Model of radiation in the near-surface accretion zone of T Tauri stars

Alexander Dodin
SAI MSU

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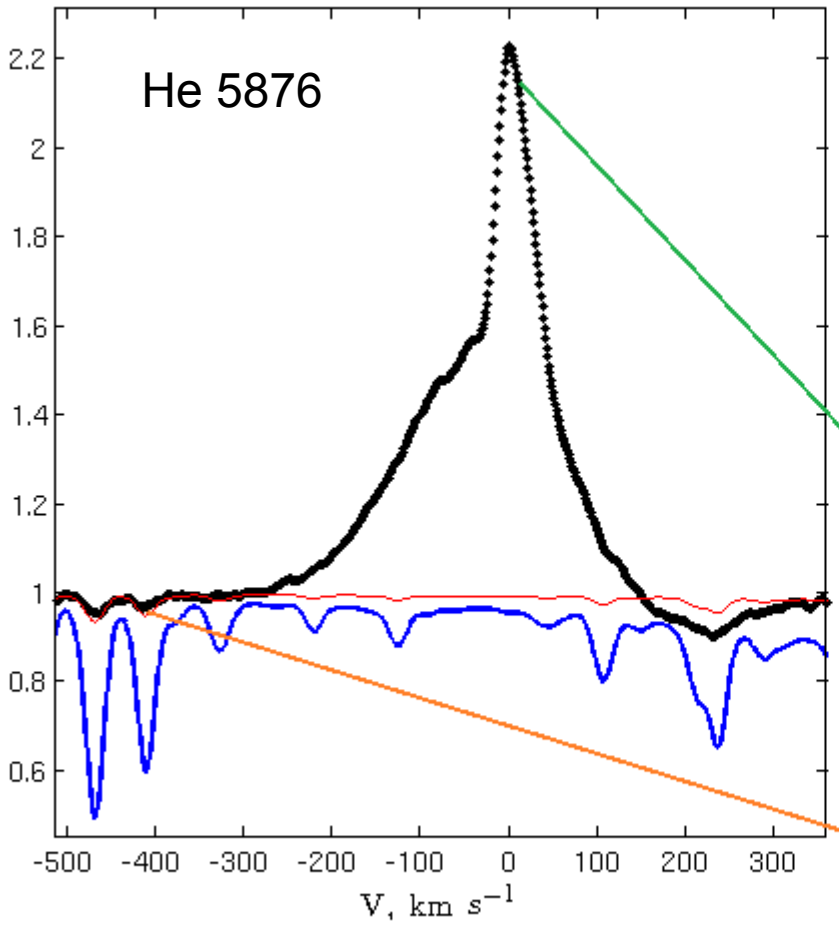
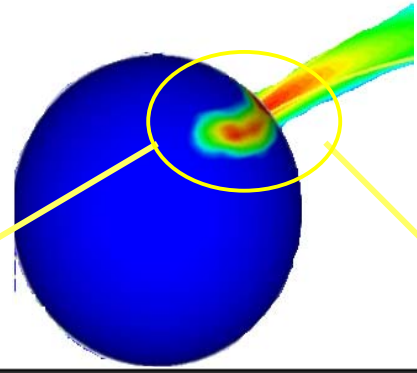
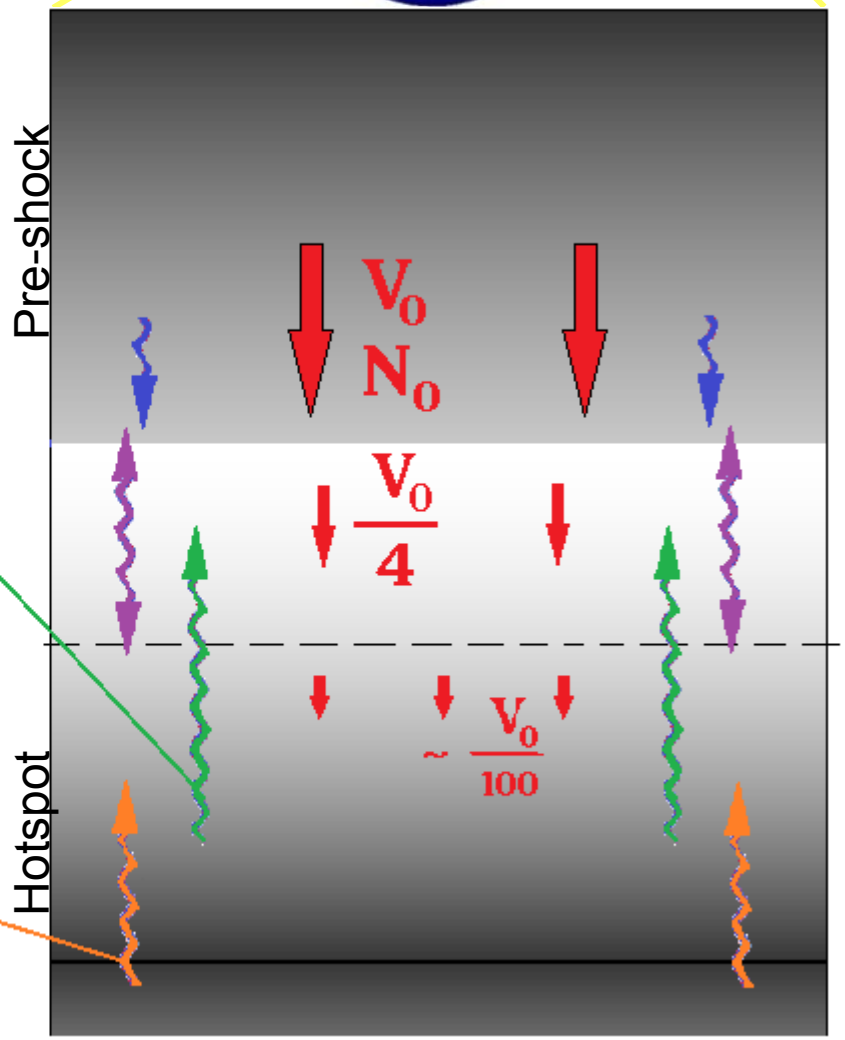

