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South West Branch

PHYSICS SOUTH-WEST

The newsletter of the South West Branch of the Institute of Physics

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The Institute of Physics,
76 Portland Place, London
W1B 1NT, UK.

Tel 020 7470 4800.
Fax 020 7470 4848.

Stellar talks wow branch

During the autumn we were fortunate to have a number of branch lectures focusing on the neutron. Earth-bound neutrons were the stars of a talk about nuclear fusion (p4). We were also treated to two lectures about the neutron star.

In Bristol we heard from Dr Roche of Cardiff University whose talk was entitled "Twinkle, twinkle, little neutron star". Paul is director of the Faulkes Telescopes Project (FTP) and is the longest-serving team member. He is also the UK National Schools' Astronomer (funded by PPARC), working across the UK with school groups, teachers, universities and amateur astronomers.

These roles fit together well because the FTP is the education arm of Las Cumbres Observatory Global Telescope Network (http://lcogt.net/), which is a wonderful scheme that provides free access to robotic telescopes and a fully supported education programme to encourage teachers and students to engage in research-based science.

At the time of writing, Stroud High School in Gloucestershire was working on an FTP project in co-operation with Cardiff University (http://faulkes-telescope.com/news/2016).

The two Faulkes telescopes are identical with 2 metre primary mirrors, and they are equipped with filters and cameras that are used on professional telescopes. Those telescopes operate in partnership with the University of Hawaii, the Institute for Astronomy and the Australian National University respectively.

Dr Paul Roche at Cheltenham.

As stated on the FTP site (http://www.astro.cf.ac.uk/faulkes): "LCOGTN operates a network of research-class robotic telescopes. Currently there are two telescopes, one in Hawaii and the other in Australia. These telescopes are available to teachers for them to use as part of their curricular or extra-curricular activities and they are fully supported by a range of educational materials and a team of educators and professional astronomers."

In Cheltenham we heard from Dr Anna Watts, newly ensconced at the University of Amsterdam, who gave a lecture entitled "Firestorms and starquakes: the dangerous life of a neutron star". Anna gained her PhD in mathematics from the University of Southampton in 2004, specialising in theoretical astrophysics, and has previously held postdoctoral research positions at NASA's Goddard Space Flight Center (Washington DC) and the Max Planck Institute for Astrophysics in Garching, Germany. Her motto in life is "be surprised".

The Boxing Day tsunami in 2004 was triggered by a tremor so violent that it left the Earth ringing like a bell for several days. Through earthquakes like this, seismologists study the interior of our planet. Less than two days later, we heard, the Earth was hit by the brightest burst of gamma-rays ever recorded, initiated by a starquake on a neutron star with an ultra-intense magnetic field, 50 000 light-years away.

Just as on Earth, the quake left the star ringing with seismic vibrations, which is the first time that this had been observed, opening up an exciting new opportunity to study these important and fascinating stars, with their crushing gravity, exotic nuclear physics and enormous magnetic fields.

Dr Watts shed light on the mysteries of neutron starquakes, triggered by everything from magnetic flares to thermonuclear explosions, and looked ahead to future observations using both gravitational-wave astronomy and the conventional spectrum of electromagnetic waves.

Roger Brewis, editor

Check out the branch website at http://sw.iop.org

Big Bang talk fires up branch

Dr Gary Mathlin, director of undergraduate studies for the physics department at the University of Bath, brought a suitably explosive and subversive mixture to Bristol on Guy Fawkes Night 2008, asking his audience: "Is the Big Bang in big trouble?".

Once Alexander Friedman had solved Einstein's field equations and had shown that there were no stable solutions, the physics world was ready to embrace the radical idea, suggested by Edwin Hubble in 1929, that the cosmological redshift was due to an expanding universe. The Big Bang itself was proposed in 1933 by Belgian civil engineer and astrophysicist Georges Lemaître, who postulated a "primeval atom", some 30 times larger than the Sun, to have exploded between 20 and 60 billion years ago. The idea was revived and revised by George Gamow in 1946, and the term itself is "according to Hoyle", Fred, not Edmond.

