Resources for teaching astronomy in UK schools

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ABSTRACT This article looks at a selection of resources currently available for use in the teaching of astronomy in UK schools. It is by no means an exhaustive list but it highlights a variety of free resources that can be used in the classroom to help engage students of all ages with astronomy and space science. It also lists several facilities with a specific astronomy/space focus that can be visited by schools groups, and briefly describes what is available at each site.

The potential of astronomy and space to inspire in students an appreciation of science as a whole is well known but, without a wide range of quality resources, it is very difficult for any teacher to unlock that potential. Fortunately, many such resources exist, although, as seen in the accompanying article on p. 63, there are often problems with finding them and identifying how they might best be used.

In this article we highlight a selection of particularly useful resources and give an idea of what their scope is. So, while this is certainly not an exhaustive list, it should provide anyone with a core of resources to support their teaching.

Online resources

The World Wide Web has had close links to astronomy from its inception and there are now a very large number of websites, software packages, archives and online tools to support any level of astronomer – from the most tentative beginner to the professional research astrophysicist.

In particular, while 'hands-on' access to the wonders of the night sky may be tricky given the typical UK weather conditions, there is no shortage of excellent material out there for the armchair astronomer. A number of free 'planetarium' software packages are available that allow users to fly through the solar system, visiting planets, moons, asteroids and comets, or to travel further afield and get 'close up' with star clusters, nebulae and galaxies, and robotic telescopes allow you to observe from the best observatories without leaving your home.

Below is a quick summary of just a selection of some of the best software, websites and online resources that UK schools can access.

Software

***Stellarium* (www.stellarium.org)**

Stellarium is a free open source planetarium package for your computer. It shows a realistic sky in 3-D, as you would see with the naked eye, binoculars or a telescope from the Earth. You can even 'turn off' the atmosphere! It comes with a database of over 600 000 stars, which can be expanded to about 210 million, and it allows you to simulate all of the planetary phenomena you could wish for, including eclipses, occultations, transits and retrograde motion. It is a fantastic way to help students visualise the night sky and the complex motions of bodies in the solar system.

***Celestia* (www.shatters.net/celestia)**

Celestia allows the user to explore the universe in 3-D. It features a zoom function that lets you explore space across a huge range of scales, from galaxy clusters down to spacecraft only a few metres across. A 'point and go to' interface makes it simple to navigate through the universe to the object you want to visit, and the database of objects and tours can be expanded with a wide range of add-on features.

***SalsaJ* (www.euhou.net)**

Part of a suite of multilingual resources developed by the European Union Hands-On Universe (EU-HOU) consortium of educators, the *SalsaJ*

software package allows users to manipulate astronomical data and make basic measurements. Telescope data are often in a non-standard format, called FITS files, which cannot be opened by normal software packages, but *SalsaJ* allows users to work on these files and examine images, measure spectra, make colour-composite images and produce animations of asteroid motion, and so on.

***LTImage* (www.schoolsobservatory.org.uk/obs/software/ltimage)**
Like *SalsaJ*, the *LTImage* software from the National Schools' Observatory (NSO) allows users to work with FITS-format data. It is designed to combine professional-quality image processing and data analysis with extreme ease of use. As such, it is an ideal introduction to many aspects of astronomical data analysis, from simple image enhancement through to brightness measurement and multi-colour imaging.

***FITS Liberator* (www.spacetelescope.org/projects/fits_liberator)**
Fancy producing some stunning colour images of astronomical objects, but want to work with a powerful image processing package like *Photoshop*? *FITS Liberator* is a powerful stand-alone piece of software that allows you to convert FITS data into a more standard image format, such as TIFF or JPEG, so that you can import them into most image processing software packages and generate incredible images of the universe on your PC.

