life than U-238).

The conditions necessary for self-sustained fission would be as follows: a uranium deposit where U-235 was present at the 3% level (the level at which modern reactors operate); the presence of material (such as water, carbon, and most organic compounds) that could moderate, or slow down, the neutrons issuing from fission reactions; and the absence of materials (such as Fe, K, Be, Gd) that would absorb the neutrons outright.

In 1972, such a natural reactor was found at the Oklo mine in Gabon, in West Africa. There a 2-billion-year-old uranium deposit some 5-10 meters thick and 600-900 meters wide was bathed by an ancient river. This "reactor" is reckoned to have released 15 gigawatt-years of energy and operated at an average power of 100 kilowatts.

Now physicists at Washington University in St. Louis have defined a likely mode of operation for this ancient reactor and confirmed one of the proposed mechanisms of its self-regulation. According to Alex Meshik, the reactor cycled on (producing heat that boiled the nearby water) typically for 30 minutes and then off (when the now-scant water failed to moderate the nuclear fission process) typically for 2.5 hours. (Meshik et al., Physical Review Letters, 29 October 2004)

Physics News Update

Neutrinos in the news

The Europa link

Peter Gorham, an astrophysicist at the University of Hawaii, has suggested using one of Jupiter's moons to detect high-energy particles such as neutrinos. Neutrinos interact very weakly with matter. This means they can travel enormous distances across the universe and through matter without losing the information they carry about their sources. However, the extreme weakness of their interactions also makes them very difficult to detect. Low-energy neutrinos from the Sun have been observed in a number of Earth-based experiments. However, high-energy neutrinos from cosmic sources are much rarer, so enormous detectors are needed to see them.

When neutrinos travel through large blocks of
ice, they produce flashes of Cerenkov radiation when they collide with protons and neutrons in the ice. These flashes can then be detected and analysed to reveal information about the neutrino and its source. One such detector, AMANDA, is already operating in the Antarctic and can capture neutrinos with energies of up to 1015 eV. Future detectors - including IceCube and ANITA - may be able to capture neutrinos up to 1018 eV.

Garham suggests that the large volumes of ice that exist in various parts of the solar system would be capable of detecting neutrinos at even higher energies, possibly up to 1021 eV. The neutrino-induced events in the ice would be monitored by an orbiting spacecraft.

He suggests that Europa is a good candidate for this as it may have a covering of ice that is larger than that on Earth and that its much lower temperature (about 90 K) means that thermal noise would be lower than in the Antarctic.

Garham presented his idea to NASA at a workshop aimed at brainstorming future missions for the agency.

**PhysicsWeb/New Scientist**

**Neutrino oscillations are here to stay**

New results from the KamLAND experiment in Japan have provided the most direct evidence yet that neutrinos have mass and can oscillate between different flavours. The new evidence comes from measurements of the energy spectrum of electron antineutrinos produced by 53 nuclear power reactors in Japan (arXiv.org/abs/hep-ex/0406035).

Neutrinos come in three flavours - electron, muon and tau neutrinos - that are assumed to have no mass in the Standard Model of particle physics. However, the evidence for neutrino mass is now so strong that this model needs to be revised.

Large numbers of electron neutrinos are produced by the Sun, and all three flavours are generated in supernova explosions. Antineutrinos are the antiparticle equivalents of neutrinos and can be created in fission reactions in nuclear power plants. The Kamioka Liquid scintillator Neutrino Detector (KamLAND) is only sensitive to electron antineutrinos, and previous measurements at the facility have shown that it detects fewer of these particles than it would if they did not oscillate into other flavours.

In the current study, the KamLAND team plotted the number of antineutrinos detected as a function of L/E, where L is the distance travelled by the neutrino and E is the energy measured in the detector. According to Stuart Freedman, who is the spokesperson for KamLAND's US team, L/E can be viewed as being proportional to time in the rest frame of the antineutrino.

The oscillations show that the antineutrinos disappear, and then reappear again. Moreover, the shape of the plot is consistent with neutrino oscillation and inconsistent with a no-oscillation hypothesis and two other models that seek to explain the disappearance.

The results confirm earlier work at the Sudbury Neutrino Observatory in Canada and Super-Kamiokande in Japan that also provided strong evidence for neutrino oscillation.

**PhysicsWeb**

**Quantum errors can be corrected**

Physicists in the US have demonstrated a method for correcting errors in quantum bits based on trapped ions (J Chiaverini et al. 2004 Nature 432 602). The result could bring large-scale quantum computers a step closer to reality.

Quantum bits or "qubits" are very fragile and any noise in a quantum computer could change the state of a qubit quite easily. The technique uses a "pump" to inject qubits into a quantum computer. The technique allows qubits to have strong correlations that are not possible in classical physics. In the NIST experiment it means that any errors that occur in one of the ions have an effect on the other two ions.

The NIST physicists then apply an artificial error of known size to their system, before disentangling the three ions and measuring the quantum state of the two ancilla qubits. Depending on the result of this measurement, they are able to determine what needs to be done to return the primary qubit to its initial state.

**PhysicsWeb**

**Hubble UnCOVERS A Baby Galaxy in a Grown-Up Universe**

Scientists using NASA's Hubble Space Telescope have measured the age of a galaxy that may be the youngest galaxy ever seen in the universe. By cosmological standards it is a mere toddler seemingly out of place among the grown-up galaxies around it. Called I Zwicky 18, it may be as young as 500 million years old (so recent an epoch that complex life had already begun to appear on Earth). Our Milky Way galaxy by contrast is over 20 times older, or about 12 billion years old, the typical age of galaxies across the universe. This "late-life" galaxy offers a rare glimpse into what the first diminutive galaxies in the early universe look like.

The galaxy is a member of a catalog of 30,000 nearby galaxies that Swiss astronomer Fritz Zwicky assembled in the 1930s by photographing the entire northern sky. Though astronomers have long suspected that this galaxy was a younger, due to its primordial chemical makeup, Hubble's exquisite sensitivity allowed astronomers to do a reliable census of the total stellar population in the galaxy. This allowed them to reliably identify the oldest stars harboring the galaxy, thereby setting an upper limit on the galaxy's age.

The baby galaxy galaxy remained in an embryonic state as a cold gas cloud of primitive hydrogen and helium for most of the duration of the universe's evolution. As innumerable galaxies blossomed all over space this late-bloomer did not begin active star formation until some 13 billion years after the Big Bang, and went through a sudden first starburst about 500 million years ago.

Located only 45 million light-years away — much closer than other young galaxies in the nearby 14 billion light-year span of the universe — I Zwicky 18 might represent the only opportunity for astronomers to study in detail the building blocks from which galaxies are formed. It remains a puzzle why the gas in the dwarf galaxy, in contrast to that in other galaxies, took so long — nearly the age of the universe — to collapse under the influence of gravity to form its first stars.

"I Zwicky 18 is a bona fide young galaxy," said Thinh Thuan, professor of astronomy at the University of Virginia, who co-authored the study with Yuri Izotov from the Kiev Observatory. "This is extraordinary because one would expect young galaxies to be forming only around the first billion years or so after the Big Bang, not some 13 billion years later. And young galaxies were expected to be very distant, at the edge of the observable universe, but not in the local universe," Izotov said.
The finding, reported in the December 1 issue of the Astrophysical Journal, provides a new insight into how galaxies first formed. The galaxy I Zwicky 18 offers a glimpse of what the early Milky Way may have looked like 13 billion years ago. Another set of Hubble observations by a different team give a slightly older age of 1 billion years to the galaxy, still keeping it a comparative newborn. Goran Oestin of Stockholm Observatory, and Mustapha Mouhcine of the University of Nottingham, used Hubble’s Near Infrared Camera and Multi-Object Spectrometer to find a population of cool red stars, which are slightly older than the stars seen by the Advanced Camera for Surveys Camera. The results are to be published in Astronomy & Astrophysics.

To prove that I Zwicky 18 is a new galaxy, Thuan and Izotov needed to show that it was devoid of stars from the first several billion years after the Big Bang, the period when a large fraction of stars in the universe were formed. Though astronomers had suspected that the galaxy was exceptionally young, they had to wait for Hubble to provide the needed sensitivity to detect whether or not older stars, faint red giants, existed within the dwarf galaxy. Hubble’s Advanced Camera for Surveys needed a very long exposure, requiring 25 telescope orbits to look for the faintest stars in the galaxy. The presence of old stars in the galaxy would have indicated that the galaxy itself was old, like all other known galaxies in the universe.

Further evidence for the youth of I Zwicky 18 is the fact that its interstellar gas is “nearly pristine,” Thuan said, and composed mostly of hydrogen and helium, the primary two light elements created in the Big Bang, during the first three minutes of the universe’s existence. The dwarf galaxy includes only a sprinkling of the other heavier elements such as carbon, nitrogen, or oxygen that are created later as stars develop. The near absence of such heavy elements suggests that much of the primordial gas in the dwarf galaxy has not managed to form stars that subsequently manufacture heavy elements.

**Swift BAT**

The first space mission dedicated to gamma-ray bursts has been launched from the Kennedy Space Center in Florida.

Gamma-ray bursts are violent explosions that give off intense flashes of gamma rays that can last for times that range from a few milliseconds to about a hundred seconds. The initial burst of gamma rays is then followed by an afterglow of longer wavelength radiation that can last for weeks or even years. It is thought that an average of about one gamma-ray burst takes place every day in the universe, and many believe that they happen when a massive star undergoes a supernova explosion at the end of its life and collapses to form a black hole.

The Swift observatory has three instruments. The Burst Alert Telescope (BAT) will continually observe the sky for flashes of gamma rays. Within 20-75 seconds of spotting an event the spacecraft will be able to “swiftly” reposition itself so that its other two telescopes point towards the burst to observe its afterglow at optical/ultraviolet and X-ray wavelengths. The X-ray telescope will also be used to perform the most sensitive survey to date of the sky at wavelengths below about 10 Angstroms and possibly discover as many as 400 new supermassive black holes.

There are thought to be two main types of burst: long bursts lasting for over two seconds, and shorter bursts with durations of just a few milliseconds. Swift will be fast enough to identify afterglows from short bursts for the first time. Moreover, it will be able to detect fainter - and therefore more distant - bursts than previous satellites. Information from these distant bursts will help astronomers to understand how the first generation of stars formed in the universe.

The mission, which has a total cost of $250m, is a joint effort by NASA, the Italian Space Agency and the Particle Physics and Astronomy Research Council in the UK. It will run for at least two years and is expected to observe at least 100 events per year.

**Physicist solves desert mystery**

From Marco Polo onwards explorers have told stories about strange sounds they have heard in the desert. It is known that the sounds are produced by sand dunes when they avalanche, but the exact mechanism behind the phenomenon has remained a mystery. Now, Bruno Andreacci from the University of Paris-7 has proposed that the sounds come from vibrations in the sand bed that have been excited by collisions between grains of sand (Phys. Rev. Lett. 93 238001).

“Singing dunes are one of the most puzzling and impressive natural phenomena I have ever encountered,” says Andreacci. “The sounds produced can be heard up to 10 kilometres away and resemble a drum or a low-flying jet.” The sounds can be as loud as 105 decibels and have frequencies between about 95 and 105 Hertz. The French physicist took his equipment from Paris to the Atlantic Sahara in Morocco, which contains more than 10,000 crescent shaped dunes known as barchans. The wind in the desert can erode the back of these dunes, causing sand to build up at the top of the dune. When too much sand has accumulated, an avalanche occurs and the dunes start to “sing”.

Andreotti simultaneously measured vibrations in the sand bed and acoustic emissions in the air, and then extracted information about the frequency, amplitude and the phase of these signals. He found that the vibrations in the sand behaved like slow-moving elastic sound waves that were localized at the surface of the dune and had an amplitude that was about a quarter of the diameter of an individual grain of sand.

**Physics Web**

**Magnetic effects seen in water**

Physicists in Japan have discovered that the melting point of water increases slightly in a strong magnetic field. Hideaki Inaba and colleagues at Chiba University found that it increases by 5.6 millikelvin for ordinary water in a field of 6 Tesla, and by 21.8 millikelvin for heavy water (J. Appl. Phys. 96 6127).

Water has relatively high melting and boiling points for a small molecule, and the liquid state can also be denser than the solid state. These properties are thought to arise from the 3D network of hydrogen bonds in the molecule. Recently, it was discovered that the near infrared spectrum and refractive index of water can be affected by a strong magnetic field. While some researchers have suggested that the magnetic field somehow strengthens hydrogen bonds, the exact mechanism behind these results is still a mystery.

Inaba and co-workers measured the melting temperatures of ordinary water and heavy water - in which the hydrogen atoms are replaced by deuterium - with a highly sensitive differential scanning calorimeter (DSC). The changes in the melting points observed with the DSC were proportional to the square of the magnetic field, and also about three orders of magnitude larger than those calculated using the so-called magneto-Clapeyron equation.

