China's High Energy Experiment Goes Into Space

– An Interview with ZHANG Shuangnan, Principal Investigator of the Hard X-ray Modulation Telescope

By XIN Ling (Staff Reporter)

Astrophysicist ZHANG Shuangnan from the Institute of High Energy Physics.

Editor's Note

At long last, after two decades of endeavor, China's first high energy astrophysics research probe is about to take off. The 2.5-ton Hard X-ray Modulation Telescope (HXMT), which is set to be sent 550 km above the ground early 2017, will be carrying a trio set of detectors to gather X-rays emitted by black holes and neutron stars in the 1-250 keV band, and enable Chinese scientists to explore the distribution and property of these mysterious sources – with their own data, for the first time in history, in the next four years or more.

In August, *BCAS* reporter XIN Ling had the privilege to meet astrophysicist ZHANG Shuangnan of the Institute of High Energy Physics (IHEP), Chinese Academy of Sciences who is now principal investigator of the HXMT project. During the interview, ZHANG talked about the telescope's research missions, potential challenges in orbit, as well as its history and lessons to be learned in developing one of the nation's first science satellites.

Understanding Black Holes and Neutron Stars via Cosmic X-rays

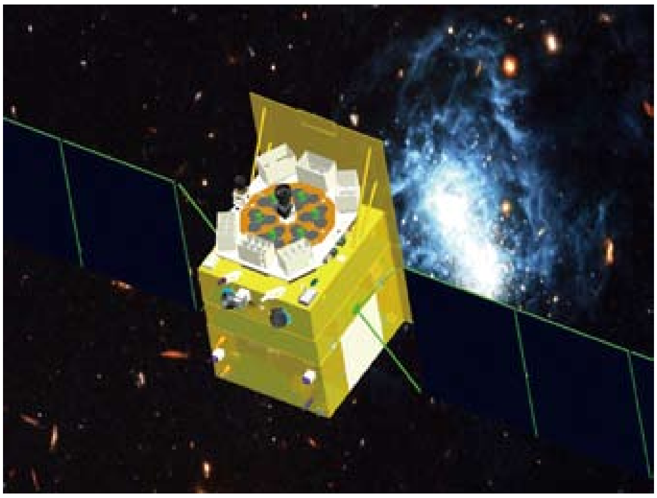
BCAS: We're all familiar with everyday applications of X-rays on Earth: body scanning, airport security and so on. What about the X-rays out there in space? Where do they come from, and why do we need to study them?

ZHANG: X-rays are very high energy radiation, and extreme conditions are needed to create them: super speed particles, exceptionally high temperatures, strong enough magnetic fields, etc. For instance, for the X-ray imaging machines we use at the hospital or airport, they generate highly penetrating X-rays by hitting a metal target with accelerated electrons. X-rays can also be emitted from synchrotron radiation facilities based on the magnetic properties of high speed particles.

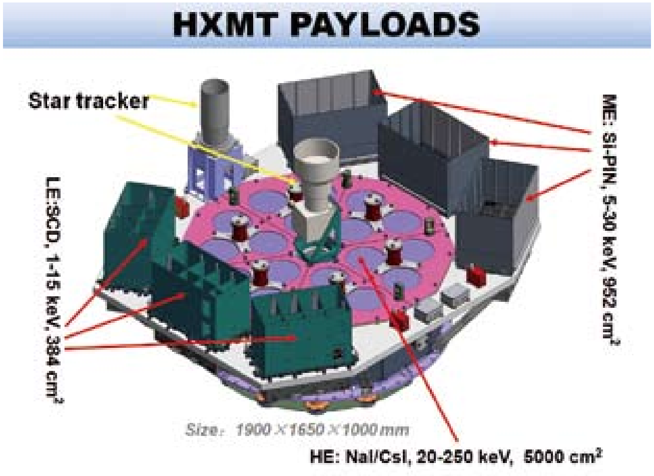
There are two major sources of X-rays in the universe: black holes and neutron stars. As black holes absorb everything around them with an immense gravity pull, the temperature of nearby gases dramatically increases to release X-rays. Similarly, highly condensed neutron stars exert strong gravitational fields around them too. And they are highly magnetic – an additional mechanism to create X-ray emission.

