SOLARNET

SEVENTH FRAMEWORK PROGRAMME

This project is supported by the European Commission's FP7 Capacities Programme for the period April 2013 - March 2017 under the Grant Agreement number 312495.

KIS Kiepenheuer-Institut für Sonnenphysik

WP80: Synoptic Observations The Solar Physics Research Integrated Network Group – SPRING

Sanjay Gosain, Joe Staiger, Markus Roth

Kiepenheuer-Institut für Sonnenphysik

Solarnet IV International Conference, Lanzarote

January 20, 2017

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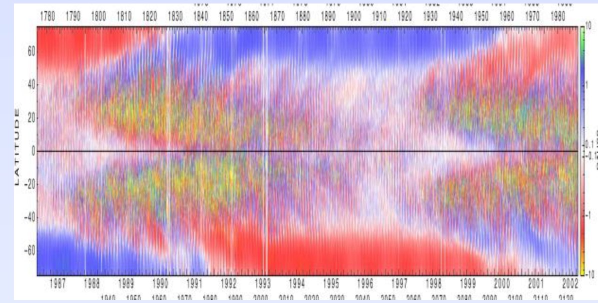
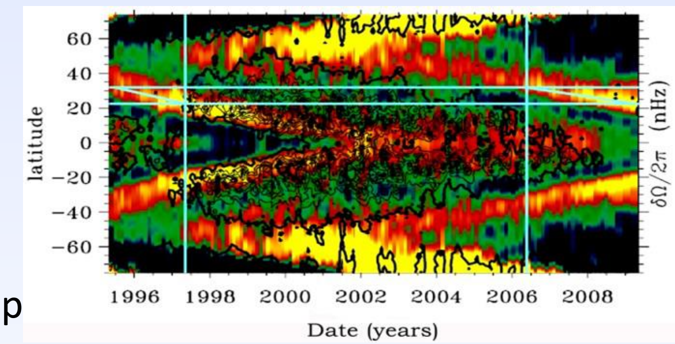
The Need for Synoptic Observations of the Sun

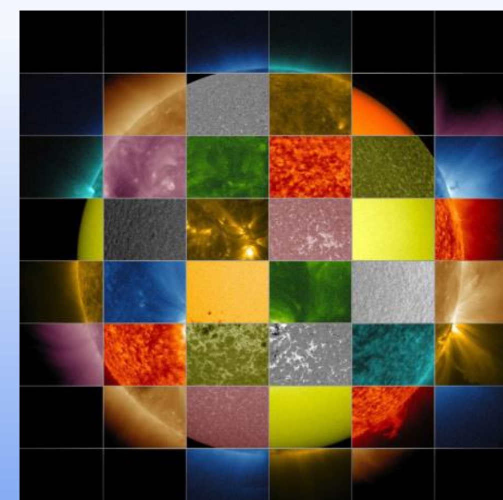


- **Long term monitoring of the solar magnetic fields**
  - to understand solar dynamo
  - evolution with solar cycle (polar and active region fields)
  - Active region evolution for space weather studies
  - surface flows via feature tracking



- **Long term monitoring of velocity fields**
  - subsurface flows via helioseismology
  - solar cycle variations and relationship to solar dynamo
  - Flows beneath emerging flux regions and active regions for sp weather studies

- **Context imaging for next generation high-res telescopes such as DKIST and EST**
  - Large scale effects (flares, filament eruptions) of small scale events such as flux emergence.



*** Hill, F. *et al. Space Weather, 11, 392, 2013***

*** Elsworth, Y . *et al., Space Sci. Rev., 2015*, *196, 137***

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SPRING Activity – Three Working Phases

1. **Science requirement study**
   - describe the supporting data required by high-resolution observing programs
   - the scientific objectives to be achieved by high-quality synoptic observations
   - study of the relation with other existing ground-based solar observation networks

To be studied:

- List of small aperture telescopes and other ground-based solar observations networks available
- Develop a strawman document discussing the goals and preliminary support instrumental concepts
- **Write a Science Requirement Document (SRD) which shall be consistent, tangible and in accordance with other plans for the next 25 years (commissioning of large-aperture telescopes, space missions, etc.)**

