MHD waves in chromospheric fibrillar structures as observed with ALMA

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Goal and motivation

Waves and oscillations have been shown to be a primary means of transporting energy through the solar atmosphere, thus, contributing to the high temperature of the upper layers. In particular, magnetohydrodynamic (MHD) waves are observed in a number of structures in the solar chromosphere, often with observations in the near-ultraviolet (UV) to infrared wavelength range.

In this poster, we present our recent work on identification of MHD wave modes in a number of fibrillar structures using high-temporal resolution observations with the Atacama Large Millimeter Array (ALMA).

Observations

date	project id	band	Cad. (s)	obs. time (UTC)	μ	T_{mean} (K)
2017-04-22	2016.1.00050.S	6	2	15:59:07–16:43:26	0.92	7746 ± 859

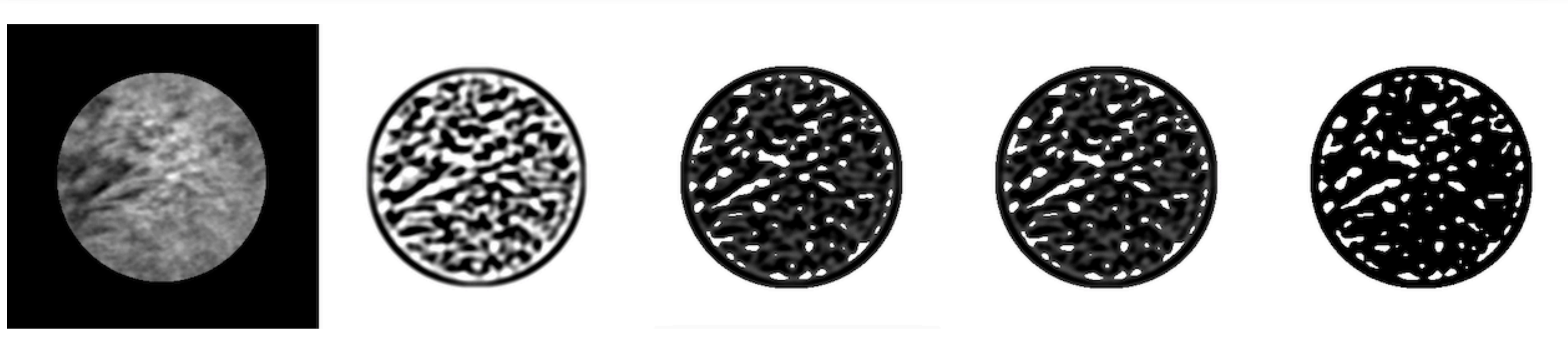


Fig. 1. Steps of image processing of ALMA Band 6 data. An unsharp mask algorithm and an adaptive histogram equalization procedure are used to identify and track long-lasting dark fibrils.

