Oscillations in small-scale bright features observed with ALMA

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Abstract

Small-scale chromospheric bright features in a plage/enhanced network are identified in solar ALMA observations. The features present oscillations in brightness temperature, size and horizontal velocity. Interestingly, an anti-correlation between brightness temperature and size is also evident, suggesting that these features might be associated to fast-sausage MHD modes. A statistical analysis is carried out to quantify the oscillation periods of the three quantities and the phase angles between the perturbations in temperature and size. The values found are in agreement with periods of high frequency oscillations in other layers of the solar atmosphere.

Observation and Methods

- The ALMA Band 3 (2.8–3.3 mm) observations used here were carried out on 22nd April 2017 between 17:20 and 17:54 UTC, program **2016.1.00050.S.**
- 2 seconds cadence.
- 3 scans of ~10 minutes long each with gaps in between of about 140 seconds.
- 0.34 arcsec is the pixel size of the reconstructed time series.
- The median ALMA beam size during the observation was 2.21 arcsec × 1.70 arcsec (1607 km × 1235 km) and 54° of inclination.
- The observations are over a plage/enhance network region on the east side of NOAA AR12651.
- The photospheric magnetic field underneath the ALMA FOV during the observation oscillated in the range [-1819,961] Gauss.

For a more complete description of the observations please refers to Jafarzadeh et al. 2021 and Guevara Gómez et al. 2021

The method used to identify and trace the bright features on the data consists on identifying local maxima in each frame and taking all the pixels around with a tolerance of one standard deviation of the whole frame temperature. For a full description of an identical method for dark features refers to 10.5281/zenodo.4567443

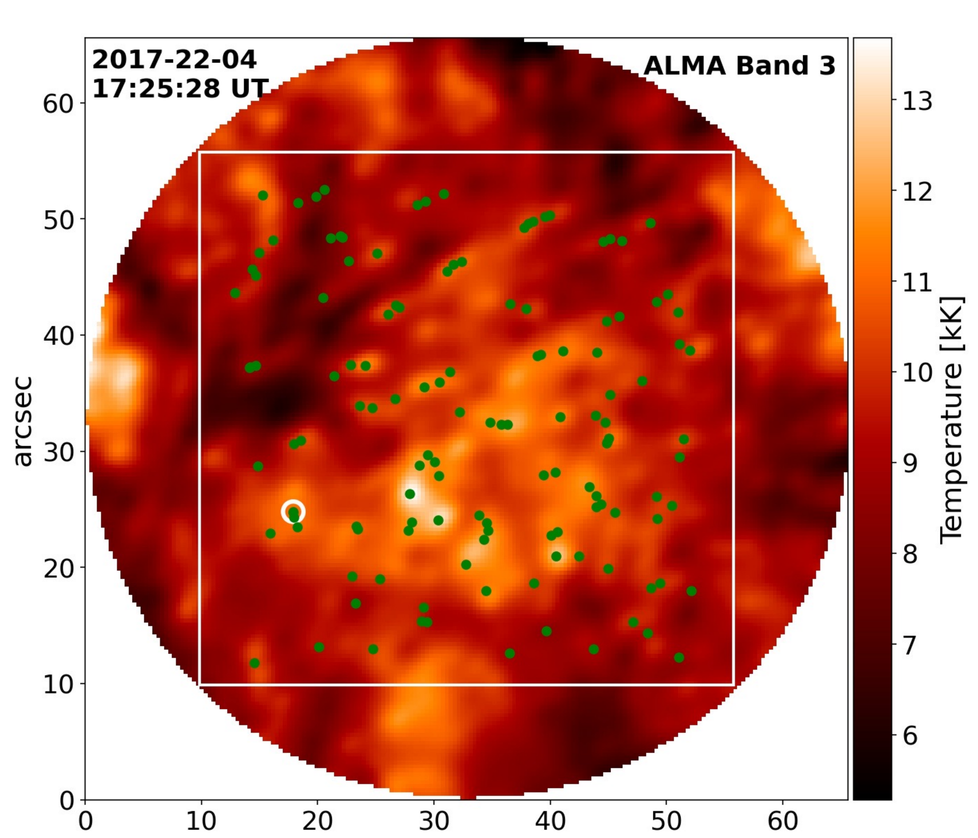

Figure 1. ALMA Band 3 image at 17:25:28 UT. The white square delimits the area within which features were seeked. Each green dot represents the location of one of the 130 features analysed in this study. The white circle around the position (18,25) shows the location of the example feature.

