Line and continuum reflection in NLSy1

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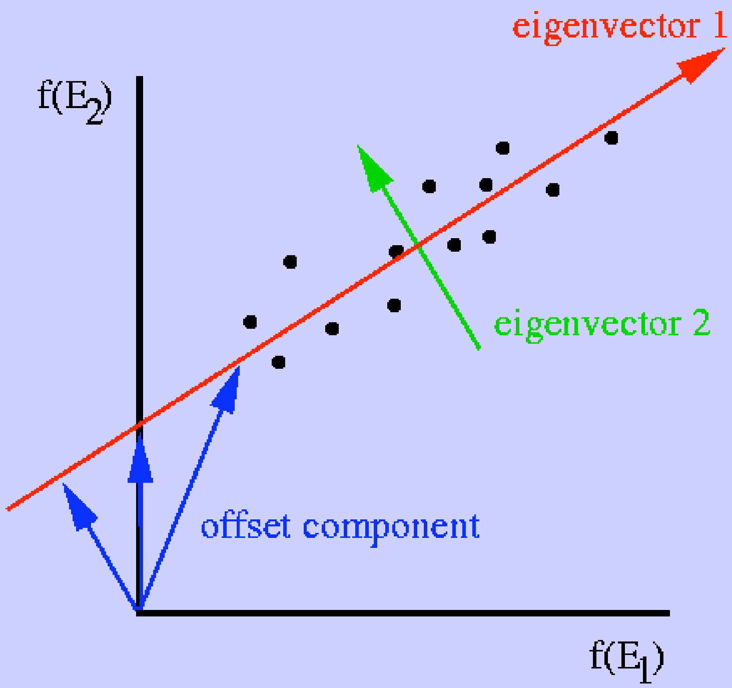
Line and continuum reflection in NLSy1

- If FeK emission arises from accretion disk reflection, its flux should vary and correlate with X-ray continuum
  - FeK emission is known to vary but statistically-significant correlation has not previously been demonstrated - until our long observation of Mkn766 (Jane Turner's talk: Miller et al 2006, July A&A)
  - but the FeK red-wing in particular appears to be constant and not correlated with continuum (motivation for light-bending models)
- Use spectral variability in NLSy1 to test/explain this
  - evidence for ionised FeK directly correlated with continuum variations in long observations of Mkn766 (40 + 120 + 450 ksec)
  - disentangle continuum reflection components using strong spectral variability: analyse using Singular Value Decomposition PCA
  - discuss contribution and nature of reflection components
  - compare with MCG-6-30-15

SVD principal components analysis



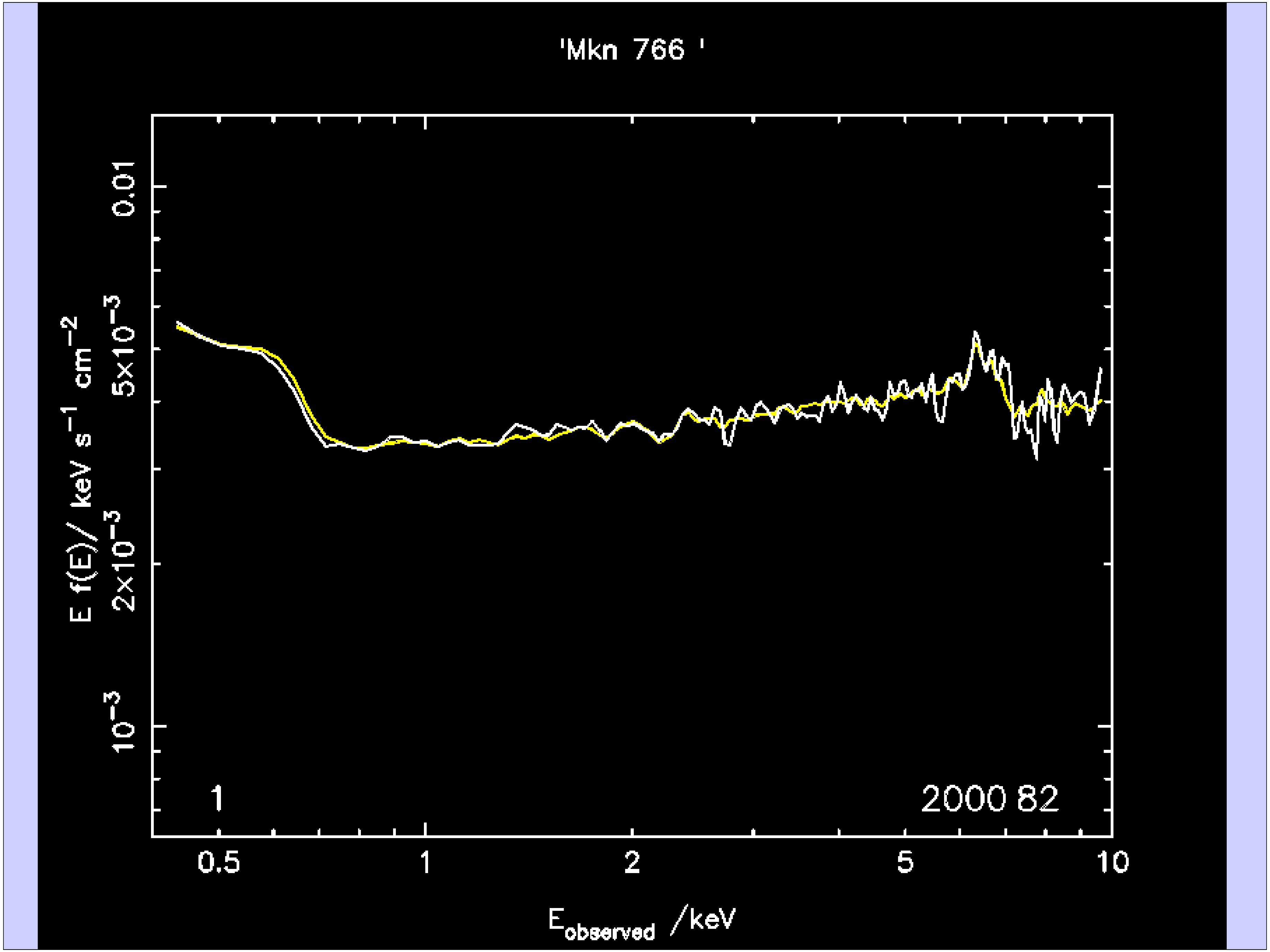
PCA assumes data (e.g. time-varying spectrum) can be described by addition of orthogonal spectral components (eigenvectors) whose amplitudes vary with time

