2[nd] URSI AT-RASC, Gran Canaria, 28 May – 1 June 2018

The "Hydrogen Epoch of Reionization Array" (HERA): simulations of the chromatic effects in HERA 19 and impact on the EoR delay power spectrum detection

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The "Hydrogen Epoch of Reionization Array" (HERA) is a new radio-telescope under construction, and dedicated to the study of the early universe. Its main goal is to characterise the period during which the first quasars, galaxies and stars started to form, by measuring the evolution of the distribution of the neutral hydrogen present in the intergalactic medium (IGM). During the "Dark Ages" of our universe, until about 300 million years after the Big Bang, the background emission was dominated by the CMB and the neutral hydrogen 21-cm signal. Following the formation of the first stars and galaxies, the IGM started to be heated and ionized by the X-rays and UV radiations emitted. Thus, due to the decrease in the quantity of neutral hydrogen, the 21-cm signal progressively disappeared. The study of the spectral and spatial fluctuations of this signal during the "Epoch of Reionization" (EoR) is the key to better understand the formation and evolution of the first structures of our universe.

In its first version, HERA was designed to detect the delay power spectrum of the redshifted hydrogen signal between 100 and 200 MHz. This is equivalent to probing a period between 325 million and 915 million years after the Big Bang. The antenna consists of a 14-m diameter faceted parabola illuminated by two perpendicular 1.3-m long dipoles surrounded by a 1.7-m diameter metal cage, 4.9 m above the dish. The final configuration of this radio-interferometer, built in the Karoo desert in South Africa in an extremely radio quiet zone, will comprise 350 antennas, 320 forming a very dense hexagonal core plus 30 outriggers to improve the resolution.

However, the detection of the EoR signal is a real challenge: this signal is extremely faint and contaminated by the foreground signal which can be up to 6 orders of magnitude more intense. In order to differentiate these two signals, HERA will use a "foreground avoidance" method based on the fact that the frequency power spectrum of the foreground is rather smooth whereas the spectrum of the EoR signal should in theory fluctuate more. By translating this property in the time domain, one can expect to obtain a very compact foreground delay power spectrum, while the EoR delay power spectrum should spread in the time domain. Thus, the portions of the EoR spectrum not contaminated contain partial but fundamental information about the Reionization. However, in order to succeed, the "EoR window" must be preserved by limiting the chromatic effects, mainly additional reflections between the feed and the dish, and mutual coupling between adjacent antennas separated by only 60 cm. Indeed, these reflections spread the foreground delay power spectrum, which contaminates the EoR window [1].

In my talk, I will present in more detail the configuration and performance of this radio-telescope. I will also explain how we manage to accurately model the chromatic effects of the antenna array, by combining an electromagnetic model of the first 19 elements of HERA along with the RF analogue chain, in a time simulation performed with CST. Lastly, I will emphasise the impact of these effects on the antenna EoR detection.

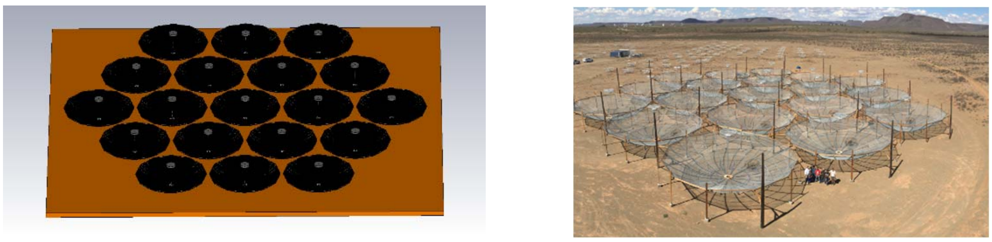

Figure 1. CST electromagnetic simulation and picture of the fisrt 19 elements built in the Karoo desert

1. D. R. DeBoer, et al., "Hydrogen Epoch of Reionization Array (HERA)," *Astronomical Society of the Pacific*, **129**, 974, April 2017, doi: 10.1088/1538-3873/129/974/045001.