Investigating the band-splitting of a type II solar radio burst using LOFAR imaging and spectroscopy

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Introduction

Band-splitting of type II solar radio bursts is a phenomenon where the emission lanes split further into two thinner lanes. The origin of band-splitting is still an open question, however, there are two alternative theories explaining this phenomenon (see Fig. 1):

1. One component of the split band originates upstream and the other downstream of the shock (Smerd et al., 1974, 1975)
2. Both components of the split band originate upstream of the shock but at two different locations (Holman & Pesses, 1983)

In this study, we investigate the origin of a split-band type II burst using radio imaging and spectro-polarimetric observations from the Low Frequency Array (LOFAR; van Haarlem et al., 2013). The type II burst occurred on 23 May 2022, and it was associated with a faint CME (see Fig. 2).

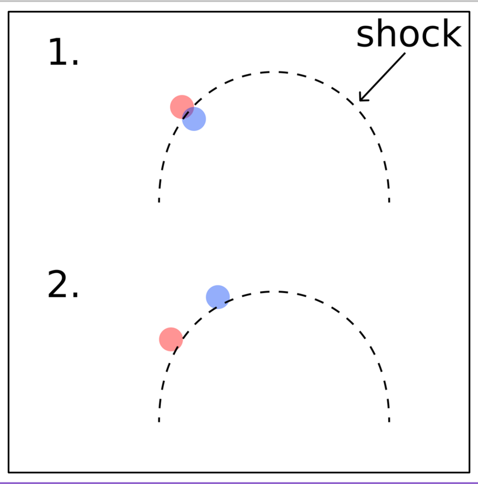


Figure 1: The Smerd et al. (1974, 1975) and Holman & Pesses (1983) model on band-splitting.

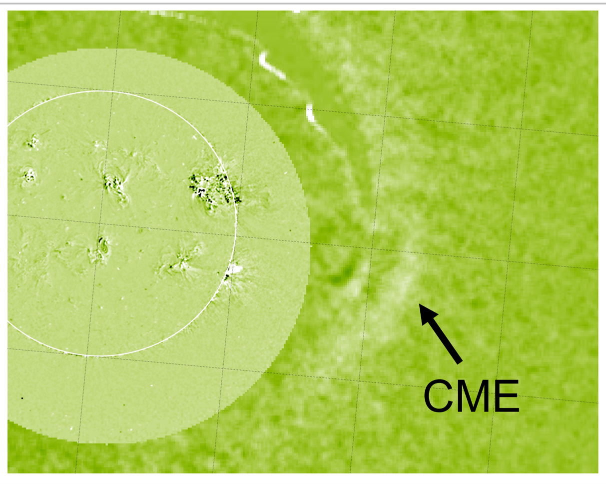


Figure 2: The CME associated with the type II burst observed by STEREO-A

Methods

We use LOFAR radio imaging at multiple frequencies to track the locations of the type II radio sources. We then use LOFAR's full Stokes dynamic spectra to estimate the degree of circular polarisation (dcp) for the higher-frequency and the lower-frequency component of the split emission lane. The Stokes I and V fluxes are corrected using the methods of Morosan et al. (2022).

Results and conclusions

Figure 3 shows the dynamic spectra of the type II together with the imaging. The frequencies and times chosen for the imaging are shown in Fig. 3b and the contours of the brightest radio emission are shown in Fig 3c. The imaging reveals two close but distinct radio sources. Figure 4a shows the full Stokes dynamic spectra at the same time. The part of the spectra with the most Stokes V signal is outlined. The extracted and corrected Stokes I and V fluxes for the lower-frequency and the higher-frequency component are shown in Fig. 4b together with the dcp and its mean. The dcp values are low and similar for both components of the split band. The plasma upstream and downstream are different environments, with downstream being more turbulent and thus expecting higher values of dcp with high amplitude fluctuations (Dulk & Suzuki, 1980; Koskinen, 2011).

Both results support the Holman & Pesses (1983) theory.

