The recombination spectrum in 0.1 second

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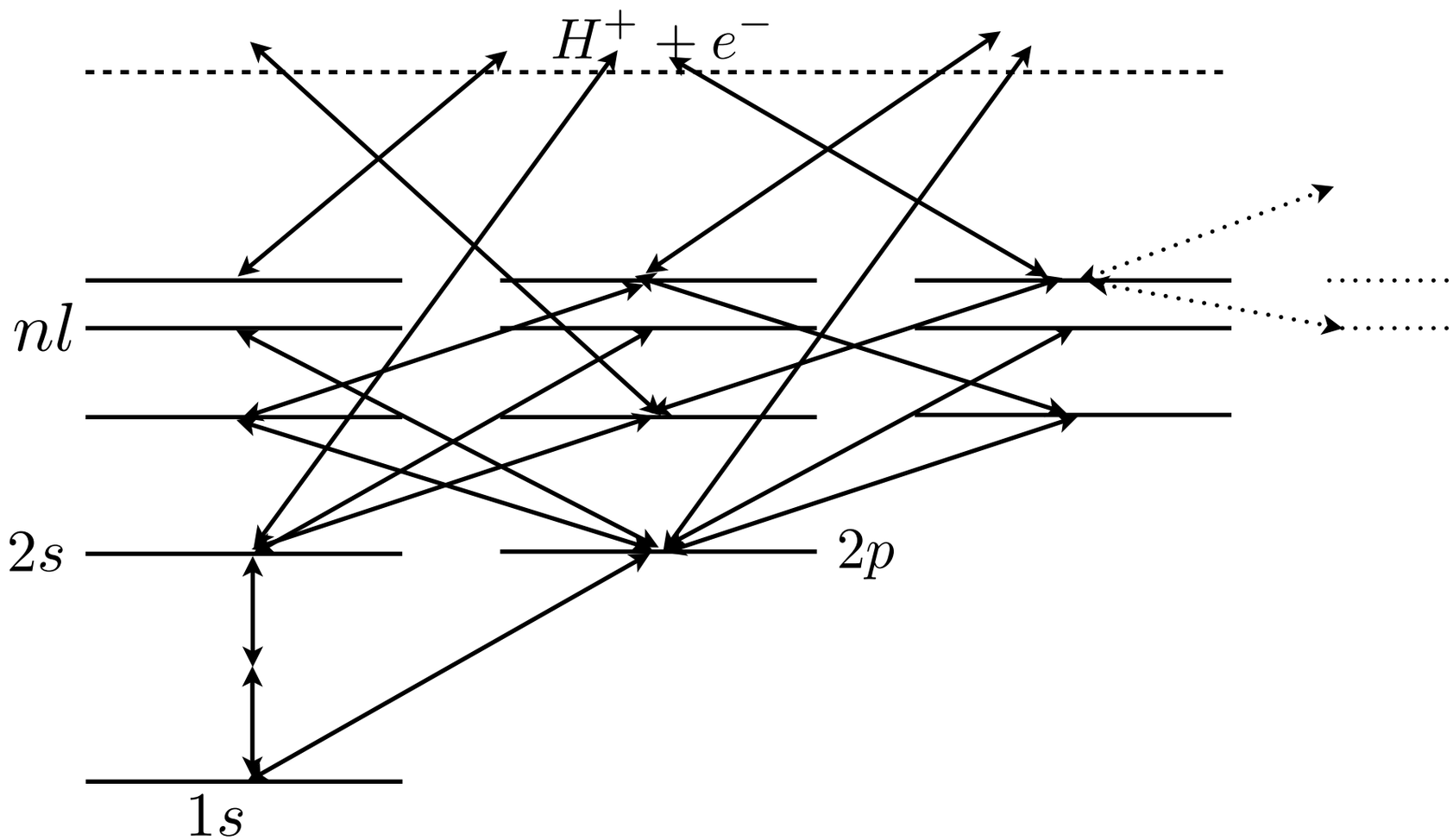
The need for speed

- Help designing search strategies for needle-in-a-haystack signal
- Efficiently exploring parameter space (e.g. MCMC)
- We may as well do it fast if we can!

