Image credit: ESO

Self-consistent photoionized plasma modelling of NGC 3783 in X-rays

Junjie Mao

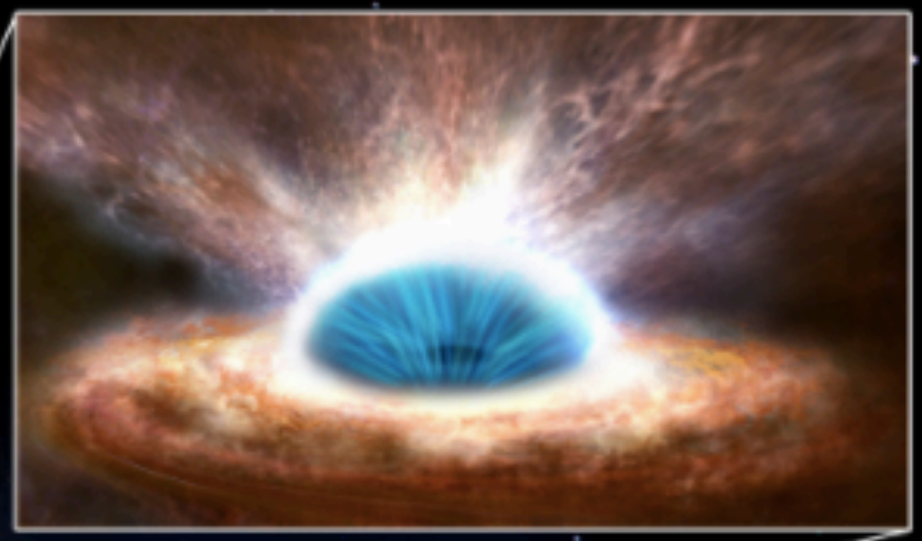
J. Kaastra, M. Mehdipour, G. Kriss and NGC 3783 team

SRON
Netherlands Institute for Space Research

Sterrewacht Leiden

JUNE 26, 2017 | AGN WINDS 2017

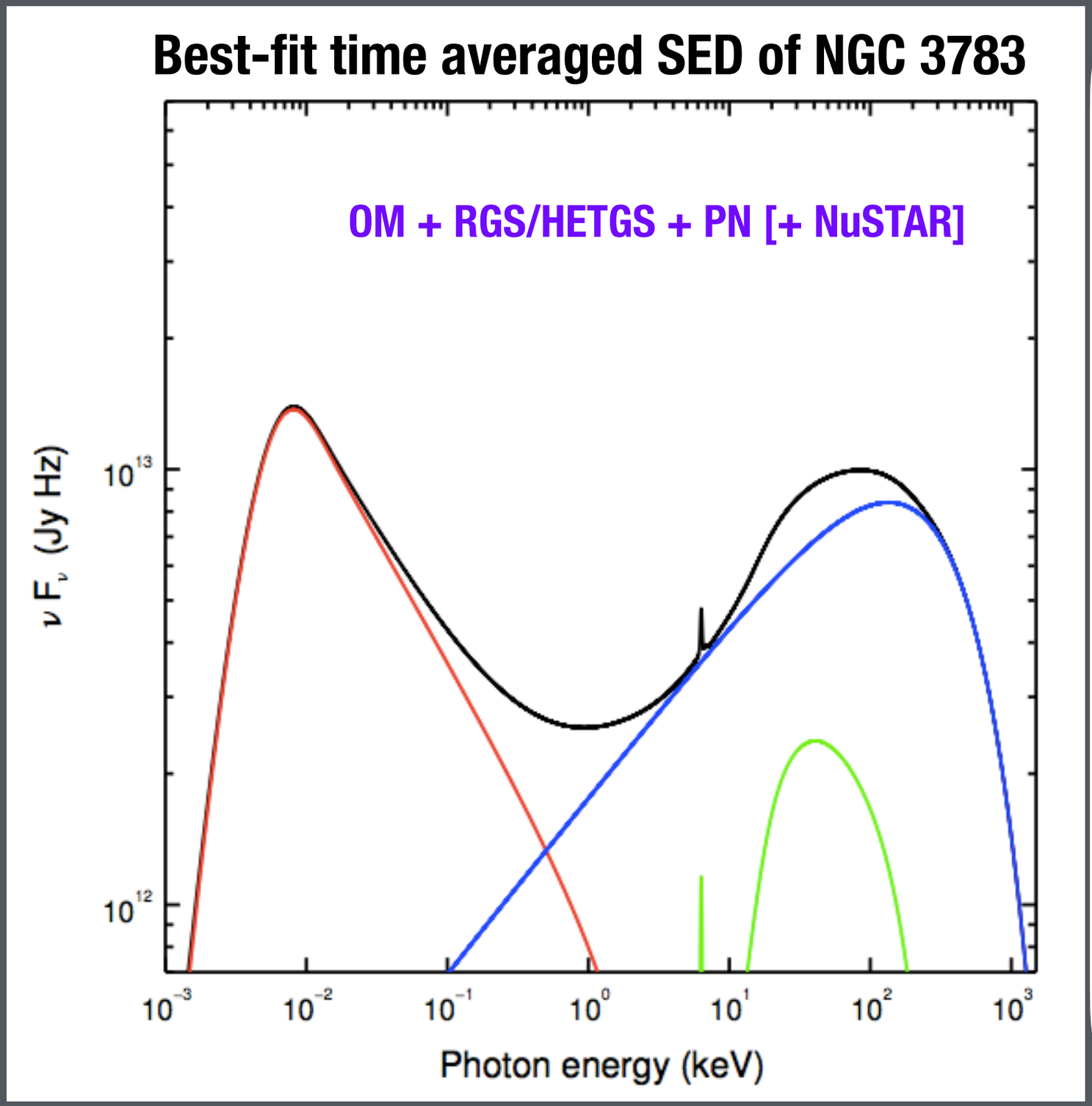
- SMBH-galaxy coevolution
- AGN feedback
- Ionized outflow



