Science and Technology Facilities Council

World-class research

Pushing the frontiers of human knowledge and understanding: the UK as a global leader in the search for a deeper understanding of the Universe

Ambitious, curiosity-driven research and sustained strategic investments have established the UK as a world-leader in STFC's many areas of science, and the UK regularly ranks among the top three leading scientific nations, measured by citation impact.

The science that we support aims to provide answers to some of the most challenging questions facing us today: How did the Universe begin and how is it evolving? How do stars and planetary systems develop and how do they support the existence of life? What are the basic constituents of matter and how do they interact?

In order to respond to these questions, we develop and exploit frontier research in particle physics, astronomy and space science, and nuclear physics at UK universities and our national laboratories, and manage international research projects in support of a broad cross-section of the UK research community.

We are one of Europe's largest multidisciplinary research organisations, supporting scientists and engineers to perform high-quality, world-leading research. We operate world-class, large-scale research facilities, and manage the UK access to large-scale facilities in other countries. The facilities that we provide include: lasers, accelerators, neutron and muon sources, synchrotron light sources and free electron lasers, scientific computing, and atmospheric and space science.

Generating new knowledge

- First direct visual evidence of supermassive black hole
- Scientists capture image of black hole emitting high-energy jets
- UK-built spacecraft makes its first observations of the Sun
- Sun's surface revealed in unprecedented detail
- UK scientists contribute to a new understanding of matter and antimatter
- New X-ray technique to enable scientists to probe conditions at heart of planets
- Ultrasound breakthrough to enable precision detection of cancer
- New compound identified for potential treatment of antibiotic-resistant superbugs
- New understanding of plant biology could lead to more disease-resistant crops
- Decoding 2,000-year-old scrolls using Diamond Light Source

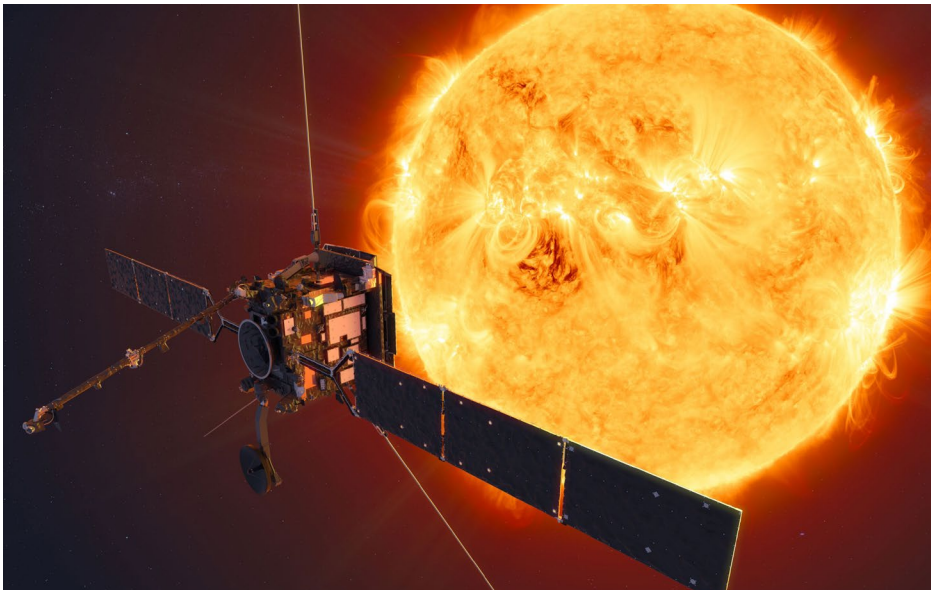
First direct visual evidence of supermassive black hole

The international team behind the Event Horizon Telescope (EHT) project has succeeded in producing the first direct visual evidence of a supermassive black hole, 55 million light years from Earth with a mass 6.5 billion times that of our Sun. The EHT project links telescopes from around the world to form an unprecedented Earth-sized virtual telescope. This breakthrough was enabled by STFC technology and engineering teams and their development of key instruments at the eight ground-based radio telescopes responsible for capturing the image[i].

