Modelling the cold ISM in the next generation of cosmological simulations

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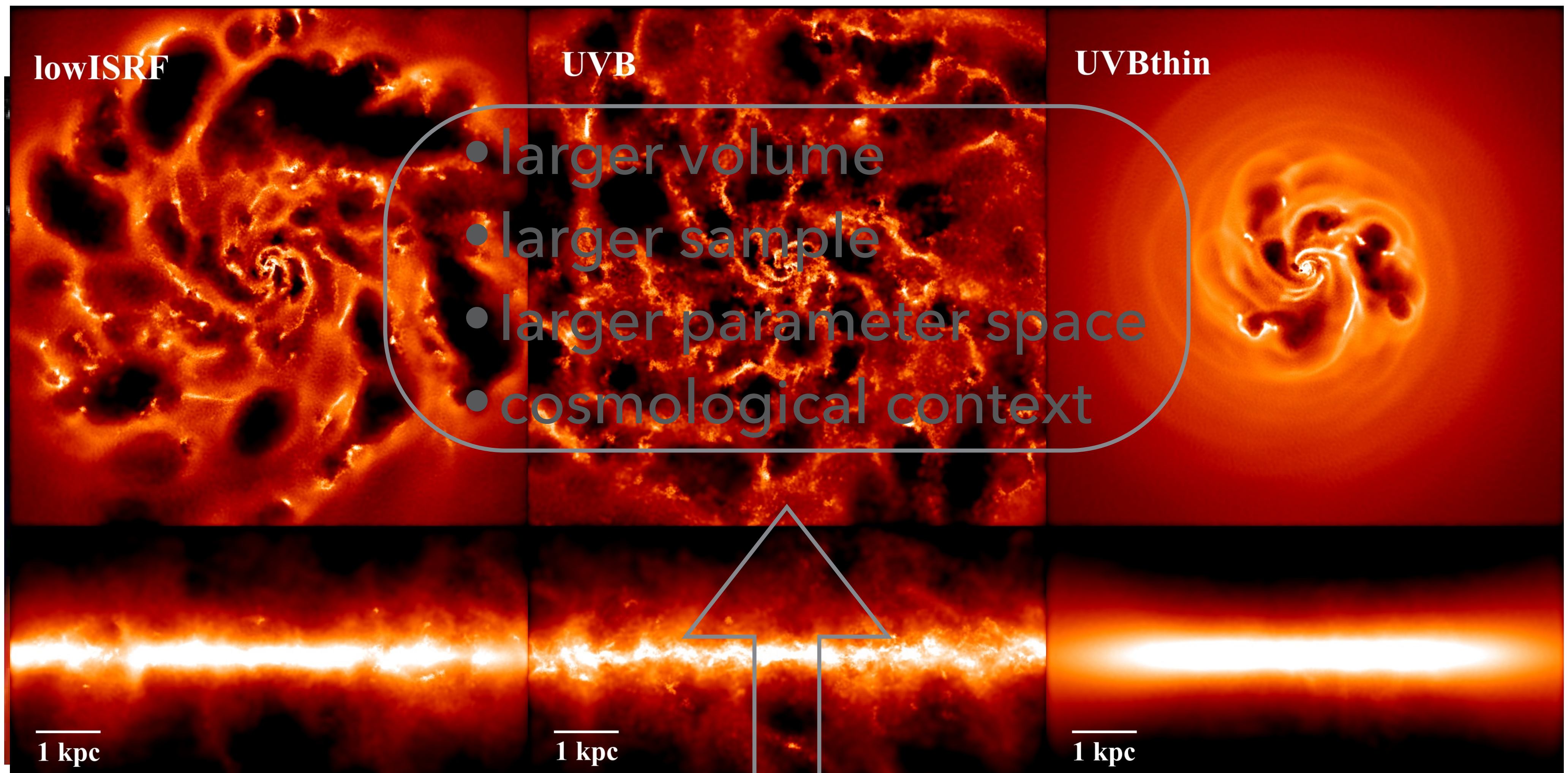
with: Joop Schaye, Joki Rosdahl, Alexander Richings

Modelling the Universe

Bottom up:



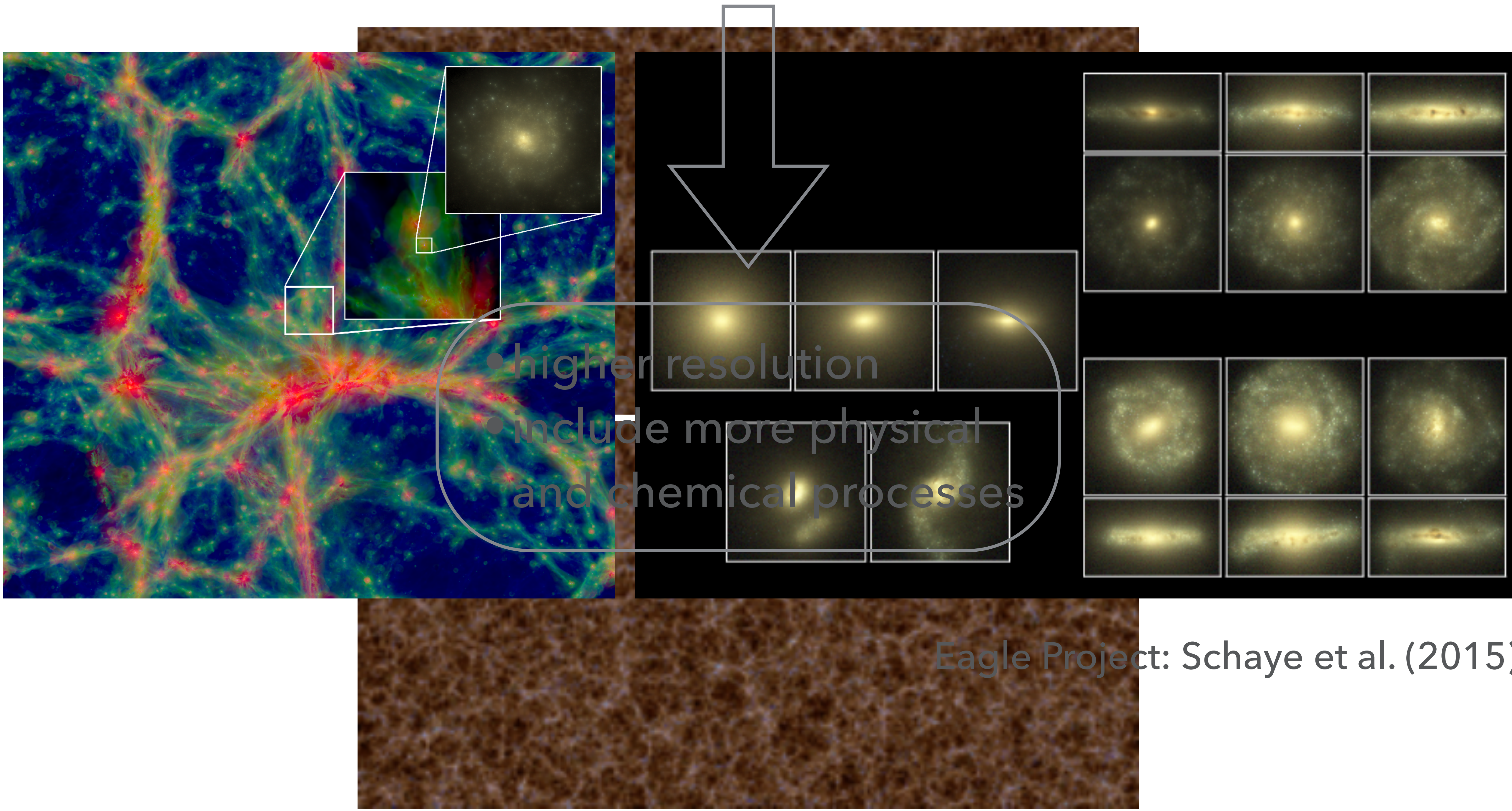
- larger volume
- larger sample
- larger parameter space
- cosmological context

Falceta-Goncalves, Bonnell, et al. (2015)

Richings et al. (2016)

Modelling the Universe

Top down:



- higher resolution
- include more physical and chemical processes

Eagle Project: Schaye et al. (2015)

Magneticum simulation (Dolag et al. 2015)

Modelling the cold gas in cosmological simulations

Status quo

Simulatorspeak:

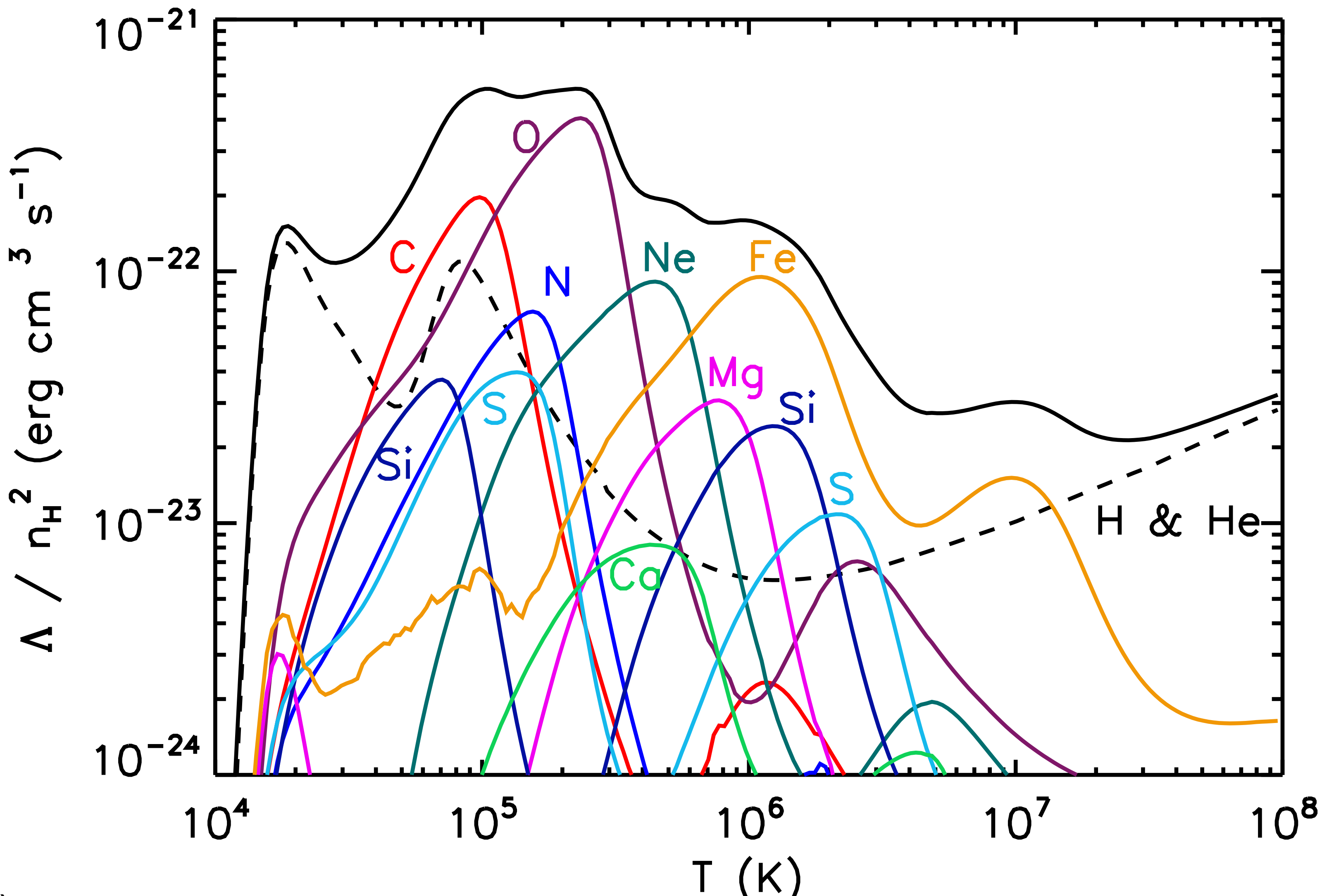
Limited spatial / mass resolution
equivalent to:
pressure and / or temperature floor