Websites

D2E (education.down2earth.eu)
Ever wished that a giant meteorite would crash into the school and remove all your problems in one go? Well, with the impact calculator function on the UK Science and Technology Facilities Council (STFC)-funded 'Down to Earth' project, you can at least do that in virtual space. The D2E project is based on the assertion that one way to get students interested in science, technology, engineering and mathematics (STEM) subjects is to allow them to work with the '3Ds' – death, destruction and dinosaurs. Build virtual asteroids and comets, then slam them into the location of your choice and see the resulting impact crater on *Google Maps* – gravity and kinetic energy have never been so much fun …

Zooniverse (www.zooniverse.org)
The Zooniverse contains some of the most innovative resources currently available online, allowing users to help scientists in a range of data-crunching tasks from classifying galaxies (GalaxyZoo) to helping meteorologists reconstruct the weather from old wartime ships' logs. The site has a variety of highly engaging interactive projects in astronomy, where users can contribute towards real scientific research – 'citizen science' in action.

ESERO-UK (www.esero.org.uk)
The website of the UK branch of the European Space Education Resource Office (ESERO-UK), also known as the UK Space Education Office, is a one-stop shop for space and astronomy education. So, if there is something that you would like to see but cannot find, a good place to go for more information is the 'Teacher support' section of the ESERO-UK website. You will also find the contact details of your local Space Ambassador, who is there to help you use astronomy and space to enhance your teaching.

Other resources

In addition to the packages listed above, the educational resources associated with the NSO and the Faulkes Telescope Project (FTP) (see the next section) both offer a wealth of material for use in the classroom, including sample data sets for students as well as ideas for engaging students with ongoing scientific research projects:

- FTP – Educational Resources: resources.faulkes-telescope.com;
- NSO: www.schoolsobservatory.org.uk/activ.

Robotic telescopes for UK schools

A challenge when teaching astronomy or space is not enthusing pupils (that comes largely automatically, given the subject area) but ensuring that the scientific nature of astronomy comes across. However, the very aspects of astronomy that inspire and enthuse – the fundamental questions, the scope and scale, the ongoing struggle to find answers – are the very things that make it a scientific activity so, if that step can be made, astronomy provides a very powerful tool to promote a better appreciation of science as a whole.

The NSO and the FTP were set up to exploit that opportunity by allowing pupils to work alongside professional astronomers on world-leading research telescopes. In addition, UK

schools can access a suite of smaller instruments located on the island of Tenerife through the Bradford Robotic Telescope, so there are many opportunities to gather your own images remotely, regardless of local weather conditions.

The National Schools' Observatory
www.schoolsobservatory.org.uk

The NSO is a truly wonderful resource which is so much more than just a sophisticated eye to the universe. Just as importantly, it gives us a powerful platform from which to proceed with inspiring students in science through astronomy. (science teacher)

The NSO uses the £5 million Liverpool Telescope (LT), which is owned and operated by Liverpool John Moores University (LJMU). One of the world's largest fully robotic telescopes (together with its clones the Faulkes telescopes in Hawaii and Australia), it is sited not in Liverpool, of course, but on La Palma in the Canary Islands on one of the best observing sites in the world. With a 2 metre diameter primary mirror and a comprehensive suite of instruments (from simple optical imaging cameras to spectrographs and polarimeters), it is used by professional astronomers all over the world. However, it is not the size that makes it special (there are much larger telescopes) but the unique way in which it operates that make it such a powerful tool.

Most telescopes require a person to control them – either in person or remotely via the internet. However, many scientific questions require observations on timescales that are difficult to deal with in that way. From reacting to dramatic unpredictable events such as supernovae, or their even bigger cousins gamma ray bursts, through to monitoring of extra-solar planets or asteroids, so-called 'time-domain astrophysics' is becoming increasingly important and requires a new kind of telescope.

Figure 1 Pupils busy on the NSO website; image courtesy of the NSO

The LT works by collecting 'observing programmes' from astronomers and using computer systems at the telescope to build and update an observing schedule in real time, without human involvement (which means we all get some sleep!). Able to react to sudden events, optimise observations to the current weather and atmospheric conditions, and even to analyse its own data, the scheduling system is not only much more efficient than a human operator, it can carry out observations that no other telescope could manage and so lead to some very exciting new science.

