

ABSTRACT

The vector magnetic field pipeline of the Synoptic Optical Long-term Investigations of the Sun (SOLIS) Vector Spectromagnetograph (VSM) is currently undergoing an overhaul. Improved algorithms for fringe removal, quicklook vector magnetic field estimation, Milne-Eddington inversion, and geometrical image distortion correction are being implemented, which will result in dramatically improved data products which the National Solar Observatory (NSO) routinely provides to the solar community. This poster highlights the recent improvements we are making and points users to our new spectropolarimetric and magnetic field data products.

FRINGE REMOVAL

- ▶ Previous method relied on (somewhat) ad-hoc model of spatio-spectral behavior of fringes...resulted in incomplete/non-robust removal.
- ▶ New method uses wavelet filtering to identify fringe component in power spectrum (see Figure 1), assumes no prior information about fringe behavior. Adapted from Rojo & Harrington (2006).

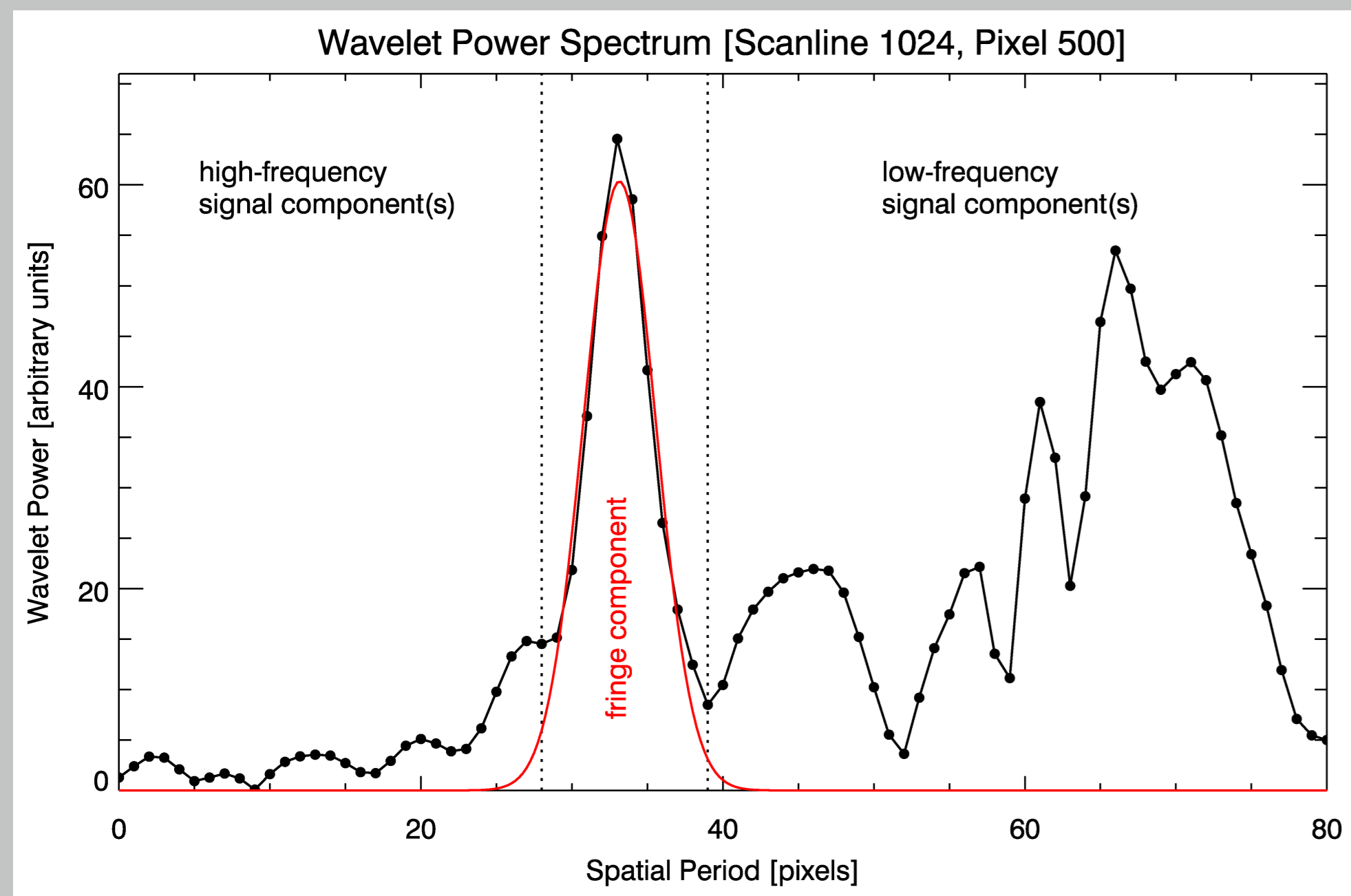


Figure 1: Identification of fringe component in wavelet power spectrum.

