THEMIS spectropolarimetry of quiescent prominences

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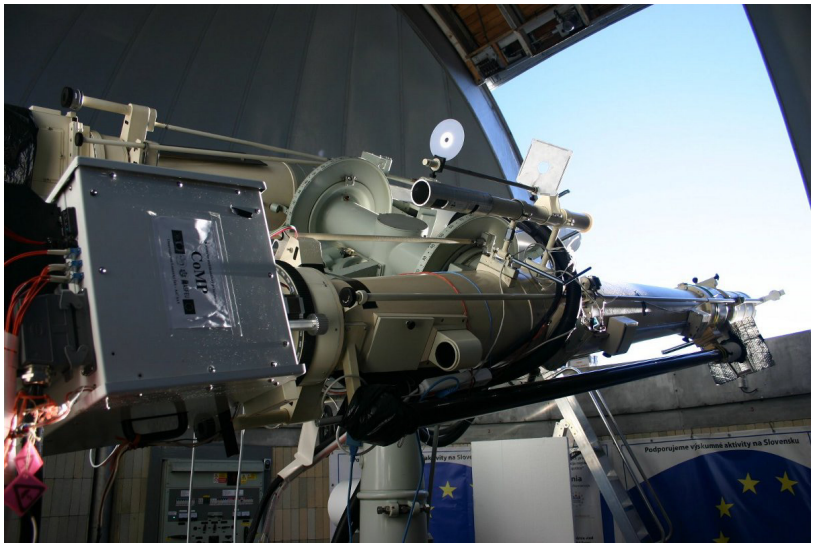
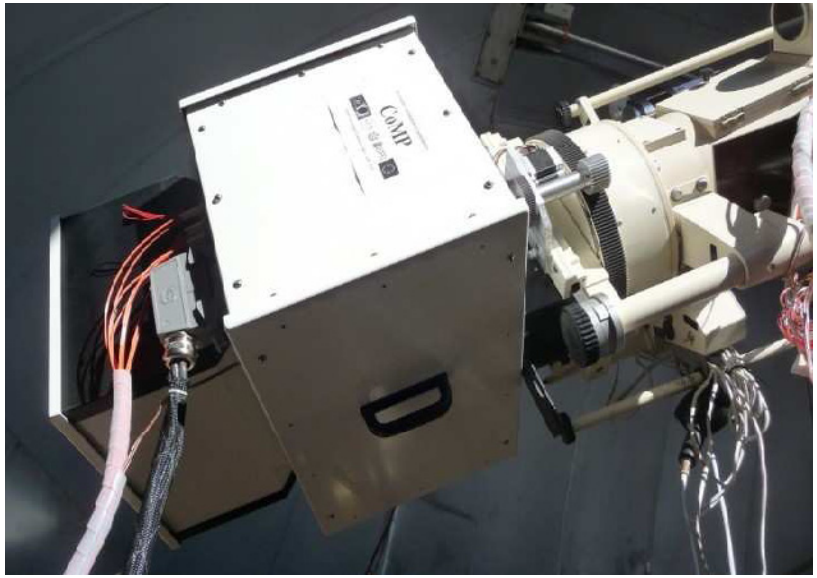
Lomnicky Peak Observatory

- 2633 m above see level
- the 2nd highest peak of the High Tatras mountain in the Northern Slovakia
- in operation since 1962
- equipped with twin co-pointed 20-cm Zeiss coronagraphs
- past dedication:
  patrol observation of prominences and emission corona in the green coronal line Fe XIV 530.3 nm

Coronal Multichannel Polarimeter (CoMP-S) at 20-cm Zeiss coronagraph





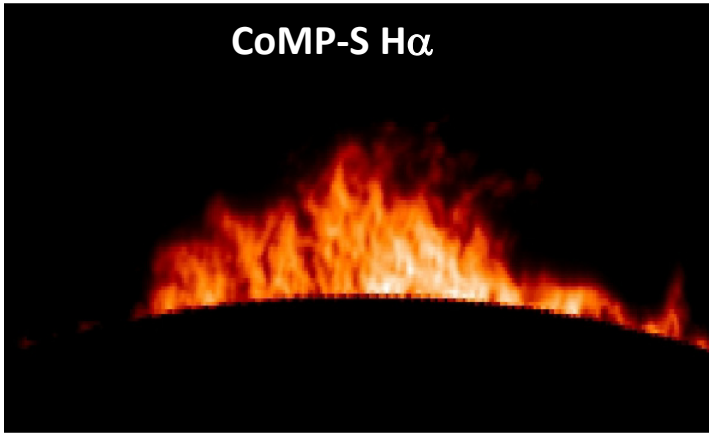
- 2D wide-field polarimeter for VIS and near-IR emission lines of prominences and corona
- core: tunable Lyot filter with polarimeter
- expected deliverables: 2D full Stokes I, Q, U, V
- May of 2013: start of regular observations of prominences in VIS
- prefilters available for prominence observations in:
  - He I 587.6 nm D_3
  - Hα 656.3 nm
  - Ca II 854.2 nm
  - He I 1083.0 nm
- current status: deployment and testing a new camera module with new optics and cameras for VIS and IR

Example of observation and results

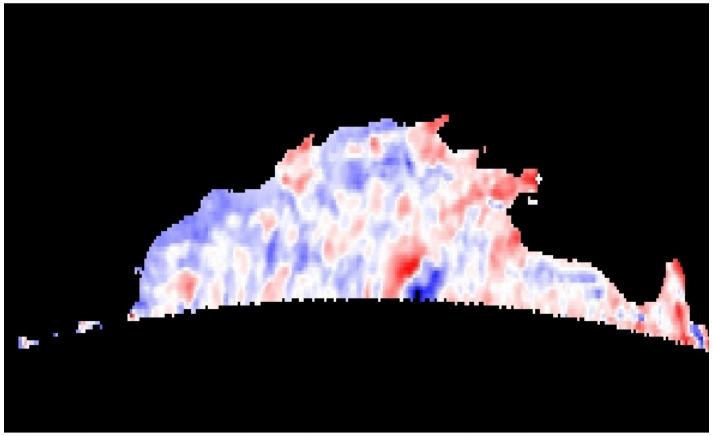
- taken during HOP 186
  „Mass loading of quiescent prominences from multi-wavelength observations“
  PI: P. Schwartz
- a quiescent prominence on 20 October 2012 at 07:09 UT
- Hα profile scanned in 11 wavelength settings, only Stokes I
- total scan time: 20.75 s
- wavelength steps
  core: ± 0.1 Å, wings: ± 0.2 Å
- FWHM of filter: 0.45 Å
- post-facto 4 × 4 pixel binning, final sampling: 1.3 arcsec/px
- Gaussian fitting of 11 samples of Hα profiles through formula:

$$f(\lambda) = A\,exp\left\{-\frac{(\lambda-\lambda_C)^2}{2w^2}\right\}$$

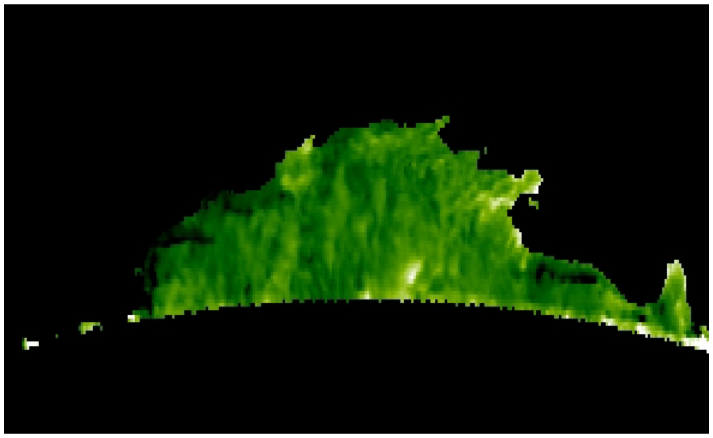
- derived parameters:
  - Gaussian amplitude A
  - Dopplershift of λ_C
  - Gaussian halfwidth w



Gaussian amplitude



Dopplershifts: ± 12 km s^{-1}



Gaussian halfwidths: 0.2 – 0.45 Å

Coordinated observation of quiescent prominences in the Hα and He I D_3 lines

- main instruments involved: THEMIS and CoMP-S
- observing campaign supported through SOLARNET access program
- campaign duration: July 28 - August 7, 2014
- aims:
  - to infer spectropolarimetric characteristics and magnetic structure of quiescent prominences
  - to acquire reference data for CoMP-S calibration
  - merging CoMP-S 2D spectropolarimetric imagery with THEMIS high-spectral-resolution spectropolarimetry

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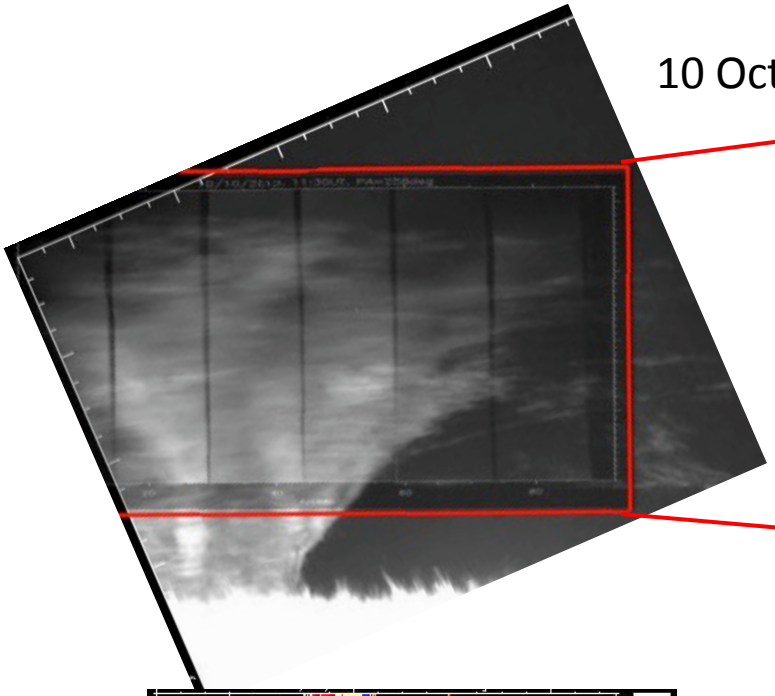
- THEMIS – dedicated to measurements of solar magnetic fields, in particular filaments and prominences
- "its 90-cm primary is superb polished" (M. Faurobert, Toulouse 2014)
- installation of adaptive optics in 2015-2016

