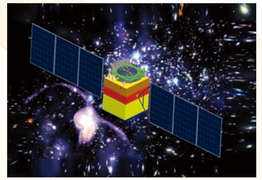
>> Advanced space astronomical facilities



An artistic impression of HXMT satellite in orbit

■ The Hard X-ray Modulation Telescope (HXMT) will be a collimated hard X-ray (20-200 keV) telescope that, once built, will have the highest sensitivity and spatial resolution power in the world. Pre-research began in March of 2011, and it will be developed and sent into space with the nation's twelfth five-year plan. It will perform an all-sky hard X-ray survey, in which about 1,000 new hard X-ray sources, including sensitive pointed observations of important cosmic X-ray sources, such as black holes and neutron stars, should be discovered.

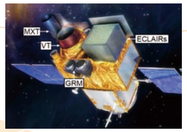
■ Main scientific objectives:

1. HXMT will conduct an all-sky hard X-ray survey to discover new hard X-ray sources, including possible new types of objects, and observe important high-energy celestial bodies..

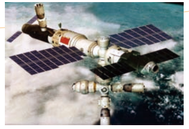
2. HXMT will observe the temporal variability of X-ray binaries, study the formation and evolution of accretion disks, jets and black holes, and perform further tests of general relativity.

3. HXMT will observe the hard X-ray spectra of the X-ray binaries and pulsars, measure the rotation of black holes, and study the magnetic fields and inner structures of neutron stars.

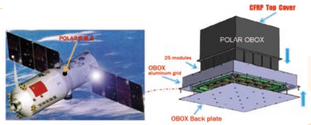
The commissioning site of HXMT payload high energy X-ray telescope



The picture shows an artistic impression of the multi-wave length gamma-ray burst satellite SVOM in orbit. The satellite launch will be between 2016 and 2017. IHEP is responsible for building the GRM instrument.



The high energy space radiation detecting devices will be operating in Chinese Space Station around 2020.



POLAR is the first dedicated high sensitivity instrument to measure the polarization of gamma ray bursts. It is planned to be launched in 2014 onboard China's spacelab TG-2.

>>Large High Altitude Air Shower Observatory (LHAASO)

■ Listed as one of the major science facilities in the nation's twelfth five-year plan, the LHAASO project is to be built at Shangri-La, Yunnan Province, China. This observatory is intended to explore the origins of high-energy cosmic rays, study the evolution of the universe and high-energy celestial bodies, and push forward the frontiers of new physics.

■ Features of LHAASO

1. LHAASO will be the most sensitive high-energy gamma ray survey facility in the world, greatly enhancing the sensitivity for the discovery of gamma ray sources. The discovery of many new sources, extra-galactic ones in particular, will boost the statistical significance of new types of gamma ray emitters.

2. It will also be the most sensitive detector for gamma rays above 10 TeV in the world. This will enable high precision measurements of the high-energy end of the spectra for most gamma ray sources, which will lead to the identification of cosmic accelerators of galactic high-energy cosmic rays.

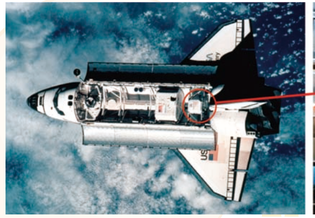
3. The cosmic ray spectrum measurement will cover a wide energy range by using a co-site combination of multiple techniques. Bridging the space-borne direct measurements of cosmic rays and the large facilities of ground-based air shower measurements, LHAASO will accurately measure the energy spectra of all cosmic ray species above 0.1PeV.

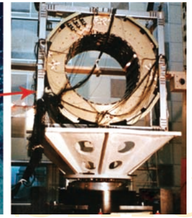
>> Alpha Magnetic Spectrometer Experiment

■ The Alpha Magnetic Spectrometer (AMS) experiment is a large international collaborative program under the leadership of Professor Samuel Chao Chung TING, a famous physicist and a Nobel Prize laureate in physics. The experiment will use the unique environment of space to study the universe and its origin by searching for antimatter and dark matter while performing precision measurements of the composition of cosmic rays and their flux. Taking part in this program are over 600 scientists and engineers from about 60 research institutions in 16 countries, including the United States, China, Russia, Finland, Germany, Italy, Romania, and Switzerland.

■ As part of the AMS-01 program, scientific researchers from the Institute of Electrical Engineering (IEE), IHEP, the Center for Space Science and Applied Research (CSSAR), and the Chinese Academy of Launch Vehicle Technology (CALVT) joined in the design and manufacture of the permanent magnet. Loaded on board the American space shuttle ST91 of "Discoverer" on June 2, 1998, the permanent magnet of AMS-01 was the first large magnetic spectrometer ever sent into space.

■ In the AMS-02 program, scientists and engineers from IHEP, the University of Pisa in Italy, and the Laboratoire d'Annecy-le-vieux de Physique des Particules in France developed an electromagnetic calorimeter weighing 700kg. The AMS-02 was successfully installed on the International Space Station (ISS) in 2011 and released its first results on the search for dark matter particles in April of 2013.