So basically, we use X-rays as a *tool* to infer the circumstances in which they are generated, and to understand the property of those sources.

BCAS: Specifically speaking, how do these rays help us understand black holes and neutron stars?



An artist's rendering of HXMT in space.

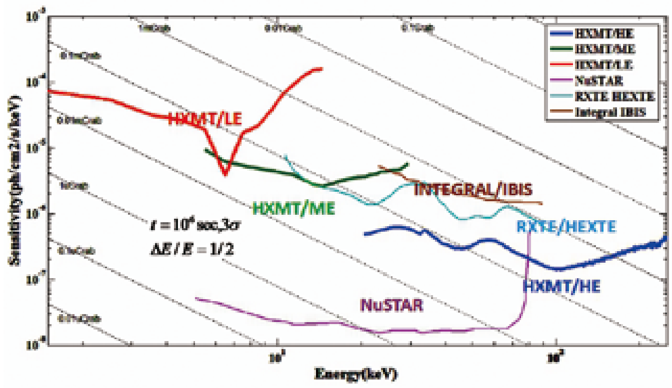


The payloads of HXMT.

HXMT PROPERTIES

Detectors	LE: SCD, 384 cm²; ME: Si-PIN, 952 cm² HE: NaI/CsI, 5000 cm²
Energy Range	LE: 1-15 keV; ME: 5-30 keV; HE: 20-250 keV
Time Resolution	HE: 25μs; ME: 180μs; LE: 1ms
Working Temperature	HE: 18±1℃; ME: -50~-20℃; LE: -80~-45℃
Energy Resolution	LE: 2.5% @ 6 keV ME: 14% @ 17.8 keV HE: ≤16% @ 60 keV
Field of View of one module	LE: 6° ×1.6° ; 6° ×4° ; 60° ×3° ; blind; ME: 4° ×1° ; 4° ×4° ; blind; HE: 5.7° ×1.1° ; 5.7° ×5.7° ; blind
Source Location	<1' (20σ source)

A list of properties of HXMT.



The sensitivities of the three telescopes of HXMT.
The sensitivities of NuSTAR, INTEGRAL/IBIS and RXTE/HEXTE were reprinted from Koglin et al. (2005).

The sensitivities of telescopes on HXMT compared to those onboard NuSTAR, INTEGRAL/IBIS and RXTE/HEXTE.

ZHANG: For example, a black hole the mass of Sun has a diameter of just a few kilometers. Given the speed of light, any small fluctuation in the state of photons will be very prominent. By tracking the photons' movement, we may know the distribution of substances around the black hole. And by measuring their energy, we can reveal the temperature, density and eventually the mass and size of the black hole.

To understand a neutron star, one important thing is to know how magnetic it is. There are several ways to do this: like you can measure its magnetic field through the fast spinning star's interaction with surrounding gases. A recent methodology is to use its X-rays. Interestingly, when its magnetic field gets really, really strong, the entire neutron star takes on a "resonant cyclotron absorption effect" to behave like *a huge atom*. The subsequent absorption lines, which resemble an atom's spectral lines but fall into the energy range of X-rays, tell exactly how strong the magnetic field is. Scientists have already successfully studied a number of neutron stars in this way.

BCAS: So what will HXMT be doing?

ZHANG: HXMT will be mainly collecting X-rays in the energy range 1–250keV to study the black holes and neutron stars in the Galaxy, by means of both sky survey in the Galactic plane and source-pointed observation. Theoretically, any star tens of times the mass of Sun could easily evolve into a black hole, and there should be over a million black holes in our Milky Way. But by far, scientists have only confirmed the existence of less than a hundred of them. The satellite aims at creating a high precision hard X-ray sky map, and discovering new hard X-ray sources including possible new types of objects in the Milky Way.

It should be noted that though HXMT is by name a "hard X-ray" telescope, its energy range actually goes into the medium and low bands to as low as 1 keV, thanks to the two sets of detectors we proposed to add around 2006 to increase the satellite's usefulness.

