High cadence SST/CRISP data of spicular-type events

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We present spectroscopic and imaging observations of apparent ultra–fast spicule–like features observed with CRISP at the Swedish 1-m Solar Telescope (SST). The data shows spicules with an apparent velocity above 500 kms^{-1}, very short lifetimes of up to 20 s and length/height around 3500 km. The spicules we are analysing are seen as dark absorption structures as seen in the Hα wings $\pm$516 mÅ, $\pm$774 mÅ and $\pm$1032 mÅ which suddenly appear and disappear from the FOV. These features show a time delay in their appearance in the blue and red wings of Hα by 3-5 s. Previous authors have suggested that these features arise from current sheets. We suggest that their appearance/disappearance is due to their Doppler motion in and out of the 60 mÅ filter. See Fig. 2 for the evolution of the event in two line positions.

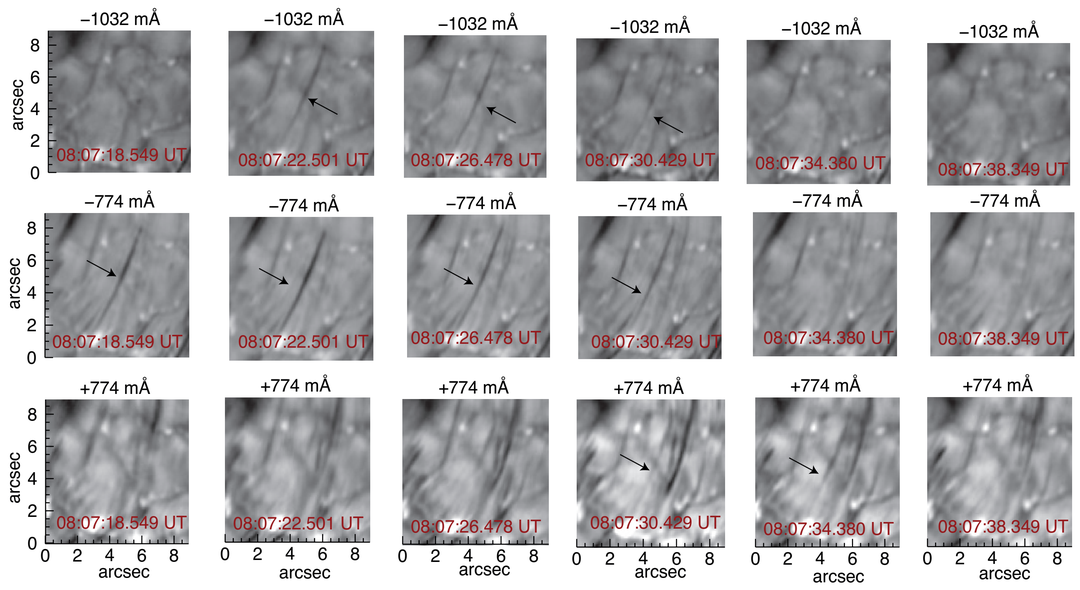

Figure 1: Evolution of spicule from the 10 June dataset displaying signature at different wavelengths at -1032 mÅ and $\pm$ 774 mÅ. The black arrow represents the time the spicules were first observed at that wavelength.

What are ultra-fast spicules ?

In general, spicules are highly dynamic structures. There is evidence of two types of spicules, Type I and Type II, that have different lifetimes and velocities. Type I spicules generally show rising and falling phase. These spicules exhibit apparent lengths between 0.5 Mm and 15 Mm, velocities of ≈20 km s^{-1} (100 km s^{-1} for Type II) and lifetimes between 3 and 7 mins (50 s for Type II) **(Langangen et al. 2008; De Pontieu et al. 2007a,b)**. RBEs are considered as on–disk counterparts of spicules with average length of 1.2 Mm, widths of 0.5 Mm and Doppler velocities between 15 to 20 kms^{-1} **(Langangen et al.2008; Rouppe van der Voort et al. 2015; Sekse et al. 2013a,b; Kuridze et al. 2015)**. **Judge et al. (2011,2012)** and **Lipartito et al. (2014)** questioned the traditional interpretation that all spicules consists of a flux tube where plasma flows along it length, instead **Judge et al. (2011,2012)** suggested that in some instances spicules can form in current sheets. The features reported in this paper are similar to those reported by the above authors.