Each axis corresponds to the flux in one bin of photon energy. Each "point" is a spectrum of a single timeslice. PCA is a rotation of coordinate axes to align them along the direction of variation

As well as these orthogonal components we can define an "offset component" from the origin, but note that this does not have a unique definition

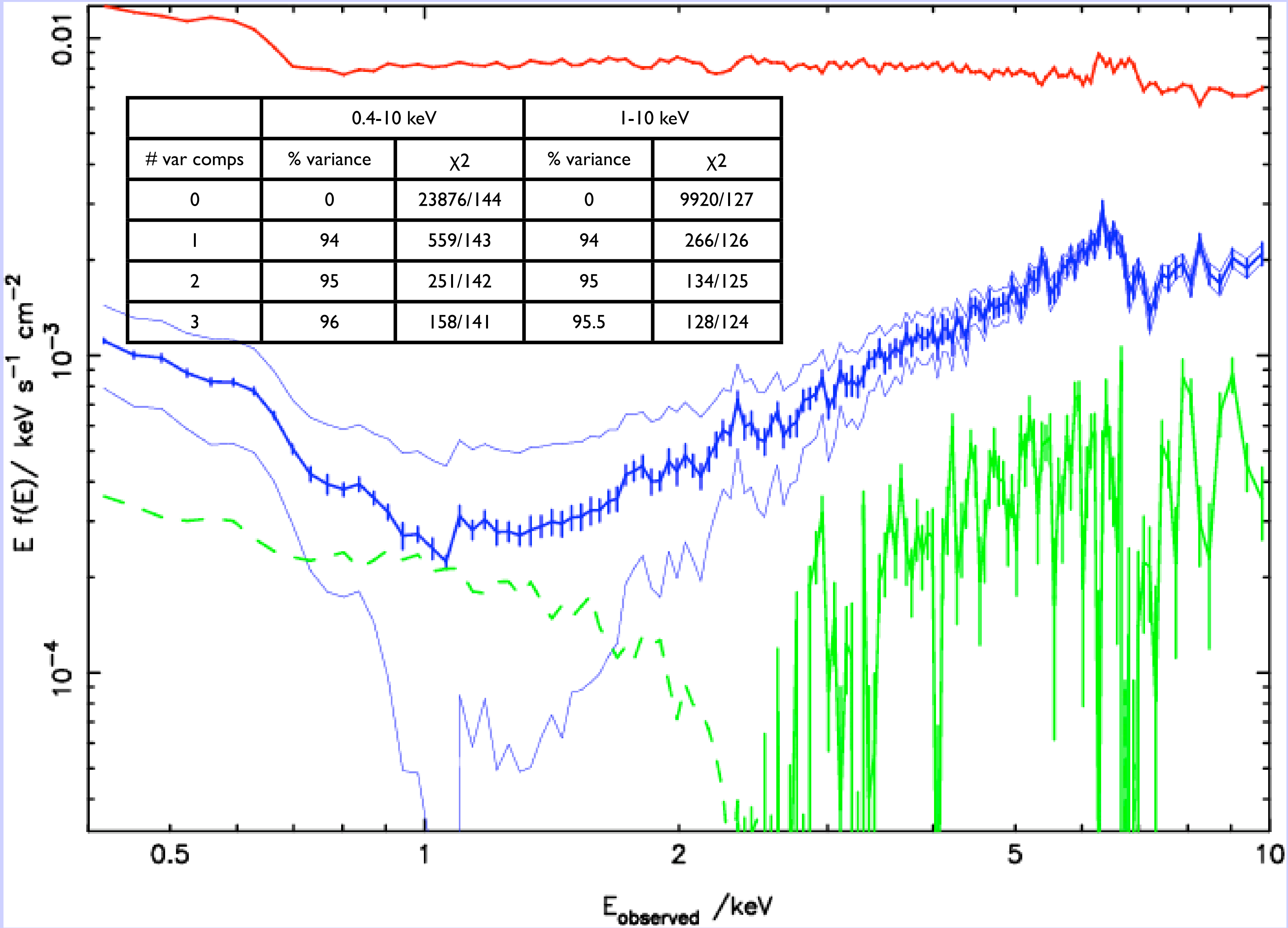
Normally need as many datapoints (*n* timeslices) as axes (*p* spectrum energy bins) otherwise the coordinate rotation is not uniquely defined. Can be overcome when $n<p$ using Singular Value Decomposition of the covariance matrix to produce n eigenvectors. *SVD allows us to do PCA at the full instrumental resolution.*

Note: multiplicative (eg absorption) variations not correctly handled (treated as additive) although *constant* absorption is fine.



