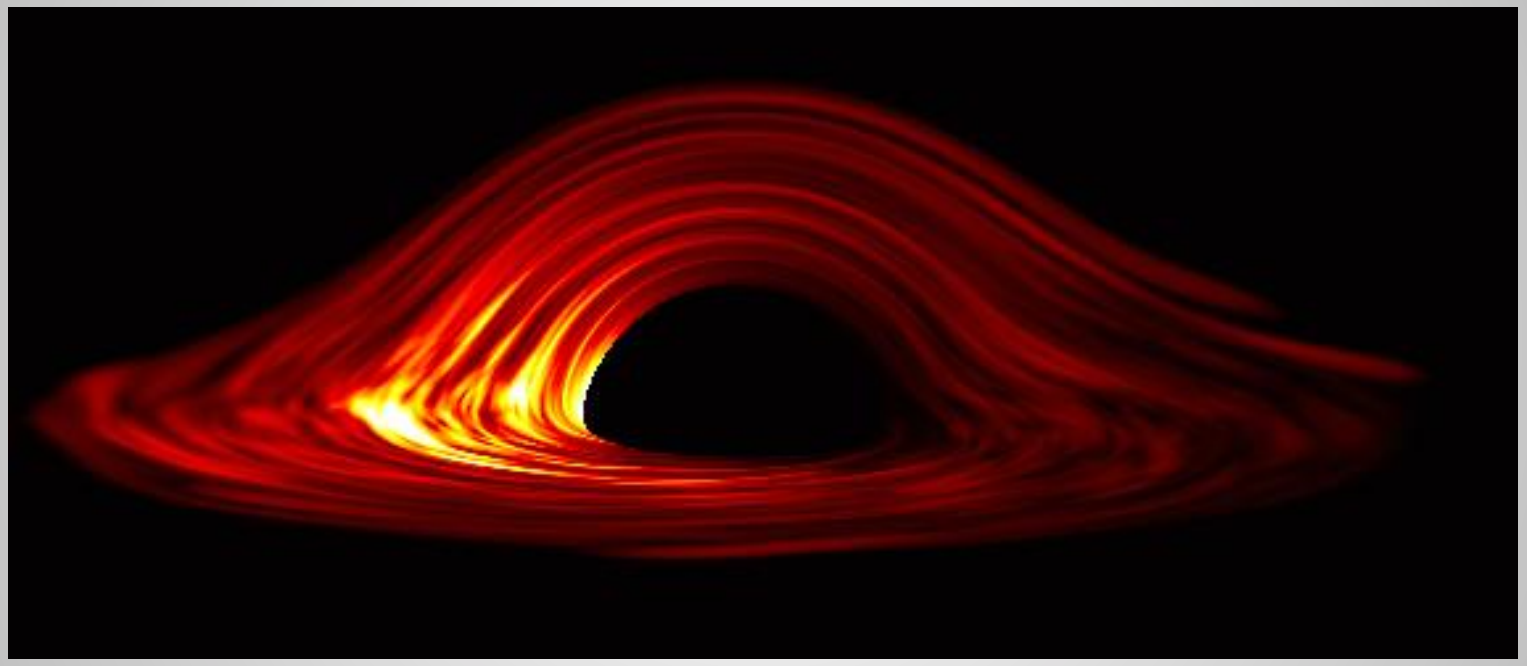
Suzaku's View of Inner Disk Eclipses in NGC 1365



Laura Brenneman
Collaborators: Guido Risaliti, Martin Elvis, Chris Reynolds, Jonathan McDowell
Harvard-Smithsonian Center for Astrophysics

