Hinode: A New Solar Observatory in Space

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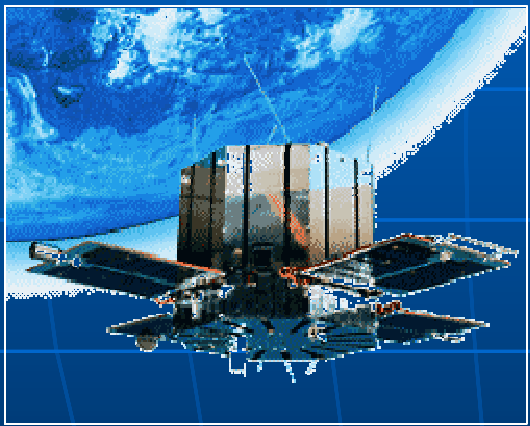
and the Hinode team

2006 Dec 6

Japanese Sun Observing Spacecrafts

Hinotori (ASTRO-A)



188 kg
Launched in 1981 Feb

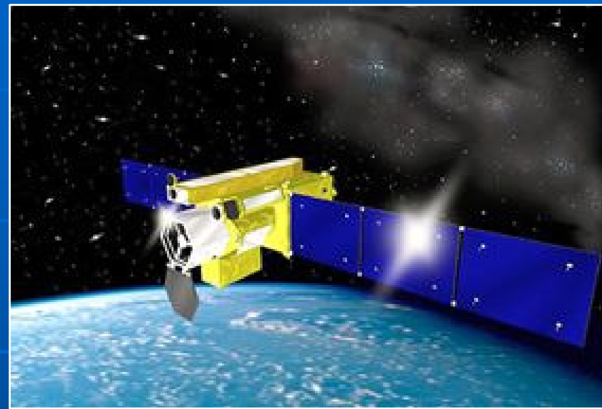
Particle acceleration and plasma heating in solar flares

Yohkoh (SOLAR-A)

390 kg
Launched in 1991 Aug

Particle acceleration and plasma heating in solar flares and general coronal activities

Hinode (SOLAR-B)



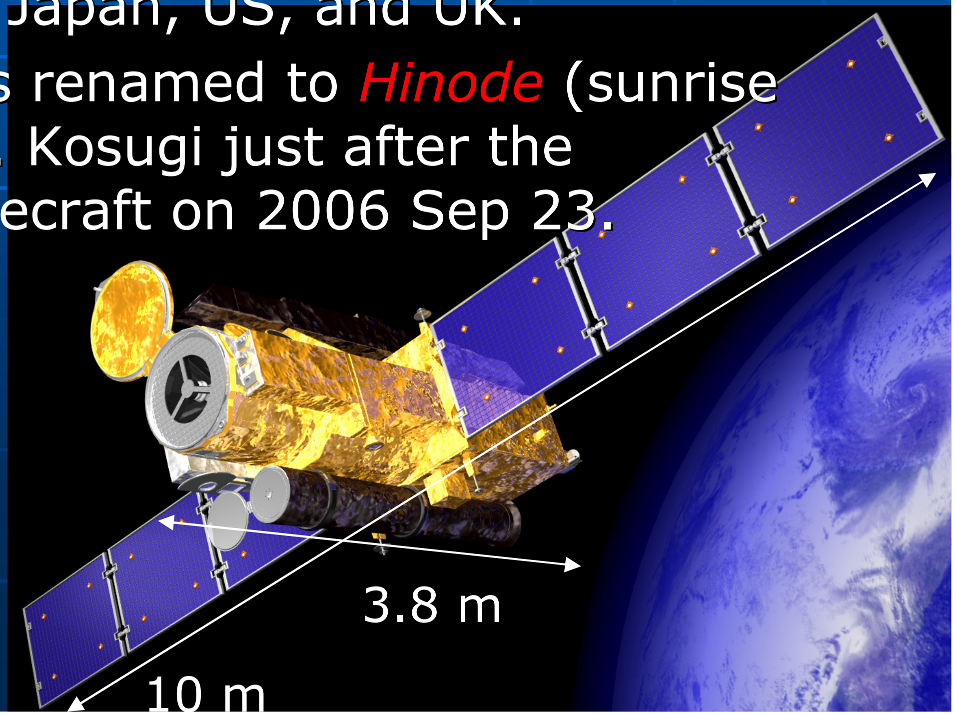
900 kg
Launched in 2006 Sep

General solar activities of magnetized plasmas

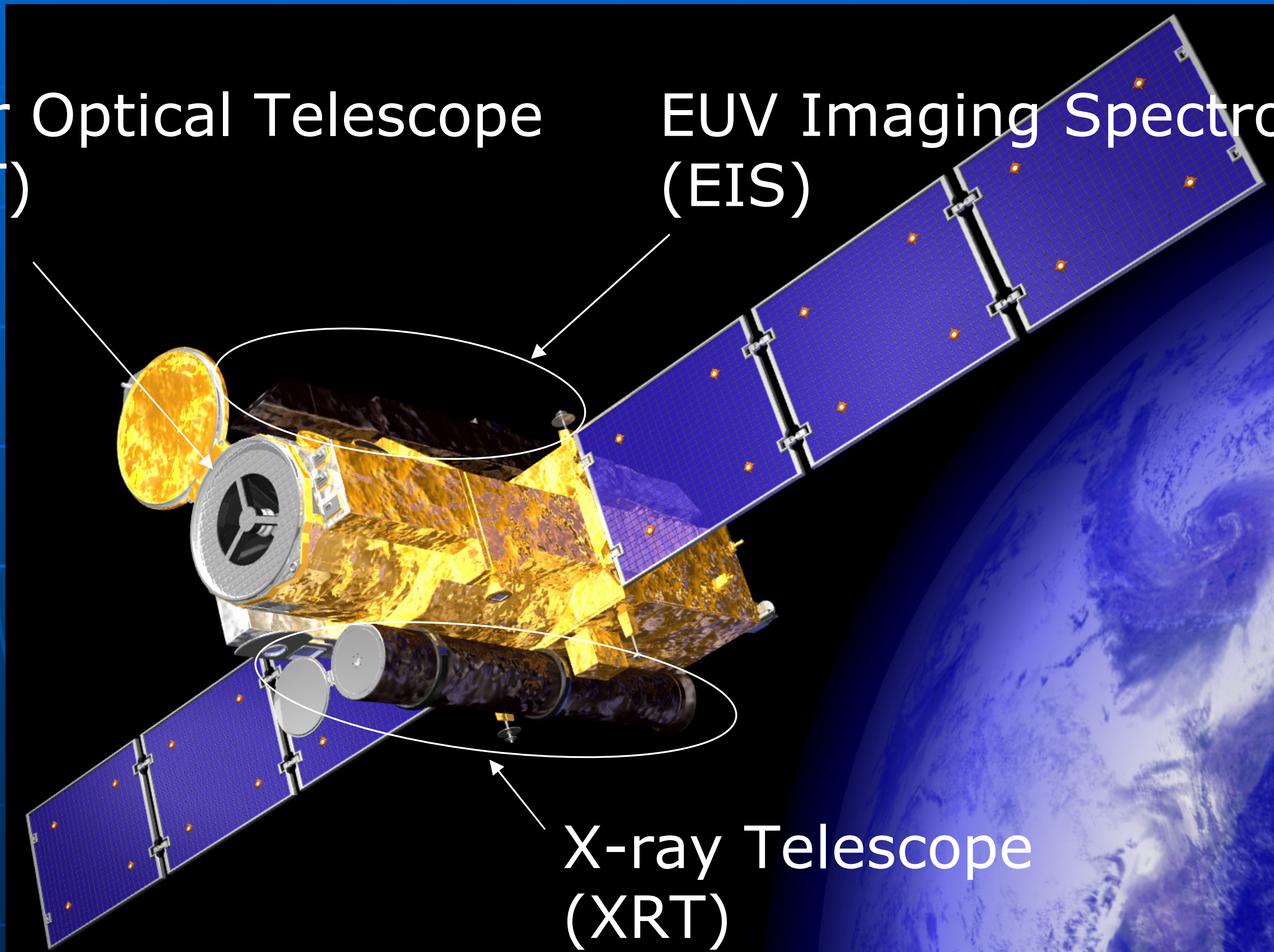
SOLAR-B Mission

- Causal linkages between the photosphere and the upper solar atmosphere, regarding the existence of the chromosphere and corona and their characteristic structures, are investigated.
- SOLAR-B carries Solar Optical Telescope (SOT), X-ray Telescope (XRT) and EUV Imaging Spectrometer (EIS).
- These three telescopes have been developed in an international collaboration of Japan, US, and UK.
- The code name SOLAR-B was renamed to *Hinode* (sunrise in Japanese) by the late Prof. Kosugi just after the successful launch of the spacecraft on 2006 Sep 23.

