Space Science in China
Current and Planed Missions

Ji WU, National Space Science Center, CAS

OUTLINES

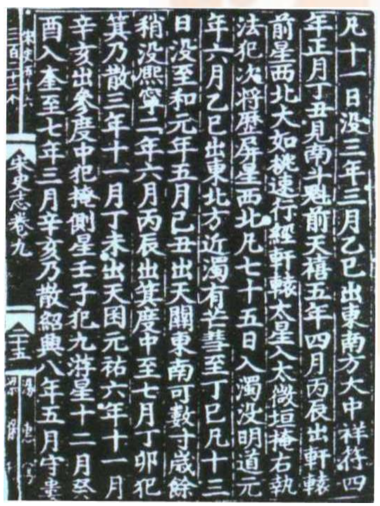
- Brief History of Space Observation in China
- Space Science in Modern Times in China
- New Initiative and Current Missions
- Selecting New Missions for 2020
- Remarks

Ancient Chinese Observation and Learning of Space

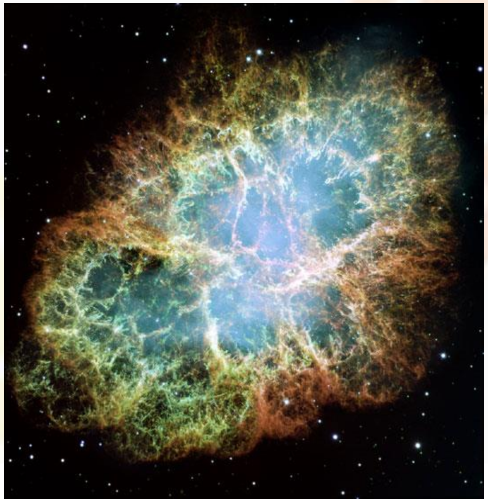
- Observation of Solar Eclipse:

  "*The Book of History: Yinzheng*" as the earliest observation record of solar Eclipse (2042 BC) in China

- Observation of Nova:
  - ✓ The oracle bones of Yin Dynasty Ruins (1300 BC) as the earliest records of Nova in the world "——Joseph Needham （李约瑟）
  - ✓ *"The Astronomy Part of the Records of Song Dynasty"*: Supernova Explosion (1054 AD)



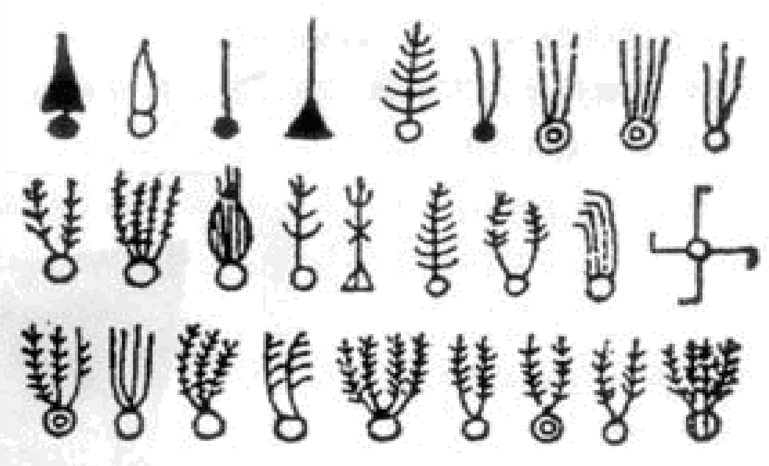
凡十一日没三年三月乙巳出東南方大中祥符四
年正月丁丑見南斗魁前天禧五年四月丙辰出軒轅
前星西北大如桃速行經軒轅太星入太微垣掩右執
法犯次將歷屏星西北凡七十五日入濁没明道元
年六月乙巳出東北方近濁有芒彗至丁巳凡十三
日没至和元年五月己丑出天關東南可數寸歲餘
稍没熙寧二年六月丙辰出箕度中至七月丁卯犯
箕乃散三年十一月丁未出天囷元祐六年十一月
辛亥出參度中犯掩側星壬子犯九游星十二月癸
酉入奎至七年三月辛亥乃散紹興八年五月守婁
宋史志卷九



Remnant: Crab Nebula

Ancient Chinese Observation and Learning of Space

- Observation of Comet:
  - ✓ Halley's Comet: two earliest observations (613 BC & 476 BC), Recorded in "*Spring and Autumn Annals*".
  - ✓ The 28 returns of Halley's Comet (240 BC~ 1910 AD) : all found in ancient Chinese books.
    - Observation from Halley: in 1682 AD, 76 years period
  - ✓ Ancient Chinese first pointed out that the direction of Comet tail was always against the sun.
  - ✓ No less than 500 records of Comets can be found in ancient Chinese books.

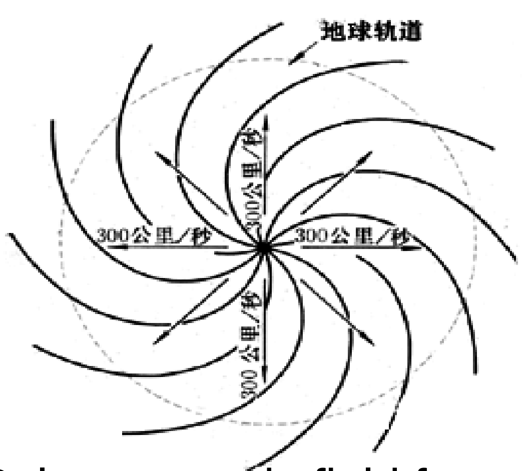


29 Comet pictures were found in the silk books unearthed from Hunan Mawang Dui in 1973.

Ancient Chinese Observation and Learning of Space

- Observation of Sun-Spots: the most complete records are found in China.
  - ✓ Observation: started from 28 BC, "1000 years earlier than the Western world"——Joseph Needham
  - ✓ Size: close to a "copperplate" or an "egg"…
  - ✓ The Sun God Bird images (3000 years ago): found in Chengdu Jinsha Relic (unearthed in 2001).

——It resembles the spiral structure of interplanetary magnetic field.

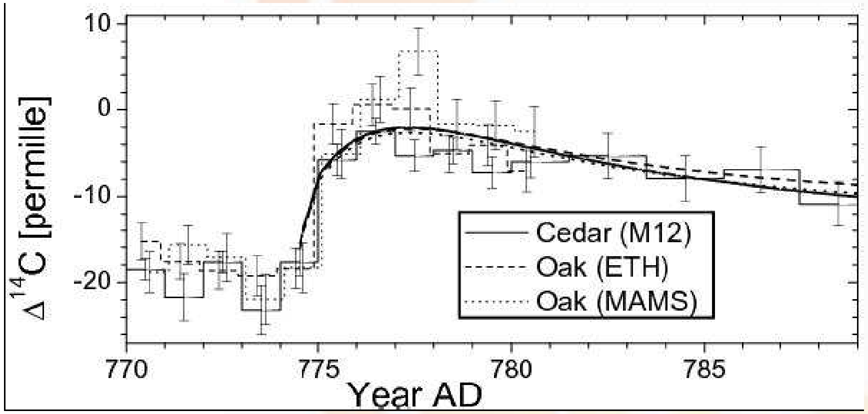


Solar magnetic field from modern text book

Solar beam pattern from Jin Sha site 3000 years ago

Ancient Chinese Observation and Learning of Space

- Auroras observation in China
  - 13,000 BC cave painting discovered
  - AD775 and many other records



The Solar Cosmic-Ray Origin for the Rapid ^{14}C Increase in AD775

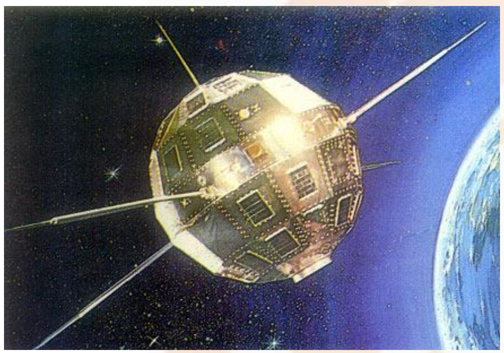
D. Zhou[1], C. Wang[1], R. Rutledge[2], Y. Sun[1], J. Liang[1], G. Zhu[1], S. Zhang[1], B. Zhang[1], P. Zhou[1], J. Wu[1]