Jeans length has to be resolved to avoid numerical fragmentation
Truelove et al. (1997)

Modelling the cold gas in cosmological simulations

T > 10^4 K:

Status quo



Wiersma et al. (2009)

Modelling the cold gas in cosmological simulations

$T < 10^4$ K:

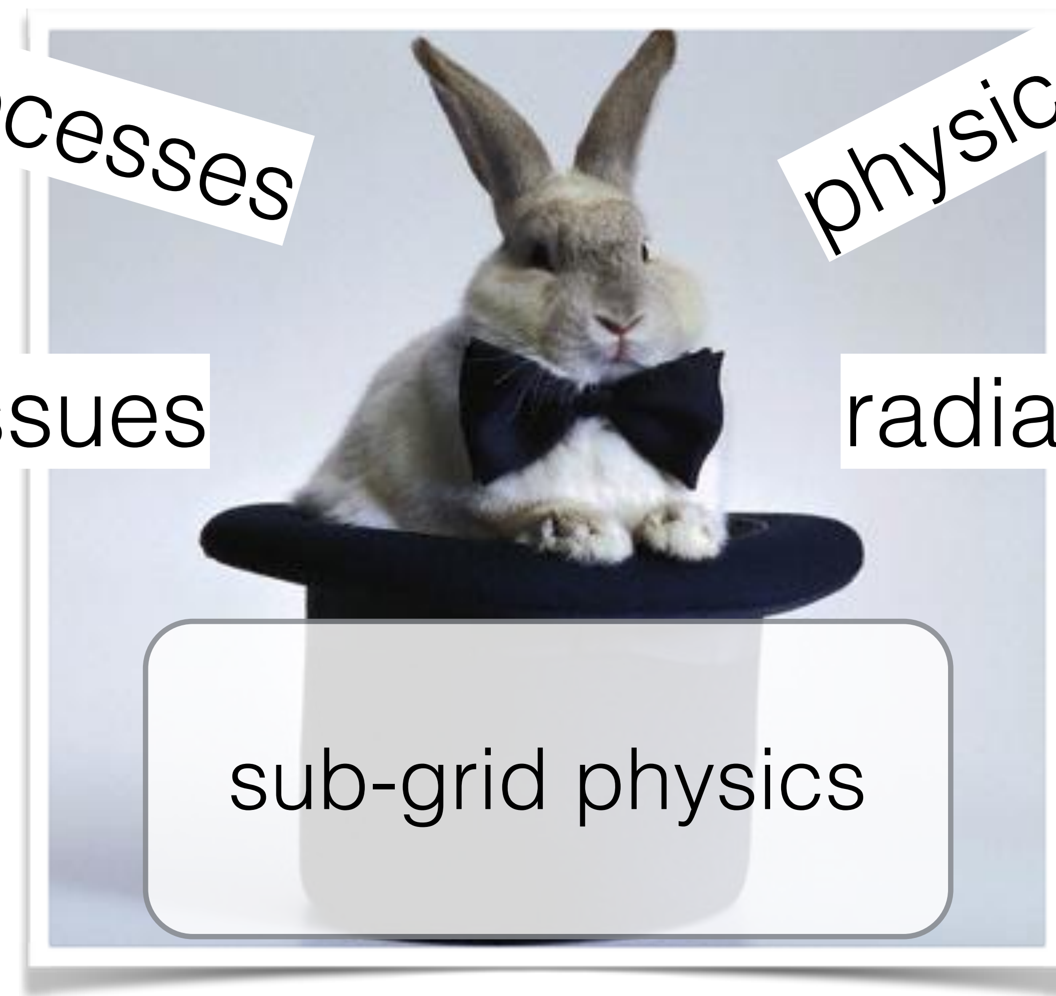
Status quo

chemical processes

physical processes

numerical issues

radiative processes



sub-grid physics

Modelling the cold gas in cosmological simulations

Long term goal:

Self-consistent modelling of physical, chemical, radiative, magnetic, [...] processes

Modelling the cold gas in cosmological simulations

Next milestone:

Increase resolution to model the gas below 10^4 K

Why?

star formation

thin disks

dwarf galaxies

Modelling the cold gas in cosmological simulations

Just increase resolution and drop temperature floor?

molecules

dust

self-shielding

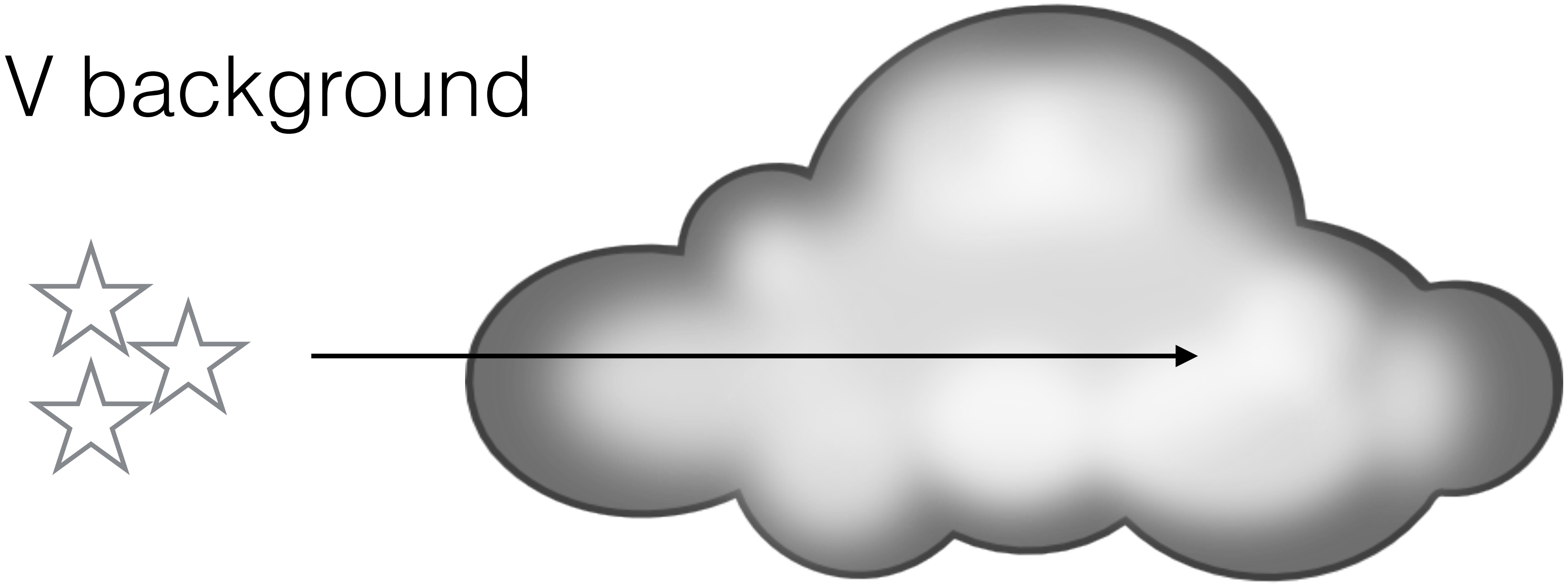
would require:

chemistry

radiative transfer

New self-shielding treatment

UV background



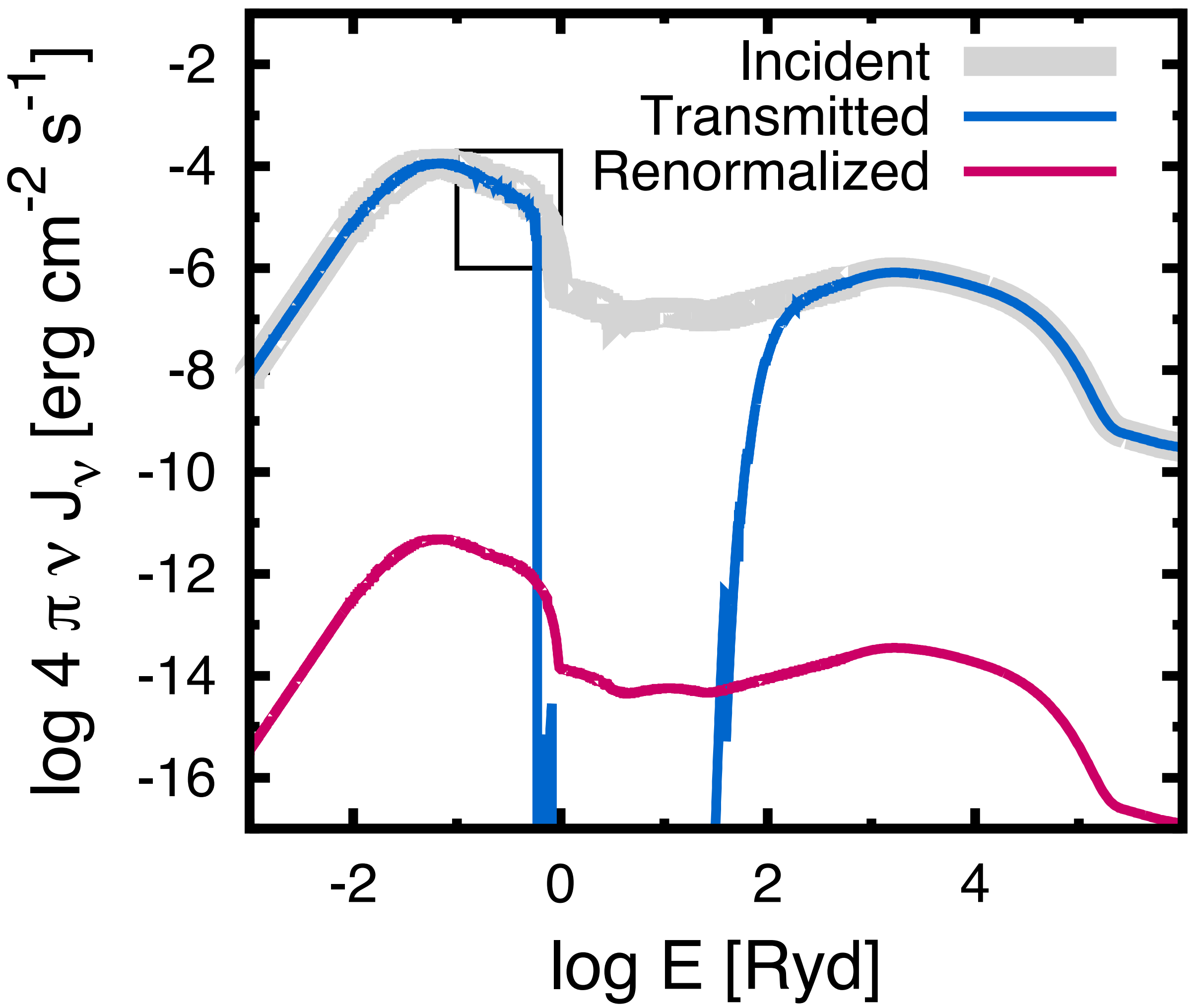
ISRF

with Cloudy v13.03 (Ferland et al. 2013)

