Measuring masses in low mass X-ray binaries via X-ray spectroscopy: the case of MXB 1659-298

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on behalf of

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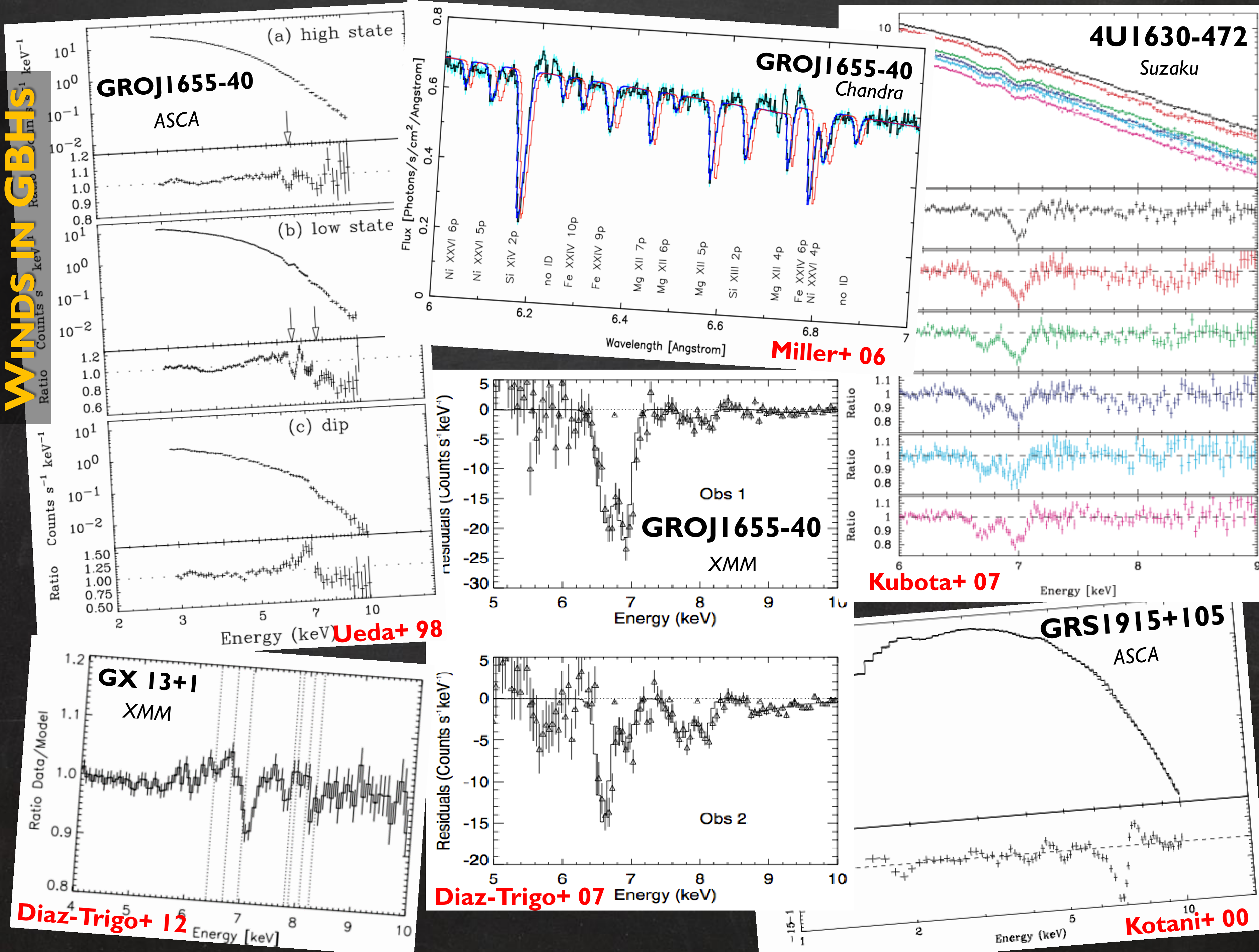
WINDS IN GBHS



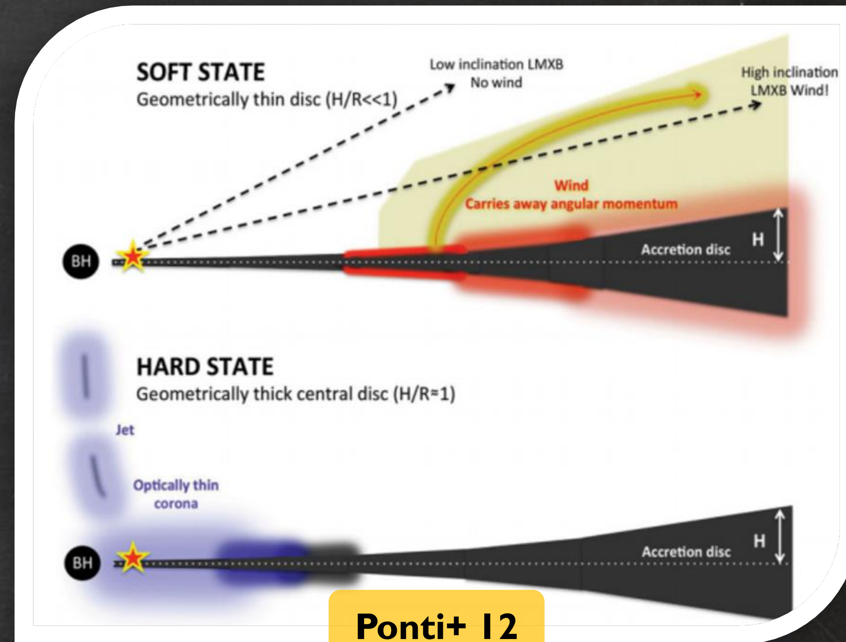
WINDS IN GBHS

Equatorial geometry

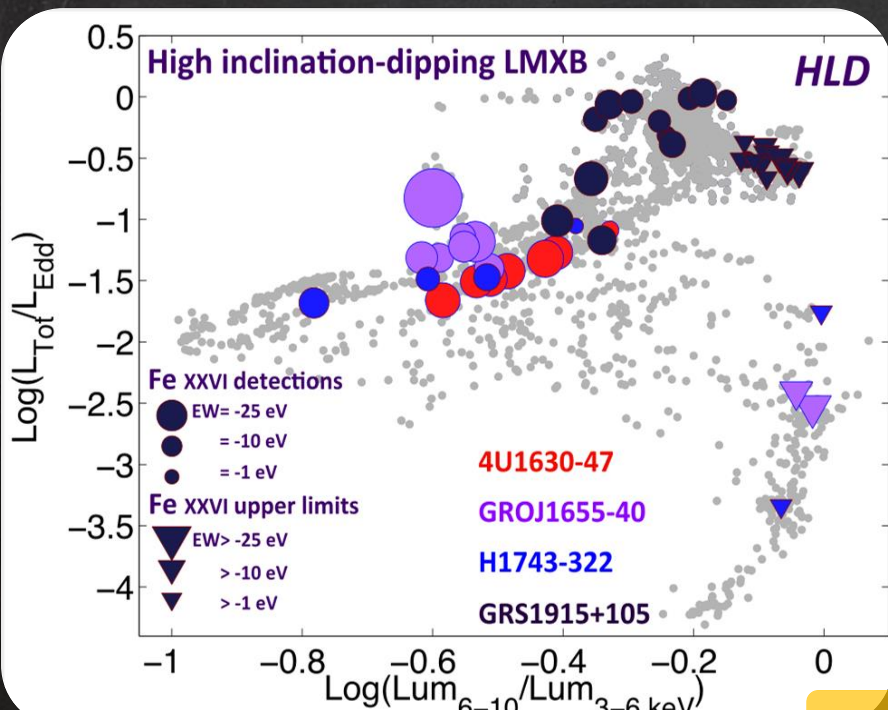
Ubiquitous in soft state (jet off)

