Istituto Nazionale di Astrofisica
Osservatorio Astronomico di Brera

ON THE NATURE OF THE LOW-FREQUENCY OSCILLATIONS IN BLACK HOLE BINARIES

A variability study of the black hole candidate GX 339-4

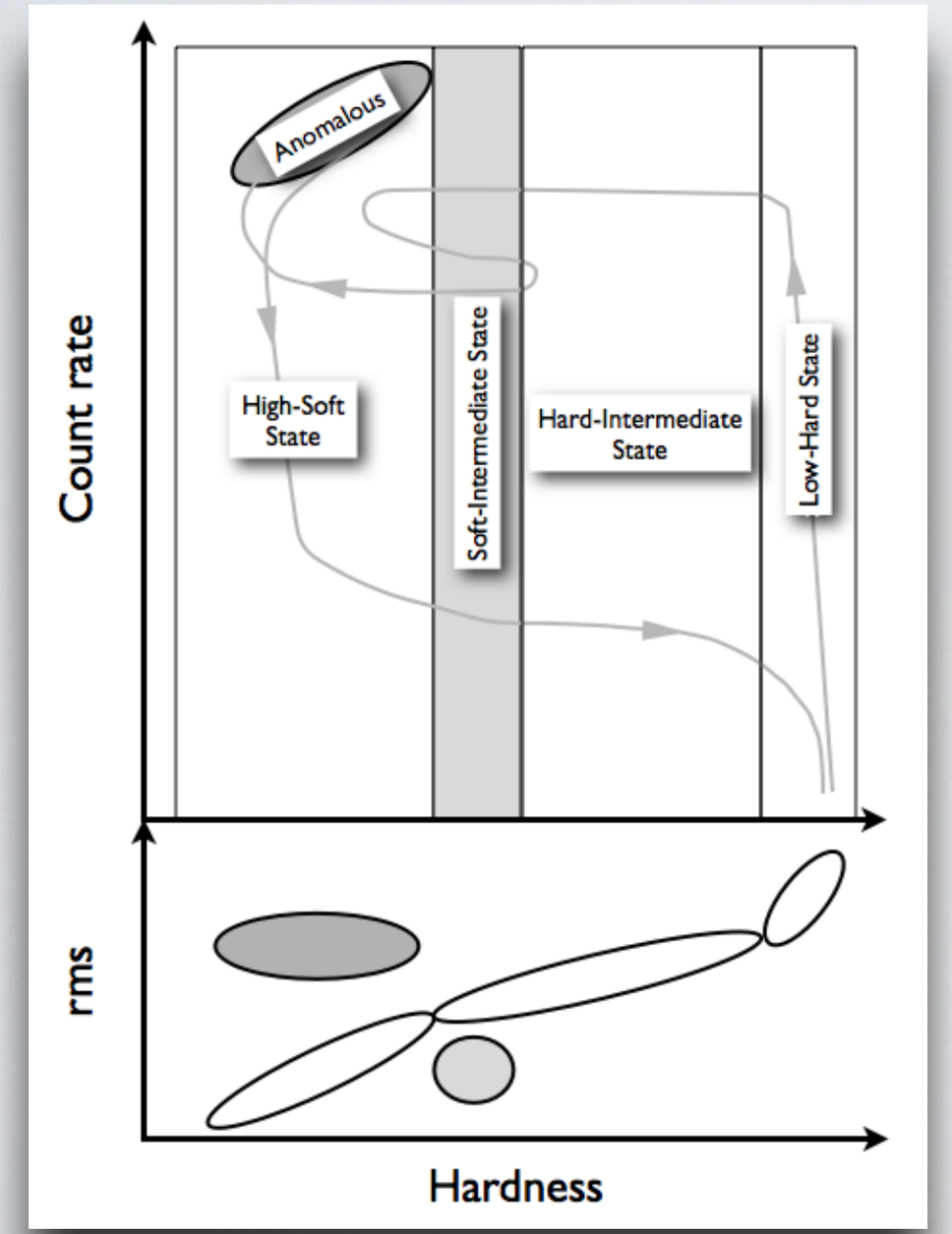
Sara Motta

and Teo Munoz-Darias, Piergiorgio Casella, Tomaso Belloni, Jeroen Homan

Thursday 21st July, Winchester

STATES AND TRANSITIONS

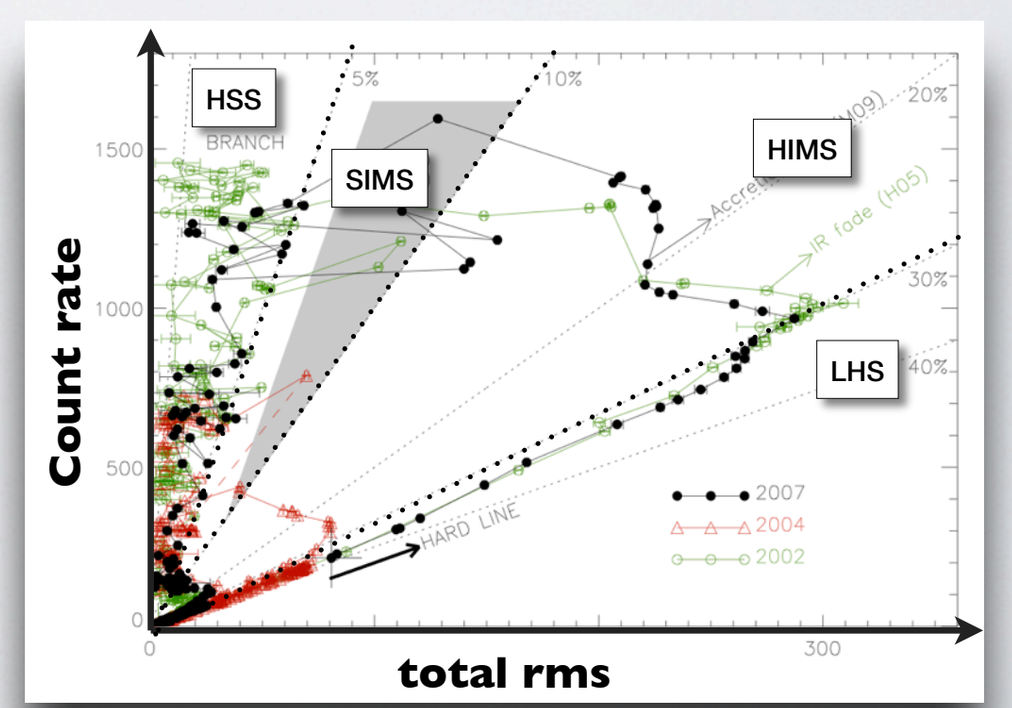
Hardness Intensity Diagram



Hardness rms Diagram

Belloni 2010

+



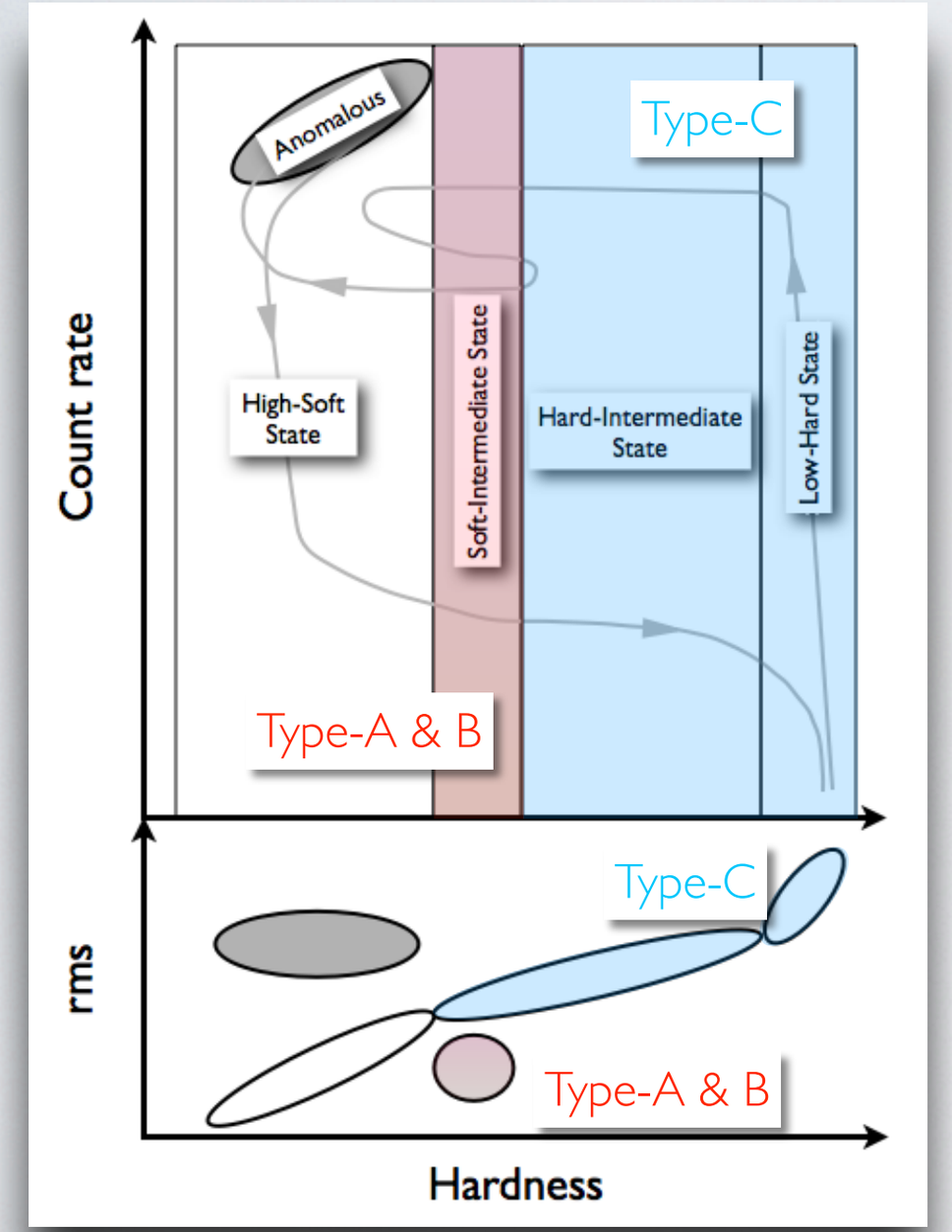
