High Resolution X-ray Spectroscopy of Seyfert Galaxies: Why Key Science is in the Details

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QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

National Aeronautics
and Space Administration

What are we hoping to get from AGN studies?

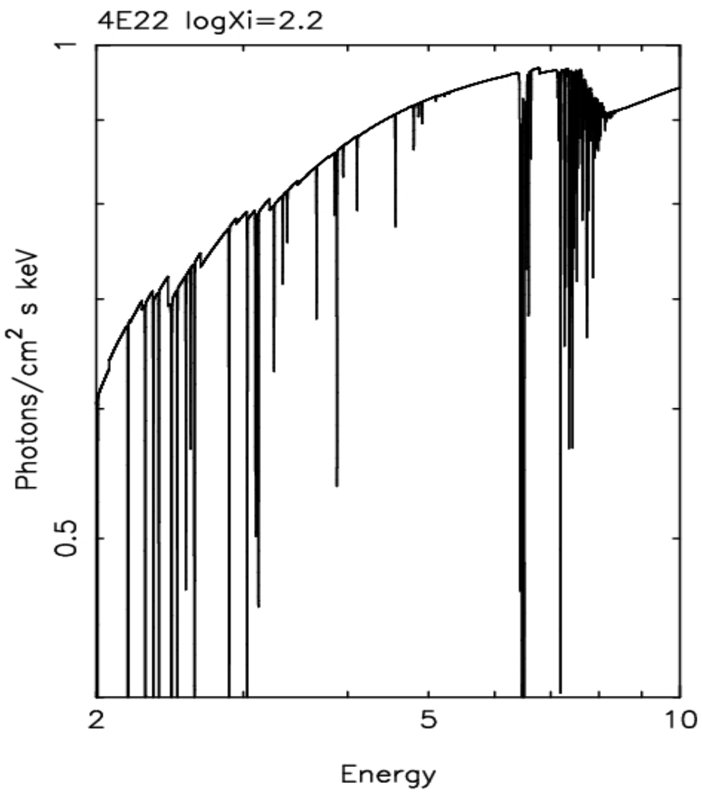
Ultimately we hope to understand something fundamental:

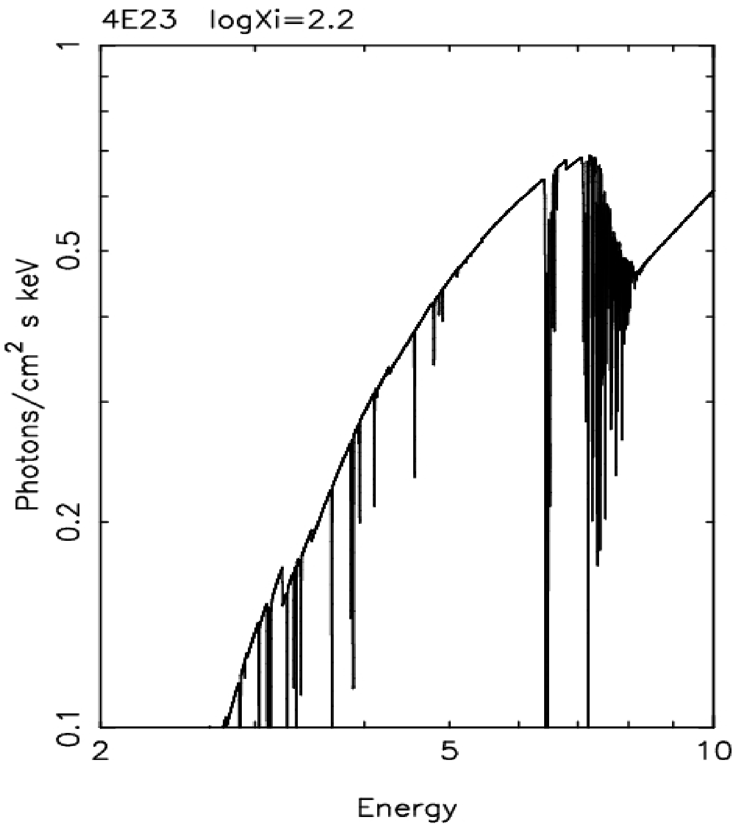
- black hole accretion/fueling (hence growth, evolution, structure formation) *Warm Absorbers & "Hot Absorbers"*

-physics in the strong gravity regime *Fe Kα*

Study of narrow features breaks key ambiguities

To understand Fe K profiles, X-ray abs^n needs to be accounted for ...





Column of moderate-ξ gas -> curvature from Fe L edge (0.7 keV) up to Fe K-band, difficult to distinguish from red wing of diskline (Kinkhabwala thesis 2003)

Example - NGC 3783

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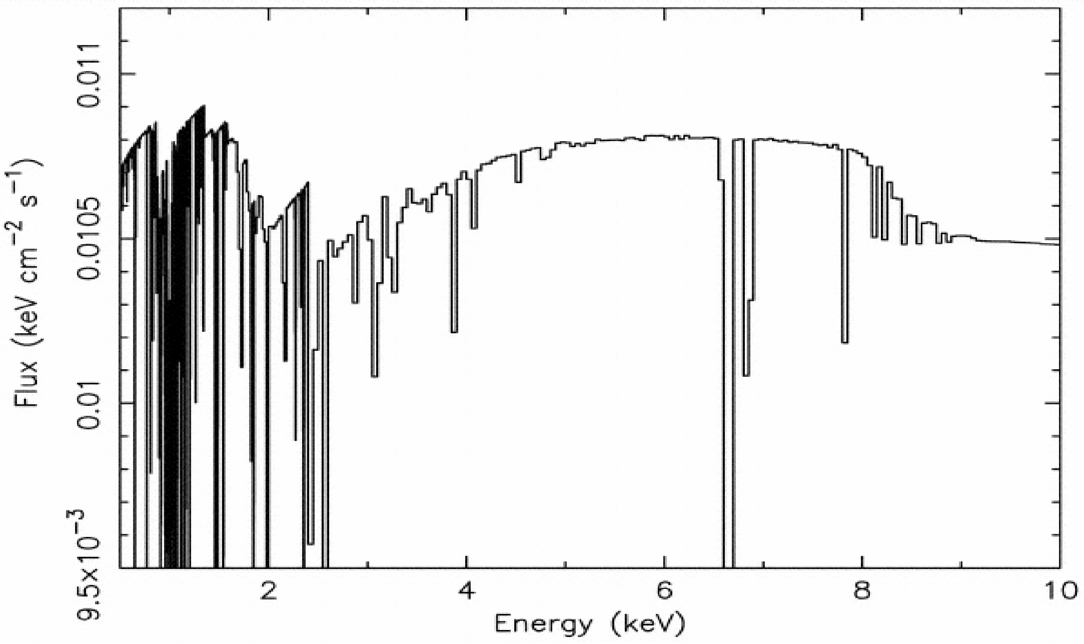
NGC 3783 - abs^{n} line from ionized Fe
$N_H \sim 5 \times 10^{22}$ cm^{-2}, log $\xi \sim 2.9$



