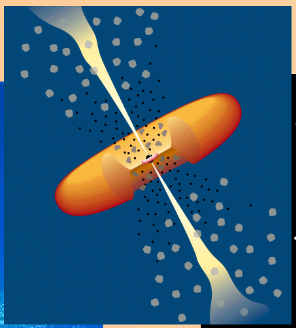
X-ray absorption and high-velocity outflows in AGNs - a second look

Shai Kaspi

Technion – Haifa; Tel-Aviv University

Israel



"Physics of warm absorbers in AGN" – Warsaw, Poland – 5 October 2005

Outline

- Mass outflow and identifying Outflows
- Alternative interpretation for PG1211+143
- The problematic second look;

  and also, PDS456, NGC3783
- Further directions

Mass Outflow From AGNs

Does mass outflow from the AGN?

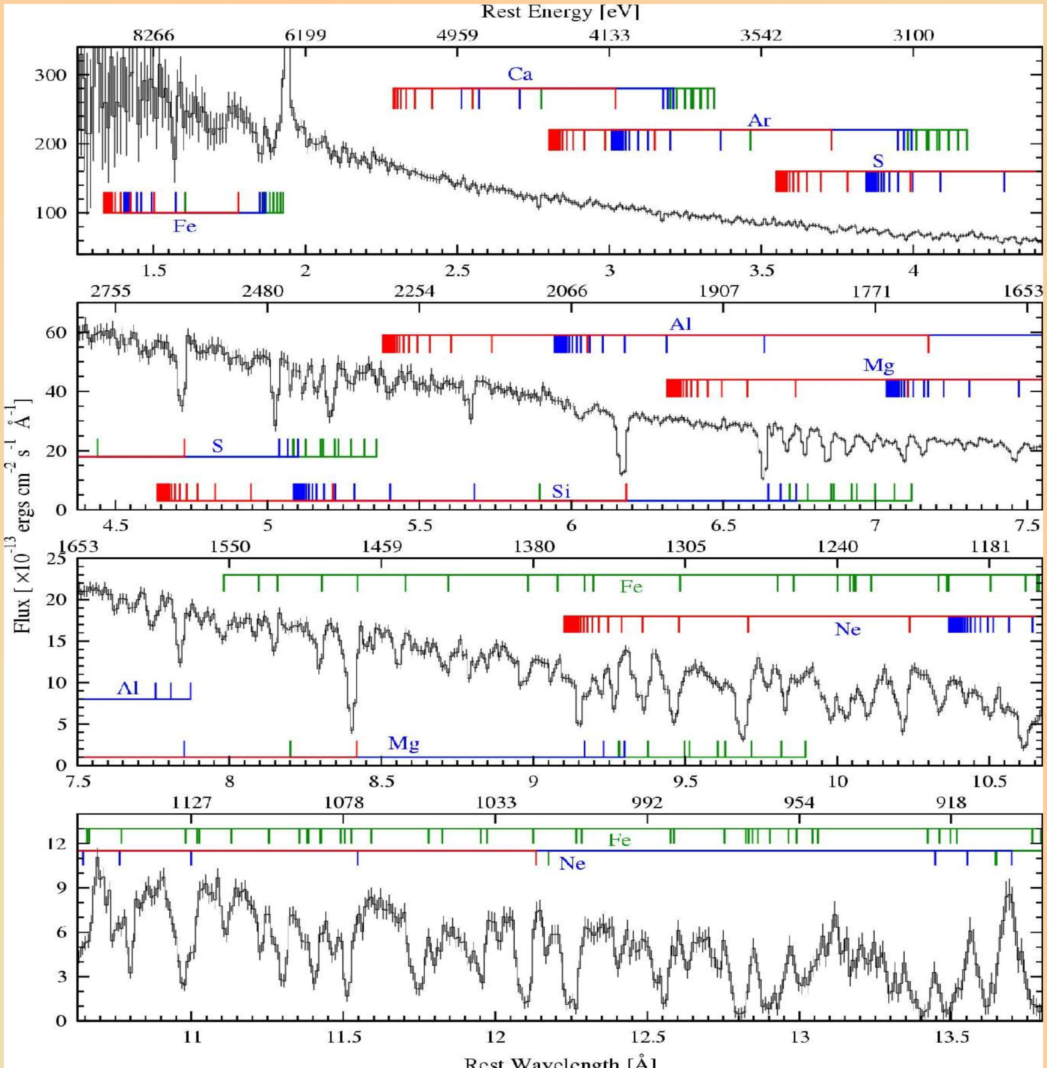
• Collimated jets and/or lobs in “Radio load” quasars – 5%-10% of quasars are “Radio load”.

• Broad absorption lines (BALs) – Blueshifted up to 0.1c - in the rest-frame UV lines of ~10% “radio quiet” quasars.

Is mass loss an important component in most AGNs?

“Recent” (~7 yr) UV (HST) and X-ray (Xmm & Chandra) observations detected outflowing mass in the majority of moderate luminosity Seyfert galaxies (~70%), indicating the importance of mass outflow.