→ Science Requirement Document

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Working Groups

Group 1: Synoptic magnetic fields
- Sunspots (problems with cool atmospheres)
- Active regions
- Quiet Sun magnetism
- Synoptic Hanle Observations

Head: A. Pevtsov

Group 2: Solar seismology
- Waves (solar interior)
- MHD waves (magnetoseismology)
- Velocity field inside and on the Sun

Head: R. Jain

Group 3: Transient events
- Flow of energy through the solar atmosphere (3,2)
- Transient events (flares, prominences, CMEs)

Head: M. Sobotka

Group 4: Solar Awareness
- TSI / SSI
- Space Weather (4,3)
- Space Climate
- Sun-as-a-star

Head: I. Ermolli

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Workshops

Synoptic Network Workshop, April 22 – 24, 2013, Boulder, USA

1st SPRING Meeting, November 25 – 28, 2013, Titisee

2nd SPRING Meeting, October 12 – 16, 2014, Tatranska Lomnica

3rd SPRING Meeting, May 16 – 18, 2016 ,Boulder, USA

Deliverable D80.1

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SPRING Activity – Three Working Phases

2. Feasibility study

2.1 Instrument design concepts

Definition of technical requirements for the instrument, based on scientific goals

Definition of alternatives of instruments concepts

2.2 Operational concepts

Develop operational ideas (remote operations, data pipelining, delivery of real-time data to operating telescopes)

Develop high-speed image post-processing routines

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- Technical Study
  - Seeing conditions
    - Inputs from GONG sites is studied.
  - Fabry-Perot-Approach
    - Simulations with SOLIS data
    - Full-disk experiments with HELLRIDE at VTT
    - Polarimetric capabilities (being tested)
  - Spectrograph Approach
    - Full-disk experiments with DST, SacPeak.

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Filtergraph Approach to SPRING

1. Michelson Interferometer : Examples: GONG, MDI, HMI
Advantage: large FoV, stable, compact
Disadvantage: Not suitable for multi-wavelength work as proposed in SPRING

2. Lyot type filters: Examples: UBF, Chromag
Advantage: large FoV, high contrast
Disadvantage: Requires lot of Calcite, Dual beam polarimetry not possible, slow tunability, low transmission for narrow passbands

3. Magneto-optical-filter : Examples : MOTH, GOLF
Advantage: stability, large FoV
Disadvantage: Not suitable for multi-wavelength work as required in SPRING

4. Fabry-Perot Interferometer: Examples: IBIS, CRISP
Advantage: Large wavelength range, rapid tunability, high transmission
Disadvantage: Field dependent passband shift, long-term drifts in FP profile, maintaining plate parallelism.

