What we can and cannot learn from Super Soft Source X-ray grating spectra

Jan-Uwe Ness
XMM-Newton Science Operations Centre
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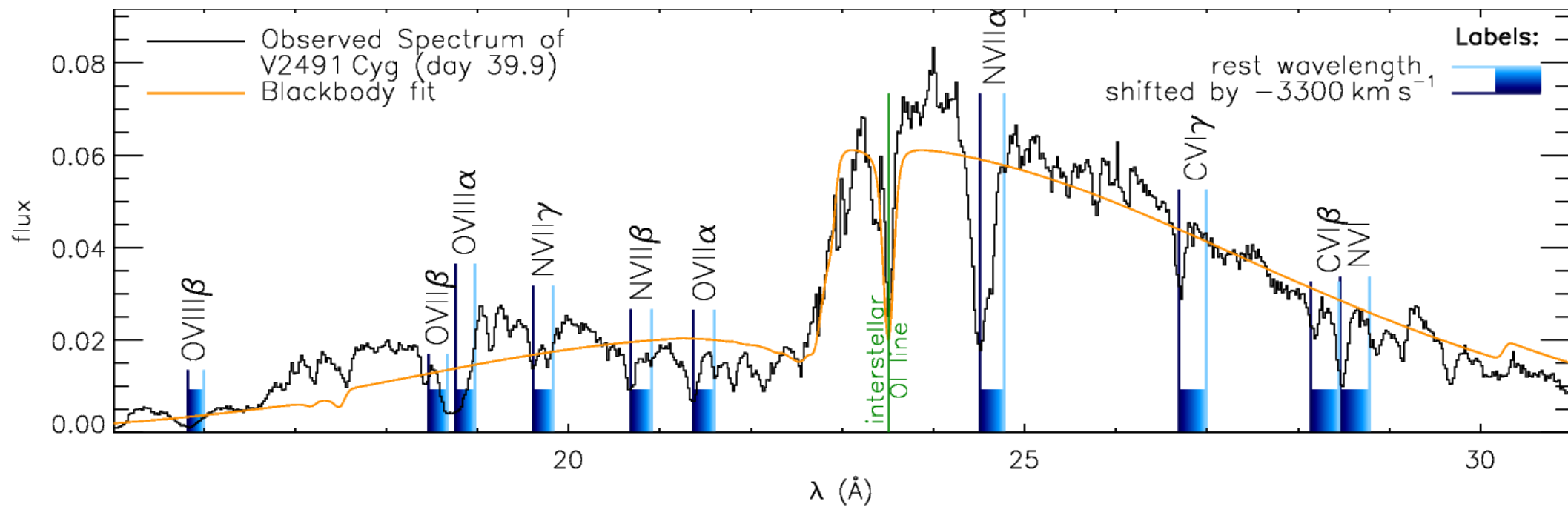
Madrid, Spain

Today = t_{60} + 179 days = t0 + 21550 days



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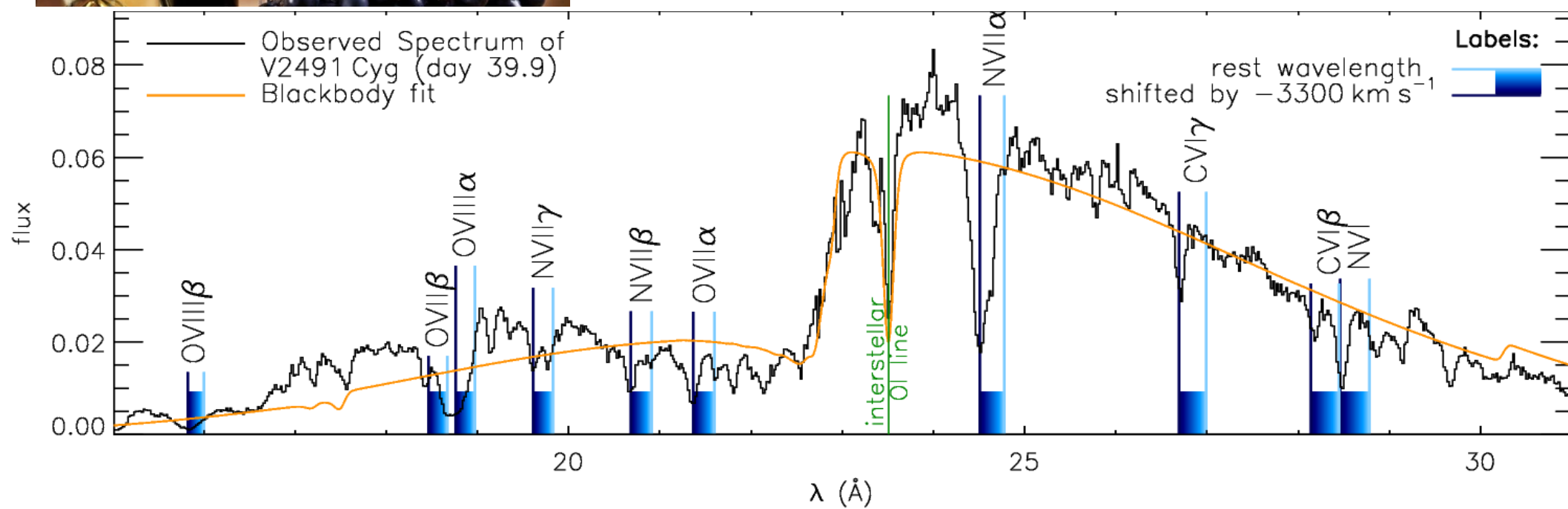
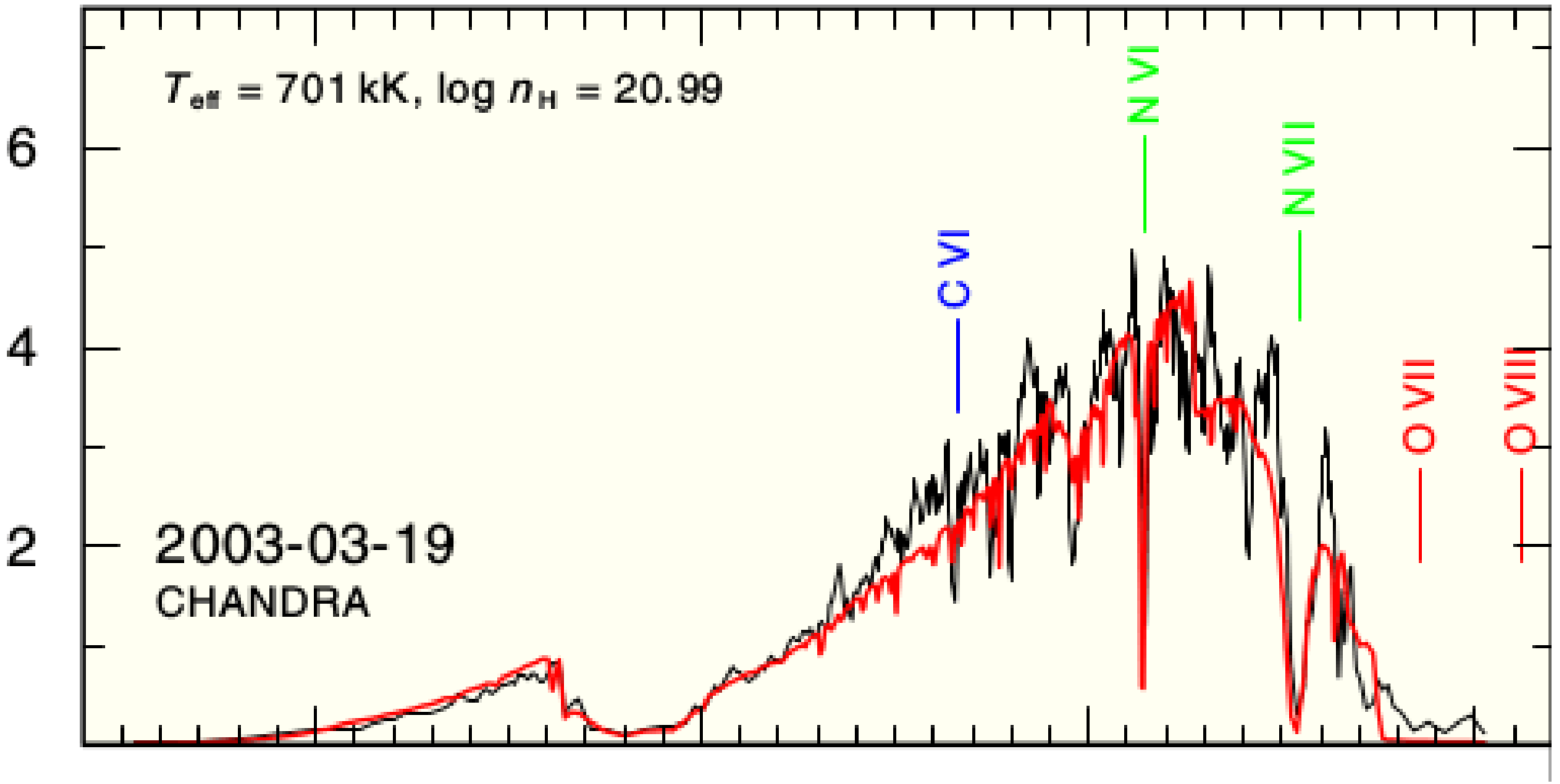
Keeping the best wine to the end:

Jan-Uwe

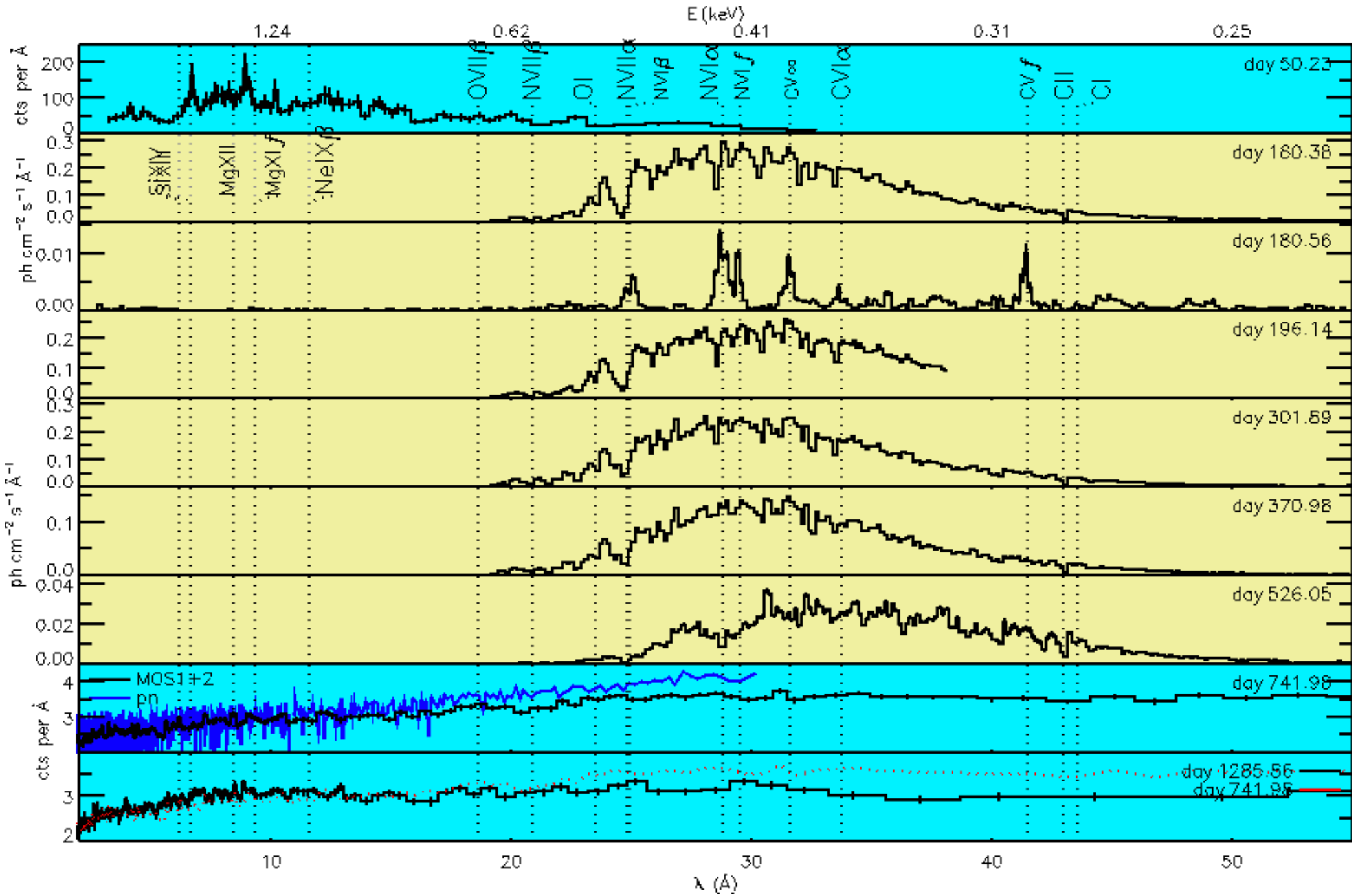
Martin



SSS spectrum of V4743 Sgr with TMAP Atmosphere model Rauch et al. (2010)