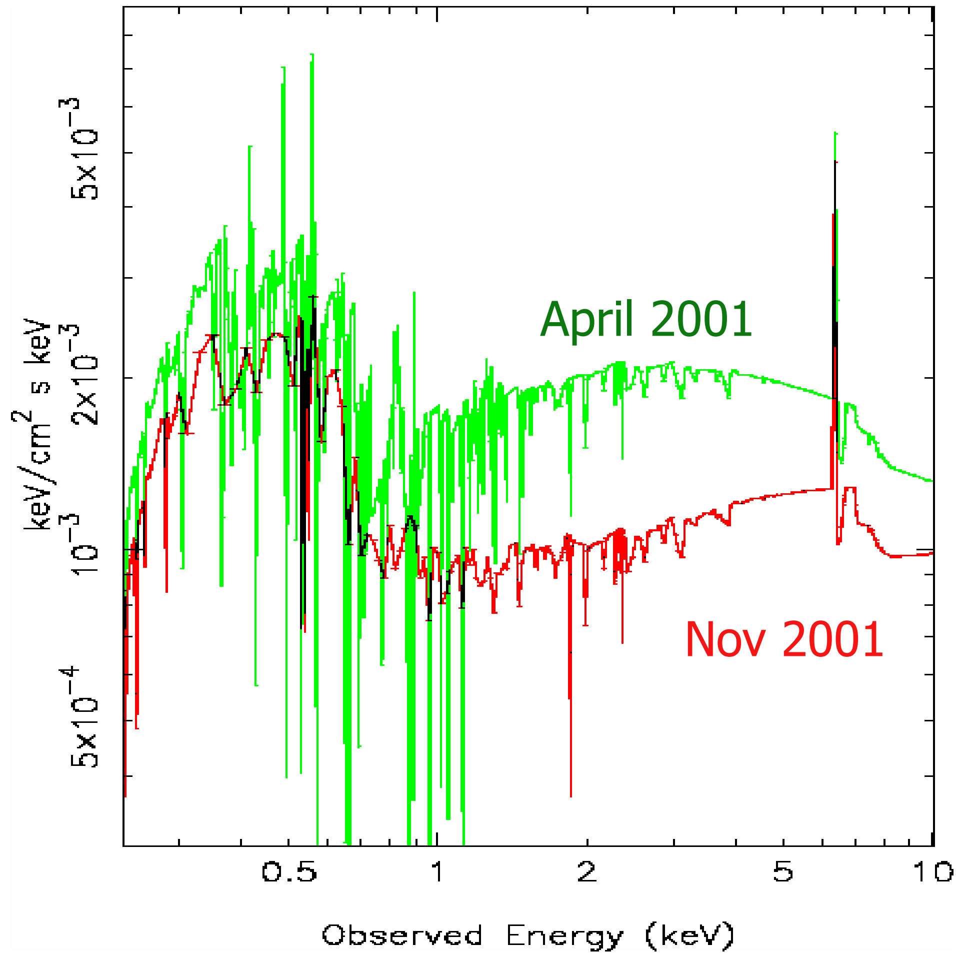
(Reeves et al 2004)

Example - NGC 3516

New high-column/ξ zones found
(Turner et al 2005)

N_{Hi}~$2x10^{22}$ cm^{-2}
log ξ ~ 4.7

N_H~$3x10^{23}$ cm^{-2}
log ξ > 4.2
covering ~ 50%



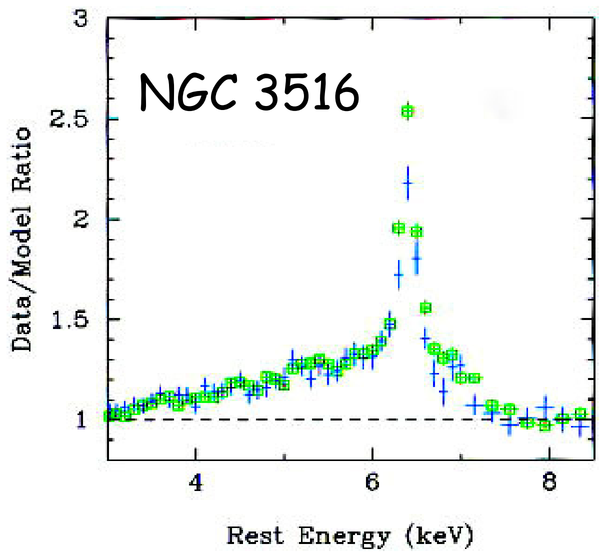
absorbers respond to continuum flux - explains spectral variability

Warm Absorbers - not just AGN "weather"

Inclusion of high-ξ/high-column absorption reduces implied broad red wing .....*but how much ?*

Reeves et al 2004

Turner et al 2002



broad residual explained by reflection & complex absorption

NGC 3783 - broad base consistent w/ Compton shoulder from absorber

Room for a diskline but no compelling evidence…!

No need for diskline here!

