

LANBRIA

The newsletter of the Lancashire and Cumbria Branch of the Institute of Physics

Issue 33 March 2009

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Lancaster physics is

Every 5–7 years all of the research that is undertaken in UK universities is assessed. Imagine the scene last December as physics researchers held their breath while the results of the 2008 Research Assessment Exercise (RAE) were announced. When all of the numbers for the five categories of excellence were added up, the best physics department for research in the UK was Lancaster University. This news came as a big surprise for physicists in Lancaster (and the country), even though Lancaster was ranked 5* in the 2001 RAE, one of only five physics departments in the UK to get this top rating.

LANBRIA wishes to congratulate everyone involved: researchers, support staff, managers and RAE statistics administrators. Of course, the branch is also home to the University of Central Lancashire and we do not wish to neglect the good work being done there, so LANBRIA congratulates all of its university physics researchers.

The national physics rankings are not official, but based on RAE “quality profiles”. The following list was created by the *Times Higher Education Supplement*:



1	Lancaster	2.90	25	45
2	Cambridge	2.85	25	40
3	Nottingham	2.85	25	40
4	St Andrews	2.85	25	40
5	Bath	2.85	20	50
6	Edinburgh	2.80	20	45
7	Durham	2.75	20	40
8	Imperial	2.75	20	45
9	Sheffield	2.75	20	40
10	UCL	2.75	20	40
11	Glasgow	2.75	20	40

The numbers represent the average score, the percentage of researchers conducting

world-leading research (4*), and the percentage who are internationally excellent but not world leading (3*). A similar list has been produced by the *Guardian*, again with Lancaster at the top of the table.

Oxford (2.65/20/35), rather unfairly, does not make it into the top 10. This arises from the amount of research rated at 1* rather than a lack of 4* research. In terms of research volume, Oxford (and Cambridge) greatly exceed Lancaster’s output but the RAE emphasises quality rather than quantity.

To celebrate Lancaster’s remarkable achievement, we will publish a series of articles about the various research groups in the department: experimental condensed matter, particle physics and theoretical physics. To avoid bias, the articles will be written by a physicist uninvolved with the department – Louisa Reynolds, LANBRIA’s new assistant editor. This issue, Louisa interviews Dr Haley of the ultra-low temperature group (p2).

The newsletter also includes reports on two recent branch lectures, an evaluation of the December Galactic Gig tour and pictures from Lab in a Lorry in Lancashire.

Chris Bowdery

Louisa says hello

My name is Louisa Reynolds and I am a branch member. I grew up in Lancaster and now live on the outskirts.

I went to Lancaster and Morecambe College of Further Education (when it still had a science department) to take A-levels, then I went to the University of Oxford to study physics. After graduation I went

on to study for a Master’s in remote sensing at the University of Edinburgh, which I completed last year.

I now hold two editorial assistant posts, one of which is for LANBRIA, and I am looking for further ways to use my training in science. I enjoy music, art and film as well as discussing ideas about the modern world.

Louisa Reynolds



Louisa, our new assistant editor.

Liz Bartlett

Look what's boiling in our fridge

The experimental condensed matter group in Lancaster University's physics department has several subgroups. One is the low-temperature subgroup, which consists of the ultra-low temperatures (ULT) section and the superfluid helium-4 section. This article concentrates on the work of the ULT section, which is led by Prof. George Pickett FRS and consists of Dr Ian Bradley, Prof. Shaun Fisher, Dr Richard P Haley and Dr Viktor Tsepelin, plus students and technicians.

Lancaster University physics department has one of the world's leading low-temperature laboratories. It has been doing research in ULT since 1980 and its work has achieved international renown. It has set records for the lowest temperature ever achieved in a laboratory, of the order of a microkelvin. The group works with superfluid helium-3 and helium-4 at millikelvin temperatures.

I wanted to find out more about the ULT group by interviewing one of its key members, Rich Haley. Having studied superfluid helium-3 at the University of Manchester, and solid mixtures of helium-3 in helium-4 at the University of Florida, he now works at Lancaster as a lecturer and Royal Society research fellow.

Dr Haley's research specialises in using dilution refrigeration (similar to conventional refrigeration but using a mixture of helium-3 and helium-4), followed by an adiabatic demagnetisation technique, to reach temperatures lower than 0.001 K. This creates a helium-3 superfluid, a quantum fluid or condensate that can be described using a single wavefunction. It has no viscosity and presents no friction to an object moving through it.

