Modelling the X–ray spectrum of classical novae with PHOENIX

Alexander Petz

Hamburger Sternwarte

Overview

- X–ray emission of novae
- Modelling novae with PHOENIX
- Comparison with measured spectrum
- LTE- vs. NLTE–Model
- Conclusions and outlook

X–ray emission of novae

- Only a few X–ray observations of novae today.

X–ray emission of novae

- Only a few X–ray observations of novae today.
- Emission of X–rays (Krautter 2002):
  1. Early fireball phase: soft X–ray radiation with a spectrum from a hot stellar atmosphere
  2. After ejection of the shell: T decreases while r increases, shell will become optical thick for X–rays $\Rightarrow$ No X–ray emission
  3. Const. L_{bol}–phase: remaining material on WD with CNO–cycle burning

     $\Rightarrow$ Soft X–ray radiation like in the early fireball pase + emission due to shocks in the nova outflow

Nova models in the X–ray

- Calculation of hot nova models ($\sim 10^5 - 10^6$ K) emitting X-rays with PHOENIX
- Comparison of synthetic and CHANDRA–spectra

Modelling novae with PHOENIX

- 1D–Spherical, expanding, line blanketed, NLTE models

Modelling novae with PHOENIX

- 1D–Spherical, expanding, line blanketed, NLTE models
- Solving the sherical, special relativistic radiation transfer equation in 1D
- Coupled with radiative equilibrium and NLTE–rate equations

Modelling novae with PHOENIX

Model assumptions:

Modelling novae with PHOENIX

Model assumptions:

- Density law: $\rho(r) = \rho_{out}(r/r_{out})^{-n} \propto r^{-n}$
- Velocity field: $v(r) = \dot{M}/4\pi r^2 \rho(r)$
- $\dot{M} =$ const

New physics in PHOENIX

- $\Rightarrow$ New physics implemented in PHOENIX
  - X–ray spectral lines
  - Electron collision rates
  - Proton collision rates
  - Bremsstrahlung

New physics in PHOENIX

- $\Rightarrow$ New physics implemented in PHOENIX
  - X–ray spectral lines
  - Electron collision rates
  - Proton collision rates
  - Bremsstrahlung
- $\Rightarrow$ Work in progress
  - Free–bound coefficients
  - Dielectronic processes
    - Dielectronic recombination
    - Autoionization

Model parameters

- Basic physical model parameters:
  - $T_{\text{eff}} = (10^5 - 10^6)$ K
  - r_{out}
  - $v_{\text{out}} = (1000 - 3000 - ...)$ km/s
  - $n = 3$

Model parameters

- Basic physical model parameters:
  - $T_{\rm eff} = (10^5 - 10^6)$ K
  - $r_{\rm out}$
  - $v_{\rm out} = (1000 - 3000 - ...)$ km/s
  - $n = 3$
- $r_{\rm out}$:

$$L_{\rm bol} = 4\pi r_{\rm out}^2\, \sigma\, T_{\rm eff}^4 = 50,000 \text{ L}_\odot$$
$$T_{\rm eff} = 1 \cdot 10^5 \text{ K} \Rightarrow r_{\rm out} = 5.2 \cdot 10^{10} \text{ cm}$$
$$T_{\rm eff} = 6 \cdot 10^5 \text{ K} \Rightarrow r_{\rm out} = 2.1 \cdot 10^{9} \text{ cm}$$
$$T_{\rm eff} = 1 \cdot 10^6 \text{ K} \Rightarrow r_{\rm out} = 5.2 \cdot 10^{8} \text{ cm}$$