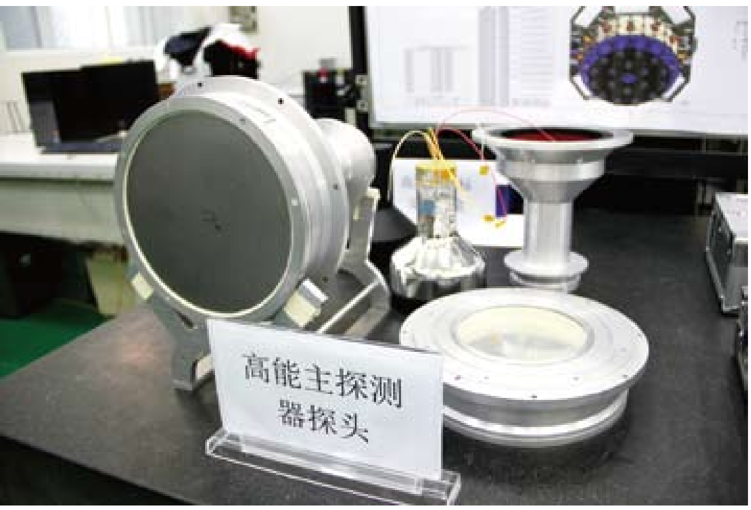
BCAS: Besides black holes and neutron stars, what else will it be looking at?

ZHANG: It will observe many other things like X-ray binaries and clusters of galaxies. It will also try to understand the cosmic X-ray background. We all know that the cosmic microwave background is a result of the Big Bang. X-ray background radiation is generally thought to have come from the remote black holes in the depth of our universe. But it's still unclear, for example, if there is any other contributing factors.

Thanks to a special design on HXMT's high energy detector, we'll be able to detect gamma-ray bursts up to 3000 keV energy. We'll also use the satellite to explore the mechanisms of neutron star and pulsar timing, which might lead to future navigation techniques, probably in synergy with the Five-hundred-meter Aperture Spherical radio Telescope located in southwest China.

Our work has certain theoretical implications, too, including testing Einstein's General Relativity Theory. If we could find some cases that go against the predictions of the theory, then we would be approaching its limit – this is how new theories have been typically advanced in physics. Of course, it's still the best theory of gravity we have so far.

The 18 HXMT/HE main detectors that will be onboard HXMT. (IHEP, November 2015)



The components of the HE main detector. (XIN Ling, August 2016)

"A Technical Odyssey"

BCAS: How does HXMT's "modulation" technique work?

ZHANG: The technique was proposed by LI Tipei, a senior astrophysicist at my institute who masterminded this project with his colleague WU Mei in the 1990s. The rationale is not complicated: it uses a type of device called "*collimators*" to filter rays so that only those travelling parallel to a specified direction are allowed through. Then by assembling different collimators into a detector or by swinging the detector in different directions, we can reconstruct the image of the X-ray source and even the entire X-ray sky.

Such a technique had emerged because back then, people didn't know how to focus radiation with such short wavelengths – especially hard X-rays above 10 keV – into an image like they did with lenses for radiation at optical or near-optical wavelengths.

Later, the focusing technique for hard X-rays was invented and today it is used on some X-ray satellites in orbit. Typically, the NuSTAR mission launched by NASA in 2012 was the first telescope to apply focusing optics to the detection of high energy X-rays. The new technique greatly enhanced the detection sensitivity of X-ray telescopes, but its main downside is narrow field of view. Modulation telescopes, on the other hand, are quite on the opposite. They are not that sensitive, but they can scan across large sky areas. These two techniques are complementary. So once HXMT is operating stably, we plan to launch collaborative observation with those satellites including NuSTAR.

BCAS: Have you encountered major technical difficulties in the research and development of the satellite?