The standard computation



emissivity:

$$j_\nu^{(n'n)} = n_H \sum_l \frac{h\nu}{4\pi} \left[x_{n'l'} R_{n'l,nl} - x_{nl} R_{nl,n'l'} \right] \delta(\nu - \nu_{n'n})$$

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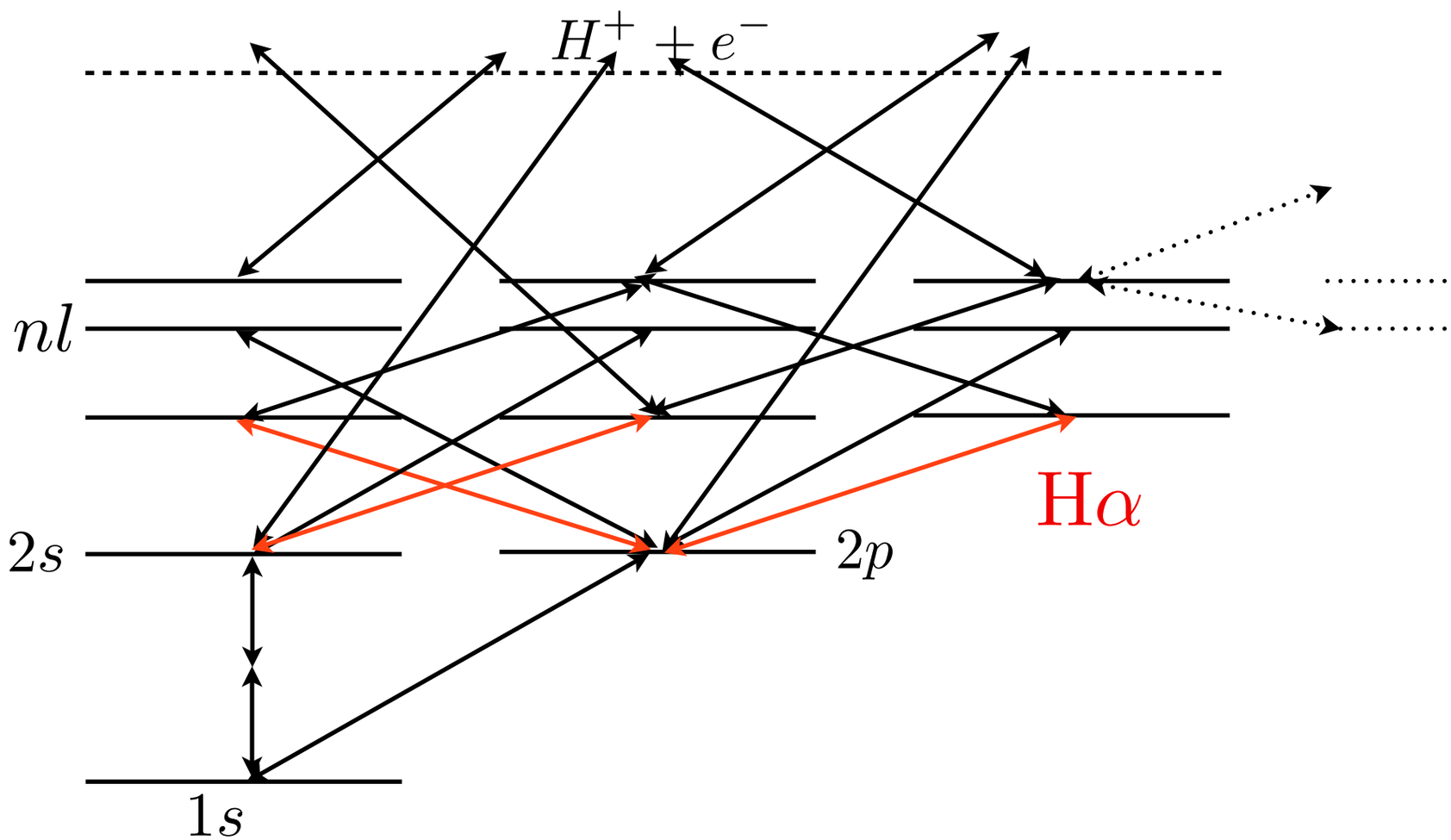