As water is diamagnetic, it shouldn’t be affected by a magnetic field. The researchers believe that the thermal motion of the partially charged atoms in the water gives rise to a Lorentz force when a magnetic field is applied. By suppressing the thermal motion, the Lorentz force makes the hydrogen bonds stronger, which could account for the increase in the melting points.

The Chiba team now plans to investigate the effect of magnetic fields on phase transitions in other diamagnetic materials including gallium, indium, mercury and benzene.
PHYSICAL AND HUMAN FACTORS ASSOCIATED WITH THE POLITICS OF WATER

R.E. ROBSON

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Introduction

Popular opinion has it that water, rather than oil or even terrorism, will be the main global political issue of the century. It is already a major issue in this country, a perception which has been sharpened in recent times by the prolonged drought and well-publicised arguments about irrigation - in regard to both its equity and adverse environmental effects.

Like the weather, just about everyone has some opinion about water, but as any weather forecaster will tell you, the general public just doesn’t understand. There is no doubt that weather forecasting can be considered to be a problem in physics - the Bureau of Meteorology requires its forecasters to have a degree in physics and maths - but no one would claim that the issues surrounding water per se are the realm of the physicist in particular, or even scientists in general. Nevertheless the physicist is in a particularly good position to bring to bear the sort of rigorous analysis and reasoning that we apply to all sorts of systems, both naturally occurring and man-made. One of the things we are taught to do is to reduce the essential components of a system or process to their simplest elements, making models where appropriate, and to produce estimates of crucial parameters and constraints, quickly if necessary via “back of the envelope” calculations. In the present note we will attempt to crystallise some of the issues surrounding water in this way, with a view to encouraging further input from physicists to the debate. This is preceded by a brief discussion of the relevant atmospheric physics.

Water in the atmosphere

Elementary physical considerations

Water vapour diffuses upward from the surface through turbulent stirring processes and convection into the troposphere. This is the lowest layer of the atmosphere, some 10-15 km thick, in which most of the phenomena that we associate with weather occur. The concentration of water vapour in the atmosphere is usually < 1% and generally decreases with height. On the whole, tropical regions are sources of water vapour, and the polar regions sinks. Rising air expands and cools adiabatically, until the dew point is reached and water vapour condenses to form droplets, clouds, rain etc. This is the most commonly perceived significance of water in the atmosphere, but it plays a central role in atmospheric energetics as well.

Latent heat

Latent heat is liberated during the condensation process, and therefore it is clear that movement of water vapour is an important mechanism for transporting energy from the surface to the upper atmosphere. Similarly, on a global scale, the poleward flow of moist air from the tropics to the poles transports a large fraction of the net radiative income of the tropics to higher latitudes, which suffer a net radiative loss. The effects are quite large because of the large coefficient of latent heat of evaporation $L = 2.4 \times 10^6 \text{ J kg}^{-1}$.

Radiation

The rotational and vibrational levels of a water molecule are such that it is a good absorber in the infrared, and hence the radiative properties of air itself depend strongly upon water vapour concentration. Water is indeed an excellent “greenhouse” gas, though this is not always recognised. Clouds radiate and absorb much more efficiently than clear air. Thus, for example, the coldest winter mornings generally occur for clear skies, after the earth’s surface has been in good thermal contact with the night sky (temperature ~ 4 K) for several hours. Overall, the distribution of water over the earth’s surface determines source and sink regions for energy, and affects the global circulation patterns.

The atmospheric water budget

Like economists, atmospheric scientists like to refer to “budgets” as they consider income and loss of physical quantities. (Unlike economists, the physicist is constrained by the immutable conservation laws of nature.) Thus for example, an energy budget might detail the way in which incident solar radiation is scattered and absorbed in its passage through the atmosphere to the surface, where it is further partitioned into various modes of energy transfer. Our present interest is in the global atmospheric water budget, shown in the table below:

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Robert Robson first trained as a weather forecaster with the Bureau of Meteorology before completing a Ph. D. in theoretical physics at ANU in 1972. He is a Fellow of the Royal Meteorological Society and the Australian Institute of Physics. Over the past 30 years he has lectured in atmospheric and environmental physics in Australia and overseas.
There are a number of useful pieces of information to be gleaned from this information.

**Precipitation**

The average annual global precipitation (rain, snow, dew) of ~4 x 10^8 m³ is equivalent to a layer of liquid approximately 780 mm deep over the entire earth’s surface. (For comparison, the average rainfall for Australia is roughly 500 mm per year.) Given that the amount of water in the atmosphere at any one time is equivalent to a 24 mm layer, this means that water in the atmosphere is replaced on the average 780/24 ~ 32 times per year, or every 11 days.

**Energetics**

The power required to evaporate 4 x 10^8 m³ = 4 x 10^11 kg of water in one year is approximately 3 x 10^13 kilowatts, or nearly 1/3 of the total solar power reaching the earth’s surface. For comparison, this is about 15 times the rate of kinetic energy generation (2 x 10^12 kilowatts). Latent heat is truly a major factor in driving the global climate.

**The human implications**

**Global constraints**

Barring radical climate change, the third column of Table 1 gives a constraint on the total annual amount of water that can expected from precipitation on a global scale. There are other sources of water of course, both real and potential, for example glaciers (2.9 x 10^13 m³) and the oceans themselves (1.4 x 10^13 m³). As residents of Middle-Eastern countries, Egypt in particular, would also be quick to point out, this precipitation need not be direct, and run-off in rivers (on a global scale equal to 3.7 x 10^12 m³, derived by subtracting column 2 from column 3 of the “land” row in Table 1) can also be crucial for maintaining life. It is clear that the atmosphere represents the main source of water for most of us, and will continue to do so until new technology provides alternatives, eg, large-scale economically viable desalination plants, or the means to harvest icebergs. Note that this constraint represents a real, upper limit on the water supply, which no economic policy can change. Countries may trade water to maximise efficiencies as discussed below, but viewed from a global perspective, we are stuck with column 3 of Table 1 as a limiting factor for formulation of global water policies for the foreseeable future.

**What is the maximum population that the earth can support?**

The answer to this question (from the perspective of water supply alone) requires a knowledge of how much water is required to keep a person alive. In round figures, in one year an average person drinks 1 m³ of water and uses about 100 m³ of water for domestic purposes. Convert to litres (1 m³ = 1000 litres) and adjust for your own purposes by consulting your annual water bill if you wish. The major demand on water, however, arises in agriculture: at least 1000 m³ is required every year to grow the food needed to keep the average person alive. Coincidentally, this is of the same order of magnitude as the water required to grow a tonne of wheat. In effect, some 90% of the overall water budget is devoted to the agricultural sector. Is it any wonder that irrigation is at the centre of the debate on water policy in this and other countries, with seemingly perennial conflict between upstream and downstream users in particular?

If all the precipitation over land, amounting to ~10^11 m³, were to be somehow harvested for the purposes of directly supporting human life, according to the standards described above, then the planet could support no more than N_{max} ~ 90 billion people. Of course there is no suggestion whatever that this crude, gross estimate of the upper limit of population is possible, let alone desirable. For one thing, the environmental effects would be horrendous if all water were channelled exclusively for human use. For another, rainfall is distributed very unevenly over the earth’s surface, and getting water to the population centres is enough of a problem for many of the present N ~ 6 billion inhabitants as it is.

**The saturation factor**

We emphasise that the global water supply is finite, a fact which imposes some upper limit on the sustainable global population. No amount of economic or religious dogma can alter this. N_{max}, as calculated from Table 1 does at least give us something to start with, from which we can work backwards, taking into account the myriad of other factors which determine sustainable and acceptable water distribution. Thus we might write for the maximum possible sustainable global population N_{max} = f_{global} N_{max}, where f_{global} is a global “saturation factor”, which might be put at around 1/15, if it is believed that the present global population N is around the maximum possible, i.e., if N ~ N_{max}. Otherwise there is an awful lot of science, economics and politics required to determine an accurate value f_{global}. One thing is certain, f_{global} cannot exceed unity. Interestingly enough, the corresponding quantity defined on a national basis can, as now discussed.

**National water budgets**

There is of course an enormous variation of precipitation over the earth, and likewise a highly non-uniform distribution of population with, not surprisingly, often a high degree of correlation between the two. For a given country i one can estimate a corresponding value of N_{i, max} from rainfall or other data. If we denote by N_i the current population, and for the sake of argument assume that the maximum possible population is N_{i, max} ~ N_i, we can calculate the corresponding national saturation factor, f_i = N_i/N_{i, max}. The results show a substantial variation over the globe: for Australia, f_i ~ 5 x 10^4, for Egypt, dependent virtually entirely on the Nile for its water.
supply, \( f \sim 1 \), while for the Middle East as whole, \( f \sim 1.5 \). Although the latter figure looks puzzling at first sight, it is indeed quite possible to have \( f_\text{total} > 1 \). The Middle East may be living beyond its domestic water supply means, but it can import water, or virtual water\(^4\), from another country with a low saturation factor, e.g., Australia, in the form of food. There is no such possibility for the totality of countries on the global scale, i.e., \( f_\text{total} < 1 \).

This leads us to the question of trade.

**Trade and the true cost of water**

When I first visited Europe in 1978, supermarkets were stocked with high quality oranges imported from Israel, but nowadays I doubt that you would find any – the Israelis have since established that they were getting a poor return from this particular export, once the true cost of the water used to grow them was taken into account. In effect, as has already been pointed out, exporting food is equivalent to exporting water. One tonne of wheat requires 1000 m\(^3\) of water to produce it, and exporting that amounts to exporting this quantity of water. Conversely, importing one tonne of wheat virtually saves 1000 m\(^3\) of water, or allows it to be used for other purposes - this is how the Middle East has survived its fundamental shortfall in water resources over a long period of time. To pay for these imports they have put the land to other more productive uses requiring far less water, e.g., buildings to house IT companies\(^4\).

One must conclude that there are obvious lessons here for Australia, a net exporter of food and therefore of virtual water, and obvious questions to be asked. For example, is the true cost (however that is measured) of irrigation being properly accounted for and costed into our exports? If not, why not, and who pays?

Time to hand over to the economists and politicians!

**References**


   _Other more recent excellent texts include:_


2. R.E. Robson, “Atmospheric and environmental physics” (James Cook University Physics Dept., 1994)


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**Australian Institute of Physics**

**Women in Physics Lecture Tour 2005**

The **Australian Institute of Physics Women in Physics Lecture Tour** celebrates the contribution of women to advances in physics. The AIP Women in Physics Group is pleased to announce the AIP Women in Physics Lecturer for 2005.

**Professor Helen Quinn,**

FAPS, FAAS

**Stanford Linear Accelerator, USA**

Dirac Prize winner, 2000

**President of the American Physical Society, 2004**

Professor Quinn is another outstanding addition to the Australian Institute of Physics proud tradition of WiP Lecturers.

Professor Quinn is a Plenary Speaker at the 16th National AIP Congress. She will be involved in WiP activities in Canberra during the Congress and will then visit each of the six Australian State capital cities during February 2005 on dates to be confirmed. She may also visit universities and other scientific centres throughout Australia, to give research colloquia. AIP members will be notified when details of the lectures, their times and venues are finalized.

For further information:  [www.aip.org.au](http://www.aip.org.au/)

Or please contact:

Australian Institute of Physics, WiP Lecture Tour Coordinator

Marion Stevens-Kaleeff, School of Physics, UNSW

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Awards for Australia's leading university teachers

On 30th November, a number of Australian academics and teams recognised as part of the annual university teaching awards. Six academics, one team of Indigenous university teachers and four university teams were the winners of the 2004 Australian Awards for University Teaching.

Professor Mark Israel from Flinders University of South Australia took out the top honour - the Prime Minister's Award for University Teacher of the Year. He also won a Teaching Award in the category of Economics, Law, Business and Related Studies. The two awards provide Professor Israel with $75,000 to continue valued work in his field.

The Neville Bonner Award for Indigenous Teaching this year went to a team of indigenous teachers at Curtin University of Technology for their work engaging students with indigenous culture and history.

Winners in the teaching award categories receive a grant of $40,000 each. Institutional award winners receive $50,000 each. The Prime Minister's Award winner receives an additional $35,000. The total pool of awards this year is valued at $515,000.

Physics or science based awards went to:

Professor Joe Wolfe, The University of New South Wales - Joe Wolfe, a Professor of Physics, has developed a new course — Physics Thinking — for Advanced Science students. This small, problem-based course, without lectures, aims to teach students to think like a physicist rather than just "learn some physics". This course is considered to be one of the School of Physics' most important recent teaching innovations. Professor Wolfe has taught a range of subjects including electronics, thermal physics, biophysics and modern physics. He is a prolific author of educational web pages on a range of topics in physics, especially music acoustics, about which he has also written a radio series. He is a highly motivational teacher with tremendous commitment and outstanding talent who is extremely responsive to students' needs.

