



太陽紫外線観測ロケット実験 CLASP/CLASP2でのコンタミ管理

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Frédéric Auchère (IAS), CLASP & CLASP2チーム



Contamination control in our solar UV sounding rocket projects: CLASP/CLASP2

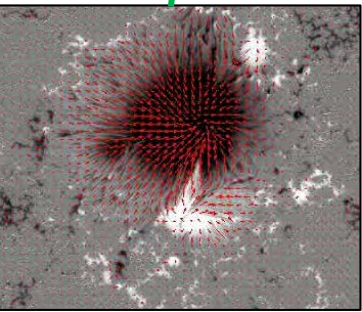
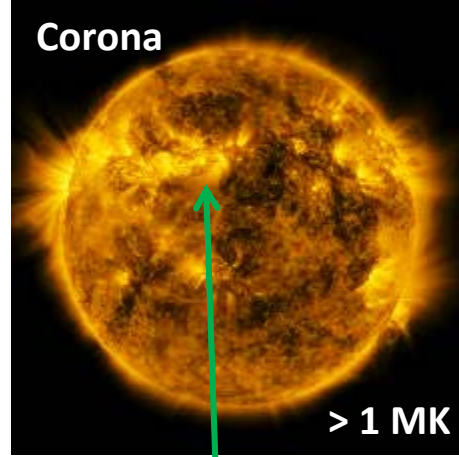
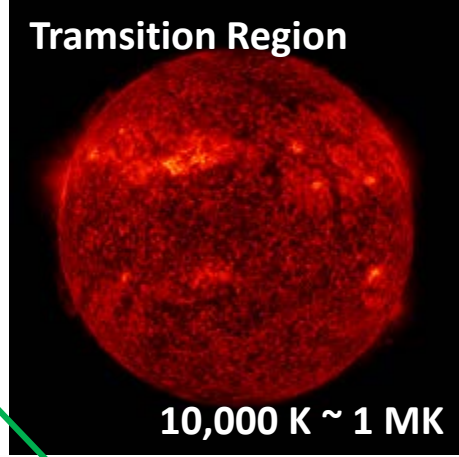
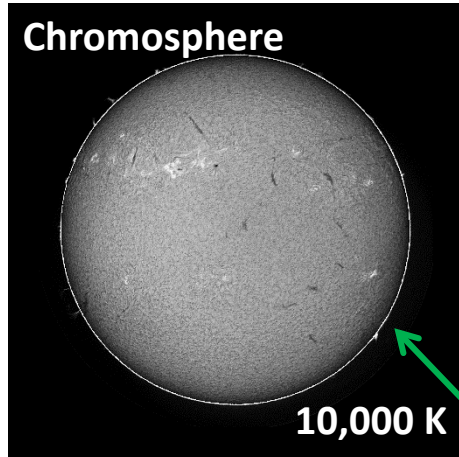
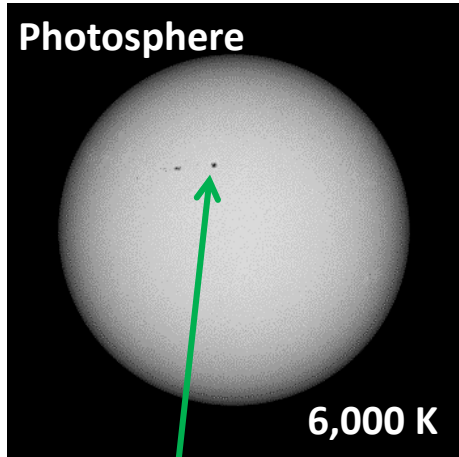
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Masahito Kubo, Takamasa Bando (NAOJ), Amy Winebarger, David McKenzie
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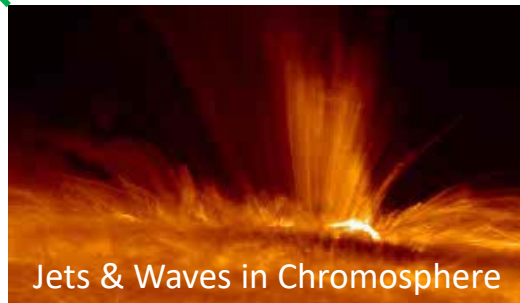
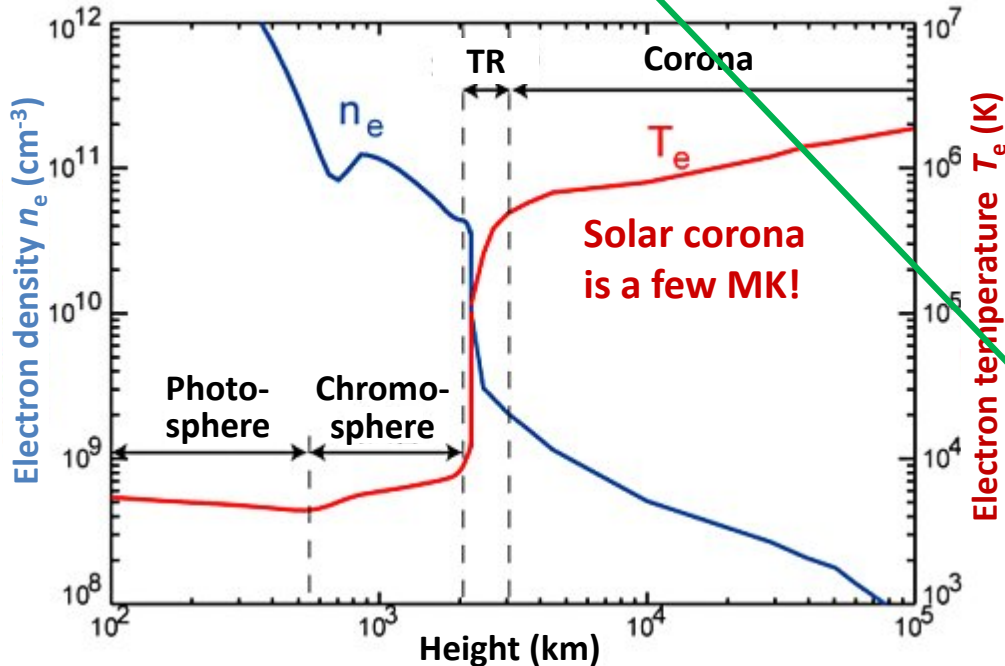
Outline (TBD)

- CLASP/CLASP2 sounding rocket projects
 - Scientific motivation
 - Instruments
- Contamination control
 - Strategy
 - Coating
 - Witness samples
 - E2E tests
 - In-flight data

How is the solar atmosphere activated? “Chromosphere-Corona Heating” & “Flare Trigger”



