Short Dynamic Fibrils in Sunspot Chromospheres

Luc Rouppe van der Voort[1] & Jaime de la Cruz Rodríguez[2]

1: Institute of Theoretical Astrophysics, University of Oslo, Norway - 2: Department of Physics and Astronomy, Uppsala University, Sweden

published in 2013 ApJ 776, 56 (arXiv:1308.3893)

scan the QR-code to access the preprint and movies

Abstract

Sunspot chromospheres display vigorous oscillatory signature when observed in chromospheric diagnostics like the strong Ca II lines and Hα. New high resolution observations with CRISP at the Swedish 1-m Solar Telescope on La Palma reveal the ubiquitous presence of small-scale periodic jets that move up and down. This phenomenon has not been described before. Their widths are often less than 0.5 arcsec and they display clear parabolic trajectories in space-time diagrams. The maximum extension of the top of the jets is lowest in the umbra, a few hundred 100 km, and progressively longer further away from the umbra in the penumbra, with the longest more than 1000 km. These jets resemble dynamic fibrils found in plage regions but at smaller extensions. These periodic jets are different from the transient penumbral and umbral micro-jets reported earlier.

Observations and Methods

CRISP is a Fabry-Pérot type narrow band (FWHM 66 mÅ at Hα) tunable filter imaging instrument that allows fast wavelength switching (< 50 ms). The SST adaptive optics system and Multi-Object Multi-Frame Blind Deconvolution (MOMFBD, van Noort et al. 2005) image restoration allow for near-diffraction limited imaging (0.17 arcsec at Hα).

Here we analyse a 52 min time series of a large sunspot at μ=0.87 in Hα and Ca II 8542.

Hα was sampled at two line positions (line core and -1300 mÅ) and Ca II 8542 at 14 line positions in spectro-polarimetric mode.

Magnetic field vectors were determined from inversions of the Ca II 8542 profiles in the 4 Stokes parameters *I*, *Q*, *U*, and *V* using the inversion code Nicole (Socas-Navarro et al. 2000).

Conclusions

We conclude that the small-scale periodic jets that we observe in sunspot chromospheres are the sunspot counterpart of dynamic fibrils found in plage regions (Hansteen et al. 2006, De Pontieu et al. 2007a).

The top of the sunspot dynamic fibrils follow clear parabolic trajectories and we find strong correlation between maximum velocity and deceleration, and between duration and maximum length. These correlations agree well with corresponding measurements in plage (Hansteen et al. 2006, De Pontieu et al. 2007a, Langangen et al. 2008a, b), some mottles in quiet Sun (Rouppe van der Voort et al. 2007), and type I spicules at the limb (De Pontieu et al. 2007b, Pereira et al. 2012).

Numerical simulations of dynamic fibrils showed that they are driven by waves that propagate from the lower atmosphere into the chromosphere where they steepen into shocks. The new solar feature we report here represent a new class within the family of dynamic field-guided wave phenomena.