Identifying outflows in X-ray spectra

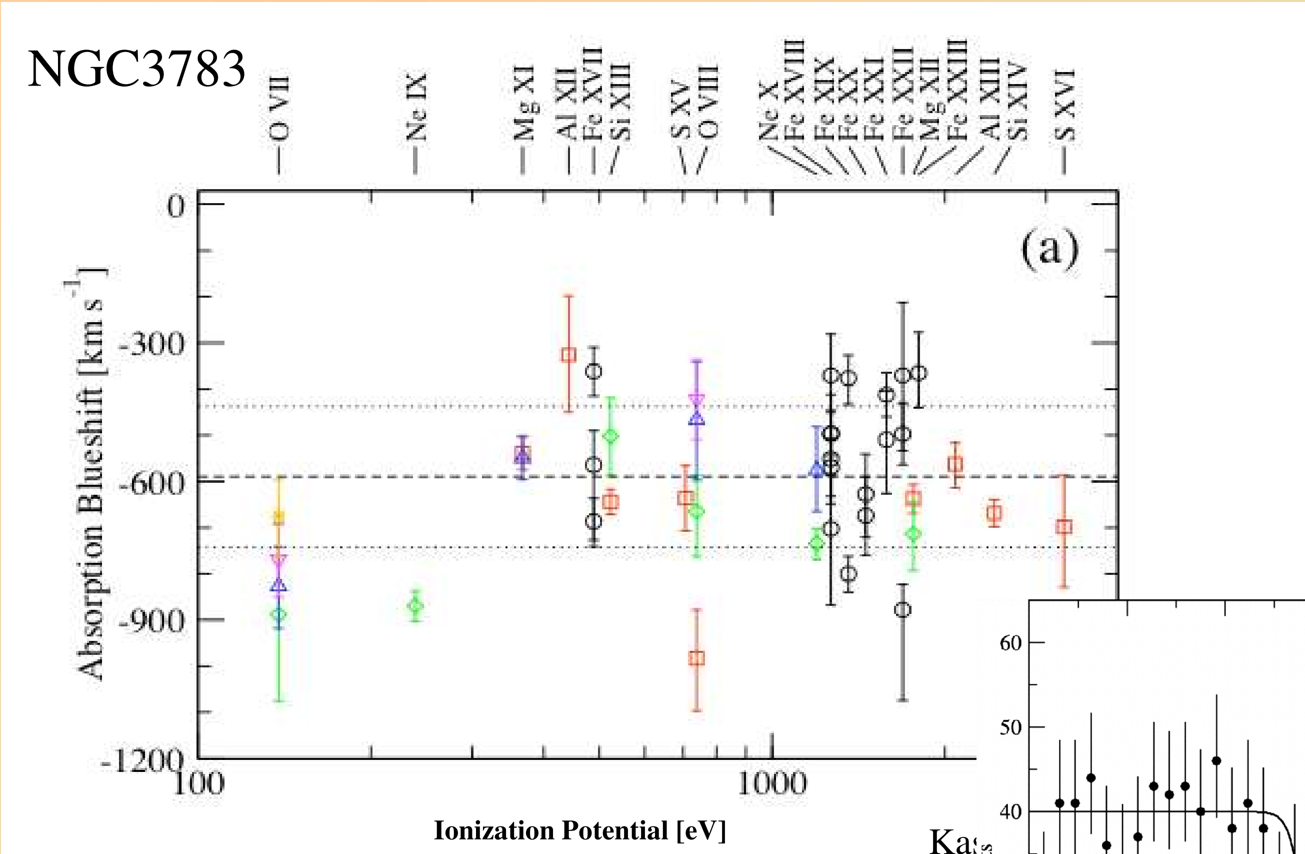


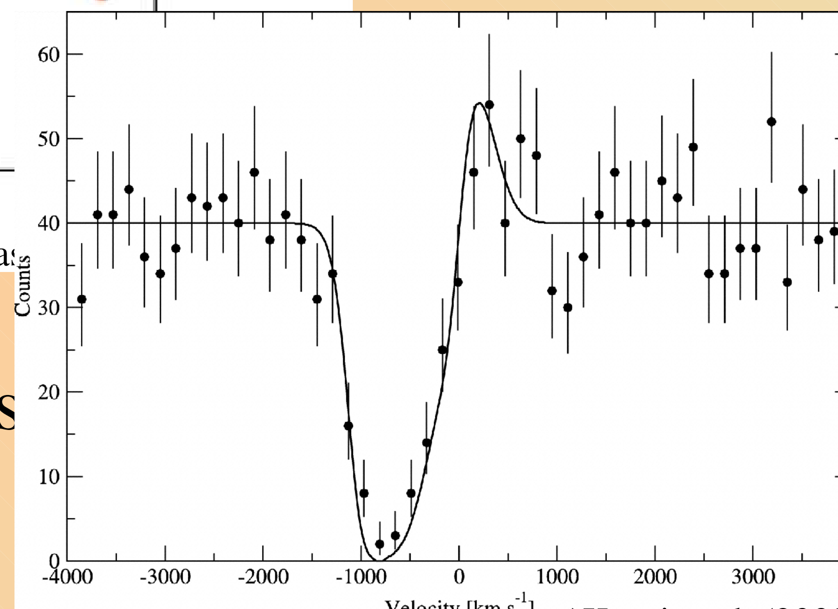
)Kaspi et al. 2002(

NGC3783 900 ks with the Chandra HETG

- Evenly spaced binned data vs. minimum counts per bin
- Finding series of lines
- Several ions with the same outflow velocity
- Taking into account emission lines
- Globally fitted model

Velocities are not Straightforward





)Kaspi et al. (2002

Individual line measurements s
from systematic uncertainties
(emission line filling?)

Mass outflow

- How much mass is carried out of the AGN by the outflow?

- How does it compared to the amount of matter being accreted?

- Does the ionized outflow carry a significant fraction of the energy output of the AGN?

Answers are currently model dependent

Mass outflow

Blustin et al. (2004) - All X-ray high resolution spectra

23 Seyfert 1, 17 with outflows, 14 with outflow models

Assuming a model of :

- constant density outflow
- average openning angle of the outflow of 1.6
- a filling factor of the outflowing gas

Find:

$\dot{M}_{out}$ ~ 0.5-5 M yr^{-1}

$\dot{M}_{acc}$ ~ 0.1-5 M yr^{-1}

$\dot{M}_{out}/\dot{M}_{acc}$ ~ few

L_{KE} ~ 10^{40} erg/s

% of L_{bol} ~0.05-0.1

High Velocity Outflows

Source	]V_{out}[c	N_H][10^{23} cm^{-2}	UV BAL)(km/s	L /L_{Edd}
APM 08279+5255)Chartas et al. (2002	0.4 , 0.2	0.5 ± 1	) Y(12.4k ~ 0.04c	high
PG 1211+143)Pounds et al. (2003	0.1 - 0.08	5	N	1.1
PG 1115+080)Chartas et al. (2003	, 0.1 0.34	,0.05 ± 0.1 6.9	)?(Y	0.7
PG 0844+349)Pounds et al. (2003	0.26 0.2-	4	N	0.3
PDS 456)Reeves et al. (2003	0.16	5	)Y(?~12k	1.0

Mass outflow of several M yr^{-1}

PG 1211+143

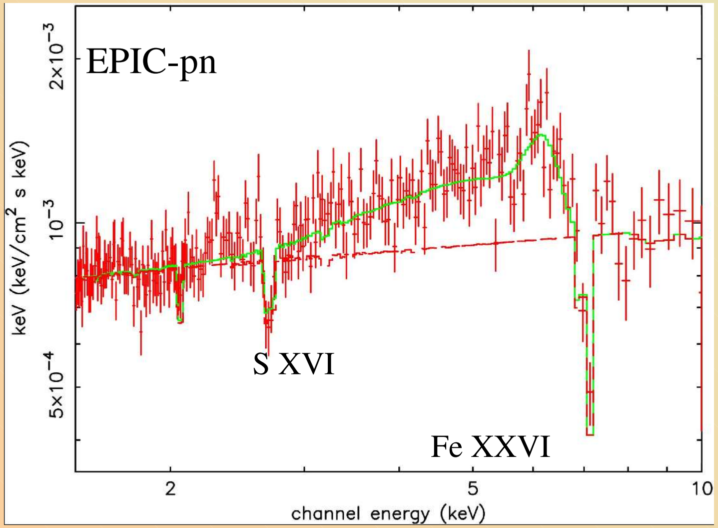
Pounds et al. (2003) analyzed ~ 60 ks XMM-Newton observation (2001-06-15) and find an ionized

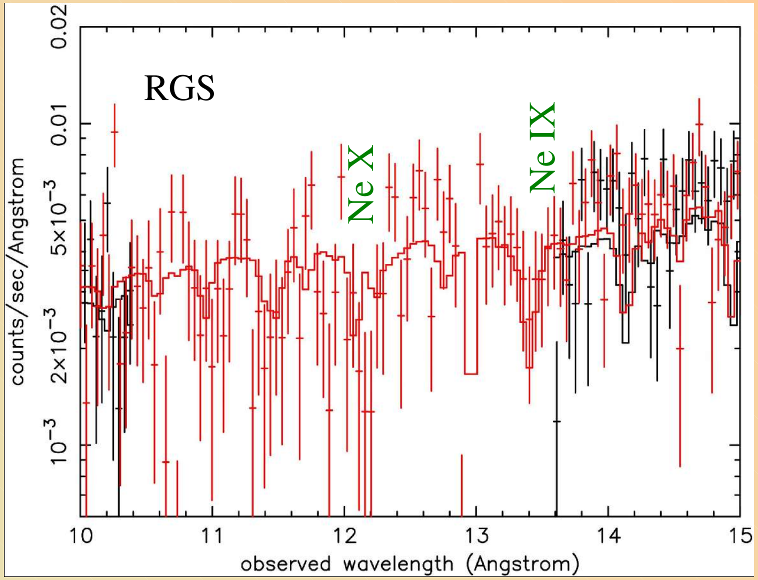
.outflow velocity of ~ 24000 km/s

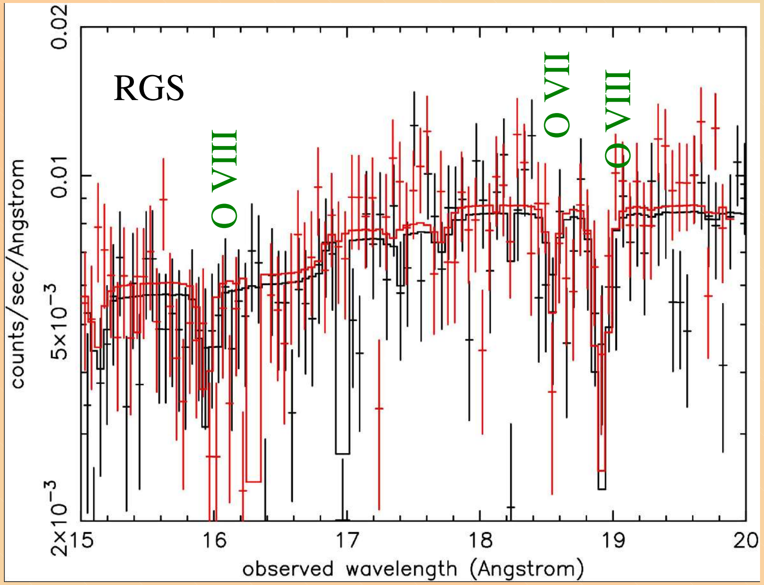
.Column density of $\sim 10^{24} cm^{-2}$

Assuming accretion at Eddington rate

.the mass outflow rate is ~3M yr[-1]

