SOLAR-C

Future plans for solar physics in Japan

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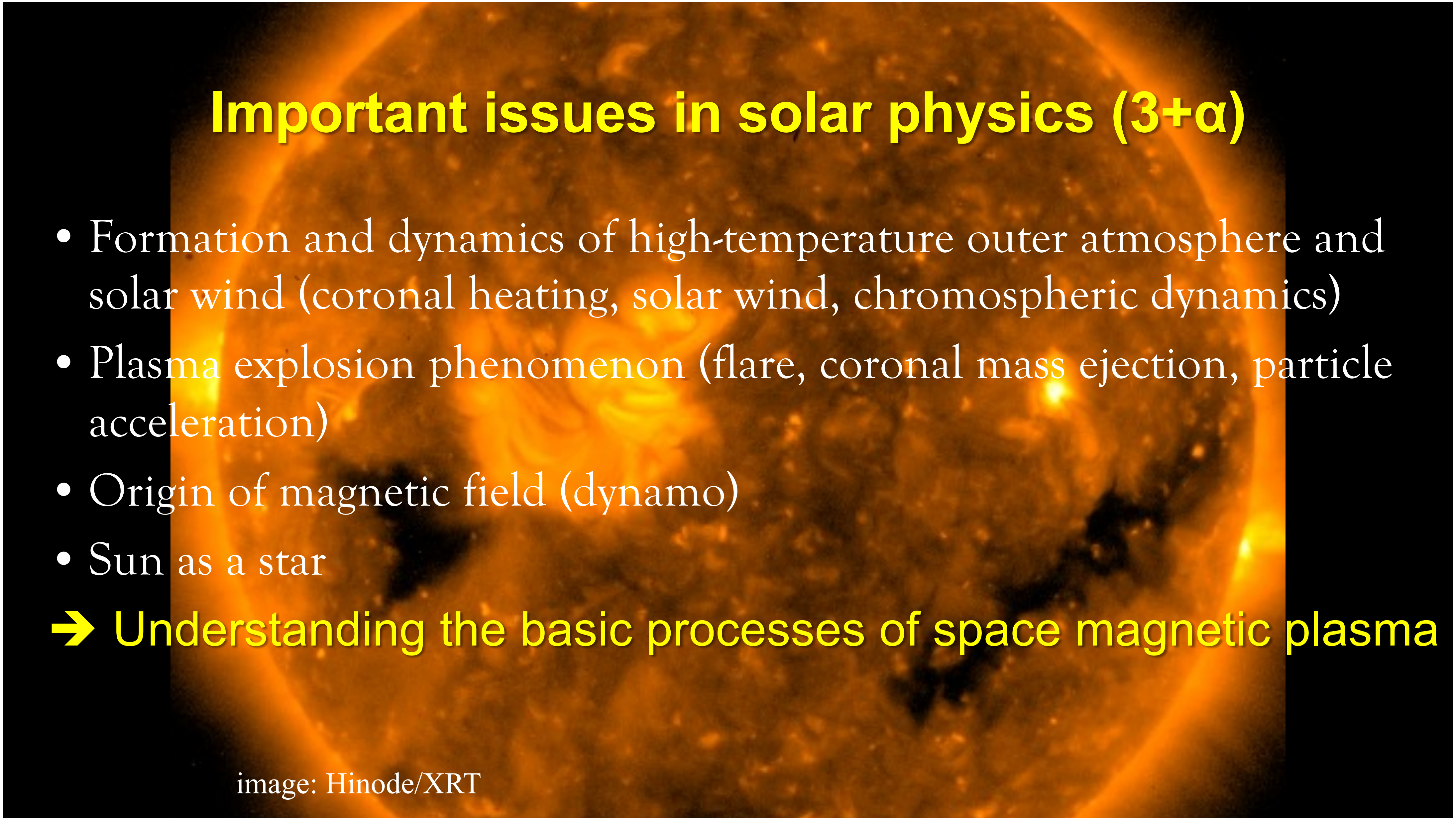
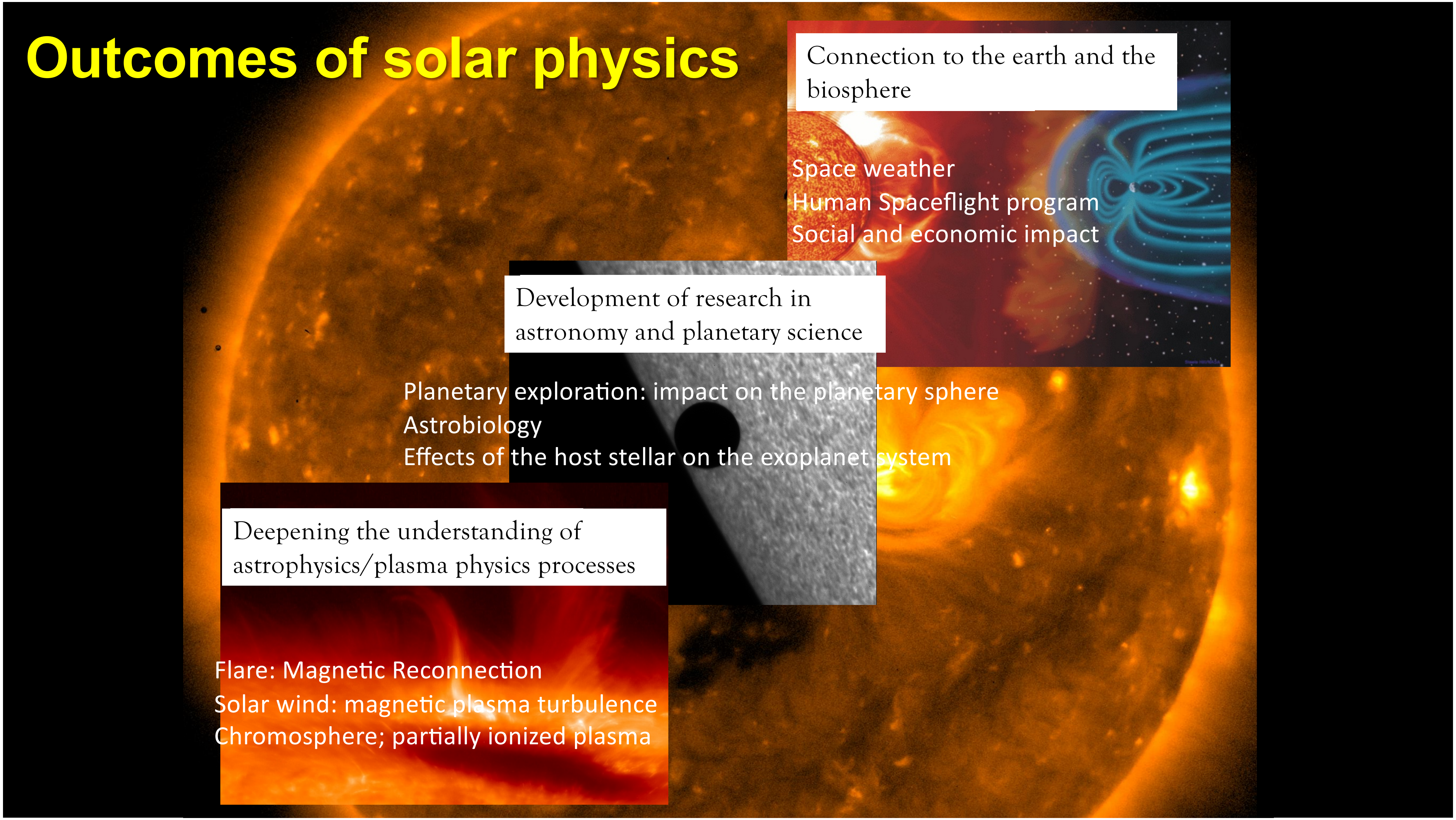
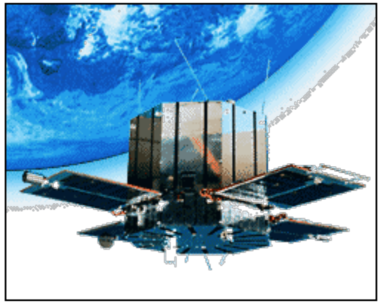
Based on「Goals, strategies, and schedule for the solar and hemispheric physics」（2022） in JSPC webpage