Exploring the X-ray Universe: *Suzaku* and Beyond
July 22, 2011

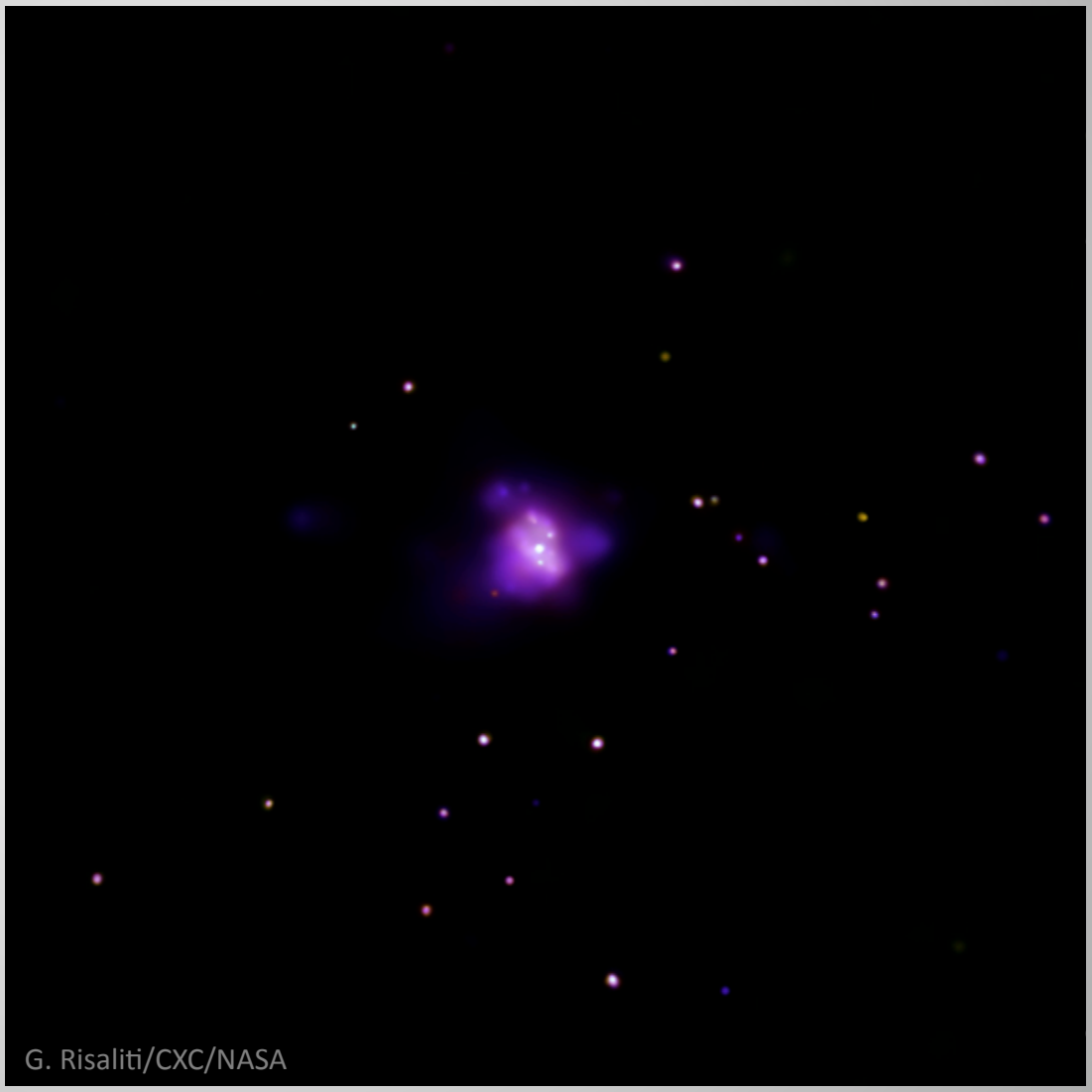
NGC 1365 Background

• Barred spiral galaxy 200,000 ly across at z=0.0055 (60 Mly) in Fornax cluster.

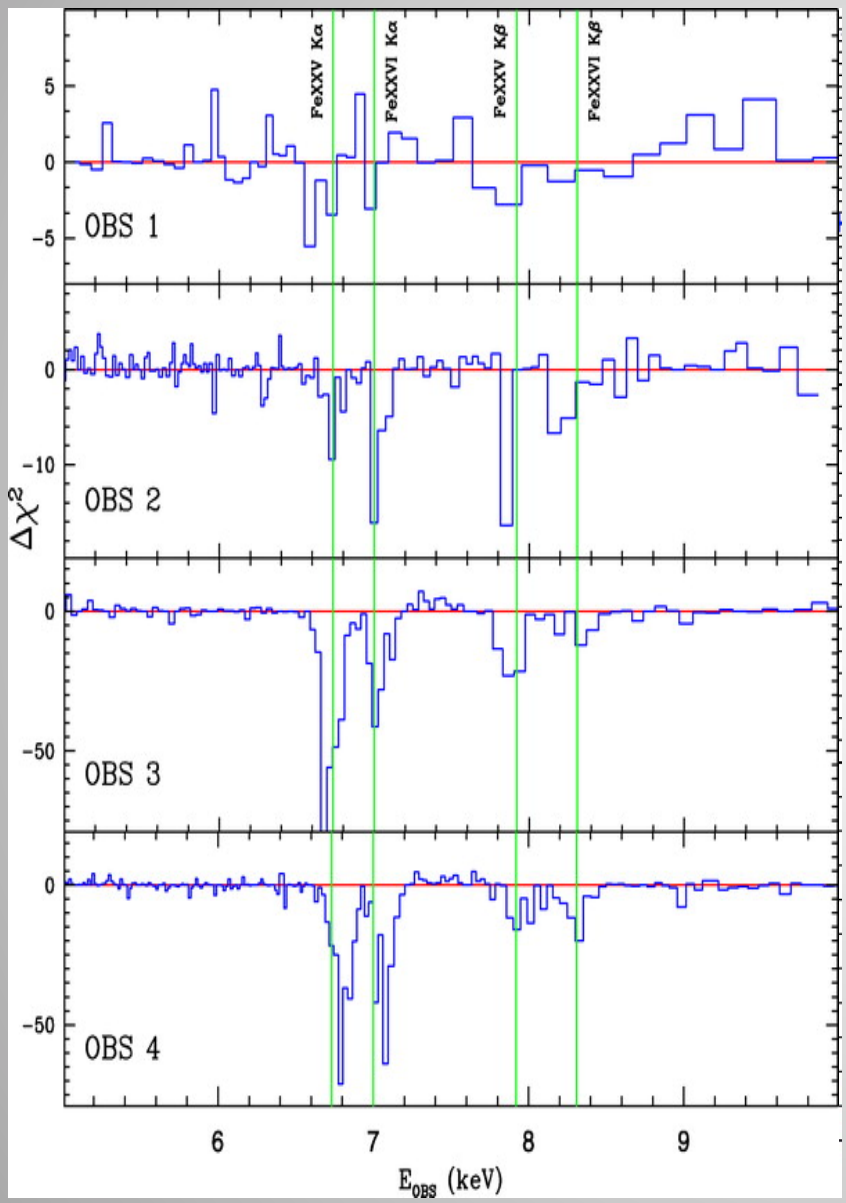
• Bar linked to circumnuclear starburst activity ~1.3 kpc from nucleus, extended and diffuse X-ray emission (photoionized and collisionally ionized gas, e.g., Wang+ 10, Guainazzi+ 10).