The Big Bang is perhaps a logical consequence of the Doppler interpretation of the redshift, but Dr Mathlin suggested that Lemaître might have had another agenda. The Belgian trained as a priest before being initiated into cosmology by Eddington at Cambridge, and this "cosmic egg" offered a suitable universal genesis. We heard also of Hubble's discovery, based on the identification of Cepheid variables, that there were galaxies beyond our own.

Having interpreted redshifts, and indeed some local blueshifts, as Doppler effects the discovery of redshifts in excess of unity must have been something of a shock, as these implied, in the Doppler model, expansion rates exceeding light speed. Dr Mathlin passed over this significant recognition that the simple and plausibly mechanical expansion of Hubble and others had failed, and took us straight to the ad hoc and difficult-to-falsify replacement theory, that the space between galaxies is expanding, whatever that might mean.

Hubble's calculations suggested that the expansion speed was 500 kilometres per second for every mega parsec of separation, and this was readily discernable from the graph shown. Dr Mathlin pointed out that this was now taken to be closer to one tenth of that figure, and indeed a value of about 70–75 km s^{-1}/Mpc is now used. Hubble is known to have underestimated the distances to Cepheid variables in nearby galaxies, with his estimate for Andromeda (M31), at 285 Kpc, about one-third of the current estimate of 770 Kpc.

The rest of Hubble's apparent error was, it was suggested, due to misinterpreting local random motion of galaxies as indicative of the universe in general, though this explanation broke

Dr Gary Mathlin.

down under questioning from the floor, as the modern line through Hubble's data would show that 95% of the supposed random local motion was away from us. Since Hubble's data covered 46 galaxies, the suggestion that this was random was accepted to be implausible. A wag from the floor suggested mischievously that this was just another probabilism conundrum for physics.

Next, Dr Mathlin took an attentive and inquisitive audience through the traditional requirements of such a lecture: the story of lambda, "Einstein's greatest blunder"; the question of how the universe would end, whether with a bang or a whimper in the form of a re-collapse or an ever-expanding heat death; Hoyle's demonstration of stellar nuclear fusion; and finally Penzias and Wilson – their big ear and guano removal.

That brought us more explicitly to the several problems of the theory. First was the evidence for dark matter in the rotation profiles of galaxies and clusters of galaxies, and the failure, after some decades, to find solid evidence for this.

Second was the "horizon problem", the remarkable near-uniformity of the visible universe, given that the universe we see 13.5 billion years in one direction cannot have been in communication with the universe that we see a similar distance in the other direction for, well, a lot more than 13.5 billion years.

Then there is the "flatness problem", which is the observation that the current density of the universe is implausibly close to its critical value at which space is perfectly "flat" – this being the state of the expanding universe whereby its expansion will slow to almost nothing, but will not collapse. The current calculated figure for the density of the 1 ns-old universe, we were informed, is 4472259172185074012840 15 gm/cc, being within 1 gm/cc of flatness.

Finally, in Dr Mathlin's analysis, there is the rather remarkable conclusion that the expansion of the universe is speeding up, based on the observations of one type of standard candle, the type I supernova. This leads to the even more remarkable discovery of "dark energy".

Roger Brewis, editor

Message from the branch chair

Having become branch chair is both a responsibility and a chance to do new things. I was always impressed by the energy and time that the previous two chairs put into the events programme. They put together a series of successful talks, an interesting Festival of Physics each year, and even managed to arrange talks to school students across the region, such as the Liquid Nitrogen Show. This is a hard act to follow, but I will try to ensure that the branch continues to promote physics in the region with as wide a range of events as we can manage.

My own time is often severely limited, with several other major responsibilities both at the University of Bristol, where I teach several courses and lead my own research group, as well as being involved in several major national and international projects involved in computational quantum mechanical studies of materials. With these duties I often travel a great deal and can be out of the country for weeks at a time. Nevertheless, I am hopeful that with the help of the rest of

the branch committee, we can maintain the energetic events programme that Peter and Vince have done so much to develop.