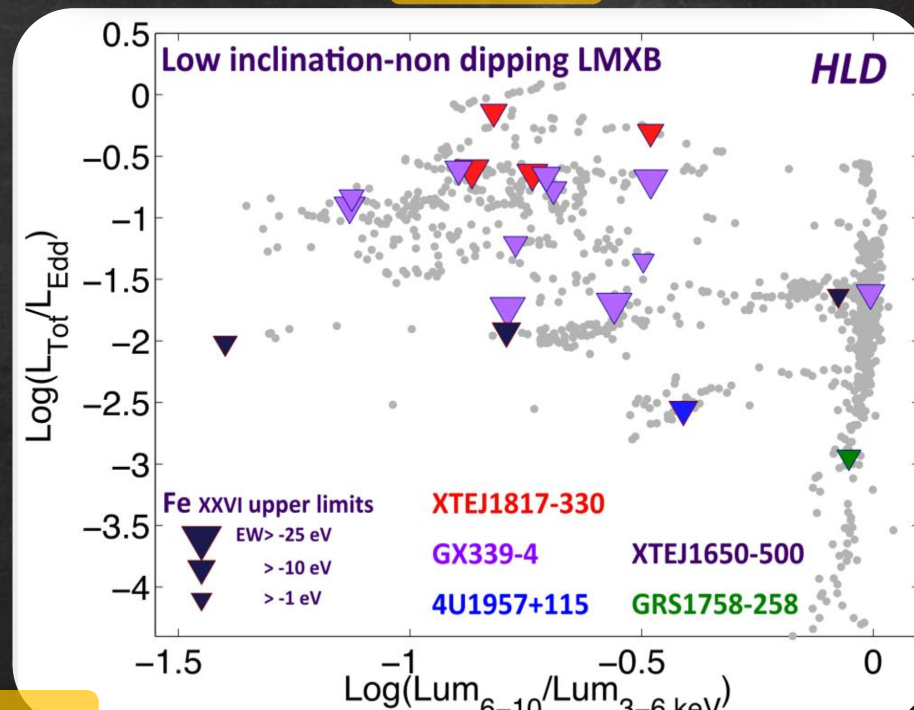
Absent in hard state (jet on)

Outflow velocities
$\sim 10^2 - 10^3$ km s^{-1}



Ponti+ 12





Ponti+ 12

Winds in NS LMXBs

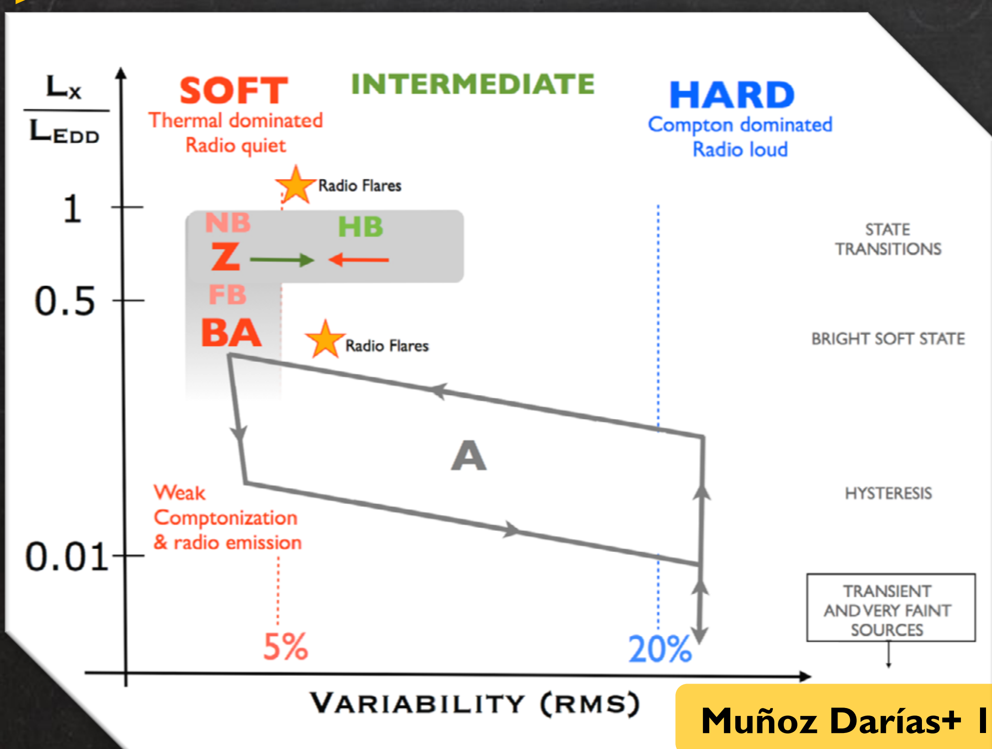
Equatorial geometry

Outflow velocities:
$\sim 10^2 - 10^3$ km s^{-1} (*winds*)
~ 0 km s^{-1} (*disc atmospheres*)

State (jet) connection!

Díaz Trigo & Boirin 16

Source	P_{orb}	N_H^{Gal} [10^{21} cm^{-2}]	NS	Dips	i (°)	log ξ < 3	log ξ ≥ 3	Flow
XB 1916−053	0.83 h	2.3	NS	D		x	x	atm
1A 1744−361	1.62 h	3.1	NS	D			x	atm
4U 1323−62	2.93 h	12	NS	D			x	no grat.
EXO 0748−676	3.82 h	1.0	NS	D		x	x	atm
XB 1254−690	3.93 h	2.0	NS	D			x	atm
MXB 1658−298	7.11 h	1.9	NS	D		x	x	atm
XTE J1650−500	7.63 h	4.2			> 50	?[a]	?[b]	?[c]
AX J1745.6-2901	8.4 h	12	NS	D			x	no grat.
MAXI J1305−704	9.74 h[d]	1.9		D		x		in
X 1624−490	20.89 h	20	NS	D			x	atm
IGR J17480−2446	21.27 h[e]	6.5	NS	D			x	out
GX 339−4	1.76 d	3.6			> 45[f]	x		?[g]
GRO J1655−40	2.62 d	5.2		D			x	out
Cir X−1	16.6 d	16	NS	D		x	x	out
GX 13+1	24.06 d	13	NS	D			x	out

