New and upcoming instruments for observing the chromo-sphere and corona from Earth

Jorrit Leenaarts - 2023-02-27 - Longyearbyen

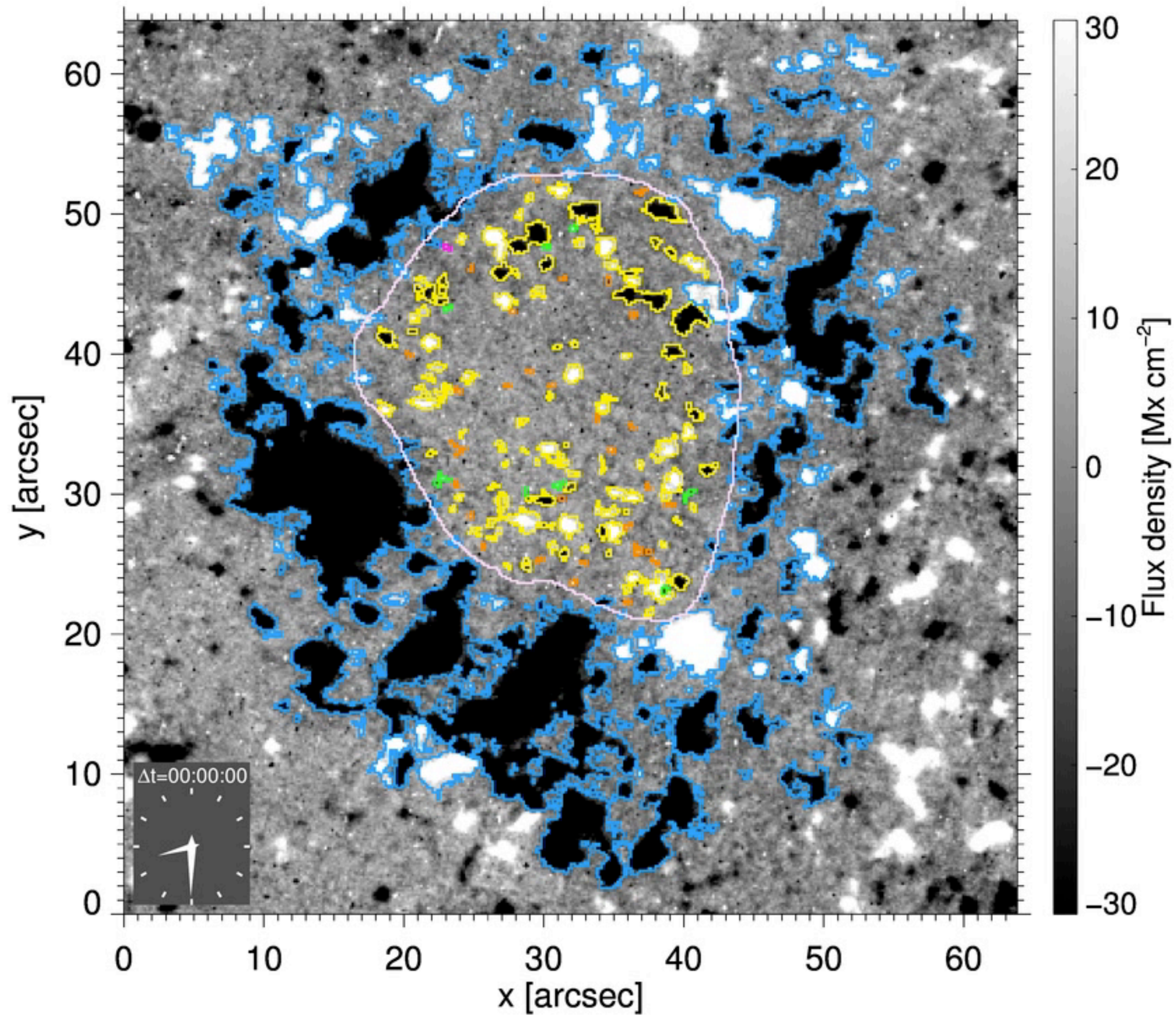

DKIST
GREGOR
EST
SST

Large parameter space

- $T \in (10^3\,\mathrm{K} - 10^7\,\mathrm{K})$
- $\Delta t \in (1\,\mathrm{s} - 1\ \mathrm{month})$
- $|\mathbf{B}| \in (10\,\mathrm{G} - 5000\,\mathrm{G})$
- $|\mathbf{v}| = (0\,\mathrm{km\,s^{-1}} - 300\,\mathrm{km\,s^{-1}})$

Long time series from space are great

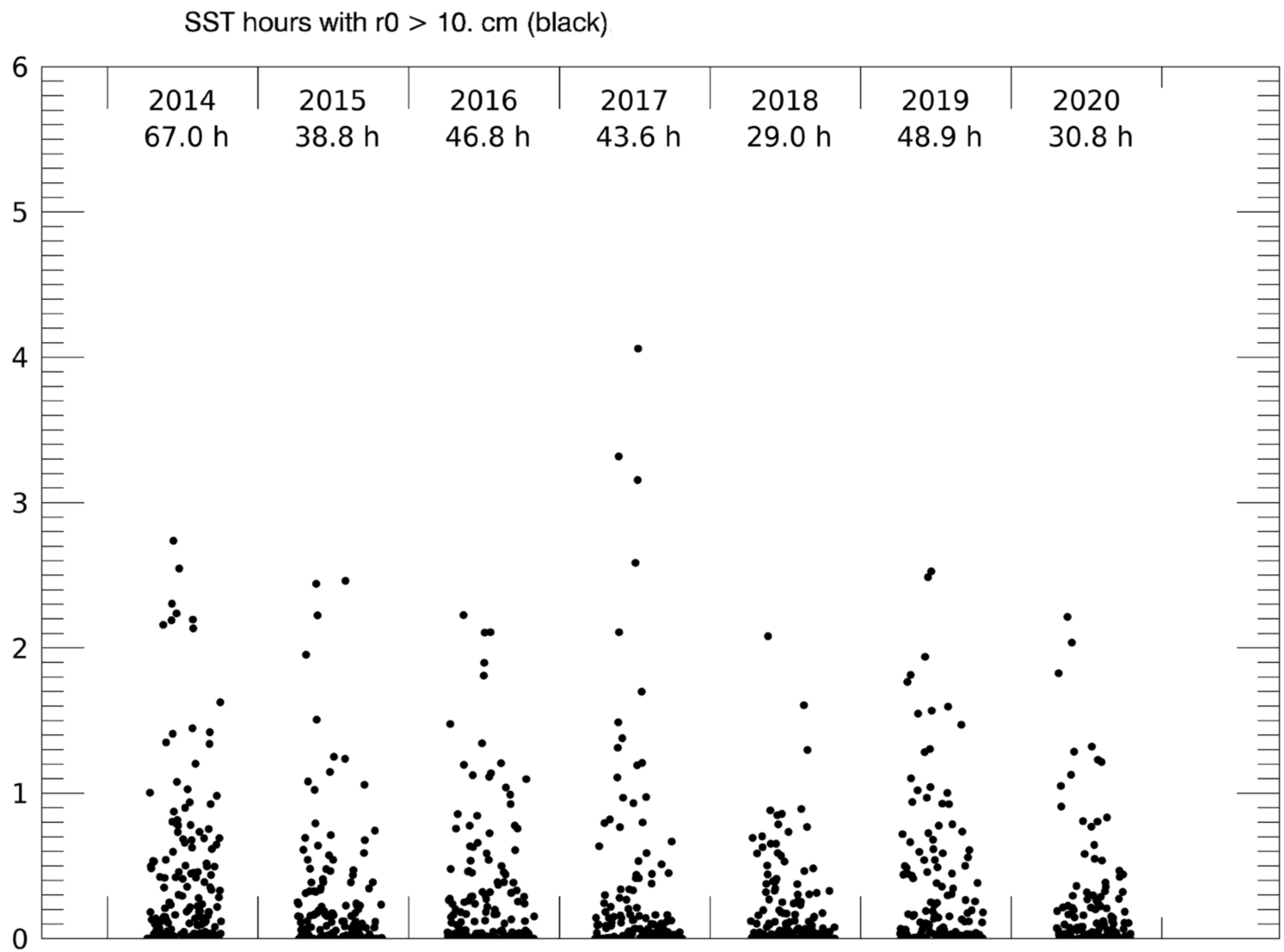
- hi-res optical from space expensive and unlikely…
- …but highly desirable: Hinode, SDO



Gošić et al., 2014

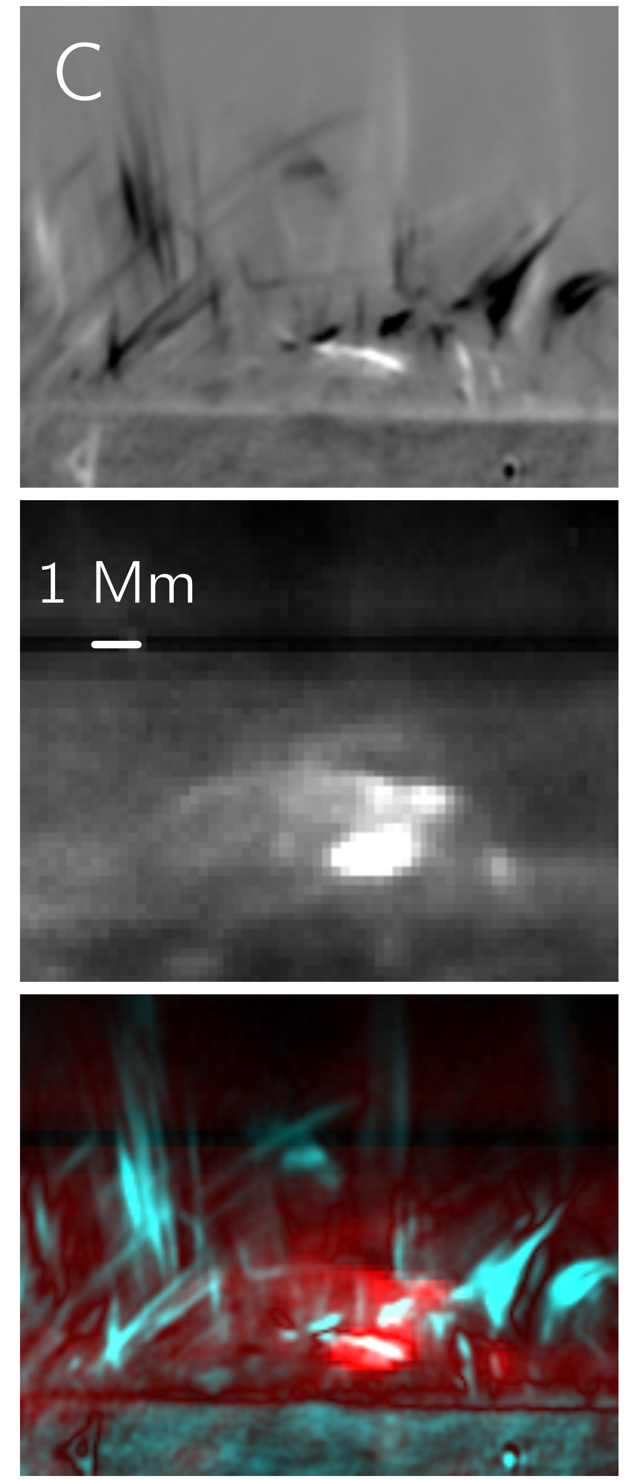
Situation on the ground less rosy

- good ground-based datasets rarely longer than 1 h.
- Multiple- day coordination with space MUSE, EUVST essential



Ground & space as complements

- space: UV, X-rays, ~0.5 arcsec, limited magnetic field measurements
- design ground based instruments to complement space



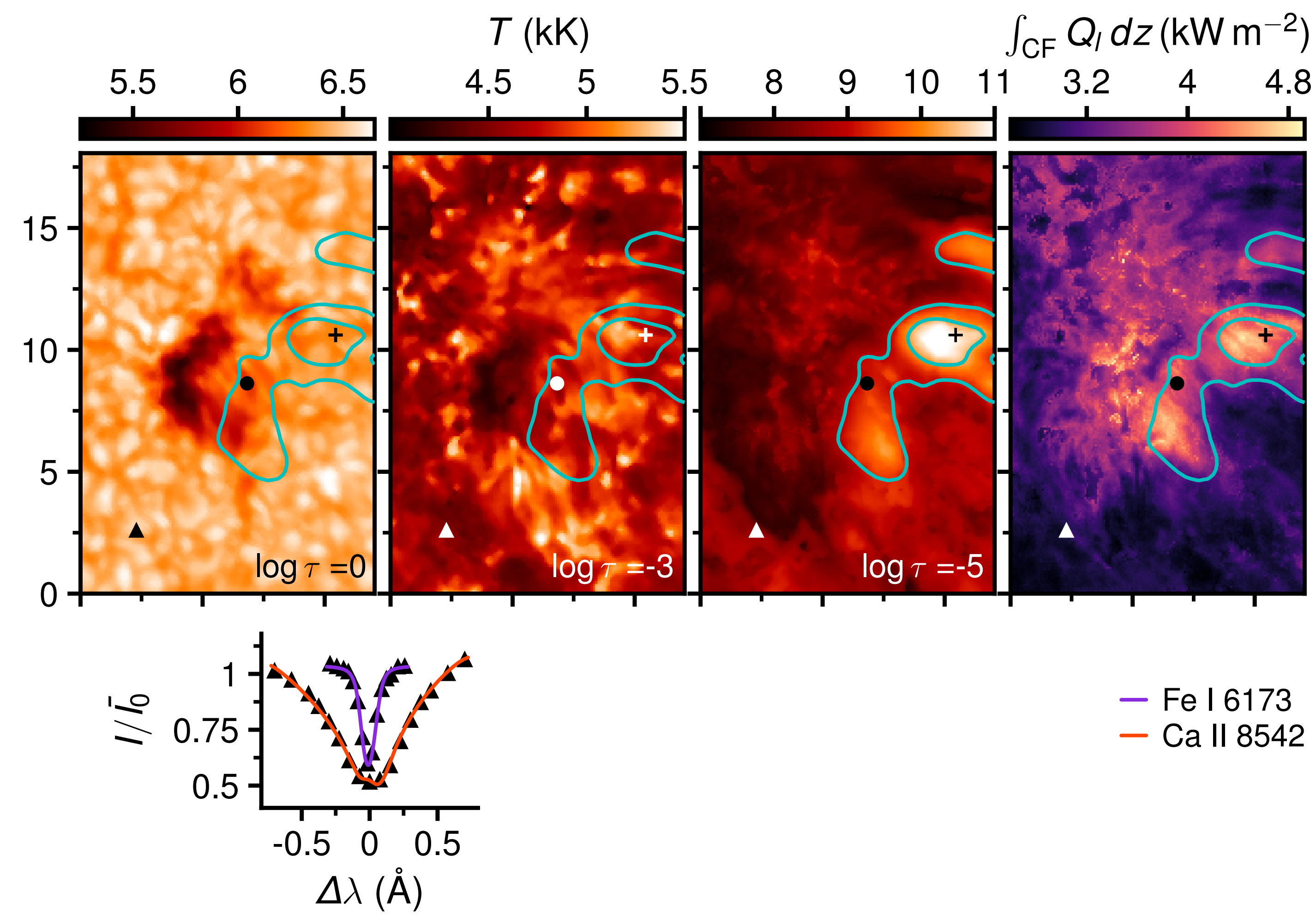
Hα

Si IV 140 nm

Pereira et al., 2018

Better physics through inversion

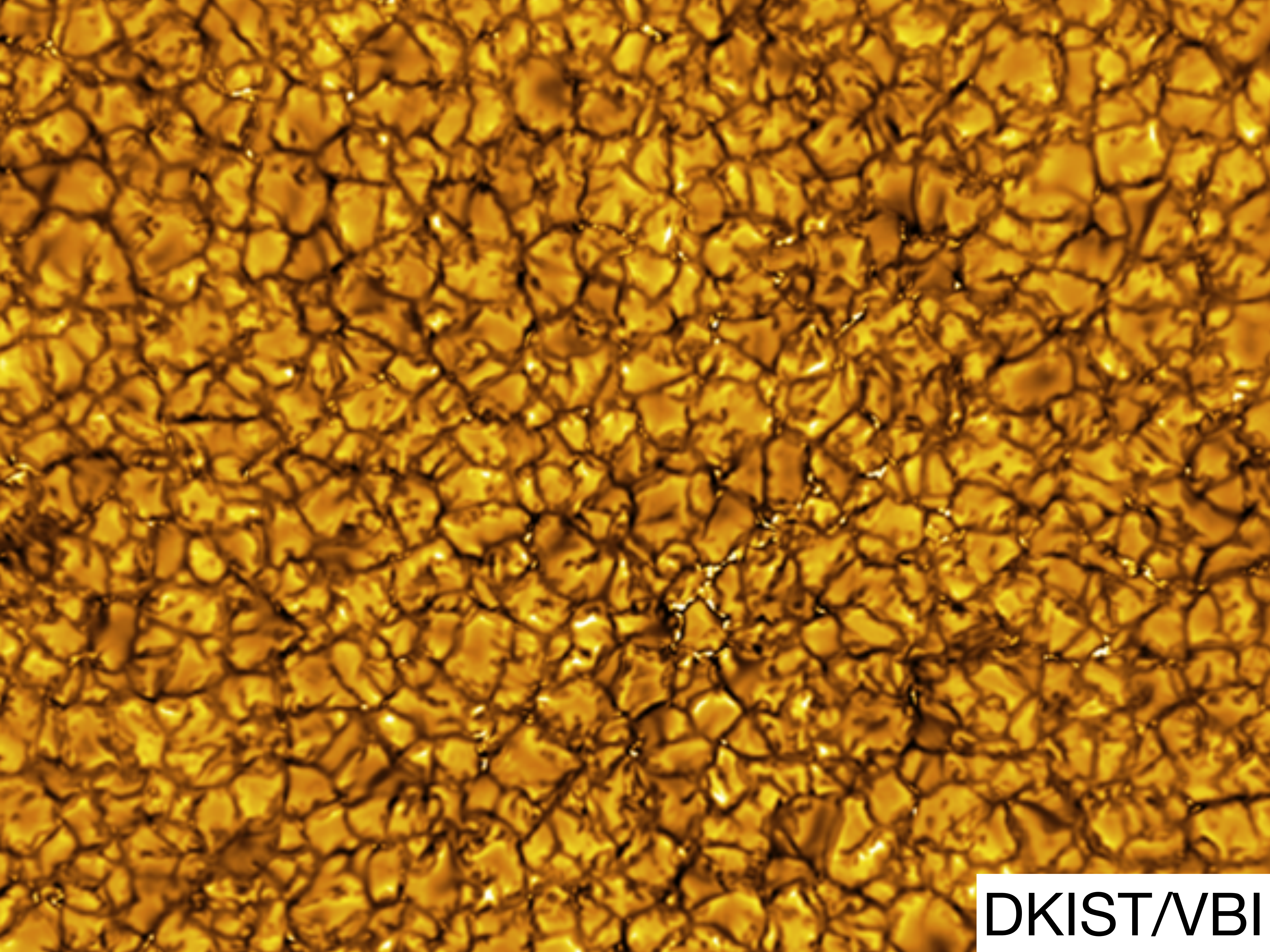
- non-LTE inversions will be most common tool
- spectropolarimetry is a must
- multiple lines and atoms desirable
- as time-coherent as possible
- Example: SST + ALMA*