- High-resolution spectra
- Atomic database
- Plasma diagnostics

AGN outflow

SPEX

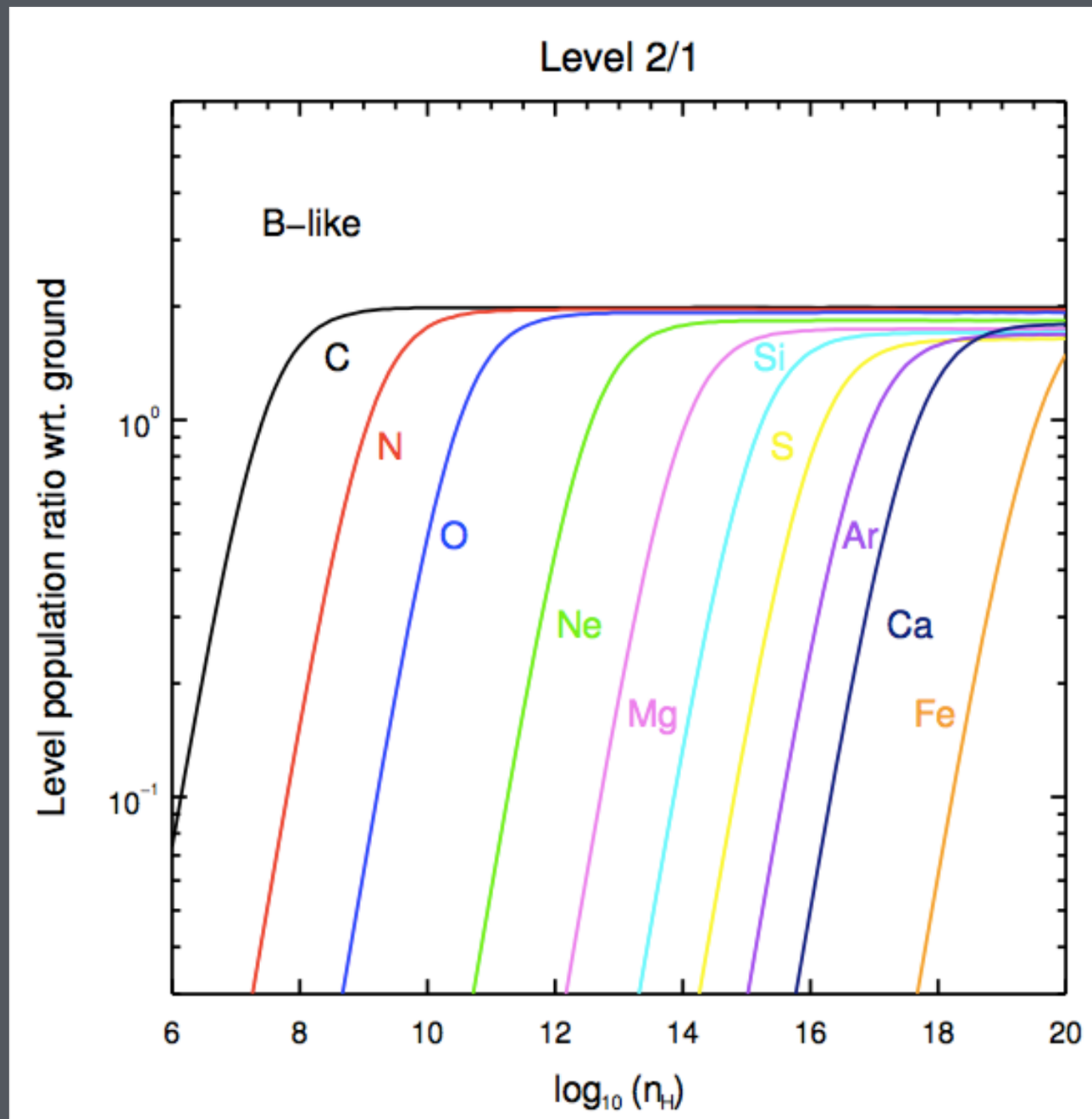


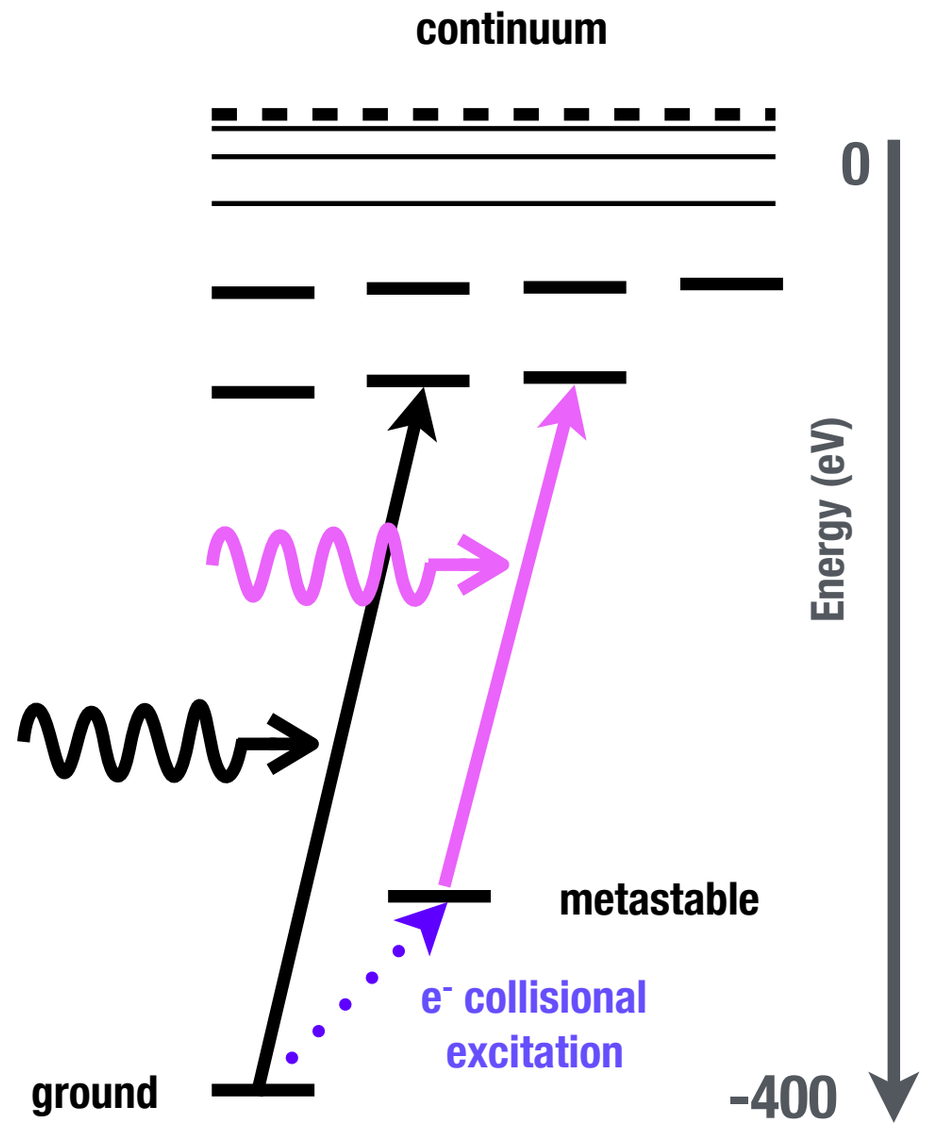
Self-consistent

On the fly (fast, accurate)

- **SED**
  - Opt. to hard X-ray
- **PhotoIONization (opt. thin)**
  - Thermal equilibrium
  - Ionisation balance
  - **Level population**
- **Absorption & emission**
  - Line
  - Edge

