Solar Sounding Rocket Experiment CLASP2 & CLASP2.1

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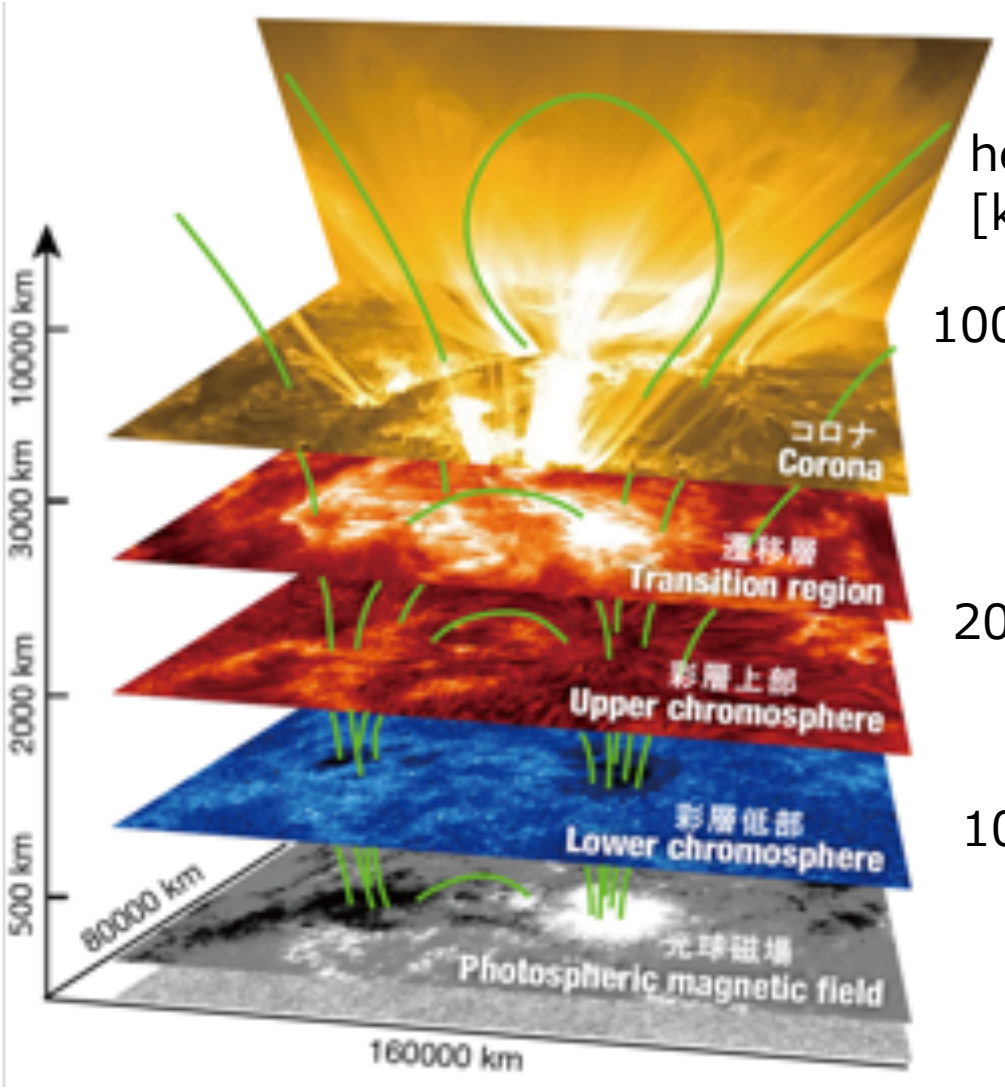
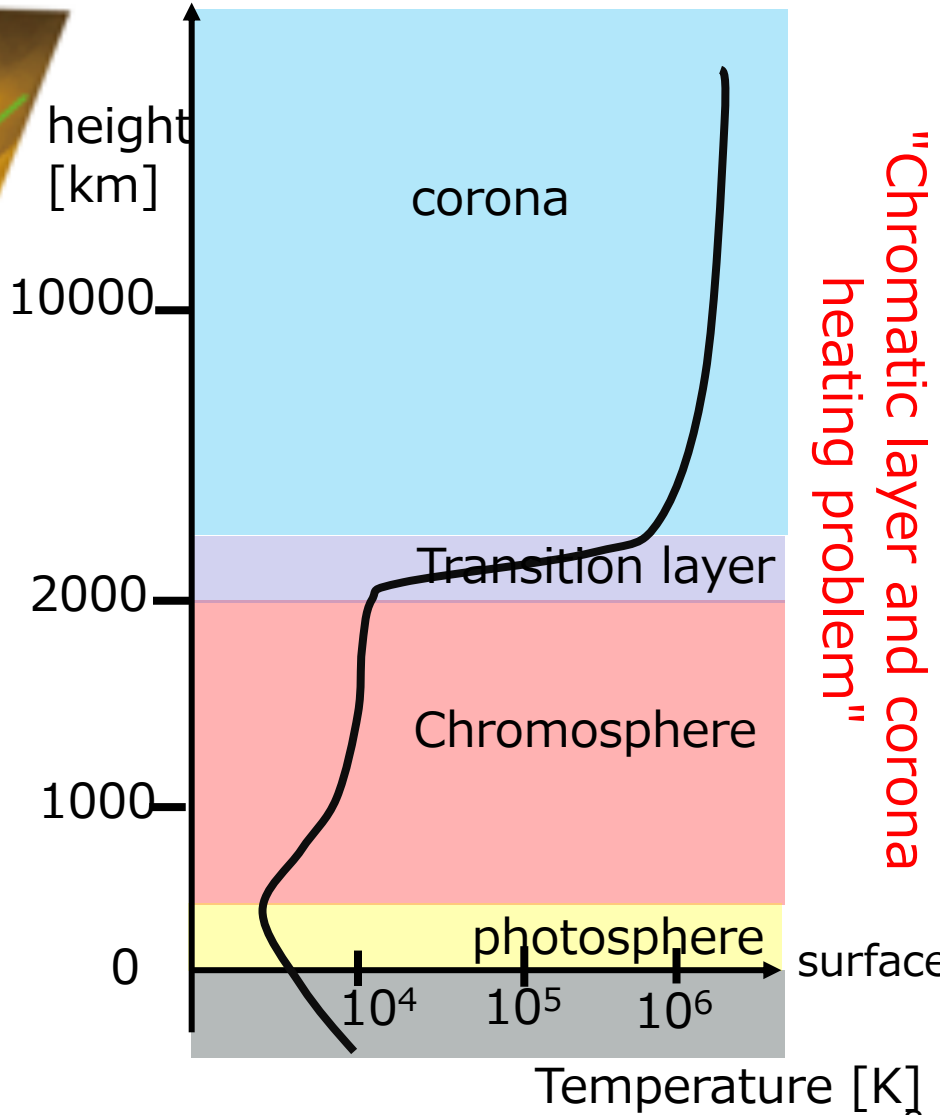
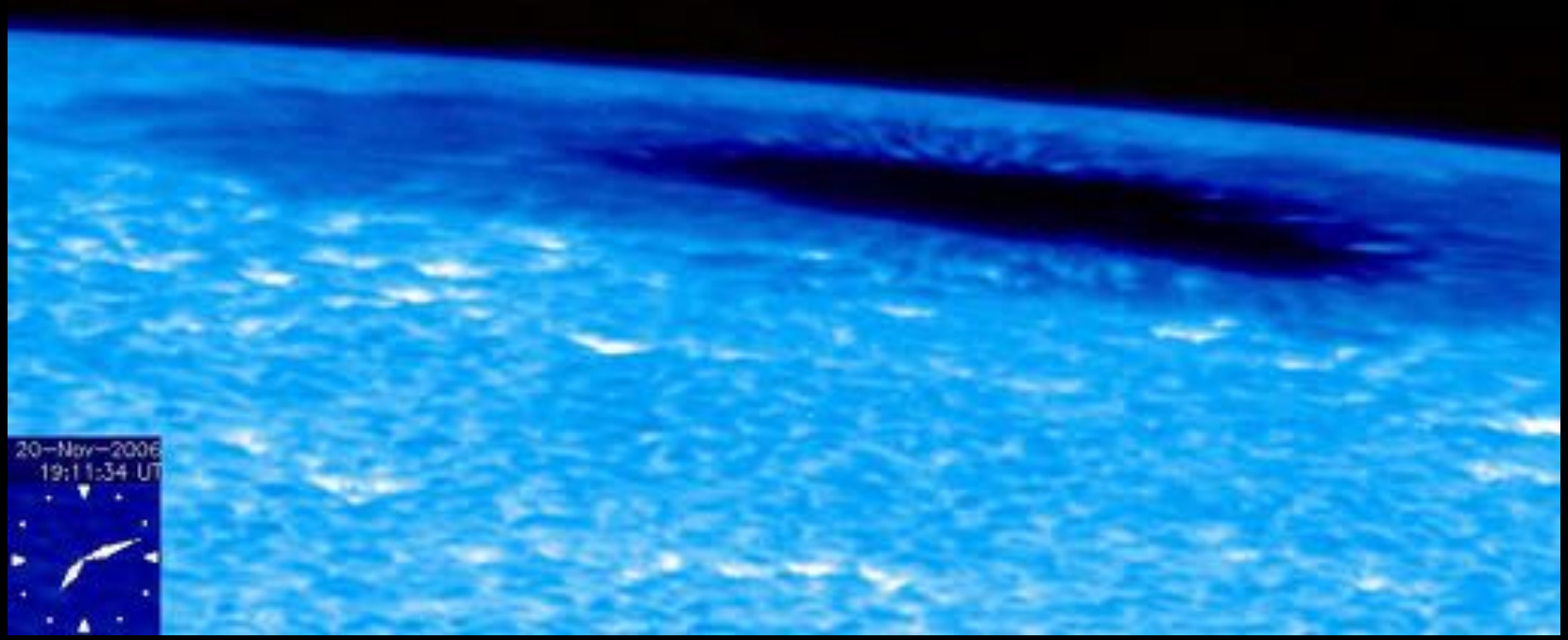
Solar Atmospheric Structure and The Mysteries Left Behind