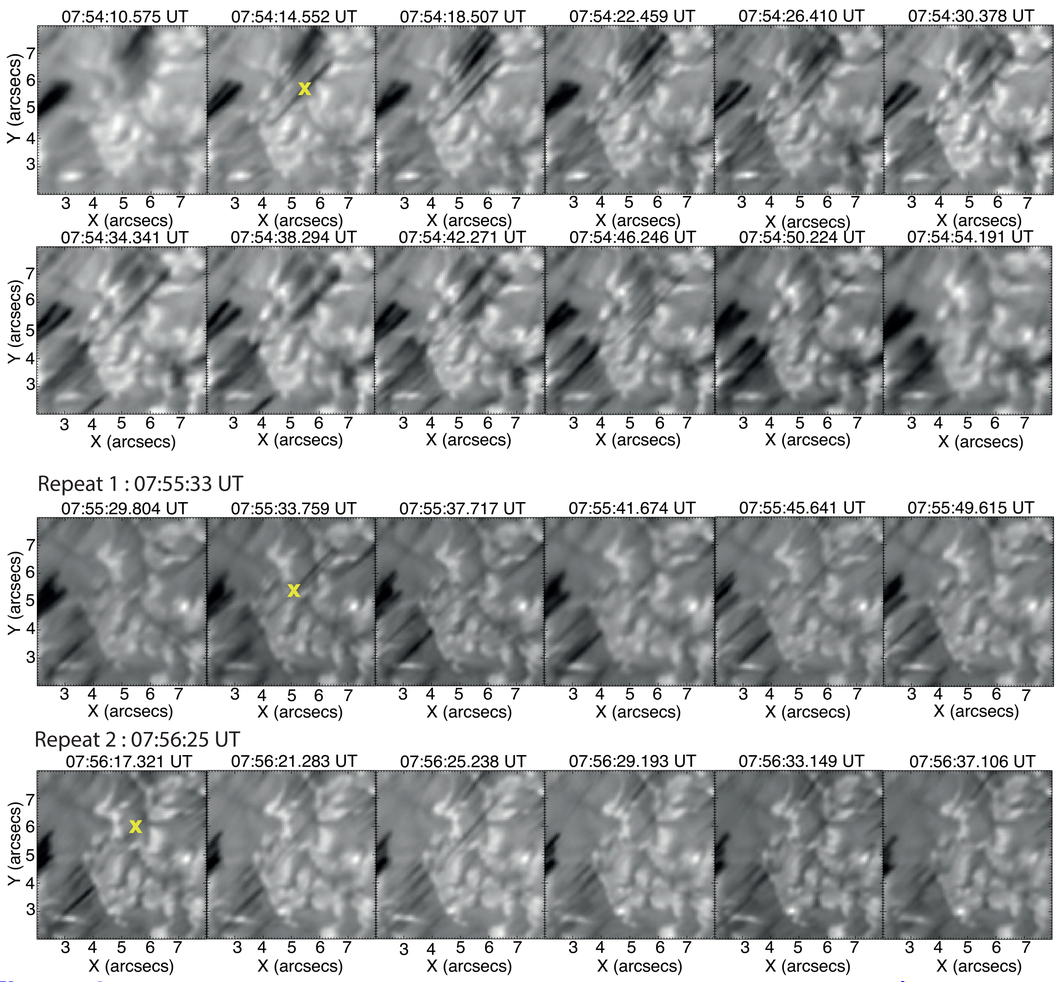

Figure 2: Evolution of spicule from the 10 June dataset taken at – 774 mÅ showing two re-appearances at the same position. The yellow cross represents the time the spicules were first observed at that wavelength.

Our observations

We are discussing observations from two days: 10 June 2014 (on disk) and 5 June 2014 (limb but detections were on disk) along nine Hα line–positions viz : 6563 [LC = 0] at [$\pm$1032, $\pm$774, $\pm$516, $\pm$258 mÅ] taken from the CRISP instrument located at the Swedish 1-m Solar Telescope. We used speckle and MOMFBD reconstruction technique on 10 June dataset and only MOMFBD reconstruction for the 5 June dataset.