Griffith University - An Introduction to Science Education Dr Richard Swindell, Senior Lecturer, School of Curriculum, Teaching and Learning. The course Primary Science Education 1 is a compulsory science education course for approximately 350 students enrolled in the Bachelor of Education (Primary). The overarching teaching philosophy of the course is "a desire to instill in our students a positive view of science and the conviction that they can be, and most importantly want to be, effective primary school science teachers". The course uses strategies such as configuring classes to maximise engagement (e.g. by using small group self-paced study as well as lectures), establishing a welcoming and engaging environment and using quality control systems, such as student feedback to steer the teaching and course structure. The strategies used by Dr Swindell and the course teaching team are very well received by students and are highly regarded. The course is considered to be an excellent example of innovation in teaching large first year classes.

DESI press release

Fermilab names new director

Pier Oddone, a particle physicist at the Lawrence Berkeley National Laboratory in California, has been appointed as the new director of Fermilab, the highest energy physics laboratory in North America. Located outside Chicago, Fermilab is home to the Tevatron proton-proton collider and a range of other experiments in particle and astrophysics.

Oddone, who is 60, is best known for proposing an asymmetric electron-positron collider as a way to study the difference between matter and antimatter in B mesons — a proposal that earned him the 2005 Panofsky Prize of the American Physical Society. The collider is called asymmetric because the electron and positron beams have different energies; it is also known as a B factory because it produces enormous numbers of B mesons. The B factories currently operating at the Stanford Linear Accelerator Center (SLAC) in the US and the KEK particle physics lab in Japan are both based on Oddone's approach.

Oddone, who will take up his position on 1 July next year, succeeds Michael Witherell, who is moving to the University of California at Santa Barbara to become vice-chancellor for research. Fermilab is owned by the US Department of Energy and operated by Universities Research Association, a consortium of 90 universities.

100th Anniversary of Electronics

Researchers marked November 16, 2004 as the 100th birthday of electronics, which began with British scientist John Ambrose Fleming's 1904 invention of the first practical electronic device. Known as the thermionic diode, this first simple vacuum tube, containing only two electrodes, could be used to convert an alternating current (ac) to a direct current (dc).

A special AVS meeting session, taking place exactly 100 years after the day that Fleming applied for a British patent on the diode, celebrated this seminal invention and the subsequent evolution of electronic components based on vacuum devices.

Physics News Update

CSIRO to become an Additional Node of the NANO-MNRF.

NANO (www.nano.org.au) is a Major National Research Facility operating as an unincorporated joint venture between The University of Sydney, The University of Queensland, University of New South Wales, University of Western Australia and the University of Melbourne. It receives funding from the Commonwealth and State Governments as well as industry.

It unites major Australian microscopy and microanalysis centres to form an integrated research facility that brings together outstanding equipment and research expertise. It provides the peak Australian facility for the characterisation of physical, chemical and biological materials from the macro to the micro and down to the nanoscale.

In becoming an Additional Node of the NANO-MNRF, all divisions of CSIRO have open access to NANO's facilities and expertise. This includes the state-of-the-art in microscopy and microanalysis platforms such as nanoSIMS, Cryo-TEM, dual-beam FIB, advanced electron microscopy and state-of-the-art atom probe tomography instrumentation.

"This is a significant collaboration between Australia's largest and most diverse scientific research organisation and the university sector, via the major national research facilities program. I am very pleased that the instrumentation and expertise in nanostructural analysis available across NANO-MNRF is aligned effectively with the scientific aspirations of the CSIRO," said Simon Ringer, executive director NANO-MNRF.

"The arrangement provides seamless access for CSIRO to the NANO facilities in a way that will promote collaboration between university and CSIRO scientists. This is also a good example of how research-intensive universities can partner together in MNRFs to achieve synergies that draw in new, higher level relationships that would not otherwise exist." Michael Barber, Executive Director, CSIRO (Science Planning) said "the arrangement between CSIRO and NANO-MNRF gives CSIRO scientists easy access to the major NANO instruments and to an extensive range of other facilities and expertise within the university Nodes."
“This access will benefit CSIRO research activities, including Flagship Programs and Major Cross-Divisional Programs. Many CSIRO teams are already planning their use of NANO facilities for a diverse range of applications including nanostructured materials and devices; energy conversion and storage; bioscience and bioengineering studies; study of foods on the nanoscale; surfaces and interfaces; mineral exploration, production and processing; manufacturing and light metals,” Michael Barber said.

“I look forward to the growth in linkages and to the enhancement of collaboration between the universities and CSIRO that are expected to develop as a result of this arrangement.”

Sydney University media release

Space bubbles and radio waves help researchers probe the early universe

Published this week in the journal Nature, Dr Stuart Wyithe from the University of Melbourne's School of Physics and Professor Abraham Loeb from Harvard University's Astronomy Department describe a method for mapping the universe in the important era when the first galaxies appeared, about 12 billion years ago.

The findings will be used in the design of a new telescope, made of chicken wire and many pairs of dipoles, being designed by the Massachusetts Institute of Technology in collaboration with University of Melbourne, Harvard University and Australian National University research teams.

The research is based on the changing state of the cosmic gas, or the intergalactic medium, in the transition from a smooth simple universe to a complicated one that was filled with galaxies and stars.

Researchers think that 300,000 years after the Big Bang the universe was primarily filled with neutral hydrogen gas and dark matter. It was one billion years after the Big Bang that the first galaxies had appeared and by this time most of the hydrogen had been ionised, or charged. The time in between is known as the cosmic dark ages, which towards the end, consisted of a period of re-ionization of the hydrogen gas. This is the era that Dr Wyithe and his colleagues are primarily interested in.

Dr Wyithe and Professor Loeb's finding is an extension of previous research by the pair (Nature, Feb 26, 2004) that looked at stars and quasars (black holes) that first appeared a few million years after the beginning of the dark ages. These stars and quasars react with the gas surrounding them, ionizing the nearby hydrogen atoms. As more of these stars and quasars appeared, the universe started to fill with bubble of ionised hydrogen embedded in the surrounding neutral gas.

Professor Loeb suggests that over a few tens of million years, the bubbles started to overlap, until eventually the whole universe had been re-ionised. “By simply mapping where the neutral hydrogen gas existed during the time before complete re-ionisation, we can get a picture of where the bubbles were (because they would appear like holes in the map) and what the universe looked like in this era,” he says.

The researchers needed to firstly consider how the expansion of the universe could have affected the size of the wavelength in the time it took to reach Earth today, and secondly how they could map the three-dimensionality of the universe using this knowledge.

Dr Wyithe says, “We know that the radio waves emitted by neutral hydrogen gas have a wavelength of about 21cm. However as cosmic radiation passes through the expanding universe, its wavelength is stretched — a phenomenon known as redshift. Therefore, the further the emitting hydrogen is from the Earth, the more its wavelength will be stretched.

“We estimate that radiation emitted by neutral hydrogen at about the time when re-ionisation was taking place will have a wavelength of about 1.5 metres when it reaches Earth today. And, because of this changing dimension, by looking at different wavelengths we can effectively get a picture of the universe at a specific distance and then step through many different wavelengths to build a three dimensional view.”

Teams from MIT, Harvard University, ANU and CSIRO recently visited the University of Melbourne to discuss plans for the telescope.

Melbourne University press release

Australia Telescope online archive released

ATNF announced the public release of the Australia Telescope Online Archive. This provides access to the Australia Telescope Compact Array archive data files (uncalibrated) for observations taken between 1990 and 2004.

You may access this system at http://atoo.atnf.csiro.au/

ATNF media release

News

Quantum cryptography wins Descartes prize

A collaboration that involves physicists from six European countries and the US has been awarded part of the European Union's Descartes prize for research for their work on quantum cryptography. They share the €1m prize with life scientists studying mitochondrial DNA.

The IST-QuComm collaboration is made up of research groups in Sweden, Germany, France, Switzerland, Austria and the UK, plus a team at the Los Alamos National Laboratory in the US. Quantum cryptography allows two parties to share a secret "key" that could make communications between them much more secure than existing cryptographic techniques by encoding the key with single photons. Any attempts by a third party to eavesdrop on the communications can be readily detected. Quantum cryptography could have applications in electronic communications, e-banking and e-voting.

Progress in quantum cryptography and related areas - such as entanglement and teleportation - has been rapid in recent years. Last year, for instance, physicists at the University of Vienna succeeded in sending entangled photons 600 metres across the river Danube, while a group at the University of Geneva recently demonstrated quantum teleportation at telecom wavelengths through a 4-kilometre optical fibre cable. The IST-QuComm consortium also performed the first ever quantum cryptographic bank transfer over a 6-kilometre fibre link in Vienna this summer.

The prizes were awarded in Prague today by Janec Potocnik, EU commissioner for science and research.

Physics Web

NASA boss to resign

Sean O'Keefe, who was appointed as NASA's administrator in 2001 will leave the Space Agency to pursue a job at Louisiana State University. O'Keefe will reportedly remain at NASA until the White House names a replacement.
This section contains feedback received regarding the content of The Physicist. The letters and emails that appear in this section are edited, if necessary.

To the Editor,

As far as the specific content, layout and design of The Physicist is concerned, allow me to offer some of the feedback requested by you:

- The magazine needs far more content accessible to, and by, the student physics community of Australia. Perhaps students have not been forthcoming in the past when it comes to offering articles and contributions to The Physicist, but a way to remedy this could be to make a more concerted effort to encourage them to do so.
- I don’t recall there being a ‘letters to the editor’ section, though I could be mistaken. I feel this would be an interesting section to include, as many of the articles presented in The Physicist probably prompt a good deal of thought and debate. It would be good to provide a forum for physicists to have their questions and concerns aired publicly, and I think a ‘letters’ section would achieve this.
- More book reviews!!
- The profiles of physicists are always interesting to read and I would be interested in seeing this part of the magazine expanded - perhaps by having Australian physicists send in short biographies of themselves.

That will do for now. Having said all that, let me say that I think the job you’re doing currently is excellent, and I always look forward to reading the publication when it arrives.

Thank you, and keep it up!

Wade Shell,
President, SPACED (Adelaide University Physics Society; Student Co-ordinator, AIP SA Branch)

Hello Corinna,

This is a response to your latest editorial. I write as a graduate of a 3-year BSc (Maths/Physics, Flinders University, 1999), now pursuing a PhD in Applied Mathematics (Fluid Mechanics) at the University of Adelaide.

When I joined the AIP five years ago, The Physicist sometimes made for depressing reading, clearly reflecting the gloom within the Physics community. Over the last three years, however, I have found the magazine to be more inspiring, and perhaps a little more focussed. (No, I’m not calling for false optimism; in fact, I found “The Culture of No” debate relevant and constructive.)

So, which sections of The Physicist do I like?

My favourite is the Samplings section. I also try to find time to read each of the following: News/FASTS/Press Room, President’s Column and Editorial. I may also read a feature article in its entirety, and skim-read the book reviews. Finally, the crossword is always seized upon by my father!

Nearly all of the full-length articles of late have been relevant, in my opinion. My criterion is simple: an article should be complementary to the regular Physics journals. Articles that fit this criterion include the Graduate Destination surveys, the “Culture of No” debate, Branch News, and more. But they also include semi-technical articles (yes, a few equations are fine!) on interesting new lines of research. An example is the Jan/Feb 2004 on photonic crystals in 1, 2 and 3 dimensions - some of them in nature.

You ask whether articles should be limited to the traditional domain of physics. A sensible policy, I think, is a qualified no. “Samplings” and “News” would be great places to tell us what’s happening in the wider scientific world. But all of the full-length feature articles, I think, should be physics-based (or at any rate, clearly relevant to physics). One theme is curiously lacking in The Physicist, though: a vigorous discussion of physics education. True, there is much good news on such matters as student prizes/tournaments and outreach programs to schools and institutes. What is lacking, however, is detailed discussion of Physics courses, from senior high school through to Honours level.

What, exactly, is being taught at various institutions at particular year levels? What, in each case, are style, philosophy, and level of rigour of instruction? Are there significant (perhaps even appropriate) differences between Sandstone and technical universities? Is there much discussion of the “bread-and-butter” issue of service teaching?

On the matter of service teaching, physics has a great deal in common with maths/stats and chemistry departments. I recall attending a half-day mini-symposium on service teaching at ICIAM 2003 in Sydney (ICIAM being a quadrennial international conference on applied maths).