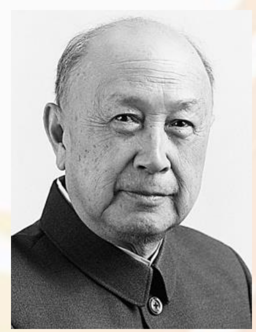
[1] *National Space Science Center, Chinese Academy of Sciences, Beijing 100190, China*

[2] *NOAA - Space Weather Prediction Center, Boulder, CO 80305, USA*

Early Days of Modern Chinese Space Program

- **First Chinese satellite was launched in 24 April, 1970**
  - ✓ **DFH-1: 173kg, 439-2384 km elliptical orbit**



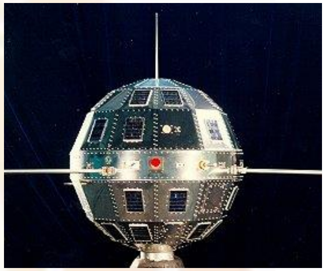


Qian, Jaw and Sun

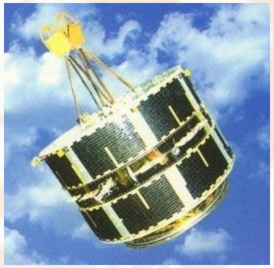
Early Days of Modern Chinese Space Program

- Space science instruments got fly opportunities

1971 SJ-1 High energy particles



1981 SJ-2 Geo-transfer orbit environment



1994 SJ-4 Single particle event

1999 SJ-5 Single particle event and microgravity

Space Science in Chinese Space Program

- Experiments onboard of the Chinese manned space program

  2001 SZ-2 First space astronomy test/space life science, space material science, atmosphere detector

  2002 SZ-3 Moderate-Resolution Imaging Spectro-radiometer/Material science/Atmosphere

  2002 SZ-4 Multi-Mode Microwave Sensors

  2008 SZ-7 Space material science

  2011 SZ-8 Space life science

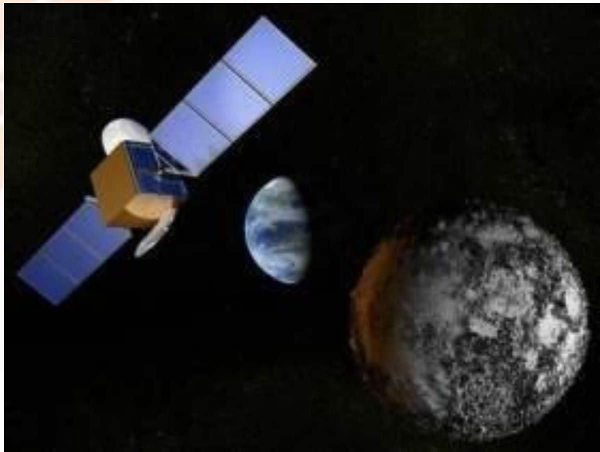
Space Science in Chinese Space Program

- **Lunar Exploration Program**

  2007 CE-1, Lunar orbiter, 8 scientific payloads onboard: Microwave radiometer, γ/X ray spectrometer, Laser altimeter, High energy particle detector, plasma detector, CCD stereo camera and Optical interferometric spectrometer

  2010 CE-2, Lunar orbiter, 8 scientific payloads onboard

  2013 CE-3, Lander and rover with 4 scientific payloads on each



Geospace Double Star Program

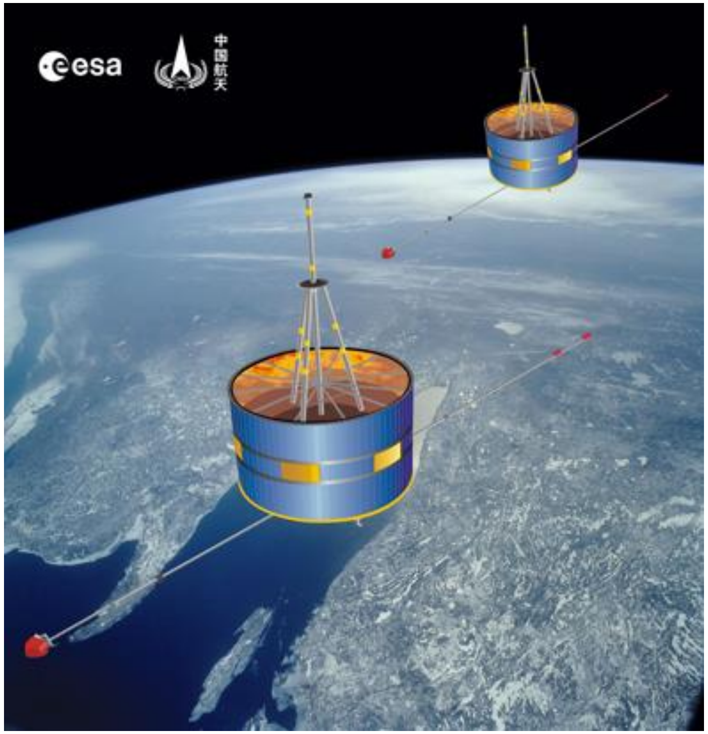
- **The Geospace Double Star Program -** The first Chinese space science satellite mission, which consists of two satellites, TC-1 and TC-2, launched on 30 December 2003 and 25 July 2004 into equatorial and polar orbits respectively. The operations of TC-1 terminated in Oct. 2007 and TC-2 terminated in Aug. 2008.

TC-1 Equatorial 28º

565-78,960km

TC-2 Polar 90º

684-38,216km



New Initiative in Space Science

2010.3.31

No.105 Executive Meeting of the State Council

- **Approved Innovation 2020 of Chinese Academy of Sciences to take the lead to implement Strategic Priority Program**
- **Space Science is one of the major program in the Strategic Pioneer Program**

Strategic Priority Program on Space Science

Strategic Priority Program on Space Science

Main Goal

Through independent and co-operational science missions, dedicating to deepen our understanding of universe and planet earth, seeking new discoveries and new breakthroughs in space science.

The Hard X-ray Modulation Telescope (HXMT)

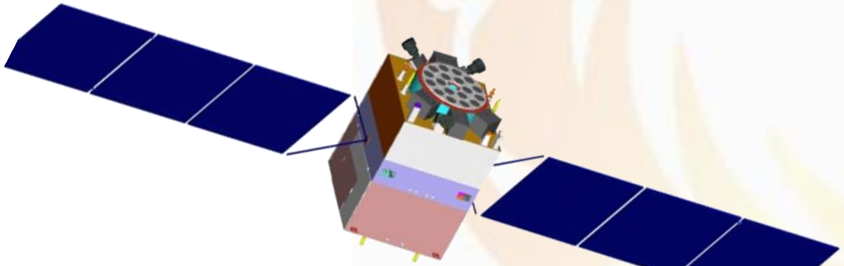
➢ Scientific Objectives:

✓ Large area X-ray survey

- Cosmic and Galactic diffuse X-ray background
- Discover new transients and monitor bright sources

✓ Broad band (1-250 keV) and large collection area (5000 cm^2@100 keV) pointed observations of high energy objects

- dynamics and radiation near BH horizons of stellar mass



Satellite Facts:

