Winds and jets in X-ray binaries

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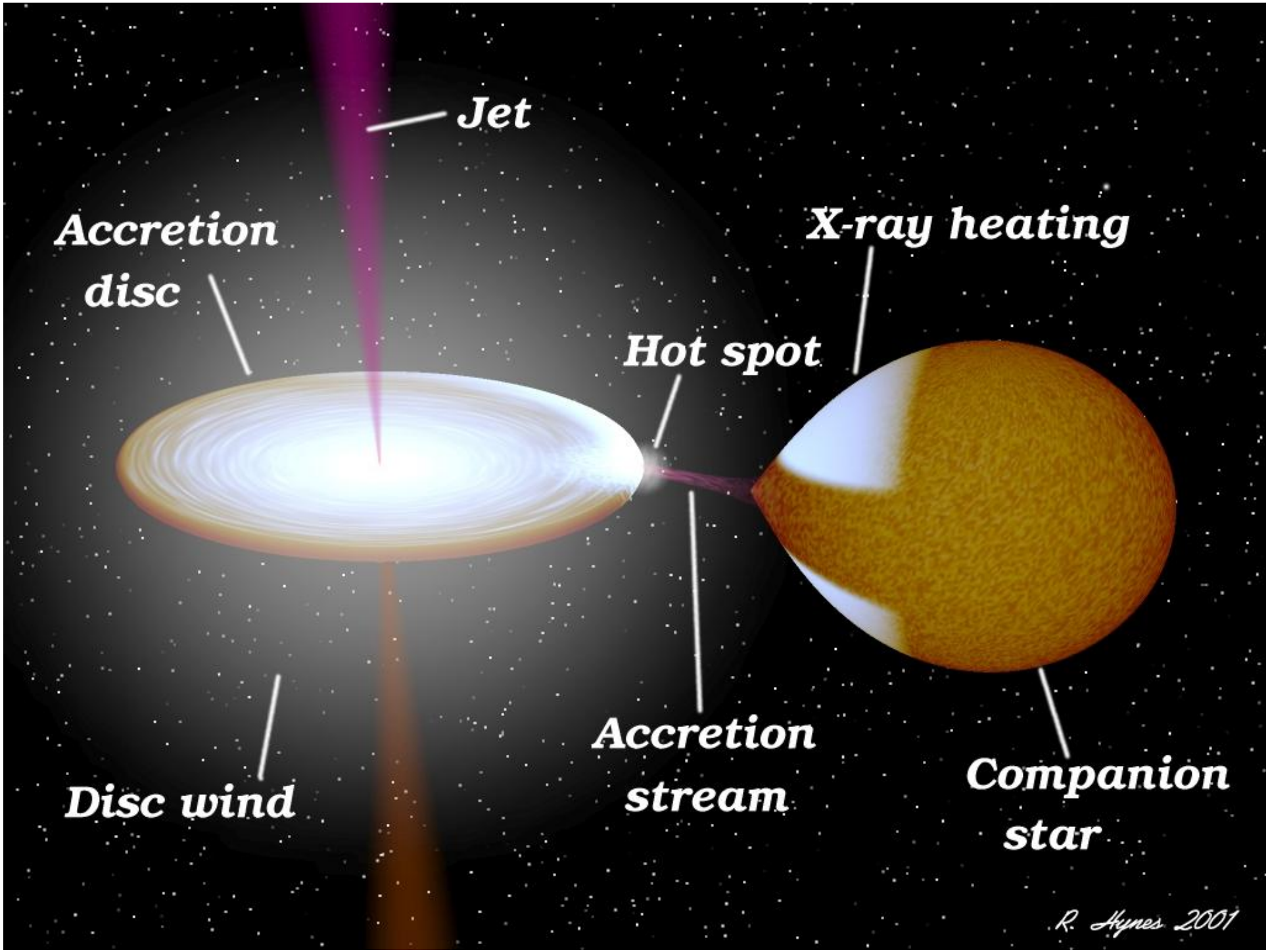
(ESO)

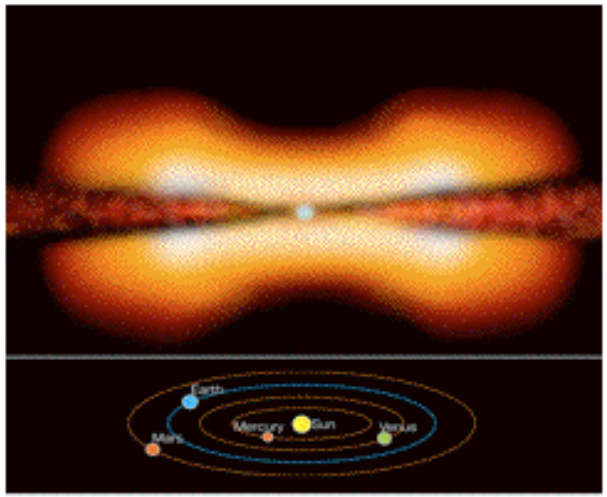
Vulcano workshop, 31/05/2012

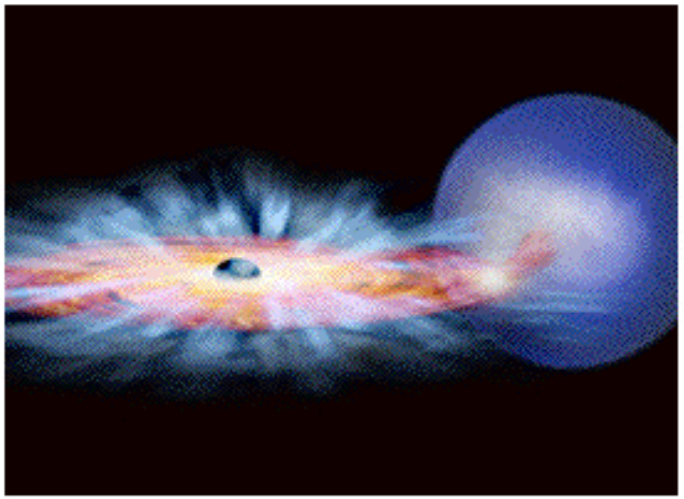

Jet
Accretion disc
X-ray heating
Hot spot
Disc wind
Accretion stream
Companion star
R. Hynes 2001

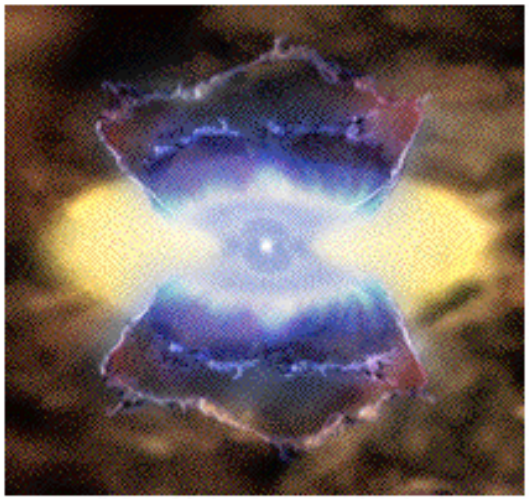
What you should remember from this talk

- Photoionised plasmas
  - Equatorial & (most likely) ubiquitous in X-ray binaries
- Winds
  - Consistent with a thermal launching mechanism, often aided by radiation pressure
  - Reprocessed component of the wind may contribute significantly to the continuum and line emission
- Wind/jet anti-correlation?
  - Still an open question

