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ORIGINAL ARTICLE

Lee yang theory for cosmological many body problem

Mohammad S. Khan · Manzoor A. Malik

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Abstract We study the phase transition in a gravitating system by analyzing grand canonical partition function as a function of complex fugacity. We extend the Yang-Lee theory to study phase transitions in the gravitational galaxy clustering of galaxies having a variety of masses. This generalizes our previous work based on the same theory for the single-component system to a multicomponent system. We find that galaxy clustering is sensitive to masses and number densities of individual galaxies at early stages while at later stages collective behavior of the particles is more pronounced. This validates our earlier work obtained from different considerations.

Keywords Cosmology: theory · Galaxies: clusters: general · Gravitation · Large scale structure of universe · Methods: analytical

1 Introduction

The cosmological many-body problem deals with a very large number of particles clustering under their mutual gravitational interaction in a statistically homogeneous slowly expanding universe. These two conditions (statistical homogeneity and slow expansion) can be utilized to treat the system in equilibrium over a wide range of spatial scales. Observations indicate that while the large scale distribution of galaxies appears to be essentially uniform, the small scale distribution is appreciably influenced by the well known tendency towards clustering. The universe is isotropic and homogeneous on scales of 100–200 Mpc, whereas on smaller scales its fundamental units (galaxies) cluster together to form groups, clusters and even super clusters.

Initially, we consider universe consisting of particles (galaxies) having uniform density distribution and refer this as one phase which corresponds to the uncorrelated particle situations. At about one initial Hubble expansion, a gravitational graininess builds up and small groups and clusters of groups are formed. Most of these groups are gravitationally bound and form the nuclei around which more galaxies will cluster. At a later stage clusters shrink and become denser and number of field galaxies decreases. This depletion in some places leaves large regions completely devoid of galaxies and the process is reminiscent of a phase transition.

For the cosmological many body problem, we make use of Lee-Yang (1952a, 1952b) theory which gives us a very powerful method to analyze phase transitions. The theory has been applied to study phase transitions in both equilibrium and non equilibrium systems (Evans et al. 1995a, 1995b; Arndt et al. 1998; Derrida et al. 1993). A hallmark of many non-equilibrium systems is the absence of detailed balance and the support of stationary states with non-vanishing currents. Hence, these systems build a larger class than respective equilibrium systems and phase transitions may appear under less restricted conditions. For example, it is known that spontaneous symmetry breaking and a first

M.S. Khan · M.A. Malik (✉)
Department of Physics, University of Kashmir, Srinagar 190006, India
e-mail: manzoor@iucaa.ernet.in

M.S. Khan
e-mail: mskhan62@rediffmail.com

M.S. Khan
Department of Physics, GDC Bemina, Srinagar 190018, India

M.A. Malik
Inter-university Centre for Astronomy and Astrophysics, Pune 411007, India