The NSO is designed to let you and your pupils do exactly the same thing – create

Figure 2 The Liverpool Telescope at sunset; image courtesy of the LT and A. Gomboc

observing programmes that are scheduled alongside those of the professionals and then take the subsequent observations and study them – not just as pictures but as scientific data to be measured and experimented on. Through the NSO you have all the tools you need to easily prepare your programmes and analyse and explore the data, with the LT doing all the tricky work of observing.

Getting involved is very easy. The NSO is free to all schools and further education colleges in the UK and Ireland – you just need to register. You can then set up as many accounts for your students as you wish as there are no limits on either the number of accounts or observations requested. Observing itself uses a specially designed 'Go Observing' web interface that guides you or your pupils through the process of choosing your observations and then simply passes them to the telescope to be done as soon as possible (often overnight). The interface adjusts to the age group and experience of the pupil so, while initially very simple, with more experience more options become available. Special software (which can be easily installed on almost any computer system) can then be used to process the data to make images, explore colours and measure sizes and brightness, and so on. This combination of simplicity and increasing flexibility makes it possible for students to work not just in the classroom but in their own time. Indeed, we strongly encourage you to set your pupils loose and see what they come up with, thereby increasing their involvement and motivation while saving valuable teaching time.

Figure 3 The Triffid nebula (M20); image courtesy of the LT, Andy Newsam and B. Davies

All development on the NSO has been led by teachers and so all of these activities are backed up by a wealth of support material, from teacher notes and introductions to short 'how to' videos. There are also a number of online tools and activities that, while not directly related to observing with the LT, support some of the trickier areas of teaching, from tides and orbits through to redshifts and stellar evolution.

For the more ambitious student, there are several large-scale collaborative projects where data are collected or analysed by students all over the country and collated by LJMU staff. These projects often involve genuine research – from studying the evolution of supernovae through to exploring the orbits of potentially hazardous asteroids or searching for extra-solar planets.

With this wide range of possibilities – suitable for years 4 to 13 (ages 8–18) – and with more than 2000 schools already registered and more than 30 000 observing programmes carried out for them, the NSO is an excellent tool for anyone teaching science.

The Faulkes Telescope Project
www.faulkes-telescope.com

In years 11 and 12, I used the Faulkes telescope in Hawaii over the internet, which any students in any school can use … It was really brilliant to be able to take the project in my own direction rather than just follow the instructions in a textbook. That was really great. (evidence to a UK House of Commons Select Committee, 2011)

The FTP was established in 2004 with the aim of enthusing students in subject areas such as science, mathematics and information technology. With funding from the Dill Faulkes Educational Trust and the UK Government, two 2 metre telescopes (essentially identical twins to the LT) were built in Hawaii and Australia, specifically for UK students to control and use over the internet from their classrooms.

In 2005, the US-based Las Cumbres Observatory Global Telescope (LCOGT) network took over the reins of the project and bought the two Faulkes telescopes for the beginnings of its network of telescopes across the globe. LCOGT

Figure 4 Faulkes Telescope North image of the supernova in the M51 spiral galaxy in June 2011, spanning 10 arcmin × 10 arcmin of sky; image courtesy of the FTP/LCOGT and Gain Lee

aims to build two networks of telescopes, one with approximately 24 × 0.4 metre telescopes for use in education and one with 20 × 1 metre telescopes for scientific use. Eventually, access to all these telescopes will be provided free of charge to schools all over the world, enabling students to carry out their own personal astronomy research.

FTP provides a fully supported education programme to encourage teachers and students alike to engage in research-based science education using robotic telescopes. All the educational resources produced by the FTP team can be accessed free of charge from the Faulkes resources portal (resources.faulkes-telescope.com). The portal, written in the *Moodle* online virtual learning environment, contains projects and activities that are mainly aimed at 11- to 14-year-olds. However, with input from astronomers across the world, more advanced research projects are being introduced, giving older students (or even the more gifted younger students) the chance to carry out real astronomical research, helping astronomers in their quest to answer some of the key questions in astronomy.

