

**The HETGS View of GRS 1915+105:  
The Disk-Jet Connection and Fast Spectral  
Variability**

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# Outline

## ❖ Historical Behavior

- ◆ Probing the disk-jet connection

## ❖ Recent Chandra Results (Mar. 26 Nature)

- ◆ Long-term spectral variability
- ◆ Wind-Jet Interaction

## ❖ Current Work

- ◆ Some things you (maybe) didn't know you could do with the HETGS



# GRS 1915+105

\*  $D = 12.5$  kpc

\*  $M = 14 M_{\text{sun}}$

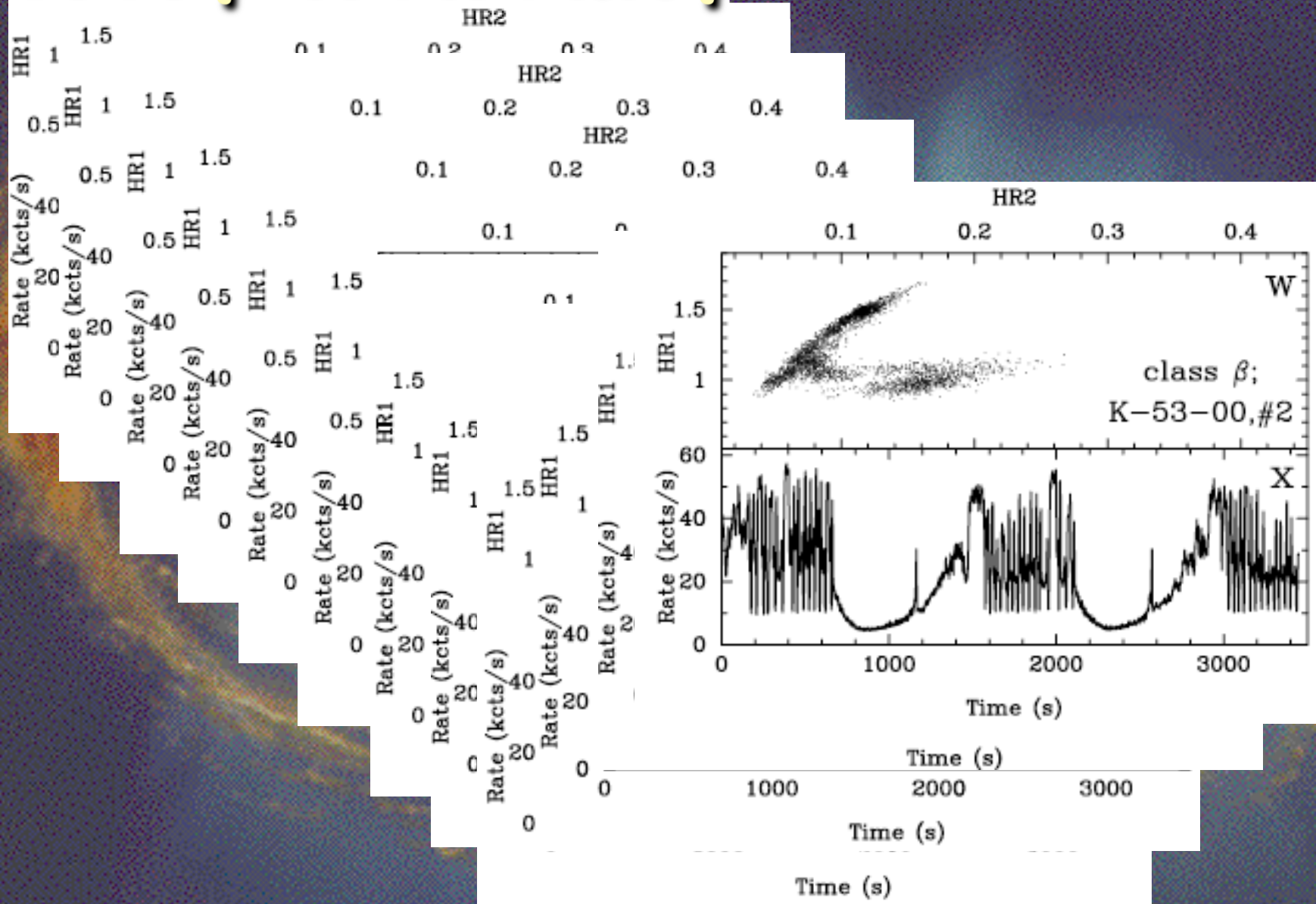
\*  $P_{\text{orb}} = 33.5$  d

\* Bizarre variability (at least fourteen distinct classes of X-ray variability)

\* Connection between disk, jet established conclusively in multi-wavelength studies (Fender, Mirabel)

