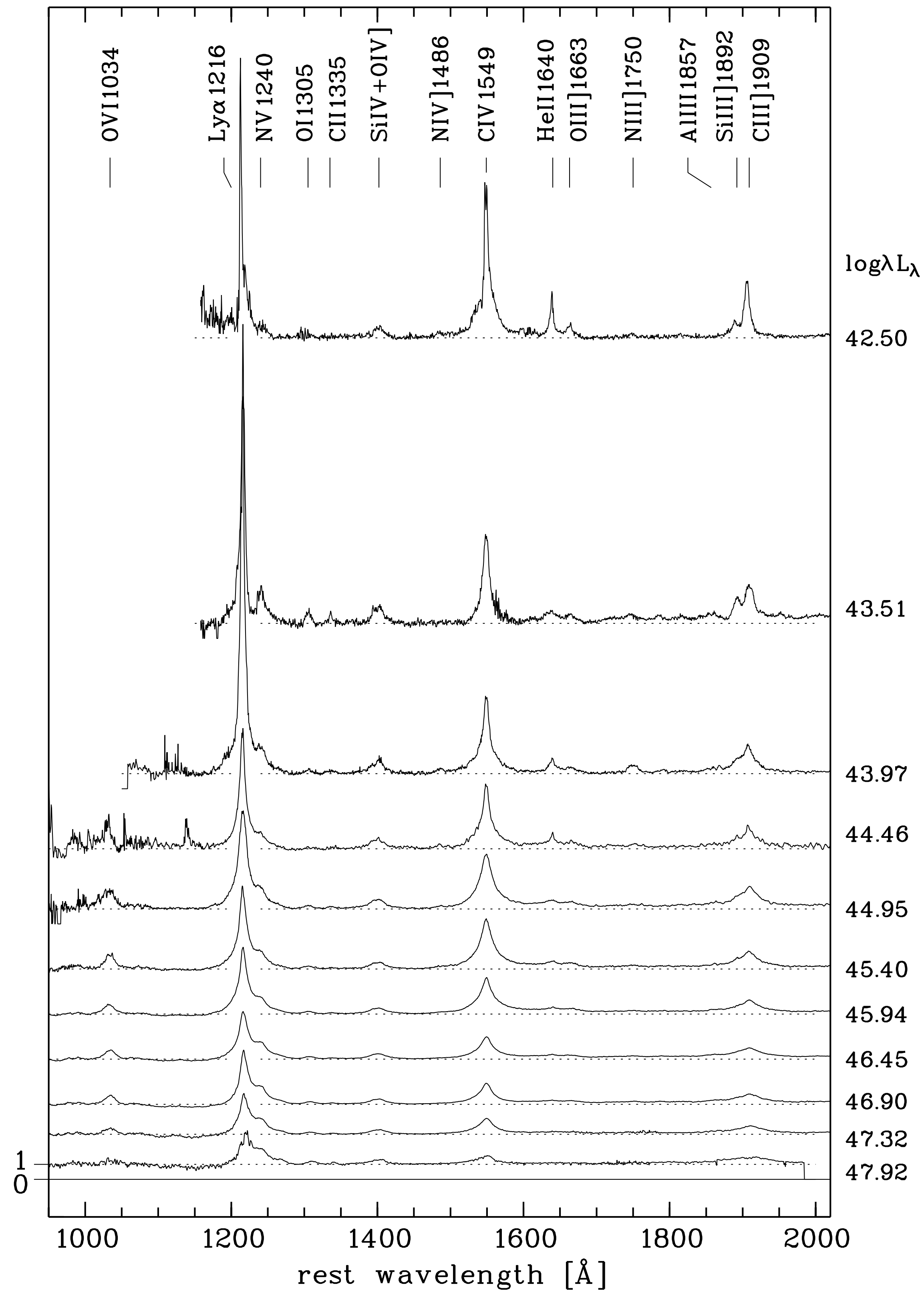
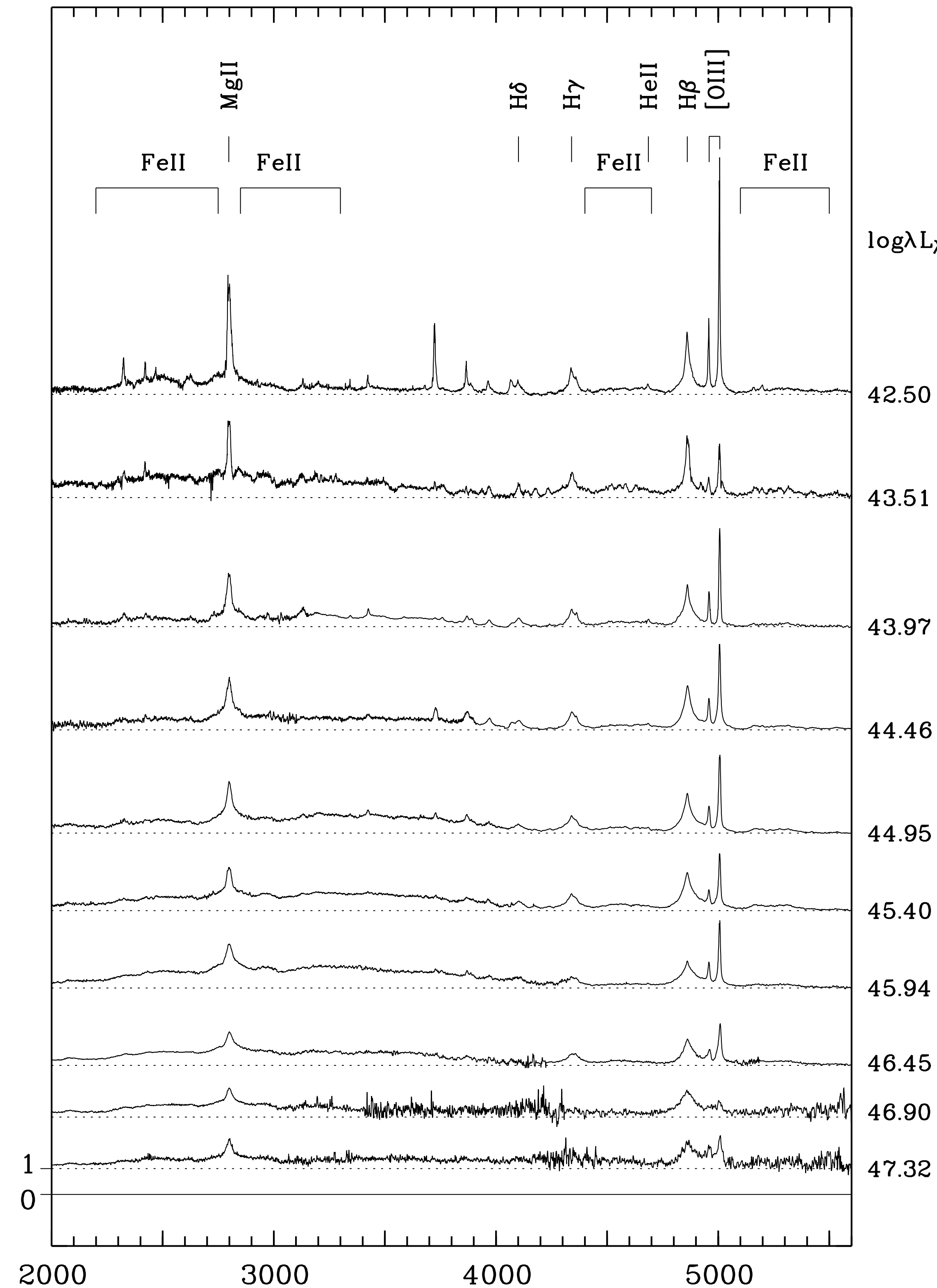
Why is the BLR emission similar in AGN at L=10^39-10^47?