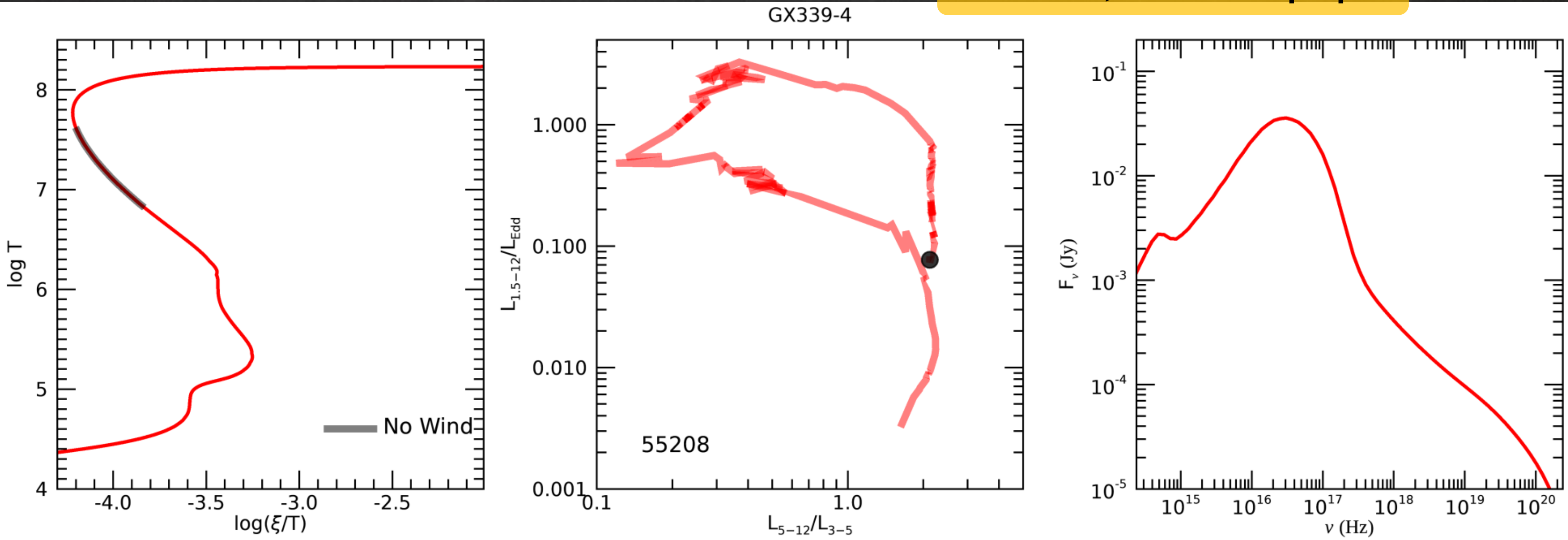


Muñoz Darías+ 14

NSs LMXBs fit in the canonical state scheme of BH systems: variability is the key for classification

The connection between Fe K absorption and states is a general characteristic of accreting sources

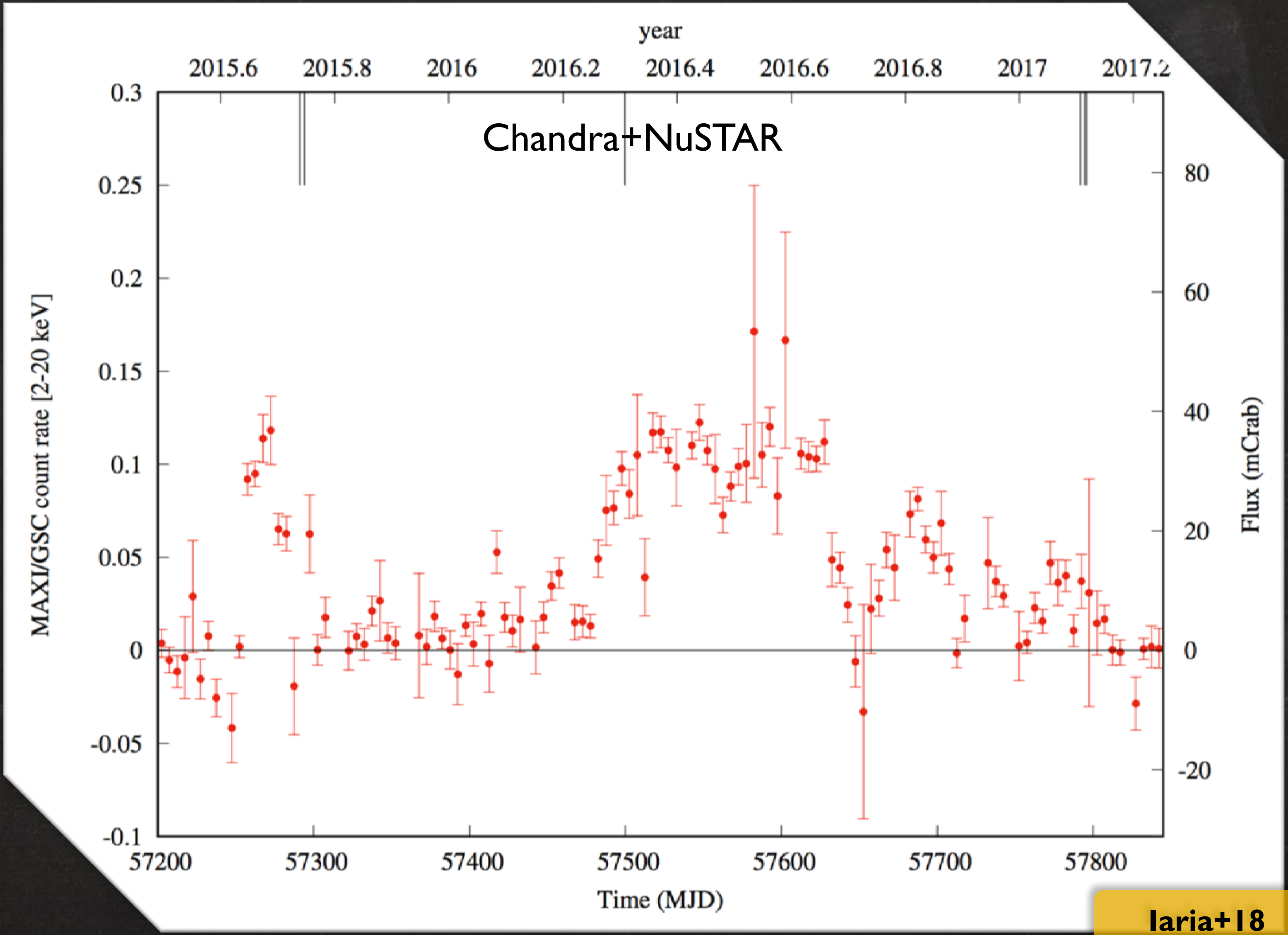
Petrucci, Bianchi+ in prep.