The portal is laid out in an easy-to-use fashion, with the resources split into categories such as 'Observation planning', 'Solar system', 'Stars', 'Galaxies', etc. Access is open to anyone, whether student or teacher, and includes videos and interactive animations to help explain and bring the subjects to life for students. Downloadable paper-based resources are also available for those schools with limited computer facilities, and these range from step- by-step instructions on how to use the telescopes to question-and-answer sheets for key stage 3 (ages 11–14) and key stage 4 (ages 14–16) students. All resources aim to address curriculum topics, so that they complement the teachers' lessons and do not add 'extra' work to them.

The 2 metre Faulkes telescopes are professional instruments and can be used to carry out real and exciting astronomical research in the classroom. In May 2008, a British amateur astronomer discovered the fastest rotating natural object known in the solar system using data from Faulkes Telescope South, and the hunt for new 'superfast' rotating lumps of rock in the solar system has exploded from there. Schools from around the UK and Europe have helped to observe candidate objects and discover even more superfast rotators.

In the summer of 2011, a work experience student, Hannah Blythe, achieved international recognition for her work hunting for asteroids with the Faulkes telescopes, helping astronomers locate over 20 new objects, and this was followed up by a University of Glamorgan undergraduate, Antos Kasprzyk, whose images helped reveal the first-ever 'Jupiter Trojan Comet', locked into an orbit with the gas giant planet.

From hunting for previously unknown asteroids to measuring the light from newly exploded stars, the possibilities for making new discoveries using the Faulkes telescopes are quite literally out of this world.

The Bradford Robotic Telescope
www.telescope.org

In this age of light pollution, the Bradford Robotic Telescope (BRT) aims to reclaim the 'wow' of seeing the night sky for all schoolchildren. With three cameras, it delivers images ranging from whole constellations such as Orion (with a 40° field encompassing) to the whole of our nearest galaxy neighbour, Andromeda (with Cluster Cam and its 4° field) or individual distant galaxies with a 20 arcminute field of view. The telescope is a service instrument with users making a request for

their observation and the telescope returning it as soon as observing conditions allow.

The BRT supports many websites. There is the free site for amateur astronomers (www.telescope.org) but for education purposes there are the subscription sites. In reality, the BRT is much more than a telescope. It is a whole learning structure with various sites. Its primary aim is to support children and their teachers in England following the National Curriculum from key stage 2 (ages 7–11) up to year 13 (ages 17–18) with GCSE Astronomy and the space parts of Physics included. There are games, simulations and competitions, with children pushed into thinking like scientists to explain natural phenomena such as the changing shape of the Moon or the different colours of the stars. They are presented with the BRT as a real data-gathering resource accompanied by data-processing tools for them to test out their ideas in the real world. There is extensive support for teachers, both in class management and in presenting the ideas to the children.

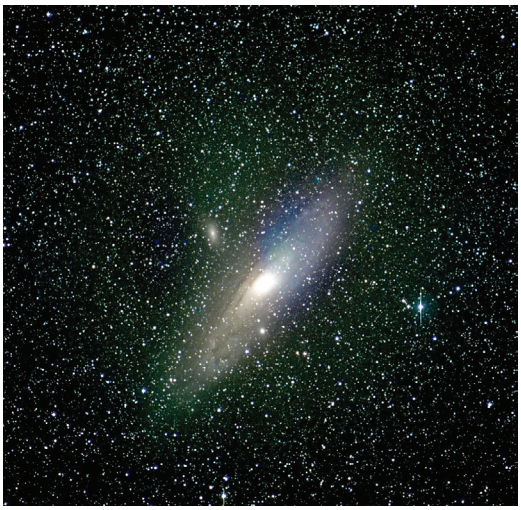

Figure 5 The Andromeda galaxy, as observed by the Cluster Cam on the Bradford Robotic Telescope – the larger field of view of the BRT compared with the LT and FT is clear from this image, which covers 4°; image courtesy of John Baruch/BRT

