Synthetic spectra for the hydrogen-poor accretion disk of the ultracompact X-ray binary 4U 1626-67

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Outline

- Introduction: 4U 1626-67
- Non-LTE disk modeling
- First results

Properties of 4U 1626-67

Low mass X-ray binary, orbital period: 42 min

Accretor: 7.7s X-ray pulsar, B=3•10^{12} G (Orlandini et al. 1998)

Donor: very low mass degenerate star M=0.02-0.08M$_\odot$ (Chakrabarty 1998)

Progenitor: WD with C/O core, Ne abundance enhanced by chemical fractionation (Yungelson et al. 2002)
check by disk abundance determination

Disk: inner edge at 6500 km (corotation radius)
outer edge at 200 000 km (tidal truncation)
mass transfer rate: 2•10^{-10} M$_\odot$/yr
inclination 33°-8° (Chakrabarty 1998)
chemical composition: O-Ne-rich (Schulz et al. 2001)

X-ray luminosity L_x=2•10^{36} erg/s (depending on distance)

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NLTE disk modeling

- Radial structure: _-disk (Shakura & Sunyaev 1973)
- Divide disk into concentric rings
- Each ring: plane-parallel radiating slab, detailed vertical structure
- Computation of vertical structure by new code AcDc (Accretion Disk code)
  - hydrostatic equilibrium (gas and radiation pressure)
  - radiative equilibrium (full line blanketing, no convection, generalized Unsöld-Lucy scheme)
  - NLTE rate equations (pre-conditioned → linear)
  - radiation transfer equations (short characteristics, allowing for irradiation)

NLTE disk modeling

- Computational method: Accelerated Lambda Iteration (ALI) for simultaneous solution of all equations
  - kinematic viscosity parameterized by Reynolds number (Re=10 000 → _=0.01-0.1)
  - vertical run of viscosity according to Hubeny & Hubeny (1997)

