Visible & near IR DKIST Diagnostics

- *Continua*
- *Molecular bands*
- *Photospheric & Chromospheric lines*
- *Coronal diagnostics*

DKIST
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NSO
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AURA

NSF

1. Continua

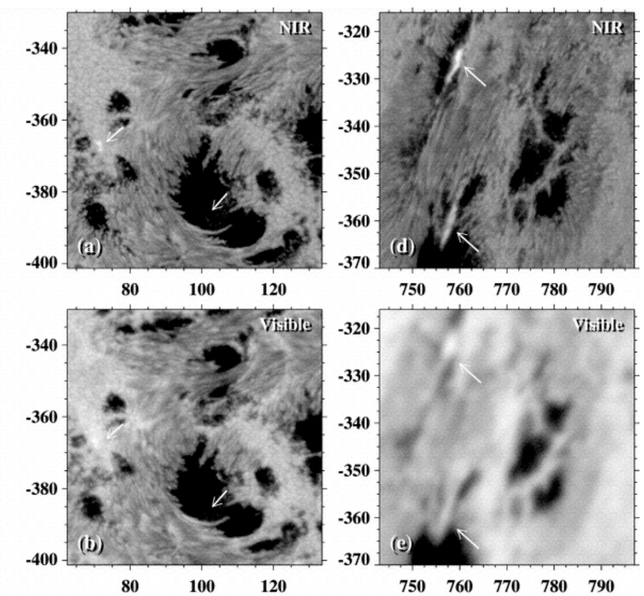
- Visible continuum formed at “base of photosphere”: h~ 0 km (τ_{5000} = 1)
- IR continuum at ~ 1.5 μm forms at continuum opacity minimum – h ~ – 50 km

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

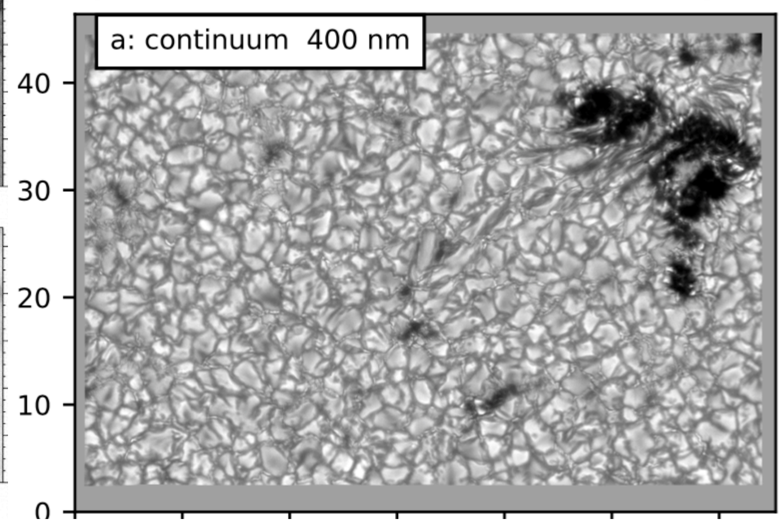
~ DL-NIRSP mid res

~ VBI blue

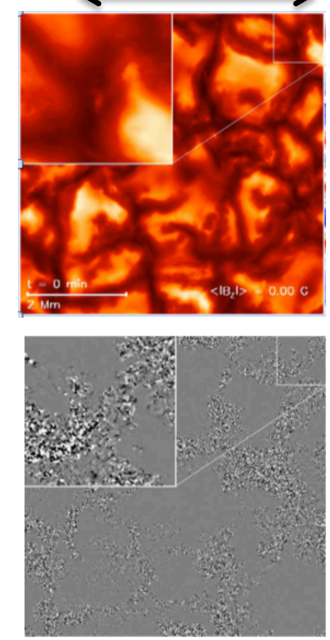
~ VTF



Xu et al 2006



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



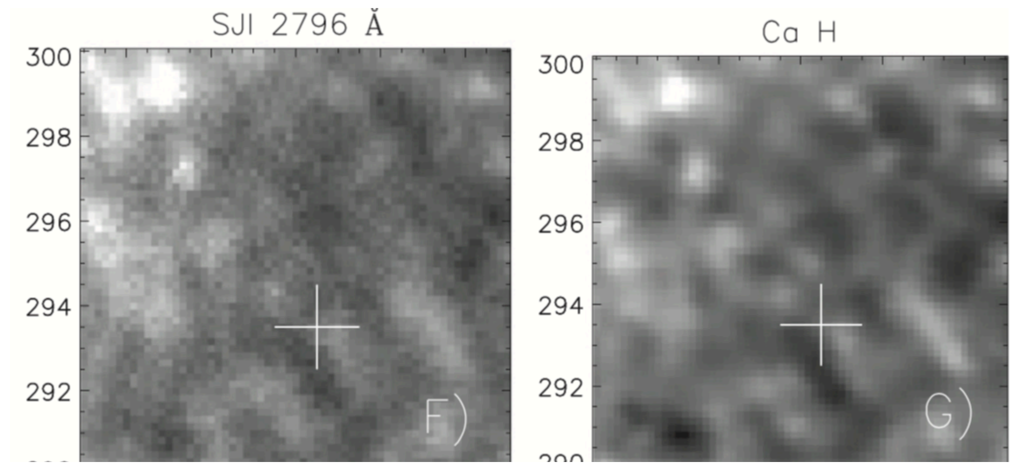
Rempel 2014
8 km res.

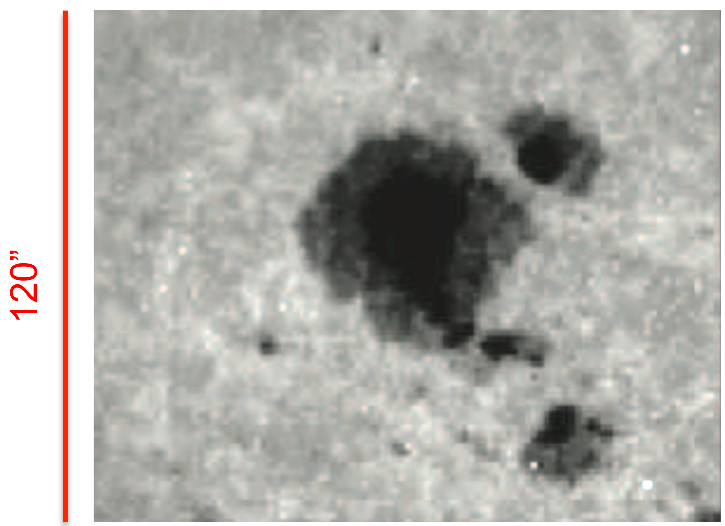
1. Continua

- IR continuum (~ 3-4 μm and above) forms higher in the atmosphere, ~ mid-photosphere (like, e.g. 170nm channel of AIA, or IRIS SJI 279.6)

Reverse granulation, waves, shocks

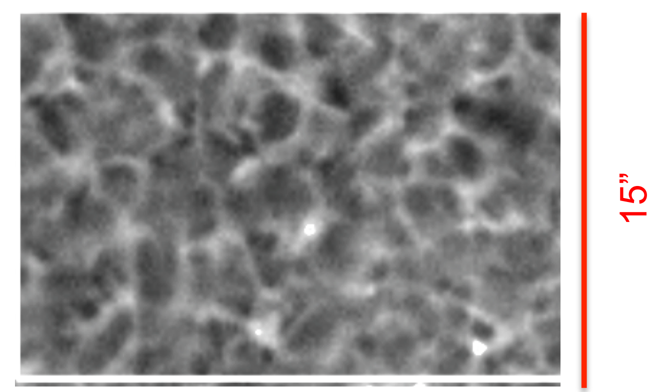
UV vs. Ca II H filter
Martinez-Sykora et al 2015,





Penn et al 2016, 5 μm

Janssen & Cauzzi, 2006,
Ca II 854.2 wing;



1. Continua: DKIST instruments

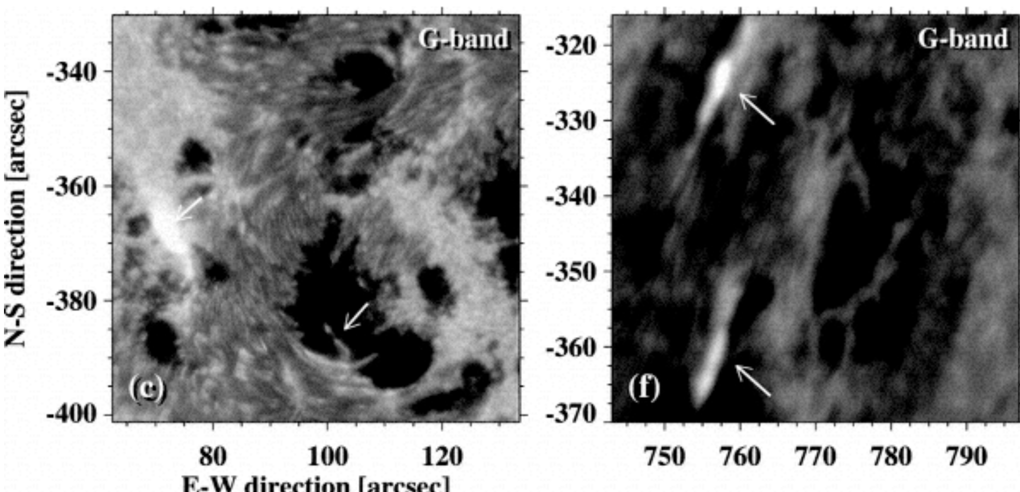
Spectral Window	Spatial Resolution (*)	DKIST Instrument
450.3 nm	0.022” ; 16 km	VBI
668.4 nm	0.034” ; 25 km	VBI
590, 630, 660, 860 nm	0.030 – 0.043”; 20-40 km	VTF (broad band)
860, 1080 nm	0.06”, 0.15” ; 43, 108 km	DL-NIRSP
1565 nm	0.08”, 0.15” ; 60, 108 km	DL-NIRSP
1080, *[2300, 3000,]* 3900, 4600 nm	0.24 x 0.30” ; 175 x 215 km	Cryo-NIRSP *[not at first light]*
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

