# Non-Extensive Statistics Solution to the Cosmological Lithium Problem

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First proposed in 1946 by George Gamow [1], the hot Big-Bang theory is now the most widely accepted cosmological model of the universe. The theory has been vindicated by the observation of the cosmic microwave background, our emerging knowledge on the large-scale structure of the universe, and the rough consistency between calculations and observations of primordial abundances of the lightest elements in nature. The primordial Big-Bang Nucleosynthesis (BBN) began when the universe was 3-minutes old and ended less than half an hour later when nuclear reactions were quenched by the low temperature and density conditions in the expanding universe. Big Bang nucleosynthesis (BBN) theory predicts the abundances of the light elements D, $^3$He, $^4$He and $^7$Li produced in the early universe. The primordial abundances of D and $^4$He inferred from observational data are in good agreement with predictions, however, the BBN theory overestimates the primordial $^7$Li abundance by about a factor of three [2,3,4,5]. This is the so-called “cosmological lithium problem”. Solutions to this problem using conventional astrophysics and nuclear physics have not been successful over the past decades, probably indicating new physics during the era of BBN [6,7].

We have investigated [8] the impact on BBN predictions of adopting a generalized distribution to describe the velocities of nucleons in the framework of Tsallis non-extensive statistics [9]. This generalized velocity distribution is characterized by a parameter $q$, and reduces to the usually assumed Maxwell-Boltzmann distribution for $q$ = 1. We find excellent agreement between predicted and observed primordial abundances of D, $^4$He and $^7$Li for $1.069 \le q \le 1.082$, which is shown in Fig. 1, suggesting a new solution to the cosmological lithium problem.

We encourage studies to examine sources for departures from classical thermodynamics during the BBN era so as to assess the viability of this mechanism. Furthermore, the implications of non-extensive statistics in other astrophysical environments should be explored as this may offer new insight into stellar nucleosynthesis. The Tsallis statistics has already applied to the stellar distribution and dynamics in the galaxies, and enjoyed a success in the description of various phenomena induced by plasma fluctuations.

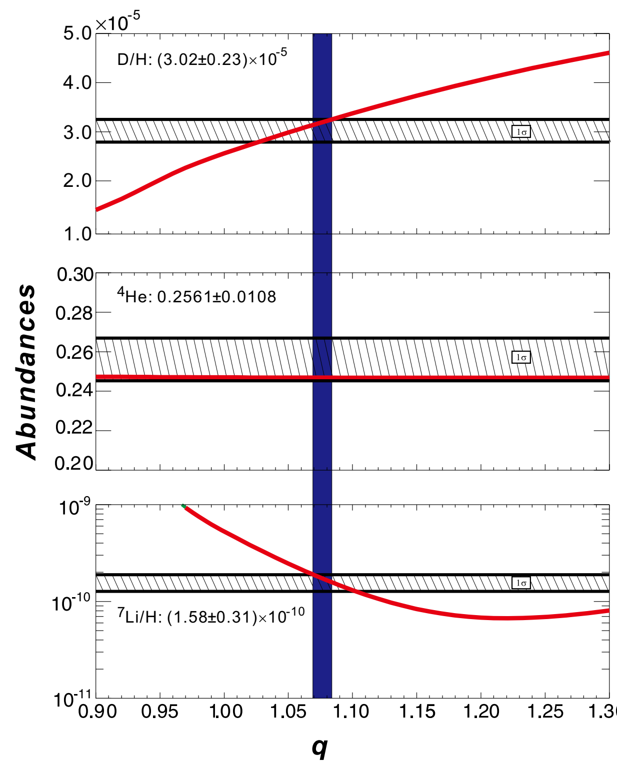


**Figure 1**: Predicted primordial abundances as a function of parameter $q$ (in red solid lines). The observed primordial abundances [10,11,5] with $1\sigma$ uncertainty for D, $^4$He, and $^7$Li are indicated as hatched horizontal bands. The vertical (blue) band constrains the range of the parameter $q$ to $1.069 \le q \le 1.082$.

## References

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