

Additional DKIST Diagnostics

Kevin Reardon (NSO)

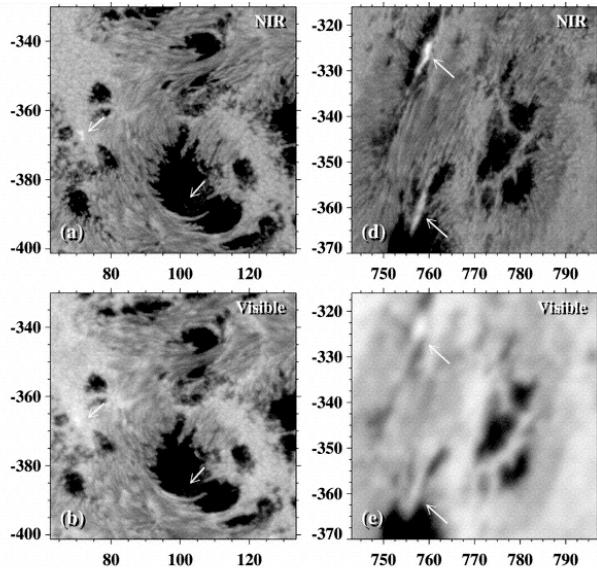
- ***Continua (visible, IR)***
- ***Molecular bands***
- ***Photospheric lines (magnetic and non-magnetic)***
- ***Chromospheric lines (dynamics, density)***



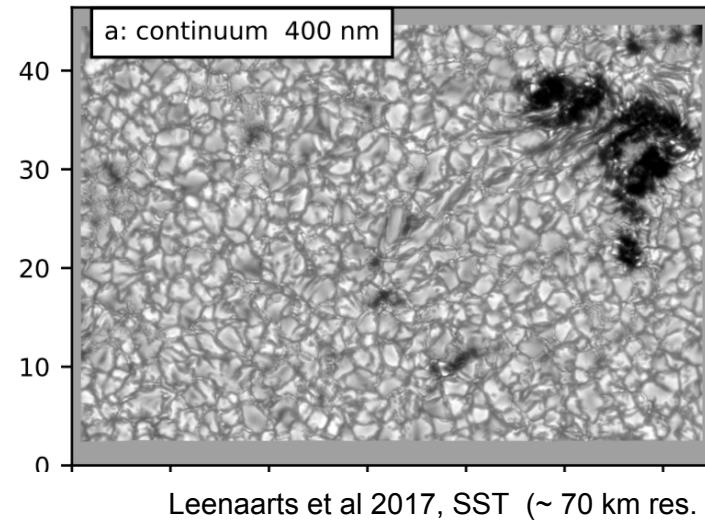
1. Continua

- Visible continuum formed at “base of photosphere”: $h \sim 0$ km ($\tau_{5000} = 1$)
- IR continuum at ~ 1.5 μm forms at continuum opacity minimum – $h \sim -50$ km

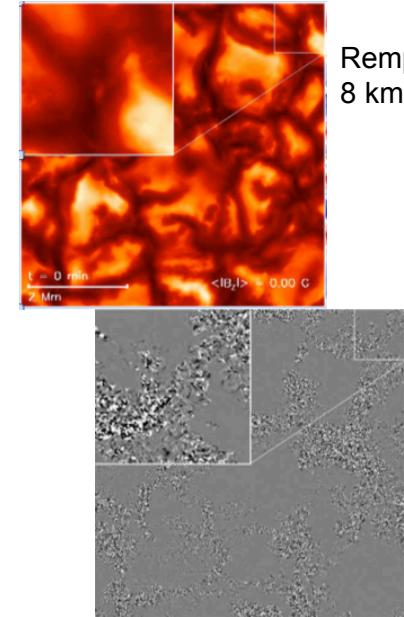
Granulation, intergranular “bright points” (magnetic?), horizontal motions. Occasionally, WL flares



Xu et al 2006



Leenaarts et al 2017, SST (~ 70 km res.)



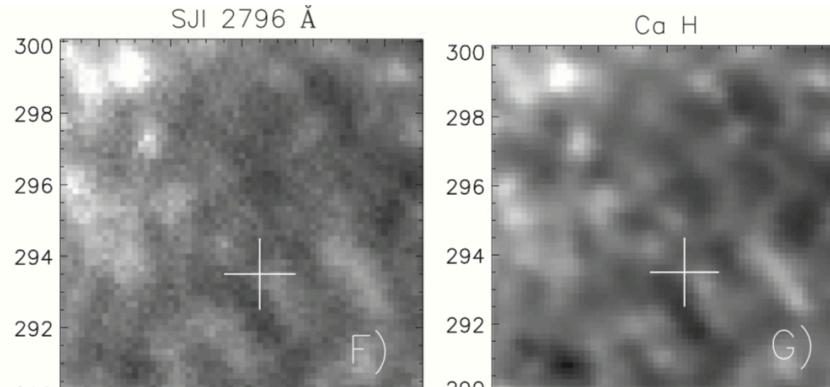
1. Continua

- IR continuum ($\sim 3\text{-}4 \mu\text{m}$ and above) forms higher in the atmosphere, \sim mid-photosphere (like, e.g. 170nm channel of AIA, or IRIS SJI 279.6)

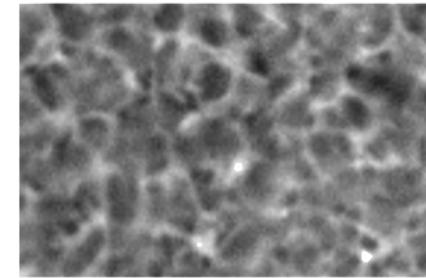
Reverse granulation, waves, shocks



Penn et al 2016, 5 μm



Martinez-Sykora et al 2015,
UV vs. Ca II H filter



Janssen & Cauzzi, 2006,
Ca II 854.2 wing;

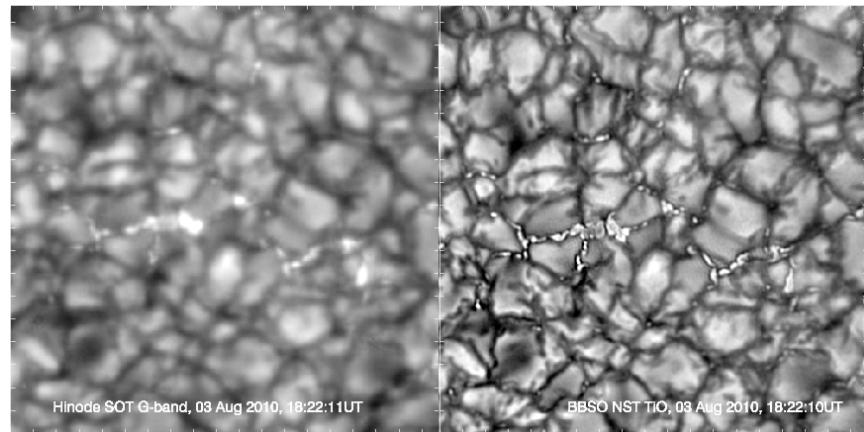
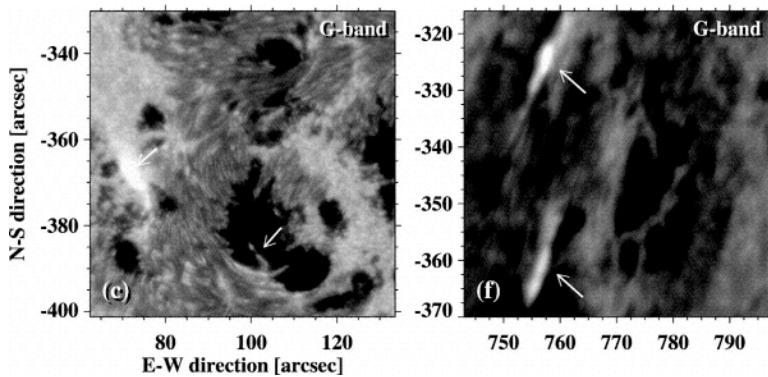
1. Continua: DKIST instruments

<u>Spectral Window</u>	<u>Spatial Resolution</u>	<u>DKIST Instrument</u>
450.3 nm	0.022" ; 16 km	VBI
668.4 nm	0.034" ; 25 km	VBI
590, 630, 660, 860 nm	0.030 – 0.043"; 20-40 km	VTF
860, 1080 nm	0.06", 0.15" ; 43, 108 km	DL-NIRSP
1565 nm	0.08", 0.15" ; 60, 108 km	DL-NIRSP
1080, 2300, 3000, 3900, 4600 nm	0.24 x 0.30" ; 175 x 215 km	Cryo-NIRSP Spectrograph
1080, 1250, 3900, 4600 nm	0.10–0.23" ; 75 – 165 km	Cryo-NIRSP Context Imager
390 – 900 nm	0.04" x 0.06" ; 30 x 40 km	ViSP

2. Molecular lines, bands

- Formed in the low photosphere, provide large intensity contrast for “hot” vs. “cold” structures (strong T dependence of opacity). E.g. TiO, CN (G-band), CH.

