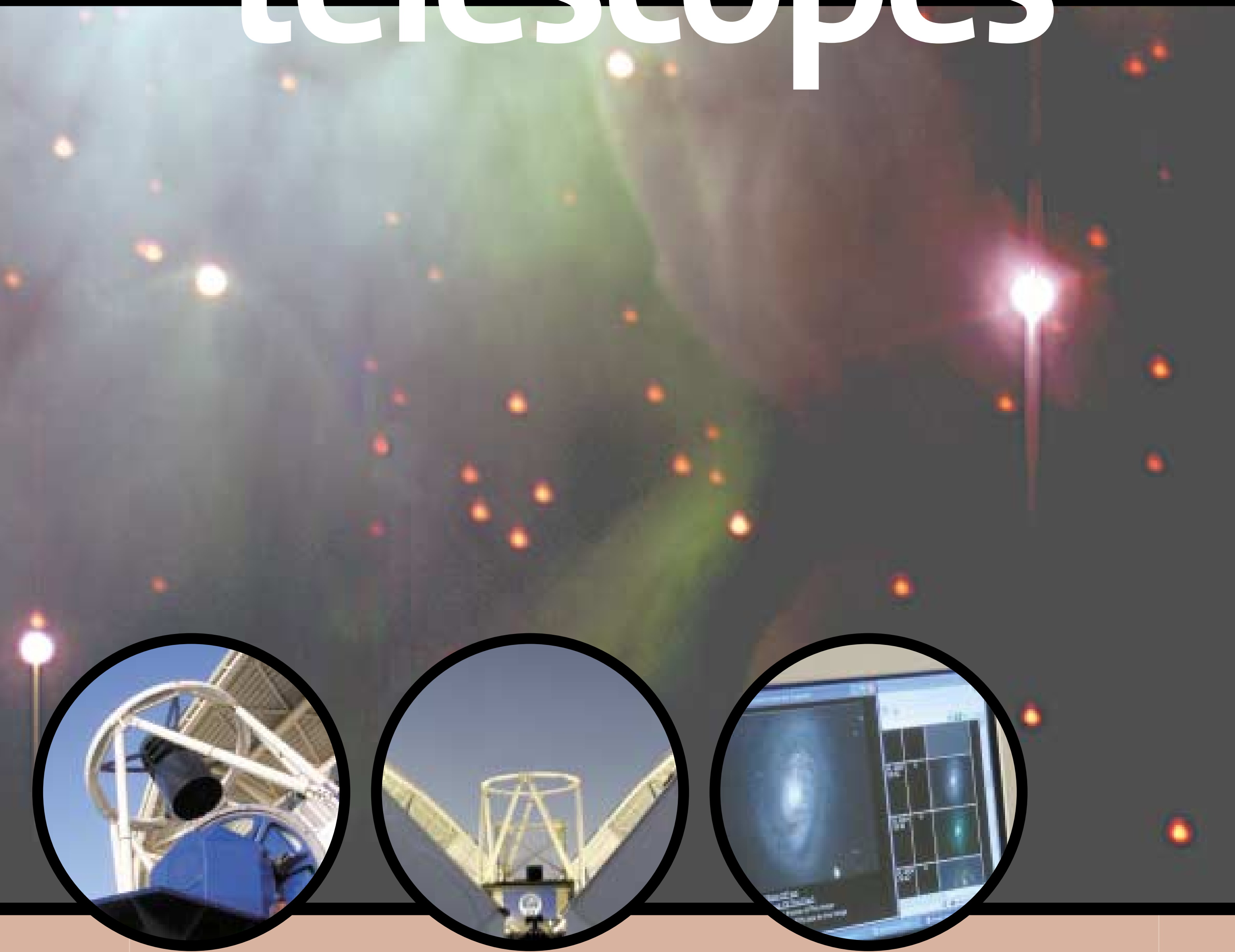
PPARC

Robotic telescopes



Real-time astronomy for research and education

Colour image of the Crab Nebula from Faulkes Telescope North. This is typical of the images that will regularly be obtained by schools

The largest, most powerful robotic telescopes

Astronomers have traditionally been caricatured as hardy, outdoor types who think nothing of spending long nights, wrapped in coats and scarves, observing the wonders of the universe through their telescopes.

In fact, this scene is now a rarity. Today's astronomers are able to take advantage of modern telecommunications and information technology to control the latest, state-of-the–art instruments and receive digital data about far-flung galaxies.

