Timing of Cyg X-1 with INTEGRAL

Stefan Larsson, Andrzej Zdziarski, Katja Pottschmidt,
Magnus Axelsson

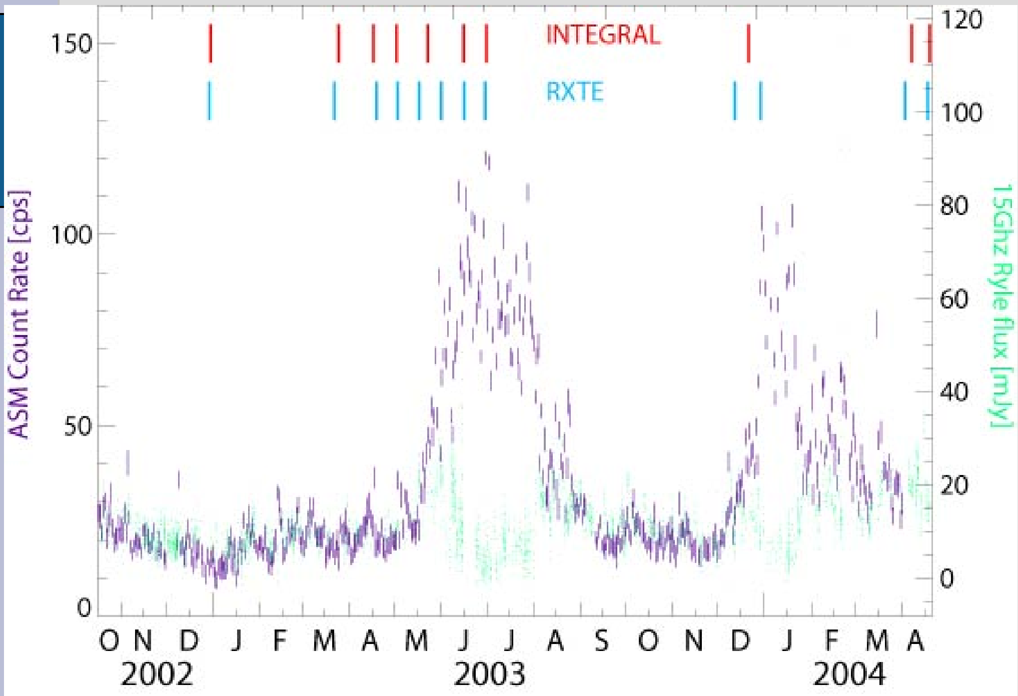
Why INTEGRAL?

- *Wide spectral coverage*
- *Cover time scales ~ 1 day*

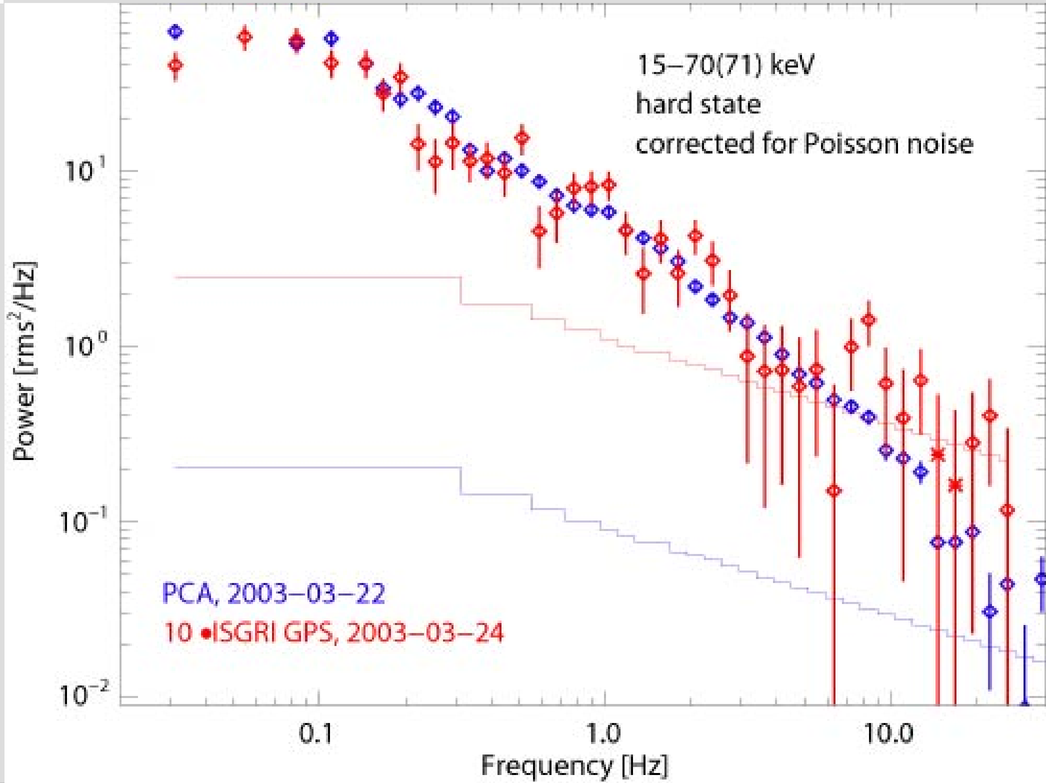
INTEGRAL & RXTE Power spectra of Cygnus X-1