$$N_{\mathrm{H,J}}[\mathrm{cm}^{-2}] = \left(\frac{\pi X \gamma n_{\mathrm{H}}}{G m_{\mathrm{H}}} f_g\right)^{1/2} \max\left(\frac{kT}{\mu}, m_{\mathrm{H}} \Delta v_{\mathrm{turb,1D}}^2\right)^{1/2}$$

Jeans column density (Schaye 2001)

Comparison with renormalized spectrum



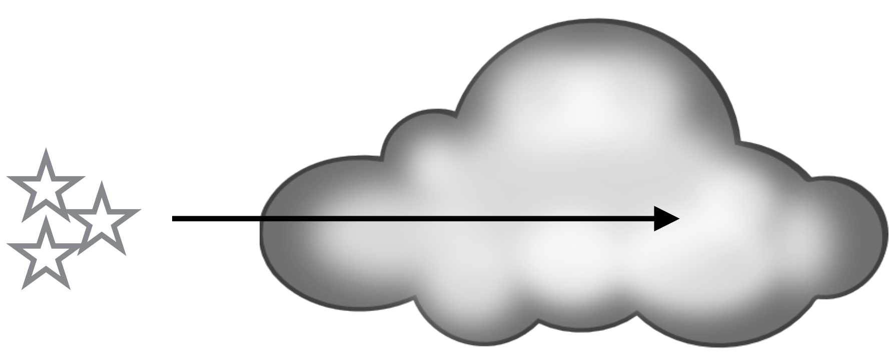
Transmitted:
Ploeckinger et al. (in prep.)

Renormalized:
Rahmati et al. (2013):

$$\frac{\Gamma_{\rm Phot}}{\Gamma_{\rm UVB}} = (1-f)\left[1+\left(\frac{n_{\rm H}}{n_0}\right)^{\beta}\right]^{\alpha_1} + f\left[1+\frac{n_{\rm H}}{n_0}\right]^{\alpha_2}$$

$$f, n_{\rm H}, \alpha_1, \alpha_2, \beta, n_0$$

… fits to RT simulations for different redshifts



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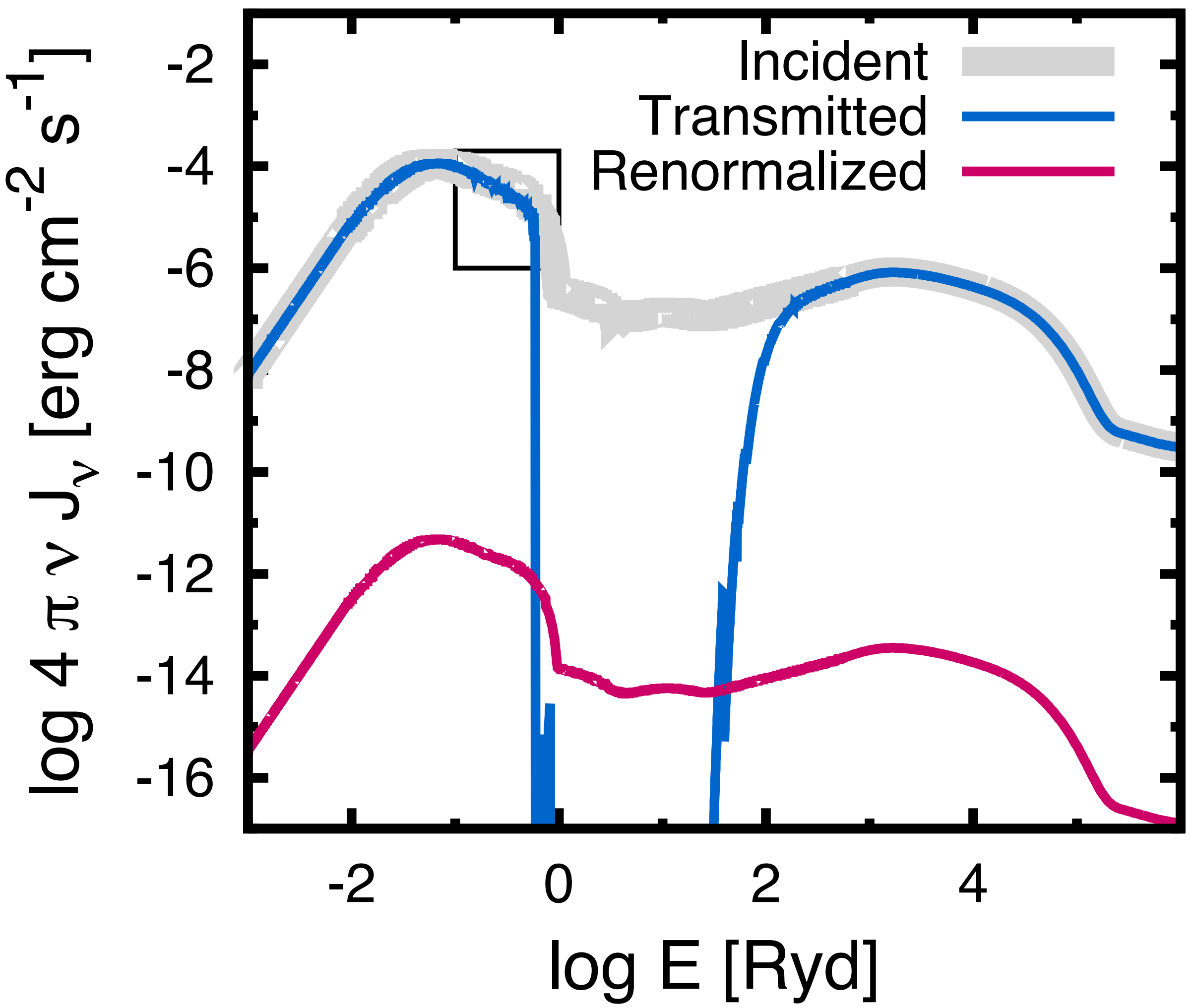
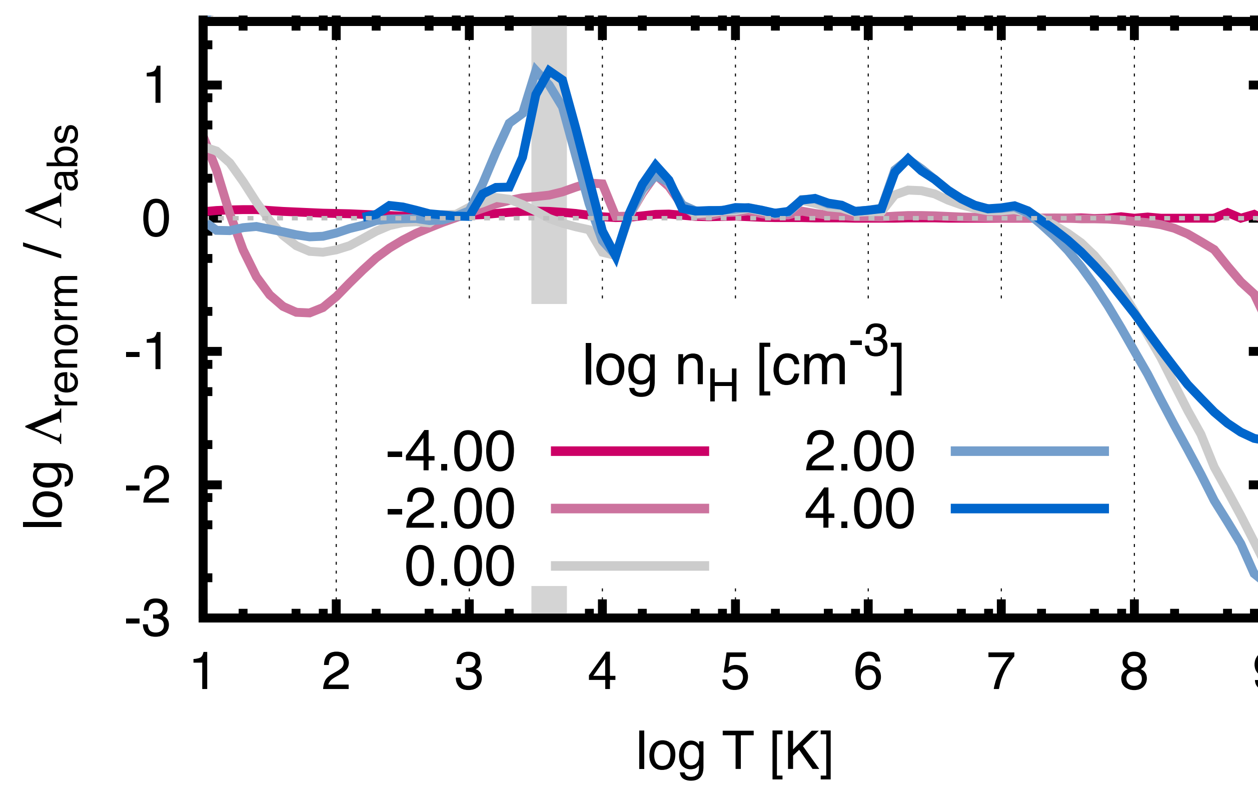
Comparison with renormalized spectrum



Significant differences in the cooling rate!



