Primordial 21cm line global signal in the Dark Ages

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Introduction

During the next decades, 21cm neutral hydrogen line will become a powerful cosmological probe [1]. As far as we know, it is especially the only known signal which could be observable during the Dark Ages. The signal intensity and shape are predicted to be strongly affected by the recombination and chemical processes, as well as the baryonic temperature modifications due to exotic interactions [2]. The precise prediction of the global signal is a crucial step for our understanding of the underlying physics [3].
It is also known that after recombination, neutral atoms and molecules are forming [4].

In this work, we developped the recombination code CHEMFAST, whose particularity is to describe the whole chemical network evolution, including molecules. It will allow us to evaluate the sensitivity of the 21cm line global signal to species abundances, or different cosmological models.

Computational methodology

The CHEMFAST code solves a stiff system of ordinary differential equations for the dynamics (temperatures and baryon density) and the chemical network (chemical reaction for every species). We resolve the whole recombination period, starting from $z_i = 10\ 000$ to $z_f = 10$.
We get the redshift evolution of each element chemical abundances (Fig. 1-2).

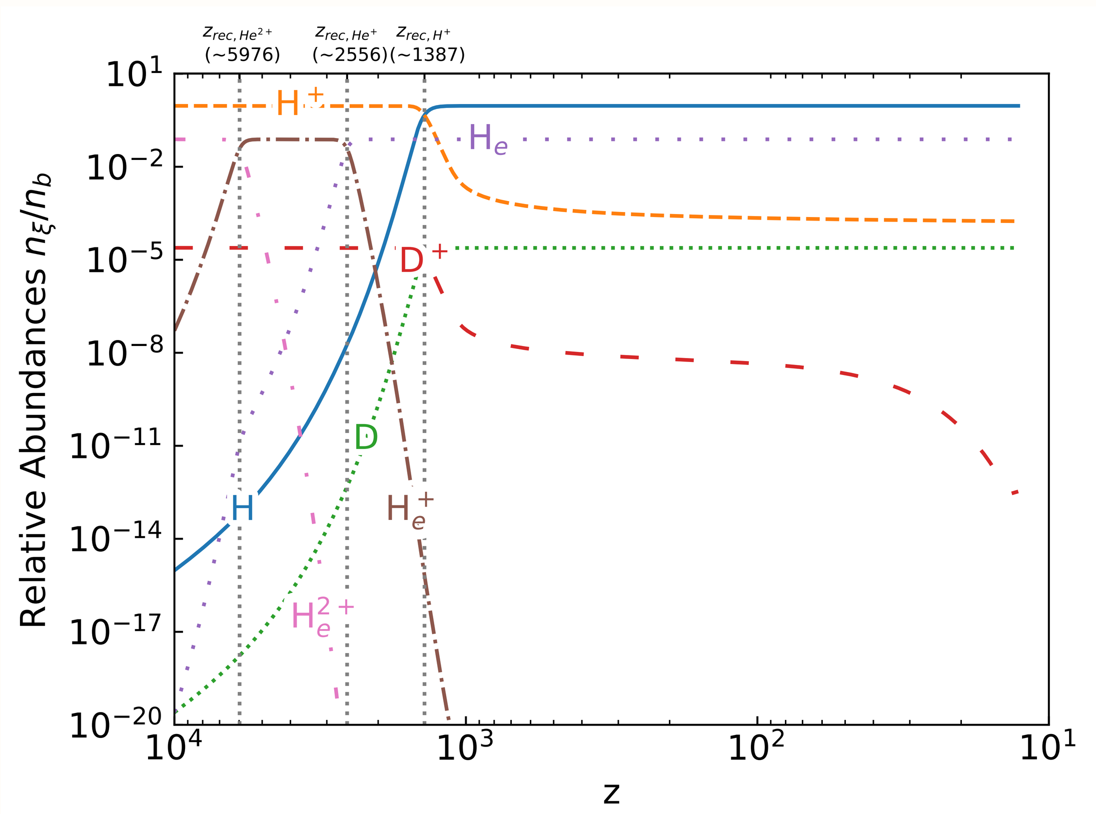

Figure 1: Abundances evolution of main atomic species during recombination. Describes precisely the recombination processes of He^{2+}, He^{+}, H^{+} and D^{+}. Recombination redshifts are considered as positions of abundance crossings.

