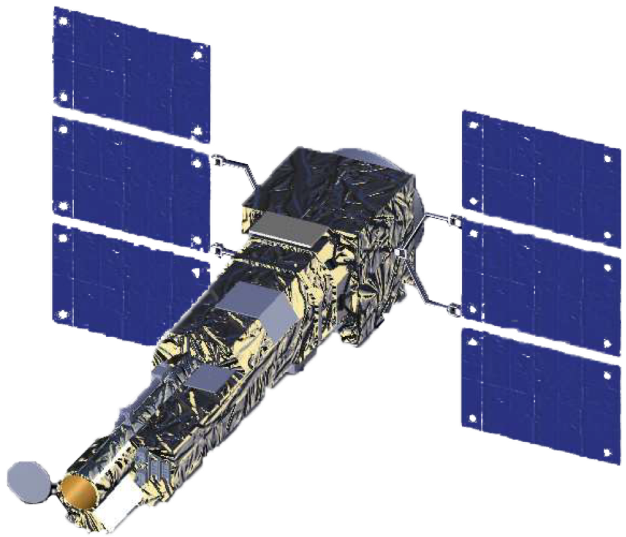
Hinode-13/IPELS 2019, 2 - 6 September 2019
@The University of Tokyo

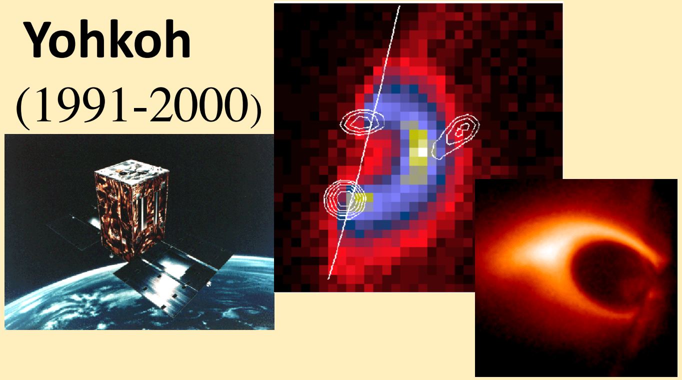
The Solar-C_EUVST mission



Toshifumi SHIMIZU
(ISAS/JAXA, Japan)

New observations, better understanding

Yohkoh (1991-2000)

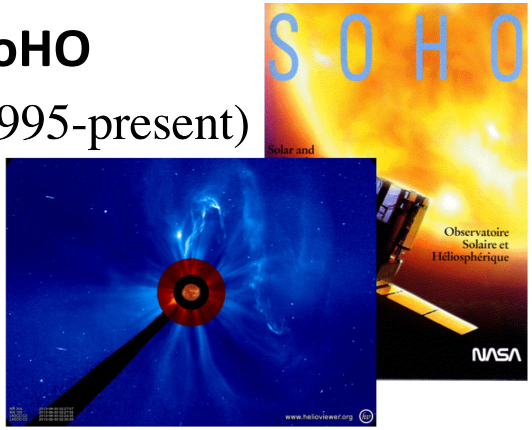


Pieces of evidence for MR

Hinode (2006-present)

Magnetic behaviors at the surface
Dynamic chromosphere (image)

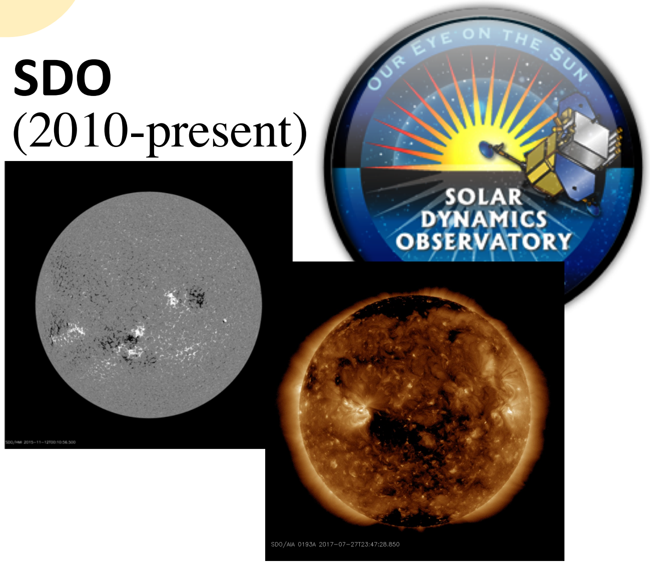
SoHO (1995-present)



Convection zone probed with helioseismology

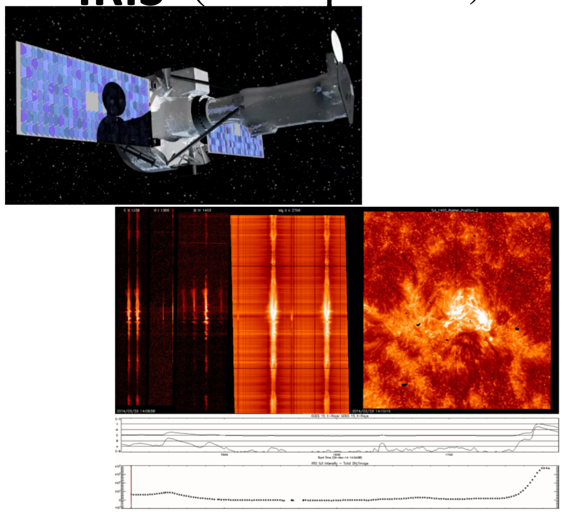
CME evolution with coronagraph

SDO (2010-present)