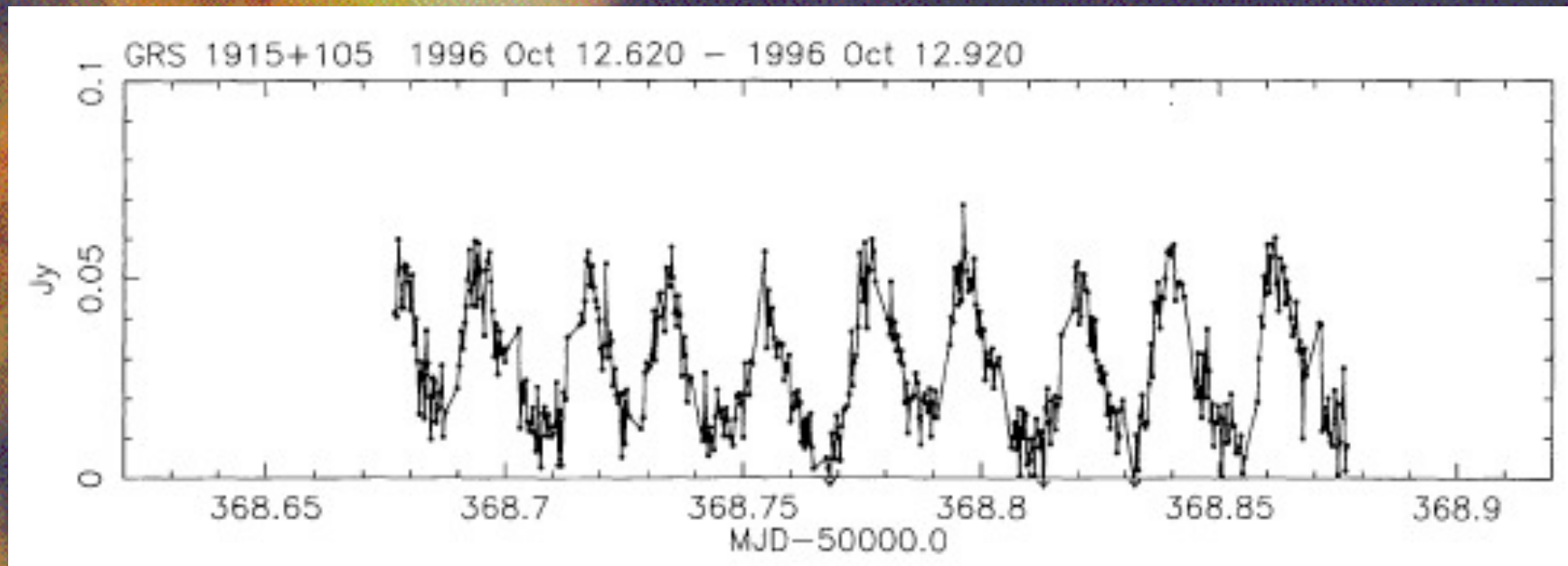


# X-ray Variability (Belloni 2000)





# IR/Radio Oscillations

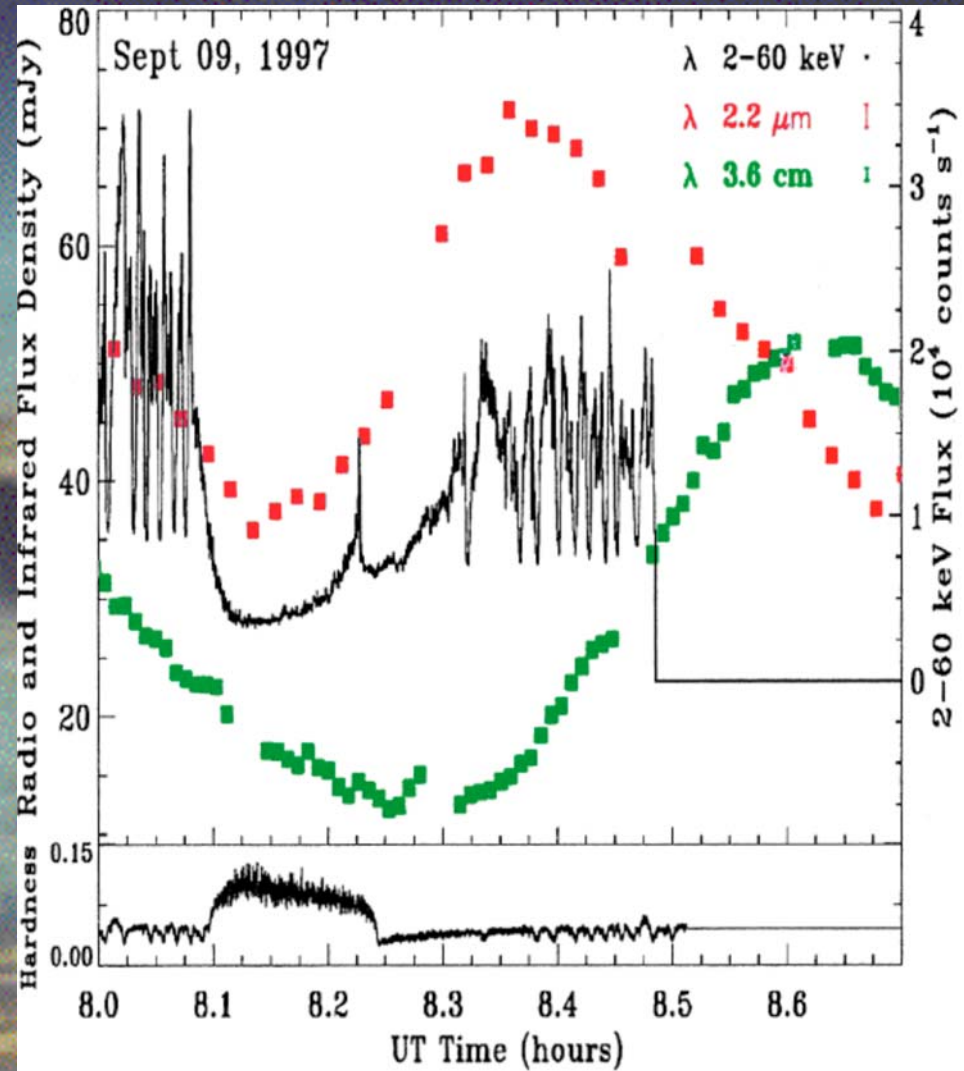


- \* IR/Radio lightcurves show 30-minute oscillations (Pooley/Fender 97...)
- \* Spectrum consistent with expanding blobs



# The Disk-Jet Connection

- Mirabel+ (1998)
- X-ray spike followed by IR, radio flares
- Decrease in hardness
- Corona/disk ejected?