Ploeckinger et al. (in prep)

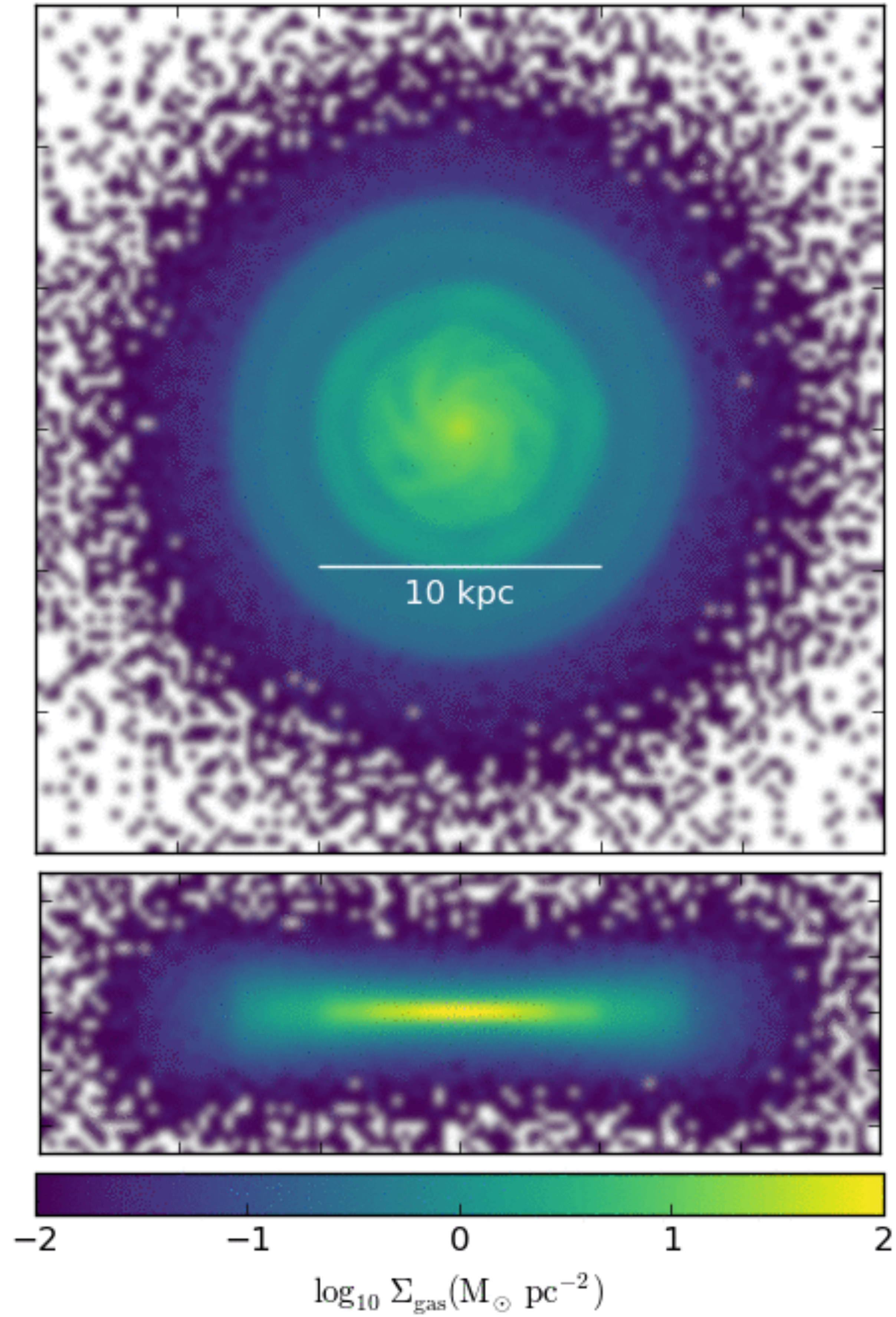
Test application

Isolated disky dwarf galaxy

$$M_{\rm DM} = 7 \times 10^{10}\,{\rm M}_\odot$$

$$M_{\rm Gas} = 3.4 \times 10^{8}\,{\rm M}_\odot$$

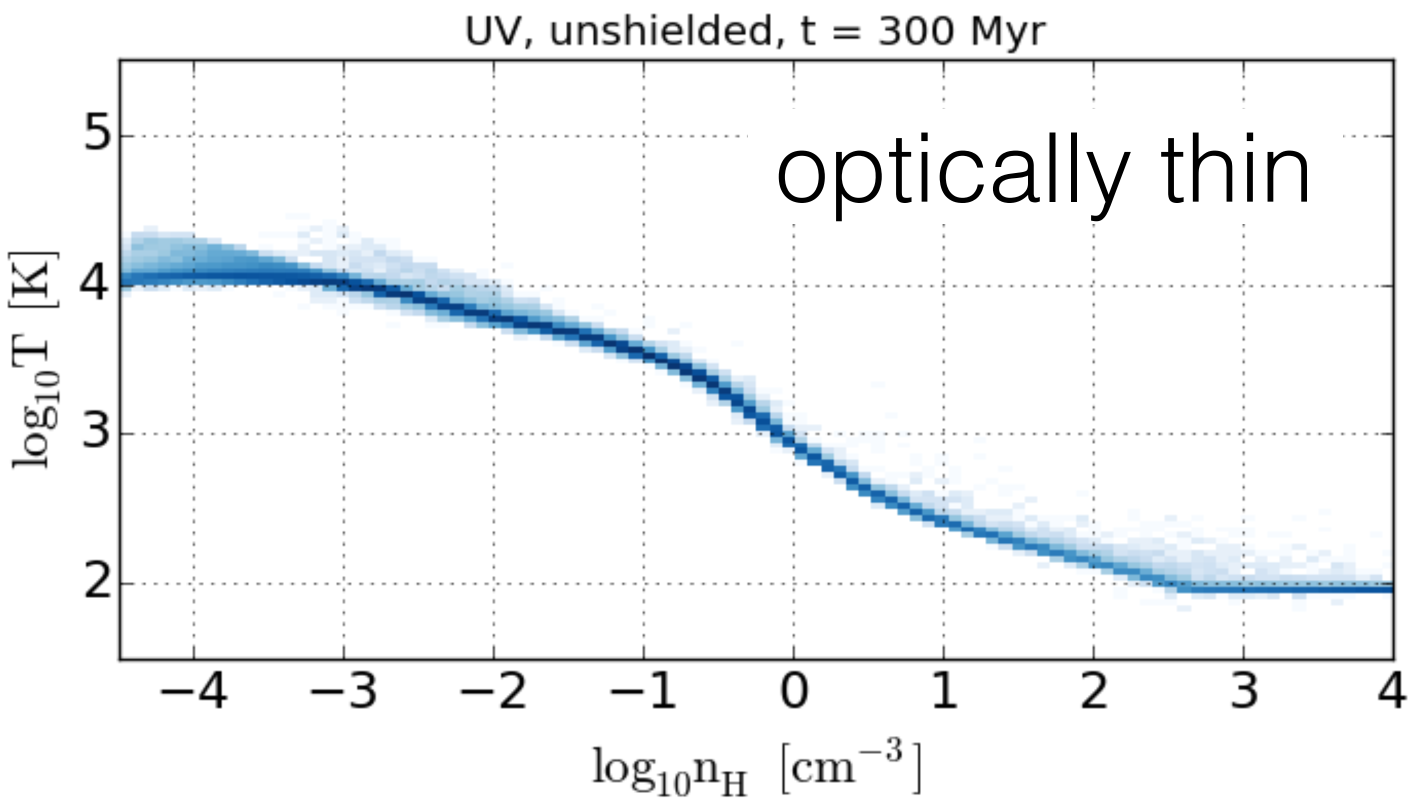
$$M_{\rm Stars} = 5.4 \times 10^{8}\,{\rm M}_\odot$$



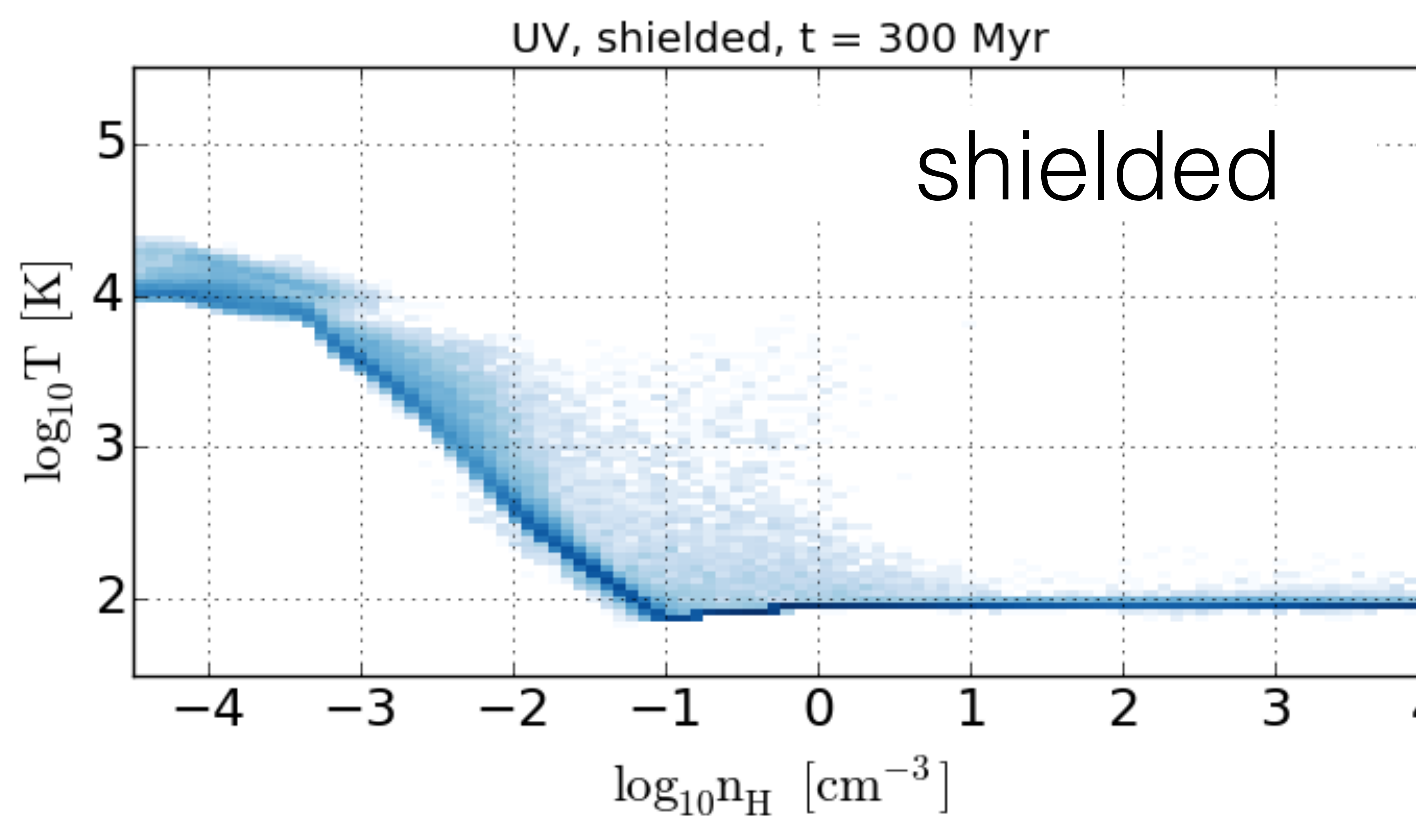
Ploeckinger et al. (in prep.)

