High resolution X–ray spectroscopy of the narrow line Seyfert 1 galaxy NGC 4051

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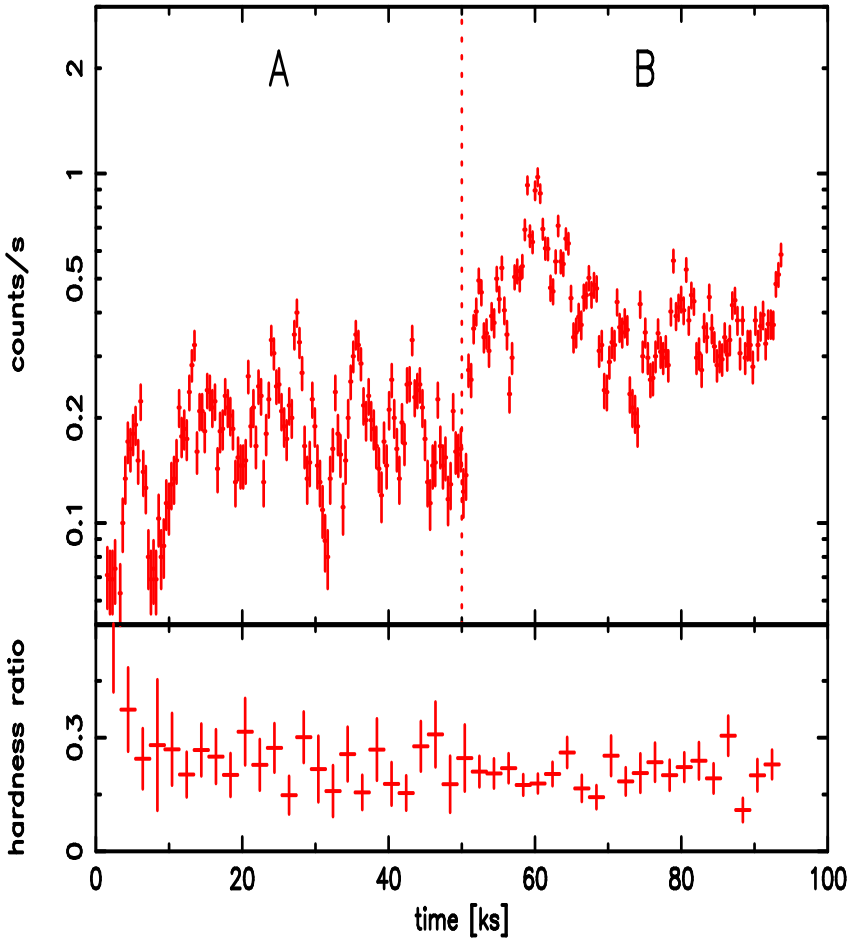
Physics of Warm Absorber in AGN 2005

