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Wavelet-based method for coronal loop oscillations analysis

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Abstract. We study the properties of Doppler shift oscillations observed in hot coronal loops by SoHO/SUMER. These oscillations have been identified as magnetoacoustic slow mode standing waves and may be an important magnetic field diagnostic for the oscillating loops. Visual inspection of the SUMER data suggests that one in three microflares trigger oscillation. So for an average active region we can expect several oscillation events per hour. To study the statistics of the oscillations, automatic identification and classification of the events is required. We have performed a Wavelet analysis on a 12 hour time series of SUMER Fe XIX data and find that almost all of the oscillation events in the data set are identified by this technique, with very few false positives. The method is expected to be useful for the analysis of future Ca XVII and Fe XXIV spectra of microflares observed with HINODE/EIS.

1 Introduction

SoHO/SUMER has recently revealed standing slow mode oscillations in hot (6-8 MK) coronal loops (Wang et al. 2002; Kliem et al. 2002). The search for coronal loop oscillations is motivated by the variety of information they can provide us with. Doppler shift oscillations give us information on the excitation site, the excitation mechanism, the energy dissipation and the coronal magnetic field. The magnetoacoustic waves are only seen in hot flare lines, such as Fe XIX, with a formation temperature above 6 MK, without any signature in cooler lines. Analysis and conclusions on coronal loop oscillations are limited because SUMER is only able to observe at the solar limb and is not able to raster across the loop structures. The HINODE mission will give us the possibility to make high cadence imaging and spectral observations of active region loops at any position on the Sun, and thus will provide us with the loop geometry and oscillations characteristics at different loop positions in a wave period. In order to understand the properties of these oscillations we will carry out a statistical study using the wavelet-based method. We would like to determine the percentage of active region microflares that trigger oscillations, find which modes are excited, their periods, damping times as well as the range of temperatures of the lines in which we observe them.

2 Observations

The spectroscopic observations of the active region AR 9176 with a hot loop system have been obtained by SUMER in the sit-and-stare-mode on September 16-17th, 2000, with an exposure time of 1.5 min (Fig. 1). Time series in five spectral lines, Fe XIX λ 1118 (6.3 MK),

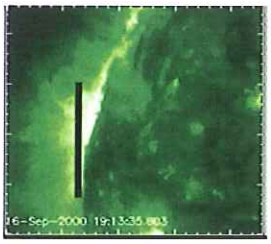

Figure 1. EIT 195 Å image of the observed active region showing the position of the SUMER slit.

Ca xv λ 1098 and λ 1110 (3.5 MK), Ca xiii λ 1134 (2.2 MK), and Si iii λ 1113 (0.06 K), were recorded and after processing the raw data line moments have been computed. The Doppler oscillations are seen in the hot Fe xix line coinciding with the flare like brightenings typical for this line.

3 Data Analysis

We use the wavelet-based algorithm À trous ("with holes") (Fligge & Solanki 1997; Starck et al. 1998) to help identify the oscillations in the velocity time series (Fig. 3). À trous reduces the noise by local thresholding on wavelet coefficients at each scale. First we determined the noise in shift, λ_s, at each position and time pixel by evaluating the error in the center of gravity of the line using the error propagation law $\sigma^2(\lambda_s) = \sigma^2(I_\lambda)(\partial\lambda_s/\partial I_\lambda)^2$, and assuming a Poisson distribution of the noise for the intensity $\sigma(I_\lambda) = \sqrt{I_\lambda}$. In order to find the noise wavelet coefficients at each scale, we applied the À trous algorithm to the relative error time series, using the same parameters as for the data. After identifying those wavelet coefficients that are significantly non-zero against the noisy background, we have used the Morlet wavelet transform to find the power of the wavelet coefficients and to reconstruct the time series at each pixel, filtering out oscillations with periods under 6, and above 15 minutes. To make this method automatic, all the criteria must be of general form giving acceptable results for any chosen time series.

4 Conclusions

We have developed a technique, based on the discrete wavelet algorithm À trous and a subsequent Morlet reconstruction, allowing automatic extraction of coronal loop Doppler shift oscillations. We have tested this method on a 12 hour time series and found 22 clear cases of oscillations (Fig. 3). Their occurrence coincides with about 33% of the microflare events typical for the line Fe xix (Fig. 2), they are usually not seen as oscillations in the intensity map. Our method has been shown to be reliable in the analysis of the subsequent three day long SUMER time series.

References

Fligge, M. & Solanki, S. K. 1997, A&AS, 124, 579

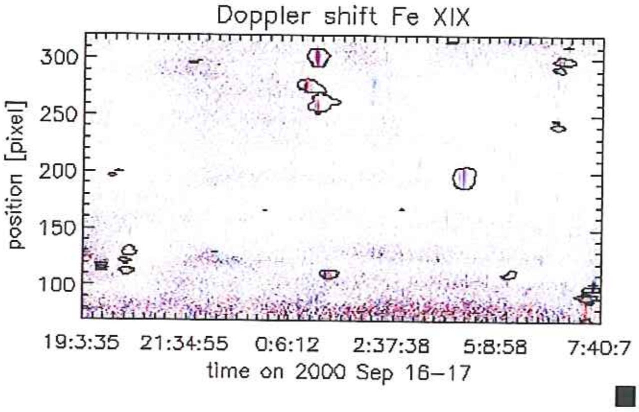

Figure 2. Intensity of the Fe XIX with the contours defining the position of the Doppler shift oscillations.

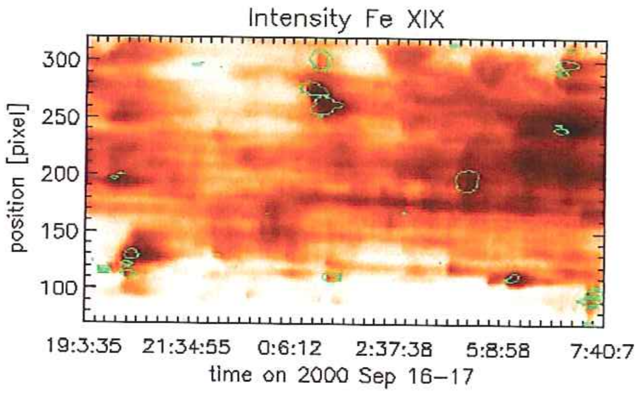

Figure 3. Corresponding Doppler shift map after denoising using À trous algorithm and after Morlet reconstruction.

Kliem, B., Dammasch, I. E., Curdt, W., & Wilhelm, K. 2002, ApJ, 568, L61

Starck, J. L., Murtagh, F., & Bijaou, A. 1998, Image Processing and Data Analysis: The Multiscale Approach (Cambridge University Press, New York, NY, USA)

Wang, T. J., Solanki, S. K, Curdt, W., & Innes, D. E. 2002, ApJ, 574, L101