
AGN Outflows
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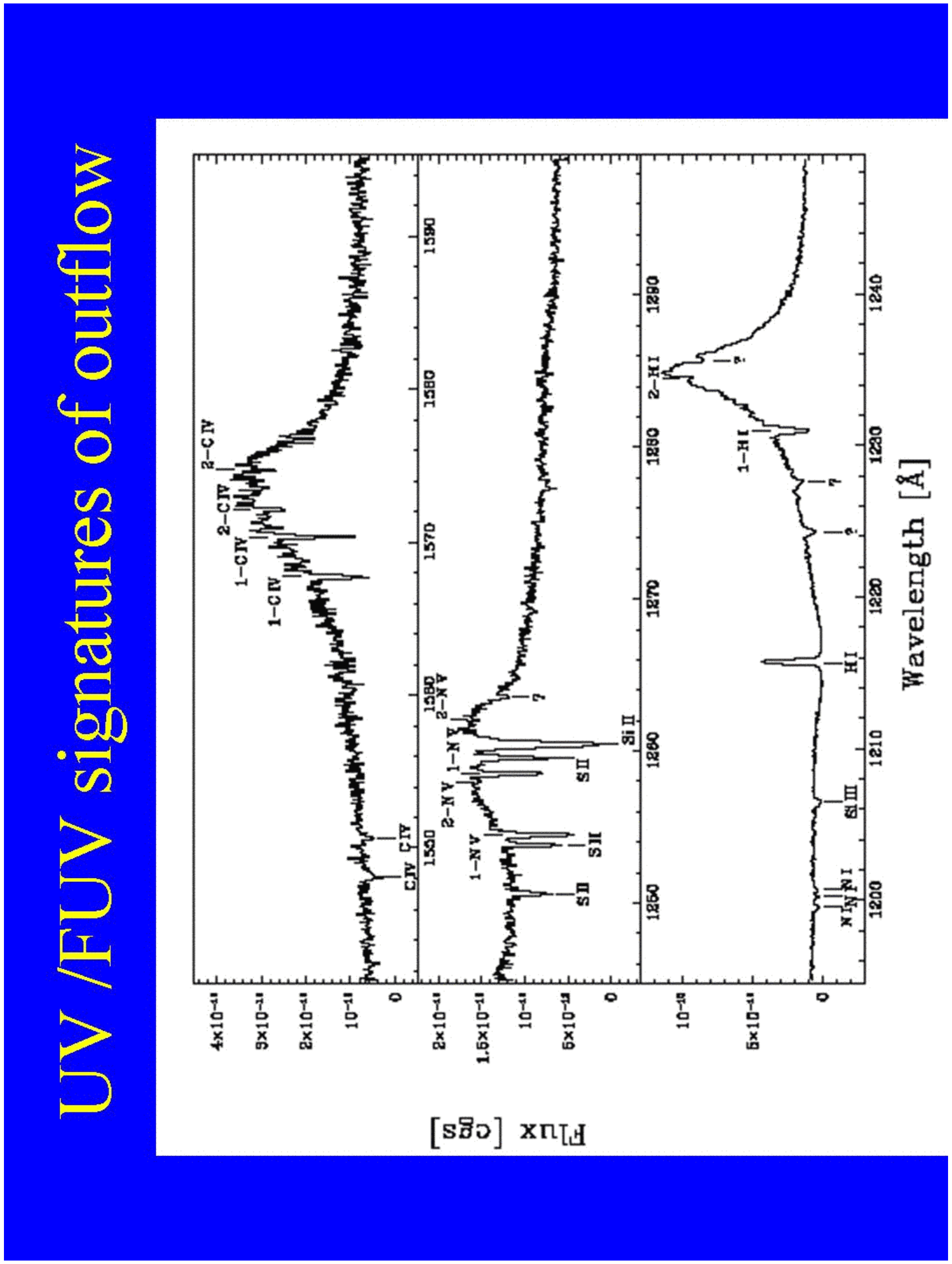
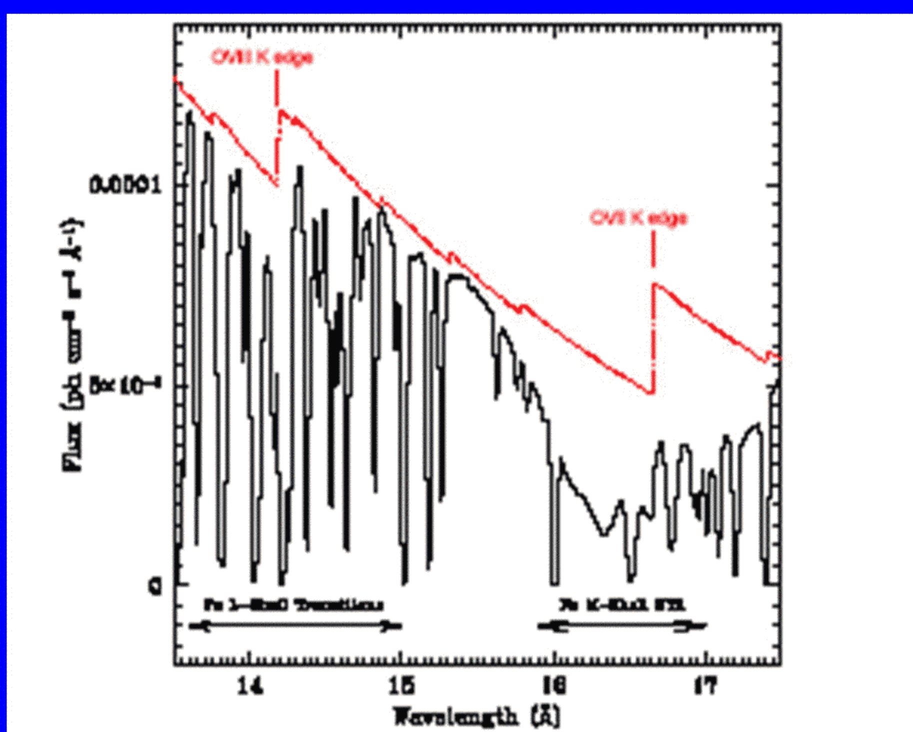

UV /FUV signatures of outflow
Flux [cgs]
Wavelength [Å]

AGN outflows: Why now?

- Newly recognized as semi-universal
- Dynamically important $m_{dot} >\sim m_{dot}$ (acc)
- Pulls together *all* atomic absorption features in AGNs?
- → physical quantities
- Qualitative advance in undertsanding AGNs

X-ray signatures of outflow



'Warm Absorbers'

- OVII, OVIII edges in ROSAT, ASCA → highly ionized gas (U~ 1)
- Photoionized
- UV absorbers blueshifted → outflow
- Chandra & XMM: 1000 km/s outflow (as predicted by Mathur et al. models)
- *WA have potential to deliver much physics*

Fully characterized plasma

- Density n: recombination/ionization time lag to continuum changes
- Radial distance r: n, ionization parameter, L
- Size δr: N, n
- Temperature T: amplitude of response to continuum change
- Pressure P: n, T
- Mass outflow rate m_{dot} : n, velocity v

Mathur et al. 1995---2001

Warm Absorber Parameters

So far only a few examples of variability:

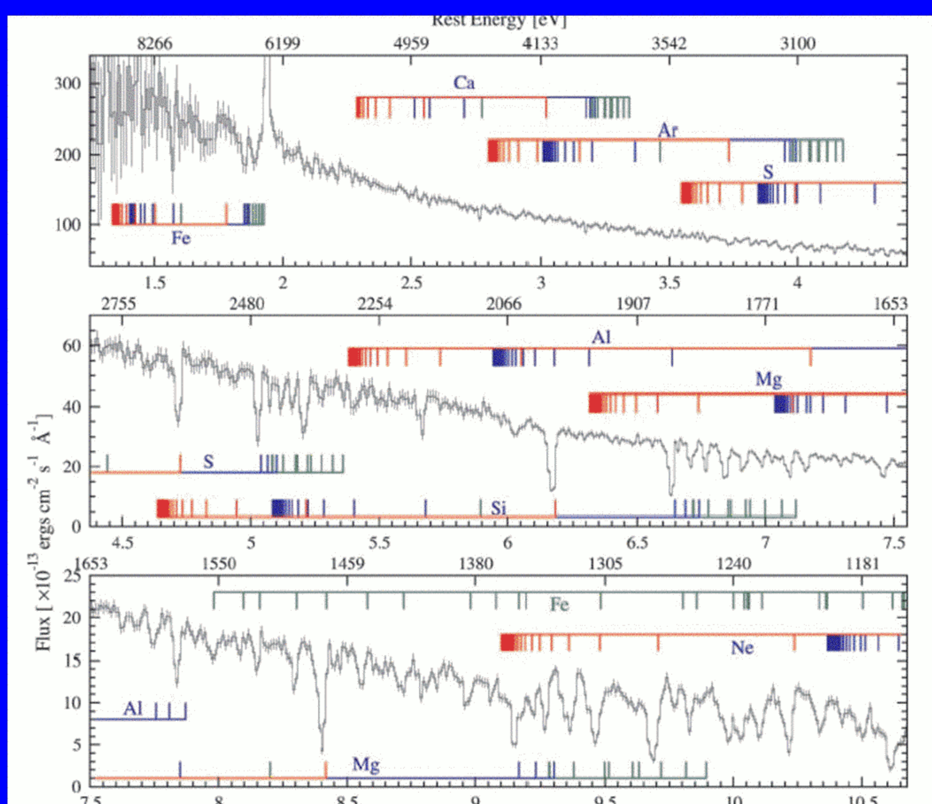
. NGC5548, NGC4051, NGC3516

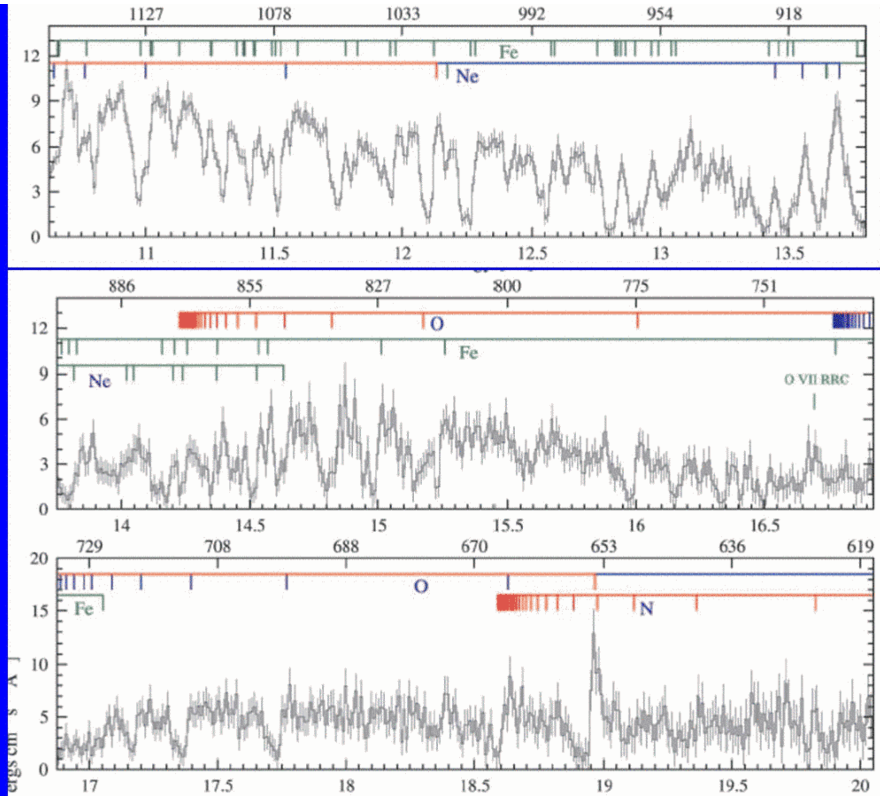
n~10^8 cm, T~ 10^4 K, r~ 10^{16} cm, δr~ 10^{15-16} cm

Suggestive of P(WA) ~ P(BELR) Kaastra etal 1995

- Large statistical uncertainties
- Systematic errors from simple physics
- *May not be the case…*

Warm Absorbers: Chandra Era





Chandra HETG 900 ksec spectrum of NGC 3783

Warm Absorbers: complicated solutions

- 2 physically separate absorbers Otani et al. 1996
- 2 or more absorbers with arbitrary parameters
- Relativistic lines Branduardi-Raymont et al. 2001
- Dust Lee et al. 2001
- High Fe abundance (> 10 x solar) Blustin et al. 2002
- Large outflow velocities McKerman et al. 2003
- Continuum range of U Krolik & Kriss 2001
- **NO easy physics *if* many many-component solutions**

Warm Absorbers: a simple solution

Our approach: build a complete model first

PHASE

photoionized **a**bsorber **s**pectral **e**ngine

Krongold et al. 2004

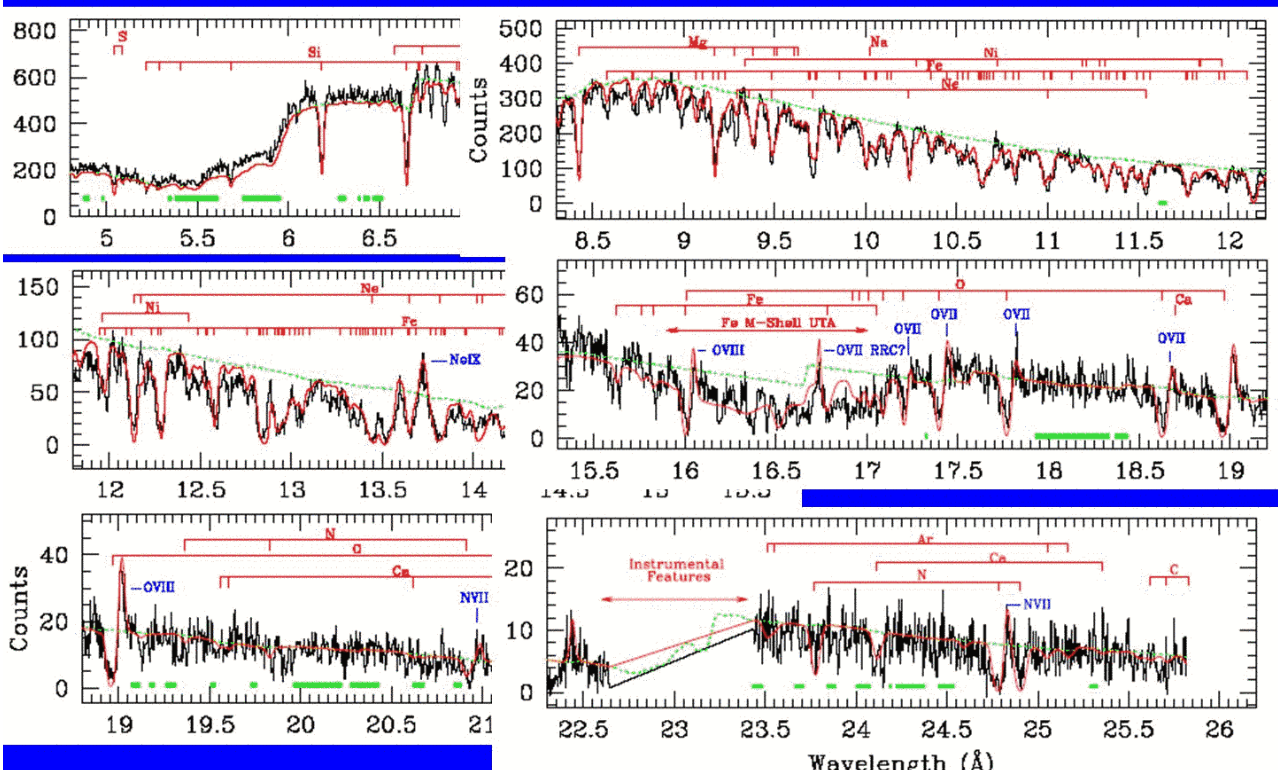
Includes:

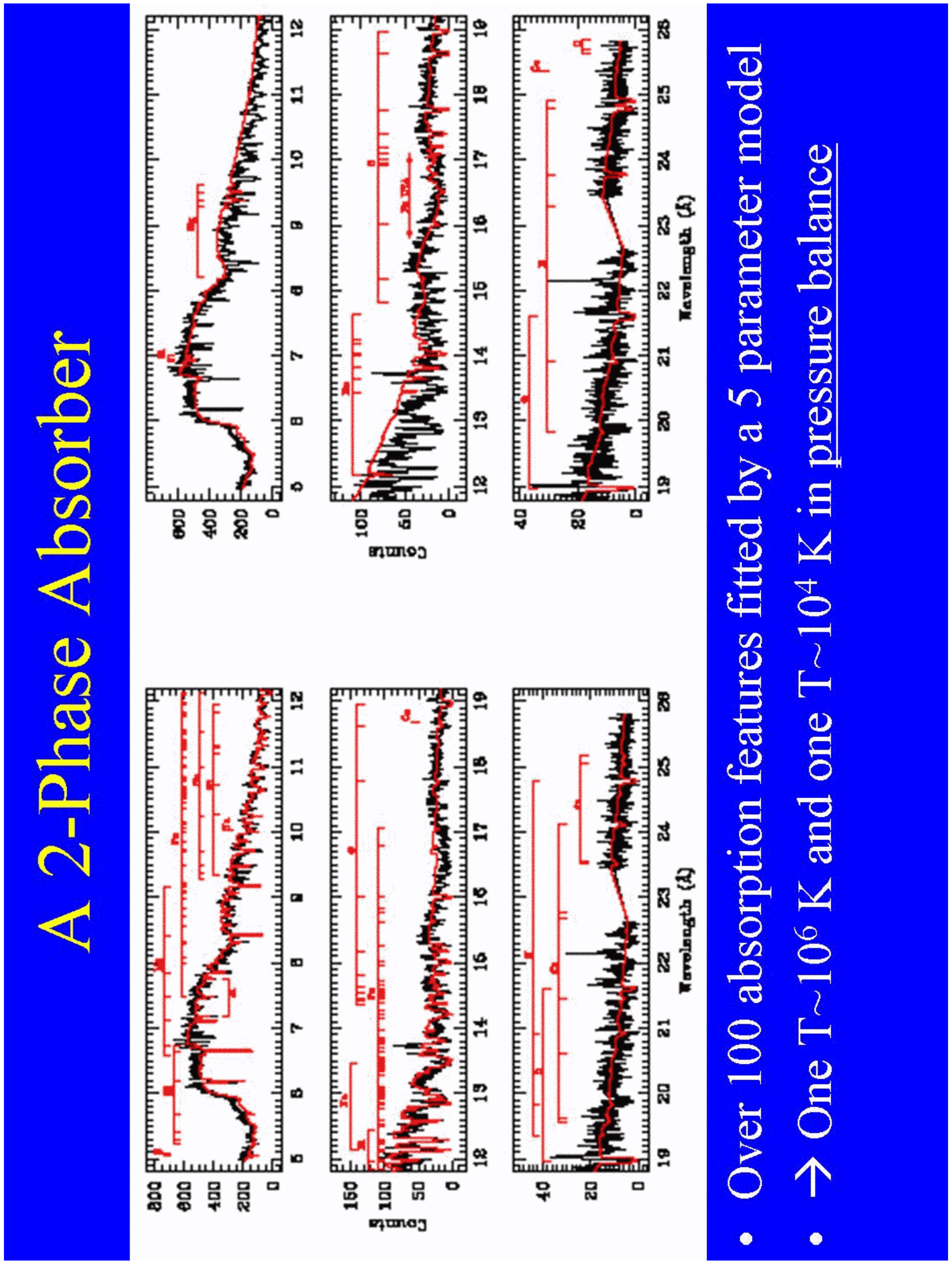
- ATOMDB atomic database
- UTA approximation
- Voigt line profiles

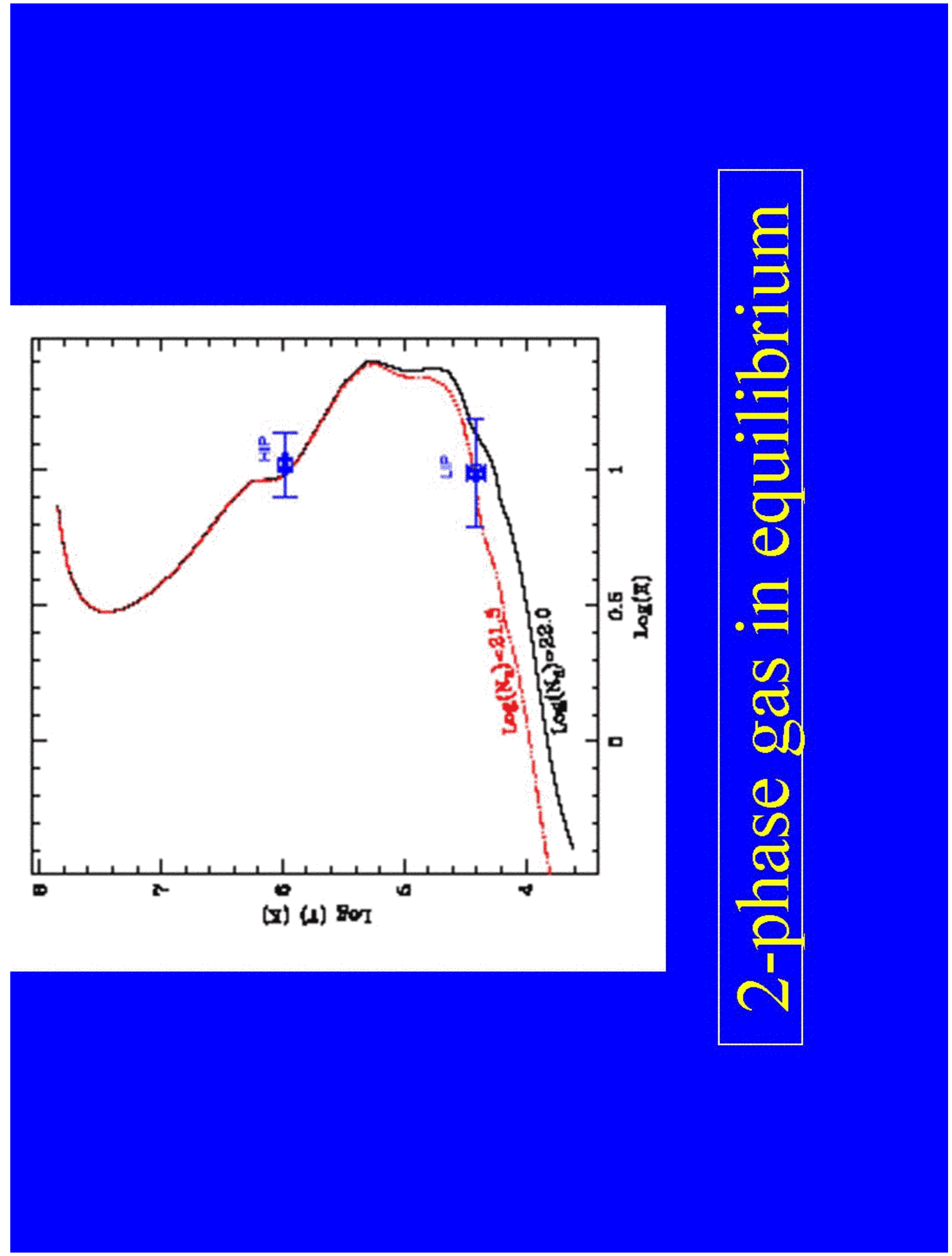
Approach:

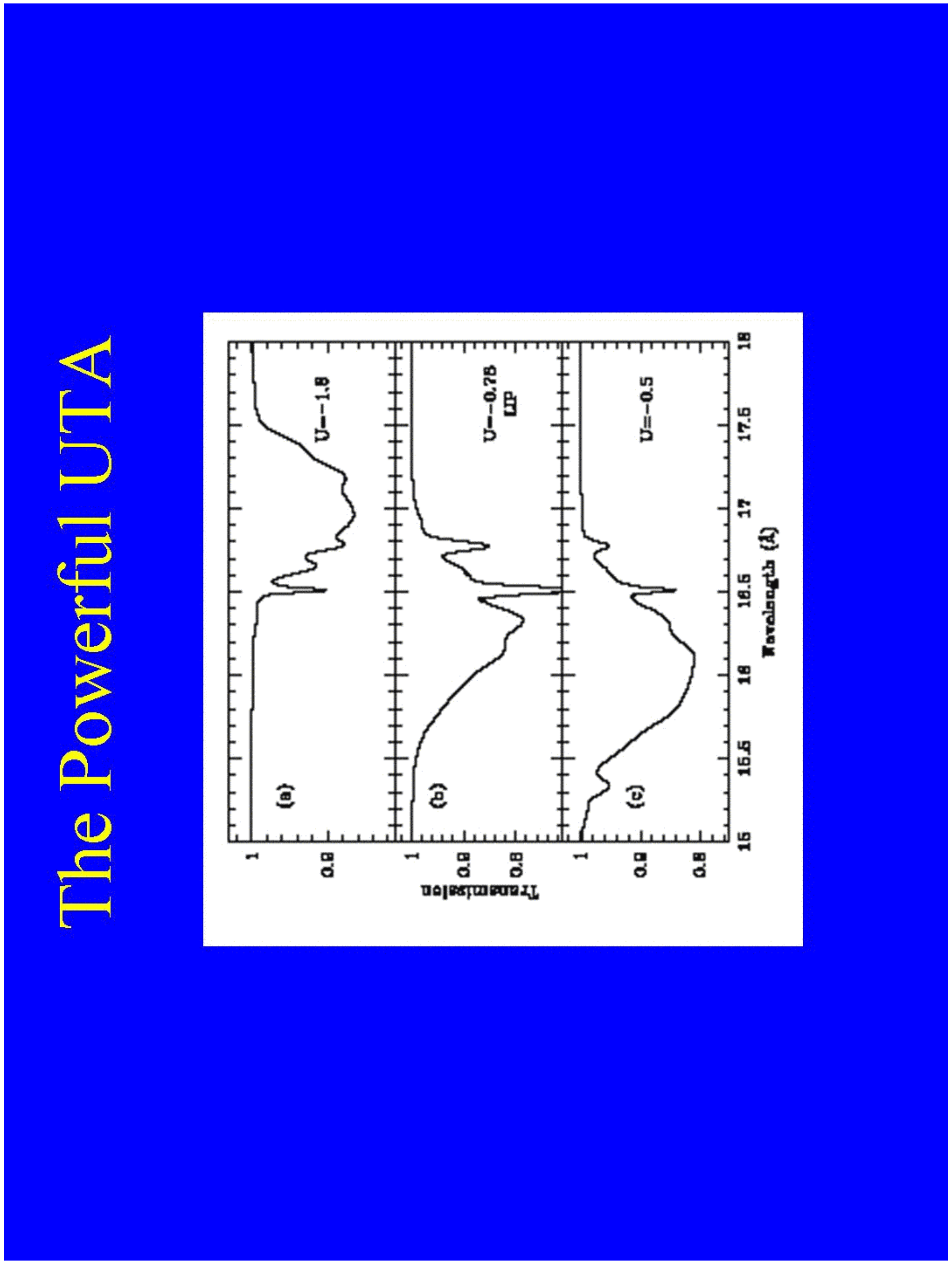
- Global fit
- Allows for emission/absorption mutual cancellation
- Minimum free parameters