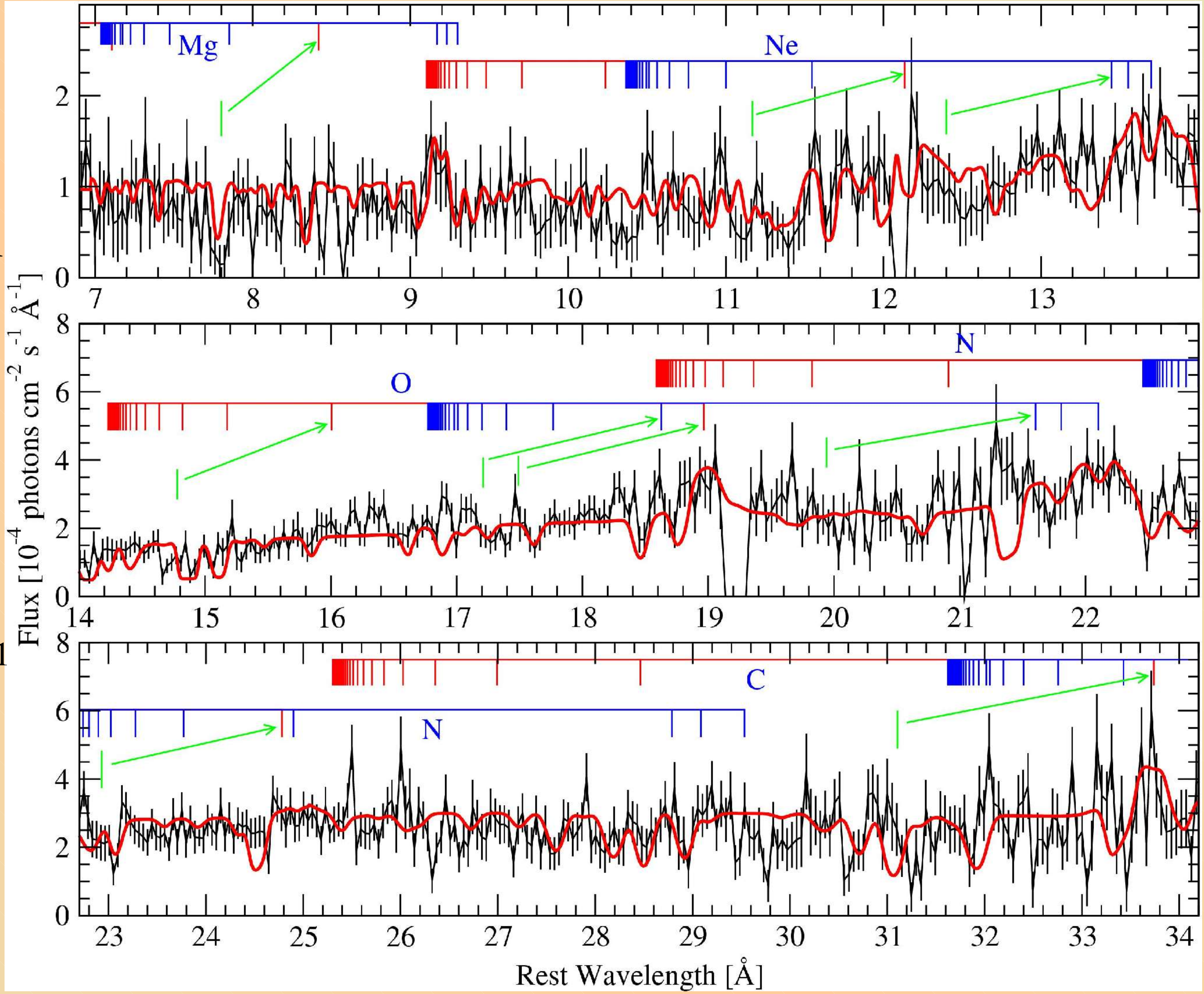






Alternative Interpretation of PG 1211+143

- RGS 1 & 2 evenly binned
- Fitting series of lines for each ion
- Absorption **and** emission lines are included
- V ~ 3,000 km/s
- Lower Column Densities 10^{21} – 10^{22} cm^{-2}
- Two orders of magnitude smaller outflow mass