Nuclear magnetic resonance can be used to image helium-3 but it is difficult to see it with the naked eye. "You can't usually look at helium-3. It's too cold, so any light going onto it warms it up." Dr Haley explains how his colleague, Dr Viktor Tsepelin, used a type of low-level camera to image the growth of helium-3

crystals in a superfluid, before he came to Lancaster: "It was an experimental *tour de force*."

Dr Haley described the transition to a superfluid state of helium-4. As the temperature of the liquid helium decreases, it boils because of the transfer of heat from one part of the liquid to another. As it reaches the superfluid state there is no friction and the transfer of heat becomes almost instantaneous, making any temperature gradients disappear. From a boiling mass, the liquid is suddenly very still. "The story is that the person who first made superfluid helium-4 100 years ago didn't realise that he'd done it because he couldn't see it. It's a very, very strange liquid. But you can see it if you know what to look for."

Superfluid helium-3 remains perfectly still until the object moving through it, such as a wire grid, moves fast enough to create excitations. For instance, quantum turbulence can occur, with quantised vortex lines appearing, like mini whirlpools. Other excitations are quasiparticles, the movements of which can be measured by observing the drag they exert on tiny wires (the vibrating wire resonance technique).

Quantum turbulence is key to the study of classical turbulence when trying to understand the behaviour of eddies in fluids, such as the decay from large eddies to smaller ones (the Richardson energy cascade). Quantum turbulence is easier to study because superfluid vorticity is quantised and there is virtually no friction to complicate the mathematics. Some of the group's interest is in how far the similarities can be observed in the two types of turbulent behaviour.

The vortex lines even exhibit behaviours that are thought to be analogous to the formation of cosmic strings that formed the first particles after the Big Bang via the Kibble mechanism.

The group studies the phase transition of superfluid helium-3 with random atomic spins (phase B) to a magnetised liquid crystal state with



George Pickett; inset Richard Ion

An ultra-low temperature fridge. Inset: Dr Richard P Haley.

spins aligned (phase A). The symmetry-breaking required to make the change from phase B to phase A is also thought to be analogous to the symmetry breaking in the very early universe as the first particles were formed. Two-dimensional boundaries can be created between the regions of phase A and phase B in the superfluid, and these may behave in a similar way to the 3D branes described by String Theory.

The group plans to image the quantum turbulence to see whether the Richardson energy cascade operates in quantum turbulence in the same way that it does in classical turbulence. "We're going to try and look more closely at the energy decay of the quantum turbulence...and image the quantum turbulence using the quasiparticle excitations that exist inside the superfluid, to shine these excitations onto the quantum turbulence and watch how they're affected by it."

The spin-demagnetisation technique using copper described on the ULT website

may be used on the solid helium-3 atoms that form on silicon fibres called "aerogel" to cool fluids to yet colder temperatures. "It turns out that the layers of the aerogel are covered with a few solid atom-layers of helium-3. It looks like that's got a magnetic transition in it and it also looks as though you can demagnetise the nuclear spins of that solid helium-3 and that may be a new cooling technique, which we're quite excited about."

I asked Dr Haley about his PhD students: "They are central to the way the lab works. A PhD student will arrive and start working on an existing experiment and gain some experience. Eventually they'll end up running the experiments themselves."

I asked him if he thought that the work his group has been doing contributed to Lancaster University physics department's success in the RAE: "I hope so. All we know is the final score. I would hope that we do world-leading research."

Louisa Reynolds

Planets clear the neighbourhood

Pluto was demoted from “planet” to “dwarf planet” at the International Astronomical Union’s meeting on 24 August 2006. At the branch meeting on 12 November 2008, Prof. Larry Marschall (Gettysburg and Lancaster) gave a highly entertaining talk about how we came to this position and how it had happened before.

The first planets were known to the Babylonians, who had a geocentric view of the universe and who also “invented” astrology and the star signs that we know today. These seven astronomical bodies eventually became known after the principal Roman gods, with the two exceptions being the Sun and the Moon, but all of them were referred to as “planets”. In 1543 Copernicus changed that to six planets plus the Moon, replacing the Sun with the Earth.

