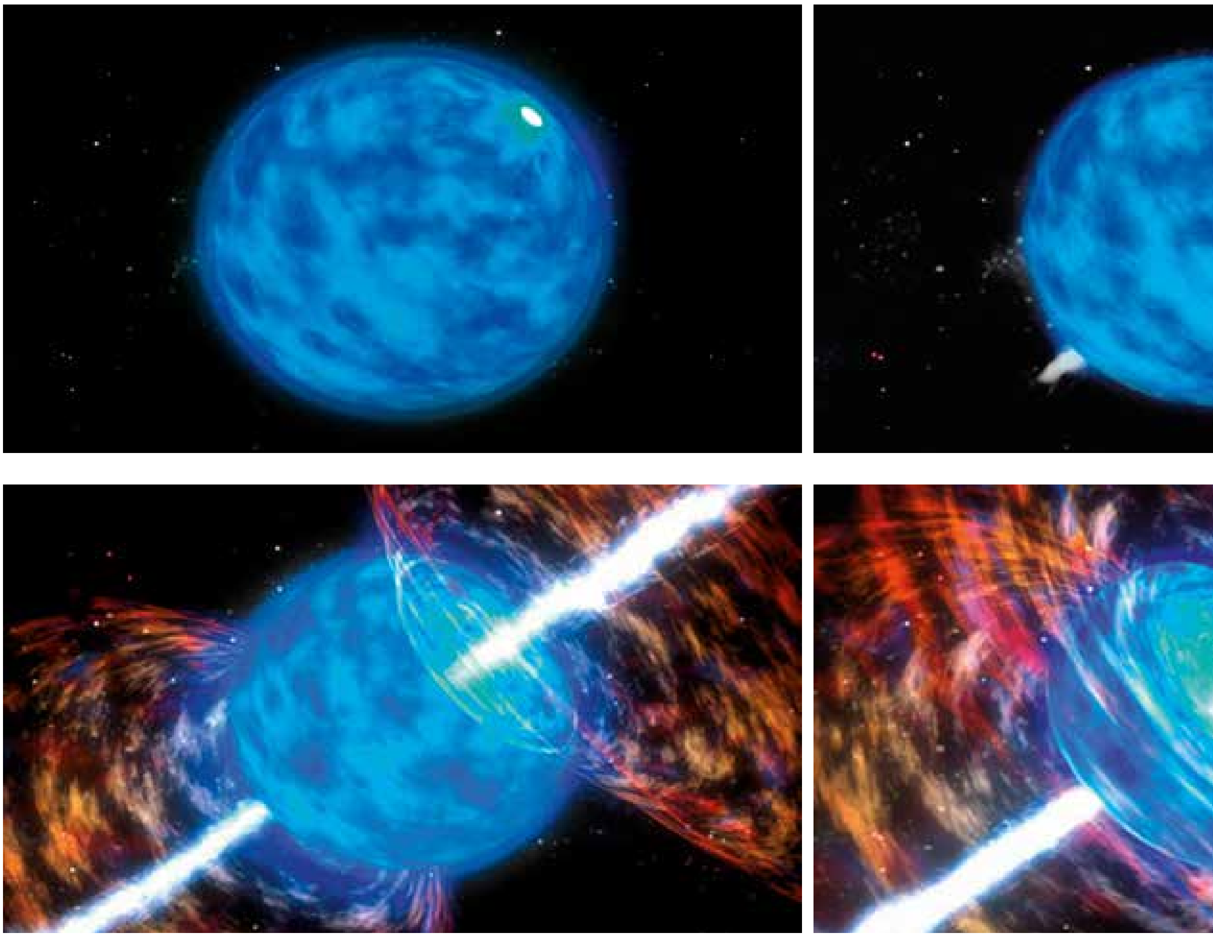
INSIGHT

ACADEMIA Astronomy

Hunting Gamma-Ray Bursts

The Long March-2F rocket was launched on 15 September 2016 from the Jiuquan Satellite Launch Centre in China, carrying the Tiangong-2 space laboratory. The laboratory is fitted with the detector of the POLAR experiment, which was prepared jointly with Polish scientists.



NASA

Schematic diagram of a gamma-ray burst emission. Most of the energy is released as jets along the rotational axis, and if those jets are pointing our way they are visible as a GRB.