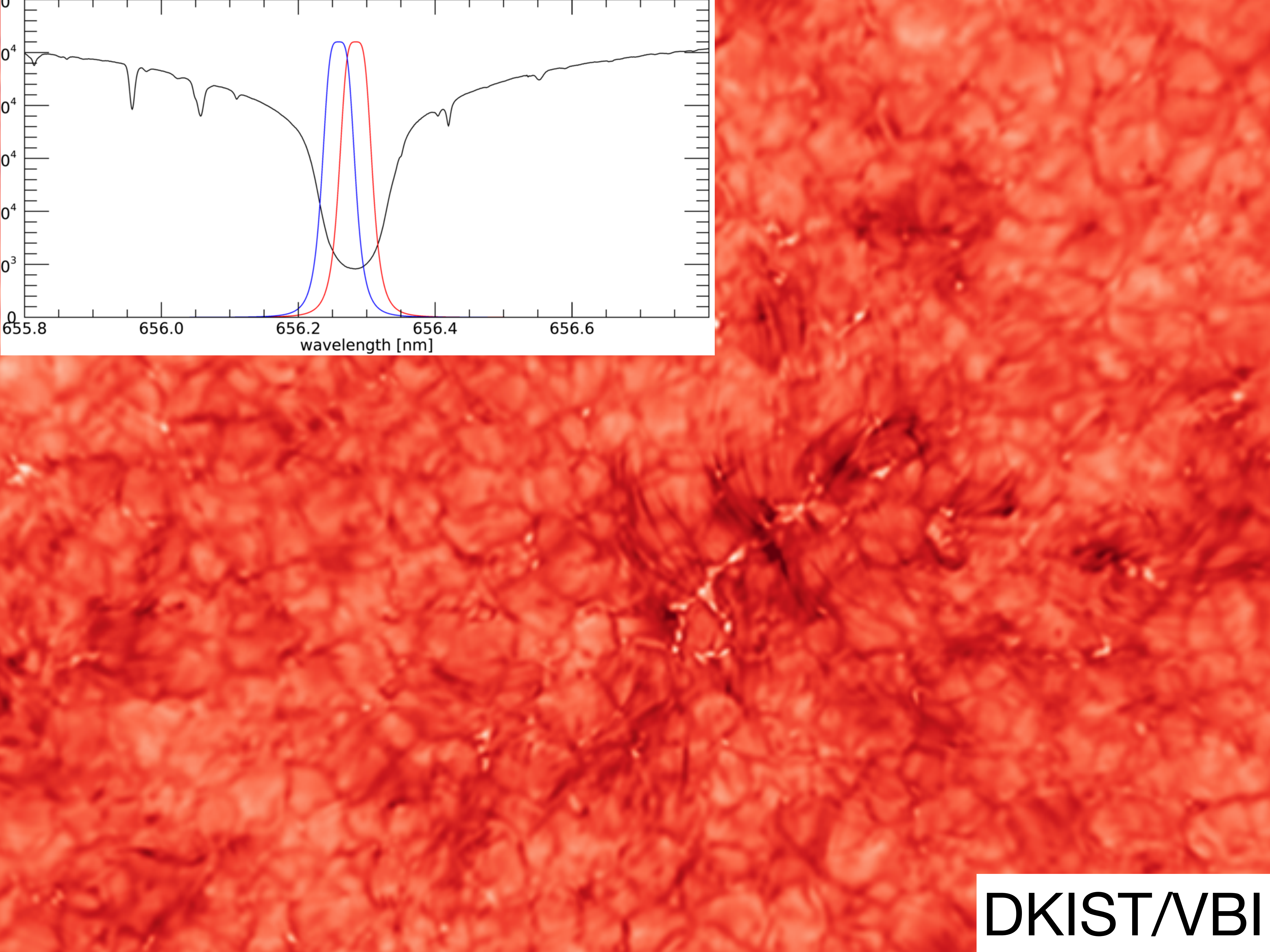


*ALMA is an interferometer

Da Silva Santos et al., 2022

	DKIST	GREGOR	GST	SST	EST
fixed-band imagers	VBI	BBI, HiFI+	BFI		
slit spectrographs	ViSP, CRYO-NIRSP	GRIS	FISS	TRIPPEL	
tunable narrowband imagers (Fabry-Perot)	VTF		VIS, NIRIS	CRISP, CHROMIS	3
integral field spectrographs	DL-NIRSP	GRIS		(MiHI), HeSP	4


DKIST/VBI


655.8
656.0
656.2
656.4
656.6
wavelength [nm]
DKIST/VBI

	DKIST	GREGOR	GST	SST	EST
fixed-band imagers	V[illegible]	[illegible]	[illegible]FI		
slit spectrographs	ViSP, CRYO-NIRSP	GRIS	FISS	TRIPPEL	
tunable narrowband imagers (Fabry-Perot)	VTF		VIS, NIRIS	CRISP, CHROMIS	3
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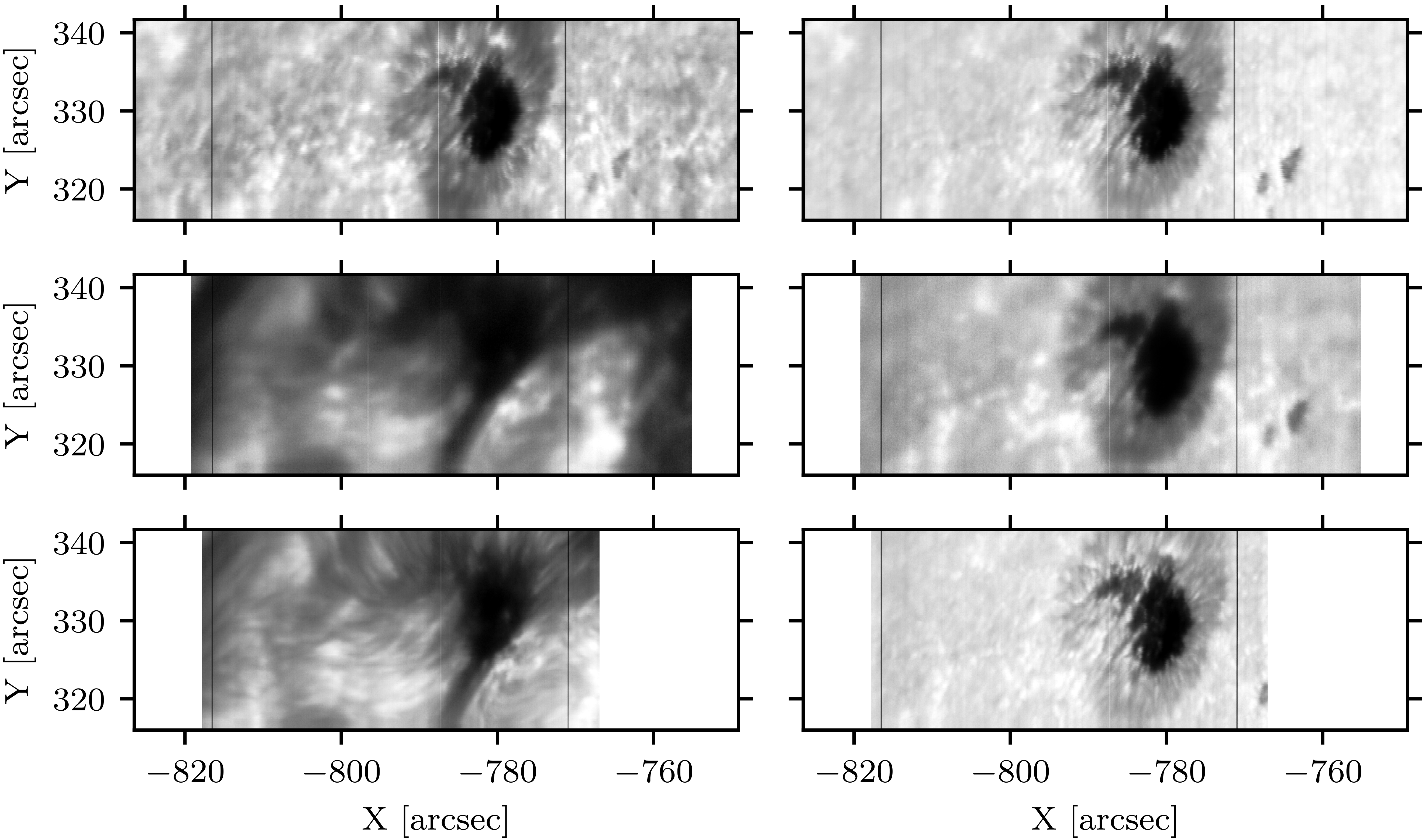
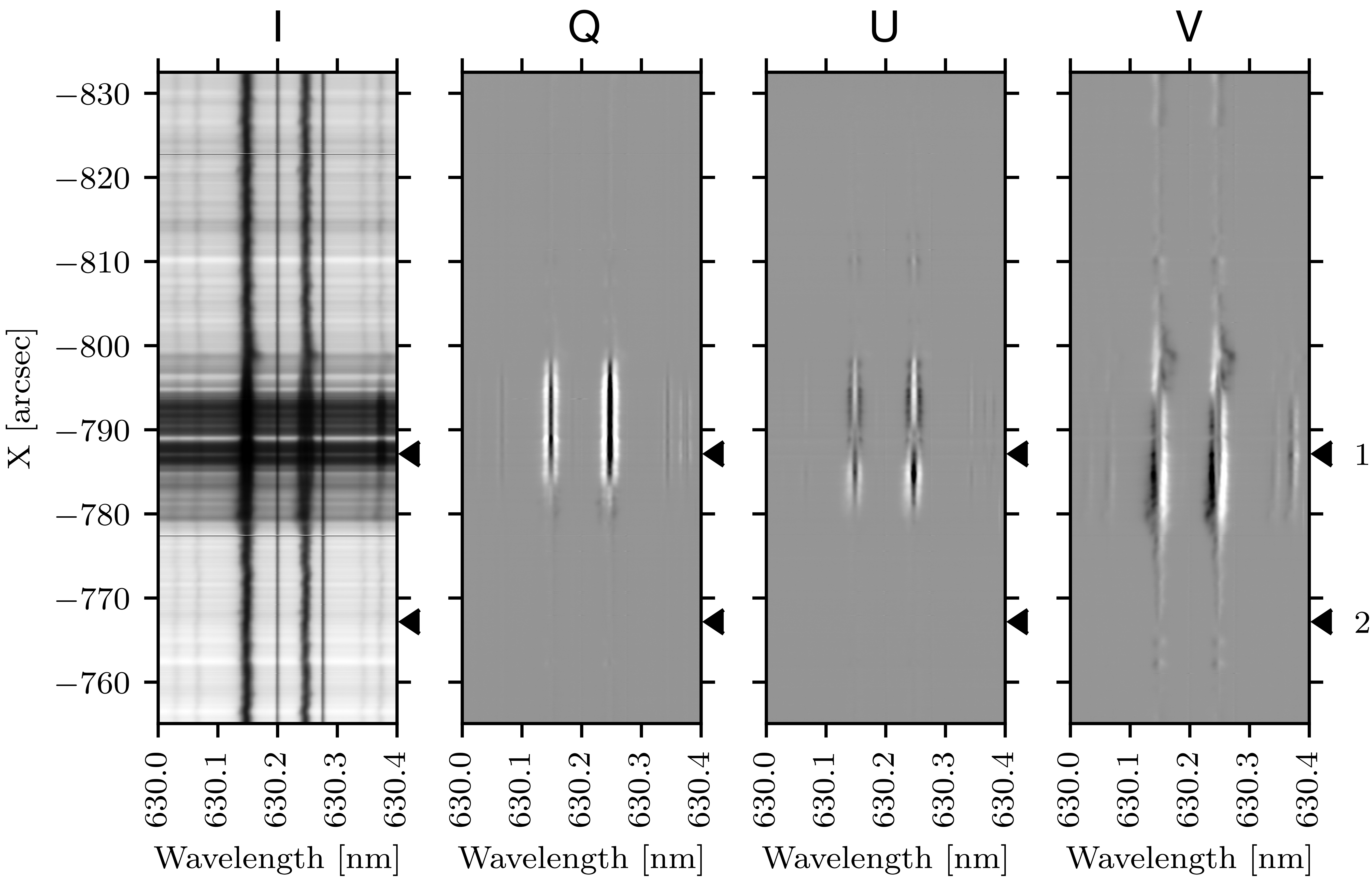
Useless