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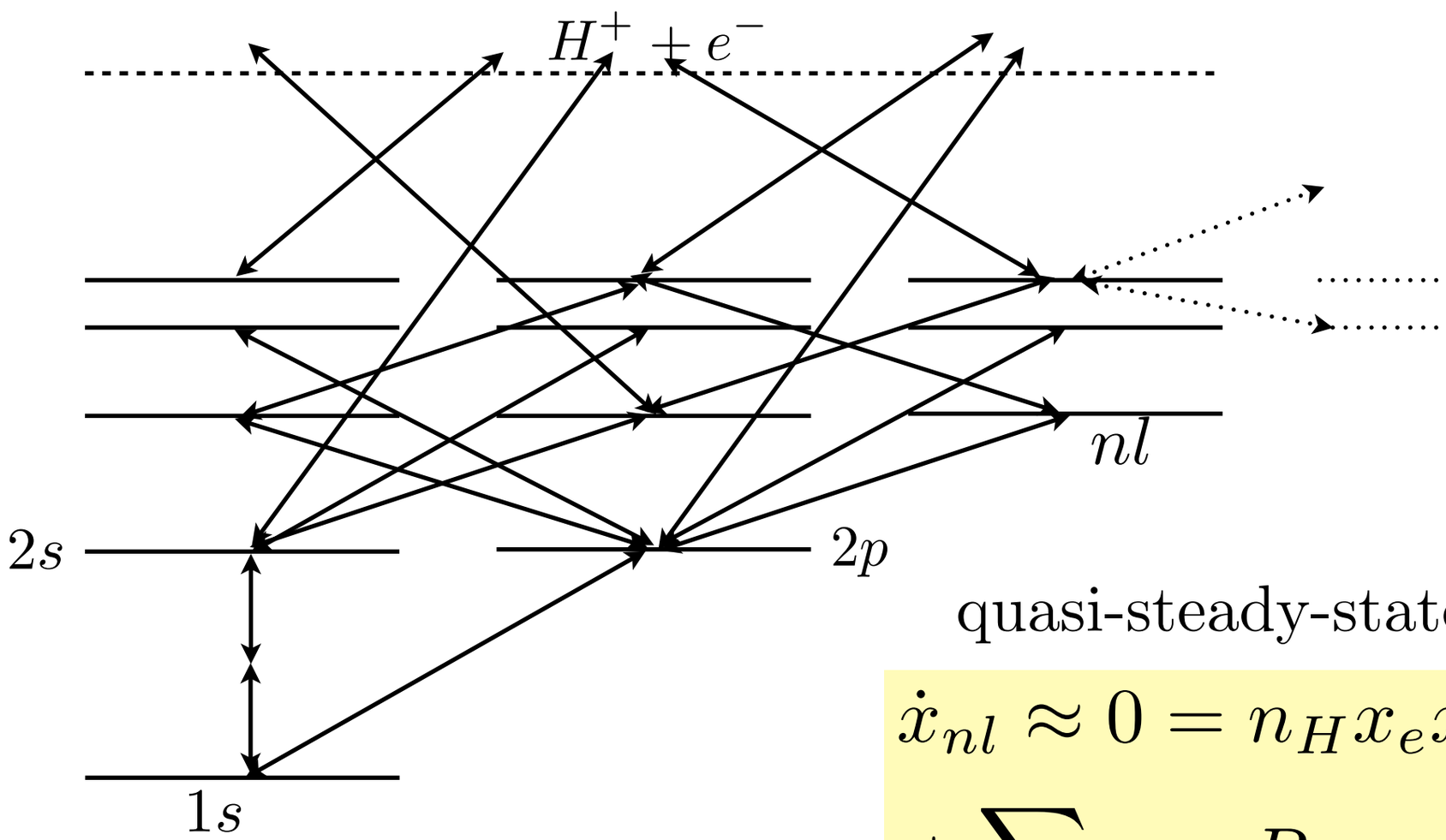