Variability Diagram

Muñoz-Darias, Motta, Belloni 2011

- Hardness ratio
- rms (root mean square deviation)
- Intensity (count rate)

STATES AND TRANSITIONS

Hardness Intensity Diagram



Hardness rms Diagram

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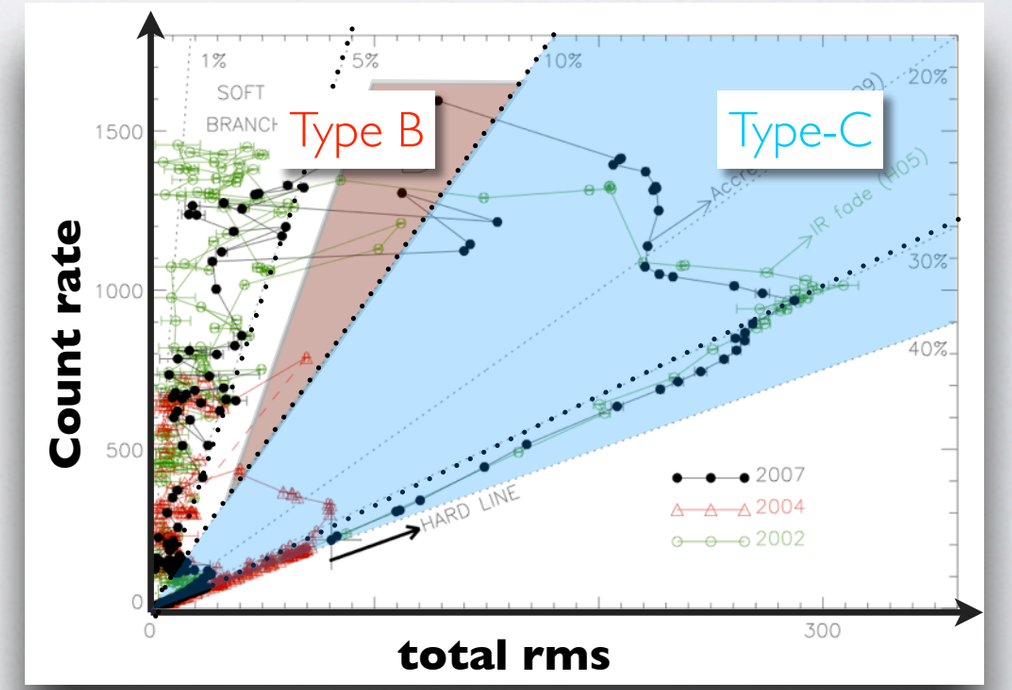


Variability Diagram

Muñoz-Darias, Motta, Belloni 2011

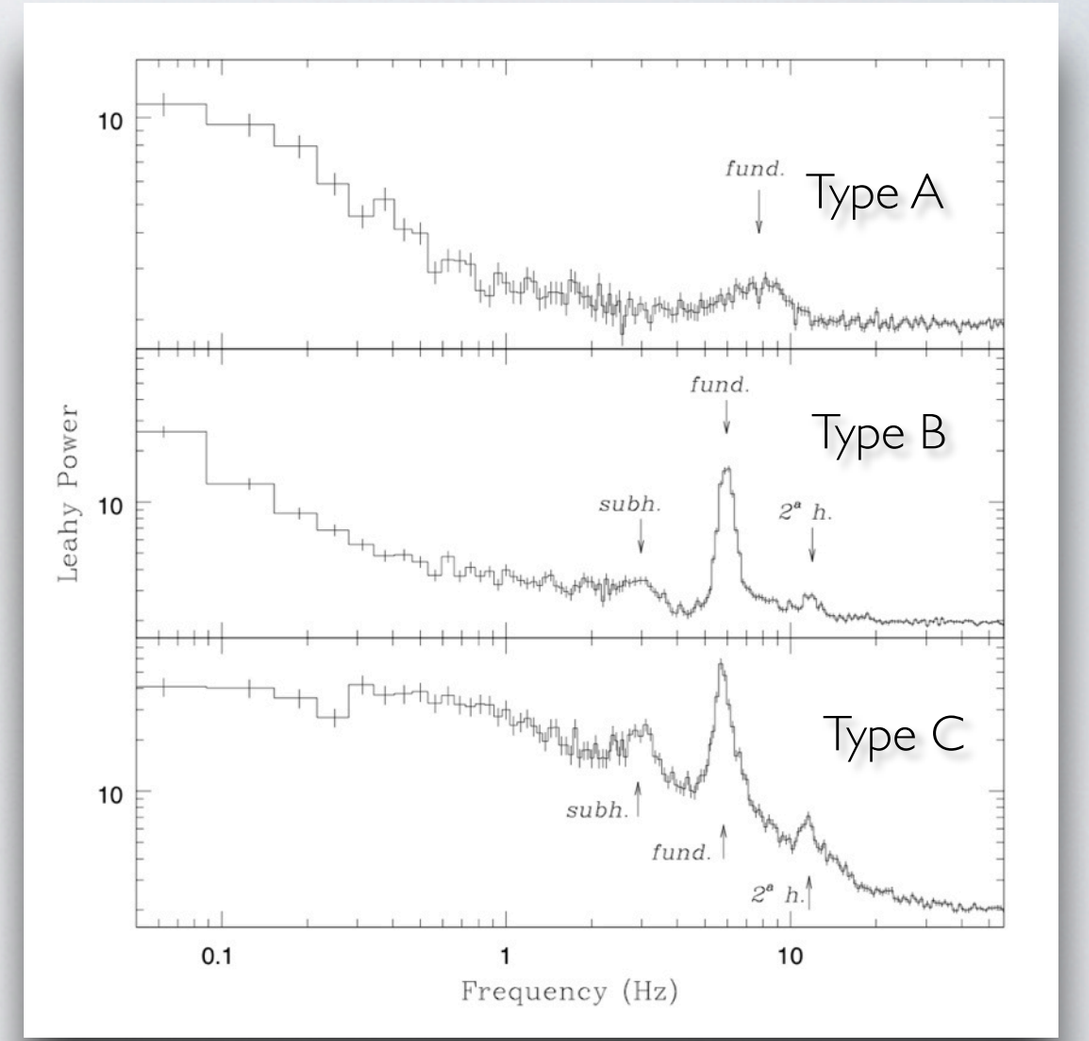
TYPES OF LOW FREQUENCY QUASI PERIODIC

Different shapes, frequency ranges, noise level, but ...

Problem:

we do do not know what they are...