(DISC) WINDS







~10^{13} cm

~10^{10} cm

~10^{15} cm

Young stellar object

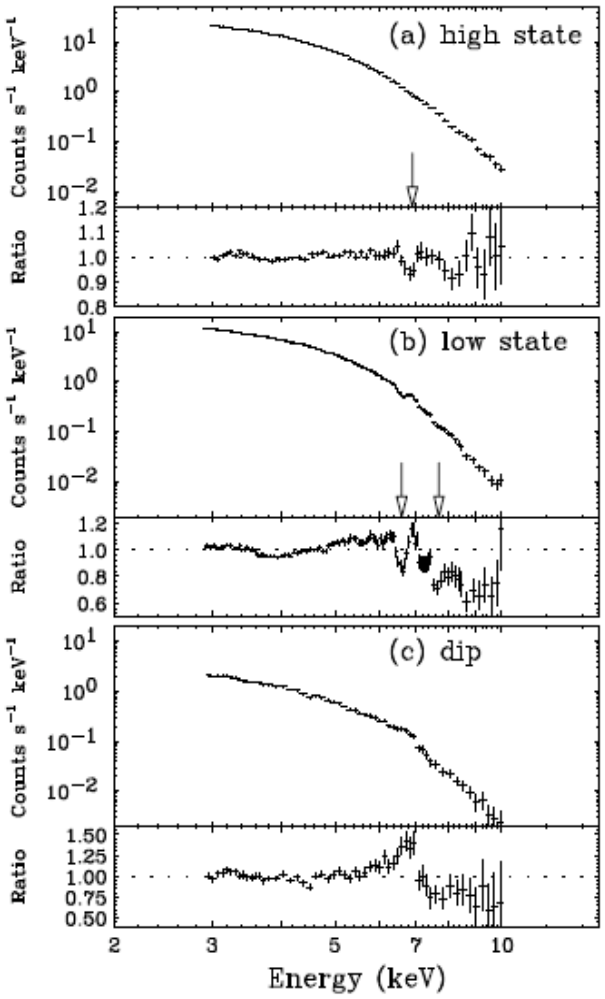
X-ray binary

Supermassive black hole

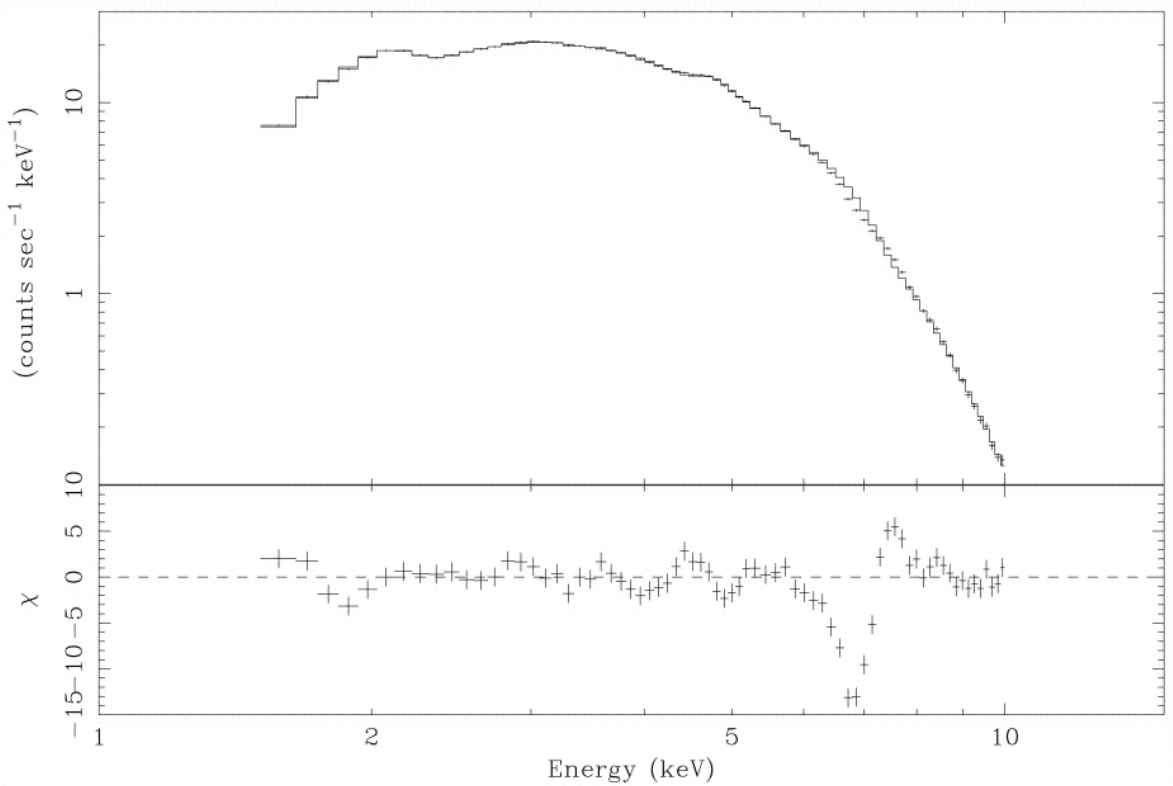
Importance of characterising the outflows:

- Feedback to the environment
- Dynamics of the system

The first warm absorbers

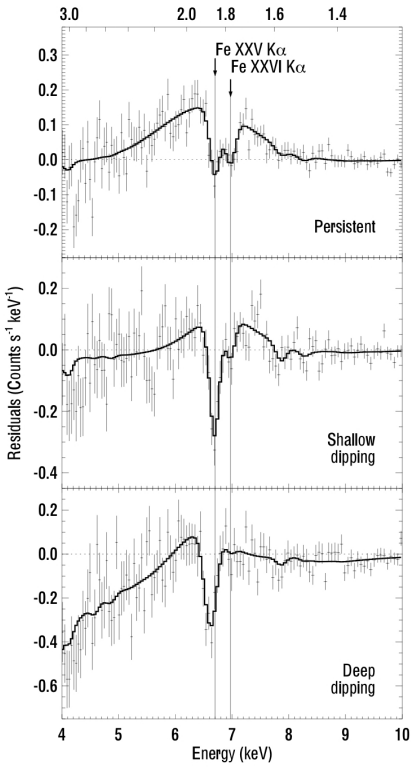


GRO J1655-40, Ueda et al. 1998

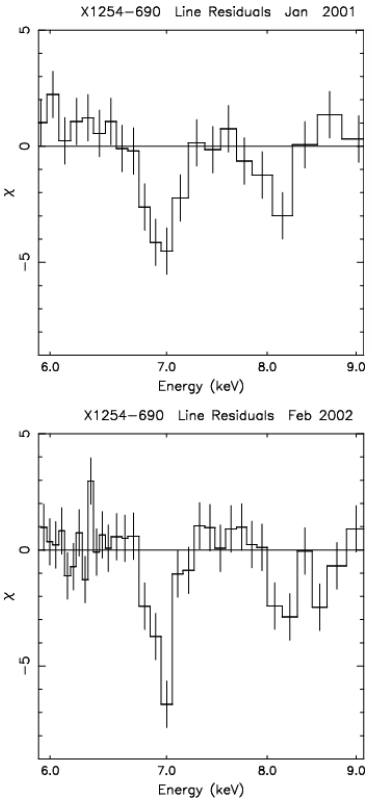


GRS 1915+105, Kotani et al. 2000

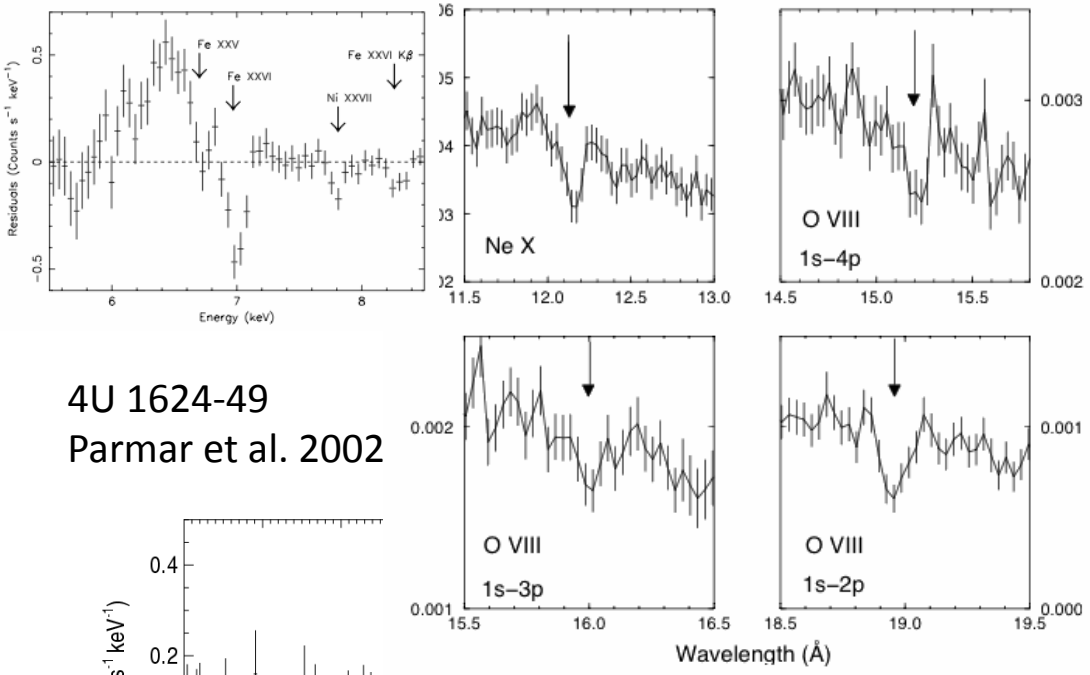
Warm absorbers everywhere…



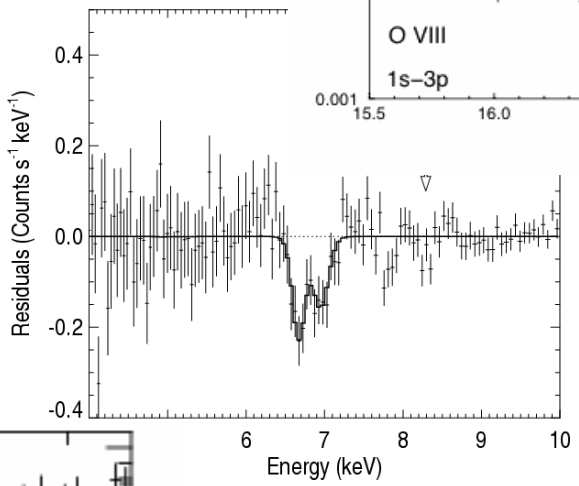
4U 1323-62
Boirin et al. 2005



4U 1254-69
Boirin & Parmar 2003

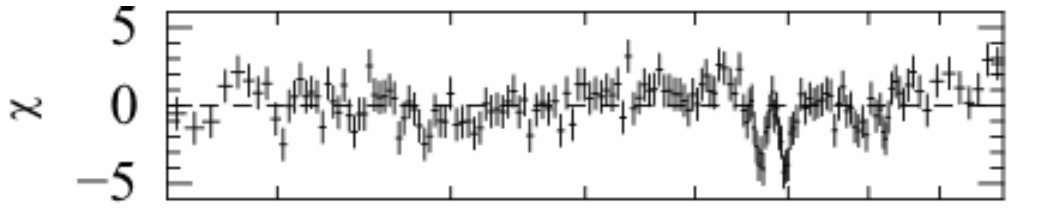


4U 1624-49
Parmar et al. 2002



MXB 1659-298
Sidoli et al. 2001

4U 1916-15
Boirin et al. 2004

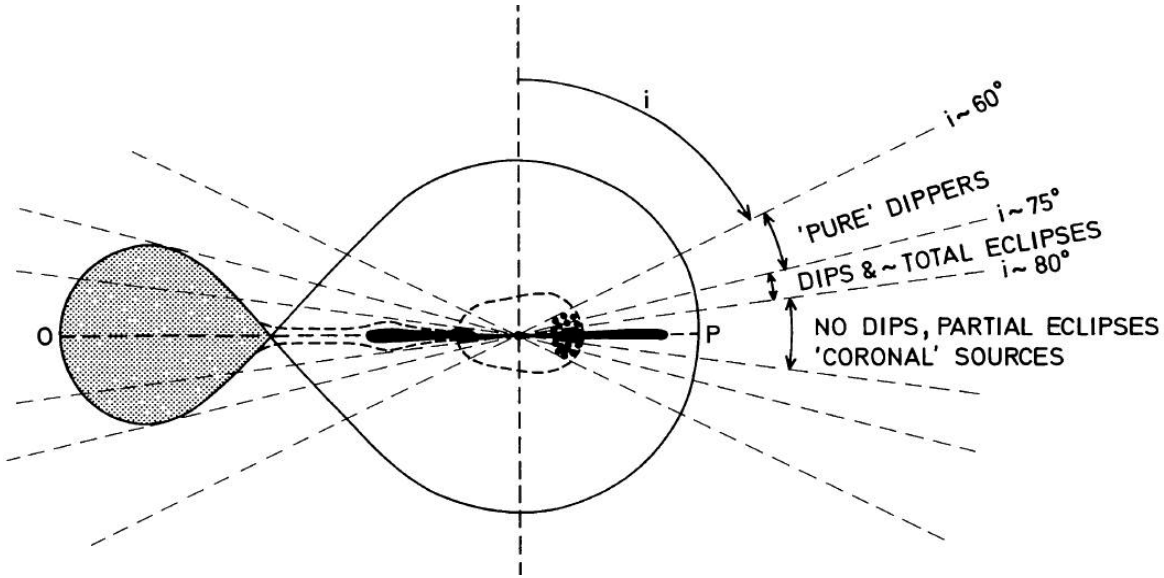


AX J1745.6-2901
Hyodo et al. 2008

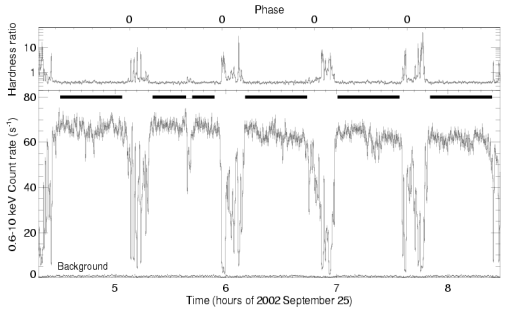
Characteristics of the plasma

- **Highly ionised**: Fe XXV and Fe XXVI are present
- **Photoionised**: based on responses to changes in continuum
- **Flat ("pancake") geometry** above the disc: probably ubiquitous to all XRBs

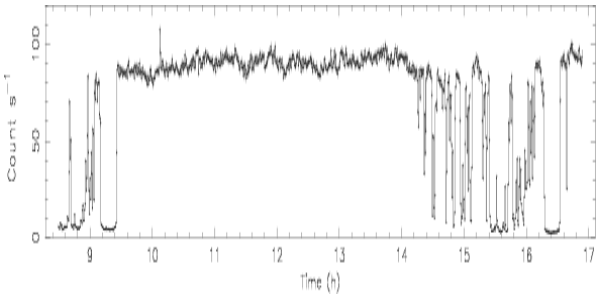
Geometry



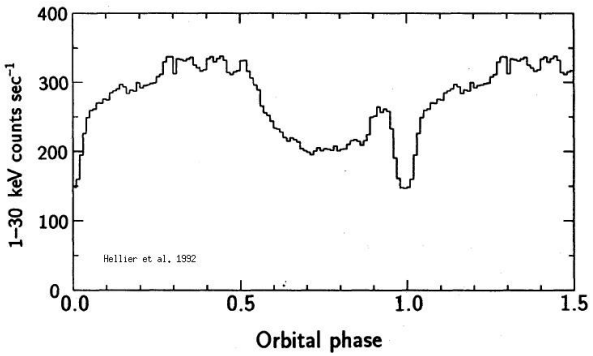
Frank, King & Lasota, 1987



60-75 deg. 'Pure' dippers

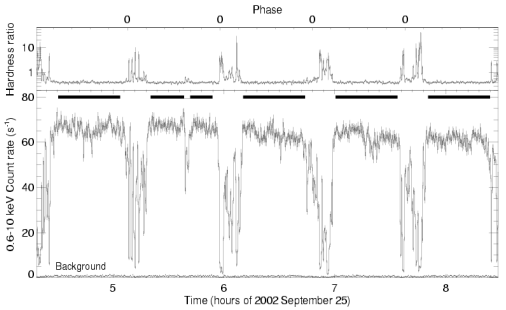


75-80 deg. Dips & ~'total' eclipses



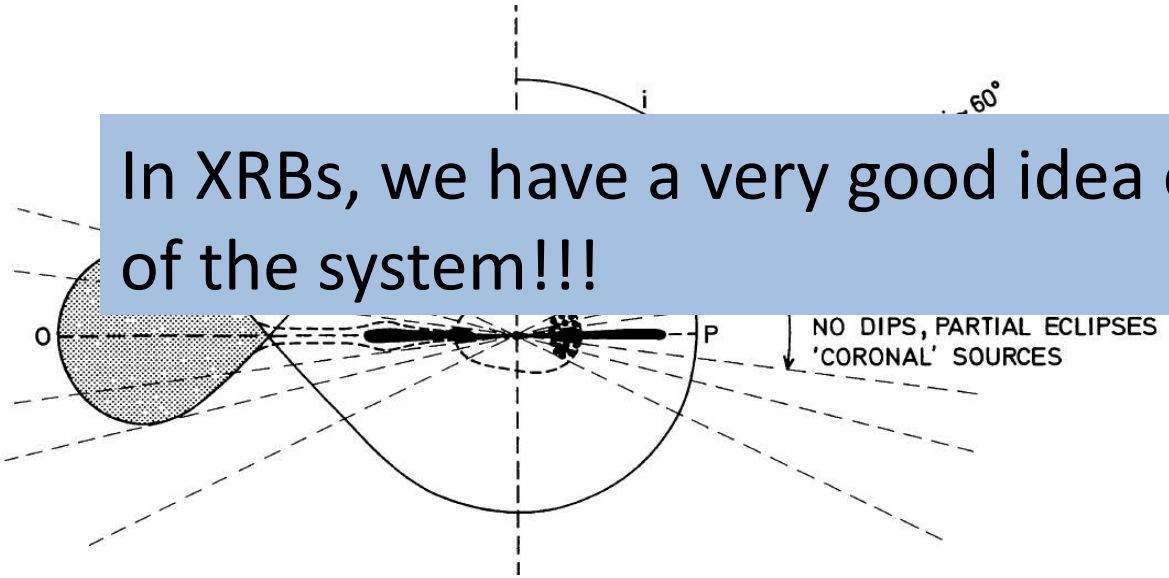
80-90 deg. No dips, partial eclipses

Geometry

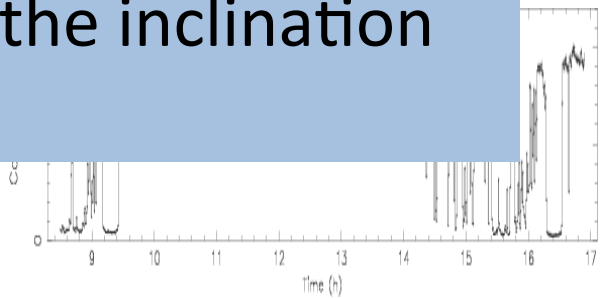


60-75 deg. 'Pure' dippers

In XRBs, we have a very good idea of the inclination of the system!!!



