# Warm Absorbers in Galactic X-Ray Binaries

Norbert S. Schulz

## Absorption in X-ray sources

## Warm absorbers in compact binaries:

Overview

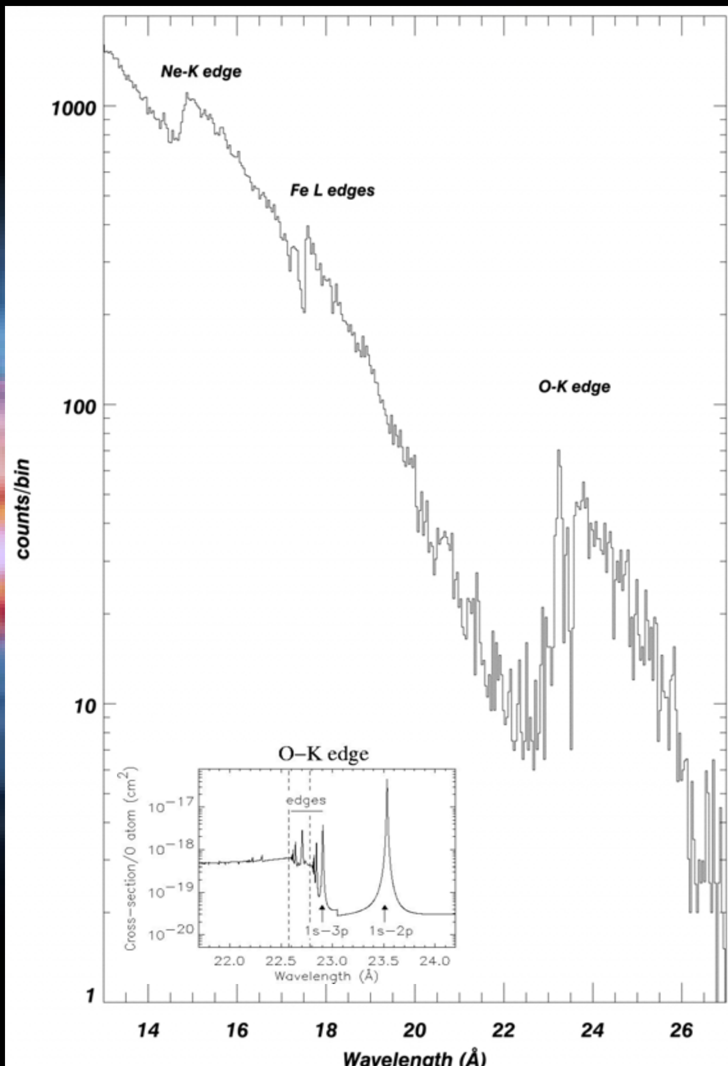
Neutron star binaries

Black hole binaries

# Absorption in X-ray sources

Absorption in cool matter/plasmas:

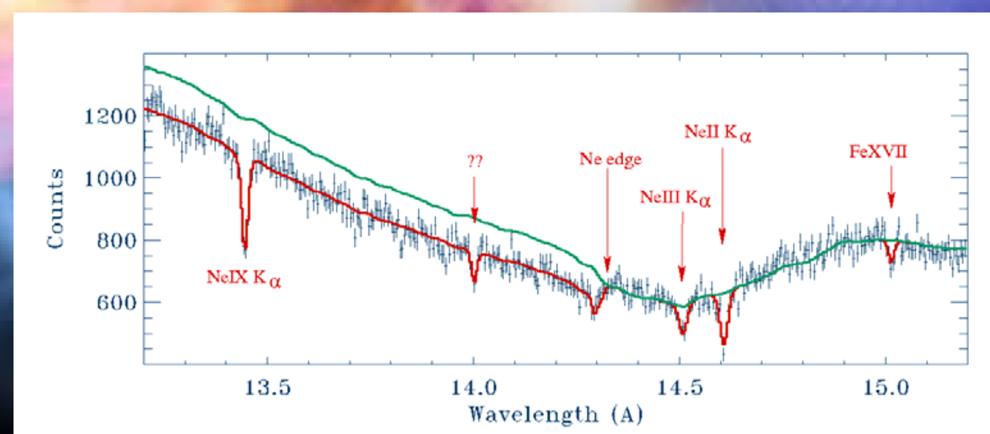
Photo-electric continuum absorption




Collisional Ionization Equilibrium kT > MK

H-, He-like resonance absorption

( and Li-, B-like for Fe)



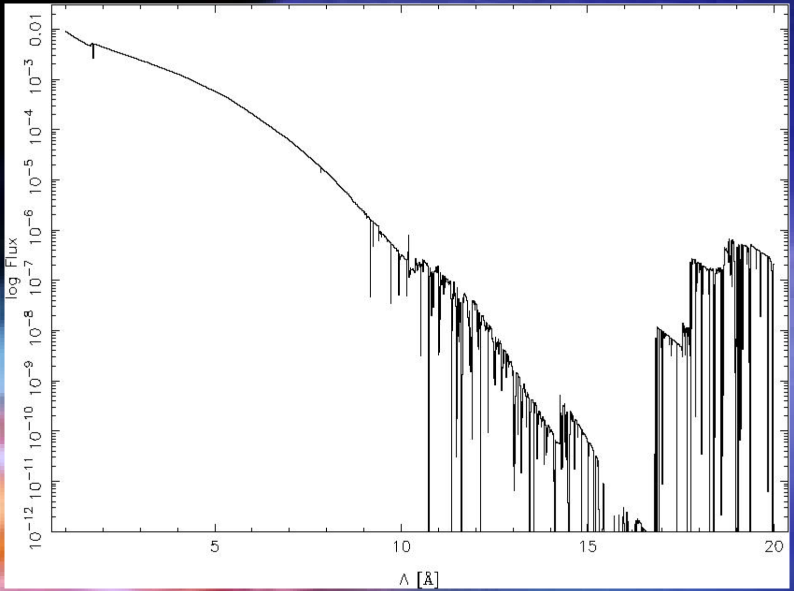
# Absorption in X-ray sources

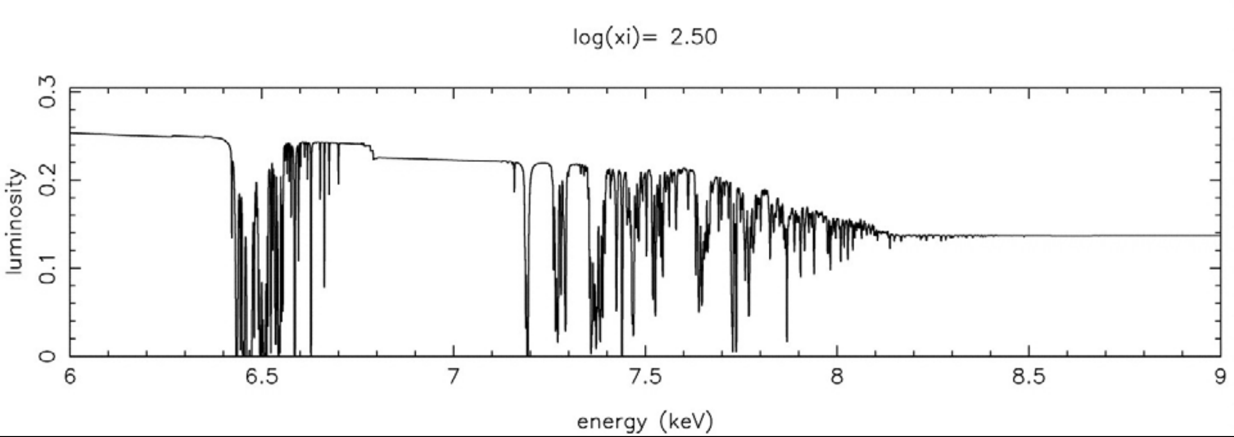
Absorption in photo-ionized (warm) plasmas:

**Warm absorber:**
**electron temperature** of illuminated matter << $10^6$ K in contrast to a collisionally ionized gas gas with a **similar level of ionization** ( Halpern 1984)

Ionization parameter $\xi = L_x / n_e d^2$

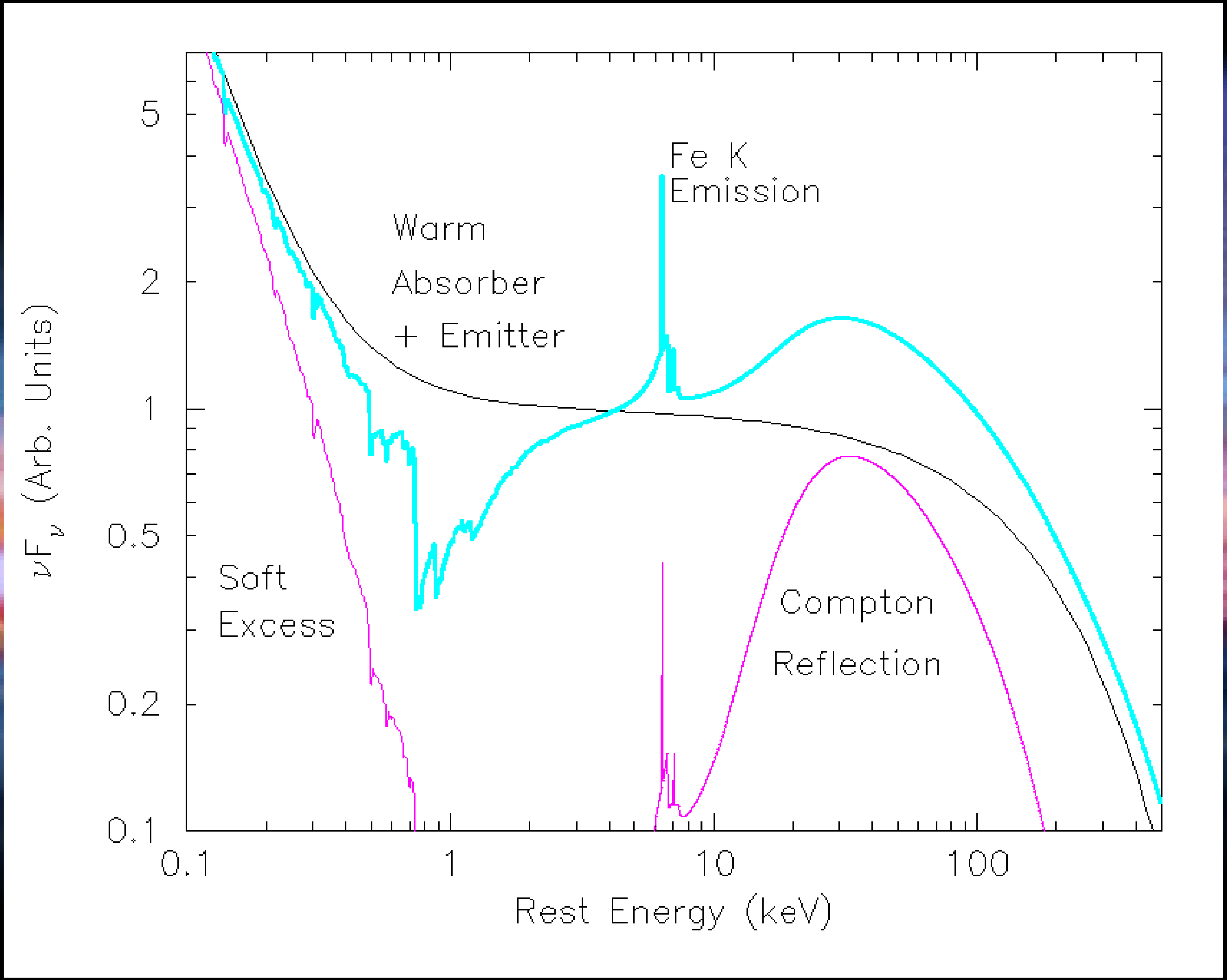
XSTAR simulations, version 2.1kn7 (March 2007):