Property	Type A	Type B	Type C
Frequency (Hz)	~6	~6	0.1–10
Q ($\nu/FWHM$)	≲3	≳6	≳10
Amplitude (%rms)	3–4	~4	3–16
Noise	weak red	weak red	strong flat-top



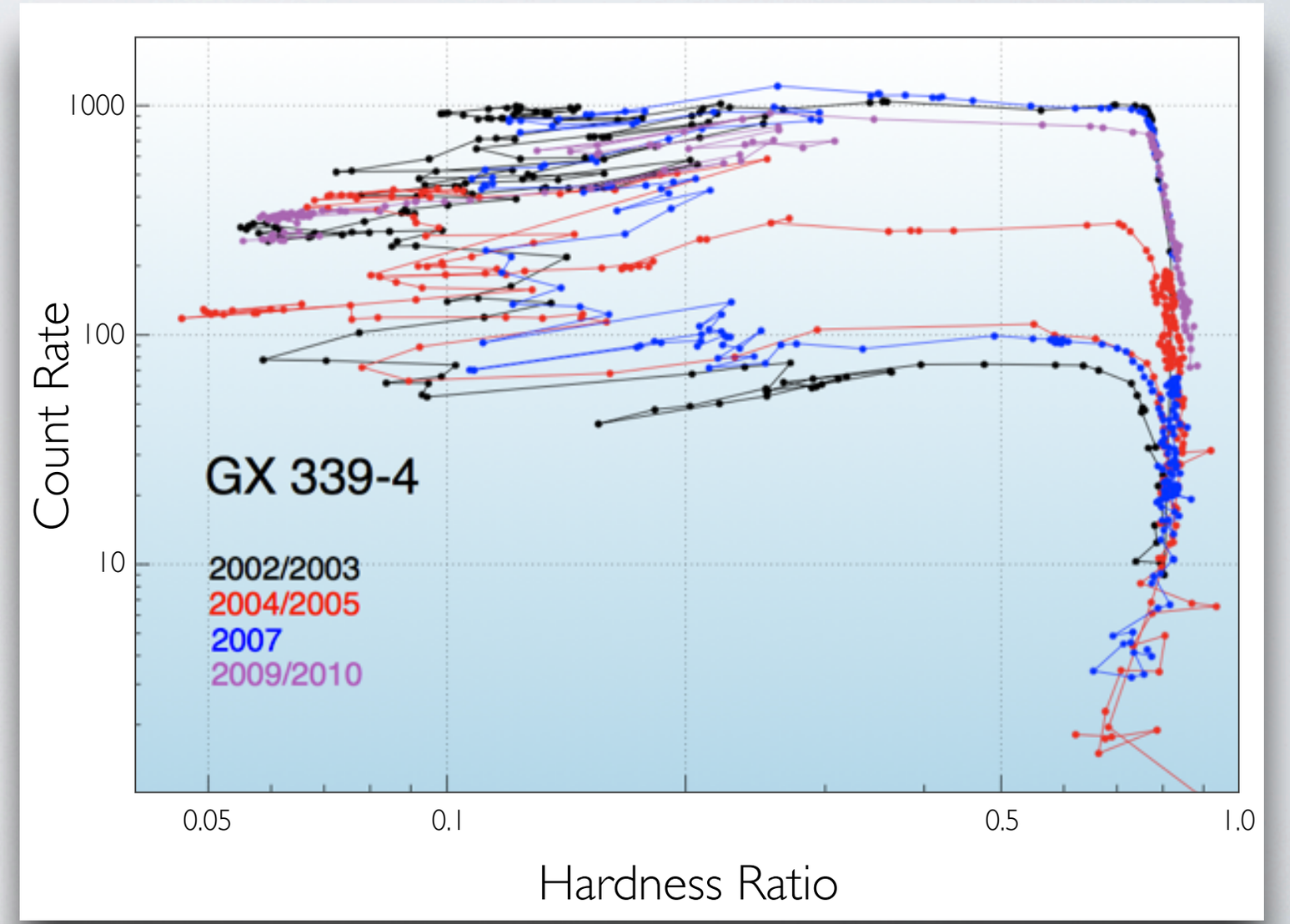
Casella et al. 2004

see also Wijnands et al. 1999; Homan et al. 2001; Remillard et al. 2002

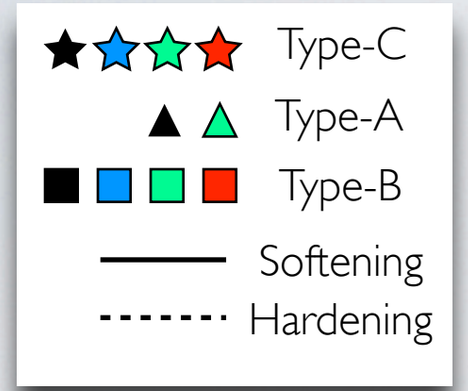
GX 339-4: PROTOTYPICAL BLACK HOLE

- 4 outbursts
- ***117*** detected QPOs (in ***1007*** observations)
- full spectral and timing analysis