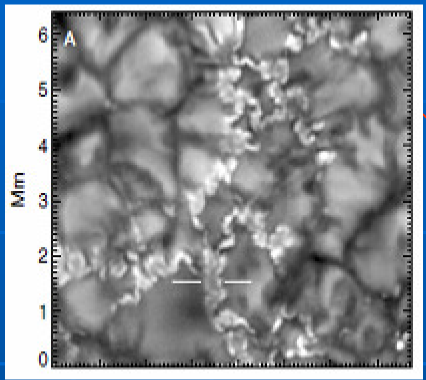
Weight: 900 kg at launch
Launch vehicle: M-V-7th
Orbit: Sun-synchronous orbit
680 km altitude

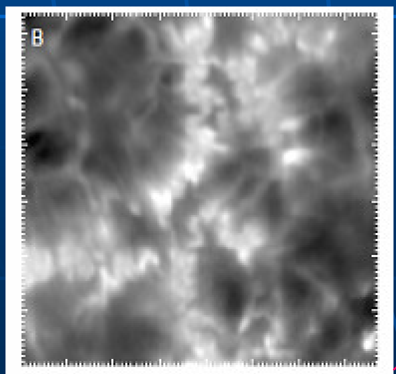


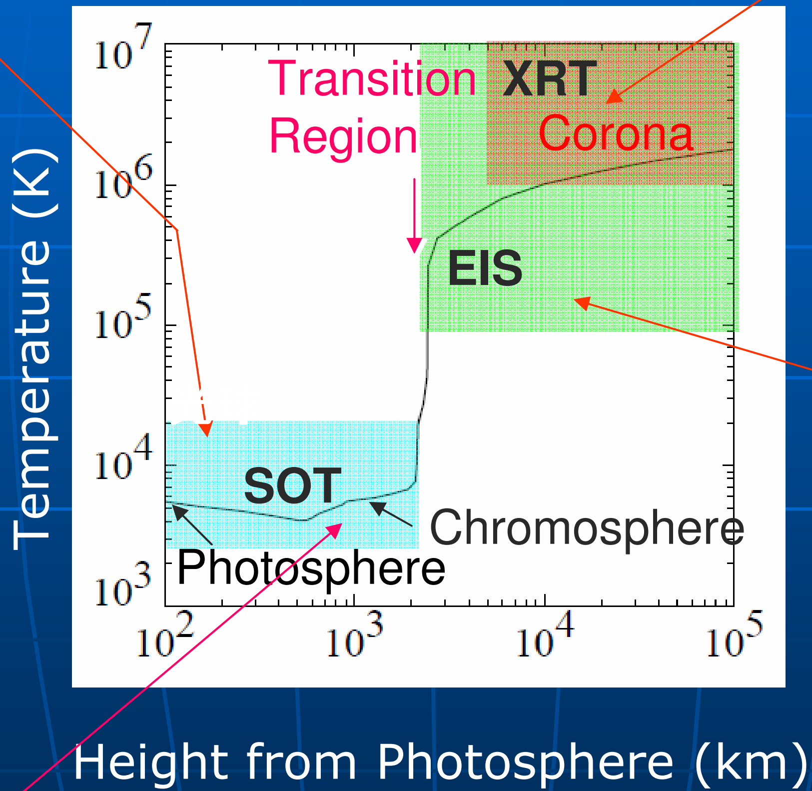
Telescopes aboard Hinode



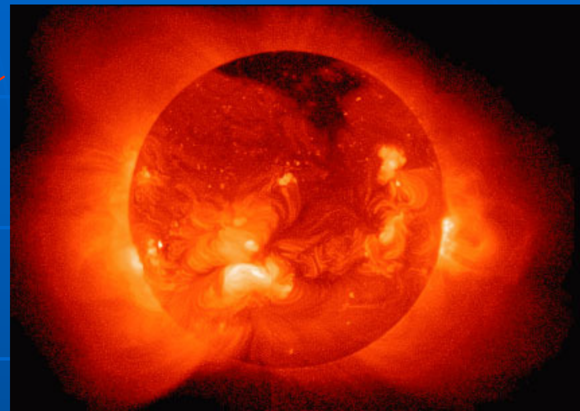
Solar Atmosphere







Corona



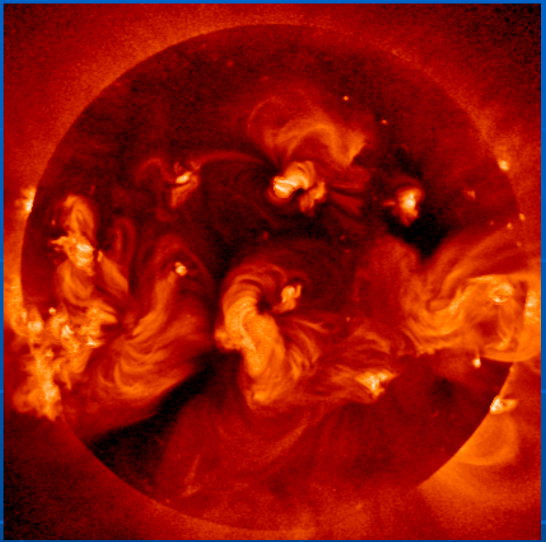
TR/Corona (EUV)

scientific targets

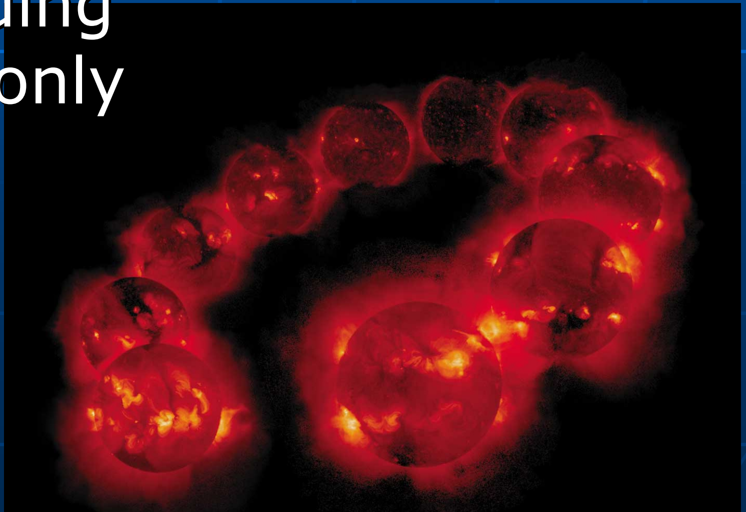
Why the Corona is so Hot?