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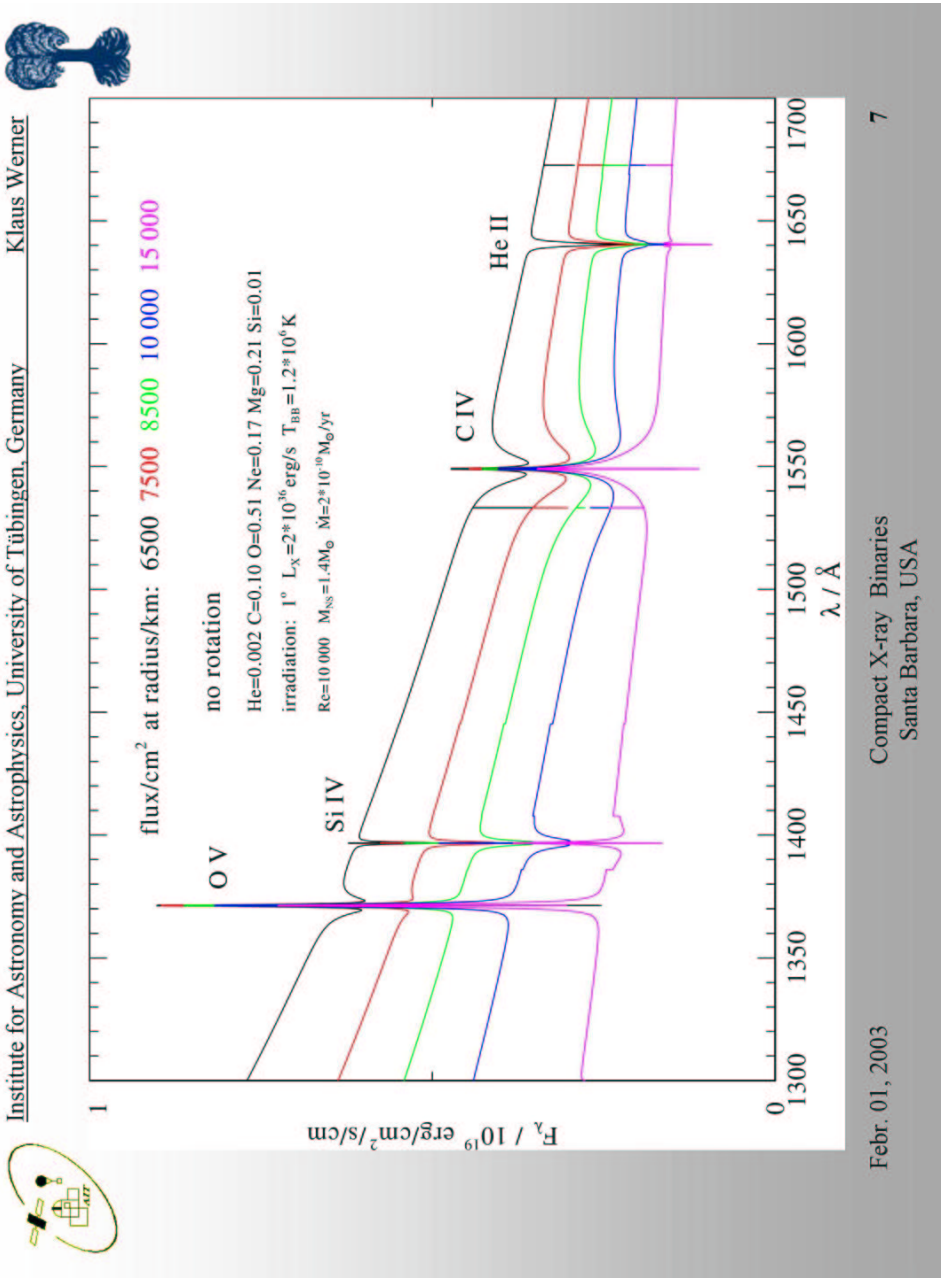
- Input parameters for disk model (here: inner region of 4U1626-67)
  - $M_{primary}$=1.4 $M_{\odot}$
  - Inner and outer disk radii: 6500, 15 000 km
  - Accretion rate: $2 \cdot 10^{-10}$ $M_{\odot}$/yr
  - Chemical abundances (mass fractions): He=0.002 C=0.10 O=0.51 Ne=0.17 Mg=0.21 Si=0.01
  - Re=10 000
- Irradiation: central source, $L_x=2 \cdot 10^{36}$ erg/s, bb-spectrum with $T_{bb}=1.2 \cdot 10^6$K, irradiation angle 1°
- Computation of synthetic spectra, aim: quantitative analysis of
  - UV spectra (HST, Homer et al. 2002)
  - X-ray spectra (Chandra, Schulz et al. 2001)
- Double peak emission lines of C,O,Ne,Si (highly ionized, IV-X)
