UNIVERSITÀ degli STUDI di CATANIA

Multi-line spectropolarimetric NLTE inversions of the X1.6 Flare occurred in AR12192

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In October 2014, during Solar Cycle 24, the large and complex active region AR12192 appeared on the east limb of the Sun. It produced 6 X-class and 30 M-class flares.

The green box shows the Field-of-View of IBIS observations.

The upper-left panel shows a HMI/SDO magnetogram of the AR, the upper-right panel shows the AR observed at 1600Å, the lower left panel shows the AR observed at 171Å and the lower right panel shows the AR observed at 131Å by AIA. The green box shows the IBIS FoV.

Data overview

We inverted the full Stokes data obtained by the Interferometric BIdimensional Spectropolarimeter (IBIS) instrument of the inner region of AR 12192 during the X1.6 confined flare SOL2014-10-22T14:02 with DeSIRe.

Fe I

Ca II

Maps showing a vertical cut (λ-Y) of the observed Stokes I and V at X = 19 arcsec.

1 pix ~ 0.095 arcsec
Full FoV ~ 35x80 arcsec

Data Preparation

- Normalization to the averaged local continuum of the “quiet” Sun inside the FoV.
- Re-normalization considering the heliocentric angle ($\mu = 0.9$).
- Interpolation of the non-uniform wavelength grid to a uniform one containing the original spectral points.
- Mask out of the non-original spectral points so they are not included in the χ^2 computation.

Inversion Tests – Simultaneous inversion

We inverted the two lines simultaneously using 3 initial atmospheres for the first test and the node configuration shown below. Weights are (2, 1, 1, 2) for (*I*, *Q*, *U*, *V*), respectively.

Parameter	**Nodes**			
	Cycle 1	**Cycle 2**	**Cycle 3**	**Cycle 4**
Temperature	2	3	5	6
Line-of-Sight Velocity	1	2	3	5
Field Strength	1	2	3	5
Inclination	1	2	3	5
Azimuth	1	1	1	1
Microturbulence	1	1	2	2

Configuration 1

Inversion Tests – Sub-FoV of 150x150 pixels

As we are interested in the flare ribbon, we decided to select a sub-FoV and refine the inversions by testing different configurations changing:

- number of nodes;
- weights;
- initial atmospheres.

Final configuration

The best configuration that provides the best results so far is presented below. Weights are (2, 1, 1, 5) for (I, Q, U, V), and we use up to 21 initial atmospheres per pixel.

Parameter	**Nodes**			
	Cycle 1	**Cycle 2**	**Cycle 3**	**Cycle 4**
Temperature	2	3	5	6
Line-of-Sight Velocity	1	2	3	5
Field Strength	1	2	2	3
Inclination	1	2	2	3
Azimuth	1	1	1	1
Microturbulence	1	1	2	2

Final configuration

Input

First configuration

Final configuration

Final configuration – χ^2 values

Maps showing the inverse χ^2 provided by the parallel wrapper for the first (left) and the final (right) configuration.

Inversion Accuracy - profiles

Maps of the inferred Stokes I in line core of Fe I and Ca II. The two squares indicate the locations of the two pixels whose analysis is shown in the in the rightmost figure.

Upper panels show Stokes profiles relative to Fe I. Lower panels show Stokes profiles relative to Ca II. Black crosses are the observed profiles, while the pink lines represent the fit obtained with inversions.

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Inversion results - Atmospheric parameters

Plots showing the atmospheric parameters at different optical depths.
We can see a strong increase in temperature along the flare ribbon and large upward velocities.

Inversion results - Stratification of the atmospheric parameters

Maps of the inferred Stokes I in line core of Fe I and Ca II.

The panels show the stratification of the atmospheric parameters in two pixels located on the flare ribbon. The line colors match the locations in the maps on the left. The black line in the temperature plot shows the temperature stratification in the FALC model, included for comparison.

Summary

We inverted the full Stokes profiles of Fe I 6173 and Ca II 8542 lines simultaneously during an X1.6 flare.

- We prepared the data for the DeSIRe format.
- Then, we ran different tests to optimize the configuration until a good accuracy was obtained even for the most demanding pixels, e.g., Ca II in emission.
- We analyzed the atmospheric parameters and found a strong increase in temperature in upper layers along the flare ribbon, and large upward velocities.

We plan to continue this work by refining the inversions and further studying the atmospheric parameters.

Inversion Accuracy – Stokes I Fe I

The first panel shows a map of the observed Stokes I in the line core of Fe I (6173.3 Å) , the second panel shows the values inferred through inversion, and the third panel represents the difference between the input and the inferred Stokes I.

Inversion Accuracy – Stokes I Ca II

Same as before for the Stokes I near the line core of Ca II (at 8542.16 Å)

Inversion Accuracy– Stokes V Fe I

The first panel shows a map of the observed Stokes V in the red wing of Fe I line (6173.44 Å) , the second panel shows the values inferred through inversion, the third panel represents the difference between the input and the inferred Stokes V.

Inversion Accuracy– Stokes V Ca II

Same as before for the Stokes V in the red wing of Ca II line (8542.38 Å)