The Importance of X-ray winds in shaping AGN Spectra and Variability

Jane Turner

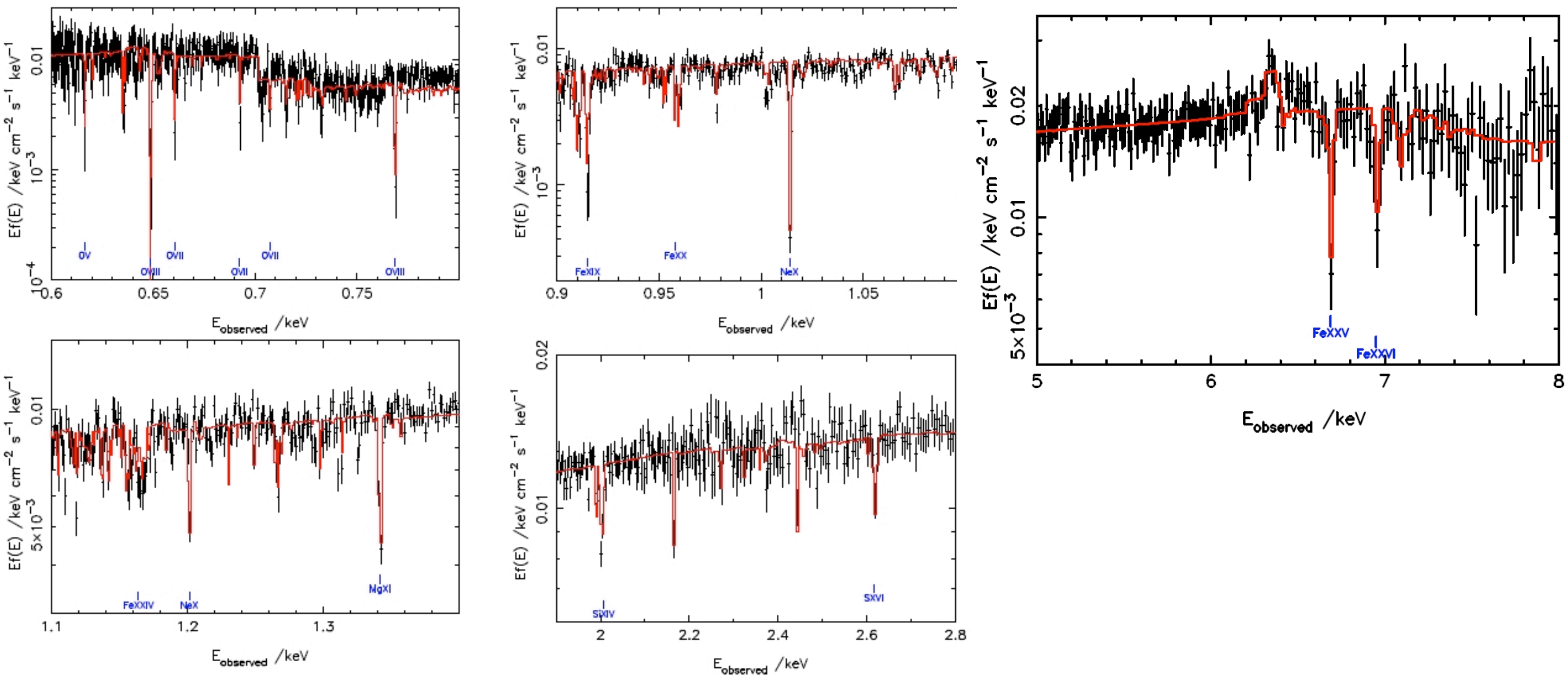
Collaborators:
Lance Miller (Oxford)
James Reeves (Keele)
Steve Kraemer (CUA)

COSPAR:
Montreal
July 2008

UMBC
AN HONORS UNIVERSITY IN MARYLAND

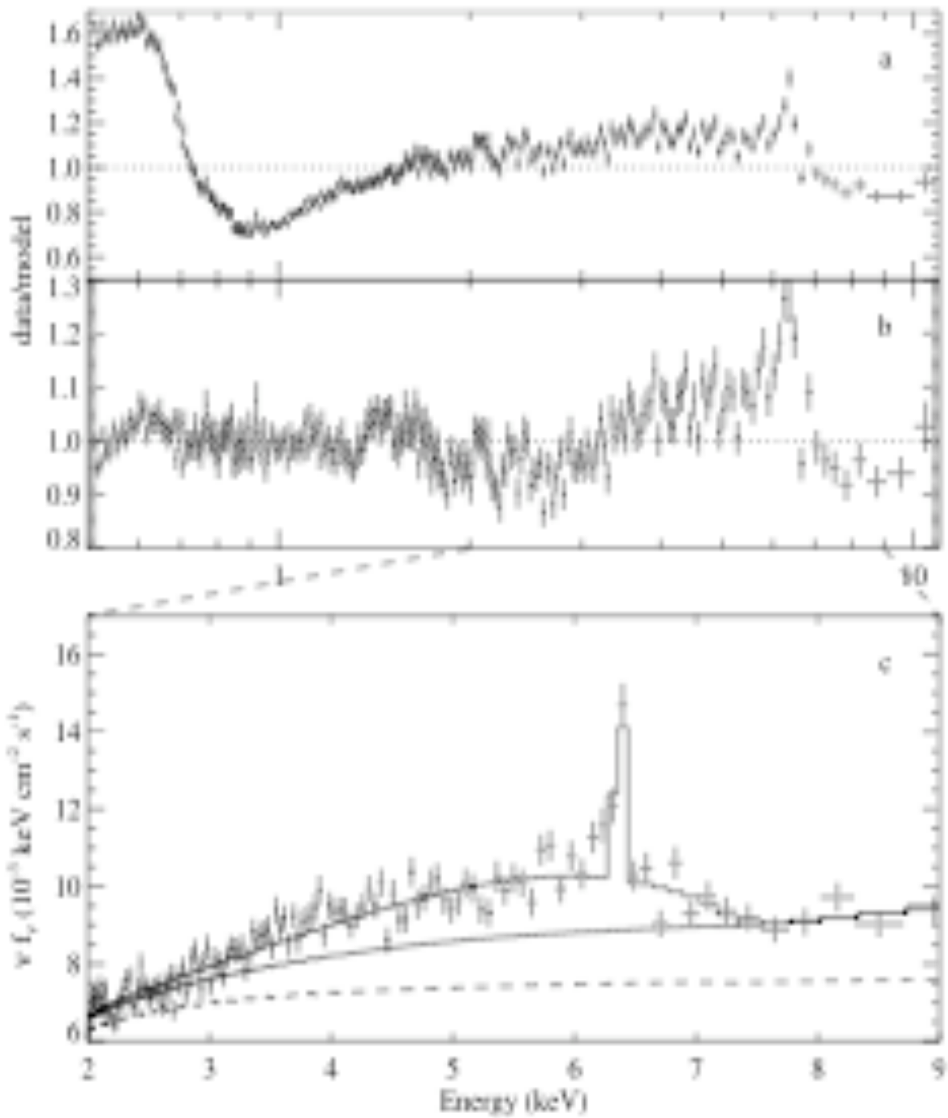
National Aeronautics
and Space Administration

