スピキュール諸々

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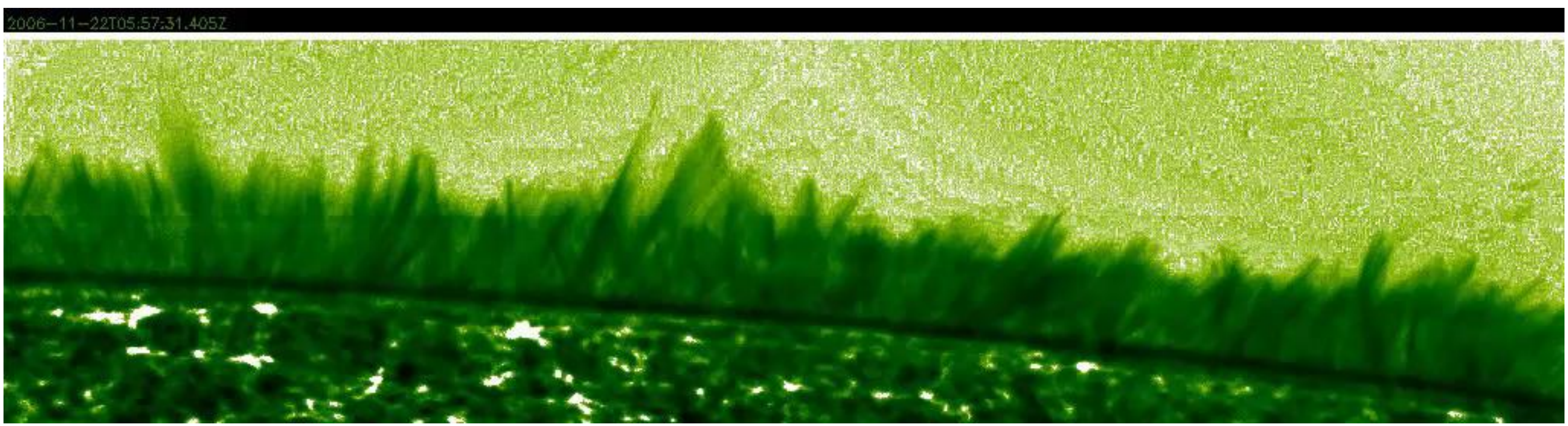
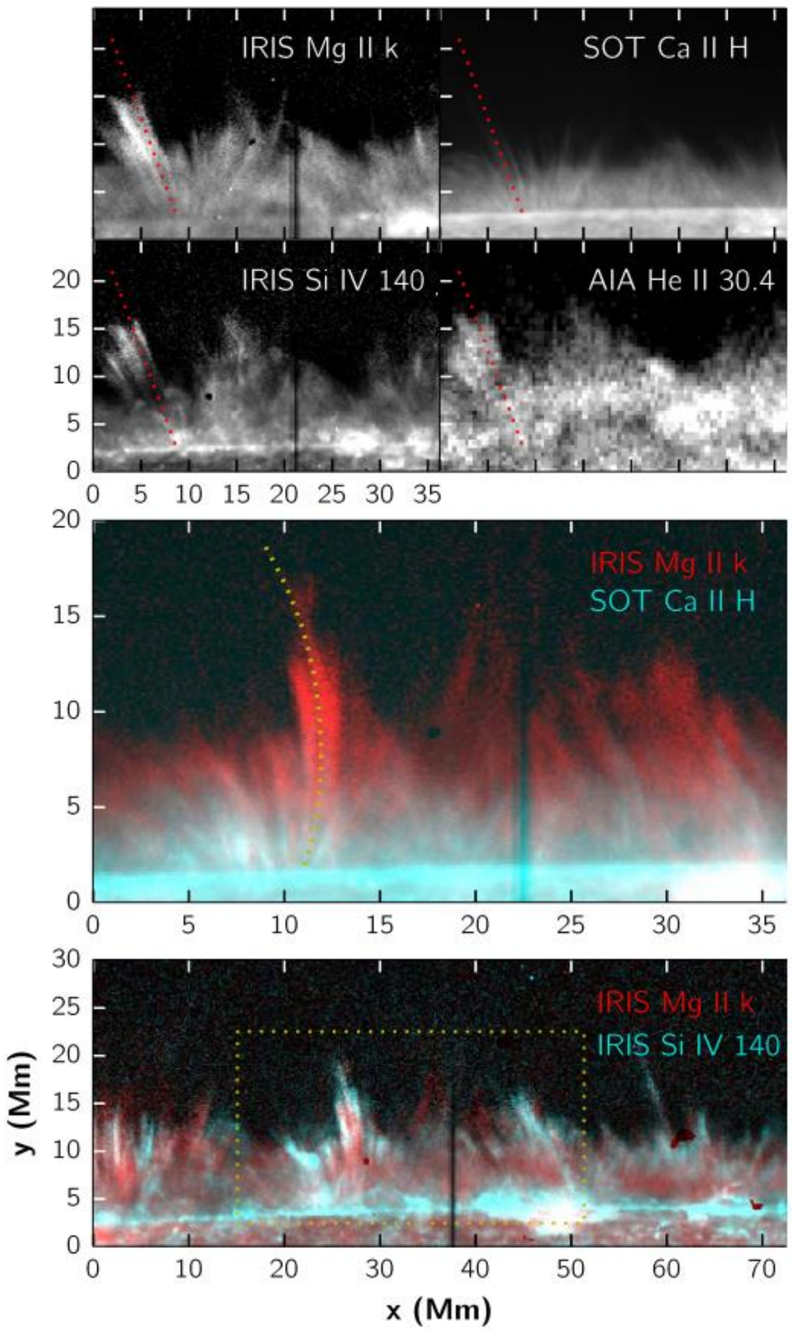
Solar Chromosphere