DKIST/ViSP



De Wijn et al., 2022

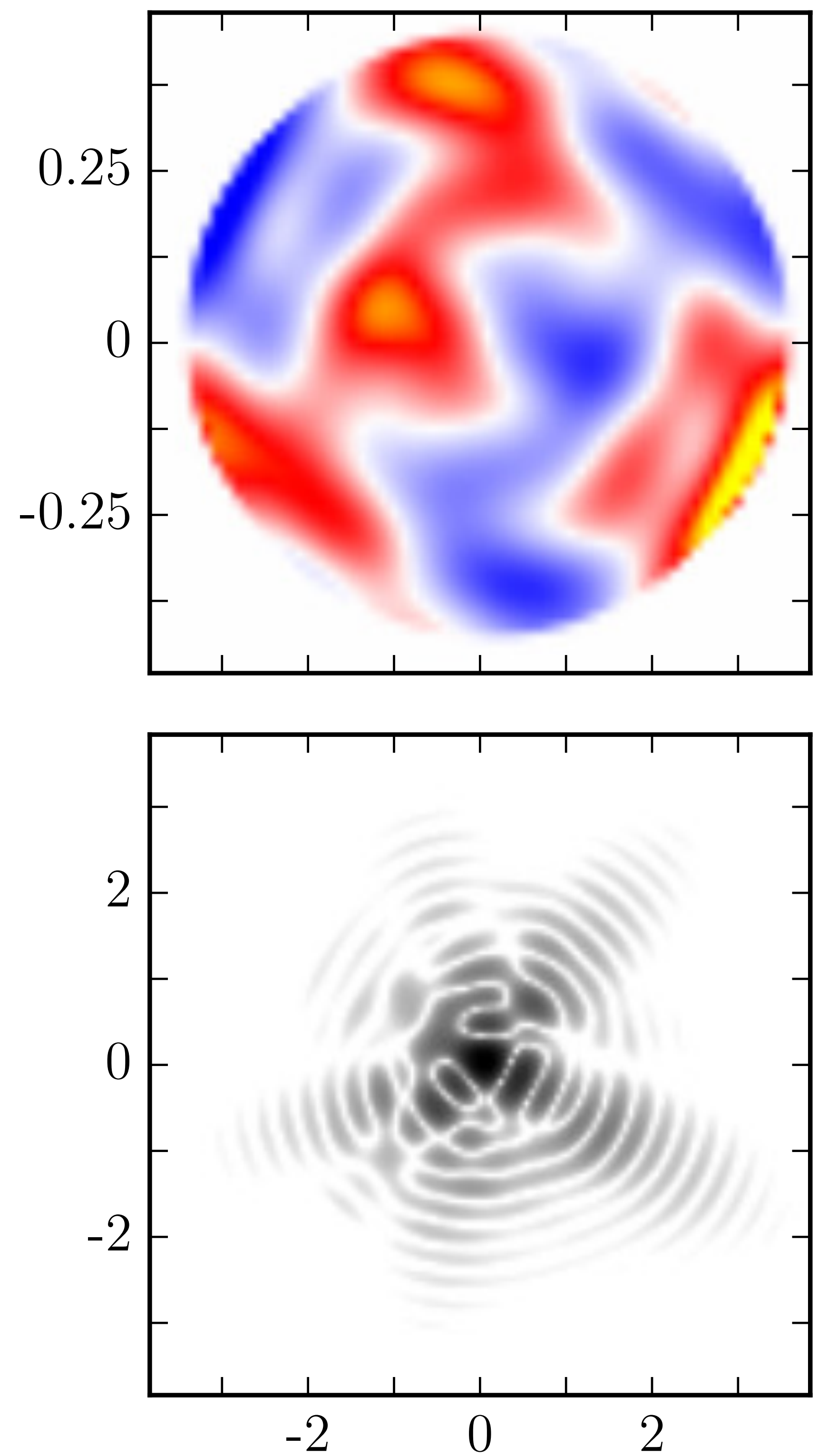
DKIST/ViSP



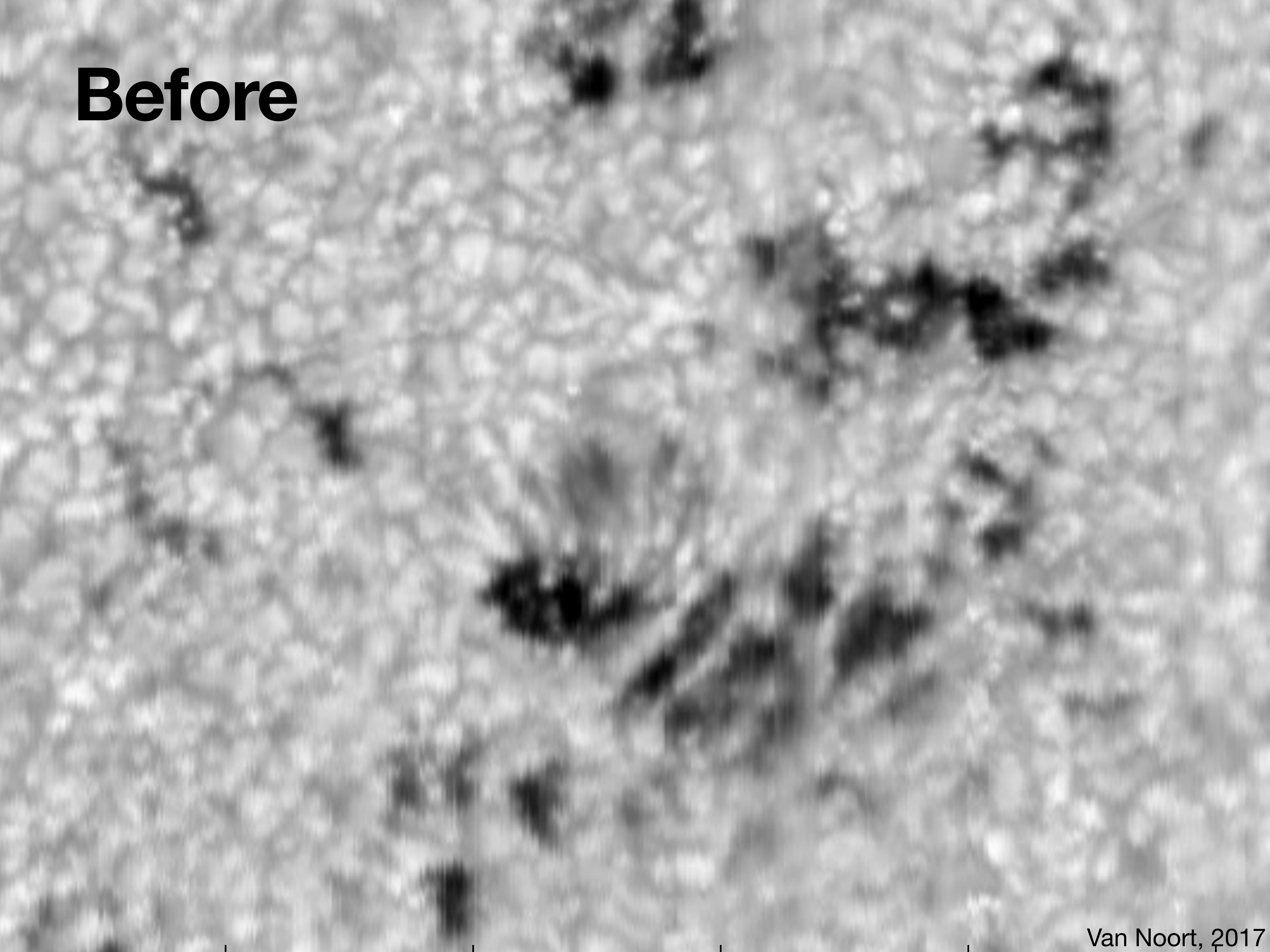
De Wijn et al., 2022

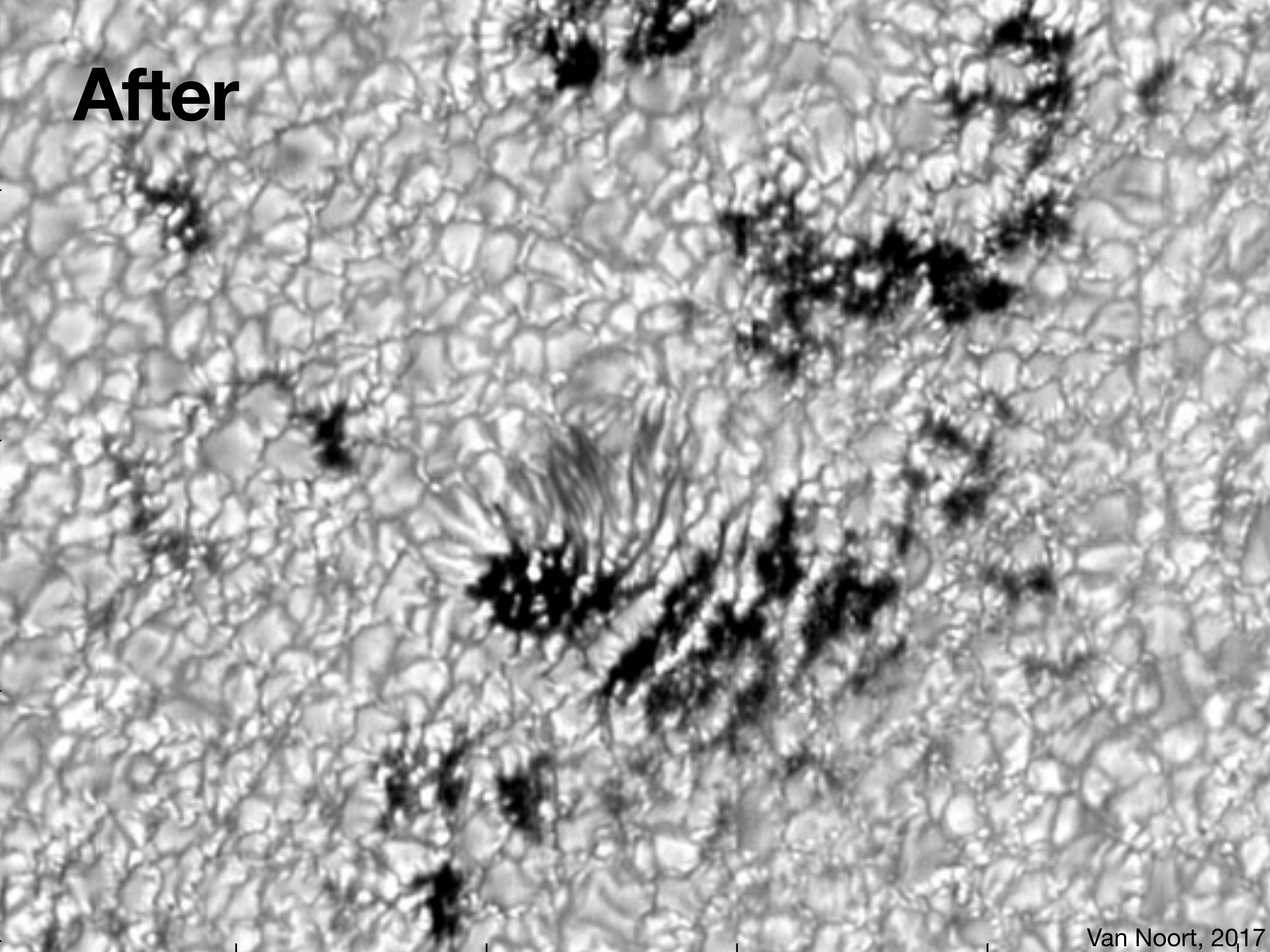
Image reconstruction of spectrograph data

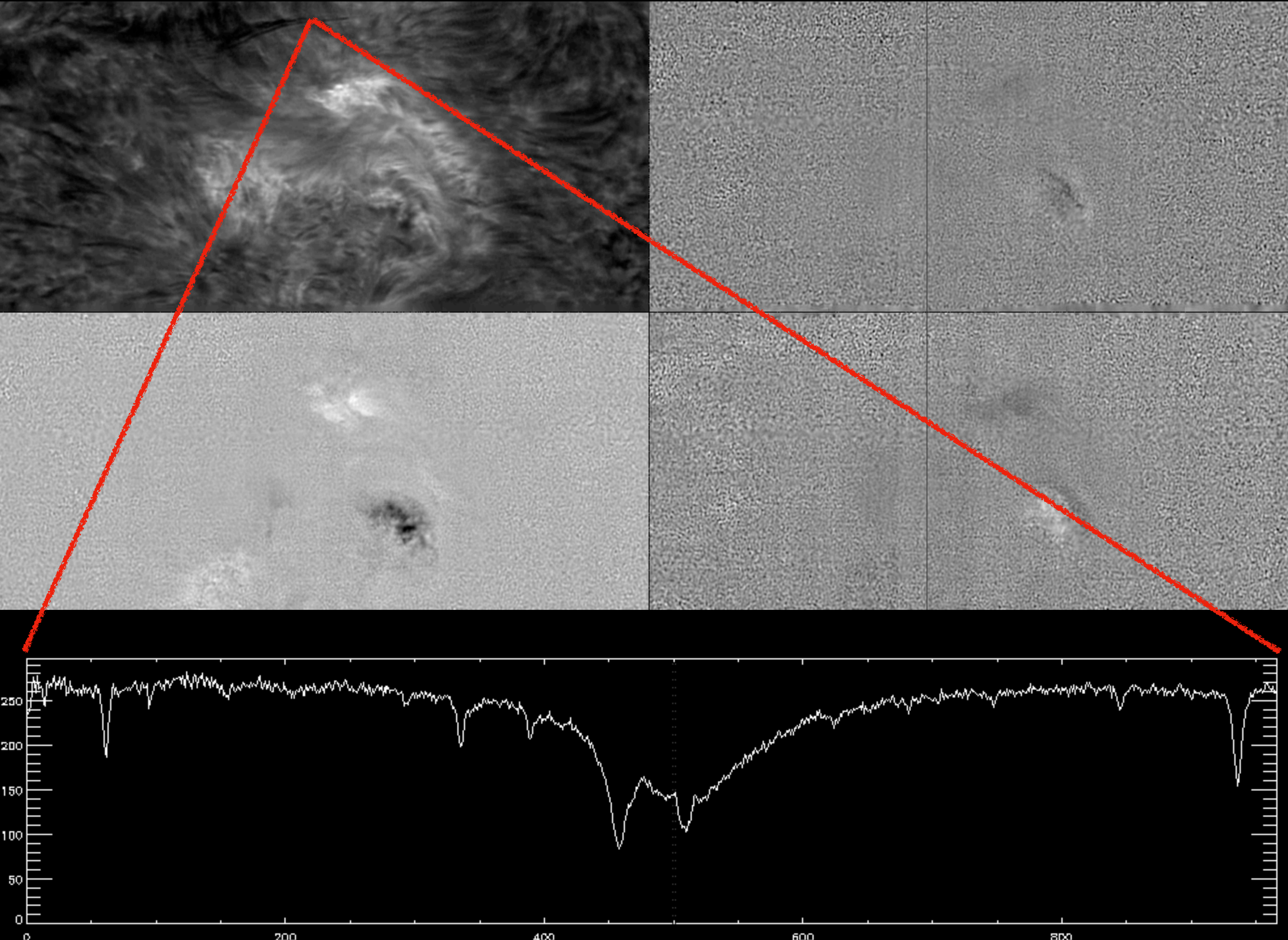
- Use slit-jaw images to estimate wavefront errors and apply MOMFBD



Van Noort, 2017


Before
Van Noort, 2017


After
Van Noort, 2017

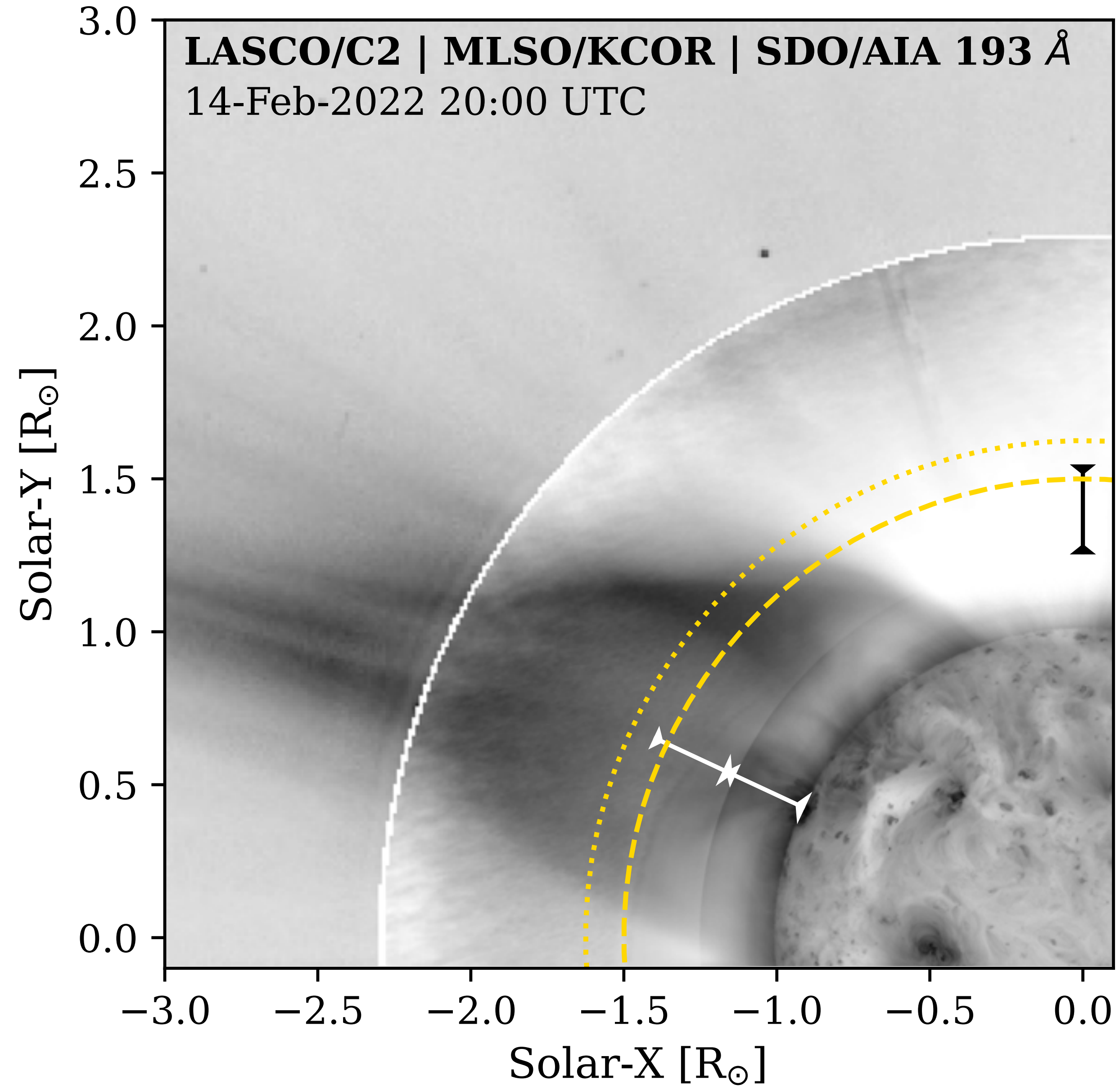


Van Noort, et al.

