DOT studies of chromospheric fine structure in active region AR10486

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Introduction

The chromosphere is where switch from the dense, matter dominated photosphere to the tenuous corona happens. It is arguably the least understood region of the solar atmosphere, yet it is of major importance in understanding processes in the outer atmosphere, such as the solar wind and coronal heating. Not only is it full of structures on all scales, but it is also highly inhomogeneous. This is demonstrated by Fig. 1, showing quiet (little magnetic field) sun at the bottom, and active sun at the top. The dark structures near the limb are sunspots, with magnetic fluxtubes extending mainly radially outwards.

Active region AR10486 produced the largest X-flare ever recorded starting around 19:36 UT on November 4 2003. We present an analysis of the chromospheric fine structure, dynamics and magnetic topology of this active region only three hours before the flare.

We use data from the Dutch Open Telescope (DOT) [4] in the Ca II H line core, sampling the low chromosphere. Observations from the Transition Region and Coronal Explorer (TRACE) in its 1600 Å (low chormosphere) and 195 Å (high chromosphere) passbands complement the high DOT resolution by providing a much larger field of view suitable for studying larger scale structures.

Figure 1 shows a sample Ca II H image. The active region is clearly visible at the top. The solar limb is obscured by a myriad of fluxtubes, spicules and other chromospheric structures. Of particular interest for study are spicules around (5,65), (30,65), and (52,65) arcsec, and a bright, elongated structure known as a surge, which starts around (38,62) arcsec and extends upward beyond the field of view. We focus on the latter object.