… may not “work” for all sources…

MCG-6-30-15 500 ks HETG, Young et al 2005

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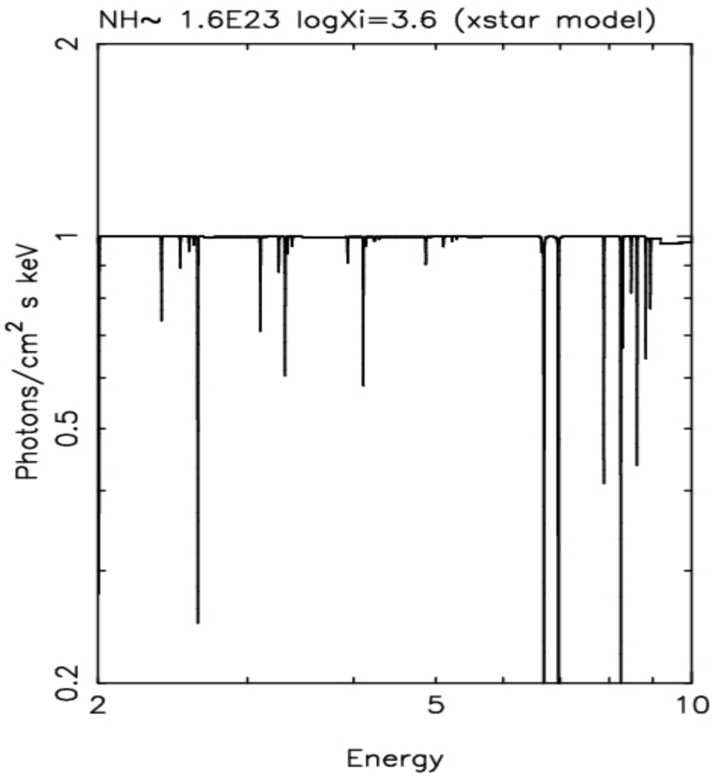
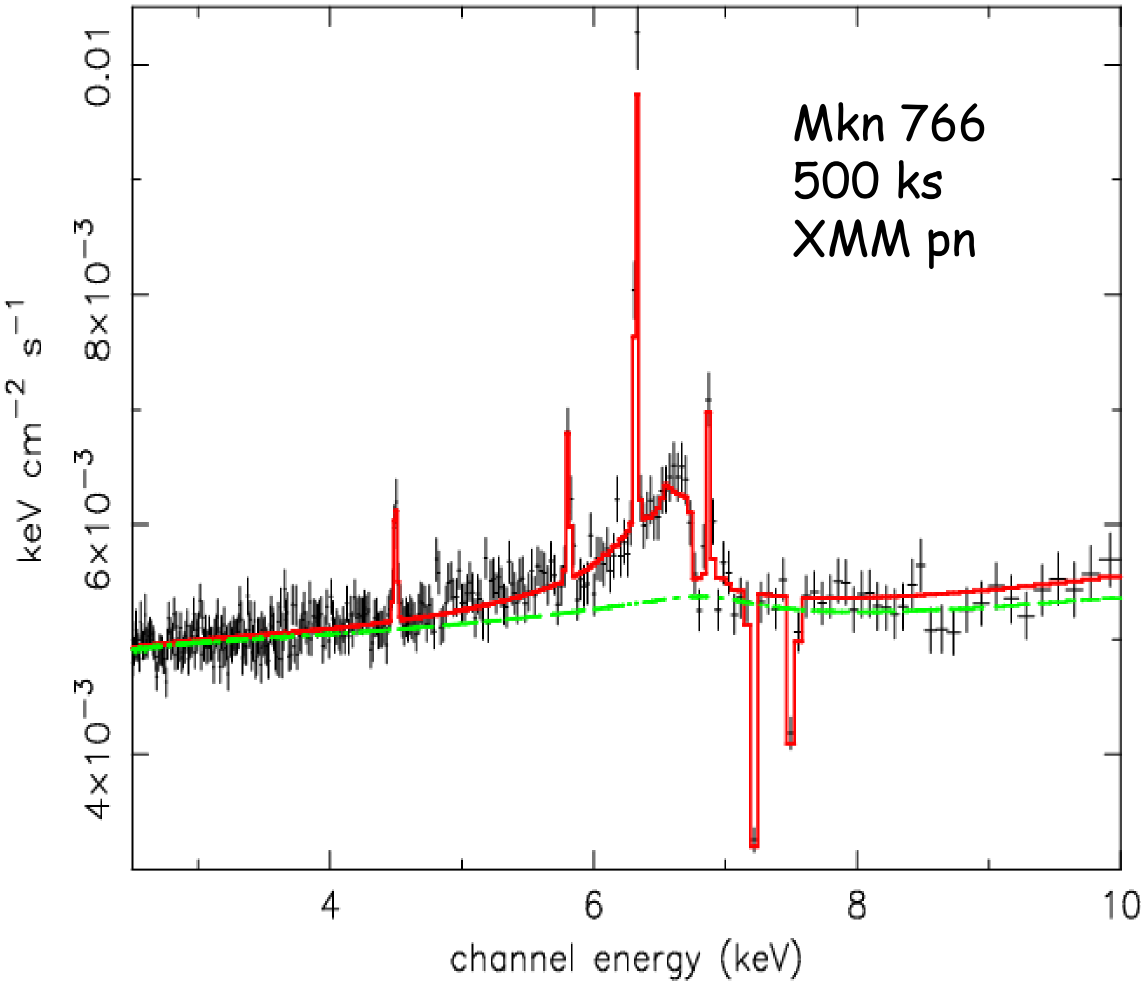


Strong features ~6.5 keV, not always observed - e.g. MCG-6-30-15
- if abs^n “hidden” in line flux then there must be broad line there anyway

Another absorption ambiguity



NGC 5506 & Mkn 766 show abs^n features at 7.3, 7.6 keV
-hard to identify

H-like & He-like Fe abs^n lines at v ~0.1 c , **disk wind?**

But same in NGC 5506 - seems unlikely both AGN have wind of same v

Con-X Improvement over HETG for narrow features

Con-X x ~300 area improvement over HEG (summed 1st-order) Spectral resl^n improves ~ order of magnitude at Fe-K (40eV -> 4 eV) !