Photospheric
Magnetic Fields

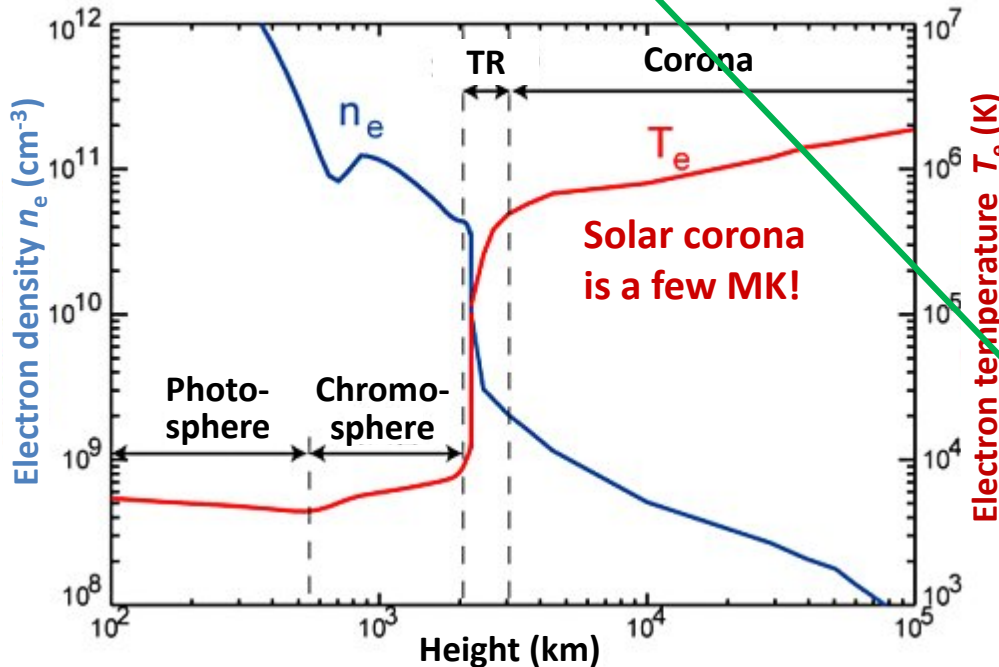


How is the solar atmosphere activated?

“Chromosphere-Corona Heating” & “Flare Trigger”

Magnetic fields must play an important role in most of activities and heating in the solar atmosphere.

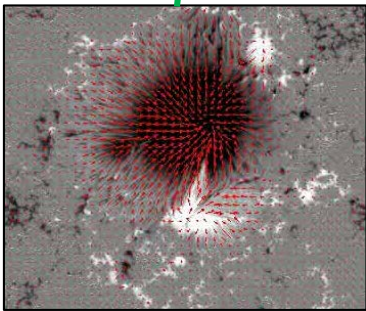
However, magnetic field measurement is very limited outside the photosphere.



Solar Flares in Corona

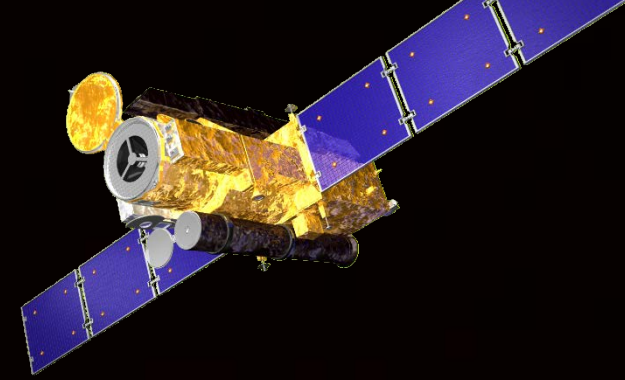


Jets & Waves in Chromosphere



Photospheric
Magnetic Fields

Discovery by “Hinode”



Quiet Photosphere

(CH G-band)

λ 430 nm

Active Chromosphere

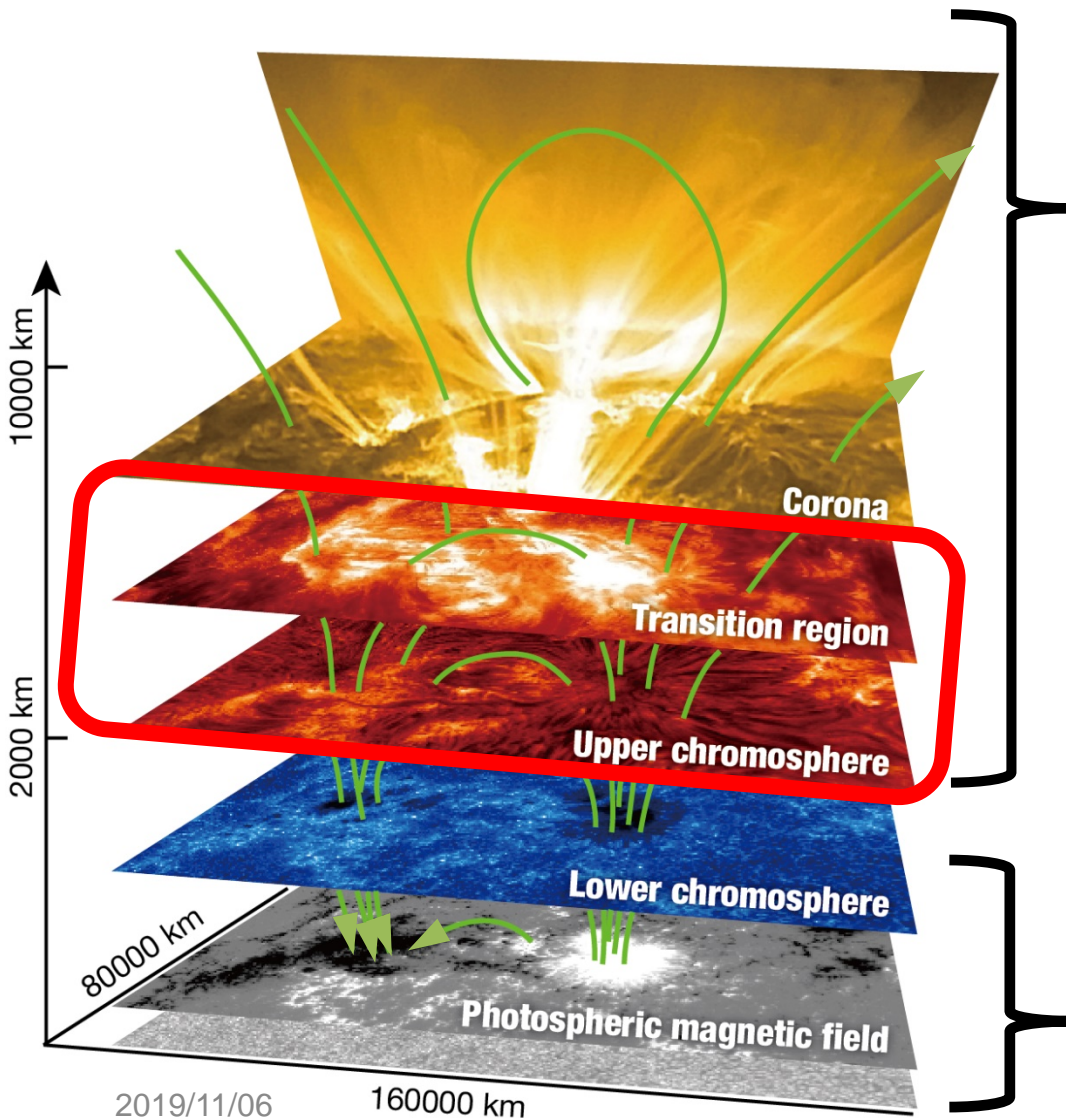
(Ca II H)

λ 396 nm

Sunspot

→ Next challenge is to extend magnetic field measurements to **chromosphere/transition region**, and then more.

B in **Photosphere** by Zeeman effect,
but not for above it → Hanle effect



plasma $\beta < 1$: i.e. $\rho_B > \rho_{\text{gas}}$
→ Magnetic fields build the plasma structure.

Extrapolated mag.-fields from the photosphere ($\beta > 1$) must not be so accurate.

→ We look forward to measuring mag.-fields in the Chrom. and TR ($\beta < 1$).

plasma $\beta > 1$: i.e. $\rho_B < \rho_{\text{gas}}$
→ Plasma flow can easily modify magnetic fields.

