Space station MAXI-mizing our understanding of the universe

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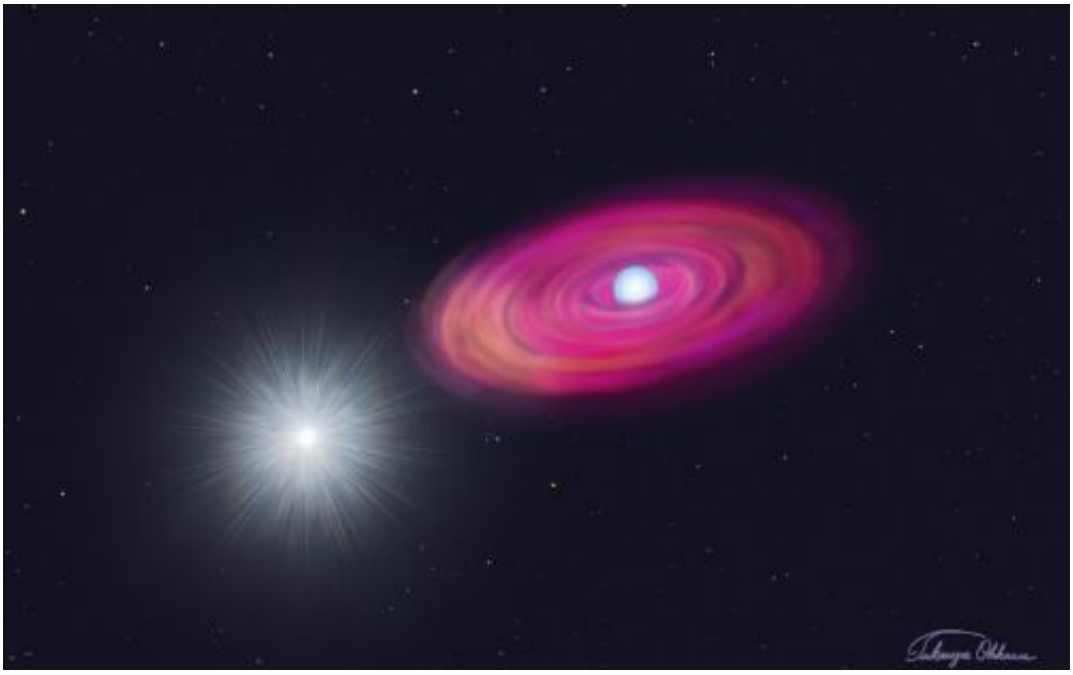

This artist rendering shows the binary system of MAXI J0158-744, consisting of a white dwarf (left) and a Be star (right). Credit: Takuya Ohkawa

Look up at the night sky ... do you see it? The stars of the cosmos bursting in magnificent explosions of death and rebirth! No? Well, then maybe you are not looking through the "eyes" of the Monitor of All-sky X-ray Image (MAXI) investigation, mounted on the exterior of the International Space Station Kibo module. MAXI, along with other sky watching instruments, such as Swift, collect data that help researchers

discover, study and understand the physics behind the powerful lifecycle of our universe. MAXI was key in two recent publications sharing results that make strides in advancing astrophysics.

Using this collection of instruments, researchers look at snapshots of a celestial dance that took place long ago. These explosive moments and their aftermath happened millions and even billions of years ago, but were only visible recently due to their distance from Earth. The events have something to teach about our past and our future, as we have our own star to be mindful of—the sun.

MAXI is operated by the Japan Aerospace Exploration Agency (JAXA) and has open access to the space environment. This allows the investigation's sensors to perform an entire sky scan once every orbit of the space station around Earth—there are 16 orbits per day. The information from the sky scans downlink to a data center at the Institute of Physical and Chemical Research (RIKEN), a Japanese research institution where the MAXI team disseminates data to scientists around the globe for study.

The first paper focuses on an event MAXI discovered on Nov. 11, 2011, when it captured X-ray data from the ignition of a nova. This explosion occurred in the binary system of a white dwarf and a Be star. The results from the study of this event were published in December in *The Astrophysical Journal* article titled "Extraordinary Luminous Soft X-Ray Transient MAXI J0158-744 as an Ignition of a Nova on a Very Massive O-Ne White Dwarf." This data shares with the world the sighting of an especially bright X-ray emission, named MAXI J0158-744, which provides evidence of the explosion of the star.

These findings help us understand how the sun will evolve when it becomes a white dwarf 5 billion years from now. They also help researchers learn about the origins of the universe.

"Some novae may be progenitors of type Ia supernovae, which are used as standard candles to measure the distance scale—thus expansion—of the universe and used in research that was awarded the 2011 Nobel prize in physics," said lead author Mikio Morii, Ph.D., RIKEN. "MAXI J0158-744 offers an extreme case of a nova, and it is therefore very useful for understanding the physics in nova explosions."

