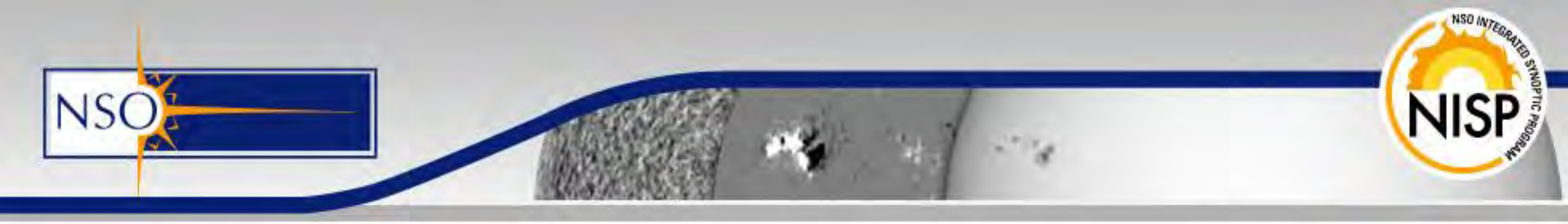


Full-disk Full-Stokes Spectropolarimetry of the Solar Chromosphere

First Results from SOLIS VSM

Sanjay Gosain, Jack Harvey, Brian Harker, Valentin Martinez Pillet

and

the SOLIS Team

National Solar Observatory

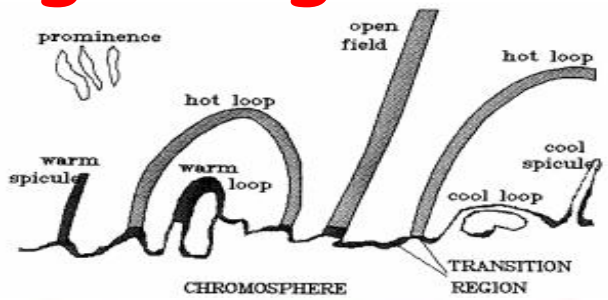
Outline of the presentation

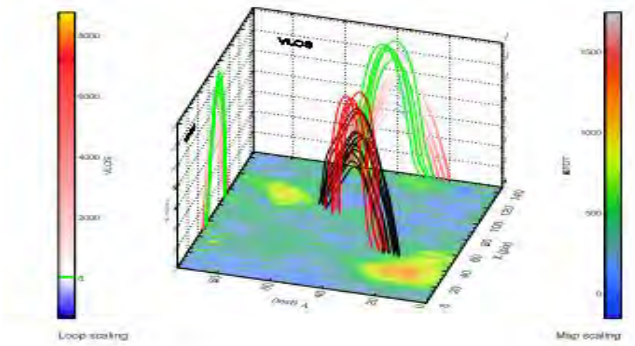
- Brief introduction
- Advantages of Magnetic Field Measurements in the Chromosphere
- Some Results from SOLIS VSM

  -Longitudinal Field Measurements
- Recent Upgrade to Full Stokes Polarimetry
- Sample Full Stokes Data from SOLIS VSM
- Quick Look Magnetograms from Chromospheric Observations
- Future Outlook

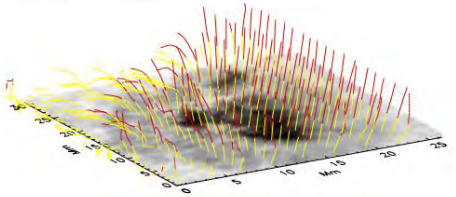
Advantages of Chromospheric Magnetograms

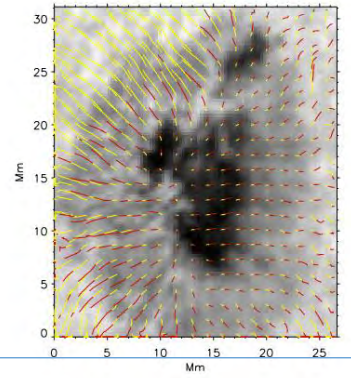
- Very important to understand connection between photosphere, chromosphere, interface region and corona.
- Proves an alternative and better boundary condition for force-free field extrapolations into the corona (Metcalf et al. 1995; Socas-Navarro, 2005).
- Gives us an extra layer to infer/constrain 3-D magnetic structure of the solar magnetic fields from photosphere to corona (Wiegelmann et al. 2012; Choudhary et al. 2001).
- Could also be used to resolve 180 degree azimuth ambiguity (Crouch et al. 2009, 2015).
- Compute free energy and its evolution in solar active regions (Wheatland et al. 2005)
- Compute electric currents, twist and torsion of the magnetic field in the chromosphere (Socas-Navarro, 2005).





(Lagg, et al. 2005)





(Socas-Navarro. 2005)

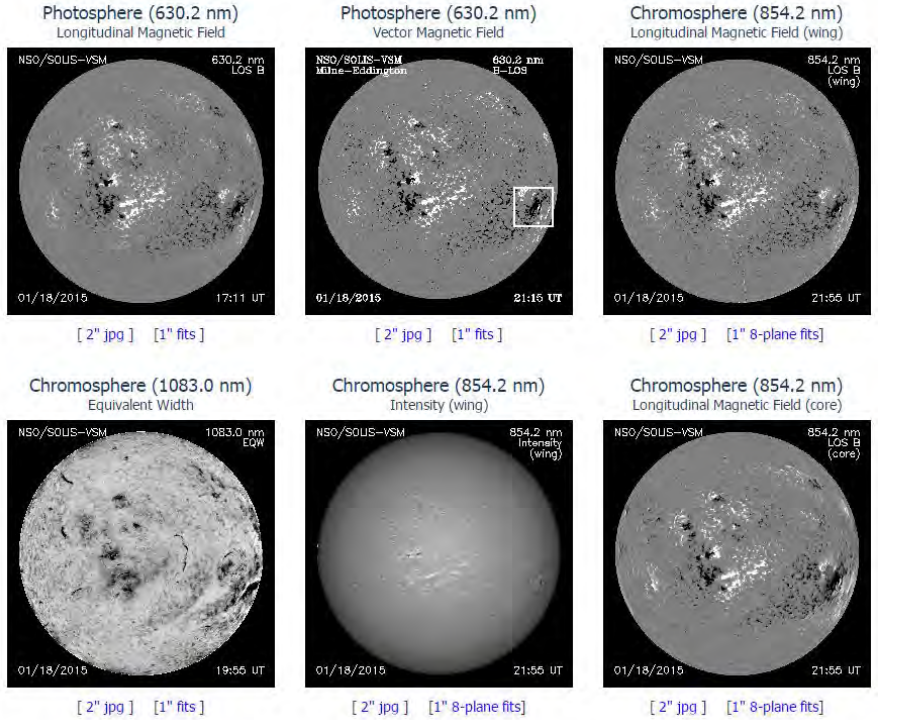
SOLIS-VSM: An Introduction

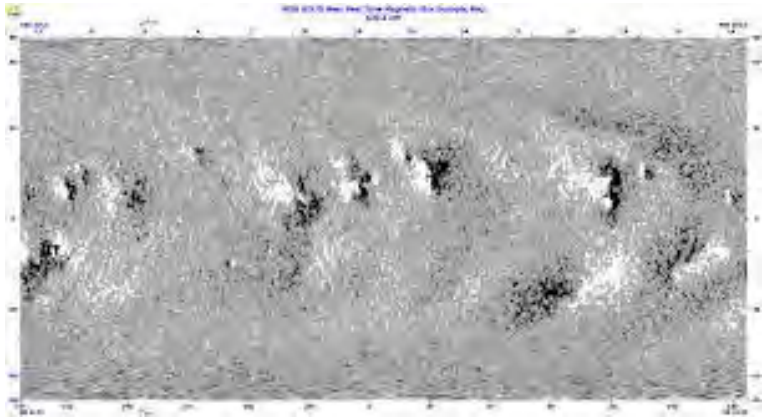
The Vector Spectromagnetograph (VSM) was designed for observing Zeeman-induced polarization signals in the spectral lines of photosphere and the chromosphere.

