X-ray observations of accretion disc winds in LMXBs

Maria Diaz Trigo

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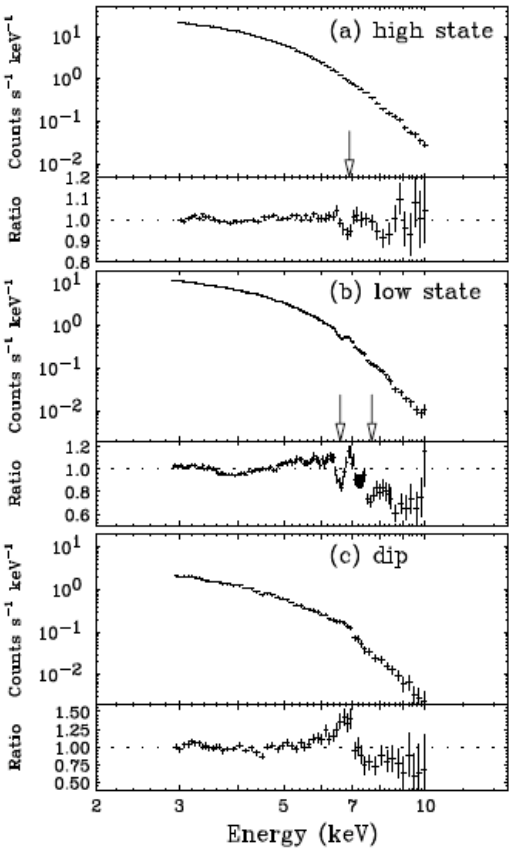
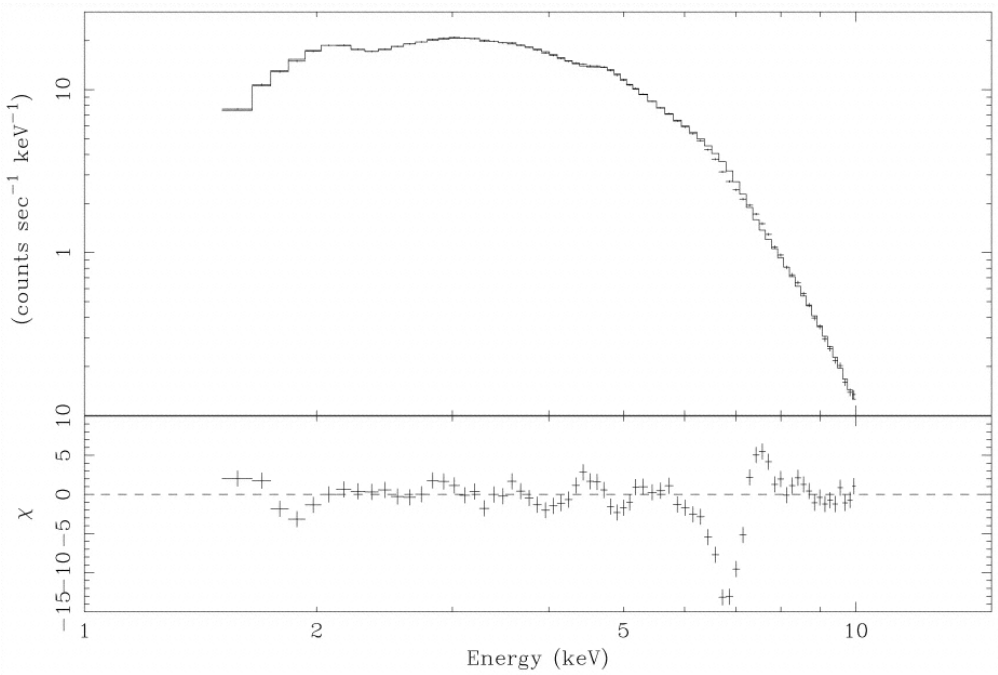
M. Mendez, J. Miller-Jones, S. Migliari, D. Russell, F. Rahoui)

A bit of history



GRO J1655-40, Ueda et al. 1998



GRS 1915+105, Kotani et al. 2000

Until 2015:

Source	P_{orb}	N_H^{Gal} 10^{21} cm^{-2}	NS	Dips	i (°)	log ξ < 3	log ξ ≥ 3	Flow	References on the warm absorbers
XB 1916−053	0.83 h	2.3	NS	D		x	x	atm	Boirin04, Juett06, Díaz Trigo06, Iaria06, Zhang14
1A 1744–361	1.62 h	3.1	NS	D			x	atm	Gavriil12
4U 1323−62	2.93 h	12	NS	D			x	no grat.	Boirin05, Church05, Bałucińska-Church09
EXO 0748−676	3.82 h	1.0	NS	D		x	x	atm	Díaz Trigo06, van Peet09, Ponti14
XB 1254−690	3.93 h	2.0	NS	D			x	atm	Boirin03, Díaz Trigo06/09 , Iaria07
MXB 1658−298	7.11 h	1.9	NS	D		x	x	atm	Sidoli01, Díaz Trigo06
XTE J1650−500	7.63 h	4.2			> 50	?[a]	?[b]	?[c]	Miller02/04
AX J1745.6-2901	8.4 h	12	NS	D			x	no grat.	Hyodo09, Ponti15
MAXI J1305–704	9.74 h[d]	1.9		D		x		in	Shidatsu13, Miller14
X 1624−490	20.89 h	20	NS	D			x	atm	Parmar02, Díaz Trigo06, Iaria07b, Xiang09
IGR J17480–2446	21.27 h[e]	6.5	NS	D			x	out	Miller11
GX 339−4	1.76 d	3.6			> 45[f]	x		?[g]	Miller04, Juett06
GRO J1655−40	2.62 d	5.2		D			x	out	Ueda98, Yamaoka01, Miller06b/08, Netzer06, Sala07, Díaz Trigo07, Kallman09, Luketic10, Neilsen12
Cir X−1	16.6 d	16	NS	D		x	x	out	Brandt00, Schulz02, , D'Aí07, Iaria08, Schulz08
GX 13+1	24.06 d	13	NS	D			x	out	Ueda01/04, Sidoli02, Díaz Trigo12, Madej14, D'Ai14
GRS 1915+105	33.5 d	13		D			x	out	Kotani00, Lee02, Martocchia06, Ueda09/10, Neilsen09/11/12
IGR J17091–3624	>4 d[h]	5.4			> 53[i]		x	out	King12
4U 1630−47		17		D			x	out	Kubota07, Díaz Trigo13/14, King13/14, Neilsen14
H 1743−322		6.9		D			x	out	Miller06a

Diaz Trigo & Boirin 2016

2016-2017:

V 404 Cyg (King et al. 2015)

GX 340+0 (Miller et al. 2016)

Observables

- Line width
- Line shift
- Line depth
- Line species
- Line shape (emission/ absorption/ P-Cygni)

- Velocity of the plasma (atmosphere/wind)
- Ionisation (stage/mechanism)
- Column density
- Density
- Temperature

- Launching radius
- Geometry

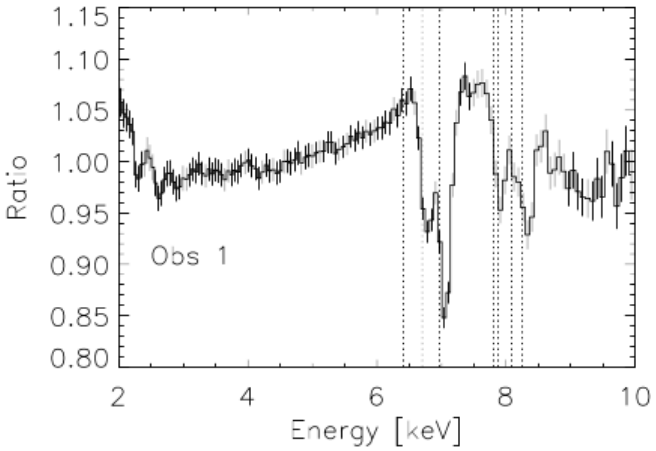
- Launching mechanism

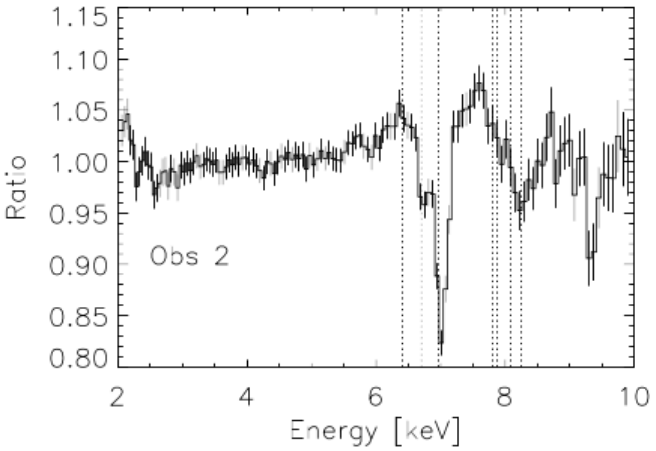
- Predictions about existence/observability in different accretion states

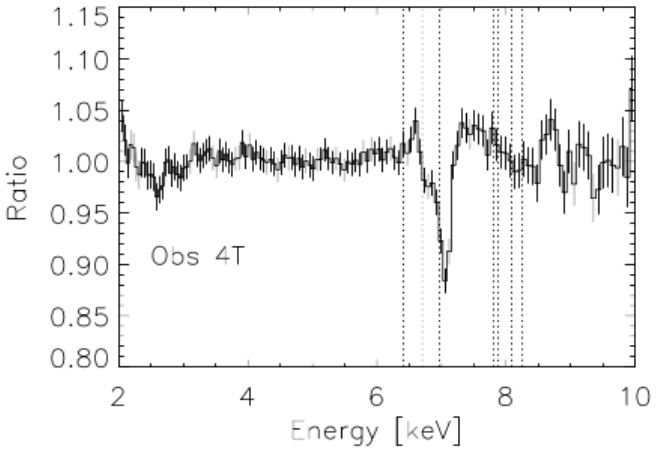
- Influence on other accretion components (e.g. jets) or on an accretion episode

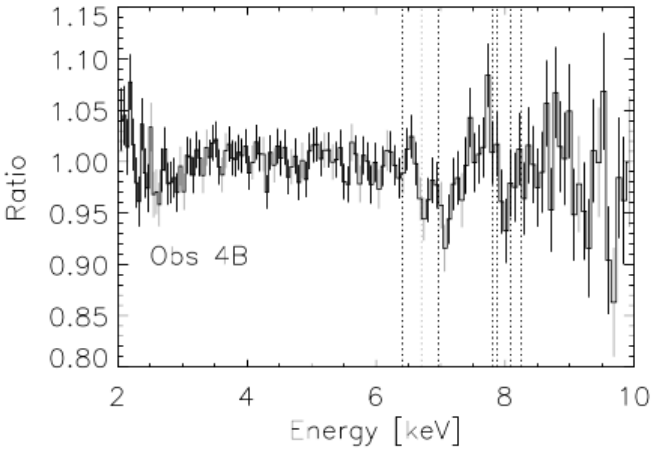
Observables

- Line identification/shift (more secure if several lines present)
- Ratio of Kβ to Kα lines (line saturation, column density)
- Ratio of Fe XXV to Fe XXVI and SED (ionisation of the plasma)