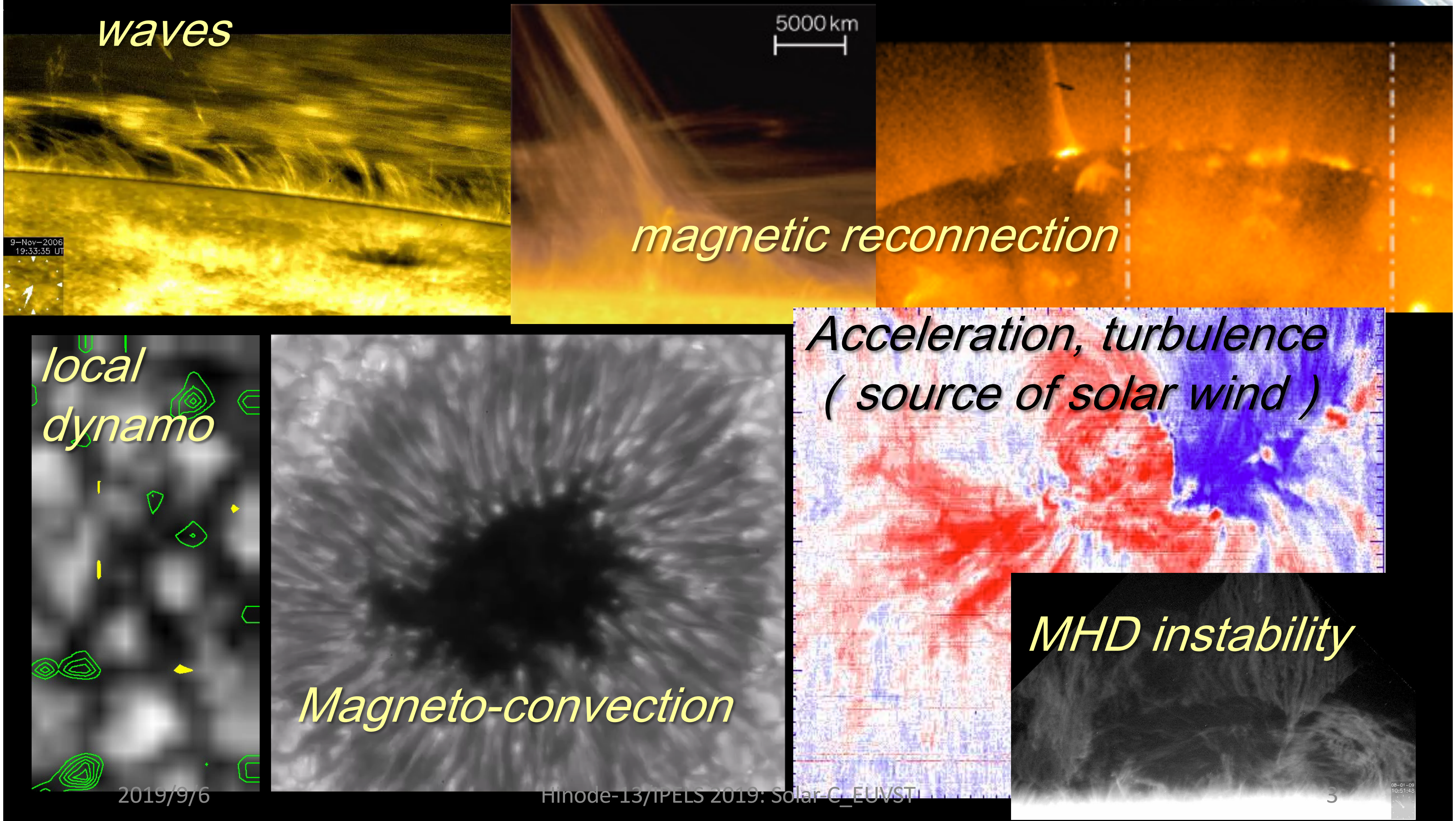
Full Sun monitoring for space weather

IRIS (2013-present)



Quantified dynamic chromosphere

Better understanding of MHD processes, advanced with Hinode observations



New observations, better understanding

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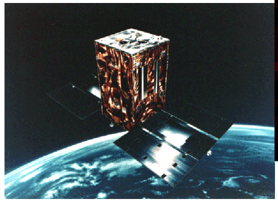
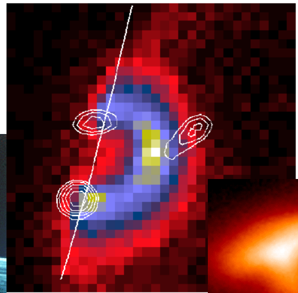
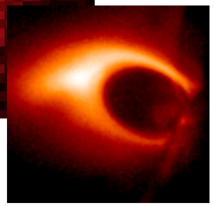

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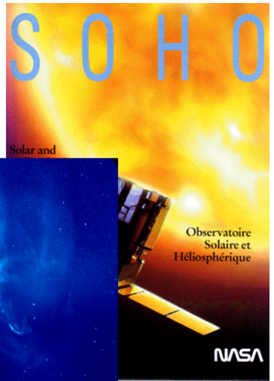

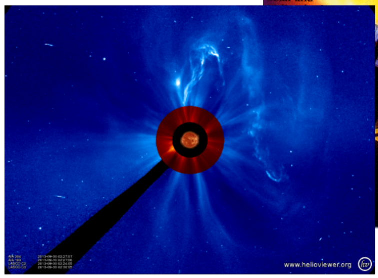

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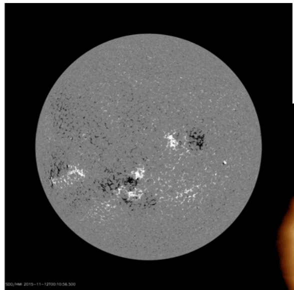
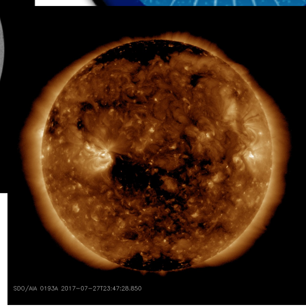

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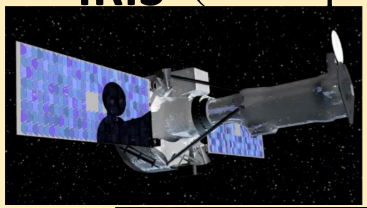
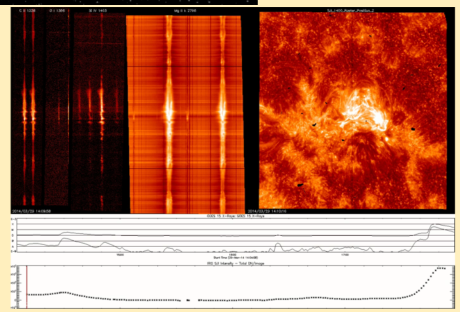
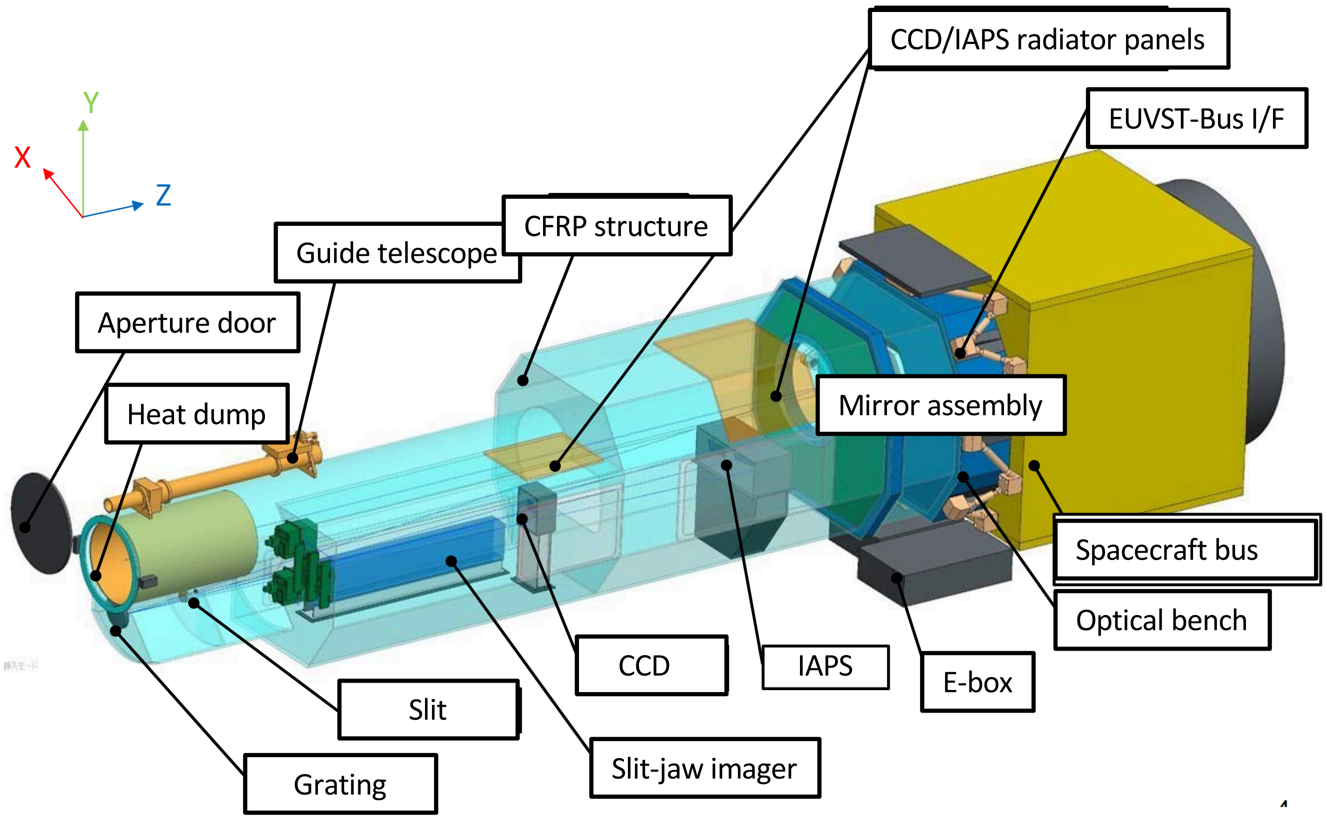



