X-ray Spectral Signatures of Outflows in AGN

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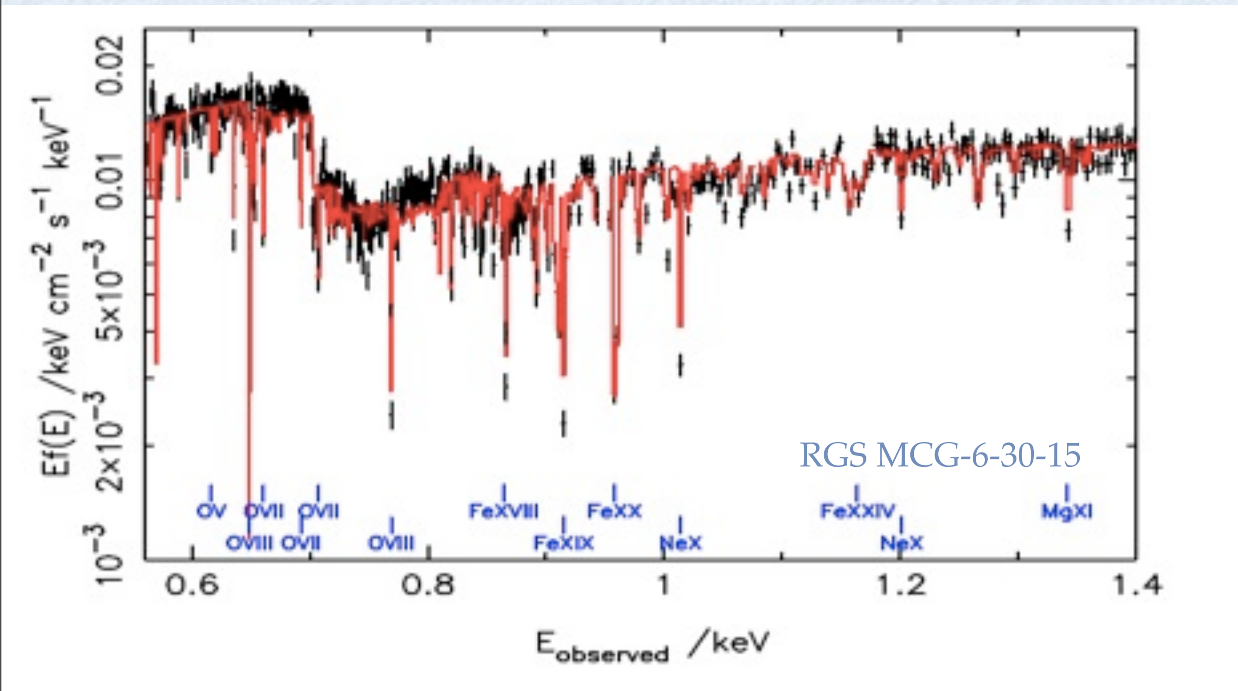
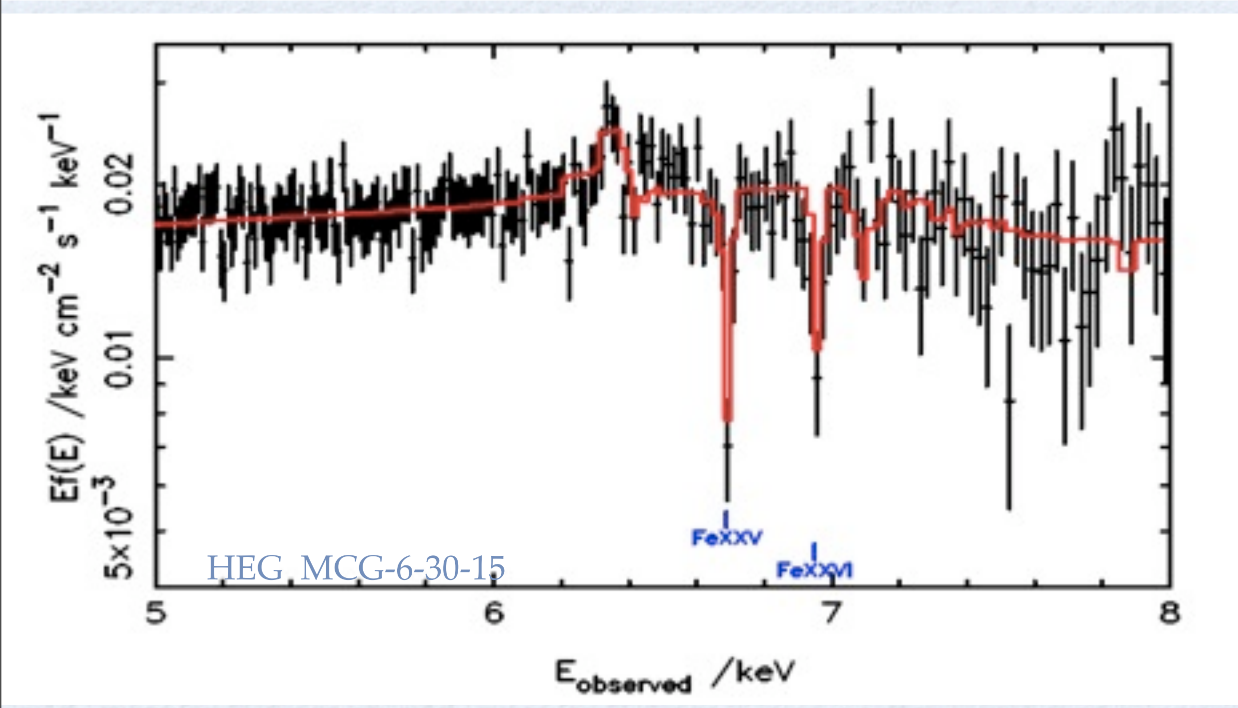
Overview

- X-ray observational results
- Absorption models for observed X-ray properties of AGN

X-ray signatures of circumnuclear gas





Miller, Turner & Reeves 2008

Intrinsic X-ray absorbers in most nearby AGN (e.g. Blustin et al 2005, McKernan et al 2007)

Multiple X-ray zones

X-ray gas covers ~6 orders mag in ξ

Columns 10^{20} - few x 10^{24} cm^{-2}

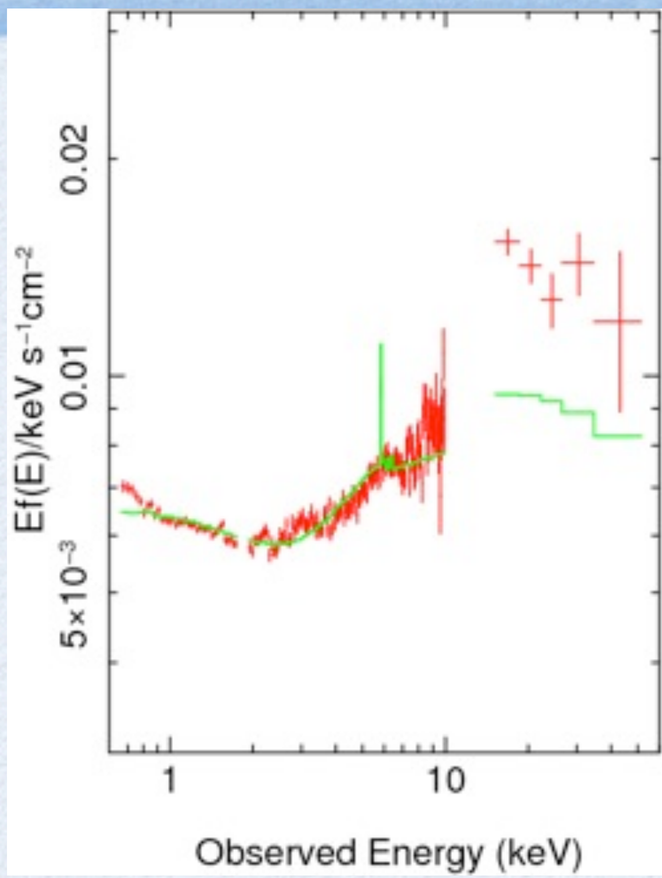
Few hundred - few thousand km/s outflow, low N_H/ξ zones