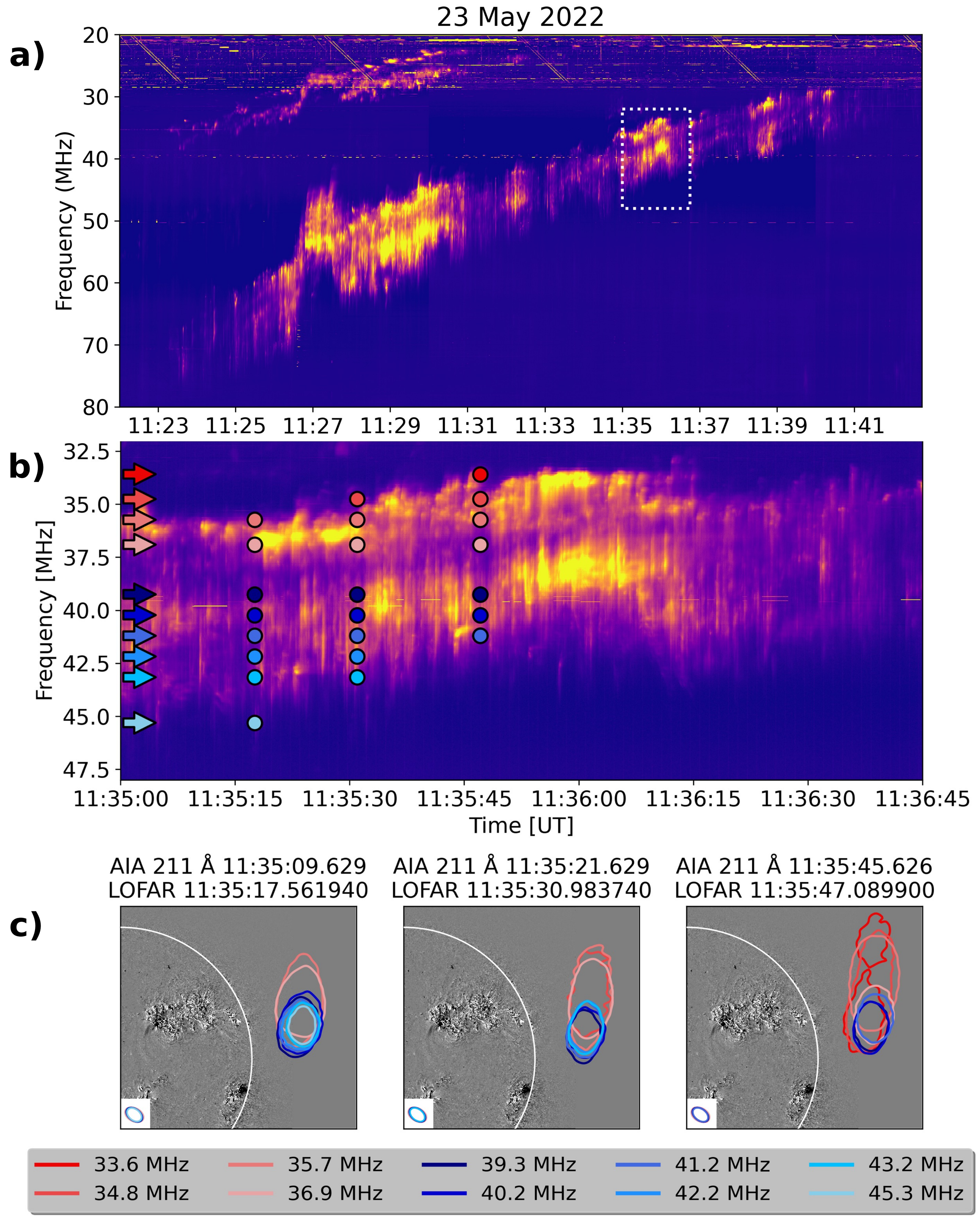