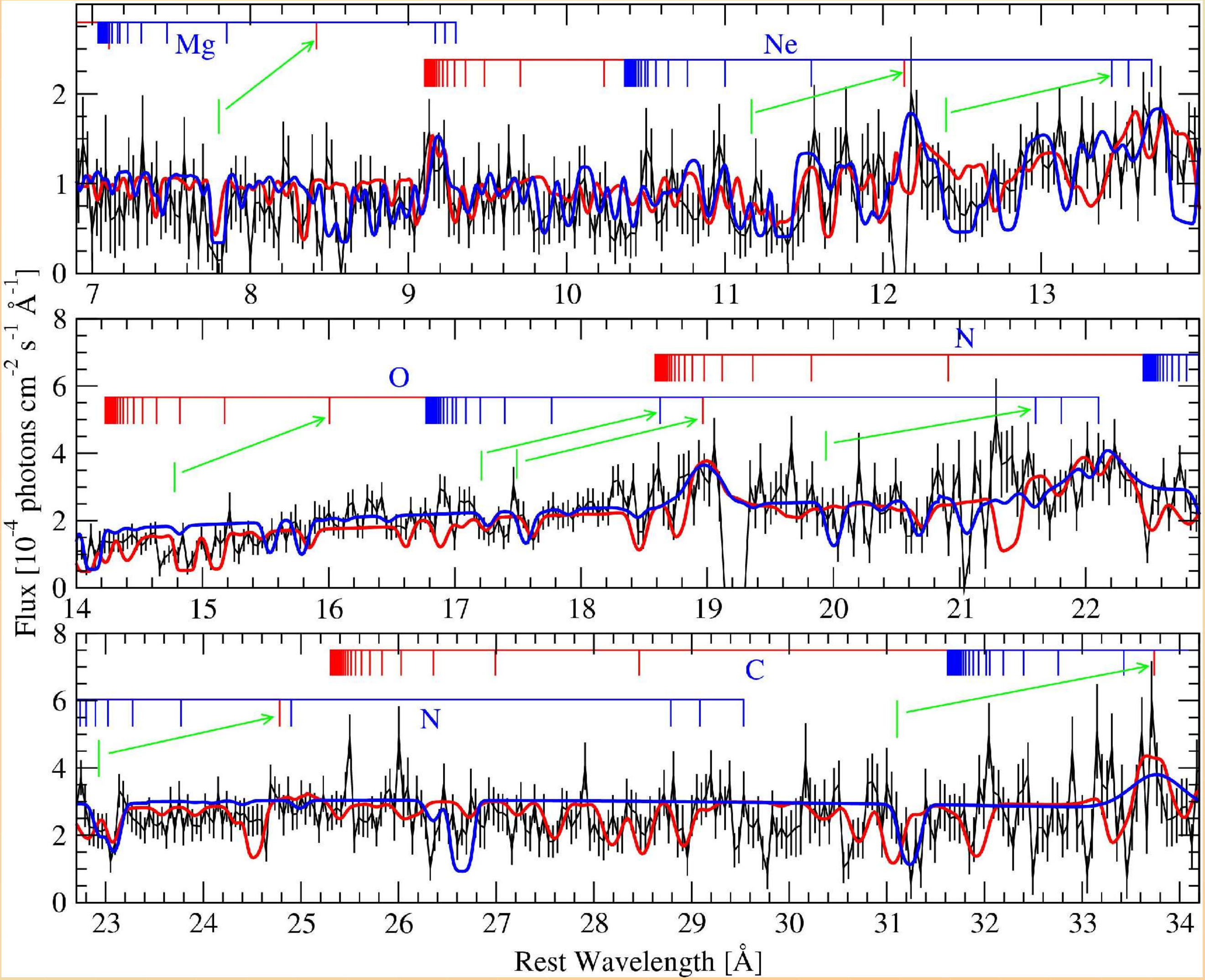


Kaspi & Behar (2006) astro-ph/0509562

Comparison with 24,000 km/s

km/s 3000

km/s 24000



Both velocities. are consistent with the data

.Though, 3000 km/s has more line identifications

Lines identified in the spectrum

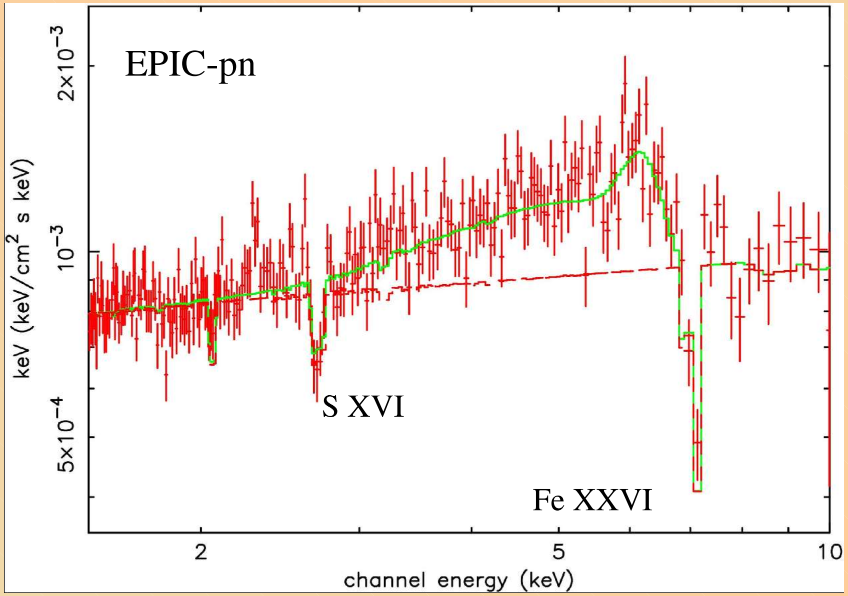
TABLE 1
IDENTIFIED ABSORPTION LINES IN THE RGS SPECTRUM

Present Work				Pounds et al. (2003a)			
λ_{source}[a] [Å]	EW [mÅ]	Line ID [Å]	Velocity [km s^{-1}]	λ_{source} [Å]	EW [mÅ]	Line ID [Å]	Velocity [km s^{-1}]
7.789 ± 0.033	127^{+35}_{-29}	Mg XI Heβ (7.851)	2400 ± 1300	7.80 ± 0.15	86 ± 34	Mg XII Lyα (8.421)	24300 ± 1000
8.316 ± 0.036	59^{+21}_{-16}	Mg XII Lyα (8.421)	3700 ± 1300			...	
9.025 ± 0.034	41^{+30}_{-14}	Mg XI Heα (9.169)[b]	...			...	
11.376 ± 0.037	185^{+57}_{-48}	blend at ~ 11.5[c]	$\sim 3230 \pm 970$	11.17 ± 0.03	50 ± 20	Ne X Lyα (12.134)	23700 ± 800
11.649 ± 0.032	54^{+54}_{-16}	blend at ~ 11.8[d]	$\sim 3840 \pm 810$			...	
		...		12.40 ± 0.05	70 ± 15	Ne IX Heα (13.447)	23400 ± 1100
14.902 ± 0.031	48^{+18}_{-11}	Fe XVII (15.014)	2240 ± 620	14.78 ± 0.07	60 ± 25	O VIII Lyβ (16.006)	23000 ± 1300
15.051 ± 0.032	32^{+13}_{-8}	blend at ~ 15.22[e]	$\sim 3330 \pm 630$			...	
17.268 ± 0.040	46^{+25}_{-14}	O VII Heδ (17.396)	2210 ± 690	17.21 ± 0.05	25 ± 10	O VII Heβ (18.627)	22900 ± 810
17.621 ± 0.035	42^{+28}_{-12}	O VII Heγ (17.768)	2480 ± 590	17.49 ± 0.03	120 ± 25	O VIII Lyα (18.969)	23400 ± 470
18.482 ± 0.032	61^{+23}_{-12}	O VII Heβ (18.627)	2335 ± 520			...	
18.706 ± 0.035	47^{+23}_{-11}	O VIII Lyα (18.969)	4160 ± 550			...	
		...		19.94 ± 0.05	60 ± 15	O VII Heα (21.602)	23100 ± 700
22.488 ± 0.032	40^{+17}_{-9}	O IV Kα (22.729, 22.777)	3490 ± 420			...	
23.052 ± 0.032	66^{+19}_{-15}	O II Kα (23.302, 23.301, 23.3)	3200 ± 410	22.93 ± 0.03	50 ± 10	N VII Lyα (24.781)	22400 ± 360
27.574 ± 0.037	62^{+35}_{-15}	Ar XI (27.846, 27.881)	3260 ± 400			...	
28.528 ± 0.049	91^{+63}_{-27}	N VI (28.780)	2630 ± 510			...	
28.948 ± 0.036	115^{+61}_{-27}	Ar XIII (29.209)	2680 ± 370			...	
30.626 ± 0.037	139^{+30}_{-25}	Si XII (31.018, 31.027)[f]	$\sim 3830 \pm 360$			...	
31.273 ± 0.036	162^{+62}_{-37}	Ar XII (31.374)[g]	...	31.10 ± 0.03	90 ± 25	C VI Lyα (33.736)	23300 ± 270
33.461 ± 0.036	82^{+33}_{-24}	C VI Lyα (33.736)	2450 ± 320			...	

[a] Measured wavelength at the rest-frame of the source.
[b] Blend with emission line which partially fills the trough.
[c] Blend of Fe XXII (11.427, 11.495), Fe XXIII (11.326, 11.319, 11.315, 11.423) and Ne IX (11.547) Heβ.
[d] Blend of Fe XXII (11.78) and Fe XXI (11.825).
[e] Blend of O VIII Lyγ (15.176) and Fe XVII (15.261).
[f] Blend with an unidentified line.
[g] Not a certain identification.

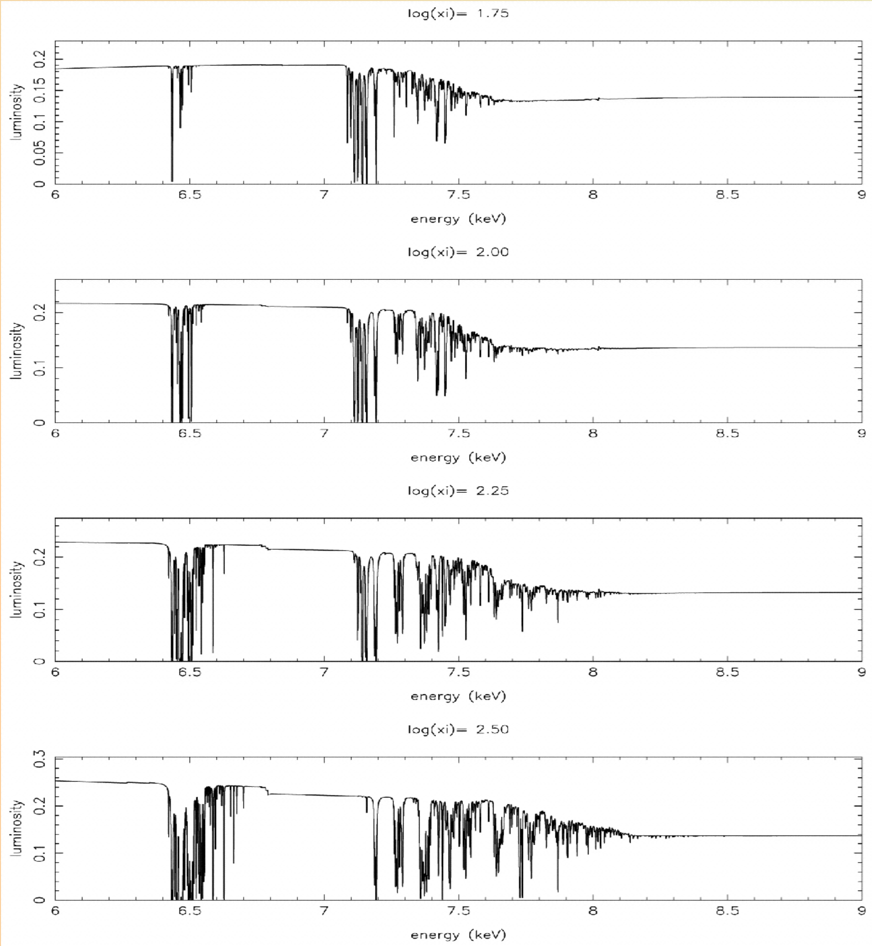
Kaspi & Behar (2006) astro-ph/0509562

Absorption at > 6.4 keV



)Pounds et al. (2003

Feature at 7 keV (rest frame 7.6 keV) traditionally identified as Fe XXVI Lyα



Could be absorption from a different ion!

)Kallman et al. (2004

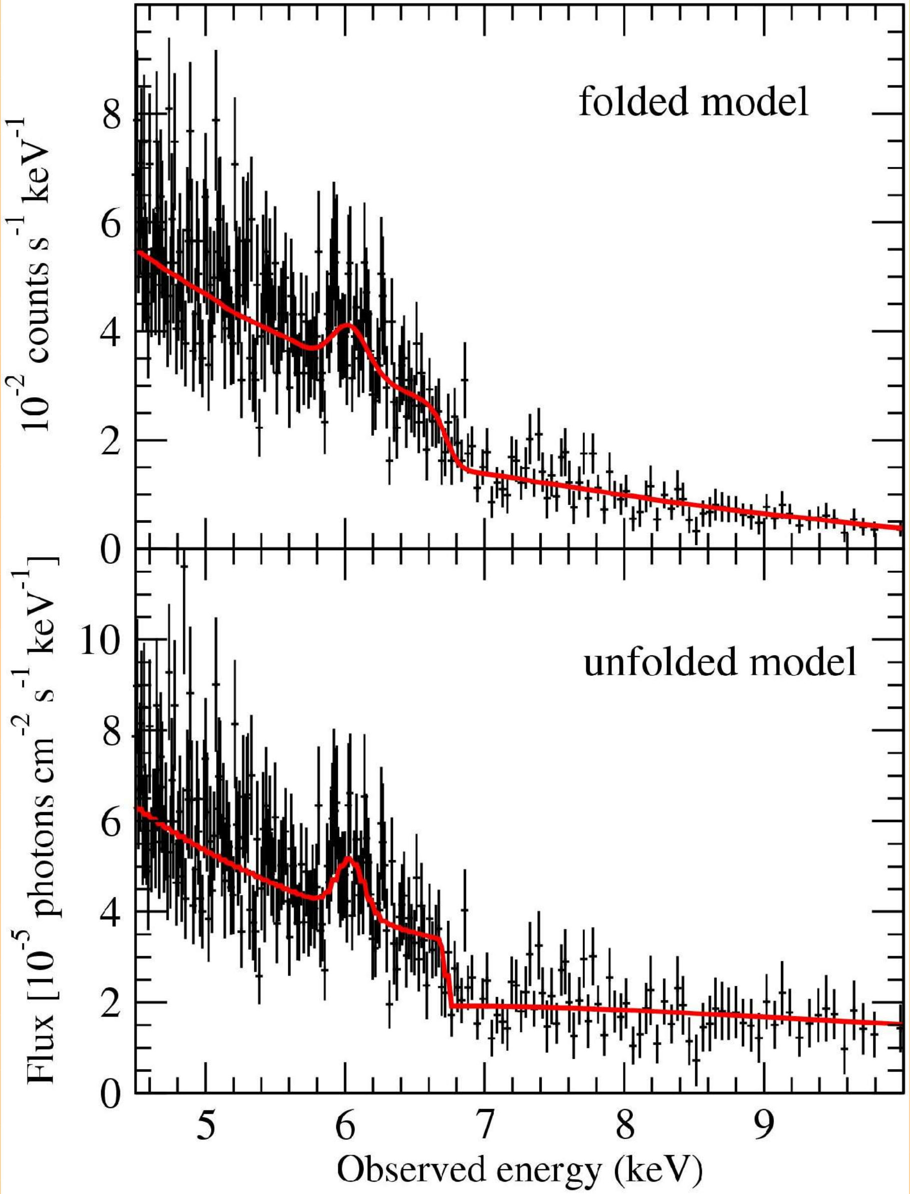
Complex absorption of Fe XVII to Fe XXIII