He 5876
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
-500
-400
-300
-200
-100
0
100
200
300
V, km s^{-1}




Pre-shock
Hotspot
V_0
N_0
$\frac{V_0}{4}$
$\sim \frac{V_0}{100}$

Non-LTE calculations of the hotspot

Reading atomic data and initial model

Solution of the hydrostatic equilibrium equation

Iterations

- Rates of all atomic transition
- Level populations and radiation field (DETAIL:ALI,OS)
- Convection (MLT)
- Temperature correction

non-LTE:

H: n = 1 – 20 (Przybilla&Butler, 2004)

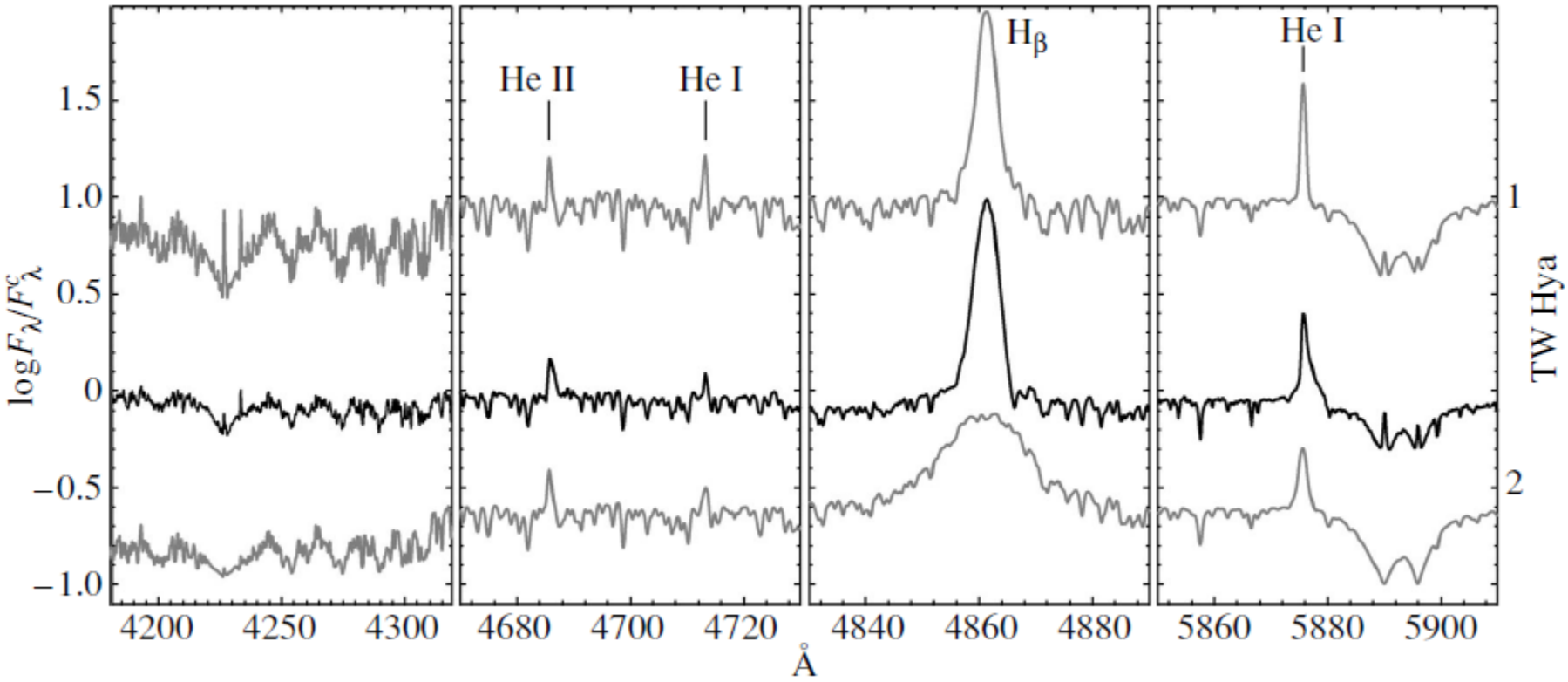
HeI: n = 1 – 10 (Przybilla, 2005)

HeII: n = 1 – 40

Atoms and ions of C – Zn with $E_i < 250$eV are treated in LTE.

