Sputnik-1 60yrs

Space Weather

—— History and Current Status

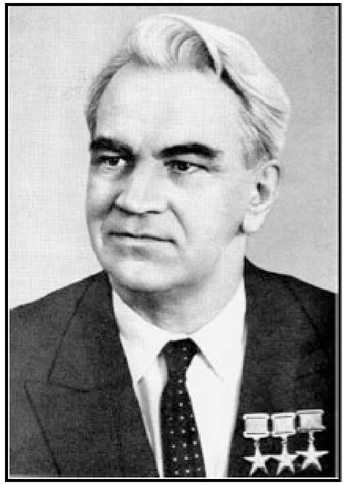
Ji Wu
National Space Science Center, CAS

Oct. 3, 2017

Contents

1.Beginning of Space Age and Dangerous Environment

Space Age



Kai'erdishi

Korolev

"All the News That's Fit to Print"

The New York Times.

LATE CITY EDITION

SOVIET FIRES EARTH SATELLITE INTO SPACE; IT IS CIRCLING THE GLOBE AT 18,000 M. P. H.; SPHERE TRACKED IN 4 CROSSINGS OVER U. S.

HOFFA IS ELECTED TEAMSTERS HEAD; WARNS OF BATTLE

COURSE RECORDED

Navy Picks Up Radio Signals—4 Report Sighting Device

560 MILES HIGH

Visible With Simple Binoculars, Moscow Statement Says

Device Is 8 Times Heavier Than One Planned by U.S.

FAUBUS COMPARES HIS STAND TO LEE'S

ARGENTINA TAKES EMERGENCY STEPS

SATELLITE SIGNAL BROADCAST HERE

Ex-Premier Mollet Accepts Bid To Form a New French Cabinet

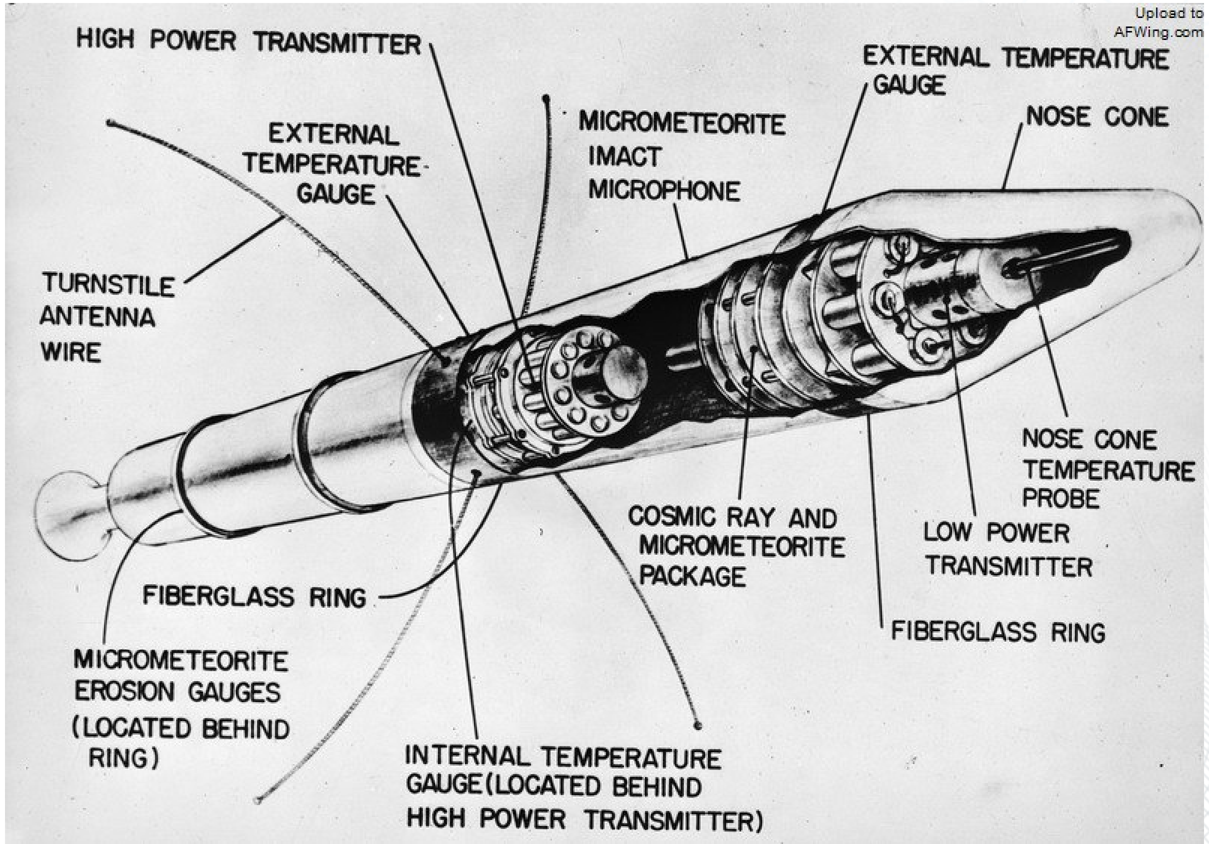
City Sifts Charge That Schupler, Brooklyn Councilman, Sold a Job

Warsaw Crushes New Protest; Clubs, Tear Gas Rout Students

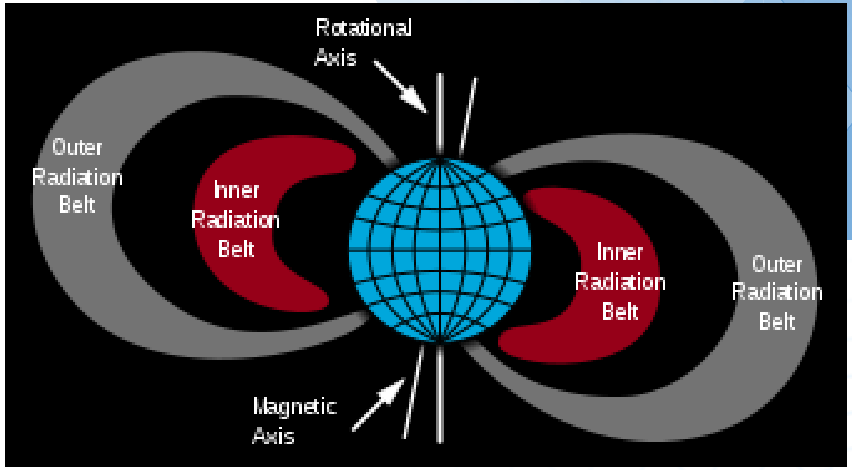
Oct. 4, 1957, humanity‘s first artificial satellite, Sputnik-1, has launched, ushering in the Space Age.

Space Age

Explorer 1 was the first satellite of the United States, launched on Jan 31, 1958, with scientific object to explore the radiation environment of geospace.



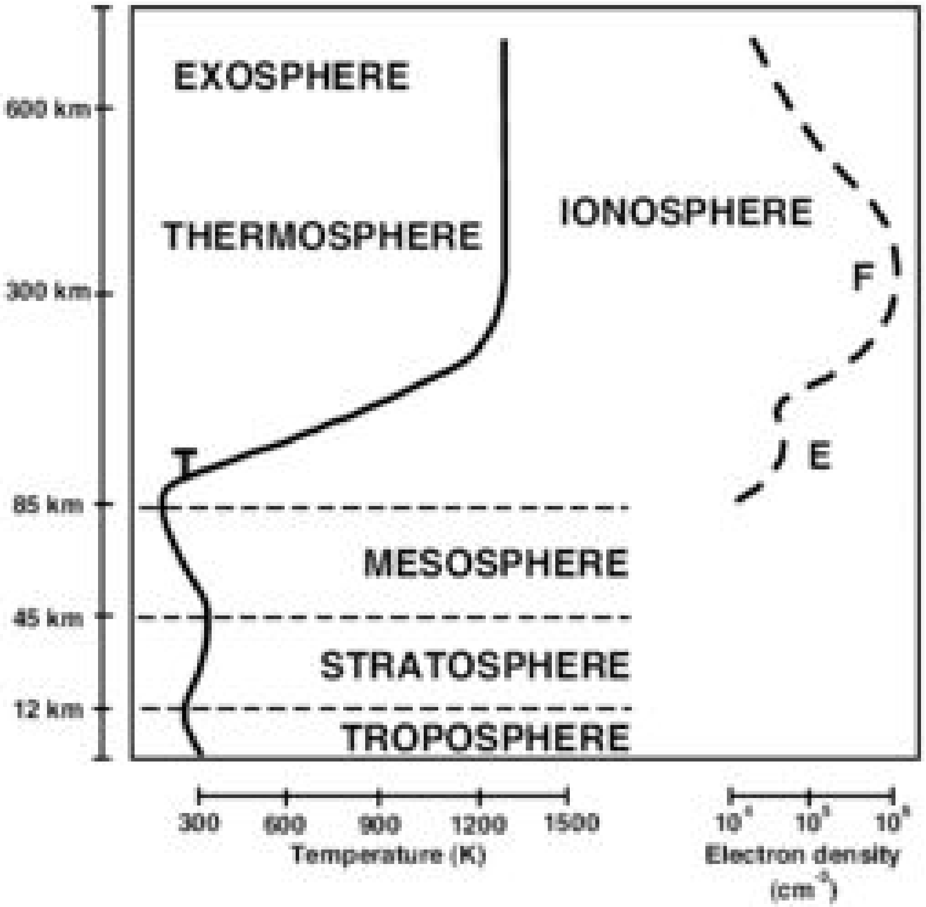
Unknown Space Environment

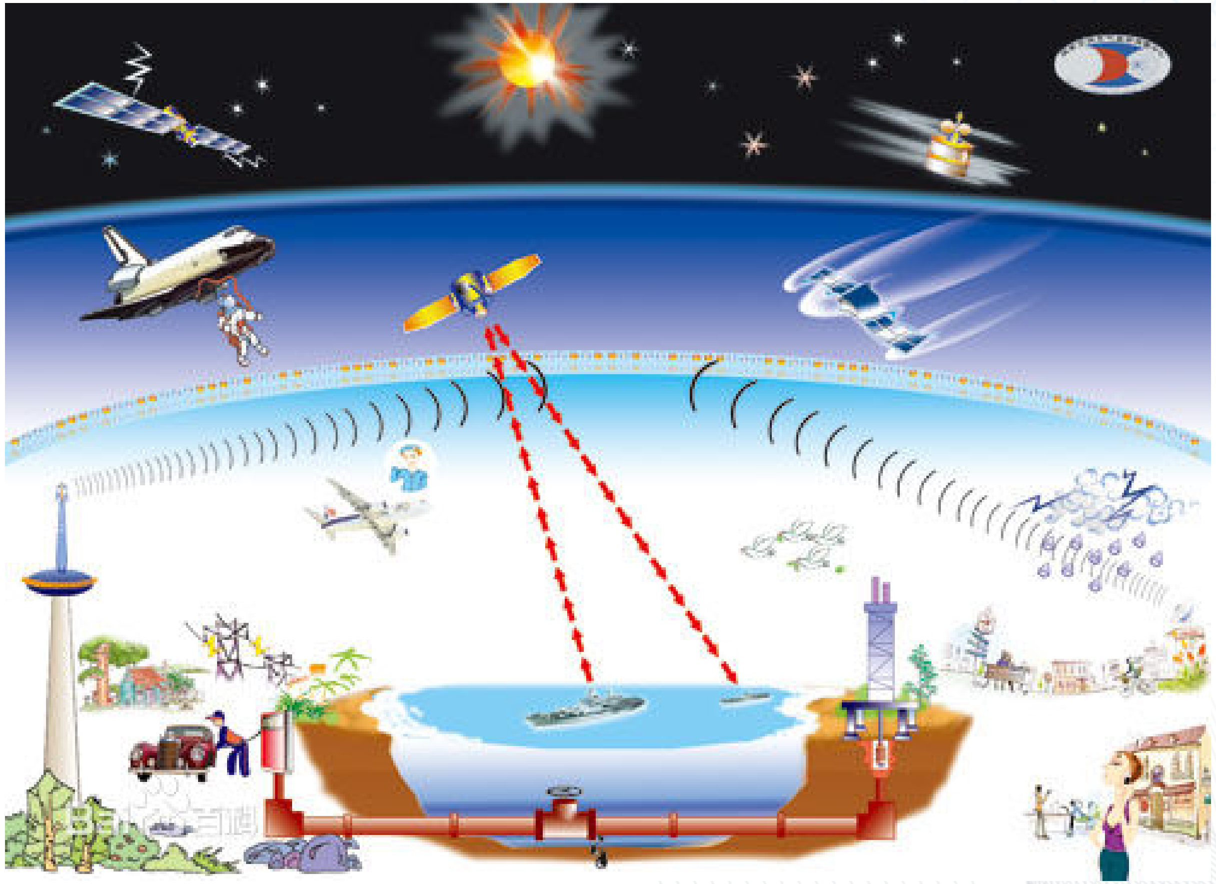


- Sputnik-2 (Nov 3, 1957) detected the Earth's outer radiation belt in the far northern latitudes, but researchers did not immediately realize the significance of the elevated radiation because Sputnik 2 passed through the Van Allen belt too far out of range of the Soviet tracking stations.

- Explorer-1 detected fewer cosmic rays in its orbit (which ranged from 220 miles from Earth to 1,563 miles) than Van Allen expected.

Space Age - unknown and dangerous space environment

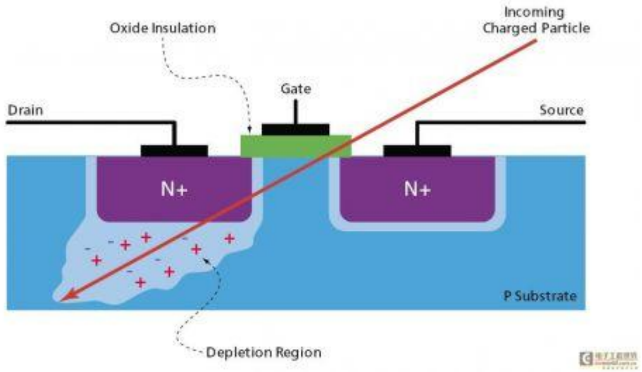


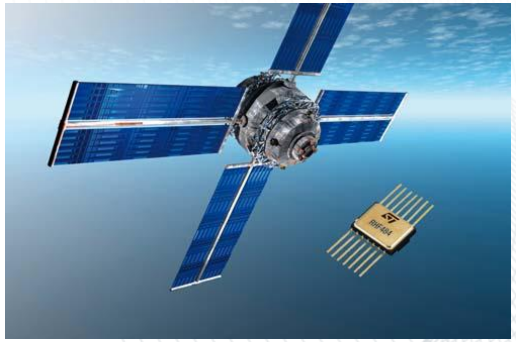


Satellite failures due to the unknown and dangerous space environment

Particle Radiation！

- Statistics show that the space radiation environment is one of the main causes of satellite failure.
- The space radiation environment caused about 2,300 satellite failures of all the 5000 failure events during the 1966-1994 period collected by the National Geophysical Data Center.
- Statistics of the United States in 1996 indicate that the space environment caused more than 40% of satellite failures in 1958-1986, and 36% in 1986-1996.



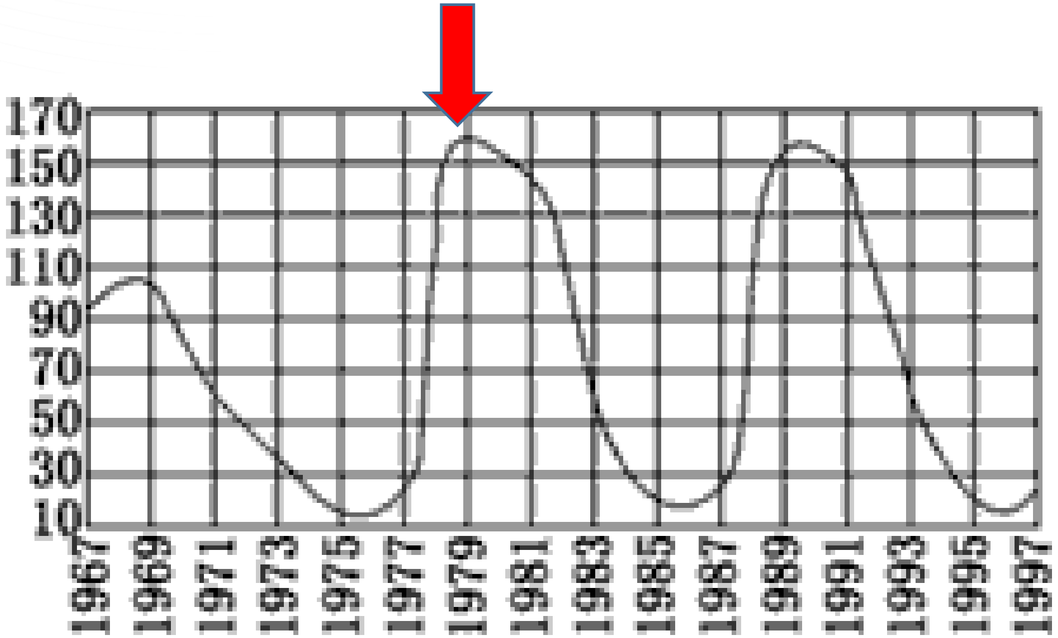


Space Environment speeded up the falling down of the Skylab

Magnetic Field and Atmosphere！

In 1979, the Skylab space station succumbed to the long-term effects of atmosphere drag and plunged back to earth.

Sunspot number



Environment can be very serious! 1989 Geomagnetic Storm

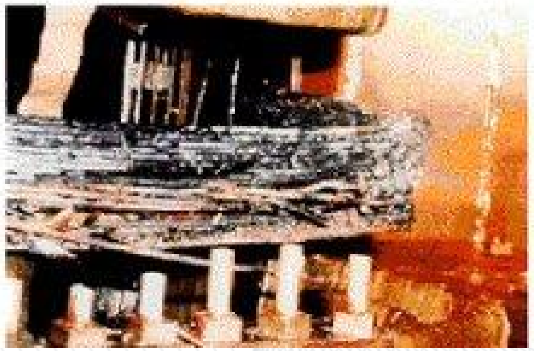
- A severe geomagnetic storm struck Earth on March 13, 1989. It occurred during solar cycle 22 and caused a nine-hour outage of Hydro-Québec's electricity transmission system.
- This storm bringing down the Galaxy 4 satellite, halting news transmissions and electronic pagers across North America for days.

Photograph of the aurora of March 13, 1989, taken from, NY

Thousands of users lost contact from Galaxy 4 Comm. Sat.

