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# Introducing Einstein's Universe: Exploring Relativity and Cosmology at High School

**Dr Martin Hendry**

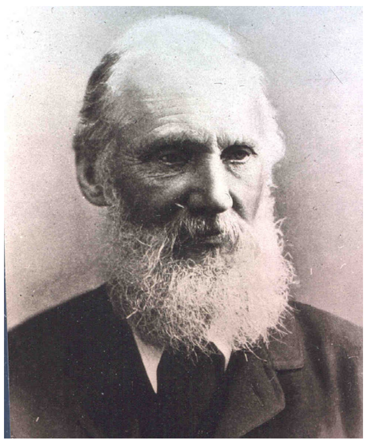
**Astronomy and Astrophysics Group, Institute for Gravitational Research**

**School of Physics and Astronomy, University of Glasgow**

## *Who am I?...*

Senior Lecturer,
Director of Teaching
in the Department of
Physics & Astronomy

*(the **Kelvin** Building)*



William Thompson
(Lord Kelvin)
1824 - 1907

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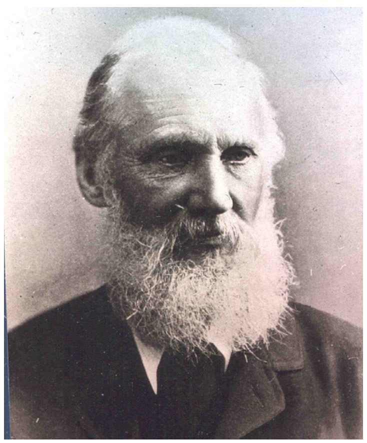

William Thompson
(Lord Kelvin)
1824 - 1907


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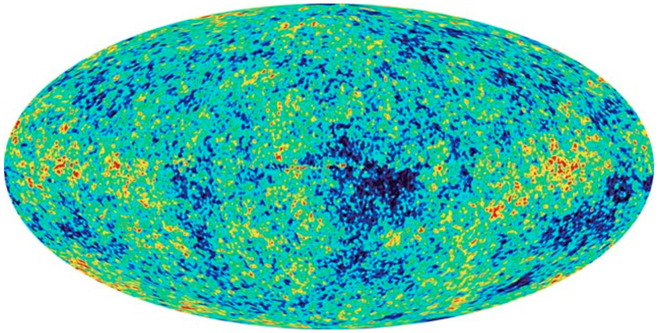
# What do I work on?...

## Cosmology:

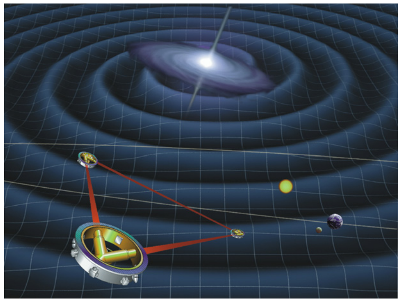
how big is the Universe?
how did it begin?
why is it expanding?
will it expand forever?

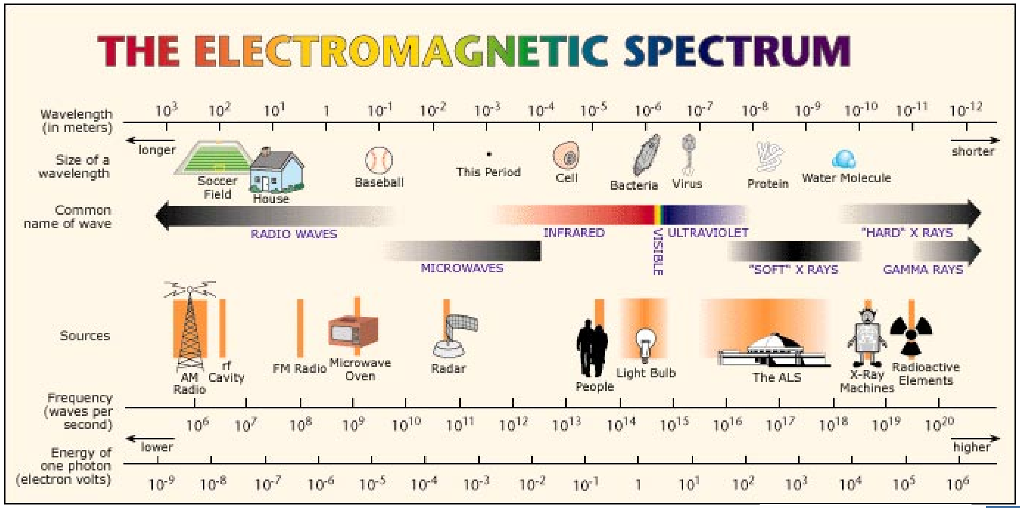


## Gravitational wave astronomy:

what are black holes and neutron stars?
what happens when they collide?
was Einstein's picture of gravity correct?

## Multi-messenger astronomy



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# Public Engagement and Outreach


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SciTech, Perth, Oct 2010

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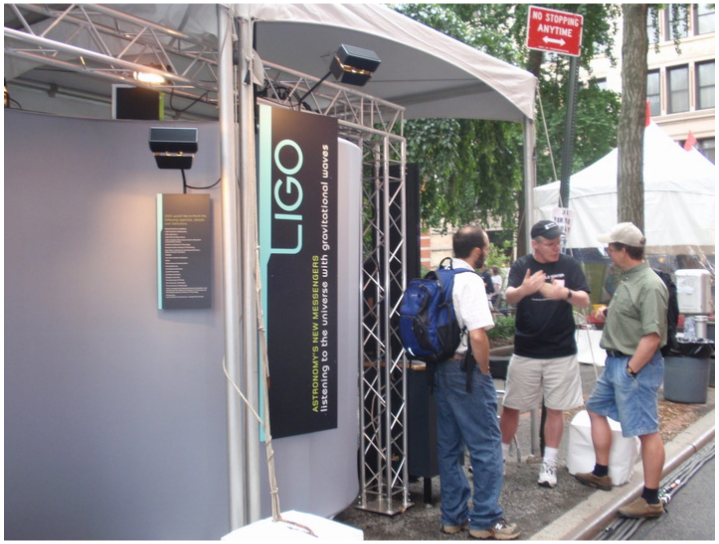
# Public Engagement and Outreach

World Science Festival





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In the Beginning
Dr Martin Hendry
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PPARC
Odyssey 2001
The 2nd International Philosophy, Science & Theology Festival
Grafton NSW
The British Council
Cosmic Catastrophes
Dr Martin Hendry
University of Glasgow
12th Orkney Science Festival
Dark Energy
Dr Martin Hendry
University of Glasgow
Deep Impacts
Dr Martin Hendry
Dept of Physics and Astronomy, University of Glasgow
Einstein's Universe
Dr Martin Hendry
Dept of Physics and Astronomy, University of Glasgow
Extra-terrestrial life: Is there anybody out there?...
Dr Martin Hendry
University of Glasgow
Stirling Physics Meeting: 2nd June 04
The Solar System from Galileo to Galileo
The Copernican Revolution
Exploring the Solar System
Finding Extra-Solar Planets
Dr. Martin Hendry
Glasgow University
Moray Science Festival
12th June 2001
A History of Astronomy at Glasgow University
Dr. Martin Hendry
Dept of Physics and Astronomy
University of Glasgow
To Infinity and Beyond
Dr Martin Hendry
University of Glasgow
11th Orkney Science Festival
Putting the Iron in Irn Bru
Dr Martin Hendry
University of Glasgow
The Life and Death of Stars
Dr Martin Hendry
University of Glasgow
Getting the Measure of the Universe
Dr. Martin Hendry
Glasgow University
Light in Lumps or ripples?
Reach for the Stars
Dr Martin Hendry
University of Glasgow
Skywatchers of Ancient Mexico
Dr Martin Hendry
Department of Physics and Astronomy
University of Glasgow
What if the Moon Didn't Exist?
Dr Martin Hendry
University of Glasgow
BORDERS
Overwhelmingly Large Telescopes
Dr. Martin Hendry
Dept of Physics and Astronomy
University of Glasgow
BORDERS
A Recipe for Galaxy Formation
Dr. Martin Hendry
Dept of Physics and Astronomy
University of Glasgow
Rocket Science
Dr. Martin Hendry
Glasgow University
Reach for the Stars
The Runaway Universe
Dr Martin Hendry
Dept of Physics and Astronomy
University of Glasgow
The Physics of Star Wars
Dr Martin Hendry
Dept of Physics and Astronomy
University of Glasgow
13th Orkney International Science Festival
Strings, Membranes and Quantum foam
Dr Martin Hendry
Dept of Physics and Astronomy
University of Glasgow
Sun and Moon, Clocks and Calendars
Dr Martin Hendry
University of Glasgow
Captain Cook and the Cosmic Yardstick
Dr Martin Hendry
Dept of Physics and Astronomy, University of Glasgow
Sacred Sites and the Archaeo-Astronomical Work of Alexander Thom
Dr Martin Hendry
Dept of Physics and Astronomy
University of Glasgow
Astronomy from Galileo to Hubble, and beyond
Dr. Martin Hendry
University of Glasgow
4th Feb 2001

# Debunking “Moon Hoax” theories

Science & Technology Facilities Council

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## Funding and Grants

- Funding Allocations
- Fellowships
- Joint Grant Scheme
- Funding for Public Engagement
- Research Grants
- Postgraduate Studentships
- Business and Innovation
- Research in industry funding

Printer-friendly

Home > Funding and Grants > Fellowships > Science and society fellowships > Current Science in Society Fellows

# Current Science in Society Fellows

Dr Martin Hendry
School of Physics and Astronomy, University of Glasgow - Exploring the Dark Side of the Universe: an Integrated Programme of Astronomy Outreach for Schools and the Public

The fact that 95% of the cosmos appears to consist of unseen matter and energy, which is driving the accelerated expansion of the Universe, is widely regarded as one of the most startling discoveries - and biggest unsolved mysteries - in all of science. Dr Hendry will inspire audiences who would not normally engage with science, to convey the excitement and implications of recent cosmological discoveries and explain in a clear and engaging way both what we know about the universe and how we know it.

---

Dr Maggie Aderin
Science and Technology Studies, University College London and EADS Astrium - Monsters in the Laboratory and Cosmic Safari

A series of promotional events to mark the International Year of Astronomy, covers Climate Change, what space can teach us about Planet Earth, working with BBC and Teachers TV to produce a series of inspirational and informative programmes related to space science, and many public talks & school visits.

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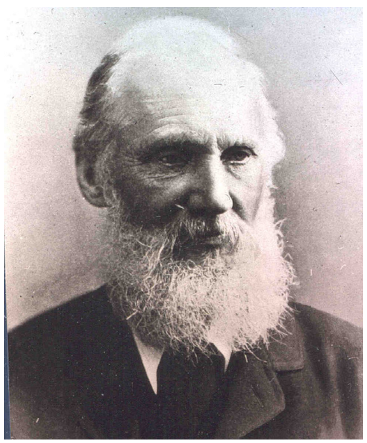

William Thompson
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1824 - 1907

"There is nothing new to be discovered in physics now.

All that remains is more and more precise measurement" (1900)

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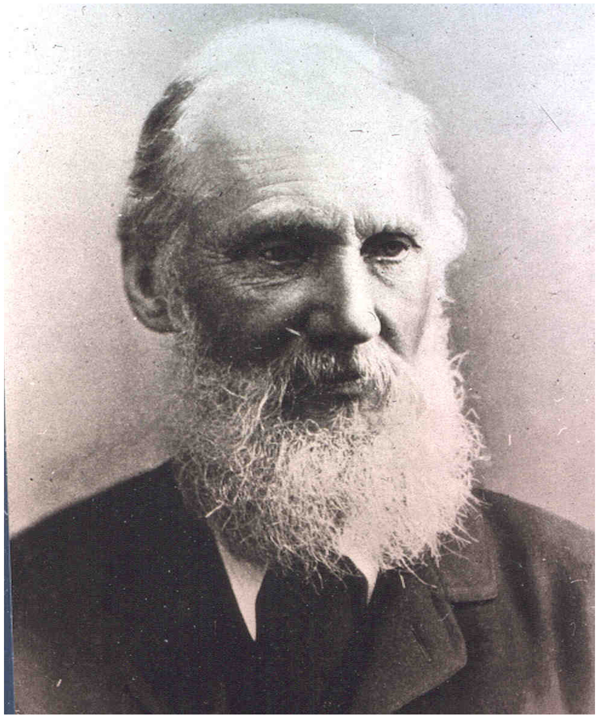
## Lord Kelvin didn't *always* get things right….

1895 "Heavier-than-air flying machines are impossible."

1897 "Radio has no future"

1903 "X-rays will prove to be a hoax"



But he was one of the most influential scientists of all time.

# Science:

*(From the New Oxford dictionary)*

The intellectual and practical activity encompassing the **systematic study** of the structure and behaviour of the physical and natural world through **observation** and **experiment**.

Kelvin's approach put **observation & experiment** at the centre – revolution in how we teach science, from pre-school to PhDs !!

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Kelvin believed passionately that:

- Physics is fun
- Physics is fundamental
- Physics is practically useful

*"The life and soul of science is its practical application"*

- Physics is all around us

*"Blow a soap bubble and observe it. You may study it all your life and draw one lesson after another…from it."*

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**Kelvin's legacy lives on in new developments today**

"Curriculum for Excellence aims to achieve a transformation in education in Scotland by providing a coherent, more flexible and enriched curriculum from 3 to 18.

The curriculum aims to help every learner develop knowledge, skills and attributes for learning, life and work, which are encapsulated in the four capacities.

- **Successful learners**
- **Confident individuals**
- **Responsible citizens**
- **Effective contributors**

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www.curriculumforexcellencescotland.gov.uk

**Planet Earth** incorporates
- Biodiversity and interdependence
- Energy sources and sustainability
- Processes of the planet
- Space.

**Forces, electricity and waves** incorporates
- Forces
- Electricity
- Vibrations and waves.

# How are the experiences and outcomes structured in sciences?

**Biological systems** incorporates
- Body systems and cells
- Inheritance.

**Materials** incorporates
- Properties and uses of substances
- Earth's materials

**Topical science**

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## Sciences
## Experiences and outcomes

The sciences framework provides a range of different contexts for learning which draw on important aspects of everyday life and work.

