Millihertz to hectohertz variability in low mass X-ray binaries as seen by XMM-Newton

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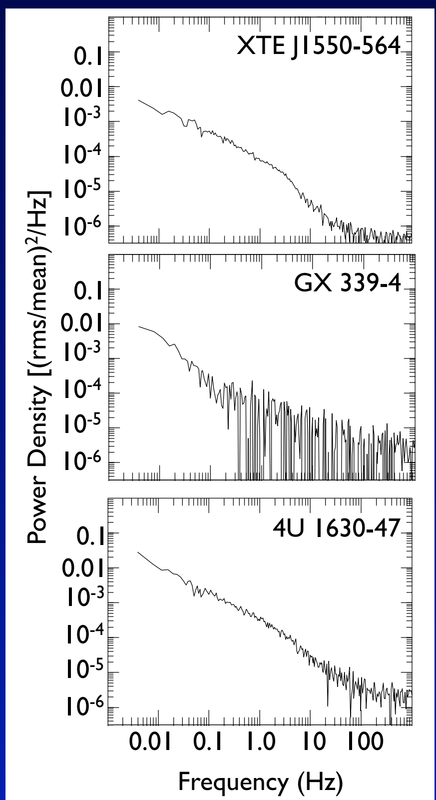
Main result

- The observed power spectral shape depends on the energy band, and hence spectral component, we are looking at.