Level population



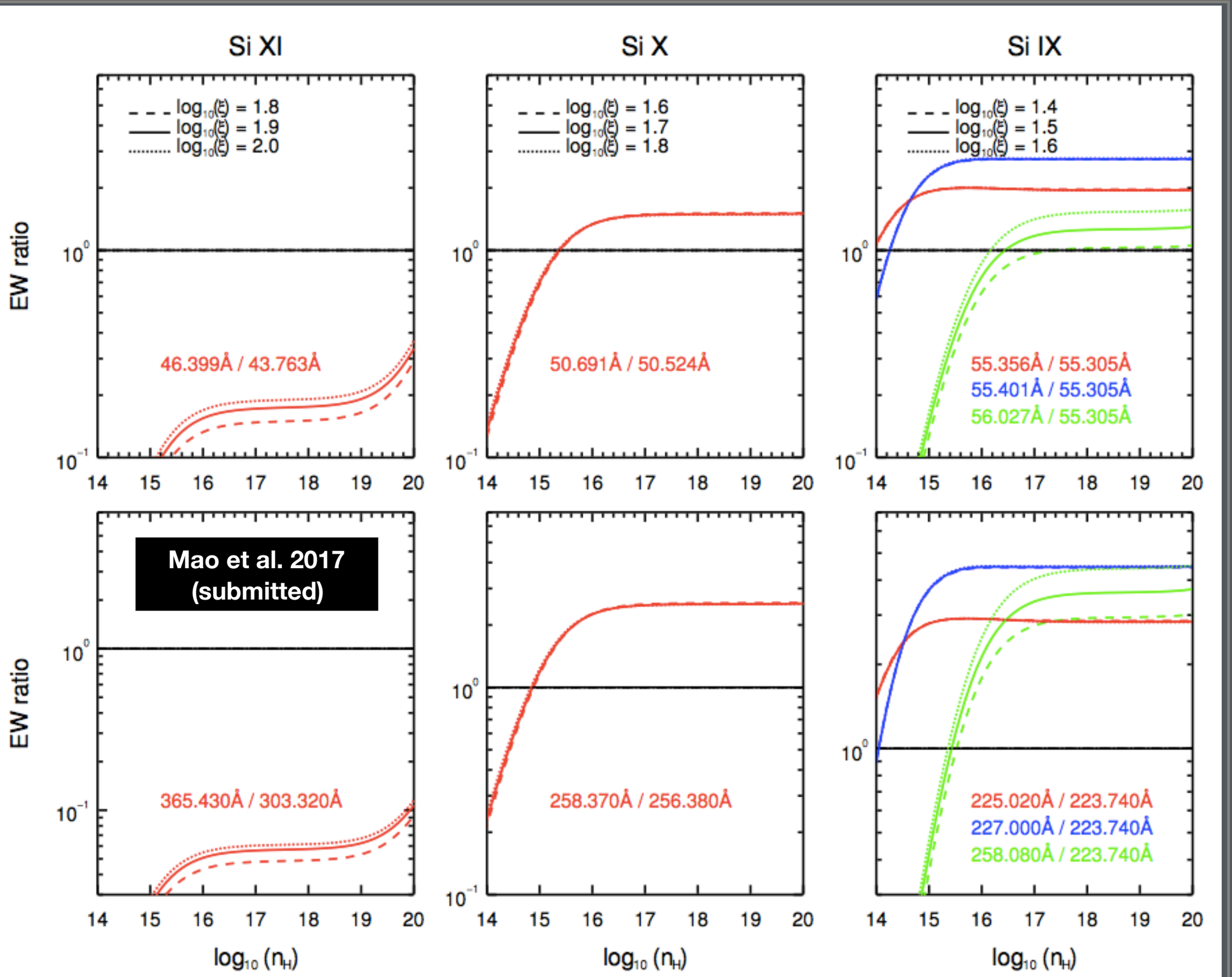


Metastable (Level 2) $2s^2 2p \quad {}^2P_{3/2}$

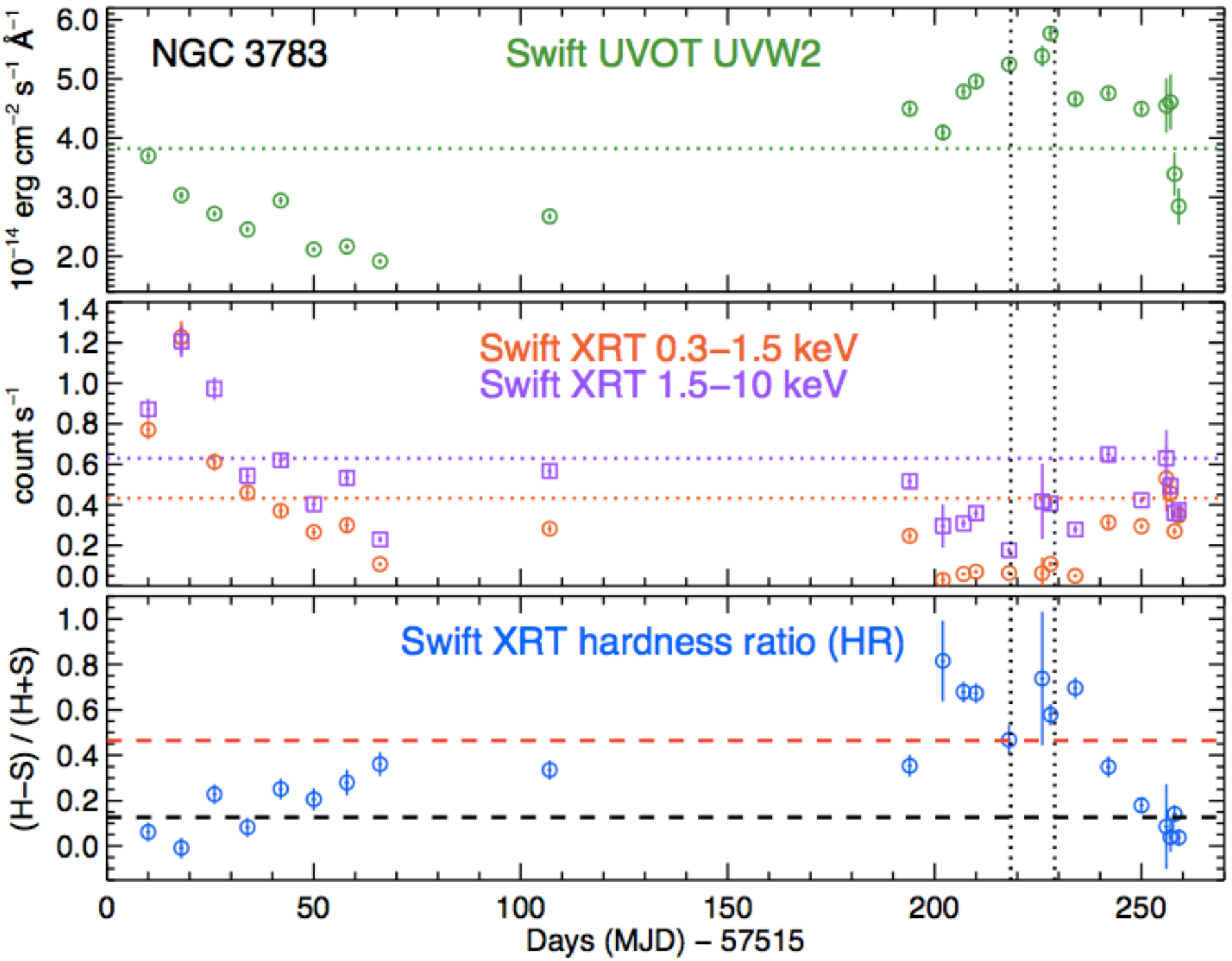
Ground (Level 1) $2s^2 2p \quad {}^2P_{1/2}$

Mao et al. 2017 (submitted)