Outline

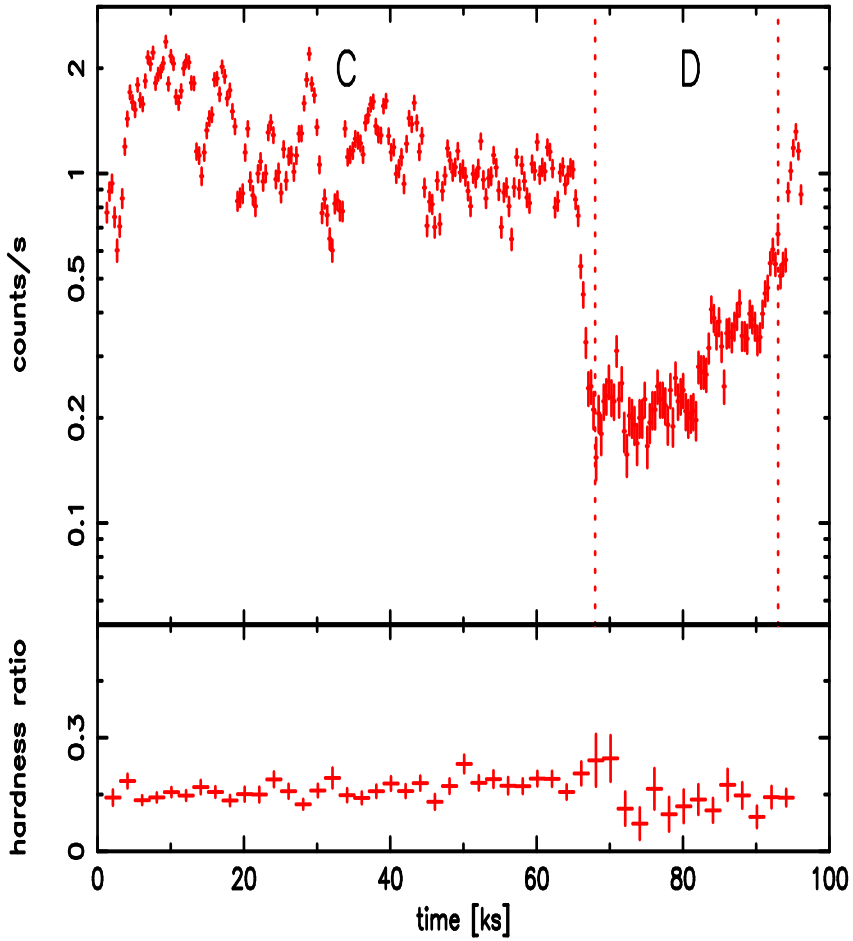
Introduction: properties of NGC 4051

- nearby at z=0.0023 (10 Mpc)
- bright in optical (V$\approx 13^m$) and in X–rays (F$\approx 2 \times 10^{-14}$W m^{-2})
- flux variability
- continuum = power law + modified black body or relativistic lines
- well studied in X–rays