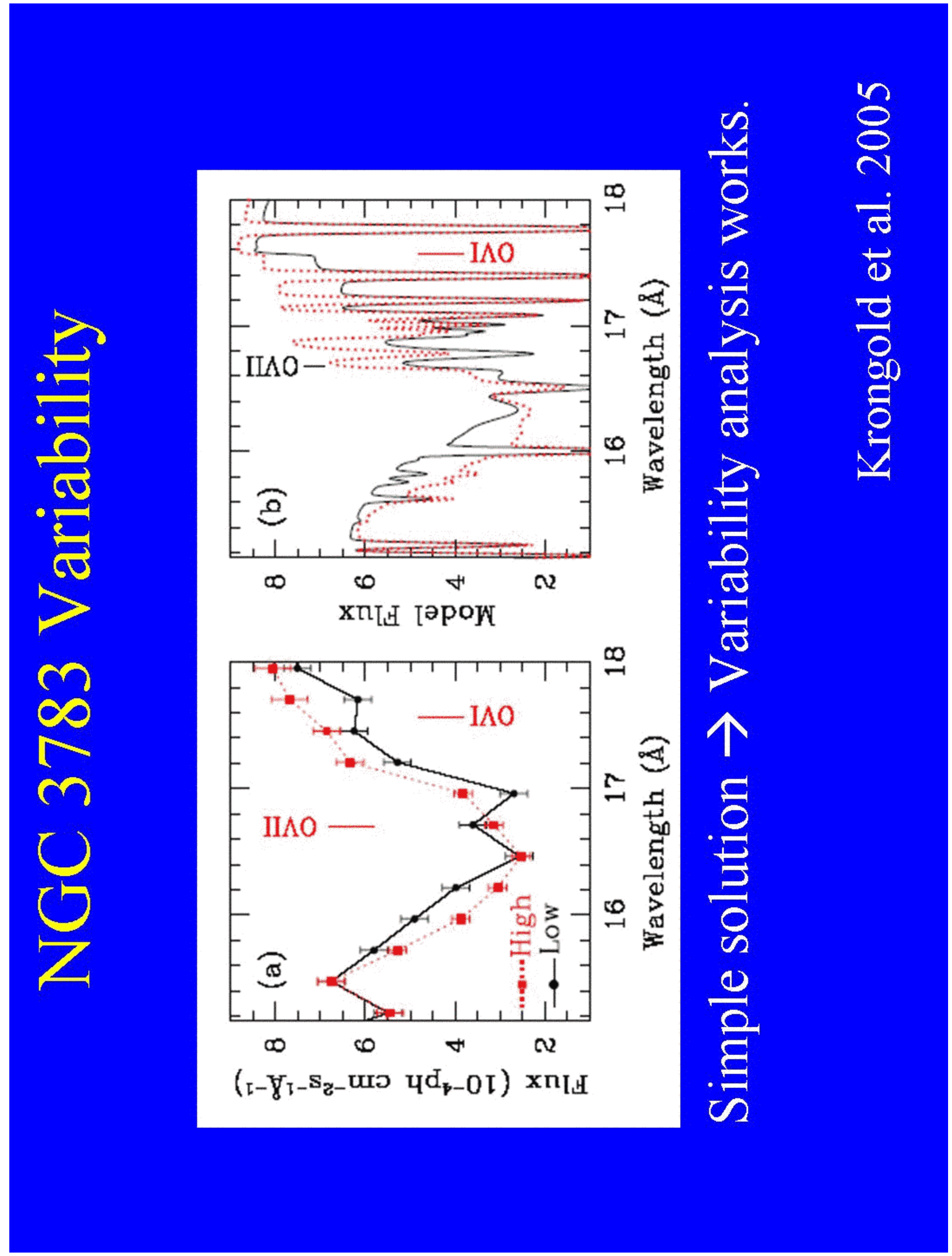
Chandra HETG Spectrum of NGC 3783

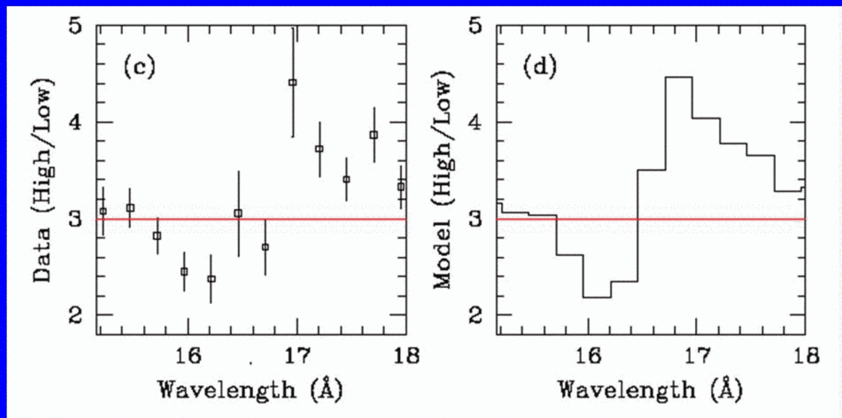



A 2-Phase Absorber
Counts
Wavelength (Å)
• Over 100 absorption features fitted by a 5 parameter model
• → One T~10^6 K and one T~10^4 K in pressure balance


Log (T) (K)
Log(Ξ)
HP
LP
Log(N_H)=21.5
Log(N_H)=22.0
2-phase gas in equilibrium


The Powerful UTA
(a)
(b)
(c)
Transmission
Wavelength (Å)


NGC 3783 Variability
(a)
(b)
OVII
OVI
High
Low
Flux (10^-4 ph cm^-2 s^-1 Å^-1)
Model Flux
Wavelength (Å)
Simple solution → Variability analysis works.
Krongold et al. 2005

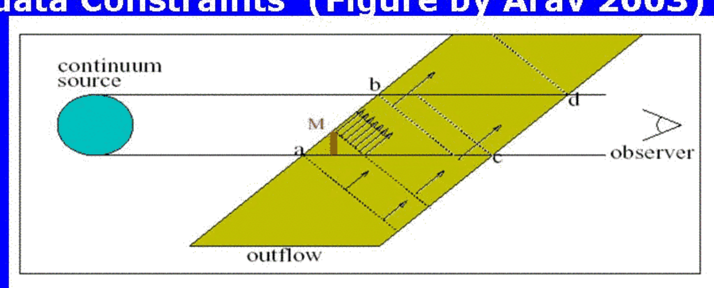


- The UTA opacity variation observed at 10σ
- → $n > 10^4\ cm^{-3}$ → $d < 6$ pc
- Suggestive of heavily clumped gas
- *Continuous range of ionization parameter* *ruled out* (Ogle et al 2004)

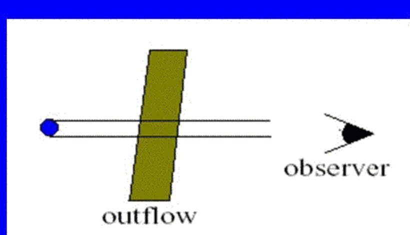
Constraining the Geometry

UV data Constraints (Figure by Arav 2003)