- The solar corona is a tenuous 10^6 K magnetized plasma above the photosphere of 6000 K.
- Most of stars and cluster of galaxies have the hot corona.

  → A mystery in Astronomy
- Detailed studies for understanding the basic reason can be made only for the Sun.



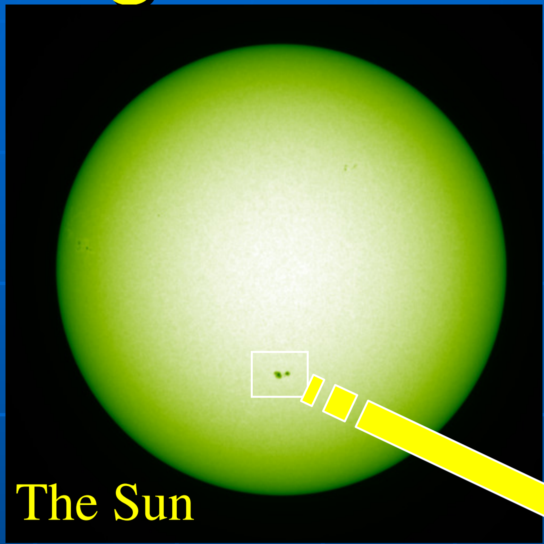
Yohkoh X-ray Image

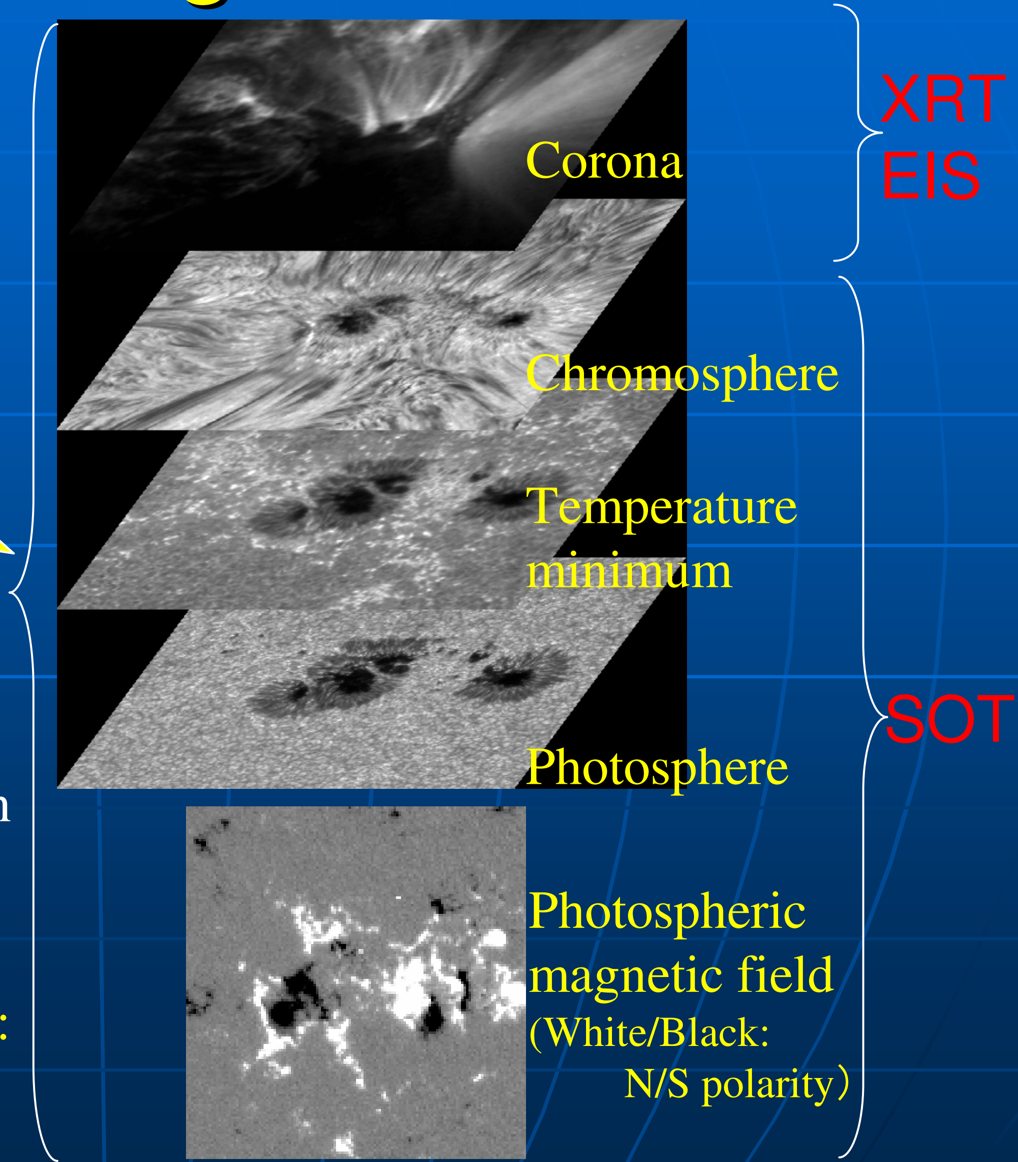


The solar corona over 10 years

scientific targets

Origin of Solar Magnetic Activities





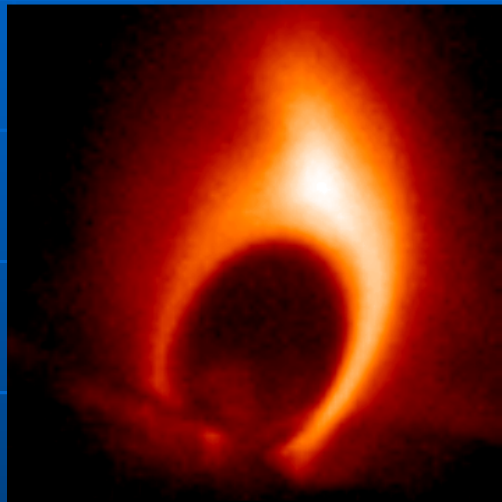
- Active phenomena observed in the solar atmosphere are strongly coupled with magnetic fields.
- Causal linkages between evolution of elementary magnetic fields and the active phenomena are investigated.
- Size of elementary magnetic fields:

0.2-0.3 arcsec (150-220 km)

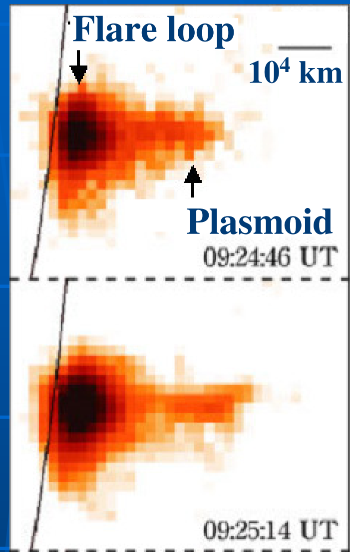
scientific targets

Fundamental Process in Space Plasmas - magnetic reconnection -

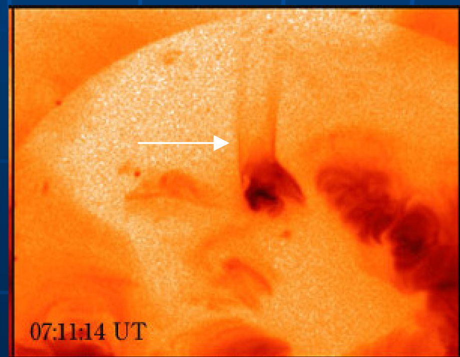
- Magnetic reconnection plays an important process to understand solar dynamic events such as solar flares, CME, X-ray jets, and micro-flares.
- This process is also important to understand the dynamics around star-forming region, stellar flares, and etc.
- Vector magnetic field measurements with SOT
  →Energy build-up process for solar events becomes a new target.
- Coronal velocity fields are measured with EIS.