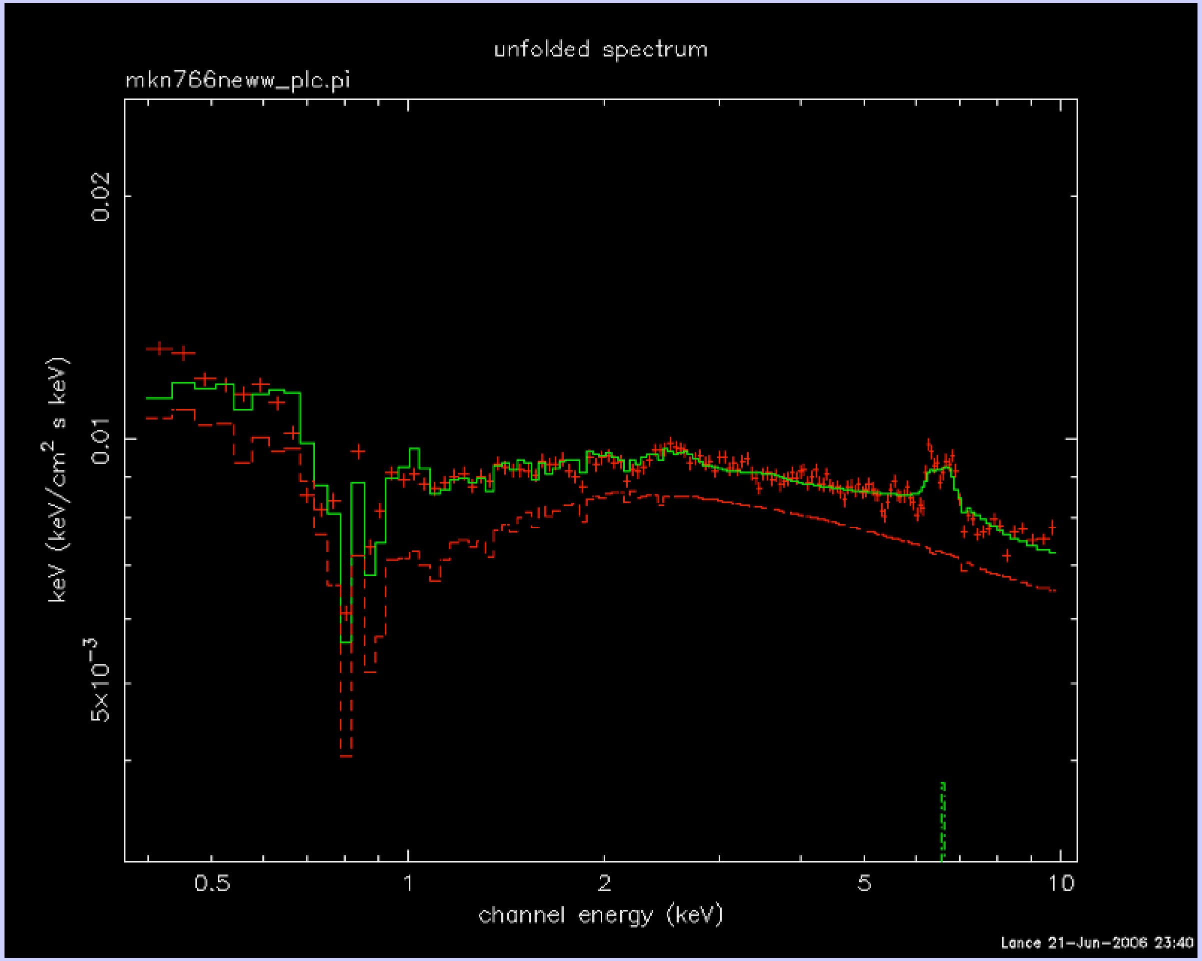
'Mkn 766 '
E f(E) / keV s^-1 cm^-2
0.01
5×10^-3
2×10^-3
10^-3
0.5
1
2
5
10
E_observed /keV
1
2000 82

PCA of Mkn766 spectral variations



	0.4-10 keV		1-10 keV	
# var comps	% variance	χ2	% variance	χ2
0	0	23876/144	0	9920/127
1	94	559/143	94	266/126
2	95	251/142	95	134/125
3	96	158/141	95.5	128/124

