Project SunbYte: solar astronomy on a budget

Viktor Fedun, **Yun-Hang Cho** and their team of students, academics and enthusiasts hope that Project SunbYte will begin a new era of low-cost, high-altitude solar astronomy.

The SunbYte team

1 SunbYte project presenters at the European Space Agency. (Left to right): Fernando Alvarez, Richard Cook, Helena Livesey, Chris Hare and Yun-Hang Cho (team leader).

The multidisciplinary SunbYte team is made up of students from first-year undergraduates to PhD level, from astrophysics, mathematics, aerospace, civil, electrical, mechanical, materials, economics and automatic control systems departments within both the Faculty of Engineering and the Faculty of Science at the University of Sheffield, the Department of Mathematics, Physics and Electrical Engineering at Northumbria University and the E.A. Milne Centre for Astrophysics at the University of Hull. The student lead is Yun Hang Cho, a PhD student from the Department of Civil and Structural Engineering. Dr Viktor Fedun, the academic lead, is from the Department of Automatic Control and Systems Engineering. At a national level, the project also has academic support from Northumbria University, Queen's University Belfast and the University of Hull.

The Sheffield University Nova Balloon Lifted Solar Telescope (SunbYte) is a high-altitude balloon experiment devised and run largely by students at the University of Sheffield, and is scheduled for launch in October 2017. It was the only UK project in 2016 to be selected for the balloon side of the Swedish–German student programme REXUS/BEXUS (Rocket and Balloon Experiments for University Students; see box on p2.25). The success of the SunbYte team in the REXUS/BEXUS selection process is an unprecedented opportunity for the students to gain valuable experience working in the space engineering industry, using their theoretical knowledge and networking with students and technology companies from all over Europe.

Aims

The main aim of Project SunbYte is to design and build instrumentation that will gather scientific-quality data from high-altitude observations of the Sun's highly magnetized and dynamic chromosphere. We want to design and test an observational platform that can obtain high-resolution solar images and will allow future missions to capture UV wavelengths. The Earth's atmosphere is dense and distorts much of the light that arrives at its surface, reducing the quality of ground-based solar observations. Ground-based solar telescopes are expensive to build: they need significant investment for mirrors and hardware if they are to obtain images of the Sun that have scientific value. In contrast, the SunbYte team will use novel manufacturing techniques such as 3D printing to optimize the mechanical performance of the platform and produce a low-cost, high-altitude alternative. A balloon will lift the SunbYte telescope above the Earth's lower atmosphere to observe the Sun's chromosphere in the Hα spectral line. In principle, a small and high-quality telescope at an altitude of 25 km could be as effective as a large and expensive telescope on the ground.

"A small telescope at 25 km can be as useful as an expensive one on the ground"

The experiment will be equipped with a high-frame-rate camera, taking fast cadence, chromospheric images of the whole of the Sun's disc in Hα, and has the potential to provide unique, scientifically valuable data.

For this investigation, a scientifically valuable image is one from which information can be collected about processes in the Sun's chromosphere. It is hoped that the resulting observations of plasma waves, flows and eruptions in the dynamic chromosphere will be much sought after by both the solar and stellar physics international communities. This is because high-cadence full-disc, or Sun-as-a-star Hα observations provide a

REXUS/BEXUS: Rocket and Balloon Experiments for University Students

The REXUS/BEXUS programme allows students from universities and higher education colleges across Europe to carry out scientific and technological experiments on research rockets and balloons. Each year, two rockets and two balloons are launched, carrying up to 20 experiments designed and built by student teams.

The programme is realized under a bilateral Agency Agreement between the German Aerospace Center (DLR) and the Swedish National Space Board (SNSB). The Swedish share of the payload has been made available to students from other countries through collaboration with ESA. Experts from DLR, SSC, ZARM and ESA provide technical support to the students throughout the project.

EuroLaunch, the collaboration between the Esrange Space Center of SSC and the Mobile Rocket Base (MORABA) of DLR, is responsible for the campaign management and operation of the launch vehicles.

http://rexusbexus.net

connection between the integrated chromospheric intensity and the chromospheric activity, with potential applications to measurements of chromospheric activity of other stars. Furthermore, the large field-of-view of the Sun offers the chance to capture novel data on some of the most powerful events in the solar system, such as solar flares and coronal mass ejections.