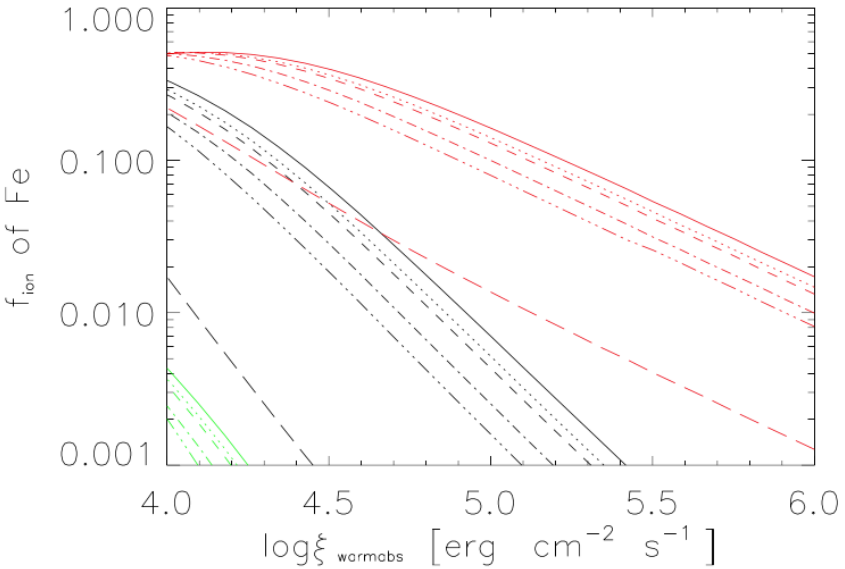


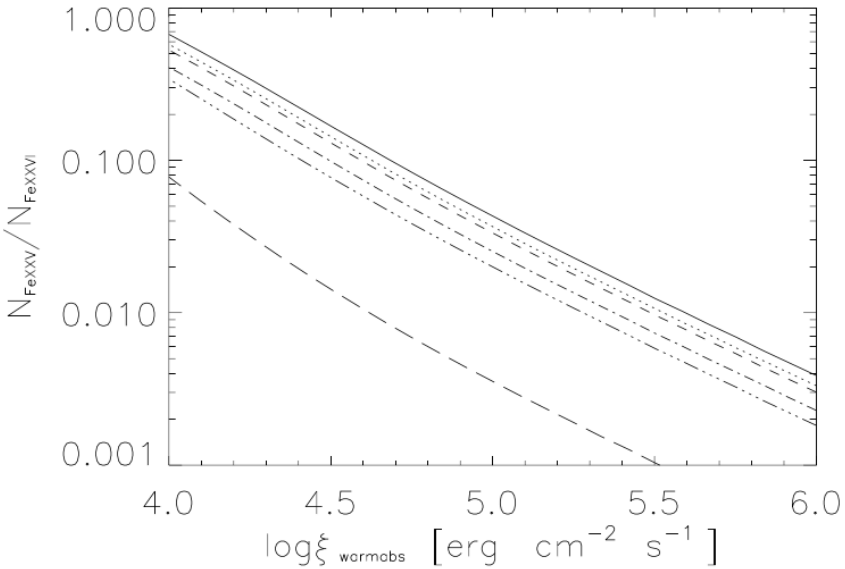






Observables



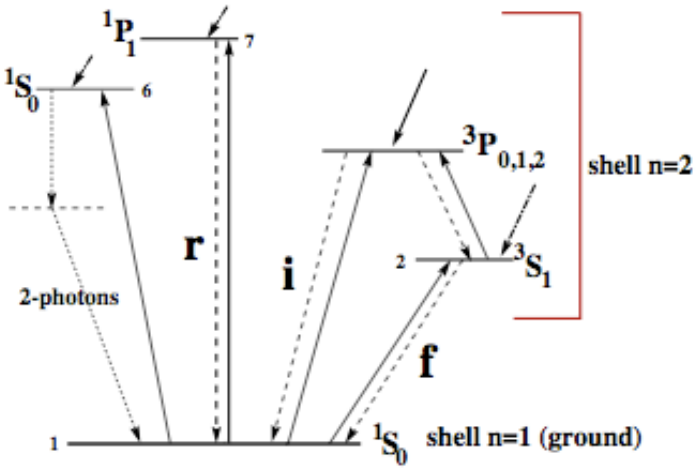


Diaz Trigo et al. 2014

Observables

- Lines associated with electronic transitions (mostly 1s–2p Ly) in H-like and He-like ions

  => Presence of a highly-ionised plasma in the system



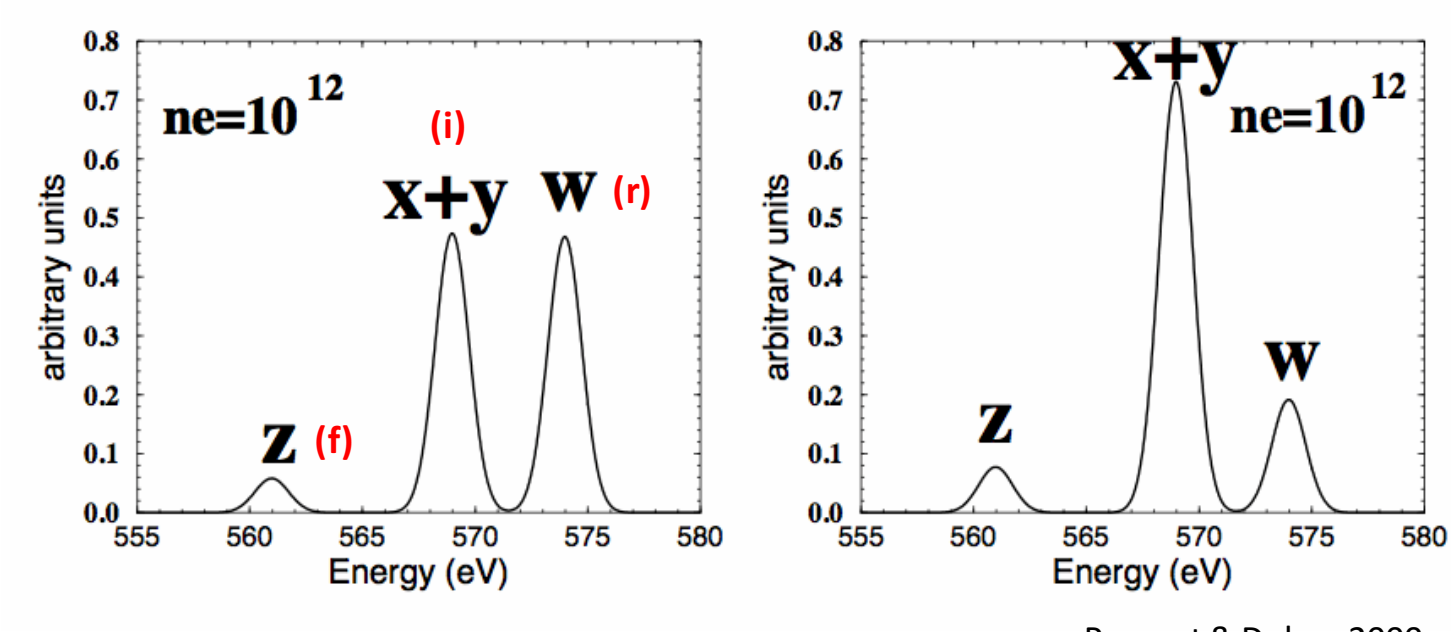
He-like atoms (e.g. OVII or Fe XXV)

- in absorption: the resonance line
- in emission: (the "triplet") resonance, intercombination, forbidden

Line ratios depend on the physical conditions of the plasma:

- collisional or photo-ionisation
- density
- temperature

Observables

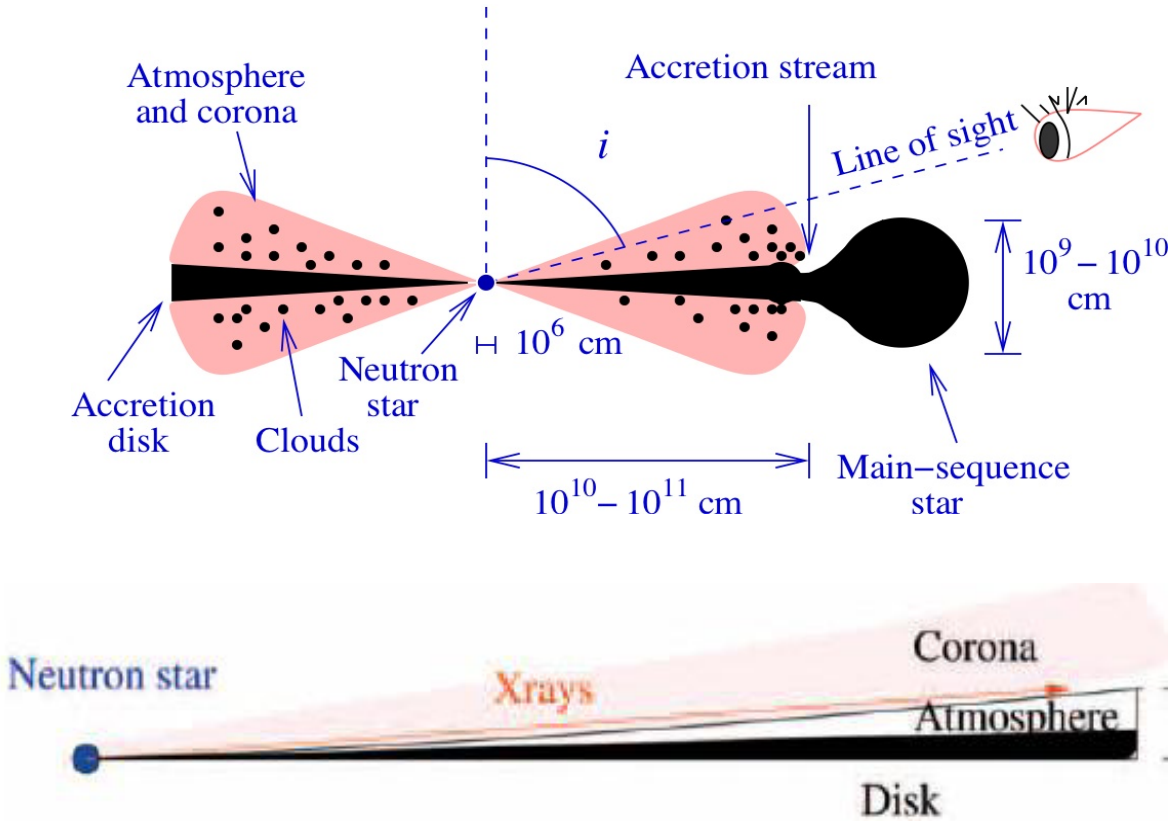


Porquet & Dubau 2000

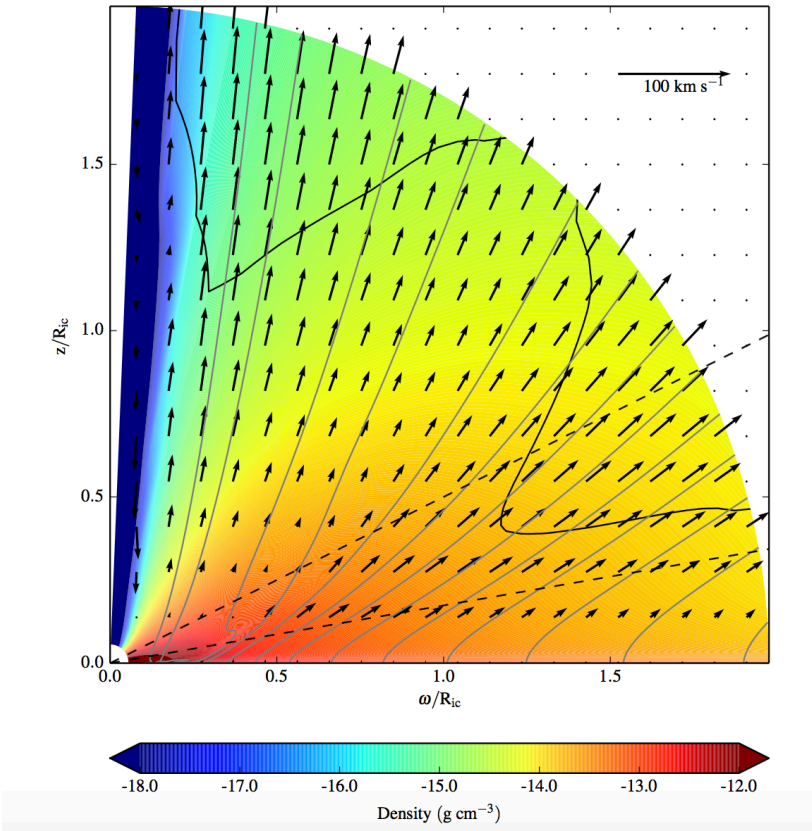
Hybrid plasma

Photoionised plasma

Geometry



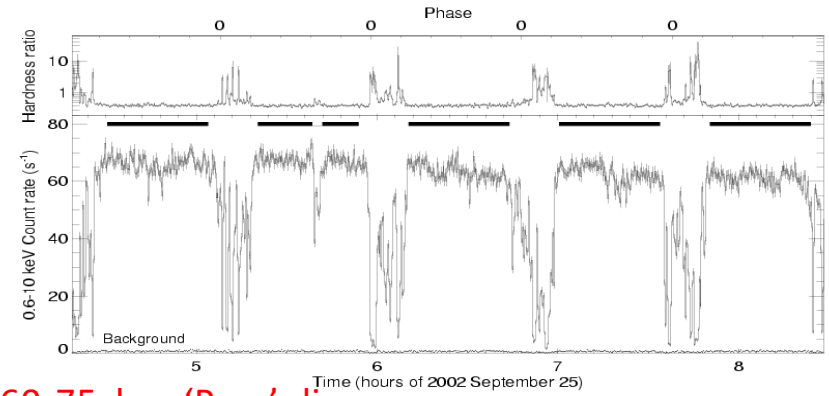
Jimenez Garate et al. 2002



Higginbottom & Proga 2015

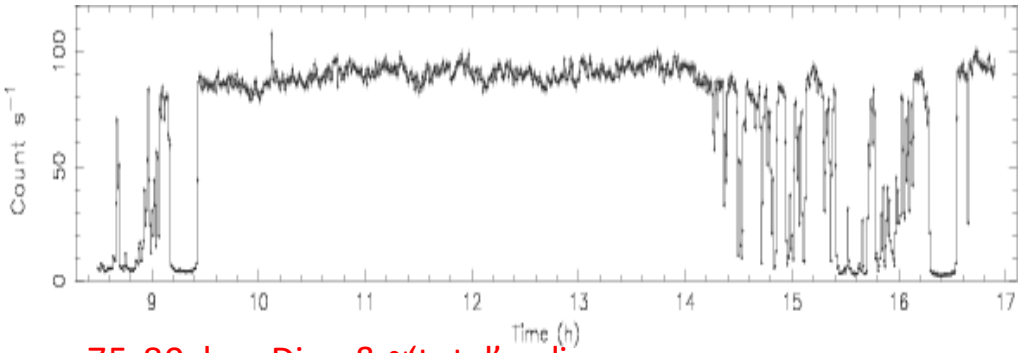
Geometry

84% are dippers (Diaz Trigo et al. 2006, Ponti et al. 2012)



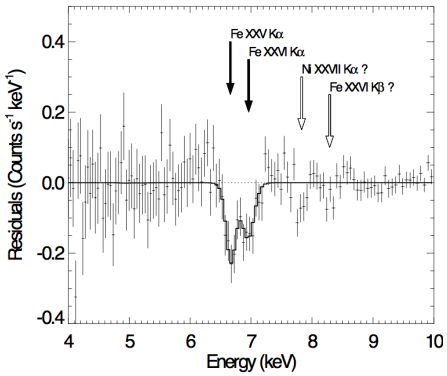
60-75 deg. 'Pure' dippers

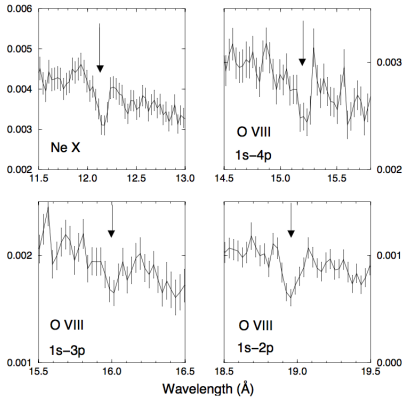
Boirin et al. 2004



75-80 deg. Dips & ~'total' eclipses

Sidoli et al. 2001





Geometry

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MXB 1658−298	7.11 h	1.9	NS	D		x	x	atm	Sidoli01, Díaz Trigo06
XTE J1650−500	7.63 h	4.2			> 50	?[a]	?[b]	?[c]	Miller02/04
AX J1745.6-2901	8.4 h	12	NS	D			x	no grat.	Hyodo09, Ponti15
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GX 339−4	1.76 d	3.6			> 45[f]	x		?[g]	Miller04, Juett06
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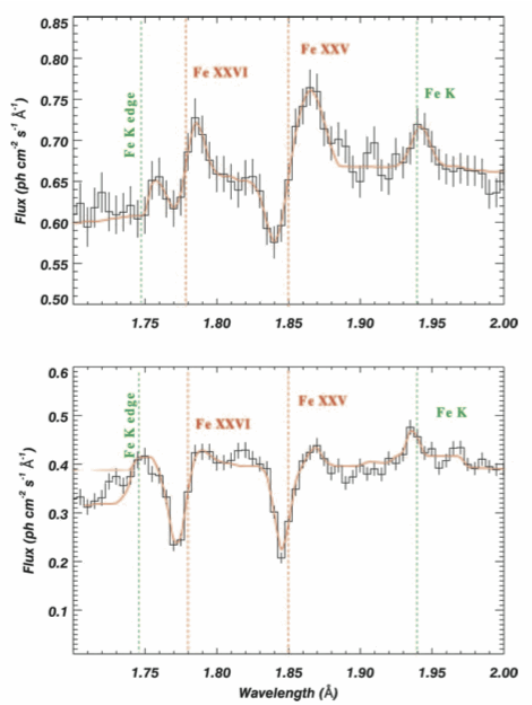
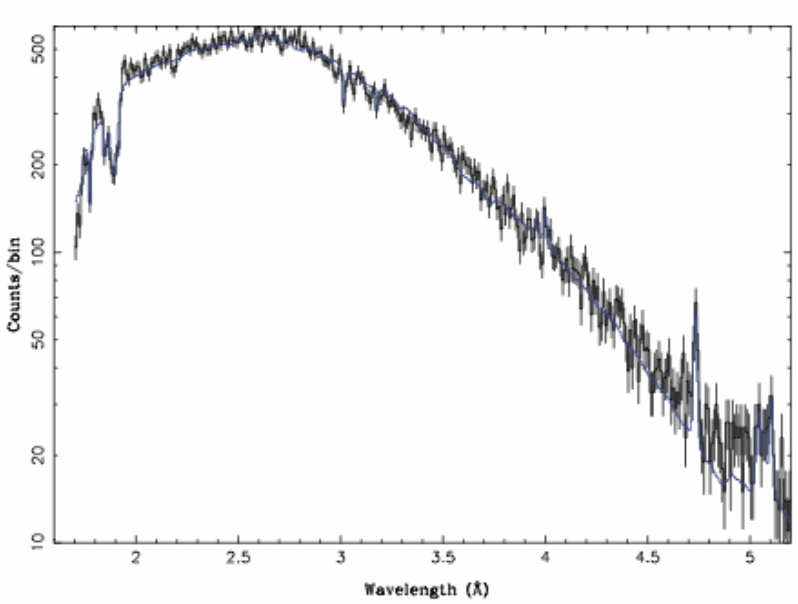
Diaz Trigo & Boirin 2016

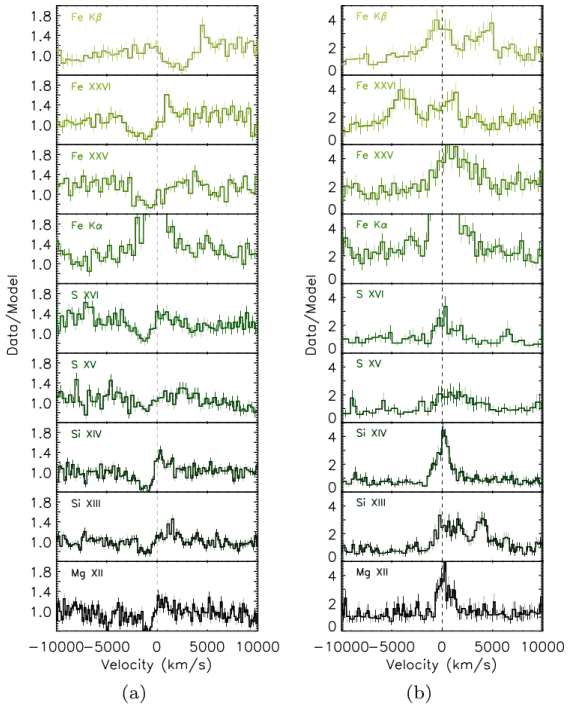
Geometry



Brandt & Schulz 2002



Schulz et al. 2008



King et al. 2015

Velocity of the plasma

100% of BHs vs 30% of NSs show winds

v ~ 200-3000 km/s (wind)

v <~ 200 km/s

(“atmosphere”, shift not measurable with current instruments)

Orbital period

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MXB 1658−298	7.11 h	1.9	NS	D		x	x	atm	Sidoli01, Díaz Trigo06
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GX 339−4	1.76 d	3.6			> 45[f]	x		?[g]	Miller04, Juett06
GRO J1655−40	2.62 d	5.2		D			x	out	Ueda98, Yamaoka01, Miller06b/08, Netzer06, Sala07, Díaz Trigo07, Kallman09, Luketic10, Neilsen12
Cir X−1	16.6 d	16	NS	D		x	x	out	Brandt00, Schulz02, , D'Aí07, Iaria08, Schulz08
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IGR J17091–3624	>4 d[h]	5.4			> 53[i]		x	out	King12
4U 1630−47		17		D			x	out	Kubota07, Díaz Trigo13/14, King13/14, Neilsen14
H 1743−322		6.9		D			x	out	Miller06a

Diaz Trigo & Boirin 2016

Velocity of the plasma

Challenges to determine velocities:

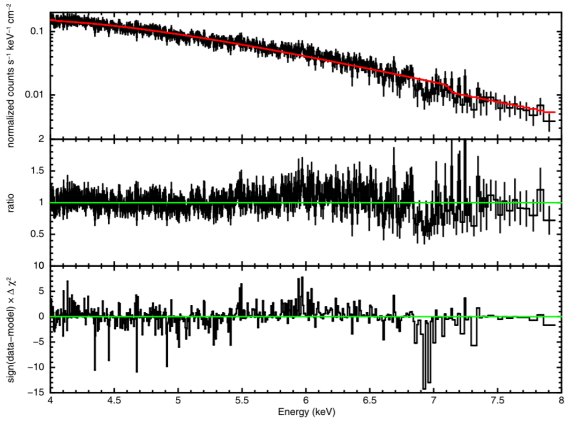
Line identification

Multiple velocities for a given ion

Low/high ionisation ions show (in general) small/large velocities

Line saturation

Line identification

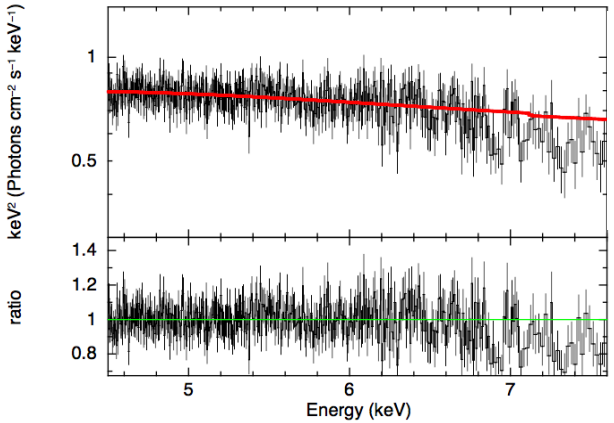


GX 340+0 (Miller et al. 2016)

6.94 +/- 0.02 keV (measured)