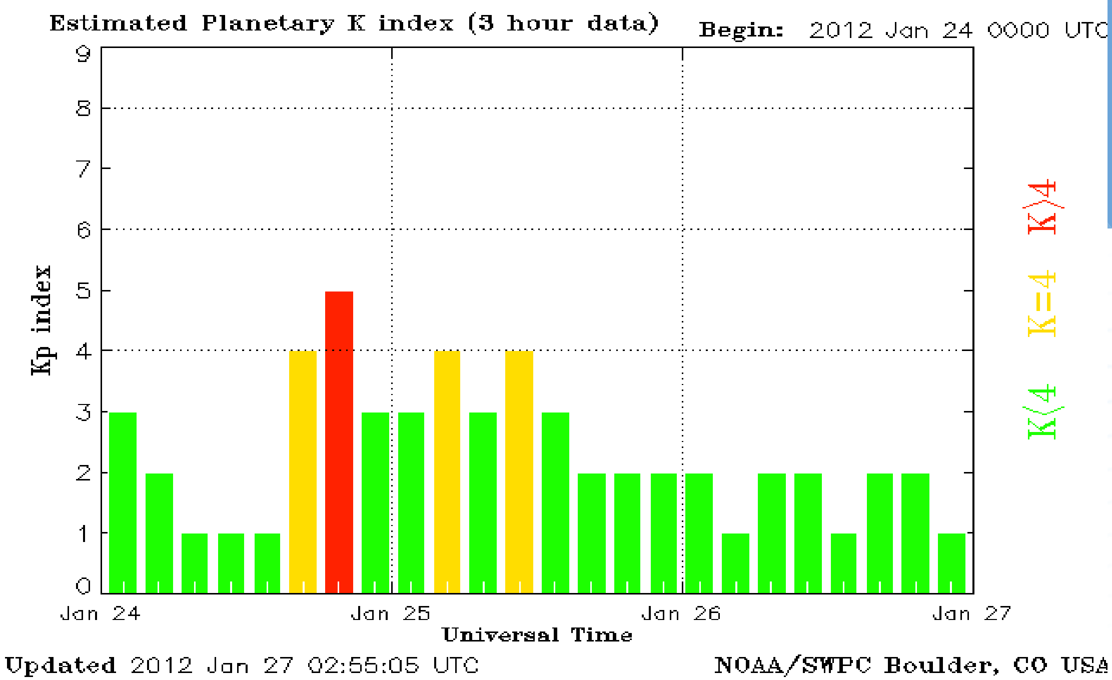
PJM Public Service
Step Up Transformer

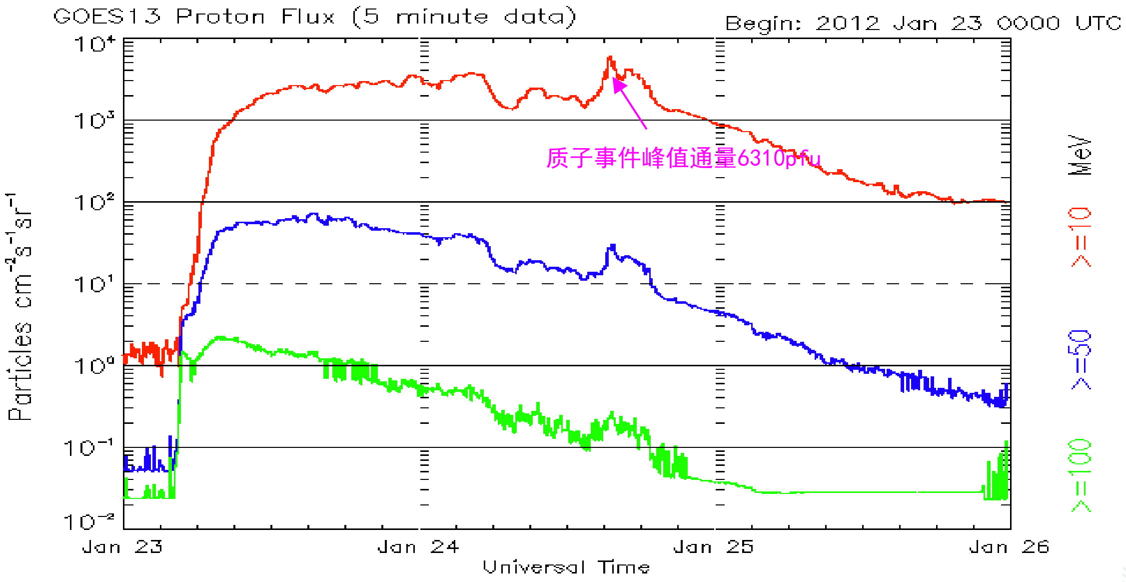
Severe internal damage caused by the space storm of 13 March, 1989

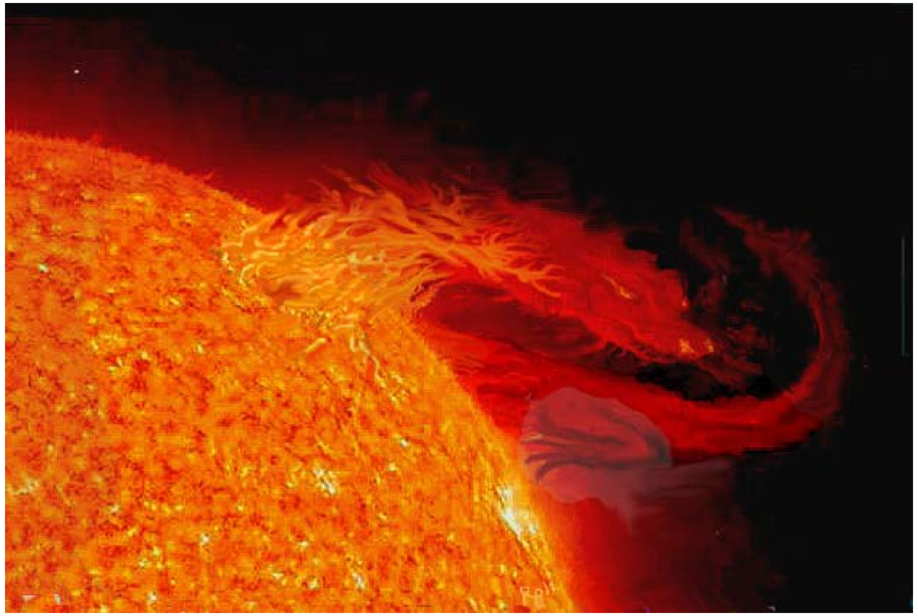


China Dragon Event

- AR1402 bursted a M8.7 flare with solar proton event on **Jan 23 in 2012**. The flux of solar proton event reached 6310pfu, high-speed CME reached earth in 1.5 days and caused the geomagnetic disturbance.



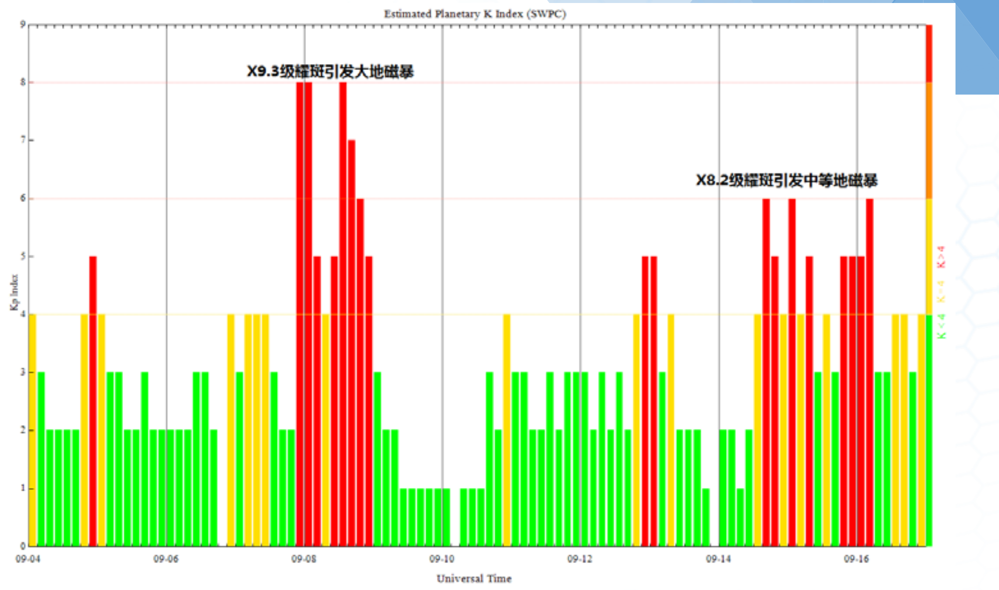


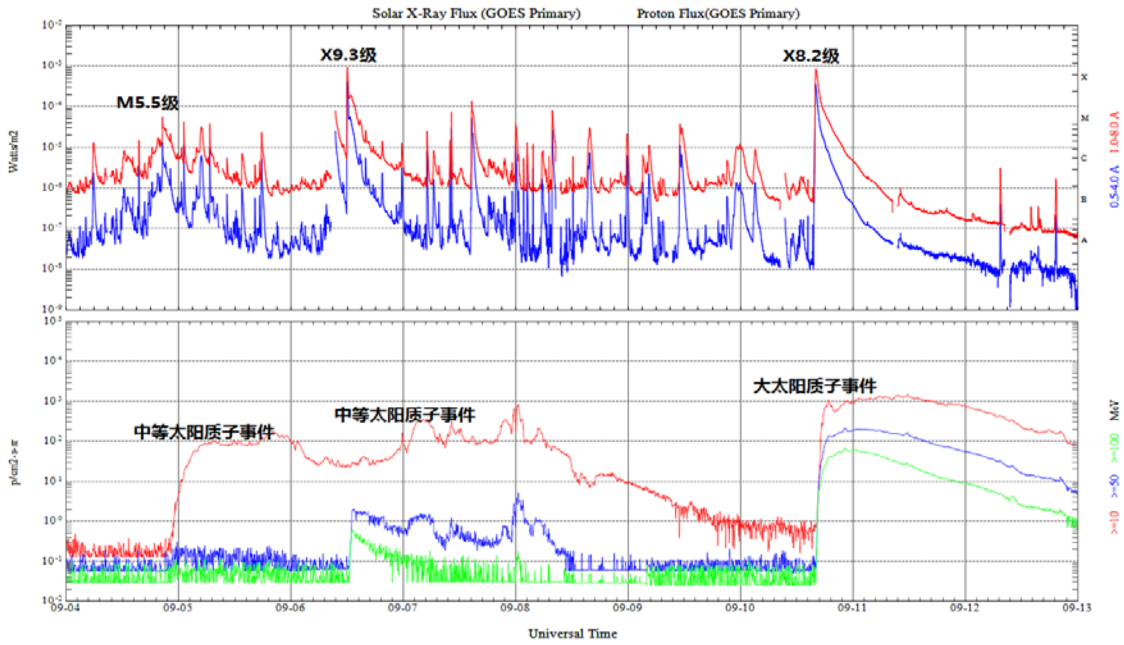


Hungry Ghost Festival Event

- At 7:53 in the evening of September 6, 2017, a large flare (X9.3) triggered solar proton events and CME. It was the strongest solar activity since 2005, and fired the first shot of a new solar storm.

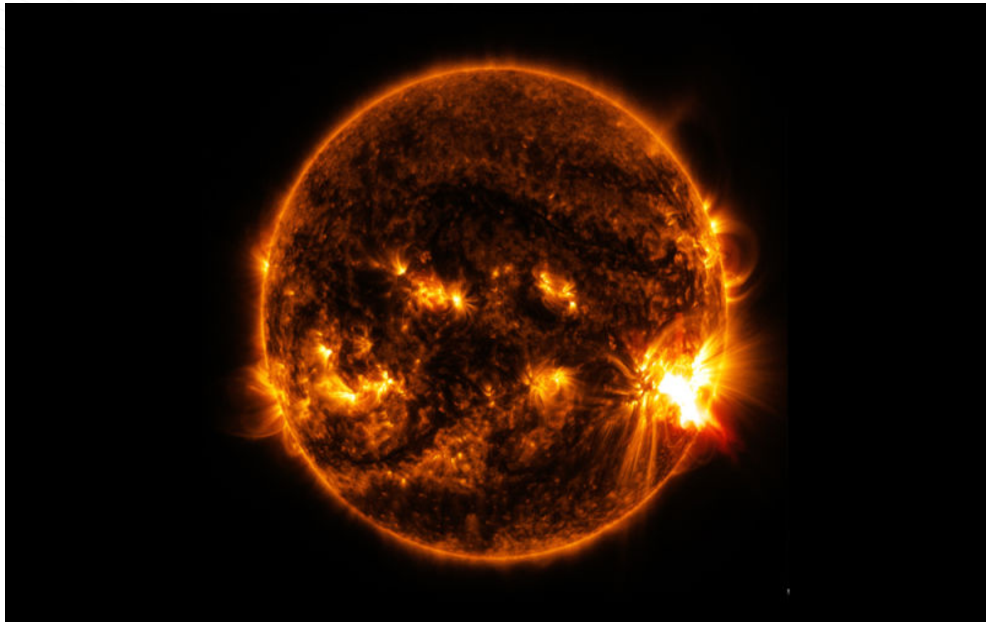
- The second day of this event coincides with the traditional festival – ‘Hungry Ghost Festival’, so the name of this great event was named as ‘Hungry Ghost Festival Event’.





中国科学院国家空间科
National Space Science Ce

The important fact is:
We have be in space for only 60 years, nevertheless the Sun was there for several billions years already!



We never know if we will get a much stronger Solar Storm tomorrow!

Artist's concept depicting energetic particles from solar super flares raining down on the early Earth.

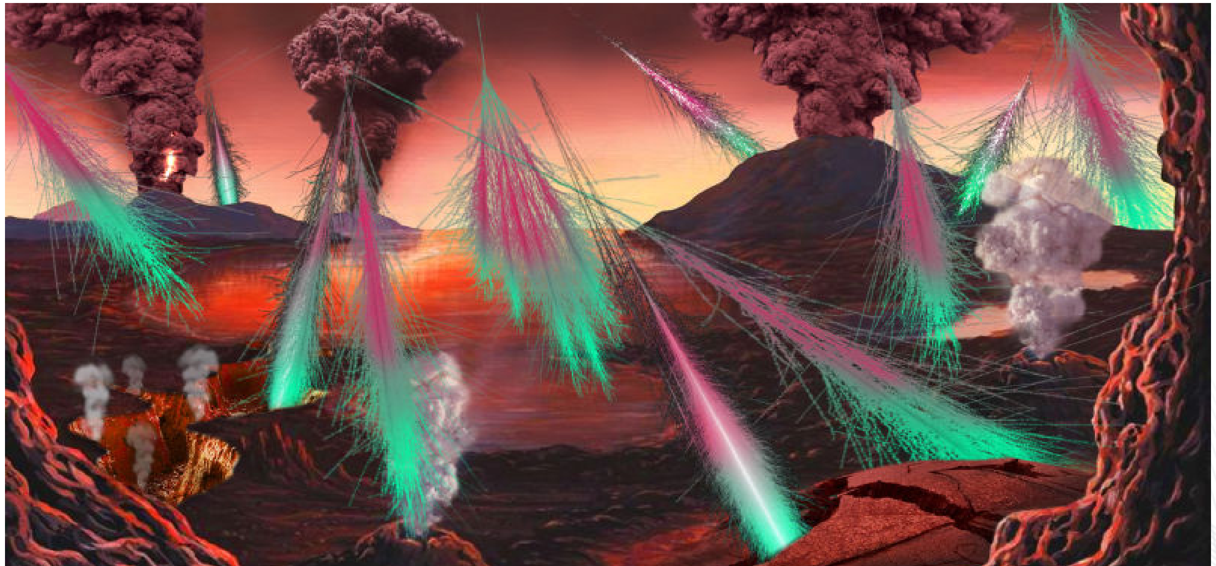
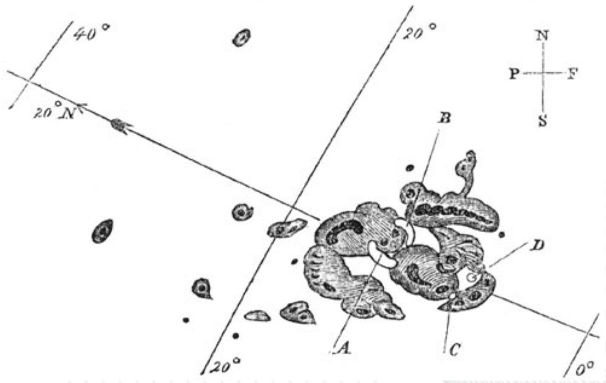


Image via Vladimir Airapetian

The Carrington Event

A solar coronal mass ejection hit Earth's magnetosphere and induced one of the largest geomagnetic storms on record, September 1–2, 1859.

- Telegraph systems all over Europe and North America failed;
- Southern auroras were observed as far north as Queensland, Australia

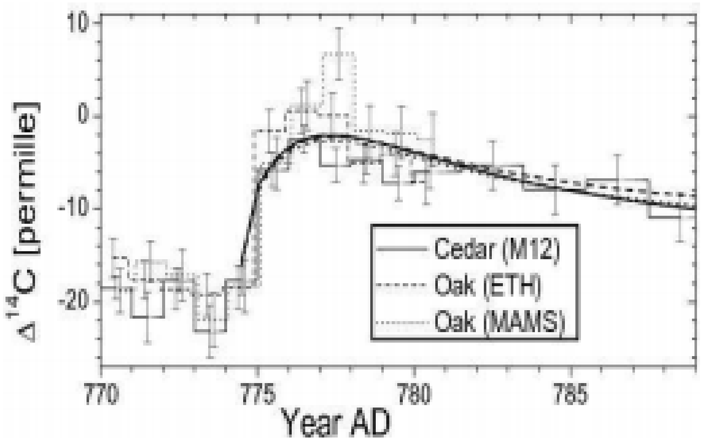


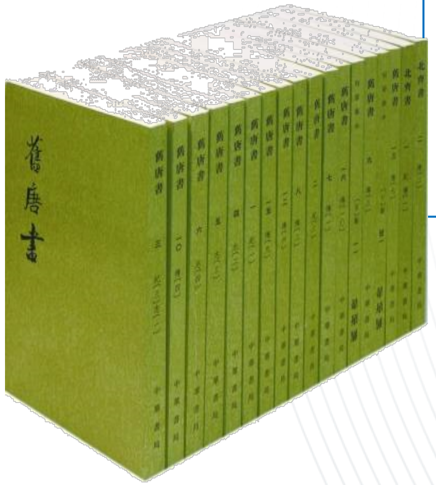
Sunspots of September 1, 1859,
as sketched by Richard Carrington.

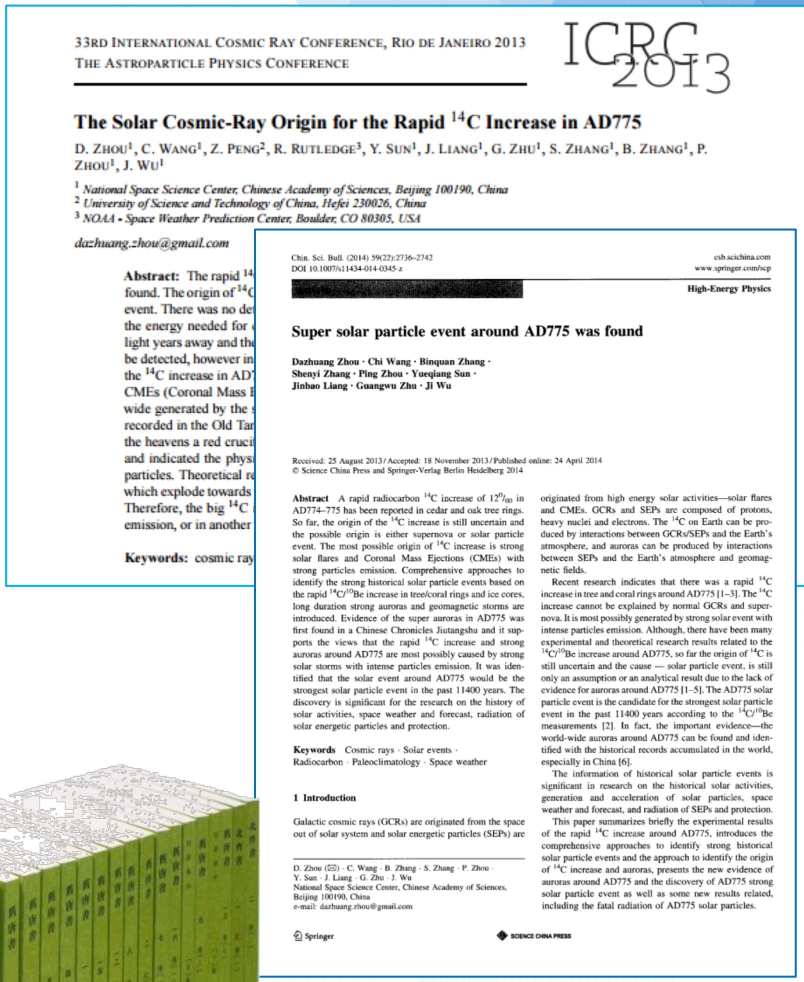
中国科学院国家空间科学中心
National Space Science Center, CAS

AD775 Event

- In the evening on the Chinese lunar calendar day of 11 Dec. 774, i.e., 17 Jan. AD775, in the east and above Moon, there were more than ten bands of white lights like the spread silk, penetrating and covering eight grand constellations named in Chinese. The lights were ceased gradually after middle night, as recorded in the Old Tang Book - a Chinese.