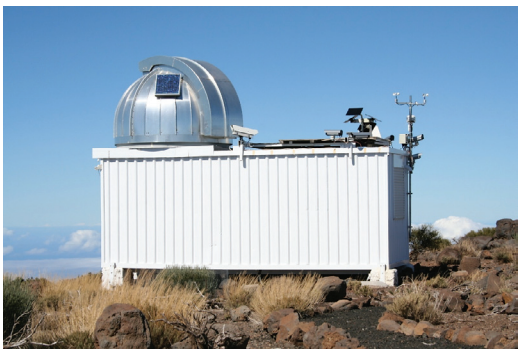

Figure 6 The Bradford Robotic Telescope on Tenerife; image courtesy of John Baruch/BRT

The education sites have a great deal of value-add in education terms and are well worth the subscription, which is subsidised by the University of Bradford. For schools in England there is schools.telescope.org and for those in Scotland scotland.telescope.org; for Chinese-speaking students there is cn.telescope.org. The annual subscription costs are £70 for a primary school and £195 for a secondary school, and this provides unlimited access to users within that establishment. The schools need to have *Java* and *Flash* installed on their computers.

The system is designed to support those primary teachers whose science is limited to a double GCSE subject with its thin gruel of physics or those in secondary school who are teaching physics and astronomy outside their prime specialism. It aims to give them enough confidence to pursue many of the projects available to them on the BRT site and to go on to work with the LT and the Faulkes telescopes on real research programmes with professional astronomers.

The work with school students in China and the UK is leading to a new use for the telescope as a stimulant for learning foreign languages. The current view of linguists is that language studies are better pursued through inspirational projects in the foreign language rather than by traditional methods. We are pushing out the boat with Chinese funded by the British Council and we are talking to the French, German and Spanish embassies.

Although we are working with partners from the Shetland Islands to Kent, who take the project out to schools and introduce it to the children and deliver the teacher training, there are many schoolchildren who cannot use the telescope because their school has not subscribed, so we are launching a set of personal space missions on my.telescope.org for £7.99 each. These are designed more as educational games than as a serious school project, but the science is serious and possibly more memorable for being part of

a game. In the long term, we expect to expand the mathematics and physics projects on the site and include chemistry and biology, based on real online data from the outside world using the extensive educational structure we call the Bradford Robotic Telescope.

The planetarium experience

The Armagh Planetarium

Planetaria are places where you can see the night sky when you are wide awake during the daytime. You can sit back and relax in a comfortable seat while the planetarium presenter takes you on a tour of the night sky. This is an easy way to learn how to navigate the heavens, and you will soon see that, although it looks very complex, everything in the night sky has its place and, once you can spot the right landmarks (skymarks?), you will be ready to explore. The planetarium staff will be happy to act as your guide.

While the stars are very variable, and can be difficult to see unless you are in a really dark place, the Moon and the solar system planets are much easier to spot. The brightest 'stars' are usually planets and, once you know the rules, you can work out where to look. I suppose the best way to start this exploration is to find some place where you are away from bright lights. From space, the night side of our planet shows a ghostly outline of the continents, delineated by a skein of lights marking our largest cities and the roads and other networks that connect them. Aliens would have no need to check it out: our night-time lights leak energy into space and positively scream out that we humans are down here on the planet's surface.

If you can find a really dark site and you can position yourself in such a way that a mountain or forest is in the way to block out the orange glow of city lights, then you are in for a treat. As soon as your eyes are properly dark adapted and you are seeing as much detail as possible, the first thing that you will see is a band of stars across the heavens. Some human cultures see it as a river of light across the sky. This is our home galaxy, the Milky Way, and it is home to billions of stars. All of them are suns, just like ours, although some are older, or younger, and many are bigger and brighter. We can show the Milky Way in the planetarium but seeing the real thing is much more satisfying. I [TM] have seen it from many different places on Earth: from the garden of my daughter's house in New Zealand; lying on my back on a sand dune in the middle of the Namib Desert; sitting on a karst limestone outcrop in the Fermanagh highlands in Ireland; and most recently beside a fiord in northern Norway. It is a spectacular sight.

