Temperature evolution code - TECO

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Temperature evolution equation

$$\frac{\mathrm{d}T}{\mathrm{d}t} = -2HT + \frac{2T}{3\Delta}\frac{\mathrm{d}\Delta}{\mathrm{d}t} - \frac{T}{\sum_i X_i}\frac{\mathrm{d}\sum_i X_i}{\mathrm{d}t} + \frac{2}{3k_B n_{\mathrm{tot}}}\frac{\mathrm{d}Q}{\mathrm{d}t},$$

- first term on RHS - cooling due to adiabatic expansion;
- second term - adiabatic heating and cooling due to structure formation;
- change in the number of gas particles owing to ionizations and recombinations;
- heating and cooling rates;

Temperature evolution equation

- last term on the RHS adds all the heating and cooling rates which are expanded below:

$$\frac{\mathrm{d}Q}{\mathrm{d}t} = \sum_X \frac{\mathrm{d}Q_{\gamma,X}}{\mathrm{d}t} + \frac{\mathrm{d}Q_{\mathrm{Compton}}}{\mathrm{d}t} + \sum_i \sum_X R_{i,X} n_e n_X$$

- here the first term is the photoheating of species X={HI,HeI,HeII} from the ionizing UV background;
- the second term is the cooling resulting from inverse Compton cooling due to electrons scattering with the CMB radiation.
- the last term corresponds to the cooling rates.

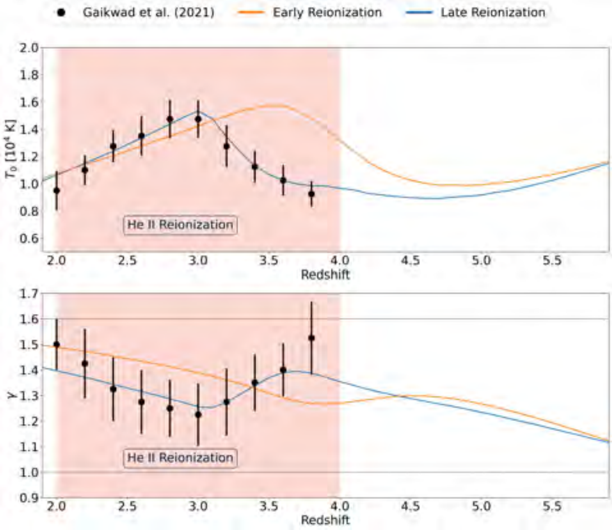
Cooling rates

Process	Species	Rate [ergs s^{-1} cm^{-3}]
Collisional excitation	H^0	$7.50 \times 10^{-19} \exp[-118348/T](1 + T_5^{1/2}) n_e n_{H_0}$
	He^+	$5.54 \times 10^{-19} T^{-0.397} \exp[-473638/T](1 + T_5^{1/2})^{-1} n_e n_{H_{He+}}$
Collisional ionization	H^0	$1.27 \times 10^{-21} T^{1/2} \exp[-157809.1/T](1 + T_5^{1/2})^{-1} n_e n_{H_0}$
	He^0	$9.38 \times 10^{-22} T^{1/2} \exp[-285335.4/T](1 + T_5^{1/2})^{-1} n_e n_{He_0}$
	He^+	$4.95 \times 10^{-22} T^{1/2} \exp[-631515.0/T](1 + T_5^{1/2})^{-1} n_e n_{He_+}$
Recombination	H^+	$8.70 \times 10^{-27} T^{1/2} T_3^{-0.2} (1 + T_6^{0.7})^{-1} n_e n_{H_+}$
	He^+	$1.55 \times 10^{-26} T^{0.3647} n_e n_{He_+}$
	He^{++}	$3.48 \times 10^{-26} T^{1/2} T_3^{-0.2} (1 + T_6^{0.7})^{-1} n_e n_{He_{++}}$
Dielectric recombination	He^+	$1.24 \times 10^{-13} T^{-1.5} \exp[470000.0/T](1 + 0.3 \exp(-94000.0/T)) n_e n_{He_+}$
Free - free	All ions	$1.42 \times 10^{-27} g_{ff} T^{1/2} (n_{H_+} + n_{He_+} + 4 n_{He_{++}}) n_e$

Recombination and collisional ionization rates

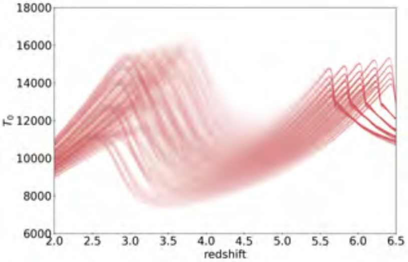
Parameter	Value
α_{H_+}	$8.4 \times 10^{-11} T^{-1/2} T_3^{-0.2} (1 + T_6^{0.7})^{-1}$
α_{He_+}	$1.5 \times 10^{-10} T^{-0.6353}$
α_{d}	$1.9 \times 10^{-3} T^{-1.5} \exp(-470000.0/T)[1 + 0.3 \exp(-94000.0/T)]$
$\alpha_{\mathrm{He}_{++}}$	$3.36 \times 10^{-10} T^{-1/2} T_3^{-0.2} (1 + T_6^{0.7})^{-1}$
Γ_{eH_0}	$5.85 \times 10^{-11} T^{1/2} \exp(-157809.1/T)(1 + T_5^{1/2})^{-1}$
Γ_{eHe_0}	$2.38 \times 10^{-11} T^{1/2} \exp(-285335.4/T)(1 + T_5^{1/2})^{-1}$
Γ_{eHe_+}	$5.68 \times 10^{-12} T^{1/2} \exp(-631515.0/T)(1 + T_5^{1/2})^{-1}$

Application I.

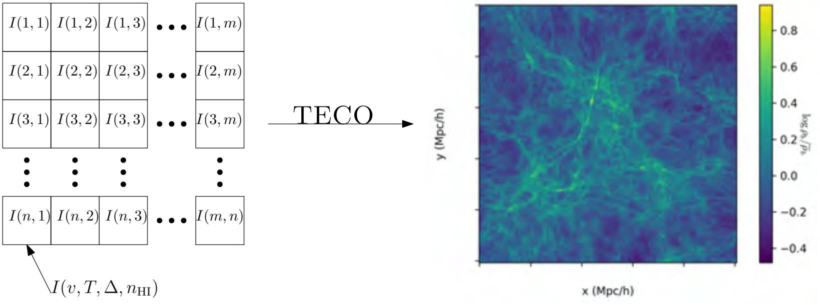


Application II.

- generate the different representations of the UVB;
- modification of the chosen UVB model by rescaling rates;
- shifting the redshift dependence of the rates by an ofset Δz;
- only models that fulfills chosen condition will be used for calculation.



Application III.



Thank you for your attention :)