Available online at www.sciencedirect.com

ScienceDirect

Advances in Space Research 47 (2011) 2019–2029

ADVANCES IN SPACE RESEARCH (a COSPAR publication)

www.elsevier.com/locate/asr

Contribution to the modeling of solar spicules

E. Tavabi [a,b,c,*], S. Koutchmy [c], A. Ajabshirizadeh [b,d]

[a] Payame Noor University (PNU), 45138-69987 Zanjan, Iran
[b] Research Institute for Astronomy & Astrophysics of Maragha (RIAAM), 55134-441 Maraghe, Iran
[c] Institut d'Astrophysique de Paris, UMR 7095, CNRS & UPMC, 98 Bis Bd Arago, F-75014 Paris, France
[d] Department of Theoretical Physics and Astrophysics, Tabriz University, 51664 Tabriz, Iran

Received 29 July 2010; received in revised form 13 January 2011; accepted 19 January 2011
Available online 26 January 2011

Abstract

Solar limb and disk spicule quasi-periodic motions have been reported for a long time, strongly suggesting that they are oscillating. In order to clear up the origin and possibly explain some solar limb and disk spicule quasi-periodic recurrences produced by overlapping effects, we present a simulation model assuming quasi-random positions of spicules. We also allow a set number of spicules with different physical properties (such as: height, lifetime and tilt angle as shown by an individual spicule) occurring randomly.

Results of simulations made with three different spatial resolutions of the corresponding frames and also for different number density of spicules, are analyzed. The wavelet time/frequency method is used to obtain the exact period of spicule visibility. Results are compared with observations of the chromosphere from (i) the Transition Region and Coronal Explorer (TRACE) filtergrams taken at 1600 Å, (ii) the Solar Optical Telescope (SOT) of Hinode taken in the Ca II *H*-line and (iii) the Sac-Peak Dunn's VTT taken in $H\alpha$ line. Our results suggest the need to be cautious when interpreting apparent oscillations seen in spicule image sequences when overlapping is present, i.e., when the spatial resolution is not enough to resolve individual components of spicules.

Keywords: Chromosphere; Spicules; Oscillations; Wavelet analysis; Simulation

1. Introduction

Spicules are an important extended rather cool structure between the solar surface and the corona, partly filling the space occupied by the chromosphere and surrounded by a thin transition region. Their origin, formation and dynamical properties are still mysterious.

They look like jet-like structures ejected from a region (sometimes called a rosette) situated near the supergranulation boundaries and they are one of the most important and dramatic dynamic phenomena in the Transition Region (TR) and the chromosphere. The mechanism of spicule formation and evolution is not well understood (for the mechanism of formation, see the review of Sterling, 2000 and also Lorrain and Koutchmy, 1996; Filippov et al., 2007).

The investigation of solar spicules is necessary to understand the TR and the coronal heating (Kudoh and Shibata, 1999). The typical lifetime of spicules is 5–15 min and the speed of spicules from the low chromosphere layers is about 25–50 km/s. They usually reach heights of 5000–10,000 km before fading out of view or fall back towards the solar surface. Their smallest widths are only 100–200 km (Tavabi et al., 2011), Tavabi et al. found that indeed spicules show a whole range of diameters, including unresolved "interacting spicules" (I-S), depending of the definition chosen to characterize this ubiquitous dynamical phenomenon occurring into a low coronal surrounding. A definite signature in the 0.18–0.25 Mm range exists, corresponding to the occurrence of the newly discovered type II spicules and, even more impressively, large Fourier amplitudes are observed in the 0.3 to the 1.2 Mm range of diameters and spacing. They are observed in many

* Corresponding author at: Payame Noor University (PNU), 45138-69987 Zanjan, Iran. Tel.: +98 2414224062; fax: +98 24142487120.
E-mail addresses: tavabi@iap.fr (E. Tavabi), koutchmy@iap.fr (S. Koutchmy), a-adjab@tabrizu.ac.ir (A. Ajabshirizadeh).

0273-1177/$36.00 © 2011 COSPAR. Published by Elsevier Ltd. All rights reserved.
doi:10.1016/j.asr.2011.01.023

optical lines, such as $H\alpha$, $H\beta$, H & K of Ca II and EUV. We want to point out that a series of papers was devoted to $H\alpha$ and to He^{+} spicules by Georgakilas et al. (1999) and Christopoulou et al. (2001) and an exhaustive new observational paper devoted to $H\alpha$ and Trace UV spicules was recently published by Pasachoff et al. (2009), among many other papers published during the last decade.