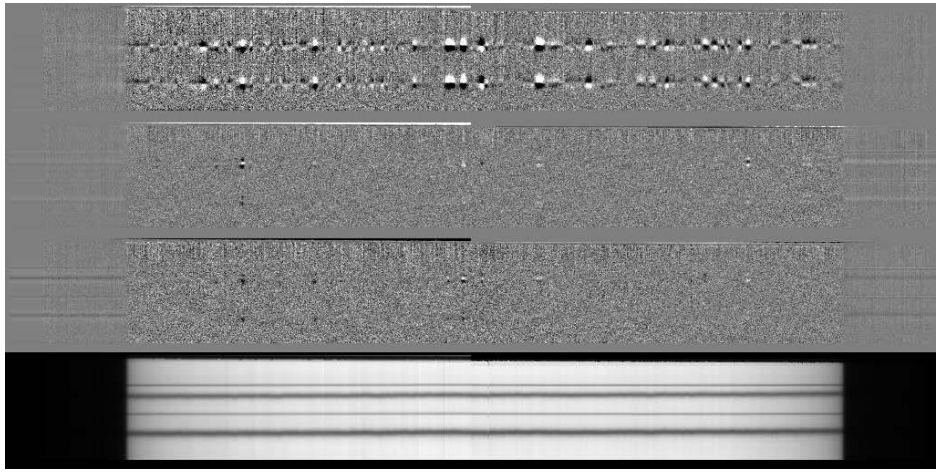
Keller et al. Proc. SPIE 4853, 194 (2003)

The VSM provides the following data products:

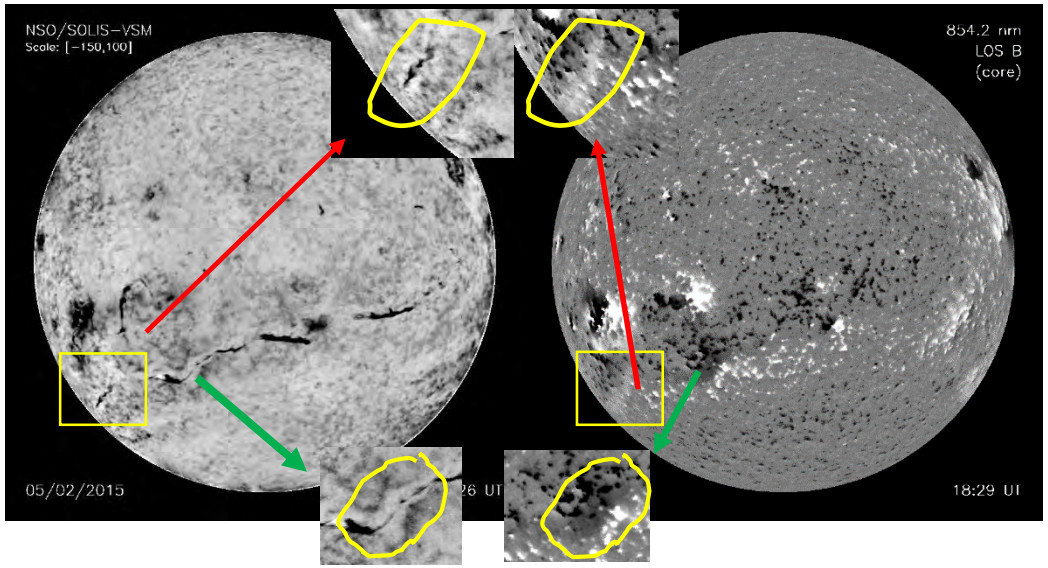
- Photospheric magnetograms :: LOS and Vector Fulldisk
- Chromospheric magnetograms :: LOS Fulldisk
- Chromospheric:: Full Stokes Vector Spectro-Polarimetry Fulldisk

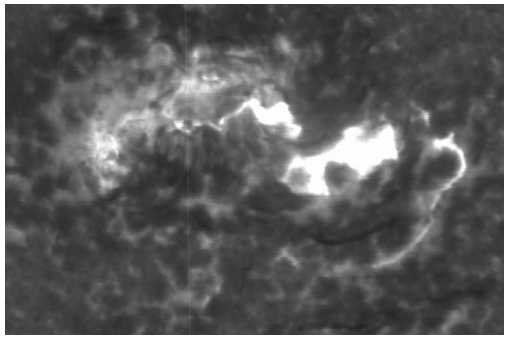


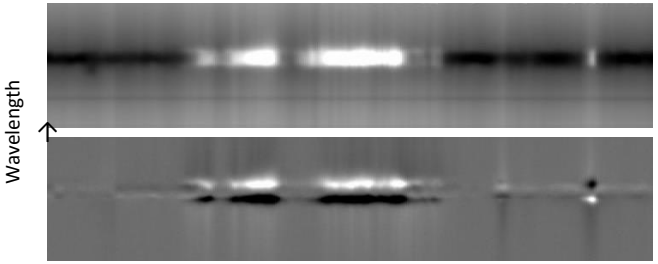




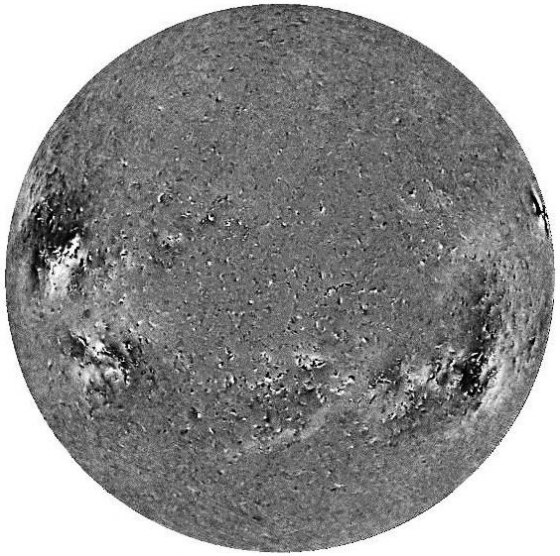
Results from Longitudinal Chromospheric Magnetograms