If it is a clear night and maybe a bit frosty, you may be lucky enough to see falling stars. They look like they have just been displaced from the heavens

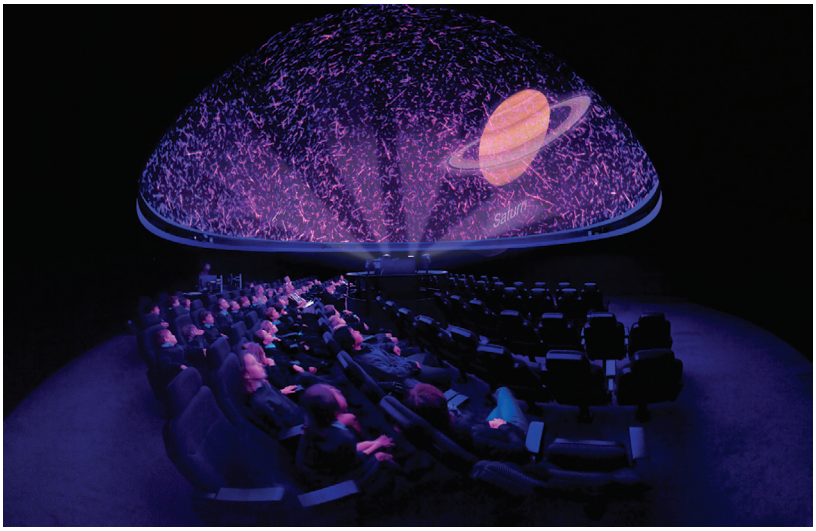

Figure 7 A modern planetarium can offer a surround sound, digital projection experience that can really aid understanding of the difficult concepts in astronomy; image © Armagh Observatory

and are falling down on to the Earth. In reality, they are tiny particles from space, some no bigger than a grain of rice, that are burning up high in Earth's atmosphere. They flare for an instant and are gone, and often you will just catch a glimpse of their fiery end, flaring like a spark from a bonfire. In the Armagh Planetarium we can generate shooting stars at will and can also let you handle a meteorite, which is like a shooting star's bigger relative.

When you ponder these things, and grow to appreciate the enormous size of the universe, it rather puts all of our human worries into perspective. We are smaller than fleas on a dog when you compare us with the size of our planet: insignificance appears to be our trademark. But then think some more: our Stone Age ancestors may not have known as much about the science of astronomy as we do today but they still knew enough to build great monuments, such as Stonehenge in England and Newgrange in the Boyne Valley in Ireland and countless stone circles, corridors and aligned tombs and burial sites. They probably worshipped the Moon and the Sun, and their wise men knew when it was time to plant and time to harvest so that they could survive the bone-numbing cold of winter. And they knew that summer always returned as the certain cycle of seasons is majestically written in the constellations in the sky.

I was in Norway recently to photograph the northern lights, huge shimmering curtains of light glowing all across the sky as billions of charged particles are caught up in the Earth's magnetic field. At the planetarium we can show you how this happens and explain how the aurora is created by an enormous burst of energy from the Sun.

At your local planetarium we can show you all of this and more in our computerised night sky. We can fly you out to the edge of the solar system and beyond, skim the moons of Jupiter and surf Saturn's icy rings, and still be back in time for tea. So come and pay us a visit – we'd love to show you around our neighbourhood. Martian volcanoes, anyone?

A planetarium near you?

There are many planetaria around the UK, including a number of portable ones. To help you find out what is available in your area, the British Association of Planetaria has a search tool at www.planetarium.org.uk/planetaria.asp.

Astronomy and space centres in the UK

Armagh Planetarium, Northern Ireland
www.armaghplanet.com

The Armagh Planetarium is dedicated to astronomy education for all levels. It offers a curriculum-broadening experience for school visitors, and the educational programme has been designed to dovetail with the new Northern Ireland curriculum while retaining characteristics that are central to an understanding of basic astronomy. All of the school theatre shows are interactive, so that presenters and pupils take an active part in the show. Follow-up tasks back in the classroom are facilitated by downloadable PDFs and astronomical factsheets for teachers to use as supplementary teaching material.