Consists of many jet-like structures (spicules), seen everywhere over the Sun; 10^5 – 10^6 spicules at any time.
Important ingredient for mass and energy transport into the Corona.
However, its driving mechanism is still mysterious!

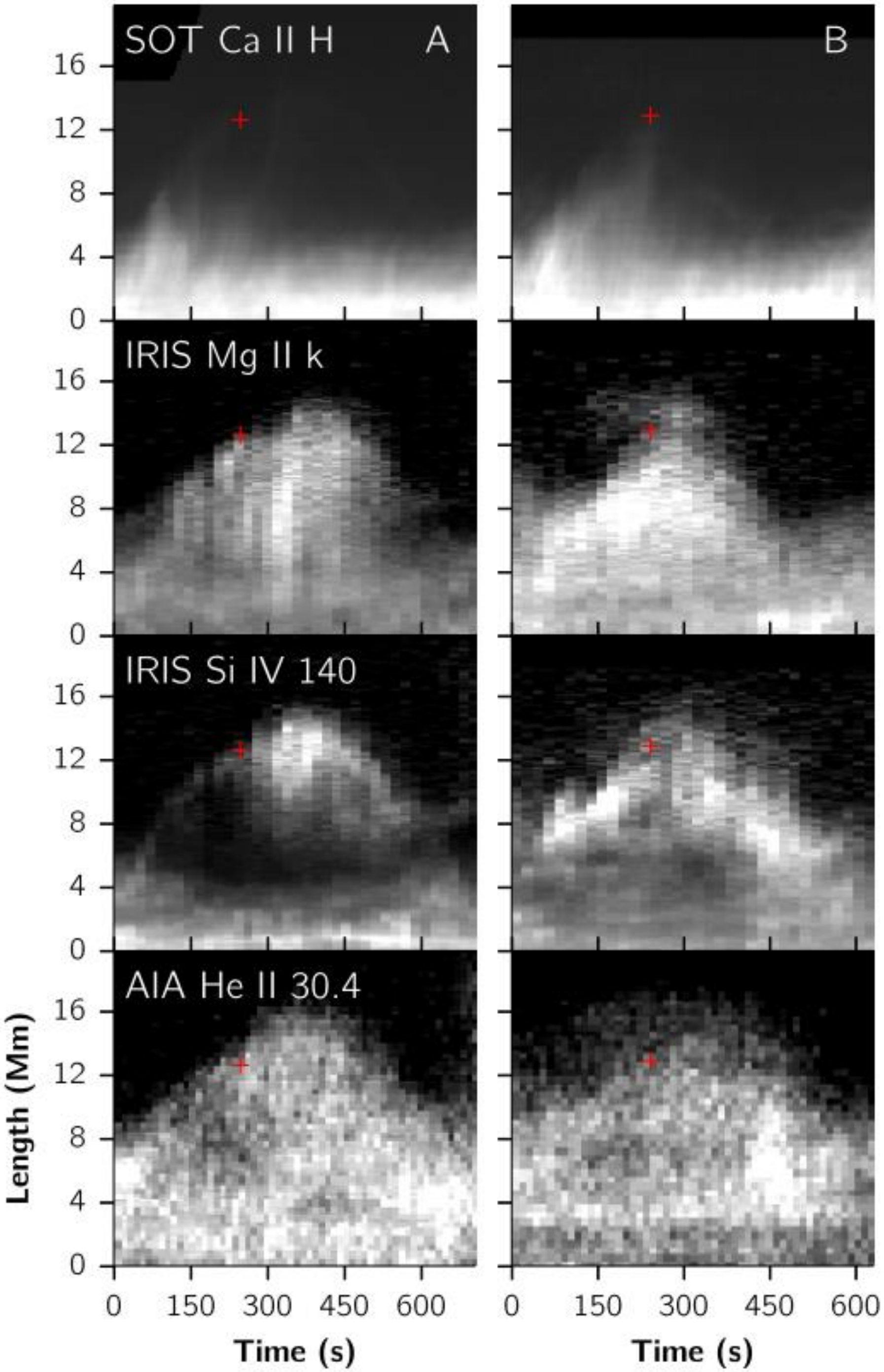
velocity: 20 – 100 km/sec (sound vel = 10 km/sec)
height: 6000 km (hydrostatic scale height = 150 km)
width : 200 – 800 km , lifetime: 1 – 15 min