# Summary

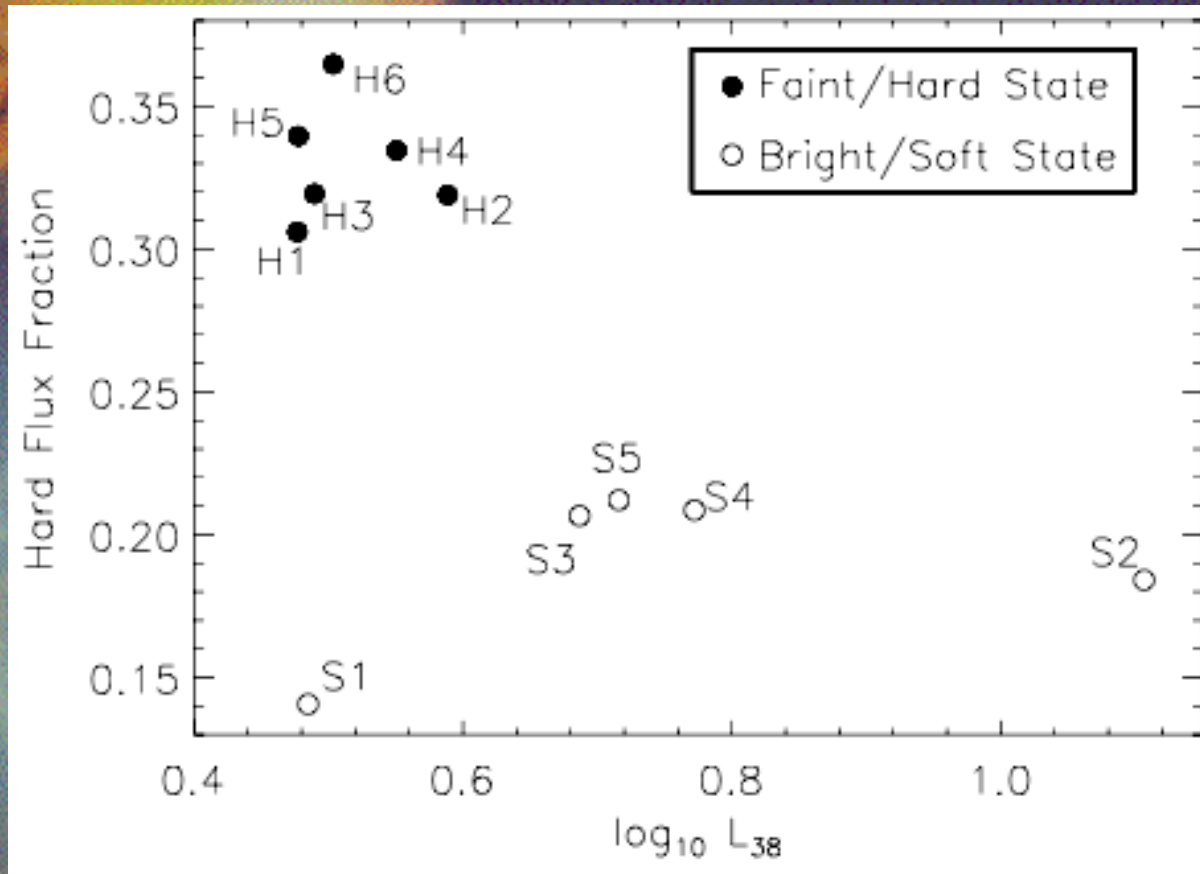
\*Previous work allows a clear association of disk/jet events

## Chandra HETGS

- Probe the disk-jet connection at high spectral resolution
- Use spectral lines to determine how plasma conditions change with X-ray state
- Eleven observations
- 5 variability classes
- Continuum calibration in progress
- $L_x$  (3-18 keV)
- $HF = (8.6-18)/(3-18)$
- Power-law strength



# Lx, HF



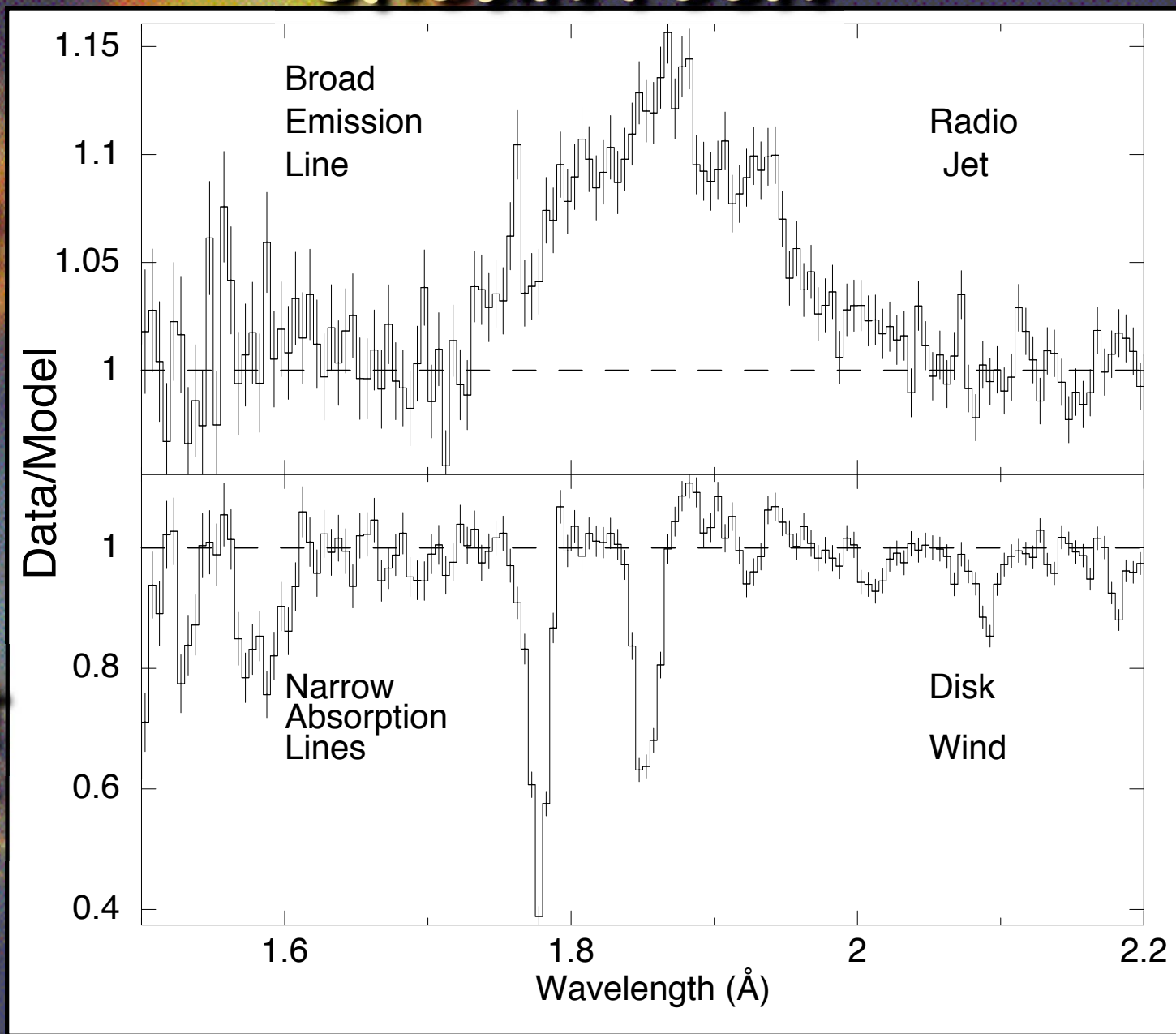
**Faint/hard or bright/soft  
Plus different line properties!!**