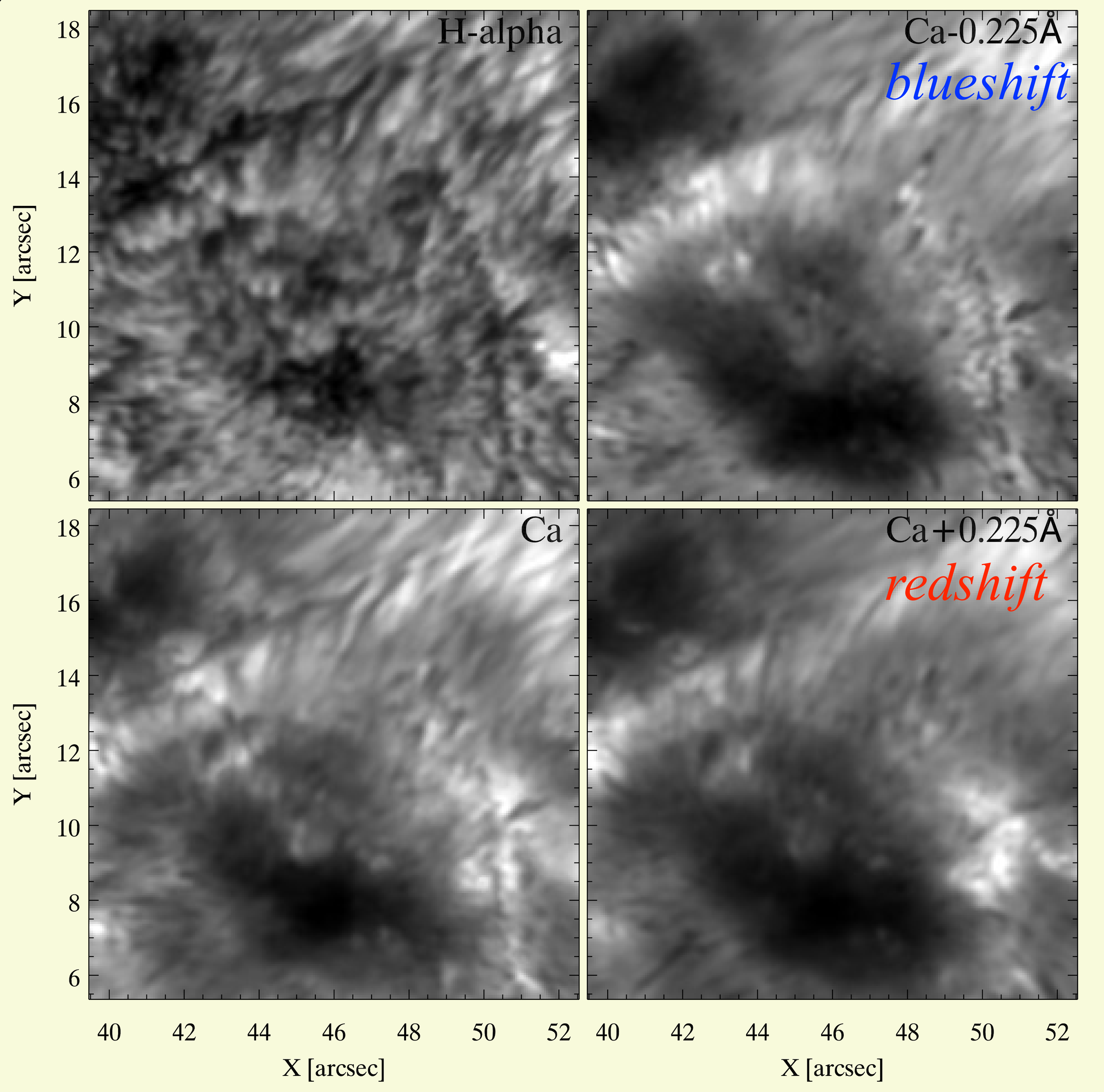

Figure 2: Zoom-in on part of the sunspot (green square in Fig. 1). The sunspot dynamic fibrils are visible as small dark specks which are most prominent in Hα. In the time series these dark specks periodically move up and down. In the Ca red wing, the specks only move down, in the blue wing only up, clearly the effect of Dopplershifts.

