ALMA observations of the variability of the quiet Sun at millimeter wavelengths

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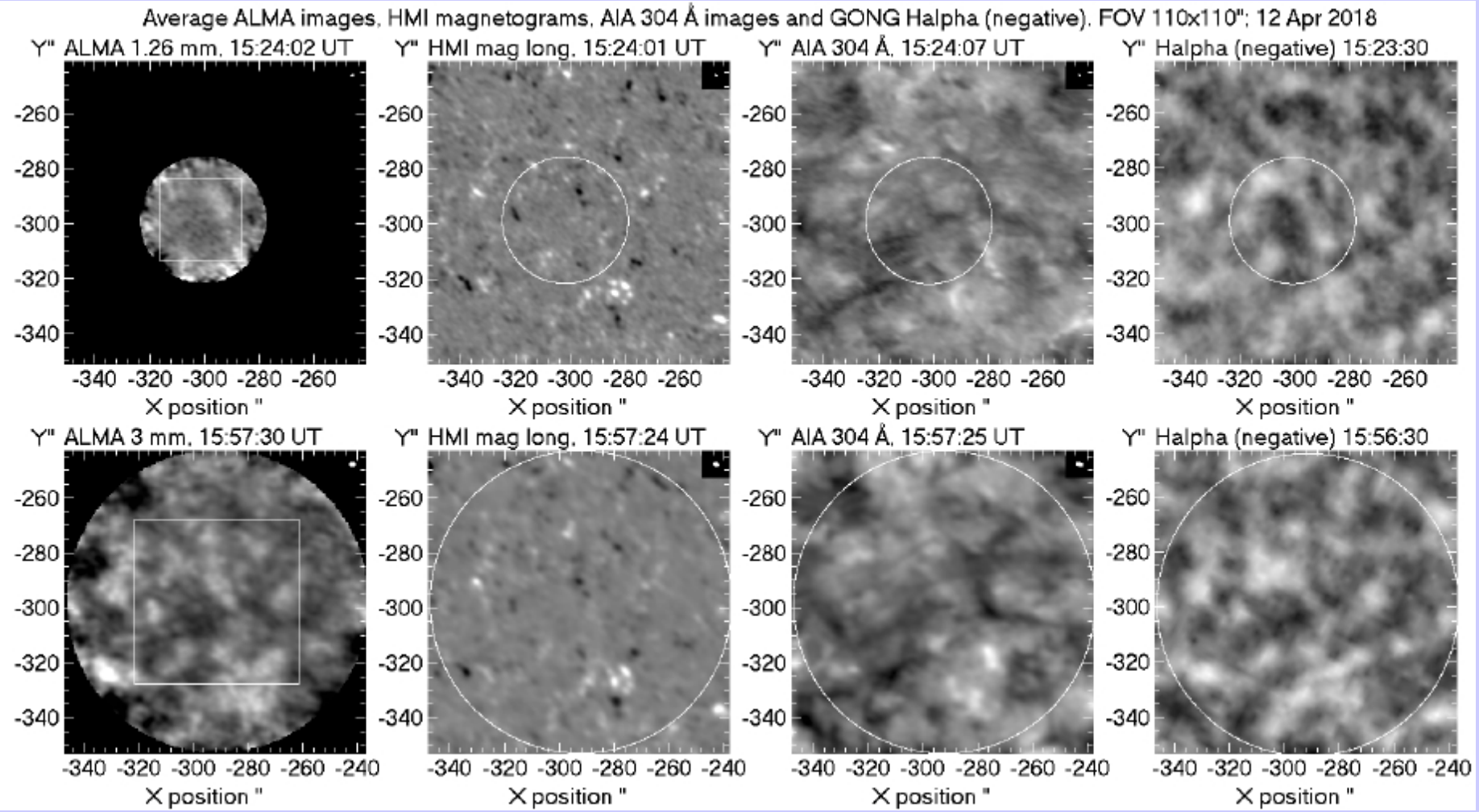
Outline

- Overall view of the observations
- Oscillations
- Transient brightenings
- Conclusions

