# Synergy with Hinode SOT/SP

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DKIST CSP Workshop at Nagoya University





#### SOT Spectro-Polarimeter (SP)

- Scanning slit spectrograph for polarimtetry.
- Stokes IQUV profiles of two Fe lines at 630nm

SP Specifications	
Slit width	0.16"
Spectral resolution	30 mA
Spectral sampling	21.5 mA
FOV (slit)	164" (N-S) max
FOV (scan)	320" (E-W) max



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(Tsuneta et al. 2008; Lites et al. 2013)

#### Flexible in mapping

Mode of operation	Normal	Fast	Dynamics	Deep	
Time per position	4.8s (3 rots)	3.2s (1+1rots)	1.6s (1 rot)	12.8s (up to 8 rots)	
Polarimetric S/N	10^3	1.15 x 10^3	580	>10^3	
Sampling along slit	0.16"	0.32"	0.16"	0.16"	
FOV along slit	164" (max)	164" (max)	32" (max)	164" (max)	
Slit-scan sampling	0.16"	0.32"	0.16"	0.16"	
Slit-scan FOV	320" (max) wide				
Time for map area (1)	83min for 160" wide	30min for 160" wide			
	50s for 1.6" wide	18s for 1.6" wide	for 18s for "wide 1.6" wide		
Data rate	191k pix/s	127k pix/s	120 kpix/s	73k pix/s	

#### Map data volume

• 2500-3500 Mbits per day for SP, depending on the resource available.

Normal map (0.16" pix)	FOV	Data	Duration	Data volume
	320"x164"	2000x(1024x112x1x4)	166 min	2280 Mbits
	164"x164"	1024x(1024x112x1x4)	85 min	1160 Mbits
	123"x123"	768x(768x112x1x4)	64 min	660 Mbits
	82"x82"	512x(512x112x1x4)	43 min	290 Mbits
	19"x82"	120x(512x112x1x4)	10 min	68 Mbits
	3.8″x82″	24x(512x112x1x4)	2 min	14 Mbits

Fast map (0.32" pix)

Normal

FOV	Data	Duration	Data volume
320"x164"	1000x(512x112x1x4)	60 min	600 Mbits
164"x164"	512x(512x112x1x4)	31 min	310 Mbits
123"x123"	384x(384x112x1x4)	23 min	170 Mbits
82"x82"	256x(256x112x1x4)	15 min	77 Mbits
20"x82"	64x(256x112x1x4)	4 min	19 Mbits
5.1"x82"	16x(256x112x1x4)	1 min	5 Mbits





#### **DKIST First Light Instrument Capabilities**



	Instrument type	Spectral range	Spectral resolution	Spatial sampling	Maximum Instantaneous Field of View	Maximum Sampled Field of View	Peak Cadence	Analogous Instruments
Visible Broadband Imager <i>VBI (Blue)</i>	High Cadence, High Resolution Imager	390–550nm (sequential filter sequencing)	N/A	0.011″	45" x 45"	2' x 2' (sequential field sampling)	3.2 sec (reconstructed) 0.03 sec (raw images)	ROSA, Hinode/BFI High cadence, high spatial resolution
Visible Spectropolarimeter <i>ViSP</i>	Scanning Slit Spectropolarimeter	380-900nm (3 spectral windows at a time)	>180,000	0.0195" (arm 1) 0.0236" (arm 2) 0.0295" (arm 3) [sampling along slit]	5 slits Width x Length 0.028" or 0.041" or 50" (arm 1) 0.053" or x 60" (arm 2) 0.106" or 75" (arm 3) 0.214"	Slit length x 2'	0.5-10 sec per slit position (polarimetry) 0.02-0.2 sec per slit position (intensity-only)	SPINOR, Hinode/SP, IRIS, GRIS Scanning spectrograph, high spectral fidelity
Visible Tunable Filter <b>VTF</b>	Fabry Perot Imaging Spectropolarimeter	520-870nm (sequential scans through multiple spectral lines)	FWHM 6-8 pm	0.014"	60" x 60"	60" x 60"	Typical scan times per spectral line: 0.5-2 s (intensity only); 2-10 s (polarimetry)	IBIS, CRISP, GFPI Imaging spectropolarimeter
Visible Broadband Imager <i>VBI (Red)</i>	High Cadence, High Resolution Imager	600-860nm (sequential filter sequencing)	N/A	0.017″	69" x 69"	2' x 2' (sequential field sampling)	3.2 sec (reconstructed) 0.03 sec (raw images)	ROSA, Hinode/BFI High cadence, high spatial resolution
Diffraction Limited Near Infrared Spectropolarimeter <i>DL-NIRSP</i>	Integral Field Unit Spectropolarimeter	500–900nm 900–1350nm 1350-1800nm (1 filter band per channel)	125,000	0.03" (high res) 0.077" (mid res) 0.464" (wide field)	2.4" x 1.8″ (high res) 6.16″ x 4.62″ (mid res.) 27.84″ x 18.56″ (wide)	2' x 2'	Depends on resolution and and total field of view. E.g. 6s for one tile, on-disk, high resolution, full polarimetry	SPIES True Imaging Spectropolarimeter: simultaneous 2D FOV and spectral information using fiber-fed IFU
Cryogenic Near Infrared Spectropolarimeter <i>Cryo- NIRSP</i>	Scanning Slit Spectropolarimeter	1000-5000nm (1 filter band at a time. About 70 s to switch filters)	100,000 on-disk 30,000 off-limb	0.12" [along slit] (no Adaptive Optics)	<i>2 slits</i> 0.15" x 120" slit 0.5" x 240" slit	4' x 3' (near limb) 5' round (off-limb)	Heavily depends on signal to noise. Maximum frame rate is 10 frames per second e.g. 1s per slit position near-limb/ chromosphere	CYRA (BBSO) Cryogenic, scanning spectrograph, novel diagnostics
Cryo-NIRSP <i>Context Imager</i>	lmager	1000-5000nm (1 filter band at a time, with fast switching time to support sequential observations during a single-band spectrograph scan.)	N/A	0.052″ (no Adaptive Optics)	100" x 100"	4′ x 3′ (near limb) 5′ round (off-limb)	Heavily depends on signal to noise. Maximum frame rate is 10 frames per second e.g. 1s per slit position near-limb/ chromosphere	CYRA (BBSO) Cryogenic, scanning spectrograph, novel diagnostics