Chandra data demonstrate the existence of complex ionized absorption: (i) log $\xi \simeq 0.5$ & (ii) log $\xi \simeq 2.0$ (Lee et al 2001, A.K.Turner et al 2003, 2004, Miller et al 08) (iii) log $\xi > 3.5$ v $\simeq$ 1800 km s^{-1} (Young et al 2005, Miniutti et al 2007) in MCG-6-30-15



Results typical of other nearby AGN (e.g. Blustin et al '05)
AGN have outflows with column densities and ξ detected over at least 4 orders of mag

The ‘mid-band’ problem: e.g. MCG-6-30-15



Wilms et al 2001

ratio to power-law

ratio to empirical warm absorber

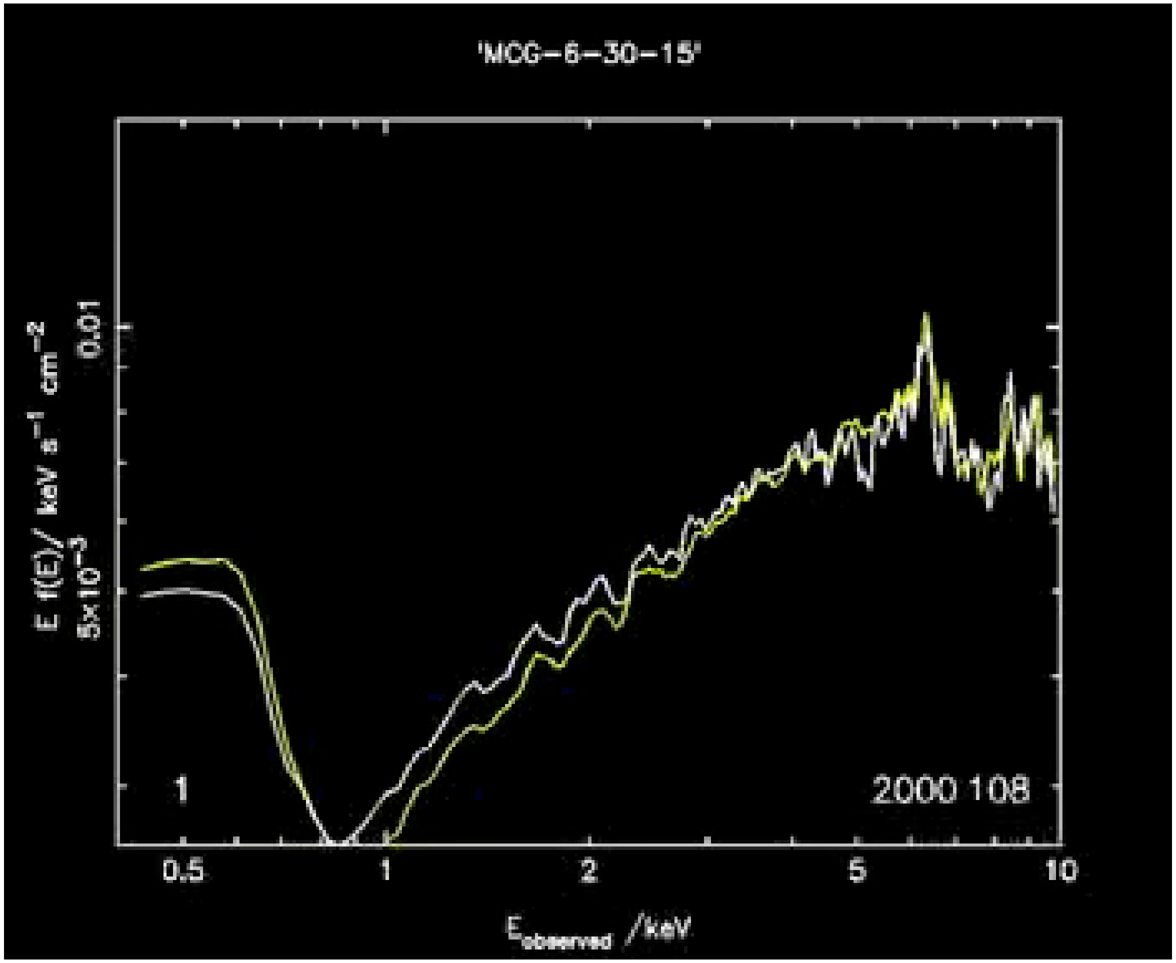
the residual - blurred line or absorption signature?