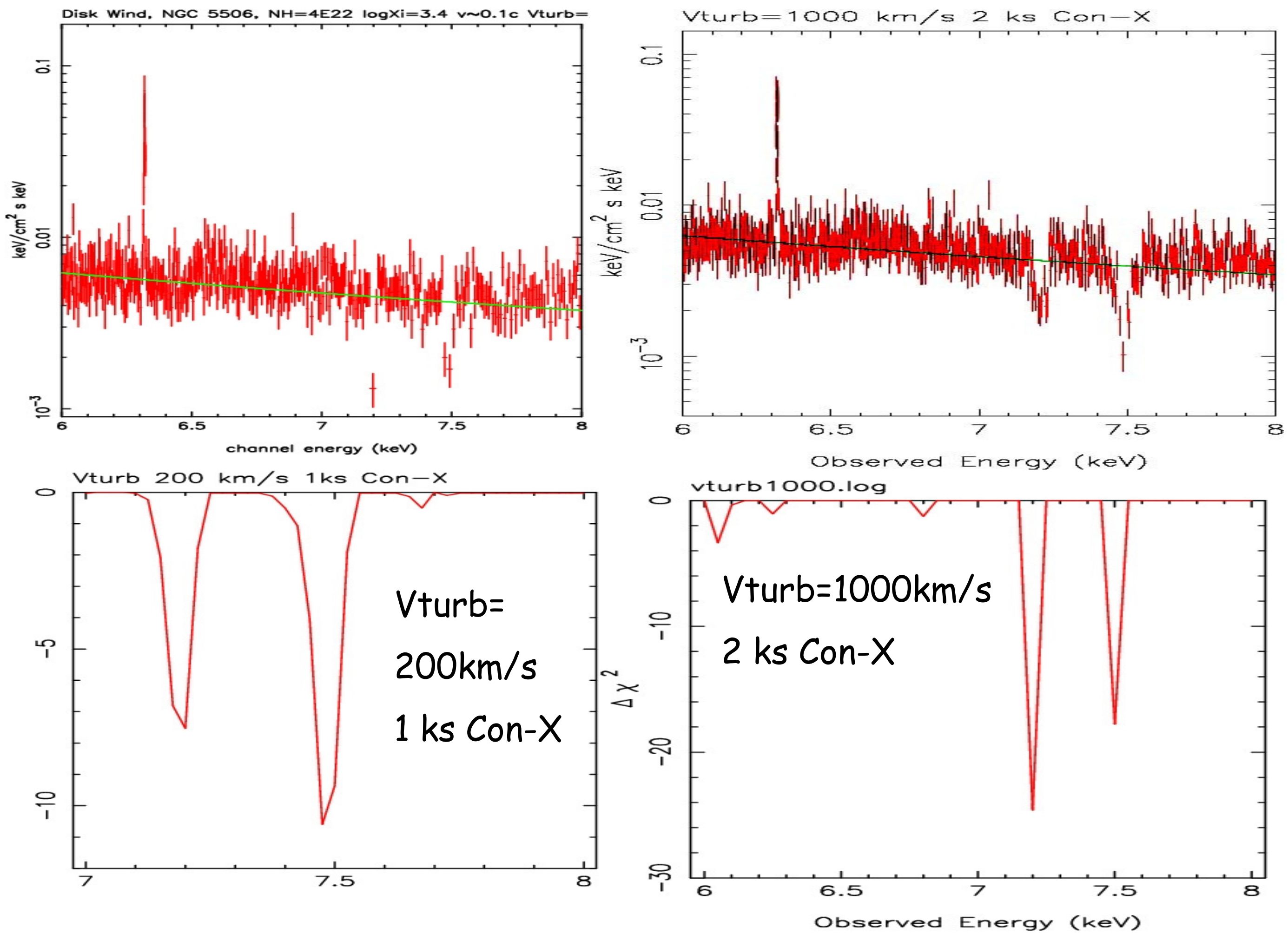
<u>Goals:</u>

Identify abs^n lines -> separate layers of absorption -> track response to continuum flux thus get broad <u>diskline right</u>

Track wind acceleration/deceleration

- -launch radii
- -mass outflow etc

NGC 5506 Con-X simulations



Track lines on ~ksec timescales for brightest AGN

F_{2-10}~ 7×10^{-11} erg cm^{-2}s^{-1}

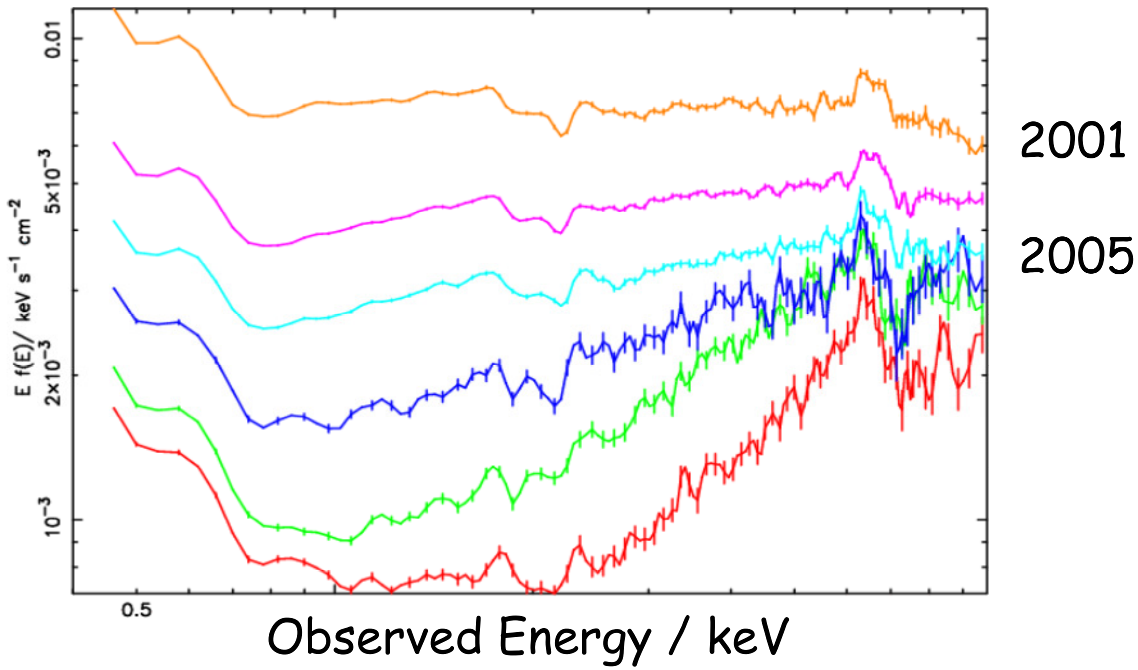
Model has N_H=4E22 log ξ = 3.4 vel~0.1c

Continuum & Broad Line Emission & Variability

Once we separate abs^{n} components from emission - can understand spectral variability