Our UV sounding rocket projects

CLASP

Chromospheric Lyman-Alpha Spectro-Polarimeter



CLASP2

Chromospheric Layer Spectro-Polarimeter



Sep. 3, 2015

April 11, 2019

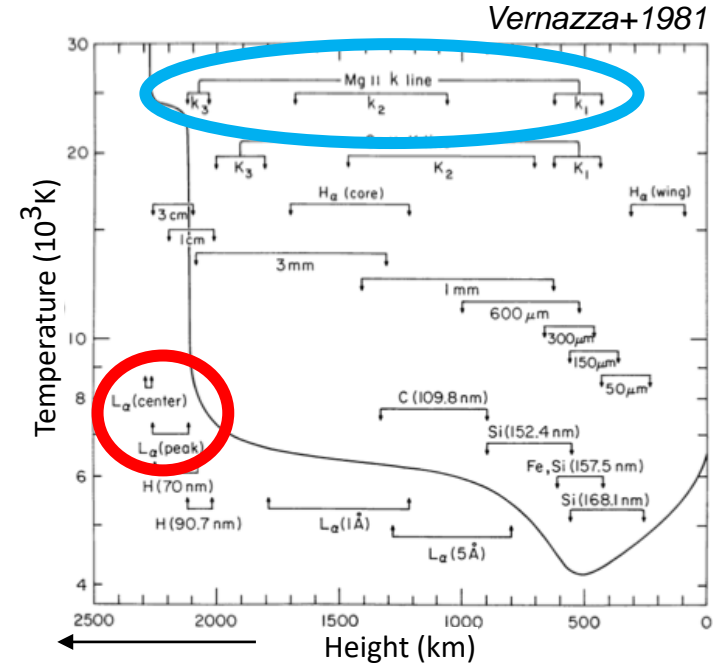
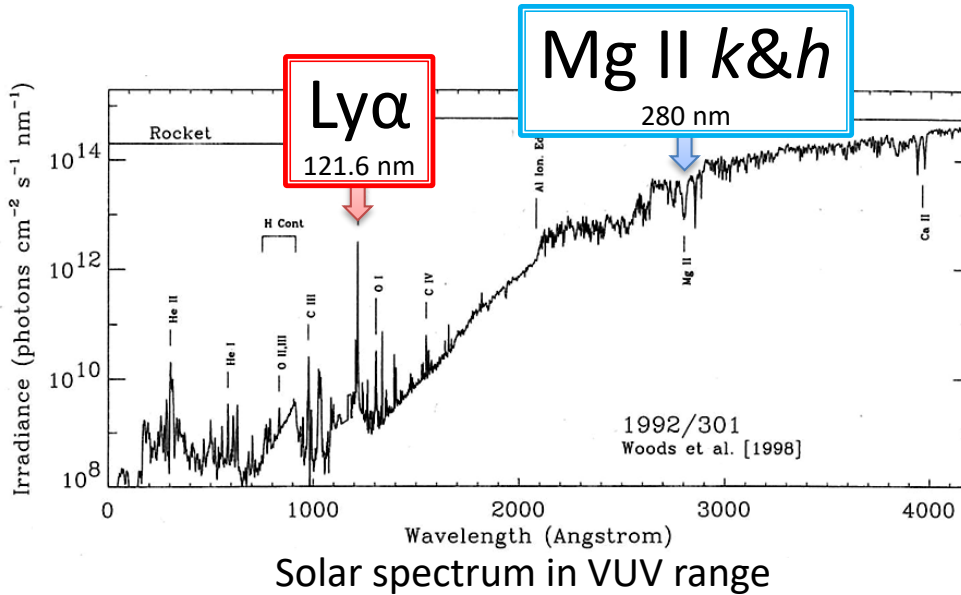


Both are **sounding rocket experiments**

- to observe the solar **chromosphere** and **transition region**
- with the **high-precision** ($<0.1\%$) **spectro-polarimetry** in a UV spectral line, and then
- to infer **magnetic fields** in such upper solar atmosphere.



Why UV lines?



- **Brightest line** in VUV chromospheric emission lines, and **bright even in quiet Sun** as well as active regions.
- Line core is emitted by the plasma located between **upper chromosphere and transition region (TR)**.
- Good sensitivity to magnetic field of **10 – 100 G** via Hanle effect.
 - ➔ $\text{Ly}\alpha$ line is a suitable candidate to constrain magnetic fields and the geometrical complexity of the low- β TR plasma over the entire solar disk.

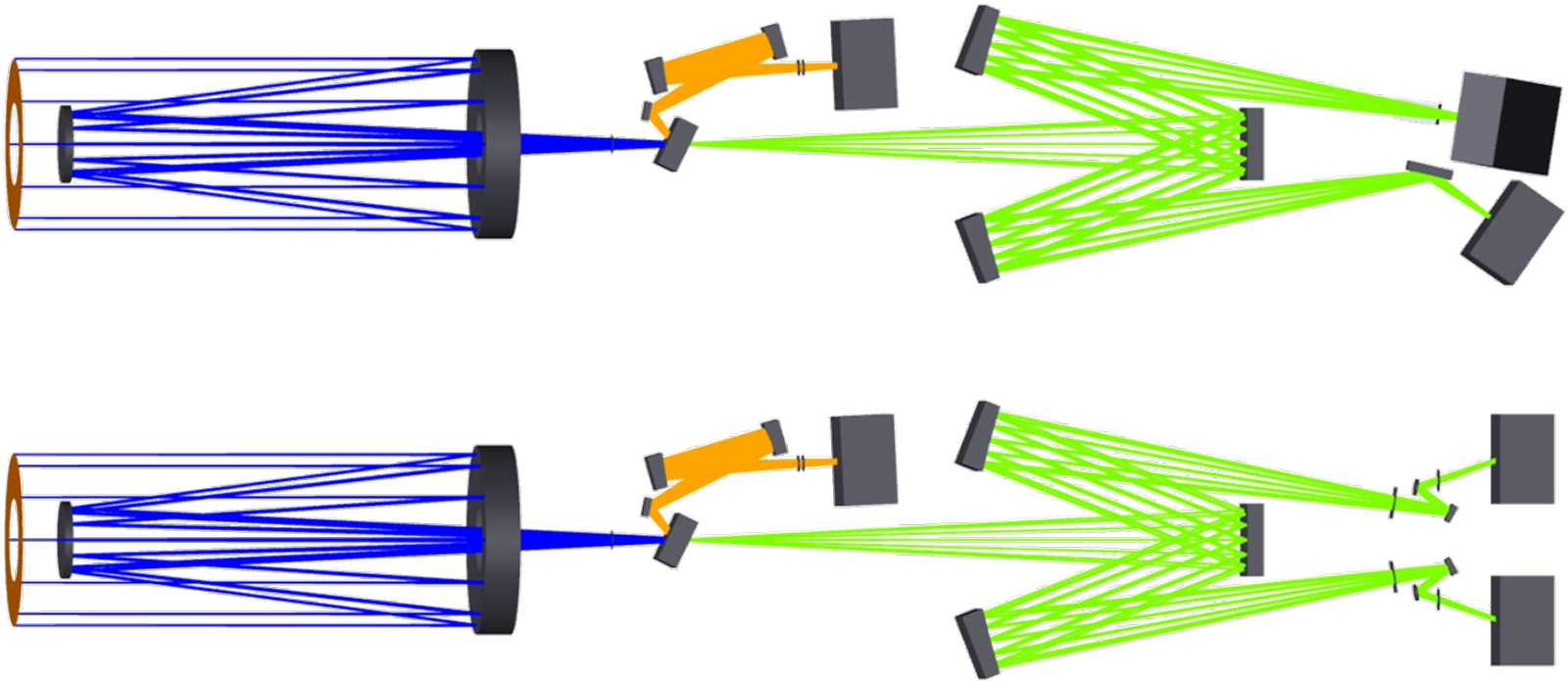
Candidates of Hanle-sensitive spectral lines for $30\text{cm}\phi$

UPPER CHROMOSPHERIC LINES ONLY!

