The Era of Multi-Messenger Solar Physics
Proceedings IAU Symposium No. 372, 2023
G. Cauzzi & A. Tritschler, eds.
doi:10.1017/S1743921322005099

Understanding Weak Impulsive Narrowband Quiet Sun Emissions (WINQSEs)

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Abstract. The confluence of data from the Murchison Widefield Array and an imaging pipeline tailored for spectroscopic snapshot images of the Sun at low radio frequencies have led to enormous improvements in the imaging quality of the Sun. These developments have lowered the detection thresholds by up to two orders of magnitude as compared to earlier studies, and have enabled the discovery of Weak Impulsive Narrowband Quiet Sun Emissions (WINQSEs). Their spatial distribution and various other properties are consistent with being the radio signatures of coronal nanoflares hypothesized by Parker (1988) to explain coronal heating in the quiet Sun emissions. We present the status of the multiple projects we have been pursuing to improve the detection and characterisation of WINQSEs, ranging from looking for them in multiple independent datasets using independent detection techniques to looking for their counter parts to estimate the energy associated with them and understanding their morphologies.

Keywords. Sun: corona, Sun: radio radiation

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1. Introduction

The search for observational signatures of Parker's nanoflares, hypothesised to explain coronal heating, has usually focussed on detecting their thermal signatures in the EUV and X-ray bands. A convincing detection of nanoflares satisfying the requirements for coronal heating is yet to come by. The electron beams generated by these nanoflares are also expected to give rise to metrewave radio emission, though their detection had remained beyond the reach of most exist instrumentation. Recently, using data from the Murchison Widefield Array (MWA) (Tingay et al. 2013) and a highly optimised solar radio interferometric imaging pipeline (AIRCARS; Mondal et al. 2019), Mondal et al. (2020) presented the first detection of Weak Impulsive Narrowband Quiet Sun Emissions (WINQSEs). Their typical flux densities lie in the range of a few mSFU (1 SFU = 10,000 Jy) and they are found to occur in large numbers all over the Sun, including the quiet regions. In the solar radio images, they appear as compact sources and our estimate of their median duration is limited by the instrumental resolution of 0.5 s. These could potentially be the radio counterparts of these nanoflares. This work summarise the results and status from the follow up studies of WINQSEs.

2. Results, Conclusions and Future Directions

Given the implications of the discovery of WINQSEs and the challenges involved in detection of weak, transient, narrowband emissions, it is important to first put their detection on a firm footing. We have done so by establishing their presence in data taken during a period of exceptionally low solar activity alongside improving the imaging quality and detection methodology (Mondal et al. 2022, submitted). Apart from establishing their ubiquity and everpresence even during the very quiet solar data, it also helps better understand the distribution of WQINSEs. To further bolster the confidence in WINQSEs detection, we have used yet another dataset and an independent analysis procedure and software pipeline for their detection. Sharma et al. (2022) have detected WINQSEs in images made using the so called *residual visibilities* and their results are consistent with the other detections of WINQSEs. This work goes beyond earlier attempts as it also provides morphological information about the WINQSEs. From the coronal heating presepctive, the primary quantity of interest is the energy deposited in the corona. It is, however, very hard to derive this quantity from the radio observations, while this is routinely done using differential emission measure (DEM) techniques in the EUV band. While the EUV counterparts of individual WINQSEs seem to lie below the detection threshold of the current generation of instruments, Mondal (2021) identified the EUV counterpart of a group of WINQSEs. Using the DEM technique, he estimated the energy associated with it to be $\approx 3 \times 20^{25}$ergs, comfortingly close to the expectations from a group of nanoflares. As the numbers of WINQSEs detected runs into tens of thousand per hour per MHz, characterising their observational properties requires robust automated tools. For this we have developed and implemented a machine learning based approach for WINQSEs detection in solar radio images (Bawaji et al. 2022, submitted). In addition to significantly improving the detection methodology, this work also establishes that the bulk of isolated WINQSEs can be described well by a 2D Gaussian model and opens the interesting possibility of using the observed morphology of WINQSEs to constraint coronal turbulence and scattering at these otherwise hard to access coronal heights.

Ongoing and planned investigations of WINQSEs include estimating the bandwidth of some of the brighter WINQSEs, studying their time profile using higher time resolution data and their polarisation properties using the newly developed polarimetric imaging pipeline (Kansabanik et al. 2022). WINQSEs continue to meet all of the requirements for being the radio counterparts of Parker's nanoflares and we are carefully evaluating their role in coronal heating. We expect the the upcoming MWA Phase-III and the future Square Kilometer Array Observatory to enable the next big steps in this direction.

Acknowledgements

DO and AB acknowledges support of the Department of Atomic Energy, Government of India, under the project no. 12-R&D-TFR-5.02-0700. SM acknowledges partial support by USA NSF grant AGS-1654382 to the New Jersey Institute of Technology. RS acknowledges support of the Swiss National Foundation, under grant 200021 175832.

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