IRIS Obs. of spicules

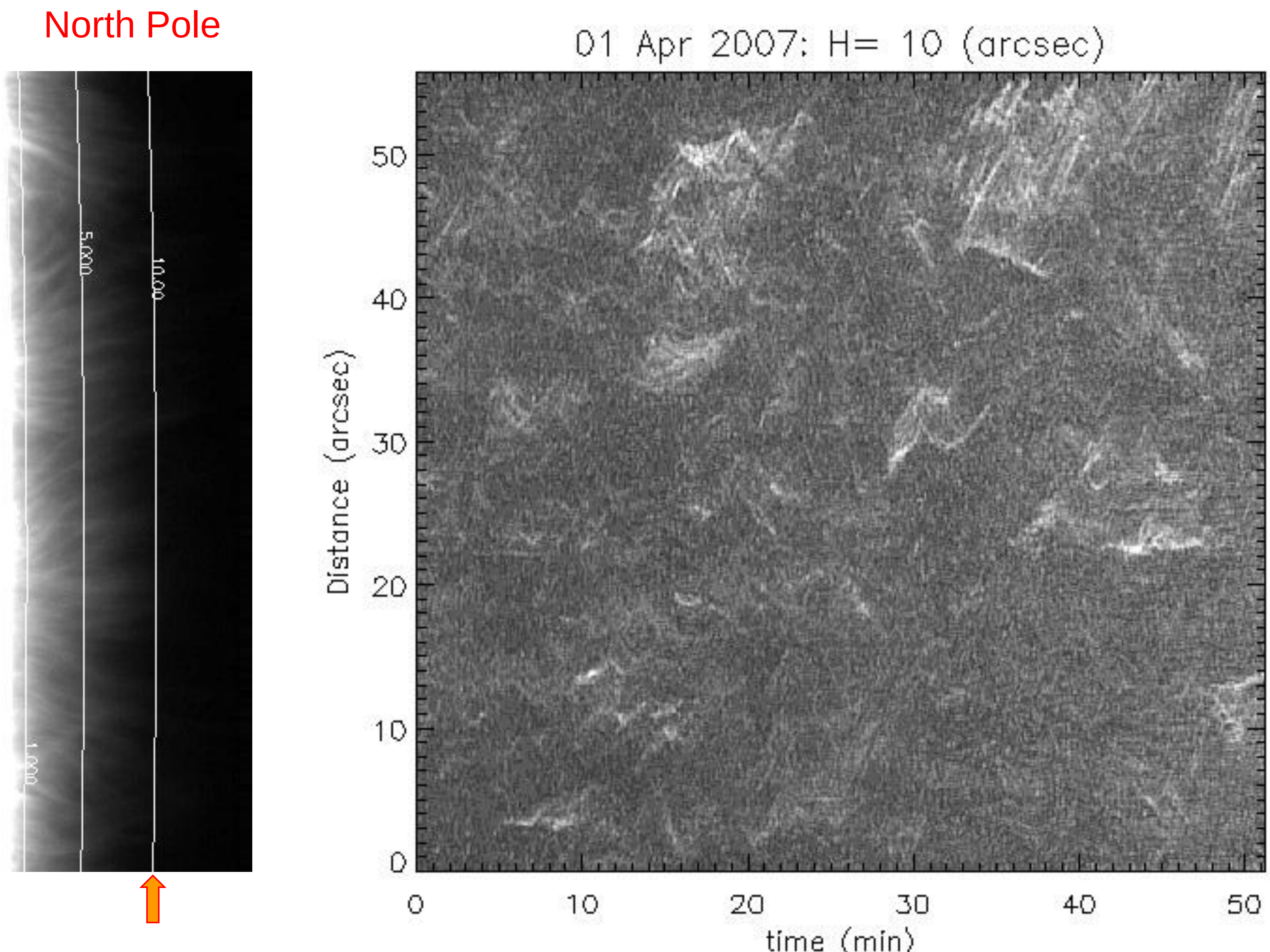


The Mg II k (T=10K)spicules are seen as a natural upward extension of the Ca II H (T=10K) spicules. They are consistently taller and in several cases twice as tall. The Si IV (T=80K) spicules show a continuation of the Mg II spicules and expand even farther. Many of the Si IV spicules have a much darker bottom third or half, with the top part of the spicule noticeably brighter. This suggests that such spicules are being heated out of the Ca II passband, and continue evolving reaching higher layers and temperatures.



Time evolution of spicules in IRIS

Spicules show a fast rise (>50 km/s) and then fading from the Ca II H filtergrams. In the IRIS filtergrams, they have a similar upward velocity but continue to rise after they fade in Ca II, reaching heights up to 20 Mm above the limb and often falling down later in a parabolic motion. In several cases, this rise and fall is also seen in the He II 30.4 nm (T=100K) filtergrams. This suggests that such spicules are being heated out of the Ca II passband, and continue evolving reaching higher layers and temperatures.