Case Study MCG-6-30-15

L Miller, Turner & Reeves 2008

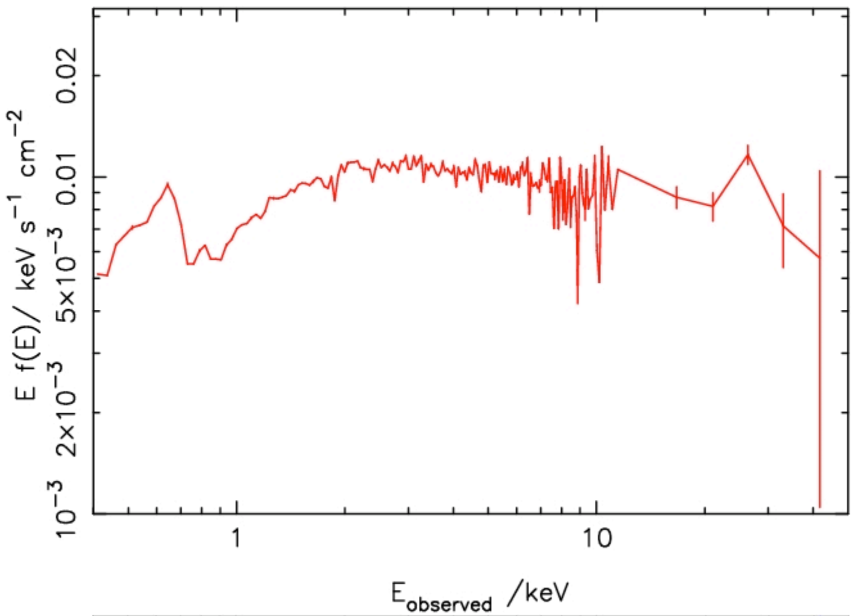
MCG-6-30-15	2000	2001	2004	2006	total
XMM-Newton pn + rgs	89ks	330ks			419ks
Chandra HETGS			522ks		522ks
Suzaku xis + pin				253ks	253ks

Generally see large systematic spectral variability -there is something important to be understood

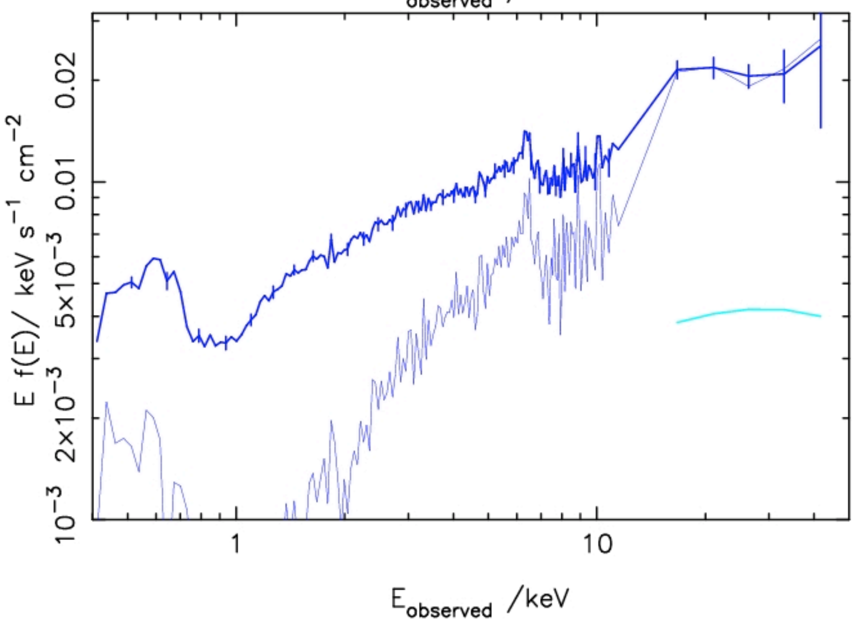


Here MCG-6-30-15 (also see e.g. Vaughan & Fabian '04) but also Mkn 766, L Miller et al '07, Turner et al '07; NGC 3516 Netzer et al '02 Turner et al '05 & '08; 1H0419-577 Pounds et al 2004 etc)

SVD-PCA MCG-6-30-15



2006 Suzaku xis+pin
eigenvector 1

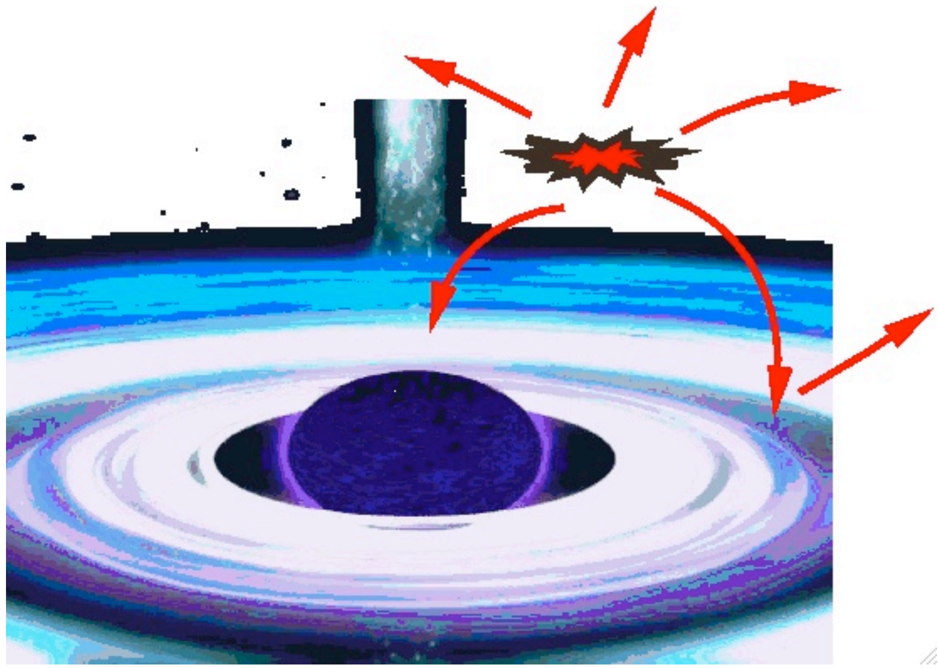


Suzaku xis+pin "constant"

