Towards Lucky Imaging for Quiet-Time Low-Frequency Radio Solar Observations

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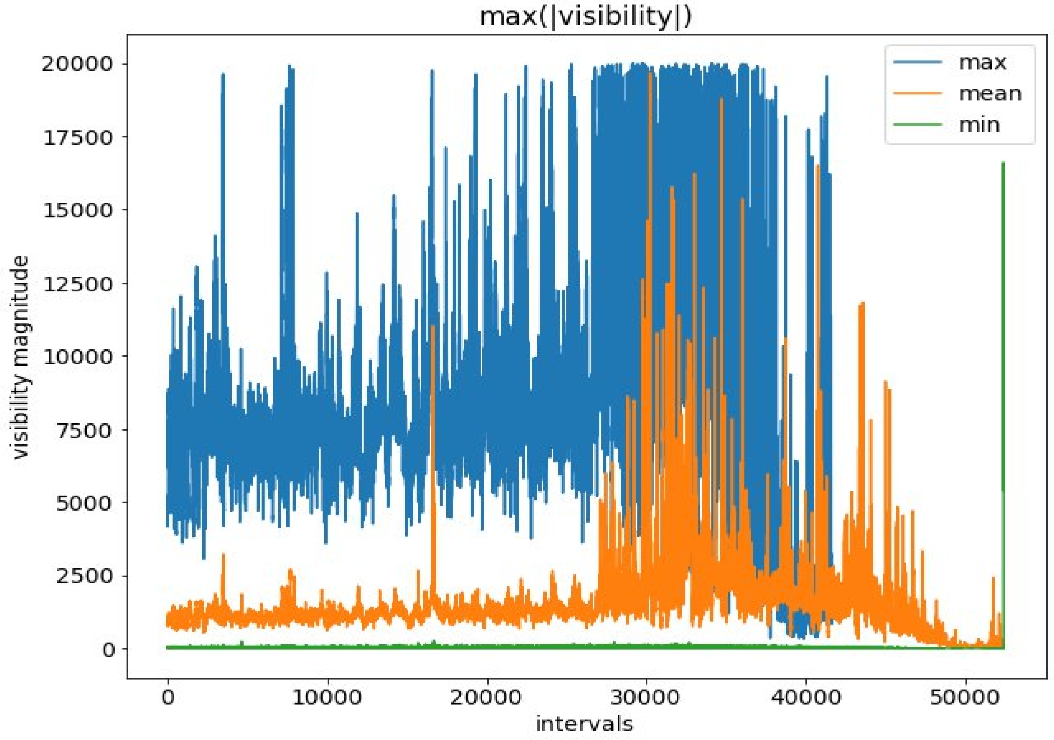
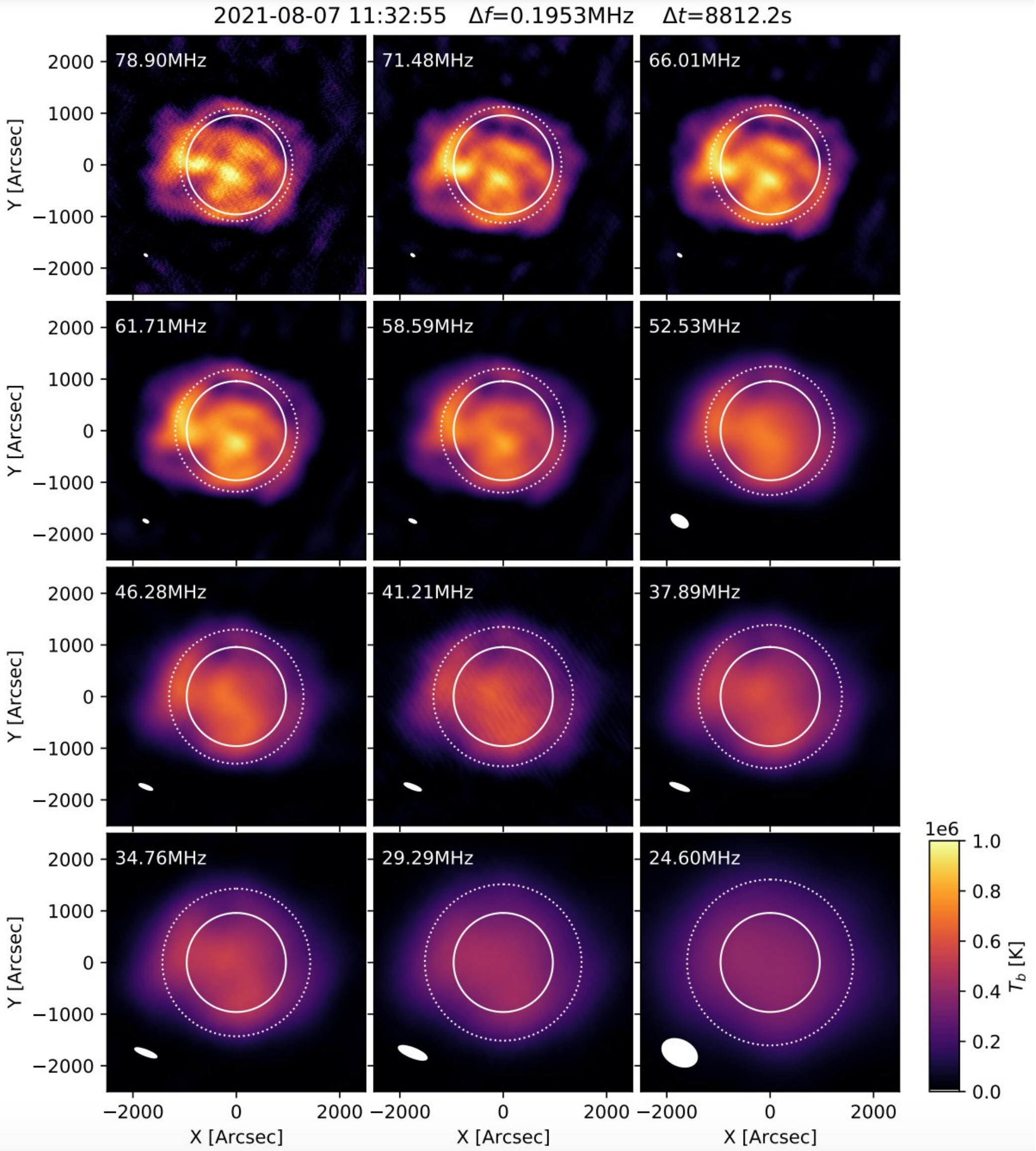
Introduction