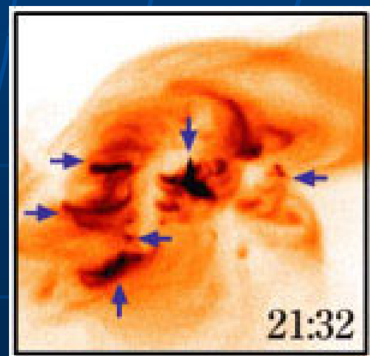
A Solar flare with Cusp Apex



Plasmoid eruption



X-ray Jet



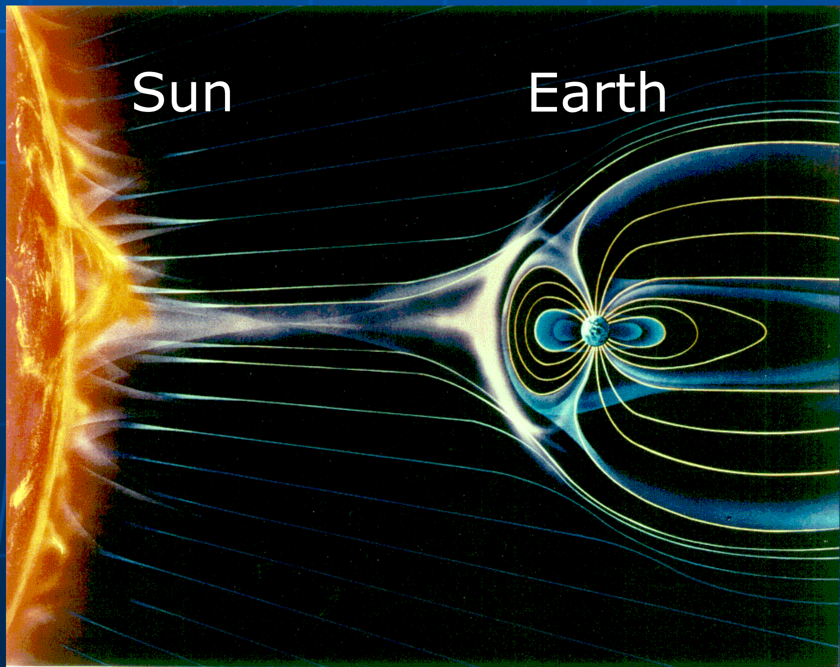
Micro-flares

Sun-Earth Connection

- The space environment around the earth, 'space weather,' is largely affected by the solar activity.
- Deep understanding of flares and CME trigger mechanisms leads to prediction of the space weather conditions.

  → Practical aspect of Solar Physics study to Public

- It is expected that Hinode data will contribute to improve the space weather prediction.

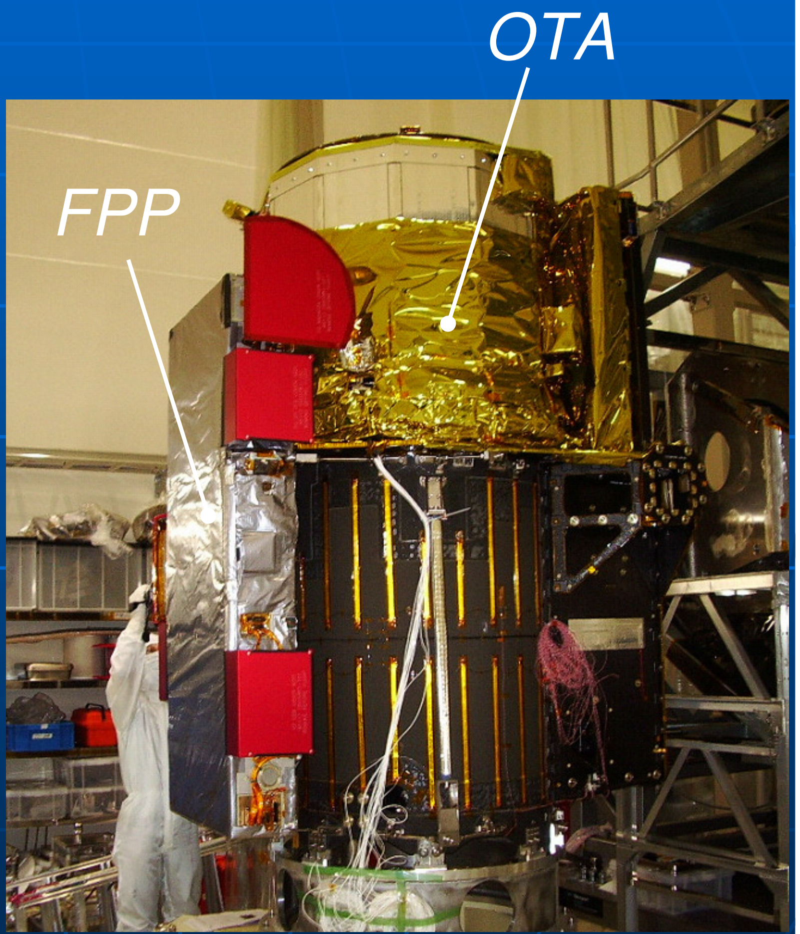


Solar Optical Telescope (SOT)

The Largest solar telescope ever flown

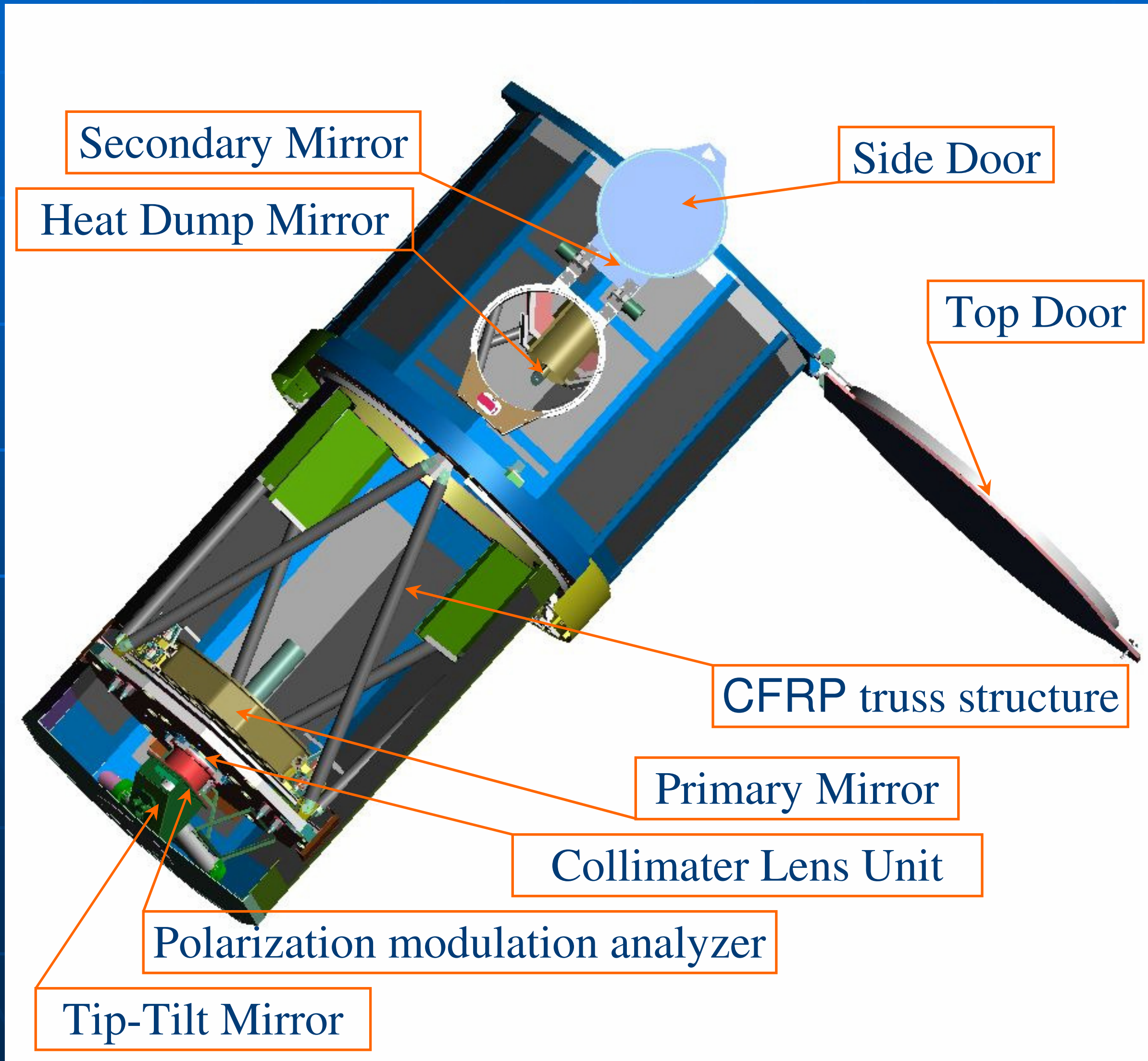
- SOT observes the photosphere and chromosphere in visible-light wavelength (380-670nm) with spatial resolution of **0.2-0.3** arcsec.
- SOT has
  - wide-bandpass ($\Delta\lambda$~0.5nm) and narrow-bandpass ($\Delta\lambda$~0.009nm) imagers
  - a spectropolarimeter for vector magnetic-field observations.
- **0.03** arcsec/10sec stability needed.