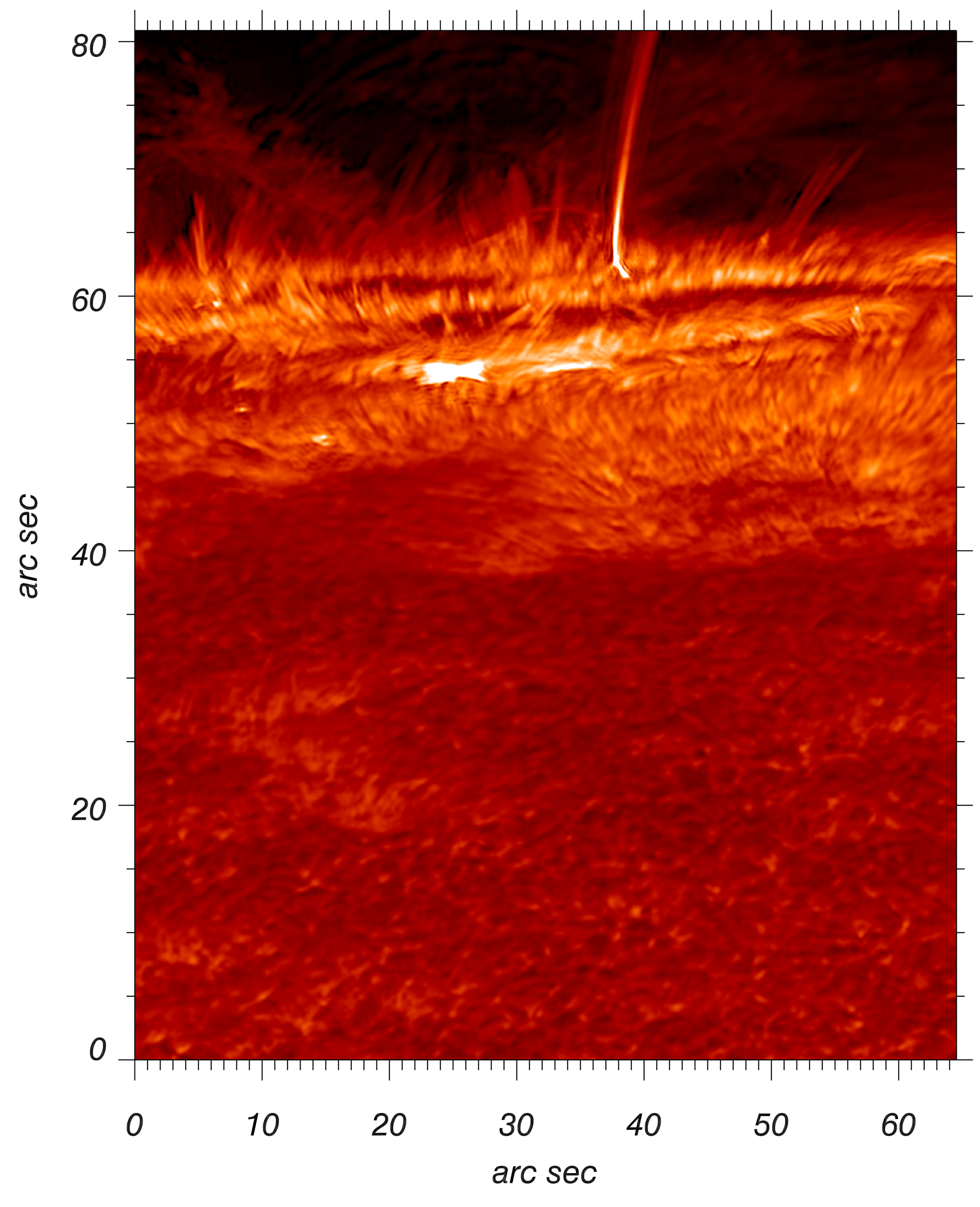

Figure 1. A sample DOT Ca II H filtergram of AR10486. It illustrates the intricate structure of the chromosphere.

Surge Morphology

Figure 2 shows an enlarged cut-out of Fig. 1. The base of the surge shows an inverted Y-shape, typical of magnetic reconnection, confirming previous suggestions [6,7]. Comparison with photospheric magnetograms recorded by the Solar Heliospheric Observatory (SOHO) a few days prior to this event shows that there are ample magnetic fields of both polarities. It is very likely that the energy required to heat and expel the gas is produced by reconnection events at the base.

Figure 3 shows alignments of the DOT data to TRACE observations in its 1600 Å (upper image) and 195 Å (lower image) passbands. The former samples plasma with low temperatures (10^4 K), but also includes the C IV emission from plasma of 10^5 K. The latter samples the high chromosphere at temperatures around 10^6 K. The surge appears bright in 1600 Å, while dark in 195 Å. From this we may conclude that the surge consists of cold (approx. 10^5 K) gas. In order to obscure the background 195 Å emission, it must also be dense.

Though the base is sometimes obscured by fluxtubes, the surge is stable throughout the 26-minute duration of the DOT sequence. Comparison with the TRACE sequences shows that it grows and shrinks repeatedly in the hours leading up to the flare.

