HERA – Hydrogen Epoch of Reionization Arrays

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RF12: Submitted for consideration by the Astro2010 Decadal Survey Program Panel
RMS: Radio (Meter/Centimeter) and Millimeter/Submillimeter

Top: Simulated history of the Universe from recombination to the present, with example 21cm signals and a Murchison Widefield Array tile overlaid. Bottom: All-sky map at 150 MHz from Precision Array to Probe the Epoch of Reionization; scale log[Jy]; peak 10\textsuperscript{4} Jy; min rms 100 mJy. Credits: G. Djorgovski, S. Furlanetto, J. Lazio, A. Parsons et al. (2009).
I. EXECUTIVE SUMMARY

US astronomers are leading the first exploration of large-scale structure in the high-redshift baryonic universe via the 21 cm line of hydrogen. We present a roadmap for the coming decade for the development of Hydrogen Epoch of Reionization Arrays (HERA) in order to achieve the key scientific goals of understanding the development of the first galaxies and their influences on the universe around them.

We repeat a statement about secondary science goals (radio sky catalog, pulsars, transient sources, solar and heliospheric physics) from our RFI1 submission, but do not develop the cost impact of this potential research that is not a simple and direct output of our main science program.

Our roadmap is divided into three phases:

1. 2010-2014—HERA I: Detection of the power spectrum of the 21 cm line emission from the epoch of reionization using the Murchison Widefield Array (MWA) and Precision Array to Probe the Epoch of Reionization (PAPER). These radio arrays are already under development (2008-2011; HERA IA). A second phase of activity during 2012-2015 has goals of completing and extending the arrays, campaigns to collect data, data analysis, and R&D leading up to a HERA II proposal in 2014. An expenditure of FY09 $25M is developed in this RFI2 (HERA IB with some costs through 2016).

2. 2015-2019—HERA II: Characterization of the 21 cm power spectrum and additional statistics yielding significant new galaxy formation astrophysics and cosmological physics by the end of the decade. A second-generation array with increased sensitivity will be constructed for this purpose. An expenditure of FY09 $62M is developed in this RFI2.

3. 2020 and beyond—HERA III: Detailed imaging of structures across a large fraction of cosmic time will be measured using a large third-generation radio array that could also serve as the core of the SKA-low.

In this HERA RFI2 whitepaper, we focus on the development and costing of the second-generation radio array capable of meeting the phase II science objectives. The reference design of the interferometer we propose is an array of 5000 dipole-based antennas with a total effective collecting area of 100,000 m². The technical challenge of this array is dominated by the enormous data rate from so many antennas and the need for a very high precision calibration solution. We name our reference array “HERA-II”. It will map 1000 deg² or more of the sky with 10 mK sensitivity over a wavelength range between 1.5 and 3 m (100 to 200 MHz).

Construction of HERA-II will commence in 2015 and the science program will begin in 2017. All of the core technology and analysis techniques required for the array will be fully demonstrated by the PAPER and MWA pathfinder arrays, both of which are scheduled to begin operations in 2010.

Significant sharing of the costs with international partners is possible. The costs already are reduced from total project costs owing to assumed infrastructure contributions from host country of the HERA. The costing estimates in this whitepaper are based on the real expenditures accrued by MWA and PAPER between 2005 and the present. With the high level of activity and progress of the two pathfinding efforts over the next few years, a HERA-II proposal mid-decade will be both firmly justified scientifically and accurately costed.