In the coming months the branch can look forward to the Festival of Physics on Saturday 21 March, as well as a further series of evening talks across the region. We are also involved in activities for schools, such as Lab in a Lorry and SciCast Physics, and outreach activities, such as Physics in the Field. Our ability to run these and other events relies on willing volunteers. Our branch is particularly immense, covering an area from Gloucestershire and Wiltshire all the way to Devon and Cornwall. We're keen to organise events so that they occur in as wide a regional area as possible. However, this will only be possible if members are willing to help. If you have an idea for a local event, don't hesitate to contact me (e-mail chair-sw@physics.org).

James Annett, branch chair

The deadline for contributions to the May issue is 31

Institute reaches out with physics

During 2008 members of the Institute were busy taking physics to the public at events around the south west. The Physics To Go experiments and demonstrations have been entertaining and enlightening audiences all across the region.

Your regional officer and a group of enthusiastic physics students from the University of Bath made a return visit to the annual Bath Taps Into Science Fair. This two-day event takes place every year during National Science and Engineering Week, attracting children and adults alike to its fun hands-on science activities. Prof. Chris Budd, from the University of Bath's Department of Mathematical Sciences, who is involved in organising the event, said: "This year's event is about having fun with science in a way that helps people to learn about the world. I am particularly proud that we have so many young people explaining the science, because by demonstrating they learn so much about it themselves." On 7–8 March we joined 20 other groups from the University of Bath, City of Bath College, Explore-At-Bristol, other societies and local schools as part of a magnificent array of stalls, featuring everything from boomerangs to bubbles and bones to frozen bananas.

With the first day taking place under cover in the university's sports hall we "warmed up" by welcoming more than 720 children from 13 local schools throughout the day. Of those, at least half visited the physics stand to try their hand at explaining our match tricks and solving the mystery of the levitating lemon. Much noise was made with balloon kebabs and straw oboes, which proved as popular as ever. Branch stalwart Peter Ford MBE also entertained the crowd with his half of the Fire and Ice show, using liquid nitrogen to perform amazing tricks and to explain some physics along the way.

The second day of the fair saw us back outdoors at Green Park Station in central Bath, where Saturday shoppers were equally intrigued by everything on show. Many of our previous day's visitors returned with their parents to show them what they had seen. It was very gratifying to hear several children authoritatively explaining the physics behind such things as expanding marshmallows to their attentive parents. We estimated that the stand received more than 500 visitors during the day. I must thank the University of Bath's physics society students for their unwavering enthusiasm throughout the two days, as well as ex-Bath student, now BAE Systems employee, Vicky Davies who travelled all the way from Cumbria to take part.

A few months later your regional officer was again braving the elements at the Devon County Show, which took place on 15–17 May at the Westpoint Arena near Exeter. This massive rural event showcases everything from the finest local produce to the latest green-energy solutions. Among the tractors and best-of-breed competitions was the "Science WithInTent" marquee where the Institute rubbed shoulders with Devon and Cornwall Setpoint, the Institute of Grassland and Environmental Research, and Gary the Musical Science Clown (http://garytheclown.co.uk).

Institute members from the local area, including physicists from the Met Office and the School of Physics at the

Branch treasurer Neil Purves (left) with other physics outreach volunteers at the Devon County Show.

Michael Grogan

Left: former branch chair Dr Peter Ford MBE remains ice cold while he does what he loves best, entertaining an audience with physics at the Bath Taps Into Science Fair. Right: Setpoint volunteers fascinate budding physicists with balloon kebabs and other "tricks" at the Devon County Show.

March. E-mail materials to chair-sw@physics.org.

