Future Research Proposal

by Juan F. Lara, Center for Relativity, UT-Austin

For my dissertation I have written my own big bang nucleosynthesis code for a model of the universe with an inhomogeneous baryon density. My IBBN code can calculate the mass fractions of 68 different isotopes for any value of the baryon-to-photon ratio η_{10} that I input into it. The data I comment on in my dissertation refers to one specific baryon distribution: A spherically symmetric region consisting of a high density inner core and a low density outer layer, with the universe pictured as a lattice of these spherical regions. This way I can characterize the inhomogeneity with one dimension, the spherical layers' radii r. I show results for various sizes (distance scales r_i) of the spherically symmetric regions, but the boundary r_b between high and low density regions is always half of r_i. In my dissertation I have contour maps that show the produced mass fractions of each isotope as functions of η_{10} and r_i. But in my sections where I explain how the mass fractions evolve over time I look only at the results for η_{10}. For my dissertation I use my 1-dimensional IBBN code to look at the specific case of spherically symmetric inhomogeneity with a boundary $r_b = 0.5r_i$, and I explain my results for the case of $\eta_{10} = 3.0$ thoroughly.

Time constraints in finishing my dissertation allow me to look only at these specific parameters. After the dissertation, I want to explore all the parameters that my IBBN allows me to do. In my contour maps of isotope abundances I see abundance results at other values of η_{10} similar to my results at $\eta_{10} = 3.0$. I can use my $\eta_{10} = 3.0$ results to infer what is happening for those other values. But after the dissertation I want to determine explicitly the reasons for this similar behavior, and explain why some differences in the shape of the contours arise depending on η_{10}. I would also like to see my code's results for different boundaries between the high density and low density regions. Papers such as (Kainulainen, et al, 1998) show contour maps where the contours contract or expand depending on the value of r_b. I can demonstrate those changes in contour maps myself with my own code. Also, the neutron diffusion equation that I solve at each timestep is where the geometry of the inhomogeneity comes into the code. For now the code is written for spherical symmetry. But I can easily modify it to get results for planar symmetry and cylindrical symmetry as well.

My model of a high density core and a low density outer layer corresponds to the inhomogeneity that would arise if the transition from a quark-gluon plasma to individual hadrons was a first order phase transition. My code can also show results for a low density core and a high density outer layer. This situation corresponds to inhomogeneities arising from an electroweak phase transition. I would like to report on this different inhomogeneous model in the future. Speaking of the phase transitions I'd also like to look at trying to explicitly connect my inhomogeneous model with these models of the formation of nucleons, those models now being poorly understood. Perhaps I could find someone who's worked in baryogenesis and make a code that runs through both baryogenesis and nucleosynthesis.

The symmetries mentioned above enable me to describe my inhomogeneities using one spatial dimension. I would like to attempt BBN codes for more general inhomogeneities, inhomogeneities that require two or even three dimensions to describe. With more dimensions comes computer codes that require much more CPU time. But the development of nucleosynthesis research has been a steady rise in the abilities that a code can do, due to computers requiring less and less time to run. Over time people gain the ability to run codes with larger nuclei networks, and including more physical effects that had been to difficult to calculate before. I then want to assess the feasibility of a 2-D or 3-D inhomogeneous code, and write such codes when they become doable.

The neutrino heating effect is one such physical effect that codes now can calculate in reasonable time. I have been able to put the effect in both my standard code and my inhomogeneous code. My results, though have been the same in both codes. The mass fraction of ^{4}He in both codes has an increase of around 0.06 % that changes little regardless of the values of η_{10} and r_i in the IBBN code. But the diffusion equation uses an equation for the diffusion coefficient between neutrons and electrons that has an integral that depends on the matrix element for neutron/electron collisions. As of now I don't calculate that integral explicitly. I would then like to understand my expression for the diffusion coefficient more thoroughly. I may have to modify it further to have a more accurate accounting for the heating effect's influence on neutron diffusion.

References

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