or Radiation Pressure Confinement and the BLR

work done with Alexei Baskin and Jonathan Stern





Dietrich et al. (2002, ApJ 581, 912)

→ <u>Similar n_e and U distributions</u> (or n_e, n_{ph})

Two interesting coincidences in the BLR

$R_{BLR} \sim R_{sub}$ - the dust sublimation radius
$P_{gas} \sim P_{rad}$ in the BLR

Davidson (1972)
Greg Shields (1978) *Pittsburgh Conference on BL Lac Objects*

But the relation were not quit valid.
(because R_{BLR} was off by a factor of ~10)

Reverberation gave the correct R_{BLR} (late 80's), and then the above relations became valid.
But by then the ideas were forgotten…

What sets n_{ph}?

Dust opacity - 10^{-21} per H
Photoionized gas opacity - $10^{-23}/U$ per H
⟶ Dust dominates the absorption when $U>10^{-2}$

Dust survives down to $R_{sub}=0.2L_{46}^{1/2}$ pc.
Sets the outer BLR radius (Suganuma+06), for $U>10^{-2}$ gas

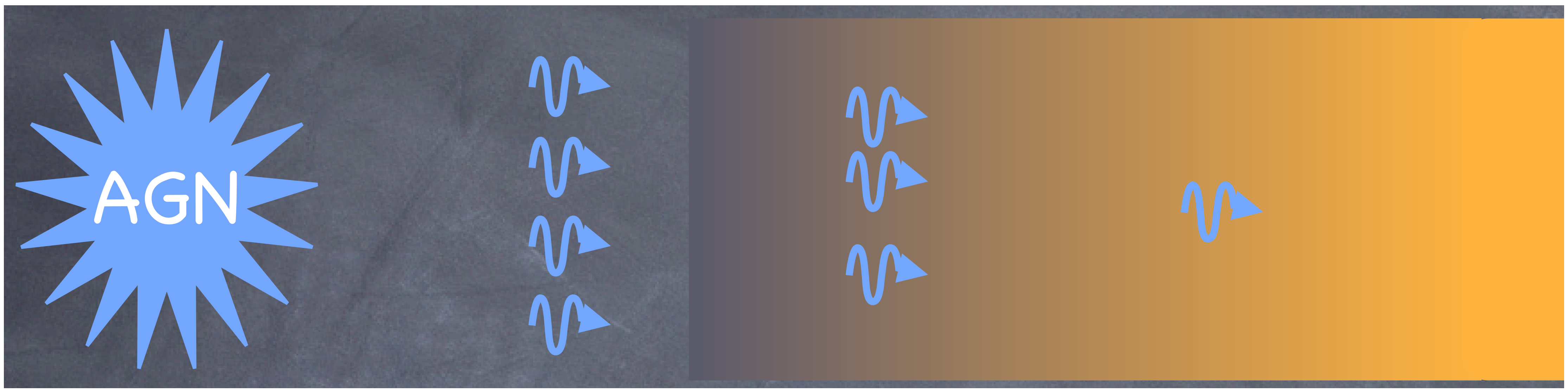
Dust survival in the accretion disk atmosphere may set the inner BLR radius (Hryniewicz & Czerny 11)

Explains the famous $R_{BLR}=0.1L_{46}^{1/2}$ RM result

Implies a **universal $n_{ph} \sim 3x10^9$** cm^{-3} in the BLR

What sets n_e?

Radiation carries energy and momentum
If the gas is not outflowing, P_{rad} must be balanced by P_{gas}

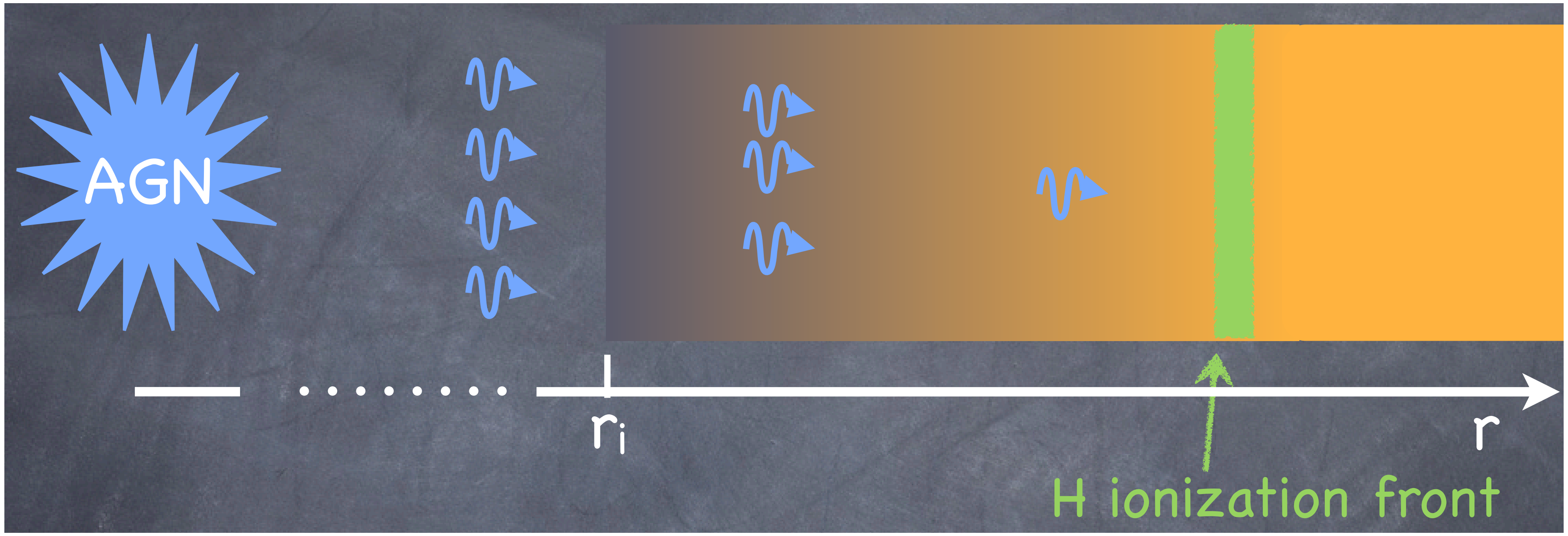


At the 0'th order level $P_{rad}=P_{gas}$

$2n_ekT=n_{ph}<hnu>$, $n_{ph}/n_e=U=2kT/<hnu>$
$2kT\sim3eV$, $<hnu>\sim30eV$

——> **U=0.1**   Independent of distance and luminosity

What is the structure of the absorbing layer?



