Structure Formation in the Universe: A Study of Interacting High Density Regions

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Cosmology is the study of the evolution of the Universe from the Big Bang to the formation of galaxies. This evolution can be described using equations that model both the Universe's overall expansion and the gravitational collapse of dense regions into galaxy clusters. Simple models assume that these higher density regions will collapse in perfect spherical symmetry to form the dark matter halos where this happens. However, realistic scenarios do not have this symmetry. This is due to the random fluctuations of temperature and energy in the aftermath of the Big Bang. A fully realistic model can best be understood using computer simulations, but we can gain deeper insight by analytically studying a simple model with broken symmetry. In this work, we consider how two distant spherical regions interact with each other. The details of the gravitational collapse involve equations describing the expansion of the Universe, the fluid dynamics of matter, the effects of gravitational force, and conservation of energy. For a single spherical region, a known solution to these equations describes how the excess density grows with time. Our work models the small deviations from this ideal spherical case by using a linear perturbation of those symmetric equations. In doing so, this can give insight into how these dense regions interact and give rise to cosmic structures. Our improved understanding of these interactions is another step toward a complete picture of how our observed Universe came to be.