Formation of primordial helium in the early Universe

Tamaz Kereselidze[1], Zaal Machavariani[1,2] and Irakli Noselidze[3]

[1]Faculty of Exact and Natural Sciences, Tbilisi State University, Chavchavadze Avenue 3, 0179 Tbilisi, Georgia
[2]Doctoral School, Kutaisi International University, Youth Avenue, 5th Lane, 4600 Kutaisi, Georgia
[3]School of Science and Technology, University of Georgia, Kostava Str. 77a, 0171 Tbilisi, Georgia

Because of the larger ionization potential, $HeII$ recombined before H. It was assumed that as for H, direct formation of the $HeII$ in the ground state by recombination was not efficient, since $HeII$ were immediately ionized by the released energetic photons. More efficient was recombination through the intermediate state with $n=2$. The main mechanism of the formation of $HeII$ was thus two-photon decay of the 2s state. For $HeII$ the probability of $2s\to 1s$ decay is $W_{2s\to 1s}=526.5\,s^{-1}$; the rate of this process is $N_{2s}W_{2s\to 1s}$, in which N_{2s} is the population of the $2s$ -level. Since $N_{2s}W_{2s\to 1s}$ is greater than the recombination rate of electrons in the $2s$-level, the electrons do not detain in this level and rapidly transit into the ground state. This assumption is supported by the numerical calculations [1], which show that the $HeIII\to HeII$ recombination proceeds in fact according to the Saha-Boltzmann law. Obviously, the influence of the nearest neighboring ion $HeIII$ on the process will change the Saha-Boltzmann scenario of recombination.

The physics of HeI recombination differs from that for $HeII$ and H recombination because of its different atomic structure [2]. Unlike early calculations where helium was treated as a three-level atom, modern numerical calculations of cosmological recombination use a multi-level atom model where the fine structure of levels is taken into account. This allows both the singlet and triplet states of helium to be taken into account in the calculations. It was shown that HeI recombination takes place in a mode that is very different from the Saha-Boltzmann equilibrium mode [3-6].

This work was supported by Shota Rustaveli National Science Foundation of Georgia (SRNSFG); grant #STEM-22-308.

REFERENCES

[1] Seager S., Sasselov D. D., Scott D., 2000, Astrophys. J. Suppl. 128, 407
[2] T. Kereselidze, Z. Machavariani, I.Noselidze 2022 arXiv:2209.04644
T. Kereselidze, Z. Machavariani, I.Noselidze GESJ (submitted)
[3] Switzer E. R., Hirata C. M., 2008, Phys. Rev. D 77, 083006
[4] Wong W. Y., Moss A., Scott D., 2008, MNRAS, 386, 1023
[5] Grin D., Hirata C. M., 2010, Phys. Rev. D 81, 083005
[6] Chluba J., Thomas R. M., 2011. MNRAS, 412, 748