Winds and warm absorbers in XRBs

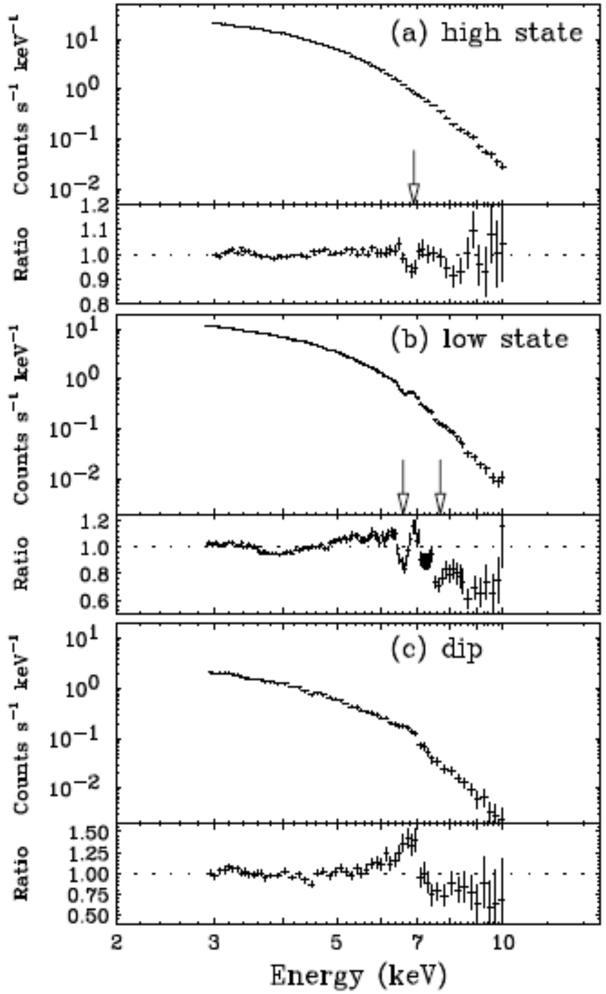
M. Díaz Trigo (ESO)

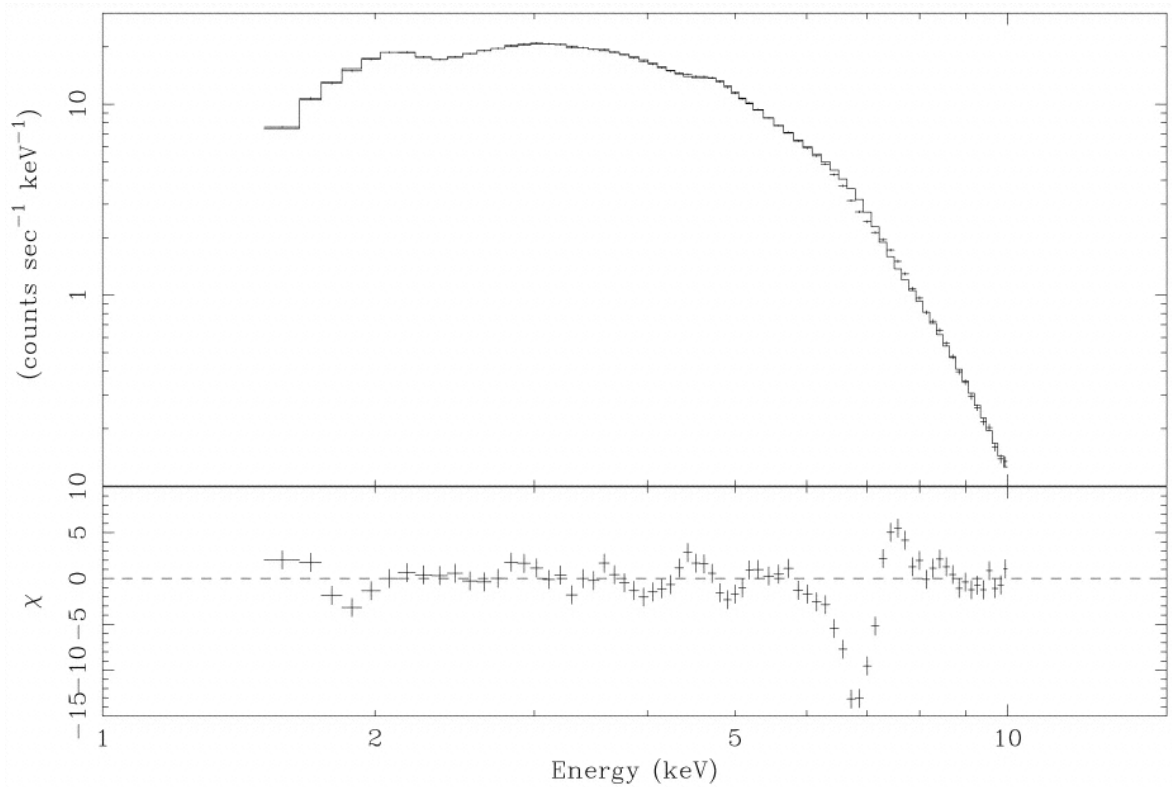
What you should remember from this talk

- Photoionised plasmas
  - Equatorial & (most likely) ubiquitous in LMXBs
- Winds
  - Consistent with a thermal launching mechanism except maybe in one case