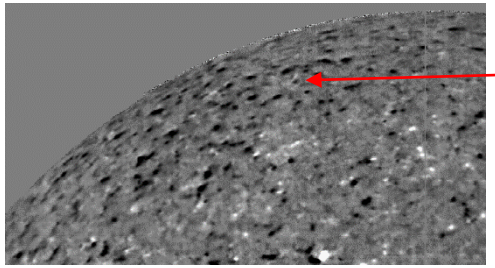




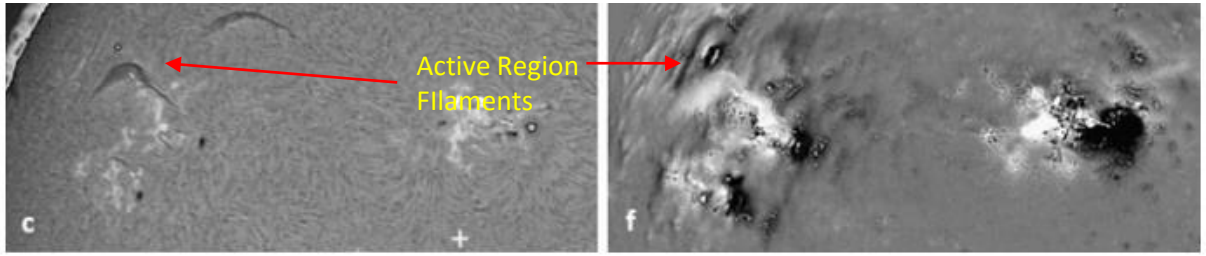
Position along slit
↔



Chromosphere – Photosphere (B_{los})

