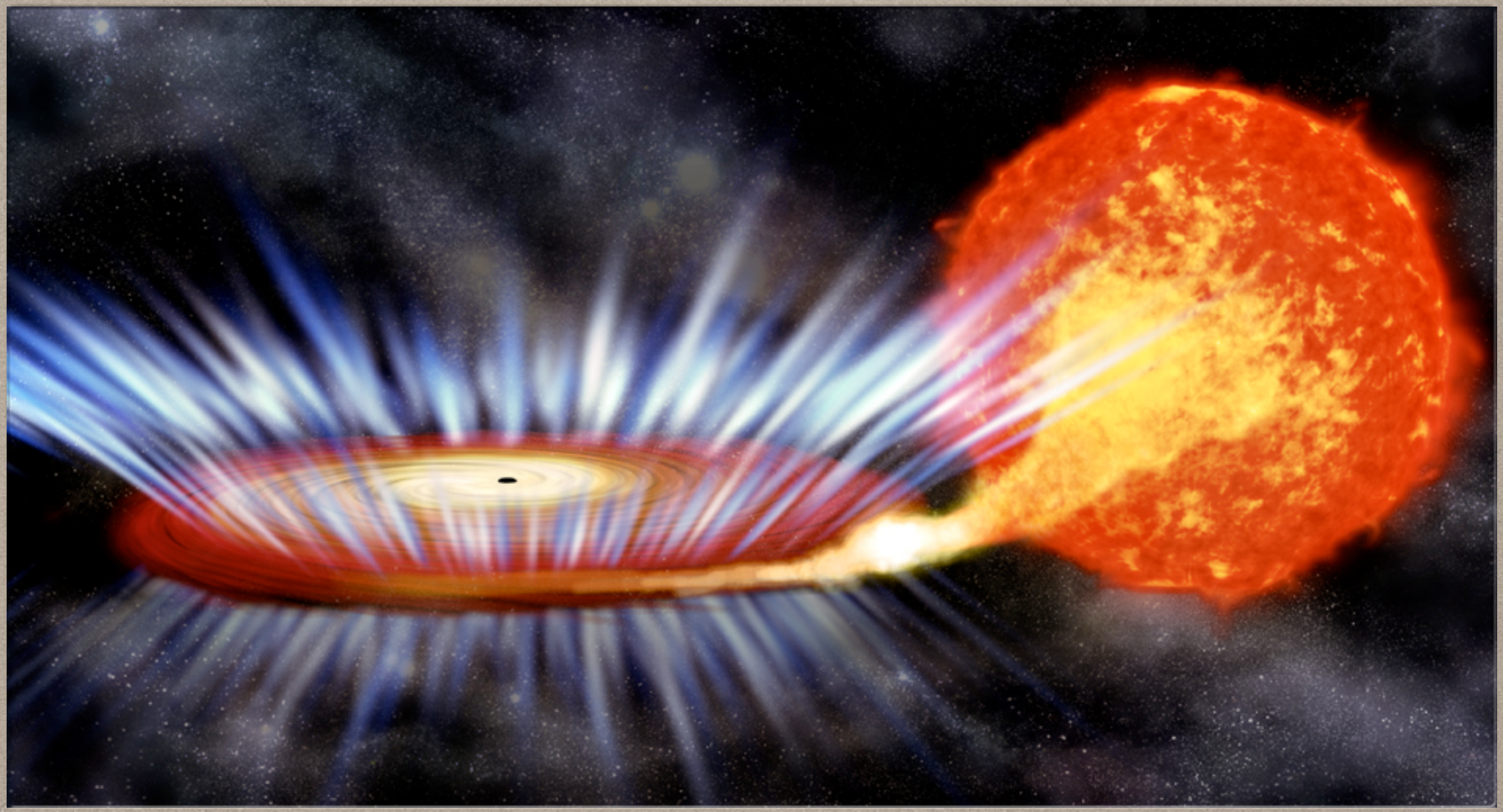


STROBE-X AND THE PHYSICS OF DISK WINDS

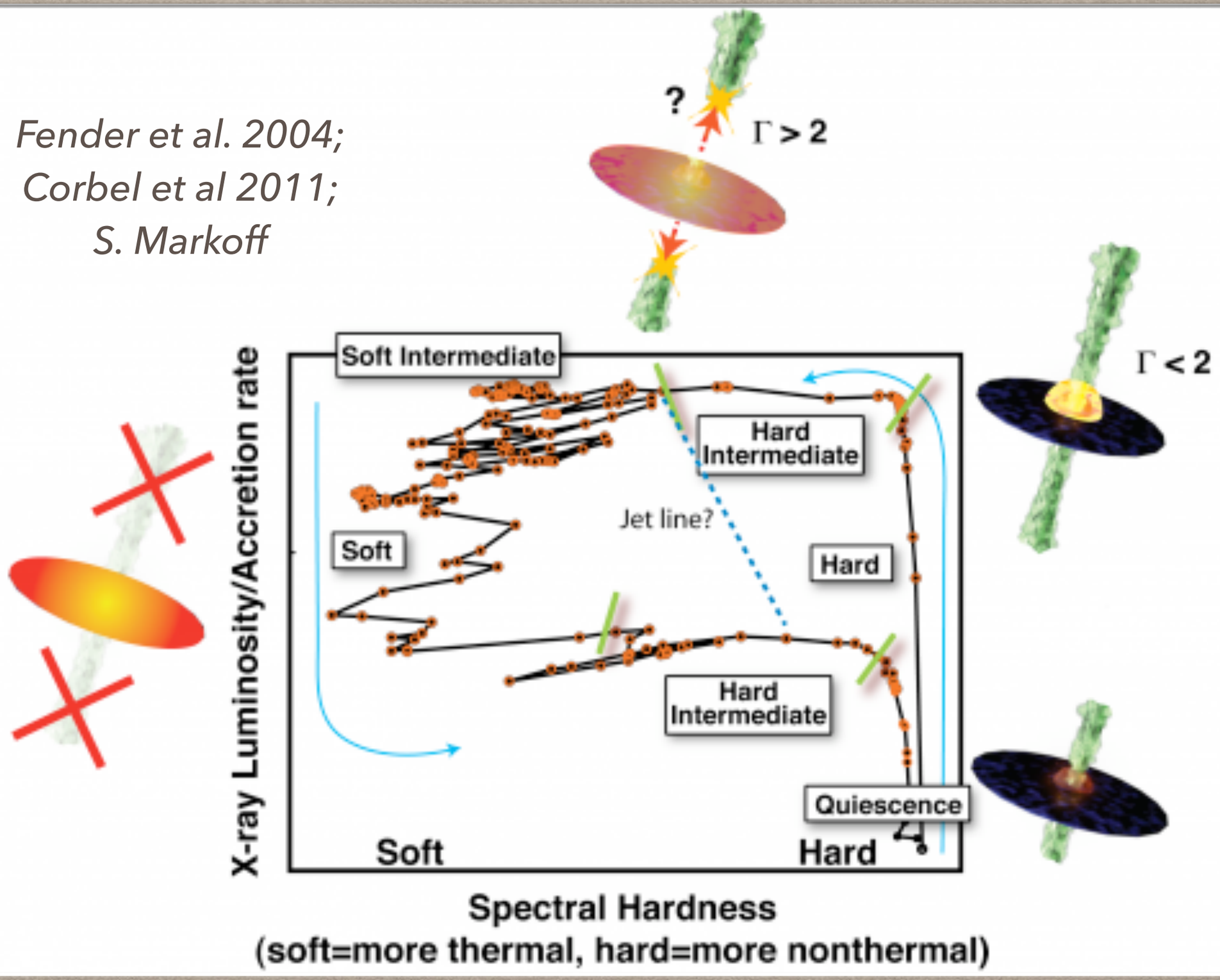
JOEY NEILSEN, VILLANOVA UNIVERSITY

STROBE-X SCIENCE DEFINITION WORKSHOP

SEPTEMBER 18 2017

FEEDBACK IN BH XRBS

Fender et al. 2004;
Corbel et al 2011;
S. Markoff

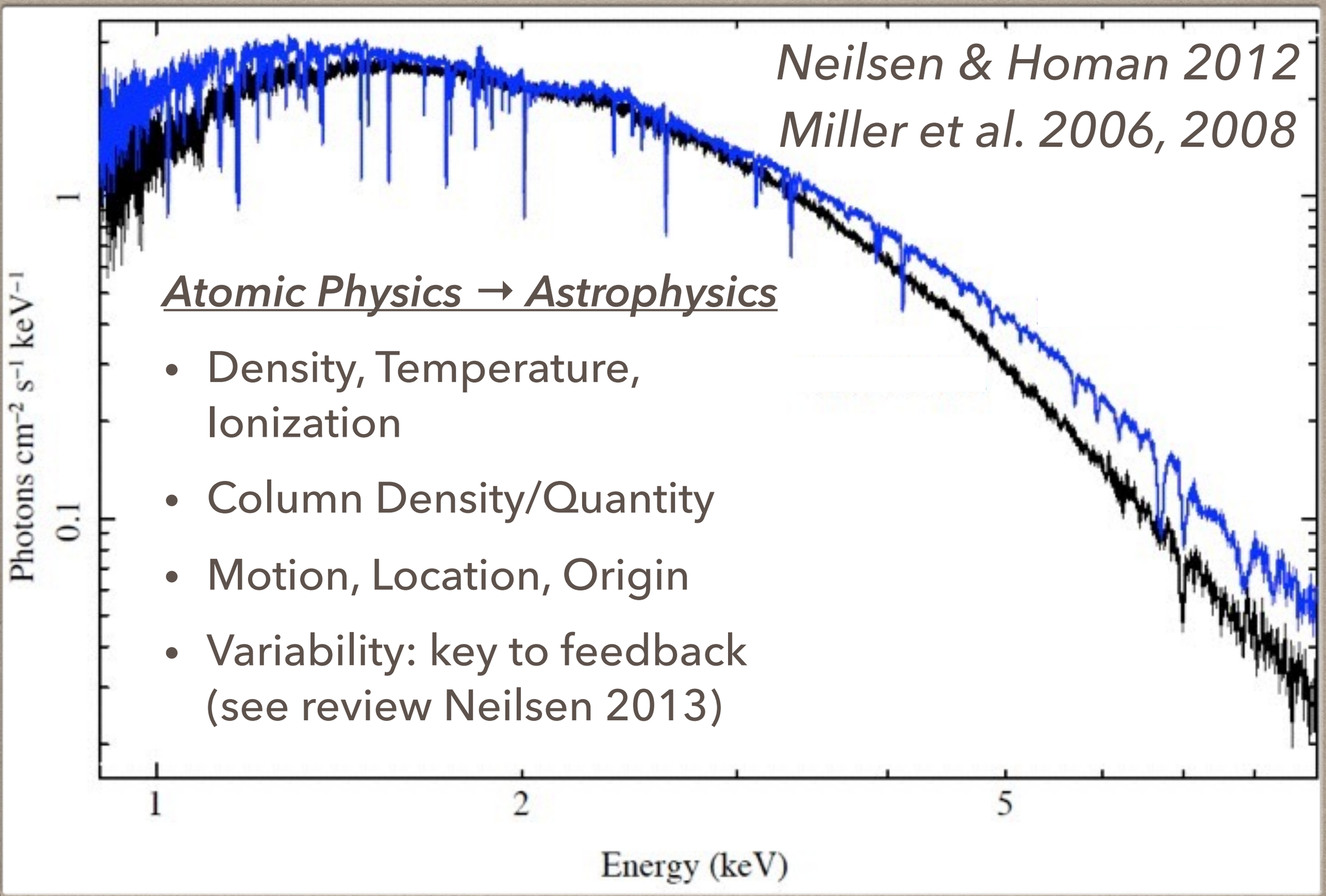


WINDS AND FEEDBACK?