WARM ABSORBERS

The first warm absorbers

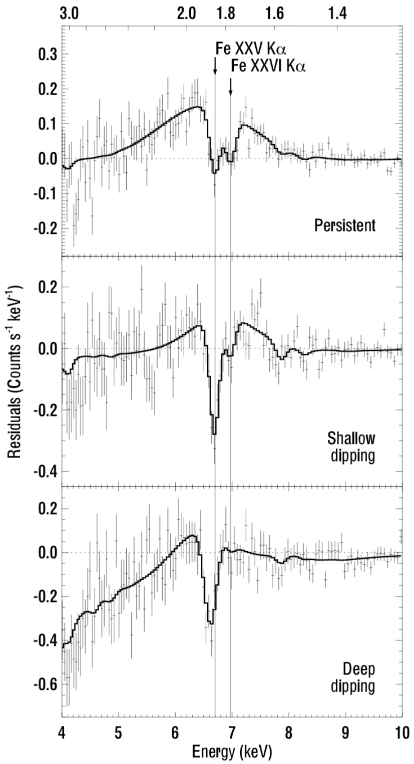




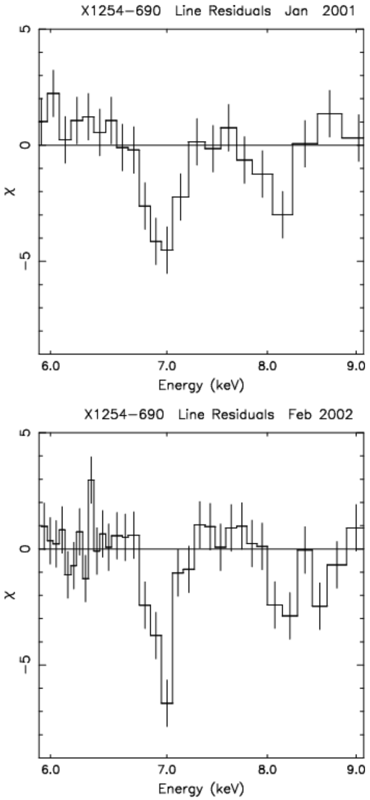
GRS 1915+105, Kotani et al. 2000

GRO J1655-40, Ueda et al. 1998

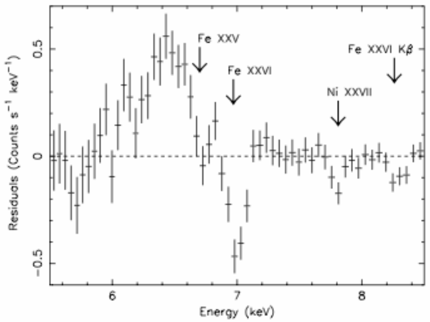
Warm absorbers everywhere…



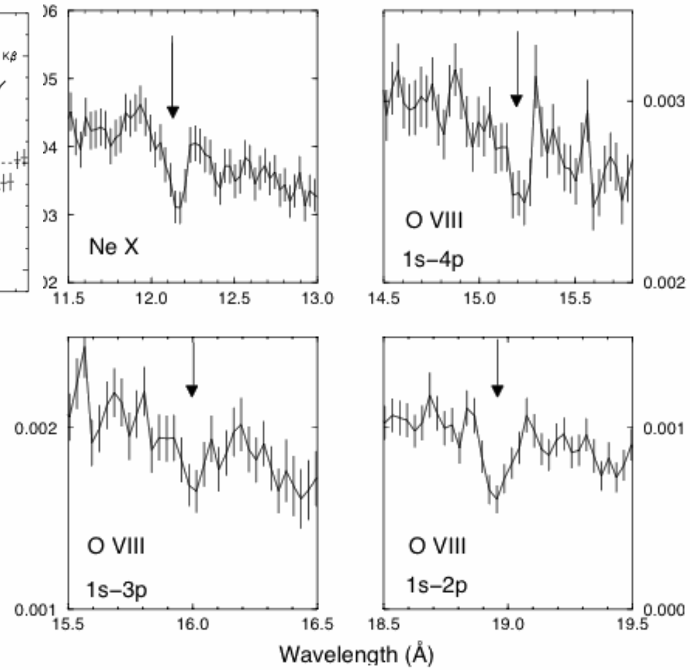
4U 1323-62
Boirin et al. 2005



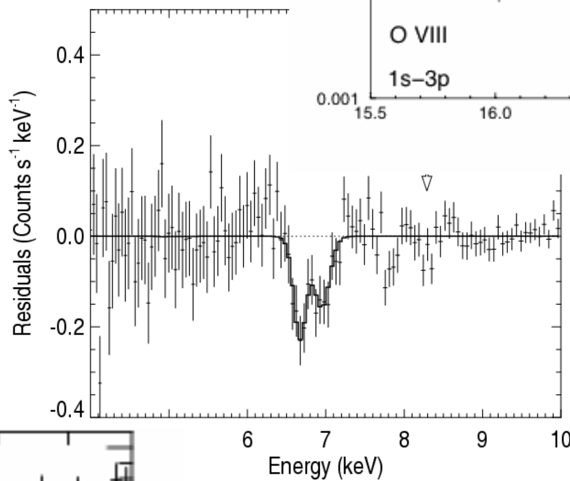
4U 1254-69
Boirin & Parmar 2003



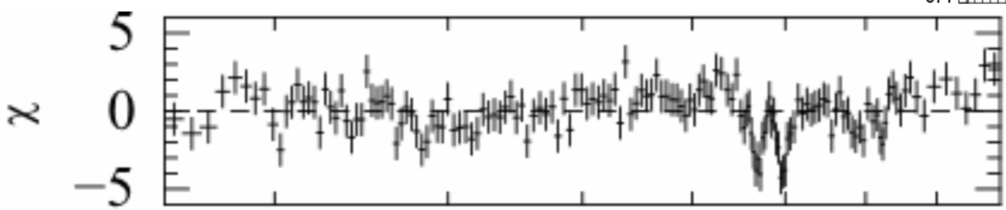
4U 1624-49
Parmar et al. 2002



MXB 1659-298
Sidoli et al. 2001

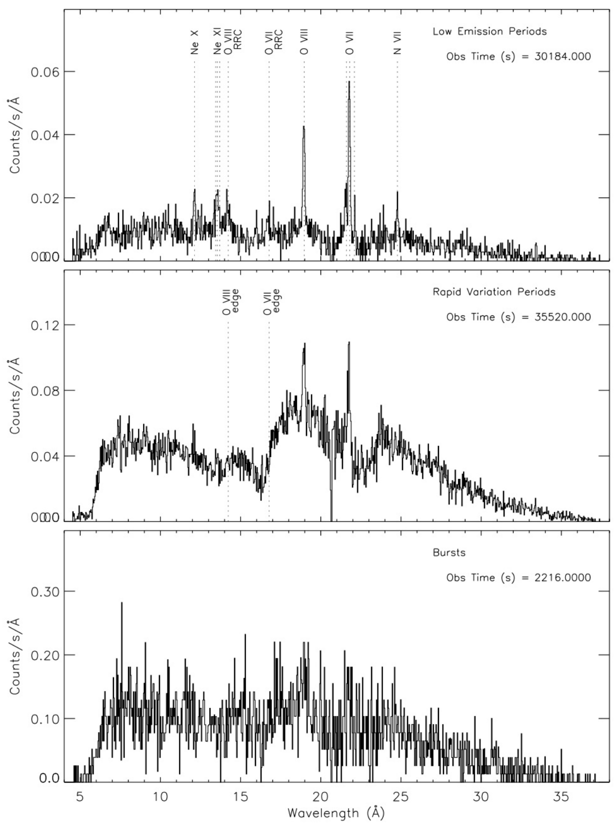


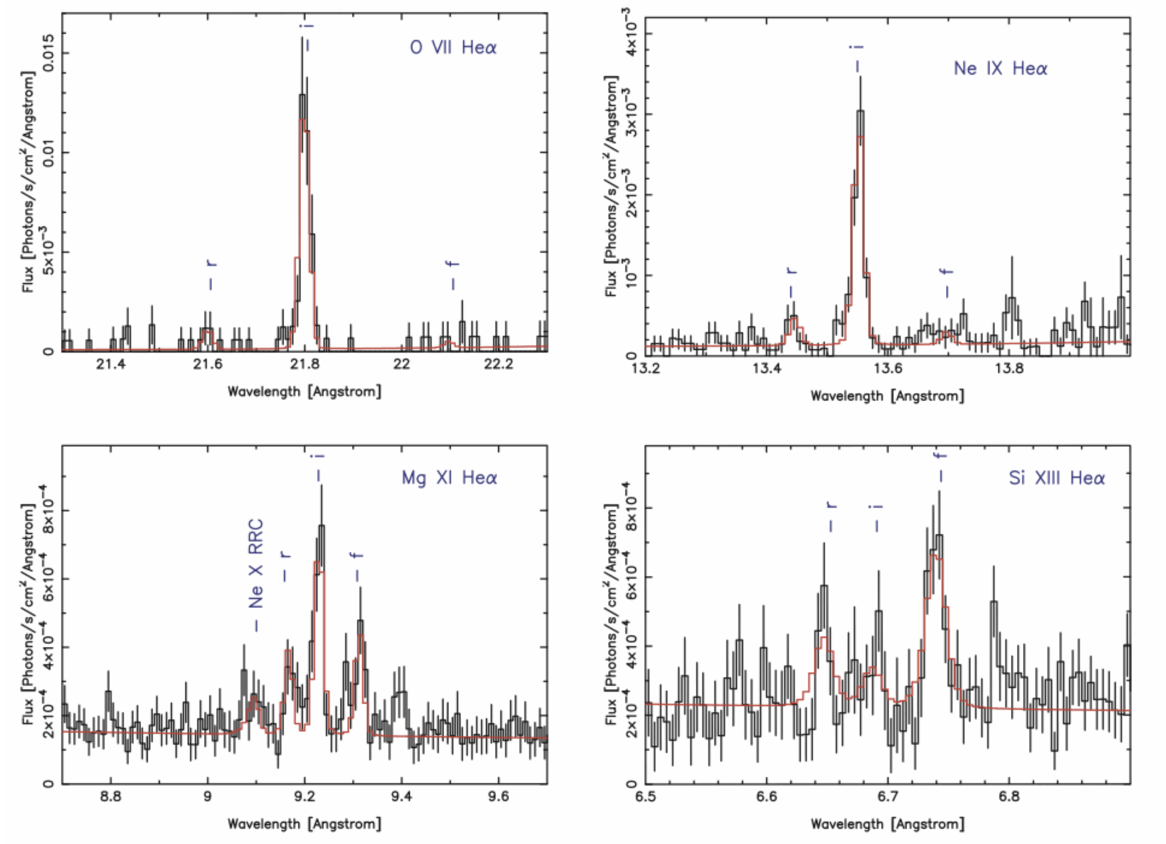
4U 1916-15
Boirin et al. 2004



AX J1745.6-2901
Hyodo et al. 2008

… but also emitting plasmas…

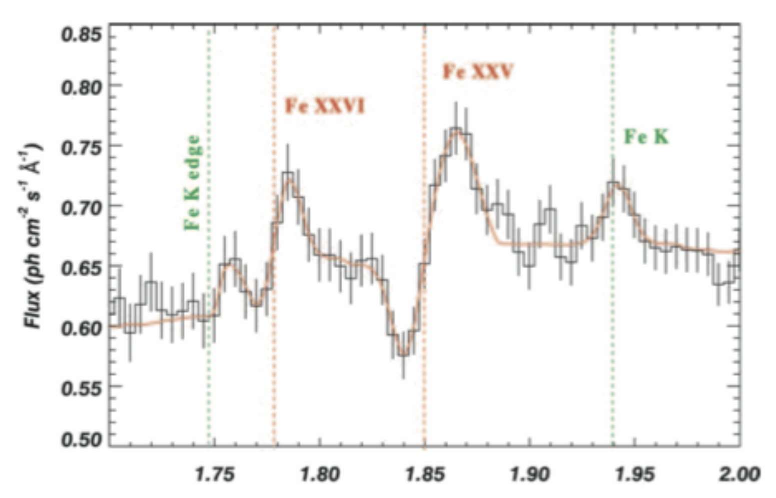


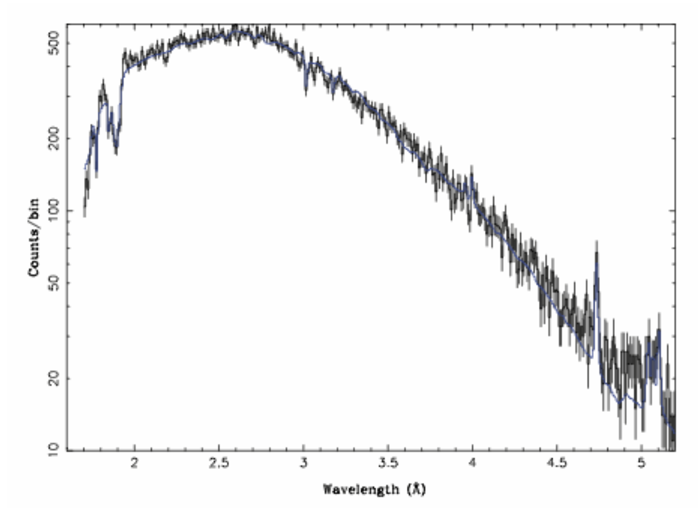


2A 1822-371, Cottam et al. 2001

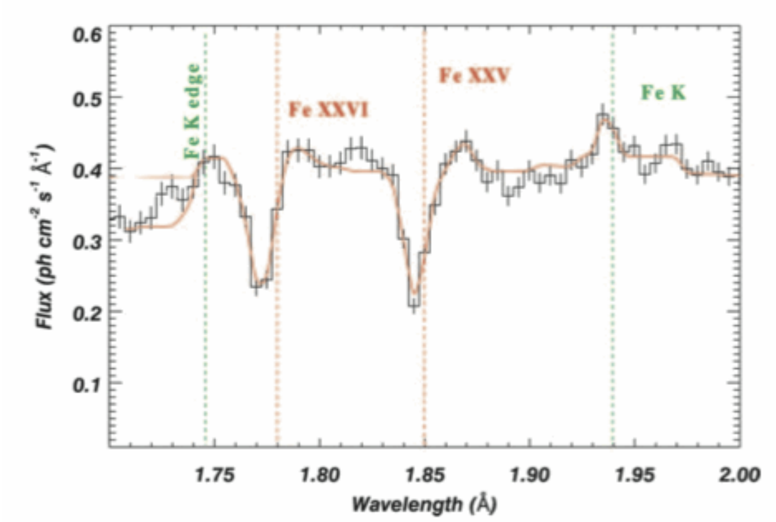
Her X-1, Jimenez-Garate et al. 2005

… and outflows

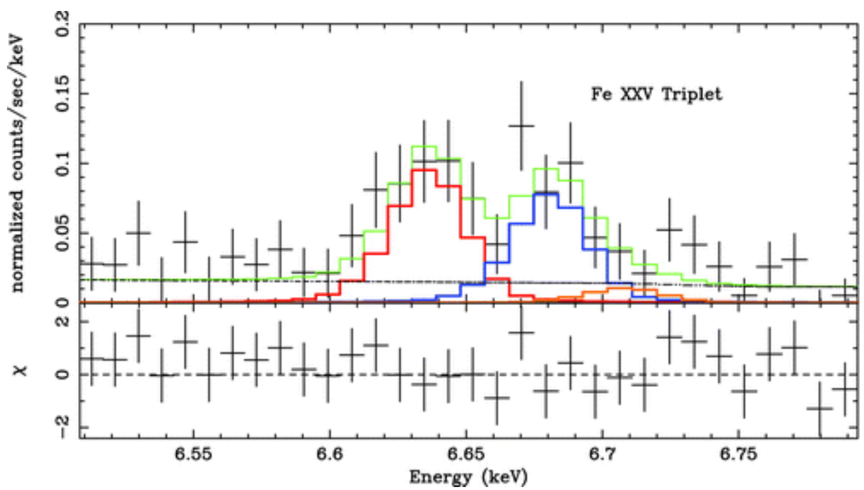




Circinus X-1,
Schulz et al. 2007



Circinus X-1, Schulz & Brandt 2002



Circinus X-1, Iaria et al. 2008

Characteristics of the plasma

- **Highly ionised**: often only Fe XXV and Fe XXVI are present

- **Photoionised** (based on responses to changes in continuum, triplet ratios in emitting plasma, recombination edges)

  - 2 cases of likely "hybrid" plasmas: EXO 0748-676 (van Peet et al. 2009) and Cir X-1 (Schulz et al. 2008, Iaria et al. 2008)

- **Flat ("pancake") geometry** above the disc => probably ubiquitous to all XRBs

- **Changes** in the plasma not only due to the change in **continuum**, but also **phase-dependent** plasma changes in column density and degree of ionisation in dipping sources

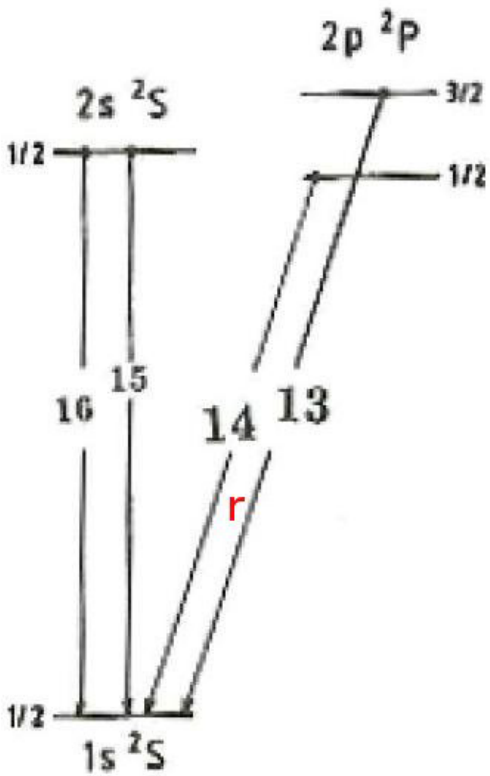
- Distance to the central source ≈ 10^{10}-10^{13} cm

- Outflows preferentially detected in BHs (200-1500 km/s)

Identification of the lines

- 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



H-like atoms (e.g. O VIII or Fe XXVI)

Resonance line in absorption or emission

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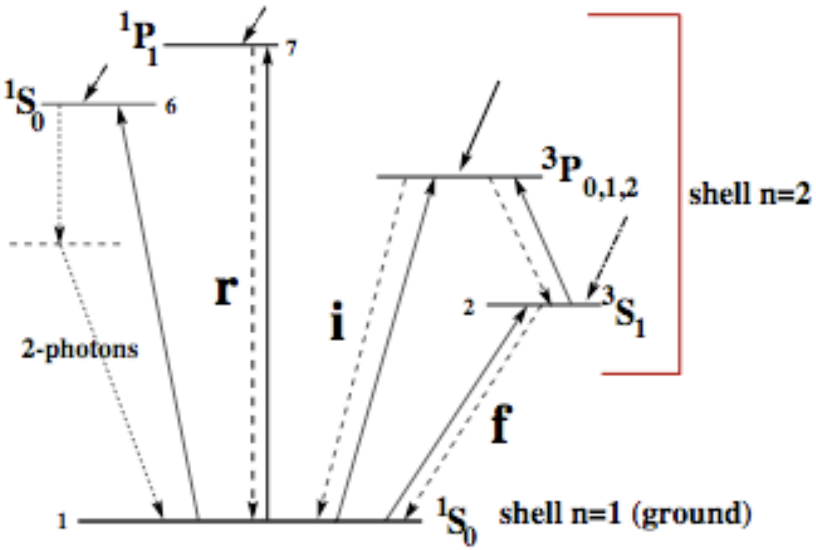


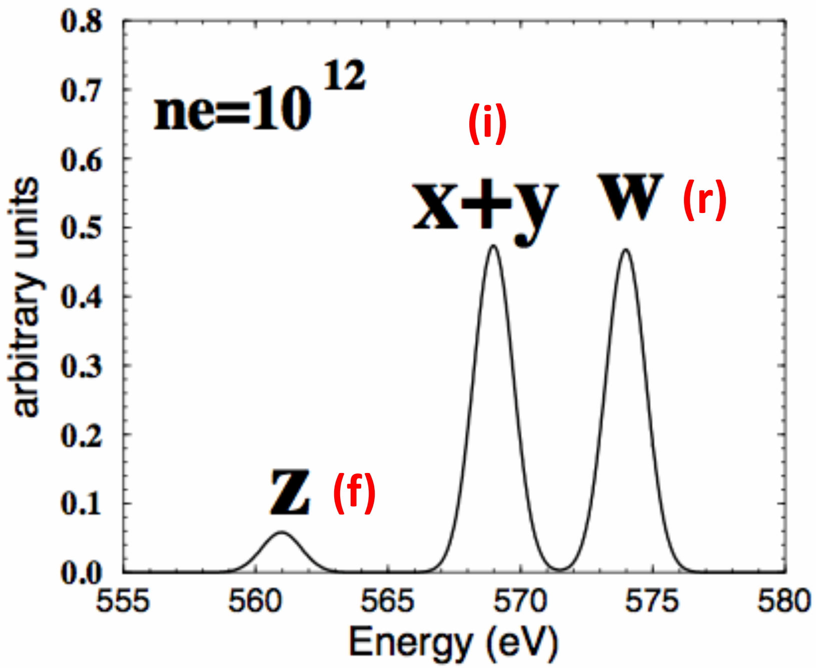
He-like atoms (e.g. OVII or Fe XXV)

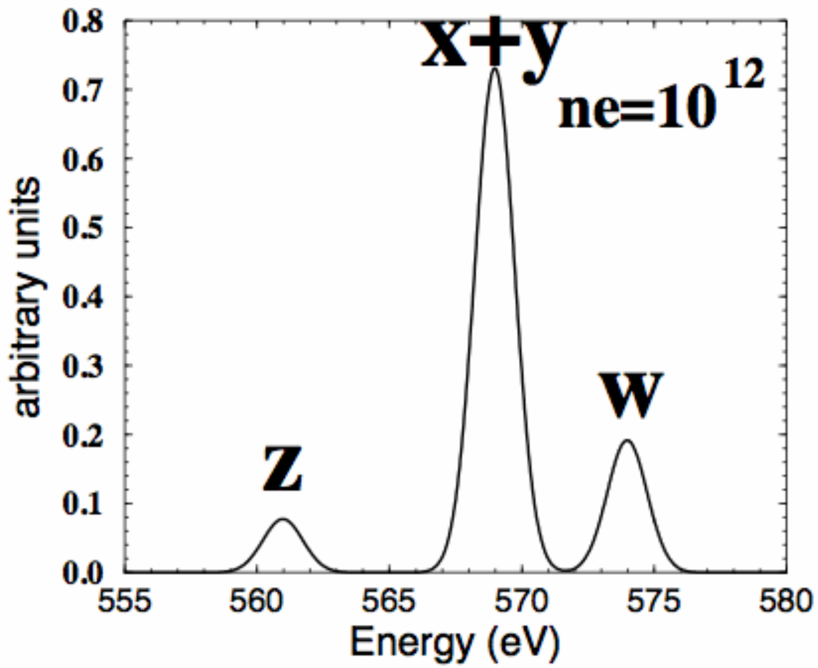
- in absorption: the resonance line
- in emission:
  the "triplet": resonance, intercombination, forbidden

Line ratios depend on the physical conditions of the plasma:

- collisional or photo-ionisation
- density
- temperature

The "triplet"