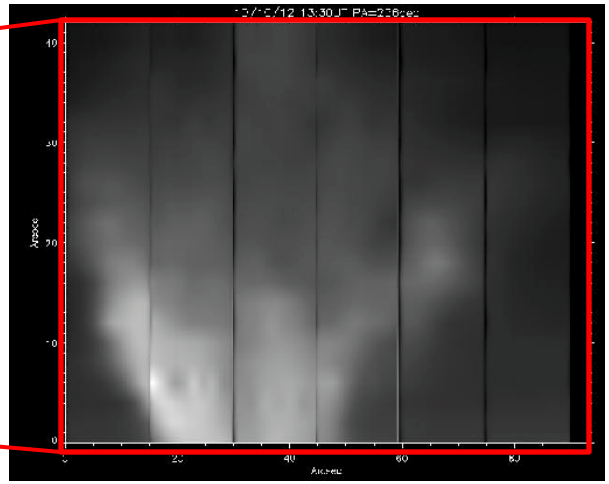
Example of observation and results

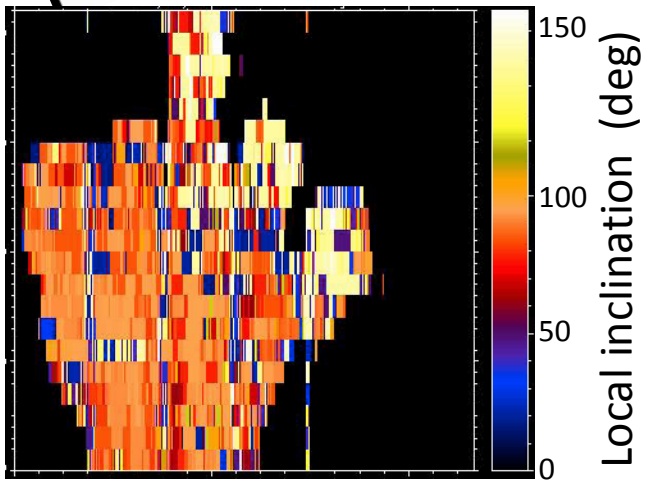
Hinode/SOT Ca II H

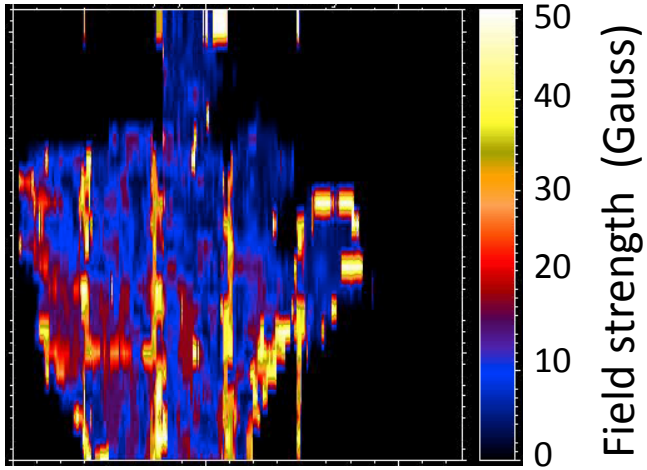
10 Oct 2012

THEMIS He I D3









Schmieder et al. (2013)

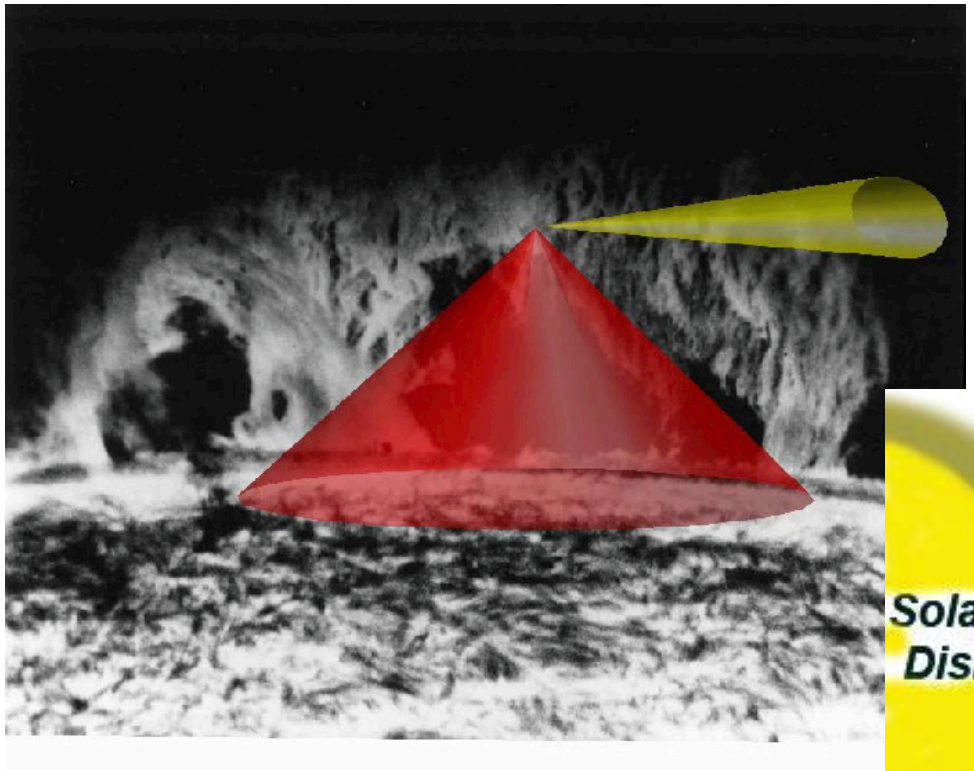
Aims of the talk

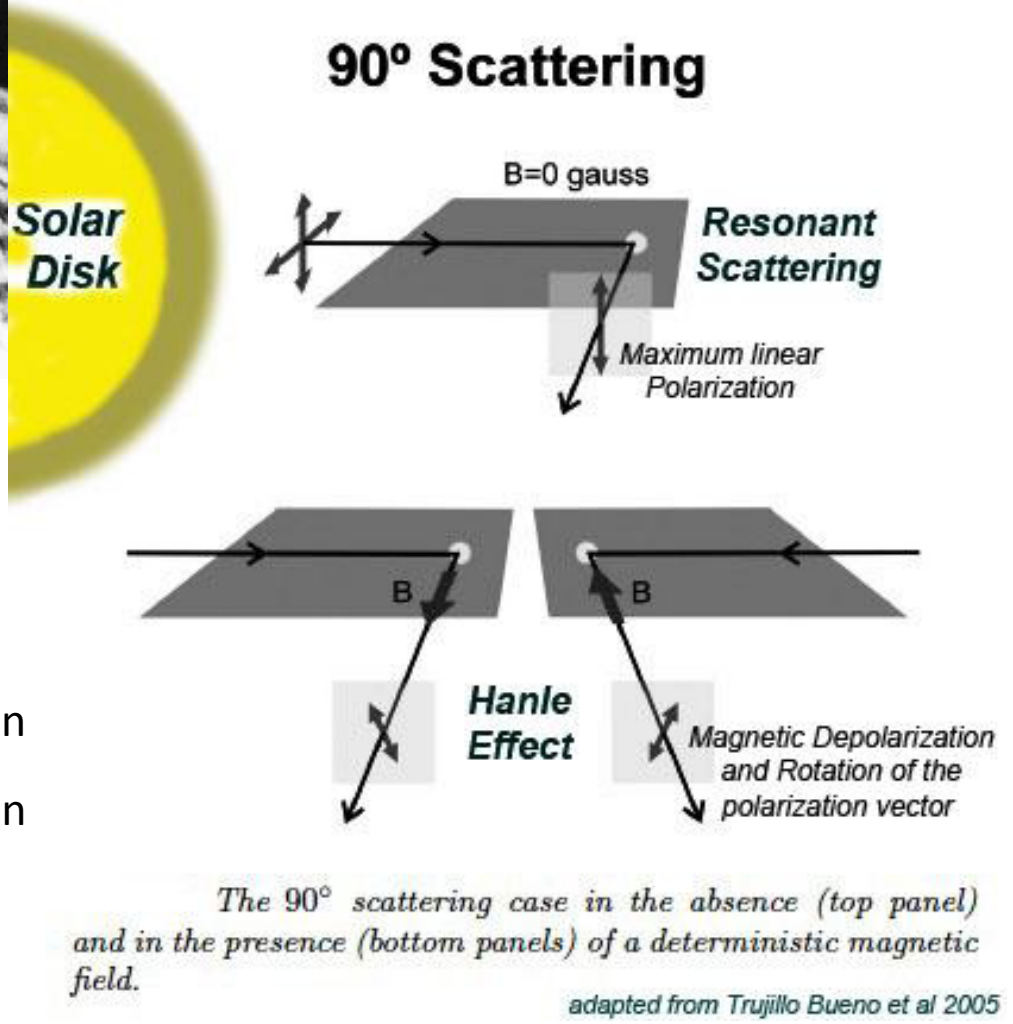
To provide a brief overview of:

- 3 selected datasetset out 16 obtained of THEMIS spectropolarimetry of prominences in the Hα and He I D_3 lines,
- results of PCA inversion of THEMIS spectropolarimetry in He I D_3 ,
- plans for testing reliability of magnetic field parameters inferred by the inversion.

Hanle effect

modification of the linearly polarized scattered radiation by the magnetic field





- sensitive to weak fields < 10 G
- mag. field depolarizes scattered radiation and modifies orientation of its polarization
- stronger field invokes larger depolarization and rotation of the polarization vector

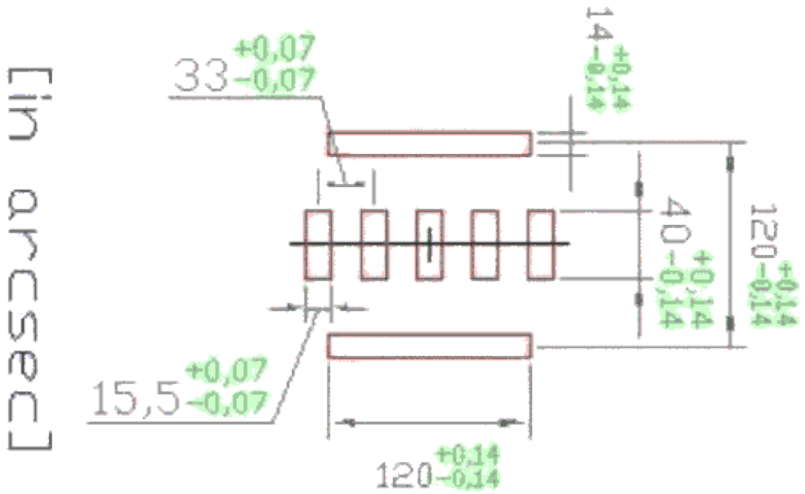
The 90° scattering case in the absence (top panel) and in the presence (bottom panels) of a deterministic magnetic field.