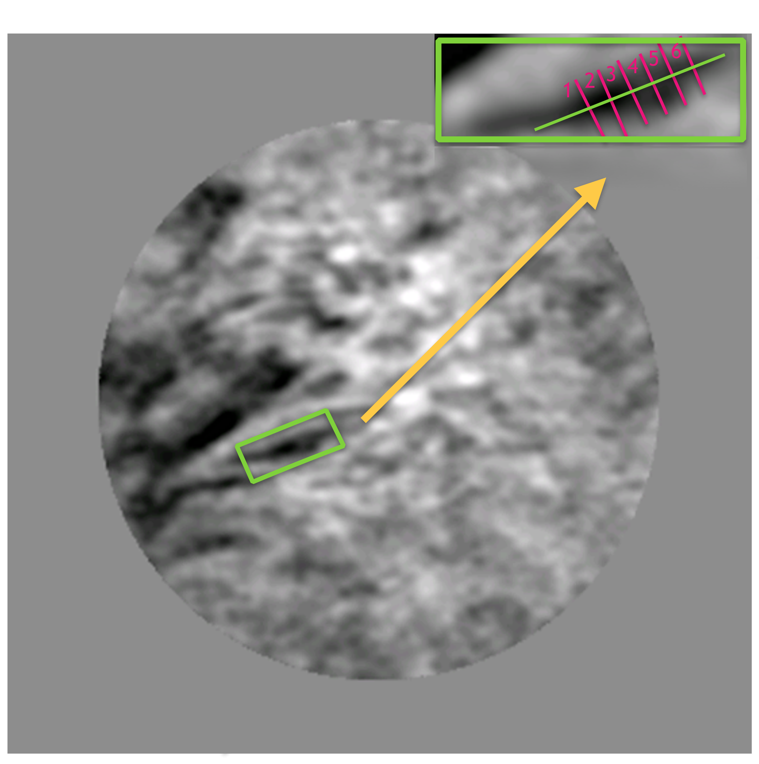


Fig. 2. Selected dark fibril that lasts during the entire observing time whose oscillations are studied along six cuts perpendicular to its long axis (illustrated in the upper right panel).

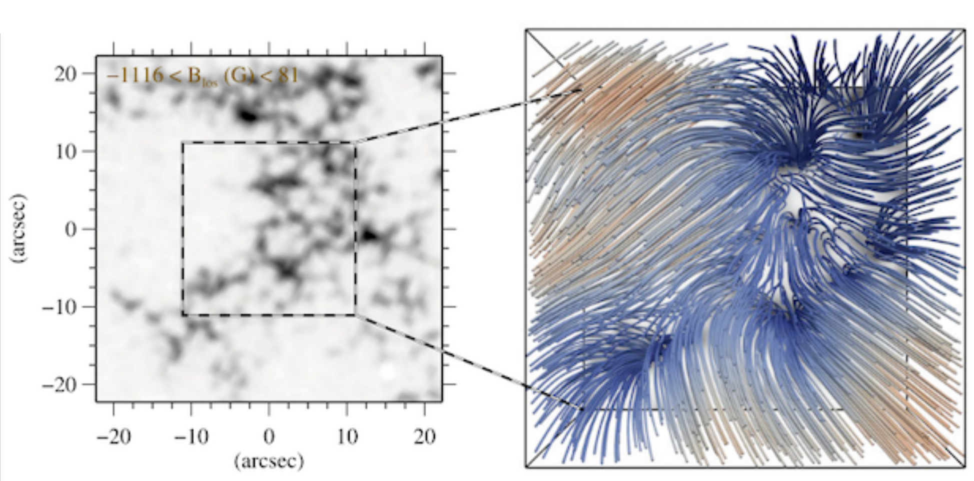


Fig. 3. Left: Line-of-sight photospheric magnetic fields (Blos) from SDO/HMI with a factor of two larger FOV than that of ALMA. The range of Blos values has been indicated in the upper left corner. The ALMA's FOV is marked with the dashed square. Right: Top view of field extrapolation of the surface magnetic field (from SDO/HMI) at the chromospheric heights(for the ALMA's FOV). The colours represent inclination, from vertical (blue) to horizontal (red). The figure is taken from Jafarzadeh et al. (2021).

