First steps towards the observation of the Epoch of Reionization with the Square Kilometre Array

Supervisors: Gianni Bernardi, Jader Monari

The study of when/how the first stars and galaxies formed, how they grew and interacted with the surrounding intergalactic medium and, ultimately, ionized it, is one of the 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 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 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). The Square Kilometre Array (SKA), in particular, is currently under construction and, once completed, it will be the largest radio interferometry ever built. One of its main goals is indeed the characterization of the EoR and CD through the observations of the 21 cm line from the intergalactic medium - a signal that still remains undetected so far. At the time of writing, the first SKA station has been deployed and commissioning activities started in order to characterize the telescope performances. Approximately twenty SKA stations are expected to be available at the end of 2025-mid 2026, allowing for the first steps in the observations of the EoR and CD.

The goal of the PhD project is to analyze the first 21 cm observations taken with the SKA, in particular:

- the student will work on the calibration of the array and the foreground characterization. The candidate will test and develop calibration methods and foreground separation techniques that are essential to observe the 21 cm signal, whose intensity is a few orders of magnitude larger than the Galactic and extragalactic foreground. The candidate will expect to produce the first upper limits on the power spectra of the 21 cm signal in the $5 < z < 35$ range with the SKA;
- the student will use the SKA observations to place the most stringent upper limits on the CD signal, i.e. the 21 cm emission at $z > 15$. In 2018, Bowman et al. claimed the first detection of the 21 cm signal as a sky-averaged signal, with an anomalously high

intensity that calls for non-standard physics in the 21 cm simulations. This result still requires independent confirmation and the SKA observations will provide the best sensitivity to confirm or reject such claim.