NASA/TRACE

Solar flares

Plasma prominences and cosmic rays

Seeing space from school

Peter Hatfield

17-year-old Peter Hatfield, UK Young Scientist of the Year 2009, writes about working in astronomy and particle physics, projects carried out by a group at Simon Langton Grammar School for Boys in Canterbury, Kent.

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Astronomical Activities

In Hawaii and Australia there two giant telescopes called the Faulkes telescopes. These are available to schoolchildren in the UK to do original research with. With the Faulkes telescopes my friends and I have done some pretty interesting research:

Faulkes Telescope North in Hawaii and the Milky Way, a composite image courtesy of Nik Szymanek.

- Colour imaging - creating high quality, detailed images of distant galaxies and nebulae.
- Supernovae observations – studying huge explosions of giant stars. Recording how their brightness changes over time lets you find out how fast it is expanding.
- Near Earth Objects (NEO's) – tracking small asteroids and rocks that could potentially hit the Earth.
- Exoplanets – we are currently planning to observe planets *outside* our solar system. Little is known about these planets that orbit other stars and some could potentially hold life!

Each of the Faulkes telescopes has a two-metre wide reflecting dish at its centre. They use a CCD-camera to record the data, a similar device to inside a digital camera. Students control the telescopes over the Internet, and you get the images and data back over it as well. The Faulkes telescopes are well worth having a go with if you get the opportunity.

An image of the Little Dumbbell nebula, made by students using a Faulkes telescope.

Set the controls for the heart of the Sun…

After a lecture from Professor Steve Rose, Head of the Plasma Physics Group at Imperial College, we started our next area of research. We would use the techniques of studying the plasma used in his labs to analyse plasma in the Sun and distant stars. Because they were similar types of plasma, the laws that worked in the labs ought also to work in stars light-years away.

(Plasma is the *fourth* state of matter after gases. In plasma, the material is so super-heated that the electrons actually separate from the nucleus and are free to move around separately to the rest of the atom. Most of the known universe is made of plasma – solids, liquids and gases are actually quite rare!)

How can you use the colour of something to work out its shape?

All plasma in stars gives off X-ray radiation. X-rays are a type of light with a very high frequency, with a lot of energy. Because distant stars are very far away, you cannot get a picture of the plasma in the stars to work out what shape they are. However you can measure the X-rays given off. It turns out that the brightness of some types of X-ray depends on how thick the plasma it has to shine through is, but others types don't. So if you can measure the brightness of these two types of X-ray, and compare them (the X-ray "colour"), you can tell what the thickness of the plasma was. We used data from the XMM-Newton satellite for our calculations. The problem is that because of the shape of the plasma, it has a different thickness when seen from different sides, so you get different values. But if you look at these plasmas lots of times, eventually you see the plasma from all angles, and you can build up a three-dimensional image of what the plasma looks like.

This sort of problem is called *mathematical modelling*. We can use sums and algebra to make something mathematical that we think behaves like the physical thing that we are trying to describe. We then do the sums and see if the results are similar to what we have observed in the real world. If they are close, then we have a "good" model, and we understand the phenomena well. If they are not very close, then maybe we didn't understand the problem properly, or maybe there was something important that we had not included in our calculations. We then try and improve the model, and have another go!

I went through about five models before I got one that fitted the data well. This model suggested that the plasma is in "loop" shapes on the surface of the stars. This is interesting, because it suggests that these stars are quite similar to our Sun – plasma on our Sun is in loop shapes as well!

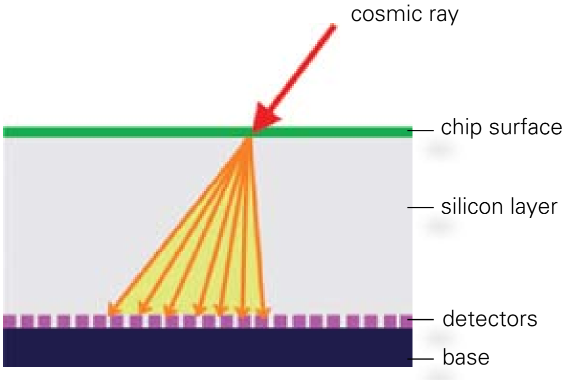
LUCID – The Langton Ultimate Cosmic-ray Intensity Detector

Recently we embarked upon one of our most ambitious projects – to design an experiment that would actually be launched on a satellite into space.

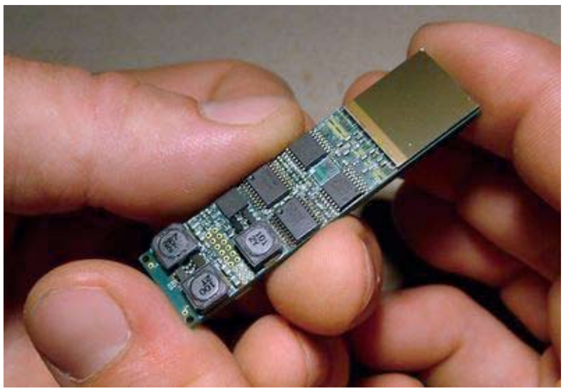
BNSC announced a competition in 2007 for students to design an experiment that would be launched on a SSTL satellite. BNSC is the British National Space Centre, the UK's organisation for space exploration, and SSTL is Surrey Satellite Technology Ltd, a company based in Guildford that specialises in small and micro satellites. After a long year of developing our design, we got a place for our experiment – a cosmic ray detector – to go on a satellite called SEEDA-Sat.