33RD INTERNATIONAL COSMIC RAY CONFERENCE, RIO DE JANEIRO 2013
THE ASTROPARTICLE PHYSICS CONFERENCE
ICRC 2013

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

D. ZHOU[1], C. WANG[1], Z. PENG[2], R. RUTLEDGE[3], Y. SUN[1], J. LIANG[1], G. ZHU[1], S. ZHANG[1], B. ZHANG[1], P. ZHOU[1], J. WU[1]

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[2] University of Science and Technology of China, Hefei 230026, China
[3] NOAA • Space Weather Prediction Center, Boulder, CO 80305, USA

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Chin. Sci. Bull. (2014) 59(22):2736–2742
DOI 10.1007/s11434-014-0345-z

[redacted]

High-Energy Physics

Super solar particle event around AD775 was found

Dazhuang Zhou · Chi Wang · Binquan Zhang · Shenyi Zhang · Ping Zhou · Yueqiang Sun · Jinbao Liang · Guangwu Zhu · Ji Wu

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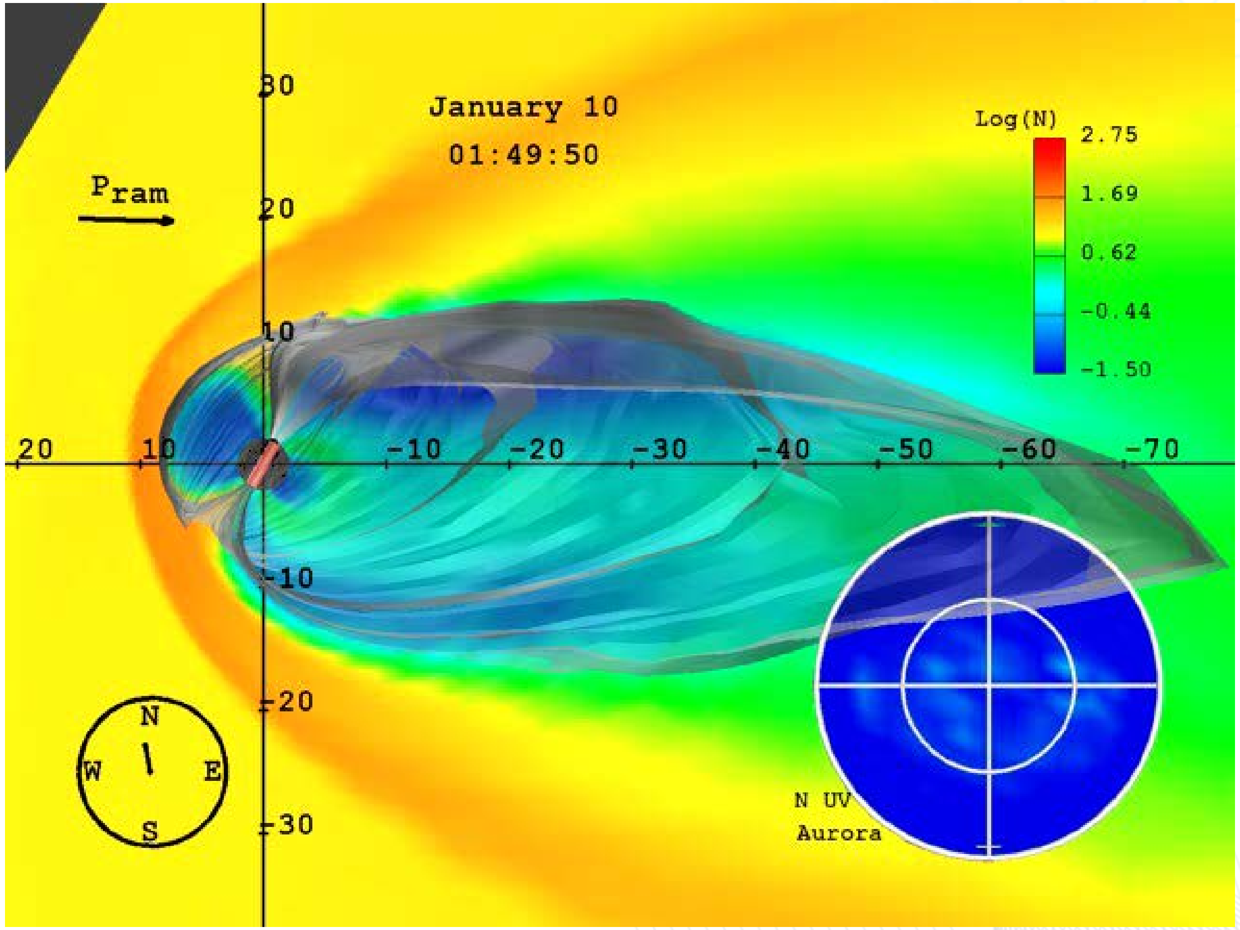
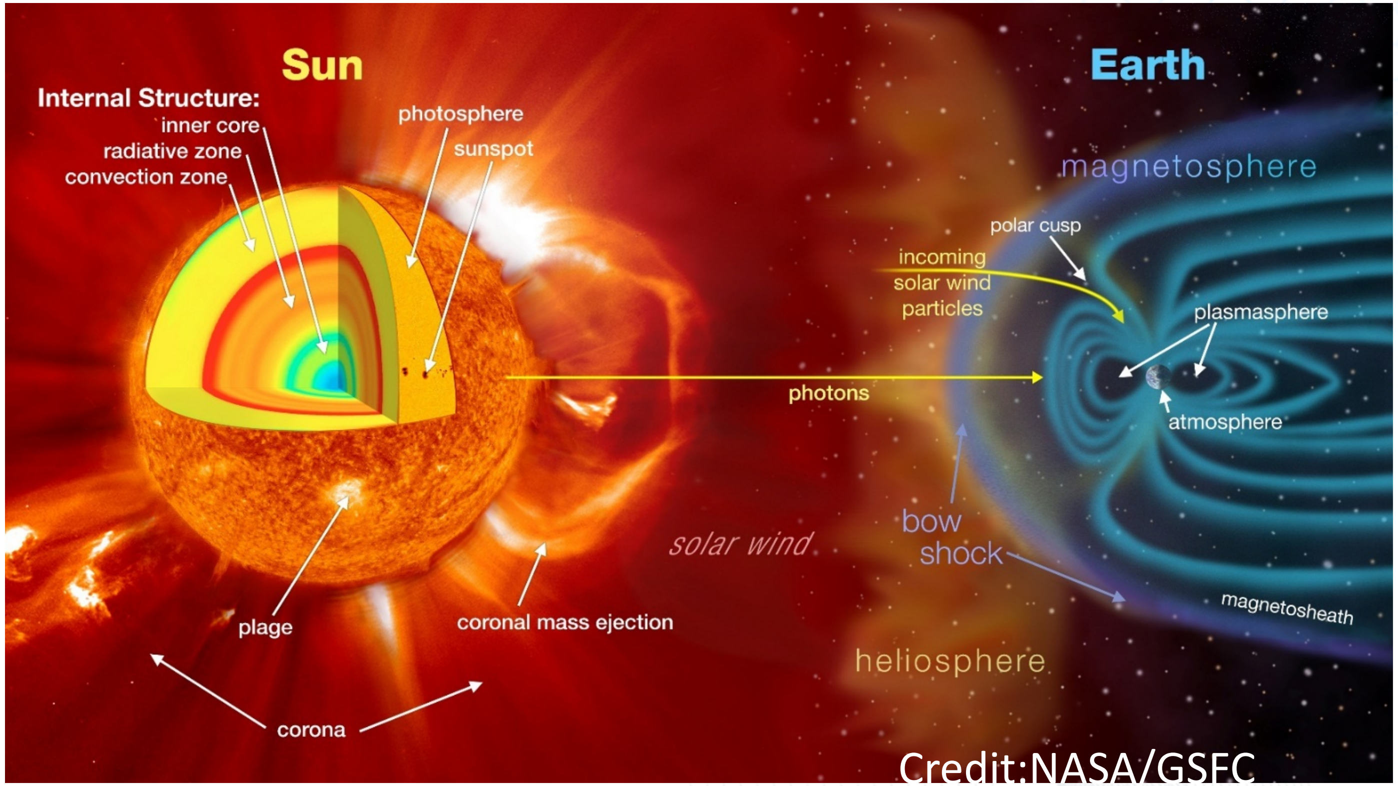
Zhou, et al, 2013

2. The Dynamic Space Environment So Far as We Know



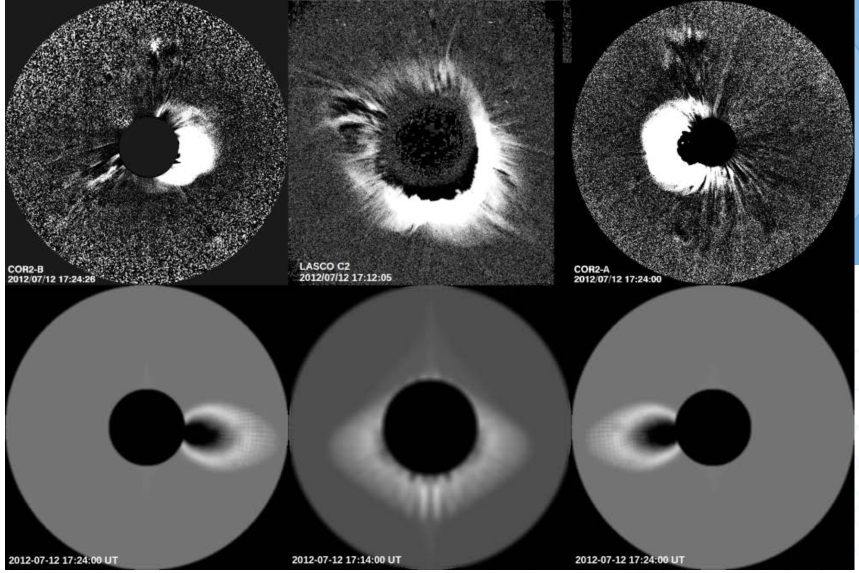
Solar-Terrestrial Physics

- ■Sun
- ■Solar Wind/Interplanetary
- ■Geospace Environment
  - –Magnetosphere
  - –Ionosphere
  - –Thermosphere

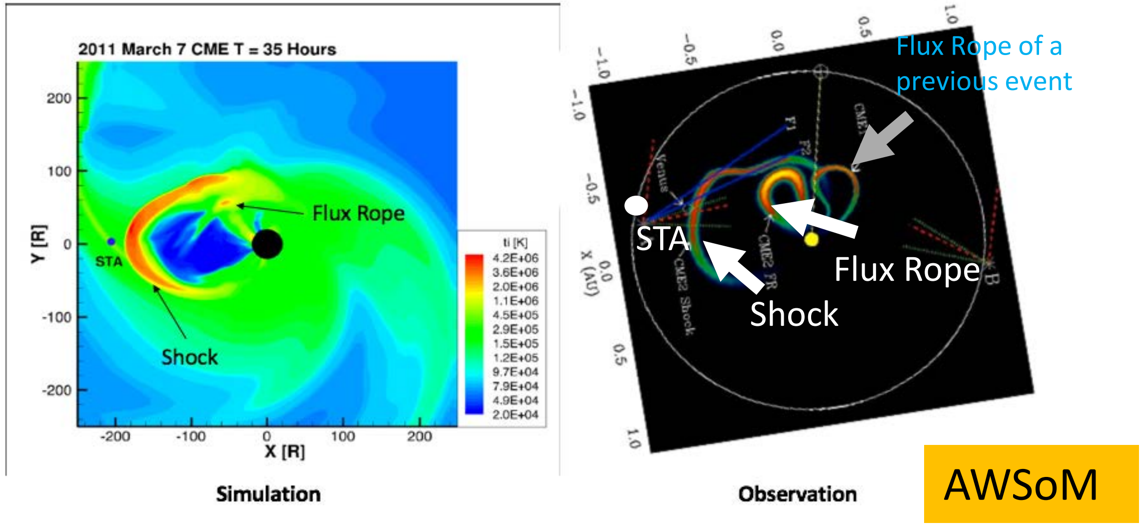


Coronal Mass Ejection

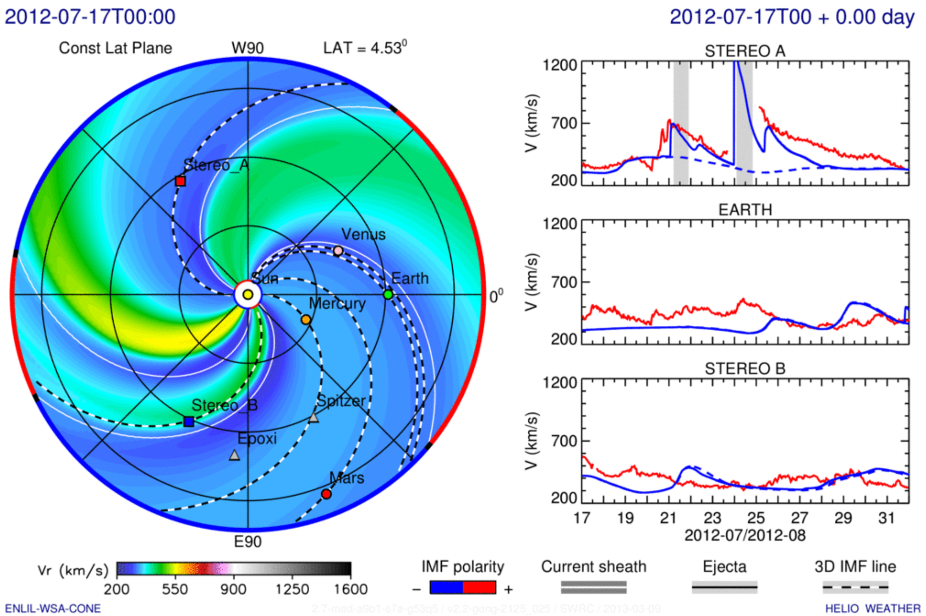
- Significant progress has been made in numerical simulation of CME events in recent years.



COIN model(SIGMA Group, NSSC)



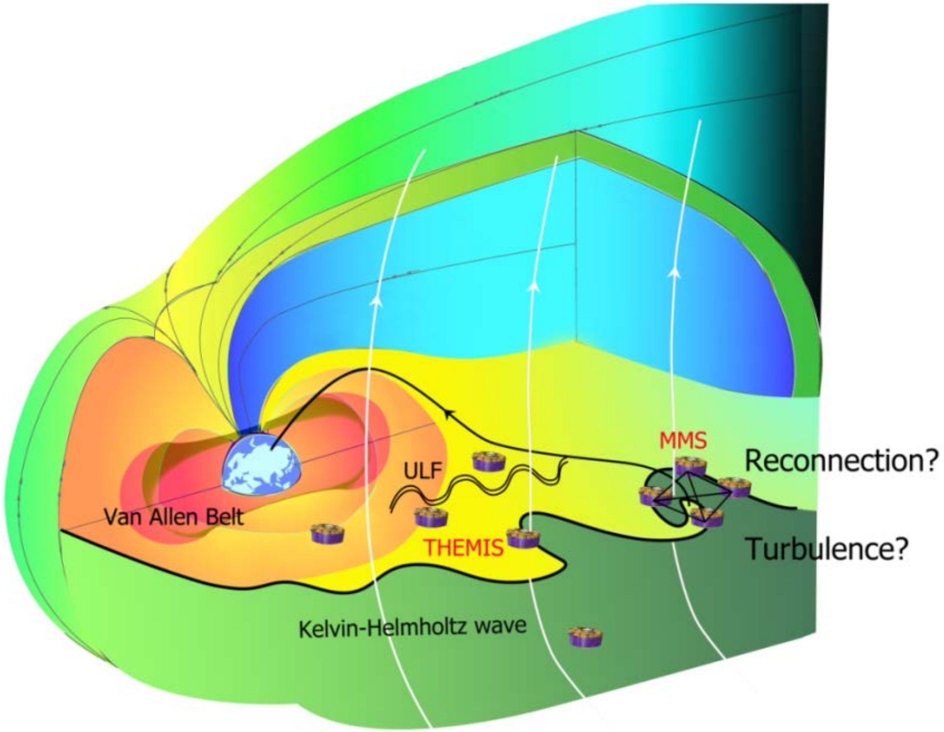
AWSOM model(Michigan University)

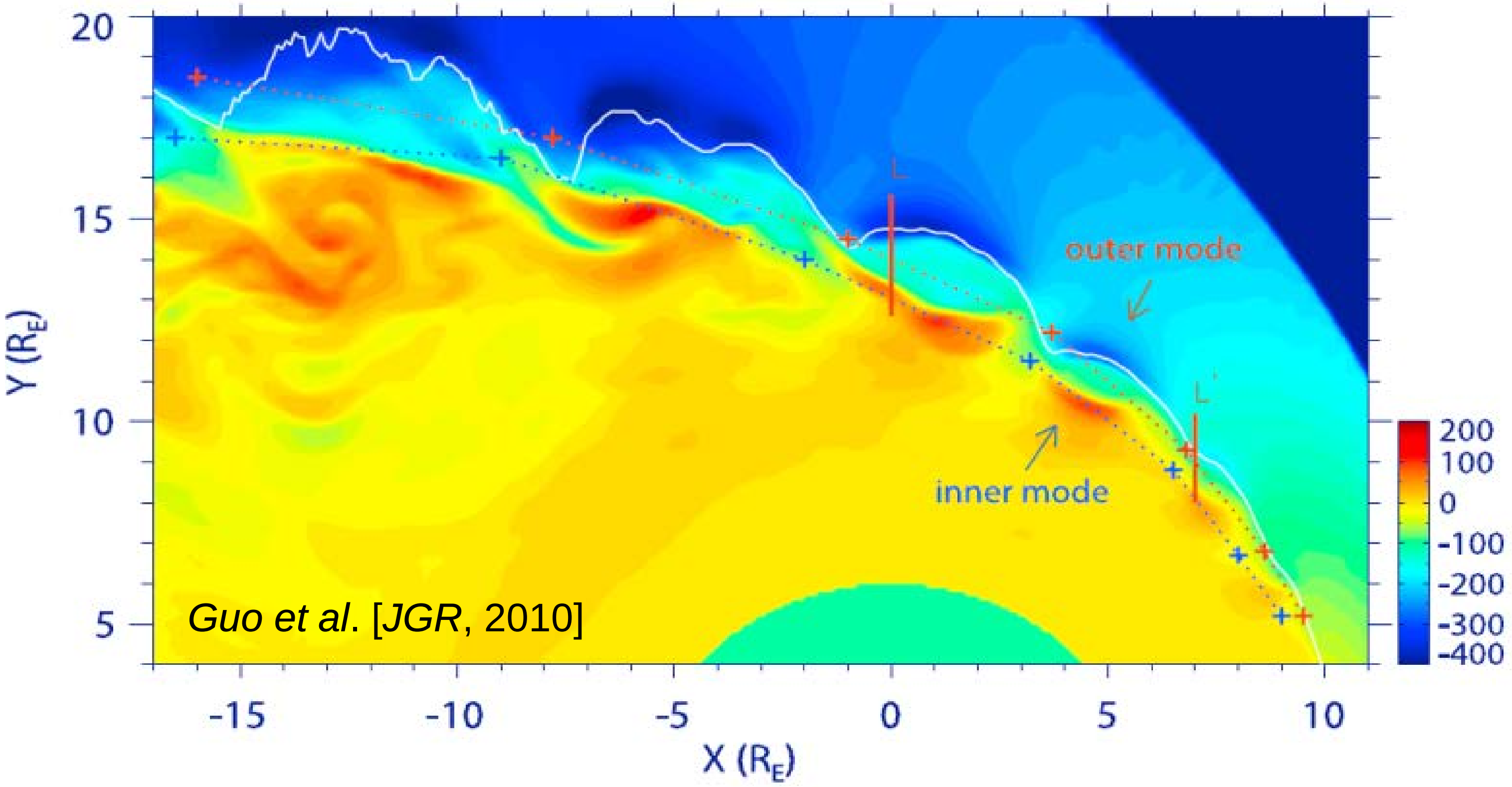


ENLIL model(US)

Magnetopause Kelvin-Helmholtz Instability

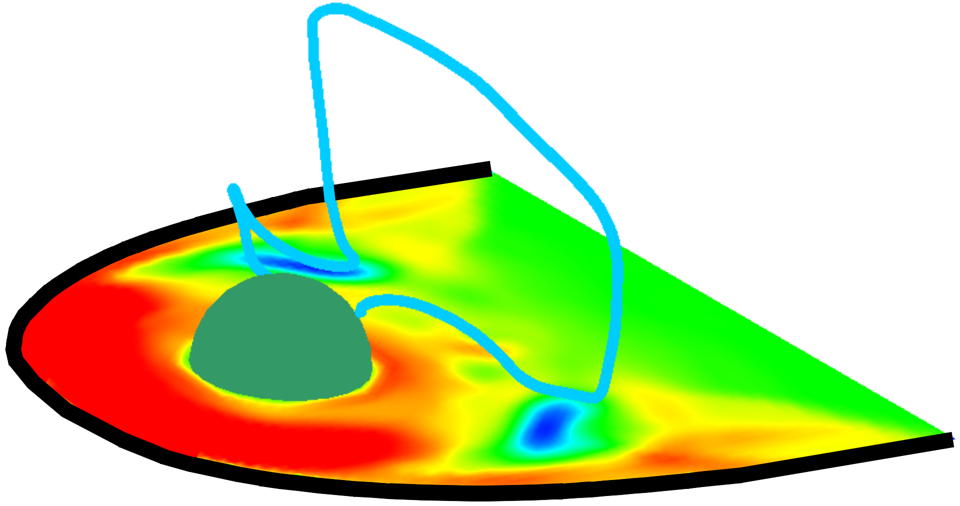
Deepen the understanding of the magnetopause instability

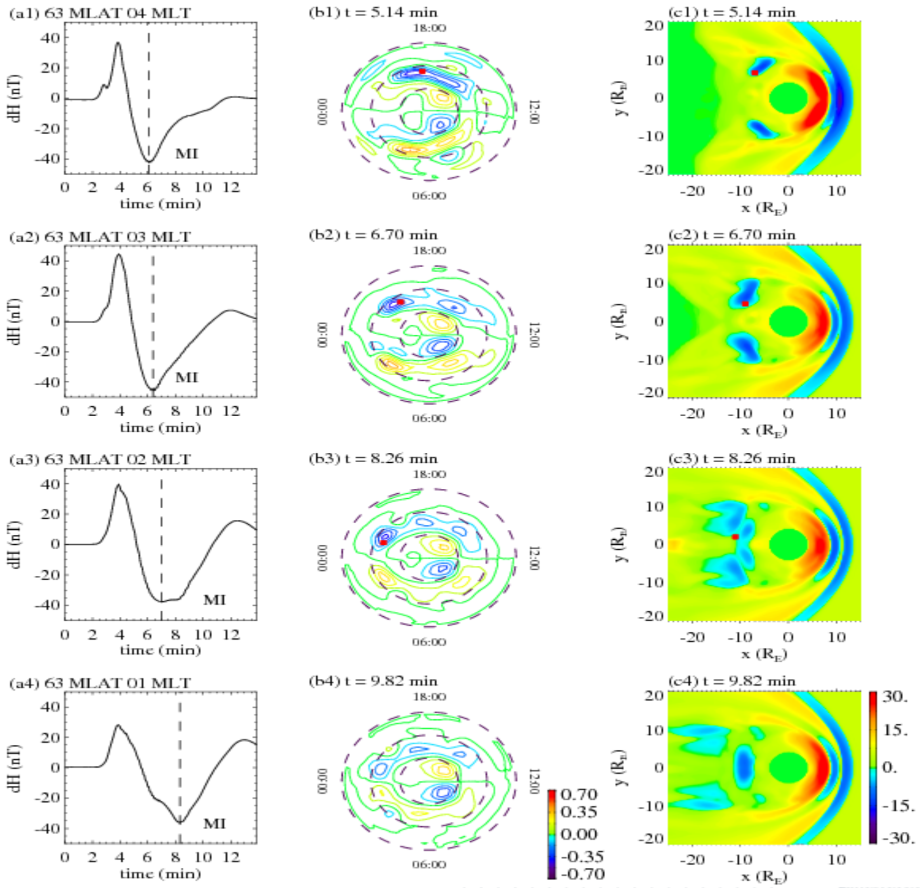




Magnetosphere Respond to Interplanetary Disturbence

Solar Wind-Magnetosphere- Magnetic Field on Earth response link.

