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Enabling real-time, sub-millisecond timescale imaging in large radio interferometers

Two of the frontier sciences that constitute the key science goals of next-generation radio astronomy include the evolution of gas and large-scale structure in the early Universe, and the characterization of mysterious explosive phenomena in the Universe through time-domain studies. High sensitivity and time-resolution are essential prerequisites to achieve these goals. Modern radio telescopes such as the Hydrogen Epoch of Reionization Array (HERA), Square Kilometre Array (SKA), Long Wavelength Array (LWA), and Murchison Widefield Array (MWA) are adopting an approach of achieving large collecting areas through hundreds to thousands of small antennas. However, traditional radio interferometry architectures face serious challenges to processing data as they rely on correlating data between antennas, and thus the computing cost scales unaffordably as the number of antennas squared (N^2). I will present the E-field Parallel Imaging Correlator (EPIC), which implements a versatile and efficient algorithm for direct imaging. For large compact arrays, the computational cost is expected to scale much more efficiently as N log N. By design, it can operate at the Nyquist speed of incoming digitized data and can produce science-ready images even on sub-millisecond timescales. Thus, it provides an ideal platform for building image-based fast transient search and monitoring systems for Fast Radio Bursts (FRB), millisecond pulsars (MSP), auroral emission from exoplanets, Solar and Jovian bursts, meteor showers and lightning, and other mysterious astrophysical events. EPIC holds significant advantage and promise for most modern radio interferometer arrays such as HERA, LWA stations, CHIME, and cores of MWA and SKA1-low. EPIC is funded by the NSF ATI division to deploy a real-time GPU-version on the LWA telescope in Sevilleta (New Mexico). I will discuss the successful preliminary deployment of EPIC on the LWA with results including high time-resolution, all-sky images obtained in real time. I will also outline the future plan and the potential for expanding the scope and deploying this ultra-efficient science-ready architecture on other modern radio telescopes.