Granulation, intergranular “bright points”, horizontal motions. Occasionally, WL flares.

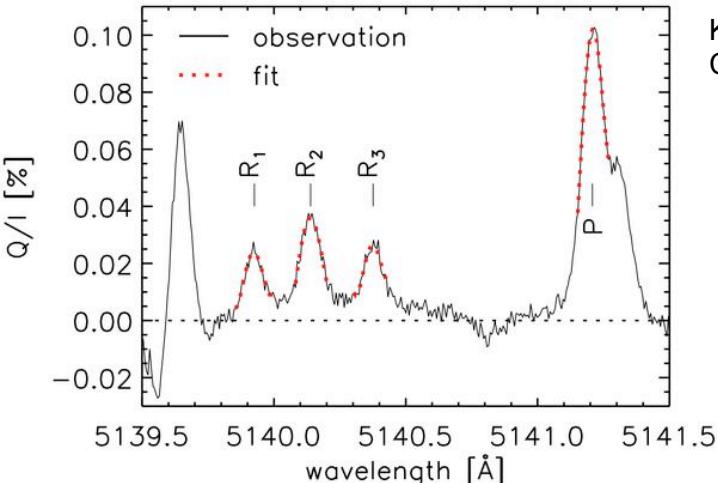


2. Molecular lines, bands

- Sensitive to Hanle effect, e.g. MgH, C₂ lines.
- Presence of molecular lines indicate low temperatures – e.g. CO roto-vibration transitions at 4.7 μm , require $T_e < 3700 \text{ K}$.

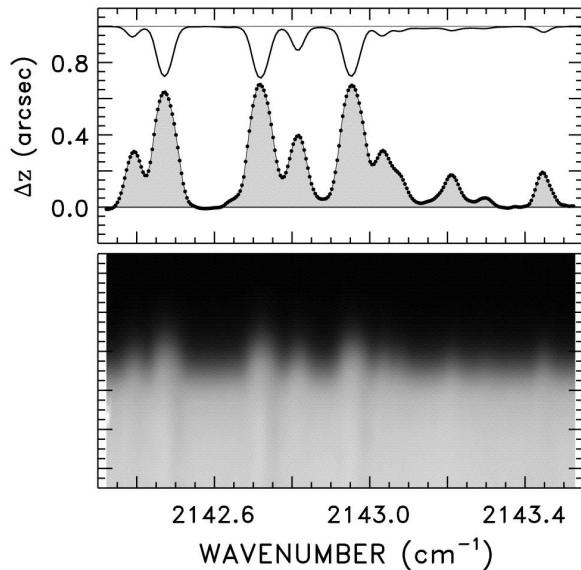
Investigate small scale, tangled magnetic fields in the photosphere (e.g. via differential Hanle effect)

Investigate spatio-temporal structure of low chromosphere, presence of cold bubbles ?



Kleint et al 2010;
C₂ R triplet + P triplet

Ayres, 2002;
Emission 7-800 km
above limb

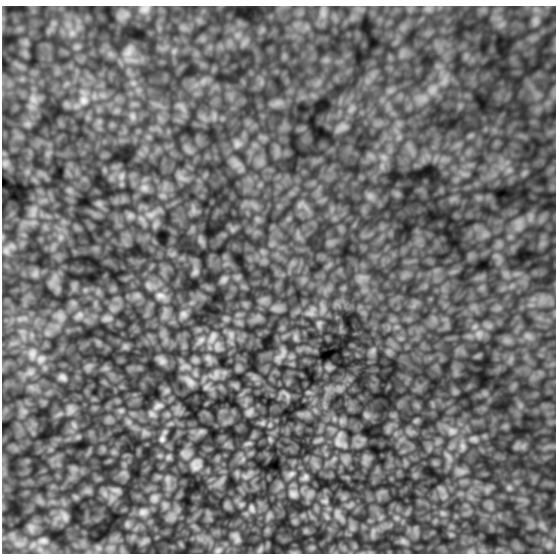


2. Molecular lines: DKIST instruments

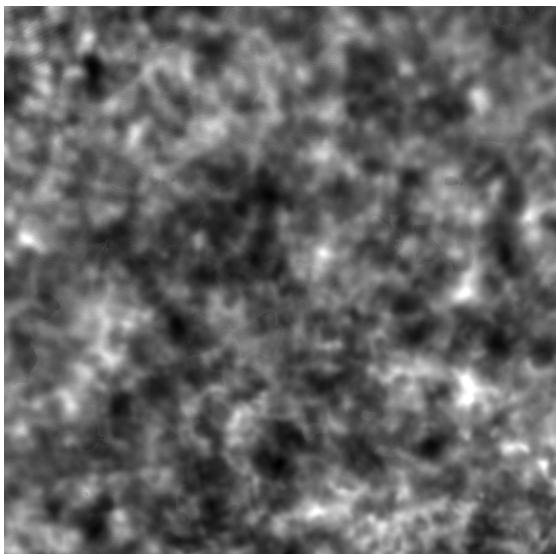
<u>Spectral Window</u>	<u>Spatial Resolution</u>	<u>DKIST Instrument</u>
430.5 nm – G-band (CH)	0.022" ; < 20 km	VBI
707.8 nm – TiO	0.034" ; 25 km	VBI
2326 nm – CO (1 st overtone)	0.24 x 0.30" ; 175 x 215 km	Cryo-NIRSP Spectrograph
4651 nm– CO (fundamental)	0.24 x 0.30" ; 175 x 215 km	Cryo-NIRSP Spectrograph
4651 nm– CO (fundamental)	0.23" ; 165km	Cryo-NIRSP Context Imager
390 – 900 nm (CH, TiO, others)	0.04" x 0.06" ; 30 x 40 km	ViSP

3. Non-magnetic photospheric lines

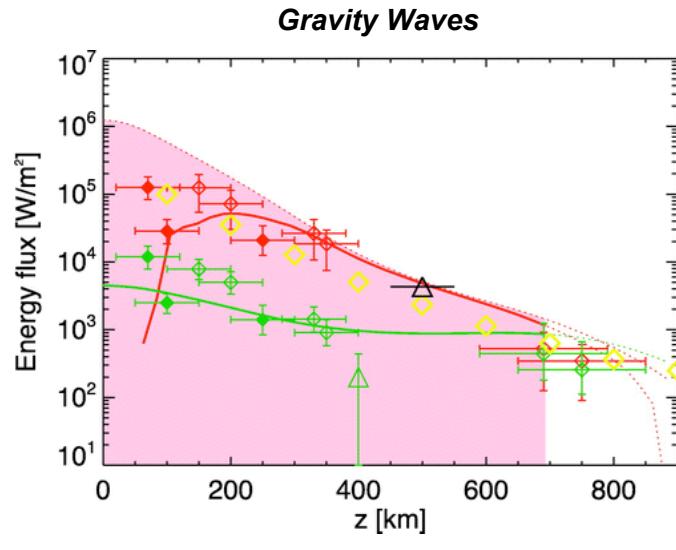
- Several photospheric lines have $g_L = 0$ and are not influenced by the presence of magnetic fields. Can be formed over a large span of photospheric heights (e.g. Fe II 512.3 nm, Fe I 543.4, Fe I 567.6; Fe I 709.0, Fe II 722.4, Ti I 839.7 nm). *Accurate thermo-dynamical structure of atmosphere, waves through T_{min}*