Results

Figure 1 shows a single image of the observation time series to give context. The locations of the 130 bright features with lifetimes longer than 180 seconds that were identified and traced are shown as green dots. Figure 2 shows the time evolution of a particular feature for which, it is already visible that the smaller the feature is, the more intense the brightness tempearture is. This pattern is common for all the features.

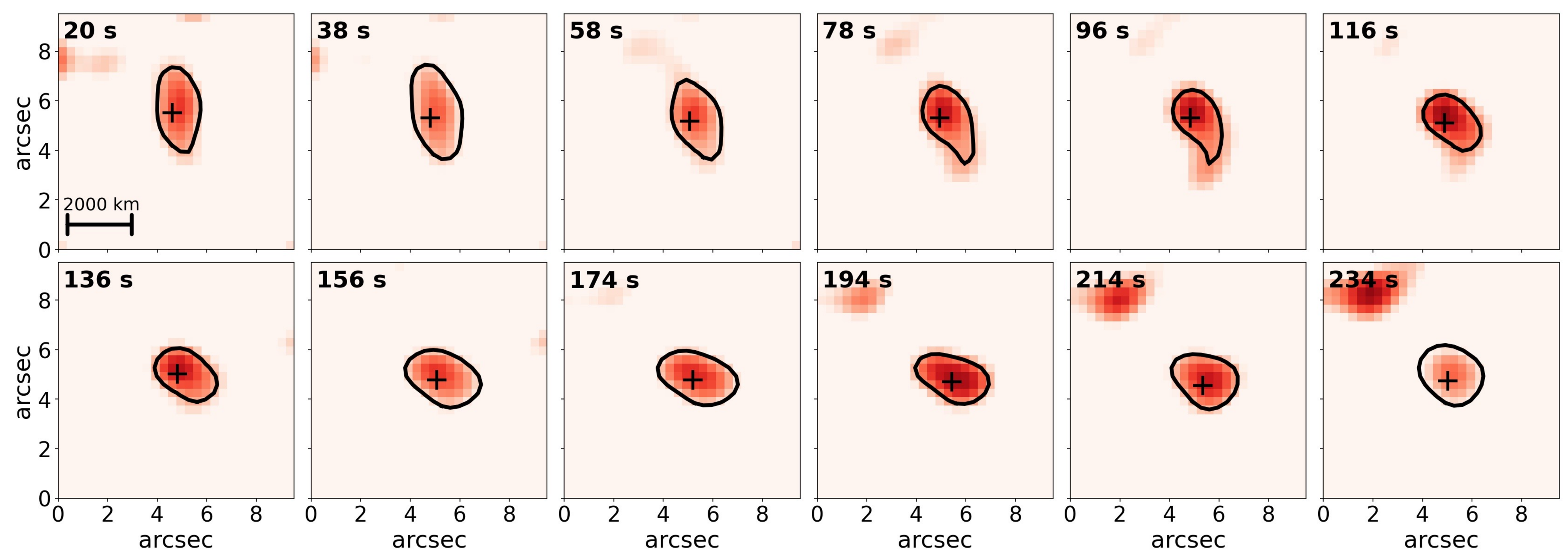

Figure 2. Close up of a feature located around (18,25) arcsec in Figure 1. For each panel: at the top left is shown the time in seconds since the feature's starting time. The black contours delimit the feature and the black crosses mark their centers of gravity. In the first panel, a scale bar in kilometers is depicted. Color scale is equal for all the panels.

A typical manifestation of MHD modes on solar observations comes in the way of bright features whose sizes and intensities change with time, as well as their locations. In particular, if the feature shows an anti-correlation between intensity and size, it might be indicating that the oscillation is due to MHD sasuage modes propagating through the solar atmosphere (e.g. Morton et al. 2011). Figure 3 shows for the feature Figure 2, the detrended temperature time series in black and the detrended size time series in blue. The size correspond to the diameter in kilometers of a circle with an area equal to the area of the feature at that time. In this plot the anticorrelation becomes clear.

