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

LOFAR search for the Epoch of Reionization

Michiel A. Brentjens[(1)], on behalf of the LOFAR-EoR team
(1) ASTRON, the Netherlands Institute for Radio Astronomy, Postbus 2, 7990 AA, Dwingeloo, The Netherlands, http://www.astron.nl

1 Extended Abstract

After the Big Bang, the universe was hot and fully ionized. Approximately 379 000 years later, it had adiabatically cooled enough for hydrogen and helium nuclei to capture free electrons, forming neutral atoms. During the Epoch of Re-ionization (EoR), UV radiation from the first generation of stars and/or the first active galactic nuclei re-ionized that gas. Before being obliterated by hard UV photons, the neutral hydrogen emitted radio waves at a rest-frame frequency of 1.420 GHz. The EoR probably happened when the universe was approximately 7 to 20 times smaller than now, red-shifting the radiation to VHF frequencies of 70 to 200 MHz. By detecting this signal and determining its frequency range, one can measure the redshift and therefore the universe's age at which the EoR occurred.

The LOFAR EoR team has observed thousands of hours at frequencies between 115 and 189 MHz. More than 2000 h were recorded on a field around the North Celestial Pole (NCP) and slightly less than that on a field centred at (3C 196). If current cosmological models are reasonable and thermal noise in the antennas is the only limiting factor, this is enough to detect the signal.

Unfortunately, the feeble signal passes through nearly the entire universe before reaching terrestrial detectors, necessitating careful calibration of the entire signal path, including corruption by extragalactic sources, the Galactic interstellar medium, the Earth's ionosphere, the antennas, and analogue electronics. Advanced signal processing is therefore required. It has taken years to understand the first 13 h of data as well as its processing to set the most sensitive upper limits to the EoR powerspectrum yet [1]. Nevertheless, this result is still in part limited by apparently non-thermal "excess noise".

Over the last year, the processing strategy was improved by

- including diffuse foregrounds in the (direction-dependent) calibration model;
- requiring spectral smoothness in the direction-dependent processing ("concensus sagecal");
- using Gaussian Process Regression (GPR) to further mitigate residual (diffuse) foregrounds and instrumental residuals.
- including accurate sub-arcsecond images of the brightest sources (e.g. 3C 196).

These changes together have reduced the excess noise, improving the upper limit.

The team is currently processing, analyzing, and verifying ten nights of NCP data. So far, the upper limit continues to go down with each additional night of data. Since last year we have employed LOFAR's multi-beam capabilities to simultaneously observe seven fields around the NCP, which can in principle improve the error on the power spectra even further.

References

[1] A. H. Patil et al., "Upper Limits on the 21 cm Epoch of Reionization Power Spectrum from One Night with LOFAR" *The Astrophysical Journal*, **838**, 1, March 2017, 65, doi:10.3847/1538-4357/aa63e7.