Nearly 20 Years of Effort, Now Realized: China's First Hard X-ray Telescope

SHANG RENCHENG, JIN YONGJIE, ZUANG RENLIN
TSINGHUA UNIVERSITY

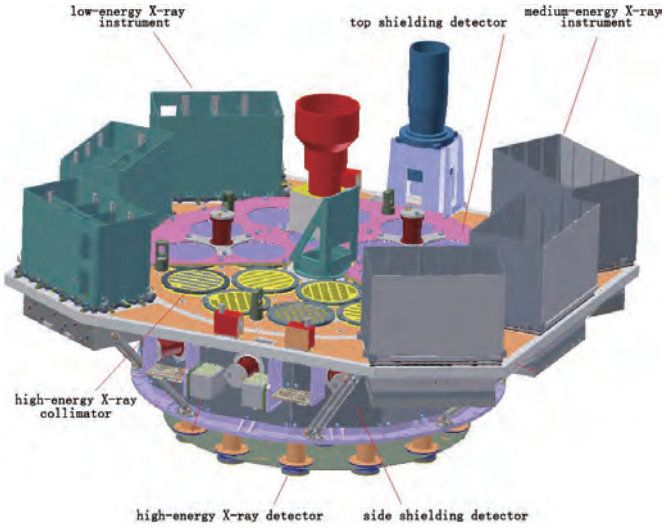
Fig. 1: Lift off the Hard X-ray Modu lation Telescope begins its mission.

China has just launched the country's first dedicated X-ray telescope to study the radiation produced by black holes and neutron stars, and to detect gamma-ray bursts. The Hard X-ray Modulation Telescope (HXMT) was launched on June 15, 2017 at 11:00 from the Jiuquan Satellite Launch Center, Inner Mongolia, China. It will now be put into low-Earth orbit with an altitude of around 550 km.

HXMT has been developed jointly by the Institute of High Energy Physics (IHEP) of the Chinese Academy of Sciences, Tsinghua University, and the China Academy of Space Technology. The 2700 kg probe carries three instruments that will detect X-rays between 1–250 keV. The high-energy X-ray instrument has a total collecting area of 5000 cm^2 and will operate between 20–250 keV. The medium-energy X-ray instrument will operate between 5–30 keV while the low-energy X-ray instrument will operate between 1–15 keV.

In addition, it has a particle monitor which is able to detect gamma-ray bursts at energies from 200keV –3 MeV. "We expect to monitor about 200 gamma-ray bursts every year," says IHEP physicist Zhang Shuangnan, who is the present principal investigator of the satellite. Since 2016, Professor Zhang has been the project's P.I., and he is the successor of Professor Li Tipei, who from 2000 – 2015, was the P.I. of the HXMT project.

Due to atmospheric absorption, cosmic X-rays can only be seen from space, where black holes and neutron stars are the two main X-ray sources. By combining sky-survey data with single-point observations, HXMT will develop a high-precision, hard X-ray sky map, looking for new



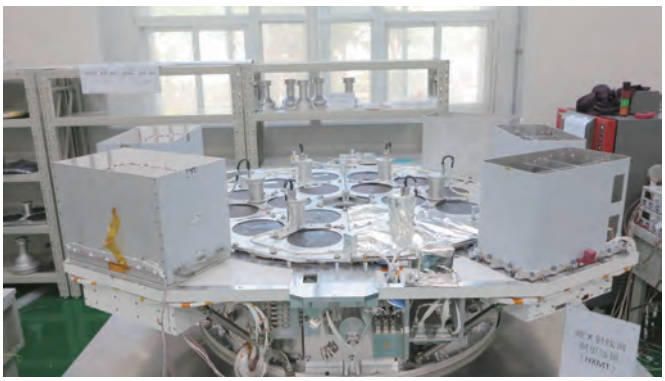


Fig. 2: The structure of HXMT. Above: the design for HXMT detectors; below: assembled detectors at the laboratory.

sources and studying in greater detail the temporal properties of known sources to significantly improve our knowledge of the X-ray sky.

MODULATION DETECTION

Dedicated X-ray astronomy began in 1970 with the launch of NASA's Uhuru. Since then, there have been more than 50 missions, including NASA's Chandra and the European Space Agency's XMM-Newton. Most of these missions have used focusing mirror technology. Instead of using focusing optics to identify X-ray sources, HXMT adopts a unique demodulation technique to detect X-rays. As early as in the 1990s, professor Li Tipei and Wu Mei proposed a data processing method, known as the direct demodulation method. Based on this method, we use collimators to modulate the incoming light so that only radiation travelling in a specific direction is allowed to go through. By swinging the detector in various directions, astronomers can then reconstruct a specific source and eventually render a map of the entire X-ray sky, and after data processing using the direct modulation method, we can achieve considerably higher resolution, when compared to methods that are limited by the geometry of the collimators.

THE RESEARCH STAGE AT TSINGHUA UNIVERSITY

The HXMT project took 17 years to come to fruition, starting with its beginnings in 2000 as a national key research project (called the 973 Plan of China), and culminating with the launching of HXMT on June 15th, 2017. Numerous institutes and hundreds of researchers have contributed to the HXMT project's development and realization.