Quantified dynamic chromosphere

Solar-C_EUVST mission

= Solar-C EUV High-throughput Spectroscopic Telescope

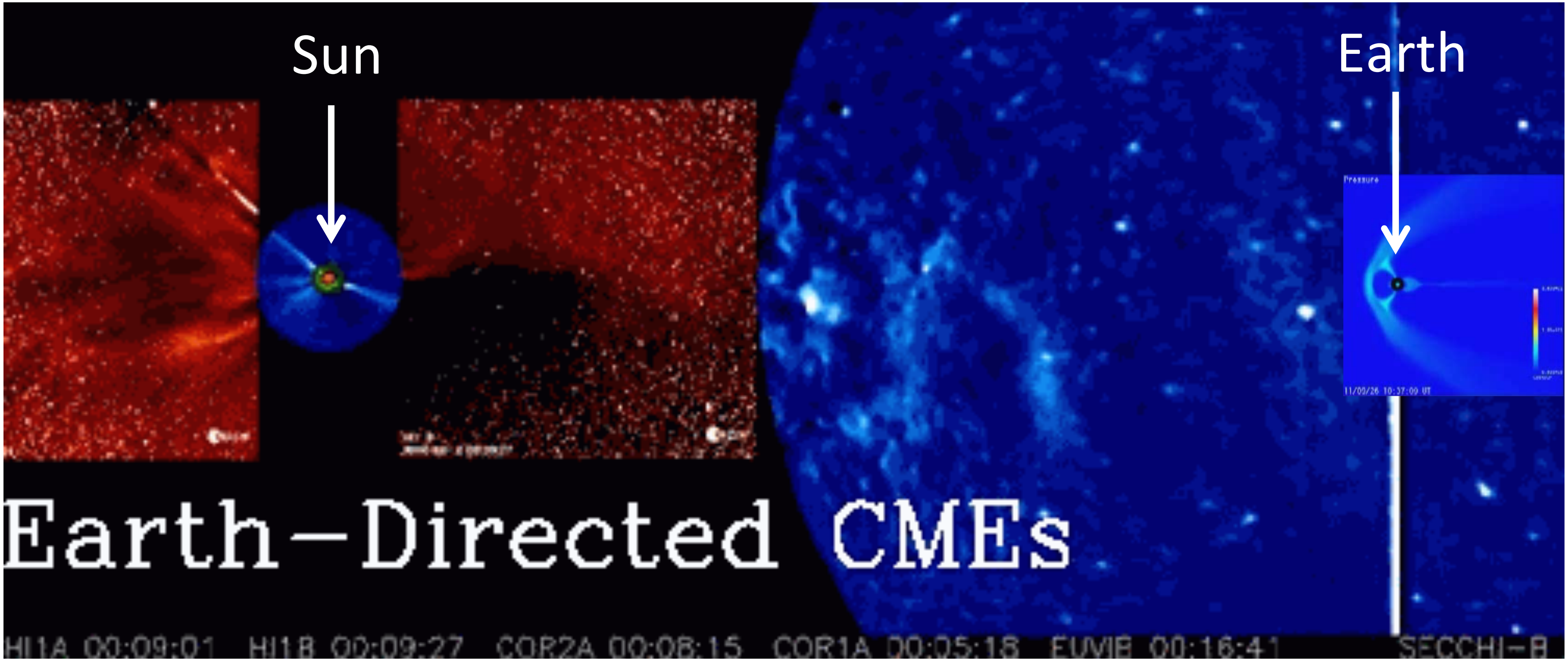


- Down-selected as a candidate for JAXA competitive M-class missions in July 2018, to be launched by a JAXA Epsilon vehicle in 2025.

Science goals of the mission

The importance of observing the solar atmosphere

- **How the plasma universe is created and evolves?**
- **How the Sun influences the Earth and other planets in our solar system?**



The interplay of magnetic fields and plasma creates behaviors

Quasi-steady: corona, solar winds

Transient: Flares, CMEs **Energy and mass transfer and energy dissipation**

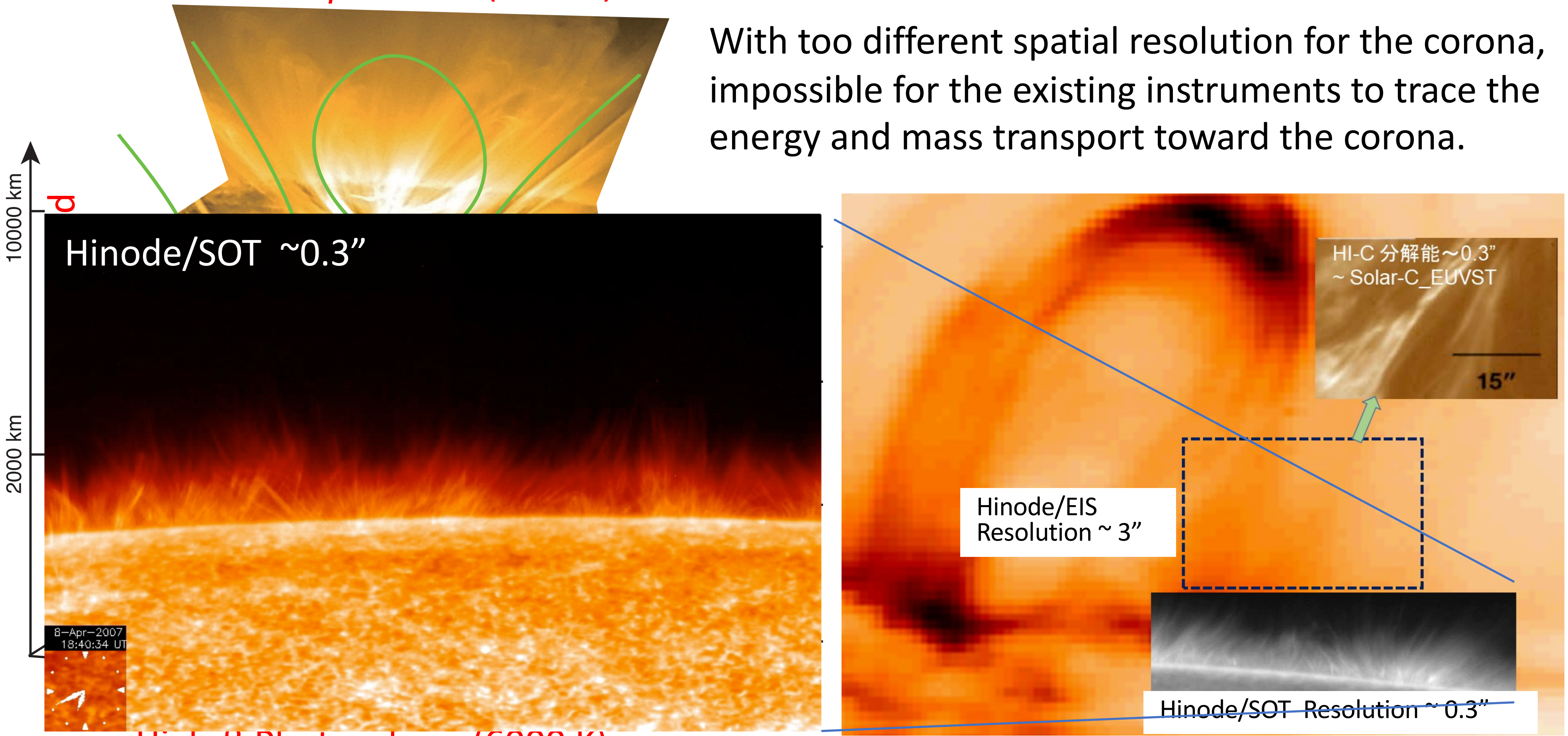
Solar-C_EUVST: Scientific objectives

I. **Understand how fundamental processes lead to the formation of the solar atmosphere and the solar wind**

II. **Understand how the solar atmosphere becomes unstable, releasing the energy that drives solar flares and eruptions**

Low-β Corona (>1 MK)

With too different spatial resolution for the corona, impossible for the existing instruments to trace the energy and mass transport toward the corona.