Neilsen & Homan 2012
Miller et al. 2006, 2008

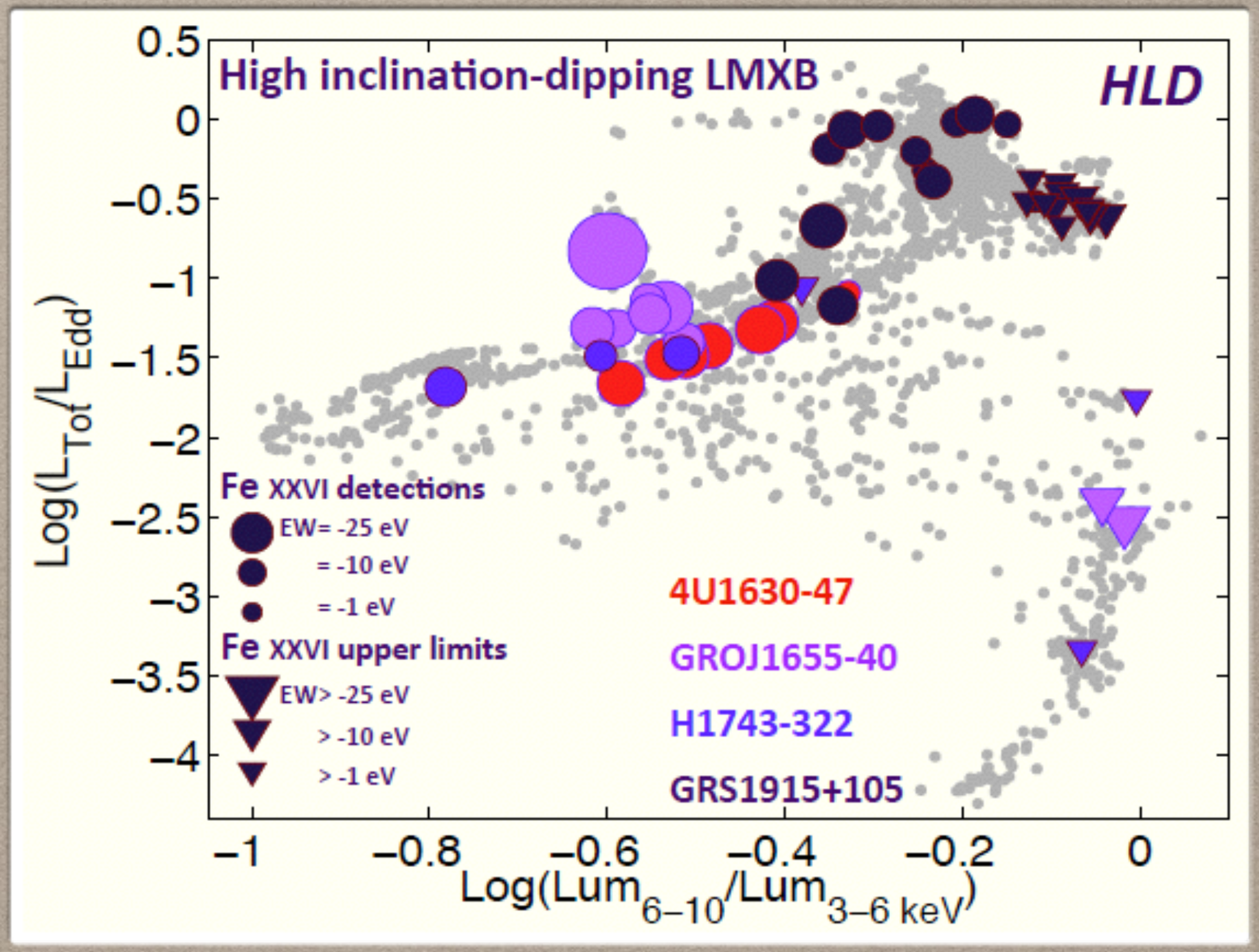
Atomic Physics → Astrophysics

- Density, Temperature, Ionization
- Column Density/Quantity
- Motion, Location, Origin
- Variability: key to feedback (see review Neilsen 2013)



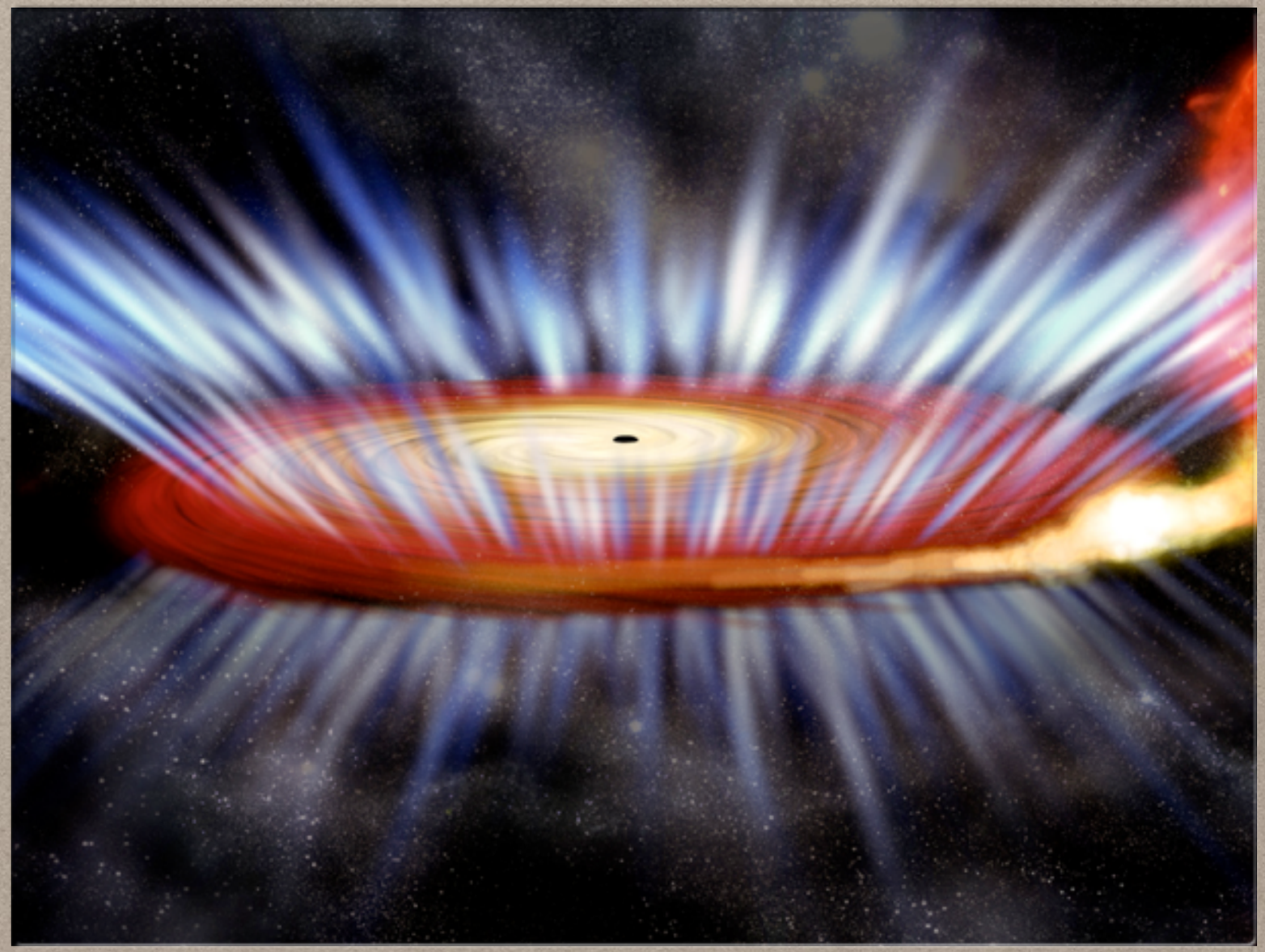
WINDS IN OUTBURSTS

- Archival study by Ponti et al. (2012)
- Preferentially detected in softer/brighter states, as opposed to harder, jet-producing states, but see Homan, Neilsen et al. (2016)



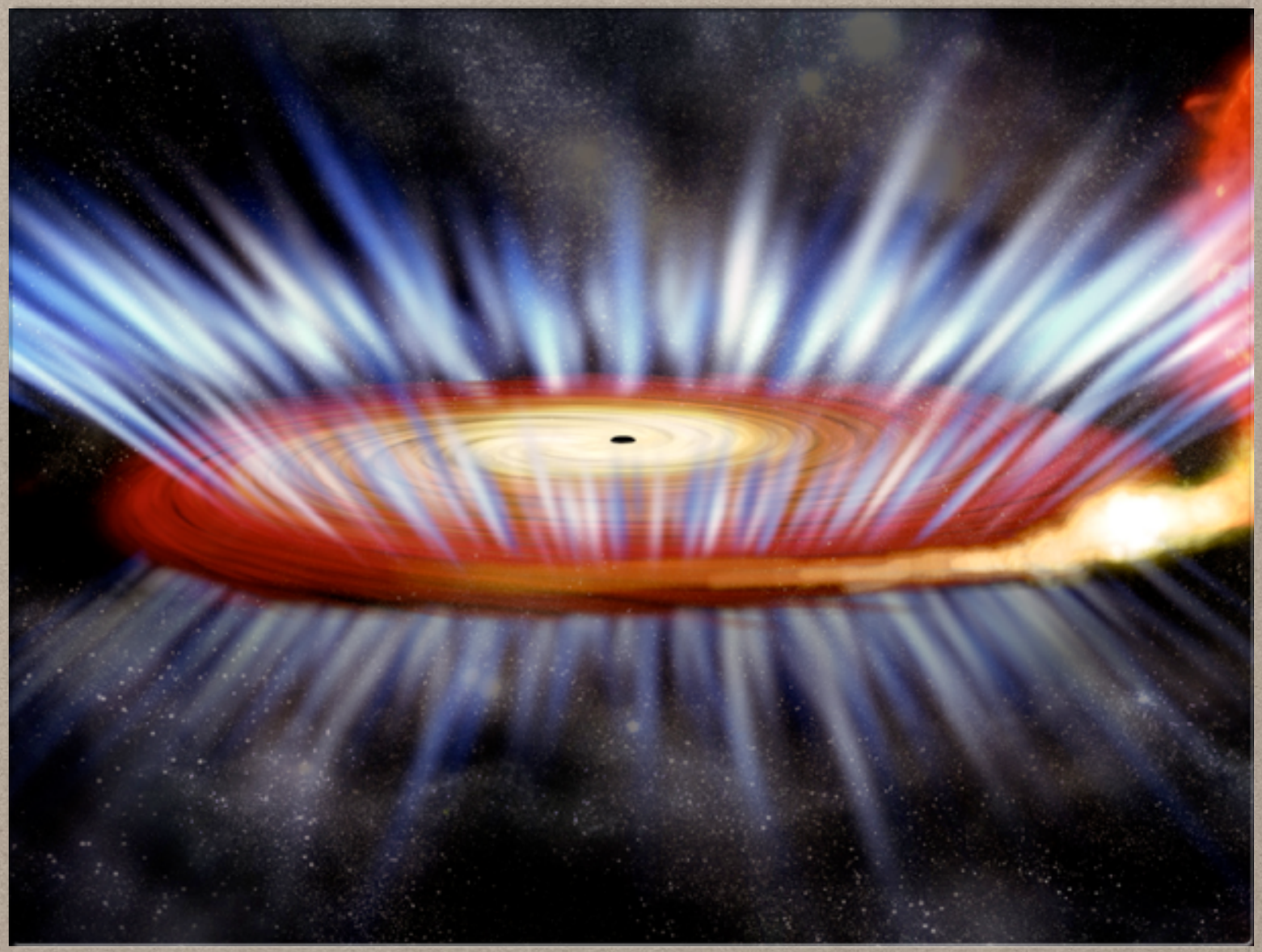
SIGNIFICANCE: I.

- Winds can be massive
- $\dot{M}_{wind} >> \dot{M}_{BH}$ Neilsen et al. 2011; Lee et al. 2002, Ponti et al. 2012
- Responsible for determining/ regulating accretion rate at event horizon??