Ver. 2017.07.13

Spectral line [nm]	1.22 λ/D [arcsec]	Response height [km]		Zeeman effect		Hanle effect	
		T_e	V	B_{long} [G]	B_{tran} [G]	Range[G]	P [%]
He II 30.4	0.02	Transition re		CLASP1	-	85 - 850	1.5
Si III 120.7	0.10	close to TR		?	?	30 - 300	?
Ly α 121.6	0.10	Transition region		-	-	0.5 - 50	0.5
Mg II k 279.6	0.23	1300	1400	130	2100	0.3 - 25	1.5
Ca II K 393.3	0.33	1000	1	CLASP2	1700	0.2 - 15	1.5
H β 486.1	0.40	1500	1000	19	1300	Collisional depolarization??	
H α 656.3	0.55	1500	1300	9.9	910		
Ca II 849.8	0.71	700	1000	5.6	280	0.001 - 10	0.01
Ca II 854.2	0.72	800	1200	6.1	330	0.001 - 0.01	0.4
Ca II 866.2	0.73	700	1000	7.6	410		0.4
He I 1083(QS)	0.91	1800	1800	20	400	Blue:0.01-0.1 Red: 0.1 -1	Blue:0.03 Red: 0.15
He I 1083(AR)				10	280		

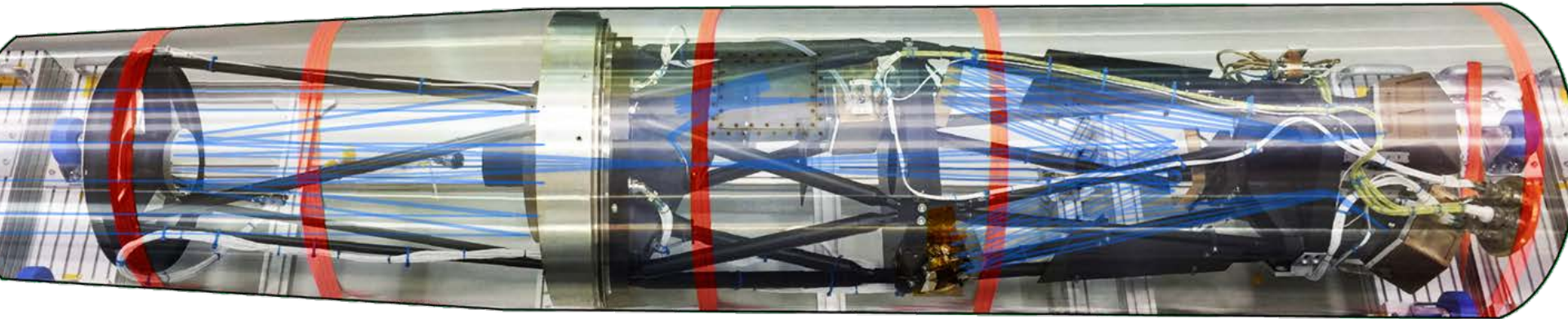
Optical Components in CLASP/CLASP2





CLASP Instrument

Narukage et al. (2015, Applied Optics)



Cassegrain Telescope

Aperture	$\phi 270.0$ mm
Focal Length	2614 mm (F/9.68)
Visible light rejection	"Cold Mirror" coating on primary mirror

Slitjaw Optics

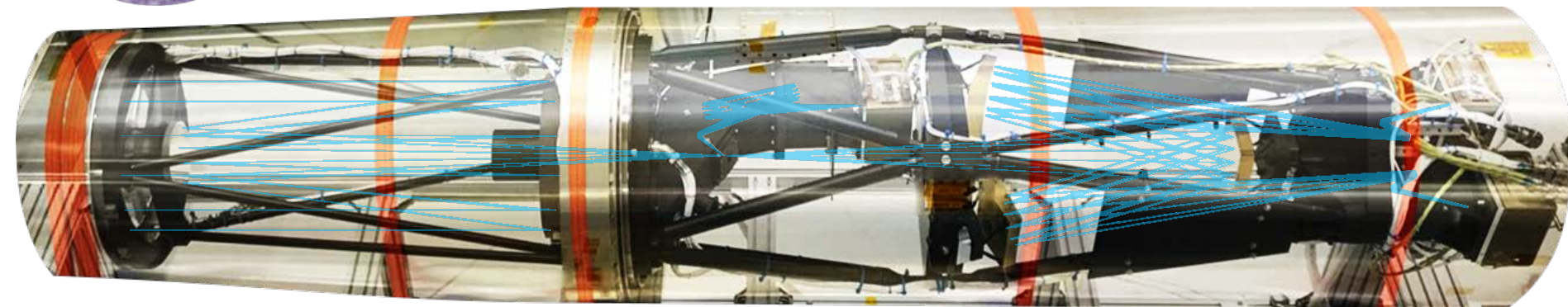
Wavelength	121.567 nm (NB filter)
Plate scale	1.03"/pixel
FoV	527" \times 527"

Spectro-Polarimeter

Optics	Inverse Wadsworth mounting	
Wavelength	121.567 \pm 0.61 nm	
Slit	1.45" (width), 400" (length)	
Grating	Spherical constant-line-spacing, 3000/mm	
CCD camera	512 \times 512 pixel	13 μ m/pixel
Plate scale	0.0048 nm/pixel	1.11"/pixel
Resolution	0.01nm	3"
Sensitivity	0.1%	



CLASP2 Instrument



Cassegrain Telescope

Aperture	φ270.0 mm
Focal Length	2614 mm (F/9.68)
Visible light rejection	“Cold Mirror” coating on primary mirror

Slitjaw Optics

Wavelength	121.567 nm (NB filter)
Plate scale	1.03"/pixel
FoV	527" × 527"

Spectro-Polarimeter

Optics	Inverse Wadsworth mounting	
Wavelength	279.45 – 280.35 nm	
Slit	0.55" (width), 200" (length)	
Grating	Spherical constant-line-spacing, 1303/mm	
CCD camera	512 × 512 pixel	13μm/pixel
Plate scale	0.005 nm/pixel	0.55"/pixel
Resolution	0.01nm	1.1"
Sensitivity	0.1%	

Contamination Control in CLASP/CLASP2

- Flight-mirror reflectivity and aging monitor **by using the witness samples for them.**
- Management and maintenance of cleanliness of the flight instrument **by baking and TQCM measurements**
- Monitor the sensitivity of the flight instrument **by End-to-End tests**

Flight-Mirror (FM) reflectivity and aging monitor by witness samples (WSs)

Coating

WSs were simultaneously coated with **FM** in the same chamber.

Storage

WSs were stored with **FM** in the same environment (desiccator).

