BLACK HOLE ASTROPHYSICS: TALES OF POWER AND DESTRUCTION

Spectral investigations of black hole binary states: state transitions in GX 339-4

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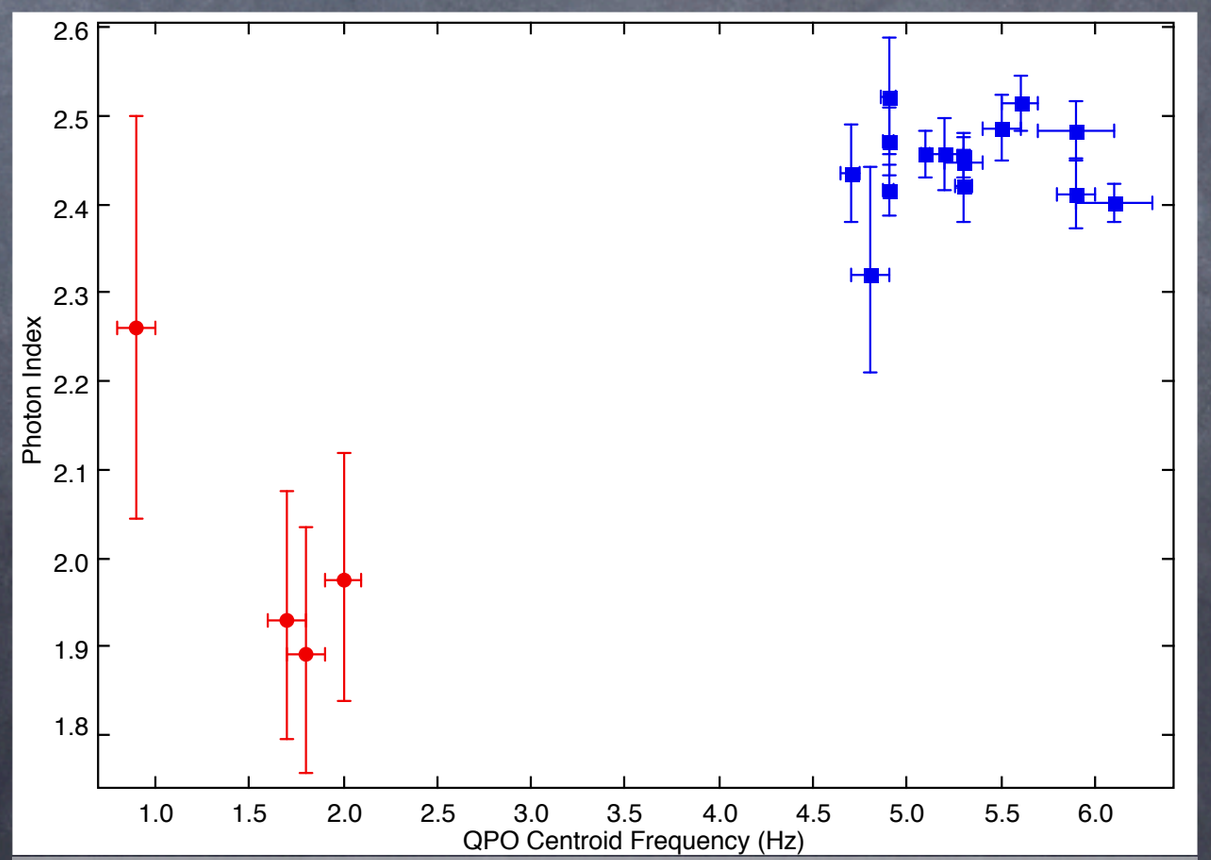
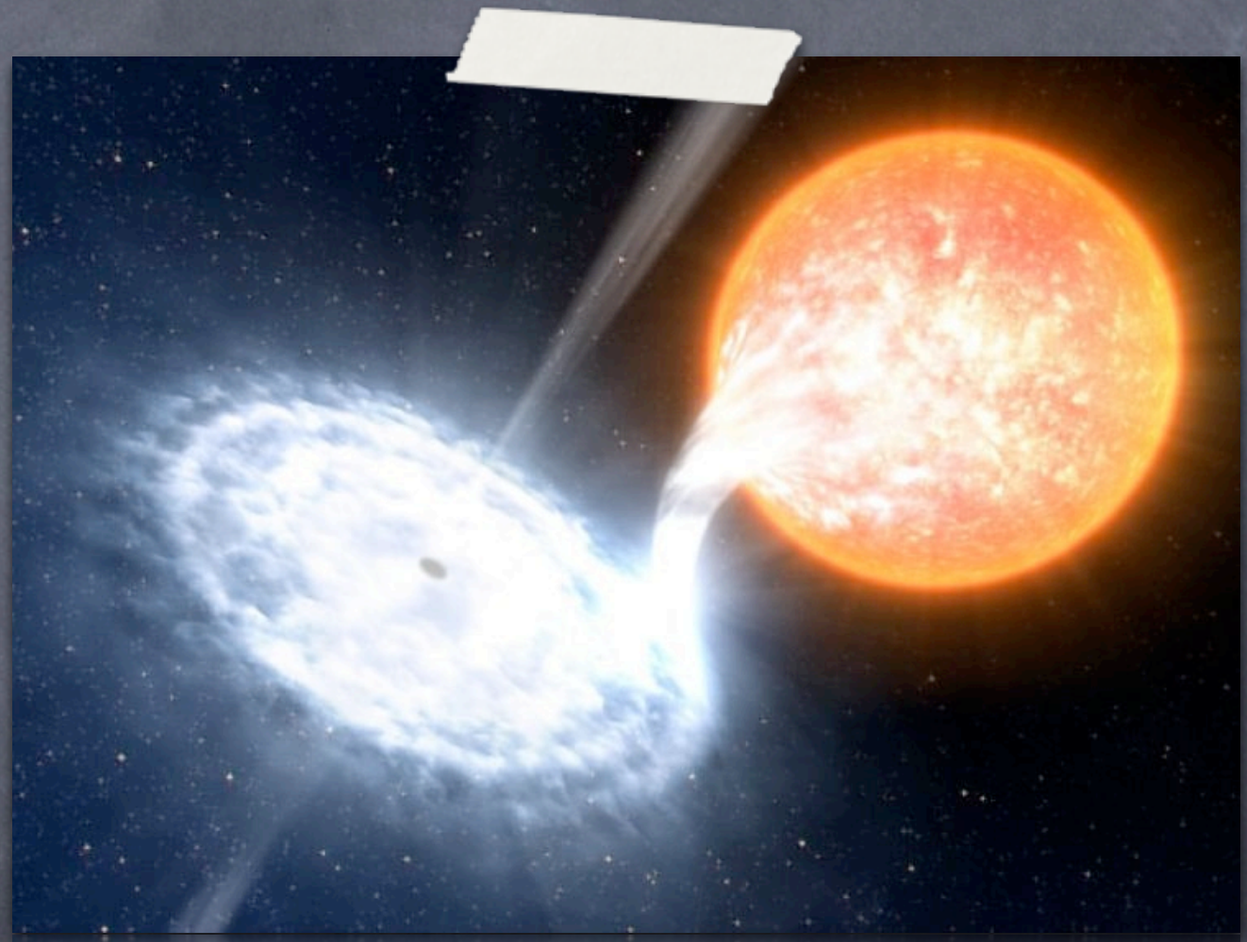
What you should take home with you

