How to trigger a galaxy-wide outflow:
the case of PDS 456

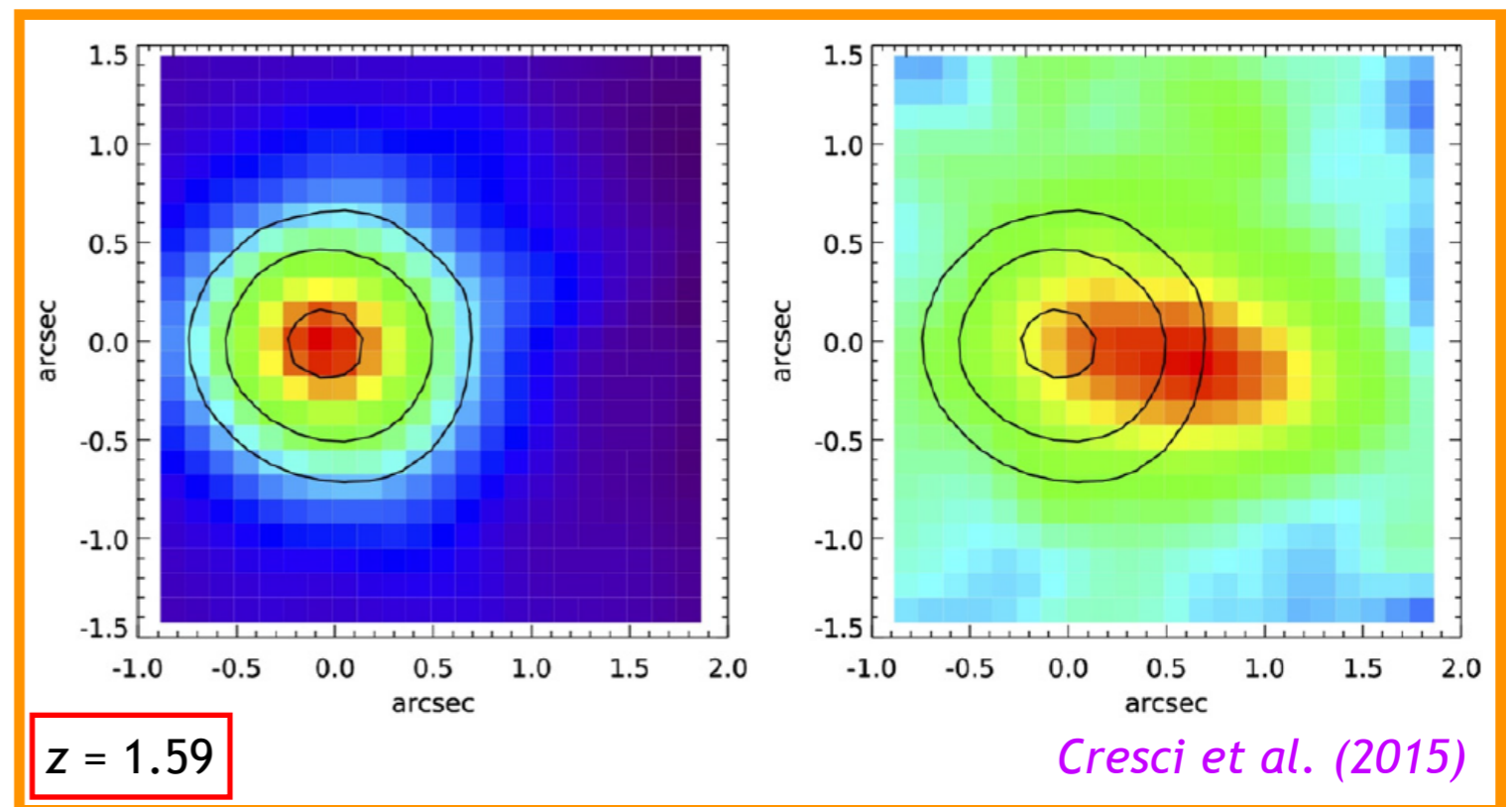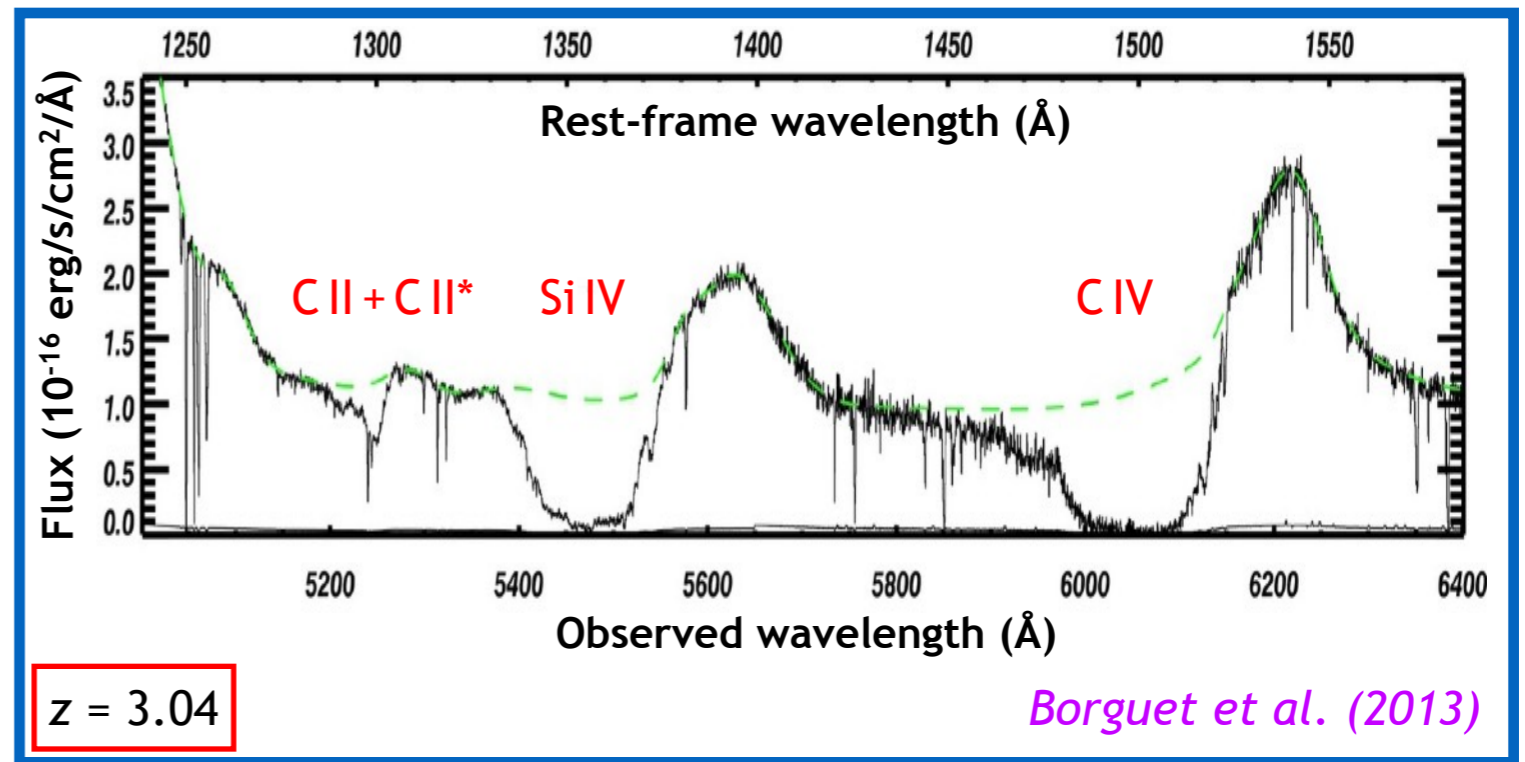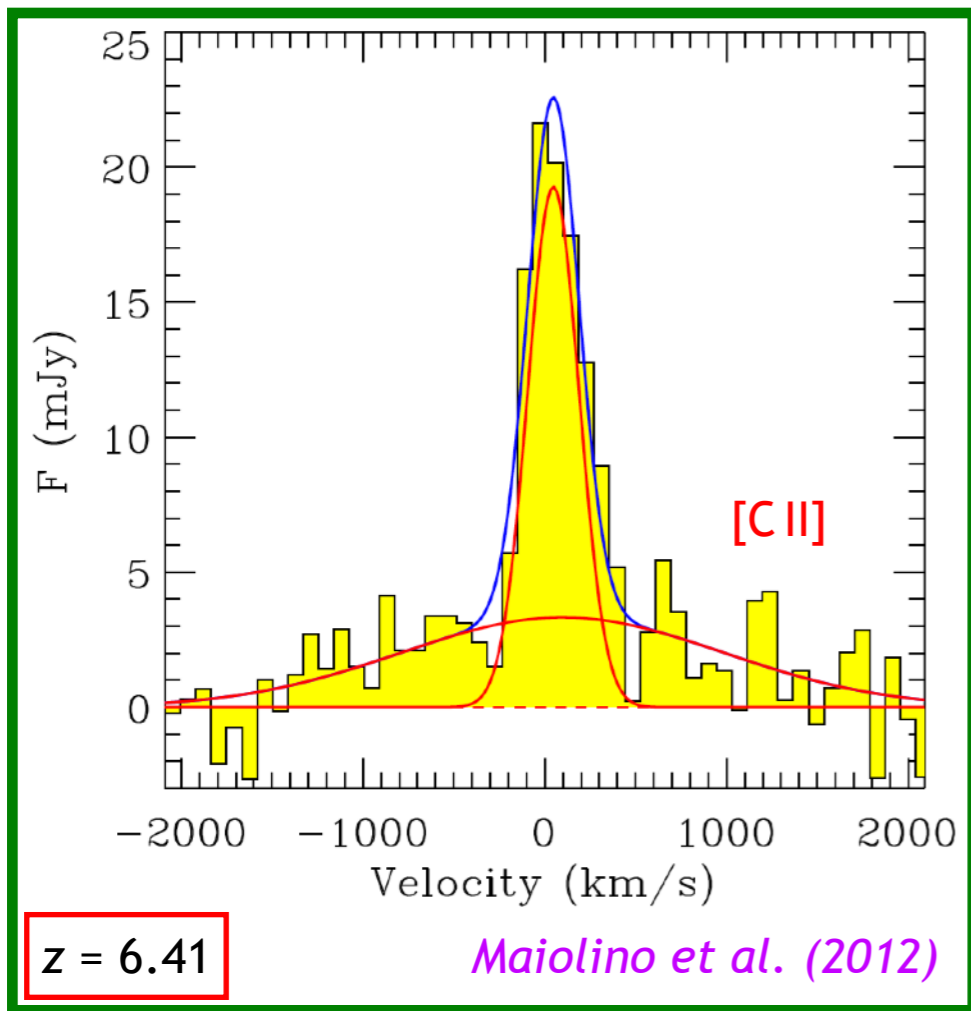## Emanuele Nardini
INAF/Arcetri