Data from ***RXTE*** satellite

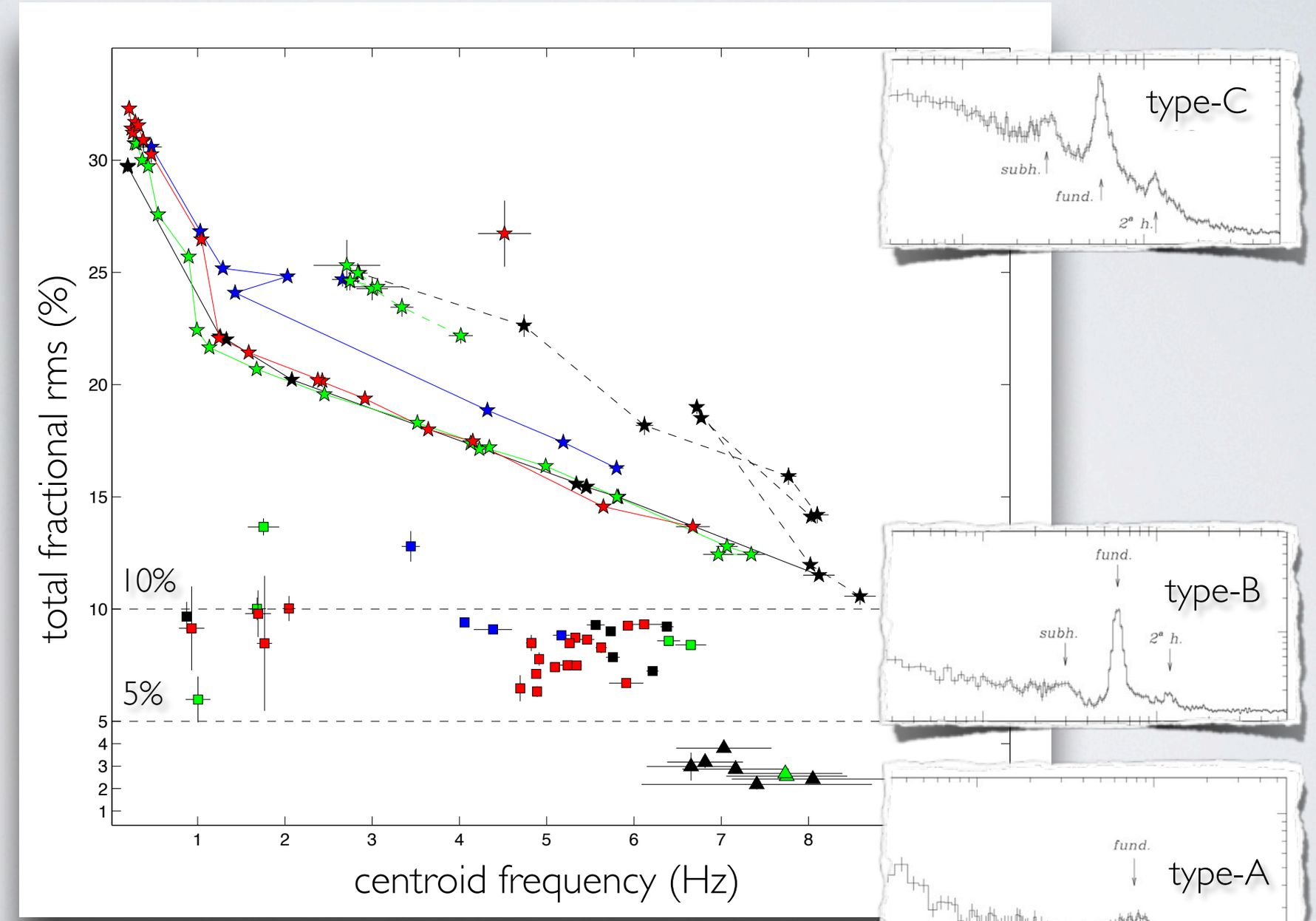


CLASSIFYING QPOS: THE ABC OF QPOS



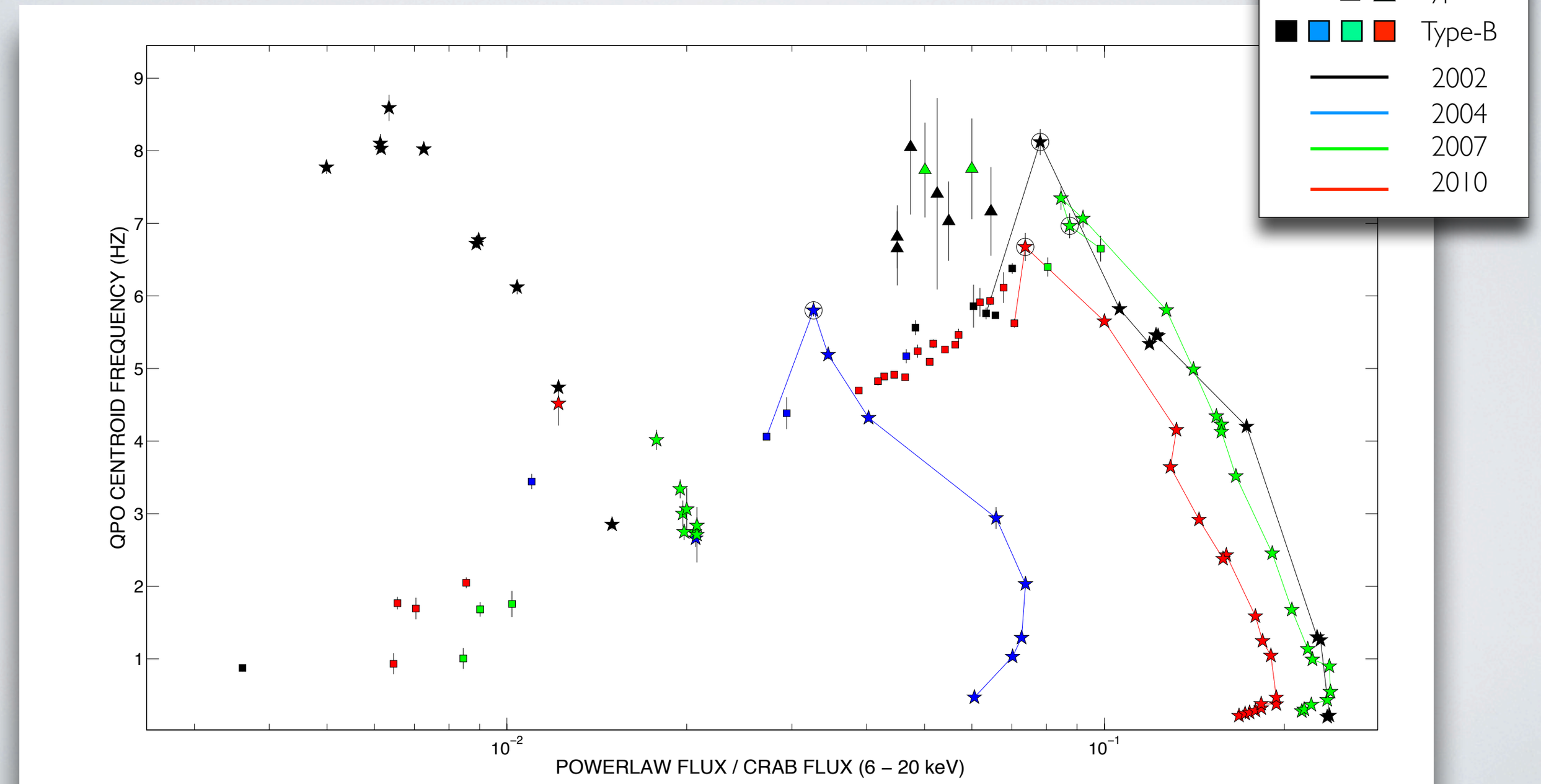
- Classification according to ABC scheme
- rms calculated for the whole power density spectrum

  (0.1 - 64 Hz)



see also Casella et al. 2005

FREQUENCY-HARD FLUX RELATION



Motta et al. submitted

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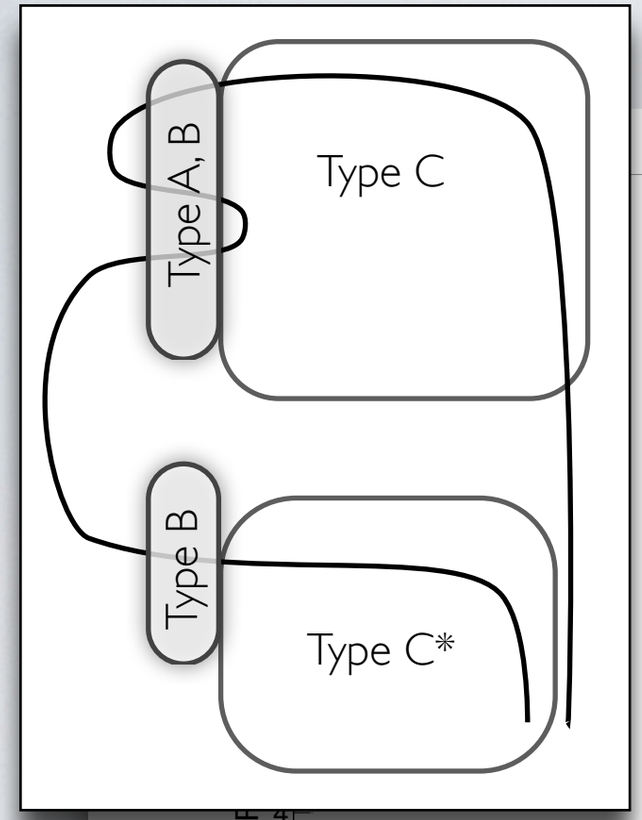
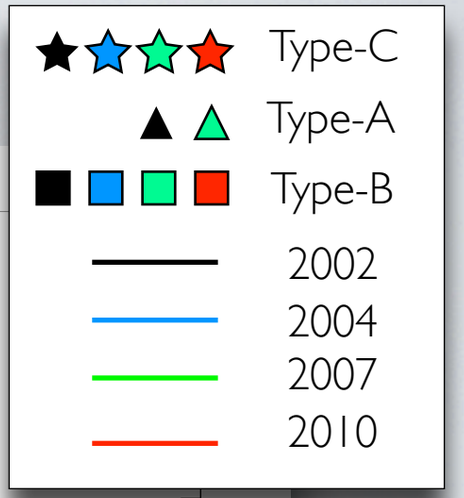
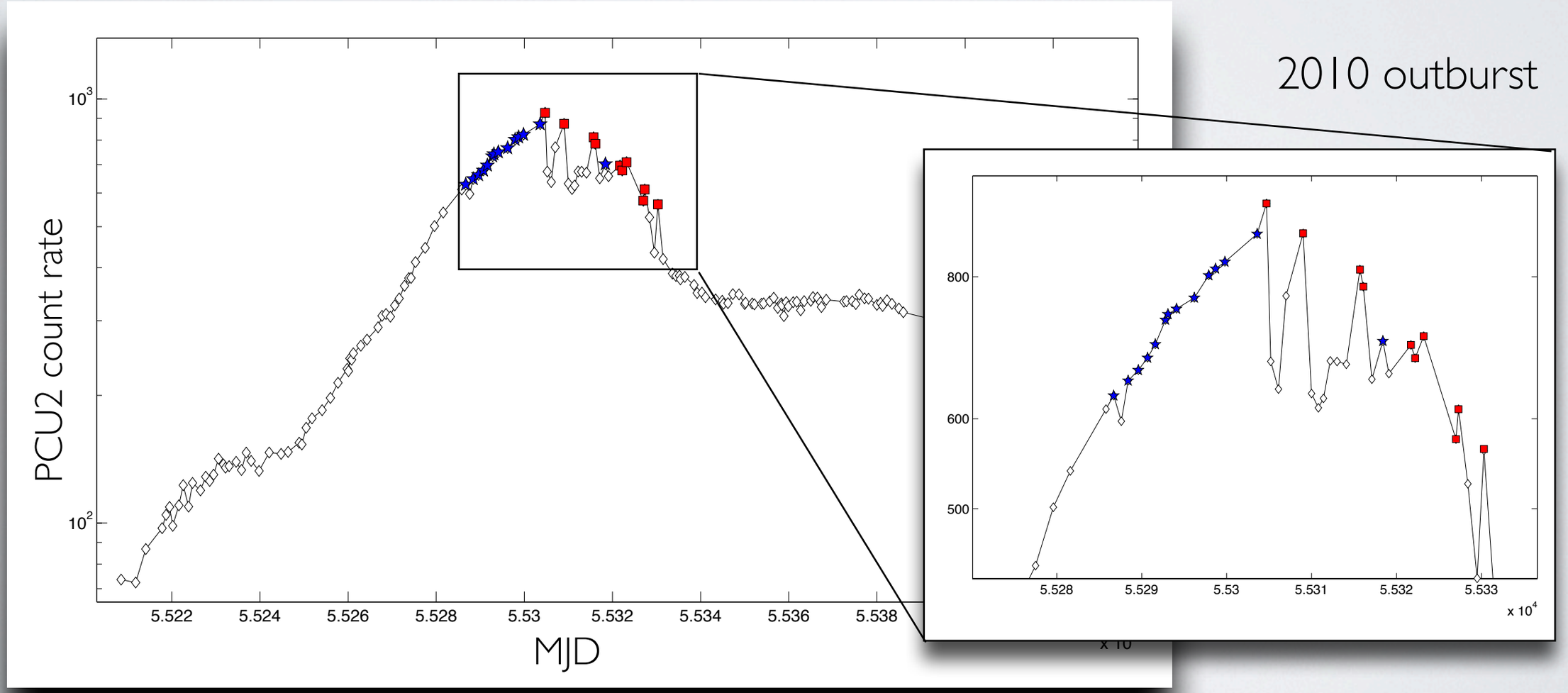