(*) nominal diffraction limit of a 4-m telescope at that wavelength

2. Molecular lines, bands

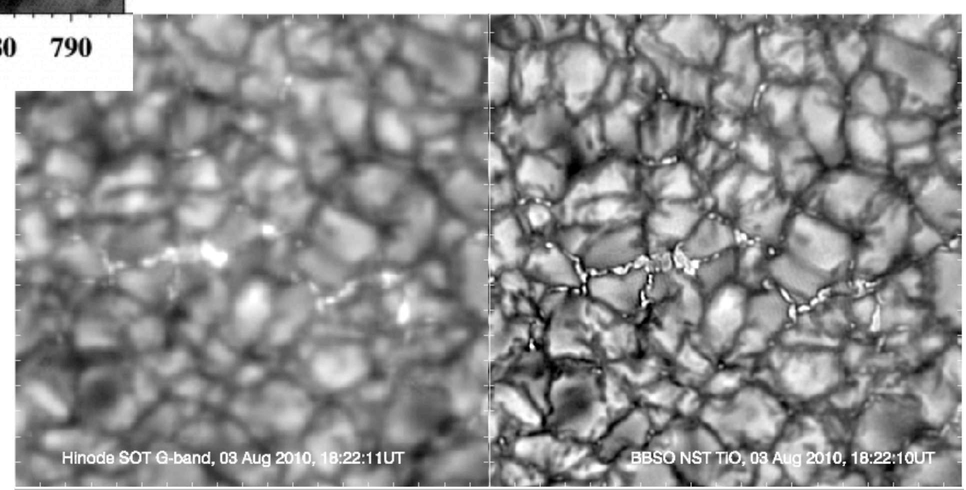
- Formed in the low photosphere, provide large intensity contrast for “hot” vs. “cold” structures (strong T dependence of opacity). E.g. TiO, CN (G-band), CH.

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



Xu et al 2006

Hinode G-band vs. NST TiO (2010)



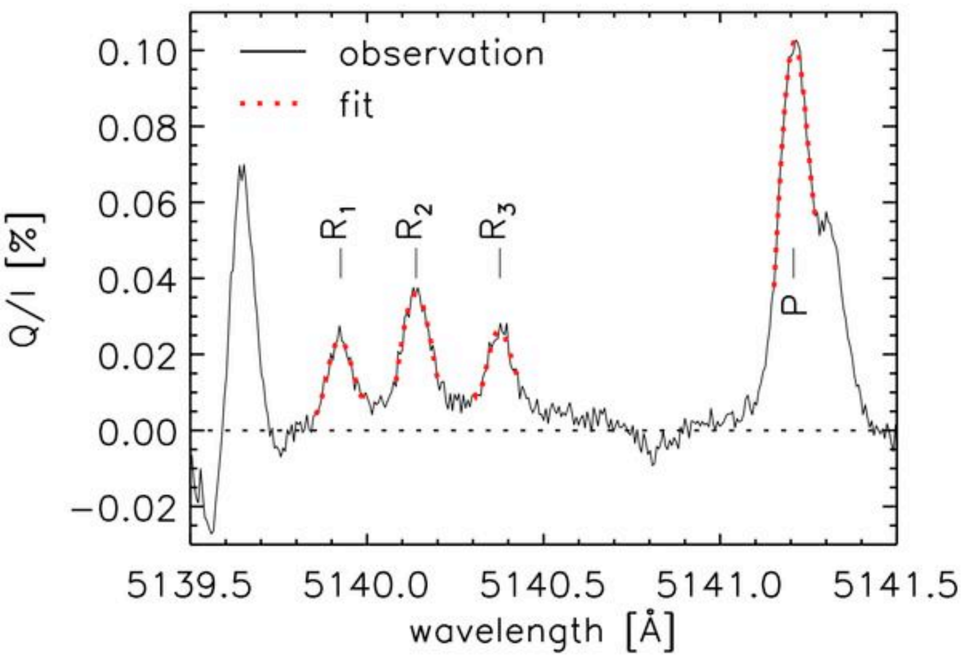
2. Molecular lines, bands

- Sensitive to Hanle effect, e.g. MgH, C_2 lines.
- Presence of molecular lines indicate low temperatures – e.g. CO roto-vibration transitions at 4.7 μm, require T_e < 3700 K.

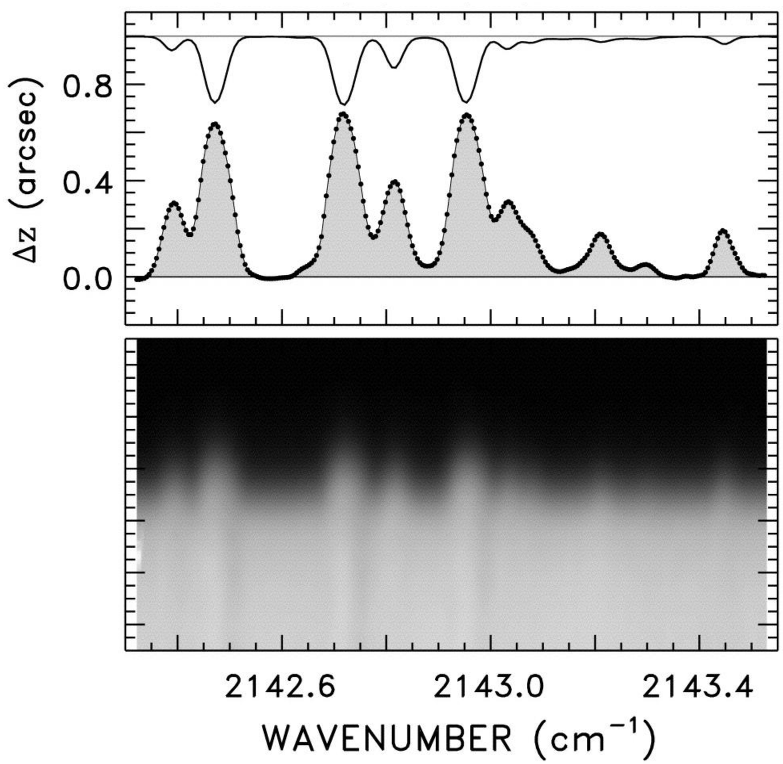
Investigate small scale, tangled magnetic fields in the photosphere (e.g. via differential Hanle effect)

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

Kleint et al 2010;
C_2 R triplet + P triplet



Ayres, 2002;
Emission 7-800 km above limb



2. Molecular lines: DKIST instruments

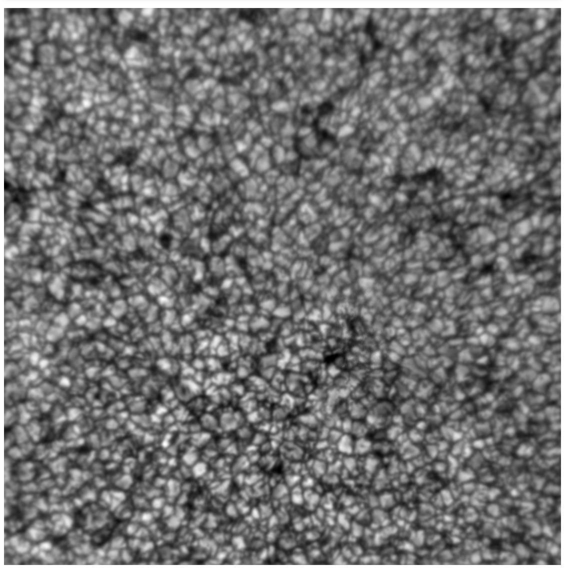
Spectral Window	Spatial Resolution (*)	DKIST Instrument
430.5 nm – G-band (CH)	0.022” ; < 20 km	VBI
707.8 nm – TiO	0.034” ; 25 km	VBI
2326 nm – CO (1st overtone)	0.24 x 0.30” ; 175 x 215 km	Cryo-NIRSP *not at first light*
4651 nm– CO (fundamental)	0.24 x 0.30” ; 175 x 215 km	Cryo-NIRSP Spectrograph
4651 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