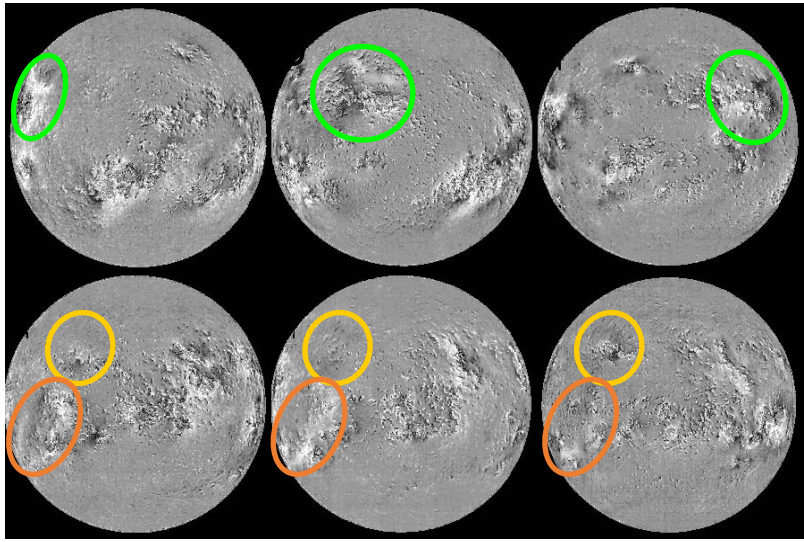


Polar Fields Better seen in chromosphere



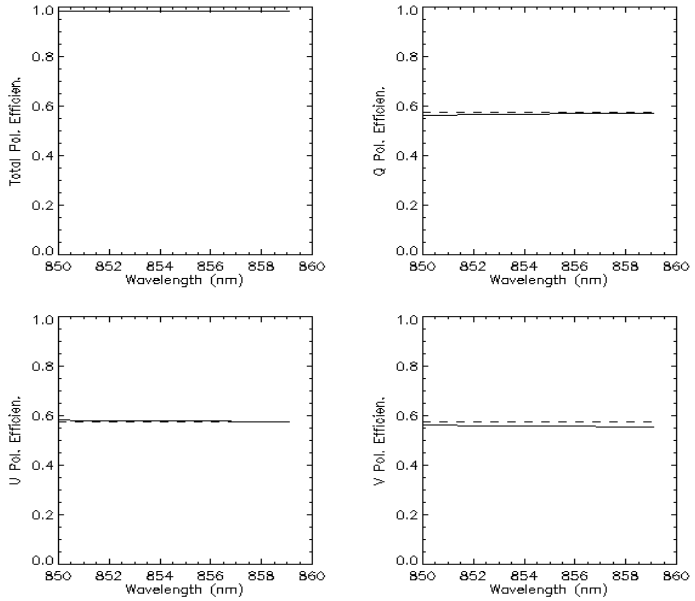
Daily Variation

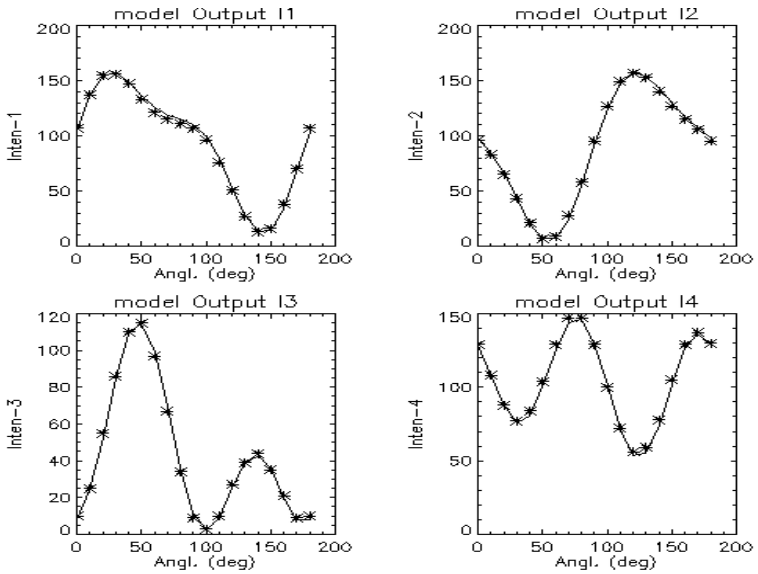
Rotational Variation



Full Stokes vector measurements in chromospheric line Ca 8542

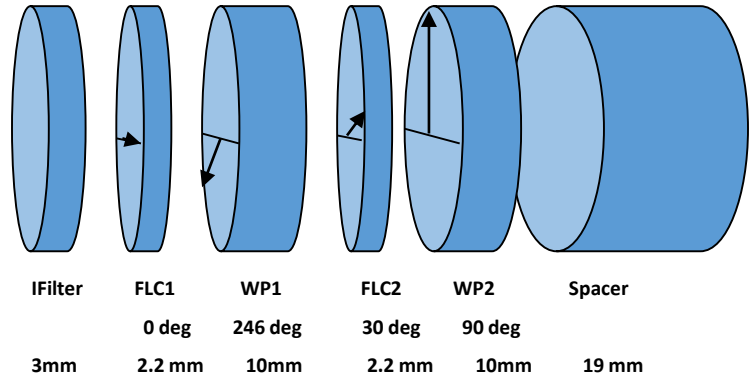
Modulator Design



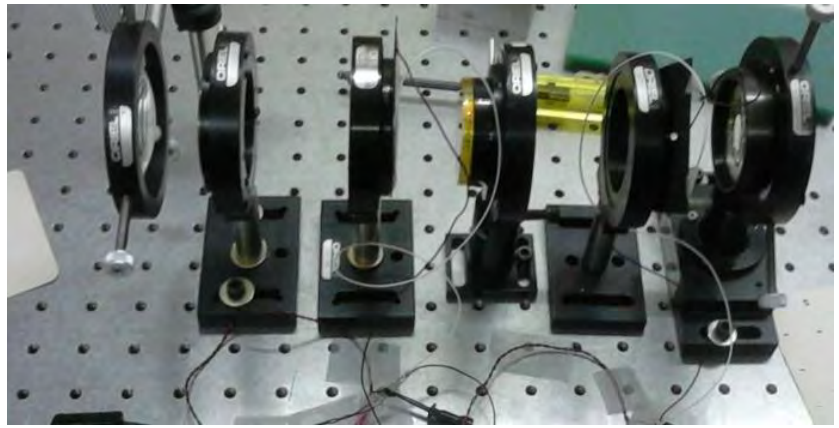


Optimum polarimetric efficiency (~ 0.57 for Q,U,V, as in J. Carlos del Toro Iniesta, 2007) can be achieved from the computed set of angles for FLC modulators and fixed retarders.

Measurement of the modulation signal (asterisks) for various known input polarization vectors, and a forward model fit from known angles and retardances (black line).



8542 Modulator Package Schematic

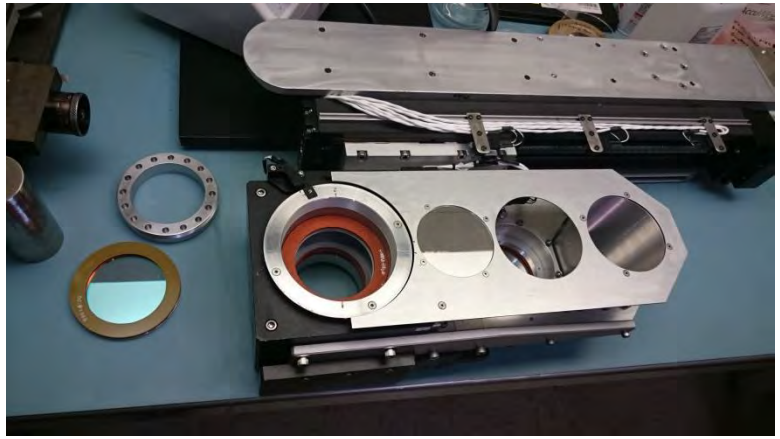


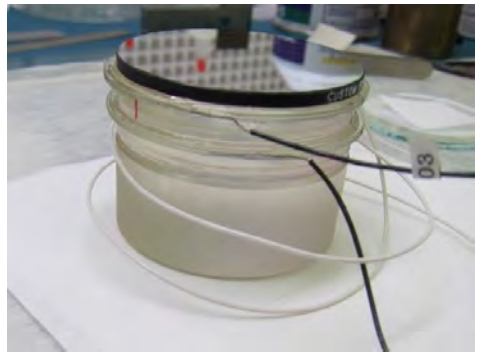
Laboratory testing of Modulator Package

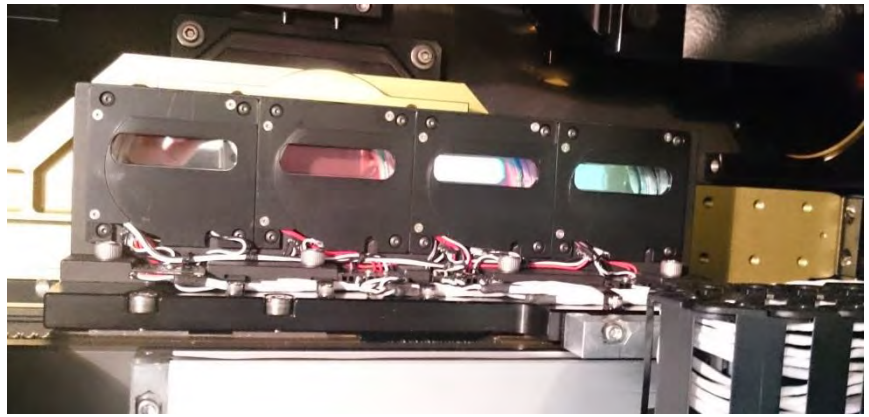
Full Stokes vector measurements in chromospheric line Ca 8542

Modulator Assembly + Installation

- Modulator package assembled as a stack with index matching compound.
- SOLIS/VSM was brought to lab. for installation of new modulator and calibration optics.
- Polarimeter Calibration unit was upgraded with dual passband prefilter for 8542 and 6302 lines.
- SOLIS/VSM is back to observing site
- Full Stokes Ca 8542 observations began in November 2015.

