Surprising Flashes from a possible Magnetar

Observations of optical flares reveal limits of established theories on magnetars

By means of the high-speed photometer OPTIMA of the Max Planck Institute for Extraterrestrial Physics (MPE), a team of MPE scientists might have detected an unexpected new sub-category of astronomical objects. It appears to be a magnetar with bursts in the visible part of the spectrum, in contrast to the X-ray and gamma flashes, which are considered to be characteristic for magnetars (Nature, September 2008).

A notice was received by the scientists around Alexander Stefanescu in real time, pertaining to a brief outburst of high-energy radiation detected by the NASA Swift satellite. After observing the location of this outburst, they quickly discovered they had not observed a normal gamma-ray burst (GRB): Instead of the slow decay in brightness usually expected along with occasional short episodes of re-brightening, the scientists observed sudden bright flashes. The observations grew stranger still, when the activity hadn't ceased the next night, but had in fact become stronger, not ceasing completely for several nights.

Examining the radiation emitted during an X-ray outburst, they found out that a part of it had been absorbed by hydrogen gas on the way from the object to Earth. After mapping the gas masses along the line of sight it became clear that the object was most probably situated within our own Galaxy. This meant it could not have been a normal GRB, because those usually do not happen so close in our "next neighbourhood", but in distant galaxies.

The breakthrough was achieved, when the scientists put the special characteristics of OPTIMA to good use. This high-speed photometer built by MPE and mounted at the 1.3m Telescope of the Skinakas Observatory (a collaborative project of the University of Crete, the Foundation for Research and Technology -- Hellas and the MPE) is the only instrument worldwide combining high time resolution with triggering on unexpected events. In the detectors of their system, the arrival time of each individual photon is recorded – down to an accuracy of four millionths of a second. This enables the scientists to reconstruct in detail how the brightness of an object changes.

Detection of individual photons is common practice in the high-energy regime, but OPTIMA is one of the few devices capable of doing this in the optical spectrum. The fast and strong variability of the brightness of the object, observable only with high time resolution, was instrumental in ruling out the initial hypothesis that this was a GRB.

The unknown object was determined to be about a tenth the size of the Sun – but at the same time almost a hundred times as bright. Assuming normal thermal radiation as it is emitted e.g. by the Sun, extraordinarily high temperatures would be necessary to explain this kind of luminosity. "So high, in fact, that it's hard to see how an object of this size can heat up and then immediately cool down so quickly", explains Stefanescu, member of the OPTIMA team and first author of the Nature paper. "So the only possible conclusion was that we had observed a non-thermal process: light that is not produced by heat as in a light-bulb or in a candle, but e.g. by particles in a magnetic field."

The observation of short, bright flashes, continuing over several days, reminded the scientists of non-thermal high-energy outbursts of so-called Soft Gamma Repeaters (SGRs). Not only the shape, but also the statistical distribution of the brightness of individual flashes, as well as a slight indication of periodic emission were quite similar to what is observed in SGRs.

Therefore the scientists conjectured that the same type of object is involved as in SGRs: a magnetar. This hypothesis is reinforced by a second Nature paper on multiwavelength observations of this source by Alberto Castro-Tirado (Consejo Superior de Investigaciones Cientificas, IAA-CSIC, Granada). Magnetars are a special type of neutron stars with an extraordinarily powerful magnetic field.

Neutron stars form in a supernova, when a massive star collapses. If a newborn neutron star rotates very quickly, its strong magnetic field can be amplified further by a factor of 1000, the resulting field reaching 100 Gigatesla – more than a billion times stronger than the strongest fields generated in labs on Earth. The field is so strong that atoms in its vicinity are distorted into thin needles, and credit cards would be erased even from the distance of the moon.

Changes in the configuration of the magnetic field during the first 10,000 years of its existence exert forces of such strength on the crust of the magnetar that the crust is heated up and can occasionally crack. The resulting star-quakes produce those outbursts of high-energy radiation so similar to the optical outbursts observed here.

But what makes the presumable magnetar emit in the optical instead of in gamma-rays? One possible theory is that highly charged ions are ripped out of the surface of the magnetar and gyrate along the field lines. Since ions are much heavier than electrons, they gyrate a lot slower, emitting electromagnetic radiation of much lower energy.

Most observations of magnetars have so far taken place in the high-energy range. “We know 15 other magnetars, but up to now, no optical flashes of these have ever been seen”, says Stefanescu. “Accordingly the main efforts of theoreticians were made in the high-energy regime. That’s why we don’t have an adequate theory against which to compare the observations with OPTIMA.” The next step of the scientists therefore must be to study the consequences established magnetar theories predict for optical emission.

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