- Low-frequency interferometric radio imaging observations (20-250 MHz) of the quiet Sun important for understanding corona
- Also important for studying the young solar wind and dim non-burst activity too dim to be observed in spectral data.
- Such observations rarely reported in the literature, because of
  - relative scarcity of observations;
  - difficulty to obtain high quality processed images.
- Daytime ionosphere severely impacts imaging observations and reduces quality, especially when imaging extended corona.
- To mitigate the effects of the ionosphere, exploring machine learning techniques to enable automated snapshot lucky imaging.
- We outline our approach for using ML to select images of sufficient quality, and present initial results.

Methodology - Data

- LOFAR solar data for 4 hours of quiet-time observations on 08/04/2017 were calibrated (baseline visibility phases and amplitudes) using standard LOFAR software DP3;
- Result is a Measurement Set (see tutorial on MS here: https://www.youtube.com/watch?v=lwgleKRqfws)
- 253 baselines and 50k+ samples (~4 hours at 0.25s per sample)
- Extract baseline visibility magnitudes:

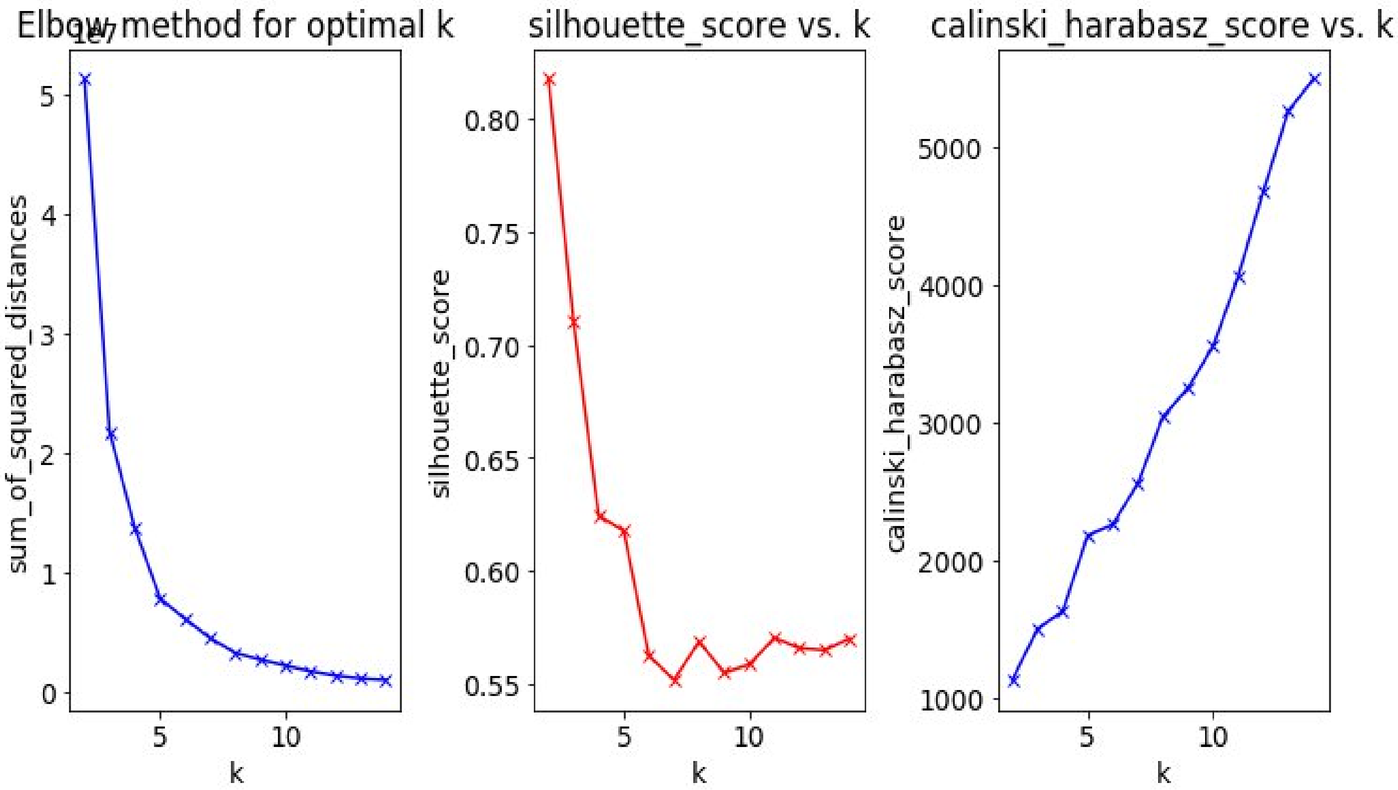


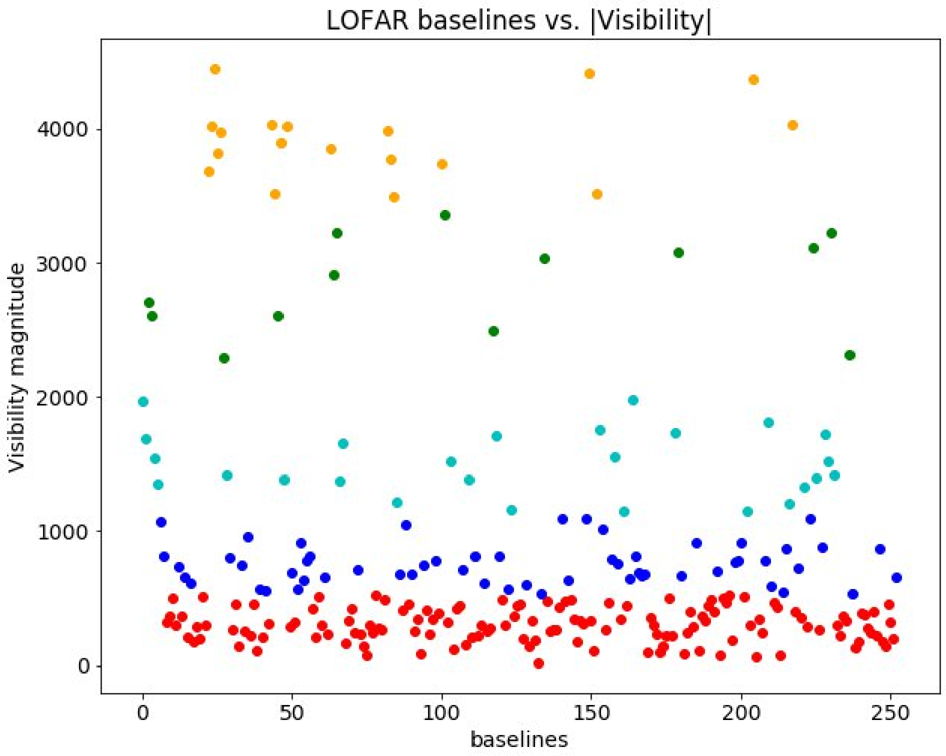


Low-frequency solar imaging observations with LOFAR (Zhang et al., under review)