$$\mathrm{d}P_{\rm gas}(r) = \frac{F_{\rm rad}}{c} e^{-\tau(r)} \mathrm{d}\tau$$ —> $P_{gas}(r) = P_{rad}(1 - e^{-tau(r)}) + P_{gas}(r_i)$

$$2kT_{\rm C} \frac{\mathrm{d}n_e(r)}{\mathrm{d}r} = \frac{F_{\rm rad}}{c} n_e \sigma_{\rm es}$$

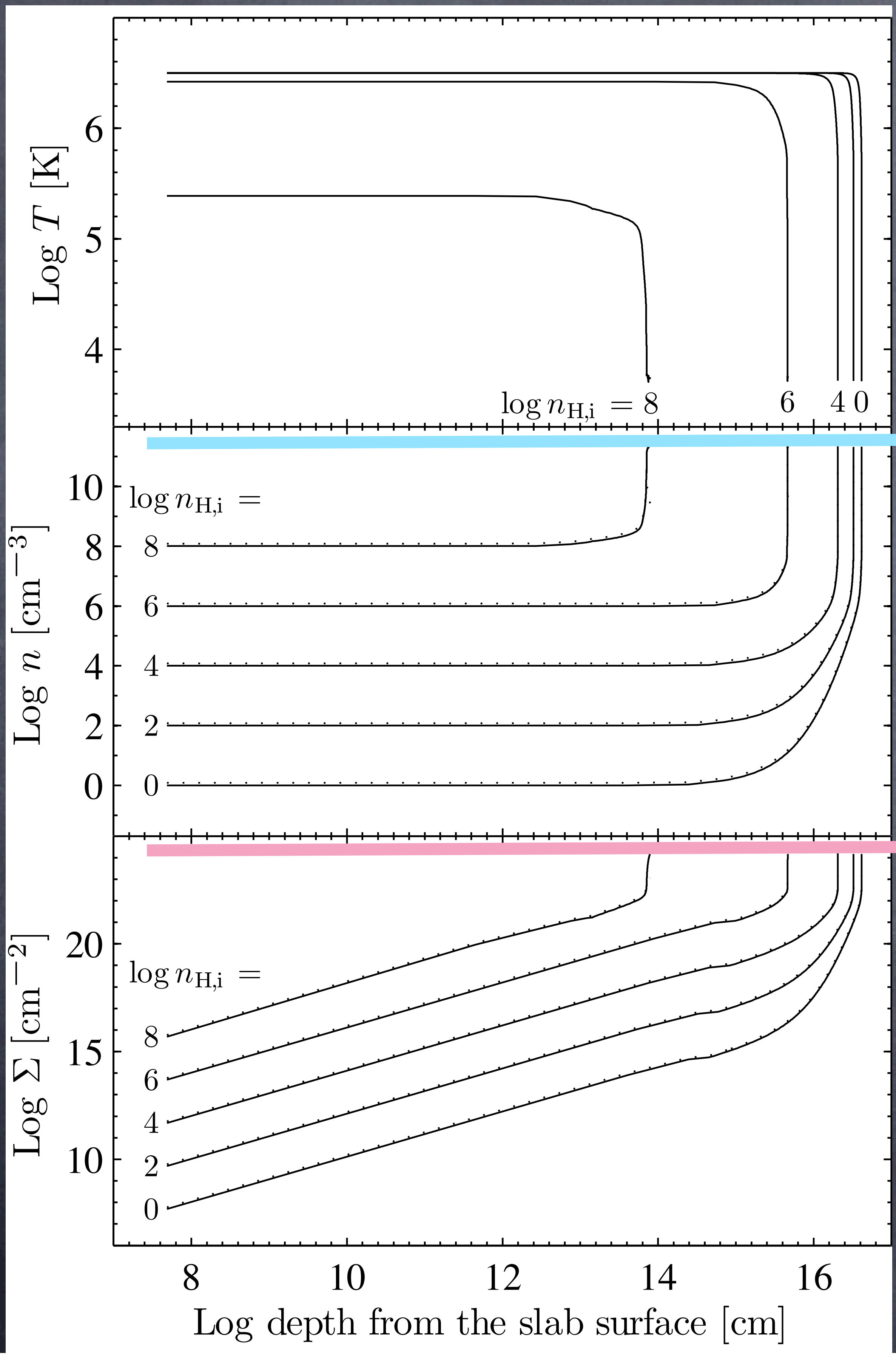
$$n_e(r) = n_{e,\rm i} \exp\left(\frac{r - r_{\rm i}}{l_{\rm pr}}\right)$$

$$l_{\rm pr} = 2kT_{\rm C} c / F_{\rm rad} \sigma_{\rm es}$$

Numerical solutions

- Cloudy 10.00
  - Executed with the "constant pressure" command.
  - Stops when H^+/total H = 1%.
  - log n_i = 0-10 (n_i - density at the illuminated side).
  - log L = 41.5-46.

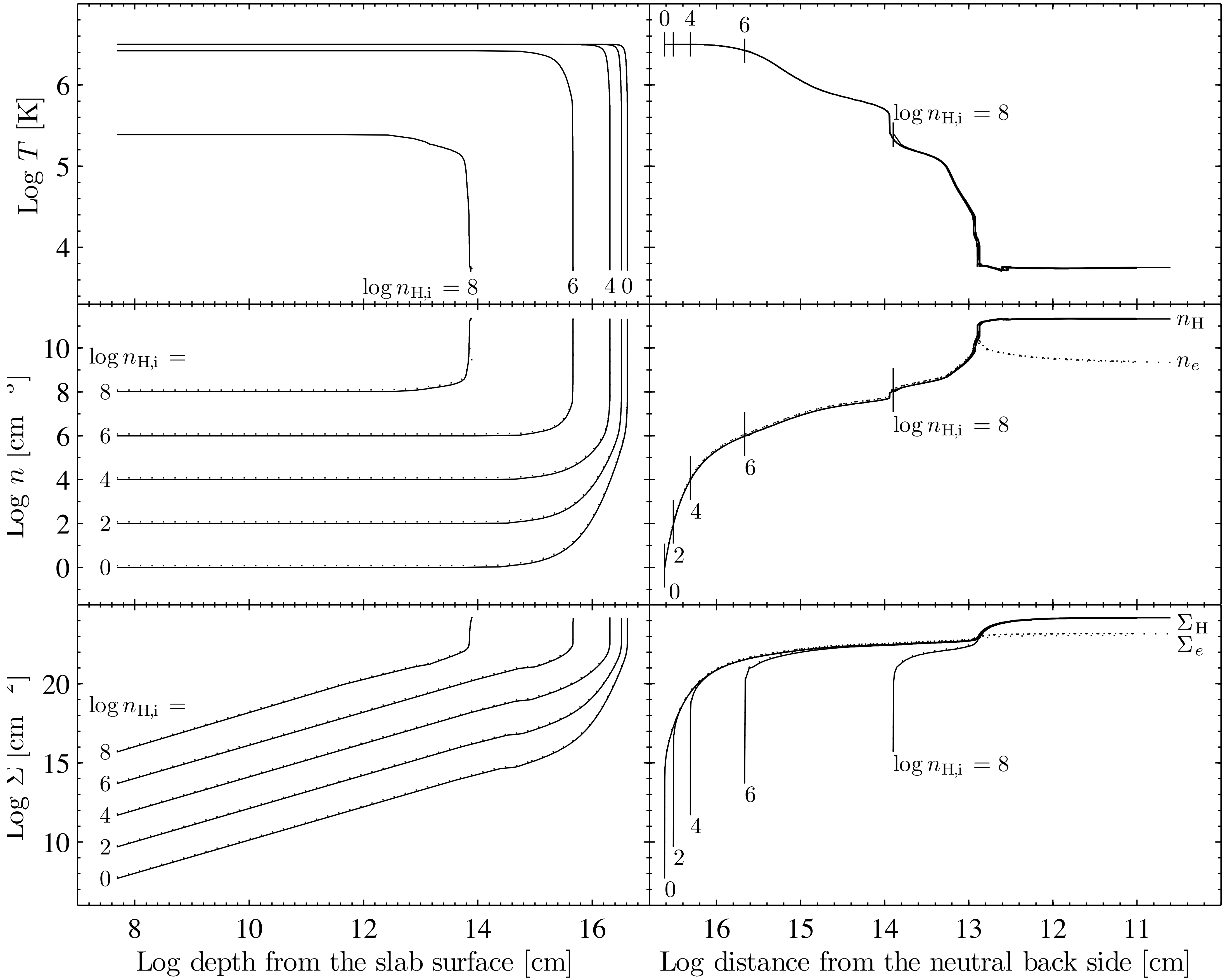
Slab structure for $L=10^{45}$ & $r=r_{BLR}=10^{17}$ ($n_\gamma \sim 10^9$)