reflection? problem is this should vary with the continuum

complex absorption? e.g. NGC 4151 Yaqoob et al 1993 1H0419 Pounds et al '04

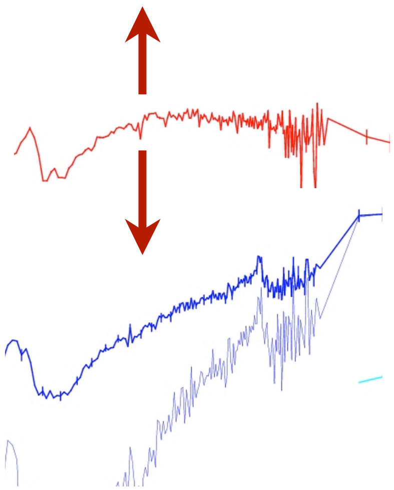
light bending



Fabian & Vaughan 2003
Miniutti et al. 2003
Miniutti & Fabian 2004

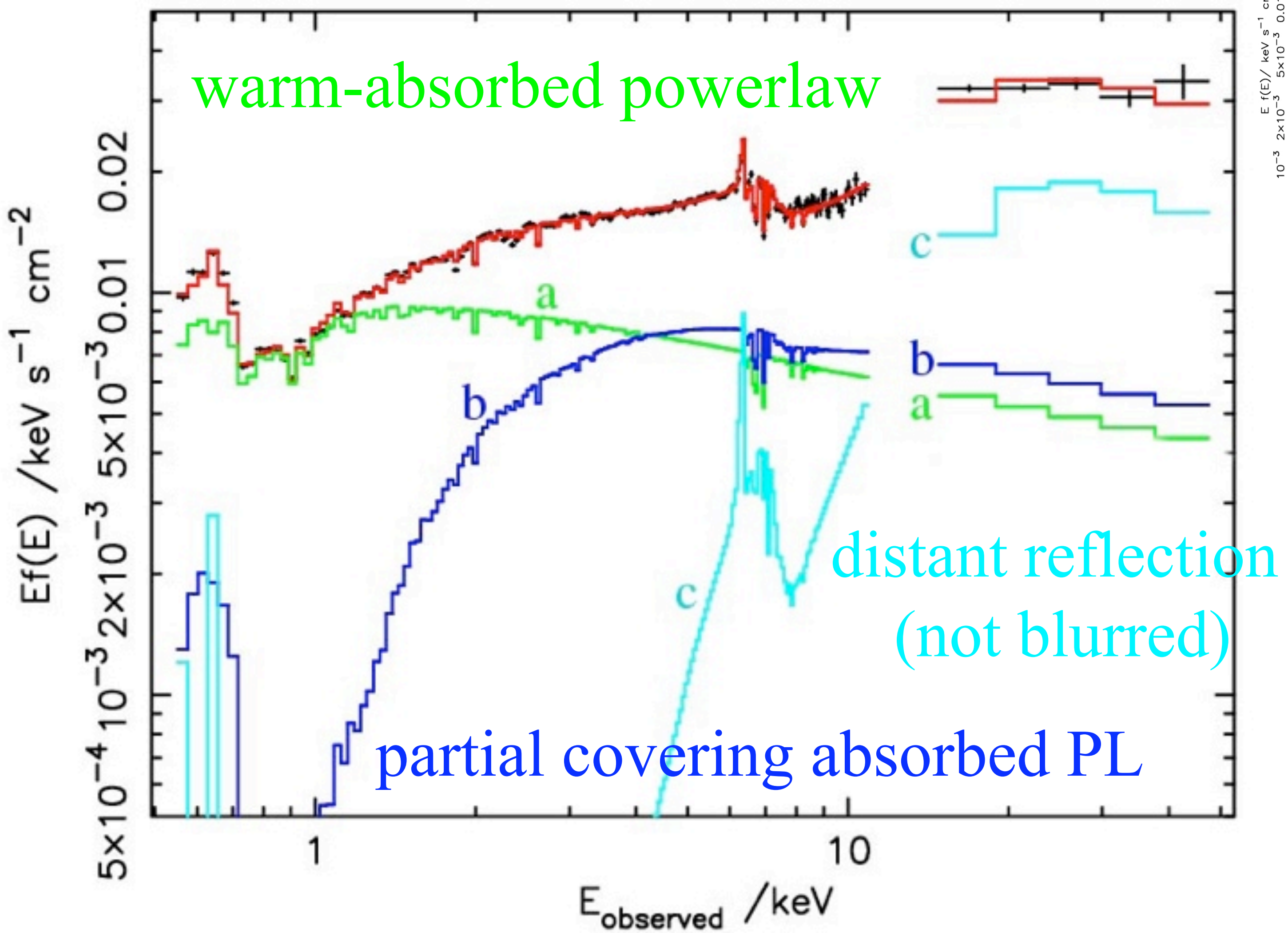
- light rays are bent more onto the disk as the hotspot moves closer to the BH
- reflected intensity more constant than direct intensity
- only inner-disc reflection model that also explains very high reflection albedo (R>3) inferred from hard X-ray band if all that emission is assumed to be unabsorbed reflection

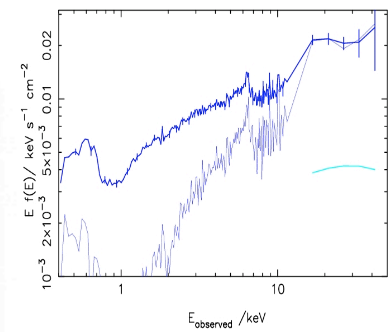
Variable covering absorption can also explain offset component shape and observed spectral variability