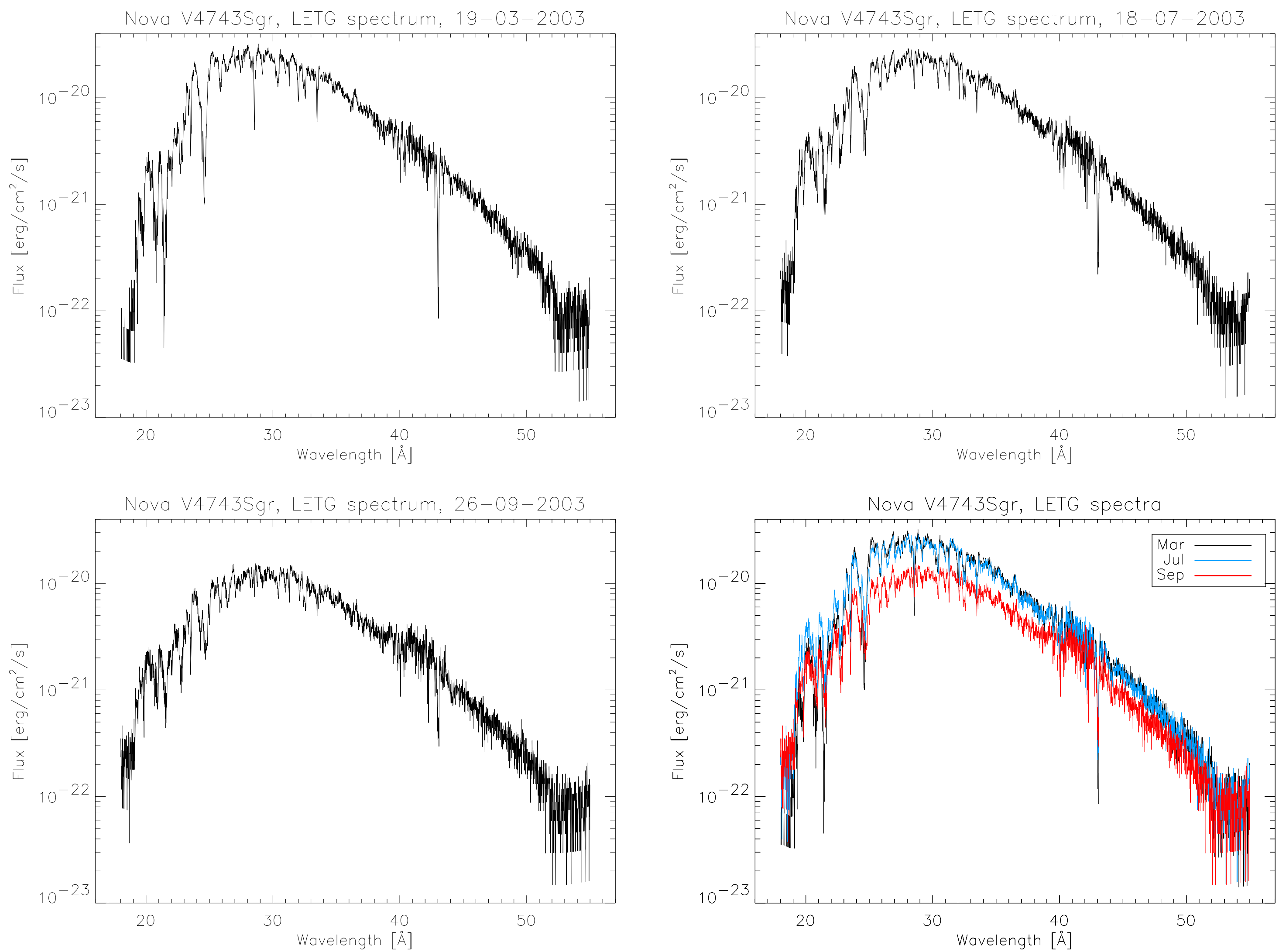
Species included in NLTE

1	H I			
2	He I	He II		
6	C IV	C V	C VI	
7	N V	N VI	N VII	
8	O VI	O VII	O VIII	
10	Ne VII	Ne VIII	Ne IX	Ne X
12	Mg IX	Mg X	Mg XI	Mg XII
13	Al X	Al XI	Al XII	Al XIII