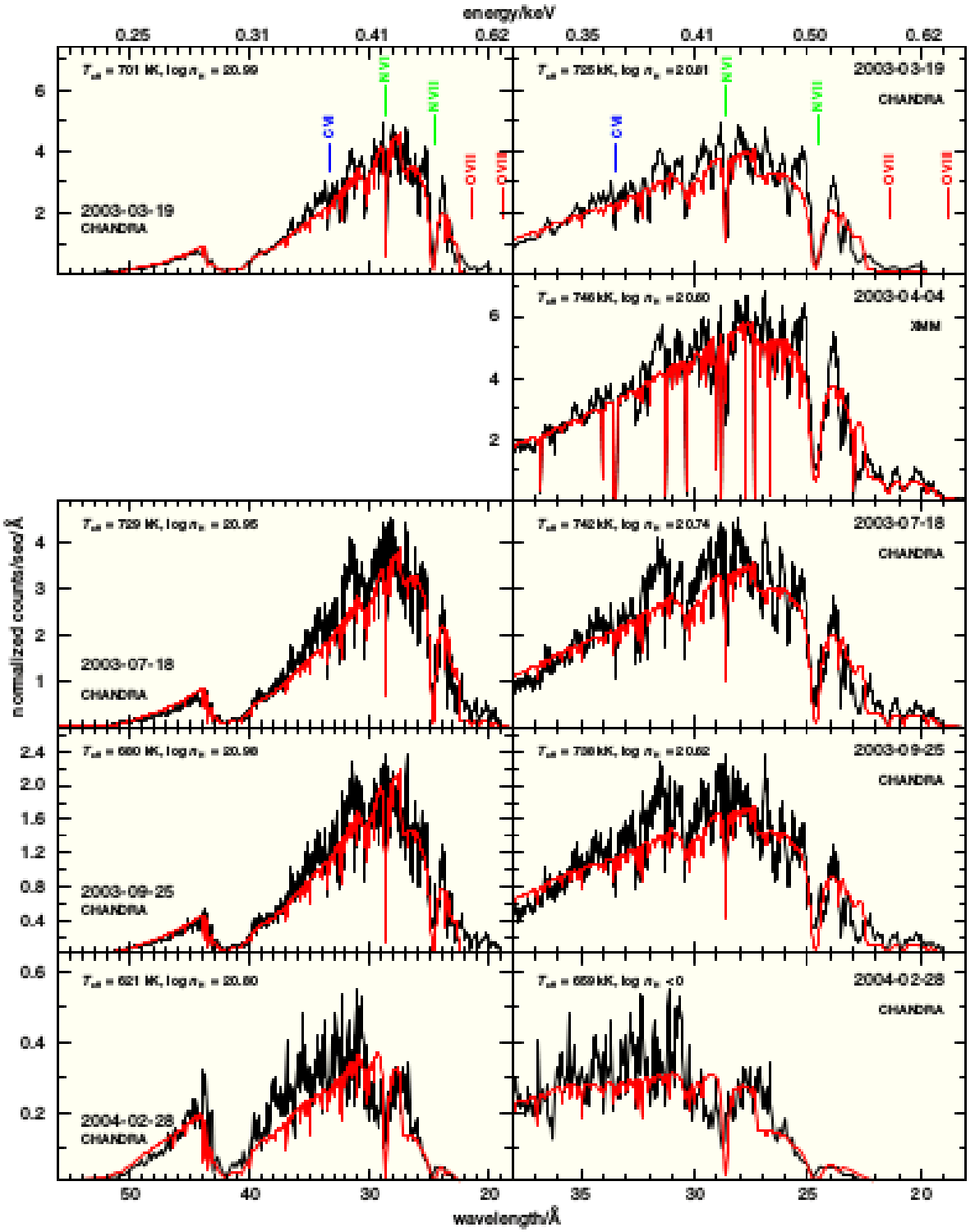


Nova V4743 Sgr (2002) in Time

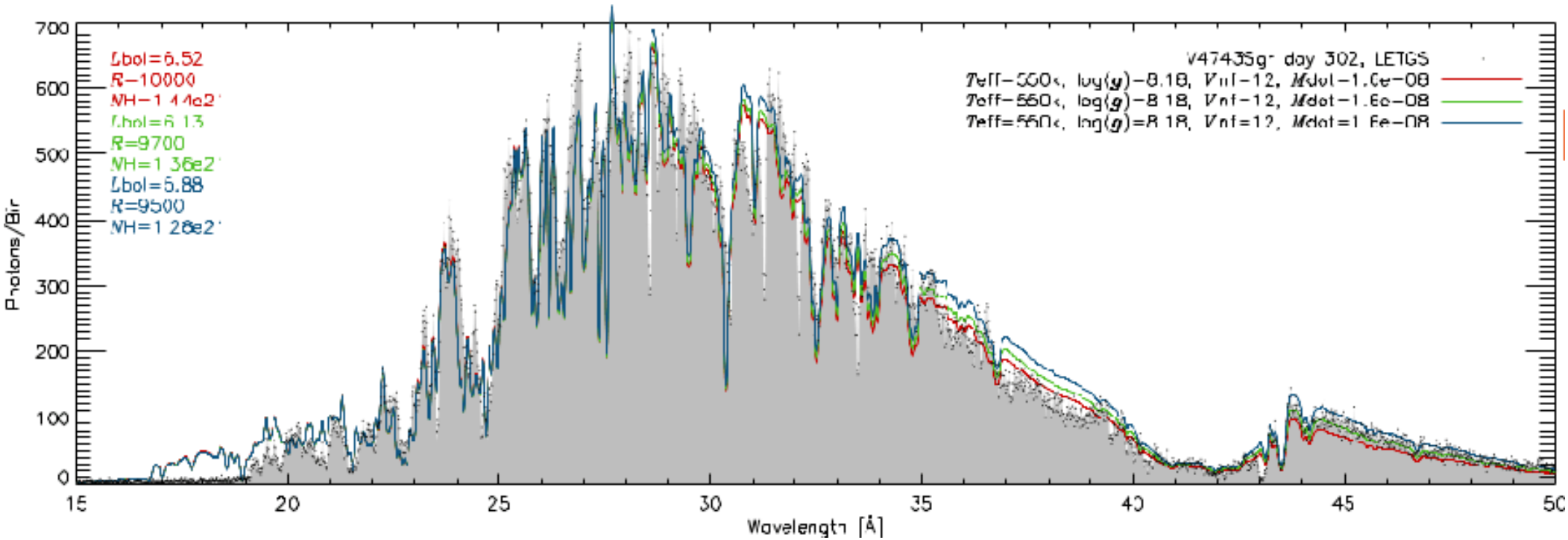


Series of SSS spectra of V4743 Sgr with TMAP Atmospheres

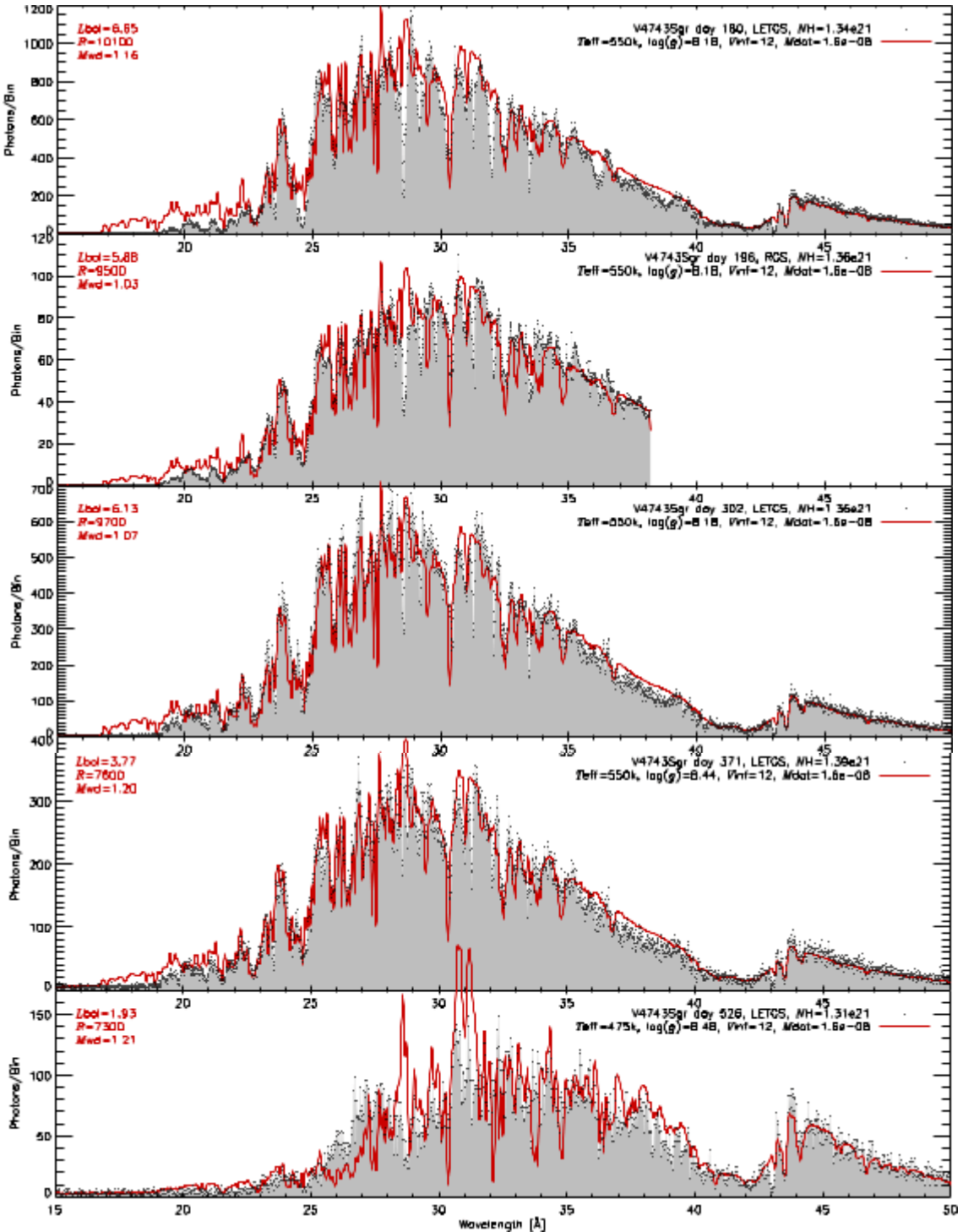
Rauch et al. (2010)



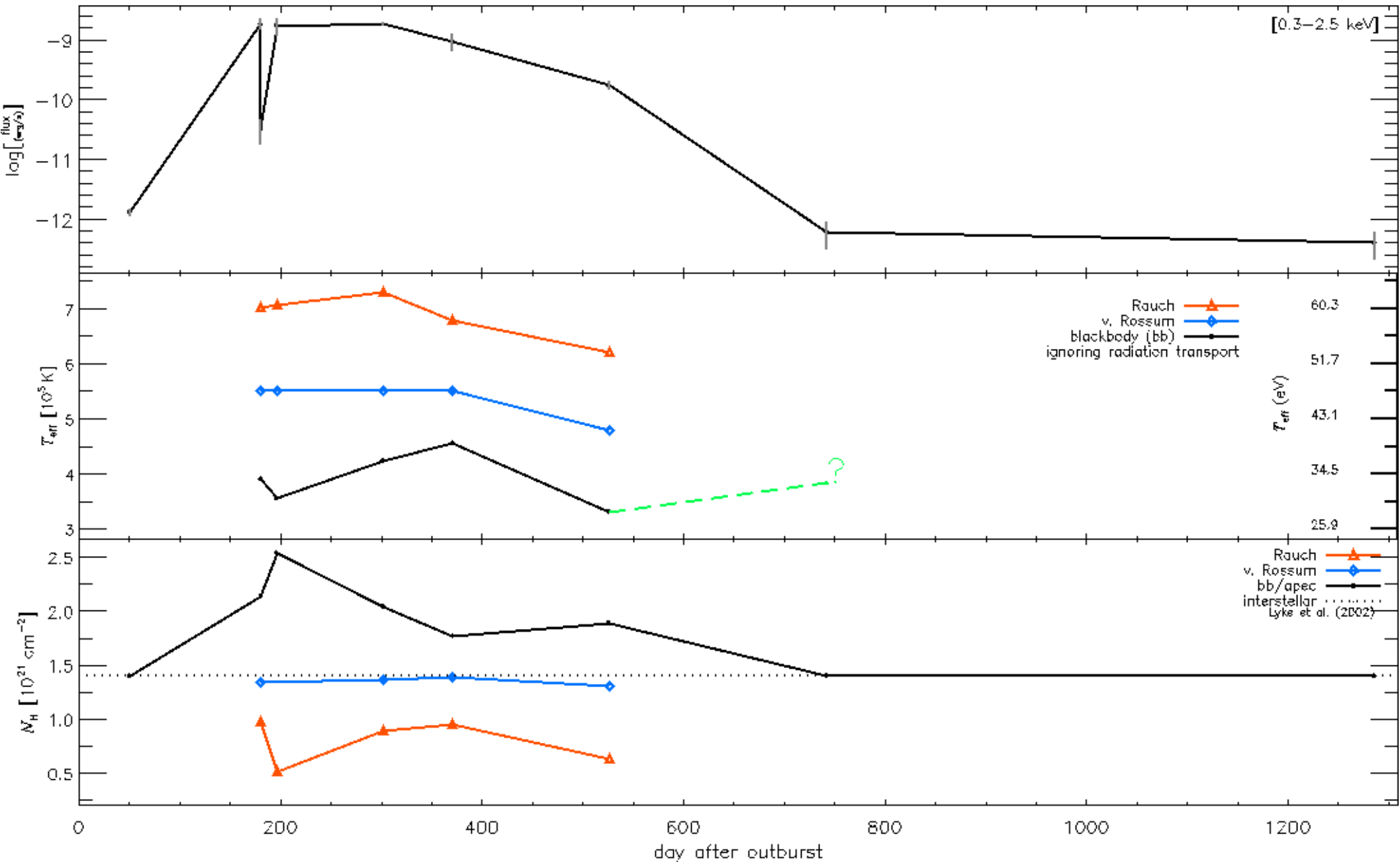
Series of SSS spectrum of V4743 Sgr with Wind-type Atmosphere model van Rossum (2012)



Series of SSS spectra of V4743 Sgr with Wind-type Atmospheres van Rossum (2012)



Evolution of atmosphere model parameters



Quantitative Approaches (How much?)