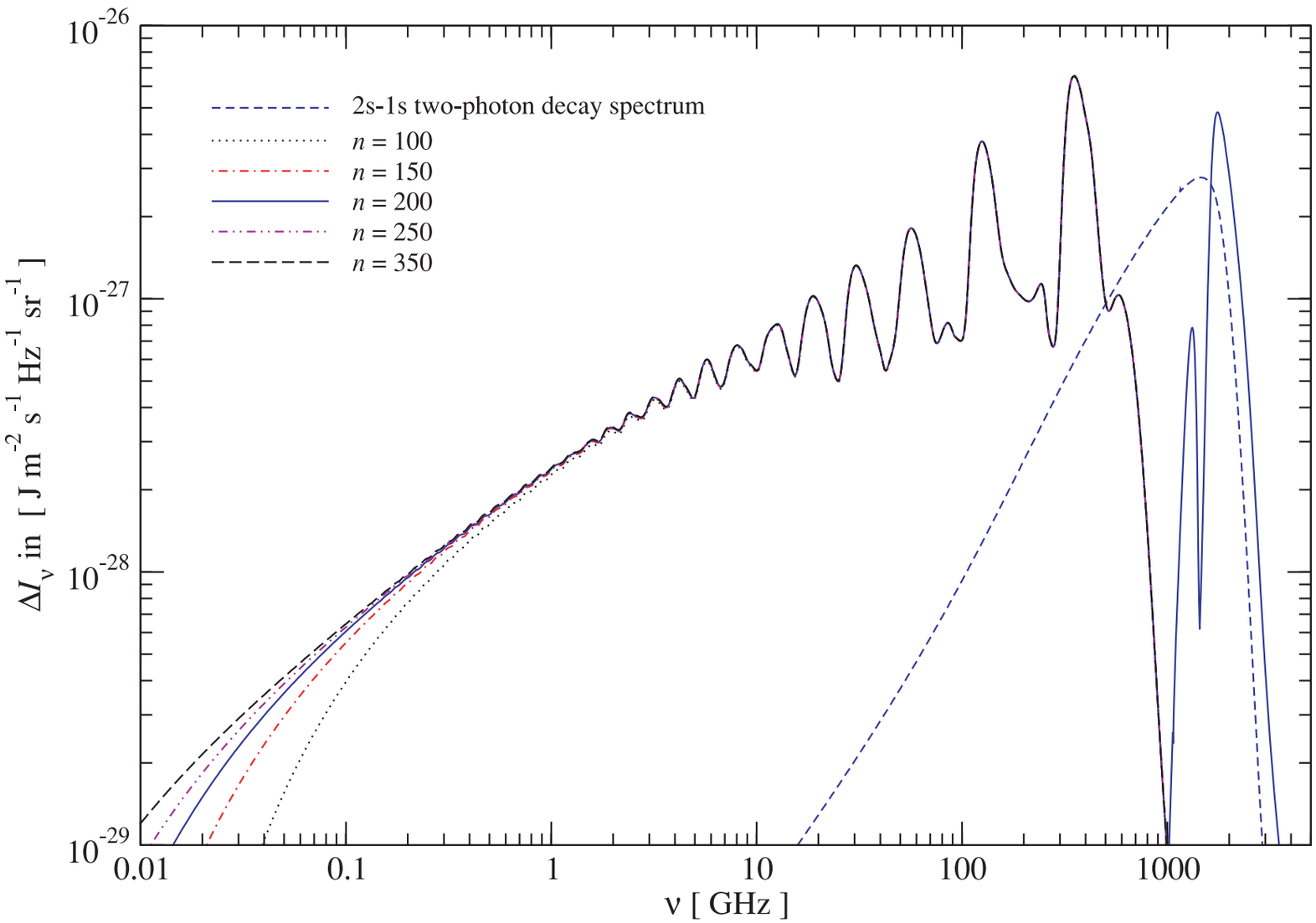
quasi-steady-state rate equations:

$$\dot{x}_{nl} \approx 0 = n_H x_e x_p \alpha_{nl} - x_{nl}\beta_{nl} + \sum_{n'l'} x_{n'l'} R_{n'l',nl} - x_{nl} R_{nl,n'l'}$$

$$\frac{n_{\max}^2}{2} \times \frac{n_{\max}^2}{2}$$ (sparse) system to solve at every timestep