Previous missions

The NASA-backed High Altitude Student Platform (HASP), was the first system designed purely to house multiple payloads in a single flight. Its purpose was to encourage students to choose a career in aerospace. Since 2006, HASP has had 12 flights, each reaching altitudes of approximately 36 km and maintaining that altitude for 15 to 20 hours each time. This project gives students a way to conduct experiments in space-like conditions at relatively low cost.

In 2010, the Sunrise mission, led by the Max Planck Institute for Solar Systems Research in Göttingen, was launched to gather high-resolution images of the Sun's lower atmosphere. The balloon-borne solar telescope worked at altitudes of about 37 km while observing in the UV range of the electromagnetic spectrum. At 1 m in diameter, the Sunrise telescope had high enough resolution to image small-scale granulation and spicules on the limb of the Sun. These balloon experiments have shown that capturing detailed images of the Sun from Earth's upper atmosphere is possible; however, the aim of Project SunbYte is to show that comparable scientifically valuable results can be obtained with widely available – and much cheaper – technology.

To design the telescope, the SunbYte team had to consider the nature of the target. The Sun subtends an angle of approximately 1865 arcsec (0.52°) to an observer on the Earth. The required resolution of 0.5 arcsec represents 3.731×10^5 m (373.1 km) on the surface of the Sun. Because the telescope will only observe the Sun, the optical system requires a narrow field of view. The telescope will be as small and light as is practicable, while producing an image at this resolution.

The SunbYte telescope

The SunbYte telescope design will be based upon a Raspberry Pi optical telescope called PiKon (http://pikonic.com), developed by team member Mark Wrigley. The new design goes a step further than PiKon as it will use larger mirrors, specialist optical filters and a higher resolution camera provided by Andor Technology Ltd (Belfast, UK; http://www.andor.com) to increase the quality of the data. Having such specialist expertise on board will help the team deliver an innovative high-performance payload that could revolutionize the industry.

The telescope will also be equipped with a sensor and a motorized system to detect and control the pointing of the telescope. The tracking and stabilization system will benefit not only Project SunbYte, but also scientists and engineers in other research fields: the stabilization system will be usable at sea as well as on land.

"Similar telescopes may be built for areas of the spectrum not visible from the ground"

Most telescopes use a primary imaging device (objective) and a secondary device to examine the image formed by the objective. For optical telescopes, that secondary device is an eyepiece, effectively a small microscope that reveals detail of the image to the naked eye. To record images, the eyepiece is replaced with film or, nowadays, a digital camera sensor. In designing a telescope, the first choice is between a refraction and reflection telescope. The SunbYte team chose a reflective design, because refractive (lens) systems are generally more expensive for the same optical aperture, suffer chromatic aberration and can limit the electromagnetic spectral range of the telescope compared to a mirrored surface.

The Newtonian reflecting telescope is a popular, low-cost design. The objective is a parabolic reflecting surface and the image is examined by an eyepiece via a flat secondary mirror at 45°. This design was modified for the PiKon telescope by replacing the secondary mirror and eyepiece with a Raspberry Pi camera sensor, which is small enough to place in the telescope tube.

The field of view of this modified Newtonian telescope is determined by the sensor size and the focal length of the objective mirror. The resolution (within the diffraction limit of the mirror's aperture) is determined by the sensor's pixel spacing and focal length. A resolution of 0.8 arcsec at optical wavelengths requires an objective mirror of 200 mm diameter and 3 m focal length. The students modified the simple PiKon arrangement using a Cassegrain design, which combines a long focal length with minimum physical size.

The "classic" Cassegrain design uses a parabolic primary mirror and hyperbolic (convex) secondary. While the design meets the requirements of long focal length with small physical size, the telescope performance is very sensitive to aberrations. But a design based on the Schmidt–Cassegrain design provides greater resilience to aberrations resulting from primary/secondary separation. The design has a relatively narrow field of view but is suitable for solar observations.

Future plans

The primary aim of SunbYte is to track and image the Sun. If this goal is achieved, the secondary aim concerns scientific analysis of the resulting chromospheric images. The team will evaluate the performance of the SunbYte system by comparing its data with that obtained by ground-based solar telescopes. SunbYte is designed to observe in Hα, but if the experiment is successful then similar telescopes may be constructed to observe regions of the electromagnetic spectrum not visible from the ground, such as UV. In the end, whatever the results, the students playing such important roles in this project will gain invaluable experience in practical high-altitude science. ●

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