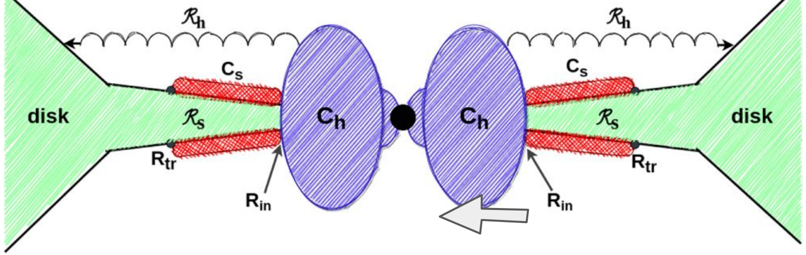
Is there disk truncation in the hard state of Swift J1727.8-1613?

Ole König
(Center for Astrophysics | Harvard-Smithsonian)
together with Jack Steiner, N. Bollemeijer, R. Connors, T. Dauser, J. García, A. Ingram, E. Kara, M. van der Klis, M. Lucchini, G. Mastroserio, E. Nathan, M. Nowak, K. Pottschmidt, R. Remillard, J. Svoboda, J. Wilms, Y. Zhang

NICER/IXPE Workshop – 2024-07-31

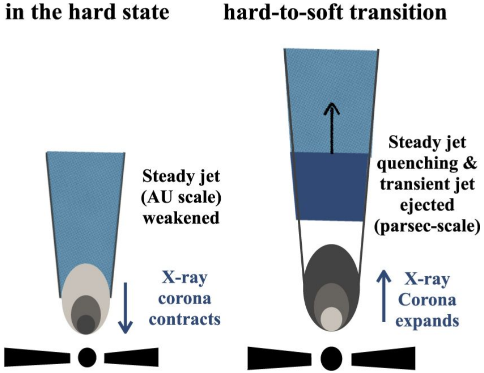
Motivation: Inconclusive geometry in the hard state

Inner hot flow corona with truncated disk



- Explains many observables well
- How does one produce broadened reflection?
- Warm corona required

Compact corona above the black hole with inner disk ~ at ISCO



Kara et al., 2019, Wang et al., 2021

- Consistent with broadened reflection
- Appears inconsistent with polarization measurements (Krawczynski et al., 2022, Ingram et al., 2024, but note Steiner et al., 2024)
- Is the paradigm soft lags = reverberation correct? (e.g., Uttley et al., 2024)

see also, e.g., Done et al., 2007,
De Marco et al., 2021, Kawamura et al., 2022

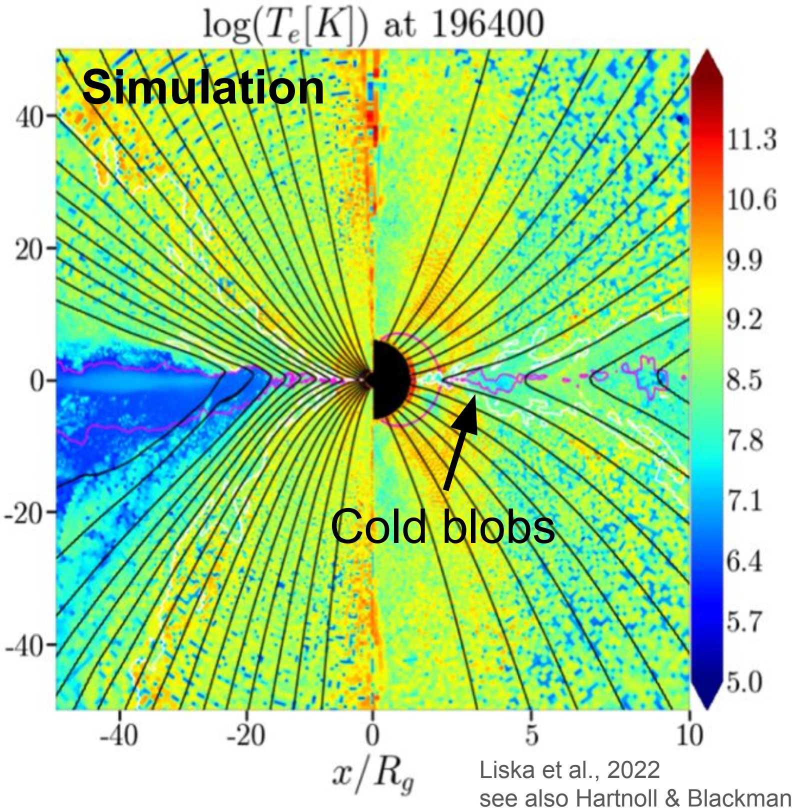
Motivation: Inconclusive geometry in the hard state

Of course, nature is more complex than a sketch!

