Comparison of Obscuration in NGC 3783 with NGC 5548

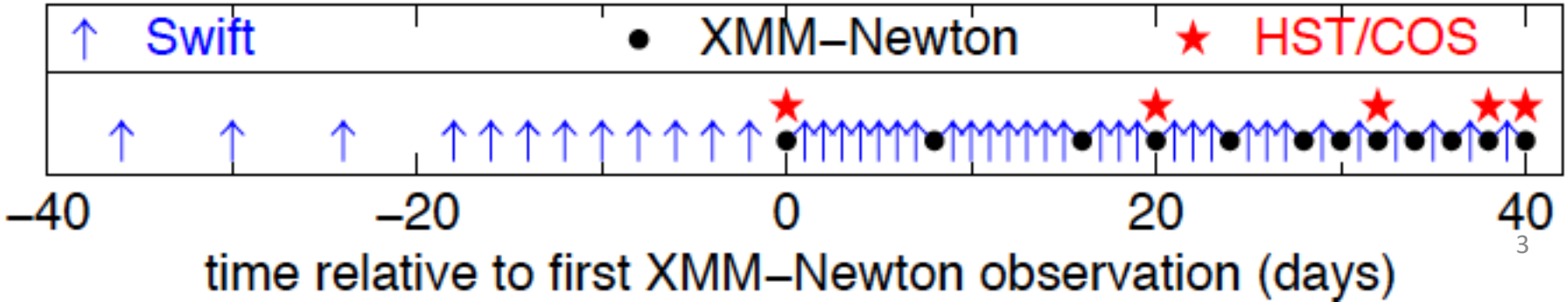
Jelle Kaastra

SRON & Sterrenwacht Leiden

The NGC 5548 campaign

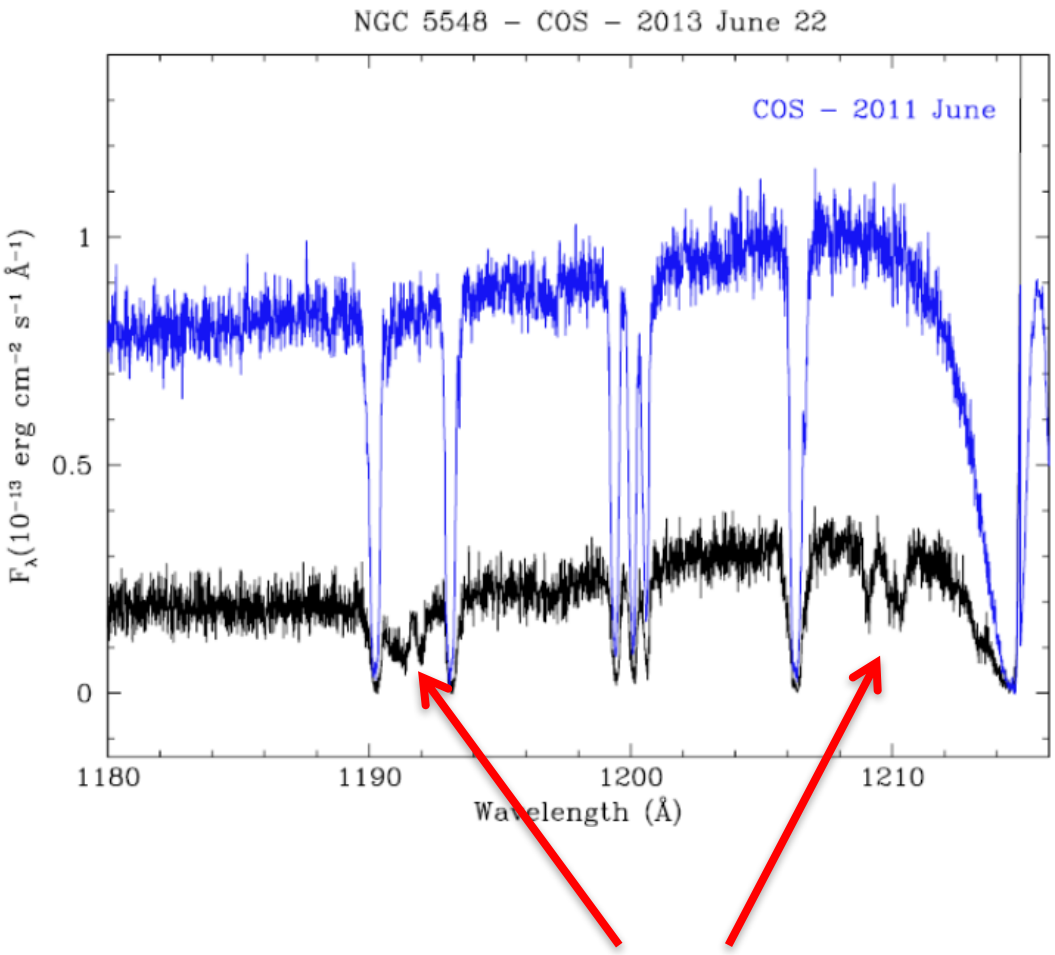
Set-up campaign

- 14 x 50 ks with XMM-Newton (RGS, EPIC, OM)
- 6 x HST/COS
- 4 x NuSTAR
- 4 x INTEGRAL
- 3 x Chandra LETGS
- Daily Swift monitoring (XRT, UVOT)
- Ground-based support (Israel, Chile)
- Core June/July 2013, 2 observations ½ year later



Four big surprises

1) Low-ionisation UV lines never seen before
2) No RGS data?
3) Strongly absorbed X-ray spectrum EPIC
4) Broad UV absorption lines



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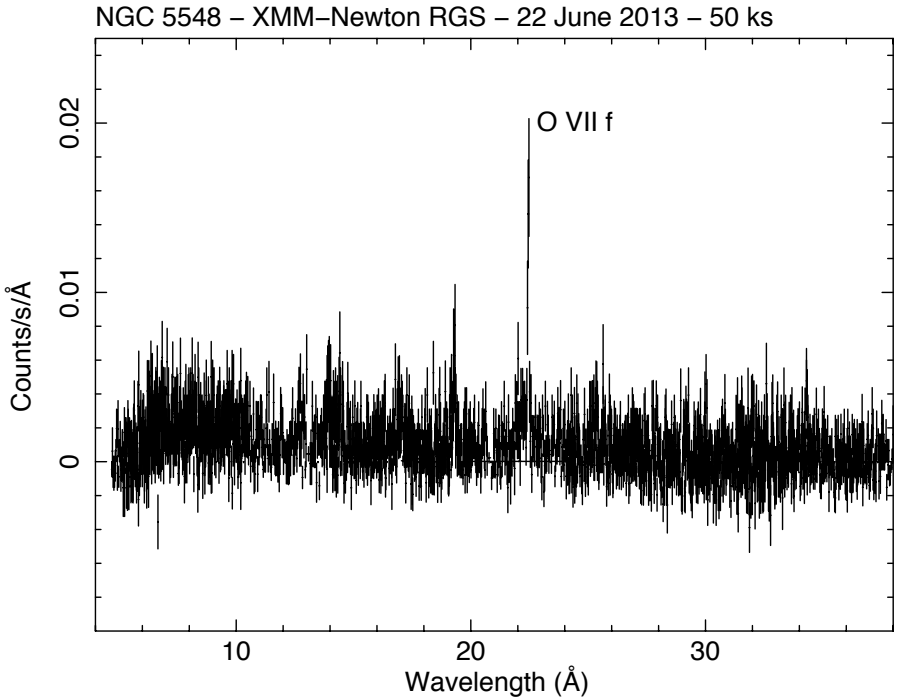

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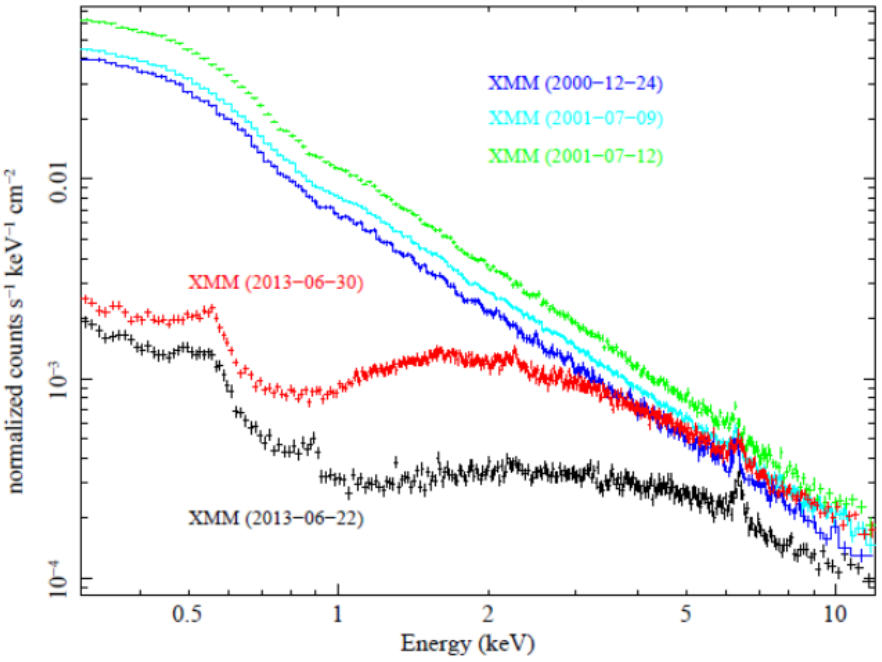