- First results: Modeling of UV spectra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flux/cm² at radius/km: 6500 7500 8500 10 000 15 000
no rotation
He=0.002 C=0.10 O=0.51 Ne=0.17 Mg=0.21 Si=0.01
irradiation: 1° L_X=2*10^36 erg/s T_BB=1.2*10^6 K
Rc=10 000 M_NS=1.4M⊙ Ṁ=2*10^-10 M⊙/yr
O V
Si IV
C IV
He II
F_λ / 10^19 erg/cm²/s/cm
λ / Å
1300 1350 1400 1450 1500 1550 1600 1650 1700
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inclination: 3°, 13°, 30°, 50°, 72°
He=0.002 C=0.10 O=0.51 Ne=0.17 Mg=0.21 Si=0.01
R_in=6500 km R_out=15 000 km
irradiation: 1° L_X=2*10^36 erg/s T_BB=1.2*10^6 K
Rc=10 000 M_NS=1.4M⊙ Ṁ=2*10^-10 M⊙/yr
O V
Si IV
C IV
He II
F_λ / 10^37 erg/s/cm/sterad
λ / Å
1300 1350 1400 1450 1500 1550 1600 1650 1700
Febr. 01, 2003
Compact X-ray Binaries
Santa Barbara, USA
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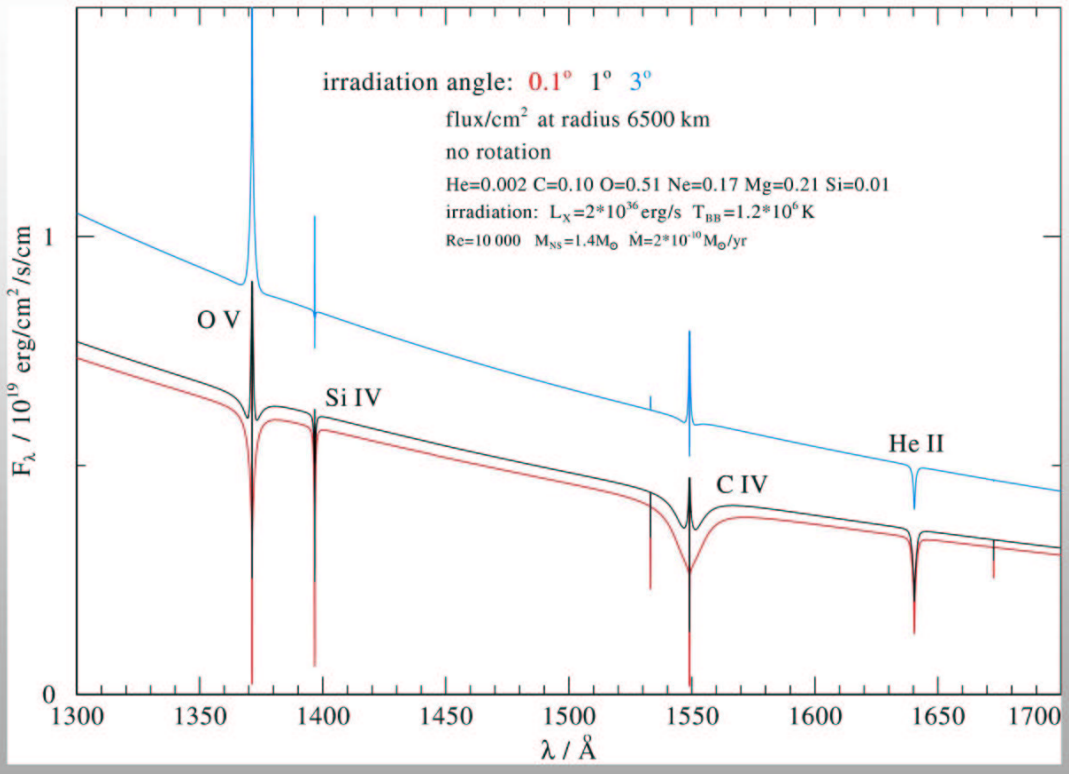
irradiation angle: 0.1° 1° 3°
flux/cm² at radius 6500 km
no rotation
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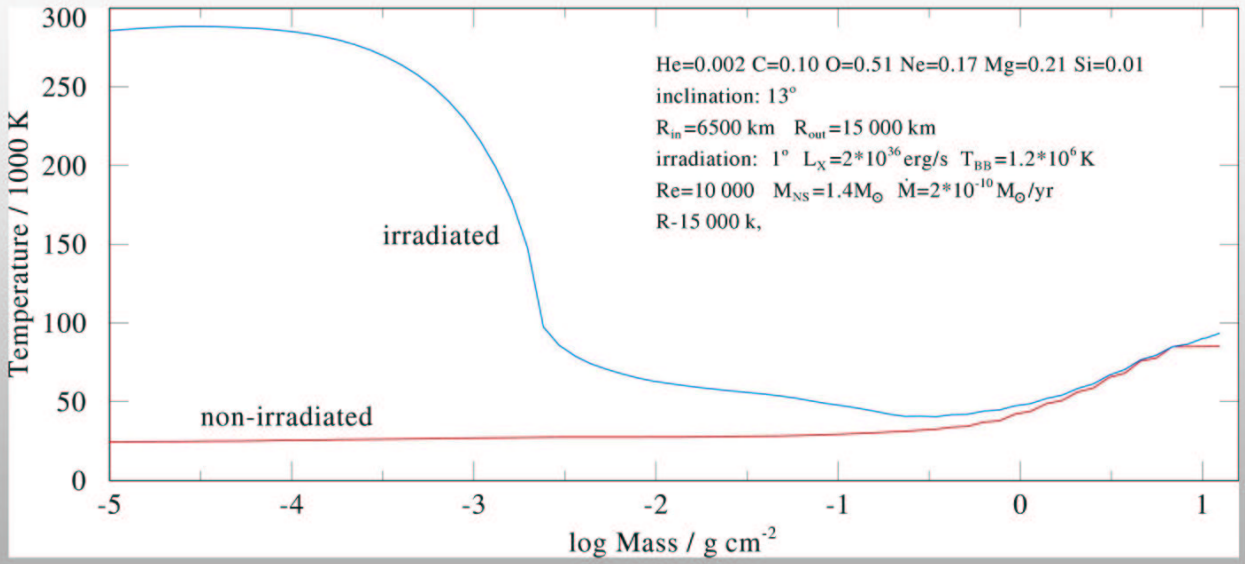
irradiation: L_X=2*10^36 erg/s T_BB=1.2*10^6 K
Re=10 000 M_NS=1.4M⊙ Ṁ=2*10^-10 M⊙/yr
O V
Si IV
C IV
He II
F_λ / 10^19 erg/cm²/s/cm
λ / Å
0
1
1300
1350
1400
1450
1500
1550
1600
1650
1700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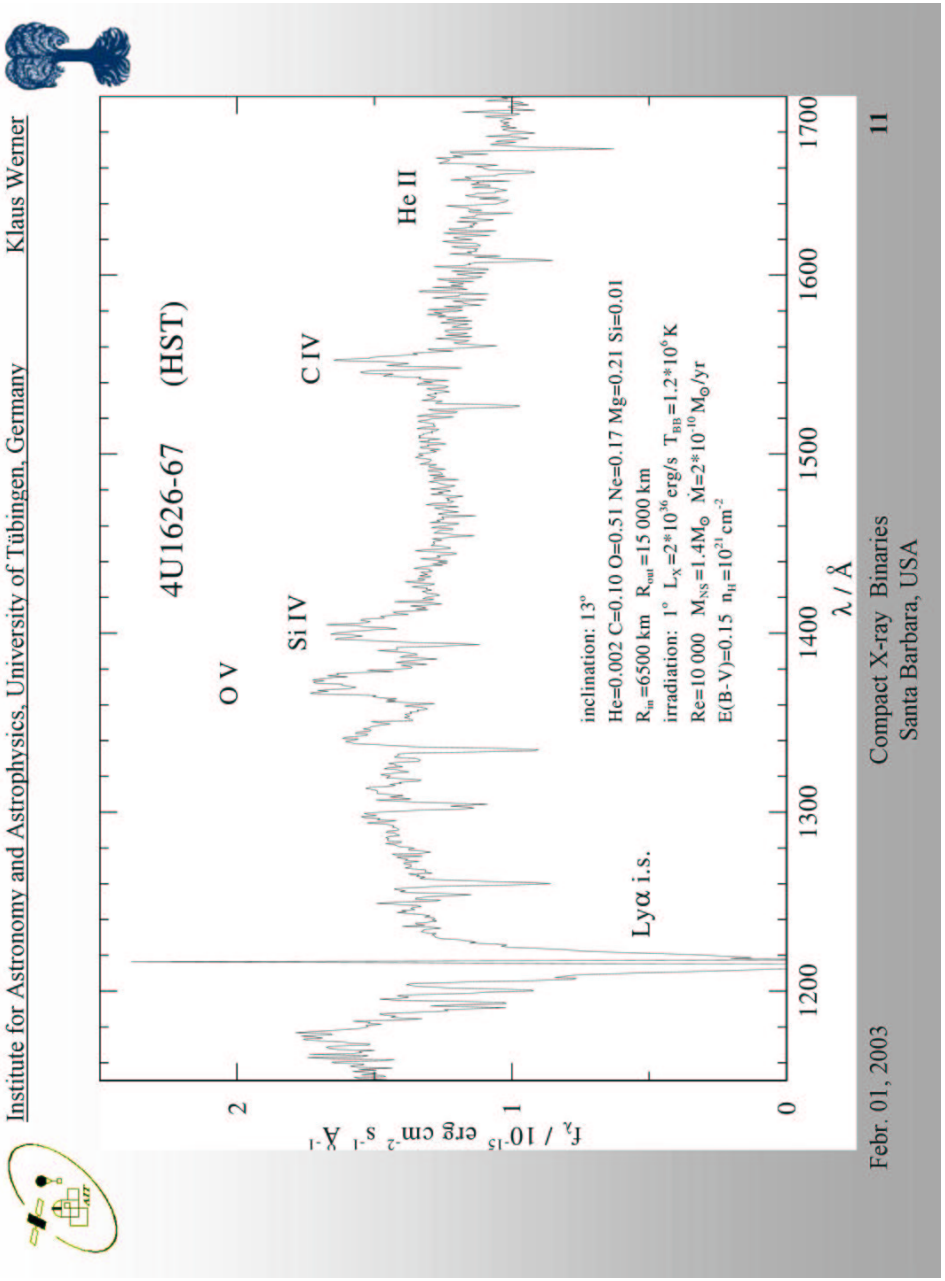
inclination: 13°
R_in=6500 km R_out=15 000 km
irradiation: 1° L_X=2*10^36 erg/s T_BB=1.2*10^6 K
Re=10 000 M_NS=1.4M⊙ Ṁ=2*10^-10 M⊙/yr