large range in T: from T_{Comp} to $\lesssim 10^4$K

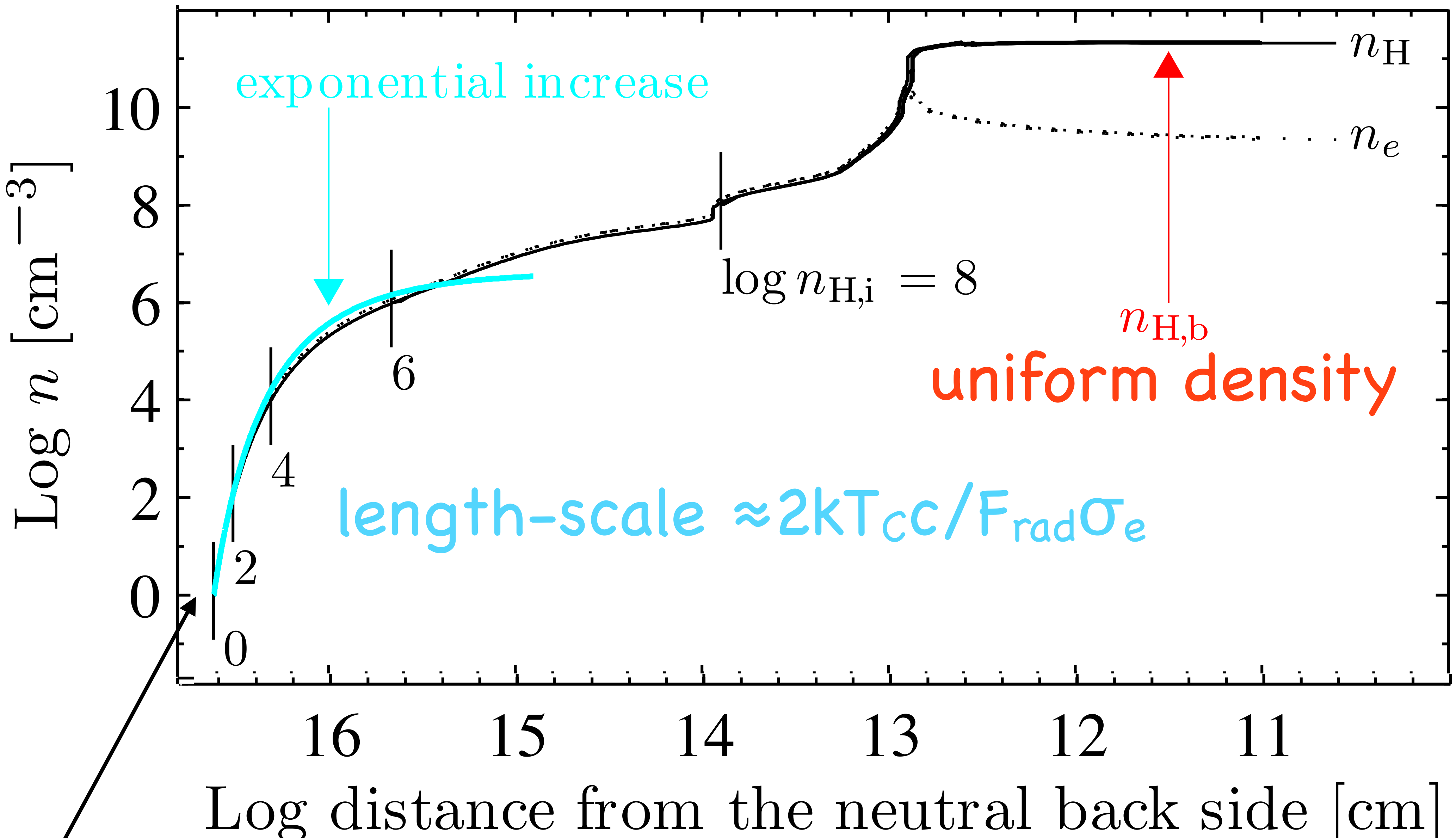
same n at the back neutral side, **independent of n_i**