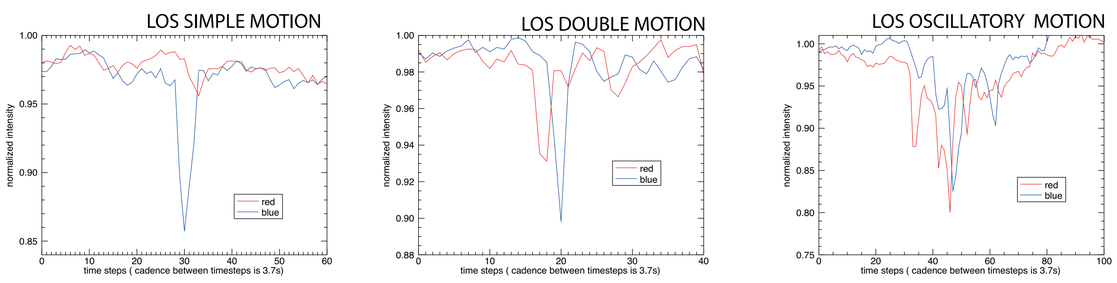

Figure 3: Normalized light curves of red and blue Doppler shifts in the cross-section of ultra-fast spicules. The left panel shows an event which had a predominant blue shift, centre panel shows and event with equally strong blue and red wing signatures and right panel shows a complex event showing simultaneous red add blue wing signatures."

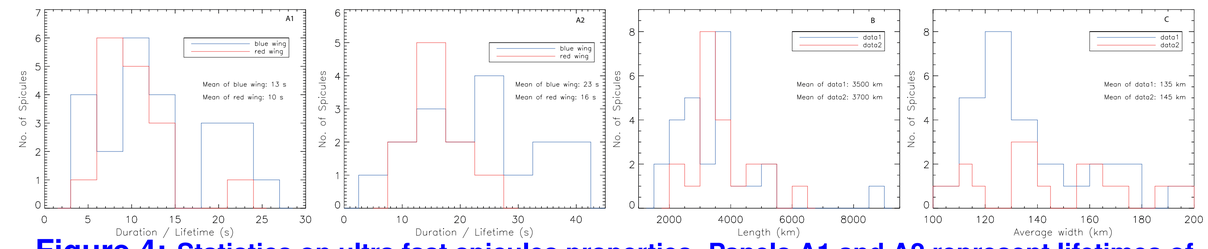

Figure 4: Statistics on ultra fast spicules properties. Panels A1 and A2 represent lifetimes of the spicules in red and blue wing from the 10 June and the 5 June respectively. Panel B represents the maximum length / height of the spicules and Panel C represents the average width of the spicuels.

Summary of Ultra-fast spicule properties ?

Total no of features detected: 47. 78% in blue wing, 60% in red wing, 75% show signatures in more than one wavelength position and ≈25% features in our datasets show lateral/transverse shifts (see Fig. 5). Another 25% shows repetitions at the same location. Physical parameters such as length (2.7 Mm – 3.0 Mm) and width (0.15 Mm) are similar to spicules, RBEs and RREs with relatively shorter lifetimes of up to 23s, see Fig.4.

Important discovery

We find that these features do not appear to have any apparent motions across the FOV and if they are to be inferred as jets which we do not resolve temporally (i.e. to catch this unobserved motion across the disk) then they would have a hypothetical velocity of >500 km^{-1}. In most cases we found signatures in far-blue and far-red wing to last shorter than the signatures near the core. This hints towards some kind of acceleration in and our of the CRISP spectral passbands. We suggest that these observations can be interpreted as the movement of highly dynamic spicules moving in and out of the narrow 60 mÅ filter used to observe in different parts of the Hα line profile, i.e. these spicules move vertically in the atmosphere and the LOS velocity components are responsible for their appearance in the wings of Hα line profile. We also see features repeating at same location as shown in Fig. 2.