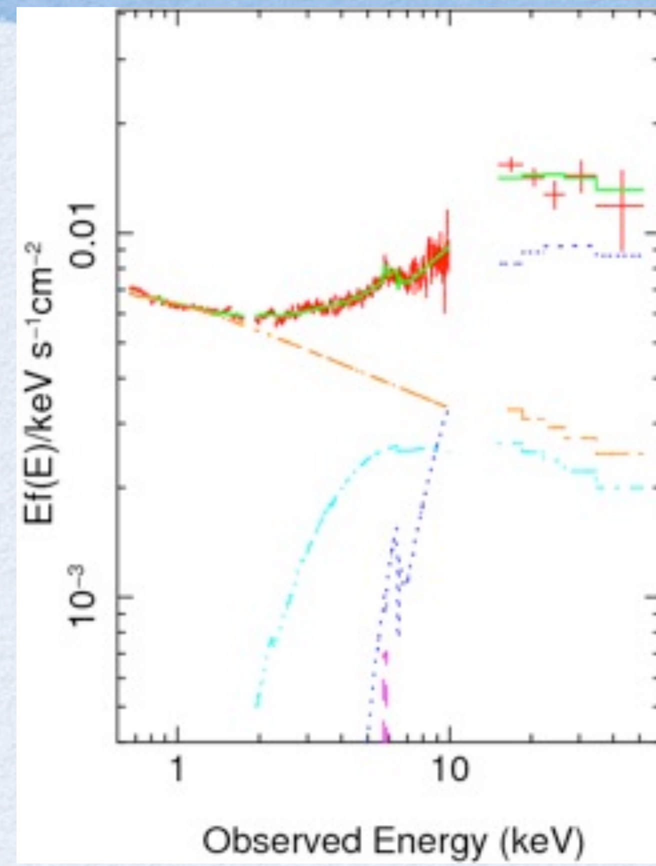
Few thousand - tens of thousands of km/s for highest N_H/ξ zones (e.g. 13,000 km/s in Mrk 766, L. Miller et al 07, also see talk by Tombesi)

Some zones are partial-covering - natural extension of UV absorber complex

Wind? -inevitable for sources accreting at high fraction of Eddington (King & Pounds 2003, King 2010)

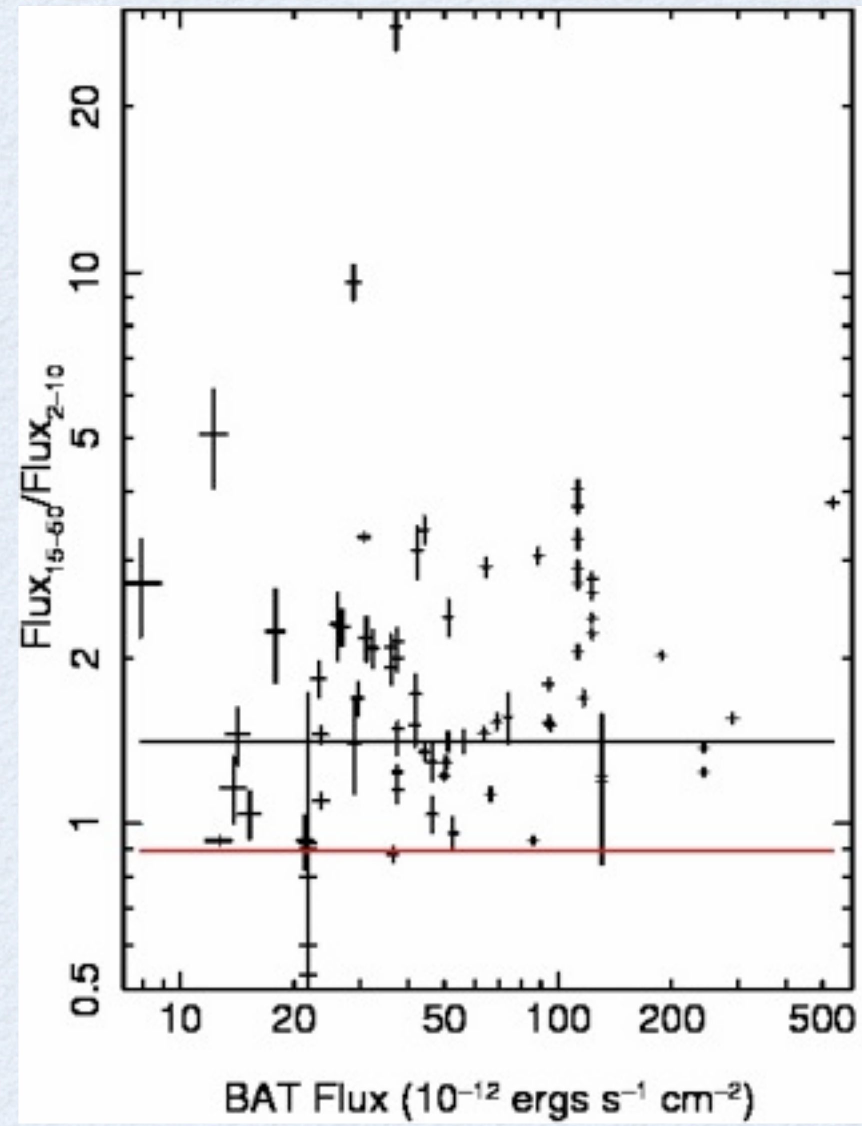
Evidence for Compton-Thick Gas in the line-of-sight





Tatum et al 2011

15-50 keV/2-10 keV



Compton-thick gas partially covering source type 1 AGN, 1H0419-577 (Turner et al 2009)

Also: PDS 456 (Reeves et al 2009)

Other sources with strong PIN flux:

NGC 4051 (Terashima et al 2009)

MCG-6-30-15 (Ballantyne et al '03, Miniutti et al '07)

Mrk 335 (Larsson et al '08)

BAT-selected type 1 AGN observed by Suzaku

Hardness & Fe EW indicative of complex absn - see poster

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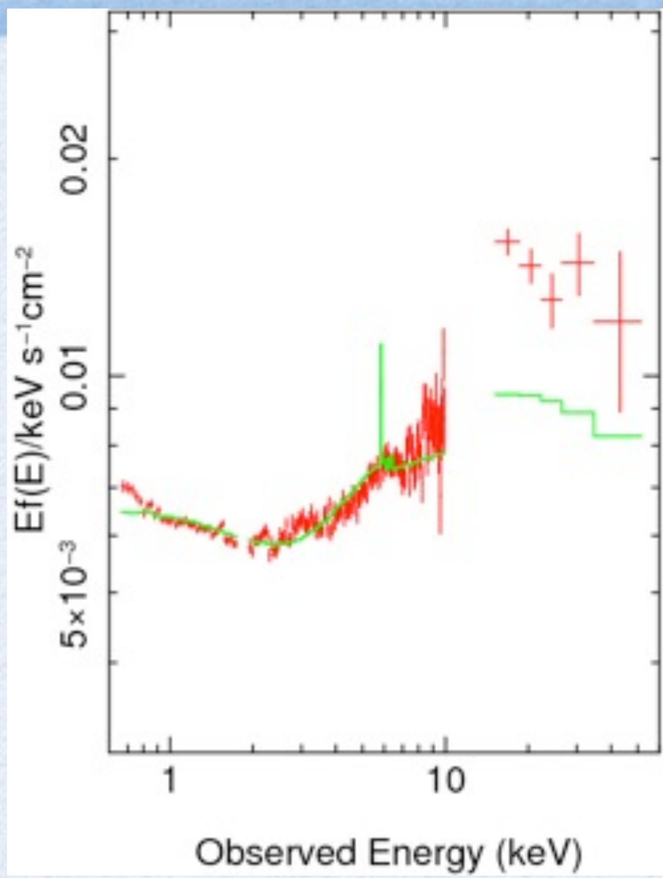