Horizon 2020

AstroFIt2/MSCA

in collaboration with:

J. Reeves, M. Costa (Keele), V. Braito, G. Matzeu (INAF/Brera)
and many others

European Week of Astronomy and Space Science
Prague, 26-30 June 2017

Evidence for AGN-driven outflows

z = 6.41 — *Maiolino et al. (2012)*

z = 3.04 — *Borguet et al. (2013)*

1 thousand is the typical number for **distance** (pc), **mass loss rate** (M_{SUN}/yr), and **outflow velocity** (km/s)
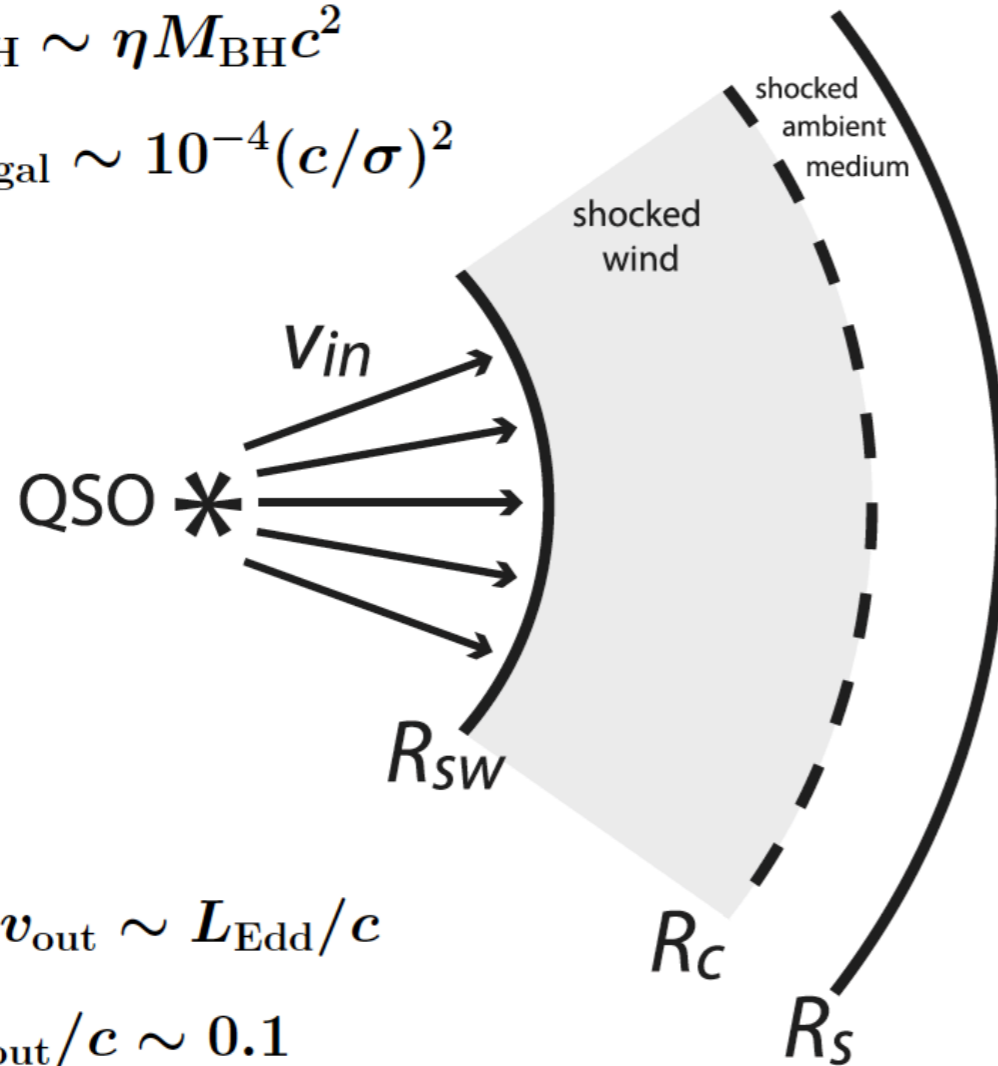
How are these winds launched?

z = 1.59 — *Cresci et al. (2015)*

Ultra-fast outflows

$$E_{\mathrm{gal}} \sim M_{\mathrm{gal}} \sigma^2$$

$$E_{\mathrm{BH}} \sim \eta M_{\mathrm{BH}} c^2$$

$$E_{\mathrm{BH}}/E_{\mathrm{gal}} \sim 10^{-4}(c/\sigma)^2$$

shocked
ambient
medium

shocked
wind

v_{in}

QSO ✳

R_{SW}

R_C

R_S

$$\dot{M}_{\mathrm{out}} v_{\mathrm{out}} \sim L_{\mathrm{Edd}}/c$$

$$v_{\mathrm{out}}/c \sim 0.1$$

$$P_{\mathrm{kin}} \sim 0.05\, L_{\mathrm{Edd}}$$

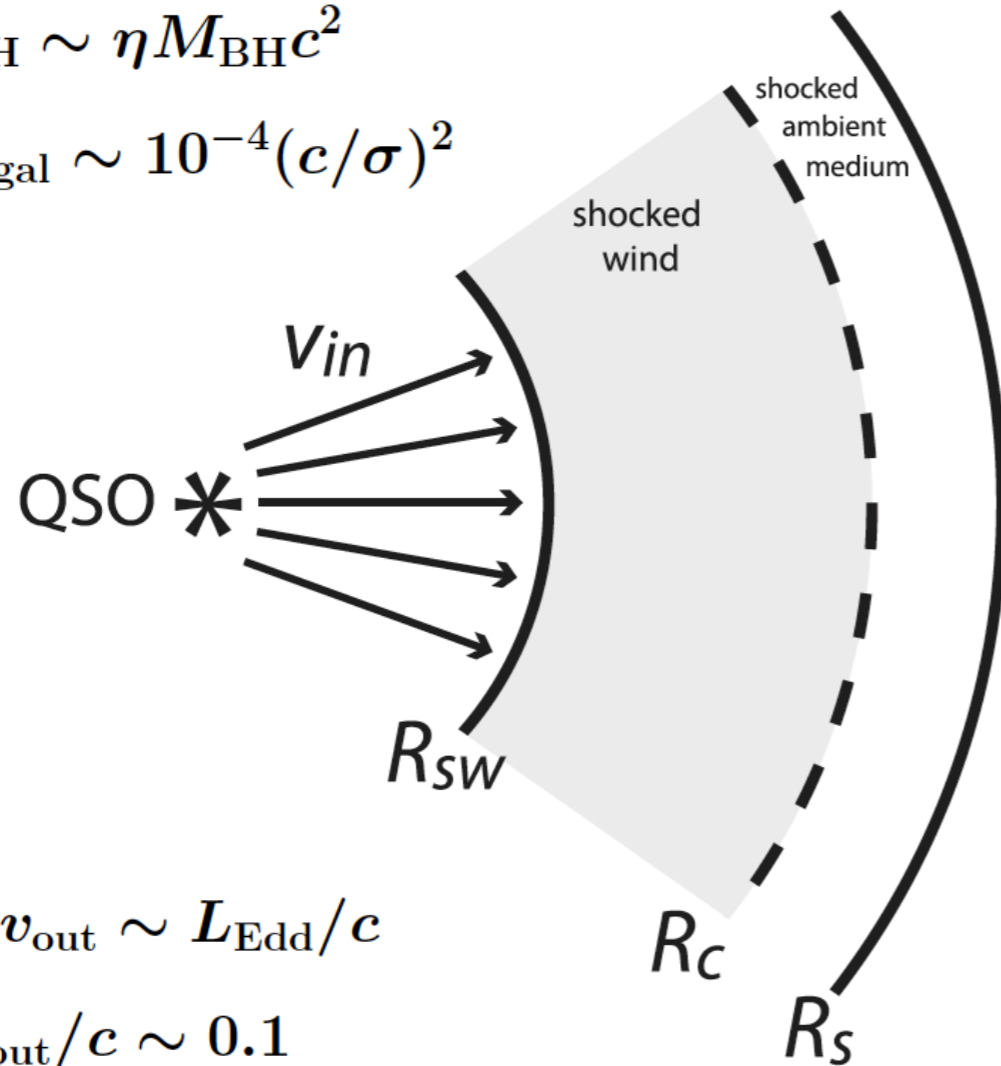*Zubovas & King*
Faucher-Giguère & Quataert
Ishibashi & Fabian

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Risaliti et al. (2005)

NGC 1365

Fe XXV   Fe XXVI

Data / continuum

shocked ambient medium

shocked wind

v_{in}

QSO ✳

R_{sw}

R_c

R_s

Zubovas & King
Faucher-Giguère & Quataert
Ishibashi & Fabian

Tombesi et al. (2010)

Fraction (%)