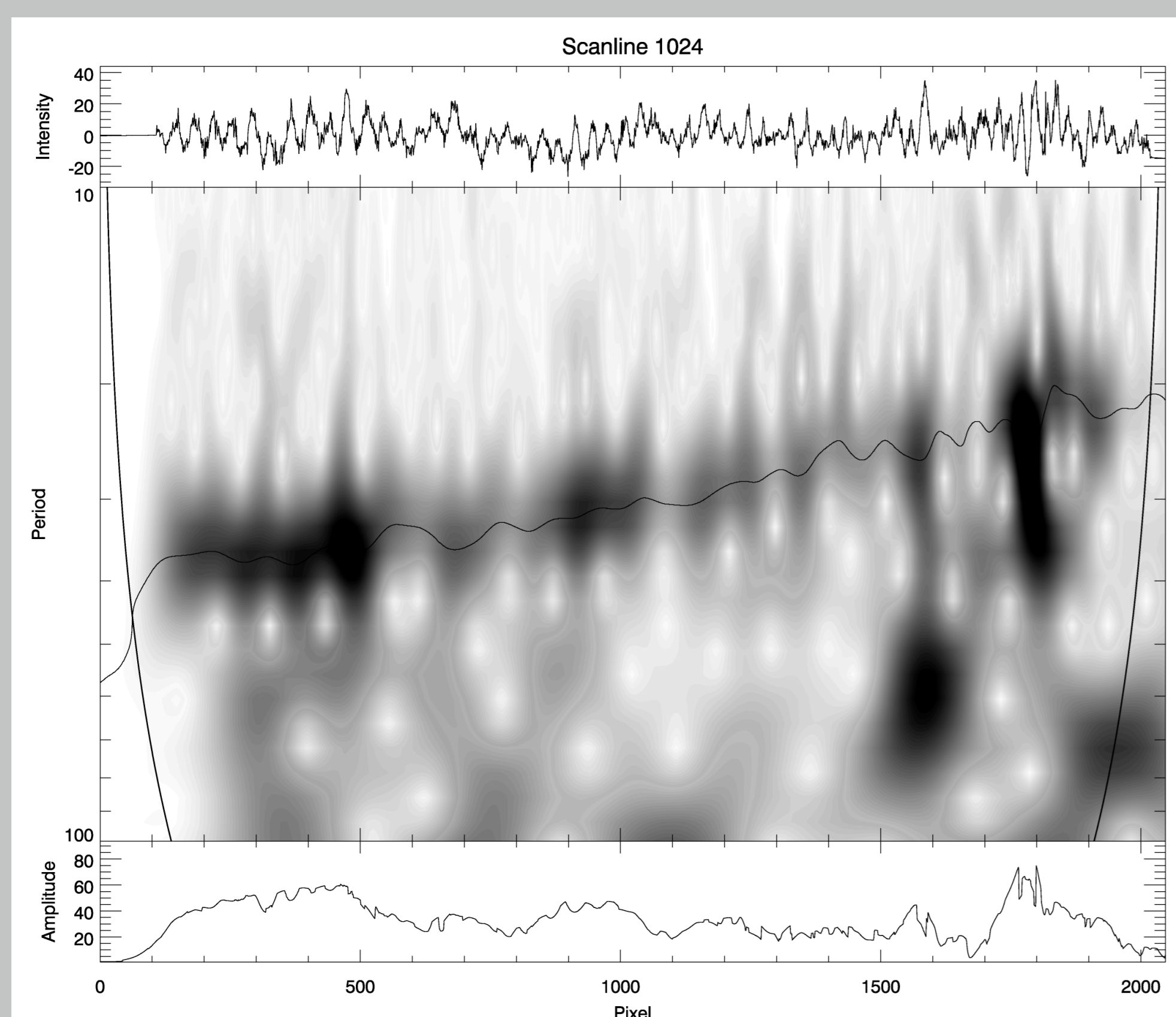


Figure 2: 2D wavelet power spectrum (created by stacking successive power spectra as in Figure 1), showing spatial variation of fringe pattern as ridge feature.