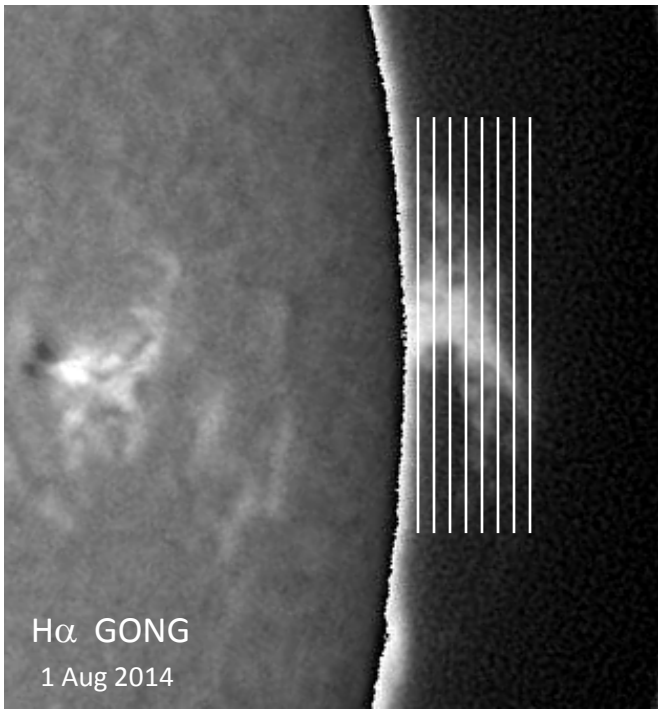
adapted from Trujillo Bueno et al 2005

THEMIS observing procedure

- MTR long-slit spectrograph with the slit width of 1 arcsec
- Hα and He I D_3 observed sequentially
- the spectrograph slit oriented parallel to the limb
- pre-slit Semel's mask at the F1 focus before the polarimeter
  - to ensure the co-spatiality of both orthogonal-polarization images
  - trade-offs are the necessity of scanning along the slit to fill the regions hidden by the mask and post-facto image reconstruction
- double scanning in directions perpendicular and parallel to the slit
- typical scan steps:
  - along the slit: 15 arcsec (typically 1 step)
  - perpendicular to the slit: 2 arcsec (typically 10 - 40 steps)
- typical scan duration: 1.5 – 2.5 hours

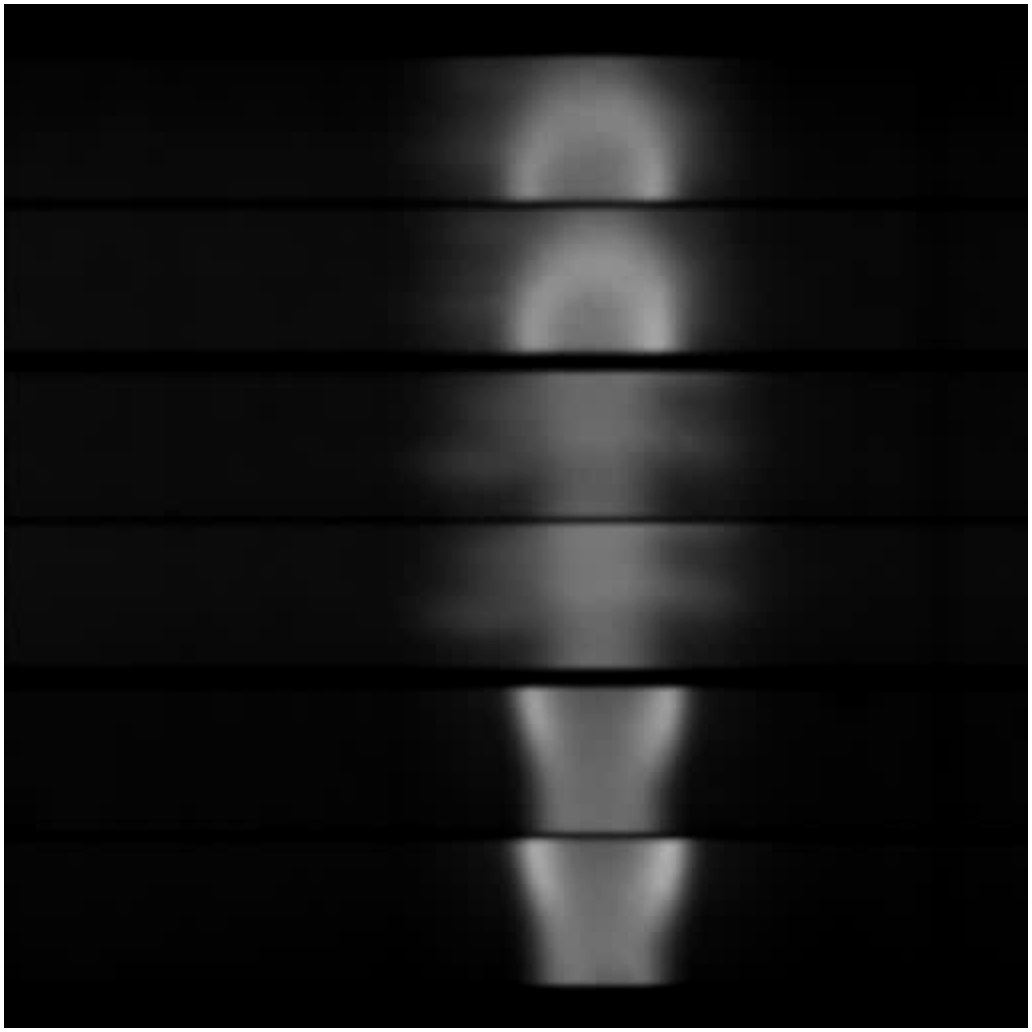
Semel's mask





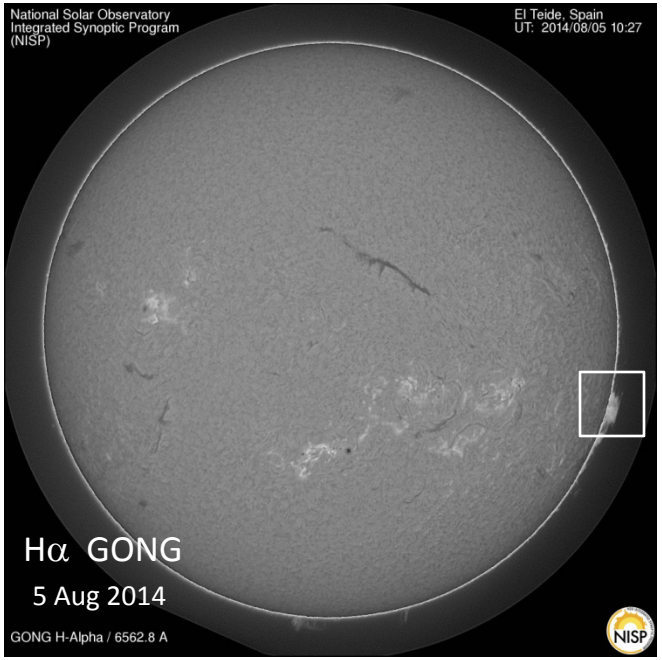
Examples of THEMIS prominence observations in Hα and He I D_3

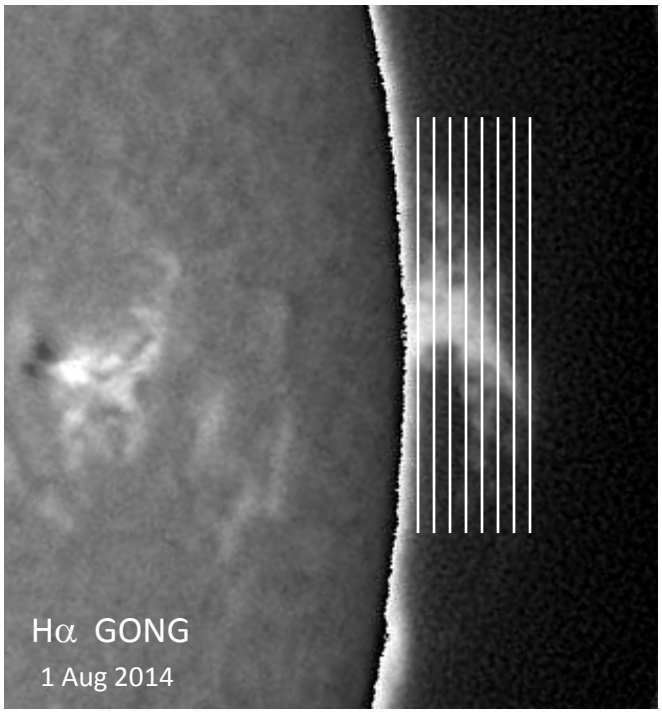
Observation in Hα from 5 Aug 2014 raw data