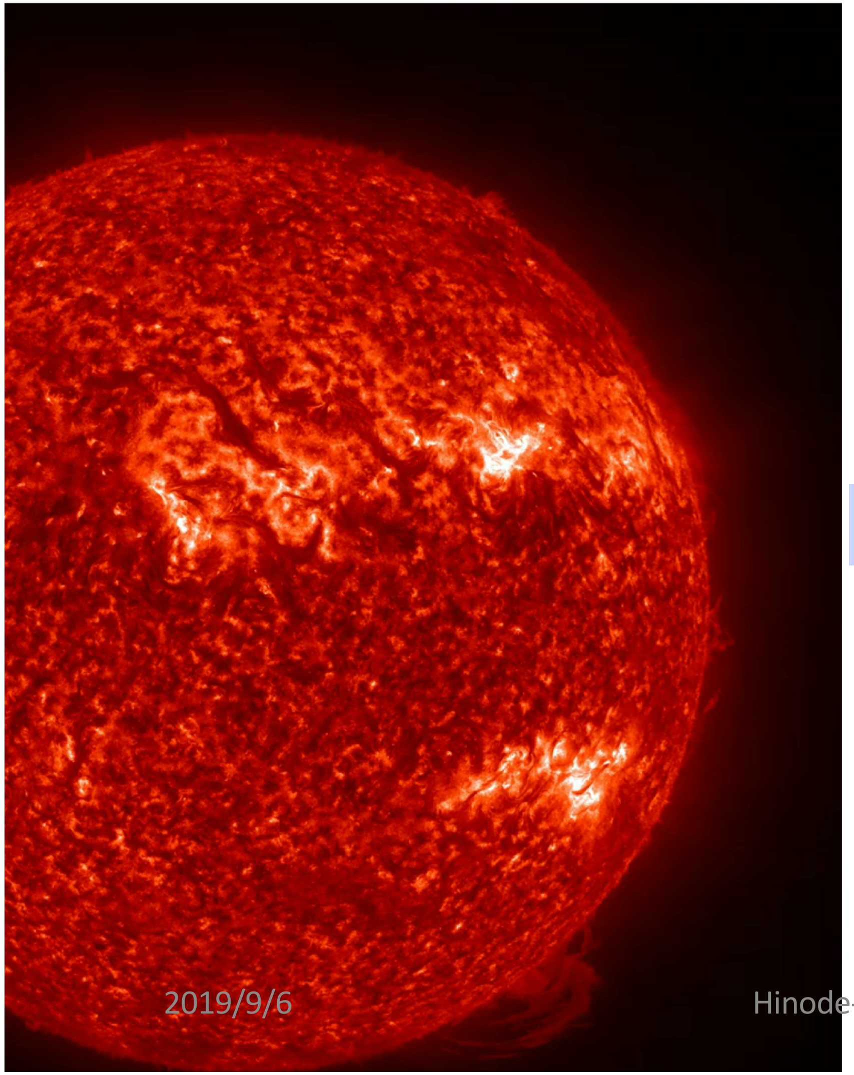


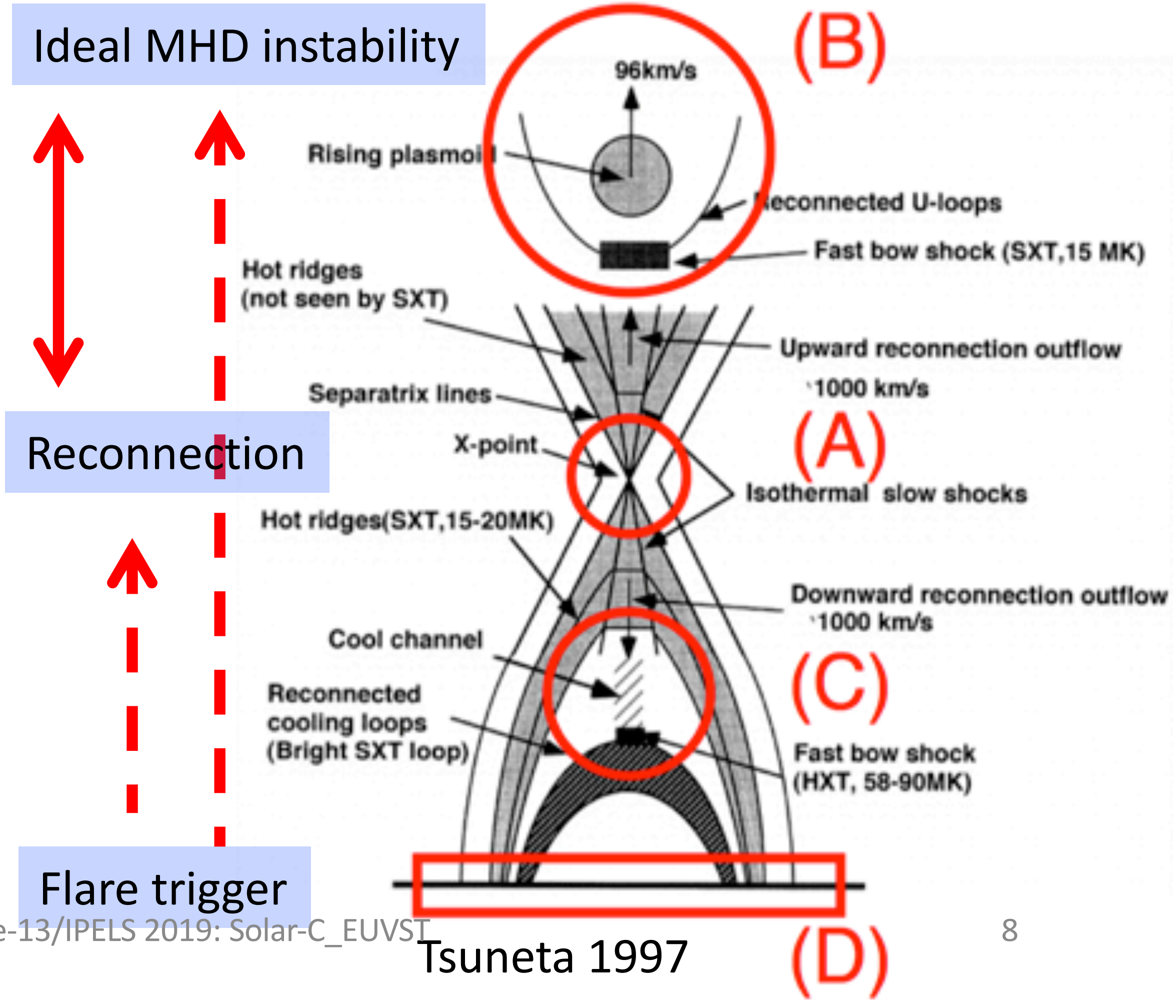
High-β Photosphere (6000 K)

Solar-C_EUVST: Scientific objectives

I. Understand how fundamental processes lead to the formation of the solar atmosphere and the solar wind

II. Understand how the solar atmosphere becomes unstable, releasing the energy that drives solar flares and eruptions





Tsuneta 1997

To achieve the scientific objectives,
The EUVST is designed to make three significant advances

A: **Seamlessly observe all the temperature regimes of the atmosphere from the chromosphere to the corona simultaneously at the same spatial resolution**
(10^4-10^7 K)

B: **Resolve elemental structures of the solar atmosphere and track their changes with sufficient cadence**
(0.4”, 1 sec exposure)