?Absorption at > 6.4 keV: a line or an edge

The Epic-pn data can be fitted with an edge model with rest frame energy of 7.27 ± 0.11 keV and^2 = 0.983

Corresponds to an edge of .Fe IV to Fe X

Epic background suffers from fluorescence emission lines .at ¿ 7 keV



…Summary so far

- PG1211+143 high resolution X-ray spectrum can be fitted with a velocity outflow of 3000 km/s.
- The approach we used is of globally fitting each ion with a column density fitted to all its lines.
- Model also includes several broad (FWHM=6000 km/s) emission lines.
- Broad and flat ionization distribution is found throughout the outflow consistent with hydrogen column of $10^{21} - 10^{22}$ cm^{-2}.
- At high energies an edge of Fe IV to Fe X is consistent with the data.

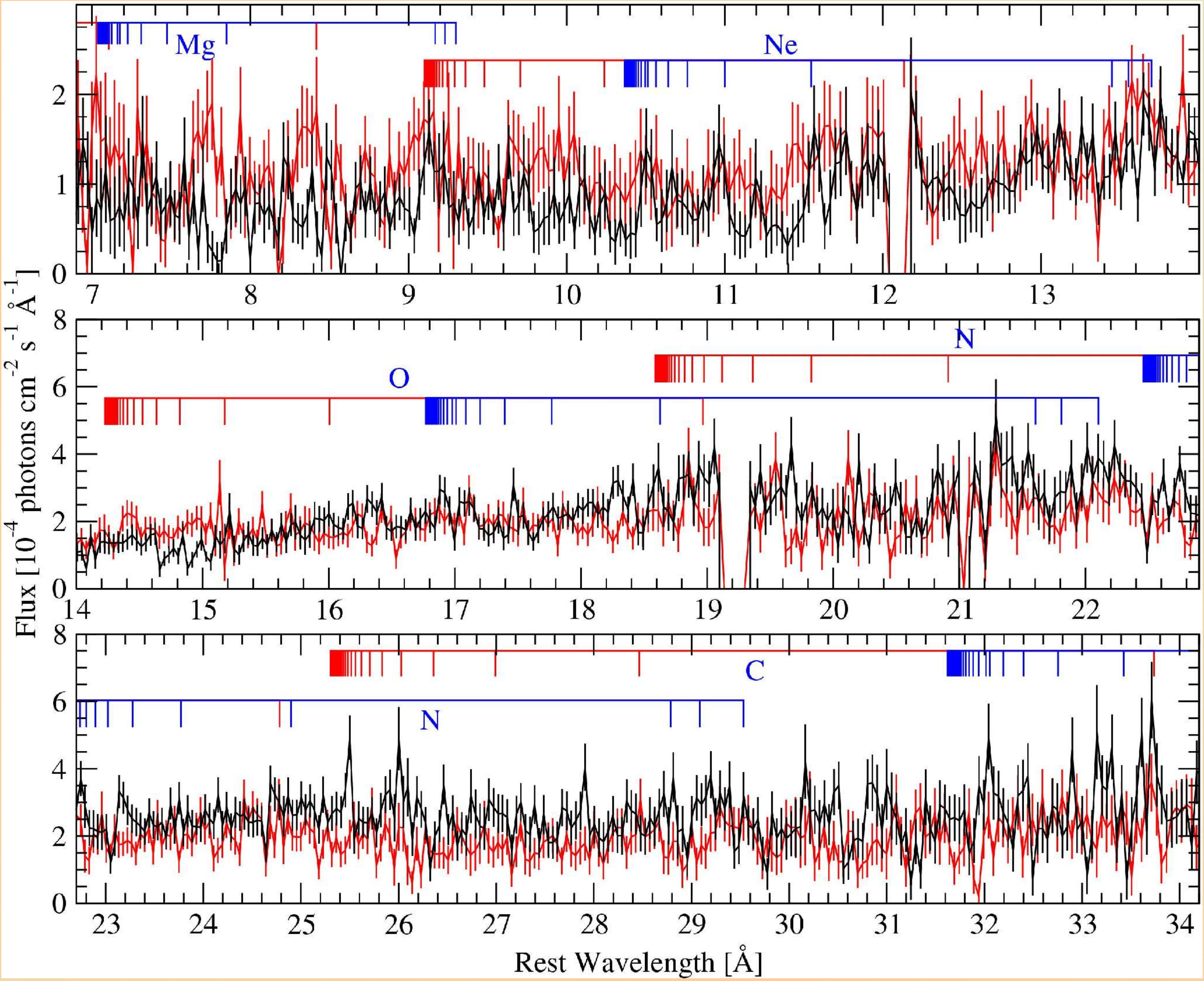
Kaspi & Behar (2006) astro-ph/0509562

Two RGS observations

2001-06-15

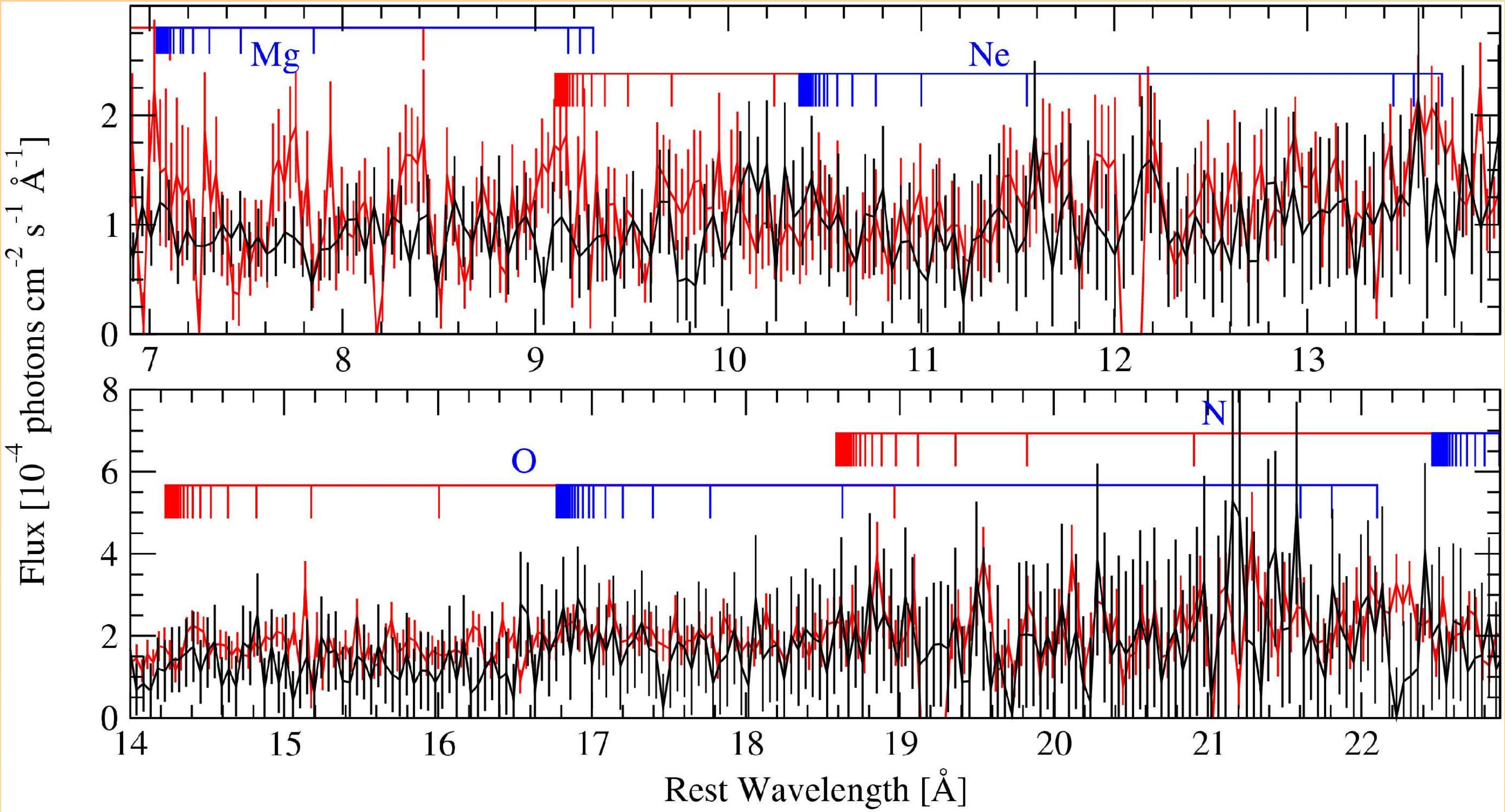
2004-06-21

Spectra are generally ,consistent but a bit different slope and some different .details