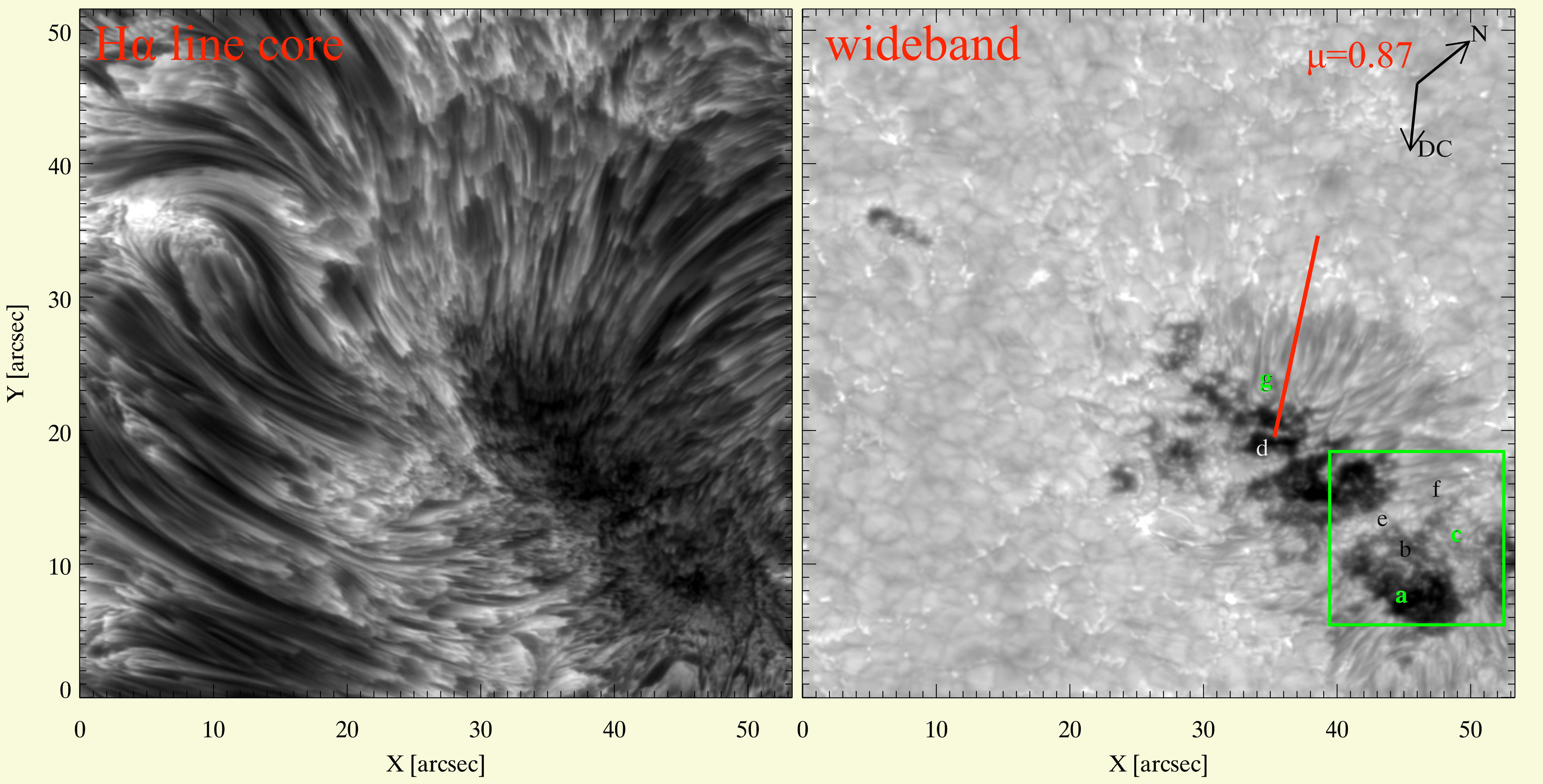

Figure 1: Active Region 11204 observed on 04-May-2011. The left image shows Hα line core, the right image the co-temporal wideband image of the FWHM 4.9 Å CRISP prefilter centered on Hα. The green square in the lower right outlines the region shown in more detail in Figure 2. The red line marks the position of the xt-diagram shown in Figure 3. Green letters a, c, and g mark locations for the λt-diagrams in Figure 5.

Movies of Figs 1 and 2 are available through scanning the QR-code (online material for the ApJ paper): the most vivid demonstration of the dynamics of the sunspot dynamic fibrils.