Important issues in solar physics (3+α)
• Formation and dynamics of high-temperature outer atmosphere and solar wind (coronal heating, solar wind, chromospheric dynamics)
• Plasma explosion phenomenon (flare, coronal mass ejection, particle acceleration)
• Origin of magnetic field (dynamo)
• Sun as a star
→ Understanding the basic processes of space magnetic plasma
image: Hinode/XRT


Outcomes of solar physics
Connection to the earth and the biosphere
Space weather
Human Spaceflight program
Social and economic impact
Development of research in astronomy and planetary science
Planetary exploration: impact on the planetary sphere
Astrobiology
Effects of the host stellar on the exoplanet system
Deepening the understanding of astrophysics/plasma physics processes
Flare: Magnetic Reconnection
Solar wind: magnetic plasma turbulence
Chromosphere; partially ionized plasma

Japanese Sun Observing Spacecrafts

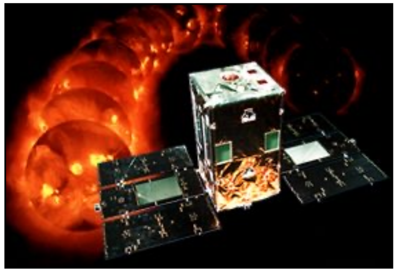
Hinotori (ASTRO-A)



188 kg
Launched in 1981 Feb

Particle acceleration and plasma heating in solar flares

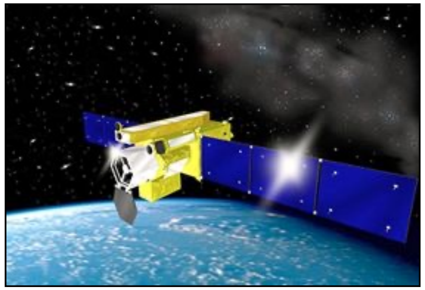
Yohkoh (SOLAR-A)



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

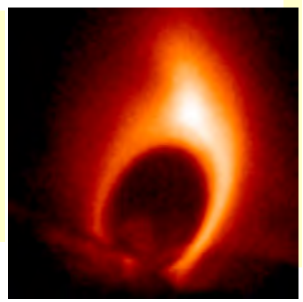
(C)JAXA

Large-scale ground observation facilities include visible light observation using the domeless telescope at Kyoto University's Hida Observatory (completed in 1979) and the flare telescope at National Astronomical Observatory of Japan Mitaka (observation started in 1992), as well as at Nagoya University's Toyokawa, Fuji, Sugadaira, and Kiso stations. Examples include IPS observations of the solar wind using a group of deployed radio telescopes (observations started in 1983) and Nobeyama's radio heliograph (observations started in 1992).

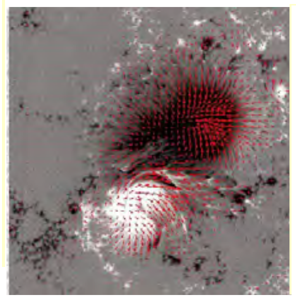
What we learned is that it is important to view the solar atmosphere as one system, from the photosphere to the corona!

What should we do next?

The first X-ray image of the early stage of the explosion was obtained.



Our understanding of the three-dimensional structure of solar flares and their temporal evolution has greatly deepened.



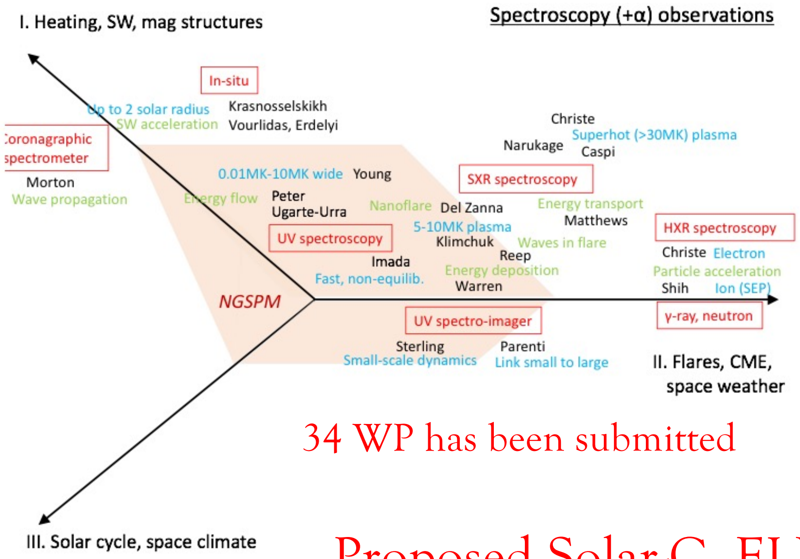
The movement of magnetic loops on the solar surface has been revealed clearly for the first time.