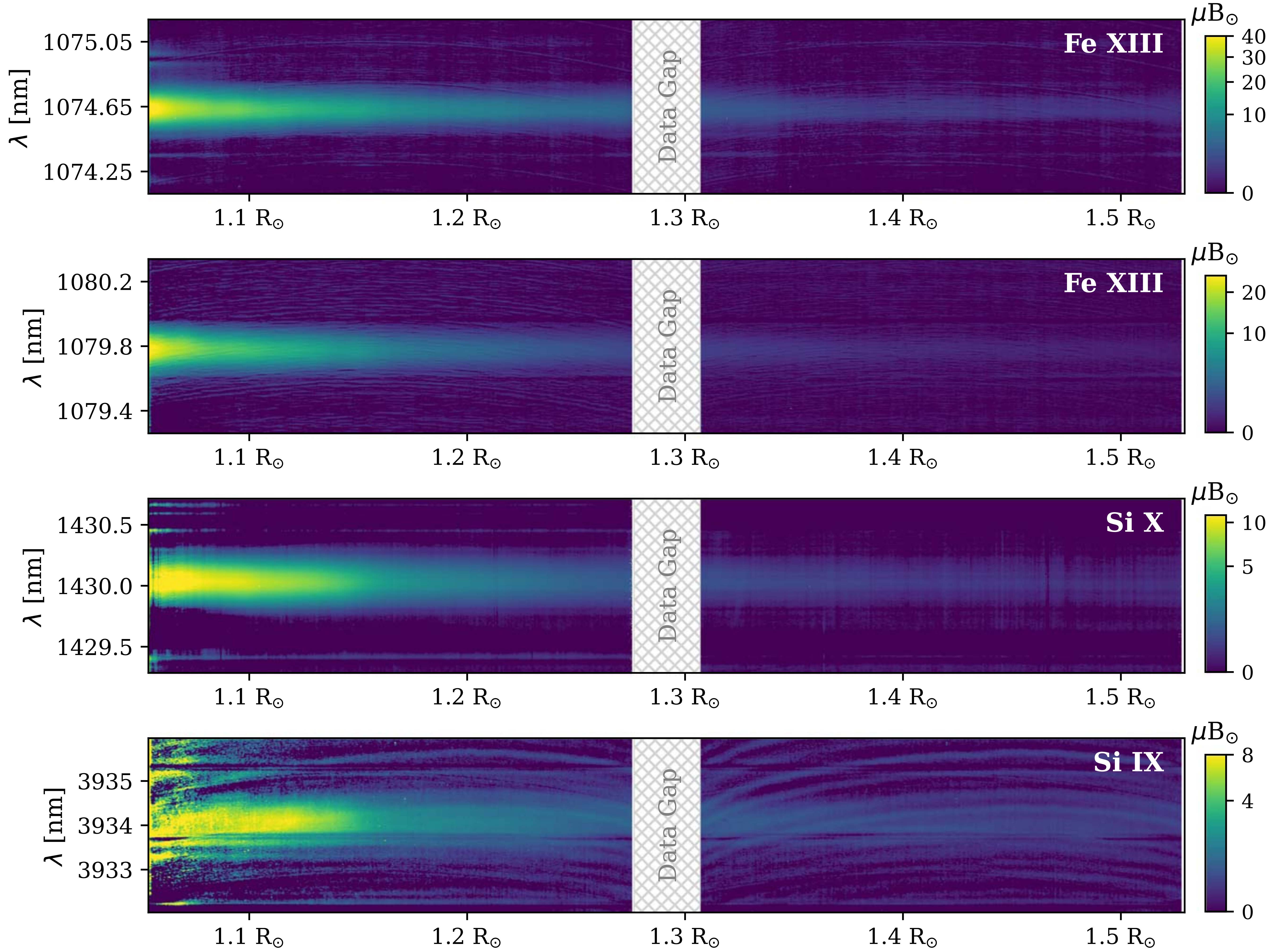
Spectra from the corona: DKIST/Cryo-NIRSP

Table 1
Targeted Coronal Forbidden Lines

Ion	λ_{air} (nm)	Transition($u \rightarrow \ell$)	log T_{eff}
Fe XIII	1074.6	$3s^2\ 3p^2\ {}^3P_{1\rightarrow 0}$	6.25
Fe XIII	1079.8	$3s^2\ 3p^2\ {}^3P_{2\rightarrow 1}$	6.25
Si X	1430.1	$2s^2\ 2p\ {}^2P_{3/2\rightarrow 1/2}$	6.15
Si IX	3934.3	$2s^2\ 2p^2\ {}^3P_{1\rightarrow 0}$	6.05



Schad et al., 2023



Fe XIII
1075.05
1074.65
1074.25
λ [nm]
μB⊙
40
30
20
10
0
Data Gap
1.1 R⊙
1.2 R⊙
1.3 R⊙
1.4 R⊙
1.5 R⊙
Fe XIII
1080.2
1079.8
1079.4
20
10
Si X
1430.5
1430.0
1429.5
5
Si IX
3935
3934
3933
8
4

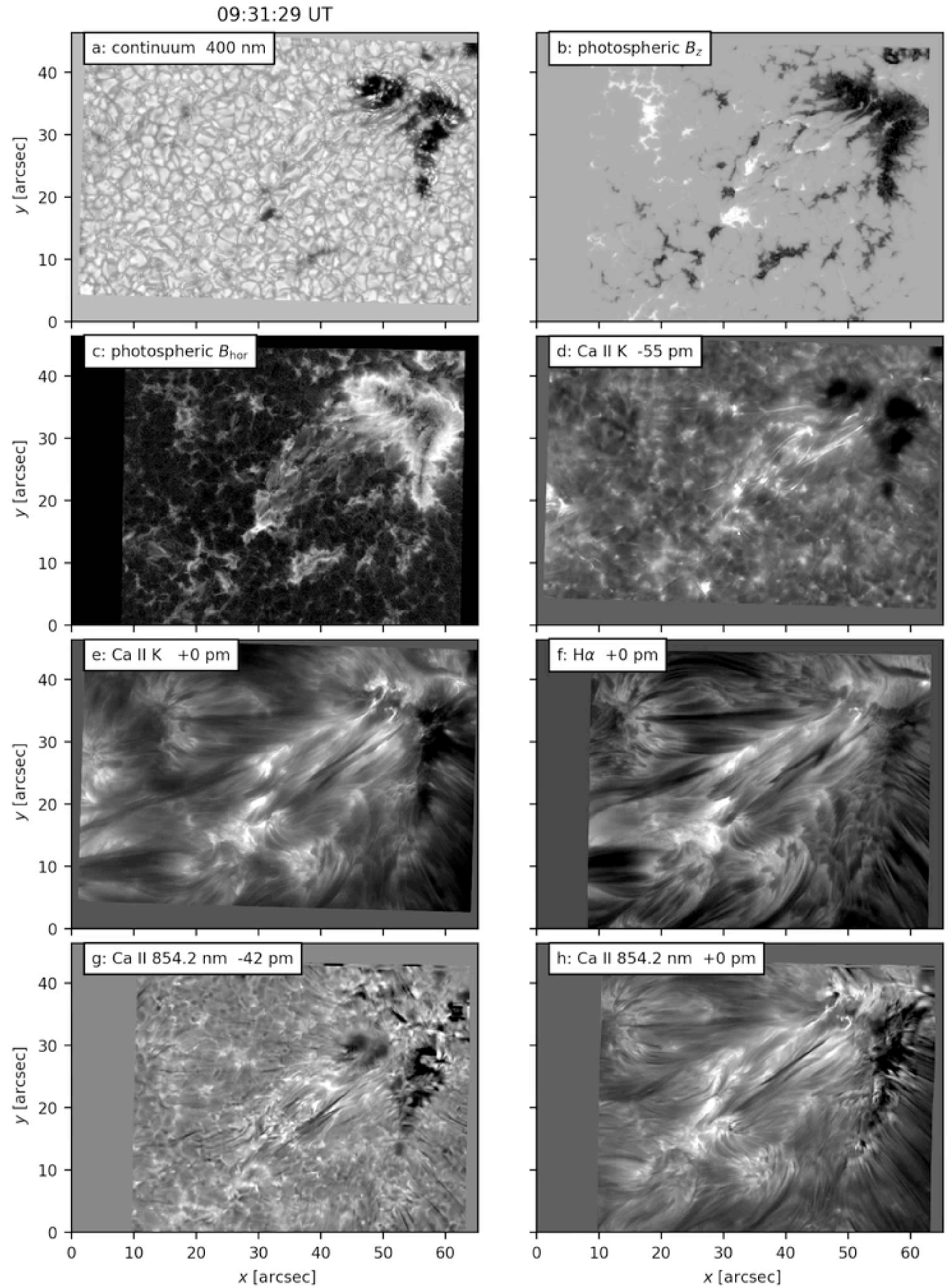
	DKIST	GREGOR	GST	SST	EST
fixed-band imagers	VE		FI		
slit spectrographs	V				
tunable narrowband imagers (Fabry-Perot)	VTF		VIS, NIRIS	CRISP, CHROMIS	3
integral field spectrographs	DL-NIRSP	GRIS		(MiHI), HeSP	4

Useless

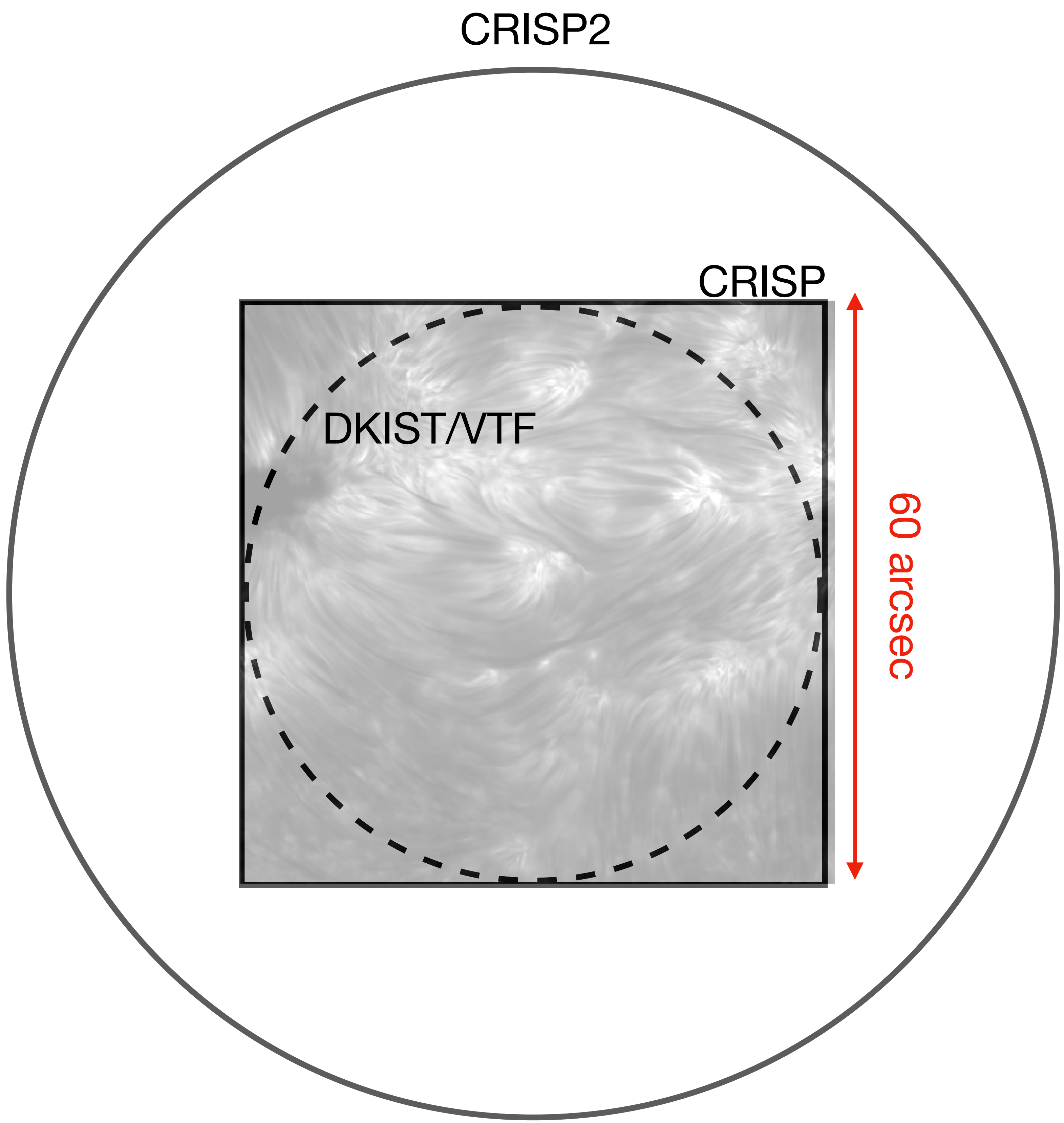
Needs image reconstruction

- R = ~50.000
- ~1 s per wavelength at SNR = 1000
- Narrow lines: 10 s per profile
- Wide lines: 30-100 s.
- FOV = ~50x50 arcsec
- Active region size: ~120 arcsec
- IRIS: 175 arcsec slit
- MUSE: 170x170 arcsec fast raster