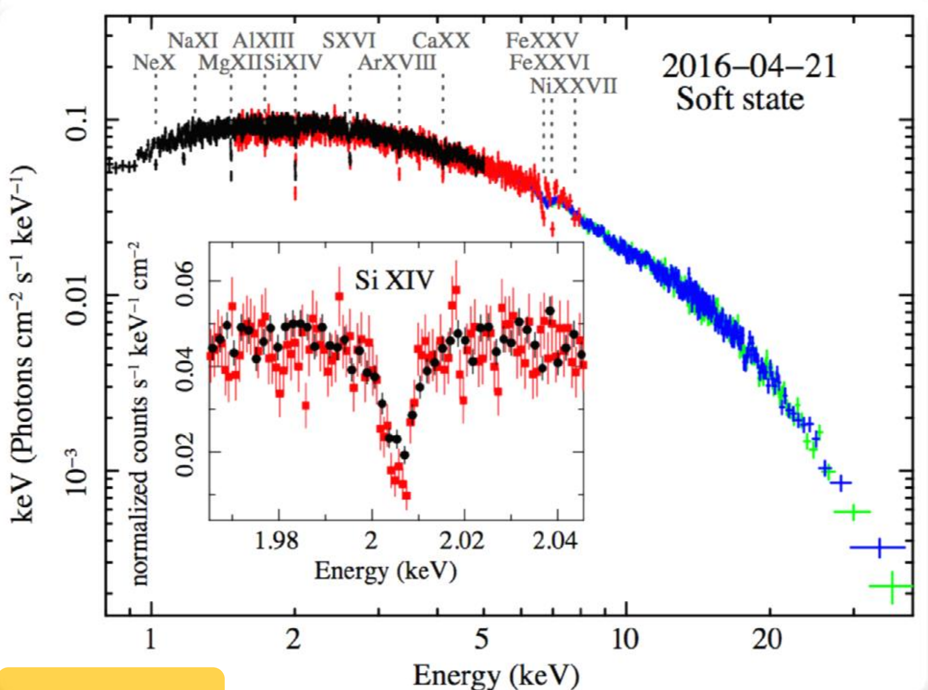
Fe K absorption does not disappear because of over-ionization in the hard state, but because of **photoionization instability** (Bianchi+18, see also Chakravorty+ 2013, 2016; Higginbottom+ 2015, 2016 ; Dyda+ 2016)

This process alone cannot reproduce a wind back to the soft state, but a disc atmosphere ($v = 0$) would be automatically re-created

The 2015-2017 outburst of the NS LMXB MXB 1659-298



Iaria+18



Chandra HETG:

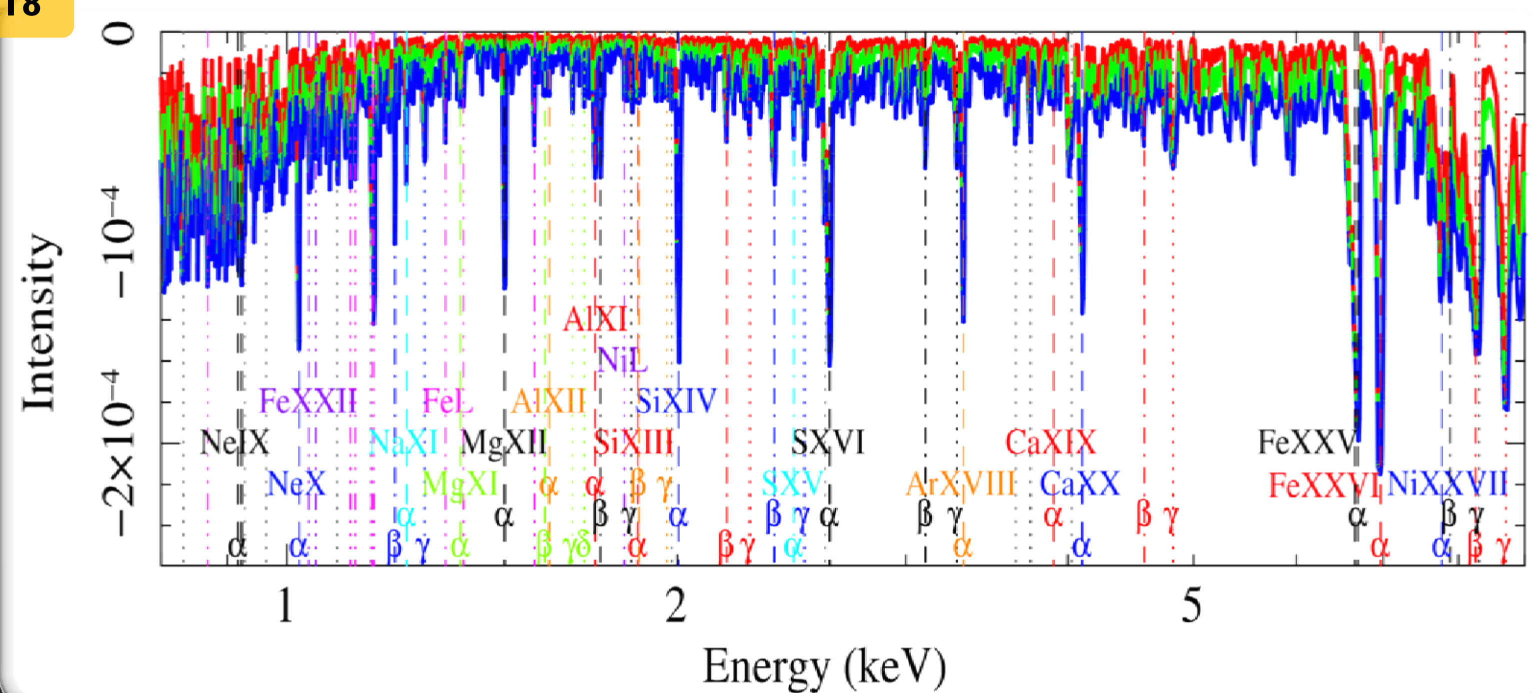
More than 60 absorption lines

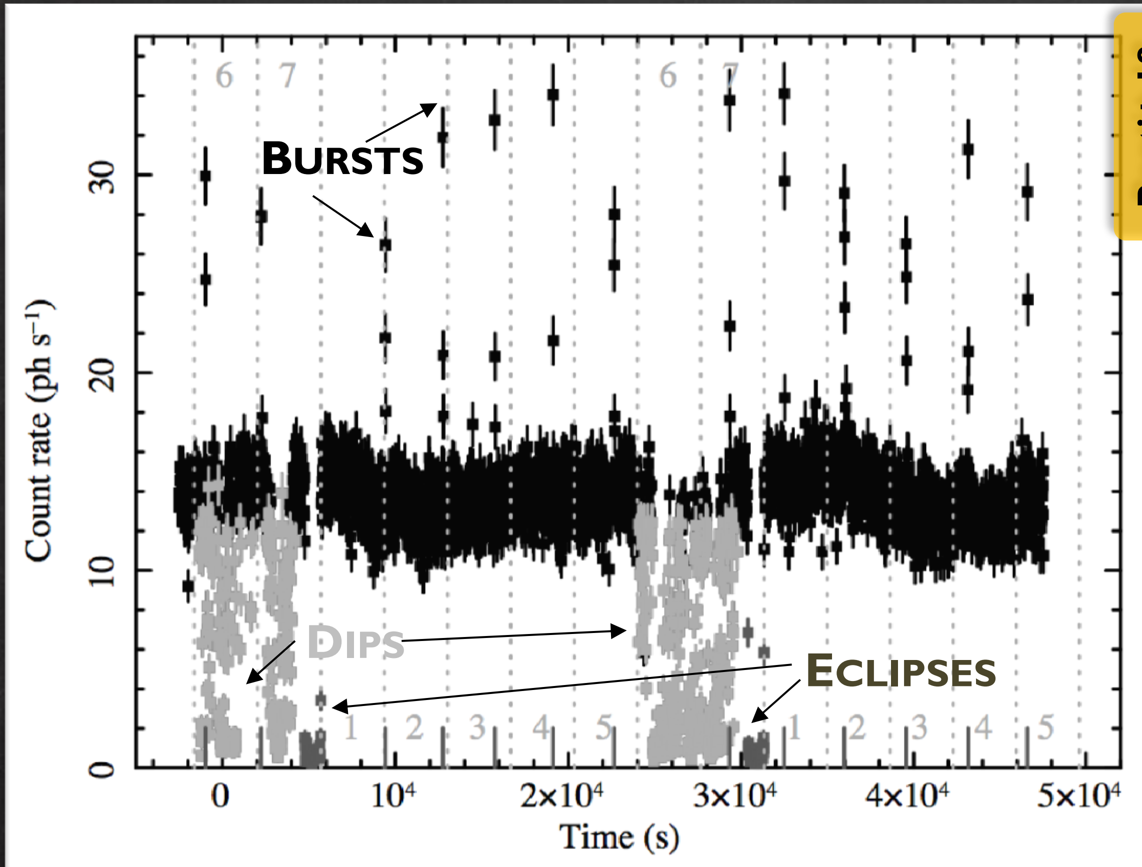
Highly ionised Ne, Na, Mg, Al, Si, S, Ar, Ca, Fe, Ni