- lower branch transition: luminosity, QPO centroid frequency, and photon index lower
- type-B QPOs associated to different spectral shapes



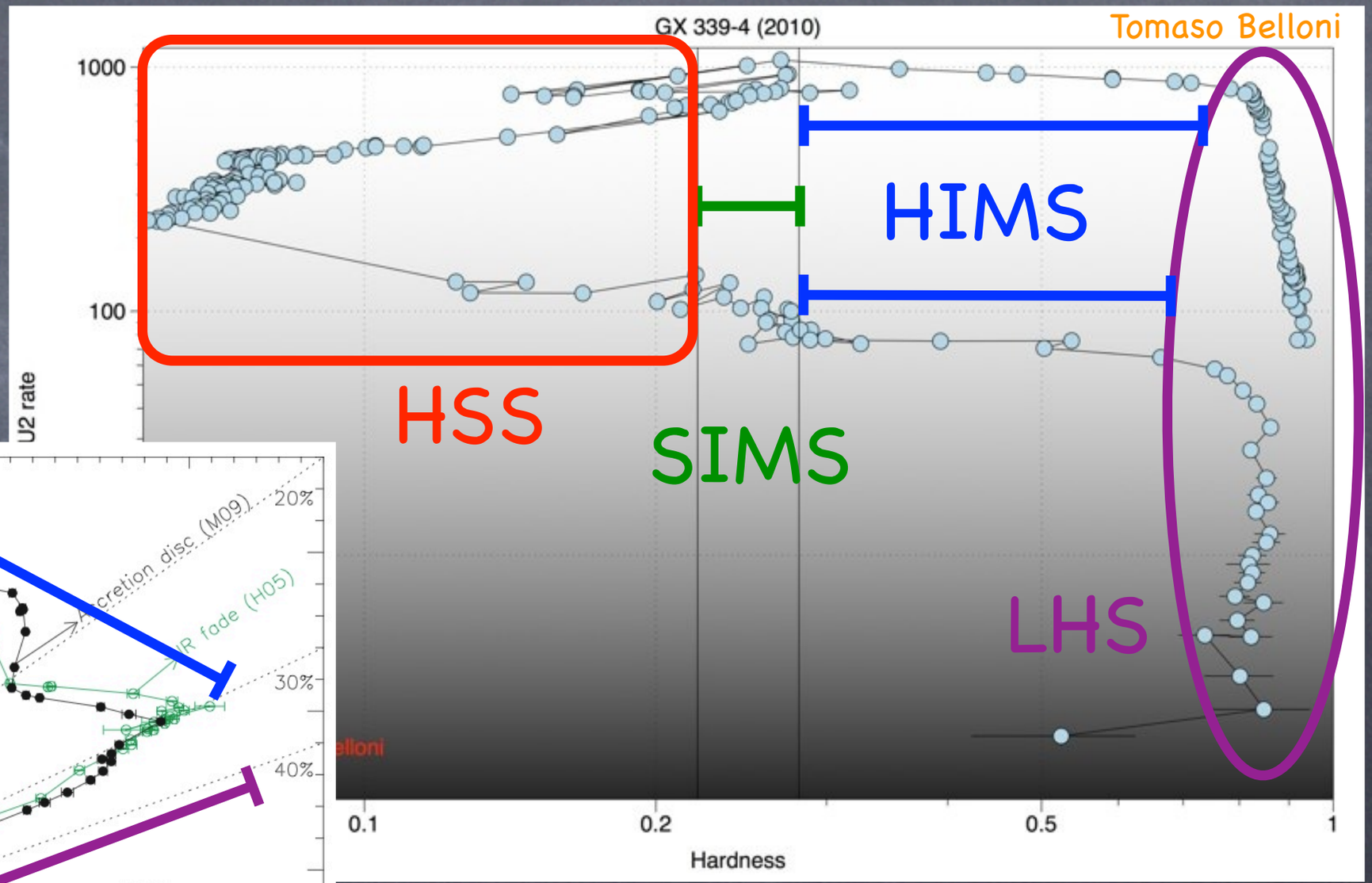
GX 339-4

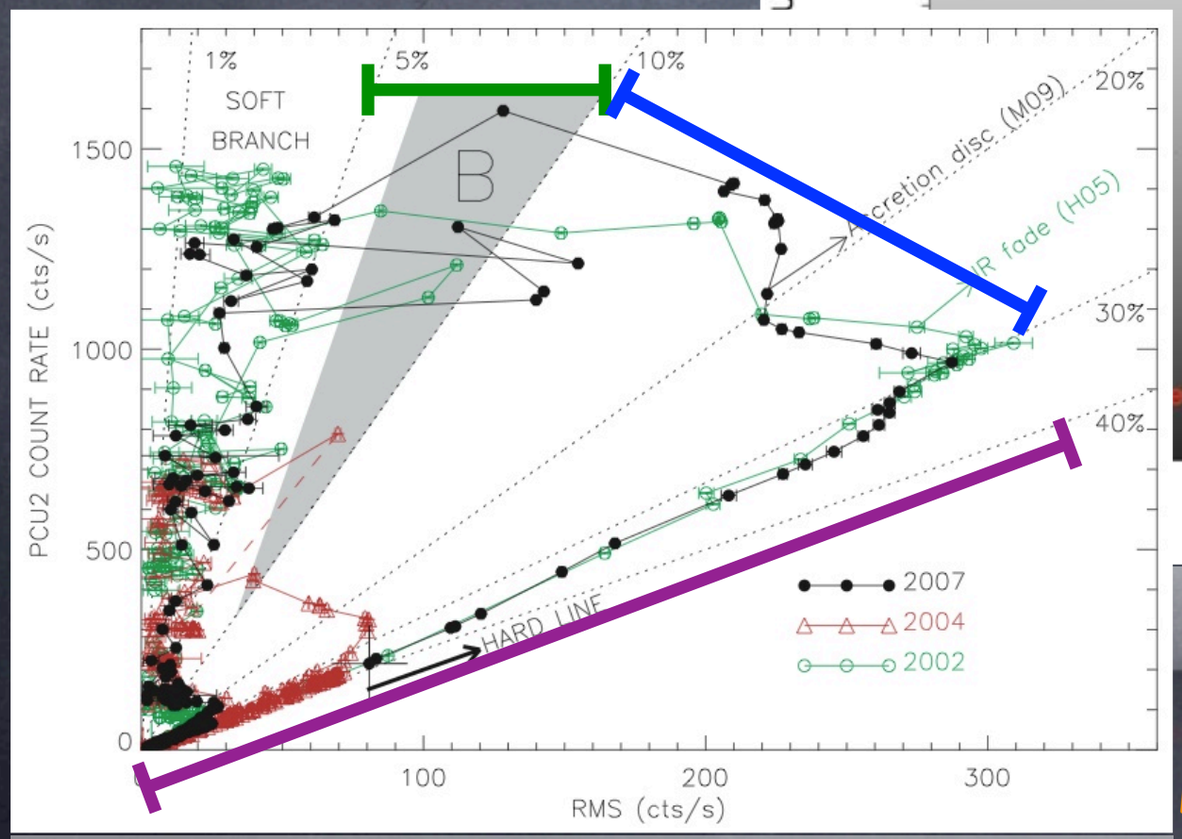
- Discovered 1973 by the OSO-7 satellite (Market et al. 1973, ApJ 184, 67)
- Several X-ray outbursts