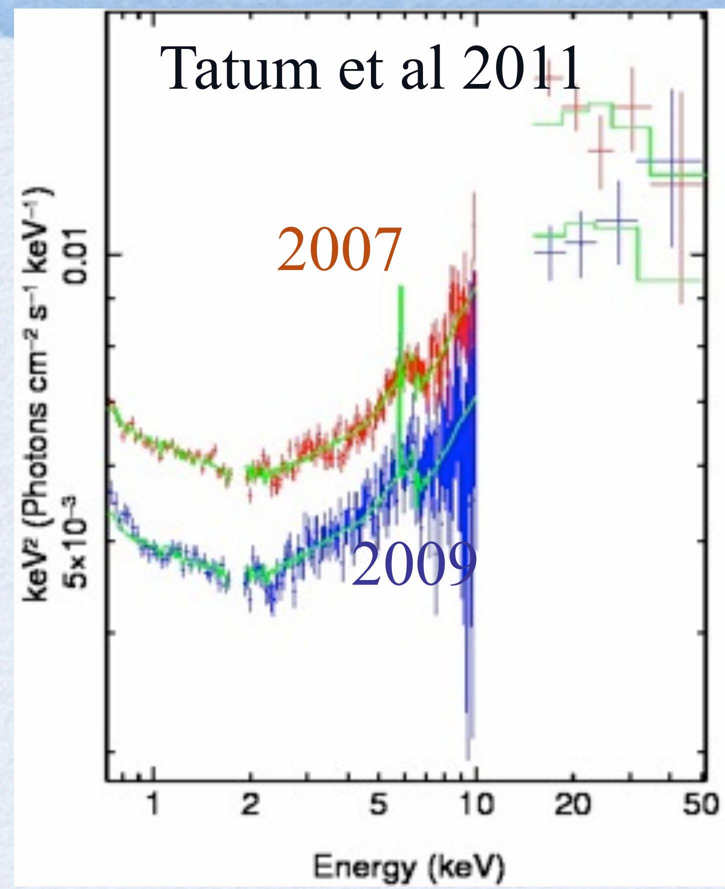

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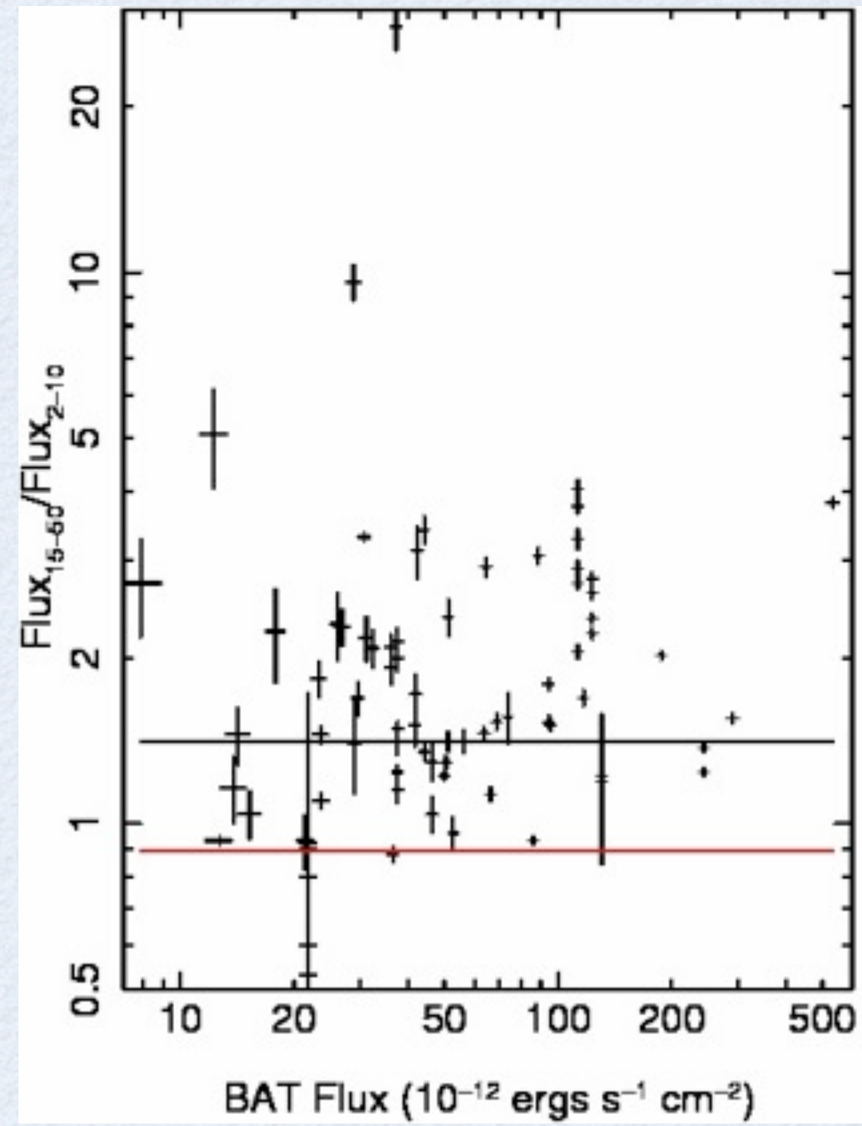

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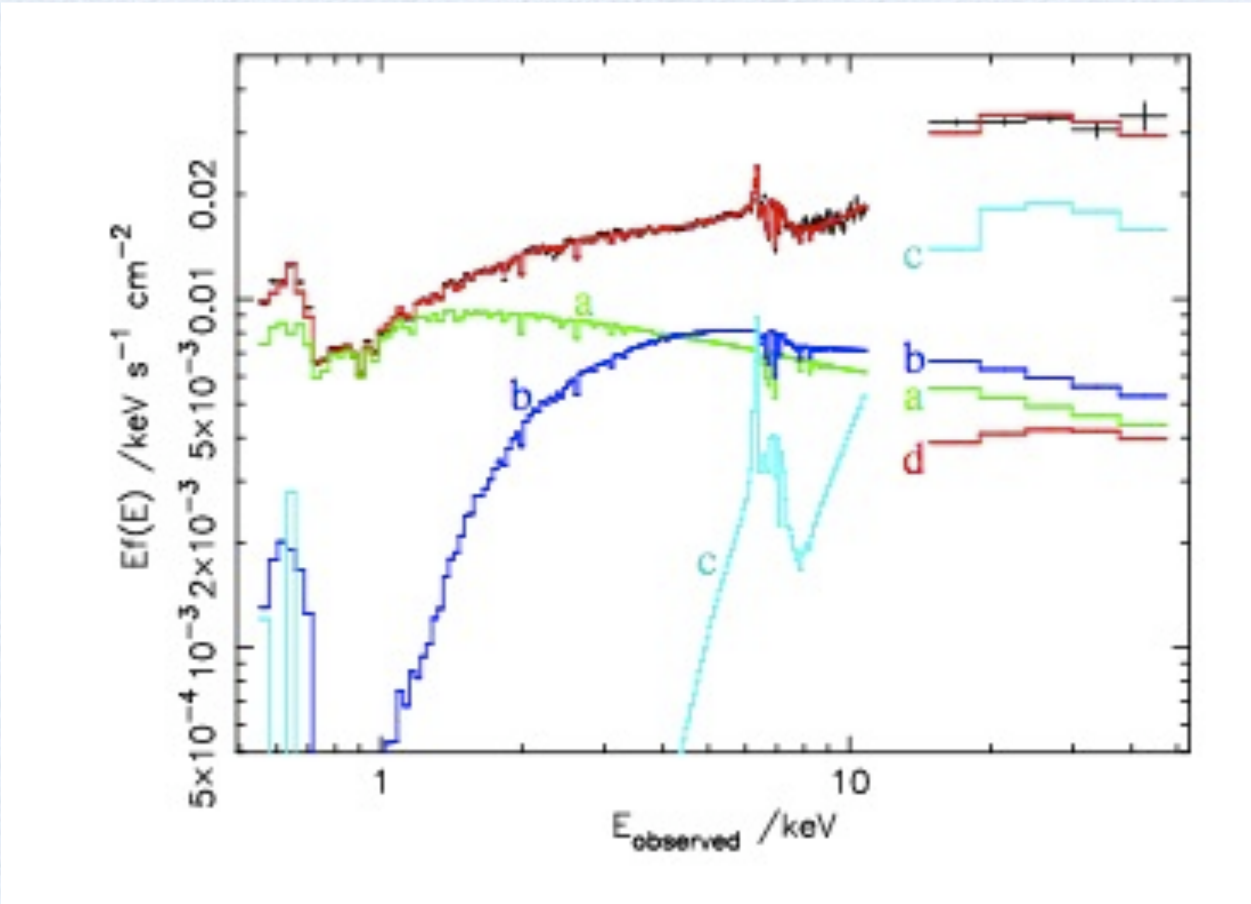
No source left behind