NGSPM-SOT

In June 2016, NASA, JAXA, and ESA chartered a Next Generation Solar Physics Mission Science Objective Team to study and report on a multilateral solar physics mission concept.

Top level science objectives

- I. Formation mechanisms of the hot and dynamic outer atmosphere
- II. Mechanisms of large-scale solar eruptions and foundations for predictions
- III. Mechanisms driving the solar cycle and irradiance variation.



34 WP has been submitted

Executive Summary NGSPM-SOT

1. 0.3" coronal/TR spectrograph
2. 0.2"- 0.6" coronal imager
3. 0.1"- 0.3" chromospheric/ photospheric magnetograph/ spectrograph

Proposed Solar-C_EUVST JAXA-NASA-ESA collaboration!

Consideration of Japan's SOLAR-C satellite program

- Sharpening of scientific objectives and missions
  - A series of symposium discussions by JSPC
  - Discussion at JSPC Steering Committee
  - Recommendation of JAXA-NASA-ESA international team "NGSPM-SOT" (2017)
- Changes in the status of the ISAS Satellite Program Roadmap

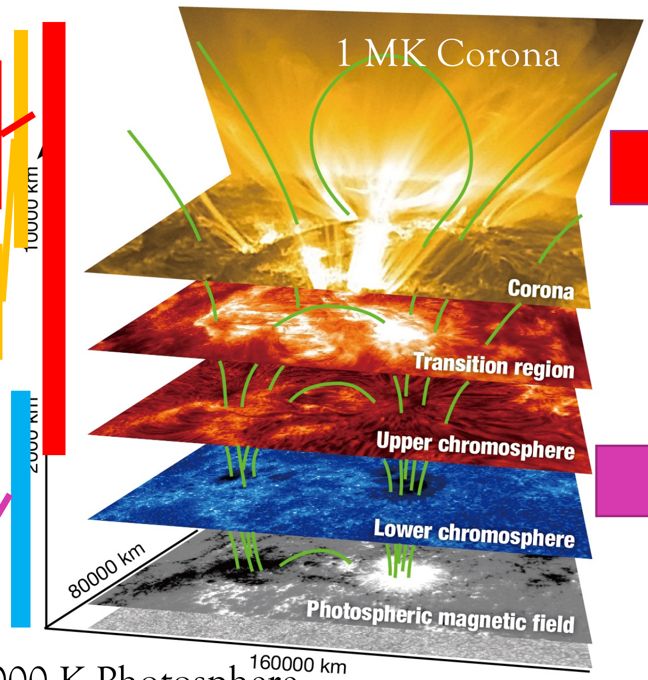
Priority by NGSPM-SOT

1. Upper atmosphere high sensitivity spectroscopic telescope (0.3~0.4")