Fe XXV rest frame: 6.70 keV
Fe XXVI rest frame: 6.97 keV

(Interpreted as ultra-fast outflow with v=0.04c)

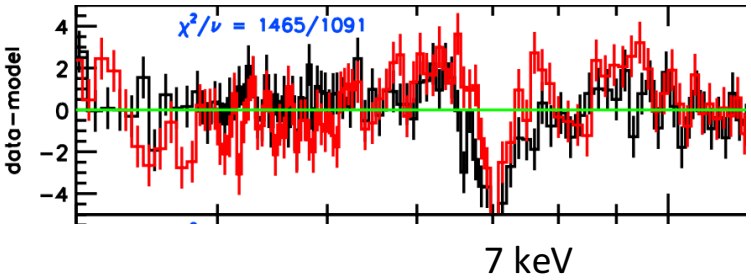


IGR J17091–3624 (King et al. 2012)

6.91 +/- 0.01 keV (measured)

Fe XXV rest frame: 6.70 keV
Fe XXVI rest frame: 6.97 keV

(Interpreted as ultra-fast outflow with v=0.03c)



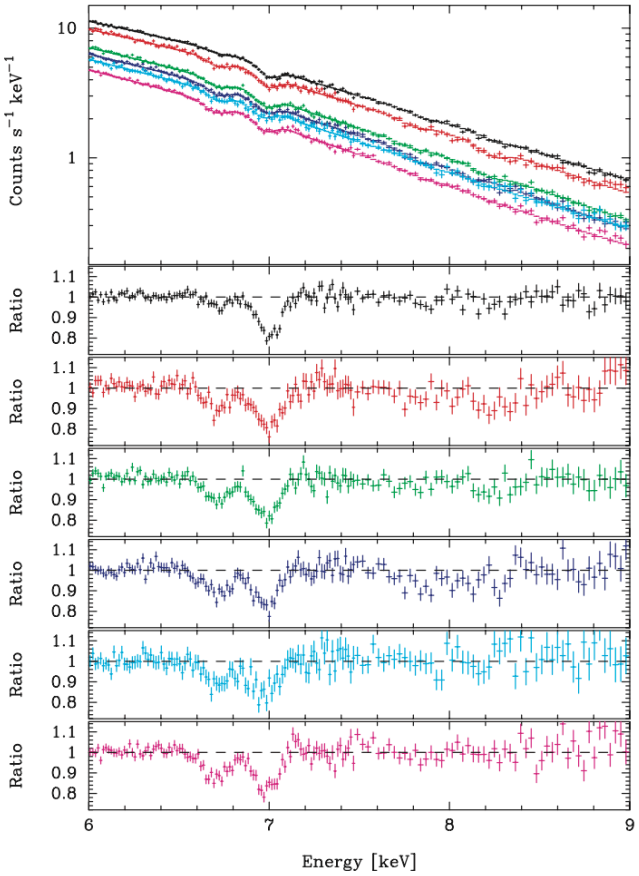
4U 1630-472 (King et al. 2014)

7.03+/- 0.03 keV (measured)

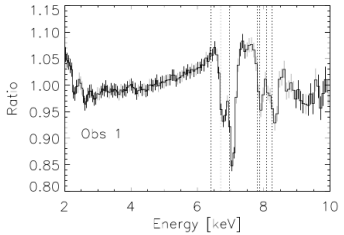
Fe XXV rest frame: 6.70 keV
Fe XXVI rest frame: 6.97 keV

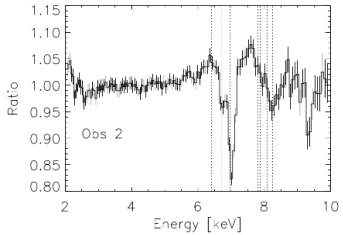
(Ultra-fast outflow with v=0.04c suggested)

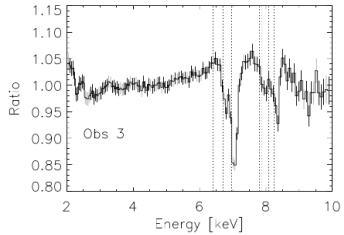
Line identification

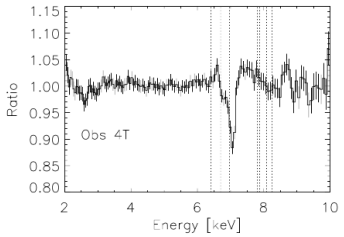


Kubota et al. 2007

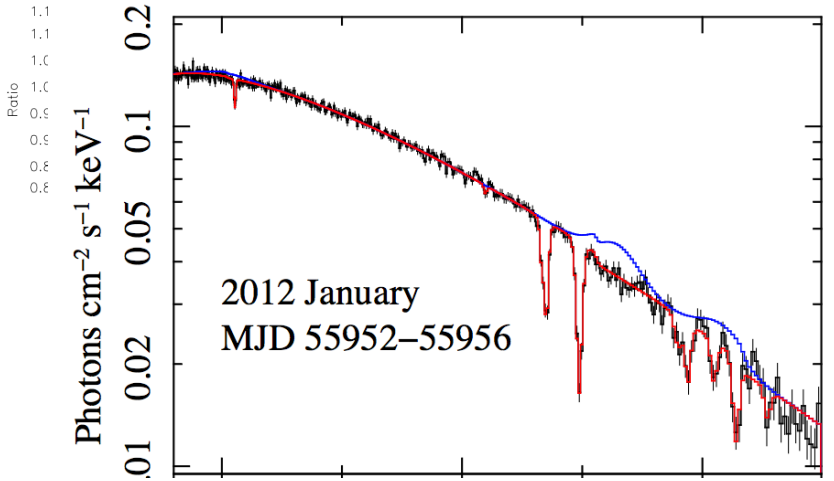






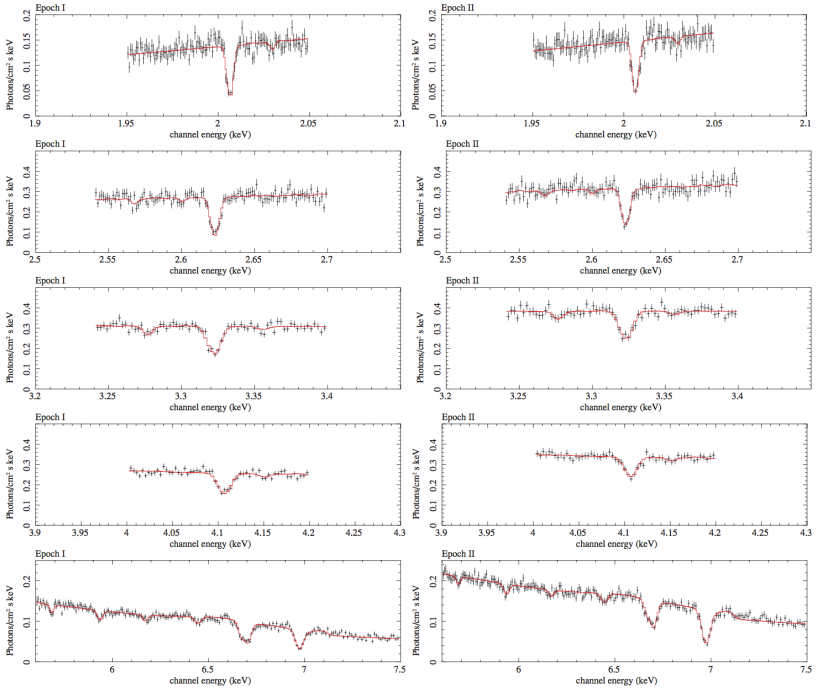


Diaz Trigo et al. 2014

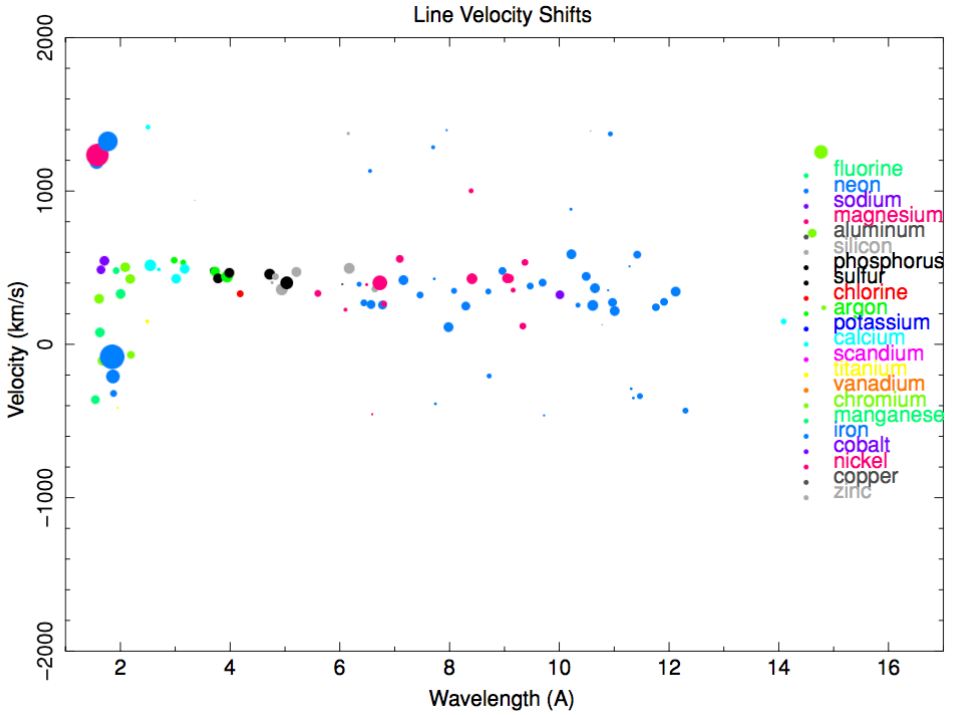


Neilsen et al. 2014

Velocity of the plasma



Ueda et al. 2009



Kallman et al. 2009

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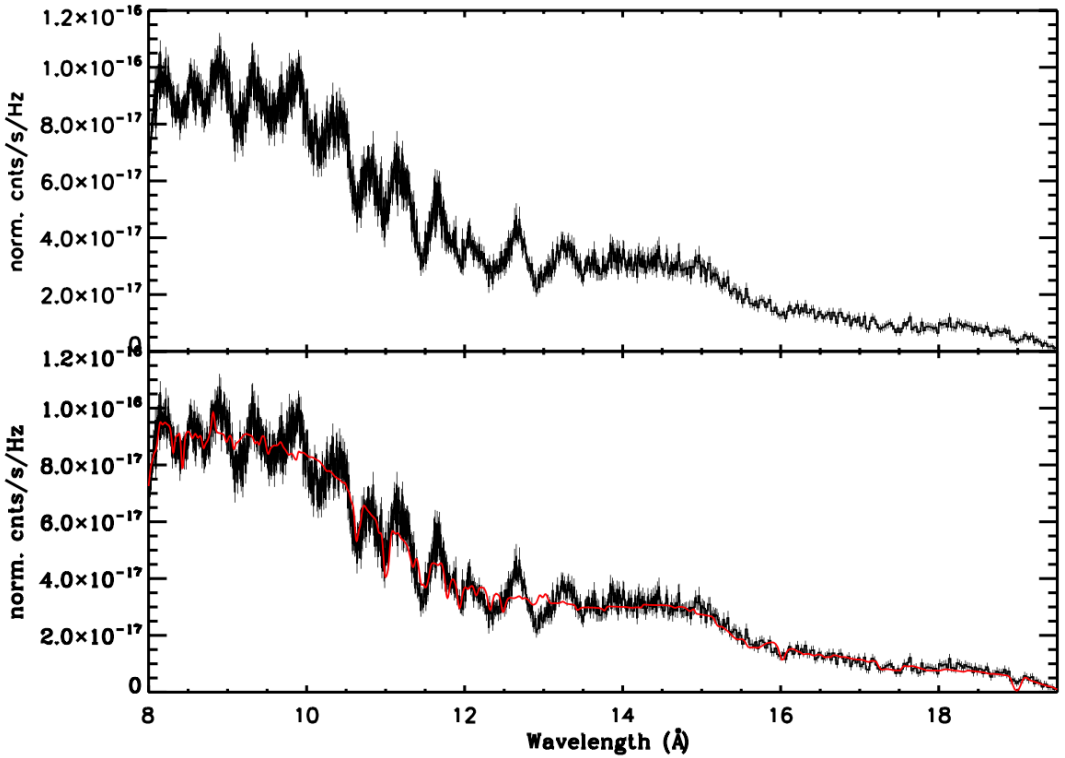
GRO J1655−40	2.62 d	5.2		D			x	out	Ueda98, Yamaoka01, Miller06b/08, Netzer06, Sala07, Díaz Trigo07, Kallman09, Luketic10, Neilsen12
Cir X−1	16.6 d	16	NS	D		x	x	out	Brandt00, Schulz02, , D'Aí07, Iaria08, Schulz08
GX 13+1	24.06 d	13	NS	D			x	out	Ueda01/04, Sidoli02, Díaz Trigo12, Madej14, D'Ai14
GRS 1915+105	33.5 d	13		D			x	out	Kotani00, Lee02, Martocchia06, Ueda09/10, Neilsen09/11/12
IGR J17091–3624	>4 d[h]	5.4			> 53[i]		x	out	King12
4U 1630−47		17		D			x	out	Kubota07, Díaz Trigo13/14, King13/14, Neilsen14
H 1743−322		6.9		D			x	out	Miller06a