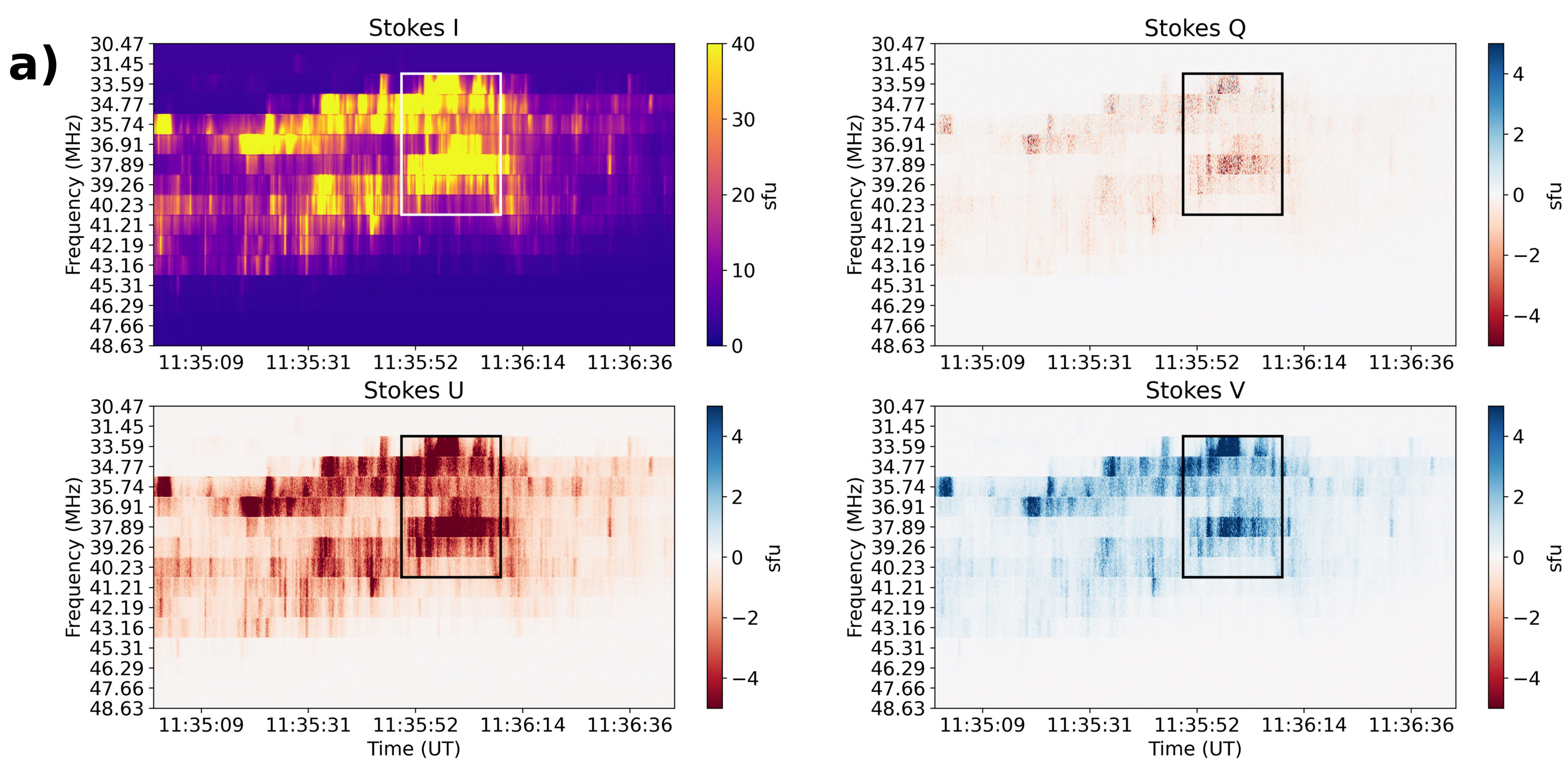