2000-2006 X-ray data



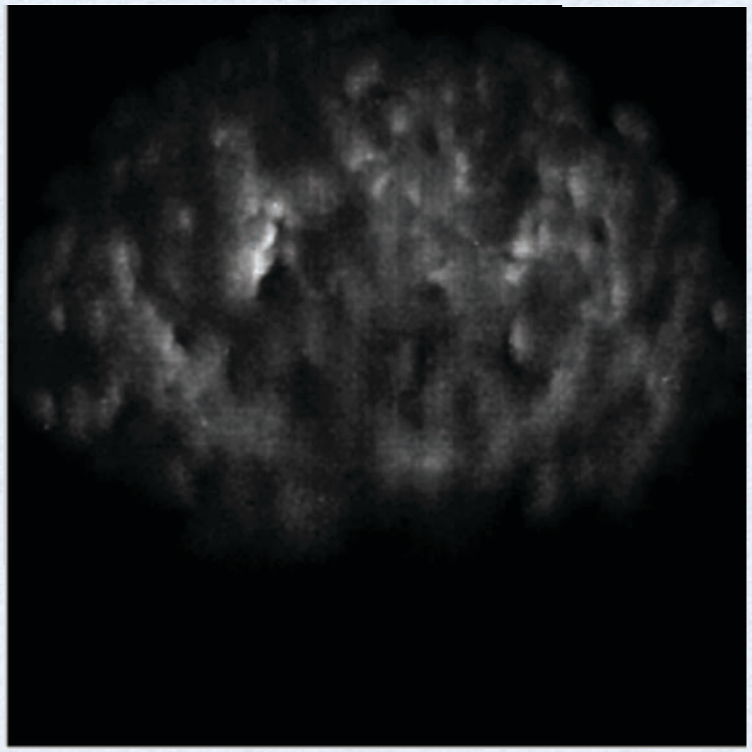
Absorption Models fit MCG -6-30-15 (Miller et al. 2008)

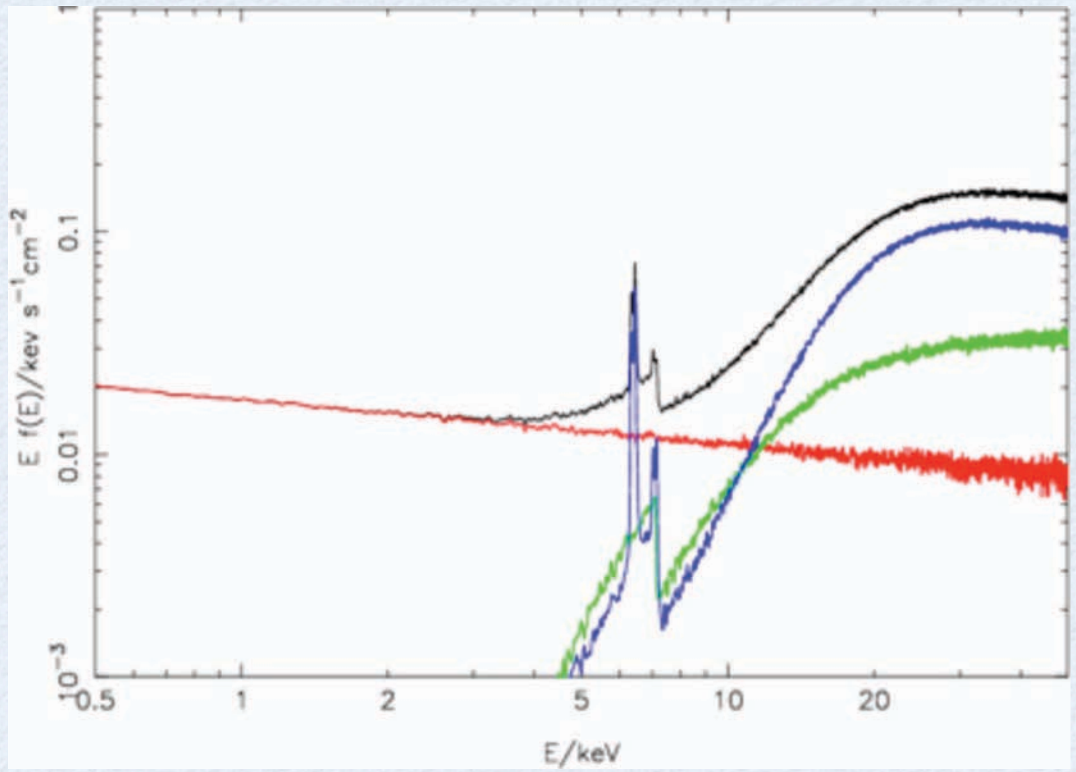
- **PL absorbed by low column complex**
- PC PL absorbed by 4E22
  - High state 50% covered
  - Low state, almost entirely covered
- **Reflection**

Fe K emission from absorber complex can be fairly weak

Miller et al 2009 & Yaqoob & Murphy - must consider all sources of opacity and cannot ignore line self-absorption with $\tau\sim3.5$ at Fe Kα

Spectral Variability





Monte Carlo simulation (L. Miller) of constant continuum surrounded by neutral absorbing clouds

Expect flux and spectral variability from absorption changes

Timing behavior depends on whether low state dominated by absorbed fraction or by reflected component

PCA offset component dominated by reflection in some AGN, absorbed state in others, timing results break degeneracy

This model explains the hardness ratio/Fe EWs of the Tatum (2011) BAT-selected sample of local AGN