Whitelight



Fe I 543.4 nm Line Core

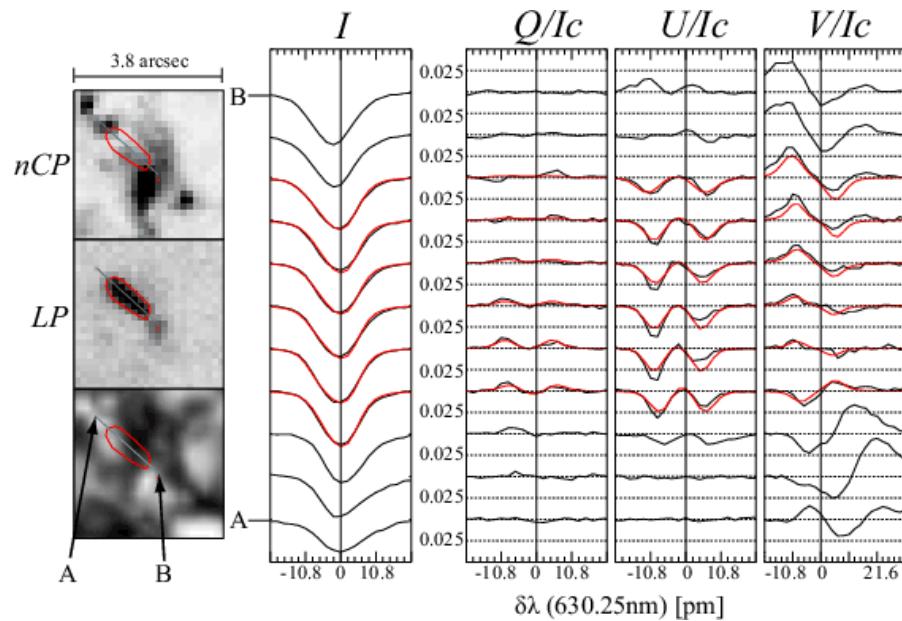


Straus et al 2008

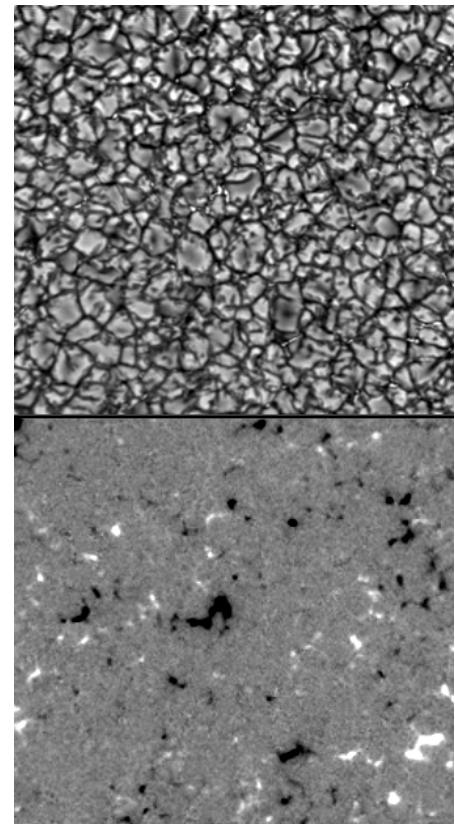
3. Non-magnetic photospheric lines: DKIST instruments

<u>Lines</u>	<u>Spatial Resolution</u>	<u>DKIST Instrument Availability</u>
Fe I 709.9 nm	0.035"; 26 km	VTF – <i>not at first light</i>
390 – 900 nm	0.04" x 0.06" ; 30 x 40 km	ViSP

4. Zeeman-sensitive photospheric lines



Ishikawa, et al., 2008



4. Zeeman-sensitive photospheric lines

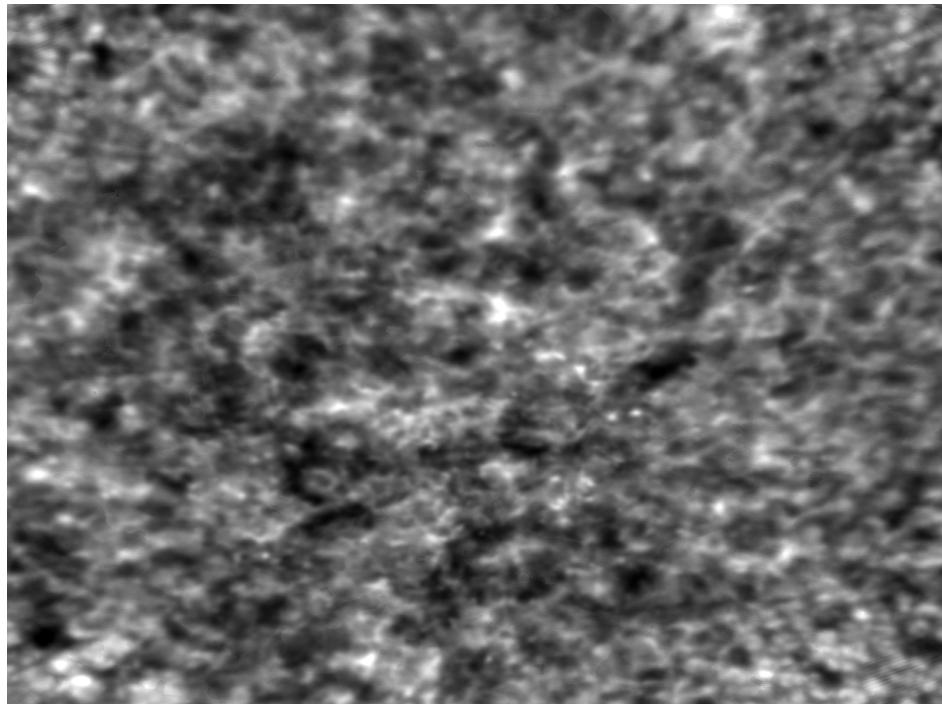
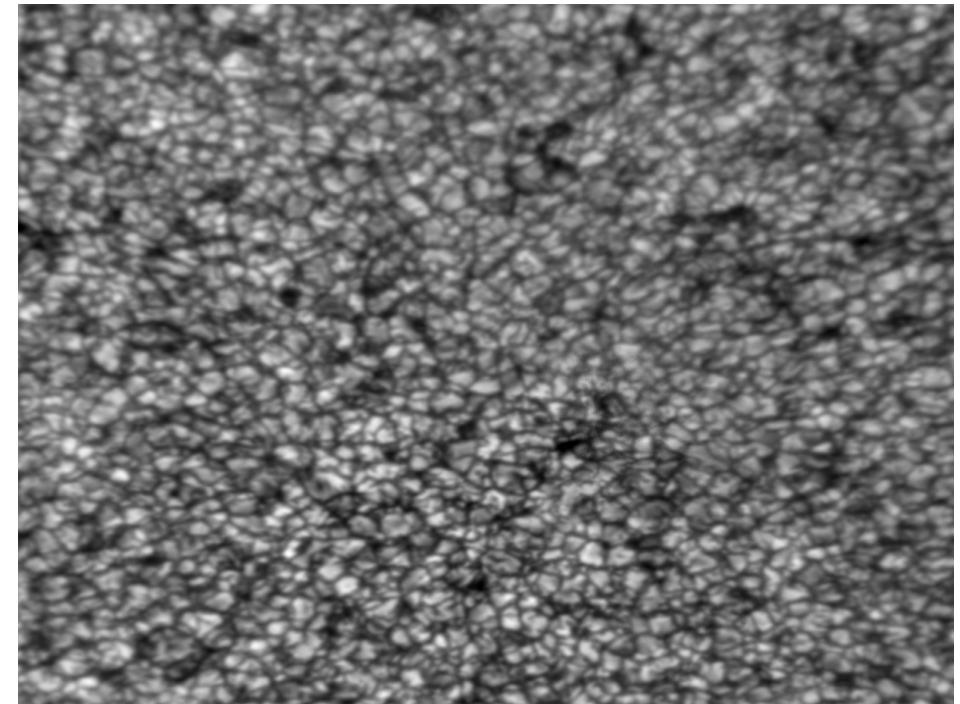
<u>Lines</u>	<u>Used By</u>	<u>DKIST Instrument Availability</u>
Fe I 524.7, 525.0 nm	IMaX	ViSP, VTF – <i>not at first light</i>
Fe I 617.3 nm	HMI	ViSP
Fe I 630.1, 630.2 nm	ASP, Hinode SOT/SP	ViSP, VTF
Fe I 846.8, 851.4 nm		ViSP
Si I 1082.7 nm	FIRS	DL-NIRSP, Cryo-NIRSP
Fe I 1564.8, 1565 nm	FIRS	DL-NIRSP
390 – 900 nm		ViSP