✓ Mass: ~2800 kg

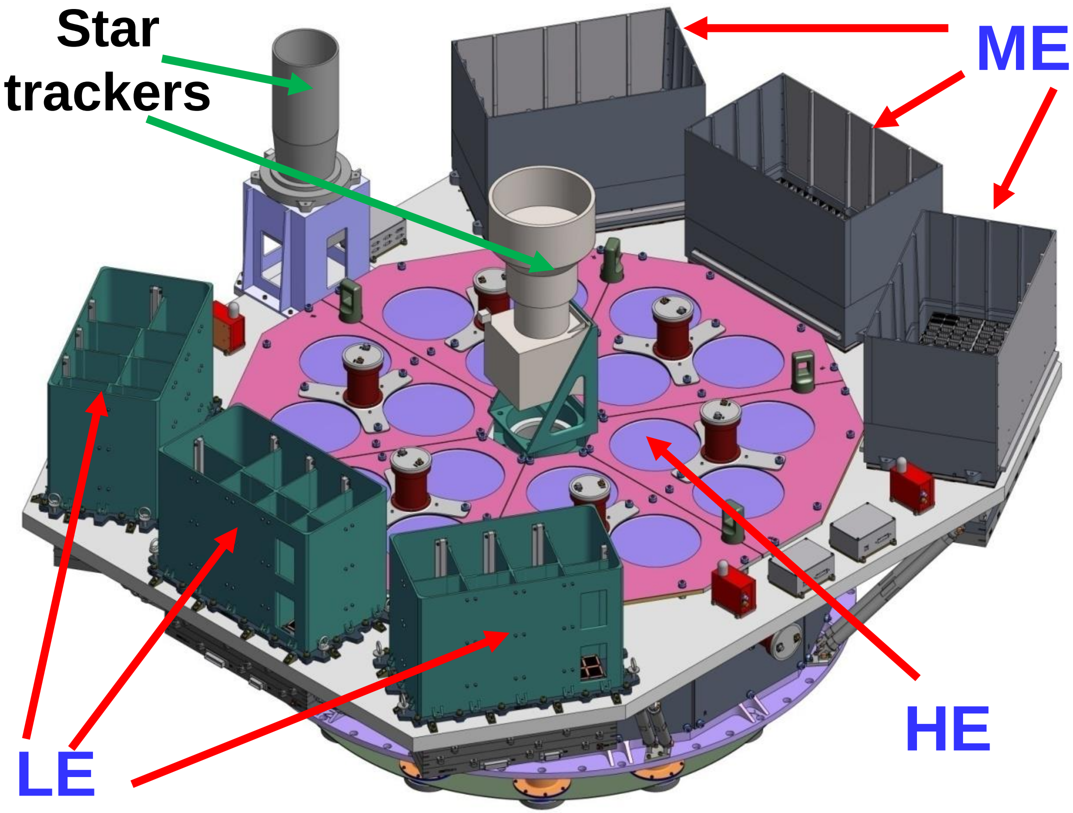
✓ Orbit: 550 km, 43°

✓ Attitude: 3-Axis Stabilized

✓ precision 0.1 °

✓ Lifetime: 4 yrs

The Hard X-ray Modulation Telescope (HXMT)



High Energy Telescope (HE):
NaI/CsI, 20-250 keV, 5000 cm^2

Medium Energy Telescope (ME):
Si-PIN,5-30 keV, 952 cm^2

Low Energy Telescope (LE):
SCD,1-15 keV, 384 cm^2

Officially approved in March 2011

Entered Engineering Model Phase in 12/2011

The qualification model will be finished soon

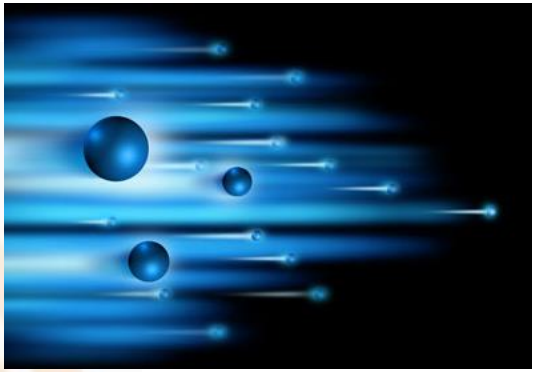
Planned launch time: Late 2015

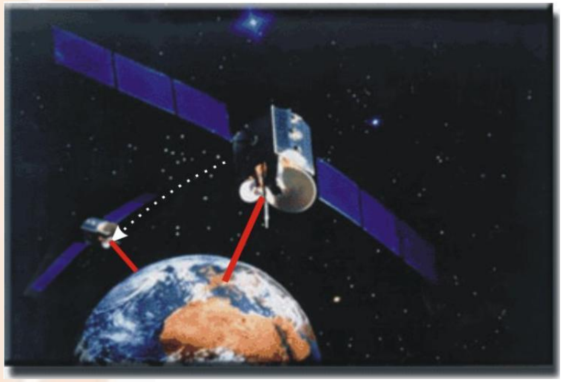
QUantum Experiments at Space Scale (QUESS)

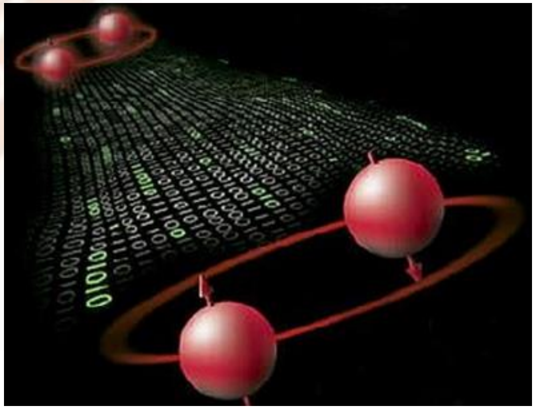
➢ Scientific Objectives:

- ✓ Implementation of long-distance quantum communication network based on high-speed quantum key distribution(QKD) between satellite and the ground station, to achieve major breakthroughs in the realization of space-based practical quantum communication.
- ✓ Quantum entanglement distribution and quantum teleportation on space scale, fundamental tests of the laws of quantum mechanics on global scale.

	Parameter
Orbit	600km
Inclination	97.79°
Mass	~620kg



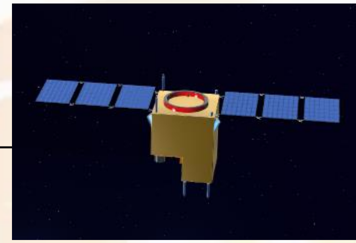


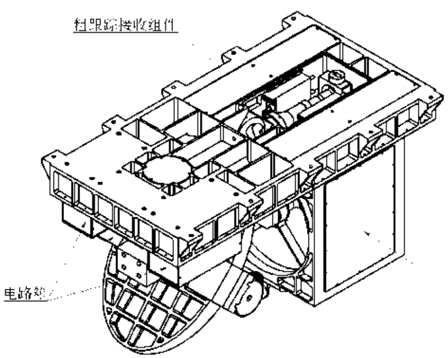


QUantum Experiments at Space Scale (QUESS)

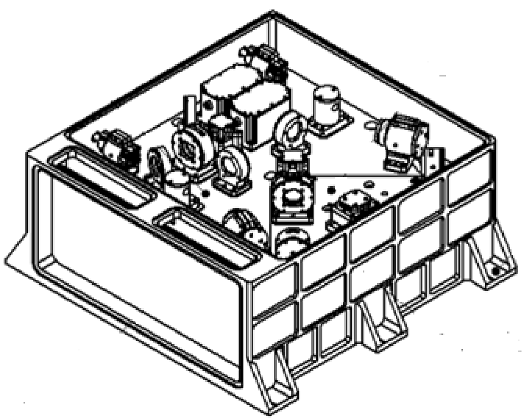
➢Payloads:

- **PDR completed in 11/2012**
- **Now in Engineering Model Phase**

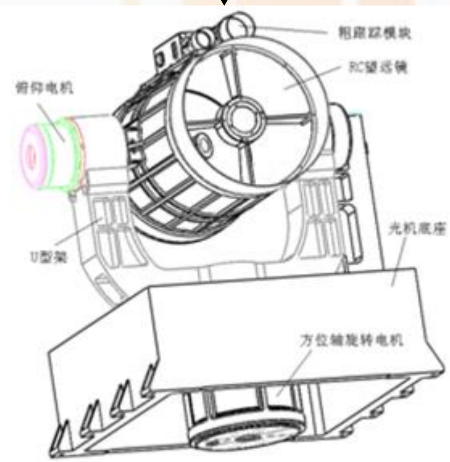




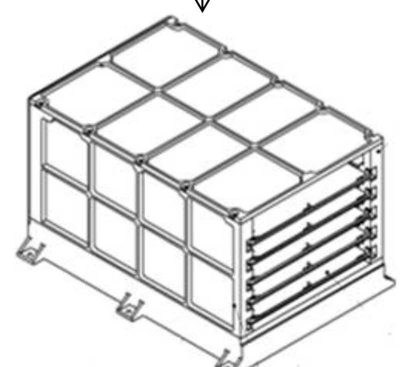
Quantum key communication equipment



Quantum entanglement source



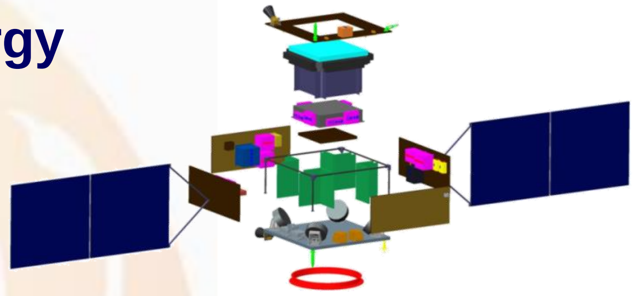
Quantum entanglement transmitter

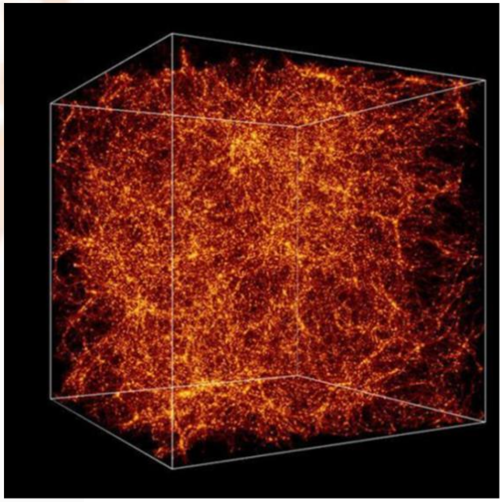


Experimental control and processing system

DArk Matter Particle Explorer (DAMPE)

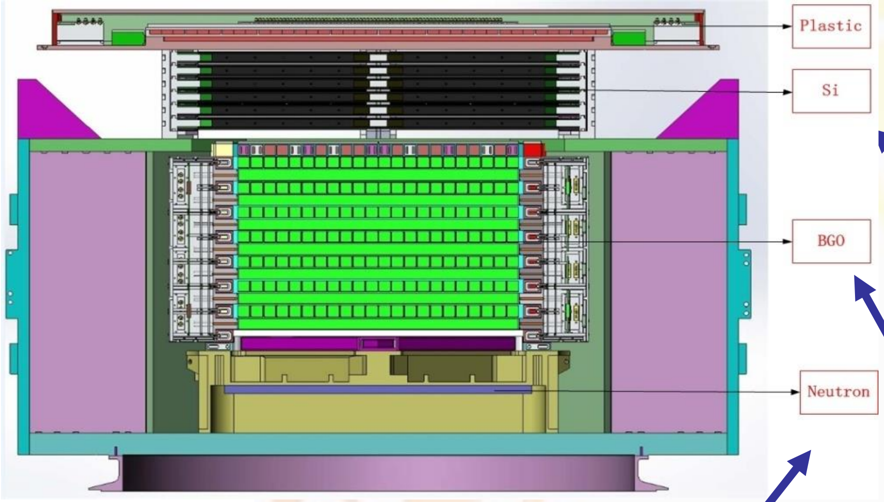
- **Scientific Objectives:**
  - ✓ **Find and study dark matter particle through high-resolution observation of high energy electron, gamma-ray spectrum and its space distribution**
  - ✓ **Study the origin of cosmic ray through observation of high energy electron spectrum and anisotropy above TeV**
  - ✓ **Study the propagation and acceleration mechanism of cosmic ray through the observation of its heavy ion spectra**





DArk Matter Particle Explorer (DAMPE)

- **Payload:**



Plastic scintillation hodoscope array

(to detect the particle direction and to discriminate gamma-rays from particles)

Si-Pin array

(to detect the charge of the injected particle)

BGO Calorimeter

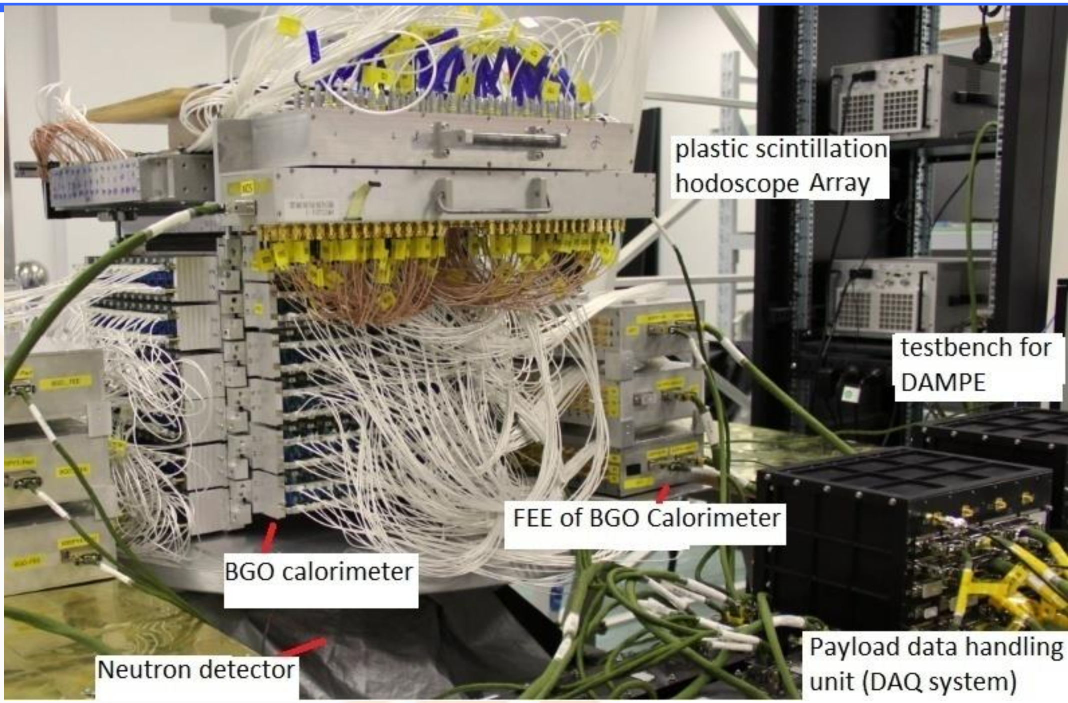
(14 layers, to measure the energy of the incident particles and to discriminate electrons from protons)

Neutron detector

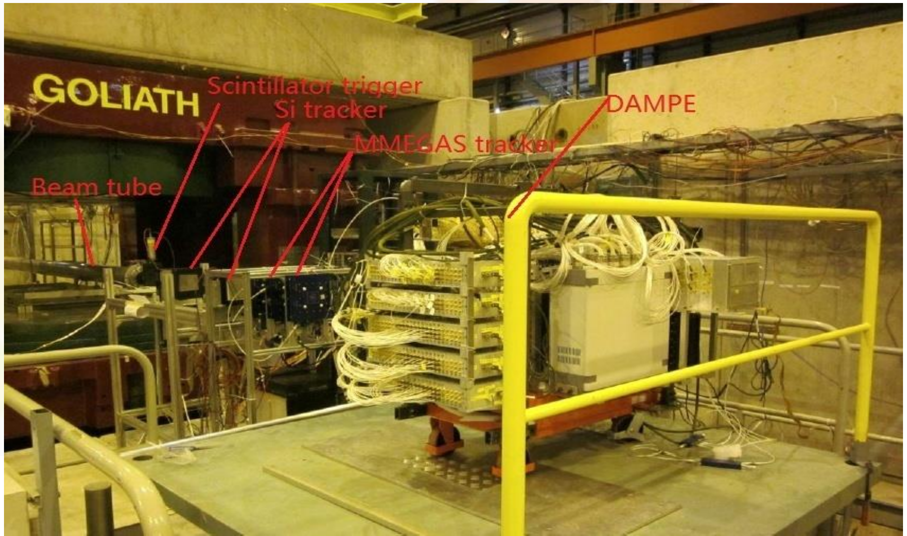
(Scintillation detector , to improve the discrimination of electrons from protons)