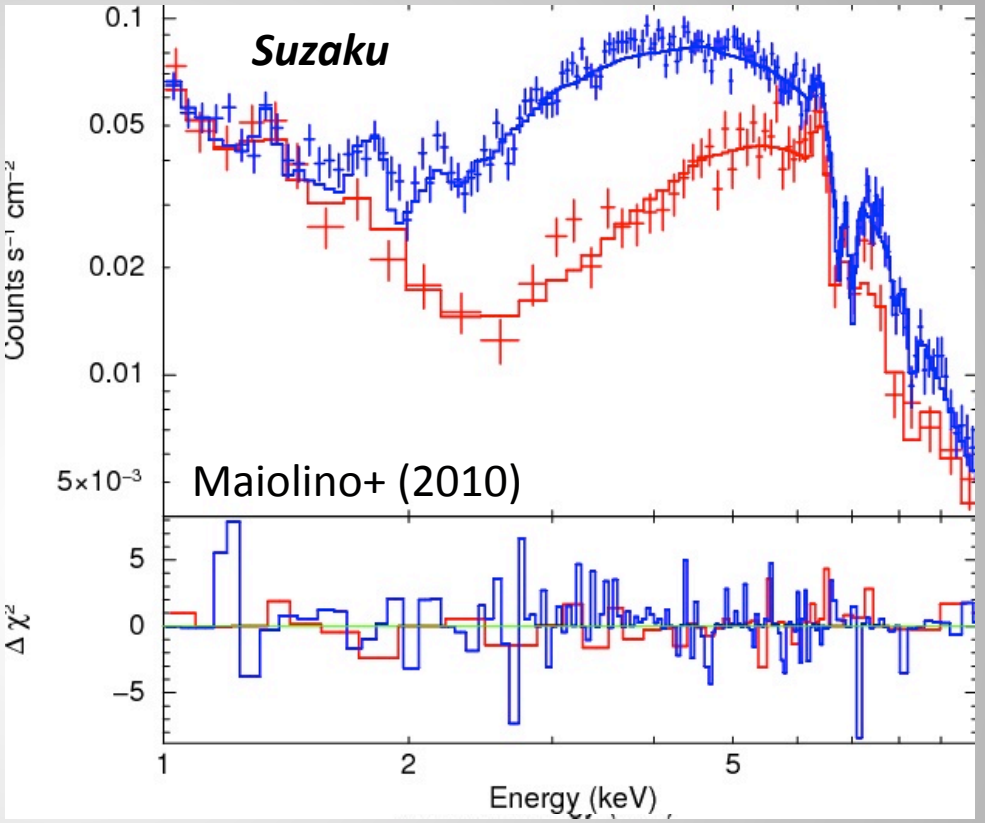
• Sy 2 AGN with SMBH at core estimated at $3.2 \times 10^7 M_\odot$ with $L_{bol}/L_{Edd} \sim 0.02$ (Vasudevan+ 09).

• Relativistic reflection, cold and ionized absorption seen.



Previous Observations of NGC 1365



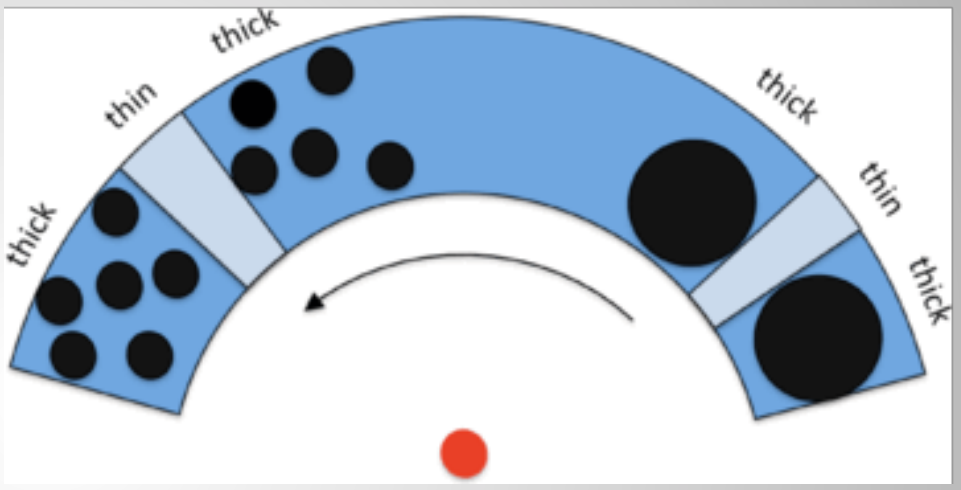


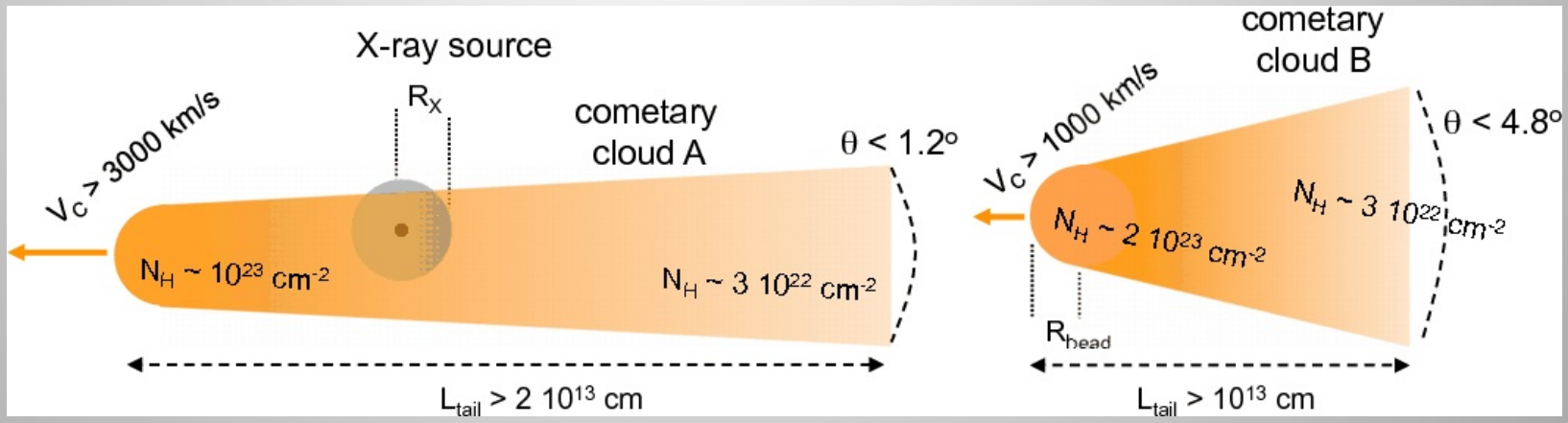
~300-ks *Suzaku* XIS (2007) shows two distinct spectral shapes at different times.

Degeneracy between N_H and f_{cov} can be broken!!

Eclipses of the Inner Accretion Disk?

- Flux varies by factor of ~10.
- Broad Fe Kα line continuously reported since 1997 (*ASCA*).
- Compton-thin and –thick eclipses observed in X-ray observations from 2005 onward: *Chandra, XMM, Suzaku…* consistent with BLR clouds.

