Canadian Association of Physicists
Association canadienne des physiciens et physiciennes

Contribution ID: **3694** Type: **Invited Speaker / Conférencier(ère) invité(e)**

(I) Modeling high redshift structure formation and reionization

Tuesday 20 June 2023 13:15 (30 minutes)

One of the exciting new frontiers in cosmology and structure formation is the Epoch of Reionization (EoR), a period when the radiation from the early stars and galaxies ionized almost all gas in the Universe. This epoch forms an important evolutionary link between the smooth matter distribution at early times and the highly complex structures seen today. Gaining insights into this epoch has been quite challenging because the current generation of telescopes are only able to probe the tail end of this process. Fortunately, a whole slew of instruments that have been specifically designed to study the high-redshift Universe (JWST, ALMA, Roman Space Telescope, HERA, SKA, CCAT-p, SPHEREx), are about to come online. This will unleash a flood of observational data that will usher the study of EoR into a new, high-precision era. It is, therefore, imperative that theoretical/numerical models achieve sufficient accuracy and physical fidelity to meaningfully interpret this new data. In this talk, I will introduce the THESAN simulation framework that is designed to efficiently leverage current and upcoming high redshift observations to constrain the physics of reionization. The multi-scale nature of the process is tackled by coupling large volume (~100s Mpc) simulations designed to study the large-scale statistical properties of the intergalactic medium (IGM) that is undergoing reionization, with high-resolution (~ 10 pc) simulations that zoom-in on single galaxies which are ideal for predicting the resolved properties of the sources responsible for it. I will briefly discuss applications from the first set of papers, including predictions for high redshift galaxy properties, the galaxy-IGM connection, Ly-α transmission and back reaction of reionization on galaxy formation. I will then highlight the potential for using line intensity mapping of spectral lines originating from the interstellar medium (ISM) of galaxies and the 21 cm emission from the neutral hydrogen gas in the Universe to constrain galaxy formation and cosmology. I will finish by highlighting how this numerical framework, coupled with accurate observational predictions promises important and potentially transformative changes in our understanding of the primitive Universe.

Keyword-1

Early Universe

Keyword-2

Reionization

Keyword-3

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Session Classification: (DTP) T3-4 Hot Topics From Theory Made Accessible | Sujets chauds de la théorie rendus accessibles (DPT)

Track Classification: Symposia Day (Tues. June 20) / Journée de symposiums (mardi, le 20 juin): Symposia Day (DTP - DPT) - Hot Topics From Theory Made Accessible | Les sujets chauds de la théorie rendus accessibles