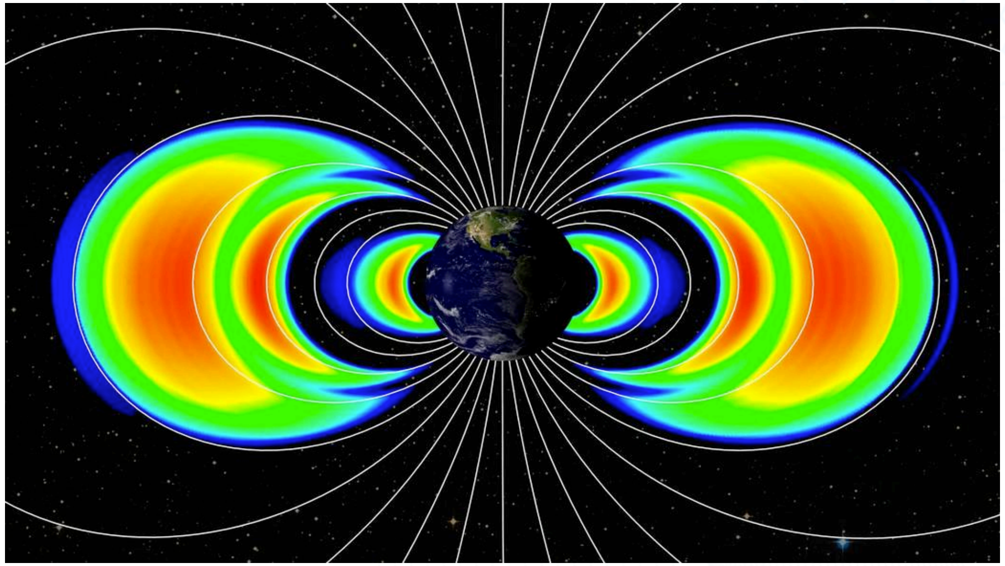




Sun et al., JGR, 2015

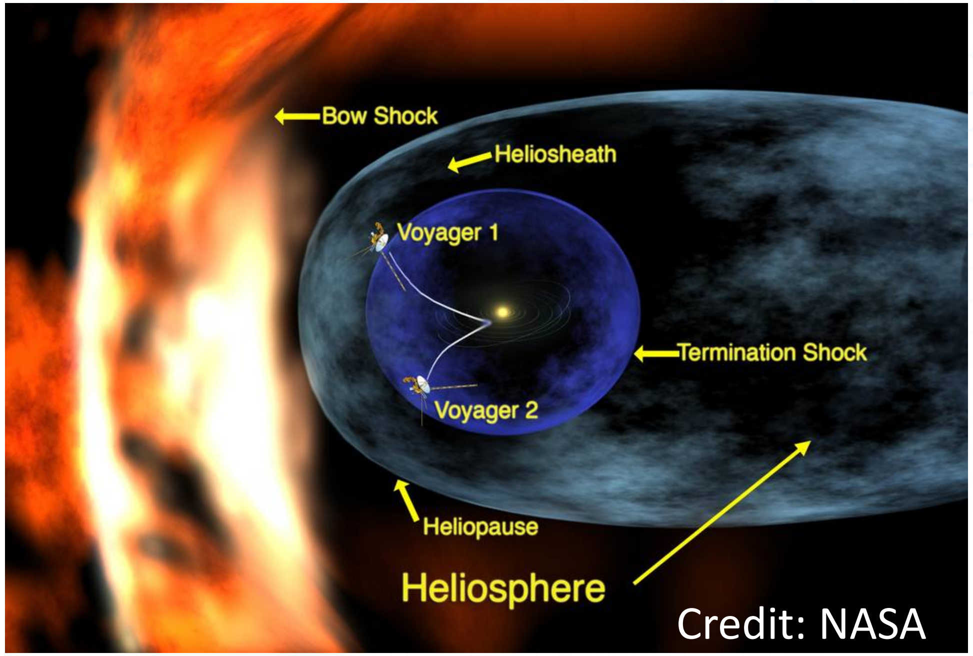
‘NEW’ Van Allen Belt

2013， A new radiation belt has been discovered around Earth by the Van Allen Probes.



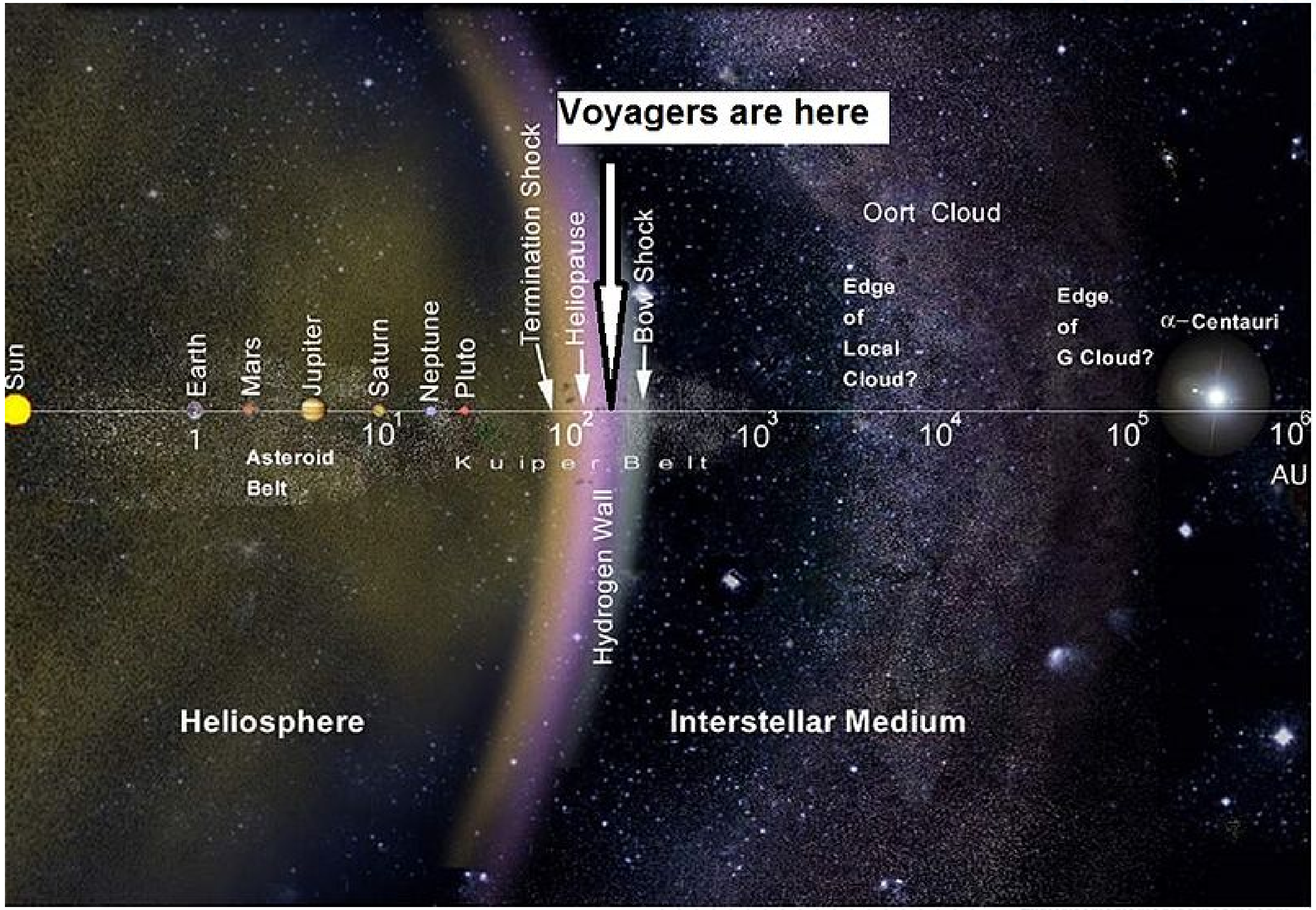
Heliosphere

1993, D. Gurnett reported the first evidence of the heliopause based on the kHz radio emissions coming from the heliopause and detected by the Voyager 1 and 2 spacecraft.



Voyager 1 and 2 crossed the termination shock

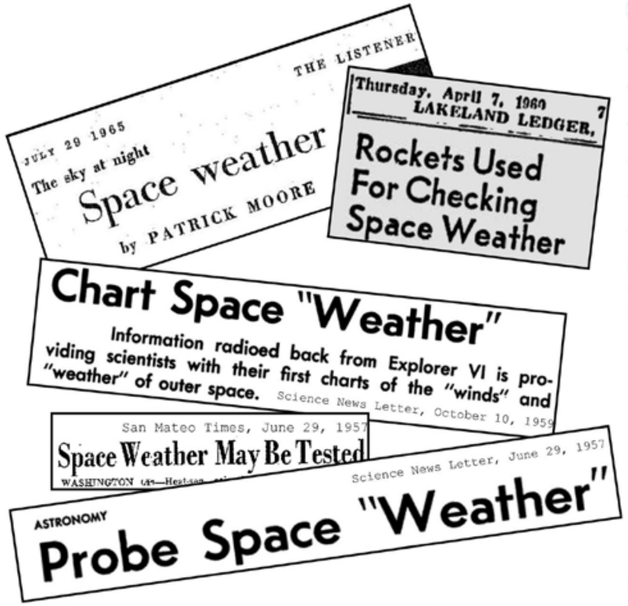
The twin Voyager 1 and 2 spacecrafts are still exploring the border of solar system.



3. The Space Weather Concept and Current Programs

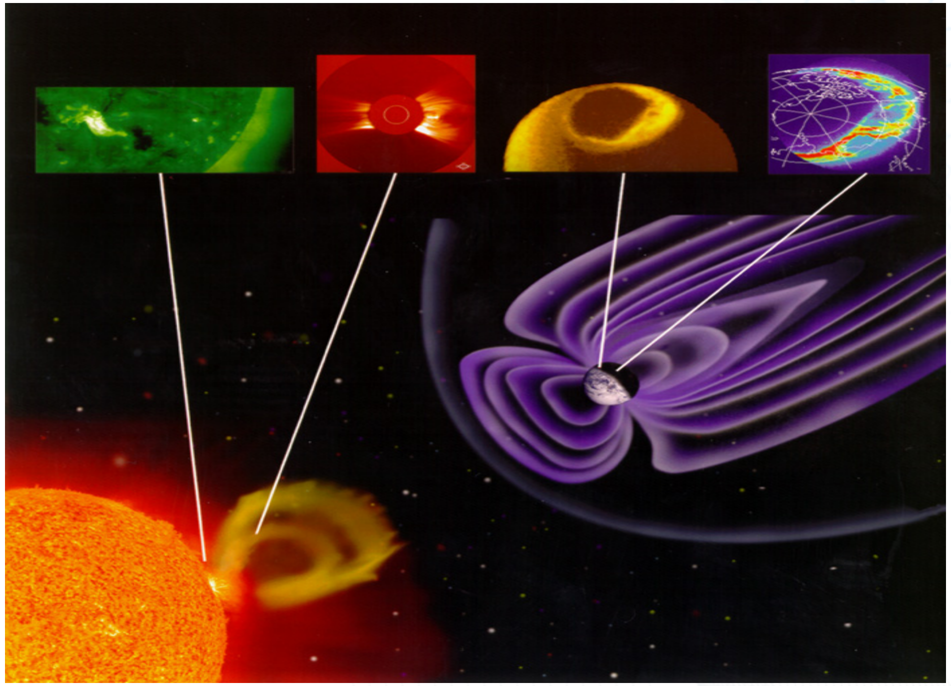
When is the term 'Space Weather' come into being?

- The term space weather was first used in the 1950s and came into common usage in the 1990s in the National Space Weather Plan of US.



The definition of Space Weather

- Space Weather is the conditions on the sun and in the solar wind, magnetosphere, ionosphere, and thermosphere that can influence the performance and reliability of space-borne and ground-based technological systems, and can endanger human life or health.

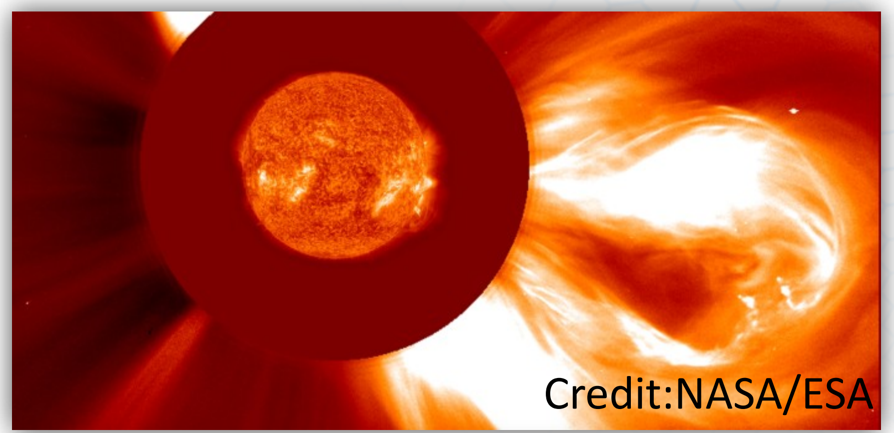


[*US National Space Weather Plan*]

Weather

Hurricanes and Tornados

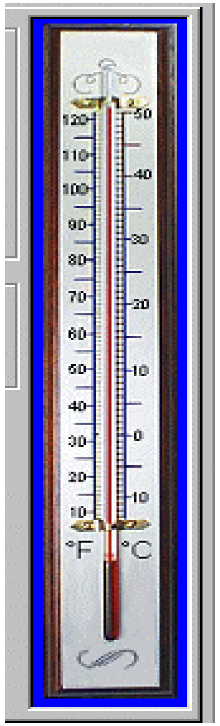
Space Weather



Solar Flares and Coronal Mass Ejection, Aurora

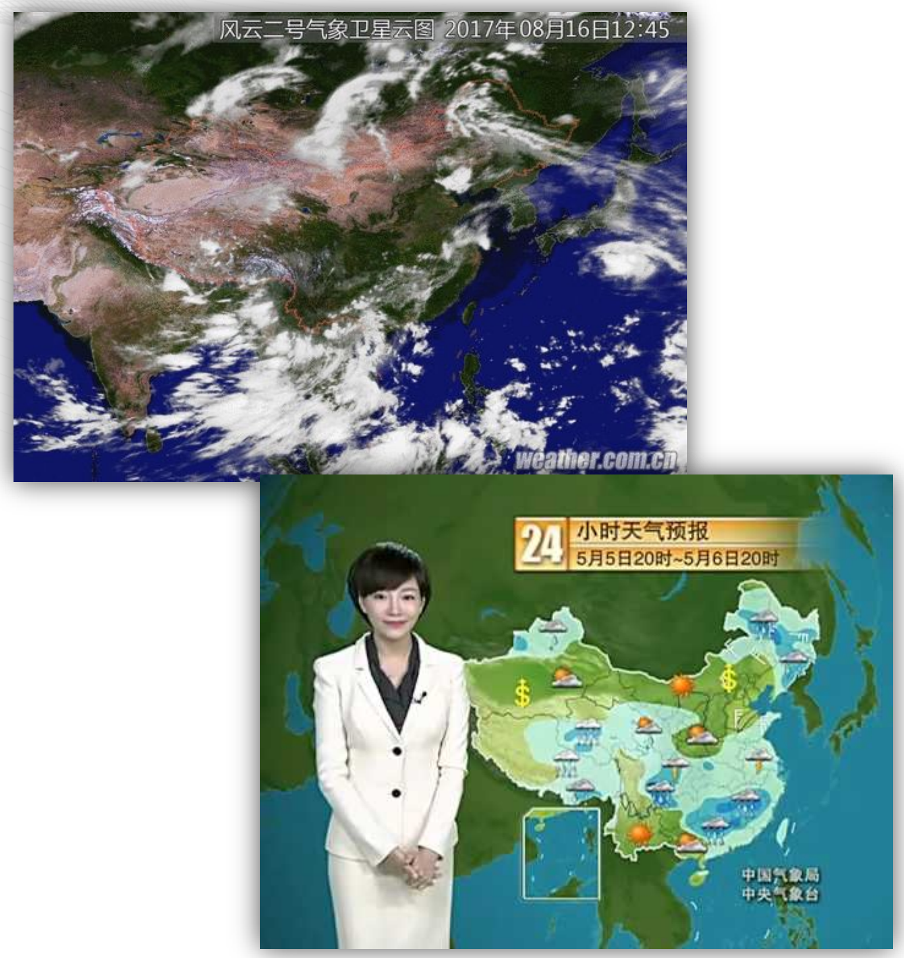
Monitor and Measure

- Thermometer

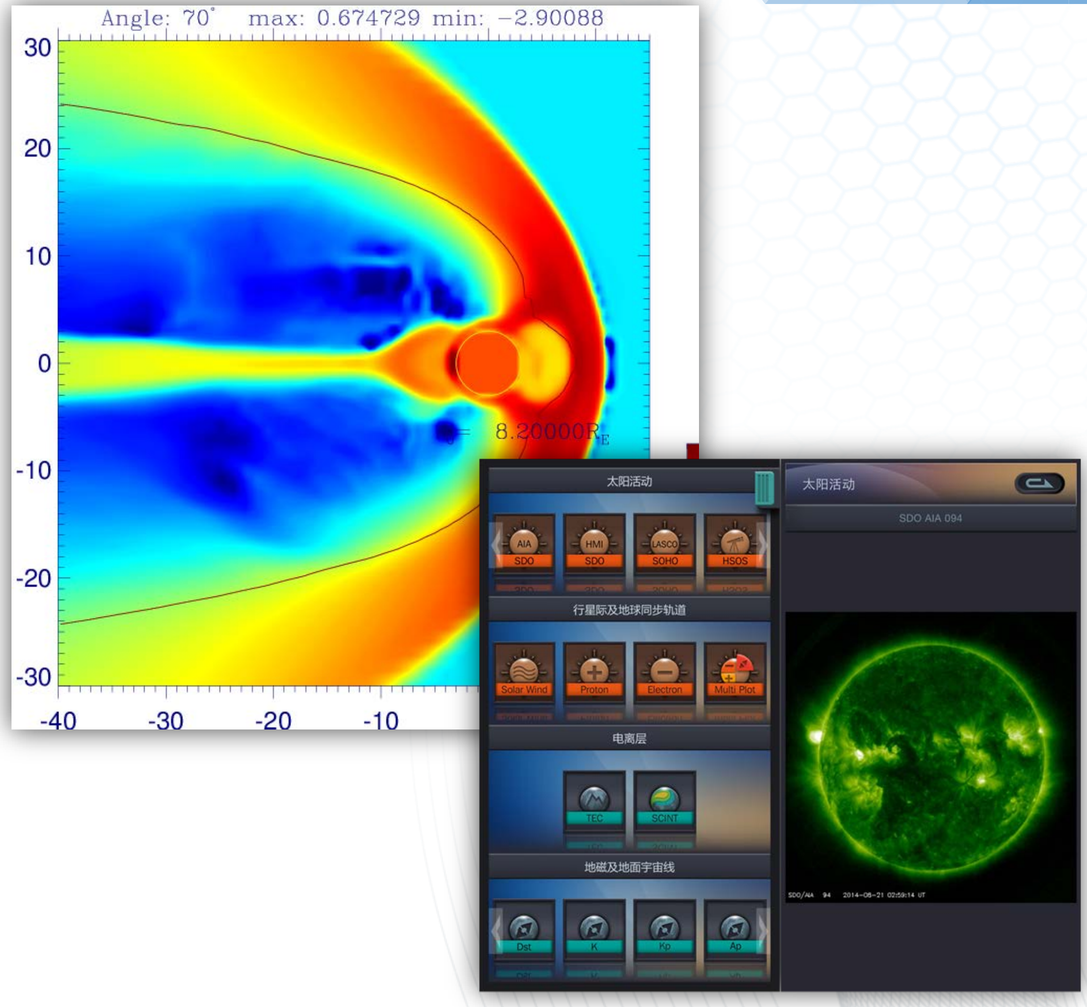


- Energetic Particle Sensor

Services



风云二号气象卫星云图 2017年08月16日12:45
weather.com.cn
24 小时天气预报
5月5日20时~5月6日20时
中国气象局
中央气象台



Angle: 70° max: 0.674729 min: −2.90088
太阳活动
行星际及地球同步轨道
电离层
地磁及地面宇宙线
SDO AIA 094

National Space Weather Program (NSWP) — USA

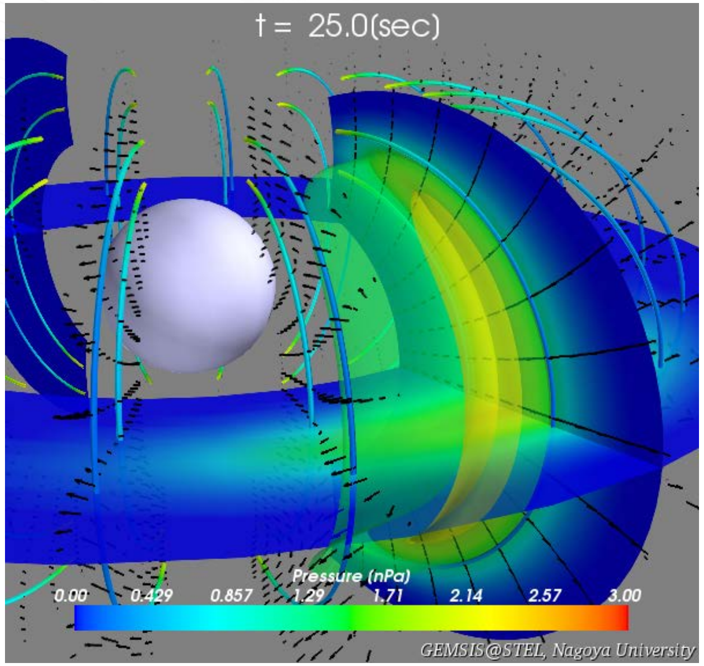
The National Space Weather Program
The Strategic Plan of US

The National Space Weather Program (NSWP) established in 1995 with publication of Strategic Plan.