C: **Obtain spectroscopic information on dynamics of elementary processes taking place in the solar atmosphere**
(Velocity, density, temperature, composition, ionization etc)

Science and instrument design requirements

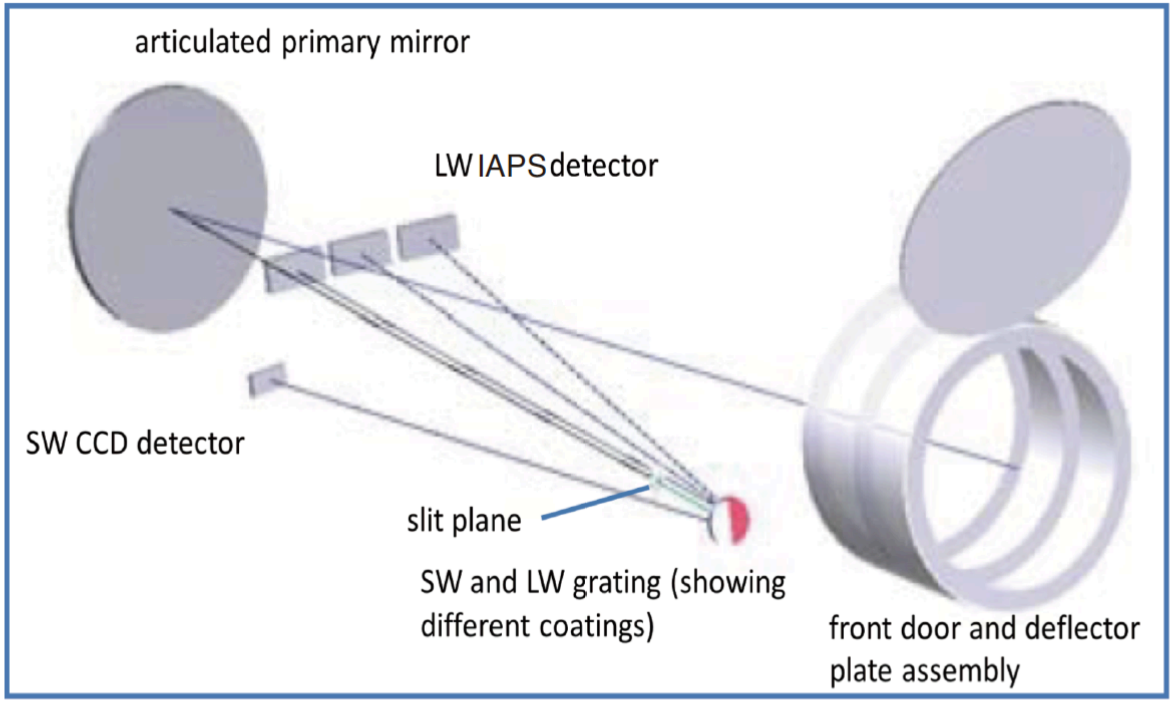
Driving requirements from science goals

→ design requirements for the instrument

Investigations' driving requirements	Instrument design parameters	design requirements
Temperature coverage: 0.02-15 MK, seamless	Wavelength	17.0-21.5 nm (SW) 69.0-85.0 nm (LW1) 92.5-108.5 (46.3-54.2) nm (LW2) 111.5-127.5 (55.7-63.7) nm (LW3)
Target spatial scale: 0.4 arcsec	Spatial resolution	0.4 arcsec
Temporal resolution: 2 sec/0.4" 0.5 sec/0.8"	Effective area Cadence of area coverage	Higher than 0.6-5.6 cm^2 0.5 sec (shortest)
Target size (max): 280 arcsec × 280 arcsec	Field of view	280 arcsec × 280 arcsec
Velocity resolution: $V_d \sim 2$ km/s, $V_{nt} \sim 4$ km/s	Spectral resolution ($\lambda/\delta\lambda$)	SW: 5000, LW: 13500
Context images: chromosphere/photosphere	Slit-jaw images (λ)	279.6, 283.3, and 285.2 nm include the corresponding ions Mg II, continuum, Mg I

Baseline architecture

- Minimum number of optical components for a spectrograph to achieve high throughput performance



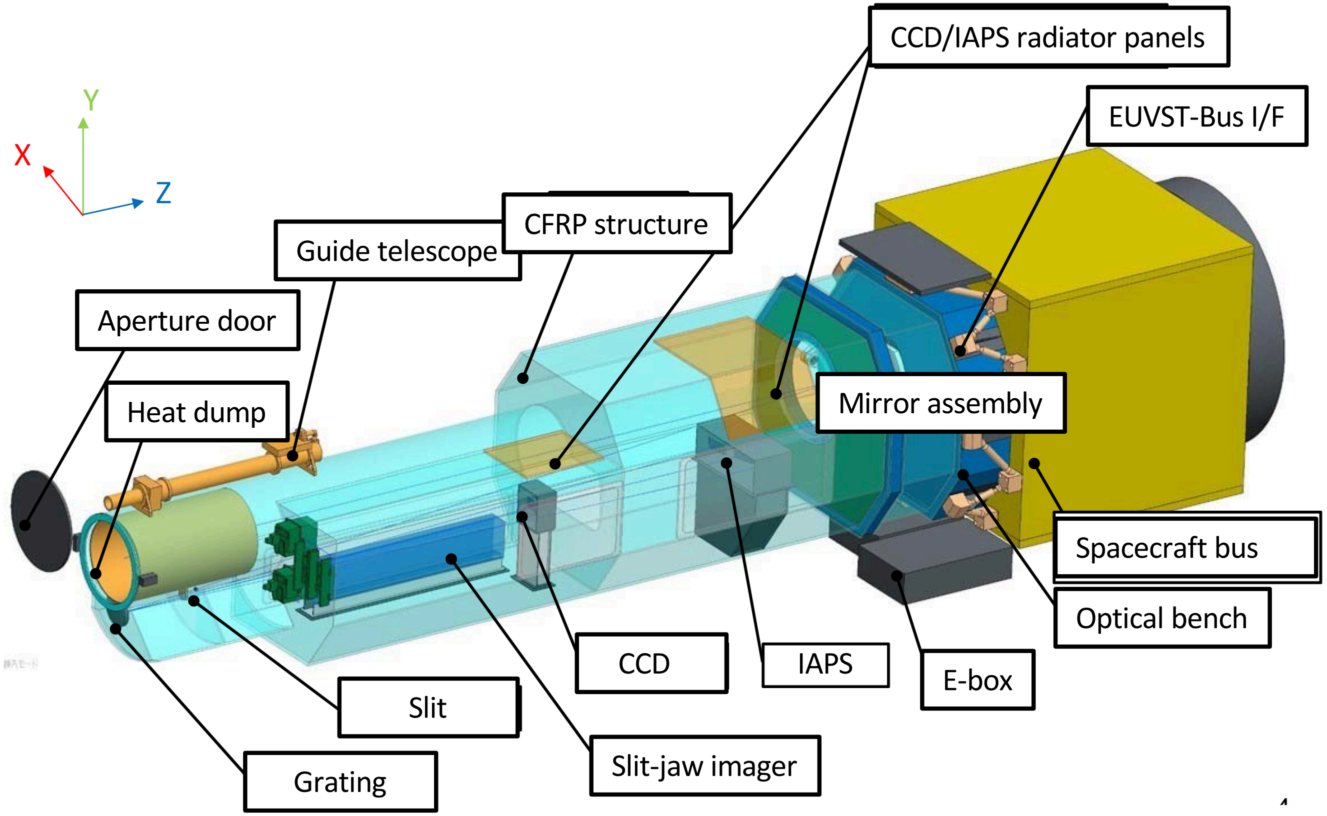
Off-axis parabola (28 cm diameter, focal length 280 cm) makes an image on the slit.