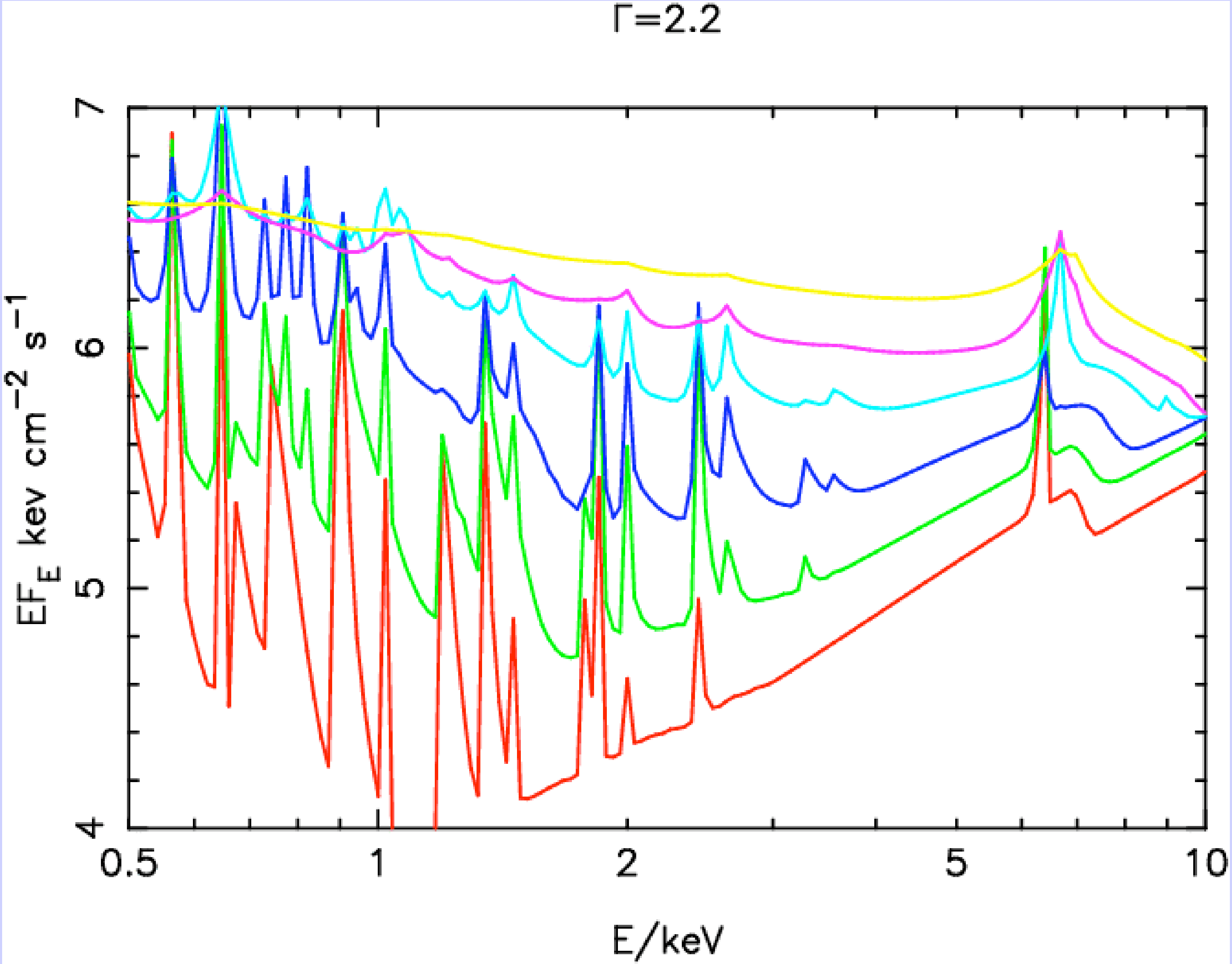
Mkn766 spectral variations: eigenvector 1



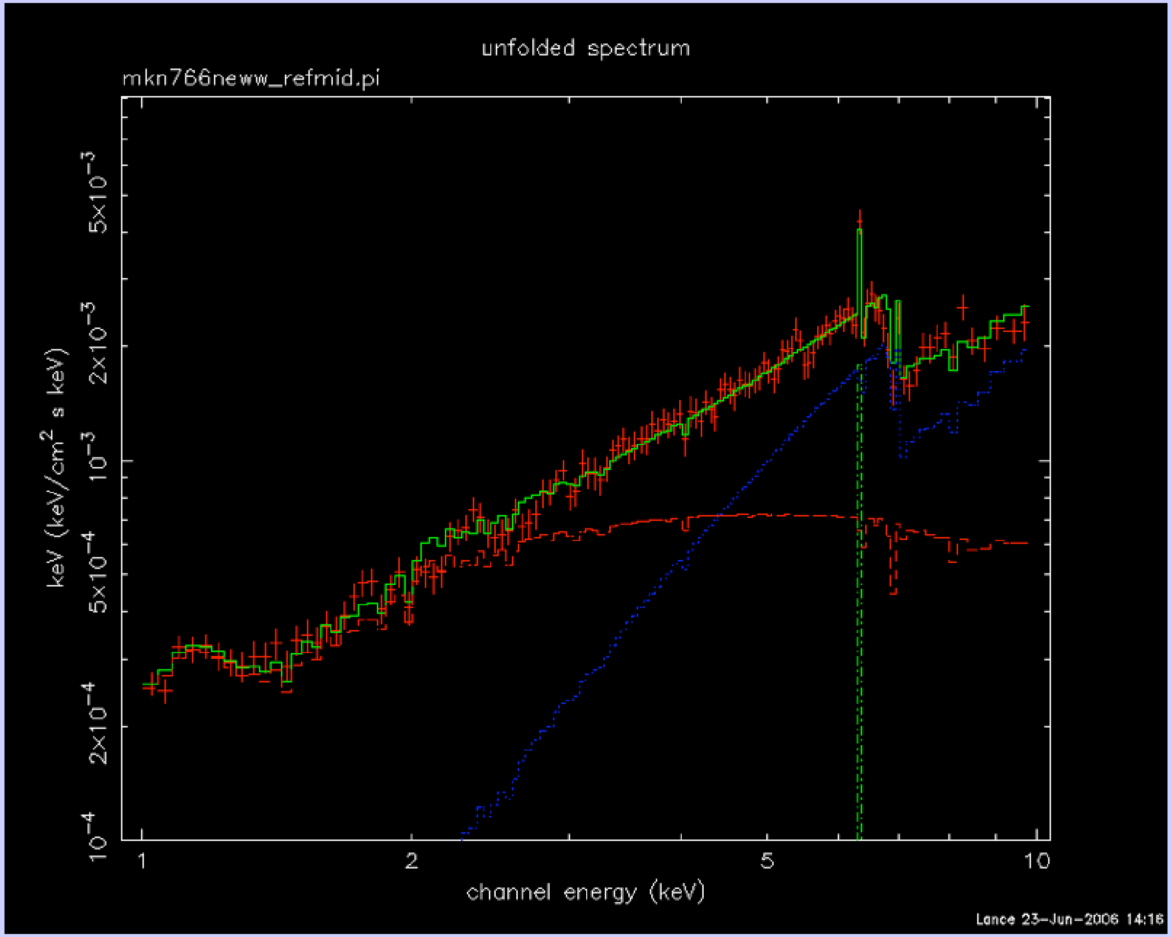
- ionised reflection (ξ~1000: reflion) *varying with power-law*
- blurring from r~100rg
- warm absorption (ξ~100: xstar)