4.5 Magnetic middle-atmospheric lines: DKIST instruments

<u>Lines</u>	<u>Spatial Resolution</u>	<u>DKIST Instrument Availability</u>
Na I 589.0 nm	0.03"; 22 km	VTF
Fe I 543.4 nm	0.04" x 0.06" ; 30 x 40 km	ViSP
Na I 589.0 nm		
Na I 589.6 nm		
K I 769.9 nm		
Mg I 517.3 nm		
390 – 900 nm		

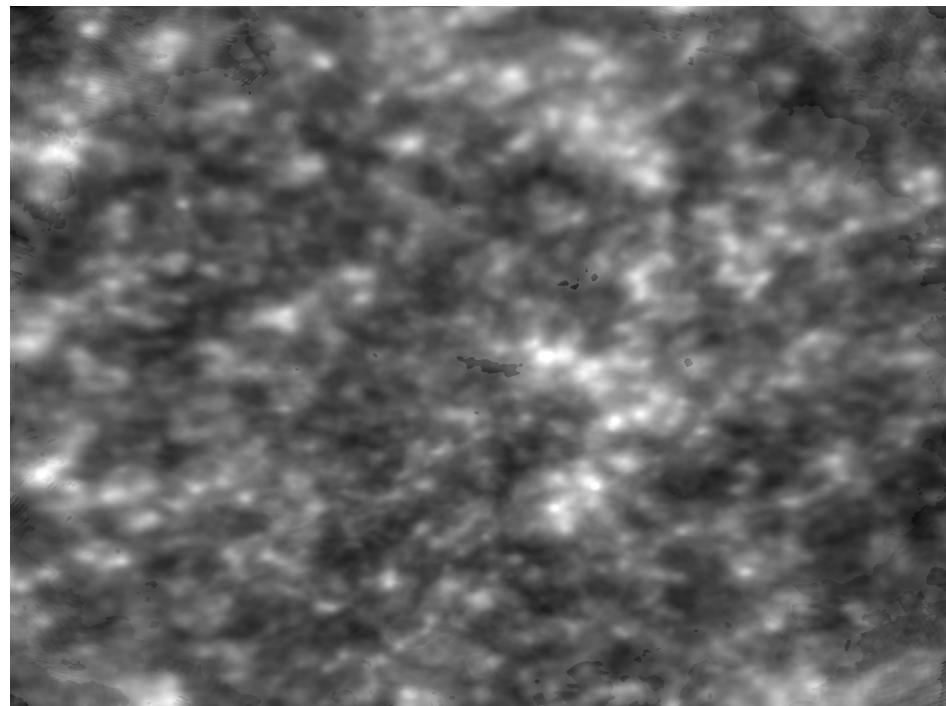
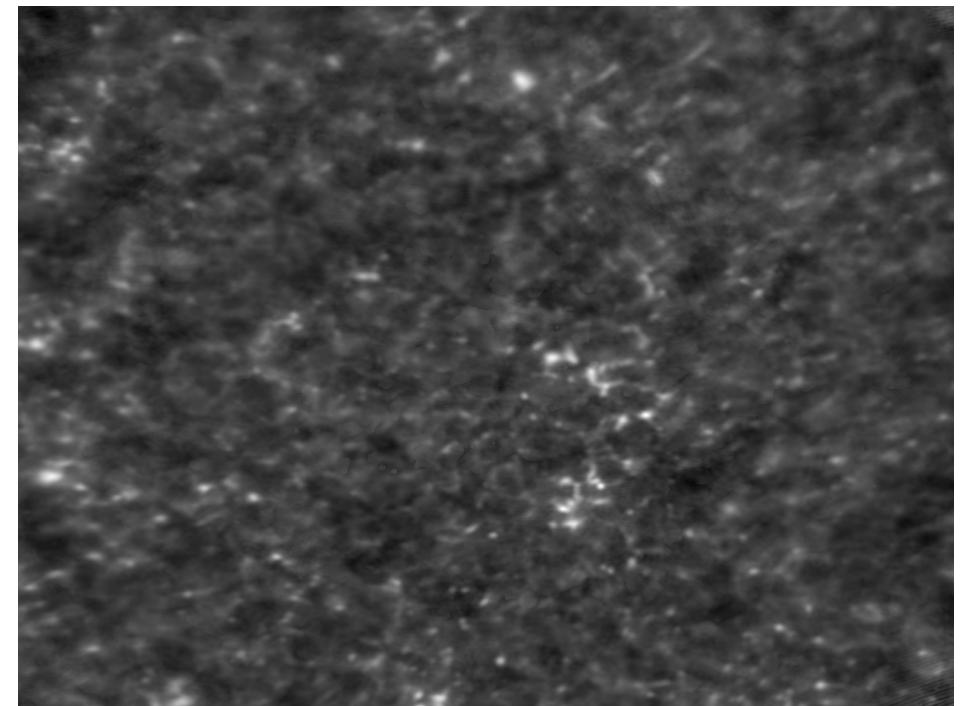
Whitelight

Fe I 5434 Å



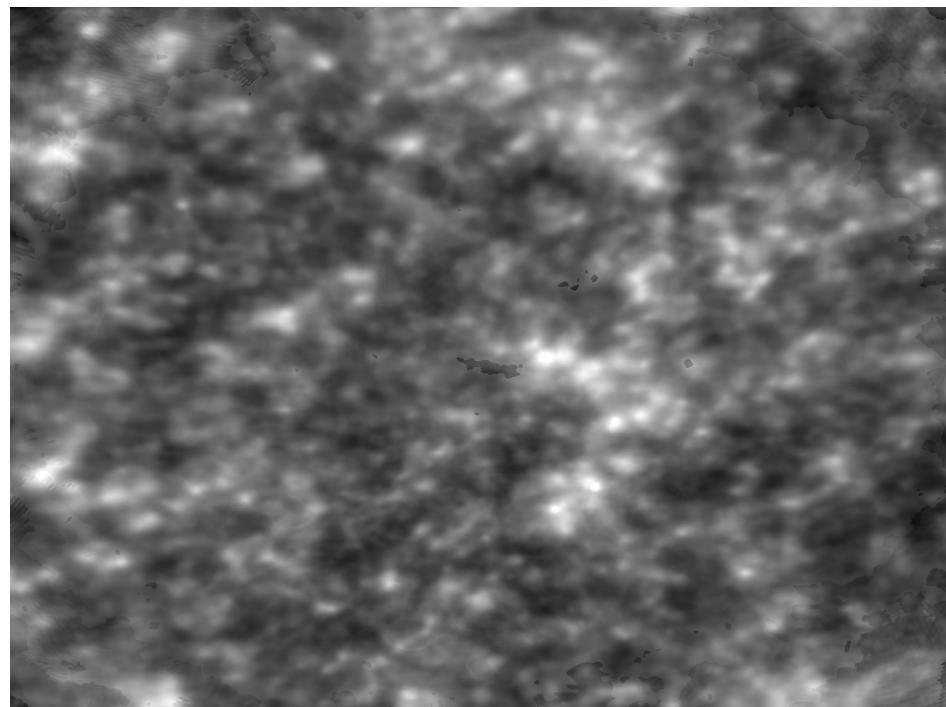
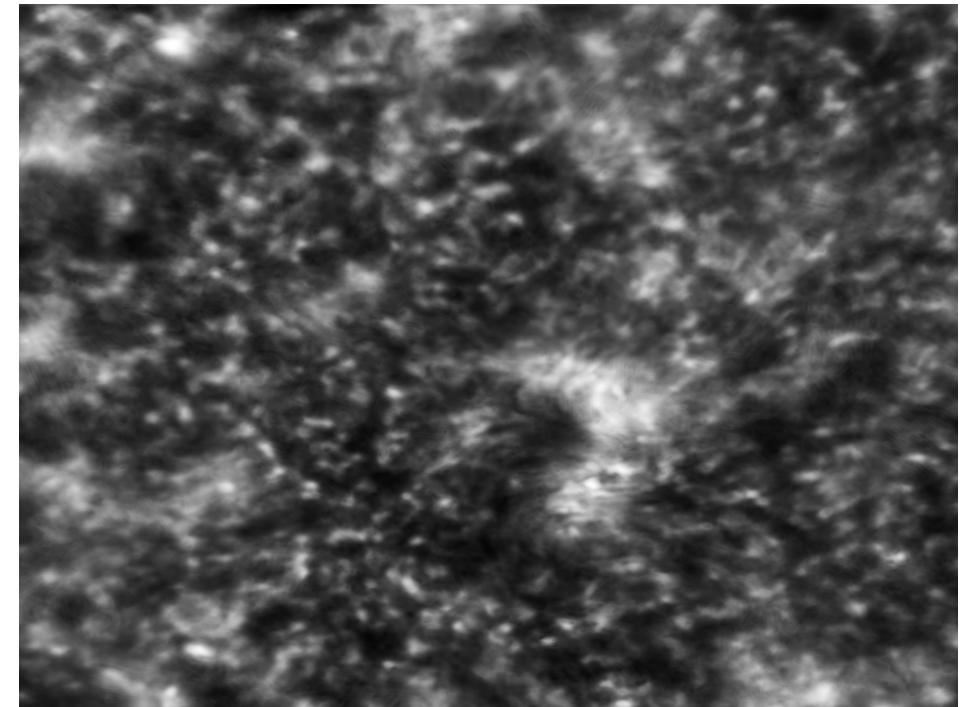
K I 7699 Å