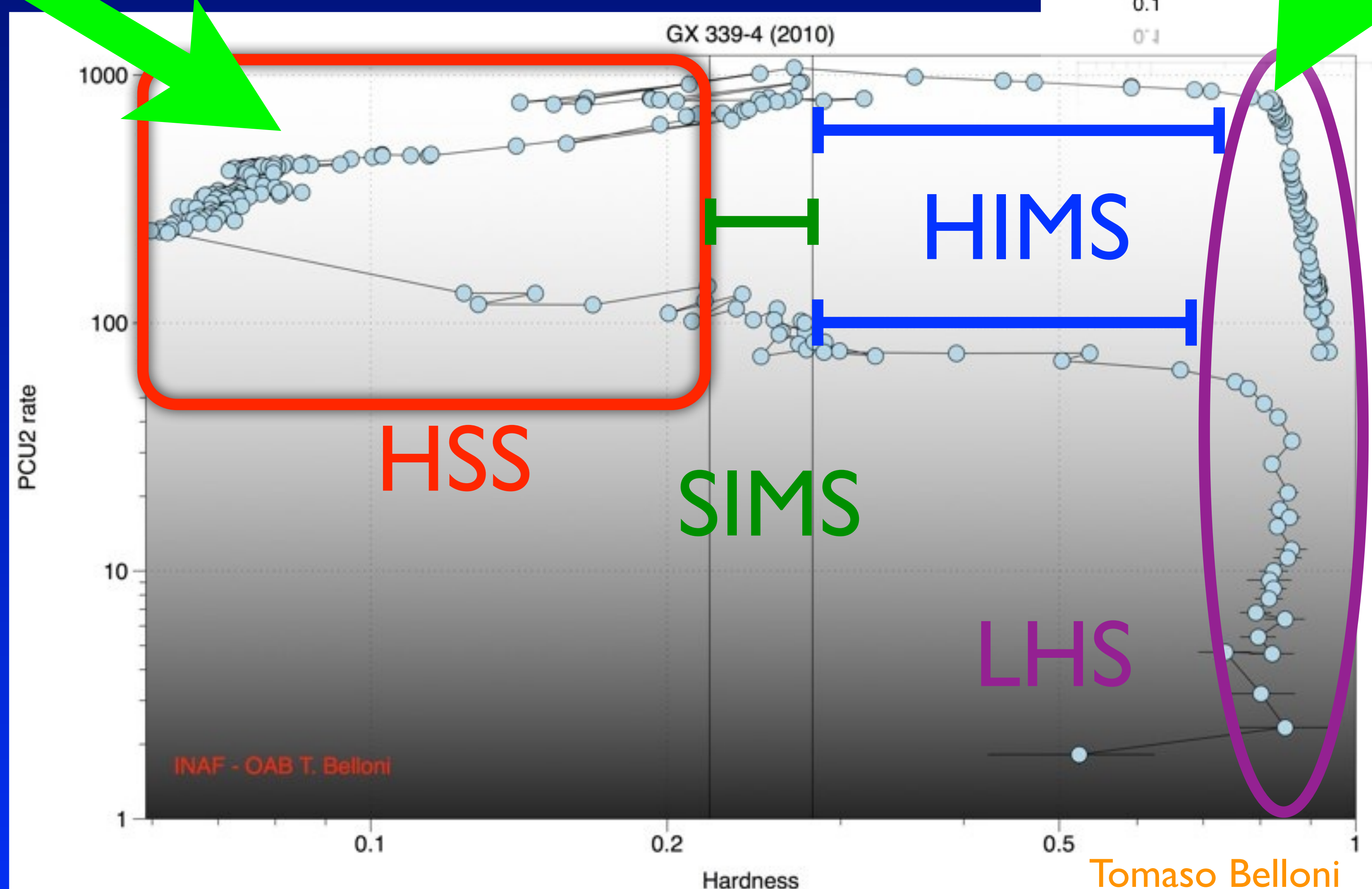
Timing properties as seen with RXTE



McClintock & Remillard 2006 Black Hole binaries

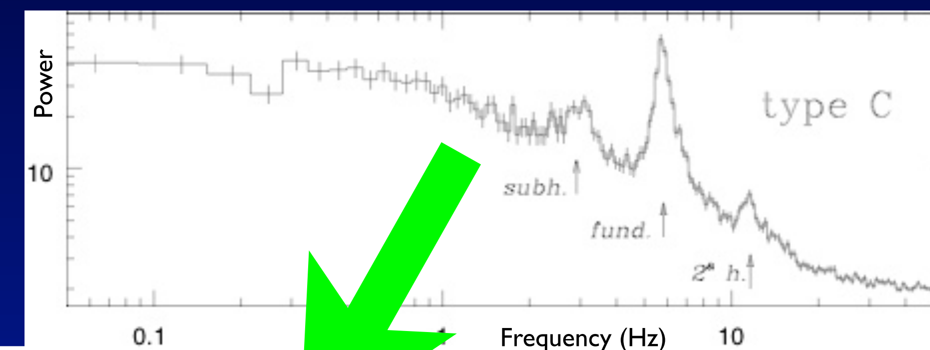
power law noise

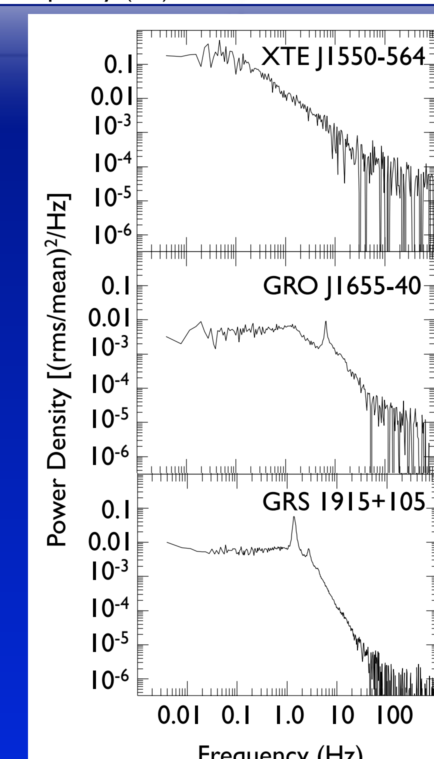
hardness - intensity diagram



Tomaso Belloni

Casella et al. 2004, A&A, 426, 587



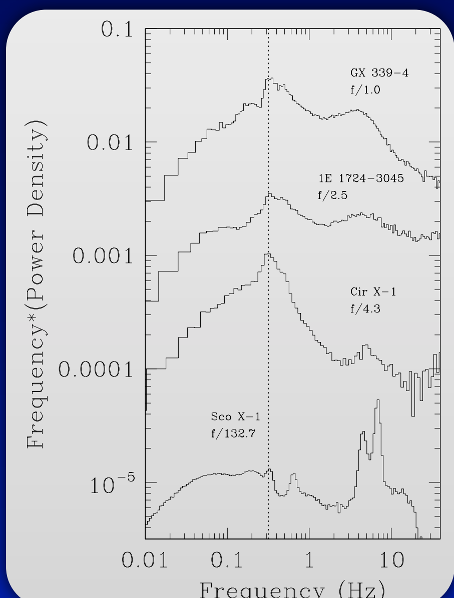


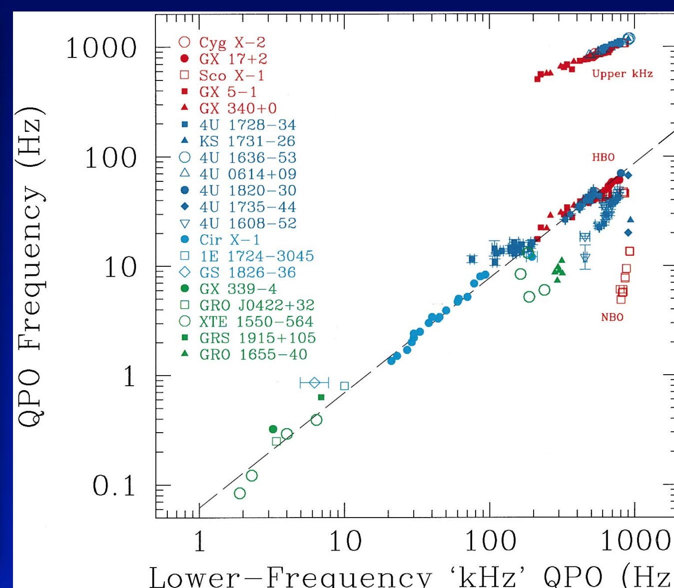
McClintock & Remillard 2006 Black Hole binaries

band limited noise and QPO

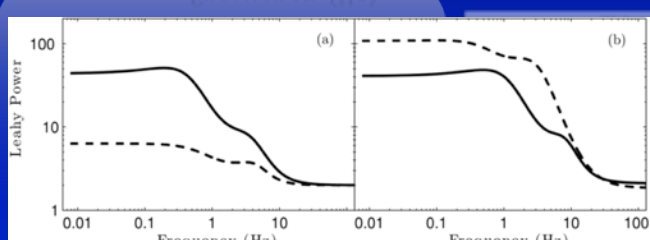
Additional PDS features

- peaked noise component

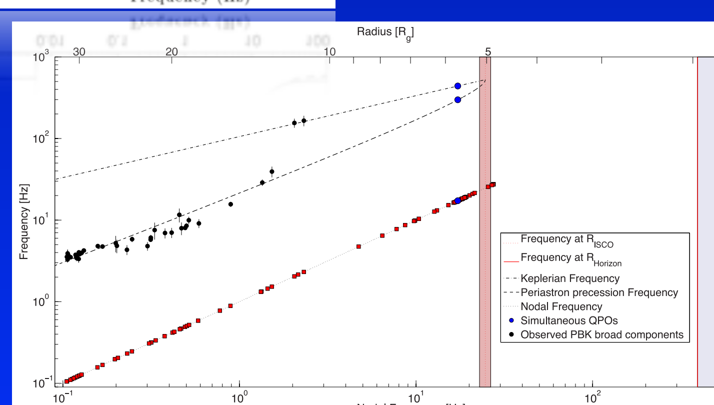




Psaltis et al. 1999, ApJ, 520, 262



Rao et al. 2010, ApJ 714, 1065



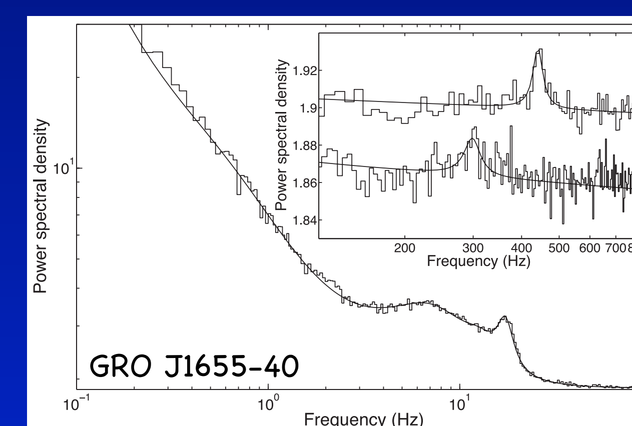
Motta et al. 2014, MNRAS, 437, 2554

- high frequency QPOs
- centroid frequency at a few hundred Hz
- mainly observed during intermediate states

