The ionization bubbles in the early Universe

After the beginning in the big bang, the Universe cooled as it expanded. At a redshift of approximately 1100, the hydrogen recombined and cosmic microwave background (CMB) photons were emitted. Thereafter, the Universe became neutral and dark, as it entered into the so called `Dark Ages', that continued up until a redshift of about 20, when the first stars and galaxies came into existence. These first sources produced ionizing photons that (re-)ionized the surrounding neutral hydrogen. The ionized regions thus created, also known as HII bubbles keep on expanding with time as they eat through (ionize) the neutral hydrogen in the Universe. The neutral hydrogen, however, has a characteristic signal at very low frequencies that is known as the 21 cm spin-flip (hyperfine) line. By detecting this redshifted line provides a probe of the sizes of diminishing neutral hydrogen islands (and conversely that of the sizes of expanding HII bubbles).

Research Field
Cosmic reionization/gas dynamics

Project Suitability
Honours
Masters

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The Square Kilometer Array (SKA) will measure the 21 cm signal precisely.
The ionized HII bubbles created by stellar populations in first galaxies expand as they are fuelled by ionizing photons generated during the lifetime of stars, and the dynamics of their expansion can be worked out with radiative transfer equations. It is of paramount importance to know whether an expanding HII bubble will break out of the galaxy or not. However, the brute force method that envisages detailed radiative transfer calculation for every galaxy in a simulation running at cosmological scales is computationally not feasible.

The idea is to develop remedies to bypass the brute force approach, and this project therefore will undertake the modelling of HII bubbles in galaxies. The stars act as sources and the already ionized gas has a tendency to recombine that acts as sink. The aim is to derive an efficacy factor, that is, how many photons per H atom are needed to ionize a galaxy. The project can be extended to investigate the implications for 21 cm power spectrum which is one of the main objectives of major radio telescopes (MWA, SKA). A parallel study will be carried out to investigate the variation in efficacy factor for bubbles expanding in different hydrostatic density profiles.

The Epoch of Reionization and early HII bubbles: image taken from Loeb 2006