University of Exeter, kindly volunteered their time to demonstrate a number of the Physics To Go experiments. During three somewhat damp days we had a wide variety of visitors, including many school groups and families, some of whom had made a beeline for our tent and its promise of practical activities, and others who were just looking for shelter from a rain shower. Some visitors were surprised to see a science stand at an agricultural show, but nevertheless they had a go at doing the activities as well as trying to explain the physics behind them. Many people were pleasantly surprised to find that they could do both successfully.

Paul Hartley, the organiser from Devon and Cornwall Setpoint, said: "The Institute of Physics team really helped to make the 'Science WithIntent' marquee such a success this year. We had 1460 young people try out the activities over the three days. It was great to have some fresh activities for visitors to try and they were put over so well by the Institute volunteers." Thanks once again to everyone who gave up their time and came along to help. Had there been a prize for "Best Physicists in Show", they definitely would have got it.

The great thing about visiting an event like this is that it gets people thinking about science in an unusual context and hopefully it opens a few eyes to the ubiquity and possibilities of physics. The experiments are all simple to demonstrate and to make, so I would encourage any Institute member to take a look at the Physics To Go online resources and to consider where they could take them next. For further details, navigate to the "Interact" section at www.physics.org or the "Engaging the Public" resources section at www.iop.org.

Alison Rivett, regional officer

● If you are interested in visiting these and similar physics demonstrations or helping to present them, Alison is looking forward to hearing from you.

Talk focuses on fusion power

Periodically the branch invites speakers on fusion power. Every few years we get an update on this cutting-edge research, but this time it was a different story.

In December Dr Tim Jones of UKEAE at Culham came to Cheltenham to talk about magnetically confined fusion plasmas, in particular the latest developments based on the most effective magnetic configuration, the tokamak, originally developed in Russia in the late 1950s.

Towards the end of the last century, the two largest and most powerful fusion experiments in the world were the Japanese JT-60 and the Joint European Torus (JET) based at Culham. This was constructed from 1978 to 1983 and it operated until the turn of the century. Of the two, only JET used a deuterium–tritium fuel mixture of the sort now planned for future commercial power stations. In 1991 JET became the first experiment to produce controlled fusion power and in 1997 it reached a record 16 MW.

A torus, of course, is naturally the shape of a smoke ring or ring doughnut, but the torus cross-section does not need to be circular. Considerable promise is shown by experiments that force the torus more and more into an overall spherical shape, where it looks much more like a cored apple. Vortices of this kind have been known in hydrodynamics for some time, and this configuration, from 1990 to the present, has been under active investigation with fusion reactors.

From JET was developed START, which ran at Culham from 1991 to 1998. The Small Tight Aspect Ratio Tokamak is a triumph of theory and make-do-and-mend ingenuity. It was constructed out of spare parts in the penny-pinching early 1990s by Professors Heath and Robinson. It was the forerunner of the current generation worldwide of spherical tokamaks and achieved a world record, trebling the previous best ratio of plasma pressure to magnetic field pressure. START was used to help create injector technology for the next generation, first at Culham and since 2004 at Frascati in Italy where they are working on multi-pinch designs.

One advantage of the spherical tokamak is in the simplicity of design, having a natural system for power and particle exhaust. The toroidal magnetic field is naturally more compact and better integrated, leading to significant efficiencies. A clever combination of magnetic field and electric current is used.

By 1995 funding was available to design and build a brand new spherical reactor, designated MAST, the Mega Amp Spherical Tokamak. By 1999, when MAST began operation, START had demonstrated improved plasma confinement, with a very sharply defined edge, clearly visible, to the plasma, indicating a low level of turbulence and hence good confinement. We saw slides and even a video of the actual operational cycle, brief as it currently is. The plasma itself was transparent, appearing as a thin mist.

A custom-built machine with a stainless steel vacuum tank and modern power supplies facilitates sustained high-current plasmas with additional heating. More advanced processes for initiating the plasma could be trialled, including improved diagnostics using Thompson scattering and – non-trivial for an integrated European collaboration – improved remote participation facilities.