   Seamless observation

2. High resolution corona imager (0.2~0.6")

→ MUSE by US

3. Photosphere/chromospheric magnetic field telescope (0.1~0.3")



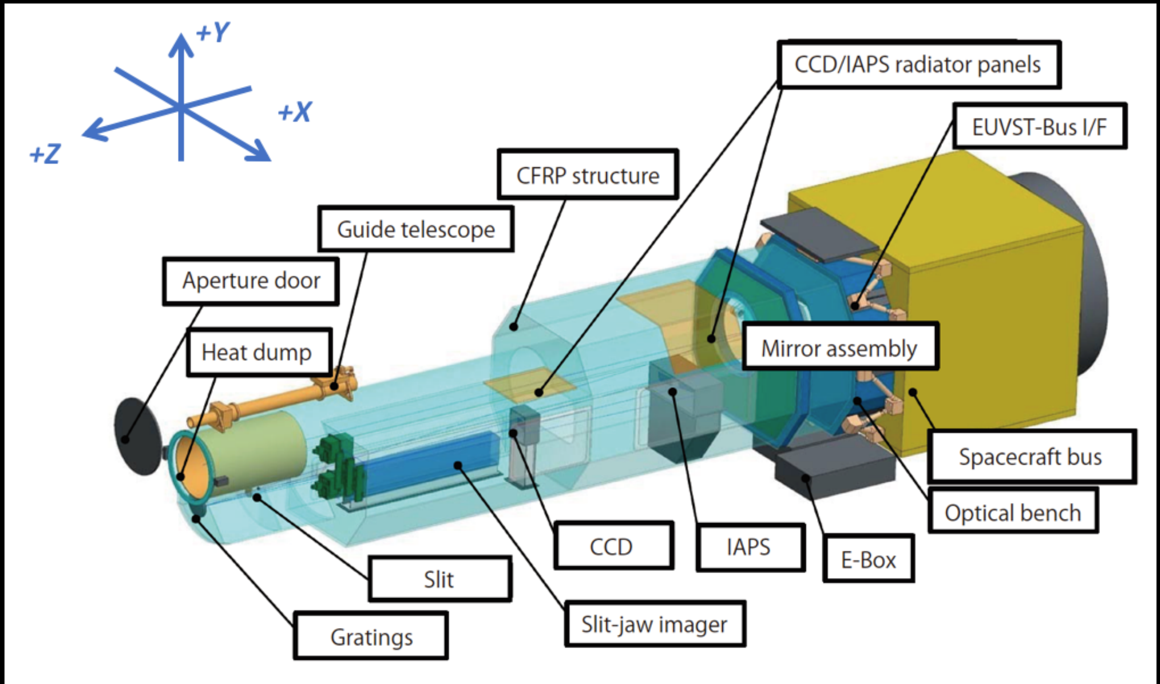
Strategy for the second half of 2020s

Early realization as SOLAR-C for upper atmosphere diagnostics

Precise magnetic field observation
1) Developing new methods with CLASP, Sunrise-3 (NAOJ)
2) Cooperating with overseas ground-based large telescope (DKIST) and collaborating with SOLAR-C

Space telescope observations in the 2030s

NEXT-GENERATION SOLAR OBSERVATION SATELLITE SOLAR-C



Observation wavelength :
17-21.5nm, 46-128nm
→ Covers the entire temperature range from 10,000 degrees to 15 million degrees without any gaps.

High spatial resolution: 0.4”

FOV: 280”x280”

High temporal resolution: 0.5s (shortest)

Solar Physics Community’s top priority mission

Japan will take the lead in cooperating with the US and Europe.
Scheduled to launch on an Epsilon rocket in 2028

Solar-C_EUVST

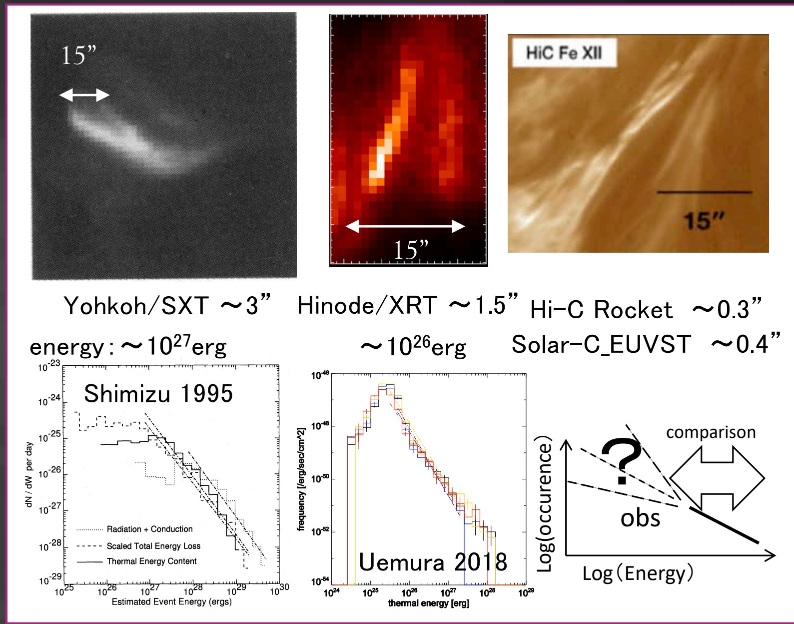
Scientific objectives I: Understand how fundamental processes lead to the formation of the solar atmosphere and the solar wind

