Detection and characterization of fast drifting radio bursts : application to NDA/Juno-N high resolution observations of Jupiter

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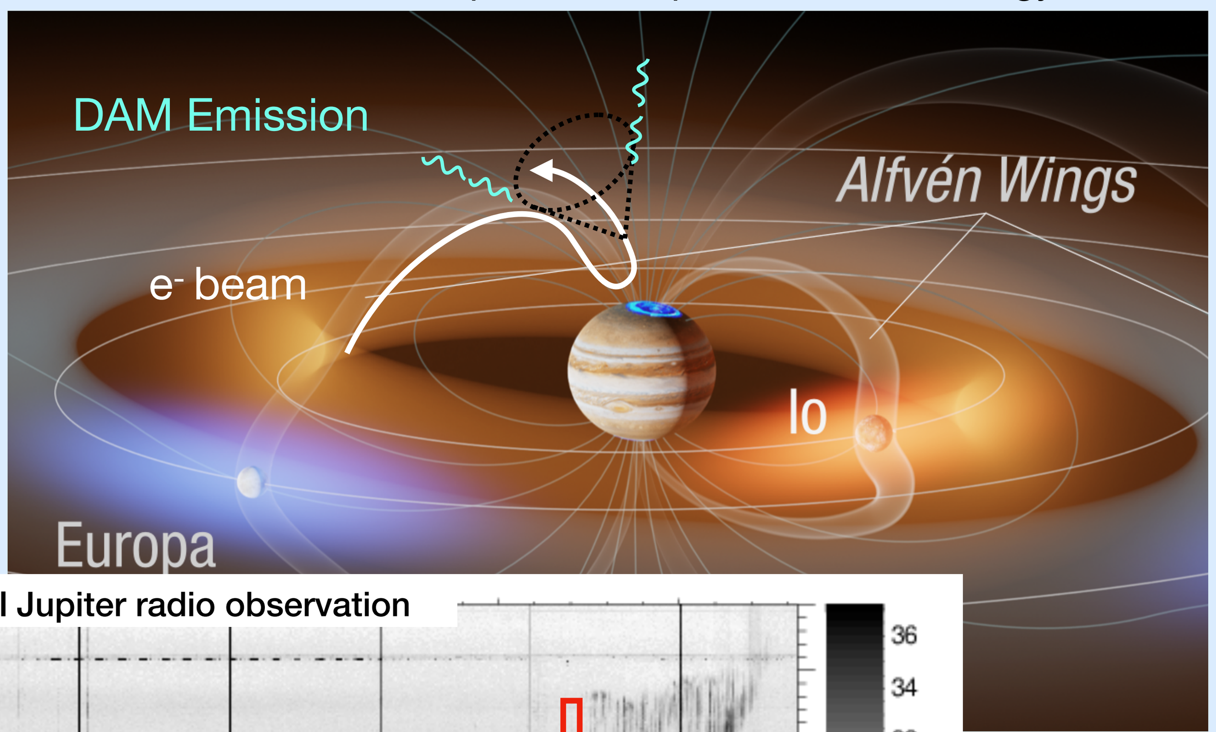
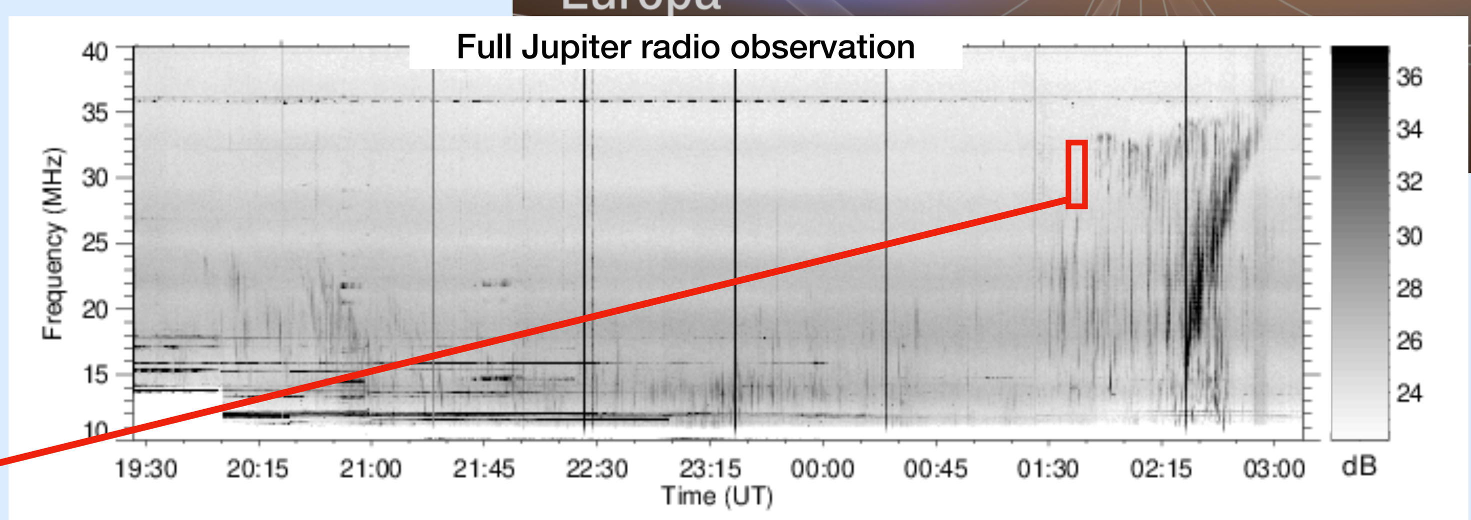
Keypoints