Installed

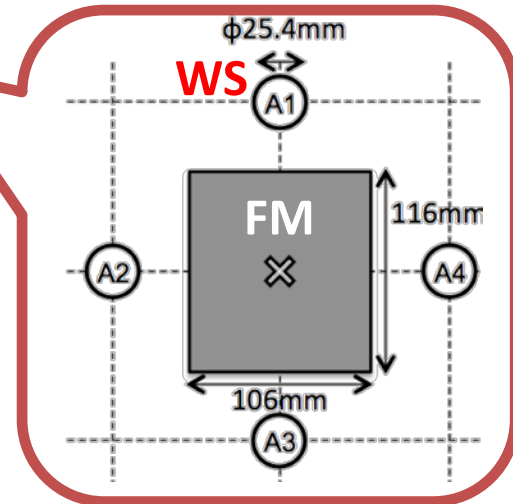
After **FM** installation, **WSs** were also installed in the instrument.

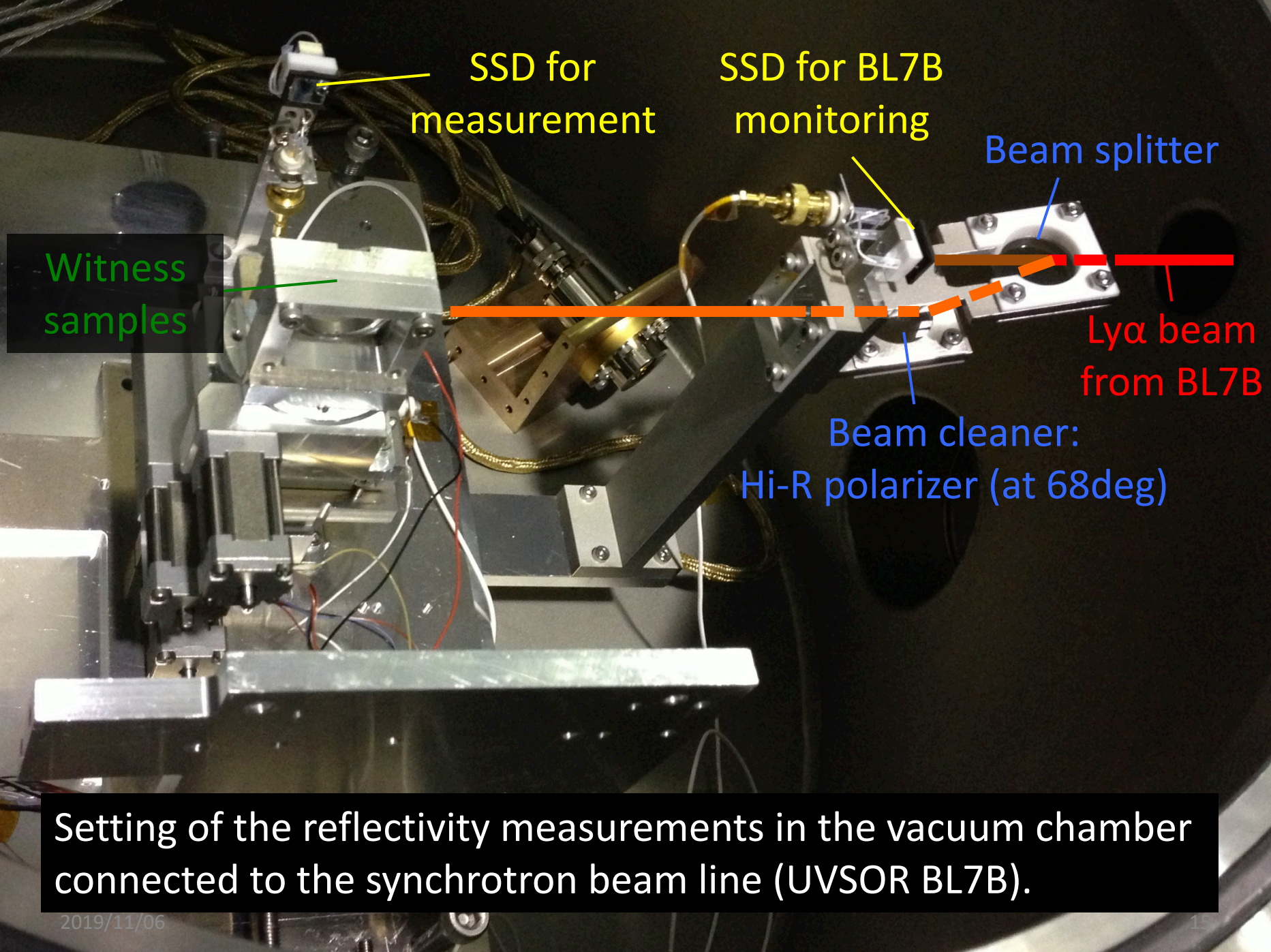
Flight

WSs were removed before the flight.

initial meas.
of **WSs**
@UVSOR

final meas.
of **WSs**
@UVSOR





SSD for measurement

SSD for BL7B monitoring

Beam splitter

Witness samples

Ly α beam from BL7B

Beam cleaner: Hi-R polarizer (at 68deg)

Setting of the reflectivity measurements in the vacuum chamber connected to the synchrotron beam line (UVSOR BL7B).

Reflectivity of each mirror

CLASP Mirrors

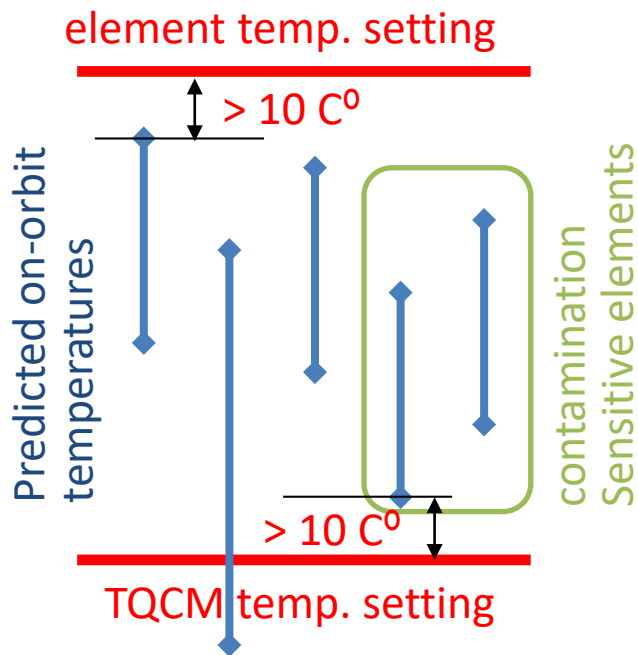
Element	Spec.	Initial	Bef. Flight @2015/01
M1 1mary M.	> 40 %	56.5 %	53.3 %
M2 2ndary M.	> 80 %	82.0 %	80.0 %
Grating *1	> 18 %	29 %	29 %
M3 camera M.	> 80 %	82.0 %	82.0 %
reflective polarization analyzer	> 50 %	54.5 %	54.5 %
slit M.	> 75 %	78 %	*2
SJ fold M.	> 35 %	48.3 %	48.3 %
SJ parabolic M.	> 80 %	82.0 %	*2

CLASP2 Mirrors

Element	Spec.	Initial	Bef. flight @2019/02
M1 1mary M.	> 70 % > 40 %	72 % 53 %	71 % 50 %
M2 2ndary M.	> 80 % > 80 %	89 % 84 %	88 % 80 %
Grating *1	---	89 %	84 %
M3 camera M.	> 80 %	89 %	88 %
M4 magnify M.	> 80 %	87 %	88 %
M5 fold M.	> 80 %	87 %	87 %
slit M.	> 75 %	76 %	76 %
SJ fold M.	> 35 %	*2	36 %
SJ parabolic M.	> 80 %	*2	*3