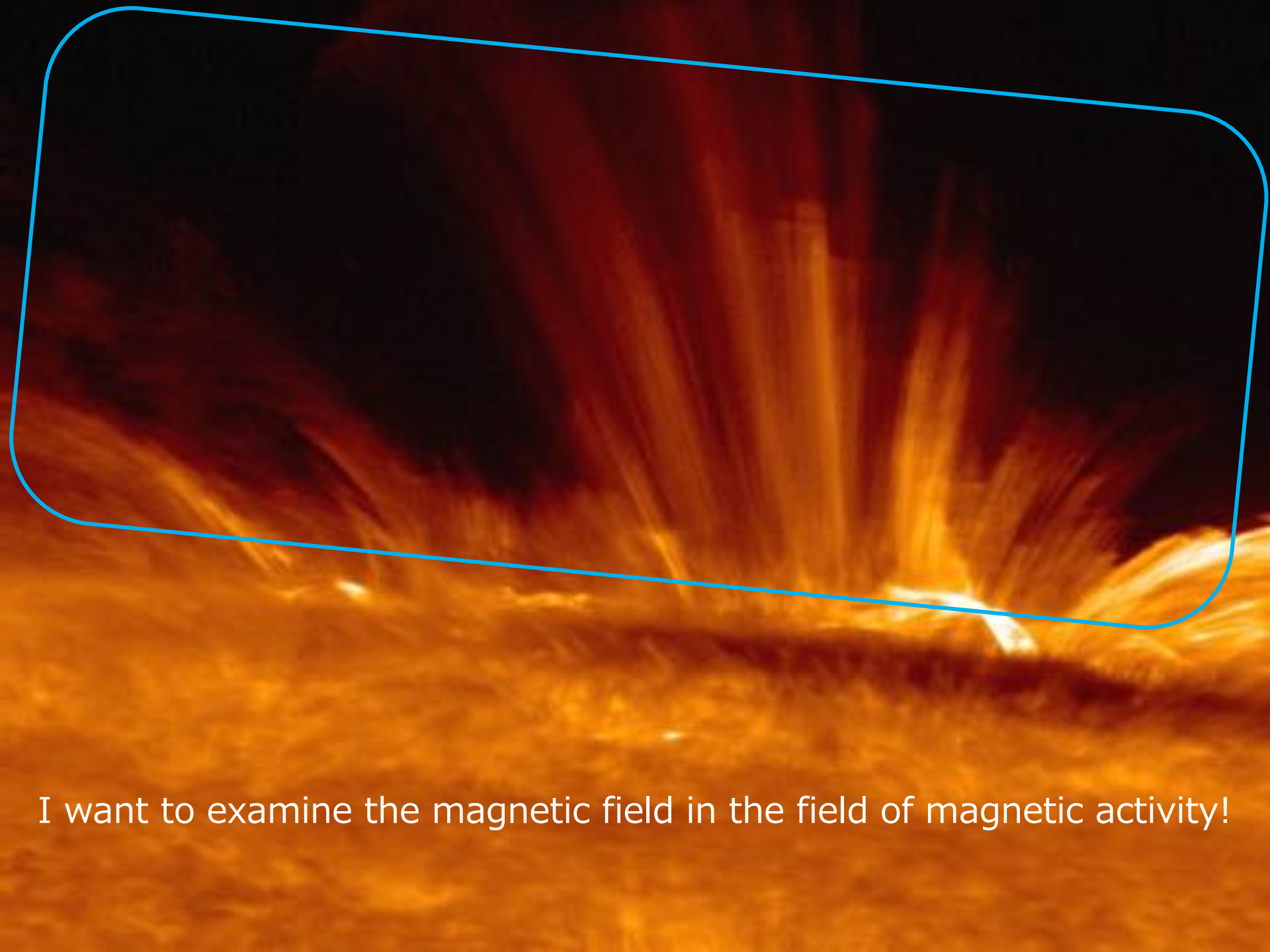




Imaging observation by Hinode satellite: Calm photosphere
(430 nm) → active chromatic layer (396nm)

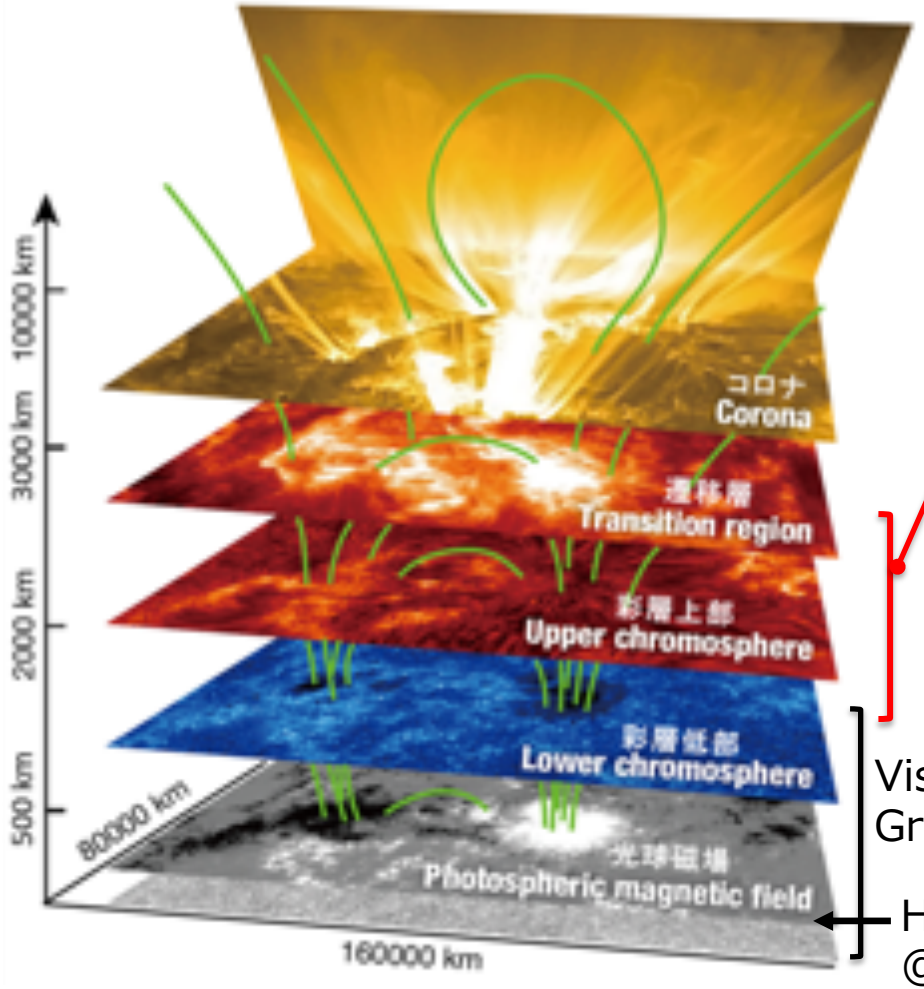


Credit: National Astronomical Observatory



I want to examine the magnetic field in the field of magnetic activity!

New Door: Ultraviolet Polarization



- Ultraviolet spectral lines
- Plasma origin of 100,000 to 100,000 degrees. Access directly below corona (upper to transition layers of the chromatic layer)
- The theory suggests that polarization is generated by magnetic fields
- Ultraviolet polarization
- No observational examples so far
- Can polarization be detected? Can magnetic field information be extracted from polarization?