- Jupiter's magnetosphere's activity is driven by internal dynamics on which many questions persist.
- We prepare a systematic analysis of a 150 Tb dataset of daily high resolution Jupiter observations, accumulated by the Nançay Decameter Array over 10 years.
- Our study is based on the Spyburst algorithm developed by (Mauduit et al., 2023), that detects Jovian millisecond drifting bursts (S-bursts) in high resolution data. Their slope in the time-frequency plane probes the parallel kinetic energy of source electrons.
- We present some preliminary work to update the Spyburst processing steps, notably a new RFI-mitigation method based on applying low-pass filters in Fourier space.
This method significantly improves the quality of the bursts' slope detection.

The Jovian Decametric Emission

- Radio waves are amplified by a resonant instability in Jupiter's auroral zone : the Electron Cyclotron Maser Instability (ECMI).
This ensues from a selective magnetic mirroring close from Jupiter, creating a population inversion.
- These radio waves are extensively constrained : they are circularly polarized, emitted with a certain angle relative to $\overrightarrow{B}$, and have $\omega \approx \omega_{ce} = eB/m_e$.
- Much of these emissions are induced by plasma flows coming from Jupiter's satellites
- Many emissions present S-Bursts : fast drifting structures (< 1 s) whose frequency varies at ~ -20 MHz/s. The precise measurement of the drift probes the parallel kinetic energy of emitting electrons.