I do recall one Physicist article on teaching a couple of years ago. I don’t recall the title or date, but I do recall the gist of it. The writer, a NSW physicist, was telling how his department had introduced a third-year subject on the nature and role of physics, and the careers it offers. He said that the idea initially met with some opposition from lecturers who feared that it would dilute the quality of the university’s Physics degree. But their concerns were allayed when lecturers and students alike took the new course seriously. In the end, everyone found it tremendously worthwhile.

Once again, keep up the good work!

Nathaniel Jewell

Dear Ms Horrigan,

Your comments in the Editorial of the most recent issue of The Physicist suggest that I am not the only member of the AIP to have failed to respond to your earlier requests for feedback on the publication, but they did remind me again that I should do something more than think about making some comments.

Thank you for your work as Editor over the past two years. I will try to be more explicit below, but let me say at the start that I have appreciated some of the changes, and find I am now much more interested to spend time reading and thinking about its contents. Although incremental change is always hard to detect and measure, a reflection on my response to The Physicist over recent years does suggest to me that in fact the shift has been significant and helpful.

My response is no doubt a comment on my relationship to the AIP and to the world of Physics in general, so a couple of notes may help to put that in perspective. After completing an M.Sc. over 30 years ago, I worked for some years in an area which could be classed within the “narrow” definition of Physics, but have since moved into areas related to Information Technology. However, I have maintained an interest in science in general and Physics in particular, and have continued my membership of the AIP despite the apparent tendency of the organisation to ignore those who may have qualifications and interest, but an area of employment outside the more academic or esoteric and theoretical realms of the discipline.

While there is still much in The Physicist that challenges my understanding of recent developments, one of the things I have appreciated over the past couple of years is an increase in material which is of general interest, and which is helpful in understanding current trends and new directions.

You asked for response to some specific questions, so let me start with those.

Samplings - I find that I read the whole of this section with considerable interest. The nature, length and style of the items are all appropriate, and I have been interested to read about the wide range of issues which have been covered. Although I do not have the motivation to seek more detail, I note the inclusion in most items of some reference to allow those who wish to do so to access further details, and
would encourage this for all items.

Press Room - Once again, a vital source of information about the state of Physics in our society. Although we may be frustrated at the actions (or lack thereof) of government and its related bodies, it is important that you are collecting this information and providing it in a way that makes it accessible.

General or in-depth? - I am probably atypical of your general readership, but from my perspective it is important that *The Physicist* concentrates on general articles. I have always felt that papers presenting in-depth research and results probably belong in more widely recognised and distributed journals (no offence!), and have wondered at times how many people would come to this journal as a source for such material. I am not suggesting there is not a place for articles of reasonable technical content, but would encourage the selection of papers which are accessible to those with a general background in Physics (even those for whom it is 30 years old).

Perspective articles - These are thought-provoking and are of interest. There is always the danger of preaching to the converted, but if you are able to choose or encourage articles from a range of perspectives - even to generate some controversy and debate - this is very helpful.

Favourite section - For the first time in years, I now find that I read right through *The Physicist* (well, perhaps I skip some of the highly mathematical sections and more rarefied articles, but even then it will be after at least reading what the article is about). However, I think I find most interest in the Samplings section. The range of areas covered, and the ease with which the information is assimilated mean that this section is of high value. The "News" section also comes into this area, and perhaps you could consider combining the two, since although I understand the difference, it is probably not an important one. A longer section would not be a difficulty, in my view, as I would not want to see either section cut back as a result of such a combination.

To comment on some other issues:

Paper or web? This is an often-debated issue these days, and there is a tendency to say that everything should be on "the web". Even though I work in the IT area (for IBM), and my life revolves around use of my computer and its associated technologies, I do NOT want to receive this type of information in an electronic format. The paper journal is something that I can have with me, read on the train, pick up while I am waiting for the jog to boil, or even go back to when it is hidden in a pile of other stuff on my desk. Email-based distribution is not, in my opinion, suitable for the distribution of this type of publication.

Frequency: While I know from my own experience in other areas that a two-month cycle is incredibly challenging for a journal like this, I would encourage you to retain it. It provides a good balance between timely information and information overload. It also takes me about two months to find enough time to work from front to back!

Personal profiles, obituaries: These are always of interest, although the quality is very dependent on the author. You have been successful in presenting some very interesting papers recently. Incidentally, I noted a death notice recently for Prof John Cowley, who was at Melbourne University in the late 1960s (and was my supervisor at that time). His contribution to crystallography was very important, and I hope you will be able to include a significant obituary and review of his life and work in a future issue.

Book Reviews: Perhaps it is just my generally more favourable reading of the journal recently, or perhaps it is the selection of books, but even though I have little likelihood of purchasing most of these books, I do find the reviews to be interesting and of a high quality. The selection in the latest issue was very interesting.

AIP News: It is important that *The Physicist* continue to provide information about the Institute to its members, but I find many of the Branch News articles long, wordy, and of little interest. When a speaker has made a presentation to a Branch, it may be of interest to know that it occurred, but if the material is of sufficient interest to be written up as a paper, it should be done in that format. For example, in the latest issue, there is a summary of a lecture about the history of astronomy in Tasmania. This was of some interest to me as my Grandfather was a member of the major Expedition to observe the total eclipse of the sun in 1910 (not mentioned in the article), but because it was presented merely as part of a Branch report, it might easily have been overlooked. I suggest that there could well be a place in the journal for short articles based on such lectures, which would give them a more appropriate prominence and increased readership. This would decrease the size of the Branch News section, also, perhaps, encouraging more people to read what is currently often lengthy and tedious material.

Scientific Articles: I have made some comments already about the need to ensure these are accessible to the general Physicist. I am left wondering, at times, what is the level and nature of the review that you undertake of these prior to publication. Clearly it is important that they are reviewed by experts in the relevant field, but I would hope that you also send them for review to someone who is not an expert and who would be able to check them for readability and comprehension for the general (I mean general Physicist, not general lay person) reader. As an example, the paper Bending waves in a wrong way, in Volume 41, made fascinating reading, but I felt that even though there was an attempt to avoid too much technical or highly theoretical material there was still an assumption of a detailed familiarity with this area of Physics research. Maybe that is a valid assumption for your readership in general, but I would like to see *The Physicist* being of interest to anyone who has a basic degree in Physics.

To conclude on this note, and to echo remarks I made in a letter to the President of the AIP some years ago, I believe that the future of the AIP will be more and more dependent on our ability to interest, attract and retain those qualified in Physics, whether or not they are employed specifically in this field. I realise that there are probably some who see the role of the Institute in terms of support for and a forum for those who do work within the more narrow definition of Physics, but I hope that I can continue to find value, interest and enjoyment from my own membership.

Yours sincerely,

Geoffrey R Grimson, M.Sc, B.A, MAIP

Dear Corinna,

I am an Australian physicist working temporarily overseas in Canada. From this perspective the *Physicist* is a welcome publication which helps to keep me in touch. Despite computers being all around us, I prefer the paper copy which I can read at my leisure wherever I want.

I spend about 2 to 3 hours on each issue, typically reading the president's column and the editorial, followed by whatever else seems interesting. Having written many book reviews for the Physicist myself in the past, I always spend some time going through the reviews. In the Sept/Oct issue I enjoyed the Press Room, please keep this up. I also enjoyed reading about the young physicists' tournament. The questions are fun and I intend to share some with my students.

Therefore, in summary, I like the Physicist and think the coverage and depth is just about right.

Associate Prof Tomos Kron, PhD, FInstP, FACPSEM, FCCPM
London Regional Cancer Program, London Health Sciences Centre, Department of Physics and Engineering, London Ontario, Canada
THE PHYSICIST'S CROSSWORD NO. 17

by Conrad Burden

Across
1. Physicist constantly found behind the bar (6)
4. Surprise! Over two thousand pounds is hidden in tree (8)
9. 'Hydrocarbon polymer' can't be rewritten in old English (6)
10. Tacit nuns poke no-one in the middle (8)
11, 26. Popular account of denatured ribosome; fifty hear it (1, 5, 7, 2, 4)
13. Positron smashing into planet (10)
14. How many can be found in the smallest size room? (4)
18. Joe and nun Mary produce qualified tradesman (10)
21. Aunt treasurer made manager of food outlet (12)
23. Not the usual rendition of one act play (8)
24. Kangaroo shooter said to blush (6)
25. Beach souvenir reportedly collected by lady's astronomer (8)
26. see 11

Down
1. Particle found in tail of scorpion (4)
2. Masses, unlike charges, do (7)
3. Console pilots (7)
5. Accelerator constructed from Ronny's torch (11)
6. Resist having to sit beneath upturned chamber pot (6)
7. Smokier, chaotic and irritating (7)
8. Oh, no money, sadly, after the wedding (9)
12. Take away order a ripe export (11)
13. Wake following algebra lesson in America (9)
15. Man and beast, we blossom upwards (8)
17. Tester of metals in the role of speaker (7)
19. "I do not leave it until the last minute to study for my exams", said rising radio engineer (7)
20. The result of mother raising Cain (6)
22. Payment includes resistance to let go (4)

Edna Cordburn, Dr. Duncan Bore, Baron Dud (CERN), C. D. Roundbrane, Bad Corn Under, Born and Cured, Dr. Car on U-Bend and Crude Brandon very much regret that, due to pressure of work, they are unable to continue compiling the Physicist's Crossword. They thank you for allowing them to divert them from their work for the last three years.

Solution of Crossword No. 16

The Physicist Volume 41, Number 6, November/December 2004 190
CONFERENCES & MEETINGS

2005

January 11 - 14
International Conference on Relativity
Amaravati, India
www.amtuni.com/

January 14
Establishing, Optimising and Producing Microarrays
London, UK
www.euroscicon.com/comp://www.amtuni.com/

January 31 - February 4
16th Biennial Congress 2005 The Australian Institute of Physics
“Physics for the Nation”
The Australian National University,
Canberra ACT 0200, Australia
Contact: ACTS Conferencing Pty Ltd
Tel: 02 6257 3299 Email: aipc2005@ausconvservices.com.au
aipcongress2005.anu.edu.au

February 6 - 12
Planet Formation and Detection
Aspen, Colorado
www.astro.northwestern.edu/AspenW05/

March 7-8
Science Meets Parliament
Mar 2005, Canberra, ACT
www.fastsci.org

March 13 - 17
Eleventh Australian International Aerospace Congress,
Melbourne Convention Centre, Melbourne, VIC
www.aiac-11.com

April 27-28
Science 2005
Melbourne Convention Centre

May 8 - 12
Nanotech2005
Anaheim, USA
www.nsti.org/Nanotech2005/

Nanotechnology Conference and Trade Show
Anaheim, USA
www.nanotech2005.com

November 3-5
Asia-Pacific Space Agency Forum
Canberra, Australia
http://www.aprsaf.org/

November 27 – December 2
International Conference on Neutron Scattering
Sydney Convention Centre, Australia
www.icns2005.org
ADAM AND EVE AND THE COLLAPSE OF THE MORAL WAVE FUNCTION

NEVILLE H. FLETCHER

Research School of Physical Sciences and Engineering,
Australian National University, Canberra 0200

An analogy is drawn between the collapse of the quantum wavefunction caused by observation, as exemplified by the famous Gedankenexperiment of Schrödinger’s cat, and the collapse of the metaphysical moral wavefunction into one or other of the states ‘good’ or ‘bad’. Again observation is necessarily involved, and perhaps making that observation requires certain innate or conferred abilities.

A study of quantum mechanics is included in few, if any, courses on religion or moral philosophy. That is a pity, because it can provide insights into some very basic questions, as I hope to demonstrate. But first, let me remind you of a fragment of the subject appropriate to the present discussion — the wave function and the strange case of Schrödinger’s cat.

In quantum mechanics the state of a simple system such as an electron is completely specified by its wave function, a mathematically complex function that extends throughout all space, though it is usually nearly zero except in a small locality. According to the orthodox ‘Copenhagen’ interpretation, the square of the wavefunction amplitude, or more generally of its projection upon some sub-space of its definition, allows us to calculate the probability of the particle being found in that particular place or state. This is particularly interesting in the case of a radioactive atom, which gradually evolves from its intact to its decayed state, the wavefunction after one half-life being an equal superposition of these two possible states. The only way in which the state of the atom can be determined is to perform an observation or experiment on it, in which case the wave function ‘collapses’ to one or other of its possible states and we see either an intact or a decayed atom.