Na D₁ 5896 Å

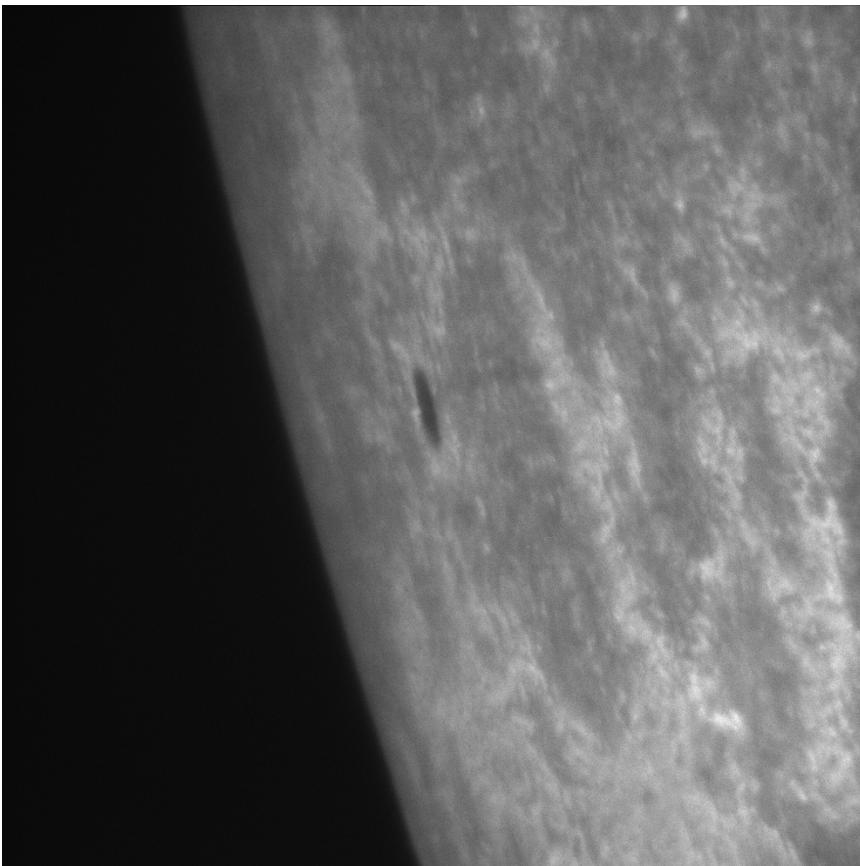


Ca II 8542 Å

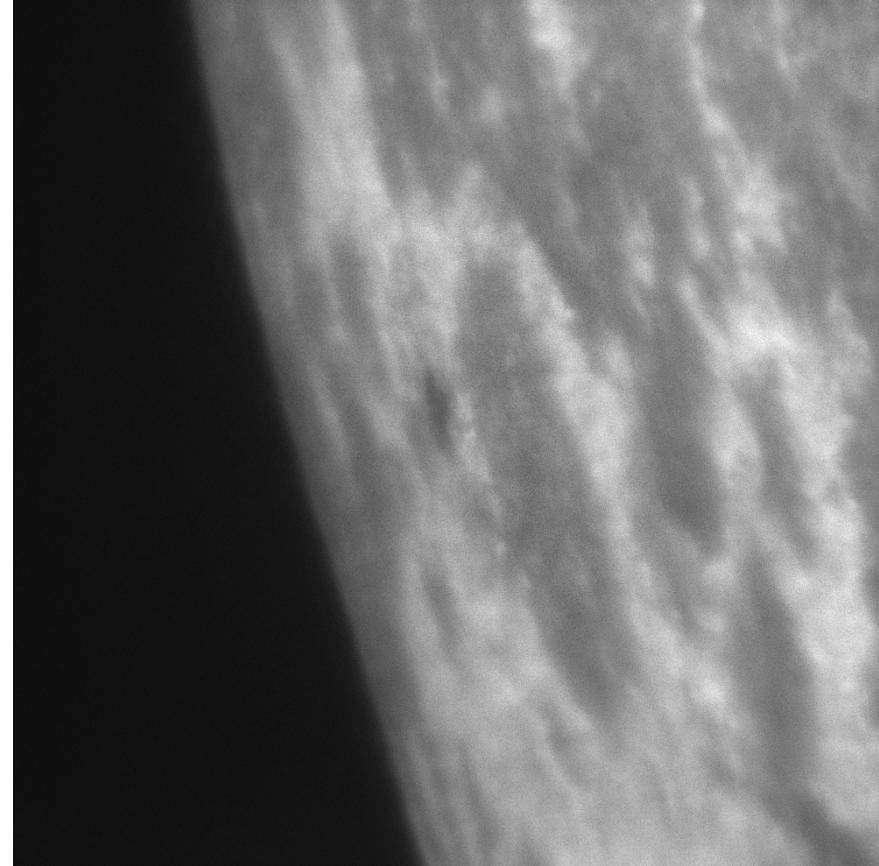
Na D₁ 5896 Å



K I 7699 Å

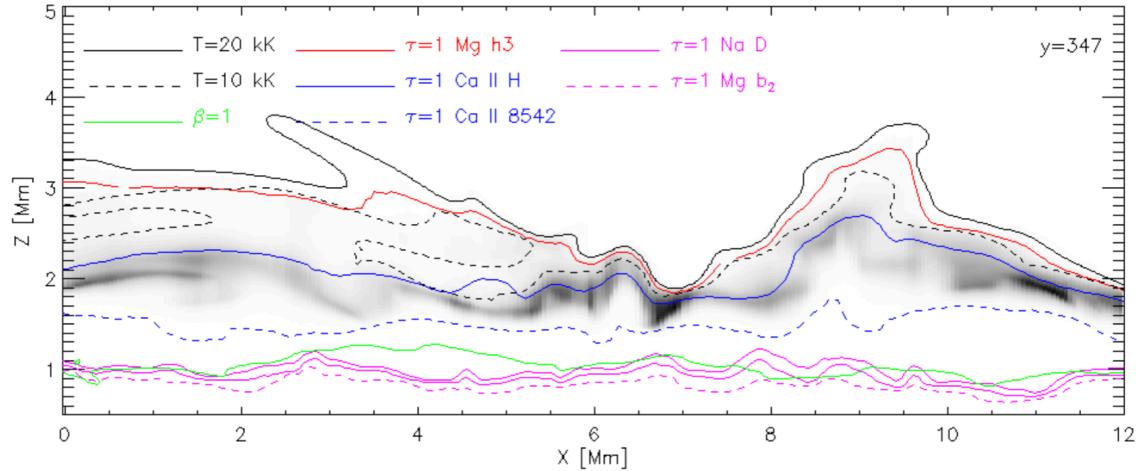
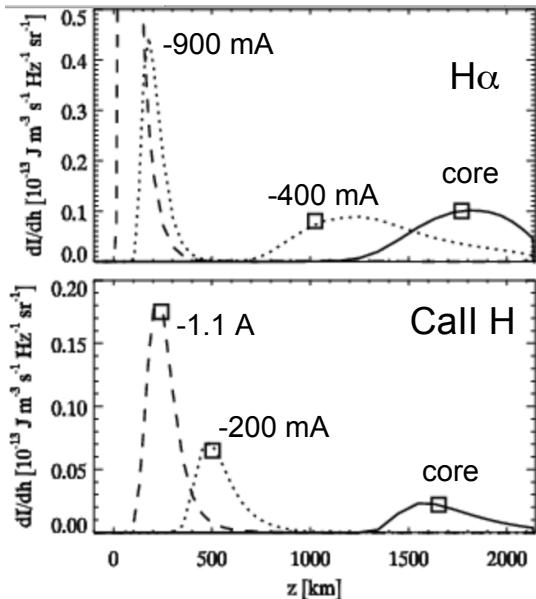


