MHD WAVES IN ACTIVE REGION FILAMENT FROM SOHO-THEMIS JOINT OBSERVATIONS

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ABSTRACT

The stability of solar filaments and their implications for eruptive events can be revealed by the existence of magnetohydrodynamic (MHD) waves. During the MEDOC campaign on May 2000, we performed joint observations involving SOHO and THEMIS instruments (CDS and MSDP respectively). We analyse the modes of oscillations for several spectral lines (Hα at 6563 Å, HeI at 584 Å and MgX at 609 Å): intermediate (6-40 min) and short (< 5 min) periods are found and are discussed in terms of MHD waves. The Hα time series (MSDP) in both line center intensity and line-of-sight Doppler shifts provide constraints on models of filament oscillations.

Key words: Sun: oscillations; Sun: MHD waves; Sun: filament.

1. INTRODUCTION

In a previous work (Régnier, Solomon & Vial 2001), we analyzed the oscillation modes observed in an active region filament using SUMER/SOHO (Wilhelm et al. 1995) velocity time series in the 584 Å HeI line. For a total duration of about 7 h 30 min, we found long (> 40 min) and intermediate (6–40 min) oscillation periods in the filament. The observed periods were compared to MHD waves primary periods using a simple model of filament (Joarder & Roberts 1993): Alfvén modes are associated with periods of about 65 min (odd mode) and 10 min (even mode), and one fast magnetoacoustic mode has a period of 20 min. In addition to this wave identification, we performed a diagnosis of the observed structure: we estimated the angle between the magnetic field and the filament (~ 18°) and the relation between the square root of the filament density and the magnetic field strength (B \( \propto \sqrt{\rho} \)). In order to confirm the above results, we recently performed new multi-wavelength observations using instruments from SOHO and THEMIS observatories in the frame of Joint Observing Program 124 (JOP124). JOP124 mainly involves the CDS/SOHO spectrometer (Harrison et al. 1995) and the MSDP/THEMIS imaging spectropolarimeter (Mein 2002).

Figure 1. Hα image (Meudon Observatory) of Active Region 9005 in which the "May ring" filament was observed on May 2000.

The filament observed during MEDOC campaign #5 on May 2000 belonged to the Active Region NOAA 9005. The filament was located in the South hemisphere in a weak magnetic field active region with a main negative polarity surrounded by positive polarities. This fact justifies the given name of "May ring" filament (see Fig. 1).

In this article, we apply the method described by Régnier, Solomon & Vial (2001) to the Hα MSDP observations (Sect. 2) and to two EUV lines observed by CDS (Sect. 3), namely the 584 Å HeI line and the 609 Å MgX line. In Sect. 4, we deduce some relevant parameters of the filament which give us new inputs for filament-prominence models of oscillations.
2. MSDP DATA

Hα observations were obtained by the MSDP (Multichannel Subtractive Double Pass, Mein 1991, 2002) instrument of THEMIS/Tenerife. We performed the observations using the optics A (9 channels, resolution of 24 pm) for a scanned field-of-view of 150°×123° with a scanning time of 30 s. We only measured the intensity profile with a pixel size of 0.25° square.

Here we analyze a 1 hour time series obtained on May 14, 2000 between 10:07 UT and 11:02 UT (during this time period the seeing was good enough to obtain Hα images of high quality). We first derive the Doppler velocity using the bisector method (Mein 2002). The total duration of the time series (1 hour) and the scan time (30 s) give us the lowest detectable frequency, 0.6 mHz, and the highest one, 15 mHz. The power spectrum of the velocity time series (see Fig. 2) exhibits only one characteristic frequency:

\[ \omega_{H\alpha} = 4.16 \text{ mHz}. \]

Note that the short duration of this continuous time series does not allow us to determine the lowest frequencies often associated with MHD primary modes.

![Figure 2. Power spectrum (in unit of \( \sigma^2 \)) of the filament velocity time series observed by the MSDP. The solid straight line is the confidence level at 99% (5\( \sigma^2 \)). The characteristic frequency around 0.6 mHz is due to the Fourier analysis procedure and cannot be taken into account.](image)

3. CDS DATA

The joint CDS observations were obtained on May 14 during a long continuous time series of 6 h 12 min. The observed spectral lines are: HeI at 584 Å, HeII at 304 Å, OIII at 599 Å and MgX at 609 Å. The 2" × 120" slit is used to record the line spectra with a temporal resolution of 24 s and a spectral resolution of 110 mÅ (1st order) and 70 mÅ (2nd order). Note that for the HeII and the OIII lines the intensity signals are too weak for a Fourier analysis to be applied (Régnier 2001).

![Figure 3. Power spectra (in unit of \( \sigma^2 \)) of the filament velocity time series for the 584 Å HeI line (top) and for the 609 Å MgX line (bottom). The solid straight line is the confidence level at 99% (5\( \sigma^2 \)). The frequencies above the 99% confidence level are listed in Table 1.](image)

As for the Hα time series, we only focus our analysis on the power spectra of the Doppler velocity time series. It appears a thermal drift on the velocity measurements due to instrumental effects (e.g. moving mirror position, increase of temperature). This wavelength-dependent effect is corrected by a linear fit. The lowest (resp. highest) detectable frequency is \( 9 \times 10^{-2} \) mHz (resp. 21 mHz). In Fig. 3, we plot the power spectra for HeI line and MgX lines: 7 characteristic frequencies between 0.5 mHz and 2 mHz are found for the HeI line, and 1 characteristic frequency at 3.73 mHz for the MgX line (see Table 1).