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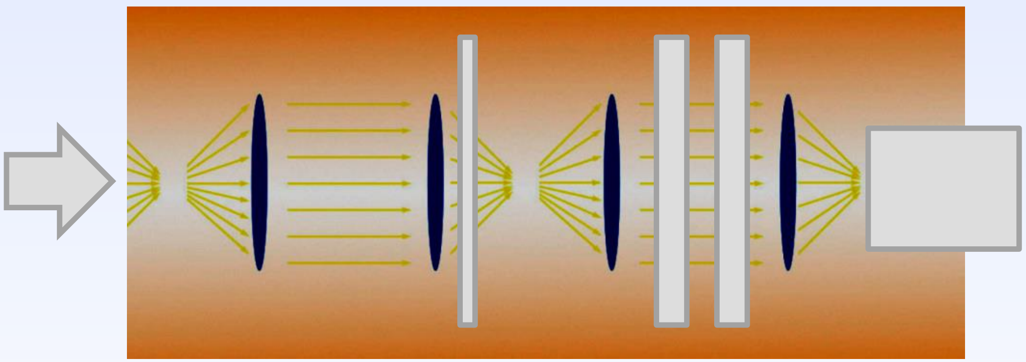
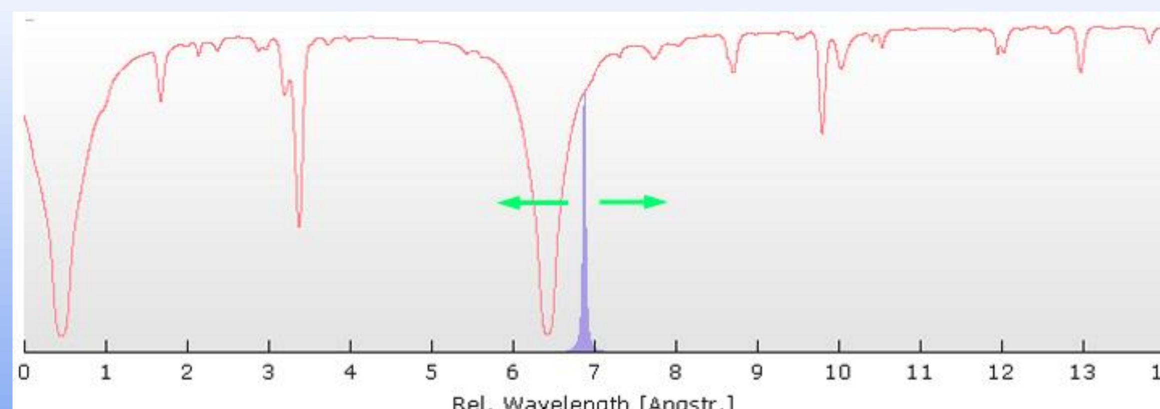
Helioseismic Large Region Interferometric Device (HELLRIDE) Instrument, VTT

Multiline Imaging Spectrometer
Dual Etalon system
Several lines (10-15) per minute
FoV 100 arcsec
Fast prefilter changing stage

Wavelength [nm]	Element	Scansteps
517.2	Mg I	20
538.0	C I	15
538.1	Fe I	15
538.2	Ti I	15
543.4	Fe I	10
557.6	Fe I	20
589.0	Na D 2	30
589.6	Na D 1	30
630.1	Fe I	20
630.15	Telluric	15
630.2	Fe I	15
632.8	He-Ne Laser	15
656.3	Hα	50
709.1	Fe I	20
777.1	Fe I	20
777.2	Fe I	10



Staiger, J. in A&A, 5353, 83, 2011



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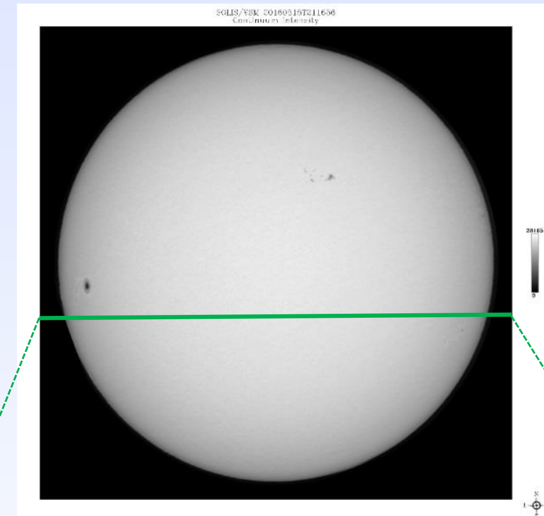
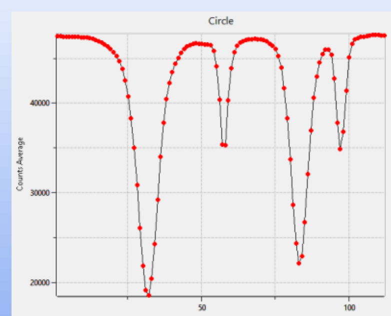
Simulation with SOLIS data