Management and maintenance of cleanliness of the flight instrument

Original MSFC-SPEC-1238



Rate < 1.0 Hz/hr by TQCM with
sens. = $1.56 \times 10^{-9} \text{ g cm}^{-2} \text{ Hz}^{-1}$

In-flight temperature of CLASP:

- CCD = -20 C°
- Others including mirrors = room-T ($+25 \pm 5 \text{ C}^{\circ}$)

- Baking of elements was performed @ $\sim +90 \text{ C}^{\circ}$ or the highest allowable temp. for each.
- Outgas from element @ room-T was checked by TQCM @ -20 C° (i.e. CCD temp.) or @ $+10 \text{ C}^{\circ}$ (i.e. mirror temp. $- 10 \text{ C}^{\circ}$).
- Criteria of the outgas rate:
 - < 1.0 Hz/hr by our TQCM**.
 - (**): sens. = $1.96 \times 10^{-9} \text{ g cm}^{-2} \text{ Hz}^{-1}$

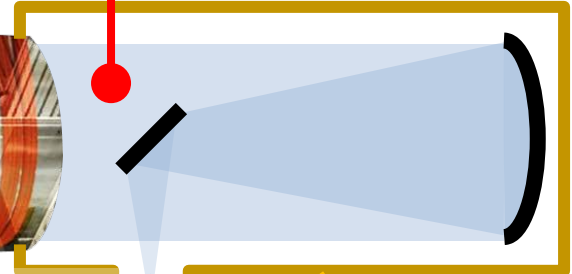
End-to-End Test Configuration

CLASP/CLASP2 Instrument

Silicon diode
(reference)



UV collimator

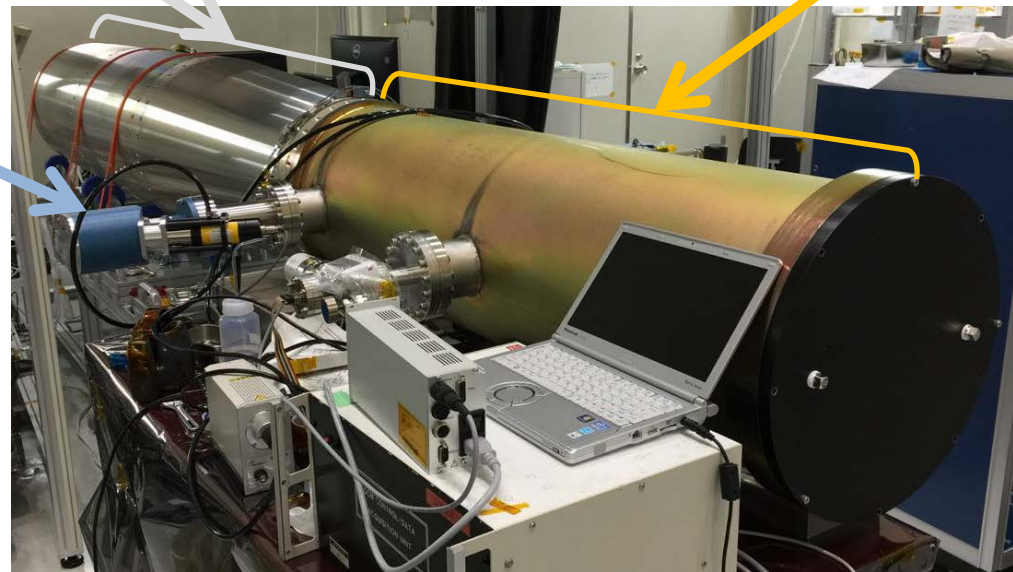


UV lamp



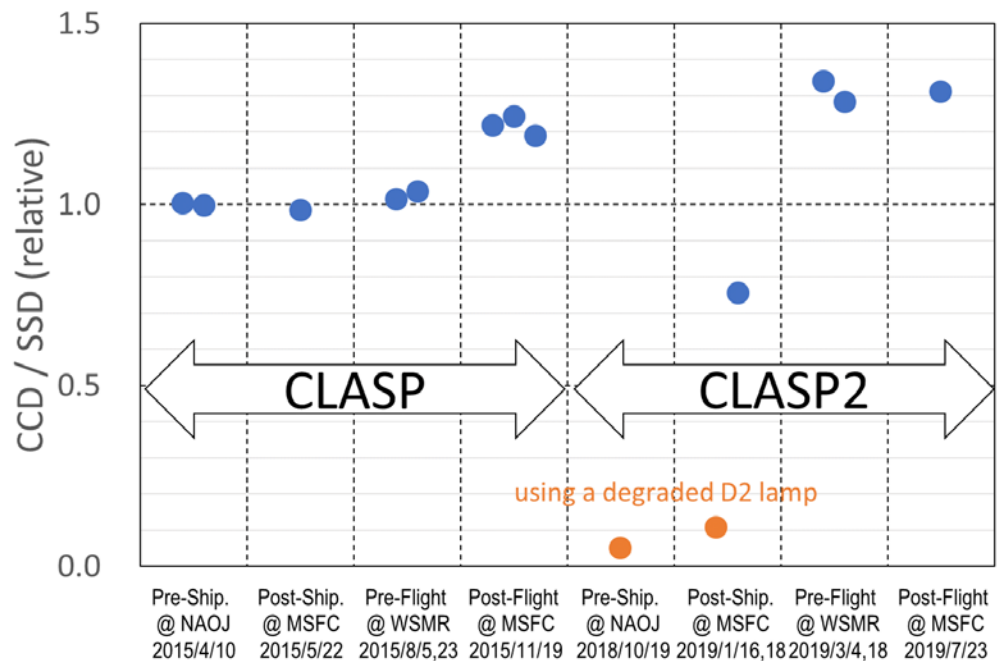
UV lamp

- For Ly α (121.6 nm):
Deuterium lamp
- For Mg II *k&h* (280 nm):
Mg hollow-cathode lamp



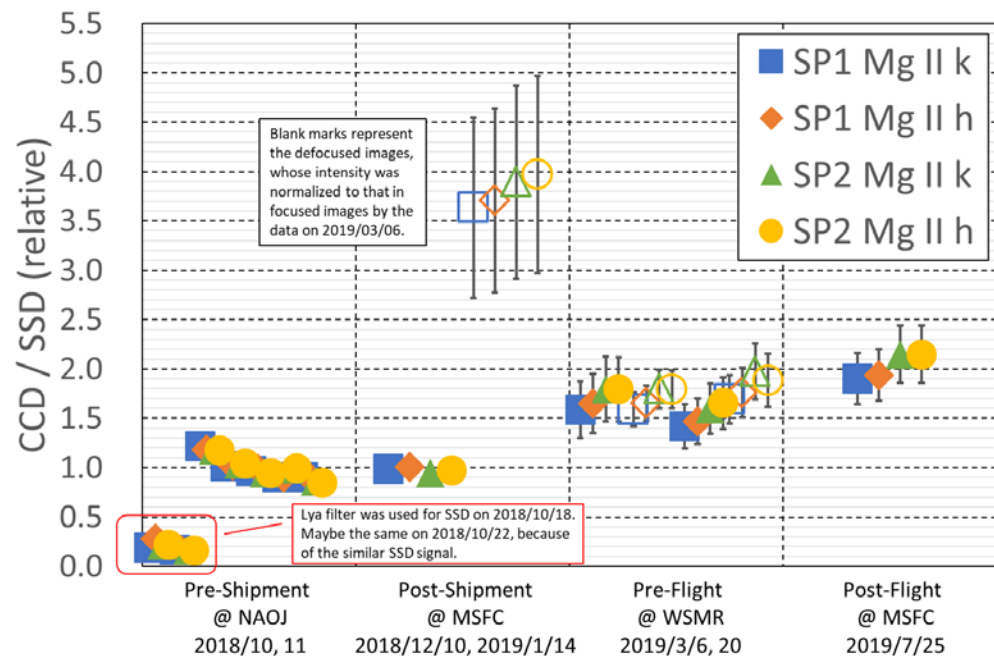
History of SJ Throughput in CLASP/CLASP2

- Except for two data points taken with the old D2 lamp in CLASP (orange circles), all the ratios are within $\pm 40\%$ of the initial value.
- ➔ This indicates no significant degradation by the contamination happened in the SJ unit during the CLASP & CLASP2 projects.