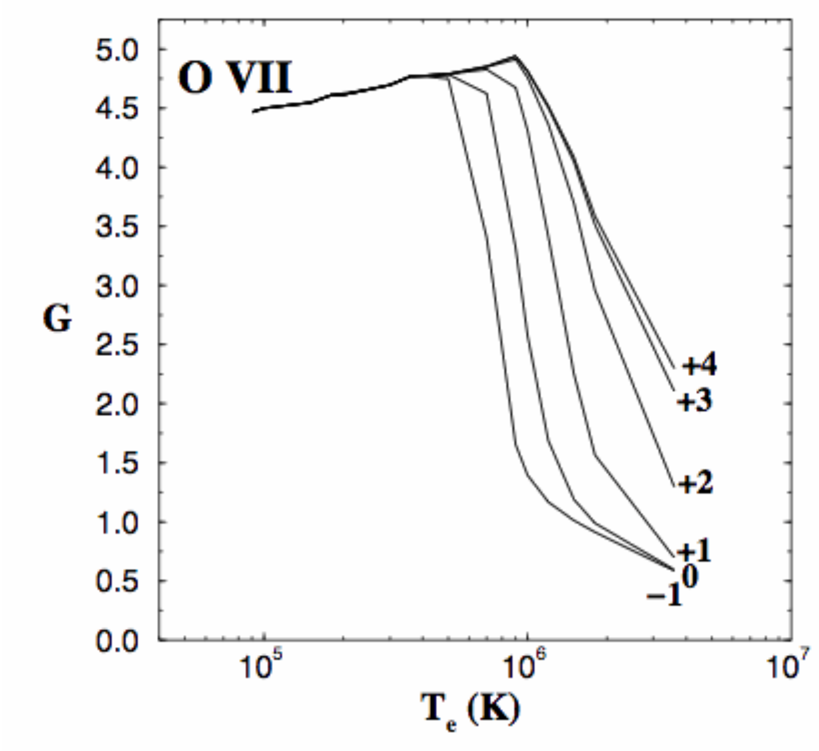


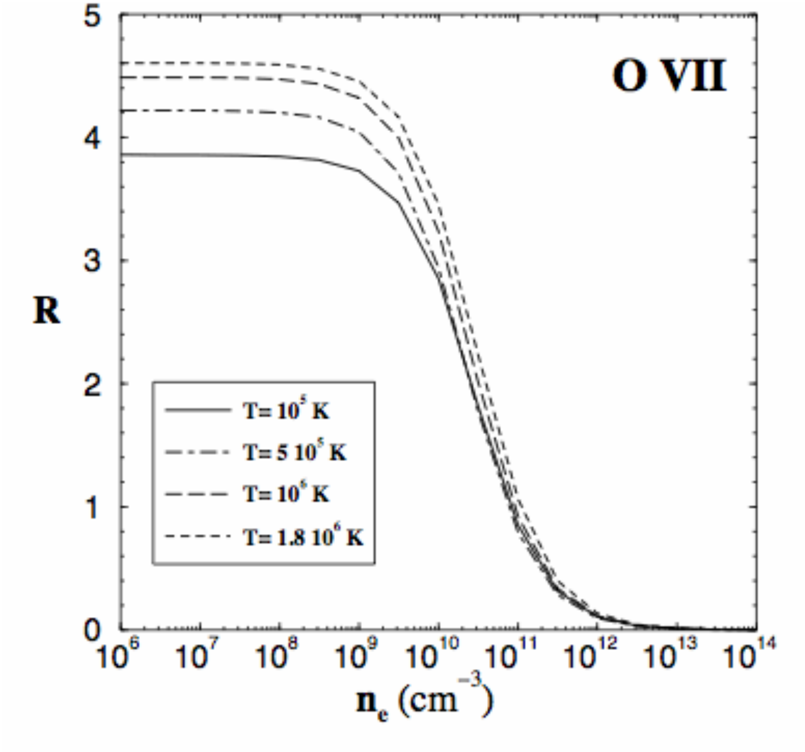
Porquet & Dubau 2000

Hybrid plasma

Photoionised plasma

The “triplet”



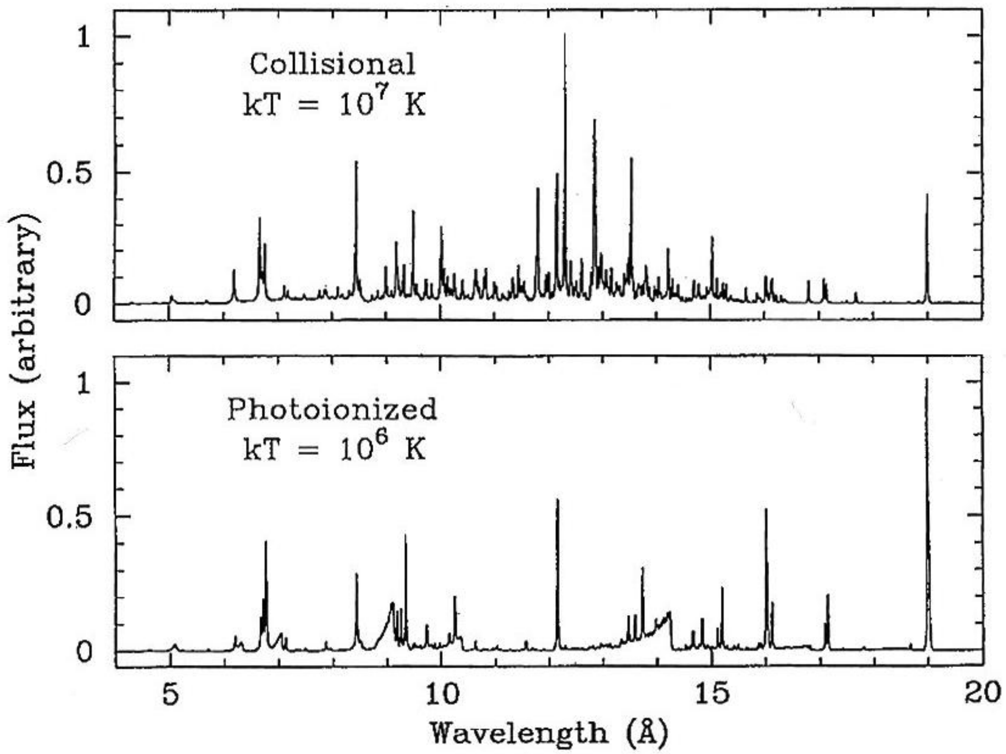


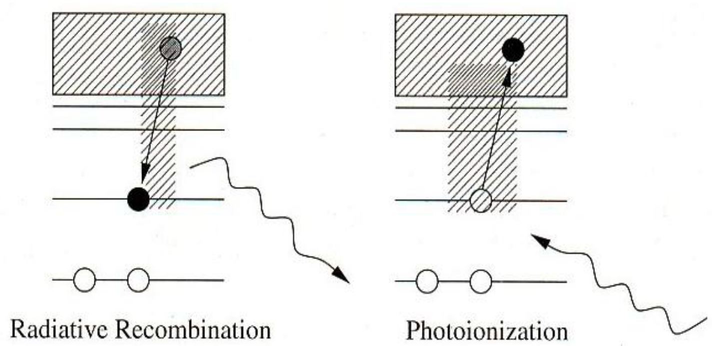
Porquet & Dubau 2000

G = (f+i)/r

R = f/i

Radiative Recombination Continua (RRC)

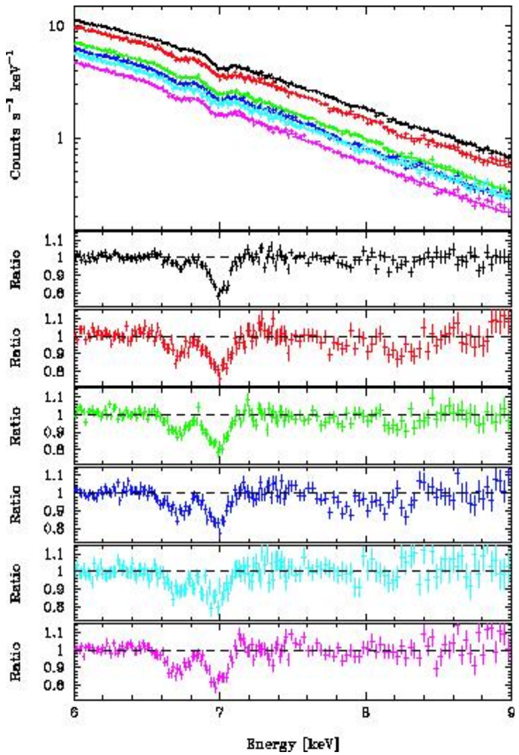




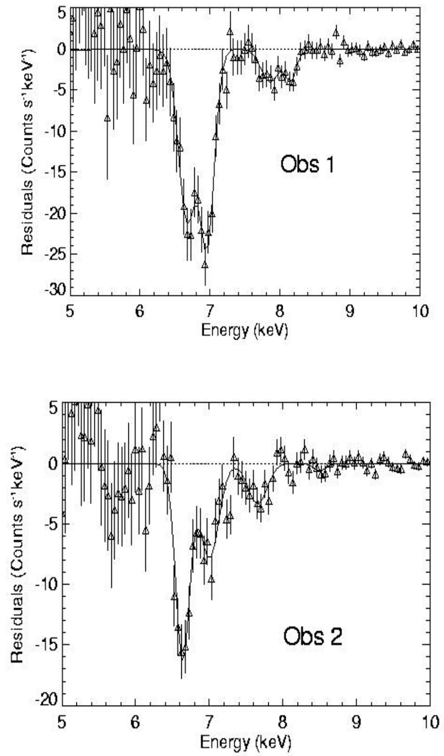
Kahn 2000

Width of RRC => direct measurement of plasma temperature

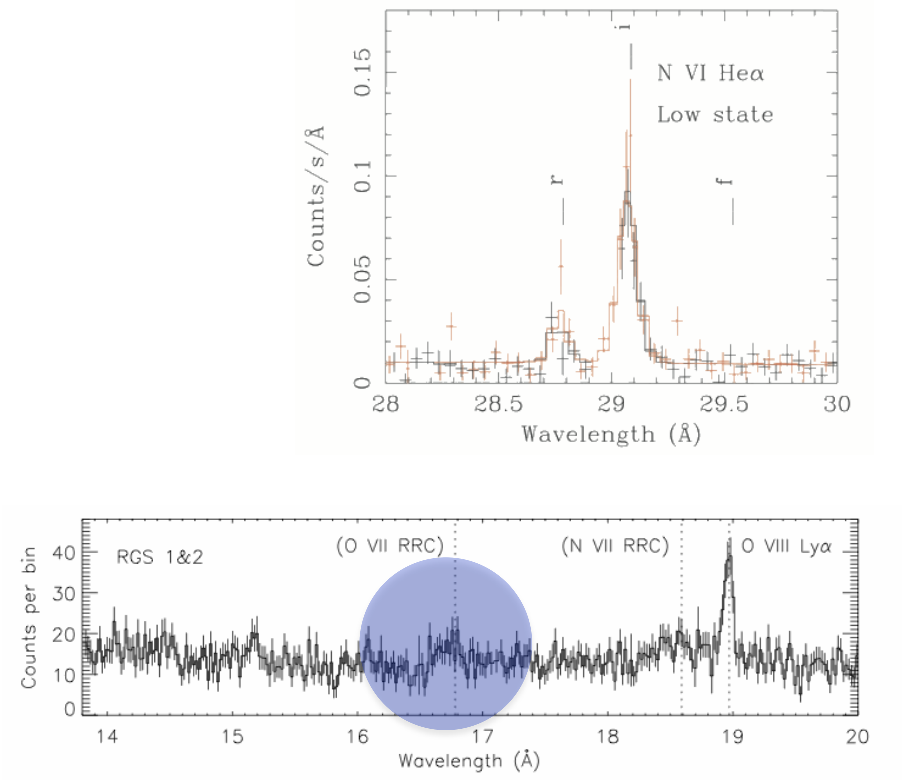
Photoionised plasma



4U 1630-472
(Kubota et al. 2007)

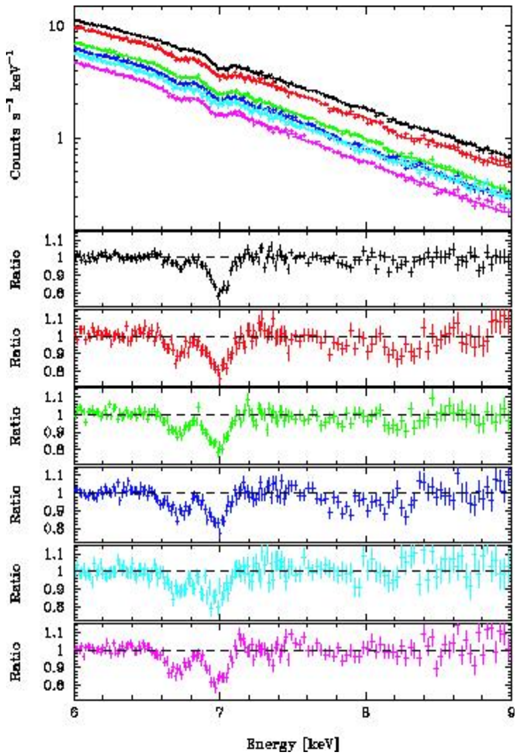


GRO J1655-40
(Diaz Trigo et al. 2007)



Her X-1
(Jimenez-Garate et al. 2001)

Photoionised plasma



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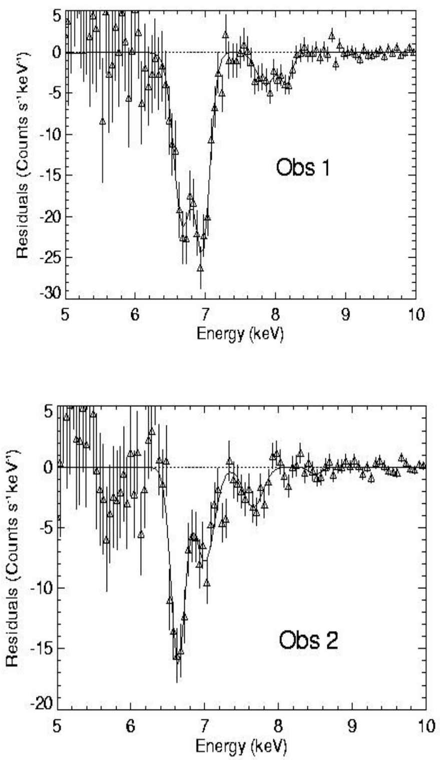
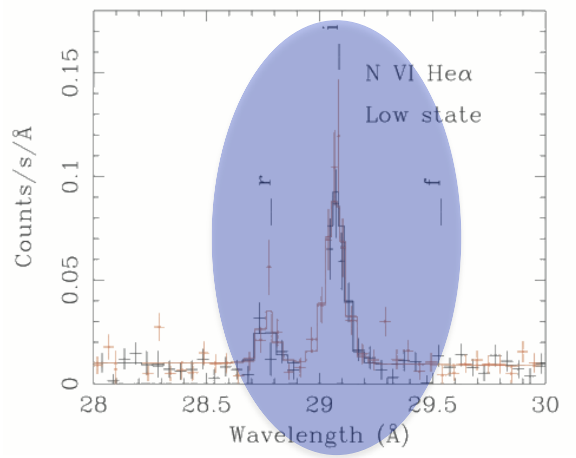
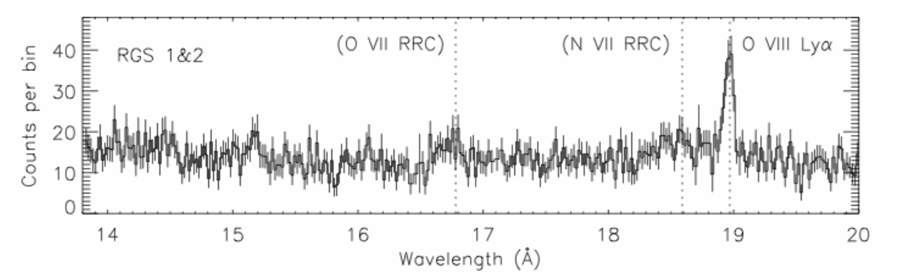