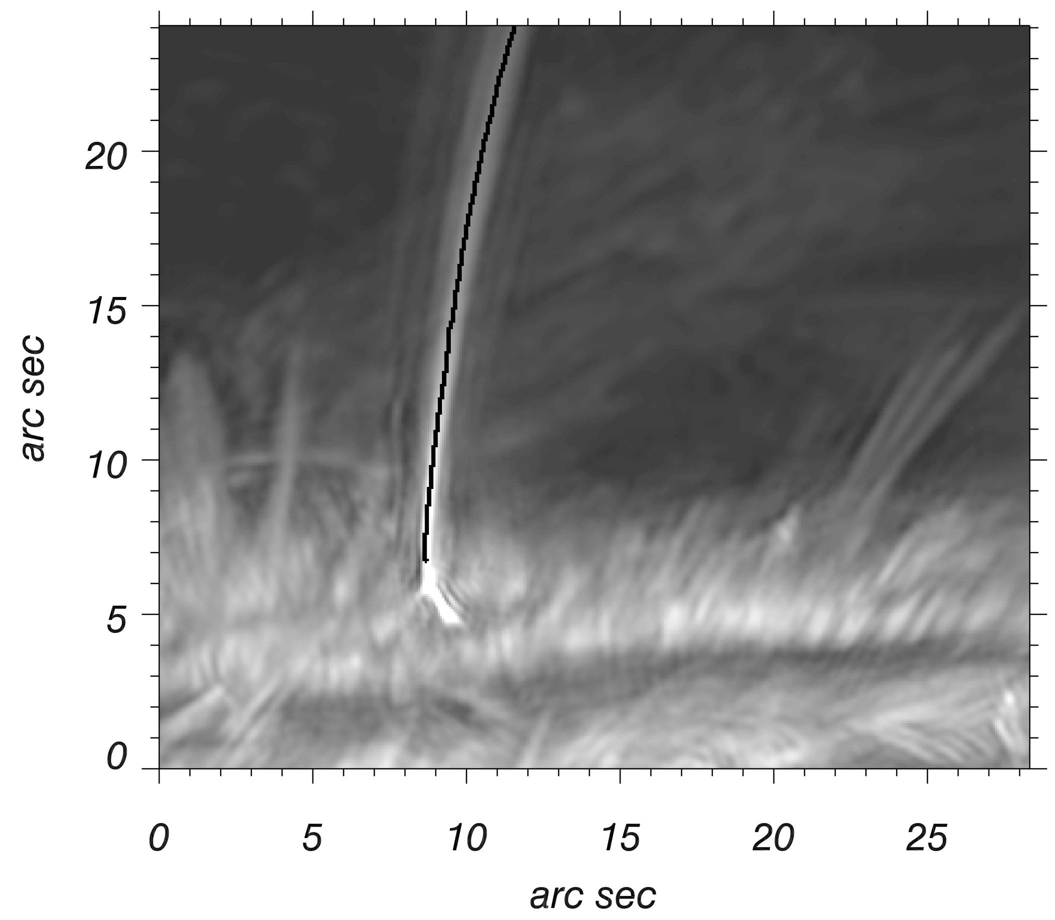

Figure 2. Close up of the surge. The black line indicates the position of the cut along the surge.

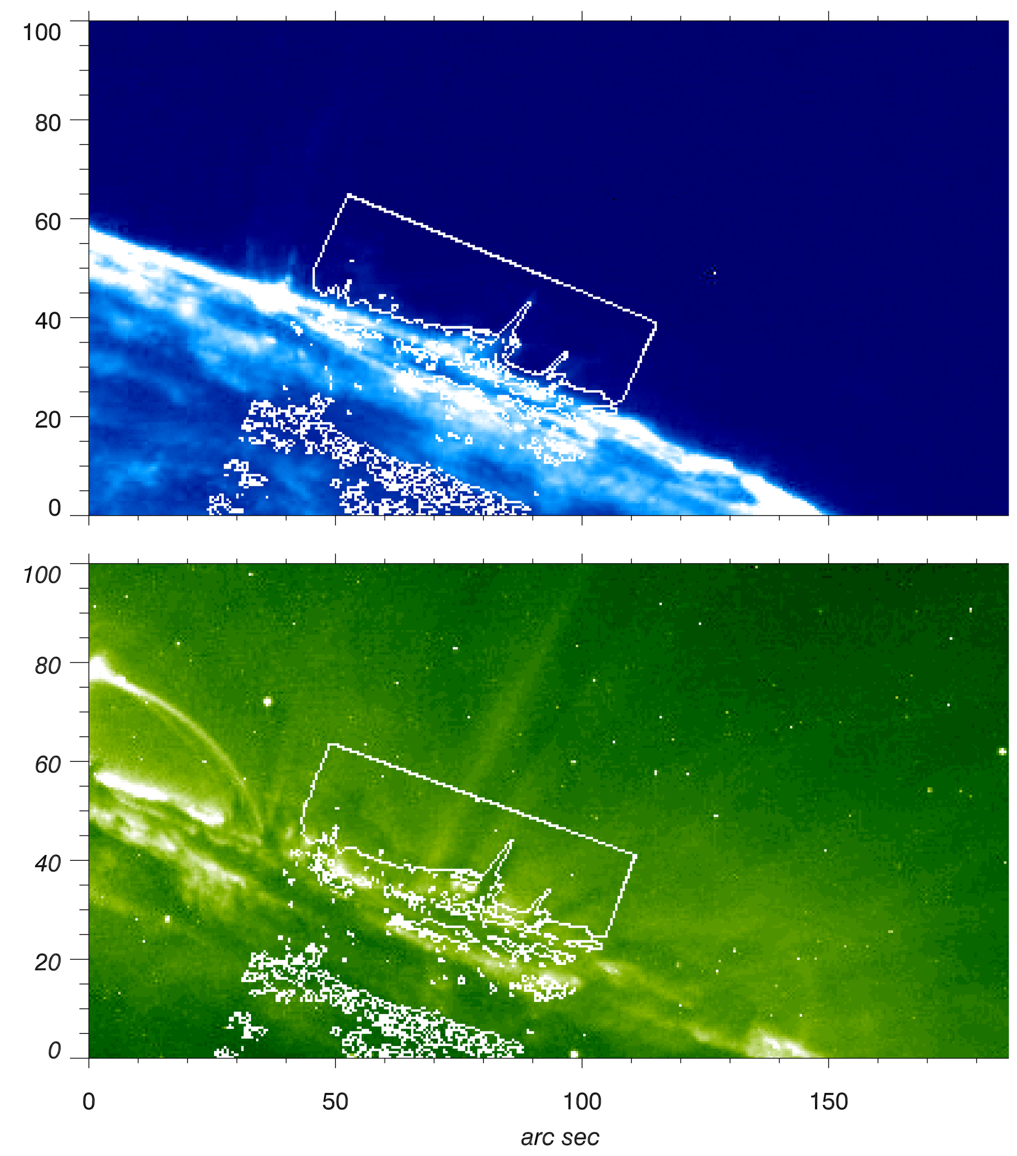

Figure 3. Top: TRACE 1600 Å image with a contour of the Ca II H data overplotted. Bottom: TRACE 195 Å image.