EW ratio


Si XI
Si X
Si IX
EW ratio
log10(ξ) = 1.8
log10(ξ) = 1.9
log10(ξ) = 2.0
log10(ξ) = 1.6
log10(ξ) = 1.7
log10(ξ) = 1.8
log10(ξ) = 1.4
log10(ξ) = 1.5
log10(ξ) = 1.6
46.399Å / 43.763Å
50.691Å / 50.524Å
55.356Å / 55.305Å
55.401Å / 55.305Å
56.027Å / 55.305Å
Mao et al. 2017
(submitted)
365.430Å / 303.320Å
258.370Å / 256.380Å
225.020Å / 223.740Å
227.000Å / 223.740Å
258.080Å / 223.740Å
log10 (nH)

NGC 3783

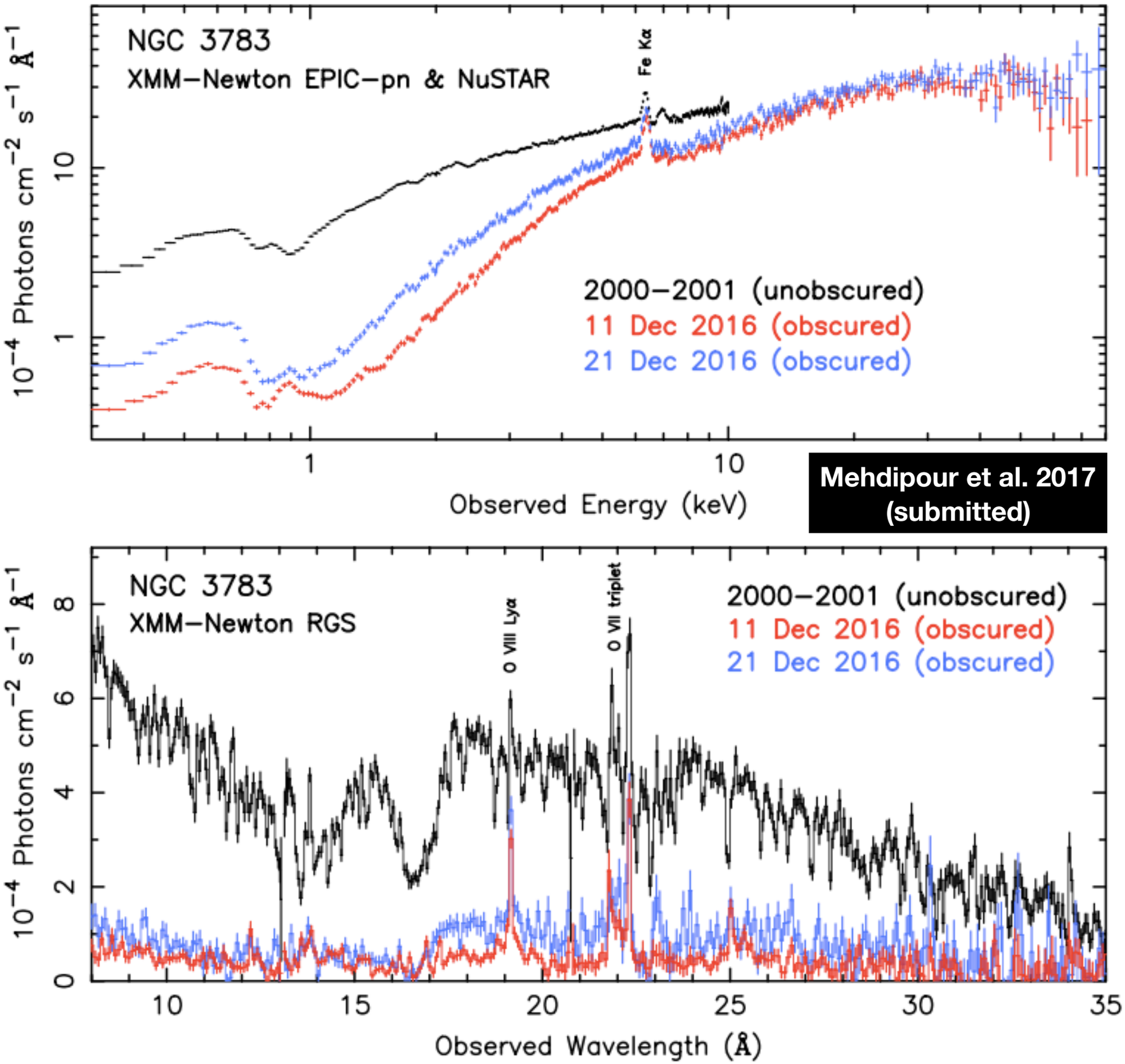


Ark 564
MR 2251
Mrk 335
Mrk 509
Mrk 841
NGC 3783
NGC 4593
NGC 7469

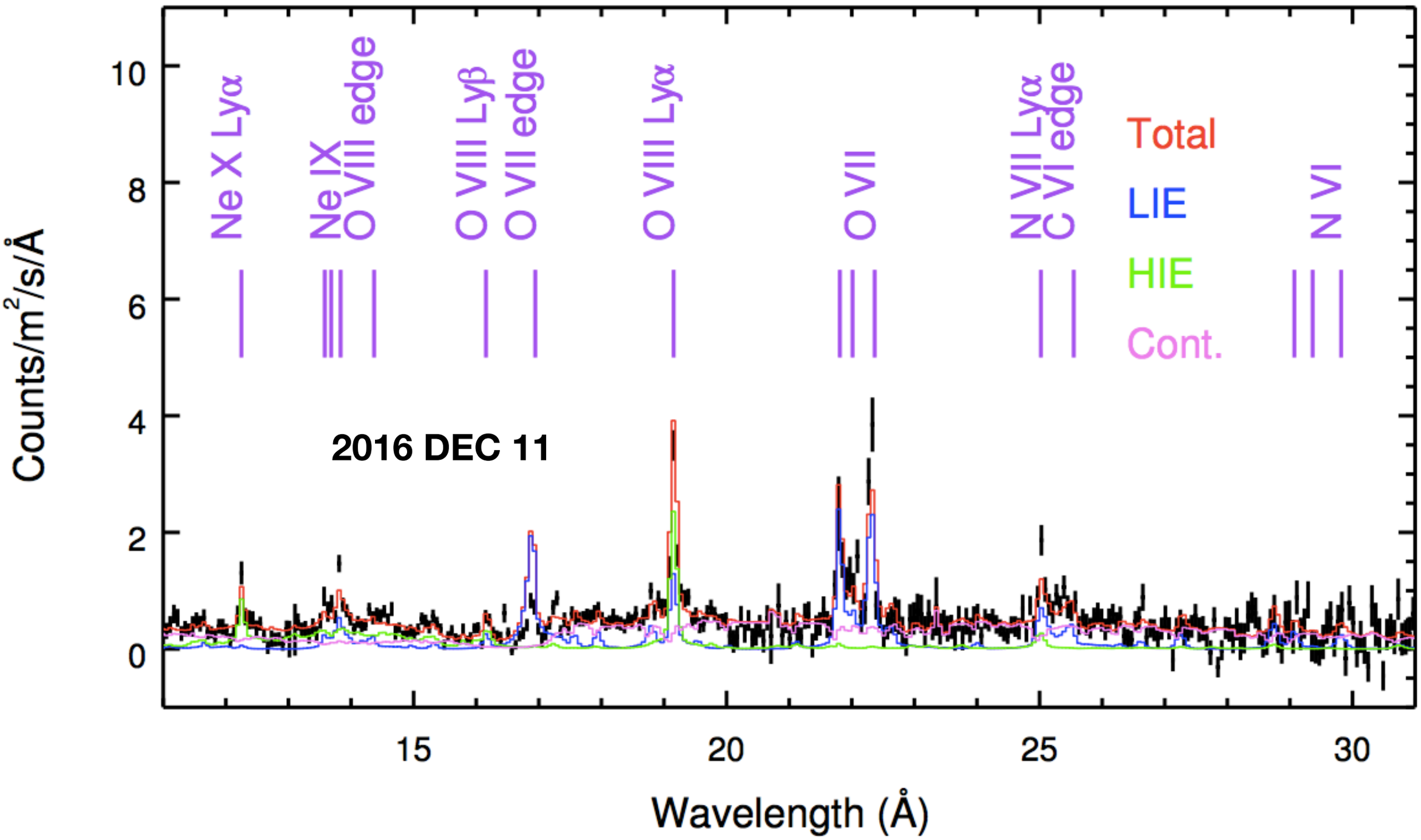
2016 - 2017
(Cycle 12)