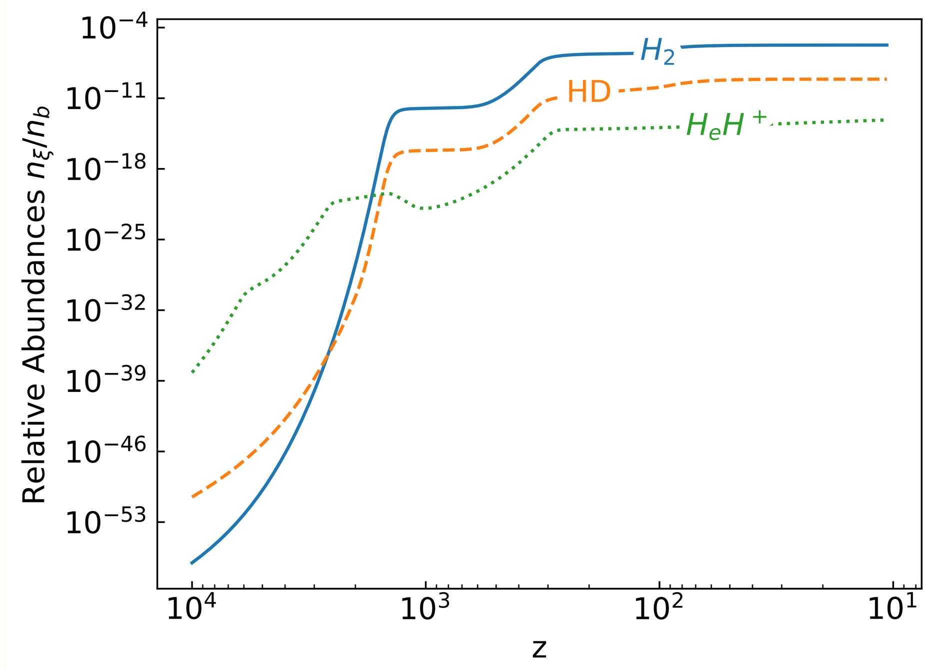

Figure 2: Evolution of the abundances of the main molecular components, starting after respecitve recombinations of atomic species.

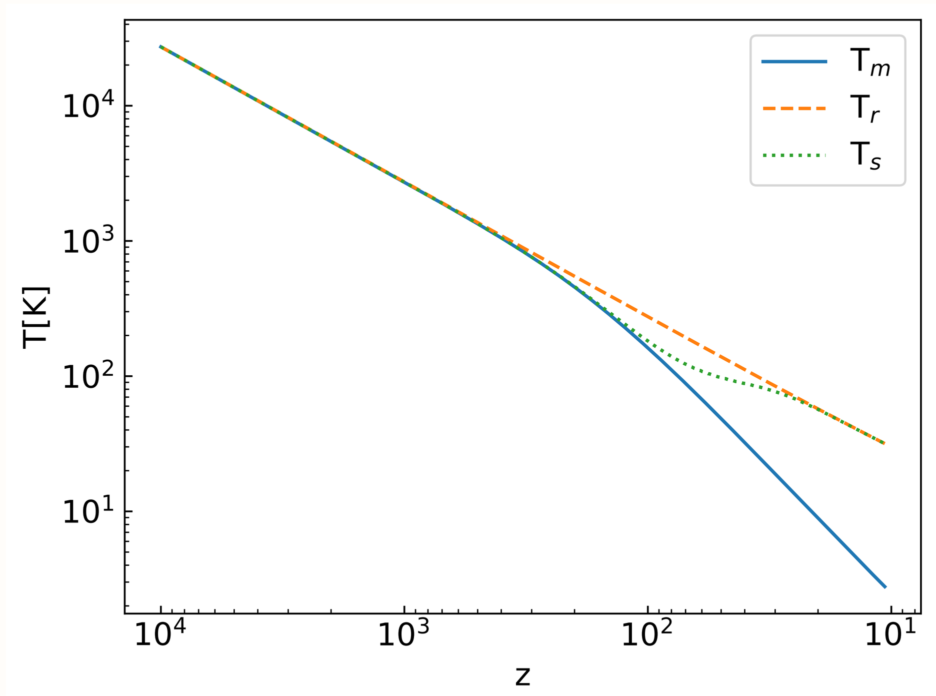

Figure 3: Baryon and radiation temperature evolution. Thermal decoupling is smoothly computed. 21cm line spin temperature behavior is shown for the Dark Ages period.