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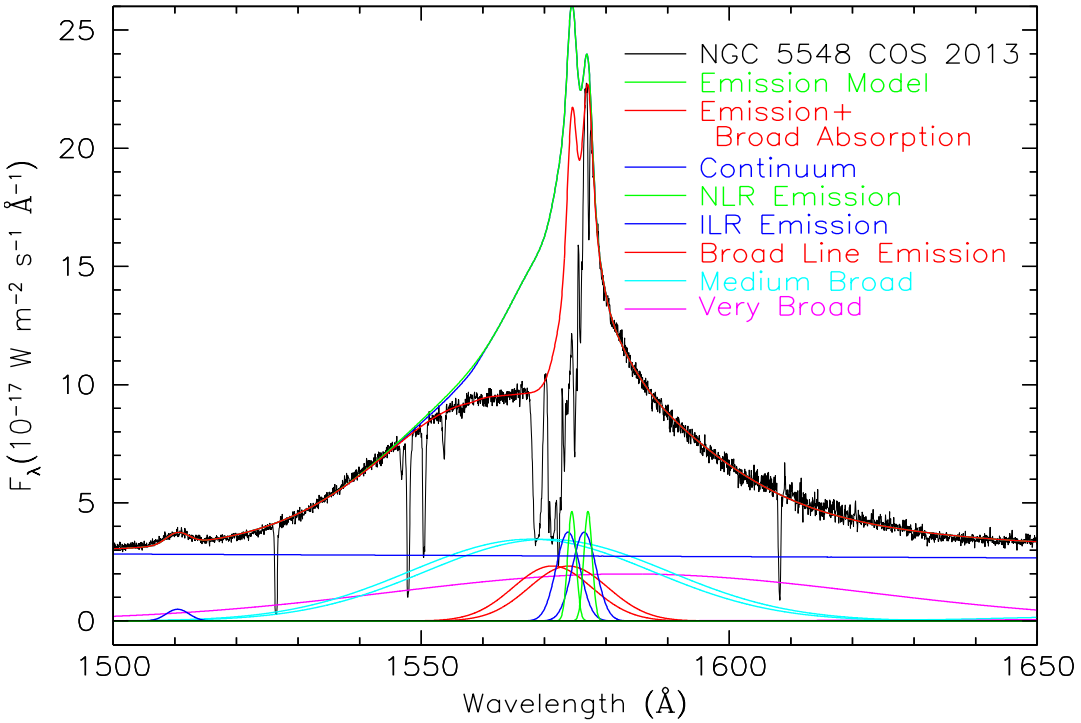
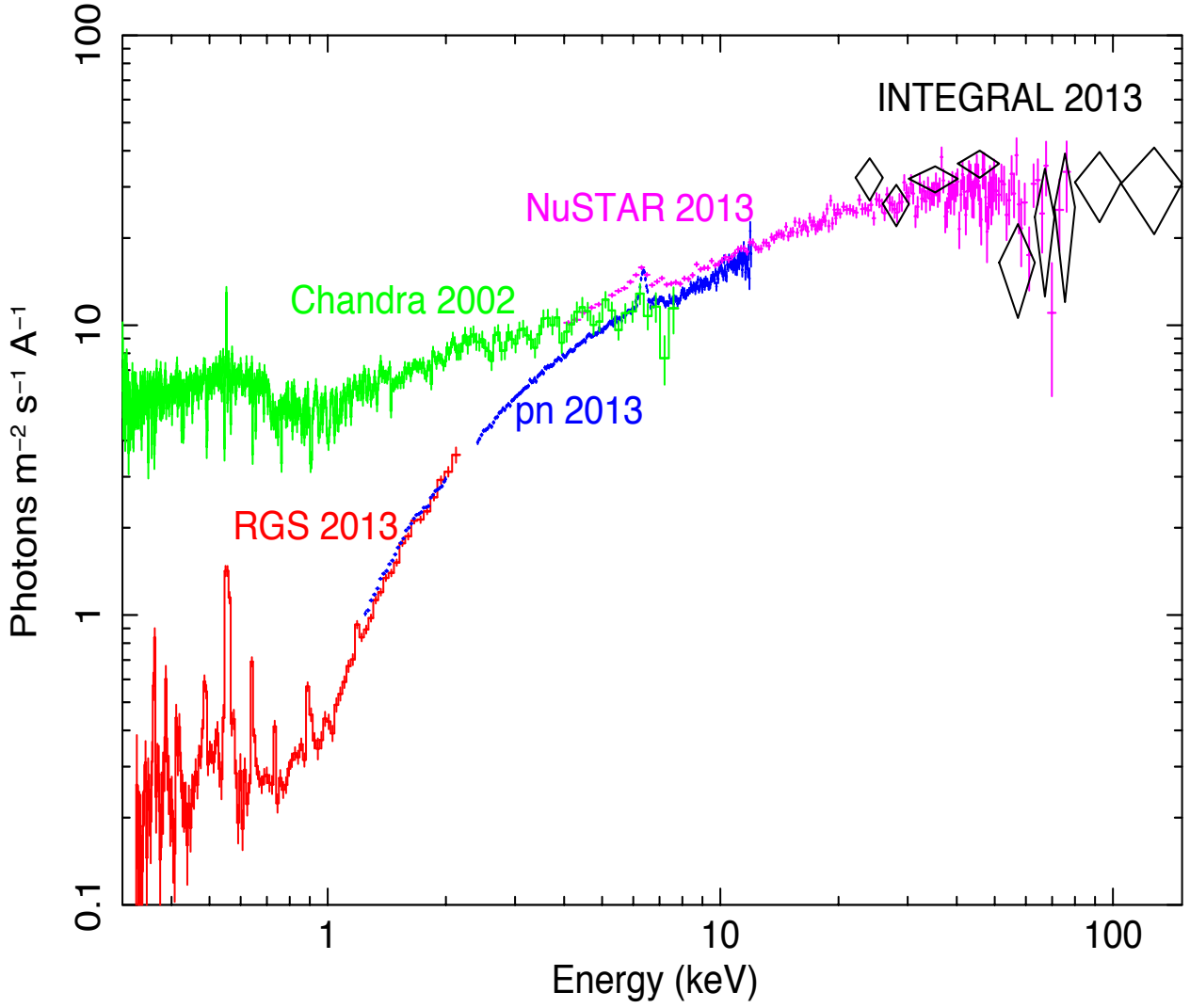
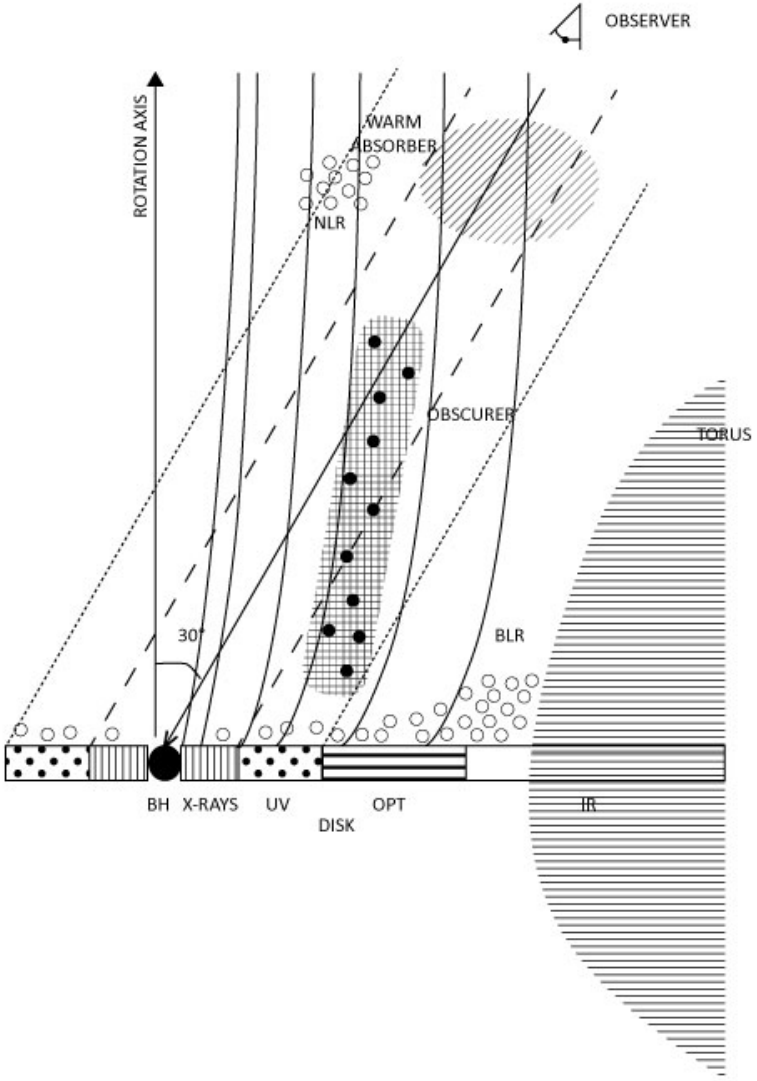


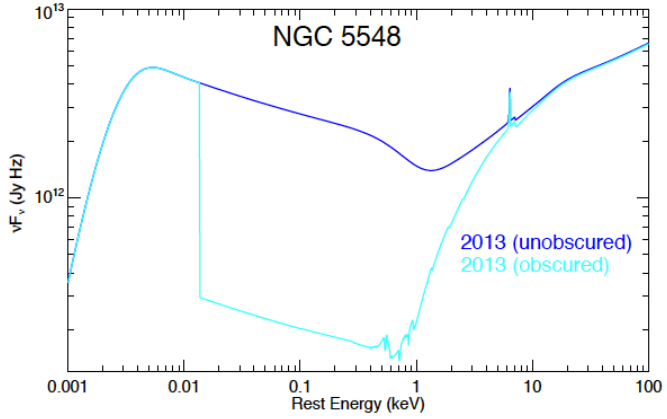
Strong absorption but normal high-E flux