GRO J1655-40
(Díaz Trigo et al. 2007)





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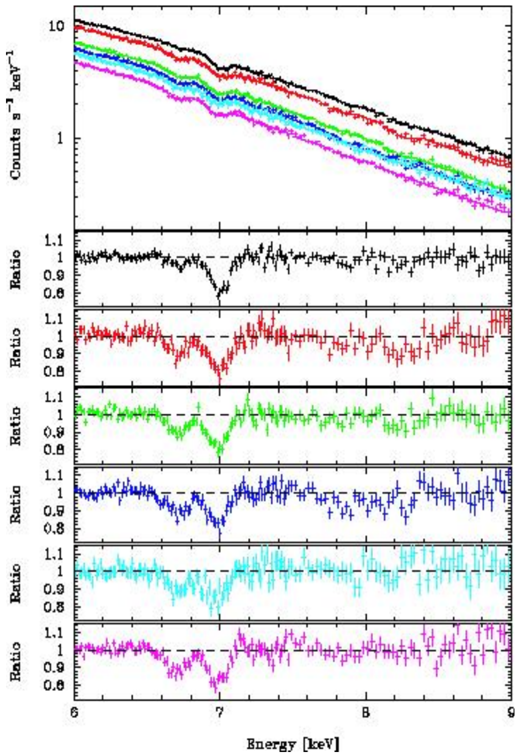
Photoionised plasma



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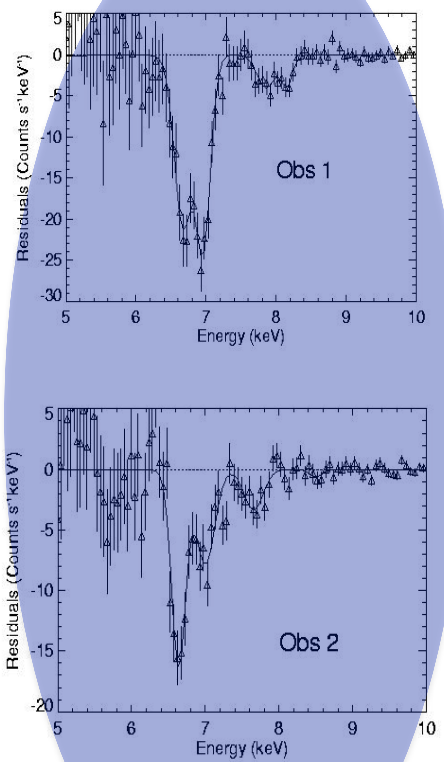

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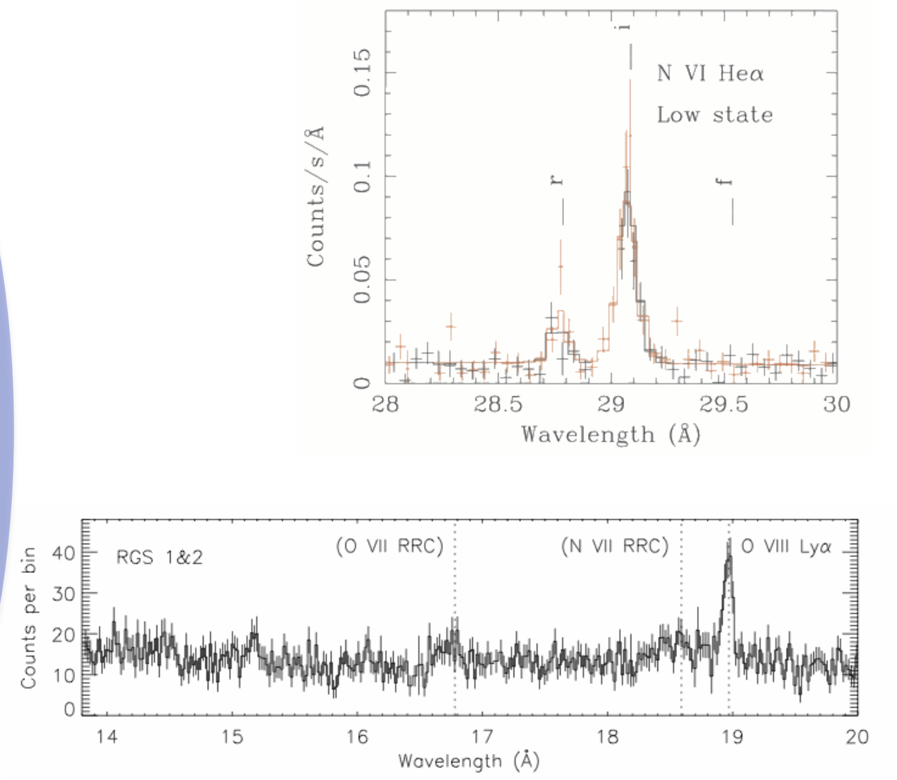
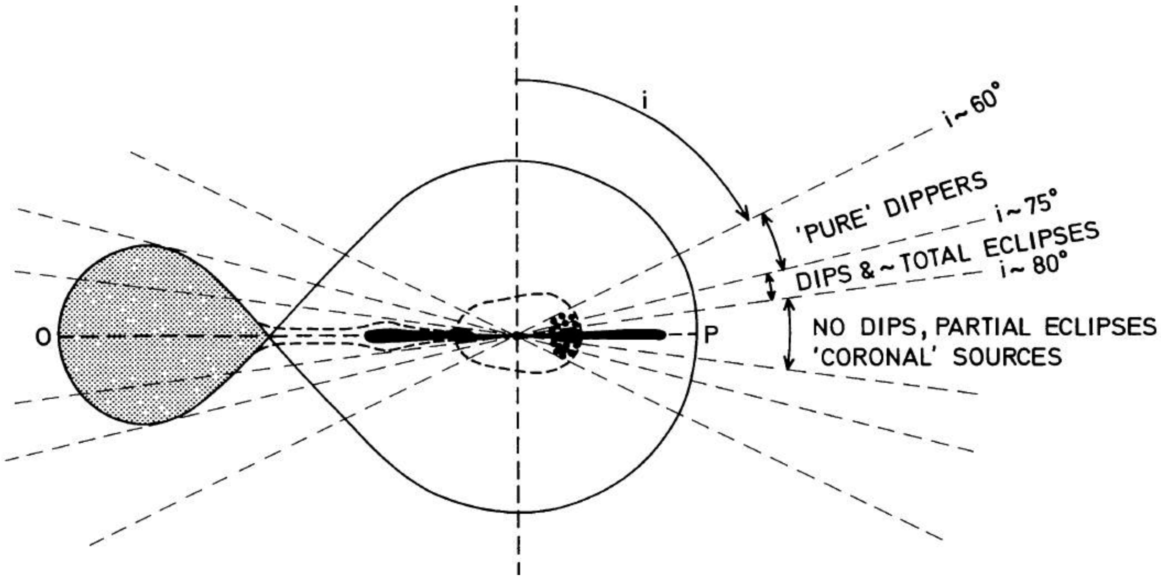
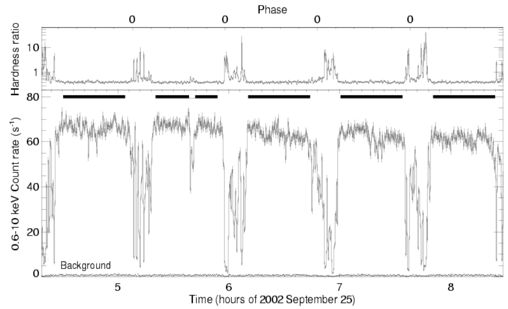


Her X-1
(Jimenez-Garate et al. 2001)