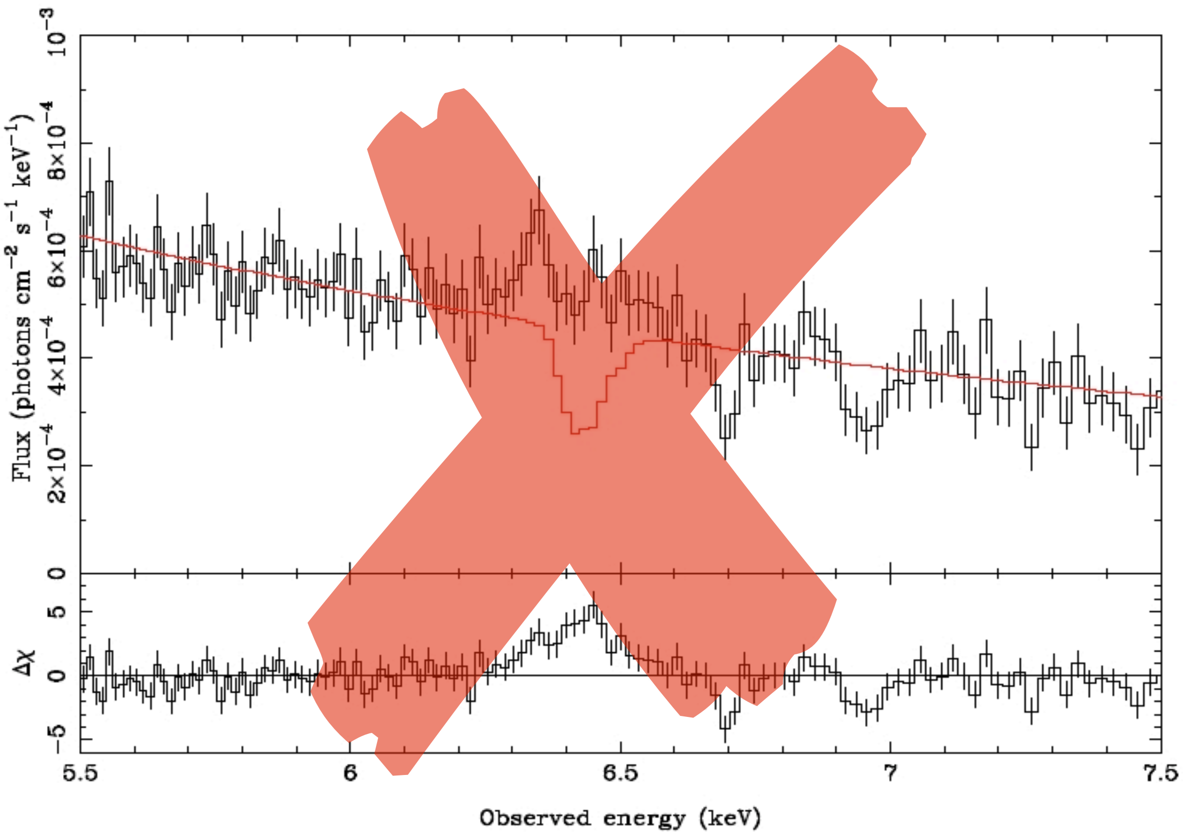
Offset component then represents the amount of continuum flux that is always obscured

Absorption model for MCG-6-30-15





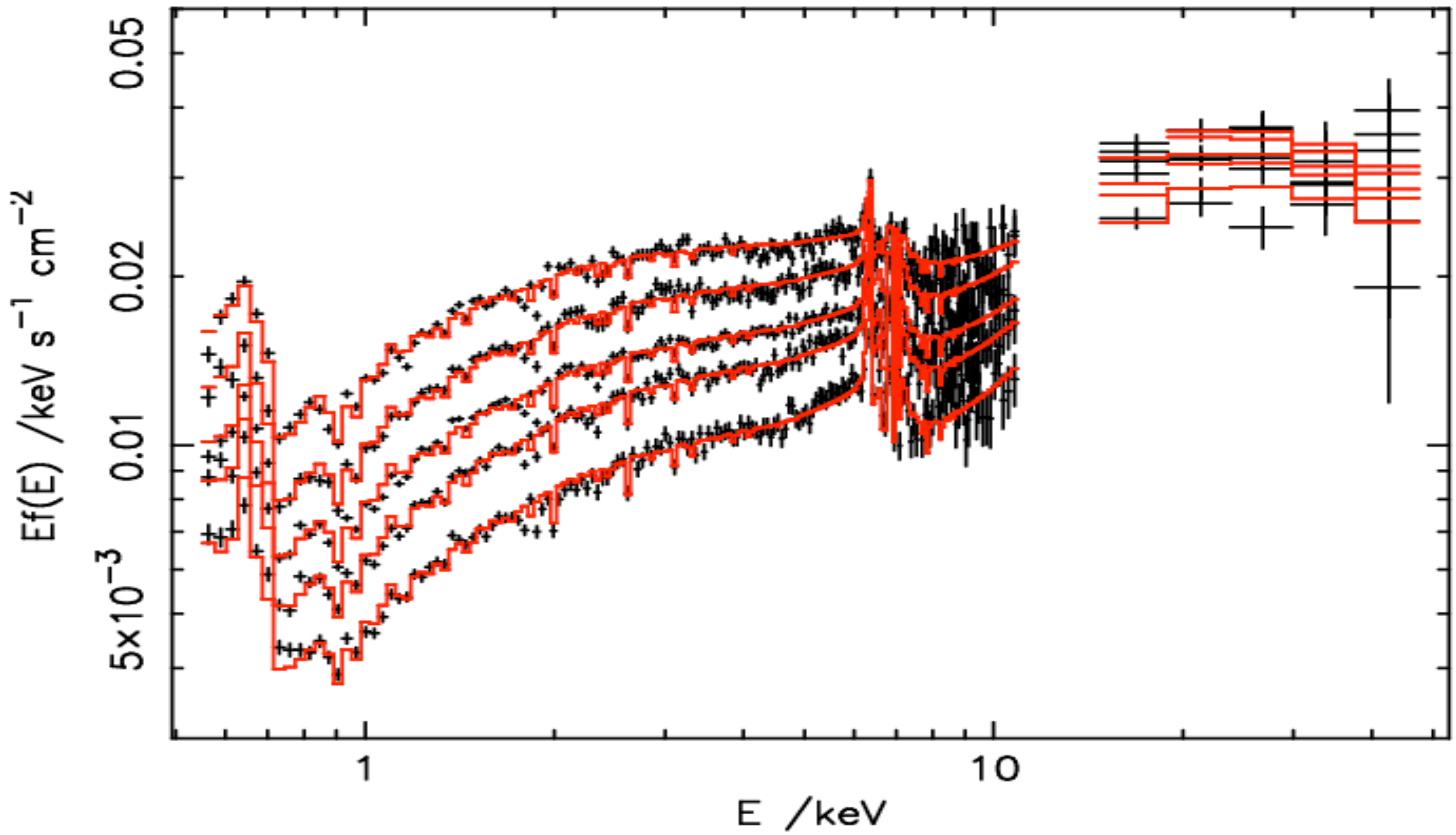
Absence of 6.5 keV absorption does not rule out our model