very similar total N_H



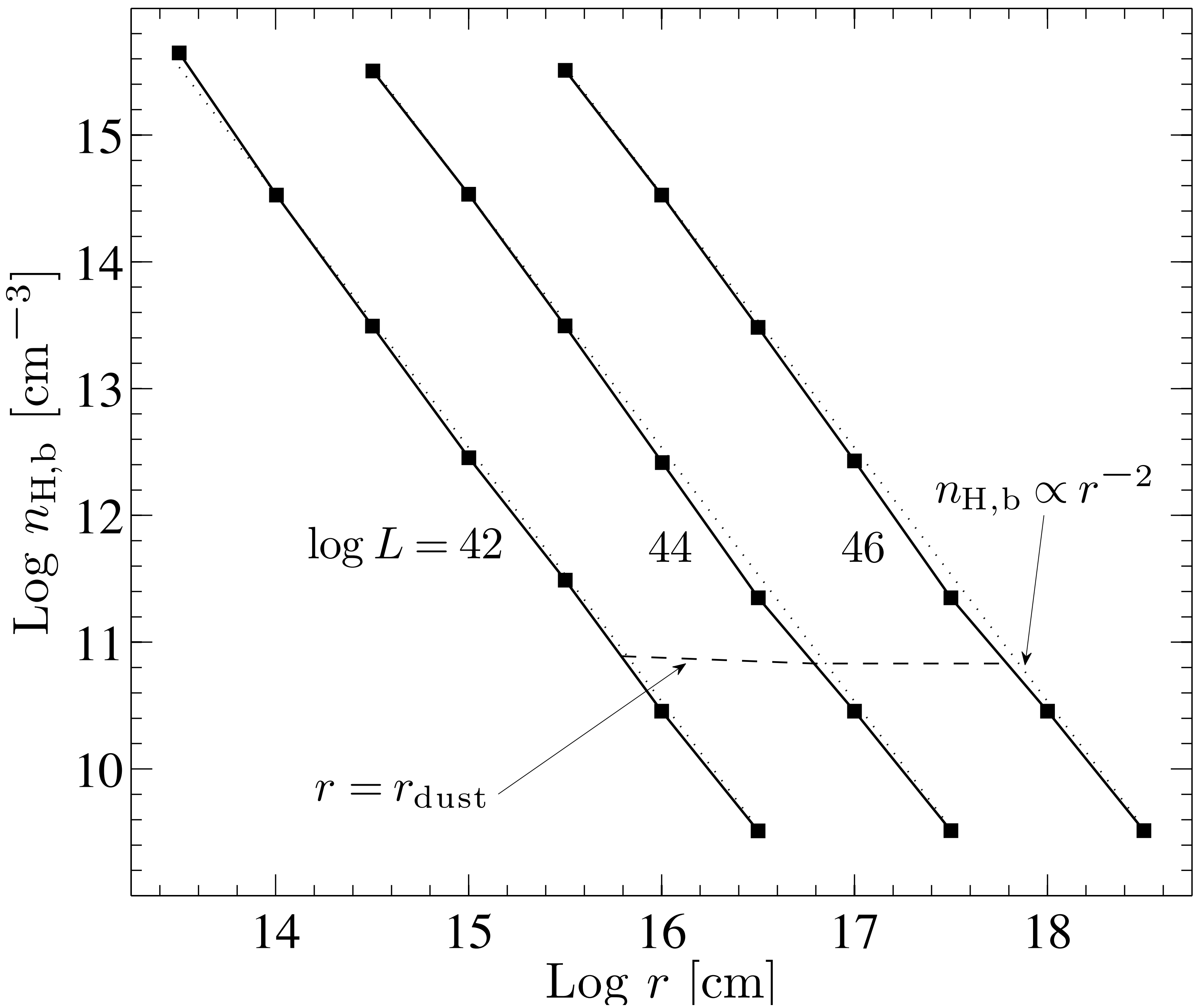
The structure is independent of $n_{H,i}$

