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Automated detection of radio transients with the LOFAR Transients Pipeline (TraP)

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Our dynamic Universe contains many explosive and highly variable sources ranging from flaring stars to cataclysmic events such as merging neutron stars. Many of these events result in emission not only across the electromagnetic spectrum, but also of other messengers including neutrinos and gravitational waves We have entered an exciting era as we can find and study these objects using a wide range of probes. Typically, transient and variable sources are found in wide-field monitoring observations before being followed up by a wide range of observatories. Historically, these sources were found in optical and high-energy surveys, due to their large fields of view. However, over the last decade, a new generation of radio observatories have come online offering comparable survey capabilities, for example LOFAR at ~100 MHz and ASKAP at ~1.4GHz. This has enabled us to conduct image plane surveys for transient and variable sources over hundreds of square degrees at radio frequencies on timescales from seconds to years.

With this rapid influx of wide field radio data, we need automated transient detection algorithms that can handle the properties of radio data and find interesting candidate sources rapidly to enable multi-wavelength follow-up campaigns. Typical datasets can contain hundreds to tens of thousands of images, each containing hundreds of radio sources, making this a data intensive challenge. The LOFAR Transients Team tackled this problem head on and developed the LOFAR Transients Pipeline (TraP) [1]. As the TraP software was made publicly available via GitHub, it is now used internationally for data processing from facilities including LOFAR, VLA and MeerKAT. The output of the pipeline is a large database containing many measurements for each uniquely detected source and the properties of the images they were found in. We have developed strategies for mining these data, including machine learning approaches [2], and we are continuously optimizing our database search strategies using a wide range of datasets from different facilities.

Looking towards the future, the ultimate goal of upcoming facilities, such as the Square Kilometer Array (SKA), is that incoming radio data will be automatically processed by a transient detection algorithm in real time. Following detection, automated alerts are to be distributed to the wider community and the data will be made available through a public science data center. We are in the process of updating TraP to process data faster to meet the larger data challenges of future facilities. Additionally, we are now working towards a new version of TraP that can be fully integrated with observatory systems, running automatically and enabling new images to be processed when they arrive and with a publicly accessible database for astronomers to query directly.

In this talk, I will outline the design and use of TraP with radio observations from a range of observatories. I will explain how to optimally extract transient and variable sources from the database in an automated manner using example datasets. Finally, I will describe the future development plans to speed up processing time and incorporating it within a publicly accessible science data center.

1. J. D. Swinbank, et al., "The LOFAR Transients Pipeline", *Astronomy and Computing*, vol. 11, pp. 25–48, 2015. doi:10.1016/j.ascom.2015.03.002.

2. A. Rowlinson, et al., "Identifying transient and variable sources in radio images", *Astronomy and Computing*, vol. 27, 2019. doi:10.1016/j.ascom.2019.03.003.