Different aspects of the data

- Reflection
- Time lags
- Variability components
- Polarization

probe different regions, processes, and timescales in the accretion flow

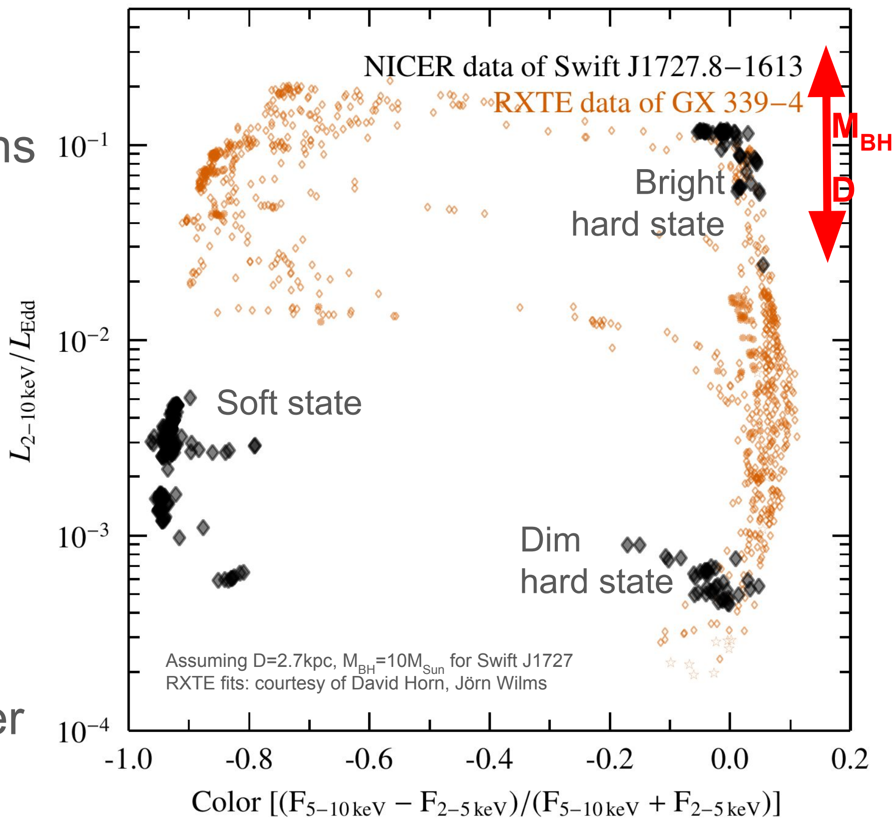


Liska et al., 2022
see also Hartnoll & Blackman 2001, Yuan 2003

Outburst of Swift J1727.8-1613

- ~ 7 Crab bright, coordinated observations with IXPE, NICER, NuSTAR, and multi-wavelength telescopes
- NICER missed the peak of the outburst due to Sun constraints
- 328 orbit night observations
- coverage of the poorly understood soft-to-hard transition

Goal: Use continuum fitting to constrain inner disk radius



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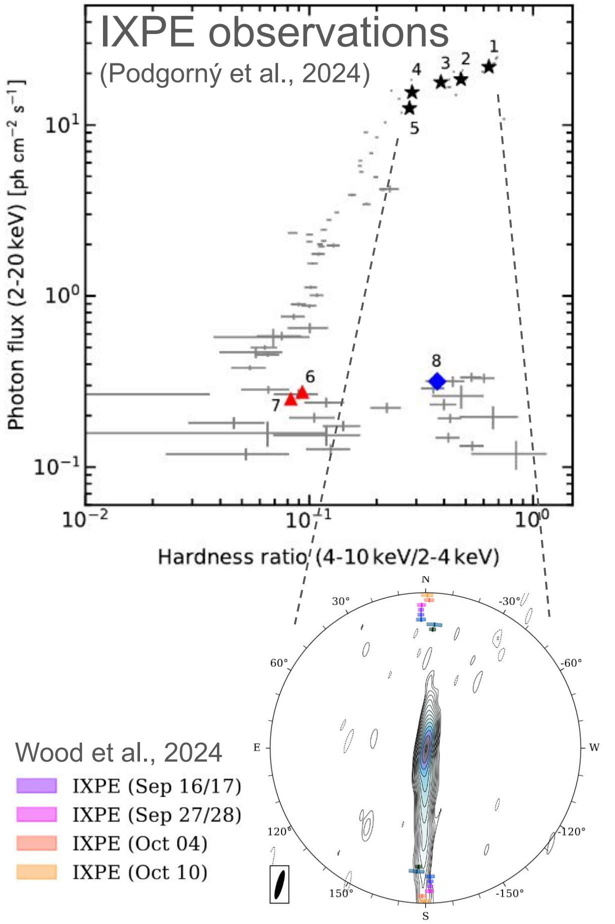
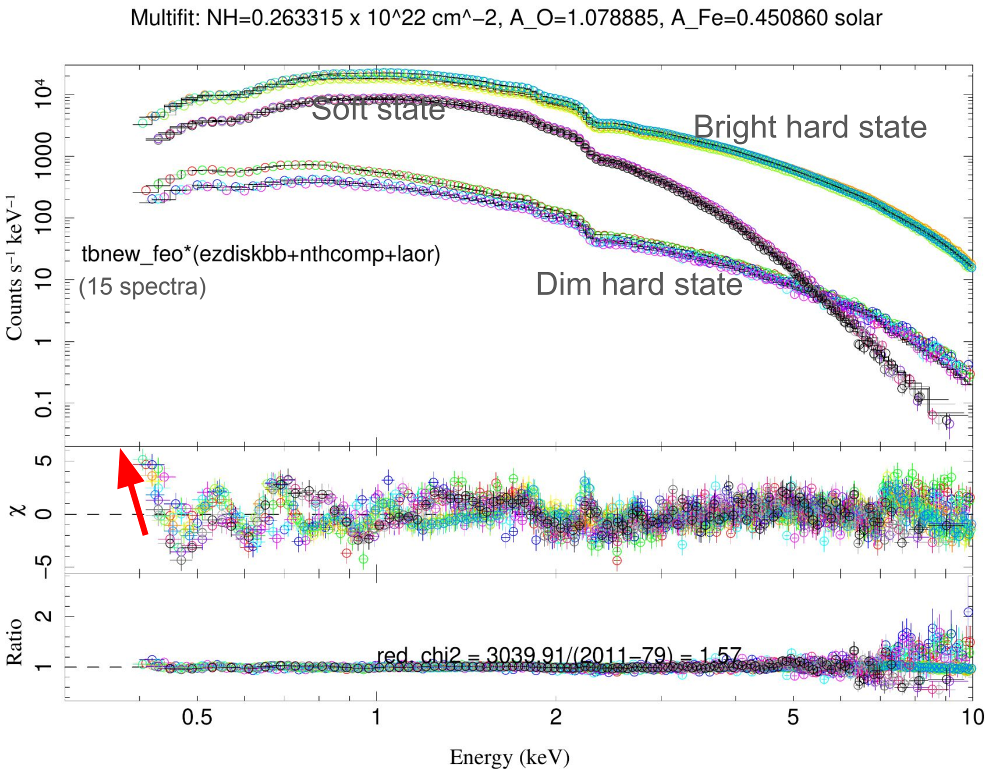


PA aligned with radio jet!