The standard computation

- State of the art: Chluba, Vasil & Dursi 2010



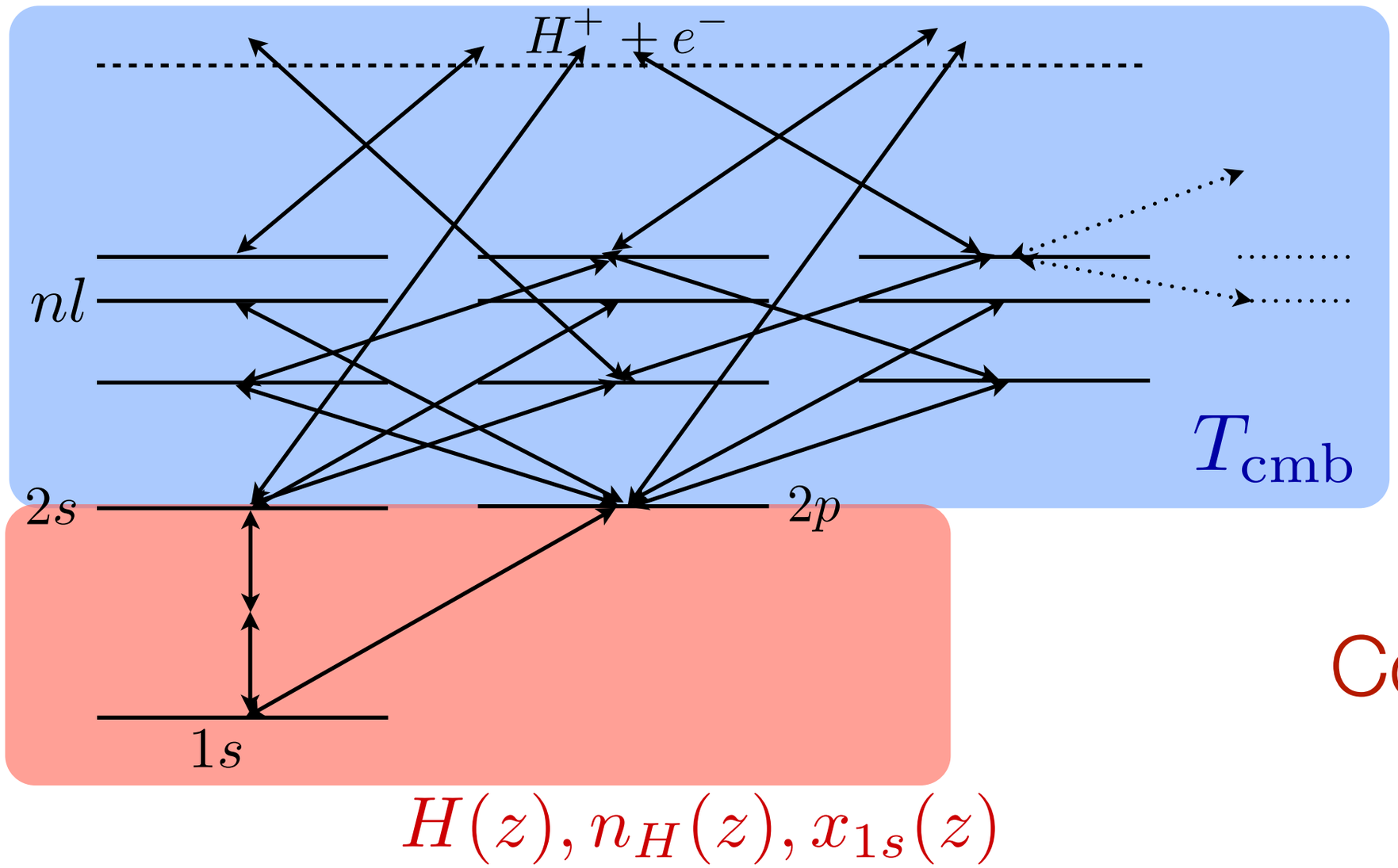
n_{max}	n_{eq}	Run A
100	5050	52 min
150	11 325	3.4 h
200	20 100	9.7 h
250	31 375	22 h
300	45 150	–
350	61 425	–

Computation time
on a standard laptop

The standard computation

- Most general formulation of the problem: used for ISM
- Very special conditions at recombination: background radiation field is a nearly perfect blackbody!
- Except for Lyman transitions, all lines are very optically thin => nearly unaltered field

