Type I X-Ray Bursts: Populations, Rare Specimen, and Disk Interaction

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T. E. Strohmayer, S. Mahmoodifar, J. J. M. in 't Zand, D. R. Ballantyne, and many others

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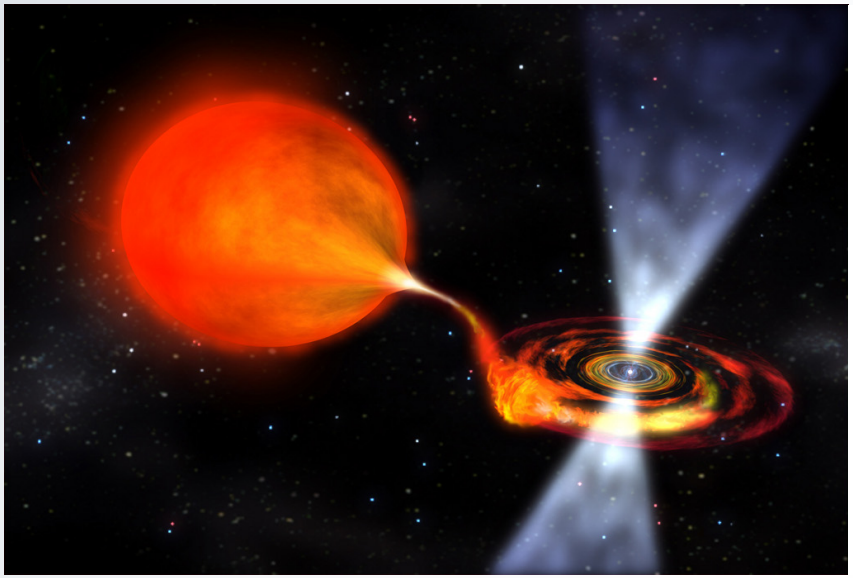
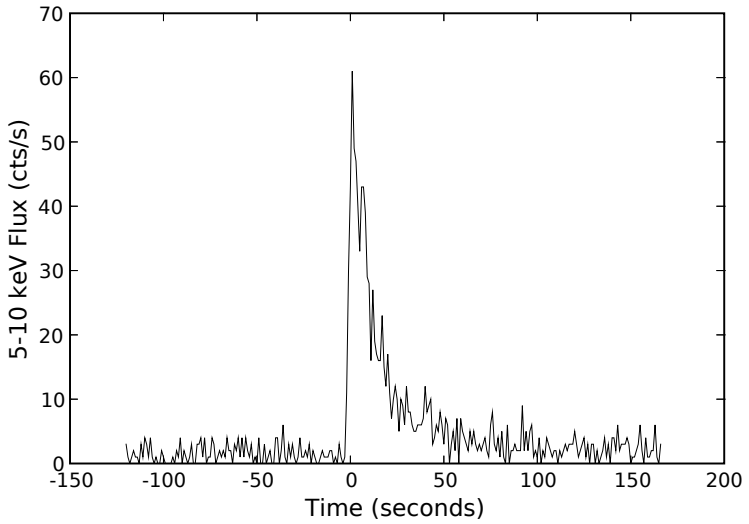
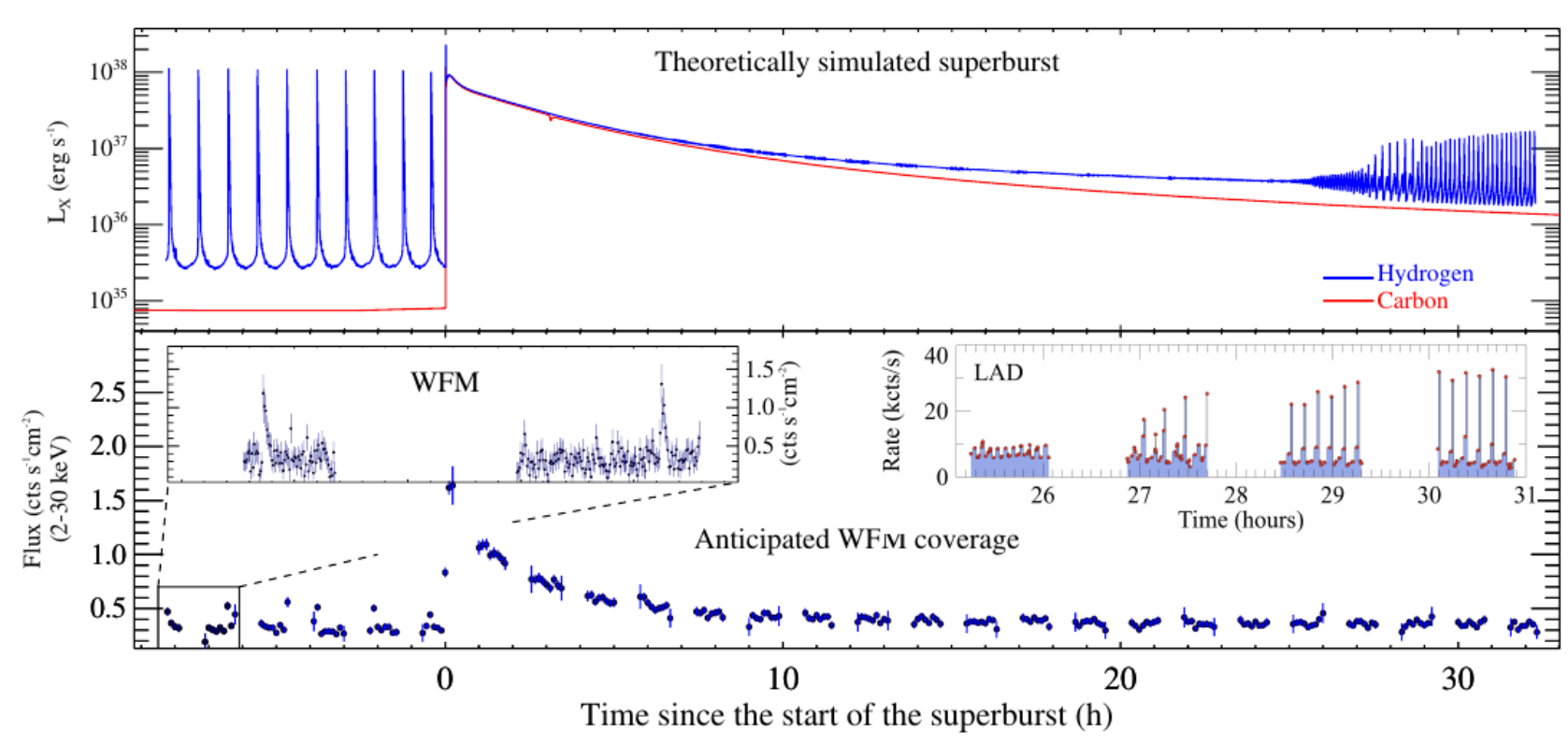
Thermonuclear flashes from Accreting Neutron Stars