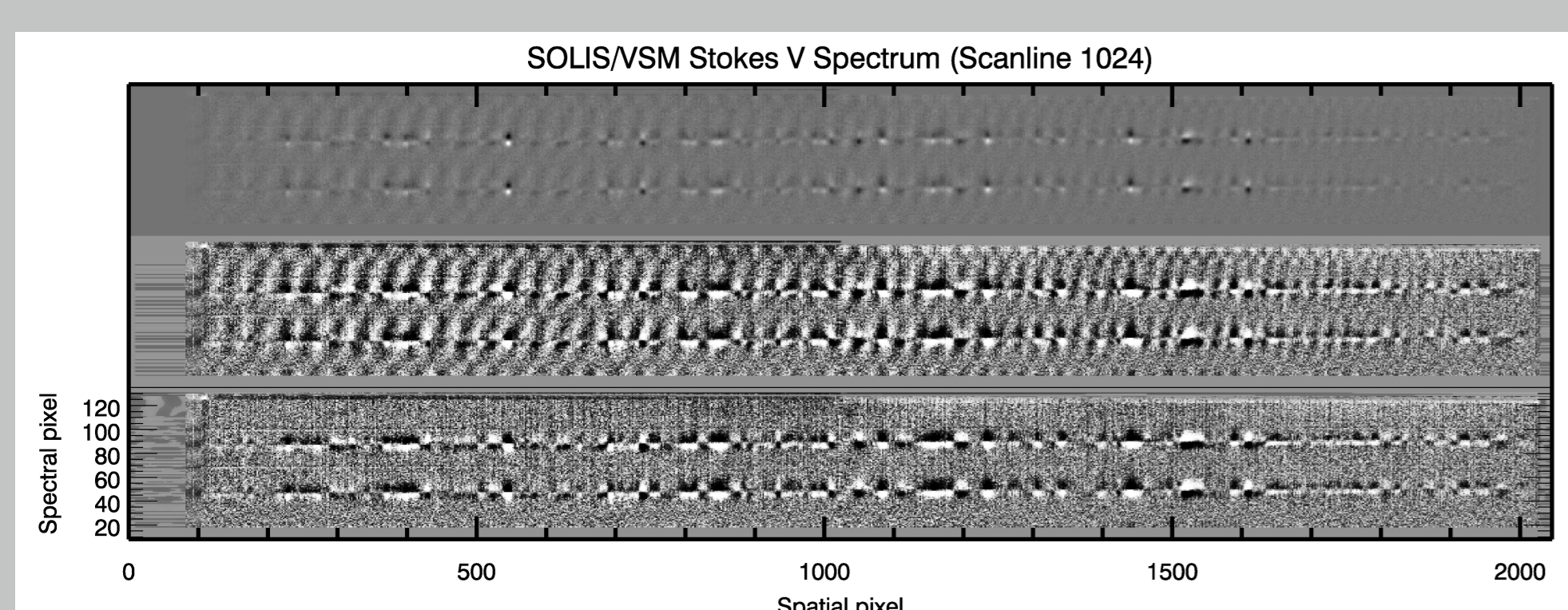


Figure 3: Result of wavelet-based de-fringing on typical Stokes V spectrum. Middle frame is contrast-enhanced version of top frame, and bottom frame is contrast-enhanced clean Stokes V spectrum.