Highly desirable because they yield key parameters such as
Composition, mass, temperature, energy budget (Luminosity, radius).

We really want them to
constrain evolutionary models of the nova outburst (e.g. Teff, L)
Determine nova contribution to chem. Composition of ISM (abundances)
Constrain Single-degenerate channel of SN Ia progenitor path (Mass)

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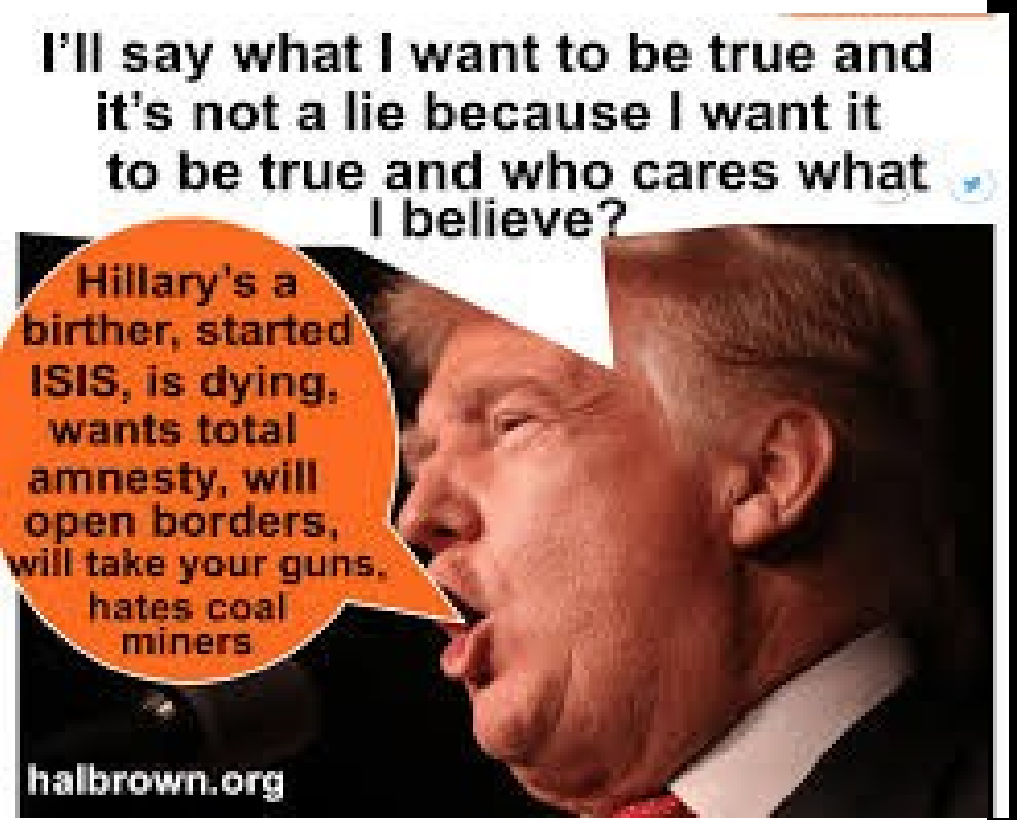
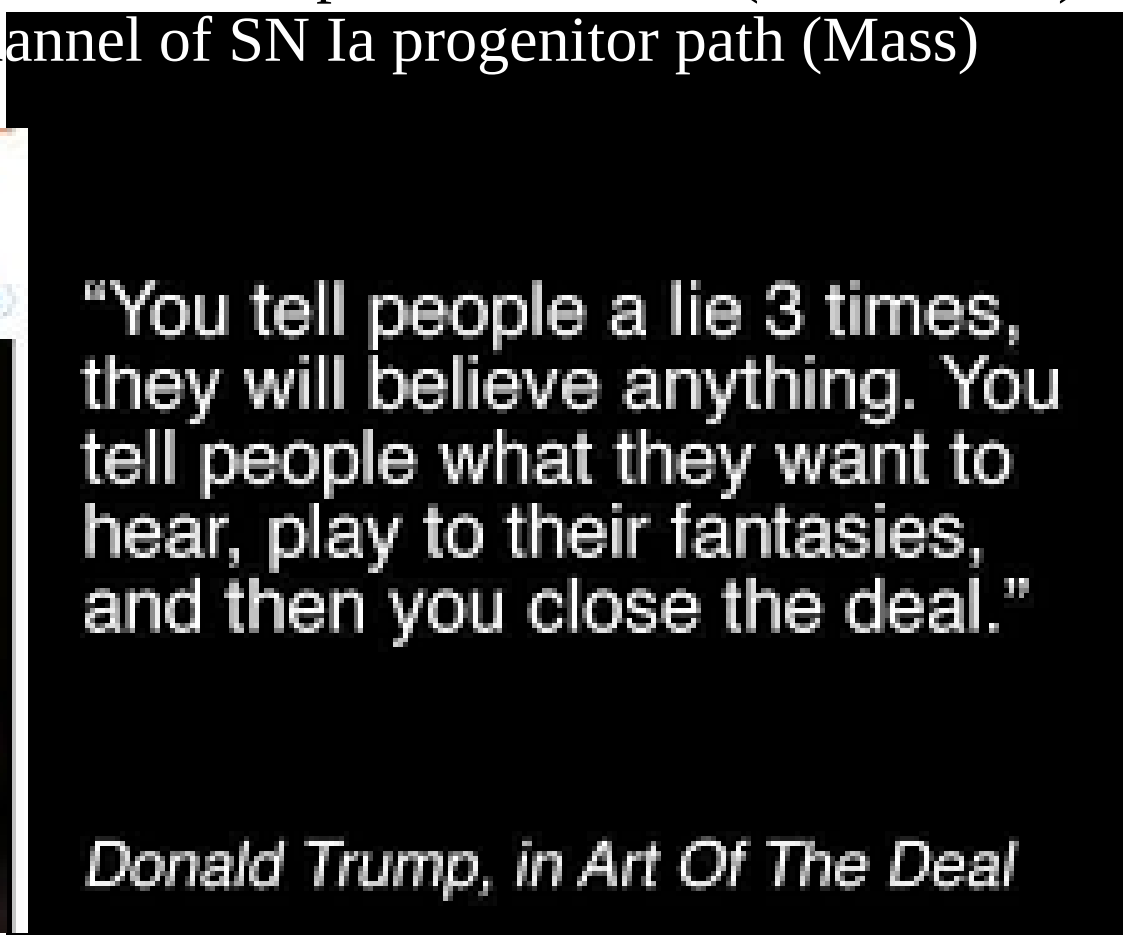




Quantitative Approaches (How much?)

However, several problems:

- Poor reproduction of observed spectra
  Only general shape, most abs. not reproduced.
- Albeit already complex model, still too simplistic (hydrostatic,
  Simple geometry (plane-parallel or spherically symmetric)
- Large values of χ^2 => No error bars!!!
- Large number of parameters, to name only some:
  + T_{eff} + log(g) + normalization (radius) + N_H
  + Abundances (at face value 92 parameters!)
  + Opacities
  + non-LTE implementation

It is not the same to freeze a **known** parameter
(from other measurements) or to freeze at an **assumed** a value

==> An example how models should work at end of talk (time permitting)

Qualitative Approaches (How?)

While no numbers are involved, we can gain clues from:

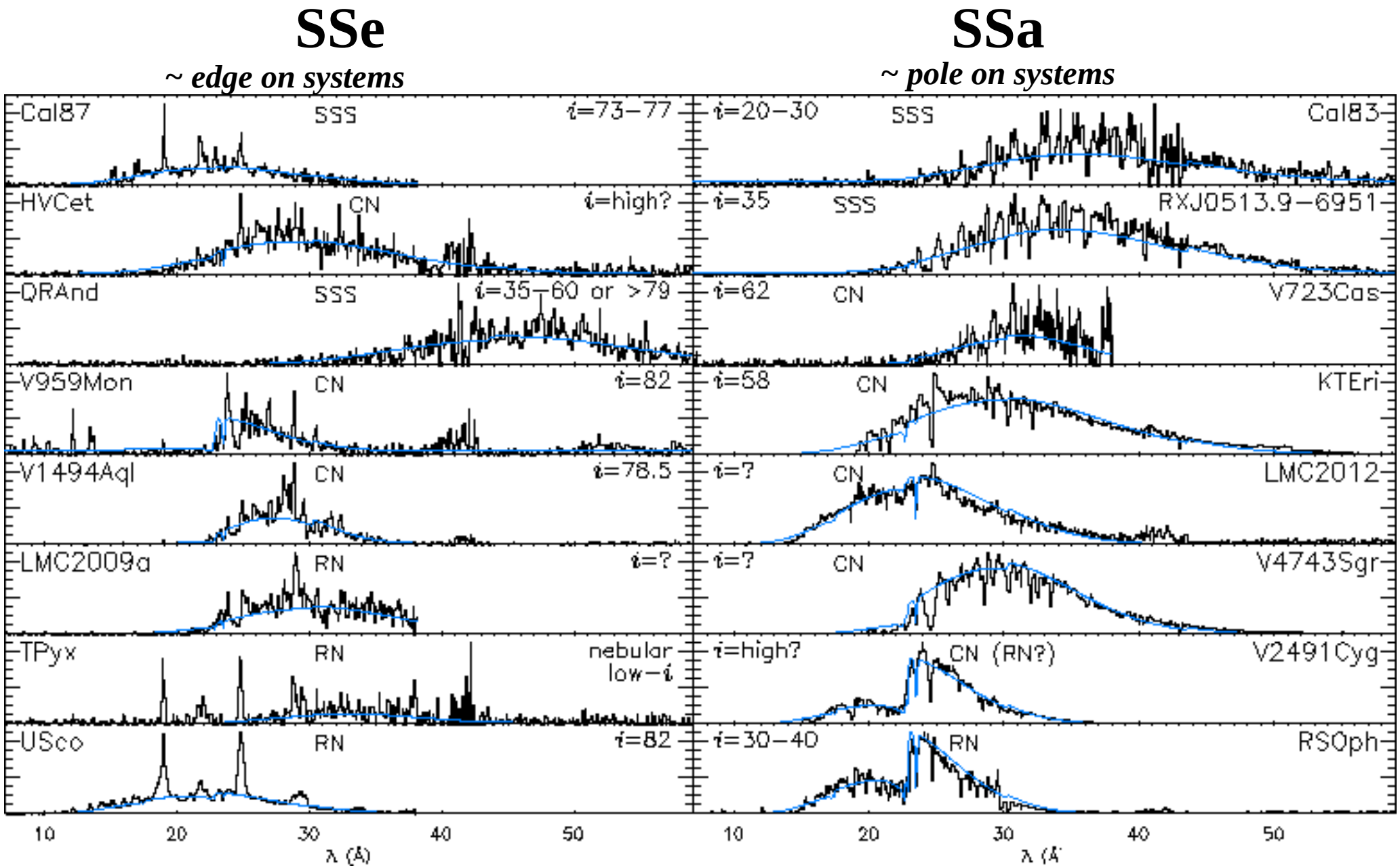
- Groups and samples of spectra to look for trends and classification