Belloni et al. 2012, MNRAS, 426, 1701

Source name
GX 339-4
4U 1630-47
GRO J1655-40
H 1743-322
XTE J1550-564
Swift J1753.5-0127
XTE J1752-223
XTE J1650-500
Swift J1539.2-6227
XTE J1817-330
XTE J1859+226
4U 1543-47
XTE J1720-318
4U 1957+115
XTE J1118+480
MAXI J1659-152
SLX J1746-331
XTE J1652-453
XTE J1748-288
SAX J1711.6-3808
GS 1354-644
GRS 1737-31

Belloni et al. 2012, MNRAS, 426, 1701



Motta et al. 2014, MNRAS, 437, 2554

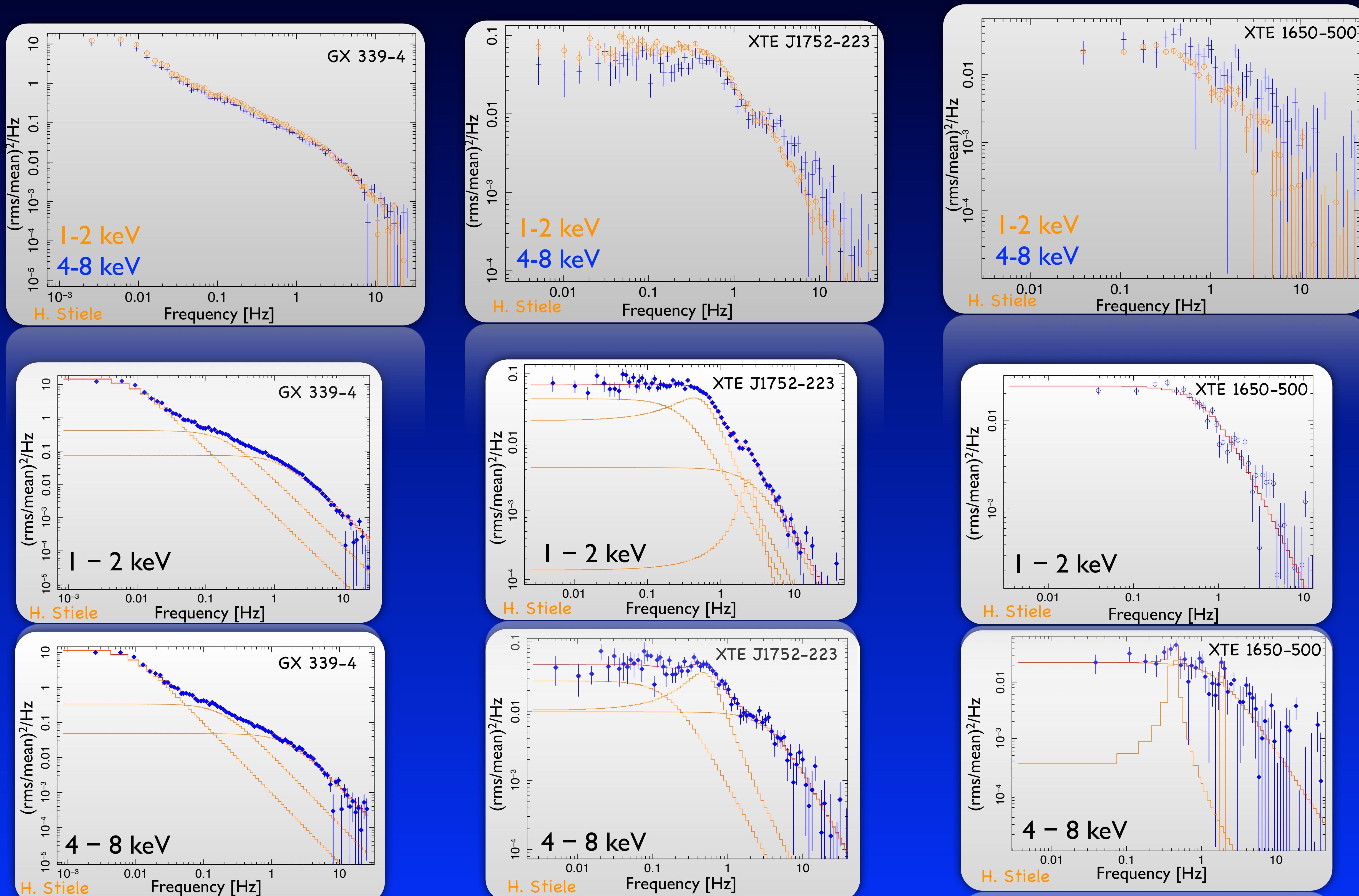
XMM-Newton black hole X-ray binary sample

- 12 black hole XRBs
- 60 archival observations in fast modes

Compared to RXTE XMM-Newton

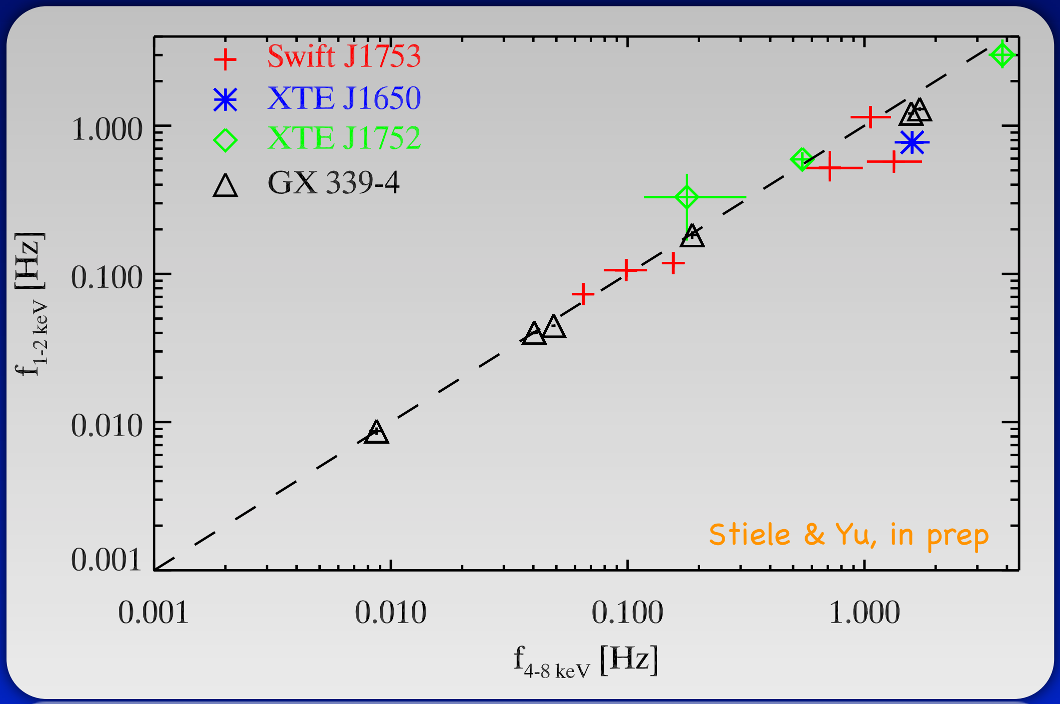
- has higher energy resolution
- covers softer energies