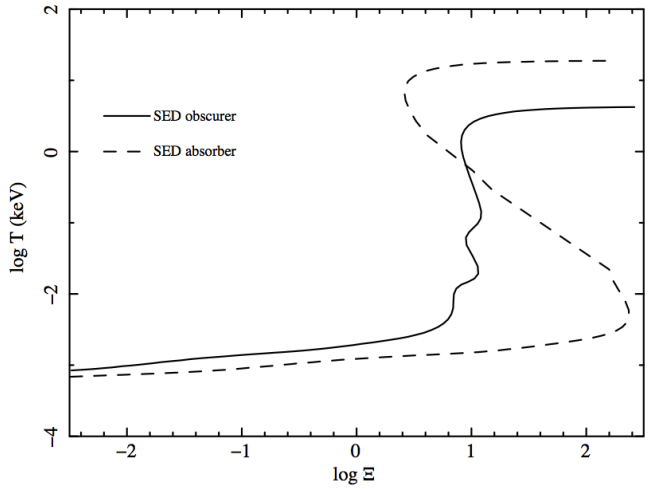


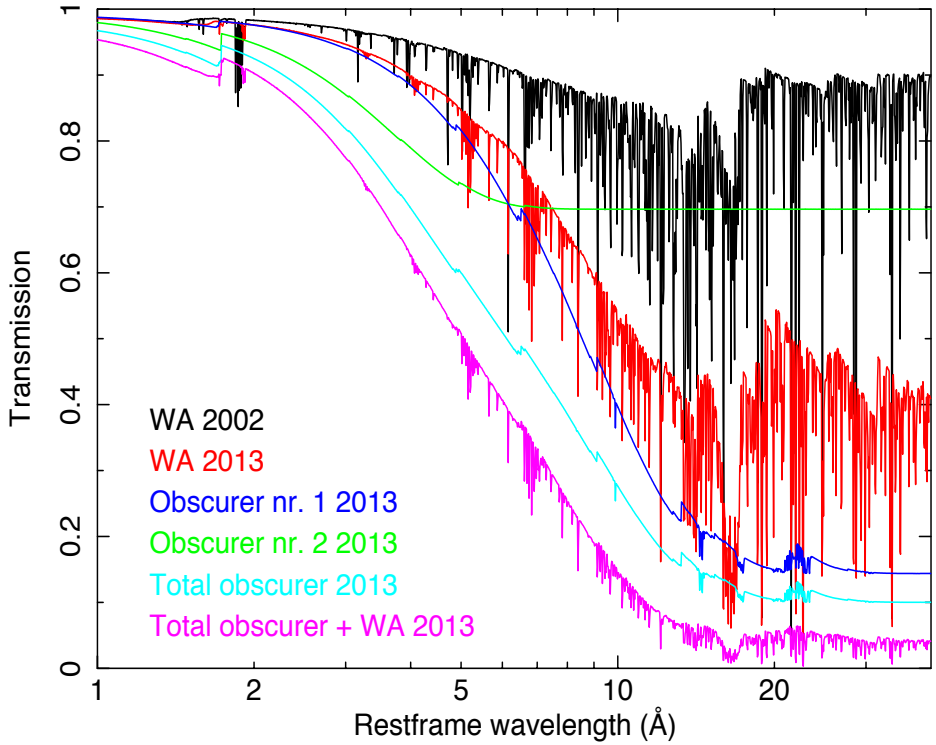
What is going on?



