

Absolute and Relative Timing with the EPIC-pn Camera

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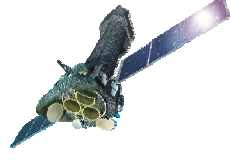
Institut für Astronomie und Astrophysik, Tübingen

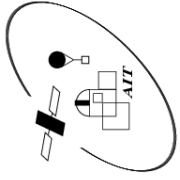
W. Becker

Max-Planck-Institut für Extraterrestrische Physik, Garching/München

U. Lammers, G. Vacanti, E. Serpell

ESA / ESTEC, Astrophysics Division (SA), Noordwijk

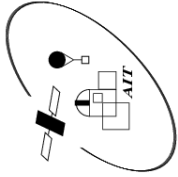




EPIC-pn Readout Modes

Mode	Live Time [%]	Time Resolution [ms]	Pile-up Limit [mCrab]
Full Frame	99.94	73.36	0.7
ext. Full Frame	99.98	199.19	N.A.
Small Window	71.01	5.67	11
Large Window	94.86	47.66	1.1
Timing	99.12	0.0296	146
Burst	2.98	0.0072	$6.3 \cdot 10^3$





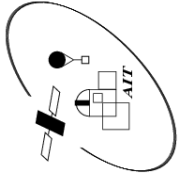
Observations

XMM–Newton

RXTE

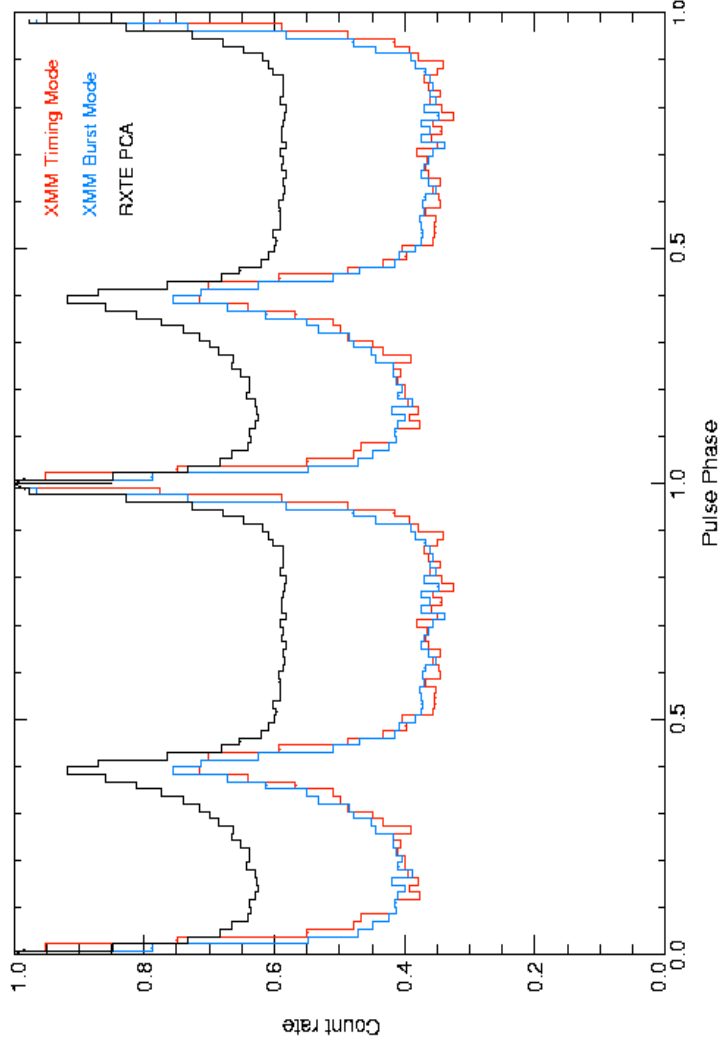
Object	Rev.	Mode	Int. Time	Object	Int. Time
PSR B1509	137	Timing	9.6 ksec	PSR B1509	2.0 ksec
(P » 150 ms)	137	Small Win	10 ksec	Crab	0.9 ksec
Crab	56	Timing	7 ksec	Additional radio data (Jodrell Bank)	
(P » 33 ms)	56	Small Win			
	234	Burst		PSR 1509 data provided by A. Rots	
PSR B0540	85	Timing	17 ksec		
(P » 50 ms)	85	Small Win	40 ksec		