Observation rocket experiment CLASP series

Japan-U.S.-Europe Cooperation Experiment using NASA Observation Rocket

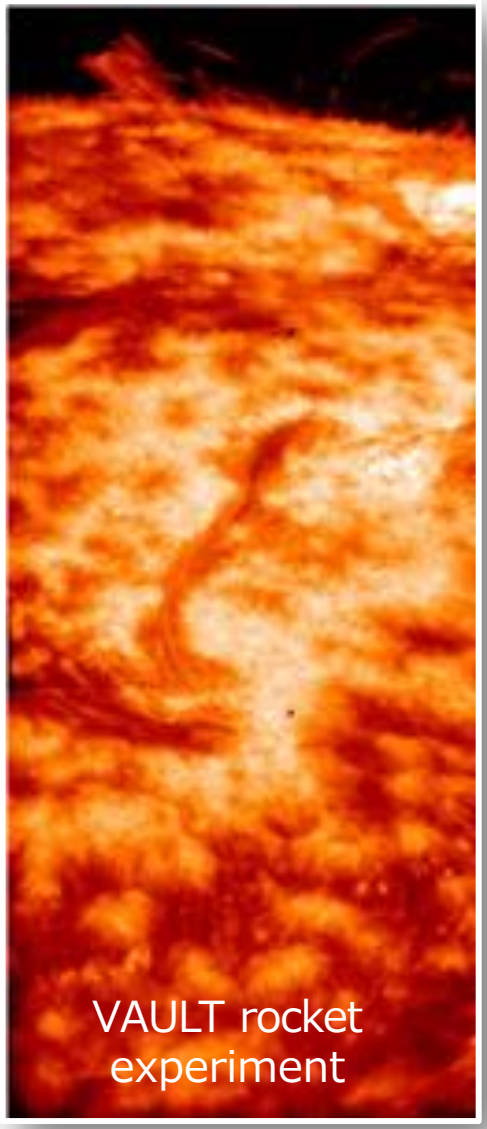
[Technical verification] Realization of high-precision polarization observation in ultraviolet rays

[Scientific verification]: Development of magnetic field measurement methods directly beneath corona

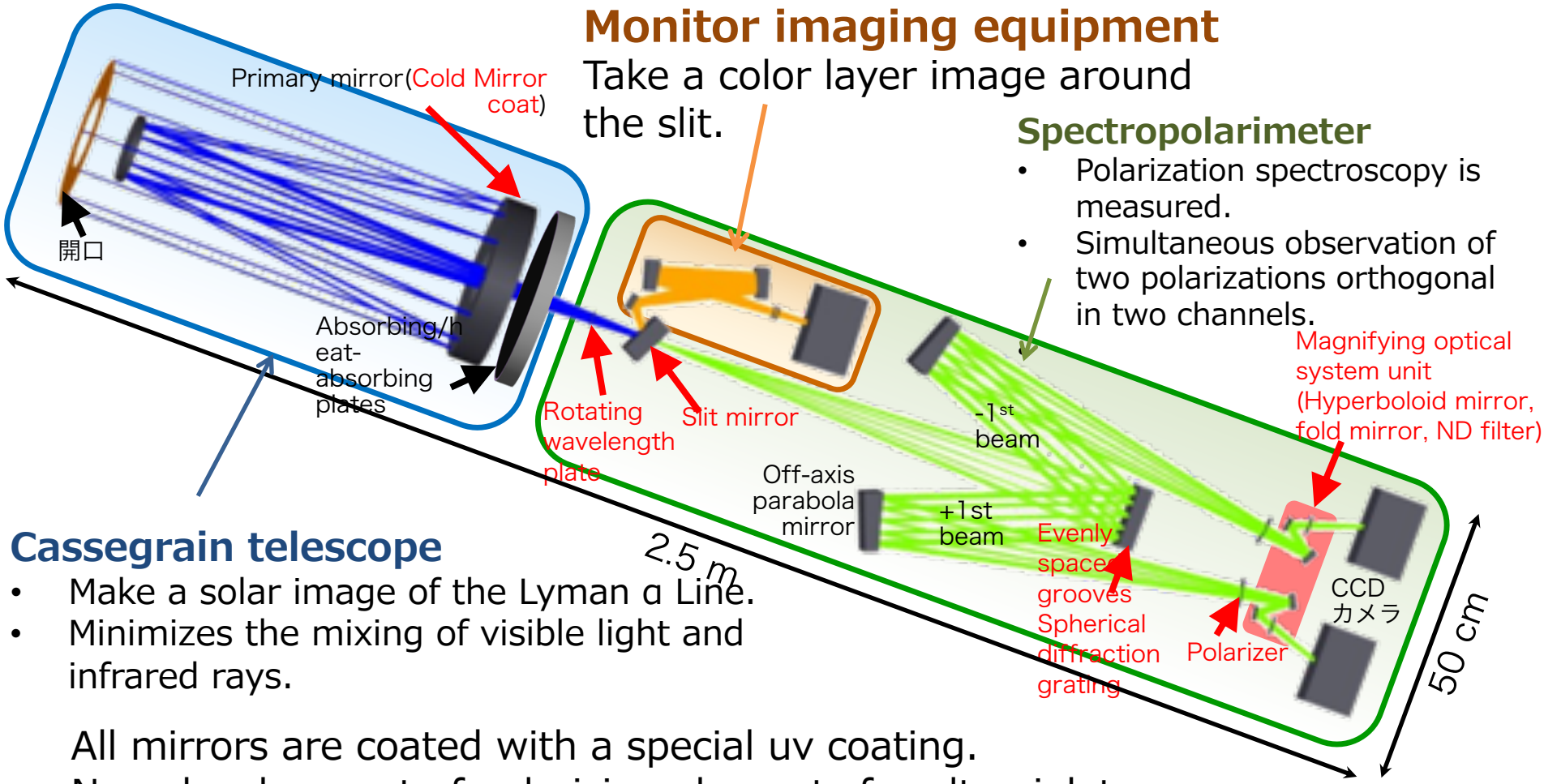
	CLASP	CLASP2	CLASP2.1
launch	2015	2019	2021
Spectral line	Lya (121.6 nm)	**Mg II h & k (280 nm)**	**Mg II h & k (280 nm)**
polarized light	Linear polarization (Q&U)	Linear & circular polarization (Q, U, & V)	Linear & **circular polarization** (Q, U, & V)
Observation area	Sun Center, Calm area	solar center, calm region, active area	Sun Center, Areas of activity
pointing	Slit fixing (1D)	Slit fixing (1D)	slit scan **(2D)**

CLASP: Chromospheric Lyman-Alpha Spectro-Polarimeter
CLASP2: Chromospheric LAyer Spectro-Polarimeter

Imaging observation of the solar transition layer (Lya)



CLASP & CLASP2: The World's First High-precision polarized spectroscopy for ultraviolet rays



Monitor imaging equipment

Take a color layer image around the slit.

Spectropolarimeter

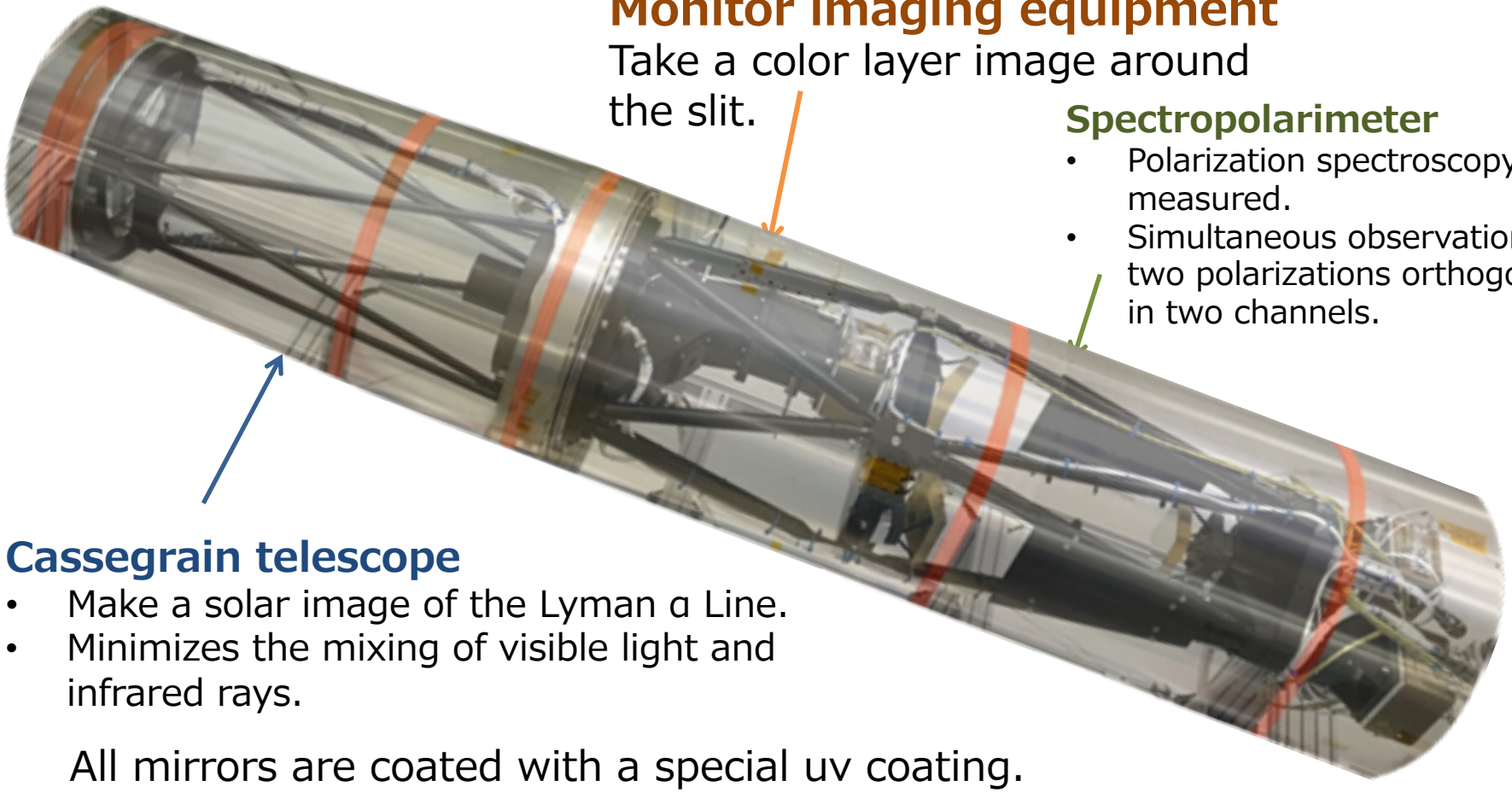
- Polarization spectroscopy is measured.
- Simultaneous observation of two polarizations orthogonal in two channels.