Learning in the sciences will enable me to:

- develop curiosity and understanding of the environment and my place in the living, material and physical world
- demonstrate a secure knowledge and understanding of the big ideas and concepts of the sciences
- develop skills for learning, life and work
- develop the skills of scientific inquiry and investigation using practical techniques
- develop skills in the accurate use of scientific language, formulae and equations
- apply safety measures and take necessary actions to control risk and hazards
- recognise the impact the sciences make on my life, the lives of others, the environment and on society
- recognise the role of creativity and inventiveness in the development of the sciences
- develop an understanding of the Earth's resources and the need for responsible use of them
- express opinions and make decisions on social, moral, ethical, economic and environmental issues based upon sound understanding
- develop as a scientifically-literate citizen with a lifelong interest in the sciences
- establish the foundation for more advanced learning and future careers in the sciences and the technologies.

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**Key words:** "curiosity", "concepts", "inquiry and investigation", "practical techniques", "accurate use", "impact", "creativity", "scientifically-literate" citizen.

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**Much greater emphasis on method than on specific knowledge**

# New Higher Physics

***Designed to promote:***

- **Deeper understanding of the physics**
- **Greater emphasis on development of skills**
- **Open ended enquiry**
- **Appreciation of topical research**

***Some streamlining of content, but balanced by more time on 'core' physics + development of research, communication, collaborative skills.***

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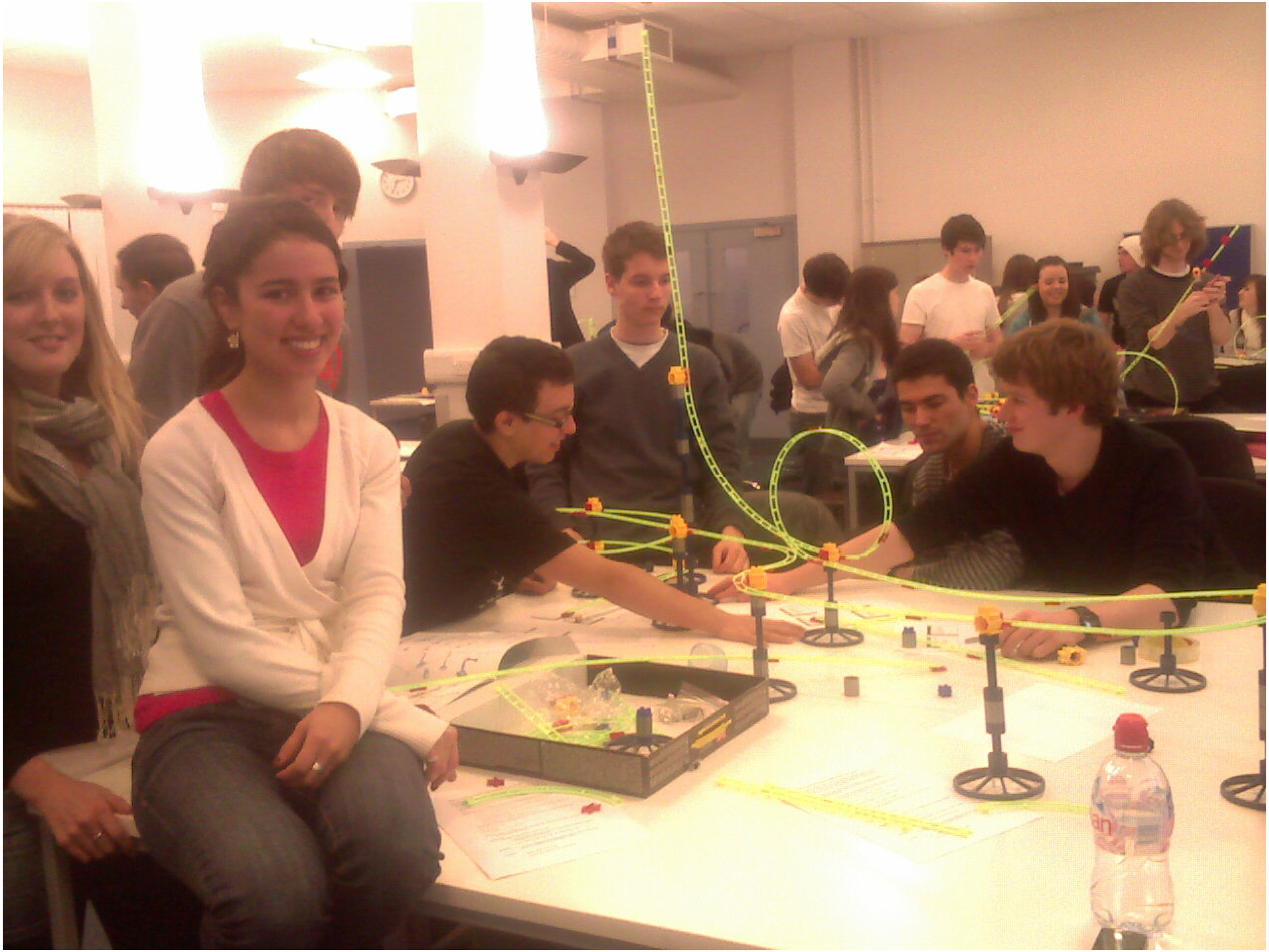

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# Perceptions, views and opinions of university students about physics learning during practical work at school

P. H. Sneddon[1], K. A. Slaughter[2] and N. Reid[1]
[1] Department of Physics and Astronomy, University of Glasgow, Glasgow, G12 8QQ
[2] School of Physics and Astronomy, University of Edinburgh, Edinburgh, EH9 3JZ

## Abstract

The teaching of physics through practical experiments has long been an established practice. It forms a key component of teaching of that subject at both school and university level. As such, students have strong views of this method of teaching. This paper reports on the view of undergraduate physics students in relation to their experiences of practical physics at school. 500 students across three Higher Education Institutions were surveyed to determine their perceptions, views and opinions in this area. This paper initially presents the overall views of the students, and then looks in more detail at the effect the different levels to which students took the subject at school affected those views. Specifically, students who took Advanced Higher vs Higher are compared, as well as those who took Advanced Higher vs A-level. Comparison was also made between the responses of female and male students. The general picture is very encouraging, with students broadly appreciating the practical side of physics.

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**Table 7.** Practical work as an integral part of the physics course.

| *Statement* | *Total %* |
|---|---|
| A: Physics is a practical subject. | 30.6 |
| B: Experiments illustrate theory for me, | **68.1** |
| C: Experimental work allows me to test out ideas. | 34.8 |
| D: Experiments assist me to plan and organise. | 8.4 |
| E: New discoveries are made by means of experiments. | **48** |
| F: Experimental skills can be gained in the laboratory. | 29.2 |
| G: Experimental work allows me to think about physics | **53.4** |
| H: Experimental work makes physics more enjoyable for me. | 27.6 |

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## Key messages:

- "The students seemed to revel in the more open-ended experimental work….less 'recipe-driven' laboratory work is essential."
- *Weaker* preference for "written instructions for experiments" among AH students.
- *The new Higher RP unit should address this disparity*

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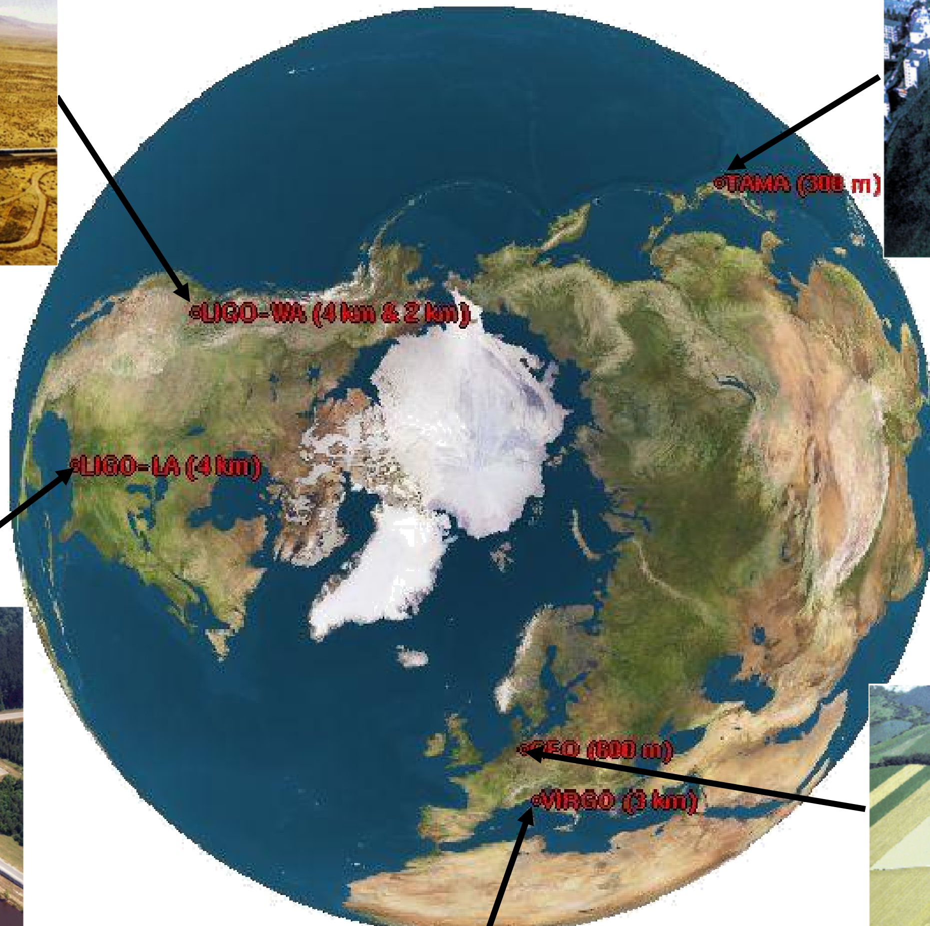
LIGO Hanford WA
(4km & 2km)

TAMA (300m)

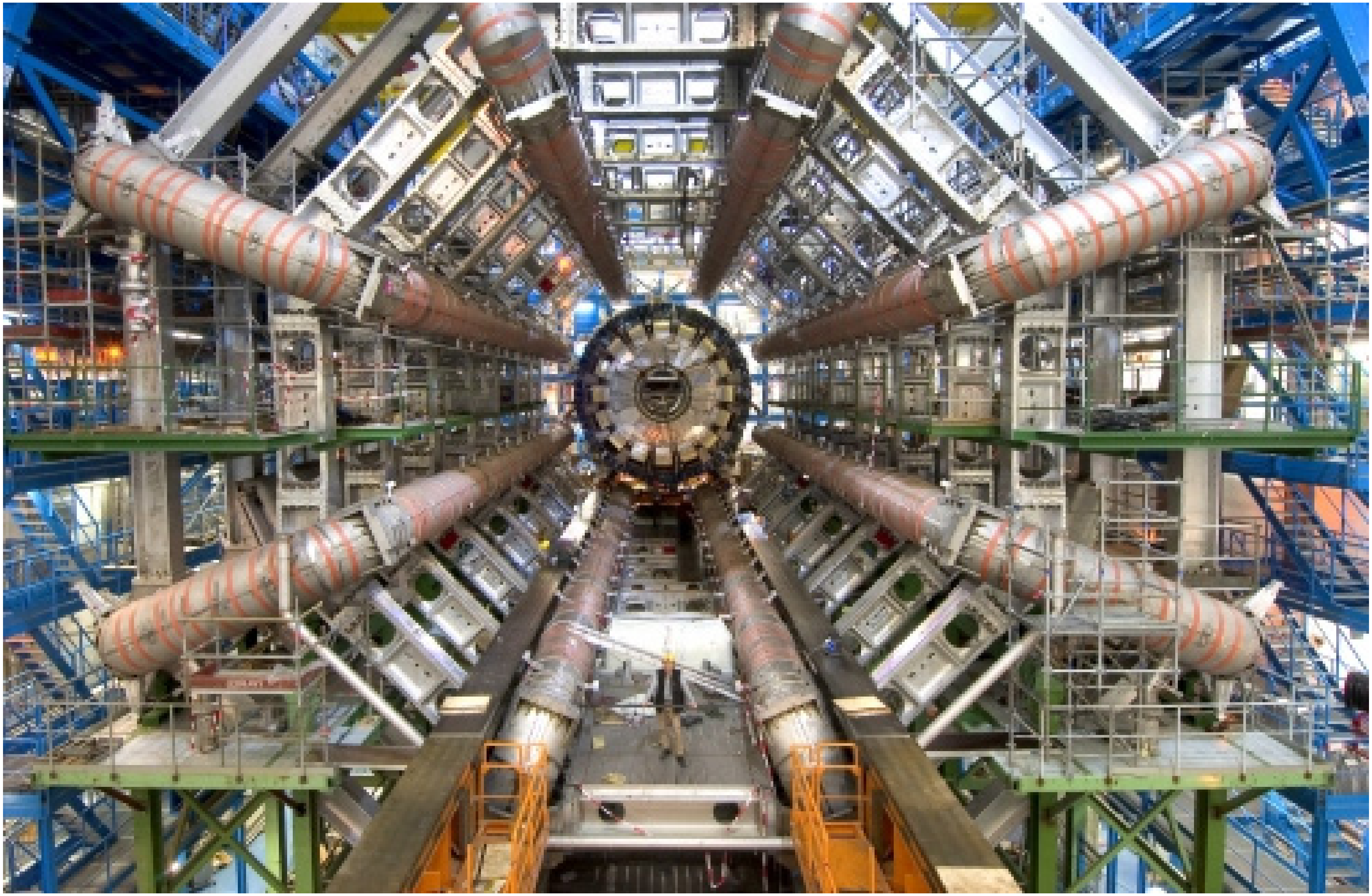



LIGO Livingston LA
(4km)

AIGO

GEO (600m)

VIRGO (3km)