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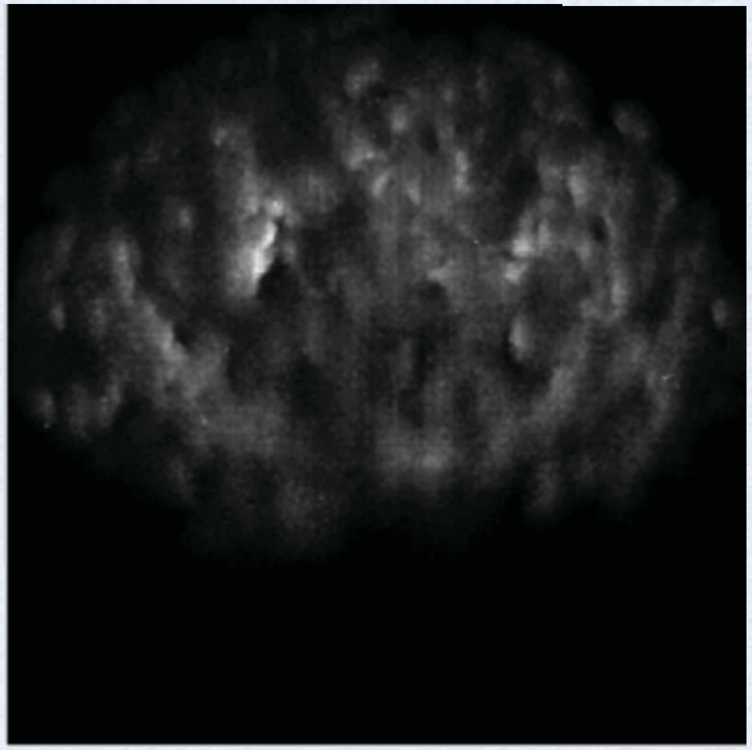