- Much effort in improving nuclear reaction data of rare p-rich isotopes
- Predictions of burst regimes still do not match observations
- NS EOS: atmosphere models used, but uncertain effect of disk

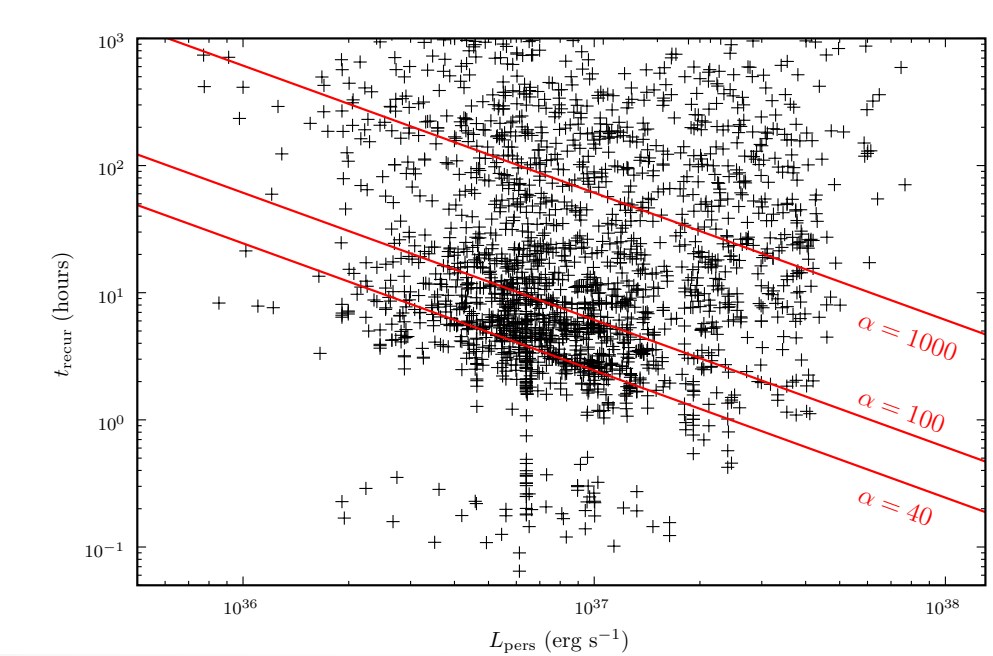
WFM and LAD view of Bursts and Superbursts



Keek, Heger, In 't Zand 2012; In 't Zand, . . . , Keek, et al. 2015

- Superburst quenches regular bursts for a day
- Transition from stable H/He burning to mHz QPOs to X-ray bursts

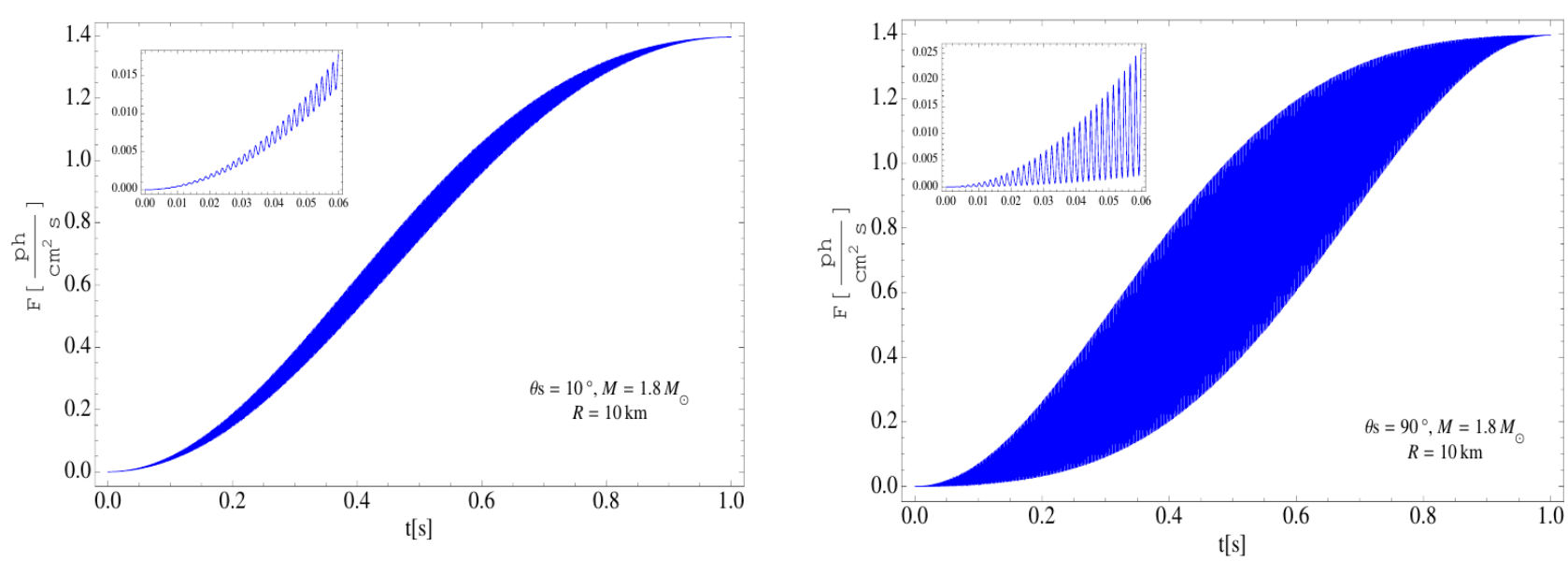
Large Samples Reveal Interesting Behavior