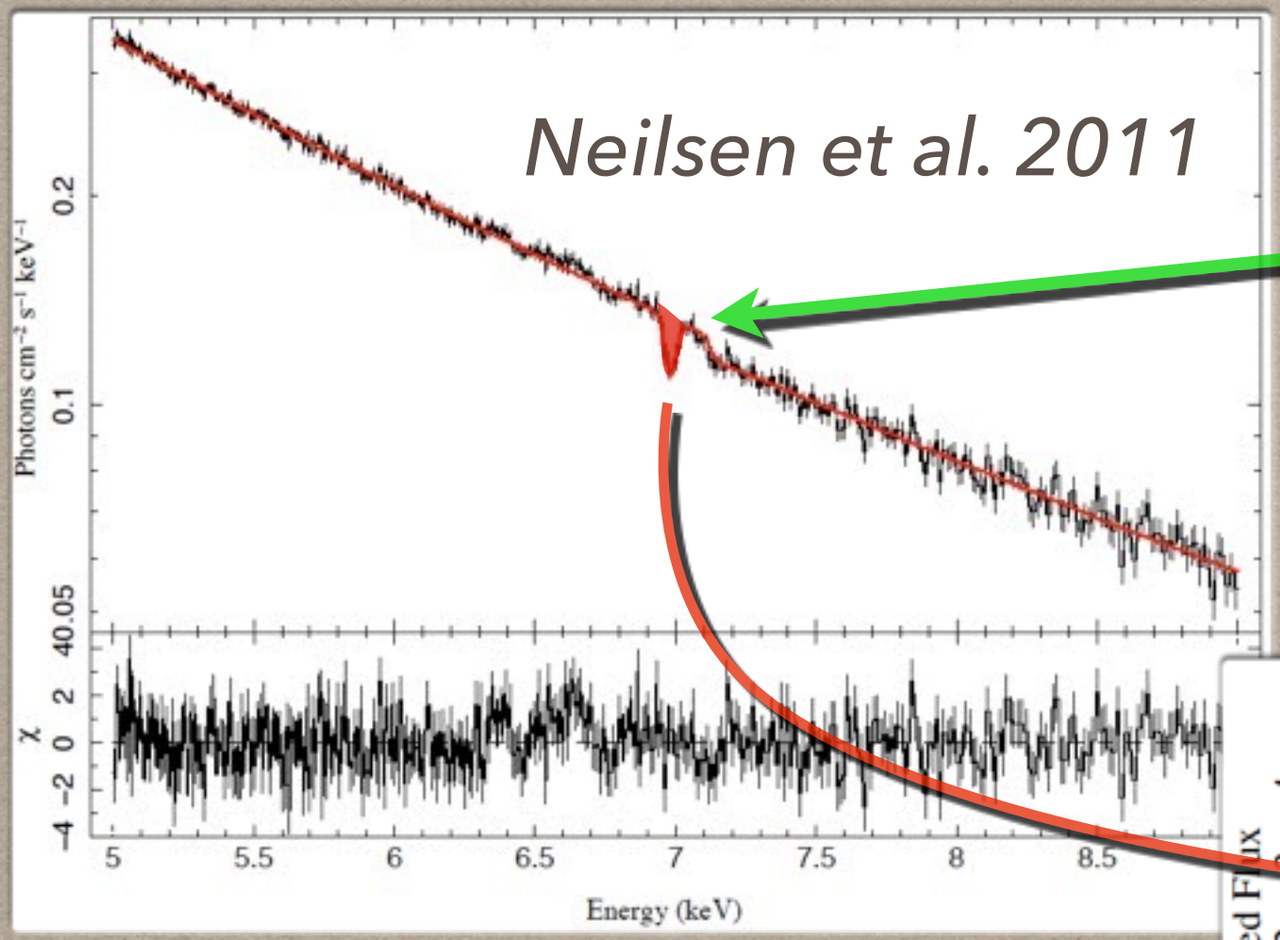


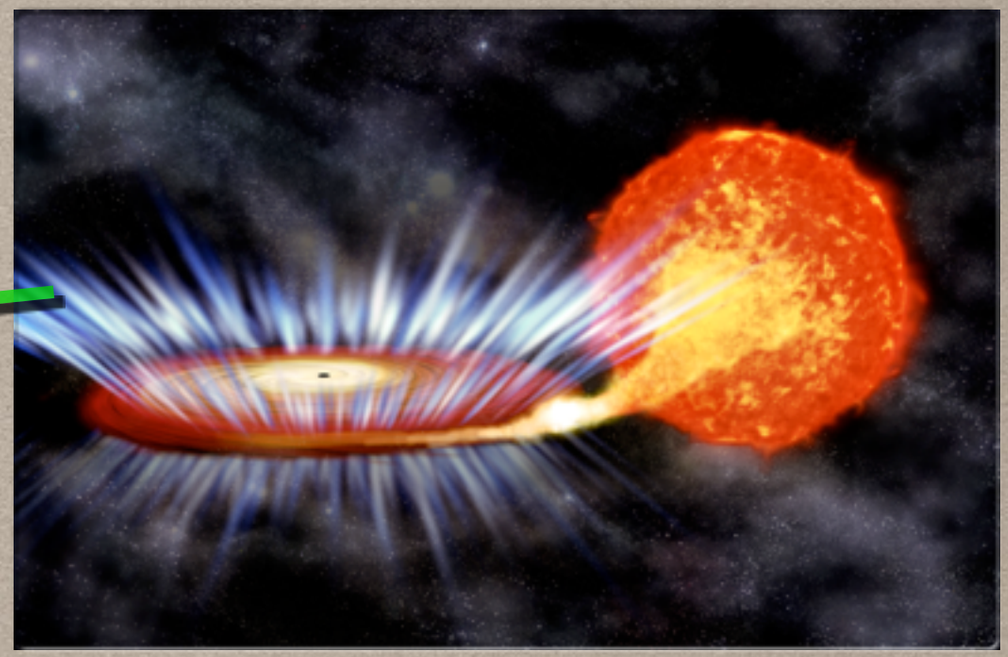
SIGNIFICANCE: II.

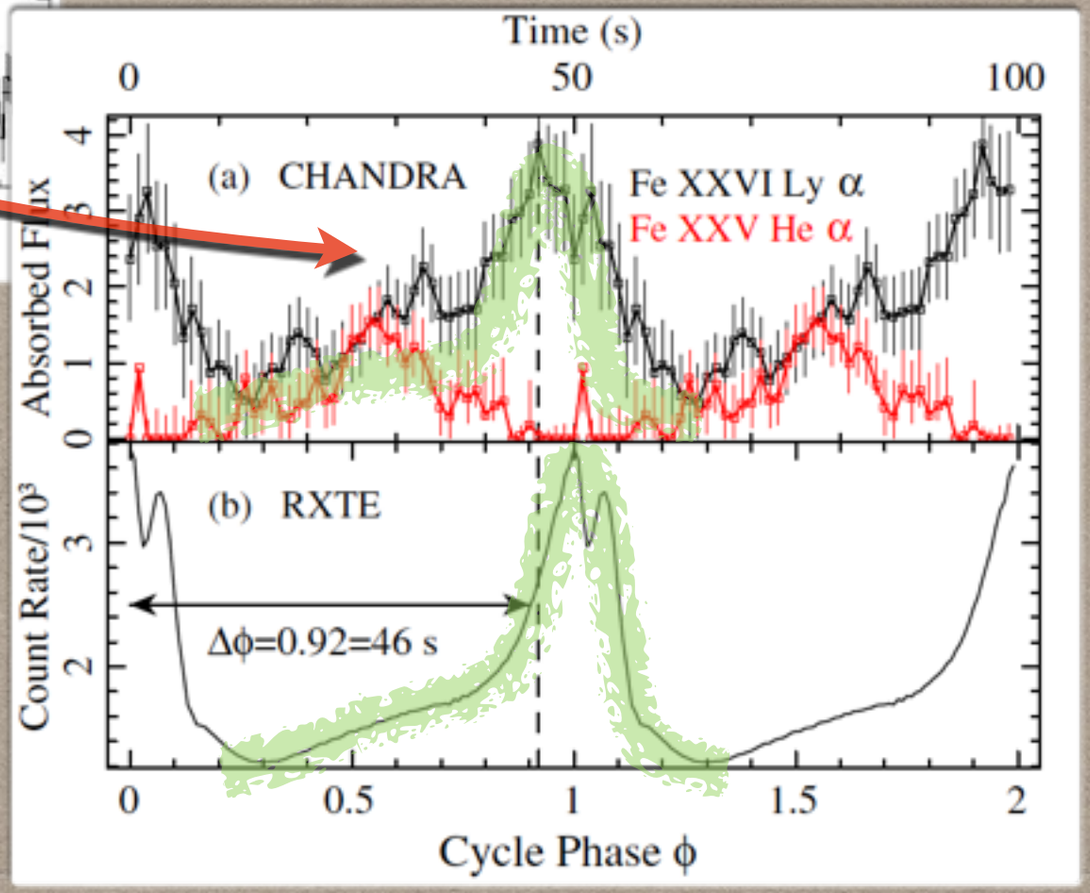
- Winds can be variable
- Δt ranging from ~s to years (Neilsen et al. 2011, 2012a,b; Neilsen & Lee 2009; Miller et al. 2006b)
- Reveals mechanisms connecting BHs and their environments



EXOTIC WIND VARIABILITY

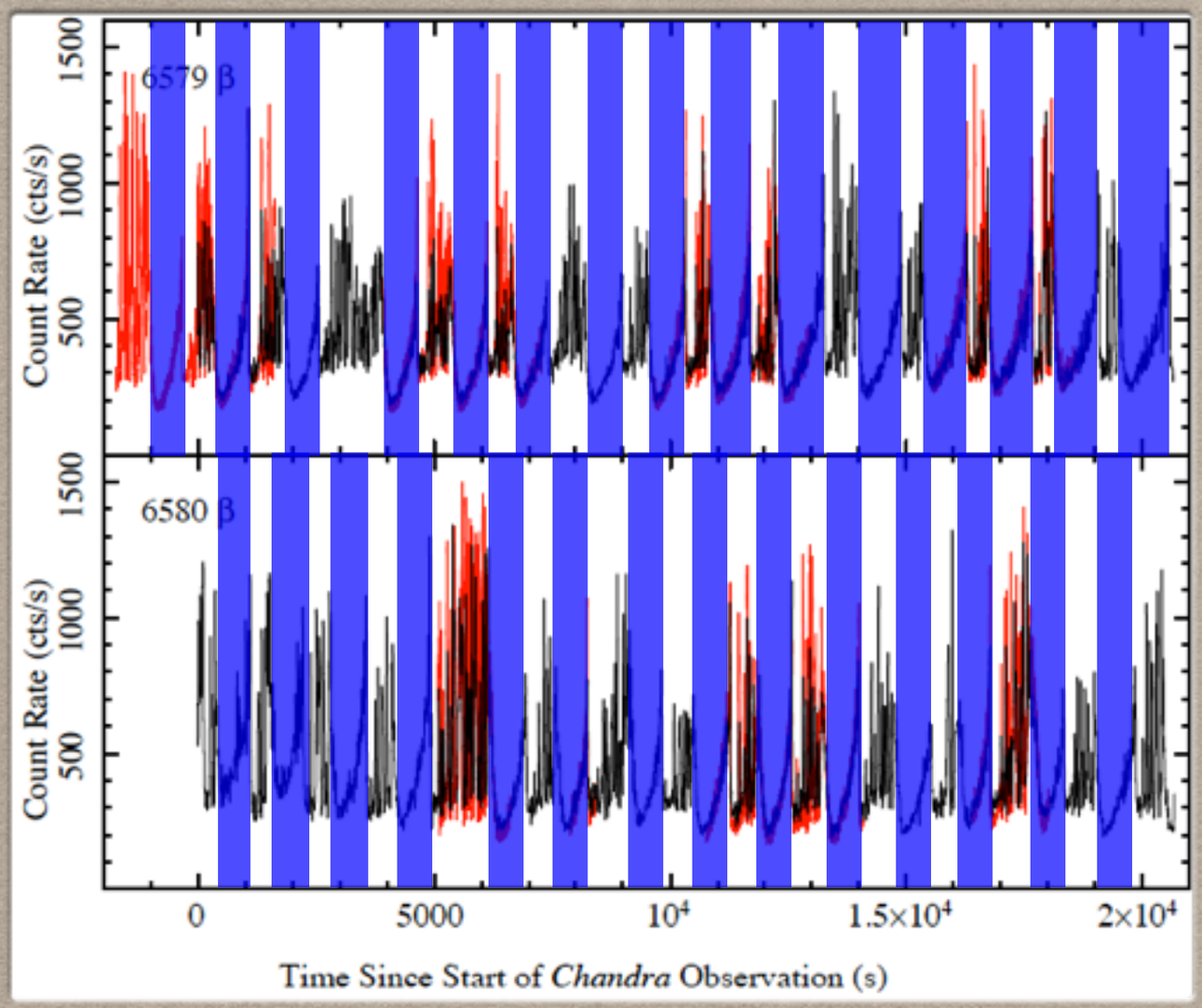




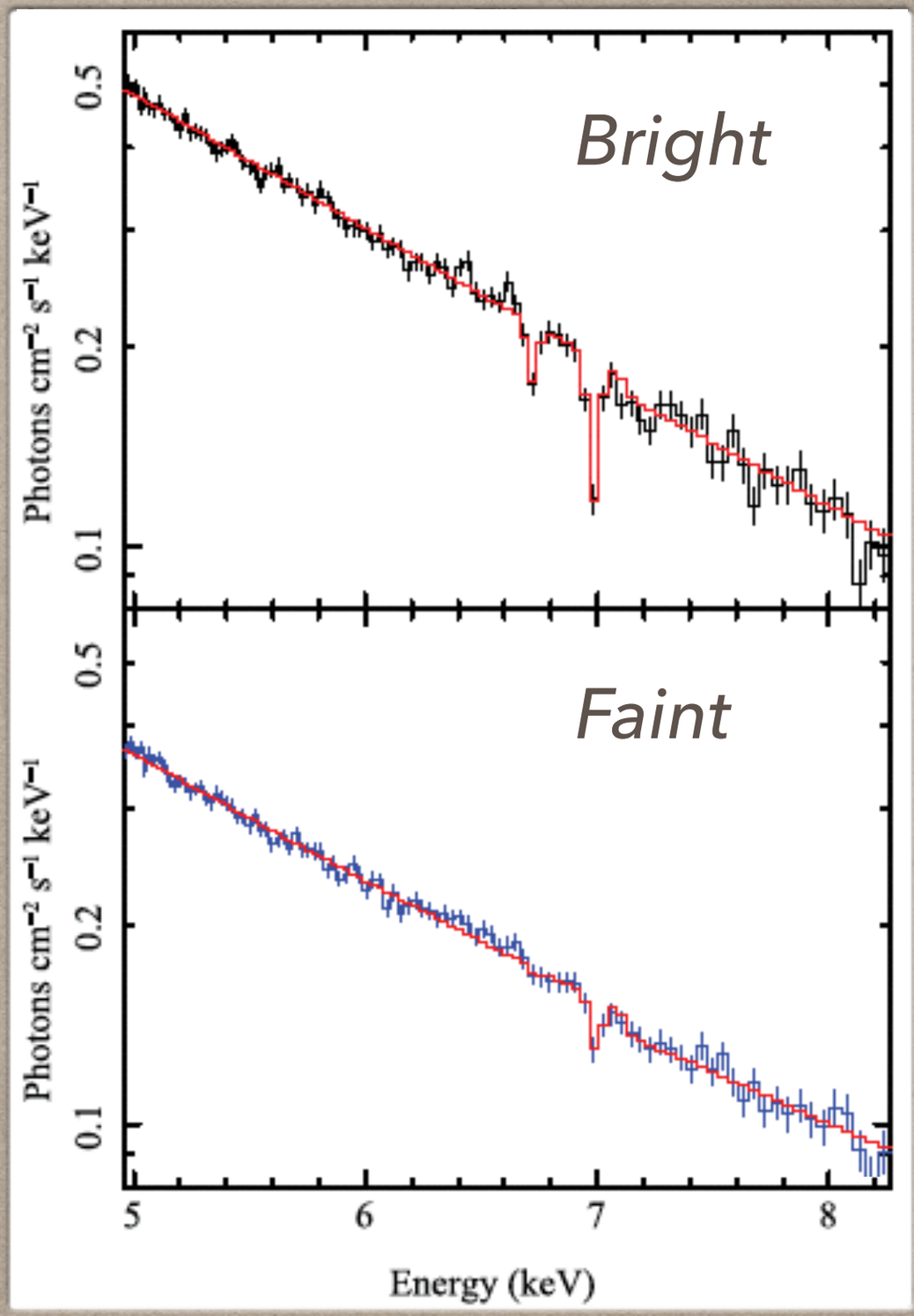


- Large-scale wind observed during bright X-ray pulsation in GRS 1915+105
- Bulk wind responds in seconds (Neilsen et al. 2011)