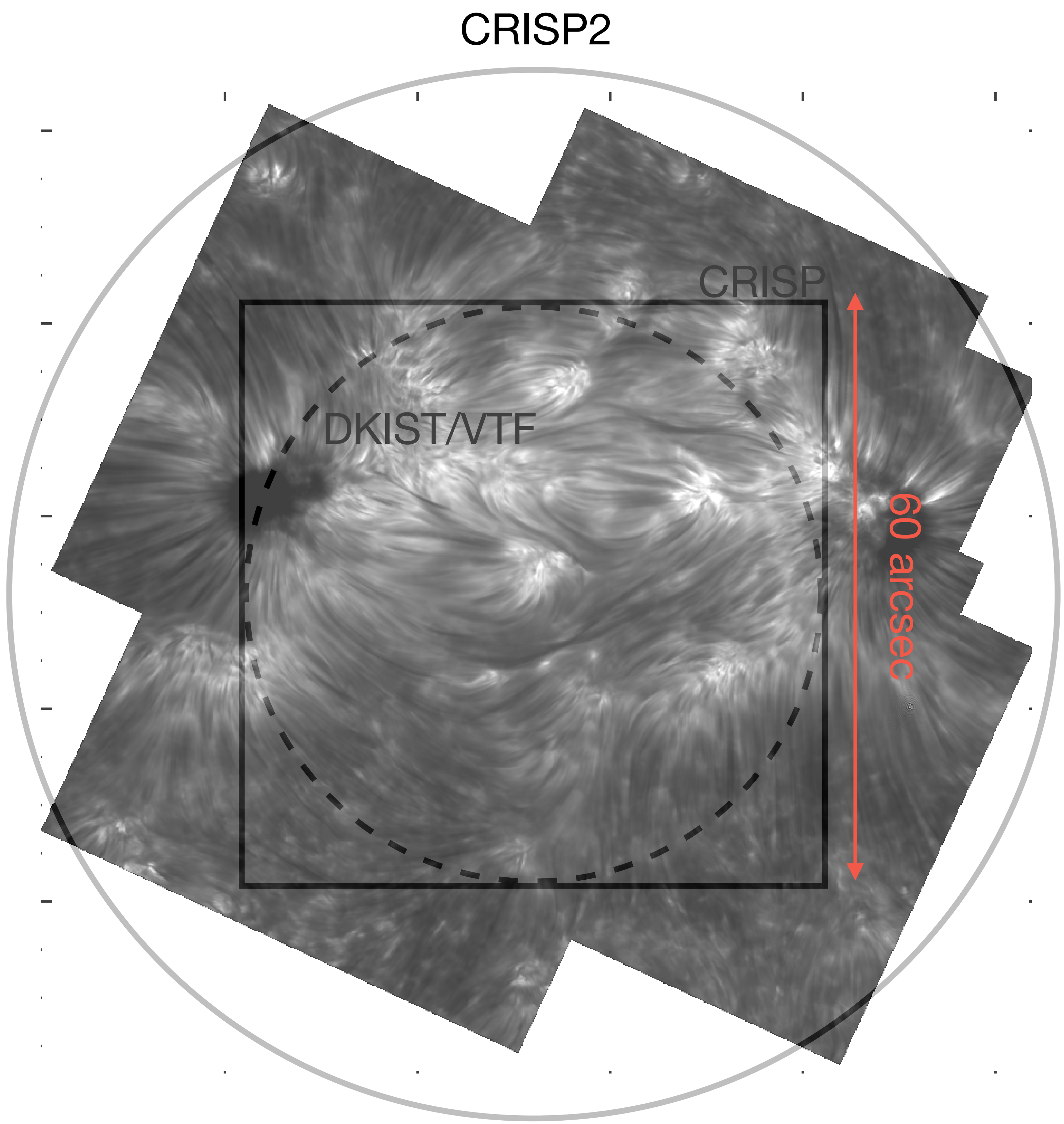
➡ Larger FOV from ground desirable



SST/CRISP

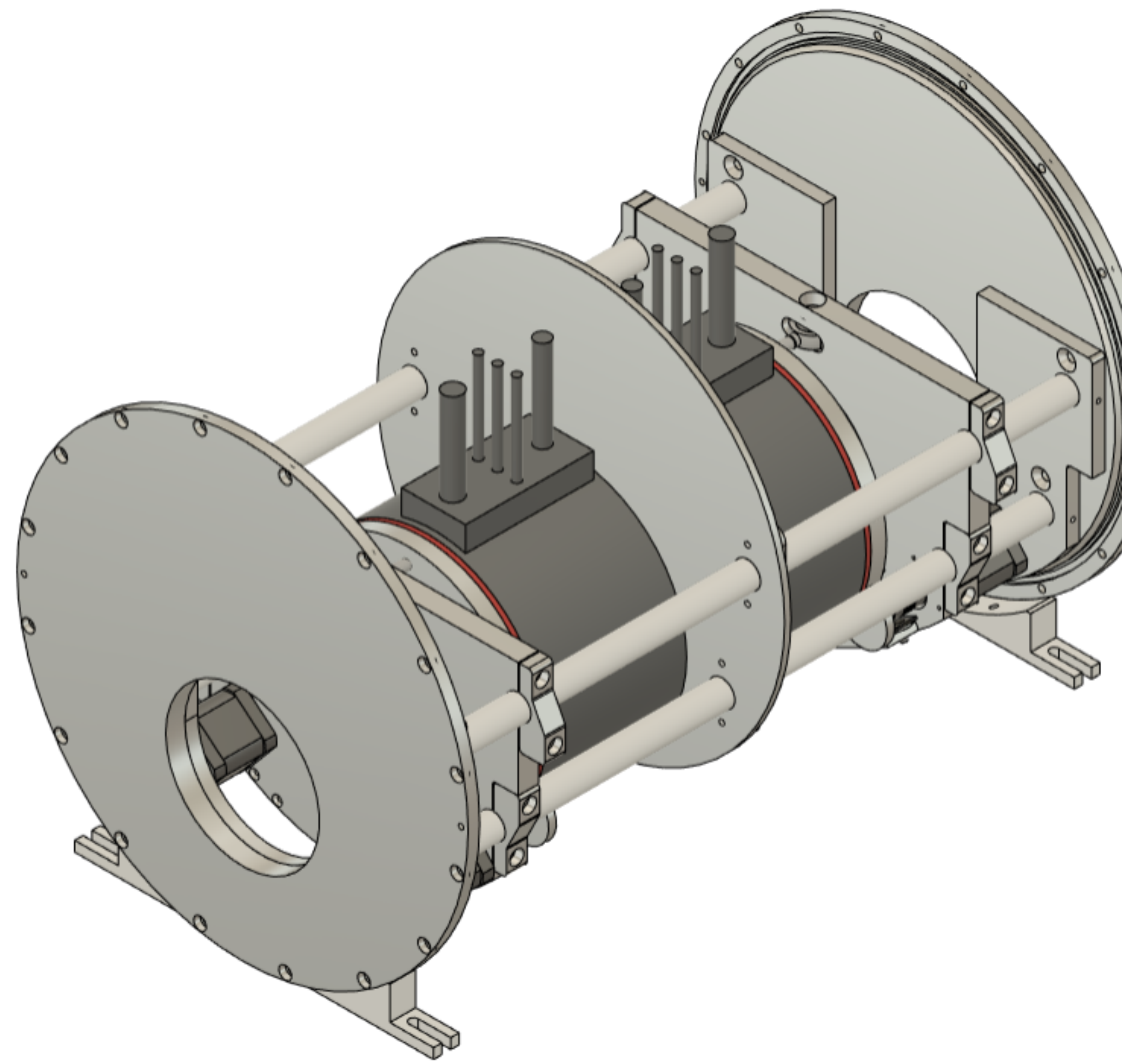


SST/CRISP2

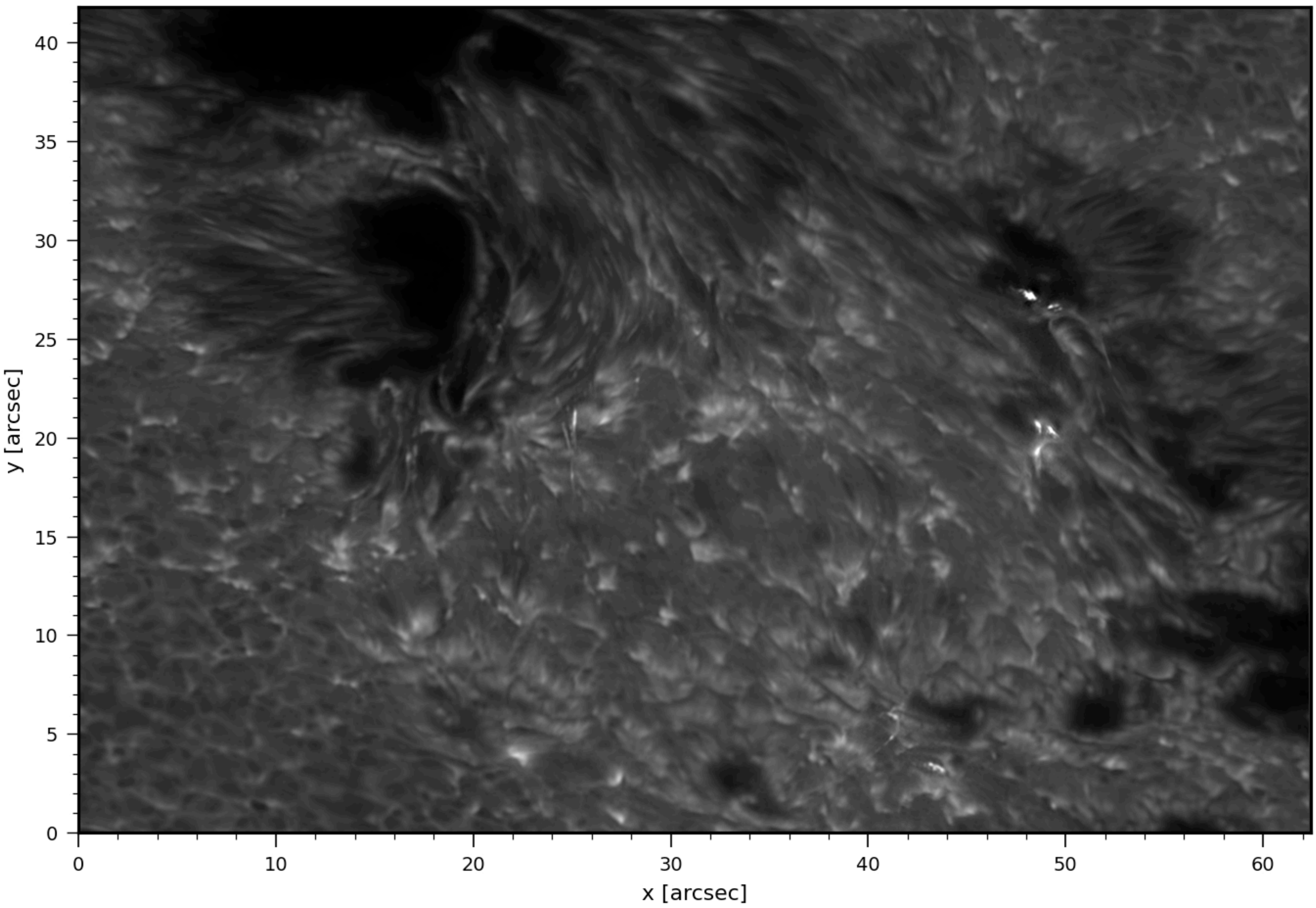


SST/CRISP2

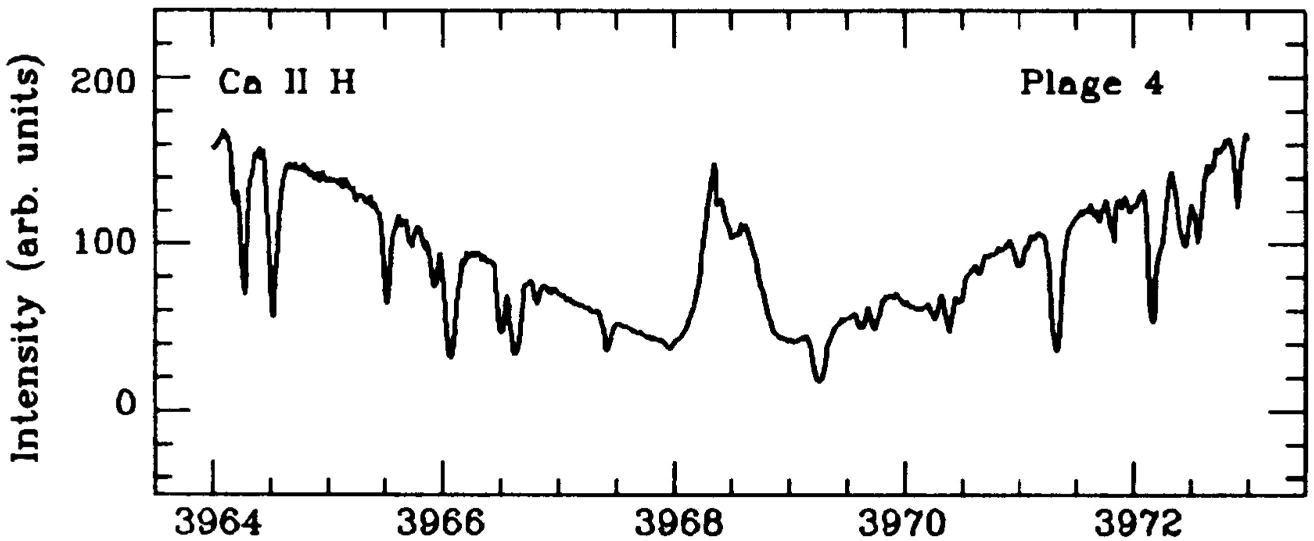
- 120 arcsec circular FOV
- 500 nm -900 nm
- Start operations mid 2024

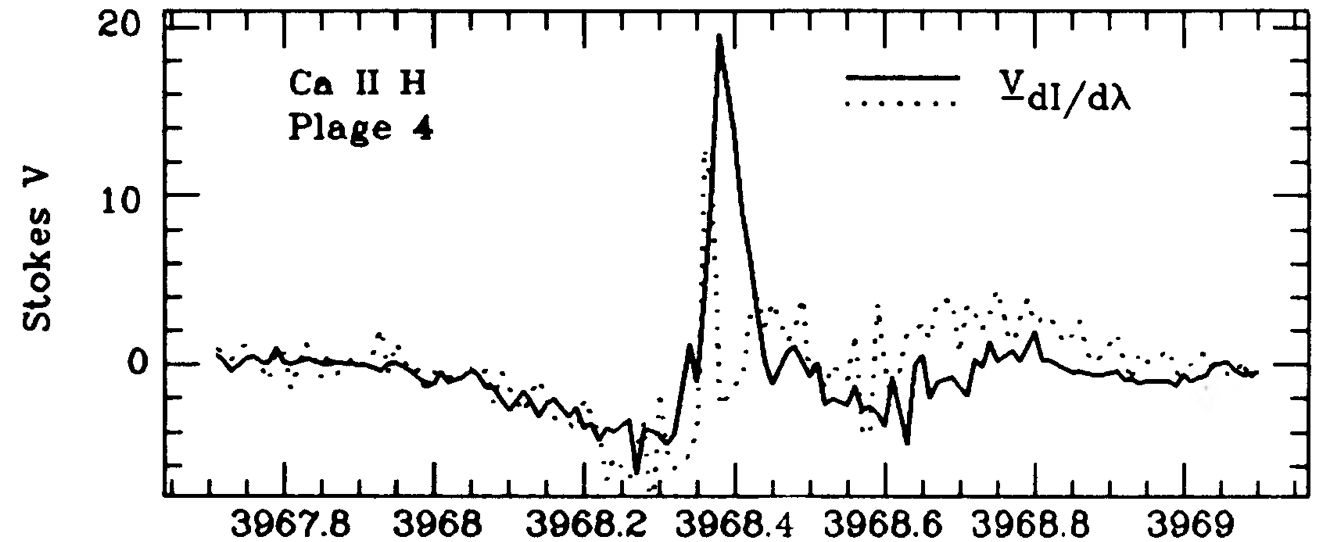


SST/CHROMIS



SST/CHROMIS

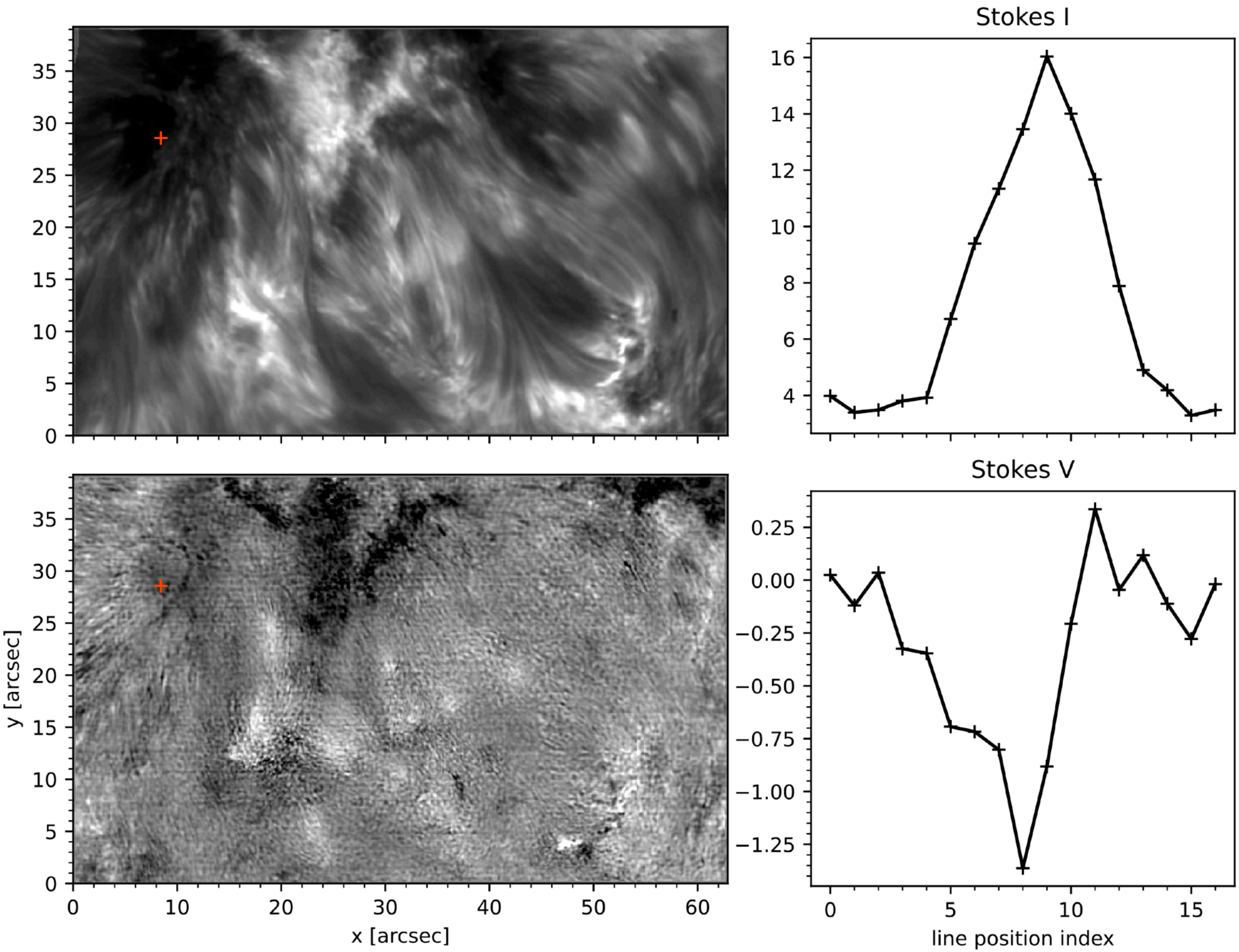




- 390 nm - 500 nm
- Polarimetry in Ca II H&K highly desirable
- FOV matching CRISP2 highly desirable

Martinez Pillet et al., 1990

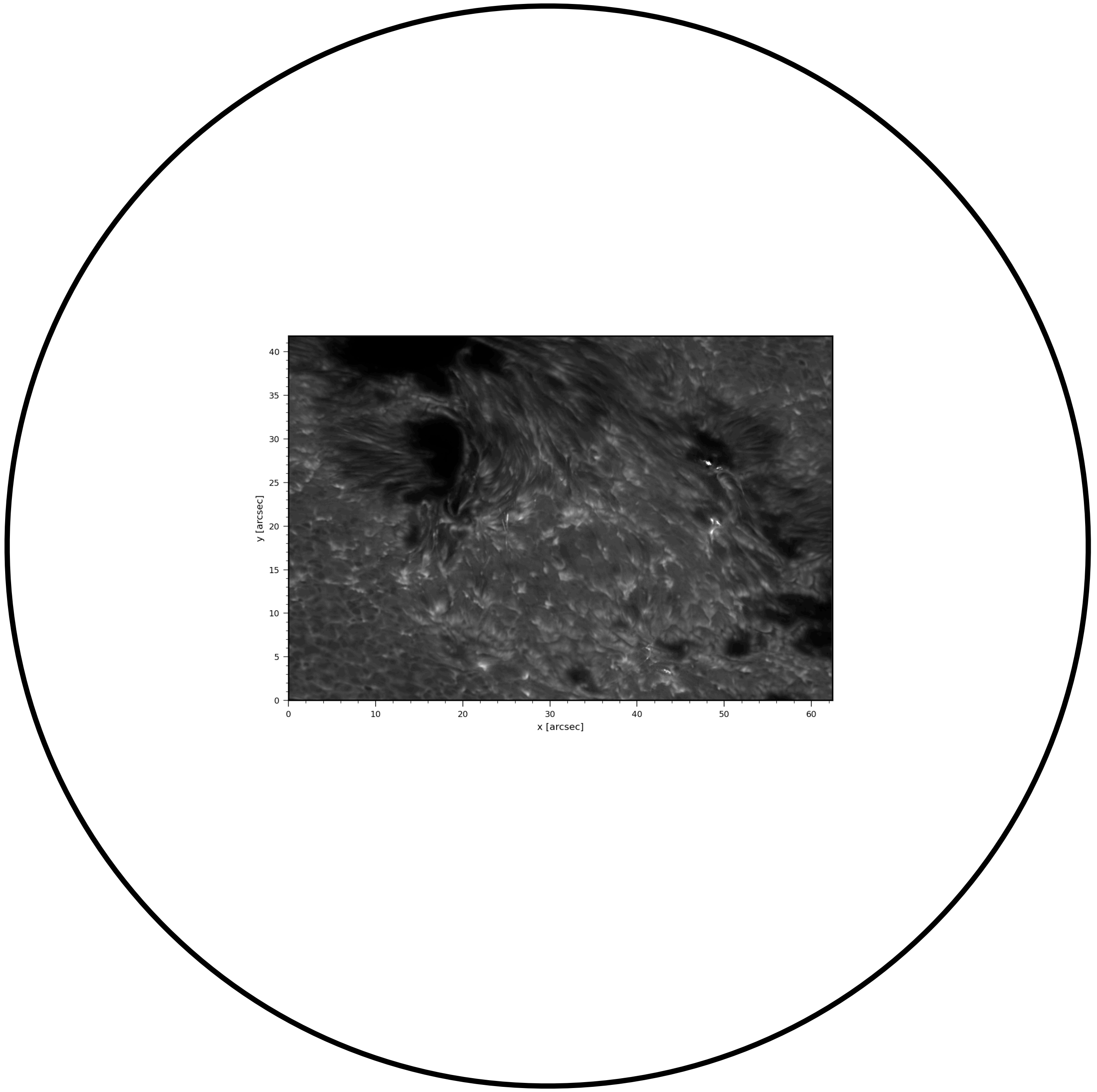
SST/CHROMIS++



Stokes I
Stokes V
y [arcsec]
x [arcsec]
line position index
0
5
10
15
20
25
30
35
40
50
60
2
4
6
8
12
14
16
0.25
0.00
−0.25
−0.50
−0.75
−1.00
−1.25