$\chi 2$ = 305/128 (1-10keV)
(affected by PCA decomposition residuals)

ionised reflection models (Ross & Fabian 2005)



Mkn766 spectral variations: offset component



$\chi2$ = 124/128 (1-10keV)

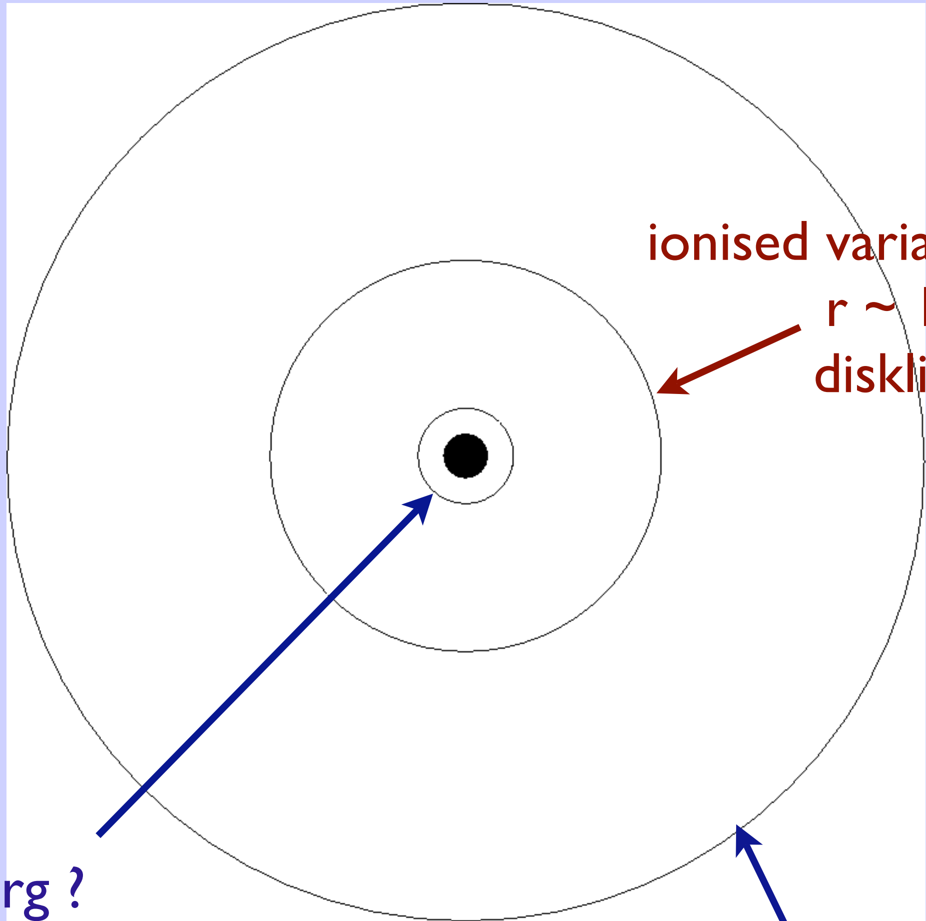
[434/145 (0.4-10 keV) but the uncertain systematic offset, variable absorption and known extended emission make the soft band unreliable]

neutral blurred reflection: 157/128

ionised blurred reflection 540/128

- strong Fe edge and hard power-law continuum implies cold reflection
- has associated narrow FeXXVI 6.97 keV absorption probably requiring $N_H > 10^{23}$ cm^{-2}
- weak Fe 6.4 keV emission
  - relativistic blurring?
  - geometry?
  - moderate ionisation (cf Ross&Fabian)?
  - Compton-scattering within high-ionisation absorber?

Where does the constant reflection come from?