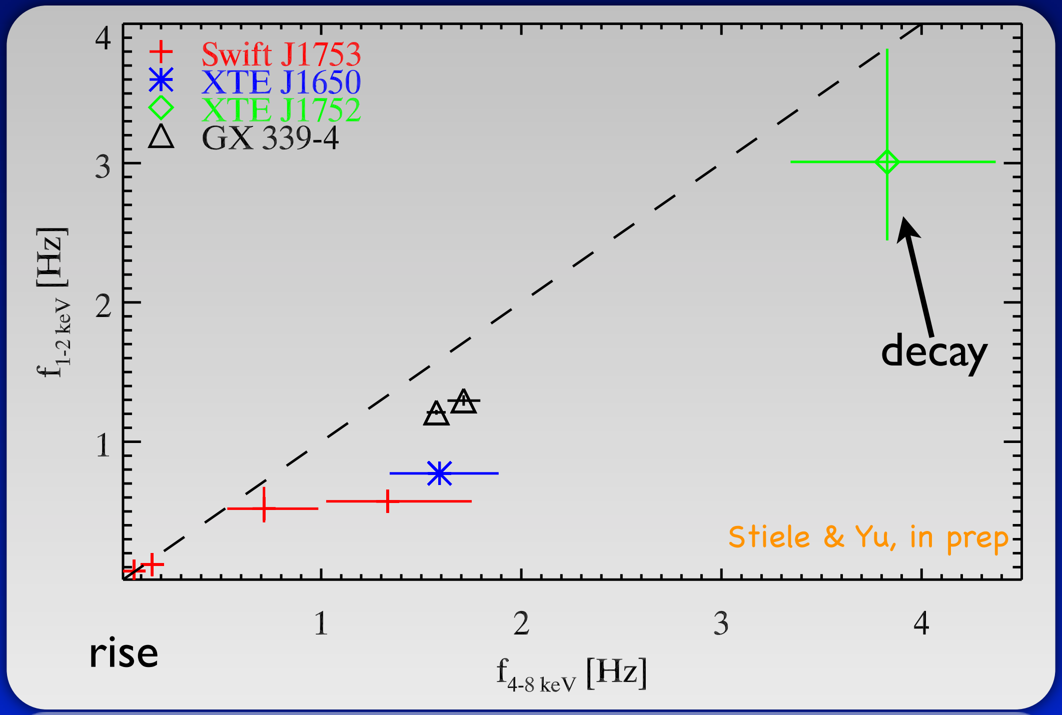
PDS in low hard state



BLN in low hard state

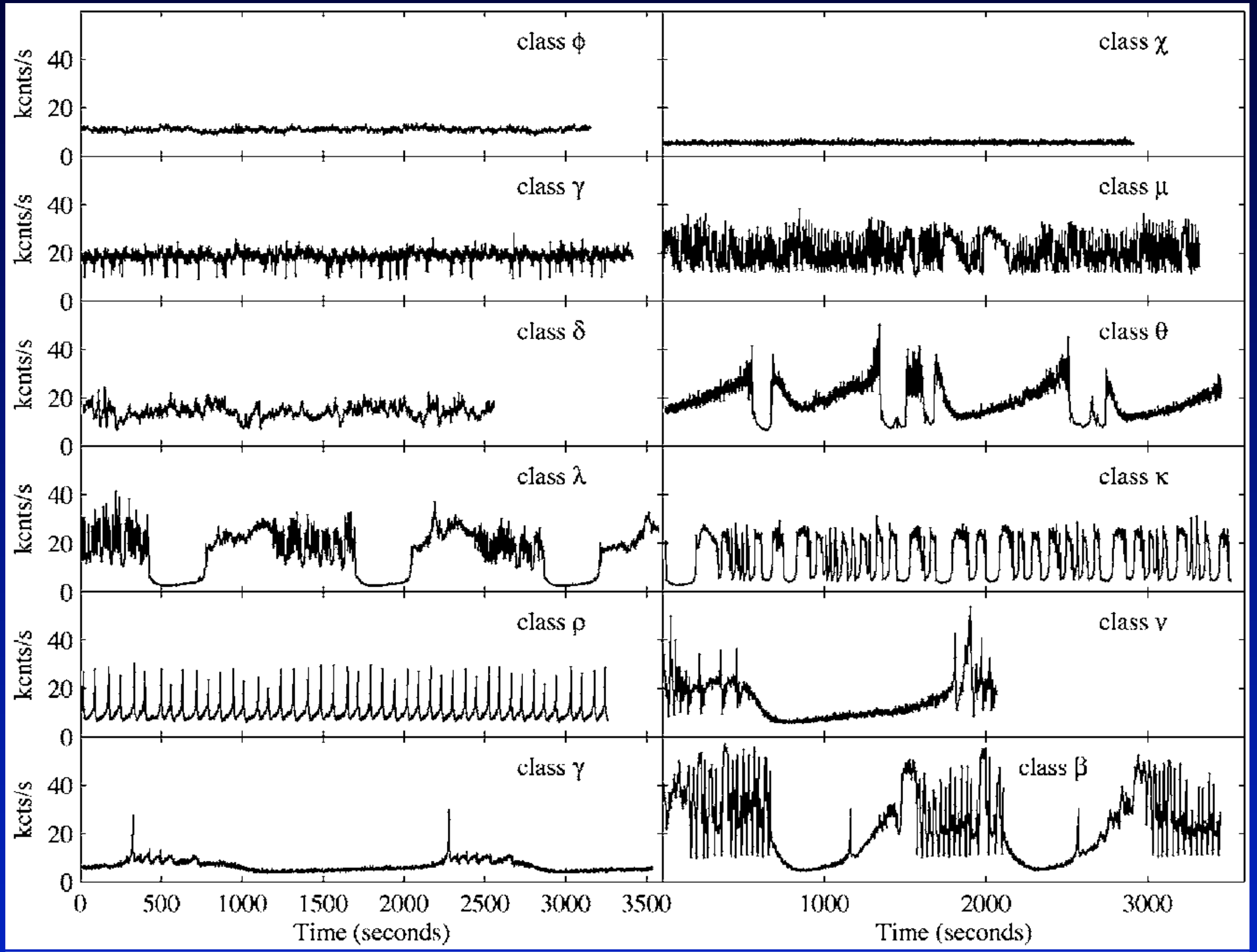
- At least one component where $f_{1\text{-}2keV} < f_{4\text{-}8keV}$