Motta et al. submitted

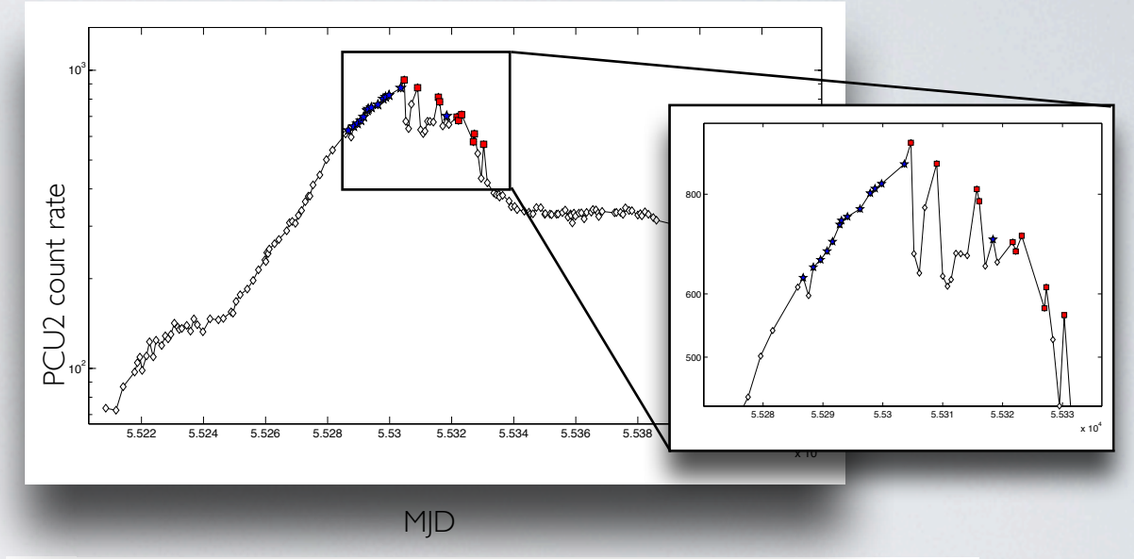
PEAK RELATION

- Type-B QPOs always appear on count peaks
- Valid for all the outbursts

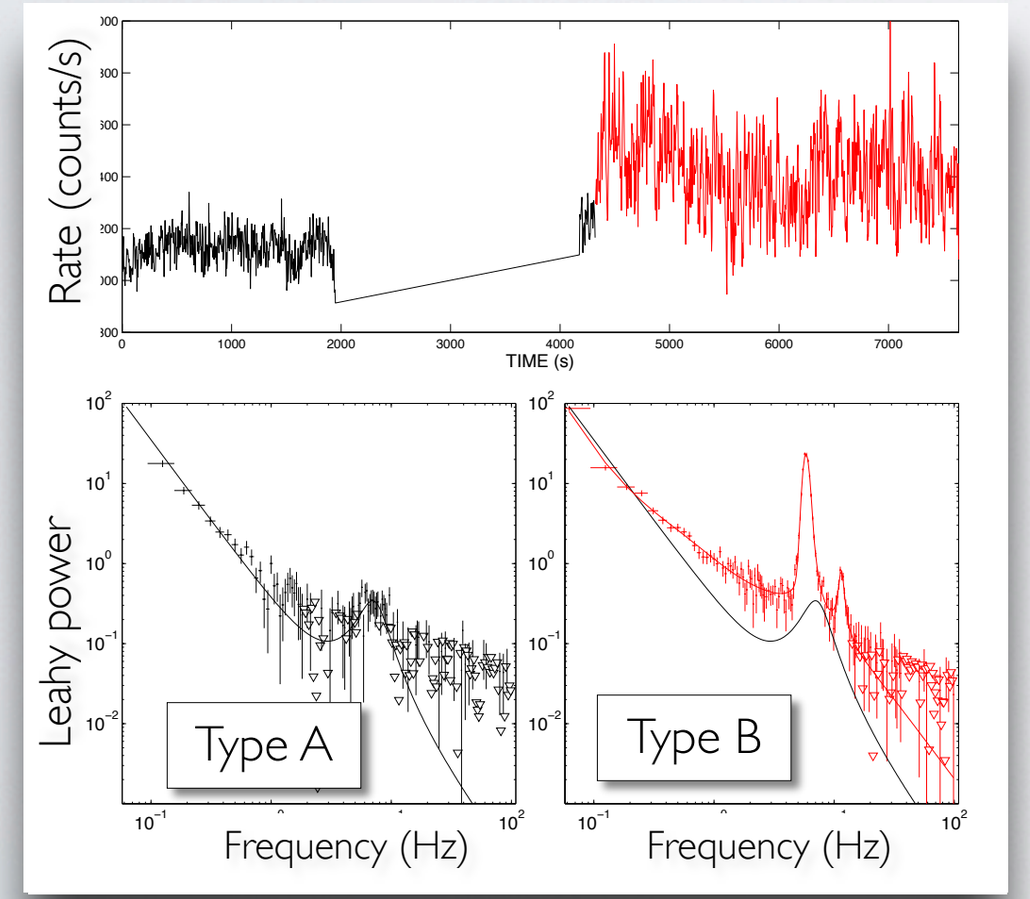


PEAK RELATION

This is valid also on shorter timescales



Obs. 70109-01-07-00, MJD 52411



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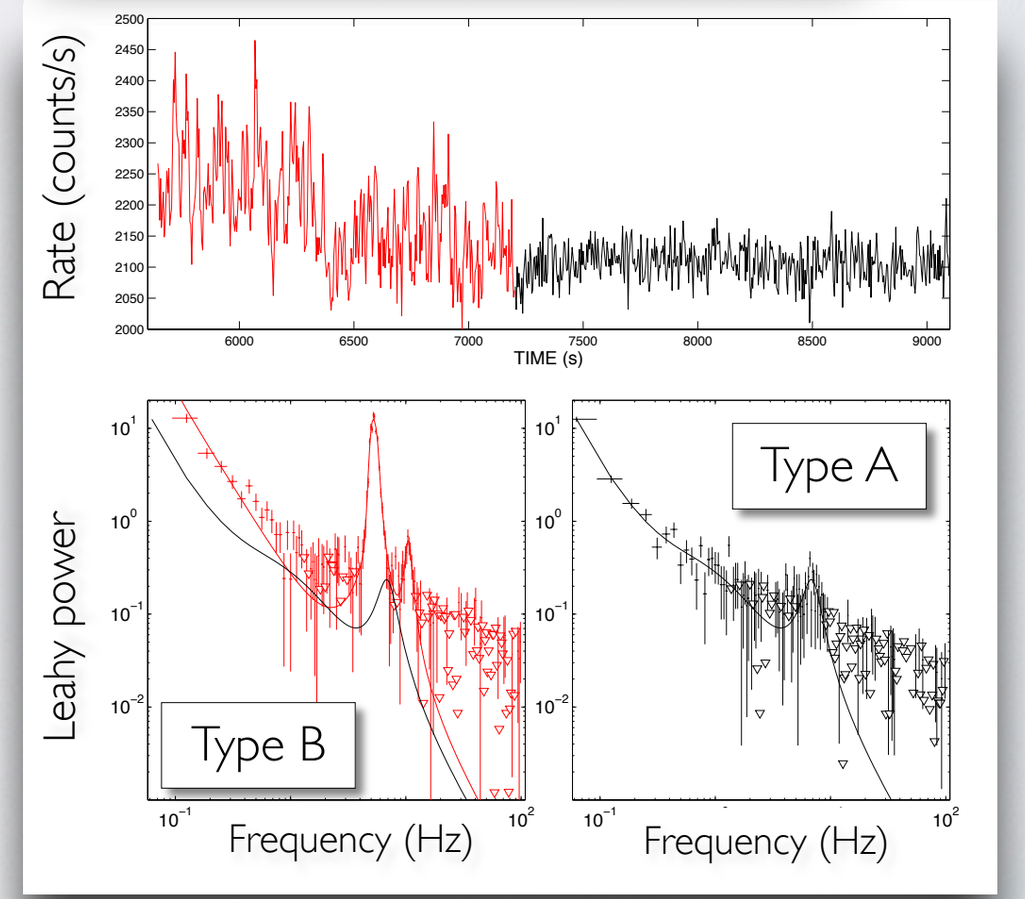


QPOS GENERAL PROPERTIES

Type-C QPOs:

- WIDE frequency, hardness and rms range
- not dependent from powerlaw flux

Type-A QPOs:

- VERY SMALL frequency, hardness, rms range
- Same frequency as last type-C QPOs

They follow a similar frequency/ powerlaw flux relation

Type-B QPOs:

- WIDE frequency range, but TIGHT rms (5-10%) and hardness range
- Associated to local increases in count rate
- Simultaneous with Type-A QPOs?
- Always lower frequency than last type-C QPOs

They follow a different frequency/ powerlaw flux relation

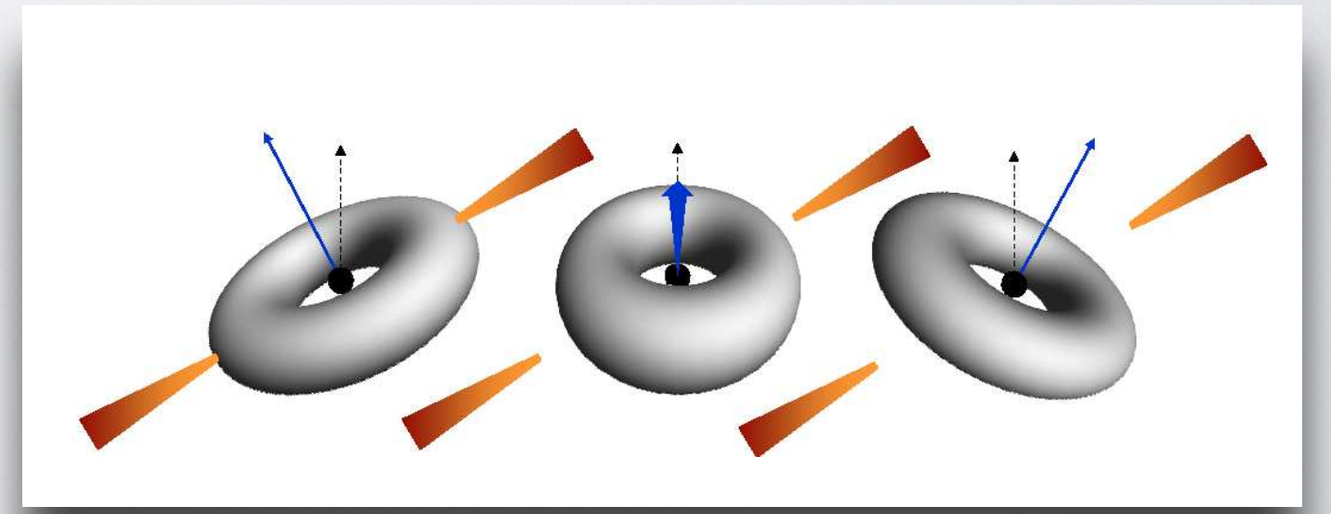
AN ANSWER? THE MODEL!

Truncated disk model
(explains spectral evolution)
Done, Gierliń ski, Kubota 2007

+

Lense-Thirring precession & MRI
(explains QPOs and noise)
Stella & Vietri 1998 ,Ingram et al 2009,
Ingram & Done 2010, Ingram & Done 2011

- spectral evolution: inward-outward movement of inner-disk radius
- Low frequency QPOs: inner flow precession
- broad band noise: Magneto-Rotational Instability (MRI)



Ingram, Done, Fragile 2009

WHAT ARE QPOs THEN?

According to the precession model:
(Ingram et al. 2009, Ingram & Done 2010, Ingram & Done 2011):

- **Type-C QPOs:** results of vertical Lense-Thirring (LT) precession
(requires misaligned black hole spin and companion star spin)

- **Type-A QPOs:** Type-C QPO-like features, but broadened and made fainter

- **Type-B QPOs:** 3 possibilities

    - from LT precession at larger radii and same physical conditions?

    - from LT precession at same radii, but different physical conditions
(different precession mode)

    - from other process(es)