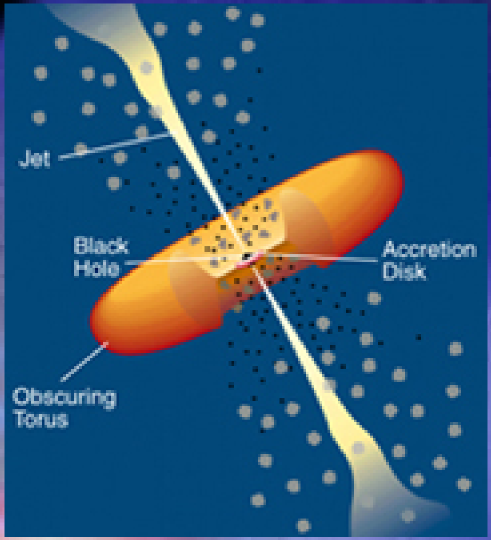


# Warm absorbers in Seyfert I galaxies:

## Soft absorber in warm plasma:



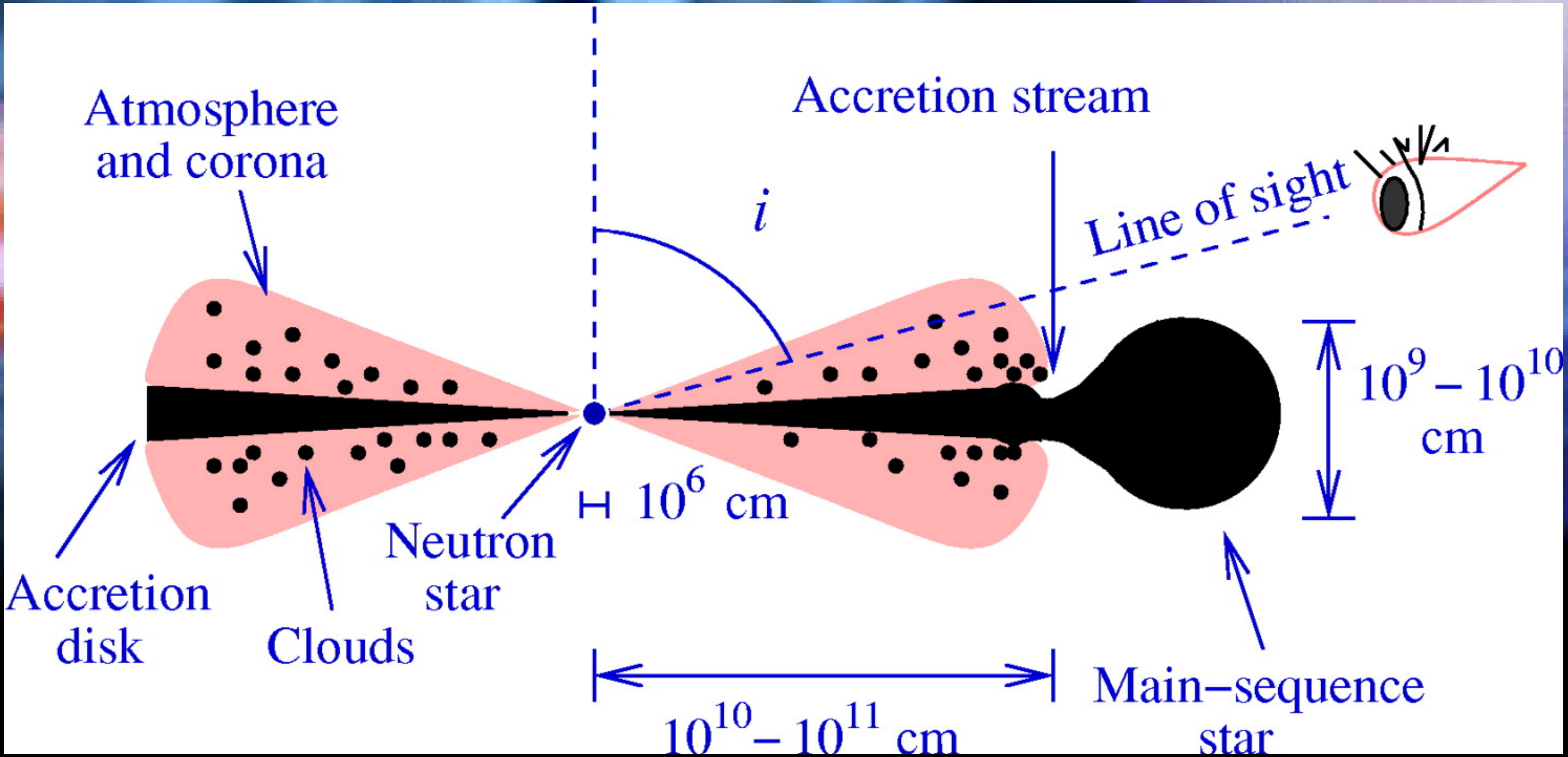

I. George

# Warm Absorbers in Compact Binaries:

## Accretion disk atmospheres and coronae

- X-ray line emission from optically thick disk surface
- plain optically thin surface layers: disk atmosphere and/or corona - not enough column to produce observed columns
- X-ray line emission from optically likely need high density material dispersed in the disk atmosphere and/or corona
- clumps/clouds stationary, randomly distributed

Jimenez-Garate et al. 2001



# Warm Absorbers in Compact Binaries:

## Summary Table:

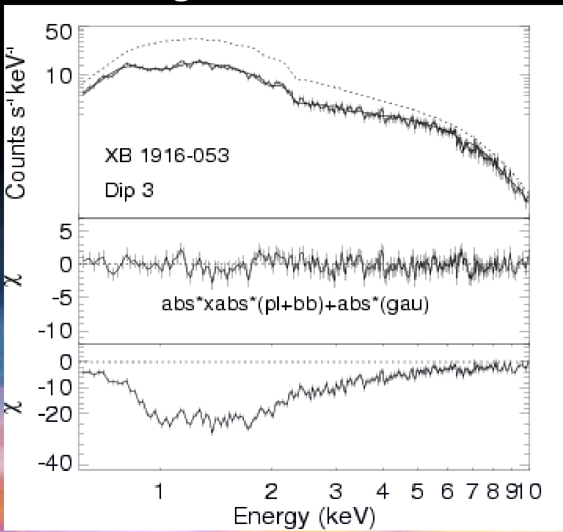
| Name | RA | DEC | Binary Type | Compact Object | log $L_x$ [erg/s] | $\xi$ [erg/s cm] | log $N_{ion}$ [$cm^{-2}$] | refs |
|---|---|---|---|---|---|---|---|---|
| EXO 0748-676 | 07 48 33.3 | -67 45 00.0 | LMXB | NS | 36.6 | 2.5 – 3.0 | 22.6 – 23.7 | [1, 2] |
| MXB 1916-05 | 19 18 47.7 | -05 14 11.2 | LMXB | NS | 36.6 | 2.5 – 3.0 | 22.6 – 23.7 | [1] |
| 4U 1323-62 | 13 26 36.1 | -62 08 10.0 | LMXB | NS | 36.7 | 3.1 – 3.9 | 22.6 – 23.6 | [6] |
| 4U 1254-690 | 12 57 37.2 | -69 17 21.0 | LMXB | NS | 37.0 | 2.9 – 4.3 | 22.9 – 23.7 | [1] |
| 4U 1746-37 | 17 50 12.7 | -37 03 08.0 | LMXB | NS | 37.0 | $> 3.5$ | $>22.5$ | [1] |
| GX 13+1 | 18 14 31.5 | -17 09 26.7 | LMXB | NS | 37.4 | $> 3.5$ | $>22.5$ | [5] |
| MXB 1659-298 | 17 02 06.5 | -29 56 44.1 | LMXB | NS | 37.5 | 2.4 – 3.8 | 23.1 – 23.7 | [1, 4] |
| 4U 1624-490 | 16 28 02.8 | -49 11 54.6 | LMXB | NS | 37.7 | 2.9 – 3.6 | 23.1 – 23.8 | [1, 3] |
| Cir X-1 | 15 20 40.9 | -57 10 01.0 | LMXB | NS | 37.2 – 38.2 | 2.2 – $> 5$ | 22.2 – 23.8 | [7, 8] |
| GX 339-4 | 17 02 49.5 | -48 47 23.0 | LMXB | BH | 37.1 | 4.0 | $<< 22$ | [9] |
| XTE J1650-500 | 06 50 01.0 | -49 57 45.0 | LMXB | BH | 37.5 | 4.3 | n/a | [13] |
| GRO J1655-40 | 16 54 00.1 | -39 50 44.9 | LMXB | BH | 37.5 | 4.2 – 4.7 | $> 22.0$ | [9] |
| XTE J1550-564 | 00 00 00.0 | 00 00 00.0 | LMXB | BH | 38.0 | $> 4$ | n/a | [12] |
| H 1743-322 | 17 45 02.0 | -32 13 40.0 | LMXB | BH | 38.3 | 5.5 – 5.7 | 21.8 – 22.3 | [10] |
| GRS 1915+105 | 19 15 11.6 | 10 56 44.0 | LMXB | BH | 38.8 | $> 4.2$ | 22.3 – 23.1 | [11] |
| 4U 1755-33 | 17 58 40.0 | -33 48 27.0 | LMXB | BH | | | | [14] |
| Cyg X-1 | 19 58 21.6 | 35 12 06.0 | HMXB | BH | 37.0 | 1.8 – 2.8 | 21.2 – 22.9 | [15] |
| X 1908+875 | 19 10 46.0 | 07 36 07.0 | HMXB | NS | | | | |
| Vela X-1 | 09 23 06.9 | -40 33 17.0 | HMXB | NS | | | | |
| Cyg X-3 | 20 32 25.8 | 40 57 28.0 | HMXB | BH | | | | |

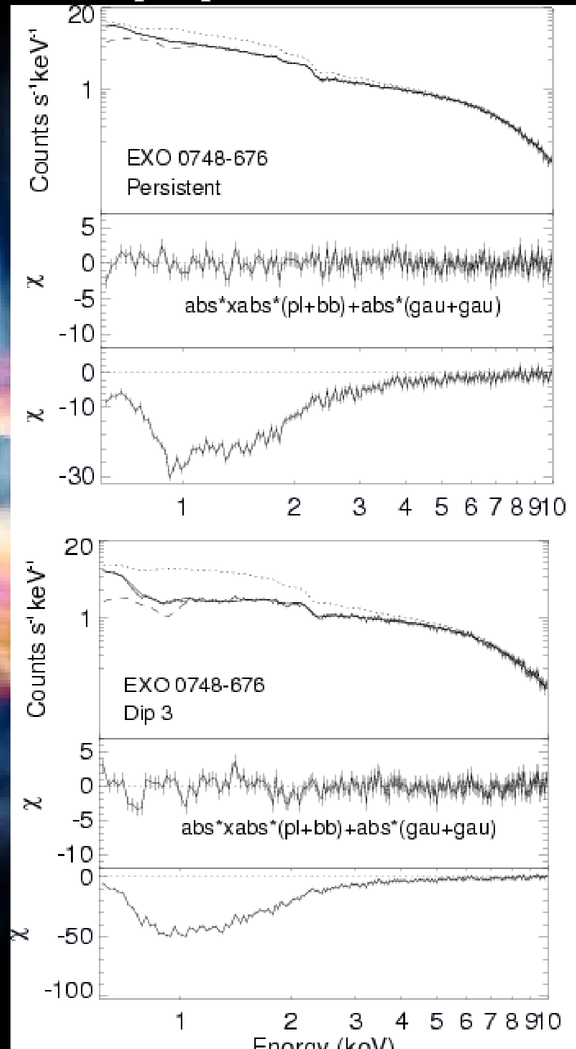
[1] Diaz-Trigo et al. 2006 [2] Jimenez-Garate et al. 2003 [3] Xiang et al. 2007 [4] Sidoli et al. 2001 [5] Ueda et al. 2004 [6] Boirin et al. 2005 [7] Schulz & Brandt 2002 [8] Schulz et al. 2006 [9] Miller et al. 2006a [10] Miller et al. 2006b [11] Lee et al. 2003 [12] Miller et al. 2003 [13] Miller et al. 2002 [14] Angelini & White 2003 [15] Miller et al. 2005