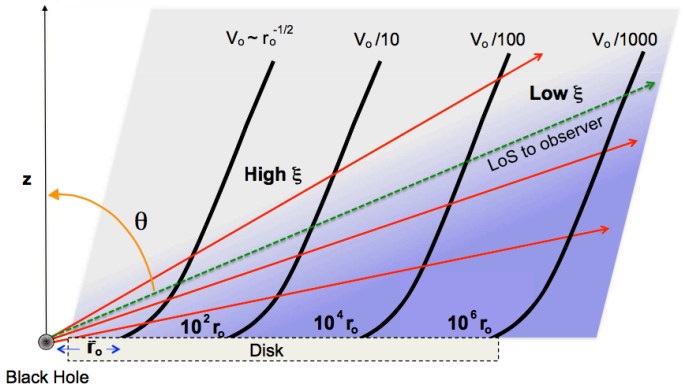
Diaz Trigo & Boirin 2016

Velocity of the plasma



Miller et al. 2014

Line width



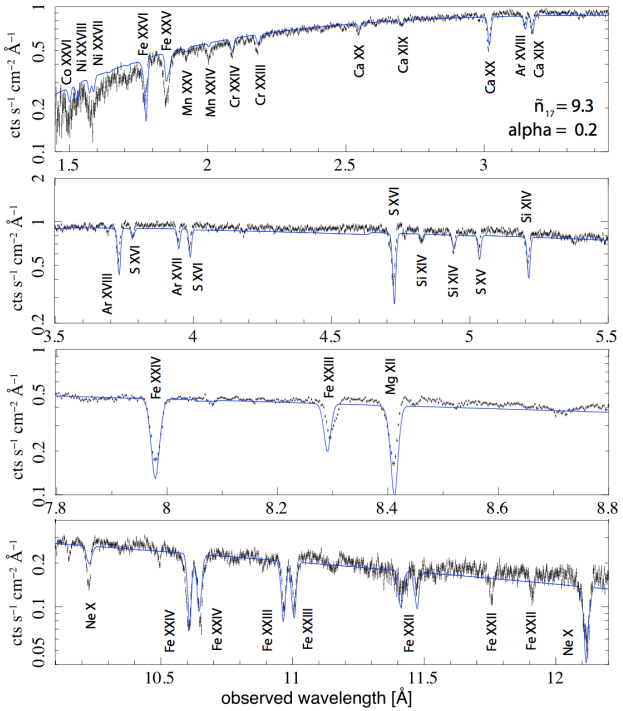
Absorption

Measurement

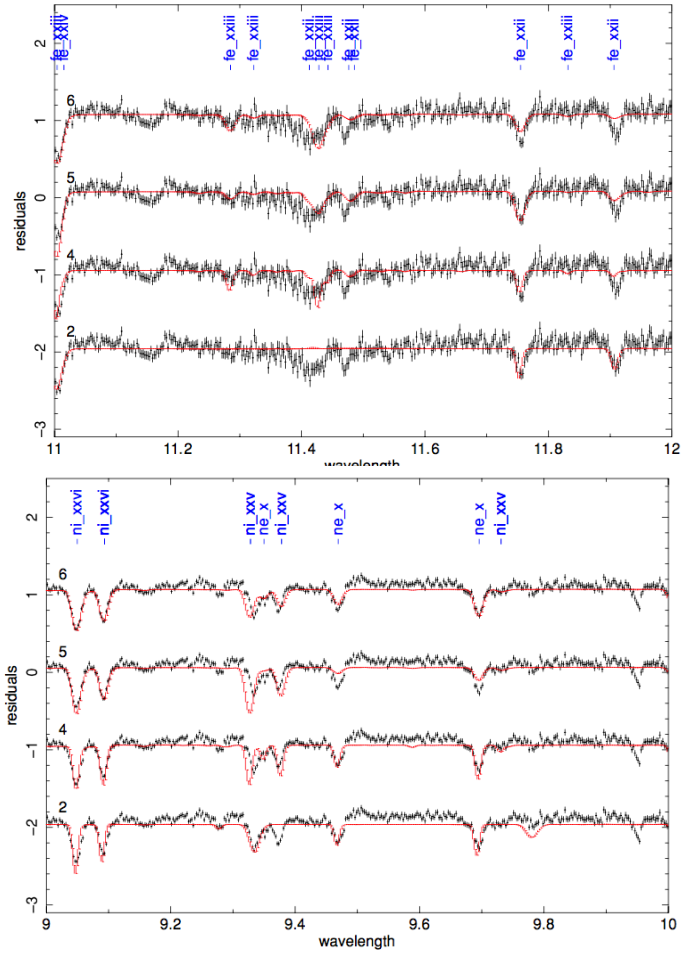
Distribution

AMD = $d(N_H)/d(\log \xi)$

(Holczer et al. 2007)



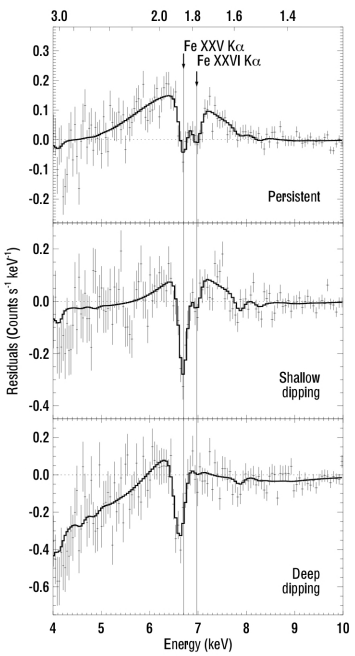
Fukumura et al. 2017



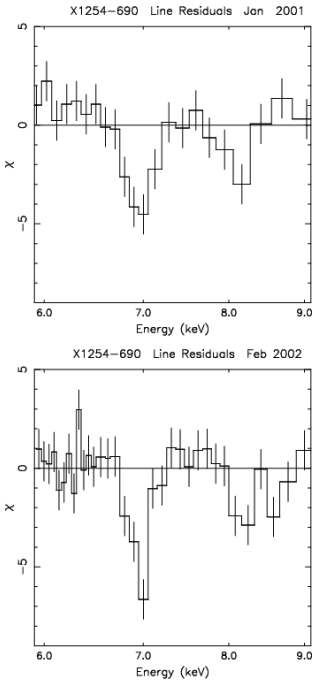
Kallman et al. 2009

Ionisation

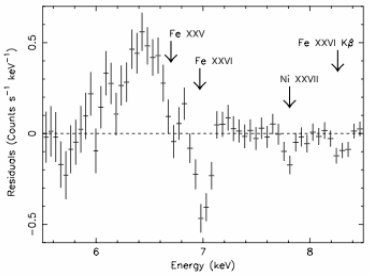
89% of the absorbers are highly ionised ($\xi > 3$)