This revolution in astronomical technology is about to arrive in UK schools, colleges and universities with the introduction of the Liverpool Telescope and the two Faulkes Telescopes, the largest, most powerful robotic telescopes ever built. Located at three of the world's best observing sites – La Palma in the Canary Islands, the island of Maui in Hawaii and Siding Spring in New South Wales, Australia – these instruments will provide access to the entire night sky from cloudy Britain.

Now operational

The first of these to become operational was the 2 metre Liverpool Telescope, which returned its initial observations of the night sky on 1 August 2003. This was followed in December by the first images from the identical Faulkes Telescope North, and the Faulkes Telescope South is expected to become fully operational by autumn 2004.

Since each telescope is fully robotic and operated remotely from the control centre at Liverpool John Moores University (JMU) on Merseyside, no operator is needed on the mountain. Instead, commands are issued to the telescopes from the PC of the observer, who could be anywhere in the world.

Situated half a world away, the Faulkes Telescopes will be observing the night sky when it is daytime in the United Kingdom, enabling their utilisation during school hours. By providing a unique opportunity to explore the heavens with the aid of powerful modern instruments, the twin telescopes will not only enable young people to learn about the wonders of the universe but provide a unique, "hands-on" experience that should help to inspire them to take up careers with a basis in science and technology.

The role of the Liverpool Telescope is rather different: it is primarily intended for professional use by the Astrophysics Research Institute at John Moores University (ARI-JMU) and the UK astronomical research community in general, although observing time is also available for educational studies.

The educational aspects of both robotic telescope projects fit together under the umbrella of the UK's National Schools' Observatory (NSO). Through the NSO, observing time for students is specially reserved on these state-of-the-art instruments. Working with the resources developed by the NSO, students can prepare and carry out their own astronomical research and share in the excitement of discovering the wonders of the universe. In this way, using the full power of the internet, the robotic telescopes are bringing cutting-edge science and technology into the classroom.

"For the first time, school children can now work alongside professional astronomers," said Andy Newsam, NSO astronomer on the Liverpool Telescope.

"Robotic telescopes are likely to revolutionise not only our ability to understand complex time-limited astronomical events but will also allow us to bring the sheer excitement of space discoveries into the classroom in real time," said Professor Ian Halliday, Chief Executive of the Particle Physics and Astronomy Research Council (PPARC). "The ability for school children and amateurs to contribute to front rank research offers tremendous possibilities." ■

The Liverpool Telescope on its first night of observing

The unusual telescope enclosure opens like a clam shell

ever built

Liverpool Telescope

The Liverpool Telescope (LT) is sited at an altitude of 2,400 metres, alongside the UK's Isaac Newton Group of telescopes at La Palma in the Canary Islands.

The LT is owned by the Astrophysics Research Institute of Liverpool John Moores University (ARI-JMU), and observes autonomously from La Palma. Financial support for telescope operations is provided by PPARC, making 40% of the observing time available to the UK astronomy community. The remaining time is divided between ARI-JMU, Spanish and international research projects, and education.

Faulkes Telescopes

The Faulkes Telescopes are the world's largest robotic telescopes built exclusively for education. With two sites in different hemispheres, half a world away from the UK, they are able to provide full coverage of the northern and southern night skies during UK daylight hours.

The northern telescope is located on the Hawaiian island of Maui. This site, at an altitude of 3000 metres, provides the excellent air quality and stability needed to make the best astronomical observations. Since it achieved first light in December 2003, the telescope has been gathering data for schools and research astronomers.

The southern telescope is located at Siding Spring in New South Wales, Australia, The installation of the enclosure has been completed and the telescope is expected to become available for use by schools from September 2004 onwards.

The Clam

All three telescopes are housed in segmented, fully opening enclosures. Made of steel frameworks clad in aluminium and wood with a protective outer membrane, these clam-like structures were designed by Telescope Technologies Ltd. and built in Merseyside and Glasgow. Although the design is novel for telescopes of this size, it has several advantages. First, the telescopes sample the image quality (seeing) of the site itself, rather than having this degraded through atmospheric and other effects caused by being inside a conventional dome.