- Low-mass X-ray binary
  - black hole > 6 $M_\odot$
  - subgiant star in a 1.7 d orbital period



Hynes et al. 2003, ApJ 583, L95;
Muñoz-Darias et al. 2008, MNRAS 385, 2205

States and state transitions in black hole X-ray binaries





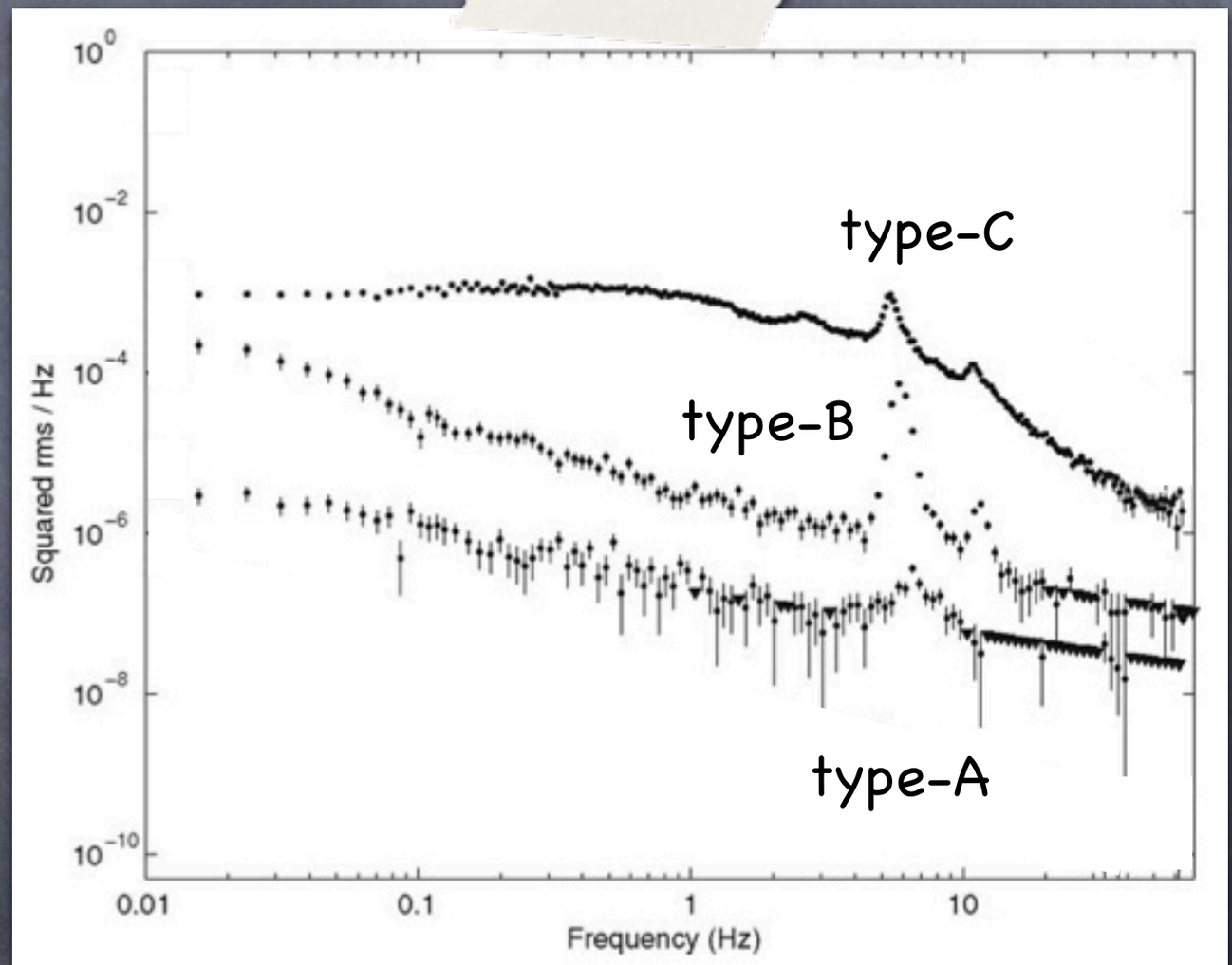
Muñoz-Darias et al. 2011, MNRAS 410, 679