The slit selects a one-dimensional portion of the image, which is incident onto a concave diffraction grating (two gratings).

The radiation dispersed in the spectral direction is imaged at detectors.

EUVST

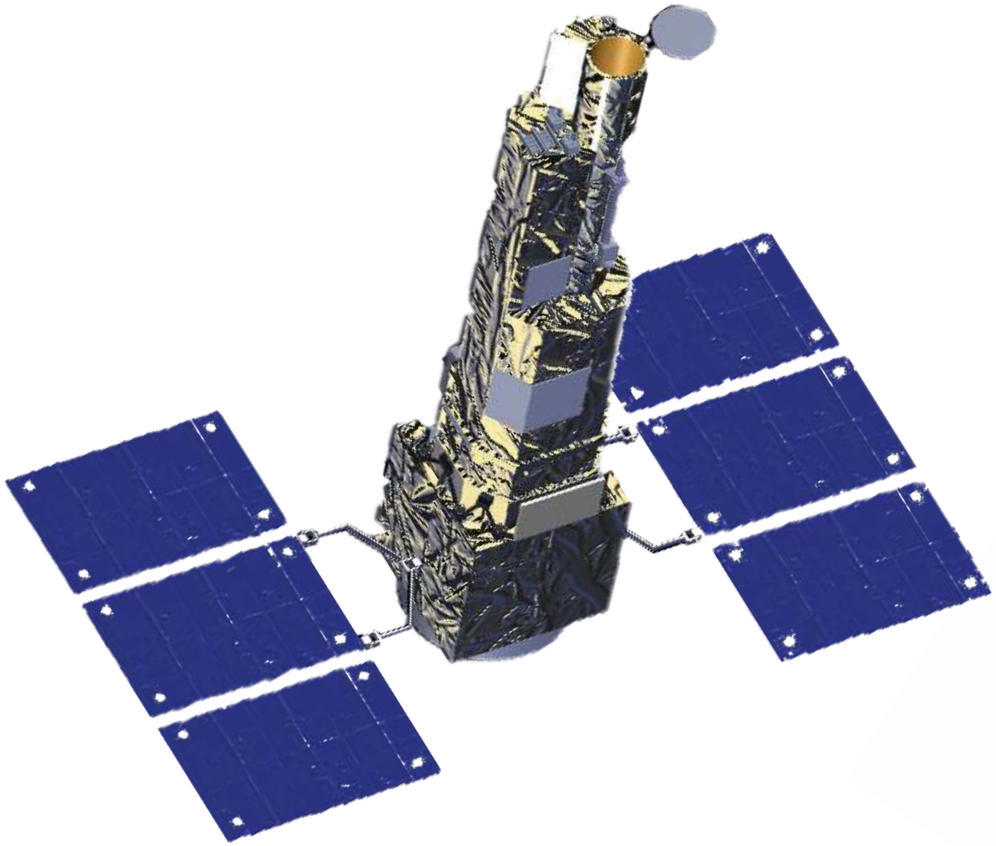
EUV High-throughput Spectroscopic Telescope



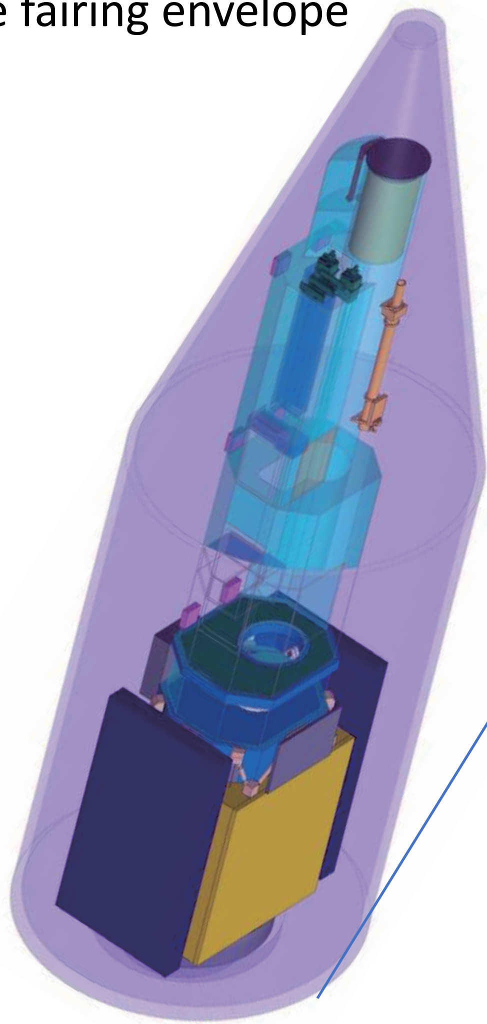
- The instrument: length 3.8 m, weight ~200 kg

Spacecraft system

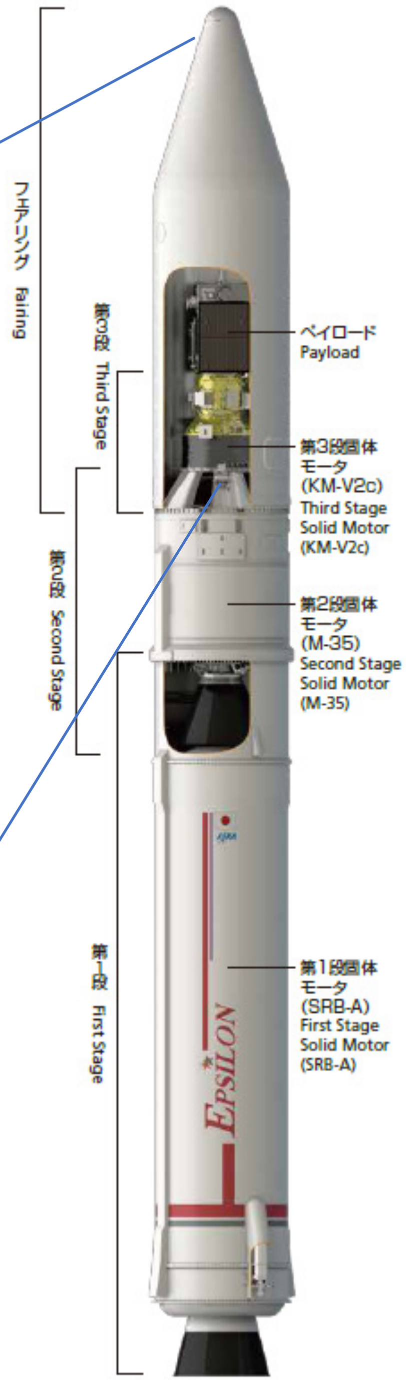
Weight 520-550 kg



Spacecraft installed
in the fairing envelope



JAXA Epsilon vehicle



Sun synchronous polar orbit (>600 km)

High pointing stability, based on Hinode knowledge

Performance (1/2)

- 7 times higher spatial resolution (3” → 0.4”)

The power to resolve about 50 times smaller features in the area size

Active-region overall structure

Distinguish magnetic loops

The image quality of the design expected: Initial budget table

Term	FWHM[1]		Remarks
Optical design	0.11”	0.19”	SW Avg Spot size: 6μm in FOV ±50” LW Avg Spot size: 15μm in FOV ±50”
Spectrograph fabrication and assembly	0.09”		Based on Hinode/EIS grating experience
Telescope diffraction-limited Performance at 182nm[2]	0.16”		13nm rms wavefront error is assumed; Scaled performance of SOT primary mirror
Thermal deformation of primary mirror	0.013”		1 nm rms wavefront error was estimated when the temperature of primary mirror increases from 20°C to 80°C (FY 2018 study)
Total optical resolution	0.22”	0.27”	
Pointing jitter	0.16”		Table 10.1: <0.2” (3σ)
Total EUVST Resolution	0.27”	0.31”	
Margin vs 0.4” [3]	54%	39%	Table 5.1: Science requirement