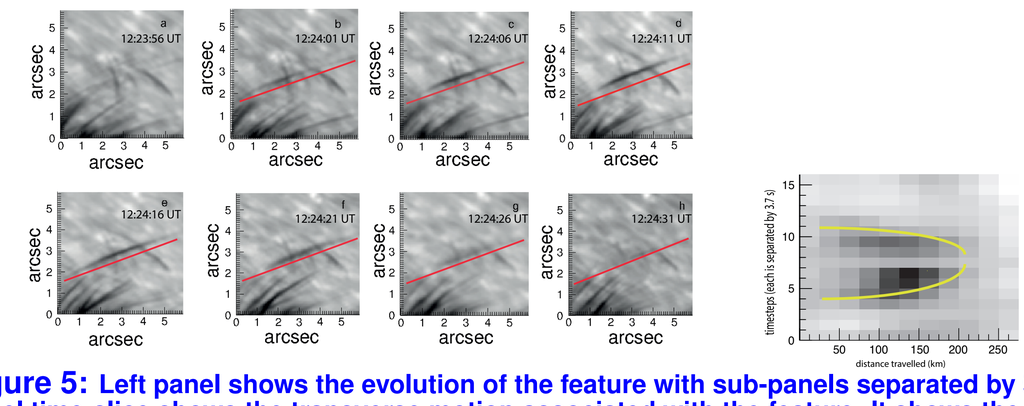

Figure 5: Left panel shows the evolution of the feature with sub-panels separated by 5s. Right panel time-slice shows the transverse motion associated with the feature. It shows the extent of transverse motions of the spicules from the rest position (50 on the x-axis) to the max displacement (200 on the x-axis) and it return to the rest position between interval 4 and 12 on the y–axis which corresponds to 29.6 seconds. The velocity amplitude of the transverse motion is 5 kms^{-1}

We found wave signatures

In Fig.5, we see example of possible transverse motion. In Fig.6 we show an example of possible m=1 mode of kink wave. Notice the change in blue-wing and red wing signature, hinting towards torsional motions or rotational motion or kink waves. The velocity amplitude of the transverse motion is 5 kms^{-1}. From this you could conservatively estimate the energy flux of these events to be 1200 W/m^2 assuming and upper chromospheric mass density in the spicules of 10^{-10} kgm^{-3} and projected apparent velocities on the order of 500 kms^{-1} (if they are interpreted as oscillating jets of plasma!).

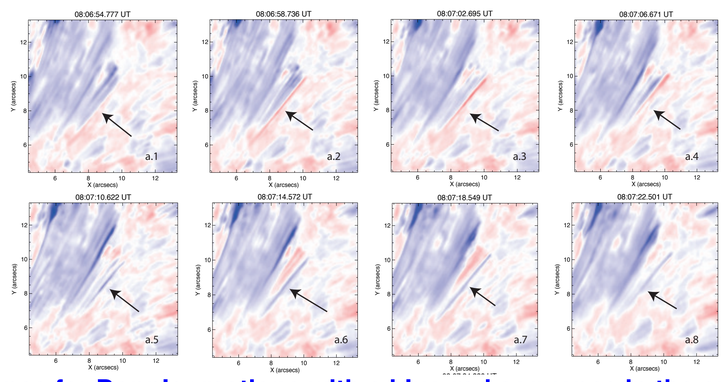

Figure 6: Evidence for Doppler motions with a blue-red sequence in the cross-section of the ultra-fast spicules.

Conclusions :

- The data shows that these highly-dynamic spicules appear at different locations within the Hα line profile within a few seconds, sometimes with a temporal offset.
- They have very short lifetimes of up to 20 s and length/height around 3500 km, which could imply that these are in some cases a subset of RBEs.
- In some instances, these features show a time delay in their appearance between the blue and red wings of Hα by 3–5 s, while some features show simultaneous or/and alternate appearances in the red and blue wing. This would indicate some sort of rotation or torsional motion.
- In some instances, the features seem to re-emerge at the same location several tens of seconds later.
- We suggest that these observations can be interpreted as the movement of highly dynamic spicules moving in and out of the narrow 60 mÅ transmission filter used to observe in different parts of the H line profile. The LOS velocity component of the observed fast chromospheric features, manifested as Doppler shifts, are responsible for their appearance in the red and blue wings of Hα line.

Reference

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