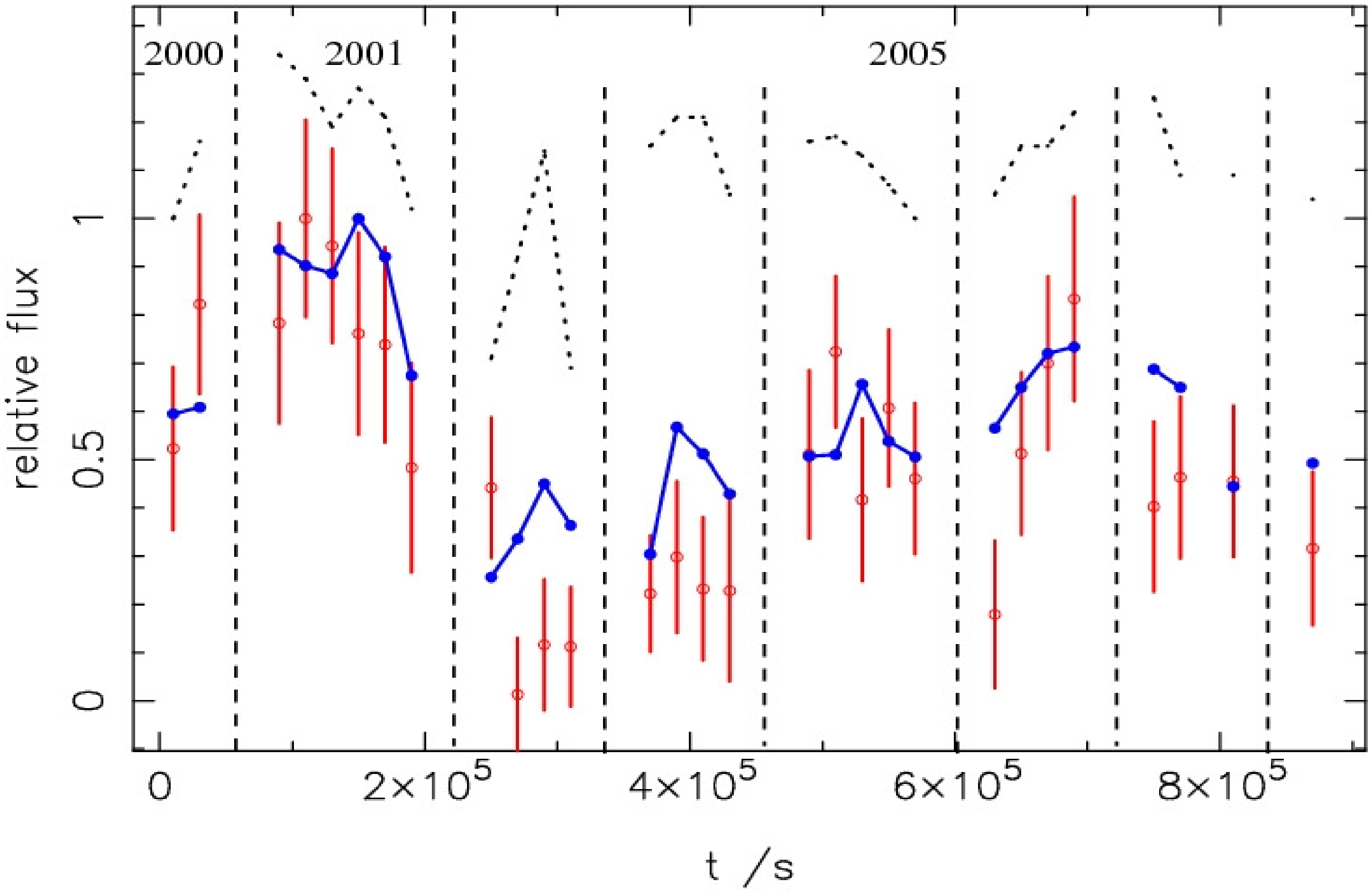
Mkn766 : lowest flux dominated by 'cold' reflection w/ strong abs^{n}

High flux dominated by PL & ionized Fe line emission while absorber obviously more ionized



XMM, Mkn766, 2000-2005, Miller et al 2006

Mkn 766 - Miller et al 2006



α ....

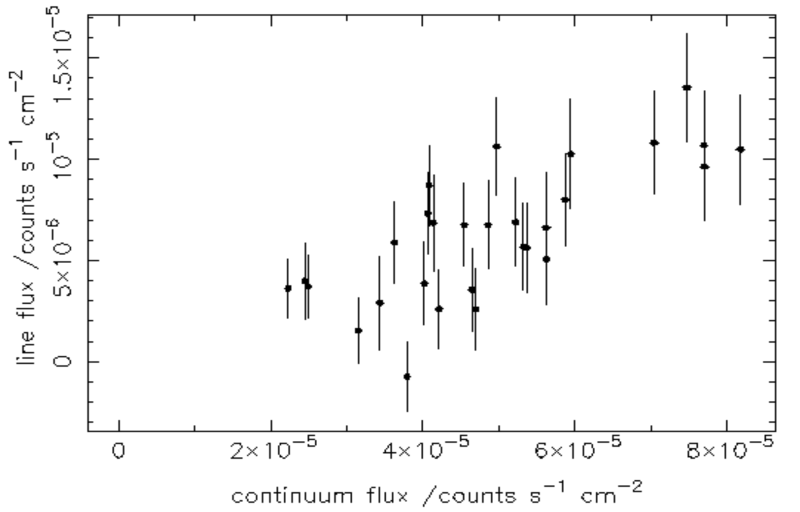
Fe Kα flux

continuum flux

He-like Fe emission correlated w/ continuum down to 10 ks (at least)

