Discovery of powerful winds in ultraluminous X-ray sources

Ciro Pinto

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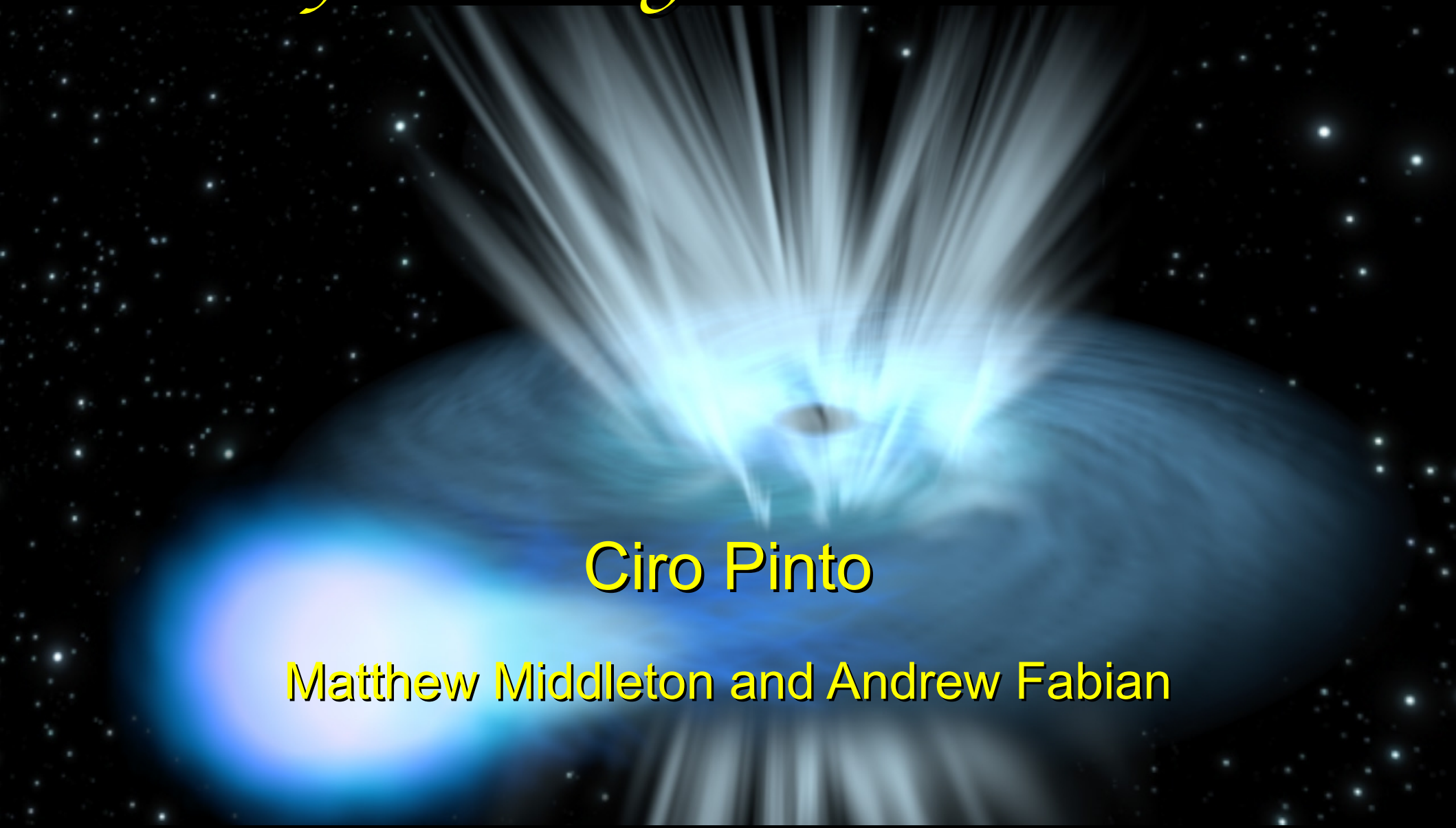
Pinto, Middleton & Fabian 2016, Nature 533, 64

Cambridge X-Ray Astronomy

Super-Eddington driven winds



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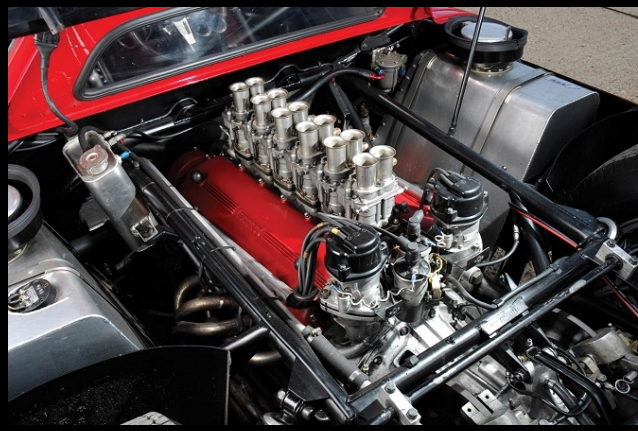
Cambridge X-Ray Astronomy

Super Eddington accretion on BH, NS: a powerful engine



$L_X \sim 10^{39–40}$ erg/s

Radio jets, variability, eclispes, and binary periods, pulsar

(e.g. Middleton+2011, Motch+2014, Cseh+2015, Urquhart & Soria 2016, Bachetti+14)

(Shakura Sunyaev '73, Poutanen+07)

$\rightarrow \rightarrow \rightarrow$ *powerful winds?*

(King & Muldrew 2015)

BUT: missing direct evidence

Soft X-ray features in CCD spectra

Soria+04 ..... NGC 5408 X-1

Goad+06 ..... Holmberg II X-1

Roberts+06 ..... NGC 5204 X-1 (Chandra)

Stobbart+06 ..... Holmberg II-IX X-1
M 33 X-8, M 83 ULX
NGC 55 ULX, NGC 1313 X-1,2
NGC 2403-3628-4395 X-1
NGC4559-4861-5204 X-1