# Sneak Peek

Faint  
/Hard

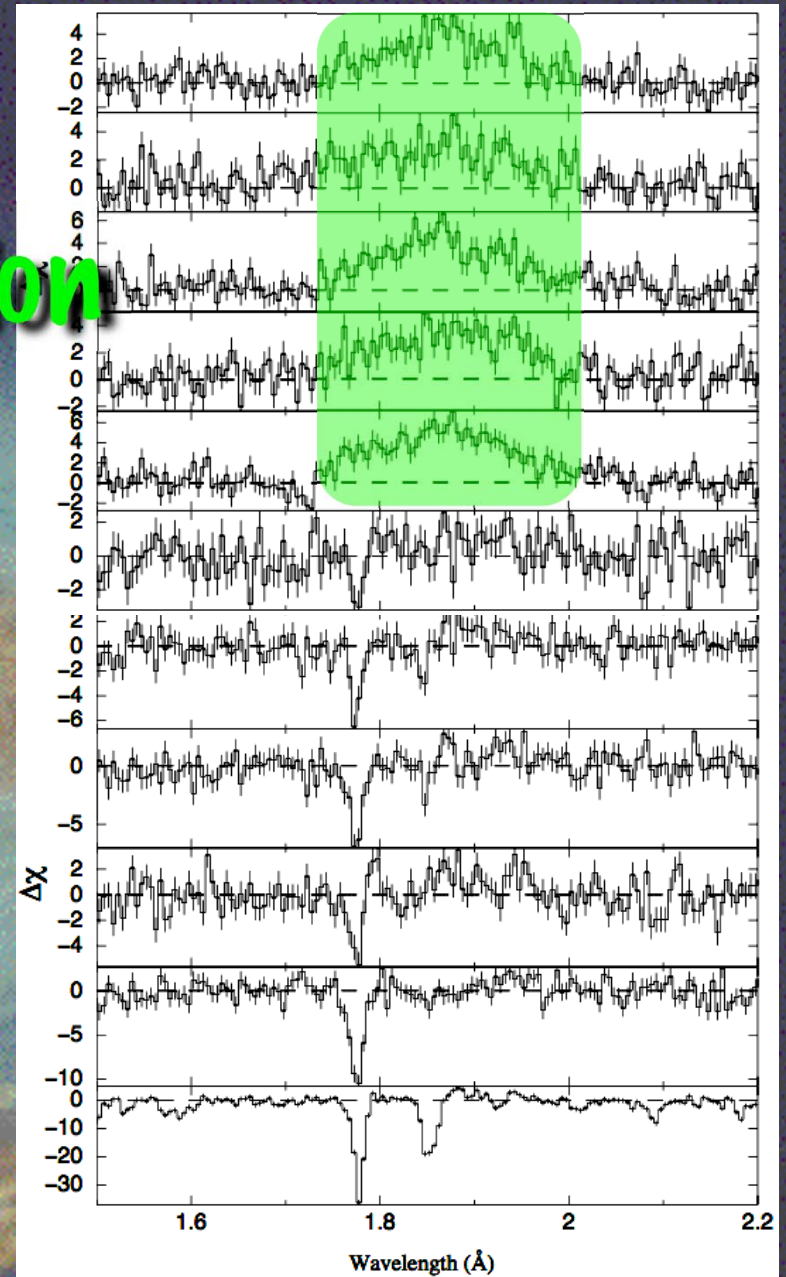
Bright  
/Soft





# The Disk-Jet Connection

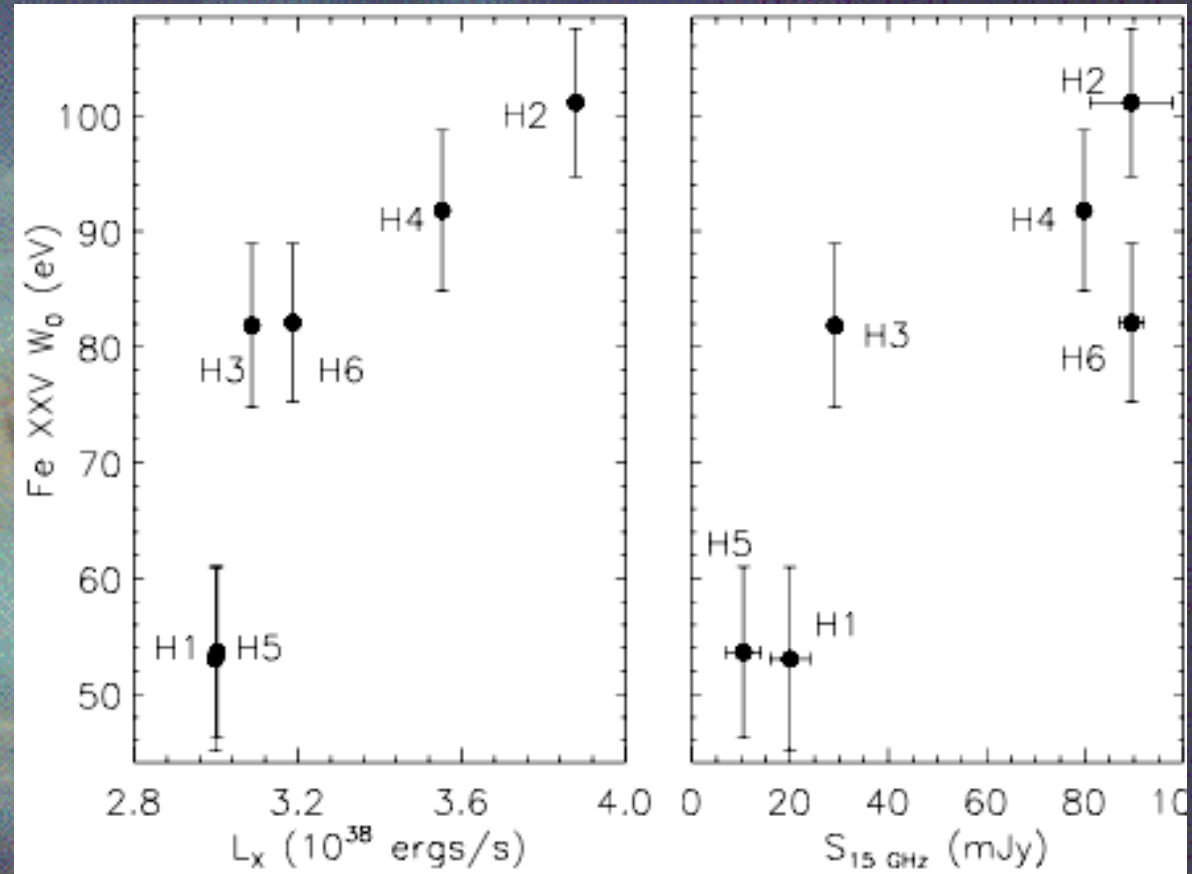
- HF decreases downwards
- Hard states: broad emission





