Detecting Dispersed Radio Transients in Real Time using Convolutional Neural Networks

David Ruhé*(1)(2), Mark Kuiack(1), Antonia Rowlinson,(1), Patrick Forré,(2) and Ralph Wijers(1)
(1) Anton Pannekoek Institute, University of Amsterdam
(2) Informatics Institute, University of Amsterdam

1 Extended Abstract

Radio astronomy has entered an era of fast-cadence imaging [Prasad and Wijnholds, 2012]. Among others, this allows for transient hunting in the long-wavelength regime. For example, fast radio bursts [Petroff et al., 2019] have yet to be discovered in the frequencies that LOFAR's AARTFAAC [van Haarlem et al., 2013, Prasad and Wijnholds, 2012] is operational in. Searching for such transient events has gained much interest in recent years. AARTFAAC is a sensitive all-sky transients program with a spatial resolution of 10s of arcmin at low frequencies (30-80 MHz). It was developed to utilize either 6 or 12 of LOFAR's core stations and expand the transient discovery space to wider fields with shorter time-resolutions (down to 1 second). The key advantage is a real-time imaging pipeline that can be analysed in a streaming fashion. Its foremost goal is to blindly search for transients, filtering only the most useful information, and alerting the multi-wavelength transient community when required. It is infeasible to archive all data that AARTFAAC generates. Therefore, only data containing potentially interesting candidates should be stored. This requires that the enormous number of spurious candidates have to be filtered automatically.

We [Ruhe et al., 2021] present a GPU-accelerated real-time pipeline for detection of astronomical dispersed transient sources in radio image streams. Among others, contributions are (1) a source detection strategy based on convolutions, (2) a neural-network based analysis approach, in which physical parameters are inferred from dynamic spectra and (3) an end-to-end GPU accelerated pipeline that can take streaming image data and output alerts in real-time. The input $\mathbf{X}_t \in \mathbb{R}^{C \times D \times D}$ consists of C $D \times D$ images of the radio sky. We analyse all channels in parallel as statistics calculated across several channels can be used to separate spurious candidates. Source detection is done by *convolutional sigma-clipping*. Source fluxes are measured and stored in dynamic spectra. These are analysed by a *convolutional neural network* machine learning model, that infers interpretable parameters. If some of the parameters (e.g., dispersion measure) reach a threshold that is interesting for the astronomer, an alert can be sent out. Results on simulated data show the efficacy of the pipeline, and from real data it discovered dispersed pulses. The current work targets transients on time scales that are longer than the fast transients of beam-formed search, but shorter than slow transients in which dispersion matters less. This fills a methodological gap that is relevant for the upcoming Square-Kilometer Array (SKA). Additionally, since real-time analysis can be performed, only data with promising detections can be saved to disk, providing a solution to the big-data problem that modern astronomy is dealing with.

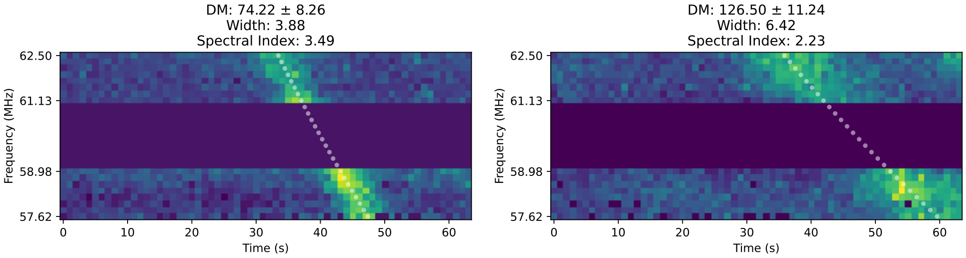

Figure 1. Examples of dispersed signals that were found after applying the pipeline. The parameters $\hat{\boldsymbol{\theta}}$ inferred by the convolutional neural network are provided above the respective samples. Additionally, we plot the dispersion sweep according to the inferred dispersion measure DM. The right example is the proposed transient candidate by Kuiack et al. [2020]. The other three are yet to be confirmed new transient candidates.

References

Mark Kuiack, Ralph AMJ Wijers, Aleksandar Shulevski, Antonia Rowlinson, Folkert Huizinga, Gijs Molenaar, and Peeyush Prasad. The aartfaac 60 mhz transients survey. *arXiv preprint arXiv:2003.13289*, 2020.

Emily Petroff, JWT Hessels, and DR Lorimer. Fast radio bursts. *The Astronomy and Astrophysics Review*, 27(1): 1–75, 2019.

Peeyush Prasad and Stefan J Wijnholds. Aartfaac: Towards a 24x7, all-sky monitor for lofar. *arXiv preprint arXiv:1205.3056*, 2012.

D Ruhe, M Kuiack, A Rowlinson, R Wijers, and P Forré. Detecting dispersed radio transients in real time using convolutional neural networks. *Astronomy and Computing*, page 100512, 2021.

Michael P van Haarlem, Michael W Wise, AW Gunst, George Heald, John P McKean, Jason WT Hessels, A Ger de Bruyn, Ronald Nijboer, John Swinbank, Richard Fallows, et al. Lofar: The low-frequency array. *Astronomy & astrophysics*, 556:A2, 2013.