Quasi-periodic oscillations (QPOs)

- Low frequency QPOs
- **quality factor Q = $\nu_{centroid}/FWHM$**

Property	Type-C	Type-B	Type-A
Q	≥ 10	≥ 10	≤ 3
rms	≥ 10%	5 - 10%	≤ 10%
noise	strong flat-top	weak red	weak red

Casella et al. 2005, ApJ 629, 403
Motta et al. 2011, subm.

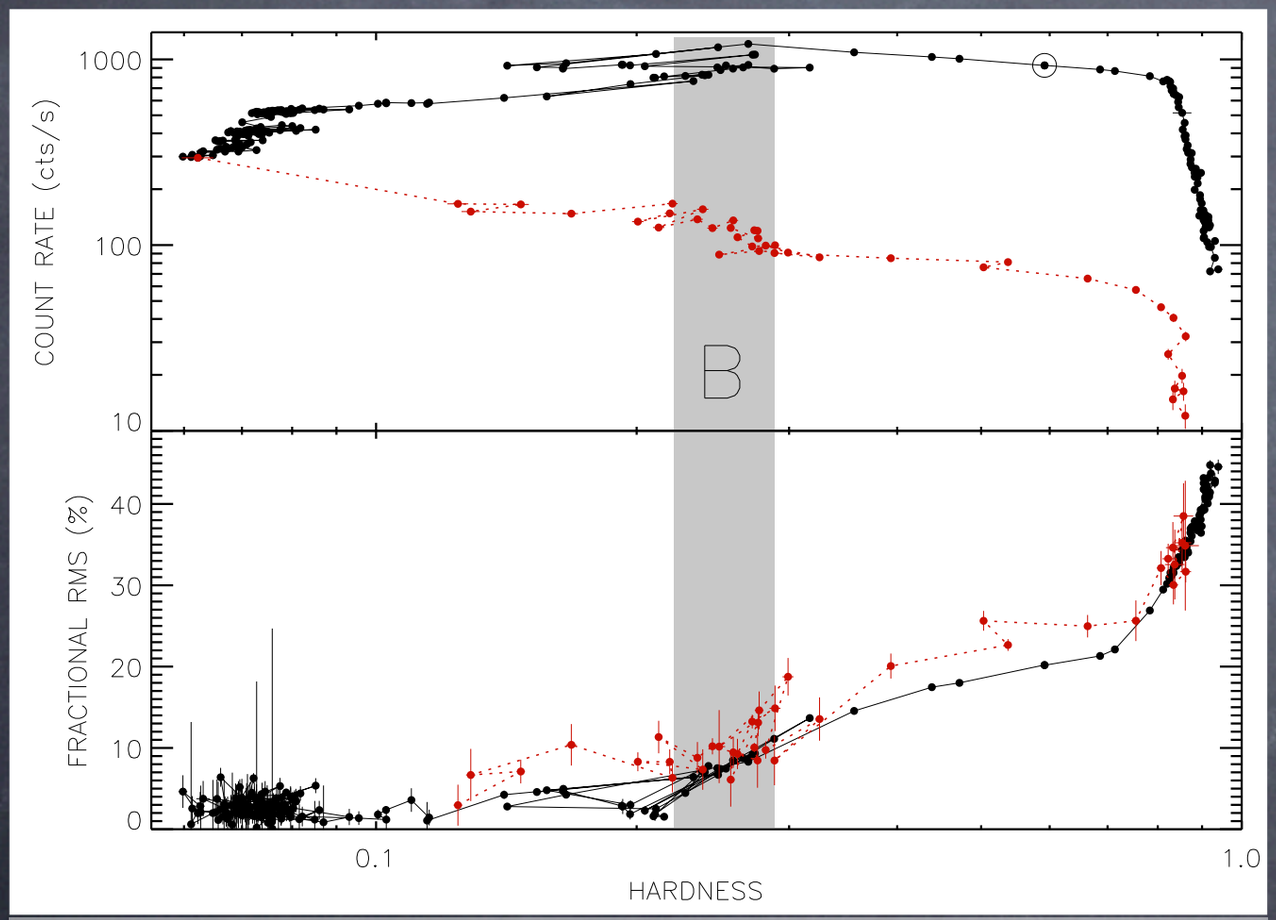


adapted from Belloni 2010, in "The Jet Paradigm"