Keet et al. 2010

- MINBAR: all *RXTE*/PCA and *BeppoSAX*/WFC bursts
- Short recurrence times from H-accretors: new models from Keek & Heger 2017
- Reduced burst rate above $\sim 20\%$ Eddington: WFM opportunity

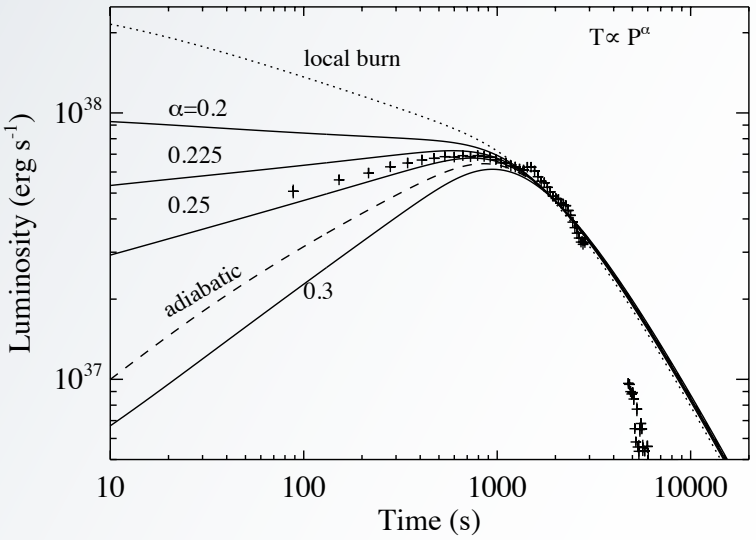
Timing: Bursts Oscillations



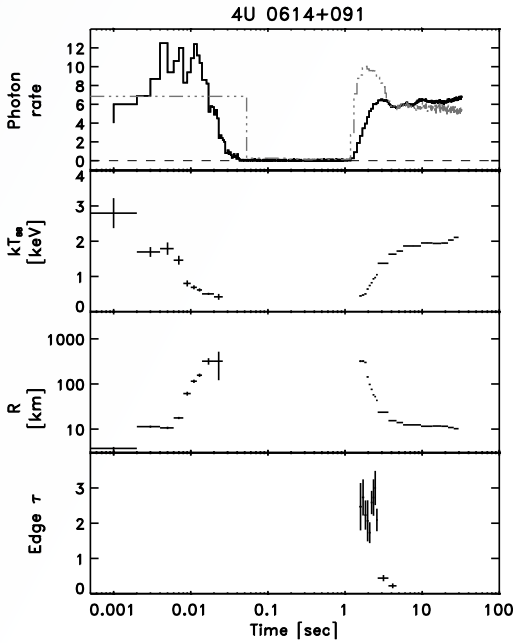
In 't Zand, Mahmoodifar, Keek, et al. 2015

- Ignition near the pole (left) and at the equator (right)
- Track the phase of pulsations to follow flame spreading
- Low-amplitude pulsations as seen in 4U 1636-536 2001 superburst?