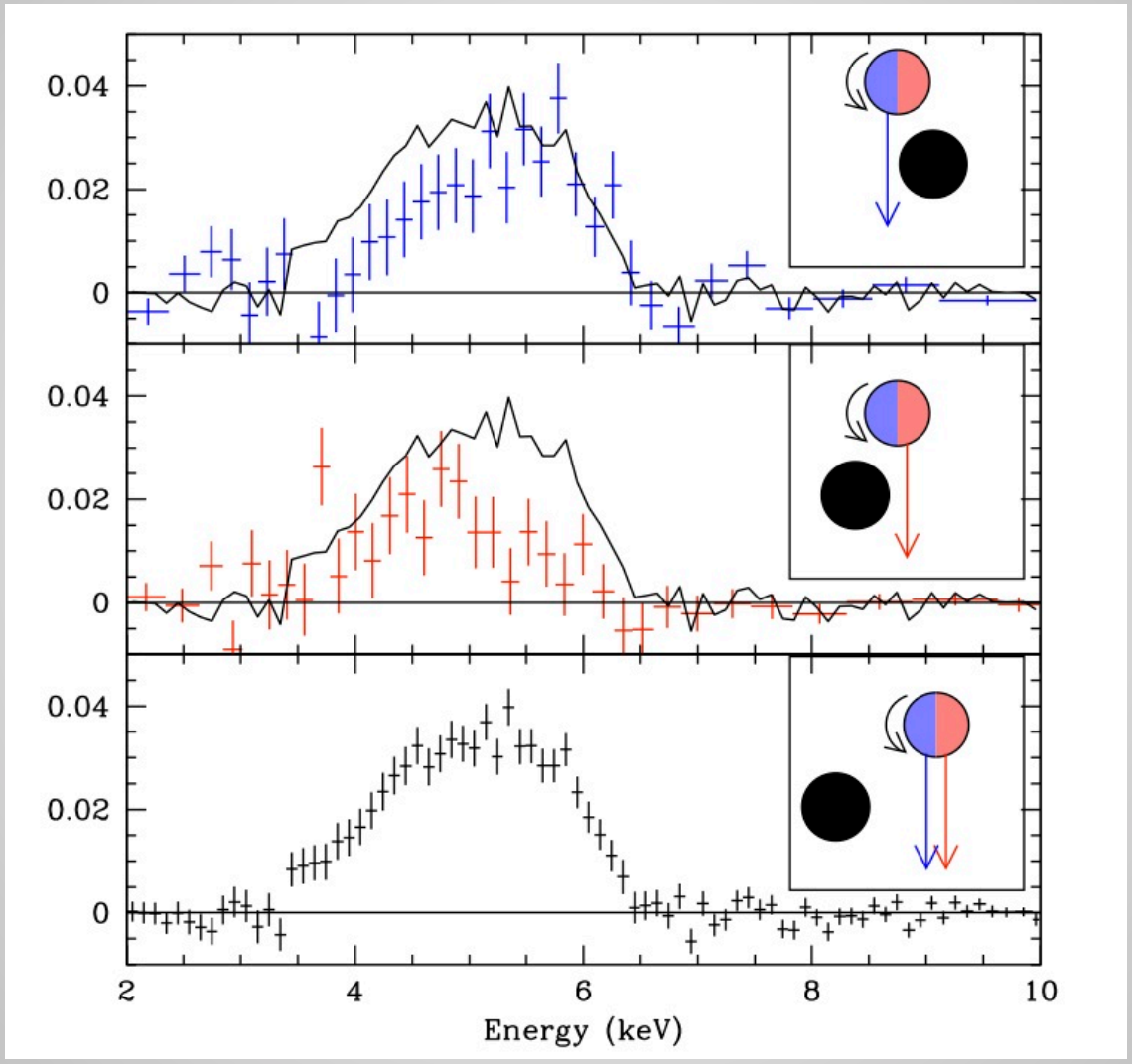




Risaliti+ (2005, 2007, 2009); Maiolino+ (2010)

credit: NASA/CXC/M. Weiss

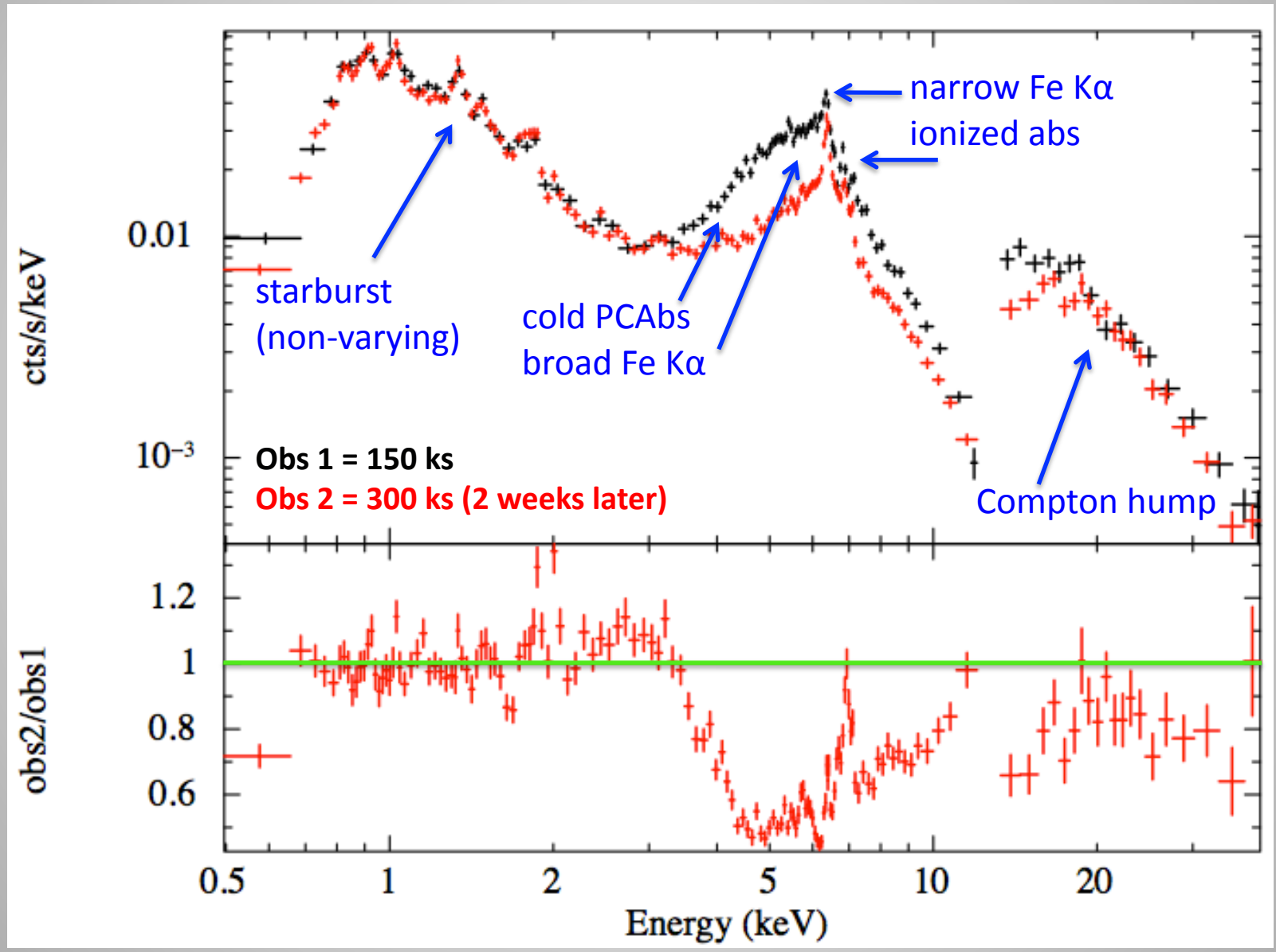
Broad Fe Kα Line Variations During a Compton-thick Eclipse



