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Imaging of Solar Type III Radio Bursts with LOFAR

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1 Introduction

In solar radio radiation, type III bursts appear in dynamic radio spectra as fast drifting ($\sim$100 MHz/s) radio events. Sometimes they drift from a few hundred Megahertz to lower frequencies, sometimes to Kilohertz and below. They are regarded as radio signatures of beams of energetic electrons traveling outwards in the solar corona and sometimes entering the interplanetary space up to 1 AU. They are explained as plasma emission excited by electron beams with typical velocities of 0.15 to more than 0.5 times the speed of light (c). The radio waves are emitted near the local electron plasma frequency f_{pe} and/or its harmonics, i.e. the emission frequencies $f \approx n f_{pe}$ with $n = 1$ or $n = 2$ for fundamental or harmonic emission, respectively. The electron plasma frequency f_{pe} is only a function of the electron number density N_{e} given by

$$f_{\mathrm{pe}}(N_{\mathrm{e}}) = \frac{1}{2\pi}\left[\frac{e^2}{\varepsilon_0 m_{\mathrm{e}}} N_{\mathrm{e}}\right]^{1/2} = 9.00 \times \left[\frac{N_{\mathrm{e}}}{\mathrm{m}^3}\right]^{1/2}, \qquad (1)$$

where ε_0 is the vacuum permittivity, e and m_{e} are the charge and mass of the electron. If the electrons propagate away from the Sun the plasma density and hence the emitted frequency decreases steadily. So solar type III bursts are valuable probes of the coronal plasma density and its propagating electrons. LOFAR is a novel digital radio interferometer that is capable of imaging type III radio bursts with unprecedented sensitivity as well as spectral, spatial and temporal resolution in the frequency range from 10 to 90 and 110 to 250 MHz. LOFAR solar observations are done through its Key Science Project (KSP) "Solar Physics and Space Weather with LOFAR", processed with its Solar Imaging Pipeline [1] and made available through the LOFAR Solar Data Center [1]. Here results of such type III burst observations by LOFAR are discussed.

2 Results

LOFAR's imaging spectroscopy reveals type III bursts as compact radio sources in the solar corona at a distance of approximately 1.5 to 2.5 solar radii ($R_\odot$). In the projected plane of sky their propagation follows the coronal magnetic field lines. In one observation on June 23, 2012 an average distance of $0.55\,R_\odot$ was propagated with a velocity of $0.23\,c$ within 5.7 s. Furthermore Eq. (1) provides the electron number density N_{e} as a function of the observation frequency $f \approx n f_{pe}$ as

$$N_{\mathrm{e}} = \left(\frac{2\pi}{n}\right)^2 \frac{\varepsilon_0 m_{\mathrm{e}}}{e^2} f_{\mathrm{pe}}^2. \qquad (2)$$

With this relation LOFAR type III burst observations provide density profiles of the solar corona.

References

[1] F. Breitling, G. Mann, C. Vocks, M. Steinmetz, K.G. Strassmeier, "The LOFAR Solar Imaging Pipeline and the LOFAR Solar Data Center," *Astronomy and Computing*, **13**, 16, September 2015, pp. 99–107, doi: 10.1016/j.ascom.2015.08.001.