SST/CHROMIS++

- CHROMIS allows 120 arcsec circular FOV
- procure 4.5k x 4.5k cameras
  - 4.7 times larger FOV
- Add polarimetric modulator designed by De Wijn at HAO for permanent polarimetry
- Start operations mid 2024



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slit spectrographs	V				
tunable narrowband imagers (Fabry-Perot)					3
integral field spectrographs	DL-NIRSP	GRIS		(MiHI), HeSP	4

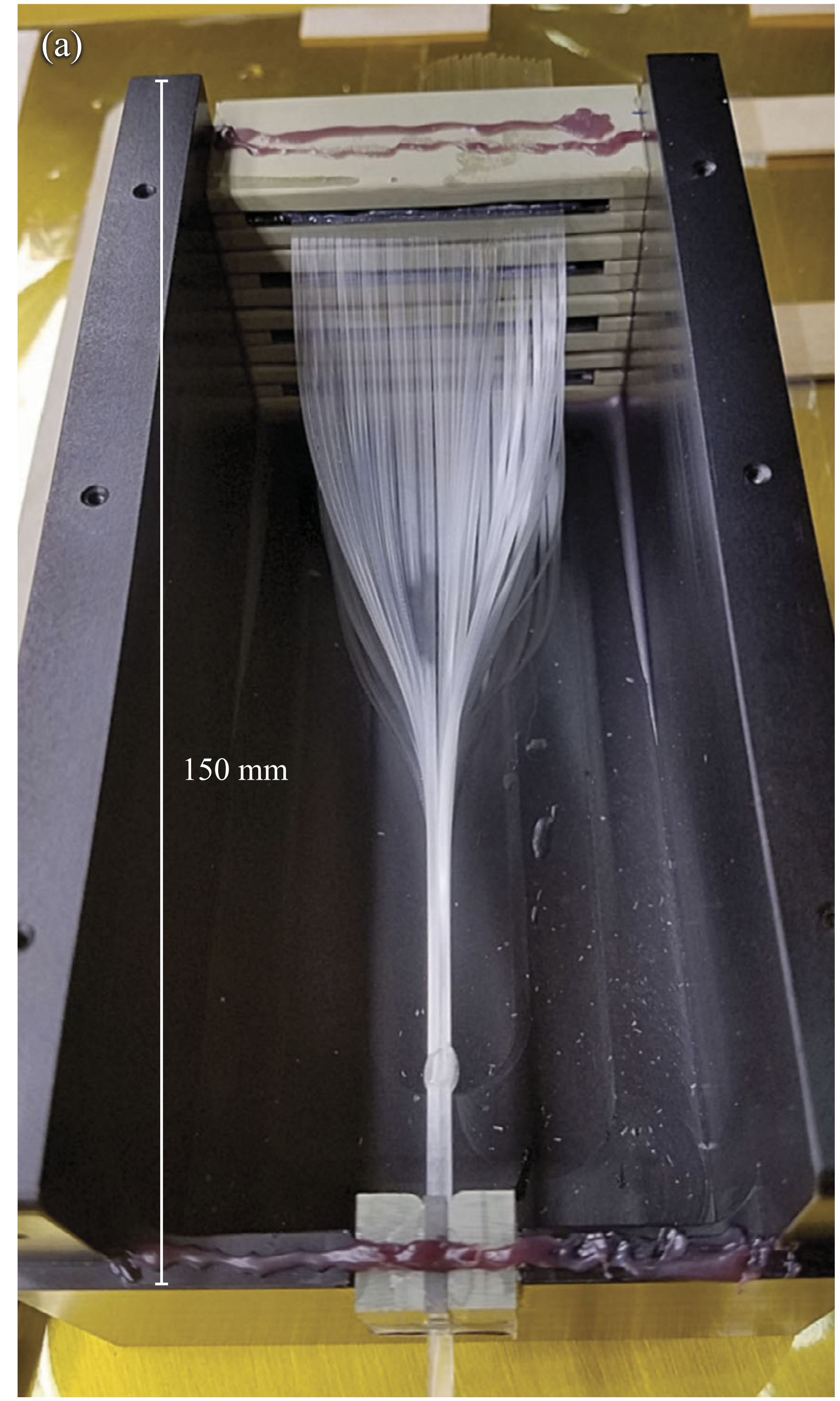
Useless

Needs image reconstruction

Needs larger FOV

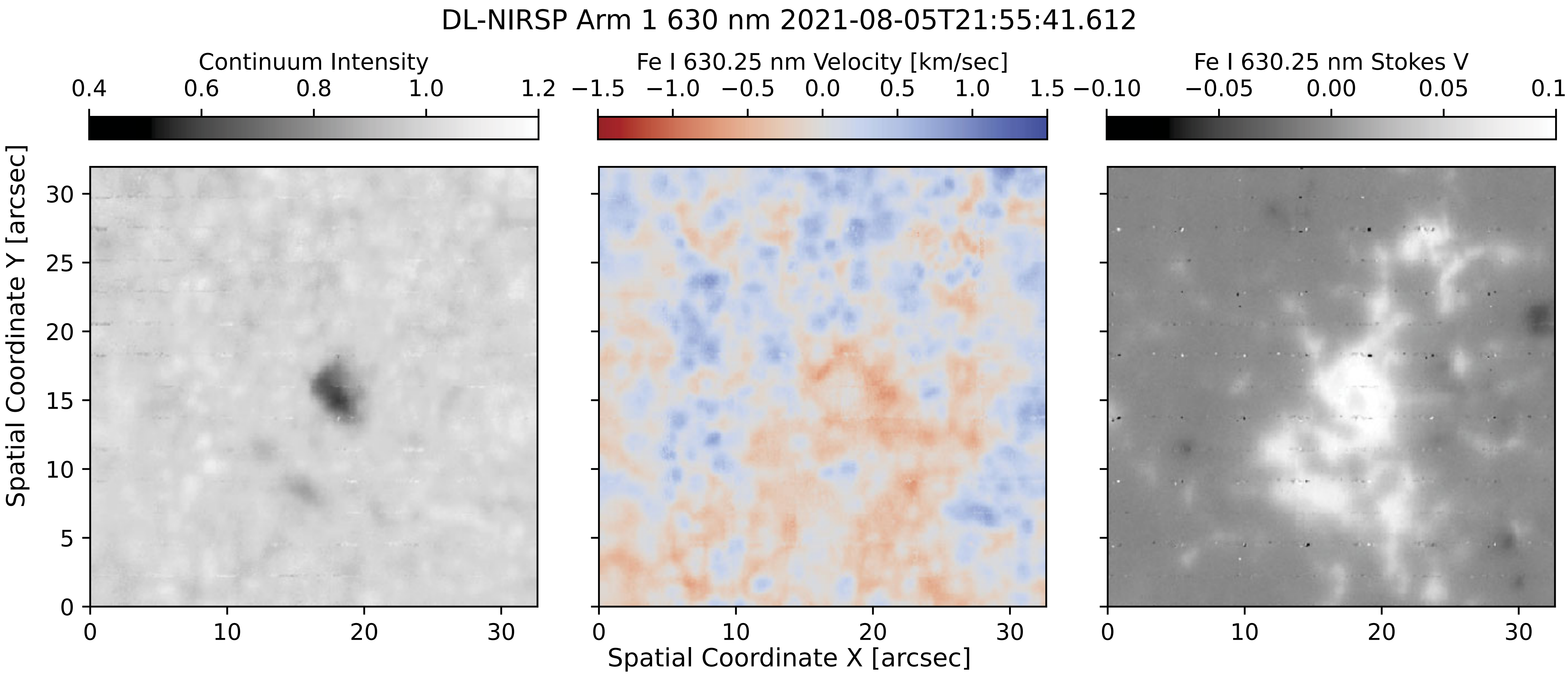
Integral field spectrographs

- Small FOV (~5x5 arcsec), **but 2D unlike slit spectrographs!**
- Time coherent
- Large spectral range
- Complicated to build, calibrate and operate