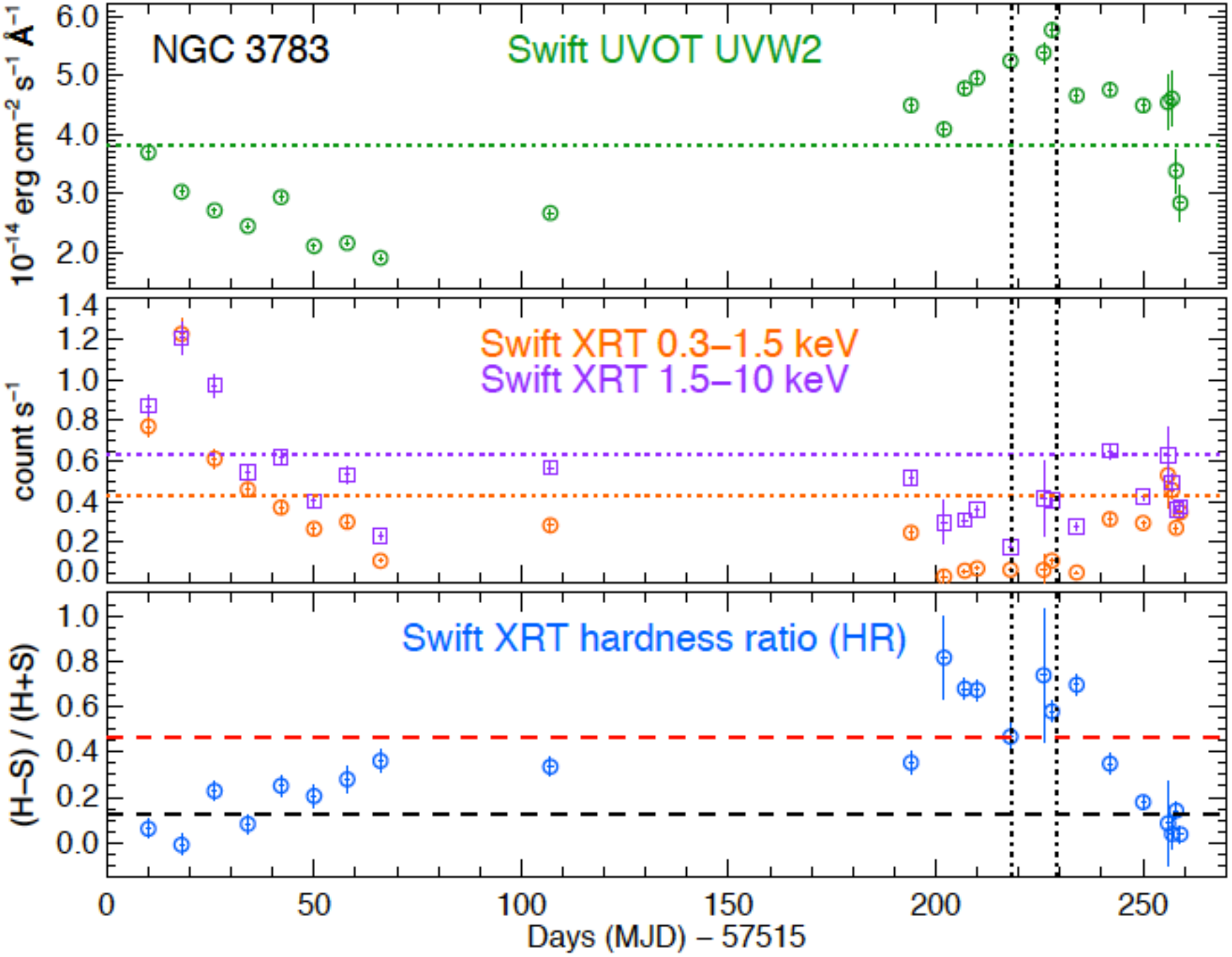
Obscured SED modeling

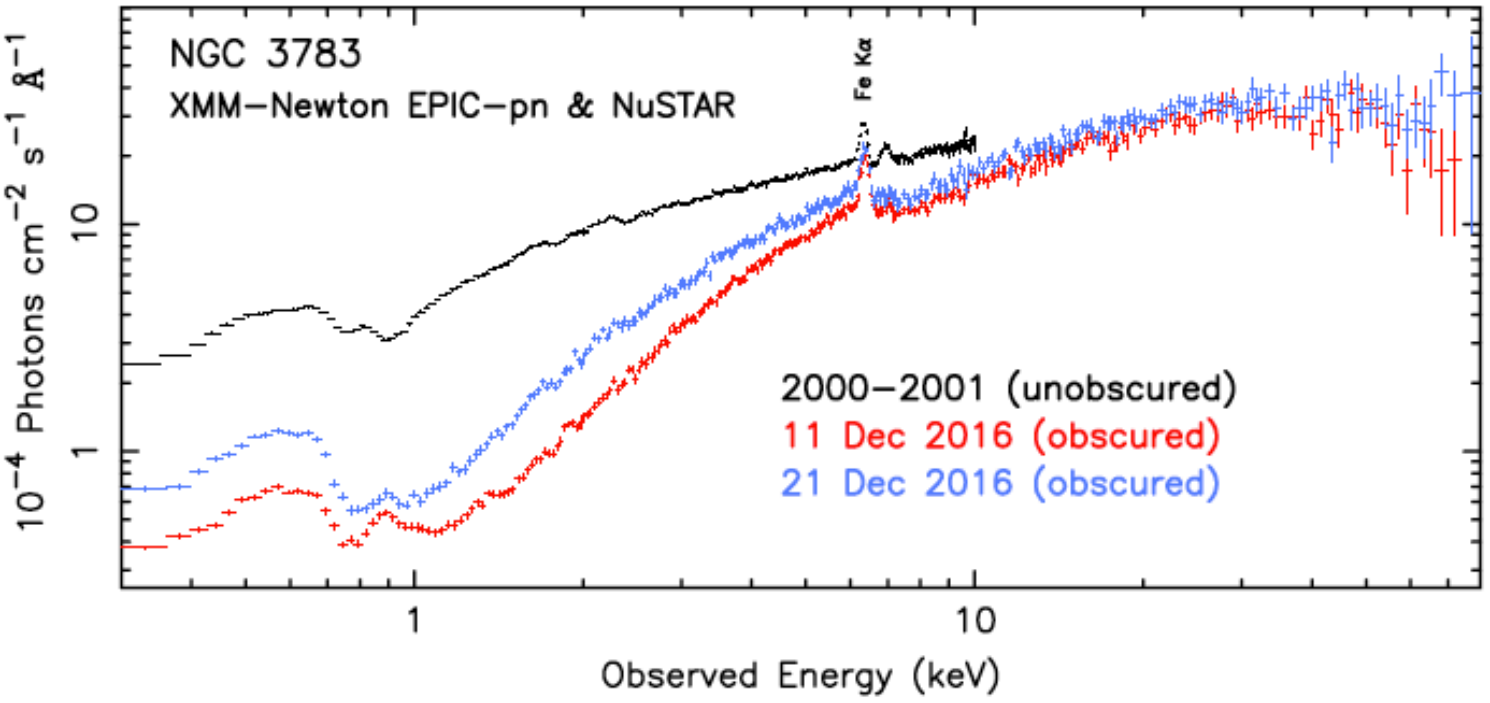


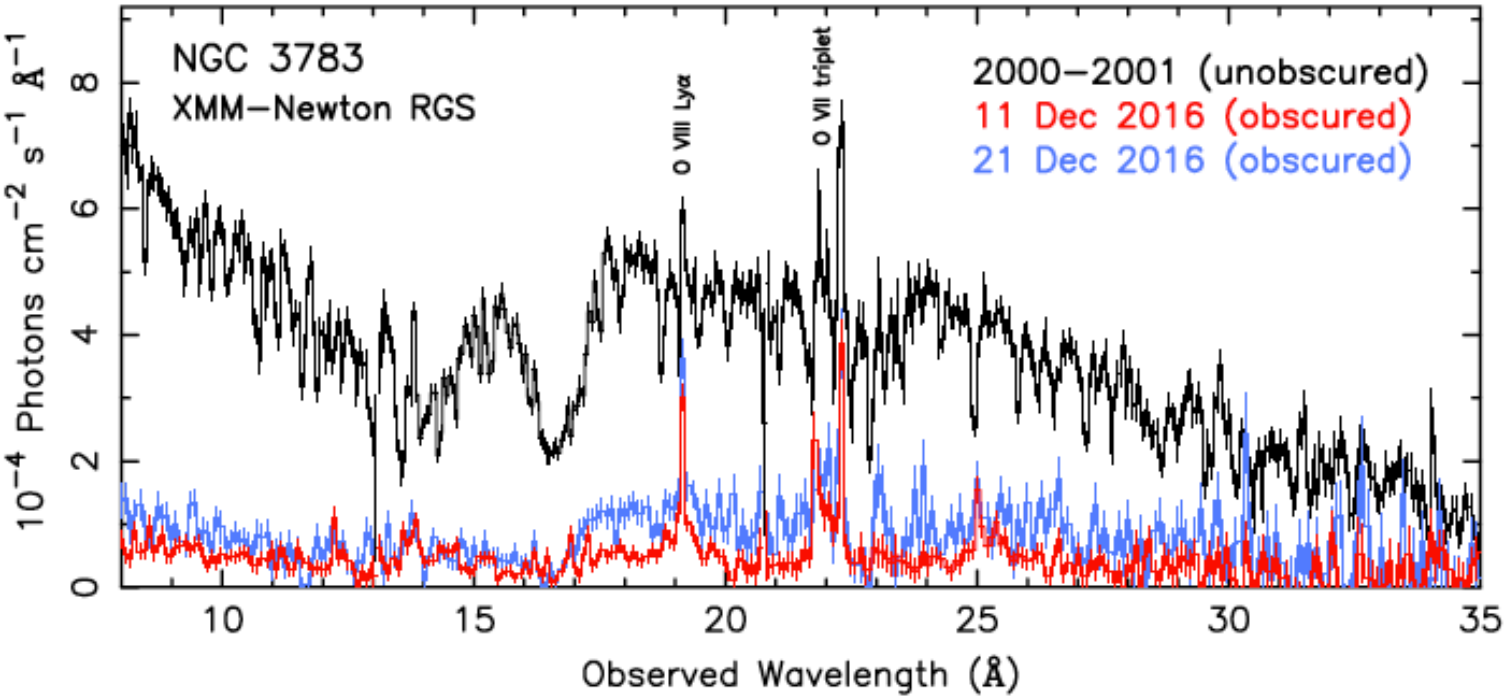


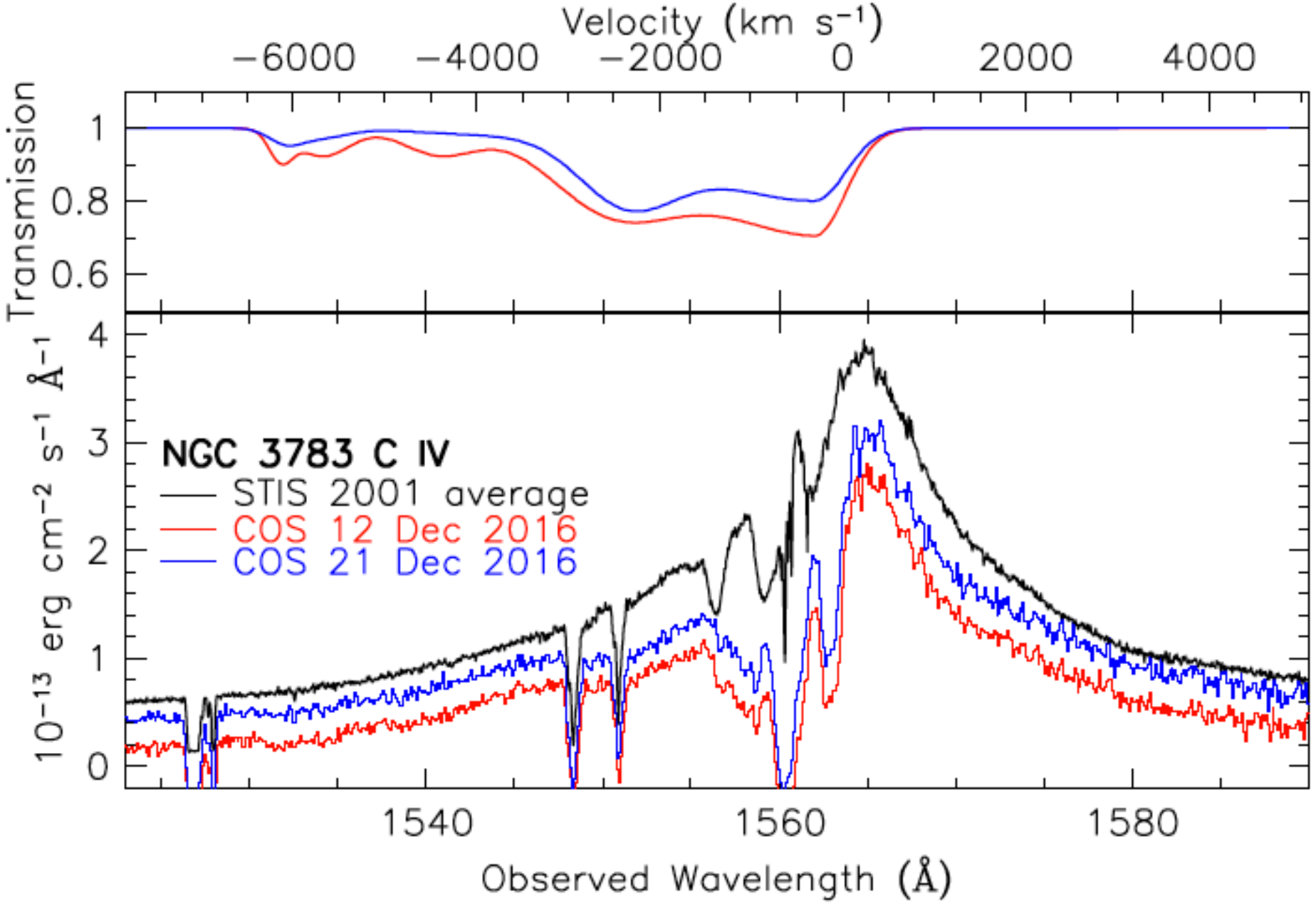


NGC 3783

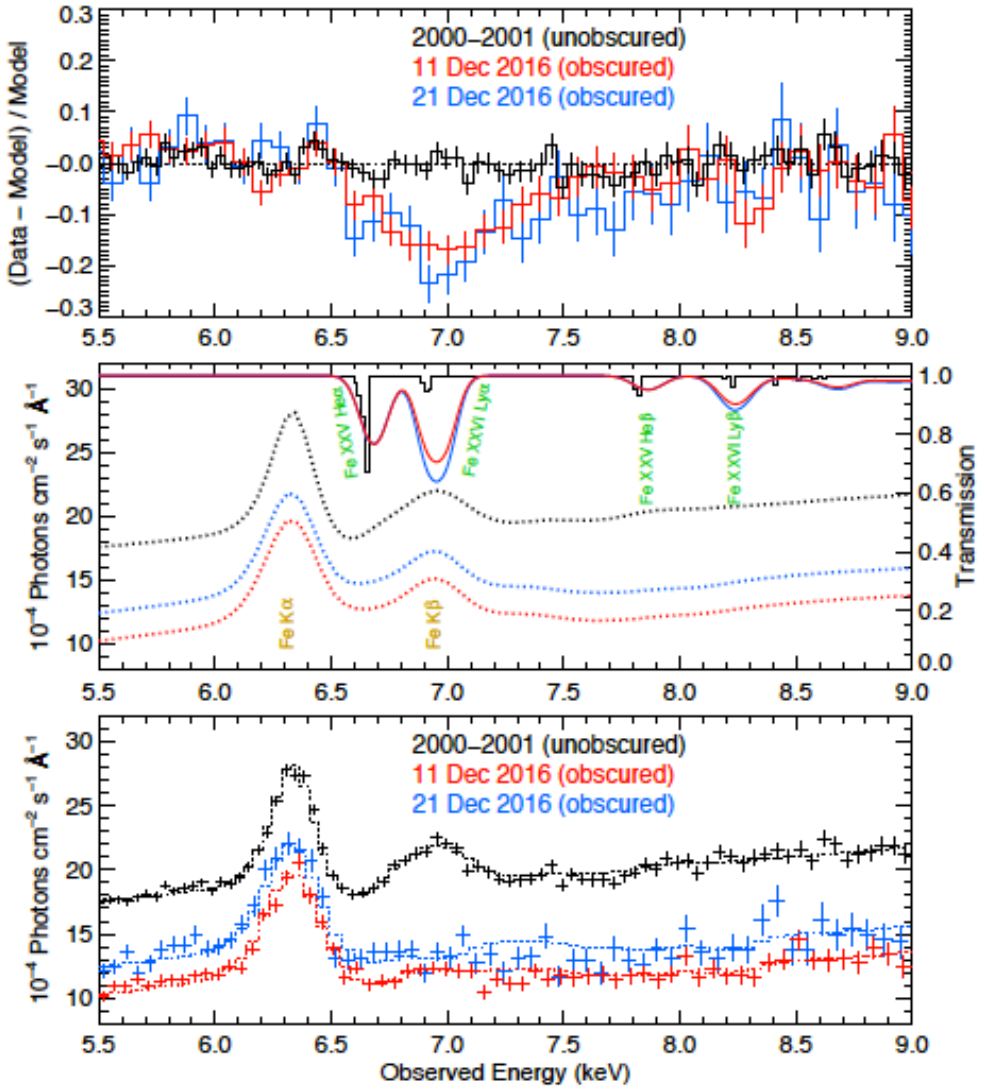

NGC 3783
Swift UVOT UVW2
10^{-14} erg cm^{-2} s^{-1} Å^{-1}
Swift XRT 0.3–1.5 keV
Swift XRT 1.5–10 keV
count s^{-1}
Swift XRT hardness ratio (HR)
(H–S) / (H+S)
Days (MJD) – 57515


NGC 3783
XMM−Newton EPIC−pn & NuSTAR
Fe Kα
2000−2001 (unobscured)
11 Dec 2016 (obscured)
21 Dec 2016 (obscured)
10^−4 Photons cm^−2 s^−1 Å^−1
Observed Energy (keV)