Frank, King & Lasota, 1987



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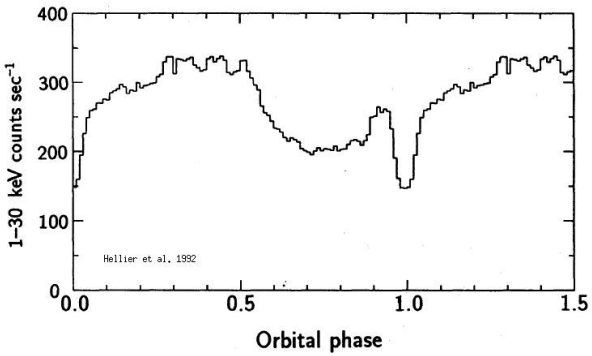

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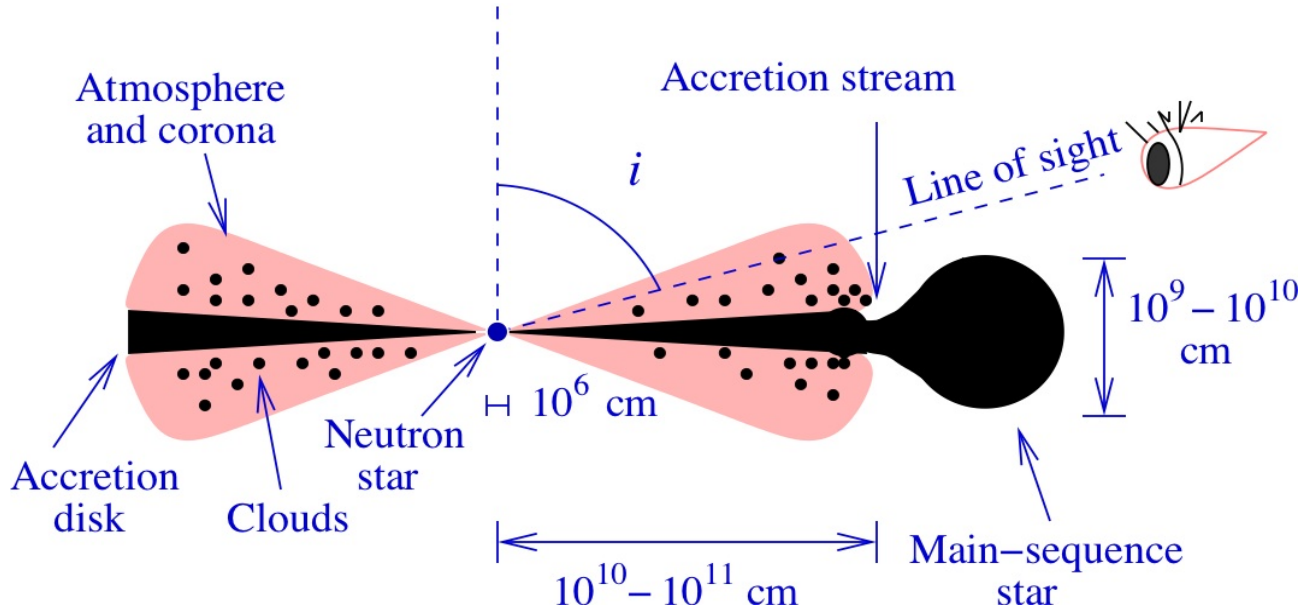
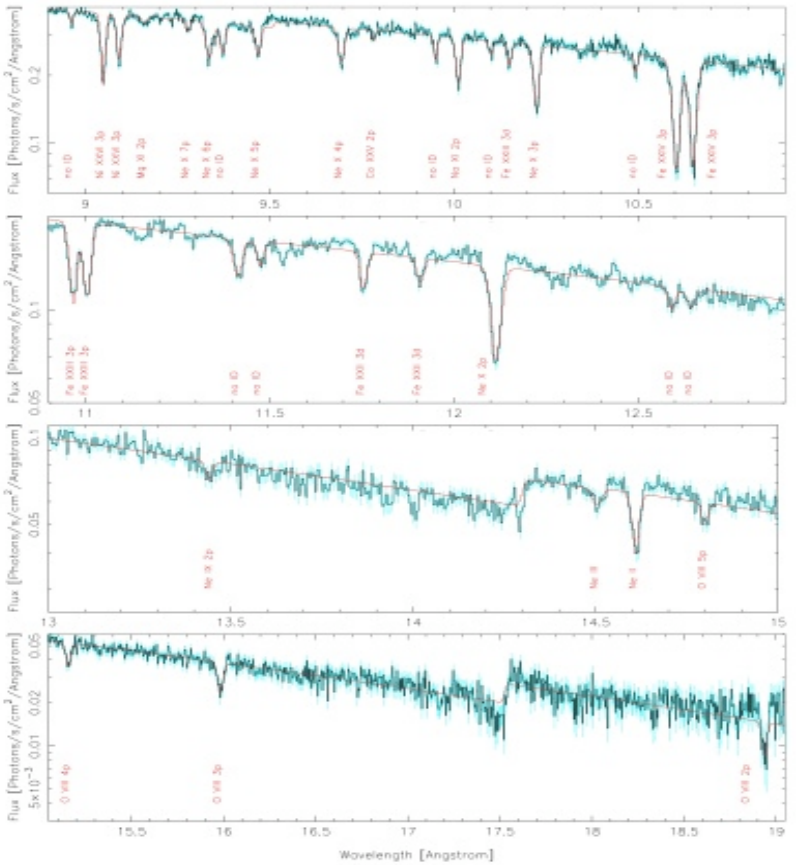


Jimenez Garate et al. 2002

Outflows



GRO J1655-40, Miller et al. 2006

Outflows detected in 3 NSs and 5 BHs (**300-3000 km/s**; ~10000 km/s in one case)

Feedback:

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

Yes!!

mass outflow rate ~ mass accretion rate

Are outflows different to warm absorbers?

What do we want to learn?

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

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  - ~~Line-driven~~ (Proga & Kallman 2002)

What do we want to learn?

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

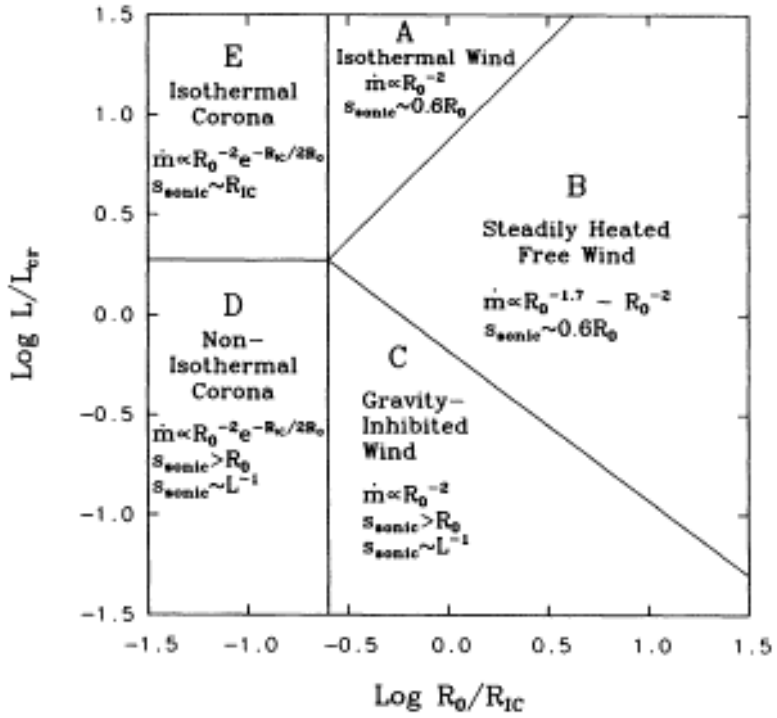
If the flux varies on a certain time the variability of the WA provides a lower limit on the density => Upper limit on the distance