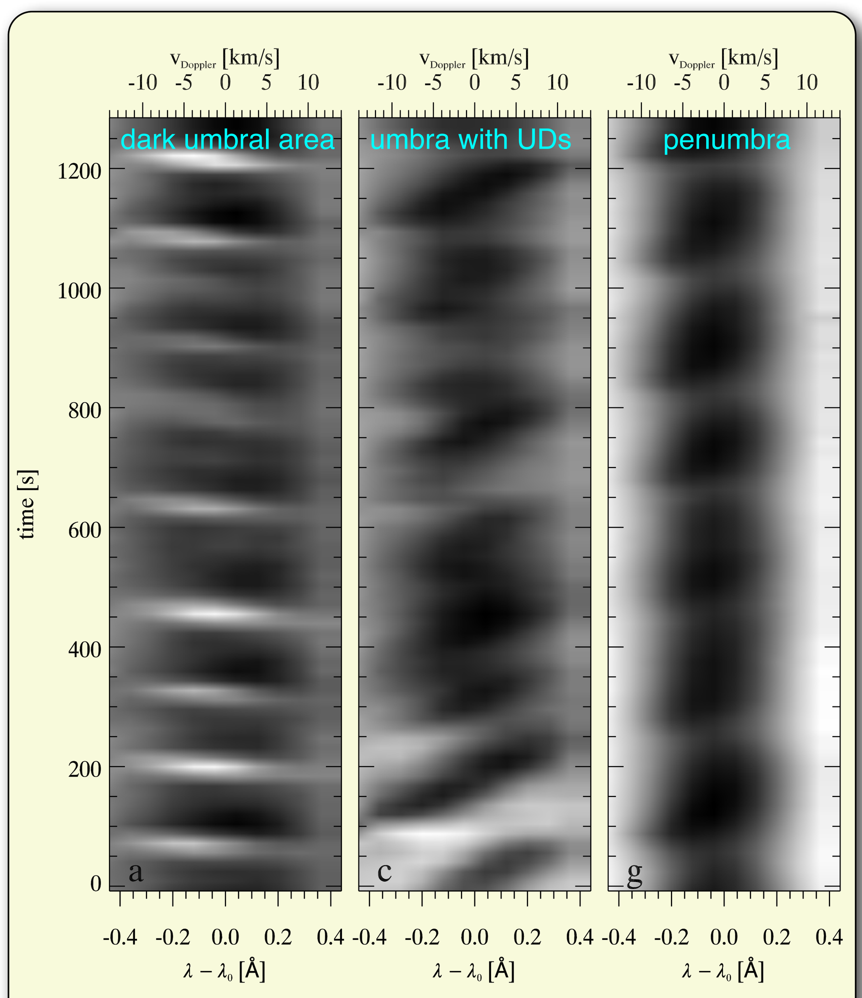

Figure 5: Ca 8542 λt-diagrams for 3 locations in the sunspot. Locations c and g show clear signature of dynamic fibrils: diagonal lines with max blueshift at the start and constant deceleration through 0 km/s to maximum redshift. a is dominated by umbral flashes.