Blue−shift velocity (v/c)
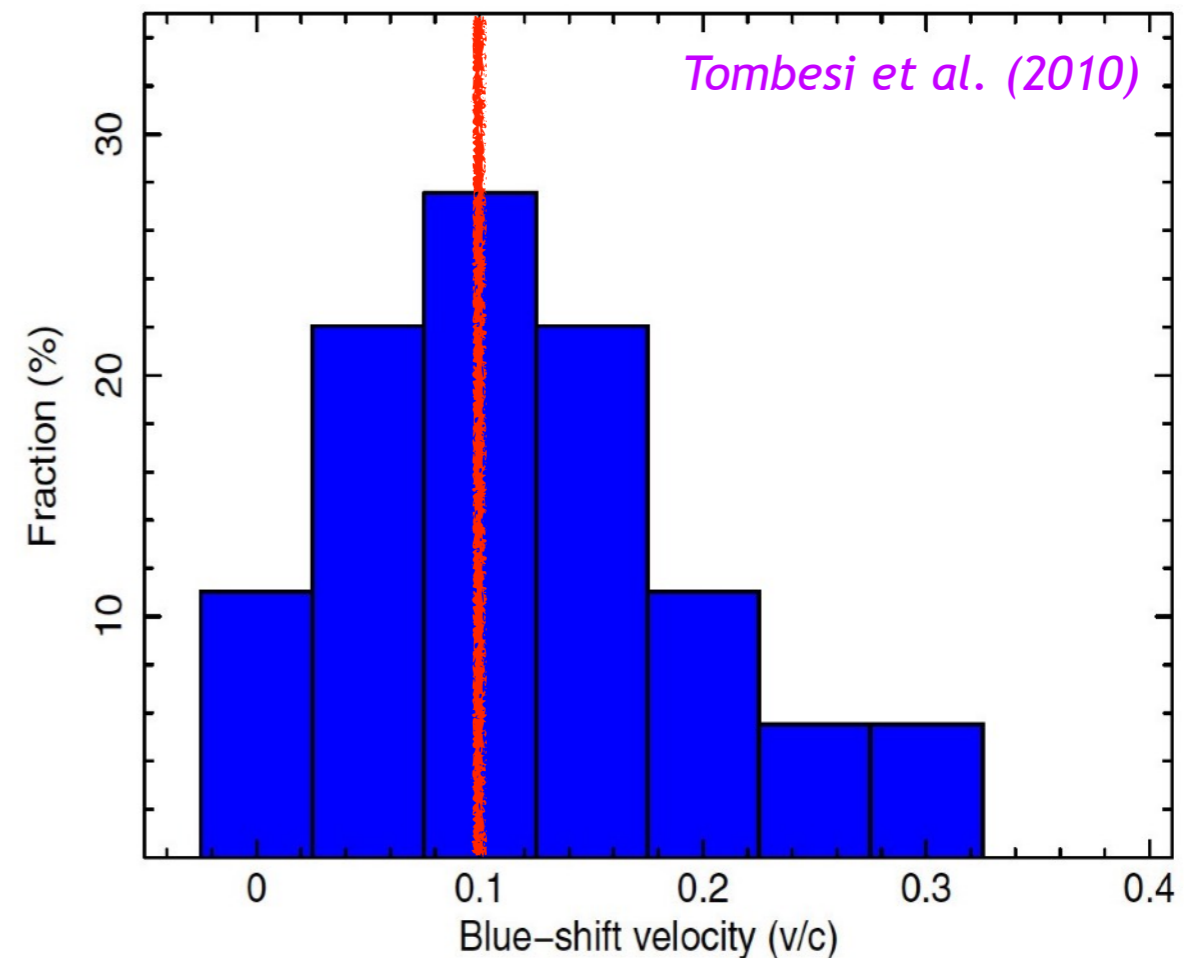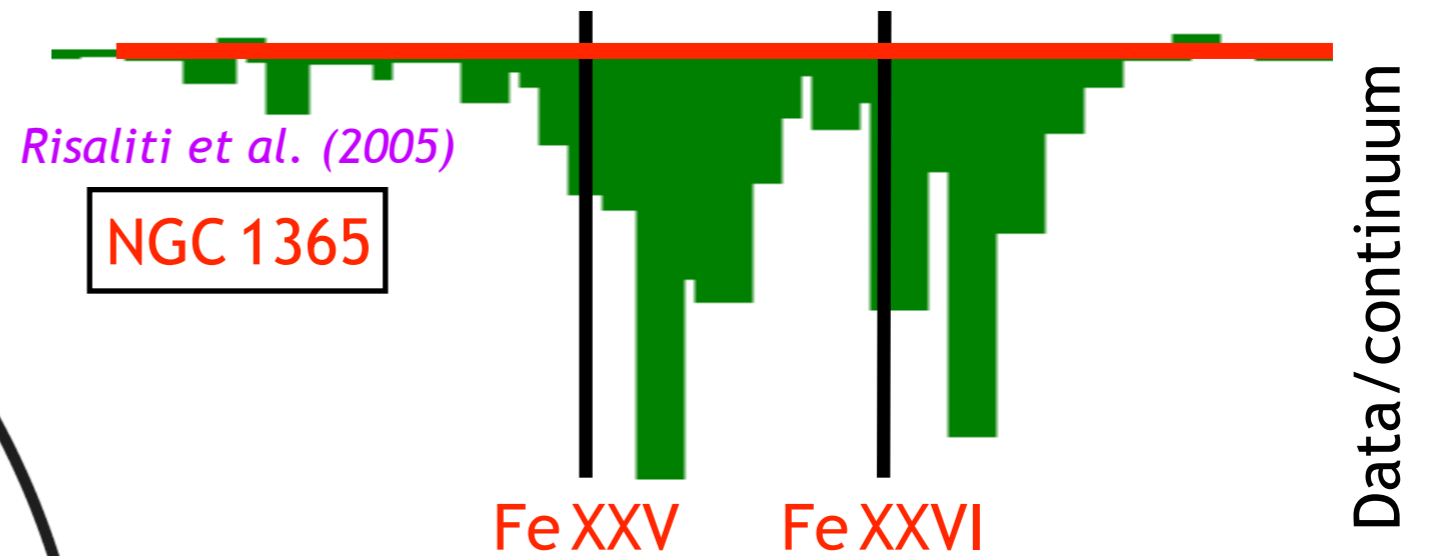
Unification of AGN winds

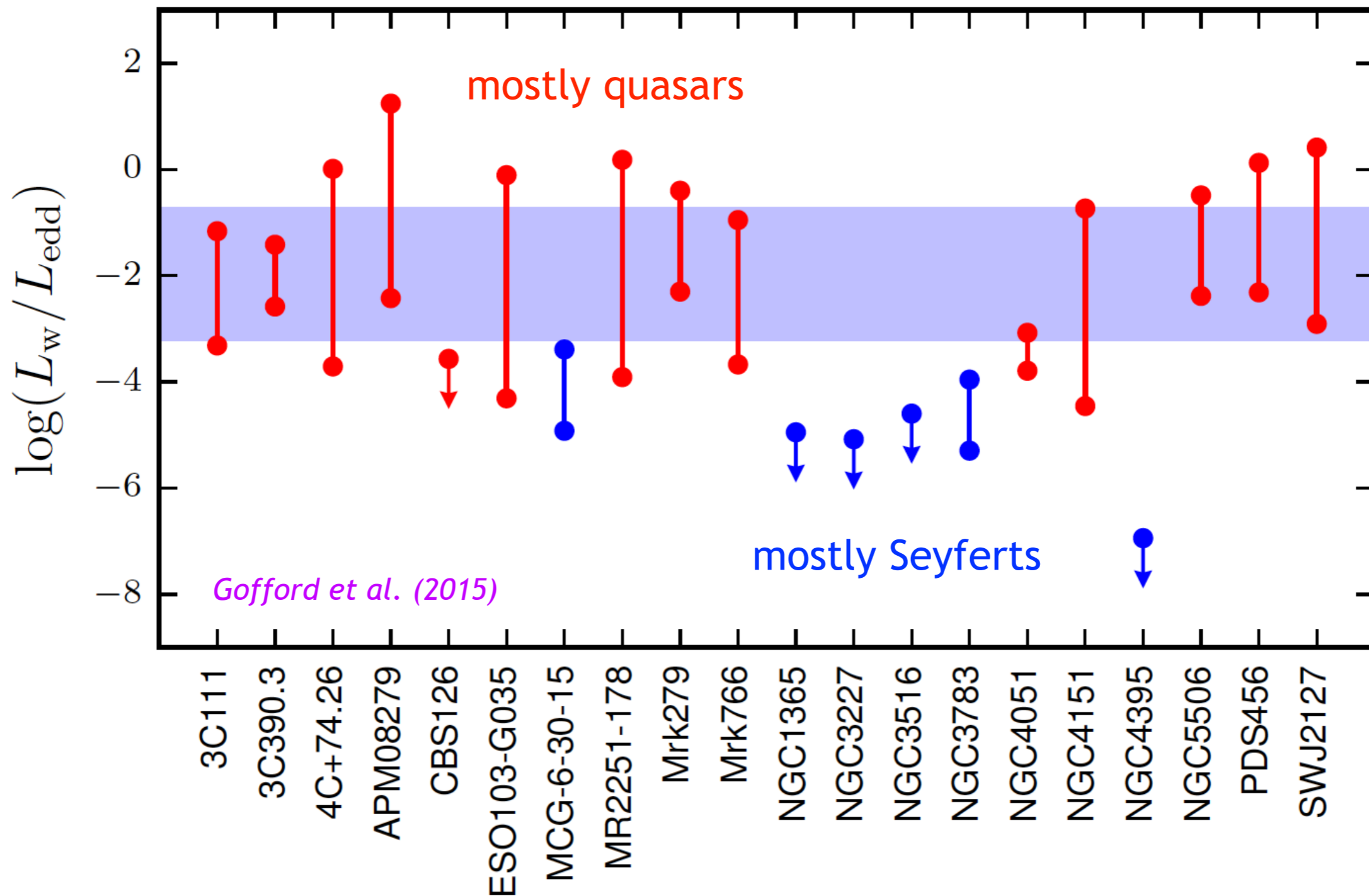# *Critical issues with X-ray winds*

Significance/reliability, transient nature, dependence on continuum modelling, ...

mostly quasars

$\log(L_{\mathrm{w}}/L_{\mathrm{edd}})$

mostly Seyferts

Gofford et al. (2015)