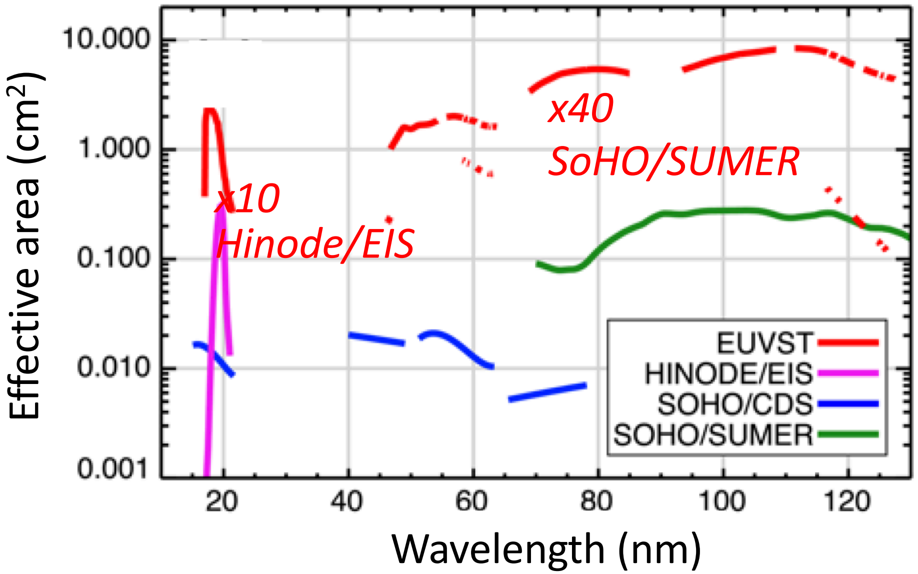
1) FWHM: SW (left) and LW (right)
2) If the telescope has a 26nm rms wavefront error, the total EUVST resolution is 0.4” for the SW case.

Performance (1/2)

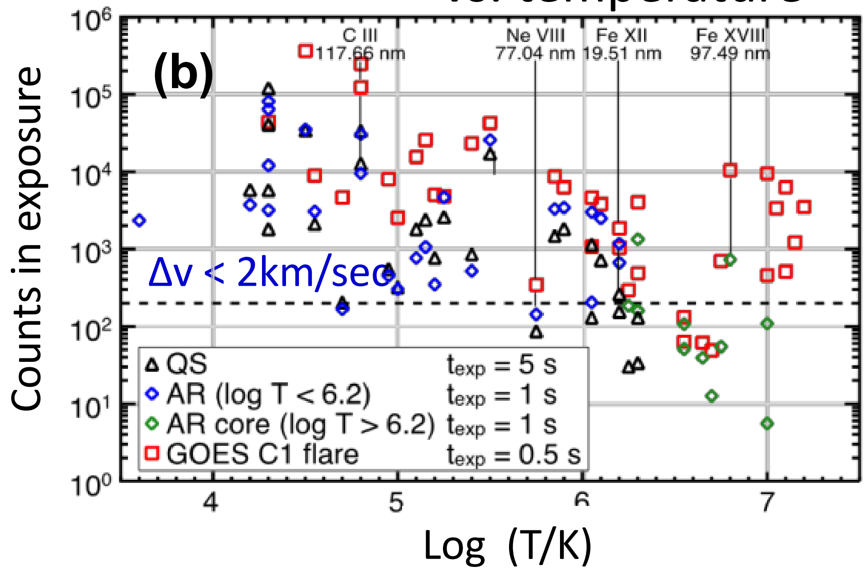
- Peak efficiencies is a factor of 10 improvement in Hinode/EIS and 40 over SoHO/SUMER

・High throughput → High temporal resolution

Effective area vs. wavelength



Count rate of spectral lines vs. temperature



・A variety of spectral lines, seamless access to plasma temperatures from 0.01 MK to 20MK

Mission status

- Selected as a candidate for JAXA competitive M-class missions in July 2018
- After an international science review in December 2018 and the pre-project candidate selection review in March 2019, the mission is currently in the Mission Definition phase (JAXA Pre-Phase A2).
- ISAS/JAXA has scheduled the final down-selection in December 2019 for competitive M-class mission #4, expected launch around 2025.
- JAXA-led mission with substantial participations from US and European countries.
  - A Partner Mission of Opportunity proposal to NASA selected!
  - Coordinating with European countries (Germany, UK, France, Italy, …) for developing components to EUVST.
  - ESA has officially started the mission definition toward the ESA participation. Involvement of ESA for securing involvement from European national agencies and for science-data downlink

Notional instrument set recommended in NGSPM-SOT final report and current view in Japan

- The NGSPM-SOT report (2017/7) recommended a minimum set of instruments with which NGSPM can address the greatest number of sub-objectives and maximize the science return of the mission.

Higher priority of notional instruments in order from the top in NGSPM-SOT report

0.3" coronal/TR spectrograph (T-9)

seamless plasma diagnostics through the atmosphere

0.2"-0.6" coronal imager (T-7)

0.1" – 0.3" chromospheric imager and magnetograph (T-4)
0.1" photospheric magnetograph (T-1)
0.1" chromospheric spectrograph (T-5)

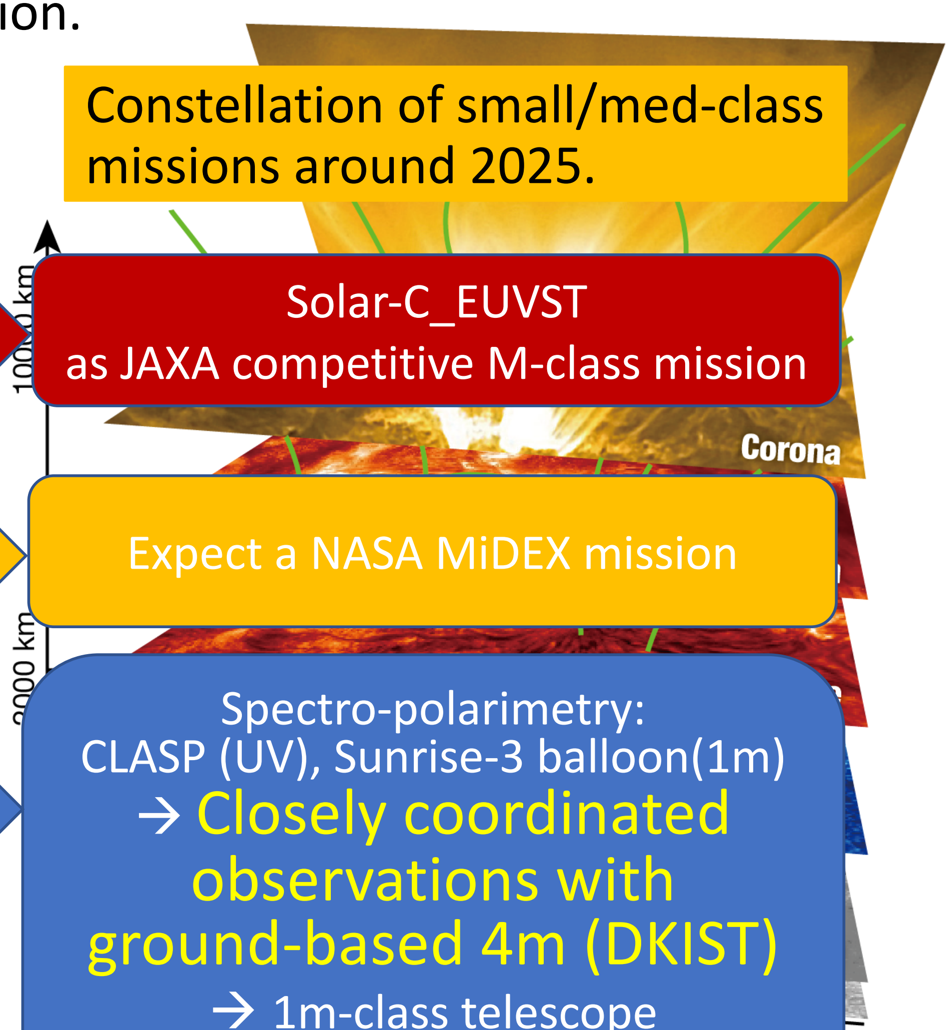
Magnetic and velocity fields at chromosphere

Constellation of small/med-class missions around 2025.