GRS 1915+105

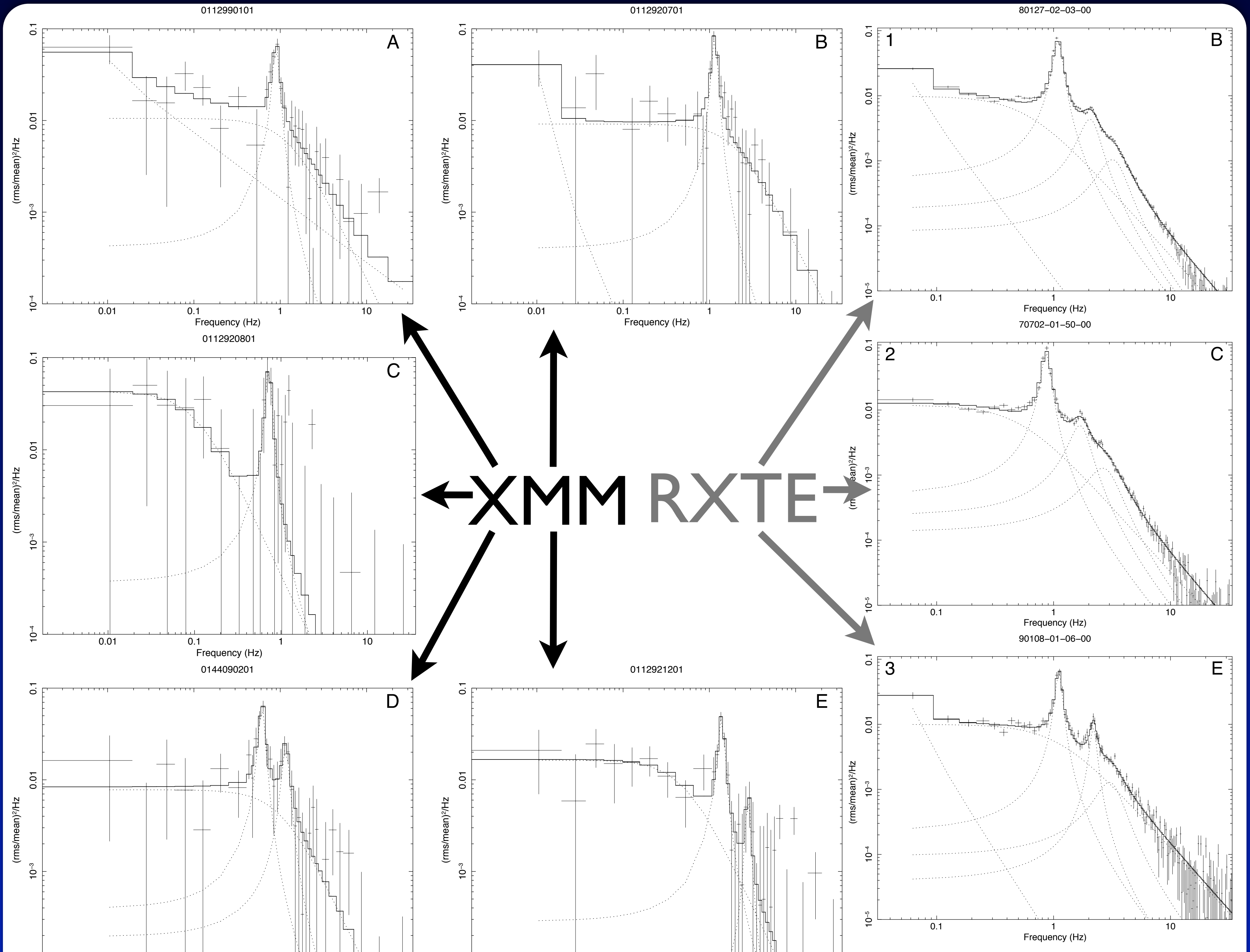
Fender & Belloni 2004, ARA&A, 42, 317



- detected 1992 with the WATCH instrument on-board GRANAT
- M_{BH} ~14±4 $M_\odot$; D ~12 kpc; orbital period ~33 d
- requires its own classification scheme ➜ shows 12 variability classes Belloni et al. 2000, A&A, 355, 271
- χ variability class ≈ conventional “hard” state Reig et al. 2003, A&A, 412, 229; van Oers et al. 2010, MNRAS, 409, 763
- 5 archival XMM-Newton observations of GRS 1915+105 during its χ variability class from 2003 and 2004
- source highly absorbed below 1.5 keV Martocchia et al. (2006, A&A, 448, 677)

PDS of GRS 1915+105

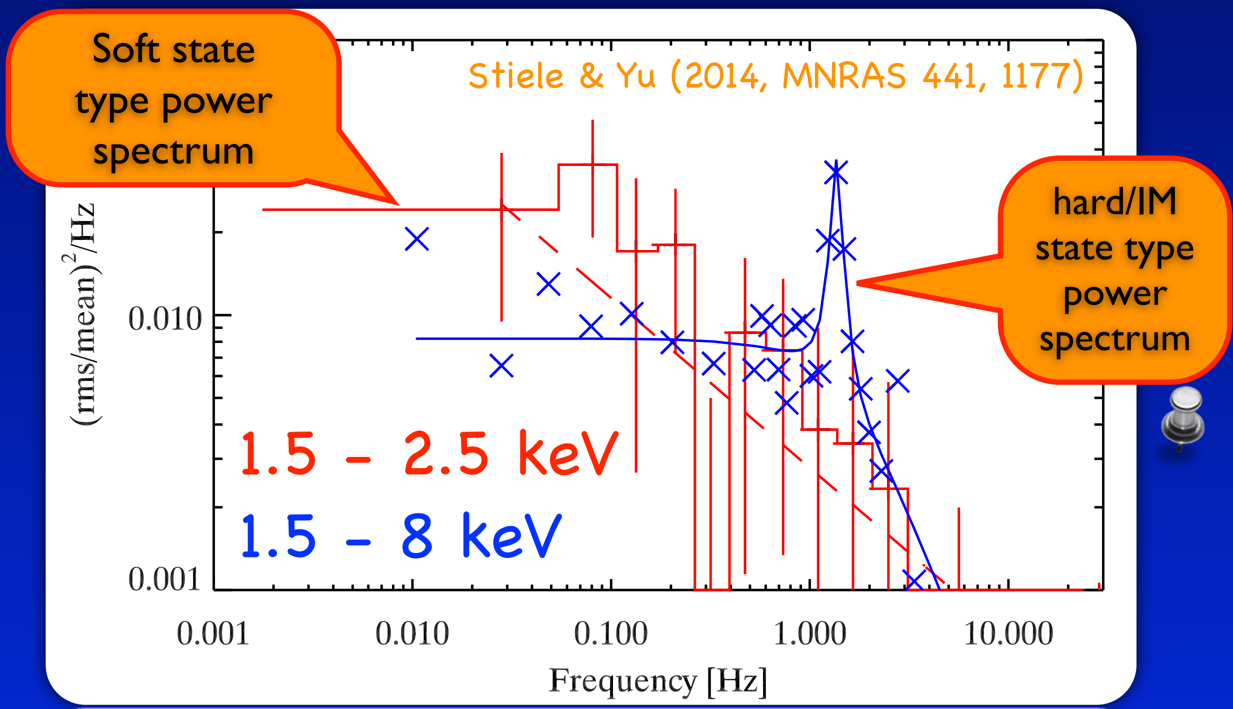
- χ variability class
- 4.5 – 8 keV
- (4.9 – 14.8 keV)
- band limited noise and quasi-periodic oscillation (+ upper harmonics)
- overall shape agrees between XMM and RXTE