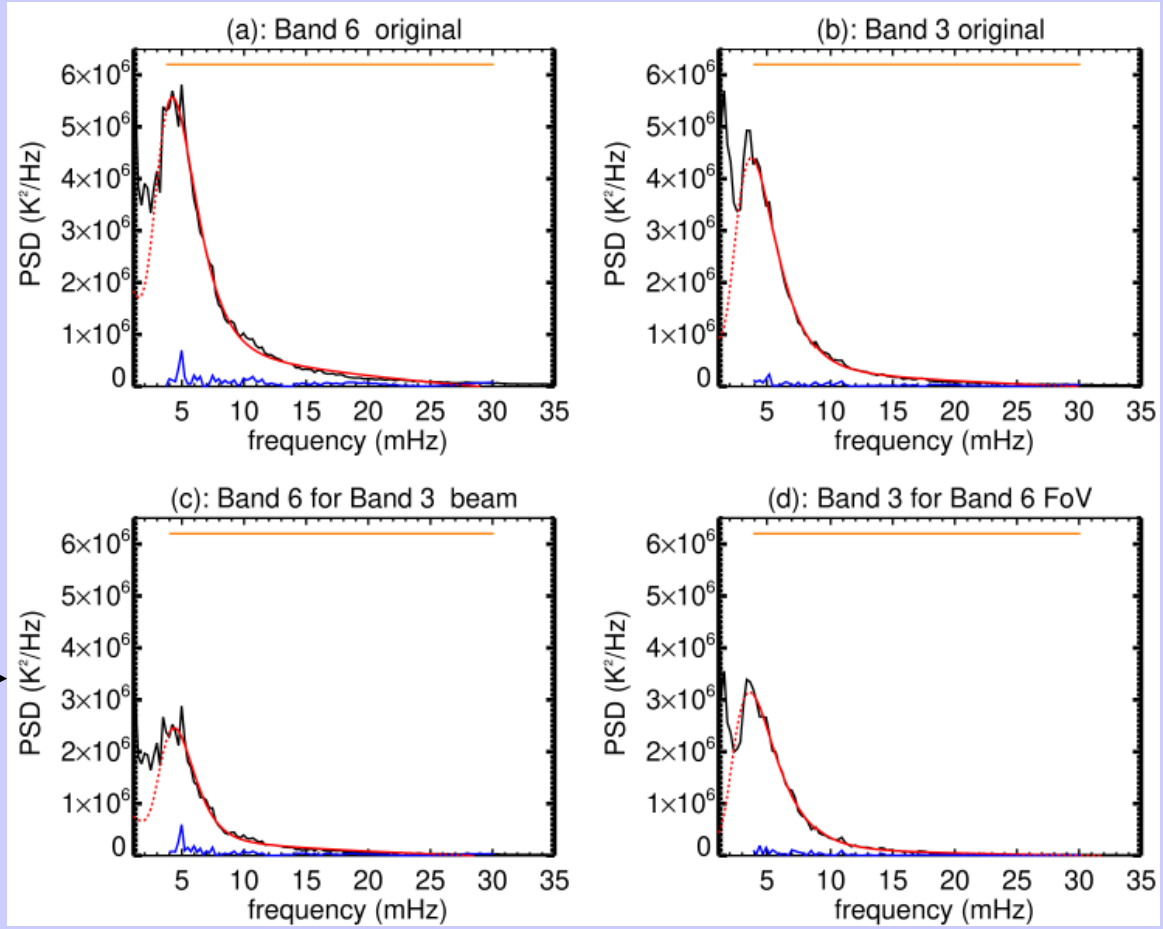
Overall view of the observations



The negative Hα images show a strong similarity to the ALMA images, at 3 mm in particular.