Oscillations along selected artificial slits

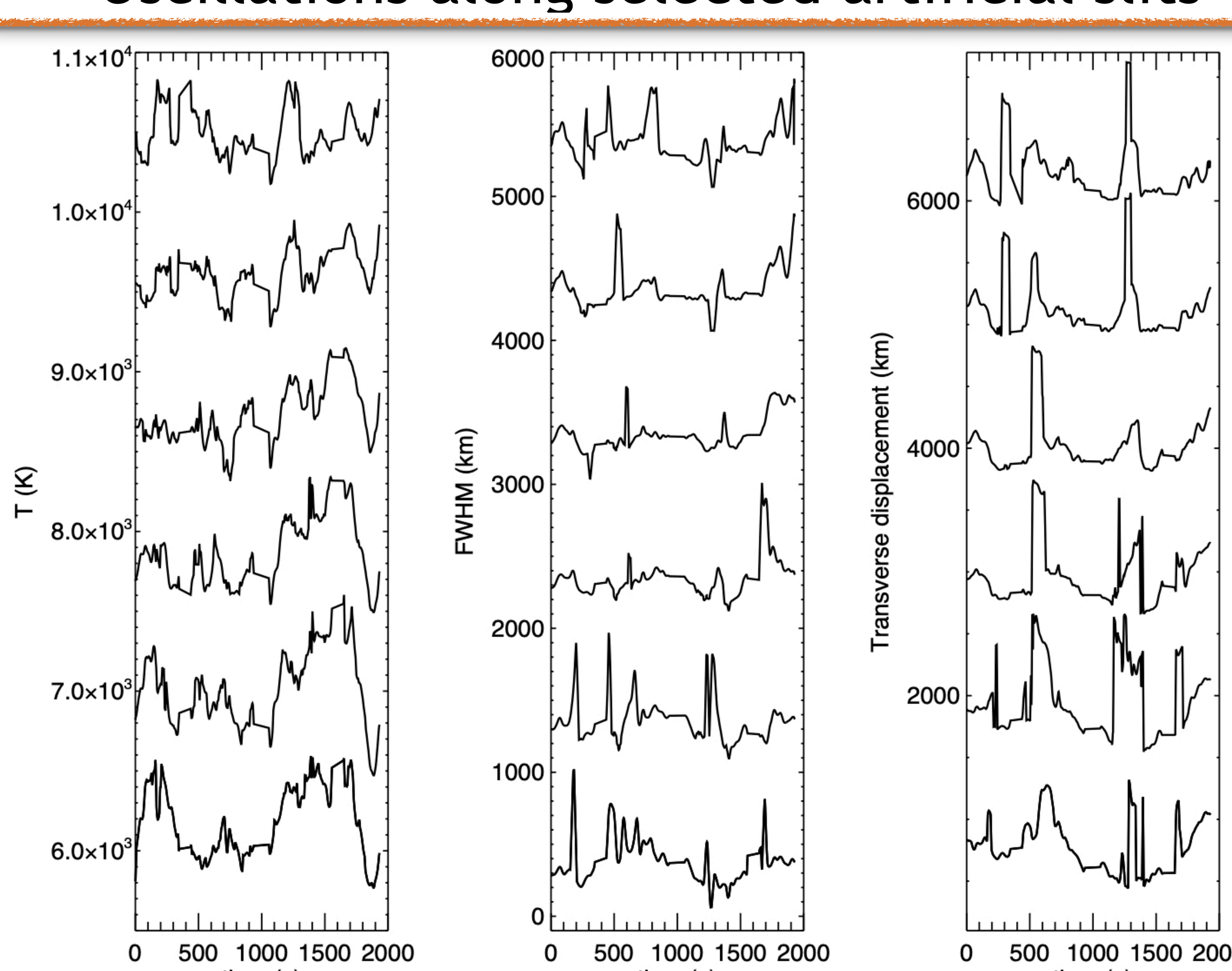


Fig4. Oscillations in brightness temperature, width, and transverse displacement along the six slits that are shown in Fig. 2 during the entire observing time from Gaussian fitting. This shows propagation of wave along the selected fibril that is shown in Fig. 2. In all three panels, the Y-axes are rescaled by ns*1000 for slits 2 to 6, where ns is the slit ID.

