The Satellite with X-ray Vision

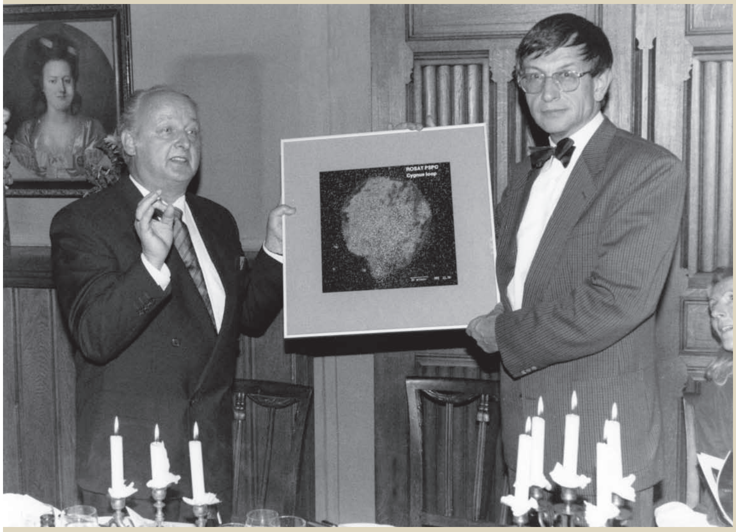
In the early hours of October 23, 2011, *ROSAT* was engulfed in the waves of the Indian Ocean. This was the end of a success story that is unparalleled in German space exploration research. The satellite, developed and built by a team led by **Joachim Trümper** from the Garching-based **Max Planck Institute for Extraterrestrial Physics**, not only found more than 150,000 new cosmic X-ray sources, it also revolutionized astronomy.

TEXT **HELMUT HORNUNG**

The pile of debris came from the southwest, flew over the Gulf of Bengal and finally crashed into the sea at 450 km/h. There were no witnesses. Didn't the most famous German research satellite deserve a more fitting finale? At least the German weekly news magazine Der Spiegel took pity and tried to save what could be saved. In an article entitled "Directly in its Path" published on January 30, 2012, it reported that *ROSAT* fell to Earth "just barely missing the Chinese capital Beijing." The satellite "would likely have torn deep craters into the city." The magazine believes that the catastrophe could even have damaged German-Chinese relations. Joachim Trümper smiles broadly when confronted with this: "The likelihood of a single person being injured was roughly one in ten billion."

When you talk to Trümper about *ROSAT*, you can certainly detect a hint of wistfulness. "It was our baby," says the professor emeritus at the Max Planck Institute for Extraterrestrial Physics. The 78-year-old has dedicated more than half of his research life to the X-ray satellite. Joachim Trümper remembers the launch date on June 1, 1990 like it was yesterday, and was, of course, present at Cape Canaveral Space Center in the US. A few days before lift-off, he once again traveled in the elevator to the top of the *Delta II* launch system. "I took a final look at *ROSAT* through a window there," says the astronomer.

Celebration with cirrus clouds: In 1991, Joachim Trümper (left) presents Research Minister Heinz Riesenhuber with the *ROSAT* image of a supernova remnant in the Cygnus constellation.

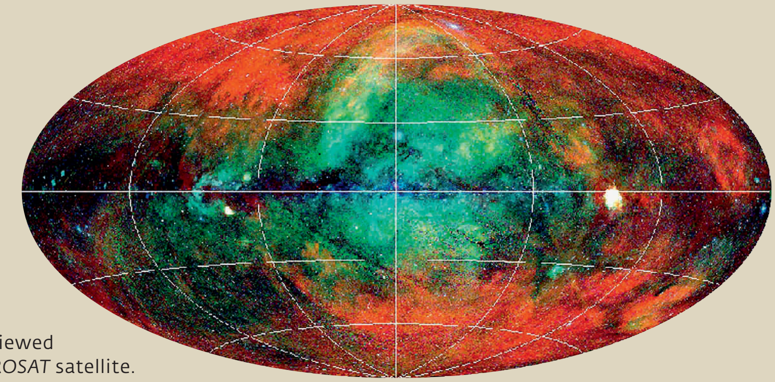


While Trümper was with some of his team members in the US, those who had remained at home witnessed the launch at the Oberpfaffenhofen-based research center. The control center at the German Aerospace Center (known by its German acronym DLR, Deutsches Zentrum für Luft- und Raumfahrt) is the Bavarian equivalent of America's Houston, and was involved in manned projects such as the two space shuttle missions D1 and D2 in the 1980s and 1990s. The experts were now expected to "fly" the two-and-a-half ton *ROSAT*, worth several hundred million Deutschmarks at the time, monitor its functionality, and constantly send commands and receive data via the DLR antenna in Lichtenau, near Weilheim, Germany.

Friday, June 1, 1990. In the evening, more than 500 guests have gathered at the German Space Operations Center in Oberpfaffenhofen. The live transmission from Cape Canaveral was broadcast on a large screen. Five minutes before the scheduled take-off, a civilian plane suddenly appeared above the campus; the countdown had to be interrupted. "That was the standard joke played by the launch team, to increase the tension," recalls Trümper. Ten minutes later, everything was back on track. In Oberpfaffenhofen, hostesses served champagne, and the guests counted down the last seconds. As the rocket took off into a perfect blue sky 8,000 kilometers away, everyone shouted 'Go, go, go!' and the Gilching brass band played march music.

