Leibniz-Institut für Astrophysik Potsdam

LOFAR observations of fundamental and harmonic type III emission during an M class flare

C. Vocks[1], M. Bisi[2], E. Carley[3], B. Dabrowski[4], R. Fallows[5], P. Gallagher[3], A. Krankowski[4], J. Magdalenic[6], G. Mann[1], C. Marque[6], B. Matyjasiak[7], D. Morosan[8], H. Rotkaehl[7], P. Zucca[5]

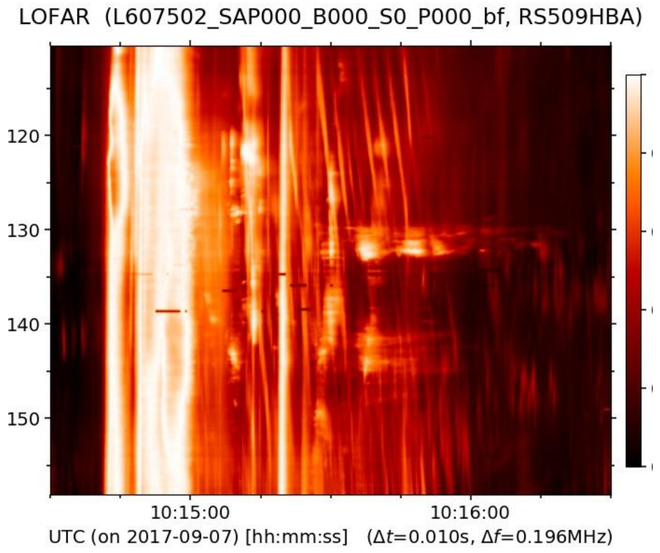
1 Leibniz-Institut für Astrophysik Potsdam (AIP), Germany **2** RAL Space, UK **3** Dublin Institute for Advanced Studies, Ireland **4** University of Warmia and Mazury in Olsztyn, Poland **5** ASTRON, The Netherlands **6** Royal Observatory of Belgium **7** Space Research Centre of Polish Academy of Sciences, Poland **8** University of Helsinki, Finland

LOFAR solar observations on 7 Sep 2017

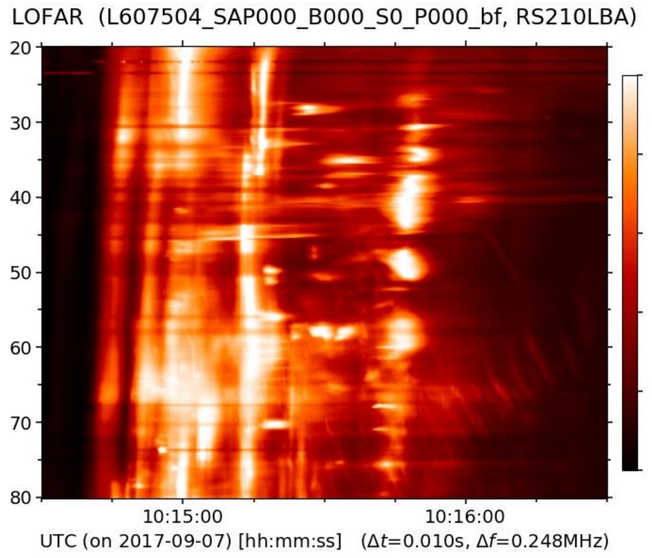
Interferometric in low band, dynamic spectra in low and high band, for 6 h around local noon with 0.25 s imaging cadence.
An M class flare was observed around 10:15 UT, that was accompanied by strong type III radio bursts. LOFAR dynamic spectra are shown to the right.

