

PHYS 480/581  
Cosmology

Worksheet #17  
Monday 11/07/2022

**Question 1.**

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In a famous 1968 paper (which he basically got the Nobel prize for), Peebles argues that recombination of an electron directly to the ground state of an hydrogen atom would not lead to a net decrease of the ionization fraction  $X_e$ . Instead, recombination has to proceed through excited states, especially the  $2s$  and  $2p$  states of hydrogen.

- (a) Could you think of a reason why recombination directly to the ground state (accompanied by the emission of a 13.6 eV photon) would not lead to a direct decrease of  $X_e$ ? Think about what happens to that 13.6 eV photon.
- (b) If an electron recombines into the  $2s$  state, how does it get to the ground state ( $1s$ )? Is this an allowed transition? Think about selection rules and angular momentum conservation. How many photons are emitted in this  $2s \rightarrow 1s$  transition?
- (c) If an electron recombines into the  $2p$  state, how does it get to the ground state ( $1s$ )? What kind of photon are emitted in this transition? Does this  $2p \rightarrow 1s$  transition lead to a net recombination event? Under which conditions?