Herschel found the seventh planet in 1781 and called it Georgius Sidus (George’s Star, for King George III), but it became known as Herschel’s planet and later Uranus. Discrepancies in its orbit eventually led to the discovery of Neptune in 1846. Meanwhile, it became clear that the gap between Mars and Jupiter was populated with asteroids, Ceres being the most notable. So by the time Neptune was first seen, there were 11 “planets”.

By the end of the 19th century the invention of photography had identified more than 1000 asteroids. This led to a *de facto* classification system of the Sun, the planets (down to eight) and asteroids (many). Based on further data from the orbit of Uranus (not Neptune as is commonly stated) Percival Lowell predicted another planet, which Tombaugh thought he had found in 1930. This was Pluto, but it eventually transpired that it was too small to fit Lowell’s predictions. So now there were nine “planets”.

But are there 10? Theories of planetary formation suggest that there should be, and there are. Xena (properly 2003UB313), now called Eris,



The result of the IAU assembly and votes on the definitions of “planet” and “dwarf planet”.



An artist’s concept of the Kuiper belt object nicknamed Eris with its moon, dubbed Dysnomia, just above and the Sun top left.

was found using the Gemini Observatory in Hawaii and the Samuel Oschin 42”. The Hubble Space Telescope spotted a moon (Dysnomia) and was able to confirm that Eris is somewhat bigger than Pluto and much further away in the Kuiper belt.

Now several objects are known to be of similar size to Pluto, plus there are more than 300 000 other objects, forcing astronomers to ask the question: “What is a planet?”

The body regarding itself as competent to answer this is the International Astronomical Union (IAU). Founded in 1919, it is both the professional body for astronomers (8858 individual members) and the international forum for matters astronomical, with 65 countries represented. It had

taken on the task of naming or numbering the blizzard of small objects being found by modern telescopes, but until 2006 it had not tried to define a planet. After discussion, at the end of a conference with some 400 members present, a planet was defined, by a large majority of those present, as follows.

“IAU Resolution: Definition of a ‘planet’ in the solar system

“Contemporary observations are changing our understanding of planetary systems, and it is important that our nomenclature for objects reflect our current understanding. This applies, in particular, to the designation ‘planet’. The word ‘planet’ originally described ‘wanderers’ that were known only as moving lights in the sky.

Recent discoveries lead us to create a new definition, which we can make using currently available scientific information.

“Resolution 5A: The IAU therefore resolves that planets and other bodies in our solar system, except satellites, be defined into three distinct categories in the following way:

“(1) A ‘planet’ is a celestial body that (a) is in orbit around the Sun, (b) has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape, and (c) has cleared the neighbourhood around its orbit.

“(2) A ‘dwarf planet’ is a celestial body that (a) is in orbit around the Sun, (b) has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape, (c) has not cleared the neighbourhood around its orbit, and (d) is not a satellite.

“(3) All other objects, except satellites, orbiting the Sun shall be referred to collectively as ‘small solar-system bodies’.

“Resolution 6A: The IAU further resolves that Pluto is a dwarf planet by the above definition and is recognised as the prototype of a new category of trans-Neptunian objects.”

And then there were eight. By way of consolation, dwarf planets beyond Neptune are to be known as “plutoids”.

John Bradshaw

Qubits are the key to secrecy

If Alice wants to talk to Bob without Eve overhearing, then the only way to ensure secrecy is to use a one-time pad. If Eve intercepts the communication, it just looks like noise. But this means that Alice and Bob still have to exchange pads, which is insecure and inconvenient.

At the branch meeting on 13 January, Tim Spiller from HP Labs, Bristol, spoke to us about quantum information technologies. He explained the latest method using quantum effects to detect and defeat the activities of Eve in a fascinating talk about quantum computing and communications.

The key to quantum computing is to exploit the properties of qubits as superpositions of classical bits, 0 and 1. Classical bits (black) can be likened to the north and south poles of a sphere, whereas the qubits (red) are at the ends of any axis through the centre. Then qubit 0 is a superposition of 1 and 0.

A classical register of N bits holds only one of the possible 2^N binary numbers at a time. A quantum register can be in a state with an amplitude for each of the 2^N numbers. However, the aim is to get an answer. To do that you need to make a measurement and, although the quantum computer contains all of the answers to the problem, measurement still only gives you one value governed by the probability determined by quantum mechanics.