Stiele & Yu, 2014, MNRAS, 441, 1177

PDS: Zoom in Low Energies

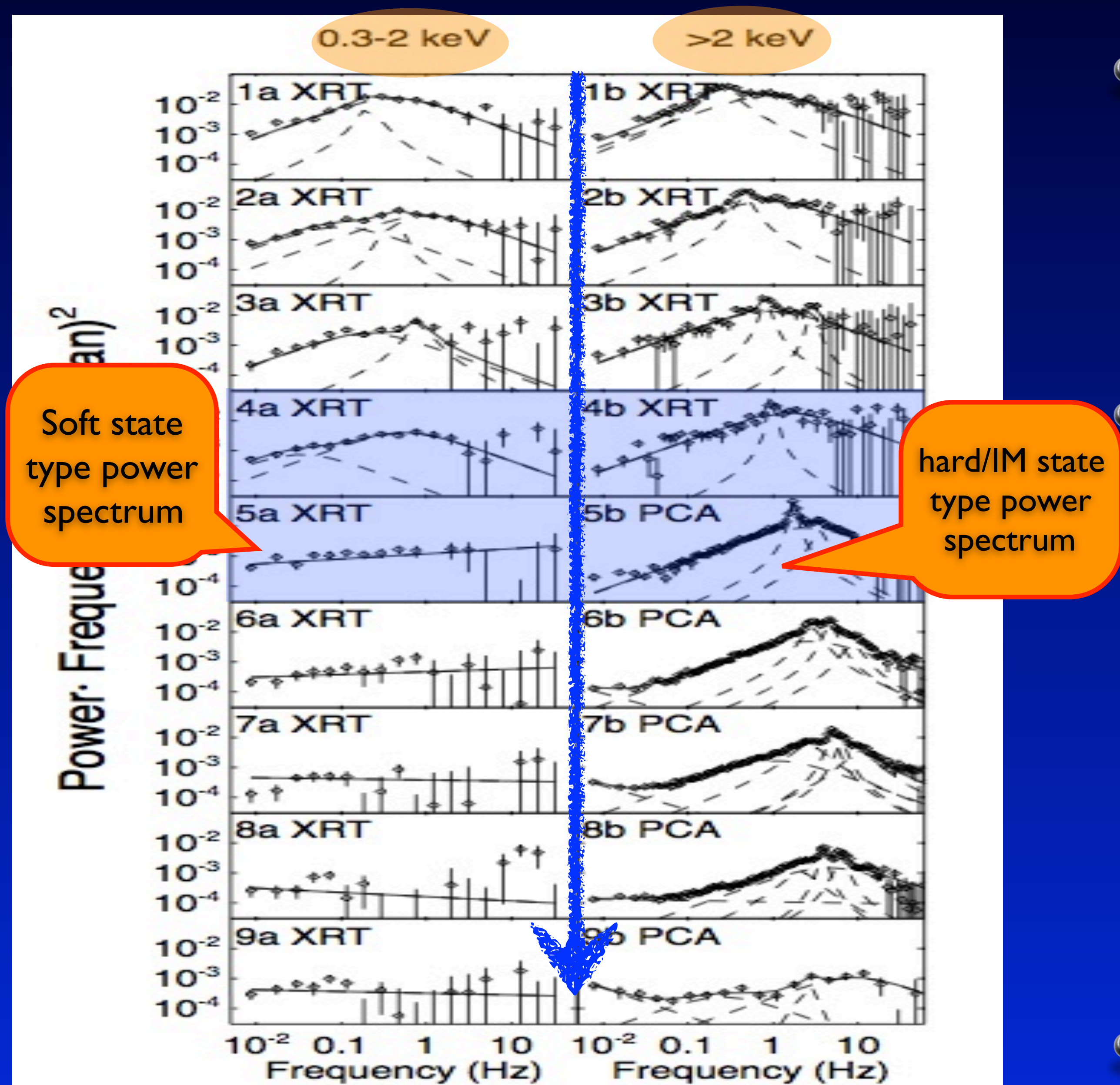
- 1.5 – 2.5 keV
- decent fit with power law



- QPO upper limit of 7.2% rms, slightly below the soft band rms given in Rodriguez et al. (2004, ApJ, 615, 416) for a similar centroid frequency; QPO rms of ~11.5% in 1.5 – 8 keV
- using a ZC-Lorentzian break frequency at ~0.45 Hz, while at ~3.35 Hz in the 1.5 – 8 keV band