Dr Jones took us quickly through the main points of this history. Heating methods under experimental consideration are by electromagnetic waves or by injection of neutralised accelerated particles. These are very different technologies, and both are difficult processes to do efficiently. Particles, for example, have first to be charged to be accelerated and there are at present significant losses during their conversion, once at high velocity, to neutral ones. One hope for

Fusion expert Dr Tim Jones.

the future is to use particles of anti-hydrogen instead and then to neutralise them using photons, we were told. Apart from this, a huge focus of future fusion experiment and design is to discover more appropriate materials.

The level of political support is the highest that it has ever been, which is hardly surprising when you realise that one of fusion power's clear advantages is that no greenhouse gases are involved. The fuel, being naturally occurring or easily produced hydrogen isotopes, plus lithium, is essentially limitless. Neutrons erode and irradiate the confinement vessel, but we were assured that no long-lasting radioactive waste would be produced because "everything is recyclable after a century".

An interesting claim relates to operational safety. The amount of energy involved at one moment is insufficient to do major damage, while any breakdown in control systems leads the plasma to collapse, aborting the reaction automatically and damaging only the container. The speaker spoke somewhat diffidently about these various claims, but they stood up to scrutiny.

So where is the key contrast to past presentations? At five- to ten-year intervals, the claim was routinely made of fusion power in 20 years. The current claim is at once more modest and more detailed. The new International Thermonuclear Experimental Reactor (ITER, in southern France) is intended to be the final set of experiments before commissioning the design for a prototype commercial reactor, and it is expected to be operational from 2017 to 2037. Operating in parallel to this will be the International Fusion Materials Facility, which aims to solve the materials problems. These are significant, but there are some promising avenues to explore.

Roger Brewis, editor

Branch looks for big answers to the big question

Dr Gary Mathlin, who gave a recent branch talk about the Big Bang, is himself a researcher on the subject. In the formal discussion at the end of his talk, and the informal one that followed, it was evident from his work and the contributions of others that the theory is in even worse trouble than we had so far realised.

Taken to explain both the horizon and flatness problems is "inflation" – the notion that there was an early, rapid (10^{-32} s) and entirely unexplained increase in size. This is not the only part of the ever-expanding theory that is entirely without causal elucidation. Apart from the Big Bang, dark energy and dark matter appeared ad hoc and remain improperly established.

Dr Mathlin pointed out that the "theory" of inflation was a posteriori by definition, and offered no testable predictions. It had the flavour of "epicycles on epicycles", he said, referring to the failed cosmology of Ptolemy.

It raised, indeed, the whole thorny question of causation in physics, and how and why a very specific argument against causal modelling at the smallest of levels appeared psychologically to justify the abandonment of this most scientific of processes at the first sign of difficulty across all scales in physics, but most especially the largest. Another local researcher had famously given a South West Branch lecture saying that the "cause" of inflation was a vector field, conflating causation with mathematical description.

One set of problems discussed was whether the universe is infinite in size or has an "edge". This is such a thorny one that it is generally honoured by being avoided. Whichever choice is made, more problems are created.

Another area of concern is a set of difficulties related to age. Models of star formation had to be amended to avoid exceeding the 13.6 billion year limit imposed by the Big Bang model. The Earth's Sun is at least a third-generation star, but how could that happen in the time? That specific question was side-stepped by another past speaker to the South West Branch, now an Institute luminary.

Yet another past lecture, by the now Astronomer Royal, had detailed the fundamental difficulty of the universe condensing out into galaxies under the weak force of gravity, while it is rapidly expanding. But we see fully formed galaxies at the extreme limits of vision of the Hubble space telescope, at 100 or 200 million years after the postulated Big Bang, looking remarkably normal.

Dr Mathlin introduced his own research into the discussion. Spectroscopic investigation of the metallicity of distant stars and galaxies shows problems of lithium abundance, with high-metal galaxies showing up at high redshifts, when, like our Sun, they should not have had the time to evolve. Echoing the problem raised by Martin Rees, he and colleagues had found too much star formation too early in the universe: "all data is outside the model".