XMM Fast Modes \Leftrightarrow *RXTE* PCA

Pulse Profile Crab Pulsar (Rev. 0056)



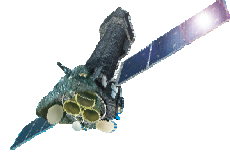
XMM: TM $t = 7.0$ ksec
el. Chopper 25
 $\rightarrow t_{\text{eff}} \approx 0.3$ ksec

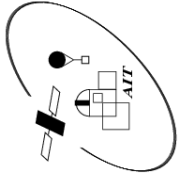
BM $t = 7.0$ ksec

RXTE: $t_{\text{eff}} = 0.9$ ksec

Light curves are binned with
 $\Delta t = 1$ ms

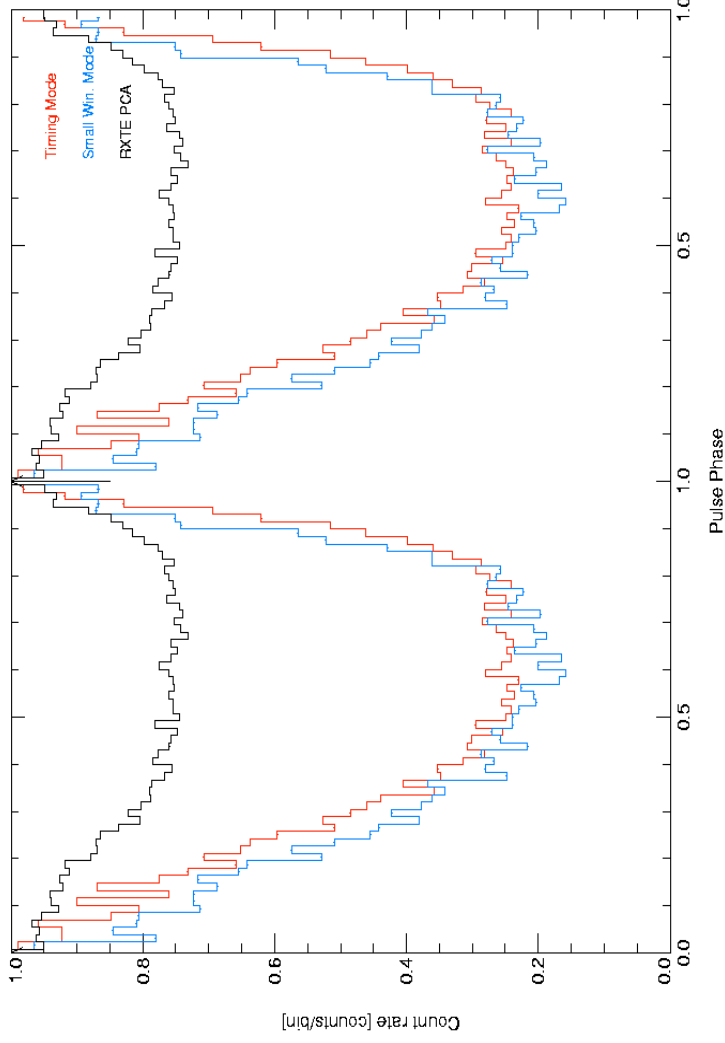
XMM fast modes: only central emission region used
 \Rightarrow less non pulsed flux





Timing Mode \Leftrightarrow Small Window Mode

Pulse Profile PSR B1509 (Rev. 137)