- Pulled federal community together
- Set a vision for the future

Space Weather Team in U.S.

George L. Siscoe



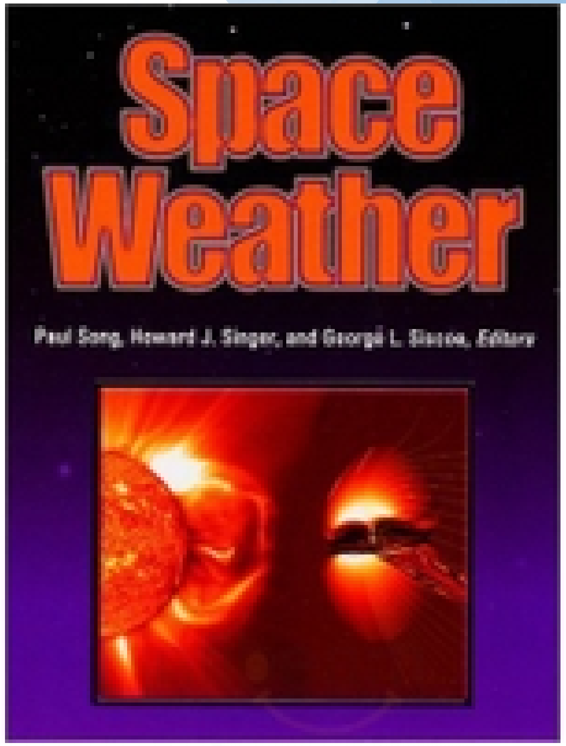
- George Siscoe initiated the Geospace Environment Model plan (GEM).

- It is this plan that led to the National Space Weather Plan established by several Departments of US.

George L. Siscoe

- George Siscoe published a series of impactive papers concerned about space weather, and he was one of the editors of the book “Space Weather”.

- He also was the first editor-in-chief of the “Space Weather” journal.



The Development of European Space Weather

1996: ESA Round Table on Space Weather.

1998: First ESA Space Weather Workshop.

1999-2001: ESA feasibility study on a Space Weather Programme.

2000: Setting up of Space Weather Working Team.

2003: ESA Space Weather pilot-project formally starts.

European Space Weather Program focused on monitoring conditions at the Sun and in the solar wind, and in Earth’s magnetosphere, ionosphere and thermosphere, that can affect spaceborne and ground-based infrastructure or endanger human life or health.

Space Weather in Russia

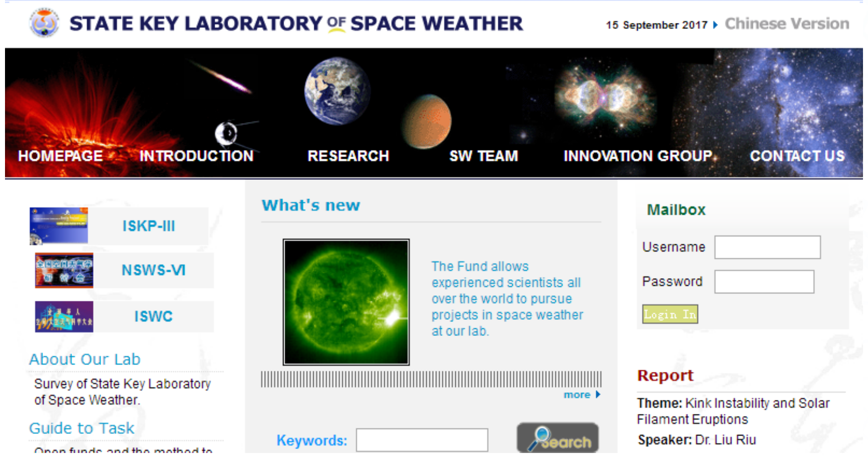
Prof. G. A. Zherebtsov made a significant progress Space Weather especially focus on the incoherent scatter radar, ionosphere, global climate change, earth observation, solar observation in Russian.

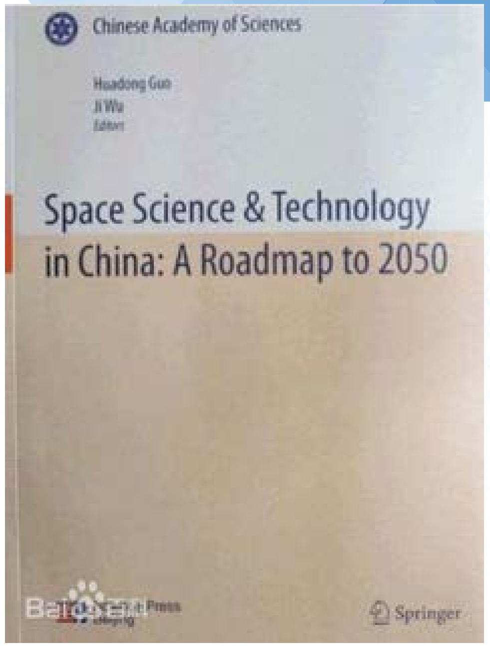
Jointly with ISTP, IKI and IZIMIRAN are also proposed may observation and missions for space weather studies.

Space Weather in China

China established its own Space Weather Laboratory ,Space Weather Prediction Service and a roadmap to 2050.

The State Key Laboratory of Space Weather was founded in 2006, which is the first state key laboratory approved by the Ministry of Science and Technology in the field of space physics in China.





Academician Wei Fengsi

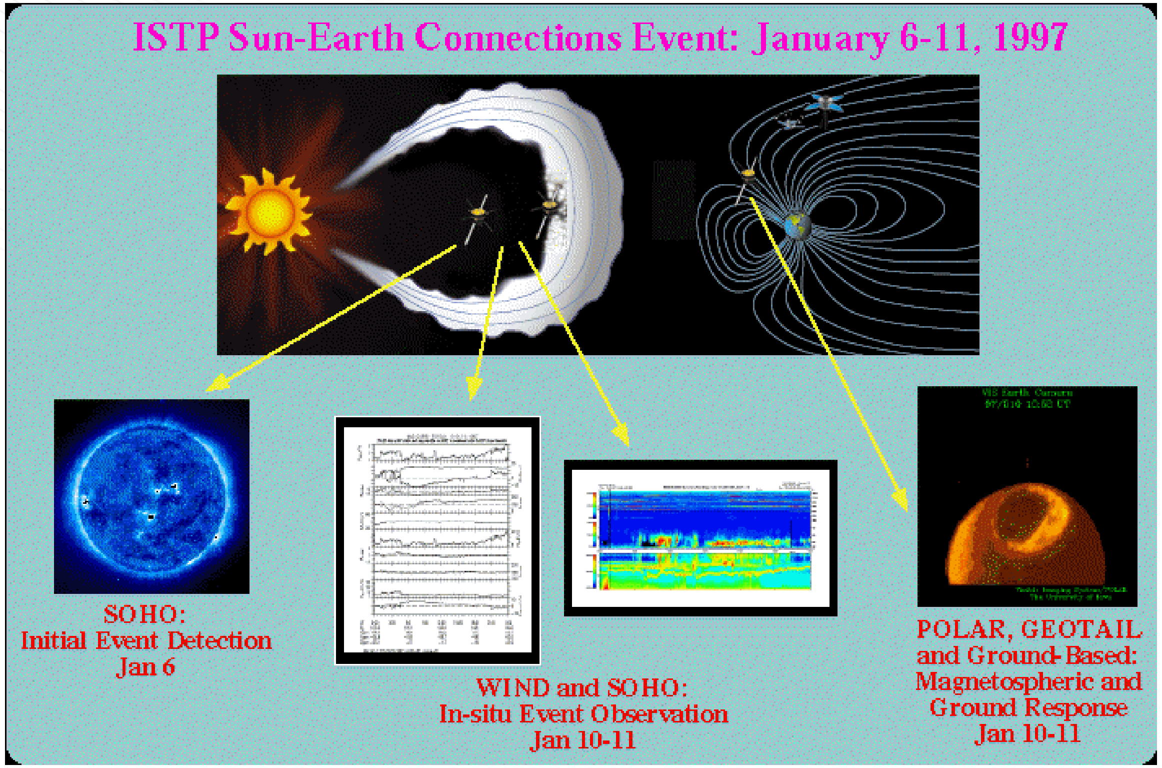
- **Academician Wei Fengsi** initiated ‘Space Weather’ concept in China. He contributed to the establishment of the State Key Laboratory of Space Weather.
- He dedicated in promoting Chinese Meridian Project.
- He proposed the International Space Weather Conference which enhance the global cooperation in space weather.

China and Russian’s contribution to Space Weather

Sino-Russia Joint Space Weather Research Center

For more than a decade, we have held bilateral seminars 11 times (once a year)

International Solar-Terrestrial Physics



The International Solar Terrestrial Physics (ISTP) Program is a large, multi-national program involving three space agencies and up to eight spacecraft.

IACG for Space Sciences was formed in 1981 and until 1986 coordinated the six space missions to Halley's Comet.

Inter-Agency Consultative Group for Space Science (IACG)

Living With a Star

Living With a Star (LWS) is a NASA scientific program to study those aspects of the connected Sun-Earth system that directly affect life and society. LWS is a crosscutting initiative with goals and objectives relevant to NASA's Exploration Initiative, as well as to NASA's Strategic Enterprises. The program is managed by the Heliophysics Division of NASA's Science Mission Directorate.

Operating Missions:

- Van Allen Probes (Radiation Belt Storm Probes-RBSP) Mission
- Solar Dynamics Observatory (SDO) Mission
- Stereo A and B

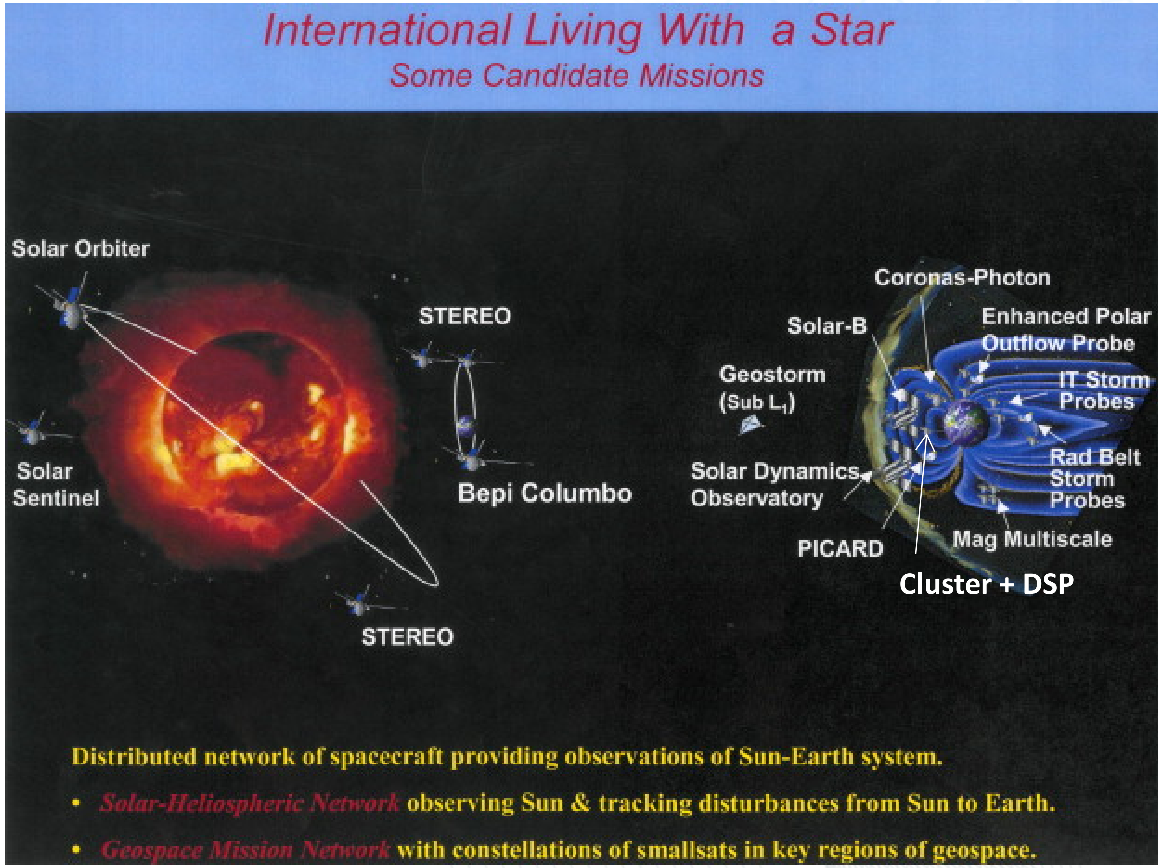
Missions in Development

- Space Environment Testbeds (SET)
- Solar Orbiter Collaboration
- Solar Probe Plus

International Living With a Star

MISSION:

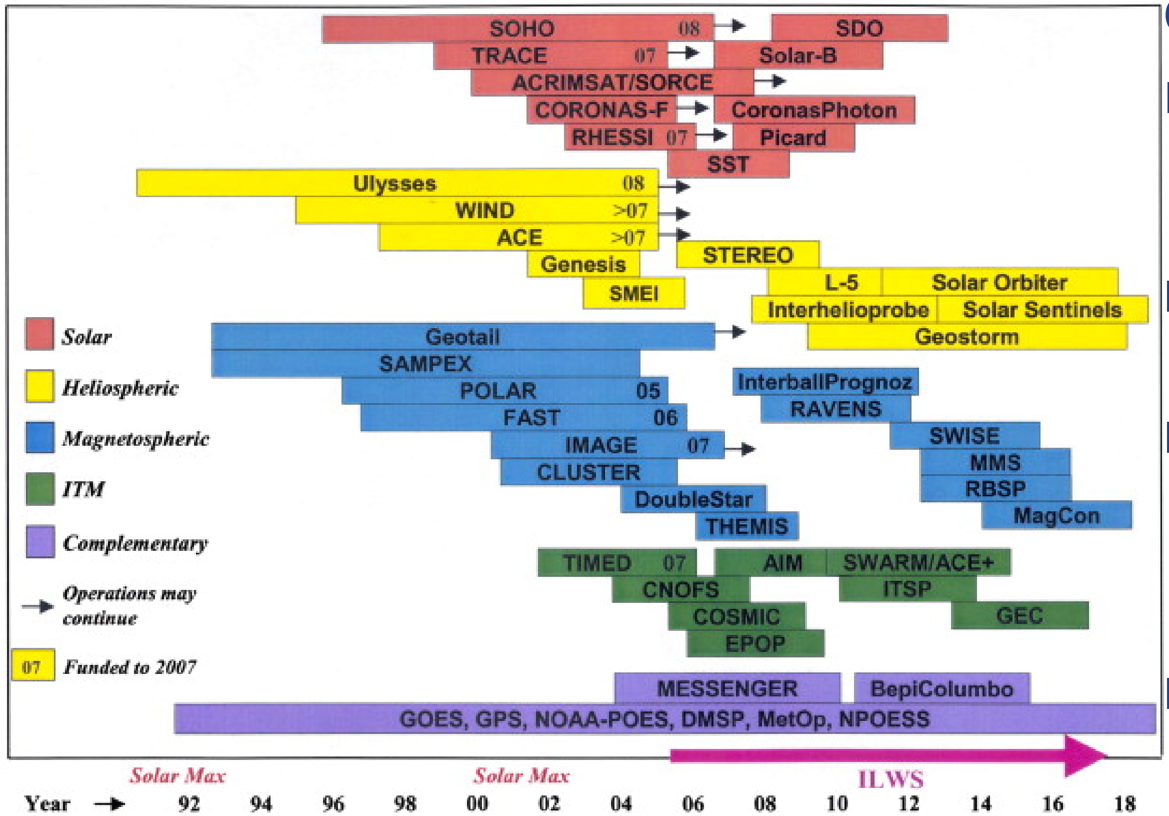
Stimulate, strengthen, and coordinate space research to understand the governing processes of the connected Sun-Earth System as an integrated entity.



International Living With a Star

Madhulika Guhathakurta

Present Solar-Terrestrial Missions & “First Order” ILWS Missions

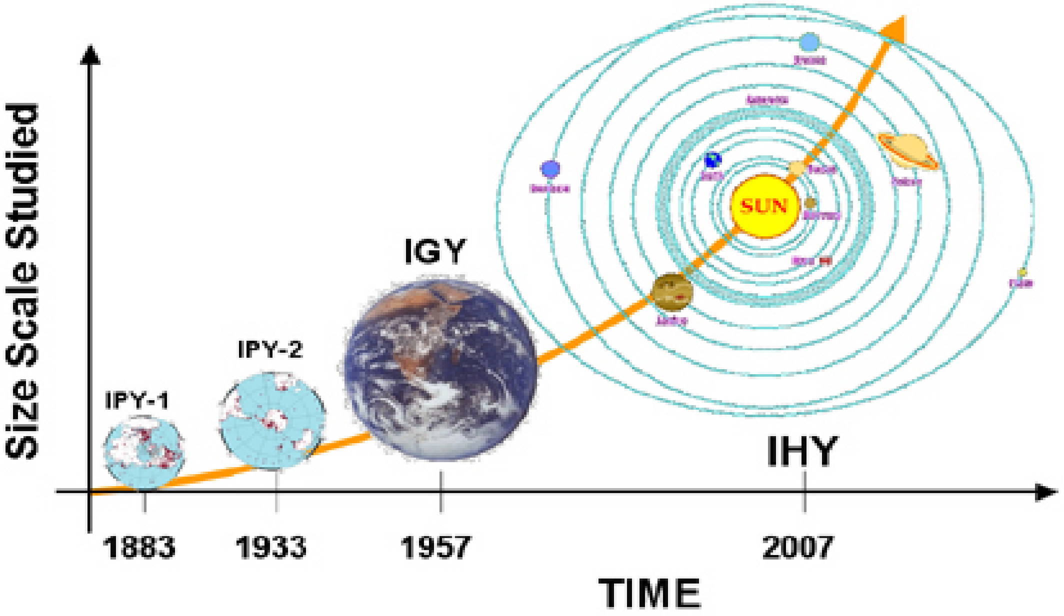


OBJECTIVES:

- Study of the Sun-Earth connected system and the effects which influence life and society.
- Collaboration among potential partners in solar-terrestrial space missions.
- Synergistic coordination of international research in solar-terrestrial studies, including all relevant data sources as well as theory and modeling.
- Effective and user driven access to all data, results, and value-added products.