→The telescope has an image stabilization system to achieve this requirement.
Correlation tracker + tip-tilt mirror



SOT: Optical Telescope Assembly (OTA)

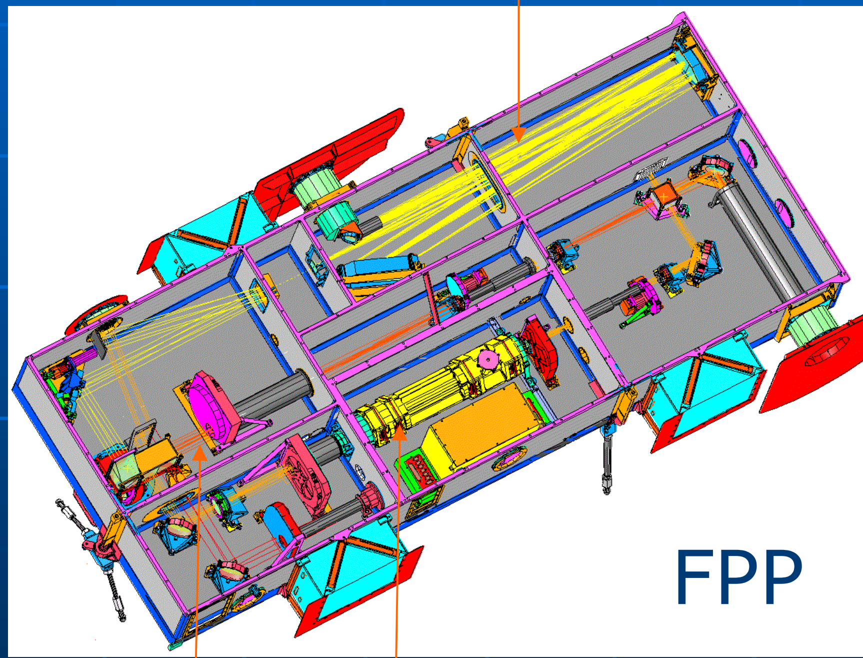
The diffraction-limited solar telescope of 50cm aperture



SOT: Focal Plane Package (FPP)

- Filtergraph (FG)
  12 wavelength bandpasses are available.
  Dynamical motions of magnetized plasmas are observed.

- Spectropolarimeter (SP)
  Polarization of Fe I absorption lines at 630 nm is precisely measured.
  →high-resolution vector magnetic fields

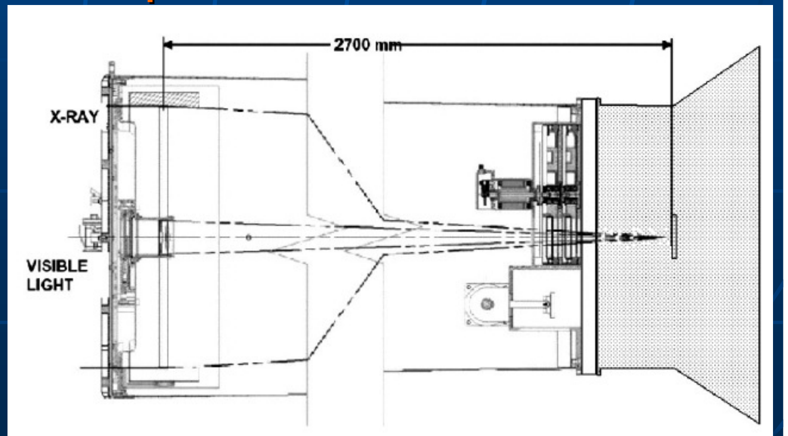


X-Ray Telescope (XRT)

The high-resolution Solar X-ray Imager

- A wide-field (2Kx2K arcsecs) grazing-incidence telescope of 2 arcsec resolution
→three times better than Yohkoh's

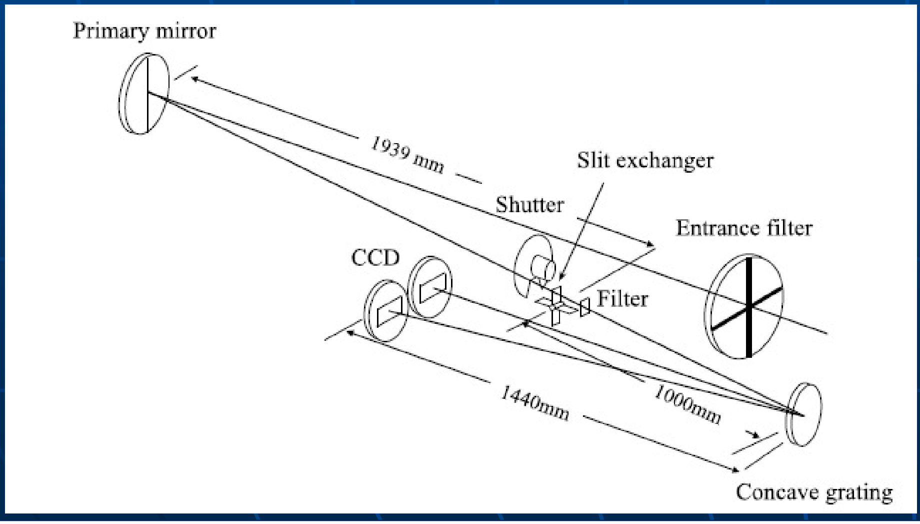
- Imaging observations of dynamic phenomena in the solar corona
- High sensitivity for low (1MK) temperature plasmas
  → 1 – 30 MK temperature response
- On-board flare detection functionality



EUV Imaging Spectrometer (EIS)