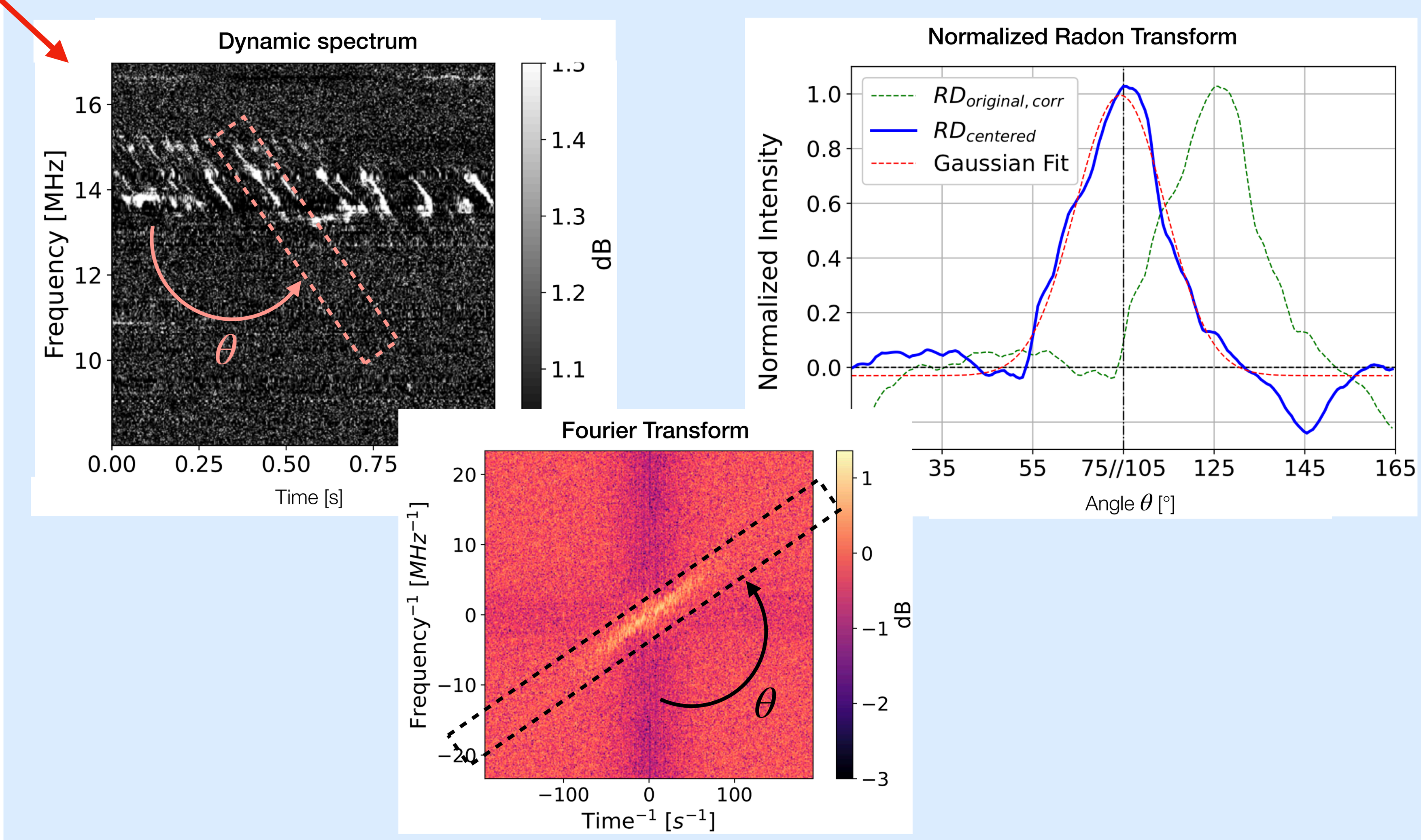


The Spyburst algorithm

We have at our disposal 10 years of daily observations by the digital Juno-N receiver of the Nançay Decameter Array : 150 Tb of high resolution data (time : 2.6 ms , frequency : 3.5 kHz)

Our work is based on Spyburst, developed by E. Mauduit et al. (2023)

The algorithm computes Fourier transforms of portions of dynamic spectra to concentrate S-burst intensities, and computes a Radon transform to detect the mean slope of the bursts (integrating along inclined lines)