3C111 · 3C390.3 · 4C+74.26 · APM08279 · CBS126 · ESO103-G035 · MCG-6-30-15 · MR2251-178 · Mrk279 · Mrk766 · NGC1365 · NGC3227 · NGC3516 · NGC3783 · NGC4051 · NGC4151 · NGC4395 · NGC5506 · PDS456 · SWJ2127
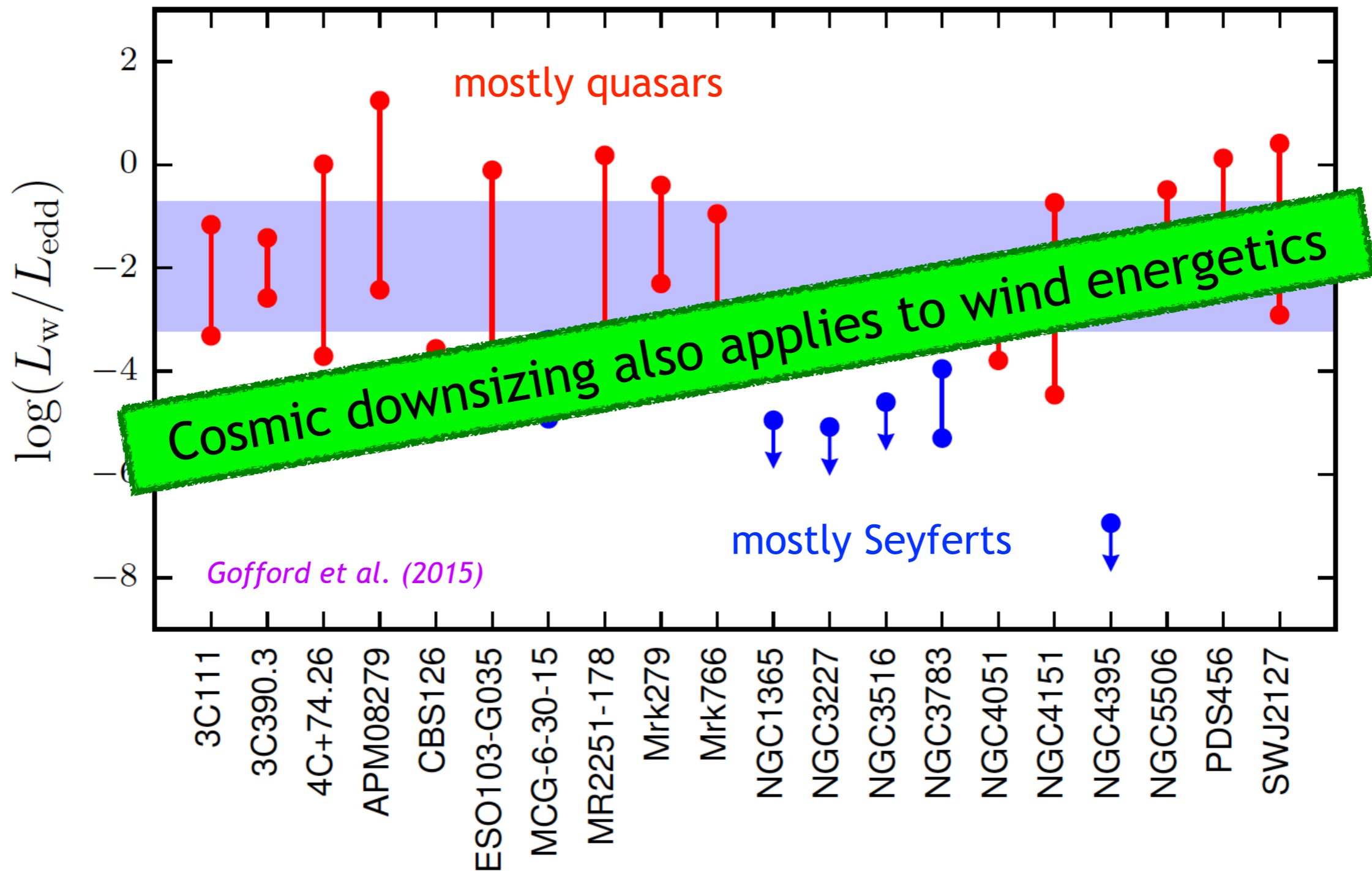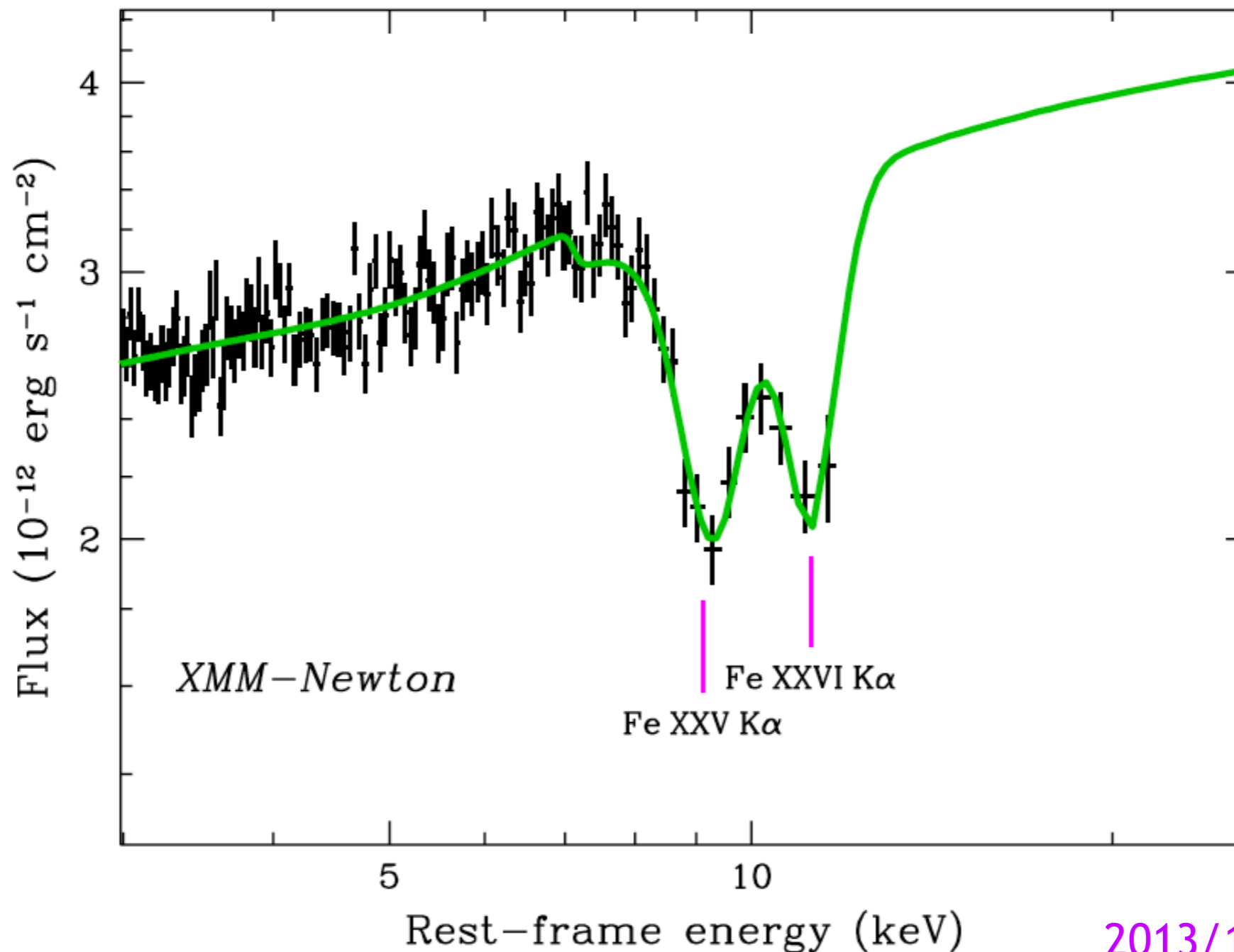
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Cosmic downsizing also applies to wind energetics

The Rosetta stone of SMBH winds

PDS 456 is the most luminous radio-quiet AGN in the local Universe ($z < 0.3$), and it is a <u>unique target</u> to study X-ray winds in the Eddington-limited regime