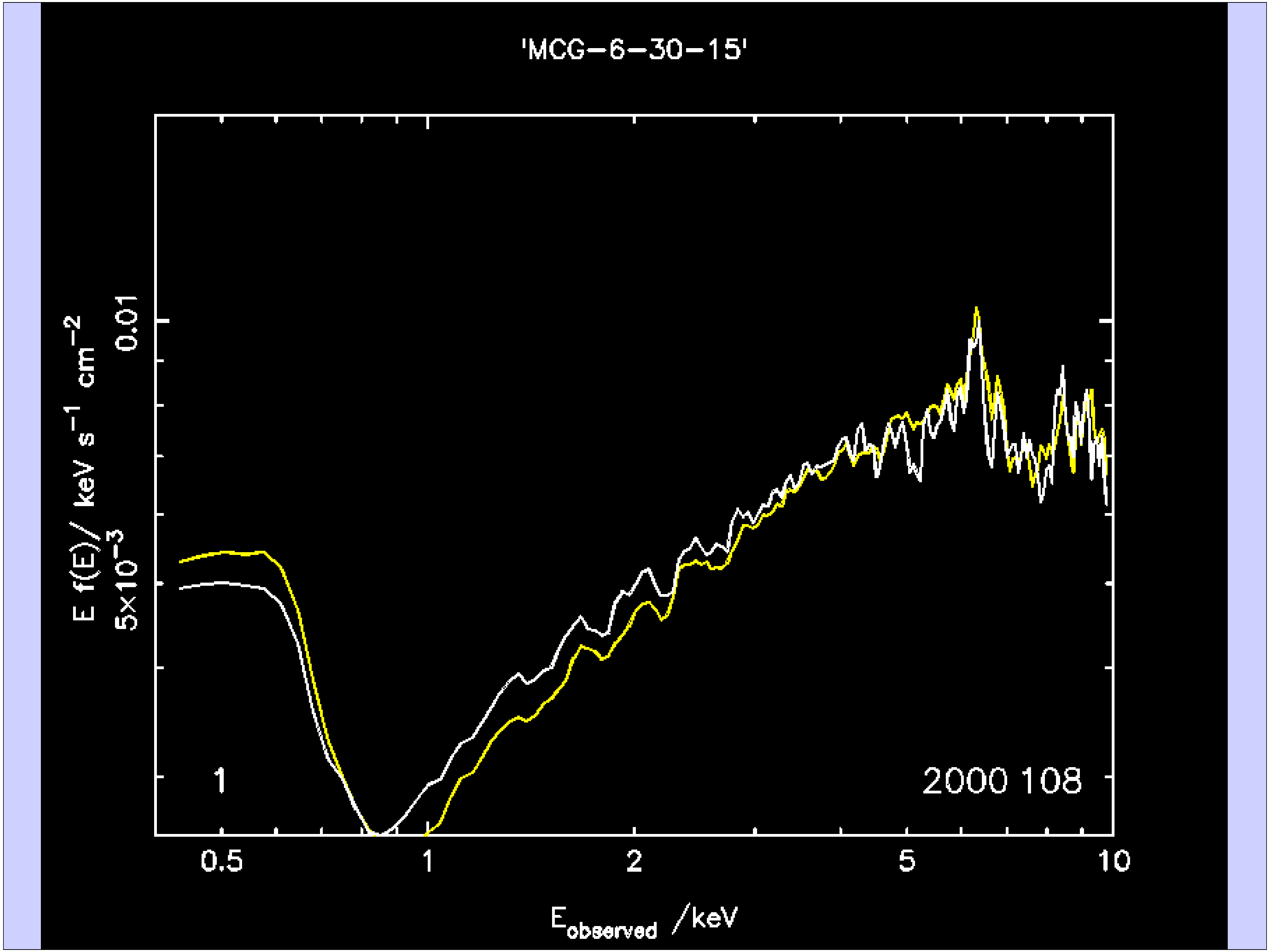
ionised variable reflection
r ~ 100 rg
diskline! ✔

r ~ 6 rg ?
why constant?
(can't invoke light-bending)
why neutral?
why unblurred 6.97keV abs?

r > 100 rg ?
why such weak Fe emission?