Calibration strategy

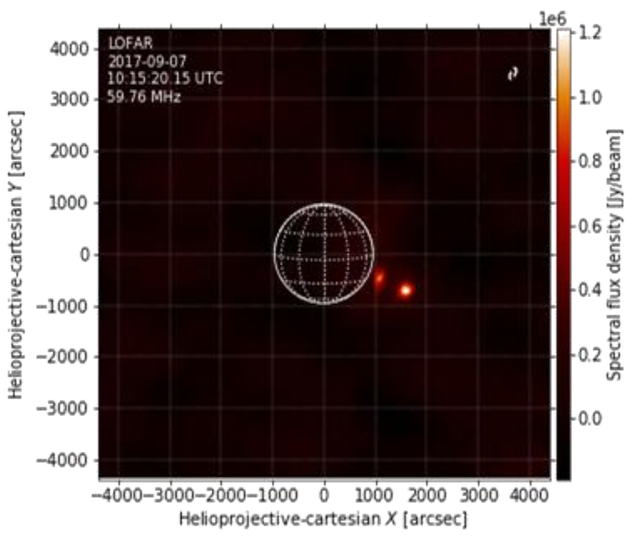
Since the flaring Sun outshines the external calibrator Tau A, a relatively quiet period before the flare has been used to get a calibrated image of the Sun.
Then, this calibration solution is used during the flare.



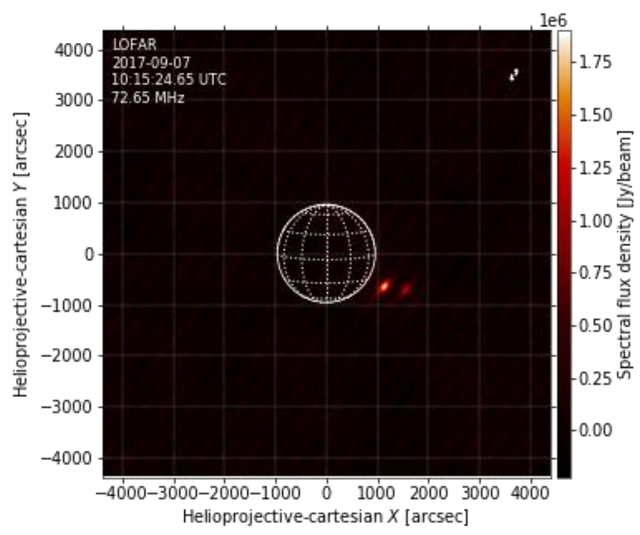
LOFAR high-freq. dynamic spectrum of type III bursts.



LOFAR low-frequency radio spectrum of type III bursts.



LOFAR type III image of the Sun at 60 MHz.

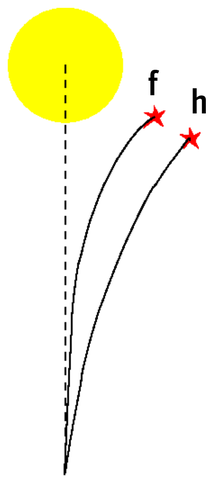


LOFAR type III image of the Sun at 77 MHz.

Dual-source structure observed by LOFAR

During the flare, an image was produced every 0.25 s on all observed frequencies. The pictures to the left show two representative examples. The type III source region outshines the quiet corona completely.
A frequently observed feature is an intermittent dual source structure. The sources appear and disappear, and vary in relative brightness.