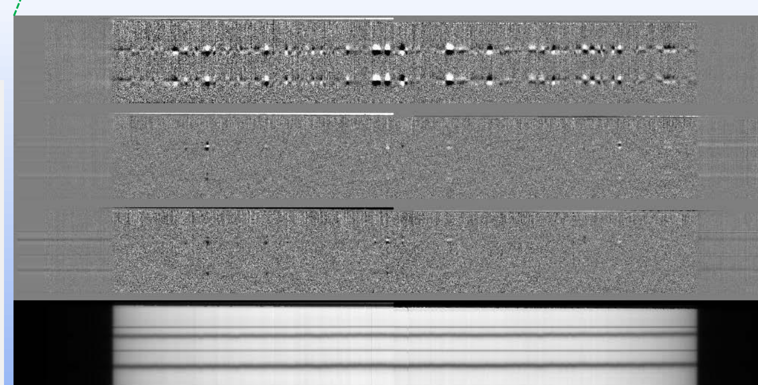
SOLIS is a Fulldisk Slit-spectrograph (2k x 2k x 128 x 4)
Long-slit scans the full solar image in N-S direction

Fe I 630.2nm :
Stokes-I,V observations are done in 12 min.
Stokes I,Q,U,V observations in 25 min.

Ca II 854.2nm :
Stokes-I,V in 45 minutes
Stokes-I,Q,U,V in 45 minutes







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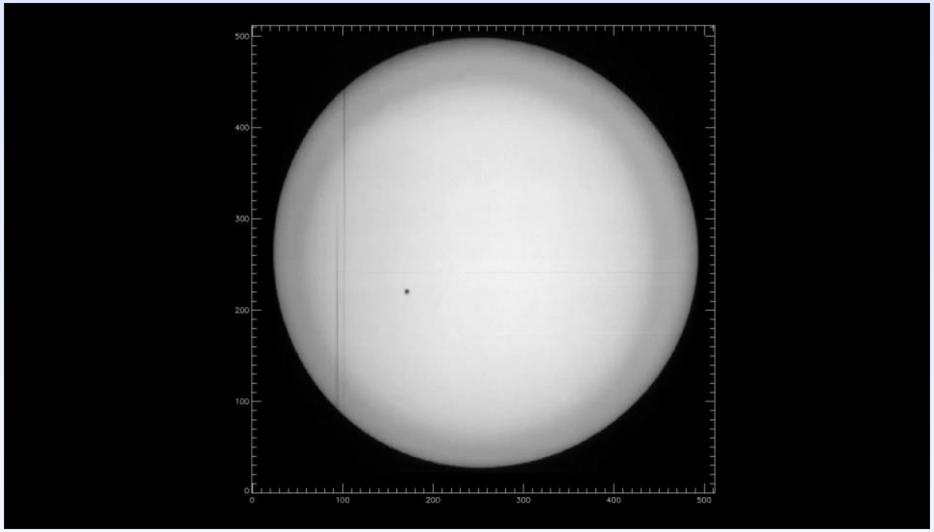
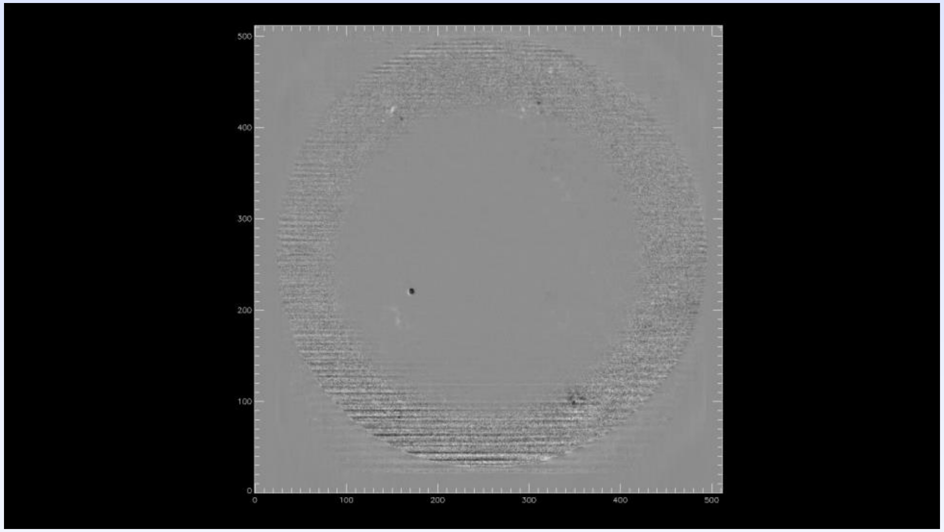
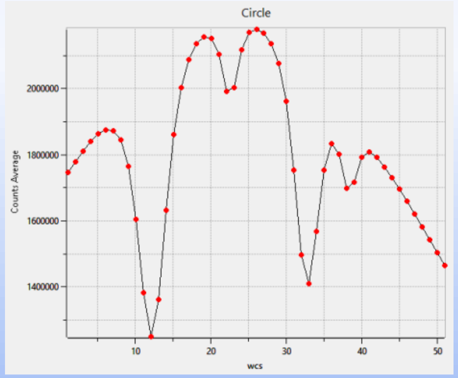
Simulation with SOLIS data