Also, once open, the telescope can be rapidly deployed without waiting for the dome slit to rotate to the right position. This is particularly important in the case of transient events, such as gamma ray bursts, when an alert comes down from a satellite and the telescope schedule is automatically over-ridden so that it can slew to observe the explosion within a minute or so. ■

THE CONTRIBUTORS

The telescopes were designed, constructed and commissioned by Telescope Technologies Ltd., a spin-off company of Liverpool John Moores University (JMU), with contracts issued to companies and academic institutions in the UK and overseas. Their instrumentation and robotic software development has been led by JMU-ARI, which also houses the Telescope Management Centre for all three instruments.

The Liverpool Telescope is owned and operated by the Astrophysics Research Institute of JMU, with financial support from PPARC, the European Union, JMU and the generous benefaction of Mr. Aldham Robarts. Other project partners include the Universities of Manchester and Southampton, Imperial College London, Swinburne University Melbourne, the Instituto de Astrofisica de Canarias and National Museums Liverpool.

The Dill Faulkes Educational Trust has contributed £10 million to construct the twin Faulkes Telescopes and their protective enclosures. Other partners in the Faulkes Telescope project include PPARC, the Dept. for Education and Skills (DfES), Cardiff University, University of Warwick, Liverpool JMU, the National Space Science Centre, University of Leicester, University of Hawaii, the Australian National University, the Anglo-Australian Observatory and Swinburne University.

The telescopes are located at three of the world's best observing sites

Research

Primarily intended for front line astronomical research by UK and overseas universities, the Liverpool Telescope (LT) is funded by PPARC as a National Facility. Schools are also able to participate in cutting-edge astronomical projects through their observations with this and the Faulkes Telescopes.

The telescopes' most valuable contributions to research will result from flexible scheduling and rapid response, which are very difficult to achieve with more traditional astronomical facilities. These rare capabilities will put the UK at the forefront of exciting new research in so-called "time domain" astrophysics.

Quick response

One great strength of such telescopes is their ability to make regular observations of objects that vary in brightness over periods lasting anything from seconds to years. They can also track newly discovered objects such as comets or near-Earth asteroids, allowing accurate calculations of their paths and (in some cases) their potential threat to Earth.

Many astrophysical events, such as gamma ray bursts (GRBs), supernovae, novae and gravitational lensing are intrinsically rare, occur at unpredictable times, and have lifetimes ranging from just minutes through to years. To understand these types of phenomena it is necessary to conduct long term monitoring programmes, or to be able to react within minutes to chance discoveries made by other observatories or spacecraft.

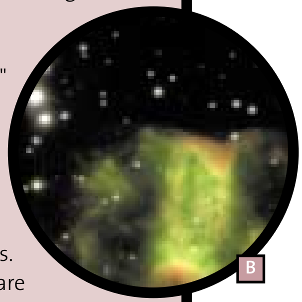
One example of the many exciting projects scheduled for the telescopes is optical imaging and spectroscopic observations of gamma ray bursts. Despite being the most energetic form of explosion known in the universe, these outbursts are poorly understood and are hard to detect as they are short-lived and occur without warning. The telescopes will be able to respond within minutes to alerts issued by NASA's new Swift satellite, allowing the earliest moments of these enigmatic objects to be observed in unprecedented detail.

The telescopes will also be used to search for, and follow the development of, novae and supernovae in nearby and distant galaxies. The ability to undertake several different monitoring programmes at the same time allows objects such as these to be observed frequently for a sustained period, providing superlative coverage of these violent stellar explosions.

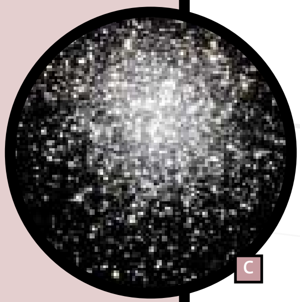
FIRST LIGHT

These are some of the first images that have been taken with the robotic telescopes.

A **Saturn** – The giant gas planet displays its magnificent ring system, tilted almost 27 degrees toward Earth.



B **The Dumbbell Nebula (M76)** – A "planetary nebula" – the glowing shroud of gas surrounding the remains of a dead star. The dramatic colours tell us about the chemical composition of the gas.



C **Globular Cluster M13** – A dense ball of stars that orbits our galaxy at a distance of 25,000 light years. Hotter stars show blue in this image. Cooler stars are yellowish.

D **NGC 2207** – Two galaxies interacting due to their mutual gravity. Billions of years in the future these two galaxies will become one.

E **NGC6503** – The bright central core of this "Seyfert galaxy" is thought to contain a super-massive black hole, producing vast amounts of energy as it swallows surrounding stars, dust and gas.