In 1998 and 2011, the permanent magnet of Alpha Magnetic Spectrometer was sent twice into the International Space Station. This permanent magnet was jointly developed by IHEP, the Institute of Electrical Engineering and the China Academy of Launch Vehicle Technology, and was the first large permanent magnet sent into the space by humankind.

IHEP
HIGH ENERGY PHYSICS

Particle Astrophysics

Institute of High Energy Physics

>> Disciplinary development

Luoxue Mountain Cosmic Rays Research Center

■ Particle astrophysics, also known as astroparticle physics, is a branch of particle physics dealing with elementary particles of astronomical origin and their relationship to astrophysics and cosmology. It is a relatively new field of research emerging at the intersection of particle physics, astronomy, astrophysics, detector physics, relativity, solid state physics, and cosmology. Partly motivated by the discovery of neutrino oscillations, the field has undergone remarkable development, both theoretically and experimentally, over the last decade.

■ In 1954, the Luoxue Mountain Cosmic Rays Research Center was established at 3,200 meters above sea level in Dongchuan, Yunnan Province. There, the Multiplate Cloud Chamber Group, the Magnet Cloud Chamber Group, and the Cloud Chamber Group were set up to conduct high-energy physics research on cosmic rays. In 1972, a heavy particle with mass possibly exceeding 12GeV, was obtained at the Luoxue Mountain Cosmic Rays Research Center. From 1983 to 1988, IHEP scientists set up an extensive air shower array in Huairou, Beijing, where the first measurement of the ultra-high energy cosmic ray spectrum was performed in China.

■ In 1977, the Laboratory of Cosmic Rays started to develop balloons and balloon-borne hard X-ray observation experiments. The largest balloon launched had a volume of 400 km3; the largest load was 1,500 kilograms; the highest altitude was 42 kilometers; and the longest flying time was 18 hours. At the same time, HAPI-1, HAPI-2, and HAPI-3 were developed to observe the Crab Pulsar and Cygnus X-1. These observations won many national and CAS awards. In September of 1993, HAPI-4, a balloon-borne hard X-ray telescope, was launched to observe the Cygnus X-1. This was the first successful X-ray imaging observation in China.

>> Disciplinary orientation

■ Particle physics and astrophysics research in the 21st century is faced with many puzzles. The latest astronomical observation proved that only 5% of the matter in the universe can be explained by our current understanding of particle physics. The dark matter, which makes up 27% of the universe, and the dark energy, which makes up 68% of the universe, cannot be explained by current models. There also appears to be a deficit of anti-matter in the universe. Answering these questions would be a historic breakthrough in the physics of the 21st century.

IHEP studies on particle astrophysics

■ Particle astrophysics research at the Institute of High Energy Physics focuses on these fundamental physics frontiers. Scientists at IHEP combine research on the microscopic structure of matter with the study of large-scale physical laws. By observing cosmic rays in diverse locations, from underground to the tops of mountains, and by conducting neutrino experiments, as well as balloon-borne and satellite-borne space observation experiments, scientists can study the components of various kinds of cosmic rays, different phenomena in the universe, and the structure of condensed objects, such as galaxies, clusters of galaxies, black holes and neutron stars. Scientists probe the laws of particle physics at both the microscopic level and in large-scale astrophysics; they investigate the structure and the evolution of the universe; and they explore dark matter and dark energy. These topics are among the most active cross-disciplinary frontiers in current physics research.

>> Yangbajing International Cosmic Ray Observatory in Tibet

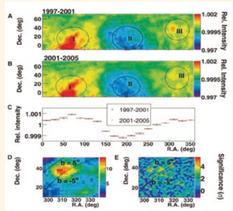
■ Cosmic rays are very high-energy particles, which mainly originate outside the Solar System. An Extensive Air Shower (EAS) happens when a cosmic ray enters the Earth's atmosphere and creates secondary particles, which in turn create even more particles, some of which reach the Earth's surface. A precise observation of an EAS can best be performed at high elevations.

The YBJ International Cosmic Ray Observatory. In the picture, the left is ASγ arrays (Sino-Japanese Cooperation) and the right is the ARGO-YBJ experiment hall (Sino-Italian Cooperation).

■ The YBJ International Cosmic Ray Observatory is located in the Yangbajing (YBJ) valley of the Tibetan highland. YBJ's wide and flat topography, convenient traffic, lack of heavy snow, and rich geothermal power source, make it among the best sites in the world for a high altitude observatory. The YBJ Observatory was founded in 1990. It has hosted the Tibet ASγ Experiment (Sino-Japanese Cooperation) and the ARGO-YBJ Project (Sino-Italian Cooperation).