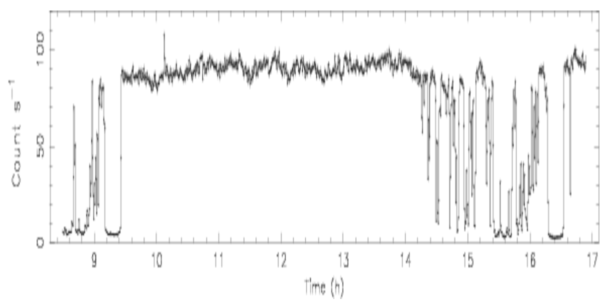
Geometry



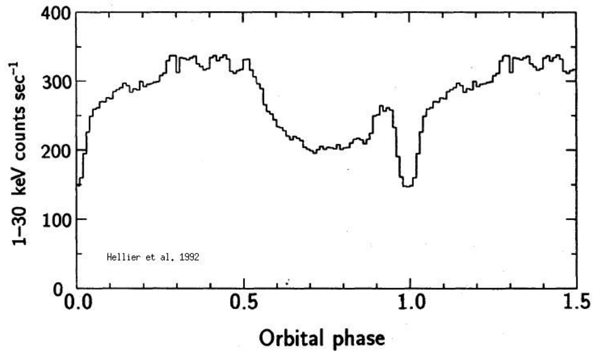
Frank et al. 1987



60-75 deg. ‘Pure’ dippers

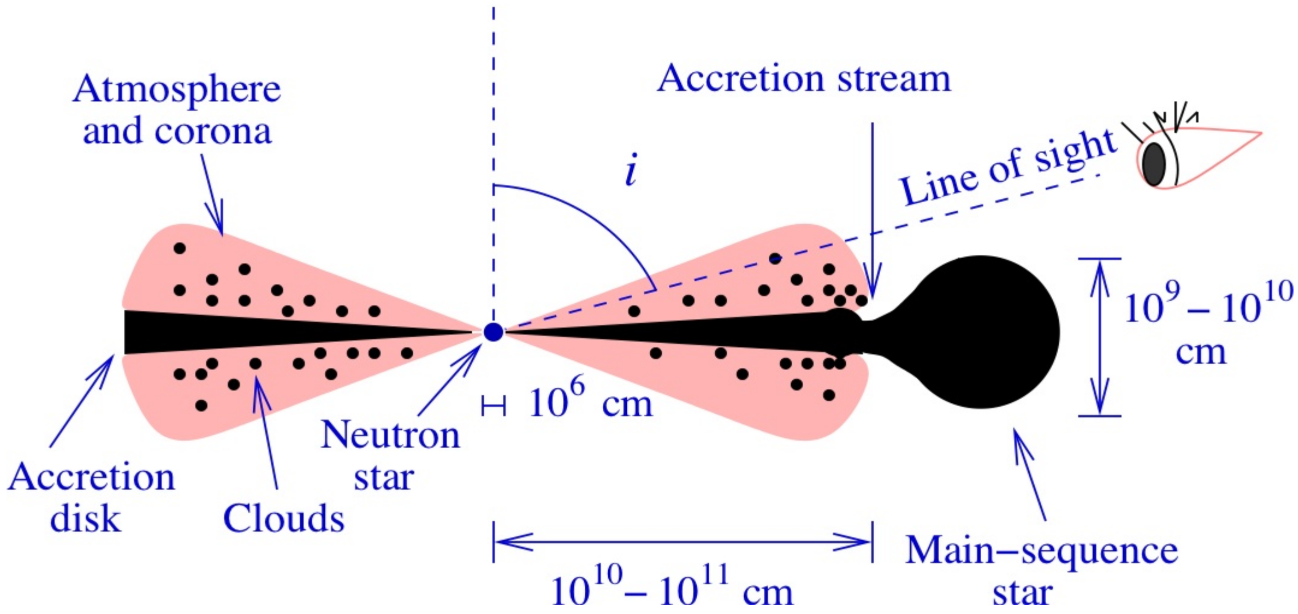


75-80 deg. Dips & ~‘total’ eclipses



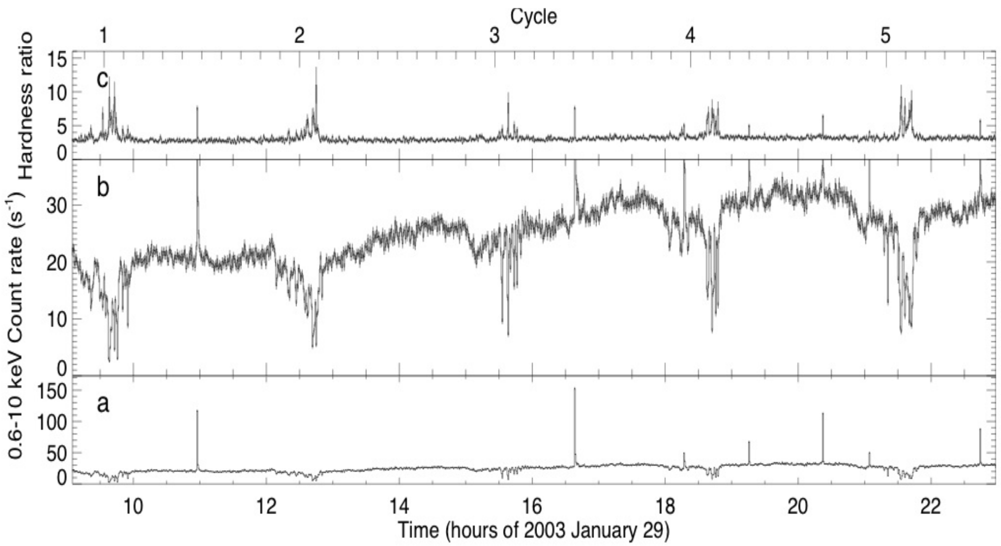
80-90 deg. No dips, partial eclipses

Geometry

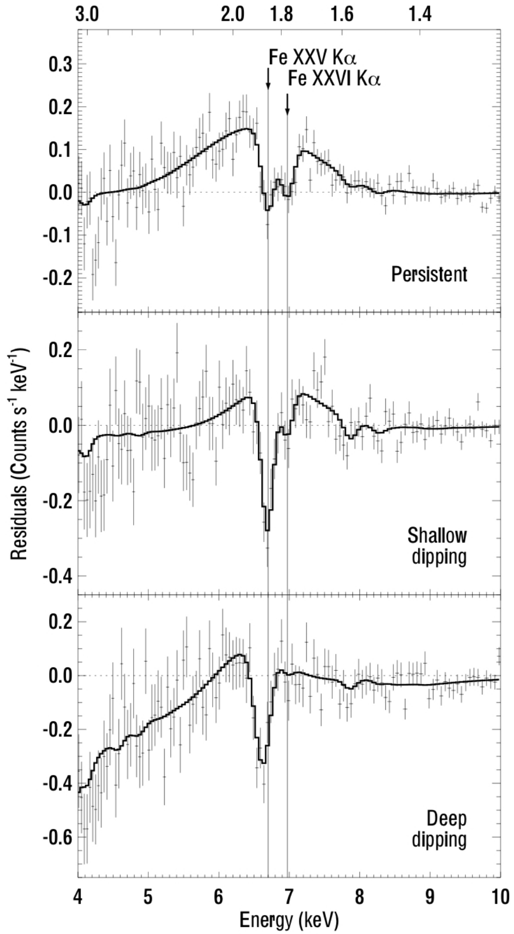


Jimenez Garate et al. 2002

Mapping the disc: phase dependence in dippers



Boirin et al. 2005, Díaz Trigo et al. 2006



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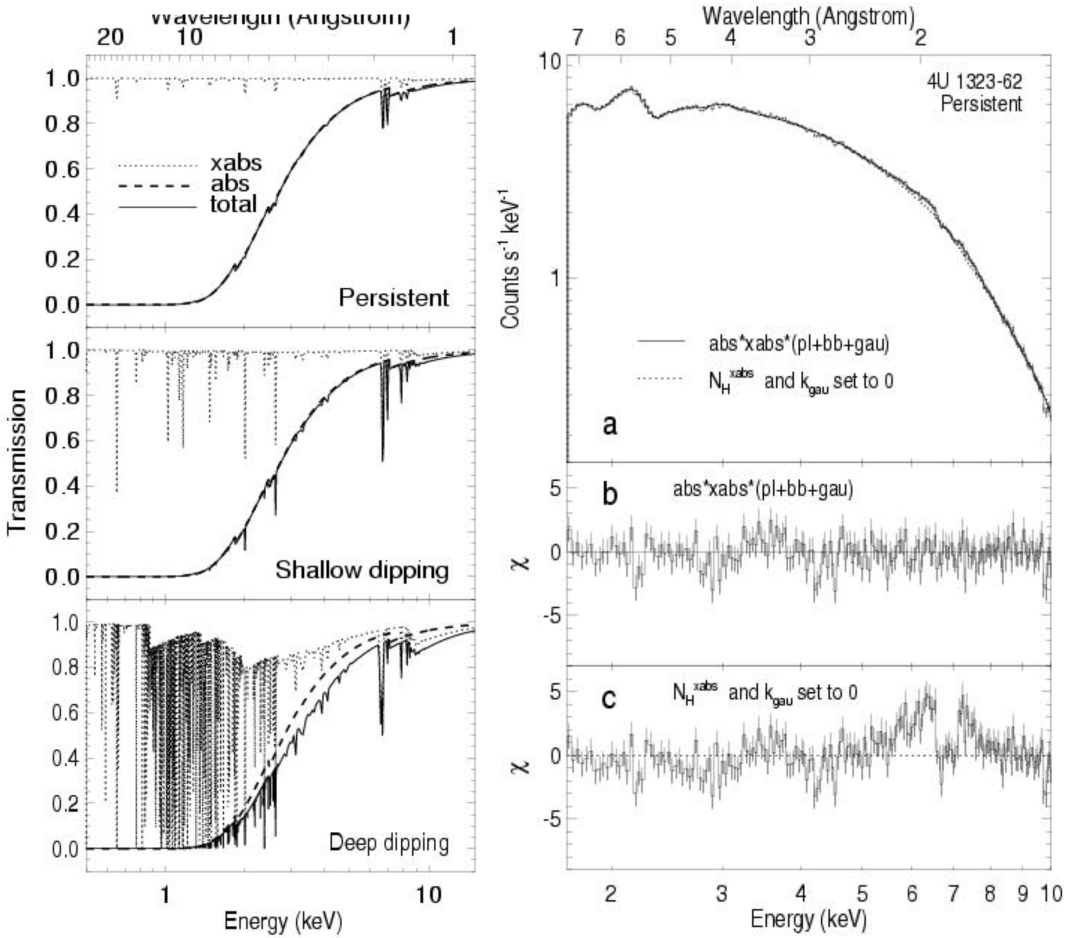
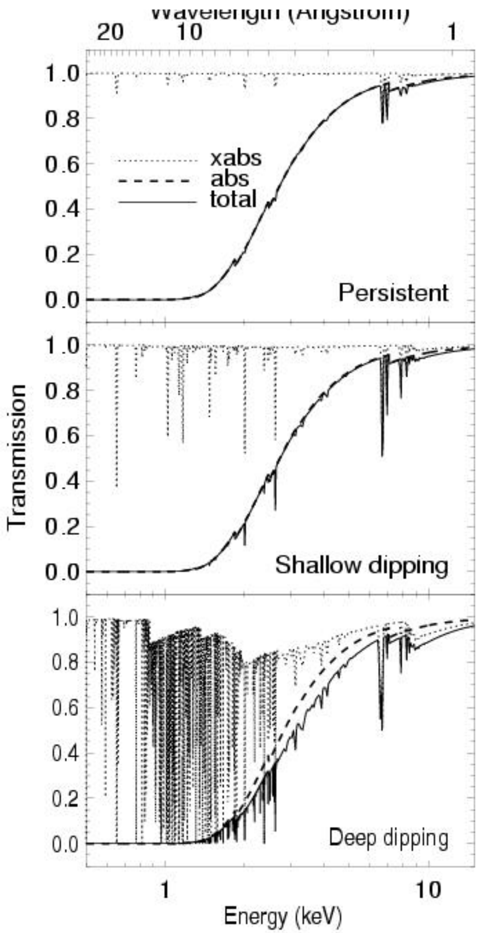


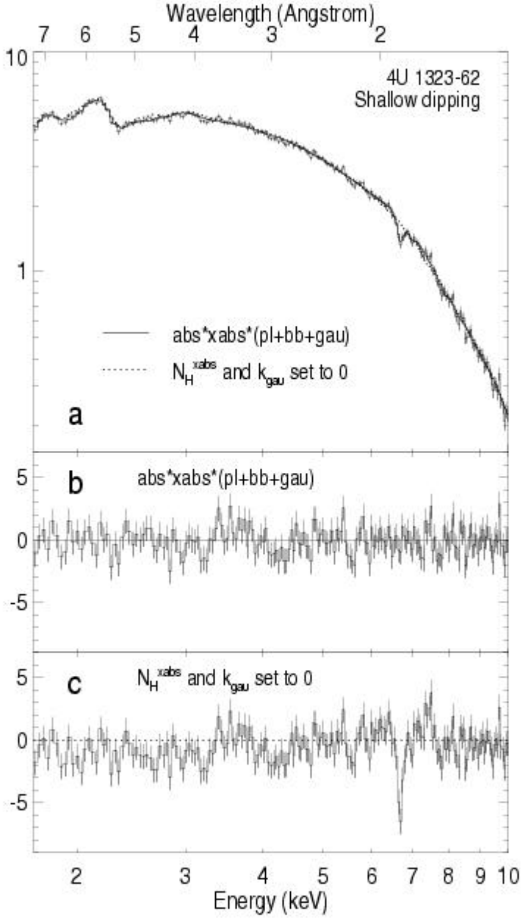
The properties of the warm absorber change during dipping:

- ionization stage decreases
- column density increases

Boirin et al. 2005, Díaz Trigo et al. 2006

Mapping the disc:
phase dependence in dippers





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Boirin et al. 2005, Díaz Trigo et al. 2006

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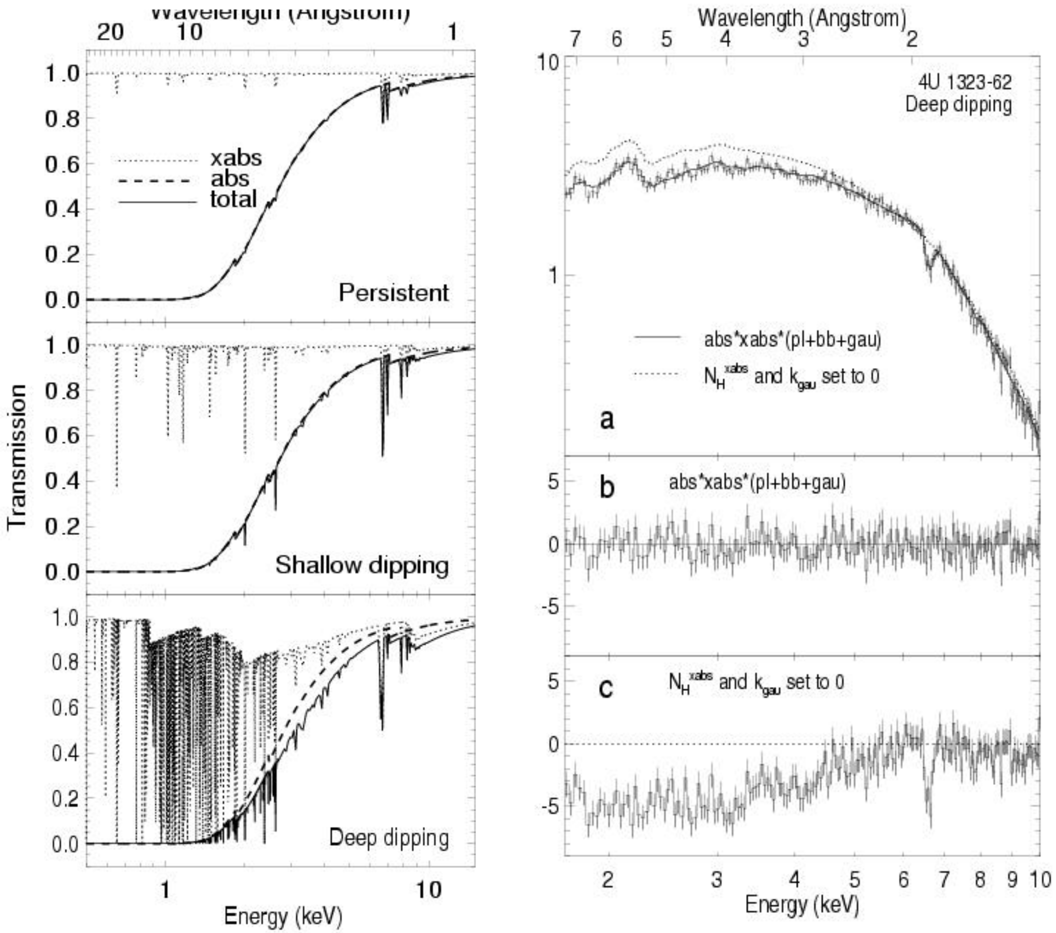
phase dependence in dippers



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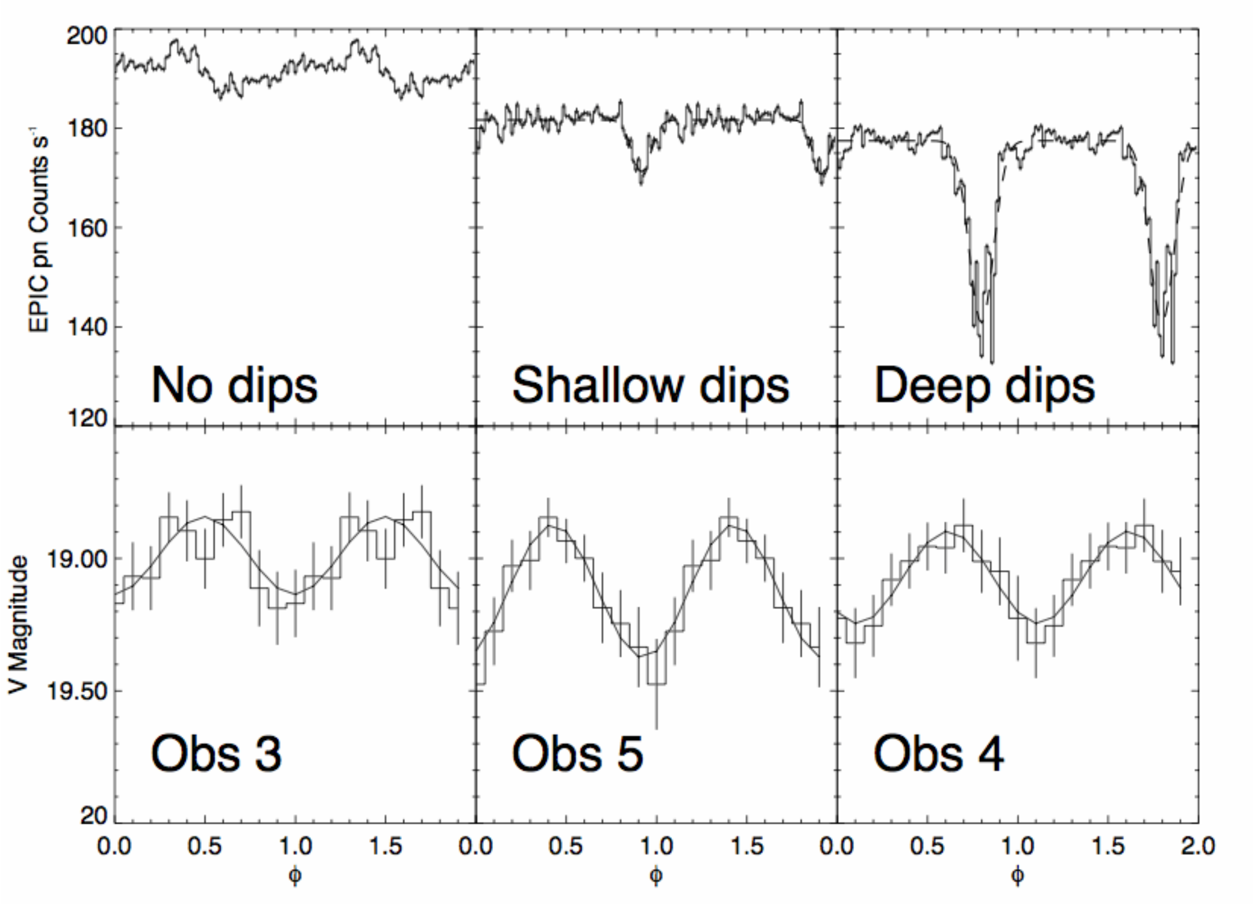
Boirin et al. 2005, Díaz Trigo et al. 2006