Introduction: Chandra LETGS light curves

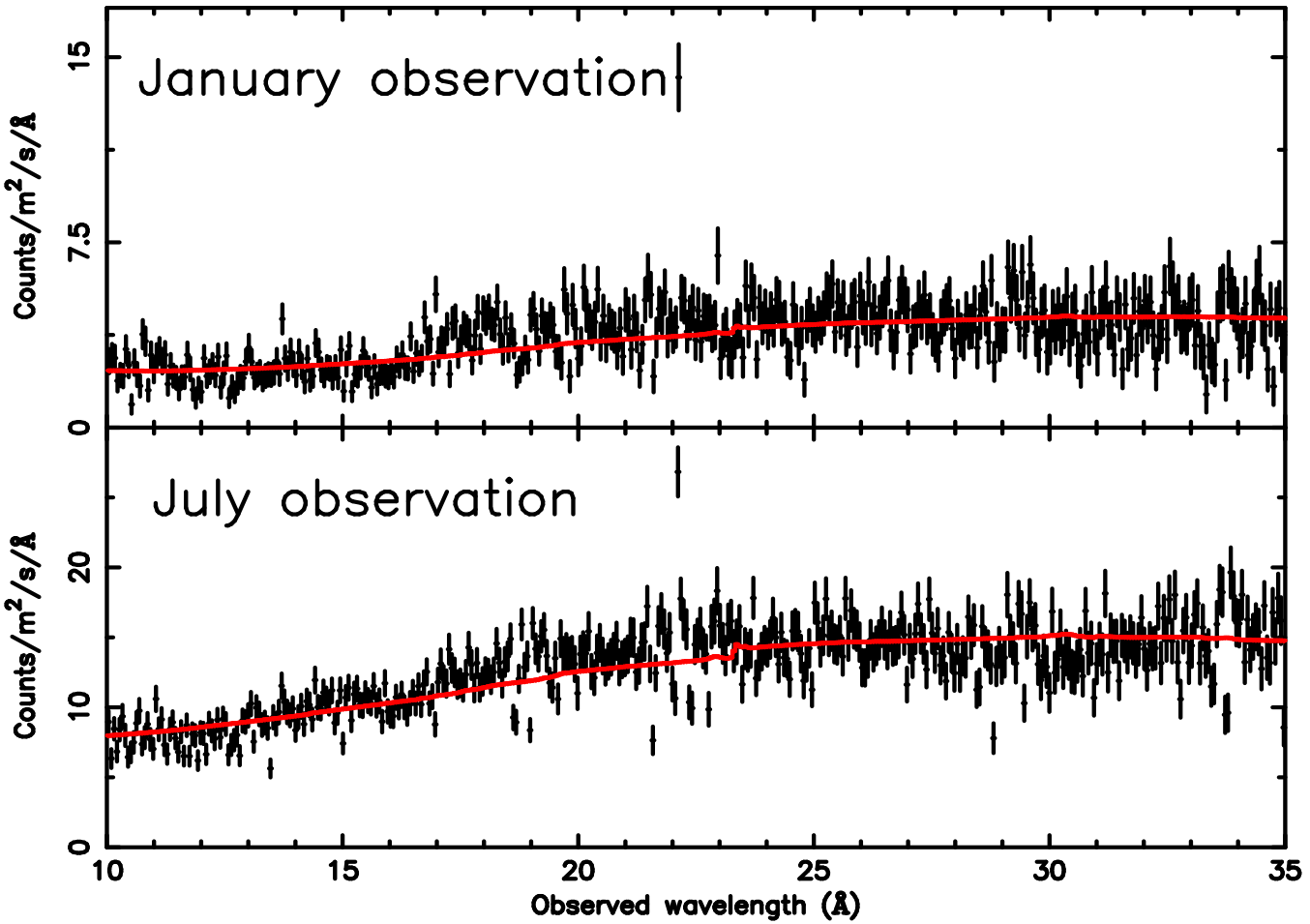


January, 2002



July, 2003

Introduction: continuum



Data and continuum model

Warm absorber: July observation

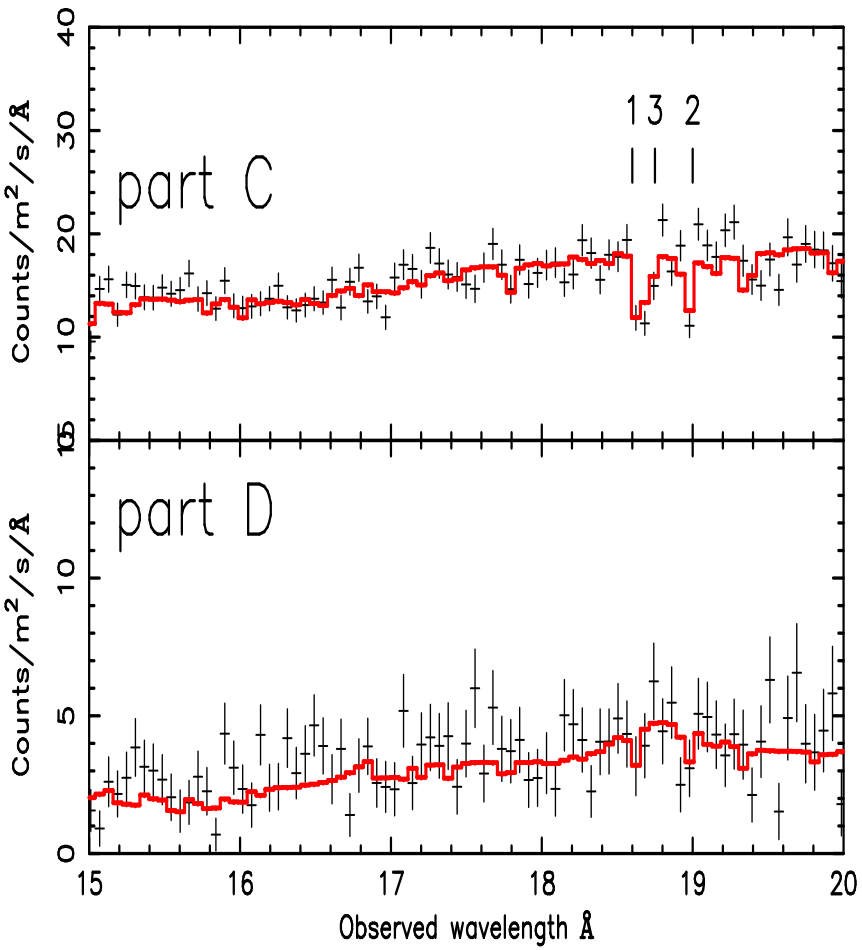
- C part – three different outflow components

C	N_H ($\times 10^{25}$ m^{-2})	$\log \xi$ ($\times 10^{-9}$ W m)	v_{out} (km/s)
1	0.41 ± 0.04	0.74 ± 0.06	-420 ± 20
2	1.9 ± 1.0	2.44 ± 0.08	-820 ± 40
3	15^{+10}_{-6}	3.2 ± 0.1	-4810 ± 120