2013/14 *XMM+NuSTAR*
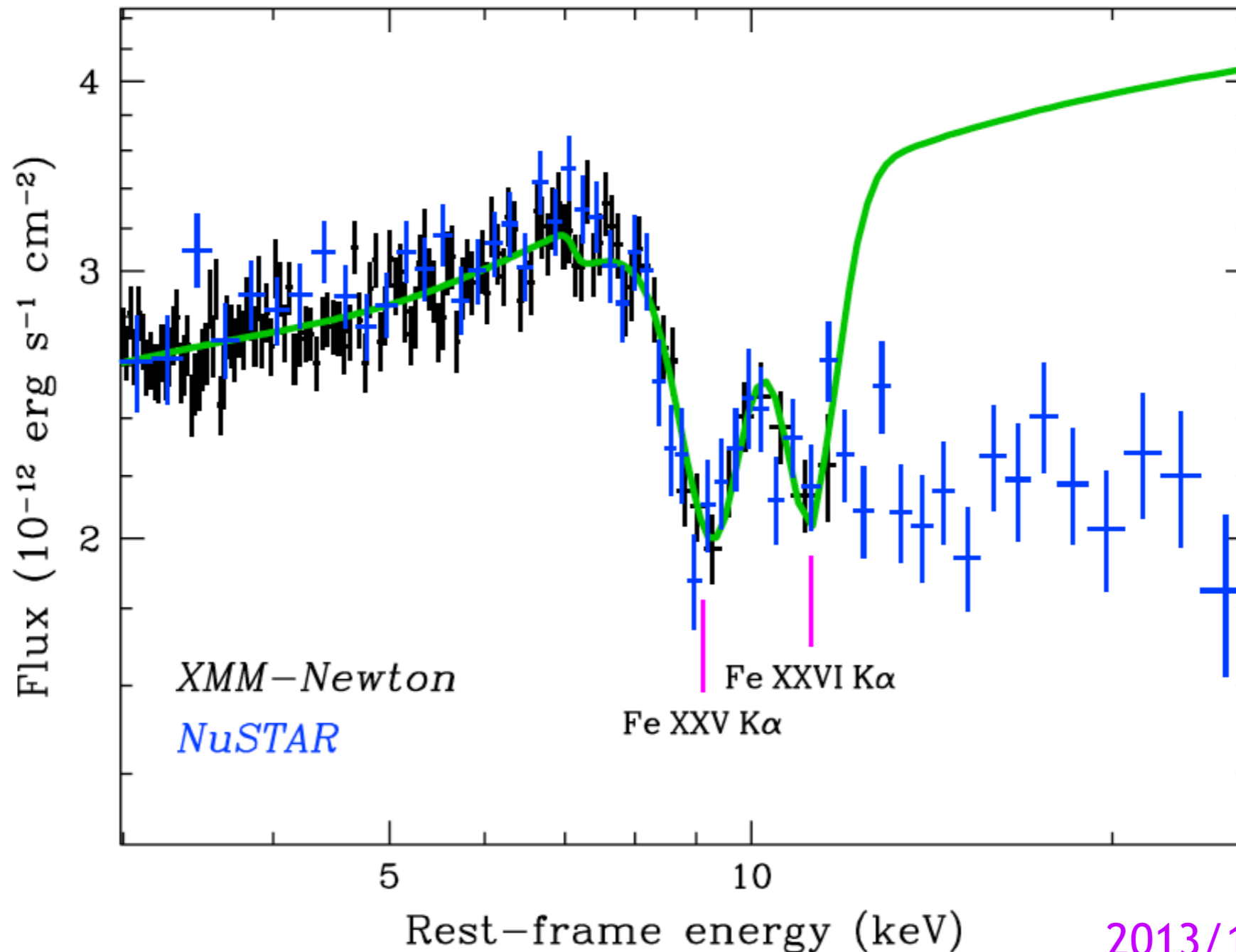
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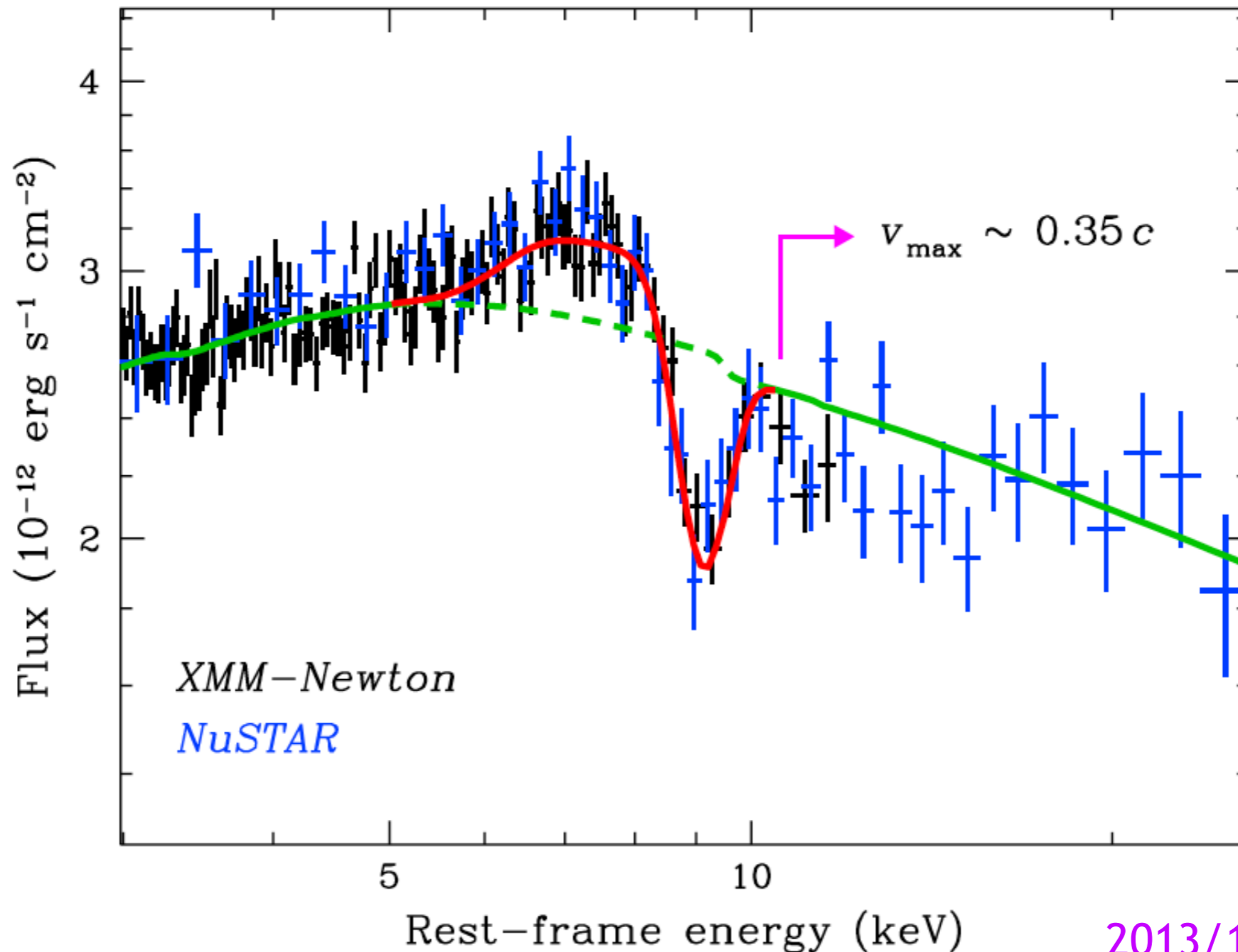
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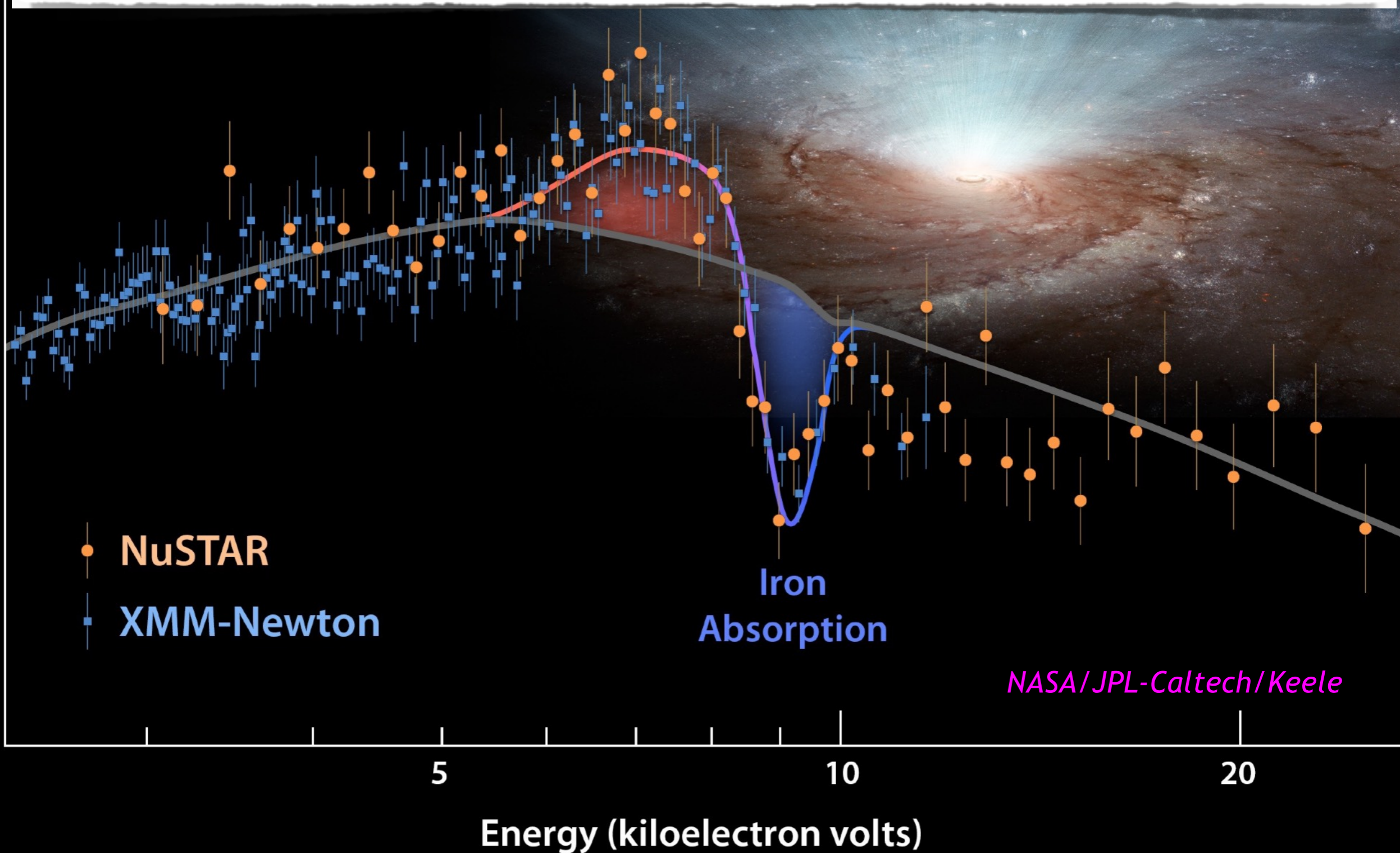

$v_{max} \sim 0.35\,c$

XMM–Newton

NuSTAR

2013/14 *XMM+NuSTAR*

Iron Blowing in Quasar Winds

$$\dot{M}_{\mathrm{out}} \sim 10\, M_{\odot}\, \mathrm{yr}^{-1} \Rightarrow P_{\mathrm{kin}} \sim 2 \times 10^{46}\, \mathrm{erg\, s}^{-1} \sim 0.2\, L_{\mathrm{bol}}$$

Brightness

NuSTAR

XMM-Newton

Iron
Absorption

NASA/JPL-Caltech/Keele

5   10   20

Energy (kiloelectron volts)

The wind's footprint in the soft X-rays

XMM 06 Sep 2013
XMM 26 Feb 2014

EF_E (relative)