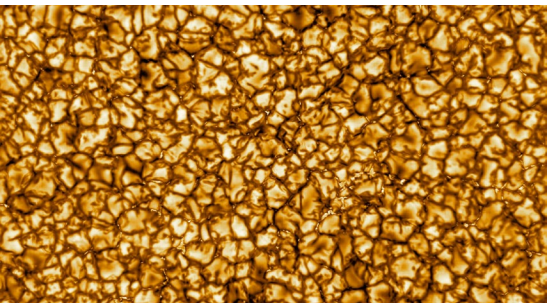
Scientists capture image of black hole emitting high-energy jets

Ejections of material travelling at close to the speed of light from the black hole known as MAXI J1820+070 were tracked successfully for 200 days following their appearance in 2018[ii]. Observations of the extremely powerful, long-lived ejections have given researchers a deeper understanding of how black holes feed energy into their environment. According to Project Co-Lead Rob Fender: "We've been studying these kind of jets for over 20 years and never have we tracked them so beautifully over such a large distance." Funded by STFC, the research team, based at the University of Oxford, used the radio telescope array e-MERLIN, and the Very Large Array and MeerKAT telescopes, based in the US and South Africa, respectively, to track the ejecting material over a period of months. The e-MERLIN array comprises seven radio telescopes spanning 217 km across the UK and connected by a superfast optical fibre network to its HQ at Jodrell Bank Observatory in Cheshire, the UK's facility for high resolution radio astronomy observations, which is operated by The University of Manchester for STFC[iii].

UK-built spacecraft makes its first observations of the Sun



In collaboration with NASA, the European Space Agency (ESA) Solar Orbiter spacecraft was launched on 10th February 2020 at the start of its mission to observe solar activity, including what drives the solar wind, the stream of charged particles ejected by the Sun that can cause major disruptions to communications and other technological systems on Earth. Just two weeks later, the on-board SPICE instrument took its first high-resolution measurements of the Sun. SPICE was developed and built over a five-year period by a team of more than 80 people from across Europe and the USA. STFC's RAL Space with UCL and Imperial College led the project to build SPICE, and were involved in developing another three of the ten on-board instruments: the Solar Wind Analyser, the Magnetometer, and the Extreme Ultraviolet Imager. Airbus Defence and Space, based in Stevenage, was selected by the ESA as the prime contractor for the mission and built the majority of the spacecraft. The contract was valued at around €300 million, one of the largest ever signed between the ESA Science Programme and a UK company[iv].



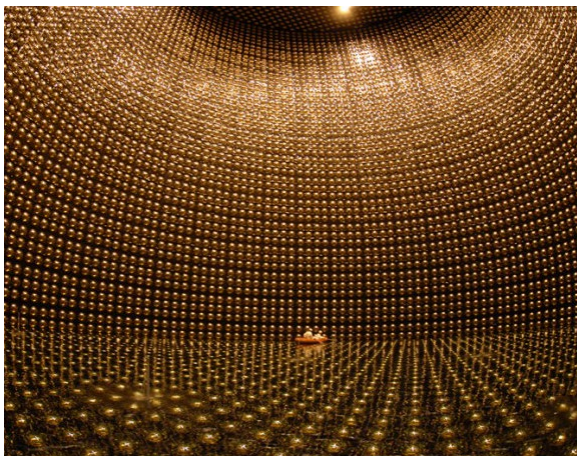
Sun's surface revealed in unprecedented detail

Images and videos taken by the US National Science Foundation's Daniel K. Inouye Solar Telescope in Hawaii have revealed the Sun's surface in unprecedented detail. The new images were captured by cameras developed by a UK consortium and funded by STFC. The images show cell-like structures, each of which is about the size of Texas, which are the signature of violent motions that transport heat from inside the Sun to its surface[v].

UK scientists contribute to a new understanding of matter and antimatter

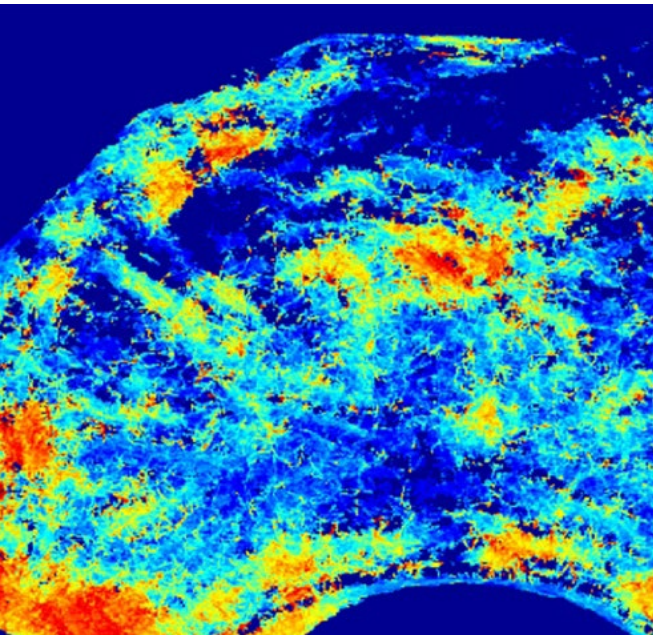
The Big Bang should have created equal amounts of matter and antimatter in the early Universe, but everything that we can see today, from the smallest life forms on Earth to the largest stellar objects, is made almost entirely of matter. Comparatively, there is not much antimatter to be found. Something must have happened to tip the balance. One of the greatest challenges in physics is to understand why

we see this asymmetry between matter and antimatter[vi]. UK scientists have contributed to new research that puts further support behind the theory that neutrinos are the reason that the Universe is dominated by matter. The new results published by the T2K Collaboration show the strongest evidence yet that neutrinos and antineutrinos behave differently, and therefore may not wipe each other out. According to Dr Patrick Dunne, from the Department of Physics at Imperial College London: "This result brings us closer than ever before to answering the fundamental question of why the matter in our universe exists. If confirmed – at the moment we're over 95 per cent sure – it will have profound implications for physics and should point the way to a better understanding of how our universe evolved[vii]."