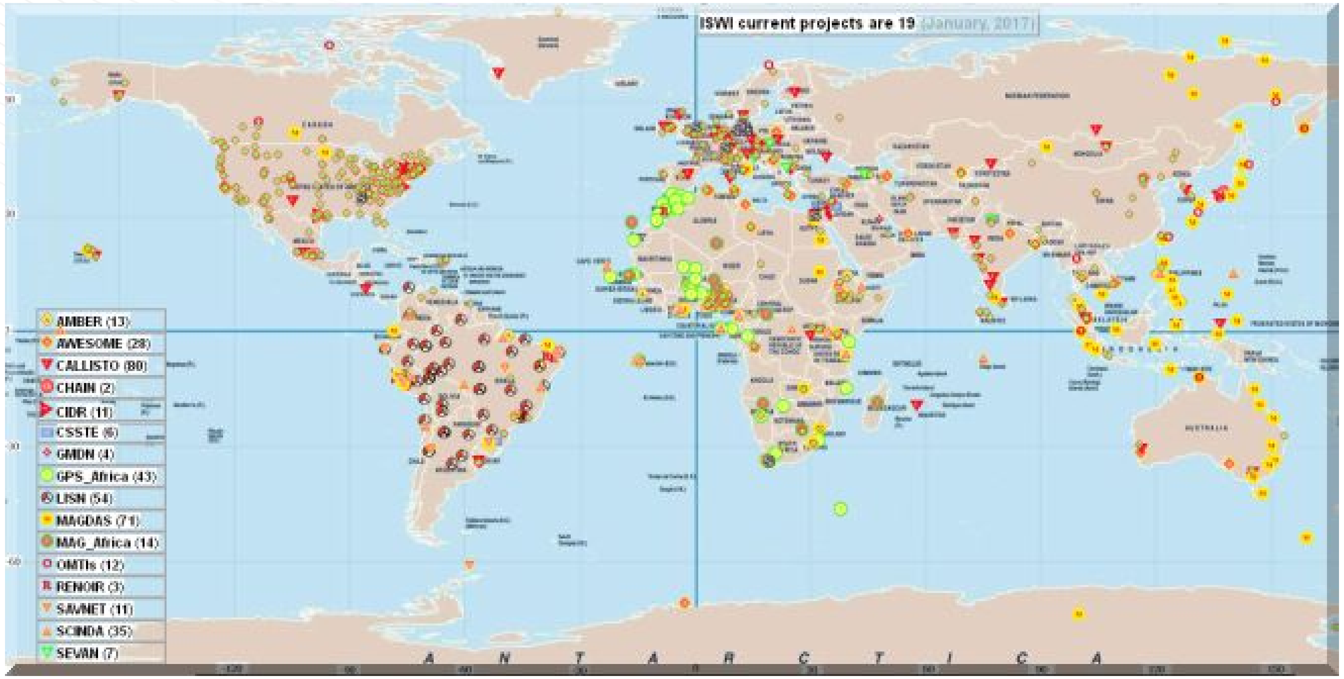
International Heliophysical Year

Joseph Davila



The International Heliophysical Year is a UN-sponsored scientifically driven international program of scientific collaboration to understand external drivers of planetary environments and universal processes in solar-terrestrial-planetary-heliospheric physics.

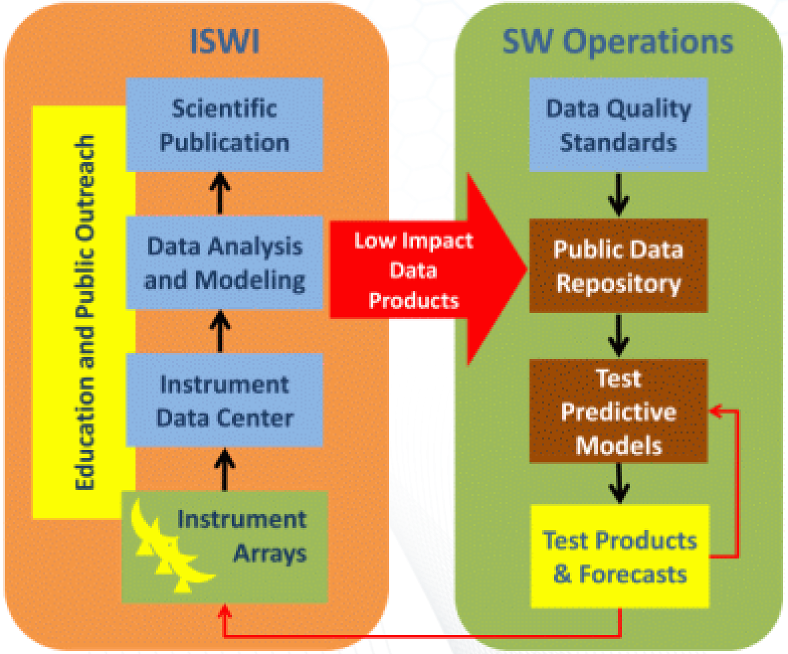
The International Space Weather Initiative



ISWI is a program of international cooperation to advance the space weather science by a combination of instrument deployment, analysis and interpretation of space weather data from the deployed instruments in conjunction with space data, and communicate the results to the public and students.

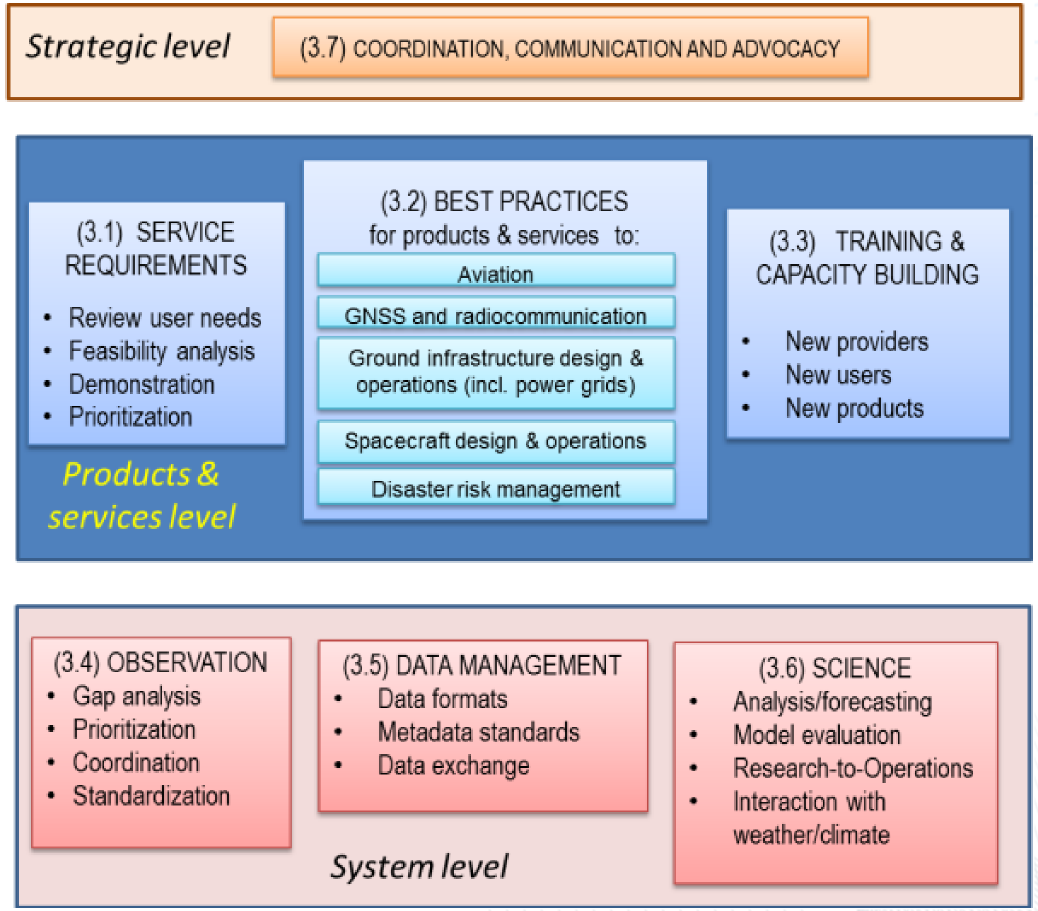
The Goals of ISWI

- To develop the scientific insight necessary to understand the science,
- To reconstruct and forecast near-Earth space weather.
- These include instrumentation, data analysis, modeling, education, training, and public outreach.

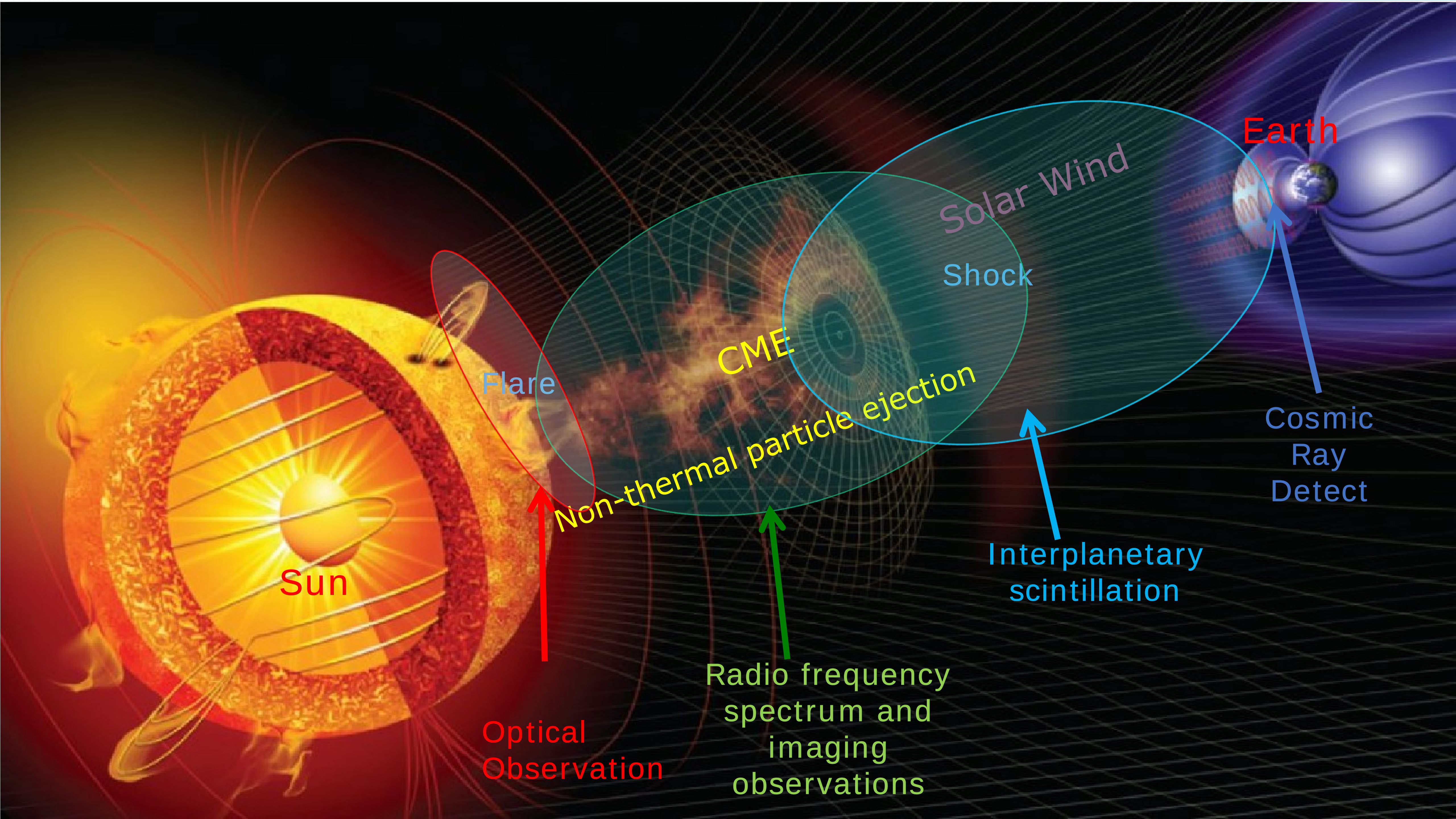


Space Weather program of WMO

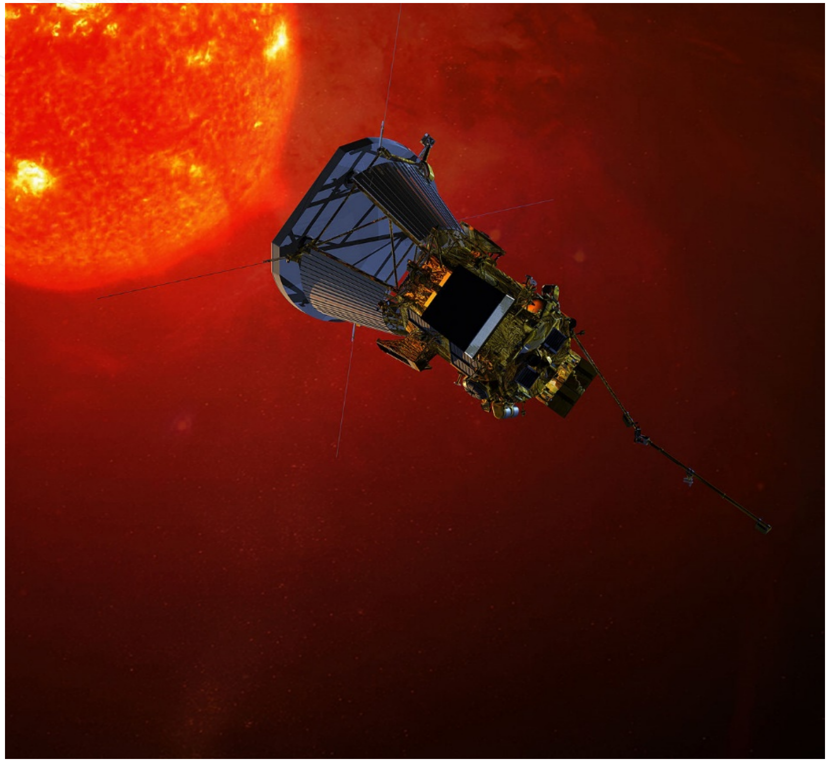
- In May 2010, WMO established the Interprogramme Coordination Team on Space Weather (ICTSW) with a mandate to support Space Weather observation, data exchange, product and services delivery, and operational applications.
- As of May 2016, ICTSW involves experts from 26 different countries and 7 international organizations.



4. Looking at the Future Space Weather Programs


Earth
Solar Wind
Shock
CME
Flare
Non-thermal particle ejection
Cosmic Ray Detect
Sun
Interplanetary scintillation
Optical Observation
Radio frequency spectrum and imaging observations

Parker Solar Probe (Solar Probe +)



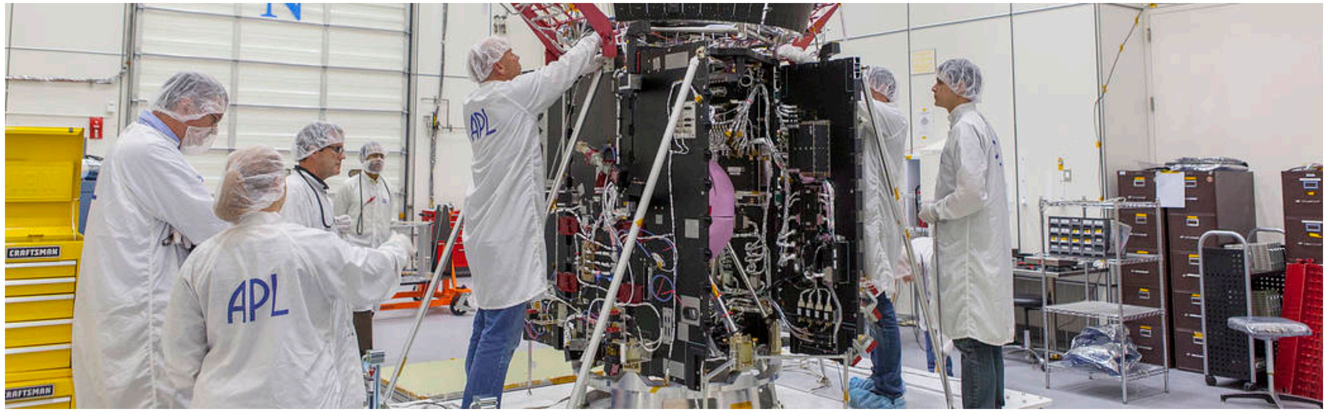
- Parker Solar Probe (previously Solar Probe, Solar Probe Plus, or Solar Probe+) is a planned NASA robotic spacecraft to probe the outer corona of the Sun. On May 31, 2017 the probe was renamed after solar astrophysicist Eugene Parker. This was the first time a NASA spacecraft was named after a living person
- It will approach to within 8.5 solar radii (5.9 million kilometers or 3.67 million miles) to the 'surface' (photosphere) of the Sun

Perihelion	6.0 million km; 0.040 AU (3.7 million mi)
Apohelion	109.3 million km; 0.730 AU (67.9 million mi)
Inclination	3.4°
Period	88 days

Parker Solar Probe (Solar Probe +)

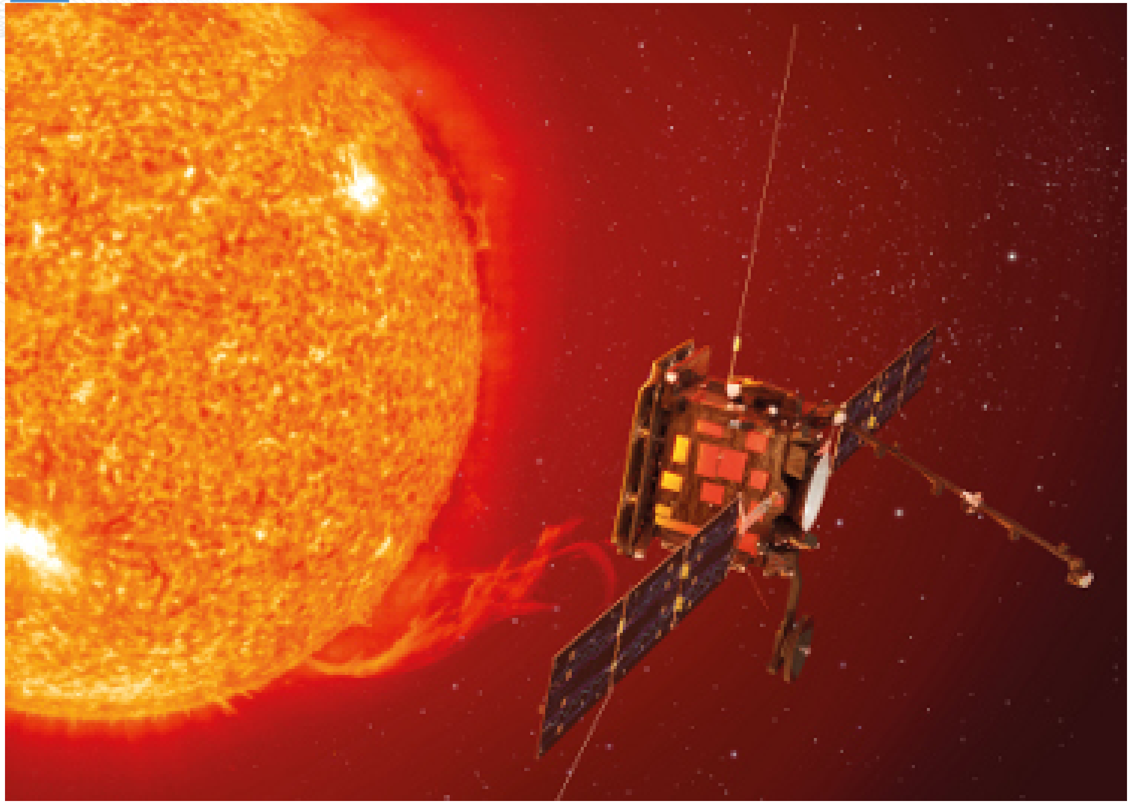
Scietific goals

- Determine the structure and dynamics of the magnetic fields at the sources of solar wind.
- Trace the flow of energy that heats the corona and accelerates the solar wind.
- Determine what mechanisms accelerate and transport energetic particles.
- Explore dusty plasma near the Sun and its influence on solar wind and energetic particle formation.



- The project was announced as a new mission start in the fiscal 2009 budget year.
- The launch date has since been pushed back to 2018.