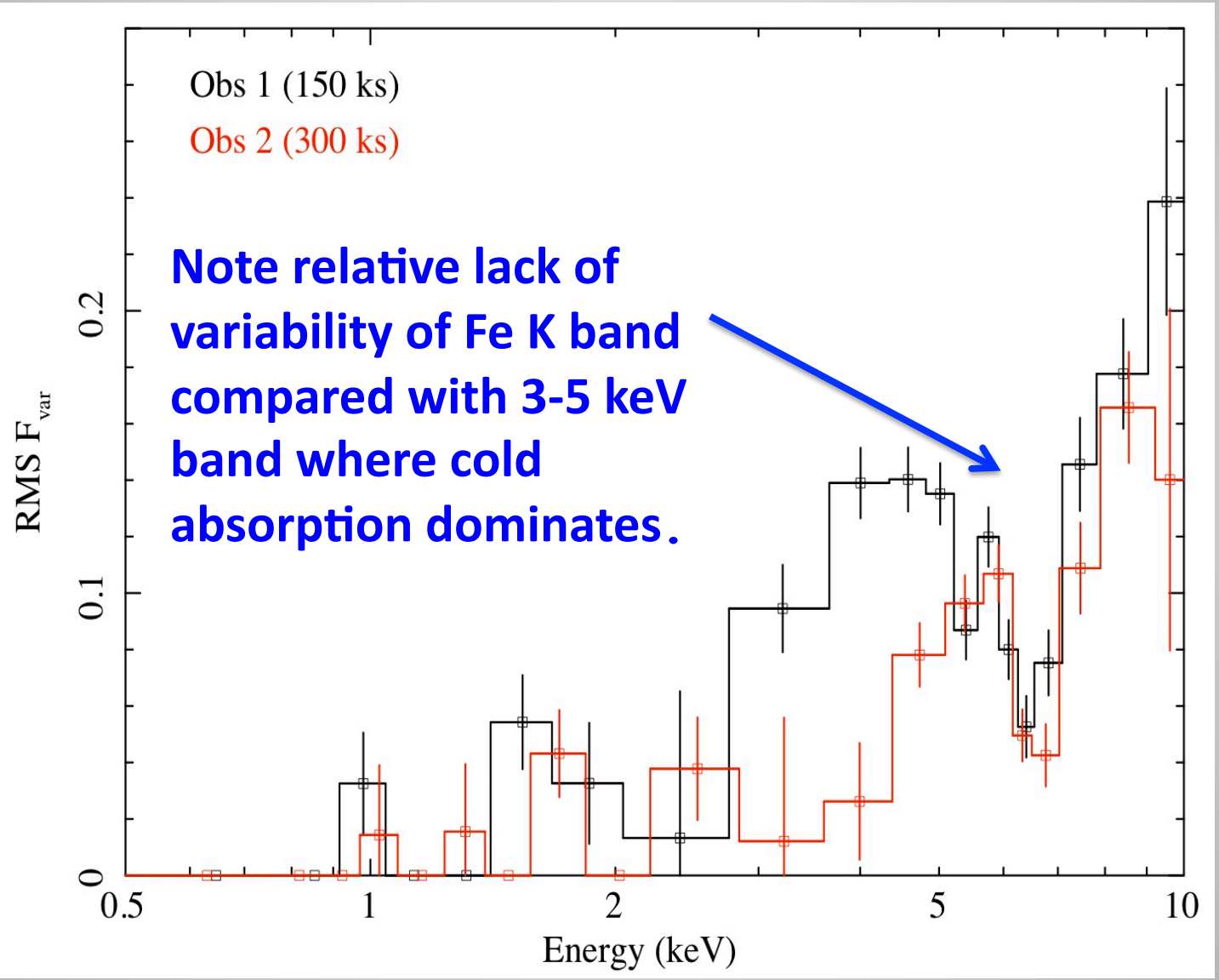
Definitive proof of inner disk reflection… need a revised model with eclipses! Subject of current theoretical work by Brenneman, Risaliti, Reynolds, Elvis & McDowell (in prep.).