⇨ Tomaso Belloni's talk

The sample

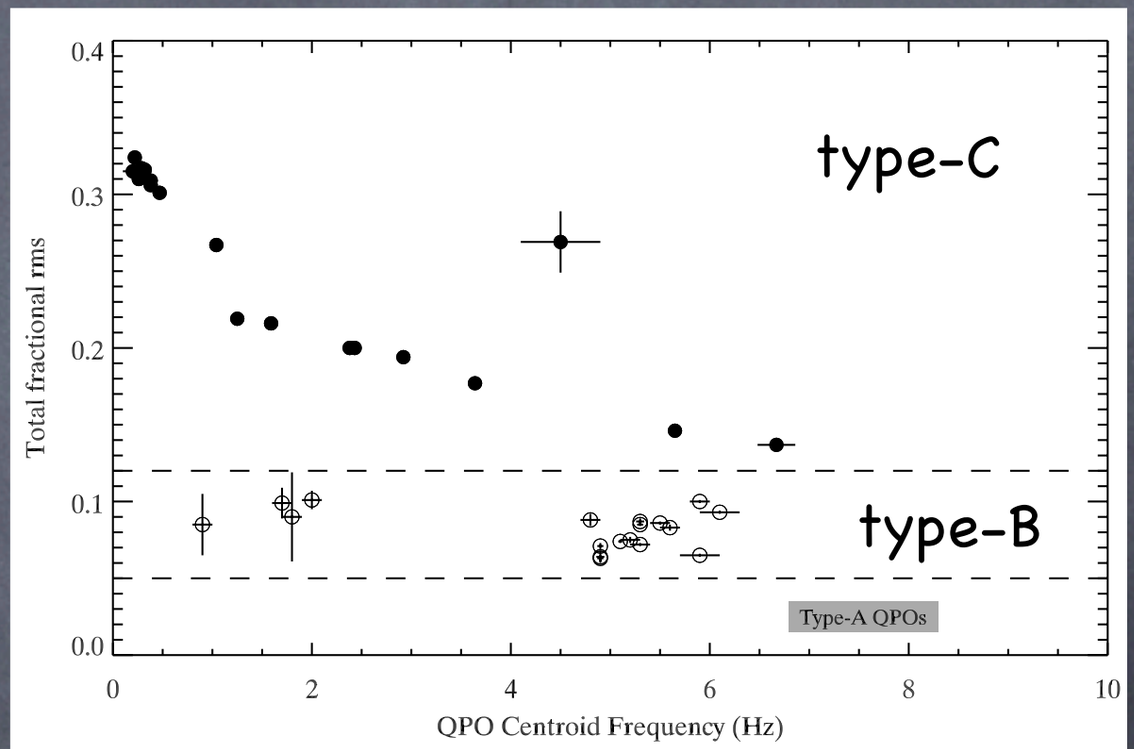
- RXTE data from 2010 outburst



- in upper branch: All observations with type-B QPOs
  ➜ 0.2208 < HR < 0.2883
- same hardness ratio range in lower branch
- fractional rms: 5 - 10 %
- added HIMS:
  0.2883 < HR ≤ 0.8

Power density spectra

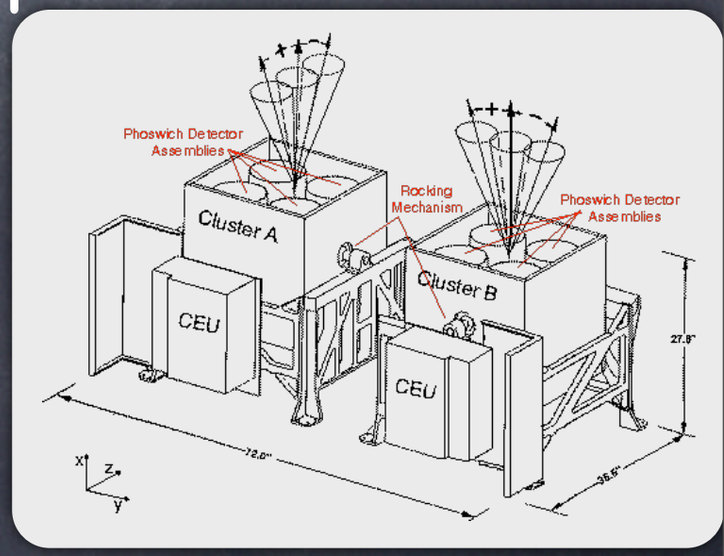
- PDS from 16 s long stretches
- PCA 2 - 15 keV
  rms: 0.1 - 64 Hz
- fitted noise components and QPOs (Lorentzian and Gaussian shapes) following Belloni et al. 2002 ApJ 572, 392 ➜ $\nu_{centroid}$
- $\nu_{centroid}$ versus rms ➜ QPO types separate clearly