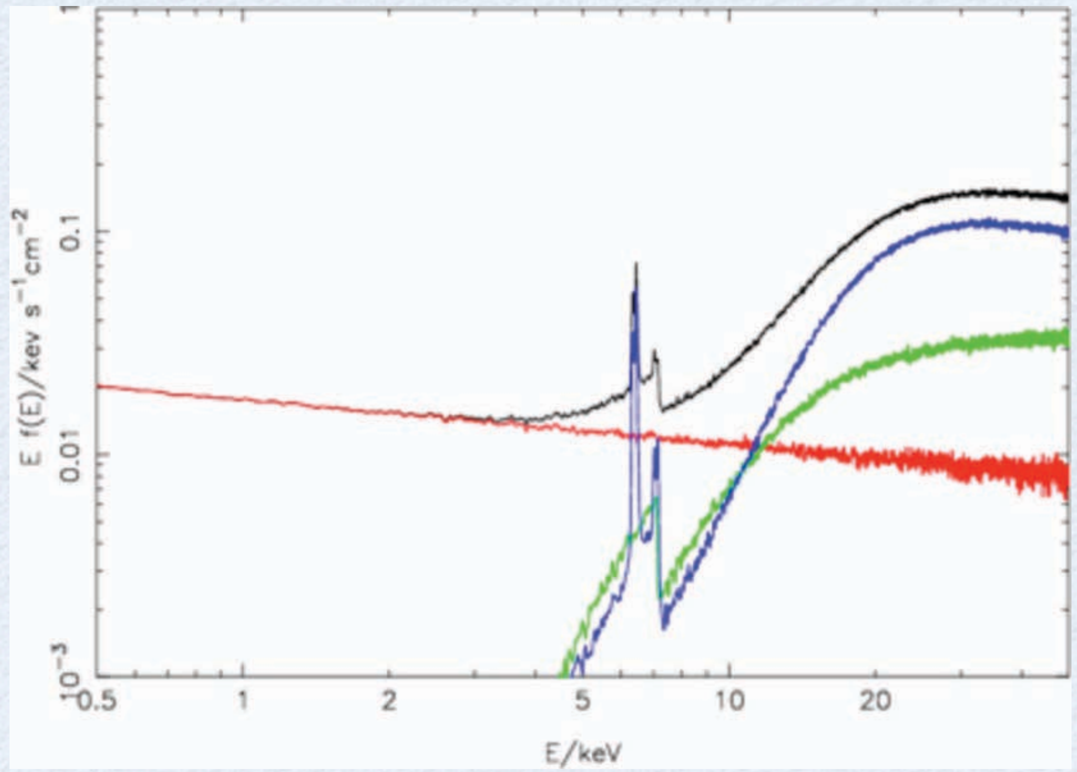

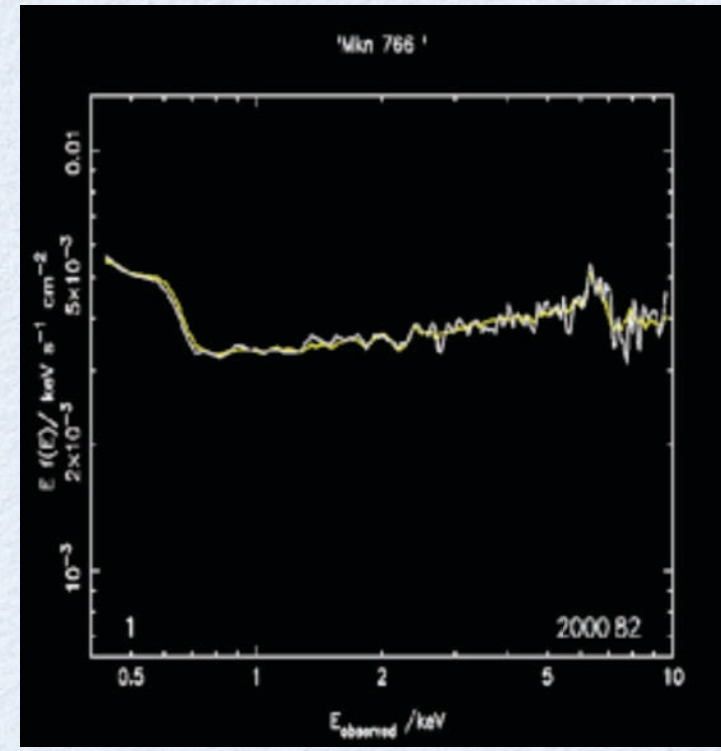

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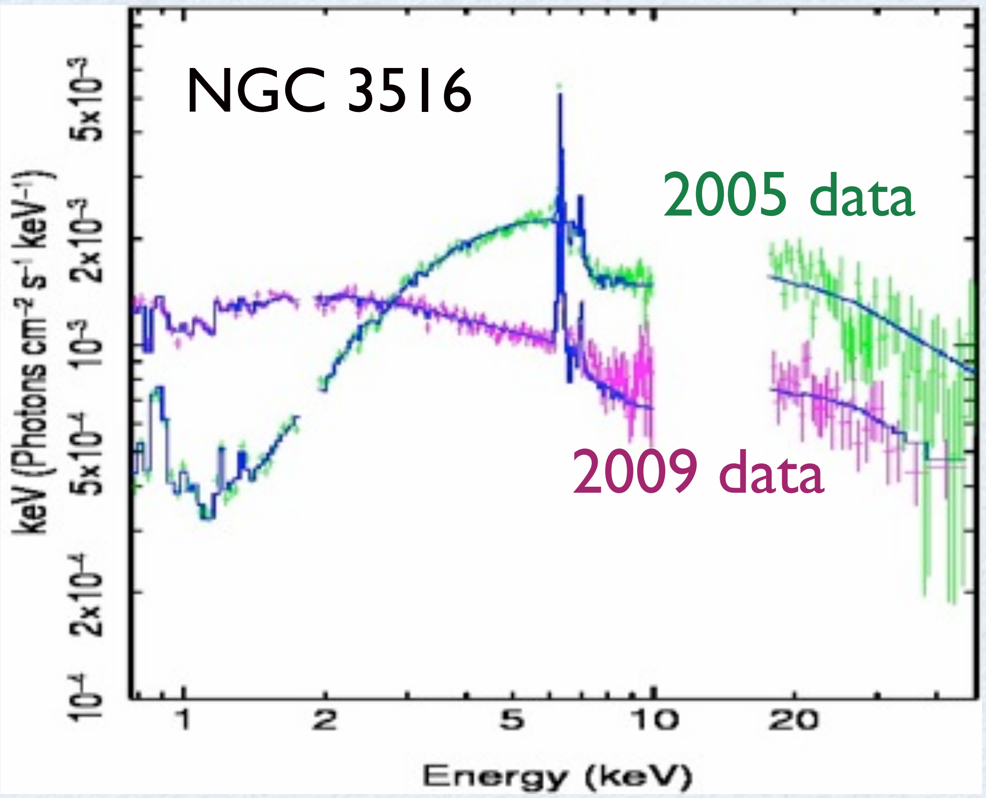
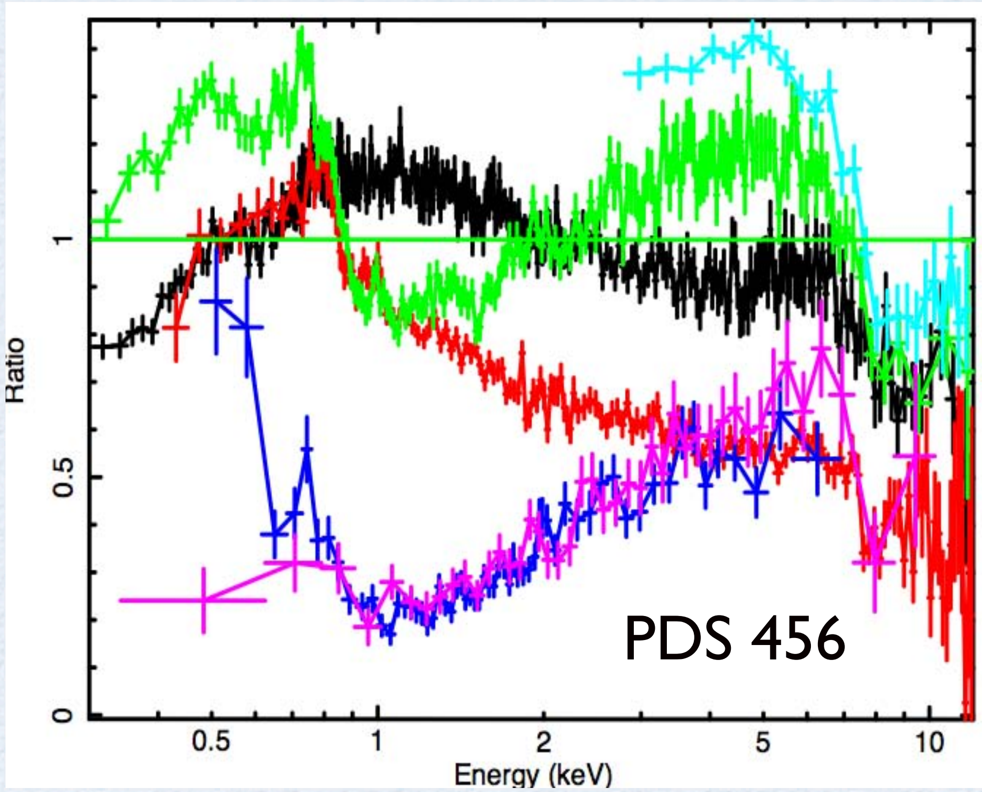
Evidence for clumps ~10^{25} cm^{-2}



Turner et al. (2011)

Hard high states



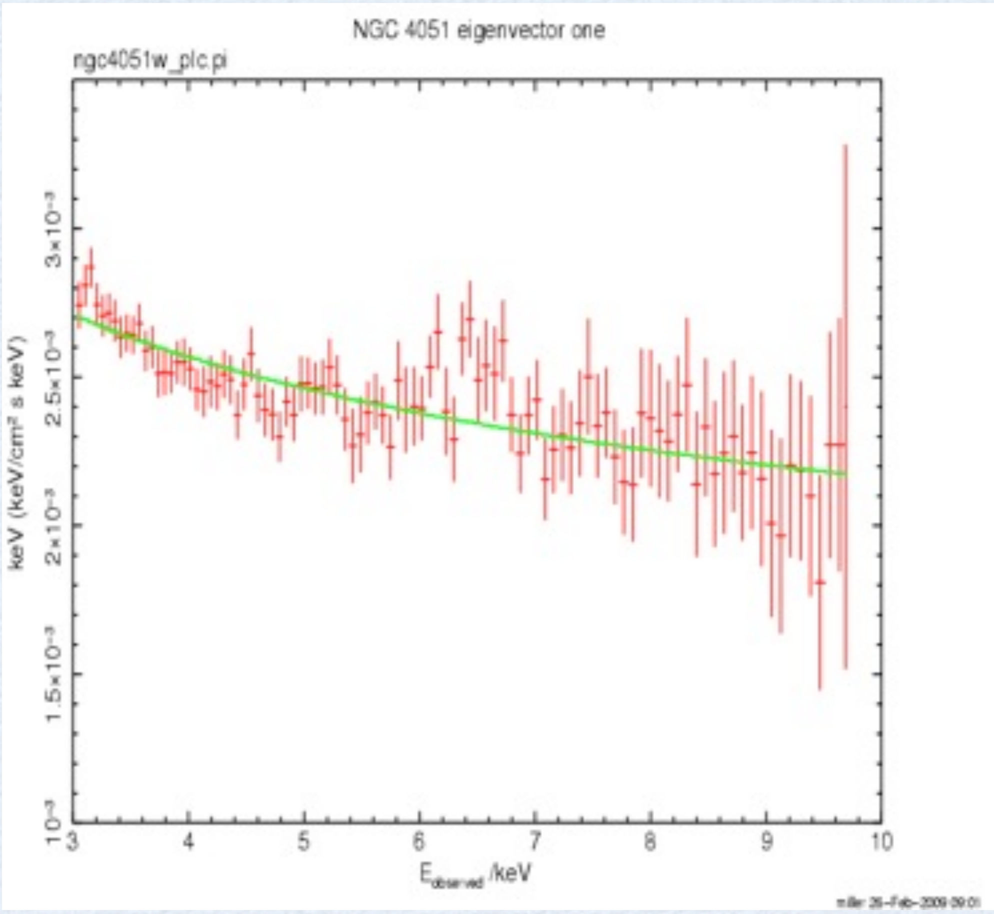
Reeves et al 2009, Behar et al 2010

PIN-band variability - intrinsic continuum changes or obscuration by clumps > 10^{25} cm^{-2} ?

No reverberation signal seen in lag spectrum (Turner et al 2011) -most of the material in los?
Clumps > 10^{25} cm^{-2} favored over continuum variability - compact and close to source