Radiation Pressure Confinement - RPC



$$n_e(r) = n_{e,\rm i} \exp\left(\frac{r - r_{\rm i}}{l_{\rm pr}}\right)$$

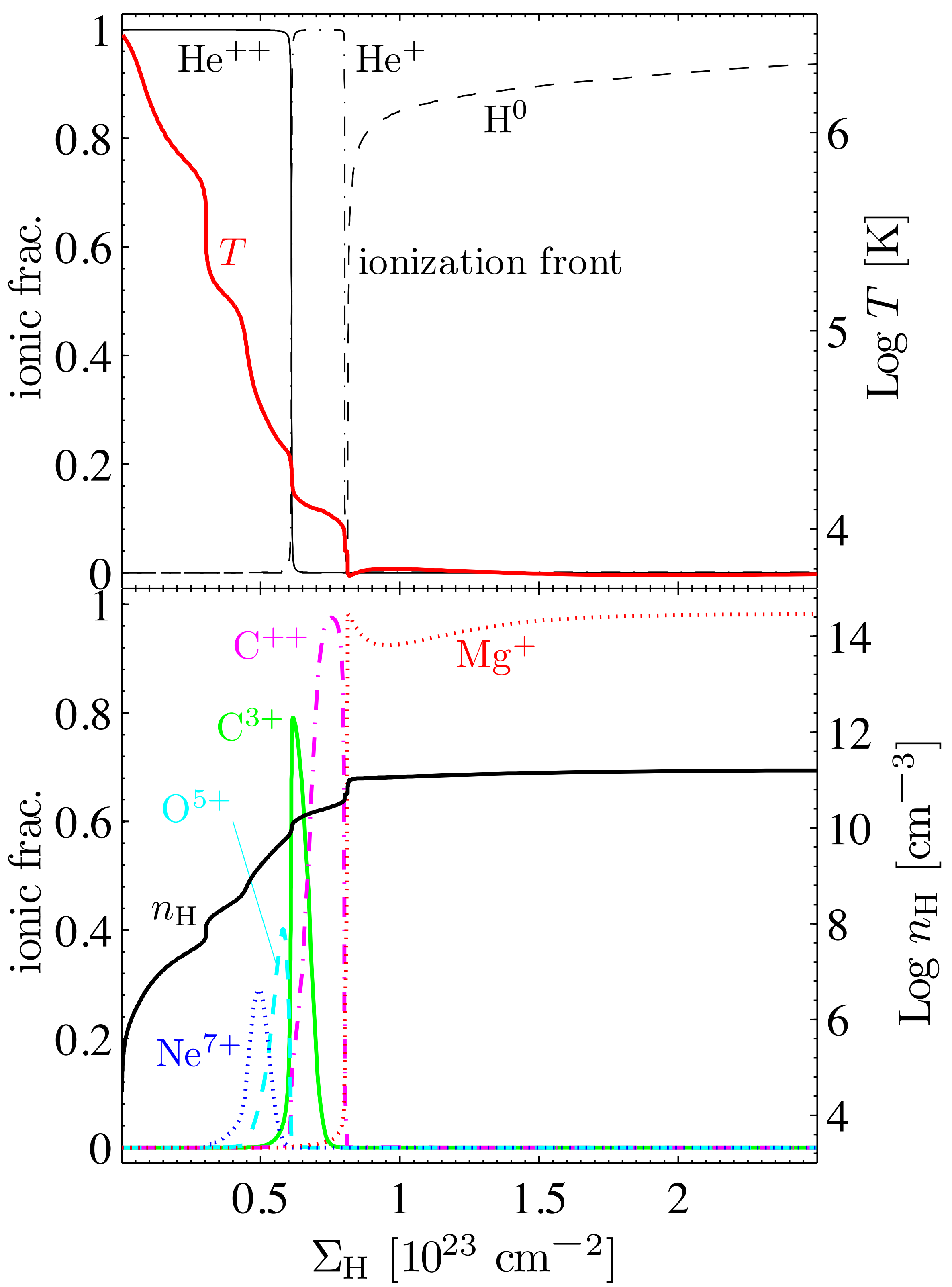
The maximal density



$$n_{\rm H,b} \simeq 3 \times 10^{14} L_{46} r_{16}^{-2}$$

Ionization structure of a given RPC slab

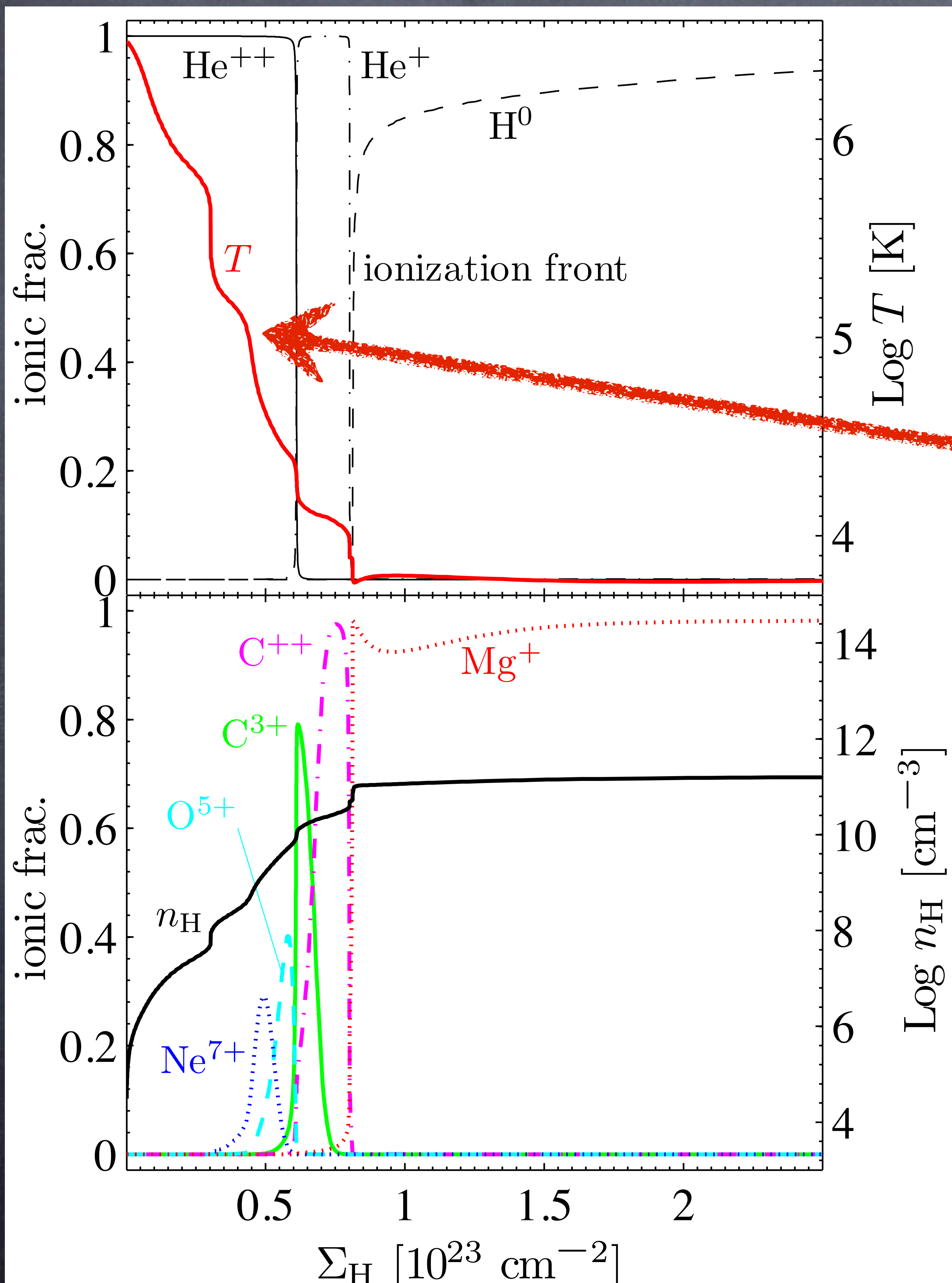
$r = r_{BLR}$



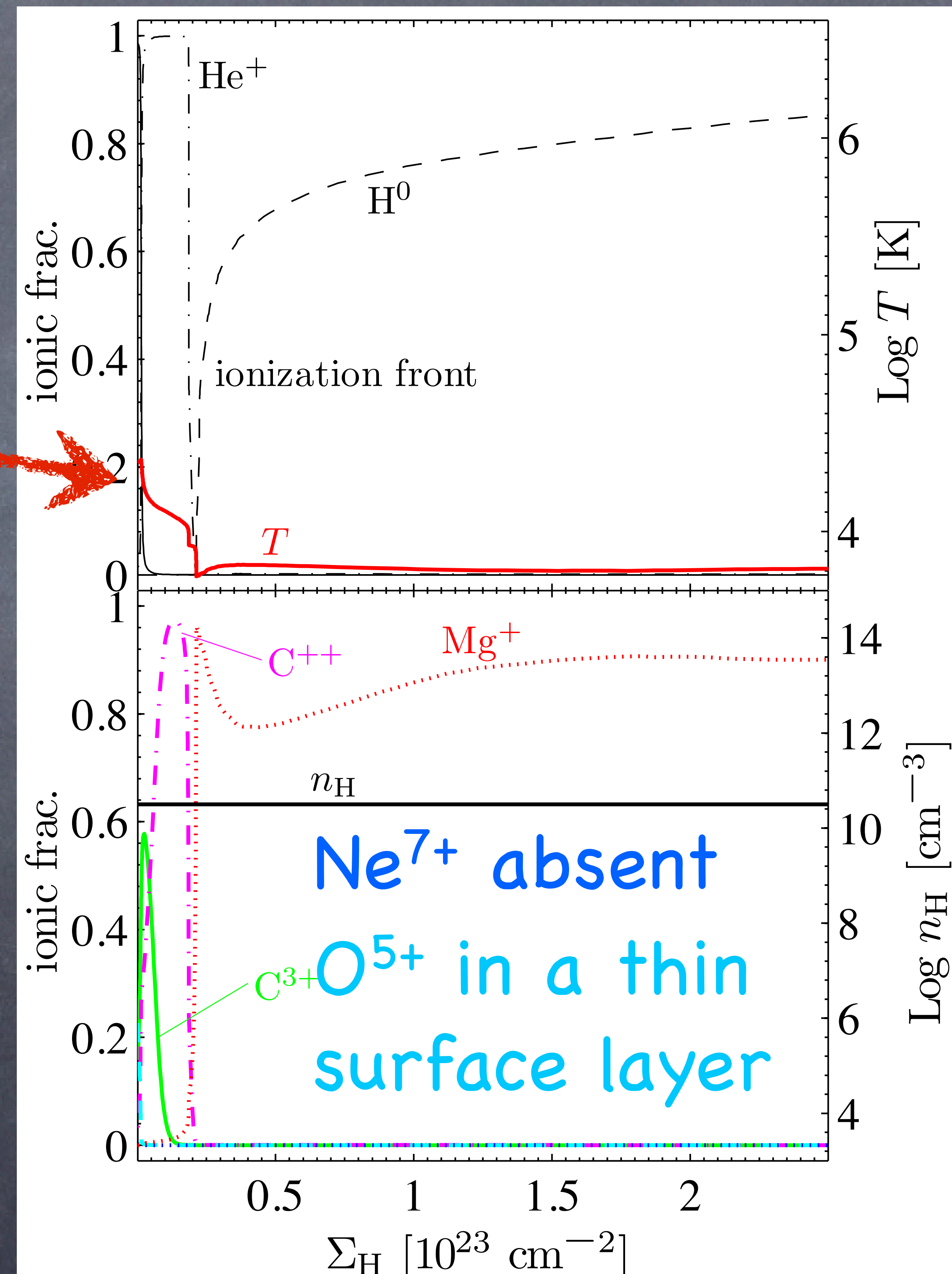
large range in n => large range in U => both very high- and very low-ionization ions **in the same slab**