BAL-like profiles with velocity of 0.1–0.2c

Rest-frame energy (keV)
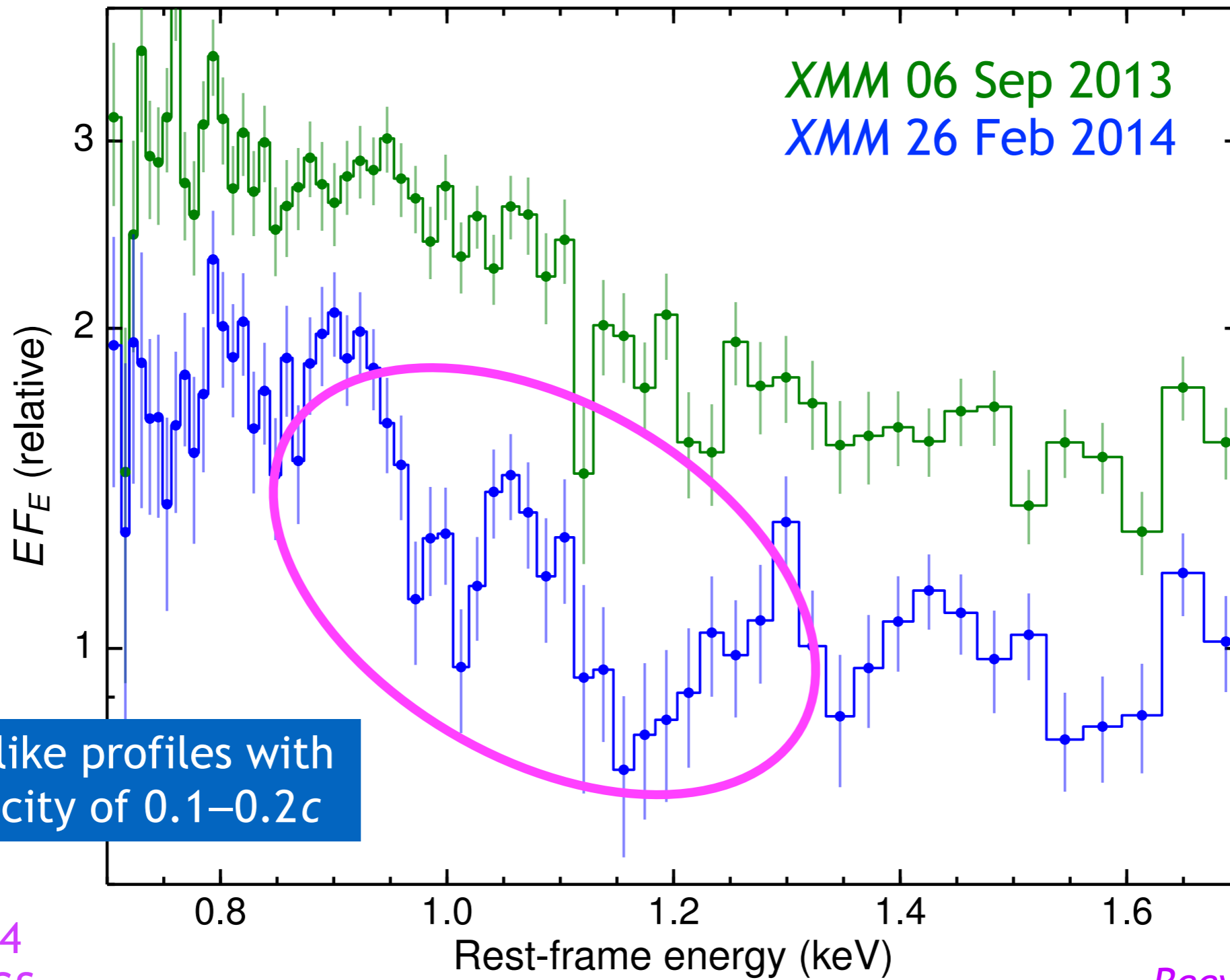
2013/14
XMM/RGS

Reeves et al. (2016)

The wind's footprint in the soft X-rays

Ne IX Ne X

XMM 26 Feb 2014

Ne IX Ne X

XMM 26 Feb 2001

Residuals (σ)

Rest-frame energy (keV)

Fe K

Data/continuum

Reeves et al. (2003)

Rest-frame energy (keV)
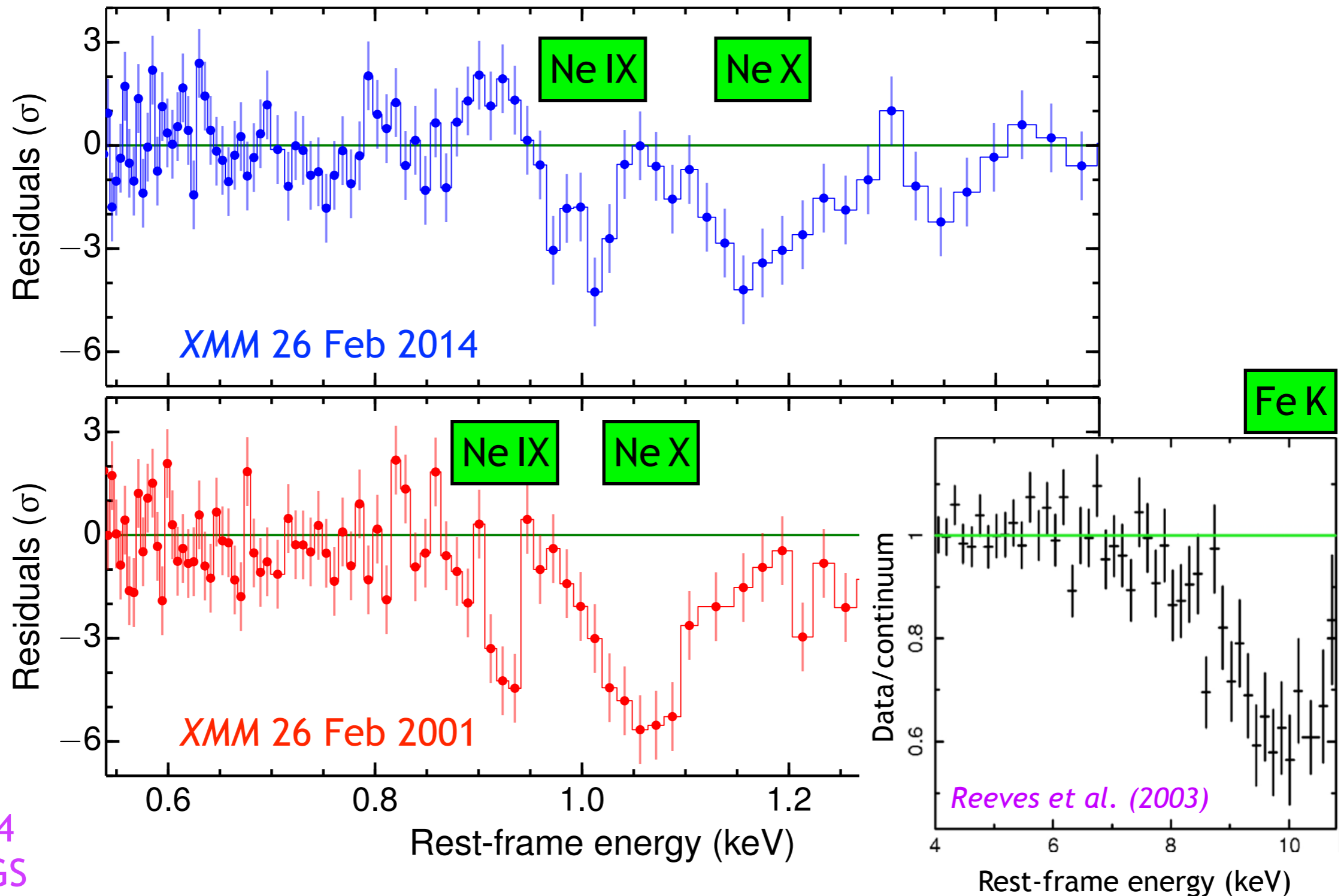
2013/14
XMM/RGS

Possible UV signatures

Much of the slide is a scientific figure. Text labels within the figure:

HST/STIS 14 May 2000

Lyα / N V

Lyα?

Si IV / O IV

C IV

If Lyα, velocity range of 0.05–0.08c

Much shallower in 2014 in a low-flux state. New 2017 spectrum simultaneous with X-rays (work in progress)

Flux density (erg s^{-1} cm^{-2} Å^{-1})

Observed wavelength (Å)
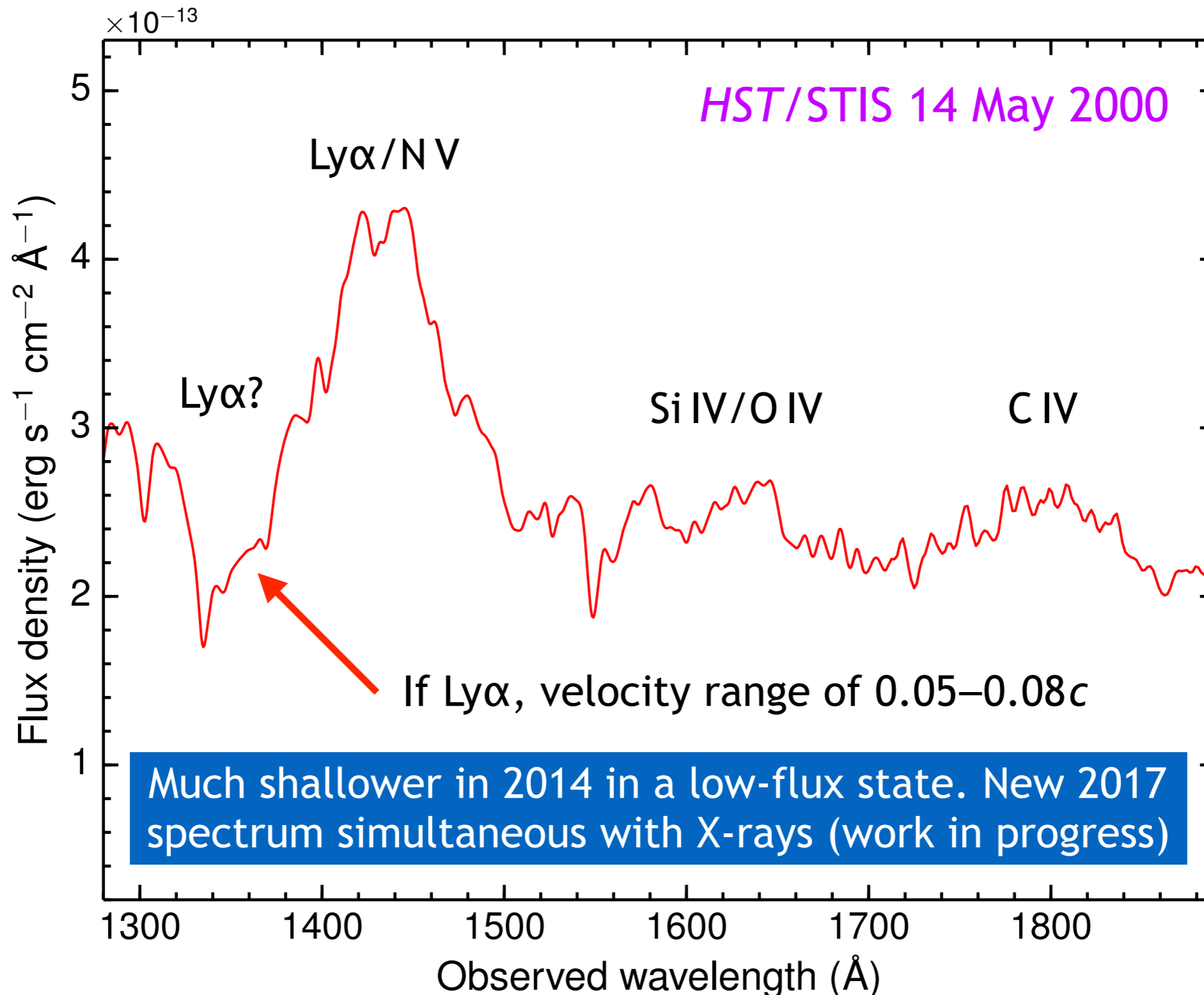
Evidence for radiative driving?