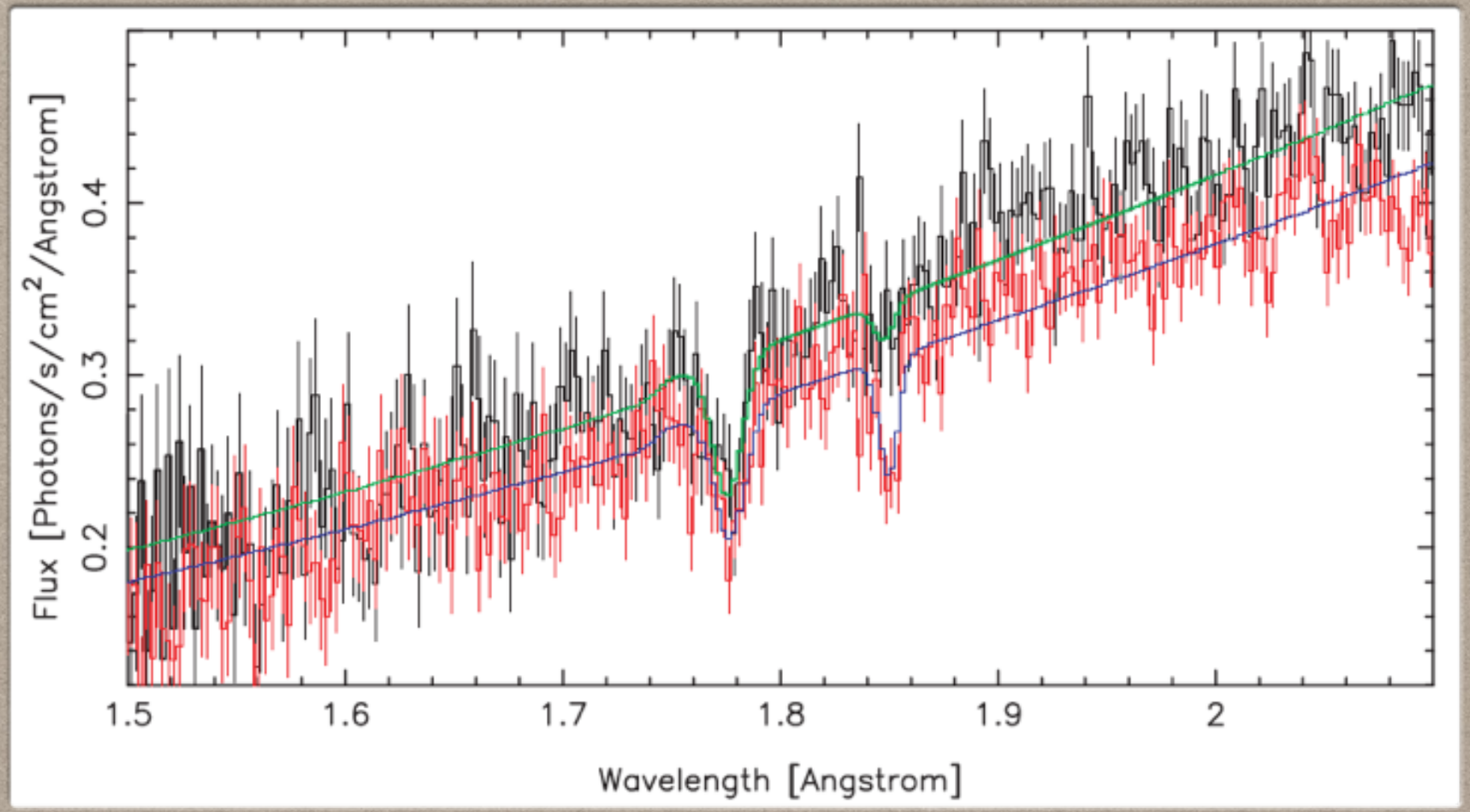
EXOTIC WIND VARIABILITY



- ~Hour-long GRS 1915 cycles also associated with variable winds (Neilsen et al. 2012a)



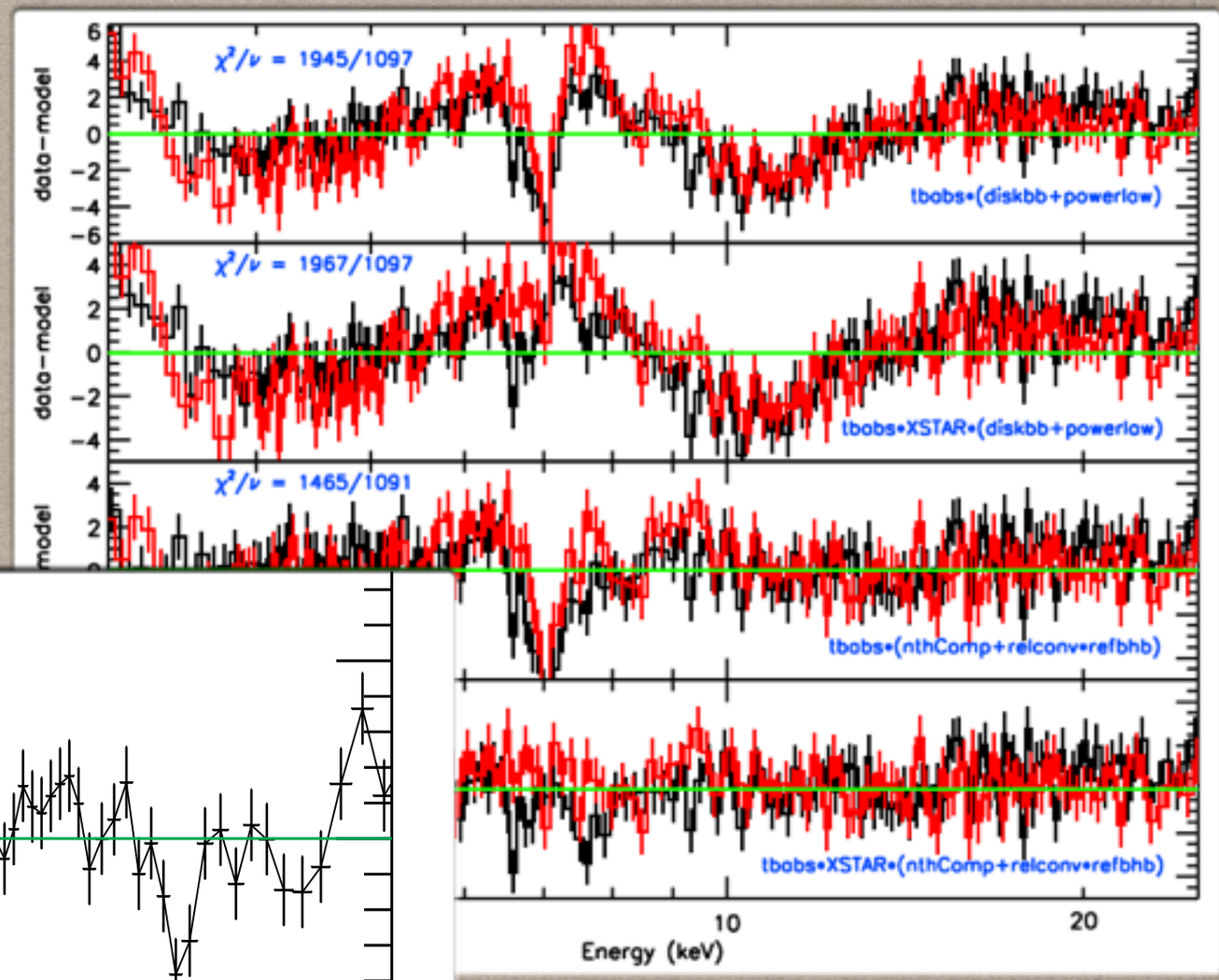
NOT JUST GRS 1915+105

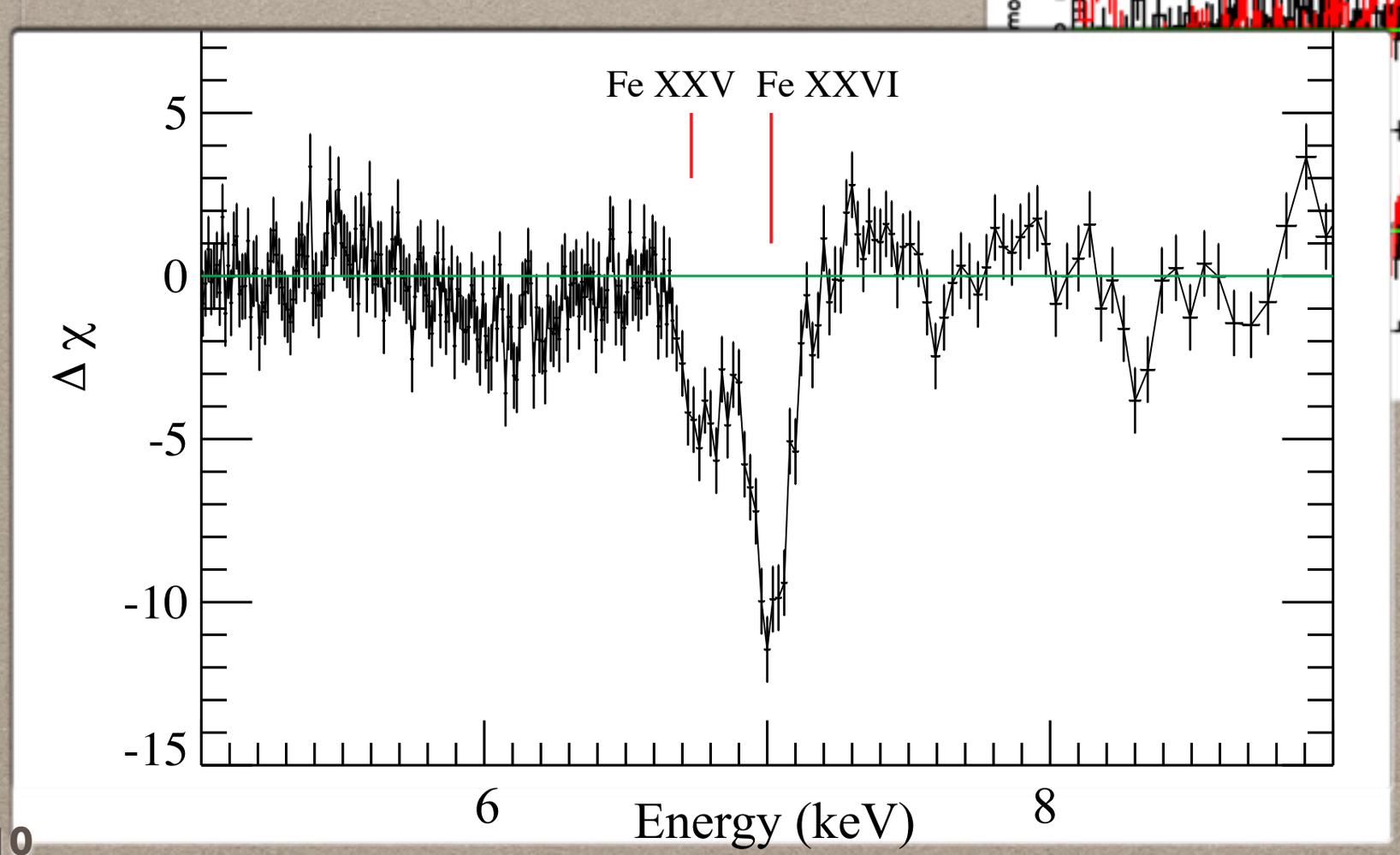


- H1743-322 during a 300s oscillation (Miller et al. 2006b)
- Mechanism unclear; density variations? obscuration?

NOT JUST FOR CHANDRA!