Exploring time variability over a wide spectral range

Pottschmidt, Wilms, Nowak, Larsson, Zdziarski, Pooley

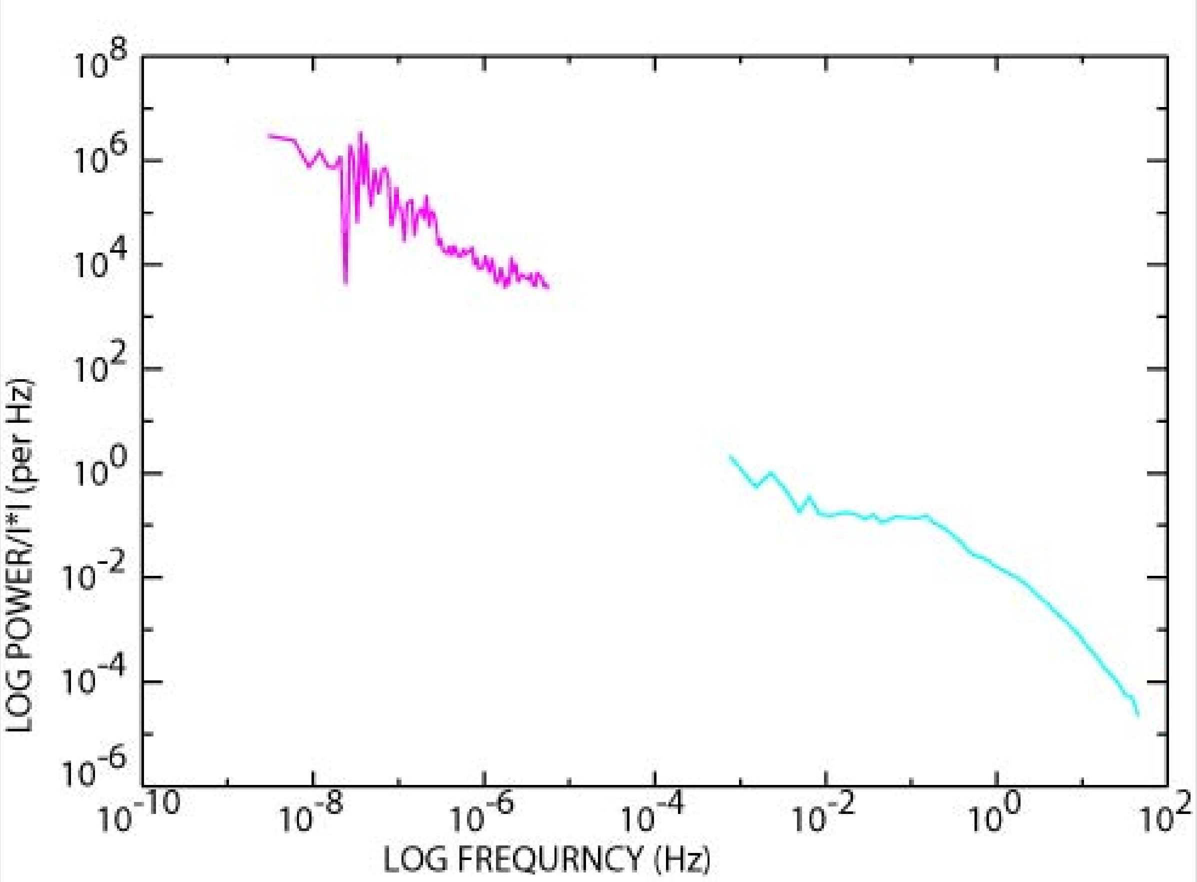