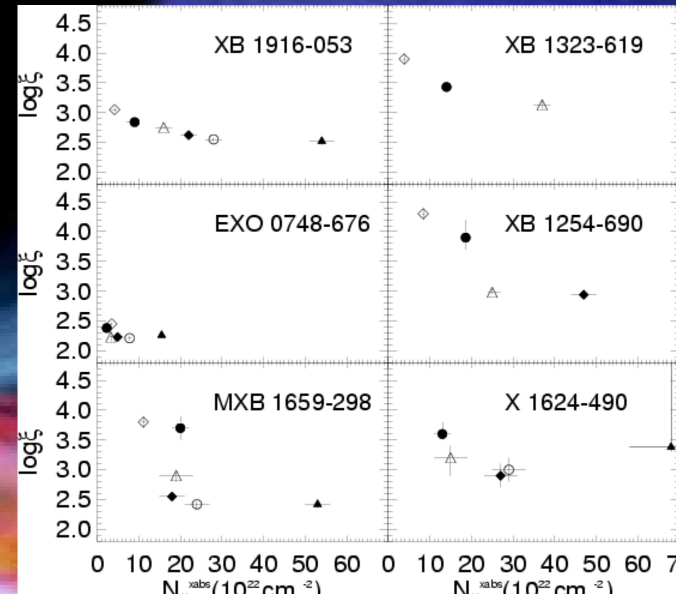
# Warm Absorbers in Compact Binaries:

## Low luminosity accreting neutron stars - atoll sources

Diaz-Trigo et al. 2006: XMM-Newton Epic-pn:

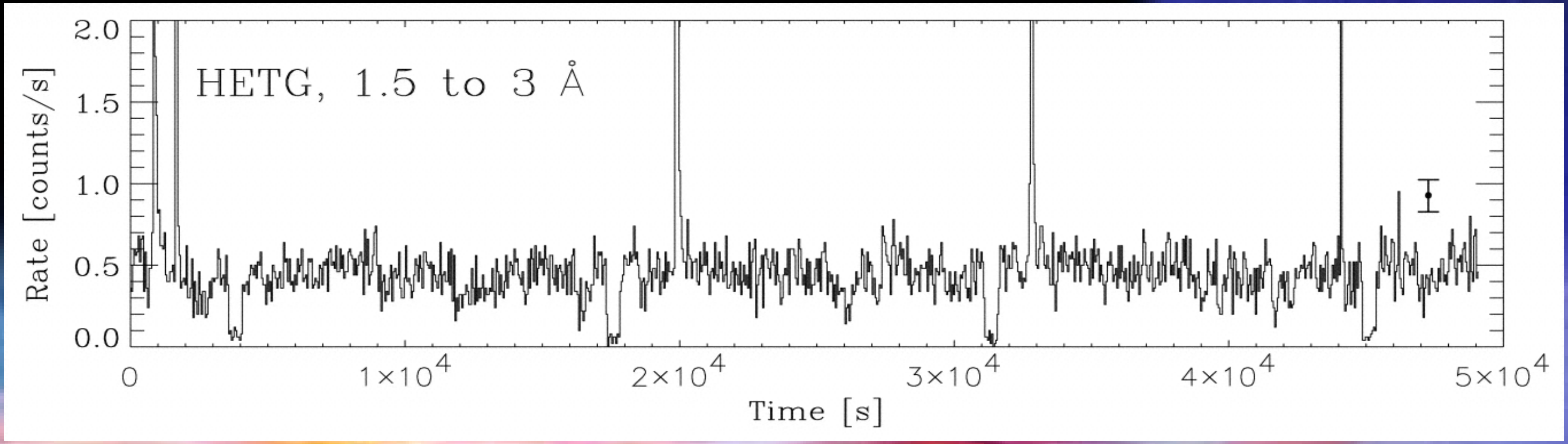


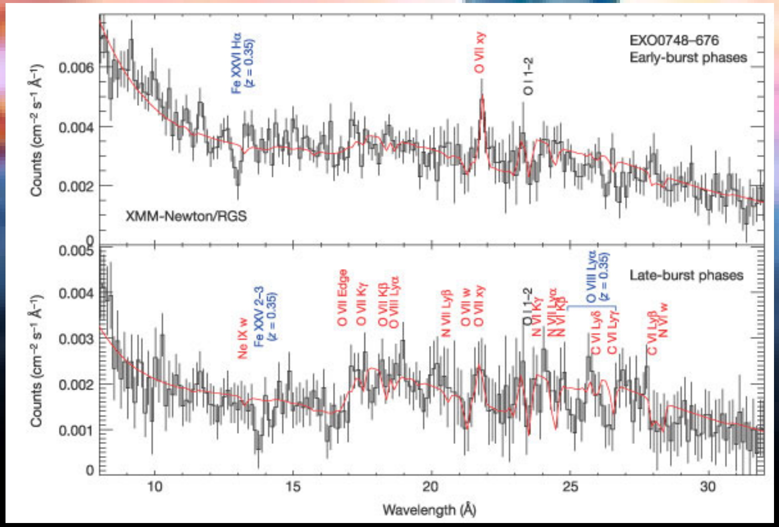



# Warm Absorbers in Compact Binaries:

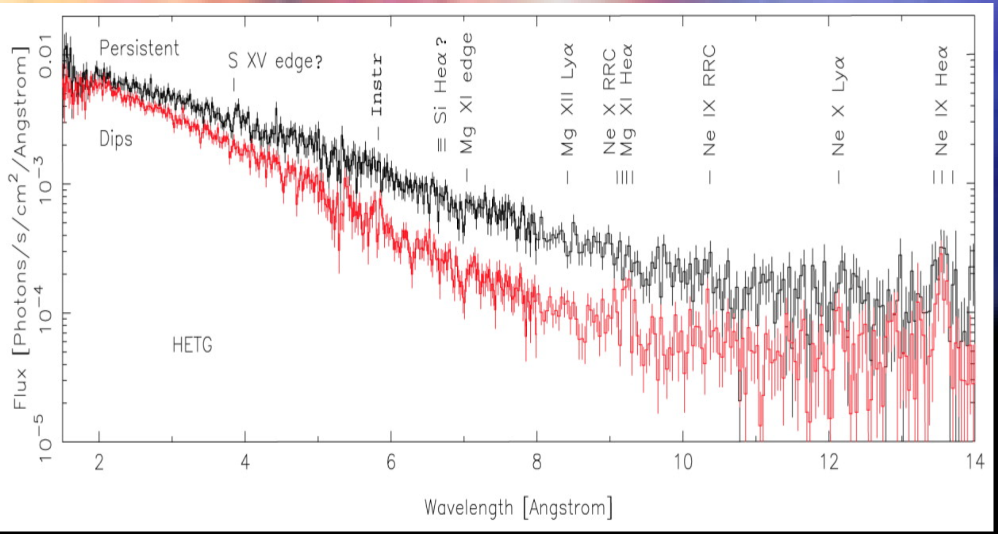
EXO 0748+676




Cottam et al. (2003)