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

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

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

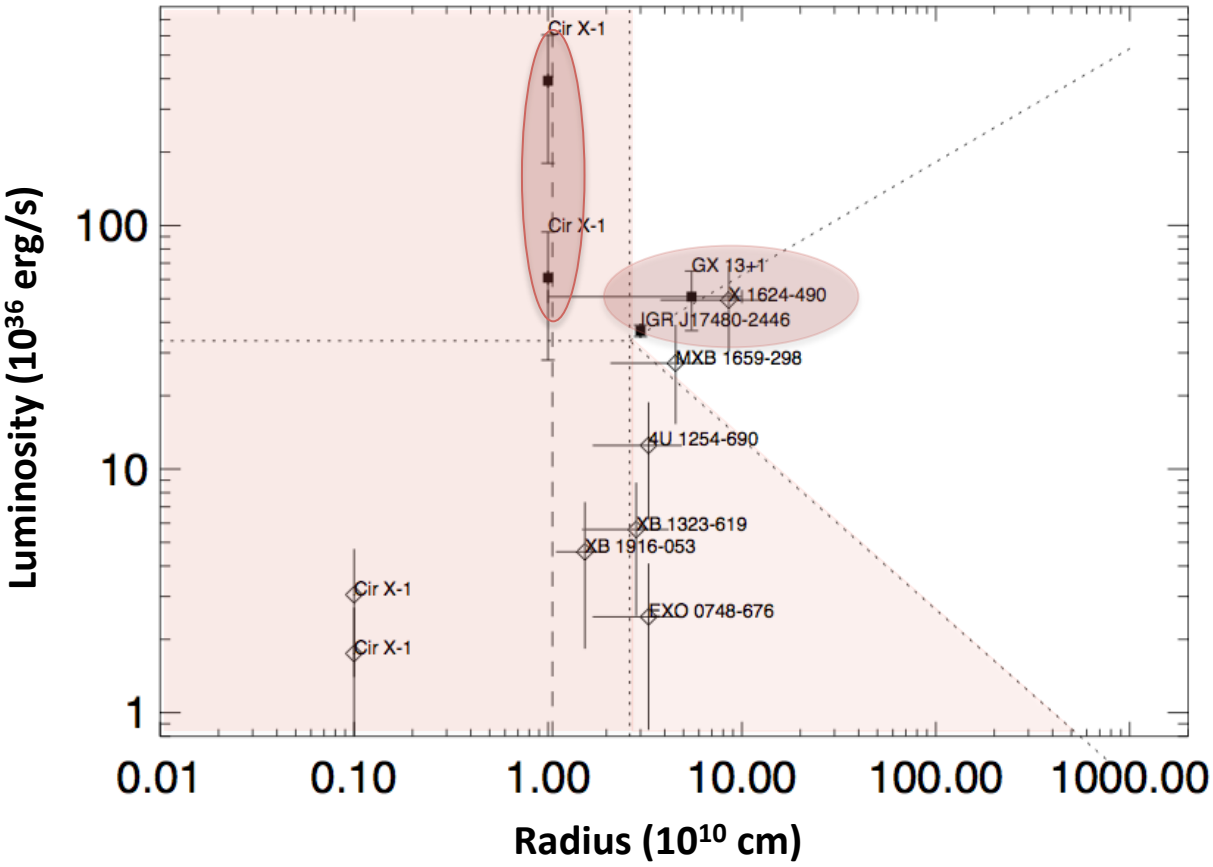
Thermal winds



Begelman et al. 1983, Woods et al. 1996

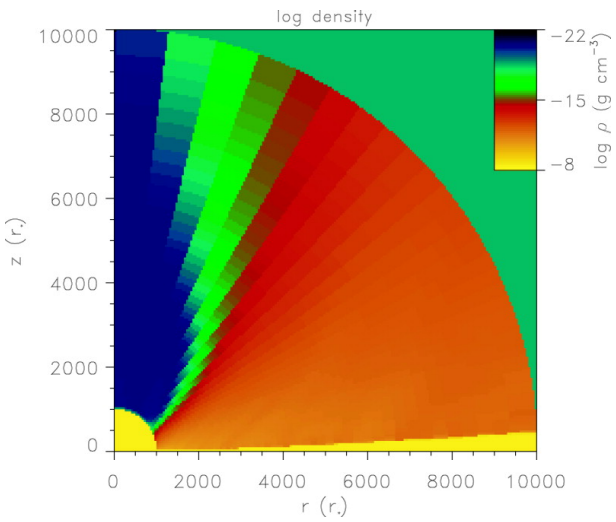
Compton radius: distance at which the escape velocity equals the isothermal sound speed at the Compton temperature

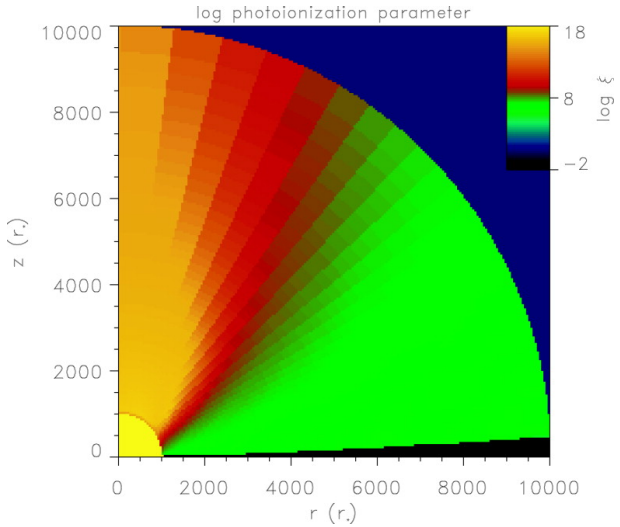
Thermal winds

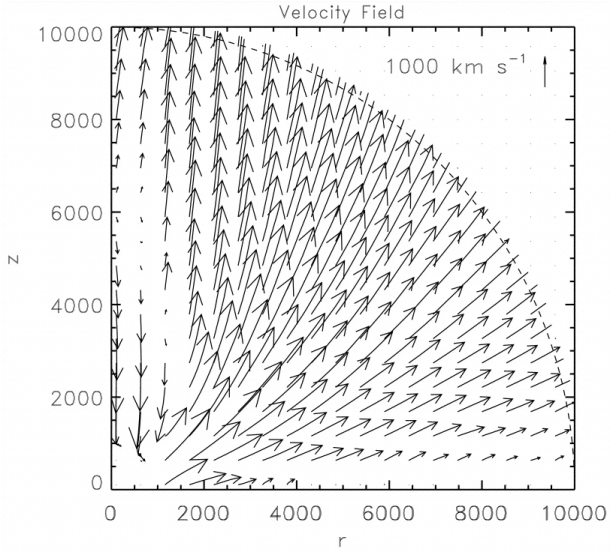


Diaz Trigo et al., in preparation

Thermal winds

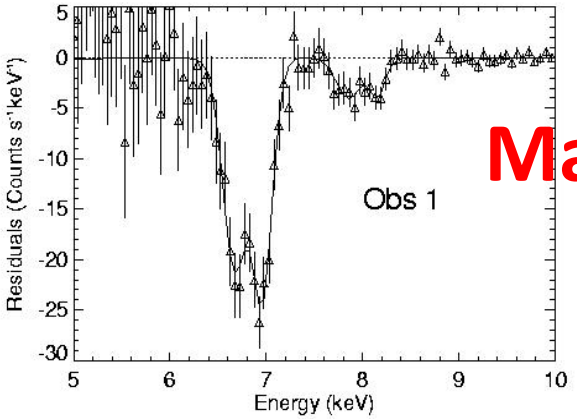




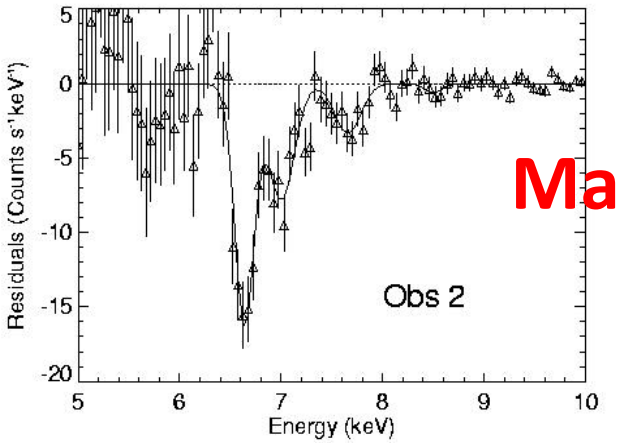


Proga & Kallman 2002

GRO J1655-40: the exception?

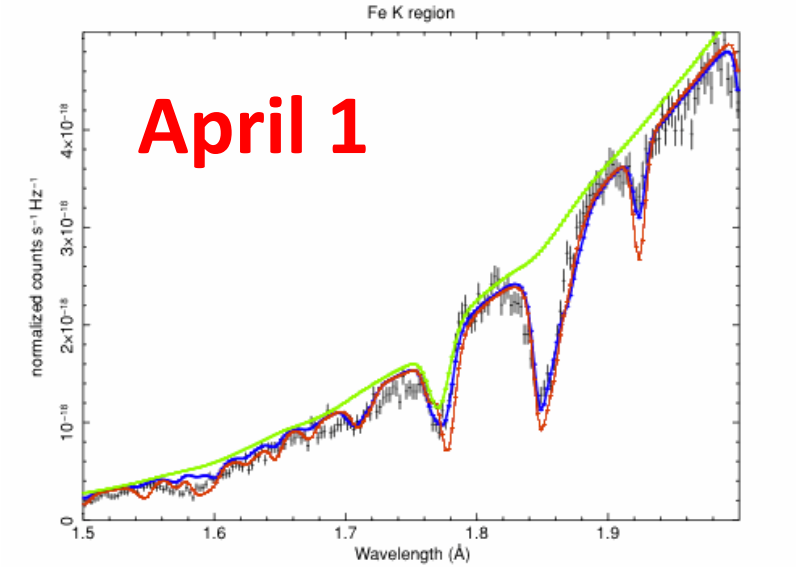


March 18



March 27

Diaz Trigo et al. 2007



April 1

Miller et al. 2006, Kallman et al. 2009
(see also Netzer 2006, Miller et al. 2008,
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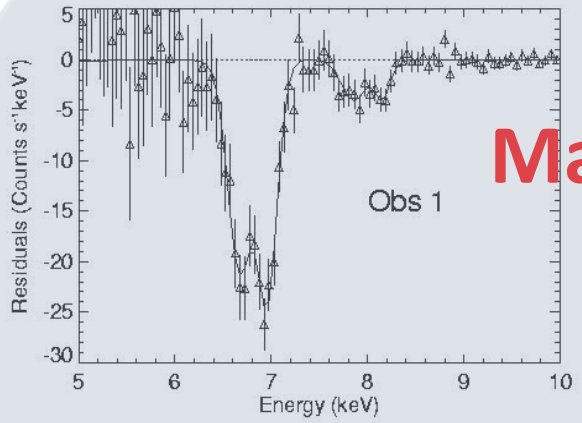
GRO J1655-40



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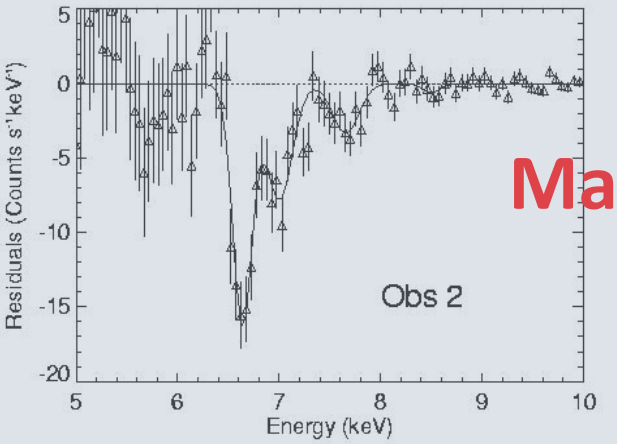