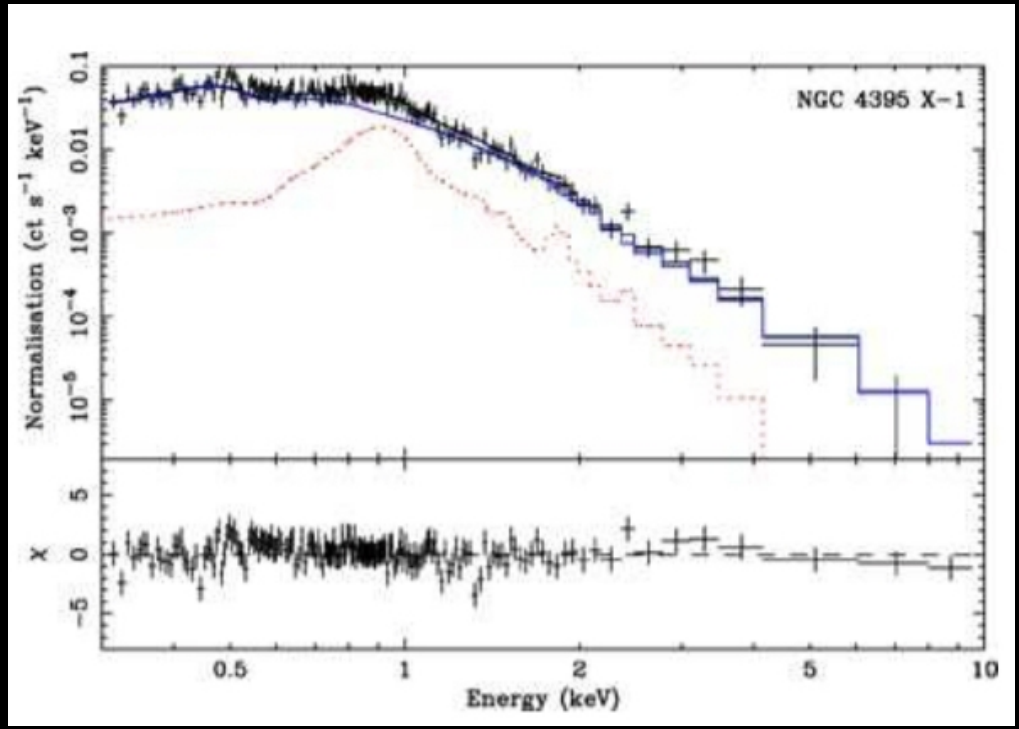
Soria+07 ..... NGC 1365 X-1, X-2

Gladstone09 ..... Same as Stobbart + IC 342 X-1, M 81 X-6

Bachetti+13 ..... NGC 1313 X-1,2

Middleton+14 .... NGC 5408-6946 X-1

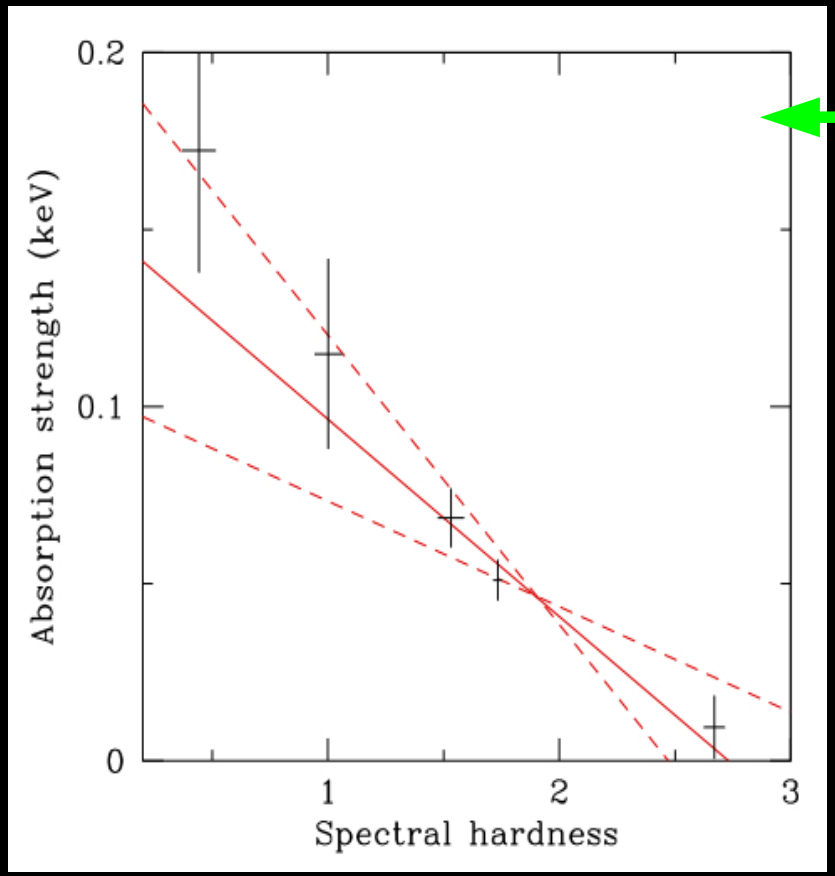
Sutton+15 ..... NGC 5408 X-1 (Chandra)



Stobbart et al. 2006

(also H. Earnshaw talk's on ULSs!)

Shape & ubiquity



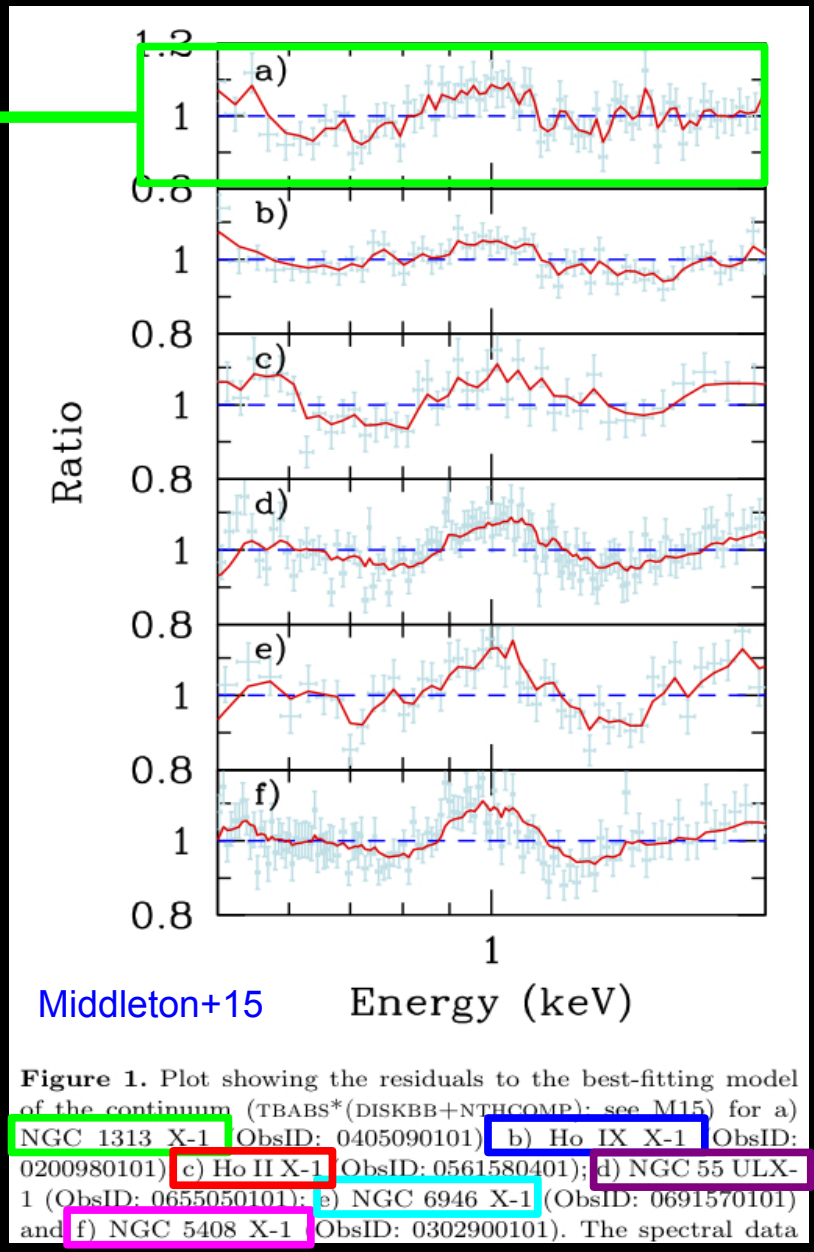
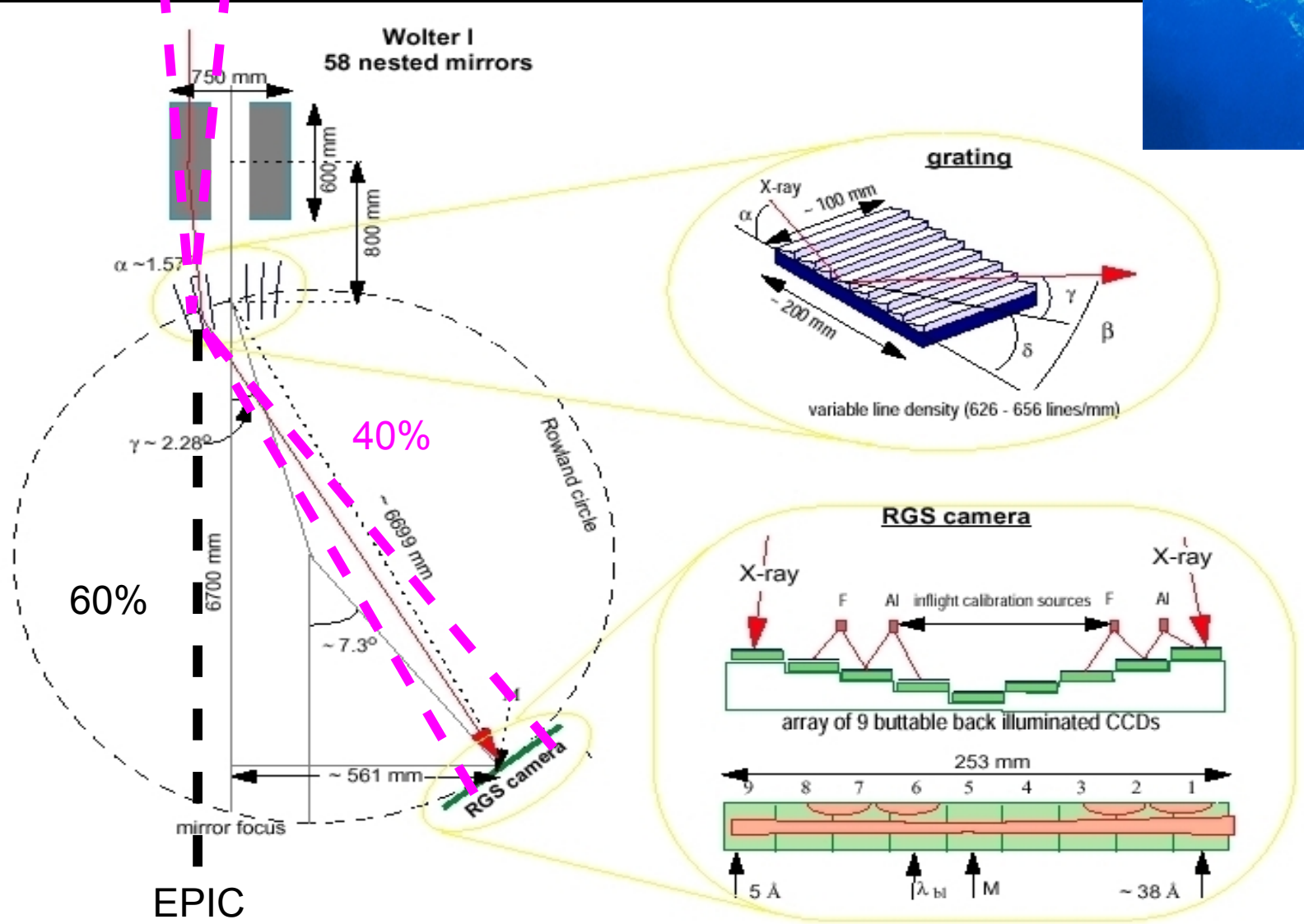