R-15 000 k,
irradiated
non-irradiated
Temperature / 1000 K
log Mass / g cm^-2
300
250
200
150
100
50
0
-5
-4
-3
-2
-1
0
1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4U1626-67 (HST)
O V
Si IV
C IV
He II
Lyα i.s.
inclination: 13°
He=0.002 C=0.10 O=0.51 Ne=0.17 Mg=0.21 Si=0.01
R_in=6500 km R_out=15 000 km
irradiation: 1° L_X=2*10^36 erg/s T_BB=1.2*10^6 K
Re=10 000 M_NS=1.4M_⊙ Ṁ=2*10^-10 M_⊙/yr
E(B-V)=0.15 n_H=10^21 cm^-2
f_λ / 10^-15 erg cm^-2 s^-1 Å^-1
λ / Å
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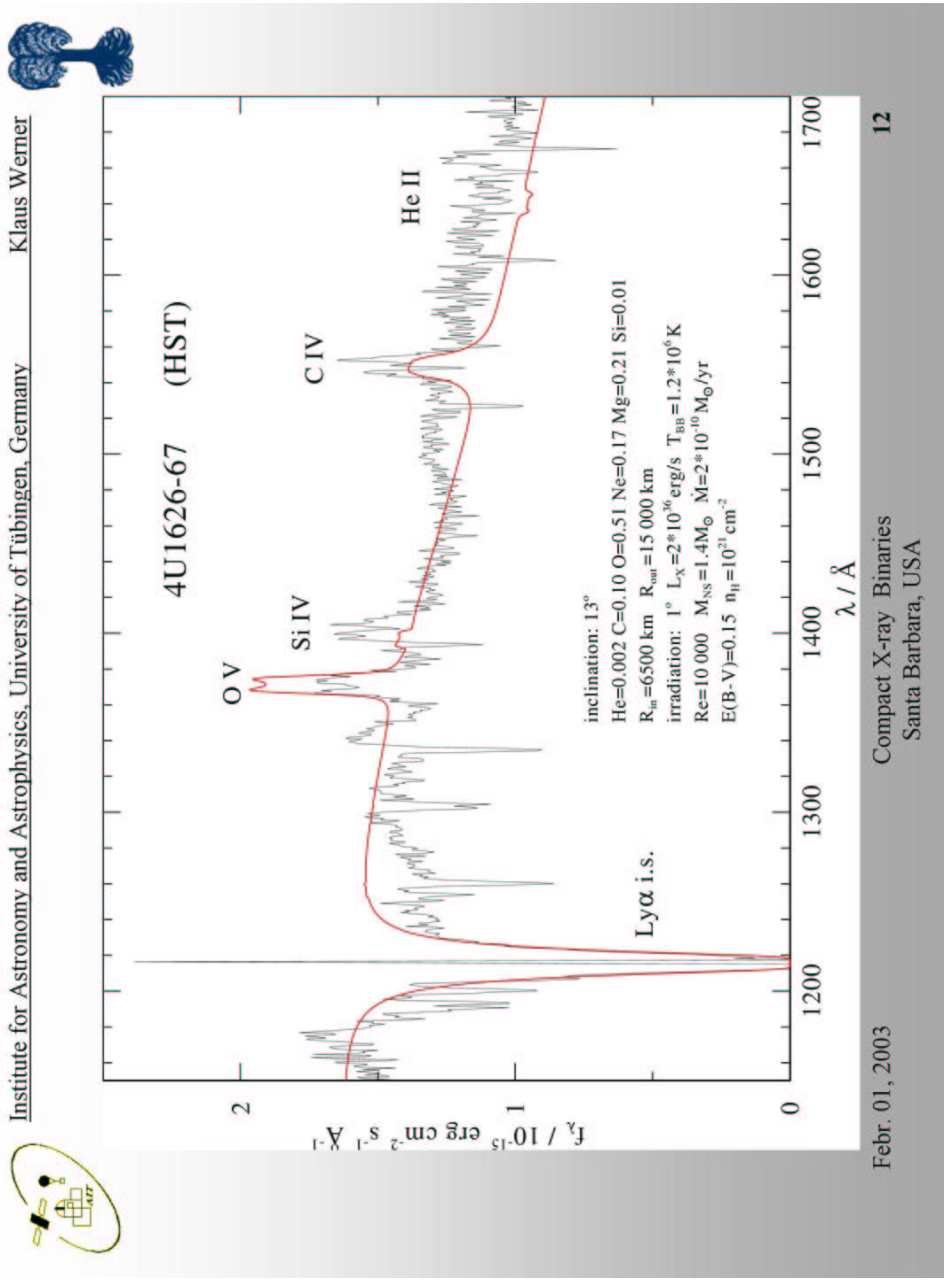
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4U1626-67 (HST)
O V
Si IV
C IV
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Lyα i.s.
inclination: 13°