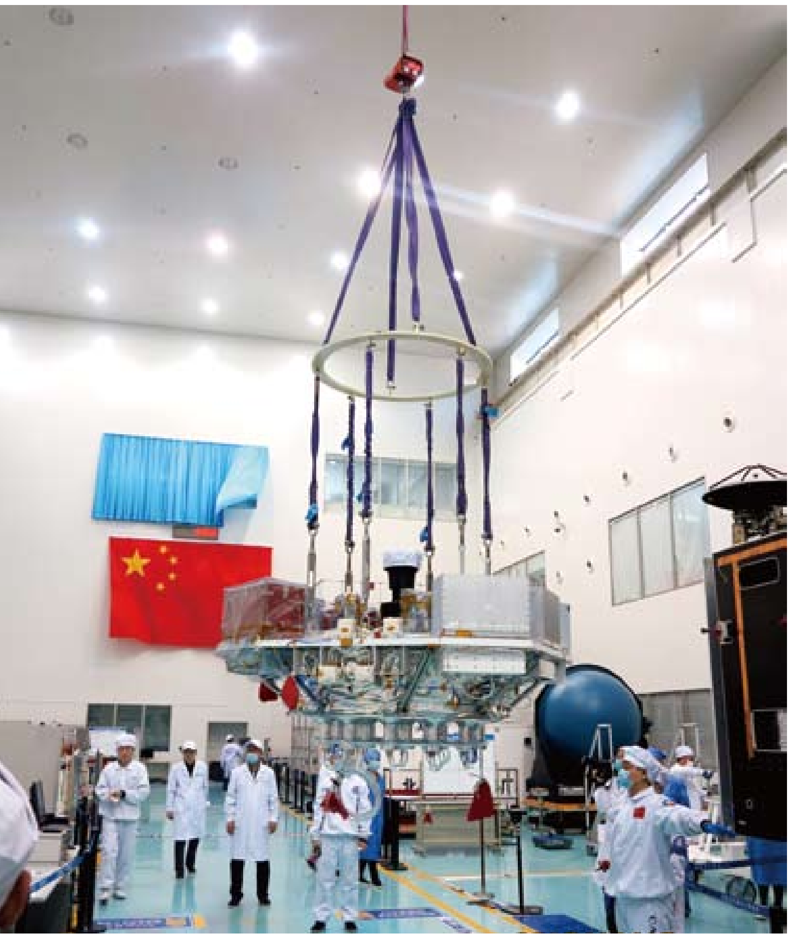
ZHANG: We did. Actually, the technical difficulties we faced were unexpectedly huge.

Our coworkers from China Academy of Space Technology (CAST) told us that HXMT is probably the most complicated satellite they've ever worked on. This is partly because all previous satellites China has launched are faced towards the Earth, but HXMT needs to look toward the sky. That makes a major difference.

In terms of payloads, the diversity and complexity of devices aboard are unprecedented, too. HXMT has three sets of detectors – the high, medium and low energy X-ray detectors. Within each set of detector, we basically had to develop all the parts on our own. We went through various embargos and overcame countless problems. But in the end we also remarkably improved the technical level of those devices, and built up a very hard-working and dedicated talent team.

HXMT is the first satellite with all science payloads independently developed by IHEP. Although we had built some space payloads before, like for Shenzhou-2 and lunar probes, they were relatively small and just a part of a big system. In this sense, HXMT is completely a first-time experience for us all. We also have to design

Cross-calibration of the HXMT/HE main detectors at the University of Ferrara in Italy. (IHEP, October 2015)



Payload assembly in December 2015. (IHEP)

and build the complete HXMT science data center from scratch, which will solicit HXMT observation proposals, organize proposal evaluation, plan HXMT observations, pipeline and archive all data products, calibrate all instruments in orbit, and provide data analysis software for all scientists using HXMT data. You can imagine the enormous challenges we had. But I'm glad that we pulled it through with enormous help and support from CAST, and now the satellite is ready to go.

BCAS: When will the satellite be launched?

ZHANG: It's scheduled for liftoff in the first half of 2017. It's going to be launched from the Jiuquan Satellite Launch Center.

BCAS: What will be the challenges when it goes into orbit?

ZHANG: The biggest challenge will come from space radiation – especially when it passes the South Atlantic Anomaly area, where there is an increased flux of energetic particles and all satellites will be exposed to higher than usual levels of radiation from space. The radiation will hinder HXMT's performance and harm its devices. So we will be closely monitoring the space radiation.