Figure 1. Plot showing the residuals to the best-fitting model of the continuum (TBABS*(DISKBB+NTHCOMP); see M15) for a) NGC 1313 X-1 (ObsID: 0405090101) b) Ho IX X-1 (ObsID: 0200980101) c) Ho II X-1 (ObsID: 0561580401); d) NGC 55 ULX-1 (ObsID: 0655050101); e) NGC 6946 X-1 (ObsID: 0691570101) and f) NGC 5408 X-1 (ObsID: 0302900101). The spectral data

1 keV emission / V_{out} ~0.1*c* absorber

No reflection, no diffuse emission, possibly L.O.S

XMM-Newton Reflection Grating Spectrometer (RGS)



Normally switched on when you observed with XMM / EPIC ...

Best targets for high-resolution X-ray spectroscopy

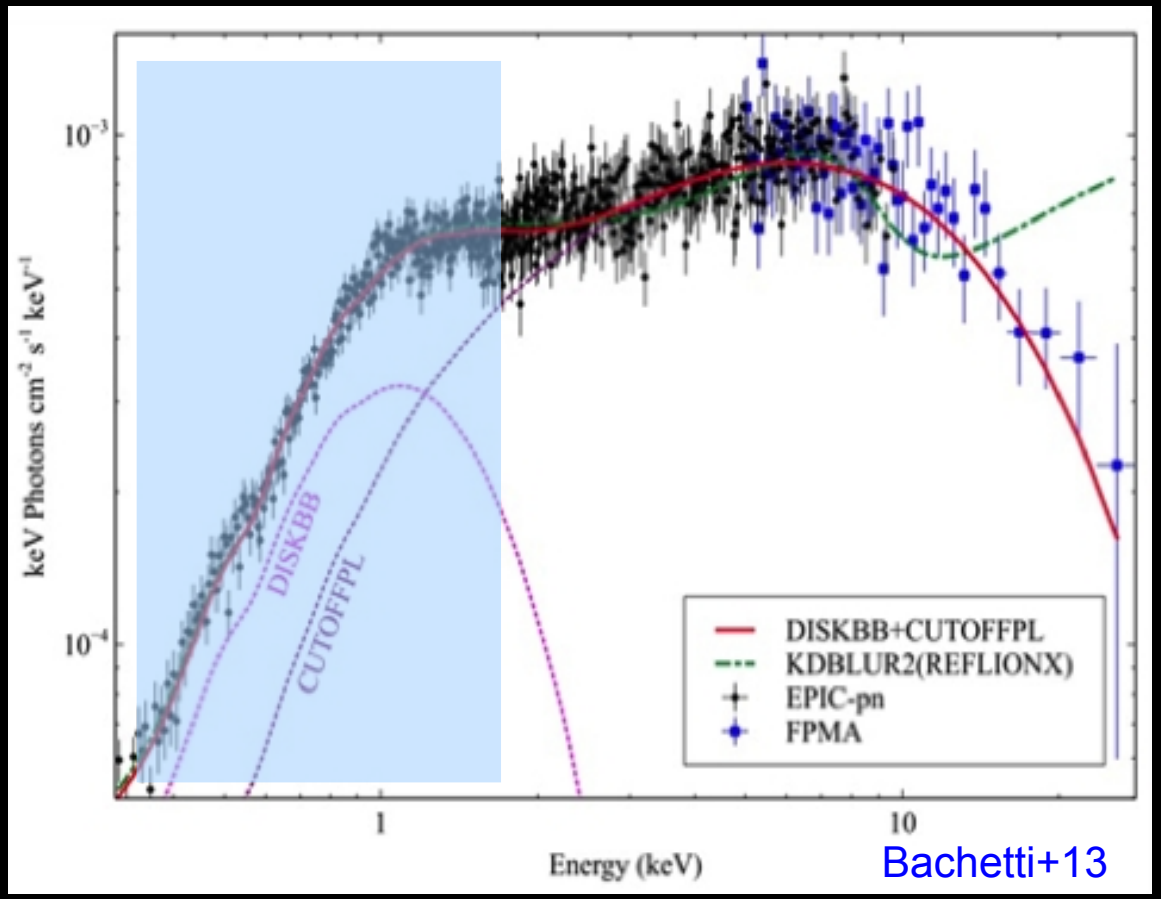
NGC 1313 X-1 NGC 5408 X-1

- Long on-axis (350 ks, 650ks) exposures
- Bright, nearby, ULX "prototypes"
- Luminous soft states