- D part – only one outflow component detected

C	N_H ($\times 10^{25}$ m^{-2})	$\log \xi$ ($\times 10^{-9}$ W m)	v_{out} (km/s)
2	3.5 ± 1.0	1.54 ± 0.10	-790 ± 40

- non–detection of component 1&3 in the D part



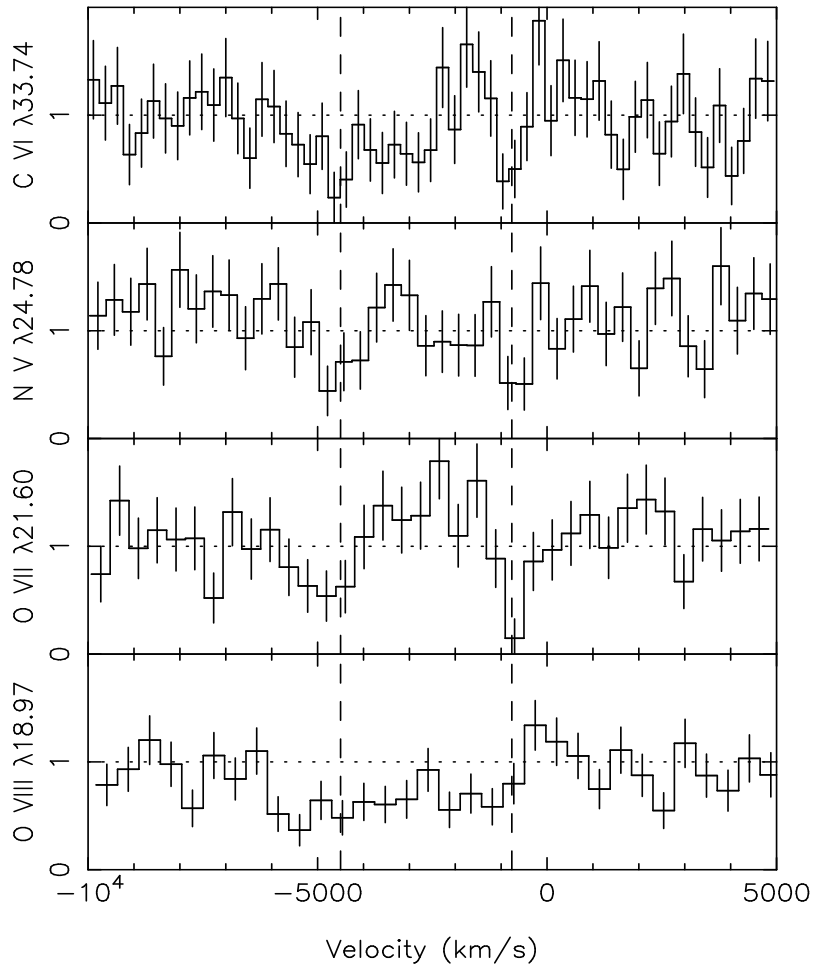
Warm absorber: January observation

- A part – two components detected

C	N_H ($\times 10^{25}$ m^{-2})	$\log \xi$ ($\times 10^{-9}$ W m)	v_{out} (km/s)
1	$1.95^{+22.0}_{-1.39}$	2.37 ± 0.26	-675^{-630}_{+190}
3	74^{+74}_{-51}	$3.4^{+0.7}_{-0.1}$	-4310^{+720}_{-520}