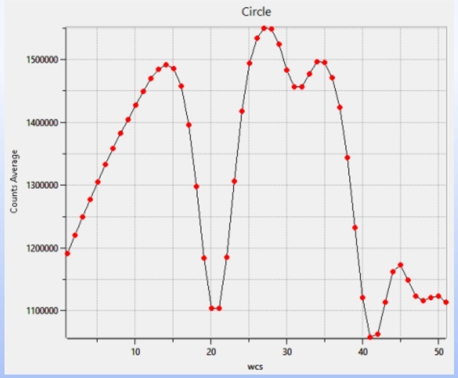




Disk Center



Solar Limb



- Angular shift of FP and prefilter are not same.
- Prefilter coatings may be optimized for angular shift matching or similar to etalon

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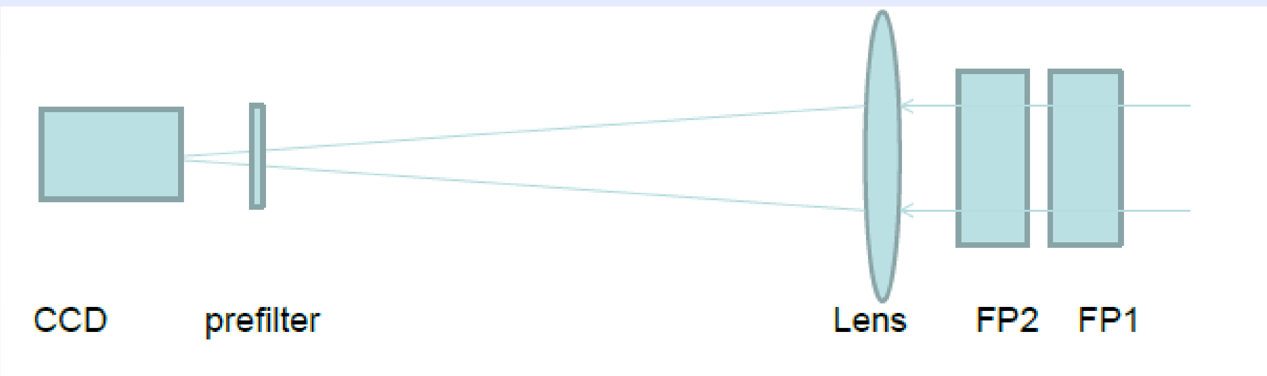
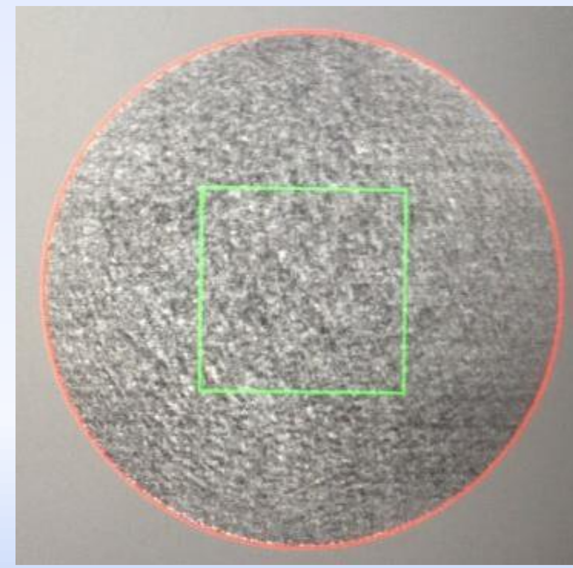
HELLRIDE Fulldisk Tests