SciTech, Perth, Oct 2010

# SQA New Higher Physics modules

## *Our Dynamic Universe*

- Equations of Motion
- Forces, Energy and Power
- Collisions and Explosions
- Gravitation
- Special Relativity
- The Expanding Universe
- Big Bang Theory

# New Higher Physics modules

## *Particles and Waves*

- The Standard Model
- Forces on Charged Particles
- Nuclear Reactions
- Wave Particle Duality
- Interference and Diffraction
- Refraction of Light
- Spectra

# New Higher Physics modules

## *Electricity*

- **Electrons and Energy**
- **Electrons at Work**

## *Researching Physics*

# New Higher Physics modules

## *Researching Physics*

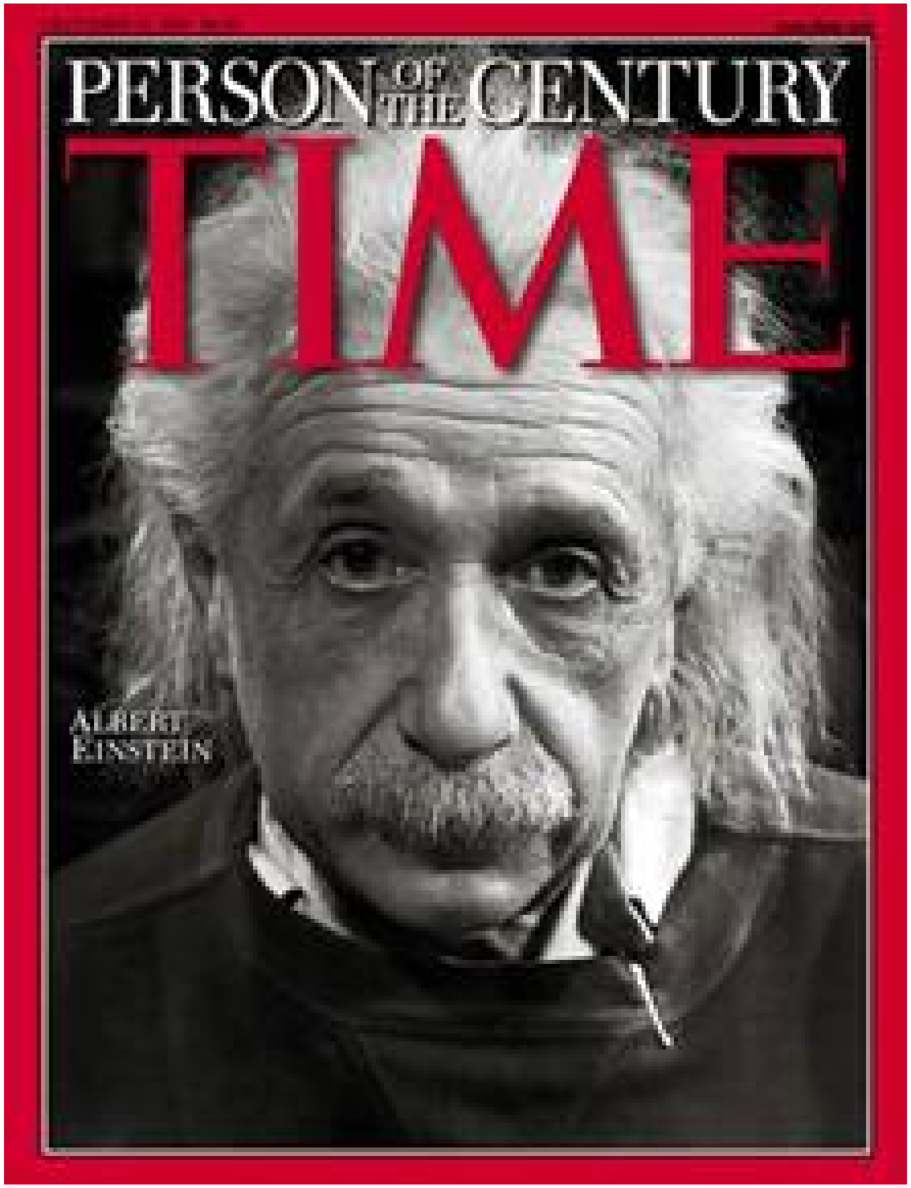
**OUTCOMES**

1. Research the physics underlying a topical issue to a given brief.
2. Plan and carry out investigative practical work related to a topical issue in physics.
3. Prepare a scientific communication which presents the aim, results and conclusions from a practical investigation related to a topical issue in physics.

# New Higher Physics modules

## *Our Dynamic Universe*

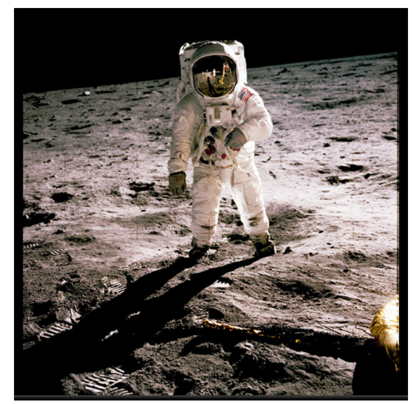
- **Equations of Motion**
- **Forces, Energy and Power**
- **Collisions and Explosions**
- **Gravitation**
- **Special Relativity**
- **The Expanding Universe**
- **Big Bang Theory**


PERSON OF THE CENTURY
TIME
ALBERT EINSTEIN


ALBERT
EINSTEIN
ACTION FIGURE

THE UNIVERSE
YOURS TO DISCOVER

INTERNATIONAL YEAR OF
ASTRONOMY
2009



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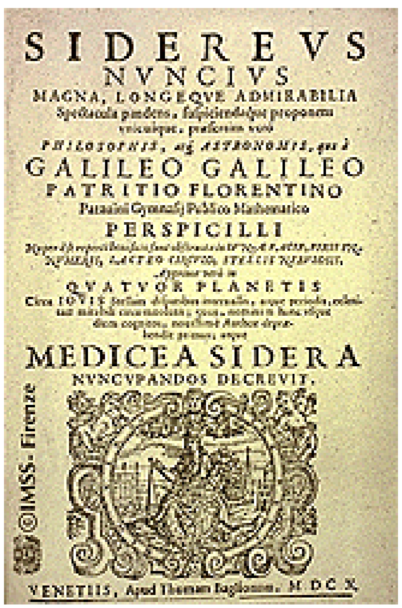
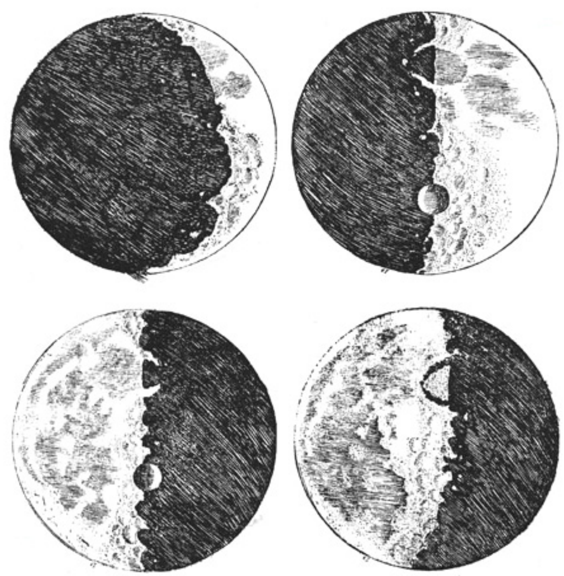
•In 1609 Galileo observed:

- craters of the Moon
- phases of Venus
- moons of Jupiter
- sunspots on the Sun's disk
- the stars of the Milky Way

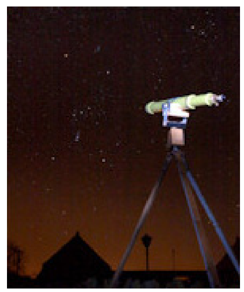


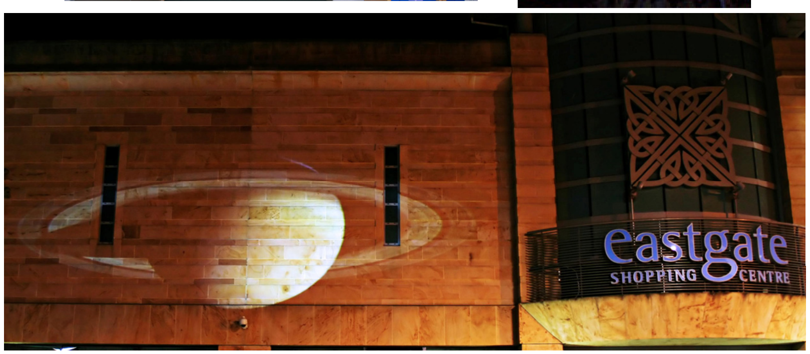
SIDEREVS
NVNCIVS
MAGNA, LONGEQVE ADMIRABILIA
PHILOSOPHIS, atq; ASTRONOMIS, qui à
GALILEO GALILEO
PATRITIO FLORENTINO
PERSPICILLI
QVATVOR PLANETIS
MEDICEA SIDERA
NVNCVPANDOS DECREVIT.
VENETIIS, Apud Thomam Baglionum. M DC X.






**http://www.scottishsolarsystem.org.uk**





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SciTech, Perth, Oct 2010


Clydesdale
Astronomical Society
Solar System - EARTH


HAS


Uranus • Hubble Space Telescope ACS/HRC WFPC2
2003
2005
2007
Solar System - URANUS


**HOME**

**ABOUT THE MOON**

**SCHOOLS' TELESCOPE**

**MOONWATCH**

The phase of the Moon right now

courtesy U. S. N. O.

*First quarter Moon*

## About the Moonwatch Weeks 2009

**Put these dates in your diary!**

*Mare Crisium*

**MoonWatch weeks**

**Spring MoonWatch** 28 March – 5 April

**Autumn MoonWatch** 24 October – 1 November

**Schools MoonWatch** 19 – 29 November

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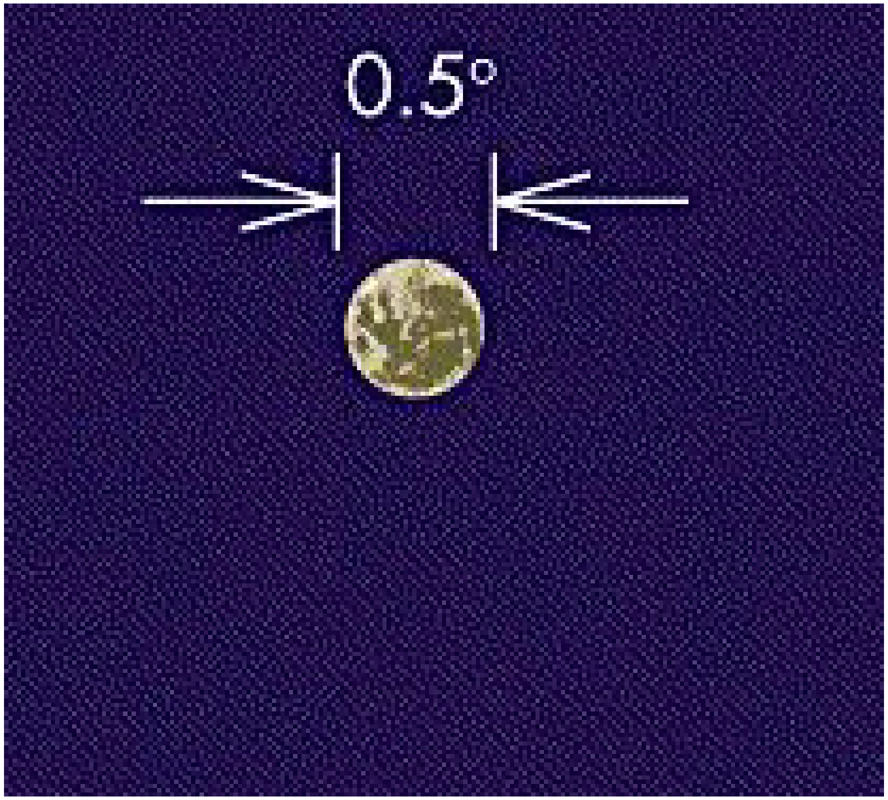
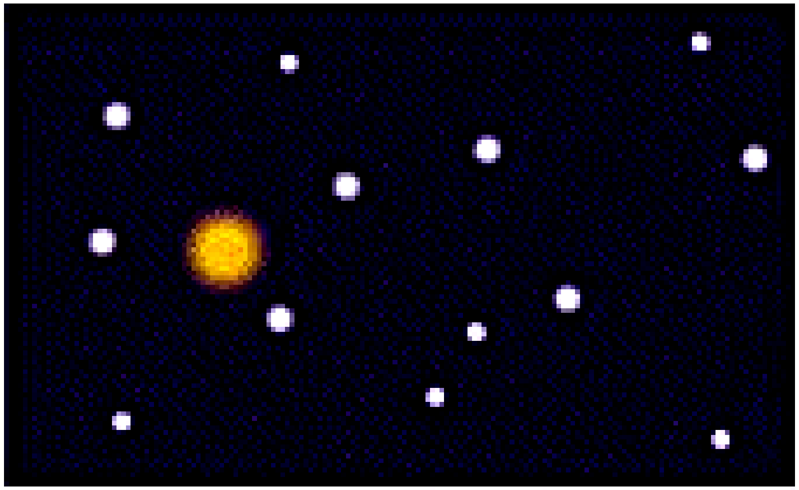
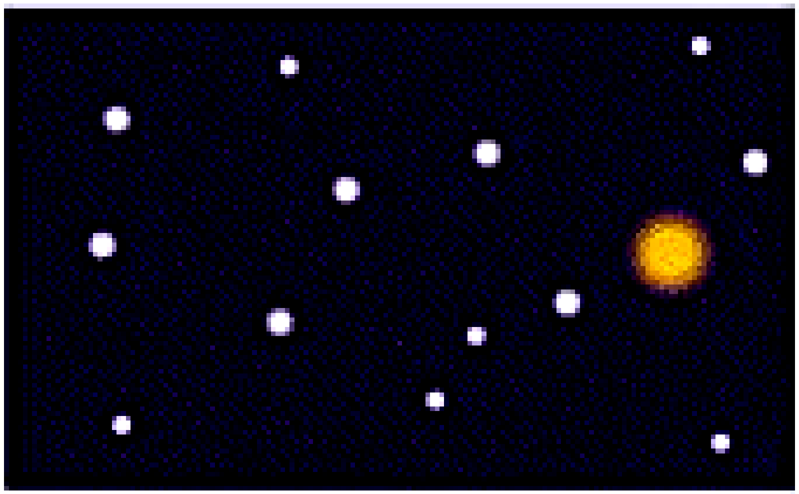
# Parallax Shift