Superbursts and Long Helium Bursts



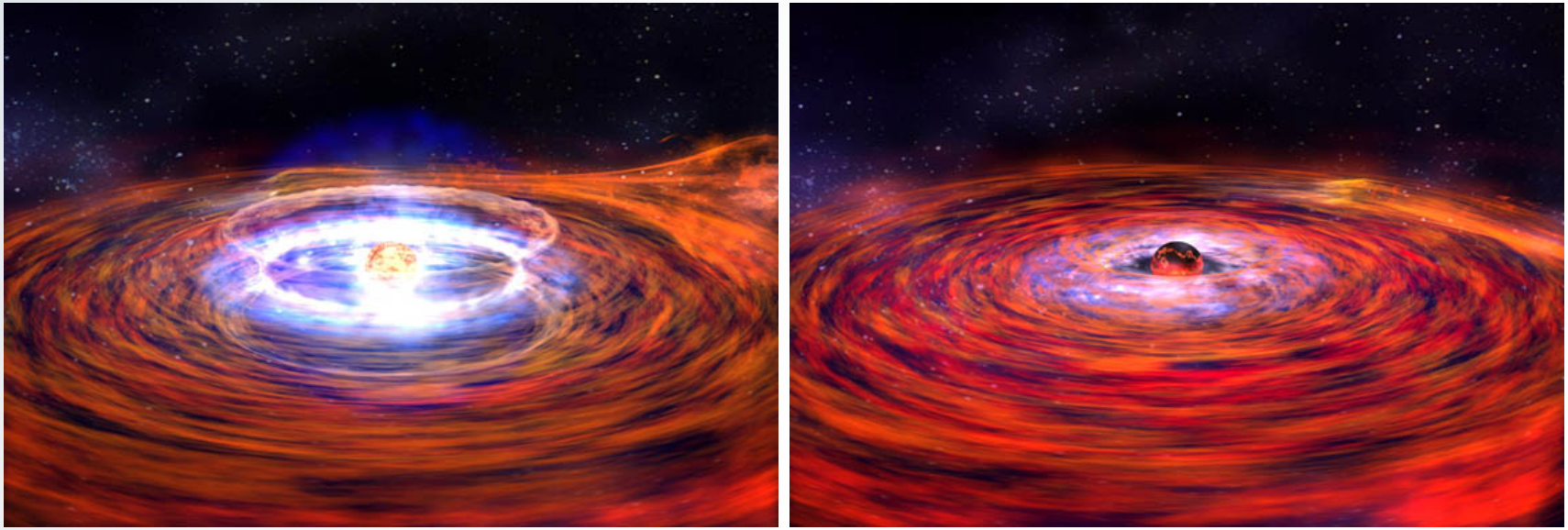
Keek, Cumming, et al. 2016



In 't Zand & Weinberg 2014

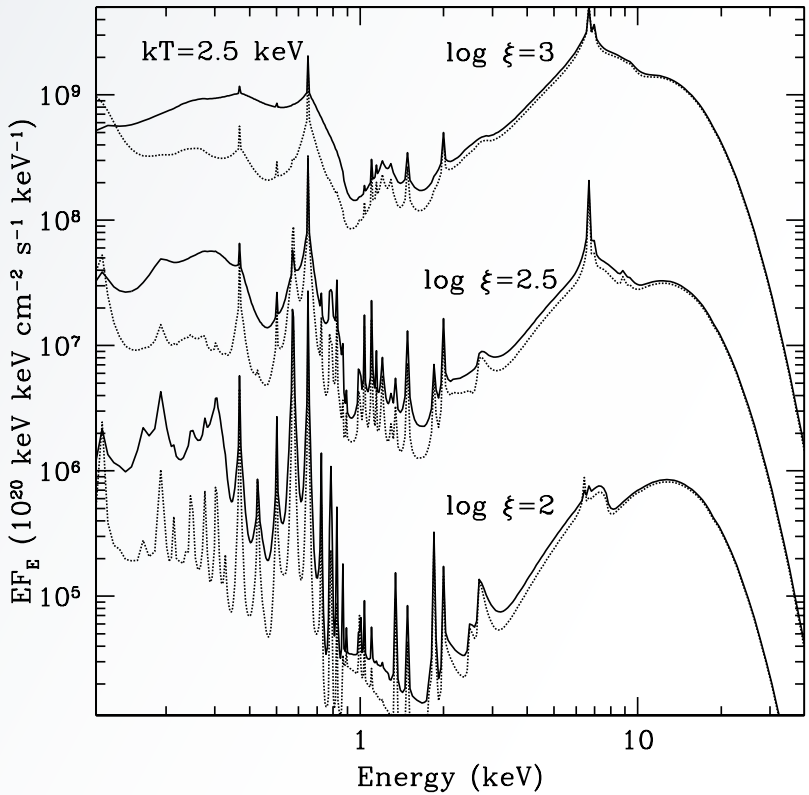
- Slewing on WFM trigger
- First 1000 s of superburst constrain carbon flame propagation
- First few minutes of intermediate duration burst show superexpansion and absorption edges from NS surface: EOS constraint