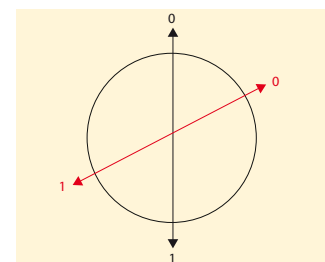
In some cases, such as factorising large primes, the quantum system and its algorithm can be organised so that it gives the desired result. The most likely use, certainly

LAB DEMONSTRATOR					
Alice polariser	Alice sends a	Alice keeps	Bob analyser	Bob receives	Bob keeps
↔	0	0	↔	0	0
↑	1		↑	1	
↑	1		↓		
↑	0		↓	1	
↔	0	0	↑		0
↔	0		↓	1	
↑	1		↔	0	
↓	1		↑		
↓	1	1	↓	1	1
↑	0	0	↑		0

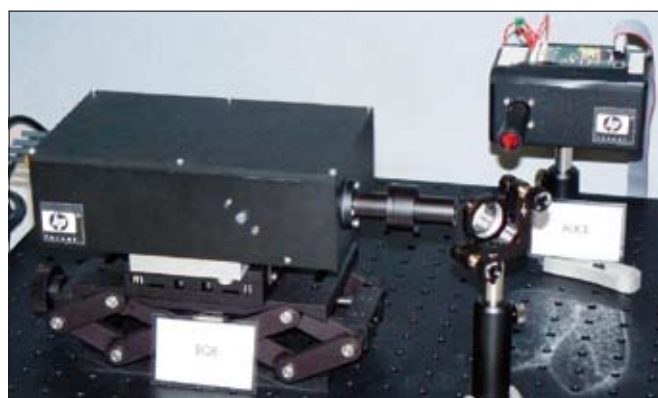
in the near term, is to simulate real quantum systems with ones that can be measured more easily.

The key to quantum cryptography is the fragility of quantum states: measurement destroys them. Measurement also gives a binary answer and this can be exploited by Alice and Bob to create a one-time key that is random. This can be done with a number of quantum systems. The easiest to understand is single photons polarised vertically (1), horizontally (0) or at $\pm 45^\circ$ (0,1). Alice sends single photons selecting one of the four directions of polarisation at random. Bob also sets the polarisation of his detector at random. Alice can then send the information Black or Red to indicate the order of the pairs of orthogonal polarisations that she had sent and Bob can scrap measurements that are indeterminate. Bob can do the same for Alice (see table).

They now have a random key, 0010, extracted randomly from Alice's original random message of 0110001110. For Eve to intercept, she too has to guess polarisations and corrupts 25% of the transmission (that Alice and Bob keep) that she intercepts



Qubits are more general than classical bits, which lie on the N-S axis of a rotating sphere.



HP has a prototype for a quantum key distribution device.

and therefore gives herself away. (She guesses the wrong basis to measure 50% of the time, but Bob will accidentally correct half of these data back to the correct value, leaving 25% in error.)

Single photons have been transmitted over distances of 120 km, in fibre and through the atmosphere. This is long enough to communicate with satellites to enable the renewal of their binary one-time pads, currently done either by a visiting space shuttle or by scrapping and replacing the whole satellite.

Spiller foresees a commercial application in the near future. A device like a PDA could hold a few kilobits

of random numbers to act as a key. Consumer quantum key distribution (QKD) separates "use" and "top up". The top up is quantum and done regularly at a machine much like an ATM via the mechanism outlined in this article (as the use consumes the key) but the use is purely classical. The secret key can be used for access, to authenticate internet or other financial transactions needing a secure ID.

Watch out – quantum information technology is coming soon (if any banks are left in business to invest in it). However, practical quantum computing may take a qubit longer to arrive.

John Bradshaw

Branching out

The branch AGM will be held on Wednesday 13 May. Members are invited to make nominations for branch officer and committee posts. Send them to the honorary secretary (see p1 for details). A formal agenda will be published in the

May branch newsletter.

The 2008/2009 round of the SciCast Physics competition has ended. Sadly there were no entries (short films explaining a physics idea) from the Lancashire and Cumbria area. This is rather disappointing. But one area saw a very impressive number of entries:

London and the South East had 49 videos submitted. The overall number of entries was 87. Judging will have been completed by the time you read this and the next round will be under way for 2009.

Prof. Dame Jocelyn Bell Burnell, Institute president, will be visiting Lancaster to

give a talk at the university on 8 April (4.00 p.m.). This has been arranged by the Faculty of Science and Technology in association with the branch. Everyone is welcome to attend.