Wavelet Analysis

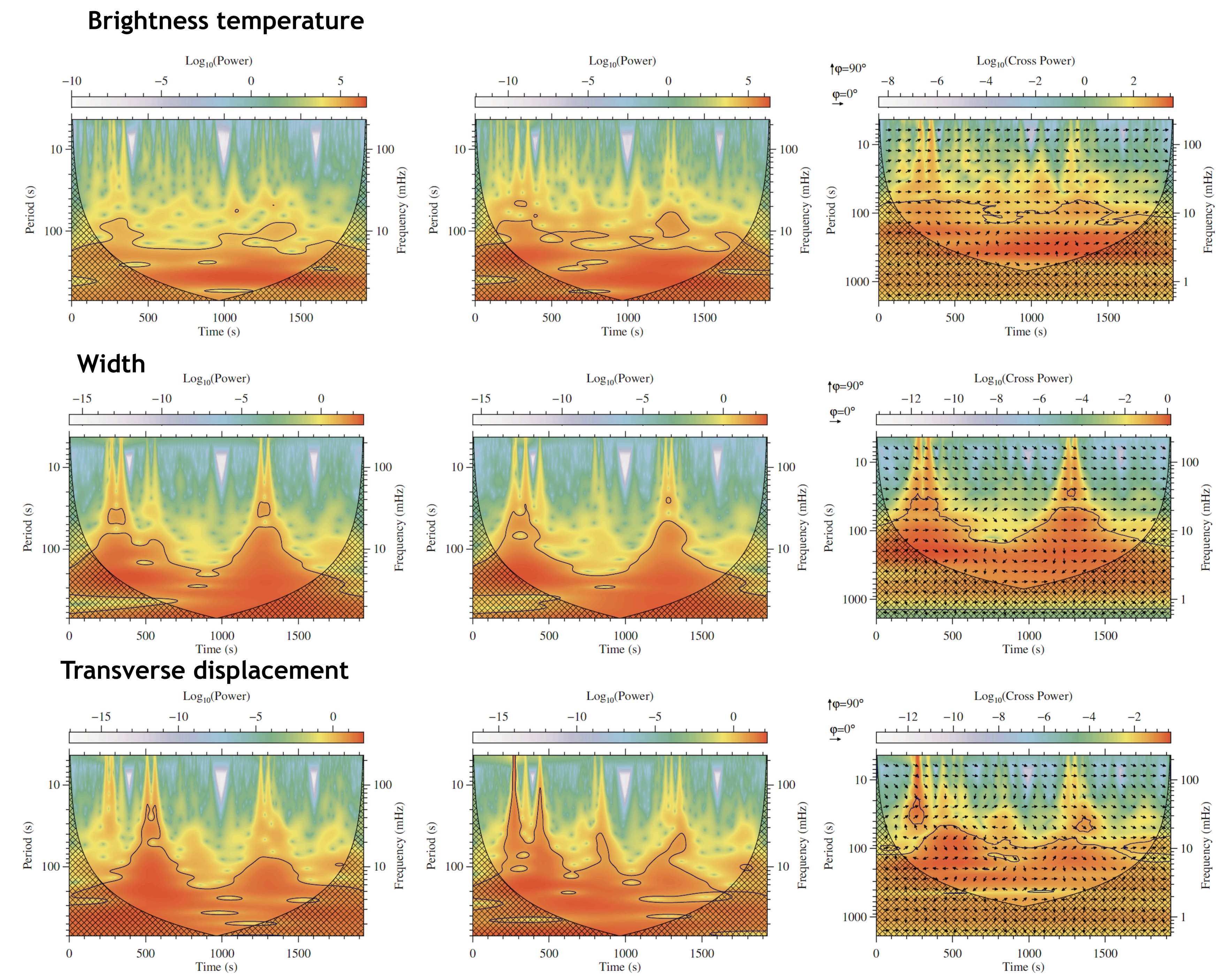
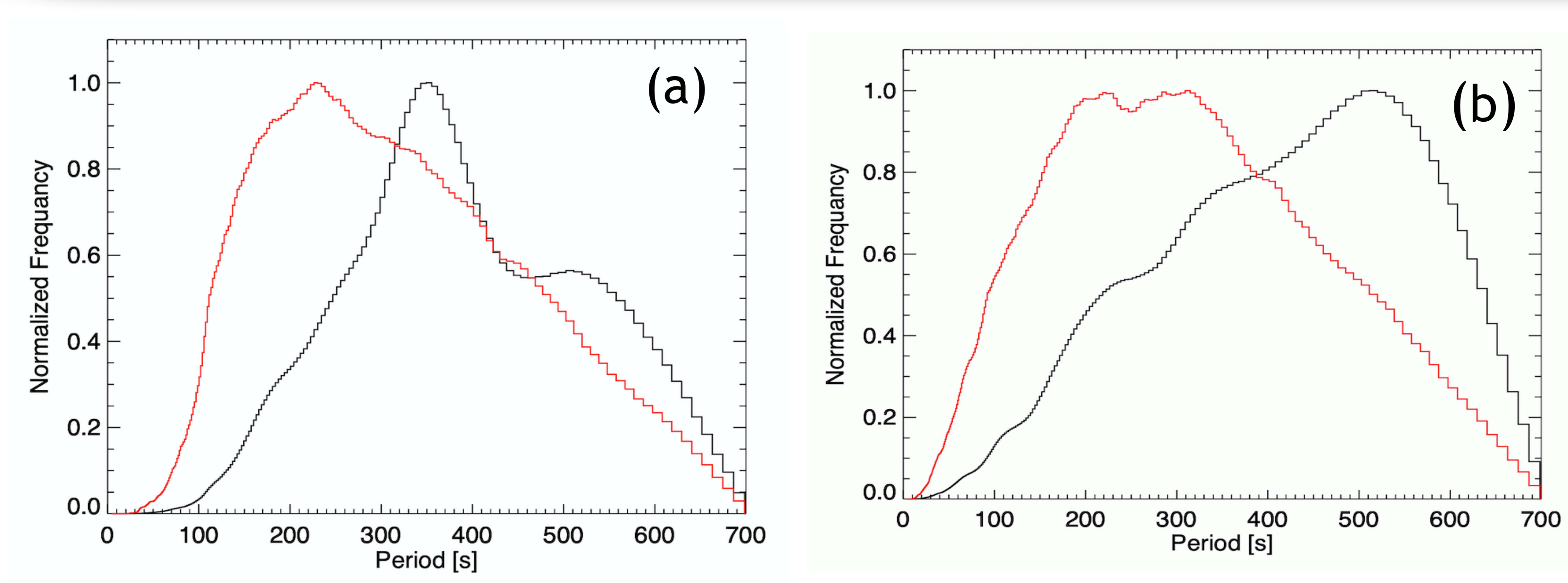