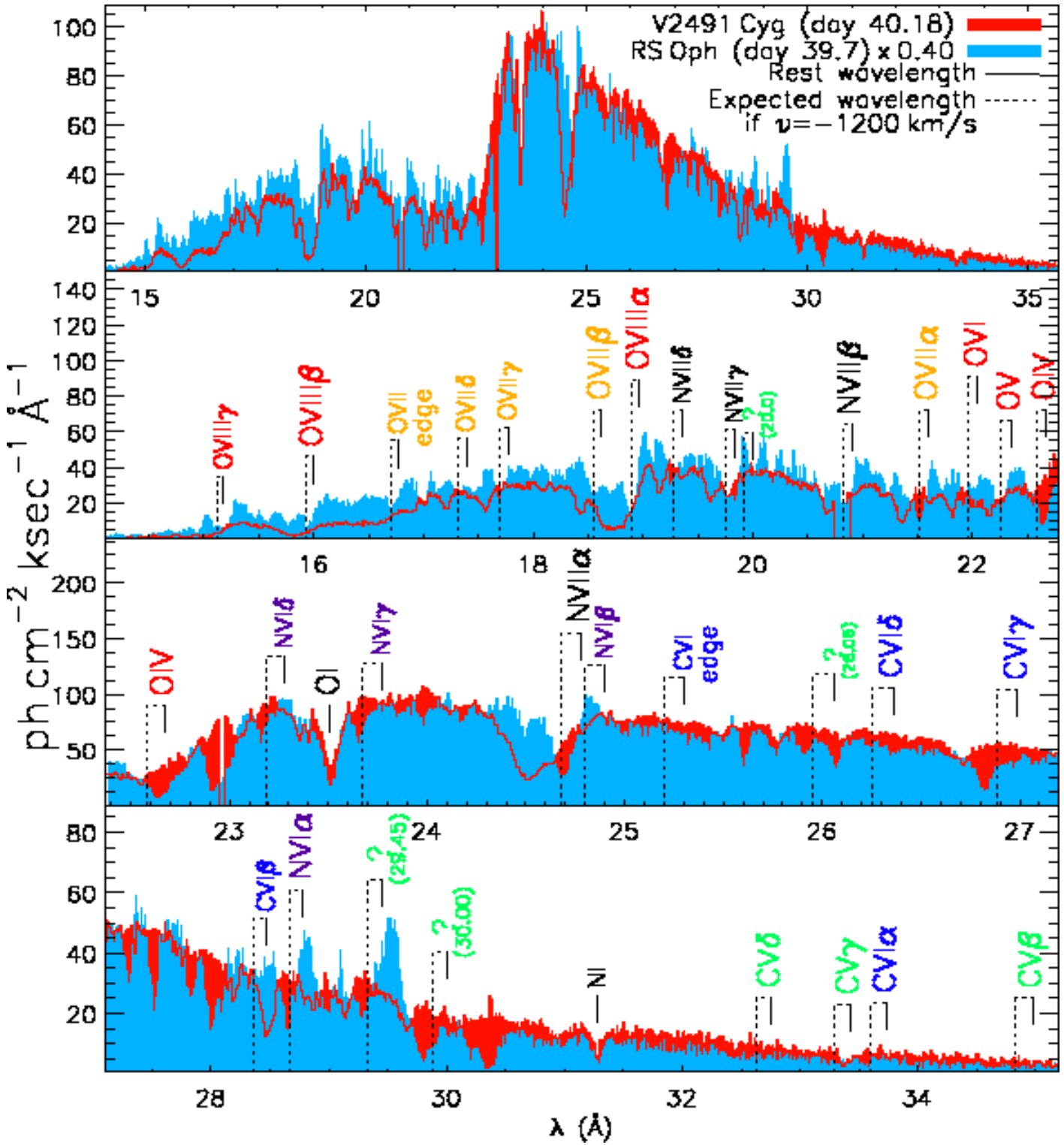
- Line profile analysis (actually gives some numbers)

- Short/Long-term spectral evolution

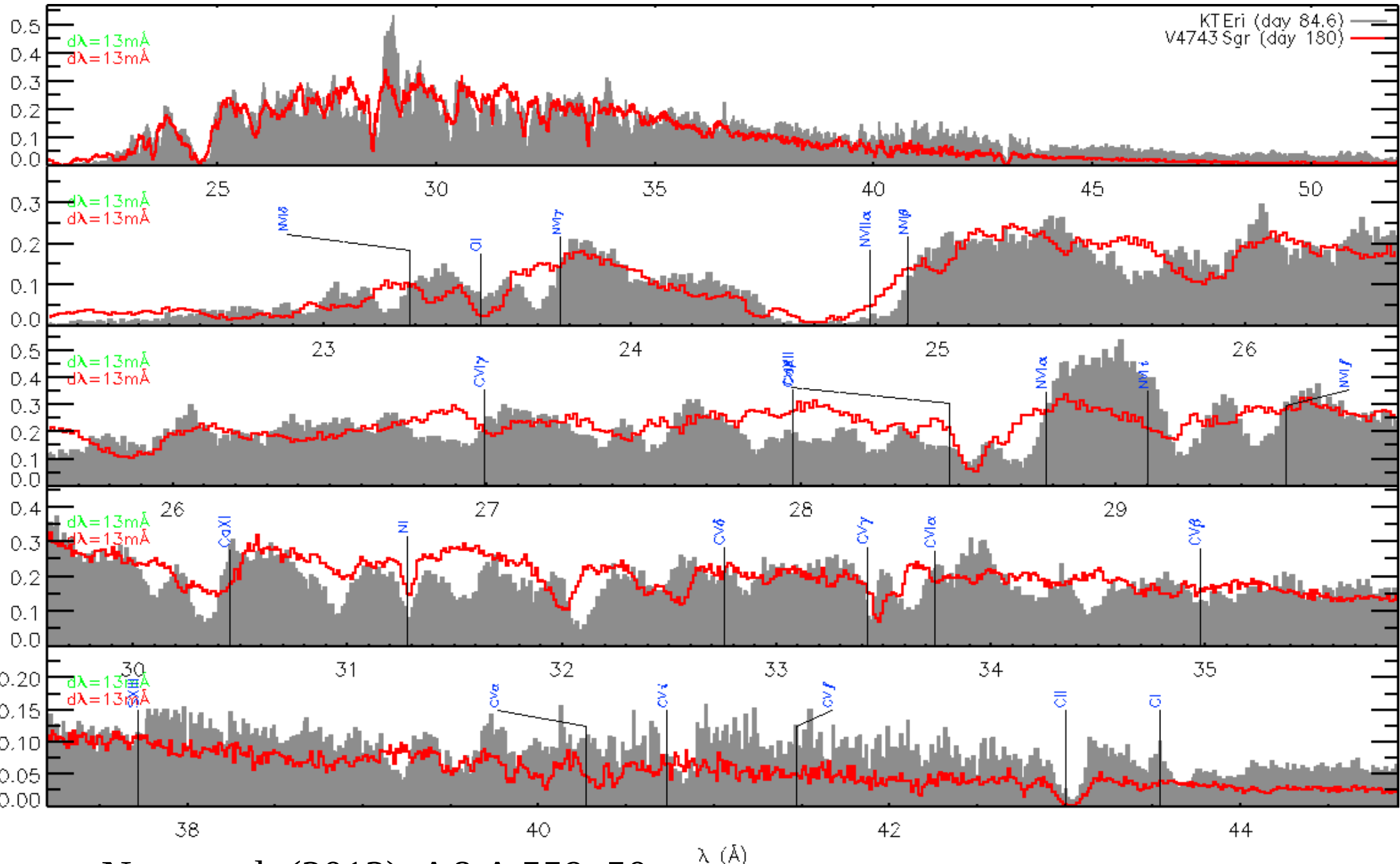
X-ray grating spectra of
- Super Soft Sources (SSS)
- Classical Novae (CN)
- Recurrent Novae (RN)

Ness et al. (2013)
A&A 559, 50

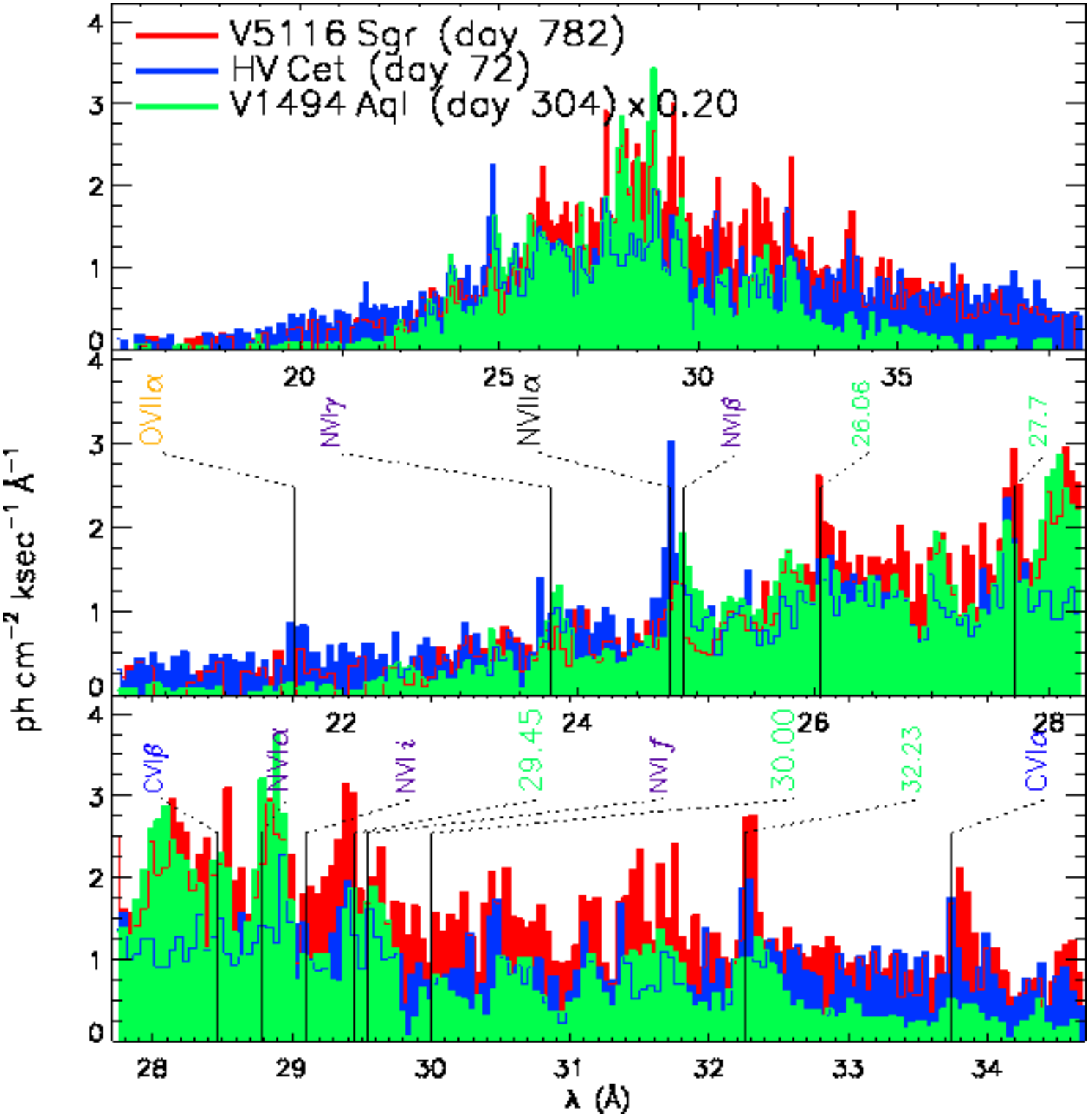


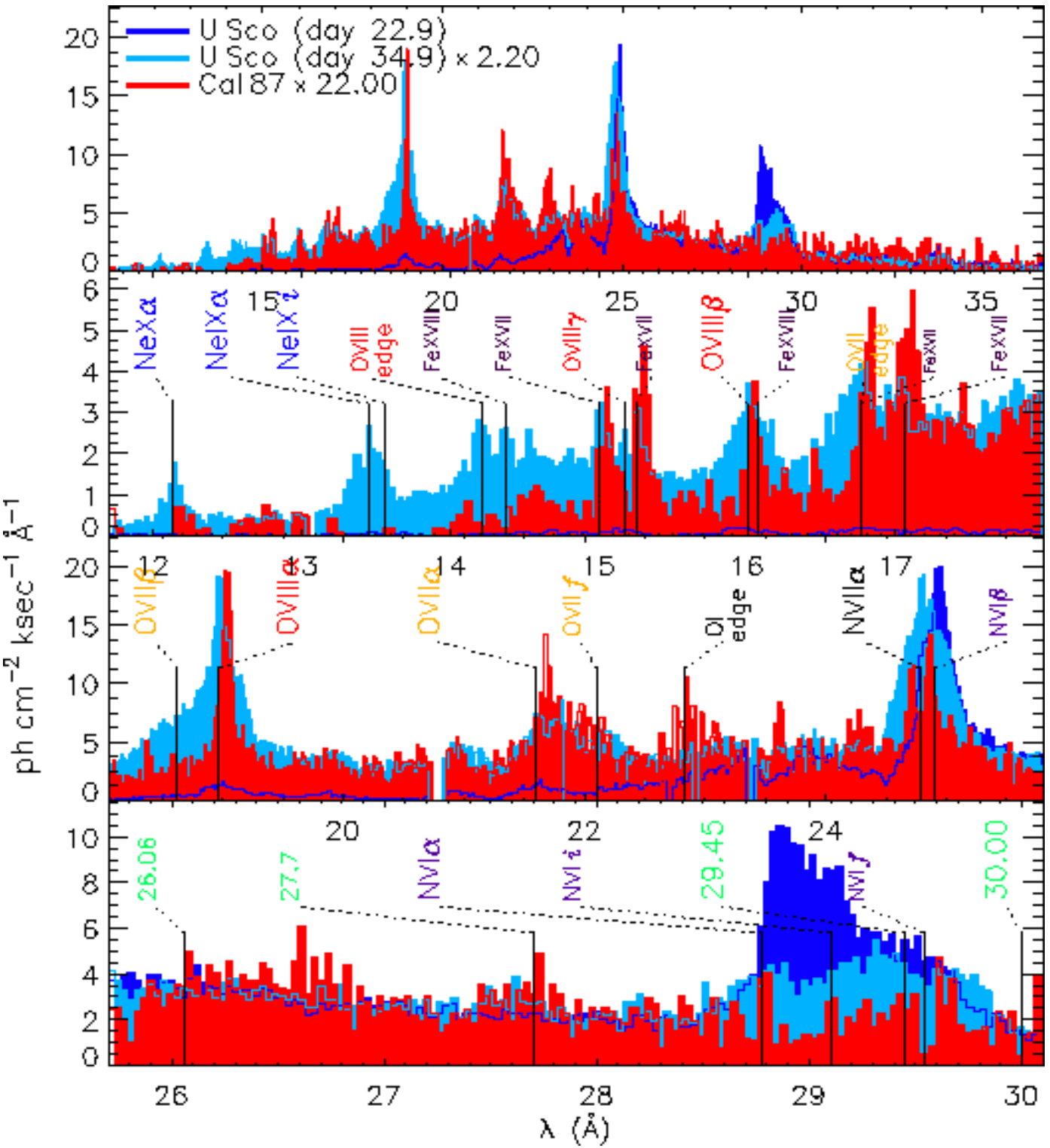


Ness et al. (2011)
ApJ 733, 70



Ness et al. (2013), A&A 559, 50


V5116 Sgr (day 782)
HV Cet (day 72)
V1494 Aql (day 304) x 0.20
OVIIIα
NVIIγ
NVIIα
NVIβ
26.06
27.7
CVIβ
NVIIδ
NVI i
29.45
NVI f
30.00
32.23
CVIα
ph cm^{-2} ksec^{-1} Å^{-1}
λ (Å)