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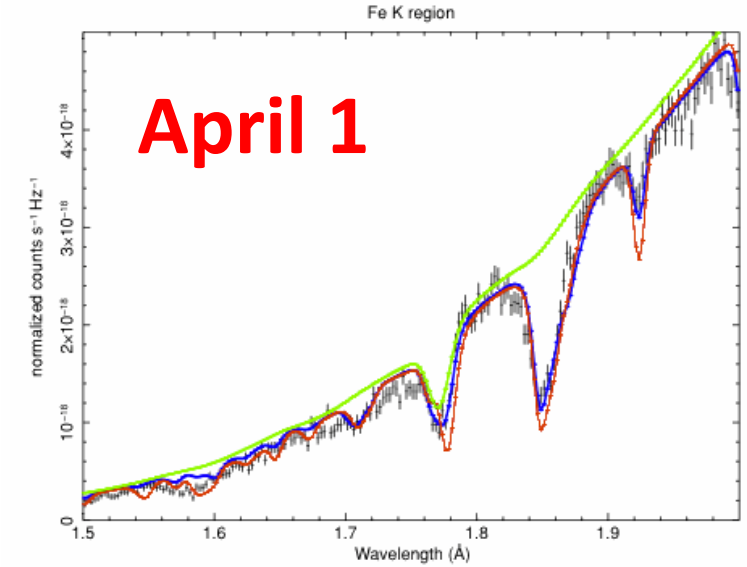

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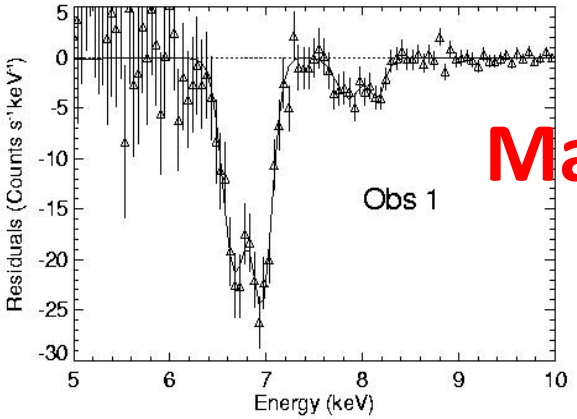

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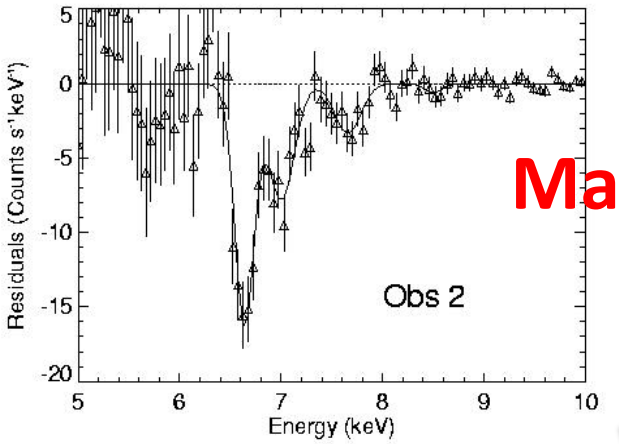

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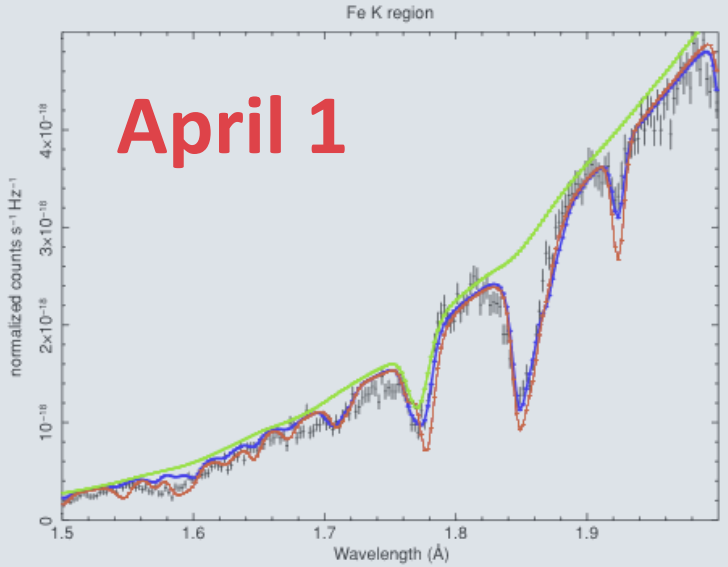

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r ≈ 5x 10^8 cm => Magnetic driving (Miller et al. 2006)

r ≈ 10^{11} cm => Thermal driving (Netzer et al. 2006)

r < 2x 10^9 cm => Magnetic driving (Miller et al. 2008)

r ≈ 7 x 10^9 cm => Magnetic driving (Kallman et al. 2009)

Hybrid wind (Neilsen & Homan 2012)

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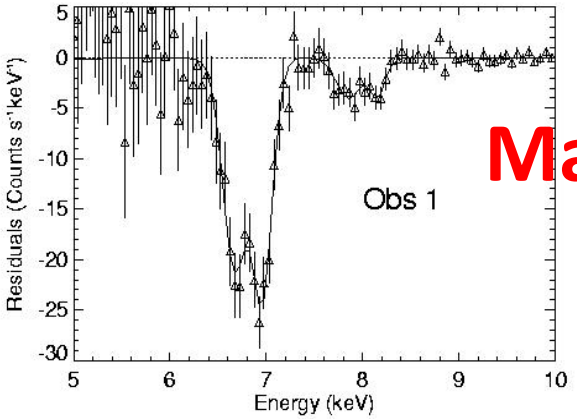

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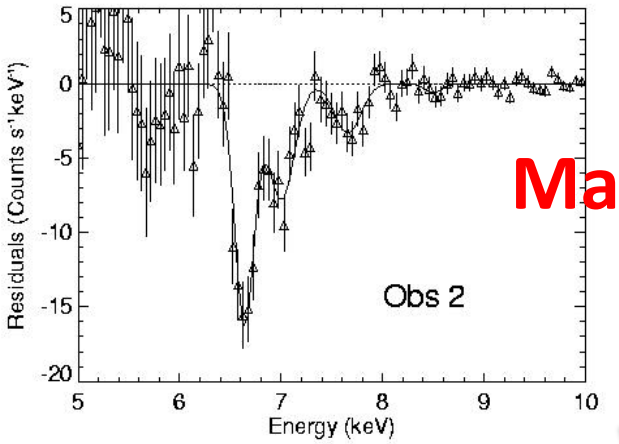

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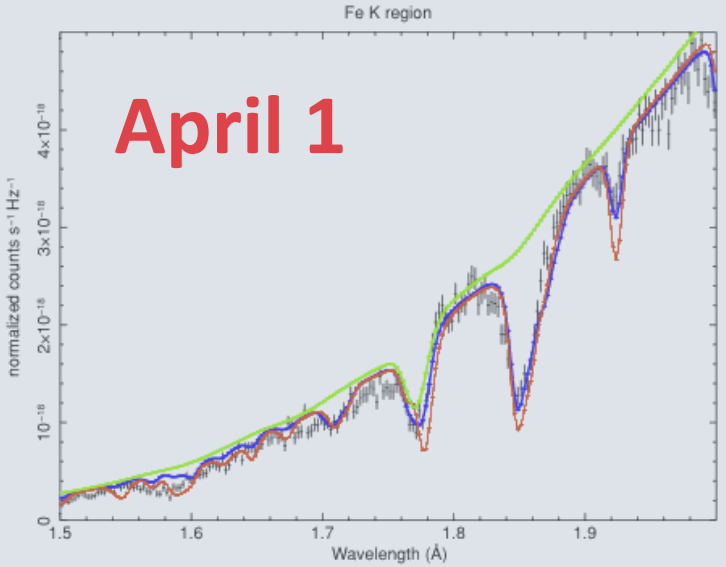