- *VTT guiding telescope used to record multi-line dopplergrams*

  → long time series possible: Instrument stable enough.





Technical Realization:

→ Implement a diffuser + lens system to obtain flat-fields
→ Online spectral drift monitoring system: using Laser
→ Simultaneous white-light camera for image restoration.
→ Polychromatic Polarimeter:
to obtain LOS/vector magnetic and velocity maps in various lines.

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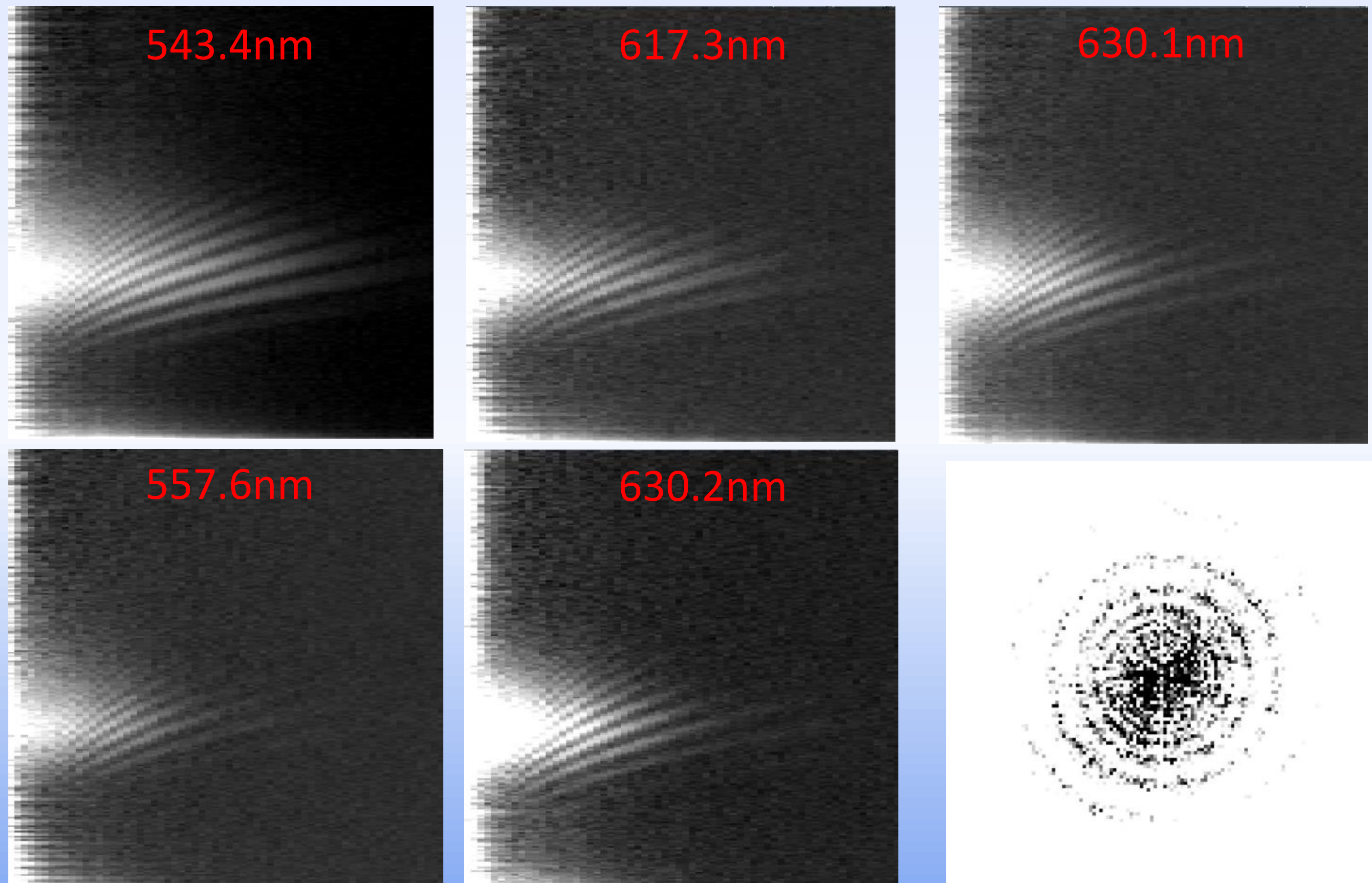
HELLRIDE Multiline Fulldisk Test Results