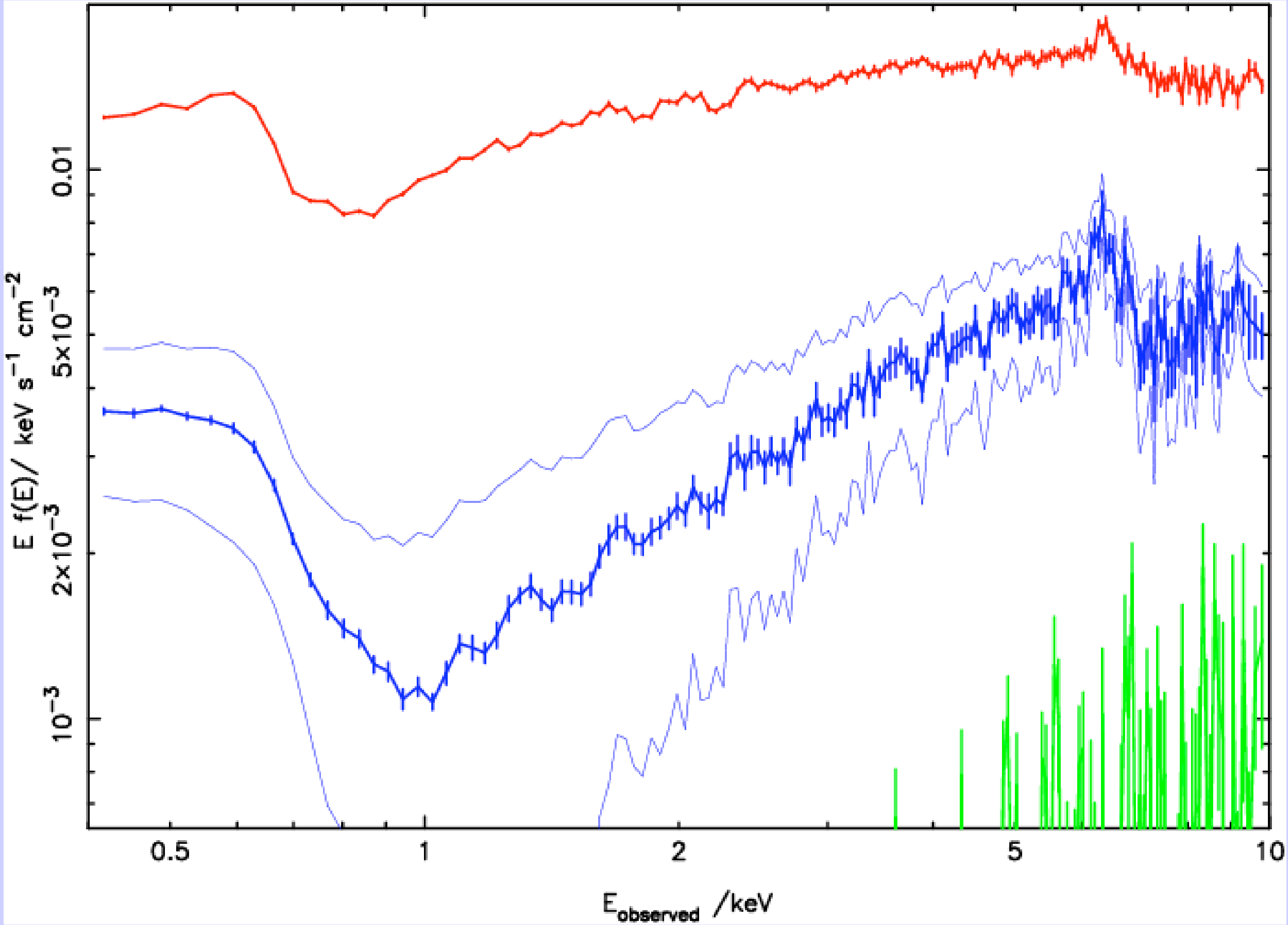
Mkn766 spectral variations: conclusions

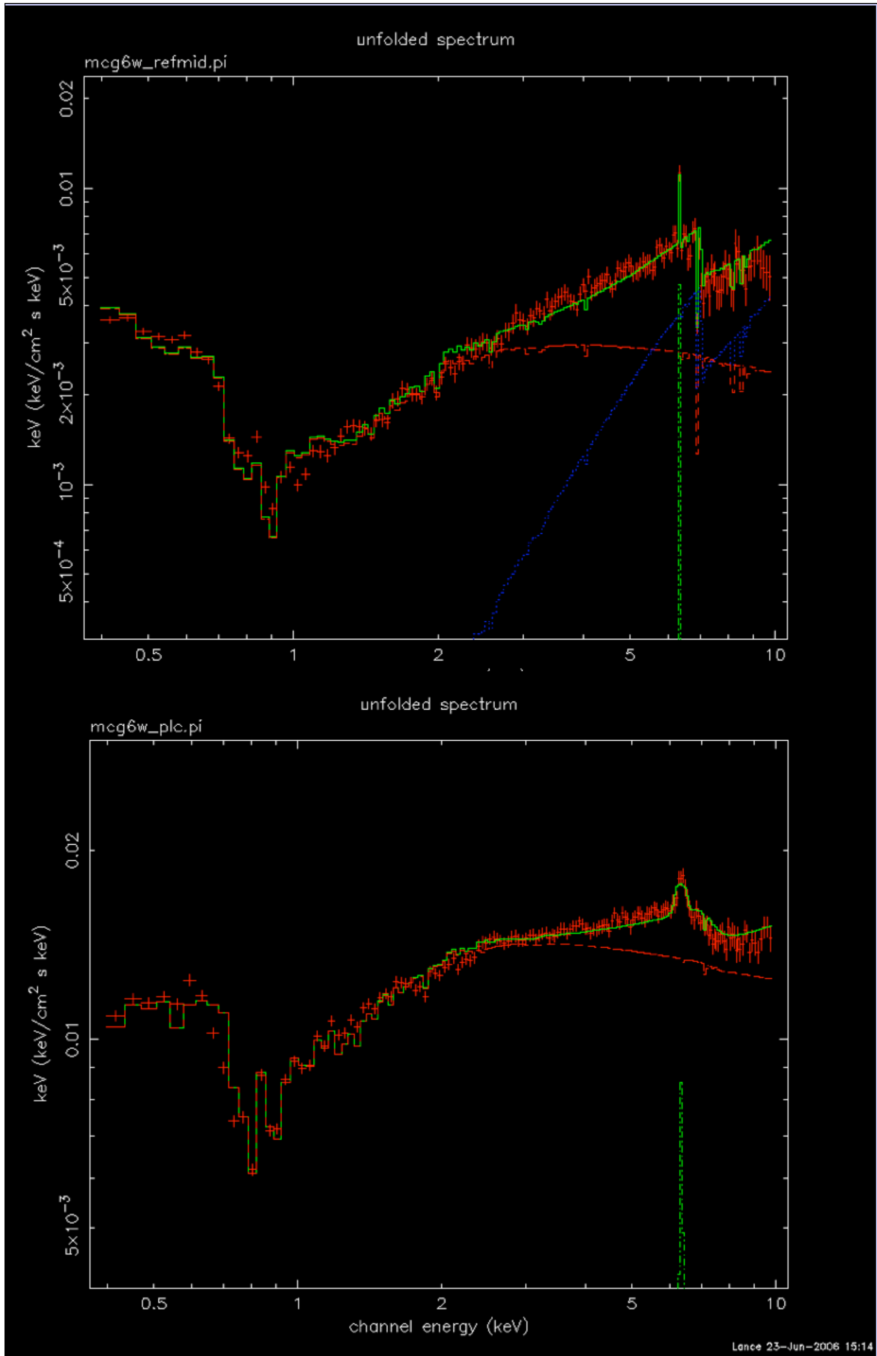
- variable component: power-law plus ionised disk emission from r~100rg
  - future observations may detect reverberation delay
- additional cold reflection component: probably from r>>100rg (lower ionisation than variable component; little variation; unblurred absorption)
  - need to explain weak neutral Fe emission
- some amount of absorption variation
- ~30% variation of cold reflection component also detectable but difficult to disentangle from absorption variation



