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Instrumentation and the detection of 21cm signals from the infant Universe

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The Cosmic Dawn and Epoch of Reionization define two remarkable periods in the history of the early Universe, witnessing the birth of the first generations of stars, the cosmic transition from a neutral to an ionized Universe, and the transformation of the Universe from dark to luminous. One tracer for exploring this first billion years of the Universe is the neutral hydrogen gas that fills the medium between the young protogalaxies, and has a hyperfine transition with a rest frequency of 1420 MHz (the "21 cm line"). The brightness temperature of this transition encodes key physical properties of the intergalactic medium, including gas density, neutral fraction, radiation environment, and peculiar velocity. Low-frequency radio telescopes are tuned to detect this 21 cm signal and map its spatial and temporal evolution with the aid of cosmological expansion, which allows astronomers to associate emission frequency with age of the Universe. Exploration of these key epochs is one of the primary science goals for the SKA Observatory, with the SKA-Low telescope in Western Australia able to access hydrogen signals from the early Universe [1].

Detection of this hydrogen signal has not yet been definitively achieved, due to its weakness relative to the foreground radio sky at these frequencies, the spatial and spectral complexity of the intervening radio sources in the data, and the complexity of the instrument and its response to the sky. In recent years, the importance of understanding the instrumental response has become apparent. Current and future instruments have invested resources in designing antennas and how they are placed relative to each other, and understanding the impact of their choices on the data.

I will review the single element and interferometric experiments that have attempted detection of this signal, with an emphasis on the role that instrumentation and instrumental design have played in this research field. I will then describe the SKA experiments, and how the design of the receptor and array shape and inform the analysis methodology.

References

[1] Koopmans, Pritchard, Mellema, Aguirre, Ahn, Barkana, van Bemmel, Bernardi, Bonaldi, Briggs, de Bruyn, Chang, Chapman, Chen, Ciardi, Dayal, Ferrara, Fialkov, Fiore, Ichiki, Illiev, Inoue, Jelic, Jones, Lazio, Maio, Majumdar, Mack, Mesinger, Morales, Parsons, Pen, Santos, Schneider, Semelin, de Souza, Subrahmanyan, Takeuchi, Trott, Vedantham, Wagg, Webster, Wyithe, Datta, 2015, Advancing Astrophysics with the Square Kilometre Array (AASKA14), 1