Jimenez-Garate, Schulz, & Marshall (2003)



# Warm Absorbers in Compact Binaries:

## The low flux state of Cir X-1

low X-ray fluxes (<100 mCrab)

Heinz etal, 2007, ApJ, 544, L123, Schulz et al.2008, ApJ, Jan. 10

low ionization parameter: log ξ = 2 -- 3
no blueshifts
cold, lukewarm, warm absorber present

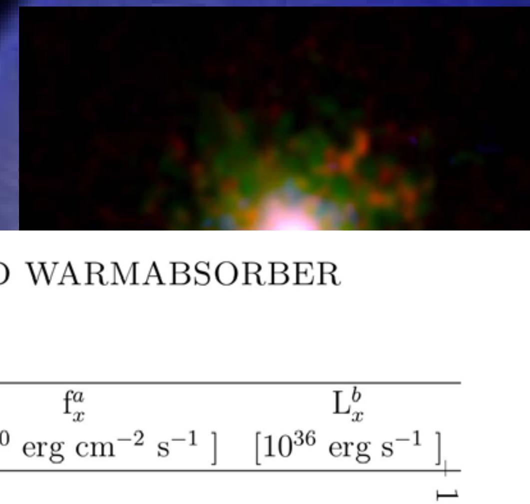
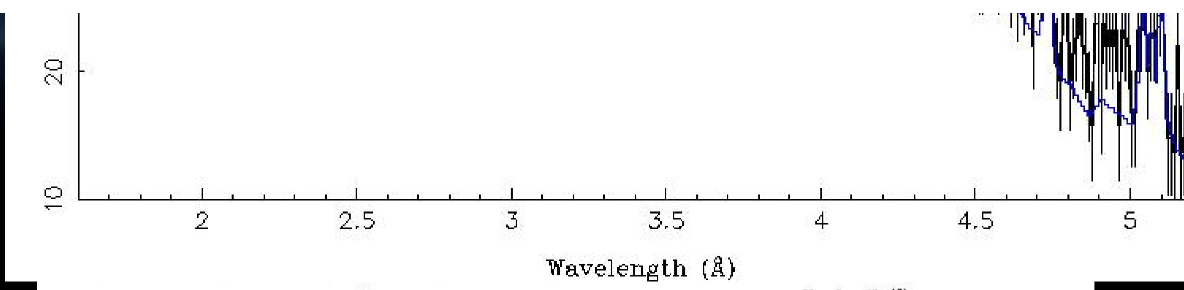


TABLE 3. THE FIT RESULTS USING THE PHOTOIONIZATION (PH) AND WARMABSORBER (WA) MODEL IN XSTAR

| Obsid | Model | log $N_H^{cold}$ [cm−2] | log $N_H^{warm}$ [cm−2] | ξ [ergs cm $s^{-1}$] | Γ | z | $f_x^a$ [$10^{-10}$ erg $cm^{-2}$ $s^{-1}$ ] | $L_x^b$ [$10^{36}$ erg $s^{-1}$ ] |
|---|---|---|---|---|---|---|---|---|
| 6148 | PH | $22.9^{+0.0}_{-0.0}$ | – | 3.0 | $1.58^{+0.00}_{-0.00}$ | 0.001 | 1.219 | 0.496 |
| 5478 | WA (low) | $22.3^{+0.1}_{-0.1}$ | $23.9^{+0.1}_{-0.0}$ | $1.6^{+0.4}_{-0.2}$ | $0.38^{+0.29}_{-0.19}$ | $-0.0077^{+0.0028}_{-0.0047}$ | 1.51 | 0.614 |
| 5478 | WA (high) | $22.3^{+2.4}_{-0.7}$ | $22.8^{+0.1}_{-0.1}$ | $2.7^{+0.1}_{-0.2}$ | $2.62^{+0.12}_{-0.12}$ | $-0.0019^{+0.0019}_{-0.0021}$ | 8.31 | 3.38 |

a) between 2 – 10 keV
b) for a distance of 6 kpc

– 18 –



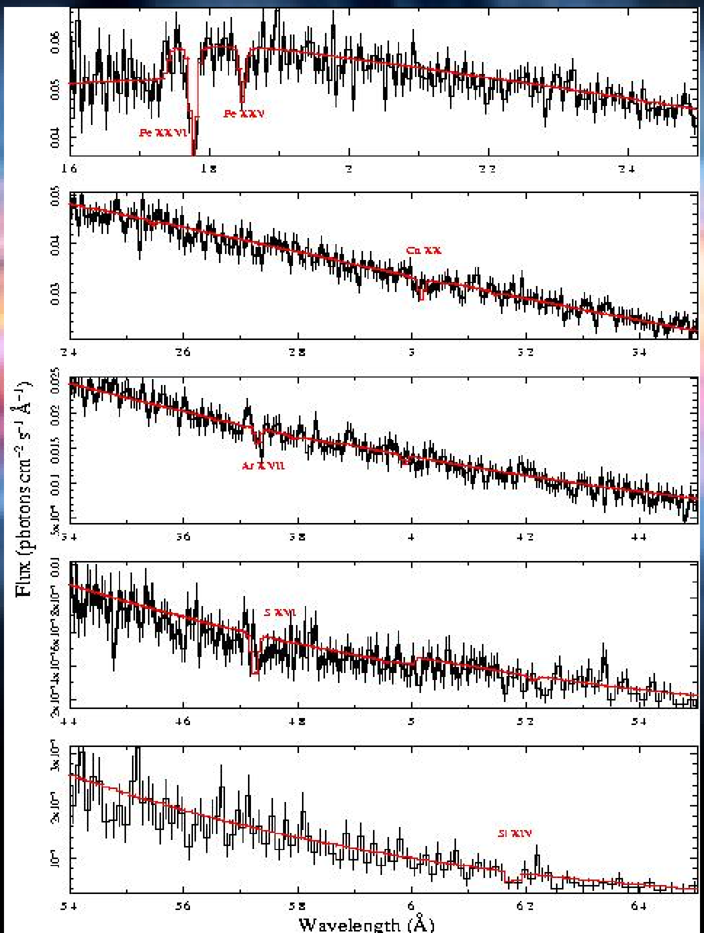
# Warm Absorbers in Compact Binaries:

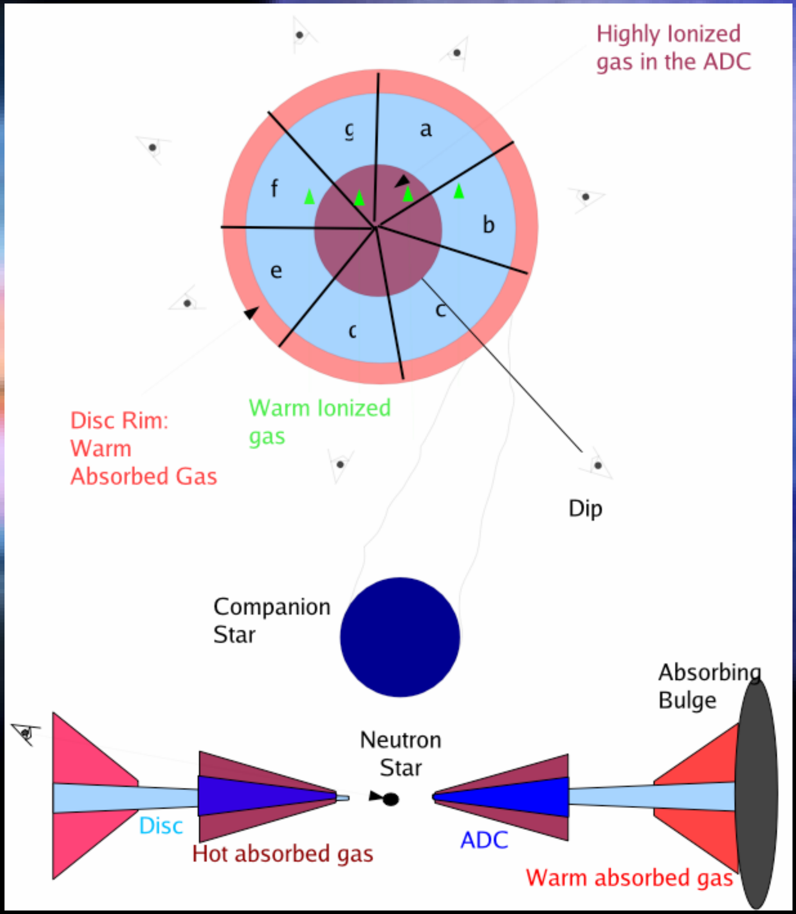
## The Big Dipper: 4U 1624-42

- X-ray absorber seen in XMM Epic Spectra (Parmar et al. 2002): hot absorber Fe XXV, XXVI, Ni XXVII
  warm absorber (< Fe XXV), 6.58 keV

- Xiang et al 2008: XSTAR fit to HETG spectrum: hot ($3 \times 10^6$ K), warm ($10^6$ K), cool ($< 10^5$ K)

see poster 104

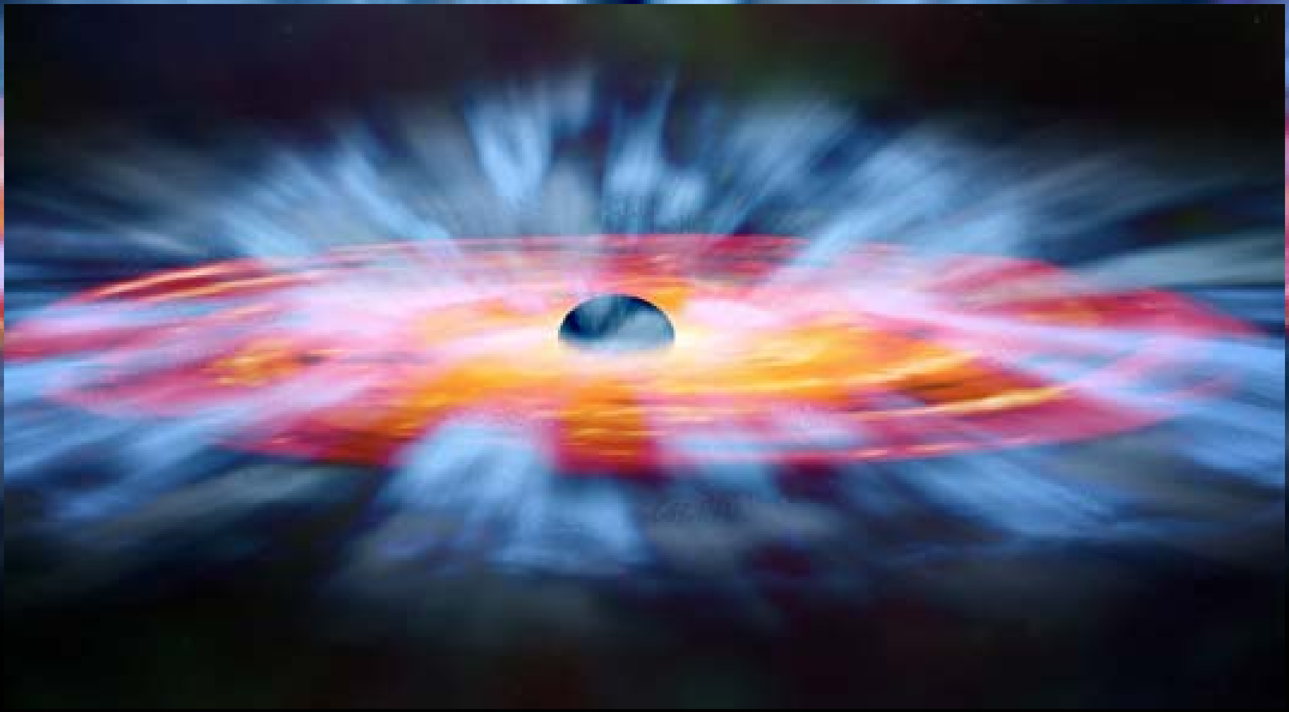


# Warm Absorbers in Microquasars:

Accretion disk atmospheres/coronae gone wild

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Cir X-1 | 15 20 40.9 | -57 10 01.0 | LMXB | NS | 37.2 – 38.2 | 2.2 – > 5 | 22.2 – 23.8 | [7, 8] |
| GX 339-4 | 17 02 49.5 | -48 47 23.0 | LMXB | BH | 37.1 | 4.0 | << 22 | [9] |
| XTE J1650-500 | 06 50 01.0 | -49 57 45.0 | LMXB | BH | 37.5 | 4.3 | n/a | [13] |
| GRO J1655-40 | 16 54 00.1 | -39 50 44.9 | LMXB | BH | 37.5 | 4.2 – 4.7 | > 22.0 | [9] |
| XTE J1550-564 | 00 00 00.0 | 00 00 00.0 | LMXB | BH | 38.0 | > 4 | n/a | [12] |
| H 1743-322 | 17 45 02.0 | -32 13 40.0 | LMXB | BH | 38.3 | 5.5 – 5.7 | 21.8 – 22.3 | [10] |
| GRS 1915+105 | 19 15 11.6 | 10 56 44.0 | LMXB | BH | 38.8 | > 4.2 | 22.3 – 23.1 | [11] |
| 4U 1755-33 | 17 58 40.0 | -33 48 27.0 | LMXB | BH | | | | [14] |
| Cyg X-1 | 19 58 21.6 | 35 12 06.0 | HMXB | BH | 37.0 | 1.8 – 2.8 | 21.2 – 22.9 | [15] |



