Absorption and wind reprocessing of X-rays from the inner regions of AGN Lance Miller (Oxford)

I shall look in detail at the spectral variability of well-known AGN (esp Mrk 766 & MCG-6-30-15) and argue that much of what we observe is dominated by the effects of absorption (including partial-covering absorption) likely from an accretion disc wind. I shall then describe the first stage in modelling the radiative transfer through such a wind.

collaborators: Jane Turner (UMBC/GSFC), James Reeves (Keele), Steve Kraemer (Catholíc), Stuart Sím (MPA), Knox Long (STScI)

The initial problem.



Figure 1. (a) Ratio between data and model from fitting a power law to the 0.5-11 keV data. (b) Ratio from fitting a power law and the empirical warm absorber model (see text). (c) Deconvolved spectrum of the Fe K α band, showing the total LAOR model and the continuum with and without (dashed) the reflection component for a model with reflection from an ionized disc. For clarity, the data have been rebinned and only the single-event data

Wilms et al 2001

spectral variability is key:



SVD-PCA MCG-6-30-15





The baseline modeL



model fits to multiple flux states - Suzaku xis & pin.



model fits to multíple flux states - XMM-Newton mean RGS (símultaneous fit with pn)



Chandra data demonstrate the existence of complex ionised absorption: (i) log $\xi \approx 0.5 \&$ (ii) log $\xi \approx 2.0$



Chandra data demonstrate the existence of complex ionised absorption: (iii) log $\xi > 3$



- highly ionised outflow log ξ > 3, v ≃ 1800 km s⁻¹ (Lee et al 2001, Young et al 2005)
- these lines significantly affect the Fe K α edge at low resolution

•model fits to multiple flux states - Suzaku mean spectrum. (same model parameters as multiple flux states)



towards a better future: wind models

- partial covering implies absorber and source are likely of comparable size
- coupled with 20ksec variability implies a (likely clumpy) accretion disc origin for the absorber(s)
- we should expect composite absorption and reflection from a clumpy wind
- winds are expected from high Eddington-ratio AGN (e.g. King & Pounds 2003)



Multi-dimensional modelling of X-ray spectra for AGN accretion-disk outflows MNRAS 388, 611 (2008)

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

NB significant improvement in over widely-used reflion "slab" model - assumes a constant density slab with no atmosphere - accretion disc photospheres are not expected to look like that (e.g. Nayakshin et al. 2000)

Sim et al. 2008

a gríd of wind models

Viewing angle increasing away from disk 💳 🗲



(each grid point requires ~ 8 hours on 4 nodes of Beowolf cluster)

Sim et al. 2008

try it against some data...

2-10 keV XMM-Newton mean spectrum of Mrk 766



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Element	Ions	Element	Ions	O g. for		1 1 1 1 1		
С	V – VII	S	XV – XVII	••••	-			-
N	VI – VIII	Ar	XVII – XIX	-	-			, ALM A
0	VII – IX	Ca	XIX – XXI		-	F	e K	
Ne	IX - XI	Fe	XXIII – XXVII		-		. distri	MAMMER -
Mg	XI – XIII	Ni	XXV – XXIX		-		I WANT'	_
Si	XIII – XV			Щ.		c ⁱ		
		1			Fe L	a tahili	h that	-
Initial limitations: only K-shell ions, L. M-								-
shall ions now included New also						ALMAN .		
311011								
improved ionization balance and thermal $_{0.}$								
balanc	e calculat	ion. Also	currently	Ő.	¹ I I ^{1.0}	energy(keV)	ÎÔ.	100.
smooth and steady-state: clumpy time-				E /keV				
variable winds are next.								

Summary

- Fitting to mean spectra alone provides insufficient information to diagnose emission/absorption regions - spectral variability is key. Essential to use full range of available data: e.g. MCG-6-30-15 we can fit over entire the range 0.5-40 keV at grating and CCD resolution, combining Chandra HETGS, XMM-Newton EPIC pn/RGS and Suzaku XIS/PIN (Miller et al. 2008)
- MCG-6-30-15 requires kinematically-distinct multiple absorption zones covering a wide range of ionisation. The full data is well fitted by additional partial-covering absorption plus some distant reflection
 - explains the 2-6 keV red wing
 - explains the relative constancy of the hard X-ray flux
 - reduces the otherwise R>>1 reflection albedo
 - explains the soft excess
 - current observations cannot measure BH spin
- We expect winds to be driven off accretion discs. We have made the first steps at modeling the radiative processes in an accretion disc wind using 3D Monte Carlo (Sim et al. 2008)