He=0.002 C=0.10 O=0.51 Ne=0.17 Mg=0.21 Si=0.01
R_in=6500 km R_out=15 000 km
irradiation: 1° L_X=2*10^36 erg/s T_BB=1.2*10^6 K
Re=10 000 M_NS=1.4M_⊙ Ṁ=2*10^-10 M_⊙/yr
E(B-V)=0.15 n_H=10^21 cm^-2
f_λ / 10^-15 erg cm^-2 s^-1 Å^-1
λ / Å
Febr. 01, 2003
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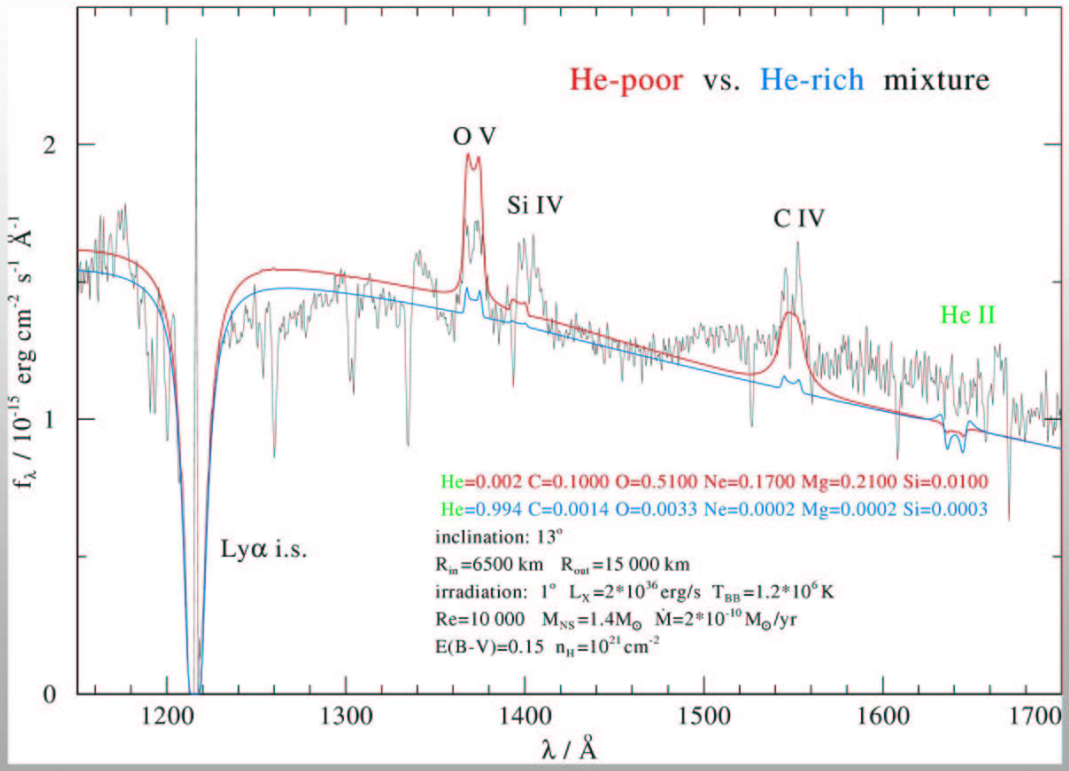
He-poor vs. He-rich mixture
O V
Si IV
C IV
He II
Lyα i.s.
He=0.002 C=0.1000 O=0.5100 Ne=0.1700 Mg=0.2100 Si=0.0100
He=0.994 C=0.0014 O=0.0033 Ne=0.0002 Mg=0.0002 Si=0.0003
inclination: 13°
R_in=6500 km R_out=15 000 km
irradiation: 1° L_X=2*10^36 erg/s T_BB=1.2*10^6 K
Re=10 000 M_NS=1.4M_⊙ Ṁ=2*10^-10 M_⊙/yr
E(B-V)=0.15 n_H=10^21 cm^-2
f_λ / 10^-15 erg cm^-2 s^-1 Å^-1
λ / Å
0
1
2
1200
1300
1400
1500
1600
1700