Young et al (2005) claimed absorption models do not explain the red wing because they would predict 6.5keV Fe Kα absorption, which is not observed

Not a constraint if the zone is allowed to be partially covering continuum. In such a case   The PC zone has ionization < 100 erg cm s^{-1} so the Fe L shell is filled and there is no Kα absorption

model fits to multiple flux states - Suzaku xis & pin simultaneous fit



model also an excellent fit to RGS and HETG data

PC too complex?? the inner regions MUST be complex!

c.f. Brenneman & Reynolds (2006)

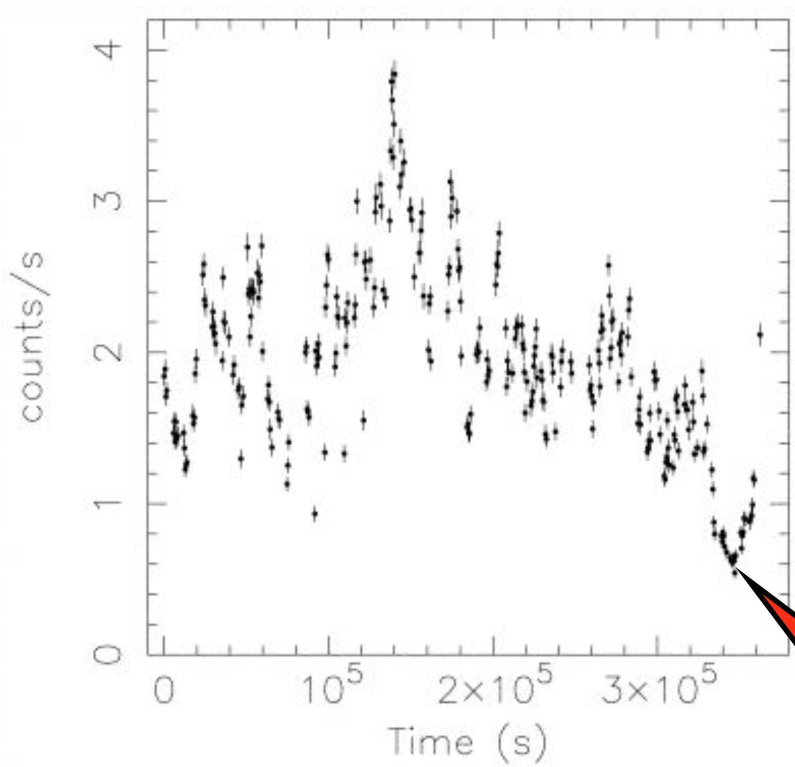
TABLE 1
BEST-FIT PARAMETERS FOR MCG –06-30-15

MODEL COMPONENT	PARAMETER	VALUE: Model 1	Model 2	Model 3	Model 4	Model 5
phabs	N_H (cm^{-2})	0.041	0.041	0.041	0.041	0.041
WA 1	N_{H_1} (cm^{-2})			4.221×10^{22}	1.995×10^{22}	4.172×10^{22}
	$\log \xi_1$			0.837 ± 0.493	1.762 ± 0.085	1.663 ± 0.033
WA 2	N_{H_2} (cm^{-2})				3.489×10^{23}	2.187×10^{23}
	$\log \xi_2$				3.898 ± 0.17	3.454 ± 0.085
Fe edge	$\log N_{Fe}$ (cm^{-2})				17.535 ± 0.026	17.681 ± 0.006
bbody	kT (keV)				$(9.359 \pm 0.281) \times 10^{-2}$	
	flux (photons cm^{-2} s^{-1})				$(3.379 \pm 0.682) \times 10^{-6}$	
po	Γ_{po}	1.907 ± 0.007	1.903 ± 0.007	1.966 ± 0.014	1.947 ± 0.07	2.090 ± 0.007
	flux (photons cm^{-2} s^{-1})	$(1.387 \pm 0.009) \times 10^{-2}$	$(1.363 \pm 0.01) \times 10^{-2}$	$(1.303 \pm 0.063) \times 10^{-3}$	$(1.066 \pm 0.027) \times 10^{-4}$	$(1.182 \pm 0.033) \times 10^{-4}$
kerrdisk	E (keV)		6.576 ± 0.037	6.497 ± 0.043	6.400 ± 0.056	
kerrconv	α_1		5.652 ± 0.629	5.461 ± 1.127	6.555 ± 0.428	6.057 ± 0.255
	α_2		2.863 ± 0.151	2.655 ± 0.255	2.439 ± 0.265	2.776 ± 0.183
	r_{br} (r_g)		5.747 ± 0.816	5.679 ± 1.622	5.139 ± 0.867	5.555 ± 0.662
	a		$0.970^{+0.003}_{-0.015}$	$0.997^{+0.001}_{-0.035}$	0.997 ± 0.001	$0.989^{+0.009}_{-0.002}$
	i (deg)		20.405 ± 2.236	23.800 ± 1.906	29.700 ± 1.498	29.699 ± 0.709
	r_{min} (r_g)		1.738	1.278	1.278	1.615 ± 0.074
	r_{max} (r_g)		113.260 ± 1.692	102.109 ± 1.178	134.060 ± 0.638	397.028 ± 494.559
	flux (photons cm^{-2} s^{-1})		$(2.980 \pm 0.359) \times 10^{-4}$	$(1.781 \pm 0.332) \times 10^{-5}$	$(2.677 \pm 0.515) \times 10^{-6}$	
refl	Fe/solar					10.000 ± 0.713
	$\log \xi_{refl}$					2.027 ± 0.001
	Γ_{refl}					2.090 ± 0.006
	flux (photons cm^{-2} s^{-1})					$(1.512 \pm 0.317) \times 10^{-7}$
χ^2/dof		4577/1106 (=4.139)	960/1096 (=0.876)	934/1094 (=0.854)	1742/1375 (=1.267)	1793/1374 (=1.305)