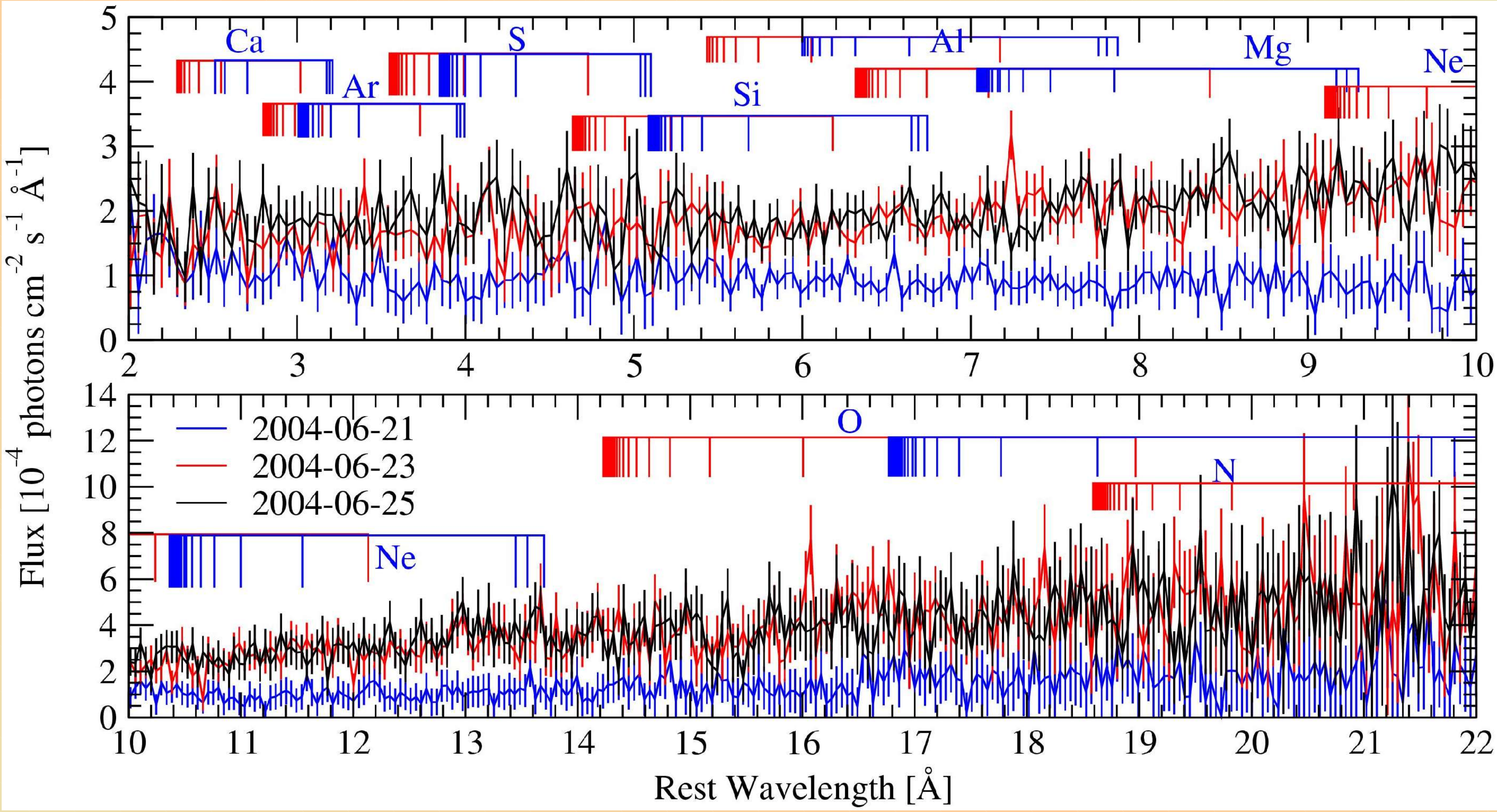
⇒ Object varied in timeor a result of the poor S/N

SimultaneousXMM-Newton and Chandra



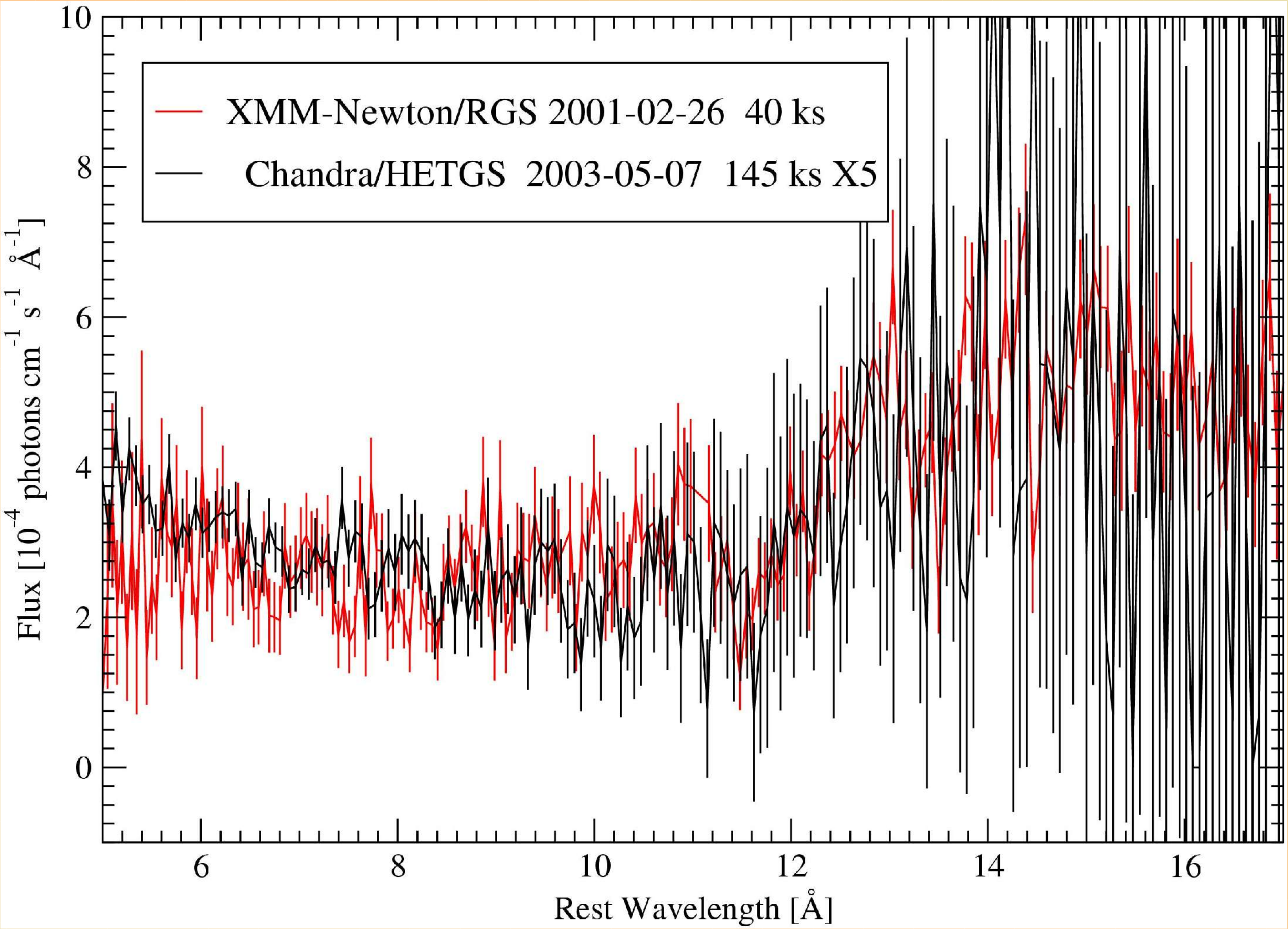
Xmm-Newton/RGS and Chandra/LETGS spectra are consistent overall,**but** – differ in many details .probably a consequence of the poor S/N