The two sides of primordial recombination

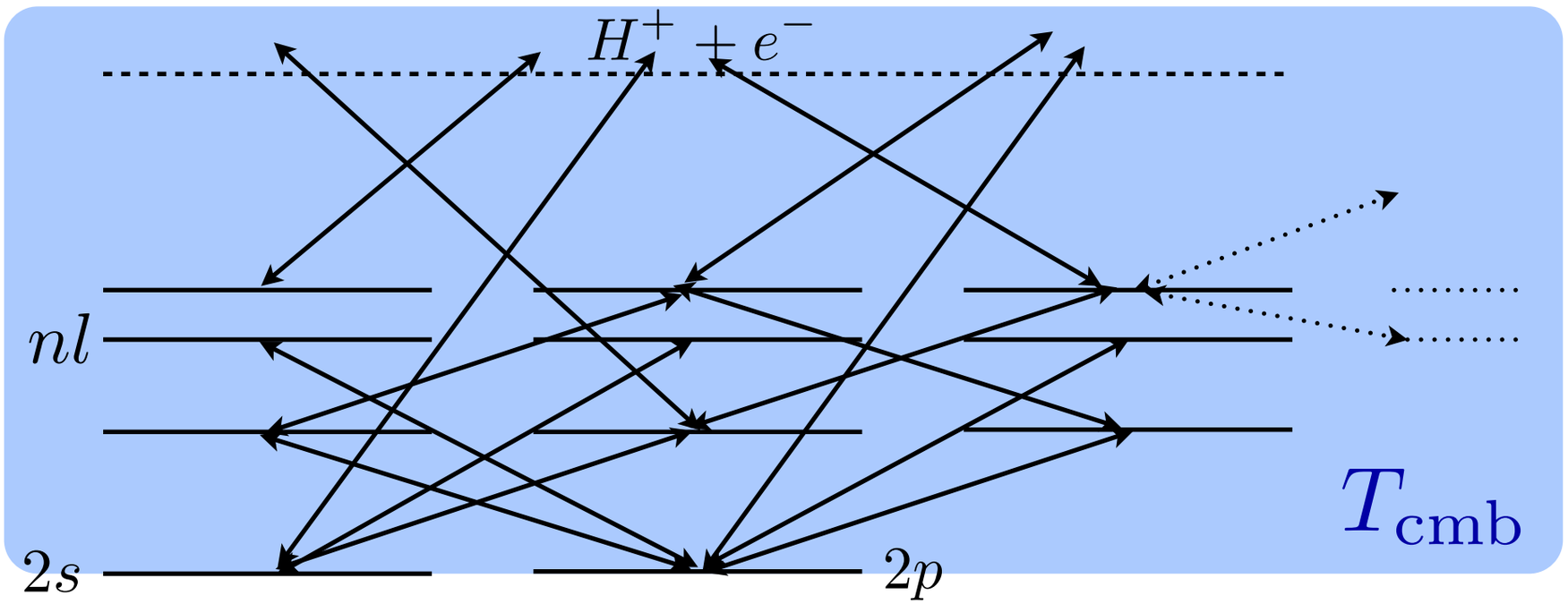


Simple!

Complicated

Factorizing the problem: effective conductances

[arXiv:1211.4031]



- If all states were in Saha equilibrium with plasma, no net emission.
- Linear system of equations

$$\frac{j_\nu}{n_H} = \mathcal{G}(\nu, T_{\rm cmb}) \times (x_2 - x_2^{\rm Saha})$$

Expensive but simple (cosmology-**in**dependent)