(*) nominal diffraction limit of a 4-m telescope at that wavelength

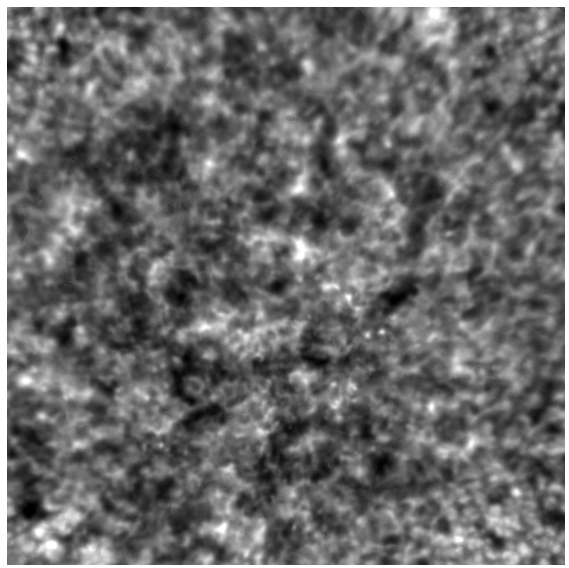
3. Non-magnetic photospheric lines

- 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 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}*

95”

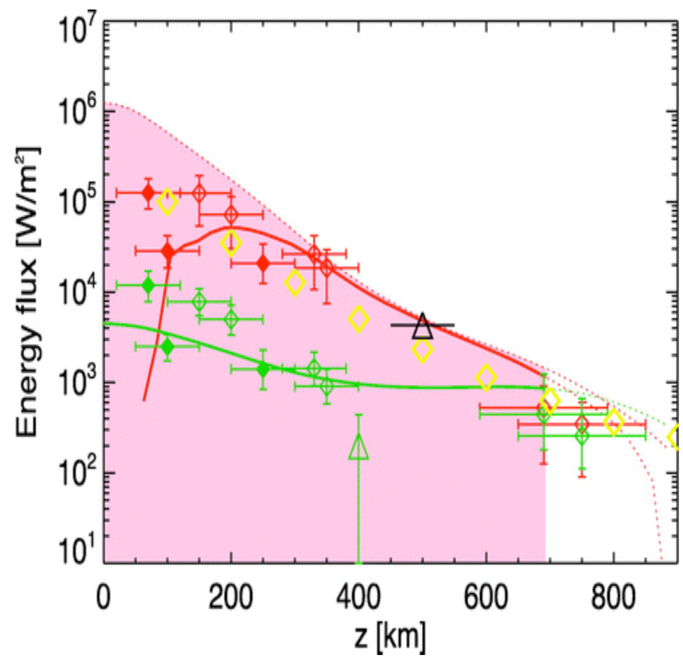


Whitelight (IBIS)



Fe I 543.4 nm Line Core (IBIS)

Gravity Waves

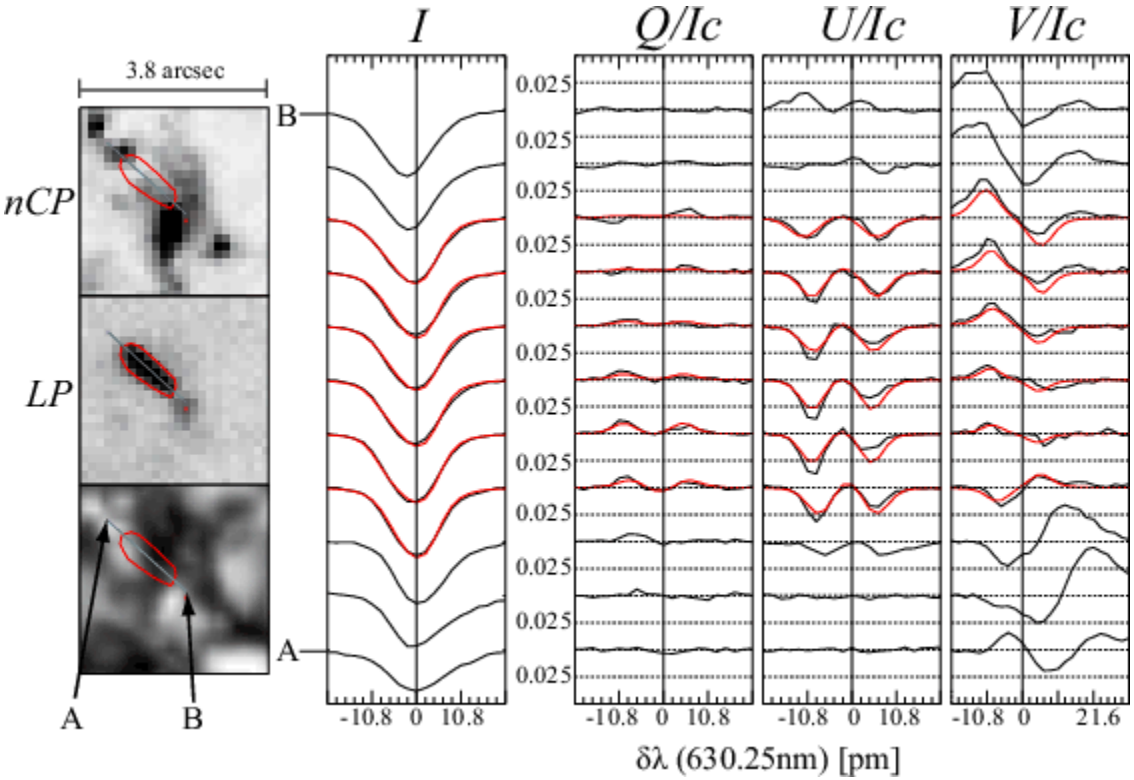


Straus et al 2008

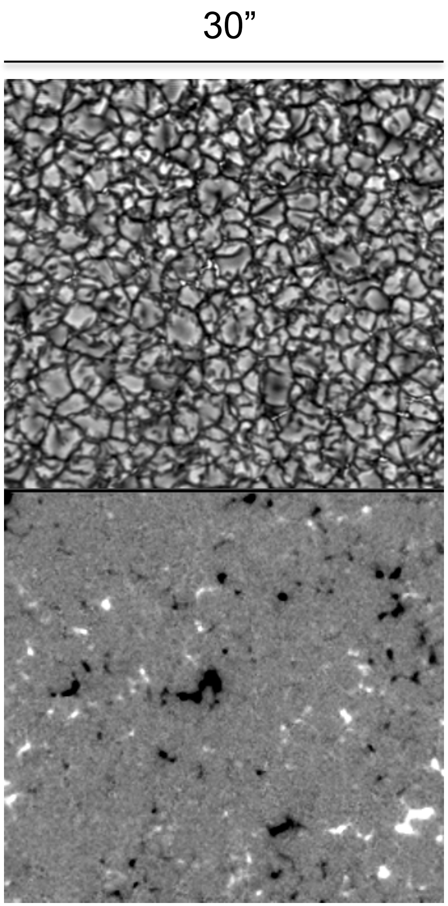
3. Non-magnetic photospheric lines: DKIST instruments

Lines	Spatial Resolution	DKIST Instrument
Fe I 709.9 nm	0.035”; 26 km	VTF – *not at first light*
390 – 900 nm	0.04” x 0.06” ; 30 x 40 km	ViSP

4. Zeeman–sensitive photospheric lines



Ishikawa, et al., 2008



IBIS – White Light and Circular polarization

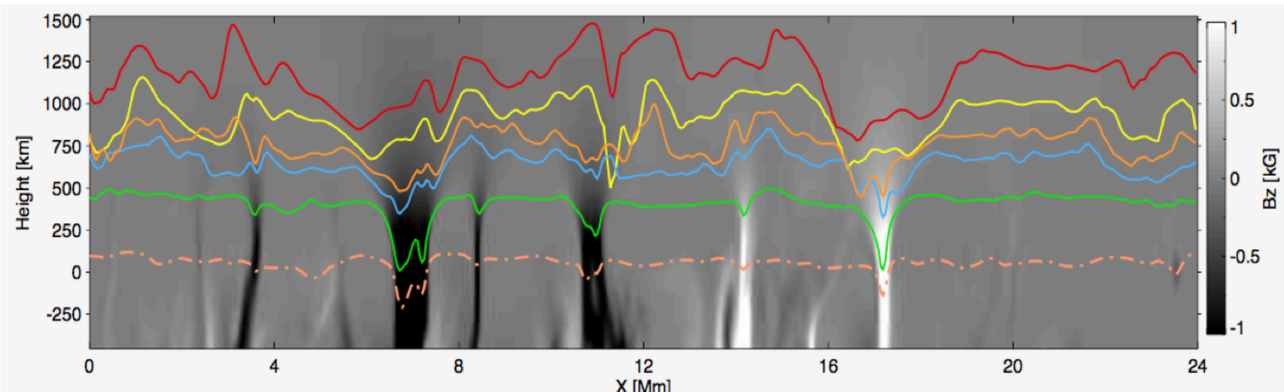
4. Zeeman–sensitive photospheric lines

Lines	Used By	DKIST Instrument
Fe I 524.7, 525.0 nm	IMaX	ViSP, VTF – *not at first light*
Fe I 617.3 nm	HMI, IBIS	ViSP
Fe I 630.1, 630.2 nm	ASP, Hinode SOT/SP, IBIS	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