"Better Late Than Never"

BCAS: How did you get involved in the project in the first place?

ZHANG: That was more than 30 years ago. Back in 1984 when I was still a postgraduate student at IHEP, I was working in LI Tipei's team and participated in balloon testing for the techniques used on the satellite today. Then I went abroad to study. In 2001, the project received some funding from the Ministry of Science and Technology, and LI invited me to come back and work with him again. So I left the United States and returned to China. After that I was assistant to LI (who was principal investigator of HXMT) for many years, until early this year I was appointed the principal investigator (LI is now the principal advisor of HXMT). For me, not much has changed. I only feel more responsibility, because the launching date is close, and also the pressure to fully use the satellite for scientific research afterwards.

BCAS: So you came back to China for this project.

ZHANG: That's right. Back in the United States, I was working at the University of Alabama and NASA on similar science topics, as I've always been interested in the observation and theoretical research of black holes. In fact, this is an exciting field – it opened up the entire era of space astronomy. But in the States I was more focused on science. In China, I spent a lot of time developing instruments.

BCAS: It's been a long journey for HXMT to come to where it is today. Would you talk about what happened? Why was the project delayed, and what are the lessons to be learned?

ZHANG: Like I said, the notion of the telescope was proposed in the 1990s. At that time, it was a very pioneering idea to explore the distribution of supermassive black holes in the universe, and we had come up with a technique to do it. So IHEP scientists finished preliminary design and went on with the balloon testing. But due to many reasons, the project failed to get a grant until 2001 when part of the money eventually started to cash in – but for mission development only. Actually the funding gap was never closed until in 2011 when China's National Space Agency and CAS formally approved HXMT.

The reason, as it may seem, was the funding deadlock. However, I think the real problem was – and still is – the lack of a national space science program, instead of space science projects. All these years, China's space science has been project-based, working in a bottom-to-top and case-by-case way, instead of a top-down, overall *program* way that features steady, lasting funding to the field, with a long term strategic plan at national level. This is the case even for CAS's four science satellites being launched in a row within the past few years – including HXMT – they were still operated in a case-by-case, project-by-project way. The absence of such a *program,* I believe, is unhealthy for the standard application, evaluation and implementation of space science projects, and for the development of space science discipline in this nation in the long run.

The electro-magnetic compatibility test in February 2016. (IHEP)

The HXMT/LE team (December 2012)

HXMT Brings Long Collaboration in Hard X-ray Astronomy between Italy and China to New Height

Filippo Frontera

Professor of the University of Ferrara and Associated Scientist of the National Institute of Astrophysics in Bologna, Italy

High energy astrophysics is a relatively young science, born about 60 years ago with the serendipitous discovery of a strong X-ray source, Scorpius X-1. Since then thousands of X-ray sources have been discovered and many of them, mainly the strongest, have been well investigated at hard X-ray energies (>15 keV). With the last satellite missions devoted to high energy astrophysics, starting with Italian satellite BeppoSAX and the American Rossi-XTE, it has been demonstrated that broad band observations, from below 1 keV to 200 keV, are of key importance for the understanding of the physics of celestial X-ray sources, the emission mechanisms of the radiation at work and other issues of fundamental physics.

HXMT will continue this investigation process given its broad energy band that extends from 1 keV up to 300 keV, with a sensitivity which is expected to be better than the currently operational satellite missions, like the European INTEGRAL. In addition the satellite can investigate the still fascinating sources of Gamma Ray Bursts. The satellite will provide a useful vehicle for the advancement of the high energy astrophysics in China.

The direct demodulation technique adopted by the HXMT team, initially proposed by Prof. LI Tipei, has never been applied in astrophysics, even if it is already known in medical physics. It will require the scanning of the sky region of which the image is needed. On the basis of preliminary investigations also performed by our science group, it is expected to provide a better angular resolution (by a factor 2) than the coded mask technique, which is the imaging system adopted so far at hard X-ray energies. However for the flux derivation of the imaged sources and their temporal behavior a different method probably will be required.