Analysis of oscillations

PSD from original 1 mm images



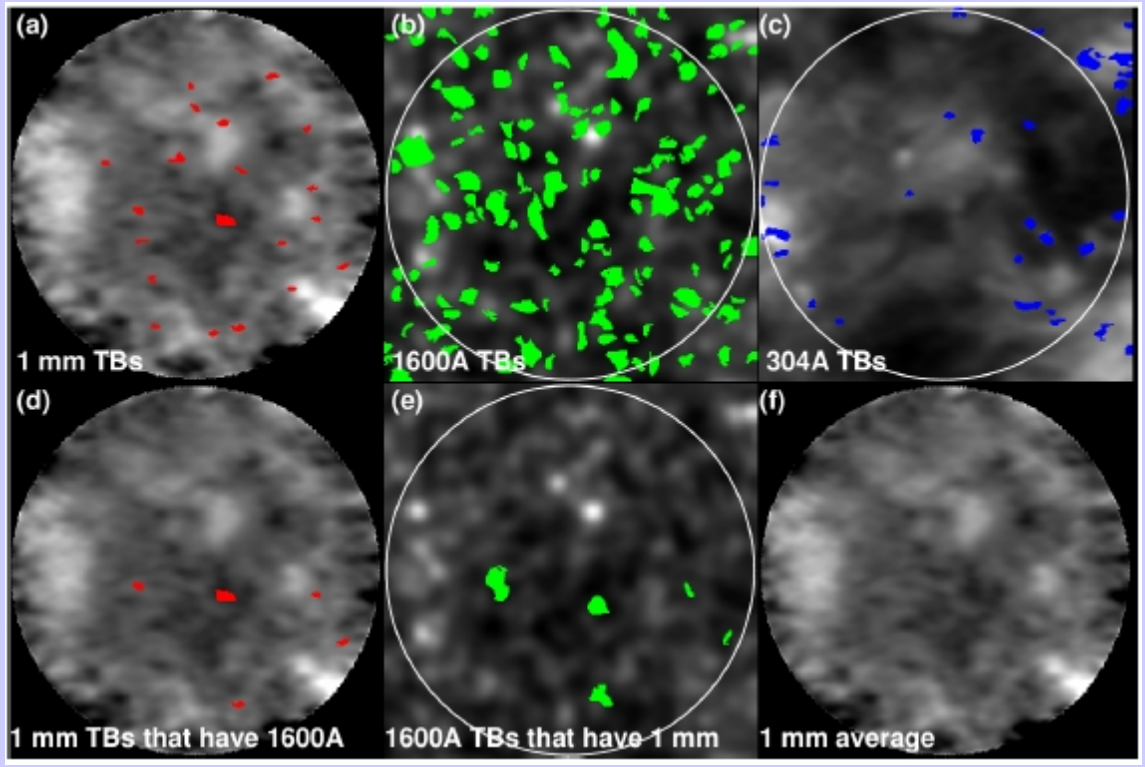
PSD from original 3 mm images

PSD from 1 mm images degraded to the resolution of the 3 mm images

PSD from 3 mm images trimmed to the FoV of the 1 mm images

- At both frequencies detection of p-mode oscillations in the range 3.6-4.4 mHz (see Patsourakos et al. 2020 for the first detection of ALMA 3-mm oscillations)
- The corrections for spatial resolution and FoV decreased the rms of the oscillations by a factor of 1.6 and 1.1, respectively
- In the corrected data sets, the oscillations at 1.26 and 3 mm showed T_b fluctuations of ~1.7-1.8% with respect to the average quiet Sun, corresponding to 137 and 107 K, respectively
- The energy density of the oscillations at 1.26 mm was 0.03 erg cm^{-3}

Detection of transient brightenings (TBs)