Figure 3: **a)** The dynamic spectrum of the observed type II at 11:22-11:42 UT observed by LOFAR. **b)** Zoomed-in dynamic spectrum representing the part of the spectrum outlined **a**. The arrows and dots show the frequencies and time steps used for imaging. **c)** Contours of the radio emission overlaid on SDO/AIA 211Å running difference images.



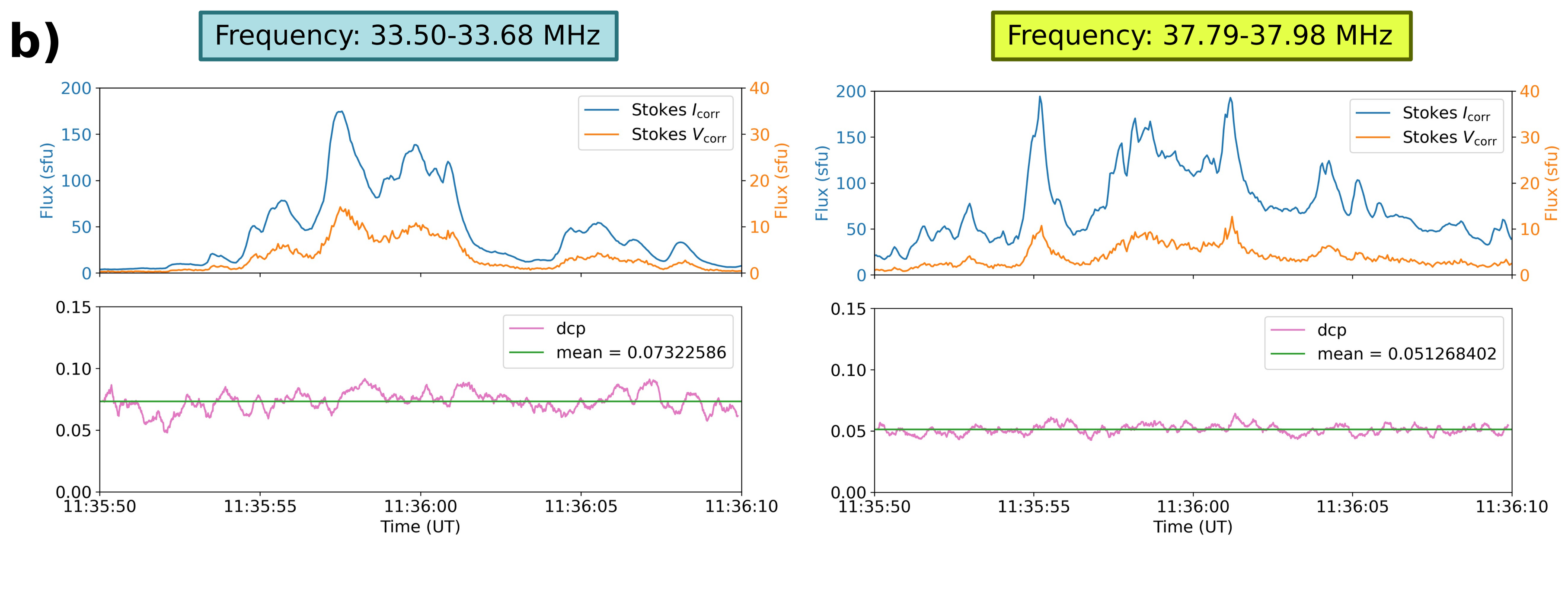


Figure 4: **a)** Full Stokes (I, Q, U and V) dynamic spectra observed by LOFAR. **b)** The top panels show the extracted and corrected Stokes I (blue) and V (orange) flux. The bottom panel shows the calculated degree of circular polarisation (pink) and its mean (green). The time corresponds to the outlined part of the spectra in **a.** The frequency of the left panels corresponds to the lower-frequency component and the right panels to the higher-frequency component of the split band. The mean dcp for the components are 7% (lower-frequency) and 5% (higher-frequency)

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