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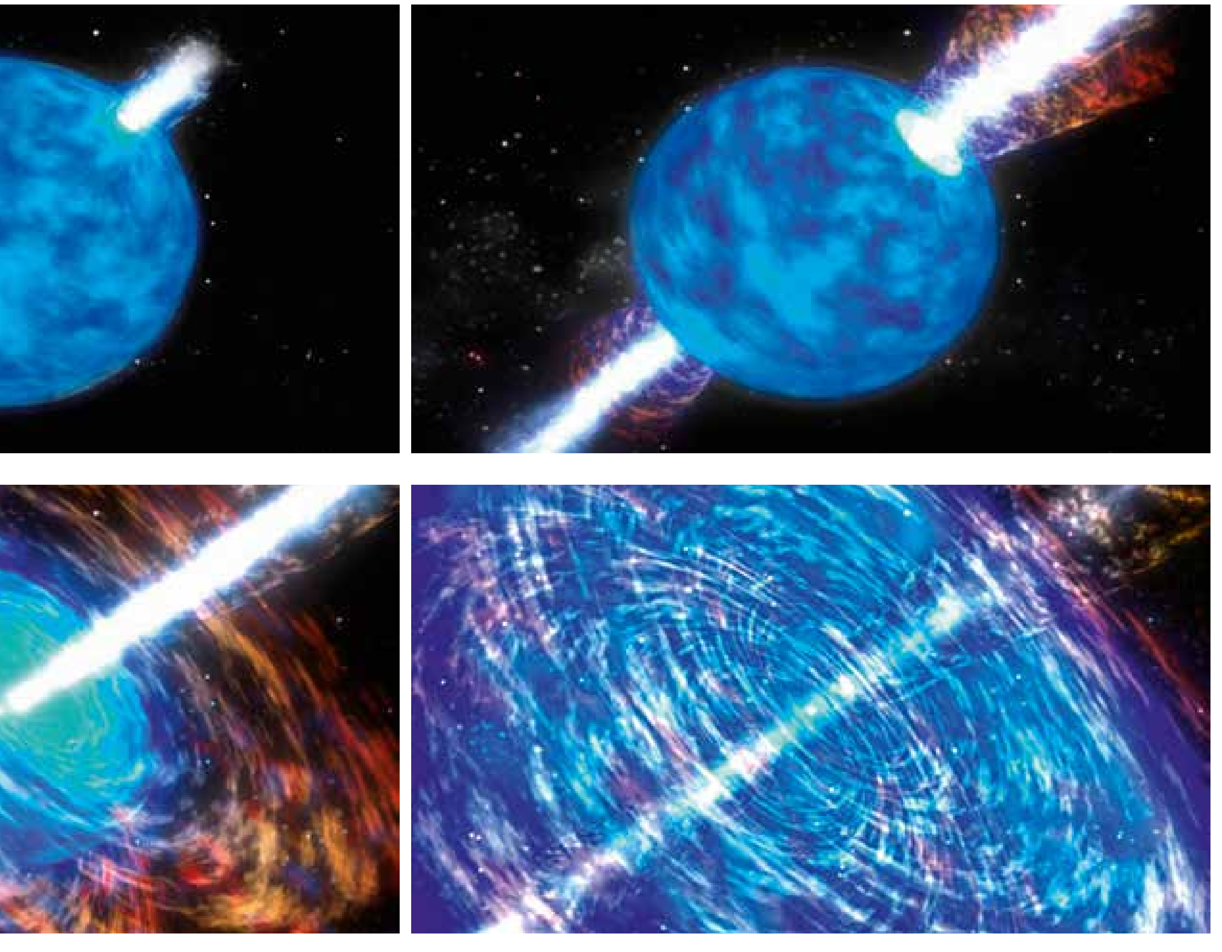
Gamma-ray bursts (GRB) have been puzzling astronomers since their discovery in the 1960s by America's Vela military satellites. Lasting between a fraction of a second and several minutes, they are large beams of photons of high-energy electromagnetic radiation originating from a single spot in the sky. They are even more energetic than the X-ray radiation that is commonly used for medical X-ray imaging.

The bursts appear in different points in the sky, and they almost never originate from the same location. They can't be detected from Earth's surface, since they are blocked by the planet's thick atmosphere. Instead, they are observed from satellites in a low Earth orbit, with several hundred reported every year.

It was debated for many years whether the bursts originate from our nearby surroundings (our own galaxy, the Milky Way, or perhaps even our Solar System) or other galaxies in farther reaches of the cosmos. The problem is that the sources of GRBs can be identified with a significantly lower precision than sources of radiation with lower frequencies. This is why GRBs haven't been associated with other objects in the sky. The problem was finally solved in the 1990s by observing "afterglows" – optical bursts found to accompany GRBs – which made it possible to determine the location of the galaxy where the burst originated, and finally to measure its distance from Earth. It turned out that GRBs originate from other galaxies, as far as billions of light years away. One proponent of the hypothesis of such "cosmological" origins of GRBs was the eminent Polish astrophysicist Prof. Bohdan Paczyński.