Cassegrain telescope

- Make a solar image of the Lyman α Line.
- Minimizes the mixing of visible light and infrared rays.

All mirrors are coated with a special uv coating.
New development of polarizing elements for ultraviolet rays

CLASP & CLASP2: The World's First High-precision polarized spectroscopy for ultraviolet rays



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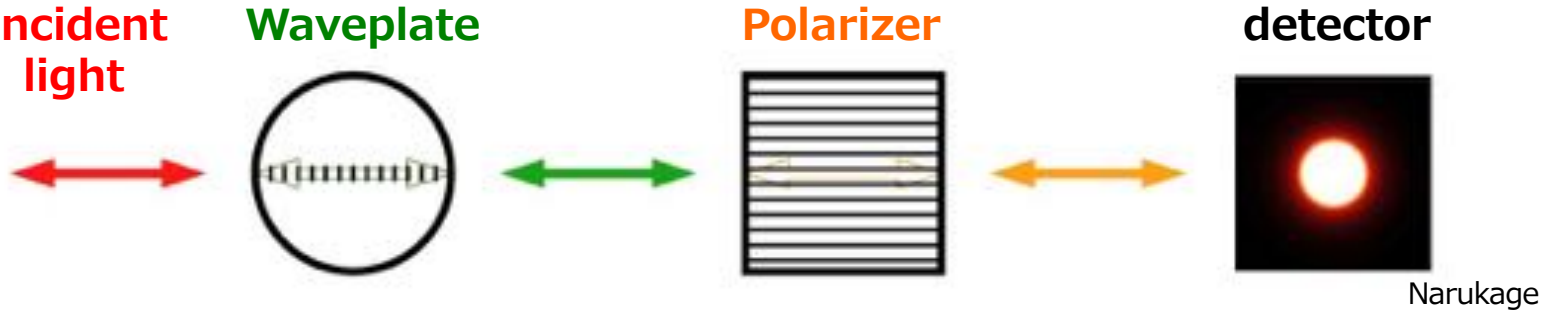
Key to high-precision polarization measurement: Rocket attitude stability

- Polarization measurement: Modulation is applied, and polarization degree and orientation are obtained by its degree and phase.

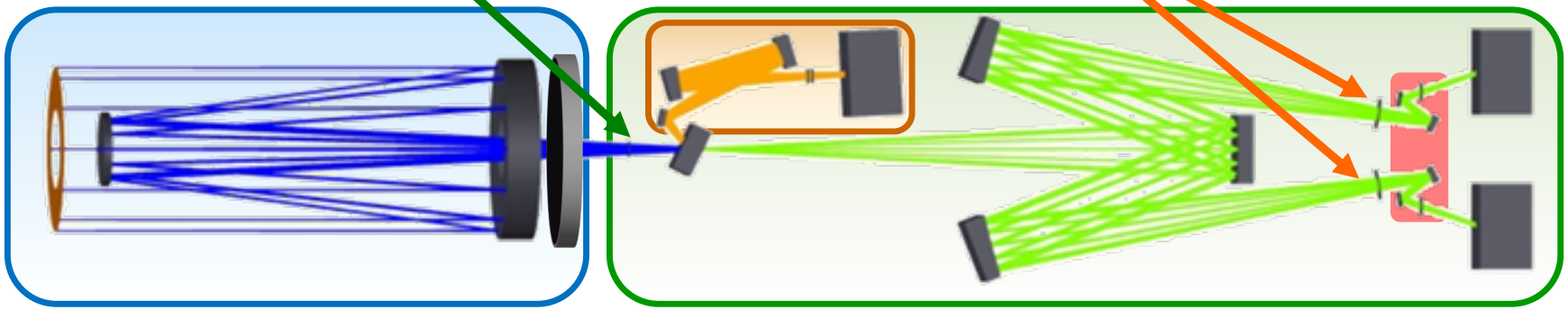
* CLASP2 must detect modulation at the 0.1% level!

- 

Narukage

MgF2 Zero Order Wavelength Plate + Rotational drive mechanism

UV Wire Grid Polarizer

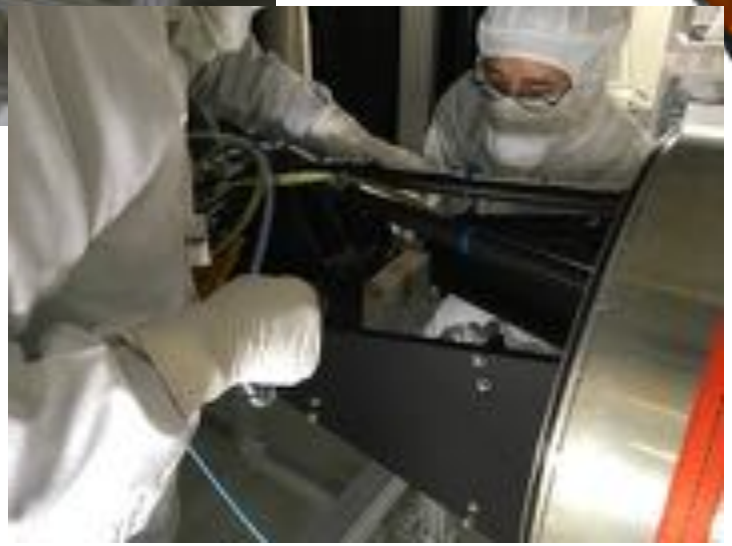


Equipment Development @ NAOJ

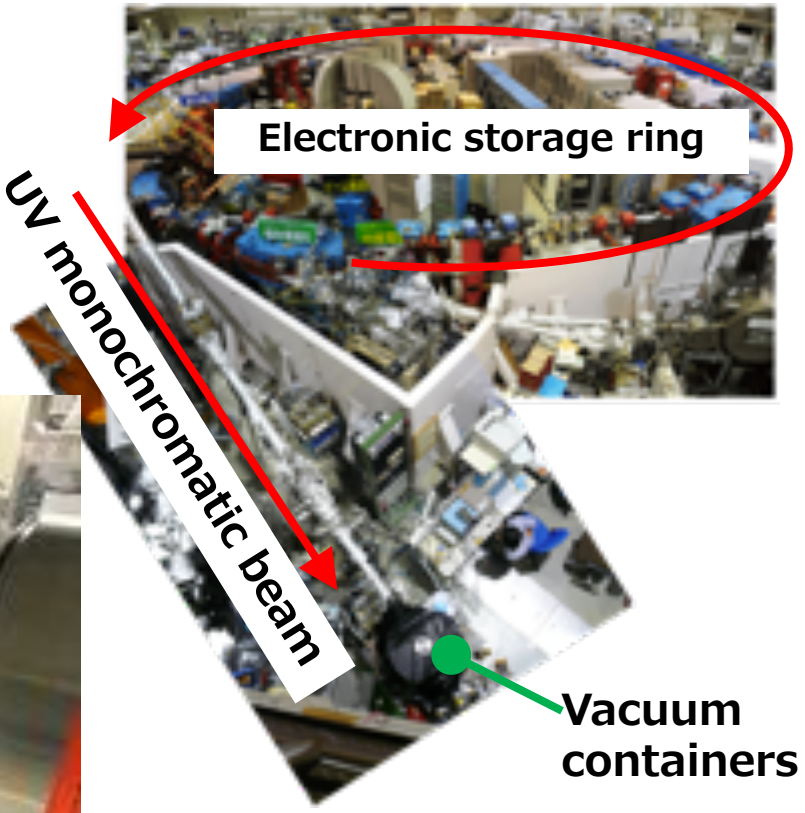
- Design of observation equipment, element development, assembly, performance confirmation with our own hands!

