Modelisation of the 21cm signal from the Cosmic Dawn and the Reionization

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Context : The very first sources of light (stars and active galactic nuclei) appeared a few hundred million years after the Big-Bang during *the Cosmic Dawn*, and initiated the *Cosmological Reionization.* During these epochs, the UV and X-ray radiation of these first sources ionized and heated the cosmic hydrogen, leading to a Universe essentially devoid of atomic hydrogen one billion years after the Big-Bang, around a redshift z=6. This process is driven by the cosmological buildup of large scale structures and the small scale physics of the formation of the first galaxies : its study is therefore extremely promising to improve our understanding of the physics of the very first structures and their cosmological context.

While observationnal probes of the latest stages (z<10) of the process exist (Ly-A forest, CMB, deep galaxy surveys), they only provide a crude or biased view of its development. Furthermore, the Cosmic Dawn (z>15) is essentially out of reach of current observational capabilities. A notable exception is the EDGES result [1] with a claim of a strong detection of a 21cm radio signal produced by the diffuse cosmic gas excited by the radiation background of the first stars. This detection, if confirmed, is completely at odds with our current understanding of the physics at play during these times as it reveals a very cold cosmic gas, whereas cooling channels are inexistent in the primeval Universe.

Our view of these times is about to radically change with the next generation of low-frequency radio observatories, that will capture the 21cm radio emission of the intergalactic gas at these times. For example SKA [2], whose construction is to start in 2023 in Australia and South Africa, will be able to map the hydrogen being 'lit up', heated and ionized from the Cosmic Dawn until the end of Reionization, providing a wealth of informations on the first sources and the transforming intergalactic medium. Beforehand, SKA-precursors, such as NenuFAR, located in France, will at least put detection limits on this emission and at best confirm or the existence of the EDGES signal.

PhD Project : For the last decade, we have been developping in Strasbourg state-of-the-art cosmological simulations codes to model the Reionization and the Cosmic Dawn [3,4]. We are also member of the SKA science working group on the Reionization and members of the 'Cosmic Dawn' Key Science Program of the NenuFAR observatory, that is currently acquiring 1300h of observation of the North Celestial Pole to probe z>15 epochs. In this context, we are currently developping methods to forecast the 21cm radio signal from our simulations, ultimately including foregrounds and instrumental nuisance. We are also investigating statistical methods to infer the physical parameters from the 21cm data, using our mock observations, including ones using machine learning, scattering transforms or topological caracterization. Depending on the PhD student own interests, he/she will contribute to these developments, on simulations, on the 21cm forecast from simulations or on the associated statistical analysis. This work will be done in the context of the growing implication of the French community in the SKA Observatory (joined by France early 2021) and will involve notably collaborations with scientists of the Observatoire de Paris and ENS, stronlgy involved in the french participation to the instrument and its precursor NenuFAR.

[1] Bowman, J. D., Rogers, A. E. E., Monsalve, R. A., et al. Nature, 555, 67, 2018
[2] Mellema, G., Koopmans, L. V. E., Abdalla, F. A.,., et al., Exp. Astronomy, 36, 235, 2013
[3] Aubert, D., Deparis, N., Ocvirk, P., Shapiro,., et al., ApJL, 856, L22, 2018
[4] Ocvirk, P., Gillet, N., Shapiro, P. R., Aubert, D., et al., MNRAS, 463, 1462, 2016