DKIST/DLNIRSP
Jaeggli et al., 2023

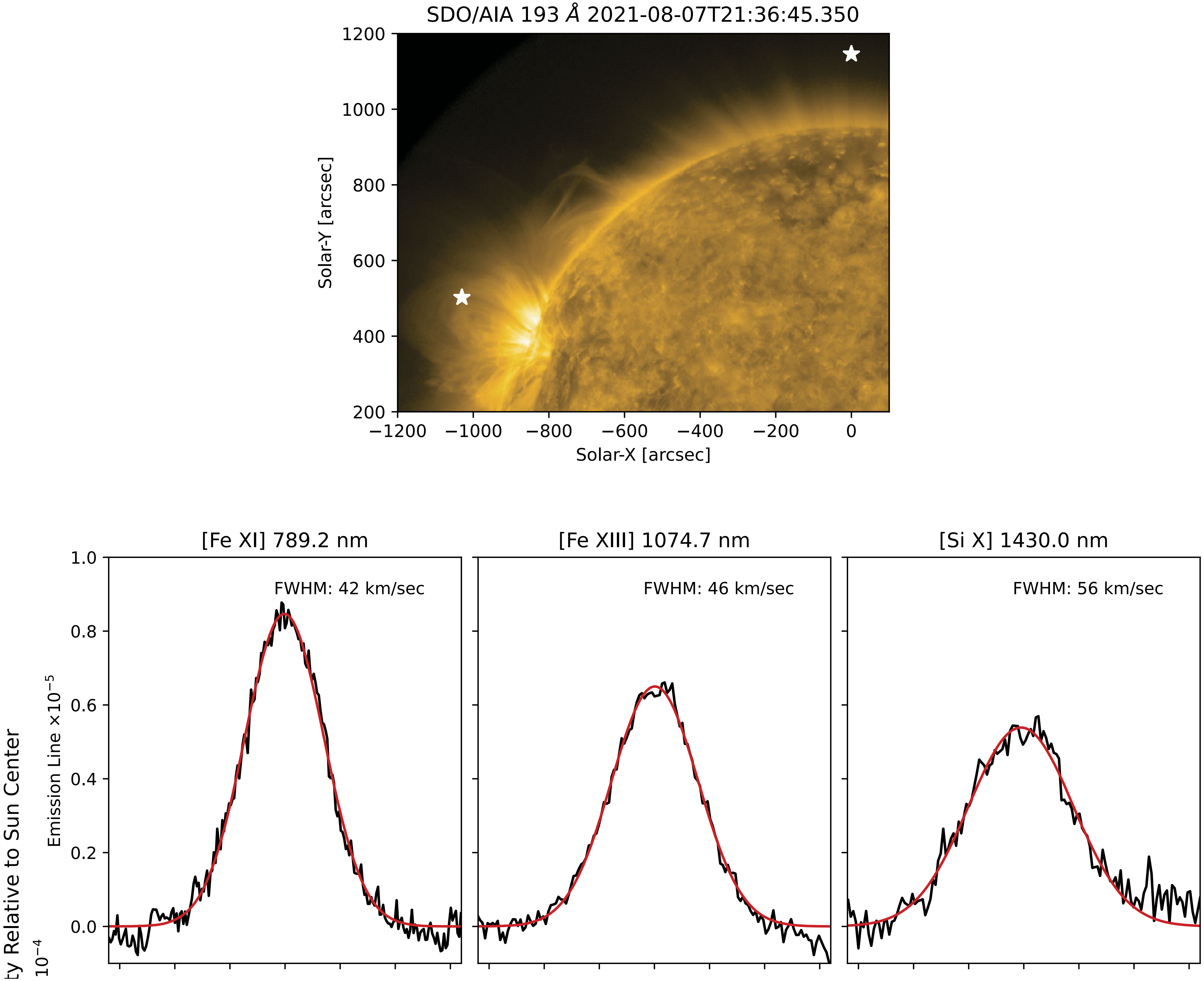
DKIST/DLNIRSP



- Fiber based
- 500-1800 nm
- 64x40 pixels
- 2x2, 5x5 or 15x28 arcsec FOV

Jaeggli et al., 2023

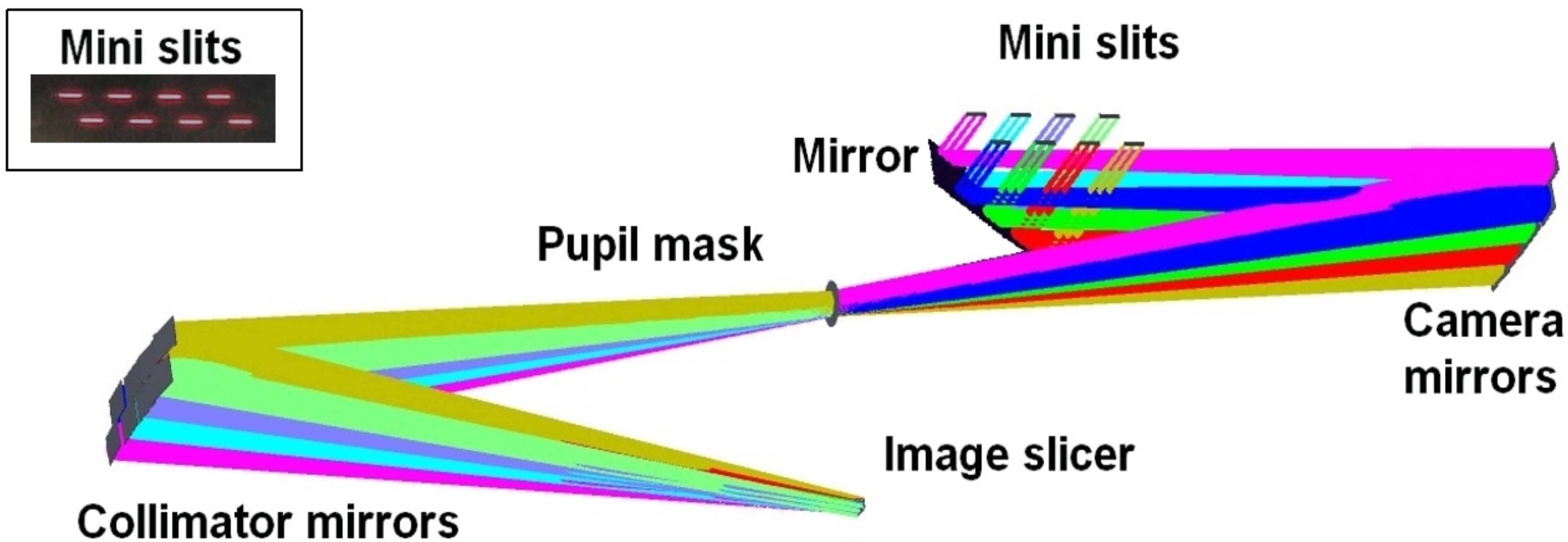
DKIST/DLNIRSP



Jaeggli et al., 2023

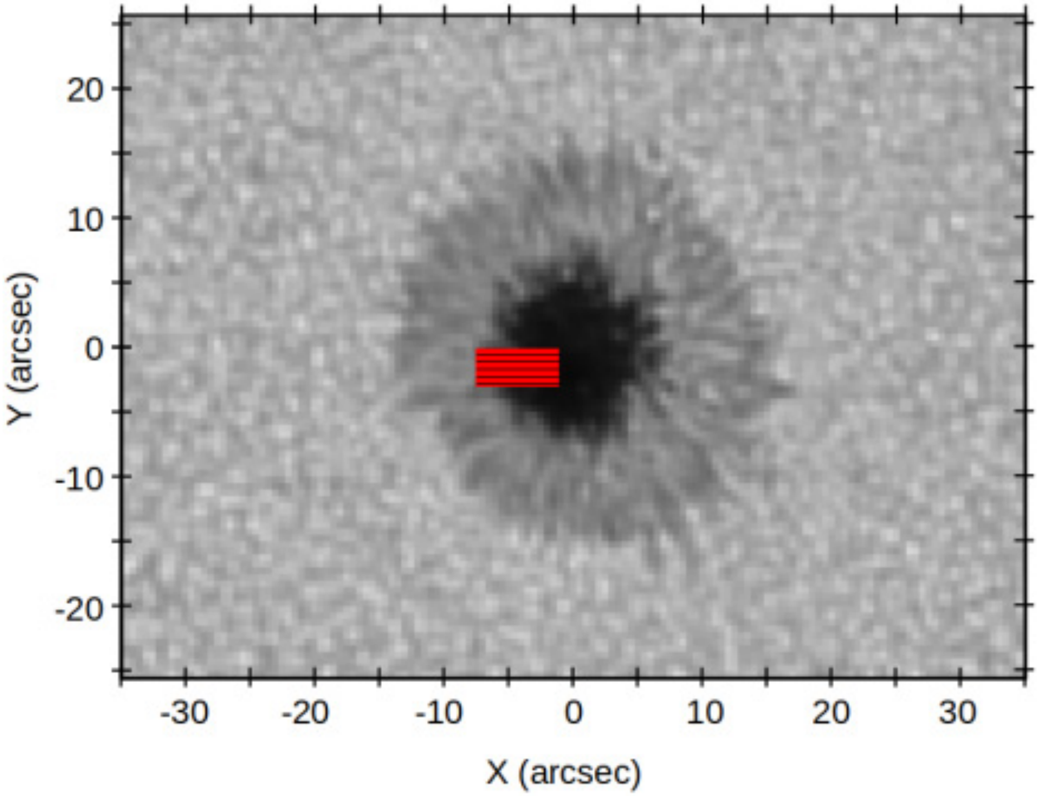
GREGOR/GRIS

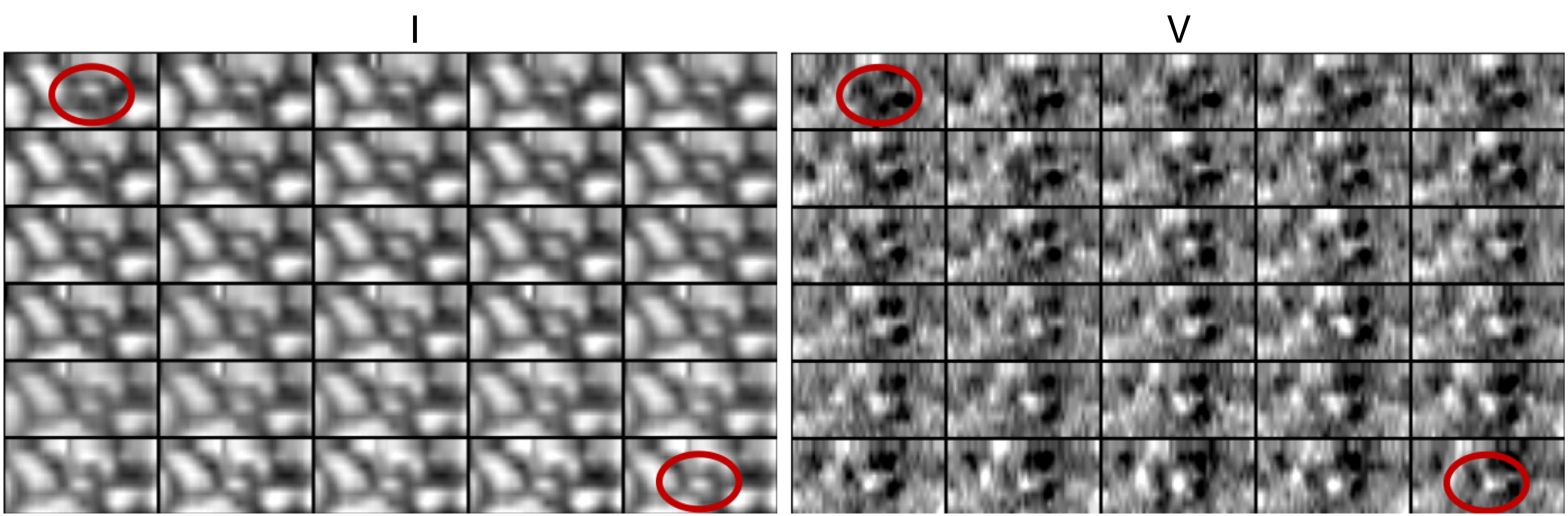
- 3x6 arcsec FOV
- 8 x 34 pixels
- 1000-2300 nm