List of 42 million lines for the line-blanketing

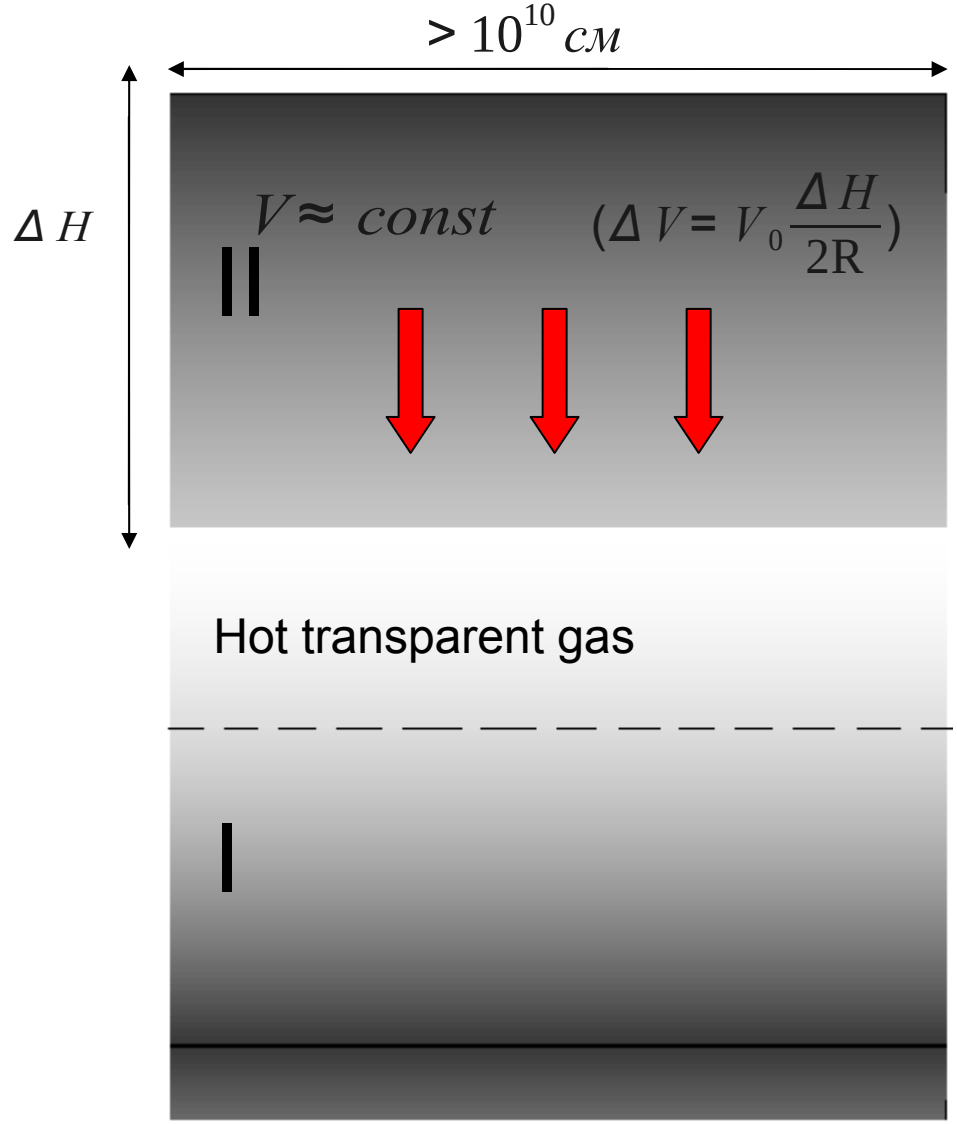
Photoionization cross sections are taken from TOPBase for C, N, O, Si, Mg, Al, Ar, Ne



$$F = C\left[f(H_{\rm hs} + H_{\rm pre}) + (1-f)H_*\right]$$

II infalling gas

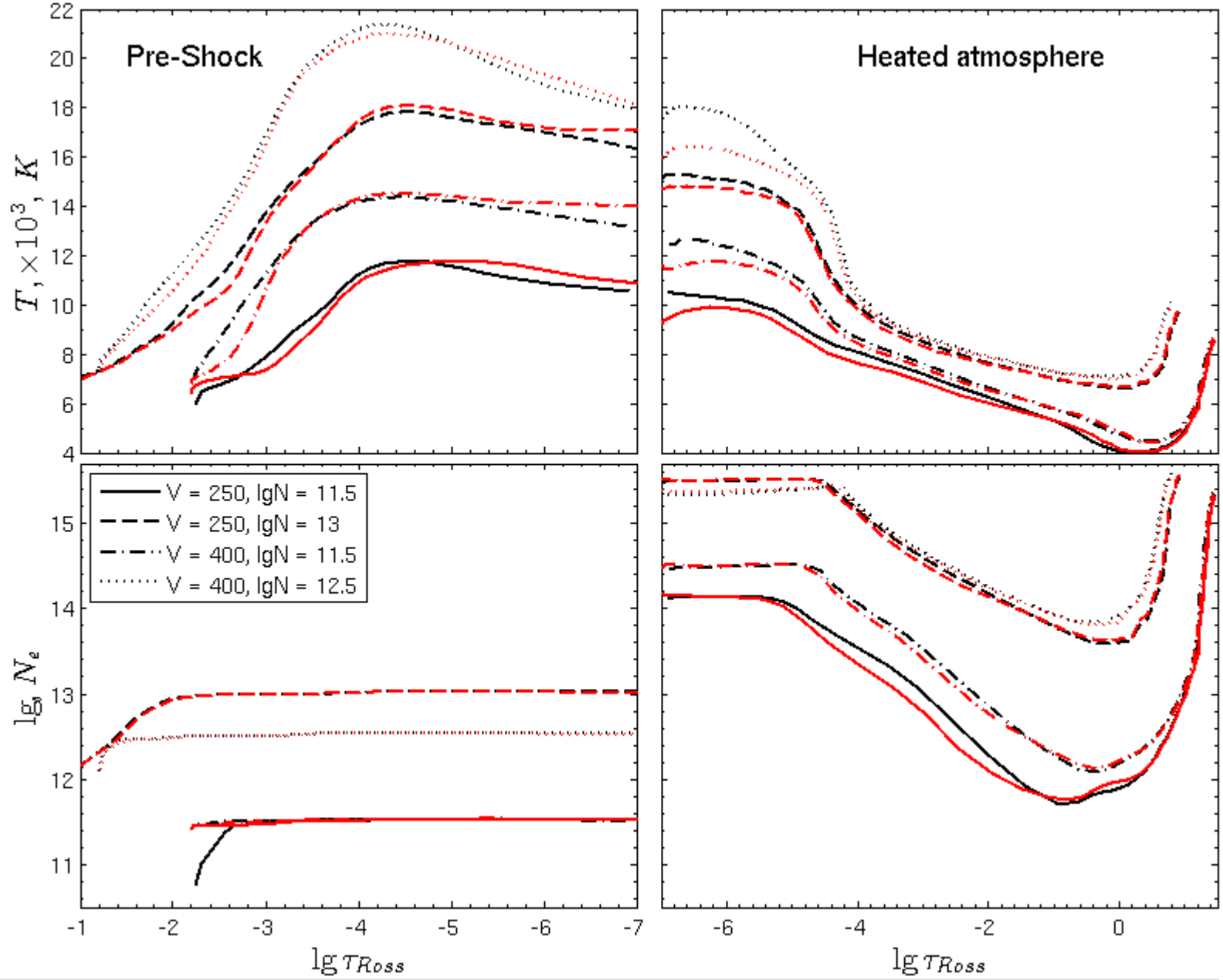
Plane-parallel gas slab with constant velocity

