The pre-flight test and observation results of the Sunrise Chromospheric Infrared spectroPolarimeter (SCIP)

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Sunrise III/SCIP

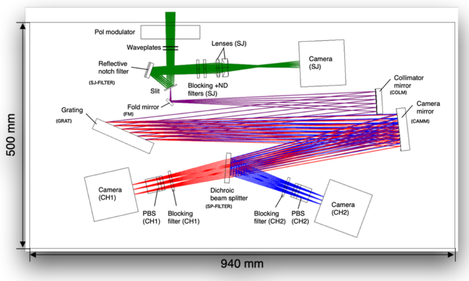
International balloon solar observation experiment using a large optical telescope with a 1-meter aperture

Sunrise Chromospheric Infrared spectroPolarimeter (SCIP)

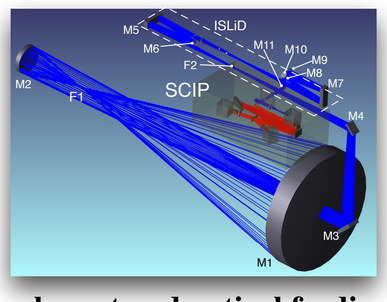
- Aims to understand the plasma heating and acceleration mechanisms in solar atmospheres
- Composed of a single slit spectropolarimeter (SP) and a slit-jaw imager (SJ)
- Multi-wavelength spectropolarimetry in 850 (CH1) and 770 nm (CH2) band
- High spatial and spectral resolution: 0.21 arcsec in 850 nm and 2×10^5
- High polarization precision: 3×10^{-4} in continuum
- On-board demodulation
- Bit and image compression

The pre-flight activity at the launch site (Esrange Space Center)

- Assembly
- End to end polarization calibration
- Optical test, electrical function test, Hang test
- Timeline function development
- Compatibility test
- Flight on 10th July 2022 (terminated before obtaining science data).



Optical system of SCIP



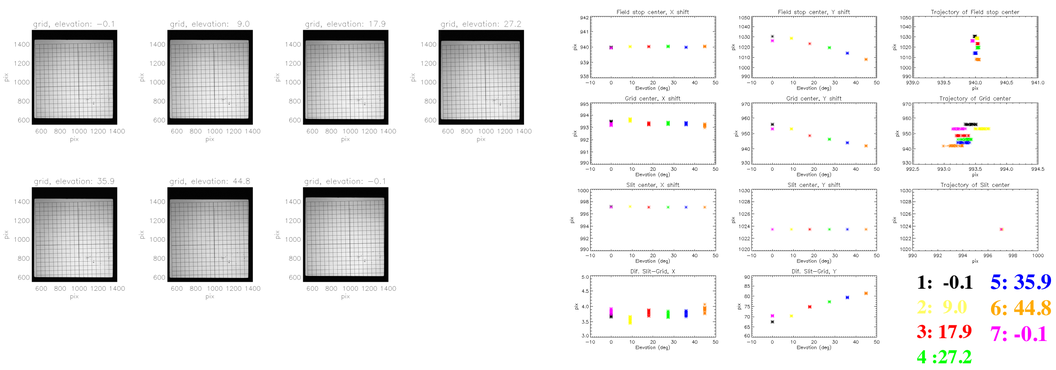
Telescope layout and optical feeding system

Optical Test with LED

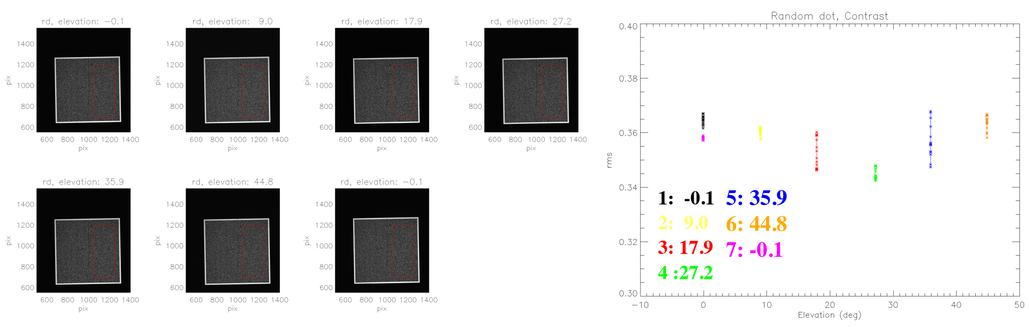
Alignment and contrast were optically evaluated with LED illumination with F2 target (Grid and Random dot target).

