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Solar radio observations with LOFAR and space weather applications

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Extended Abstract

LOFAR is a novel radio interferometer consisting of a central core near Exloo in the Netherlands, remote stations in the Netherlands, and international stations all over Europe. It observes in two frequency bands, the low band of 10 - 90 MHz, and the high band of 110 - 250 MHz. LOFAR data are digitized at the station level and sent to a central correlator in Groningen. This provides LOFAR with great flexibility, and enables it to observe multiple beam directions in the sky simultaneously.

The Key Science Project "Solar Physics and Space Weather with LOFAR" observes the Sun with LOFAR. Non-thermal solar radio radiation in the low and high band originates from the upper and middle corona, respectively. This makes LOFAR a well-suited instrument for studying the phenomena of the active Sun, like flares and coronal mass ejections (CMEs). Imaging and spectroscopic observations of type III solar radio bursts, caused by energetic electron beams, provide information on source locations as well as electron and radio wave propagation in the corona. Observations of type II bursts, caused by coronal shocks, reveal CME launches and allow for investigating the electron acceleration mechanism at shock waves. Such LOFAR observations of the upper corona are crucial for studies of the sources of space weather, and a driver of future developments of the LOFAR system.

This is demonstrated by our current project of LOFAR observing campaigns during Parker Solar Probe (PSP) perihelion passes. For a period of four weeks around each perihelion, we observe the Sun each day for six hours around local noon. We make use of LOFAR's flexibility of assigning frequency bands and LOFAR stations to different observing modes. This way, we can simultaneously record solar dynamic radio spectra, obtain interferometric and "beam-formed" images, the latter by pointing multiple beams around the Sun and recording with high temporal cadence. Furthermore, we do interplanetary scintillation measurements and Faraday rotation studies of pulsar emission to study CME magnetic fields in interplanetary space.

The combination of these LOFAR observations with remote and in-situ observations of PSP is very useful for space weather studies. PSP probes the inner heliosphere and provides information on radio and plasma waves, magnetic fields, particle and plasma data, and heliospheric imaging data. Together with LOFAR data, this allows for tracing space weather events from their coronal source through the inner heliosphere on their way towards Earth. With PSP data obtained near the Sun, it is e.g. possible to follow type III burst electrons along their path, and then record them in-situ when they have just made it into the heliosphere, if there is a magnetic connection between the source and PSP. CMEs can be observed in the corona by LOFAR imaging, and then be traced through the heliosphere by interplanetary scintillation measurements and PSP's heliospheric imager. We will present first results of this observing campaign.