QUICKLOOK VECTOR MAGNETIC FIELDS

- ▶ New method uses integral technique of Ronan *et al* (1987) and derives fill-factor estimate from Bommier *et al* (2009).

$$B_{\parallel} = K_{\parallel} \left[\frac{\int a_{\lambda} V_{\lambda} d\lambda}{\int I_{\lambda} d\lambda} \right] \quad B_{\perp} = K_{\perp} \left[\frac{\left(\int b_{\lambda} Q_{\lambda} d\lambda \right)^2 + \left(\int c_{\lambda} U_{\lambda} d\lambda \right)^2}{\left(\int I_{\lambda} d\lambda \right)^2} \right]^{\frac{1}{2}}$$

$$\gamma = \tan^{-1} \left[\frac{B_{\perp}}{B_{\parallel}} \right] \quad \chi = \frac{1}{2} \tan^{-1} \left[\frac{c_{\lambda} U_{\lambda} d\lambda}{b_{\lambda} Q_{\lambda} d\lambda} \right] \quad \alpha \approx \frac{|V|_{\max}^2 \tan^2 \gamma}{(\sqrt{Q^2 + U^2})_{\max} (I_c - I_0)}$$

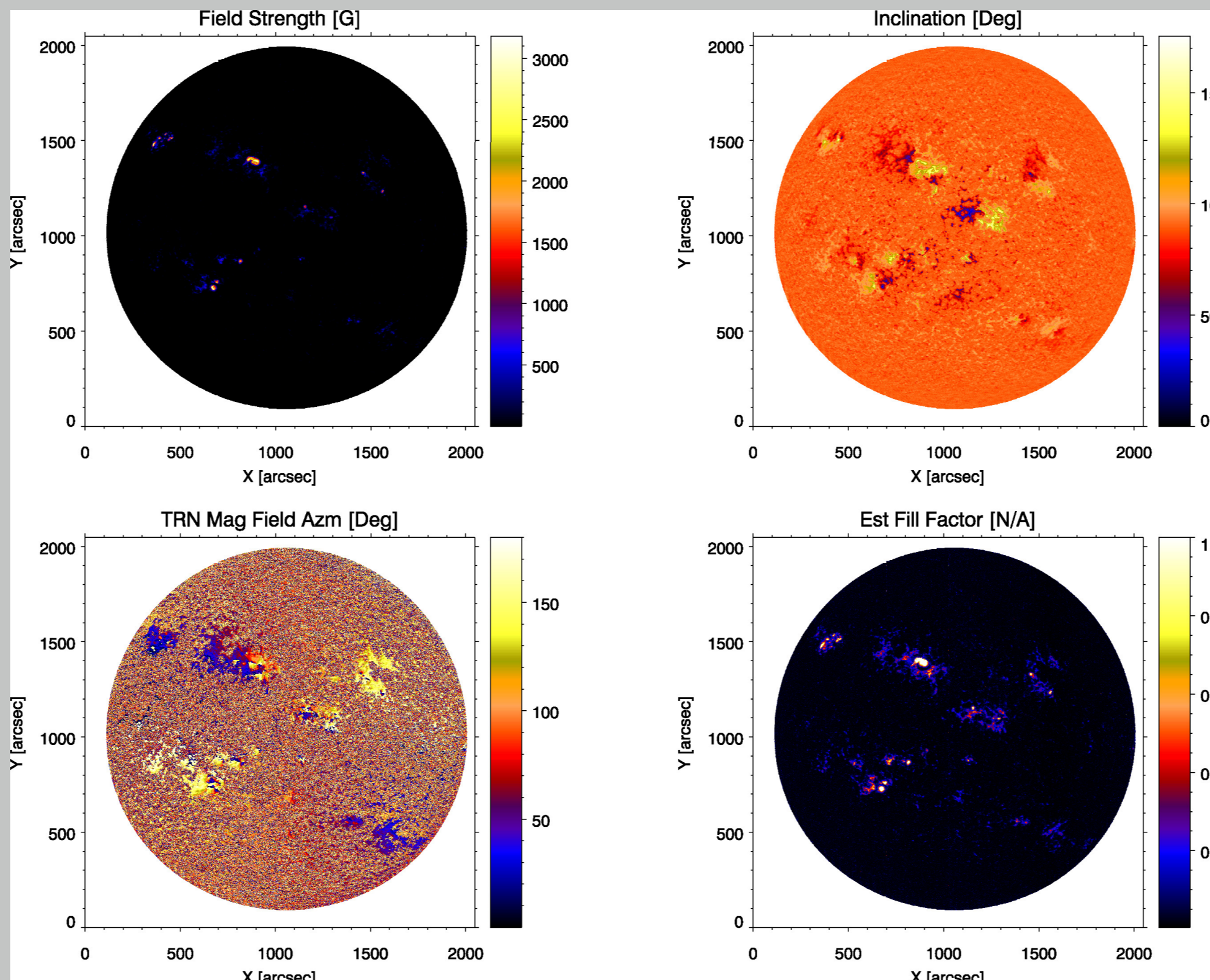


Figure 4: Field strength, inclination, azimuthal angle, and fill-factor on 15 May 2013 15:31UT, as derived by the new SOLIS/VSM quicklook code.

