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Localizing Fast Radio Bursts with Triggered Synoptic VLBI and CHIME/FRB Outriggers

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For more than a decade, enigmatic extragalactic flashes called fast radio bursts (FRBs) have defied a definitive explanation for their origin [1]. The Canadian Hydrogen Intensity Mapping Experiment (CHIME) is the only radio telescope capable of instantaneously observing hundreds of square degrees with the sensitivity of a 100-meter scale aperture. As a result, its fast transient search instrument, CHIME/FRB [2], has detected thousands of FRBs, increasing the known sample by an order of magnitude [3] and discovering numerous clues about the nature of these mysterious transients. CHIME/FRB's main limitation is the roughly arcminute precision with which it can localize FRB sources [4], which is usually insufficient to unambiguously identify host galaxies.

The CHIME/FRB Outriggers project will overcome this limitation using very long baseline interferometry (VLBI) between CHIME and newly-constructed Outrigger Telescopes. The Outriggers will share an optical design and field of view with CHIME, but will be smaller arrays. They will be located in Green Bank, West Virginia; Hat Creek, California; and near Princeton, British Columbia (85 km from CHIME), with staged construction and commissioning phases throughout 2022 and 2023. VLBI on the CHIME–Outrigger baselines will yield < 50-milliarcsecond localizations for nearly all CHIME-detected FRBs.

A central challenge is continuously recording the requisite baseband data, whose rate is two orders of magnitude higher than can be digested by state-of-the-art VLBI recorders used by the Event Horizon Telescope. We adopt a buffer–trigger approach, where baseband data for the full array is stored in a $\sim$35 s memory ring buffer and written to disk upon receipt of a low-latency trigger from CHIME/FRB [5]. We also require an always-ready calibration solution, for which we exploit our wide field of view to continuously monitor pulsars and make use of many in-field continuum VLBI calibrators [6]. Our wide 400–800 MHz band provides precise measurements of differential dispersive delays from the ionosphere, which normally limits VLBI at these low frequencies [7].

Together, these methods form the new observing technique of triggered synoptic VLBI, which will enable ultra-precise localization, and redshift determination, for thousands of FRBs. The resulting dataset will be transformational for understanding the FRB phenomenon. In addition, the duel information of redshift and FRB dispersion will provide a completely new dataset with which to probe the evolution of plasma in the Universe.

References

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