→ Corona likely aligned with plane

Simultaneous bright hard, soft, and dim hard state fit

- First step: Determine N_H and understand systematic uncertainties (“chemistry problem”)
- ~weak reflection features in hard state
- Fit NICER archive with disk models:
  - simpl(ezdiskbb)
  - ezdiskbb+nthcomp
  - kerrbb(2)

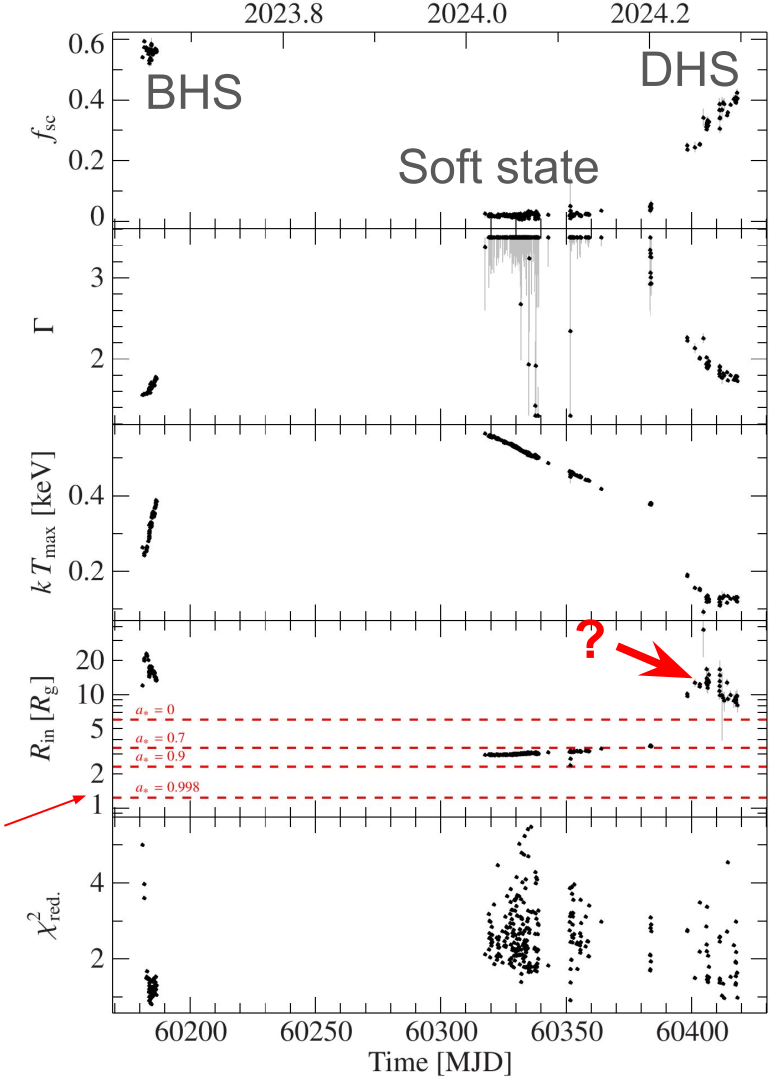


Spectral parameter evolution

- tbfeo*(**simpl**(ezdiskbb)+laor)
- Assuming
  - D=2.7 kpc
  - M_{BH}=10 M_{Sun}
  - i=30deg

- **Central question:** Are we confident enough to claim disk truncation or can we only give an upper limit?

(note: ezdiskbb is non-relativistic)