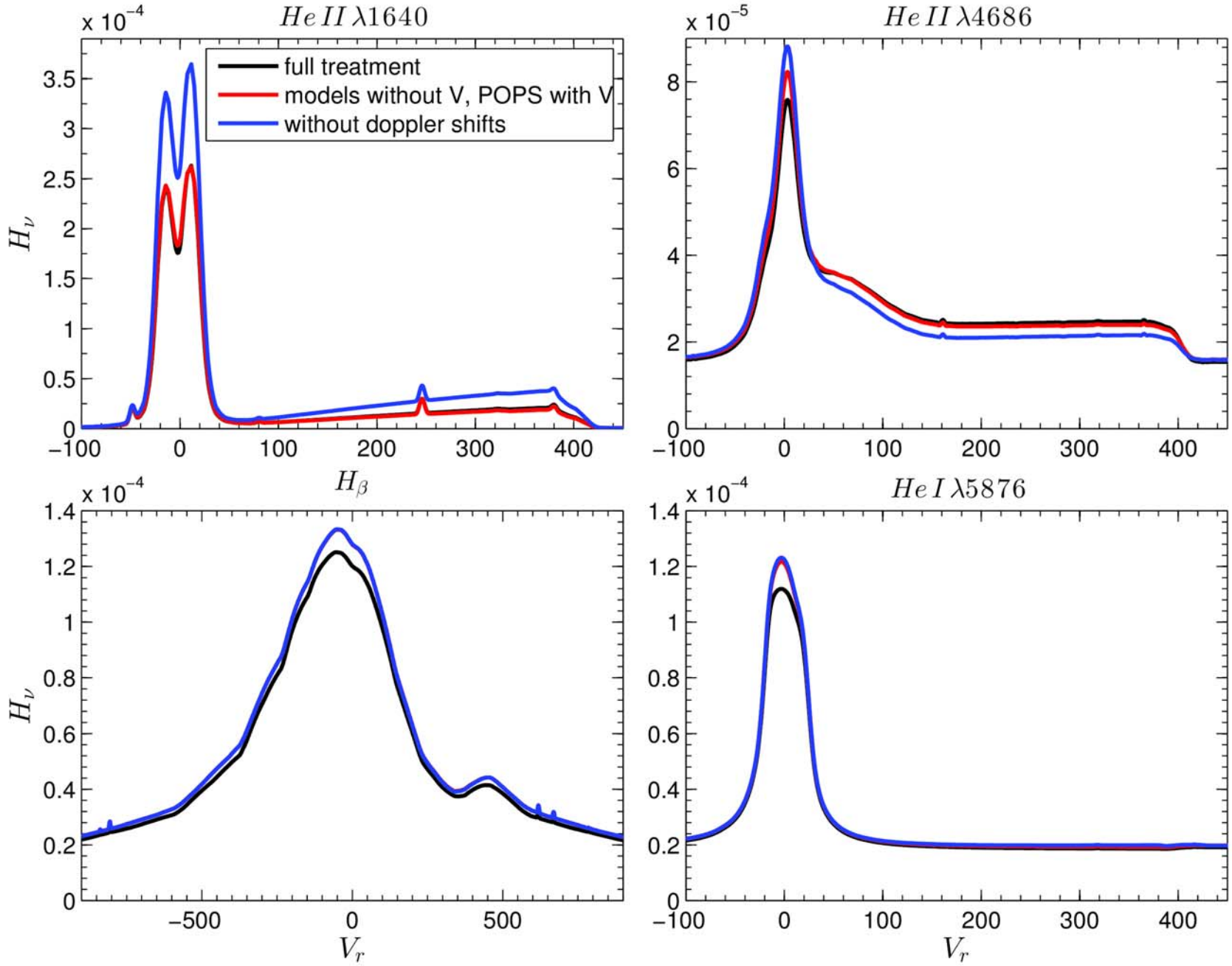


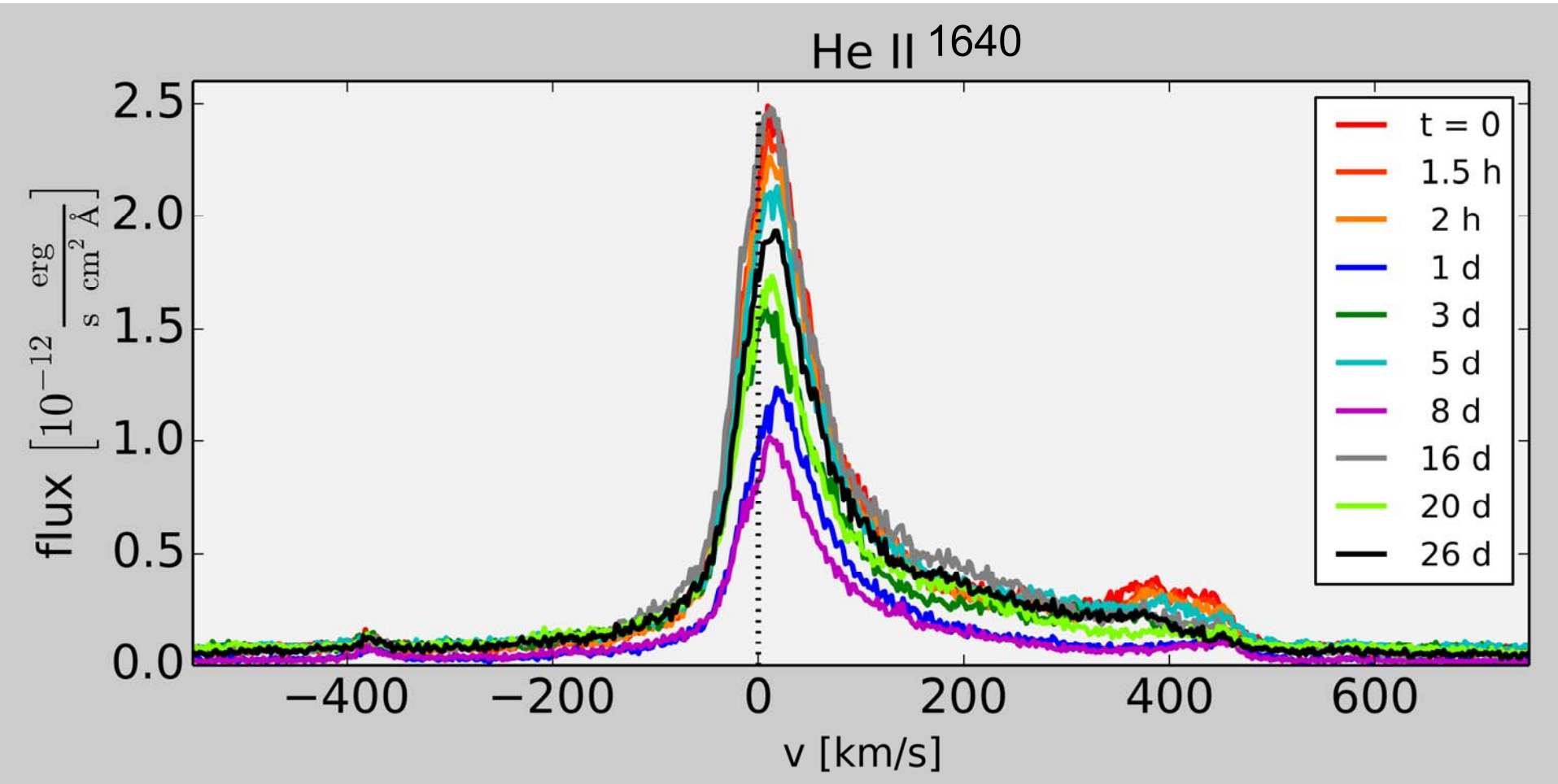
1 Doppler shifts

2 No statistical equilibrium

3 No radiative equilibrium


Pre-Shock
Heated atmosphere
$T, \times 10^3, K$
$\lg N_e$
$\lg \tau_{Ross}$
$\lg \tau_{Ross}$
V = 250, lgN = 11.5
V = 250, lgN = 13
V = 400, lgN = 11.5
V = 400, lgN = 12.5


He II λ1640
x 10^-4
full treatment
models without V, POPS with V
without doppler shifts
H_ν
He II λ4686
x 10^-5
Hβ
x 10^-4
H_ν
V_r
He I λ5876
x 10^-4
V_r