New X-ray technique to enable scientists to probe conditions at heart of planets

Using STFC's Central Laser Facility (CLF), researchers from Imperial College and CLF have developed a pioneering technique that could be used to probe conditions at the heart of planets. The technique will allow scientists to capture, in unprecedented resolution, information about extremely dense and hot matter, such as can be found inside gas giant planets or on the crusts of dead stars. It could also be used to probe fast-changing conditions inside new kinds of batteries and memory storage devices[viii].



Ultrasound breakthrough to enable precision detection of cancer

A research team based at Heriot-Watt University and part-funded by STFC has unveiled a new technique that uses super-resolution ultrasound methods to improve resolution by five-10 times compared to standard ultrasound images. The breakthrough method uses adaptive optics, first applied in astronomy and then (under STFC funding) successfully adapted for use in optical microscopy, and has enabled the development of micrometric-resolution ultrasound imaging. This permits the scanning of whole organs in super-resolution for the first time, an advance that could lead to earlier cancer diagnoses and allow medical staff to target treatments to any malignant tissue more effectively. It could eventually replace the need for biopsy altogether. Moreover, hospitals would not need new equipment; nor would new hardware technology be required[ix].

New compound identified for potential treatment of antibiotic-resistant superbugs

A multidisciplinary team including scientists from the University of Sheffield and STFC's Central Laser Facility (CLF) has been using the CLF Octopus laser to test a new compound on antibiotic-resistant bacteria, including pathogenic E. coli. These particular bacteria strains can cause infections including pneumonia, urinary tract infections and bloodstream infections, and there have been no new treatments for such bacteria in the last 50 years. Using a technique called simulated emission depletion (STED) microscopy, the team was able to study in super-resolution the uptake and effect of the new compound on the bacteria. The compound appears to make it more difficult for resistance to emerge in the bacteria. The next step will be to test it against other multi-resistant bacteria. "This breakthrough could lead to vital new treatments to life-threatening superbugs and the growing risk posed by antimicrobial resistance," according to Project Lead Professor Jim Thomas of the University of Sheffield[x].

New understanding of plant biology could lead to more disease-resistant crops

A team of multidisciplinary scientists working at the CLF are conducting research that has the potential to lead to more disease-resistant crops. Using high-resolution microscopy at the Octopus imaging cluster, the team was able to investigate the interaction between proteins and cell walls in plants[xi]. According to Dr Dan Rolfe, Lead Data Scientist at Octopus: "This is a great example of how multidisciplinary research is needed to address key challenges for humanity. A combination of advanced microscopy and analysis techniques originally translated from astronomy and applied to gain insights into human cancers has been applied in this plant research. And it has revealed a new understanding of plant biology which has important implications for food security."

Decoding 2,000-year-old scrolls using Diamond Light Source

Ancient scrolls are being virtually "unwrapped" using the UK's national synchrotron facility, Diamond Light Source, combined with special techniques developed by a team from the University of Kentucky. The 2,000-year-old Herculaneum Scrolls were discovered in 1752 in an ancient Roman villa near the Bay of Naples, believed to belong to the family of Julius Caesar. Buried and carbonised by the eruption of Mount Vesuvius in 79 AD, the scrolls are too fragile to be opened by hand. Using the bright, high-energy X-ray beam at Diamond, and the University of Kentucky's virtual unwrapping" software pipeline, a machine-learning algorithm allows the carbon ink on the scrolls to be detected[xii].

References

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ii https://www.nature.com/articles/s41550-020-1023-5

iii https://stfc.ukri.org/news/black-holes-ejections-are-tracked-by-new-telescope-observations/

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viii https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.123.254801

ix https://journals.lww.com/investigativeradiology/Fulltext/2019/08000/Super_Resolution_Contrast_Enhanced_Ultrasound.8.aspx

x https://stfc.ukri.org/news/scientists-discover-new-compound-that-kills-antibiotic-resistant-superbugs/

xi https://stfc.ukri.org/news/octopus-reveals-secrets-of-plant-cell-walls/

xii https://stfc.ukri.org/news/decoding-2-000-year-old-scrolls-with-diamond-light-source/