Na D₁ 5896 Å



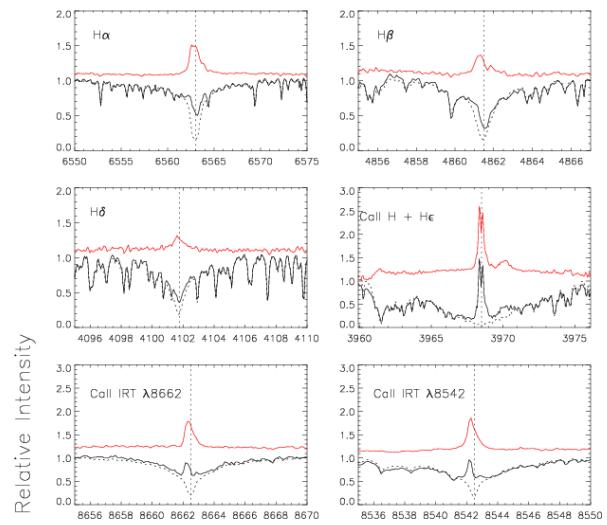
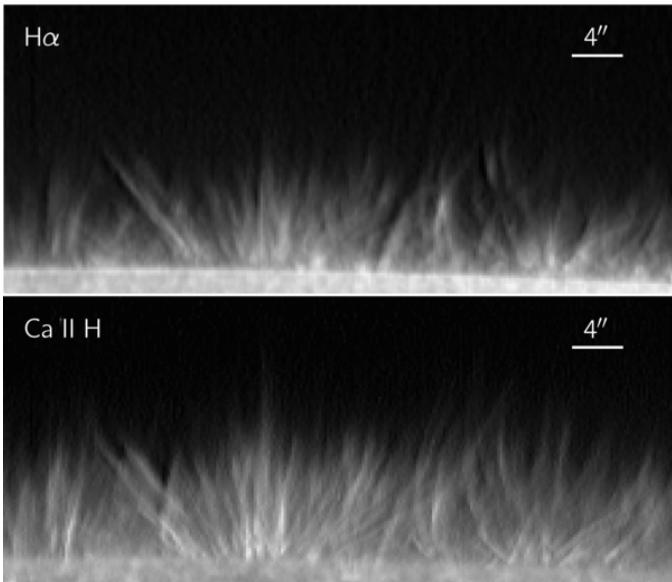
5. Chromospheric lines

- Chromosphere is optically thin in most of the visible/near IR, apart from few strong lines: Balmer and Paschen series, CaII resonance (H&K) and subordinate triplet (849.8, 854.2, 866.2 nm), HeI triplet (1083 nm), subordinate HeI D₃ (587.6 nm)
- “Height of formation” is an over-simplification. Lines form over a large span, and heavily depend on local spatio-temporal conditions. HeI also strongly depends on local UV irradiation.

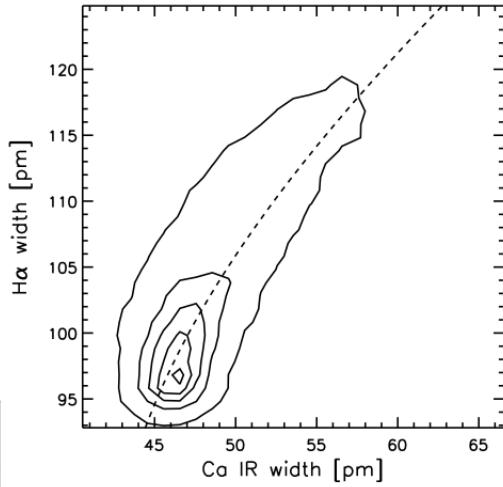


5. Chromospheric lines

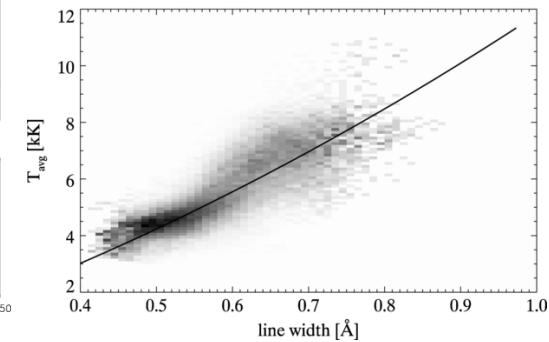
- $H\alpha$, Balmer series: dynamics, temperature, density, depth of TR
- Paschen lines: electric fields
- Call lines: chromospheric dynamics, temperature
- HeI: dynamics, density in flares (esp. D_3)



Garcia Alvarez et al 2005



Cauzzi et al. 2009



Leenaarts et al 2012

5. Chromospheric lines: DKIST instruments

Hydrogen Lines

<u>Spectral Window</u>	<u>Observing Mode</u>	<u>Spatial Resolution</u>	<u>DKIST Instrument</u>
656.3 nm	spectral scan	0.033" ; 25 km	VTF
656,3 nm	filtergram	0.034" ; 25 km	VBI
486.1 nm	filtergram	0.024" ; 18 km	VBI
656.3, 486.1, 434.0, 410.1, 397.0 nm	spectrograph	0.04" x 0.06" ; 30 x 40 km	ViSP
P ₁₁ and higher, 820.4 (Paschen limit)	spectrograph	0.04" x 0.06" ; 30 x 40 km	ViSP