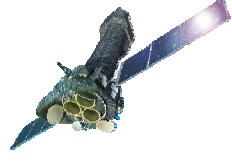
XMM

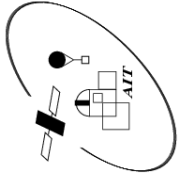
Timing Mode $t_{\text{eff}} = 9.6 \text{ ksec}$
 $\Delta t = 1 \text{ ms}$

SW Mode $t_{\text{eff}} = 9.6 \text{ ksec}$
 $\Delta t = 6 \text{ ms}$

RXTE

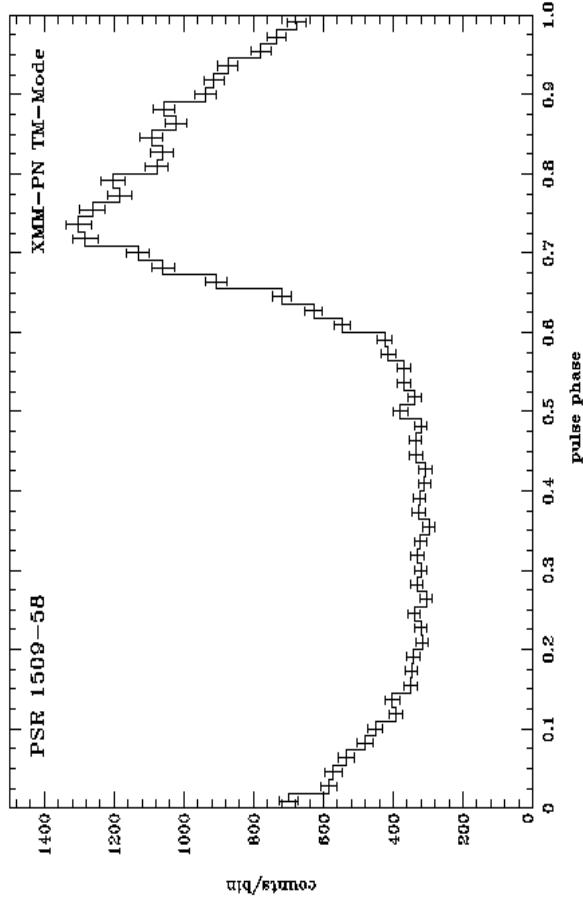
PCA $t_{\text{eff}} = 2.0 \text{ ksec}$
 $\Delta t = 1 \text{ ms}$