Dependency on telescope elevation

Alignment (Slit-jaw images, F2:Grid)



Contrast (Slit-jaw images, F2: Random dot)

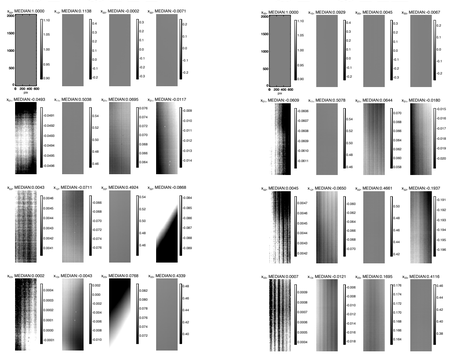


Alignment: Significant dependency on elevation along the slit direction
Contrast: Small dependency on elevation

End to End Polarization Calibration

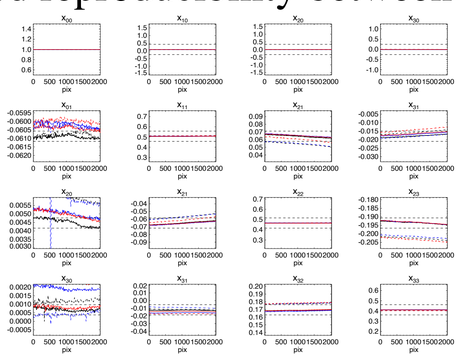
Polarization calibration of SCIP at NAOJ (Kawabata et al. submitted)
End to end polarization was done at MPS and Esrange

SP CH1 SP CH2



Response matrix

Good reproducibility between MPS and Esrange

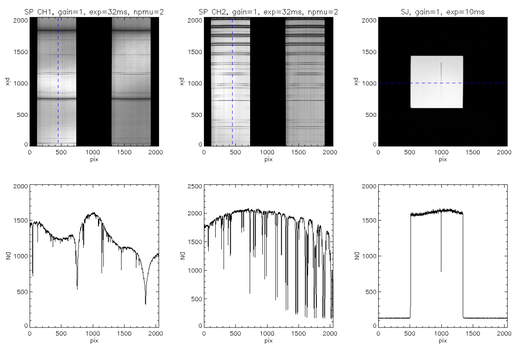


Solid:Kiruna
Dashed: MPS

Center
Negative
Positive

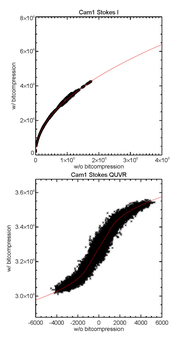
Hang Test

Sunlight images



Check Items
- Intensity level: ✔
- Wavelength position: ✔
- Spatial alignment: ✔

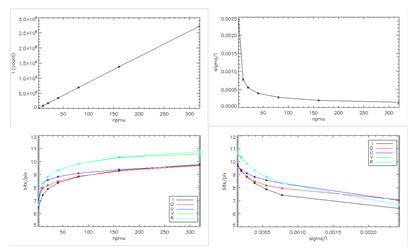
Bit Compression



Nonlinear image transformation based on a square root function

Stokes I:
22U bits/pix-> 16 U bits/pix
Stokes QUVR:
21S bits/pix -> 16U bits/pix

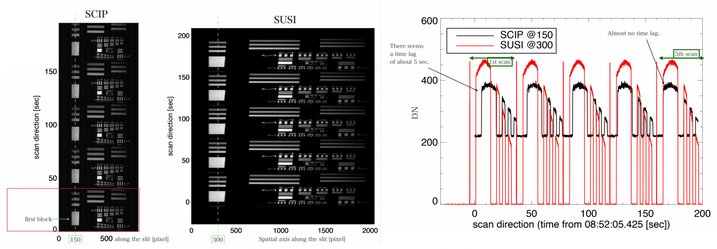
Image Compression



Efficiency at intensity for 3×10^{-4}
Stokes IQU :~9 bits/pix
Stokes VR: ~10 bits/pix