Suggestions for lectures or outreach events are most welcome. The new programme is currently being discussed.

Lab in a Lorry visits Lancashire

The Institute's Lab in a Lorry number 3 toured Lancashire in January and February. Dayna Mason and volunteers (many of whom are branch members) demonstrated physics experiments to high-school pupils. A camera crew from Teachers TV came to Blackburn to record the experiments. The itinerary included:

20–22 January Fleetwood Sports College, Broadway, Fleetwood

27–29 January Ripley St Thomas Church of England High School, Ashton Road, Lancaster

3–5 February Morecambe High School, Dallam Avenue, Morecambe

10–12 February Pleckgate High School, Pleckgate Road, Blackburn



All Images: Chris Bowdery

Clockwise from top: Lab in a Lorry 3 at Ripley St Thomas, Lancaster; John Bradshaw explains how oil is extracted while Dayna Mason looks on; Dayna Mason, Lab in a Lorry operations coordinator (NW).



Branch events programme spring 2009

Wednesday 18 March, 6.30 p.m.
The climate of Venus and the greenhouse effect

Prof. Fred Taylor (University of Oxford)
Preston

Venus is the same size and mass as Earth, and our nearest neighbour in the solar system. The permanent cloud cover reflects 75% of the incoming solar energy, leaving Venus with less solar heating than Earth, despite orbiting closer to the Sun. Nevertheless, the mean surface temperature is much too hot for liquid water, a consequence of a CO₂-driven greenhouse effect similar in principle to that which regulates the climate on Earth.

The atmospheric circulation seems to be hemispheric Hadley cells with high zonal winds, powerful and extensive quasi-permanent polar vortices and exotic weather patterns in the deep atmosphere below the cloud tops.

A-level prizes will be presented at this meeting.

Wednesday 8 April, 4.00 p.m.
In pursuit of pulsars

Prof. Dame Jocelyn Bell Burnell (University of Oxford/Institute president)
Biology lecture theatre, Lancaster University
Pulsars, or neutron stars, are some of the most bizarre objects in the galaxy. Their discovery 40 years ago took the astronomical community by storm and they are still springing surprises on us.

Like lighthouses in the sky, they may one day be used as navigation beacons for interstellar travel. Meanwhile, they have stretched our understanding of the behaviour of matter and serve as very accurate clocks to check out Einstein's theory of relativity.

This talk will be accessible to scientists of all abilities and ages. It is held jointly with

Lancaster University's Faculty of Science and Technology.

Wednesday 15 April, 6.30 p.m.
Wind power: the engineering considerations

Prof. Nick Jenkins (Centre for Integrated Renewable Energy Generation and Supply/ School of Engineering, Cardiff University)
Preston

Wind power is developing at a very fast rate. Larger turbines are possible and generator and converter designs are still evolving. This talk will also discuss the problems of integrating wind farms into the national grid.

Wednesday 13 May, 6.30 p.m.
AGM

The physics of brain imaging: a window on autism, shopping and learning

Prof. Stephen Swithenby (Open University)
Lancaster

Over the last 40 years physicists, aided and abetted by engineers and computer scientists, have developed many new ways of studying the living brain. First came structural imaging instruments followed by a new generation of systems that could image brain function.

Prof. Swithenby's lecture will review these methods and it will describe how the enormous magnetic-field sensitivity of superconducting quantum interference devices (SQUIDS) can be exploited to measure the currents flowing in the brain.

The talk will also explain how SQUIDS throw light on the neurophysiological basis of autism, and Prof. Swithenby will outline current studies in the decision-making processes involved in shopping, explaining how the brain changes as we learn symbolic mathematics.

Galactic Gig gets the thumbs-up

EXIT QUESTIONNAIRE

	strongly agree	agree	disagree	strongly disagree	mean score
1. I am glad that I came to this event					3.53
Our Ladies and All Saints, Parbold	8	10	0	0	
Cathedral RC Primary School, Lancaster	35	26	1	0	
2. I learned something about physics here that was worth learning					3.40
Our Ladies and All Saints, Parbold	6	12	0	0	
Cathedral RC Primary School, Lancaster	29	31	1	1	
3. I feel more positive about physics now than before I came here					3.26
Our Ladies and All Saints, Parbold	6	10	2	0	
Cathedral RC Primary School, Lancaster	26	30	3	3	

Five performances of Galactic Gig were given in December to 330 pupils from four primary schools: Ashfield Junior School, Workington; Cathedral RC Primary School, Lancaster; Our Ladies & All Saints RC Primary School, Parbold; and Parbold Douglas C of E Primary School.