Therefore, HXMT is expected to continue the study of the physics of celestial X-ray sources, extending this study to weaker sources given its better sensitivity, and to sources in crowded fields, like in the case of the Galactic Center region given its very good angular resolution (few arcminutes).

There is a long collaboration between the hard X-ray astronomy groups operating in Ferrara and Bologna and the IHEP team involved in HXMT, led by Prof. LI Tipei and Prof. ZHANG Shuangnan. Our collaboration was born thanks to a temporary position given to a member of the IHEP team, ZHANG Chenmo, in the 1990s – during the development of the high energy instrument PDS for the BeppoSAX satellite, of which I was Principal Investigator. The high energy instrument aboard HXMT is designed following the very successful PDS. We met several times both in China and in Italy. Prof. ZHANG Shuangnan also visited us for one month as Copernicus Visiting Scientist, a prestigious position given by the University of Ferrara, who had Nicolaus Copernicus as a student.

In the last year, two detection units of the high energy instrument aboard HXMT were tested in our X-ray facility at the Physics and Earth Sciences Department of the University of Ferrara, upgraded for the specific goal with the support of our Space Agency ASI. Finally, with ASI support, in July some scientists of our group, Mauro Orlandini, John B. Stephen and myself, visited IHEP for a four day meeting devoted to HXMT. In that occasion we have established the terms for the continuation of our collaboration. These will concern the joint scientific exploitation of the HXMT mission, the participation by the Italian team to astrophysical projects under development in China, e.g., eXTP, and the involvement of the IHEP team in THESEUS, a mission proposal led by Lorenzo Amati from our team, with a European participation, for a deep study of the transient high energy sky and of the early Universe (the proposal will be soon submitted to the European Space Agency), and the possible inclusion in future Chinese missions of hard X-ray (up to 600 keV and beyond) focusing instruments under development in Ferrara.

The Chinese space program is very impressive. I expect that, with this program, China can become a leader in space science with great scientific and economic returns. Indeed the foreseen space missions require the development of new high level technologies that can be later exploited in different fields, like medical physics, information technology, etc. In other words, in addition to a great science return, this mission program can be a sort of "flywheel" for the Chinese economy.

For ESA and China, "the Most Interesting Collaboration Is Yet to Start on HXMT"

Arvind Parmar

Head of the Scientific Support Office in the Science Directorate, European Space Agency

HXMT will be China's first astronomical satellite. It will study X-rays from objects such as black holes, neutron stars and the remains of exploded stars. These are exciting topics that are of interest to scientists from all over the world. HMXT will join a number of X-rays satellites already in operation such as ESA's XMM-Newton. Each mission has its own strengths and for HXMT this is probably the wide range energy coverage together with its good spatial resolution and sensitivity. The wide energy coverage of 1–250 keV can be thought of as the range of X-ray "colours" that HXMT can see while the good spatial resolution means sharp images and the ability to separate and study the emission from sources that are close to each other in the sky. Good sensitivity is of course very important and HXMT will excel at energies above 80 keV being able to provide views of unprecedented clarity.

The strengths of the modulation technique used by HXMT are the large field of view and good sensitivity that this technique can deliver. ESA's INTEGRAL used a different technique using "Coded Masks" to provide similar energy coverage and fields of view. The analysis of the images from both these techniques is complicated and I am sure it will take the Chinese investigators some time to find the optimum techniques, just as it did on INTEGRAL. At low energies, X-ray mirrors can provide even better sensitivity, but this cannot provide the required large fields of view.

I am really looking forward to the first data! HXMT will investigate the diffuse X-ray emission in our galaxy, it will look for new, transient, X-ray sources, it will study many types of neutron star systems as well as the massive black holes that lie at the centres of galaxies. Since the X-ray sky is so variable, it is difficult to predict what HXMT will find as each new transient source seems to provide new discoveries and insights, but also new questions to be answered.