Cheap (with EMLA method). Contains all cosmology dependence

Factorizing the problem: effective conductances

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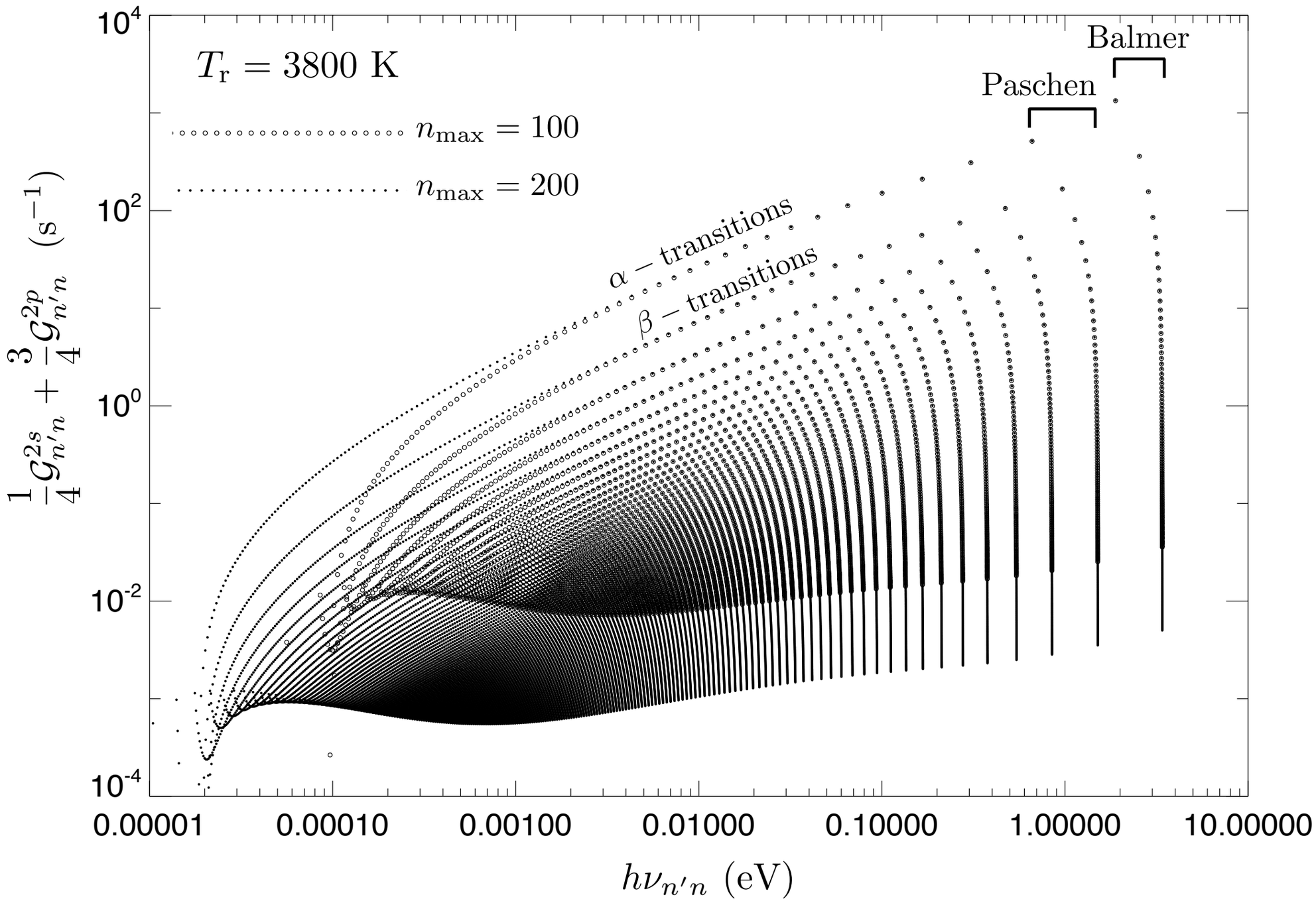
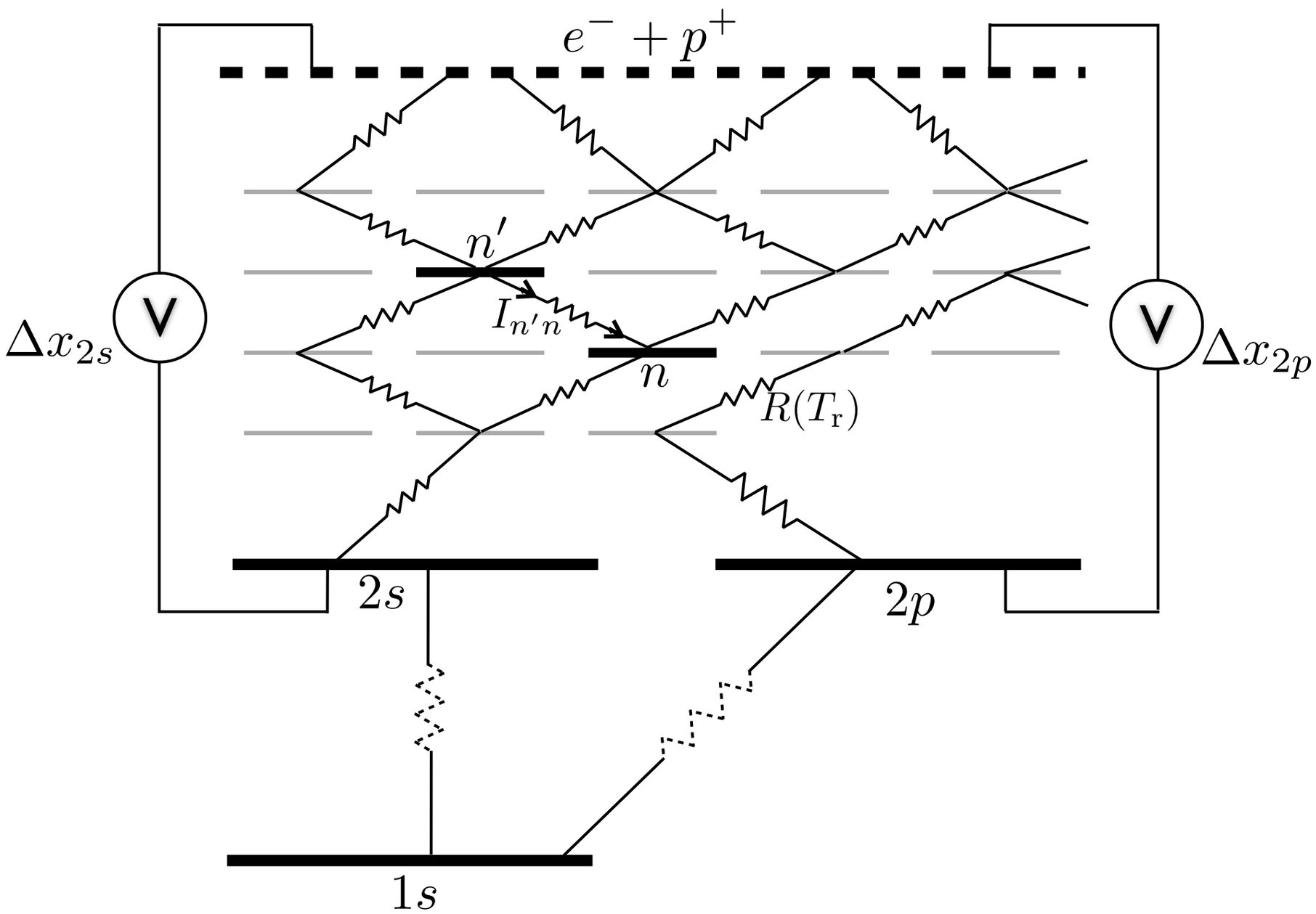