During the research stage, three departments, one research institute and one university based company were involved in the project. For example, the charged particle shielding detectors (Fig. 3), the collimator (Fig. 4), the electronics, the ground simulation system (Fig. 5) and the initial HXMT mechanical structure design and its stress distribution analysis at different pressure were overseen by the physics department at Tsinghua University, the department of engineering physics at Tsinghua University, the company " Tongfang Weishi" and the department of precision instruments and mechanology at Tsinghua University, respectively.

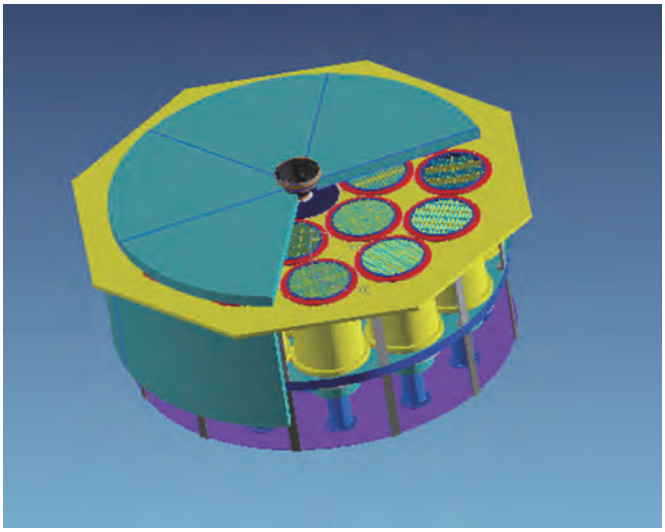


Fig. 3: Schematic plot of charged particle shielding detectors (in green). The six fan shaped ones are called top detectors, and are put in front of the 18 collimators. 12 side detectors are put around the sides of the collimators and main detectors.

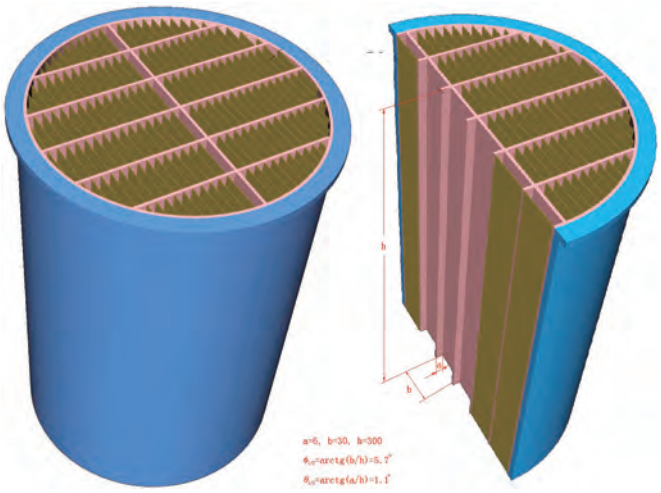


Fig. 4: Schematic plot of the collimator and its cutaway view. Hundreds of tantalum sheets (in brown) are inserted and conglutinated in the gaps of the alloy frame. The pointing precision of the telescope greatly depends on the geometric precision of the collimators.

Fig. 5: The ground simulation system. Before the satellite was completed, the system was designed and manufactured to simulate the operation of the satellite in the sky, which can rotate the telescope around Z axis and the axis perpendicular to Z axis. The platform can support a load of 1000 kg, and all rotations are controlled by computer. A laser beam is used to collimate and adjust the system. Collimated radioactive sources of different kinds were put more than 20 meters away to simulate starlight from the space.

During the research stage, Tsinghua University was in charge of the electronics of the entire detector's electrical controls and data acquisition. Tsinghua University also created the initial mechanical structure design for HXMT and conducted stress distribution analysis at different pressures.

THE ENGINEERING STAGE

In 2011, the Chinese government approved the HXMT plan. We then started the engineering stage. During this stage, Tsinghua University performed fewer tasks as compared to the previous stages. We completed the following three major works:

We created charge particle shielding detectors, using thin scintillation plats to directly transport scintillation light, in order to replace previous optical fiber technologies. We developed a special technique that greatly enhanced transportation efficiency. Finally, we improved the assembling and measurement technologies of the collimator, and manufactured 22 high quality collimators. 18 of those pieces have been assembled on the satellite, and the others will be used for spare parts.

Tsinghua University has finished the majority of the work on the electronics of HXMT. The electronics were developed and manufactured at Tsinghua University, and during the last two years, the remainder of the work was finished at IHEP.

As the satellite flies in the sky, we anticipate that a tremendous amount of observed data will successively transfer to the ground for further analysis. The ground application system was founded a few years prior to the launching of the satellite. Tsinghua University has also joined part of the work on the ground application system.

During the near 20 years of research and engineering work on HXMT, Tsinghua University has trained 22 MS students and 34 PhD students. During their study for degrees and even following their graduation, many of these students contributed substantially for the project.

Shang Rencheng is a professor emeritus of Tsinghua University in P.R. China. He graduated Tsinghua University in 1965. After he had studied the polarization in nuclear reaction in Canada, he came back to Tsinghua University and held various positions including a director of nuclear physics division, a vice chairman of the department of physics, and a member of academic committee. He also joined the international collaboration project on SSC in the United States in 1992. In 2001, He co-founded Tsinghua Center for Astrophysics(THCA) of Tsinghua University. He served as a professor and a deputy director and studied the Harder X ray Modulation Telescope(HXMT). His specialization is a nuclear technology and its application in astronomical instrument.