SPLITTING LIGHT

One of the most important astronomical tools on the robotic telescopes will be spectrographs built through collaboration between Liverpool John Moores (JMU), Manchester and Leicester universities. This instrument splits the light received from planets, stars and galaxies into its constituent wavelengths, enabling astronomers to determine the chemical elements that are present, the temperature, the presence of magnetic fields, the speed the object is moving, and its distance from us.

The LT is also equipped with an infrared camera built through collaboration between JMU and Imperial College London. An advanced, medium resolution spectrograph will be added in 2005 as a joint project between JMU and the University of Southampton.

Education and inspiration

Through astronomy, young people can learn more about the nature of the universe in which they live. Unfortunately, there are few opportunities for students to actually observe the night sky through a large telescope. This is about to change, with the introduction of powerful robotic telescopes and educational programmes that are designed to give students first hand experience of astronomical research.

In particular, the twin Faulkes Telescopes have been funded for educational use, with several thousand hours of observing time available to schools each year.

More than 450 hours per year observing time on the Liverpool Telescope (LT) have been allocated for schools' use by Liverpool John Moores University (JMU). At any time students can send their requests for observations to the telescope from the classroom or while at home.

The entire registration and observation process takes place using the Internet. Schools pay an annual subscription of £50 for access to the LT and a range of software supporting the use of robotic telescopes in the classroom. In the case of the Faulkes Telescopes, schools that pay a subscription of £160 per annum can book up to three, half-hour observing sessions, with an additional 10 minutes of off-line time.

Real-Time and Off-Line

Schools can operate the Faulkes Telescopes in two ways, real-time mode and off-line mode. The LT will be accessible in off-line mode only via the interface found on the NSO website.

- REAL-TIME MODE – Users will be able to control a large telescope and point it at any object visible in the night sky from their classroom. The project has developed a simple web interface that will allow a class to use the telescope with little training. The images taken with the telescope will be returned immediately, enabling the users to see their data within minutes of telling the telescope to start the observation. Webcam images of the telescope will show users what is happening at each step.
- OFF-LINE MODE – This mode will be used to carry out observations that do not need to be made in real time. Users will access the relevant NSO web interface to request observations of a particular object. The telescope will carry out this observation at the next available opportunity, usually within days, after which the users can download their images via the NSO website.

Projects and Materials

User support will be available from both the LT project team in Liverpool and the Faulkes Telescope Operations Centre at Cardiff University. Astronomy groups and science centres across the UK will also help to provide a national network of support for users.

Meanwhile, the Faulkes Telescope Education and Science Unit is developing a wide variety of research projects and educational materials to be used by participating schools. Funding from PPARC and the Department for Education & Skills is contributing towards this educational outreach. In addition, specially developed teaching materials are described on the Faulkes Telescope and NSO/LT web pages.

THE NATIONAL SCHOOLS' OBSERVATORY

The National Schools' Observatory (NSO) was founded by JMU with support from PPARC. It is a major web-based resource that allows UK schools to use world-class astronomical telescopes sited all around the world.

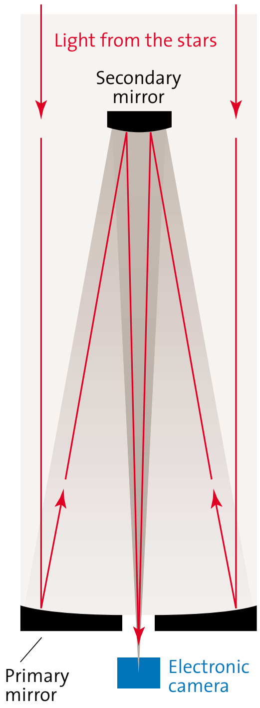
Students will be able to make requests for observations of a huge number of astronomical objects. The observations of planets, stars and galaxies will be made by the telescope, either in real-time or off-line mode, followed by rapid download of images and data. Working with the resources developed by the NSO, students can prepare and carry out their own astronomical research and share in the excitement of discovery.

In this way, using the full power of the internet, the robotic telescopes bring cutting-edge science and technology into the classroom.

The telescopes are controlled via simple web interfaces

Telescope design

The three robotic telescopes are the first of a new generation of instruments designed and constructed by Telescope Technologies Ltd. Although each reflecting telescope weighs 24 tonnes, it can move independently in elevation and azimuth (bearing), with the two axes controlled by computer to track the movement of stars across the sky.