Mapping the disc: dips appearance

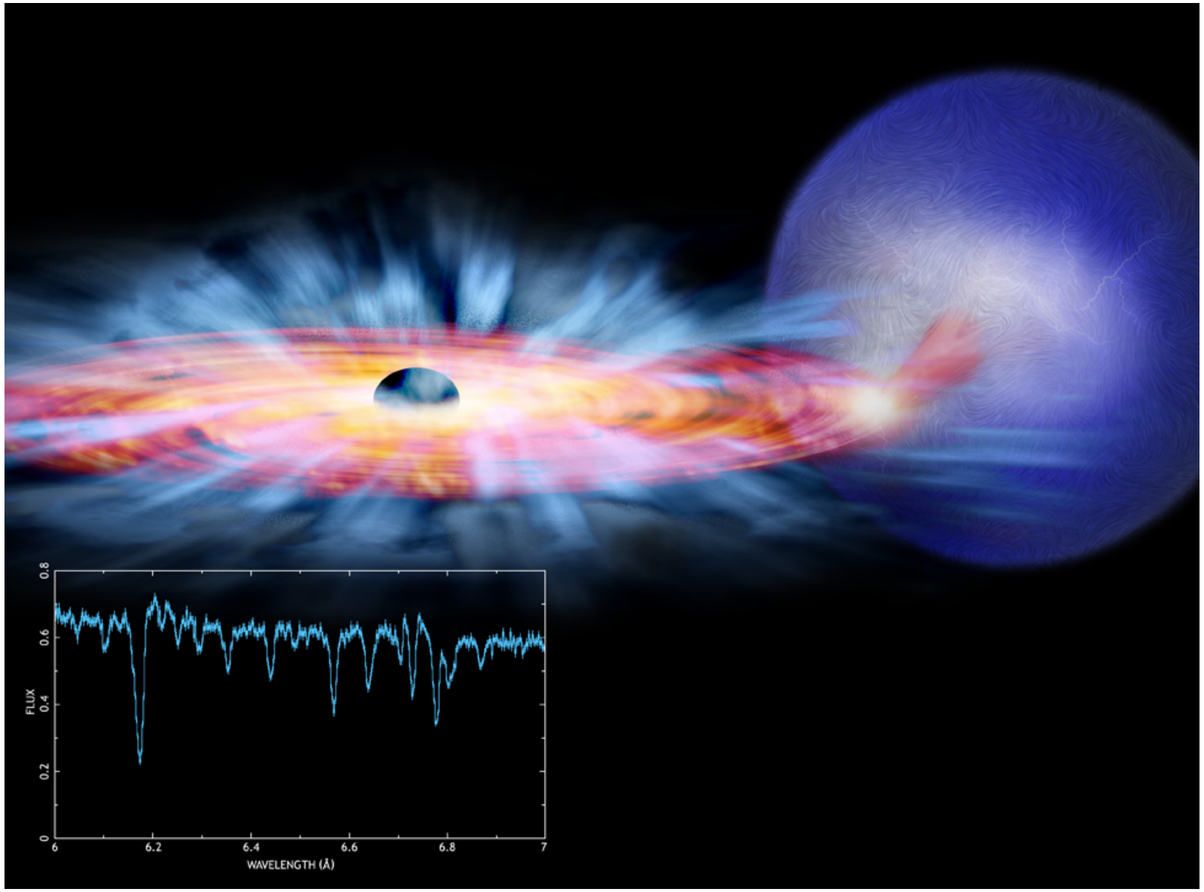


Tilted disc?

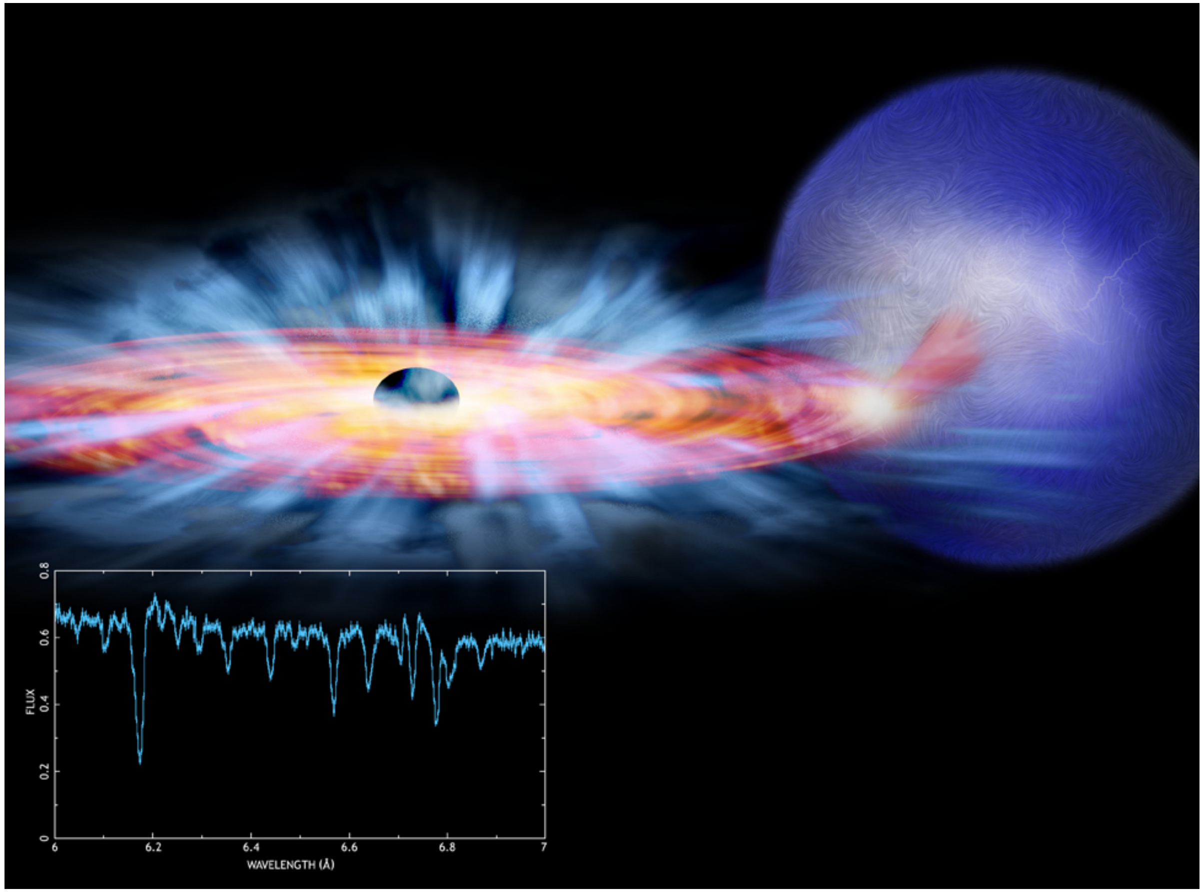
Díaz Trigo et al. 2009

WINDS

Winds are present in all kinds of accretion powered objects



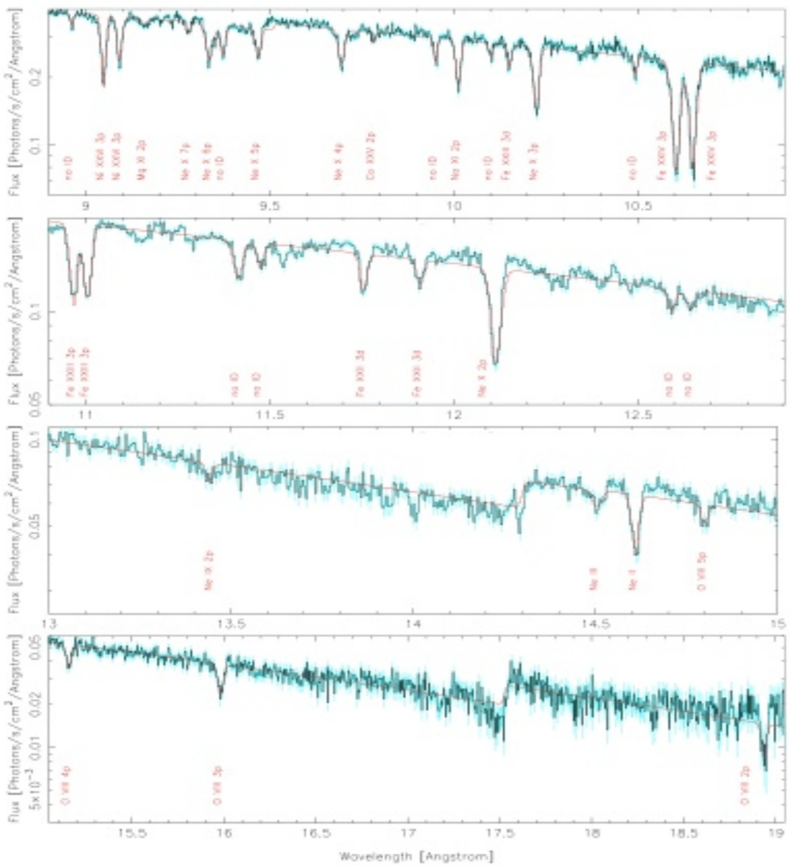
Credit: Illustration: NASA/CXC/M.Weiss; X-ray Spectrum: NASA/CXC/U.Michigan/J.Miller et al.



Importance of characterising the outflows:

- Dynamics of the system
- Feedback to their environment

Outflows preferentially detected in BHs
(but see Cir X-1, GX 13+1 & IGR J17480–2446)



GRO J1655-40, Miller et al. 2006

Outflow velocities ≈ 300-1500 km/s

mass outflow rate ≤ mass accretion rate

(10^{17}-10^{19} g/s)

This component certainly plays an important role in the overall properties of the system and in its evolution.

What do we want to learn?

- Launching mechanism (we need to know the launching radius):
  - Magnetic
  - Thermal
  - Line-driven (UV radiation pressure)

- Feedback:

  Is the mass expelled important enough to affect the dynamics of the system or the environment?

What do we want to learn?

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

If the flux varies on a certain time the variability of the WA provides a lower limit on the density => Upper limit on the distance

Other methods: detection of excited levels associated with a given collision strength and decay rate or metastable levels

$$\mathbf{n_e \approx 10^{12} - 10^{13}\ cm^{-3}}$$

$$\mathbf{r \approx 10^{10} - 10^{12}\ cm}$$

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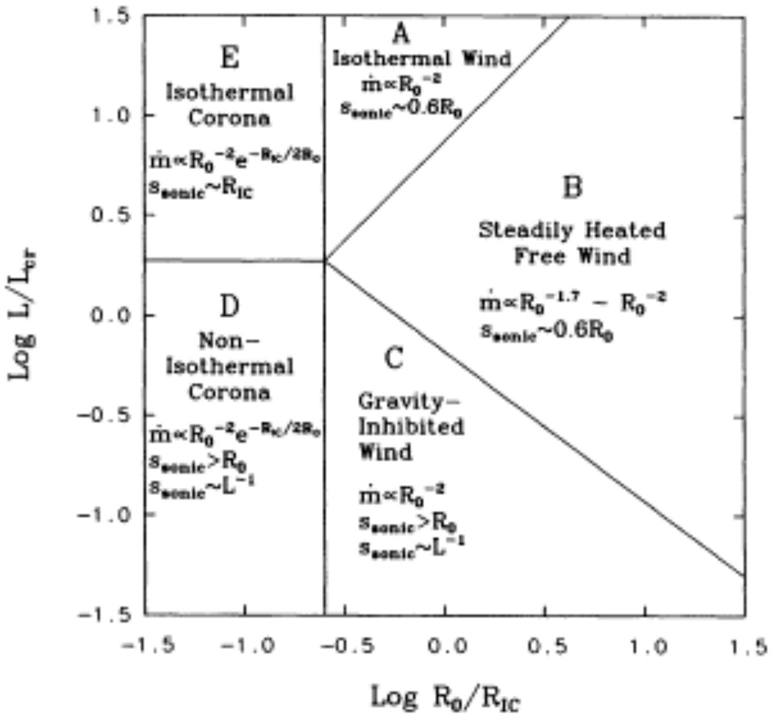
- Launching mechanism (we need to know the launching radius):
  - Magnetic
  - Thermal
  - ~~Line-driven~~ (Proga & Kallman 2002)