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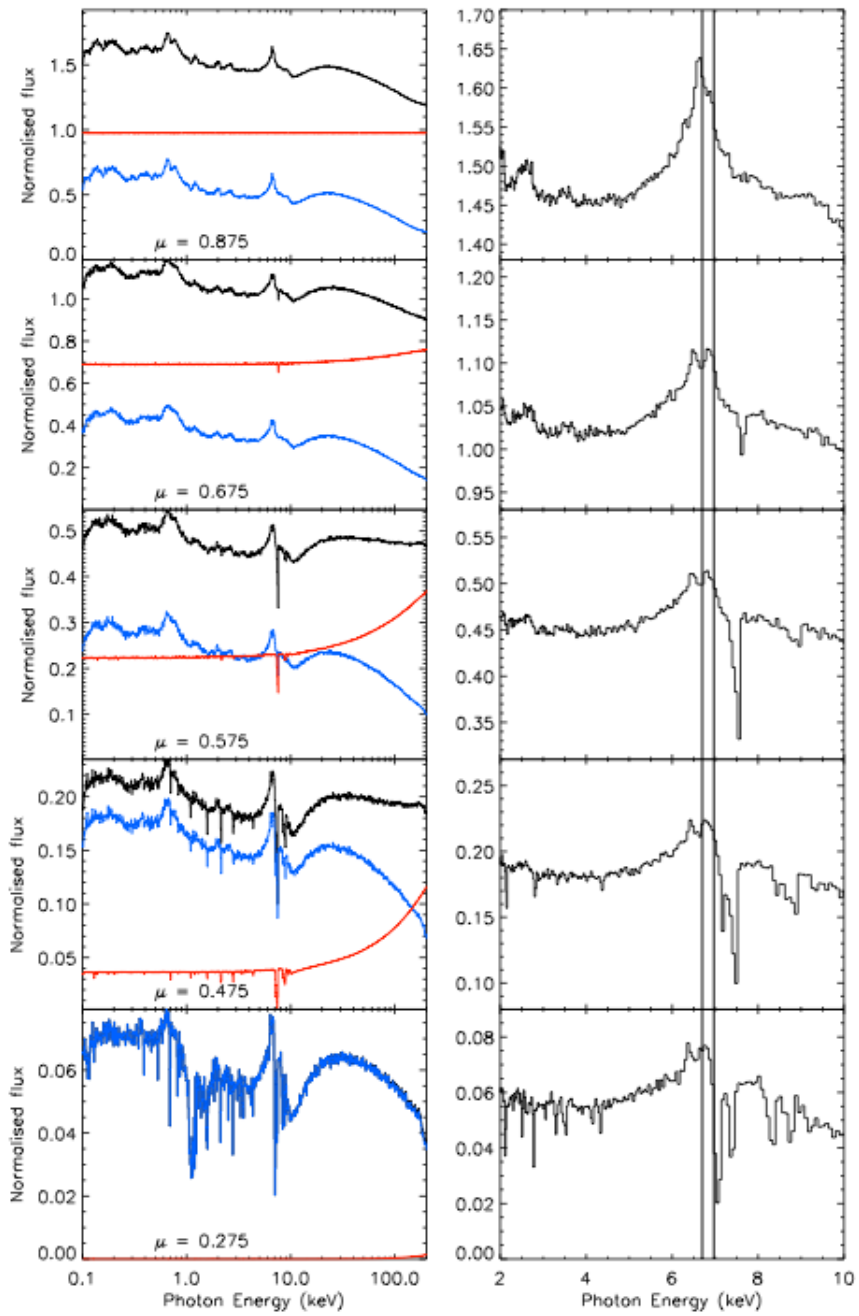


The reprocessed component of the wind

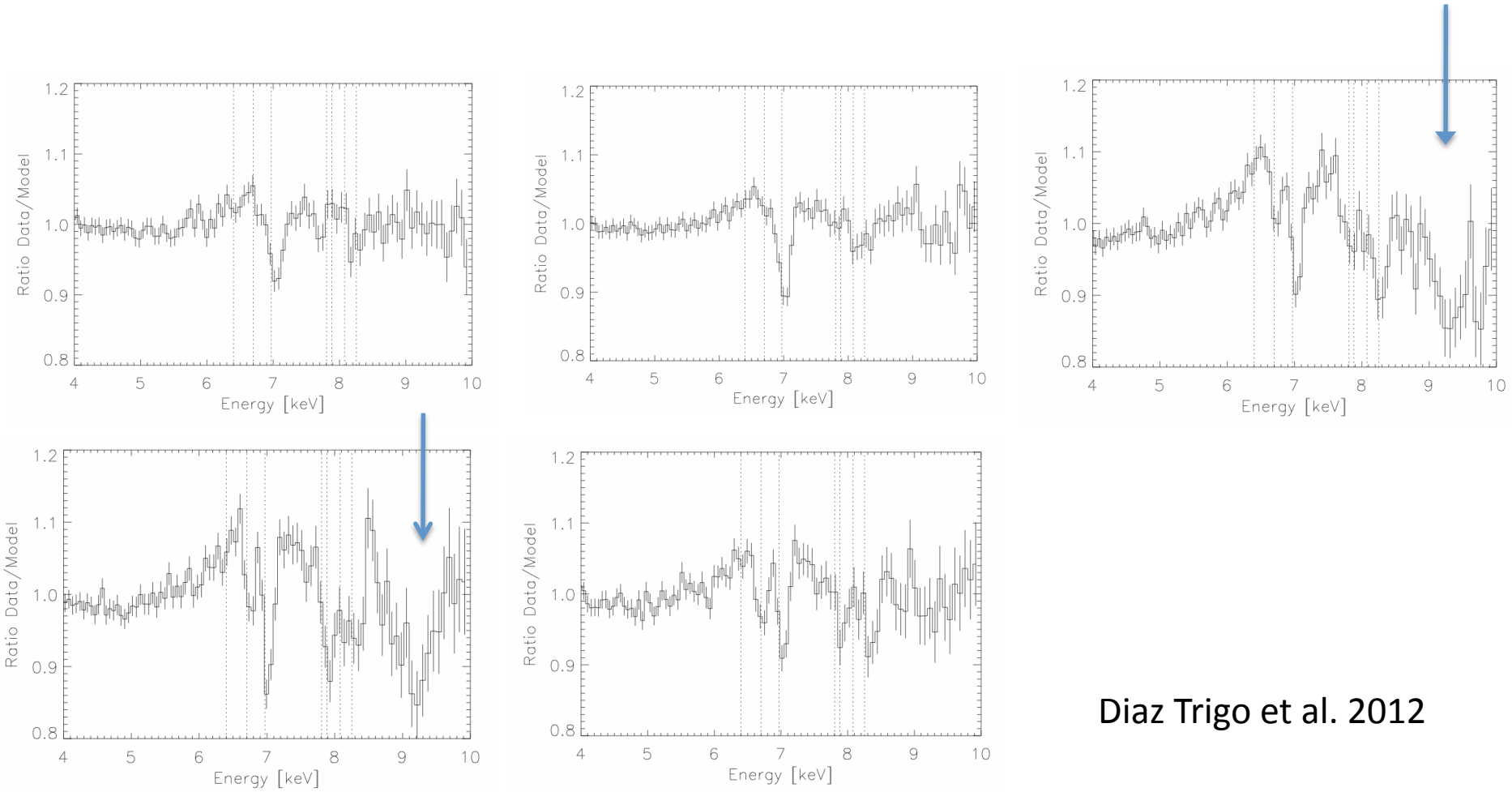
1.Compton scattering (dominant in most strongly radiated regions)

2.Line absorption leads to excited atoms...they want to re-emit

3.Photo electric/free-free absorption heats material...will try to cool

Sim et al. 2010

The reprocessed component

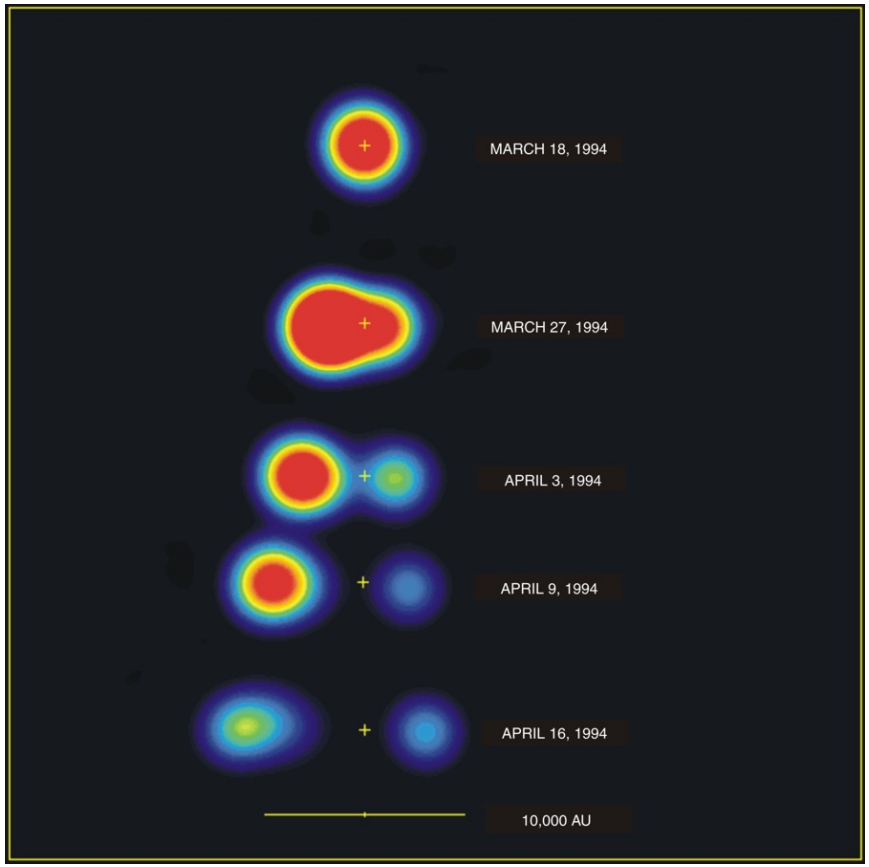


Diaz Trigo et al. 2012

First evidence of a reprocessed component: changes in broad Fe line and photoionised absorption are correlated