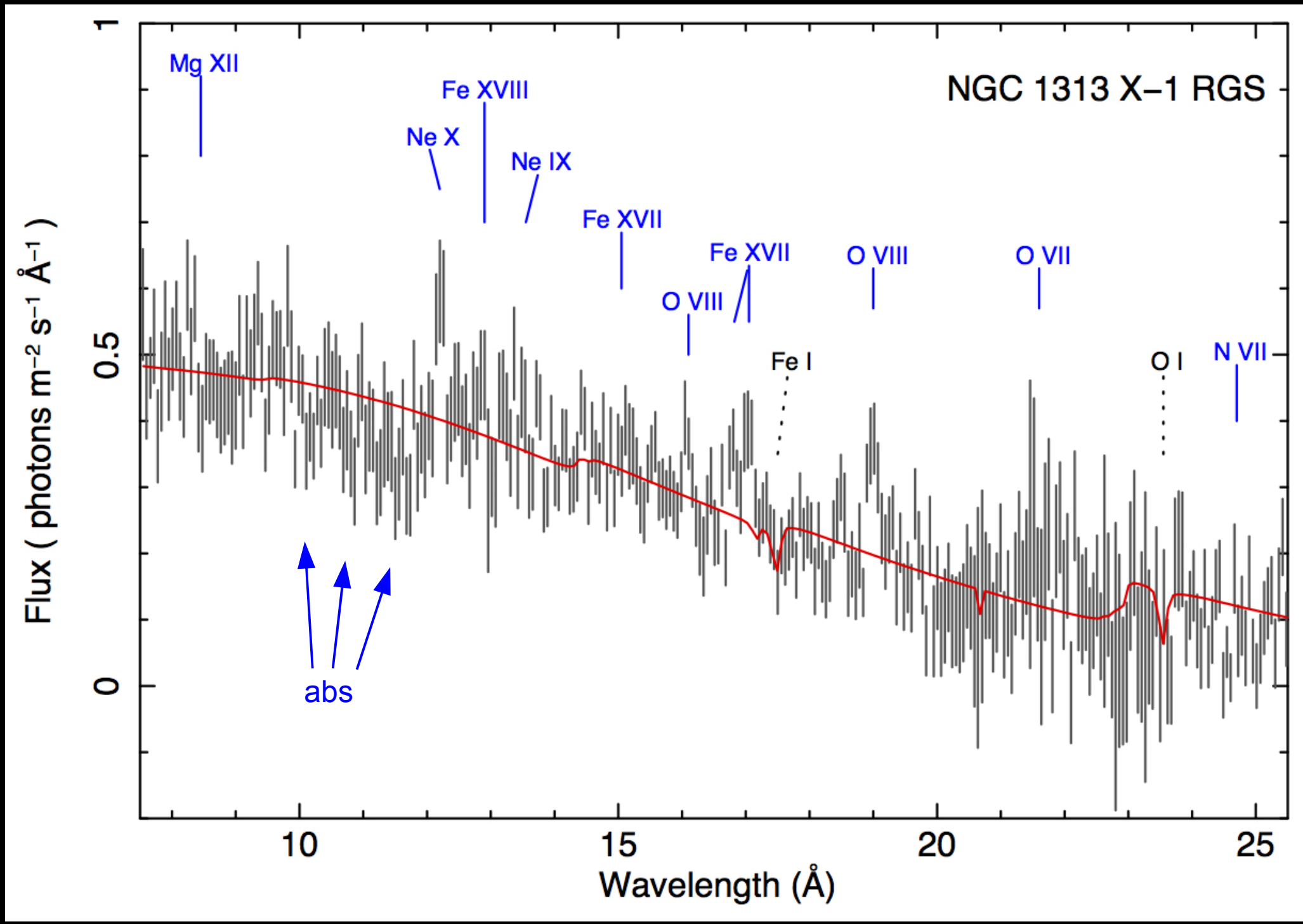
Spectral analysis of NGC 1313 X-1

Continuum: EPIC + RGS

Features: RGS



Bachetti+13



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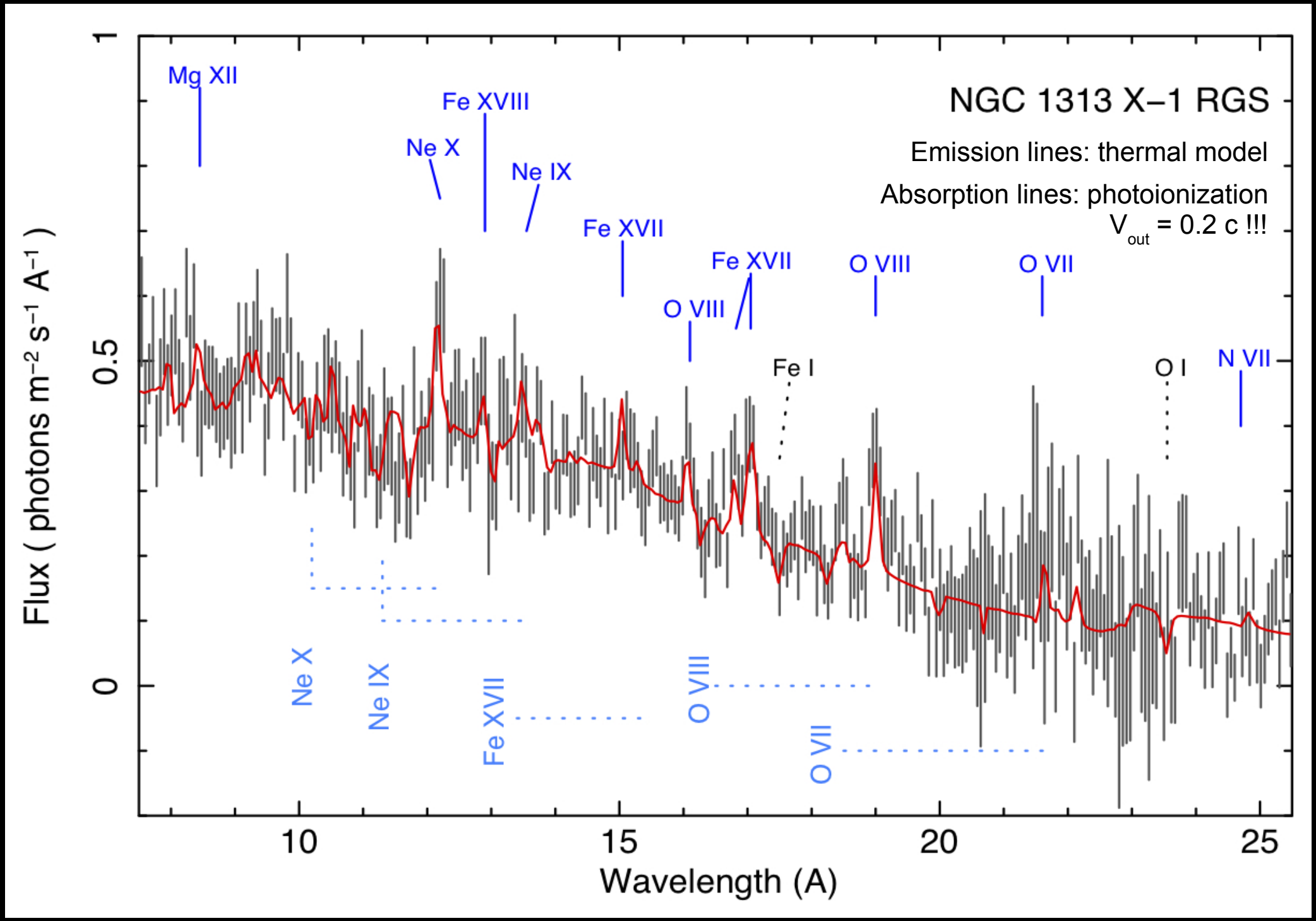