The high-sensitivity solar EUV imaging spectrometer

- Wavelength ranges: 17-21 nm, 25-20 nm
- Observation of transition region and corona
- 2 arcsec spatial resolution
- $\lambda/\Delta\lambda \sim 4000\text{-}5000$ spectral resolution
- An order of magnitude higher sensitivity than SOHO CDS
  → Higher cadence observation is possible for dynamic events
- Temperature and density diagnostics from line ratio



Key Issues in Spacecraft

- Selection of sun-synchronous orbit for high pointing stability
- CFRP optical bench with high heat conduction coefficient for high pointing stability
- Sub-arcsec resolution of sun sensors
- Reduction of micro-vibration

  Low transfer characteristics for mechanical disturbance from attitude sensors and actuators (gyros and momentum wheels) to Optical Telescope Assembly (OTA) for achieving the OTA optical performance

- Strict contamination control for longer life of science instruments
- Development of 12bit JPEG compression hardware chip for reducing the size of science data

International Collaboration

- Japan: Development of OTA, XRT camera and control electronics, spacecraft, and launch vehicle

- US (NASA) : Development of FPP, XRT telescope, and EIS optics & mechanisms

- UK (PPARC) : Development of EIS

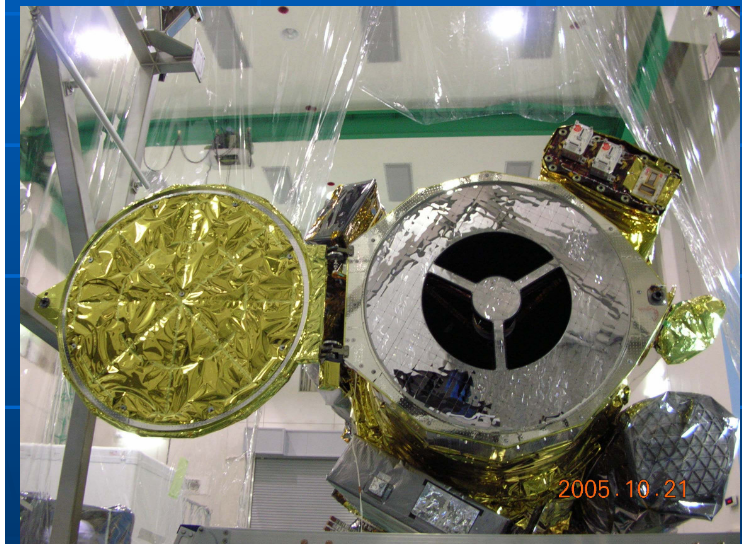
- ESA : Telemetry data reception at Svalbard (N78°, Norway)
  15 contacts/day → 300-400 kbps/ave.

Schedule up to Launch

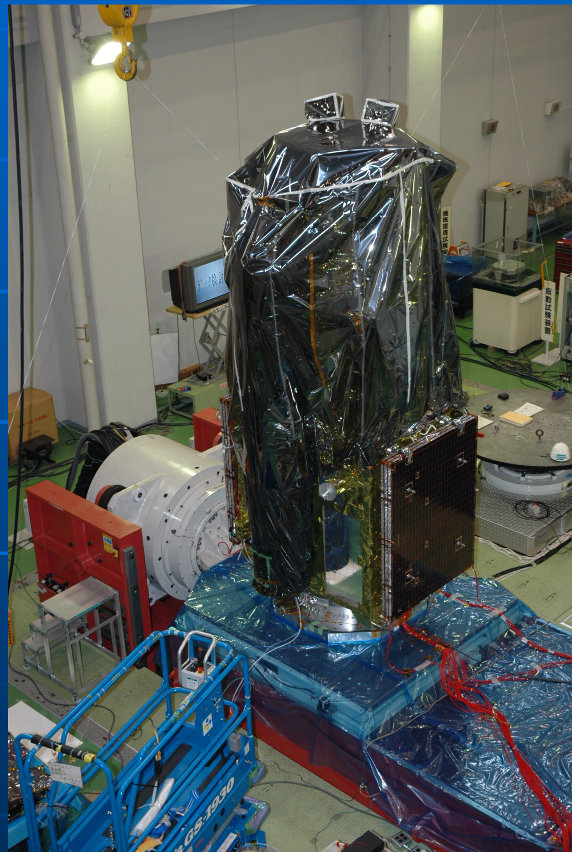
- 1991: First mission concept
- 1995: Submission of proposal
- 1998: Approval by government
- 1999: Start of mission design
- 2001: Proto model test
- 2002: Structure and thermal model tests
- 2003: Fabrication of flight models
- 2004: Electrical and mechanical interface check
- 2005: Assembly and Environmental Test
- 2006: Final performance test
- 2006 Sep 23: Launch of spacecraft