DArk Matter Particle Explorer (DAMPE)

- **Progress:**
  - **Prototype design of DAMPE 07/2012**
  - **Beam test of DAMPE in CERN 10/2012**
  - **PDR completed 04/2013**
  - **Now in Engineering Model Phase**



Cosmic test in Nanjing

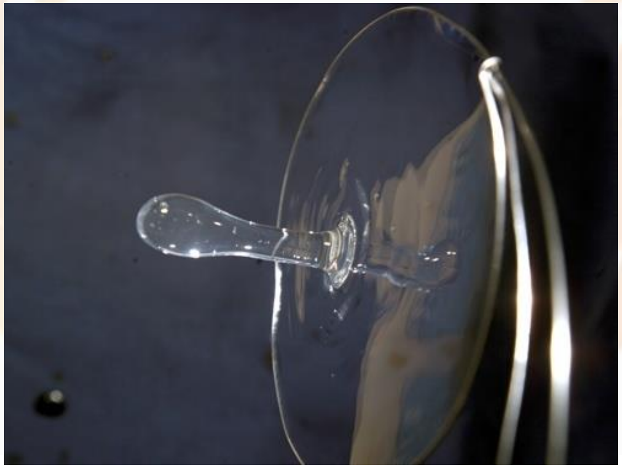
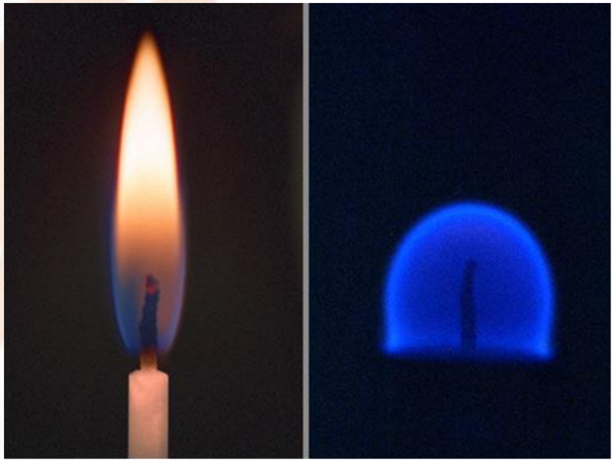


Beam test in CERN

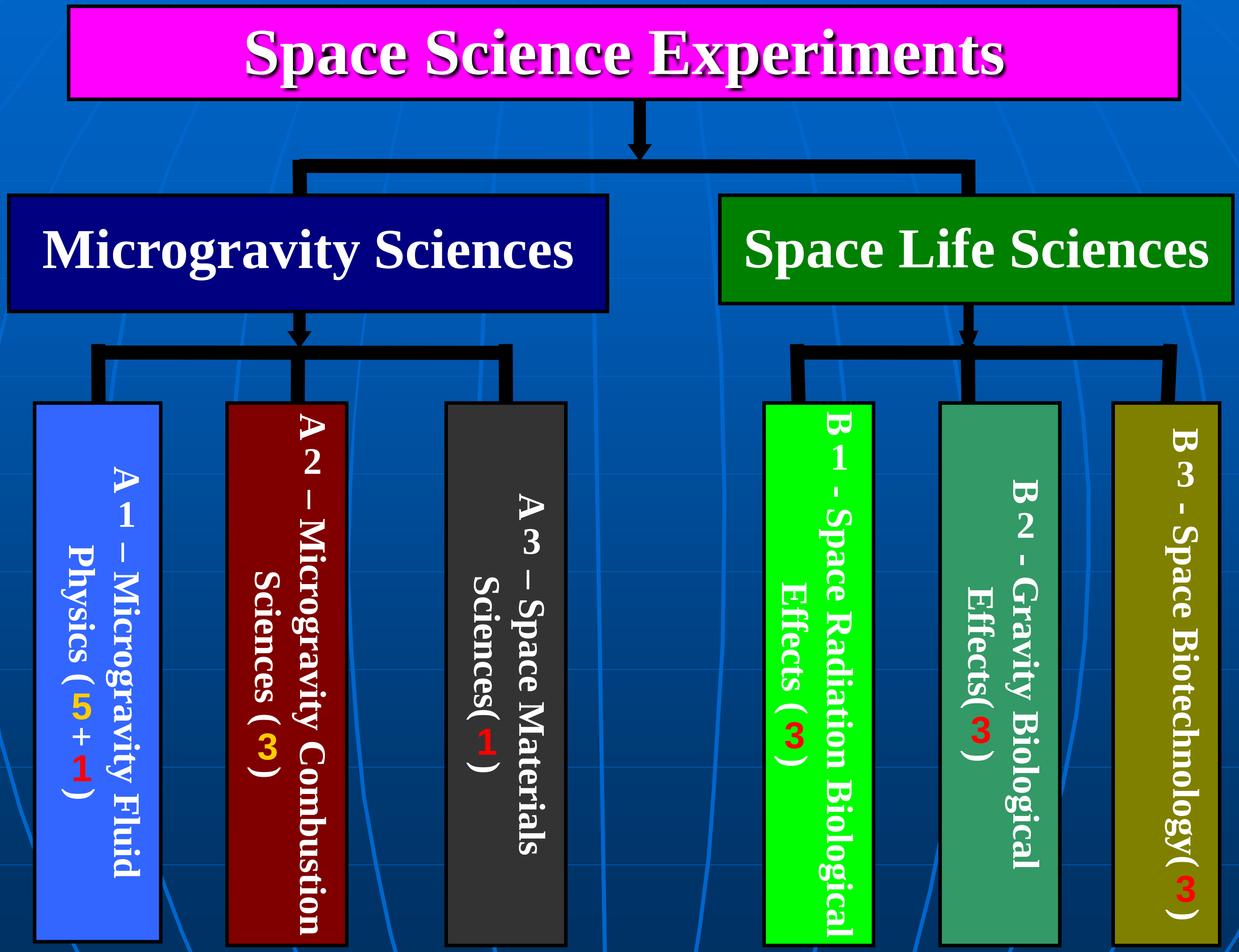
Recoverable Satellite for Microgravity and Space Life Sciences (SJ-10)

SJ-10 is expected to make breakthroughs in

- ✓ The basic laws of motion for matter
- ✓ High performance material preparation
- ✓ Mechanism of combustion
- ✓ Biological effects of gravity or space radiation
- ✓ Space biotechnology

Recoverable Satellite for Microgravity and Space Life Sciences (SJ-10)

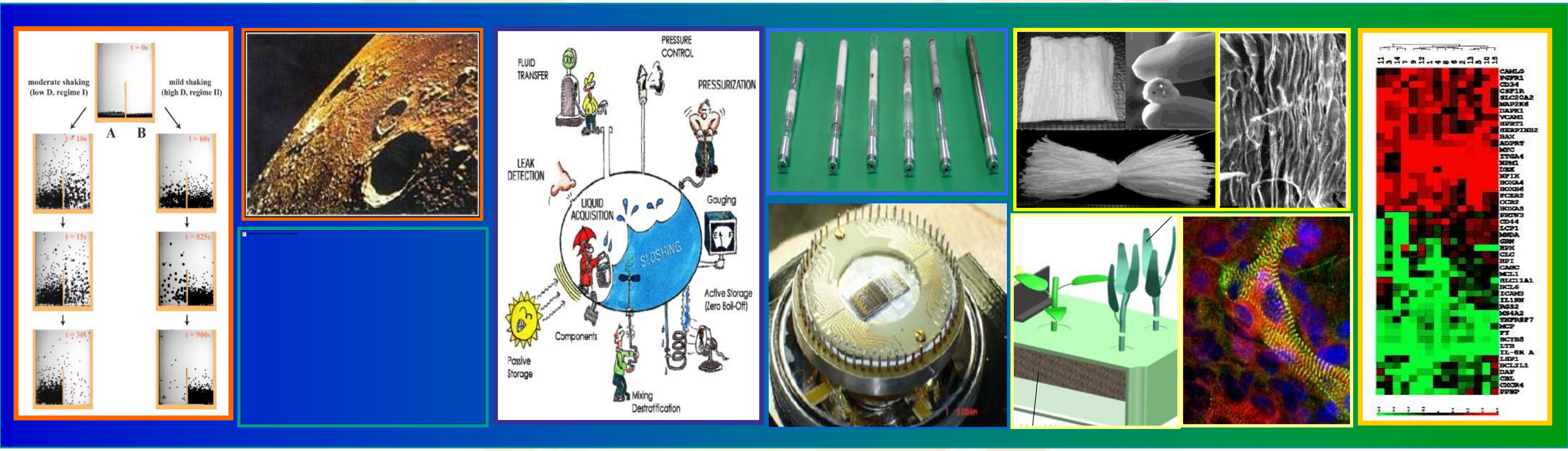


8 experiments aboard the orbit capsule + 11 aboard the reentry capsule

Recoverable Satellite for Microgravity and Space Life Sciences (SJ-10)