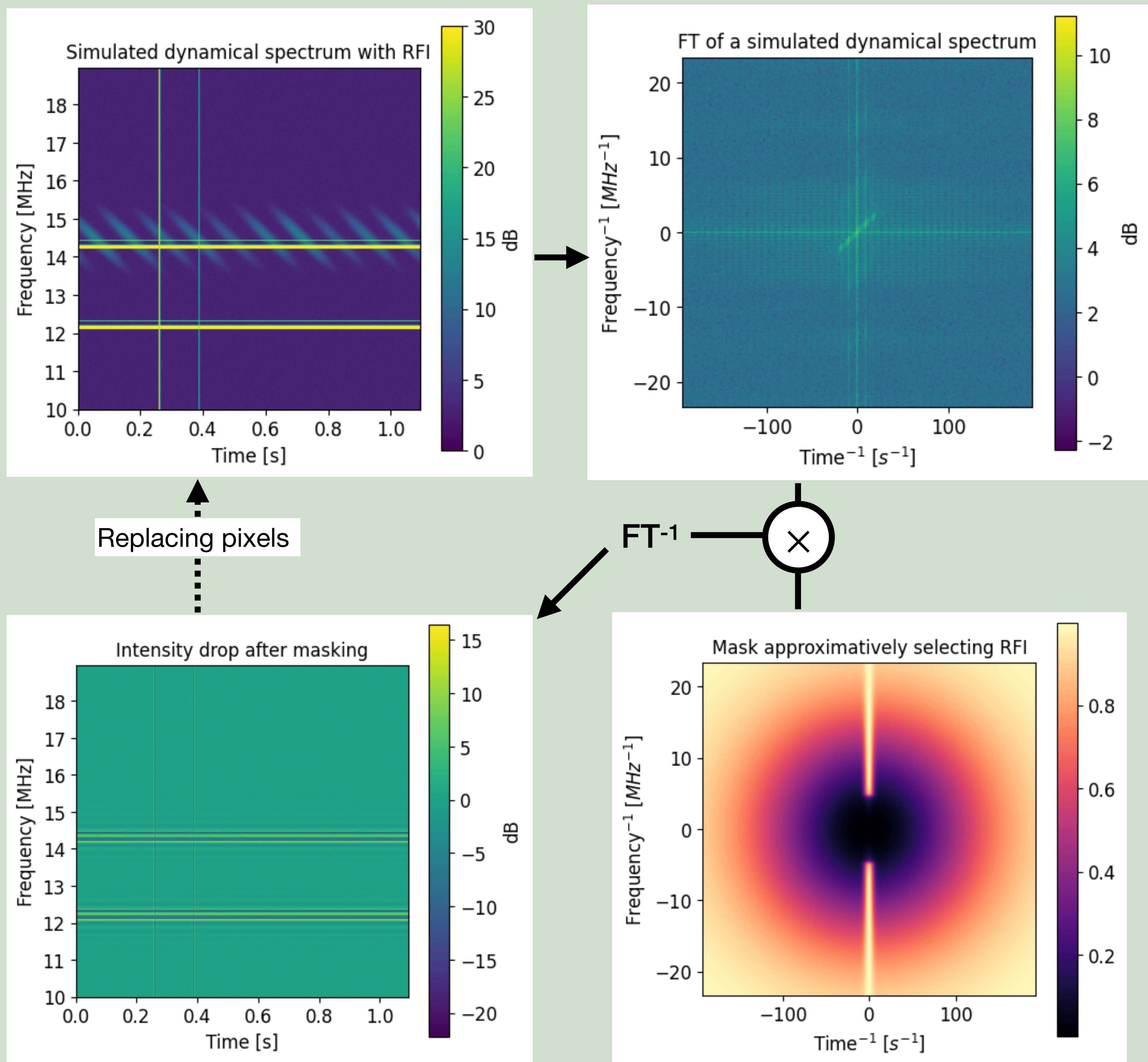


New RFI Mitigation technique

The 2022 RFI mitigation is time consuming, and sacrifies the SNR to mitigate the artefacts. It was developed for detection, and not precise characterization of S-bursts.