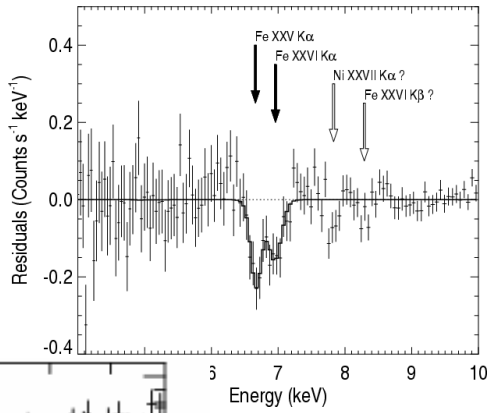
4U 1323-62
Boirin et al. 2005



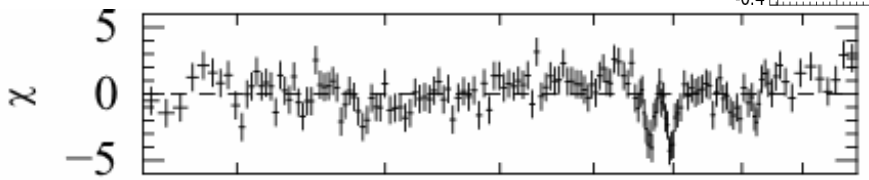
4U 1254-69
Boirin & Parmar 2003



4U 1624-49
Parmar et al. 2002



4U 1916-15
Boirin et al. 2004



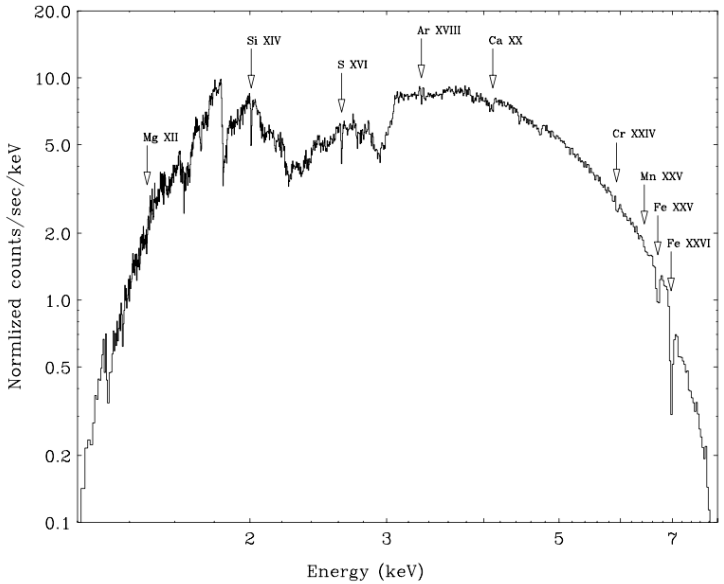
AX J1745.6-2901
Hyodo et al. 2008

Ionisation

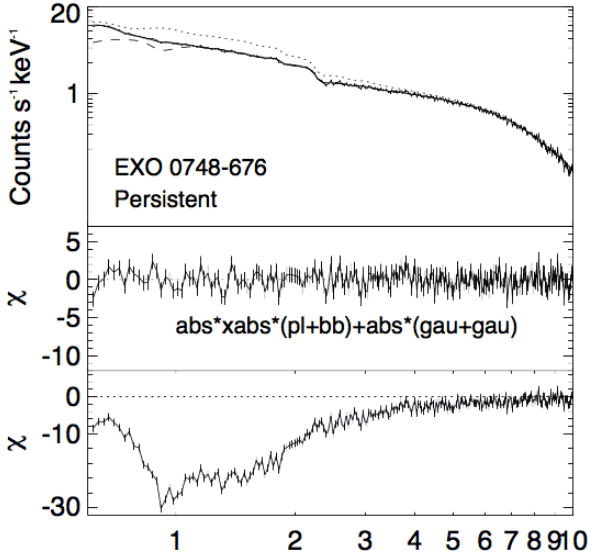
Source	P_{orb}	N_H^{Gal} 10^{21} cm^{-2}	NS	Dips	i (°)	log ξ $< 3 \geq 3$		Flow	References on the warm absorbers
XB 1916−053	0.83 h	2.3	NS	D		x	x	atm	Boirin04, Juett06, Díaz Trigo06, Iaria06, Zhang14
1A 1744−361	1.62 h	3.1	NS	D			x	atm	Gavriil12
4U 1323−62	2.93 h	12	NS	D			x	no grat.	Boirin05, Church05, Bałucińska-Church09
EXO 0748−676	3.82 h	1.0	NS	D		x	x	atm	Díaz Trigo06, van Peet09, Ponti14
XB 1254−690	3.93 h	2.0	NS	D			x	atm	Boirin03, Díaz Trigo06/09 , Iaria07
MXB 1658−298	7.11 h	1.9	NS	D		x	x	atm	Sidoli01, Díaz Trigo06
XTE J1650−500	7.63 h	4.2			> 50	?[a]	?[b]	?[c]	Miller02/04
AX J1745.6-2901	8.4 h	12	NS	D			x	no grat.	Hyodo09, Ponti15
MAXI J1305−704	9.74 h[d]	1.9		D		x		in	Shidatsu13, Miller14
X 1624−490	20.89 h	20	NS	D			x	atm	Parmar02, Díaz Trigo06, Iaria07b, Xiang09
IGR J17480−2446	21.27 h[e]	6.5	NS	D			x	out	Miller11
GX 339−4	1.76 d	3.6			> 45[f]	x		?[g]	Miller04, Juett06
GRO J1655−40	2.62 d	5.2		D			x	out	Ueda98, Yamaoka01, Miller06b/08, Netzer06, Sala07, Díaz Trigo07, Kallman09, Luketic10, Neilsen12
Cir X−1	16.6 d	16	NS	D		x	x	out	Brandt00, Schulz02, , D'Aí07, Iaria08, Schulz08
GX 13+1	24.06 d	13	NS	D			x	out	Ueda01/04, Sidoli02, Díaz Trigo12, Madej14, D'Ai14
GRS 1915+105	33.5 d	13		D			x	out	Kotani00, Lee02, Martocchia06, Ueda09/10, Neilsen09/11/12
IGR J17091−3624	>4 d[h]	5.4			> 53[i]		x	out	King12
4U 1630−47		17		D			x	out	Kubota07, Díaz Trigo13/14, King13/14, Neilsen14
H 1743−322		6.9		D			x	out	Miller06a

Diaz Trigo & Boirin 2016

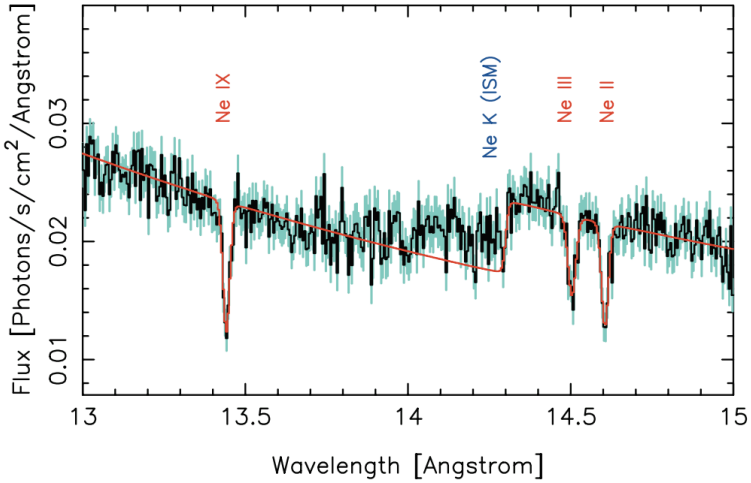
Ionisation



Ueda et al. 2004



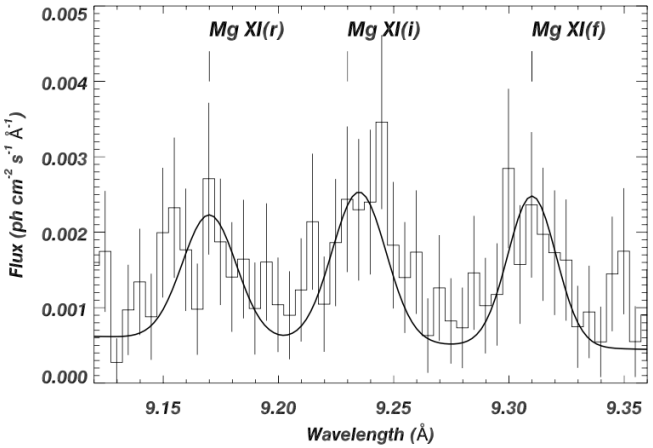
Diaz Trigo et al. 2006



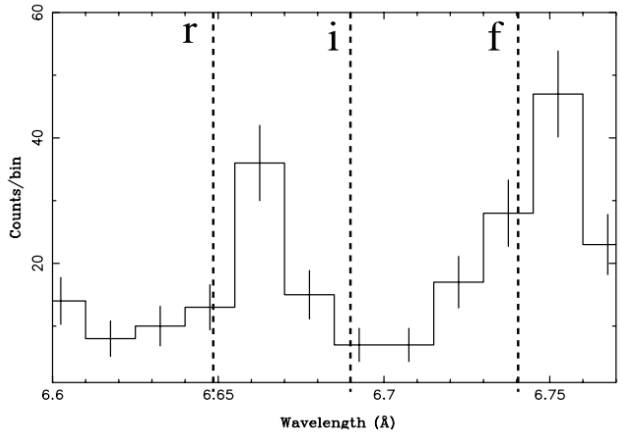
Miller et al. 2004

Low ξ cannot be detected in 37% of the sources due to ISM absorption

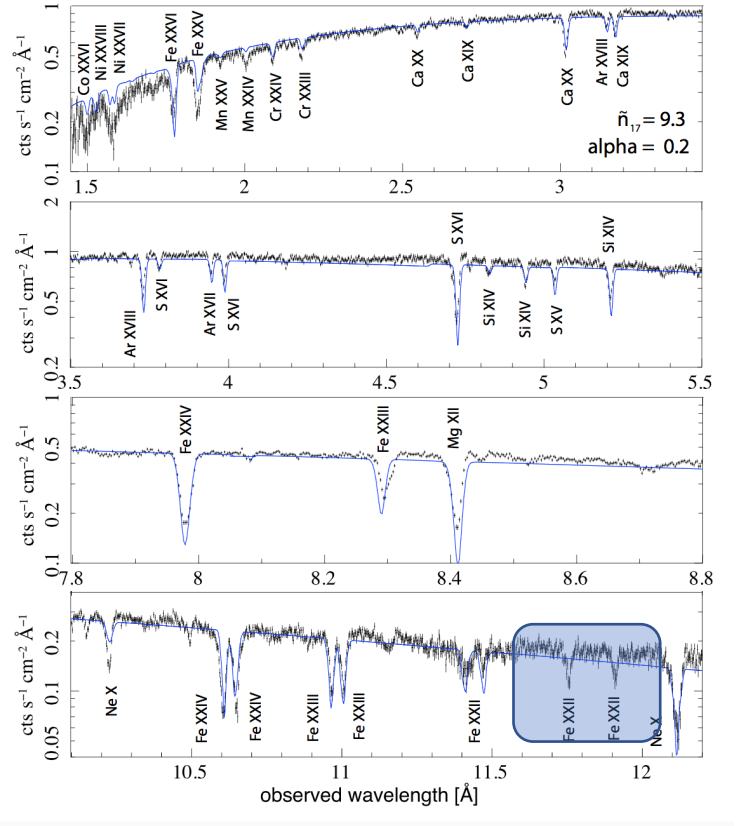
Density



Schulz et al. 2002



Schulz et al. 2008



Fukumura et al. 2017

Launching radius

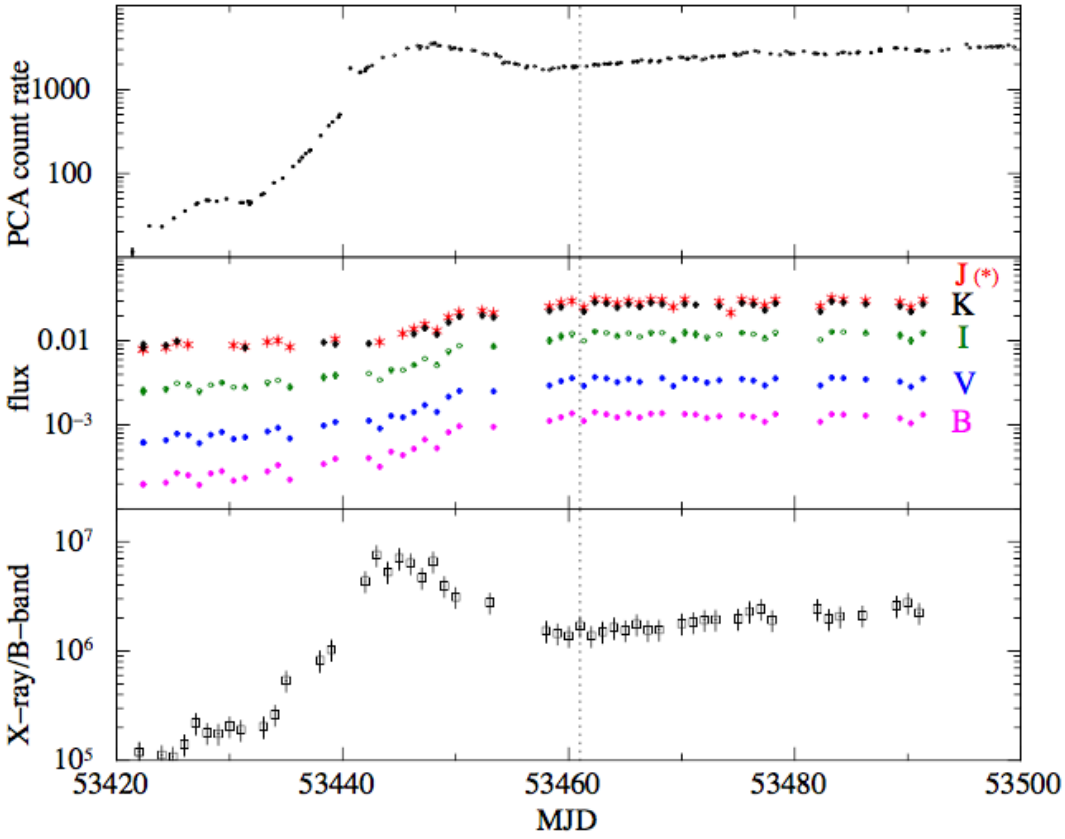
$$\xi = L / n_e r^2$$

Luminosity underestimated by more than one order of magnitude due to the opacity of the wind: $L > 0.7\ L_{Edd}$

Two effects:

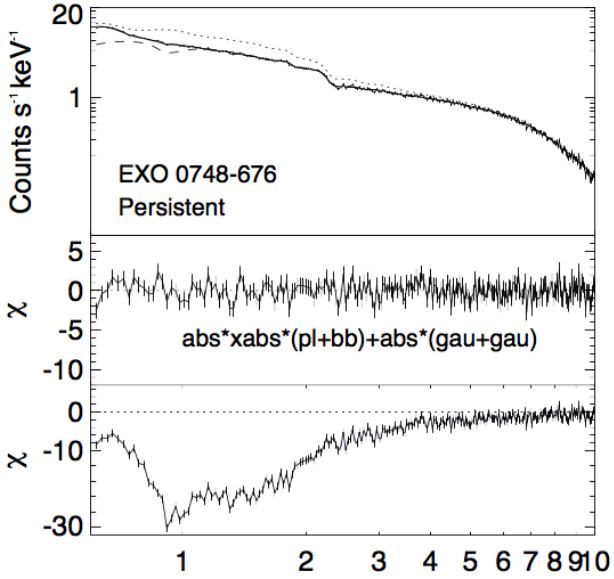
- Allowed distance from compact object
- Increase of radiation pressure due to electrons

Winds launched close to the BH/NS should be faster!