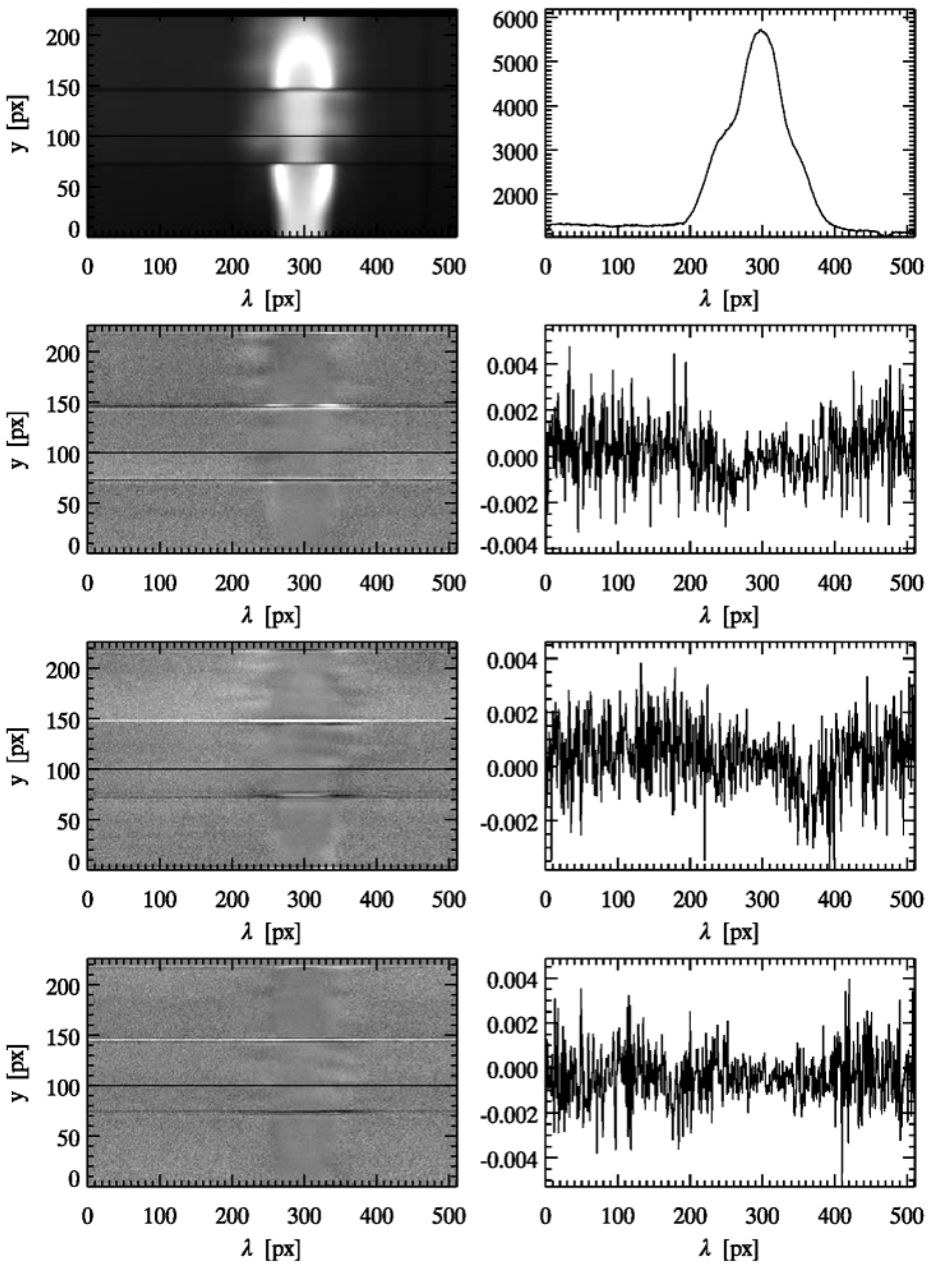
along slit

dispersion direction





Observation in Hα from 5 Aug 2014 - reduced data

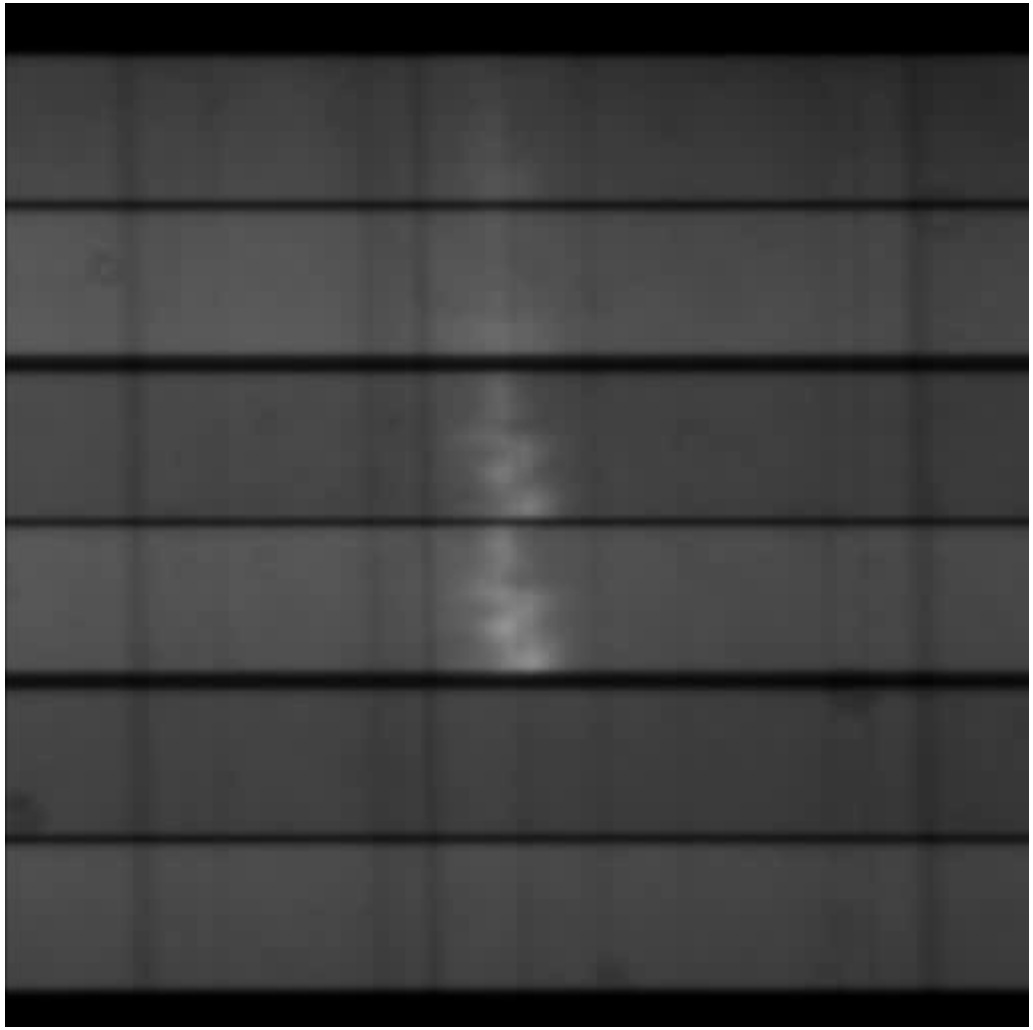


- case of a bright prominence
- saturated Hα core with central reversal
- optically thick plasma with many scattering processes along line of sight resulting in **depolarized desert**

Upshot

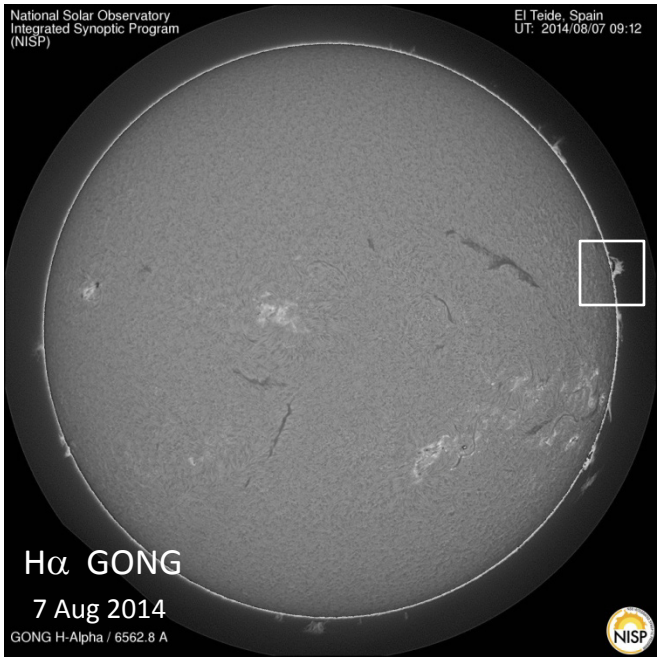
Too bright prominence is not a right target for Hα spectropolarimetry.

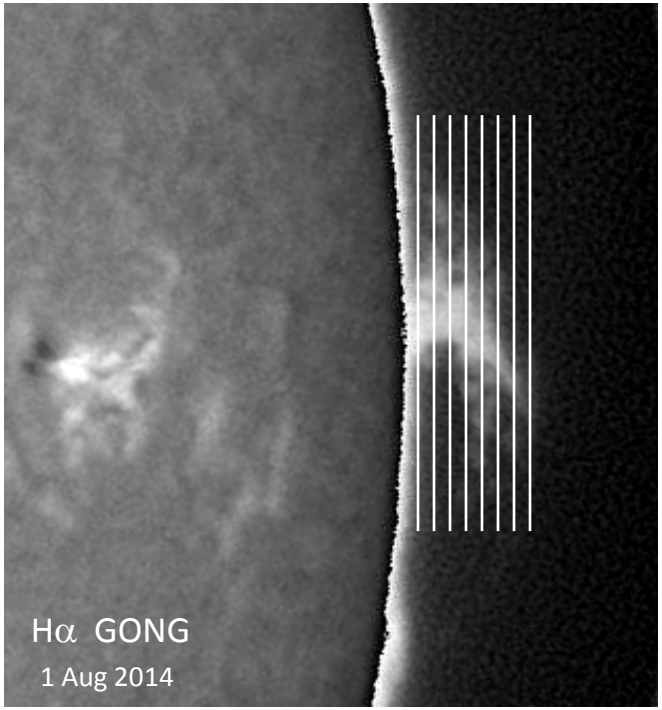
Observation in He I D_3 from 7 Aug 2014 raw data