Evidence for radiative driving?

$\gamma = 0.21 \pm 0.04$

Hidden dependencies?
(e.g. SED shape,
ionization parameter,
launch radius)

v_w/c

$\log (L_{7\text{-}30\ keV}/erg\ s^{-1})$
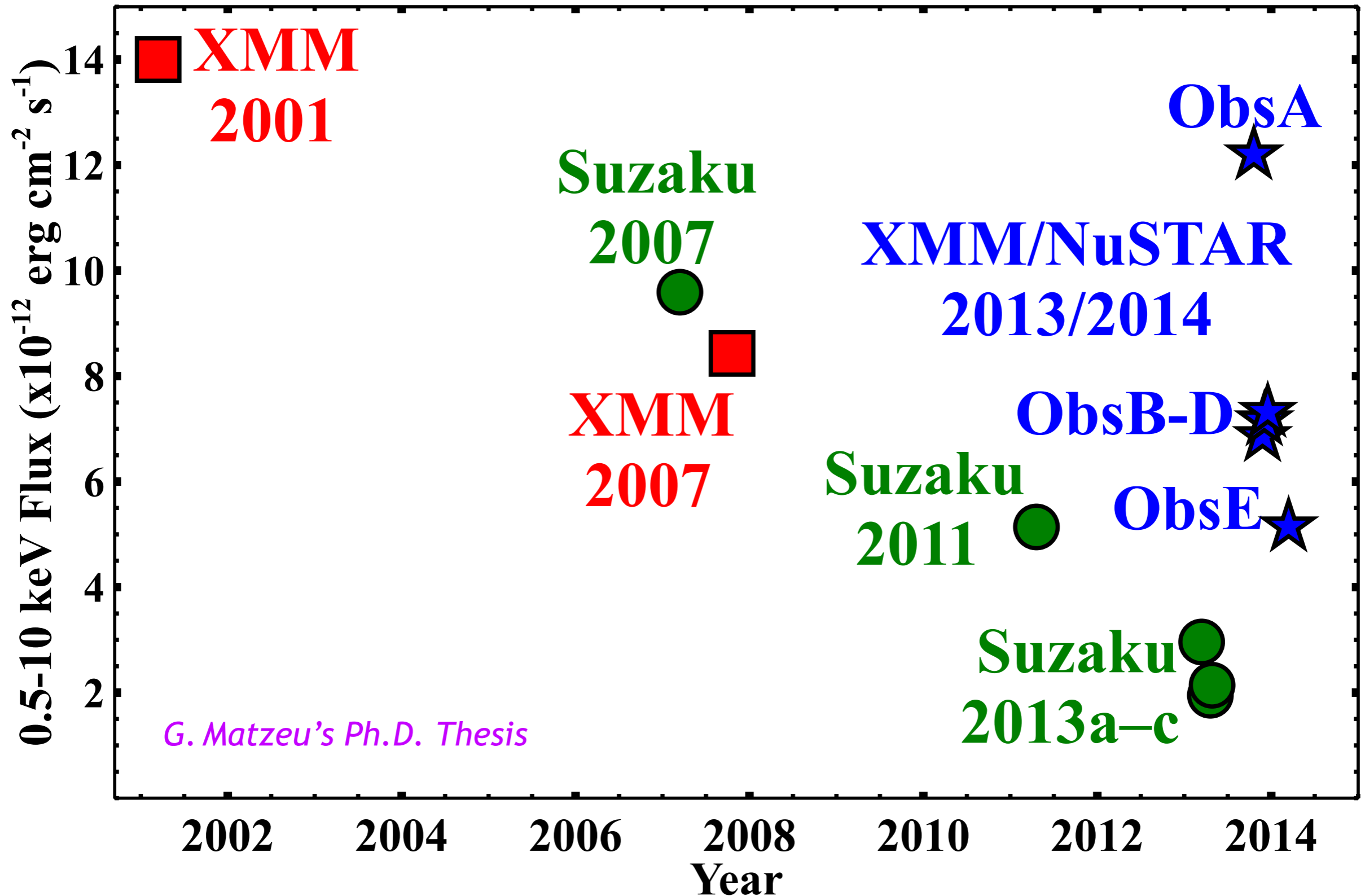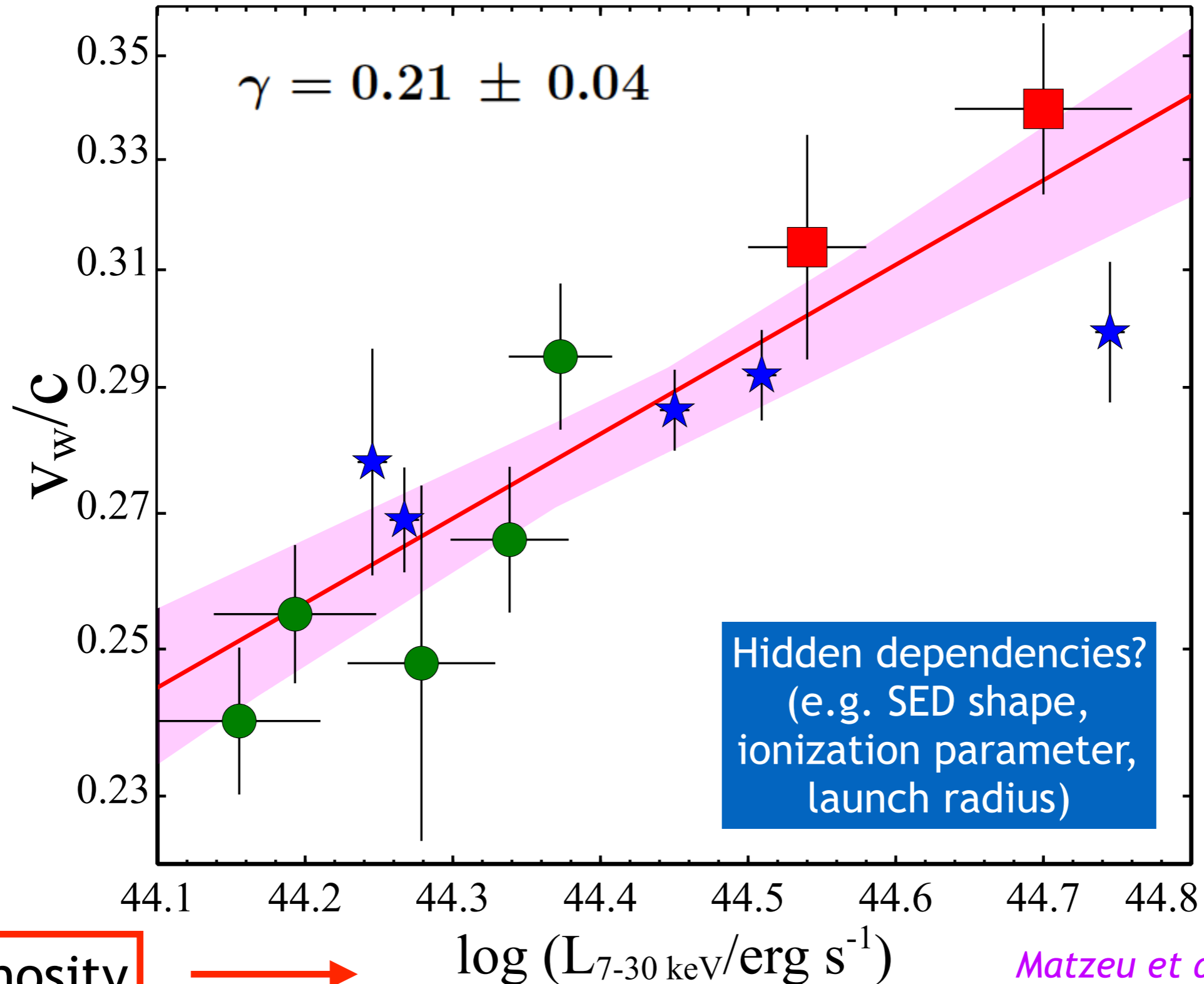
Velocity

Luminosity

Matzeu et al. (submitted)

The new observations (2017)