NGC 3783
XMM−Newton RGS
O VIII Lyα
O VII triplet
2000−2001 (unobscured)
11 Dec 2016 (obscured)
21 Dec 2016 (obscured)
10^−4 Photons cm^−2 s^−1 Å^−1
Observed Wavelength (Å)

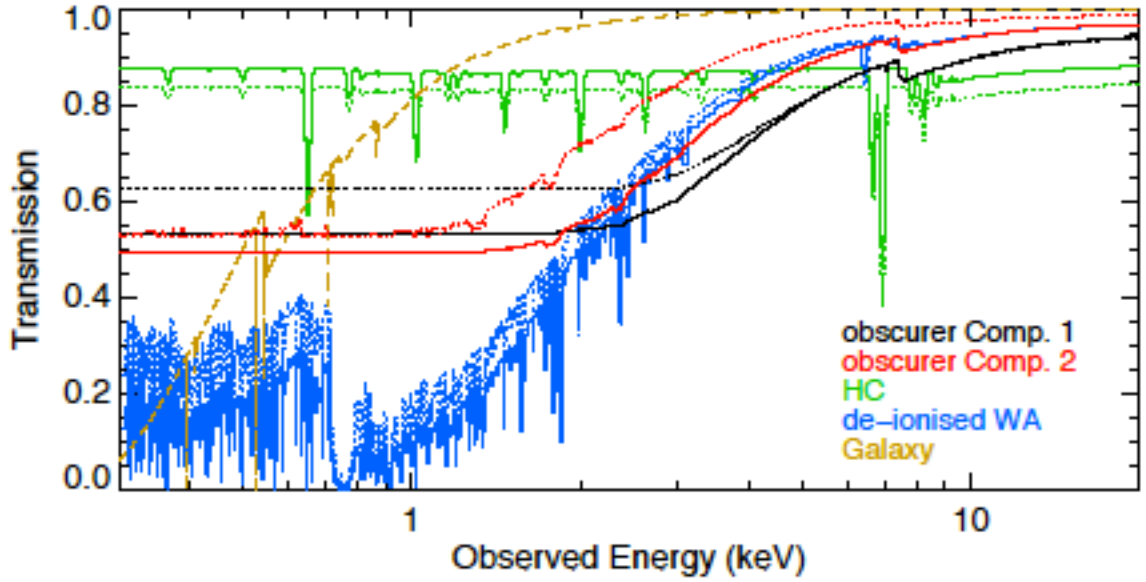

Velocity (km s⁻¹)
−6000
−4000
−2000
0
2000
4000
Transmission
1
0.8
0.6
NGC 3783 C IV
STIS 2001 average
COS 12 Dec 2016
COS 21 Dec 2016
10⁻¹³ erg cm⁻² s⁻¹ Å⁻¹
4
3
2
1
0
1540
1560
1580
Observed Wavelength (Å)

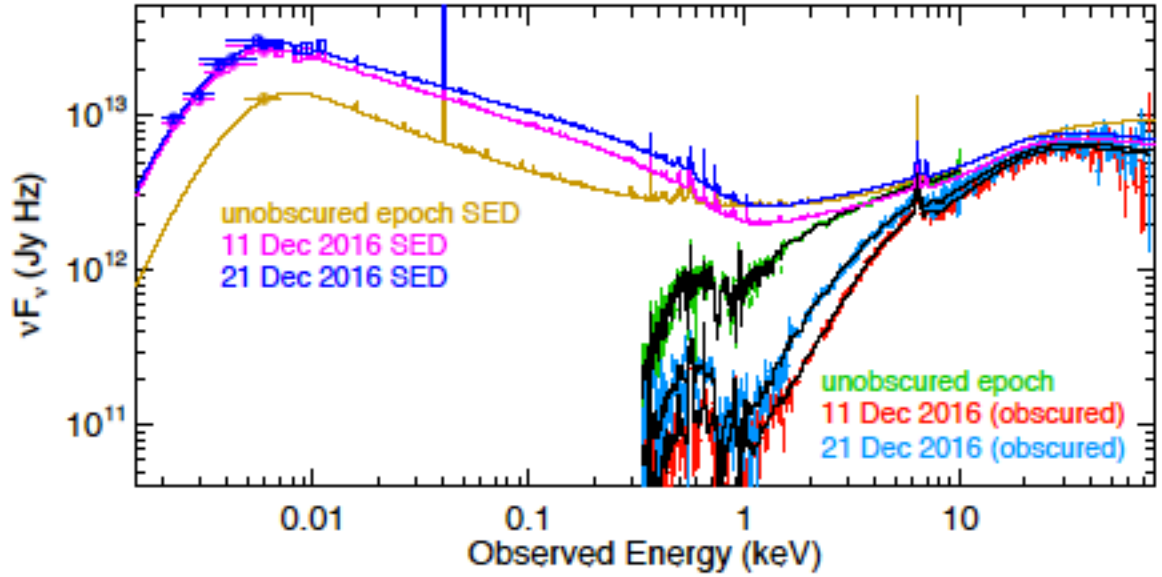
New high-ionisation component



Complex modeling

- Need model with *48 components*
- Includes 16 *pion* components, all stacked and influencing each other
  - 2 for the emission lines
  - 11 for the WA (different v, ξ)
  - 3 for the obscurer
- 19 free parameters (L/ξ is fixed)
- Fit: optical to hard X-ray spectrum
- *80 s* calculation time per full model allows interactive fitting
- Details: see paper: Mehdipour et al. 2017


Transmission
1.0
0.8
0.6
0.4
0.2
0.0
1
10
Observed Energy (keV)
obscurer Comp. 1
obscurer Comp. 2
HC
de–ionised WA
Galaxy


νF_ν (Jy Hz)
10^{13}
10^{12}
10^{11}
0.01
0.1
1
10
Observed Energy (keV)
unobscured epoch SED
11 Dec 2016 SED
21 Dec 2016 SED
unobscured epoch
11 Dec 2016 (obscured)
21 Dec 2016 (obscured)

Comparison between sources

Comparison of sources

	NGC 5548	NGC 985	Mrk 335	NGC 3783
Components	2	1	?	3
N_H (10^{26} m^{-2})	1 & 10	2	?	20 & 5 & 2
log ξ	-1 & <-2	-1	?	-1.8 & -1.8 & 3.7
F_{cov} (X-ray)	0.86 & 0.30	0.92	?	0.4 & 0.5 & 1
UV Center (km/s)	-1000 (up to -6000)	-6000	-6500	-1900 & -1900 & -2300
UV FWHM	3000	1400	750	2500 & 2500 & 6000
UV depth	40%	25%	15%	30 %
Duration	> 6 years continuous	> 18 month??	Frequently, month?	1 month

Questions

- what is the difference between obscuration and an eclipse?
- What are the timescales for obscuration: weeks, years, centuries?
- where is the obscuring stream originally born and how?
- is there a connection between certain accretion disk behavior and the obscuration?
- What fraction of the AGN continuum is covered by the obscuration?

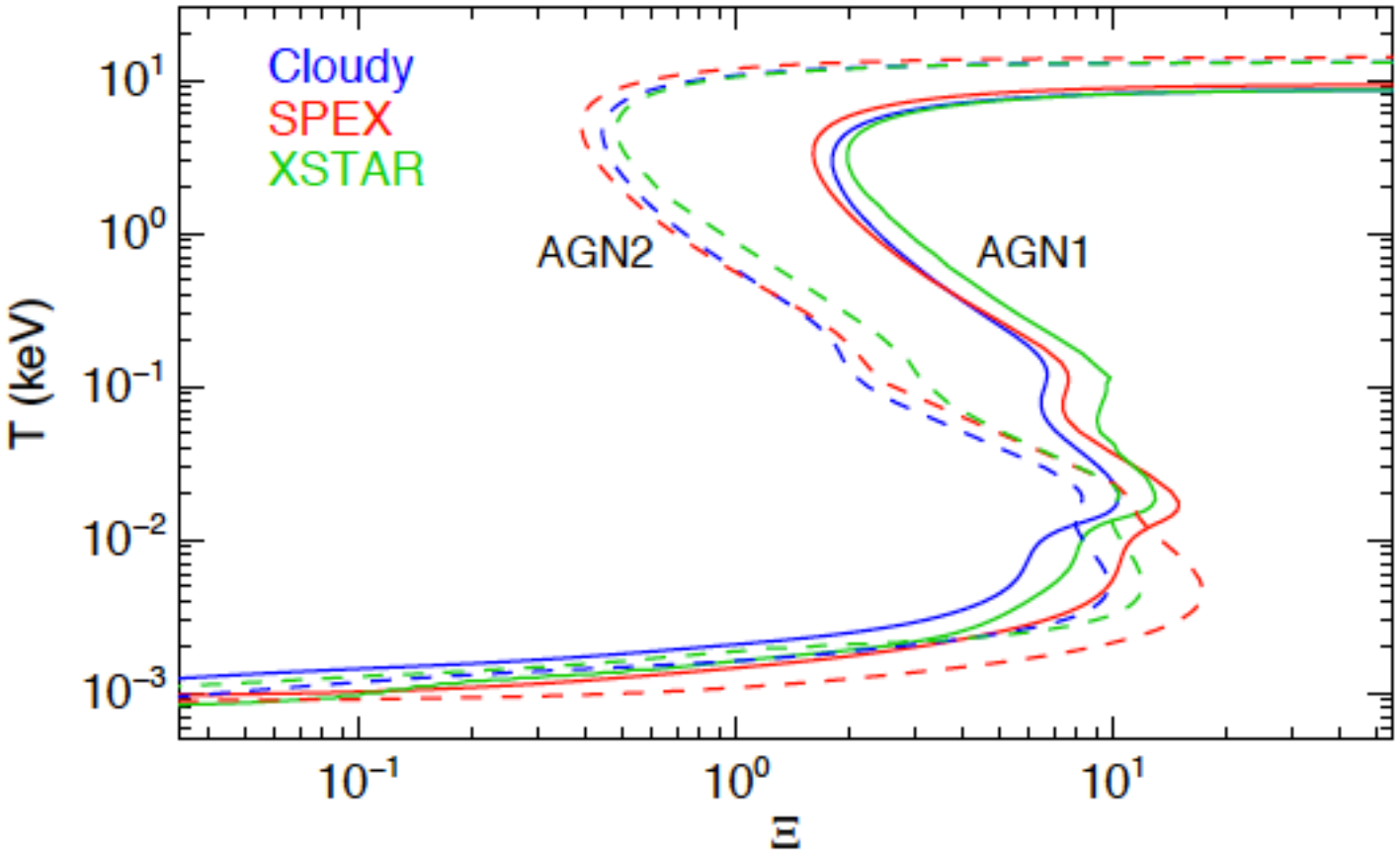
Spectral modeling

Advantage pion model
(within SPEX package, www.sron.nl/spex)

