A Study of the Signal Morphology from Fast Radio Bursts

Daniela Breitman,*
under the supervision of Keith Vanderlinde, Ryan McKinven, and Daniele Michilli
University of Toronto
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I. Introduction & Background Fast Radio Bursts (FRBs) are extremely powerful ($10^{38} - 10^{40}$ erg) [1] radio sources which emit short (μs-ms) extragalactic radio bursts [1]. The Canadian Hydrogen Intensity Mapping Experiment (CHIME) is a transit telescope. It observes at frequencies of 400 - 800 MHz and has a field of view of about 200 square degrees [2], much larger than most traditional telescopes. This makes it an excellent candidate for FRB detection. Over the past two years, the FRB population has grown significantly due to the large CHIME/FRB data set (500 +). However, we still do not know what is the cause of FRBs: what are the physics behind them and what extragalactic events could generate such signals? To add to the mystery, certain FRBs have been found to repeat, and today over 20 of these repeaters are known [3]. The aim of my project is to analyse the pulse structure in frequency and time, also known as morphology, of hundreds of FRBs at microsecond resolution. This analysis will then be used to test existing theories of FRB origin, as many emission mechanisms and progenitor theories [4] have been proposed since the discovery of the first FRB over a decade ago [5].

II. Research Goals Current studies of FRB morphology have two main limitations: sample size and resolution. For example, [6] consider a sample of about thirty FRBs in their study, while [7] uses real-time CHIME/FRB intensity data with 1-ms resolution. At 1-ms resolution, a significant fraction of bursts is unresolved. The CHIME/FRB real-time pipeline saves high resolution (2.56μs) data for the brightest events, in addition to the usual 1-ms resolution intensity data. For my masters project, I will be analysing the high resolution data of about 150 FRBs. It is then possible to study the morphology of the burst in greater detail by characterising the lower limit of the burst width distribution, key to constraining possible FRB emission mechanisms since some FRB models based on magnetic reconnection predict that shorter intrinsic widths should yield higher flux densities [4]. Recent morphology studies of FRB repeaters such as [7] suggest that the population of repeating FRBs is distinct from that of non-repeating FRBs based on the distribution of pulse widths, and so another goal is to test this hypothesis.

III. Progress The high time resolution data analysis pipeline is composed of three main stages: refinement, localisation, and analysis. The first stage involves improving already known properties of the burst such as dispersion measure (DM) and localisation. During the Fall semester, I improved the refinement stage by correcting for a recording artefact in the data that sometimes resulted in burst signal being cut short. I also worked on the localisation component of refinement by adapting an MCMC algorithm used for intensity data. The MCMC analysis uses the spectral information in every formed beam and the CHIME telescope beam model to improve the localisation of the event. A new version of this processing pipeline that includes these improvements I wrote has just been released, and the processing of available FRB data is gradually starting. Both of these tasks included an enormous amount of testing, so I am already familiar with the processing method. The goal of the project is to process about 150 FRB events through this pipeline and analyse the results. Processing one event takes around 3 hours and I expect to start analysing the first results by the end of February. While I will refine the data analysis, more and more events will be processed with the goal of studying the full sample by the end of the project.

* daniela.breitman@utoronto.ca

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