Synchronized Observations

Simultaneous scan with SCIP and SUSI during hang test



Scan speed for the flight observation was optimized based on the test.

Example of timeline table

TuMag	SUSI	SCIP	ICU	PS	CW		Start	End
Reset	Reset	Reset	Open	Pointing	Autolock	0:02:40	0:00:00	0:02:40
Setting	Wavelength (396.8 nm)	Camera setting	Open	Pointing	Autolock	0:00:10	0:02:40	0:02:50
Prefilter	Wavelength (396.8 nm)	preobs	Open	Pointing	Autolock	0:04:00	0:02:50	0:06:50
call_2	call_2	call_2	call_2	call_2	call_2	0:00:05	0:06:50	0:06:55
finepointing	finepointing	finepointing	finepointing	finepointing	finepointing	0:01:00	0:06:55	0:07:55
Idle	Idle	Camera setting	Open	Pointing	Autolock	0:00:05	0:07:55	0:08:00
QS1	QS1	QS1	Open	Pointing	Autolock	0:30:10	0:08:00	0:38:10
QS1	Idle	Camera setting	Open	Pointing	Autolock	0:00:05	0:38:10	0:38:15
QS2	QS2	QS2	Open	Pointing	Autolock	1:48:00	0:38:15	2:26:15
cals_1	cals_1	cals_1	cals_1	cals_1	cals_1	0:00:05	2:26:15	2:26:20
Idle	Wavelength (396.8 nm)	idle	Open	Pointing	Autolock	0:02:10	2:26:20	2:28:30
cals_1	cals_1	cals_1	cals_1	cals_1	cals_1	0:00:05	2:28:30	2:28:35
Idle	Idle	Camera setting	Open	Pointing	Autolock	0:00:05	2:28:35	2:28:40
QS4	QS4a	QS4	Open	Pointing	Autolock	1:00:10	2:28:40	3:28:50
QS4	Wavelength (409 nm)	QS4	Open	Pointing	Autolock	0:02:10	3:28:50	3:31:00
QS4	QS4b	QS4	Open	Pointing	Autolock	1:00:10	3:31:00	4:31:10
cals_1	cals_1	cals_1	cals_1	cals_1	cals_1	0:00:05	4:31:10	4:31:15
Idle	Idle	Camera setting	Open	Pointing	Autolock	0:00:05	4:31:15	4:31:20
QS8	QS8	QS8	Open	Pointing	Autolock	1:48:00	4:31:20	6:19:20
call_2	call_2	call_2	call_2	call_2	call_2	0:00:05	6:19:20	6:19:25

We developed timeline table to achieve synchronized observations of three scientific instruments, SCIP, SUSI, and TuMaG. Calibration measurements are also included to the timeline.

Summary

- The pre-flight activities were successfully done.
- The flight was terminated few hours after launch. Further investigation on the failure is on-going.
- The health assessment of the instruments is now going on.
- The Sunrise team is eager to try the re-flight and prepare for it.

Reference

Katsukawa et al. 2020, Proceedings of the SPIE, Volume 11447, id. 114470Y 10 pp.
Kubo et al. 2020, Proceedings of the SPIE, Volume 11447, id. 11447A3 14 pp.
Uraguchi et al. 2020, Proceedings of the SPIE, Volume 11447, id. 11447AB 16 pp.
Tsuzuki et al. 2020, Proceedings of the SPIE, Volume 11447, id. 11447AJ 16 pp.
Oba et al. 2022, Solar Physics, 297:114 (22p)
Kawabata et al., Submitted to Applied Optics