Verification Test

Door deployment test

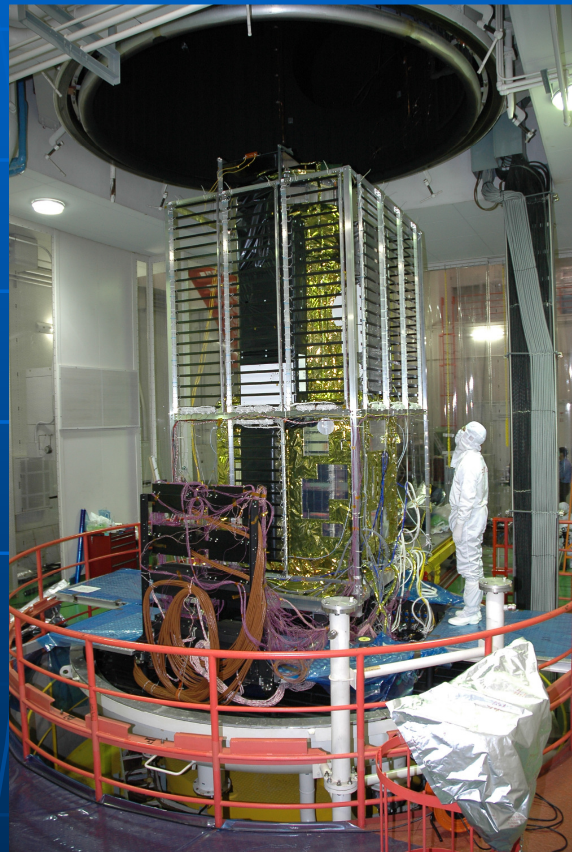


2005 Oct



Mechanical load test

2005 Oct

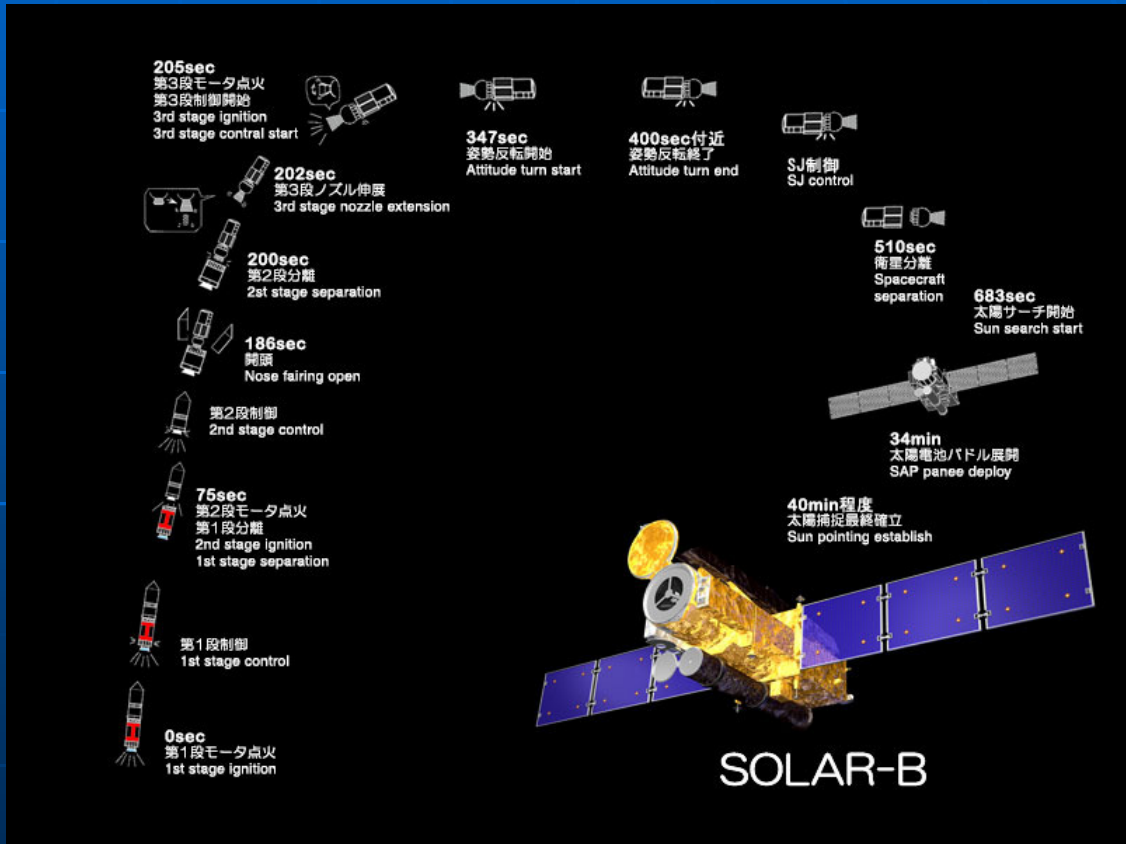


Thermal vacuum test

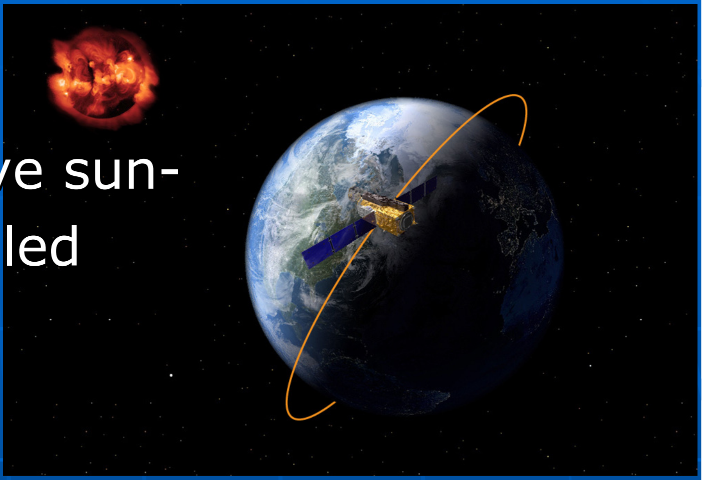
2006 Mar

Launch !

2006 Sep 23 06:36 JST



Hinode Operation after Launch



- 2006 Sep 23: Launch
- Oct 03: Finish orbit control to achieve sun-synchronous orbit as scheduled
- Oct 23: Start XRT PV observations
- Oct 25: Start SOT PV observations
- Oct 28: Start EIS PV observations

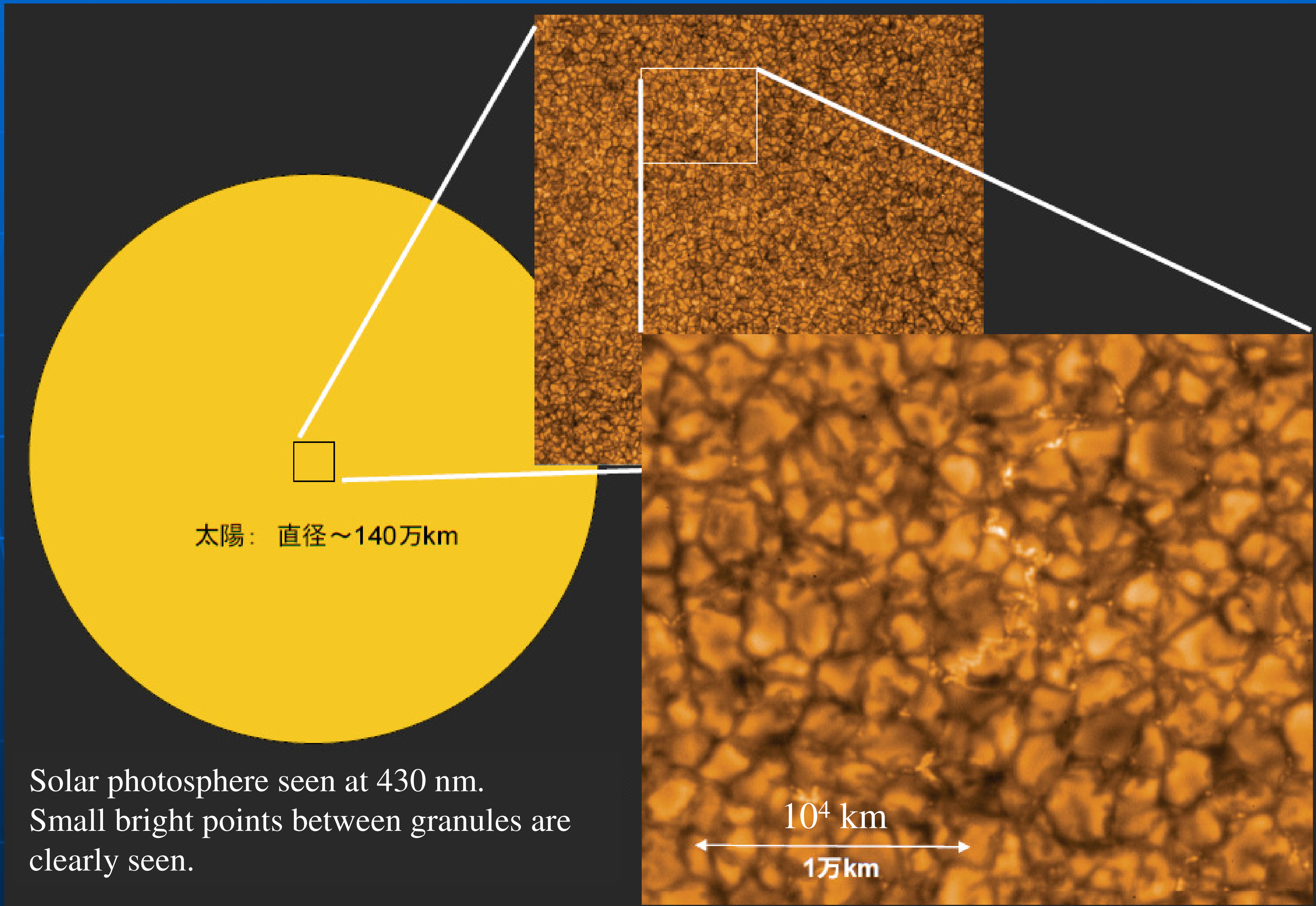
PV: Post-launch Verification

- End of Nov: Partially start initial observations
- 2007 Mar:

Start observations that are proposed from the outside of the Hinode team.