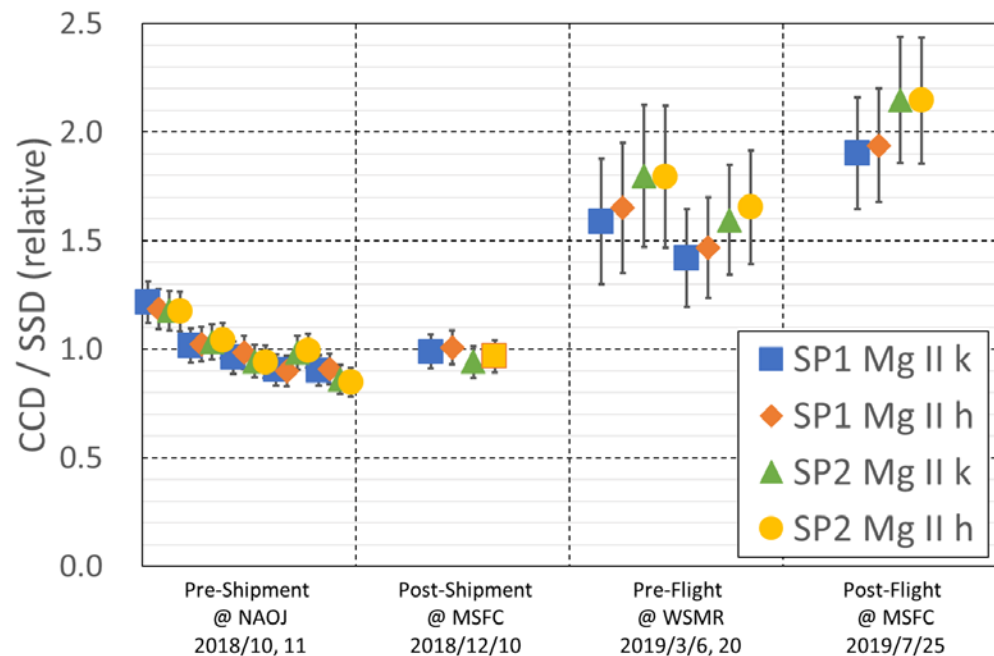
History of SP Throughput in CLASP2 (1/2)

- All data points in CLASP2/SP E2E tests are plotted.
- Some data points show a significant difference:
 - In the initial two tests encircled by red, we used the Lya filter for SSD instead of the 280nm filter.
 - The blank marks show the results from the defocused images. The data on 2019/01/14 are different from the others, even though they were normalized by the data on 2019/03/06.



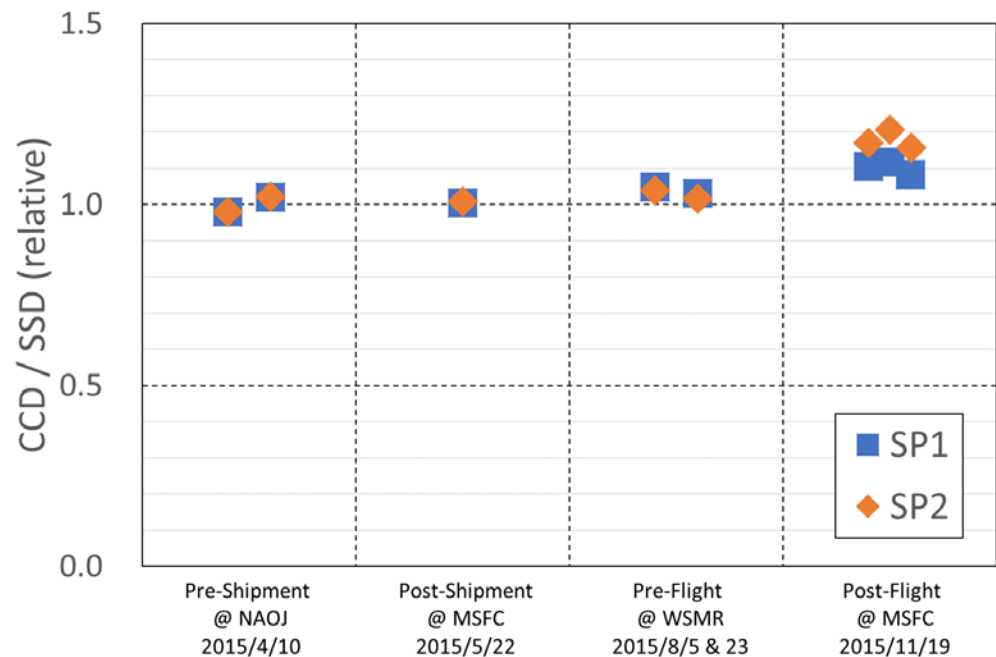
History of SP Throughput in CLASP2 (2/2)

- We plot only data points from the focused image with the usage of the 280nm-filter at the SSD.
 - No decrease of the ratio happened during the CLASP2 project.
- ➔ This indicates no significant degradation by the contamination happened in the SP unit during the CLASP2 project.