- Full disk spectra obtained in 10 spectral lines
- Cadence: 1 minute
- Data reduction (flat, dark and velocity computation) done on-the-fly
- Multi-line mode first light tested in January 2017



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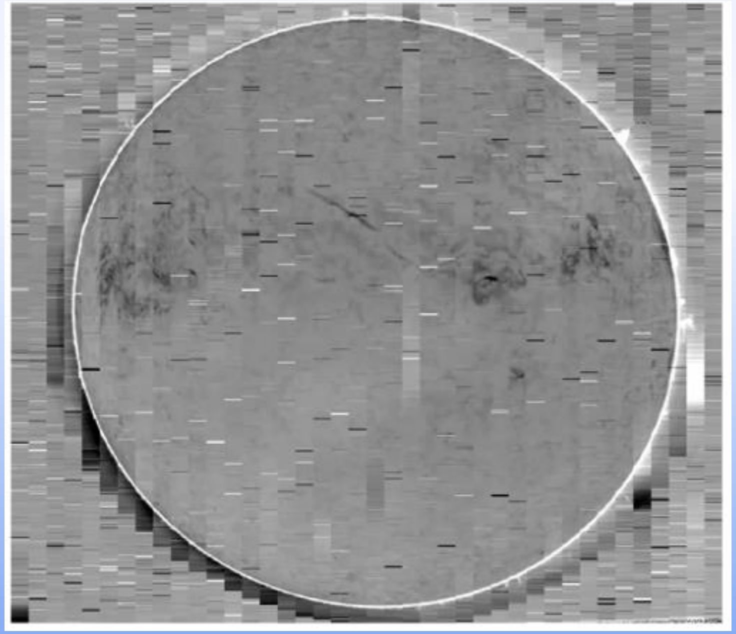
Spectrograph (Feasibility)

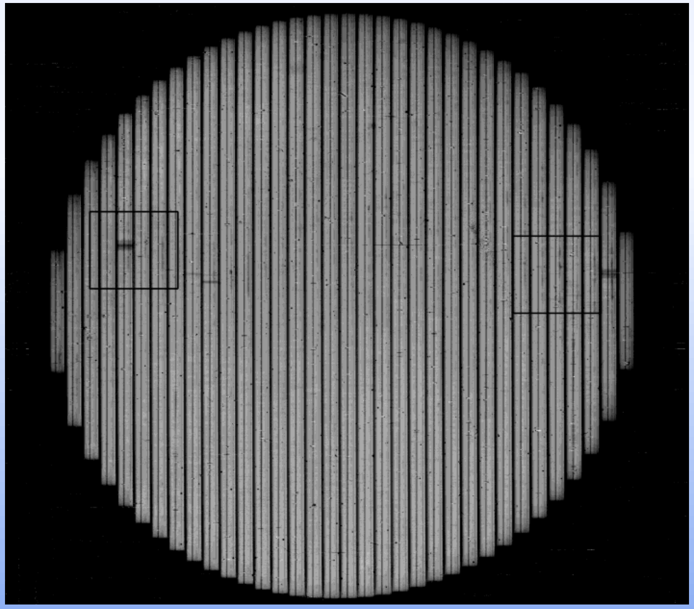
- **Slit spectropolarimeter:** e.g. SOLIS/VSM
  - Cadence is ~20 minute for full disk vector magnetogram with single slit.
  - Multiple-slit design can be implemented for improved cadence

H. Lin of IFA, Hawaii carried out multi-slit demo. observations with NSO DST for Stokes-I in He 10830, achieving cadence of 1 minute with 35 slits.