Fig. 5. Wavelet power and cross-power spectra between a pair of oscillations in brightness temperature (upper row), transverse displacement (middle row), and width (lower row), respectively. The hatched areas indicate the cone of influence. The arrows in the cross-power spectra (right columns) indicate the relative phase relationship between the pair of oscillations (with in-phase pointing right, anti-phase pointing left, and the second oscillation leading the first one by 90° pointing straight down).

Statistics



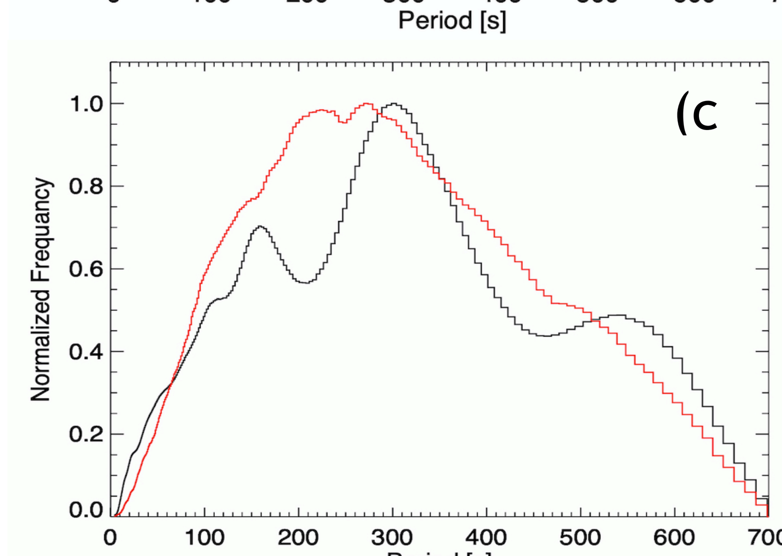


Fig. 6. Distributions of brightness temperature (panel a), transverse displacement (panel b), and width (panel c) from wavelet analysis. The black histograms corresponds to data points weighted by power and red histograms corresponds to unweighted data points. The histograms are normalized to their maximum values.

Outlook

We are planing to identify wave modes, characterize wave propagation, and estimate energy they carry in the selected fibrils by analysing correlations between oscillations of the same parameter in any two consecutive slits along the fibrils, and of the various parameters in the same slit.

References

Gafeira, R., et al. 2017a, ApJS, 229, 7; Gafeira, R., et al. 2017b, ApJS, 229, 6; Jafarzadeh, S., et al. 2017, ApJS, 229, 10; Jafarzadeh, S., et al. 2021, Phil. Trans. R. Soc. A.; Wedemeyer, S., et al. 2020, A&A, 635, A71

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