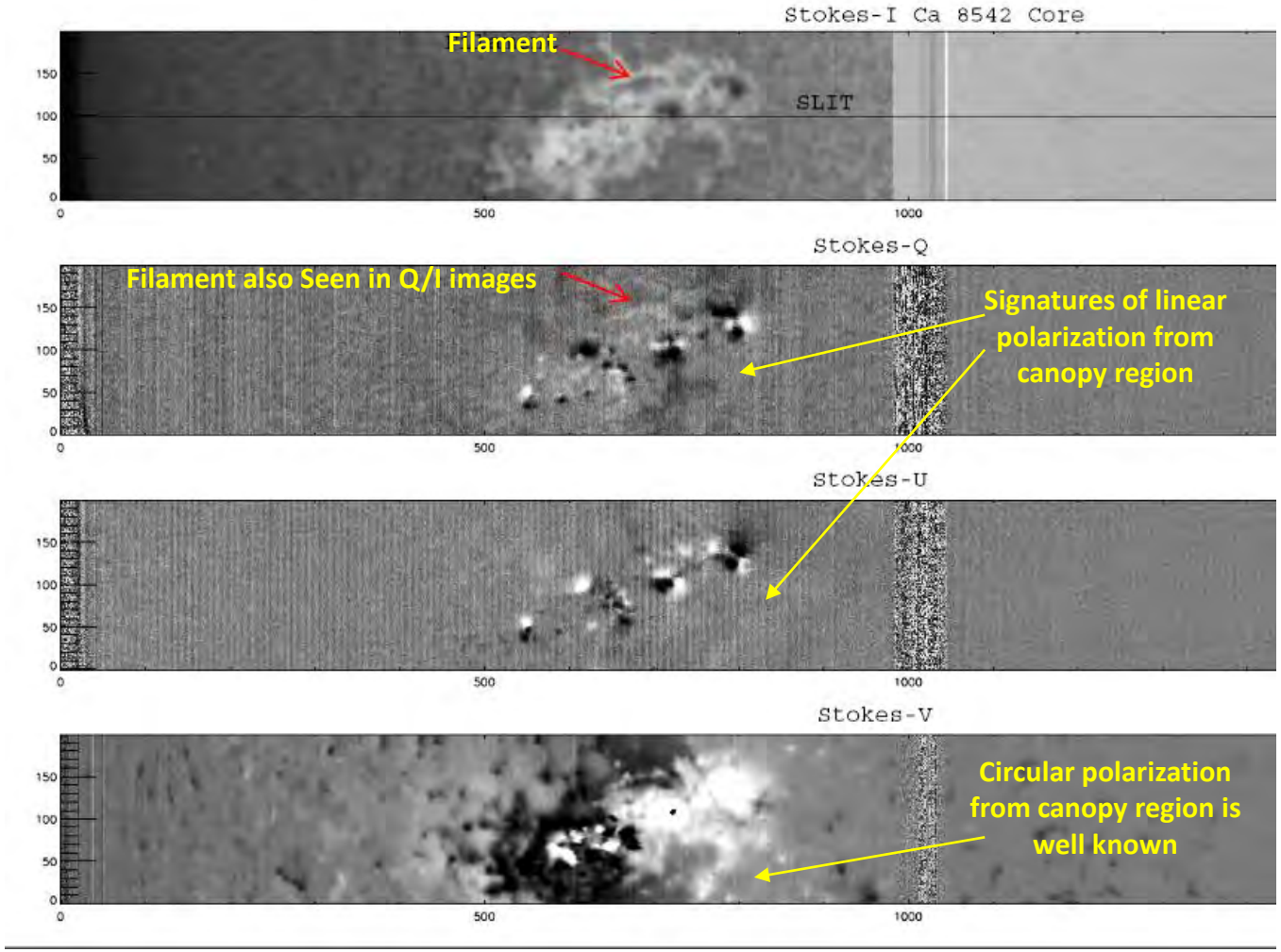


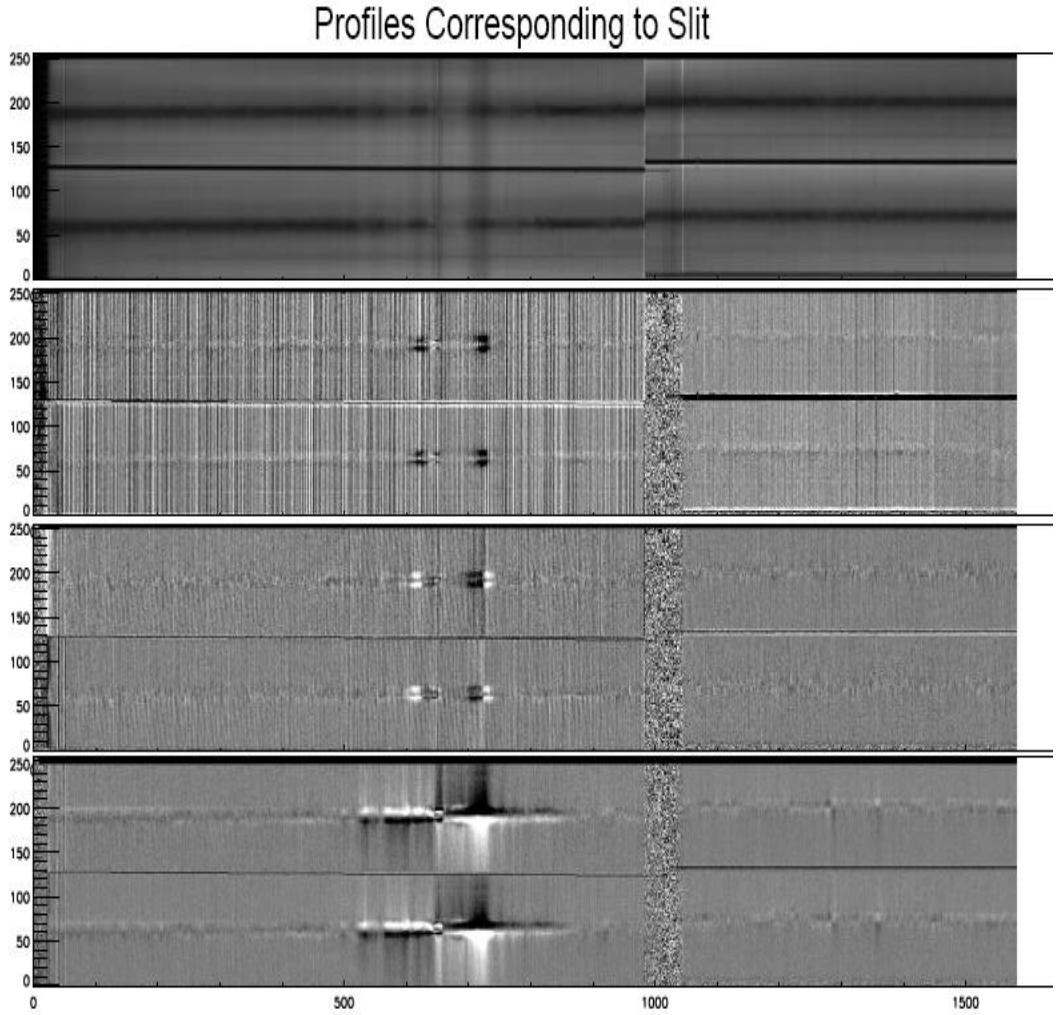




Full Stokes Observations in Ca II 854.2 nm

First Light Results



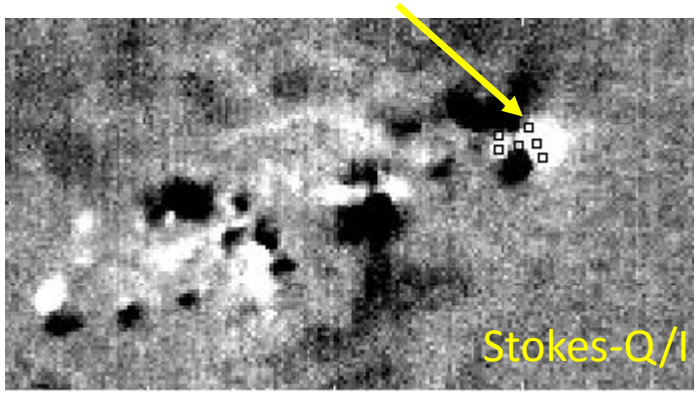


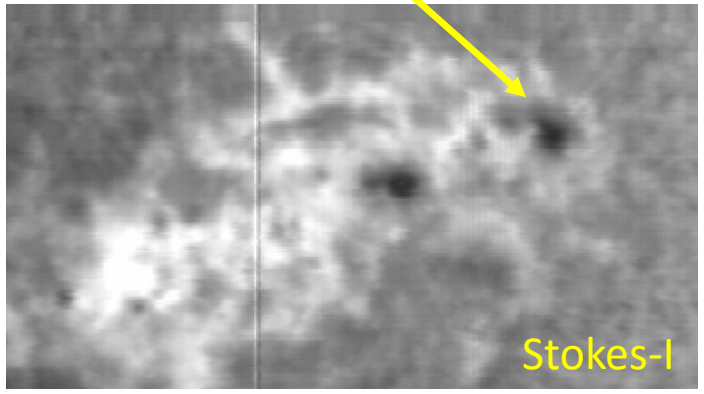
Full Stokes Observations in Ca II 854.2 nm