15-70 keV PDS evolution over
Hard – soft state transition
PCA & ISGRI PDS consistent



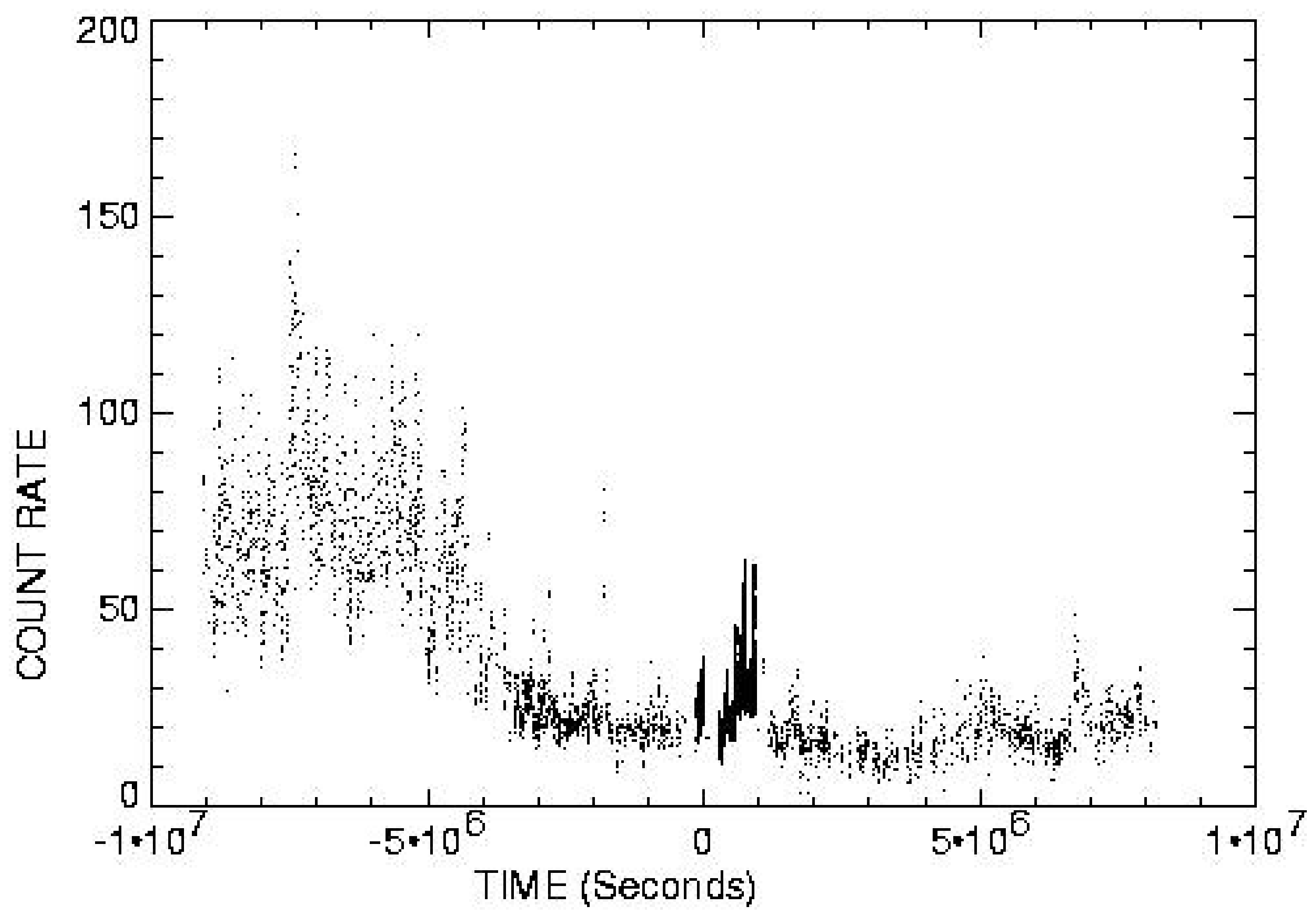
BROAD BAND PDS (RXTE ASM & PCA)