- ▶ Proportionality constants, K_{\parallel} & K_{\perp} , determined by linear regression with inversion results
- ▶ Method does not show PIL-related artifacts
- ▶ Based on weak-field approximation; can show saturation effects in strong-field regions

MILNE-EDDINGTON INVERSION

- ▶ New code: VFISV (Borrero *et al* 2011), custom spin for SOLIS/VSM
- ▶ Benefits: faster, can invert entire disc, more robust, better stray light determination, same code as SDO/HMI (facilitate inter-instrument comparison)

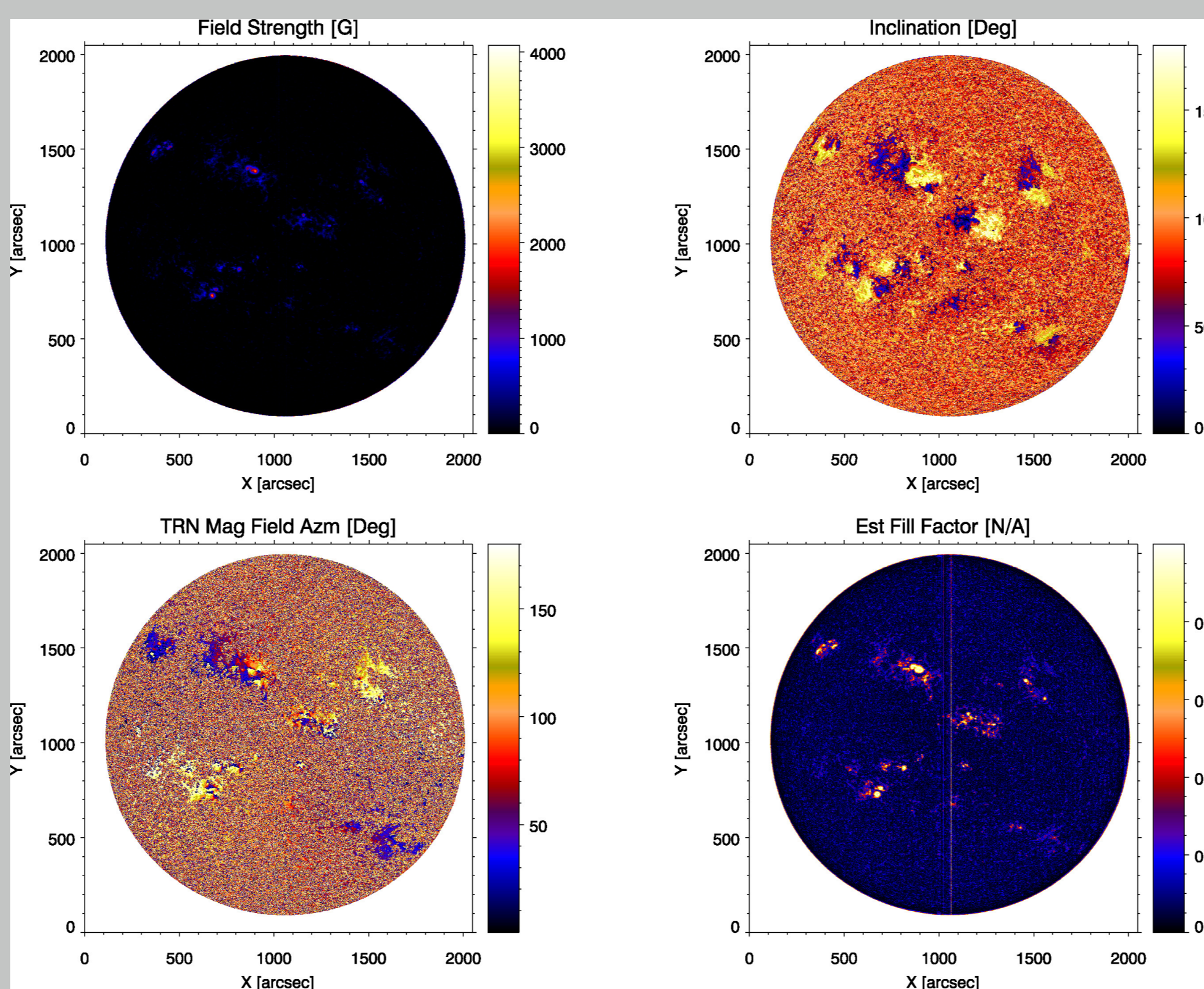


Figure 5: Field strength, inclination, azimuthal angle, and fill-factor on 15 May 2013 15:31UT, as derived by the new SOLIS/VSM remix of the VFISV code.