Mehdipour et al. 2017
(submitted)

X-ray spectra

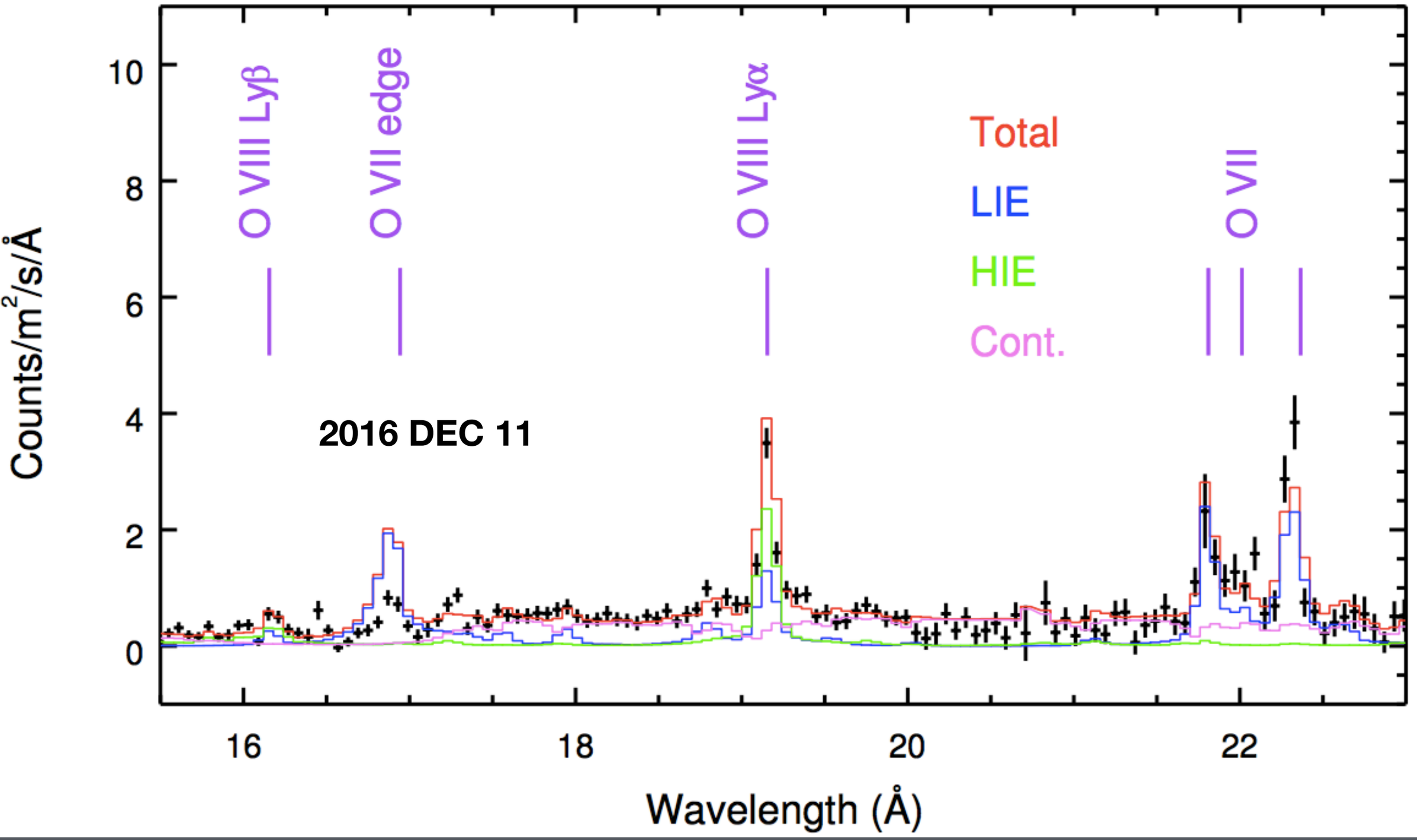


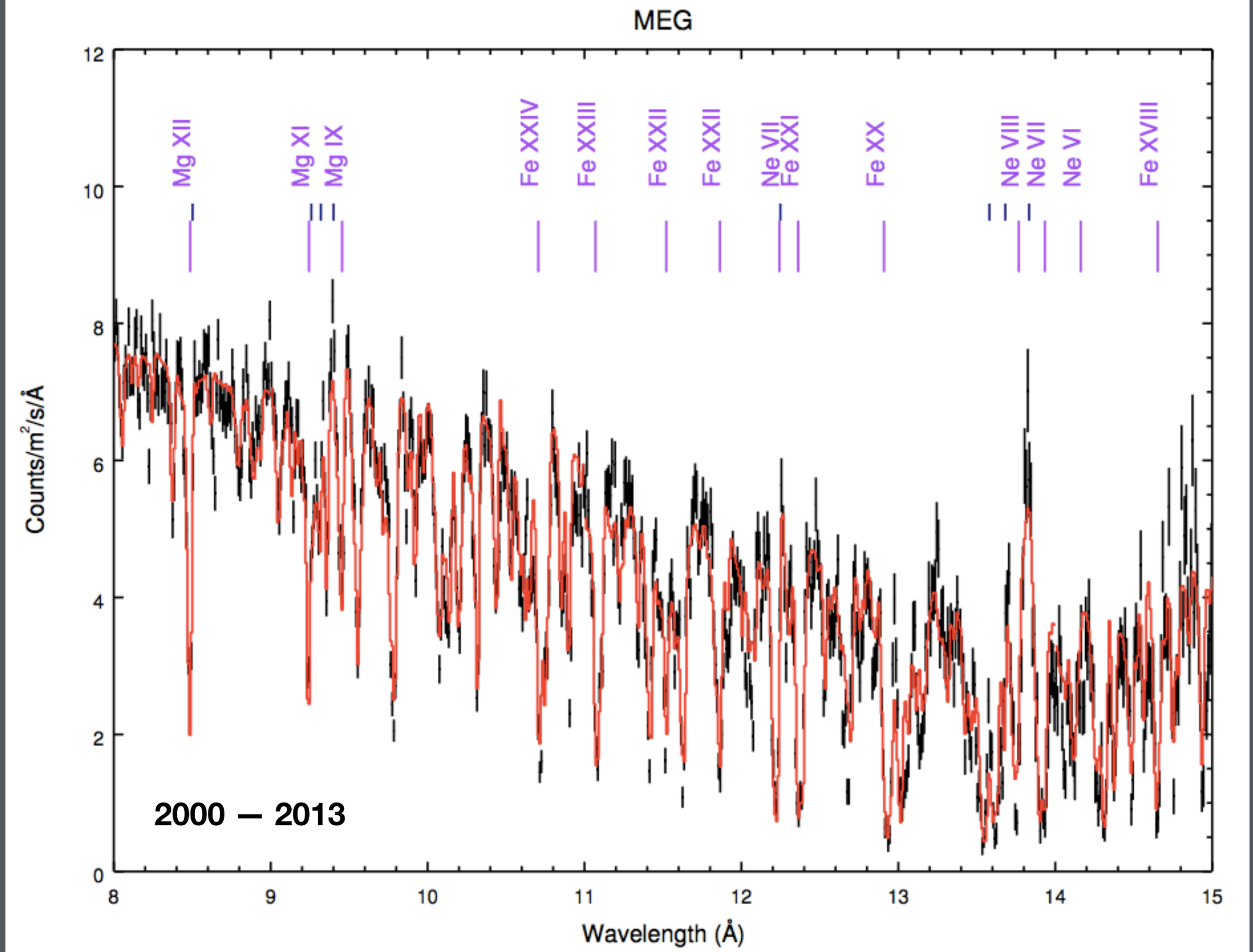
Emission (RGS)

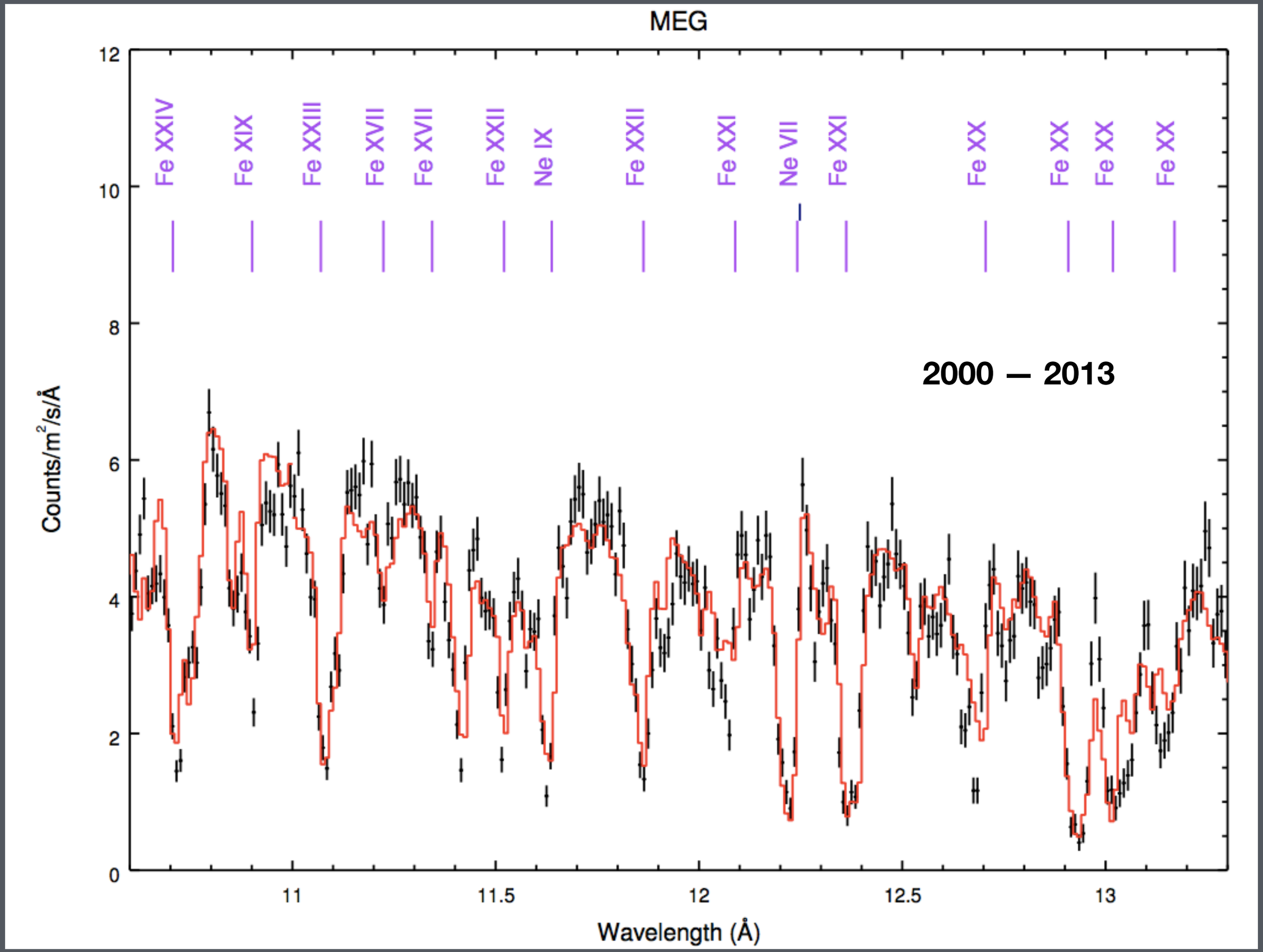


2 PIONs for emission: HIE (highly ionized) + LIE (lowly ionized)

O VII & VIII


O VIII Lyβ
O VII edge
O VIII Lyα
O VII
Total
LIE
HIE
Cont.
2016 DEC 11
Counts/m²/s/Å
Wavelength (Å)
0
2
4
6
8
10
16
18
20
22


MEG
Mg XII
Mg XI
Mg IX
Fe XXIV
Fe XXIII
Fe XXII
Fe XXII
Ne VII
Fe XXI
Fe XX
Ne VIII
Ne VII
Ne VI
Fe XVIII
Counts/m²/s/Å
2000 — 2013
Wavelength (Å)
0
2
4
6
8
10
12
8
9
10
11
12
13
14
15


MEG
Fe XXIV
Fe XIX
Fe XXIII
Fe XVII
Fe XVII
Fe XXII
Ne IX
Fe XXII
Fe XXI
Ne VII
Fe XXI
Fe XX
Fe XX
Fe XX
Fe XX
2000 — 2013
Counts/m²/s/Å
Wavelength (Å)
0
2
4
6
8
10
12
11
11.5
12
12.5
13

RGS

Mg XII
Mg IX
Fe XXIV
Fe XXIII
Ne VII
Fe XXI
Ne VIII
Ne VII
Fe XVII
Fe XVII
Fe XVII
O VIII
O VIII
Ar XIV
O VI
O V
O III
N VII
Ar XIV
Ar XIV
N VI
N IV
Ca XI
S XIII
C VI