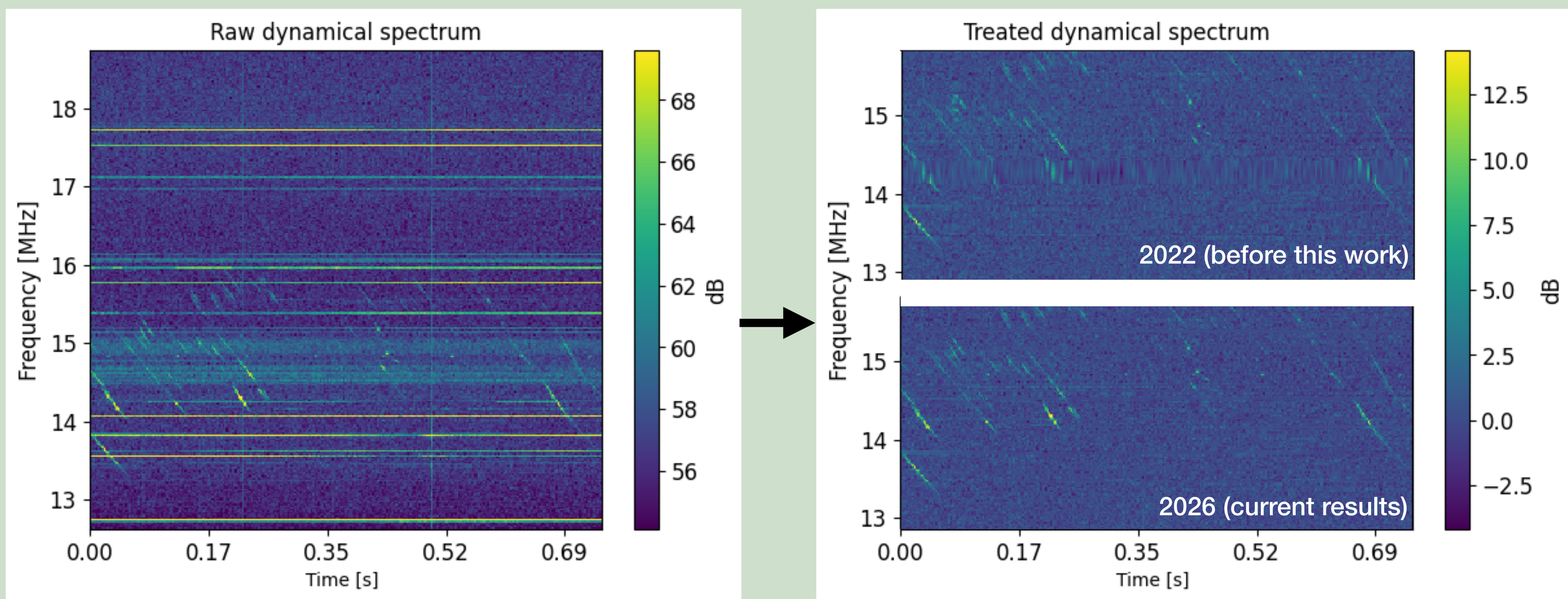
We have developed a new method :

- Masking of a relevant part of the Fourier Transform of data, to coarsely remove RFIs
- For each pixel of the dynamic spectrum, comparison between raw and filtered data
- Above a certain threshold, a pixel is discarded and replaced by a convolution of nearby pixels with a Gaussian.
- We iterate these steps on different thresholds and two masks (against horizontal/vertical RFIs)



Results on observations

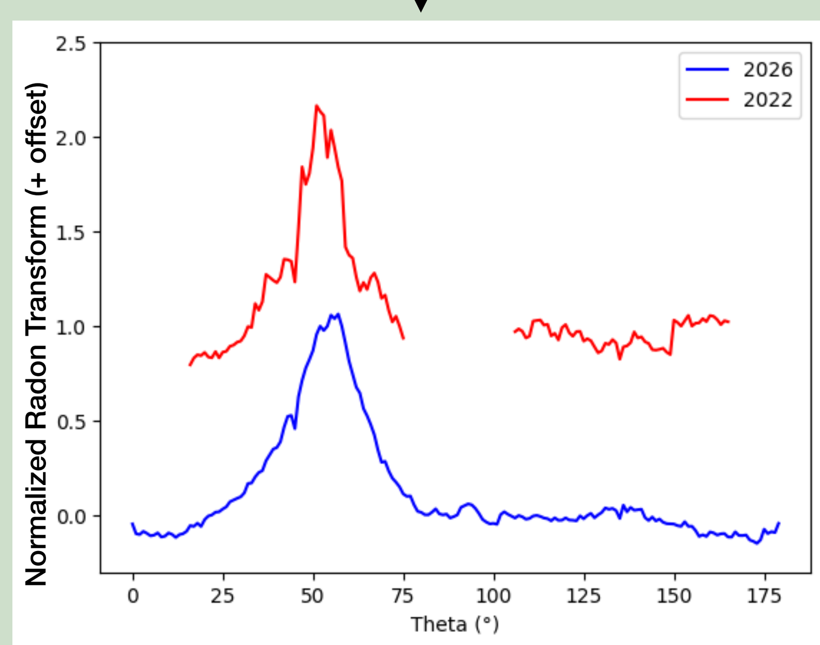
The new method provides higher quality dynamic spectra : notably, the signal reconstruction is better, with no additional computation time.