Time slice map along the limb at the off-limb height of 10 arcsec. The data were taken at the north pole on 1 Apr 2007. Lateral motion (excursion) and oscillation get prominent as the height goes up. The period of oscillation is 1 to 4 min, the amplitude is about 1 arcsec and maximum lateral velocity is about 15 -25 km/sec.

Spicule lateral oscillation

TABLE 1.
EVENT SUMMARY FOR THREE OSCILLATING SPICULES OBSERVED IN 2008 JUNE

DATE	OBSERVATION TIME (UT)	DURATION (SEC)	PERIOD (SEC)	AMPLITUDE (KM)	TRANSVERSE VELOCITY (KM S^{-1})	MINIMUM WAVELENGTH (KM)	WAVE SPEED (KM S^{-1})
JUNE 03	00:00:03 -00:07:14	431	130	1000	15	60000	460
JUNE 04	23:33:33 -23:38:52	320	180	700	8	56000	310
JUNE 04	23:42:04 -23:47:09	305	170	800	9	45000	260

Assumed wavelength

$F=1/2\ \rho\ v^2\ V_A$

ρ~10^-14g/cm^3、B~1０G → V_A＝280km/sec
V=10 km/s
F＝1.4 10^5 erg/s/cm^2

Magnetic field

Coronal seismology technique also has been applied to reduce coronal magnetic fields (Kim et al. 2008) ;
oscillating periods of 2-3 minutes, and transverse displacements of 700-1000 km.
estimating magnetic field in spicules is about 10-18 G for lower density limit and about 43-76 G for upper density limit, provided the wavelengh of 8 times of maximum spicule length.