Fundamental and harmonic emission

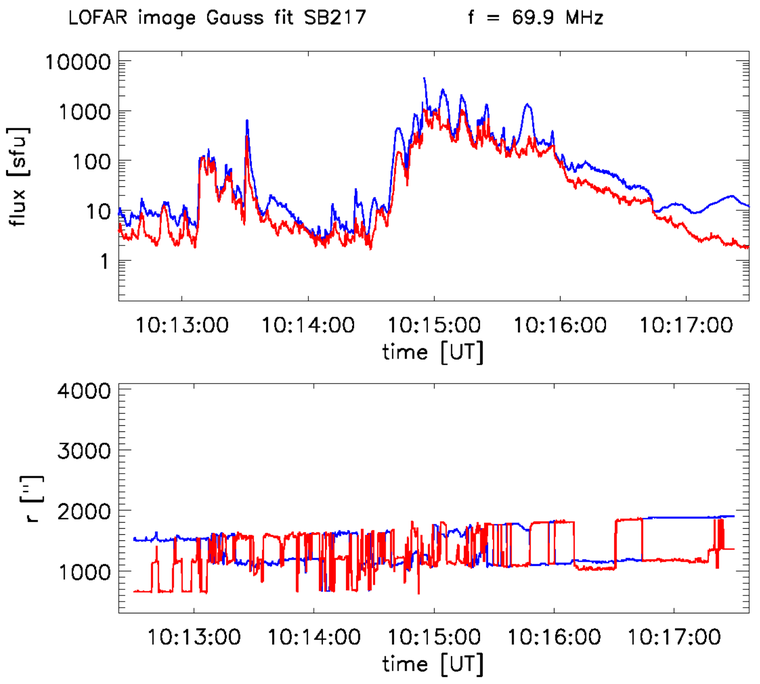


Sketch of ray paths of fundamental (f) and harmonic (h) emission

We interpret the dual structure as fundamental (f) and harmonic (h) emission. At an observed frequency, f_{obs}, the f source is where f_{obs} equals the local plasma frequency, while the h source is higher in the corona, where the plasma frequency is half of f_{obs}.
Furthermore, f emission is more affected by refraction in the large-scale coronal density gradient, leading to an additional source shift to the solar disk center.

Evolution of f and h sources

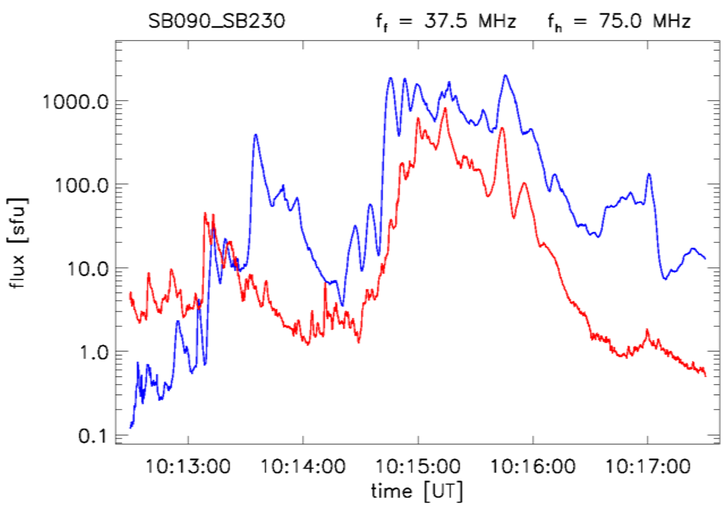
For an automatic source identification, we fit a Gaussian to the strongest source in an image, subtract it, and repeat the procedure for the second strongest source.
The figure shows the fluxes and radial positions of both sources. They switch their roles as strongest/second. From their positions the source regions of f and h emission can be determined.



Flux and position of the strongest (blue) and second-strongest (red) source.

Fundamental-harmonic pairs

With individual f and h sources, separate flux curves can be derived.
The figure shows fluxes of an f-h pair that should originate from the same source region in the corona.
An earlier onset of h is visible at 10:13:05 UT, but not later. The method of source finding is still under development.



Fluxes of fundamental (blue) emission at 37.5 MHz and harmonic emission (red) at 75 MHz.

Conclusion

LOFAR as a spectrometric imager is capable of providing separate lightcurves for f and h sources, and therefore of f-h pairs. This enables studies of radio wave propagation in the corona, as f is generally more affected by e.g. scattering or refraction than h.
Additionally, h emission at 20 MHz corresponds to f emission at 10 MHz, at the ionospheric cutoff. Such observations from the high corona are useful for joint campaigns with spacecraft, like Parker Solar Probe or Solar Orbiter.

Contact: cvocks@aip.de