- No need to pre-calculate grids of models
- Can use fitting on the fly, including ionizing SED
- Reasonably fast (best fit of very complex model obtained in a few hours)

Differences between codes

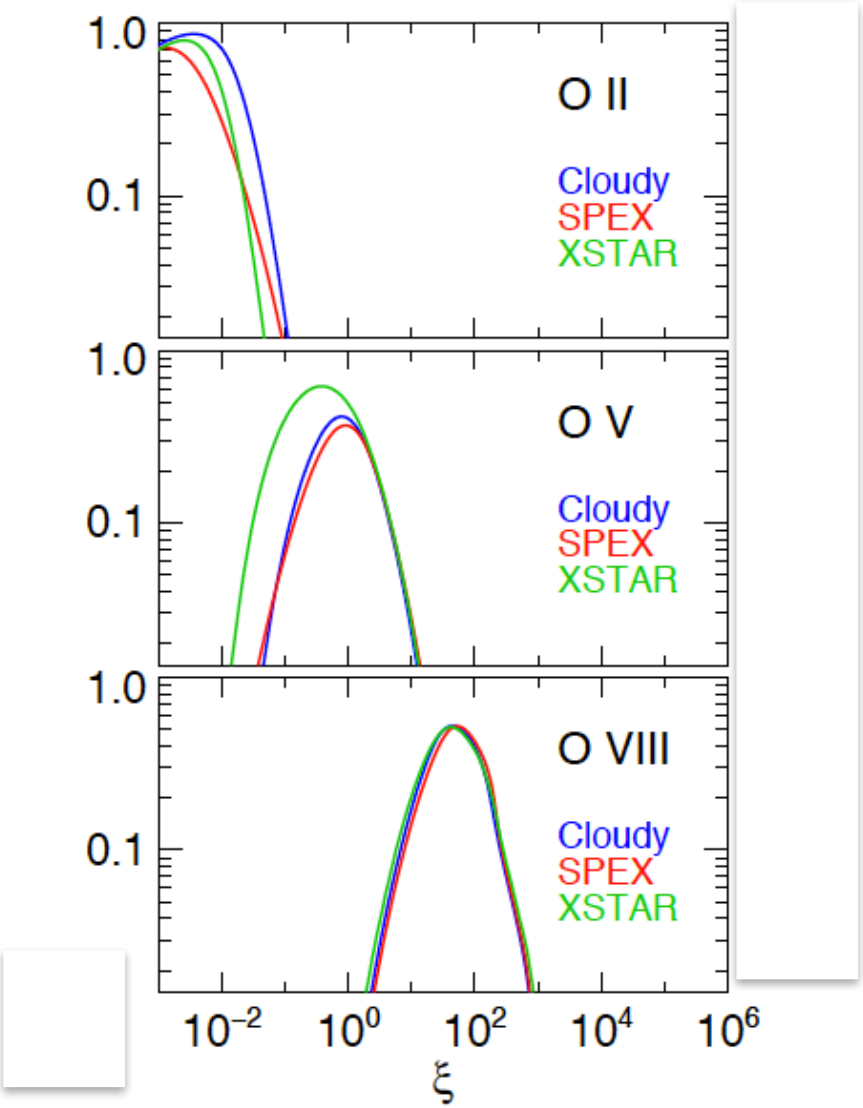
(Mehdipour et al. 2016)



(Radiation pressure / gas pressure)

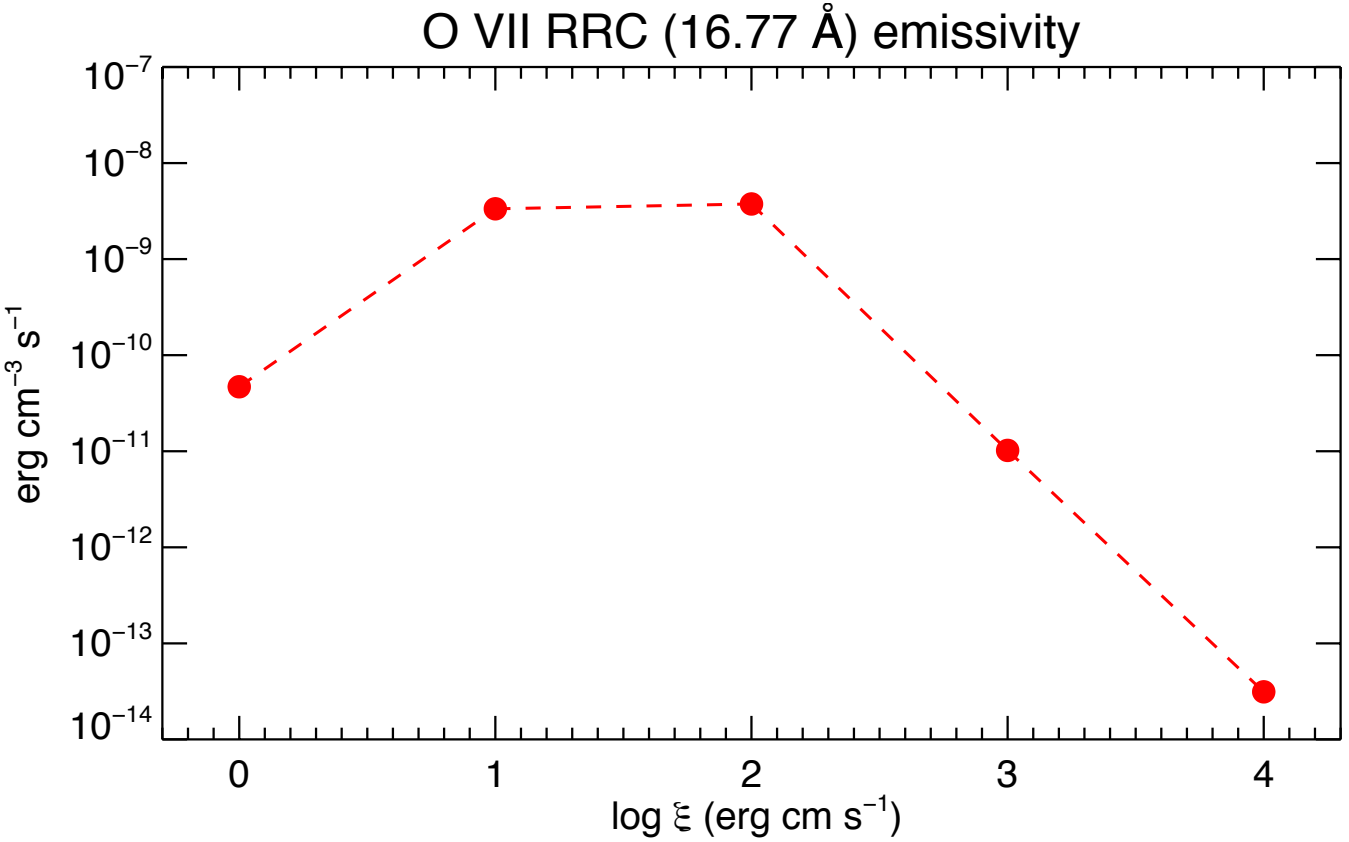
Comparison ion concentrations:

effects of different dielectronic recombination rates?