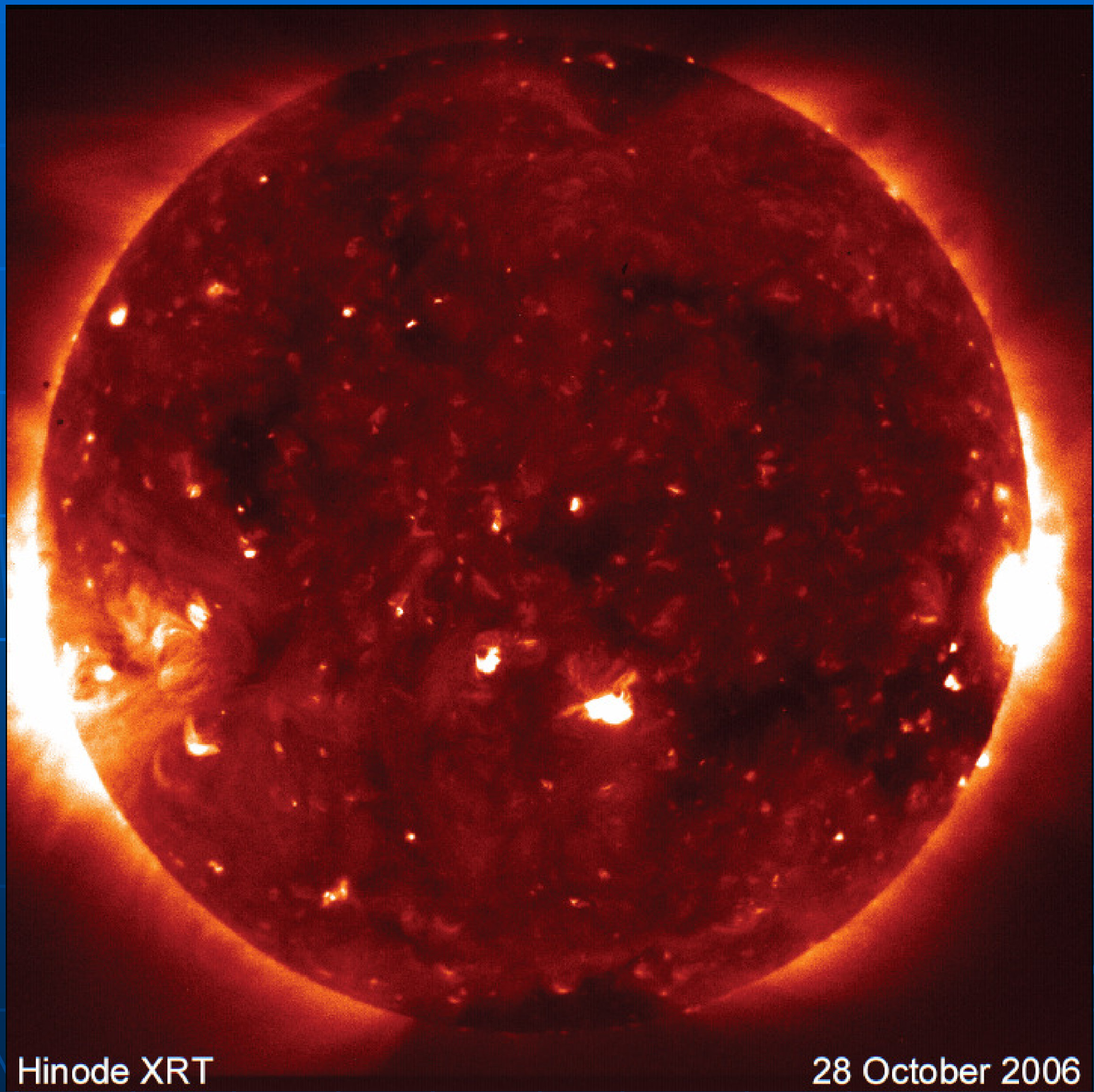
All Hinode data are opened to world-wide solar physics community.

SOT: First Press Release Image

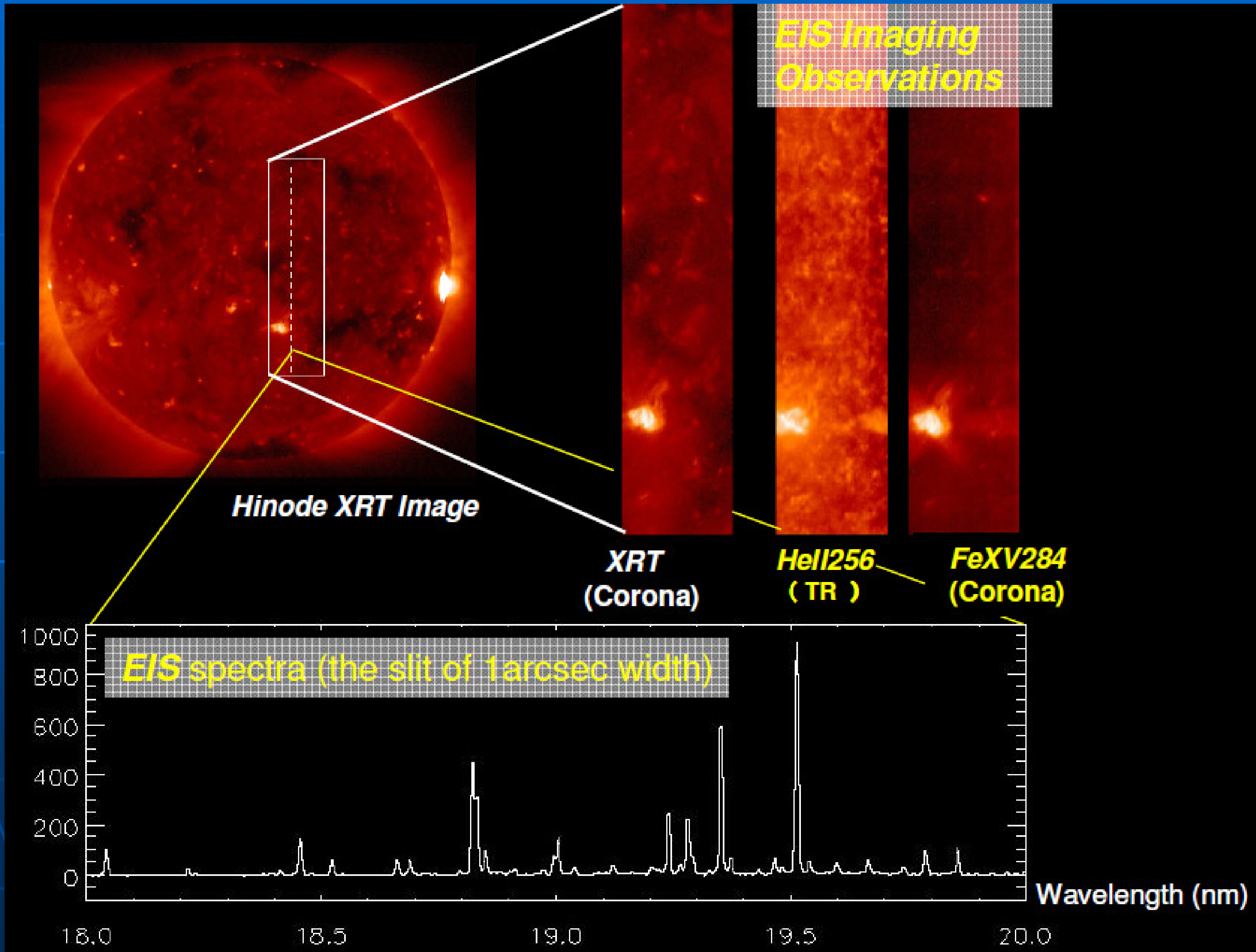


Solar photosphere seen at 430 nm.
Small bright points between granules are clearly seen.

XRT: First Press Release Image



EIS: First Press Release Image



Summary

- The launch and PV-observations were successful.
- The spacecraft operation by scientists is now stable.
- We are moving to initial science observations.

- Joint observations with ground-based observatories & other spacecrafts, and collaboration of science analysis with foreign scientists will be started after March 2007 to achieve Hinode science goals.