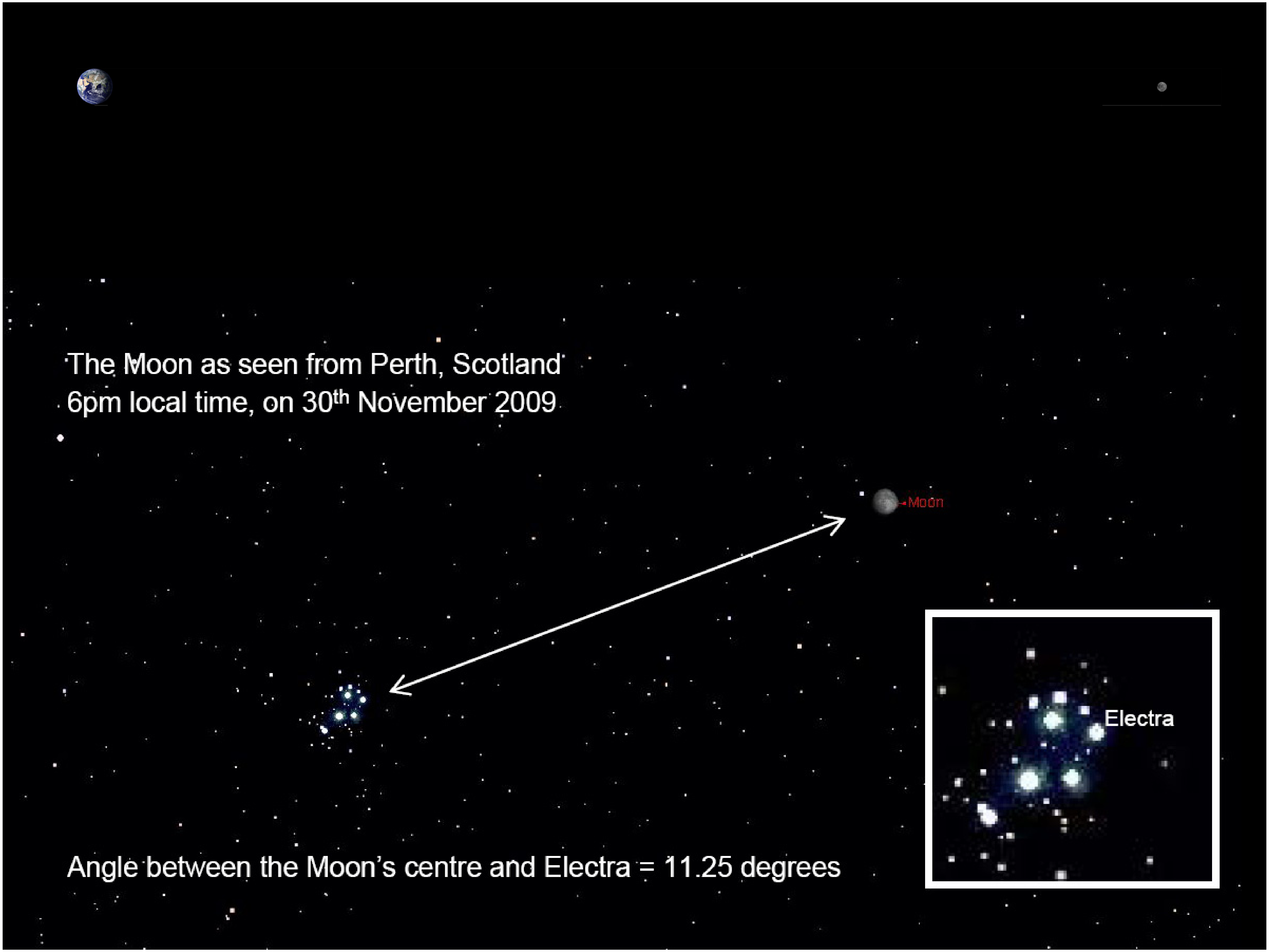



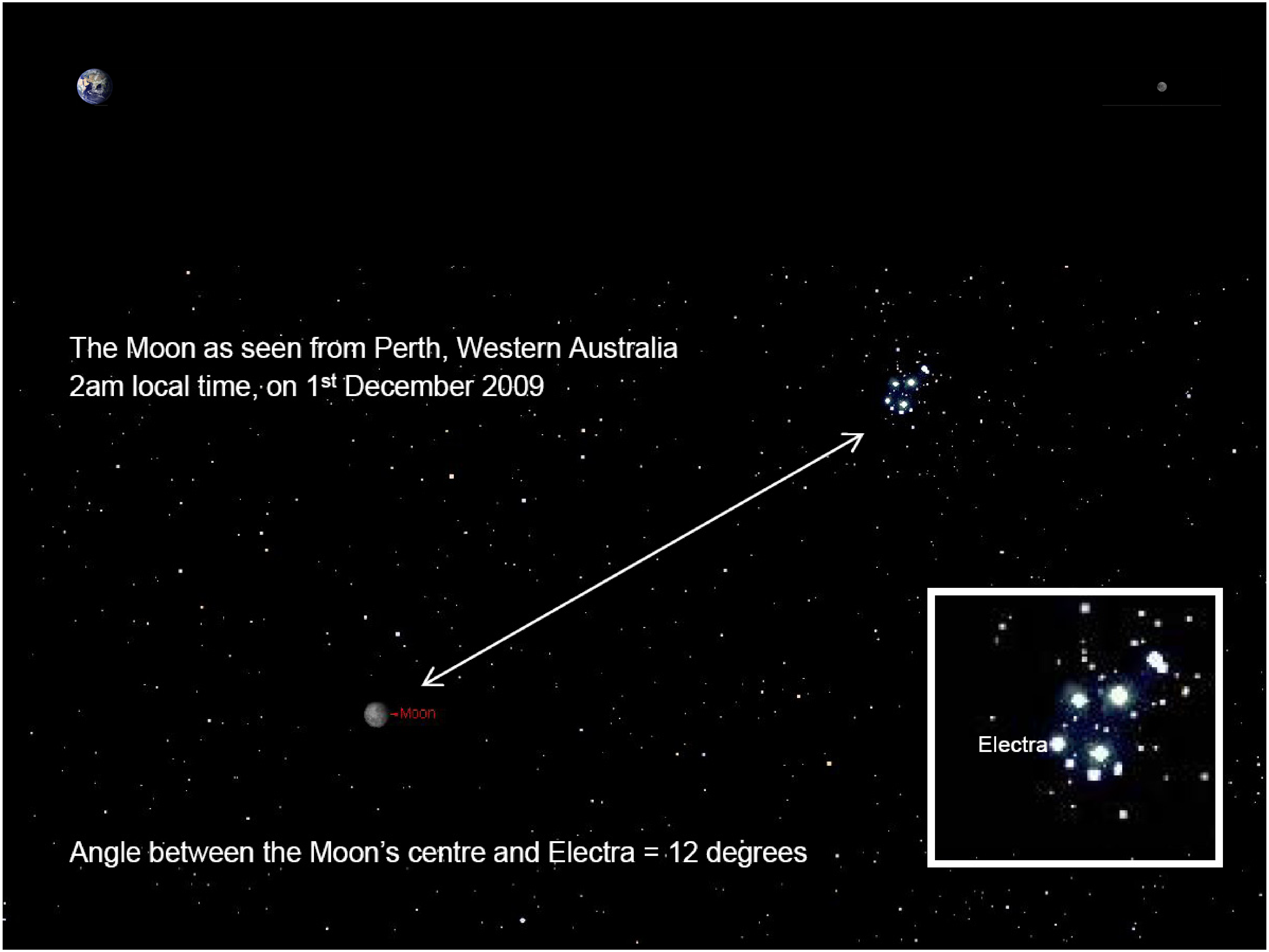
View from the Earth in January



View from the Earth in July

**Even the nearest star shows a parallax shift of only 1/2000$^{th}$ the width of the full Moon**


The Moon as seen from Perth, Scotland
6pm local time, on 30th November 2009
Moon
Electra
Angle between the Moon's centre and Electra = 11.25 degrees



The Moon as seen from Perth, Western Australia
2am local time, on 1st December 2009
Moon
Electra
Angle between the Moon's centre and Electra = 12 degrees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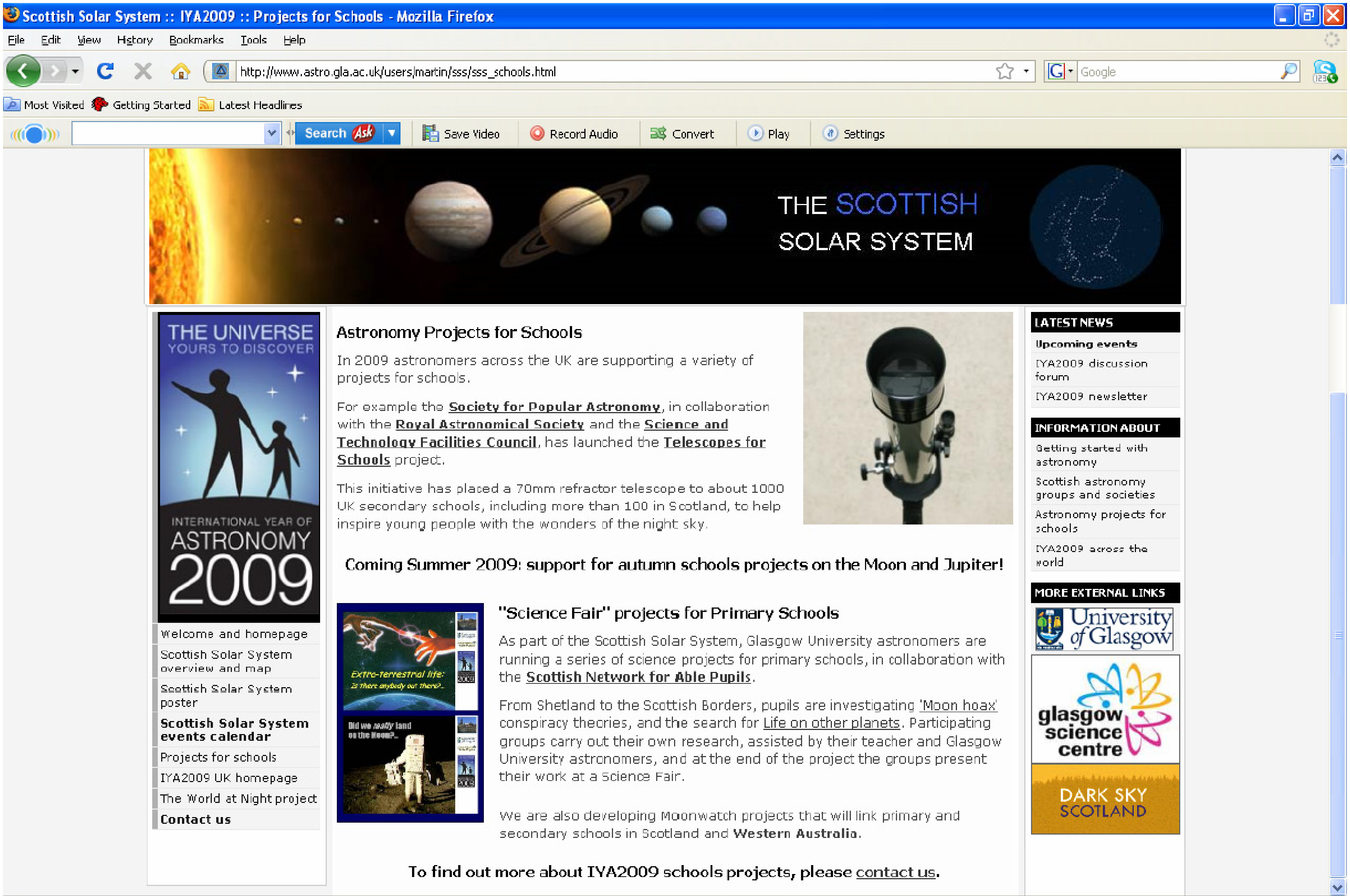

Scottish Solar System :: IYA2009 :: Projects for Schools - Mozilla Firefox
File Edit View History Bookmarks Tools Help
http://www.astro.gla.ac.uk/users/martin/sss/sss_schools.html
Most Visited Getting Started Latest Headlines
Search Save Video Record Audio Convert Play Settings
THE SCOTTISH SOLAR SYSTEM
THE UNIVERSE YOURS TO DISCOVER
INTERNATIONAL YEAR OF ASTRONOMY 2009
Welcome and homepage
Scottish Solar System overview and map
Scottish Solar System poster
Scottish Solar System events calendar
Projects for schools
IYA2009 UK homepage
The World at Night project
Contact us
Astronomy Projects for Schools
In 2009 astronomers across the UK are supporting a variety of projects for schools.
For example the Society for Popular Astronomy, in collaboration with the Royal Astronomical Society and the Science and Technology Facilities Council, has launched the Telescopes for Schools project.
This initiative has placed a 70mm refractor telescope to about 1000 UK secondary schools, including more than 100 in Scotland, to help inspire young people with the wonders of the night sky.
Coming Summer 2009: support for autumn schools projects on the Moon and Jupiter!
Extra-terrestrial life: Is there anybody out there?
Did we really land on the Moon?
"Science Fair" projects for Primary Schools
As part of the Scottish Solar System, Glasgow University astronomers are running a series of science projects for primary schools, in collaboration with the Scottish Network for Able Pupils.
From Shetland to the Scottish Borders, pupils are investigating 'Moon hoax' conspiracy theories, and the search for Life on other planets. Participating groups carry out their own research, assisted by their teacher and Glasgow University astronomers, and at the end of the project the groups present their work at a Science Fair.
We are also developing Moonwatch projects that will link primary and secondary schools in Scotland and Western Australia.
To find out more about IYA2009 schools projects, please contact us.
LATEST NEWS
Upcoming events
IYA2009 discussion forum
IYA2009 newsletter
INFORMATION ABOUT
Getting started with astronomy
Scottish astronomy groups and societies
Astronomy projects for schools
IYA2009 across the world
MORE EXTERNAL LINKS
University of Glasgow
glasgow science centre
DARK SKY SCOTLAND