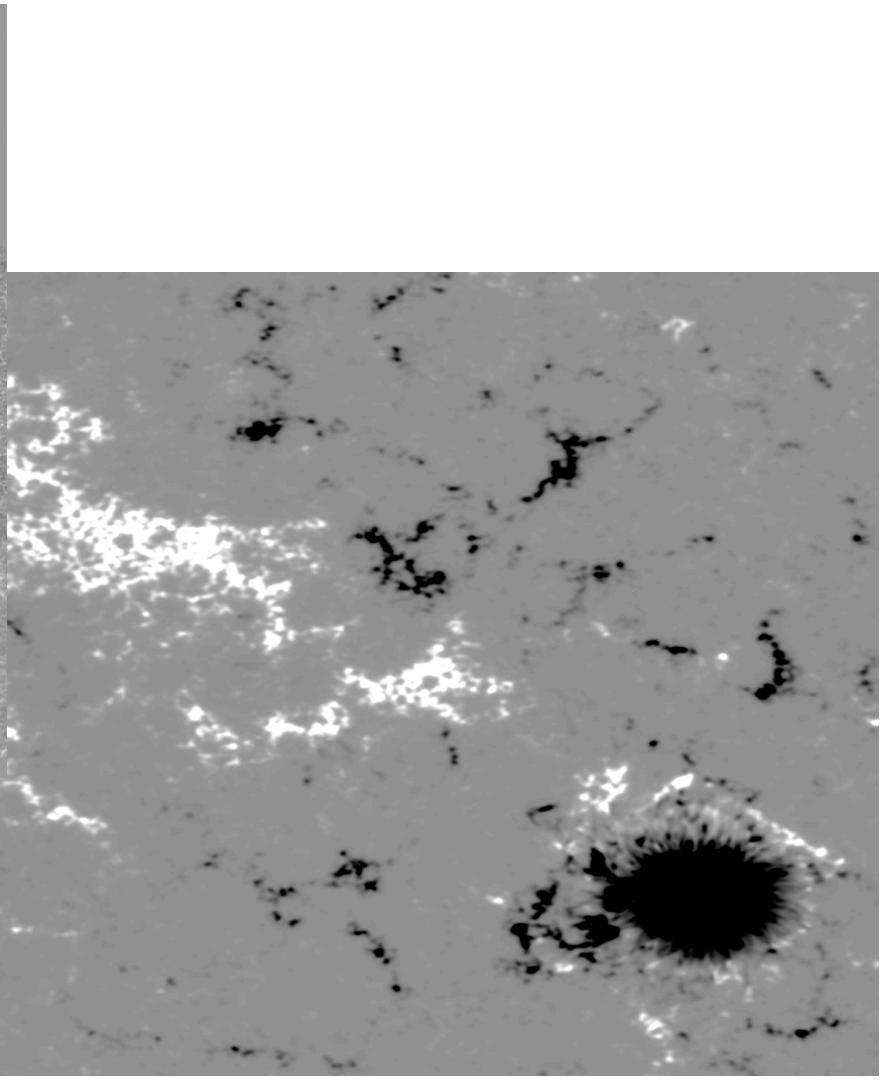
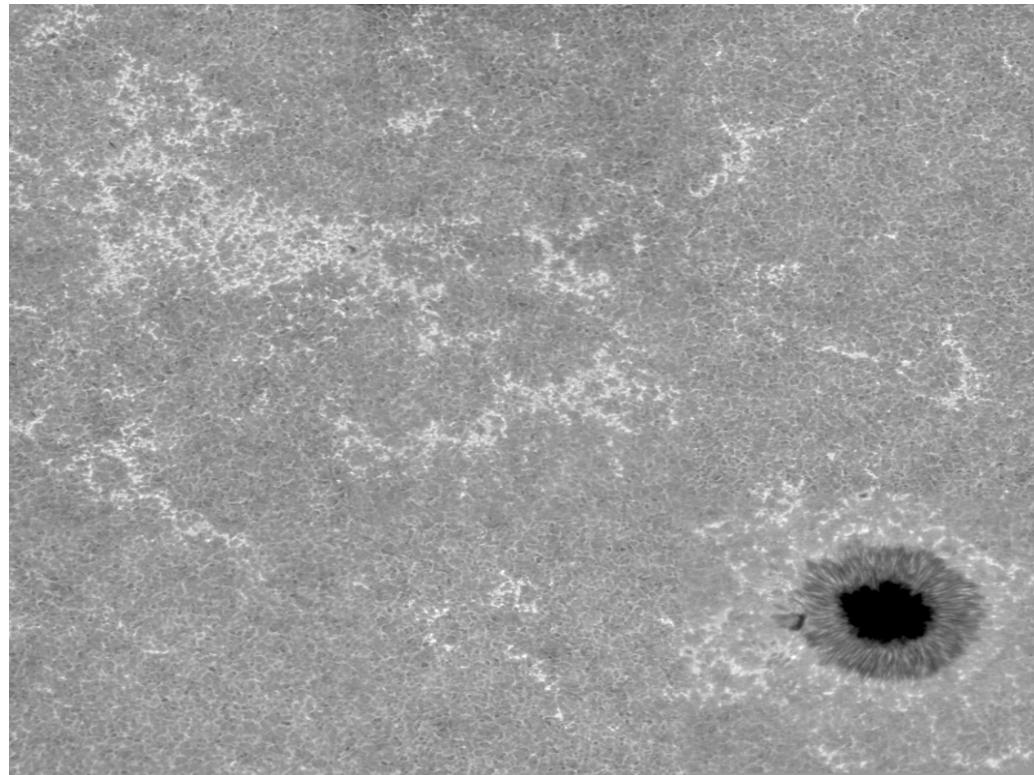
5. Chromospheric lines: DKIST instruments

Calcium Lines

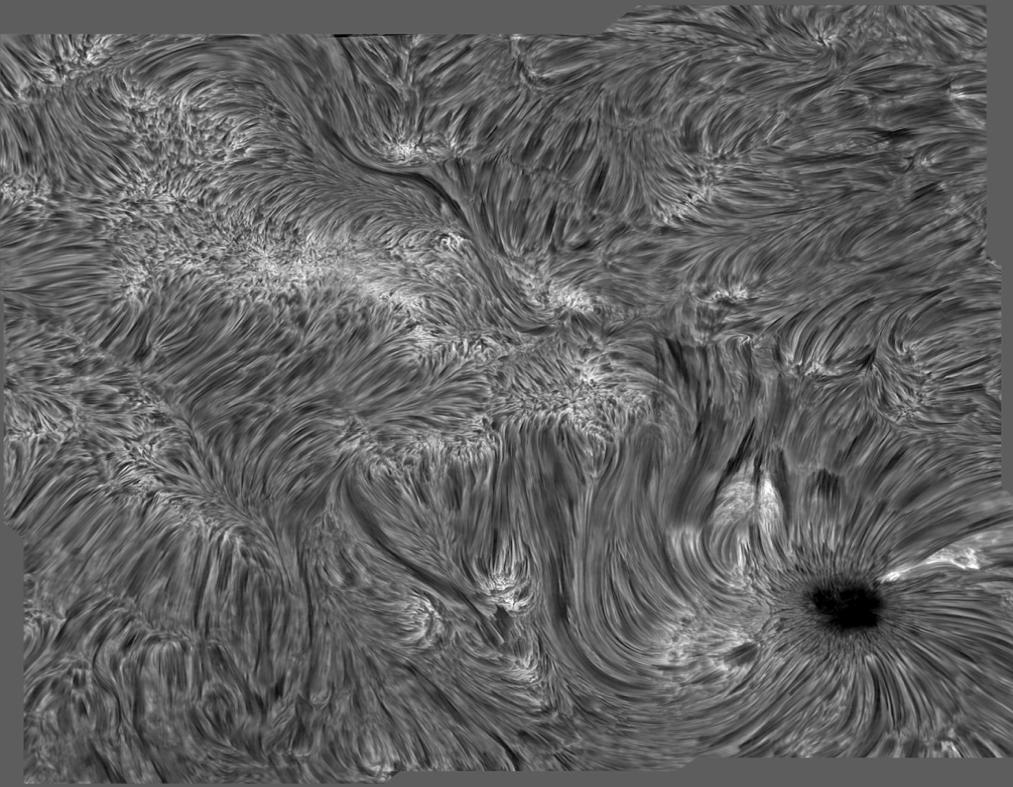
<u>Spectral Window</u>	<u>Observing Mode</u>	<u>Spatial Resolution</u>	<u>DKIST Instrument</u>
393.3 nm	filtergram	0.022" ; 16km	VBI
393.3, 396.8 nm	spectrograph	0.04" x 0.06" ; 30 x 40 km	ViSP
854.2 nm	spectral scan	0.043" ; 30 km	VTF
854.2 nm	Imaging spectrograph	0.06", 0.15" ; 43, 108 km	DL-NIRSP
854.2, 849.8, 866.2 nm	spectrograph	0.04" x 0.06" ; 30 x 40 km	ViSP

Helium Lines

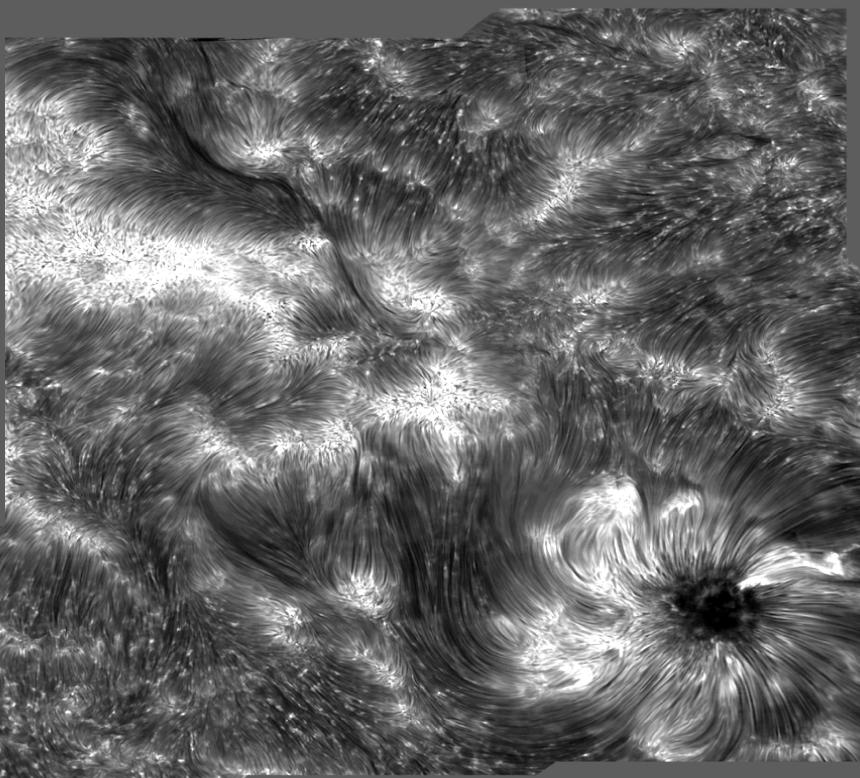
<u>Spectral Window</u>	<u>Observing Mode</u>	<u>Spatial Resolution</u>	<u>DKIST Instrument</u>
1083.0 nm	Imaging spectrograph	0.06", 0.15" ; 43, 108 km	DL-NIRSP
1083.0 nm	spectrograph	0.24 x 0.30" ; 175 x 215 km	Cryo-NIRSP
587.6 nm	spectrograph	0.04" x 0.06" ; 30 x 40 km	ViSP