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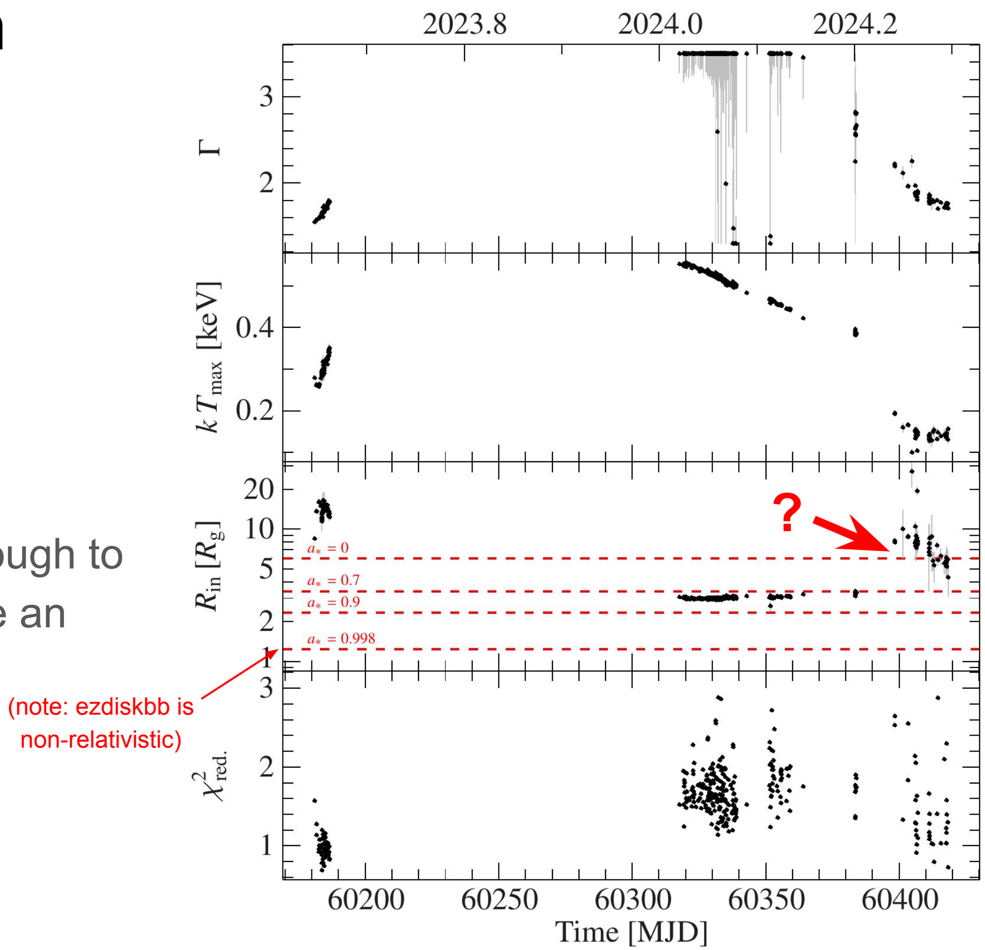
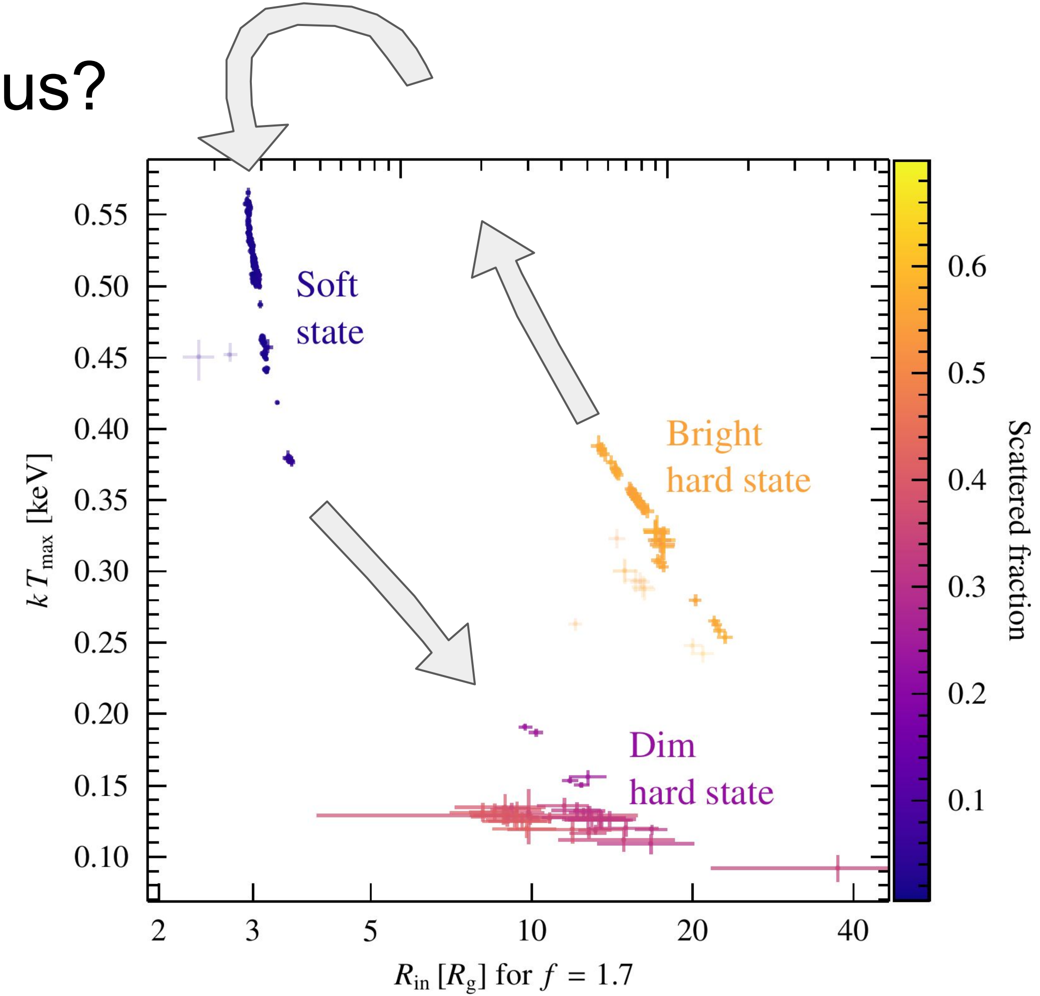
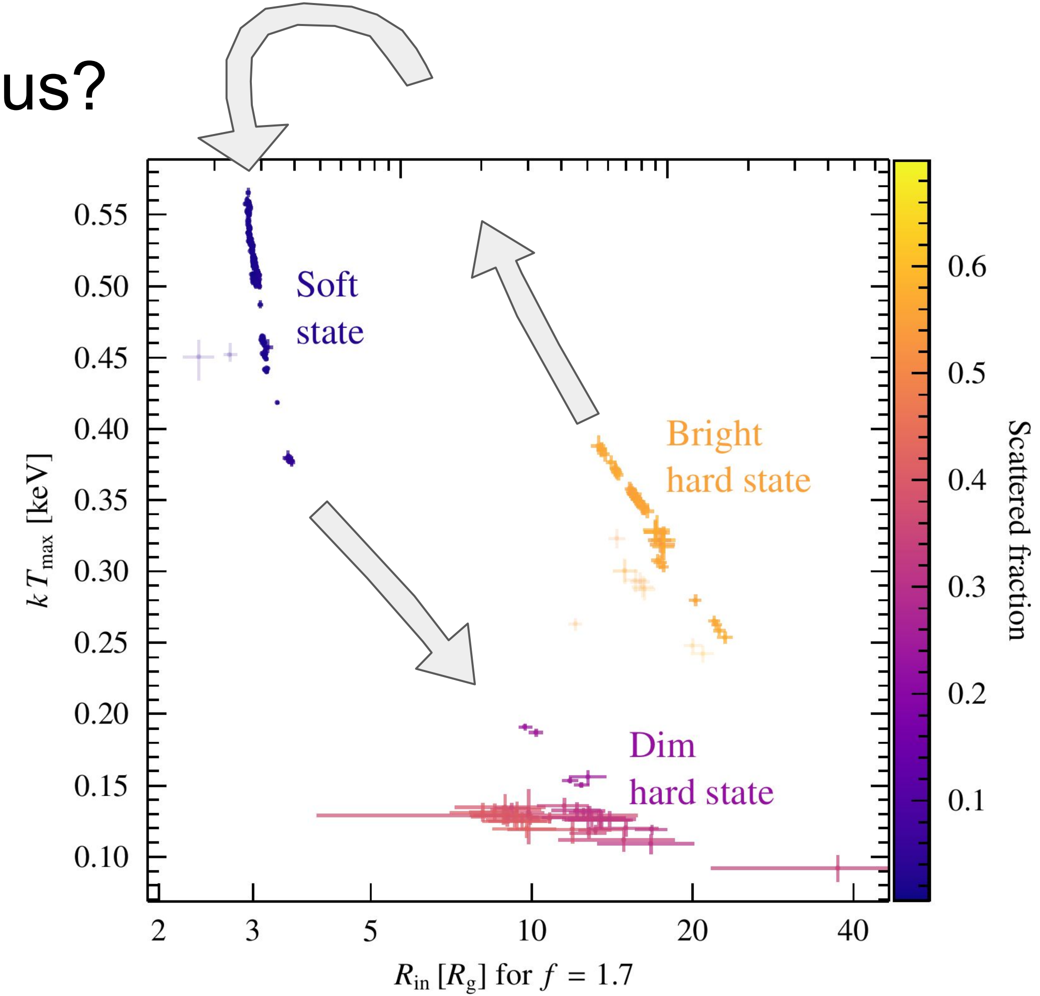


Evolution in inner disk radius?



