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Observation of kink waves in solar spicules

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Abstract. Height series of Doppler observation in H_α and D_3 spectral lines of solar spicules obtained by big coronagraph (53 cm) of Abastumani Astrophysical Observatory have been analyzed. Time duration of each height series was 7 s. Totally 8 different heights from the photosphere were covered. Spatial difference between neighboring heights was 1 arc sec. We found the periodic spatial distribution of Doppler velocities during height series in certain spicules. We suggest that the periodic spatial distributions are caused by propagating or standing kink waves. The wave length is found to be in the range 3500-4000 km which probably indicates to the granular origin of the waves.

The big 53 cm coronagraph and universal spectrograph have been used to obtain chromospheric H_α and D_3 line spectra at different heights (8 heights) from the photosphere (instrumental spectral resolution - 0.04 A; dispersion - 1 A/mm; spatial resolution - 1 arc sec). Observations were carried out as height series beginning at 3800 km height from the photosphere and upwards (Khutsishvili 1986). The distance between neighboring heights was 1 arc sec, thus the spatial distance 3800-8700 km above the photosphere was covered. The exposure time was 0.4 s at lower heights and 0.8 at higher ones for H_α. While the exposure time for D_3 was 1 s at lower heights and 2 at higher ones. The total time duration of one height series in H_α was 7 s. The consequent height series begins immediately. The total duration of the observation was 44 min. Therefore at one height we have a continuous H_α spectra with time intervals of 7 s. Approximately 300 height series was taken.

We preliminary analyzed the spatial distribution of Doppler velocities in both spectral lines for certain spicules. Nearly 20% of spicules show periodic spatial distributions of Doppler velocities in height series. The Doppler velocity spatial distributions in two height series of two different spicules in H_α spectral line are shown on Fig.1. The periodic spatial distributions are clearly seen. So the transversal velocity in that particular spicules is periodically redistributed with height at certain moment of time (the maximal time difference between the observations at different heights is 7 s, which is the duration of one height series).

In order to explain the phenomenon we model spicules as thin magnetic flux tubes anchored in the photosphere and persisted towards the corona. Kink waves propagating along the magnetic tube lead to the oscillation of the tube axis and thus will lead to the periodic spatial and temporal variations of Doppler shift if we observe in the plane of oscillations. So the observed spatial periodicity of Doppler velocity can be caused by either propagating or standing kink waves.

If the tube radius is much smaller than the wavelength of waves (i.e. $ka << 1$, where k is wave number and a is tube radius), then the dispersion relation for the kink waves is (Edwin and Roberts, 1983)

$$\frac{\omega}{k} \approx C_k = \left(\frac{\rho_0 C_{A0}^2 + \rho_e C_{Ae}^2}{\rho_0 + \rho_e} \right)^{1/2},$$

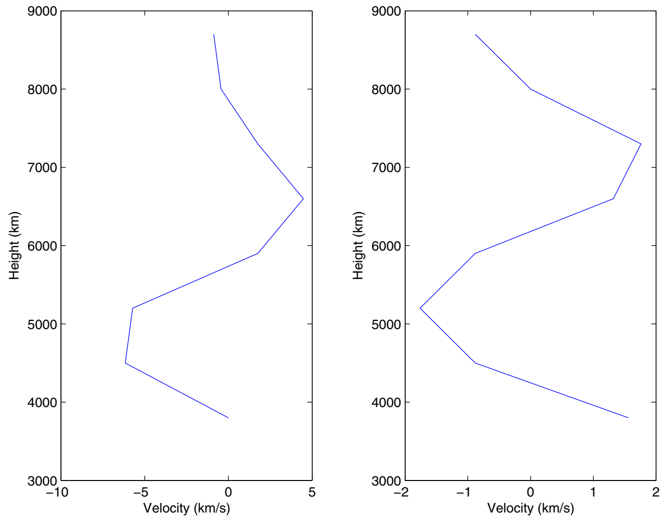

Figure 1. Two height series of Doppler velocity in two different spicules in H_α spectral line are shown. The velocity has periodic spatial distribution, which can be caused by propagating or standing kink waves. The wave lengths are ~ 4000 km and ~ 3500 km correspondingly

where 0 and e denotes the plasma parameters inside and outside the tube, $C_{A0} = B_0/\sqrt{4\pi\rho_0}$ and $C_{Ae} = B_e/\sqrt{4\pi\rho_e}$ are the Alfvén speeds, C_k is the kink speed, ρ is the density and B is the magnetic field.

If the region outside the tube is field-free i.e. $B_e = 0$, which is expected in photosphere-chromosphere, then the dispersion relation for kink waves becomes even simpler:

$$\frac{\omega}{k} = C_k = \left(\frac{1}{1+\rho_e/\rho_0}\right)^{1/2} C_{A0}.$$

Using the observed wave length and particular kink speed we may estimate the period of propagating (standing) kink waves from the dispersion relation. The typical observed wave lengths are in the range of $\sim 3500-4000$ km (see Fig.1). Then for the Alfvén speed being as ~ 100 km/s and the density ratio outside and inside the spicules as $\rho_e/\rho_0 \approx 1/2$, the expected period of kink waves is in the range of $\sim 40-50$ s.

The observed kink waves have wave lengths only slightly longer than the typical granular size. It probably indicates to the granular origin of the waves.

In nearest future we plan to analyze the time series of observations, which allow to reveal the time behavior of H_α Doppler velocities at each height with the time interval of 7 s. Then from observed periods and wave lengths we may estimate the Alfvén speed in spicules from the dispersion relation of kink waves, which can be a basis for *spicule seismology.*

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References

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