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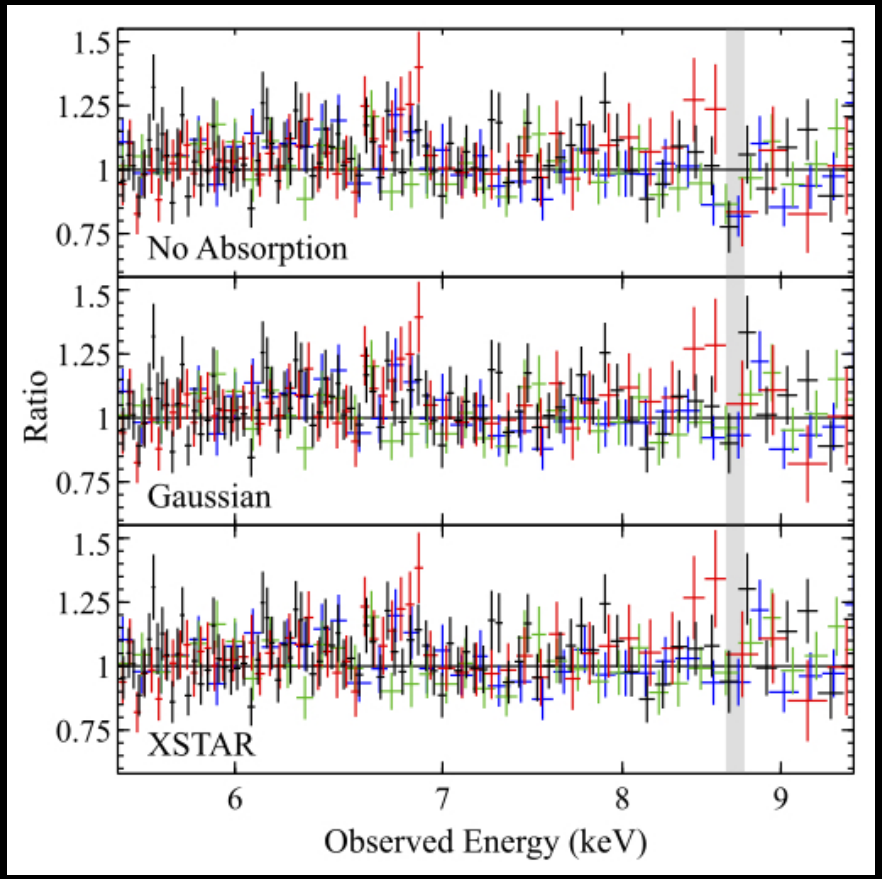
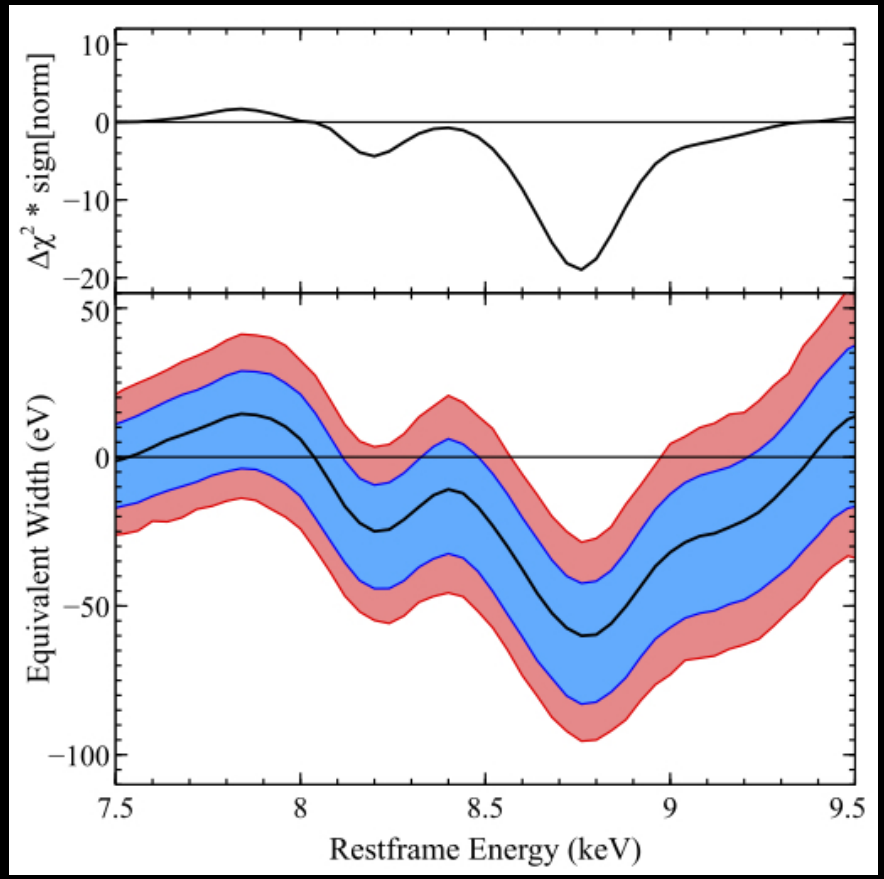
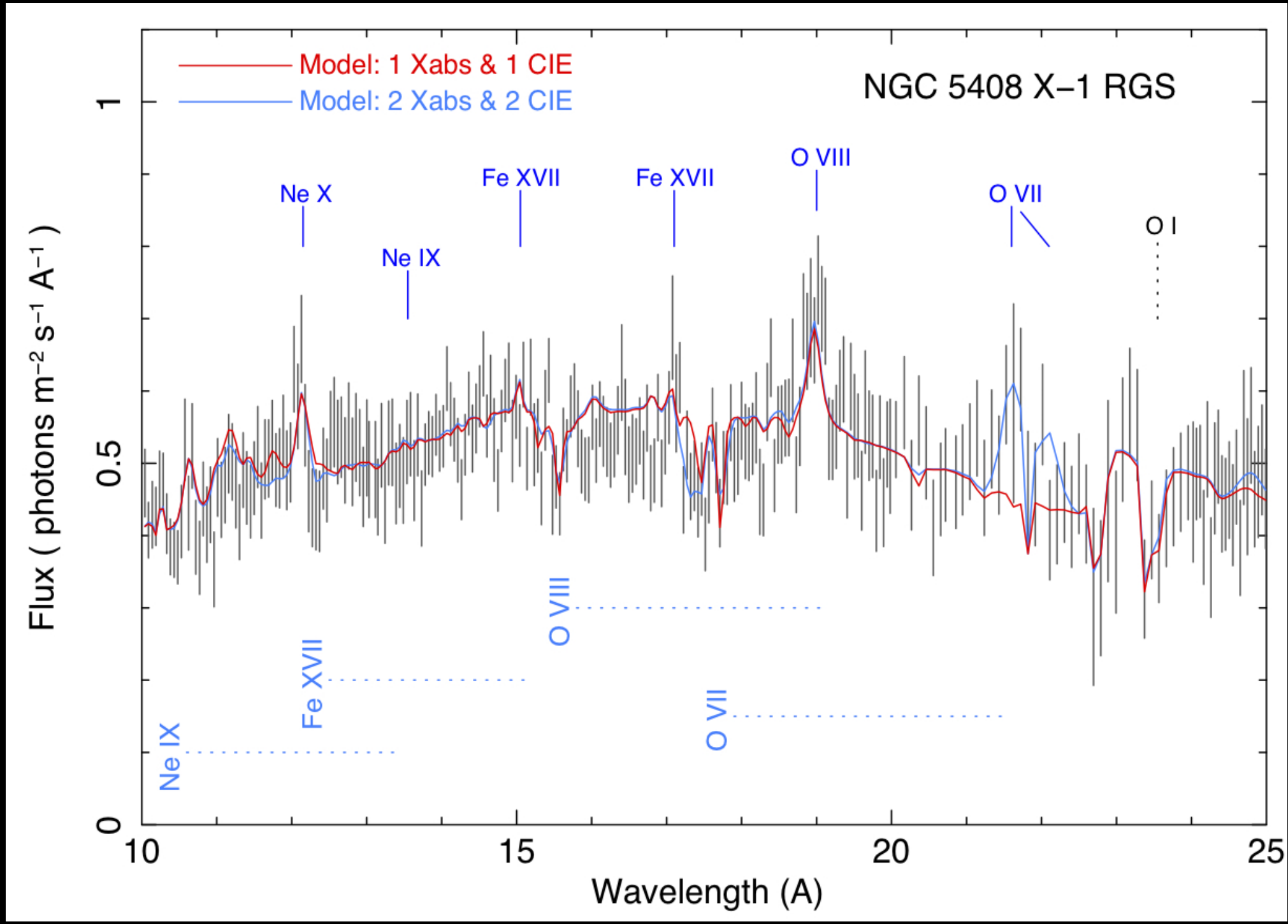
NGC 1313 X-1: Fe K UFO counterpart