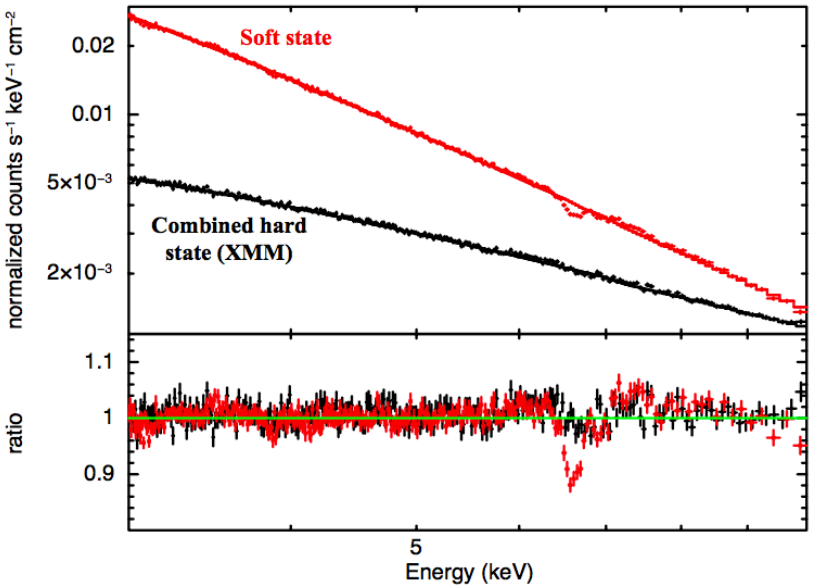


Shidatsu et al. 2016
(see also Neilsen et al 2016)

Variability

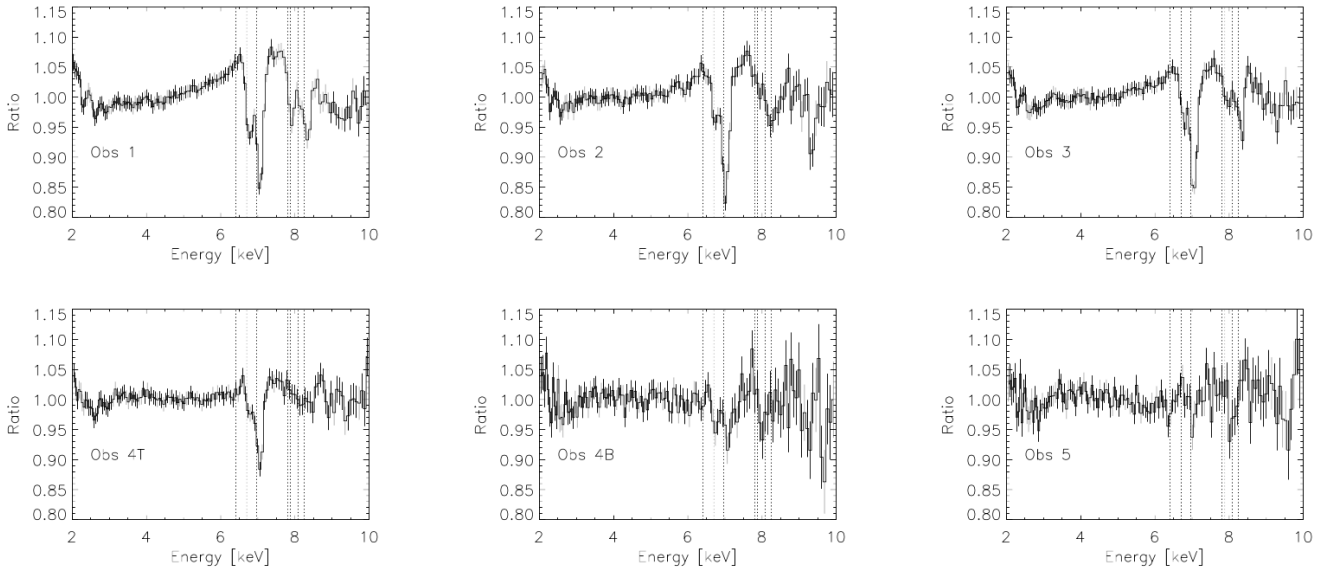


Diaz Trigo et al. 2006
(see also van Peet 2009)