NGC 1365: Suzaku Long Program

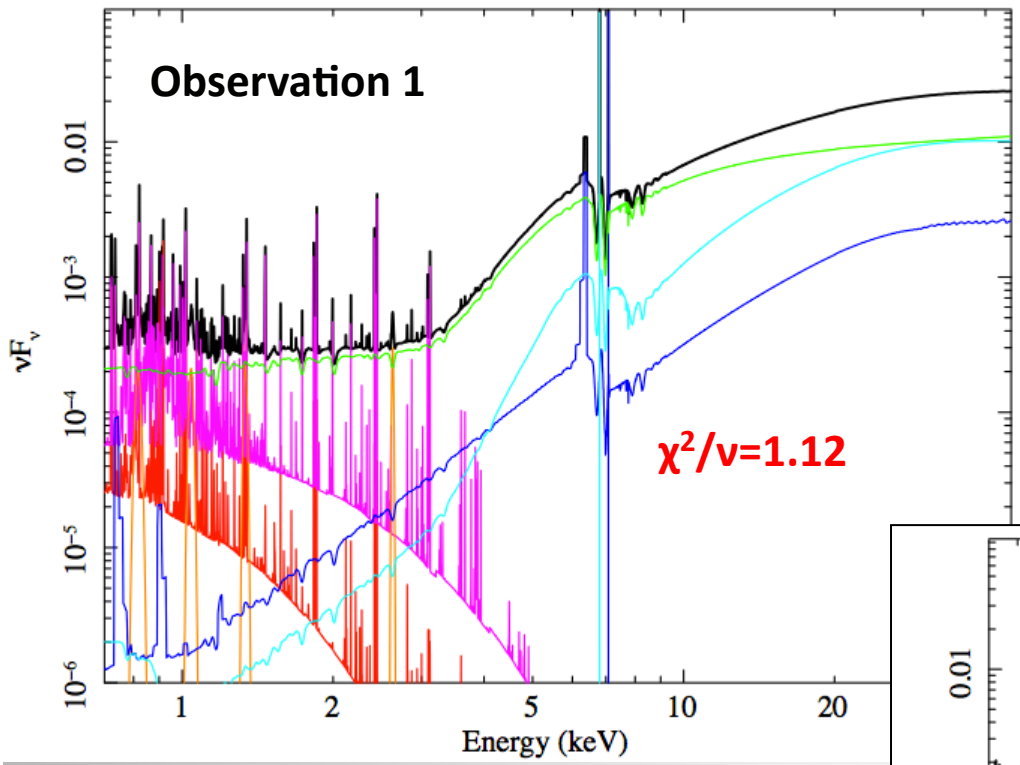
Brenneman, Risaliti & Elvis (2011, in prep.)



Spectral Variability



Time-averaged Spectra



Observation 2:

$Flux_{2\text{-}10} = 4.04 \times 10^{-12}$ ergs cm^{-2} s^{-1}

$\Gamma \sim 1.79$

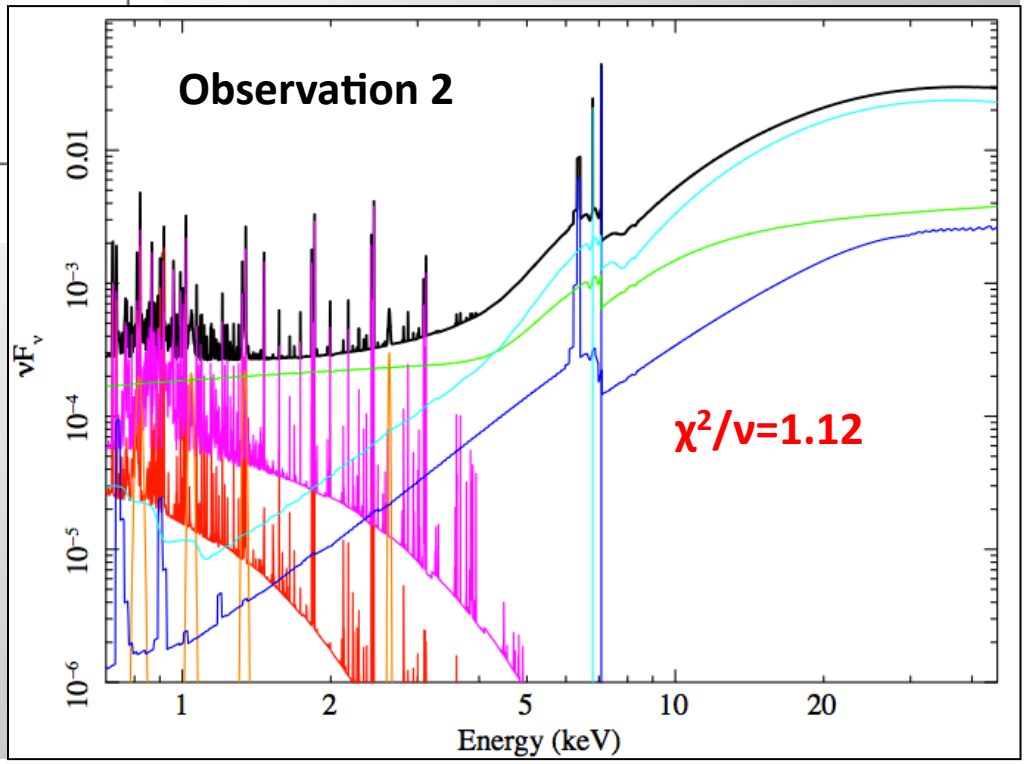
$N_{H(cold)} \sim 1.1 \times 10^{24}$ cm^{-2}

$N_{H(warm)} \leq 10^{22}$ cm^{-2}

$\xi_{abs} \sim 4000$ erg cm s^{-1}

$A_{rel}/A_{PL} \sim 0.20$

Disk $r_{in} \sim 1.3\ r_g$



Observation 1:

$Flux_{2\text{-}10} = 6.15 \times 10^{-12}$ ergs cm^{-2} s^{-1}

$\Gamma \sim 1.79$

$N_{H(cold)} \sim 5.7 \times 10^{23}$ cm^{-2}

$N_{H(warm)} \sim 1.2 \times 10^{23}$ cm^{-2}

$\xi_{abs} \sim 4000$ erg cm s^{-1}

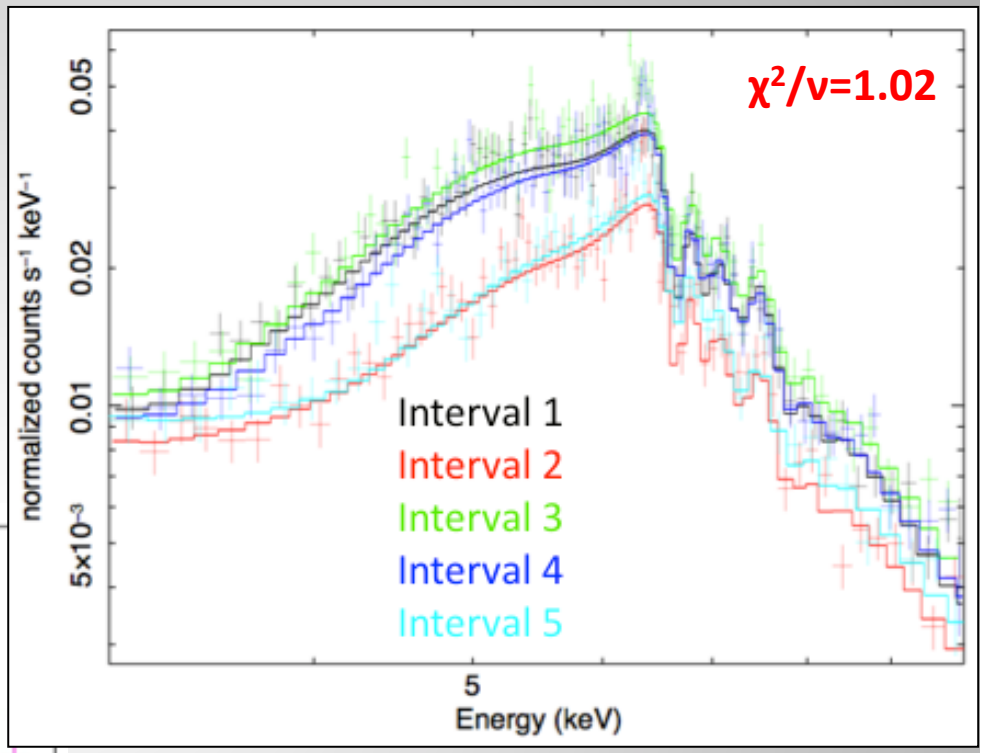
$A_{rel}/A_{PL} \sim 0.05$

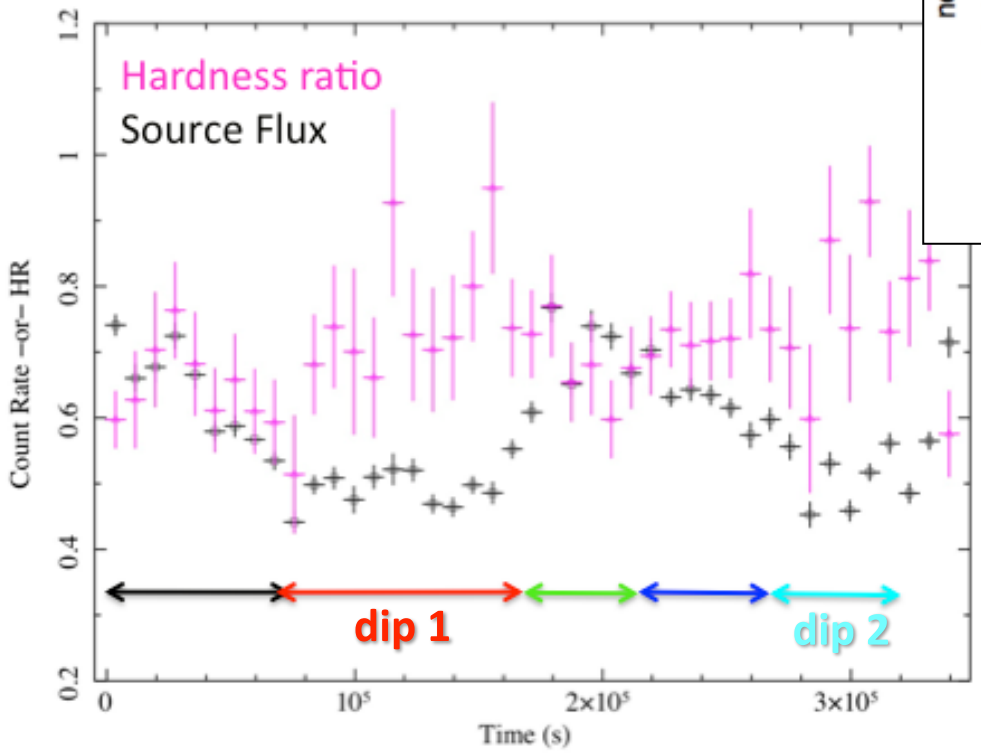
Disk $r_{in} \sim 1.9\ r_g$

Eclipses in Observation 1…

- Identify candidate eclipse events through light curve, hardness ratio.

- Isolate five intervals, two characteristic "dips" in Obs 1.