Between the folklore in Upper Bavaria and the crash into the Indian Ocean lies not only a span of 21 years and 5 months, but also an exceptionally fruitful yield of scientific findings. X-ray astronomy is a very young discipline, as the Earth's atmosphere allows only a fraction of the radiation through from outer space, including visible light and radio radiation. However, in order to illuminate the universe with X-ray eyes, we have to leave the Earth's protective atmosphere behind us. American researchers thus discovered the Sun's X-ray radiation in 1948 using a seized V2 rocket. Today, the observatories are stationed on satellites.

Photo: Max Planck Society/Udo Giesen



In a new light: The entire sky viewed through the X-ray eyes of the *ROSAT* satellite.

Visible light can easily be focused using lenses or mirrors, but this can't be done in the case of X-ray radiation. Because of their high energy levels, photons have a "penetrating" effect similar to that of bullets. For this reason, in the early 1950s, physicist Hans Wolter developed the principle of a special telescope in which parabolic and hyperbolic mirror segments focus the incidental X-ray light at a low angle. The plan was to deploy a Wolter telescope on *ROSAT*.

First, however, one or two obstacles had to be overcome. As early as 1972, Joachim Trümper resolved to begin developing the required instrument. Three years later, his group participated in a national invitation to tender in Germany for major scientific projects. Out of the large number of proposals submitted, three were chosen. *ROSAT* was among them.

In 1980, when the then German Federal Ministry of Research and Technology called for "substantial international involvement," Trümper went looking for partners. "To avoid having the project mired in bureaucracy for years, we asked the Americans to look after the launch. And we asked the British to contribute to and operate a separate, smaller telescope for the extreme ultraviolet range." The strategy panned out, benefiting the entire project.

In 1983, following years of studies, a number of companies (Dornier, MBB and Carl Zeiss) came on board. The engineers developed X-ray cameras and built a 130-meter-long test facility known as *Panter*. The telescope itself had an aperture of 83 centimeters

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» The precision instruments enable ROSAT to see into outer space, which can extend to a distance of more than ten billion light-years. Knowledge about the origin of the cosmos will be expanded considerably with this mission.

and weighed roughly one ton. It consisted of four nested mirrors made from the heat-resistant glass ceramic Zerodur. Each of the gold-coated mirrors had a unique surface accuracy: compared to an area the size of Lake Constance, irregularities would be equivalent to a wave measuring roughly one hundredth of a millimeter. As a result, the telescope made it into the Guinness Book of Records for the smoothest surface.

Then came January 28, 1986: The *Challenger* space shuttle exploded into a ball of fire just 73 seconds after take-off. All seven astronauts died, and America's manned space travel program went into hiatus for two and a half years. *ROSAT* was actually supposed to be sent into orbit in 1987 – on a space shuttle. This was no longer possible. "We now had to completely retrofit the satellite for launch with a rocket," says Joachim Trümper.

This challenge was also met successfully. And, in the end, the technology and design were not the only record-breaking features. Even the first objective of the mission – charting the entire X-ray sky with an imaging telescope – exceeded all expectations. One of *ROSAT*'s predecessors was the *Uhuru* satellite, launched in December 1970. With its simple instruments – collimated proportional counters – it discovered 300 new celestial objects. A decade later, the *Einstein* observatory, with a Wolter telescope on board, increased this number to 5,000. And then *ROSAT* came on the scene: within the first six months alone, the scout found more than 100,000 new X-ray sources.

ROSAT subsequently observed selected sources: objects in the solar system, stars and gas in the Milky Way, distant galaxies. This second phase was supposed to last one year – which then turned into eight. The Max Planck researchers could always be counted on for a few surprises. Their satellite delivered the first X-ray image of the moon, and discovered the emissions from the Hyakutake comet. The latter was initially a puzzle, as comets were considered to be "dirty snowballs." But to emit X-ray light, temperatures of millions of degrees are required, or very high-energy electrons. The solution: comets don't generate radiation themselves, but are illuminated by their interaction with the solar wind, a stream of electrically charged particles.

ROSAT delivered the first complete overview of the universe, from the tiny brown dwarfs to the red supergiants, and observed compact stellar remnants such as white dwarfs, neutron stars, black holes and supernova remnants. Studies of galaxy groups and clusters provided new information about the role of dark matter in the evolution of the cosmos. Finally, *ROSAT* proved that active galactic nuclei and quasars on the edges of space and time contribute at least 80 percent to the background radiation in the X-ray range, thus solving a 30-year-old puzzle.

While the scout diligently collected data, its gyros, used to stabilize the satellite in space, began to fail. The researchers, especially Günther Hasinger, who would later become a Max Planck Director, and the MBB engineers, quickly adapted the navigation system and equipped *ROSAT* with a new, yet age-old system: it used compasses to orient itself with the Earth's magnetic field. The satellite now worked perfectly again.

On April 25, 1998, however, the main star sensor on the X-ray telescope broke down. *ROSAT* had finally become too old. Despite the increasing obstacles, the observatory kept going until December 17, 1998. Contact was lost on February 12, 1999. *ROSAT* had done more than just fulfill its mission. A total of 4,000 scientists from 24 countries use its data. More than 4,000 articles in journals referred to the satellite, and the Max Planck Society issued its longest press release ever, at 36 pages.

Photo: Max Planck Institute for Extraterrestrial Physics