Actually much larger objects also have wave functions that are made up from the wave functions of all the particles they comprise. We could even say that a cat has a wave function, though it would be hopelessly complex to specify. But this leads us on to the famous ‘thought experiment’ proposed long ago by Erwin Schrödinger. Suppose we have a cat in a closed box, and that also inside the box is a radioactive atom. Inside the box is also a piece of equipment that will detect the decay of the atom and, when this occurs, smash a phial of cyanide that will kill the cat. Now we know that quantum mechanics is a reliable theory, and what it tells us is that, after a time equal to the half-life of the radioactive atom, the wave function of that atom will be an equal superposition of the wave functions of an intact atom and a decayed atom. No real problem about that. But quantum mechanics also tells us that the wave function of the cat will similarly be an equal superposition of two wave functions, one representing a live cat and one a dead cat. According to the theory, the cat actually is in a superposition of these two states! But if we perform an experiment, for example by opening the box and looking inside, then the wave function of the cat will ‘collapse’ to just one of these states, so that nothing strange seems to have happened. The only puzzle is the peculiar existence of the cat in its mixed state of being both alive and dead before someone performs the necessary observation or experiment. Resolution of this puzzle from a physics perspective has been the subject of much discussion in the scientific literature, and several easily understandable modern expositions are available.

So what does all this have to do with Adam and Eve in Judaeo-Christian-Islamic religions? You will remember that, according to the King James version of the book of Genesis, when Adam and Eve dwelt alone in the Garden of Eden, “They were both naked, the man and his wife, and they were not ashamed.” They lived happily in this state until the advent of the serpent who was “more subtle than any beast of the field which the Lord God had made.” And the serpent tempted Eve to eat the fruit of the forbidden tree, saying “God doth know that in the day ye eat thereof, then your eyes shall be opened, and ye shall be as gods, knowing good and evil.” Eve ate and gave the fruit also to Adam “and the eyes of them both were opened, and they knew that they were naked.” God was greatly displeased at this development: “Behold, the man is become as one of us, to know good and evil: and now lest he put forth his hand, and take also of the tree of life, and eat, and live forever: therefore the Lord God sent him forth from the garden of Eden.”

The serpent is widely thought to have been the angel Lucifer, the ‘bearer of light’ or perhaps the ‘bringer of enlightenment’, who was subsequently, or perhaps before this, exiled from heaven and sent to dwell in hell for ever.

Before this ‘fall from grace’, Adam and Eve were described by a wave function in which actions were neither good nor evil, because these terms had no meaning for them, or indeed for anyone but God. Life was perfect and there were no internal conflicts or feelings of guilt. But then the serpent initiated the equivalent of an observation of the system by providing to Adam and Eve the fruit of the tree that enabled them to distinguish between good and evil — the wicked ‘tree of knowledge’. They could then observe all their actions and
cause the wave function describing them to collapse to a state either good or evil. And indeed Adam and Eve appeared compelled to perform this observation to collapse the wavefunction at all possible times. Every action was now seen to be either good or evil. The collapse of the wave function in the moral coordinate served as the basis for Judaeo-Christian religion.

It is not clear why God disapproved so strongly of this action. Indeed the subsequent priestly foundations of Christianity depend on their very existence on the dichotomy between good and evil, on atonement for evil acts and promised rewards for those that are good. Perhaps the danger was not so much in the knowledge gained from this tree, but rather that, having eaten this fruit, Adam and Eve might well go on to eat from the 'tree of life' and so live forever, thus becoming serious rivals to the previously all-powerful God. This was not to be contemplated, and banishment was the only sure solution.

Setting aside the religious myths enshrined in this biblical account, it is clear that the distinction between good and evil is an important part of human civilised behaviour. It is taught in the home, encoded in laws, and prayed about in religious institutions. Different religions and legal codes may have slightly different definitions of the moral distinction, particularly in religious matters, but the general desire is to enforce a code of behaviour that is for the common good, or at least for the good of the tribal group involved, and to maintain the authority of the priests.

It is an interesting question whether other intelligent animals have anything comparable to this dichotomy in their mental makeup. It seems quite clear that many species of higher animals, such as primates, dogs and cats, have a significant level of self-awareness, and mental states quite similar to those of humans. But for dogs, at any rate, their God is nearly always present and quick to make moral judgments — "Good dog!" or "Bad dog!". They have had no need to eat of the forbidden tree or make their own moral judgments, and their God did not exile them from his garden.

References


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- Low temperature cleaning.
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- Post growth surface treatment / improvement.
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SmP dates confirmed

The Parliamentary sitting schedule for 2005 has been announced. The Science meets Parliament dates of the 7th and 8th of March 2005 are confirmed. The Great Hall at Parliament House has been booked for the Industry dinner on the 8th (rather than the venue at Old Parliament House).

DEST has increased sponsorship for next year's event to $25,000.

Registration forms will be on the FASTS website sometime in December.

FASTS election results

At the FASTS AGM held in Canberra, Professor Tom Spurling was elected President-elect of FASTS. Tom will serve as President-elect for one year and become President in 2006-7. Tom is currently Dean Dean, Faculty of Engineering and Industrial Sciences, Swinburne University of Technology. Previous positions include:

- 2003-4 Professor of Molecular Science and Director, Industrial Research Institute Swinburne, Swinburne University of Technology
- 2001-2002 Principal Advisor CSIRO Molecular Science
- 1999-2001 Project Leader, CSIRO MSS-LIPI, Jakarta Minister-Counselor (Research Cooperation) Australian Embassy, Jakarta
- 1997-1998 Chief, CSIRO Molecular Science
- 1991-1997 Chief, CSIRO Chemicals and Polymers

Tom is an Elected Fellow - Royal Australian Chemical Institute, Elected Foundation Fellow - Federation of Asian Chemical Societies, Elected Fellow - Australian Academy of Technological Sciences & Engineering and Elected Fellow - Australian Institute of Management. In addition to his strong academic and publications record, Tom has extensive experience with commercialisation and technology transfer issues including being a director of two technology-based firms.

The positions of Secretary and Treasurer were also voted on with Professor John O'Connor and Mike Smith being returned unopposed.

Congratulations to all candidates.

National Collaborative Research Infrastructure Strategy

As part of BAA2, the Government announced it would be changing funding arrangements for research infrastructure taking into account the comments and recommendations of the 2003/4 National Infrastructure review which was released in March this year.

The Government is establishing the National Collaborative Research Infrastructure Strategy (NCRIS). The advisory committee for NCRIS are holding a series of consultations with the sector starting Monday 29th of November.

It is intended that a Strategic Roadmap and NCRIS funding guidelines be released in June 2005 after consultation period and submissions process.

The timelines for NCRIS are:

- Consultation visits - November 2004-December 2004
- Written submissions due - February 2005
- Further development of ‘Strategic Roadmap’ - February – March 2005
- NCRIS funding guidelines issued - June 2005
- Strategic Roadmap published - June 2005
- Identification and development of initial investment priority projects - July 2005-June 2006
- NCRIS project funding - July 2006-July 2011

The advisory committee has also provided a consultation paper to guide discussions and subsequent submissions. FASTS will attend the consultations and will make a submission, however members may also like to participate.

Report on the 2003 PISA study

ACER have released a report on the 2003 PISA study. This is the 2nd stage of the OECD Programme for International Student Achievement (PISA) which looks at literacy, numeracy and scientific literacy among 15 year olds.

According to Minister Nelson’s press release Australia was outperformed by only one country in reading literacy (Finland), by three countries in scientific literacy (Finland, Japan and Korea); by four countries in mathematical literacy (Hong Kong-China, Finland, Korea and the Netherlands), and by four countries in problem solving (Korea, Hong Kong-China, Finland and Japan).

However, he points out the survey also shows more than one in ten of our students achieved only at the two lowest levels of literacy.

The 2003 PISA focused on mathematics (the next round in 2006 will focus on scientific literacy).

Again from Minister Nelson’s media release: “Australian students were generally more confident about their maths abilities than the OECD average, but reported only an average level of interest and enjoyment of maths. Australian girls tended to be less confident and more anxious about maths than boys.

The socioeconomic background of students had less of an impact on maths performance in Australia than across the OECD average, and in terms of our maths results we have been described by the OECD as a “high quality/high equity” country.”


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The Physicist Volume 41, Number 6, November/December 2004


SCHRÖDINGER’S CAT AND INTERACTION-FREE MEASUREMENT

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Introduction

In a recent article, N. Fletcher presented arguments in support of the view that the wave function of a quantum system does not represent the system concerned but represents our knowledge of that system. That view is usually taken to mean also that we cannot speak about the properties of the quantum system itself (or that quantum systems do not have properties), except perhaps that we can attribute to a quantum system a property which is the outcome of a measurement performed on the quantum system. This approach avoids the many epistemological difficulties that are raised in other versions of quantum mechanics and it is arguable that any other interpretation of quantum mechanics should properly be regarded as a different theory. Another advantage of the approach is that we can account for a change or “collapse” of a wave function as a change in our knowledge, not in the quantum system itself.

The purpose of this article is to discuss an experiment in which it is possible to collapse the wave function of a target quantum system without apparently interacting with it. The term “interaction-free measurement” is used to describe the type of experiment involved. It has been pointed out that a better term might be “energy exchange free measurement” because, for the method to work, there must be an interaction described by a Hamiltonian with non-zero matrix elements connecting the target quantum system in question with other parts of the apparatus. The peculiarity is that in the runs of the experiment which are used to collapse the target system’s wave function, there is no exchange of energy with the target system and there is usually no change in any other measurable quantity of the target system. In other runs of the experiment, which are discarded, there is an exchange of energy between the target system and other parts of the apparatus, resulting in a dramatically different experimental outcome. Thus the collapse of the wave function in the runs of the experiment of interest appears to take place as a result of the mere potential for interaction with the target system and in circumstances where there is evidence that an actual interaction with the target system did not take place. After the non-interaction, in the above sense, has taken place, it is possible to choose whether to collapse part of the wave function of the quantum system in question, or not to do so, depending on the type of measurement performed on the particle which had no direct interaction with the quantum system.

It seems unreasonable that not interacting with a quantum system could cause a change in any physical property, especially the collapse of the wave function, of the quantum system itself (assuming for the moment that properties of quantum systems is a meaningful concept). On the other hand a change can take place in our knowledge of something without a physical change in the thing we know about (e.g. that usually happens when a copy of The Physicist is read). Therefore the experiment to be described adds support to the idea that the wave function represents our knowledge rather than the quantum system itself.

Interaction-free measurement version of Schrödinger’s Cat

The remarkable concept of interaction-free measurement (IFM) in quantum mechanics was brought to light in 1993 by Elitzur and Vaidman. It has many significant and fascinating consequences and here we consider an application to the Schrödinger Cat paradox.

We deal with the usual case of a sealed, opaque box containing a quantum system, a hammer, a vial of cyanide and a cat. The quantum system can evolve into a superposition of two states, $\psi_1$ and $\psi_2$, which are such that $\psi_1$ causes the hammer to fall, breaking the vial of cyanide and killing the cat with probability equal to 1 and the other state $\psi_2$ leaves the hammer in place, the vial intact and the cat alive. It is arranged that there is a 50% probability that the quantum system evolves into either state and therefore the wave function of the contents of the box is

$$\psi_{box} = \frac{1}{\sqrt{2}} \left( \psi_{\text{hammer}} \psi_{\text{vial}} \psi_{\text{dead}} + \psi_{\text{hammer}} \psi_{\text{vial}} \psi_{\text{dead}} \right)$$

(1a)

$$= \frac{1}{\sqrt{2}} \left( \psi_{\text{vial}} + \psi_{\text{dead}} \right)$$

(1b)
at the time of interest, where \( \psi_{\text{up}} \) is the wave function of the hammer in the up position, etc and \( \psi_{\text{down}} \) and \( \psi_{\text{dead}} \) are shorthand for the corresponding product wave function in the first line of the equation.

If we open the box we will ascertain whether the cat is alive or dead and change or "collapse" the wave function to either \( \psi_{\text{alive}} \) or \( \psi_{\text{dead}} \) respectively. What is meant by the "collapse" of the wave function in the Schrödinger Cat case is discussed further below. Even if we do not go so far as to open the box, it would appear that we would need to subject the apparatus to some sort of physical interaction to ascertain whether the cat was alive or dead, leading to the wave function collapse we are considering. If the change in the wave function is always associated with a physical interaction with the box, it is not obvious that the change in the wave function is purely a change in our knowledge rather than a real change in the physical system. Consequently it is open for someone to defend the proposition that the change in the wave function reflects a physical change in the system as a result of the interaction rather than simply a change in our knowledge. As the original article referred to shows, it is difficult to defend that position. Nevertheless so long as we have to make a physical intervention such as opening the box, we could not eliminate the possibility that wave function collapse does not merely reflect a change in our knowledge but corresponds to a physical change in the quantum system itself, contrary to the explanation advanced in the original article.

It is therefore significant that we can find out, in some cases, whether the cat is alive or dead without any direct physical interaction with the box. The last point is worth specifying more precisely. Using IFM, we can find out whether the cat is alive or dead when the box containing the cat is in a region of space which no particle enters or leaves and in which there is no electromagnetic or gravitational or any other type of physical field or potential. Here the term "particle" includes photons, gravitons, neutrinos, etc. To see how to do this, consider the following experiment.