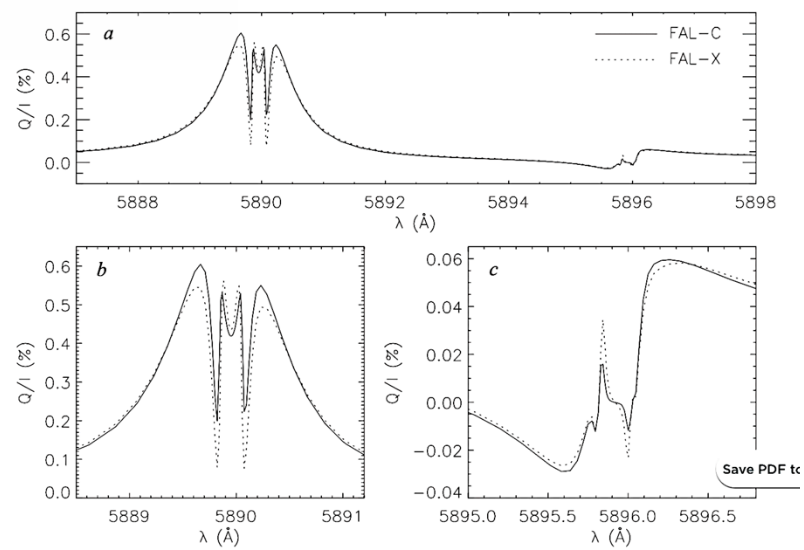
- Resonance lines of alkali – e.g. Na I D_1, D_2; K I D_1 (small g_L but sensitive to velocitiy)

Scattering polarization; magnetism at T_{min} , flares



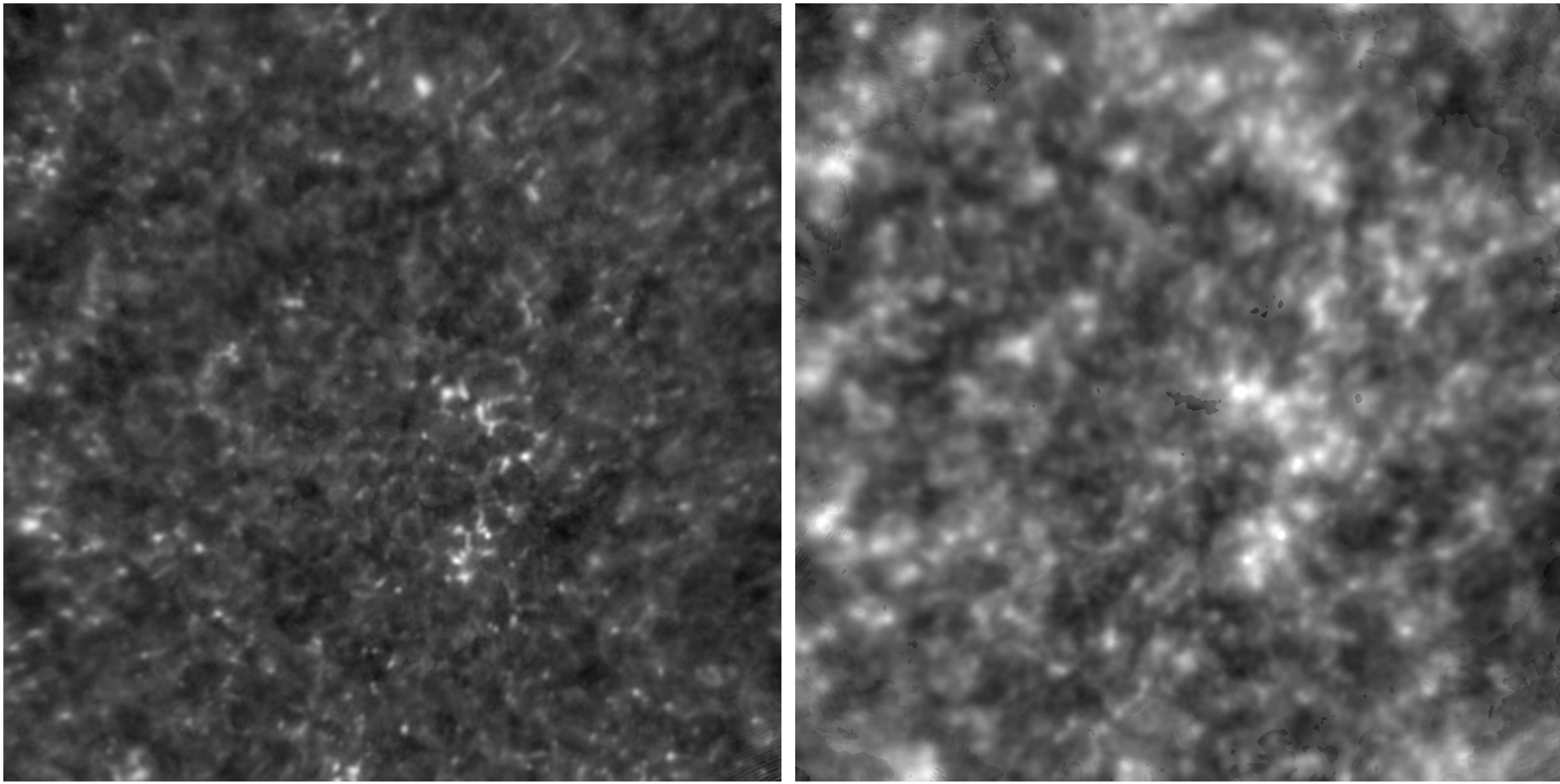
Height where τ=1 for the line core of Na I D_1 (orange), Mg I b_2 (blue), K I D_1 (green), Ca II 8498 Å (yellow), and 8542 Å (red). Dashed orange to τ=1 at continuum wavelengths.

Quintero Noda 2018



Belluzzi et al 2015
Scattering polarization in Na D lines

K I 7699 Å　　　　Na D_1 5896 Å



IBIS data

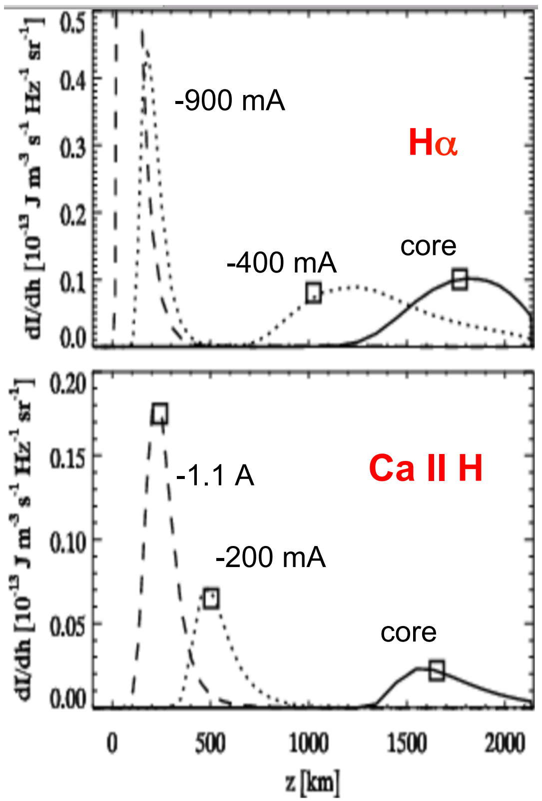
4.5 Magnetic middle-atmospheric lines: DKIST instruments

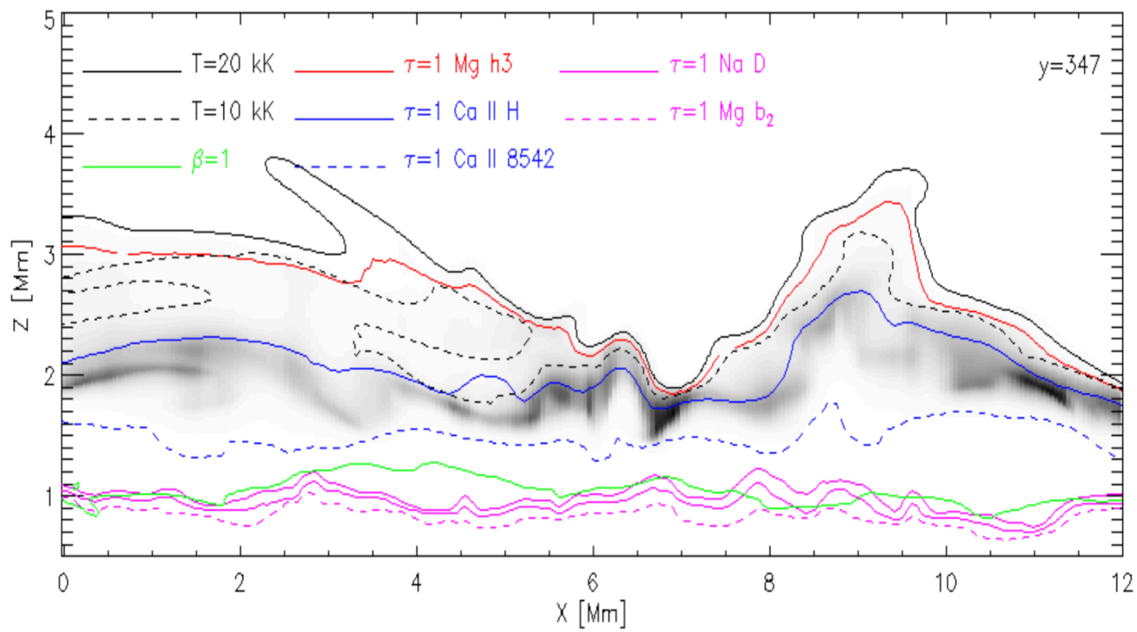
Lines	Spatial Resolution	DKIST Instrument
Na I 589.0 nm	0.03”; 22 km	VTF
Na I 589.0 nm Na I 589.6 nm K I 769.9 nm Mg I 517.3 nm 390 – 900 nm	0.04” x 0.06” ; 30 x 40 km	ViSP

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 D_3 (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.