Evolution in inner disk radius?

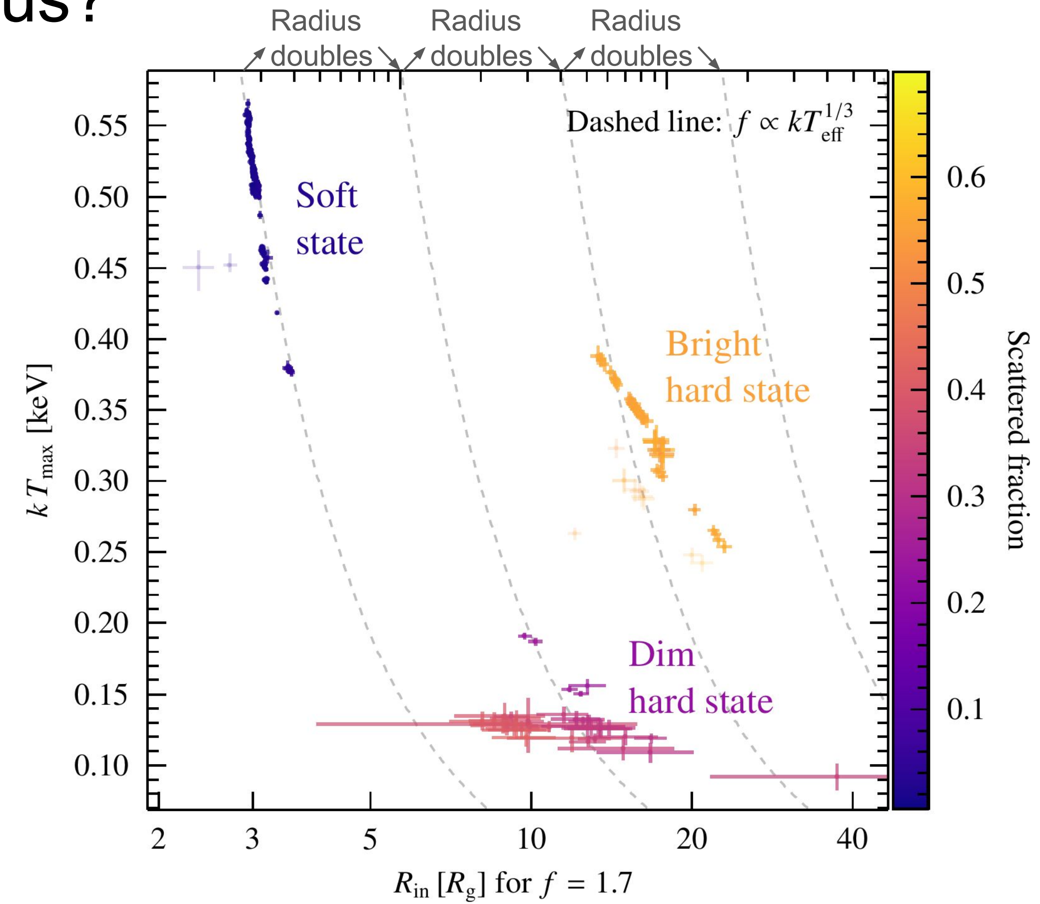
- Spectral hardening is **temperature-dependent** (e.g., Davis et al., 2006)
- Does this change the picture if we take this into account?



Evolution in inner disk radius?

- **Soft state: No** evolution, inner disk consistently at ISCO
- **Bright hard state:** Suggestive drift in radius (but: many systematic uncertainties!)
- **Dim hard state:** Maybe…

Overall: If temperature-dependent color-correction taking into account: **No sign of very large disk truncation $r_{in} \gg 10\ r_{ISCO}$**
(mild truncation of factor ~4 possible)

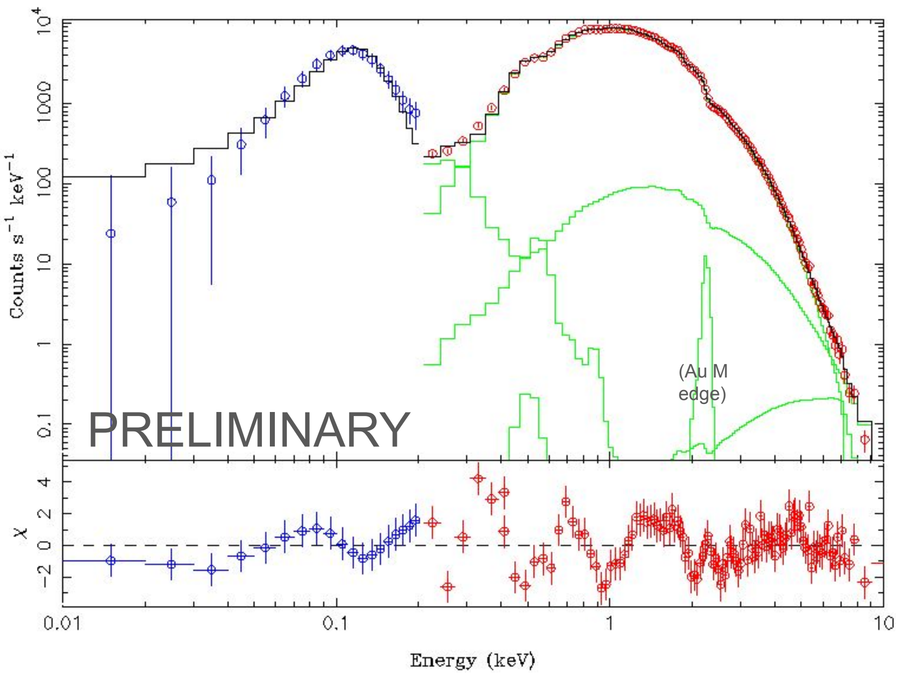


Outlook: Fitting the “0.01 - 10keV” range with NICER

- Include noise peak in fit
- Each detector has a ~Gaussian shaped noise peak at slightly different energies