$$B_0 = \sqrt{\frac{\mu_0}{2}} \frac{L}{P} \sqrt{\rho_0 (1 + \frac{\rho_e}{\rho_0})},$$

SUVIT → B_0
can derive density
EUVST → ρ
can derive B_0

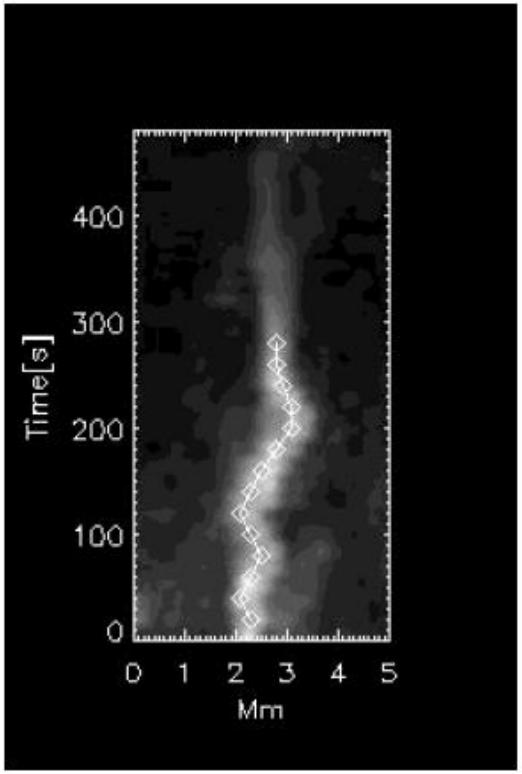


Fig. 2.— Time-slice image at the fixed position (6000 km height) on the spicule axis. The spicule occurred at 00:00 UT on 2008 June 03.

Parameters of transverse oscillations

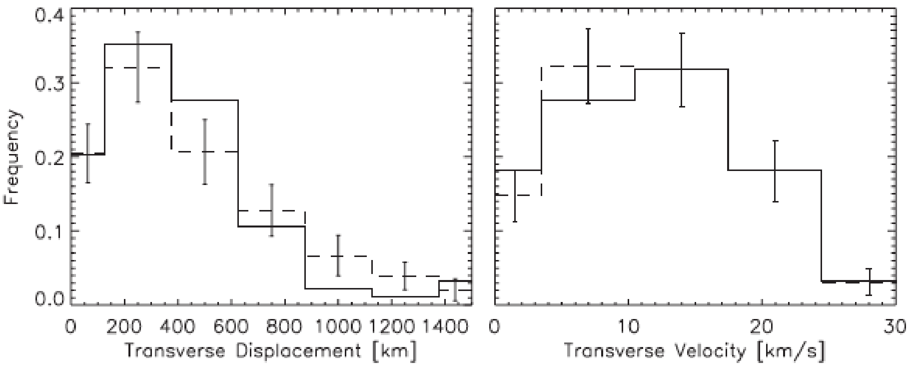
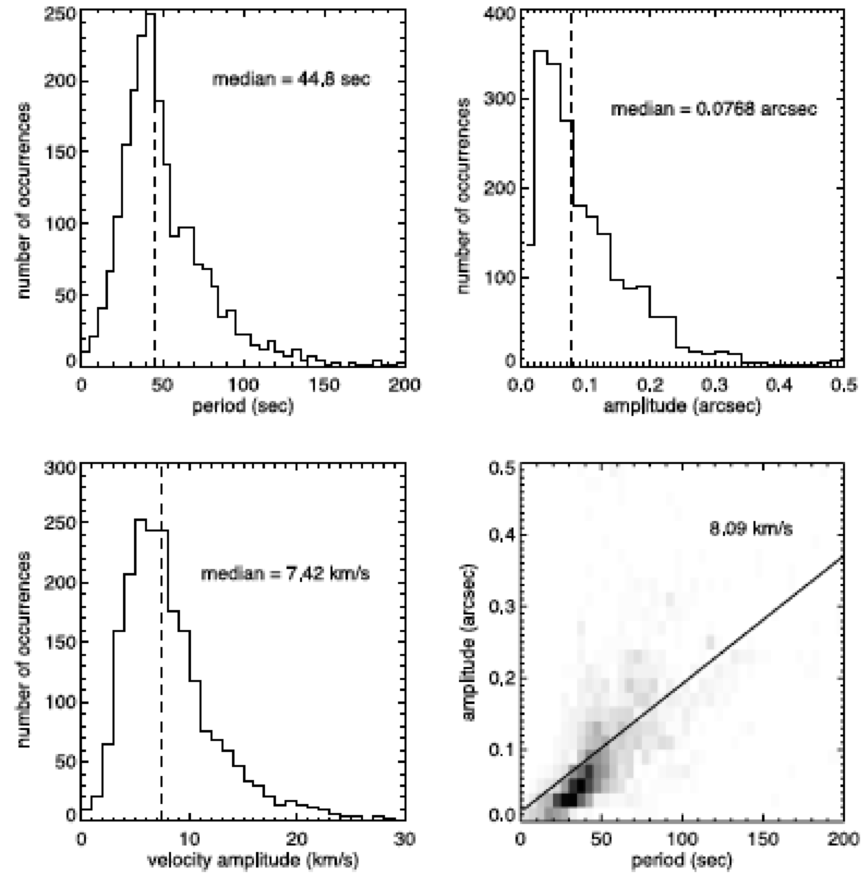