Test application

Isolated disk galaxy



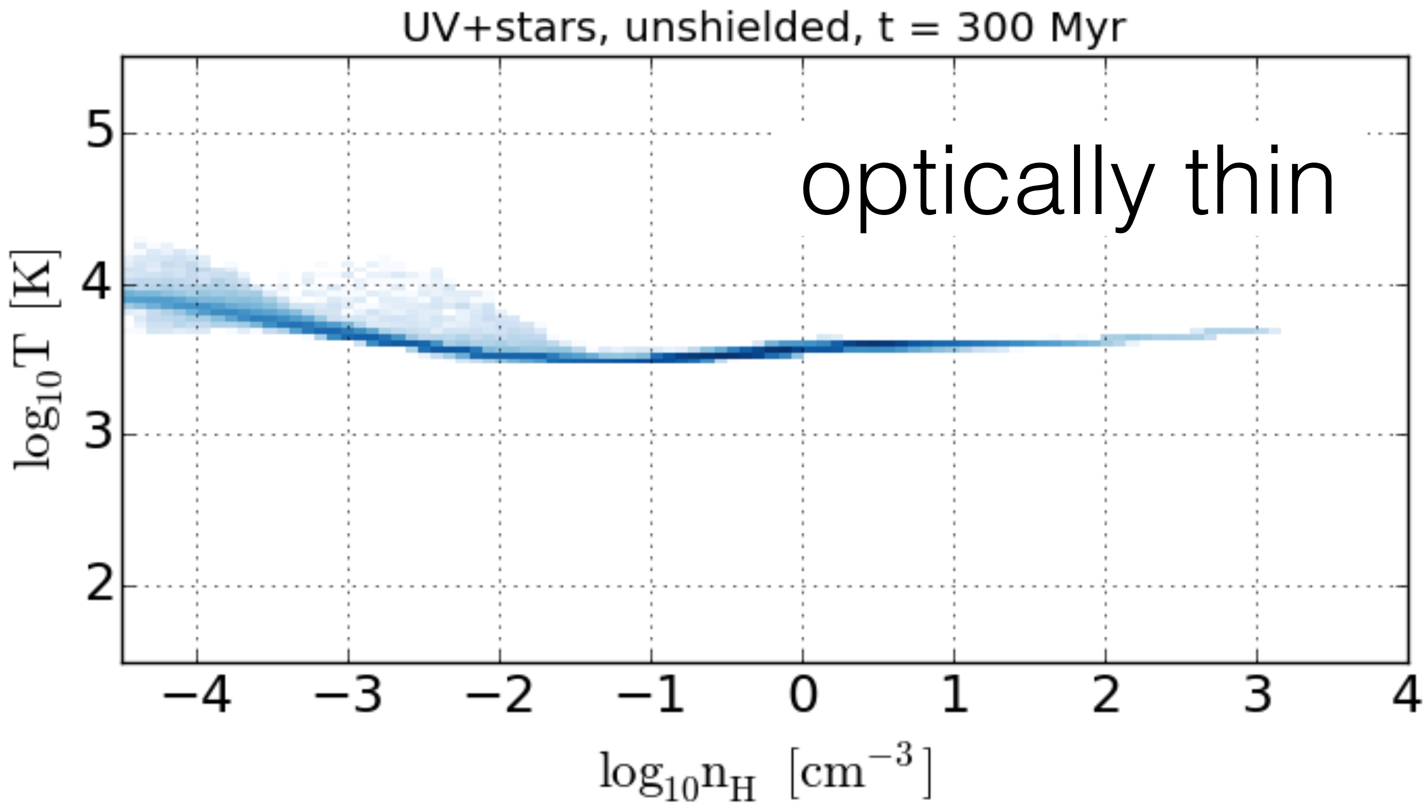
UV background



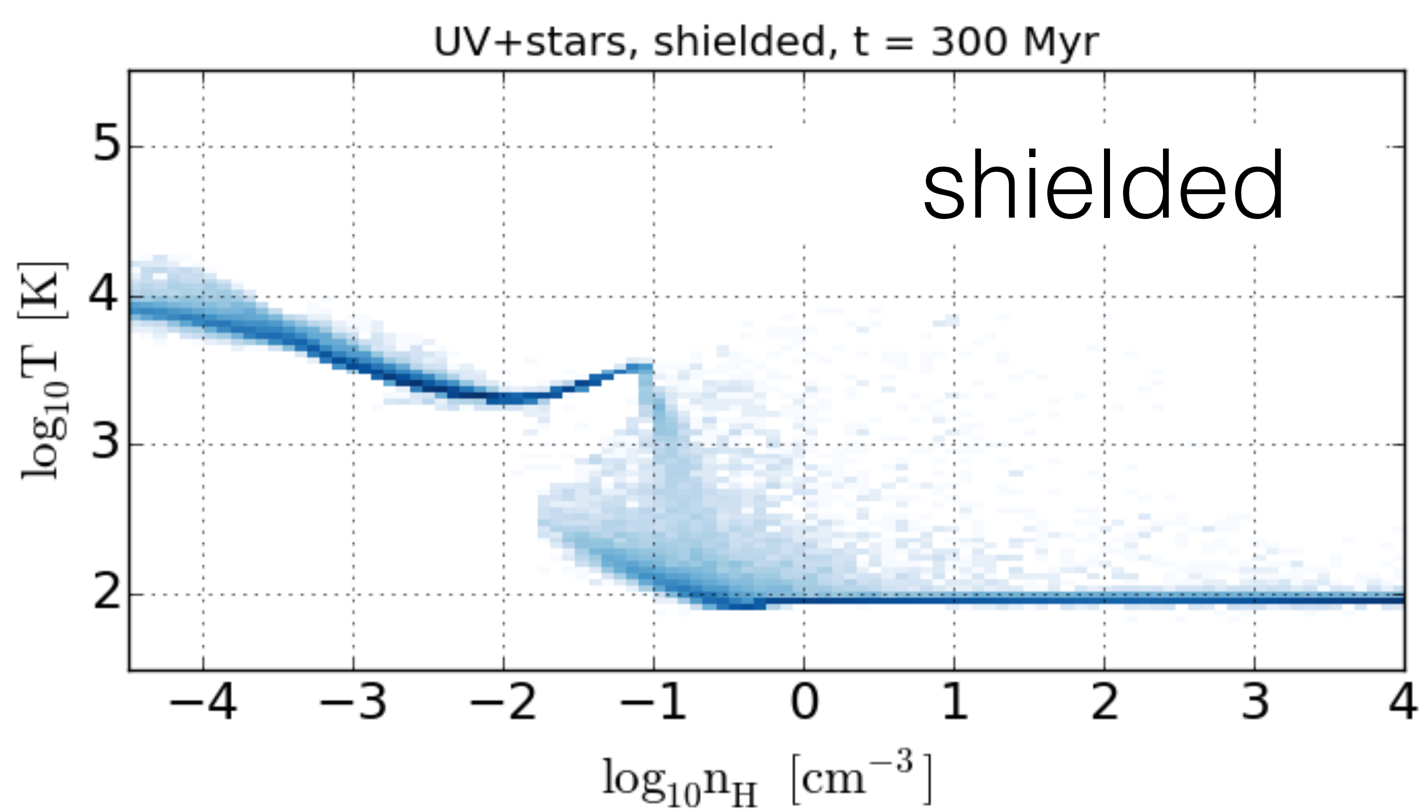
Ploeckinger et al. (in prep.)

Test application

Isolated disk galaxy



UV background
+ stellar rad. field



Ploeckinger et al. (in prep.)

Summary

We provide a complete and consistent set of cooling tables in a large range of:

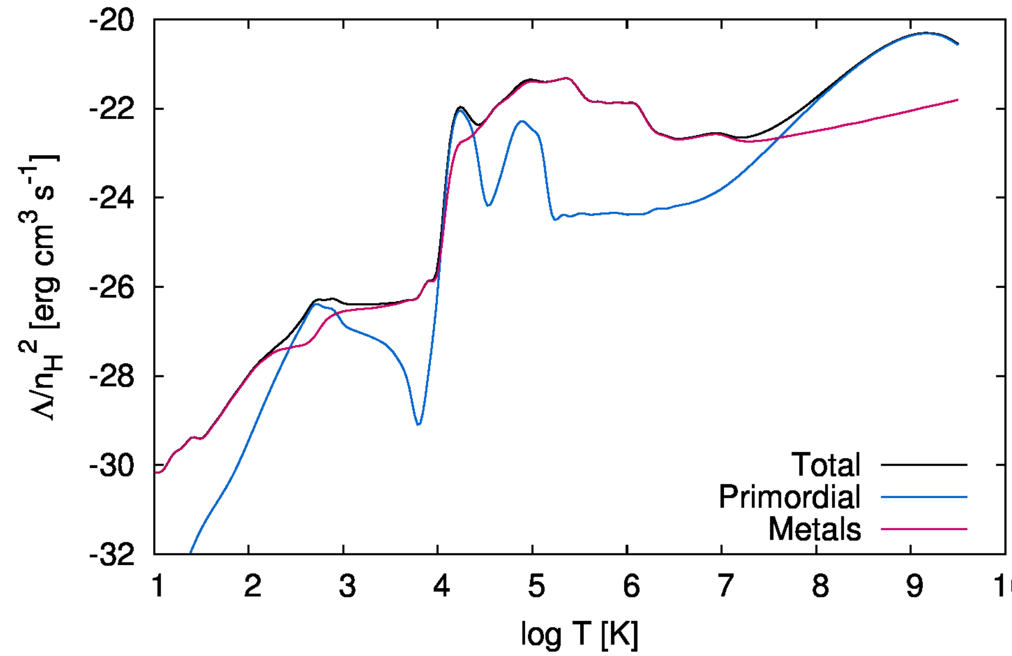
- densities (n_H from 10^{-8} to 10^{4} cm^{-3})
- temperatures (T from 10 to $10^{9.5}$ K)
- metallicities (Z/Z_{sol} from 10^{-4} to 1)