# Broad Emission Lines

- Correlated with  $L_x$ ,  $S_{15\text{ GHz}}$
- $\Delta v > 12,000\text{ km/s}$
- Implies  $R < 500 R_g$





# Summary

## ❖ Historical Perspective

- ◆ Hard states produce compact radio jet
- ◆ Jets can pump IR emission lines (Eikenberry 1998)
- ◆ Disk truncated in hard state

## ❖ This Work

- ◆ Broad iron emission line arises when the inner edge of the truncated disk is illuminated by the jet
- ◆ Supported by correlation of E.W. with  $L_x$ , radio



# The Disk-Jet Connection

- HF decreases downwards

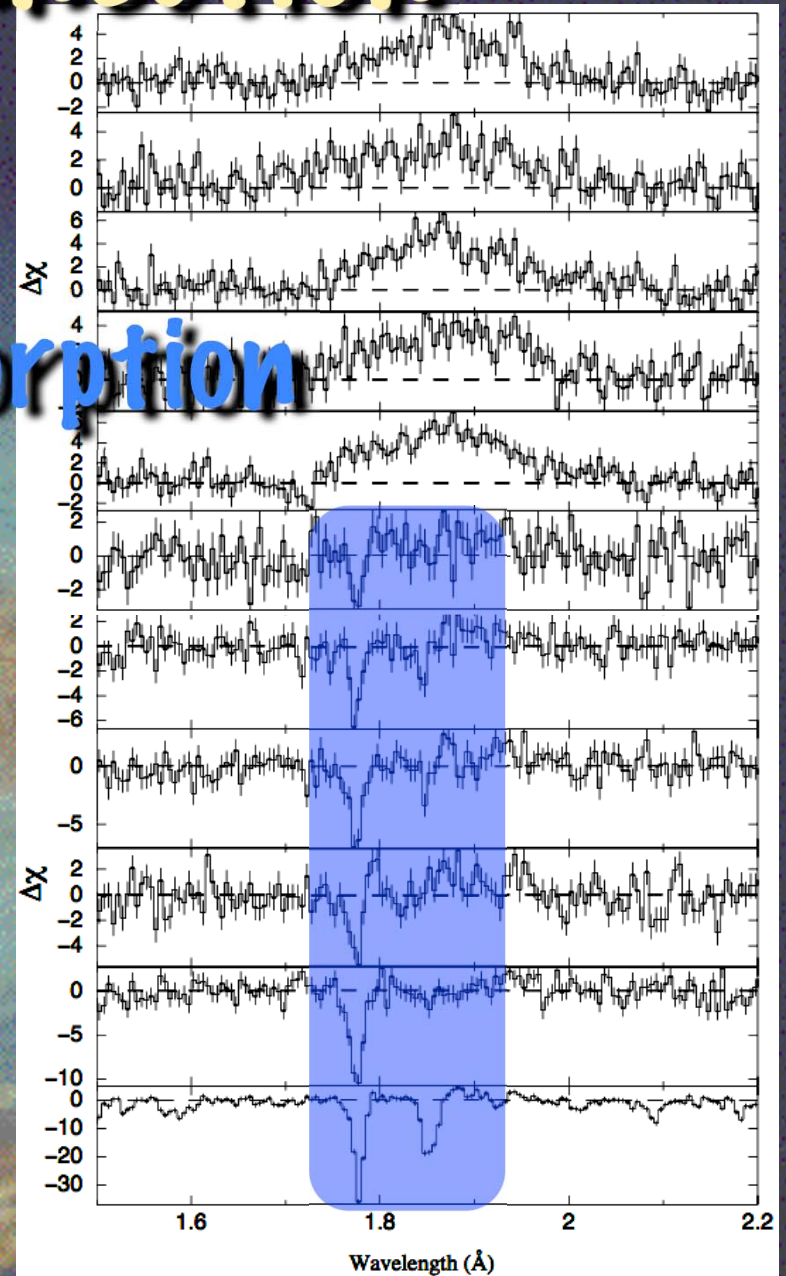
- Soft states: narrow absorption

- Blueshift:  $-1000$  km/s

- Keplerian motion implies

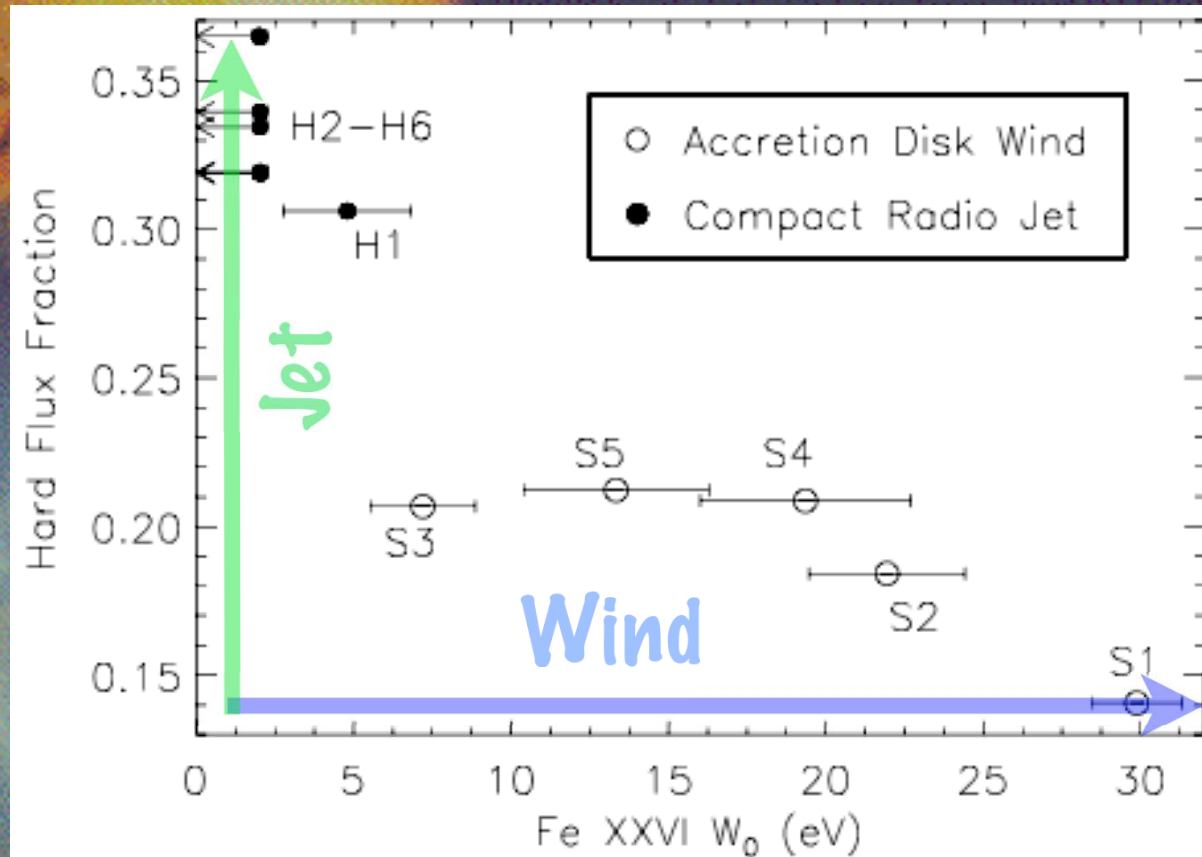
