Motion magnification technique in coronal seismology

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Outline

The talk is based on the paper

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WAVES IN THE SOLAR CORONA

Motion Magnification in Coronal Seismology

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Abstract We introduce a new method for the investigation of low-amplitude transverse oscillations of solar plasma non-uniformities, such as coronal loops, individual strands in coronal arcades, jets, prominence fibrils, polar plumes, and other contrast features that have been observed with imaging instruments. The method is based on the two-dimensional dual-tree complex wavelet transform (DTℂWT). It allows us to magnify transverse, in the plane-of-the-sky, quasi-periodic motions of contrast features in image sequences. The tests performed on the artificial data cubes that imitated exponentially decaying, multi-periodic and frequency-modulated kink oscillations of coronal loops showed the effectiveness, reliability, and robustness of this technique. The algorithm was found to give linear scaling of the magnified amplitudes with the original amplitudes, provided these are sufficiently small. In addition, the magnification is independent of the oscillation period in a broad range of the periods. The application of this technique to SDO/AIA EUV data cubes of a non-flaring active region allowed for the improved detection of low-amplitude decay-less oscillations in the majority of loops.

Motivation

Decayless oscillations are the perfect tool for the coronal seismology:

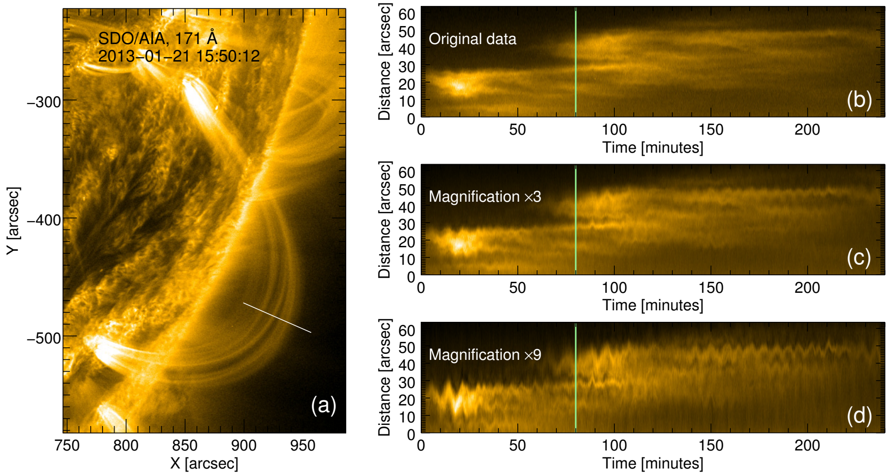
- Seismologically sensitive (standing kink waves)
- They are everywhere (occur in any active region)

Small amplitude is a big problem

Motion magnification is a microscope for small movements

Application to SDO/AIA data

Application to SDO/AIA data

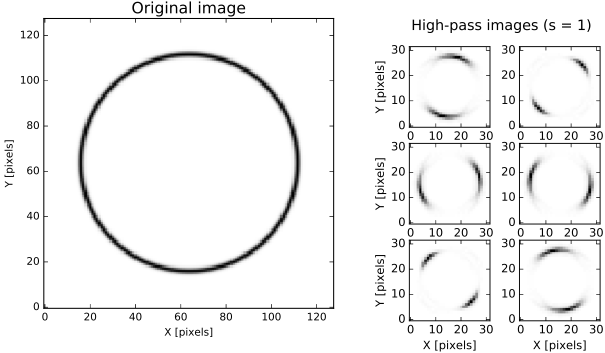


How does it work?

2D Dual Tree Complex Wavelet transform (DT$\mathbb{C}$WT)[1]s of all images.

$$I \Rightarrow H_{s=0}, H_{s=1}, \cdots, H_{s=n} \ and \ L$$

I – Image, H_s – High pass image of scale s, L – low pass image.



[1](Selesnick, Baraniuk, and Kingsbury, 2005)

How does it work?

The algorithm

Input: a sequence of 2D images (data cube).

- Compute 2D DT$\mathbb{C}$WT[2]s of all images.
- Extract the phase of DT$\mathbb{C}$WT components
- Compute the Phase trend: $\Phi_{\mathrm{trend}} = \mathit{Convolve}(\Phi, \mathit{smoothing\_window}(w))$
- Amplify phase variations : $\Phi_{\mathrm{ampl}} = \Phi_{\mathrm{trend}} + k(\Phi - \Phi_{\mathrm{trend}})$
- Reconstruct output images using inverse DT$\mathbb{C}$WT

Output: data cube with magnified motions.