MAXI J1659-152

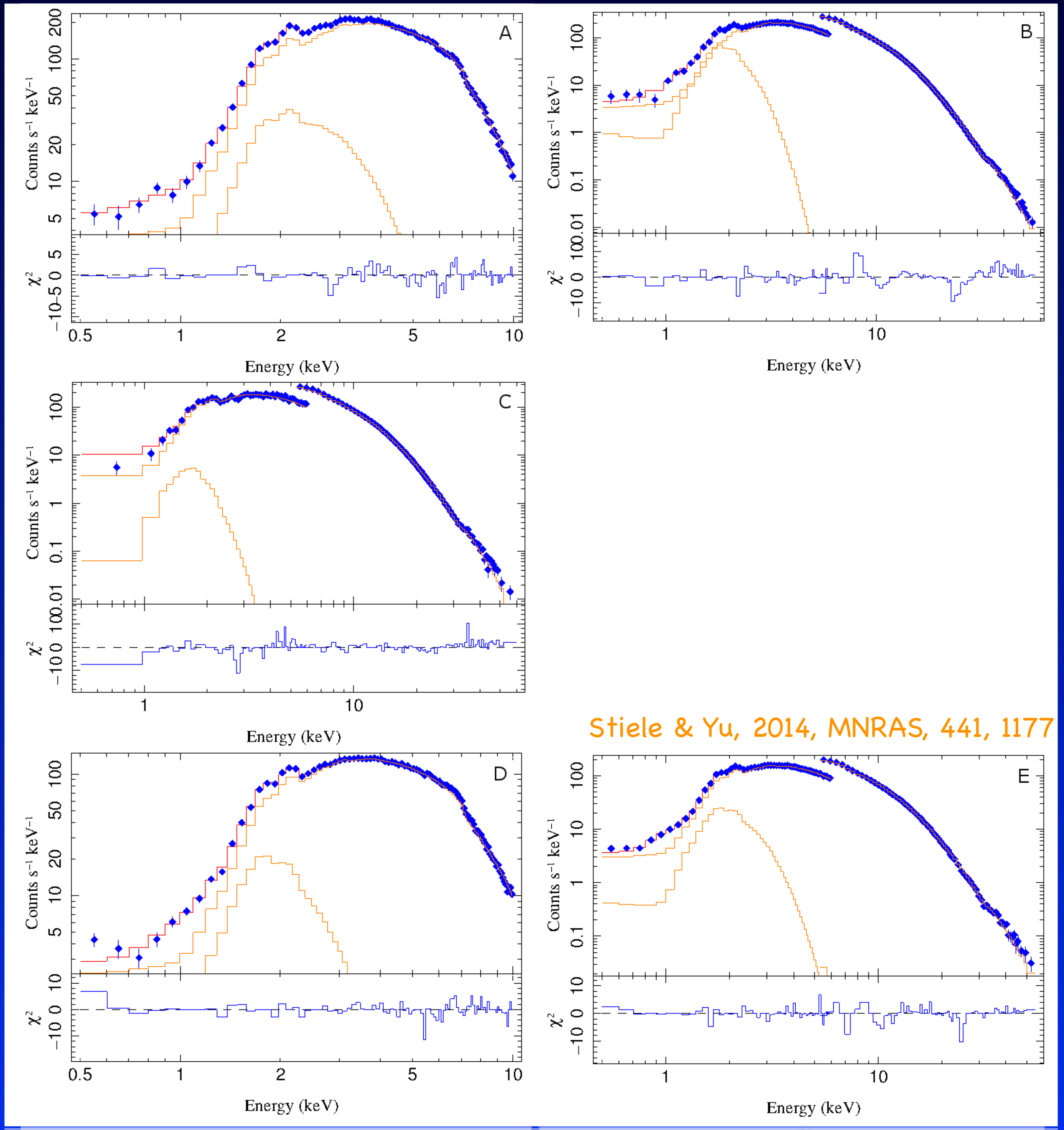
Yu & Zhang 2013, ApJ, 770, 135



- similar result found for MAXI J 1659-152 based on Swift and RXTE data
- in the HIMS, when the disc fraction exceeds ~30%:
  - above 2 keV: BLN and QPO
  - below 2 keV: power law noise
- **fits into the picture of a relation between State C and the hard intermediate state**

Energy Spectra

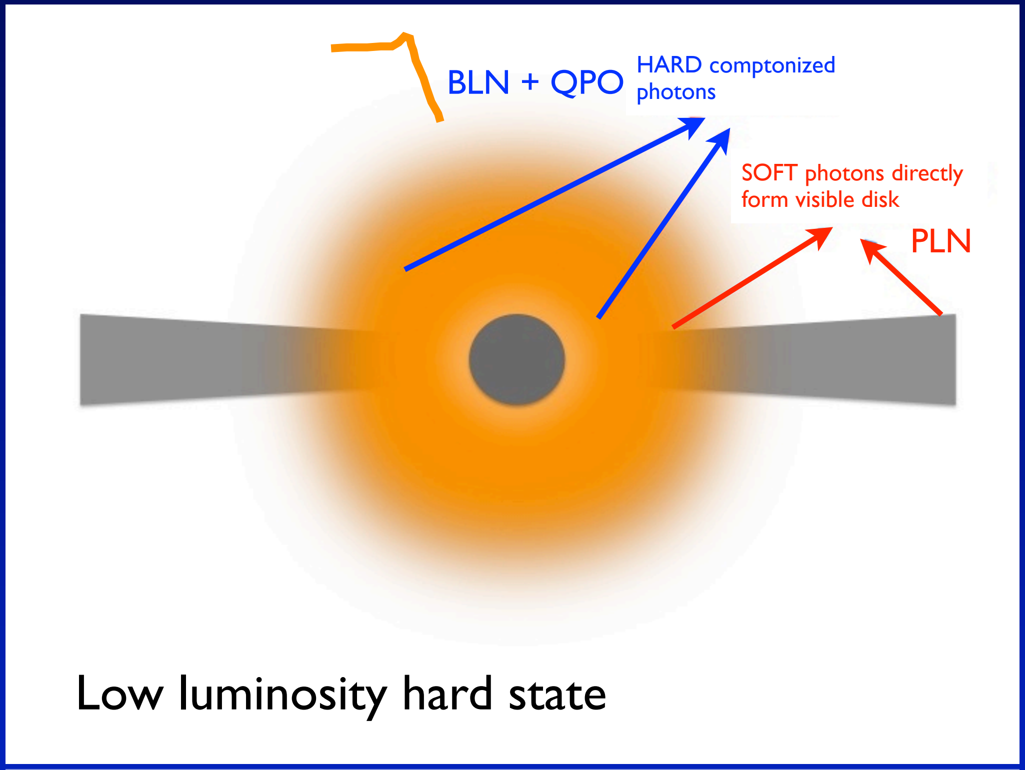
- re-analysis of quasi-simultaneous archival XMM-Newton and RXTE spectra using same spectral model as in Martocchia et al. (2006, A&A, 448, 677)
- added multicolour disc component
- vabs*(diskbb+refsch+Lines) + excess emission
- disc component needed to obtain decent fits
- contributes ~20-30% in the 1.5 - 2.5 keV band and only a few % in the 2.5 - 3.5 keV band