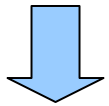


Gunther et al., 2015

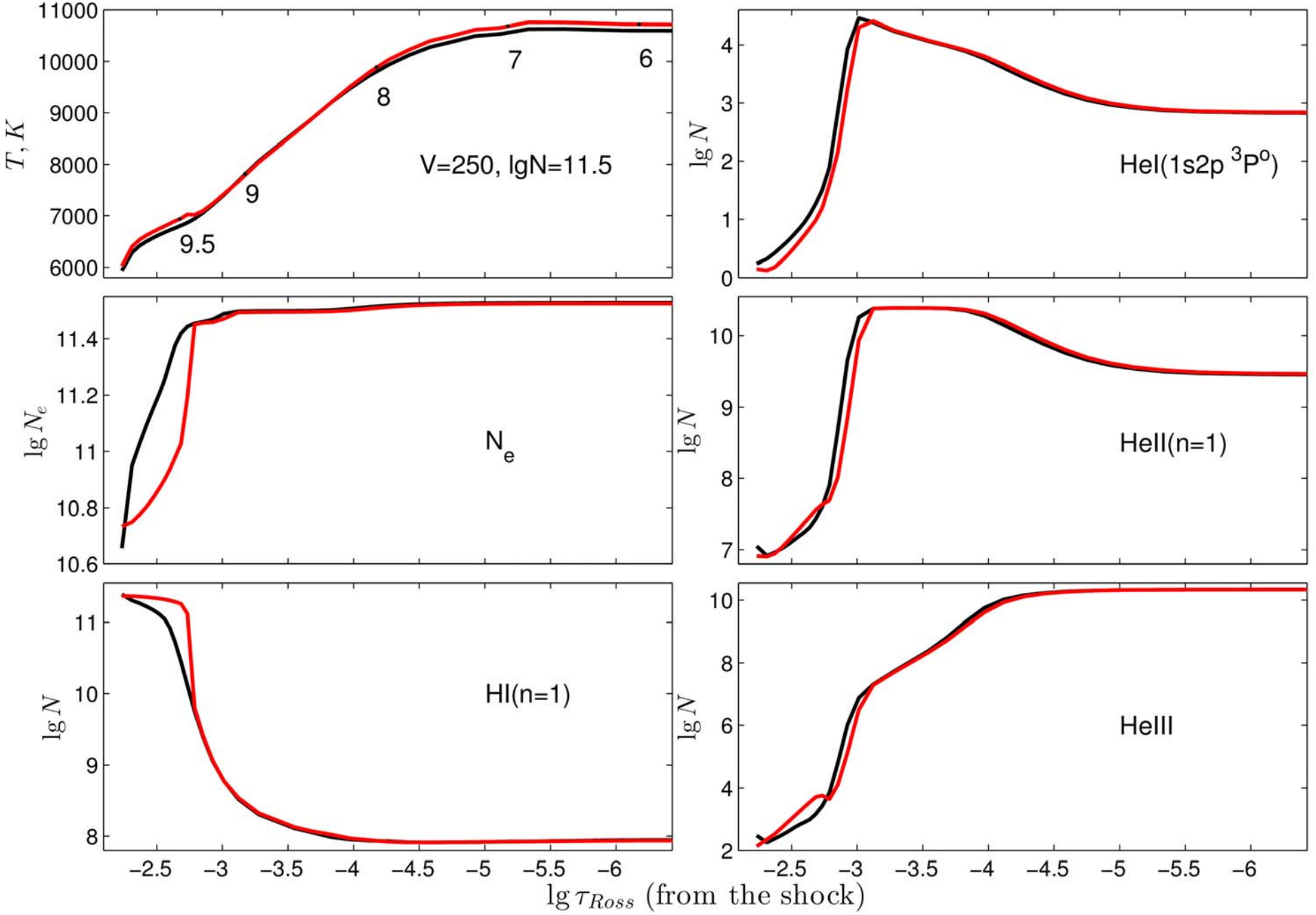
No statistical equilibrium

$$\frac{dN_i}{dt} = \sum_j R_{ji} N_j - N_i \sum_j R_{ij} \neq 0$$

$$\sum_i N_i = N_a$$



The system of stiff differential equations is solved with VODE code

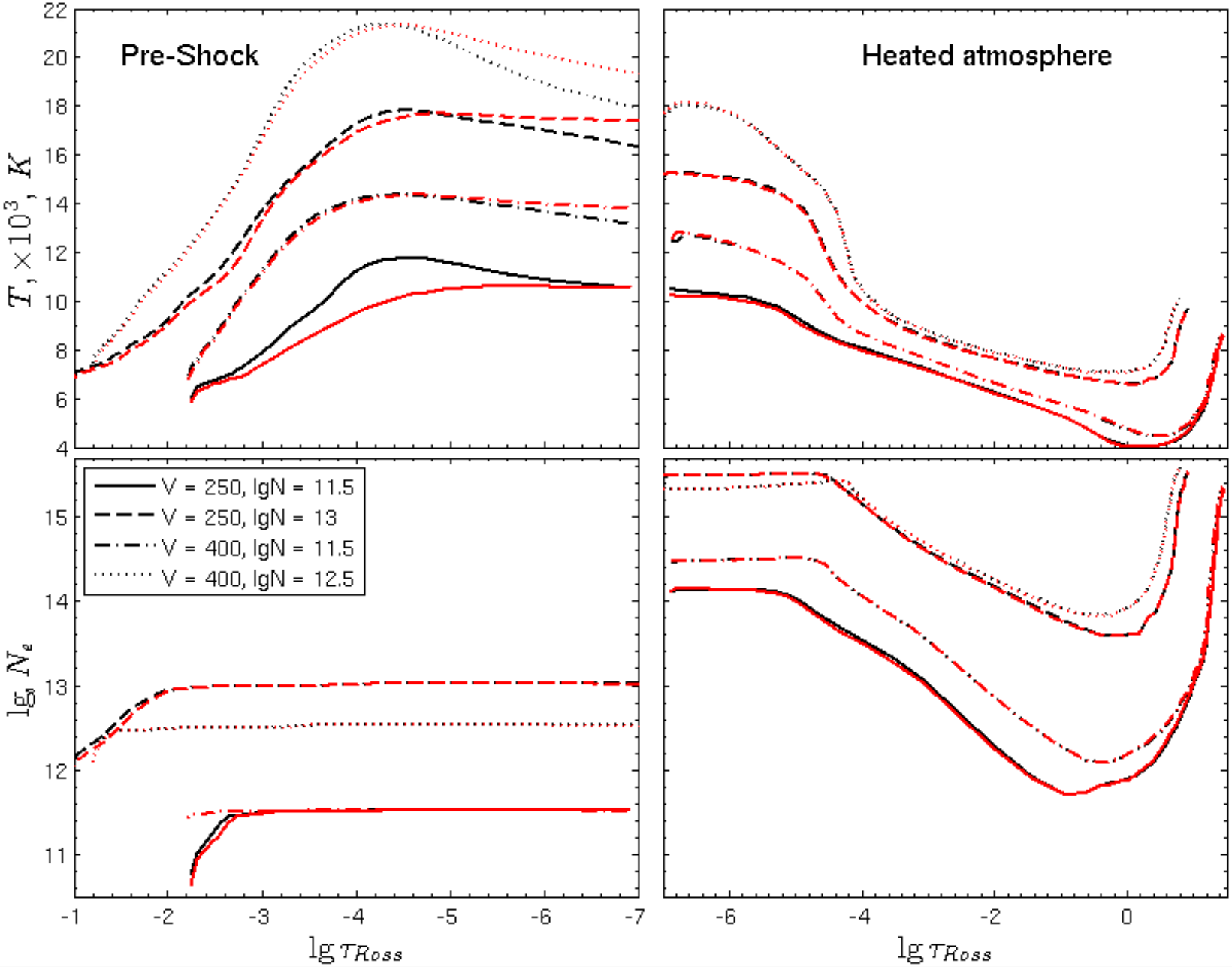

T, K
V=250, lgN=11.5
9.5
9
8
7
6
lg N
HeI(1s2p 3Po)
lg Ne
Ne
lg N
HeII(n=1)
lg N
HI(n=1)
lg N
HeIII
lg τRoss (from the shock)

No radiative equilibrium

$$H = \int_0^\infty J_\nu \chi_\nu d\nu \qquad C = \int_0^\infty S_\nu \chi_\nu d\nu$$

$$H - C = 0 \quad \Rightarrow \quad \Delta T_\Lambda = \frac{\int_0^\infty (J_\nu - S_\nu)\, \chi_\nu d\nu}{\int_0^\infty \frac{dS_\nu}{dT} \chi_\nu d\nu}$$

$$\rho V \frac{dE}{dm} = 4\pi(H - C) \quad \Rightarrow \quad \rho V c \frac{d\Delta T}{dm} = 4\pi(H - C)\left(1 - \frac{\Delta T}{\Delta T_\Lambda}\right) - \rho V \frac{dE_0}{dm}$$


Pre-Shock
Heated atmosphere
$T, \times 10^3, K$
$\lg N_e$
$\lg \tau_{Ross}$
$\lg \tau_{Ross}$
V = 250, lgN = 11.5
V = 250, lgN = 13
V = 400, lgN = 11.5
V = 400, lgN = 12.5