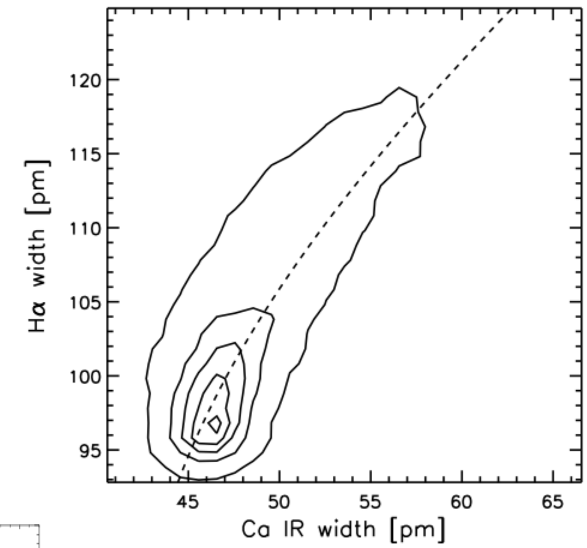




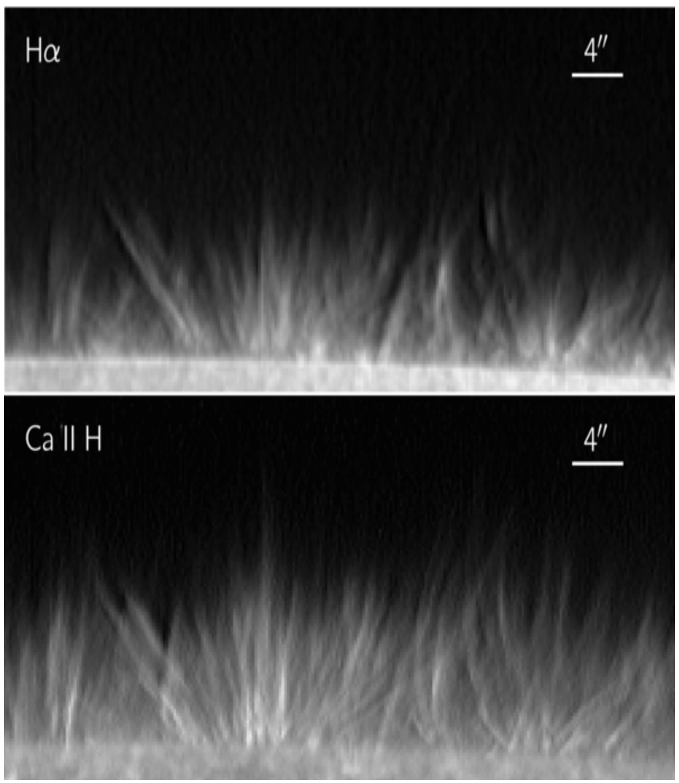
Courtesy of M. Carlsson

5. Chromospheric lines

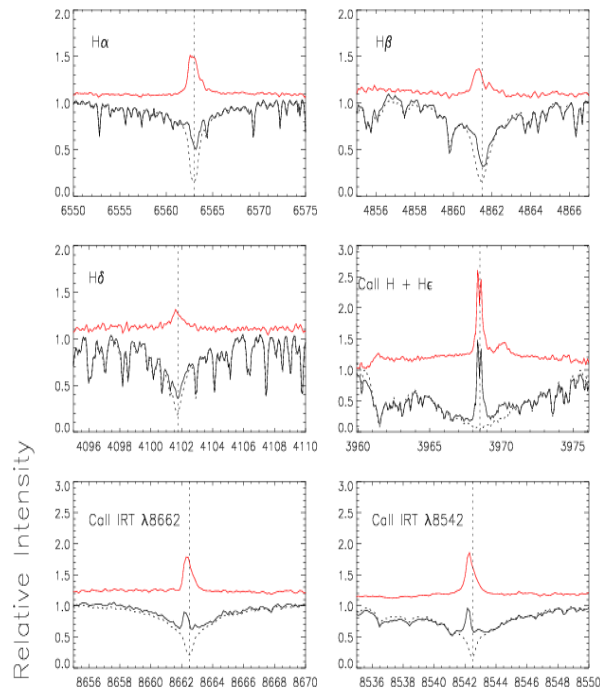
- *Hα, Balmer series: dynamics, temperature, density, depth of TR*
- *Paschen lines: electric fields*
  CaII lines: chromospheric dynamics, temperature, chrom. mag. fields
- *HeI: dynamics, density in flares (esp. D_3), chromospheric mag. fields*