Three Chandra/LETGS observations



PG 1211+143 doubled its luminosity in two days. Narrow .line features does not reproduce in the different spectra

The Variable PDS 456



Reeves et al. (2003) find iron L-shell lines outflow at 50000 km/s .In Chandra observation 2 years later the object is in a low state

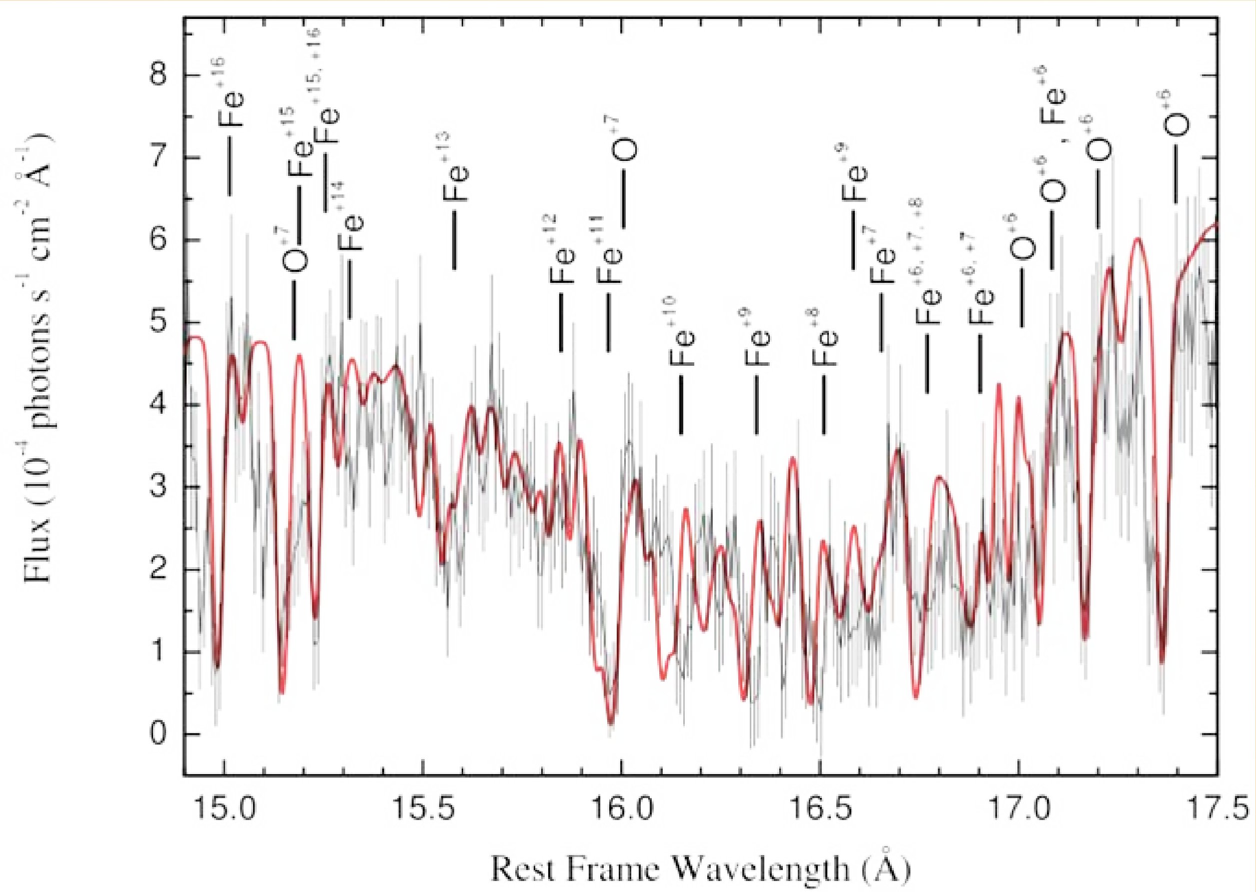
NGC3783: Second Look at the UTA

NGC 3783 has distinct
.Fe-M UTA feature

ks HETGS 900
observation provides
.excellent S/N

Low turbulent velocity
km/s) makes the 300 <(
individual UTA's
.clearly resolve

v_{out} ~ 590 km/s
outflow including
robust oxygen
.column densities



Discrepancies are found .) (Holczer, Behar & Kaspi, 2005 ApJ, astro-ph/0507027

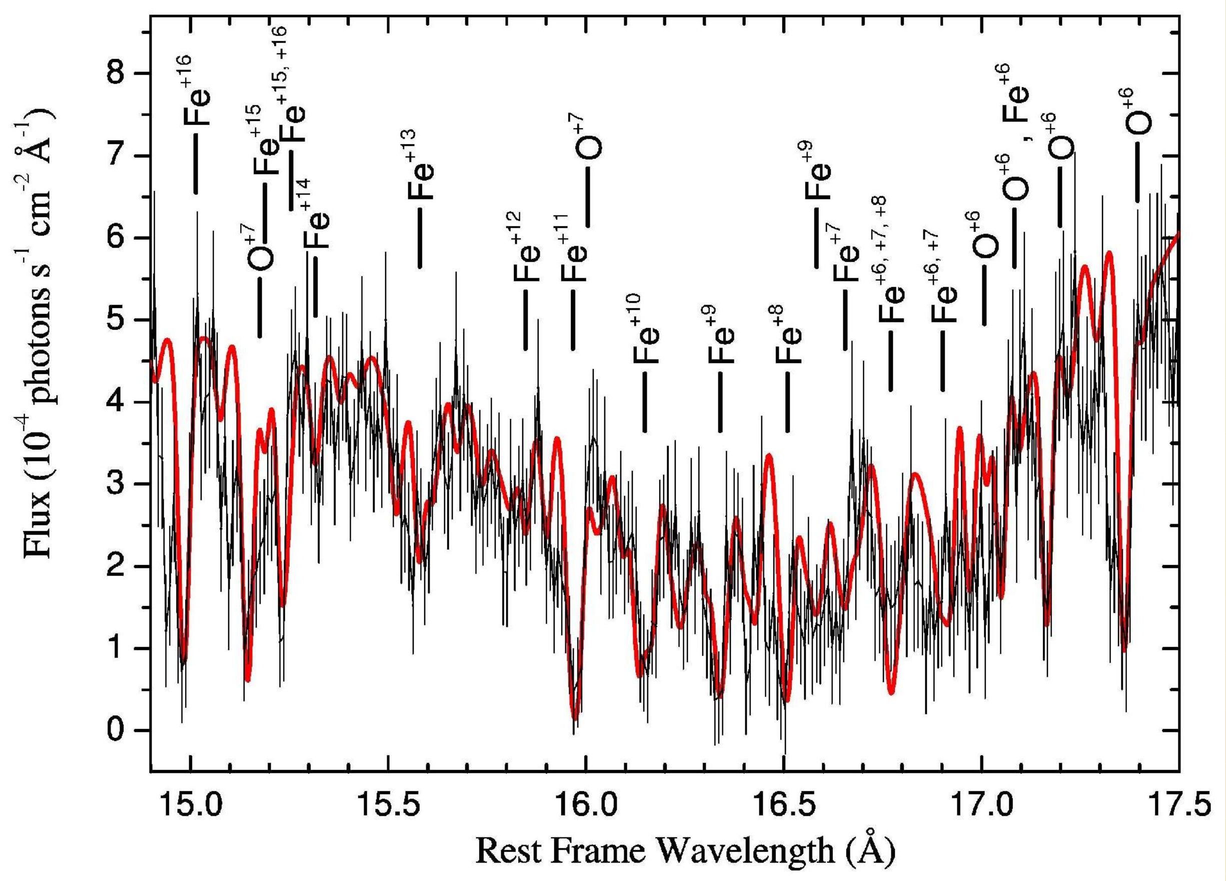
?Stationary Fe M-shell UTA in NGC3783

All lines at 590 km/s

UTA at 0 km/s

But

Might be problems
With atomic data



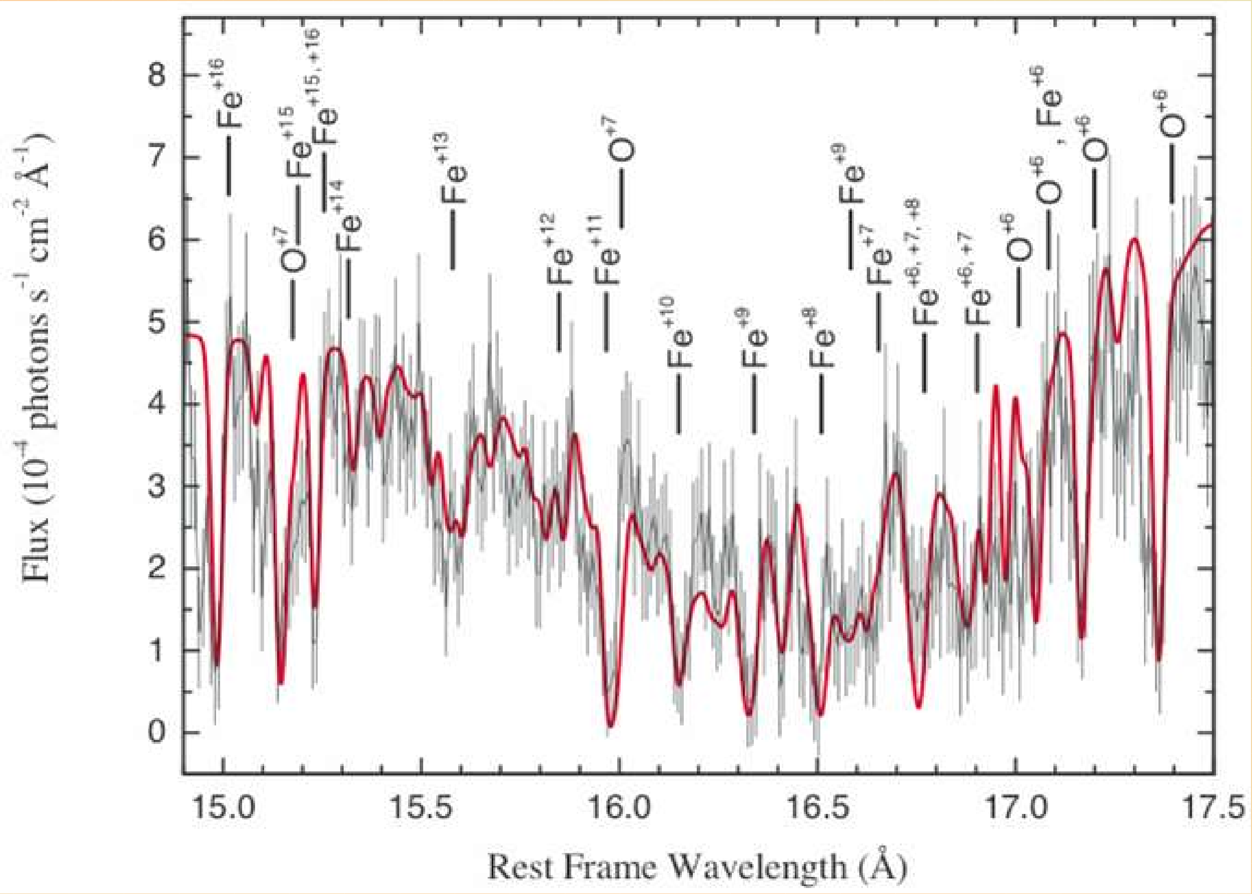
) Holczer, Behar & Kaspi, 2005 ApJ, astro-ph/0507027(

Re-calculating Line Wavelengths

Many-Body Perturbation Theory (MBPT) calculations by Ming Feng Gu

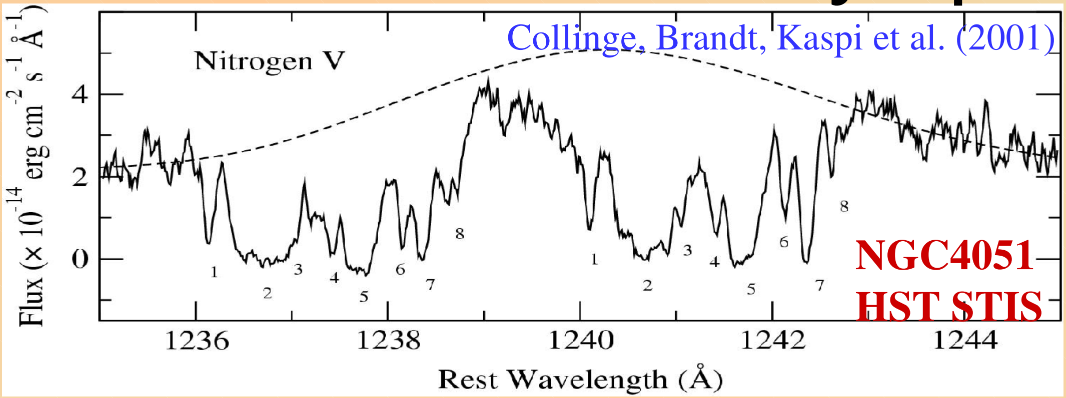
(in preparation)

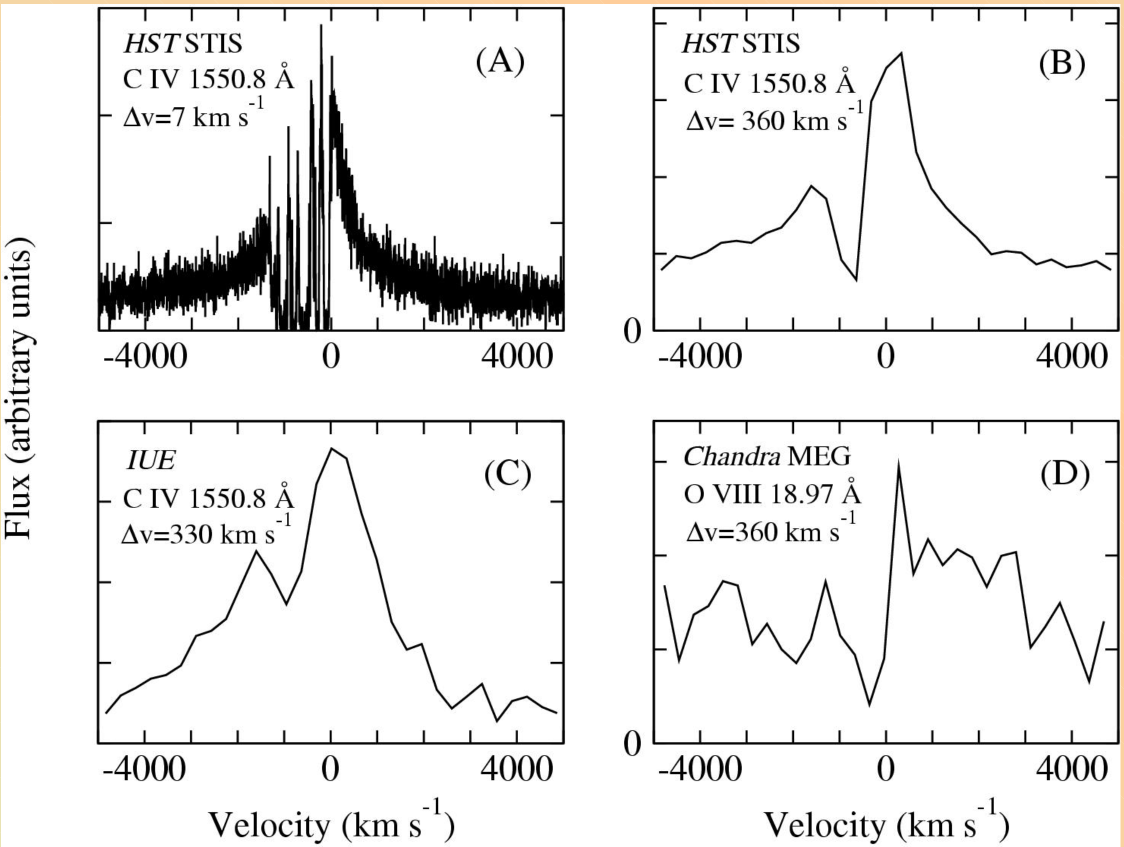
=> uniform 590 km/s



⇒ Need for better atomic data

Need for better X-ray spectral resolution





Unresolved Substructure in the X-ray lines?

'Thermal limit X-ray spectroscopy' (Elvis 2001).

Need ~ 100 km/s or better to resolve the X-ray lines.

Chandra and XMM are "IUE age" not "HST age"

…Summary

• Outflows in AGNs are a common phenomenon (~70% of objects) and seem to be significant in terms of mass loss rate.

• Outflows provide key results about AGNs' central regions, e.g.:

Dynamics: outflows velocities of few 100 km/s in multiple components.

Range of ionization parameters U_{Oxygen} ~ 0.01 to 1 (degeneracy of location and density).

Column density ~ 10^{21-23} cm^{-2}.

• Normal outflows are insignificant in terms of energy.

• High-velocity mass outflow are potentially energetically significant but are still in debate.

Summary and Conclusions…

• To the best of our understanding, a 3,000 km/s model fits the PG1211+143 data better than a 24,000 km/s model.

• In all fairness, the data can tolerate more than one interpretation.

• Admittedly, S/N of data is marginal.

• Features that appear in one data set disappear thereafter (or even in simultaneous observations?) and average out with integration.

• Data call for extra caution and careful modeling.

• If discrete features are real, they vary on short time scales.

• With the loss of Astro-E2, a very long observation of a good bright source with Chandra or XMM-Newton gratings remains as the most viable approach towards a verdict on the high velocity outflows.

• Since continuum sources vary rapidly, X-ray monitoring for triggering grating observations is recommended.