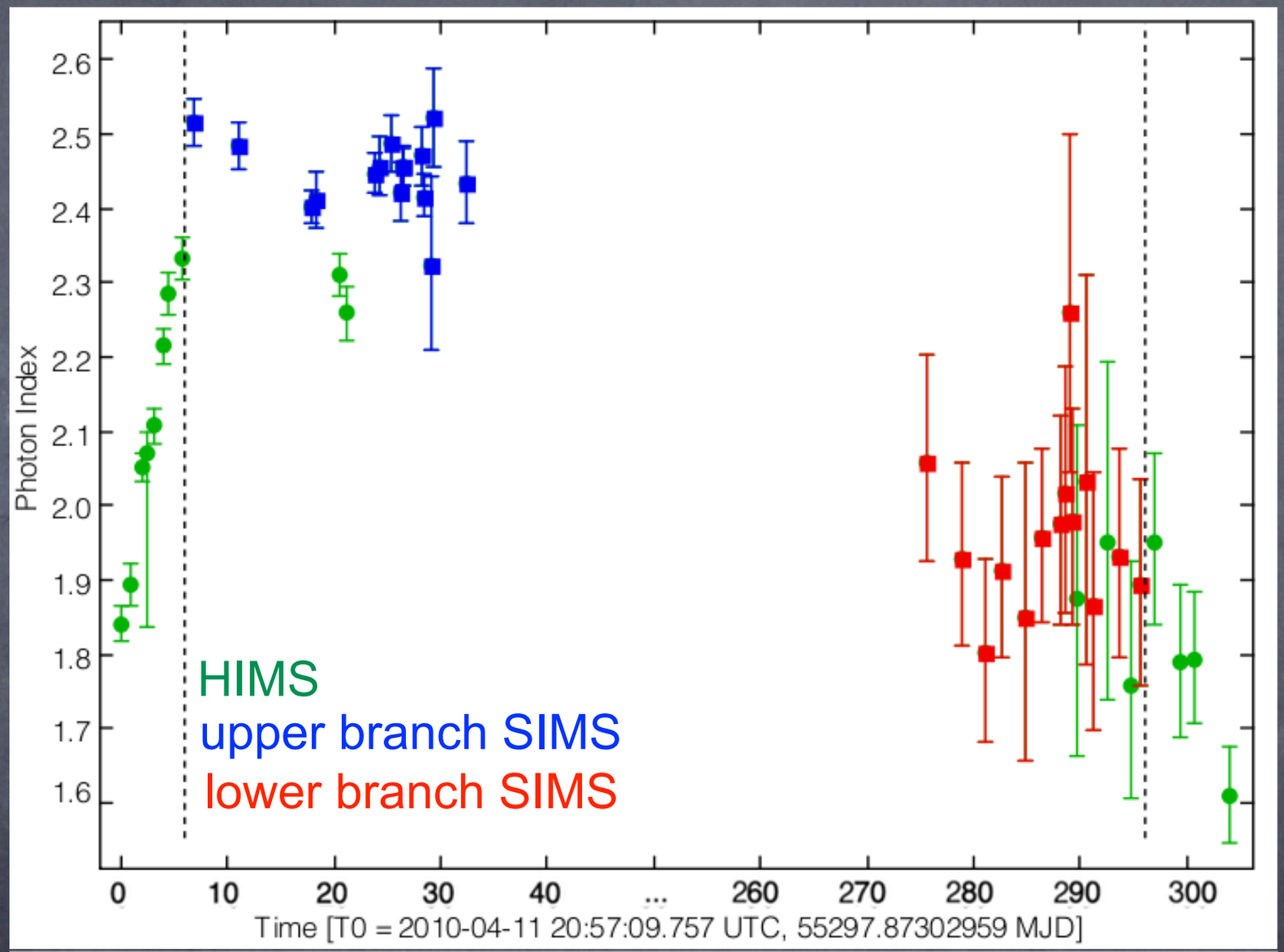
➪ Sara Motta's talk

Spectral analysis

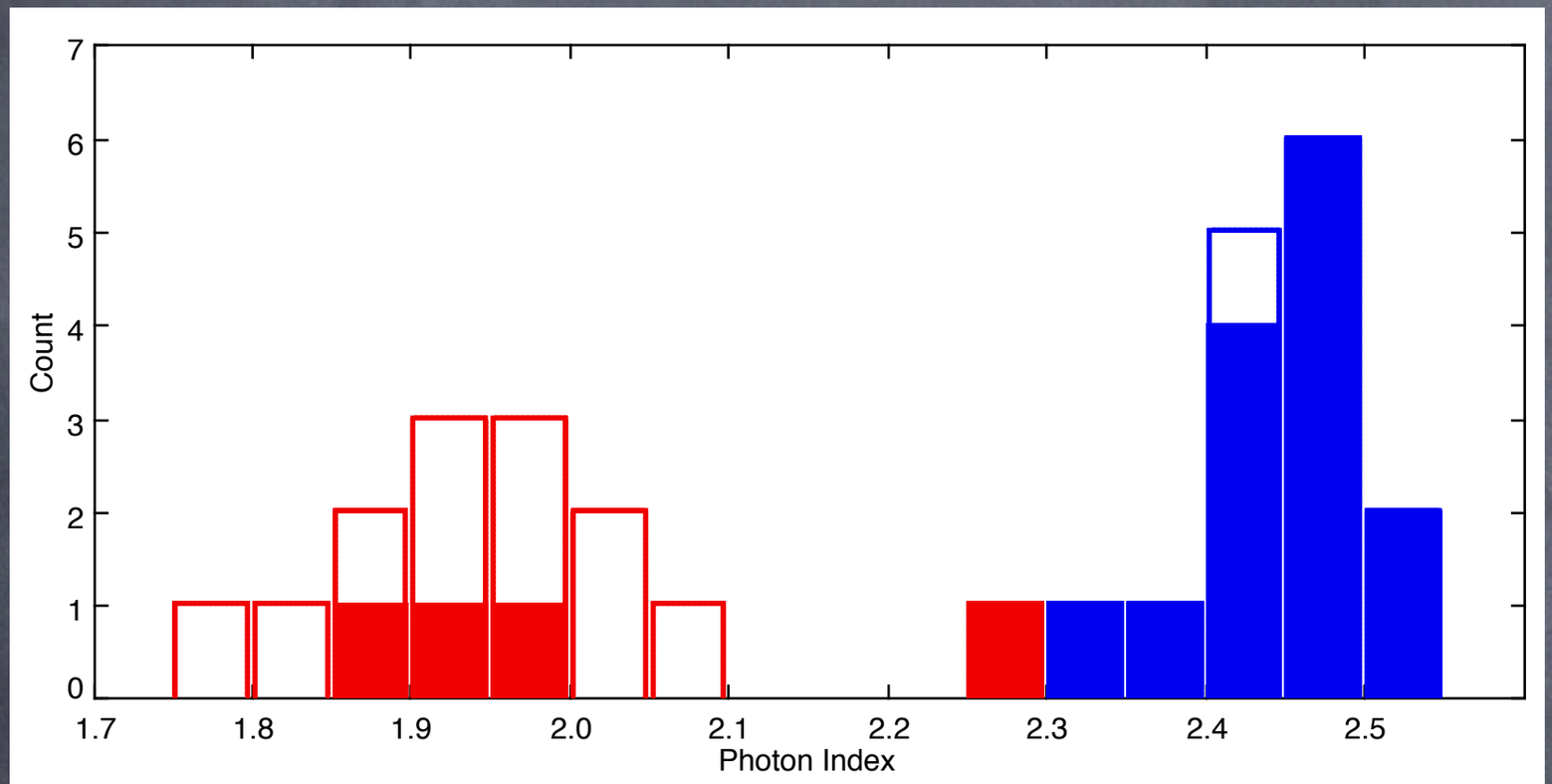
- only interested in hard spectral component
  ➜ PCA 10 - 40 keV
- HEXTE: break down of rocking mechanism ➜ problems estimating background ➜ strong residuals ➜ ignored
- Fit with ISIS:
  - power law + high energy cut off
  - power law with reflection