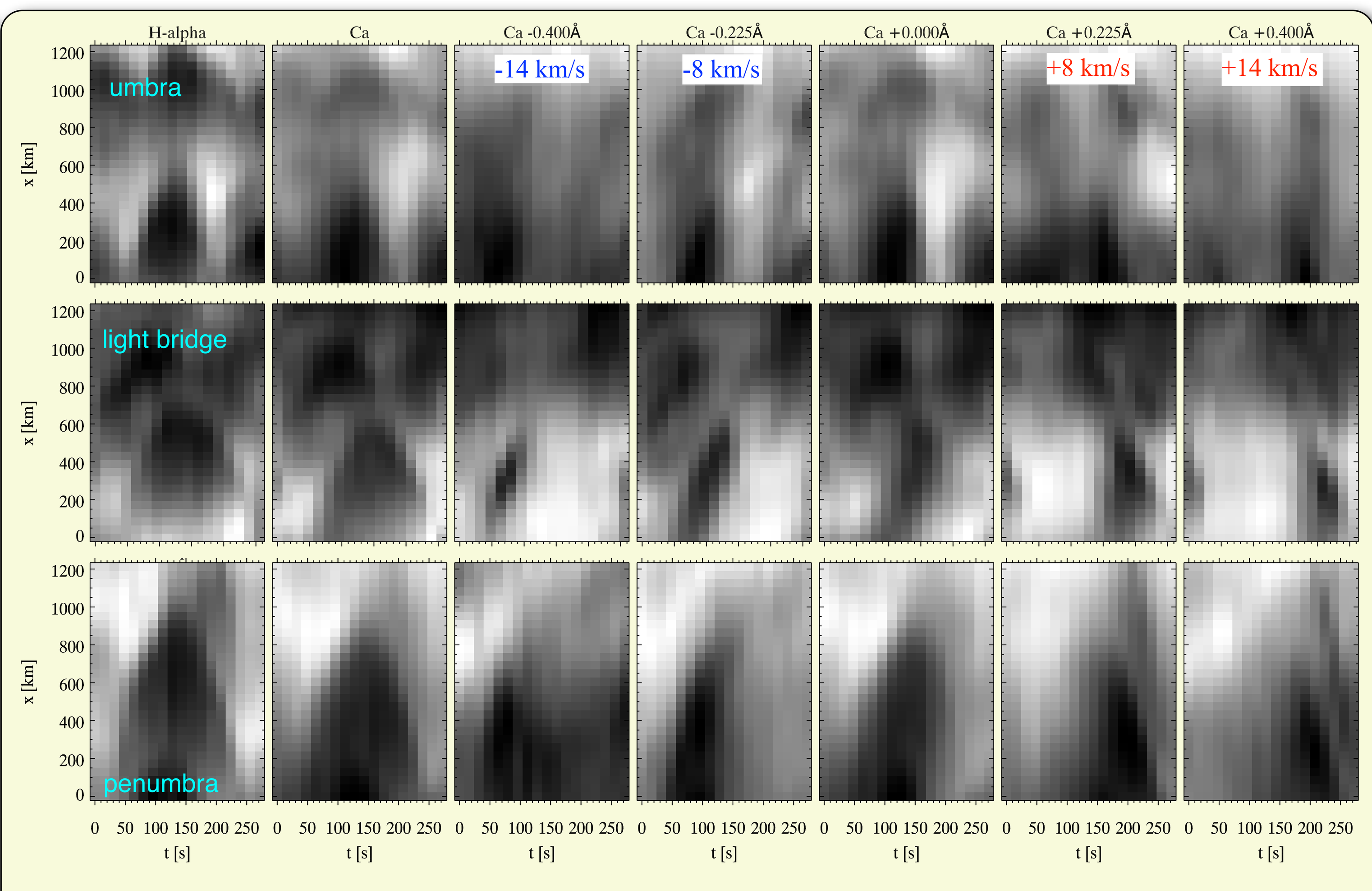

Figure 4: xt-diagrams for three different dynamic fibrils in various diagnostics. The umbral dynamic fibril is shortest, the penumbral is tallest. We can observe the dynamic fibrils in Hα slightly above Ca 8542. Different phases in the life of a dynamic fibril can be traced through the wings of Ca 8542: it first appears in the blue wing, disappears from the blue wing at maximum height in the line core, and the moving down phase can be followed in the red wing.

