Astrophys Space Sci (2012) 340:9–15
DOI 10.1007/s10509-012-1036-3

ORIGINAL ARTICLE

Phase mixing of propagating Alfvén waves in a stratified atmosphere: solar spicules

H. Ebadi · M. Hosseinpour · H. Altafi-Mehrabani

Received: 15 October 2011 / Accepted: 24 February 2012 / Published online: 17 March 2012

Abstract Alfvénic waves are thought to play an important role in coronal heating and solar wind acceleration. Recent observations by *Hinode*/SOT showed that the spicules mostly exhibit upward propagating high frequency waves. Here we investigate the dissipation of such waves due to phase mixing in stratified environment of solar spicules. Since they are highly dynamic structures with speeds at about significant fractions of the Alfvén phase speed, we take into account the effects of steady flows. Our numerical simulations show that in the presence of stratification due to gravity, damping takes place in space than in time. The exponential damping low, $\exp(-\mathrm{At}^3)$, is valid under spicule conditions, however the calculated damping time is much longer than the reported spicule lifetimes from observations.

Keywords Sun: spicules · Alfvén waves: phase mixing · Stratification

H. Ebadi (✉)
Astrophysics Department, Physics Faculty, University of Tabriz, Tabriz, Iran
e-mail: hosseinebadi@tabrizu.ac.ir

H. Ebadi
Research Institute for Astronomy and Astrophysics of Maragha, Maragha 55134-441, Iran

M. Hosseinpour
Plasma Physics Department, Physics Faculty, University of Tabriz, Tabriz, Iran

H. Altafi-Mehrabani
Physics Faculty, University of Zanjan, Zanjan, Iran

1 Introduction

The coronal heating (Edlén 1943) mechanism is one of the major unsolved problems in solar physics. Since the energy flux carried by acoustic waves is too small, the possibility of heating by MHD waves has been investigated intensively as the magnetic structure of the solar corona can play an important role here (Hood et al. 1997). The propagation of Alfvén waves is one of the candidate mechanisms that can carry energy to large distances from the surface, and heat the solar corona (Wentzel 1974; Kudoh and Shibata 1999). However, a heating theory based on the Alfvén waves faces a couple of difficulties: Firstly, the waves have to transport enough energy flux, and secondly, they have to dissipate efficiently in order to deposit the right amount of energy at the right place (De Moortel et al. 1999). The Alfvén waves may reach the corona even in the absence of highly stratified atmosphere but with lesser propagation speed. The damping length of Alfvén modes is defined by various dissipative processes such as phase mixing (Heyvaerts and Priest 1983; Browning 1991), resonance absorption (Ionson 1978), and nonlinear mode conversion (Hollweg 1982). Phase mixing is a mechanism for dissipating Alfvén waves, which was first proposed by Heyvaerts and Priest (1983). When Alfvén waves propagating in an inhomogeneous medium, on each magnetic field line, a wave propagates with its own local Alfvén speed. After a certain distance or after enough time, these neighboring perturbations will be out of phase. This ultimately results in a strong enhancement of the dissipation of Alfvén waves energy via both viscosity and resistivity. Hood et al. (2002) and Heyvaerts and Priest (1983) analytically showed that in both the strong phase mixing limit and the weak damping approximation, the amplitude of Alfvén waves decays with time as $\exp(-t^3)$. Karami and Ebrahimi (2009) calculated