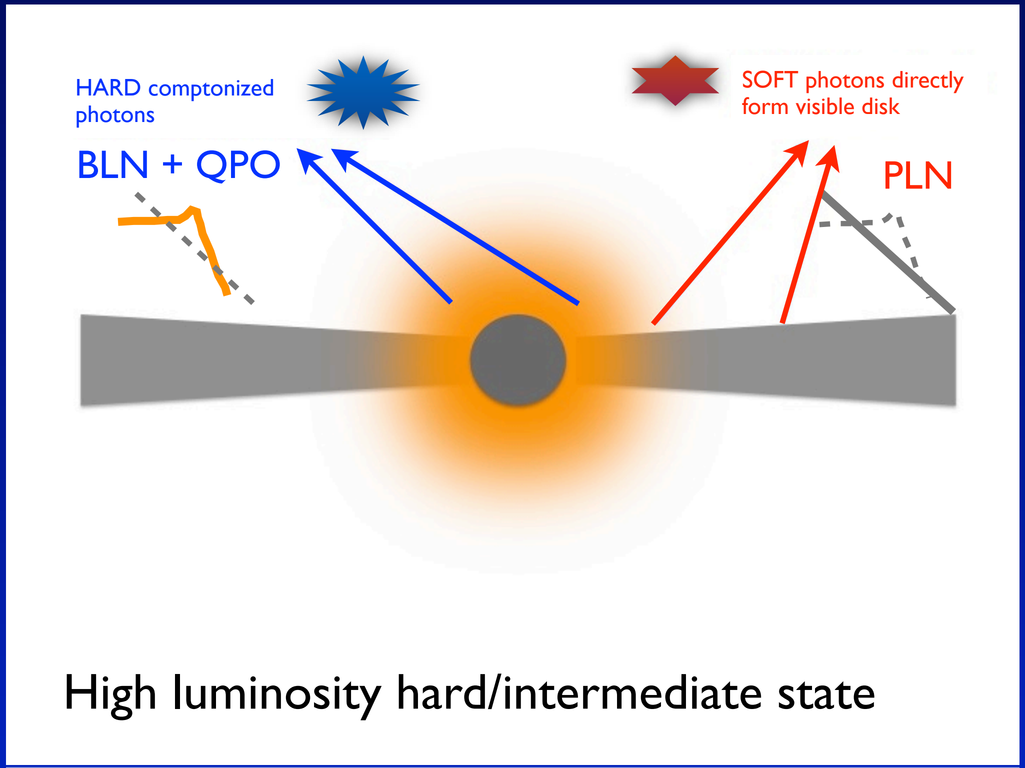


Stiele & Yu, 2014, MNRAS, 441, 1177

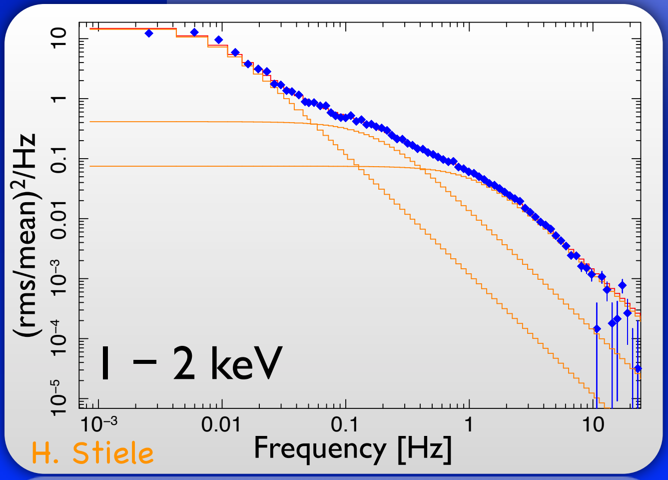
Schematic picture of the possible accretion geometry

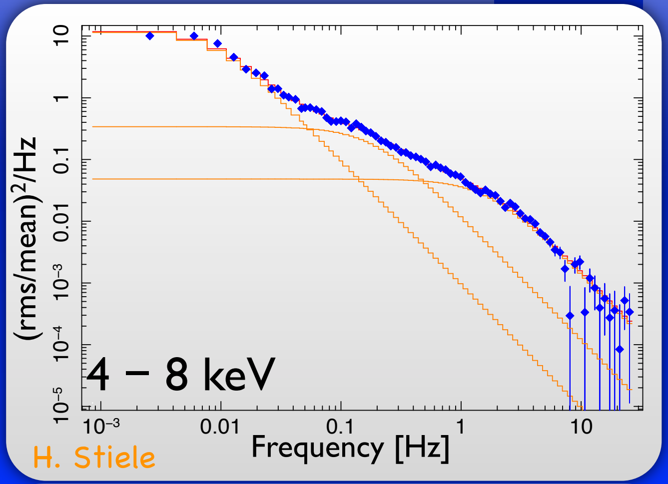
Power spectral state depends on which spectral component we are looking at !

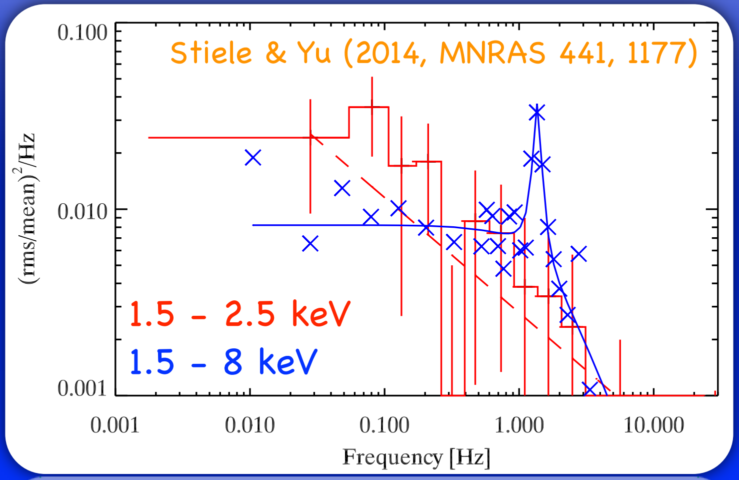




soft band dominated by Comptonized photons







Summary

- energy dependence of power density spectra
- in low hard state:
- break frequency of band-limited noise evolves with energy
- in (hard) intermediate state:
- two different PDS states coexist simultaneously in the hard and soft band
- **observed PDS state depends on which spectral component we are looking at**