XMM-Newton / EPIC & MOS , NuSTAR
show Fe K component at 0.2c



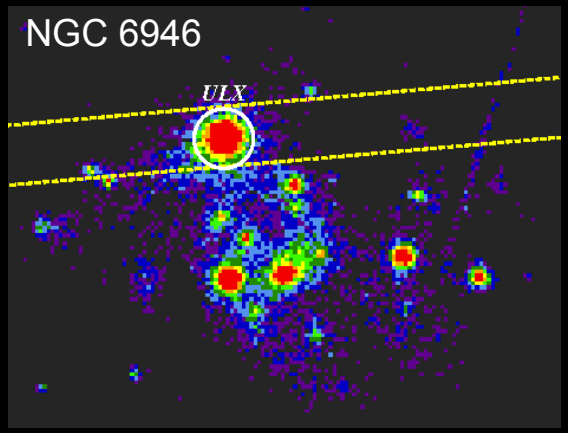


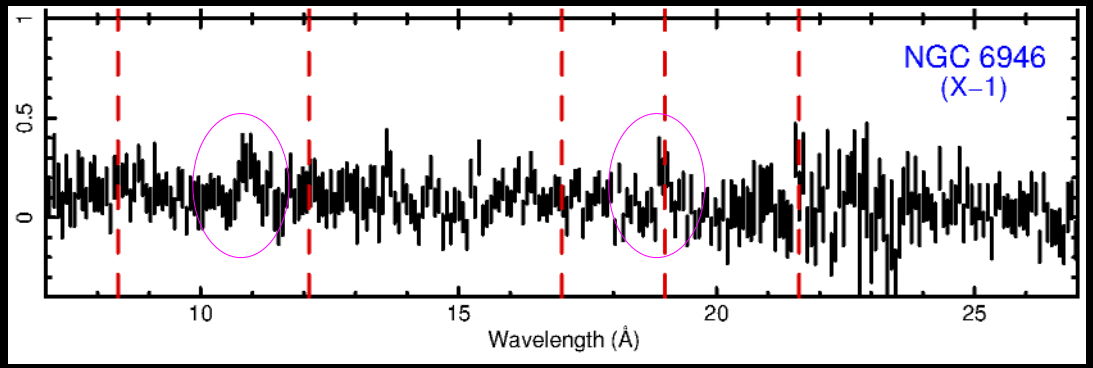
Walton et al. (2016)



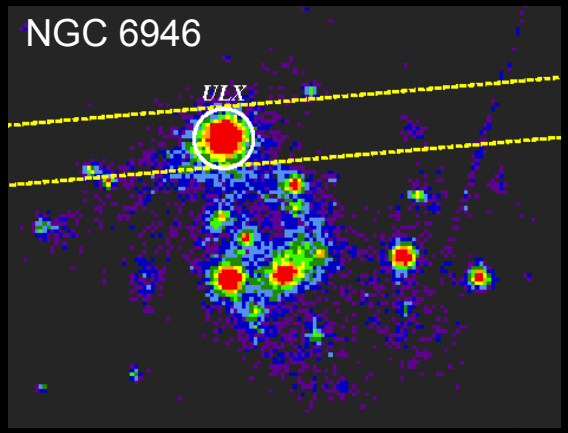
Pinto, Middleton and Fabian (2016, Nature 533, 64)

