Applying 2D motion magnification to EUV observations of the low-amplitude kink oscillations

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Abstract

We introduce a new approach for the investigation of the low-amplitude transverse oscillations of coronal loops recently discovered in SDO/AIA data. Typical amplitude of these oscillation is found to be about 0.2 Mm, that is less than SDO/AIA pixel size. Measuring parameters of such a small motion is a challenging task. The technique called motion magnification can help here and simplify the analysis[1]. Motion magnification acts like a microscope for low amplitude motions in image sequences (i.e. data cubes). It artificially amplifies small displacements making them much better visible in time-distance plots and animations. This approach is found to give good results for harmonic oscillations, including the modulated signals, such as exponentially decaying, multi-modal and frequency modulated signals. The method was tested on an artificial data set, and using the EUV observations of a non-flaring active region, clearly demonstrating the presence of low-amplitude decay-less oscillations in the majority of coronal loops associated with the active region.

Online version with movies: http://www2.warwick.ac.uk/fac/sci/physics/research/cfsa/people/anfinogentov/motion_magnification

Method description

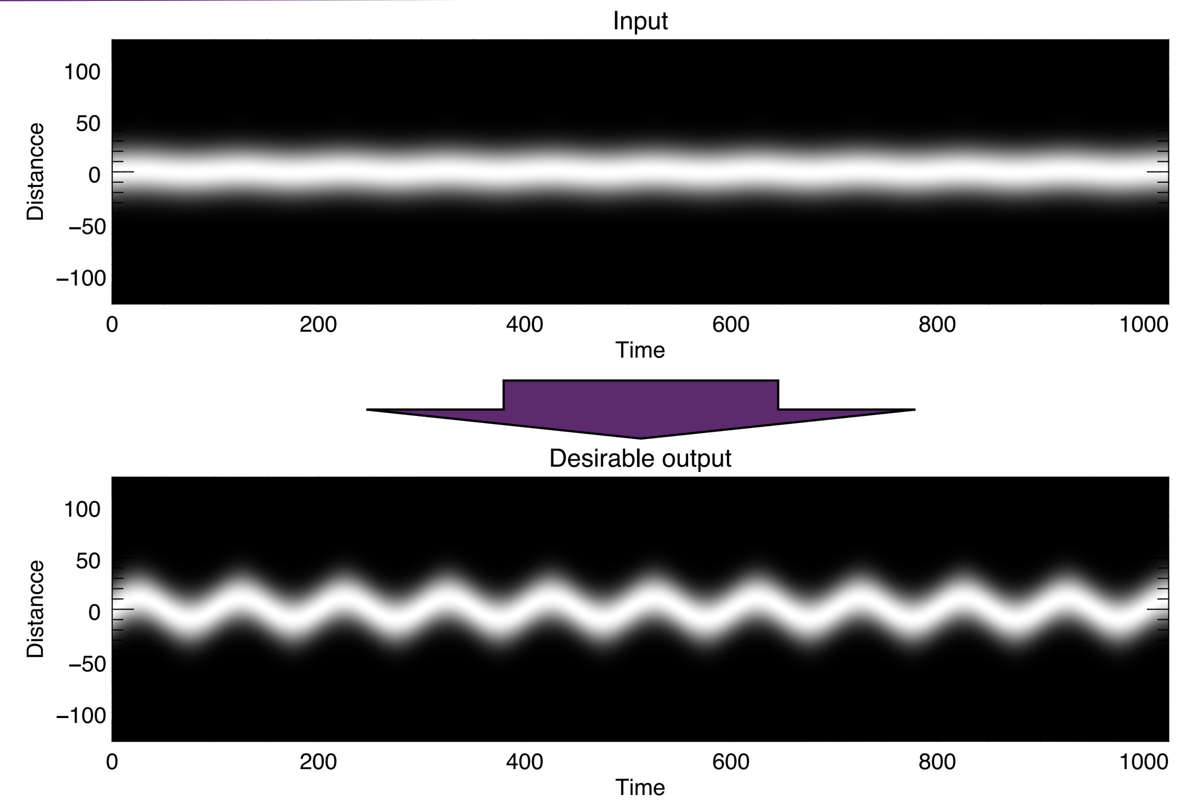
I. Input: a sequence of 2D images (data cube)
II. Compute spatial 2D dual tree complex wavelet transform (DTℂWT)[2] of each image
III. Calculate slow trend of DTℂWT components phases by smoothing them along the time dimension

$$\Phi_{trend} = smooth(\Phi, w),$$

w is the smoothing window width.
IV. Magnify phase variation of DTℂWT components:

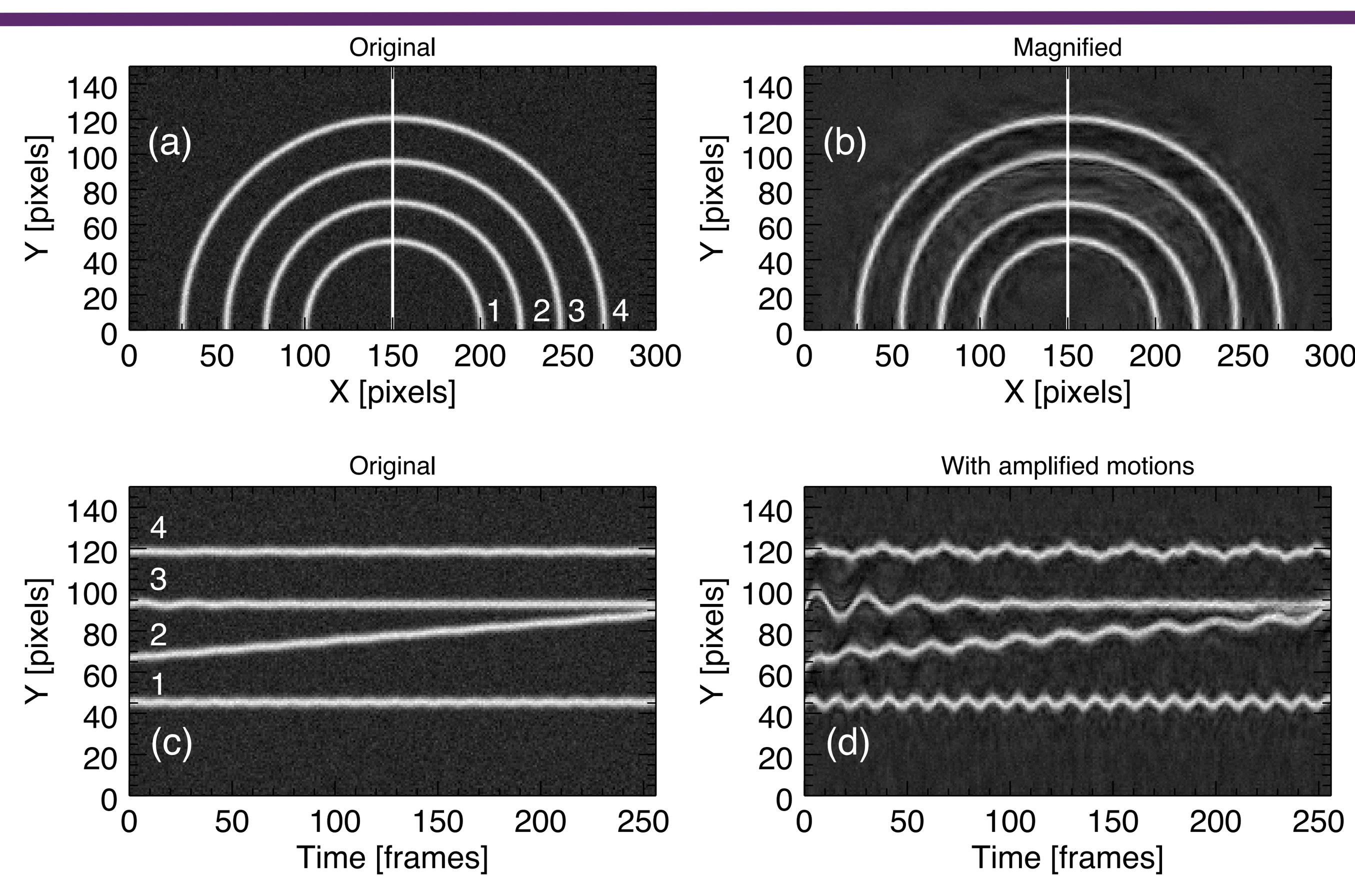
$$\Phi_{ampl} = \Phi_{trend} + k(\Phi - \Phi_{trend})$$