Brighter than the Sun

The discovery wasn't readily accepted by scientific circles: for bursts originating from such distant loca-



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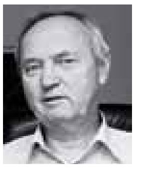

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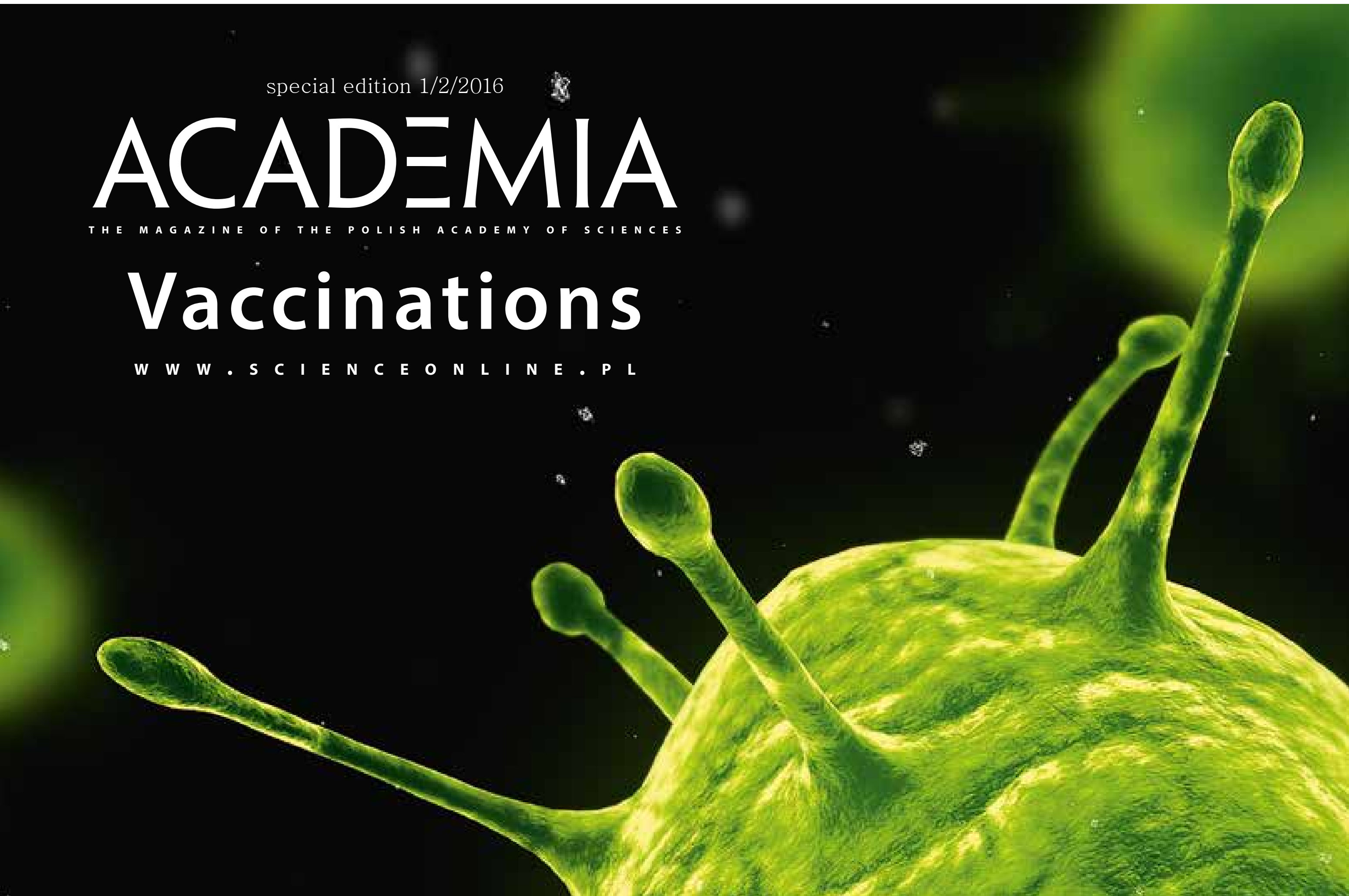
tions to be visible to us, they must be accompanying events emitting unimaginable volumes of energy. The current theory is that they originate from explosions which release energies in the range of 10^{44} joules in a very short space of time. Such events emit more energy than our Sun will radiate through the entire course of its existence. So what kinds of processes are responsible for such phenomena, and what actually happens in the "central engines" producing the burst? There are two leading potential scenarios. Longer, higher energy bursts are associated with hypernova explosions – hypothetical, more powerful equivalents of supernovae which are culminations of the existence of massive stars. In turn, shorter bursts are likely to be the result of collisions of compact objects, such as two neutron stars or a neutron star and a black hole. However, even if both these theories are true, the course of the explosions leading to the emission of such vast volumes of energy and the characteristics of the "central engines" driving them remain unclear. The most likely models are those in which matter and energy are released into space as two streams or jets moving in opposite directions at relativistic speeds. The key role could be played by very powerful magnetic fields which maintain the expelled matter in the jet form. The magnetic field arranges the matter expelled from the "central engine" in a specific way which depends on the process occurring during the emission. Data on how the matter is arranged can be obtained from polarization measurements.