Methodology - K-Means Clustering

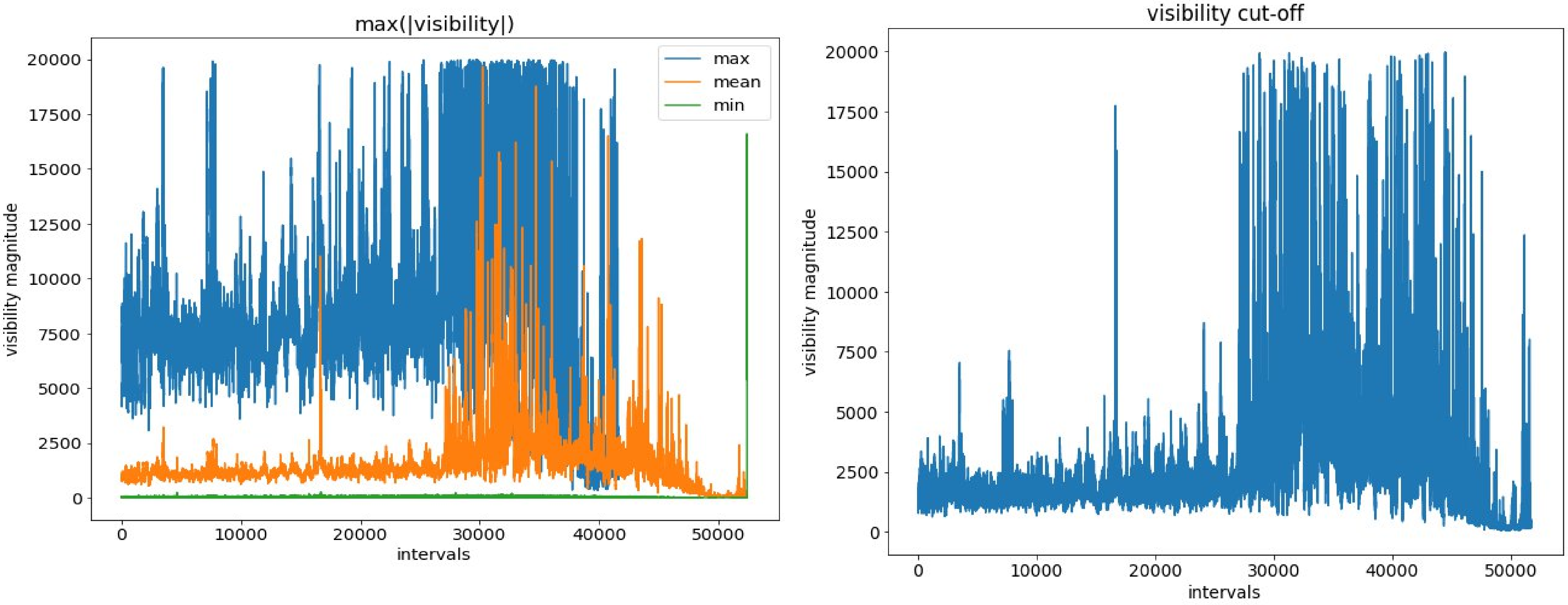
– Extremely high visibility magnitudes are taken as a sign of corrupted observations (due to bad calibration, ionospheric interference, etc.)
– To remove such baselines, perform K-Means clustering of the visibility amplitudes for each observing interval/sample of duration 0.25 seconds in the solar measurement set.
– The clustering provides self-consistently limiting value of the visibility magnitude.
– We evaluate the K-parameter, reaching a conclusion that 5 is optimal.
– The selection: the maximum visibility magnitude in the second cluster for each interval/sample.





K-Means Clustering - Results

– Clustering reduces significantly the maximum visibility magnitudes (right plot)
– All baseline points below cut-off are flagged to not use.
– This is done sequentially for all intervals (57520 in our observing dataset).
– Finally, interferometric imaging (CLEANing) is performed on the flagged data.



PRELIMINARY RESULTS

- Original images (pre-flagging, left) are compared with the flagged version (right).

- Conclusion: We find a visible improvement of the appearance of the solar signal, especially spatial resolution due to reduced smearing of signal.

- Next steps:
  - Apply technique to snapshot imaging;
  - Apply quality filters also in image domain;
  - Combine images for ‘Lucky Imaging’ of faint emission.