Let the Schrödinger Cat box have a small passage drilled through it (and with transparent windows on the holes to stop the cyanide escaping, if any is released). The passage is obscured by a portion of the hammer if the hammer has not fallen but it is completely transparent if the hammer has fallen. We could determine if the cat is alive or dead by probing the small hole in the box with a photon: if the photon passes through, we know the hammer has fallen and the cat is dead; if the photon does not pass through, we know the hammer is in place and the cat is alive. In both cases we have collapsed the wave function either to \( \psi_{\text{dead}} \) or to \( \psi_{\text{alive}} \) respectively. This method does not satisfy the criteria for an IFM because it breaks the condition that no particle passes into or out of the region containing the box. The striking of the hammer with a photon or the passage of a photon right through the box, both constitute a physical interaction with the box and its contents.

It is quite extraordinary that the IFM method allows us to ascertain whether the cat is alive of dead without striking the hammer with a photon or passing a photon right through the box. To keep ourselves honest, let us assume that the hammer is so delicately poised that any interaction with the hammer, including the striking of the hammer by a single photon of extremely long wavelength will cause the hammer to fall releasing the cyanide, etc. The only limit on the sensitivity of the hammer is that it must not respond to quantum fluctuations set by the uncertainty principle as a result of confining the position of the box so that it can be measured and the position of the hammer such that it obscures the passage through the box if it has not fallen. The hammer must be insensitive to photons of wavelengths longer than some wavelength \( \lambda_{\text{min}} \) set by the uncertainty principle, otherwise the hammer could fall at any time during the experiment due to the fluctuations. Let us use photons whose wavelength is many orders of magnitude less than \( \lambda_{\text{min}} \) and to which the hammer is most certainly sensitive.

It would appear that by using the apparatus just described, we could never ascertain that the cat was alive because our only access to the box is the passage through it and if the hammer has not fallen, and therefore the cat is alive, any attempt on our part to ascertain this, even by passing a single photon into the passage, will cause the exquisitely poised hammer to fall and kill the very cat we would otherwise be able to confirm is alive. Despite this apparently irrefutable reasoning, IFM tells us that we can ascertain that the cat is alive.

We need a Mach-Zehnder (MZ) interferometer as shown in Fig. 1. The beamsplitters have equal reflection and transmission coefficients and the lengths of the two arms of the interferometer are adjusted so that, in the absence of the box, a photon entering on path \( a \) will with probability equal to one leave the interferometer via path \( e \) because of interference between the paths \( c \) and \( d \). If one arm of the interferometer is blocked, then a photon entering on path \( a \) will be absorbed in the blockage with probability equal to 0.5 or, since the possibility of interference between the paths \( c \) and \( d \) is then removed, leave the interferometer on path \( e \) with probability equal to 0.25 or on path \( f \) with probability equal to 0.25.

Let us assume the box has been prepared and kept in the dark and the state of the box is \( \psi_{\text{box}} \) as given by Eq. (1). The box is positioned so that the path down arm \( d \) of the MZ interferometer coincides with the passage through the box. A single photon is passed down path \( a \) and is represented by \( \phi_0 \). The initial state of the box and photon is \( \phi_0 \psi_{\text{box}} \) and after passage through the first beam splitter \( BS_1 \), the state evolves as

\[
\phi_0 \psi_{\text{box}} \rightarrow \frac{1}{2} (\psi_c + i \psi_d)(\psi_{\text{dead}} + \psi_{\text{alive}})
\]

using Eq. (1b). If the hammer has fallen \( \psi_{\text{dead}} \) a photon passing down that arm of the interferometer will pass through the passage completely unimpeded and the interferometer behaves as if the box was not present, i.e. the photon emerges on path \( e \). If the hammer has not fallen \( \psi_{\text{alive}} \), path \( d \) of the interferometer is blocked and \( \phi_0 \) becomes \( \psi_{\text{scattered}} \) because the hammer will scatter the photon out of the interferometer. Thus the initial state further evolves as
\[ \psi_\text{cat} \psi_\text{atom} = \frac{1}{2} \left[ (\psi_+ + i\psi_-) \psi_\text{atom} + (\psi_+ - i\psi_-) \psi_\text{atom} + i\psi_+ \psi_\text{atom} \right] \quad (3a) \]
\[ = \frac{1}{2} \left[ \sqrt{2} i \psi_+ \psi_\text{atom} + \frac{1}{\sqrt{2}} (\psi_+ + \psi_-) \psi_\text{atom} + i\psi_- \psi_\text{atom} \right]. \quad (3b) \]

Consider the case when the photon is detected on path \( f \). That case happens in 1/8 of cases and when it does, we know with certainty from an examination the wave function in Eq. (2) that the cat is alive because the only term containing \( \psi_+ \) is with \( \psi_\text{atom} \). A modification of the original proposal allows the IFM detection to take place with efficiency approaching 100% (i.e., \( f \) will occur in 50% of cases, since the hammer is in place and the cat is alive in 50% of cases).

If the wave function represents our knowledge and not the quantum system itself, we have no basis for reasoning about what is happening to the quantum system during the experiment. Nevertheless, it is tempting for a physicist to do so and we can arrive at the same result as the examination of the wave function by the following reasoning. If the hammer had fallen both arms of the interferometer were free and the photon would have taken path \( e \) with probability equal to one because of the fact that the interferometer was deliberately set up. Since the photon was detected at \( f \), both arms of the interferometer cannot have been free, therefore, the hammer had not fallen and it blocked path \( d \). It also follows from the fact that the photon emerged on \( f \) that the photon did not go down arm \( d \), because then it would have struck the hammer. (Striking the hammer is the term involving \( \psi_\text{atom} \) in Eq. (2).) Therefore from the fact that the photon emerged on \( f \) we can conclude that the hammer is in place and the photon took path \( c \). Therefore the cat is alive. Thus we have gained some knowledge about the cat and if we change our wave function of the contents of the box to \( \psi_\text{cat} \), accordingly, we will more accurately account for any future experiments on the box and its contents, including the cat. For example, after we detect the photon on \( f \), we can look in the box (taking care to catch the hammer before it strikes the vital for our own safety) and with probability equal to one we will confirm the cat is indeed alive.

It is noteworthy, to say the least, that this collapse of the wave function occurs in the circumstance that there has been the mere potential for physical interaction with the cat and the box but this potential interaction is expressly known not to have become actual. Nothing above the level of quantum fluctuations due to the uncertainty principle, which would have occurred whether the box was on path \( d \) or not, has exchanged energy with the hammer in this experiment.

\section*{Discussion}

The fact that the wave function collapses without any direct interaction having taken place with the physical system is strong additional support for the idea that the wave function represents our knowledge rather than a property of the physical system. Further consideration gives even more support.

Firstly we should acknowledge that the (non-IFM) Schrödinger Cat paradox is not quite as paradoxical as is often made out. In any quantum calculation involving the properties of the box or its contents, we would use \( \psi_\text{atom} \) in Eq. (1b) and we would be involved with four types of terms: two "diagonal" terms involving \( \psi_\text{atom} \) with \( \psi_\text{atom} \) and \( \psi_\text{atom} \) with \( \psi_\text{atom} \) and two "off-diagonal" terms or "cross-terms" involving \( \psi_\text{atom} \) with \( \psi_\text{atom} \). It is the existence of the cross-terms which gives quantum mechanics its peculiar nature.

Because the cat, and indeed the hammer and the cyanide, are macroscopic objects involving many independent components, the cross-terms, which would normally play an important part, are so unimaginably small that we can neglect them for all practical purposes (FAPP). The only remaining terms in any calculation (FAPP) are \( \psi_\text{atom} \) with \( \psi_\text{atom} \) and \( \psi_\text{atom} \) with \( \psi_\text{atom} \). In that case, it is proper to refer the system as a mixture. FAPP at least, we should re-write the state of the box and its contents in a different form reflecting that it is a mixture and not a "pure" state whether we or not measure it using IFM or otherwise. It is then correct to say that any particular example of the system is either \( \psi_\text{atom} \) or \( \psi_\text{atom} \) and we just don’t know which. Situation is exactly the same as tossing a coin and not looking at the result. It is logical to proceed on the basis the coin is heads with a 50% chance and tails with a 50% chance. The coin is either one or the other and looking will resolve our ignorance and "collapse" the representation of our knowledge of the coin onto either "heads" or "tails". The cat is just the same and (FAPP) it is unproblematic to treat the wave function as a representation of our knowledge (or ignorance) of what is already objectively the case.

But there are many cases in quantum mechanics when the cross-terms resulting from a wave function like that in Eq. (1) are vitally important. In those cases, we cannot say the quantum system is FAPP in one state or the other and that the wave function merely reflects our ignorance of which one. In other words, there are many cases in which the quantum system is in a true superposition and not a mixture.

It is then very interesting to ask the question: does an IFM always collapse a true superposition? To deal with this question, we can consider a quantum system which is in a superposition of being located in one of two boxes and in both cases being in a superposition of two other "internal" states. If we determine which box the quantum system is in by an IFM, that part of the superposition will collapse but does the IFM collapse the second, internal superposition? If the answer is yes, the quantum system would end up in one state or the other and not exhibit any future effects due to any cross-terms. But could this happen simply because something could have, but expressly did not, interact with it? Could that happen because the wave function representing our knowledge changed but there was no physical interaction to cause the quantum system itself to change?

Before answering the question, let us be specific: there is a quantum system either in arm \( d \) of the MZ or out of it and, in both cases, it is also in a superposition of two internal states labeled + and -. The wave function can be written.
\[
\psi = \frac{1}{\sqrt{2}} (\psi_n^+ + \psi_n^-) \\
= \frac{1}{2} \left[ (\psi_n^+ + \psi_n^-) + (\psi_n^{+*} + \psi_n^{-*}) \right]
\]

(4a)

(4b)

If the quantum system is in state \( \psi_n^+ \), let it scatter right-circularly polarised light, but not left-circularly polarised light \( \sigma^- \); if it is in state \( \psi_n^- \), let it scatter only left-circularly polarised light \( \sigma^+ \) and not \( \sigma^- \). Let the box be placed in arm \( d \) of the interferometer as before and perform theMZ experiment as before with a single linearly polarised photon, i.e. one with both \( \sigma^+ \) and \( \sigma^- \) components. The state \( \psi'' \) of course leaves the arm free to the photons we use for the experiment.

If the photon is detected on path \( f \) we know the quantum system is in the box and the wave function collapses in the sense that \( \psi'' \) is eliminated. The question of what happens to \( \psi_n^+ + \psi_n^- \) has, in an analogous context, been considered by Pöting et al.

If the detection of the photon on path \( f \) is insensitive, the remaining superposition \( \psi_n^+ + \psi_n^- \) is further collapsed and the quantum system becomes a mixture. If the photon on path \( f \) is detected by a method sensitive to circular polarisation, \( \psi_n^+ \) is collapsed to \( \psi_n^+ \) if the photon is detected as \( \sigma^+ \) and a photon and to \( \psi_n^- \) if the photon is detected as a \( \sigma^- \) photon.

If the photon is detected by a method sensitive to linear polarisation, \( \psi_n^+ + \psi_n^- \) is unchanged if the photon is detected in the direction of polarisation of the incoming photon and it changes to \( \psi_n^+ - \psi_n^- \) if the photon is detected in the direction orthogonal to the direction of polarisation of the incoming photon. The latter state can be evolved back to \( \psi'' \) by a unitary transformation. Therefore it is possible to determine whether a quantum system in an internal quantum superposition is in a box or not and either to leave the internal superposition collapsed or not collapsed, depending on the choice of the method of detection of the photon involved in the IFM.

Note that if the box was slightly outside the path \( d \) of the MZ, there is no question that the quantum system state remains

\[
\psi = \frac{1}{\sqrt{2}} (\psi_n^+ + \psi_n^-)
\]

and would exhibit interference effects between \( \psi_n^+ + \psi_n^- \) in subsequent experiments. This is in contrast to the Schrödinger Cat case, in which, as described above, the wave function had FAPP collapsed and we were just removing our ignorance. It really is the case that moving the box slightly so that the passage through it aligns with path \( d \), which the photon did not pass down in the sense of transmitting energy down that path, extinguishes forever the interference effects between being in or out of the box and can also extinguish interference effects between \( \psi_n^+ \) and \( \psi_n^- \).