Hinode EIS Observation
spatial resolution ～3”

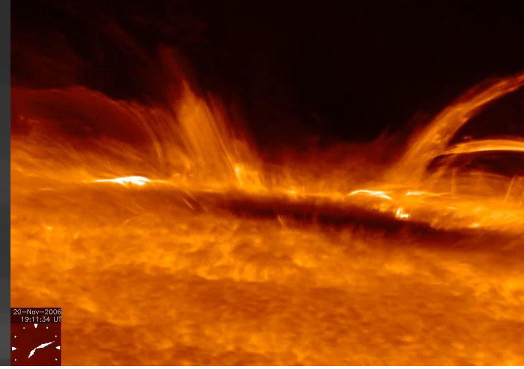
From chromosphere to corona, Solar-C resolves 0.4” structure, and clarify understand how mass and energy are transferred and dissipated throughout the solar atmosphere.

Resolution is different!

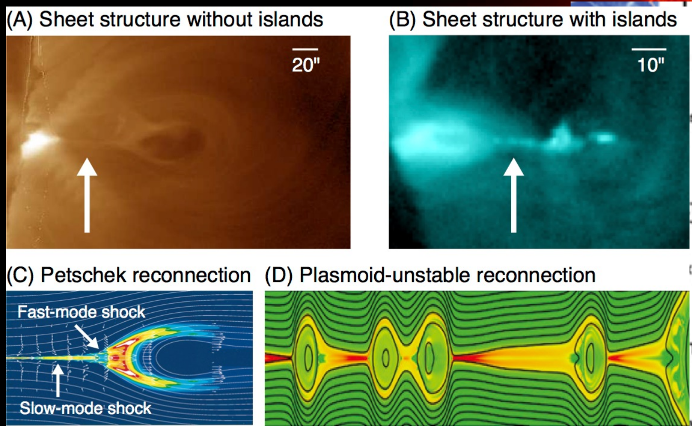
Relation is not clear



Hinode SOT Spatial resolution～0.3”

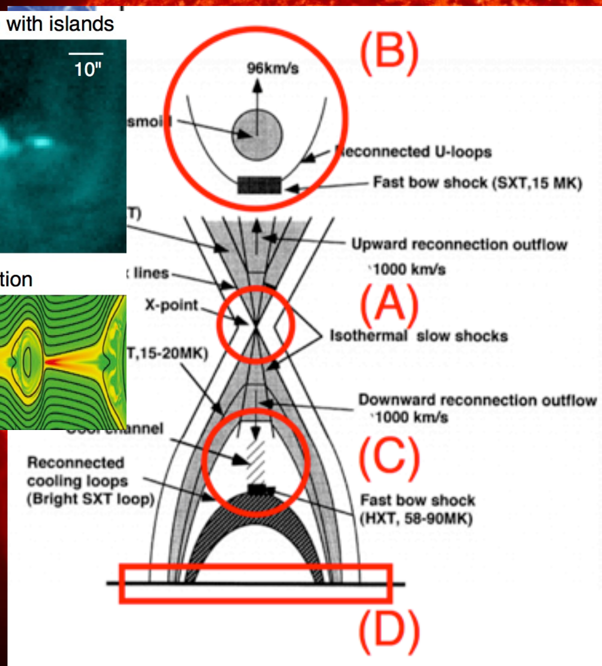


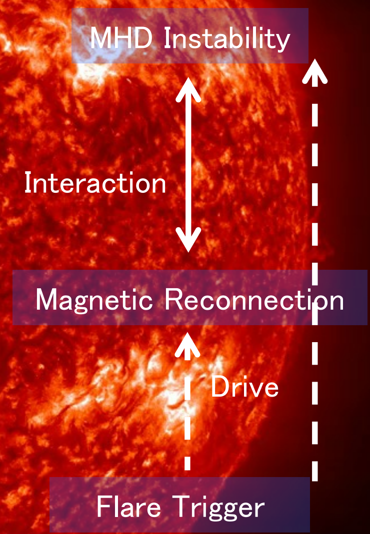
Scientific objectives II: Understand how the solar atmosphere becomes unstable, releasing the energy that drives solar flares and eruptions



