LASA and WFBT: Two Concepts for an All–Sky Radio Transient Telescope

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ABSTRACT

The 2020s promise to be the decade of transient astronomy across the electromagnetic (EM) and gravitational (GW) spectra. The multi-messenger detection and follow-up of a neutron star-neutron star merger demonstrates the power of all-sky monitoring and rapid, global follow-up of bright transients. The discovery of fast radio bursts, meanwhile, has created an entirely new field within radio astronomy with applications in high energy physics, cosmology, and possibly compact object populations. As the Large Synoptic Survey Telescope begins scientific operations, we can be confident that new phenomena will be found at optical wavelengths, as well. True, all-sky telescopes operating at radio frequencies will be an essential component of this landscape. We present two technical concepts for widefield arrays with the ability to detect and localize bright transients: LASA, the L-Band Array of Small Arrays (LASA) operating from 1.2–1.7GHz, and the Wide Field Burst Telescope (WFBT, operating from 0.4–1.2GHz. LASA would consist of a number 2-m x 2-m dipole arrays, while the WFBT would be made up of 64 closely packed feed horns. Real-time detection, imaging, and localization of bright, fast transients, such as FRBs and giant pulses from radio pulsars, is built in to the data processing pipelines. Both concepts are modular and scalable and build upon proven technologies, and are well suited to developing a global, 24/7 all-sky network of transient-detection radio telescopes that would compliment other observatories in the EM and GW bands.

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1. Multi-messenger Transient Science

The past decade has seen major advances in radio transient and multi-messenger science. The discovery of the double neutron star merger event, GW 170817, by LIGO and VIRGO was momentous in its own right, but was made all the more impactful by simultaneous detection and localization by the Fermi Gamma-ray Burst Monitor (Abbott et al. 2017b,c,a), enabling follow-up across the EM spectrum. This was possible because of LIGO’s, VIRGO’s, and Fermi’s all-sky fields of view, and the rapid dissemination of the nature and position of the event throughout the astronomical community.

Fast radio bursts (FRBs) are another transient source that would benefit from a true all-sky monitoring telescope operating at ∼ GHz radio frequencies. The discovery of FRBs has revealed an entirely new highly energetic cosmological population of unknown physical origin. Investigations of FRBs can be broadly grouped into two categories. The first is deep, detailed observations best exemplified by study of the lone repeating FRB (FRB 121102; Spitler et al. 2016; Chatterjee et al. 2017; Michilli et al. 2018). The second is detection and statistical study of large numbers of FRBs, such as with ASKAP (Shannon et al. 2018) and CHIME (Boyle & Chime/FRB Collaboration 2018). However, neither of these approaches is truly analogous to the work of LIGO/VIRGO, Fermi, and the many observatories that joined in studying GW 170817.

A global network of widefield radio telescopes that monitor the entire sky at all times is required for the study of FRBs and radio transients more broadly to truly benefit from the era of multi-messenger astronomy. To achieve sufficient sensitivity and sky-coverage, any such network must rely on relatively inexpensive, scalable technology, and searches must be real-time, with results being made public immediately, to allow for rapid follow-up. LASA and WFBT are two concepts that can meet these needs.

2. The L-Band Array of Small Arrays

LASA would consist of collections of tiles, each made up of 256 dipoles. Each dipole would have a bandwidth of 100 MHz tunable in the 1.2–1.7 GHz range. Tiles would be chained to form super-tiles, which would then be spaced over distances of several kilometers to allow for arcsecond-scale localization of sources. Synthesized beams could be pointed anywhere within 30° of zenith. The digital beamformer utilizes a compact design which can be used to monitor independent beams for transients, or to track individual sources of interest when needed (e.g. bright pulsars or fields of view being observed by other telescopes). Tracking observations can be performed commensally with the transient searches. The detection
pipeline is a straightforward expansion of GBTrans, a commensal transient detection system that operated on the Green Bank Observatory 20-m Telescope.

3. The Widefield Burst Telescope

The WFBT would consist of a number of antenna arrays each with a 20° field of view. The antennas are square, quad-ridge dual-polarization feed horns with a physical aperture diameter of 1 meter. Each array would consist of 64 horns in an 8-m by 8-m square and operate at 0.4–1.2 GHz. Individual stations could be distributed across hundreds of kilometers and would detect and localize bright transients. The WFBT will use commercial room temperature low-noise amplifiers, and signal will be transported via fiber links to computing stations colocated with each array for correlation using an ICE-based system. Real-time transient searches will be performed on GPU clusters, searching 64 beams for dispersed signals on millisecond timescales. Much of the technology needed for the WFBT has already been developed for the CHIME telescope, minimizing costs and technical risks.

The modular design is well suited to future enhancements; horns can be added to each array, increasing sensitivity; new arrays can be added at additional sites, improving localization precision and the quality of the synthesized beam; and additional arrays can be aimed at other fields of view on the sky. A global network of arrays would thus provide true, 24/7 all-sky coverage.

REFERENCES

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