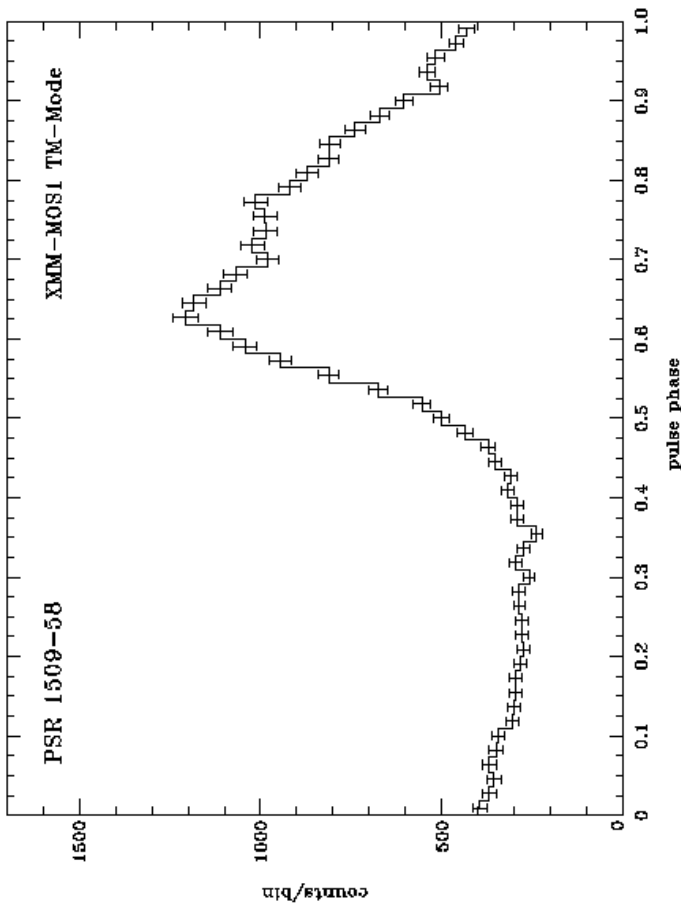


EPIC pn \Leftrightarrow MOS Timing Mode

EPIC pn / PSR 1509

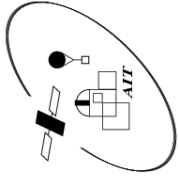


EPIC MOS / PSR 1509



We get consistent results in both cameras for: Pulse Shape
Pulse Period