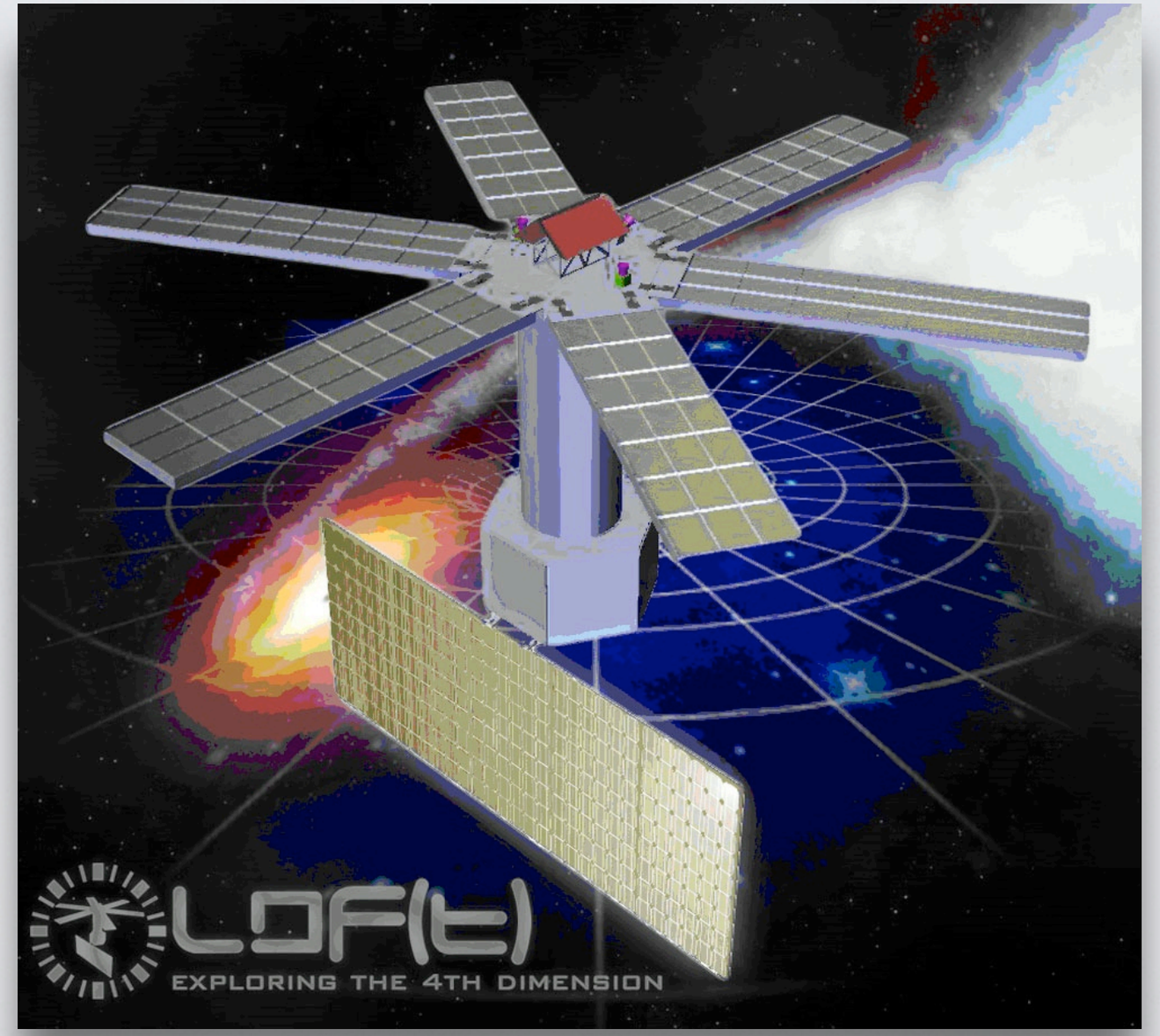
CONCLUSIONS

- Type-B QPOs are different from other QPOs
- Type-A and -C share some properties
- Lense-Thirring precession model + truncated radius model can explain the origin of QPOs...
  Quantitatively type-C QPOs (Ingram & Done 2011)
  Qualitatively type-A and B QPOs (Motta et al 2011)
- ... but still type-Bs are tricky