Fig. 3. Comparison between observed and simulated transverse displacements and velocity amplitudes. The left panel shows the distribution of measured transverse displacements of 94 observed spicules [full line (*12*)] and from a Monte Carlo simulation (dashed line) in which spicules carry Alfvén waves with periods randomly chosen from a uniform distribution between 150 and 350 s and velocity amplitudes from a Gaussian distribution around 20 ± 5 km/s. The simulated and observed distributions agree well, especially when taking into account the errors introduced by the poor statistics because of the low number of spicules measured [dashed error bars (*12*)]. The right panel shows a similar comparison for the observed and simulated transverse velocity amplitudes. The agreement between observed and simulated distributions indicates that our data are compatible with ubiquitous Alfvén waves that affect most observed spicules.

De Pontieu et al. (2007)

Transverse oscillation of spicules
v=20 km/sec

Period: 150-350 sec



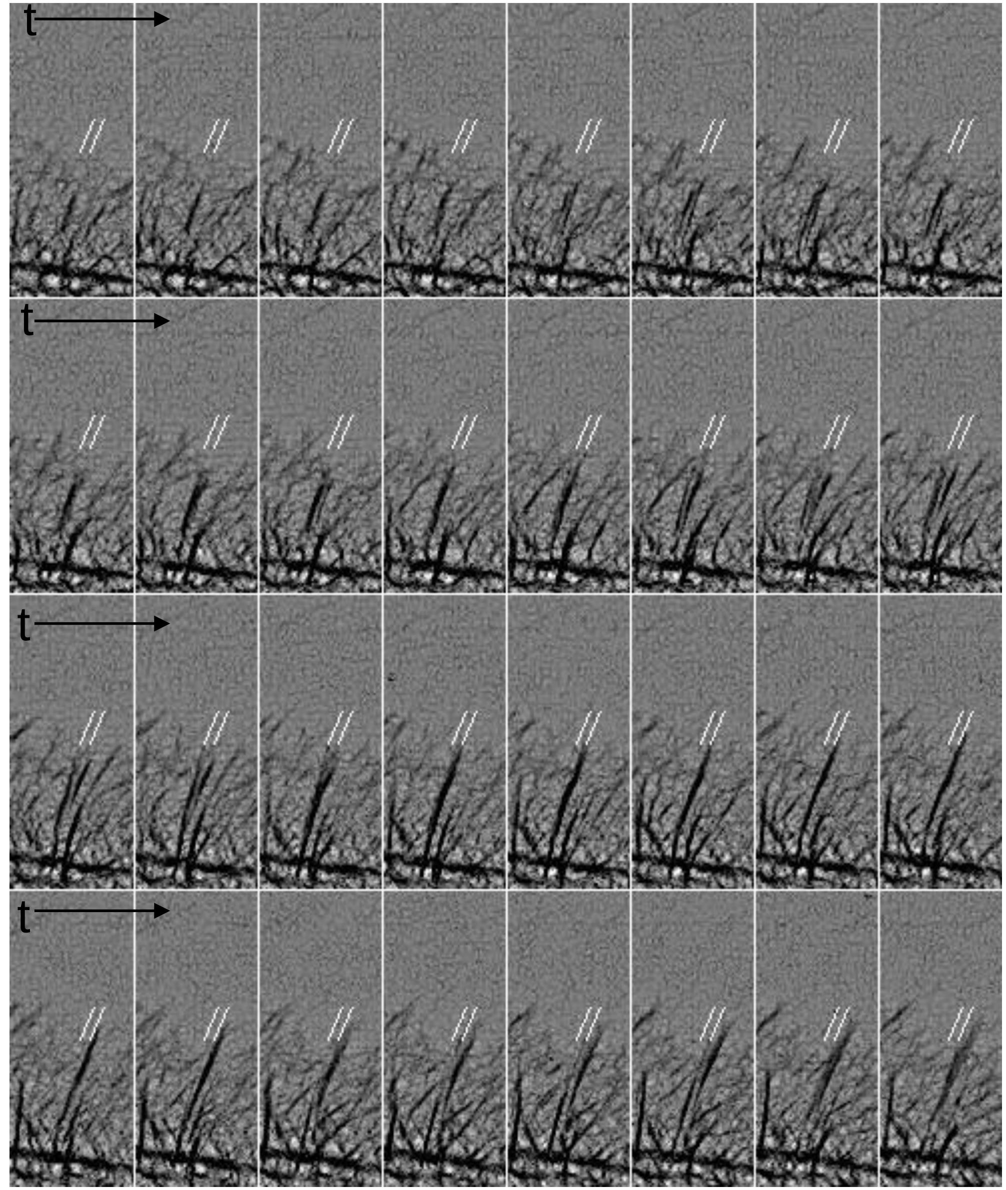
Okamoto et al. (2011)