A white dwarf is a star that has lost the ability to sustain nuclear fusion—meaning it no longer powers itself. The bigger the white dwarf, the greater the gravitational force and pressure, making it a more-likely candidate to go nova. The white dwarf's gravity allows it to "borrow" mass from nearby sources, such as other stars like the Be star seen in MAXI J0158-744. This mass addition can act like fuel, igniting a thermonuclear explosion and creating an outburst astronomers call a nova.

"The association of a Be star in a nova is very rare. In fact, MAXI J1058-744 is the first of this kind known so far, and there are only a few known binary systems consisting of a white dwarf and a Be star, and no nova has been seen from them," said Morii. "We believe that the large luminosity is related to the fact that the white dwarf is small and heavy, meaning that the surface gravity is strong. Because of the strong gravity, only a small amount of accreted matter from the companion is required to make it sufficiently dense and hot to ignite a thermonuclear runaway. Since the accumulated matter is sufficiently small, the hot fireball was directly visible."

MAXI captured data from the MAXI J0158-744 ignition, followed by observations by Swift and the Small and Moderate Aperture Research Telescope System (SMARTS) of the burning and aftermath. Novae like this are similar to a fusion bomb, and studying them helps researchers to better understand the physics behind such explosions. The white dwarf is located in the nearby Small Magellanic Cloud galaxy, which is about

200,000 light-years away and orbits our own galaxy.

"MAXI J0158-744 presented an extreme case of novae, and provided the first observation of the initial phase of novae," said Morii. "It will certainly contribute to the understanding of novae. Prediction of novae still remains very difficult, but we can keep an eye on binary star systems—though very few—similar to MAXI J0158-744 for possible similar phenomena."

When a nova takes place, the amount of mass lost by the white dwarf varies. The star may expel only what it has accrued over time, since becoming a white dwarf, or it could expel some or all of its own mass. If the explosion ejects the entire mass of the white dwarf, it destroys the star. If not, the white dwarf's cycle continues and it may nova again over the course of thousands or millions of years. In the case of MAXI J0158-744, there was a smaller ejection of mass. This ejection produced very low-energy, or "soft," X-rays. This is what the station-mounted MAXI instrument captured as it monitored the sky, opening new fields of discovery.

"Until MAXI started observing, there had been no mission that monitored the sky in the soft X-ray band with sufficiently high cadence," said co-author Professor Nobuyuki Kawai, Tokyo Institute of Technology. "Soft X-ray wide-field monitor of the sky has been scarcely done in the past. A huge discovery space is left. If some amount of energy is deposited in a tenuous medium in space, soft X-rays are expected to be radiated in many cases due to fundamental physics. Also, soft X-ray emission often carries rich information, because the elements in the medium likely show their signatures in the soft X-ray spectrum."

The second recent paper highlighting a MAXI-related discovery is titled "GRB 130427A: A Nearby Ordinary Monster" and published in *Science* on Nov. 21, 2013. The focus of this finding was on a gamma-ray burst

(GRB), which is a rare consequence when massive stars collapse. This burst took place 3.8 billion light-years away, closer than usual.

"GRBs are so bright that they can be seen even at distance of 13 billion light-years. That is, you can observe a GRB that occurred 13 billion years ago," said co-author Motoko Serino, Ph.D., RIKEN. "Since the age of the universe is 13.8 billion years, you can obtain information of the universe in its infancy less than 1 billion years old by observing such distant universe. Therefore GRBs are useful and important to understand the history of the universe."

GRBs are the most energetic explosions in the universe. The afterglow that follows the event emits various wavelengths, such as X-rays, that can be picked up by MAXI and other sensors as evidence of the GRB. Researchers then study this multi-wavelength data on Earth in an effort to better understand the phenomenon.

MAXI, Swift, ground-based facilities, and the Faulks and Liverpool telescopes all picked up on evidence of GRB 130427A, contributing to the results highlighted in the paper. The data from MAXI in particular provided proof of the steady decay of the X-ray emission during a gap in Swift's measurements of the afterglow. This burst also was unique in that it was very bright and had characteristics that led researchers to conclude that GRBs throughout time are powered by a common central engine.

"We do not know what exactly [this common engine] is," said Serino. "It is a newly formed spinning black hole in a popular theory, or it is a newly formed fast spinning neutron star in another. The fact that GRB 130427A was intrinsically powerful and occurred in neighborhood and yet had properties common to ordinary GRBs at larger distances suggests that they have common 'engines.'"

Previous MAXI findings include the 2010 X-ray nova discovery that

emerged in the constellation of Ophiuchus. MAXI's watchful eye continues to help researchers see the cosmic dance of life and death for stars, an interpretive performance that sheds light on the secrets of the universe.

Provided by NASA