HETGS

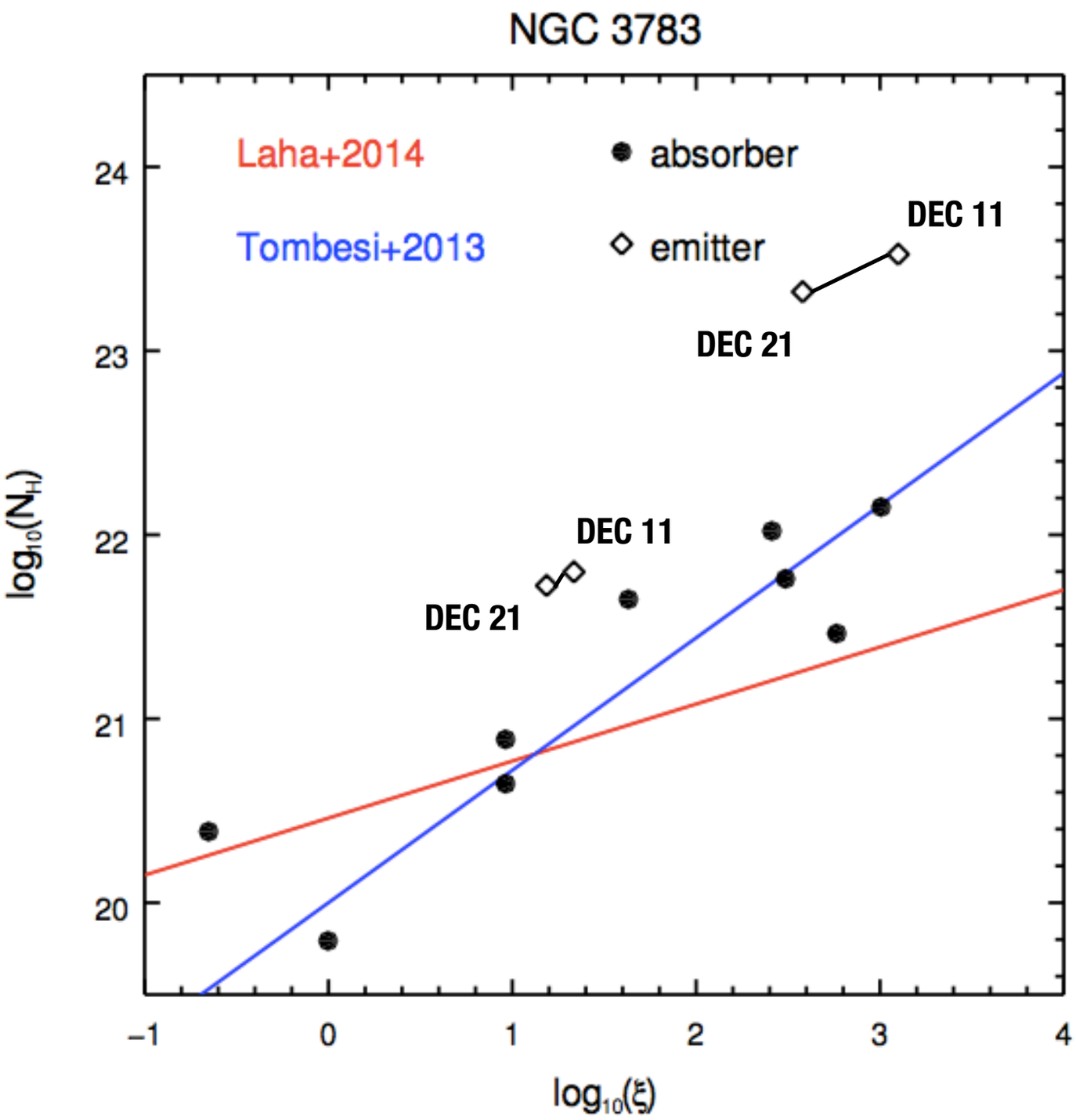
2000 — 2001

9 PIONs for absorption
2 PIONs for emission

Counts/m^2/s/Å

Wavelength (Å)

N_H-ξ



Tombesi+2013 (WA + UFO)

35 Seyfert 1 galaxies

$$\log\left(\frac{N_{\rm H}}{\rm cm^{-2}}\right) = 0.72\log\left(\frac{\xi}{\rm erg\ cm}\right) + 20.00$$

Laha+2014 (WA)

26 Seyfert galaxies

$$\log\left(\frac{N_{\rm H}}{\rm cm^{-2}}\right) = 0.31\log\left(\frac{\xi}{\rm erg\ cm}\right) + 20.46$$

