

Evidences to the pulse like origin of double spicules based on *Hinode*/SOT observations

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Abstract We analyze the time series of $H\alpha$ line obtained from *Hinode*/SOT on the solar limb. The wavelet analysis shows that there are nice correlations between dynamical properties of the two parts of a double spicule. The dominant periods for height variations are estimated ~ 90 and ~ 180 s. The length of two parts of the spicule oscillates with the period of around ~ 180 s. The mean distance between two parts of the spicule has a periodical treatment with the period of ~ 90 s. Our results show that the strong pulses may lead to the quasi periodic rising of chromospheric plasma into the lower corona in the form of spicules. The periodicity may result from the nonlinear wake behind the pulse in the stratified atmosphere.

Keywords Sun: spicules · Spicule formation · Double spicules

1 Introduction

Spicules were discovered almost 130 years ago but they still remain as one of Solar Physics mysteries (Secchi 1977). They are observable in $H\alpha$, D_3 and $Ca II H$ chromospheric lines. The general properties of them can be found in some reviews (Beckers 1968; Sterling 2000; Zaqarashvili and Erdélyi 2009).

Spicule seismology, which means the determination of spicule properties from observed oscillations and was originally suggested by Zaqarashvili et al. (2007), has been significantly developed during last years (Verth et al. 2011; Ebadi et al. 2012).

Despite the large body of theoretical and observational works devoted to the spicules, their ejection mechanism is not clear yet. Spicule formation mechanisms can be formally divided into three different groups: pulses, Alfvén waves, and p-mode leakage.

The spicule formation idea by impulsively launched perturbations is as follows: The velocity or gas pressure pulses are launched initially below the transition region. The pulse quickly steepens to a shock as a result of rapid decrease in mass density with height and lifts up the transition region which may lead to spicule formation. Hollweg (1982) showed that the Alfvén waves may be nonlinearly coupled to fast magnetoacoustic shocks, which may lead to spicule formation. Cargill et al. (1997) performed the numerical simulations of the propagation of Alfvénic pulses in two dimensional magnetic field geometries. They concluded that for an Alfvénic pulse the time at which different parts of the pulse emerge into the corona depends on the plasma density and magnetic field properties. Moreover, they discussed that this mechanism can interpret spicule ejection forced through the transition region. Kudoh and Shibata (1999) used the random nonlinear Alfvénic pulses and concluded that the transition region lifted up to more than ~ 5000 km (i.e. the spicule produced). Zaqarashvili and Skhirtladze (2008) concluded that photospheric granulation may excite transverse pulses in anchored vertical magnetic flux tubes. The pulses propagate upward along the tubes while oscillating wake is formed behind the wave front in a stratified atmosphere. Murawski and Zaqarashvili (2010), Murawski et al. (2011) studied the upward propagation of a velocity pulse launched initially below the transition region. Their numerical simulations show that the strong initial pulse may lead to the quasi periodic rising of chromosphere material into the lower corona in the form of spicules. The periodicity results from the nonlinear wake behind the pulse in the strati-

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