# “Science Fair” projects for primary schools:

- West Dunbartonshire
- East Dunbartonshire
- South Lanarkshire
- North Ayrshire
- Glasgow
- Scottish Borders

*Organised in collaboration with the* ***Scottish Network for Able Pupils****.*

*Projects aim to build:*

*investigative skills, critical thinking, IT proficiency, presentation skills*

# Science Fair Project Format:

## Session One  (half-day)

Coordinator (MAH) introduces topic to groups from 6 – 8 schools:

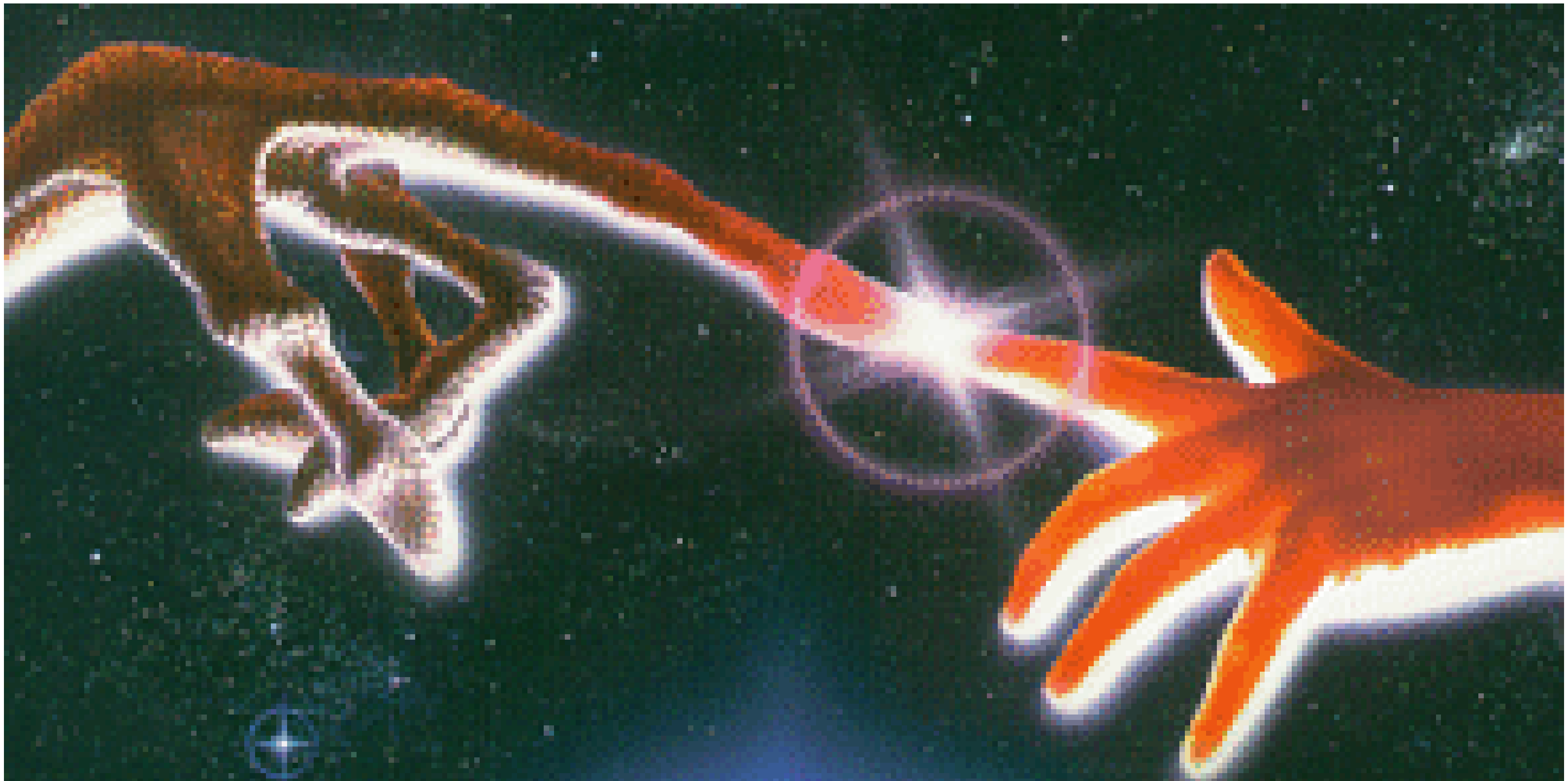
- Range of possible project activities highlighted
- Pupils begin web exploration, via **project website**
- Q&A with mentors;  groups select provisional activities.

## Project work carried out in schools  (approx. 6 – 8 weeks)

- Pupils work in a team, supported by mentor (~weekly meetings)
- Additional support from GU scientists via dedicated **email address**

## Session Two  (half-day)

- Pupils present their work to other schools, teachers, VIPs, astronomers
- ‘Science Fair’ format:  builds presentation skills, teamwork



# Extra-terrestrial life:

## Is there anybody out there?...

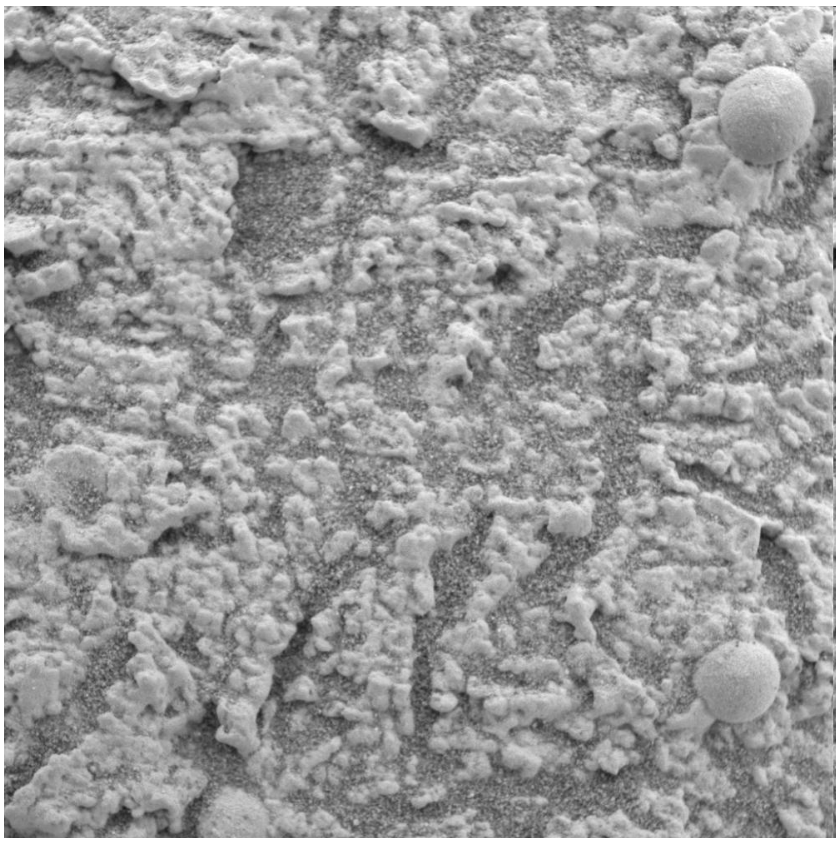

**Dr Martin Hendry**

**University of Glasgow**


http://www.astro.gla.ac.uk/users/martin/etlife/

## Some ideas and projects to investigate:

### 1. Grow crystals from **evaporating** salty water



The tiny salt deposits seen by *Opportunity* may have been left behind when an ancient, Martian salty ocean slowly evaporated away.

You can grow your own salt crystals, exploring how they grow, and what shapes and crystal patterns they make!

Learn how the other evidence found by the NASA rovers strongly points to past running water on Mars

Some ideas and projects to investigate:

## 2. Build your own spectrometer

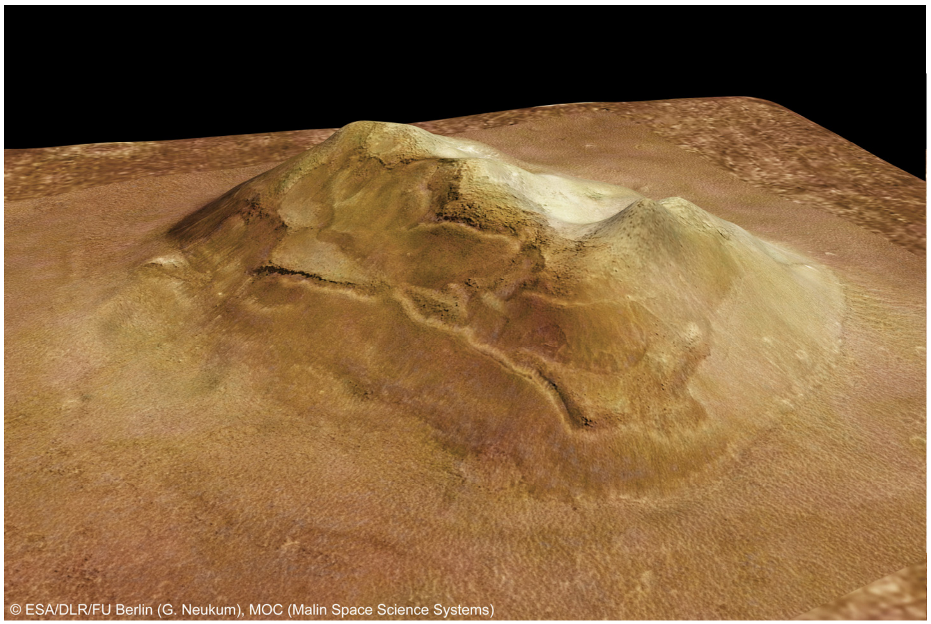
The tiny grooves in a CD make its surface a good spectrometer – splitting up light into its colours and spectral lines.

Make a spectrometer from a CD and a cereal packet, and use it to search for the spectral lines in sunlight, streetlights and even lightbulbs in your home.


Learn how spectral lines can tell us what stars and planets are made of.

Some ideas and projects to investigate:

## 3. Build your own ‘face on Mars’

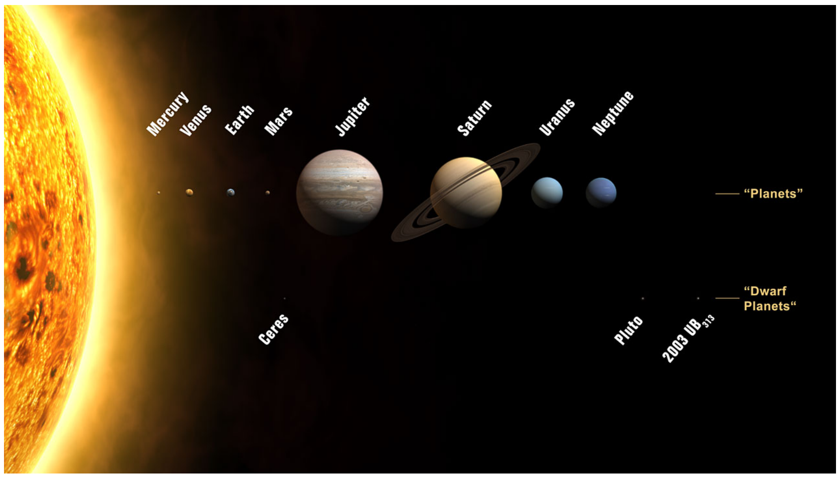



Make your very own Martian ‘optical illusion’: using e.g. clay, plasticine or even paper, craft a landscape which – in a certain light or from a certain angle resembles a surprising shape – but when seen more clearly is nothing out of this world!

Learn about other sorts of optical illusions, and how easily fooled our brains can sometimes be!

Some ideas and projects to investigate:

## 4. Make a scale model of the Solar System

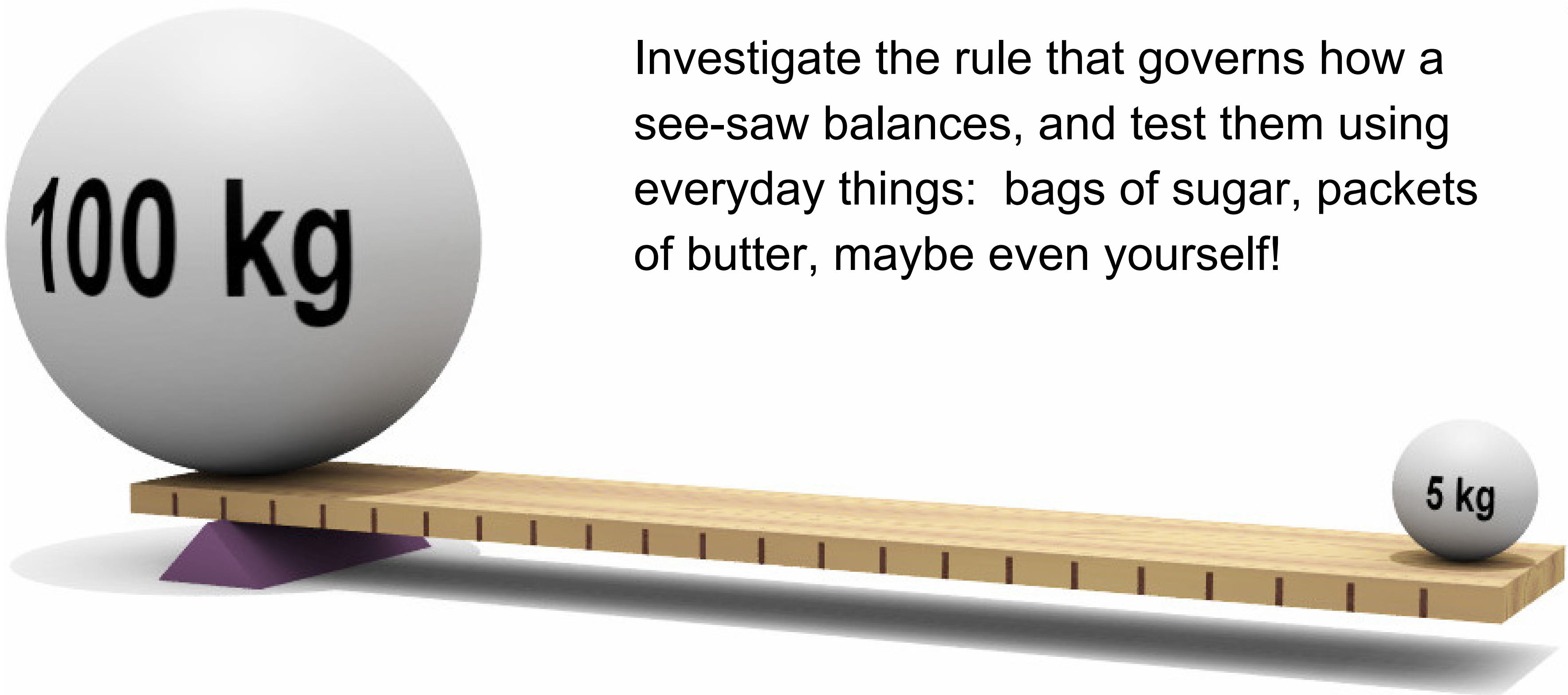



Using everyday items found in your home or classroom, build a model of our Solar System showing how big – and how far apart – the Sun and planets would be on your chosen scale.