Line goes to zero before continuum - continuum cont^{n} from cold reflector

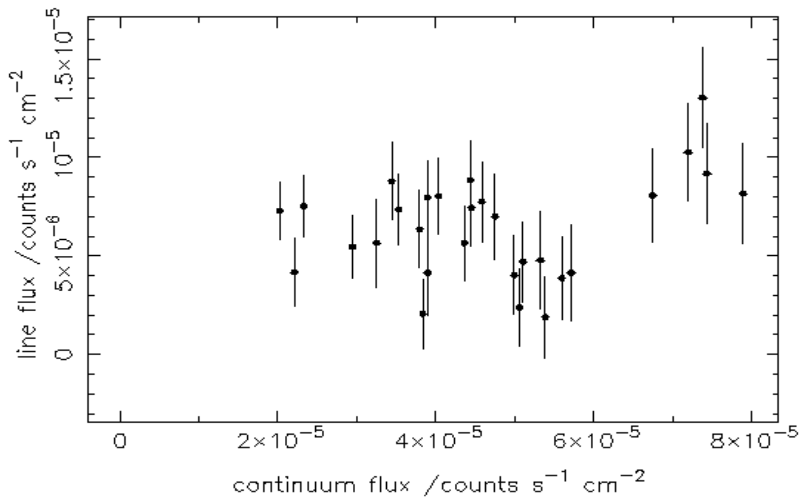
Mkn 766 - Miller et al 2006



He-like Fe emission correlated w/ continuum

Neutral Fe line not correlated w/ continuum

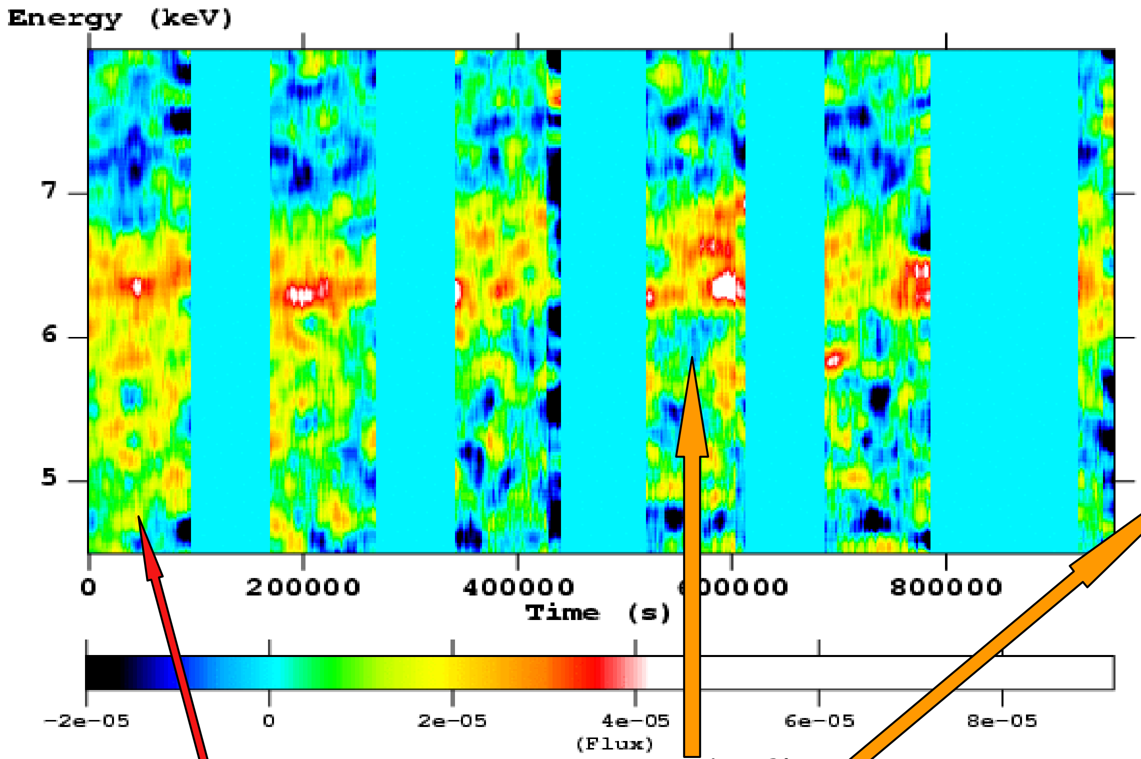
line flux

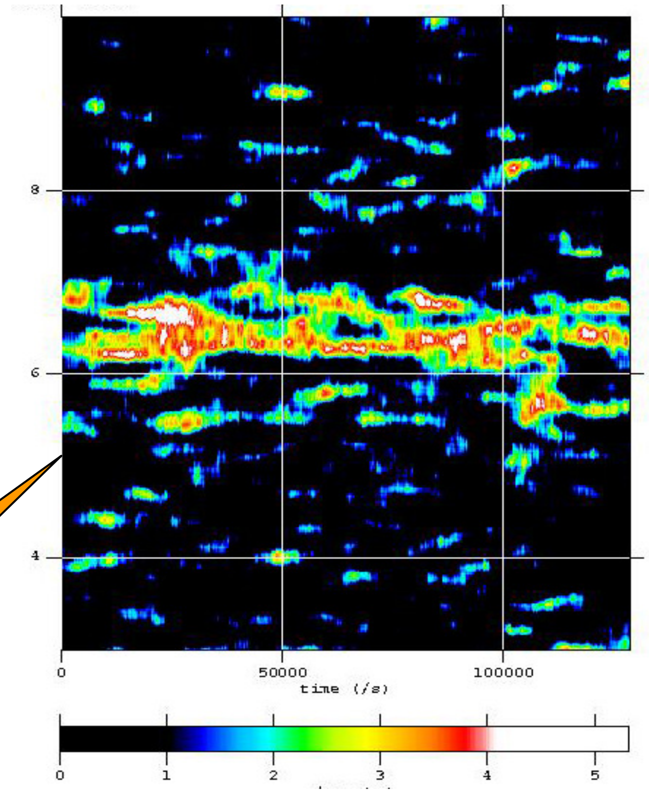


continuum

Line/flux corrl^{n} ***in Mkn 766***

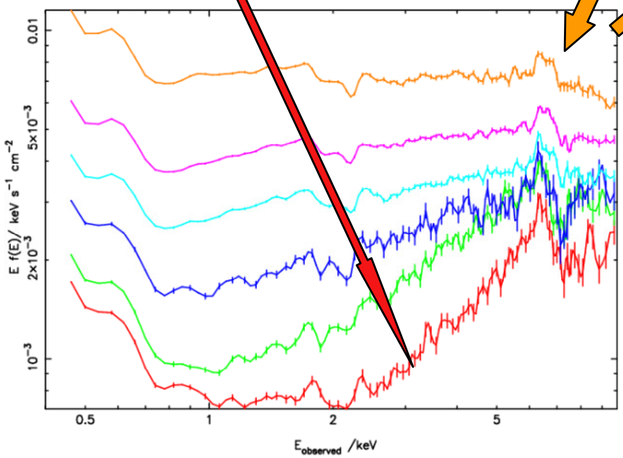
He-like Fe emission originates in disk ~150 r_g