The existence of 3–5 min oscillations in spicules were reported since a long time, for example by Kulidzanishvili and Nikolsky (1978). More recently similar periodic

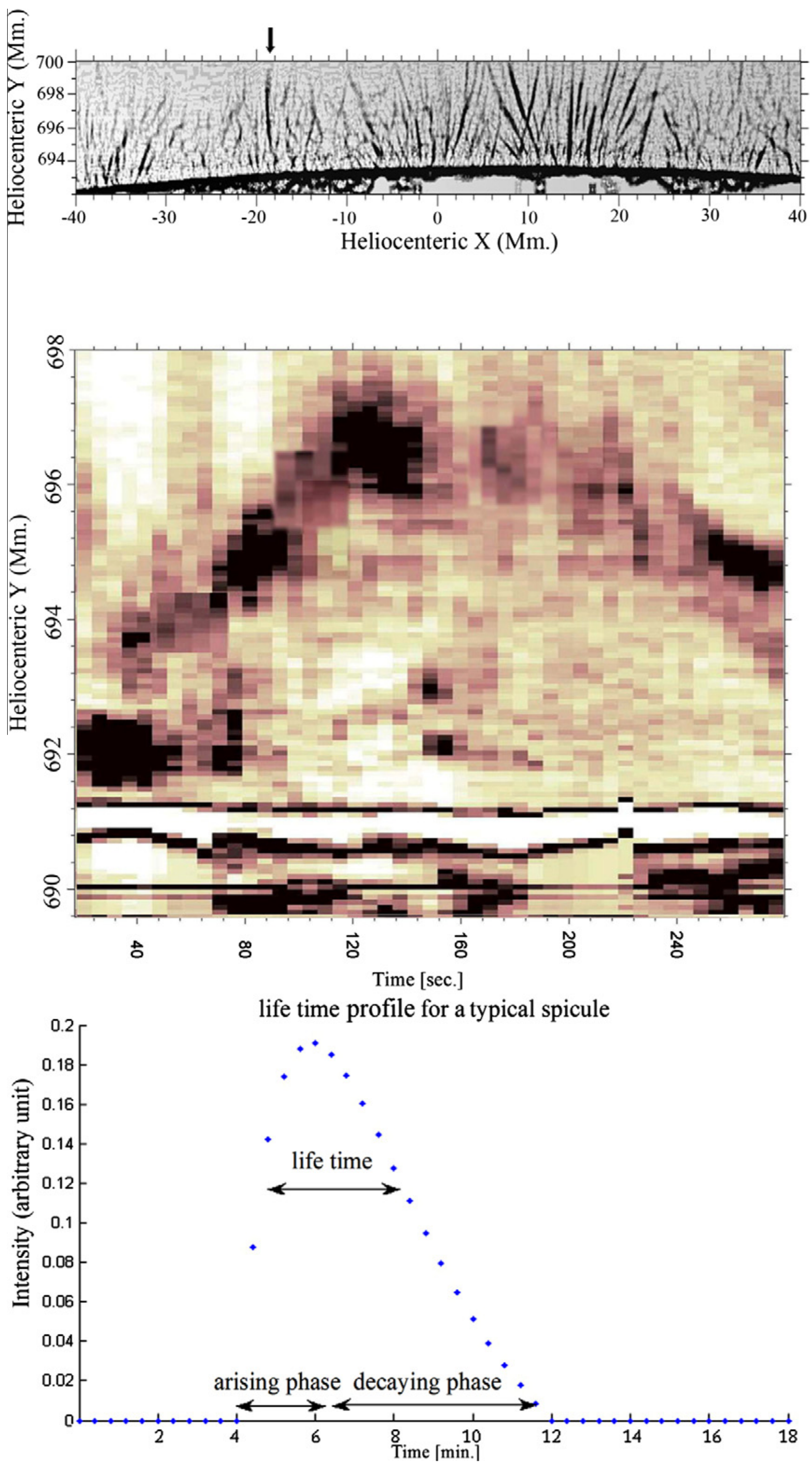

Fig. 1. Example of a mad-maxed Hinode filtergram in Ca H II, obtained on November 25, 2008, near the North pole (top image), printed in negative. Under is shown a typical Y–t diagram (time-slice diagram) deduced from the analysis of a time sequence of similar images; it gives a ballistic-type motion (see also Suematsu et al., 1995), for the typical spicule shown by a linear mark on the top image, to the left. It is clear that after reaching a maximum length, the spicules are less rapidly falling back to the solar surface as finally illustrated on the visibility function of the spicule plotted on the bottom panel.