➢Progress:

- ✓ System Design Review (SDR) completed by the end of 2012
- ✓ Preliminary Design Review (PDR) completed in Sep. 2013
- ✓ Now in Engineering Model Phase



Selecting New Missions for 2020

- New budget will be allocated to us from 2016-2020 according to the 13th 5 years plan
- Selection of new missions will be done in two steps:

1. To select mission candidates to have enhanced feasibility study, 2011, 2013
2. To select from these candidates for engineering phase 2015

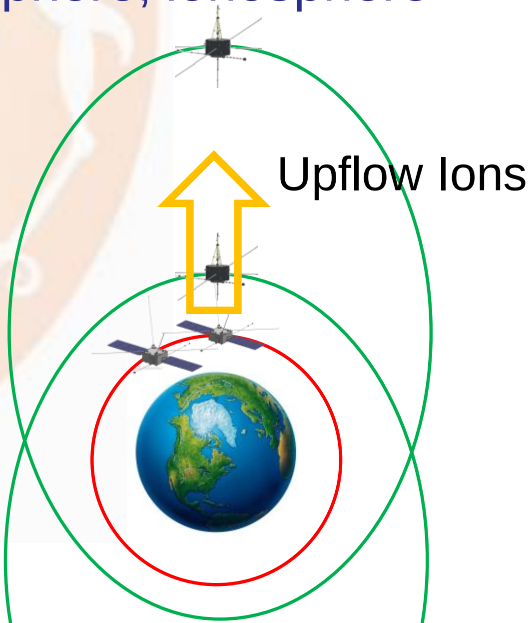
Magnetosphere—Ionosphere—Thermosphere Coupling Exploration (MIT)

➢ **Scientific Objectives：**

- ✓ Investigate the origin of the upflow ions and their acceleration mechanism
- ✓ Understand the impact of the outflows ions on magnetic storm development
- ✓ Characterize the ionosphere and thermosphere storm driven by magnetic storm
- ✓ Discover the key mechanism for the magnetosphere, ionosphere and thermosphere coupling

Period_MA/ Period_ITA=9:1

Spacecraft	ITA	ITB	MA	MB
inclination	90°	90°	90°	90°
perigee	500 km	500 km	2 Re	2 Re
apogee	1500 km	1500 km	8 Re	8Re

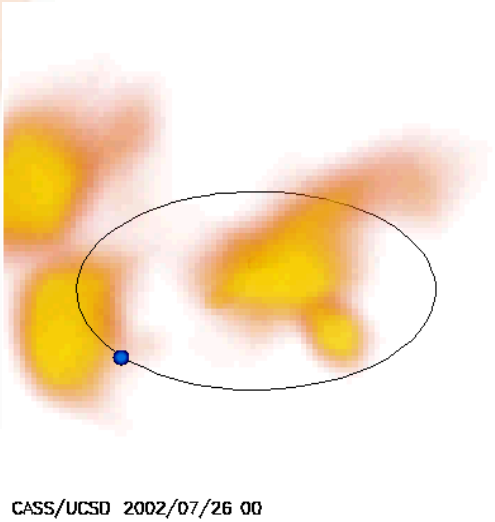


Solar Polar Orbit Radio Telescope (SPORT)

➢Science Objectives:

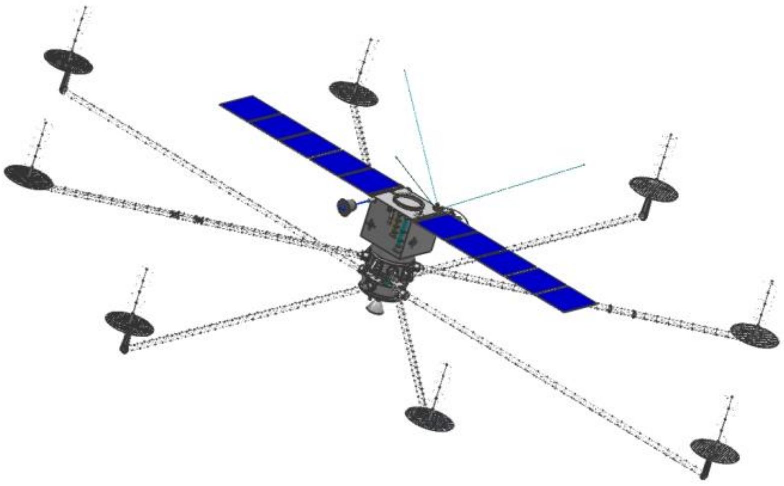
- Characterize CME propagation through, and interaction with, the inner heliosphere
- Understand the acceleration, transport and distribution of energetic particles in the corona and heliosphere
- Discover solar high-latitude magnetism associated with eruptions and solar cycle variation
- Investigate the origin and properties of the fast solar wind.

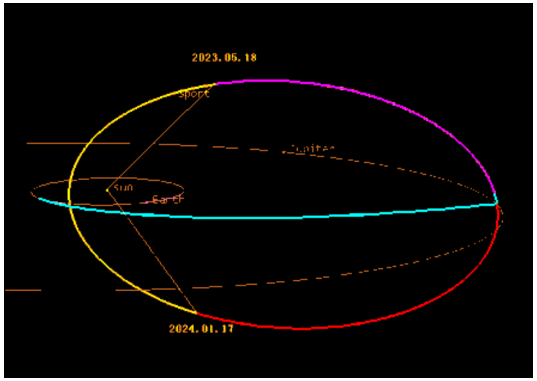
Orbit realization	solar polar orbit (with multiple gravity assist)
Inclination	>60 °
perihelion	0.7AU
aphelion	3AU