**Conclusion**

The fact that wave function of a quantum system can collapse when there is apparently no physical interaction with the quantum system gives support to the idea that the wave function represents our knowledge rather than a property of the system itself, including when the quantum system is in a superposition even under FAPP rules. The idea that the wave function represents our knowledge of the system has a long history up to the present time. The debate about whether this situation is satisfactory or not continues. Some physicists continue to assume that one can and should talk about properties of quantum systems and therefore seek a modification of conventional quantum mechanics which enables statements to be made about a quantum system rather than our knowledge of it. One possible avenue of research along those lines is to modify conventional quantum mechanics so that the properties of quantum systems depend on final as well as initial boundary conditions, i.e. a time-symmetric formulation of quantum mechanics.

**REFERENCES**

$381 million boost for new research projects

The Australian Government will allocate $381 million over five years to 1,387 new research projects from 2005. The projects will be funded through Australian Research Council (ARC) Discovery Projects, Discovery Indigenous Researchers Development, Linkage Projects, Linkage International and Linkage Infrastructure Equipment and Facilities grants.

ARC Linkage Projects grants encourage the formation of long-term strategic alliances between university researchers and their collaborating partner organisations, including from within industry. In this round, the ARC will provide $55.5 million to new collaborative research projects.

Industry and other partner organisations will contribute $80.4 million to these projects, investing $1.45 for every dollar of Australian Government funding.

New projects to be funded under the Linkage Projects scheme include:
- investigating ozone-enhanced particle removal from waste water; and
- investigating the effectiveness and appropriateness of child restraints.

ARC Discovery Projects grants support fundamental or basic research, often referred to as 'blue sky' research. The number of these grants awarded has increased from 875 in 2004 to 1,051 in 2005. Of these, almost 600 will include about 1,300 international collaborations with 68 other countries, the greatest number of collaborations being with researchers in the USA.

New projects to be funded under the Discovery Projects scheme include:
- high-resolution mapping of surface and root-zone soil moisture to achieve more efficient water use practices in agriculture;
- developing systems for the landing of unmanned aerial surveillance vehicles, by studying how bees orchestrate smooth landings, with potential application in defence and space exploration; and
- a project to develop a fatigue detection system for train drivers, to improve train safety.

Research and Infrastructure Advisory Committee announced

The full membership of the Advisory Committee appointed to develop Australia's vital National Collaborative Research Infrastructure Strategy (NCRIS) was announced by Minister Brendan Nelson on 4th December.

The NCRIS will foster greater collaboration in research, providing our researchers with greater access to major research infrastructure. The Australian Government has provided $542 million to the NCRIS as part of the Backing Australia's Ability: Building Our Future through Science and Innovation.

The Advisory Committee will be made up of highly experienced members, all leaders in their particular fields. The Chair will be Professor Rory Hume, formerly Vice-Chancellor and President of the University of New South Wales.

Professor Hume will be supported by:
1. Dr Michael Barber, Executive Director, Science Planning, CSIRO
2. Dr Robin Battersham, The Chief Scientist
3. Professor Ian Chubb, Vice-Chancellor, ANU, (representing the Australian Vice-Chancellors' Committee)
4. Dr Phil McFadden, Chief Scientist, Geoscience Australia, (representing the National Academies Forum);
5. Mr Peter Nissen, National Broadband Advisor for Education
6. Professor Alan Pettigrew, CEO, NHMRC
7. Dr Ian Smith, Executive Director, NSTO
8. Dr Stephen Walker, Executive Director, Engineering and Environmental Sciences, Australian Research Council
9. Dr Evan Arthur, Group Manager, Innovation and Research Systems Group, DEST
10. Mr Colin Walters, Group Manager, Science Group, DEST

Appointment of science and research adviser

On 2nd December, Dr Nelson announced that Dr Jade Sharples has accepted an appointment as his Science and Research Adviser.

Dr Sharples is a researcher and science policy analyst with a highly credentialed background. She commenced her studies in the Biological Sciences at the University of Western Sydney (UWS) before going on to complete her PhD in Biology at UWS and the Institute of Terrestrial Ecology at Monkwood, United Kingdom.

She is also a qualified lawyer, with specific experience in the area of intellectual property analysis and protection for scientific research.

More recently, Dr Sharples managed the science portfolio for the British High Commission, providing her with broad exposure to international science and innovation policies.

In addition to her role as Minister Nelson's Science and Research Adviser, Dr Sharples will also provide a contact point within the Minister's office for peak science bodies, research agencies and the broader scientific community.
Definitely Out of this World

Subtitled "Colliding Universes, Branes, Strings, and Other Wild Ideas of Modern Physics", Stephen Webb's latest offering, titled "Out of this World!", is a challenge to those of us who might suspect branes to be a typo and have only a utilitarian view of strings, not to mention heterotic strings.

Starting from the familiar territories of relativity (special and general) and quantum mechanics, Webb zooms off into the wild frontiers of physics where experiment has yet to catch up. It is a fascinating zoom if you can hang on.

With almost total absence of mathematics Webb skillfully conveys the meaning of many advanced concepts of theoretical physics, such as renormalisation and gauge symmetries. Mind you, I have had to re-read much of the book many times and will need to keep doing so, but one still gets a feeling of personal progress in the arcane areas of our discipline. Thank goodness the book has a useful glossary and index.

Webb is good on the history of modern thought on the mysteries of nature, introducing the original thinkers. A curious omission from his discussion of black holes is the name of Roy Kerr, whose solution of Einstein's equations of general relativity led to a vastly better understanding that underpins the work Webb describes.

There is hope that some theoretical speculations described in this book may be verified in 2007 when the Large Hadron Collider opens up new high energy physics and the Planck satellite is sent into orbit to catch a few elusive gravitons.


Colin Keay
Reviews Editor

Applied Scanning Probe Methods


Richard Feynman is credited with inventing the field of nanotechnology with his groundbreaking 1959 lecture, "There's plenty of room at the bottom". Feynman predicted that the development of a device to position individual atoms and molecules would cause a revolution in technology; a quarter of a century later the development of a class of devices known as scanning probe microscopes (SPMs) would mark the beginnings of this revolution. Today, the science of nanoscale systems is one of the most exciting fields of science.

This book describes some of the many ways in which SPMs are being used in the development and characterisation of real nano technological processes and devices. The editors have done an excellent job of maintaining a coherent theme throughout, while keeping the repetition of ideas to a minimum. It is therefore effective when read as a whole but will also find good use as a reference book.

The theory of scanning force, lateral force and interferential force microscopy is developed in some detail. Applications of these techniques are explored in areas as diverse as sensor technology; self assembled monolayers; polymer structures; semiconductor line edge characterisation; and even cosmetic science with biological substrates such as human hair. The common theme in all of these is the ability of SPM to perform tribological measurements at the nanoscale. In the last few chapters the focus shifts toward atomic scale manipulations using SPMs for the purposes of nanoelectronic device fabrication and ultradense information storage, including the use of near field optics. This is an excellent book for all users of SPM interested in real technological applications.

Steven R. Schofield
School of Mathematical and Physical Sciences
University of Newcastle

New Directions in Statistical Physics: Econophysics, Bioinformatics, and Pattern Recognition


The tools and techniques of statistical physics are increasingly being successfully applied to new areas of activity as far afield as the human genome or the stockmarket. This volume nicely illustrates some of these accomplishments through an eclectic mix of eighteen articles by some of the key initiators of the new directions. The articles are grouped under five themes: fundamental aspects, econophysics, bioinformatics, pattern recognition and other applications. The latter covers statistical physics approaches to meteorology and thermal convection.

The editor's aim was to put together a volume which would be accessible to graduate students and also be of value to professional physicists. On the whole, he has been highly successful in this endeavor. Beyond reflecting on progress to date, the articles in many cases point the way to future developments. For example, in the article on patterns in economic phenomena Gene Stanley, et al., emphasise the empirical
approach which uncovers universal scaling and power law exponents in economic data. They draw an analogy with the new field of critical phenomena in the 1960s which also lacked a firm theoretical foundation. The understanding of critical phenomena was greatly advanced by the eventual introduction of the renormalisation group. We await similar advances in the broad range of topics covered in this volume.

Murray Batchelor
Mathematical Sciences Institute
Australian National University

An approximate justification of Darcy’s law in terms of difference equations is provided. Fully worked solutions to all the exercises are available on the web.

I recommend this book as a good introductory text on the environmental physics of soils and water.

John Harries
Environmental Consultant
Heathcote 2333

Nonlinear Optics in Telecommunications

T. Schneider
Springer-verlag, Berlin 2004
xi + 415 pp., EUR 69.95 (hardcover)
ISBN 3-540-20195-5

The invention of the laser was accompanied by the parallel emergence of nonlinear optics as an important area of optical physics and a wide range of new phenomena which have been exploited in science and technology. In early optical fibre communications systems nonlinear effects were negligible and most attention focused on controlling dispersion and attenuation in the fibre. The invention of the optical amplifier, however, changed things and led to the emergence of wavelength division multiplexing (WDM) as the preferred means of transmitting information. WDM involves the simultaneous transmission of tens or hundreds of channels of information down a single fibre and a proportional increase in the optical power as well as the distance the signal travels before regeneration. Thus in WDM systems nonlinear effects could no longer be neglected.

For a while there were two schools of thought: one aimed to eliminate the effects of nonlinearity because they degraded the signal through processes such as four wave mixing. The second view was to utilise nonlinearity to improve the performance of the network. There now appears more to be gained by utilizing rather than eliminating optical nonlinearity and dispersion managed solitons, Raman amplifiers, all optical wavelength converters, etc, will all play a role in emerging networks. Thus this comprehensive new book on Nonlinear Optics in Telecommunications provides a timely overview of the physics and applications of nonlinearity in optical communications systems. I found this a high quality book providing in depth coverage of the most important topics. It is highly recommended to the specialist researcher or postgraduate student.

Barry Luther Davies
Laser Physics Centre
Australian National University

Stargazer: the life and times of the telescope

Fred Watson
Allen & Unwin, Sydney 2004
x + 342 pp., A$35.00 (hardcover)
ISBN 1 86508 658 4

Though Dutch scientist Christian Huygens happened to be in London on the day of the coronation of Charles II in 1661 he did not attend the ceremony. Instead he observed the transit of Mercury that took place on the same day. Fred Watson’s entertaining new book is full of such minor details that enliven the history of the telescope. In the book we meet a large cast of important contributors to the telescope’s development plus a few less important ones like the Scottish locomotive builder Andrew Barclay whose telescopes were so bad that they made Saturn look like a half eaten apple! Until now the only comprehensive history of the subject was H C King’s venerable “The History of the Telescope” published in 1955. “Stargazer” can easily take over as the main reference for the history of the development of the telescope. Although the text is written at a popular level there are detailed notes for each chapter plus a full bibliography.

As a reviewer does need to offer criticism as well as praise, I must report that the drawing of a Cassegrain telescope on page 122 is interchanged with that of a Gregorian telescope on page 132. More importantly, the book does seem to terminate rather abruptly with only fleeting mentions of the current generation of leading telescopes such as the two Keck telescopes and the VLT. With his long experience using telescopes and designing instruments, Fred Watson could have given an authoritative view of their history. Maybe, if this book is as successful as it deserves to be, the publisher will prevail on him to write a sequel emphasizing modern telescopes.

Nick Lomb
Sydney Observatory
Powerhouse Museum
Gravity’s Shadow
Harry Collins
University of Chicago Press, Chicago IL 2004
xii + 870 pp., US$39.00 (paperback)

Physicists Shadowed by Sociology
For many years a familiar participant at gravitational wave research conferences has been a British sociologist Harry Collins. He has befriended many in the community. With his ever present minidisc recorder he is to be found in conference sessions, meetings, and in those most important times at conferences: after the session excursions to pubs, bars and restaurants. His goal is to study the process of discovery. He wants to catalog the sociology of what will be one of the most momentous discoveries in modern physics...the discovery of gravitational waves. We have all become used to his cheeky grin and his friendly interest...so much so that some of us, me included, have some regrets about the things we allowed him to record. Over the last few decades he has had plenty of tasty morsels to chew on, analyse and regurgitate as the gravity wave community has lurched forward.

Looking back at the history, as Collins’ book has forced me to do, it is certainly a colourful story. It began with one of the most creative and eccentric physicists I have ever known: Joseph Weber at the University of Maryland. He created the field, but alienated almost everyone in it when failure to be able to reproduce his results was identified by him as a conspiracy aimed at NOT detecting gravitational waves thereby denying him the Nobel Prize. Response to Weber was bi modal. One group felt it necessary to publicly point out his errors, the other felt it better to ignore him.