Burst Impact on Accretion Geometry



- Push out inner disk or infall from radiation drag?
- Heating and ionization of the disk; launching of winds?
- Coronal cooling; boundary layer?
- Reflection spectroscopy provides a diagnostic

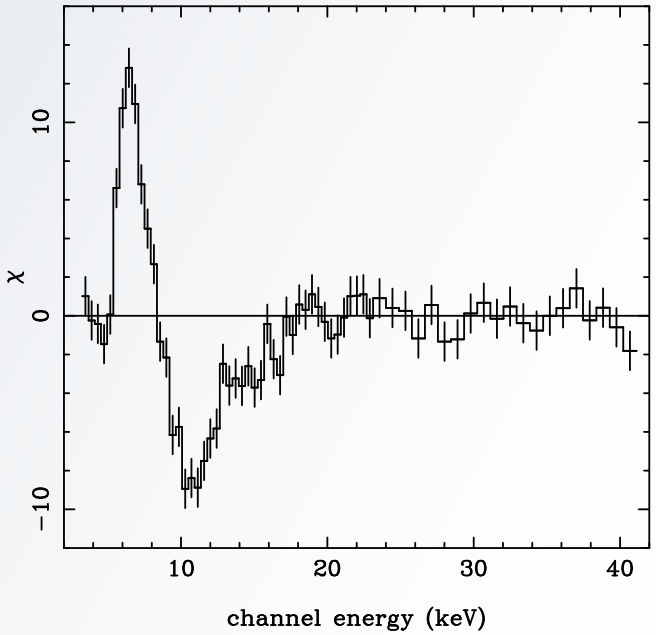
Model X-Ray Reflection Spectra



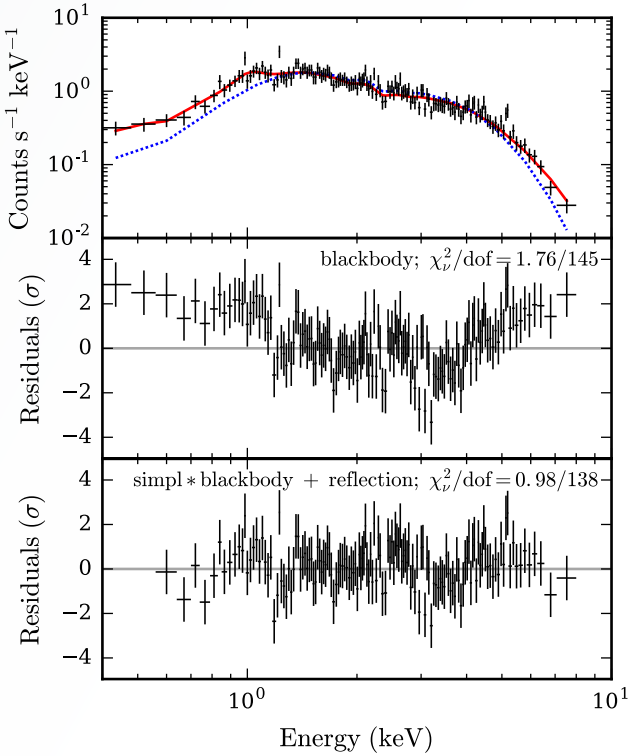
Ballantyne 2004

- 6.4 keV Iron line depends on ionization parameter ξ
- Soft band depends on density and composition

Spectra Deviate from Blackbody: Reflection?