ESA has a long history of collaborating with China on scientific missions including Double Star. This involved the launch of two satellites in December 2003 and June 2004 – each carrying experiments provided by European and Chinese institutes. Together with the 4 Cluster spacecraft this enabled scientists to analyse data sent back simultaneously from six spacecraft, each located in a different region of near-Earth space. The simultaneous, six-point study provided new insights into the mysterious mechanisms that trigger magnetic storms and brilliant auroral displays in the polar skies

On HXMT specifically, the most interesting collaboration has not yet started! Once HXMT is launched and has started making scientific observations there is great potential for joint investigations with some of ESA's scientific missions. Many scientific investigations benefit from data from more than one satellite. As an example, a simultaneous observation by XMM-Newton and HXMT would provide the best view of the source using

XMM-Newton below 15 keV and using HXMT above this energy. The best of both worlds! The Chinese and European scientists will need to work together to ensure the optimum use of our missions in this way.

I am really impressed with how China is developing its scientific space programme. The recent launches of the Dark Matter Particle Explorer (DAMPE) and the Quantum Experiments at Space Scale (QUESS) missions highlight Chinese capabilities and commitment to science as does the range of missions under study for future launch opportunities.

I am also very impressed by how open China is to international collaboration. As an example, China and Europe, together with Canadian participation, are working closely together to develop the SMILE mission. This joint CAS-ESA mission will provide X-ray and UV imaging of the Earth's magnetosphere as well as in-situ plasma measurements. The mission was jointly selected, is being jointly developed and will be jointly operated and exploited by scientists in China and Europe. To my knowledge this is the first time two major space agencies have collaborated in this way and it surely points the way forward for future collaboration.

Germany to Jointly Analyze HXMT Data with China, Where "the Future Is Being Shaped"

Andrea Santangelo

Institute of Astronomy and Astrophysics, University of Tübingen

The HXMT mission will have profound implications in the development of high energy astrophysics in China. Being a national program but with an international flavor, it will bring China among the leader nations in X-ray astrophysics and space science. As it has happened for other national communities in the past, the know-how acquired during the development of the HXMT program and the knowledge that will emerge from the exploitation of the science data will allow new generations of students and younger scientists to play in the future a key role in our understanding of the Universe at high energy.

The modulation technique has been used in the past and is a powerful technique to reconstruct an image on an X-ray source. The technique used is particularly important when scanning the sky, or part of it, in search on new sources that are transiently bright in the X-rays, or to see the recurrent or even periodic outbursts of known sources. However the large light-collecting area of HXMT is unique and many sources will be pointed directly, producing high statistics observations.

HXMT will focus on the bright sources emitting X-rays. In particular the mission capability of studying a broad band of energies (given by the combination of different instruments) will allow us to study the behavior of very exotic objects in the Universe. Other missions features a better sensitivity but in a limited region of energy. Thanks to the broad band coverage of HXMT we will see many aspects of the emission of the objects emitting in the X-rays. Now, if one wants to study and elephant, one does not just look at its proboscis or its tail. We want to see and measure the proboscis, the tail and the body!

Thanks to this broad band, we will understand much better the emission from neutron stars or black holes rotating around normal stars, systems that we call X-ray binaries, and we will try, thanks to HXMT, to unveil the properties of these objects such as the spin of the black holes. We will also be able to understand better the strong gravitational field around black holes, or the incredibly high magnetic field of the neutron star. But HXMT will also systematically look along the plane of our Milky Way to discover transients sources, sources that may stay dormant for years or decades and then become the brightest object of the X-ray sky. Many new transients will be discovered by HXMT and may be new surprises.

As of today there is a strong collaboration between the Institute of Astronomy and Astrophysics of the University of Tübingen and IHEP. The department of high energy astrophysics, that I lead, is collaborating with the Key Laboratory of Particle Astrophysics. We will work together on the analysis of the data of HXMT, joining our different expertise, sharing ideas and students.

However, any scientific collaboration must look at the future. And today we are working hard together to bring to reality a new mission for X-ray astrophysics: the enhanced X-ray Timing and Polarimetry mission or, in the short form, eXTP. When this mission will fly it will shine as a flagship of the community for the exploration of the High Energy Universe. The eXTP science consortium is lead by IHEP and many Chinese and European institutions and scientists are participating to this challenge. Although I know Prof. ZHANG Shuangnan since many years, a truly deep collaboration started when I asked whether it was possible to spend my sabbatical stay at IHEP. Why I decided to come to IHEP for the sabbatical? Easy answer: we scientists go where the future is being shaped. And by the way, beside science, the cultural environment in China is great, the human relations are easy, the food among the best in the world.