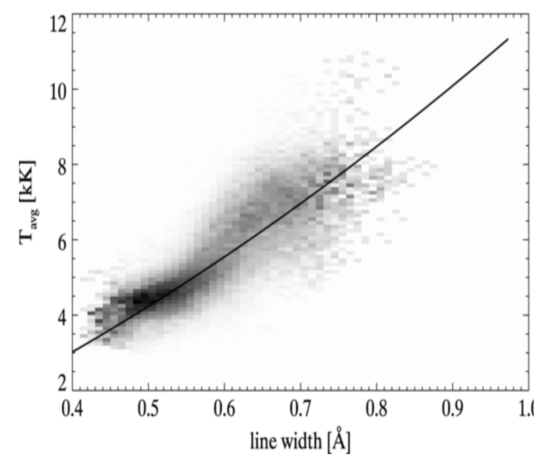
Cauzzi et al. 2009



Pereira et al 2013



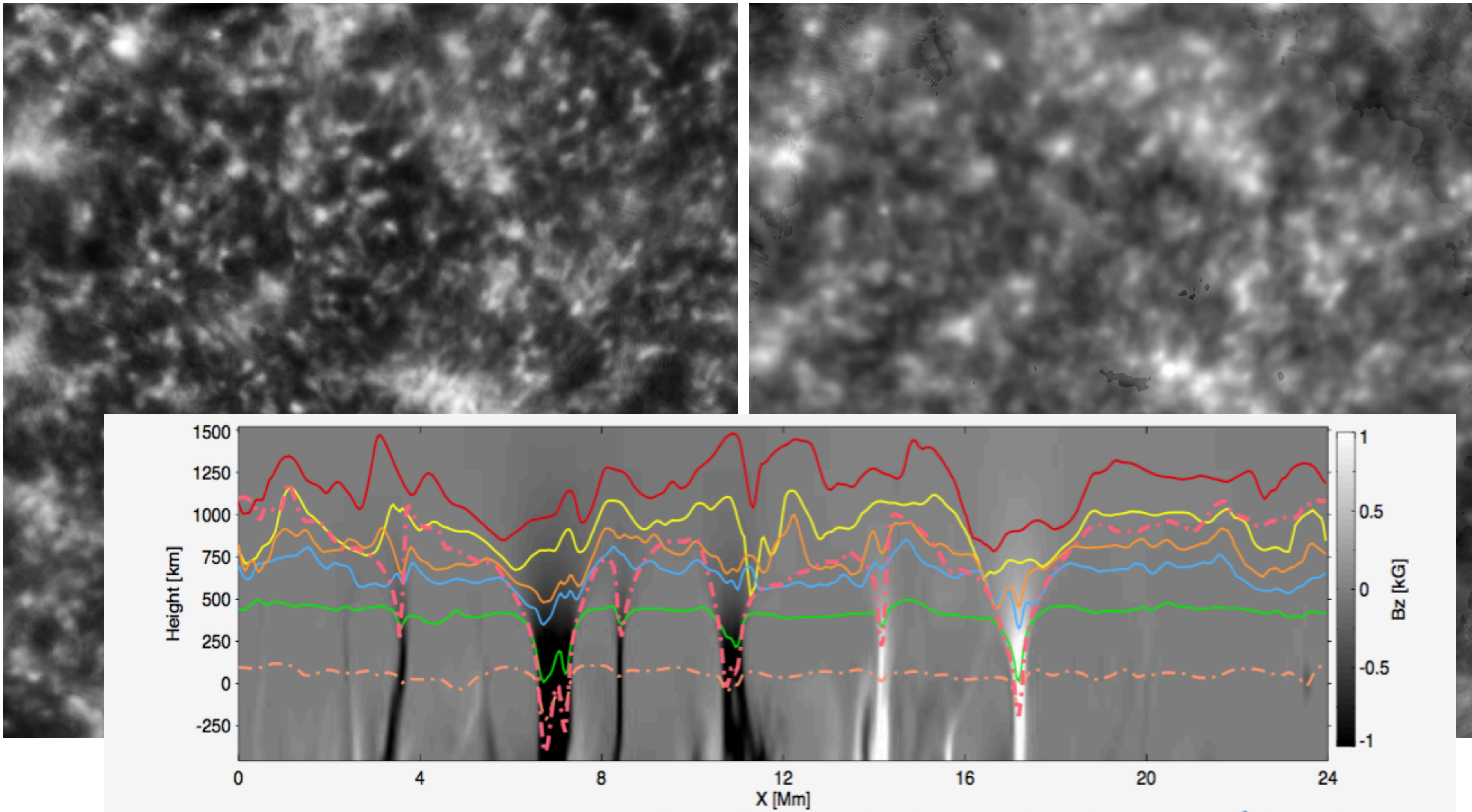
Garcia Alvarez et al 2005



Leenaarts et al 2012

Ca II 8542 Å

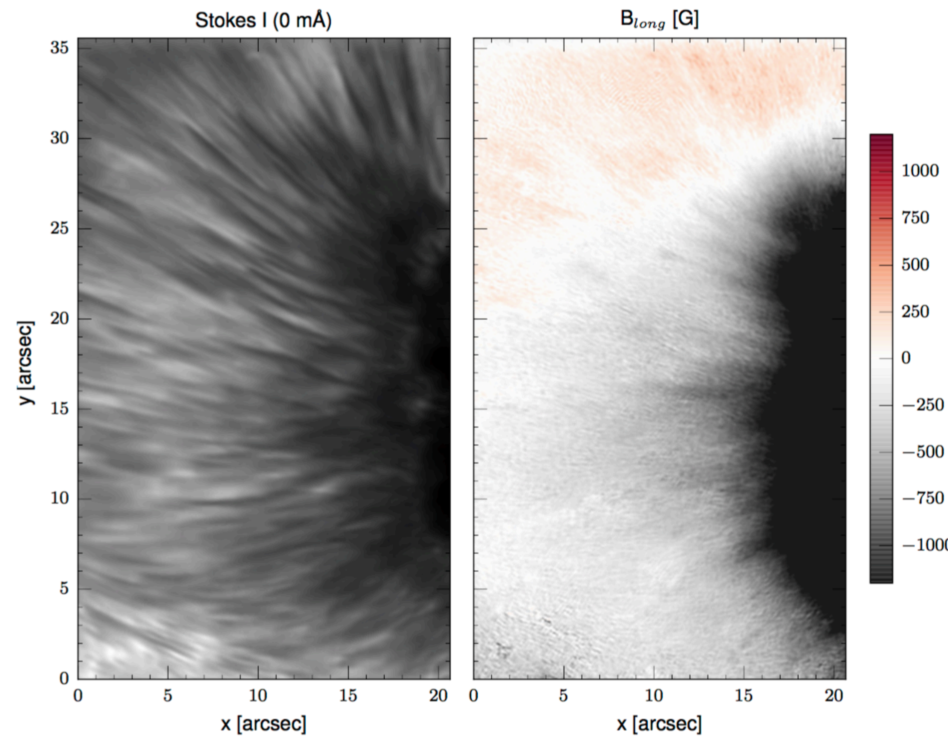
Na D_1 5896 Å



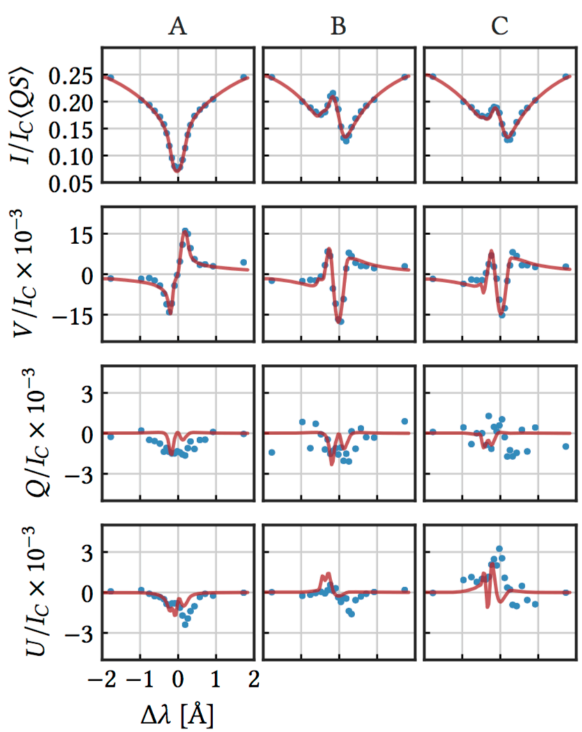
Quintero Noda 2018; dot-dashed pink line is β=1 surface; red represents τ=1 for CaII 854.2 core

CaII 854.2 nm

- Sensitive to Zeeman effect (gL=1.1)
- Sensitive to temperature stratification
- Encodes velocity gradients
- Essentially the ONLY line currently used to diagnose magnetic field in mid-chromosphere



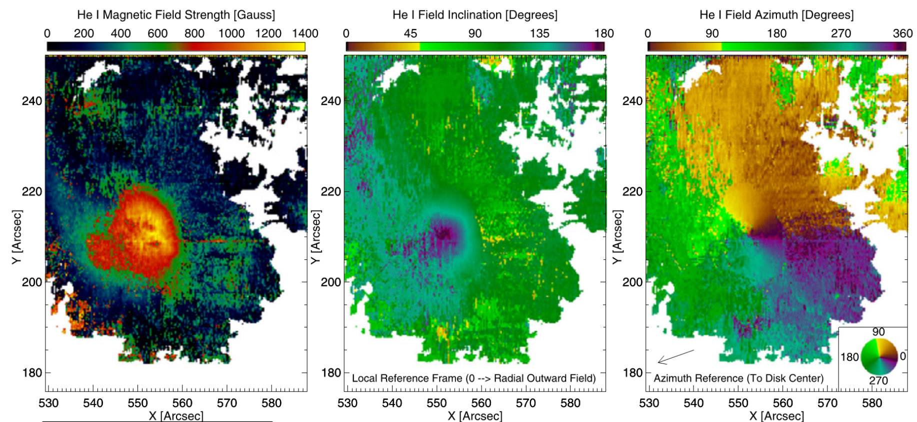
de la Cruz Rodriguez et al. 2013 (using WFA)



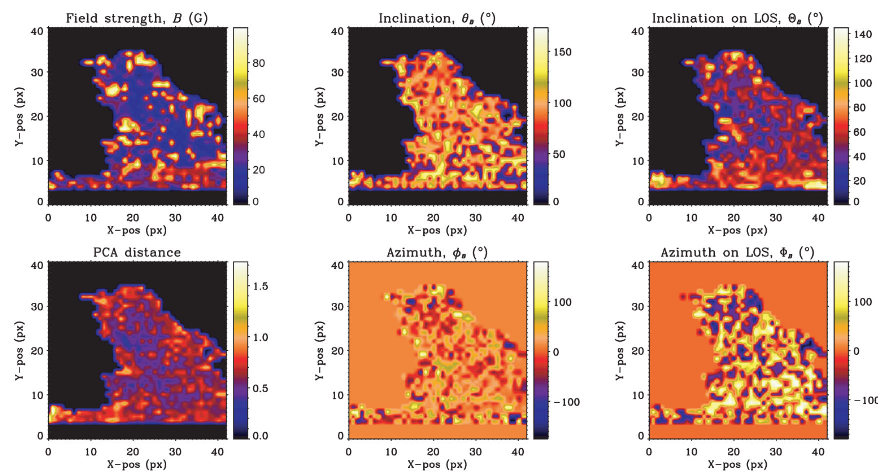
Joshi & de la Cruz Rodriguez (2018)

HeI Infrared triplet (1083 nm)

- The He I Triplet system has well-known advantages for chromospheric polarimetry. Formed by PR mechanism, sensitive to *both* chromosphere and coronal conditions.
- Formed in a (relatively) thin and localized range of heights -> slab model.
- Strongest transitions at 1083 nm and 587.6 nm (D3) have Hanle sensitivity up to 10 and 50 Gauss respectively.
- Useful for active region magnetic field mapping in the chromosphere as well as cool material in the corona!