Solar Orbiter observations of the polar regions of the Sun, which is difficult



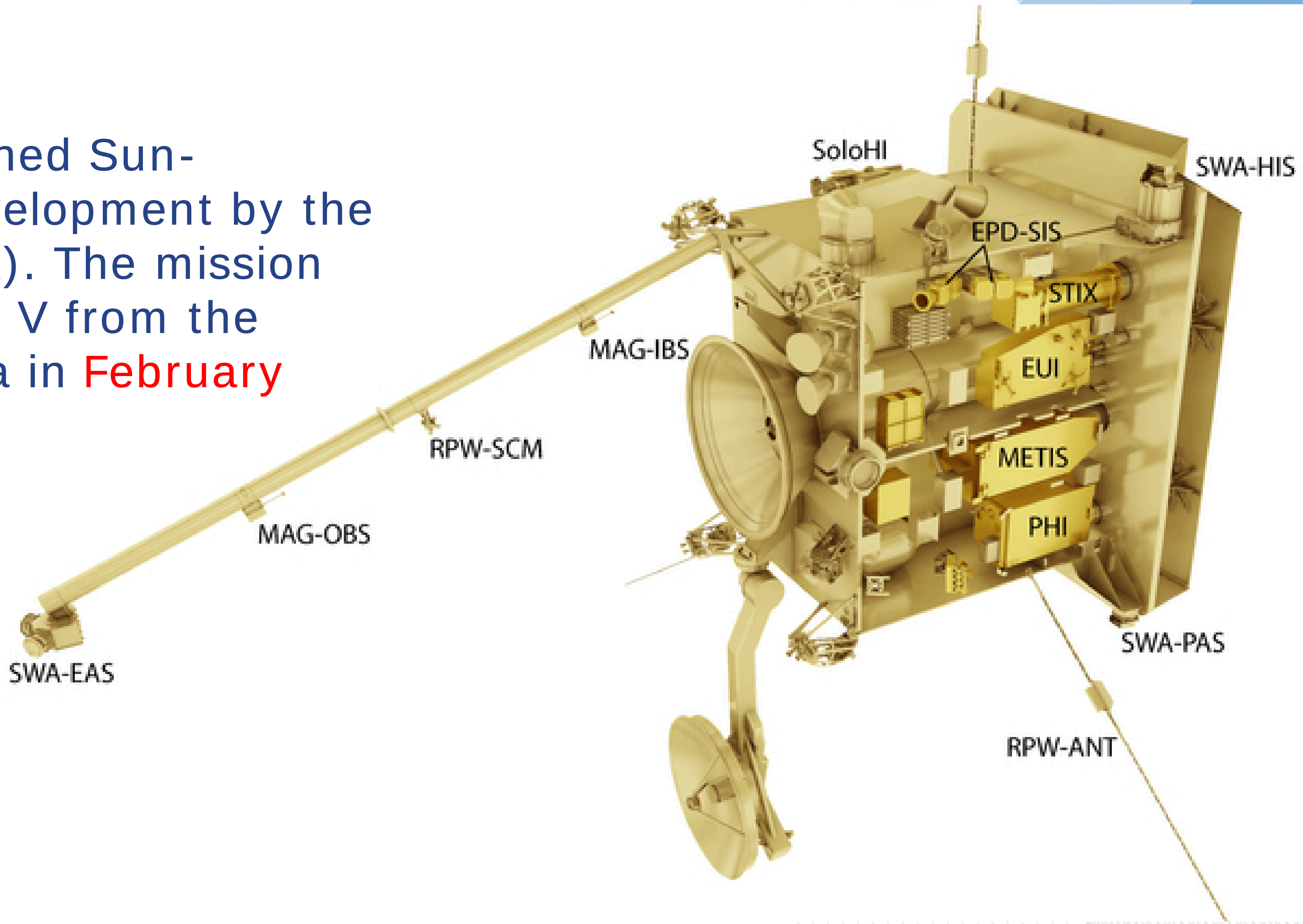
Perihelion	0.28 AU
Apohelion	0.8-0.9 AU
Inclination	0-34 degrees
Period	150 days

- SolO is intended to perform detailed measurements of the inner heliosphere and nascent solar wind, and perform close to do from Earth, both serving to answer the question 'How does the Sun create and control the heliosphere?'
- The Solar Orbiter will make observations of the Sun from an eccentric orbit moving as close as ~60 solar radii (RS), or 0.284 astronomical units (AU), placing it inside Mercury's perihelion of 0.3075 AU and providing it with the closest ever views of the Sun.

Solar Orbiter

Solar Orbiter (SolO) is a planned Sun-observing satellite, under development by the European Space Agency (ESA). The mission will be launched with an Atlas V from the Cape Canaveral AFS in Florida in February 2019.

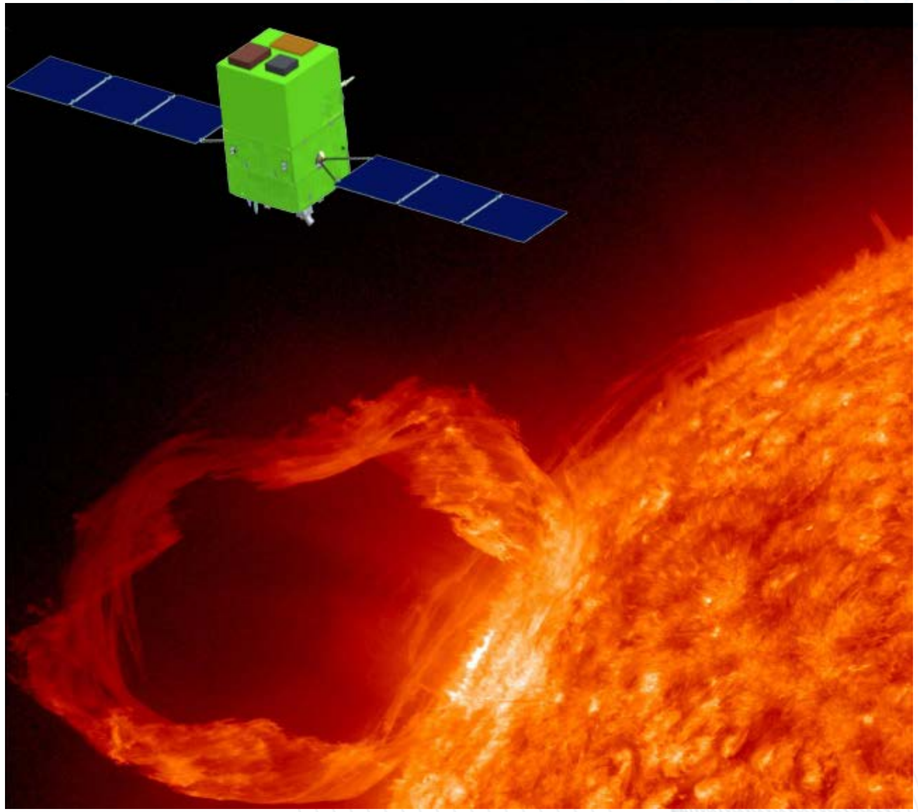
The Solar Orbiter payload accommodates a set of in situ and a set of remote-sensing instruments, with a total payload mass of 180 kg.



Major Scientific Objectives for ASO-S (Advanced Solar Observatory in Space)

- 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



ASO-S Orbits

- **Full-Disc Vector Magnetograph (FMG)**

to observe full-disc vector magnetic field of photosphere with a high time resolution. Heritage: SST/DSO as well as HSMT

- **Lyman-alpha Solar Telescope(LST)**

to observe Lyman-alpha disc image + inner corona
Heritage: SMESE and some pre-studies

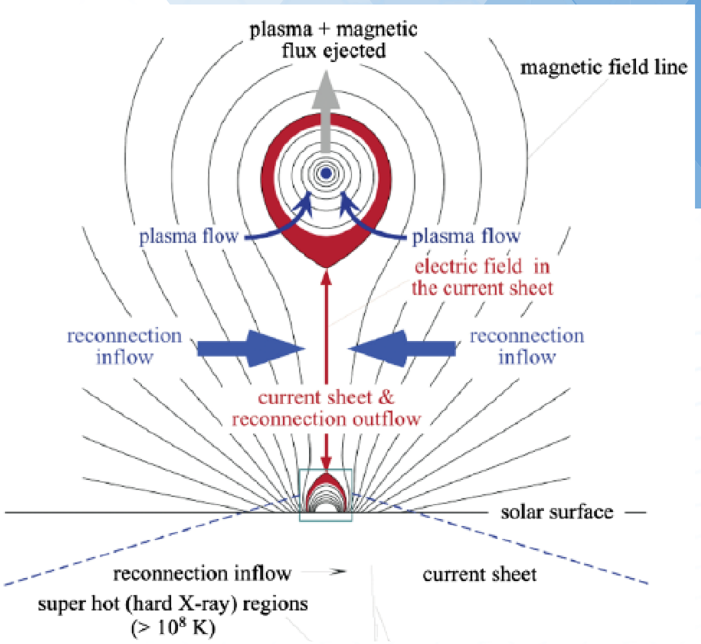
- **Hard X-ray Imager (HXI)**

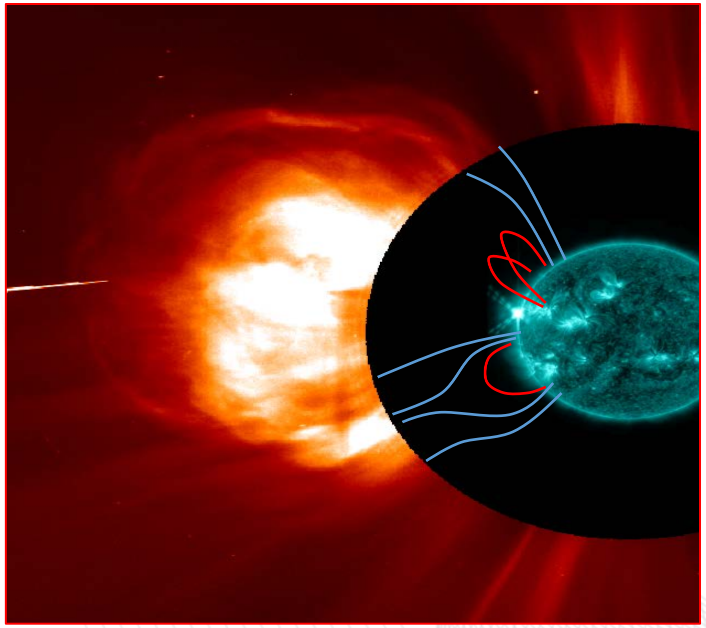
to spectrally image the Sun in 30-300 keV
Heritage: SZ-02/Chang'E/SMESE and some pre-studies

Solar Synchronous

Attitude: 700 - 750 km
Inclination: 98.27 °

Launch date: 2022





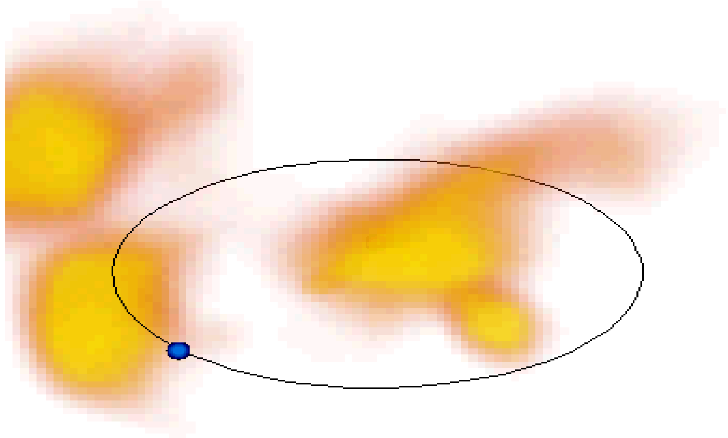
SPORT(Solar Polar ORbit Telescope)

- Reveal the complete physical process about the triggering, formation, onset, propagation, and evolution stages of coronal mass ejections (CMEs) in the inner heliosphere, and the ensuing responses of structures and dynamics of the inner heliosphere

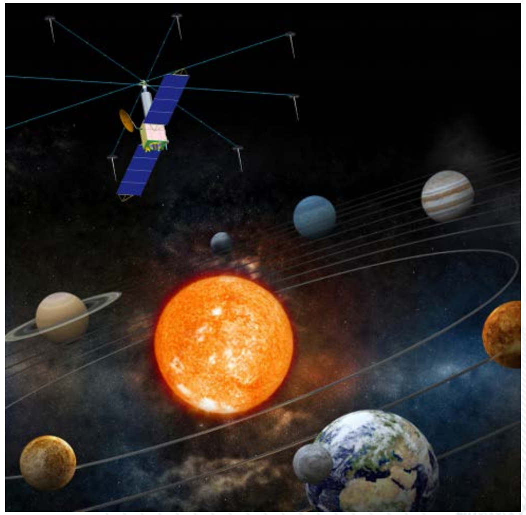
- Discover the effects of solar high-latitude magnetism on solar storm eruptions in the short term and solar cycle variations in the long term.

- Investigate the origin and properties of the fast solar wind

- Understand the acceleration, transport and distribution of energetic particles in the corona and heliosphere, and their causal relations with solar eruptions



CASS/UCSD 2002/07/26 00

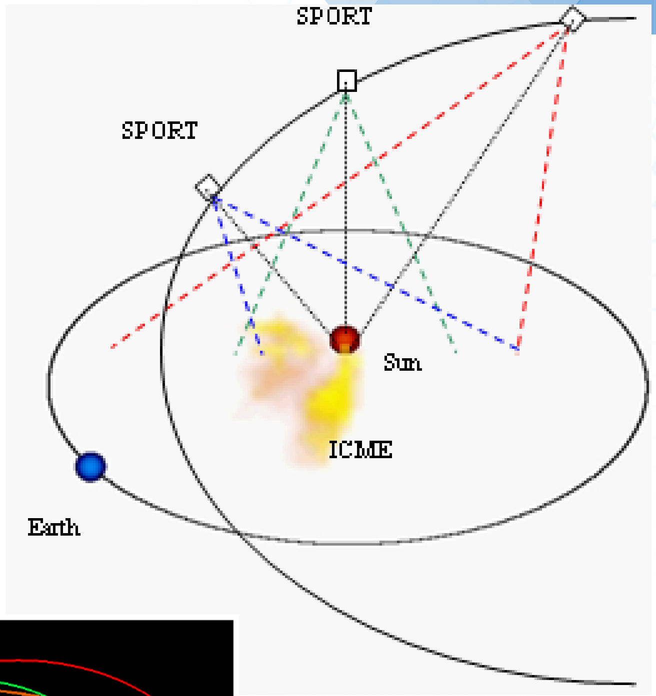


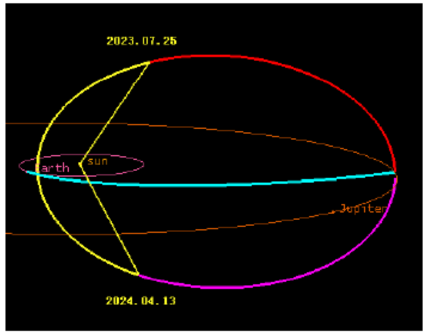
SPORT

Solar polar orbit (inclination>60) ,

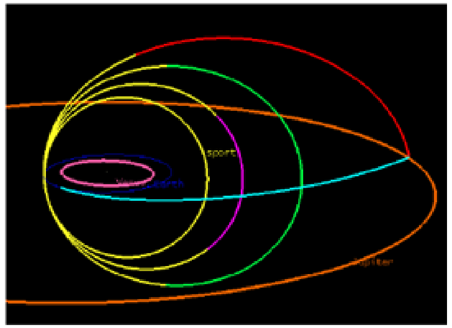
periapsis to the sun: 0.5-1AU

- ✓ Time for Imaging Observation
  - Flying over the solar polar regions, with the SPORT-sun distance within 2AU
  - During the next solar maximum
- ✓ Use multi-gravity assists (further Venus/Earth swing-by) to increase the

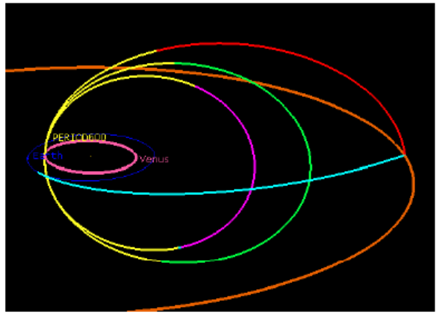




Imaging observation:17 months
2023.07.25-2024.04.13
2028.06.06-2029.02.25



Imaging observation:45 months
2023.09.25-2024.07.30
2026.08.25-2027.10.04
2028.06.15-2030.03.20

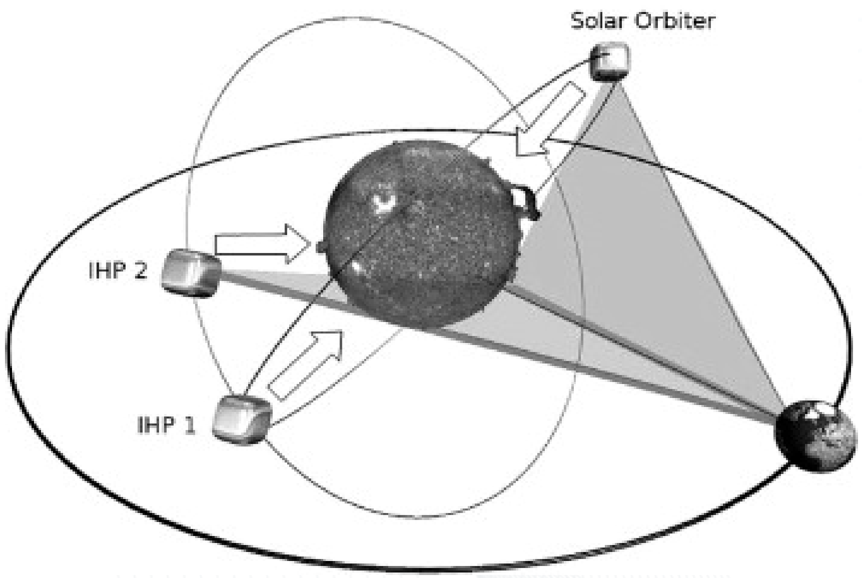


Time of observation:32months
2023.07.27-2024.05.02
2026.08.06-2027.06.24
2028.09.05-2029.08.20

Interhelioprobe

- The missions have been designed by the Russian and European Space Agencies and are aimed at studying the polar and equatorial regions from high heliolatitudes.
- Their primary task is to investigate the polar magnetic fields, plasma motions and solar dynamo, ecliptic corona and heliolatitudinal structure of mass ejections, mechanisms of corona heating and solar wind acceleration, triggering of solar flares and mass ejections, mechanisms of particle acceleration in the Sun and the heliosphere, solar wind sources in the Sun, and the relation of solar transient phenomena to variations in the heliosphere

Interhelioprobe/Solar Orbiter Cooperation



Interhelioprobe

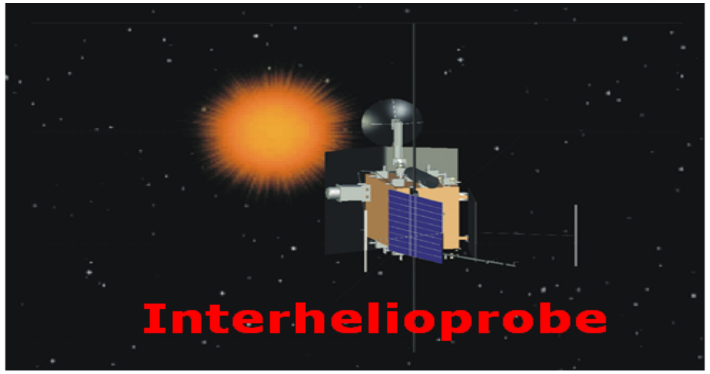
Payload

SOLAR INSTRUMENTATION-10

Optical photometer
Magnetograph
Chemical Composition Analyzer
EUV Imager-Spectrometer
Coronograph
X-ray Imager
Heliospheric Imager
X-ray Polarimeter
Gamma-Spectrometers - 2

HELIOSPHERIC INSTRUMENTATION-8

Solar Wind Ion Analyzer
Solar Wind Electron Analyzer
Solar Wind Plasma Analyzer
Energetic Particle Telescope
Neutron Detector
Magnetic Wave Complex
Magnetometer
Radio Spectrometer Detector



Heritage:
CORONAS-I (1994-2001)
INTERBALL (1995-2001)
CORONAS-F (2001-2005)
CORONAS-PHOTON (2009)
RESONANS (2014)