Transverse oscillation of spicules

In order to find wave propagation, oscillation with the short period and small amplitude is used.

Are they important to understand the energy transfer?

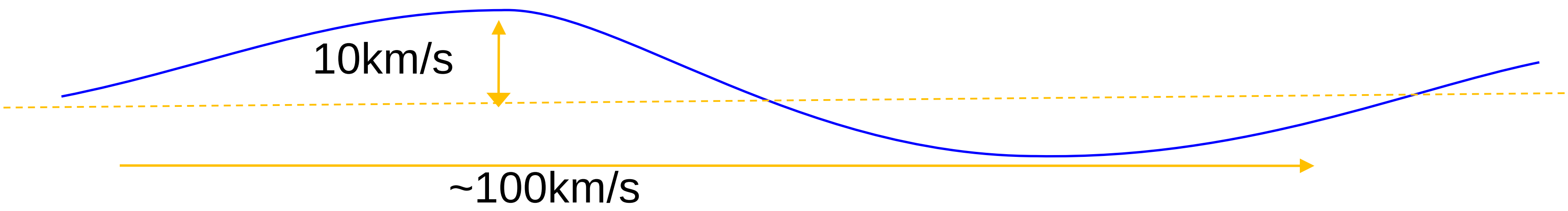
Torsional wave？



Sharpened images with a cadence of 5 sec. This series clearly show that the spicule of double threads (indicated by white lines) is spinning as a whole body (spin period: 1 - 1.5 min, v～15 km/sec).

Possible Detection of magnetic field fluctuation in the chromosphere

(Note. Oscillations of magnetic fields, Doppler velocity and Line intesity in the photosphere were studied in Fujimura & Tsuneta 2009).



- Velocity amplitude δv: ~10 km/s
- Alfven velocity V_A: ~ 100km/s
- Magnetic fields in upper chromosphere: 10 - 100G

- $\delta B/B = \delta v/V_A$ → $\underline{\delta B = 1 \sim 10G}$

- In the current configuration of the spectro-polarimeter,
  - the amplitude can be marginally detected in He 1083 nm.
  - the amplitude can be detected in Stokes-V of Ca II 854 nm.

Energy flux and dissipation

Propagating wave, and damping
- Doppler measurement at two heights
  - one SUVIT
  - the other from line in EUVST (T=100K)