Radiation in space is known as cosmic rays. These are mainly protons and electrons travelling close to the speed of light. Some are produced by the Sun, which fires out loads of particles all the time. Others, with more energy, are from other places within our galaxy. The really high energy ones are from outside the Milky Way.

The main concept of our design for a cosmic ray detector was to use the same techniques that are used to study particles in the Large Hadron Collider to study particles in space. LUCID will use four "Medipix chips". A Medipix chip is a particle detector used inside ATLAS (A Toroidal LHC ApparatuS), part of the Large Hadron Collider. They consist of a little square of electronics. There is a layer of silicon above a layer of pixels. When a particle travels through the silicon, it kicks out lots of electrons, which become an electrical current, and which then lights up the pixel. The strength of the electrical current tells you how much energy the particle had, and the shape the pixels make tells you what type of particle it was. For example, an alpha particle makes a round "splodge", whereas an electron makes a "squiggle".

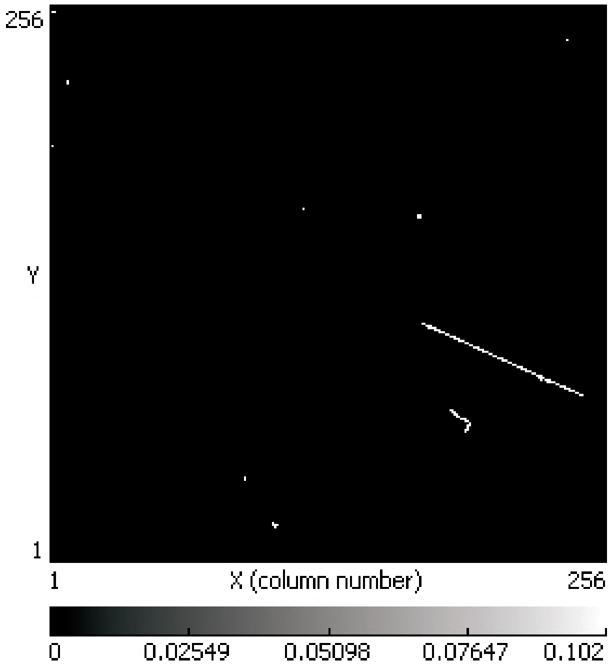


The construction of a Medipix chip.



A Medipix chip with USB interface.

How LUCID will look, when finally constructed.



The track of a muon, detected by a Medipix chip.

CERN and the LHC

CERN, or the European Centre for Nuclear Research, is the home of the Large Hadron Collider, the LHC. This is the fantastic machine in Switzerland that you may have heard about. It is built a hundred metres underground, below Geneva, and will be able to re-create conditions similar to immediately after the big bang.

But we also had various restrictions. The experiment had to weigh less than 1 kg, it had to fit within a 10 cm by 10 cm by 10 cm box and it had to be able to survive the powerful radiation that the satellite would feel when in the South Atlantic Anomaly. The SAA is a strong region of cosmic ray activity over the Atlantic Ocean that occurs because of how the Earth's magnetic field interacts with the cosmic rays. Most cosmic rays are charged, which means that they are attracted or repelled in magnetic fields. We also had to consider the temperature that our experiment would work under. With electronics on Earth, most of the heat can simply conduct into the air. However in space there is no atmosphere for the heat to escape into, and electronics just get hotter and hotter.

What do we want to discover (and why)?

Our experiment will be able to find out lots of new things that were not known before:

- The direction that cosmic rays travel in – becausee our experiment will have more than detector, each particle will pass through more than one chip. We will then be able to track them as they move through the detector.
- What particles are present – our experiment will be the first of its type that will be able to tell the difference between protons and electrons. It will also be able to investigate rarer types of cosmic rays, lithium, beryllium and boron nuclei.
- When cosmic ray storms occur – we would like to help learn how to predict when these proton bursts happen.

There are two main reasons why it is important to know about these things:

- To protect electronics in space – computers in orbit can be damaged by cosmic rays in an effect called single-event upset. If these electronics are in an important satellite it can have bad consequences for whatever was using it on Earth.
- To protect people in space – radiation can be dangerous for astronauts and cosmonauts in space, potentially causing medical problems like radiation poisoning and cancer, or potentially even death.

What's it like working in science?

I've had such fun over the last two years working on plasma physics and satellites. You get to meet such interesting people and go to such interesting places. It's such a thrill when you discover something truly original, something that no one else has ever known before.

Peter meets the Science minister, Lord Drayson.

Peter Hatfield studied for A-levels at Simon Langton Grammar School for Boys, Canterbury, Kent.

Look here!

A network of Medipix cosmic ray detectors is being set up on the ground. This will be connected to the satellite via the Internet. If you or your school are interested in getting involved, please contact us via *www.thelangtonstarcentre.org*