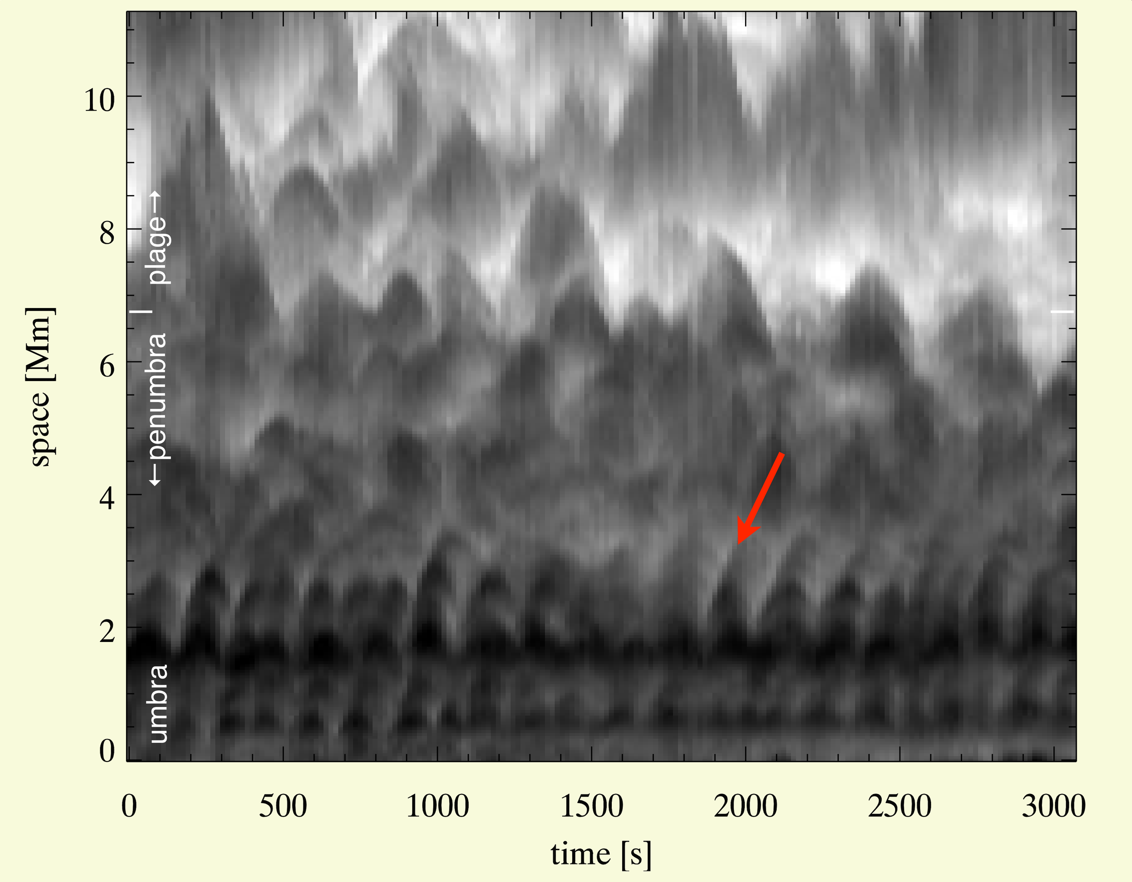

Figure 3: xt-diagram along the red line in Fig. 1 that starts in the umbra (at 0) and crosses through the penumbra and sunspot surroundings. The parabolic nature of the top of the trajectory of the dynamic fibrils in the sunspot and plage is clear. In the sunspot, the parabolas are smaller (smallest in the umbra) and more regular than in plage. The arrow shows an example where different parabolas appear successively with a phase delay; related to running penumbral waves.