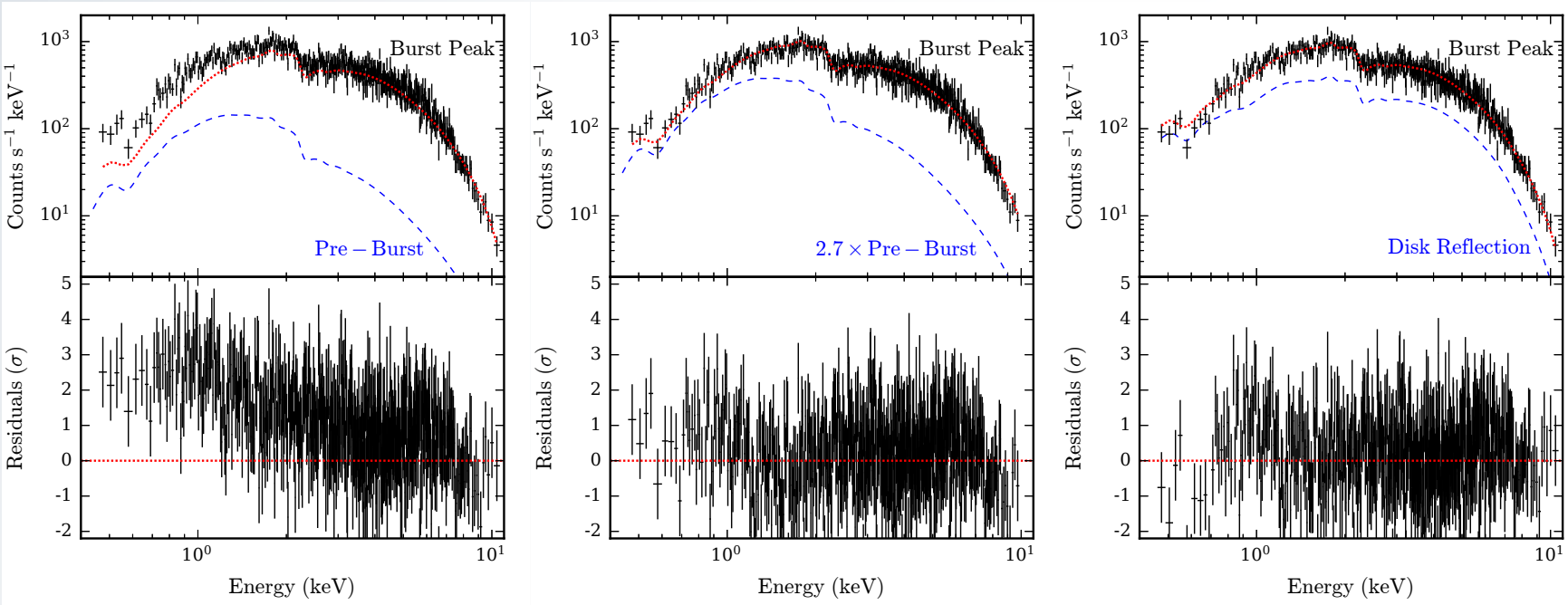
Strohmayer & Brown 2002



Keek, Ballantyne et al. 2016

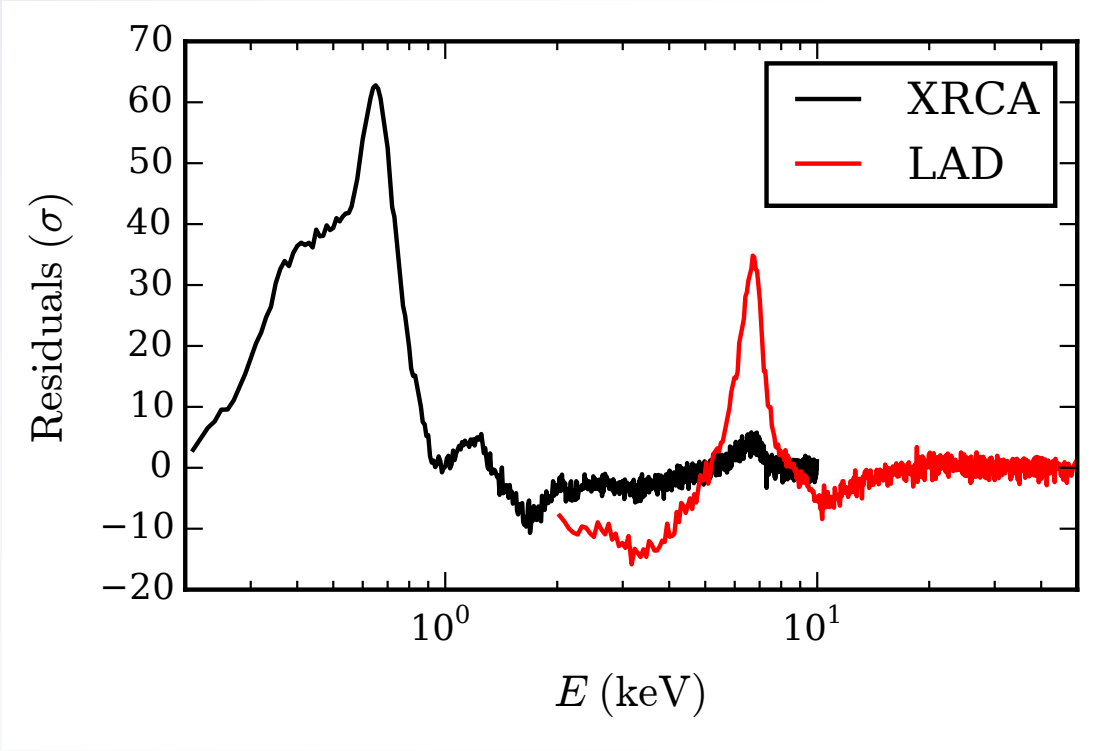
- Superburst 4U 1820-30 (*RXTE*/PCA): iron line+edge
- Helium burst IGR J17062-6143 (*Swift*/XRT): soft excess

Soft Excess in NICER Spectrum of Aql X-1



- Seen 2x with *Chandra* and *Swift*: present in 3 *NICER* bursts
- Signature of burst impact on environment: enhanced accretion or reflection?
- Increased accretion by $f_{\rm a} \simeq 2.7$, or a reflection fraction of ~ 0.5

Burst Reflection with STROBE-X



Keek, Wolf, and Ballantyne 2016

- 15×*NICER*+*LOFT*: very detailed light curves and spectra
- In 10 s, measure $\log \xi$ to 0.12%, $R_{\rm in}$ to 14%, disk inclination to 12%, emissivity profile to 4%

Conclusions

- WFM
  - Large sample of bursts
  - Better constraints on burning regimes, such as transition to stable burning (carbon creation for superbursts)
  - Triggers for rare long bursts (superbursts, intermediate duration bursts)
- Timing with XRCA and LAD
  - Track phase of burst oscillations
  - Measure spin of bursting neutron stars
  - Low-amplitude pulsations as seen in superburst
- XRCA and LAD spectroscopy
  - Burst impact on accretion environment
  - Detailed reflection features; accretion disk tomography
  - Evolution of persistent spectral component: inner disk, spreading layer, corona, etc.