V. Reconstruct output images using inverse DTℂWT
VI. Output: a data cube with magnified transverse motions



Testing on an artificial model

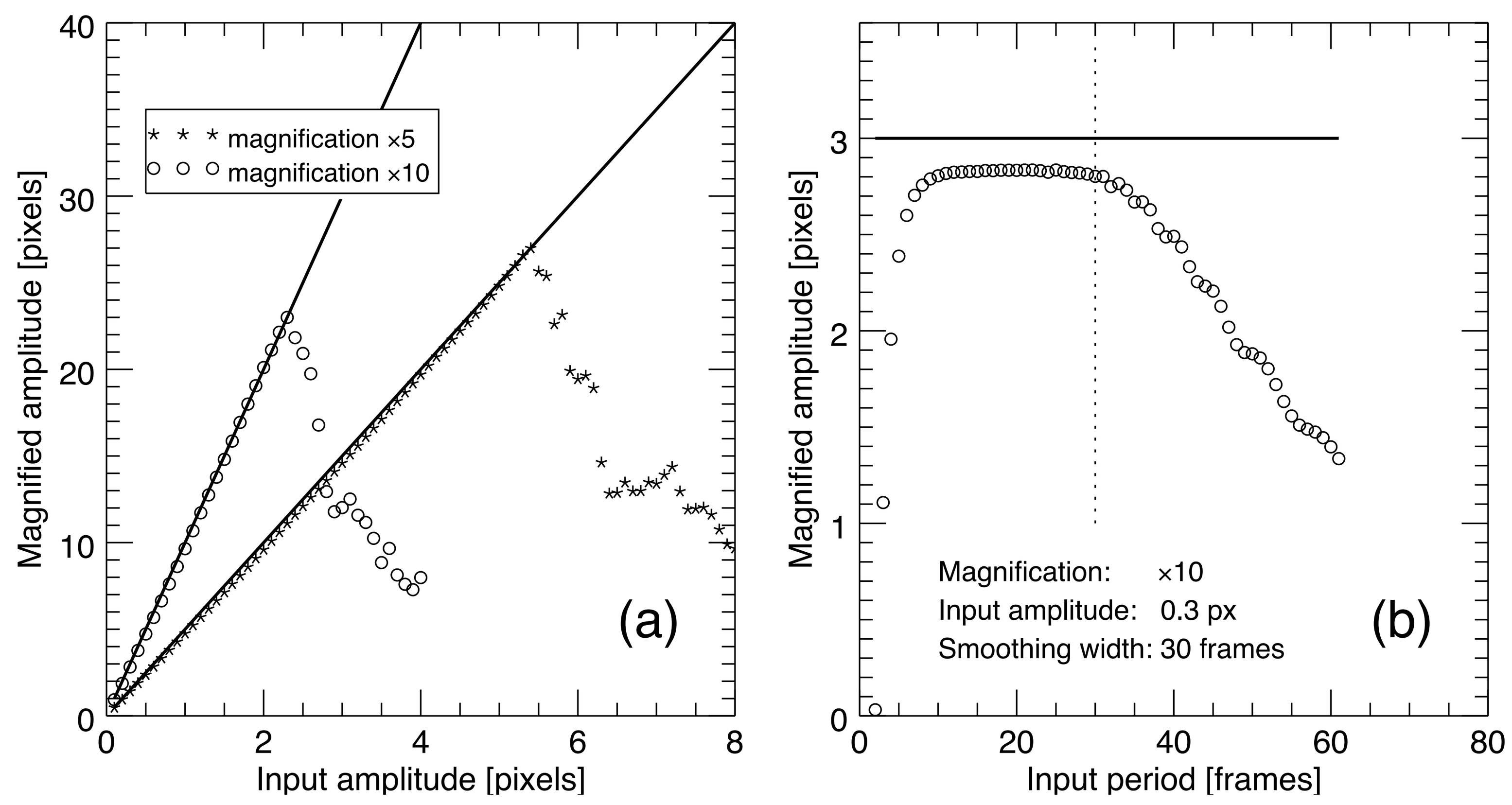
The method has been tested on a sequence of artificial images, imitating typical kinds of kink oscillations in a system of four loops.
Loop 1: harmonic oscillation with constant period and amplitude.
Loop 2: decay-less oscillation in an expanding loop. Period is changing in time.
Loop 3: exponentially decaying standing oscillation
Loop 4: coexistence of two harmonics, global mode and third harmonic
The built-in oscillations are clearly visible in the processed data for all four kinds of the kink oscillatory patterns that are difficult to see in the original data.