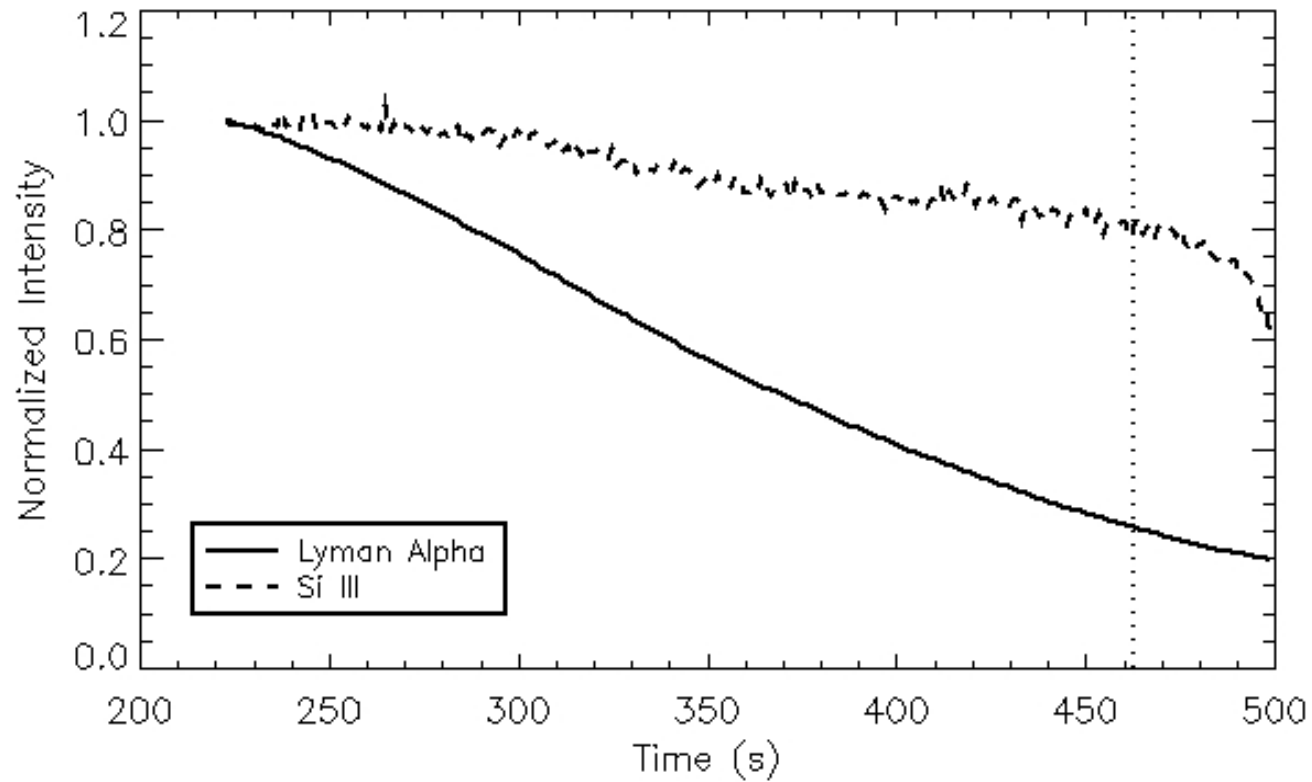


History of SP Throughput in CLASP

- All the ratios are within $\pm 20\%$ of the initial value.
- ➔ This indicates no significant degradation by the contamination happened in the SP unit during the CLASP project.



In-flight Intensity Drop in CLASP



Summary

- CLASP/CLASP2実験で、主に分子汚染防止を目的としてコンタミ管理を行い、特に有機物汚染の防止に成功した。
- ただし、CLASP観測では水分子によるLy α 線輝度の減少が発生し、容易に除去しうる分子といえどもその影響を評価することや、フライト時の排気パスを定量的に評価することの重要性を得た。

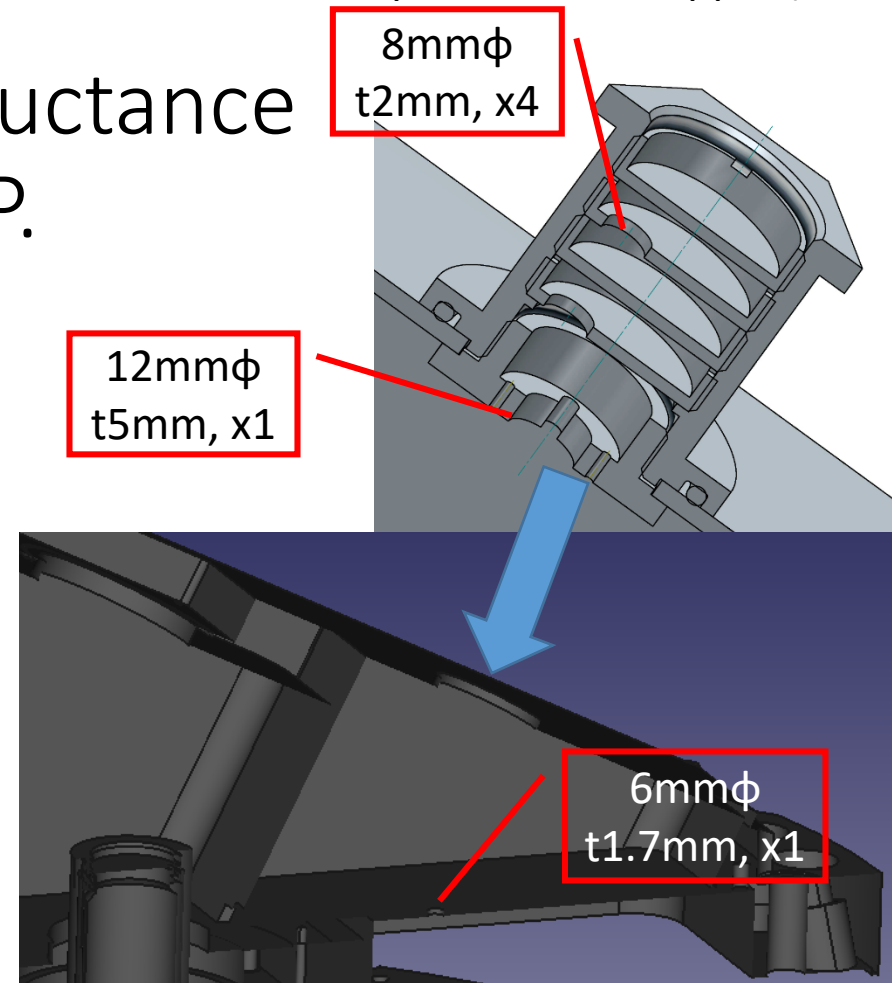
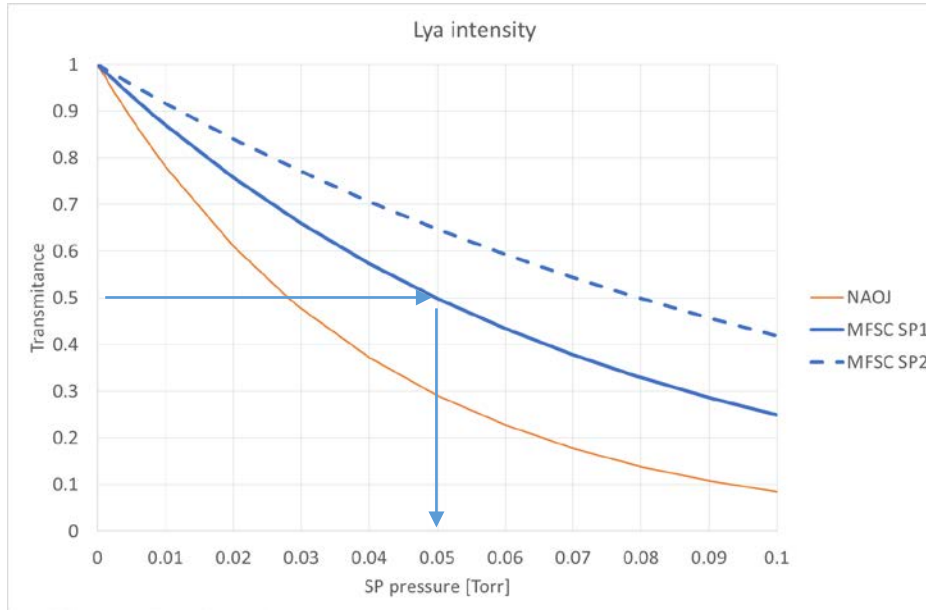
Summary

- In the CLASP / CLASP2 experiments, the contamination control was conducted mainly for the purpose of preventing molecular contamination. In particular, the organic contamination was successfully prevented.
- However, in the CLASP observation, the Ly α intensity decreased due to water molecules. Thus, we obtained the importance to evaluate the influence of molecules that can be easily removed and to quantitatively evaluate the vent path during the flight.

Back up

2. Low vacuum conductance between TL and SP.

Lya transmission based on MSFC exp.



- We requested **0.058 Torr** or lower at the launch for achieving 0.05 Torr by the observation, because we could allocate the throughput margin for the contamination (50%) to this.
- It was 0.0225 Torr by 17m45s before the launch.
- ➔ For MgII, we may be able to relax the required vacuum level at the launch.