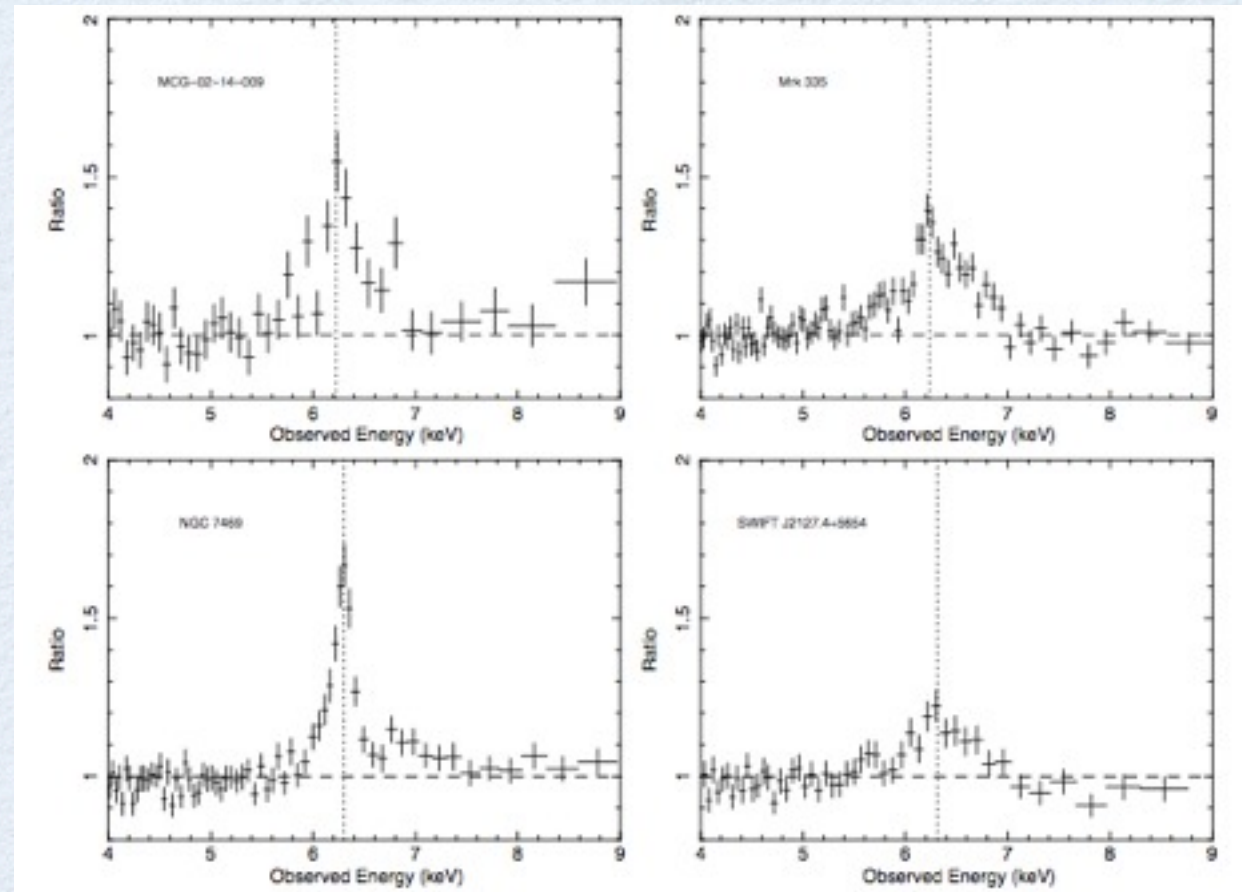
Furthermore - spectral variability not purely ξ changes (cf Mehdipour et al 2010)
However, ξ changes expected (and observed, e.g. MCG-6-30-15 Miller et al 2008)

Broad Fe lines



NGC 4051 Miller et al 2010

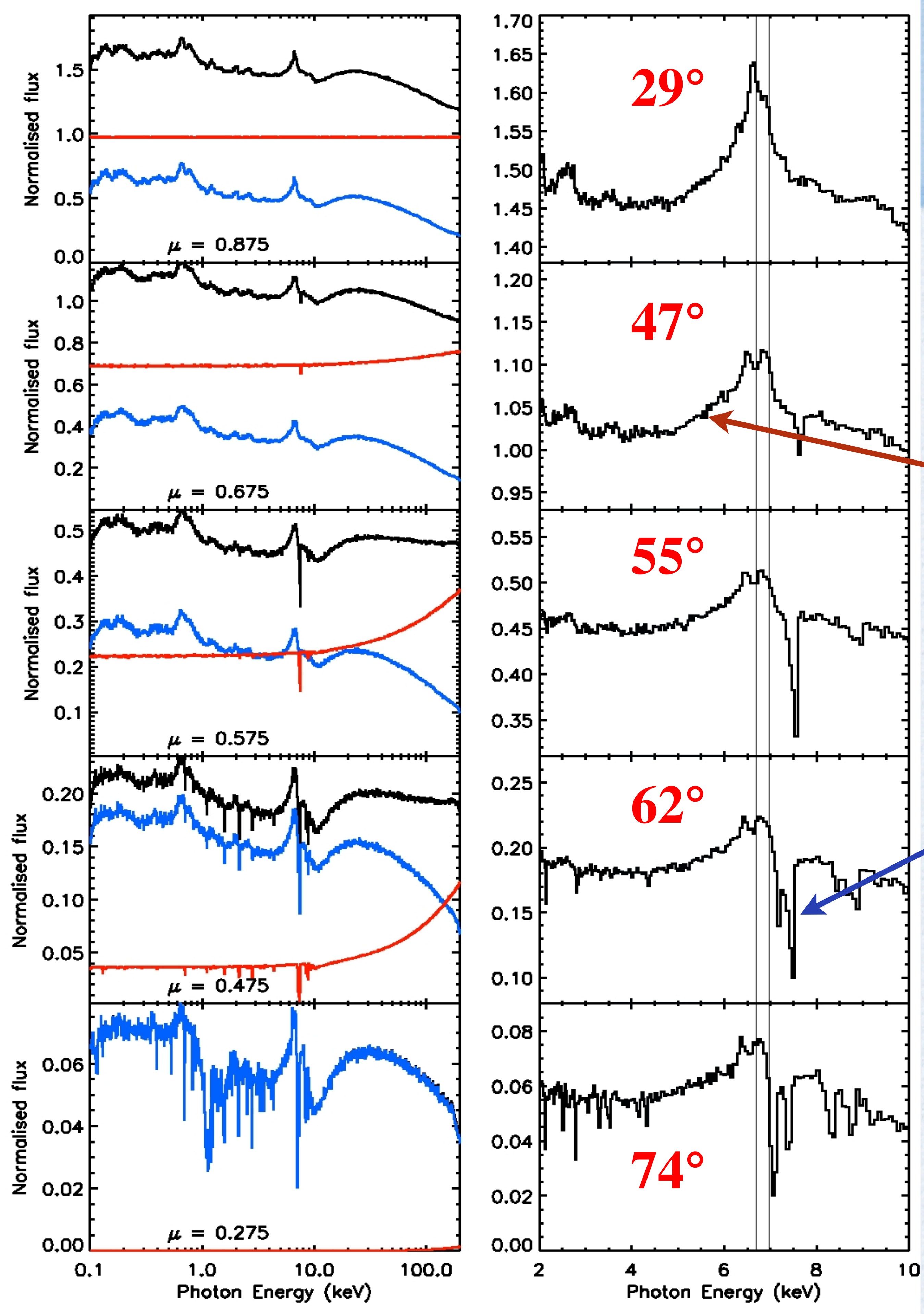
also Mrk 766 Miller et al 2006



Patrick et al 2010

Modest broad components sometimes evident after absorption properly modeled (also see Guainazzi et al 2010)

Wind predictions for line emission

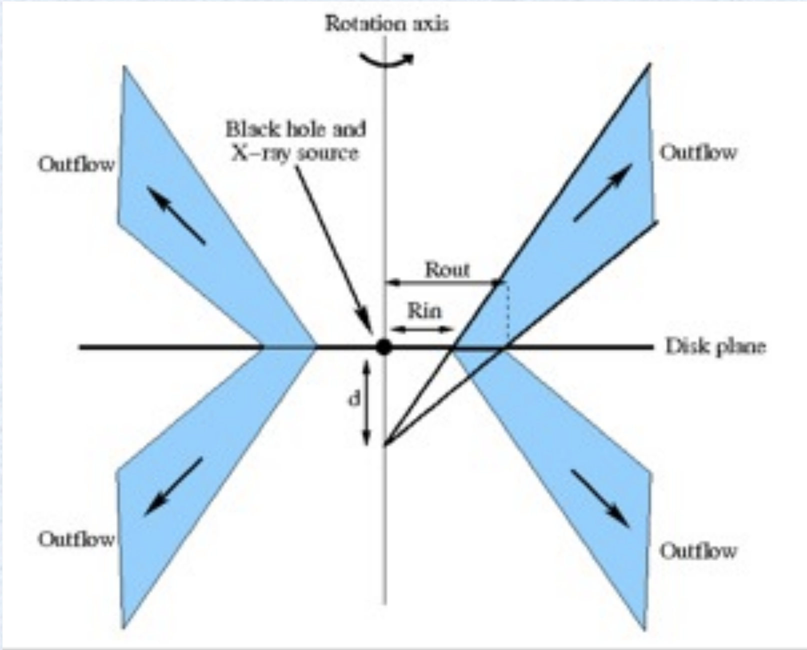


Sim et al. (2008, 2010 a,b)