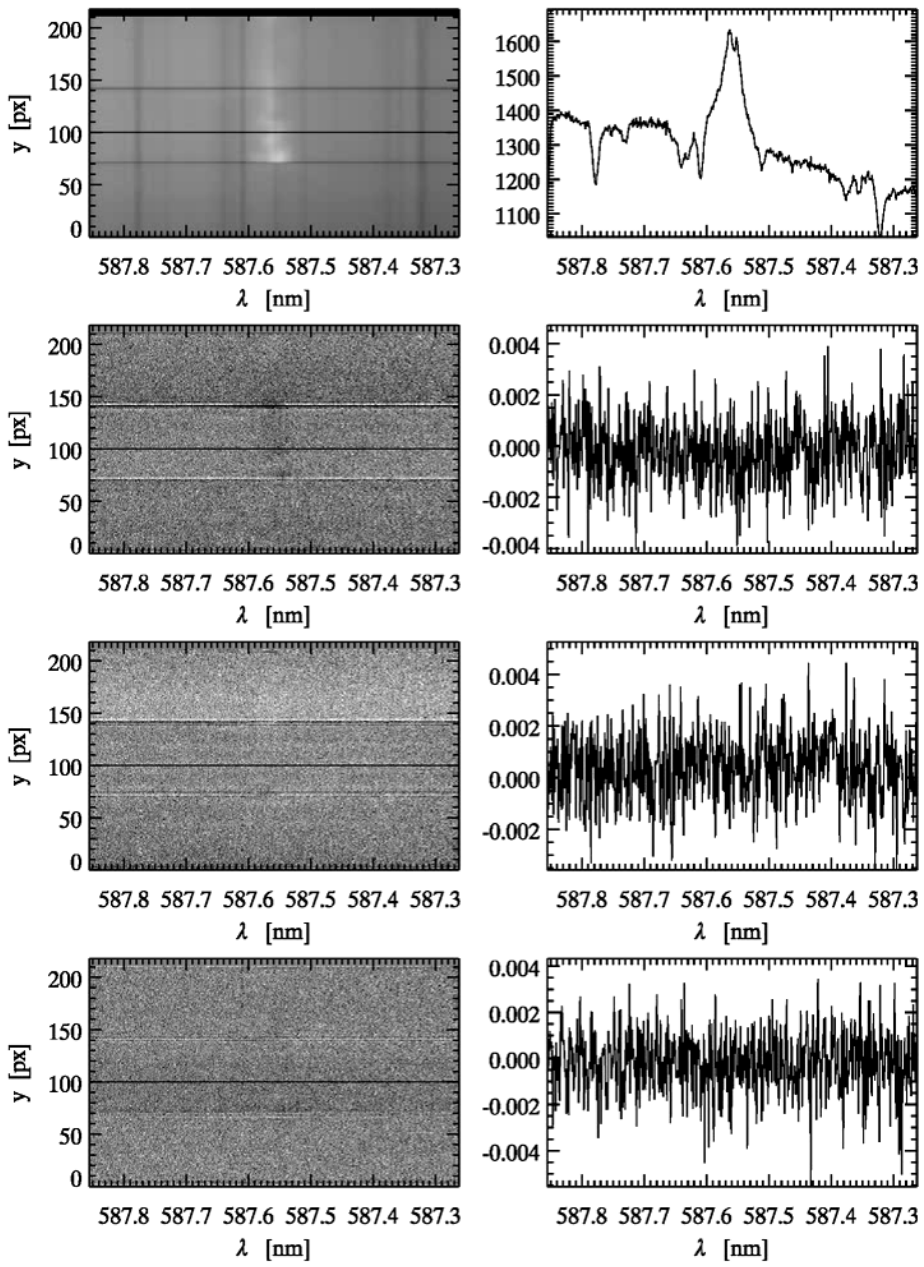
along slit

dispersion direction



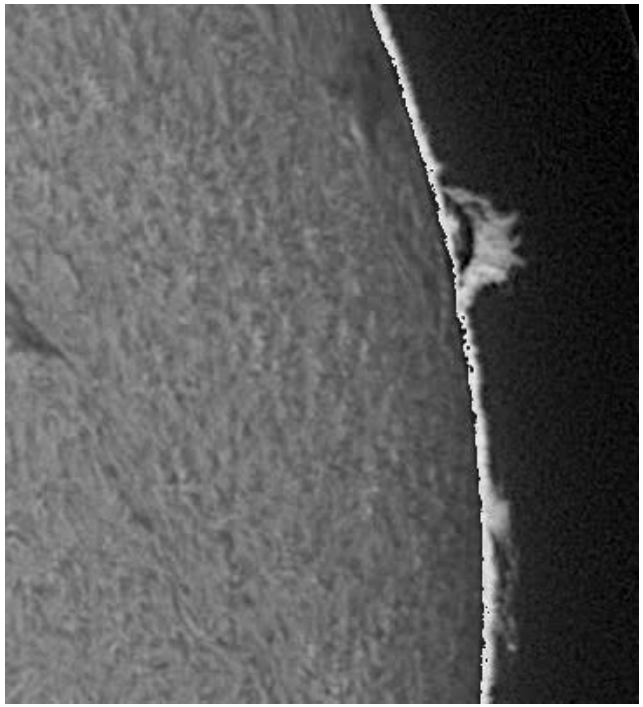


Observation in He I D_3 from 7 Aug 2014 - reduced data



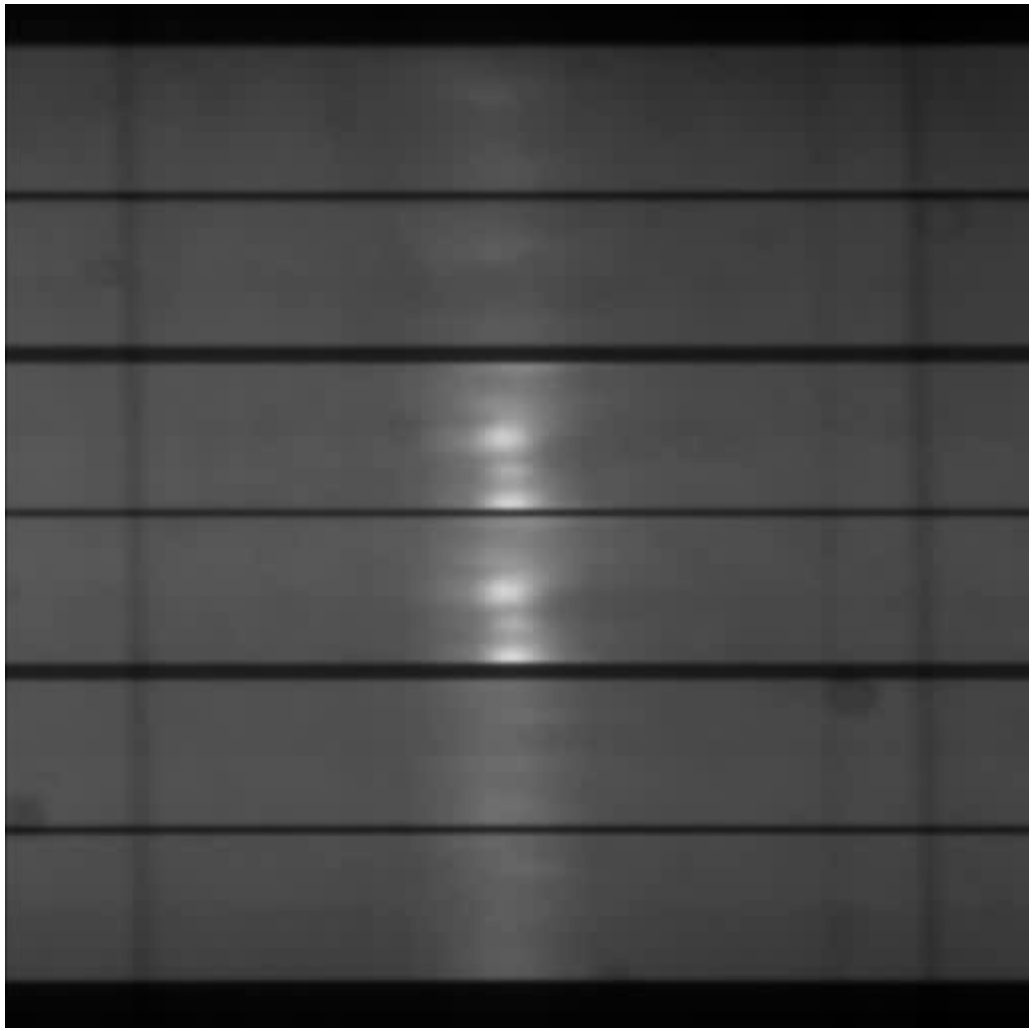
- case of a moderately bright prominence
- clear polarization signal in Stokes profiles is missing
- He I D_3 is a doublet
- trend of background?
- vigorous dynamics seen as large Dopplershifts

GONG Hα



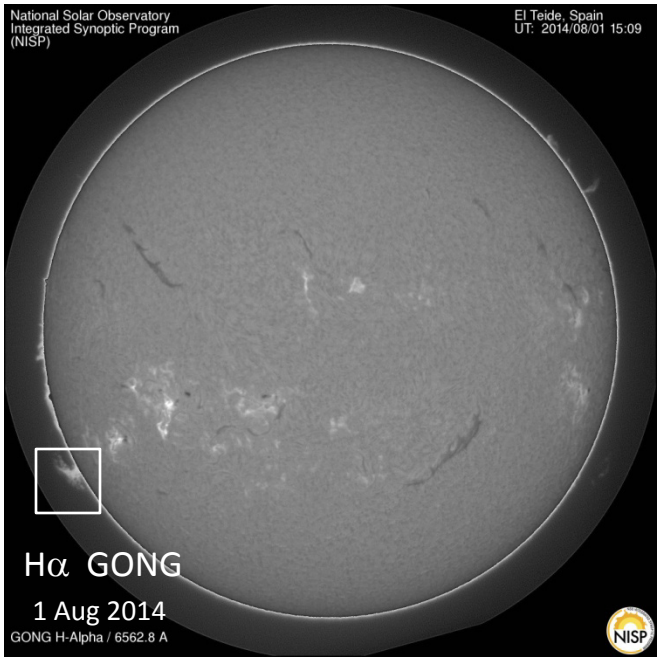
THEMIS prominence observation in He I D_3 on 1 Aug 2014

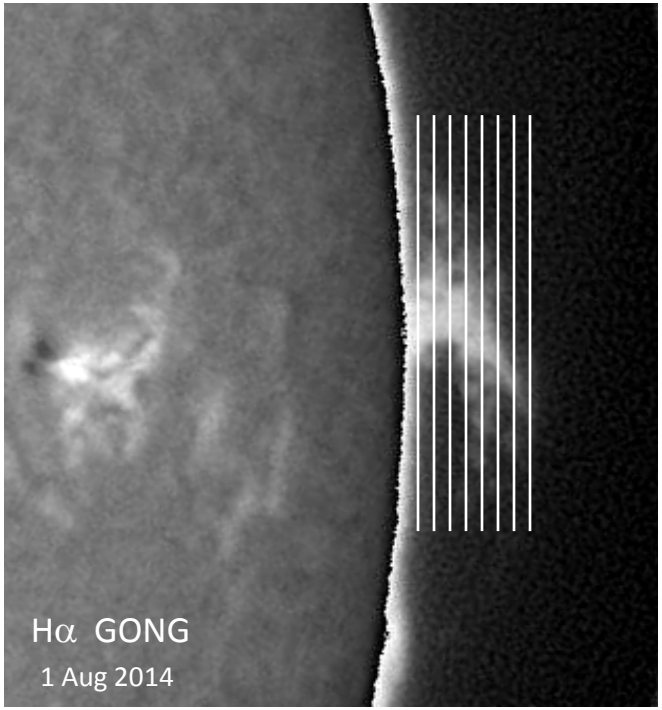
Observation in He I D_3 from 1 Aug 2014 raw data