- B part – two components detected

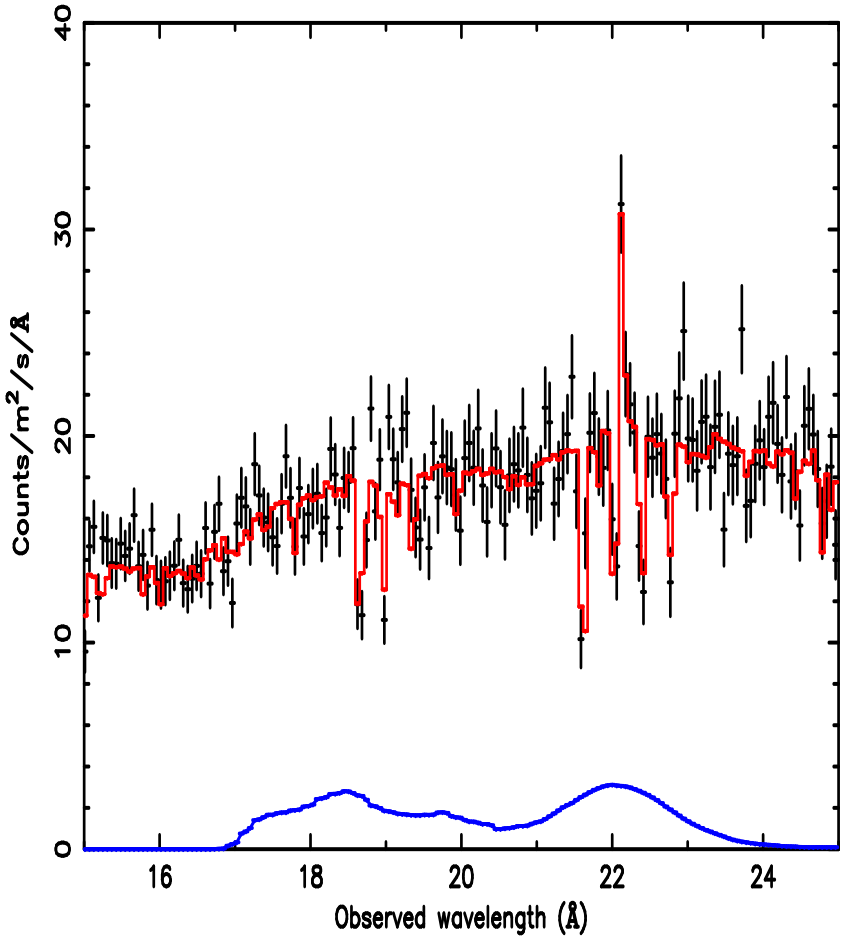
C	N_H ($\times 10^{25}$ m^{-2})	$\log \xi$ ($\times 10^{-9}$ W m)	v_{out} (km/s)
1	0.63 ± 0.23	1.40 ± 0.18	-570 ± 80
3	14 ± 8	3.0 ± 0.1	-4570 ± 120