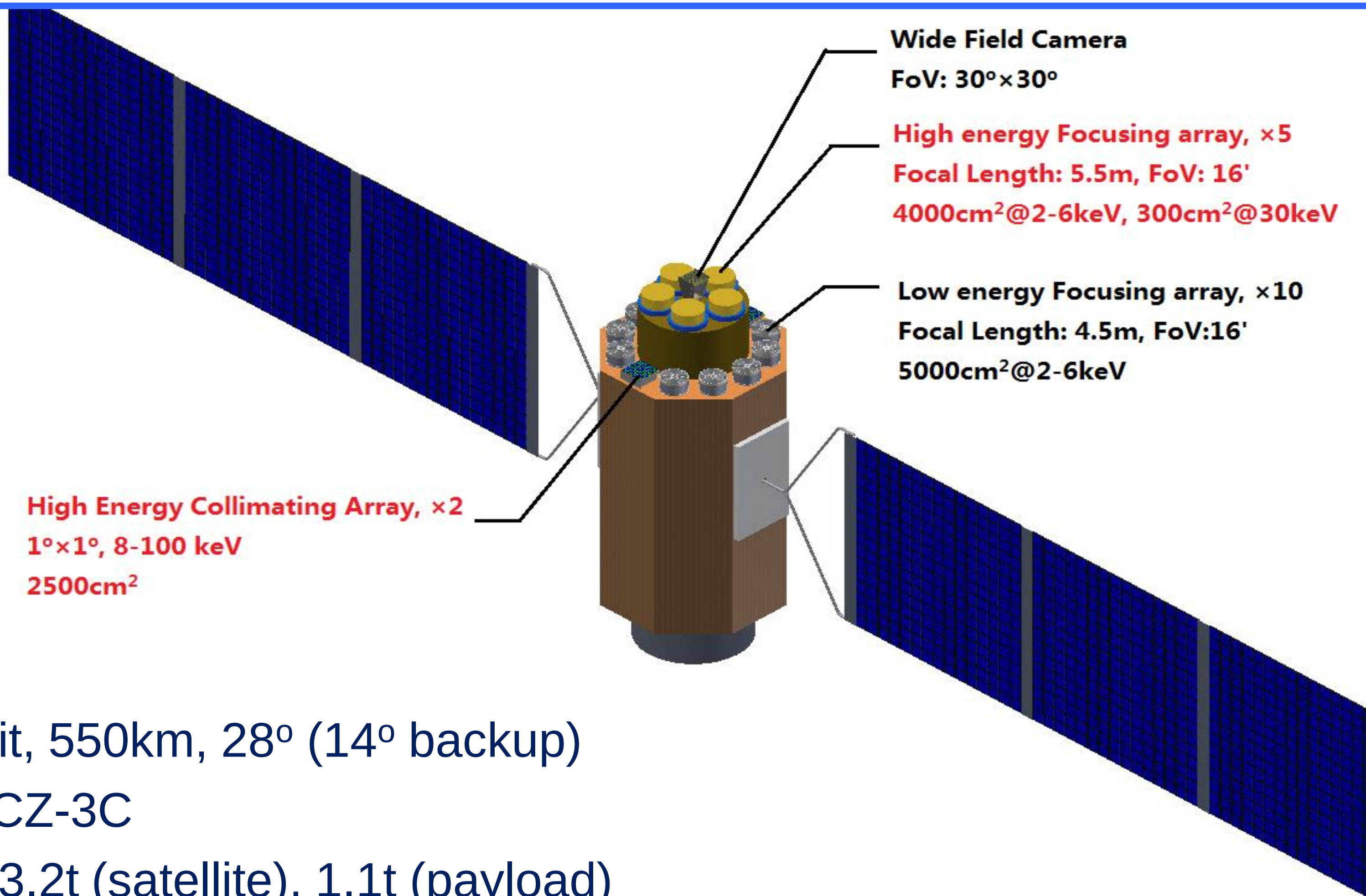
Solar Polar Orbit Radio Telescope (SPORT)

- **Payloads:**
  - ✓**Imaging Payloads**: Synthetic aperture radio imager, Heliospheric Imager, Coronagraph, Solar magnetograph, Solar ultraviolet imager (121.6 and 131 nm)
  - ✓**In-situ Measurement Package**: High energetic particle detector, Heavy ion composition detector, solar wind plasma detectors, fluxgate magnetometer, low frequency wave detector, solar radio burst spectrometer





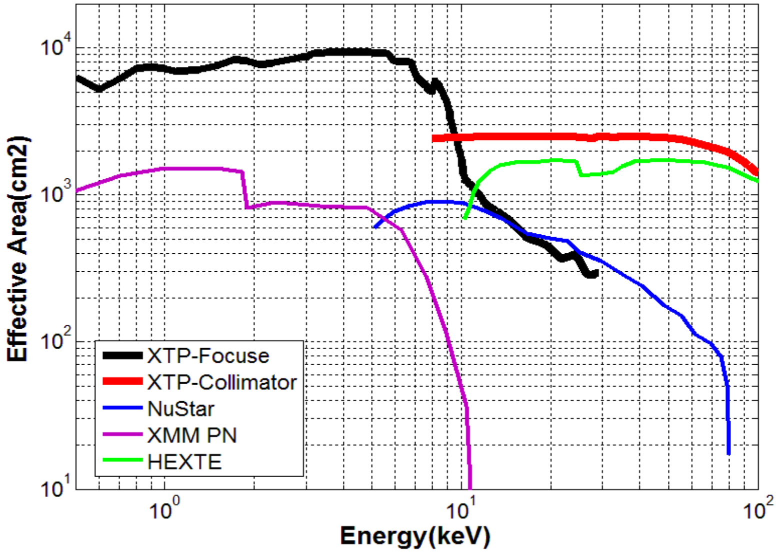
X-ray Timing and Polarization mission (XTP)



- Circular orbit, 550km, 28° (14° backup)
- Launcher : CZ-3C
- Total mass:3.2t (satellite), 1.1t (payload)
- Power: 1.3kW(platform), 1kW(payload)
- Launch time: ~2020
- Lifetime: 5 years (expected 10years)

XTP science

- Scientific objectives of XTP
  - 1 singularity (Black Hole)
  - 2 compact stars (Neutron Star, Magnetar)
  - 3 extremes (Physics under extreme gravity, density and magnetism)
- With a detection area of ~1 m^2 and a combination of various types of X-ray telescopes, XTP is expected to make the most sensitive temporal and polarization observations with good energy resolution in 1-30 keV.
- XTP will open a new window using its powerful capability of polarization observations (MDP 3%@1 mCrab, 1e6 s).



Effective area comparison between XTP and other missions

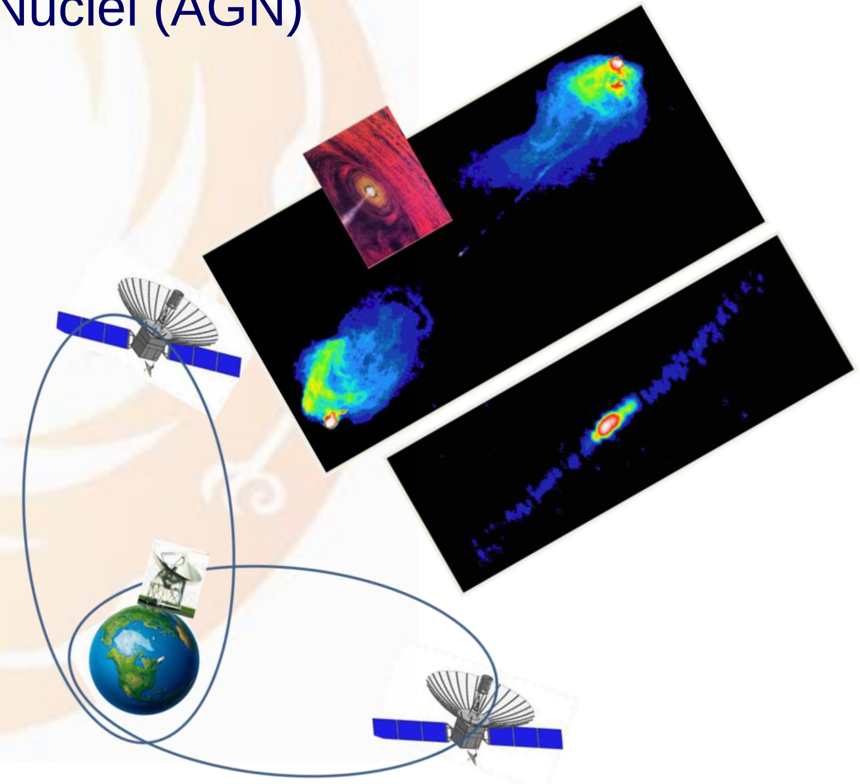
Space Millimeter VLBI Array

➢ Main Scientific Objectives:

- High-resolution imaging of emission structure surrounding super-massive black hole (SMBH) to study
  - SMBH Shadow (e.g. M87)
  - Disk structure & dynamics, SMBH mass (water mega-masers)
  - Astrophysical Jet in Active Galactic Nuclei (AGN)
- Formation and evolution of stars

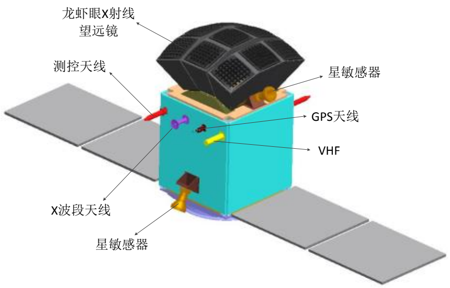
➢ Specifications:

- Two 10-m (in diameter) space antennas
- Three frequency bands (8, 22 & 43 GHz)
- Dual polarization (LCP/RCP)
- Data rate (1.2 Gbps , or 2.4 Gbps)
- Angular resolution: 20 micro-arc-second
- Optimized orbits for a better (u,v) coverage
  - Apogee: 60,000 km
  - Perigee: 1,200 km
  - Inclination: 28.5 deg
- Life time: 3 year



Einstein-Probe (EP)

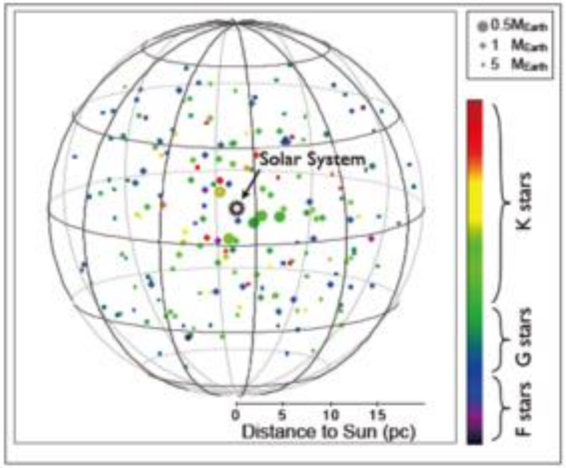
- **Science Objectives:** **Time-domain census of soft X-ray transient and variable sources in the universe**
  - Discover quiescent black holes over all astrophysical mass range and other compact objects via high-energy transients
  - Discover and locate electromagnetic-wave sources of gravitational-wave events by synergy with new GW detectors
  - Systematic census of soft X-ray transients and variability of known X-ray sources over wide time-scales at high cadence
- **Satellite Specifications / Payloads:**
  - Orbit: 600km, circular, 30° inclination
  - Mass: 380 kg
  - Life time: 5 year
  - Payloads: a wide-field (60° x60°) monitor based on established multi-pole optics (MPO) technology, with fast alerting capability

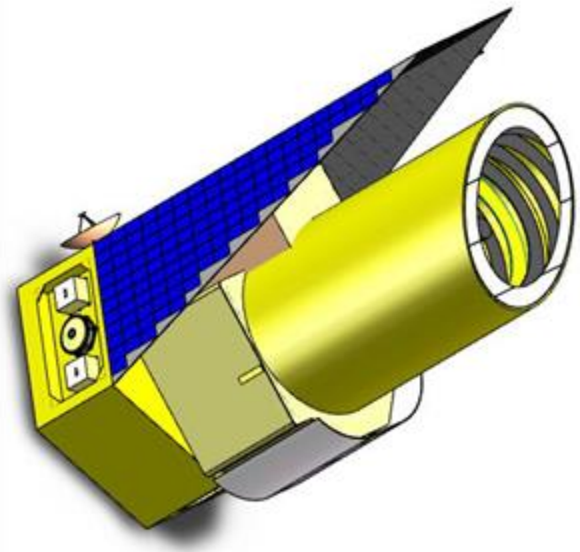


Search for Terrestrial Exo-Planets(STEP)

- **Satellite Specifications / Payloads:**
  - Orbit: Solar-earth L2 Halo
  - Mass: 500 kg   Life time: 5 year
  - Payloads: TMA design, Astrometric Telescope

    (Primary Aperture: 1.2m, f=50m, FOV: 0.44°)





➢ **Highlights**

✓ Extremely-high-precision(1uas) astrometric space mission(10^{-5} pixel centroiding)

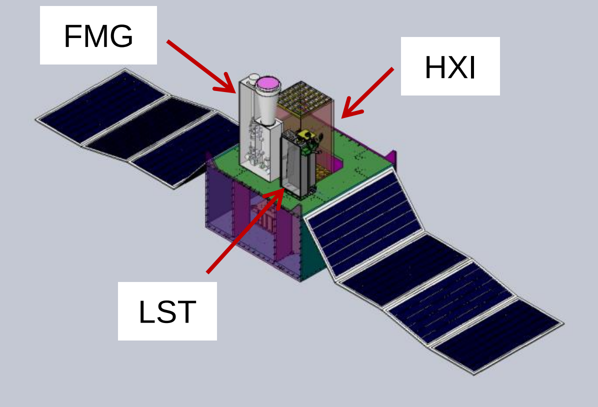
✓ Able to detect the habitable planets at earth criterion

✓ Get the actual planetary masses and the full orbital geometry for all components of the detected planetary system

Advanced Space-borne Solar Observatory (ASO-S)

➢ Science Objectives:

- ✓ Simultaneously observe the full disc vector magnetic field, non-thermal images of hard X-rays, and initiation of CME
- ✓ Understand the causality between magnetic field and flares, magnetic field and CMEs, flares and CMEs

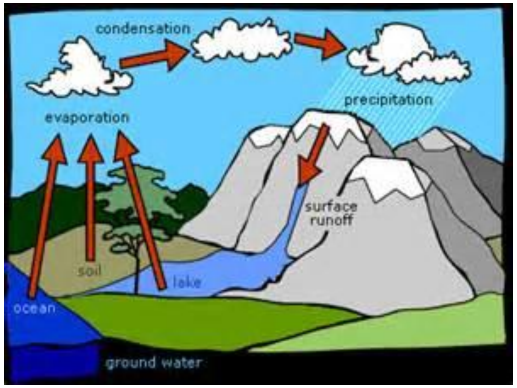


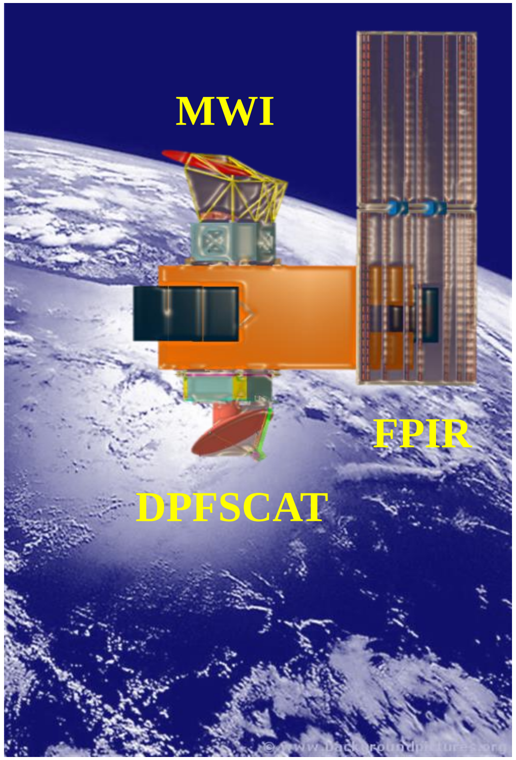
➢ Payloads:

Payload	Objective
Full-disc vector MagnetoGraph (FMG)	Magnetic field
Lyman-alpha Solar Telescope (LST)	CMEs
Hard X-ray Imager (HXI)	Solar flares

Water Cycle Observation Mission (WCOM)

- **Science Objectives:**
  - Better understanding status and process of the Earth's water cycle system under the global change environment, by simultaneous and fast measurement of a set of water cycle key parameters (soil moisture, ocean salinity, ocean surface evaporation, snow water equivalent, frozen/thaw, atmospheric vapor…)
- **Approach:**
  - Combination of multi-frequency (6.6~90GHz), full-polarized, and passive-active microwave measurements
- **Highlights/Advantages**
  - Simultaneous acquisition of multiple key parameters for synergetic understanding of water cycle status and process
  - Simultaneous measurement of main and ancillary variables to support more accurate retrieval of the target parameters





Remarks

- *China is paying more attention to space science.*
- *The goals are very challenge. However, the science outputs are highly expected.*
- *China should make adequate contribution in this area while the economy is continuously developing.*
- *International cooperation is welcome and very much encouraged for all the missions under studies.*


Thank You!