There have been many studies of time variability in Cyg X-1, in particular on time scales below 1 hour, using PCA, and on time scales Longer than 1 day, with the ASM. Much less is known about the



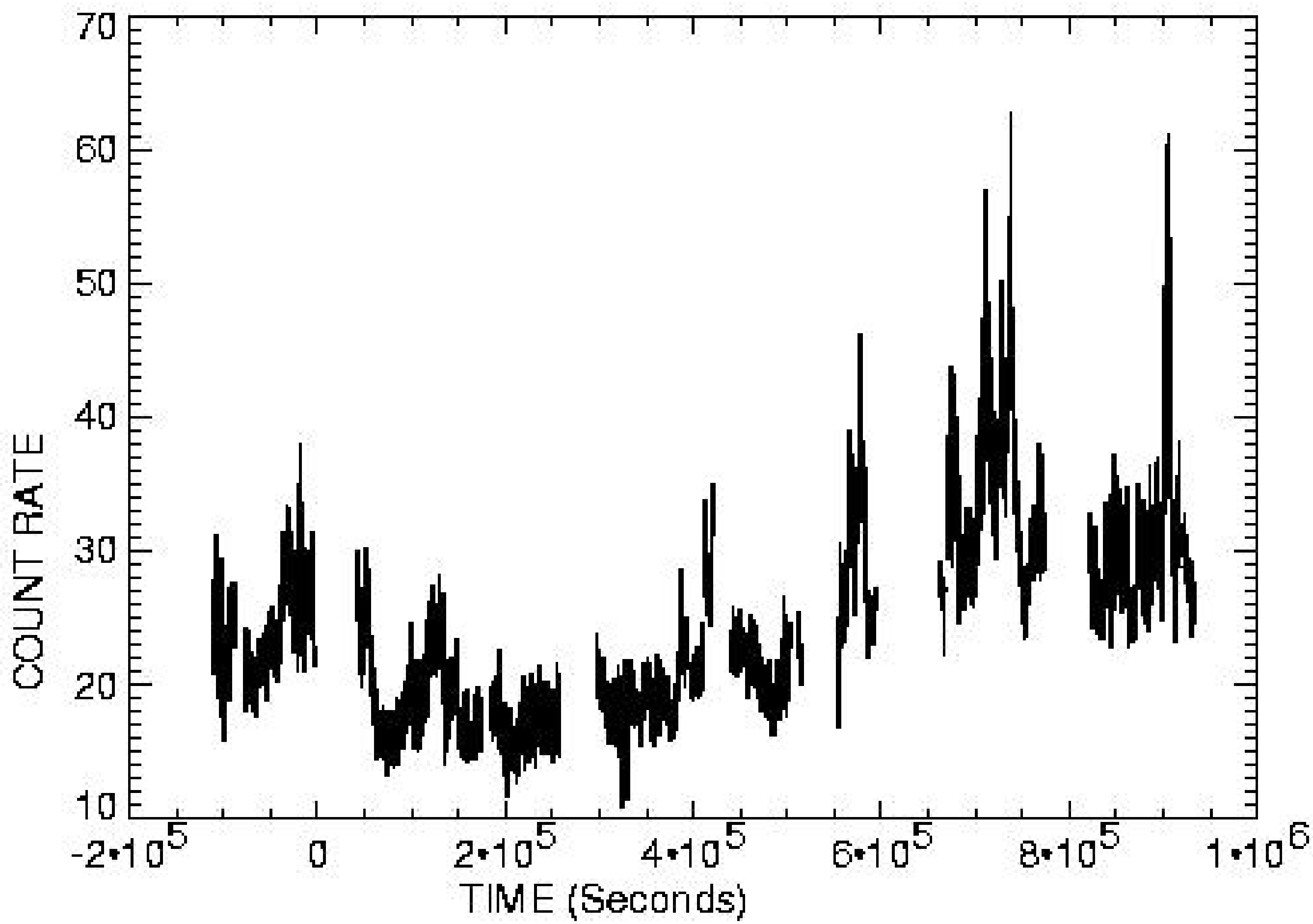
intermediate time scales. In the soft state, the overall PDS goes like 1/frequency, while in the hard state, the plateau (0.01-0.1 Hz in the case shown here) means that in order to connect with the ASM PDS, the spectrum must be steeper and have a break between 10^{-6} and 10^{-4} Hz.