Dominguez-Tagle et al., 2022

GREGOR/GRIS

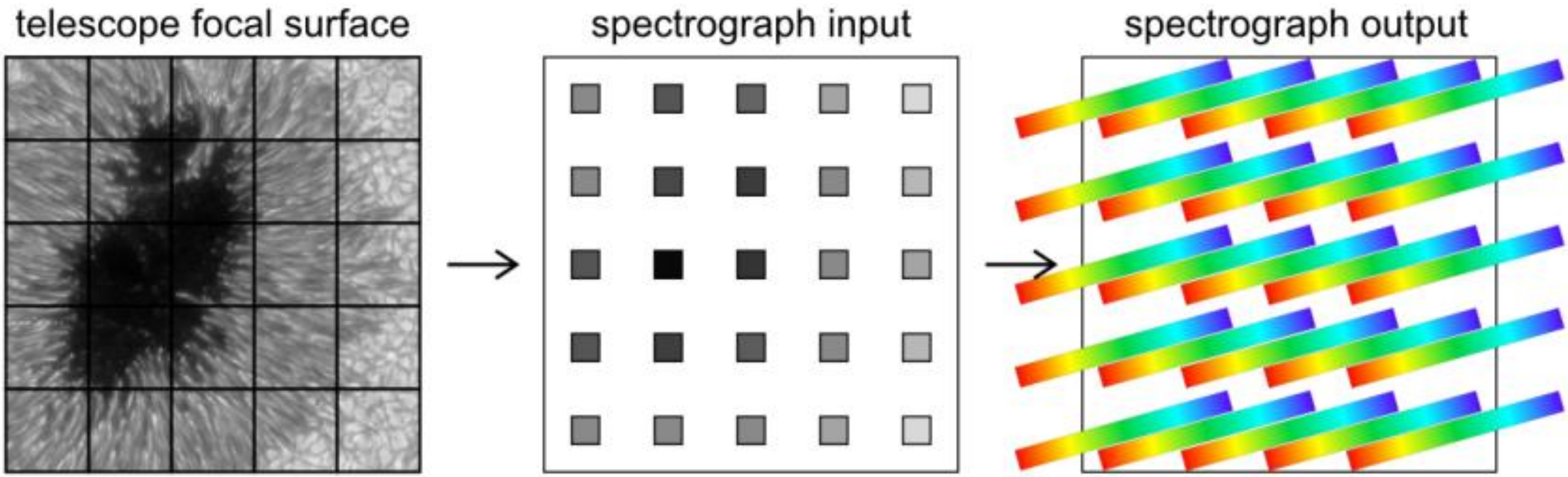




Fe I 1565 nm

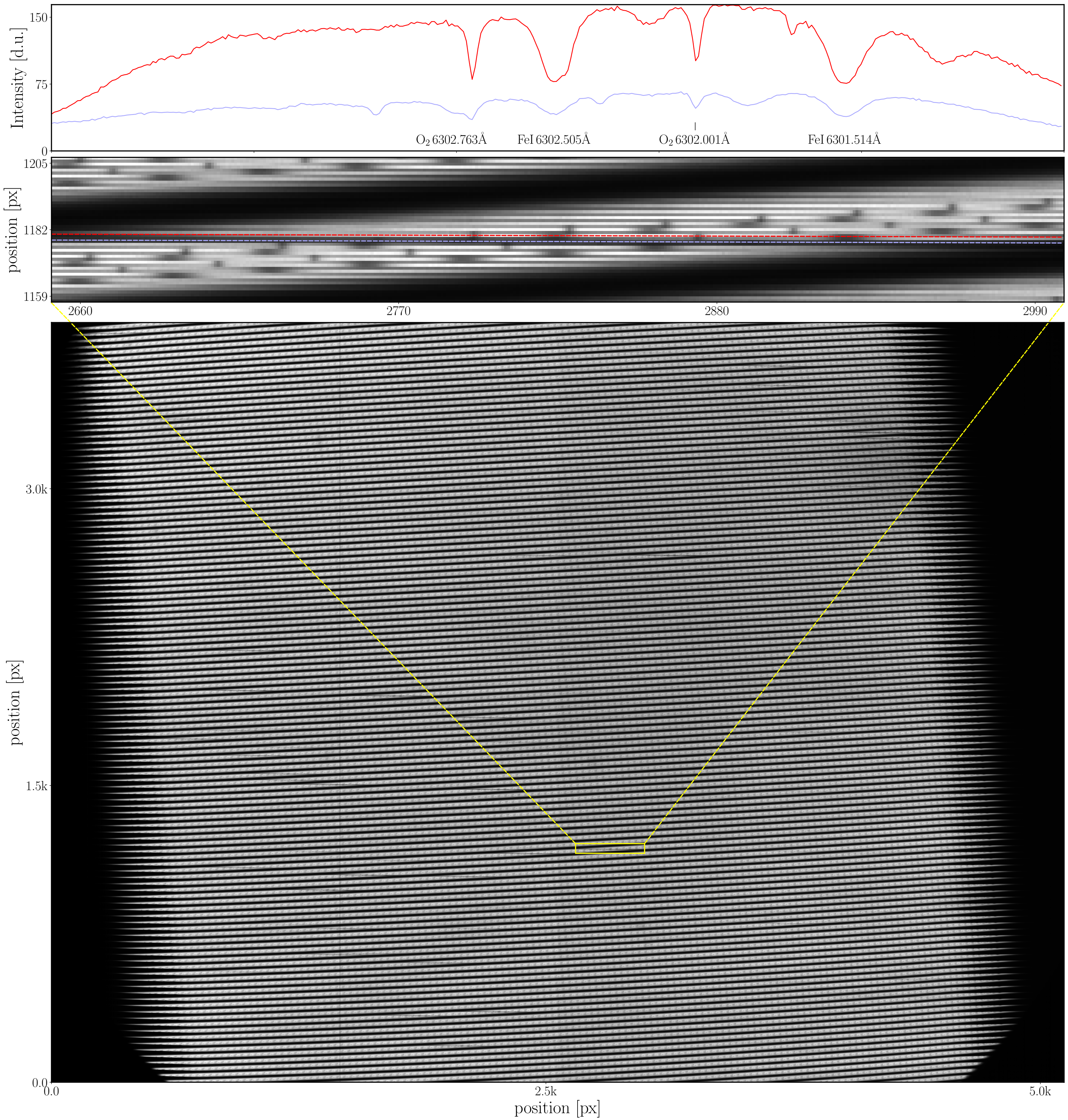
Dominguez-Tagle et al., 2022

SST/MiHI & HeSP



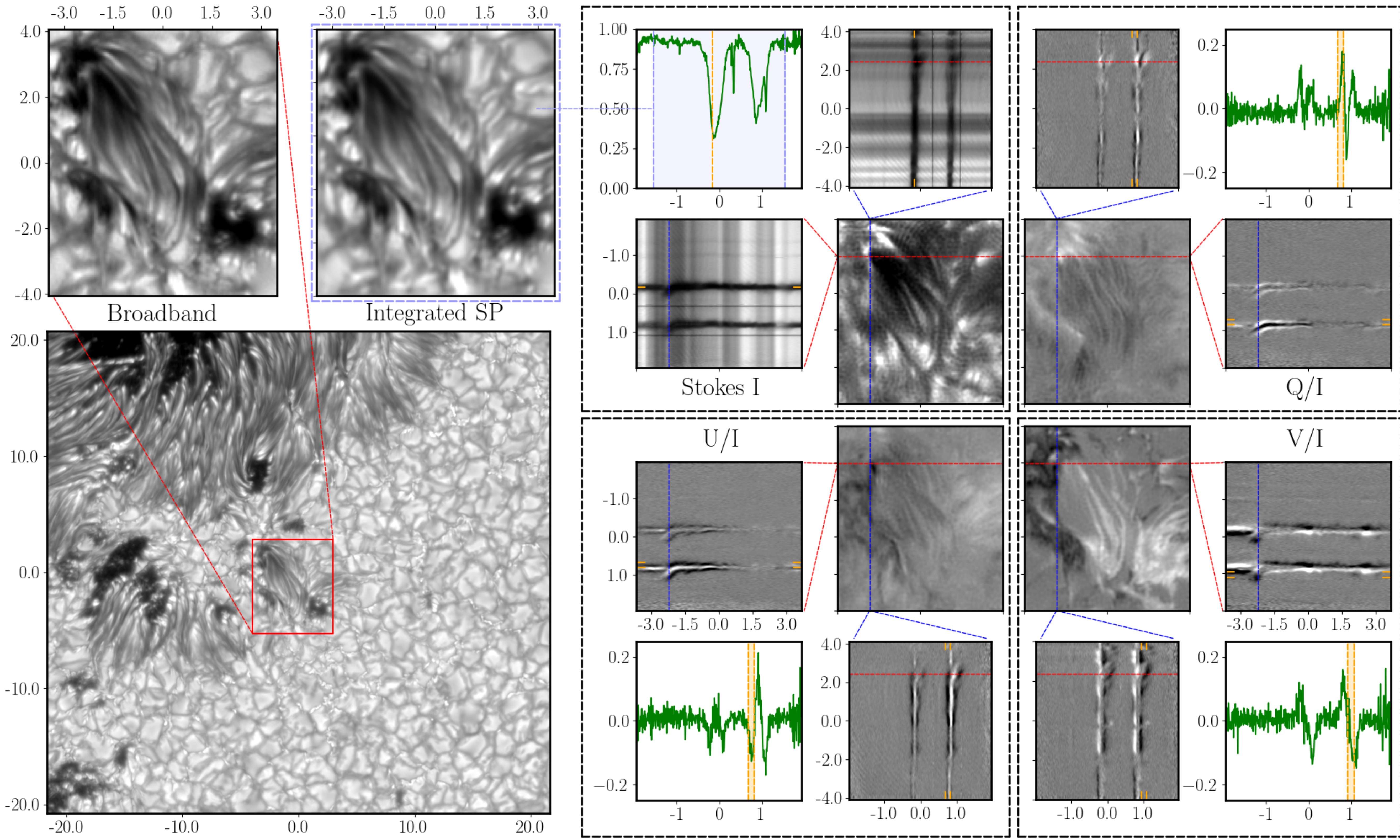
Van Noort et al., 2022

SST/MiHI



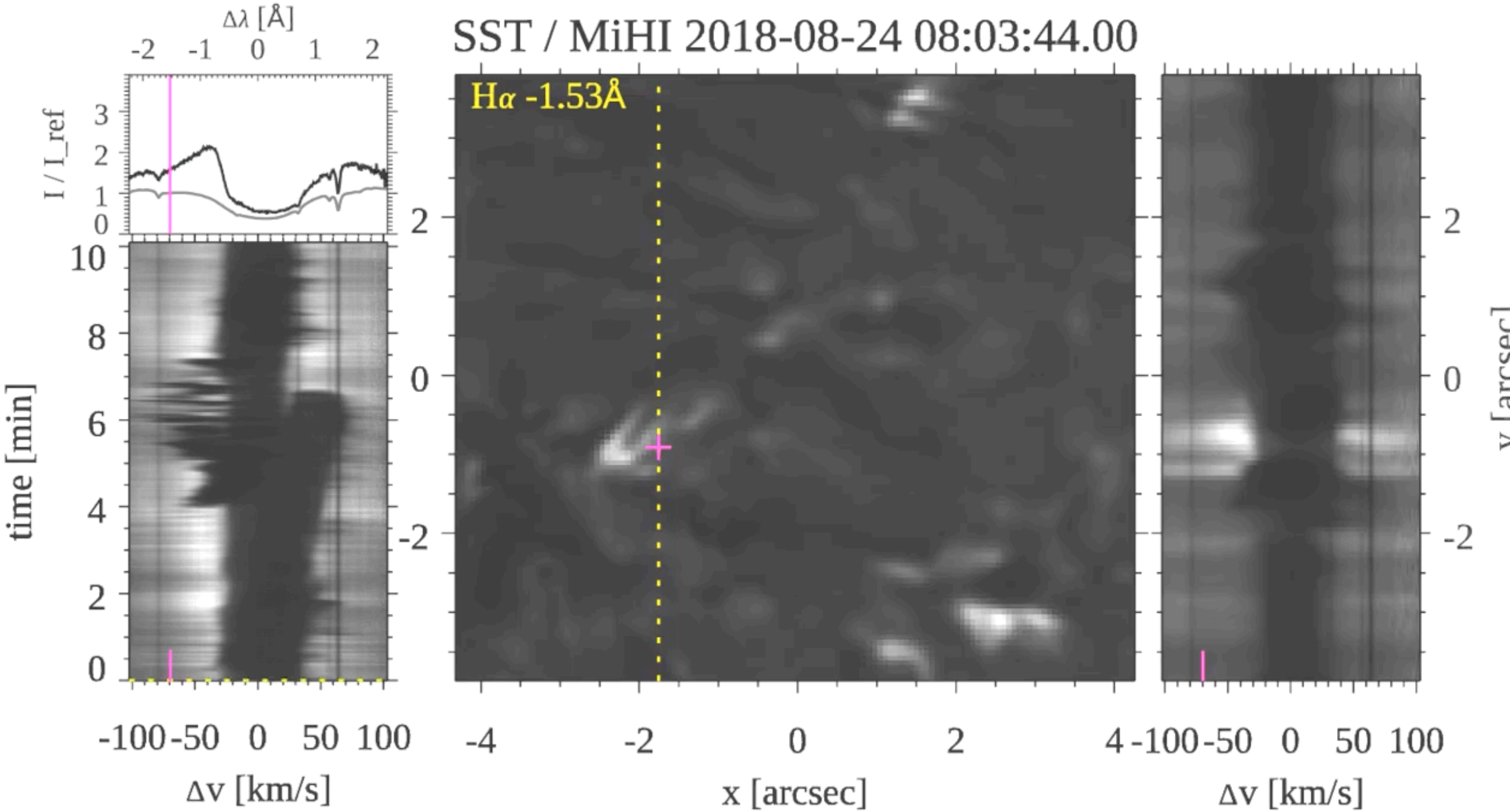
Van Noort et al., 2022

SST/MiHI



Van Noort et al., 2022

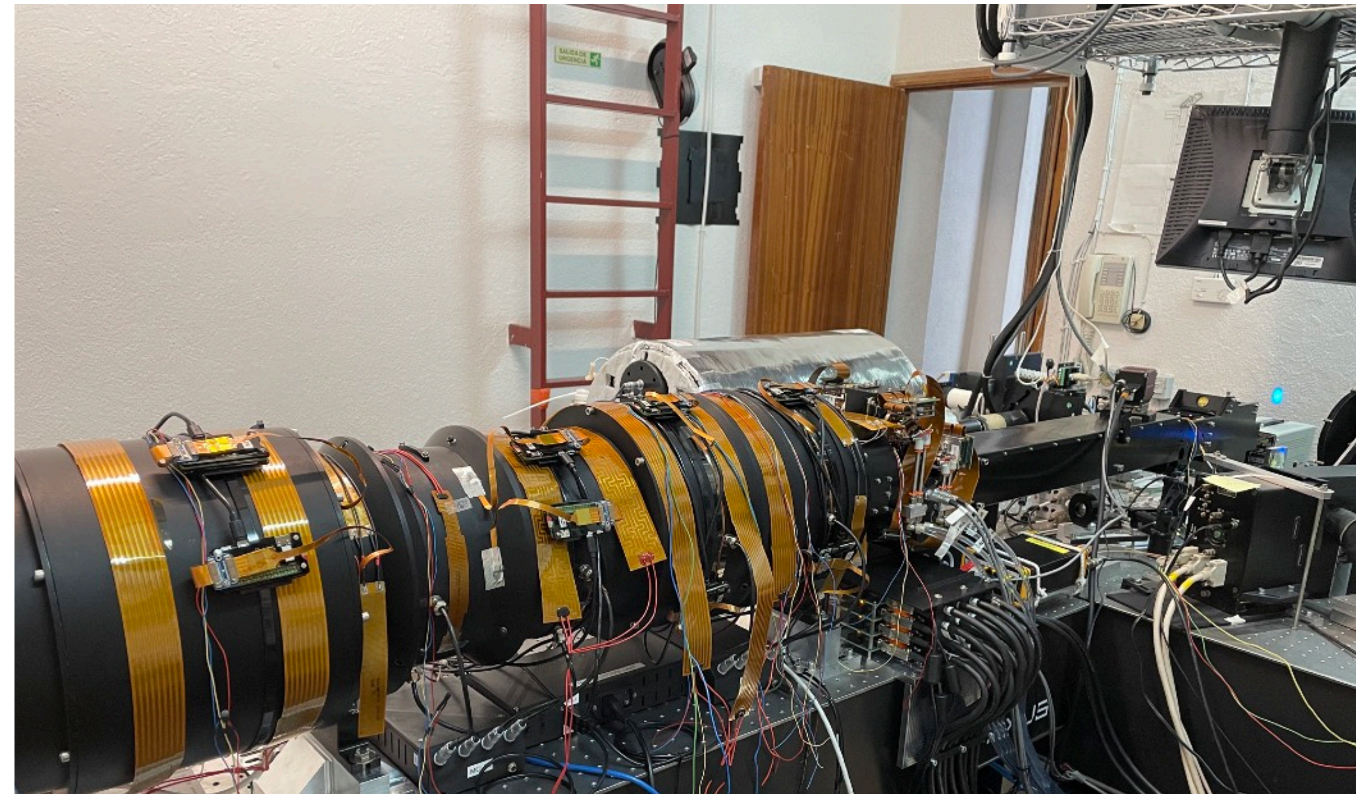
SST/MiHI

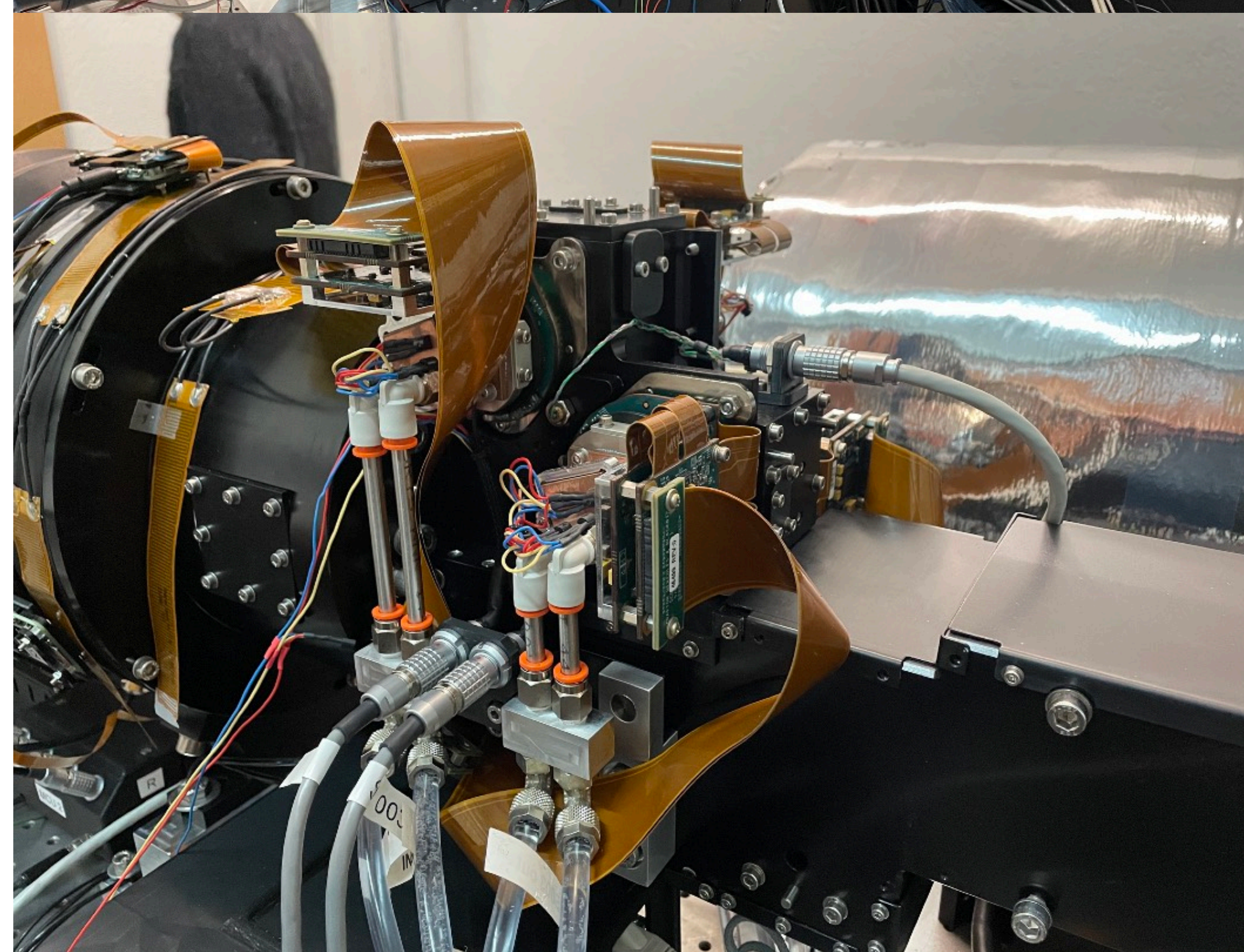


Rouppe van der Voort et al., 2023

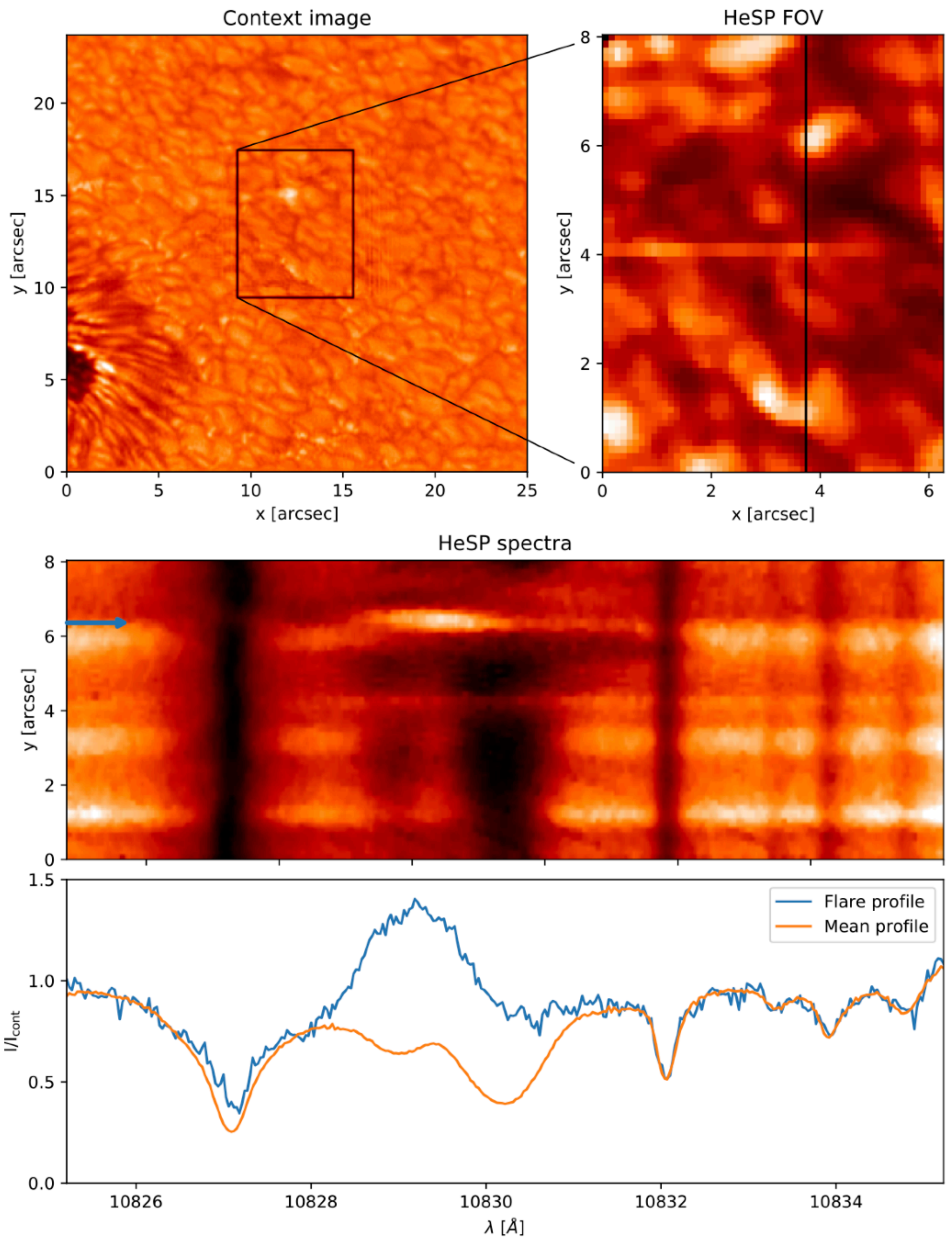
SST/HeSP

- 6x8 arcsec FOV
- 55 x 70 pixels
- 1082.5 - 1085.4 nm
- Spectropolarimetry
- 4 Custom made InGaAs cameras with 2x1.5k pixels

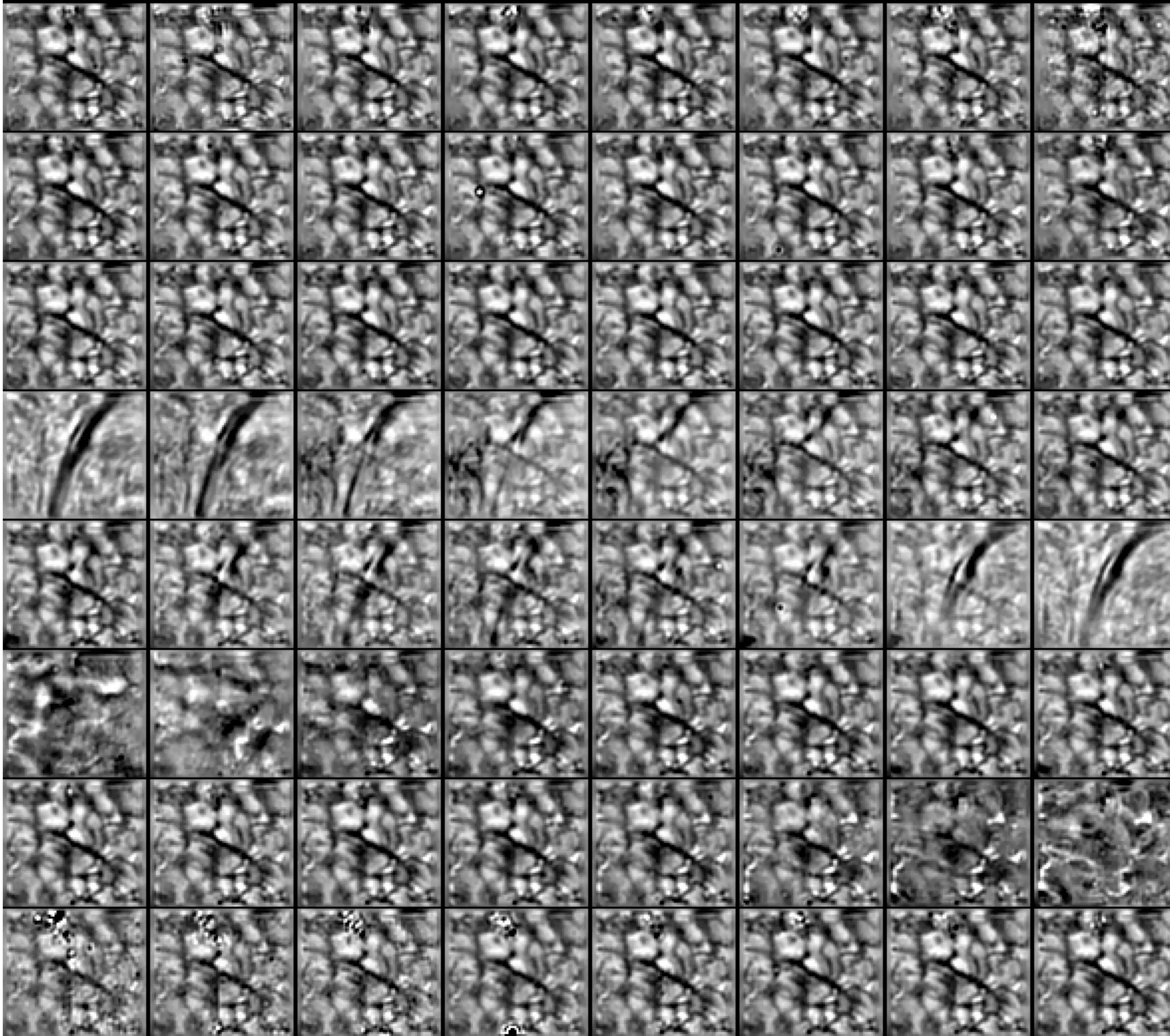




SST/HeSP



Context image
HeSP FOV
y [arcsec]
x [arcsec]
HeSP spectra
Flare profile
Mean profile
I/I$_{cont}$
λ [Å]



	DKIST	GREGOR	GST	SST	EST
fixed-band imagers	VE		FI		
slit spectrographs	V				
tunable narrowband imagers (Fabry-Perot)					3
integral field spectrographs	DL-NI				4

Useless

Needs image reconstruction

Needs larger FOV

Needs more work on calibration, reduction

Conclusions

- the Sun is not so bright at the diffraction limit if SNR>1000 is needed.
- You can’t have it all, tradeoffs in xyλt coverage are inevitable.
- But special instruments can give you a good part:
  - Reconstructed slit spectrograph data (prototype 2017, production 2025?)
  - Large FOV Fabry-Perot instruments (2024)
  - Microlens-based diffraction-limited imaging spectrographs (prototype 2016, production 2024?)