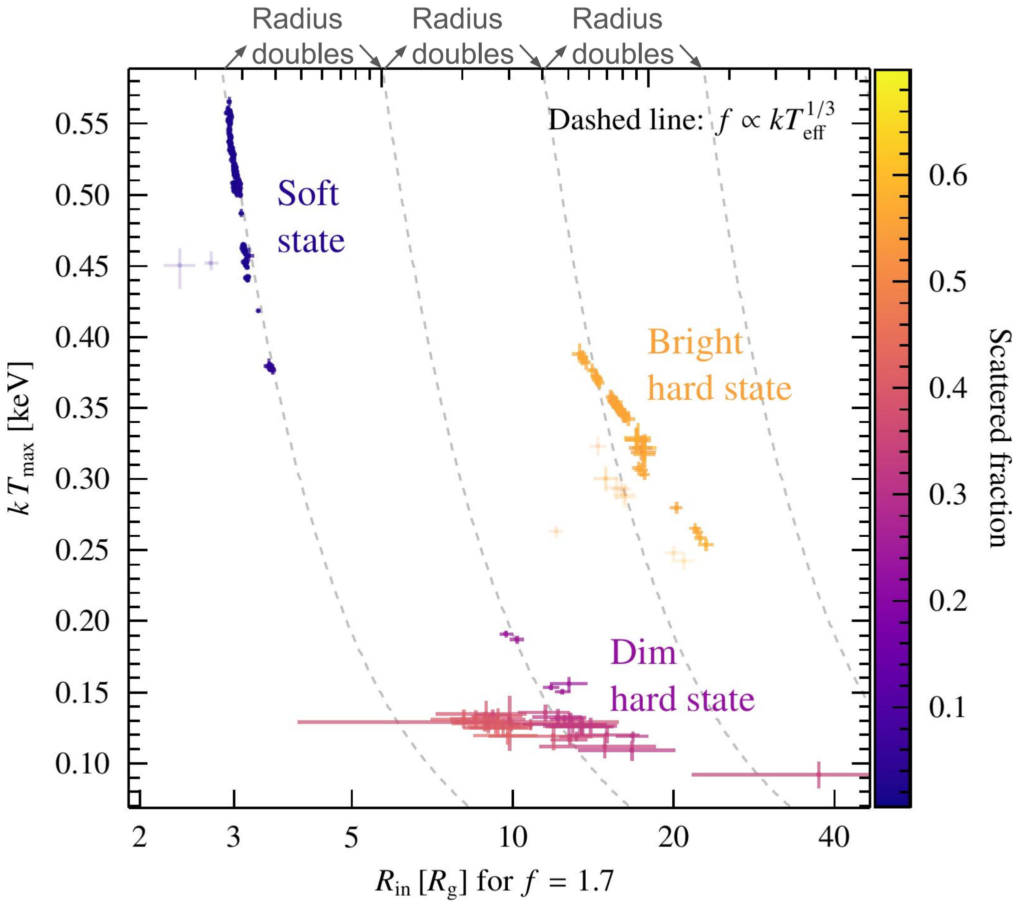
→ Model the noise peak to get more leverage on 0.2-0.4 keV data

→ More reliable disk parameters



Summary

- Overall: No sign of very large disk truncation $r_{in} \gg 10\ r_{ISCO}$
- There may be a drift in inner radius in bright hard state
- Need to further investigate systematics of models and data



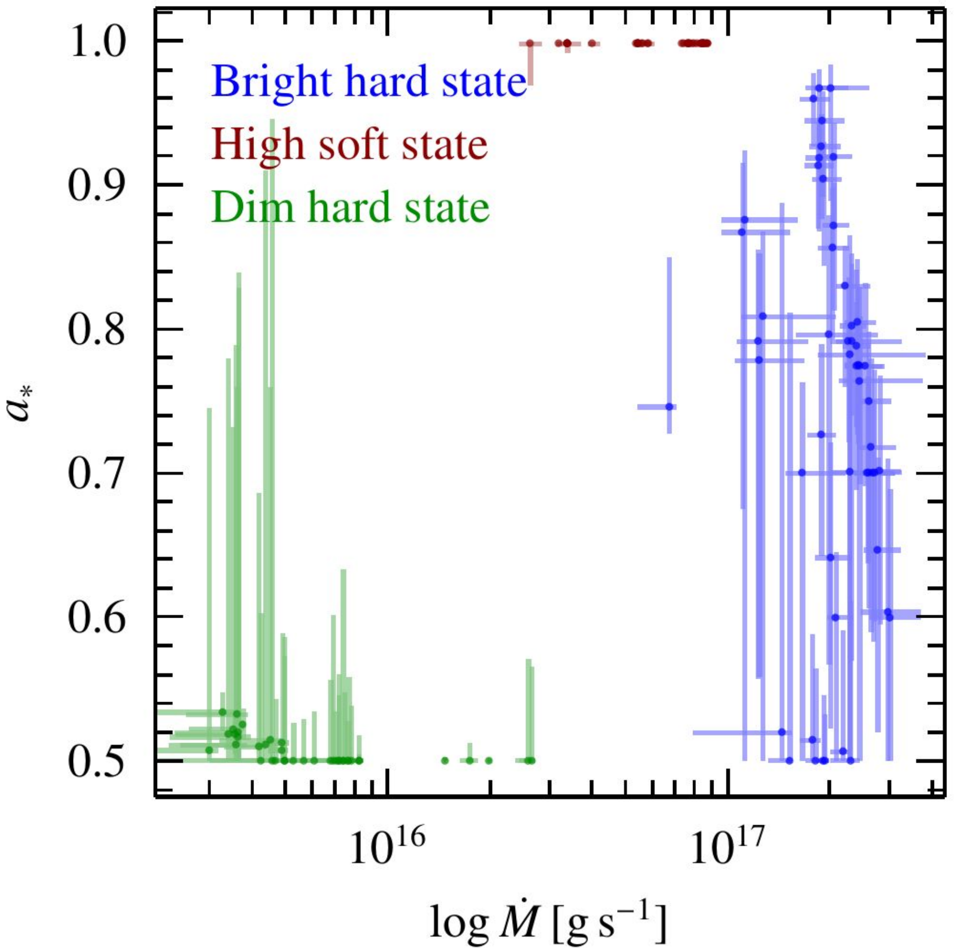
Backup Slides

Relativistic continuum fitting

tbfeo*(kerrbb+nthcomp+laor)