Petschek v.s. Plasmoid Reconnection

Reconnection Region Thickness
(a few arcsec)
Spatially & Temporally Resolve
Plasma Diagnostics
→Acceleration, Heating,
Turbulence, Shock structure





From chromosphere to corona, Solar-C resolves 0.4" structure of Flare trigger, Reconnection, MHD Instability, and clarify their relationship.

次期太陽観測衛星

Solar-C_EUVST

Launch 2028

JAXA Epsilon M-class mission

A fundamental step towards answering how the plasma universe is created and evolves, and how the Sun influences the Earth and other planets in our solar system

Science objectives;

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

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

Strategy;

Quantify the processes of mass loading and energy transport / conversion at work

Key features (not ever done);

A) ***Wide T-coverage*** (10^4-10^7 K)

Observe the whole regimes of the solar atmosphere as a single, coupled system

B) *High resolution* (spatial ~ 0.4”, temporal ~ 1 sec)

Capture the dynamic evolutions of elementary structures

C) ***Spectroscopy***

Determine the physical states of the targets

(V, ρ, T, composition, ionization)

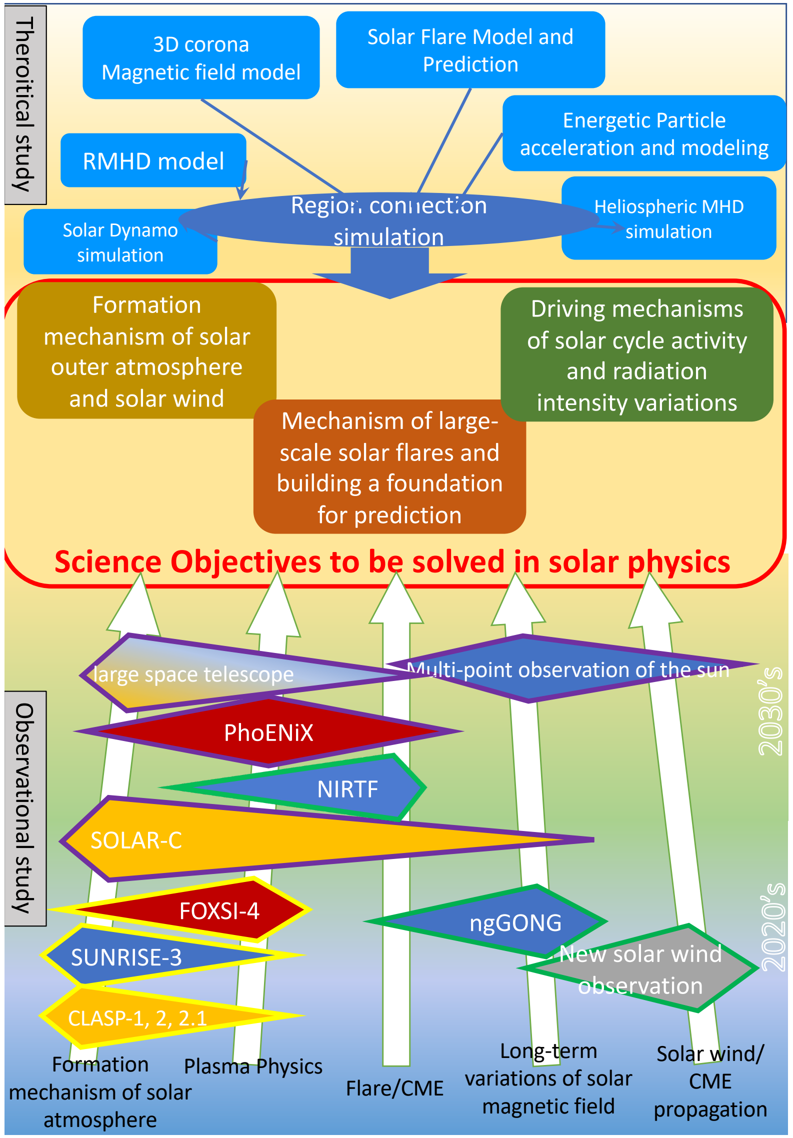
Close connection to

Astrophysics

Plasma physics

Geo-space physics (Space weather)