XMM 27 Aug 2013
XMM 26 Feb 2014
XMM 23 Mar 2017
XMM 25 Mar 2017
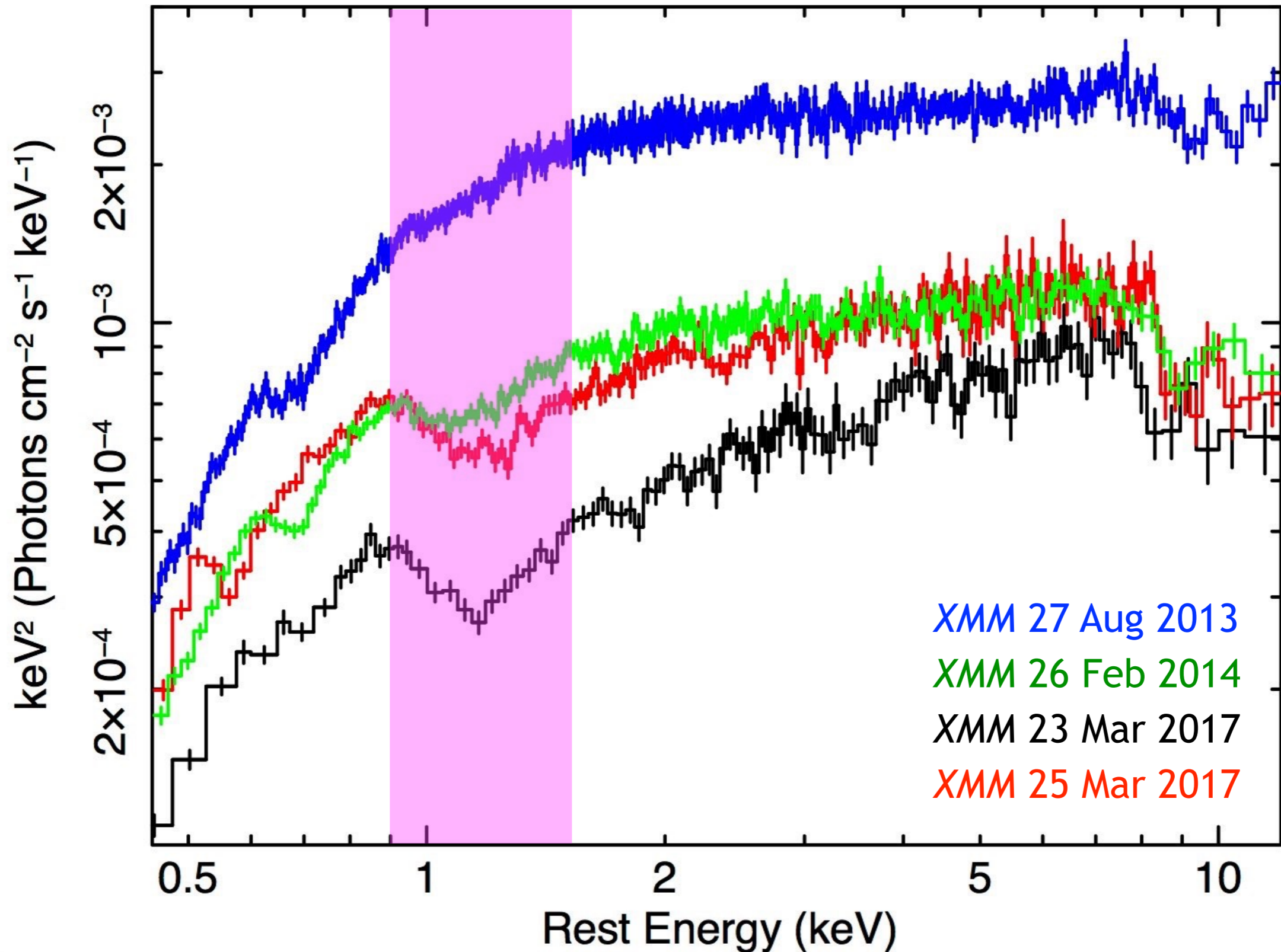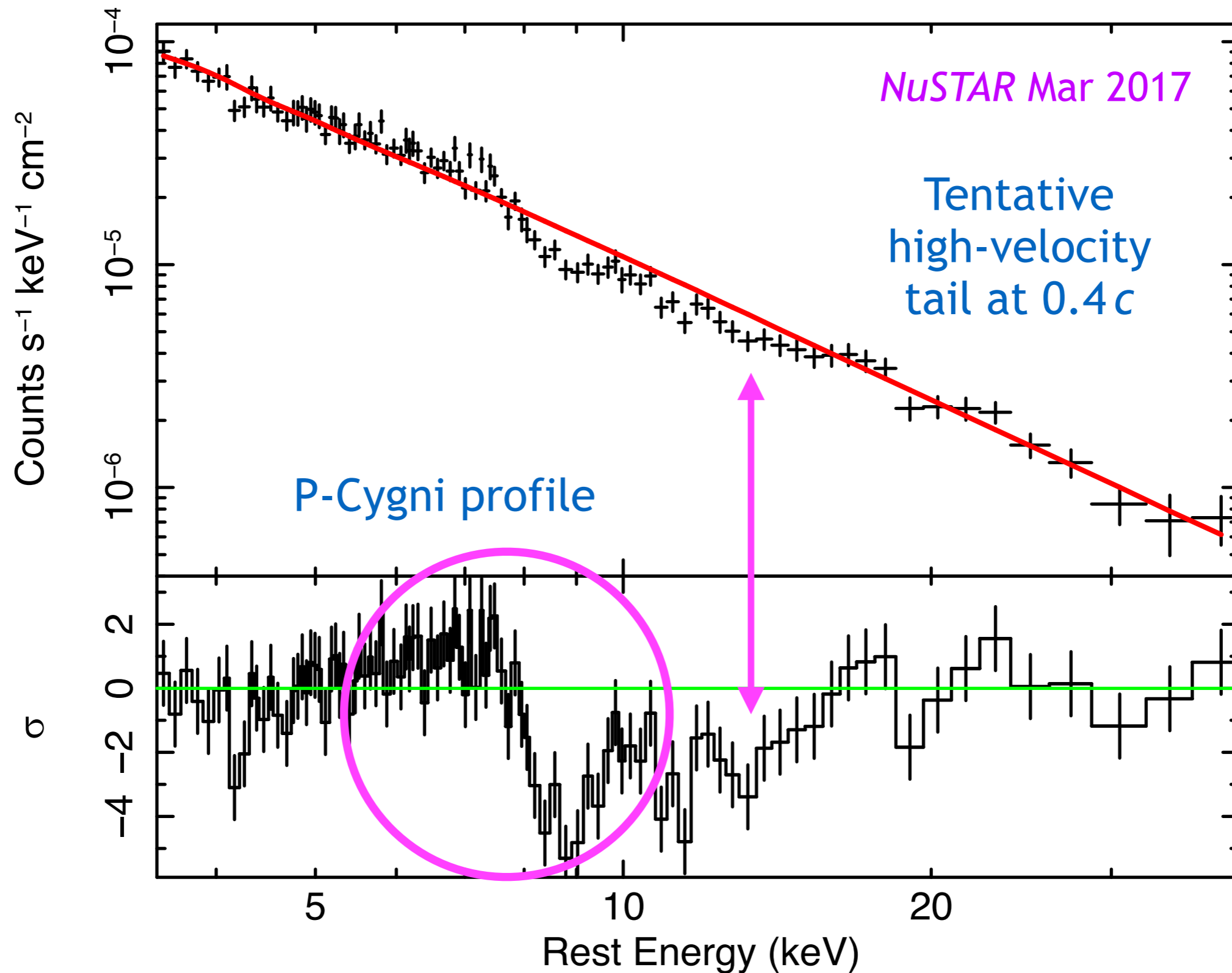
The new observations (2017)
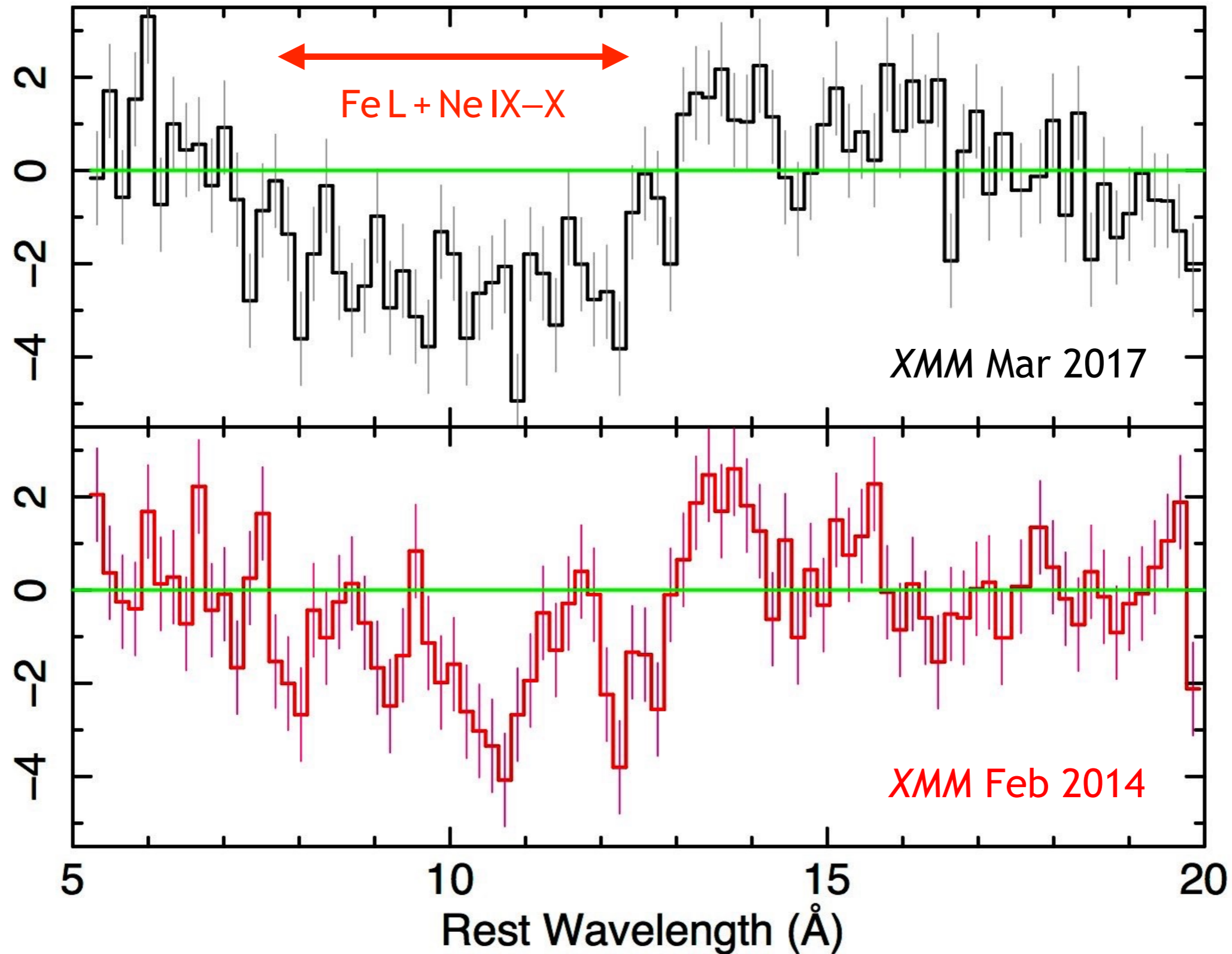
The new observations (2017)

Summary

★ Galaxy-wide outflows observed in a large number of AGN at high redshift must be powered by the energy released during the central SMBH accretion process

★ The initial stage of SMBH winds is hard to probe in X-ray faint sources, so the trigger of AGN feedback at the peak of the quasar epoch remains rather obscure

★ PDS 456 is a genuine counterpart of the brightest quasar population (e.g. the *WISSH* sample) where the effects of AGN feedback are expected to be the most dramatic

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★ Coming next: simultaneous UV to hard X-ray view of the wind (*XMM/NuSTAR/HST*, PI: Reeves); 6 months of daily/weekly monitoring (*Swift*, PIs: Nardini/Braito); search for molecular outflow phase (*ALMA*, PI: Piconcelli); ongoing effort on morphology and wind's driving mechanism