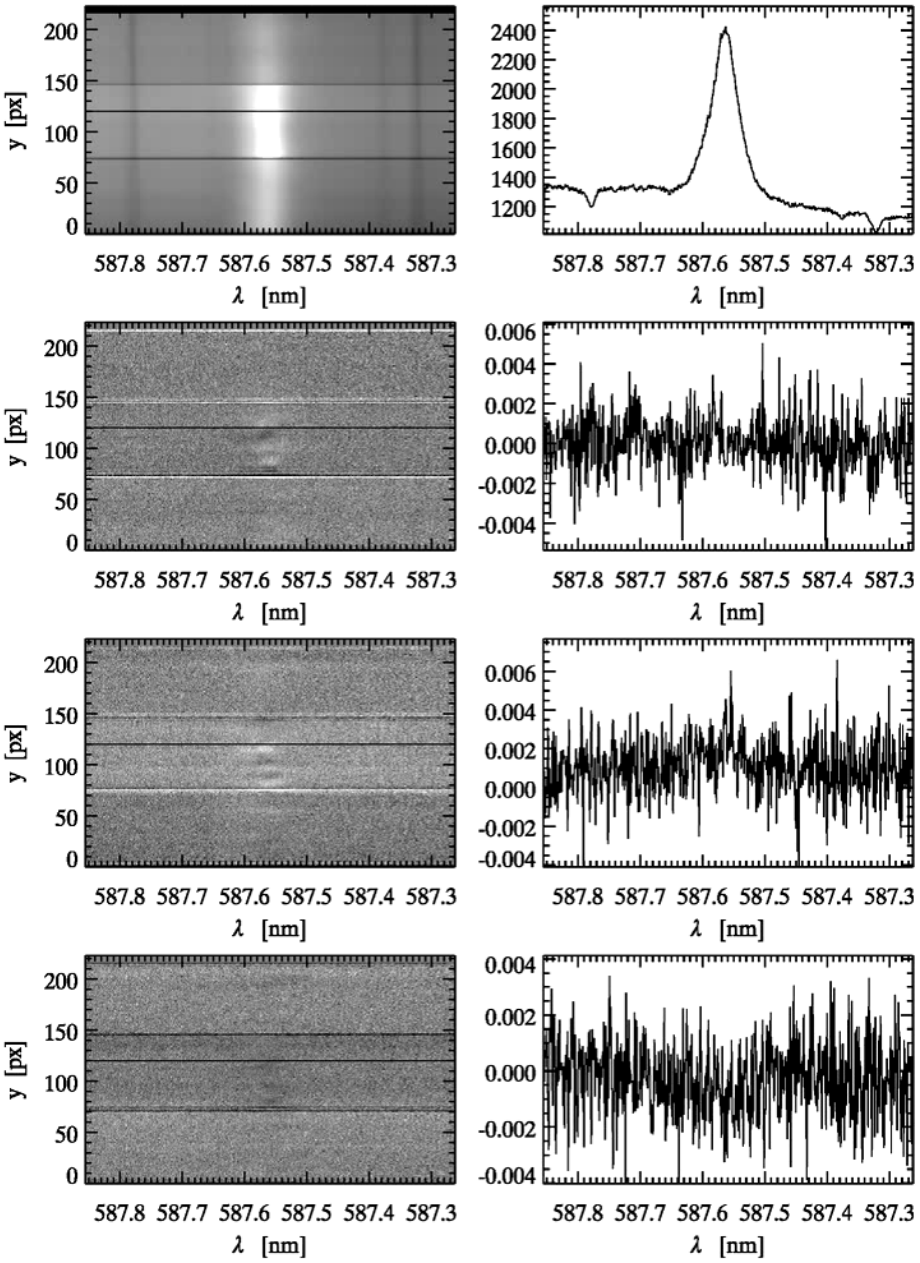
along slit

dispersion direction



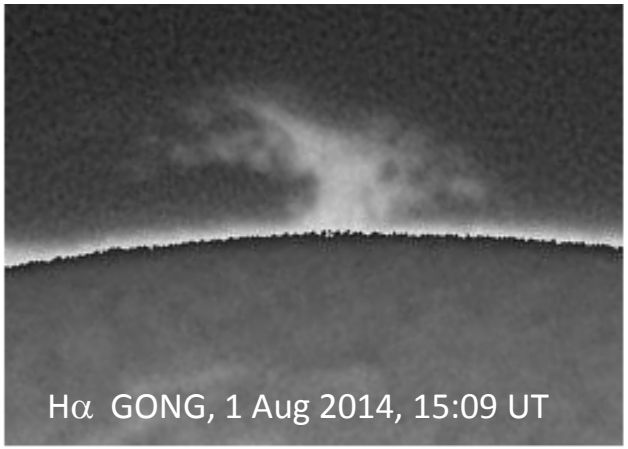


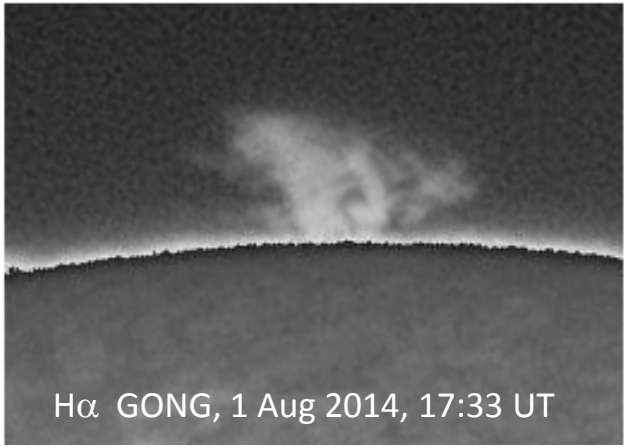
Observation in He I D_3 from 1 Aug 2014 - reduced data

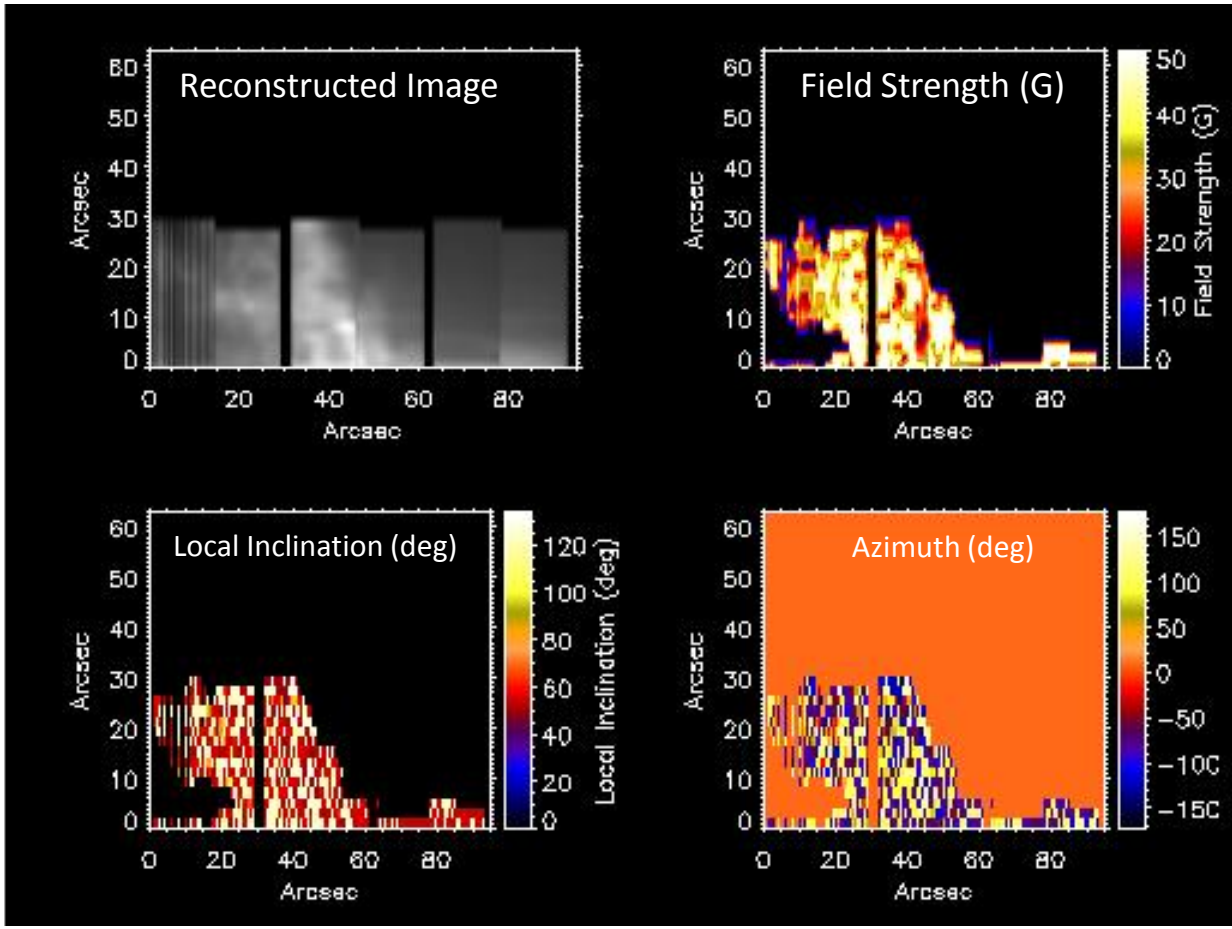


- very weak or almost no polarization signal in Stokes profiles
- just bad luck
- trend of background after reduction by DeepStokes package?