- Both NuSTAR (right, King et al. 2014) and NICER (below; c.f. Ed Cackett's HEAD talk) detect disk winds

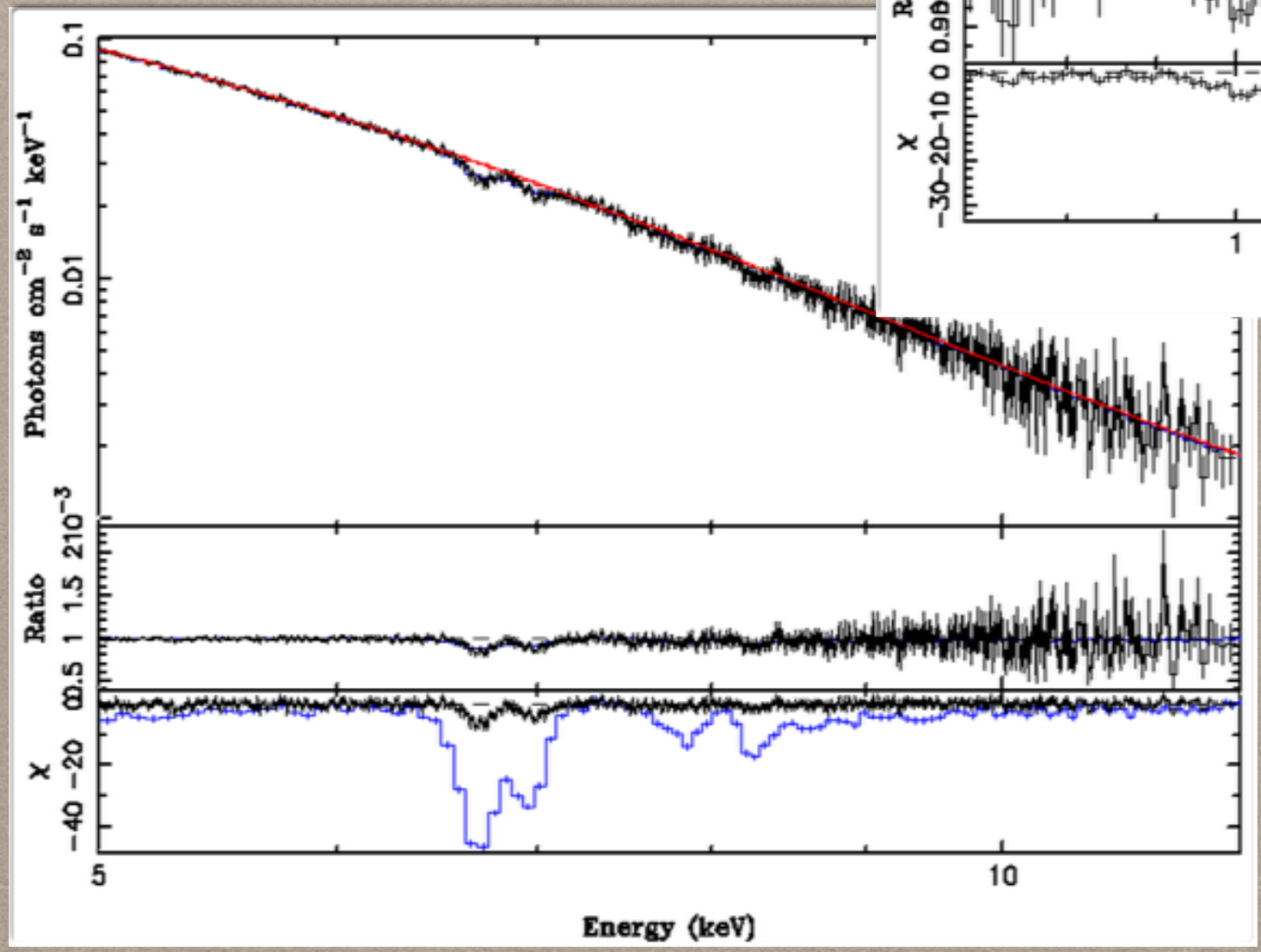


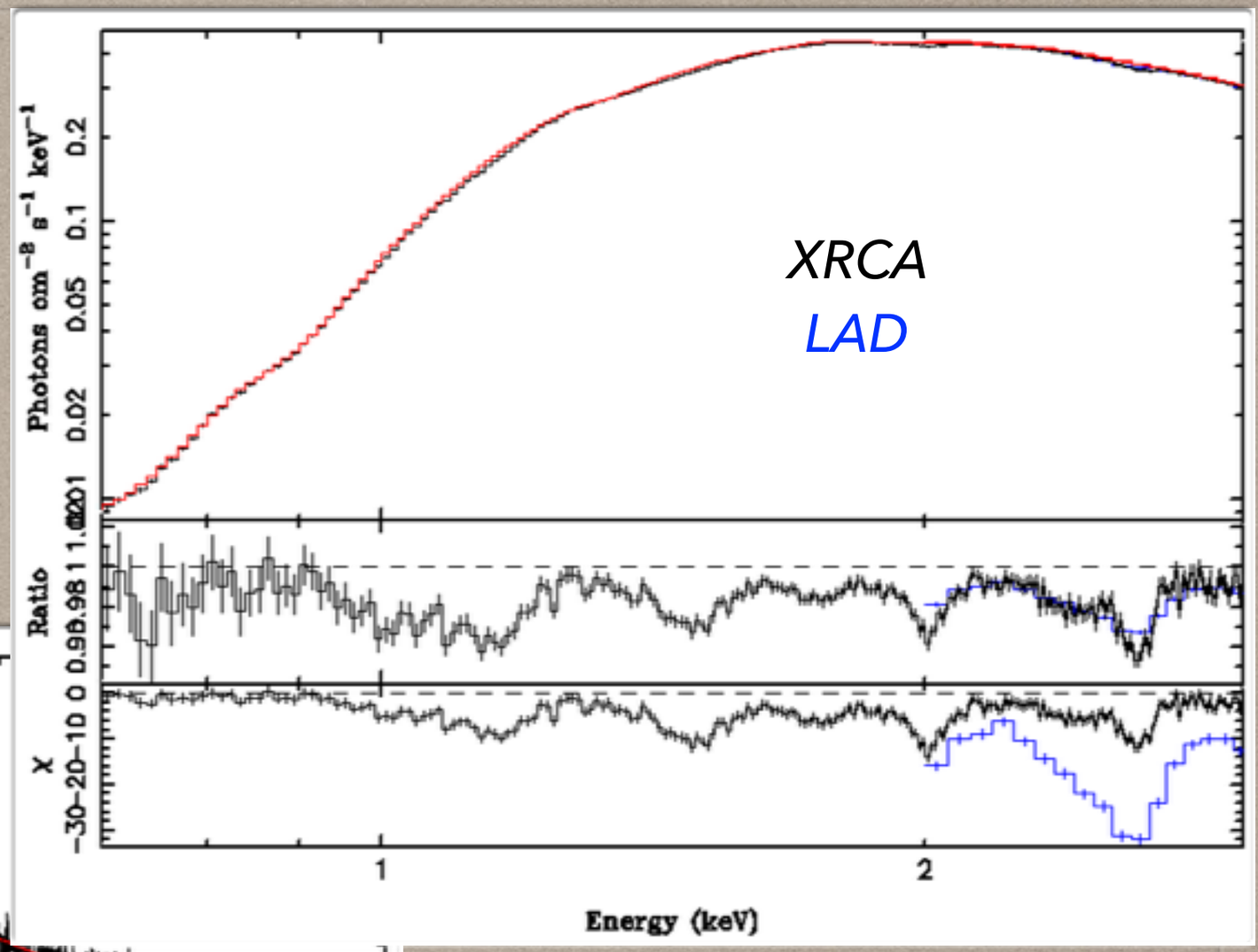


- Clearly in STROBE-X wheelhouse

WINDS WITH STROBE-X

- Texp=1 ks, F=4×10^{-9} cgs
- $N_{H,wind}$=10^{23} cm^{-2}, log ξ=4

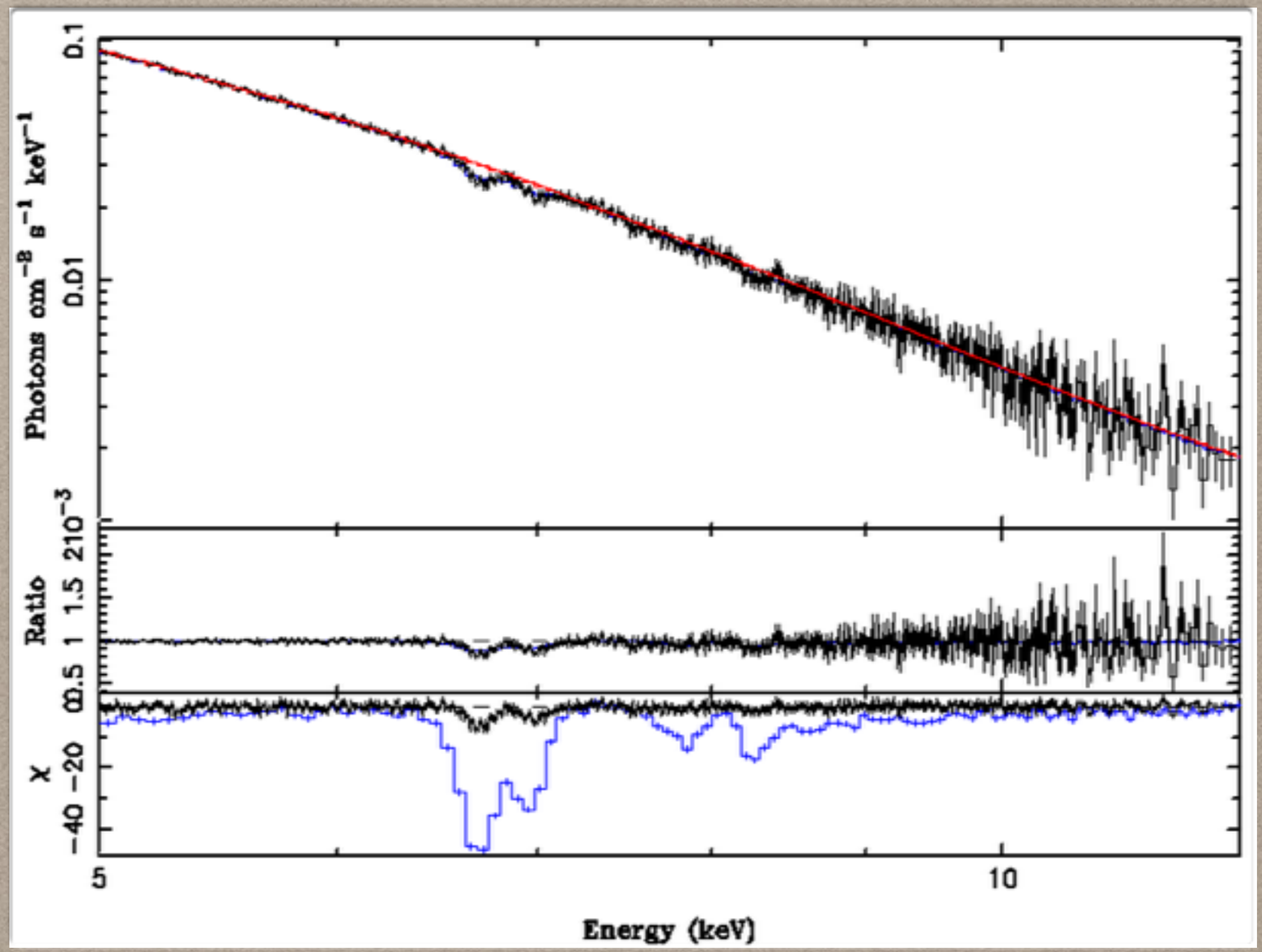




- $\Delta\chi^2_\nu$~4100
- $\Delta N_H = 4\times10^{21}$ cm^{-2}
- Δlog ξ = 0.01
- Δv ~ 50 km/s