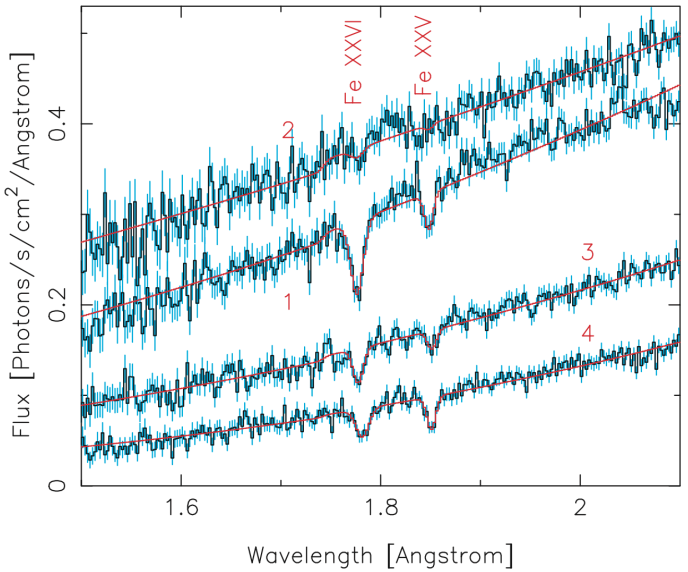


Ponti et al. 2014

Variability

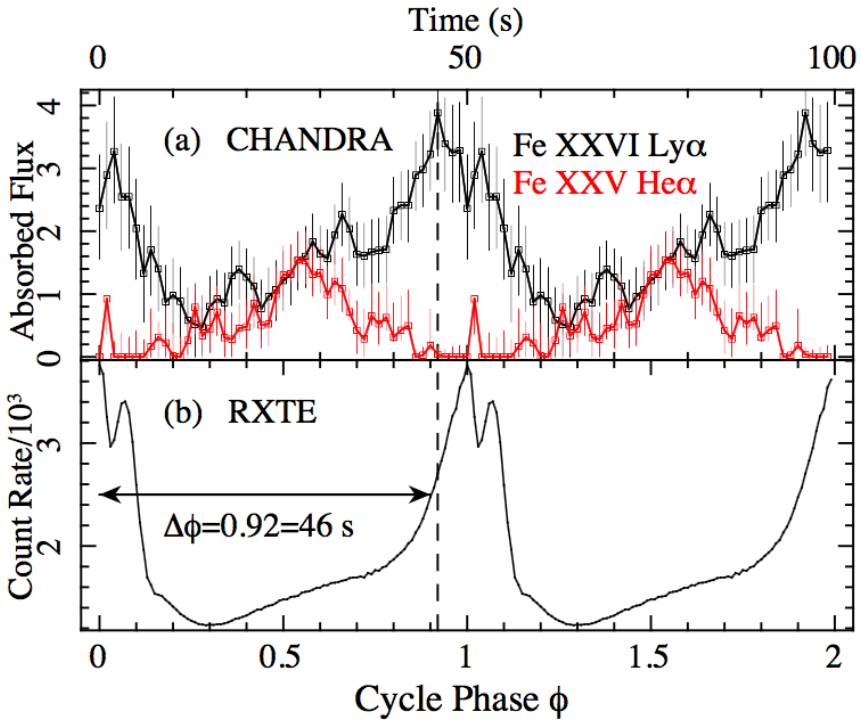


Diaz Trigo et al. 2013, 2014



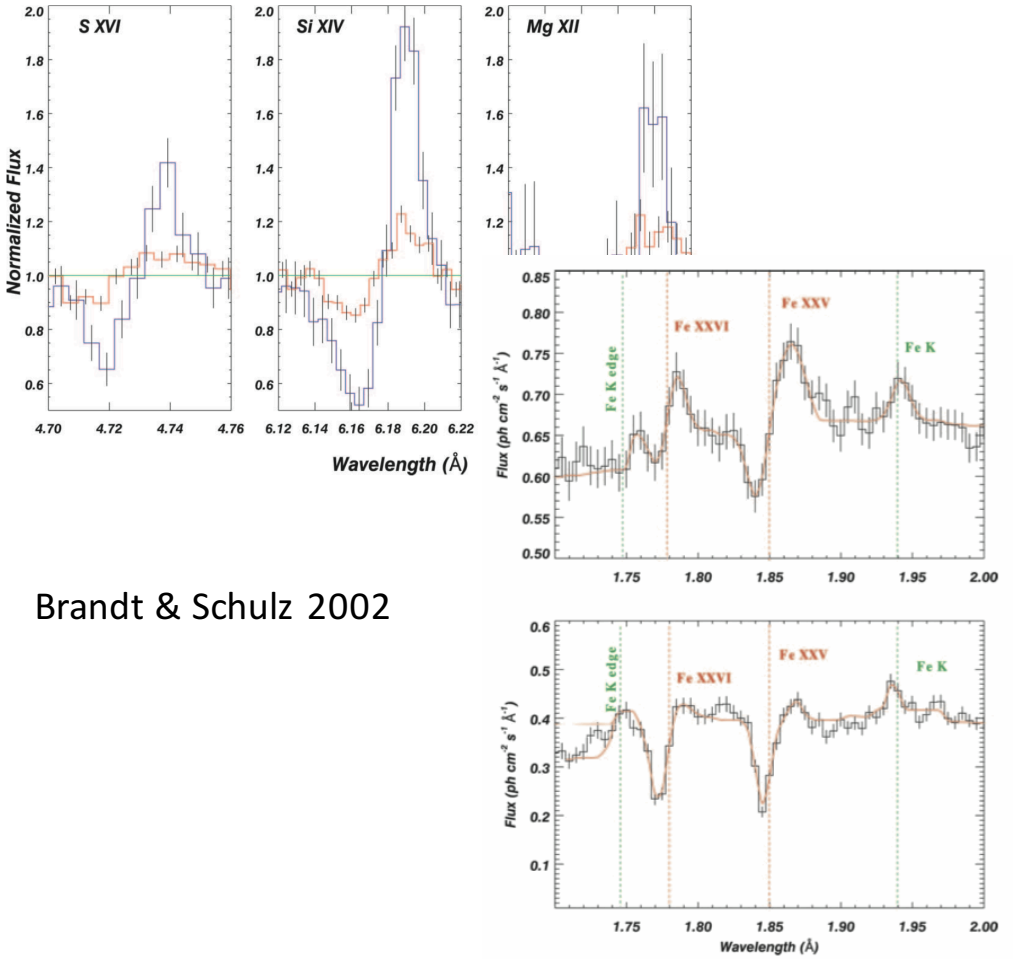
Miller et al. 2006

Variability

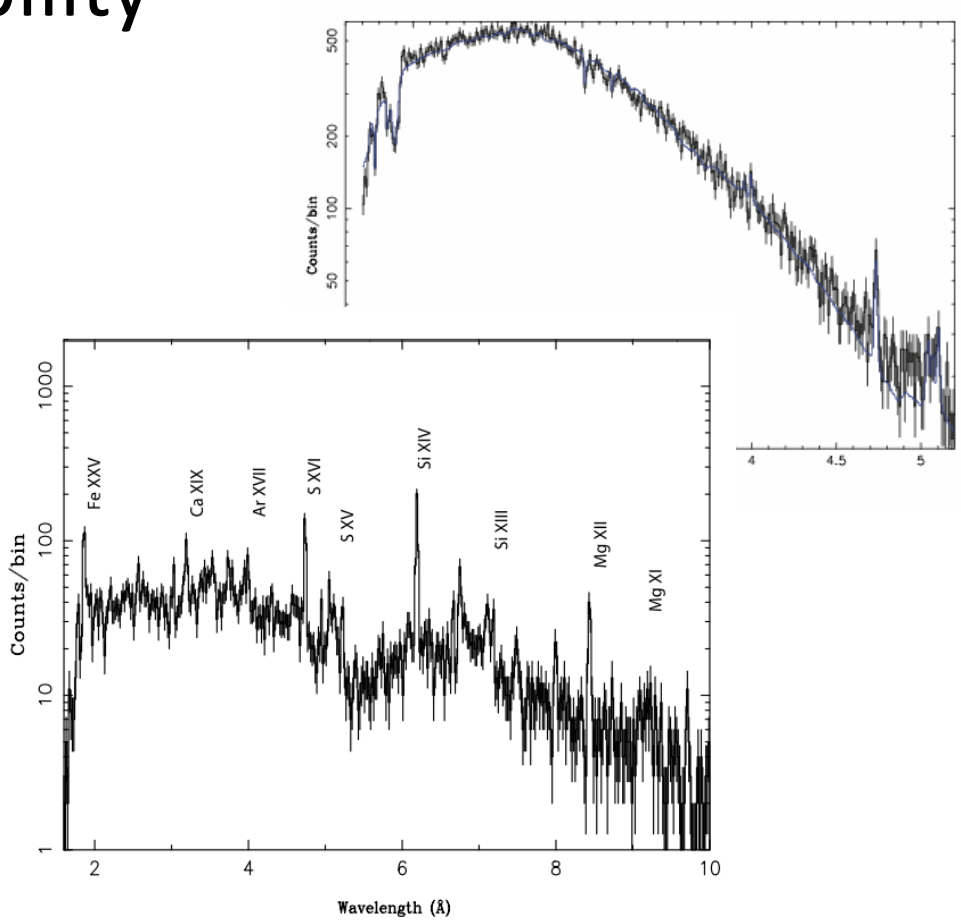


Neilsen et al. 2011

Variability

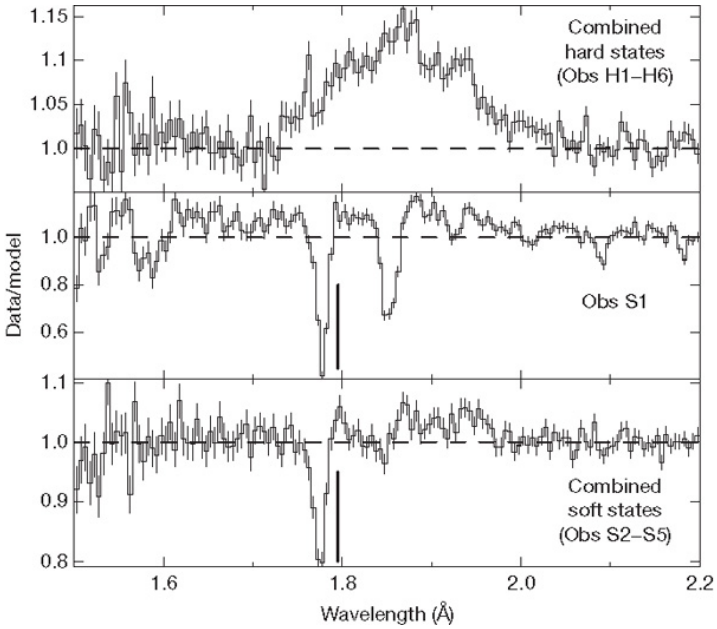


Brandt & Schulz 2002

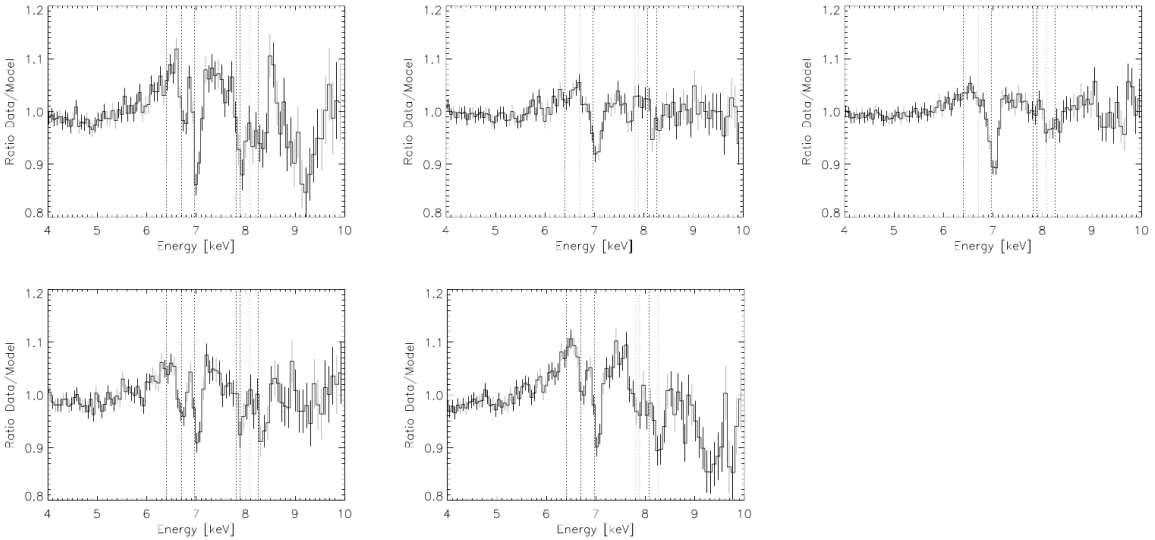


Schulz et al. 2008

Wind and other spectral components

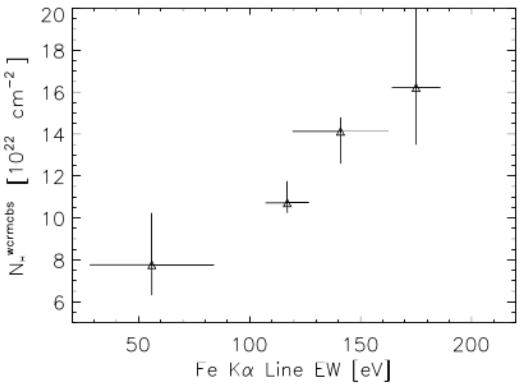


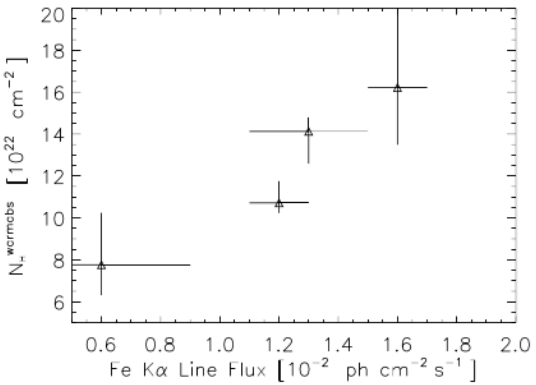
Neilsen & Lee 2009

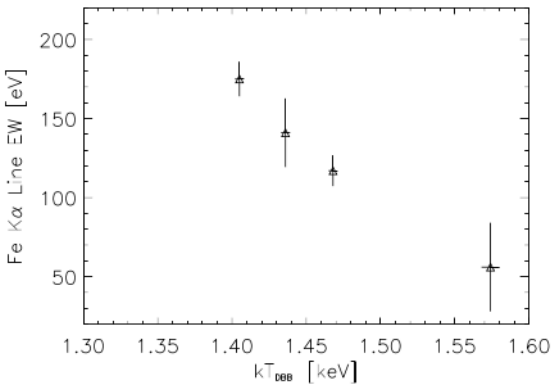


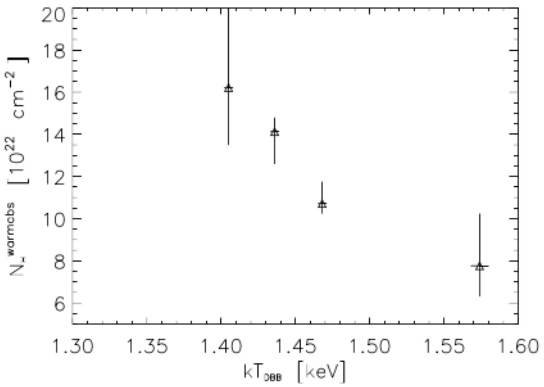
Diaz Trigo et al. 2012

Wind and other spectral components



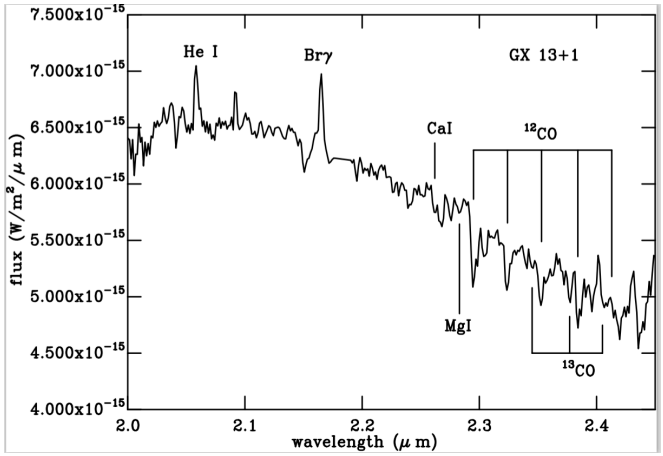




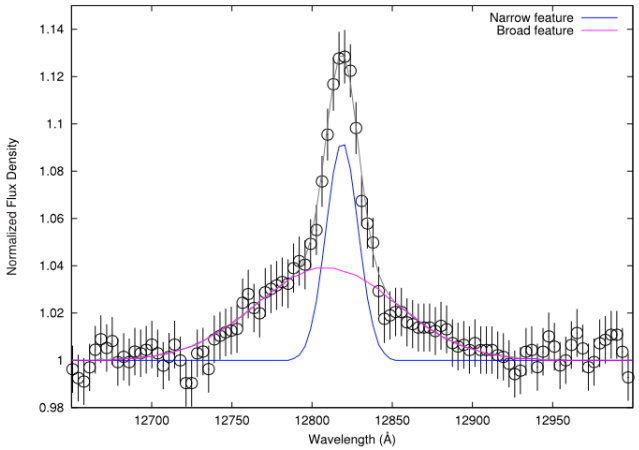


Diaz Trigo et al. 2014

The optical/IR connection?

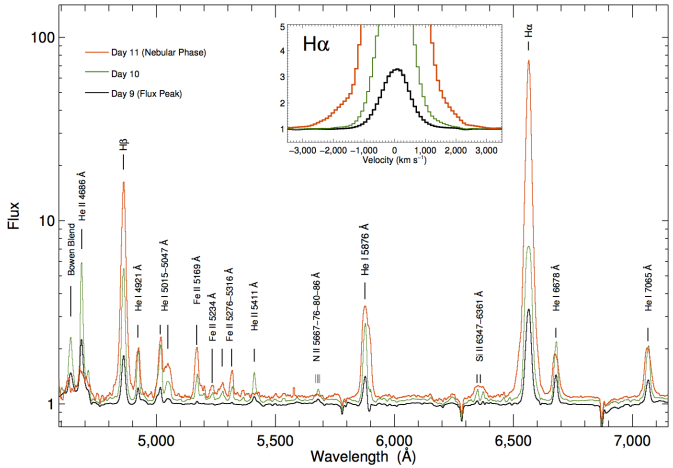


Bandyopadhyay et al. 1999



Rahoui et al. 2014

(see also Wu et al. 2001)



Munoz-Darias et al. 2016

Outlook

- Wealth of observations with challenges to theoretical models
- Some relevant observations at transitional states still missing
- Important for understanding connection of winds with accretion states, jets or significance for triggering transitions