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

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September 25
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

- $D = 12.5 \text{ kpc}$
- $M = 14 \text{ M}_{\odot}$
- $P_{\text{orb}} = 33.5 \text{ d}$
- 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**

Data/Model

Wavelength (Å)

- Broad Emission Line
- Radio Jet
- Narrow Absorption Lines
- Disk Wind

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 Lx, radio
The Disk-Jet Connection

- HF decreases downwards
- Soft states: narrow absorption
- Blueshift: ~1000 km/s
- Keplerian motion implies $R=100,000 \, R_\odot$
- A.D. 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

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

Belloni 2000
Fast Variability

PCA Lightcurve

Absorbed Flux * 1e3

Fe XXVI Absorption

Cycle Phase (P = 48 s)
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