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LOFAR4SpaceWeather: Towards Space Weather Monitoring with Europe's Largest Radio Telescope

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LOFAR4SpaceWeather (LOFAR4SW) is a new design study, recently awarded a grant under the latest Horizon2020 INFRADEV call, to commence investigations into upgrading the Low Frequency Array (LOFAR) radio telescope to enable regular space weather monitoring observations in parallel with radio astronomy operations.

LOFAR is a radio astronomy array consisting of a dense core of 24 stations within an area of diameter ~4km, 14 stations spread further afield across the north-east of the Netherlands, and a further thirteen stations internationally (six across Germany, three in northern Poland, and one each in France, Ireland, Sweden and the UK). Each station is capable of observing over a wide bandwidth across the frequency range 10-250 MHz, at high time and frequency resolutions, and forming multiple beams to point in any direction on the sky. Any number of the stations can be combined as an interferometer for radio imaging of the sky, and/or the core stations combined to form up to ~200 narrow pencil beams ("tied-array beams"). The latter enables raster imaging techniques to be used or, with some limitations, multiple radio sources to be observed simultaneously. These capabilities make LOFAR one of the world's most flexible radio instruments and enable studies of several aspects of space weather to be advanced beyond the current state-of-the-art.

Observations of interplanetary scintillation (IPS – the scintillation of compact radio sources due to density variations in the solar wind) can be used to probe the solar wind and the passage of Coronal Mass Ejections. A month-long campaign in October 2016 demonstrated LOFAR's capabilities in providing the many observations necessary for visualising the solar wind throughout the inner heliosphere, in addition to the improvements which could be made when these data are combined with those of other facilities worldwide. Long-duration observations enable the full passage of a CME to be observed, demonstrated by more than 24hours of observation designed to catch the passage of the fast 10th September 2017 CME.
Measurement of the strength and direction of the magnetic field within CMEs as they pass through interplanetary space remains something of a "holy grail" for space weather forecasting. One of the only methods by which this could be achieved is via the observation of heliospheric Faraday rotation in the polarised signal from either a polarised radio source or a Galactic polarised background. This is a challenging measurement which only low-frequency instruments such as LOFAR hold the promise to achieve.

Wide bandwidth observations of ionospheric scintillation from all stations in the array significantly expand upon the single-station, single-frequency GNSS datasets, offering an opportunity to more-fully explore large-to-small plasma scales in the presence of different scattering regimes. These novel data will be used to support and test ionospheric and scintillation modelling over a wide range of scales, and a project is underway seeking to monitor TEC gradient variations over Europe, verify GNSS IONEX data and, ulitmately, to implement near real time imaging of ionospheric structures and TIDs.
In this presentation, we summarise the aims of the LOFAR4SW study and the longer-term goals envisaged for LOFAR to become a major instrument for space weather monitoring observations.