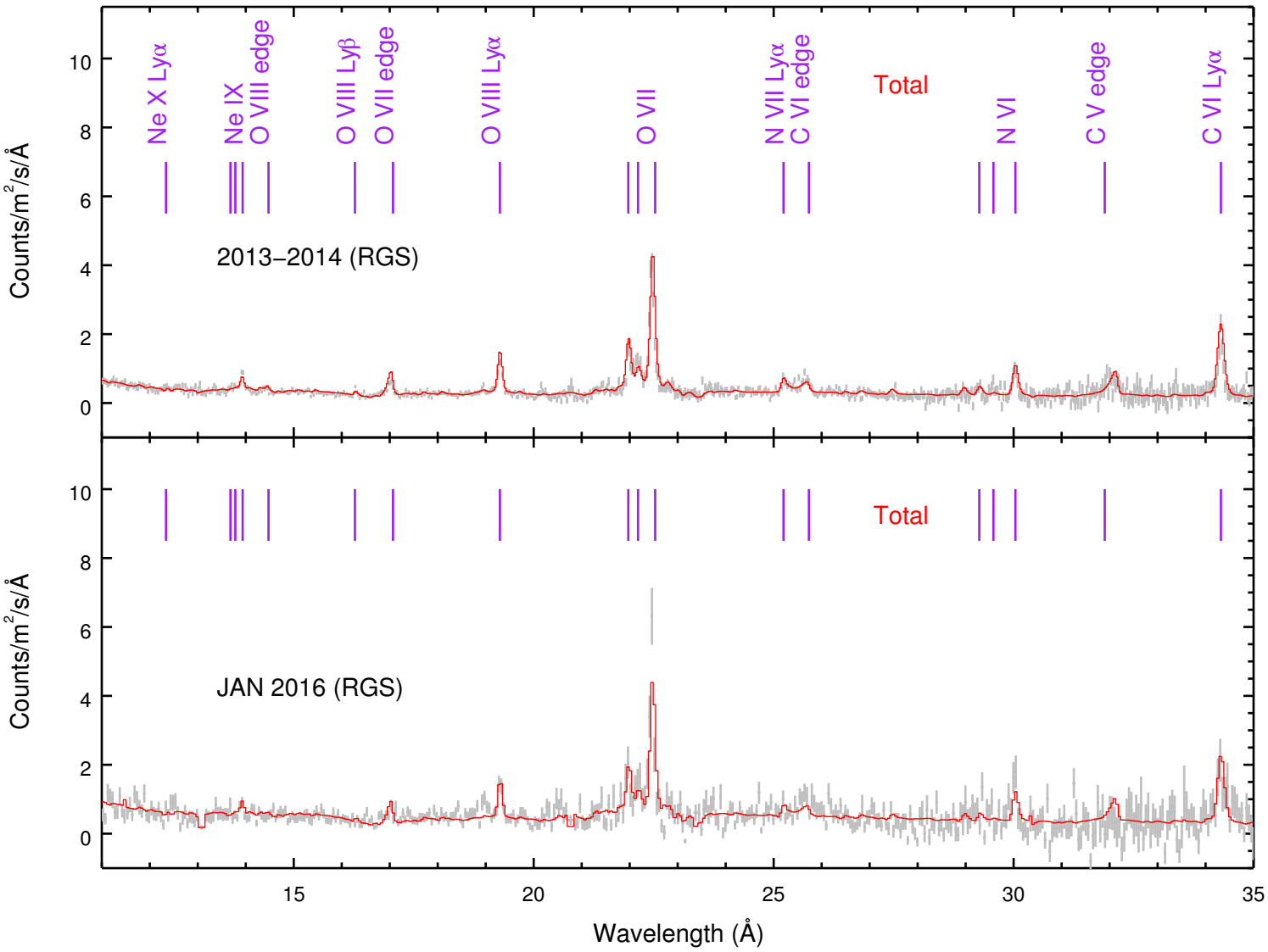
Example RRCs: Cloudy calculation

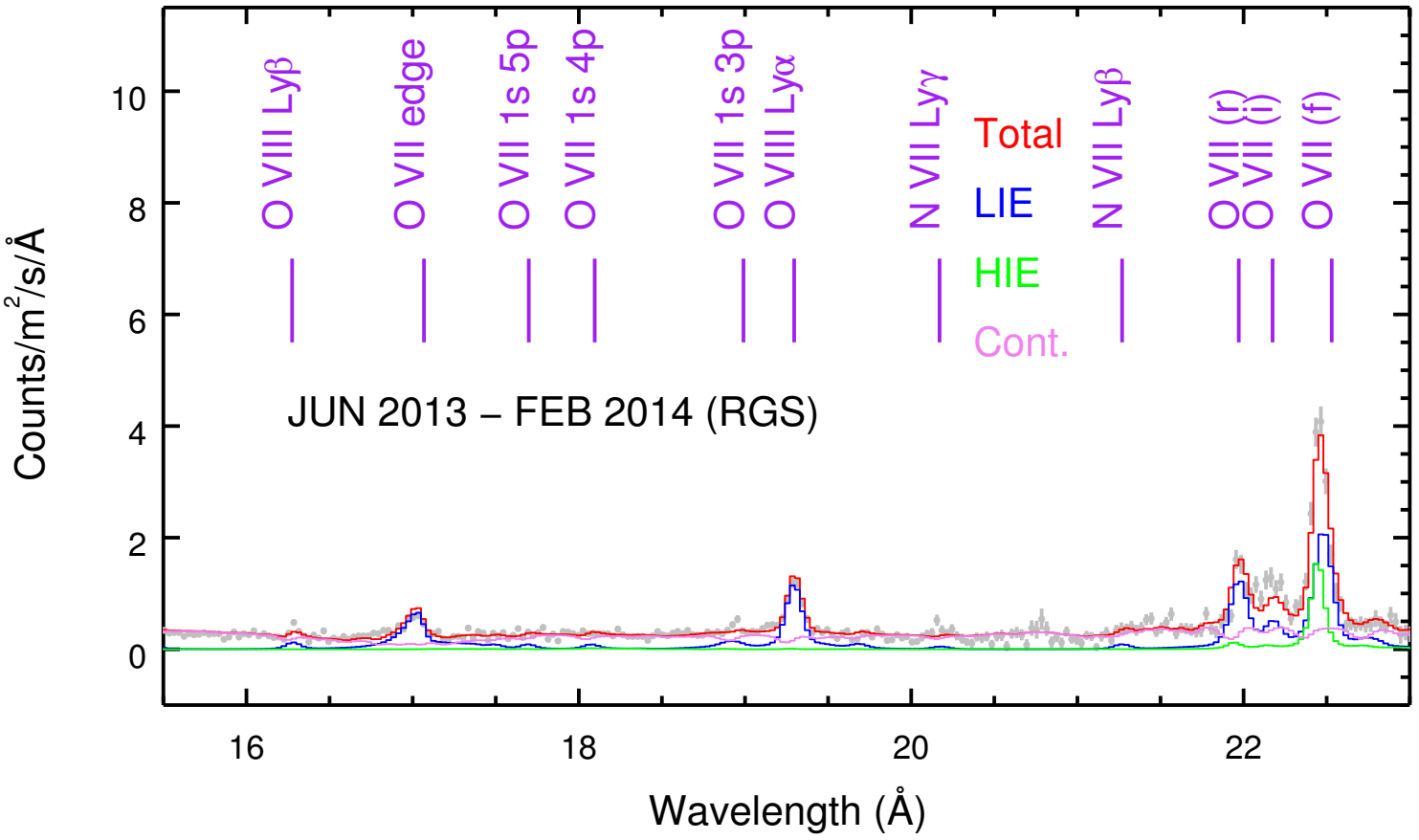
why not monotonic decrease?



Physical model NGC 5548
Junjie Mao

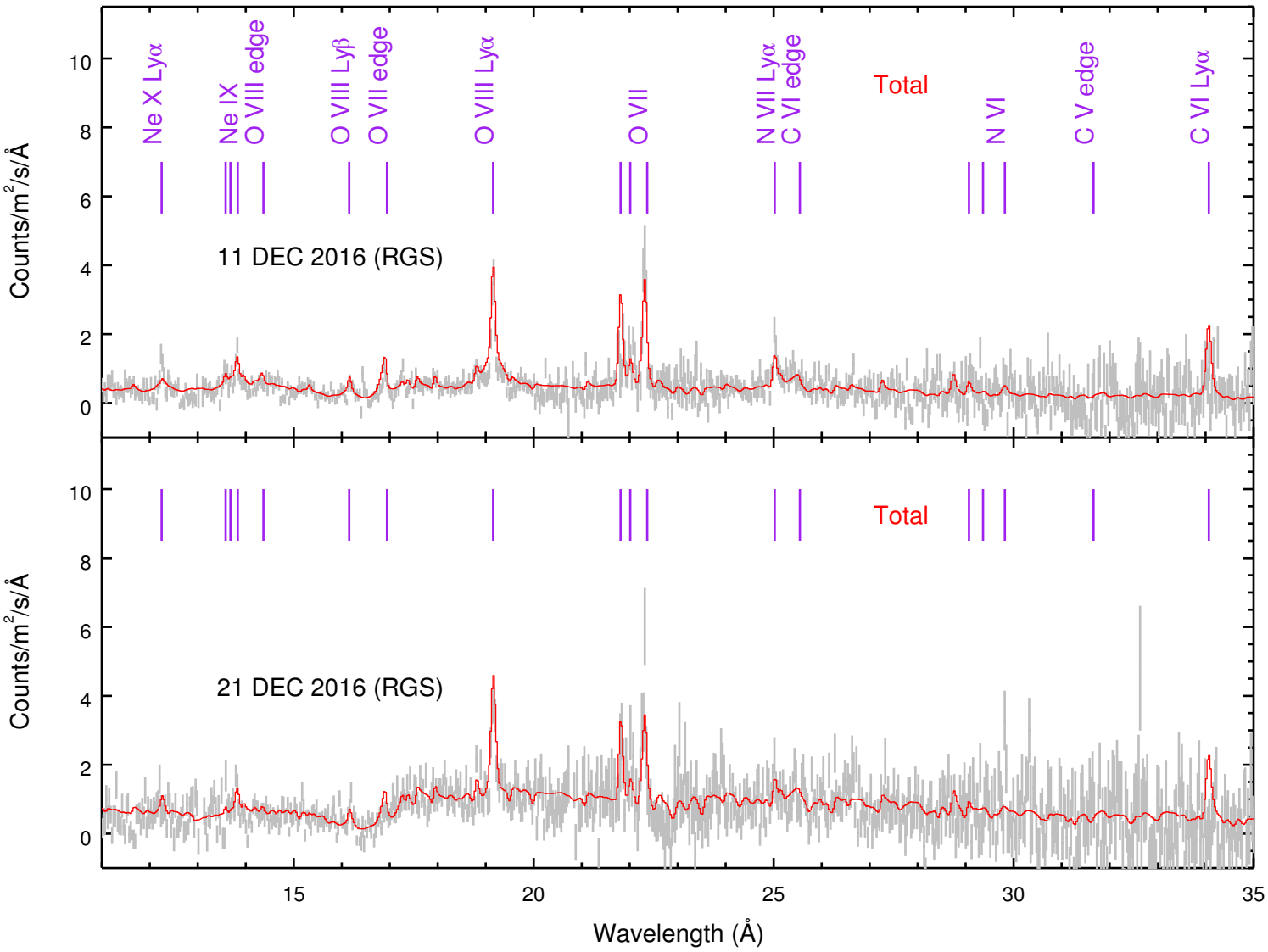
- Full modeling RGS+pn spectra
- Continuum COMT+PL+REFL (cf. Mehdipour+2015)
- Obscurer: 2 x xabs model (Kaastra+2014)
- Outflow: 6 x PION (de-ionized) (Mao+2017)
- Emitter: 2 x PION