  Need to investigate the details of the model for quantitative results

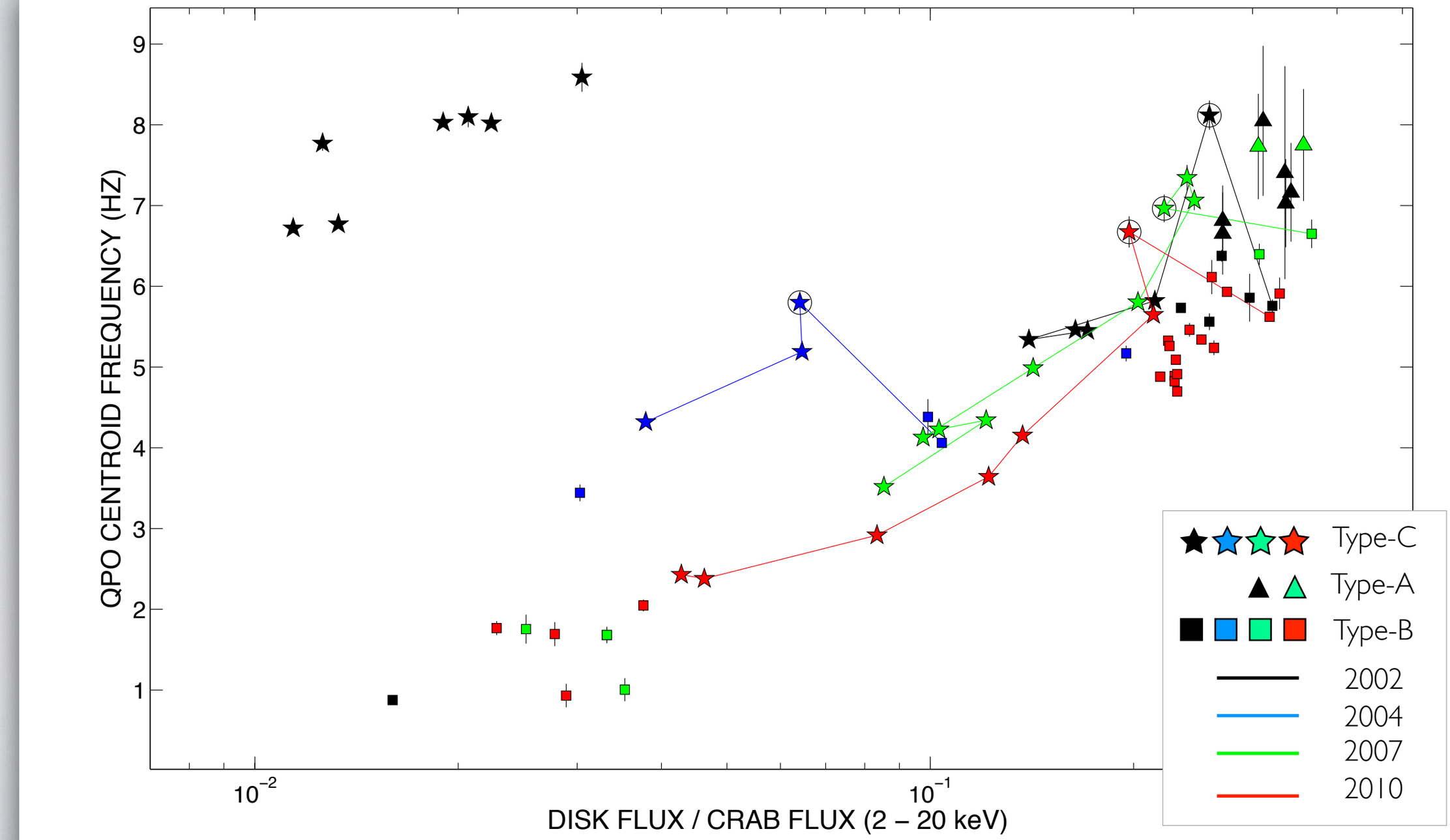
LOFT SCIENCE MEETING

Amsterdam - 2011 October 26-28

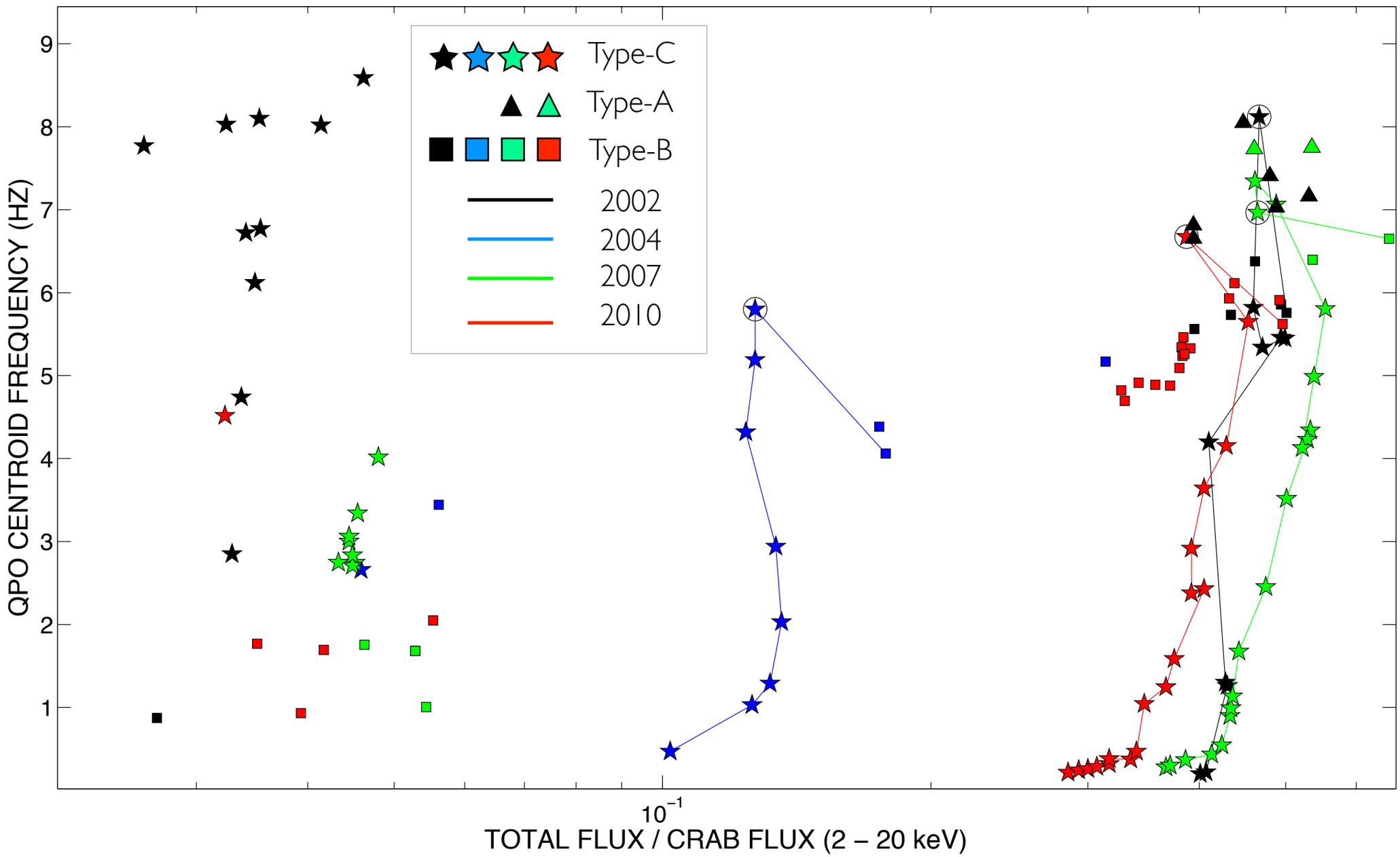


THANKS

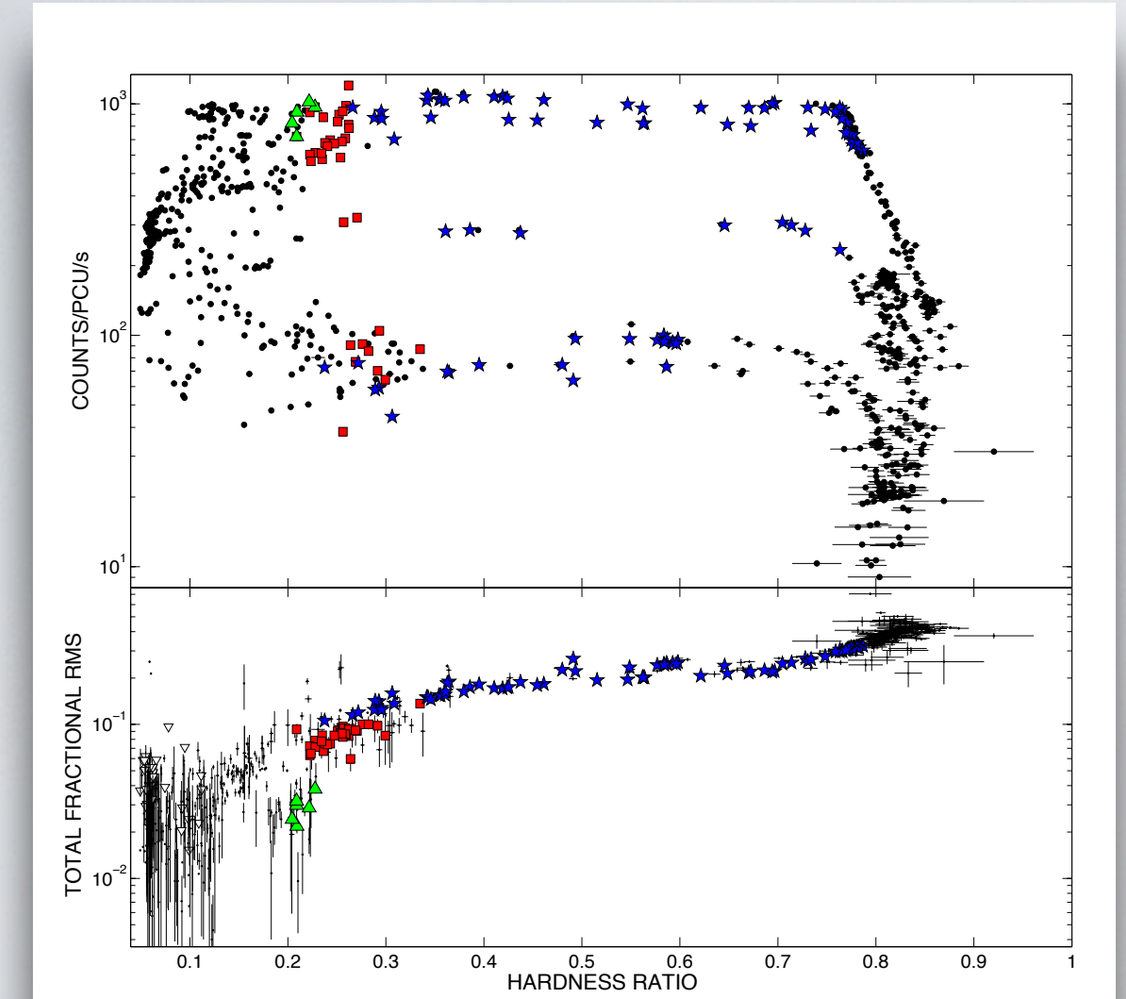