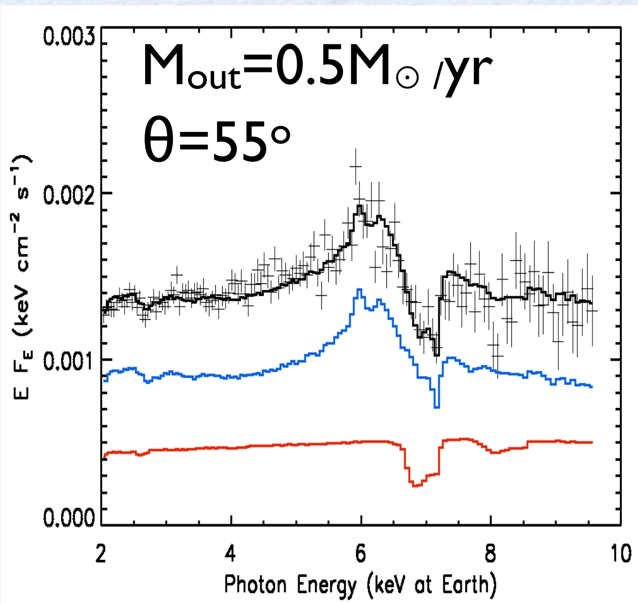
The outflow ***detected*** *in absorption lines predicts broadened Fe K emission*

"red wing" produced by scattering and absorption - not by GR effects!

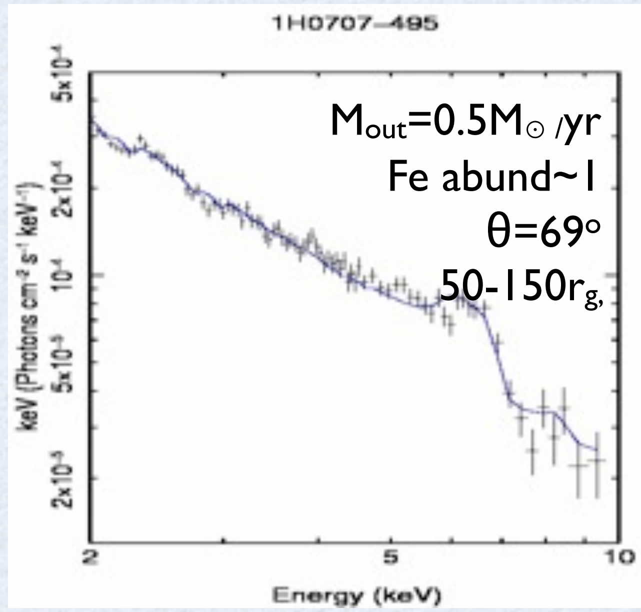
edge and blue-shifted Fe Kα absorption



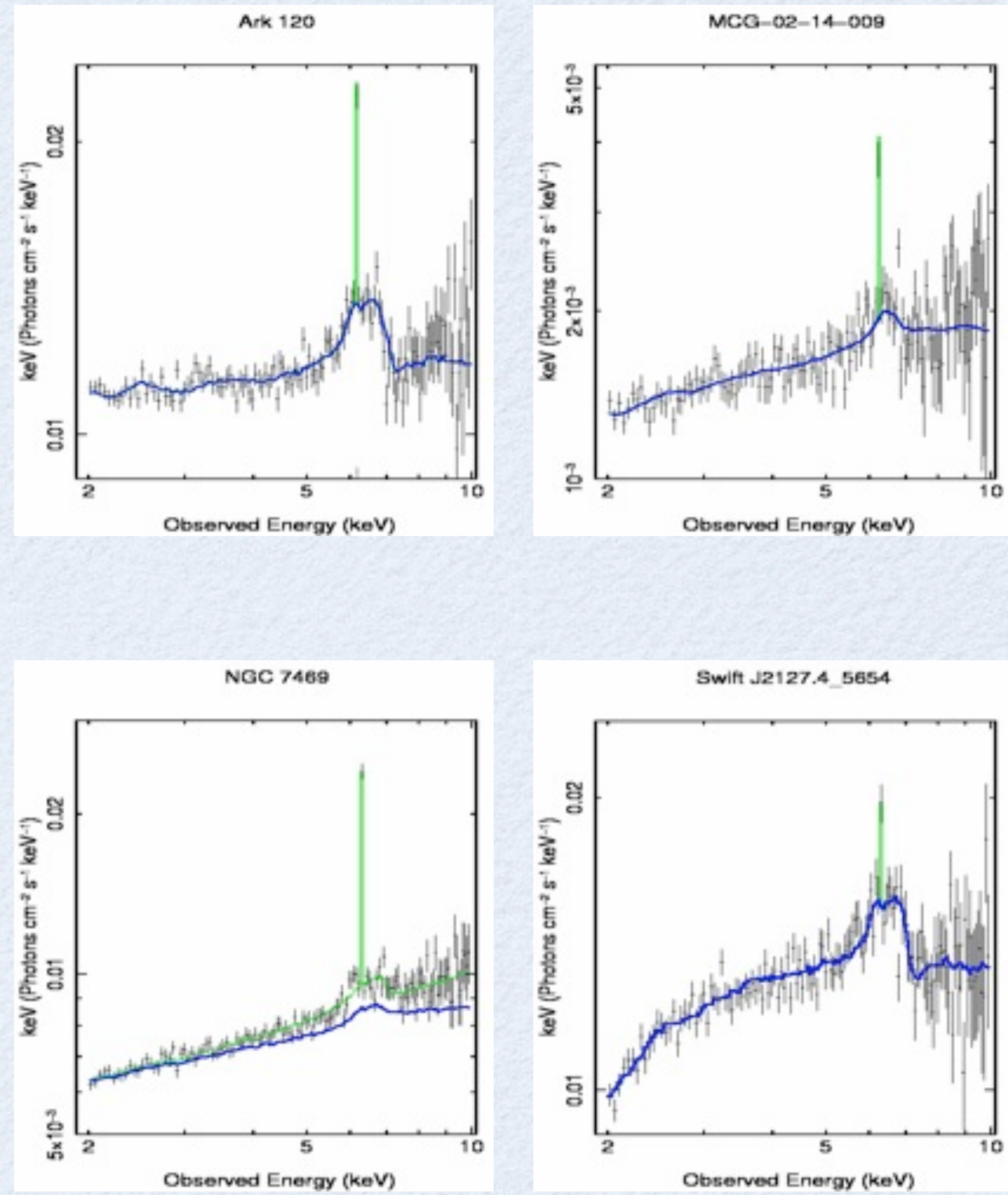
Sample of unobscured Seyferts



PG1211+143, Sim et al 2010



1H0707-495



Broad Fe Kα emission component produced in solar abundance CT wind (Sim et al 2008 2010a,b)

<Γ>=2.10+/-0.03,

Outflow rate 1.00+/-0.28 $M_\odot$/yr

Wind geometry indeterminable with current data (Tatum et al 2011)

However, the smooth flow does not explain hard excesses! Key area for model development - clumps!

Tatum et al (2011b)

Summary

- Clear evidence for outflowing X-ray absorber complex in AGN tracing columns 10^{20} - 10^{25} cm^{-2} ionized gas - natural extension of partial-covering UV gas
- Not seeing naked accretion disk- X-rays are reprocessed by large amounts of circumnuclear gas with high global covering
- Absorption models explain spectral variability properties with covering changes and reverberation (see L Miller talk)
- Compton-thick wind/reverberation models look promising to explain even the most complex sources
- High source fluxes above 10 keV, existence of “hard high states” all provide strong motivation to consider **clumpy flow** with clumps in CT regime