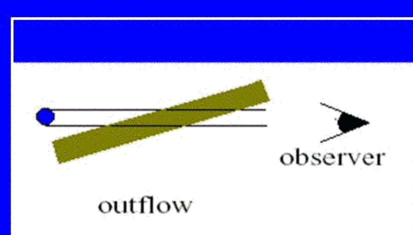
Transverse Flow



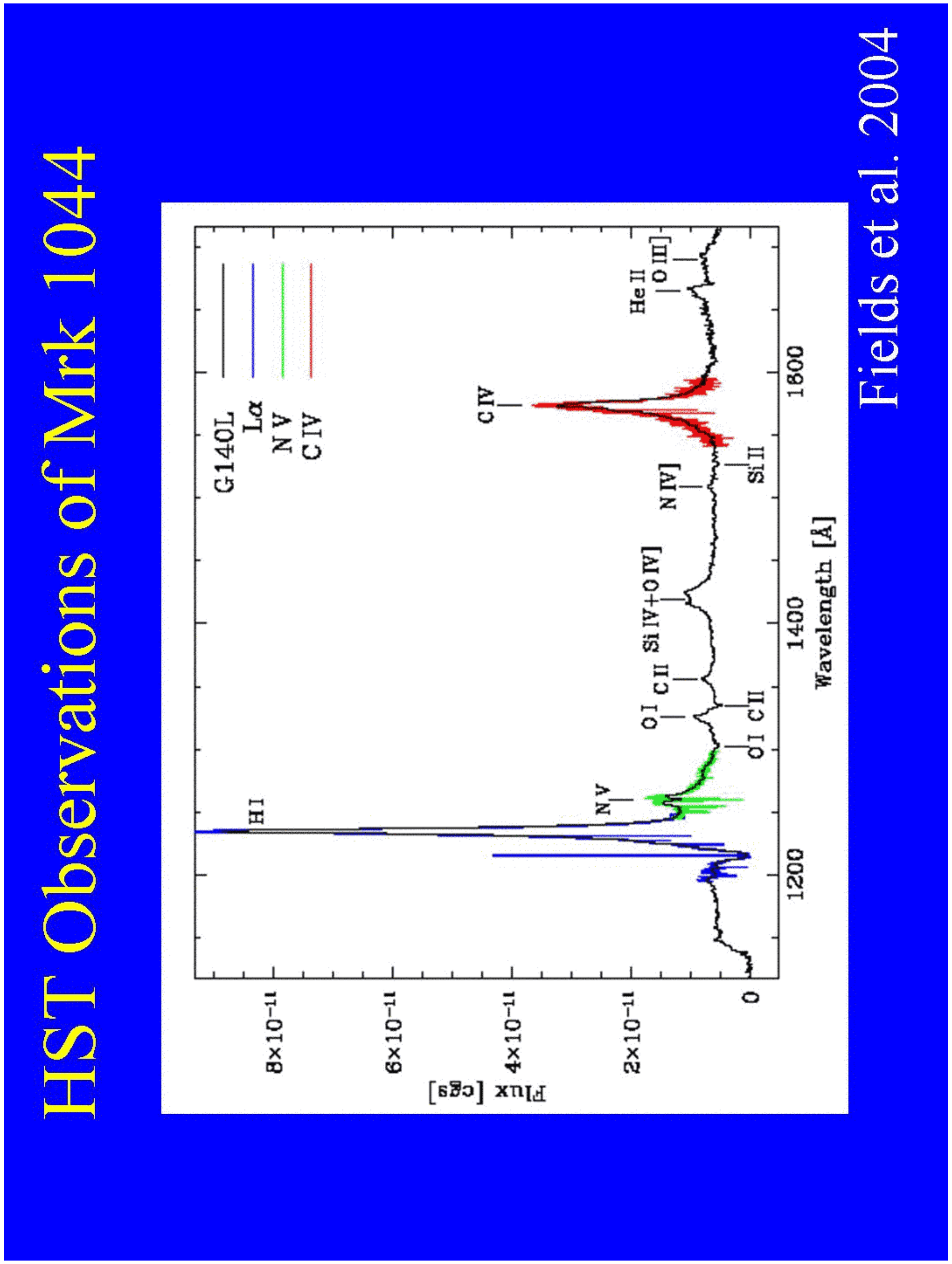
UV widths >> X-ray widths

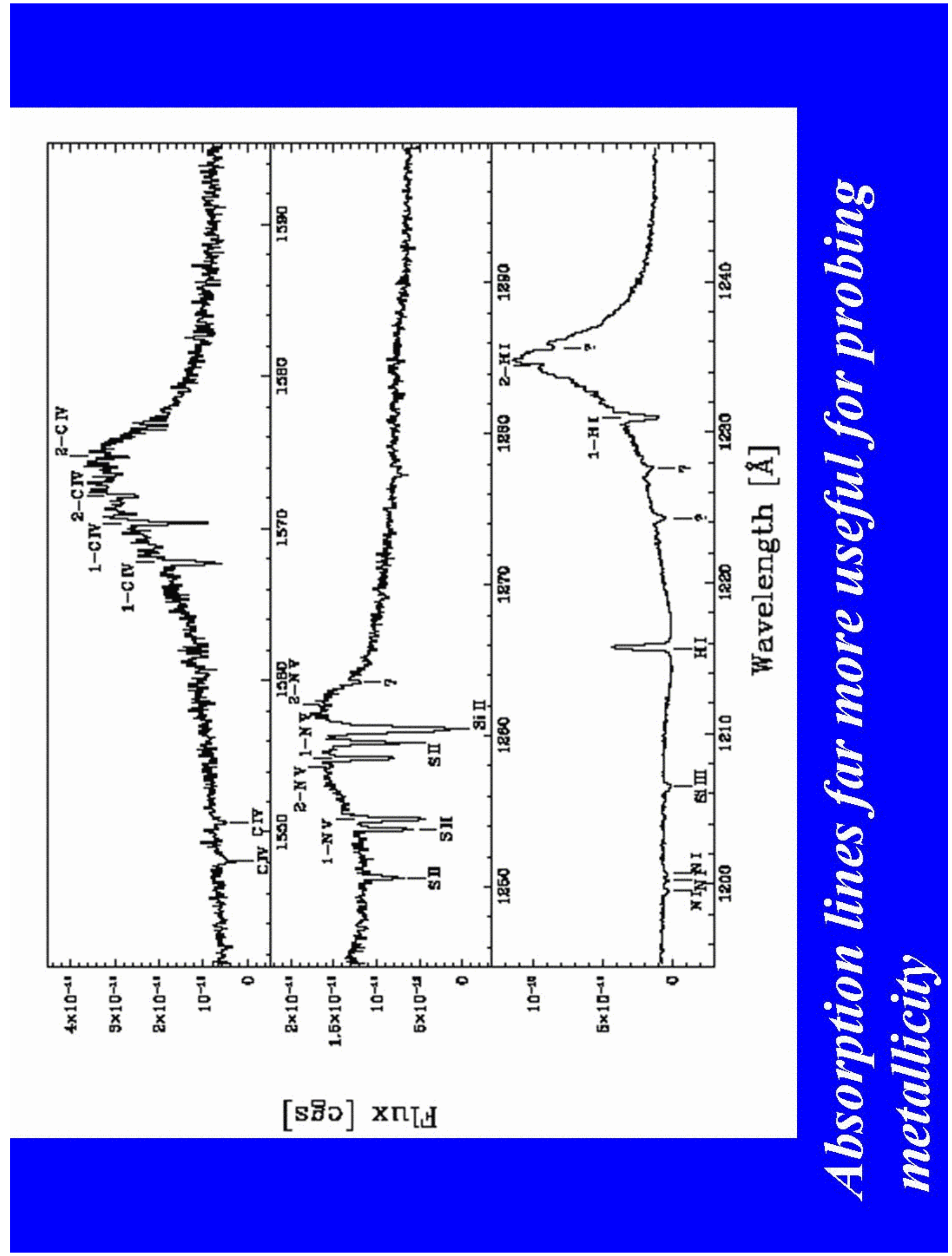


UV widths ~ X-ray widths

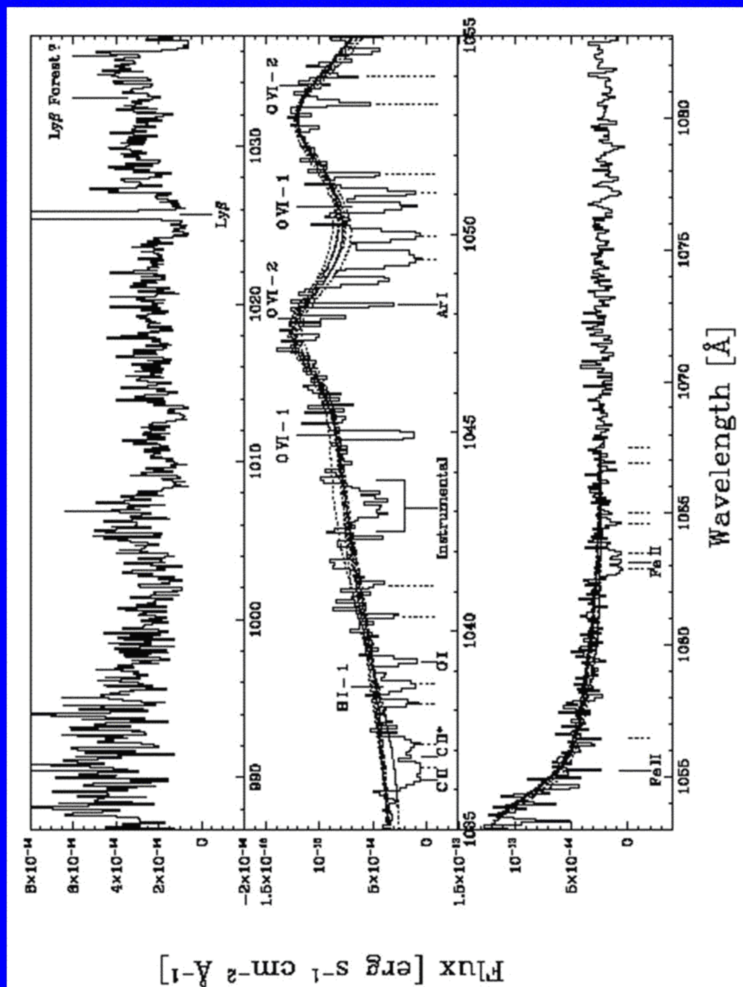


Constraining the widths we can constrain the angle of the flow

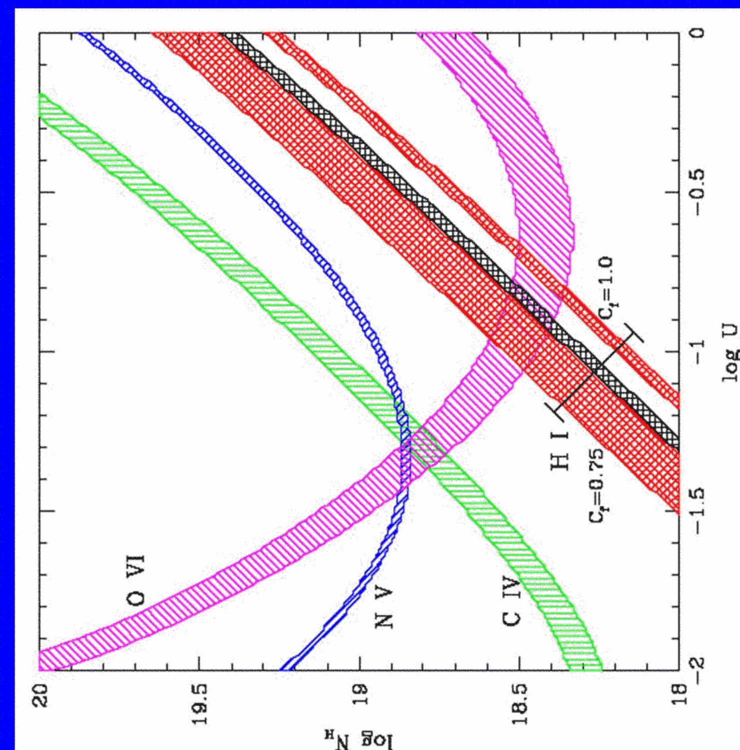

HST Observations of Mrk 1044
Fields et al. 2004
G140L
Lα
N V
C IV
H I
O I
C II
Si IV+O IV]
N IV]
Si II
He II
[O III]
Flux [cgs]
Wavelength [Å]


Absorption lines far more useful for probing metallicity
Flux [cgs]
Wavelength [Å]