FREQUENCY-SOFT FLUX RELATION



FREQUENCY-TOTAL FLUX RELATION



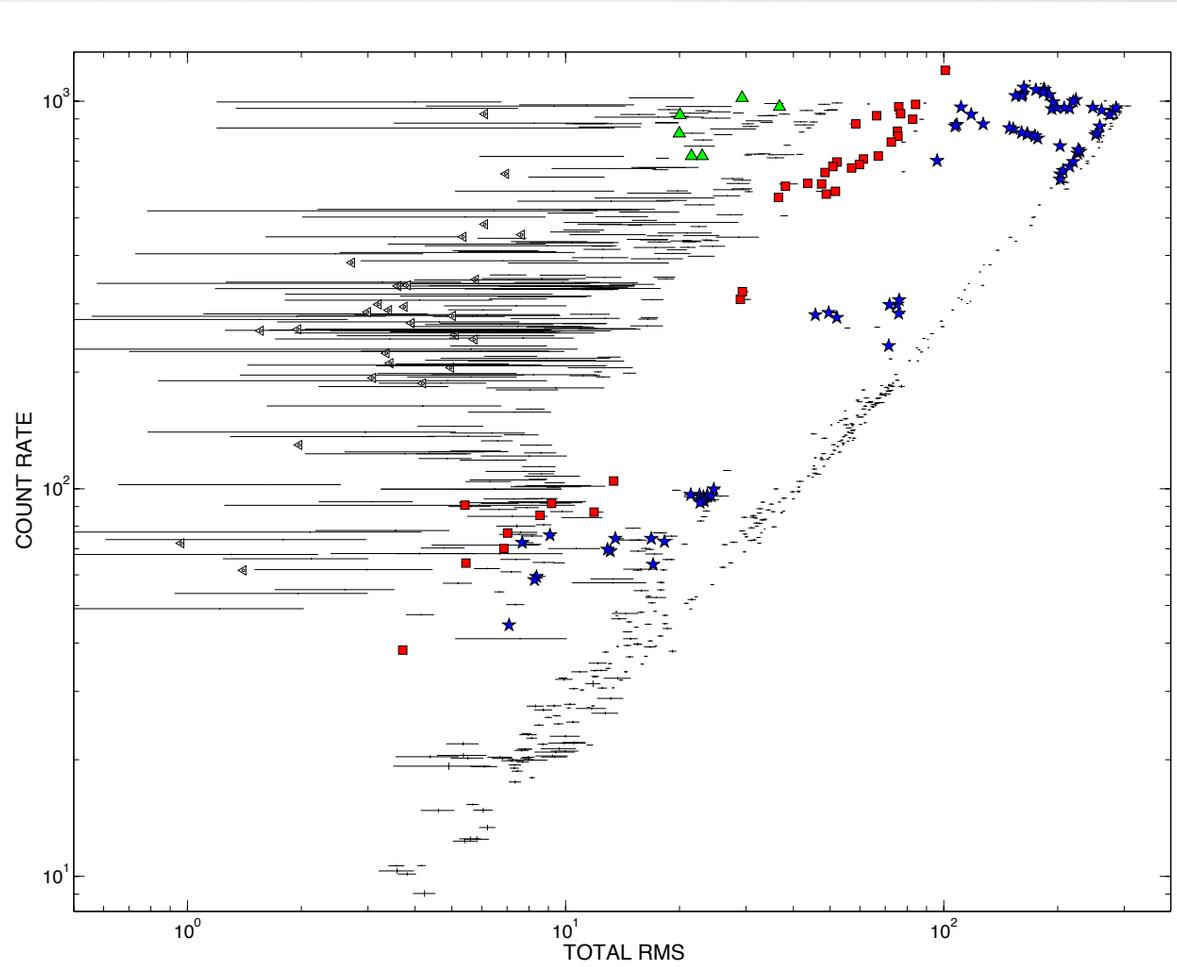
Hardness-Intensity Diagram



rms hardness Diagram

(117 QPOs, 1007 observations)

Rms-Intensity Diagram



TRANSIENT TYPE-B QPO