Evolution of photon index



Photon index

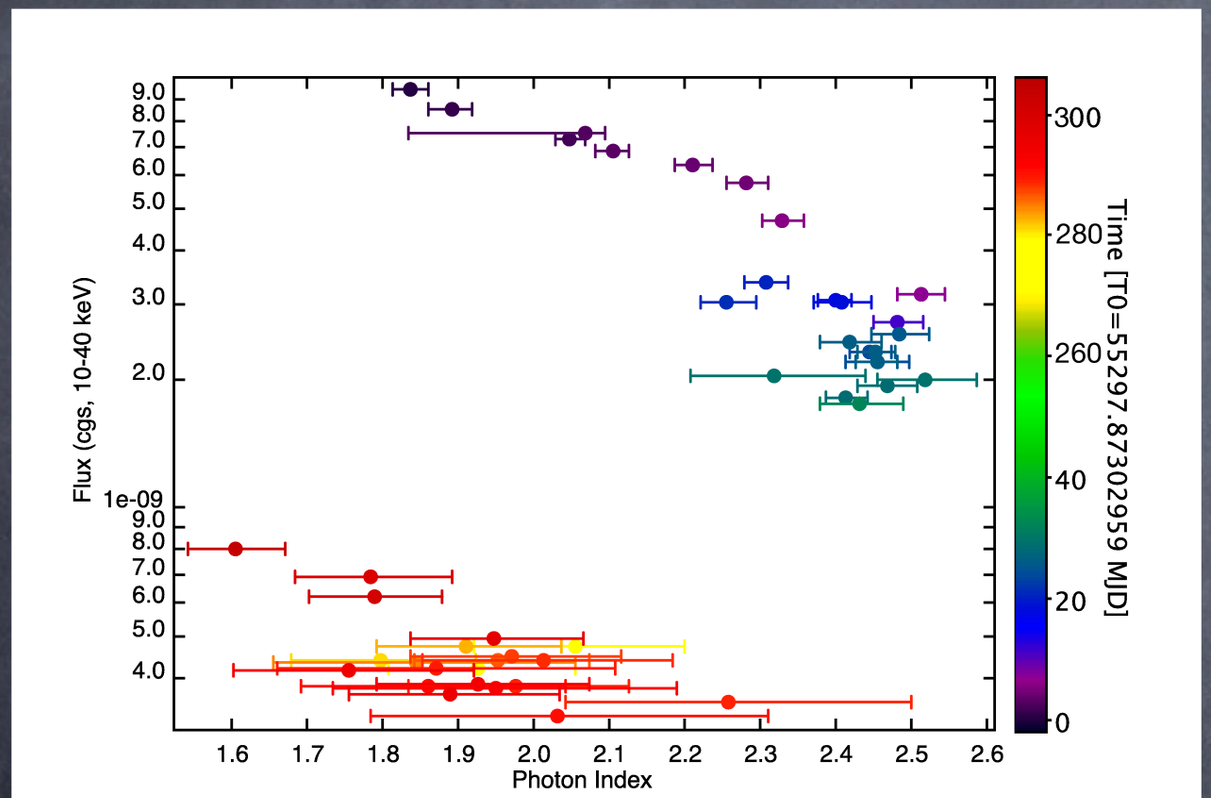


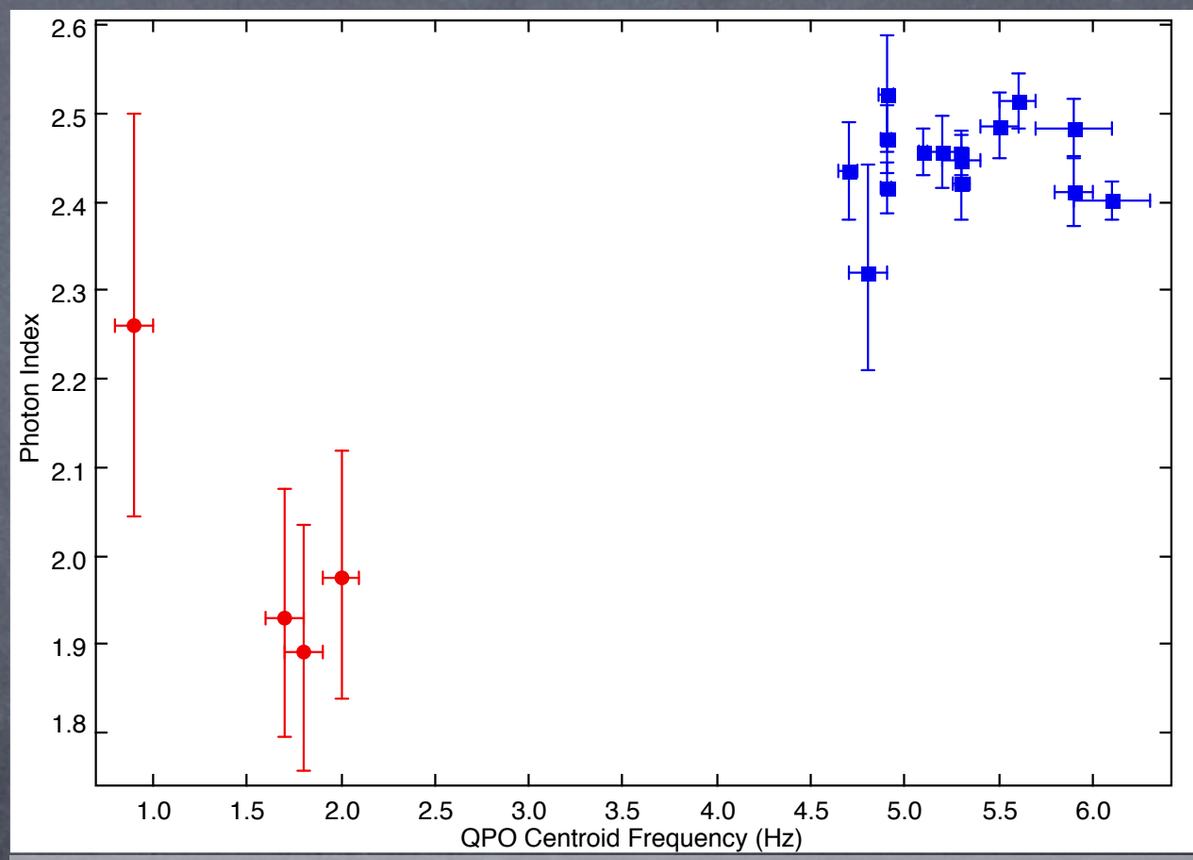
- upper branch
- lower branch
- filled: with type-B QPOs