POLAR is mounted on an external wall of the Tiangong-2 laboratory. It will collect data from one-third of the visible sky, measuring the phenomenon of polarization itself.

So far the polarization resulting from GRBs has only been measured a few times and unfortunately none of the results are very reliable, leaving us with insufficient data to verify theoretical models describing the action of the "central engine" and the physi-



The POLAR detector undergoing thermal tests at the laboratory in Terni, Italy.

cal processes occurring in the jets in GRBs. The joint Chinese, Swiss, and Polish POLAR project has been designed to gather more data.

POLAR in orbit

The POLAR detector started operating seven days after the Tiangong-2 laboratory was launched into a low Earth orbit. All elements work correctly, and the device started taking measurements. The first data transmitted to Earth reveal that the instrument is indeed capable of registering GRBs. It has now already registered close to 30 such events.

POLAR is mounted on an external wall of the Tiangong-2 laboratory. It collects data from one-third of the visible part of the sky. Its goal is to measure the polarization phenomenon. It will not be used to determine direction – this will be established using data from other satellites, which are highly likely to observe the same burst. The detector comprises 1600 scintillating rods arranged on a square surface. Data are collected automatically and transmitted to Earth twice a day.

The key elements of the POLAR experiment were designed by Polish scientists and engineers from the National Centre for Nuclear Research. About ten people were involved directly in its design and construction. One of the fruits of their collaboration was the design and construction of the central system selecting the events (trigger), together with software. Due to the limited communications between the satellite and Earth, data must be pre-selected onboard the vessel. Researchers then work on the data preliminarily classified as potentially interesting. The most important events are those in which at least two dispersions of a gamma photon are detected in a very small trigger time window of the order of 150–200 nanoseconds. The quantity of energy deposited in the detector is also considered when selecting potentially interesting events, in order to reject instances corresponding to high-energy cosmic radiation. The central trigger system makes it possible to modify the parameters of events being searched for remotely via commands transmitted from Earth, reducing or expanding the range of measurements transmitted back to Earth. Additionally, seemingly unimportant events can be registered and used for diagnostics or calibration.

Scientists at the National Centre for Nuclear Research also designed the prototype of a high-voltage power supply for 25 photomultipliers. It was the brainchild of the eminent electronics engineer Dr. Jacek Karczmarczyk, who passed away recently. In addition to such technological work, Polish scientists also participated in all testing phases during the qualification and approval of the detector. All its elements must be able to withstand extreme conditions: vacuum, violent vibrations, heavy G-forces, high and low temperatures, and high radiation doses.

The detector will collect data over the course of three years. We expect to register well more than 50 RGBs per year, including at least ten powerful bursts.

We hope that our research results and technical expertise gained during the construction of the POLAR detector will help improve future methods of studying the polarization of cosmic gamma radiation, and that they can be put to good use in the design of future experiments.

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Further reading:

Produit N., Barao F., Deluit S., Hajdas W., Leluc C., Pohl M., Rapin D., Vialle J.-P., Walter R., Wigger C. (2005). POLAR a compact detector for gamma-ray bursts photon polarization measurements, *Nuclear Instruments & Methods in Physics Research, A 550*, 616–625.

Rybka D., Hajdas W., Britvitch I., Marcinkowski R., Produit N., Gauvin N., Rapin D., Pohl M., Orsi S., Lechanoine-Leluc C., Paniccia M., Batsch T., Rutczyńska A., Szabelski J., Zwolińska A., Krakowski T., Bao T., Chai J., Dong Y., Kong M., Li L., Liu J., Liu X., Shi H., Sun J., Wang R., Wen X., Wu B., Xiao H., Xu H., Zhang L., Zhang L., S. Zhang, Zhang Y. (2013). *Realisation of Events Trigger System for space-borne Gamma-Ray Burst Polarimeter*, POLAR, Proceedings of 33th International Cosmic Ray Conference.

Xiao H., Hajdas W., Wu B., Produit N., Bao T., Batsch T., Cadoux F., Chai J., Dong Y., Kong M., Kong S., Rybka D., Leluc C., Li L., Liu J., Liu X., Marcinkowski R., Paniccia M., Pohl M., Rapin D., Shi H., Song L., Sun J., Szabelski J., Wang R., Wen X., Xu H., Zhang L., Zhang L., Zhang S., Zhang X., Zhang Y., Zwolińska A. (2016). A crosstalk and non-uniformity correction method for the space-borne Compton polarimeter POLAR, *Astroparticle Physics, 83*, 6–12.

http://isdc.unige.ch/polar/