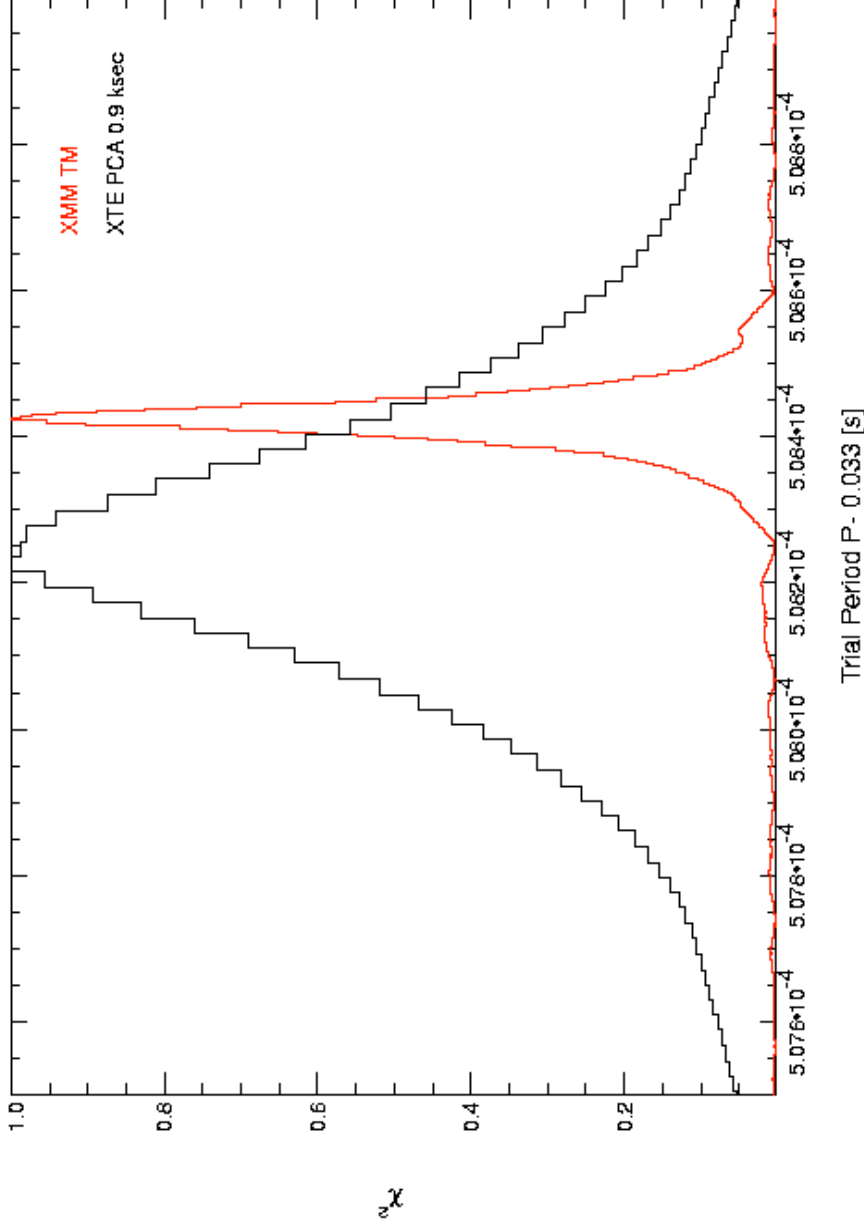




Crab – Timing Mode

Resulting Pulse Period

χ^2 -Distribution



XMM Timing Mode

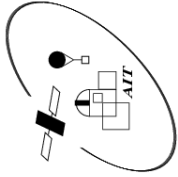
$$P = 33.50842 \pm 0.00004 \text{ ms}$$

XTE PCA

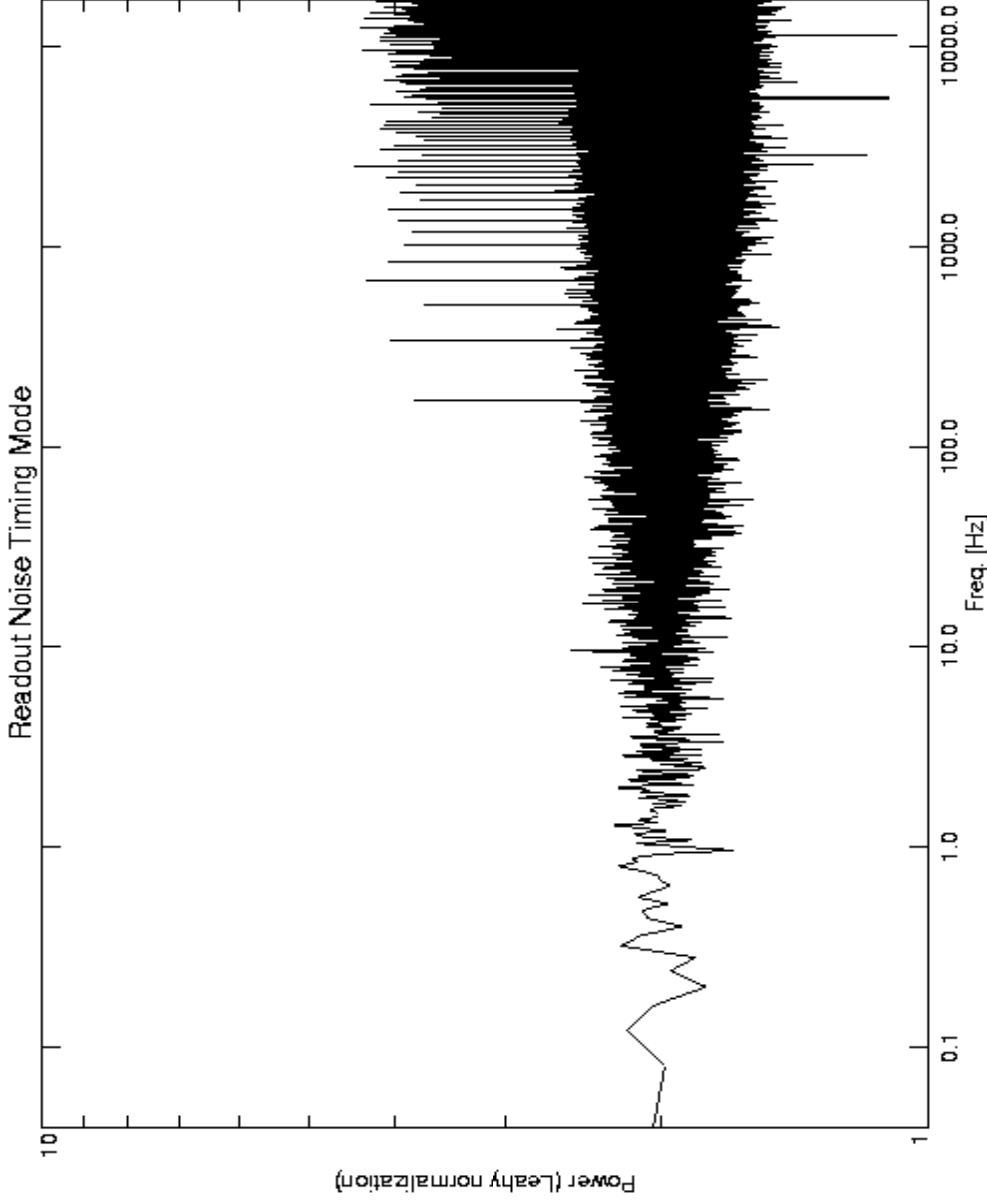