On the same scale, work out where the nearest stars would be, and how long it would take us to travel there.

Some ideas and projects to investigate:

## 5. Explore the 'centre of gravity' of a see-saw




Investigate the rule that governs how a see-saw balances, and test them using everyday things: bags of sugar, packets of butter, maybe even yourself!

Find out how this same rule lets us measure the masses of other planets.

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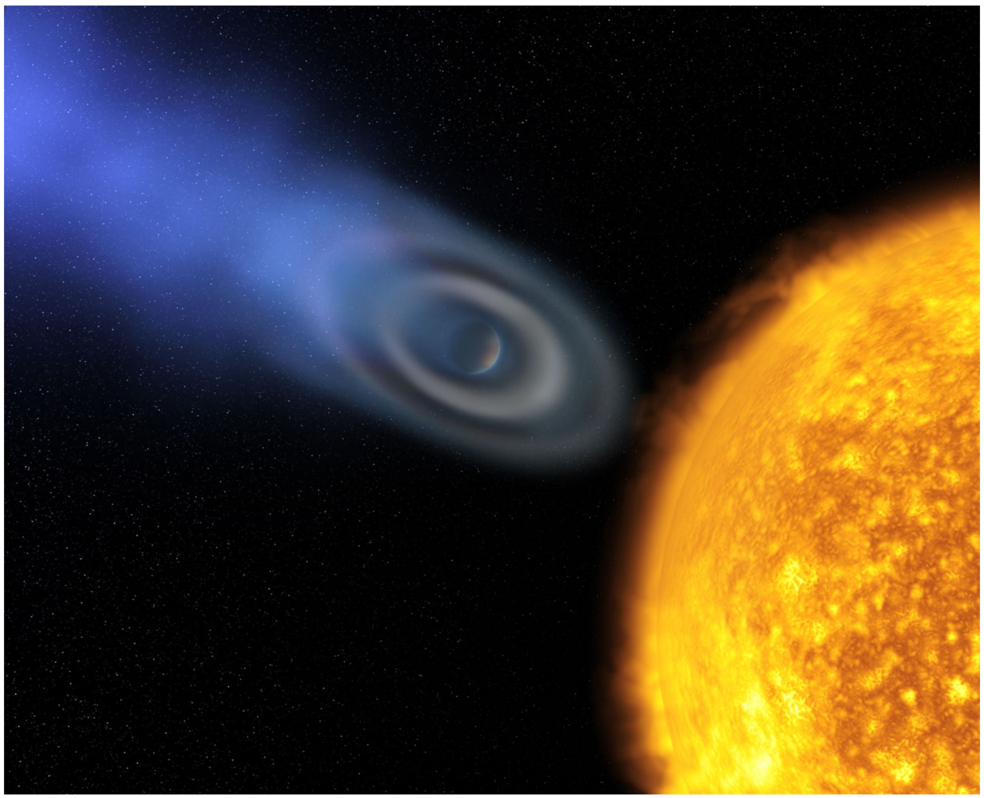
## Some ideas and projects to investigate:

### 6. Find out about 'hot Jupiters'



Learn more about the very large, hot planets we have found orbiting other stars.

Why are they so hot?

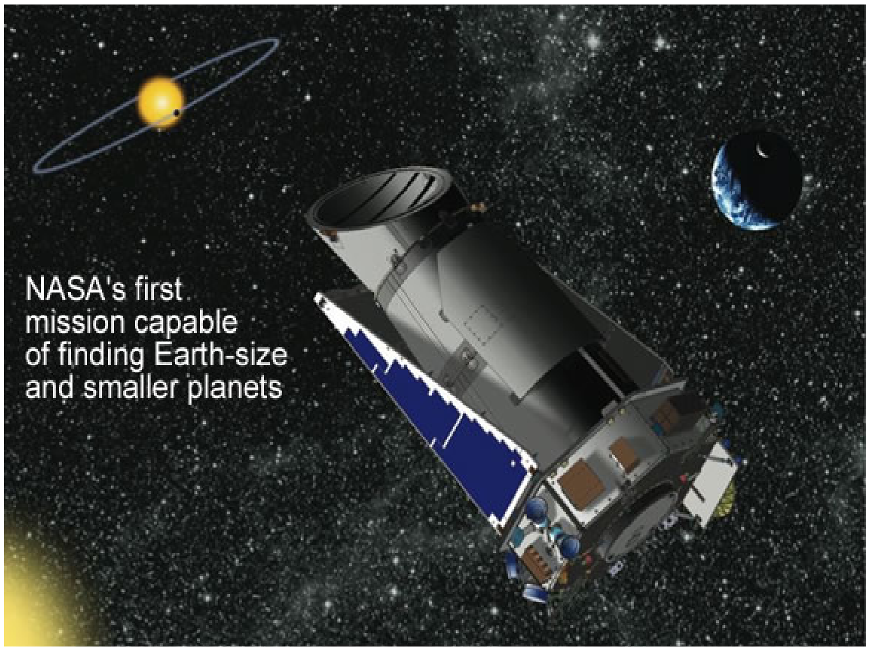
How do we think they formed?

What is happening to their atmospheres?

Could we live there?...

Some ideas and projects to investigate:

7. Learn about the planets that ‘Kepler’ might see!



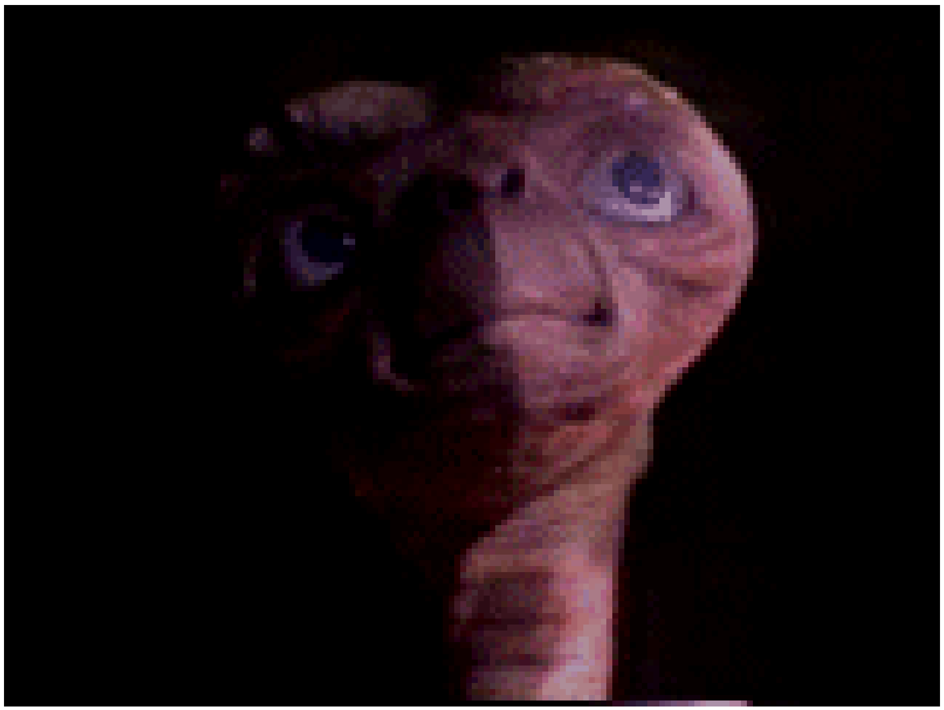

What makes the Kepler satellite special, so that it could find Earth-sized planets?

How will Kepler tell us the size of the planets it finds?

How will we tell what the planets are made of?

Some ideas and projects to investigate:

## 8. Work out how many ETs there are in our Galaxy



In 1960 astronomer Frank Drake devised a formula, now called the Drake Equation, to calculate how many alien civilisations there might be in our Milky Way galaxy.

There are lots of parts of the formula that we're unsure about, but it is fun (and instructive) to predict how many ETs we think could phone us!

Some ideas and projects to investigate:

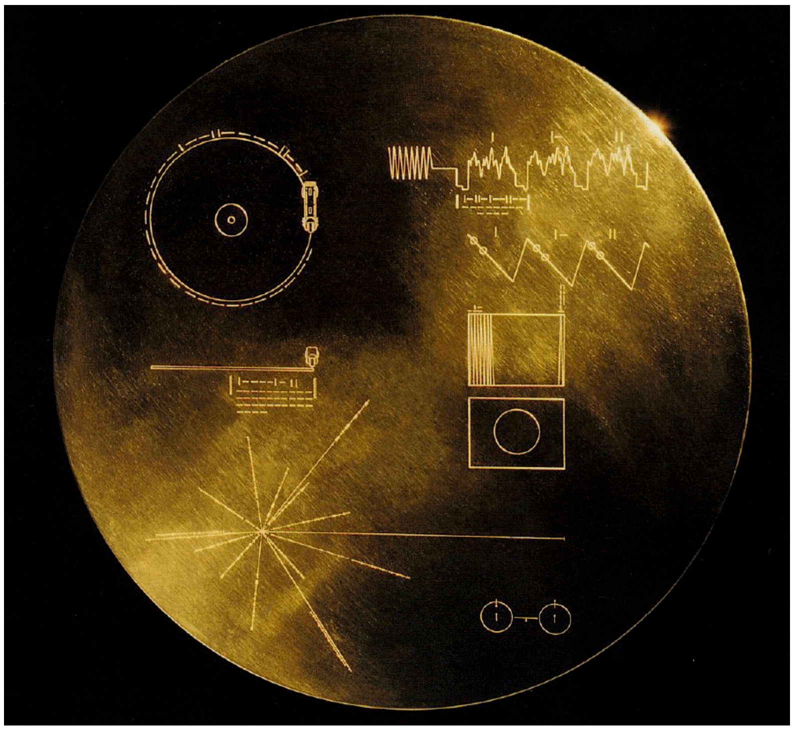
## 9. Find out how life could be *wiped out* from space

If life does exist out there, maybe it doesn't last so long…Even on the Earth there have been regular **mass extinctions**, and many astronomers think they were caused by impacts or radiation from deep space.

Learn about the different threats from space, what risks they present to us here on Earth and what we are doing to protect ourselves!

Some ideas and projects to investigate:

## 10. Compose your own message to ET!



If you could talk to an ET, what would you say? How would you describe life on Earth? How would you describe *your* life?...

Learn more about the language of mathematics and science used on the Voyager 'Sounds of Earth' disk.

Think about how you could use this language to compose *your* message.

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# Project summary:

- More than 50 schools participated so far

- Wide range of activities undertaken – exploring diverse scientific topics: gravity and forces, materials science, mechanics and engineering, colour and spectroscopy, atmospheric pressure and evaporation, air resistance, geometry and optical illusions, radiation, distances and scaling relations.

- Excellent grasp of experimental methodology: control principle, importance of reproducibility, documenting of procedures, consideration of alternative hypotheses.

- Varied and innovative presentation styles: laptops, short video segments, demonstrations, models, posters, etc…

- **The participants had fun!**

## *So how do we build on IYA2009 for the new Physics curriculum?...*

- Mixture of ‘nuts and bolts’ and high concept material
- Emphasis on methods and ideas rather than specific latest results (c.f. lessons of technology modules)
- Recognition of limited lab resources + make a virtue of Kelvin’s legacy
- Provision of a range of support for teachers: UG and PG ambassadors, training workshops, Astrosocs
- Harness topics from popular culture.