- Mass: 120-180 kg • Power: 120 W • Telemetry: 1 Gb/day

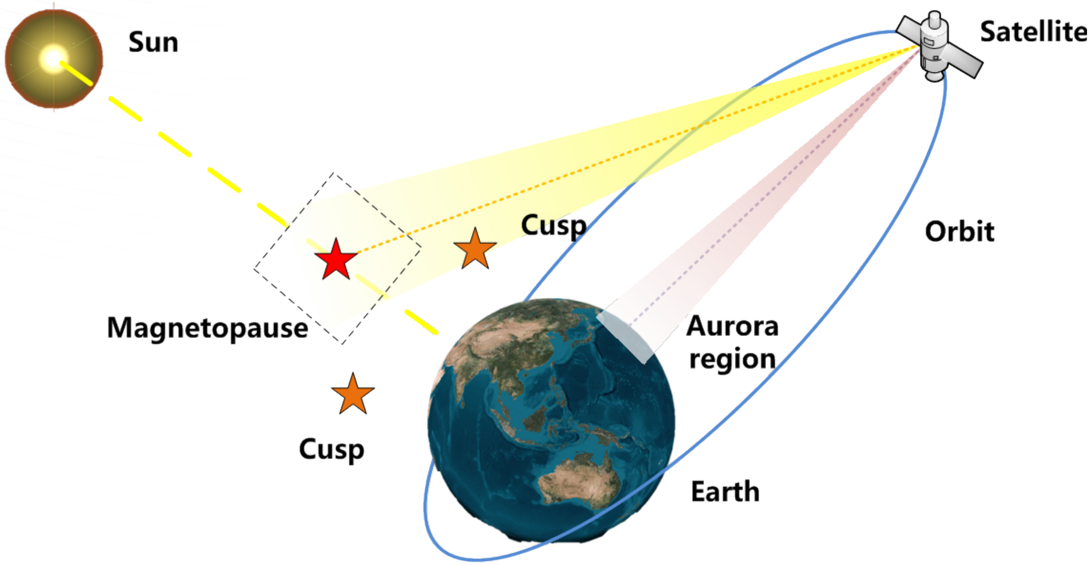
Major Scientific Objectives for SMILE

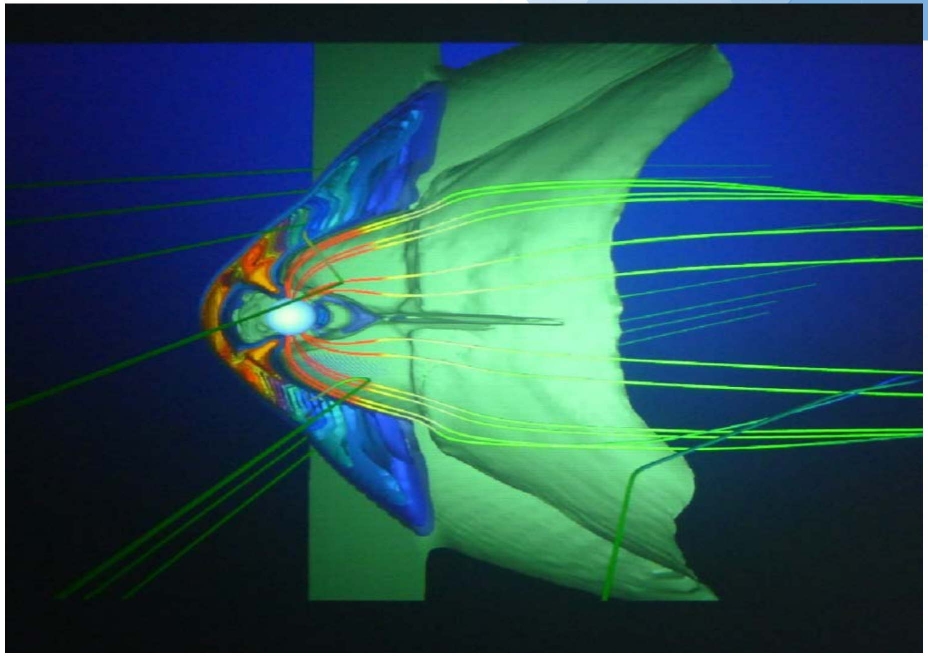
- Investigate the dynamic response of the Earth's magnetosphere to the solar wind impact in a unique and global manner
- Combine X-ray imaging of the dayside magnetosheath and the cusps with simultaneous UV imaging of the northern aurora, while monitoring the solar wind conditions in situ
- Full chain of events that drive Sun-Earth relationships: dayside reconnection / magnetospheric substorm cycle / CME-driven storms

SMILE Orbits

5000km@perigee

19 RE@apogee





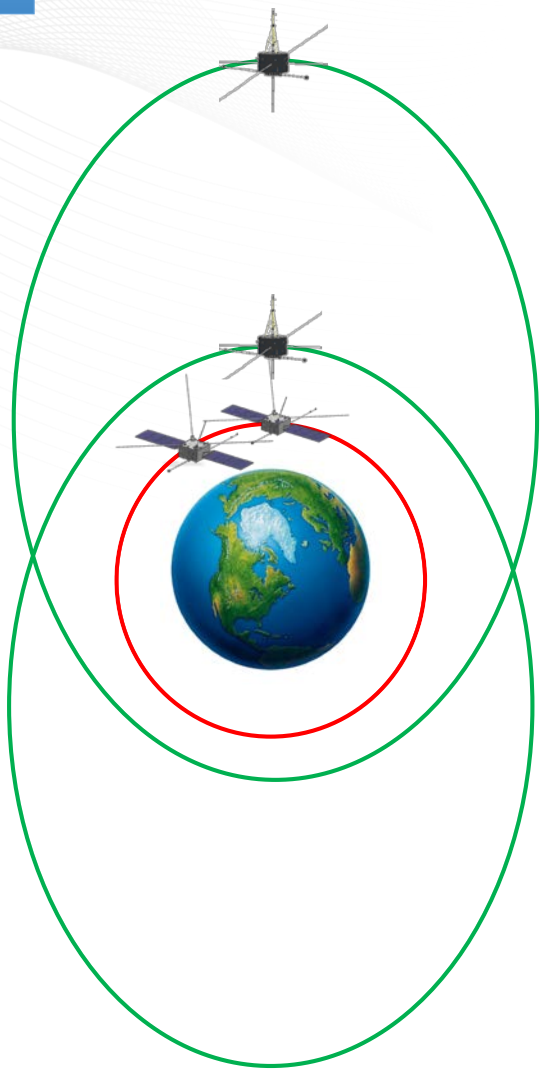
Launch date: 2022

NSSC · UCL · University of Leicester · Imperial College London · University of Calgary · Finnish Meteorological Institute · NASA Goddard · Polar Research Institute of China 1989

Magnetosphere, Ionosphere and Thermosphere Coupling (MIT)

- **Investigate** the origin of the outflow ions and their acceleration mechanism
- **Understand** the impact of the outflow ions on magnetic storm development
- **Characterize** the ionosphere and thermosphere storm caused by magnetic storm
- **Explore** key mechanisms for the magnetosphere, ionosphere and thermosphere

MIT Orbits

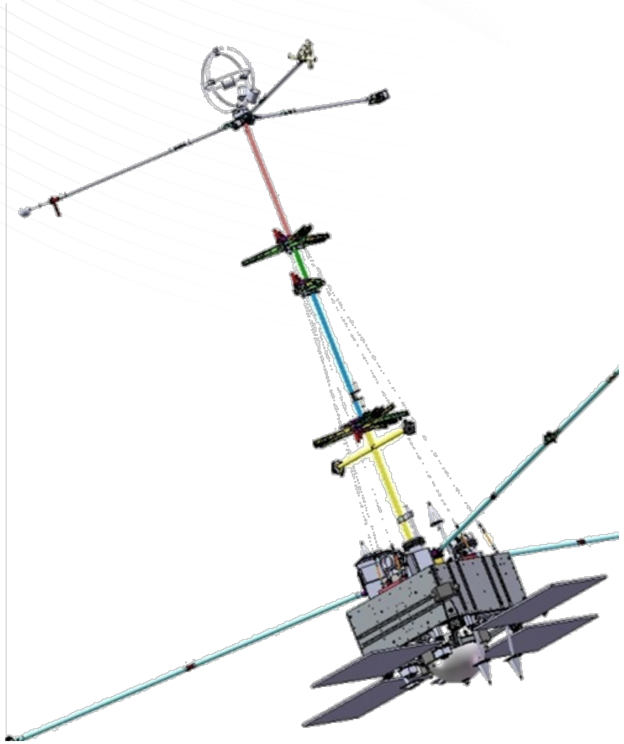


Satellite	Ionosphere/ Thermosphere Satellite-A （ITA）	Ionosphere/ Thermosphere Satellite-B （ITB）	Magnetosphere Satellite-A （MA）	Magnetosphere Satellite-B （MB）
Angle	90°	90°	90°	90°
Perigee Altitude	500 km	500 km	1 Re	1 Re
Apogee Altitude	1500 km	1500 km	7 Re	7 Re

The ratio of MA/MB to ITA/ITB period is 9:1.

Launch date: 2021

Resonance



Inner magnetospheric mission

- Space weather

  Ring current, outer radiation belt, plasmasphere

- Resonant wave-particle interactions

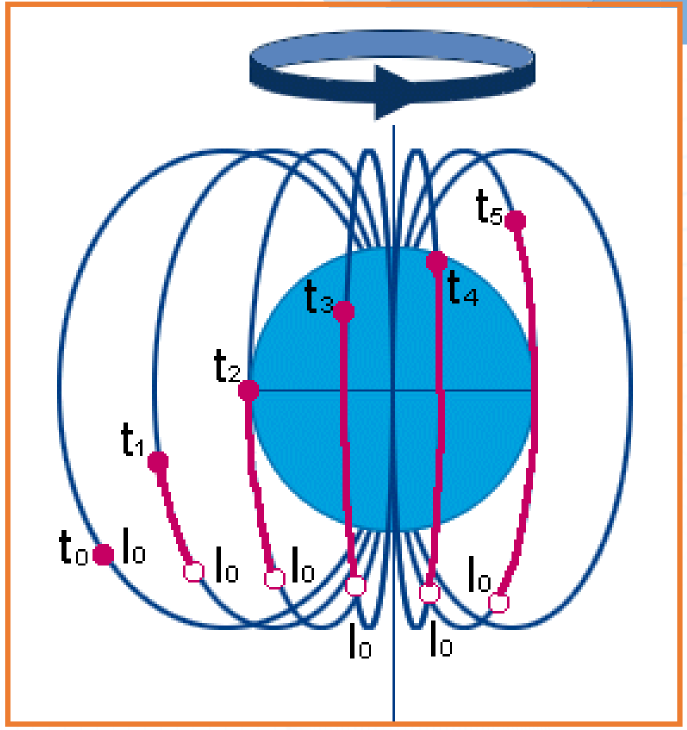
  Magnetospheric cyclotron maser

- Auroral region acceleration

  Small-scale active zones, precipitation

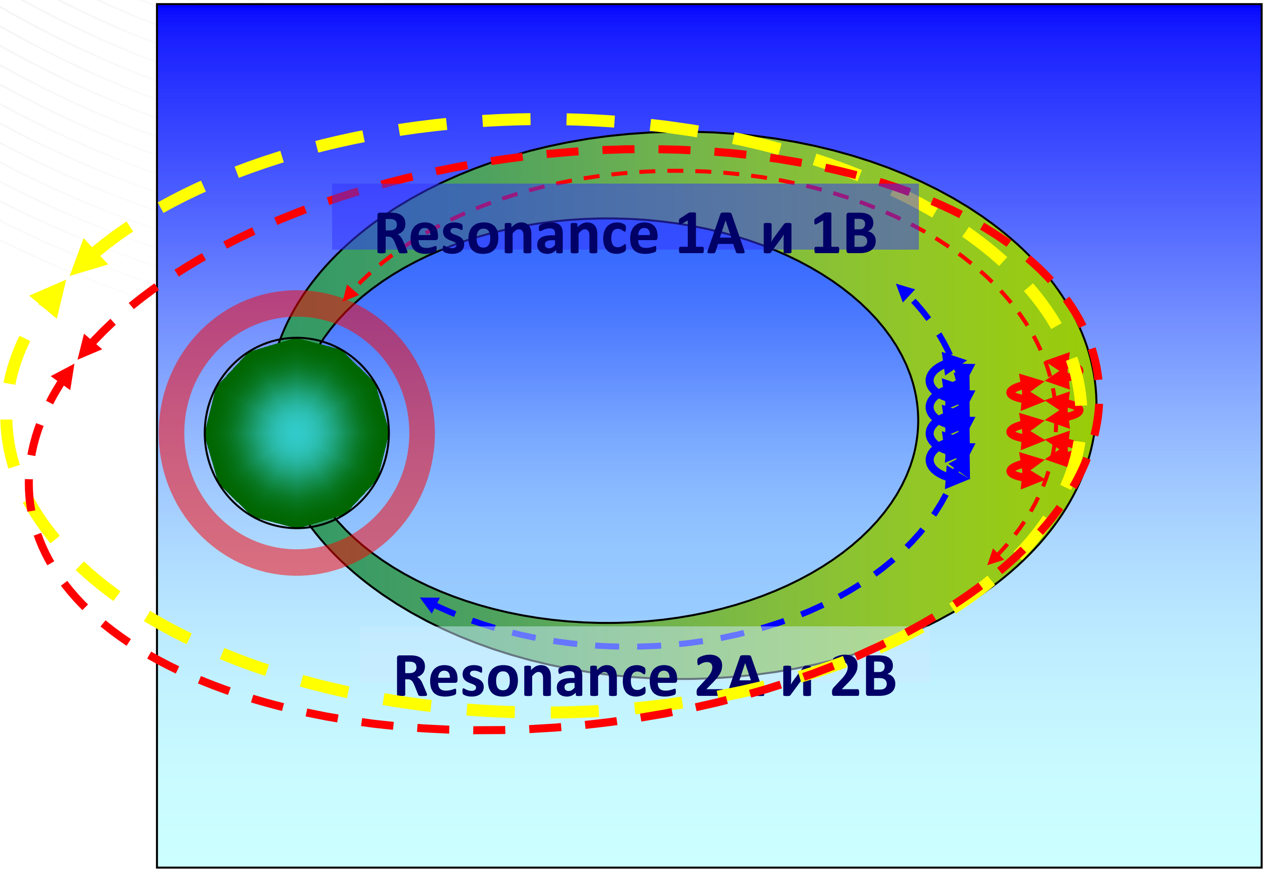
- Two pairs of spacecraft

- Magneto-synchronous orbit



Resonance

Magnetosyncronous orbit



- Electric and magnetic sensors

  Wave analyzer and interferometer

  DC – 10 MHz

- Plasma sensors

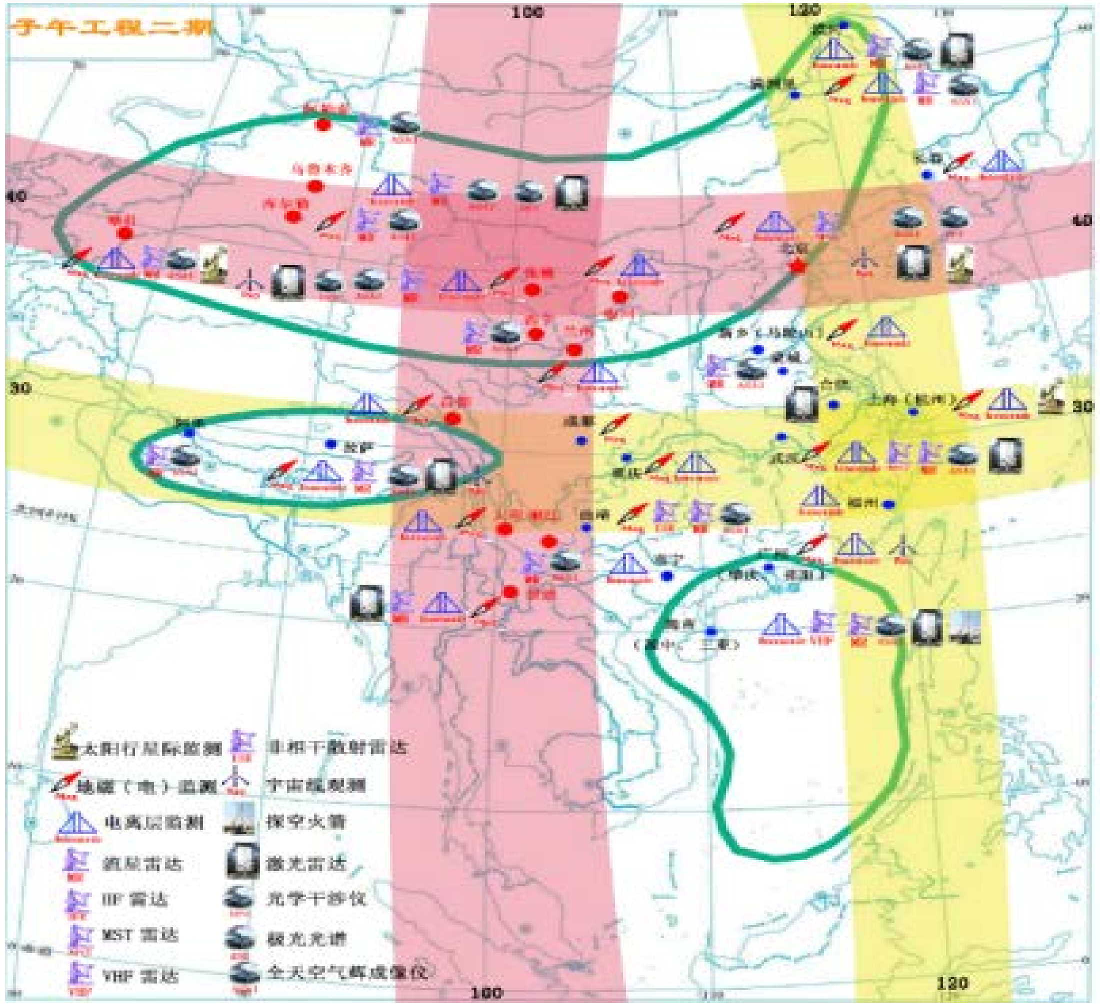
  Cold plasma

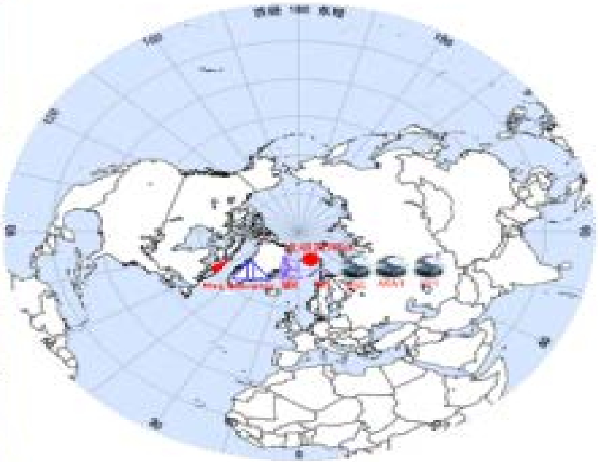
  Suprathermal plasma

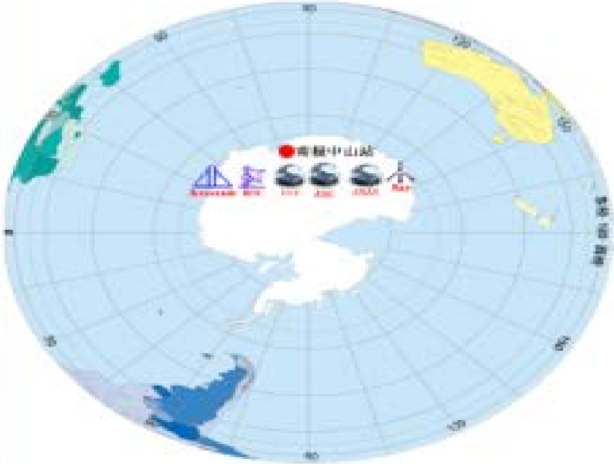
  Energetic particles

  Relativistic electrons

Chinese Meridian Project II







International Space Weather Meridian Circle Program

International Space Weather Meridian Circle Program (IMCP) connect 120ºE and 60ºW meridian lines forming chains of ground based observatories to enhance the ability of monitoring space environment worldwide.

China+ Russia+ Australia+ Canada+ Brazil … …□ International Meridian Circle Program

Time Schedule for IMCP

Phase One(2018-2020)	Phase Two(2021-2025)	Phase Three(2025-2030)
Establishing the organizational structure and objectives	Perfecting the organizational structure and carrying out project cooperation	Forming an international academic organization for multilateral cooperation

Mid-latitude Observation Chain

- Mid-latitude Observation Chain is proposed which start from Japan to Spain which is the longest (>10,000km)mid-latitude observation chain on earth.

- It is our opportunity to observe the space environment from the sun to the atmosphere cross different time zone at mid-latitude.

中国科学院国家空间科学中心
National Space Science Center, CAS

Summary

- We have entered the space for 60 years and had a good understanding of the space environment. Space is not empty, not quiet, and sometime will behave badly to us, the same as the weather on the surface of the earth, therefore we call it – SPACE WEATHER
- What we have experienced in space in the past 60 years are less than 6 solar cycles, each of them are different. The Sun may have much big storms than what we have experienced. So we'd better be prepared.
- To understand the space weather need much more efforts where new missions are encouraged and international collaborations are very much demanded.

Thank You!

Congratulations on Human's First Man-made Satellite Sputnik's 60th Anniversary