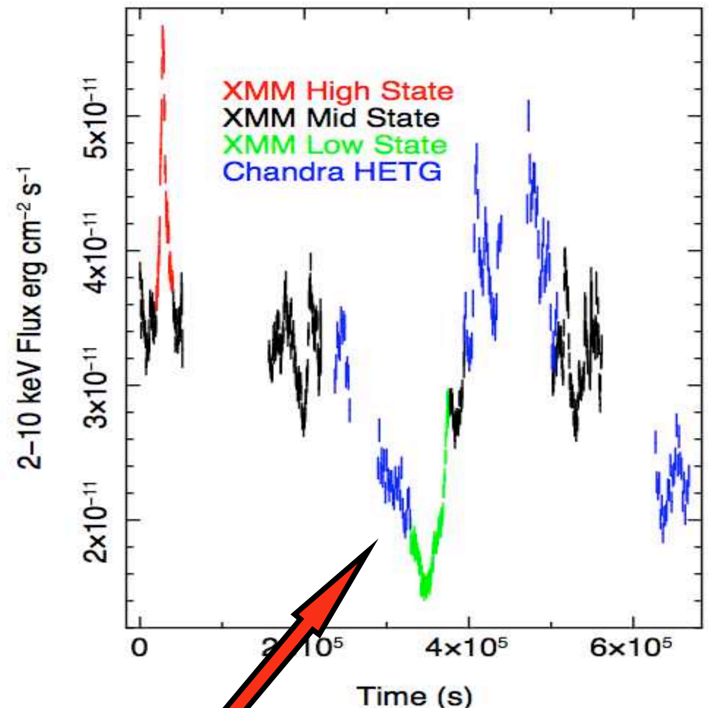
NOTES.—Models 1–3 are from 2–10 keV, models 4 and 5 also include energies from 0.6–2.0 keV. Error bars quoted are all at the 1 σ level except for those on the spin parameter, which are all at 90% confidence. Errors for the column densities of the warm absorbers cannot be well constrained due to their magnitudes. For model 5 the kerrconv component has no line energy or flux parameters, and the large error bars on the maximum disk radius indicates that this parameter is not robustly constrained.

fitting XMM-Newton mean spectrum only, 0.6-10 keV, but 19 parameters

Occultation events in MCG-6-30-15 & NGC 3516



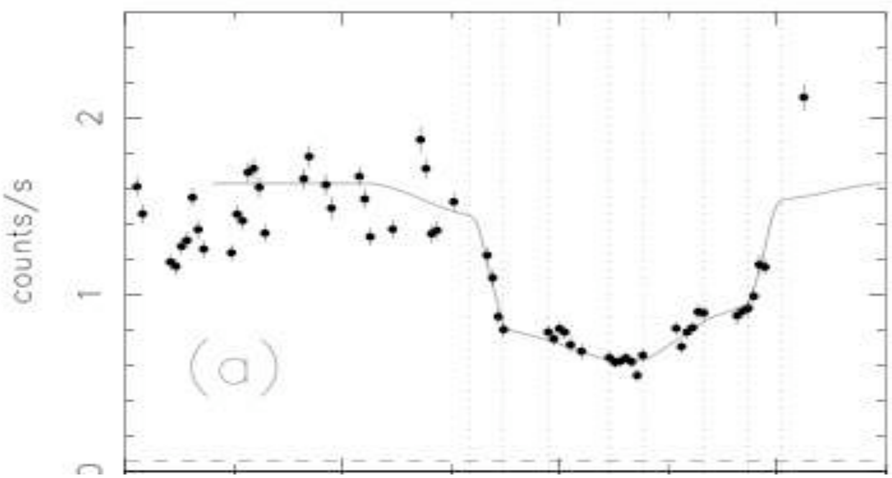
McKernan & Yaqoob 1998



Turner et al 2008

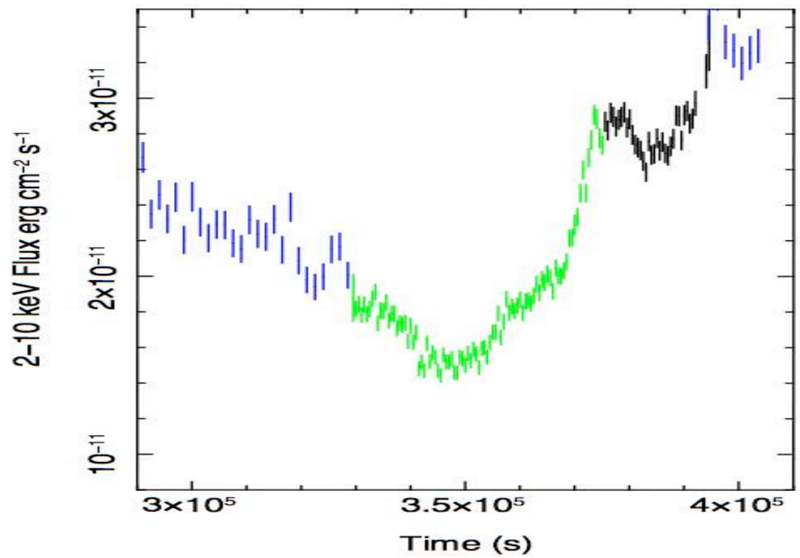
Deep dips - eclipse type events ?