- ▶ On-the-fly wavelength/dispersion calibration
- ▶ Improved (non-interpolated) Voigt profile calculation
- ▶ Optimization initialized with new quicklook vector magnetic field
- ▶ Improvements to MPI-based parallelization
- ▶ Local stray-light (quiet-sun) profile determination
- ▶ Downhill-simplex recovery strategy for non-convergent pixels

IMAGE DISTORTION CORRECTIONS

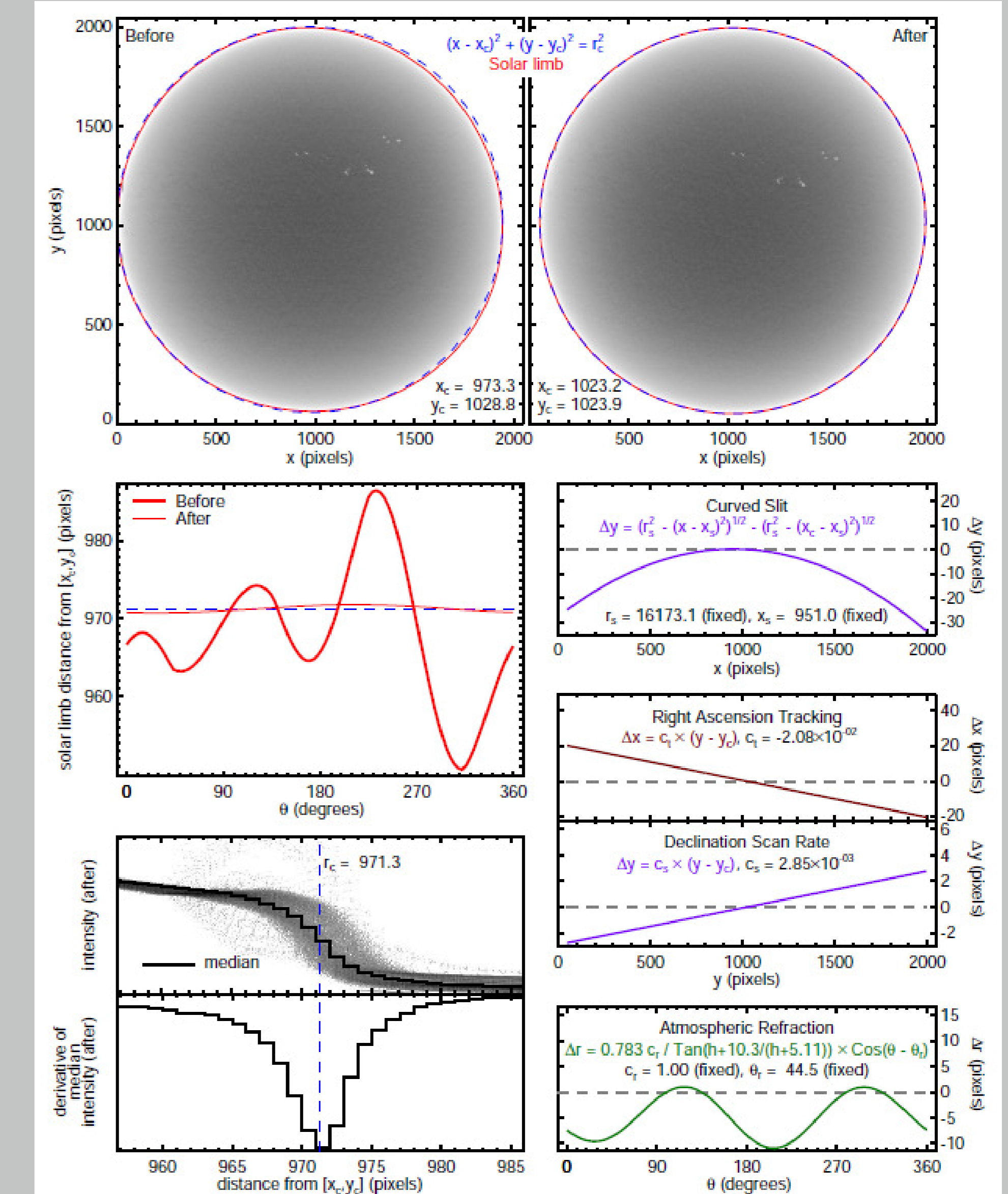


Figure 6: Summary of distortions removed by new geometrical correction algorithms.

- ▶ Level 1 data (e.g., Figures 4 & 5) is non-circular disc, due to several distortions introduced by the scan-step nature of the VSM. New data products are corrected for these (see Figure 6), without interpolation:
 - ▶ RA tracking error (linearly-increasing horizontal shift of rows w.r.t. each other)
 - ▶ DEC scan rate error (vertical stretching/compression of image)
 - ▶ Curved spectrograph slit (vertical shift of columns along slit)
 - ▶ Atmospheric refraction (complicated but smoothly-varying distortion of image that is symmetric about the axis defined by the parallactic angle)