Schad et al. (2015)



Casini and Lopez-Ariste (2002)

5. Chromospheric lines: DKIST instruments

Hydrogen Lines

Spectral Window	Observing Mode	Spatial Resolution	DKIST Instrument
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

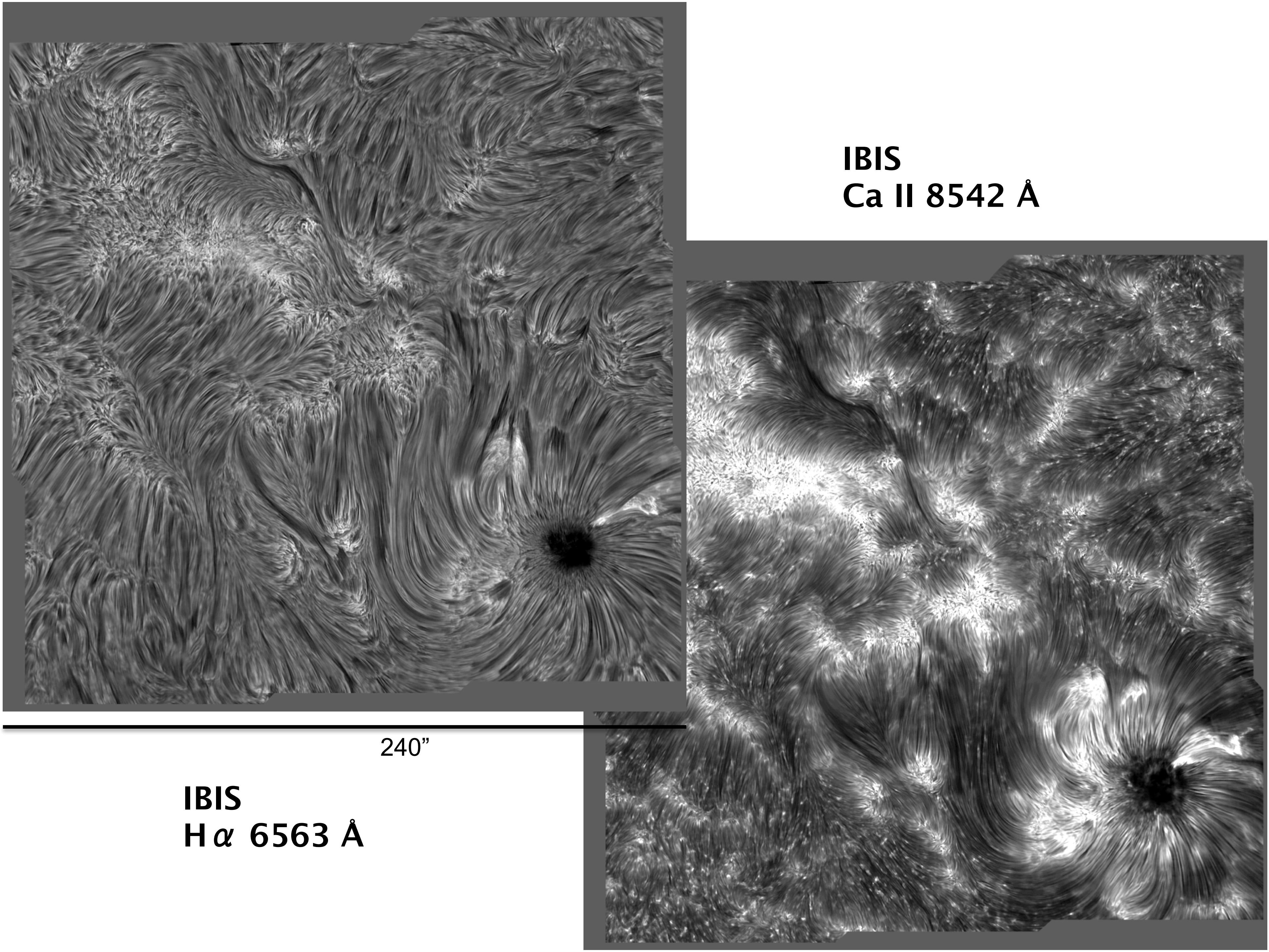
5. Chromospheric lines: DKIST instruments