~500kg in Sun-synchronous orbit



PLANS FOR 2020-2030

- Large-size plans (satellite plans, etc. >10 billion yen scale plans)

- SOLAR-C_EUVST (small satellite No. 4, JAXA-ISAS/NAOJ)

・Ultraviolet imaging spectroscopy with high spatial and temporal resolution

- PhoENiX (NAOJ/JAXA-ISAS)

・Imaging spectroscopy and γ-ray polarization spectroscopy using soft and hard X-rays

- Medium-sized project (research plan that requires a Gaisanyoukyu but can be carried out at the university)

- Next-generation solar wind observation device (Nagoya University)

・Visualization of the solar wind in the inner heliosphere through scintillation observations of radio stars

- NIRTF (Kyoto University)

・Wide-field infrared polarization spectroscopic observation device installed at the focal plane of DIKST (US 4m Solar Telescope)

-ngGONG (NAOJ)

・Participating in the solar telescope project planned by the U.S. Solar Observatory (NSO) to install solar telescopes around the world

- Small-size plan

- SUNRISE-3 balloon experiment (NAOJ/JAXA-ISAS)

・Provided infrared polarization spectroscopy (SCIP) for the international joint project SUNRISE-3 balloon experiment

- FOXSI-4(NAOJ/JAXA-ISAS)

・Providing soft X-ray spectrometer detectors, etc. for NASA's X-ray rocket experiments (PhoENiX Pathfinder)

- Large-scale plan at the idea stage

-Solar multi-point observation mission

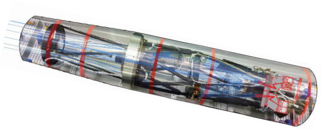
・This project aims to observe the flow deep inside the Sun.

-Next Generation Large Solar Telescope (NAOJ/JAXA-ISAS)

・This project aims to observe the chromospheric magnetic field.

Future plans for solar physics in Japan

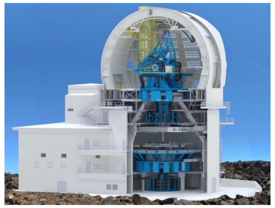
Hanle effect
Development of ultraviolet polarization Technique



Upper atmosphere magnetic field diagnosis

Developing methods in the upper chromosphere and transition layer

CLASP1 Rocket (2015)
CLASP2 Rocket (2019,2021)



Participation in the Overseas Large Telescope (DKIST) (2023~)

Ultra high resolution Photosphere/chromospheric magnetic field

Now

2023

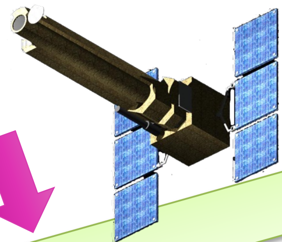
2028

2030's

Upper atmosphere plasma diagnosis

SOLAR-C (2028)

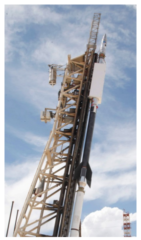
Realization of high-resolution spectroscopic observations from the upper chromosphere to the corona using ultraviolet light



SOLAR-C and beyond: Diverse directions and possibilities (Prioritization is a matter for consideration) After 2030

Hinode 2006 –(2022)

Magnetic field diagnosis at photosphere



Understanding high-energy particle acceleration
FOXSI-2 (2014), -3 (2018), -4 Rocket (2024)

SUNRISE-3 Baloon (2024)

3D diagnosis of photosphere to chromosphere

・ 1m telescope from space

Precise measurement of upper atmospheric magnetic field

・ Observation of the solar polar region through ecliptic plane escape

Understanding the Solar Cycle origin

・ PhoENiX

Understanding particle acceleration in MR