Standard Institute exit questionnaires were distributed to all schools during the events and 80 were returned by January, from two schools only. The number of returns from boys and girls were comparable. The lack of returns from the other schools, despite follow-up enquiries, was disappointing but there is no reason to believe that the results presented are not representative and they are very similar to results from earlier tours of Galactic Gig.

The Institute asks for data to be analysed by scoring “strongly agree” as 4, “agree” as 3, “disagree” as 2 and “strongly disagree” as 1. The mean scores for December’s shows are shown in the table. The maximum possible score is 4.00, so the results achieved are excellent. They are slightly higher (by 0.1–0.2) than the last survey, for the summer 2008 tour, which in turn was slightly higher than for the December 2007 tour. Clearly we are getting better at putting on the

show each year since we started in 2005.

Replies to questions 4–6 were also very positive and the comments made were similar to previous findings. Very few negative comments were made. The only point that seems worth singling out for further action is the oft-repeated lament that there was not enough time for everyone to have a go at the hands-on activities.

4. Write up to three things you have learned from this event.

“I learned about the electric hair.” [Probably Van de Graaf.]
 “If you spin and put arms in you go faster.”
 “Venus is the sister planet to Earth.”
 “Sounds travel in waves.”
 “Light is faster than sound.”
 “Jupiter is a big ball of gas.”
 “Sand makes patterns on the plate.”
 “Planets are made of three things: rock, gas and ice.”
 “The bigger the waves, the lower the sound.”
 “Sound waves that move a lot are called aunty nodes [sic].”

5. What were the three best things about this event?

“Zubi being funny.”
 “Zubi when he was dancing.”
 “Everything.”
 “When Einstein came out to tell us about different parts of

physics.”

“When the big party popper popped.”
 “It was funny when Einstein’s nose blew up.”
 “I really enjoy science so it was a bonus for me.”
 “Singing Rudolph through the microphone.”
 “The idea that they turned it into a play.”
 “When the alien said: ‘It’s another rocky planet.’”
 “When the alien had to put his voice back on.”
 “Sometimes in physics it is boring but this one was fun and interesting.”

6. How could this event have been improved?

“Nothing.” [Several replies.]
 “It’s brilliant as it is.”
 “Making it last longer.”
 “Another alien.” [Presumably a second one, not a replacement for Zubi.]
 “Man with funny nose should have turned up more often.”
 “More exciting acting.”
 “Involve more people in the play.”
 “More time for everyone to have a go.” [Several replies.]

It appears that Galactic Gig has a stellar future and schoolchildren in the Isle of Man may be the next to see performances of it in June.

Bob Jones

Digital TV comes to branch area

It’s coming. This year will see the switch-off of analogue television transmissions for everyone in Lancashire and Cumbria. In fact some parts of Cumbria have already switched to digital-only television.

Those parts of Cumbria not yet switched over will start the process on 24 June with analogue BBC2 ceasing transmissions. On 22 July the other analogue channels will stop. Lancashire has corresponding dates of 4 November and 2 December.

Many areas already have digital terrestrial television (Freeview) and after the switchover this will be available to almost everyone in our region. Basic Freeview set-top boxes are now fairly cheap (£20) with more expensive ones being able to record and pause live television. There could be a problem with aerials because some will need to be replaced but this may not be obvious until a Freeview box is installed.

Digital satellite television is already available to everyone who can put a dish on their property via Freesat, Freesat from Sky and the subscription service, Sky Digital. There is no cable service in our region (as far as I know).

Why not raise the profile of physicists by helping your neighbours with the digital switchover? This year you could be a hero in your street.

Chris Bowdery

Branch officer receives award

John Bradshaw received an award for school voluntary from Gillian Beeley, chief executive of the Lancashire Education Business Partnership.



E-mail material for the next newsletter to chris.bowdery@physics.org

The branch newsletters are published by IOP Publishing, Dirac House, Temple Back, Bristol BS1 6BE, UK.

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Printed by Warners (Midlands) plc, Bourne, Lincolnshire, UK.

The contents of this newsletter do not necessarily represent the views or policies of the Institute of Physics, except where explicitly stated.

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