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Astronomical & Astrophysical Transactions
The Journal of the Eurasian Astronomical Society
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713453505

Cosmological thermal decoupling and primordial molecules

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Online Publication Date: 01 June 2001
To cite this Article: Puy, D. (2001) 'Cosmological thermal decoupling and primordial molecules', Astronomical & Astrophysical Transactions, 20:1, 183 - 190
To link to this article: DOI: 10.1080/10556790108208211
URL: http://dx.doi.org/10.1080/10556790108208211

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Astronomical and Astrophysical Transactions, 2001, Vol. 20, pp. 183–190
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COSMOLOGICAL THERMAL DECOUPLING AND PRIMORDIAL MOLECULES

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(Received November 13, 2000)

Primordial chemistry began, in the recombination epoch, when the adiabatic expansion caused the temperature of the radiation to fall below 4000K. The chemistry of the early Universe involves the elements hydrogen, its isotope deuterium, helium with its isotopic forms and lithium. In this contribution I will discuss the influence of the primordial molecules on the cosmological decoupling.

In the framework of the gravitational instability theory, each protostructure started as a tiny local overdensity. As long as these inhomogeneities are small, their evolution can be studied by the classical linear perturbation theory. Once the deviations become large, the linear theory is no more valid. We present the role played by these molecules on the transition between the linear regime and the non-linear regime, and show that the molecules can lead to a thermal change at the turn-around point between these two regimes.

KEY WORDS Cosmology, cosmological decoupling, primordial molecules

1 INTRODUCTION

At early times the Universe was filled with an extremely dense and hot gas. Due to the expansion it cooled below the binding energies of hydrogen, deuterium, helium, lithium which led to the formation of these nuclei (Sarkar, 1996). After this nucleosynthesis period the recombination process is not instantaneous because the electrons, captured into different atomic energy levels, could not cascade instantaneously down to the ground state. Atoms reached the ground state either through the cosmological redshifting of the Lyman α line photons or by the $2s$–$1s$ two photon process. Nevertheless the Universe expanded and cooled faster than the recombination could be completed, and small fraction of free electrons and protons remained.

The principles of calculations of the primordial recombination were mentioned initially by Shklovskii (1967), Novikov and Zel'dovich (1967). Peebles (1968) was the first to present a theory in which the very complicated recombination process is