difference only in timing

Relation between photon index and source flux

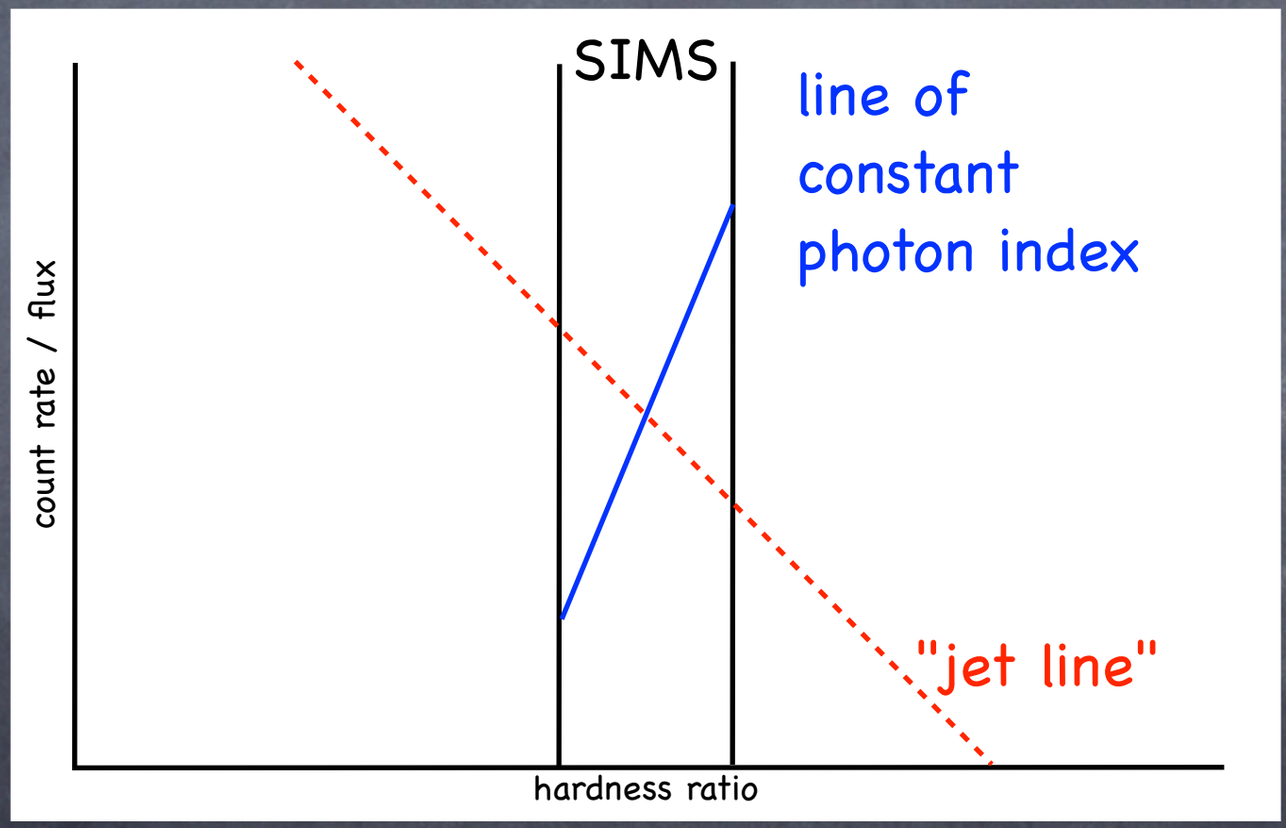
QPO centroid frequency





Discussion

- same hardness ratio range on both branches
  ➜ HR needs to be "re-calibrated" as tracker of the spectral shape, according to flux level



Discussion

- photon index lower branch SIMS ↔ value at onset of upper branch HIMS
- agrees with lagging of timing properties compared to spectral properties in lower branch Kalemci et al. 2004 ApJ 603, 231

- Known: disappearance of jet in upper branch and re-appearance in lower branch at different hardness ratios
  Now: jet appears at much lower photon index than it disappeared at
  ➜ no / complex relation between photon index ↔ radio emission

QPOs and photo index

- type-B QPOs are associated to different spectral shapes
- upper branch: $\nu_{centroid} \sim 5$ Hz; $\Gamma \sim 2.3 - 2.6$
- lower branch: $\nu_{centroid} \sim 2$ Hz; $\Gamma \sim 1.9$
- only certain combinations are allowed

→ type-B QPOs can only appear in a narrow range of properties realised during state transition

Conclusion

- state transition of GX 339-4 during 2010 outburst
- RXTE, PCA-data, 10 - 40 keV, power law
- luminosity, QPO centroid frequency, and photo index lower in lower branch SIMS
- type-B QPOs associated to different spectral shapes; can only appear in narrow parameter range during state transition

Thanks for your attention