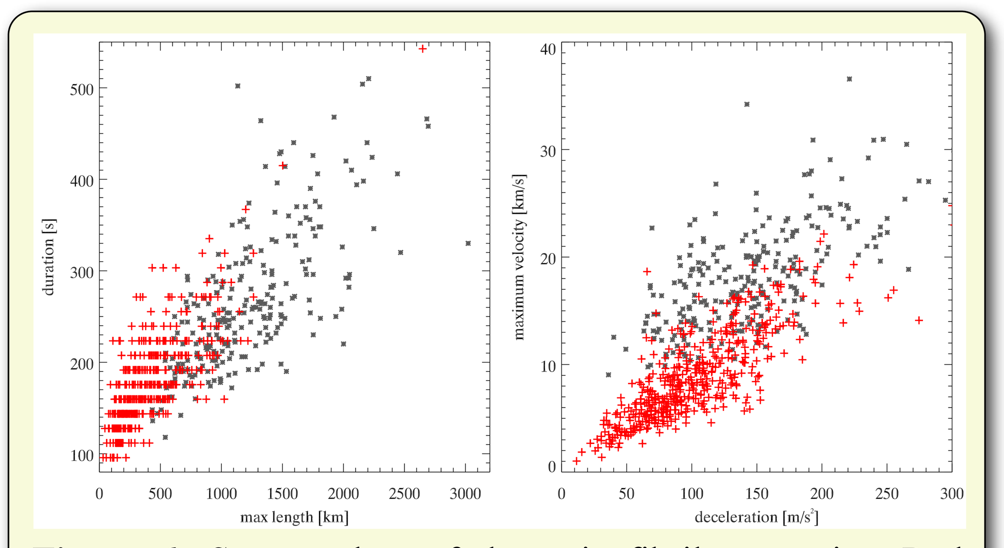

Figure 6: Scatter plots of dynamic fibril properties. Red crosses are the measurements in the sunspot (460 dynamic fibrils), smaller grey asterices are from dynamic fibrils in plage (De Pontieu et al. 2007). The sunspot dynamic fibrils show similar correlations as for plage dynamic fibrils. These correlations are signatures of jets driven by waves that propagate from the lower atmosphere into the chromosphere where they steepen into shocks.

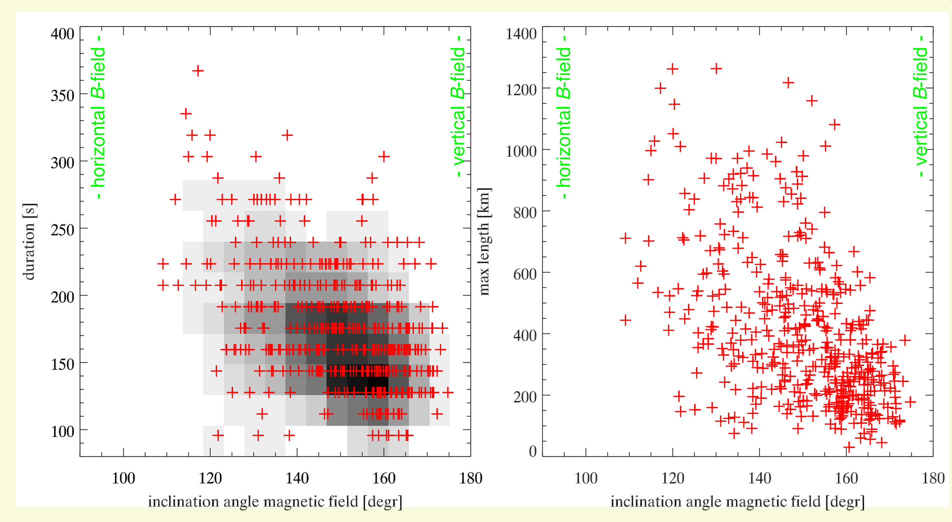

Figure 7: Relation between magnetic field inclination and dynamic fibril duration and length. The density image in the background of the left panel shows the smoothed red data points in order to better show the trend in high density areas. Spatially longer, long-period dynamic fibrils are preferentially located in regions with more horizontal magnetic fields. This trend suggests that the acoustic cut-off frequency is modified by the magnetic field inclination angle.