Complete Ly-series from Lyα to Lyɣ line of most elements

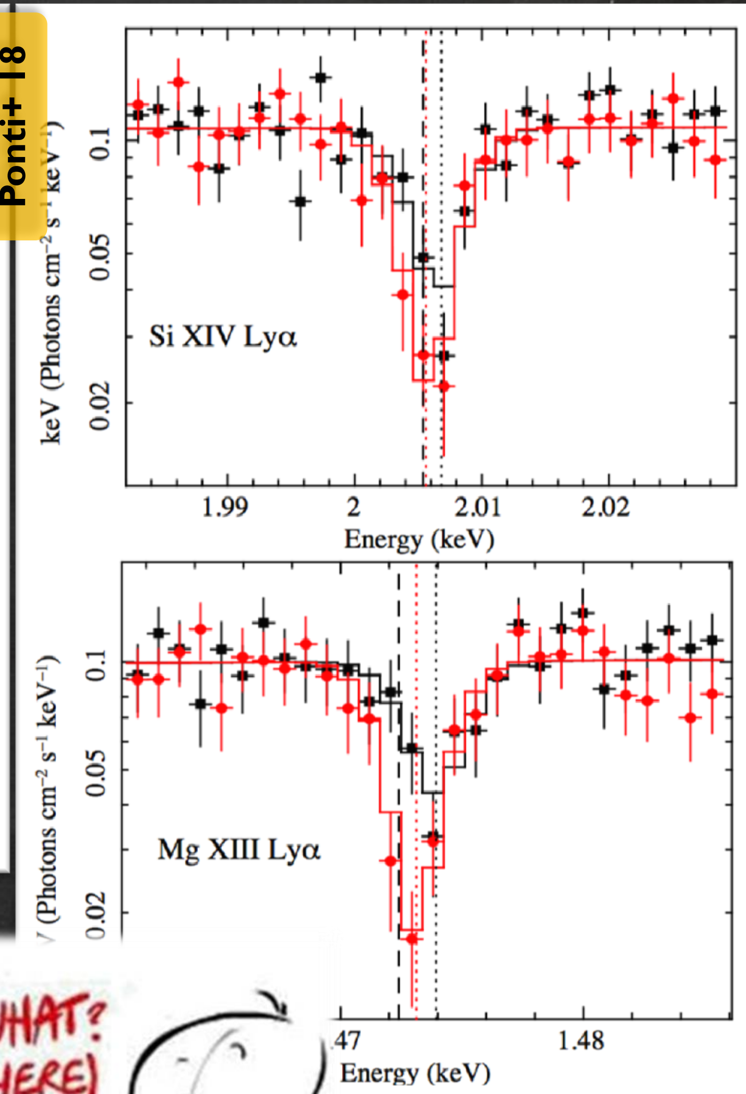
No outflow velocity ➜ disc atmosphere

Ponti+ 18



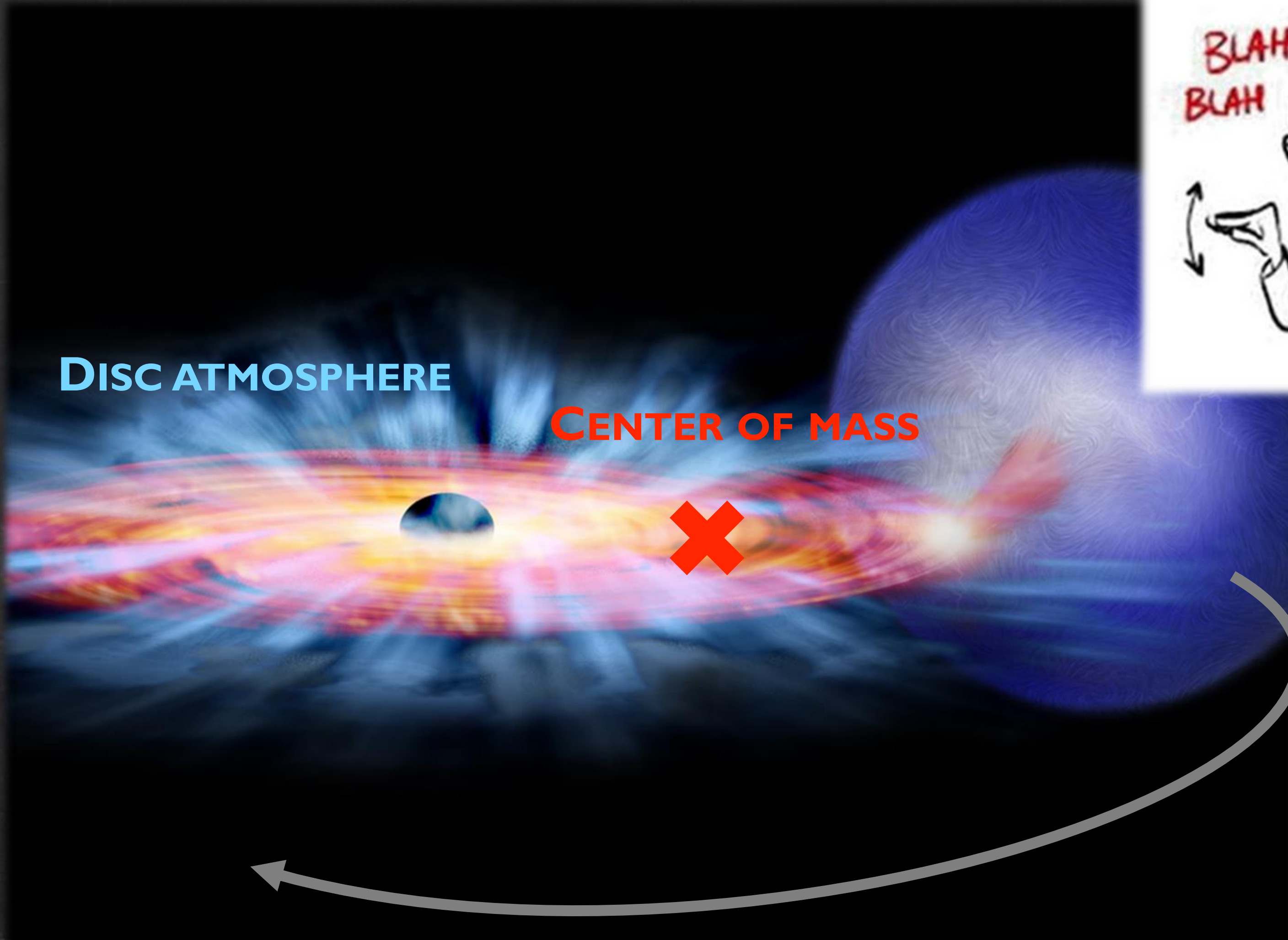


Ponti+ 18

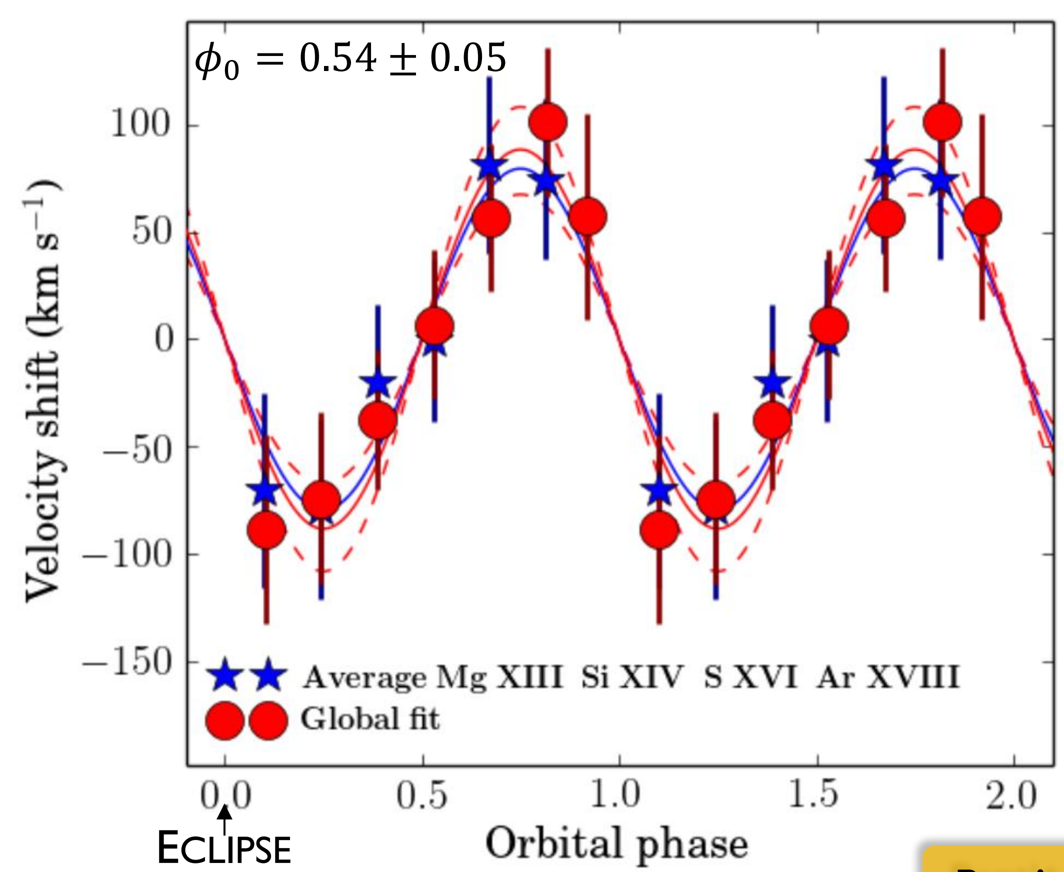


Phase-dependent absorption variations!

All the line centroid energies show systematically larger/smaller shifts in different parts of the orbit



The absorption lines arise from a confined region surrounding the compact object, so they are expected to **trace its motion around the centre of mass** of the binary system (e.g. Zhang et al. 2012)



Ponti+ 18

We can directly measure the radial velocity curve of the NS!

$K_1 = 89 \pm 19$ km s^{-1}

This has been possible so far only in X-ray binary pulsars, where the delay in the arrival time of the pulses trace the orbit

This technique has been already applied to a few systems (e.g. Zhang et al. 2012; Madej et al. 2014), but the expected radial velocity of the primary ($10 - 150$ km s^{-1}) is beyond the energy resolution of current X-ray instruments in the Fe K band

The accurate determination of the orbital motion of the compact object can be also affected by random variations of the wind outflow speed (Madej et al. 2014)