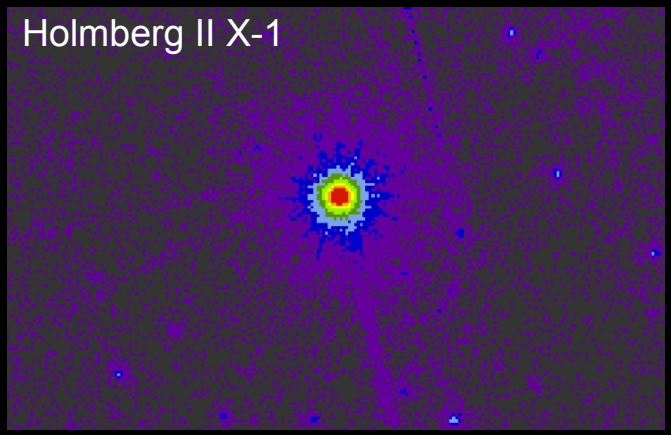
Other ULXs

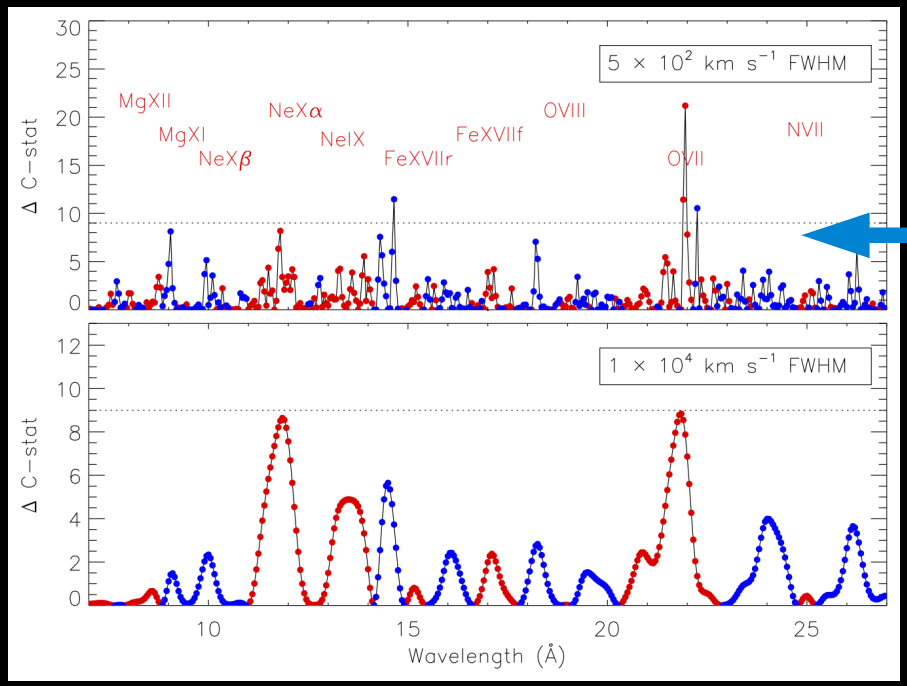


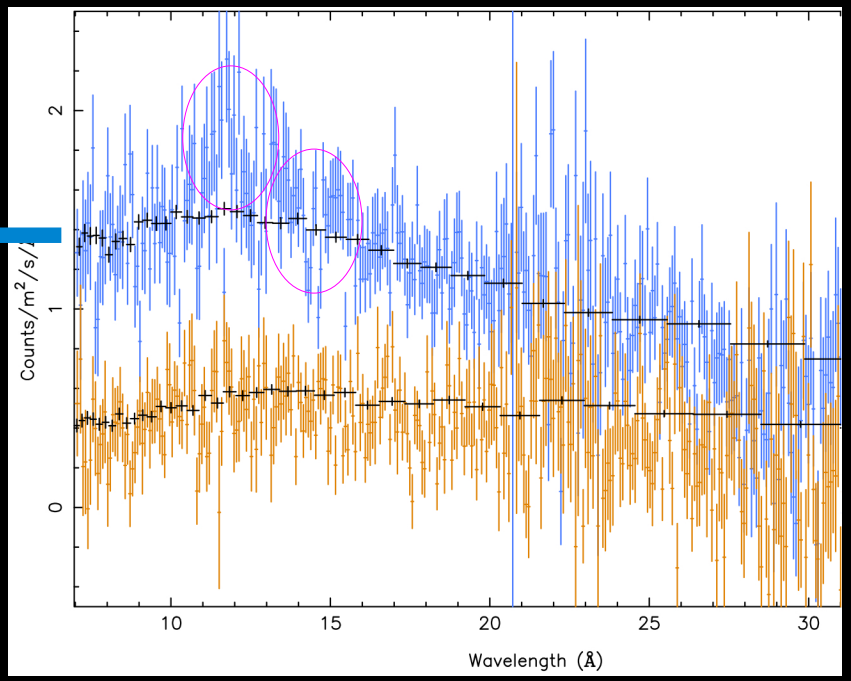


Other ULXs

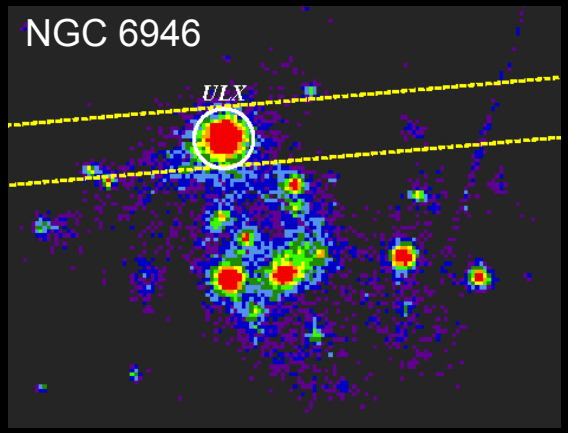

NGC 6946
ULX

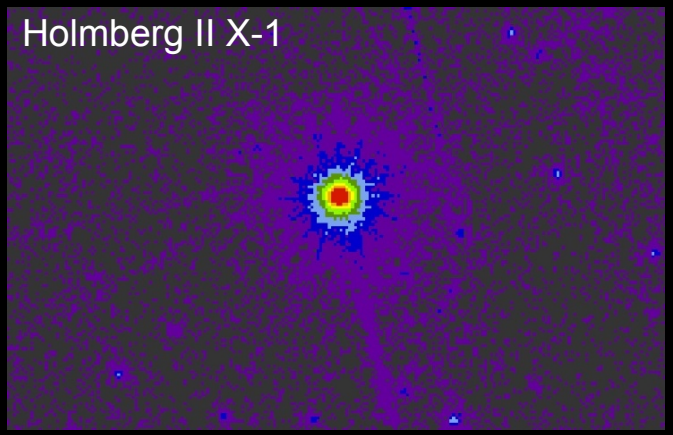

Holmberg II X-1

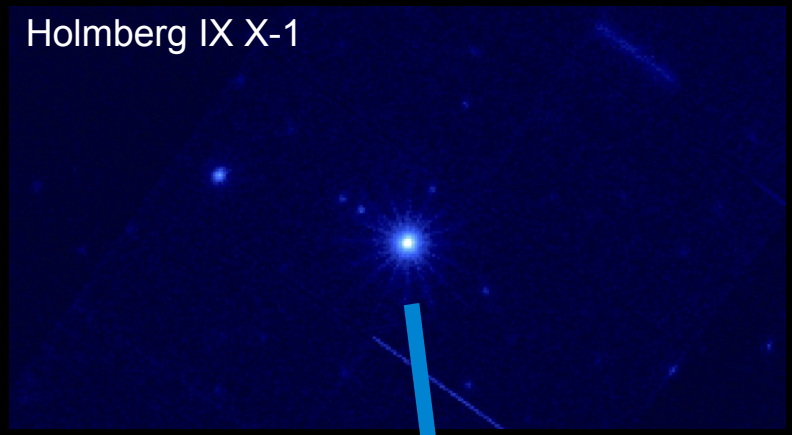

5 × 10² km s⁻¹ FWHM
MgXII
MgXI
NeXβ
NeXα
NeIX
FeXVIIr
FeXVIIf
OVIII
OVII
NVII
Δ C−stat
1 × 10⁴ km s⁻¹ FWHM
Wavelength (Å)

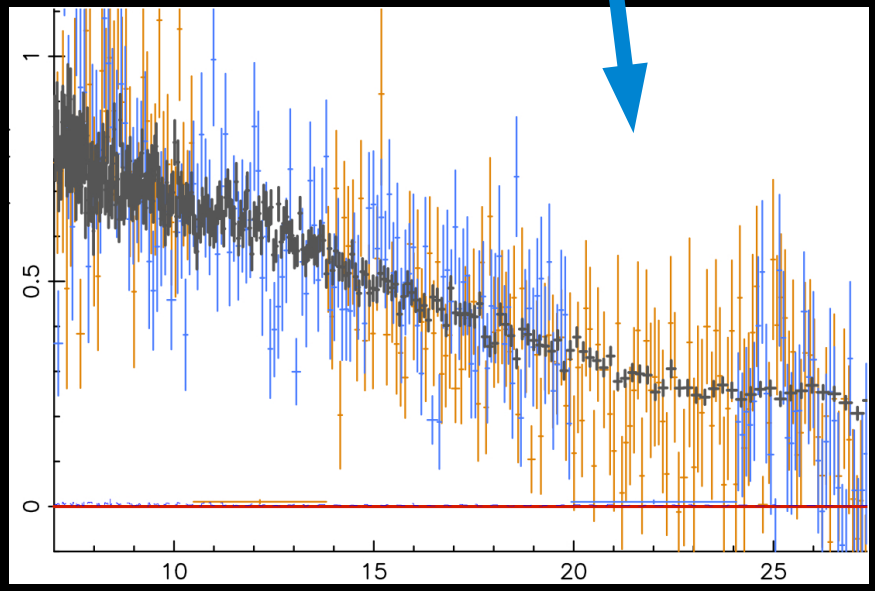

Counts/m²/s/
Wavelength (Å)