Surge Dynamics

We analyse a cut along the surge in time, indicated by the black line in Fig. 2. Figure 4 shows the brightness along the cut against time. Several propagating brightness enhancements are visible. The two clearest examples are overplotted with dotted white lines. We computed speeds of 75 km/s (upper) and 50 km/s (lower) for these two cases. The speeds far exceed the sound speed of approximately 10-20 km/s. The upper brightness enhancement stops suddenly at 10 arcsec height. The dark wedge shape starting at that position suggests it may have impacted downward moving matter entering our FOV around 1100 s at the righthand side.

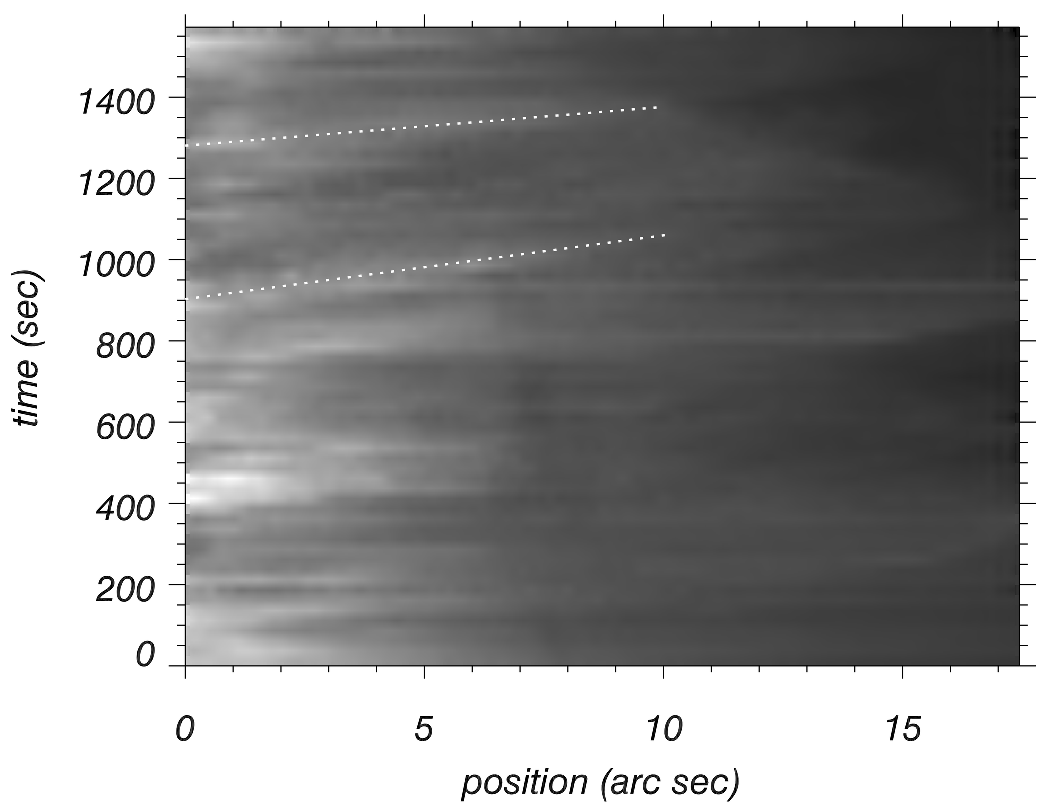

Figure 4. Brightness along the surge against time.

Surge Dynamics, contd.

We have used a wavelet analysis to determine the presence and location of oscillations. Figure 5 shows the analysis for a fixed point on the surge close to the base. There are waves present with a periods of 200 s and, more clearly, with a period of 400 s. The measurement of the latter is influenced more by edge-effects, indicated by the hashed area. The former correspond closely to the well-known 3-minute oscillations present in magnetic network [3]. Six-minute oscillations have been reported in other chromospheric structures such as spicules [1].

Figure 6 shows a 2D wavelet analysis of the cut along the surge in time. The oscillation with 350–400 second periodicity is clearly visible. Oscillation power reduces quickly beyond approx. 7 arcsec height, due to decreased brightness.