$$R = 100,000 R_g$$

- A.D. Wind





# Accretion Disk Wind



Optical depth in wind decreases with increasing hard flux  $\rightarrow$  interplay between Comptonization, photoionization.

See, e.g., Miller+ (2006, 2008) for other examples



# Implications and Questions

- ✦ Direct competition between the wind and the jet
- ✦ Outflow regulation in GRS 1915+105
- ✦ Behavior similar to Supermassive Black Holes
- ✦ Paul Green's talk on Tuesday - Low-luminosity AGN behave like XRB in the low-hard state



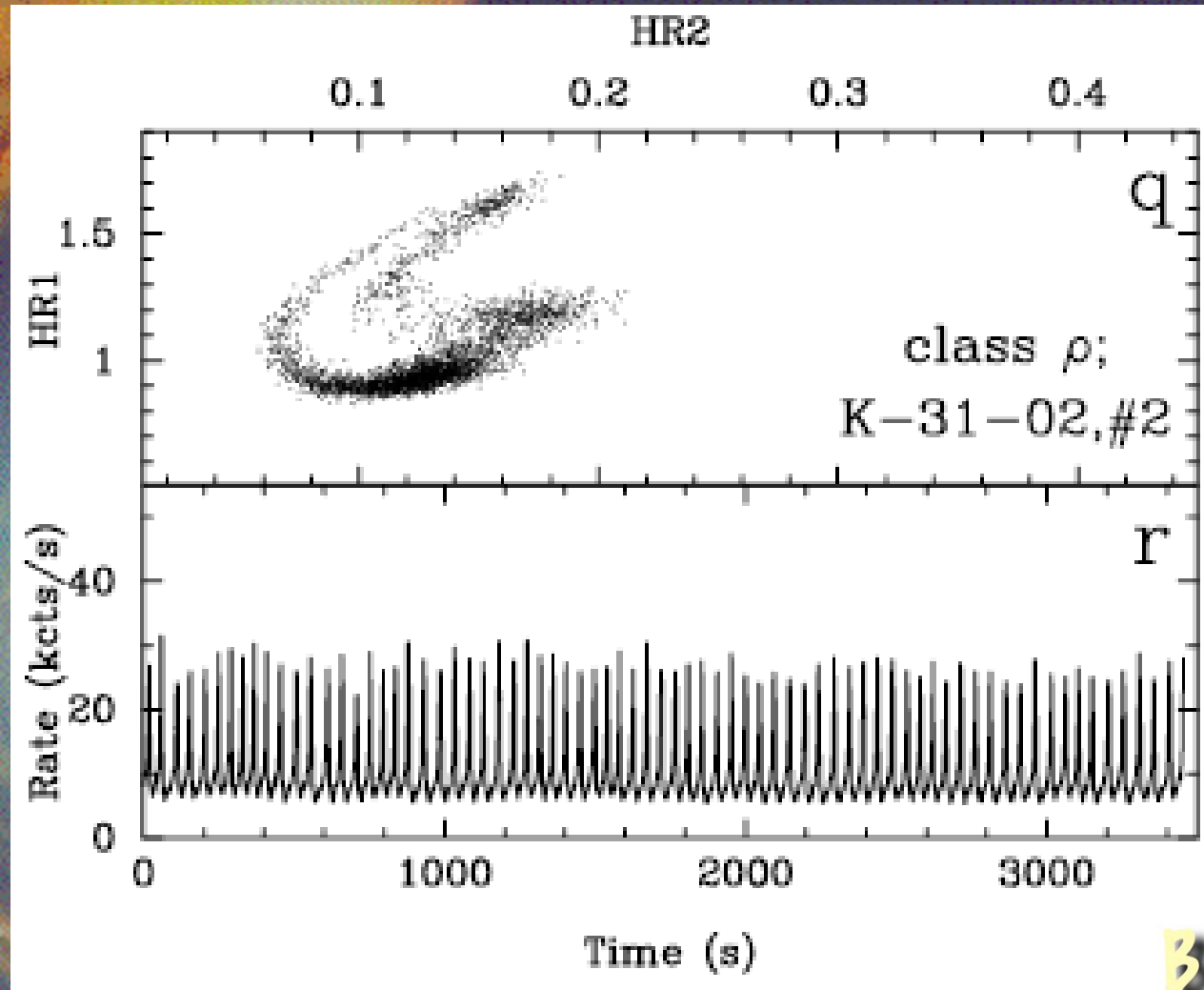


# What You Didn't Know You Could Do With the HETGS

- ◆ Color-Color Diagrams (Timing Analysis)
- ◆ Fast variability at high spectral resolution