Optical adjustment work of telescopes

National Astronomical Observatory of Japan Advanced Technology Center Clean room



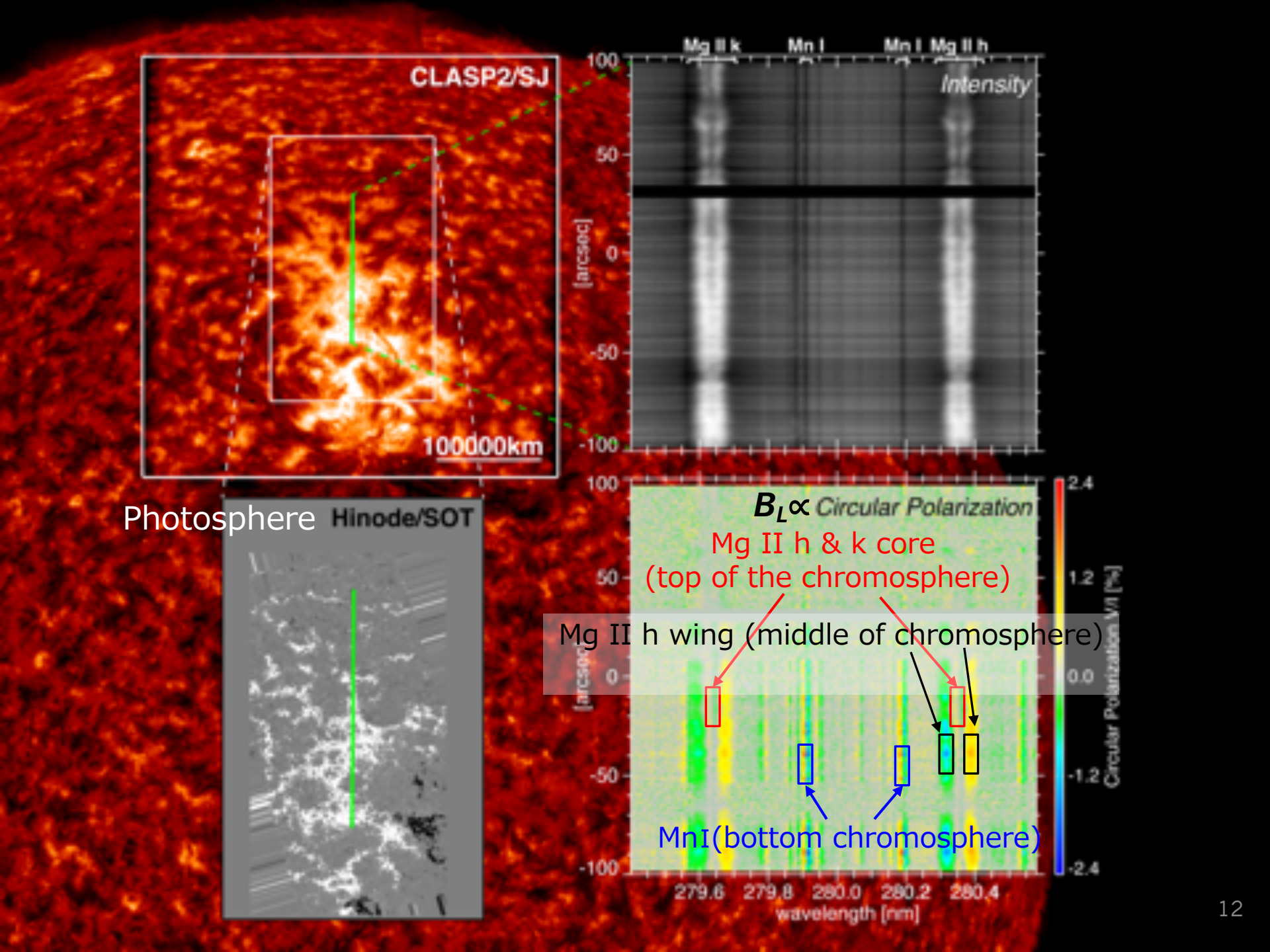
Installing flight diffraction gratings



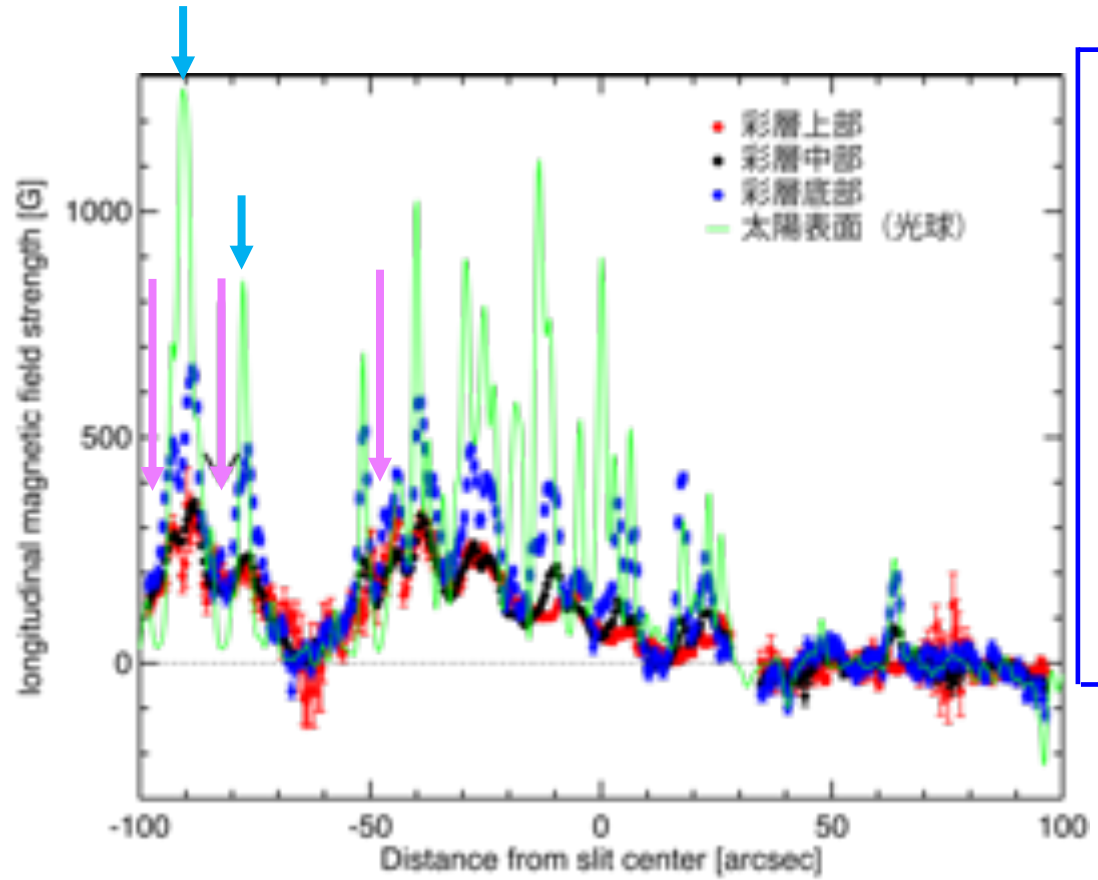
Performance evaluation of coatings and polarizing elements at synchrotron radiation facilities at the Institute of Molecular Science (Okazaki, Aichi Prefecture)

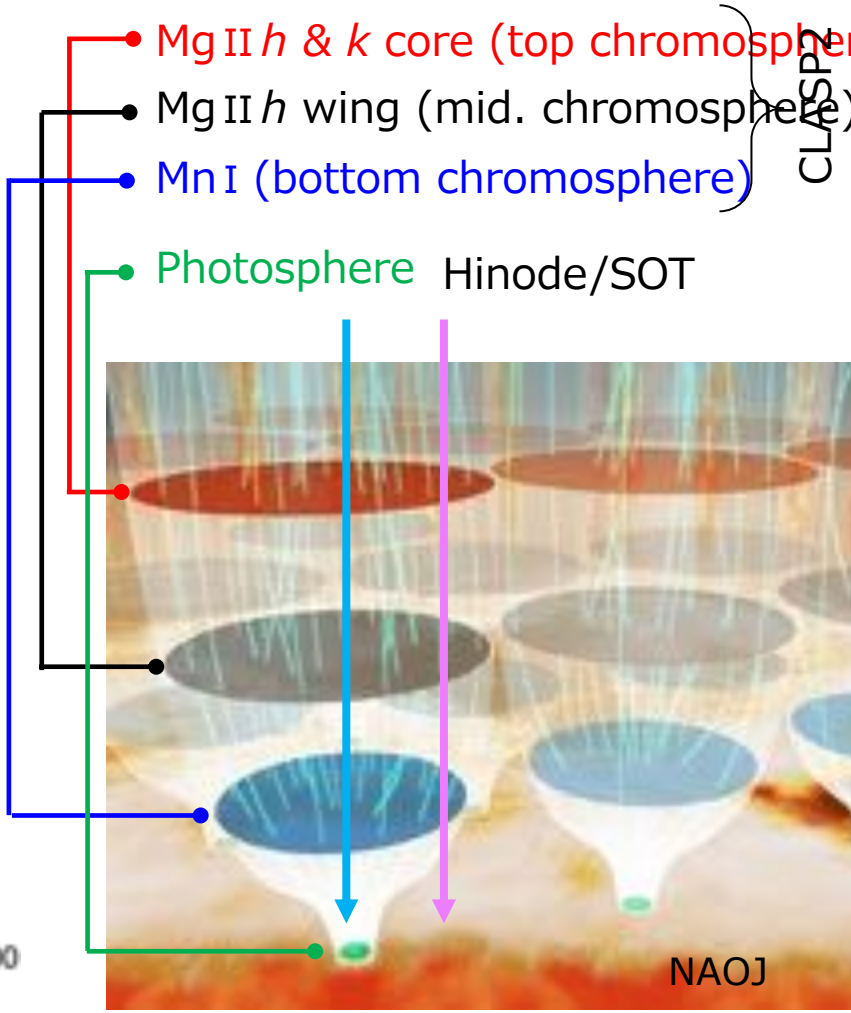
CLASP2 Launches on April 11, 2019 at 10:51 a.m. local time White Sands Missile Range, NM, USA