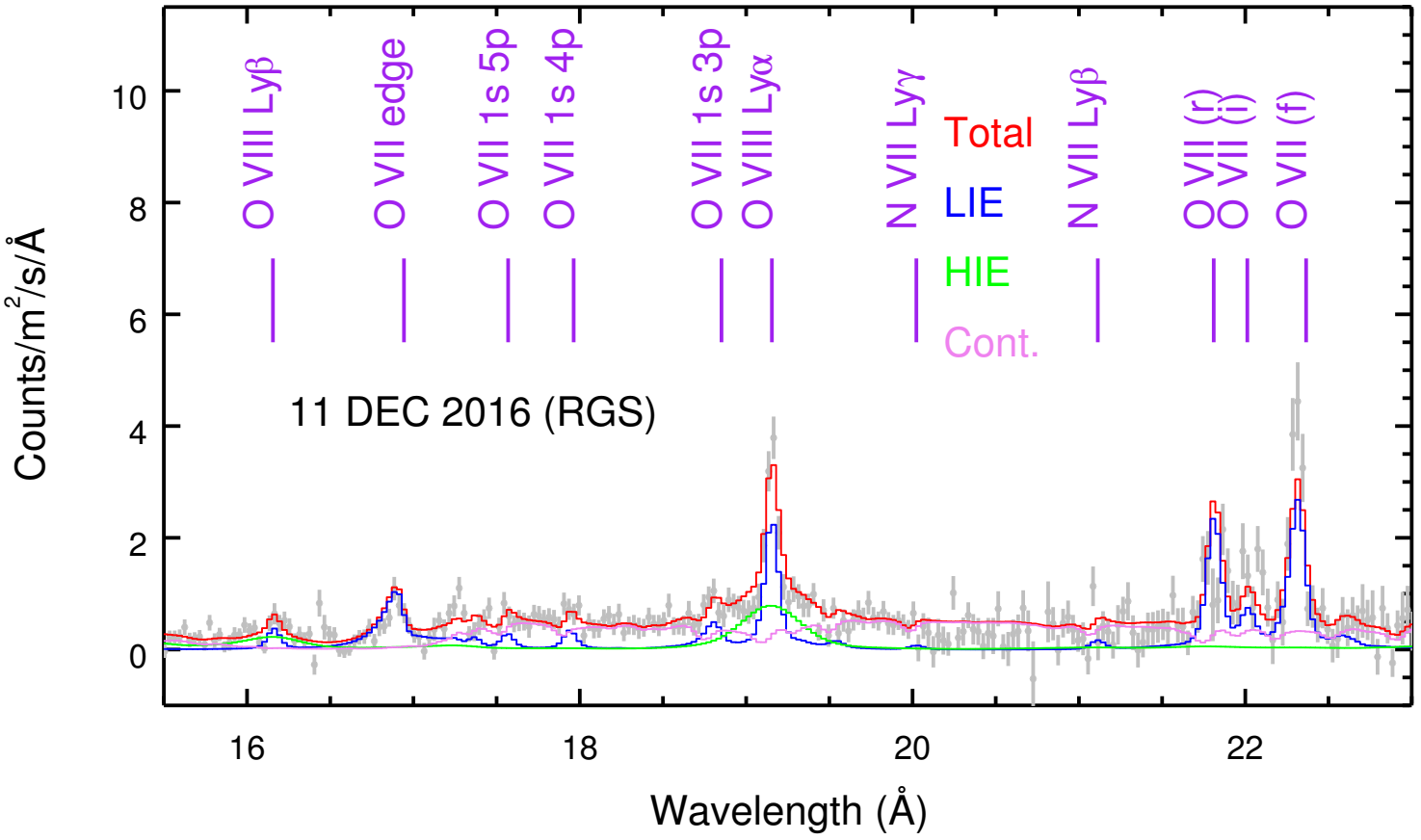

Ne X Lyα
Ne IX
O VIII edge
O VIII Lyβ
O VII edge
O VIII Lyα
O VII
N VII Lyα
C VI edge
Total
N VI
C V edge
C VI Lyα
2013–2014 (RGS)
Total
JAN 2016 (RGS)
Counts/m²/s/Å
Wavelength (Å)
0
2
4
6
8
10
15
20
25
30
35


O VIII Lyβ
O VII edge
O VII 1s 5p
O VII 1s 4p
O VII 1s 3p
O VIII Lyα
N VII Lyγ
N VII Lyβ
O VII (r)
O VII (i)
O VII (f)
Total
LIE
HIE
Cont.
JUN 2013 – FEB 2014 (RGS)
Counts/m²/s/Å
Wavelength (Å)
0
2
4
6
8
10
16
18
20
22

X-ray NLR in NGC 5548 (Junjie Mao)

Parameter/Component	1	2
N_H (10^{26} m^{-2}, 10^{22} cm^{-2})	1.03	0.32
Log ξ	1.18	0
σ_v (km/s)	485	250
Outflow (km/s)	0	-460
$\Omega/4\pi$	0.029	0.006


Ne X Lyα
Ne IX
O VIII edge
O VIII Lyβ
O VII edge
O VIII Lyα
O VII
N VII Lyα
C VI edge
Total
N VI
C V edge
C VI Lyα
11 DEC 2016 (RGS)
21 DEC 2016 (RGS)
Total
Counts/m²/s/Å
Counts/m²/s/Å
0
2
4
6
8
10
15
20
25
30
35
Wavelength (Å)


O VIII Lyβ
O VII edge
O VII 1s 5p
O VII 1s 4p
O VII 1s 3p
O VIII Lyα
N VII Lyγ
N VII Lyβ
O VII (r)
O VII (i)
O VII (f)
Total
LIE
HIE
Cont.
11 DEC 2016 (RGS)
Counts/m^2/s/Å
Wavelength (Å)
0
2
4
6
8
10
16
18
20
22

X-ray NLR in NGC 3783 (Junjie Mao)

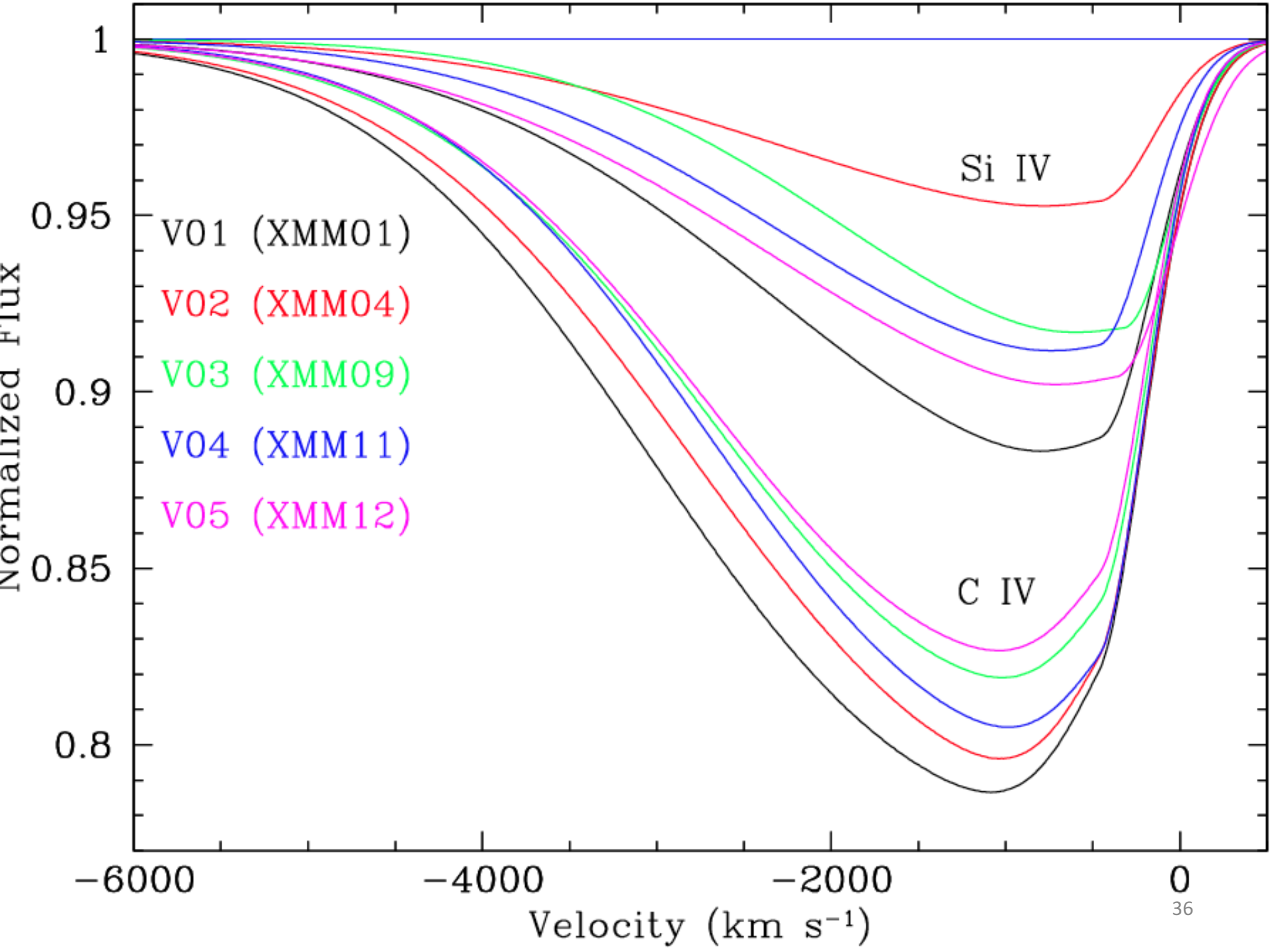
Parameter/Component	1	2
N_H (10^{26} m^{-2}, 10^{22} cm^{-2})	17.3	0.45
Log ξ	2.55	1.31
σ_v (km/s)	2510	350
Outflow (km/s)	0	0
$\Omega/4\pi$	0.005	0.05

What is the obscurer and where is it?

- UV BLR covered by 20-40% → R 2-7 lightdays from core (~10^{14} m)
- WA de-ionized → R< 3 pc (10^{17} m)
- F_{cov} high → likely close to BLR
- High velocity up to 5000 km/s → close to BLR
- Variations in obscuration @ 2 days: for size ~$20GM/c^2$ and M=$4x10^7$ M_{sun}, needed crossing velocity ~3000 km/s → comparable to v_{rad}
- Line of sight inclined by about 30 degrees (Pancoast et al. 2014) → predominantly poloidal outflow (from accretion disk?)

Obscuring stream

- *Two components:*
- Main: log ξ = -1.2, $N_H=10^{26}$ m^{-2}, f_{cov}=0.86 (X-ray) and ~0.3 in UV; produces UV BAL
- Second: almost neutral, $N_H=10^{27}$ m^{-2}, f_{cov}=0.3 (X-ray) and <0.1 in UV
- Partial covering inner BLR, v up to 5000 km/s, inside WA ➔ distance few light days (~10^{14} m, 0.003 pc)
- Obscuration already 3 years ongoing


1
0.95
0.9
0.85
0.8
Normalized Flux
V01 (XMM01)
V02 (XMM04)
V03 (XMM09)
V04 (XMM11)
V05 (XMM12)
Si IV
C IV
−6000
−4000
−2000
0
Velocity (km s⁻¹)