Observations of the redshifted 21 cm line with the SKA and its pathfinders: from cosmology to cosmic reionization

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When and how did the first stars and galaxies form? How did they grow and interact with the surrounding intergalactic medium (IGM)? How did they ionize it?

These remain paramount, open questions in modern cosmology. Observations of the cosmic microwave background and absorption spectra from distant quasars suggest that the intergalactic medium was reionized (after its recombination at $z \sim 1100$). Cosmological simulations suggest that the first stars appeared at $z \sim 30$-35, when baryons collapsed into the first dark matter halos. This epoch remains, however, largely unknown and models of galaxy formation and evolution are largely unconstrained, even in the "JWST era".

The 21 cm line emitted from neutral Hydrogen is one of the most promising probes of the high redshift universe, both of the Epoch of Reionization (EoR; when the intergalactic medium was ionized by the first luminous structures) and the Cosmic Dawn (CD; when the first stars and galaxies formed). After reionization, the 21 cm line remains a premiere cosmological probe, allowing to map the growth of structures through the intensity mapping technique and, ultimately, to measure baryonic acoustic oscillations and non-gaussianities in the $0.1 < z < 2$ range.

These goals are among the prime science cases of the Square Kilometre Array Observatory (SKAO; https://www.skao.int/en), the next generation radio interferometer (and the largest to be built), and, in the time frame of this PhD project, the SKAO will deliver its first science observations. SKAO pathfinder telescopes like HERA, uGMRT and MeerKAT have active observing programmes to study reionization and cosmology with the 21 cm line.

The goal of the PhD project is to analyze 21 cm observations taken with SKA pathfinder telescopes and initial SKAO observations in order to improve upper limits in the 21 cm signal (or detect it!), in particular:

- the student will work on HERA (https://reionization.org/) and uGMRT proprietary data with the aim to measure the evolution of the IGM neutral fraction and temperature in the $6 < z < 12$ range. In particular, the student with explore novel techniques to separate the 21 cm line from foregrounds using closure phase quantities and new 21 cm absorptions observations against high redshift sources;

- The student will also become part of the MeerKLASS collaboration (https://meerklass.org/) and use MeerKAT observations to measure the 21 cm signal in the $0.1 < z < 2$.

The student will use the first SKAO science data (expected to come in 2027-2028) to chase the Nobel-award science goal to detect the redshifted 21 cm line.