Results of PCA inversion of He I D_3 spectropolarimetry from 1 Aug 2014



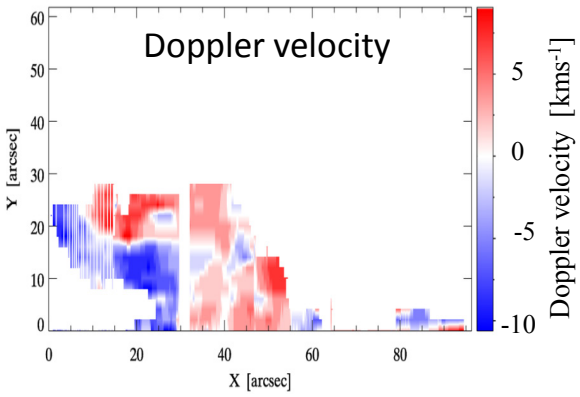


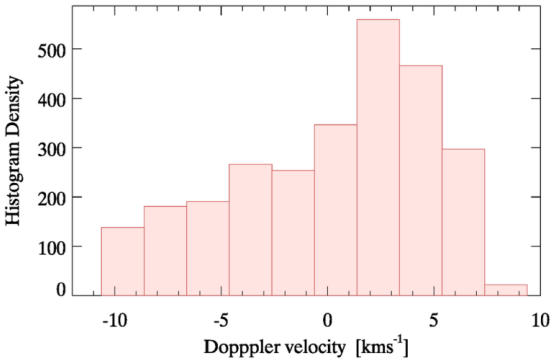


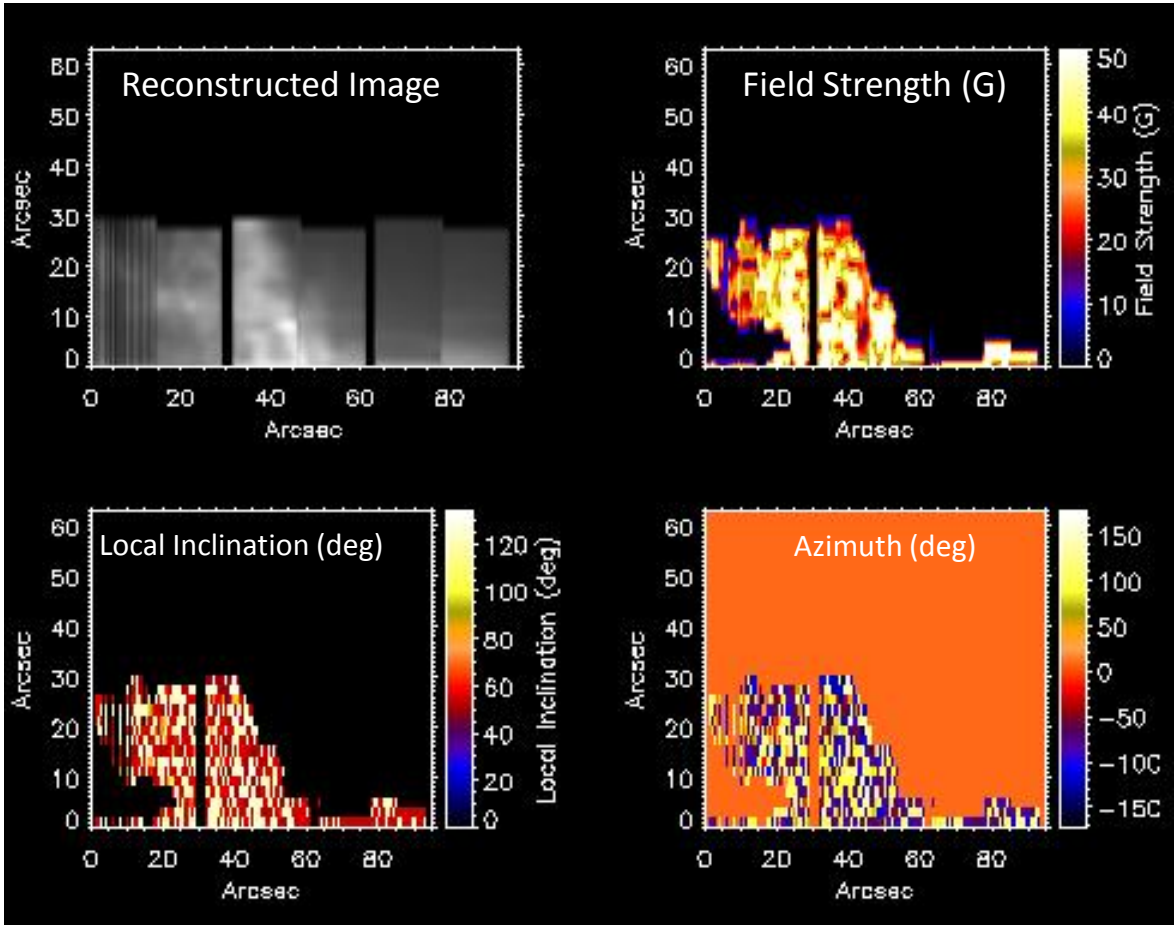
start of scanning: 15:09 UT
end of scanning: 17:33 UT

There is an obvious evolution of the prominences within the scanning interval lasting for 2.5 hours.

