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Analytically ”Solving” the N-Body Problem

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It is common physics knowledge that the N-body problem cannot be solved analytically for $N > 2$. Indeed, it has been proven that for general initial conditions the particle trajectories can not be expressed in terms of elementary functions. However, if we consider different observables, e.g., density n-point functions, this theorem does not directly apply. Moreover, when working with such collective quantities it is natural to work with statistical initial conditions, rather than explicit ones. As it turns out, the integration over such a probability distribution of initial conditions can yield a significant simplification.

Putting these two ideas together in the framework of Kinetic Field Theory, we “solve” the N-Body Problem for $N \to \infty$ for initial conditions resembling those of cosmic matter at recombination. Utilizing a new diagramatic approach to perturbative calculations within Kinetic Field Theory, we expand the expression for the matter fluctuation power spectrum in the particle interactions and the initial particle correlations. This double-expansion allows us to obtain expressions which can be evaluated reasonably easily. Keeping only linear initial particle correlations and going to high order in the particle interactions, we reproduce the linear growth of the matter fluctuation power spectrum on all scales from microscopic Newtonian particle dynamics alone. Contributions from second and higher order initial particle correlations are currently being investigated and it is expected that these non-linear initial correlations yield non-linear structure growth.

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