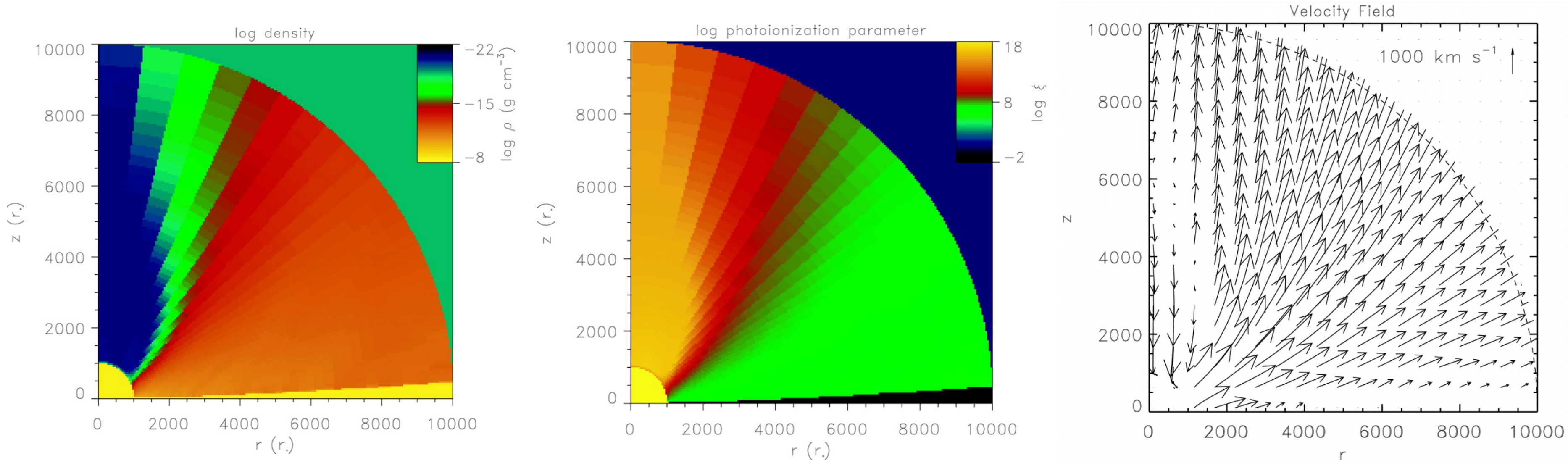
Thermal winds



Begelman et al. 1983, Woods et al. 1996

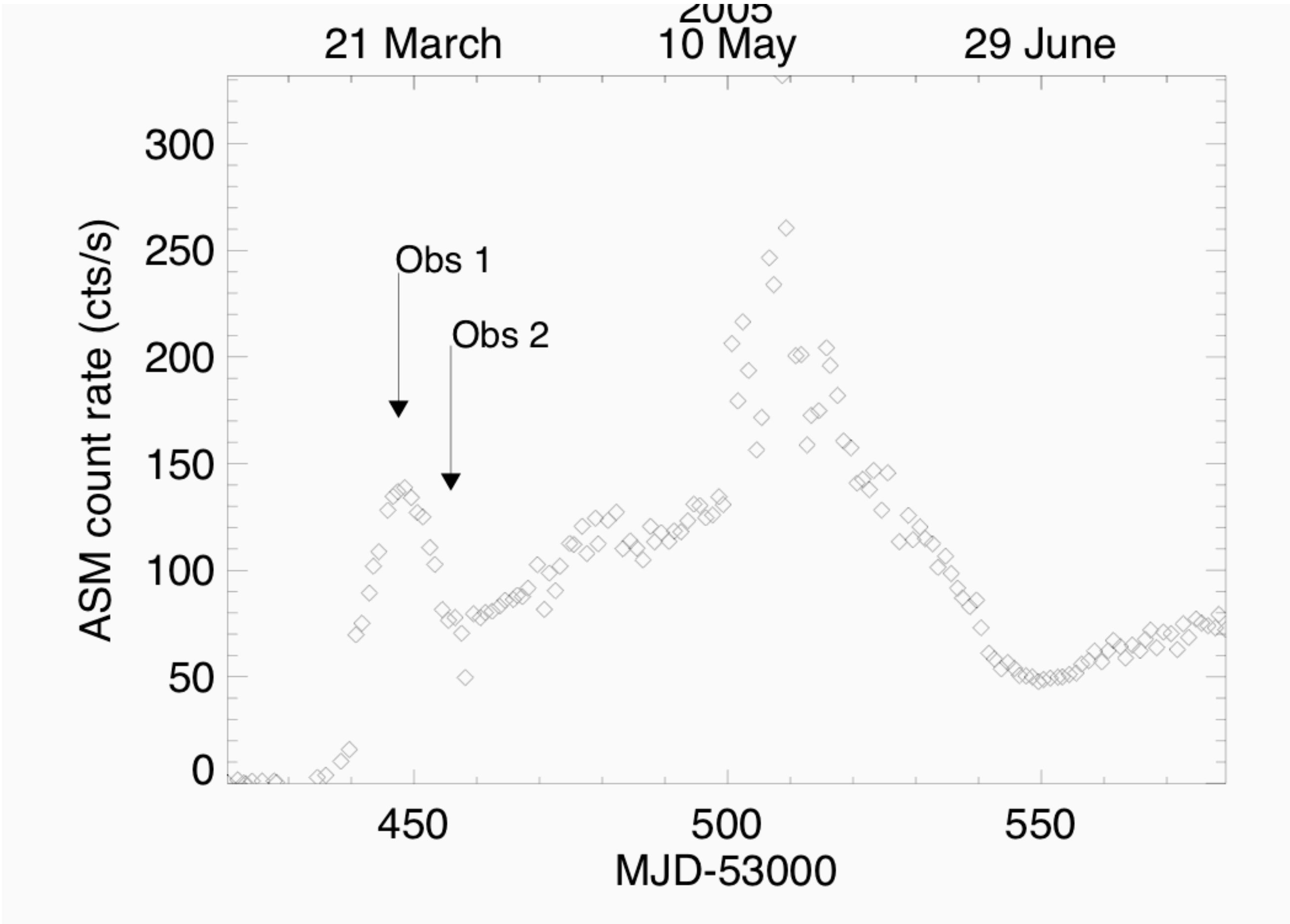
Compton radius: distance at which the escape velocity equals the isothermal sound speed at the Compton temperature

Thermal winds



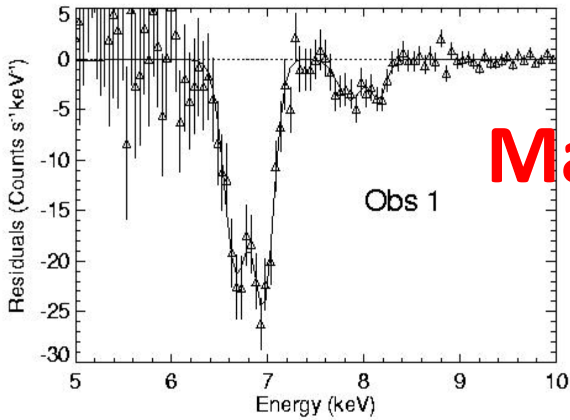
Proga & Kallman 2002

GRO J1655-40

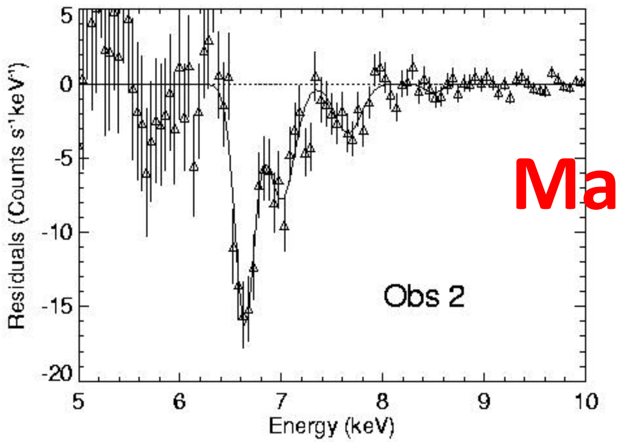


Diaz Trigo et al. 2007

GRO J1655-40

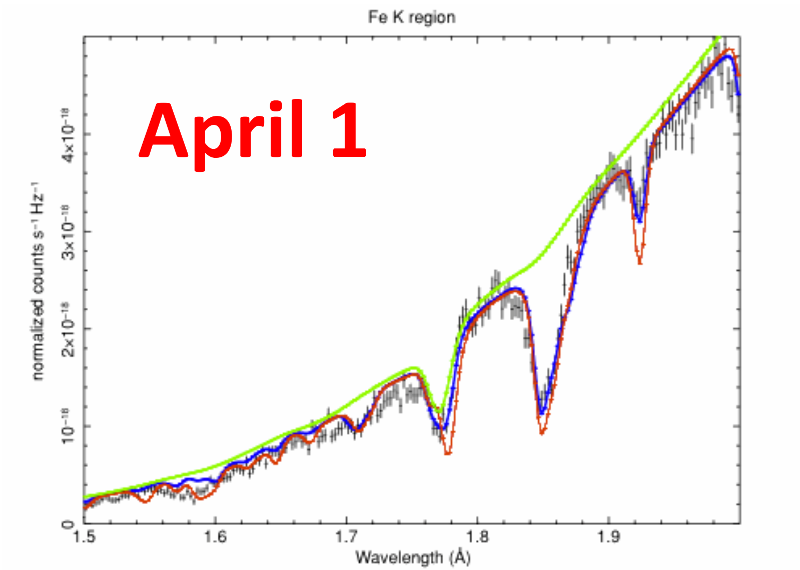


March 18



March 27

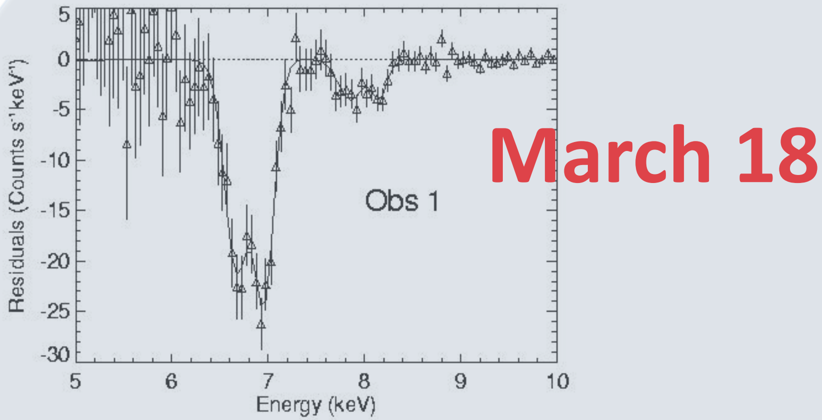
Diaz Trigo et al. 2007

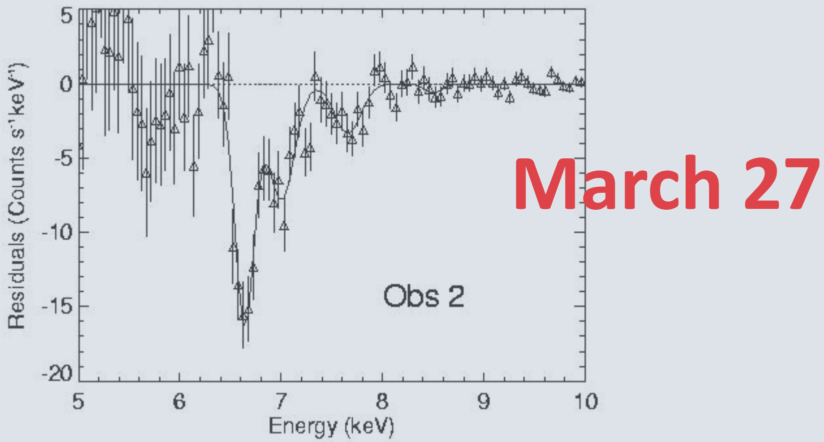


April 1

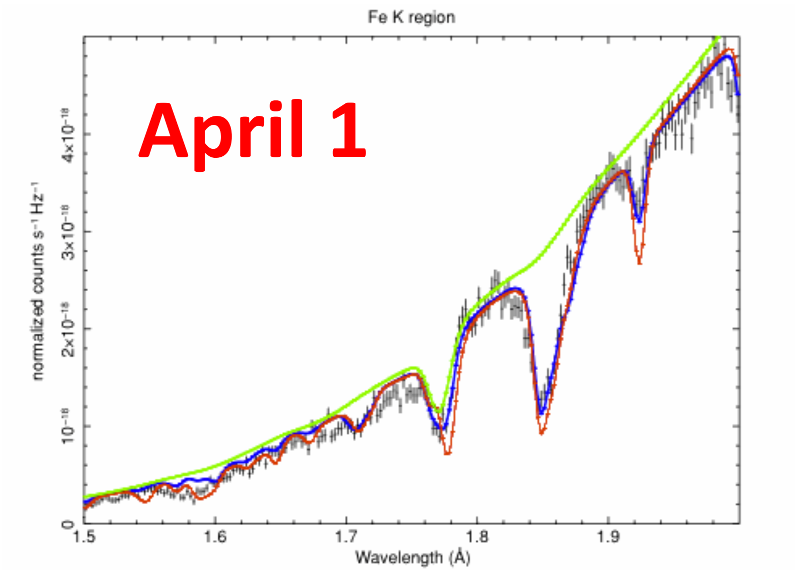
Miller et al. 2006, Kallman et al. 2009
(see also Netzer 2006, Luketic et al. 2010)

GRO J1655-40





Diaz Trigo et al. 2007



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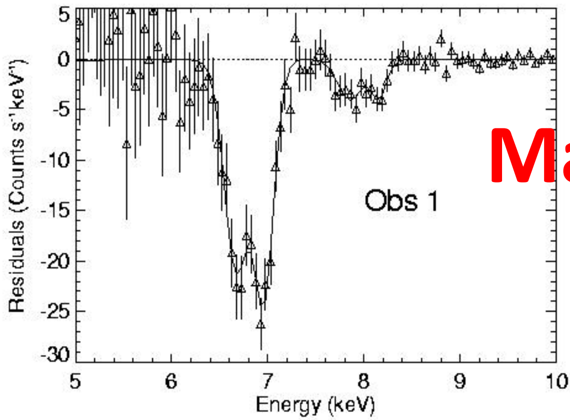
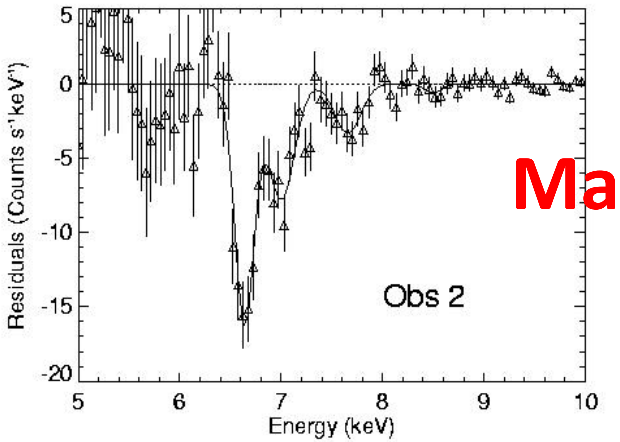


March 18



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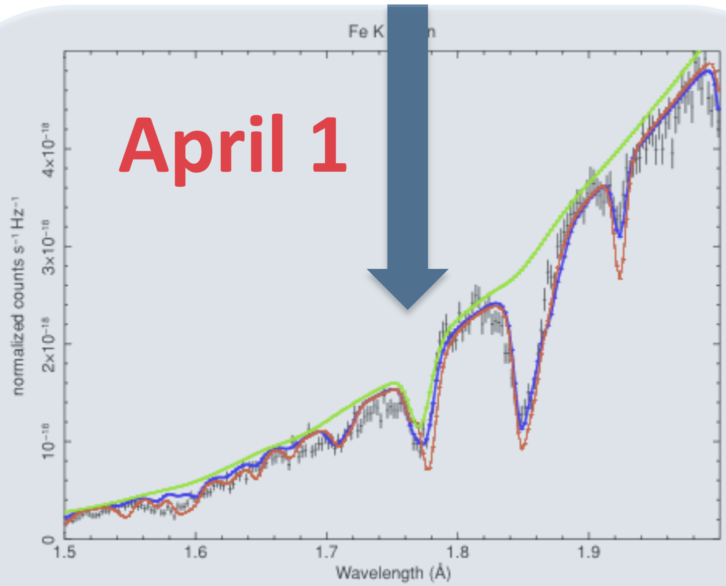
Diaz Trigo et al. 2007



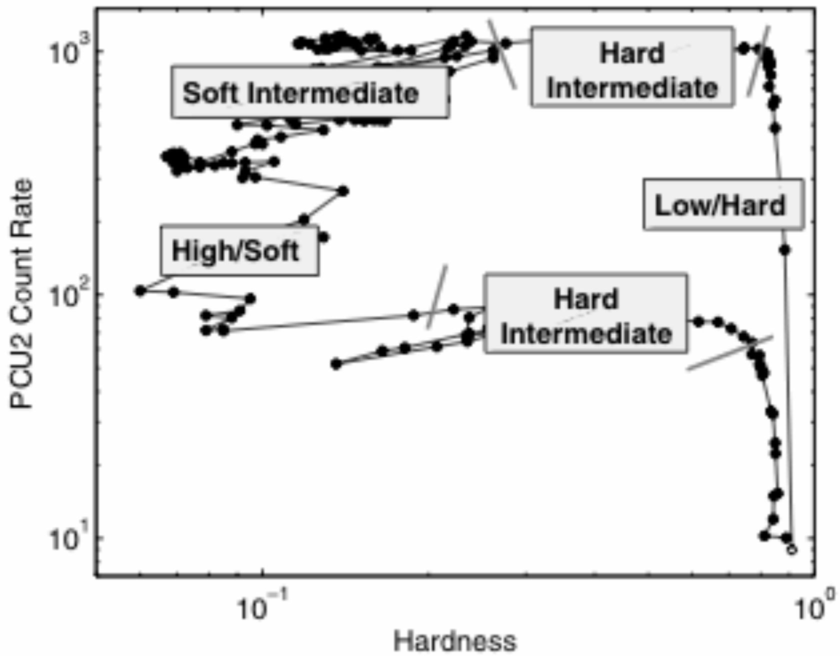
April 1

Miller et al. 2006, Kallman et al. 2009
(see also Netzer 2006, Luketic et al.2010)