The telescopes use ultra-smooth mirrors to deliver sharp images

Mirror, Mirror

The telescopes are built around a 2 metre diameter primary mirror. This reflects incoming light onto a smaller secondary mirror, which then focuses it onto the electronic (digital) camera and other instruments beneath the primary mirror.

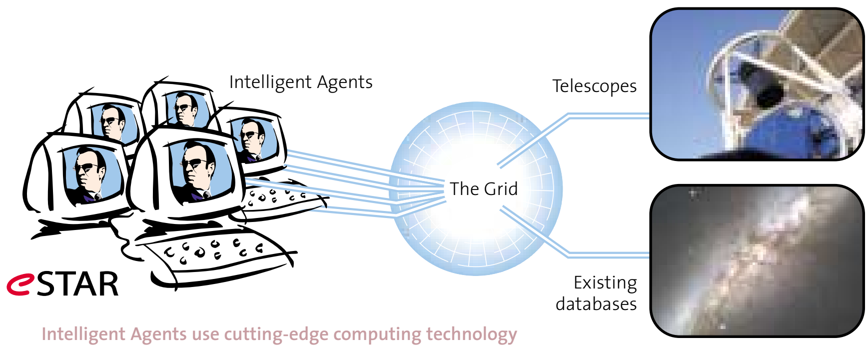
The large size of the primary mirrors means that they can capture more light and detect fainter objects such as stars and galaxies. The telescope's performance is also affected by local atmospheric conditions, particularly temperature, on the mountain sites where the observatories are located. For example, on La Palma, the air temperature can vary by 35 degrees C. Expansion and contraction would alter the shape of the concave mirror, resulting in blurred images of the stars. In order to prevent such shape-shifting changes, the mirrors are made from special glass that is not affected by the large range of temperature.

To make the surface of the 1.25 tonne mirror highly reflective, the final surface is polished smooth and coated with a layer of aluminium about 10 atoms thick.

Cool Instruments

All three telescopes are equipped with light-sensitive Charge Coupled Device (CCD) cameras, built in the UK, which have 2048 by 2048 individual picture elements (pixels). This corresponds to a 4.6 x 4.6 arcminutes field of view – about 15% the width of a full moon. Colour images can be obtained by using two, five position filter wheels, giving a total of 8 filter selections.

The detector, provided by e2v technologies in Chelmsford, is cooled to a temperature of -107°C by an IR Labs cryostat, which is designed for long (3 month) vacuum hold time. Operation at such a low temperature is essential to increase the sensitivity of the detector.



Intelligent Agents use cutting-edge computing technology

Automation

The whole telescope system operates automatically. Operations centres in the UK, Hawaii and Australia send instructions via the internet with details of the observations to be carried out. The telescope control system then decides if the weather is good enough to open the enclosure, points the telescope, takes the images requested, then moves on to the next observation.

Eventually, the robotic telescopes may become part of a global network – "RoboNet" – in which they are linked with other telescopes around the world to enable continuous, 24-hour monitoring of any object in the night sky. The plan is also to employ so-called "Intelligent Agent" computer programs, developed as part of the JMU-Exeter University "e-STAR" project, that can communicate with the telescopes and with each other, using technology designed for the GRID – the next generation internet. "Not only can these programs make observations with the telescopes, but they can also analyse the data, interrogate archives, and immediately follow up with further observations", said Dr Iain Steele of the e-STAR project.

From dream to reality

The robotic telescopes have been made possible through the efforts of many individuals, companies and institutions. These are the views of some of the key contributors.

Mike Bode is director of the Liverpool Telescope (LT) and head of the Astrophysics Research Institute at Liverpool John Moores University (JMU), though he is currently seconded onto a PPARC Senior Fellowship centred on research with the LT. He proposed the concept of a "New Generation of Astronomical Telescopes" and obtained the initial funding from the European Regional Development Fund for the construction of the robotic telescopes.

“ Our initial motivation was to undertake front rank science in largely unexplored areas of the "time domain". We soon realised that astronomy with a robotic telescope could also have significant spin-offs in education. To achieve our aims, however, we also realised we would need to design and build our own instrument, operating as a "space probe on the ground" – and so the Liverpool Telescope was born. I have no doubt that the Liverpool Telescope will revolutionise our understanding of many branches of astrophysics and, together with the Faulkes Telescopes, will allow our young people to share in the excitement of discovery in science. ”

Dave Carter is the Director of the Liverpool and Faulkes Telescope Management Centre. Originally involved in defining specifications of the LT, he is now involved in telescope commissioning and heads the group responsible for implementing the future scientific programmes.

