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Non-linear Cosmological Structure Formation: Outstanding Questions and Future Prospects

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While the fundamental parameters of cosmology, such as the energy density of dark energy, dark matter, and baryons are now known to considerable precision, the precise interplay between these sectors in the “late” Universe is still the subject of extensive research. Nowhere is this more intense than in the study of non-linear structures, such as galaxies, clusters of galaxies and even the first stars. The absence of analytical solutions, and the need for detailed predictions to compare with observations, has precipitated almost an exponential increase in the use of simulation methods in research on cosmological structure formation. Much of the focus of these explorations is on understanding how luminous matter, most often stars although radiative processes in gas are also considered, evolves within this coupled gravito-radiation-hydrodynamics problem. To make matters more complex, in last ten years it has also become clear that “supermassive” black holes have a significant role to play in the evolution of the largest galaxies. I will present a non-specialist overview of the current state of the field and highlight some of the truly challenging research questions currently being tackled, as well as the prospects for solving them.

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