Comparison to a constant-n slab

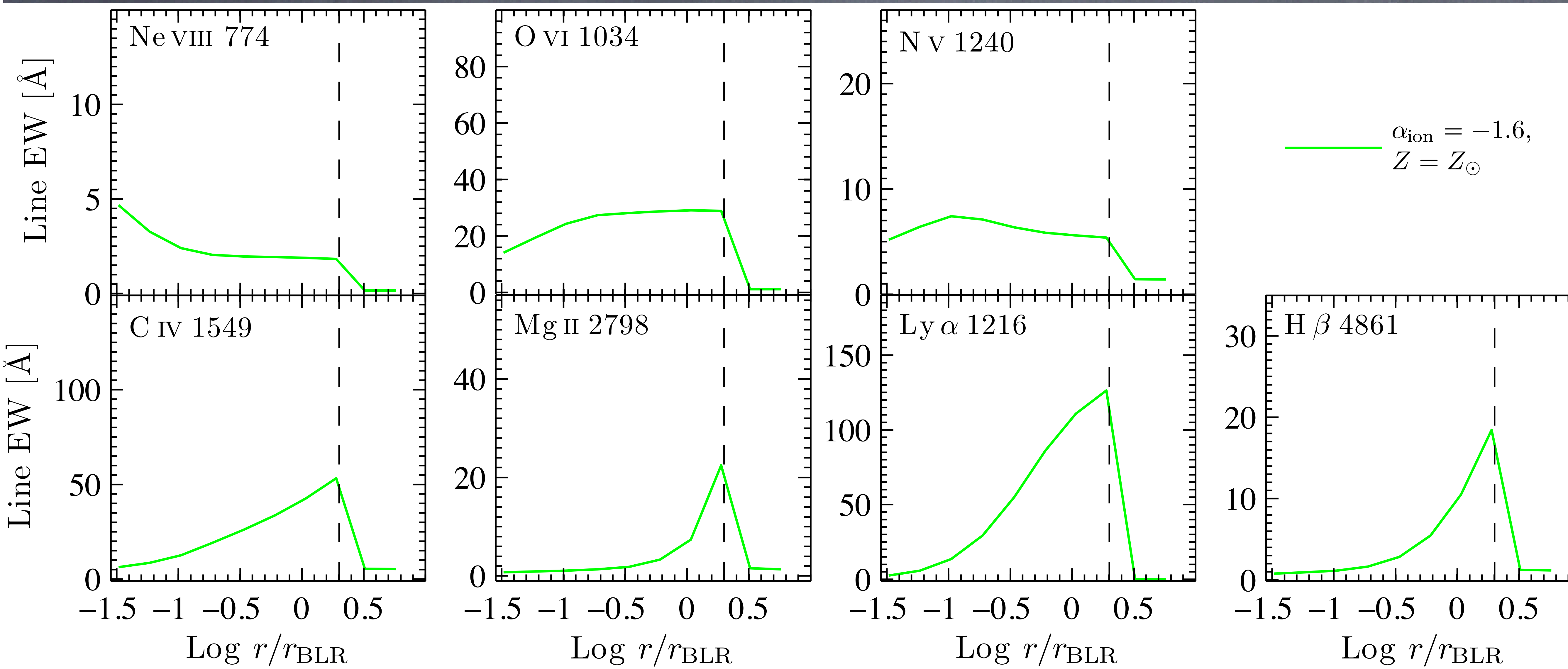
RPC slab



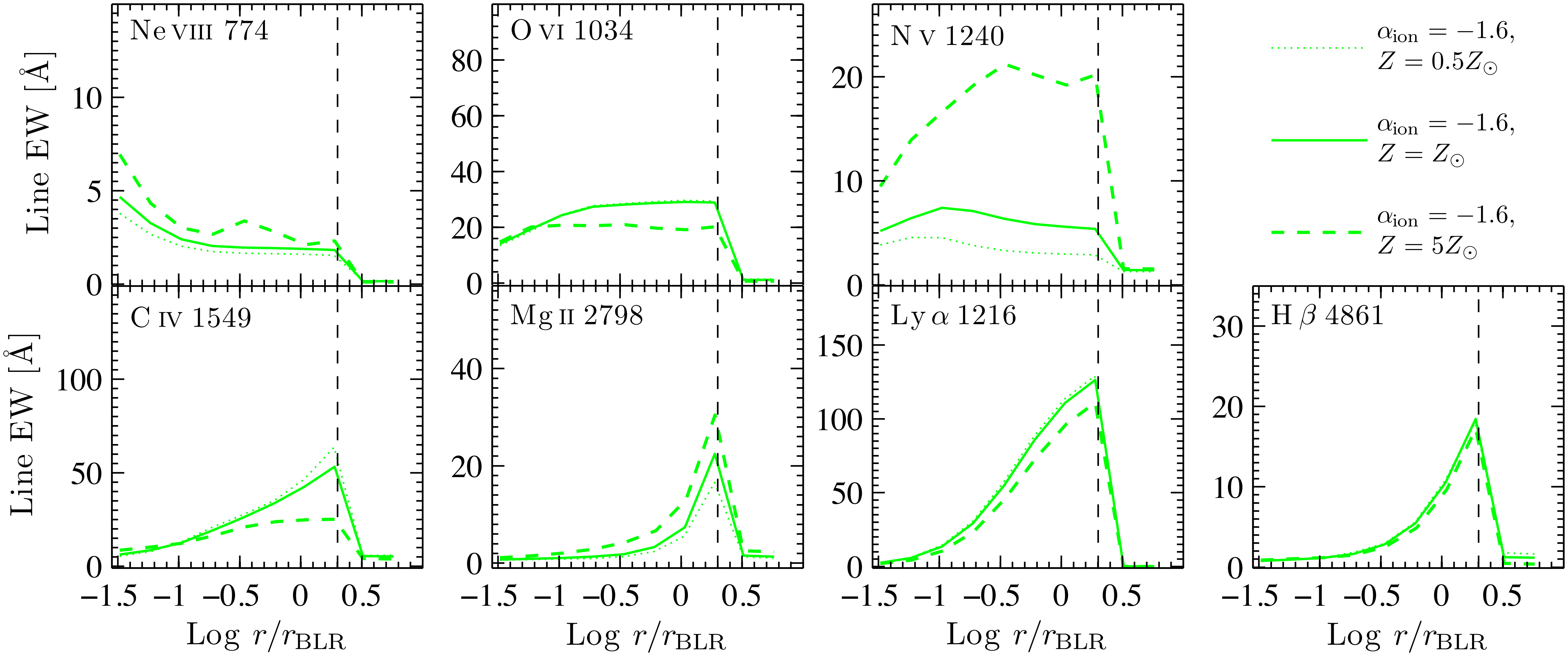
$n=10^{10.5}$ (U=0.05)