Royal Observatory, Greenwich, London
www.nmm.ac.uk/schools

The Royal Observatory, Greenwich was founded in 1675 and is one of the most important historic scientific sites in the world. Today the Observatory

Figure 8 A planetarium show can engage, amaze and educate students in equal measure; image © Armagh Observatory

Figure 9 The exterior of the Armagh Planetarium, showing the planetarium dome; image © Armagh Observatory

is a museum and science centre that provides schools and the wider public with access to information about space. A visit to the Observatory offers students an inspiring, curriculum-linked experience, with unparalleled opportunities to meet astronomers, engage with cutting-edge science and explore big ideas. It offers a wide range of facilities for visiting schools, including the award-winning Time Galleries, the interactive Weller Astronomy Galleries, the Lloyd's Register Educational Trust Learning Centre and the Peter Harrison Planetarium.

The Observatory offers curriculum-linked on-site programmes for Early Years Foundation Stage (EYFS) through to A-level (a full-day visit includes the planetarium and workshop, time in the modern astronomy galleries and lunch), and extended study days for key stage 4 (age 14–16) and post-16 groups, including a range of astronomy masterclass sessions on a relevant topic and a careers-focused 'meet the scientist' session. The website also features a range of resources, including classroom activities and relevant weblinks.

National Space Centre, Leicester
www.spacecentre.co.uk

The National Space Centre is the UK's largest visitor attraction dedicated to space. It houses six hands-on galleries, the Rocket Tower and a planetarium offering world-class educational full-dome shows. The centre welcomes over 60 000 student visitors each year and provides a large number of workshops, missions and video conferences to enhance school visits. In addition the National Space Academy, led by the National Space Centre, provides curriculum-focused support in the 14–19 age range for STEM subjects, including GCSE Astronomy, through student masterclasses and teacher continuing professional development (CPD) sessions.

Spaceport, Liverpool
www.spaceport.org.uk

Spaceport is an astronomy and space visitor centre on the banks of the Mersey. It is a partnership that brings together the research and educational experience and knowledge of the Astrophysics Group at LJMU with the tourism experience of Mersey Ferries. Housed in a listed building at the Seacombe Ferry Terminal, it has a large permanent exhibition space that covers all aspects of astronomy, a full-dome projection theatre and a visiting exhibition area that has hosted shows as diverse as a celebration of the Moon landings and *Wallace and Gromit in Space*. Teacher packs and special admission rates are available to schools.

Jodrell Bank Discovery Centre, Cheshire
www.jodrellbank.net

At the Jodrell Bank Discovery Centre you can walk around the world-famous 76 metre Lovell Telescope while it works. In the Centre's two new Pavilion buildings there are interactive exhibits and you can find out about the work that scientists and engineers are doing.

Spaceguard Centre, Knighton, Wales
spaceguarduk.com

The Spaceguard Centre is a working astronomical observatory, in a commanding location overlooking the town of Knighton in Wales. The aim of the

Figure 10 Interactive displays within the Weller Astronomy Galleries at the Royal Observatory, Greenwich; image courtesy of Royal Observatory, Greenwich

Figure 11 The exterior of the new visitor centre at Jodrell Bank Discovery Centre, with the giant Lovell radiotelescope in the background; image courtesy of Jodrell Bank Observatory

Spaceguard Centre is to develop and maintain a world-class facility for astronomical research and science education with a view to furthering the goals of public understanding of science with a specific emphasis on the Spaceguard project. The Centre is dedicated to the study of asteroids and comets that could hit the Earth. It is part of the international project set up to find and track them, and to plan ways to stop such a catastrophe happening. With a range of intriguing exhibits that include meteorites, a small planetarium and telescopes, the Spaceguard Centre is suitable for visitors of all ages.

Time to explore

It is clear that, whatever your astronomical needs, there is probably something out there to help you. It is a big universe and there has never been a better time to explore it.

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Sarah Roberts is the director of education for the Faulkes Telescope Project and a lecturer in astronomy at the University of Glamorgan.
Tom Mason is the director of Armagh Planetarium and a past president of both the British Association of Planetaria and the International Planetarium Society. He is the ESERO-UK Space Ambassador for Northern Ireland.
John Baruch is the director of robotic telescopes at the University of Bradford. The programme has 55 000 schoolchildren as registered users, together with their teachers, and is directly linked into the STEM outreach programme of the university.