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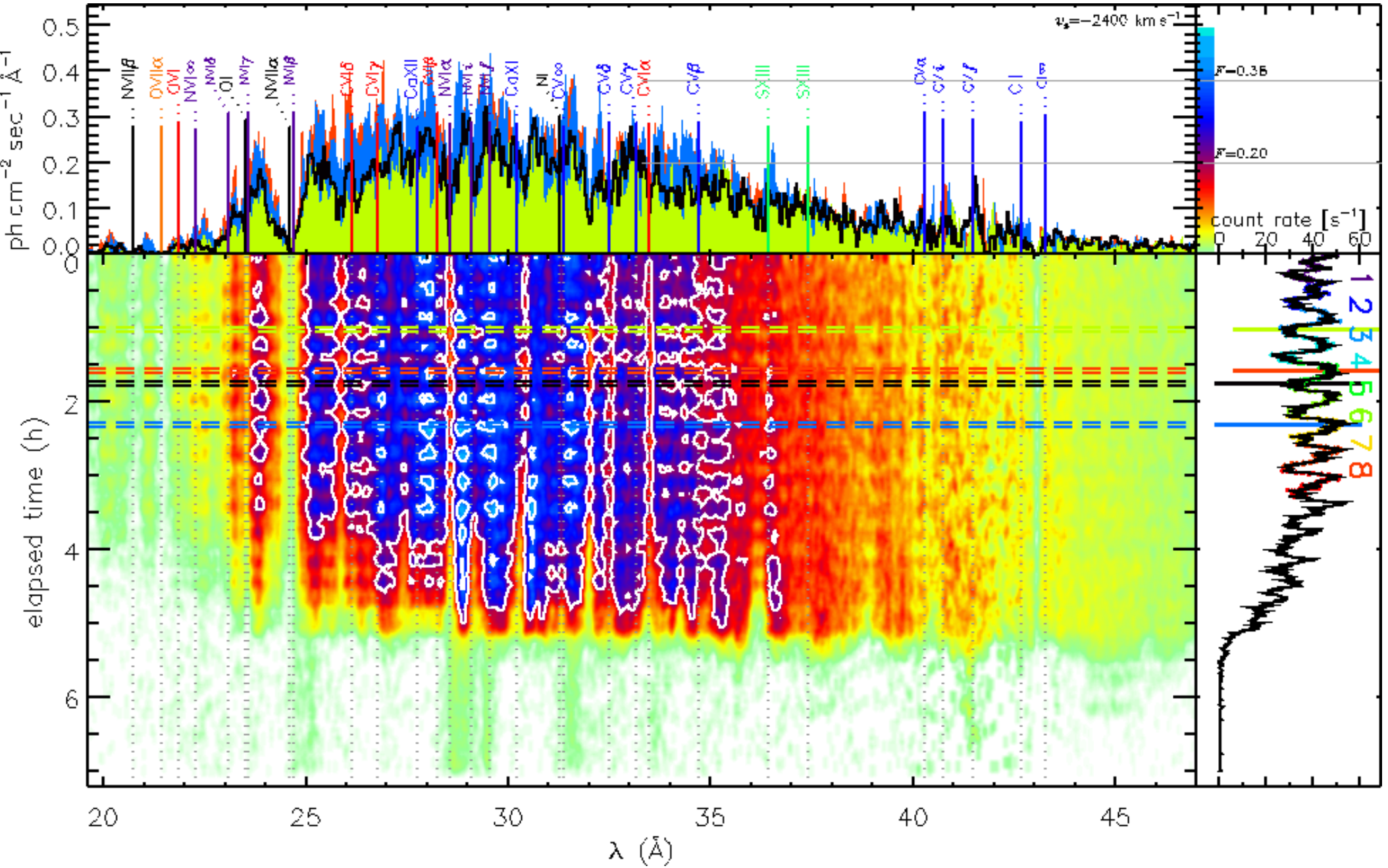
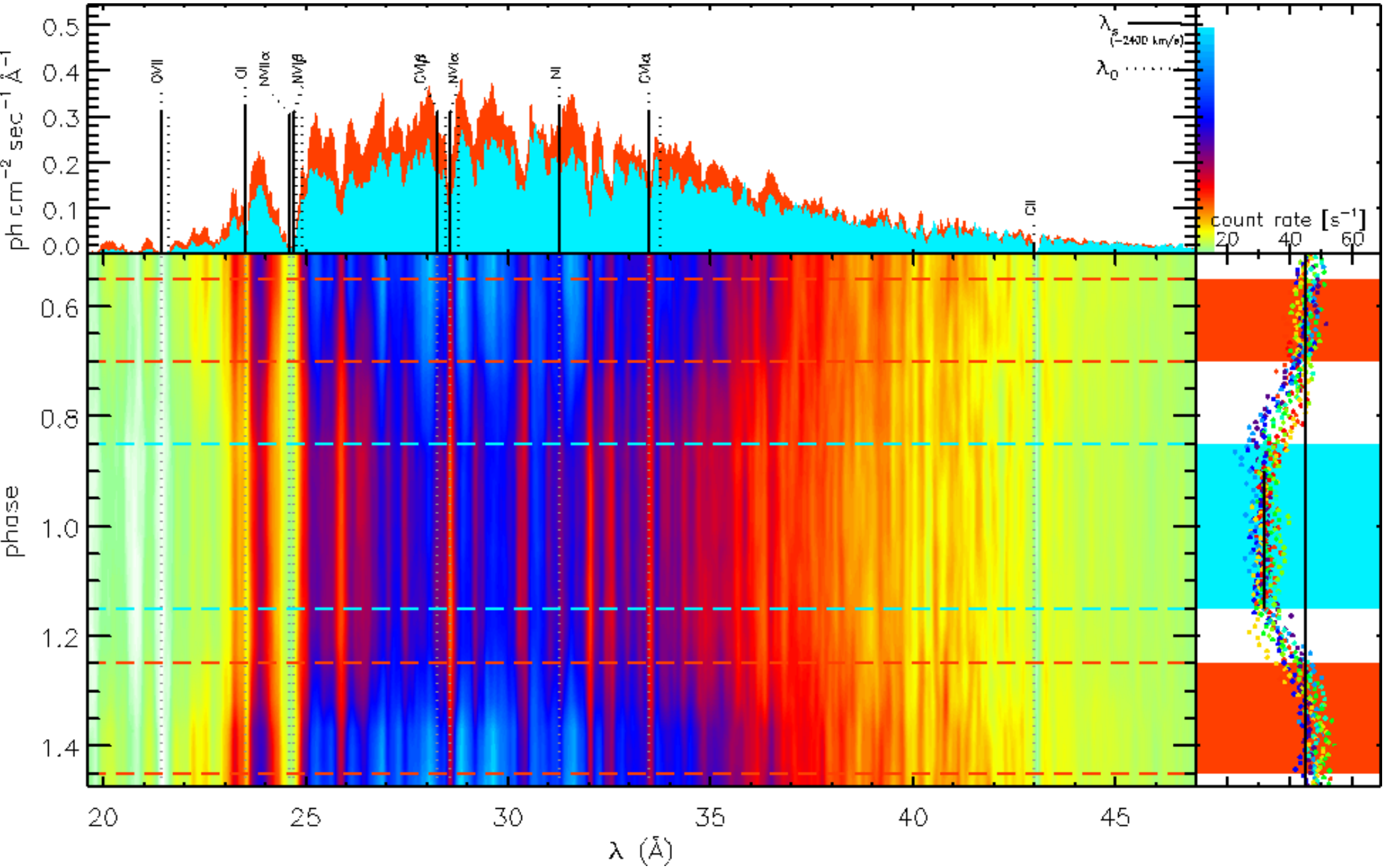
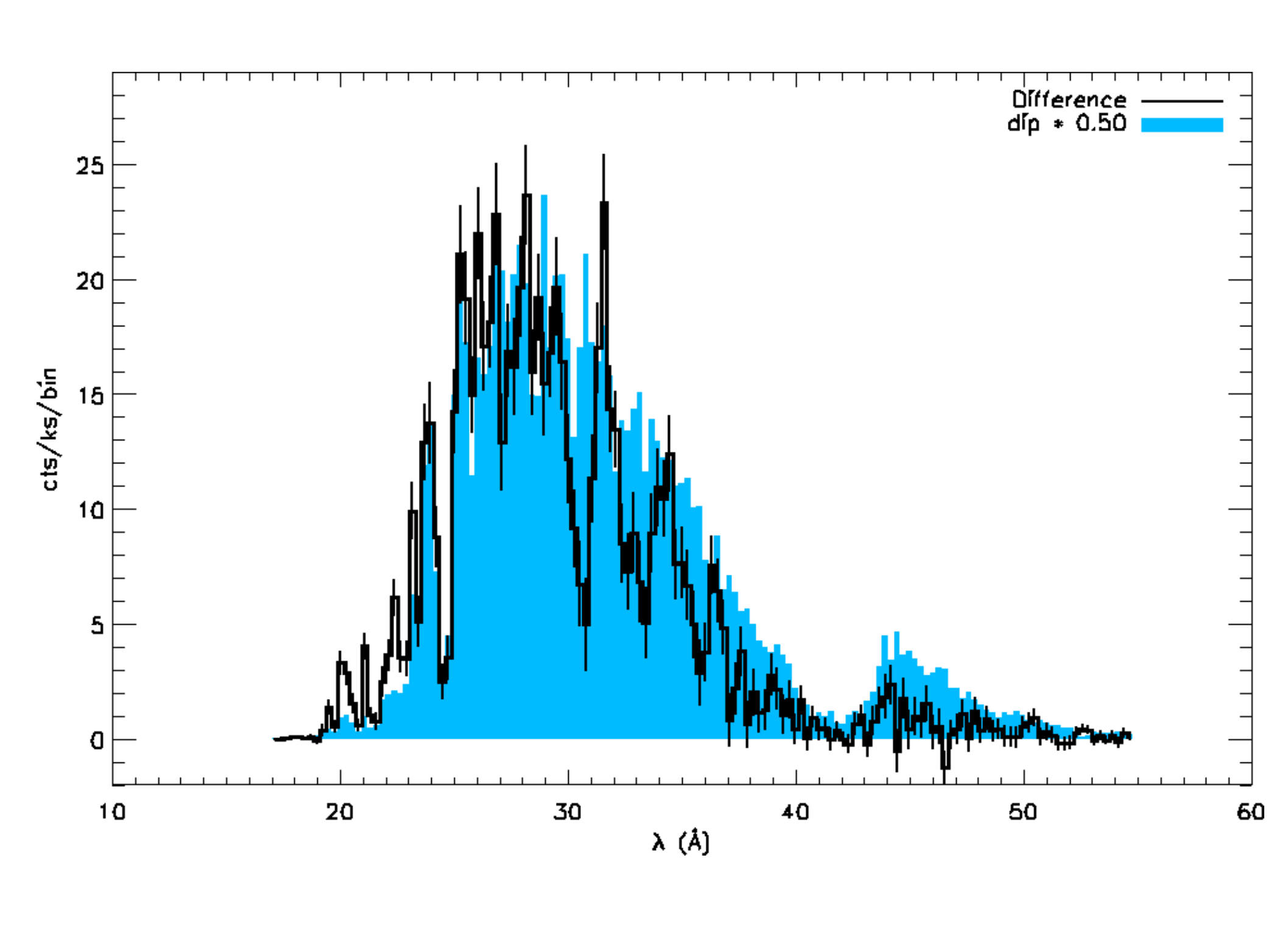
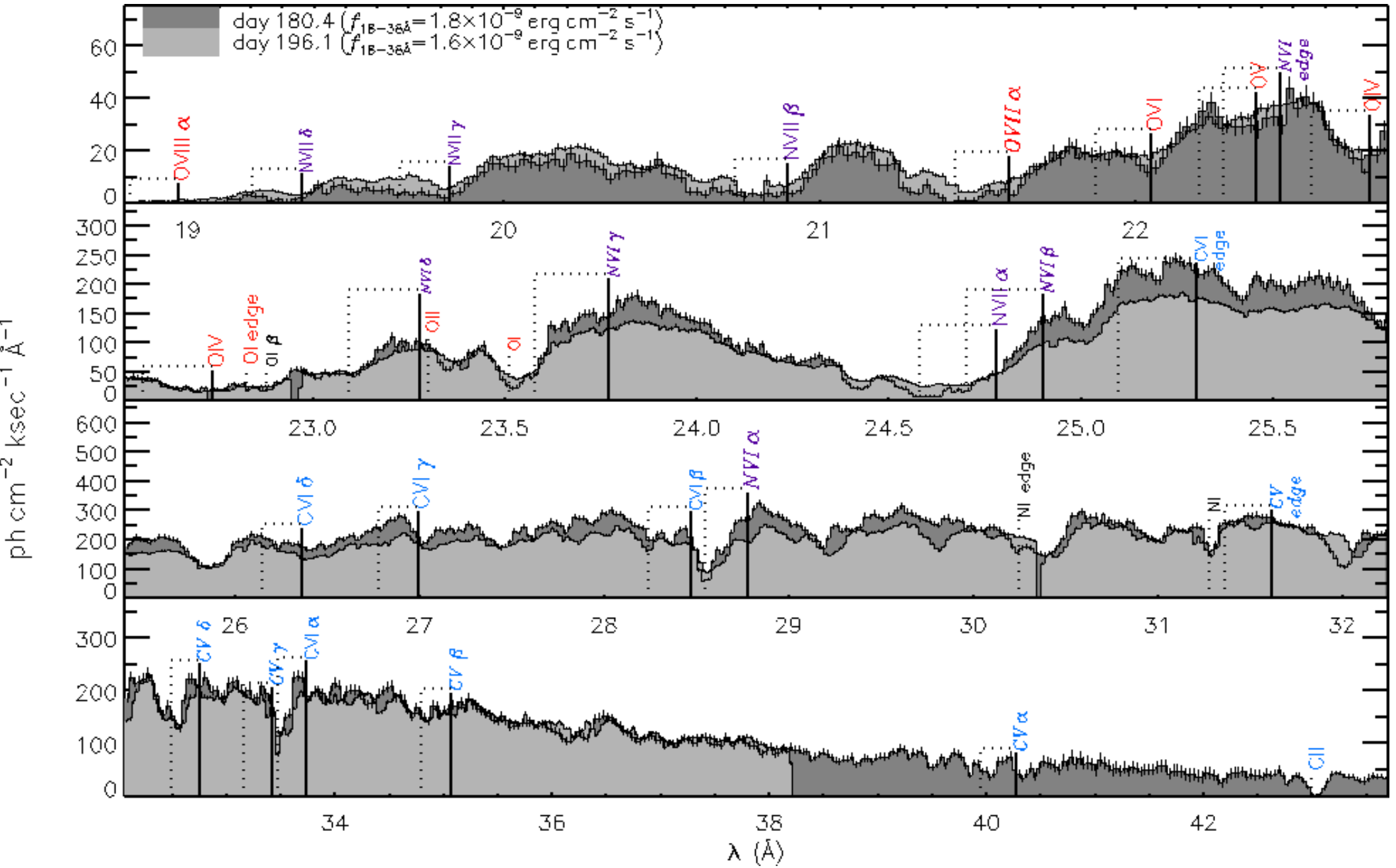
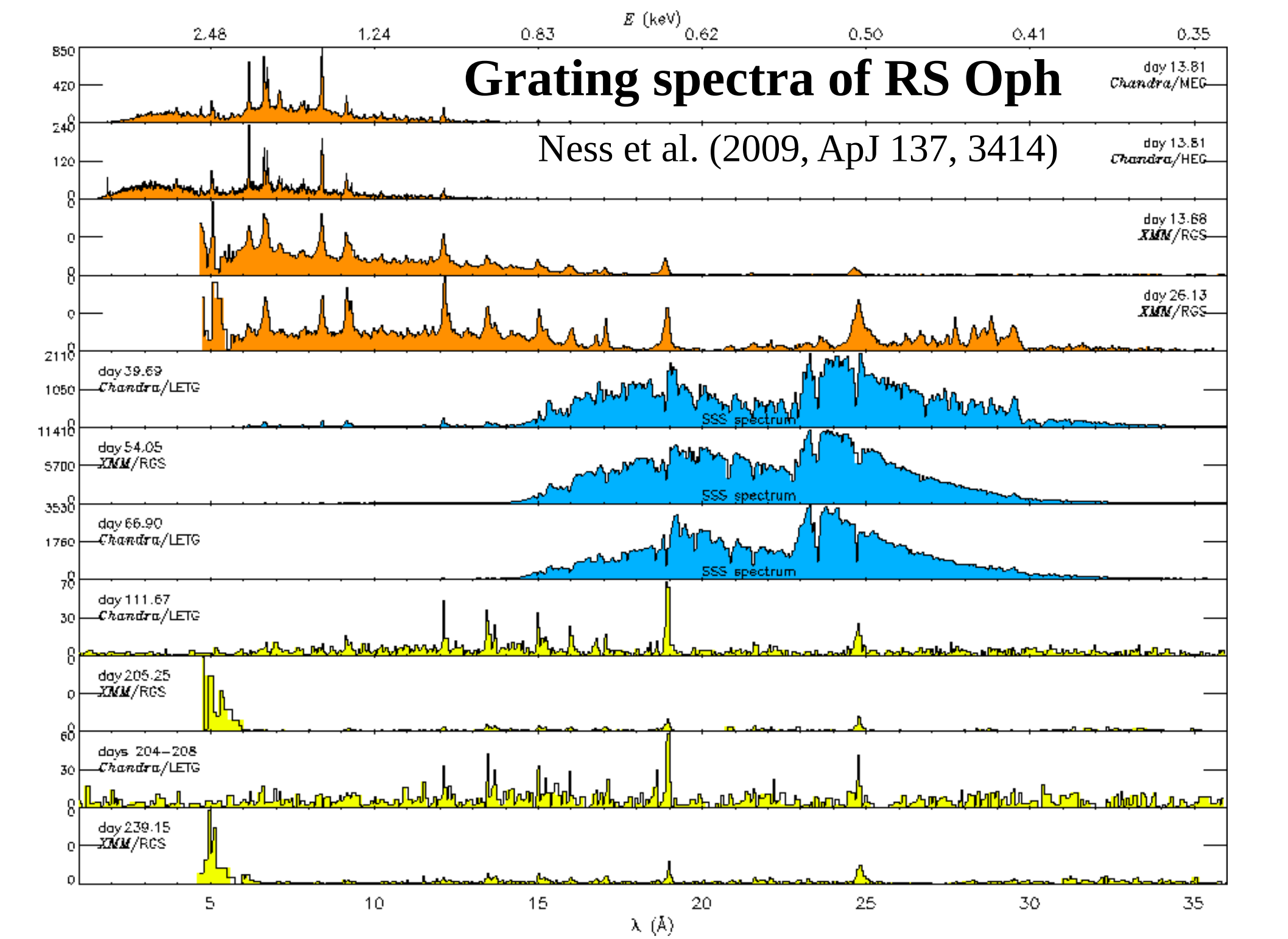
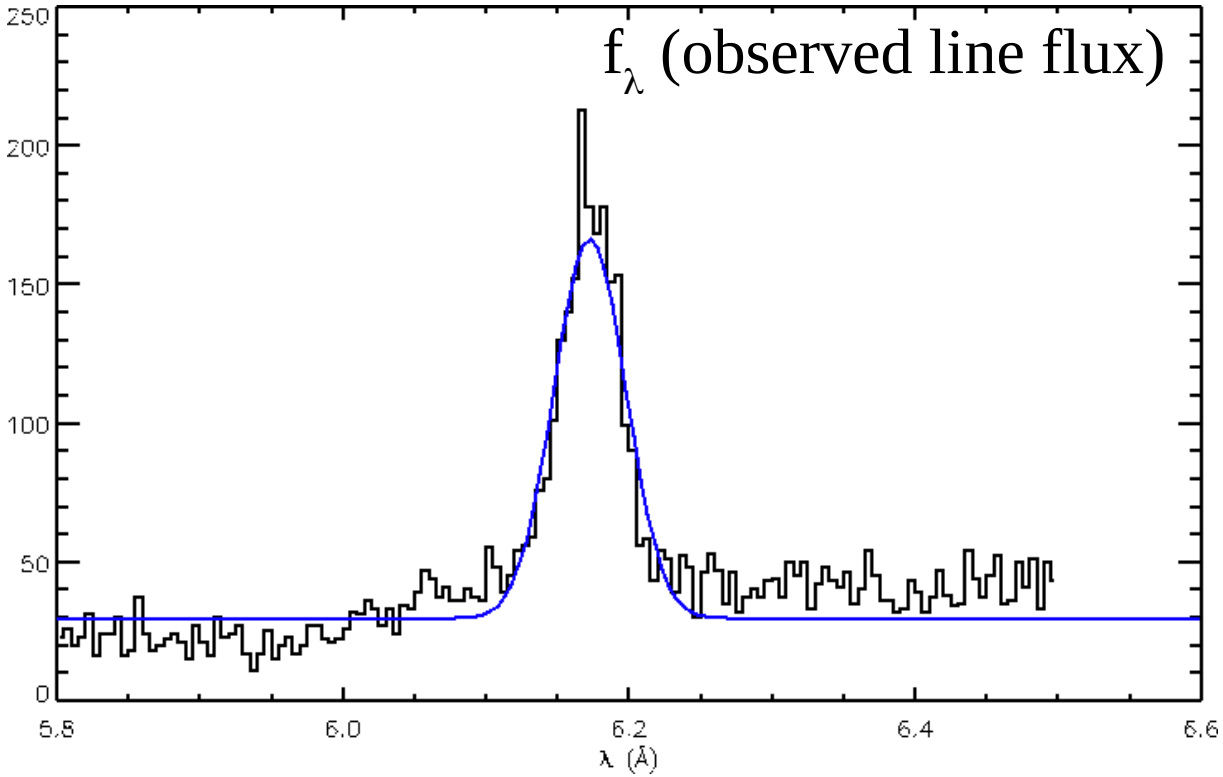