Blueshifts from equatorial flows

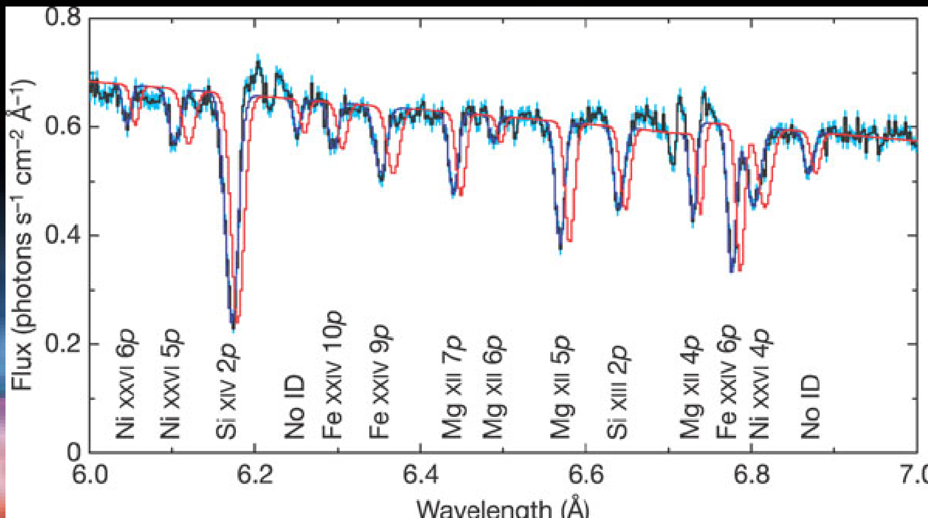
No shift or unconfirmed shifts

Redshifts from focussed winds

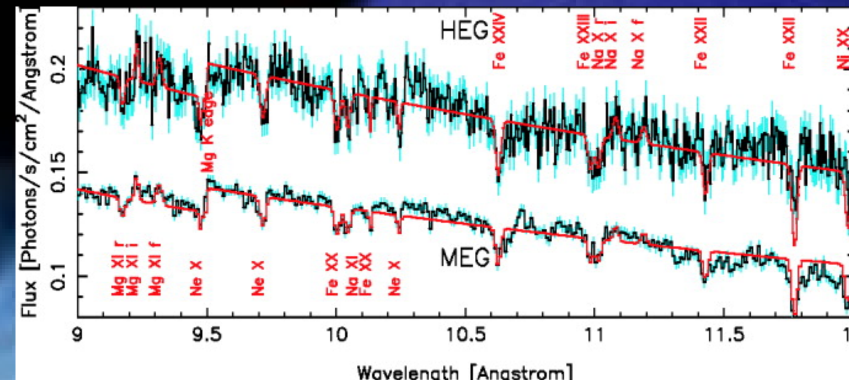
# Warm Absorbers in Compact Binaries:

## Microquasars

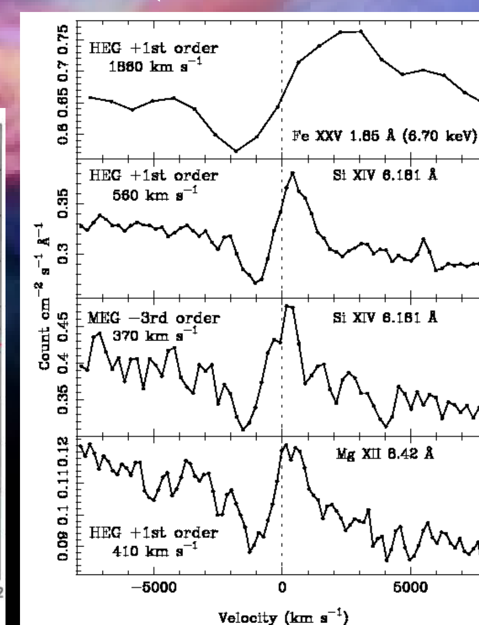
GRO J1655-40 (Miller et al.2006a)



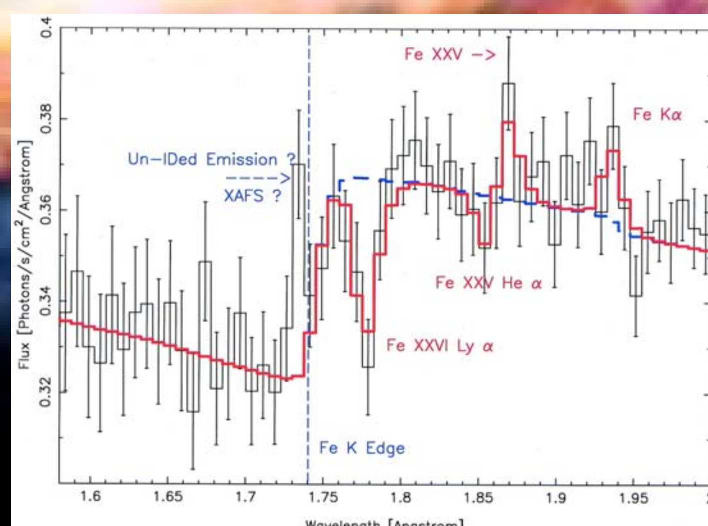

Cyg X-1 (Marshall et al. 2001, Miller et al. 2005)



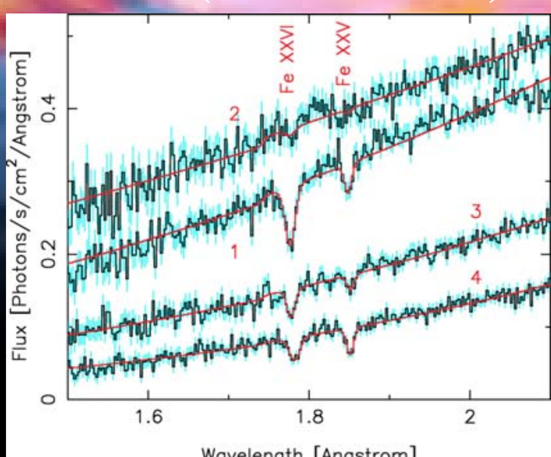

Cir X-1 (Brandt & Schulz 2000)




GRS 1915+105
Lee et al. 2002




H 1743-322 (Miller et al. 2006b)

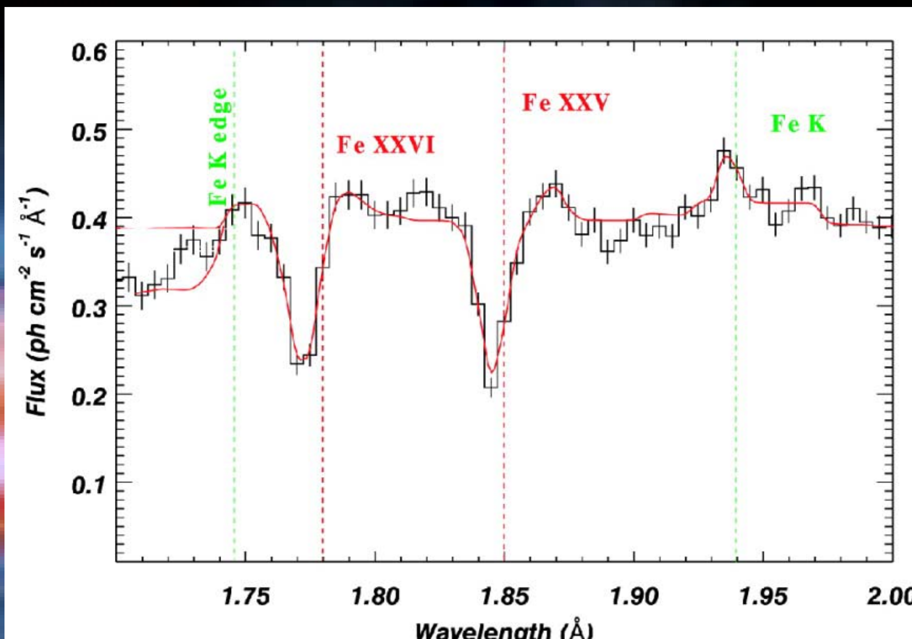


# Warm Absorbers in Compact Binaries:

Microquasars: the special case of Cir X-1

## The X-ray binary with two faces:

at high X-ray fluxes (>1 Crab)




Schulz & Brandt (2002)