"Can things get any worse?" he asked, rhetorically, answering in the affirmative. Spherical harmonic analysis of WMAP data had thrown up further disjunctions between model and observation, leading to unexplained polar effects and the phrase "cosmological axis of evil". Are we, queried the speaker, on the eve of a paradigm shift? If these observations are confirmed by the imminent Planck Surveyor, the current failing and flailing Big Bang model could be pushed over that edge, but into what theoretical abyss?

Roger Brewis, editor

Interpretation puts quantum mechanics equation under the microscope

Around the same time as Dr Gary Mathlin was uprooting the foundations of modern cosmology, your editor was examining a curious submission from a branch member at the other extreme of physics, but similarly foundational. This publication makes no claims to be peer reviewed, but we have at times published the whimsical musings of members for the entertainment of all.

For some reason the author of this, who wishes to remain anonymous, calls it the "Pryzbylewski interpretation", but for our purposes it functions as an interesting curio. He suggests that the equation at the heart of quantum mechanics, the time-dependent Schrödinger equation

$$\frac{-\hbar^2}{2m}\frac{\partial^2\Psi(x,t)}{\partial x^2} + U(x)\Psi(x,t) = i\hbar\frac{\partial\Psi(x,t)}{\partial t},$$

which is significantly different in its derivative structure from a traditional wave equation, is not merely structurally similar to the hydrodynamic equation named for Navier-Stokes

$$\frac{\partial u}{\partial t} + u\cdot\nabla u = -\frac{\nabla P}{\rho} + \nu\nabla^2 u,$$

but is actually a version of it.

To achieve this matchup, he suggests that Schrödinger's psi is a term representing momentum divided by Planck's constant, and by implication that this is occurring in a fluid analogous to a macroscopic one. This creates lots of further problems, as its author acknowledges, but we might look with interest at how he deals with the complex number argument of psi:

$$\Psi(x,t) = Ae^{ikx-i\omega t}.$$

This, he suggests, represents rotation, as complex numbers have traditionally been used to do, and specifically circular motion, and he cites Maxwell's attempt to explain magnetic interactions via hydrodynamic vortices, and the vortex ring particles of the elder and younger Thompsons. Despite the superficial similarities, string theory this ain't. It is true that the projection of circular motion onto one axis is a common way of creating a sine wave, and Schrödinger himself insisted on referring to his equation as "so-called" wave mechanics. Did the great man know something he wasn't letting on?

A curious interpretation, but it would be even more curious if by some chance this interpretation had legs, and your humble newsletter could claim first publication. We can but dream.

Members who wish to respond to the controversial points reported in this article, or to contribute to the discussion about the Big Bang, or make other submissions, are most welcome, and should e-mail the editor via the chair.

Roger Brewis, editor

Got an idea for a branch event?
E-mail chair-sw@physics.org

IOP Institute of Physics

Sponsored by Shell

The Shell and Institute of Physics Award for the Very Early Career Woman Physicist of the Year

The third annual very early career £1000 award

The Women in Physics Group invites applications from women at the start of their careers in physics who have made a substantial contribution to the subject and may also have undertaken activities to support and encourage others in the field. The prize is awarded annually to a woman who is within three years of completing her undergraduate degree in physics and who is either working as a physicist or engaged in postgraduate study.

The winner will receive £1000, donated by Shell, and an award certificate at a major Institute of Physics Women in Physics event. As well as providing recognition of the winner's work through the prize money, the award will also provide valuable networking opportunities. Applicants therefore must be working in the UK or Ireland.

The Very Early Career Woman Physicist of the Year award seeks to recognise the work done by women who are embarking on a career in physics and to promote the career opportunities open to people with physics qualifications.

All entries must be received by 28 February 2009.

For further details and application forms, visit

http://www.iop.org/activity/groups/subject/Women_in_physics/award/page_32186.html.