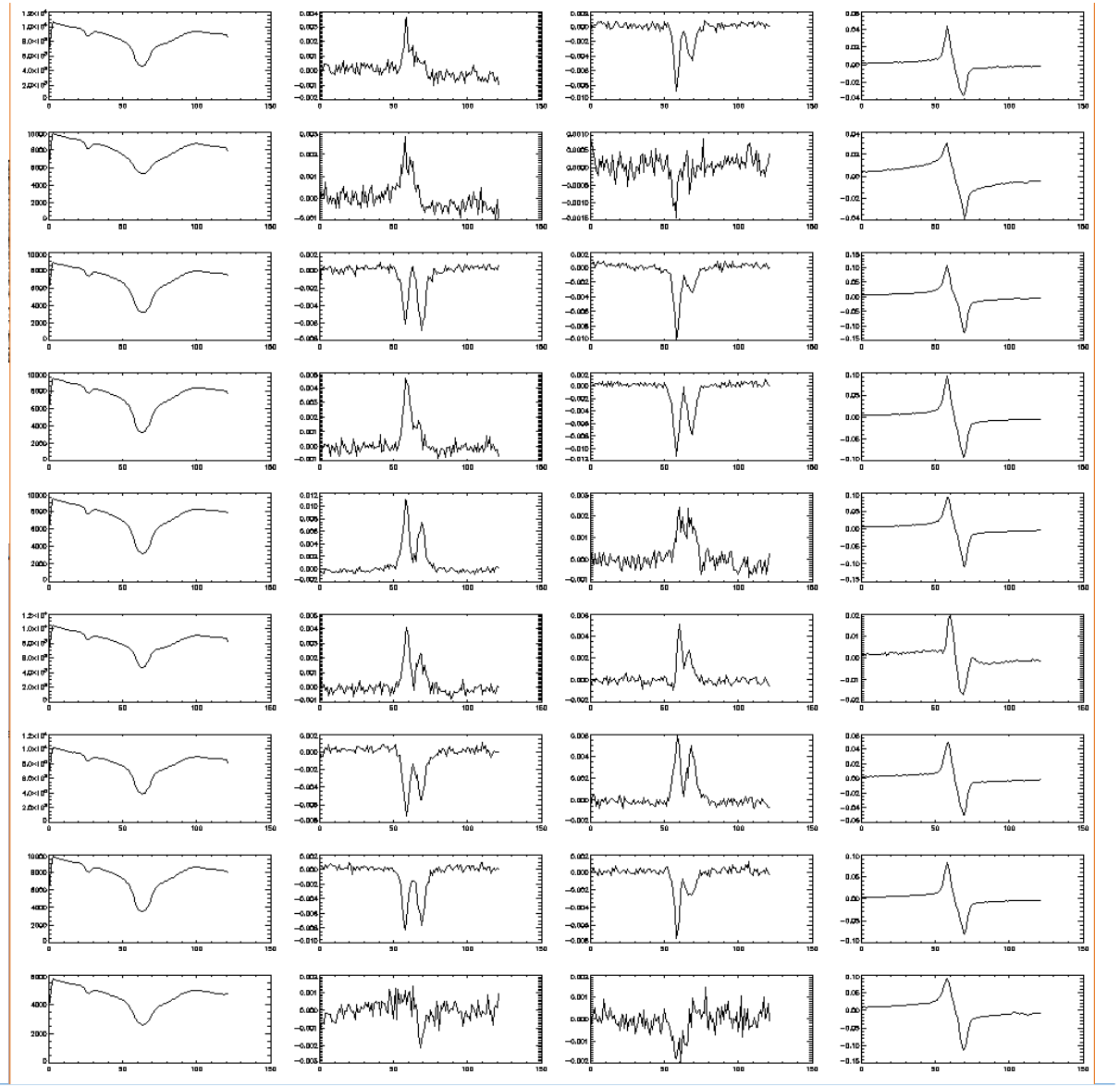
Area Scans look promising for Active Regions

- Area scans of activity belts with SOLIS VSM
- Typical scan covering an active region , as shown on the left takes 5 minutes.
- Important for studying flare related changes in the chromosphere
- Electric currents in the chromosphere above Solar active regions and Free energy estimation.