This table is meant to give an idea of the capabilities of the DKIST first light instrument suite. It cannot capture the large trade space that is provided by the flexibility of the instruments. For more information, visit http://dkist.nso.edu/CSP/instruments





### Hinode SP – DKIST collaborations

- "Initial" phase
  - Characterizing the polarimetric behaviors of DKIST spectropolarimeters to achieve high polarimetric accuracy.
  - Science!
    - For example. imaging and spectroscopic instruments (Visible broadband imager, Visible tunable filter) with Hinode SP
- Followed by (chromospheric) spectropolarimeters (Cryogenic NiR SP, Diffraction-limited NiR SP)
- Hinode SP Advantages
  - High-accuracy data from seeing free condition
  - Coverage for 24 hours, though the cadence of 2-3 hours
  - Possible to have a larger field of view

#### **Dynamic Chromosphere**





#### Sunspot light bridges Long-lasting chromospheric plasma ejections





#### Behaviors supporting MR

- Bi-directional flows
- Enhanced current along the apex of the LB

(Shimizu et al. 2009, ApJ, 696, L66) (Shimizu 2011, ApJ, 738, 83)

#### Sunspot light bridges Long-lasting chromospheric p



#### Helical weak magnetic flux tube embedded along light bridge



- Bi-directional flows
- Enhanced current along the apex of the LB

Umbral field

ejections

<u>Magnetic field and velocity measurements</u> **at the chromosphere** coordinated at the photosphere

#### Chromospheric jets

Hinode SOT CallH



(Singh et al. 2012 ApJ)

2018/2/27

- Multiple bright, plasma ejections along jets, showing <u>time-dependent</u> as well as <u>intermittent</u> nature of MR in chromosphere
- How much energy is transported upward?

(Shibata+ 2007)





## Example: High cad SP movie



# Comparison between the photosphere and chromosphere



- Sawtooth pattern in IRIS plot
- $\rightarrow$  Signature of shock formation at the chromosphere
- Higher frequency waveforms
- $\rightarrow$  Leakage of high-frequency waves (>6mHz)

2018/2/27

(Kanoh et al. 2016 ÅpJ)

#### MR in the corona: Soft X-ray microflares/jets

#### AR transient brightenings



## Synergy also with Hinode/XRT



#### From photospheric magnetic information



(Shimizu 1996 PhD, Shimizu et al. 2002, ApJ)

(Kano, Shimizu & Tarbell 2010, ApJ)

- Emergence, cancellation (classical picture)
- No apparent encounters at the photosphere for the half of samples!

#### **Emergence, Cancellation and ?**



- No major improvement only with higher-resolution "imaging" measurements of the photospheric magnetic field
- "Chromospheric" magnetic field and velocity measurements, to explore the events which origins have not yet been identified.

#### Dynamic chromosphere in computers

Martinez-Sykora et al. 2017 Science



Strong ambipolar diffusion in an expanding emerging flux bubble concentrates the perpendicular current at the edges of the bubble.

## Summary

- Hinode SOT spectro-polarimeter will support DKIST, not only calibration but also science.
- Especially, science at Initial period really need Hinode SP.
- Hinode XRT will be also an important instrument for studies on coronal microflares and jets.