Constraining masses in MXB 1659-298

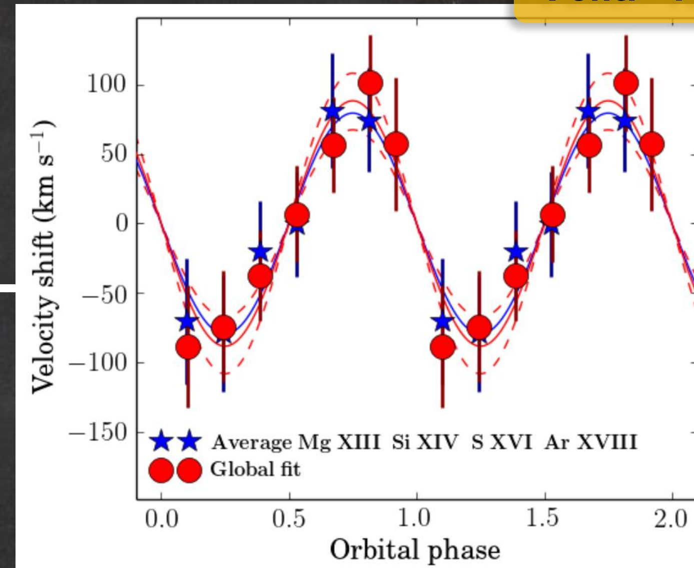
Semi-amplitude of radial velocity curve

$K_1 = 89 \pm 19$ km s^{-1}

$P_{orb} = 25.618$ ks

$\Delta T_{ecl} = 889.1$ s

Ponti+ 18



Mass function

$$\frac{K_1^3 P_{orb}}{2\pi G} = \frac{M_2^3 sin^3 i}{(M_{NS} + M_2)^2},$$

Orbital separation

$$a^3 = \frac{G(M_{NS}+M_2)}{4\pi}$$

Unknowns

M_{NS}, M_2, i

Companion fills Roche lobe

$$R_2 = R_{L2} = 0.462a\left(\frac{M_2}{M_{NS} + M_2}\right)^{1/3}$$

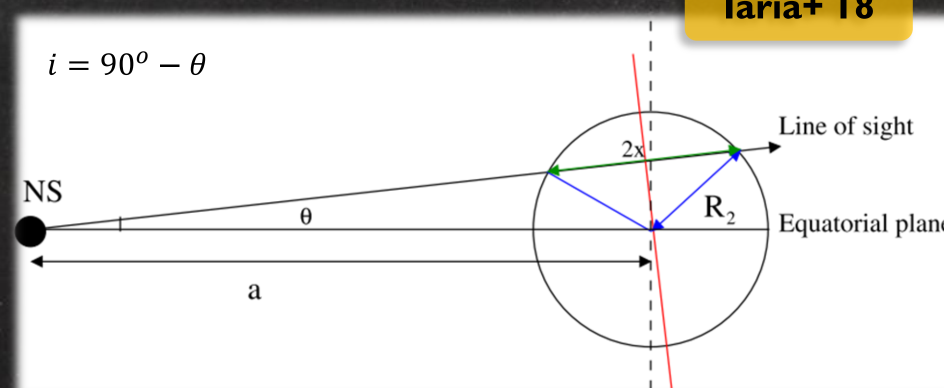
Orbital inclination

$$tan^2(i) = \frac{R_2^2 - x^2}{a^2 - (R_2^2 - x^2)},$$

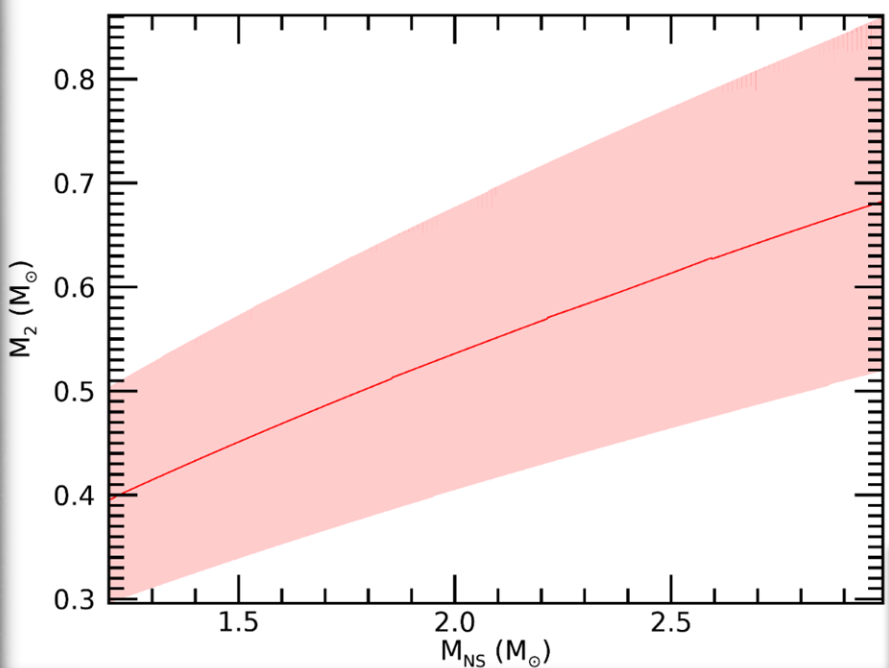
Eclipse duration

$$x = \frac{\pi a \Delta T_{ecl}}{P_{orb}},$$

Iaria+ 18



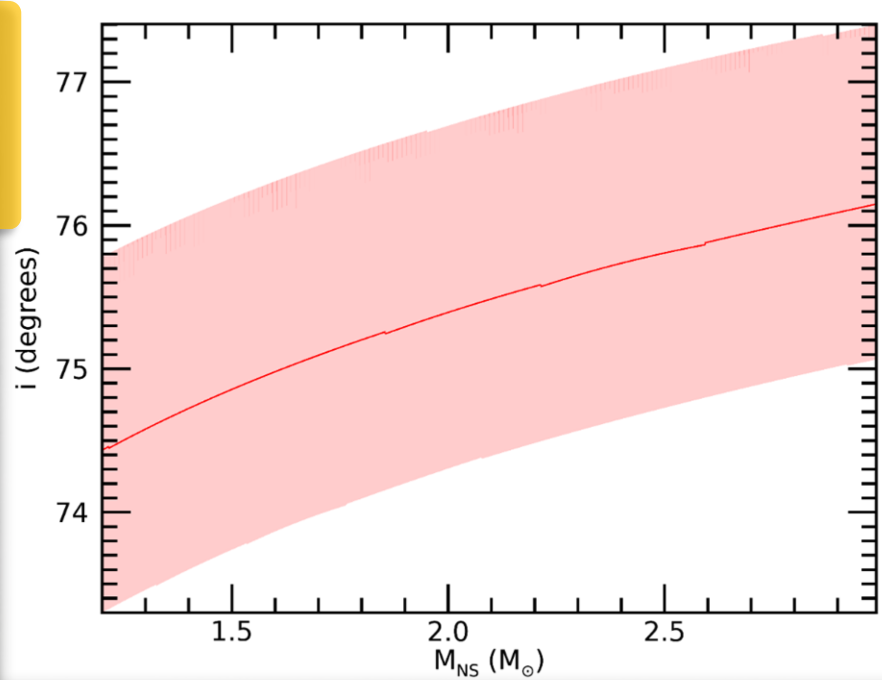
Constraining masses in MXB 1659-298



For a reasonable range $1.2 \leq M_{NS} \leq 3M_\odot$, we get $0.3 \leq M_2 \leq 0.8M_\odot$ and $73 \leq i \leq 77°$

The measured ranges of the most likely companion star masses and orbital inclinations are consistent with previous methods (Wachter et al. 2000)