for:
- optically thin
- self-shielded

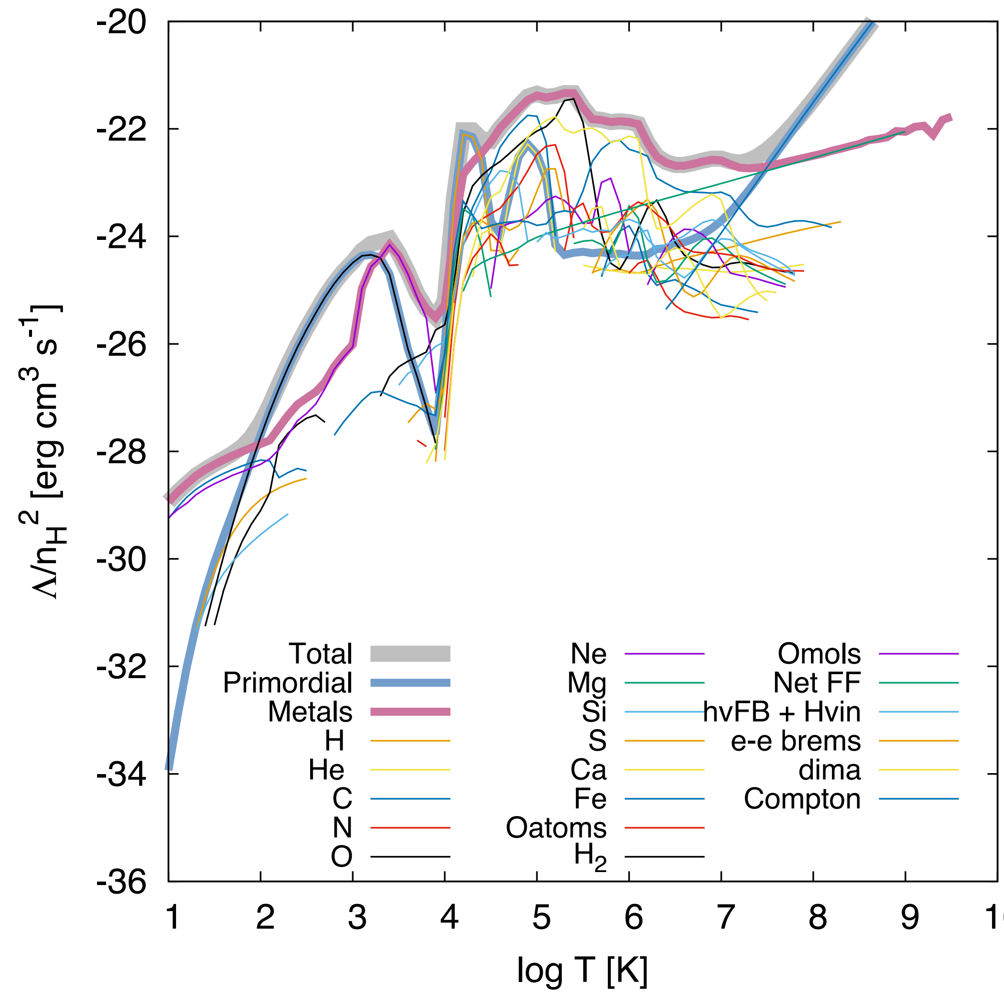
each for:
- UV background,
- UV background + interstellar radiation field

Be ready for the next generation of large-scale / cosmological simulations!