Other ULXs

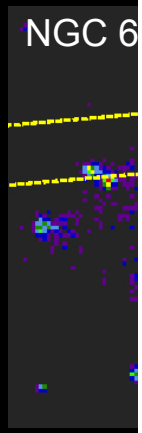


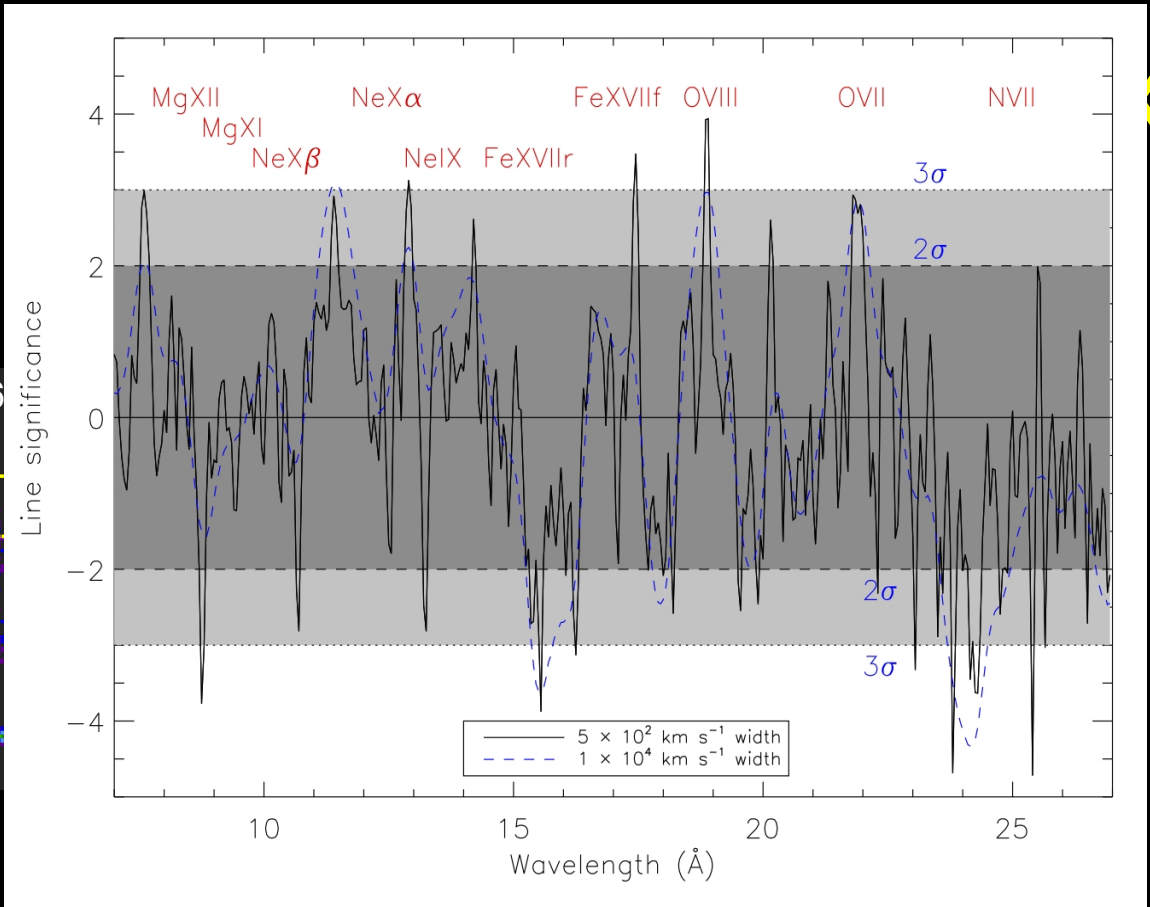


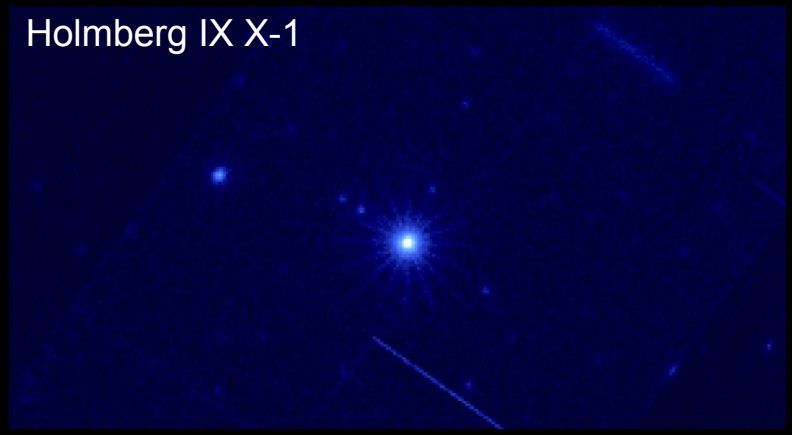


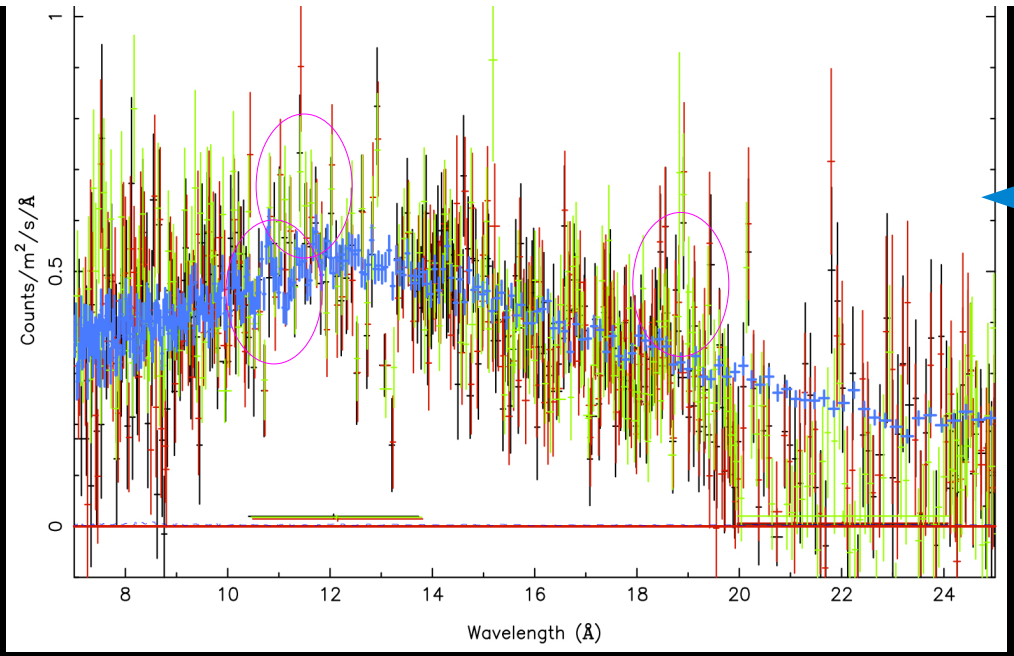


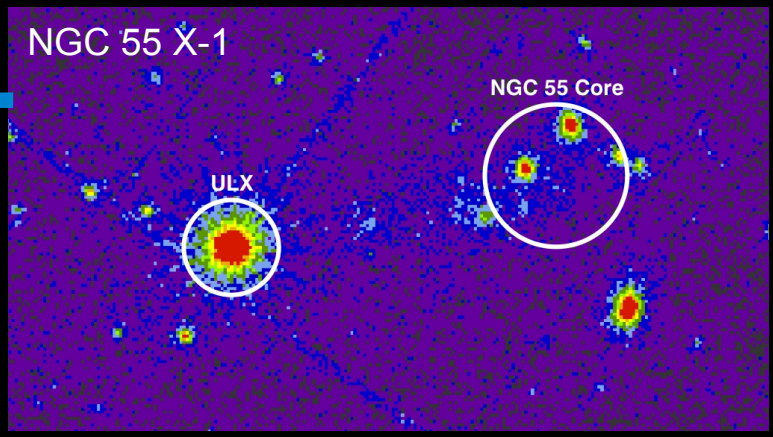
ULXs


NGC 6


MgXII
MgXI
NeXα
NeXβ
NeIX
FeXVIIr
FeXVIIf
OVIII
OVII
NVII
3σ
2σ
2σ
3σ
Line significance
Wavelength (Å)
5 × 10² km s⁻¹ width
1 × 10⁴ km s⁻¹ width


Holmberg IX X-1


Counts/m²/s/Å
Wavelength (Å)


NGC 55 X-1
NGC 55 Core
ULX

Ultra-Fast Outflows in ULXs !

Velocity (0.2*c*) ⟹ (much) Faster than XRBs

This gives justice to *super-Eddington* accretion !

(e.g. Poutanen+2007, King+2015)

Emission lines from slow-moving gas
a) colliding wind (Cooke+78/Oskinova+05)
b) photoionization of distant gas

Flux ~ (M_{BH}^{-1} , V^{-1}) favors small masses & velocities

(Xu & Cao 2016)

Line of sight & wind detection

Fully ionized?

Ho IX X1

Emission ~ Absorption

NGC 1313 X1

Emission > Absorption

NGC 5408 X1

Evacuated Funnel

Disk

Emission >> Absorption

Blueshifted Line emission, ULS

Conclusion and future

- RGS confirms, amplifies, and resolves EPIC feature:

  rest-frame emission + (relativistic) blueshifted absorption

- Consistent with *super-Eddington* accretion
- Variability suggests L.O.S origin

→ Extend to more 10++ ULXs:

(i.e. all with residuals in high-stat CCD spectra)

→ Investigate Feedback

→ Other missions: Chandra (hard) ~ 500 ks observations

Towards ATHENA & ASTRO-H2