Leading Sunspot

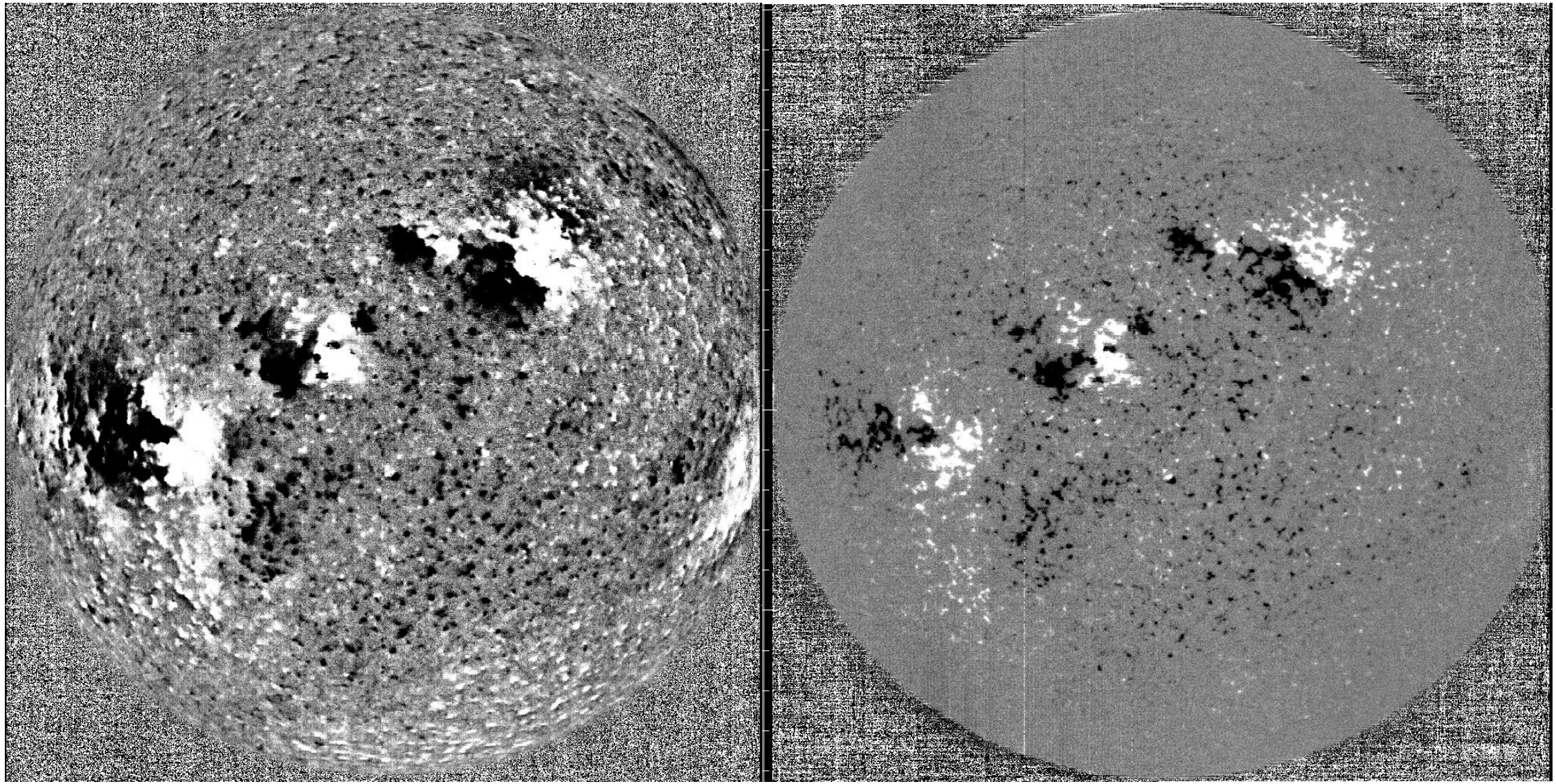






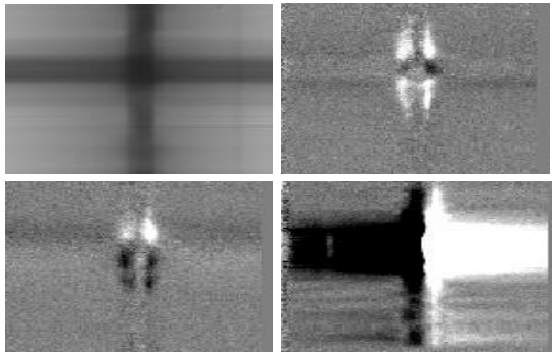
Full Stokes Observations in Ca II 854.2 nm

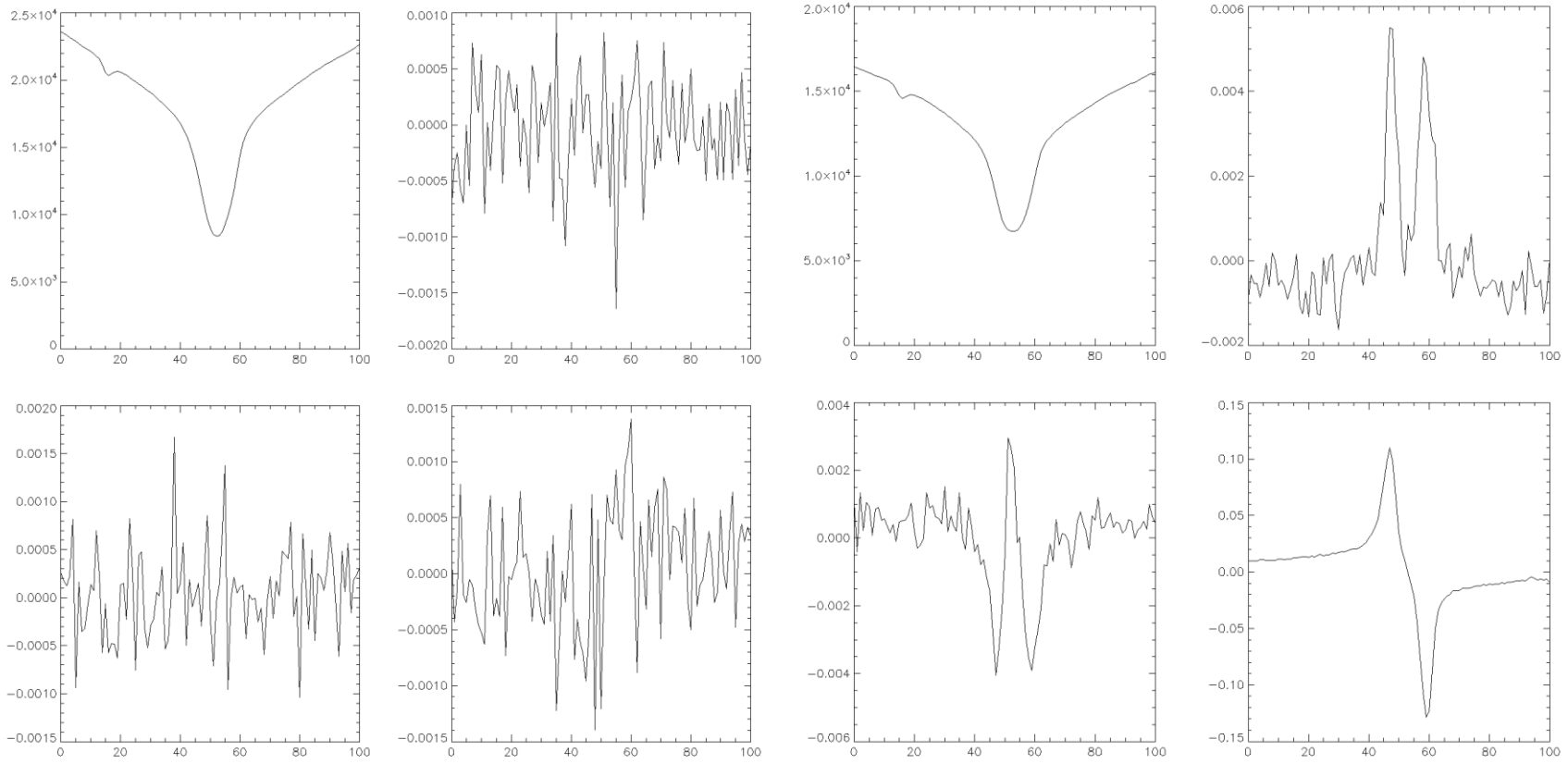
Stokes-V signal in Core v/s Wing of the line



Ca II 854.2 nm Full Stokes Spectra :Examples

Stokes-I,Q/I,U/I,V/I





Sample Stokes Profiles (Quiet Sun)

Sample Stokes Profiles (Sunspot)

Noise Level in Stokes Profiles [Quiet Sun, near wings] : 4×10^{-4} of I(λ)

Normal Exposure : 1.27 sec per slit position [for set of 4 measurements]