$$P = 33.50824 \pm 0.00012 \text{ ms}$$

$$\Rightarrow \Delta P/P = 5.7 \cdot 10^{-6}$$





Readout Noise Timing Mode



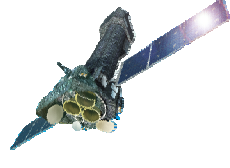
Using time resolution
higher than frame time
in fast modes

⇒ **Aliasing effect of the
readout window**

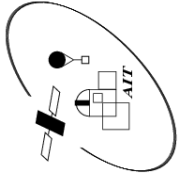
Simulation:

Poissonian Noise +
Readout Window

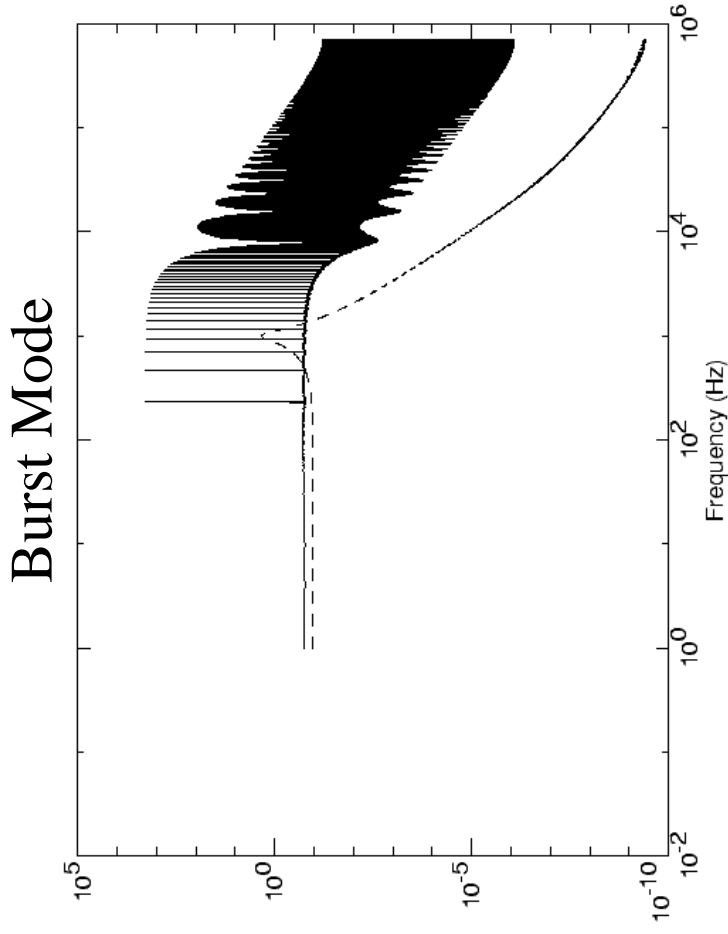
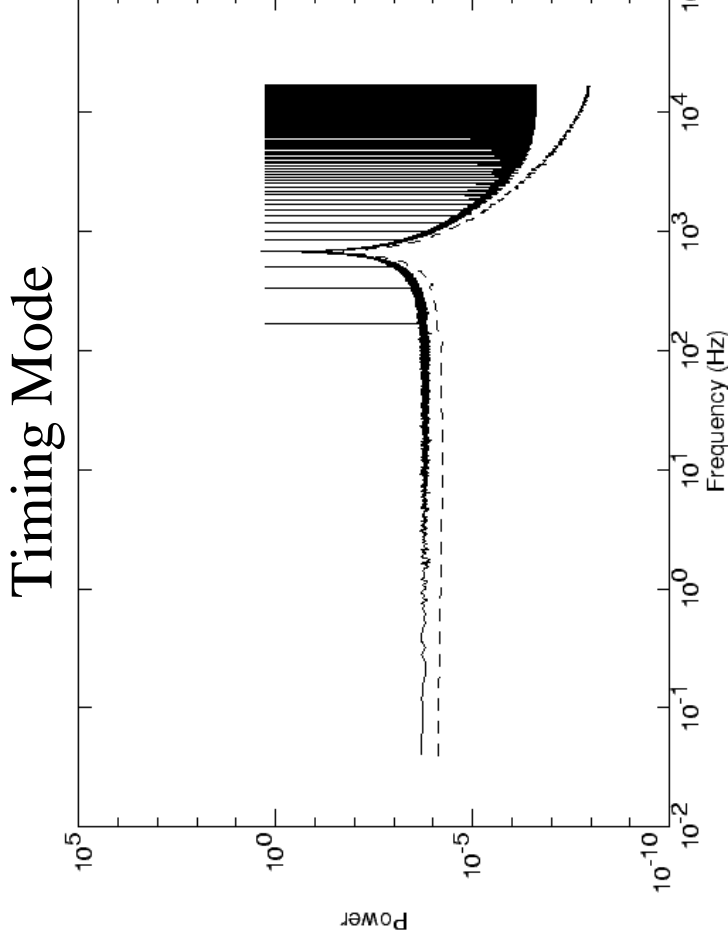
Average of 2500 PSD !
Time resolution 29.5 μ s