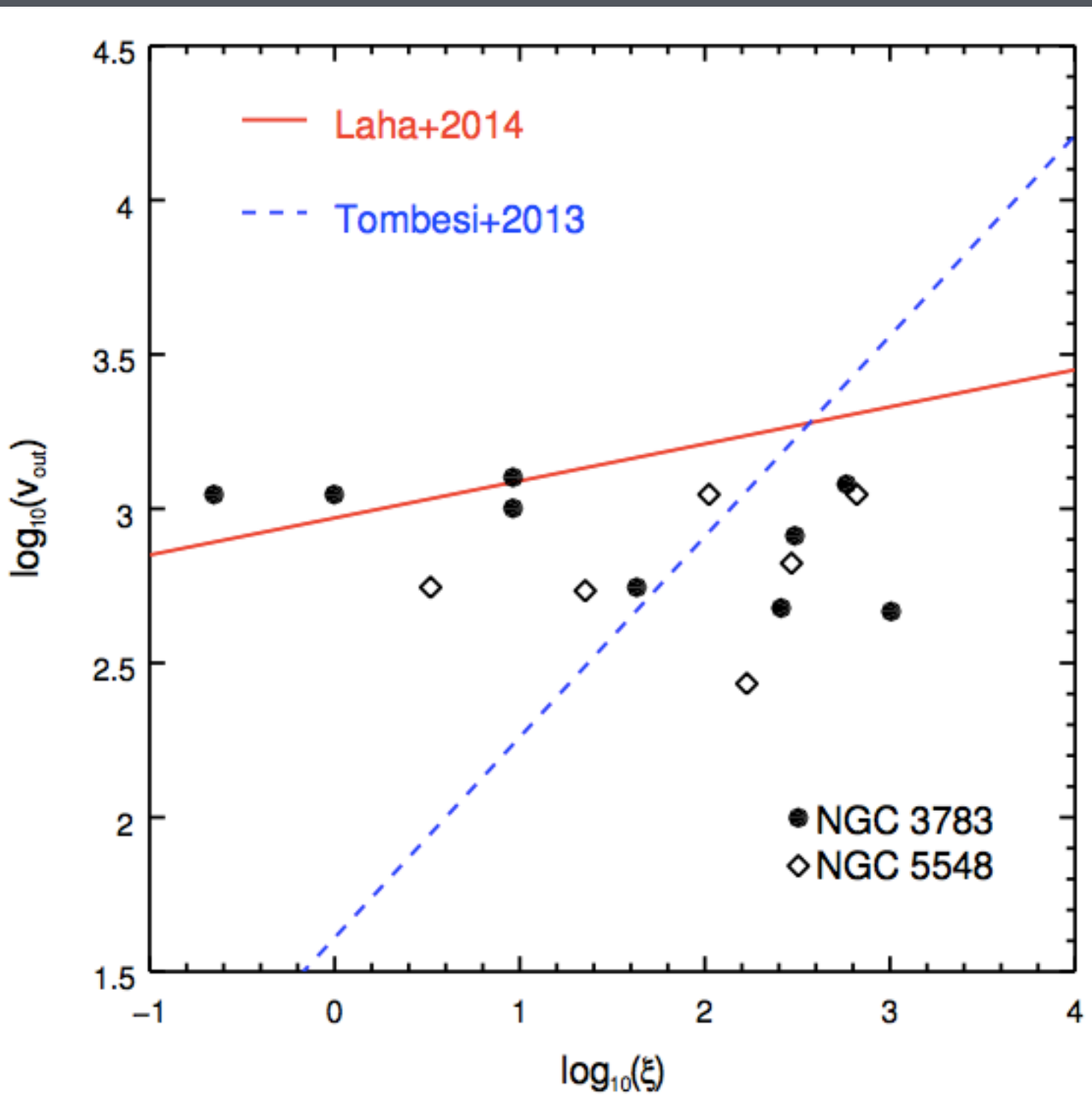
Behar 2009

$$n_{\rm H}(r) \propto r^{-\alpha}$$

$$\mathrm{AMD} \propto \xi^{-\frac{1}{2}}\ (\alpha = 0)$$

$$\mathrm{AMD} \propto \xi^{0}\ (\alpha = 1)$$

V_{out}-ξ (Part I)



Tombesi+2013 (WA + UFO)

$$\log\left(\frac{v_{\rm out}}{\rm km\ s^{-1}}\right) = 0.65 \log\left(\frac{\xi}{\rm erg\ cm}\right) + 1.61$$

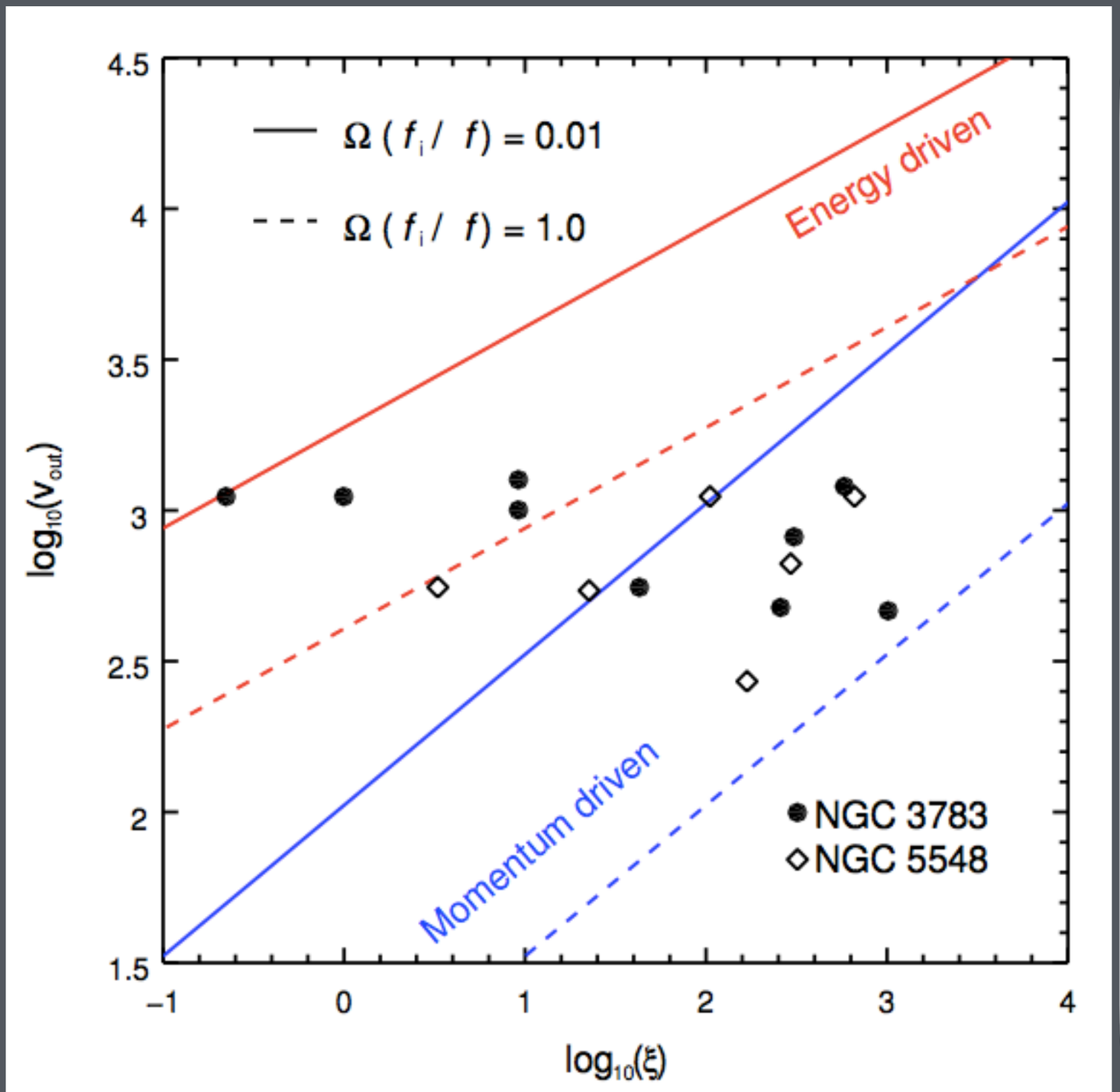
a = 0.31 (WA), 0.63 (UFO)

Laha+2014 (WA)

$$\log\left(\frac{v_{\rm out}}{\rm km\ s^{-1}}\right) = 0.12 \log\left(\frac{\xi}{\rm erg\ cm}\right) + 2.97$$

NGC 5548 (JAN 2002)

V_{out}-ξ (Part II)



$$L_i = L_{1-1000\,\mathrm{Ryd}} = f_i\, L_{\mathrm{Edd}}$$

$$\xi = \frac{L_i}{n_{\mathrm{H}}(r)\, r^2}$$

$$\dot{M}_{\mathrm{out}} = 4\,\pi\,\Omega\, r^2\, v_{\mathrm{out}}\, \rho(r)$$

Energy driven

$$\frac{1}{2}\,\dot{M}_{\mathrm{out}}\, v_{\mathrm{out}}^2 = f_e\, L_{\mathrm{Edd}}$$

Momentum driven

$$\dot{M}_{\mathrm{out}}\, v_{\mathrm{out}} = f_m\, \frac{L_{\mathrm{Edd}}}{c}$$

Summary

- Self-consistent fit
  - SED (optical to hard X-ray)
  - Spectral calculation
    - absorption & emission features
  - PhotoIONization calculation (opt. thin)
    - thermal equilibrium
    - ionization balance
    - density diagnostics