Flat Bottomed Dips



MCG-6-30-15 McKernan & Yaqoob ’98 - dip shape from inhomogeneities in emitter

Effective resolution x10^{6} greater than with current X-ray optics

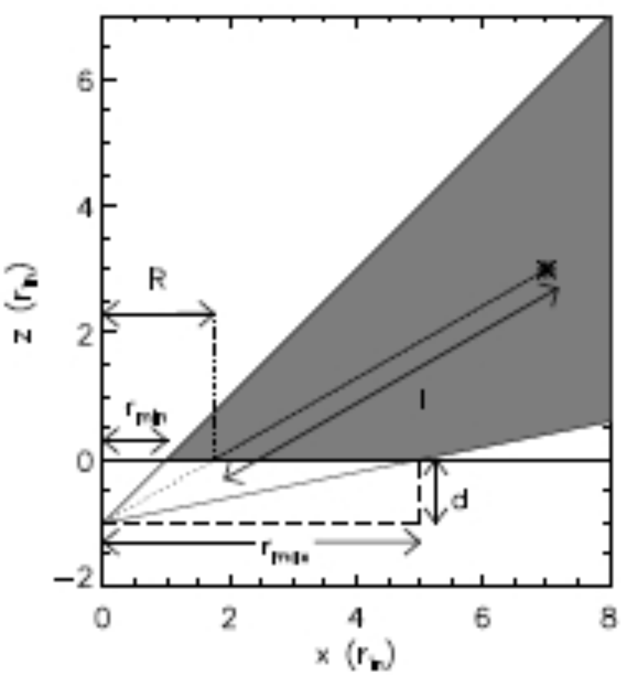


NGC 3516 Turner et al ‘08- dip shape from inhomogeneities in emitter or absorber

Multi-dimensional modelling of X-ray spectra for AGN accretion-disk outflows

MNRAS in press

S. A. Sim[1], K. S. Long[2], L. Miller[3], T. J. Turner[4,5]



simplified parameterized wind geometry, but full 3D Monte-Carlo radiative transfer

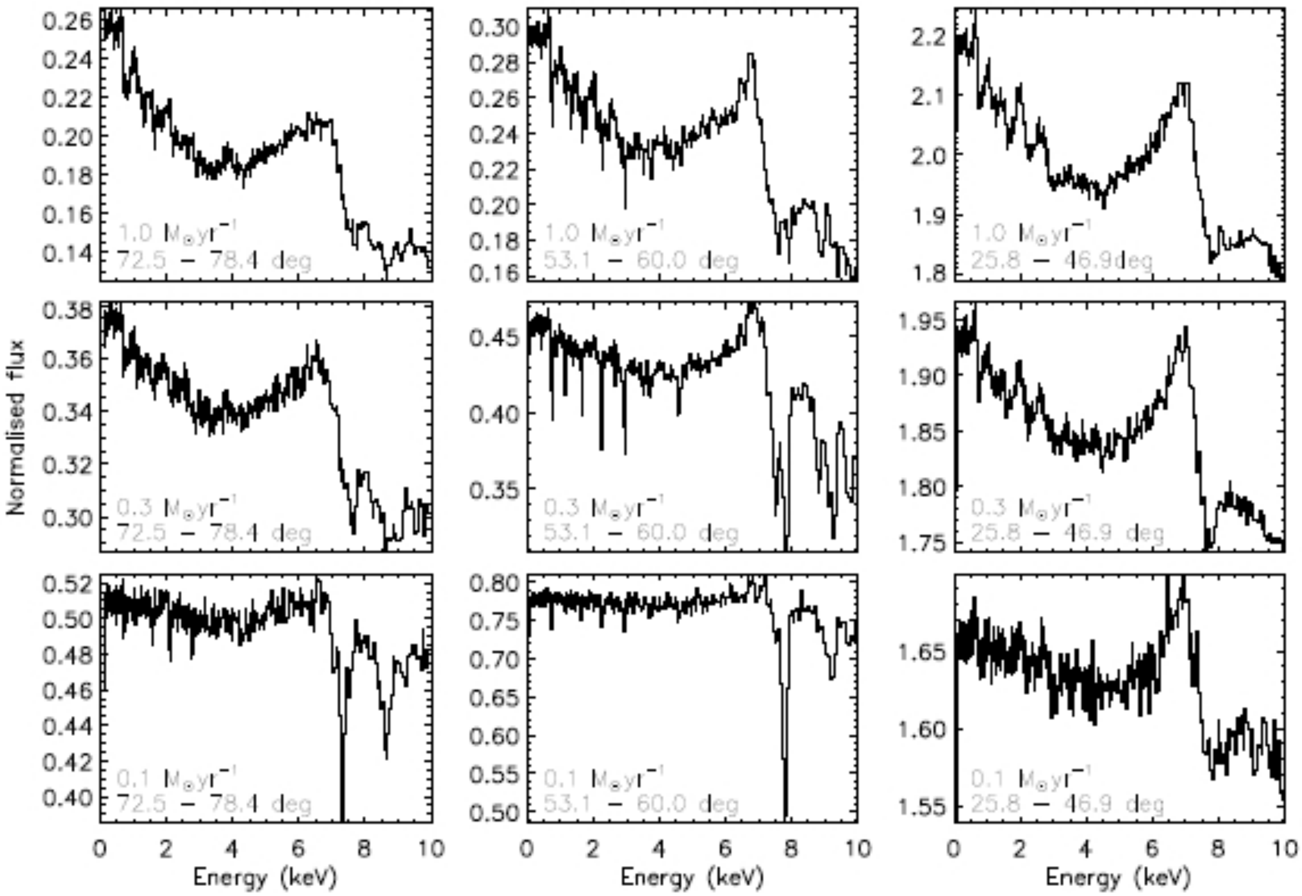
Limitations: currently only K shell transitions, L shell transitions coming soon! Also currently smooth and steady-state: clumpy time-variable winds are next

Element	Ions	Element	Ions
C	V – VII	S	XV – XVII
N	VI – VIII	Ar	XVII – XIX
O	VII – IX	Ca	XIX – XXI
Ne	IX – XI	Fe	XXIII – XXVII
Mg	XI – XIII	Ni	XXV – XXIX
Si	XIII – XV		

a grid of wind models

viewing angle increasing away from disk

increasing mass loss rate



Summary

- Fitting mean AGN spectra provides insufficient information to diagnose emission/absorption regions - studying spectral variability is key - using broadest possible energy band
- Variable covering of absorbers can explain spectral shape, flux variability and spectral variability in Seyferts, inc. MCG-6-30-15 (presence of blurred reflection component not ruled out-but absorption likely very important in shaping observed X-ray data)
- MCG-6-30-15 data well fit by additional partial-covering absorption plus some distant reflection
  - explains the 2-6 keV ‘red wing’
  - explains relative constancy of the hard X-ray flux
  - reduces the otherwise R>>1 reflection albedo
  - explains the soft excess
- Physical explanation - disk winds - developing models look promising
- Need Con-X to make the distinction between these possibilities