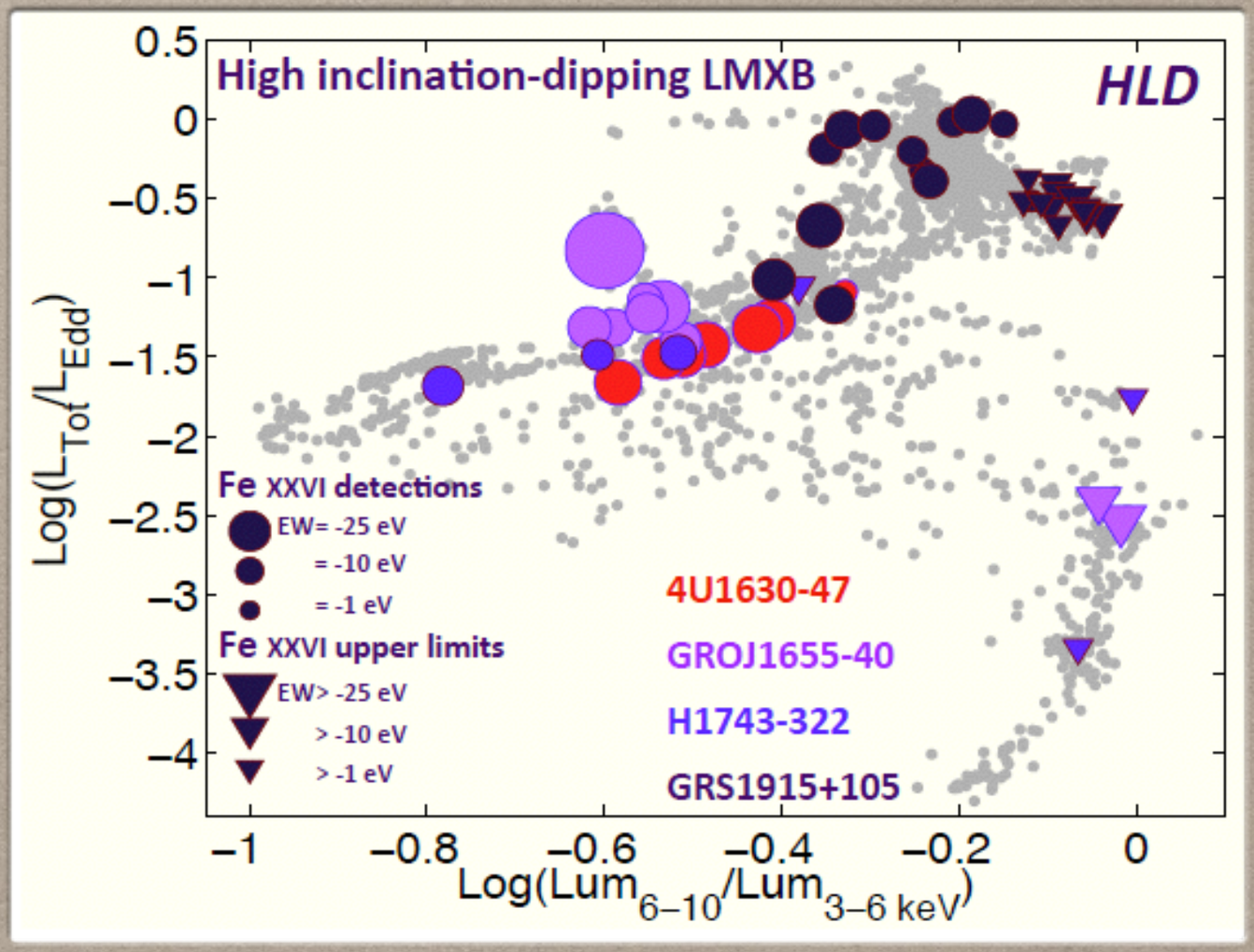
WINDS IN OUTBURSTS

- $\Delta\chi^2_\nu$~4100 in 1 ks
- For same wind parameters, can probably get a 3σ detection in ~50 s.
- Insensitive to systematic errors b/c of short exposure
- *STROBE-X* will be excellent for spectral variability studies of disk winds in BH outbursts



QUESTIONS FOR STROBE-X

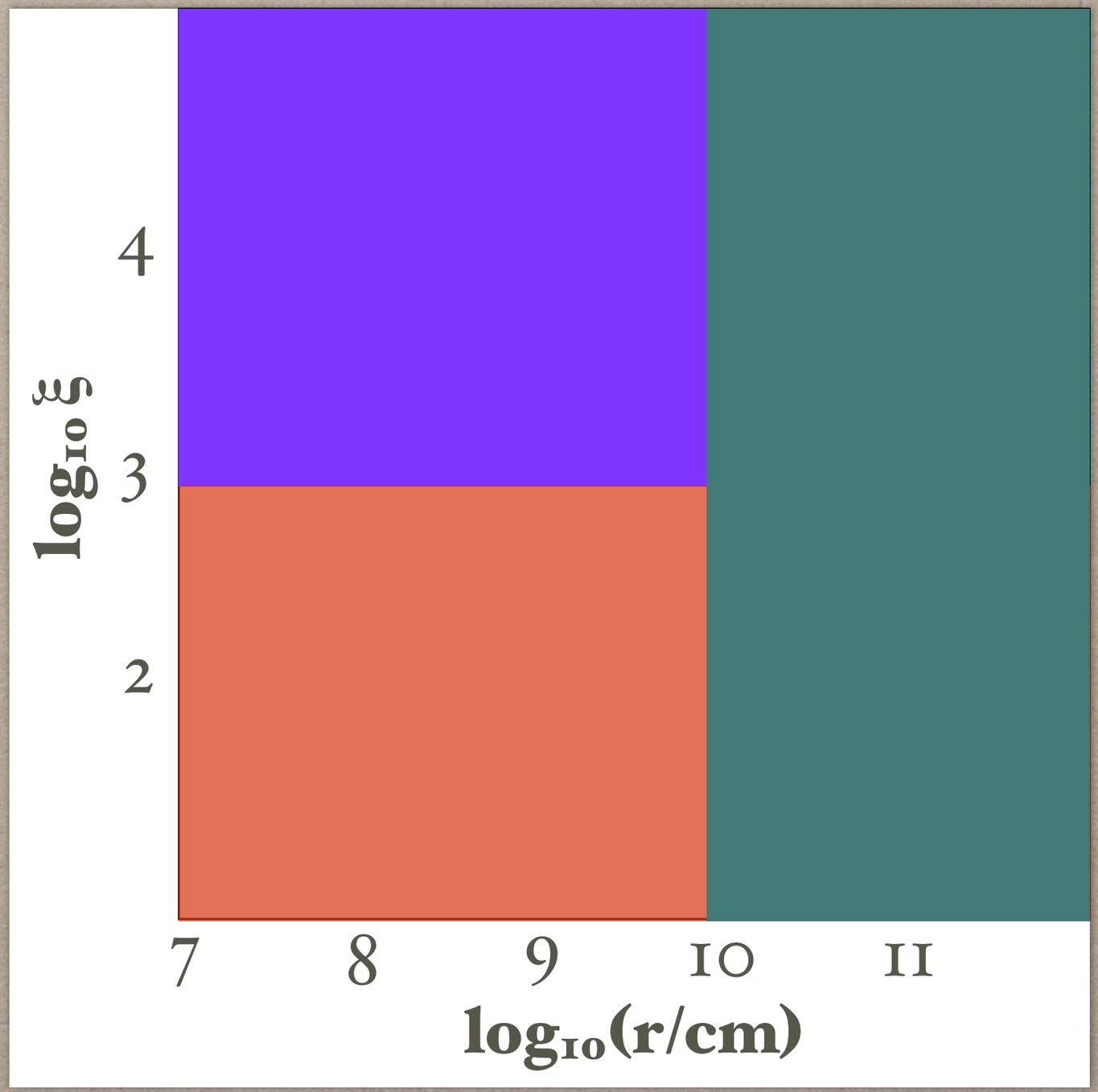
- *How* do winds form?
- *When* do winds form?
- *Where* do winds form?
- *How* do they relate to horizon-scale physics?
- Implications: mass loss rate, outburst evolution, connection to jet
- *Density is everything!*



HOW WINDS WORK

$$\xi = \frac{L_X}{n_e R^2}$$

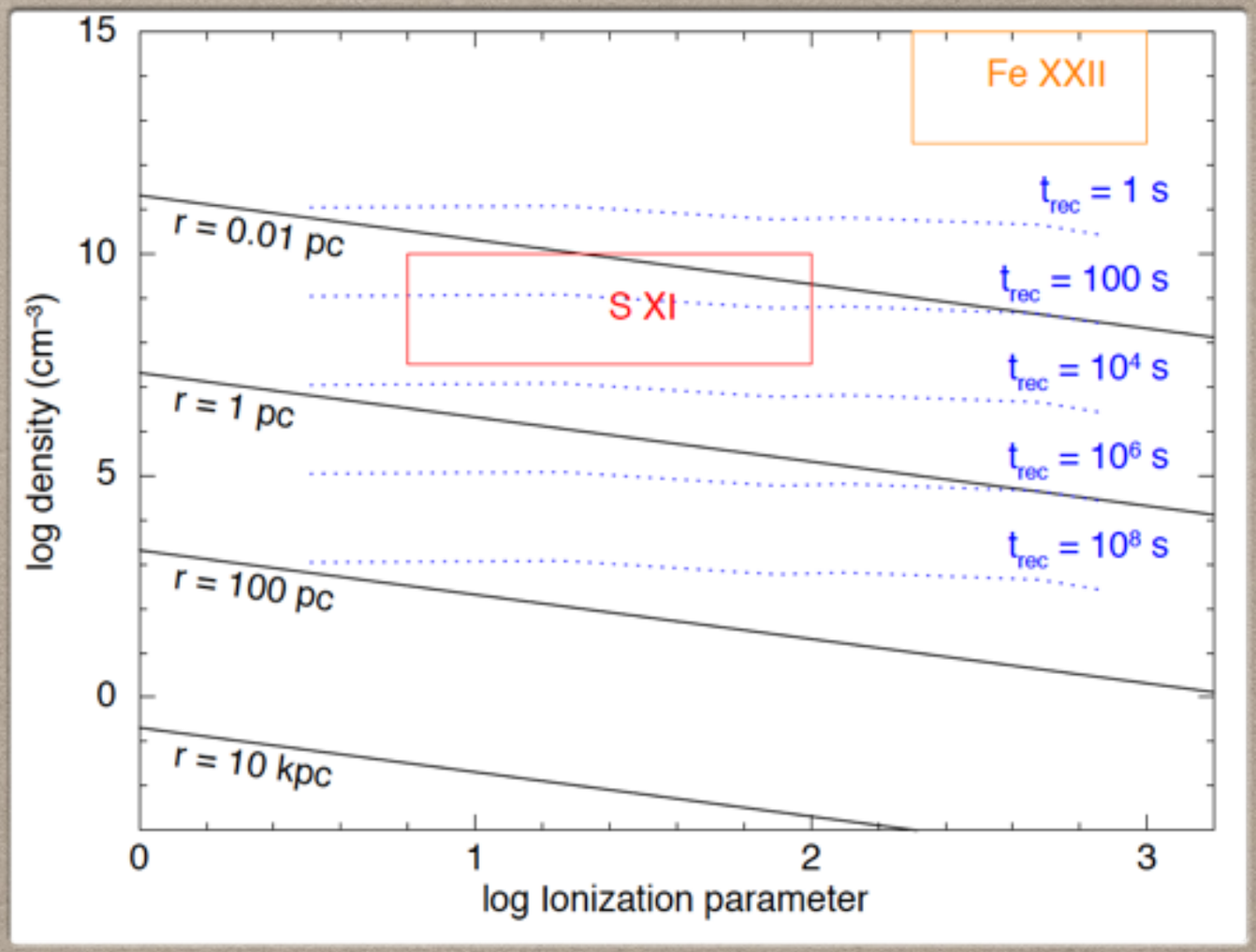
- **Radiation pressure**
- **Thermal pressure/ Compton heating**
- **Magneto-hydrodynamic processes**



Proga & Kallman 2002

STROBE-X AND DENSITY? RECOMBINATION TIMESCALE!

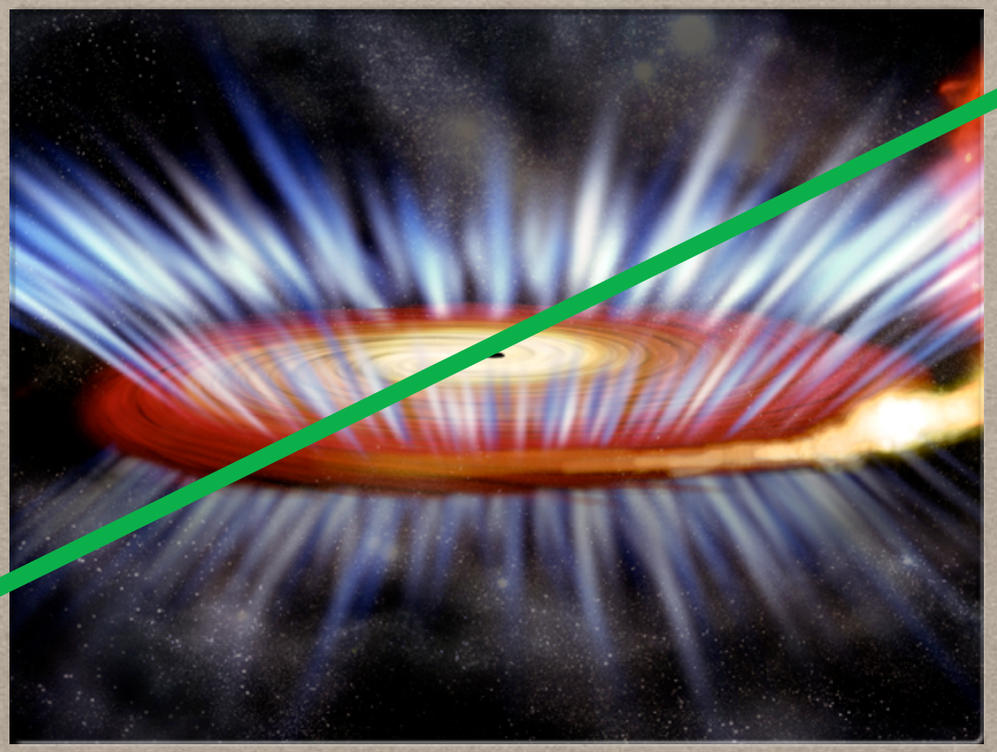
- Ionization state doesn't respond instantly to changes in radiation field
- Ionization is ~instantaneous; recombination is slower
- Lag between L and ξ
- t_{rec} ~ 1s / n_{11}
- Perfect for *STROBE-X*!