Fulldisk scan : 45 minutes

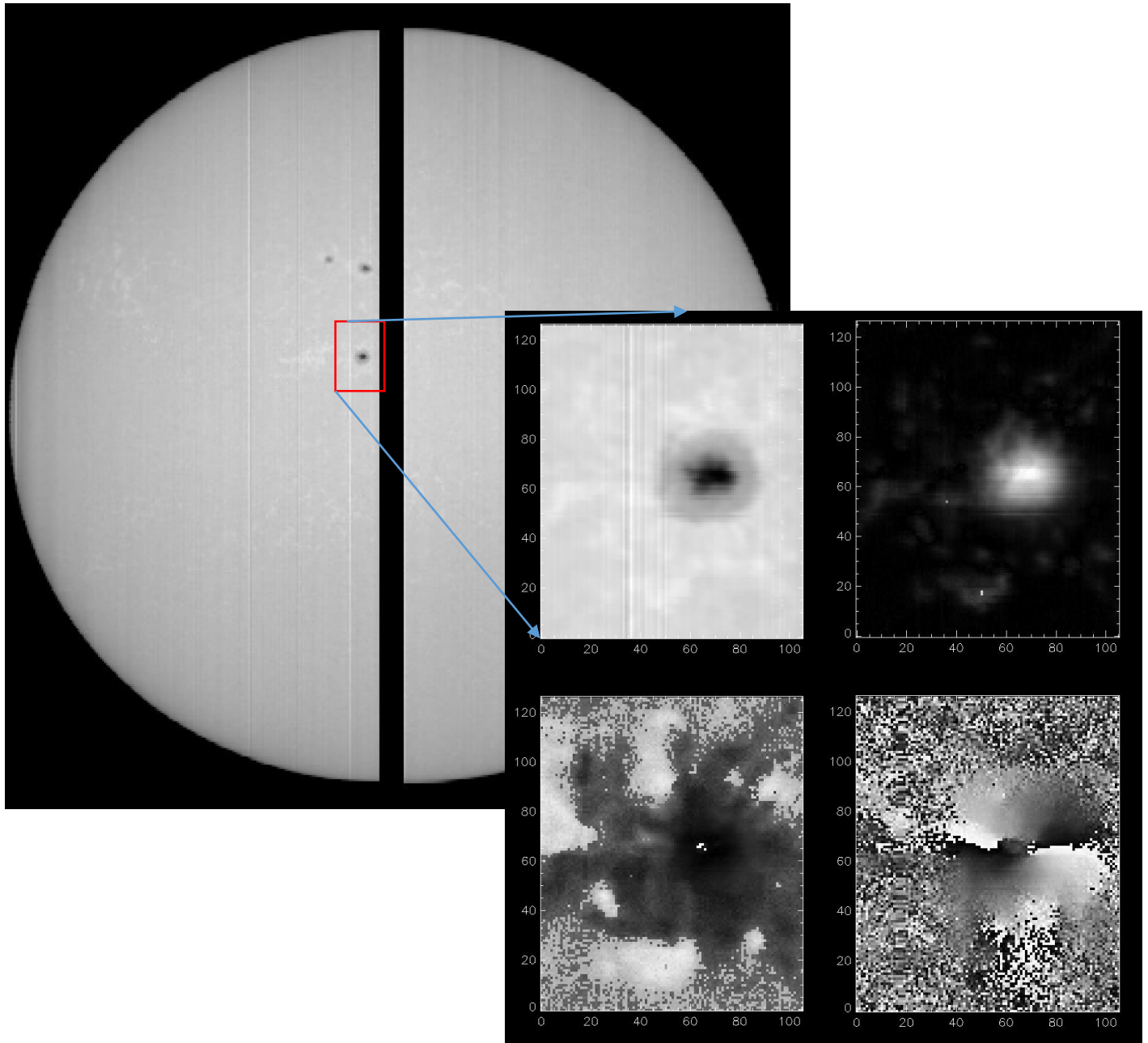
Typical Active Region : 4-5 minutes

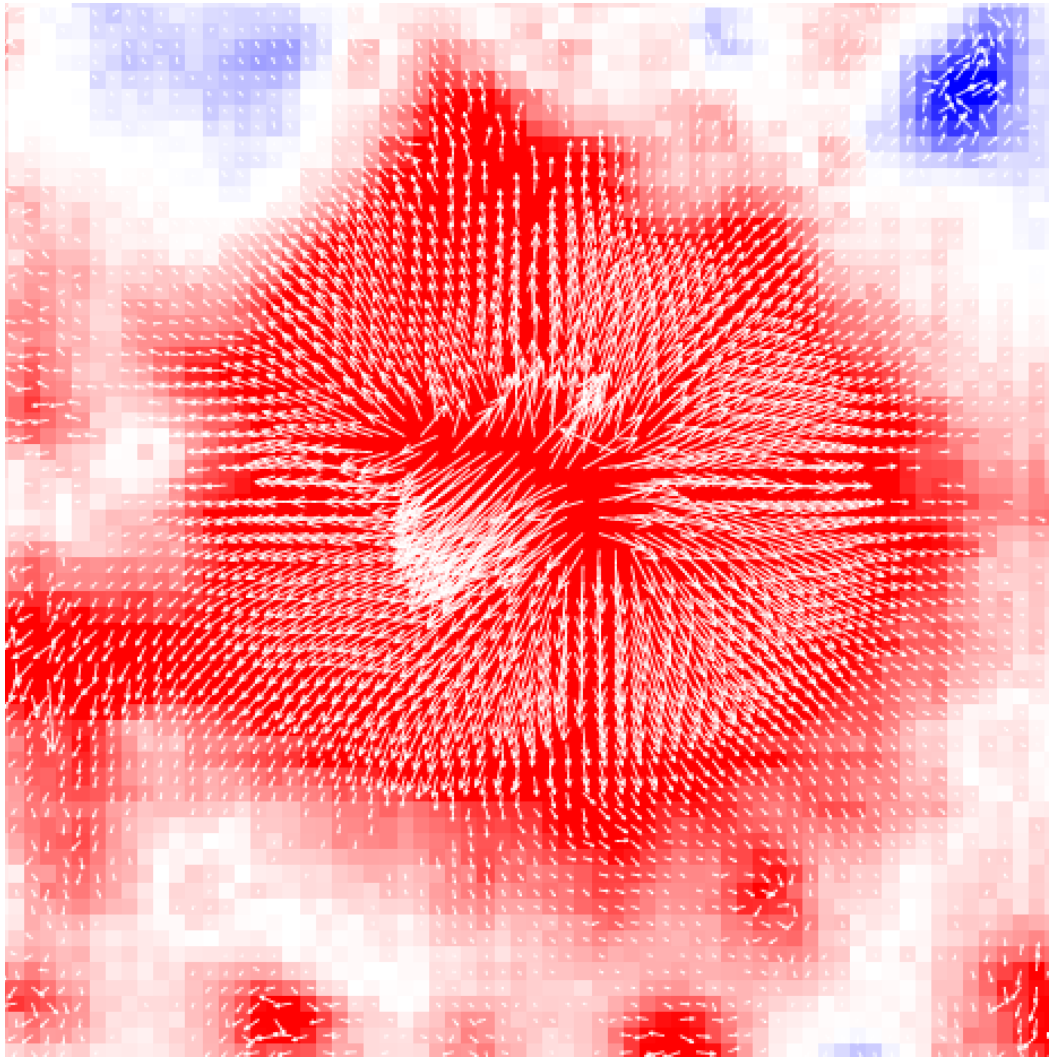
Quick Look Vector Magnetograms of Ca II 854.2nm

- The azimuthal angle is derived by using the integral method (Ronan et al 1987)
- The inclination angle is calculated from the method in Auer, Heasley, and House (1977), and
- The field strength is simply the center-of-gravity LOS field strength corrected by dividing by the cosine of the inclination angle

  (caveat: strong PILs cause problems).
- Next step is to try use the full integral method (Ronan et al 1987): Properly inverted vector fields needed to calculate the calibration constants.

QuickLook Ca II 854 nm Vector Magnetograms





Wed, 16 Mar, Sun AID, Boulder

Future Outlook: NLTE inversions with NICOLE

- Preliminary attempts to invert sunspot data are underway in collaboration with colleagues at IAC, Spain.
- For routine inversions of full disk a parallelized environment would be needed.
- Limited inversions for few selected active regions will be attempted till then.
- Calibrated spectra will be available on request.

Thanks!