Reconstructed Line Core Image



Sample 35-Slit Full Disk Spectral Image



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Expected Data Rate for SPRING

Specifications of the expected observations:

- 4k x 4k camera, 16 bits
- At least Five spectral lines
- 20 wavelength bins per spectral line
- Cadence: 10 sec
- Full Stokes vector

Estimation of the expected data rate:

- Size of one image uncompressed: 4096^2 x 16bits = 32 MB
- Number of images per cycle (=10 sec): 5 x 20 x 4 = 400 images
- Data rate per cycle: 32 MB x 400 = 12 GB
- Expected data rate: 720 GB/hr
- After data compression: ~6 TB per day (assuming 12 hours of data per site)

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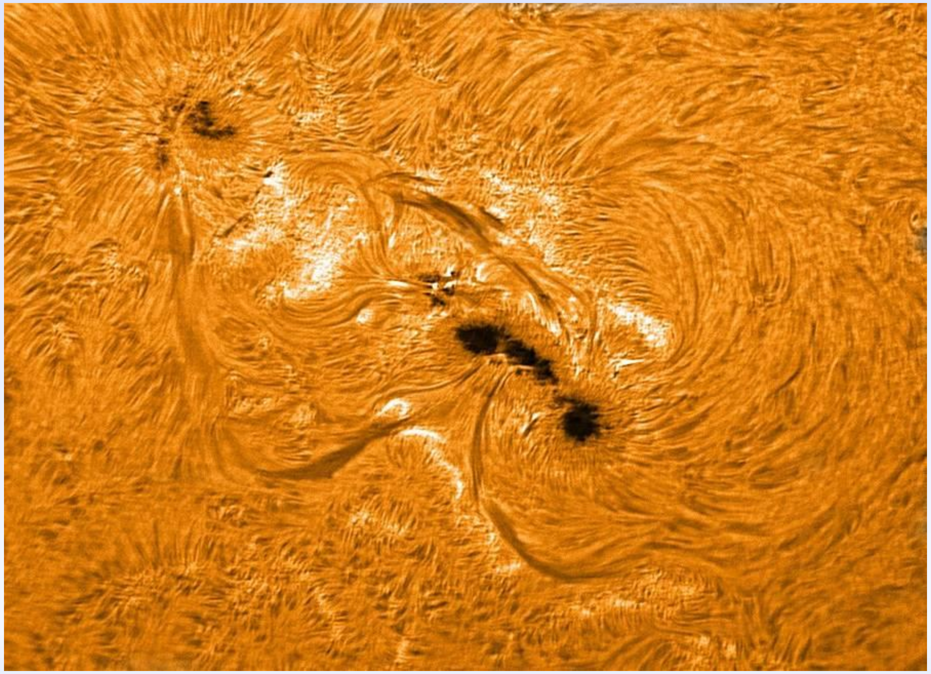
High-Resolution Context Imager for Large Aperture Telescopes:



LUNT Optical systems 150 mm refractor

General Features:

•152 mm f/6 dedicated h-alpha telescope

• Internal etalon allows a <0.65 Angstrom bandpass.

•pressure tuning system for precision tuning adjustments.

Strategy:

- Use off-the-shelf systems for different wavelengths.
- Couple with computerized GOTO mounts to scan the burst of images over the solar disk.
- Use solar speckle imaging techniques (GPU based methods are being developed for DKIST) to get image reconstructions of each patch, and then mosaic the patches together to get high-res context image (typically 1 per minute per bandpass).

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Thanks!