Structure of the post-shock

$$\rho V = u_0 = const$$

$$P + \rho V^2 = const$$

$$u_0 \frac{dE}{dm} = 4\pi(H - C)$$

$$E = V^2/2 + P/\rho + \varepsilon$$

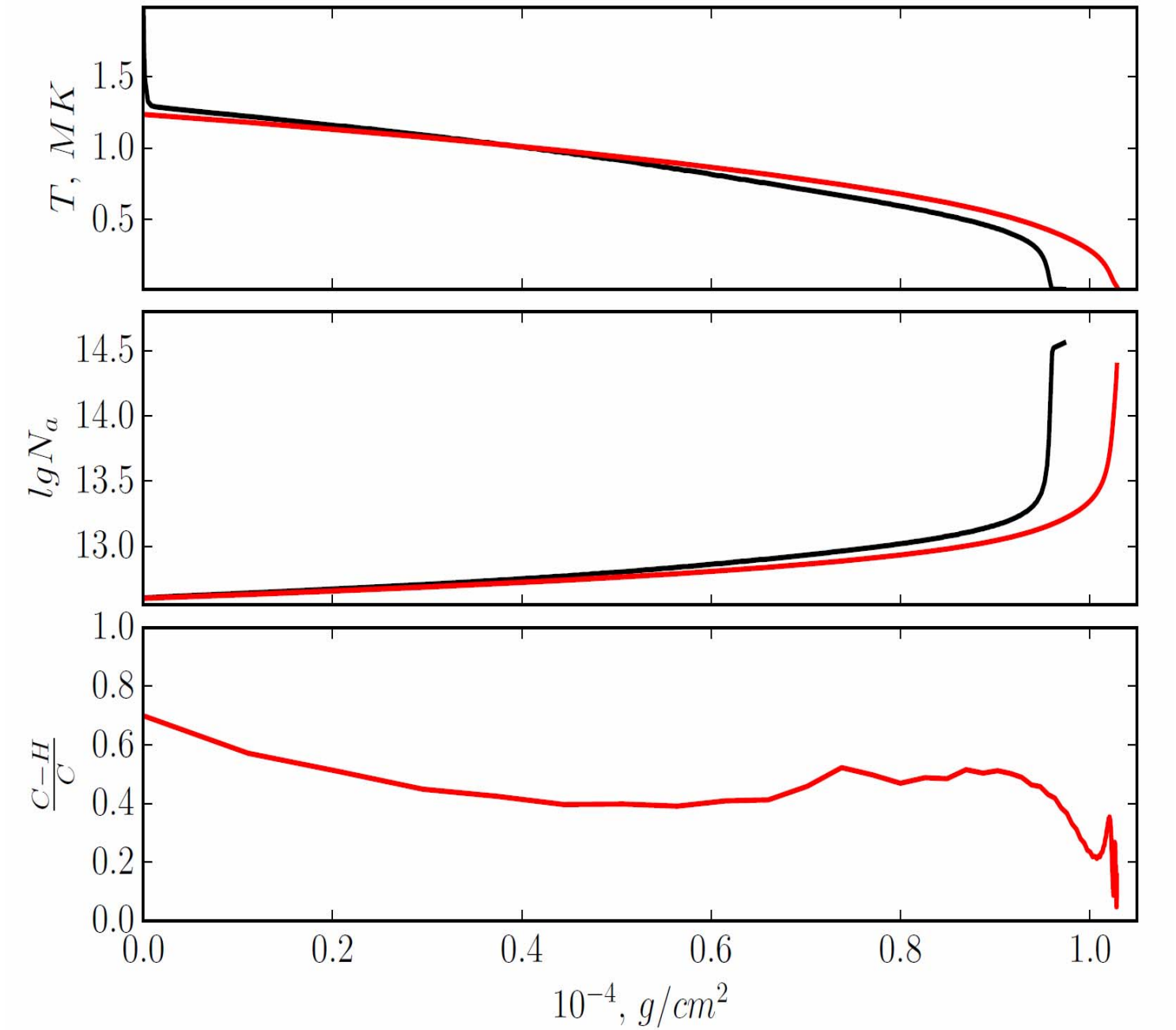
$$H - C = \int \chi_\nu (J_\nu - S_\nu) d\nu$$

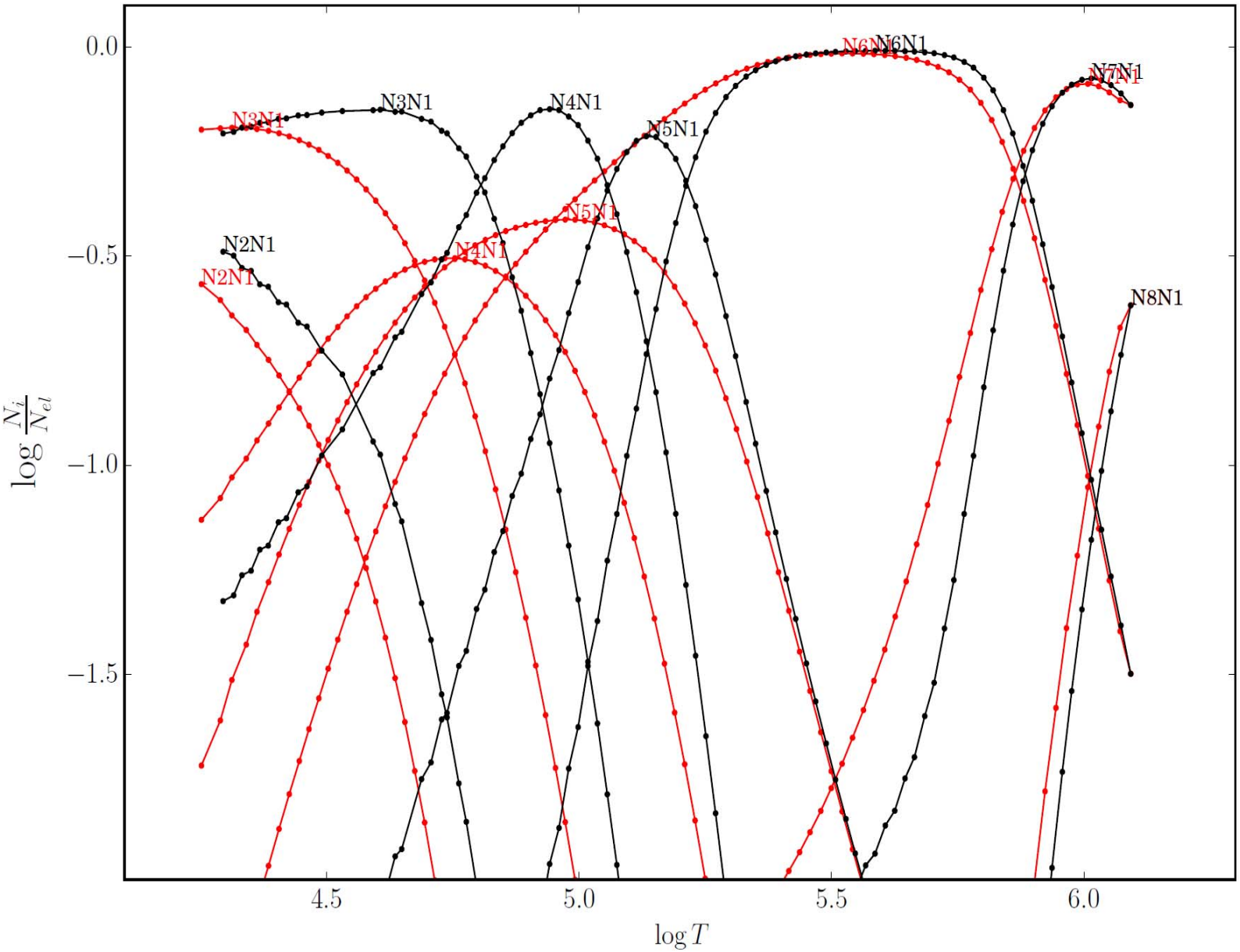
10 elements: H, He, C, N, O, Ne, Mg, Si, S, Fe