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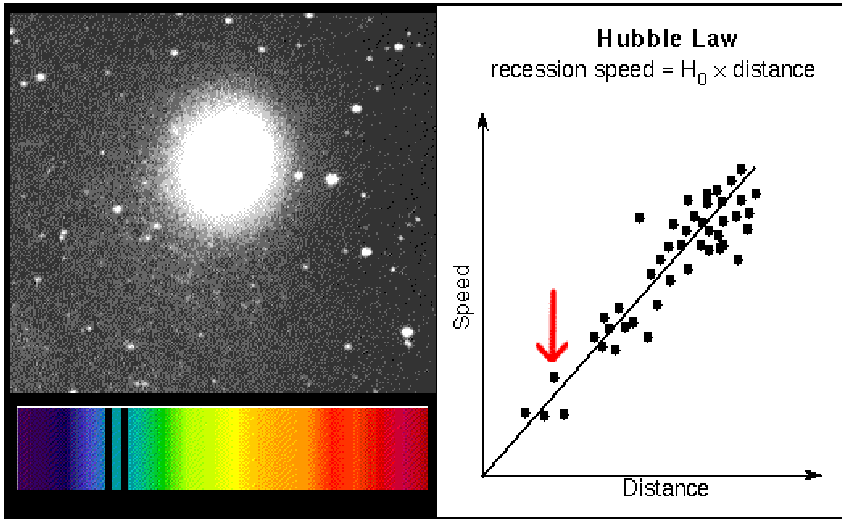


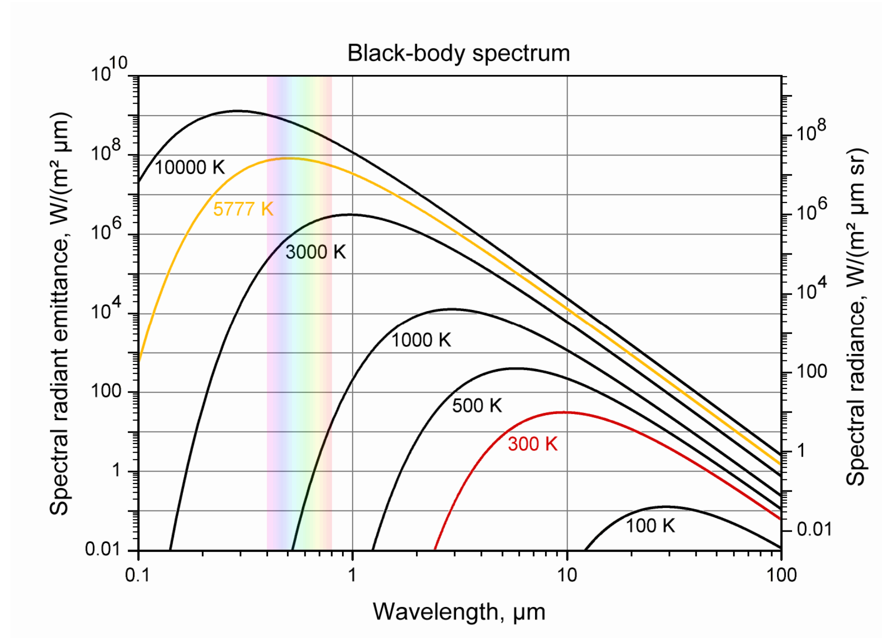


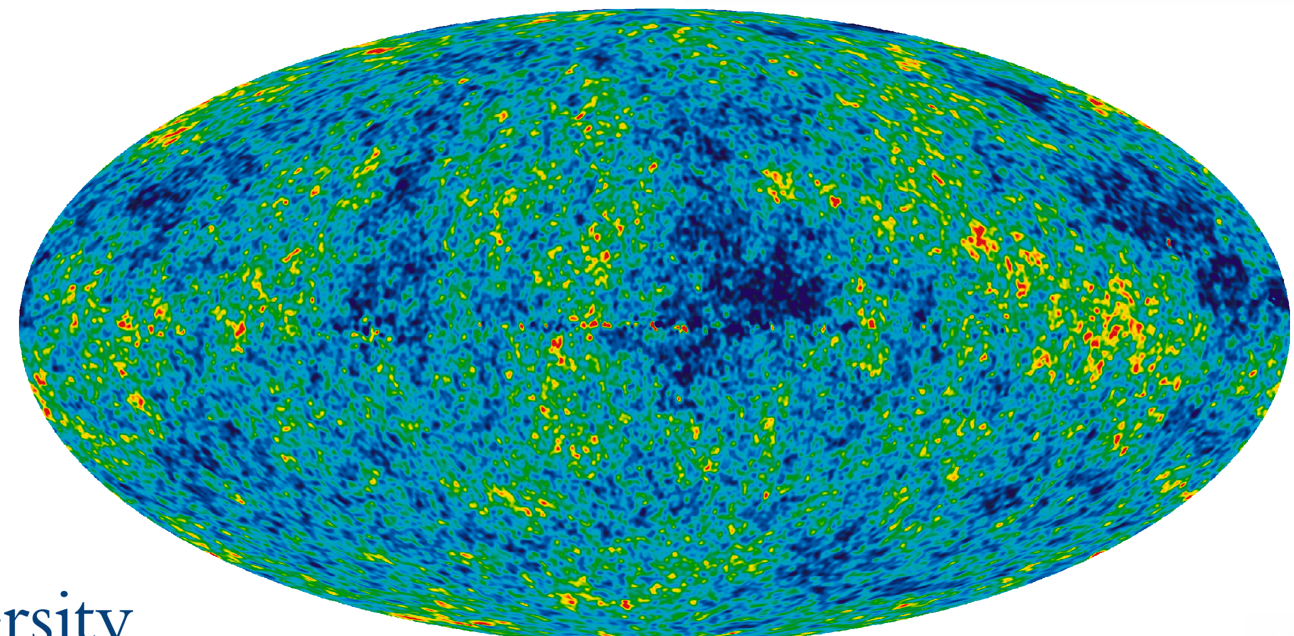

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SciTech, Perth, Oct 2010

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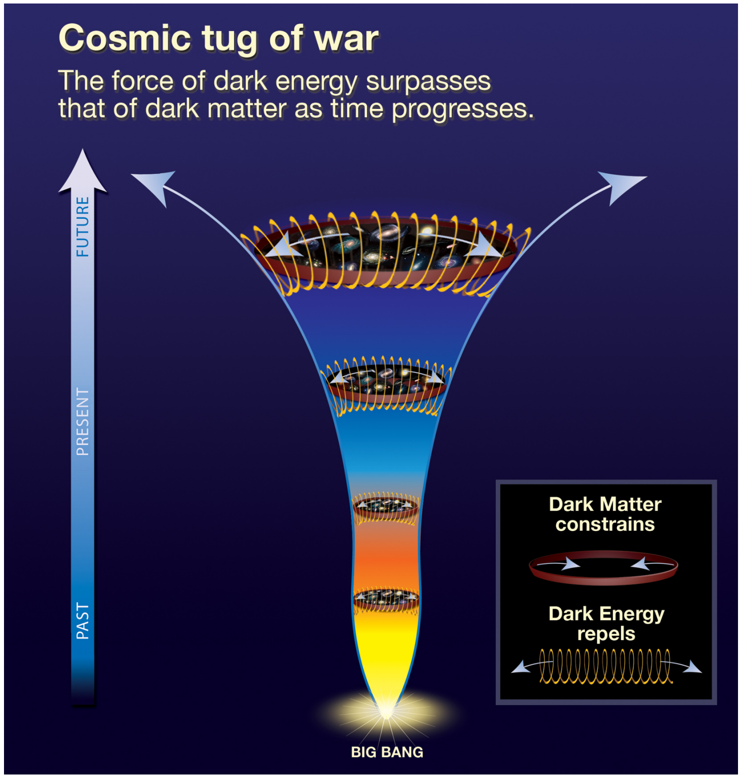


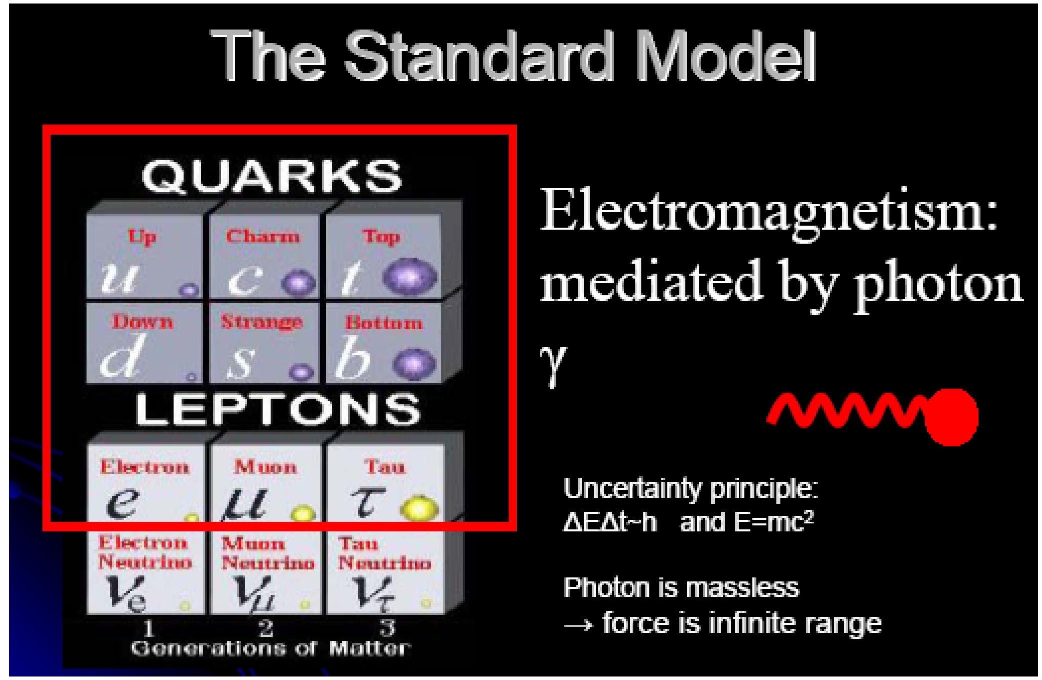


**"All science is either physics or stamp collecting"**
*Ernest Rutherford*

# Special Relativity:

## *James Clerk Maxwell's theory of light*

Light is a *wave* (caused by varying *electric* and *magnetic* fields)

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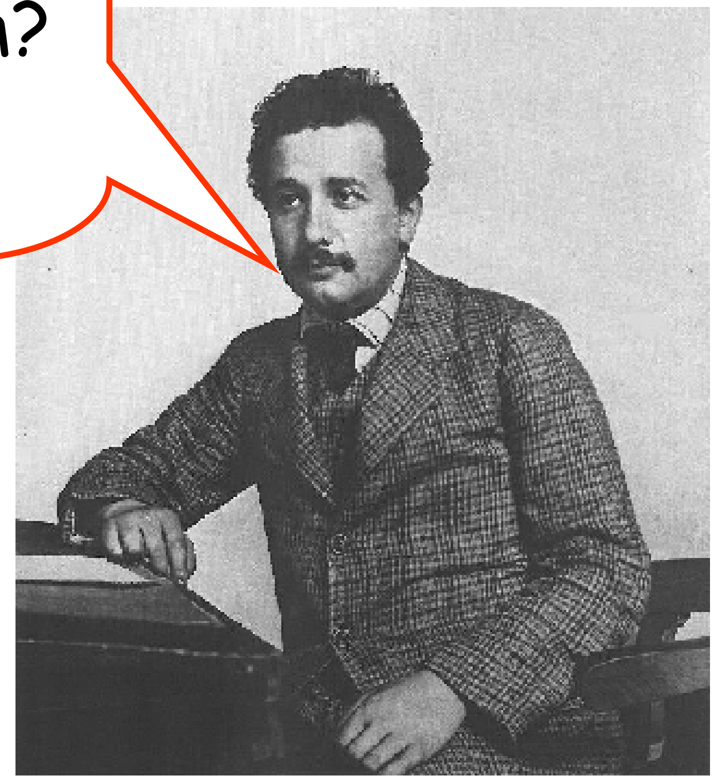
But what if I travelled *alongside* a light beam? Would it still wave?