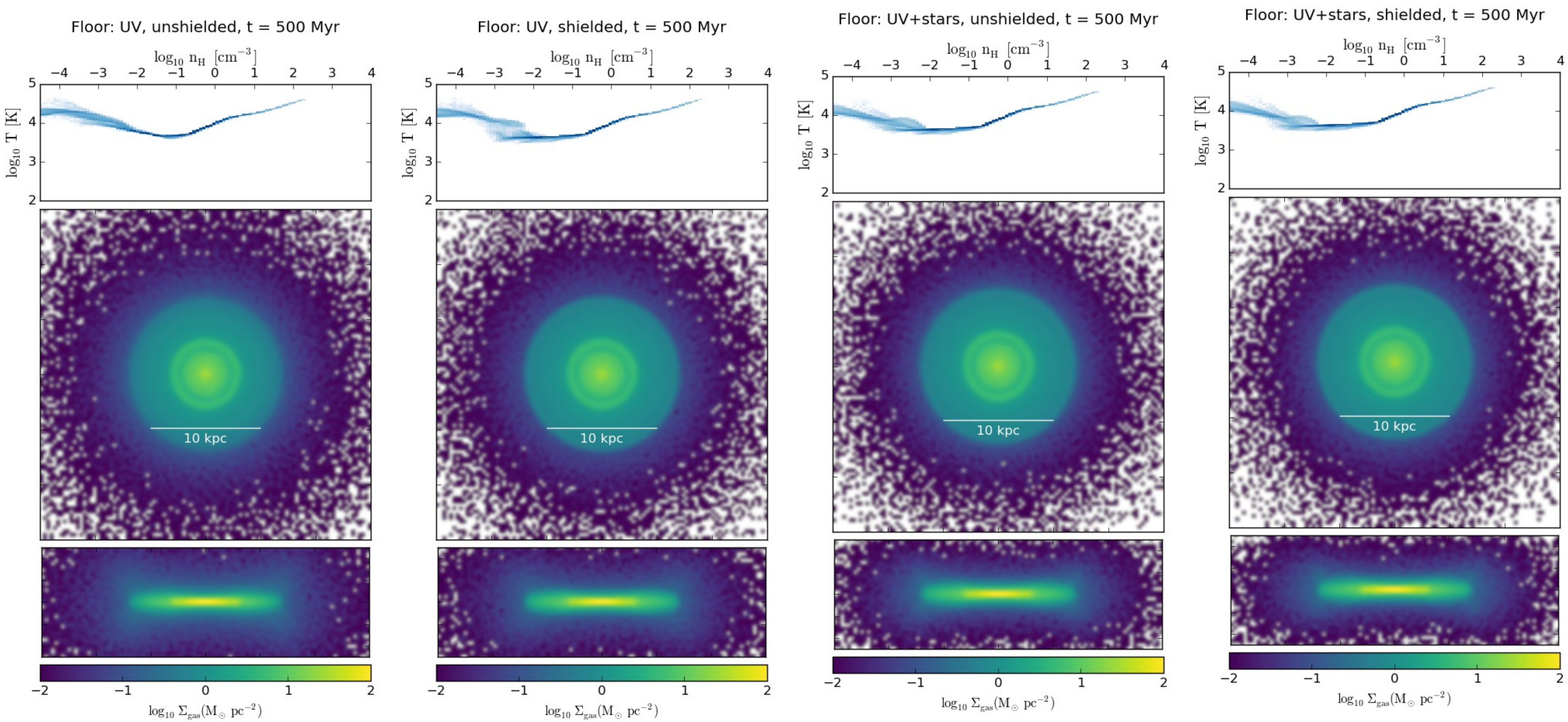
UV, shielded



In detail for n_H = 100 cm^{-3}



Eagle pressure floor



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New cooling tables

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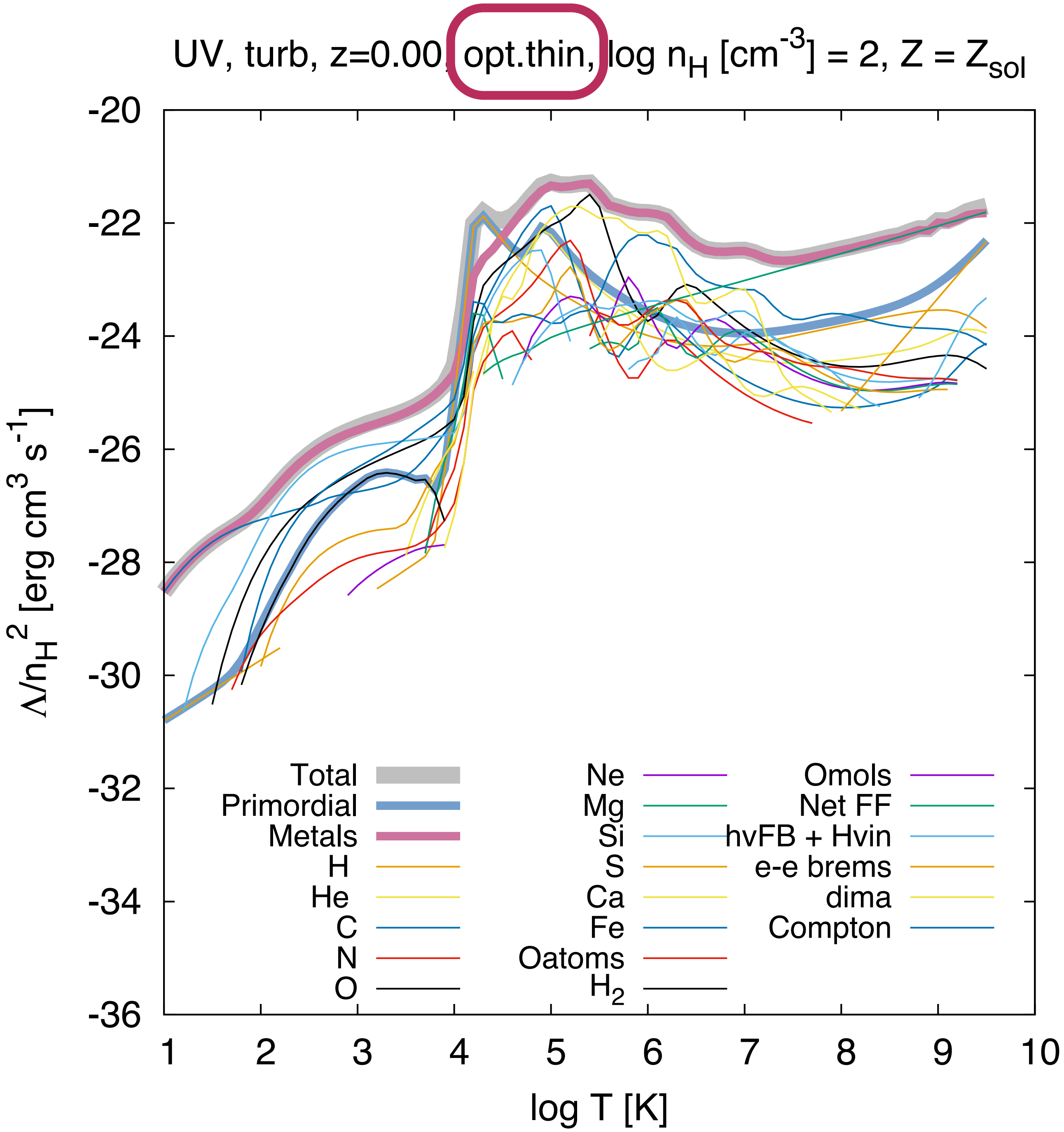
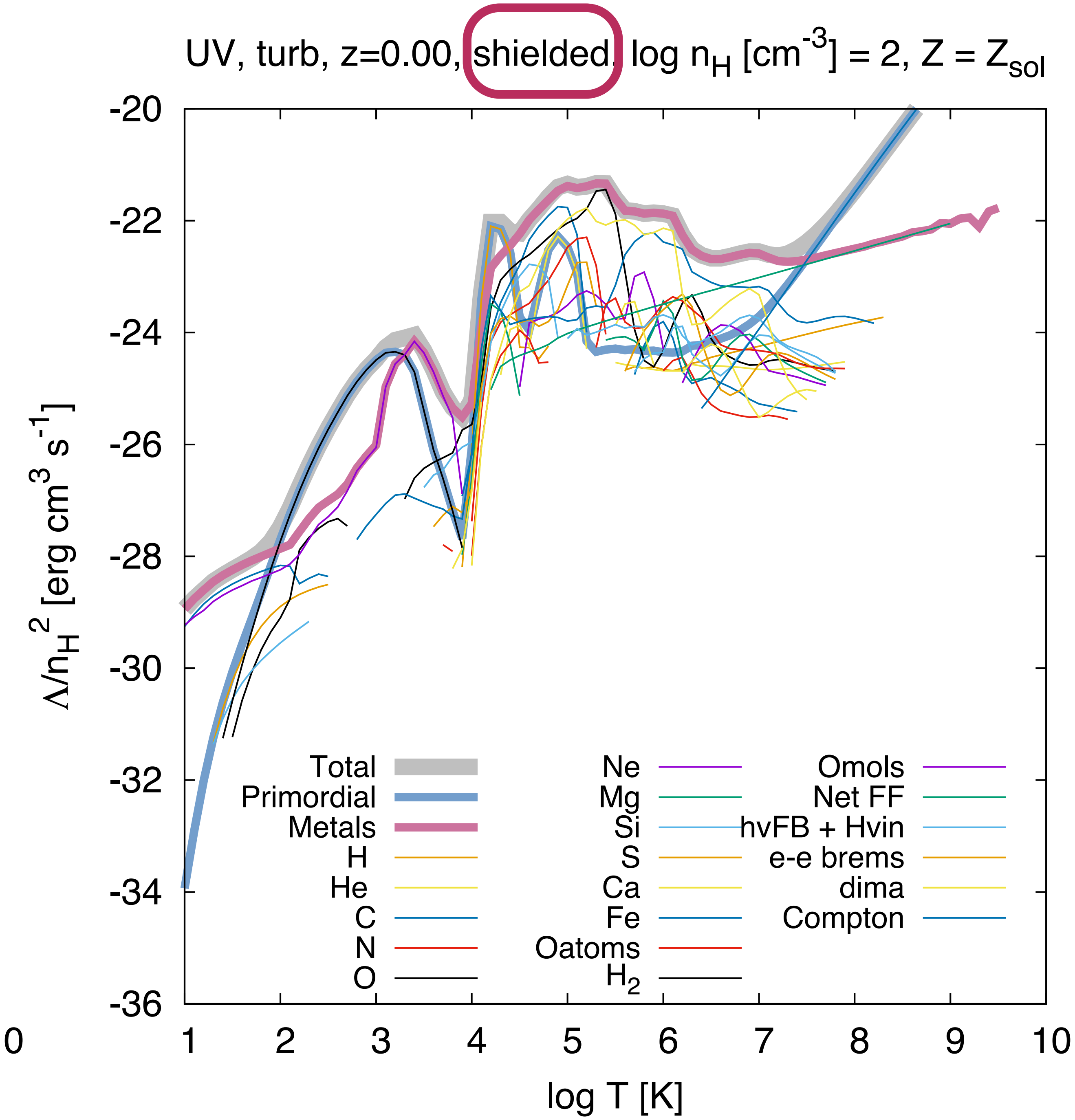
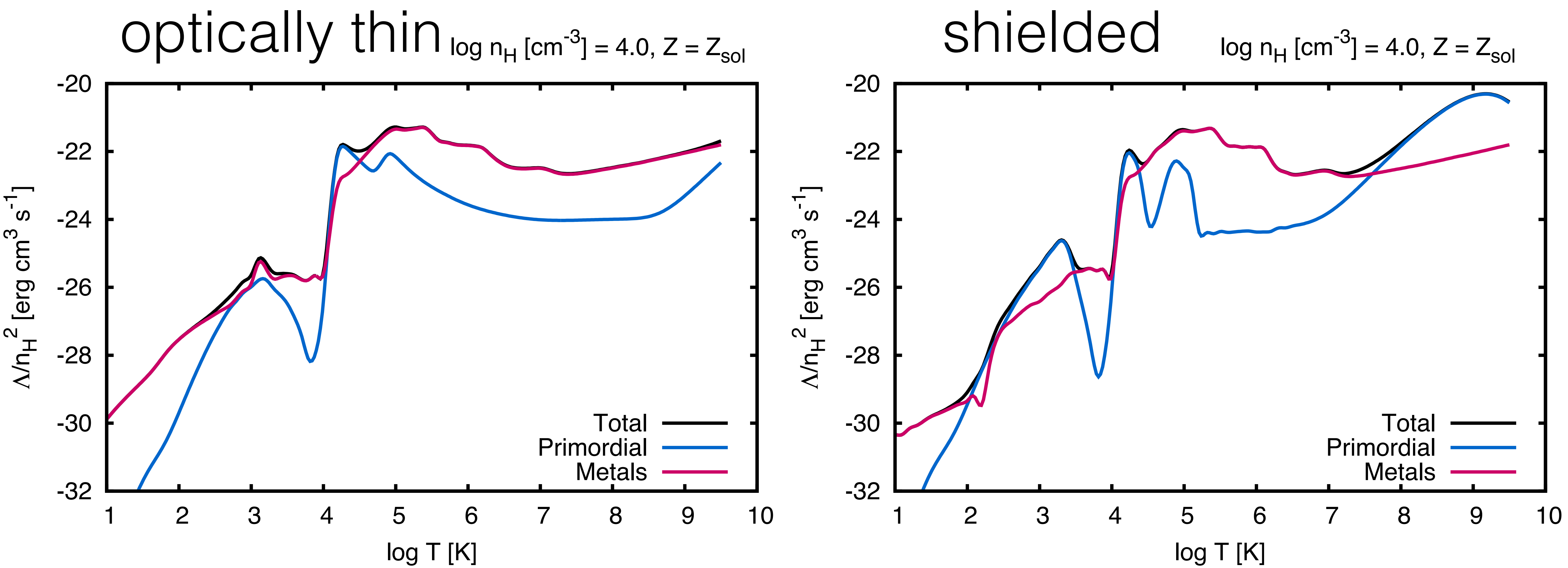




New cooling tables

z=0 UV background (Haardt & Madau, 2012)



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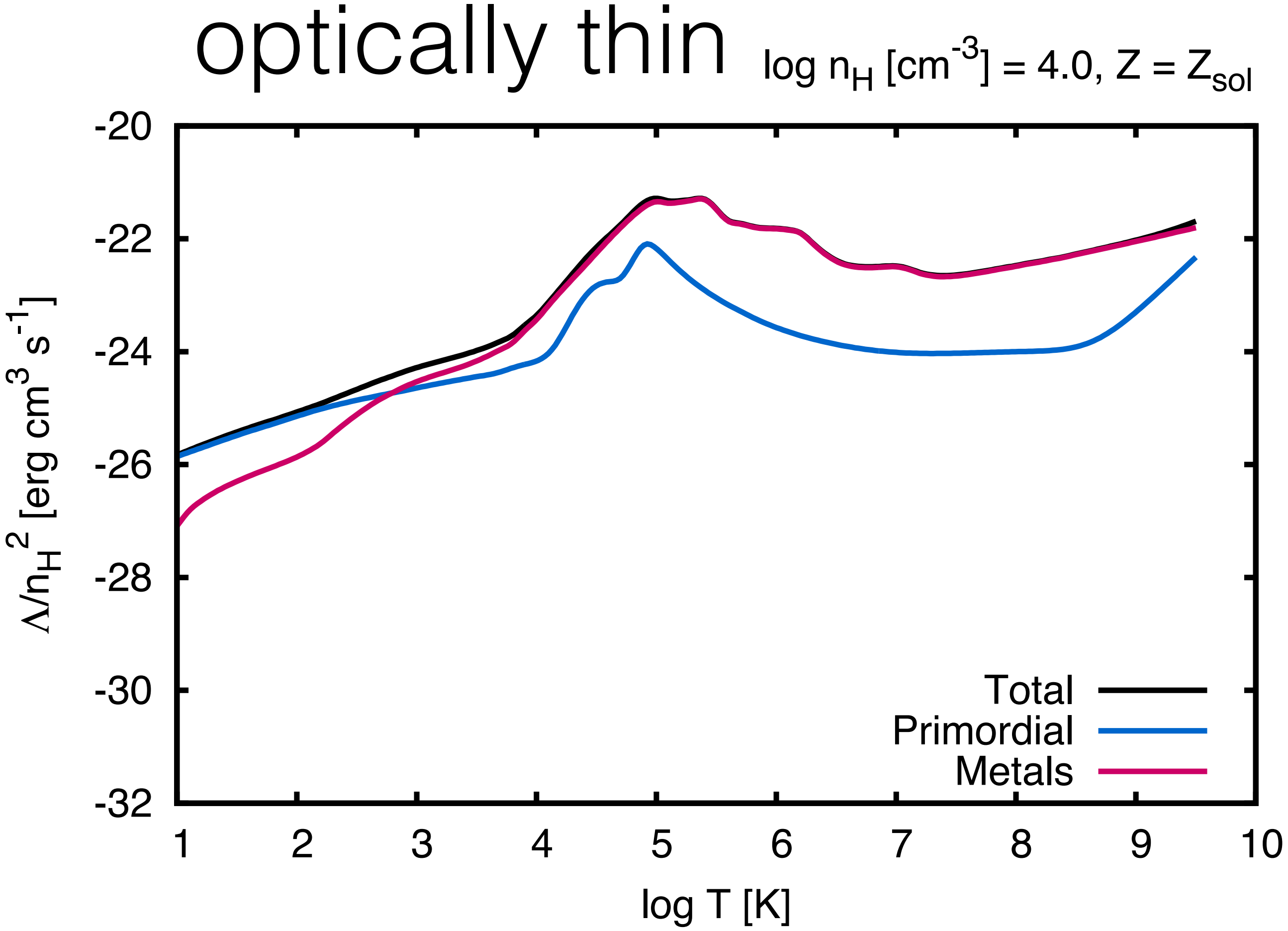
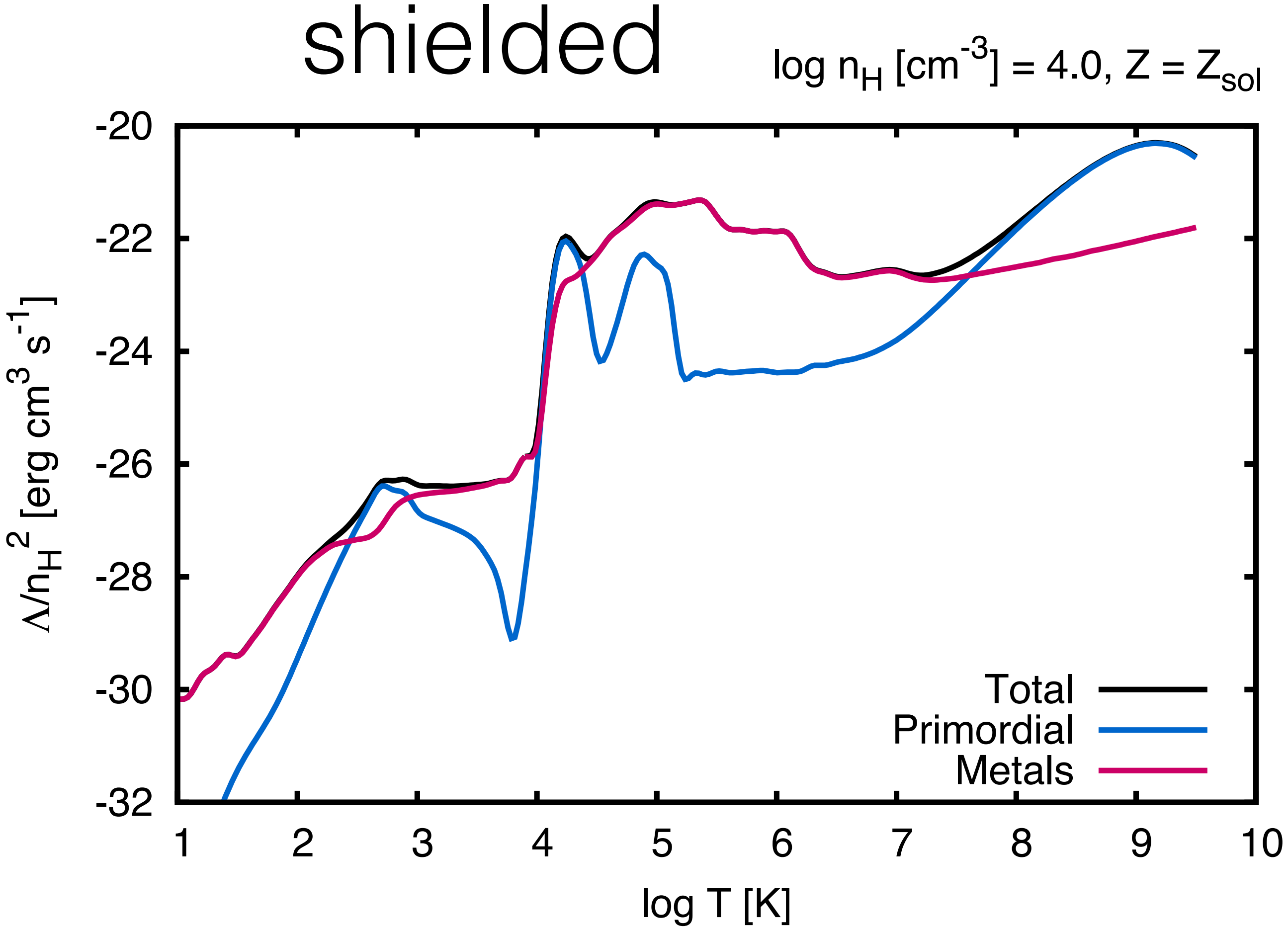
New cooling tables