(Kuster et al., Proc. SPIE '99)



QPO Detection



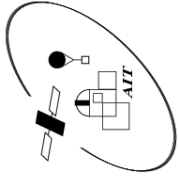
Simulation: kHz QPO (AR[2]) folded
with readout window

Time res.: TM 29.5 μ s
BM 7.2 μ s

No detection in Burst Mode above

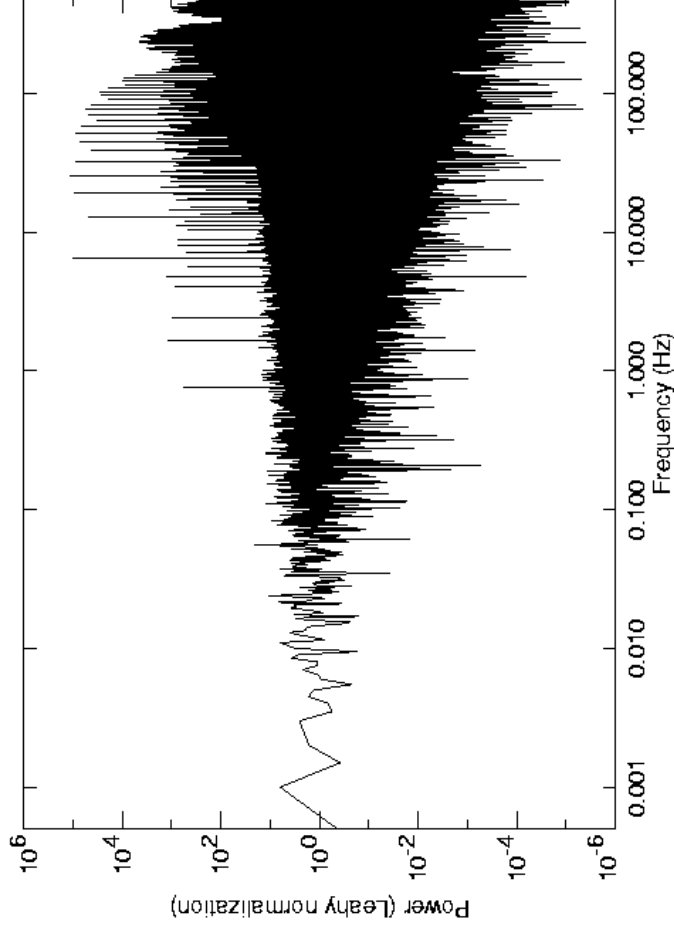
Critical Frequency = Frame Time





Influence of Detector Configuration

Electronic Chopper

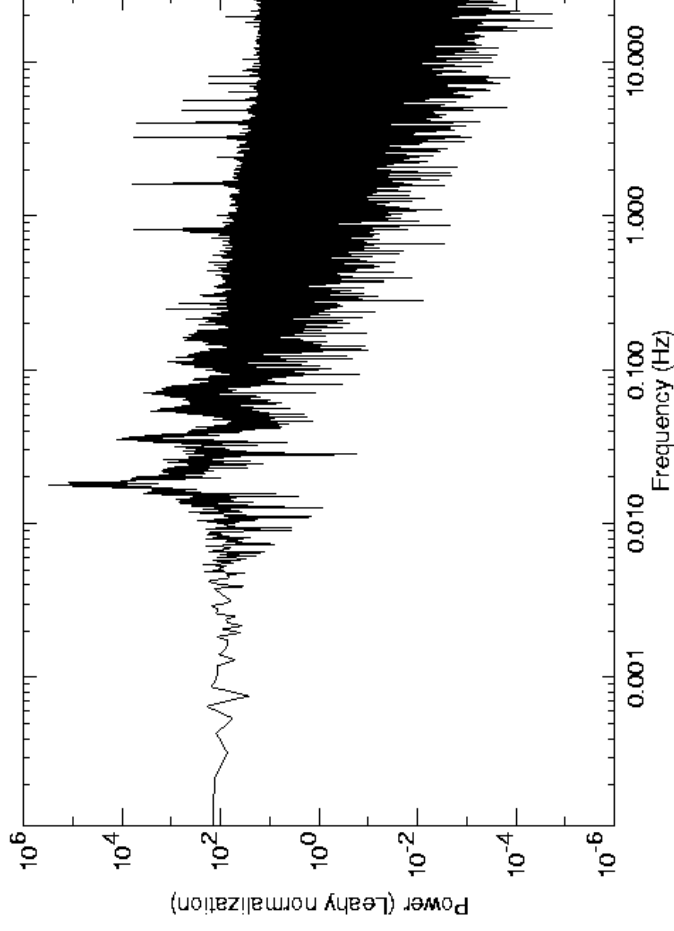


Integration time

$$t = 7.0 \text{ ks}$$

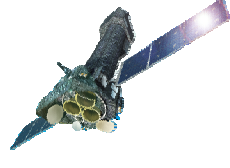
$$t_{\text{eff}} = 0.3 \text{ ks (Chopper=25)}$$

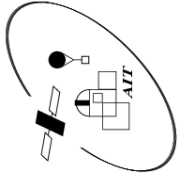
Counting Mode



Integration time $t = 9.2 \text{ ks}$

⇒ **Check telemetry constraints !**





Status of the calibration / Conclusions

- Frequencies above ≈ 500 Hz should be handled with care.
- Inconsistencies in the relative and absolute time

under investigation \Rightarrow will be solved soon

Relative time accuracy $\approx \pm 4 \mu\text{s}$ deviation in pulse periods
($\Delta P/P \approx 10^{-6}$)

- The EPIC–pn camera allows:

Pulse phase resolved spectral analysis
Pulse analysis

- The EPIC–pn camera is the fastest X–ray CCD available at the moment !