Parameters:

- Magnification coefficient(k)
- smoothing window width (w)

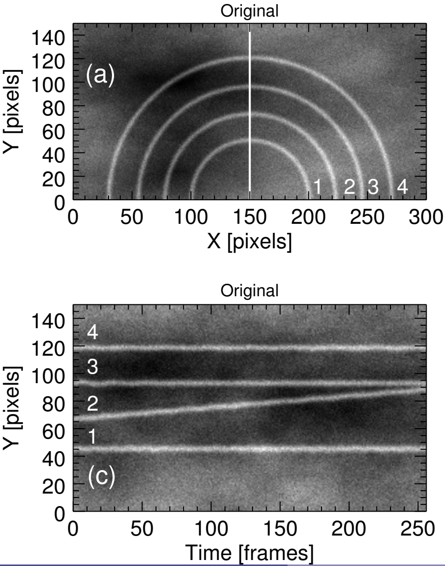
[2]Dual tree complex wavelet transform (Selesnick, Baraniuk, and Kingsbury, 2005)

Testing on a model

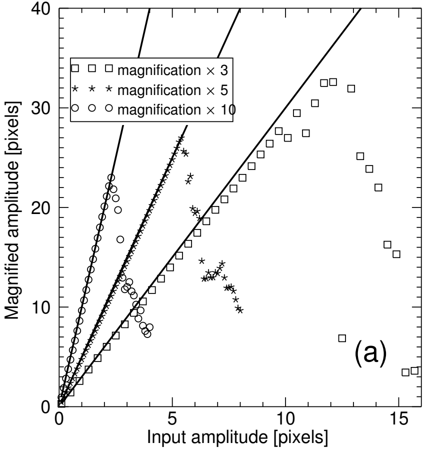
Video (magnification x10)

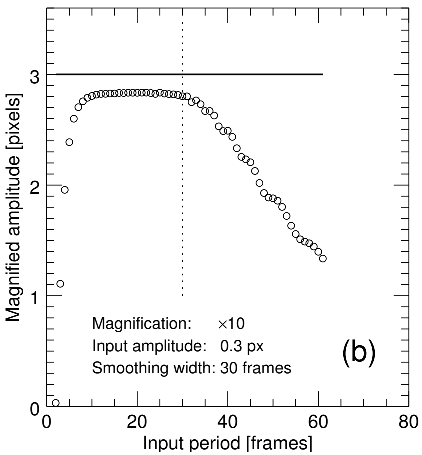
Testing on a model

Time-distance plots

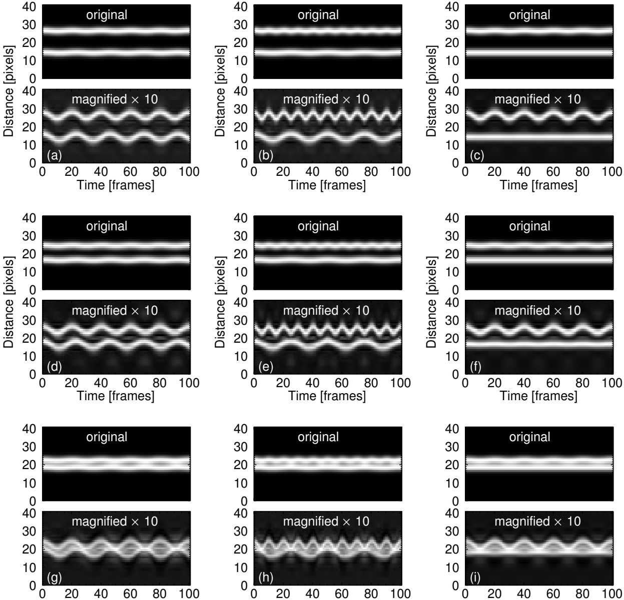


Dependence upon the oscillation parameters





Resolving different periodicities



Summary

- Motion magnification is a promising tool for the coronal seismology
- It can significantly simplify the detection and analysis of low-amplitude transverse oscillations.
- Low-amplitude oscillations become visible on movies and time-distance plots
- Magnified oscillation amplitude linearly depends on the original one
- Correct magnification of multi-modal or modulated oscillations
- Ability to resolve different periodicities in the neighbouring structures
- Possible applications beyond the coronal seismology

Want it?

Want it?

The code is in open access and available at
https://github.com/Sergey-Anfinogentov/motion_magnification

Dependencies:

- Python 3
- NumPy and SciPy
- DTCWT library https://github.com/rjw57/dtcwt

Python

result = magnify_motions_2d(input_data, k , width)

IDL

result = magnify_2d(input_data, k, width)

Thank you for your attention!

References

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