z=0 UV + stellar radiation field

optically thin



shielded



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New cooling tables

z=0 UV + stellar radiation field

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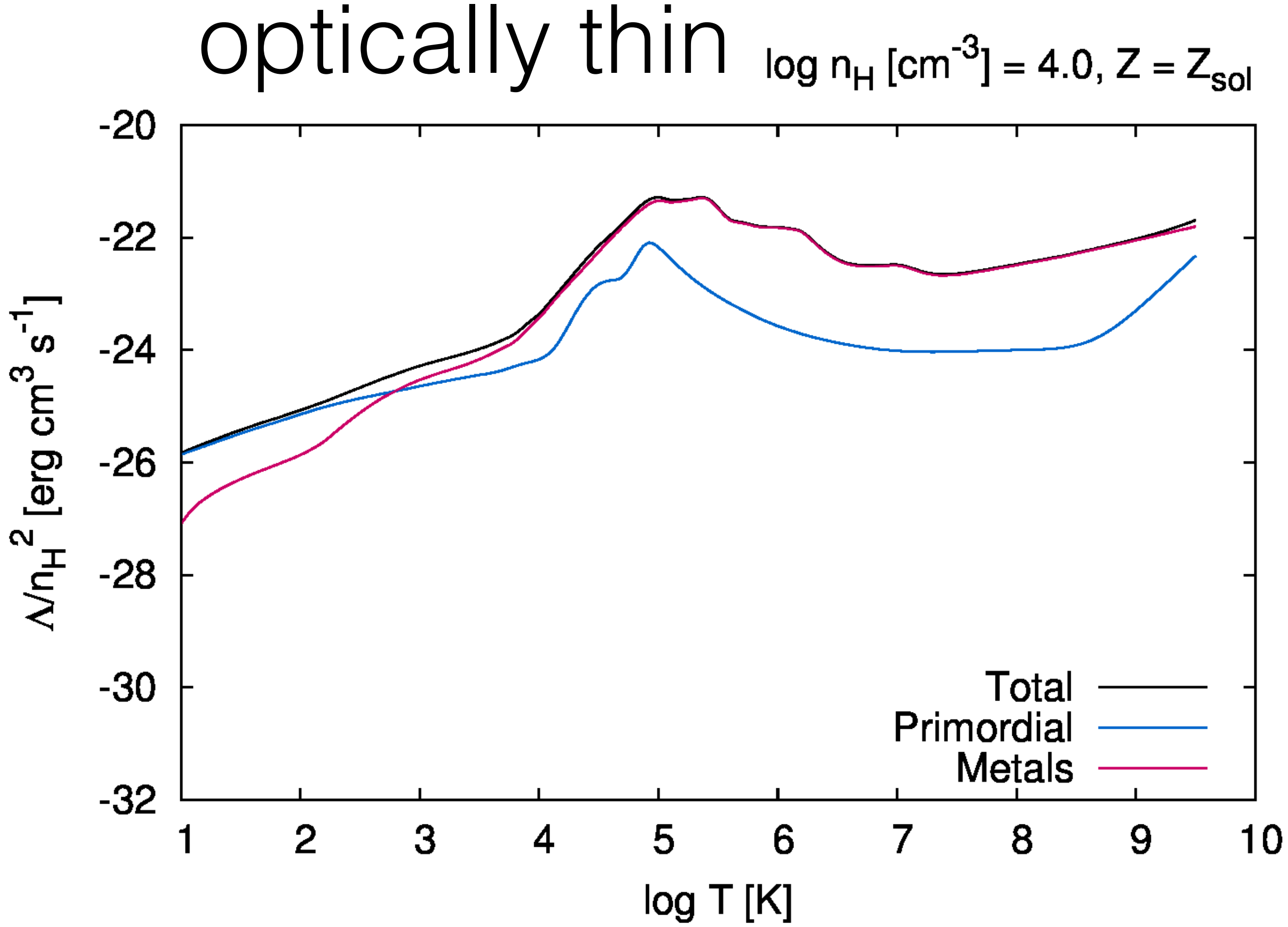
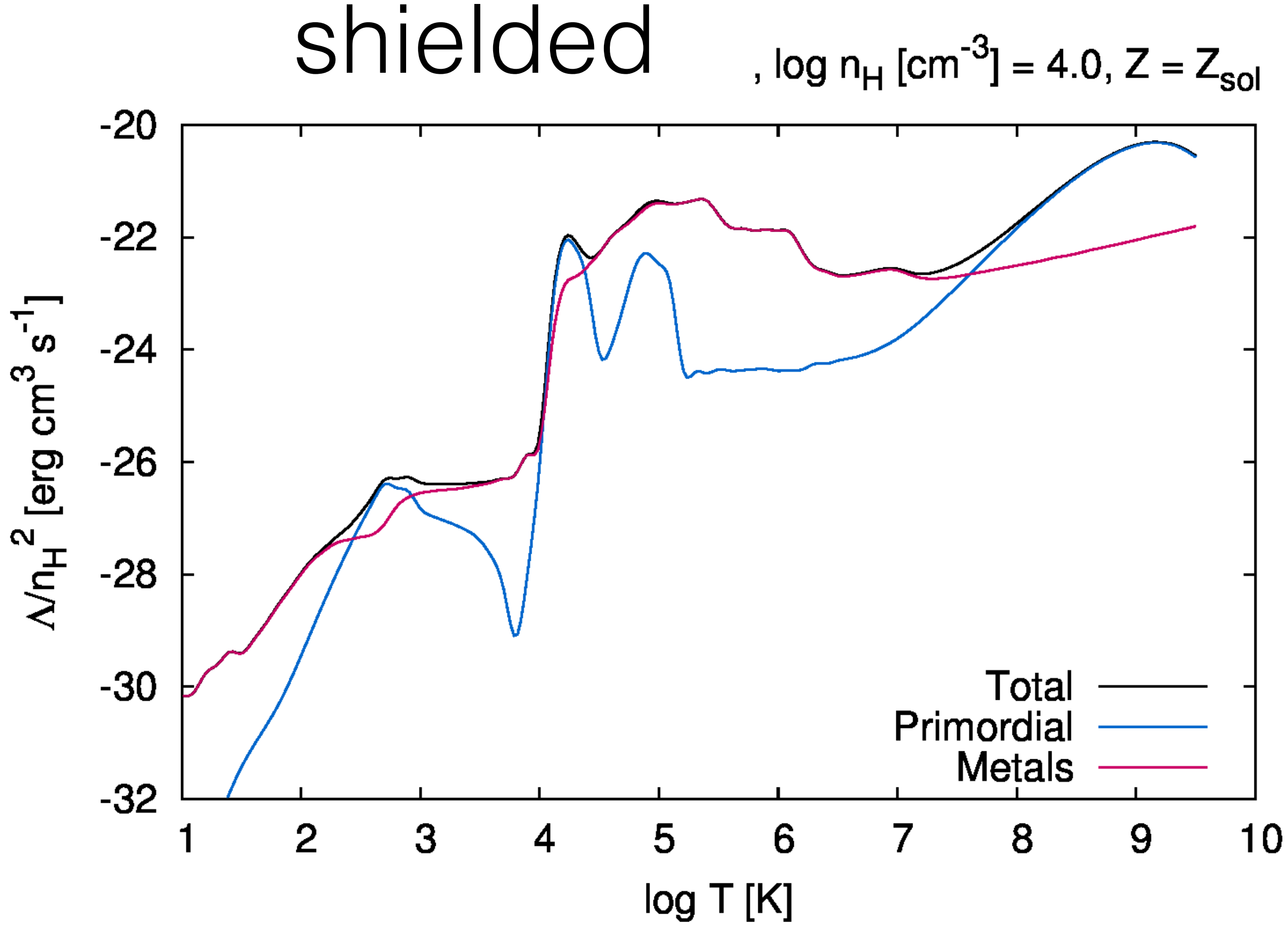


shielded



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