Credit: US Army Photo, White Sands Missile Range


CLASP2/SJ
100000km
Photosphere
Hinode/SOT
Mg II k
Mn I
Mn I
Mg II h
Intensity
[arcsec]
100
50
0
-50
-100
$B_L \propto$ Circular Polarization
Mg II h & k core
(top of the chromosphere)
Mg II h wing (middle of chromosphere)
MnI(bottom chromosphere)
279.6
279.8
280.0
280.2
280.4
wavelength [nm]
2.4
1.2
0.0
-1.2
-2.4
Circular Polarization V/I [%]

Clarified by CLASP2 a rapidly expanding magnetic flux tube





Ishikawa et al. Science Advances, 2021

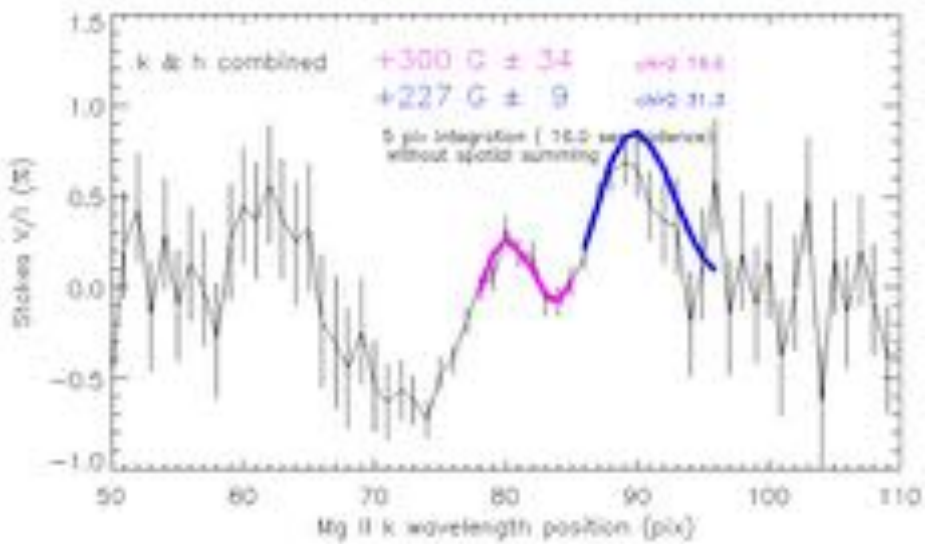
Recovery of observation equipment → optical tests confirm that there is no noticeable damage

Credit: US Army Photo, White Sands Missile Range

To the CLASP2 Re-Flight Project (CLASP2.1)

Elucidation of 3D structure of chromatic magnetic field by slit scan

- Fall 2020: Submit a proposal to NASA
- Spring 2021: NASA adopted
- 2021.8E:Start of shooting site work
  - Work scheduled to be performed at NASA/MSFC (2w: PMU installation, flight computer engagement test, torque confirmation, etc.) is carried out at WSMR [Reduction of total isolation period]
  - Small number of people (Japanese PI Ishikawa, IS Song) dispatched
-
- 2021.10.8: Launch



Observation at the solar center (for polarization calibration): 13 seconds
Pointing movement to the activity area: 10 seconds
Integration required for magnetic field derivation: 16 seconds
Pointing movement (Δ2") and stabilization with nudge capability: 3 seconds
->16 to 17 locations (30" x 200") scan is goal

Confirmation of the soundness of the observation device

Risk matrix

2. Structure – b. Shock load

Probability	Harm severity			
	Negligible	Marginal	Critical	Catastrophic
Certain	High	High	Very high	Very high
Likely	Medium	High	High	Very high
Possible	Low	Medium	High	Very high
Unlikely	Low	Medium	Medium	High
Rare	Low	Low	Medium	Medium
Eliminated	Eliminated			

2. Structure – a. Loose fasteners

✓ Check the fastening of the accessible & important screws (>100) at WSMR → Two screws on the main structure were found to be loosen and fastened again

2. Structure – c. Cyclic fatigue

✓ Analysis of lifetime and visual inspection at WSMR → OK

2. Structure – d. Adhesive failure

✓ Visual inspection at WSMR → OK

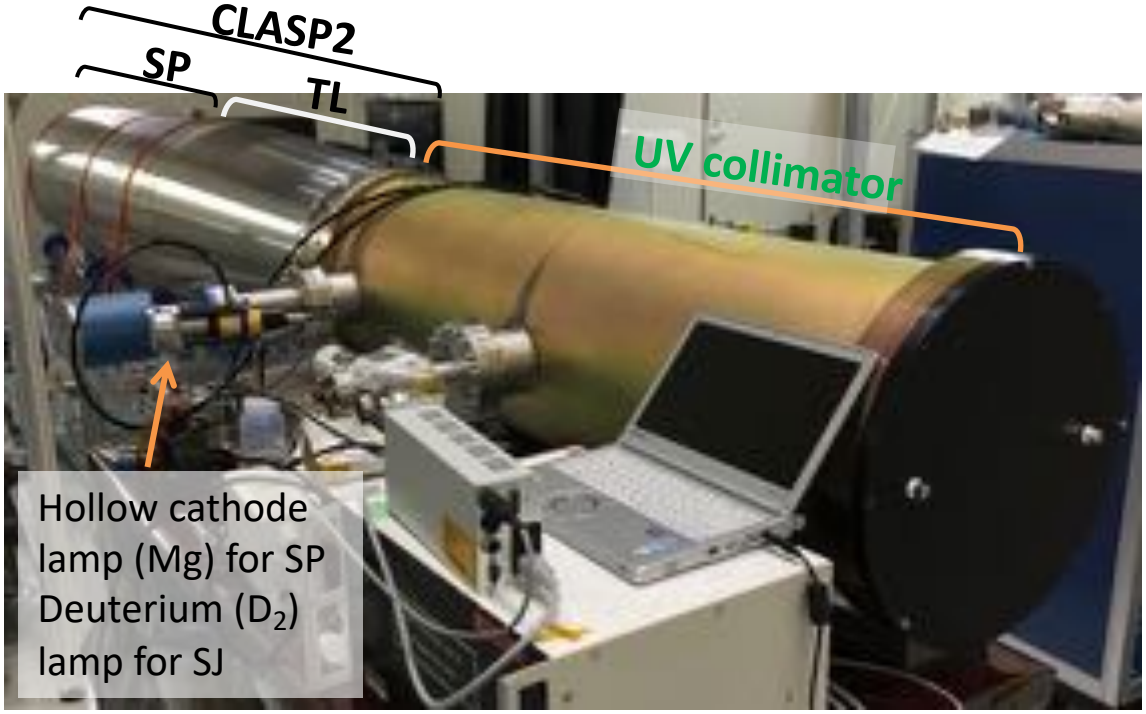
1. Optics – a. Stress corrosion

1. Optics – b. Cyclic fatigue

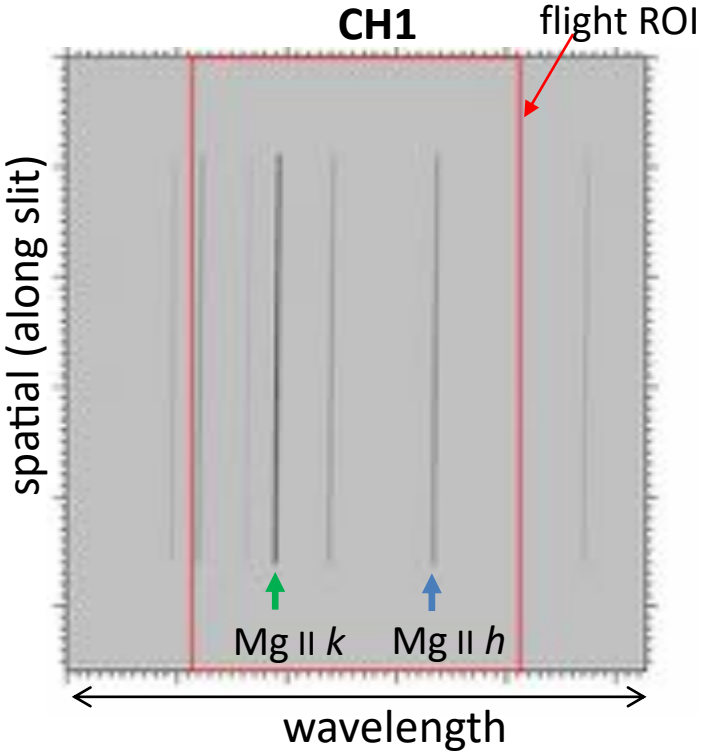
- Main structure and some optical components that had been used since CLASP
  - Three vibration tests (one at ISAS and two at WSMR) and two launchs
- Newly installed structure and optical components in CLASP2
  - Two vibration tests (one at JAXA and one at WSMR) and one launch