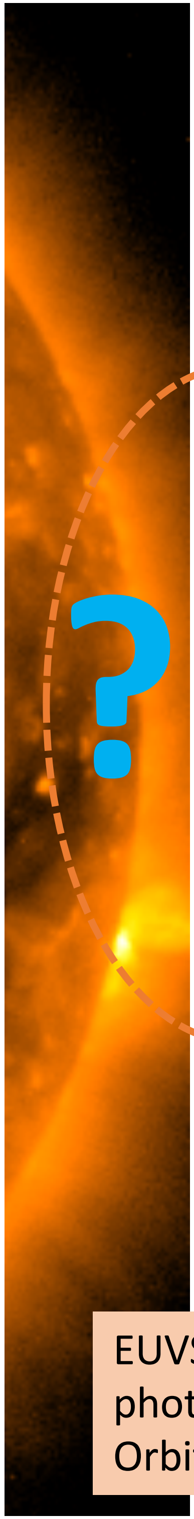
Solar-C_EUVST as JAXA competitive M-class mission

Expect a NASA MiDEX mission

Spectro-polarimetry:
CLASP (UV), Sunrise-3 balloon(1m)
→ Closely coordinated observations with ground-based 4m (DKIST)
→ 1m-class telescope for a launch in 2030's



Connecting the Sun to the Inner heliosphere



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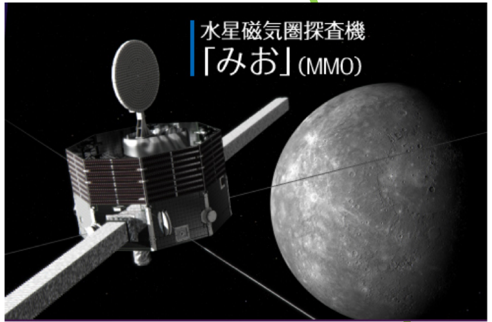
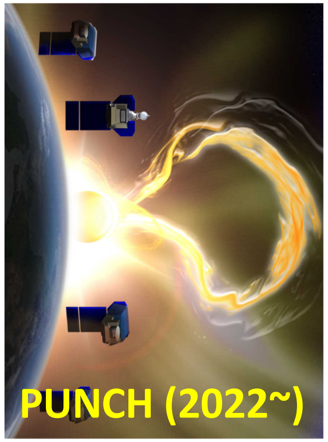
BepiColombo/Mio (MMO)

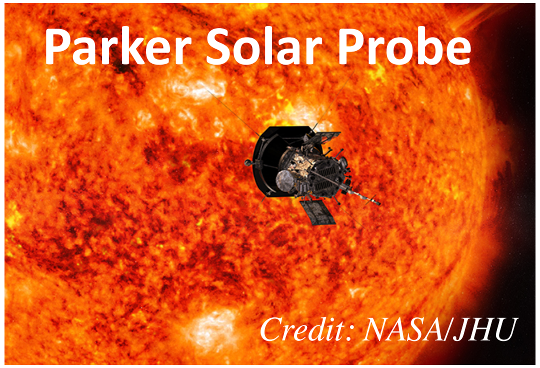


65Rs – 100 Rs @Mercury
(2025~)

"in situ" measurements



Outer corona from
5Rs outward



8.9Rs (closest @ 2025~)

"in situ" measurements

IPS

60Rs (closest), 25 deg. solar latitude
(2026~)

Coronal image/spectra,
photospheric magnetogram

(low resolution/telemetry)

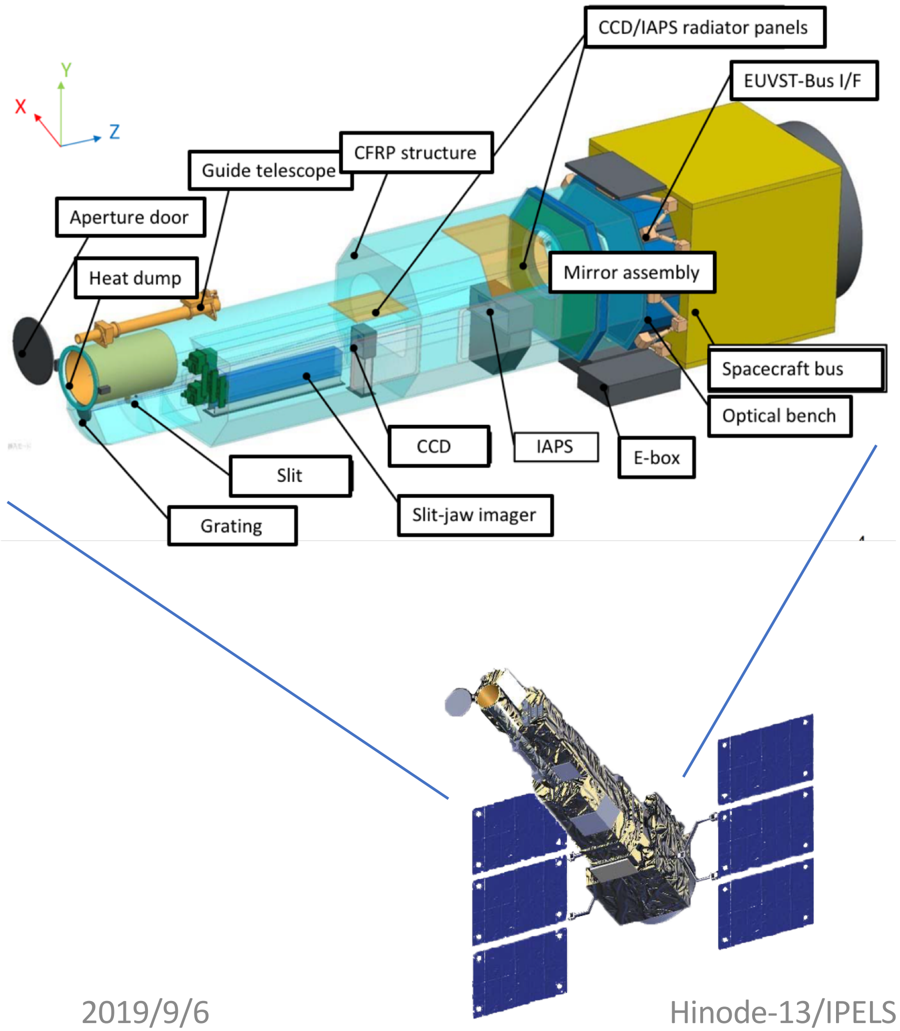
Solar-C_EUVST
(2025~)

EUVST fills a critical gap in solar observations for the next solar cycle. New observations for both the photosphere and chromosphere are planned (e.g., DKIST) and the heliosphere (PSP, PUNCH, Solar Orbiter, etc), but nothing new is planned to study the source of space weather events and solar wind.

Summary

Solar-C_EUVST mission

= Solar-C EUV High-throughput Spectroscopic Telescope



- Much advanced capabilities
  - ✓ Temp coverage: 10^4-10^7 K
  - ✓ Spatial resolution: 0.4”
  - ✓ High throughput: x10 ~ x40 higher (Temporal resolution: 1-sec cad.)
- Science objectives
  - ✓ Atmospheric heating and solar wind
  - ✓ Fast reconnection, flare/CME eruption
- Target launch date
  - ✓ 2025 (JFY 2024 – 2026)
  - ✓ In the next solar maximum