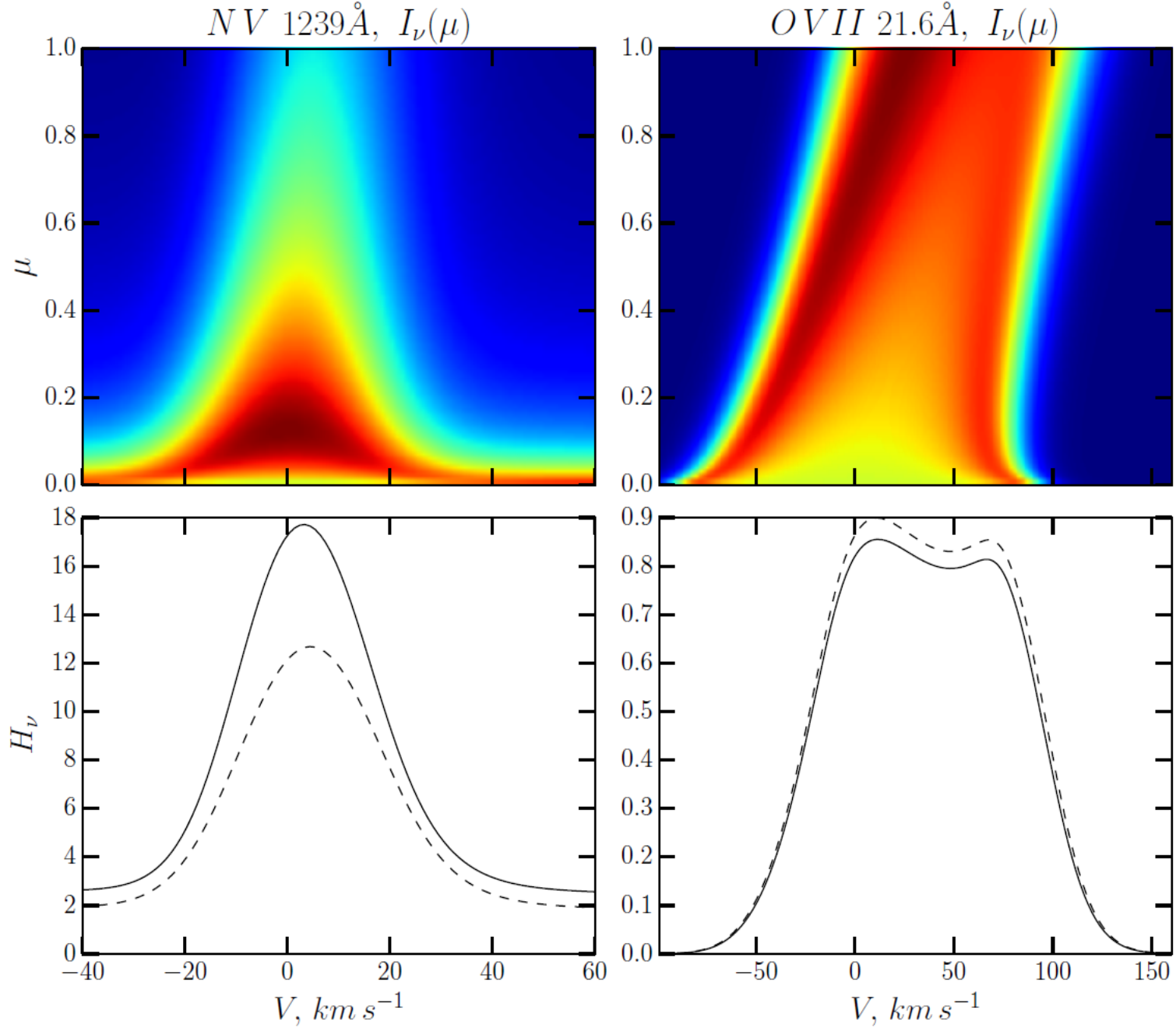
f-b, b-b from TOPBASE, NORAD

~3500 spectral lines

Collisional rates – van Regemorter, Allen, Seaton formulas


T, MK
1.5
1.0
0.5
lgN_a
14.5
14.0
13.5
13.0
(C−H)/C
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0
10^−4, g/cm^2


0.0
−0.5
−1.0
−1.5
4.5
5.0
5.5
6.0
$\log \frac{N_i}{N_{el}}$
$\log T$
N2N1
N3N1
N4N1
N5N1
N6N1
N7N1
N8N1


$N\,V$ 1239Å, $I_\nu(\mu)$
$O\,VII$ 21.6Å, $I_\nu(\mu)$
μ
H_ν
V, $km\,s^{-1}$
V, $km\,s^{-1}$