…and FUSE

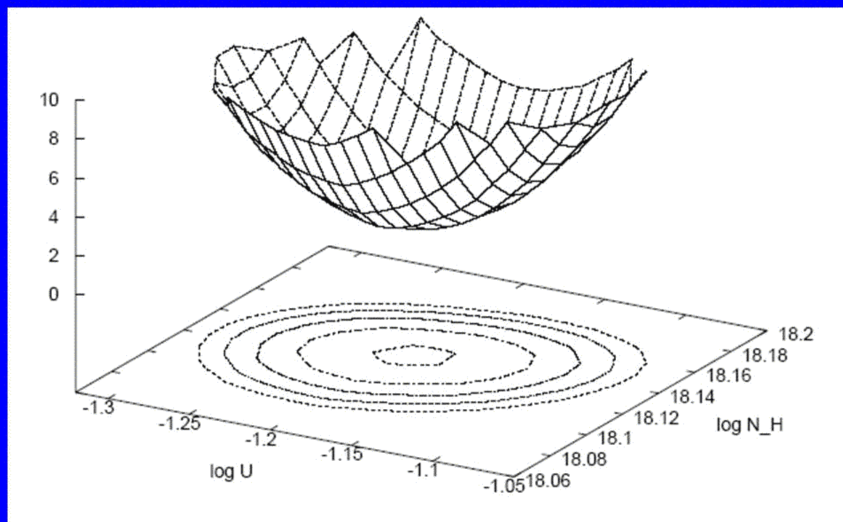


The Mrk 1044 Absorber



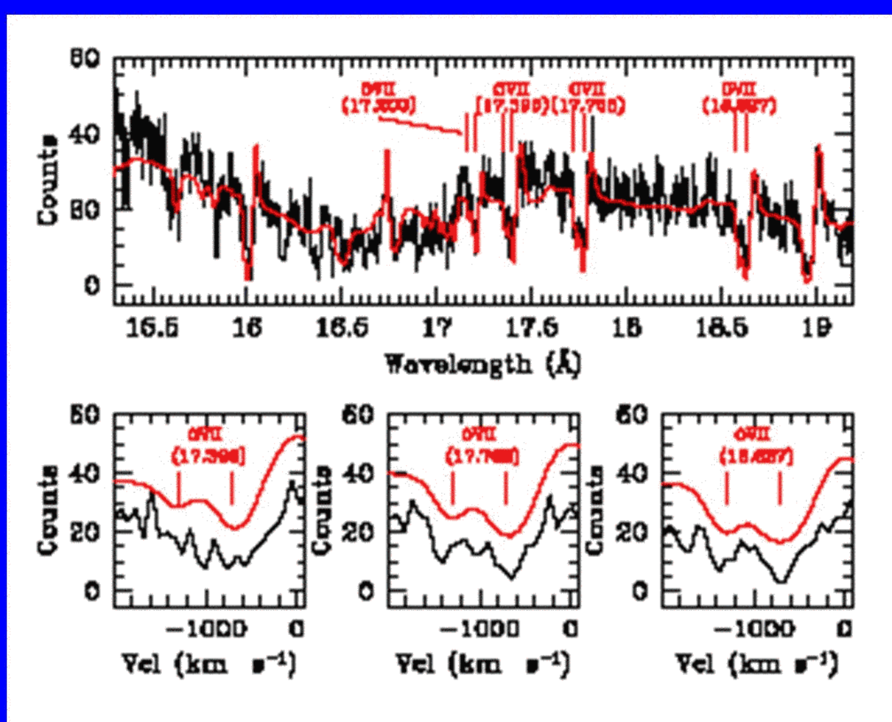
- Supersolar metallicity but Solar abundance mixture

A fit with a bulk metallicity of five times solar



Fields et al. 2005

X-Ray UV Connection



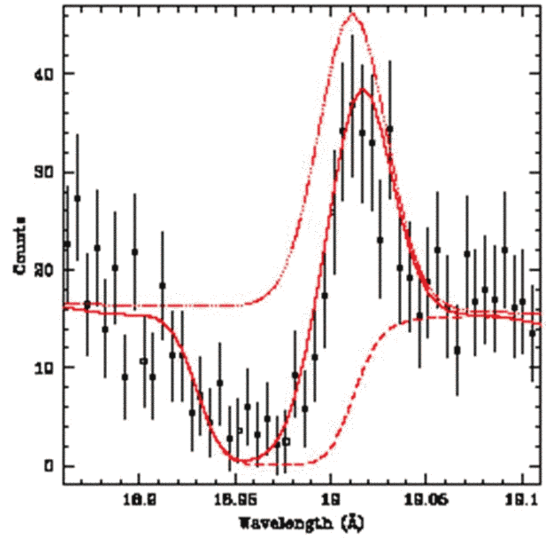


Fig. 6.— Absorption/emission blending for the O VIII(λ18.969Å) line. While the dotted line stands for the emission component, the dashed one represents absorption. The final result (our model) is plotted with the solid line. As can be observed, the measurement of EWs from the data (e.g. Kaspi et al. 2002) underestimate both absorption and emission.[9]

TABLE 3
TWO PHASE ABSORBER PARAMETERS

Parameter	High-Ionization	Low-Ionization
Log U^a	0.76±0.1	-0.78±0.13
Log N_H (cm^{-2})^a	22.20±.22	21.61±0.14
V_{Turb} (km s^{-1})	300	300
V_{Out} (km s^{-1})^a	788±138	750±138
T (K)^b	$9.52 \pm 0.44 \times 10^5$	$2.58 \pm 0.39 \times 10^4$
[Log T (K)]	5.98±0.02	4.41±0.07
Log T/U ($\propto P^c$)	5.22±0.12	5.19±0.20
Log Ξ^d	1.02±0.12	0.99±0.20

Most intense unblended absorption lines

Ion	Wavelength (Å)	Equivalent Width (mÅ) HIP	LIP	Total	Measured
SiXIV	6.182	16.1	< 0.5	16.1	$17.7^{+1.9}_{-1.9}$
SiXIII	6.648	20.4	< 0.5	20.4	$17.6^{+2.9}_{-2.7}$
MgXII	7.106	7.3	< 0.5	7.3	$7.3^{+1.9}_{-2.8}$
AlXIII	7.173	3.7	< 0.5	3.7	$4.9^{+2.1}_{-2.0}$
AlXII	7.757	3.8	< 0.5	3.8	$3.4^{+3.1}_{-2.5}$
FeXXIII	8.304	5.1	< 0.5	5.1	$11.7^{c}{}^{+4.3}_{-4.1}$
MgXII	8.421	24.7	< 0.5	24.7	$27.3^{+3.8}_{-3.4}$
FeXXII	8.714	4.5	< 0.5	4.5	$5.2^{+3.7}_{-2.3}$
NeX	10.239	20.7	< 0.5	20.7	$23.0^{c}{}^{+3.8}_{-3.2}$
FeXIX	10.816	18.2	< 0.5	18.2	$18.6^{+4.8}_{-3.9}$
FeXXII	11.770	28.4	< 0.5	28.4	$41.0^{c}{}^{+8.8}_{-7.4}$
NeX	12.134	45.4	< 0.5	45.4	[a]
FeXXI	12.284	39.7	< 0.5	39.7	$47.4^{c}{}^{+8.3}_{-7.1}$
FeXX	12.576	35.7	< 0.5	35.7	$34.7^{+10.2}_{-8.7}$
FeXX	12.754	9.2	< 0.5	9.2	$12.3^{+3.8}_{-4.3}$
FeXX	12.824	26.1	< 0.5	26.1	[a]
FeXX	12.846	38.9	< 0.5	38.9	[a]
FeXX	12.864	37.0	< 0.5	37.0	[a]
FeXIX	13.423	26.1	< 0.5	26.1	[a]
NeIX	13.447	31.5	11.0	42.6	[a]
FeXIX	13.462	30.0	< 0.5	30.0	[a]
FeXIX	13.497	36.4	< 0.5	36.4	[a]
FeXIX	13.518	48.3	< 0.5	48.3	[a]
FeXIX	13.795	28.5	< 0.5	28.5	[a]
NeVII	13.814	< 0.5	42.3	42.3	[a]
NeVI	14.020	< 0.5	41.1	41.1	[a]
NeVI	14.047	< 0.5	51.4	51.4	[a]
FeXVIII	14.208	49.2	< 0.5	49.2	[a]
FeXVIII	14.208	41.4	< 0.5	41.4	[a]
FeXVIII	14.373	30.6	< 0.5	30.6	[a]
OVIII	14.821	22.3	3.1	25.4	$36.5^{+15.1}_{-12.6}$
FeXIX	14.961	9.8	< 0.5	9.8	$9.5^{c}{}^{+6.4}_{-5.6}$

