Contribution ID: **43** Type: **not specified**

Modelling GHZs in cosmological-scale galaxy evolution simulations

Thursday 14 November 2024 10:45 (30 minutes)

Theoretical studies of galactic habitable zones (GHZs) have predominantly focused on the Local Neighbourhood, Milky Way, or the Local Group. However, with the establishment of the latest wave of cutting-edge observational instrumentation, GHZ indicators can now be observed in large numbers of other galaxies out to much further distances that ever before. This highlights the need for simulations that extend beyond our Local Group, to model galaxy chemical evolution (GCE) and the formation of GHZs across a full range of galaxy types and epochs. Such simulations have become all the more important following recent indications from JWST and ALMA that the metallicity in high-redshift galaxies (z~8) is comparable to that seen at intermediate redshift (z~2), and that in-situ dust formation should proceed rapidly in the interstellar medium. These developments open-up the possibility of life in the very early Universe and in the outskirts of local galaxies. In this talk, I will present the latest progress in the study of GHZs using cosmological-scale galaxy evolution simulations, and will signpost exciting future developments in this field.

First, I will outline the three main types of cosmological-scale simulations used, namely analytic, semi-analytic, and hydrodynamical. I will discuss each of their advantages and disadvantages for GHZ studies.

Second, I will provide an overview of the work already done on studying habitability in cosmologicalscale simulations over the last ~10 years, including the typical assumptions made about chemical enrichment and planet formation.

Finally, I will discuss future developments in this field, with a particular focus on the L-GALAXIES semi-analytic simulation. L-GALAXIES includes a sophisticated GCE model which tracks the formation and evolution of stellar populations, their nucleosynthesis of all the heavy chemical elements, and the subsequent ejection of these elements into the surrounding gas. L-GALAXIES now also includes models for binary stellar evolution and dust production & destruction, which are crucial intermediate stages in the formation of habitable planets. The next step is to implement models for (a) complex molecule formation and (b) sterilisation from rare sources such as AGN and GRBs. This will allow us to probe GHZs within galaxies across all space and time in greater detail than ever before.

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Session Classification: Session-5: Galactic Chemical Evolution: link with the Galactic Habitable Zone