Line EW from slabs at different r

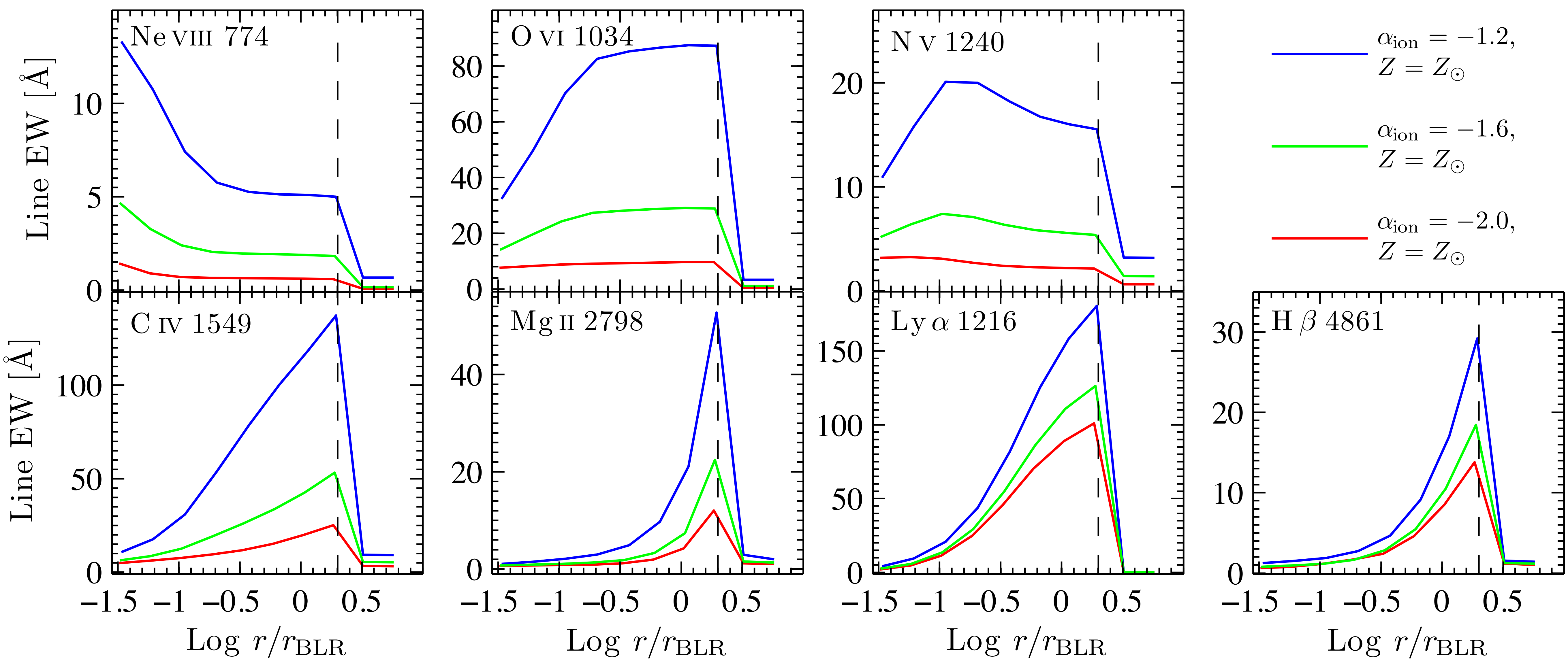


Ω_{BLR}=0.3



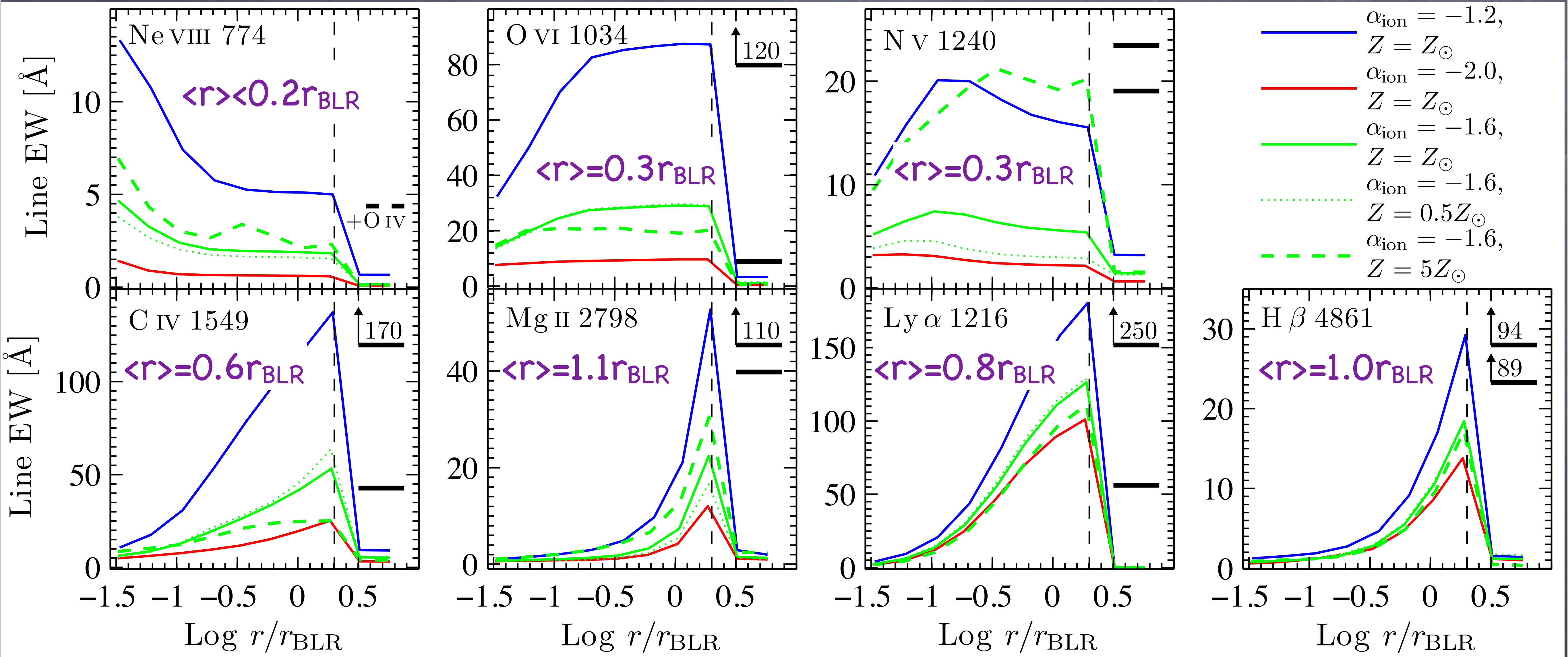
Metallicity effect.

Ω_{BLR}=0.3



Ionizing SED effect.

Ω_{BLR}=0.3



The observed range from Dietrich+02 (Ne VIII from Telfer+02). Ω_{BLR}=0.3

As the ionization potential decreases, the average-emission radius increases.

Summary

Radiation Pressure Confinement is inevitable for a hydrostatic BLR.

- explains universal U~0.1, independent of L=10^{39}-10^{48} erg/s.
- predicts U~0.1, independent of r as well.
- predicts $n \simeq 3 \times 10^{14} L_{46} r_{16}^{-2}$ at the neutral back side.
- **n, U, and r are not independent parameters.**
- predicts very high- and very low-ionization ions in **the same BLR cloud**.
- predicts BLR stratification, without any additional assumptions.

The answer:

$$P_{rad} = aT^4_{sub} \sim 0.1 \text{ erg cm-3}$$
$$P_{gas}=P_{rad} \longrightarrow nT \sim 10^{15}$$

X-ray warm absorbers measure the expected ionisation distribution

UV absorbers reveal a lower pressure in higher ionisation gas