TL Focus Check & SJ, SP E2E test

- Monitor the optical performance (resolutions and position) and the radiometry
  - Post-CLASP2 launch, post-transportation, post-vibration, post-CLASP2.1 launch



Configuration of E2E test



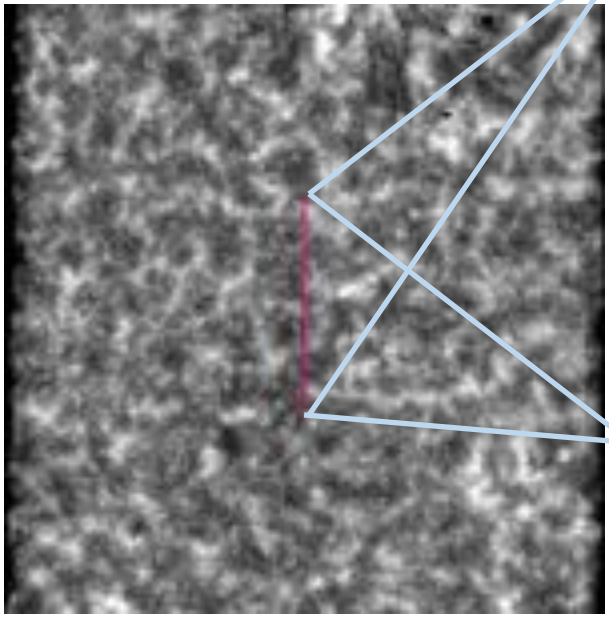
CLASP2.1 Launch on October 8, 2021 at 10:40 a.m. local time White Sands Missile Range, NM, USA

- Joint observation with THE HINO, IRIS satellites (ground observation has no data due to bad weather)

Credit: US Army Photo, White Sands Missile Range

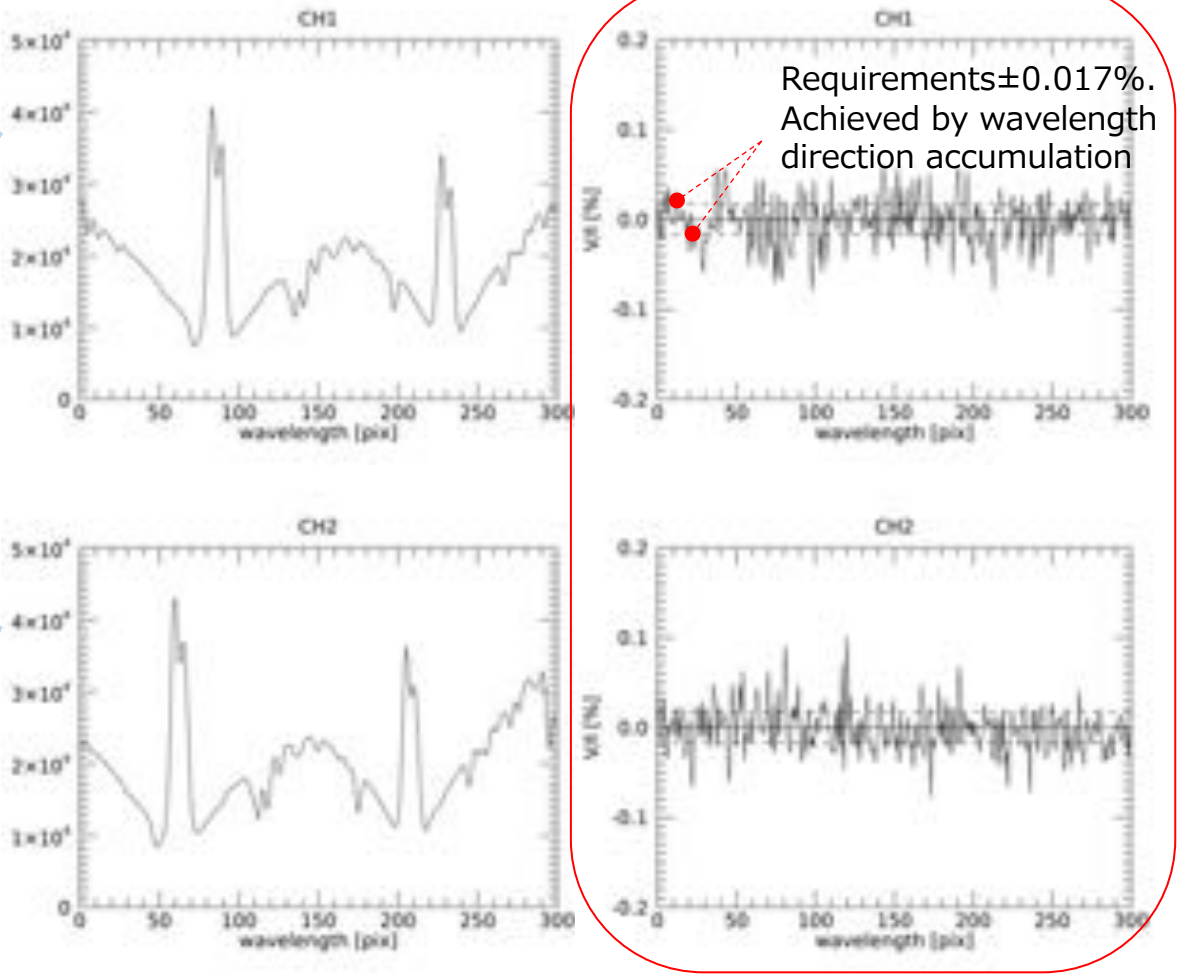
Observation at the solar center (16 seconds)

- Ensure that the device polarization is as small enough as CLASP2



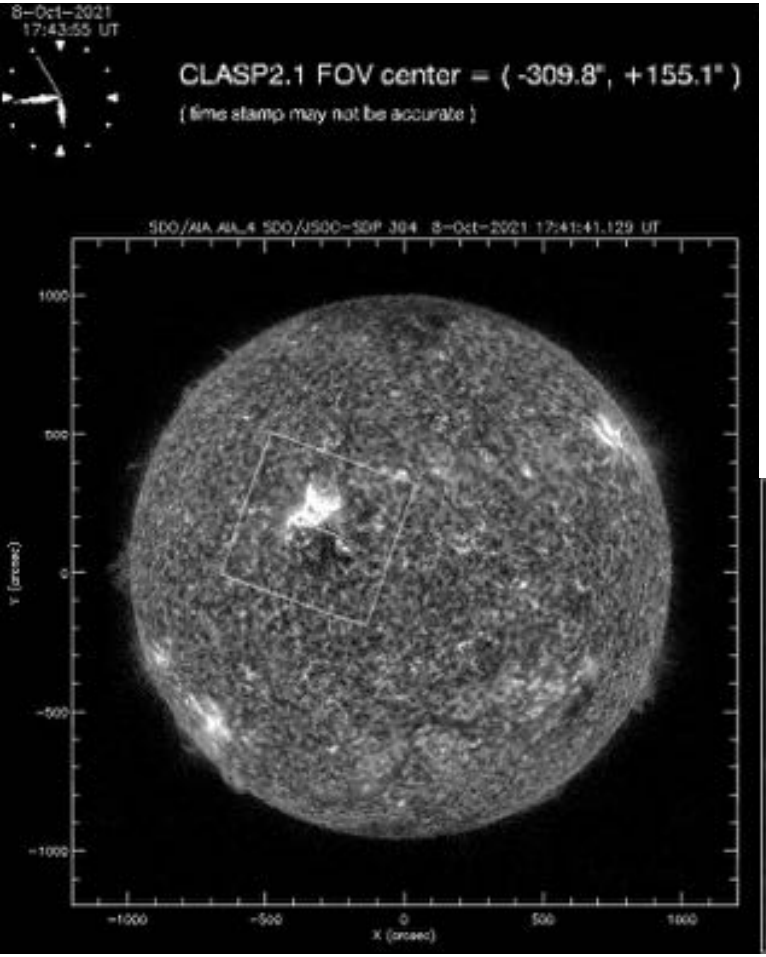
CLASP2.1/SJ

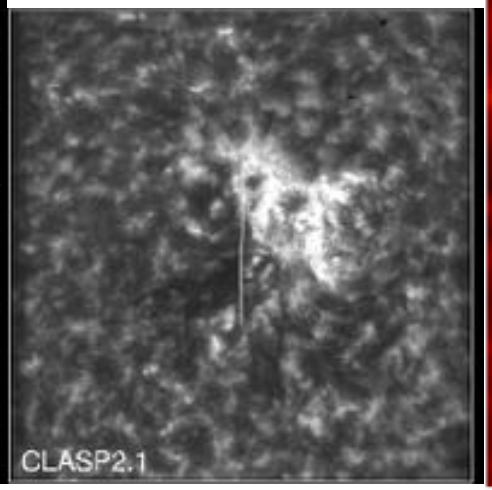
Time (16 sec) Space (200") Averaged Circular Polarization Profile