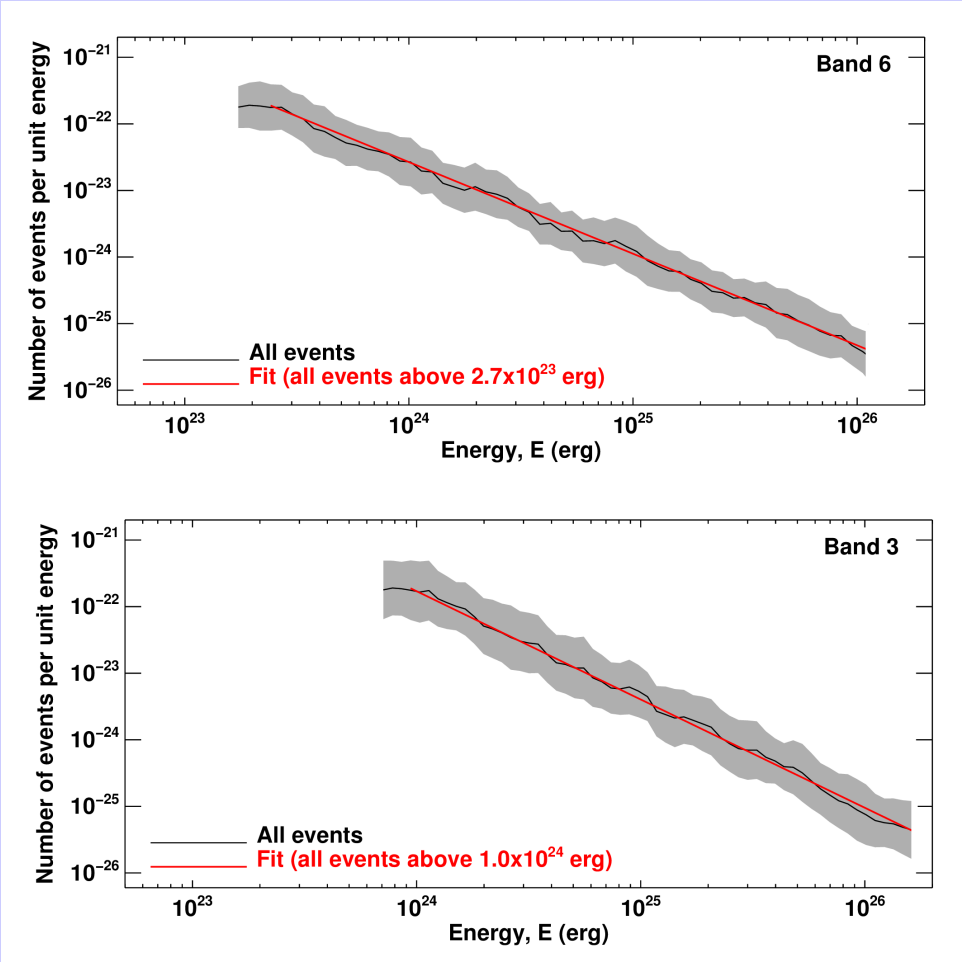


– Red: 1.26 mm TBs
– Green: 1600 Å TBs
– Blue: 304 Å TBs
– *Top row*: all events at each wavelength
– *Bottom row*: only the events that were detected both at 1.26 mm and 1600 Å (there were no 1.26 mm – 304 Å pairs)

We detected 77 TBs at 1.26mm and 115 at 3 mm (see Nindos et al. 2020 for the first survey of ALMA 3-mm TBs).

- Although their majority occurred in the cell interior, the occurrence rate per unit area of the 1.26 mm events was higher than that of the 3 mm events
- This conclusion does not change if we take into account differences in spatial resolution and noise levels.

Energetics of TBs



– Black curves: frequency distribution of the energy of the TBs detected at 1.26 mm (*top panel*) and 3 mm (*bottom panel*)
– Red curves: power-law fits

- The energy associated with the TBs ranged from 1.8 x 10^{23} to 1.1 x 10^{26} erg and from 7.2 x 10^{23} to 1.7 x 10^{26} erg for the 1.26 and 3 mm events, respectively
- The corresponding power-law indices of the energy distribution were 1.64 and 1.73
- The power per unit area of the TBs could account for less than 1% and 10% of the radiative losses in the chromosphere and corona, respectively

Conclusions

- The fluctuations associated with the p-mode oscillations represent a fraction of 0.55-0.68 of the full power spectrum.
- Their energy density at 1.26 mm is 0.03 erg cm^{-3}.
- The computed low-end energy of the 1.26 mm TBs is among the smallest ever reported, irrespective of the wavelength of the observation.
- The energy released by the TBs is not adequate to heat the chromosphere or the corona

This presentation is based on a recent paper published in A&A (Nindos et al. 2021, A&A, 652, A92)