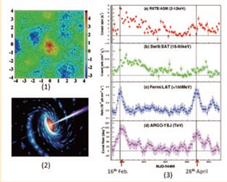
The ASγ Experiment (Sino-Japanese Cooperation)

■ In 1990, the Tibet-I ASγ array was installed in the Yangbajing International Cosmic Ray Observatory. At the time, it was the only ground array that could reach the threshold energy of 10TeV. The construction of the Tibet-II ASγ array started in 1996. By increasing the density of scintillation detectors, scientists reduced the threshold energy to 3TeV, and successfully observed γ rays from the Crab Nebula and Mrk 501 (during its flaring period in 1997). In October of 2006, Sino-Japanese Cooperation on ASγ and the Solar Neutron Experiment found evidence of anisotropy and co-rotation of galactic cosmic rays. The scientific results were published in Science Magazine, and cited as a milestone achievement in the field of particle astrophysics.



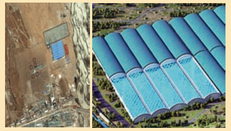
The ARGO-YBJ Project (Sino-Italian Cooperation)

■ The detectors of the ARGO-YBJ Project were installed and put into operation in June of 2006. The ARGO hall covers an area of 10,000 m^2. The detector consists of a single layer of RPCs (Resistive Plate Counters) covering an area of about 6700 m^2 and provides a detailed space-time picture of the shower front. ARGO-YBJ is devoted to a wide range of fundamental issues in cosmic rays and astroparticle physics, including gamma-ray astronomy and the physics of gamma-ray bursts. Scientists conducted a multi-wavelength analysis of Mrk421 from February to May 2010. On February 16, 2010, the EAS array began observing TeV flares every 4-5 seconds.



LAWCA Experiment

■ The Large Area Water Cherenkov Array (LAWCA), a new type of water cherenkov detector is being planned.It will be used to detect air showers at 4,300 meters above sea level. The LAWCA detector, amounting to an area of 23,000 m^2 and built adjacent to the ARGO-YBJ detector, will use water Cherenkov techniques aimed mainly at a full sky survey for new gamma ray sources. A cross calibration between LAWCA and ARGO-YBJ will give us a better understanding of systematic errors.



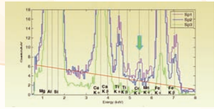
>> High-energy astrophysics research

■ Gamma-ray bursts are flashes of gamma rays associated with extremely energetic explosions in distant galaxies. They are the brightest electromagnetic events known to occur in the universe. Bursts can last from ten milliseconds to several minutes. Gamma-ray bursts were first detected in 1967 by the Vela satellites, a series of satellites designed to detect covert nuclear weapons tests. The observation and research of gamma-ray bursts is currently a hot topic, and it is also an important disciplinary orientation at IHEP.

■ The IHEP SZ/XD group designed and constructed X/γ-ray burst detectors, which were installed on the SZ-II Spacecraft launched in January 2001. They successfully observed hundreds of cosmic γ-ray bursts, solar flares, and space electron precipitation events.

X/γ-ray burst detectors, which were installed on SZ-II Spacecraft

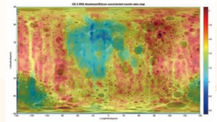
■ The X-ray spectrometer developed at IHEP is important payload for China's lunar exploration projects, the Chang'e-1 satellite and the Chang'e-2 satellite. Launched on October 24, 2007, the X-ray spectrometer aboard the Chang'e-1 satellite obtained X-rays in the energy spectrum from 10 to 60keV when it orbited the moon for one year. This task has provided a first observation of the energy spectrum in the lunar orbit, and has made the first fluorescence detection of the X- rays emanated by lunar elements.



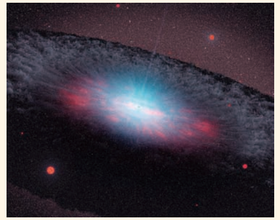
The world first Cr characteristic fluorescent X-ray spectrum line in lunar surface

■ The Chang'e-2 satellite payload X-ray spectrometer was successful launched on October 1, 2010. While orbiting the moon for 100km in one year, it has obtained 190 days of statistics. The world first Cr characteristic fluorescent X-ray spectrum line in lunar surface was observed. The first map of Al element based on fluorescent X-ray spectra on lunar surface was also observed.

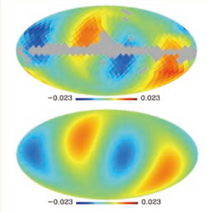
■ The alpha-induced X –ray spectrometer is one of the payloads of Chang'e-3 lunar rover of China's Lunar Exploration Project. As the only scientific facility on the arms of the lunar rover, the spectrometer irradiates the lunar surface and rocks with alpha particles and X-rays, and then analyses the chemical element composition of the sample from the scattered alpha particles, and fluorescent X-rays



The first map of Al element based on fluorescent X-ray spectra on lunar surface



A joint international research team discovered that some black holes which reached saturated luminosities above a certain accretion rate could be a new tool for estimating cosmological distances if they are properly identified by hard x-ray observations, in particular by the slope of their 2–10 keV continuum.



A research team led by Li Tibei at IHEP finds that the reported diploma of CMB (upper section) with the WMAP satellite is consistent with the systematic residuals (lower section) from observational data analysis.

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