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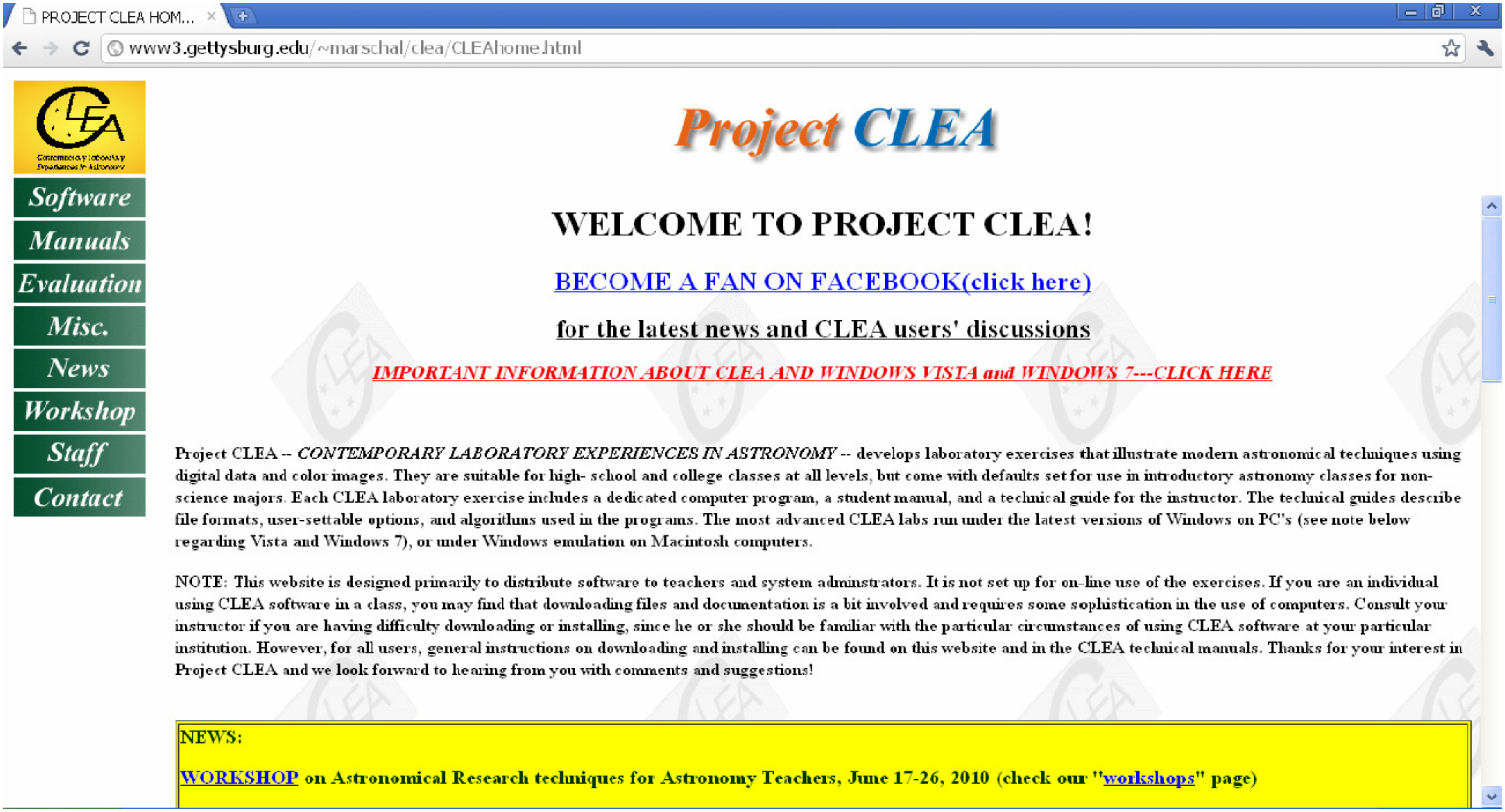
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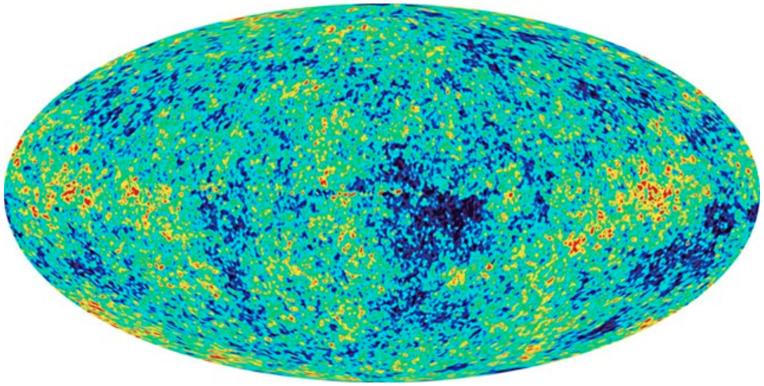
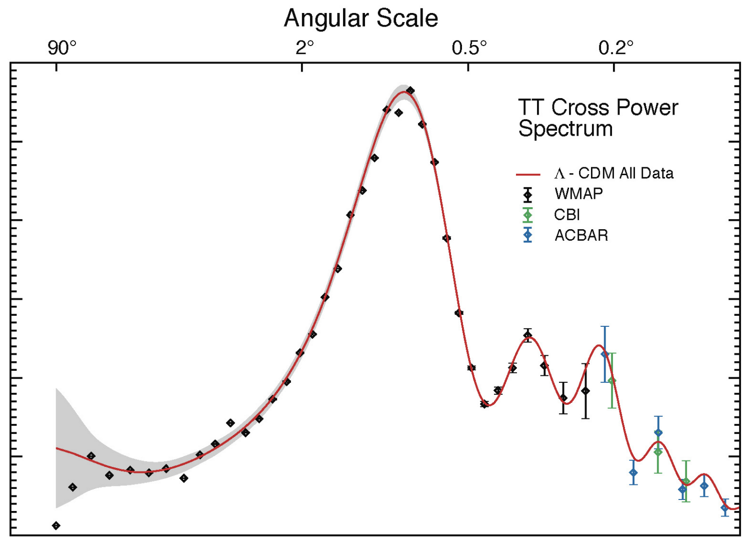
NOTE: This website is designed primarily to distribute software to teachers and system adminstrators. It is not set up for on-line use of the exercises. If you are an individual using CLEA software in a class, you may find that downloading files and documentation is a bit involved and requires some sophistication in the use of computers. Consult your instructor if you are having difficulty downloading or installing, since he or she should be familiar with the particular circumstances of using CLEA software at your particular institution. However, for all users, general instructions on downloading and installing can be found on this website and in the CLEA technical manuals. Thanks for your interest in Project CLEA and we look forward to hearing from you with comments and suggestions!
NEWS:
WORKSHOP on Astronomical Research techniques for Astronomy Teachers, June 17-26, 2010 (check our "workshops" page)






*"What fraction of the cars in the car park are red?..."*

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"Science and technology are increasingly vital in the world today and the study of these subjects benefits all of us whether we realise it or not. Scientists like me have a very important role to play in inspiring the next generation to see these areas as exciting – both through sharing experiences and offering young people the chance to get involved in practical work in a real-life scientific environment."
Lord Professor Robert Winston, a supporter of STEMNET's Ambassadors programme
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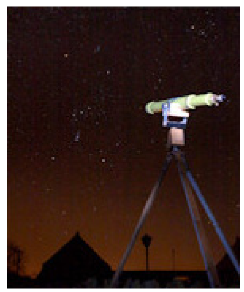
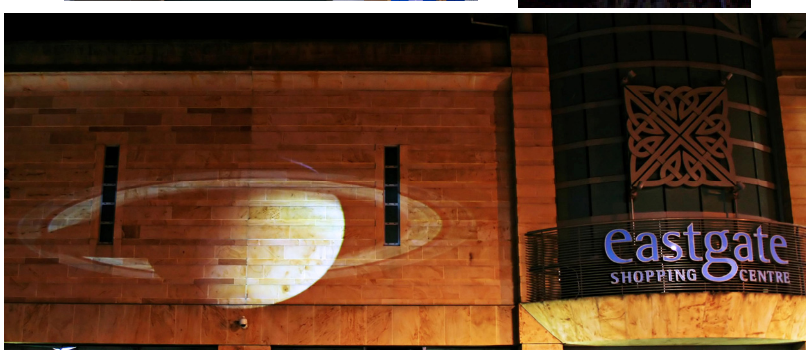
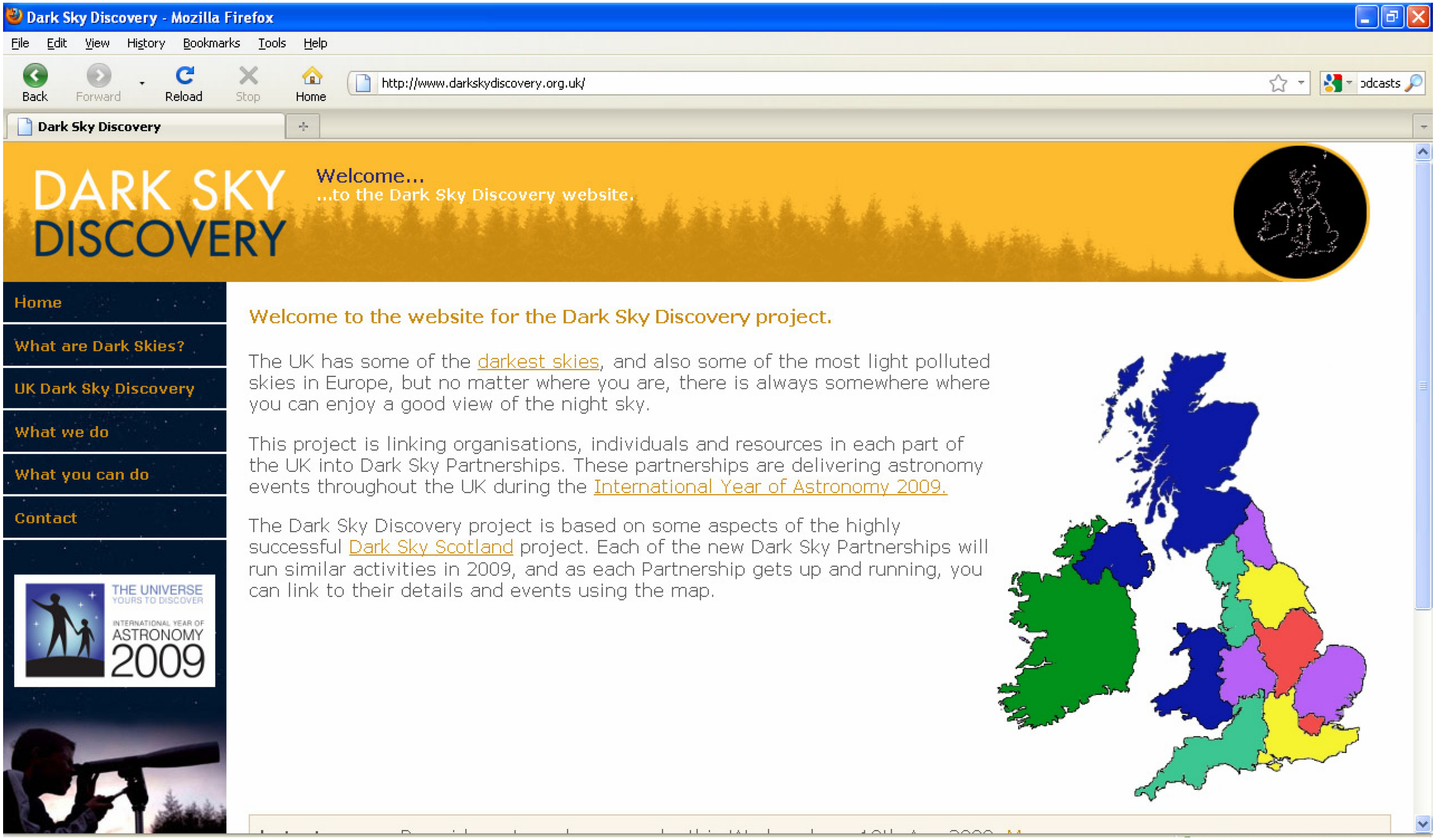




SciTech, Perth, Oct 2010

# Linking to Dark Sky Discovery Community-based events

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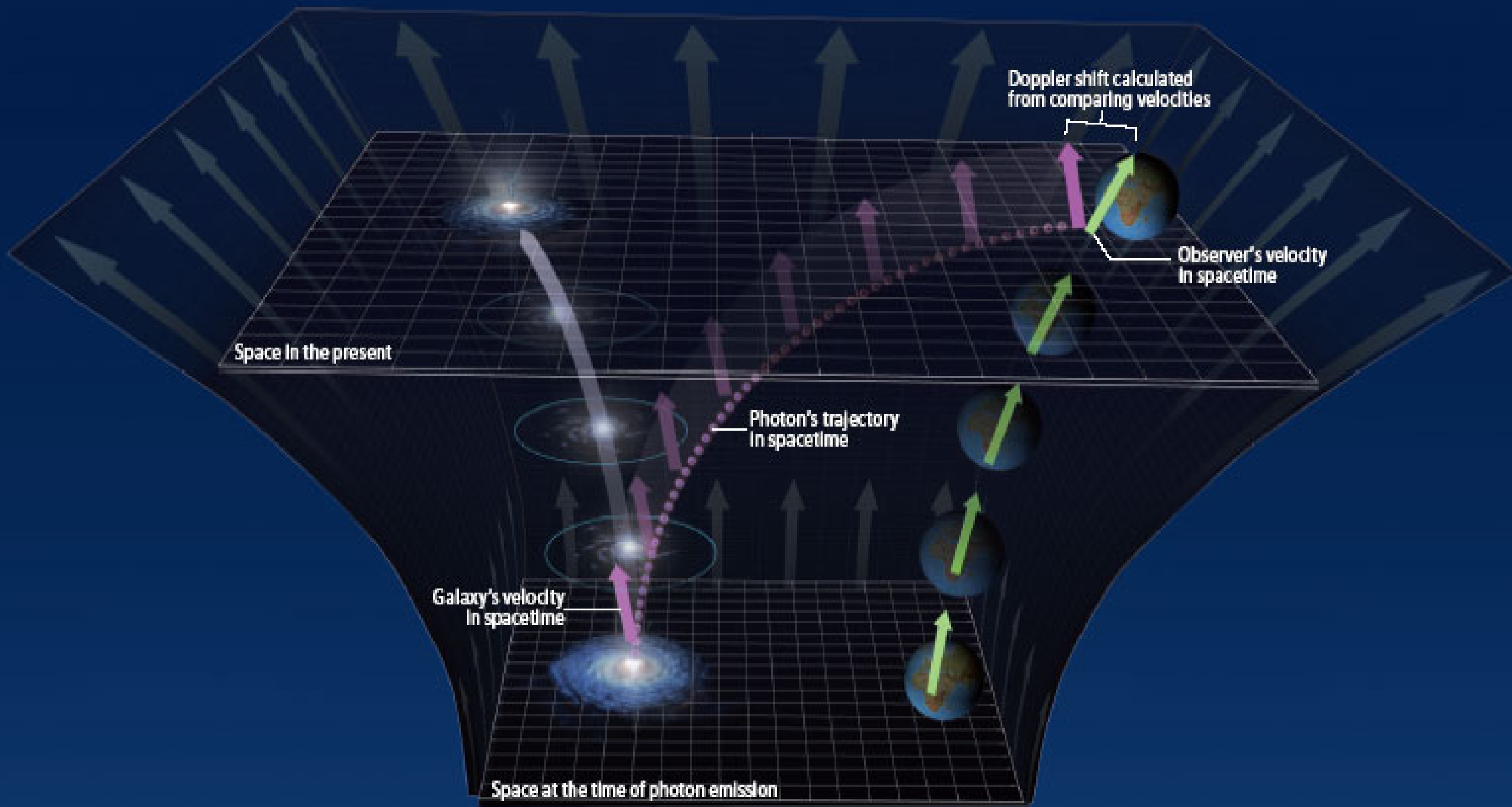
Scientific American, July 2010. (Tamara Davis, UQ)




**GALAXY REDSHIFT AS A DOPPLER SHIFT**

A galaxy's redshift is identical to the Doppler shift an observer would see when watching a police car recede at the same relative velocity as the galaxy—as long as "relative velocity" is interpreted in the appropriate way. First, one must trace the trajectories of the galaxy and of the observer not in space but in spacetime. (In the schematic view here, space is an evolving two-dimensional surface; spacetime trajectories cut through it.) Second, one must compare the velocity of the galaxy at the time when it emitted the photon (*purple arrow*) with the velocity of the observer at the time when the photon was received (*green arrow*) and then—using the appropriate math derived from general relativity—calculate the relative velocity. The Doppler shift calculated from this relative velocity coincides with the galaxy's redshift, suggesting that the galaxy's redshift can be interpreted as the result of relative motion, rather than of the expansion of space. Therefore, no energy is lost.

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