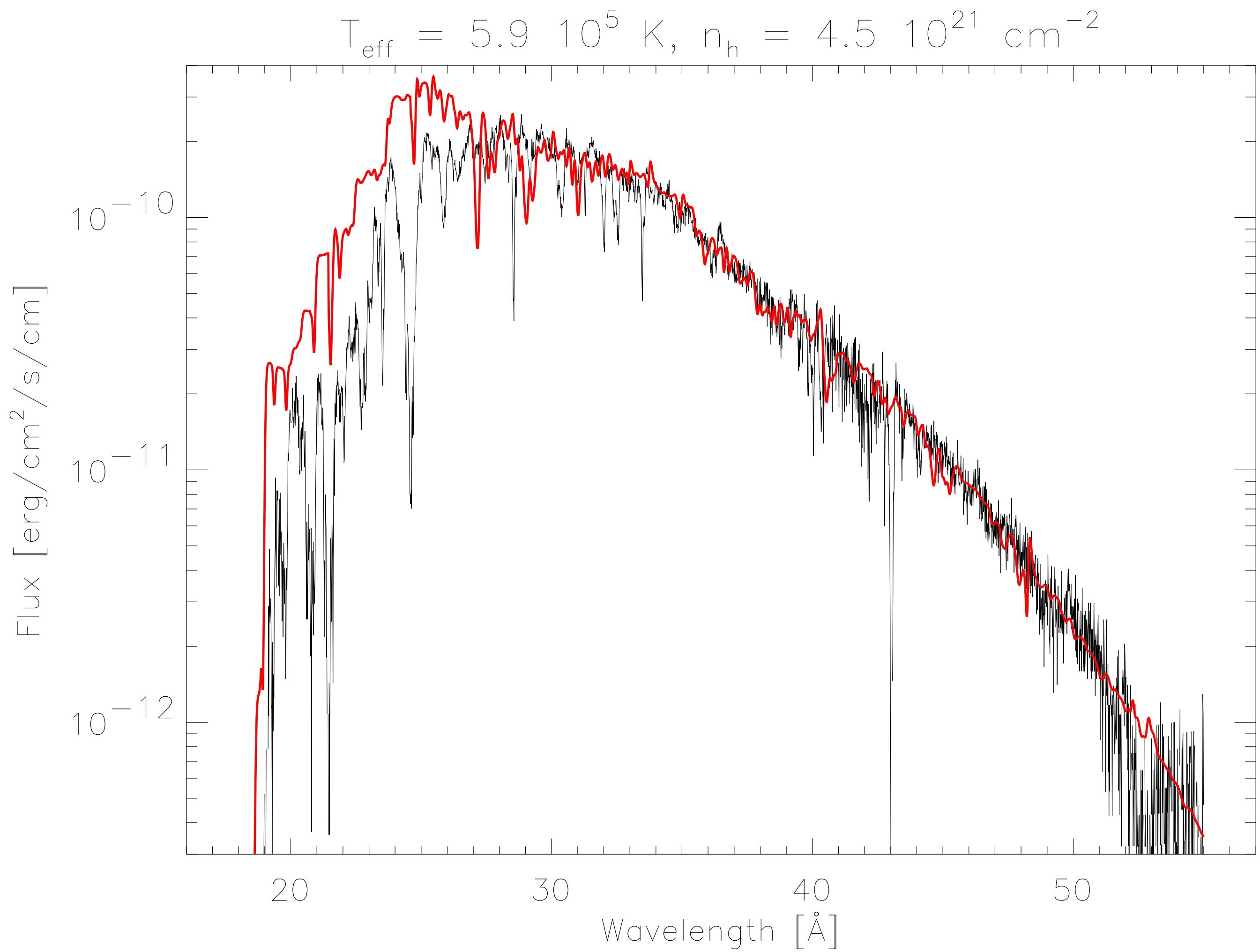
Species for future NLTE calculations

14	Si X	**Si XI**	**Si XII**	Si XIII	Si XIV
26	Fe XIV	Fe XV	**Fe XVI**	**Fe XVII**	Fe XVIII - Fe XXVI

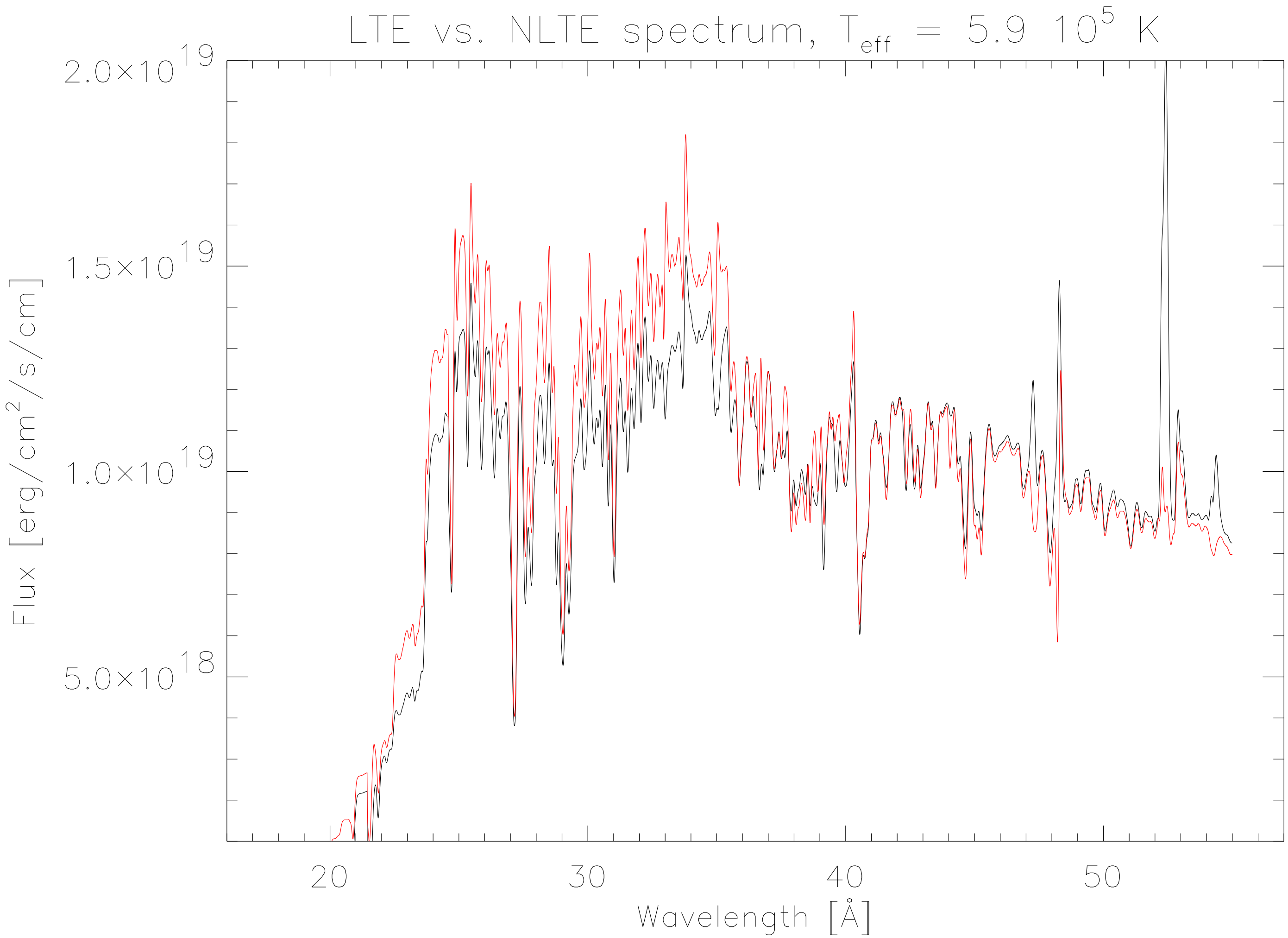
LETG–spectra of nova V4743Sgr



Model vs. LETG



LTE–Model vs. NLTE–Model



Conclusion

- Hot nova models emitting X–rays can be calculated with PHOENIX.
- Bremsstrahlungs–emission and its inverse processes are important.
- In the hard spectral range absoprtion from N and Fe is important.
- Shocks are not needed to fit the observations.
- There are very extreme physical conditions in the nova ejecta.
- There are strong deviations from LTE.

Outlook

- Implementation of further physical processes emitting and absorbing X–rays
- Calculation of models with elemental abundances deviating from solar
- Further examination of NLTE–effects
- Examination of the evolution of the X–ray emission