'MCG-6-30-15'
E f(E) / keV s^{-1} cm^{-2}
0.01
5×10^{-3}
1
2000 108
0.5
1
2
5
10
$E_{observed}$ /keV

PCA of MCG-6-30-15 variations

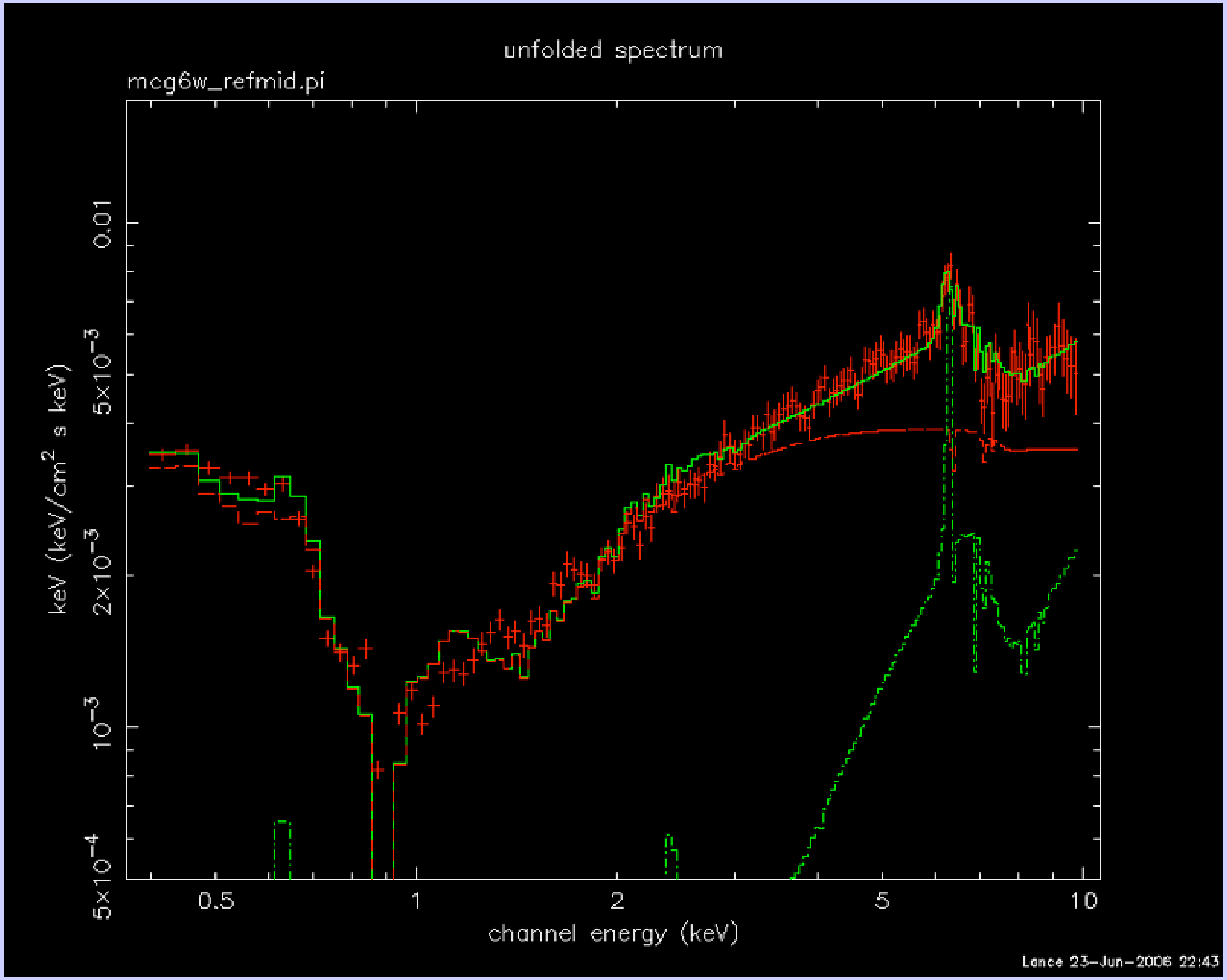




MCG-6-30-15

- same components visible as in Mkn766, with greater warm absorption
- also shows variable warm absorption
- variable disk-reflection component appears to have lower ionisation reflection (ξ~100)
- Fe line Doppler-broadened, consistent with r~100-200rg
- variable disk-reflection component may have a contribution from more relativistically-blurred emission but this is not required
- same problem with the constant component: is it blurred or just line-weak?

low-ionisation reflection (MCG-6-30-15)



$\chi2$ = 286/146 (1-10keV)

Γ=2.17
reflion ξ=140
R(in)=200 rg

Conclusions

- variability analysis allows different physical components of emission to be separated
- long observations covering wide flux range required
- disk reflection (low-moderate ionisation) varying with illuminating power-law has clearly been detected and may be a common feature in NLSy1
- reverberation mapping within reach
- lower-ionisation constant reflection also present
- hard to understand why a constant neutral component should be emitted close to the black hole when variable disk reflection is also seen
- variable warm absorption ($\log\xi \sim 1.5$) and high column $>10^{23}$ with $\log\xi \sim 4$ also detected in front of the constant reflection