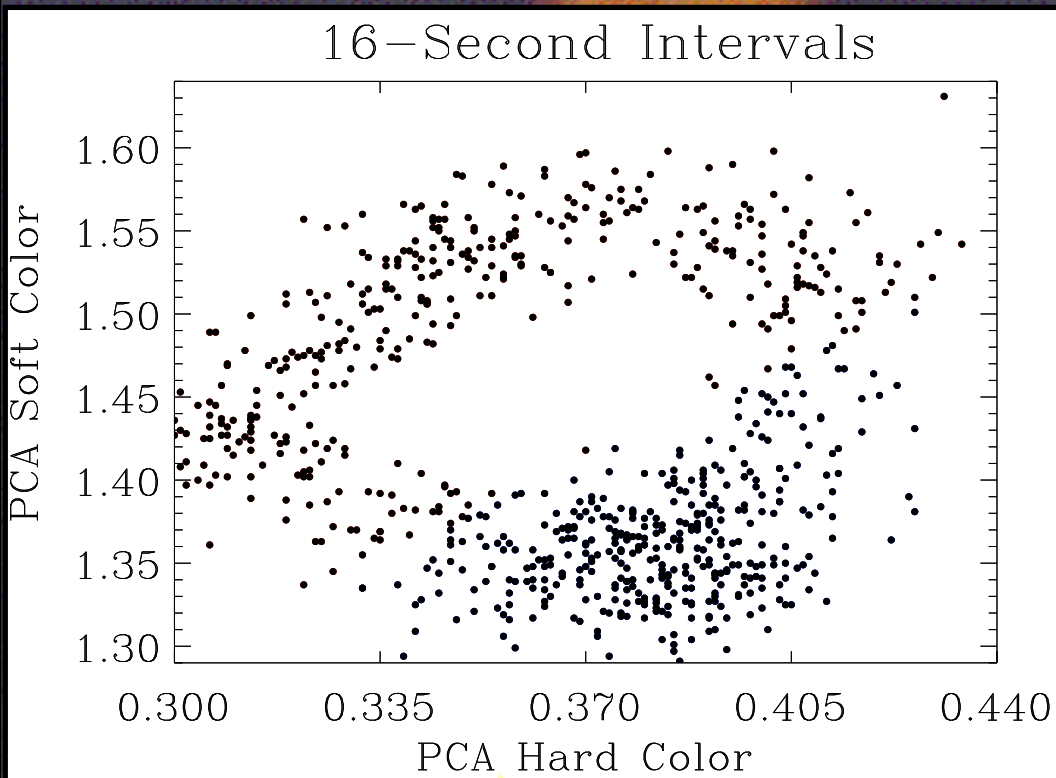
# The Heartbeat State



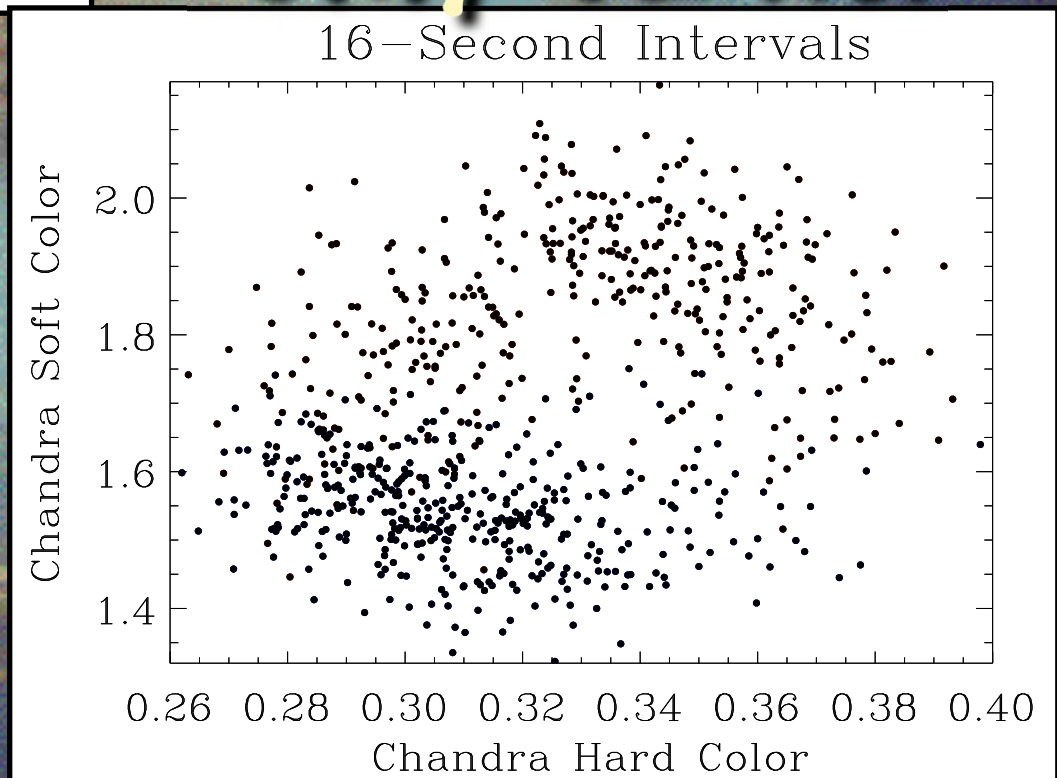
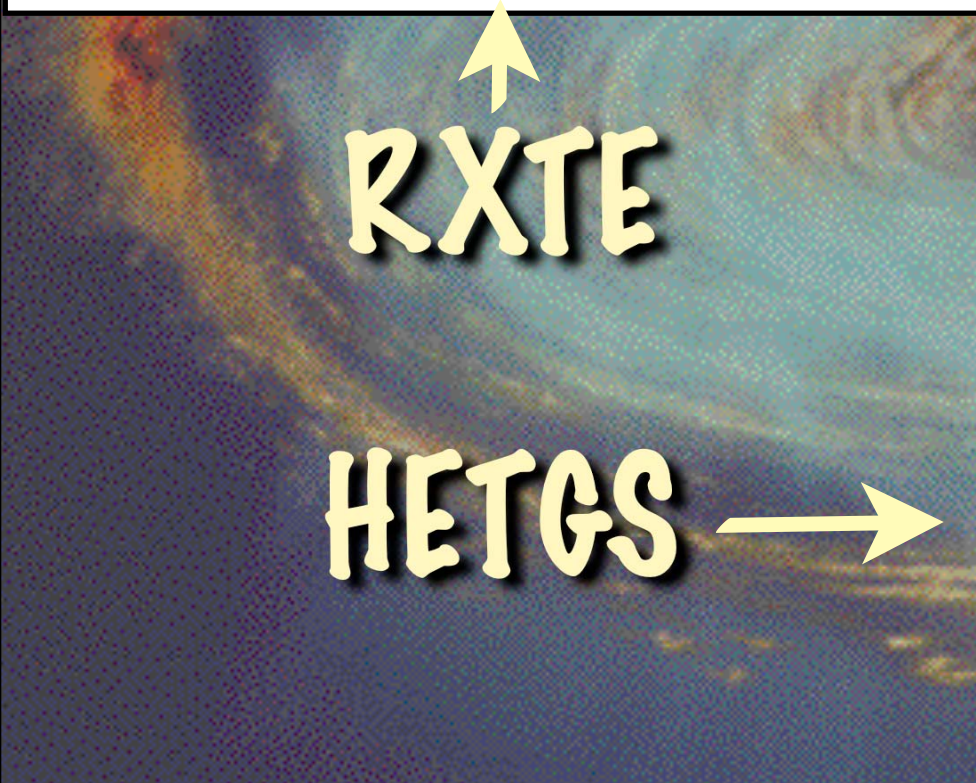
Belloni 2000

