Origin of structure in the early universe from gravitational radiation

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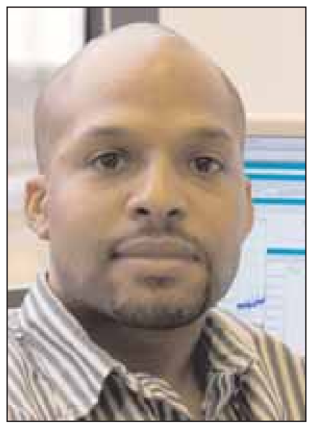
ABSTRACT—Very few cosmological models involve gravitational radiation, although these oscillations may have had an important effect on the development of our universe. This work investigates the possibility that the interaction between the primordial plasma and gravitational radiation fields had an impact on cosmic structure formation.

PREMISE OF PROJECT



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It is well established in standard cosmological theory that fields of homogenous high-energy plasma and gravitational radiation populated the early universe. However, relatively little work has been done that examines the impact of the interaction between these fields on the evolution of the universe. For example, work by Kodama and Sasaki[1] examined how scalar, vector, and tensor perturbations directly resulted in density fluctuations but neglected the dynamical effects caused by these perturbations. Adding dynamical effects such as turbulence will significantly reduce or eliminate the role of cold dark matter in early universe structure formation. We are therefore working to examine the effects of primordial gravitational waves on structure formation in the early universe through dynamic interactions with the plasma field. For this study, we will examine the effects of both isotropic and birefringent gravitational waves on the plasma field. Based on an extensive literature search, a study such as this has never been attempted.

Our hypothesis is that general relativistic magneto-hydrodynamic (GRMHD) turbulence contributed significantly to structure formation in the early universe. The goal of this work is to identify and evolve the initial conditions for the standard model that led to the development of the observed mass concentration in clusters and super-clusters of galaxies. The initial conditions are selected so that alignment with observed values of the spectrum and isotropy of the cosmic background radiation are preserved as the solution evolves forward in time.

GOALS OF THE PROJECT

Our primary goal is to model the homogenous plasma described by the standard model of cosmology on top of a perturbed Freidman-Robertson-Walker (FRW) spacetime. For this work, we use Cactus, an open-source framework for computational physics. We use this tool to develop a cosmic simulation program capable of recreating many of the conditions found in the early universe shortly after the inflationary period. This code will solve Einstein's equations given these initial conditions and evolve a set of coupled general relativistic and magneto-hydrodynamic equations. This GRMHD code can be used to solve a variety of astrophysics problems, but for this project, we will focus on the problem of cosmic structure formation. As a result, we expect to simulate the formation of certain structures from an initially homogenous plasma field and a field of gravitational radiation. These structures include: magnetic fields, density and temperature variations, and secondary gravitational waves. The spectrum and polarization of the resulting gravitational waves should be observable by future gravitational wave observatories such as LISA and advanced LIGO.

RESULTS

So far, we have managed to successfully test our code against approximate analytic solutions for a homogenous magnetofluid perturbed by a standing monochromatic plane gravitational wave as calculated by Duez et al.[2,3] We are currently working on simulations of a system of standing plane waves moving in all spatial directions and have noticed what appears to be an increase in the mean density of the system, as predicted by our theory. This may be the first evidence of cosmic structure formation resulting from GRMHD interactions. Our next step is to further analyze the results and begin simulations involving an expanding FRW spacetime. In addition, we developed and published predictions about the spectrum of relic-birefringent gravitational waves.

REFERENCES

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GRMHD–Rafael de la Torre (l.) and David Garrison review the results of simulations of standing plane waves. These simulations, coupled with further studies, will help construct a model of cosmic structure formation. de la Torre earned his M.S. in physics from the University of Houston-Clear Lake in 2007.

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PUBLICATIONS

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PRESENTATIONS

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PROPOSALS

Garrison, D. Cosmic structure formation from gravitational radiation, The Research Corporation, \$53,684 (June 1, 2007–Aug. 31, 2008) (*not funded*).

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