v_s=−2400 km s^{-1}
F=0.35
F=0.20
count rate [s^{-1}]
0 20 40 60
ph cm^{-2} sec^{-1} Å^{-1}
0.0 0.1 0.2 0.3 0.4 0.5
NVIIβ
OVIIα
OVI
NVIIε
NVIδ
OI
NVIγ
NVIIα
NVIβ
CVIδ
CVIγ
CaXII
CaXII
NVIα
NVIζ
NVIζ
CaXI
NI
CVε
CVβ
CVγ
CVIα
CVβ
SXIII
SXIII
CVα
CVλ
CVf
CI
CIα
elapsed time (h)
0 2 4 6
1 2 3 4 5 6 7 8
λ (Å)
20 25 30 35 40 45


ph cm^{-2} sec^{-1} Å^{-1}
0.0
0.1
0.2
0.3
0.4
0.5
OVII
OI
NVIIα
NVIβ
CVIβ
NVIα
NI
CVIα
CII
λ_s (−2400 km/s)
λ_0
count rate [s^{-1}]
20
40
60
phase
0.6
0.8
1.0
1.2
1.4
20
25
30
35
40
45
λ (Å)


Difference
dip * 0.50
cts/ks/bin
λ (Å)
0
5
10
15
20
25
10
20
30
40
50
60


day 180.4 ($f_{1B-36Å}$=1.8×10^{-9} erg cm^{-2} s^{-1})
day 196.1 ($f_{1B-36Å}$=1.6×10^{-9} erg cm^{-2} s^{-1})
OVIII α
NVII δ
NVII γ
NVII β
OVII α
OVI
AO
NVI edge
AO
OV
19
20
21
22
OIV
OI edge
OI β
NVII δ
OII
OI
NVI γ
NVII α
NVI β
OVI edge
23.0
23.5
24.0
24.5
25.0
25.5
CVI δ
CVI γ
CVI β
NVI α
NI edge
NI
CV edge
26
27
28
29
30
31
32
CV δ
CV γ
CVI α
CV β
CV α
CII
34
36
38
40
42
λ (Å)
ph cm^{-2} ksec^{-1} Å^{-1}


Grating spectra of RS Oph
Ness et al. (2009, ApJ 137, 3414)
E (keV)
2.48
1.24
0.83
0.62
0.50
0.41
0.35
day 13.81
Chandra/MEG
day 13.81
Chandra/HEG
day 13.68
XMM/RGS
day 26.13
XMM/RGS
day 39.69
Chandra/LETG
SSS spectrum
day 54.05
XMM/RGS
SSS spectrum
day 66.90
Chandra/LETG
SSS spectrum
day 111.67
Chandra/LETG
day 205.25
XMM/RGS
days 204–208
Chandra/LETG
day 239.15
XMM/RGS
5
10
15
20
25
30
35
λ (Å)