Ponti+ 18

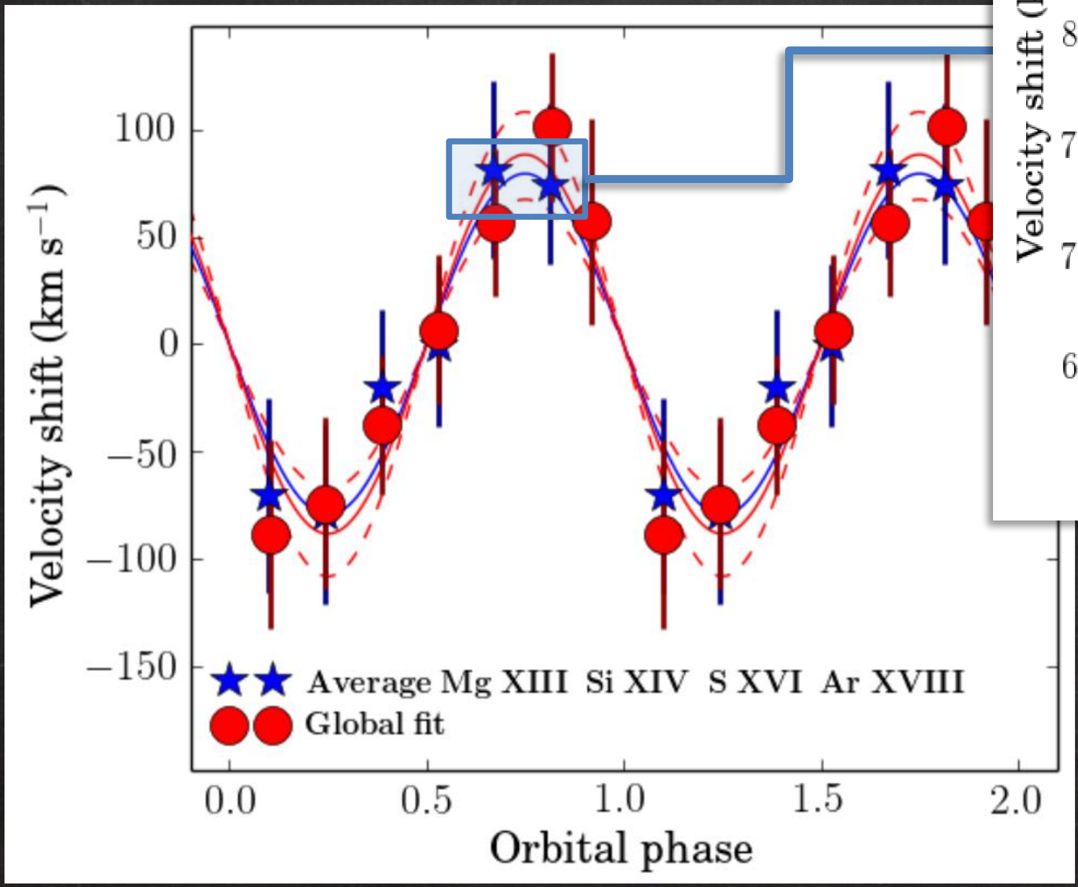


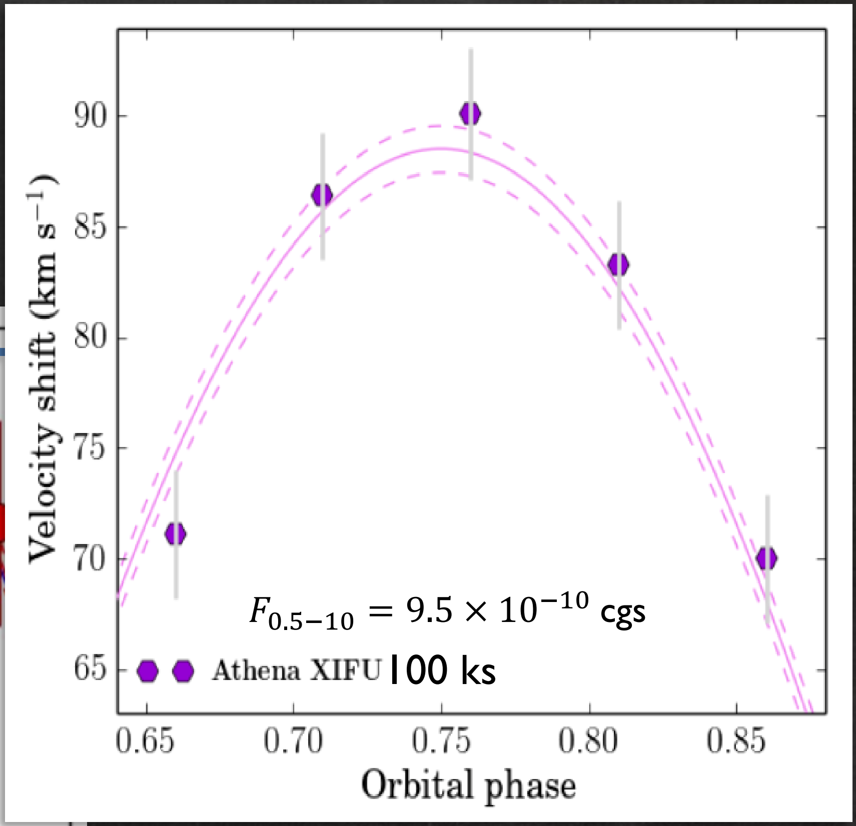
It is possible to constrain the fundamental parameters of MXB 1659-298 with current X-ray data

This method can be applied to other systems

CONSTRAINING MASSES IN MXB 1659-298

THE POWER OF ATHENA-XIFU



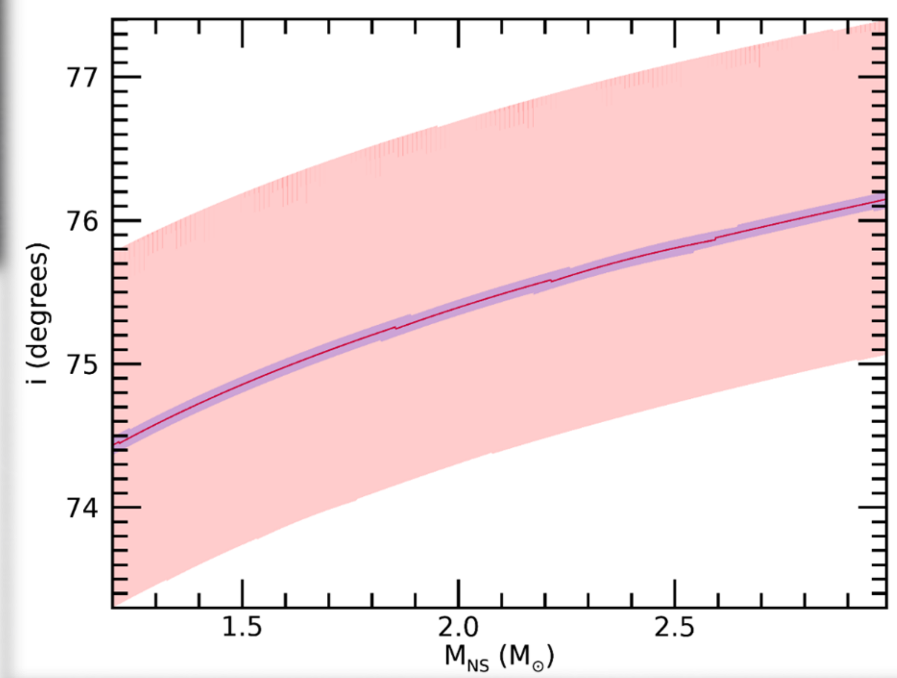


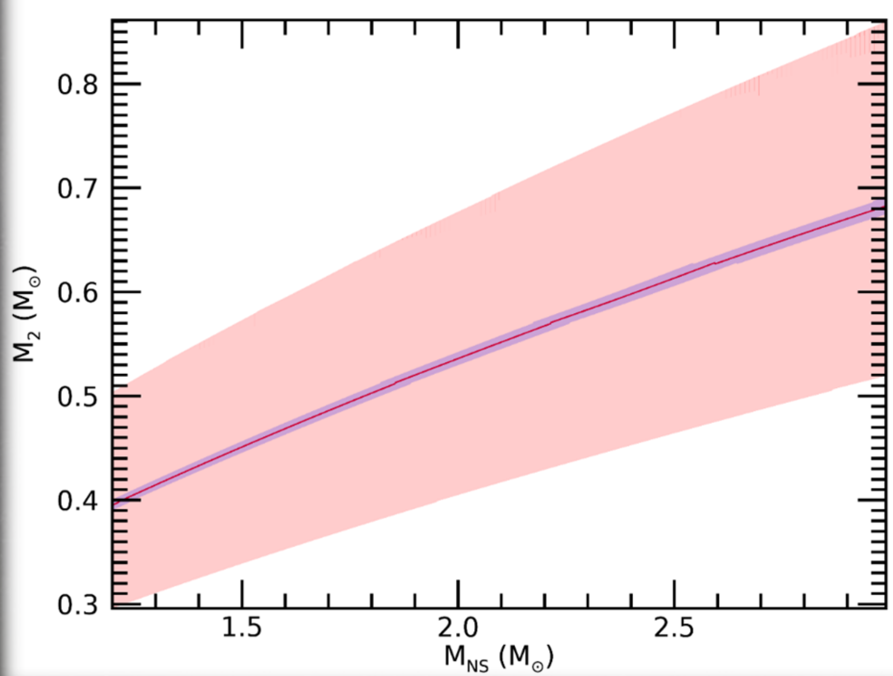
$K_1 = 89 \pm 0.9$ km s^{-1}

Athena will allow us to determine the amplitude of the radial velocity curve with an uncertainty of ~ 1%

CONSTRAINING MASSES IN MXB 1659-298

THE POWER OF ATHENA-XIFU





This translates into an uncertainty of $\sim$ 5% on the mass of the primary compact object, would the radial velocity of the companion star be known (e.g., via optical spectroscopy)