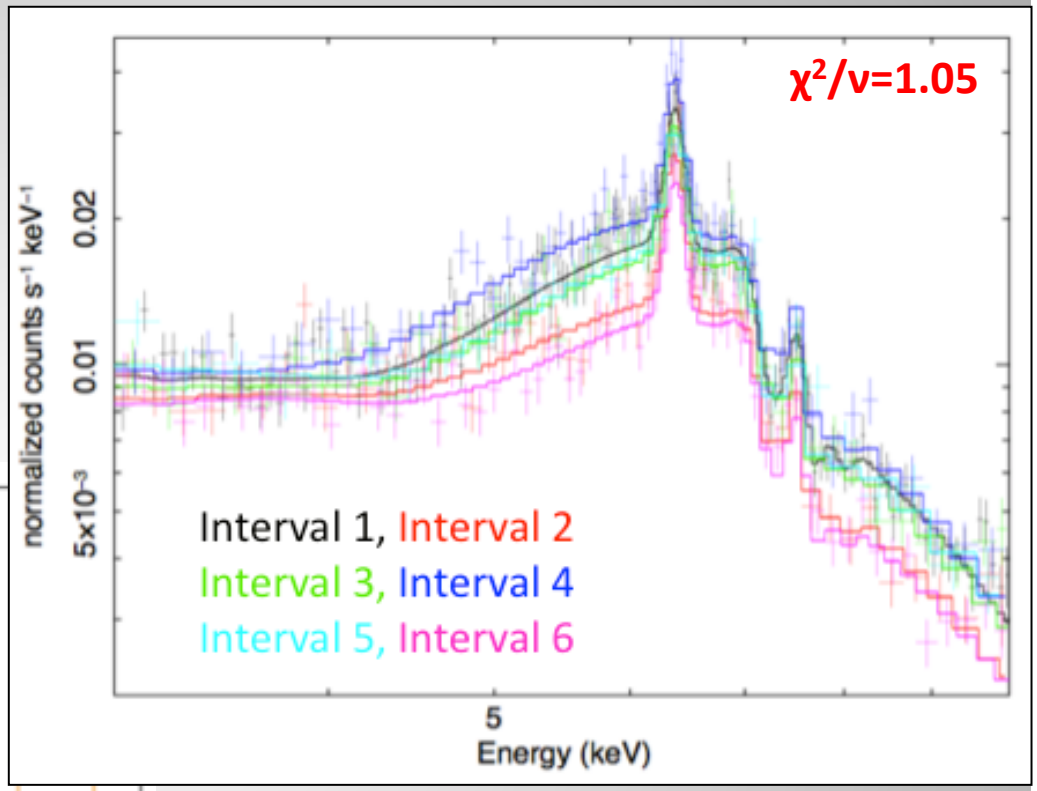
- Main change between periods is in cold absorber N_H:

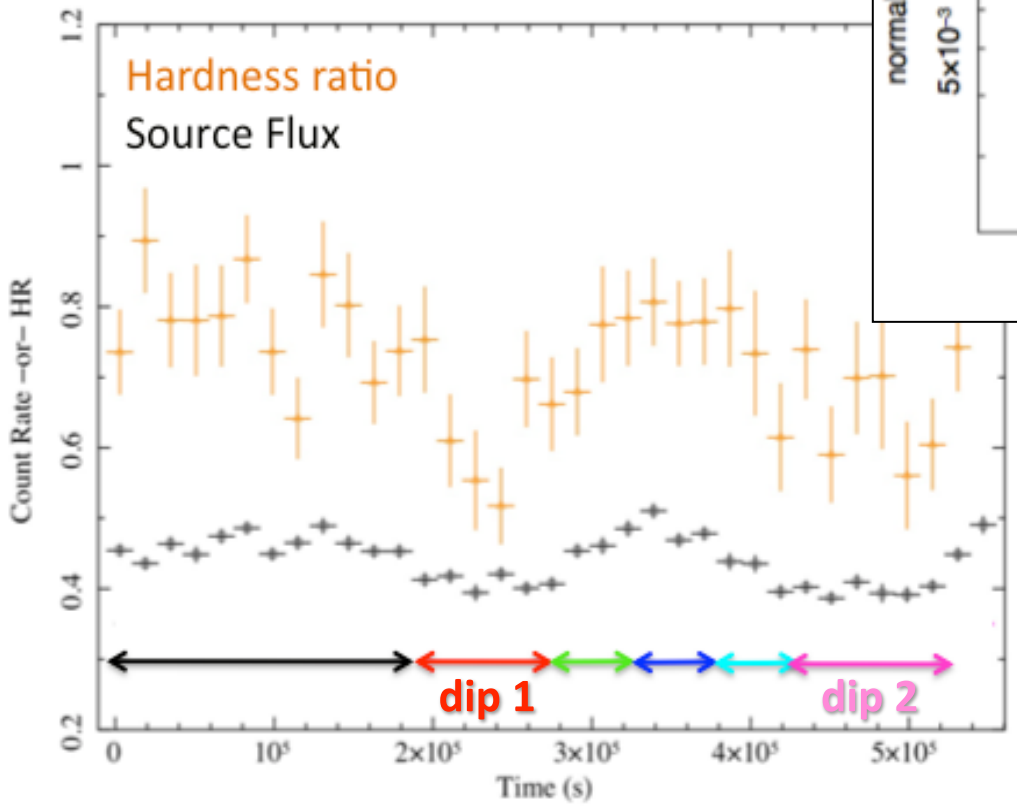
48±4 → 75±5 → 56±4 → 62±4 → 83±6
(in units of 10^{22} cm^{-2})

- All other parameters have Δ ≤ 10% except PL, which changes by ~1.8x.

…and Observation 2

- Spectrum changes less overall during Obs 2 than in Obs 1.
- Overall flux down by ~1.3x from Obs 1.
- r_{in} is marginally closer in (~1.3 r_g vs. ~1.9 r_g in Obs 1), but difficult to constrain in time-resolved spectra.





- Cold N_H changes not as pronounced or as dominant as in Obs 1:

112±4 → 123±13 → 112±11 → 99±1 → 112±10 → 140±16

(in units of 10^{22} cm^{-2})

- Also see ΔN_H (warm) ~ 2x, ΔPL ~ 1.5x.

Conclusions and Future Work

- **NGC 1365 is a Sy 2 AGN displaying:**
  - **extended, ~constant starburst emission (thermal and photoionized)**
  - **hard X-ray continuum (coronal vs. jet base?)**
  - **highly ionized, outflowing wind (v_{out} ~ 1000-5000 km/s)**
  - **variable, cold absorber ($f_{cov} \geq 95\%$, $N_H \sim 10^{23\text{-}24}$ cm^{-2})**
  - **relativistic reflection from the inner accretion disk (Fe/solar ~ 2.5, log $\xi \leq 1$)**
  - **distant reflection from outer disk or torus (~constant)**

- All components change on timescales of ~tens of ks except distant reflection.

- Eclipses going from Compton-thin to –thick state have potential to provide ***irrefutable*** proof of relativistic nature of broad Fe Kα line via accretion disk tomography.

- Our 450-ks Suzaku LP found four eclipse events, but none going from Compton-thin to –thick with large enough ΔN_H to perform this experiment.

- More long observing campaigns needed! *Suzaku, Astro-H, XMM+NuSTAR.*

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