China is becoming more and more a world leader for physical science investigation. And not only physical science. The number of space science missions which are being launched and developed by the CAS is impressive. Collaborations with the European Space Agency and other European National Agency are becoming tighter and larger. But this is happening not only for space science. Hundreds of European Scientists are participating to the BESIII and Daya Bay projects led by IHEP. It is a real pleasure for a Professor to observe how many young students are taking part to these science efforts in the Campus of the Chinese Universities and research institutions.

Modulation "A Clever Way of Observing X-ray Sky"

Paolo Giommi

Senior scientist at ASI, the Italian Space Agency

With the launch of HXMT, China is starting its exciting program of observations of our Galaxy and the deep Universe in the X-ray band. This is particularly interesting as the high-energy channel provides detailed and unique information about cosmic sources where extreme physical conditions and strong gravity are at work.

The modulation technique is a clever way of observing the X-ray sky as it provides images of X-ray sources without the need to use the more complex and costly X-ray mirrors. This will be particularly useful for the detailed observation of the Galactic plane, one of the main scientific objectives of HXMT. The modulation technique however can only provide limited sensitivity and it suffers from source confusion in crowded areas.

I expect quite interesting images of the Galactic plane, the discovery of several new transient X-ray sources, measurements of the variability of known X-ray sources, and one of the best catalogues of Galactic X-ray sources. A major strength of HXMT is its very wide range of energies of operation, form soft X-rays to almost the gamma-rays. This will lead to the measurement of the energy spectrum of many Galactic and some extragalactic sources hosting supermassive black holes in their nuclei.

We had many contacts with the HXMT team at IHEP in the past, and we have plans to collaborate more closely in the near future within the framework of a more general cooperation agreement between Italy and China in space science that is currently being defined. The expertise in X-ray astrophysics and high-energy data processing that has been accumulating in Italy over many years will be very useful for this collaboration and will help bringing HXMT data in line with international expectations.

China's program in the field of space science foresees several satellites of increasing complexity and competiveness. This, together with the construction of other large ground based scientific facilities, (e.g. for astronomical observations and cosmic-ray measurements) will definitively make China one of the major producers or knowledge in space science.

With Competitive Payload Design, HXMT Is "Important Extension of High Energy Astrophysics from Space"

Jonathan E. Grindlay

Robert Treat Paine Professor of Astronomy, Harvard University, Harvard Smithsonian Center for Astrophysics

HXMT is a significant advance for high energy astrophysics in both China and the whole international community. Its sensitivity and broad energy band coverage with its 3 principal instruments (LE, ME, HE) are very competitive. The strength of the modulation technique is its simplicity: imaging can be achieved without the need for position-sensitive detectors (for the HE), which makes it possible to build a very large area detector system. HXMT is more sensitive at higher energies (above 200 keV) and so will be particularly useful for blazars and black hole x-ray binaries undergoing outbursts.

HXMT should discover new black hole X-ray binary transients and blazars (beamed emission from supermassive black holes in active galactic nuclei). With its LE, ME and HE giving broad energy band (~1–200 keV) coverage for wide-field (5deg) imaging, it should obtain better spectral energy distributions (SEDs) than now being done with Swift/BAT (15–150 keV) or MAXI (0.3–7 keV).

I was in contact with Prof. LI at IHEP in the early days of his work on the mission concept and the modulation imaging technique. I was also very pleased to visit both IHEP and Tsinghua University in Beijing and take part in a planning meeting for HXMT that was conducted in Hainan.

China is making rapid progress in its space program for science. The recent launch of the satellite mission to measure entanglement over long baselines is very exciting. Likewise the LAMOST telescope and survey on the ground is a fine example of very competitive science. HXMT will be an important extension of high energy astrophysics from space and will complement other missions currently in operation as well as others being planned.