$r < 2x\ 10^9$ cm => Magnetic driving (Miller et al. 2006)
$r \approx 10^{11}$ cm => Thermal driving (Netzer et al. 2006)

Relation between winds and jets

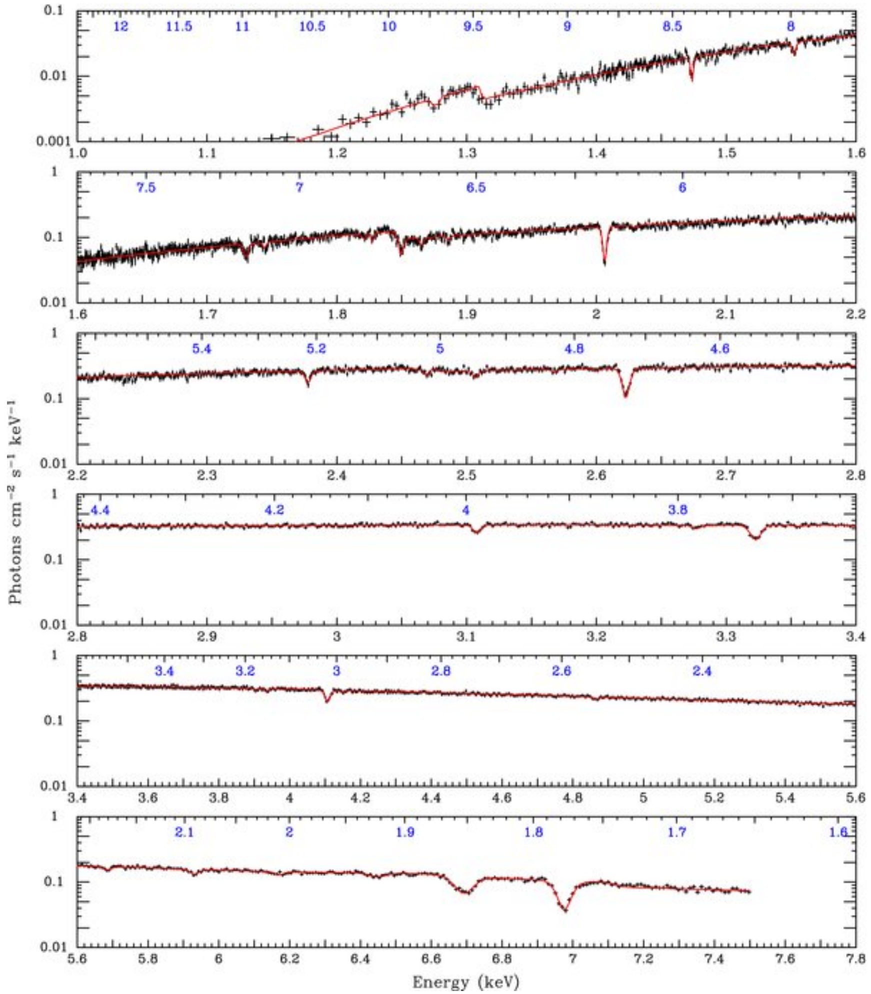
Winds



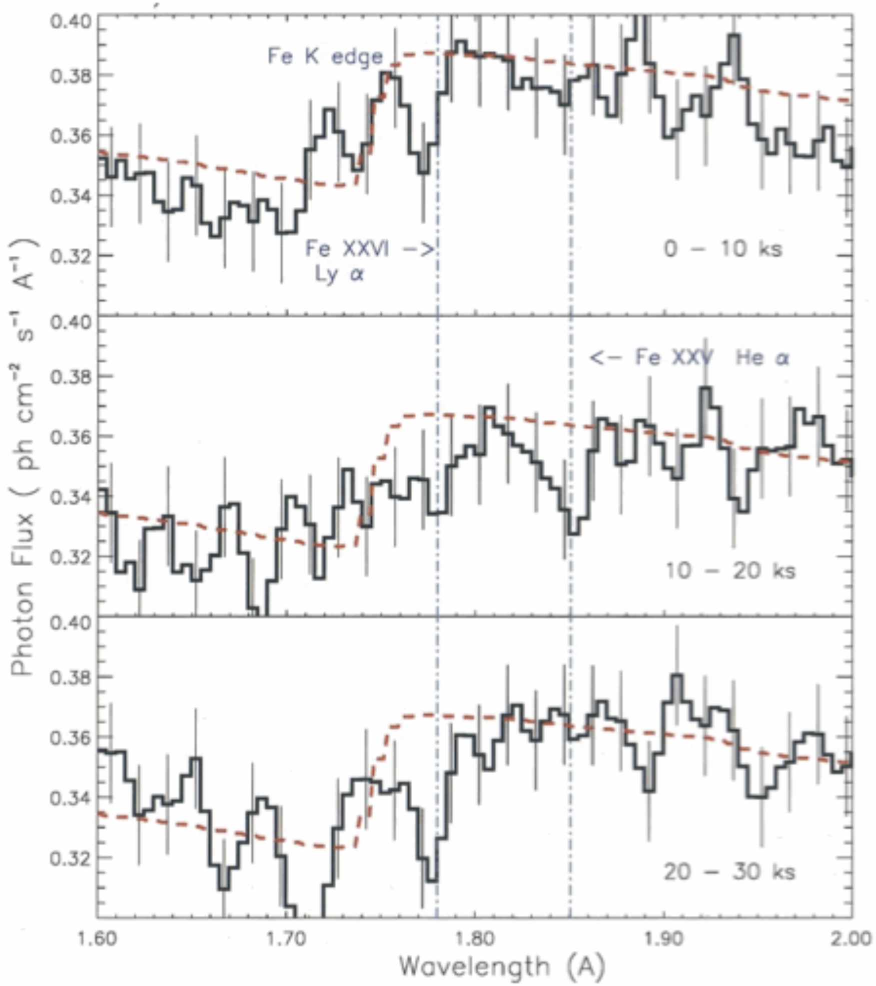
Jets

(Homan & Belloni 2005)

The case of GRS 1915+105

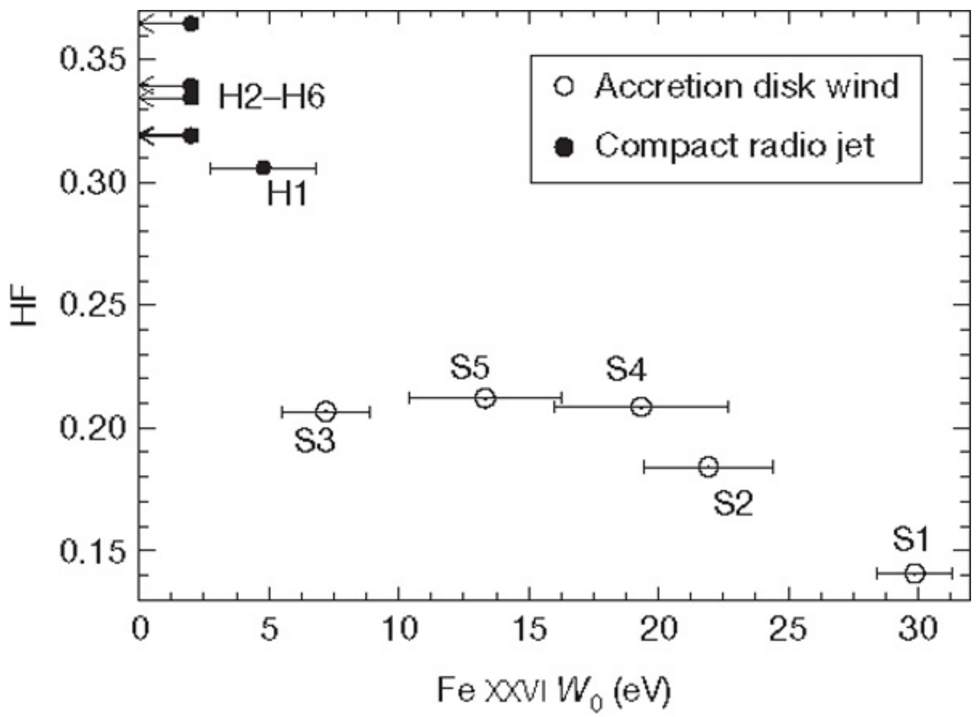


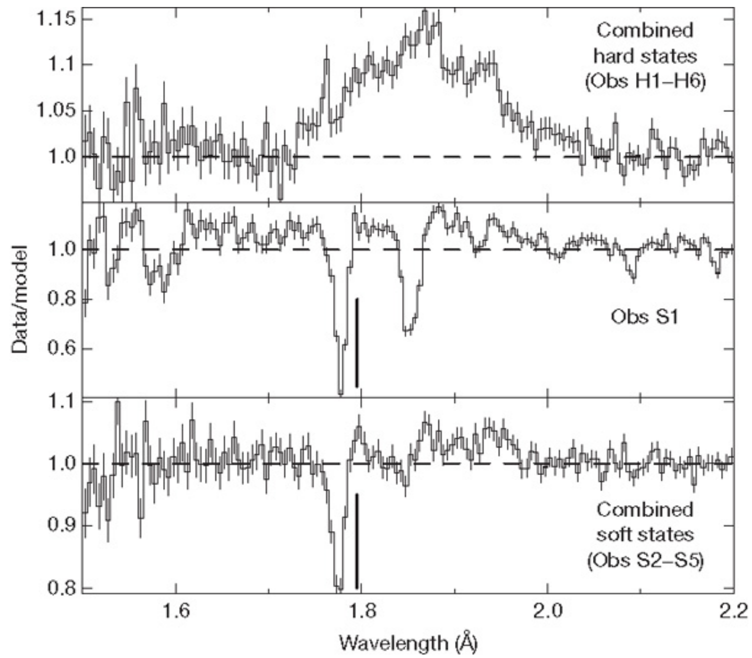
Ueda et al. 2009 (Soft, “A”, state)



Lee et al. 2002 (Hard, “C”, state)

The case of GRS 1915+105

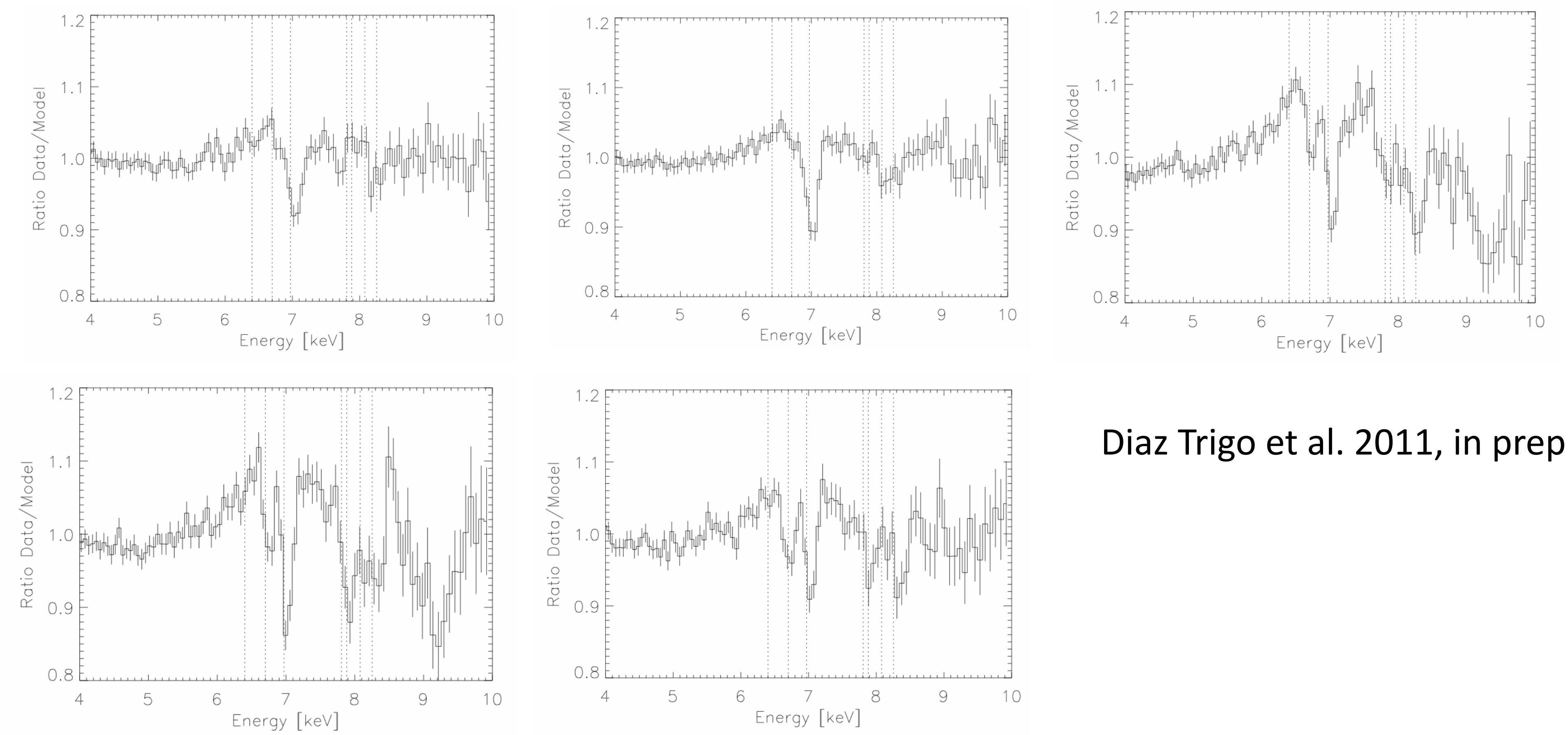




Neilsen & Lee 2009

Does the wind suppress the jet?

Is GRS 1915+105 a general case?



Diaz Trigo et al. 2011, in prep.

Broad Fe line co-exists with strong wind

Interpretations for the wind/jet relation

- The wind suppresses the jet (Neilsen & Lee 2009)
- The wind is fully ionised in the hard state (e.g. Ueda et al. 2010)
- The scale height of the wind may be too low to be observed (Ueda et al. 2010)

Open issues

- What is the launching mechanism of the wind?
- To which extent is the hard X-ray flux responsible for the disappearance of the winds?
- Are winds and jets really exclusive?

Warnings

- The availability of high resolution spectra impacts our ability to probe the physical conditions around the compact object.
- Ionised absorption should be properly accounted for to correctly model the continuum emission, any broad Fe emission line and any soft excess in LMXBs.

Conclusions

- A highly ionised atmosphere or wind is present above the accretion disc in LMXBs
- It is detected as a warm emitter and/or absorber in many LMXBs seen relatively close to edge-on.
- Photoionisation is the dominant ionisation mechanism.
- The bulge where the accretion stream impacts the disc is seen as a less strongly ionised absorber in dippers
- Winds are consistent with a thermal launching mechanism except maybe for GRO J1655-40
- Correlation between winds and jets is being investigated