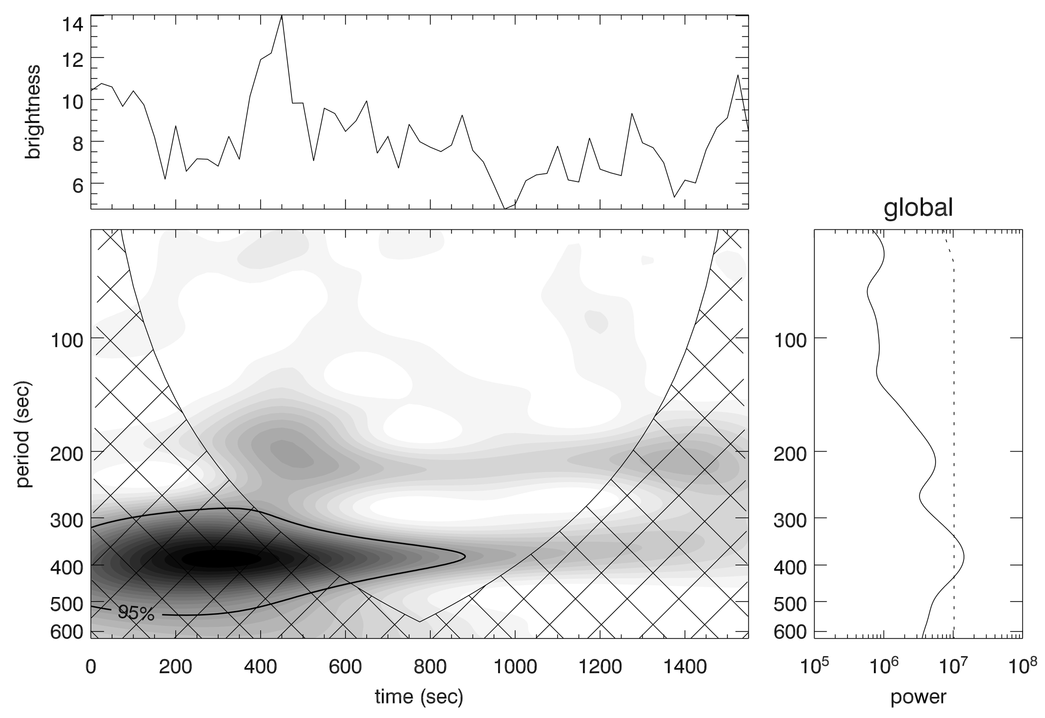

Figure 5. Wavelet analysis of the brighness of the surge at a specific height.

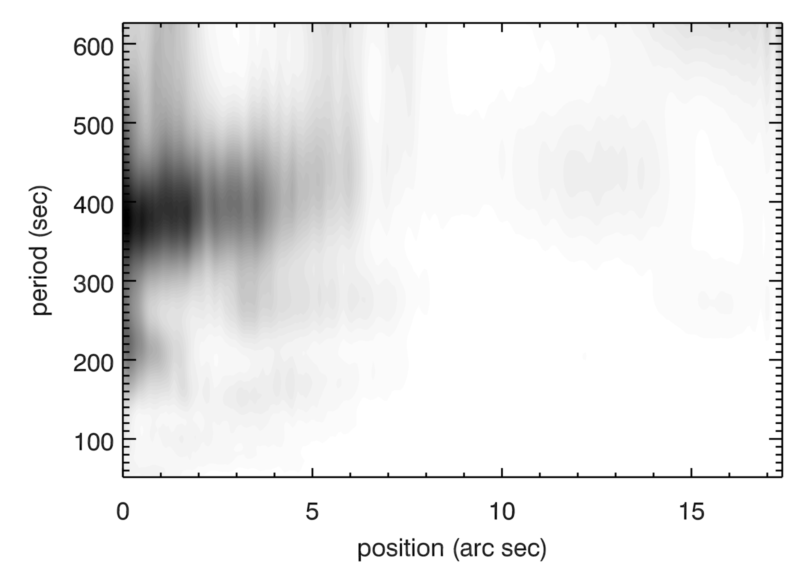

Figure 6. 2D wavelet analysis of the brightness along the surge in time.

Conclusions & Outlook

The DOT sequence provides evidence that surges are caused by long-lived magnetic reconnection events. We find oscillations with 6-minute and 3-minute periodicities. Such oscillations are not uncommon, and have been found in many chromospheric structures, e.g., spicules [1], macrospicules and polar surges [2]. The latter two classes of objects are probably close relatives of active region surges, since they are likely also driven by magnetic reconnection.

It may be possible to estimate temperatures and densities in the surge from the TRACE sequences, allowing further and more in-depth study of the magnetic reconnection at the base of the surge as well as possible shocks travelling along it.

Several spicules not covered in this poster can be studied in detail, and may provide clues about their excitation. Of particular interest are estimates of size and density. These values can provide filling-factor information for research using spicule observations with less spatial resolution at UV wavelengths.

References

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