X-ray monitoring mission comes to an end

March 13 2012, by Jennifer Chu

The All-Sky Monitor team assembles around the X-ray monitoring instrument. From left, Hale Bradt, Ed Morgan, Alan Levine; bottom, Ron Remillard.

On Dec. 30, 1995, NASA's Rossi X-ray Timing Explorer (RXTE) was launched into orbit on a mission to observe and study X-ray sources in space. For 16 years, the satellite circled Earth, detecting X-rays emitted by some of our galaxy's most extreme phenomena: bursting pulsars, flaring neutron stars and massive, spinning black holes. The instruments aboard RXTE — including one engineered by MIT researchers — captured data that helped scientists make major discoveries in X-ray astronomy for more than a decade.

Earlier this year, RXTE sent its last data transmission to Earth, and on

Jan. 5, NASA decommissioned the aging satellite. Meanwhile, astronomers at MIT and elsewhere will continue to comb through RXTE's data to gain new understanding of the galaxy's X-ray-emitting sources.

"There are some sources that came and went and we saw them for two days and never saw them again," says Alan Levine, a principal investigator on the mission and a principal research scientist at MIT's Kavli Institute for Astrophysics and Space Research. "And there are others where we saw them every day for 16 years."

Video: See 10 years of continuous monitoring from RXTE

Levine was part of a team of MIT scientists who helped design and build a device called the All-Sky Monitor (ASM), one of three instruments aboard RXTE. The device, mounted on the nose of the satellite, consisted of three cameras that rotated every 90 minutes, scanning the sky for the brightest X-ray sources. An onboard computer, administered by MIT instrument scientist Ed Morgan, packaged the ASM data for transmission back to Earth, where it was analyzed by scientists at MIT and the Goddard Space Flight Center in Maryland. If the scientists detected an interesting pattern that revealed a new X-ray source or unexpected changes in the strength of a known source, they sent a command to the satellite to swivel and direct its two other instruments — the Proportional Counter Array and the High-Energy X-ray Timing Experiment — at a particular X-ray source in the sky.

Unlike imaging satellites such as the Chandra X-ray Observatory, RXTE did not take X-ray pictures of its targets. Instead, the combination of instruments onboard monitored X-ray activity over time — from a neutron star's millisecond-long bursts to the appearances and disappearances of the galaxy's X-ray sources over months and years.

Beyond a 'five-minute look'

RXTE was named after former MIT physics professor Bruno Rossi, a pioneer in the field of X-ray astronomy. In the early 1960s, Rossi and his colleagues at a nearby company, American Science & Engineering, began the search for X-rays from outside the solar system; in 1962, they made the first detections.

"X-ray astronomy was sort of a surprise," says Hale Bradt, a professor emeritus of physics at MIT and one of the original principal investigators on the RXTE mission. "Nobody really predicted that there should be sources of X-rays out there."

After Rossi's discovery, George Clark, also a professor emeritus of physics at MIT, made the first X-ray detection from a balloon-borne experiment. Thereafter, MIT and other universities and laboratories studied the X-ray sky from rockets and balloons. While the atmosphere prevented X-rays from being seen from Earth, Bradt says rockets gave scientists a "five-minute look" above the atmosphere.

Since the 1970s, countries including the United States have launched multiple satellites into space as part of more prolonged searches for X-ray activity. Through these missions, scientists have found that many X-ray sources in the sky are binary systems, in which a normal-sized star is gravitationally bound to a neutron star. This discovery prompted scientists to hypothesize that a rapidly spinning neutron star obtains its spin by drawing matter in from its neighboring star.

"All these binary neutron stars should be rapidly rotating, but no one had ever seen a fast signal from them," Morgan says. "We wanted to detect the spin of a neutron star, to really confirm this theory, and we thought there could be a lot of other neat phenomena we could study as well."

Beginning in 1980, Bradt and his colleagues at MIT, Goddard and the University of California at San Diego drew up a plan for an X-ray timing mission — a satellite that would measure X-ray bursts and pulsations and many other phenomena on time scales from milliseconds to years. The researchers spent nearly two decades writing up proposals and designing and building the satellite's body and instruments. Late in 1995, the team launched RXTE on a Delta rocket from Cape Canaveral, Fla.

Down to the wire

Bradt recalls the days following the launch as full of highs, as well as one worrying low.

"The first time they turned on the equipment, everything was hunky-dory, and we saw beautiful data," Bradt says. "Then the next day, one of the detectors began to arc — high-voltage breakdown — and we were in despair."

The team was unable to read a signal from one of the cameras on the ASM, the instrument designed to monitor the entire sky for X-ray sources. Bradt consulted with Levine and ASM project scientist Ron Remillard, and the team settled on a likely explanation: One or more of the wires in the camera's X-ray detector might be faulty, jamming the signals from the other wires. On a gamble, the group turned the instrument back on and waited. After a week or two, the problem wires stopped making noise, clearing the signal for the other working anodes.

"One day, two days, three days, we thought it would never quit," Bradt recalls. "And then it just fixed itself."

Spinning black holes and "vampire" stars

Since then, RXTE has worked without a hitch, providing astronomers with X-ray data that has led to many exciting discoveries.

For example, the satellite revealed neutron stars with dramatic characteristics, including subclasses with huge magnetic fields, and others that eject jets of matter from their surrounding atmosphere. Yet another subclass, described as “vampire” pulsars, whittle down their companion stars to very low mass by sucking matter from the stars’s atmospheres.

RXTE also gave astronomers an X-ray view of black holes, many of them part of binary systems consisting of a normal star and a black hole. ASM measured nearly 100 outbursts from dozens of black hole binaries, and RXTE has shown that these systems exhibit three very distinct states.

“We have begun to learn how to quantitatively constrain the black hole’s physical properties, i.e., its mass and spin, by looking at the details of the X-ray emission in different spectral states,” Remillard says.

For Morgan, one of the satellite’s most bizarre discoveries was a massive black hole named GRS 1915+105. About 15 times the mass of the sun, GRS 1915 is one of the larger black holes in the galaxy. Through the years, the ASM picked up highly unusual patterns from this X-ray source.

“It’d get bright, then come down and do this oscillation thing, then go up again, and it had about 10 different steps it would do,” Morgan says. “It was an amazing source.” Using data from RXTE, scientists were able to estimate GRS 1915’s period of rotation, or spin — a first for astronomers.

The satellite is expected to reenter Earth’s atmosphere and burn up sometime between 2014 and 2023.

“For 16 years, [RXTE] followed the light curves of more than 100 X-ray sources,” Bradt says. “Nobody else will ever get that. And it is our hope that more great science will come out of them.”

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