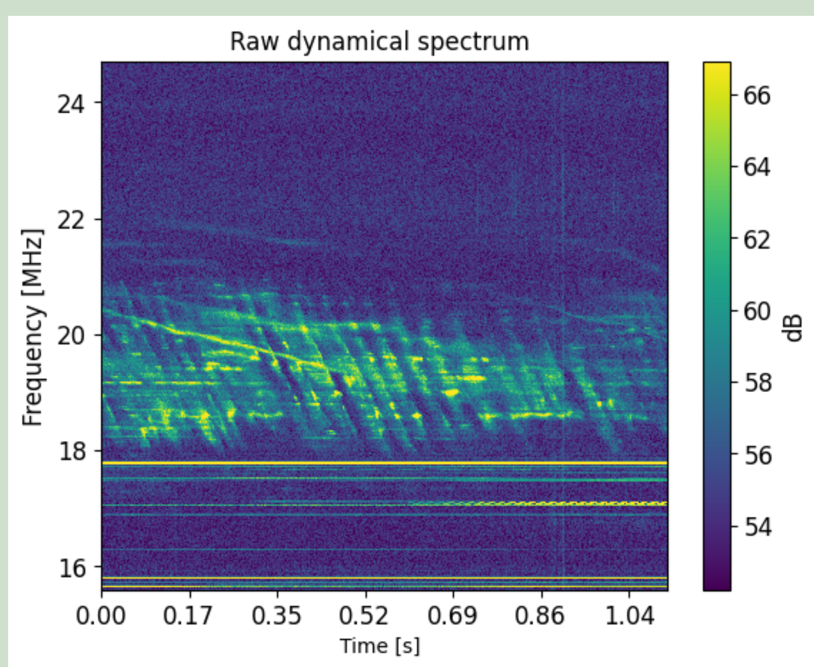


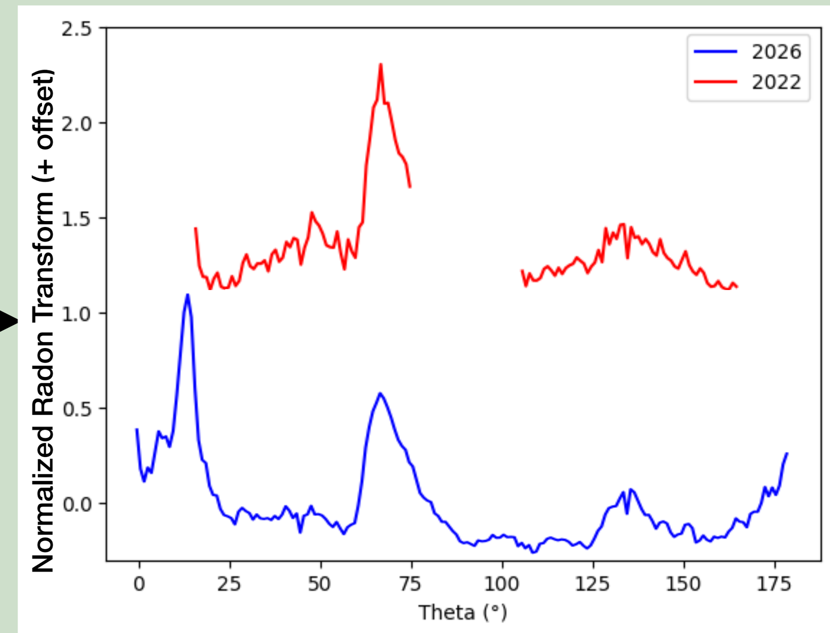
Impact on the Radon Transforms :

- The SNR is multiplied by ~2 (example on the right)
- The detection of slopes near 0° and 90° is now possible : the 2022 program was biased against them to mitigate artefacts - that's no longer necessary. (example below)

(The 2022 Radon transforms shown here are shown before smoothing)







Next steps

- Deriving mean slopes (in MHz/s) and parallel kinetic energy of electron beams
- Continue on improving the noise reduction program (for instance, a better handling of Faraday rotation)
- Refine our analysis of the bursts' shapes, that probe more finely acceleration mechanisms (for instance, electric potential gaps).
- Apply our algorithm to other datasets : NenuFAR/UnDySPuTeD , Juno / WAVES, JUICE /