Low continuum flux

High-flux



In Mkn 766, can <u>diagnose disk</u> from line variations seen when source flux is high ie during 2001 and part of 2005 dataset

Con-X improvement over EPIC for broad Fe K features

~ x10 gain in effective area over pn in Fe-K band

For targets as faint as Mkn 766 ($F_{2\text{-}10}$ ~ 1 x 10^{-11} erg cm^{-2} s^{-1}) Con-X will allow us to probe diskline/continuum down to 2-3 ks (probing 1-1.5 x 10^{7} cm, t_{orb} at 6-8 R_g)

For brighter sources like 5506 probe down to ~ 1 ks, t_{orb} at 6 R_g

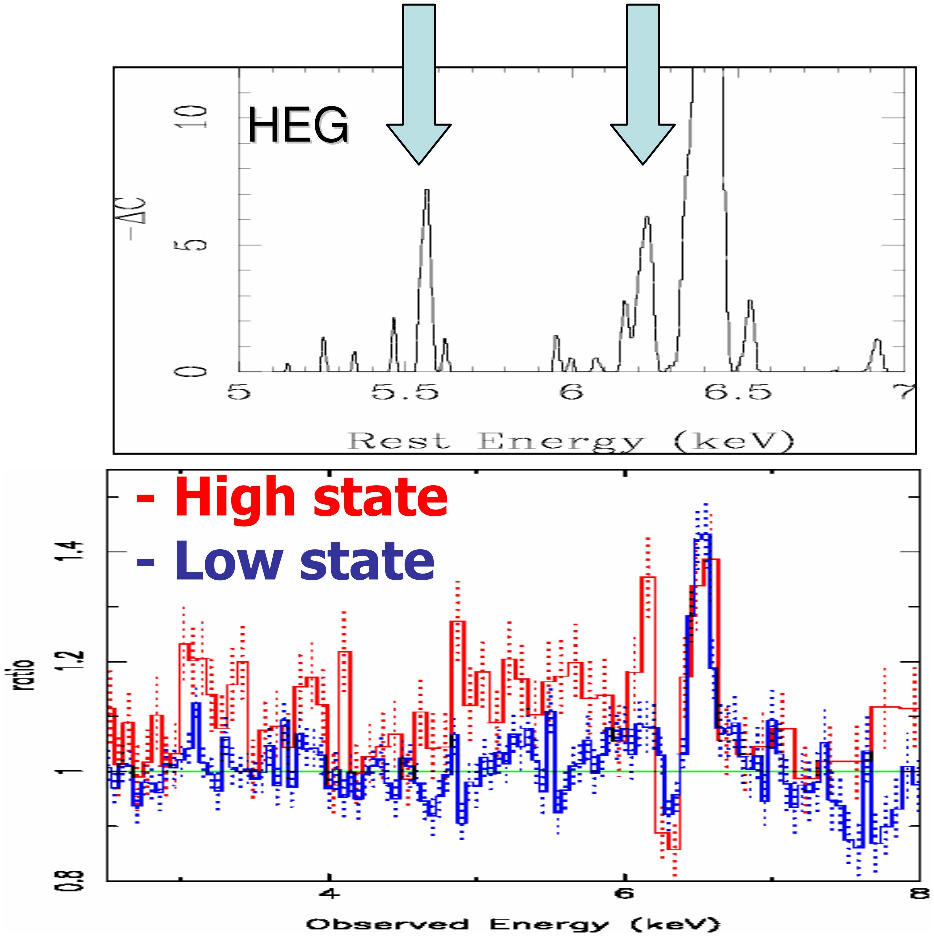
Con-X probes critical scales, may allow direct distinction between Schwarzschild / Kerr metrics !

Other probes of inner disk

Narrow Fe lines, shifted from rest-energy (Doppler/GR)

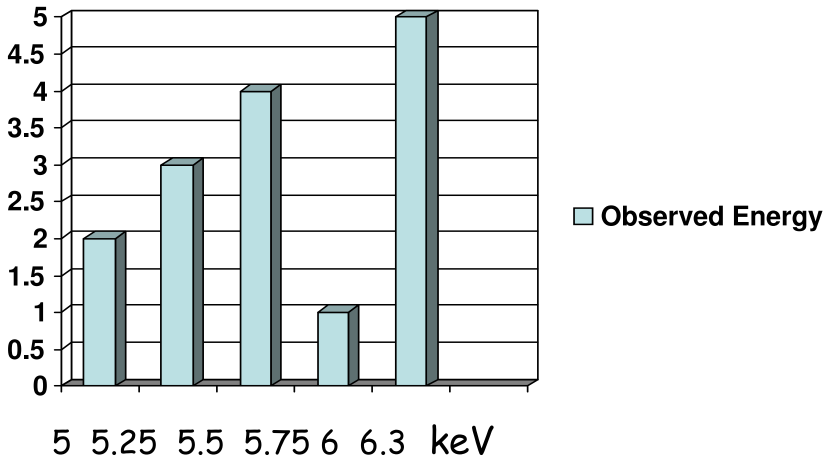
Rapid (tens of ks) flux/energy variability - <u>must be</u> diagnostics of gas very close to BH

First found NGC 3516 (Turner et al 2002) simult. XMM /Chandra
-suggested to be emission from disk hotspots integrated over partial orbits at tens-hundreds of r_g