21cm line global signal

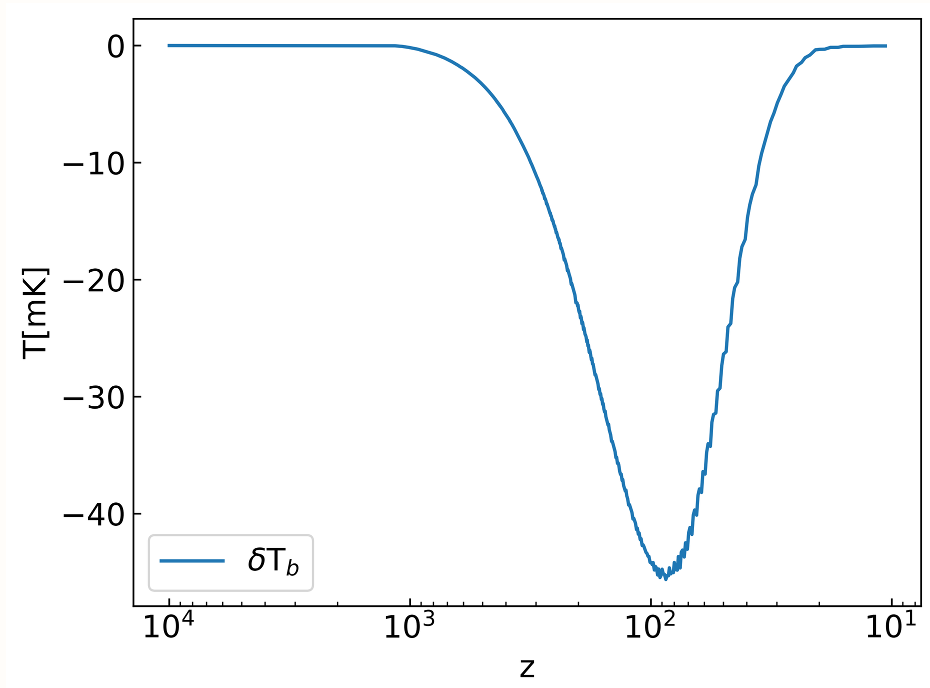

Figure 4: 21 cm line global signal in absorption during the Dark Ages, peak of $\delta T_b \sim -46$ mK around $z \sim 87$.

We added the computation of the 21cm Dark Ages signal, which has a strong dependance to the recombination process and to the evolution of baryon temperature.
We compute the spin temperature T_s [5], only considering collisionnal processes.The Wouthuysen-Field Effect [6] doesn't contribute before the beginning of reionization.
After thermal decoupling between baryons (T_m) and radiation background (T_r) temperatures , the spin temperature T_s of the 21cm line follows T_m because of the collision processes. It then relaxes to the background temperature T_r when collisions become inefficients as a consequence of the expansion of the universe (Fig 3).
All-sky differential brillance temperature is computed as :

$$\delta T_b(z) = \frac{3c^3 h_p A_{10}}{32\pi k_B \nu_{21cm}^2} \frac{n_{HI}(z)}{(1+z)H(z)} \left(1 - \frac{T_r(z)}{T_s(z)}\right)$$

Conclusion & Perspectives

- Computation of 21cm line global signal gives a absorption peak of brillance temperature around δT_b around -46 mK at redshift $z \sim 87$ (Fig. 4).
- Formation of first objects such as primordial stars lead to the mechanism of reionization. This primeval process of reionization also affects the brillance temperature (work in progress).
- Different cosmological models or exotic interactions can be included to test their observability on the global signal.

CLASS & 21cmFast codes

- We work on the interfacing of the Cosmic Linear Anisotropy Solving System(CLASS[7]) and 21CMFAST[8].
- We will use the Monte-Carlo Markov-Chain analysis tool 21CMMC[9] to look at co-varying cosmology.
- Coupled to CMB Planck data[10], it could provide us restrained constraints on cosmological parameters.

The PHONE project

- Observation of an absorption peak at $z \sim 87$ corresponds to an actual signal (i.e. $z = 0$) central frequency $\nu \sim 16$ MHz. This signal could be detected with new generation nanosatellites.
- The PHONE project (Primordial Hydrogen Observations with Nanosatellite Explorers) aims to send a nanosatellite swarm in orbit around the dark side of the moon in order to get a measure of the global 21cm line signal from the Dark Ages. This project involves french laboratories of Montpellier (LUPM, CSUm), Paris (LESIA, CENSUS) and Toulouse (IRAP).
- The project is currently in preliminary technical testing phase, particularly on test of synchronicity between two prototypes of nanosatellites.

Acknowledgements

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