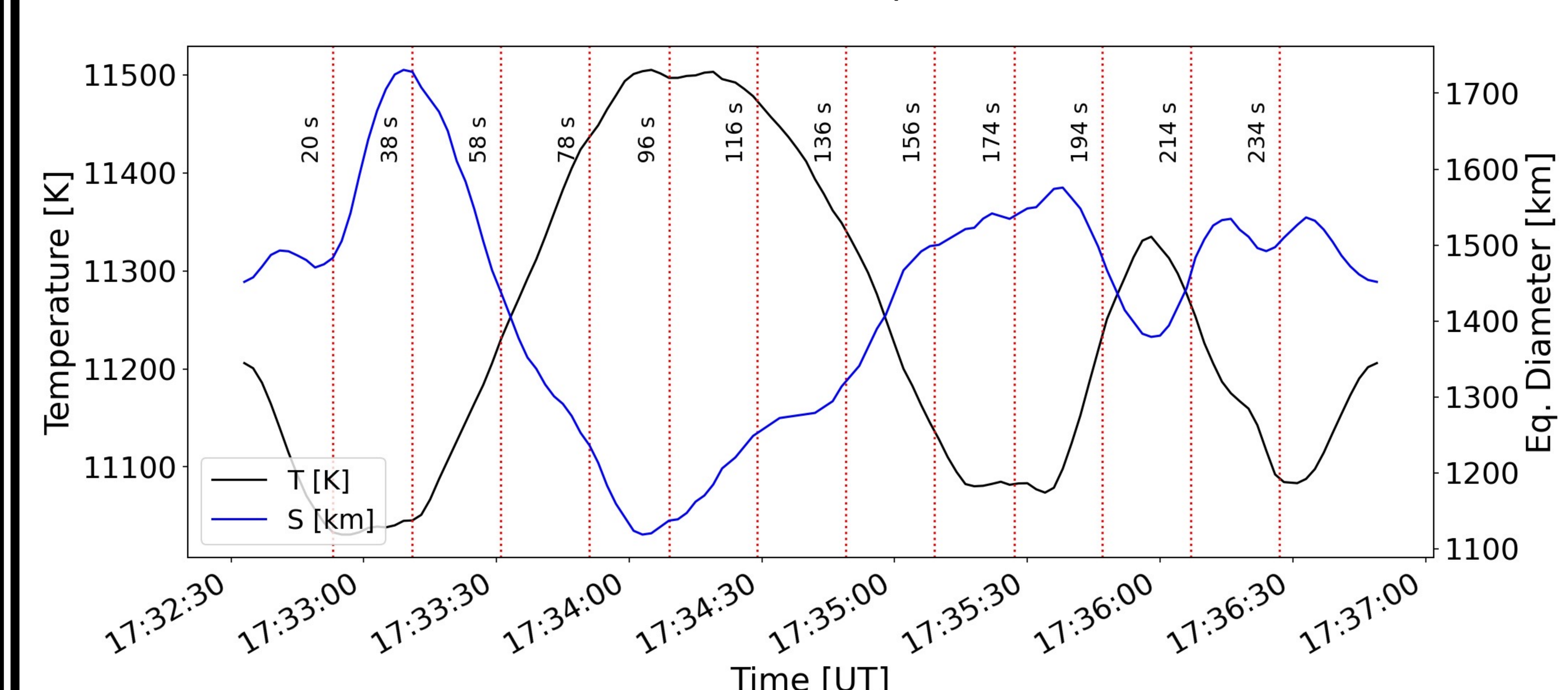

Figure 3. Fluctuations in brightness temperature (black) and size (blue) for the example feature showed in Figure 2. The vertical dotted red lines correspond to the times in the panels in Figure 2. An anti-correlation between oscillations of the two quantities is evident.

To find the the characteristic oscillation periods for each quantity, it was followed the process described in Guevara Gómez et al. 2021. In which, a continous wavelet analysis is perfomed for individual time series. The horizontal velocities for the gravity centers of the features are also computed. Table 1 summarizes the average oscillation periods as well as the average horizontal velocity.

Temperature period [s]	Size period [s]	Horizontal velocity [km/s]
90.5	80.6	7.0

Table 1. Average temperature and size oscillation periods for all the 130 features are shown in left and middle column. The average horizontal velocity of the gravity centers is shown in right column.