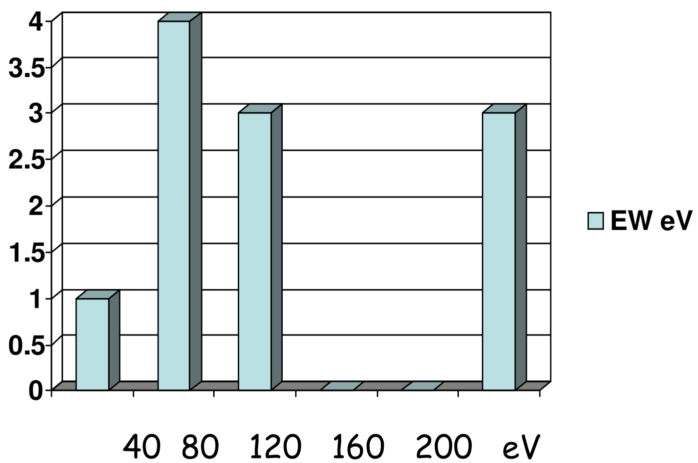


NGC 3516 XMM Nov 2001

Narrow 'shifted' lines a common phenomenon!



> dozen reported, inferred origins few tens - hundreds of r_g strengthening link to disk



Large EWS a problem ??
Selection effect -
currently only sensitive to
large EW lines

Time to rethink the uniformity of the disk !!

However, the fact EWs <u>can be</u> so large likely telling us we need to review idea that the disk has simple emissivity profile

Possible uneven illumination - X-rays can be produced in intense localized flares on disk, leading to a high EW from spots

Or lines may arise in
- -areas of enhanced density in disk
- -regions of warped geometry

Con-X will allow us to track rapid energy changes of narrow disklines
- -derive emitting radii
- -BH mass limits
- -reverberation mapping from line/continuum lags /disk tomography

Summary

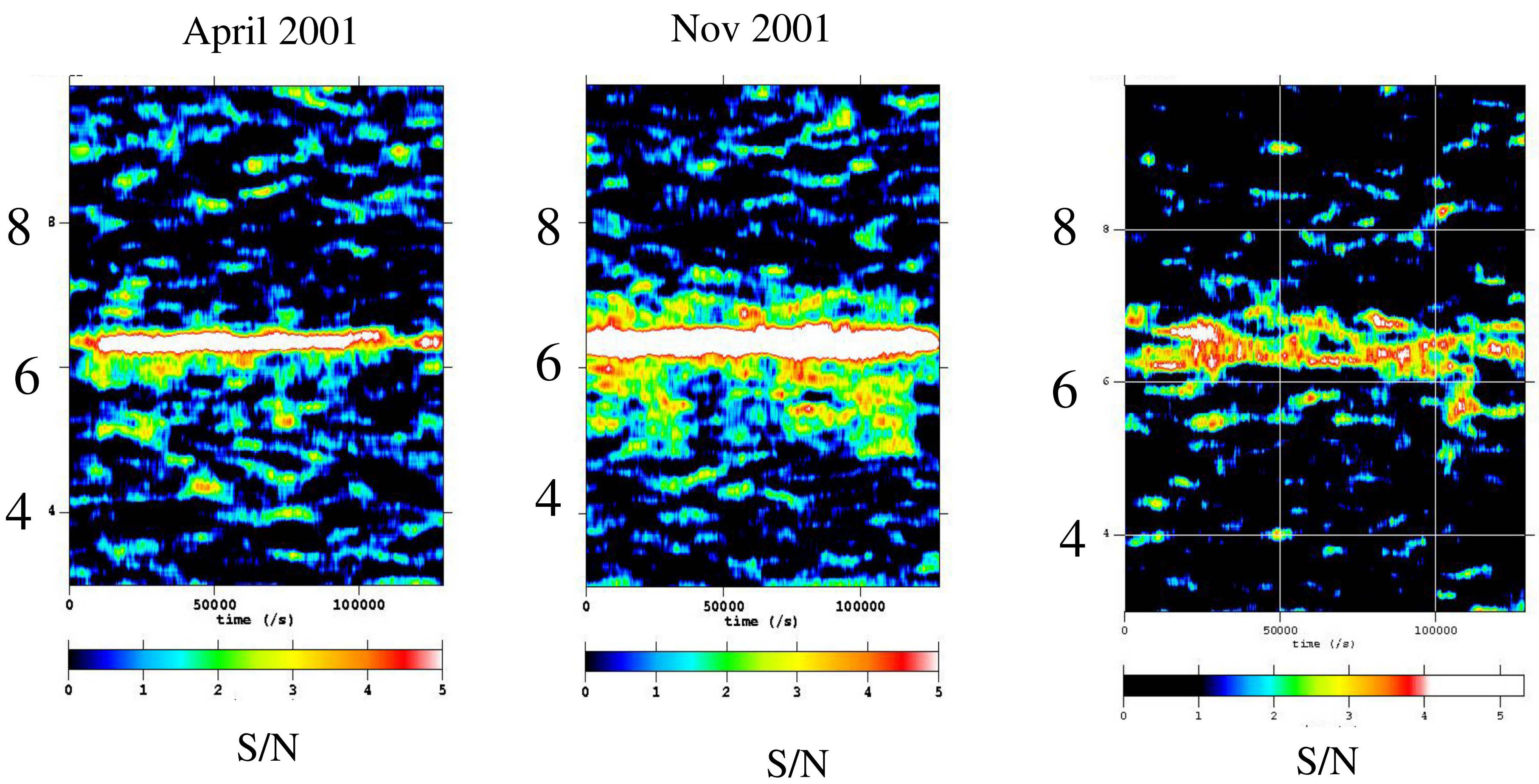
Absorber/reflector ***details*** give working model for Seyfert spectral variability featuring:-

changes in relative levels of cold reflection / PL / ionized disk
combined with the flux-linked abs^{n} effects

-*diagnose* disk from ionized line variations

Need Con-X to get to the fundamental physics

Disk interpretations supported by possible periodicity in these lines



Periodicity in flux suggested Iwasawa et al (2004) for April data from NGC 3516

Line energy varies as expected from orbital Doppler shifts in Mkn 766 (Turner et al 2006)