Broad emission: July observation

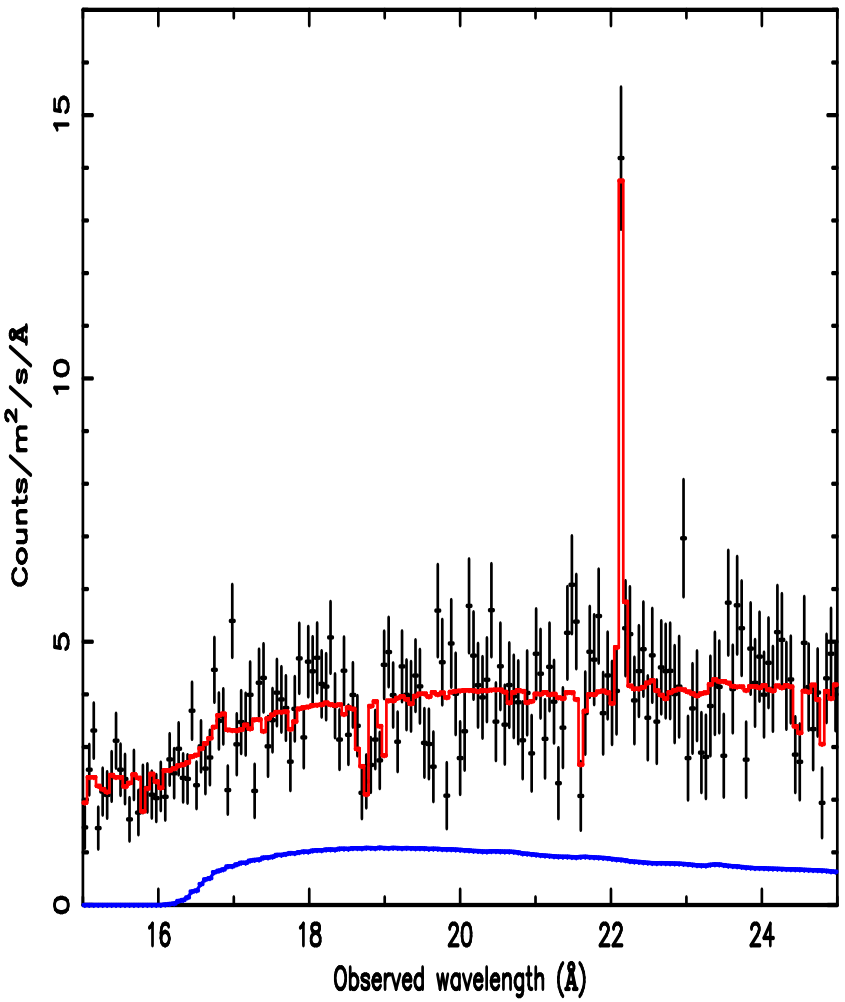
High state

- three broad lines (O VIII Lyα, C VI Lyα and O VII triplet)
- O VIII Lyα — relativistic profile (Y$\sim$r$^{-\Gamma}$) $\Rightarrow$ close to BH
- C VI Lyα and O VII triplet — gaussian profiles $\Rightarrow$ further from BH



Broad emission: January observation

- only O VIII Lyα line present in the spectrum
- constant during whole observation
- relativistic profile
- similar behaviour found for Fe K line (Iwasawa et al. 1996)



Broad emission: soft excess

Previous explanation:

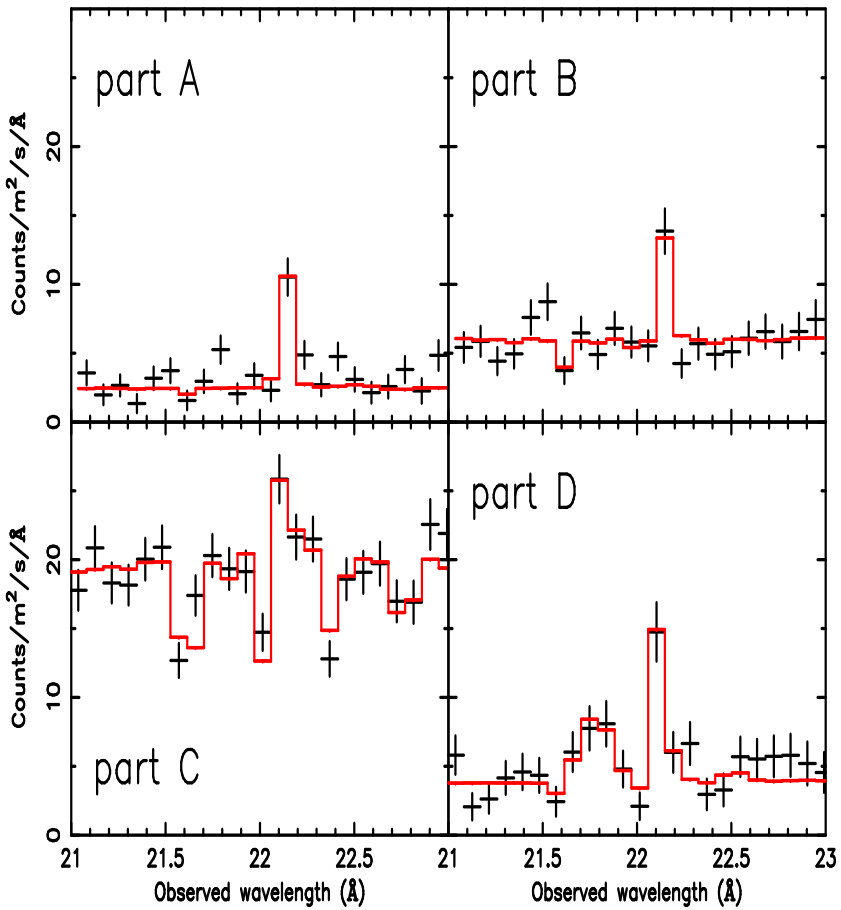
- series of relativistic emission lines and RRCs (Ogle et al. 2004)

New results:

- suffiecently explained by modified black body

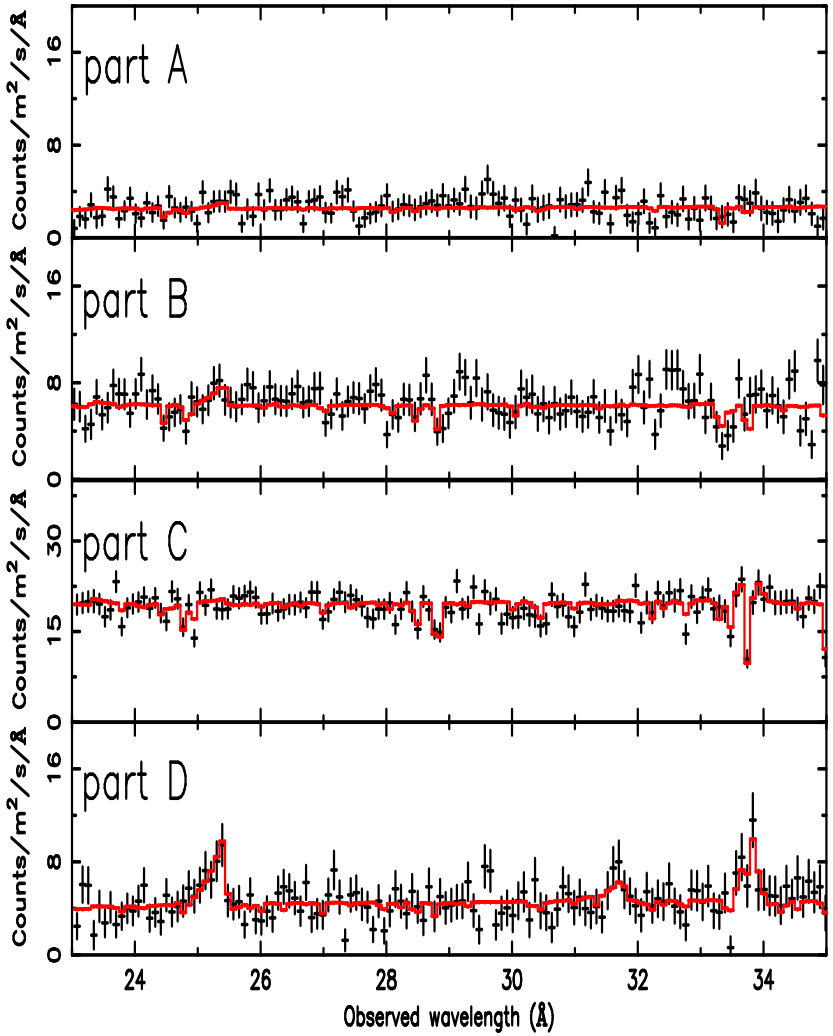
Narrow emission features: O VII forbidden line

- no response of the O VII forbidden line to the flux change
- no association with the warm absorber



Narrow emission features: RRC

- strong C VI and C V RRC
- weak O VIII, OVII, N VII & N VI RRC
- fast response
- temperature ~ 5 eV
- redshift ~ 1000 km/s



Narrow emission features: Interpretation of the RRC

- connection between RRC and warm absorber?
- O VIII RRC weak: low ionization
- O VII RRC weak: blend with Fe-M absorption
- N VII & N VI RRC weak: low abundance
- $\Delta t < 10^4 \mathrm{s} \Rightarrow r = \frac{1}{2} c \Delta t \leq 1.5 \times 10^{12} \mathrm{m}$
- $M = 3 \times 10^5 M_\odot \Rightarrow v_{\mathrm{Kepler}} \geq 5200 \ \mathrm{km/s}$

Narrow emission features: Interpretation of the RRC

$$\left.\begin{aligned} \mathrm{Y} &= \mathrm{n}^2\mathrm{V} \\ \mathrm{V} &= \Omega\, r^2 \cdot \mathrm{d}\, r \\ \Omega &\leq 4\pi \\ \xi &= \mathrm{L}/\mathrm{n}\, r^2 \end{aligned}\right\} \mathrm{N}_H = \mathrm{n}_\mathrm{H} \cdot \mathrm{d}\, r \geq 10^{26}\mathrm{m}^{-2}$$

Summary

- different flux and variablity states
- warm absorber
- broad emission lines
- narrow emission features

THANK YOU FOR YOUR ATTENTION