Results

Figure 4 shows the histogram distribution for the dominant phase angles between the time series corresponding to temperature and size for all the 130 features. To compute the phase, a cross-wavelet analysis between the two quantities for individual features were carried out. The extracted phases are those within the cone of influence of the wavelet and a confidence level of at least 95%. It is possible to appreciate that the two quantities are highly anti-correlated. This fact altogether with the found oscillation periods is an indication of **observation of fast-sausage modes at chromospheric heights.**

The statistical study of oscillations in the horizontal velocities is currently under work. It might elucidate what other kind of MHD modes are also present in the observed features.

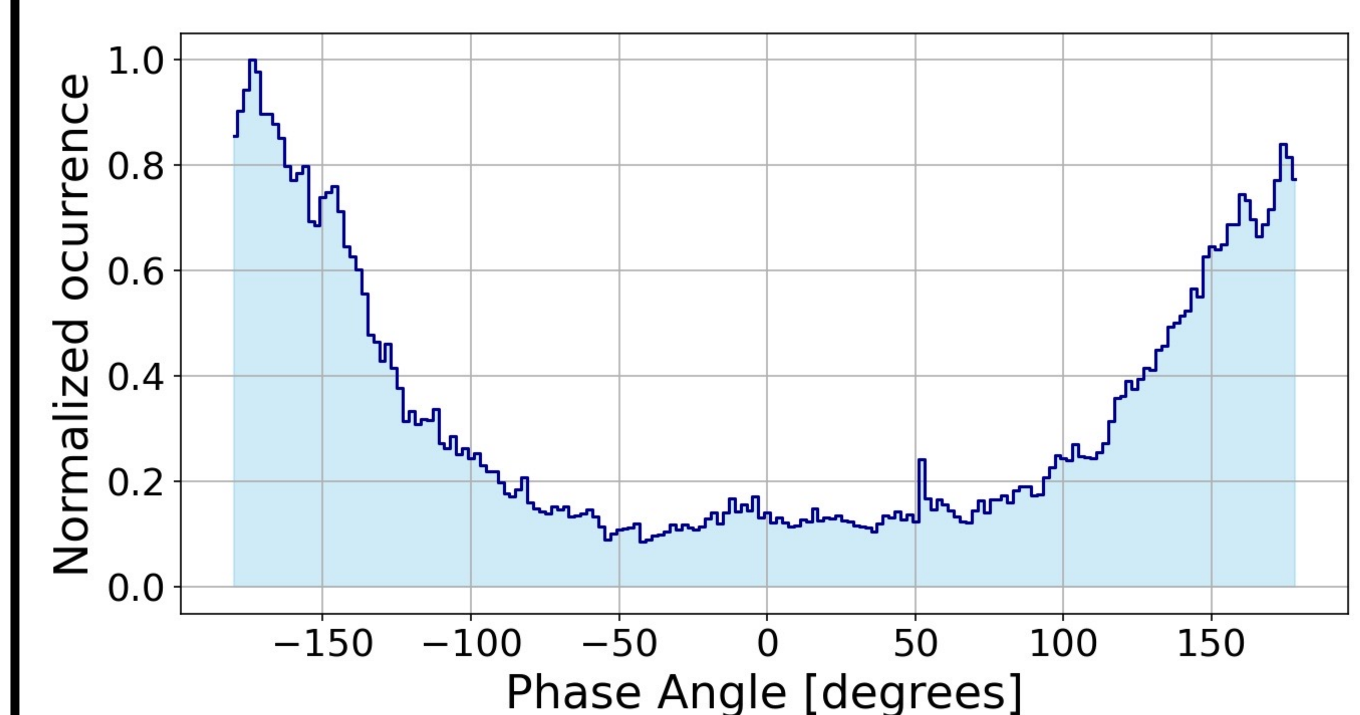

Figure 4. Histogram distribution of all the dominant phase angles between temperature and size for all the 130 features.

Discussion

130 small-scale bright features found in ALMA Band 3 data show an oscillatory behavior which suggest the observation of fast-sausage modes at chromospheric heights. It is likely that these oscillations are a mixed of different MHD modes, which is still to be proved by analyzing the oscillations in their motion. These first results look promising to estimate an energy budget in the chromosphere.

Regarding the data from Solar Orbiter, the question relies on how would it be possible to use these data together with ALMA data to study these or other kind of features.

Acknowledgments

This work is supported by the SolarALMA project, which has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement No. 682462), and by the Research Council of Norway through its Centres of Excellence scheme, project number 262622.