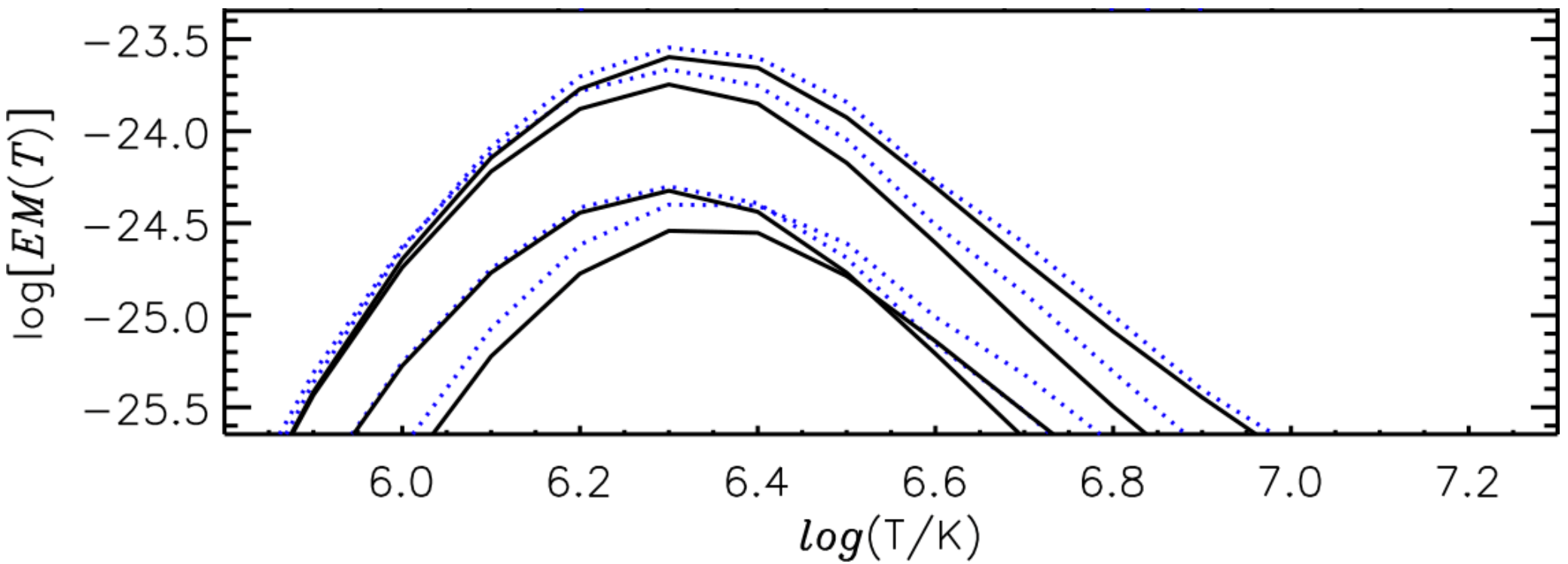
In collisional equilibrium, the flux in an emission line depends on the Volume emission measure of the plasma (**VEM = n_e * V**) and the line contribution function **$G_\lambda(T)$** for each emission line at wavelength **λ**:

$$F_\lambda = \int \mathbf{VEM}(T) \times G_\lambda(T) \times dT$$

$$G_\lambda(T) \text{ in } \quad F_\lambda = \int \mathbf{VEM\,(T)} \times G_\lambda(T) \times dT$$

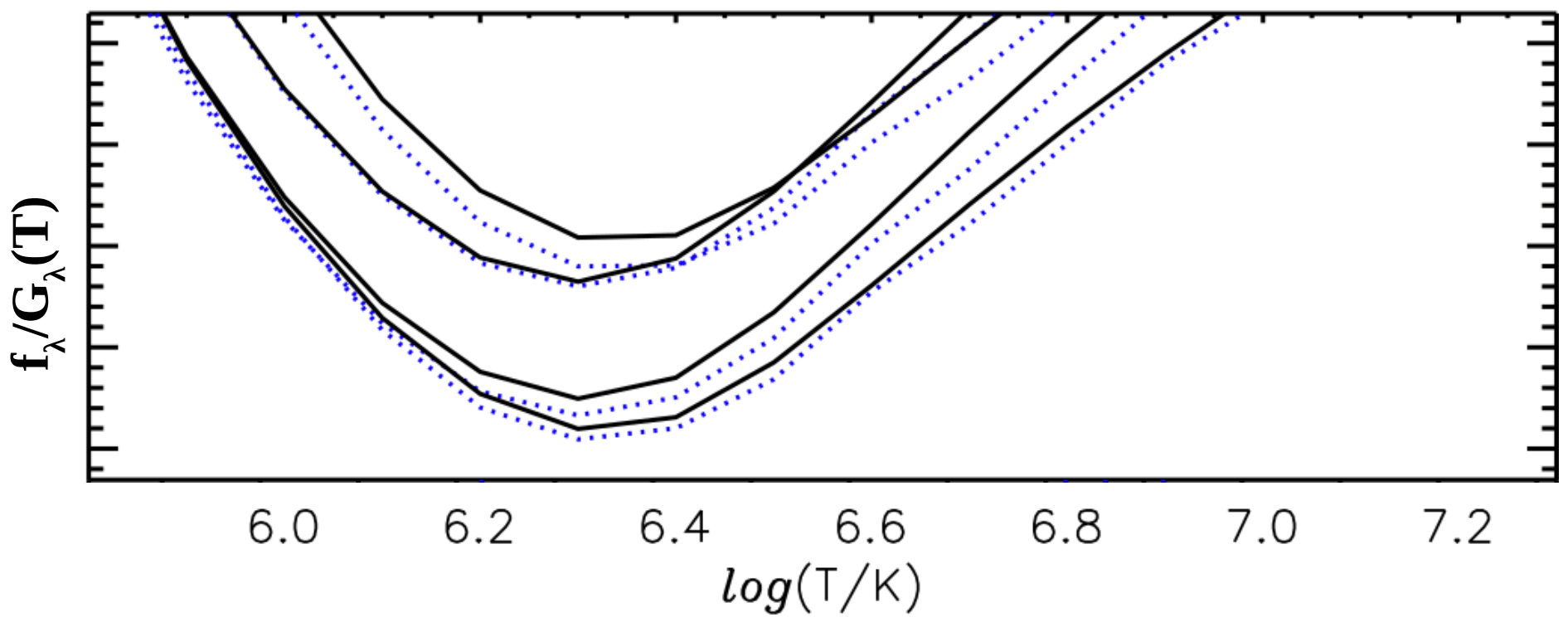
is basically product of Theory and observables:

- Number density of upper level (function of T)
- Einstein A coefficient
- Ionisation balance (function of T)
- Elemental abundances (linear factor)



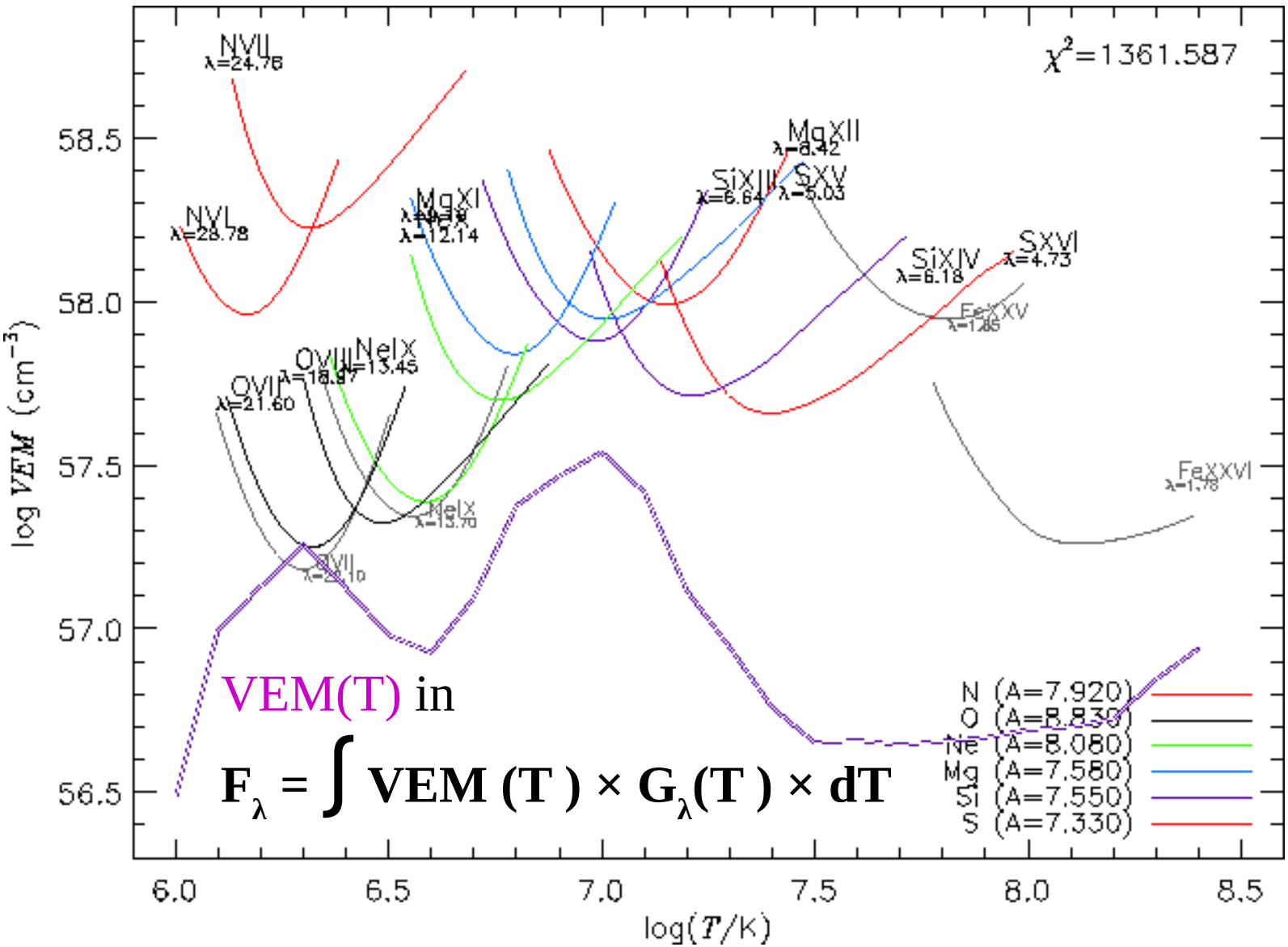
$$F_\lambda = \int \mathrm{VEM}(T) \times G_\lambda(T) \times dT$$

Ratio of observed flux f_λ to predicted flux:

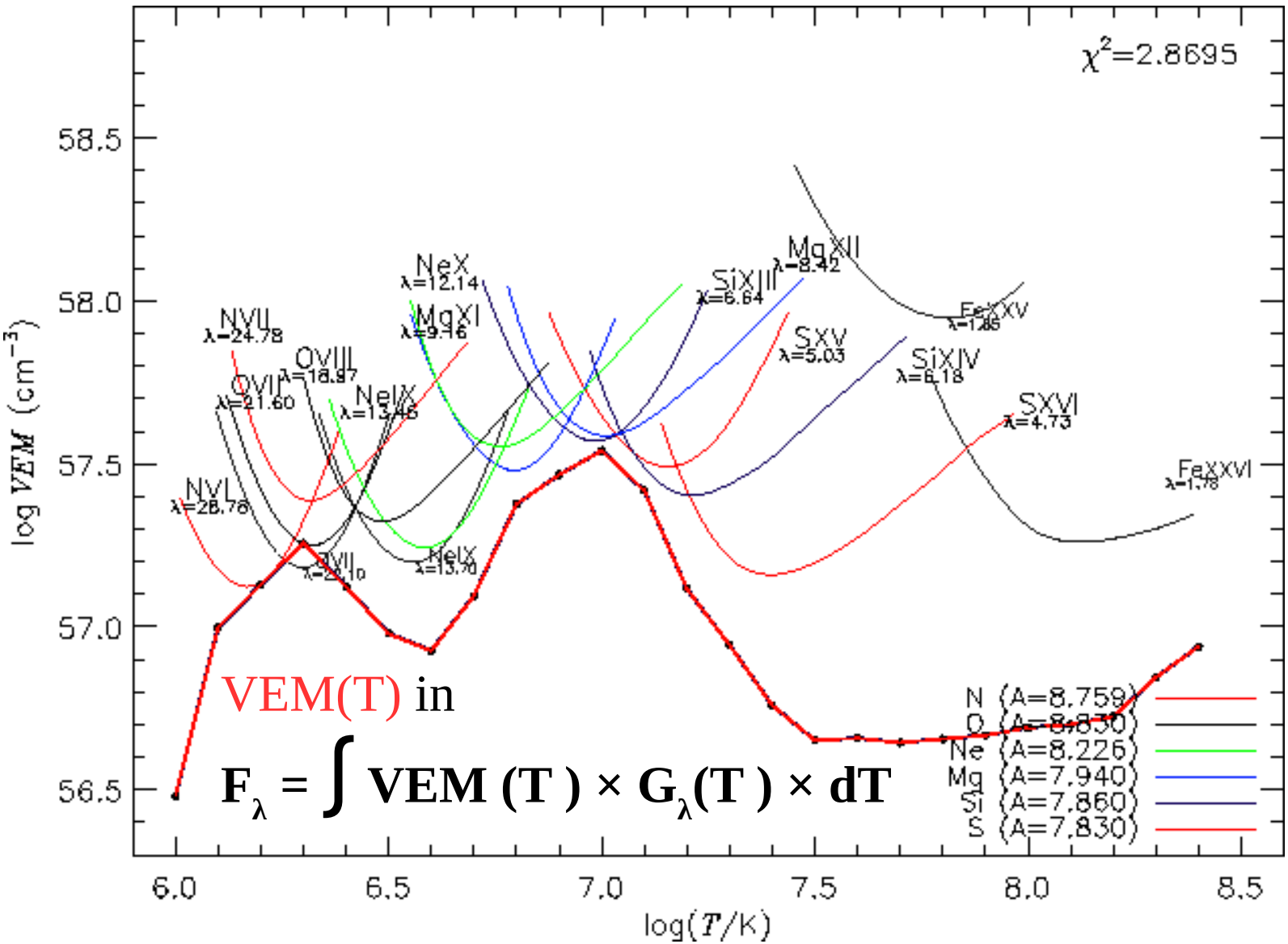


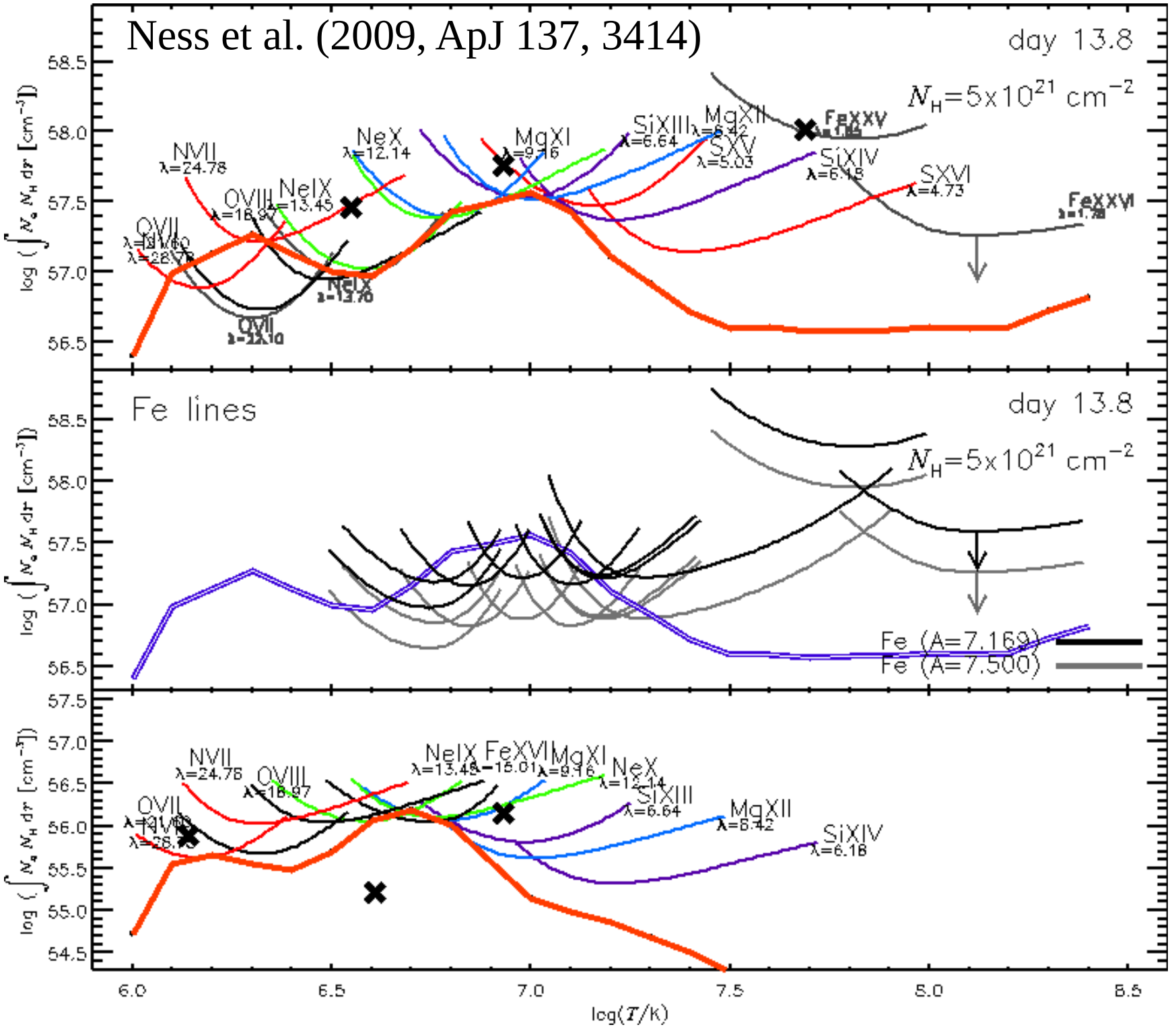
$$\frac{f_\lambda}{G_\lambda(T)}$$

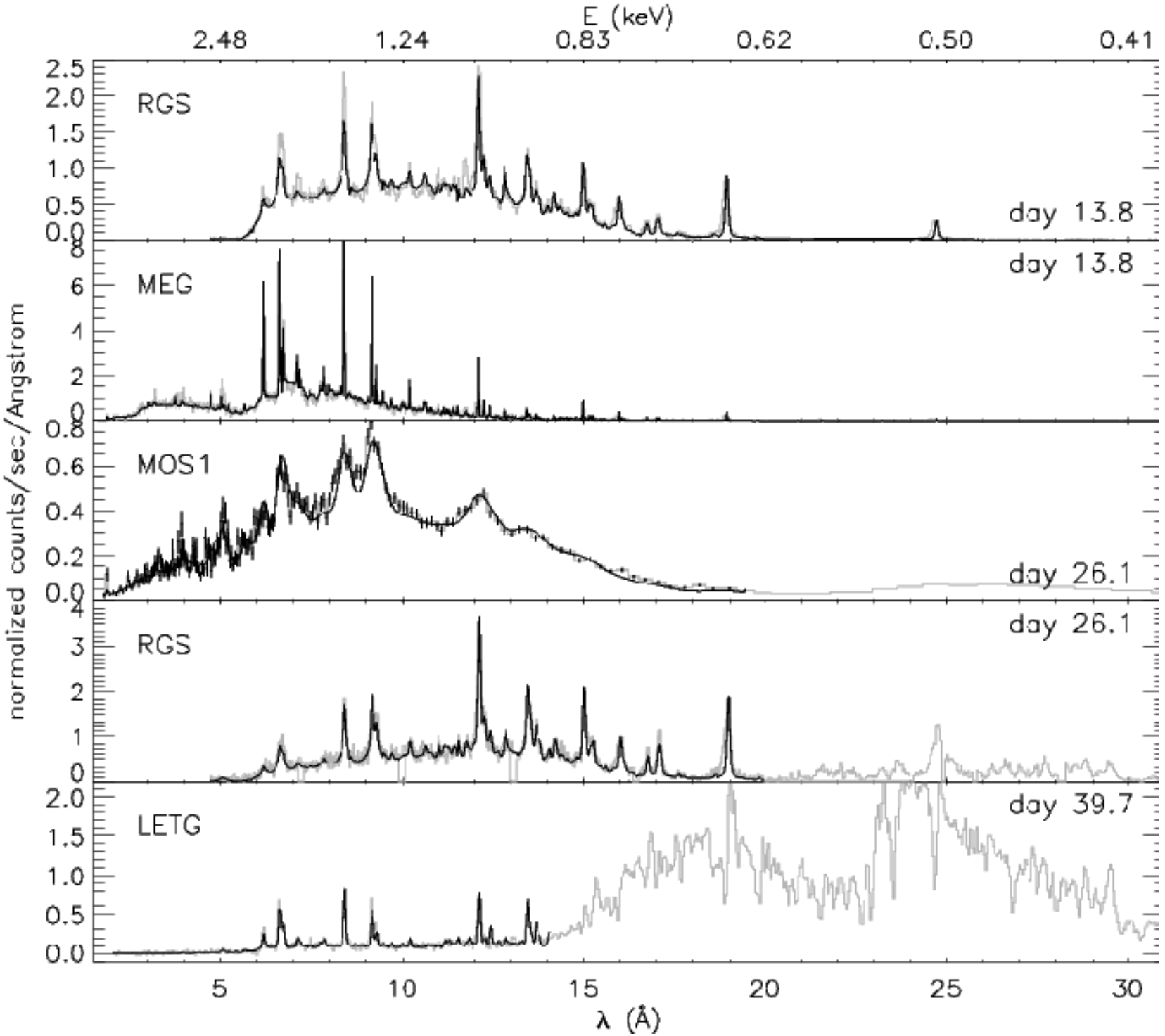
Note: G proportional to abundances

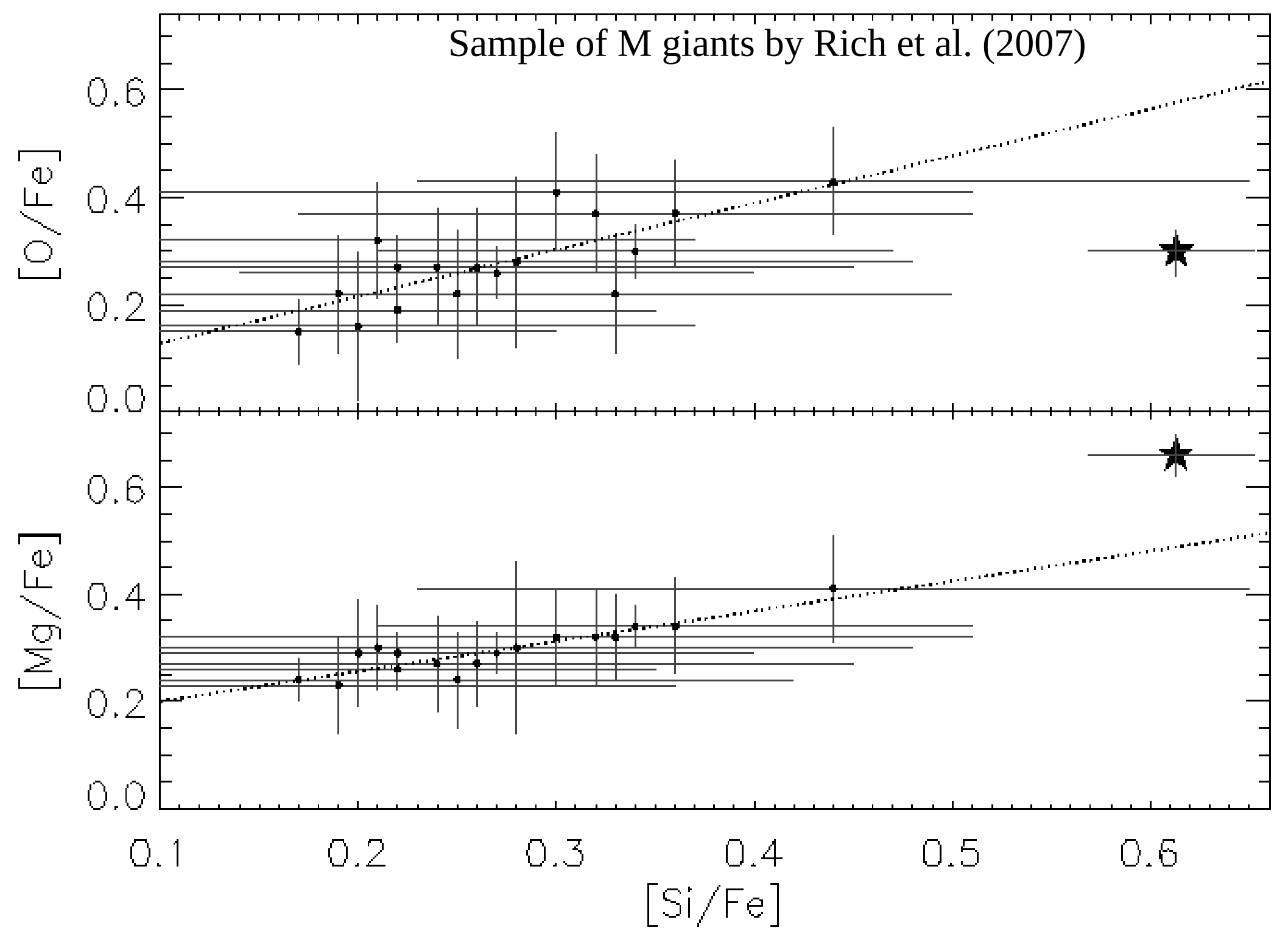


$$\frac{f_\lambda}{G_\lambda(T)}$$




Ness et al. (2009, ApJ 137, 3414)
day 13.8
N_H=5x10^{21} cm^{-2}
NVII λ=24.78
OVIII λ=18.97
NeIX λ=13.45
NeX λ=12.14
MgXI λ=9.16
SiXIII λ=6.64
MgXII λ=8.42
SiXIV λ=6.18
SXV λ=5.03
SXVI λ=4.73
FeXXV
FeXXVI
OVII
Fe lines
Fe (A=7.169)
Fe (A=7.500)
FeXVII λ=15.01
log (∫ N_e N_H dr [cm^{-5}])
log(T/K)


E (keV)
2.48
1.24
0.83
0.62
0.50
0.41
RGS
day 13.8
MEG
day 13.8
MOS1
day 26.1
RGS
day 26.1
LETG
day 39.7
normalized counts/sec/Angstrom
λ (Å)
5
10
15
20
25
30


Sample of M giants by Rich et al. (2007)
[O/Fe]
[Mg/Fe]
[Si/Fe]
0.0
0.2
0.4
0.6
0.1
0.2
0.3
0.4
0.5
0.6