kerrbb assumes $r_{in}=r_{ISCO}$

→ Evolution in inner disk radius changes the spin value



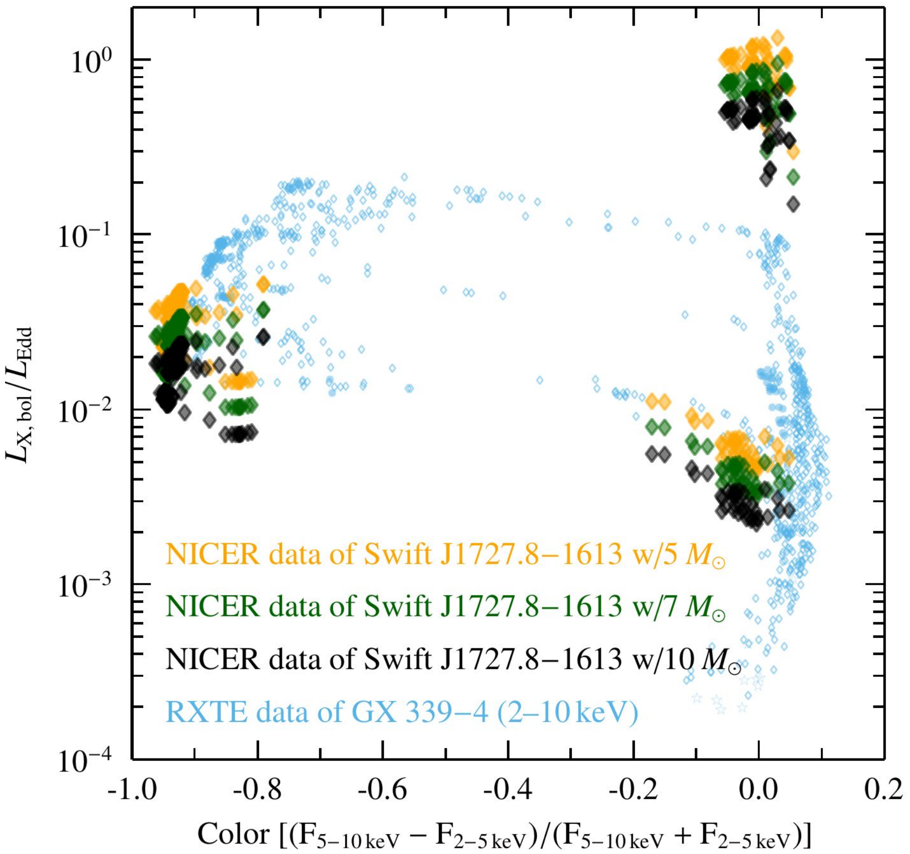
Speculation: Did Swift J1727 accrete super-Eddington?

The bright hard state seems a bit odd:

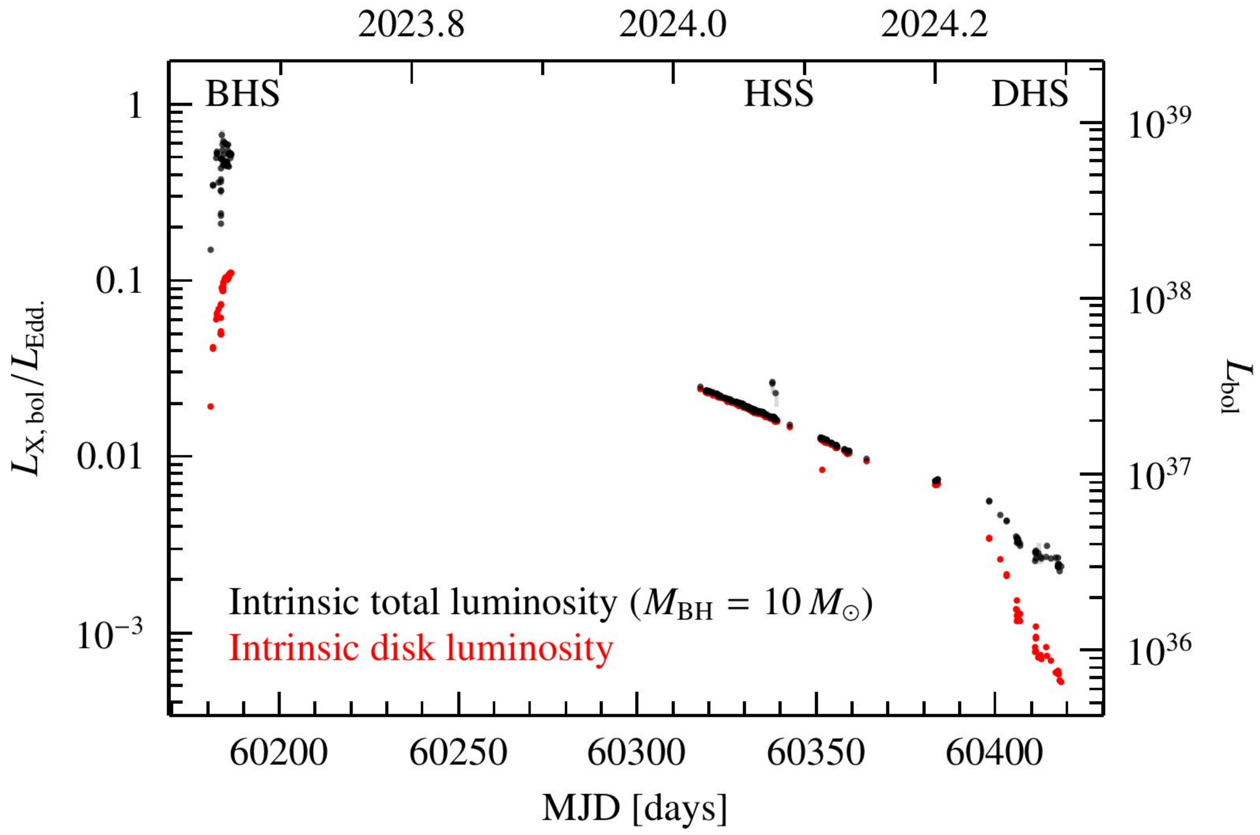
- ~weak reflection features
- Very strong QPOs

Assuming the distance is correct, may the black hole have a lower mass?