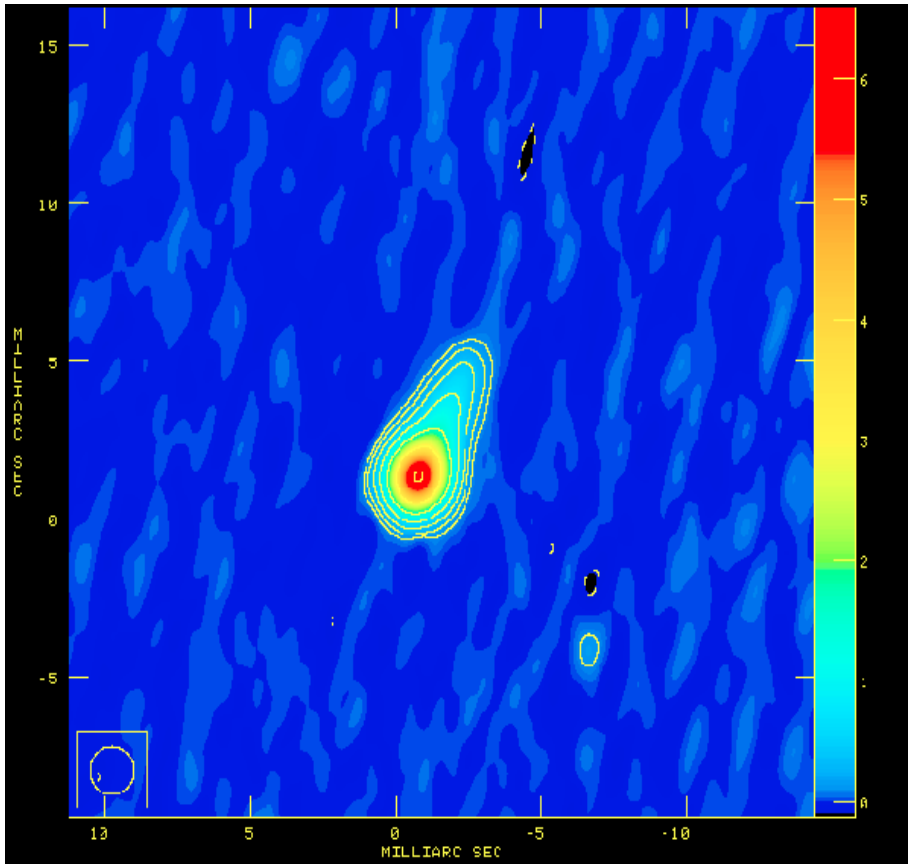
JETS

Discrete ejections (superluminal in galactic microquasars)



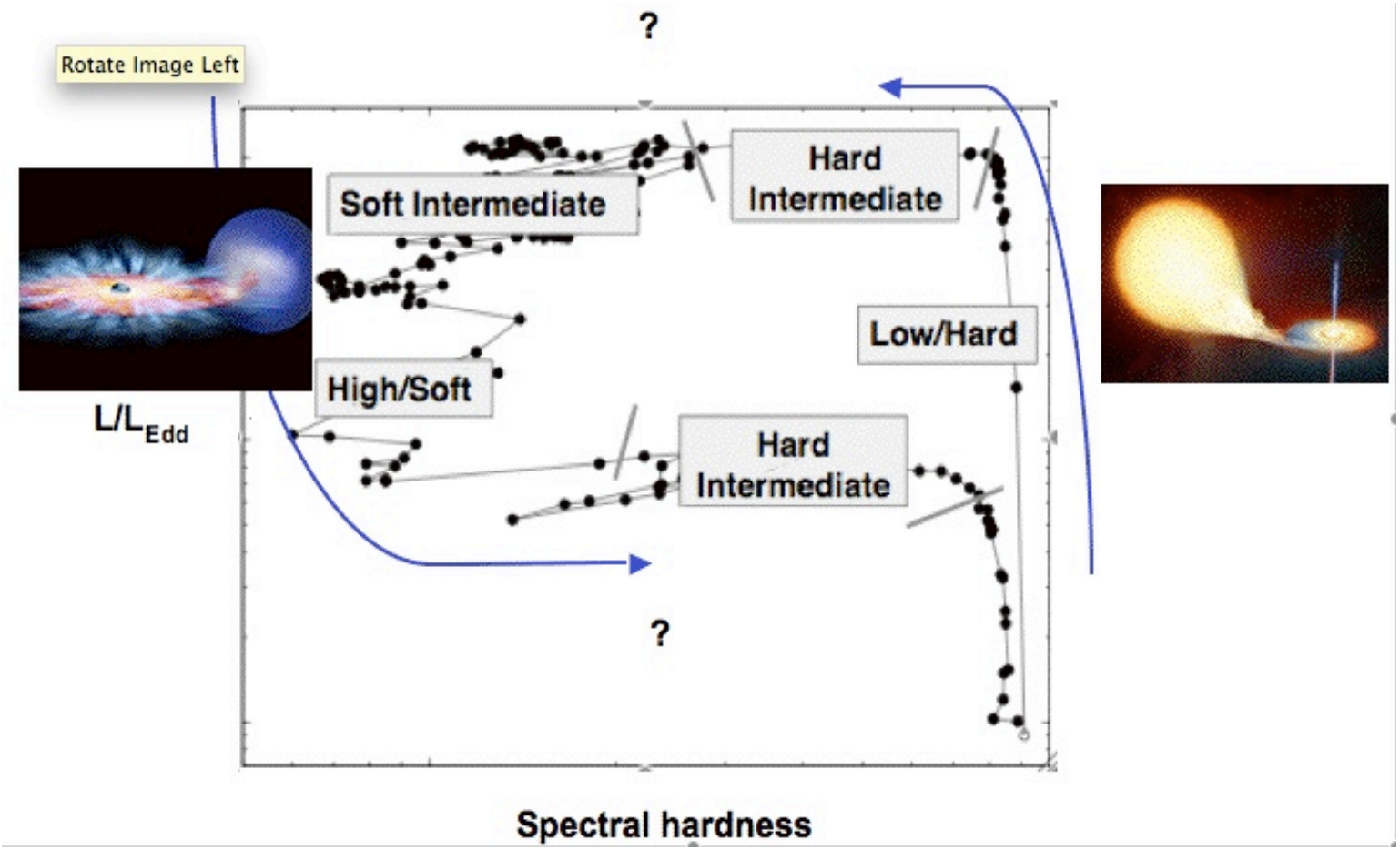
Mirabel & Rodriguez 1994 (Nature)

Compact, self-absorbed jets (milliarcsec scale)



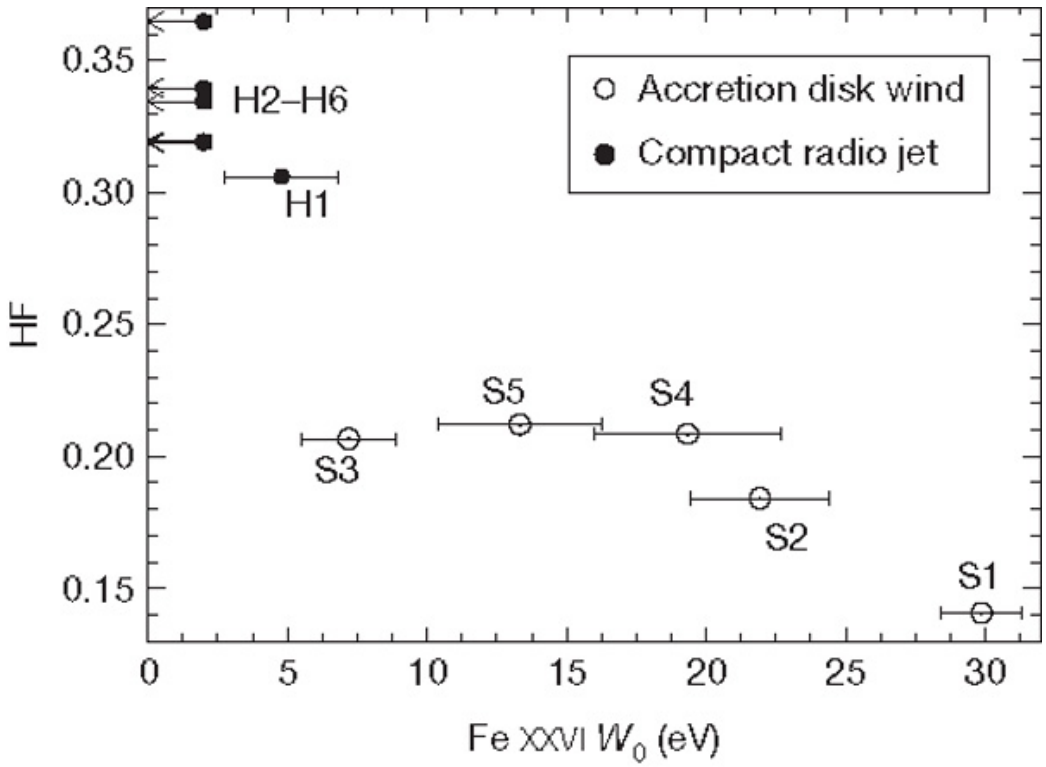
Stirling et al. 2001

Relation between winds and jets



(Adapted from Homan & Belloni 2005)

The case of GRS 1915+105

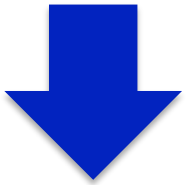


Neilsen & Lee 2009

Does the wind suppress the jet?

Interpretations for the wind/jet relation

- The wind suppresses the jet
- The wind is fully ionised in the hard state (importance of SED!)
- The scale height of the wind may be too low to be observed



- To which extent is the hard X-ray flux responsible for the disappearance of the winds?
- Are winds and jets really exclusive? Probably not…

Conclusions

- A highly photoionised atmosphere or wind is present above the accretion disc in low mass XRBs
- Winds are consistent with a thermal launching mechanism (except maybe in one case) and have mass outflow rates comparable/larger than mass accretion rates
- The reprocessed component of the wind may contribute significantly to continuum and line emission
- Anti-correlation between winds and jets is being investigated => The SED will provide crucial information