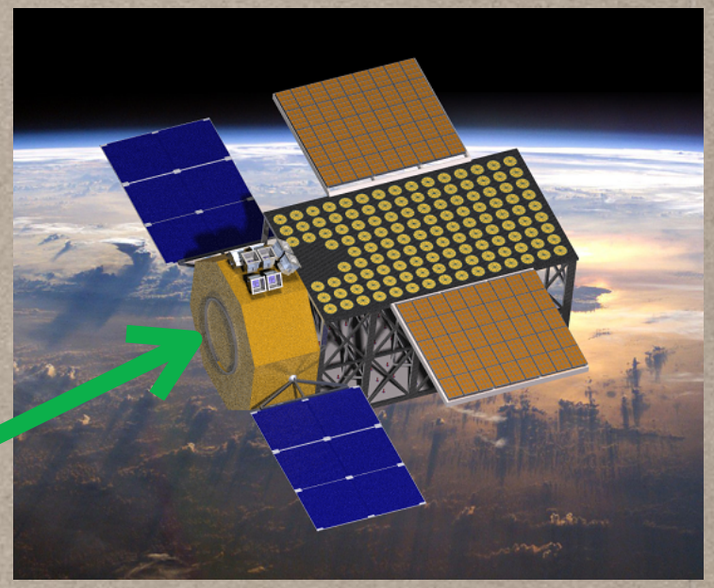


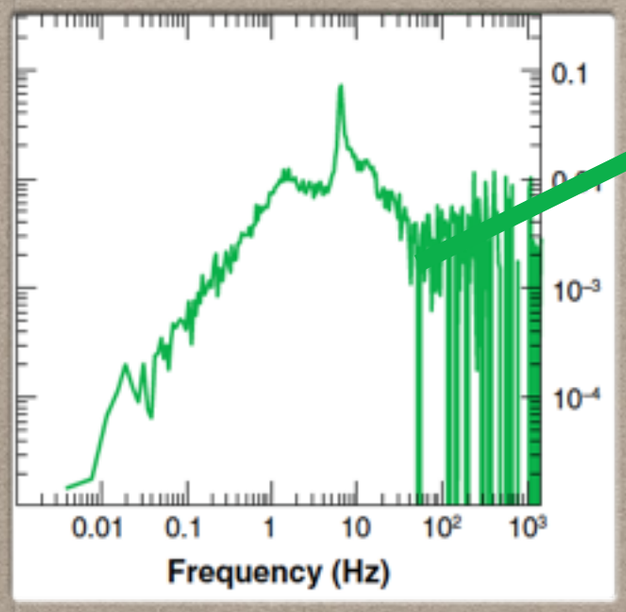
Credit: R. Smith, Lynx STDT Telecon

WATCH VARIABILITY, TRACK IONIZATION

- Ionization response time gives density



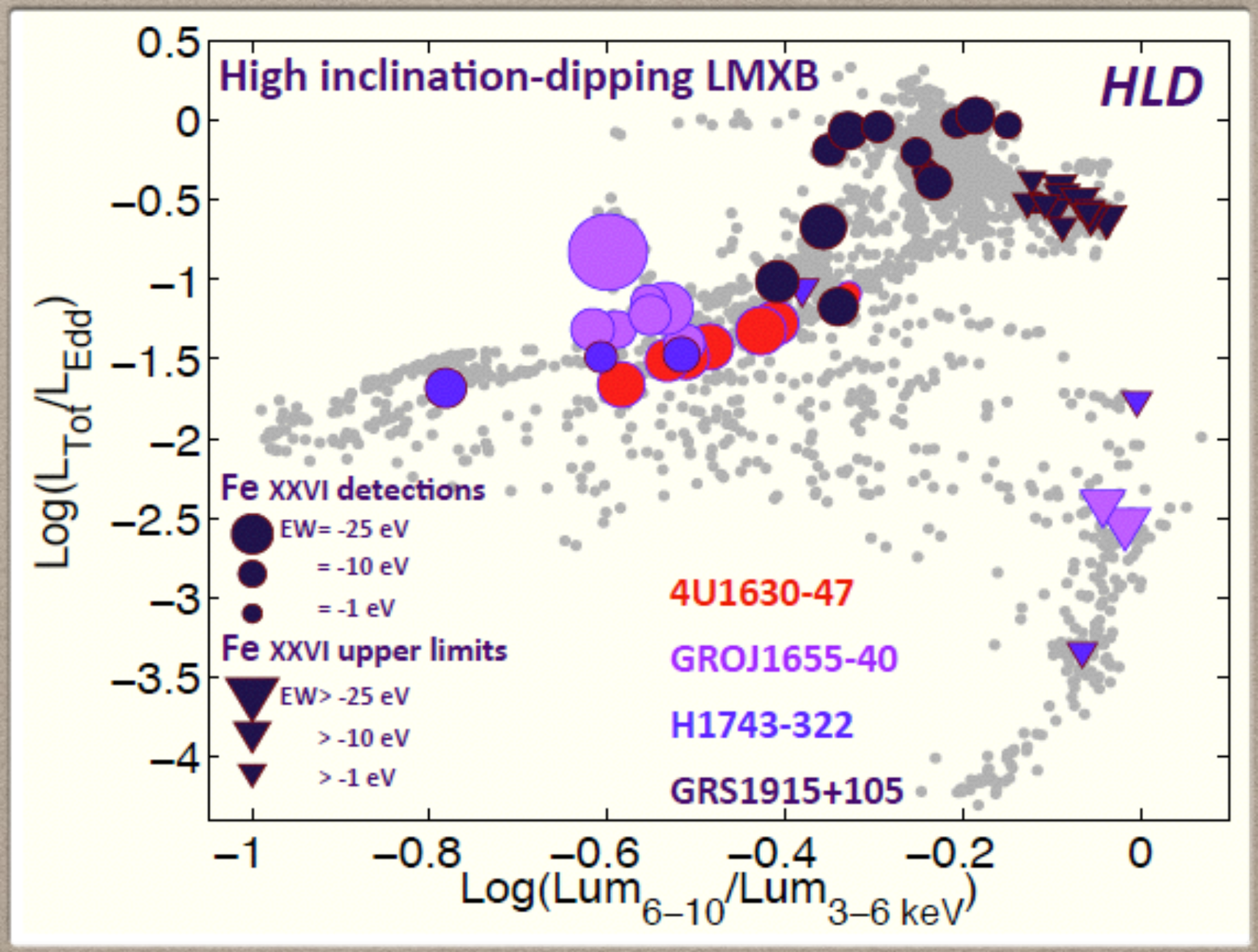




- Density gives location, launch mechanism
- Physically interpret outburst wind evolution

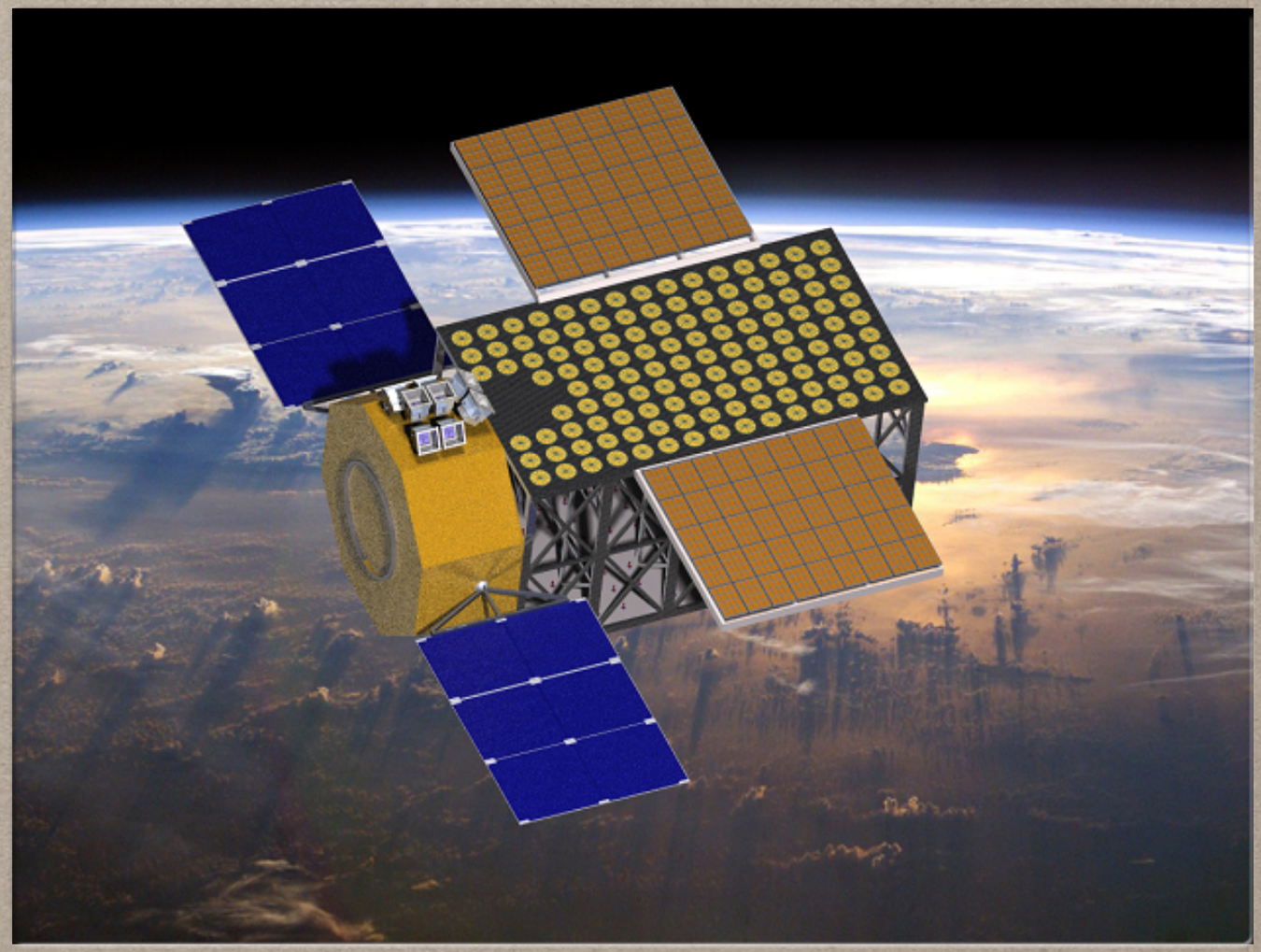
WINDS IN OUTBURSTS

- LAD & XRCA excellent for studying rapid variability of winds: response to radiation = astrophysics!
- Monitoring with WFM connects physical diagnostics of disk winds to accretion state
- Is there a “wind line?”



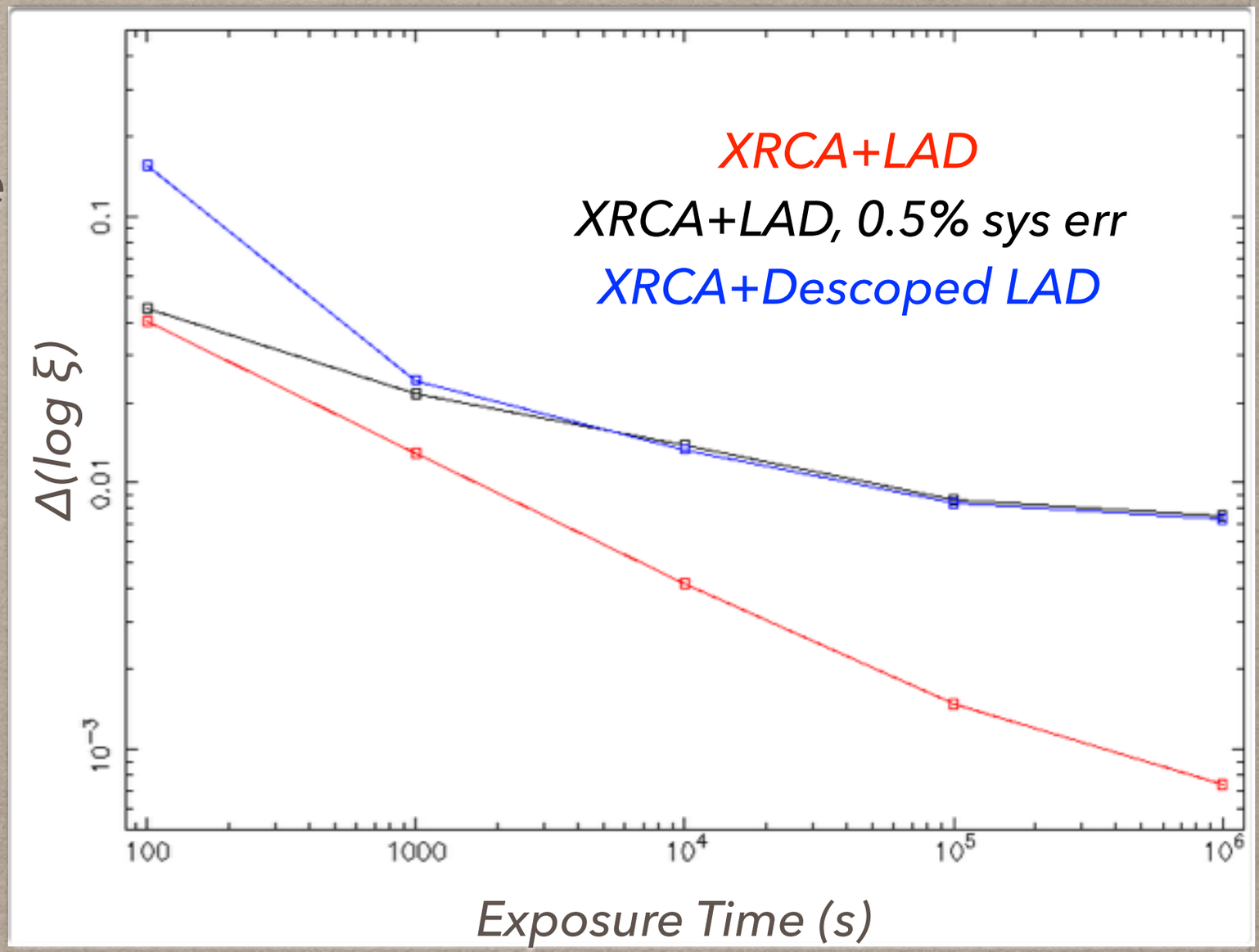
REQUIREMENTS

- Must be able to measure spectral variability ✔
- Must be able to measure ionization parameter *rapidly*
  - Spectral resolution better than 300 eV (separation between Fe XXV and Fe XXVI)
  - Ideally once per recombination time
  - In “real time” only feasible at low density
  - Stack multiple cycles, use QPO reconstruction techniques (e.g. Ingram et al)