“ The Liverpool Telescope opens up a whole new area of scientific projects and puts us in the forefront of time-variable astronomy, particularly gamma ray bursts and supernovae – two of the most exciting areas of research at the moment. ”

Mike Simcoe, the Project Manager for the National Schools' Observatory, is based at the Astrophysics Research Institute of JMU. He worked in secondary education for over 30 years before joining the project in 1996.

“ The NSO is very keen to avoid the temptation for students to just take pictures. Instead, we want to encourage the scientific process of planning, observation, analysis and evaluation. We have initially devised seven investigations that can be carried out using the LT – the Moon; Comparing Planets; Planet Sizes; A Day on Jupiter; Io; Discovering Pluto; and Galaxies. These require multiple observations, providing the opportunity for real scientific study. ”

Paul Roche has worked with the Faulkes Telescope Project since 1999, and became Director in 2001. Based in the School of Physics and Astronomy at Cardiff University, he is also the National Schools Astronomer, funded since 2000 by a PPARC National Award for the Public Understanding of Science, working with schools across the UK and Ireland.

“ The Faulkes Telescopes will inspire a new generation of scientists by teaching young people about the wonders of the universe. We have a unique opportunity to put state-of-the-art equipment into the hands of schools and other educational groups, such as amateur astronomy societies, and to allow them to contribute towards real astronomical research. Users will work directly with professional astronomers, gathering data in support of research projects ranging from studies of the solar system to cosmology. The FT project is real time, real science and real scientists. ”

M51 is a spiral galaxy very like the Milky Way, 30 million light years away

ROBOTIC TELESCOPES INFORMATION

More information about the UK robotic telescopes can be obtained from:

Professor Michael F. Bode
Astrophysics Research Institute,
Liverpool John Moores University
Twelve Quays House
Egerton Wharf
Birkenhead CH41 1LD
Tel: 0151-231-2920 (direct), 2919 (secretary)
FAX: 0151-231-2921
E-mail: mfb@astro.livjm.ac.uk
http://www.astro.livjm.ac.uk/

Dr. Paul Roche
Faulkes Telescopes Project Director
School of Physics & Astronomy
Cardiff University
5 The Parade
Cardiff CF24 3YB
Tel. 029-20-875121
E-mail: paul.roche@faulkes-telescope.com
http://www.faulkes-telescope.com

Websites:

Liverpool Telescope
http://telescope.livjm.ac.uk/

Faulkes Telescope
www.faulkes-telescope.com

National Schools Observatory:
www.schoolsobservatory.org.uk/

University of Leicester, Space Research Centre:
www.src.le.ac.uk/projects/faulkes/

Faulkes Telescope Australia:
http://astronomy.swin.edu.au/faulkes/

Telescope Technologies Ltd.:
www.ngat.com/

Particle Physics and Astronomy Research Council

The Particle Physics and Astronomy Research Council (PPARC) is the UK's strategic science investment agency. It funds research, education and public understanding in four areas of science – particle physics, astronomy, cosmology and space science.

Funded by the UK government, PPARC provides research grants and studentships to scientists in British universities, and gives researchers from British universities access to world-class facilities. It funds the UK membership of international bodies such as the European Laboratory for Particle Physics (CERN), the European Southern Observatory and the European Space Agency.

PPARC contributes towards the funding of the UK telescopes overseas in La Palma, Hawaii, Australia and Chile. It also funds the UK Astronomy Technology Centre at the Royal Observatory, Edinburgh, and supports the MERLIN/VLBI National Facility, which includes the Lovell Telescope at Jodrell Bank Observatory.

The technologies developed by PPARC research can be found in business, defence, industry and education. There are direct benefits to society in terms of development of new materials and products, raising the skills base, and maintaining the UK as a world leader in these areas.

PPARC **The UK's Strategic Science Investment Agency**
Particle Physics and Astronomy Research Council
Polaris House
North Star Avenue
Swindon SN2 1SZ
Tel: +44 (0)1793 442000
Fax: +44 (0)1793 442002
Email: pr.pus@pparc.ac.uk
URL: www.pparc.ac.uk

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