Years later the Rome Group published intriguing coincidences between their detectors, the classic signature for gravitational waves. They followed proper process. They wrote a paper, submitted it to Classical and Quantum Gravity, where it was refereed, accepted and published. A diligent science reporter read the journal’s list of contents, thought it sounded interesting and contacted leading gravity wave physicists. Again the response was bi modal. The first group’s advice was “do not take any notice of that...ignore it”. This advice set the cat amongst the pigeons and made sure that the other group was heard...New Scientist’s story “Have Gravity Waves been detected?” was picked up by media around the world. There followed some exciting conference sessions and the story was certainly not ignored. There was an intense debate about what is the right way to announce very significant results. Is the normal publication process appropriate, or should there be other safeguards against publication of incorrect results? At least there was one useful lesson: if you want a journalist to ignore something, do not tell him to ignore it. Do the opposite. Give a very long and very boring explanation! Still today intriguing coincidences do not go away but there is no satisfactory explanation. Harry Collins tells it all. The US LIGO project was designed to create detectors that would give certain detection of gravity waves. As a very expensive project led by two of the top universities in the USA (Caltech and MIT) there were certain to be tensions, and the long teething problems of this project provided lots more tasty morsels for our science sociologist. It took particle accelerator physicists who were used to big science to turn the LIGO project into what has now become a spectacular model for big scale international collaborative science (and one that we in Australia are pleased to be part of), but it was a long and difficult process.

Harry Collins tells this story and vastly more of it in fine detail. For me it was astonishing to find things I said in a bar or restaurant revealed here word for word, laughs and frowns included. There is even an appendix about my views about doing physics in the isolation of Western Australia. I found the book so long and so detailed that I cannot encourage everyone to read it. Perhaps because I was a participant in many of the events reported, it has been a struggle to get through its 800 pages of solid text. Despite reporting many colourful events I found the book rather dull, and lacking in spark. It does not make any bold conclusions. However it is a superb reference text on the history of one branch of physics and it will long be seen as a definitive study. I can imagine it being a very useful resource for novelists, and dramatists who want a moderately accurate portrayal of real scientists and the issues and disagreements that are part of scientific progress.

Gravity’s Shadow is very up-to-date, it even has a stop press from 2004. Unfortunately it is still unable to report the direct detection of gravitational waves, although this could happen any time in the next few years. I guess it was not intended to capture the excitement of the field, but rather to catalog the processes. However by focussing mostly on the times that physicists get together, and much less on the times they are beavering away in their labs, it is only a partial snapshot of the true sociology of physics.

Collins does not get all his facts right, though most errors are minor. One close to home error was his description of UWA as being made of concrete. I must also criticise his exaggeration of disagreements. For example in a caption to one of the many poor quality photos in the book, he reports a meeting of the International Gravitational Events Collaboration at UWA as “acrimonious”. Yes, there were heated disagreements but I would not describe it as acrimonious. Indeed that meeting led to the resolution of various disagreements and to a superb coincidence analysis between five detectors, including Niobe in Australia, and the best limits ever reported on gravitational wave bursts.

Overall this is an interesting book for historians and philosophers of science, an interesting book for gravity wave physicists to dabble in, and for the average physicist, definitely worth a browse in the library and then to judge for yourself whether you want to read it all!

David Blair
Gravitational Research Centre
University of Western Australia

202
The Australian Institute of Physics Women in Physics Lecture Tour celebrates the contribution of women to advances in physics. Dr Mahananda Dasgupta from the Department of Nuclear Physics, Research School of Physical Sciences & Engineering, Australian National University, was the AIP Women in Physics Lecturer for 2004.

Nanda completed her PhD at the prestigious Tata Institute of Fundamental Research in Bombay in 1992. Since that time she has worked first as a Post-doctoral Fellow, Research Fellow, then ARC QEII Fellow in the Department of Nuclear Physics at the Research School of Physical Sciences and Engineering, Australian National University. She currently holds a continuing position in the Research School.

Nuclear fusion is one of the most fundamental nuclear processes, involving quantum tunnelling of complex, composite objects. Nanda has been one of the leading researchers in a worldwide revolution in both experimental and theoretical studies in nuclear fusion. Her contributions have ranged from design and development of unique, highly efficient experimental equipment and measurement protocols, to working closely with leading international theoreticians developing better models of tunnelling which her new experimental results demanded. Her recent groundbreaking experimental measurements of nuclear breakup on fusion have broad implications for the emerging field of physics with accelerated radioactive beams. She has also undertaken work to understand the structure of excited, long-lived nuclear states, complementary to her fusion studies. Nanda has many publications in prestigious journals. She is currently developing a revolutionary 6.5 Tesla superconducting detection system.

In addition, Nanda has made an important contribution to the discipline as an active member of a number of ANU and AIP committees. She has also been an active participant in a number of programs designed to raise the profile of Physics in the community. This included being a Guest lecturer for the National Science Summer School, demonstrating experiments to National Youth Science Forum students, participating in the AIP Adopt-a-Physicist program for engaging Year 11 and 12 students in Physics and CSIRO Student Research Scheme and many more.

In August and September Dr Dasgupta participated in a series of WiP activities in Canberra and each of the six Australian State capital cities. She gave the WiP Lecture to the public in each state, gave research colloquia to members of each of the AIP State branches visited laboratories and made a series of school visits which were also very popular and well attended. It is a pleasure to thank Dr Mahananda Dasgupta for her contribution as the AIP Women in Physics Lecturer for 2004.

The WiP Tour would not be possible without the generous support of the AIP Executive and the dedication of the WiP Lecture Tour organizers and their teams of supporters in each state. The contribution of the State organizers is gratefully acknowledged: Elizabeth Chelkowska (University of Tasmania, Tas), Chris Creagh (Murdoch University, WA), Russell McLean (Swinburne University of Technology, Vic), Robert Sang (Griffith University, Qld), Manjula Sharma (University of Sydney, NSW), Peter Veitch (University of Adelaide, SA) and Anna Wilson (Australian National University, ACT) who has also been busy helping with the upcoming Congress. Some edited highlights of the 2004 Tour are described in the following paragraphs by the State organizers.

Nanda is a vivacious person who took the complex subject of fundamental nuclear processes and presented it separately to...
peers and high school students in a language each could understand. The high school student audience consisted of about 200 students and teachers from at least 8 schools. They were captivated by her and asked many interesting questions. She in turn encouraged them to follow their passion to do science (in particular Physics) into their post high school years, on the basis that you should enjoy the work you do not just the material trappings it brings. Nanda is inspirational in the work that she is doing, in the comfortable way that she lectures and builds rapport with her audience and because even though she was jet-setting around the country she could still enjoy with gusto good food, wine and company. (Chris Creagh, W2)

Nanda gave the WIP public lecture on the Thursday evening, before which she presented Merit Certificates to students attaining 20/20 in the 2003 year-12 physics exam, the AIP-SA Bragg bronze medal for the best year-12 student in 2003, and the Claire Corani memorial awards for the best level-II female students at the University of Adelaide and Flinders University in 2003. The talk was very well received by the audience of about 250. On the Friday afternoon, she presented a physics colloquium, entitled Evolving concepts in the fusion of heavy nuclei, to the Department of Physics at the University of Adelaide. (Peter Veitch, SA)

Nanda Dasgupta, the 2004 Women in Physics Lecturer toured Sydney from the 25th to 27th of August. She delivered a Public Lecture at the Australian Museum, a research seminar at the University of Sydney, and presentations at St George Girls and Rosebank High Schools. All the talks were very well received with the audiences asking some interesting questions. The highlight of the tour was the public lecture which was well attended given the competition with swimming in the Olympic Games in Athens. (Manjida Sharma NSW)

Dr Mahamanda Dasgupta meets some Rosebank College physics students during one of the visits she made to high school colleges during the NSW portion of the WIP Lecture Tour in August 2004.

The Tasmanian Branch organised two lectures, one for high school and Physics 1 students in the day and one for general audience in the evening. There was a competing event at 5pm on the day hence the lecture was attended by 30 people only, mostly professionals. Nanda adapted her lecture to the audience present. The lectures were interesting for everyone. (My son, 12, enjoyed it as well as I did). Over 40 high school students could join the Physics 1 students for the noon talk. We always try to give a speaker a small tour because (usually) it is her first visit to Tasmania. And the island is so remote ...In general, most of the members of the committee are involved in organising the WIP lecture as well. We have an excellent team of people who dedicate a lot of their time to popularise physics, to organise the public lectures. The success of the WIP Lecture Tour in Tasmania is part of their achievement. (Elizabeth Chelkowska, Tas)

Nanda gave an excellent talk to the Branch, at a level accessible to undergraduates and physicists not familiar with her area of research. Her talk was well received. She also gave an inspiring talk to about seventy Year 10 to 12 students at Melbourne Girls College in Richmond. She did a wonderful job of holding the girls’ attention for 45 minutes - no mean feat - with a mixture of humour and enthusiasm. Her visit happened to coincide with the time at which many of the girls were having to make subject choices for next year, and Nanda’s talk was a great advertisement for physics. (Russell McLean, Swinburne)

Australian Institute of Physics, WIP Lecture Tour Coordinator
Marion Stevens-Kalceff, School of Physics, UNSW
M.Stevens-Kalceff@aip.org.au
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Profiling UV Lasers with Fluorescent Plates

Warsash Scientific is pleased to announce new low-cost components for profiling of UV laser beams from Spiriion Inc. A plate whose surface fluoresces is placed in the path of a UV beam, and the fluorescence is imaged with a CCD camera and lens to capture the beam profile. The profile is analysed and displayed with Spiriion's LB1-700PC series beam analysis software. The plates provided by Spiriion are much lower in cost than previously used crystalline materials, and are available in sizes from 1” circles up to much larger 12” squares or circles.

Direct profiling of UV laser beams on CCD cameras has been difficult because of the lack of materials for beam attenuation. (A typical attenuation of 10” to 10” is needed to not overdrive the CCD.) The ND filters used for visible and IR lasers are typically made of glass which does not pass UV. Inconel metallised quartz ND filters are only made with non-fringing coatings up to ND = 1.5. (ND above 1.5 are metallised on both sides which causes interference fringes, and distorts the beam profile. Stacking multiple filters also creates interference fringes.)

The fluorescent plates provided by Spiriion provide a linear output of visible fluorescence to input UV stimulation. The fluorescence conversion provides the first attenuation, and additional attenuation is provided by the lens iris and visible attenuating ND filters placed in the path of the plate to the camera.

Beams from 5mm to 300mm can easily be imaged with standard camera lenses. Focused spots as small as 10μm can be imaged by using microscope objectives with the CCD.

The UV fluorescent profiles are useful for viewing excimer laser beams and tripled and quadrupled Nd:YAG laser beams. The plates are also useful for dosimeter measurement of semiconductor photolithography UV illumination systems. The plates can be imaged from the back side (transmission), front side (reflection), or at right angles using a turning mirror.

For more information on these and other laser beam profiling systems please contact
WARSASH Scientific Pty Ltd on (02) 9319 0122 or sales@warsash.com.au

New Scanning Stage

PI (Physik Instrumente) has unveiled a long-travel piezo scanning and nanomanipulation system that offers integrated capacitive feedback and closed-loop control that boost linearity by up to three orders of magnitude over conventional stages.

The P-563.3CD PIMars provides 300 x 300 x 300-μm travel in the X-Y-Z axes, with nanometer resolution.

It has a 66-mm clear aperture and a parallel kinematics design that features only one moving part.

Response is in the millisecond range.

Available versions include ultra-high-vacuum, invar, superinvar and titanium.

Further information on these and other nanopositioning systems is available from WARSASH Scientific Pty Ltd at (02) 9319 0122 or sales@warsash.com.au
"Physics for the Nation"

January 31 - February 4, 2005
The Australian National University,
Canberra ACT 0200, Australia

Congress Chair: Ken Baldwin, ANU, IAS
Program Chair: Hans Bacher, ANU, Faculties

The Congress will mark the UN 2005 International Year of Physics - celebrating 100 years since Einstein's discoveries in relativity, quantum theory and Brownian motion - and will highlight the contribution of physics to Australia. The occasion will bring together an unusually large and diverse group of scientists from different disciplines who share a common interest in physics.

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Introducing the New Ntegra Scanning Probe Microscope from NT-MDT

The ultimate in versatility, the Ntegra represents the next generation in Scanning Probe Microscope technology. Capable of over 40 AFM/SPM modes of operation in air, liquid, controlled gas and vacuum environments with integrated closed loop scanners, the Ntegra is ideal for the wide variety of applications found in multi-user facilities, as well as specialist techniques such as force curve spectroscopy. The Ntegra employs a range of scanner sizes, with both scanning-by-sample and scanning-by-probe configurations, for the ultimate sample size and resolution flexibility.

Furthermore, its open architecture has allowed for ready integration with other techniques such as optical and confocal microscopes, Raman spectrometers - even ultra microscopes. An objective lens incorporated into the Ntegra central base provides the stability for high resolution optical imaging, as well as long-term experiments, such as laser excitation on a direct point on the sample.

For the ultimate in performance and flexibility for your research now and in the future, Ntegra provides the answer.

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