Table 4—*Continued*

Ion	Wavelength (Å)	Equivalent Width (mÅ) HIP	LIP	Total	Measured
OVIII	15.176	34.6	6.5	41.1	$38.7^{+14.4}_{-16.2}$
FeXVII	15.261	24.5	< 0.5	24.5	$19.8^{+6.5}_{-5.9}$
OVIII	16.006	51.0	16.7	67.7	$59.8^{b}{}^{+10.8}_{-17.4}$
OVII	17.086	< 0.5	24.5	24.5	[b]
OVII	17.200	< 0.5	33.0	33.0	$28.9^{b}{}^{+6.8}_{-7.6}$
OVII	17.396	< 0.5	43.4	43.4	$38.9^{b}{}^{+7.8}_{-11.2}$
OVII	17.768	5.0	55.2	60.2	$40.1^{b}{}^{+16.0}_{-15.2}$
OVII	18.627	13.2	71.0	84.2	$46.3^{b}{}^{+16.9}_{-14.2}$
OVIII	18.969	89.0	54.1	143.1	$55.0^{b}{}^{+23.8}_{-15.4}$
NVII	20.910	19.3	12.8	32.1	$29.5^{b}{}^{+23.3}_{-21.4}$
OVII	21.602	49.5	128.3	177.8	$34.2^{b}{}^{+30.8}_{-33.1}$
NVI	23.277	< 0.5	24.8	24.8	[a]
NVI	23.771	< 0.5	41.9	41.9	$23.9^{+21.3}_{-22.5}$
CaXIV	24.114	25.2	< 0.5	25.2	$26.8^{+20.2}_{-19.9}$
NVII	24.781	67.0	54.9	121.9	$66.5^{b}{}^{+37.2}_{-34.4}$
NVI	24.898	< 0.5	68.7	68.7	$33.9^{b}{}^{+31.7}_{-27.2}$

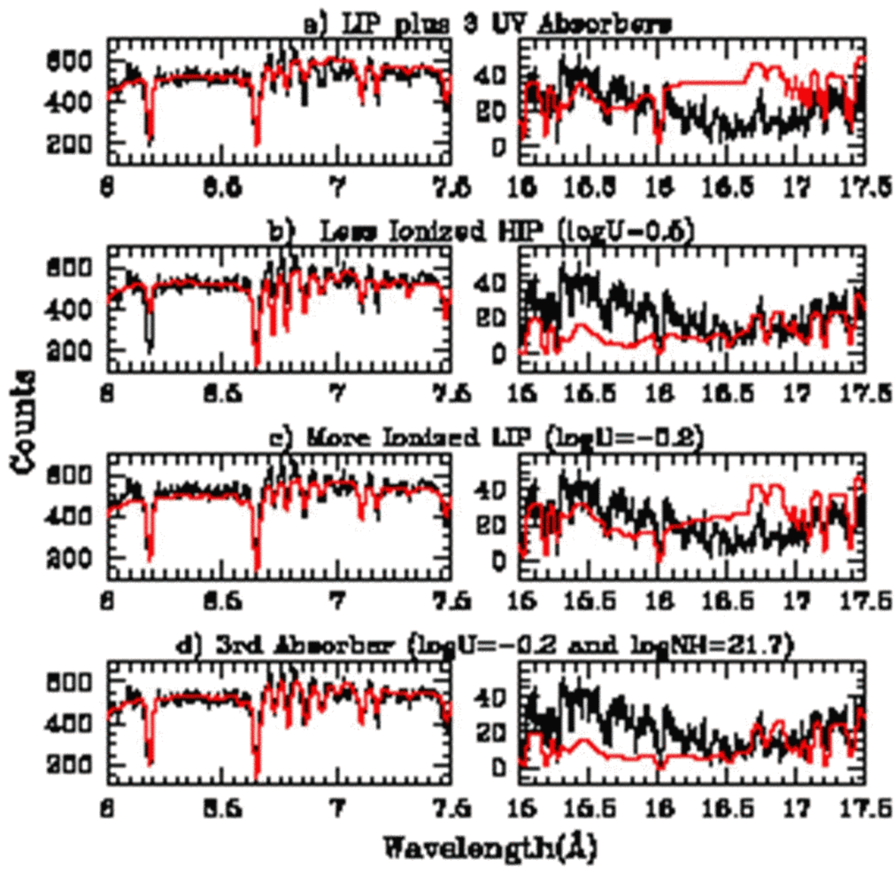


TABLE 6

COMPARISON WITH PREVIOUS MODELS

	Γ	Norm.[a]	$\log(U_{OX}^{LIP})$	$\log(U_{OX}^{HIP})$	$\log(N_H^{LIP})$	$\log(N_H^{HIP})$	$z(x)/z_o$
This paper	1.53[b]	.011	-2.77	-1.23	21.6	22.2	1
Kaspi et al.	1.77	0.015	-1.75	0.75	22.2	22.2	1
Blustin et al	1.53	.018	0.3[c]	2.4[c]	20.7	22.45	10(Fe)
de Rosa et al.	1.83[d]	0.019	...	0.4	...	22.3	1

TABLE 7

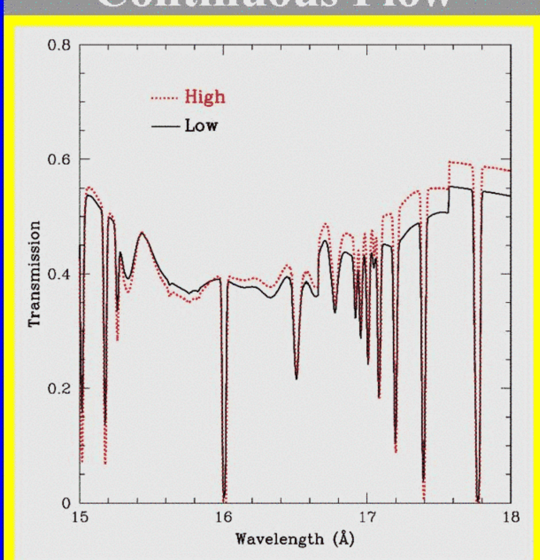
COMPARISON WITH KASPI ET AL. (2002)

λ (Å) Observed	Ion Name and Rest Frame λ (Å) identification: Kaspi et al.	This paper
10.126	FeXVII(10.112)	FeXVII(10.112), FeXIX(10.119), FeXVII(10.120)
10.524	FeXVII(10.504)	FeXVII(10.504), FeXVIII(10.537)
12.436	No identification	NiXIX(12.435)
12.560	FeXX(12.576)	FeXX(12.526)
12.592	FeXX(12.588)	FeXX(12.576,12.588), FeXIX(12.538)
13.612	...	FeXIX(13.645,13.643)
13.822	FeXIX(13.795)	NeVII(13.814),FeXIX(13.795)
14.269	FeXVIII(14.256)	NeV(14.239),FeXVIII(14.256)
15.584	...	FeXVIII(15.625)
21.466	OVII(21.602) zero redshift	CaXVI(21.450)
23.783	...	NeVI(23.771)
24.124	...	CaXIV(24.114)

Constraining the Structure of the Absorber

- Opacity variation in response to flux variations

Continuous Flow



Clumped Gas