POLAR detector flies into orbit with a Chinese space mission

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Wojciech Hajdas with transparent scintillation bars, which are also built into the POLAR detector. With POLAR, Hajdas and his colleagues want to measure the polarisation of gamma ray bursts in space. Credit: Paul Scherrer Institute/Markus Fischer

Researchers working with Wojciech Hajdas at the Paul Scherrer Institute PSI have developed a detector called POLAR. This instrument is expected to search out and investigate so-called gamma ray bursts coming from the depths of the universe. Gamma ray bursts are eruptions of high-energy light that despite being extremely strong remain, up to now, only poorly understood. Among other things, the origin of gamma ray bursts has not been resolved; it is possible that these strong flashes of light are emitted during the formation of black holes. To improve our understanding of gamma ray bursts, POLAR will measure a property of their light. POLAR was realised in cooperation with researchers at the University of Geneva and will be launched into orbit this coming September with a Chinese space mission.

Somewhere out there in the depths of the universe, there is always something lighting up with enormous energy: Researchers can observe so-called gamma ray bursts roughly once per day. These emit light, as the name says, in the highly energetic band of gamma radiation. In just a few seconds, they eject more energy than the sun does in billions of years. And yet gamma ray bursts remain poorly understood; among other things, it is not clear what their origin is.

This is the starting point for the current project of Wojciech Hajdas and his research group at the Paul Scherrer Institute: Together with scientists from the University of Geneva and the Institute of High Energy Physics of the Chinese Academy of Sciences (IHEP-CAS), they have developed a detector for gamma ray bursts. POLAR is the name of this device; it will measure the degree of polarisation of light from gamma ray bursts. This property of light can yield clues as to which cosmic events are the sources of gamma ray bursts.

Degree of polarisation as evidence for a causal

mechanism

So far it is not clear what exactly the mechanism for producing gamma ray bursts is – or if several types of source events should be considered. Possibilities being discussed include the collapse of a massive star to a black hole, the merging of two neutron stars, a special kind of supernova, and a number of other, similarly energy- and mass-intensive, processes. Depending on what degree of polarisation we measure, a number of causal mechanisms can be excluded, Hajdas says. If for example the light of the gamma ray bursts has a high degree of polarisation, we will be able to eliminate purely thermal events.

Light spreads out in oscillating waves; the polarisation is the direction of this oscillation. Hajdas would like to find out if the light waves of the gamma ray bursts oscillate perpendicularly or parallel to each other. The latter would represent, in the scientific expression, a high degree of polarisation.

Measurement from the space station

POLAR cannot simply detect gamma ray bursts from the surface of the Earth, however: The air of Earth's atmosphere precludes accurate measurements. So Hajdas sought to make contact with various space missions. He found the Chinese institute IHEP-CAS most open to the idea of collaboration. The Chinese space agency had long been planning the start of its next space station Tiangong 2 – literally Heavenly Palace 2 – for the coming autumn. Now it's clear: POLAR will fly into orbit on board the Tiangong 2 in September 2016 and will, from that vantage point, gather observational data. At present, POLAR is being installed on the space station Tiangong 2.

The mystery of the gamma ray bursts

POLAR will be able to gather sufficient data because, in the universe as a whole, gamma ray bursts are a frequent occurrence. They can be detected across arbitrarily long distances and for that reason – depending on the duration of the light's journey – from the different epochs of the universe. We expect, during the two-year research mission, to record several dozen very strong gamma ray bursts, which will enable us to accurately measure the degree of polarisation, Wojciech Hajdas says.

The problem: No two gamma ray bursts are alike. Therefore experts struggle to classify the gamma ray bursts into categories and to account for their origin. At least two coarse groupings can be identified so far, Hajdas explains: on the one hand, short gamma ray bursts that only shine for around one second, and on the other hand those that last for several tens of seconds – with the short type being observed more frequently than those that shine longer.

While the duration and frequency of gamma ray bursts can already be measured quite well, their degree of polarisation is, up to now, unknown. Thus Hajdas and his colleagues hope to expand the understanding of gamma ray bursts in this direction. They might also be able to sort gamma ray bursts into different categories with respect to their degree of polarisation: those with higher and lower degrees of polarisation, to which different causal mechanisms can be attributed.

1600 scintillator bars made from a special plastic

The high-energy light of gamma ray bursts can only be detected indirectly. Therefore the heart of the POLAR detector consists of 1600 special plastic bars, densely packed together and, to our eyes, transparent. If the light of a gamma ray burst strikes these bars, it sets off a visible flash of light – a process called scintillation. It would be more accurate to say that the light particles from the gamma ray burst must hit the electrons in the plastic bars. The molecules of the scintillator that are excited in that way then send out light particles in the range of visible energy, Hajdas says.

At the other end of the bars sits a detector for visible light, which thus provides indirect evidence for the gamma ray bursts. In the process, the instrument can infer the polarisation of the gamma ray burst. The distinctive feature of our detector system is that we analyse only those light particles from the gamma ray bursts that have first excited an electron in one plastic bar and subsequently, in a second bar, a second electron, Hajdas further explains. Only through taking these two data points together can we reliably and exactly determine the polarisation.

In addition, the aperture angle of POLAR is so large that its field of view covers around one-third of the entire sky.

Both the concept of the detector system and the electronics were developed at the PSI. The signal readout module and the central computer of POLAR were then fabricated and tested at the PSI. The researchers also developed their own software system for processing of the data. To calibrate POLAR in preparation for its mission, the scientists have used X-ray radiation from the Swiss Light Source SLS at the PSI as well as the European Synchrotron Radiation Facility ESRF in Grenoble.

The Zurich-based company Art of Technology manufactured the power supply for POLAR. The mechanical parts and the housing were built at the University of Geneva, where the components of the POLAR detector were assembled. Finally, all participants in this collaborative international project subjected the finished detector to rigorous testing.

Possible common ground with gravitational waves

Events such as the formation of black holes, which are considered a possible source for gamma ray bursts, are at the same time, with high probability, the origin of gravitational waves. Gravitational waves were predicted by Albert Einstein; in September 2015, researchers of the international LIGO collaboration were able, for the first time, to provide direct evidence for their existence. Hajdas is inspired by this great success: My dream would be for POLAR to detect a gamma ray burst and then, simultaneously, for the colleagues at LIGO to measure another gravitational wave. Maybe, in this way, a comprehensive collaboration in this still-young branch of research could develop.

Provided by Paul Scherrer Institute

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