The circuit analogy (courtesy of C. Hirata)

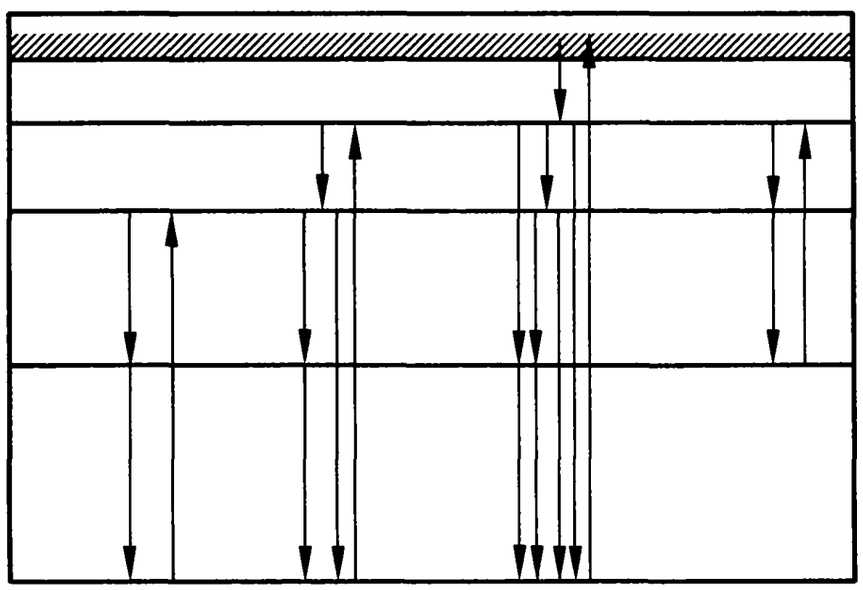


Steady-state rate equations = Kirchhoff's current law

Work in progress

Generalization to a non-thermal ambient radiation field (e.g. Chluba & Sunyaev 2009, Lyubarsky & Sunyaev 1983).

Can hydrogen and helium reprocess spectral distortions not directly observable to an observable part of the spectrum?



$$\frac{j_\nu}{n_H} = \int d\nu' \mathcal{G}(\nu;\nu';\text{standard cosmology}) \times \delta I_{\nu'}$$

Pre-existing spectral distortion