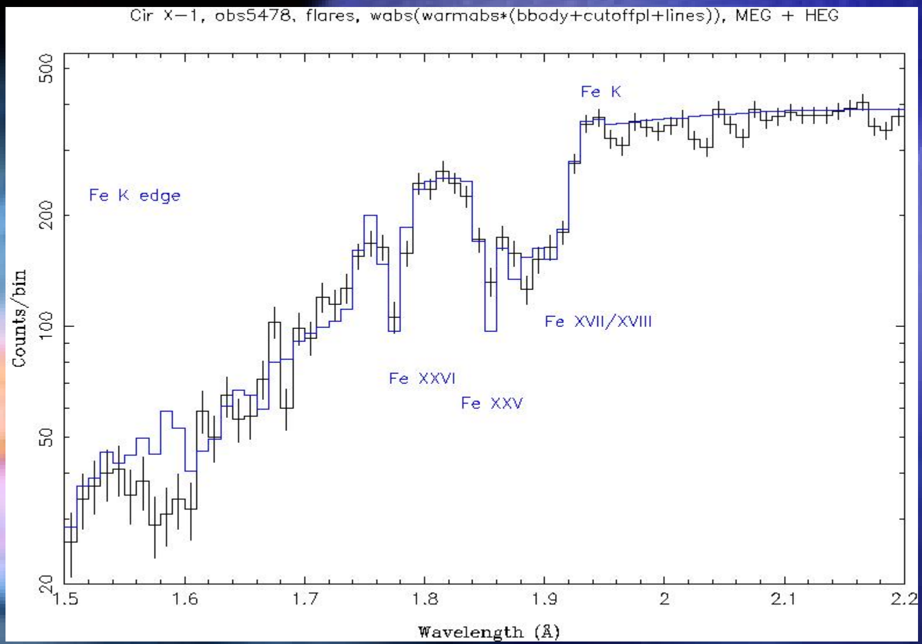
high ionization parameter: log $\xi > 4$

blueshifts: $v_{outflow}$ = 400 -- 2000 km/s

cold and hot absorber present

→ microquasar

at low X-ray fluxes (<100 mCrab)




Schulz et al. (2007) in prep.

low ionization parameter: log $\xi$ = 2 -- 3

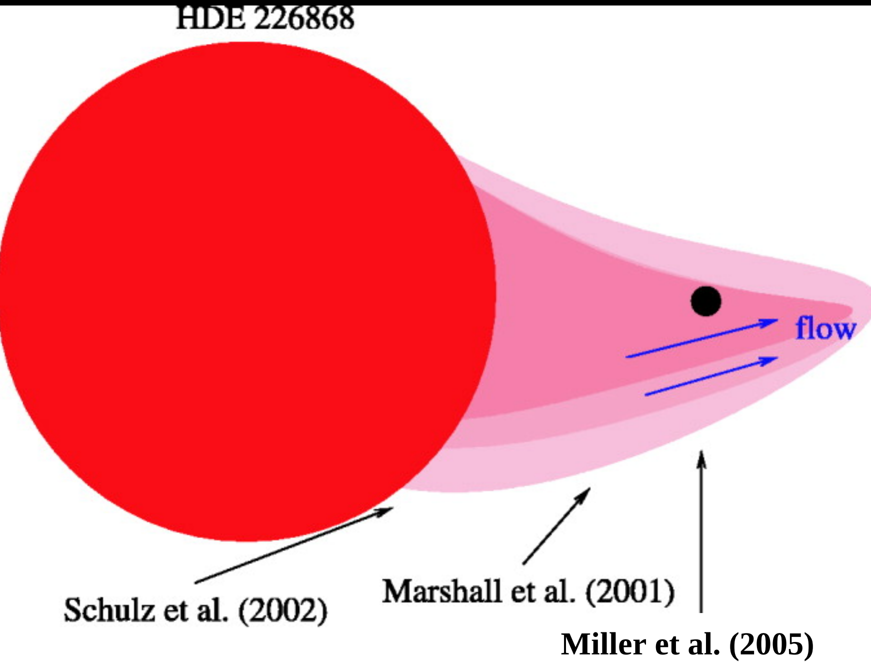
no blueshifts

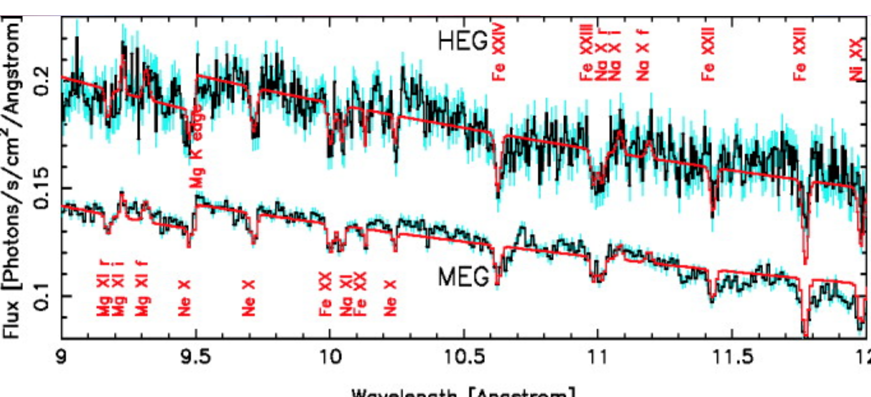
cold, lukewarm, warm absorber present

→ atol dipper

# Warm Absorbers in Compact Binaries:

## Microquasars: the case of Cyg X-1

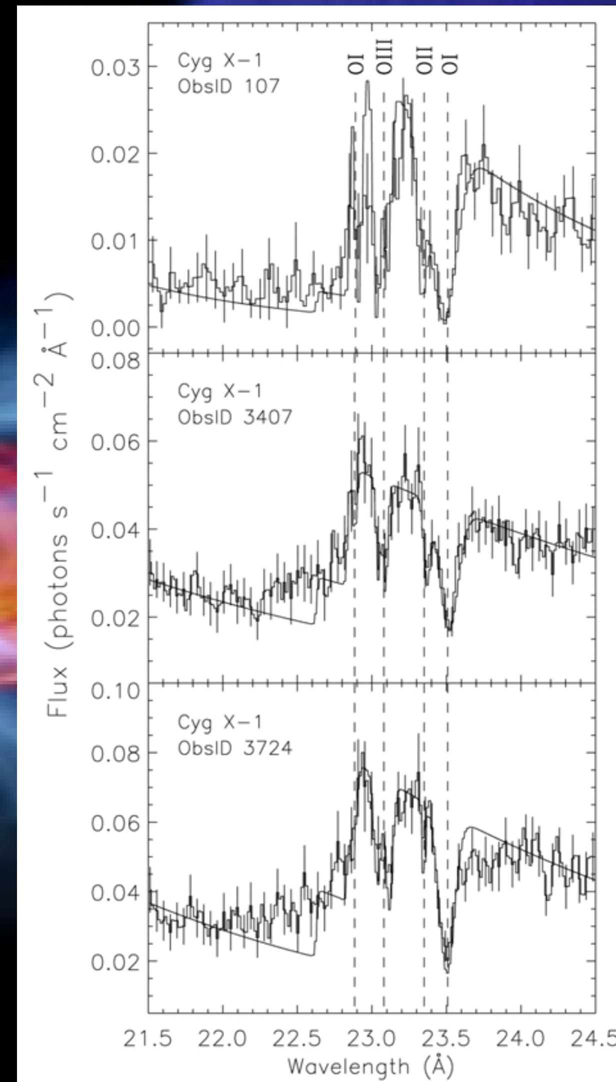



hot absorber

Juett et al. (2004)

Cool & lukewarm absorber



# Warm Absorbers in Compact Binaries:

## Summary:

-intrinsic absorption of various temperature levels now observed in more than a dozen XRB: cold (<$10^3$ K), warm (<$10^6$ K), hot (>$10^6$ K)

-warm and hot absorbers seen in atol dippers and some microquasars

- warm absorber competes with ADC at high inclination

-absorber strength increases with luminosity intrinsically as well as between atol dippers and microquasars

-so far no clear trend with respect to column densities between absorbers in accreting NS and BHs

-warm aborber regions in X-ray binaries are likely different wrpt to Seyfert Is: accretion disk atmospheres vs. halo region