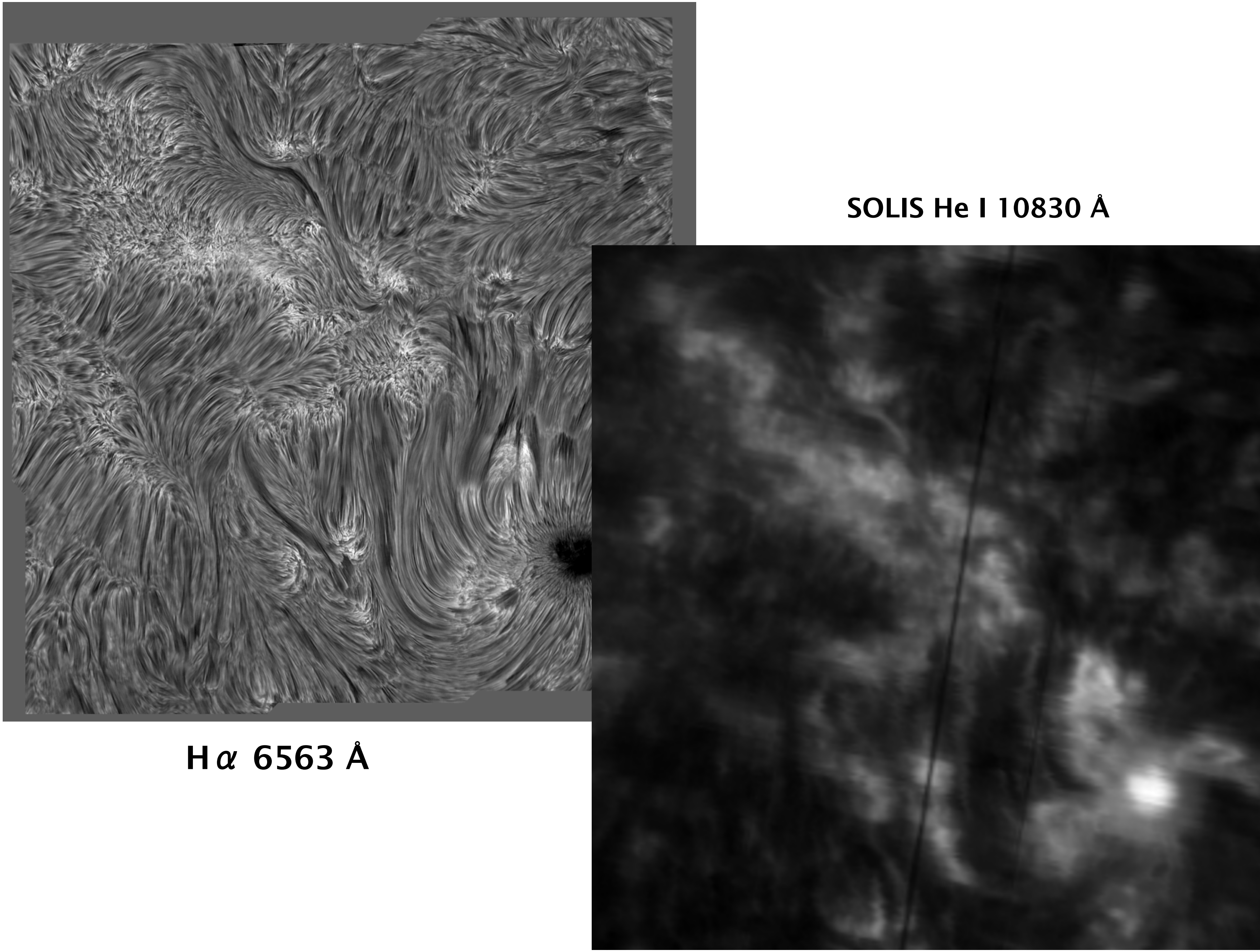
Calcium Lines

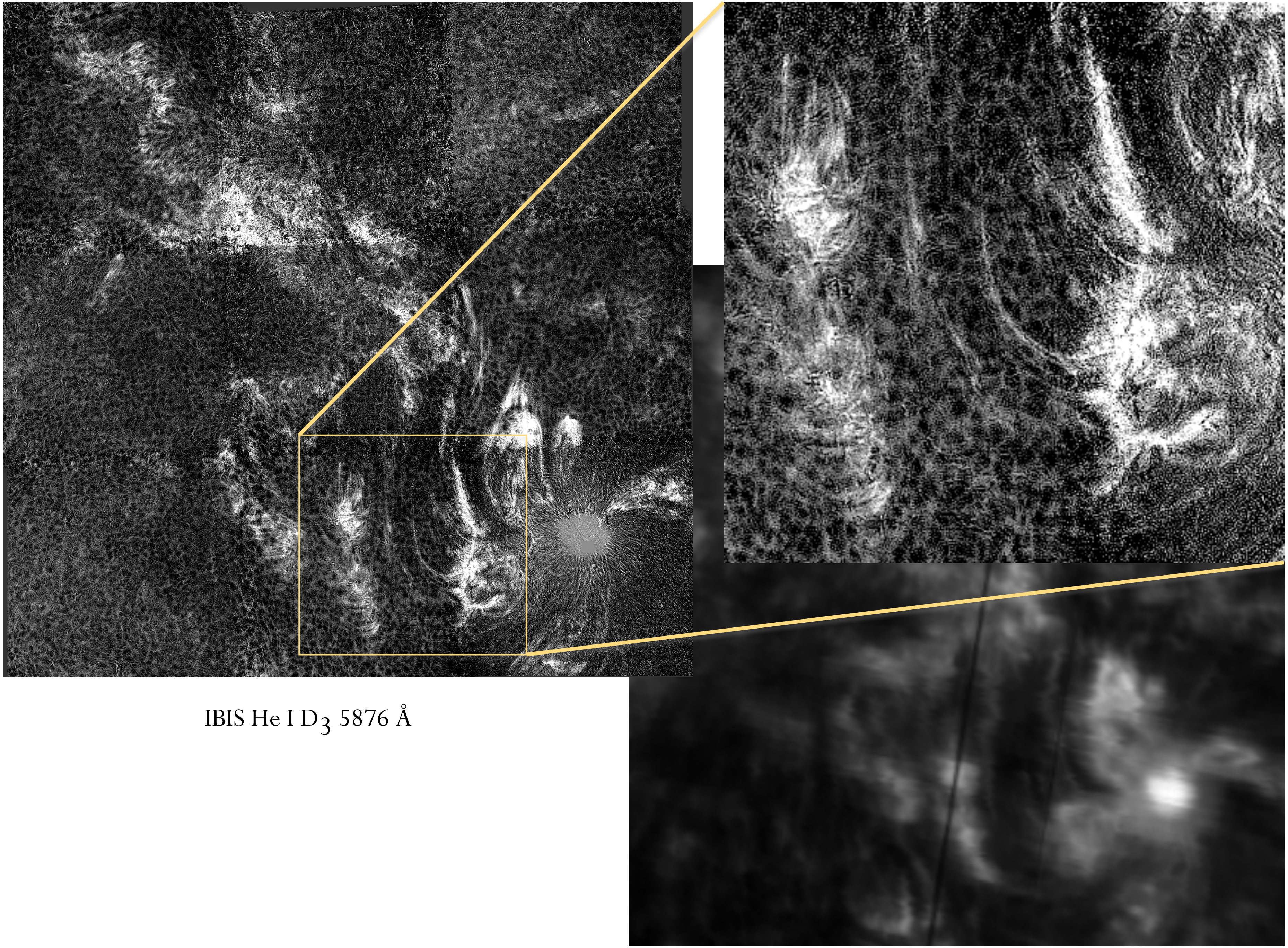
Spectral Window	Observing Mode	Spatial Resolution	DKIST Instrument
393.3 nm	filtergram	0.022” ; 16km	VBI
393.3, 396.8 nm	spectrograph	0.04” x 0.06” ; 30 x 40 km	ViSP
854.2 nm	spectral scan	0.043” ; 30 km	VTF
854.2 nm	imaging spectrograph	0.06”, 0.15” ; 43, 108 km	DL-NIRSP
854.2, 849.8, 866.2 nm	spectrograph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

Helium Lines

Spectral Window	Observing Mode	Spatial Resolution	DKIST Instrument
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

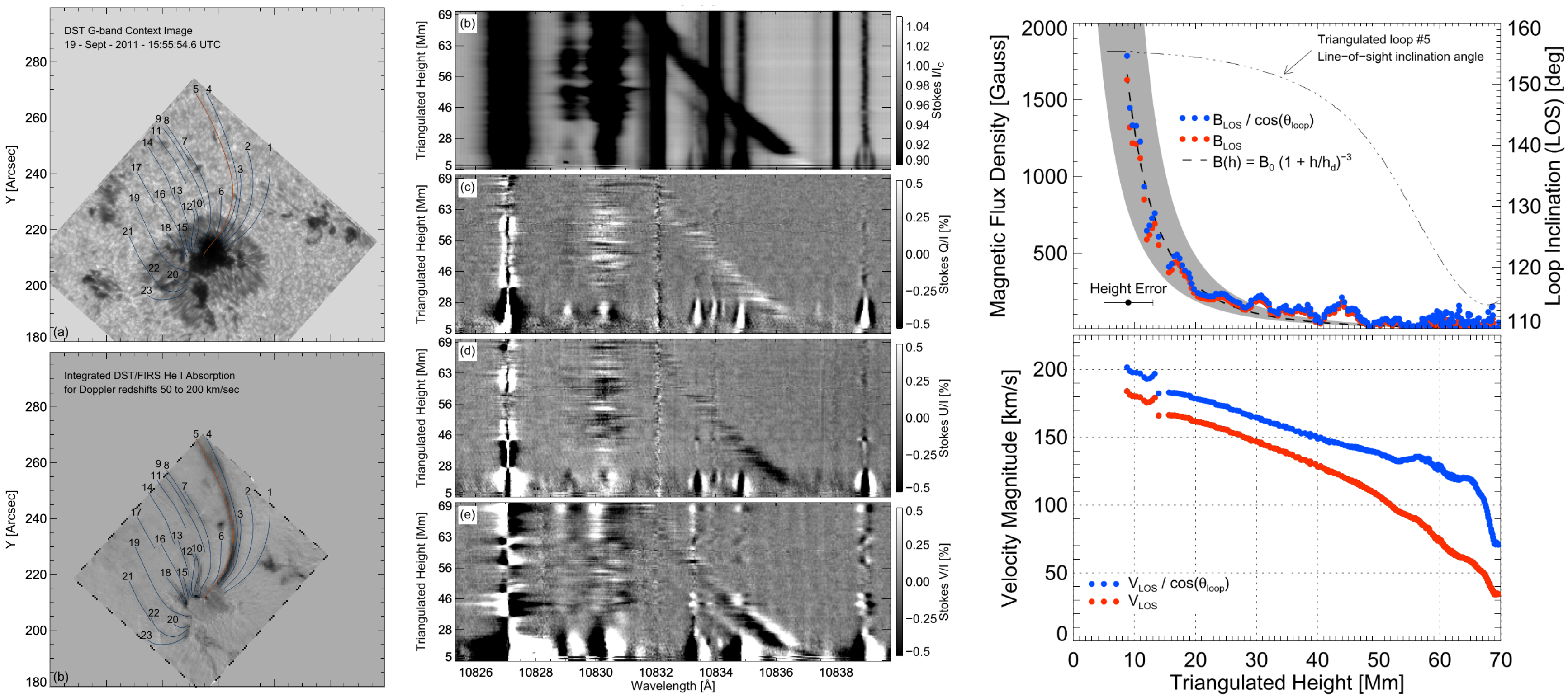

IBIS
Ca II 8542 Å
240”
IBIS
Hα 6563 Å


SOLIS He I 10830 Å
Hα 6563 Å



IBIS He I D_3 5876 Å

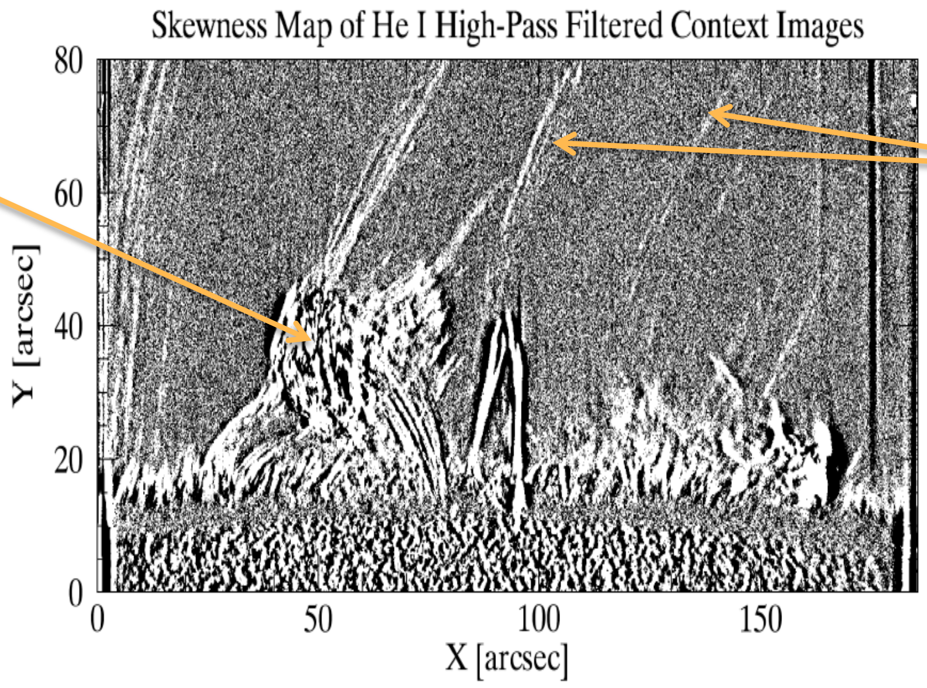
Chromospheric diagnostics II….towards the corona



He I polarimetry of down-flowing material on disk provides vector coronal magnetic field measurements (Schad et al. 2016)

Chromospheric diagnostics II…towards corona rain

Prominence



He I 10830 coronal rain

Exciting prospects to perform He I triplet polarimetry of coronal rain. See ***CSP Use Case #50.***