Slow, high-amplitude oscillation with a period near 50 seconds



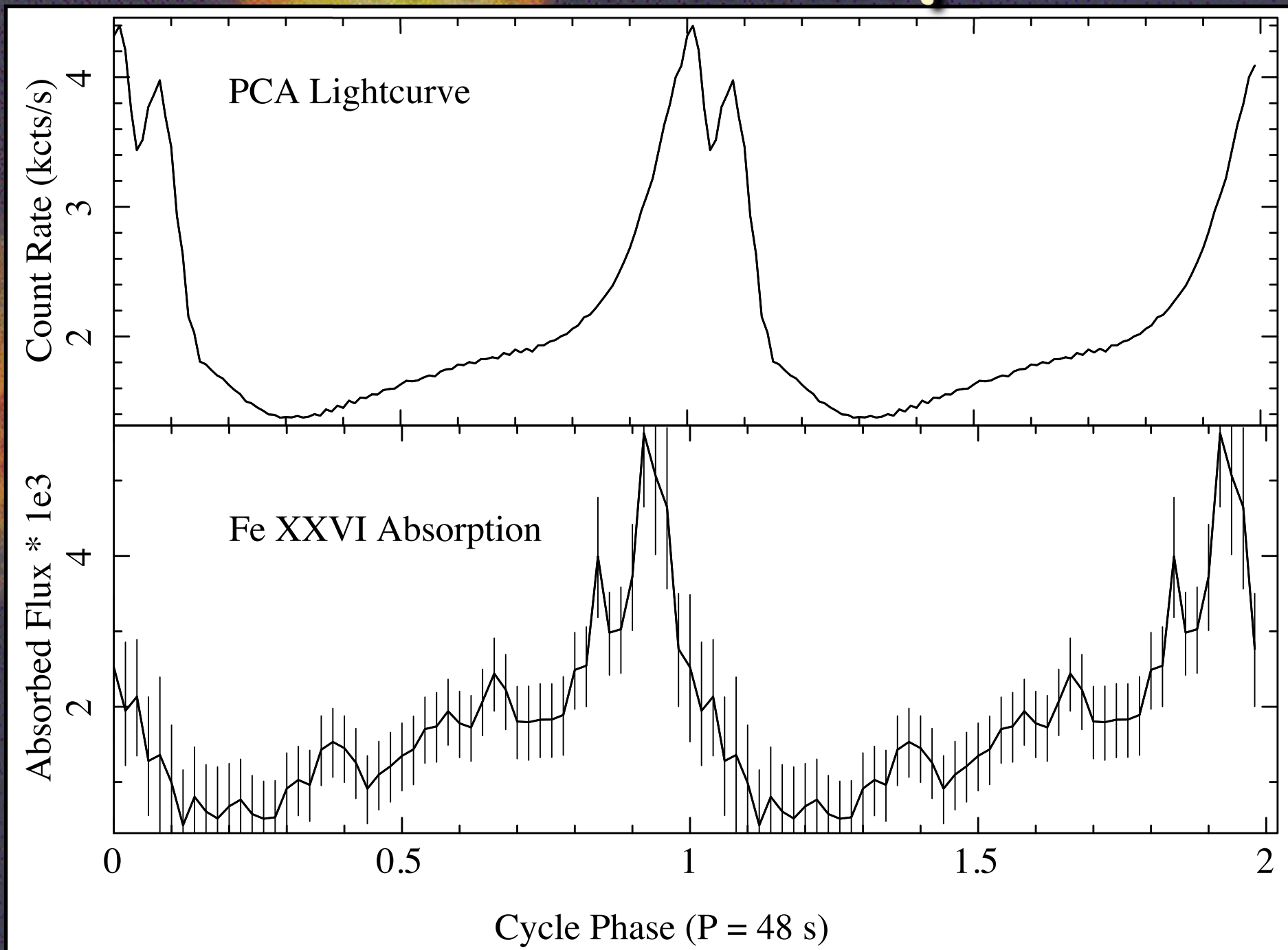


**Color-  
Color  
Diagrams  
Only 12 ks!**





# Fast Variability





# Conclusions

- ◆ Long-term studies of GRS 1915+105 reveal details of the interaction between radio jet and disk wind
- ◆ Similarities to SMBHs in outflow regulation
- ◆ Chandra can do timing analysis with grating-quality spectra!
- ◆ Fast variability -> Photoionization geometry