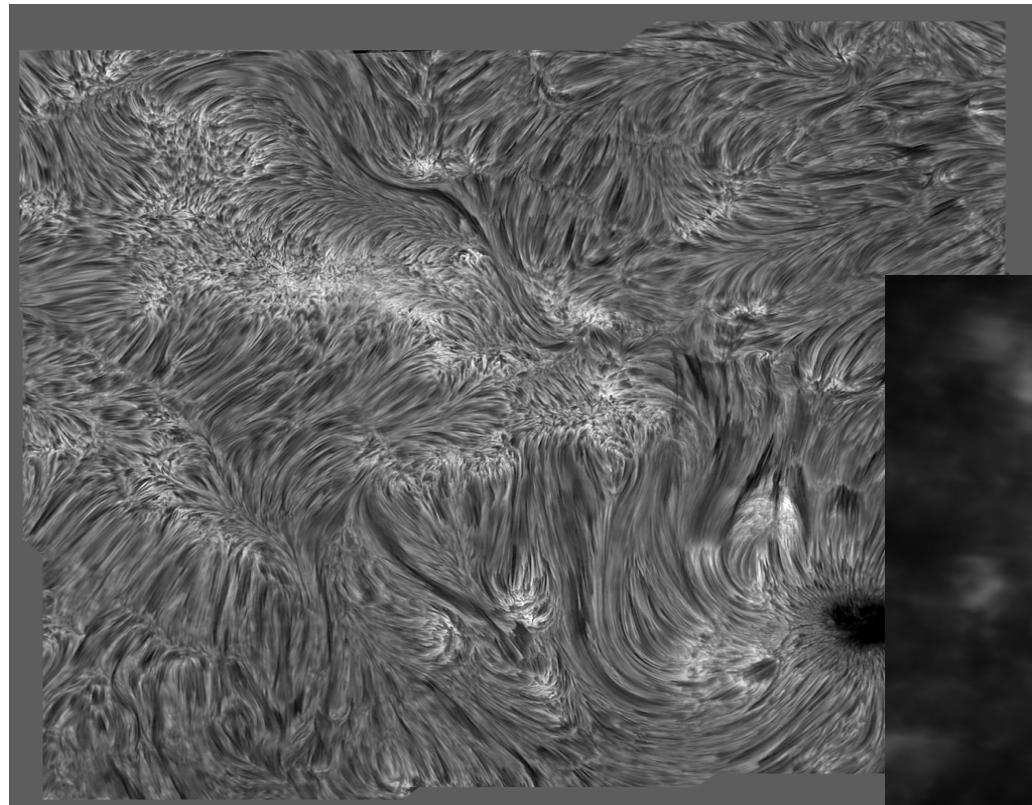


IBIS
 $\text{H}\alpha$ 6563 Å



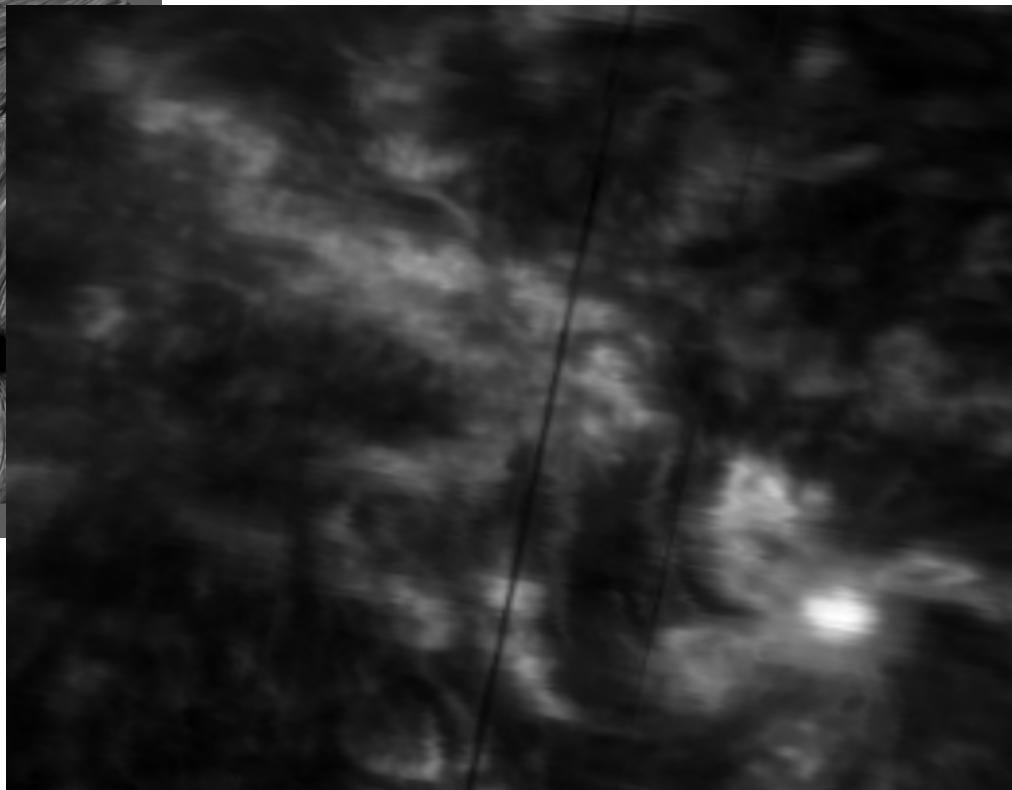
IBIS
Ca II 8542 Å

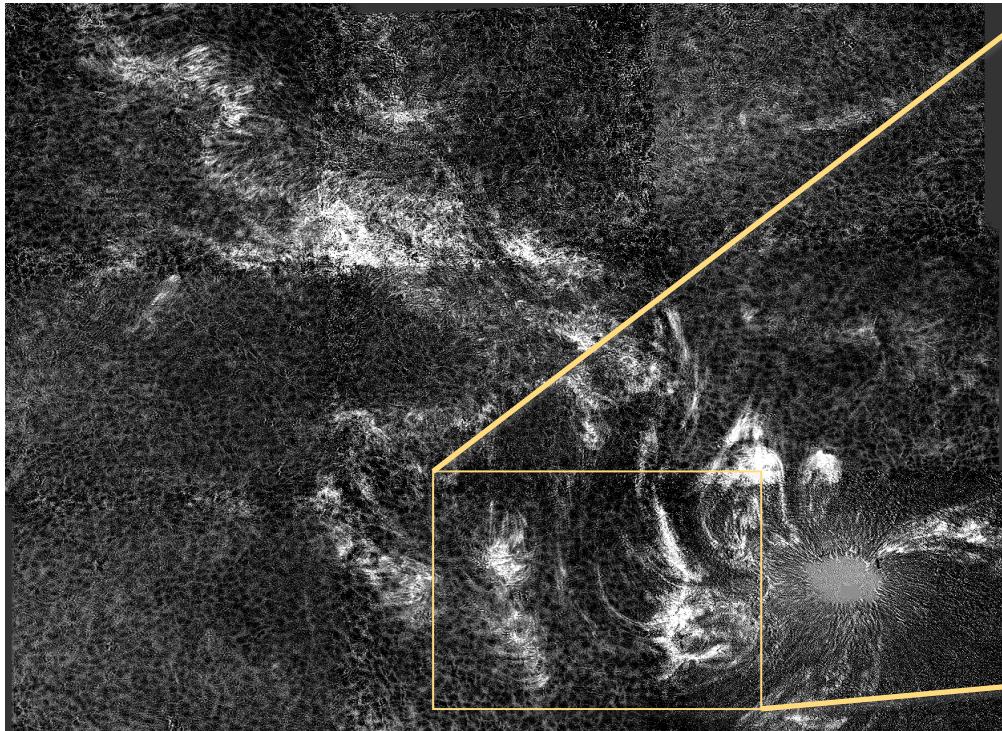




$H\alpha$ 6563 Å

SOLIS He I 10830 Å





IBIS He I D_3 5876 Å