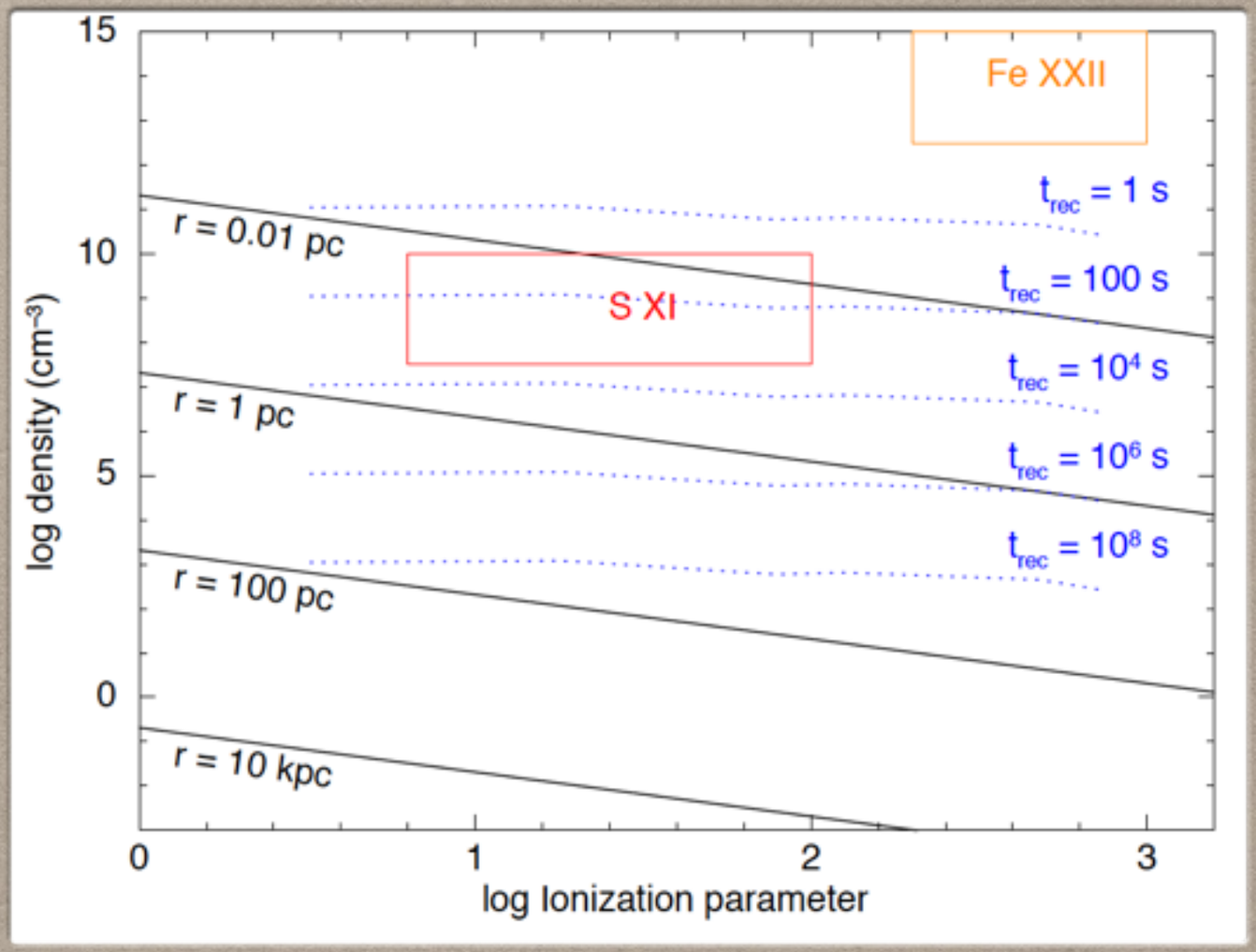
BENCHMARK

- Suppose L increases by 10%
- How long does it take to achieve precision on ξ to detect the change?
- Δ(log ξ) = 0.04
- At F=4×10^{-9} cgs (2-10 keV) takes 100-200 s UNLESS LAD descoped, then 500-100 s



WIND VARIABILITY WITH STROBE-X

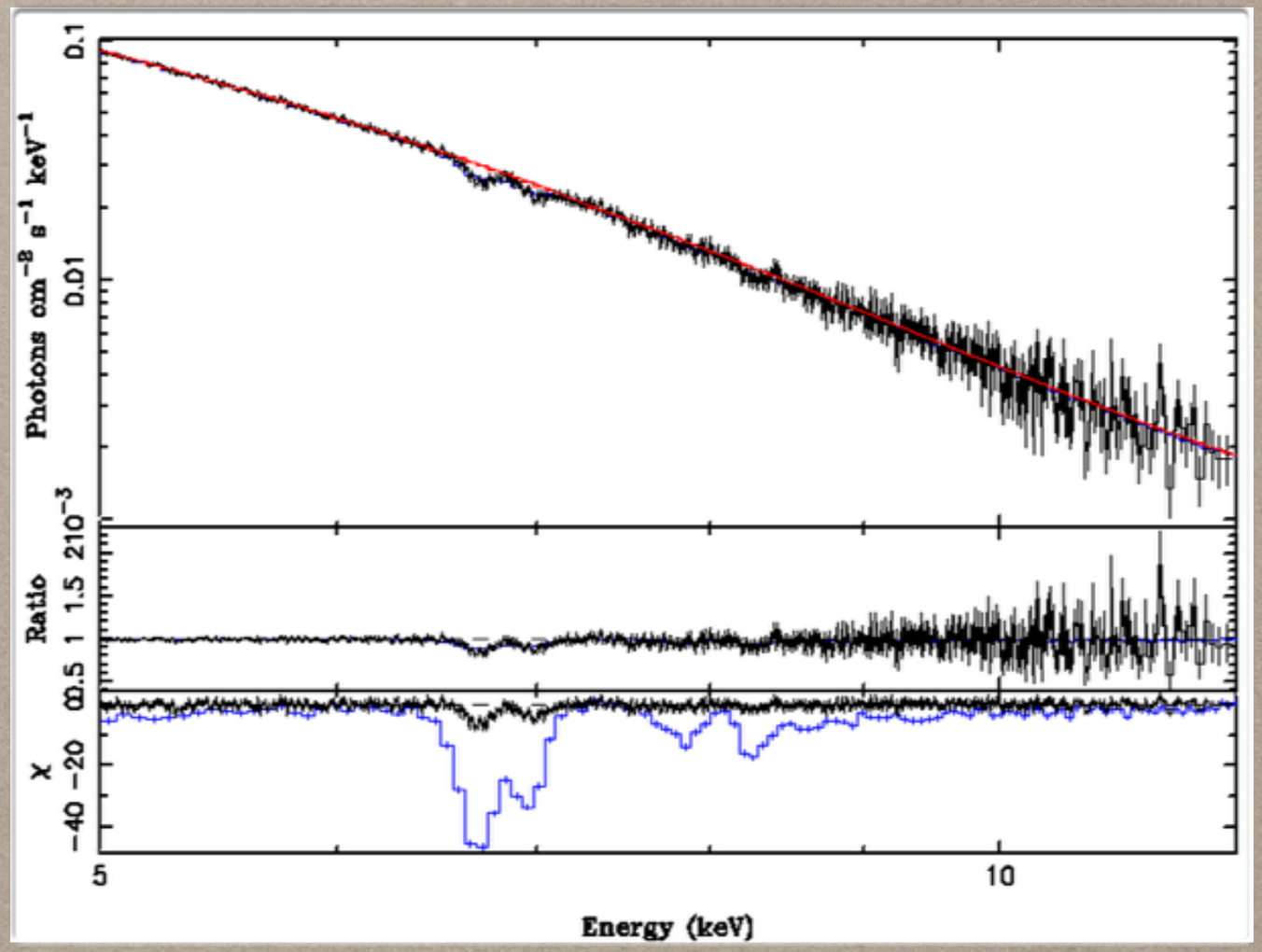
- Accumulate enough exposure to study recombination timescale in stacked data at interesting densities ($n \gtrsim 10^{12}$ cm^{-3})
- Should be doable with *STROBE-X* in few 10s of ks



Credit: R. Smith, Lynx STDT Telecon

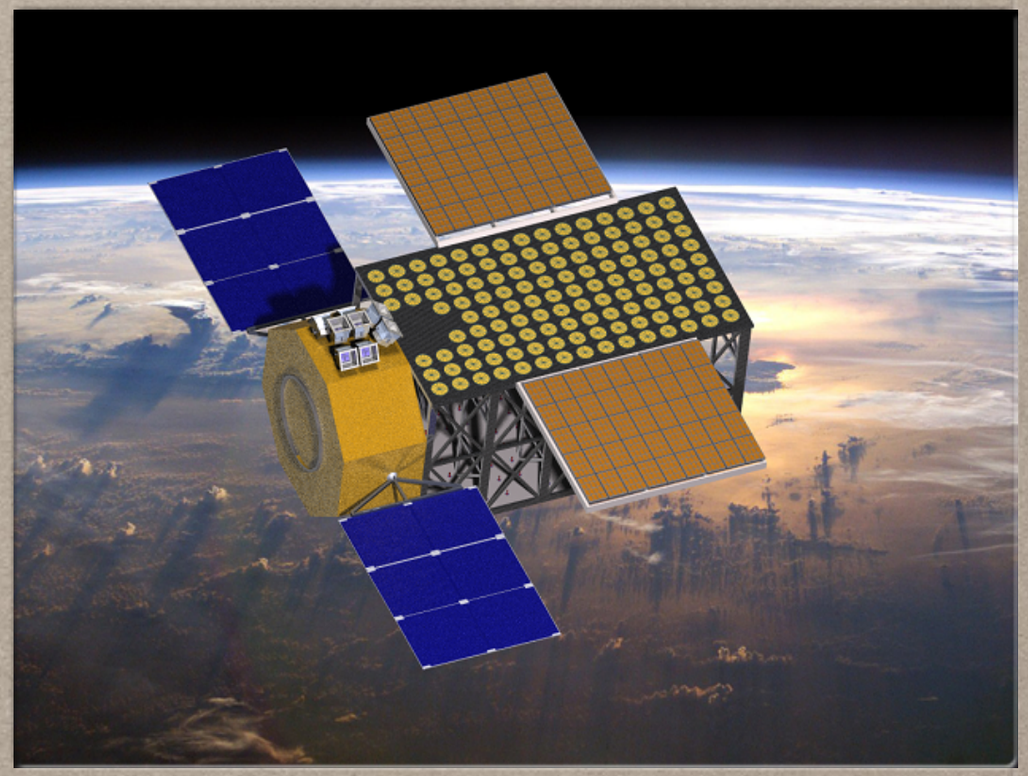
NEXT-GENERATION ASTROPHYSICS

- *STROBE-X* offers revolutionary diagnostics of accretion disk winds from BHs
- *Athena, Lynx* pursuing similar questions with microcalorimeters, gratings
- Different perspective facilitated by large area, timing capabilities
- Connect detailed studies of XRB outburst physics to AGN accretion



Q&A

- Surprise: despite better resolution of XRCA, LAD is driver of wind studies
- Descoped versions less sensitive, make detailed rapid spectral variability studies more difficult
- Better to maximize LAD/XRCA area ratio; cutting LAD resolution ~comparable to cutting LAD area
- ToOs: 1 day response fine



THE LIFE CYCLE OF WINDS

1. **Photoionization:** winds overionized (transparent)?
2. **Thermodynamics:** visible winds are unstable?
3. **Astrophysics:** the birth of winds?