URSI GASS 2021, Rome, Italy, 28 August - 4 September 2021

Precision calibration of the NenuFAR telescope for Cosmic Dawn observations

Bharat K. Gehlot*[(1)], Florent G. Mertens[(2)(3)], Leon V. E. Koopmans[(2)], and Benoit Semelin[(3)]
(1) School of Earth and Space Exploration, Arizona State University, Tempe, AZ, United States.
(2) Kapteyn Astronomical Institute, University of Groningen, PO Box 800, 9700AV Groningen, The Netherlands.
(3) LERMA, Observatoire de Paris, PSL Research University, CNRS, Sorbonne Université, Paris, France.

Extended Abstract

Observations of the redshifted 21-cm signal of neutral hydrogen from the epochs of Cosmic Dawn and Reionization hold the potential to unveil new astrophysical phenomena during the early universe. The reported detection of the 21-cm absorption feature in the sky-averaged spectrum by the EDGES collaboration is unexpectedly deep [1] and non-standard (astro)physical models are required to explain the said absorption trough [2, 3, 4]. If confirmed, a deeper absorption feature will also enhance the brightness temperature fluctuations of the redshifted 21-cm signal, which is well within reach of the NenuFAR radio telescope observing in the $z \sim 16-27$ redshift range.

NenuFAR is a new phased array radio interferometer located in Nançay (France), aiming for statistical measurement of the 21-cm signal fluctuations from the Cosmic Dawn [5]. The NenuFAR interferometer currently consists of 56 operational mini arrays (+2 outriggers) of 19 dipoles each observing in the 10-90 MHz frequency range. Precision calibration of the NenuFAR array is a crucial observational challenge and requires high dynamic range ($\sim 10^5$) calibration to detect the signal of interest successfully.

Calibration of NenuFAR is a combination of various steps that include high-accuracy bandpass calibration to calibrate the less-smooth frequency bandpass of the instrument and mitigation of cable reflections; accurate peeling of bright sources Cas A, Cyg A and Vir A that may leak to the main field of view through grating lobes; direction independent and dependent calibration. Here we discuss various methods that we utilize for different calibration steps such as combined use of bright calibrator observations and auto-correlations for precise bandpass calibration, use of available diffuse and compact source sky-models for DI and DD calibration.

References

[1] J. D. Bowman, A. E. E. Rogers, R. A. Monsalve, T. J. Mozdzen, and N. Mahesh, "An absorption profile centred at 78 megahertz in the sky-averaged spectrum," *Nature*, vol. 555, no. 7694, pp. 67–70, Mar. 2018, doi: 10.1038/nature25792.

[2] R. Barkana, "Possible interaction between baryons and dark-matter particles revealed by the first stars," *Nature*, vol. 555, no. 7694, pp. 71–74, Mar. 2018, doi: 10.1038/nature25791.

[3] A. Fialkov and R. Barkana, "Signature of excess radio background in the 21-cm global signal and power spectrum," *Monthly Notices of the Royal Astronomical Society*, vol. 486, no. 2, pp. 1763–1773, Jun. 2019, doi: 10.1093/mnras/stz873.

[4] A. Fialkov, R. Barkana, and A. Cohen, "Constraining Baryon–Dark-Matter Scattering with the Cosmic Dawn 21-cm Signal," *Phys. Rev. Lett.*, vol. 121, no. 1, p. 011101, Jul. 2018, doi: 10.1103/PhysRevLett.121.011101.

[5] P. Zarka, J. N. Girard, M. Tagger, and L. Denis, "LSS/NENUFAR: THE LOFAR SUPER STATION PROJECT IN NANÇAY," *SF2A-2012 : Proc. Annual meeting of the French Society of Astronomy and Astrophysics, Eds. : S. Boissier, P. de Laverny, N. Nardetto, R. Samadi, D. Valls-Gabaud and H. Wozniak*, pp.687-694, 2012.