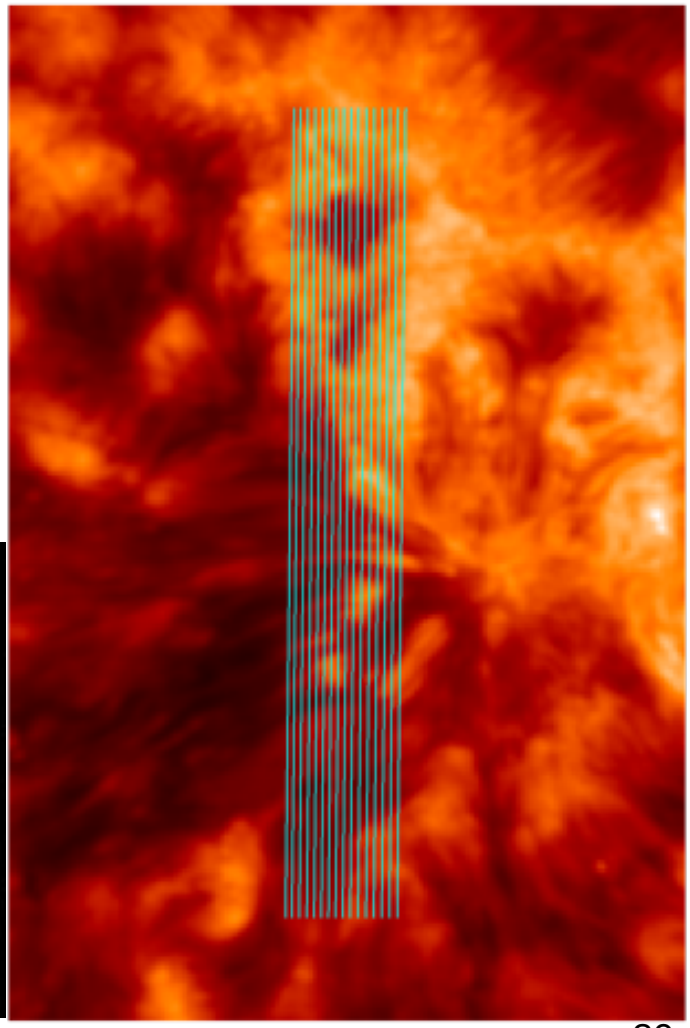
Observation in the active area (330 seconds)

- Successful 16-step (Δ1.7") scan observations with very stable pointing ~26" x 200"



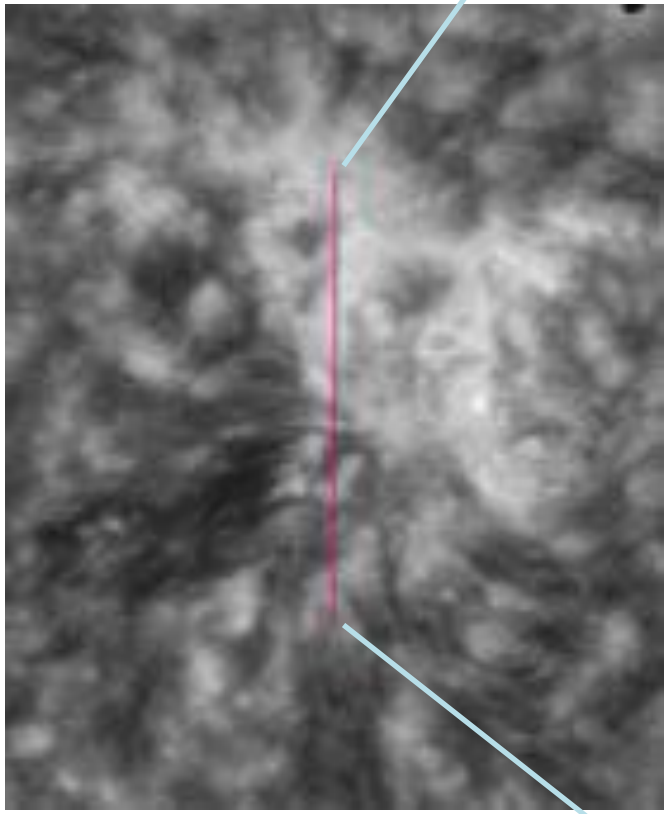


CLASP2.1/SJ (enlarged)

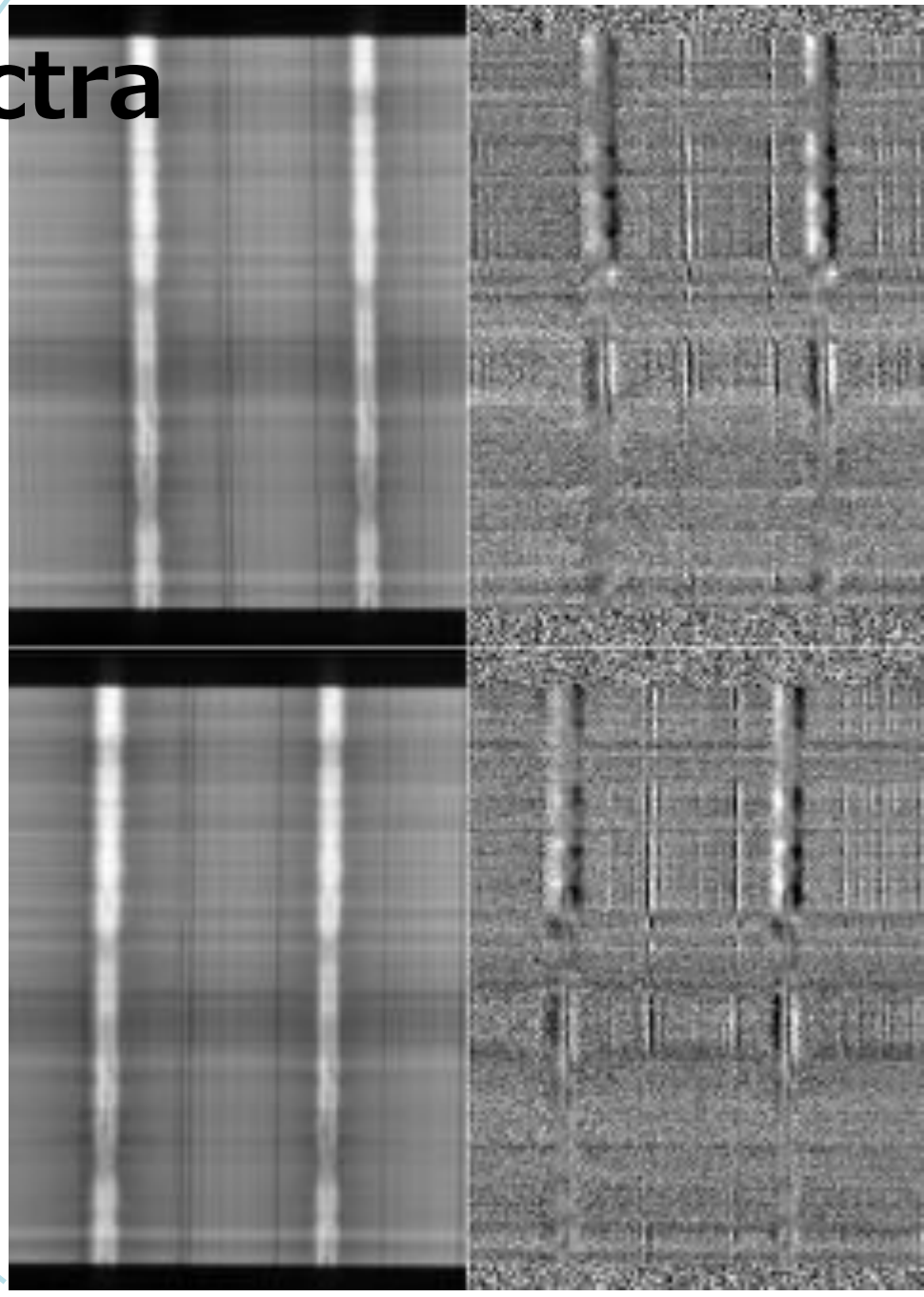


Polarization spectra

- Successful accumulation of 17.6 seconds or more at each slit position



Add the two spectra together to obtain the final polarization spectrum



Summary

- Planning and implementation of CLASP2 Re-Flight Plan (CLASP2.1) in response to the success of CLASP2
  - Successfully scan observation and obtain high-quality scientific data!
  - Currently working on data calibration
  - To the creation of scientific results (derivation of 3D structures of the color layer magnetic field)

- CLASP, CLASP2, CLASP2.1 -> Space telescope (realization of polarization spectroscopy observation by satellite)

The development of CLASP2 and CLASP2.1 in Japan received the following subsidies

・2021-2023 Basic Research (B)
・ 2019-2021 Basic Research (C)
・ 2020-2021 JAXA Small scale plan (finally without distribution)
・ 2017-2019 JAXA Small Scale Plan
・2016-2018 Basic Research (B)
・2016 NAOJ Joint Development Research
・2015 ISAS International Joint Mission Promotion Expenses
・2013-2017 Basic Research (S)