ASM light curve (points) for the end of 2002.
Solid curve, near 0 in relative time is INTEGRAL
PV phase observations (JEMX, revolution 14 – 18).



ASM and JEMX count rates are comparable and not normalised in this case. (E < 12 keV)

Cyg X-1 rev. 14 – 18
Merged JEMX1 & 2 light curve



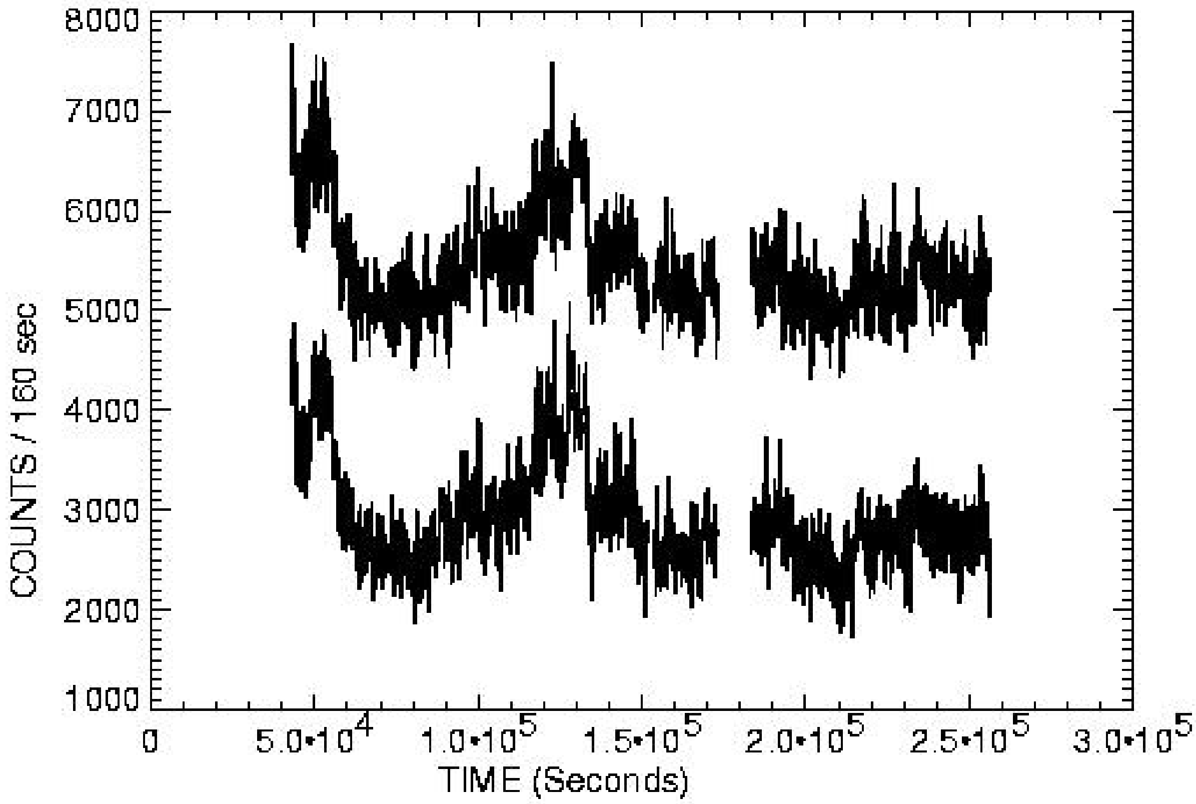
Jem-X Source light curves
The good and the bad

GOOD:
Time variability on timescales < SCW
And over identical pointings

BAD:
Flux normalization varies across the field of view,
due to unmodelled vignetting. Increasing to ~20%
At 3-4 degrees off axis.

