Research Plan

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Project title:
Galaxy formation with newly-developed mesh-free hydrodynamic simulation methods

The initial conditions for structure formation in the Universe are well constrained from measurements of the anisotropies in the cosmic background radiation. Currently, we however have only a sketchy view of the galaxy formation since it is essentially a nonlinear process where many physical processes —such as the nonlinear growth of the initial density fluctuations, radiative cooling of the gas, star formation, and associated energy feedback from hot stars and supernovae, growth of supermassive blackholes—, all playing crucial roles and constructing a complex network.

Since a huge dynamic range is required to follow galaxy formation numerically, Lagrangian fluid dynamics methods, in particular smoothed particle hydrodynamics (SPH), have been widely used in this field. Recently, however many problems of SPH have been reported, e.g. [1], [2]. In this project, we therefore employ newly-developed mesh-free hydrodynamic methods [3], in order to minimize problems originated by the inaccuracy of hydrodynamics and to see their performance for simulating galaxy formation.

The tasks to be performed by the applicant are:
1. Study and understand the basics of galaxy formation
2. Implement physics needed to study galaxy formation
3. Run simulations on massively parallel supercomputers and analyze their outcomes

[1] Okamoto et al. Momentum transfer across shear flows in smoothed particle hydrodynamic simulations of galaxy formation. MNRAS. Volume 345, Issue 2, pp 429-446. (2003)
[2] Agertz et al. Fundamental differences between SPH and grid methods. MNRAS. Volume 380, Issue 3, pp 963-978. (2007)
[3] Hopkins. GIZMO: A new class of accurate, mesh-free hydrodynamic simulation methods. Submitted to MNRAS. arXiv:1409.7395. (2014)