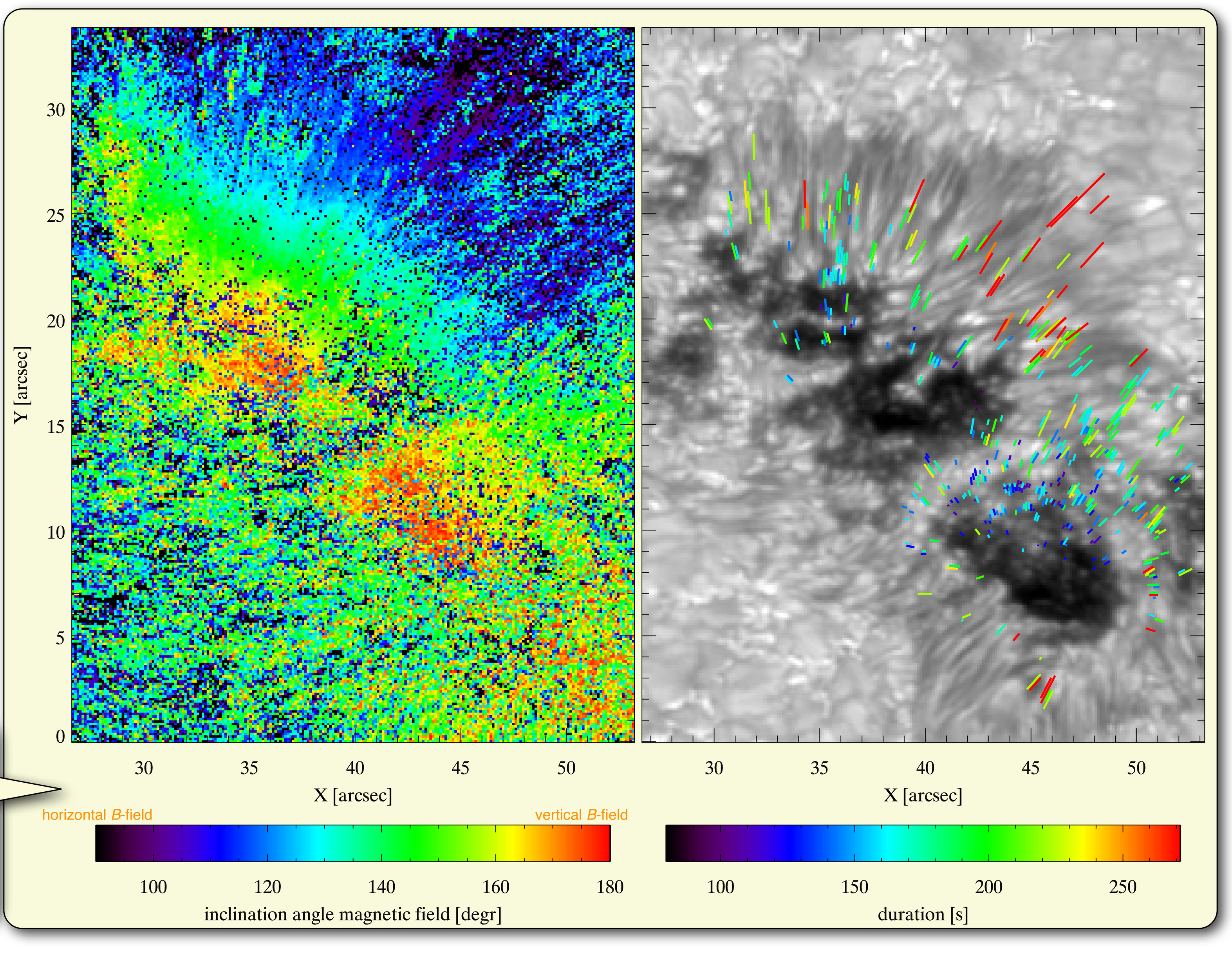

Figure 8: The left panel shows a map of the magnetic field inclination from LTE inversions of the Ca 8542 Stokes data. The right panel shows a continuum image with the path of the top of 460 dynamic fibrils drawn at their locations. The color of the paths indicates the temporal duration of the dynamic fibril. Spatially and temporally short dynamic fibrils are mostly found in the umbra where the magnetic field is more vertical, long dynamic fibrils are found where the field is more horizontal. See Fig. 7. This is direct observational confirmation that long period waves can propagate along inclined magnetic fields into higher and lower-density regions of the solar atmosphere (e.g. De Pontieu et al. 2004).