Stay tuned!

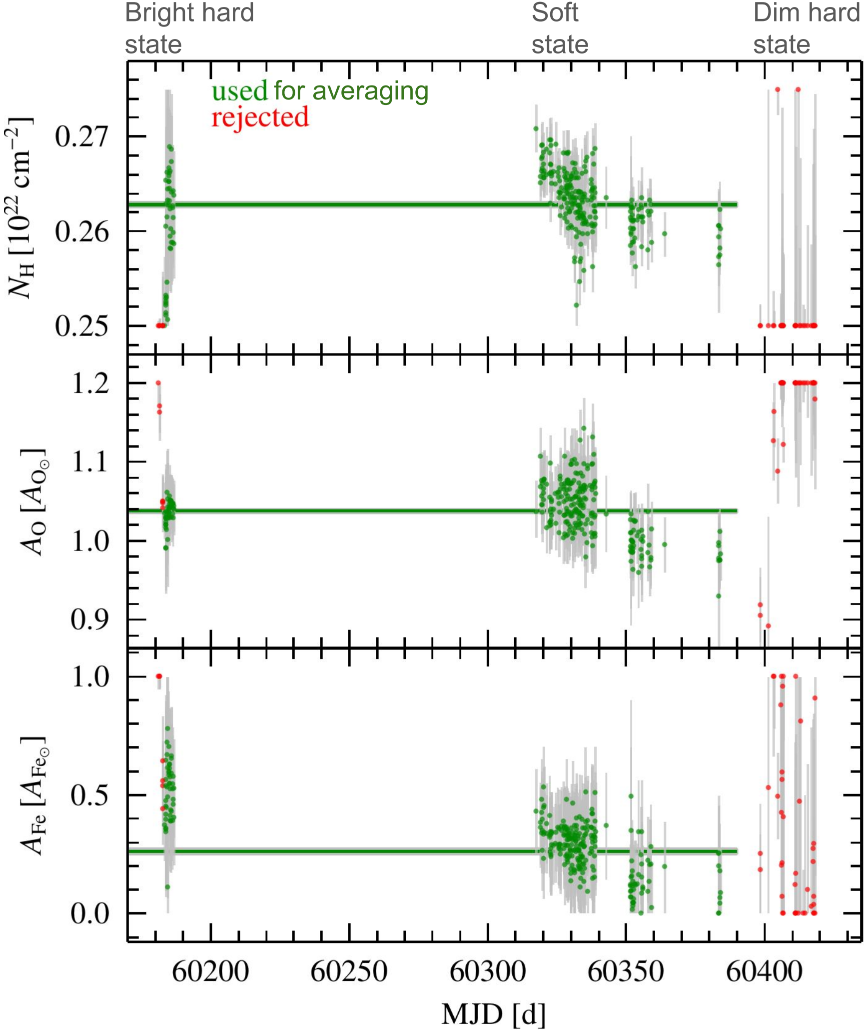


Luminosity evolution



Determination of N_H

- We do not expect significant changes in N_H
- Svoboda+24: N_H=(0.24 +/- 0.01) x 10^{22} cm^{-2} based on soft state (N_{HI4PI} = 0.2 × 10^{22} cm^{-2})
- Iron abundance systematically low
  → non-solar abundances possible but more likely that fit accounts for systematics in the low-energy calibration ("chemistry problem")
- One option: Fix N_H, A_O, A_{Fe} to weighted mean



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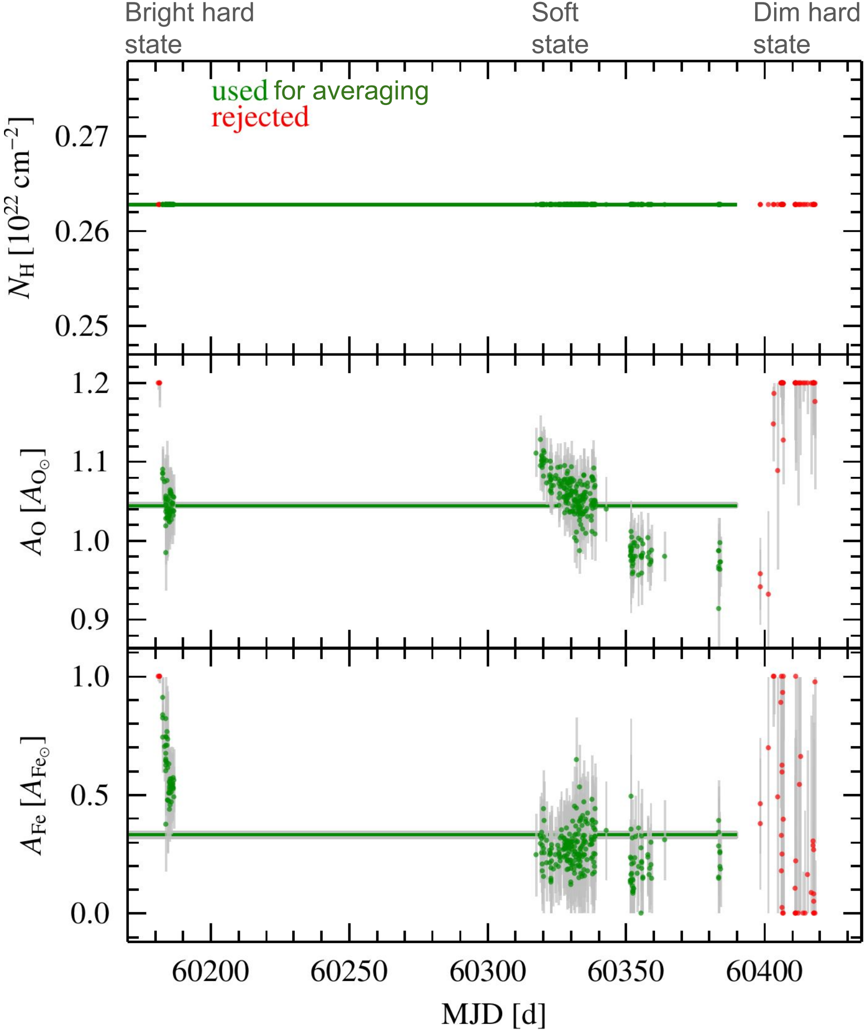

Iron line parameters