Results of PCA inversion of He I D_3 spectropolarimetry from 1 Aug 2014



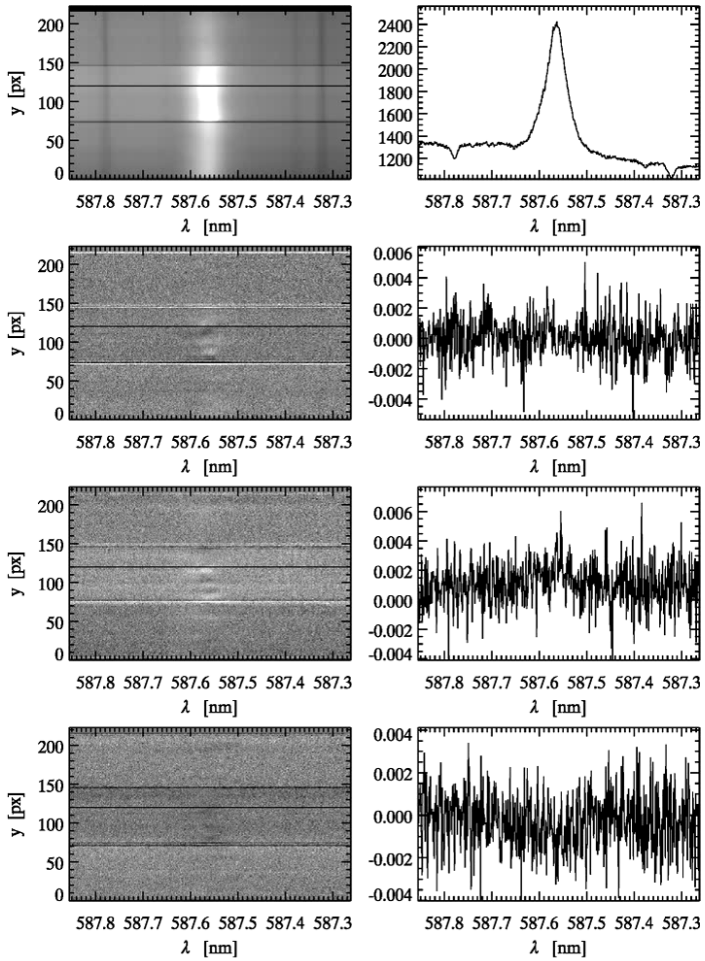


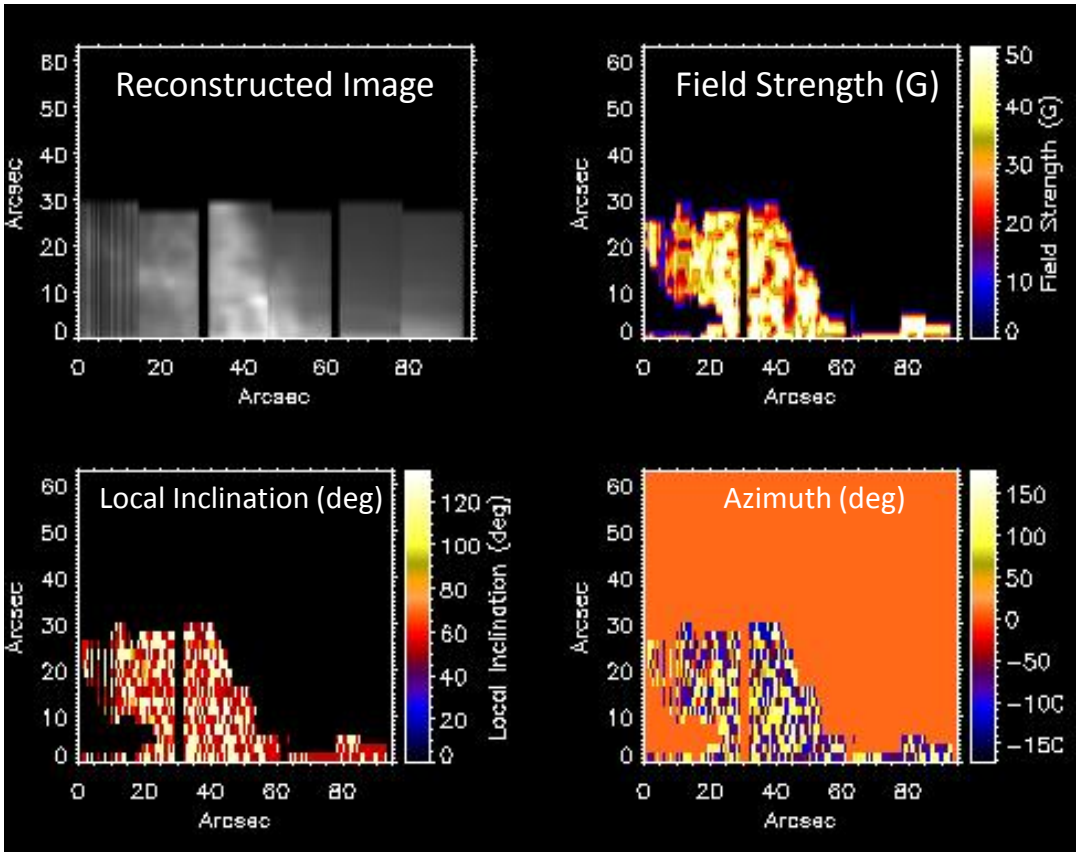


Summary

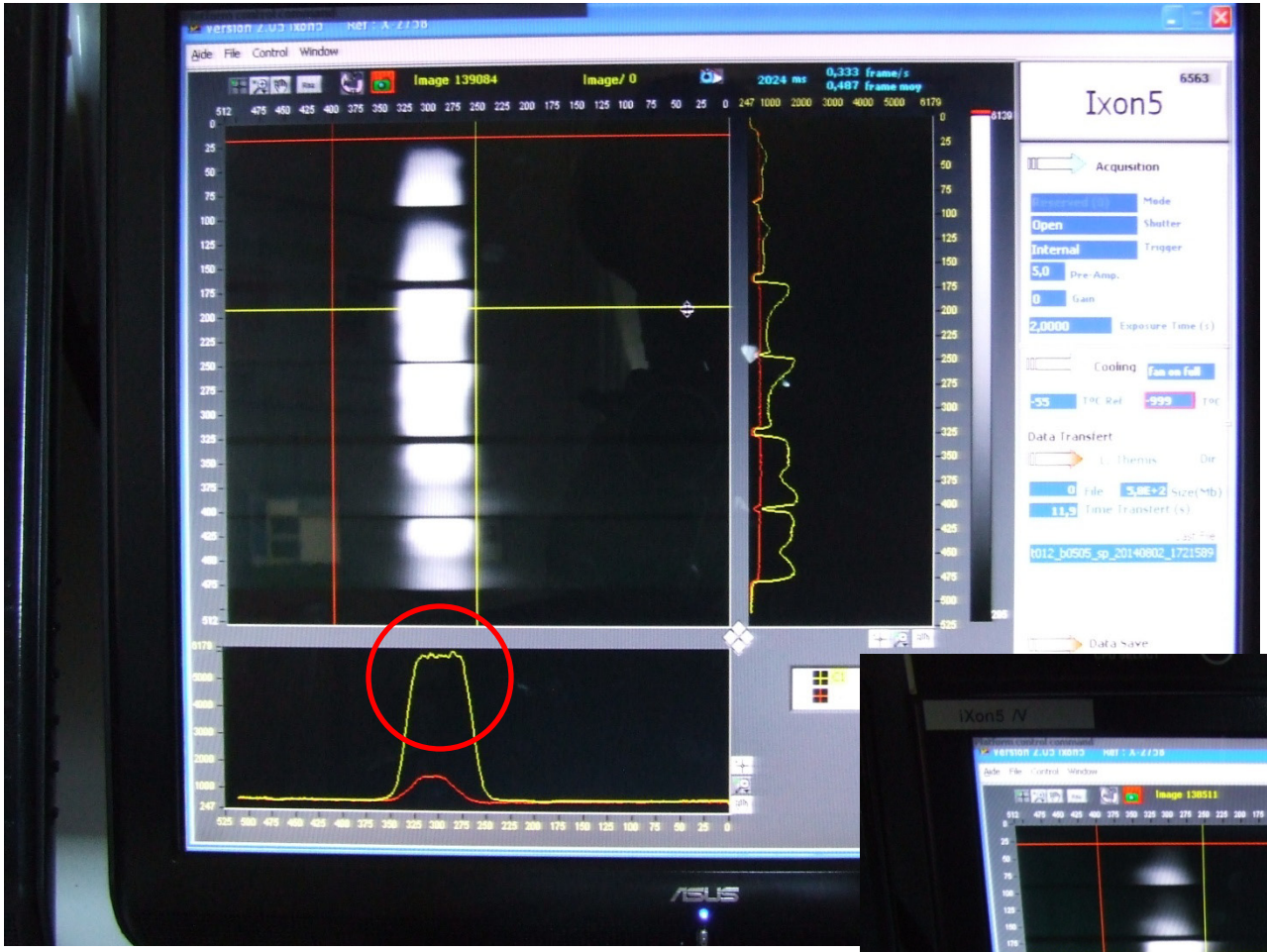
- the inversion results do not provide much insight
- weak signal in Stokes profiles forces inversion towards stronger fields larger than 30 G
- no structures in the maps of the strength and orientation of mag. field
- the absence of clear signals takes the inversion to strong fields since in the Hanle effect stronger fields depolarize
- the inversion cannot find information to fix the geometry and hence the inclination is just a random map between two values that roughly correspond to the Van Vleck angles at which scattering polarization cancels out

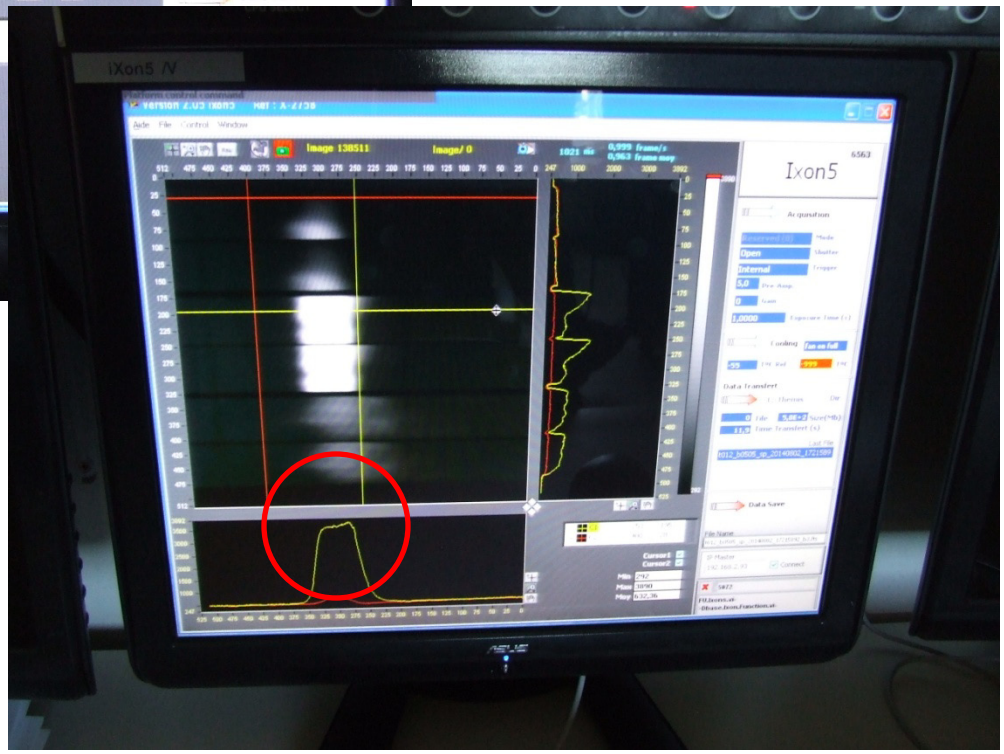
Plans what else





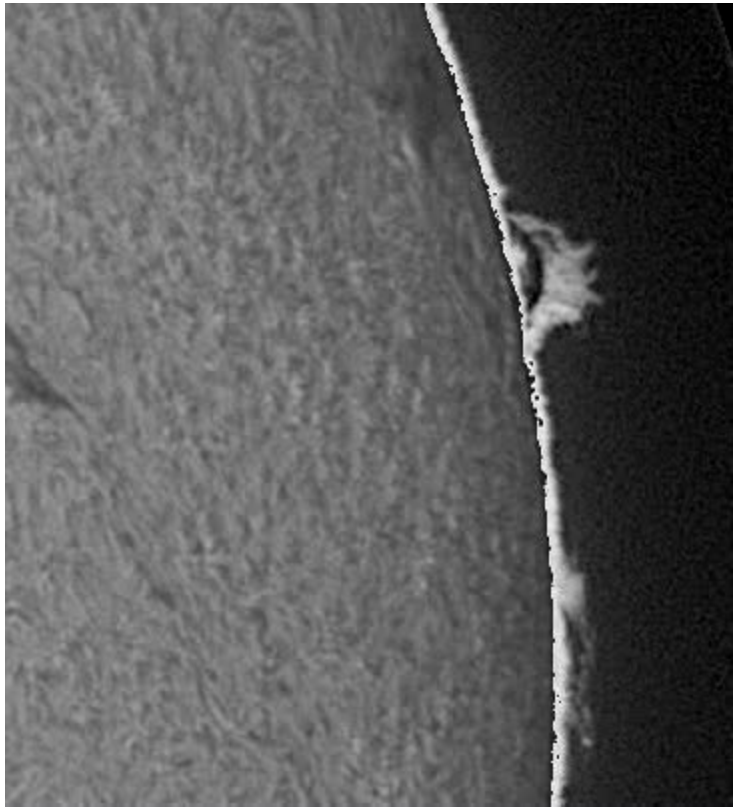
- the movie suggests some Stokes signal at many positions along the slit
- by pixel-by-pixel inspection identifying positions in the structural maps of mag. field based on clear Stokes signal
- the identified pixels should harbor field strengths < 20-30 G shown in blue and violet
- at these pixels the mag. field should be determined wit some confidence

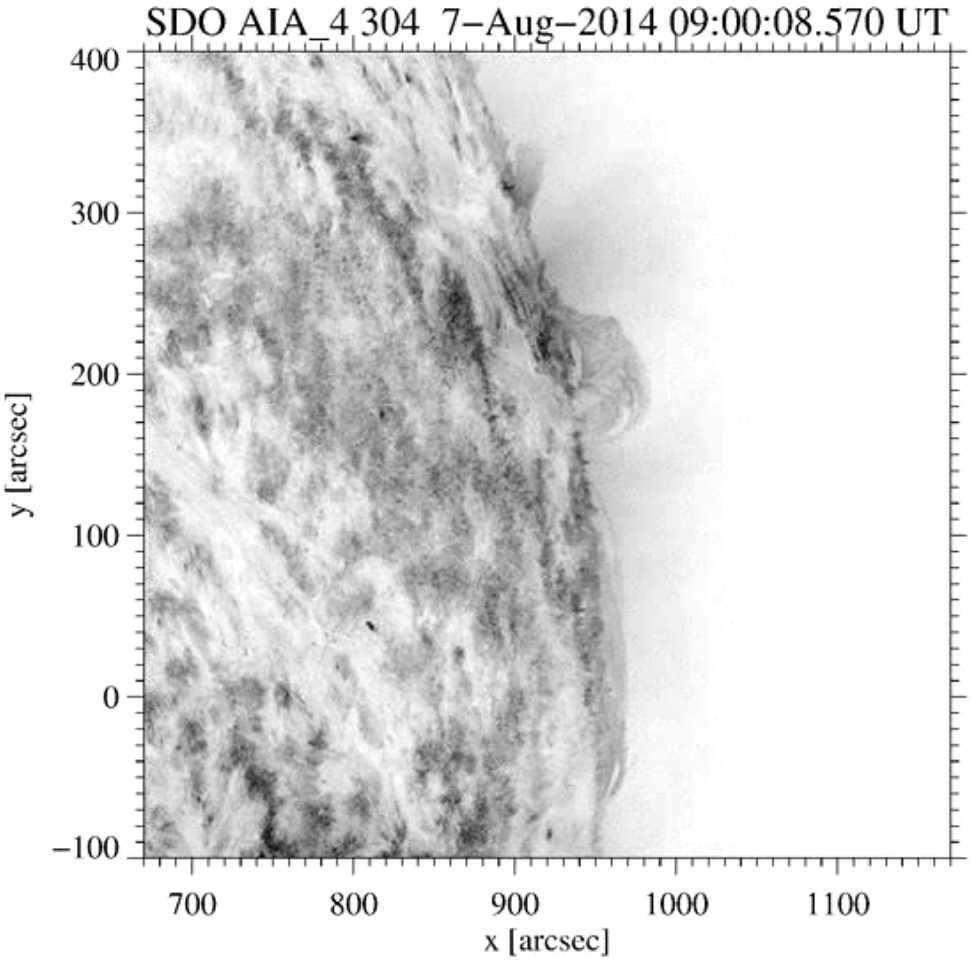




Saturated Hα on displays

GONG Hα 7 Aug 2014 09:12 – 11:15 UT





- comparison of loop-like prominence morphology in Hα and He II 304 Å shows differences
- the He II 304 Å movie suggests:
  - a hollow fluxroupe-like structure of the prominence extending on the disk with threads winding around a cavity inside the prominence
  - a burst of activity:
    - after 10:45 UT southward from the prominence
    - filling the gap bellow the prominence but with no counterpart in Hα keeping the gap unchanged
- He I D_3 Dopplershifts might be due to fast plasma motions along threads of the magnetic fluxroupe