See movie online

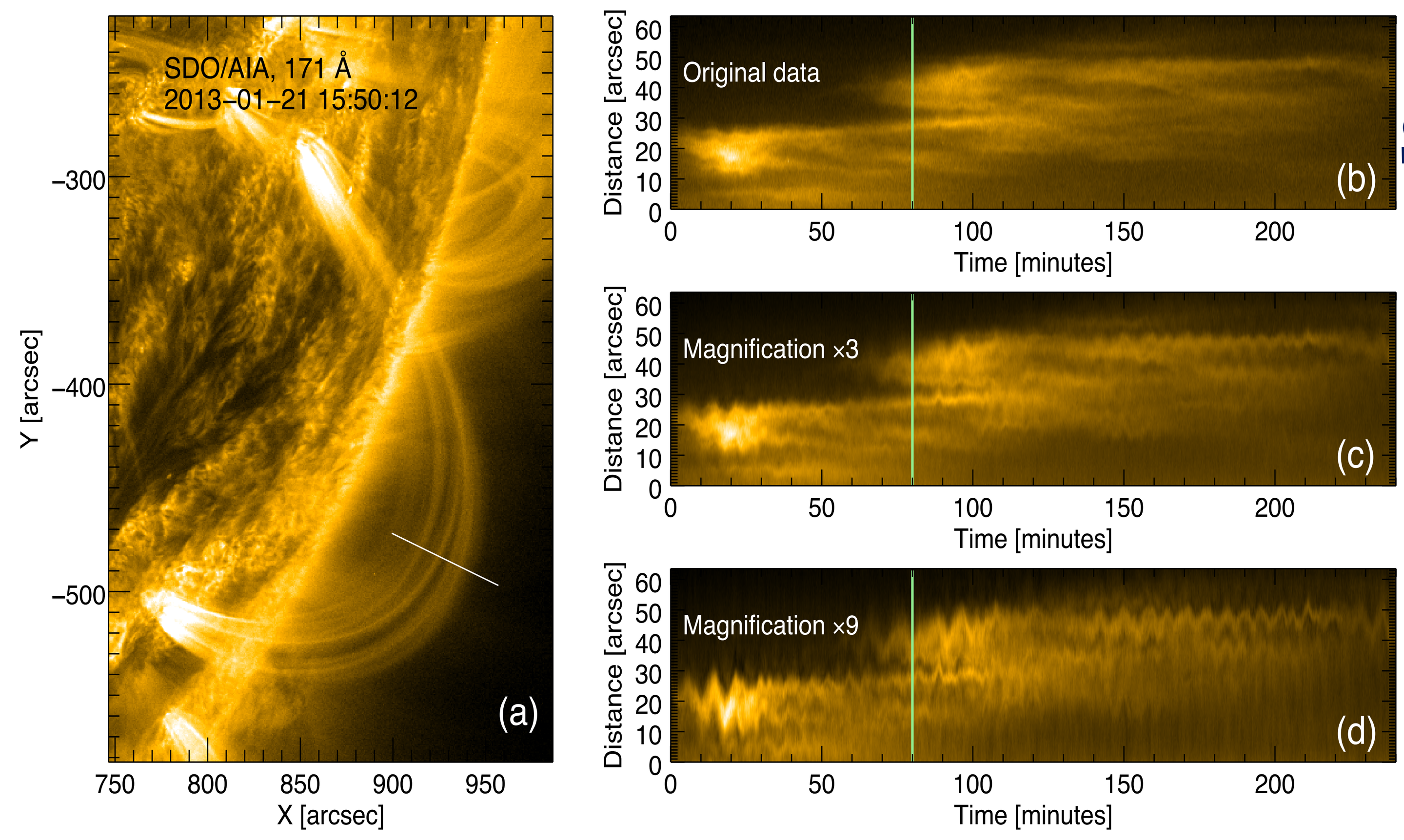
Dependence on the oscillation parameters

Panel (a) shows the dependence of the magnified oscillation amplitude upon the input amplitude for the magnification factors k = 5 and k = 10.
Panel (b) shows the dependence of the magnified amplitude upon the original oscillation period. The vertical dotted line indicates the size of the smoothing time window w that was set to 30 time frames. The solid lines in both plots indicate expected ideal dependences.
The algorithm was found to give linear scaling of the magnified amplitude with the original amplitude for a broad range of small original amplitudes. Also, the magnification is independent of the oscillation period in a broad range of the periods.



Testing on SDO/AIA data

The developed method was tested on the SDO/AIA 171 Å observations of a coronal loop bundle previously analysed by Nistico, Anfinogentov, and Nakariakov [3]. This set of coronal loops was observed by SDO/AIA on the south-western limb of the Sun on 21 January 2013 and was not associated with any NOAA active region.
In the original time-distance plot, the low amplitude oscillations could only be noticed by an experienced eye knowing where and when to look at. But, even a small motion magnification by a factor of 3 makes the oscillatory patterns visible to everyone without difficulty. Larger magnification (×9) allows one to investigate oscillatory profiles in detail, revealing possible amplitude evolution and coexistence of multiple harmonics.



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Refernces

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2. Selesnick, I.W., Baraniuk, R.G., Kingsbury, N.C., 2005, IEEE Signal Processing Magazine 22, 123.
3. *Nistico, G., Annogentov, S., Nakariakov, V.M., 2014, Astron. Astrophys. 570, A84.*

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