 - ▶ Image centering & P-angle correction (image translation & rotation)

COMING SOON

- ▶ The SOLIS Team is also currently working to implement the pipeline production/availability of our geometrically-corrected Stokes spectra. These full-disc, high spectral resolution data (Figure 7) will be made available to users.

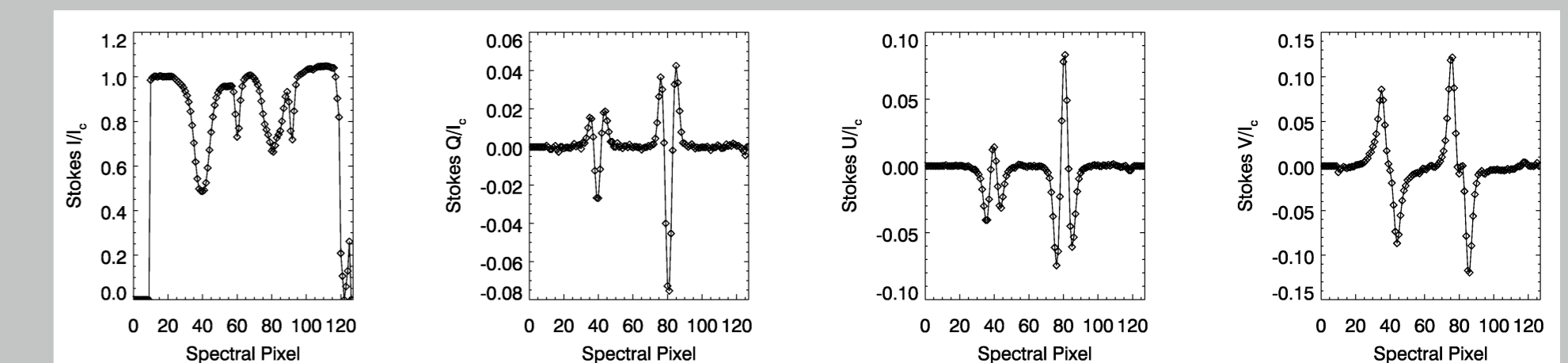


Figure 7: SOLIS/VSM Stokes I, Q, U, and V profiles, at 24mÅ dispersion.

SUMMARY & REFERENCES

- ▶ Routine vector magnetic field pipeline data products will be dramatically improved:
 - ▶ Fringe-free spectra, improved quicklook and Milne-Eddington magnetic fields, distortion-corrected image data.
- ▶ Our improved SOLIS/VSM data products will be available from <http://solis.nso.edu>
- ▶ REFERENCES:
 - ▶ Bommier, V., *et al.*, 2009, *A&A* 506, 1415
 - ▶ Borrero, J.M., *et al.*, 2011, *Sol. Phys.* 273, 267
 - ▶ Ronan, R.S., Mickey, D.L., Orrall, F.Q., 1987, *Sol. Phys.* 113, 353
 - ▶ Rojo, P.M., Harrington, J., 2006, *ApJ* 649, 553