As in Régnier, Solomon & Vial (2001), the 584 Å HeI spectral line is a good choice for determining filament oscillations. In spite of the absorption of the photospheric radiations by the cool filament material (for wavelengths less than 912 Å, e.g. Chiuderi-Drago et
Table 1. Frequencies and periods observed for the 584Å HeI line and the 609Å MgX line by CDS/SOHO, and for the Hα line by MSDP/THEMIS.

<table>
<thead>
<tr>
<th></th>
<th>Frequency (mHz)</th>
<th>Period</th>
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<tbody>
<tr>
<td>HeI (CDS)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\omega_{HeI}^1)</td>
<td>0.58</td>
<td>28 min 44 s</td>
</tr>
<tr>
<td>(\omega_{HeI}^2)</td>
<td>0.73</td>
<td>22 min 50 s</td>
</tr>
<tr>
<td>(\omega_{HeI}^3)</td>
<td>0.84</td>
<td>19 min 50 s</td>
</tr>
<tr>
<td>(\omega_{HeI}^4)</td>
<td>1.16</td>
<td>14 min 22 s</td>
</tr>
<tr>
<td>(\omega_{HeI}^5)</td>
<td>1.23</td>
<td>13 min 33 s</td>
</tr>
<tr>
<td>(\omega_{HeI}^6)</td>
<td>1.55</td>
<td>10 min 45 s</td>
</tr>
<tr>
<td>(\omega_{HeI}^7)</td>
<td>1.77</td>
<td>9 min 25 s</td>
</tr>
<tr>
<td>MgX (CDS)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\omega_{MgX})</td>
<td>3.73</td>
<td>4 min 28 s</td>
</tr>
<tr>
<td>Hα (MSDP)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\omega_{H\alpha})</td>
<td>4.16</td>
<td>4 min 00 s</td>
</tr>
</tbody>
</table>

al. 1998), the observed MgX line oscillations seem only associated with the coronal medium and the oscillations of coronal loops overlaying the filament.

4. INFERRED PARAMETERS FOR MODELS

In this Section, we apply a diagnostic method (see Régnier, Solomon & Vial 2001) to infer some relevant parameters of the filament and we discuss the assumptions of the filament model versus the high resolution observations provided by the MSDP.

We first consider the model of filament-prominence oscillations developed by Joarder & Roberts (1993). In addition to the physical parameters of the filament and its environment (temperature, density or magnetic field), the Joarder & Roberts model takes into account two characteristic geometrical parameters: the width of the filament, \(2a\) and the length \(l\) between the rigid walls describing the photospheric line-tying of the magnetic field supporting the filament. Using both Hα image and MDI/SOHO line-of-sight magnetogram, we estimate these parameters: \(2a = 25 000 \text{ km}, l = 180 000 \text{ km}\). Assuming a filament temperature of 8000 K, a filament density of \(10^{-12} \text{ g cm}^{-3}\), a coronal temperature of 1 MK and gas pressure equilibrium between the filament and its environment, we are able to identify two MHD modes:

- the primary frequency of the even Alfvén mode is associated to \(\omega_{HeI}^1\);  
- the primary frequency of the fast sausage mode \((fsm)\) is associated to \(\omega_{HeI}^2\).

(no other frequency can be identified as a primary frequency of MHD modes). This identification allows us to estimate the angle between the magnetic field and the filament for a chosen filament temperature of 8000 K:

\[
\phi = 31^\circ
\]

and,

\[
B = 2.95 \times 10^{-5} \sqrt{\rho_0}
\]

(B in Gauss, \(\rho_0\) in \(\text{cm}^{-3}\)). As for the preceding oscillations study, we are able to identify two MHD primary modes: the even Alfvén mode and the fast sausage mode. The periods of these two modes are very similar to those found in Régnier, Solomon & Vial (2001). The angle, \(\phi\) is twice times larger than in the previous work but the relation between the magnetic field strength and the filament density is still the same. That means that (1) the observed periods of about 20 min and 10 min should be observed in most stable, active region filaments whatever the geometry of the structure, (2) these frequencies are associated with Alfvén and fast magnetoacoustic modes, (3) Eq.(2) is always valid for the Joarder & Roberts model.

In the above study, we only took into account the global oscillations considering the whole filament as a single structure. Nevertheless when we look at the high resolution Hα images obtained by MSDP/THEMIS it is no longer possible to ignore the existence of fine structures. Therefore, we need to consider new methods to analyze oscillations from observed time series and new theoretical models. On the observational point of view, new methods have been recently developed to analyze 2D time series namely wavelet transform (see e.g Baudin, Bocchialini & Koutchmy 1996, De Moortel and Hood 2000). On the theoretical point of view, efforts have recently been made to take into account the fine structures (e.g. Joarder, Nakariakov & Roberts 1997, Díaz et al. 2001). We plan to apply these methods to this dataset in order to understand the excitation of fine structures and the instabilities propagated to the whole structure.

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