Simultaneous JEMX1 and 2 observation (revolution 15).

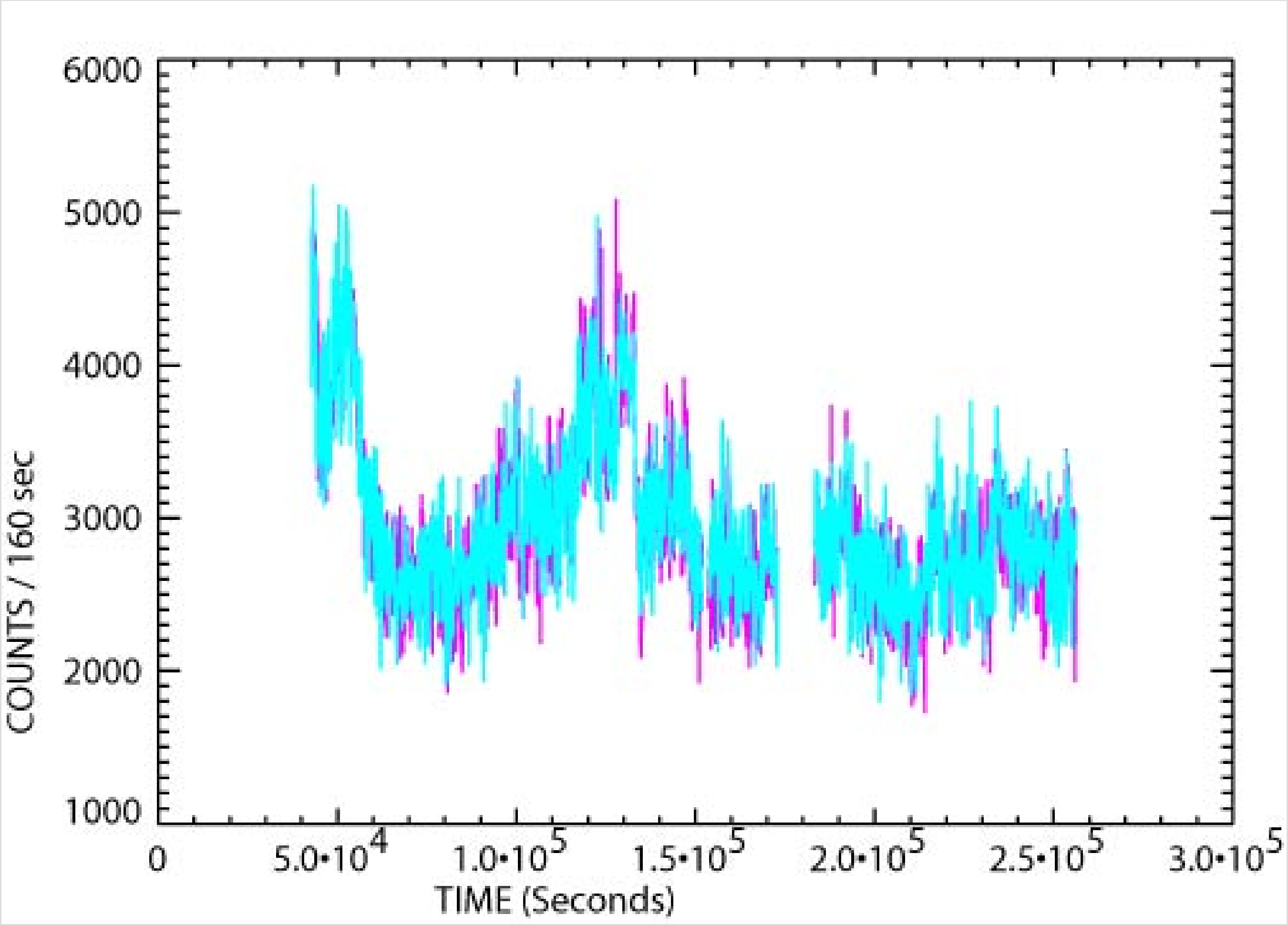
During this revolution both JEMX detectors were on, allowing us to check for consistency between the two instruments.



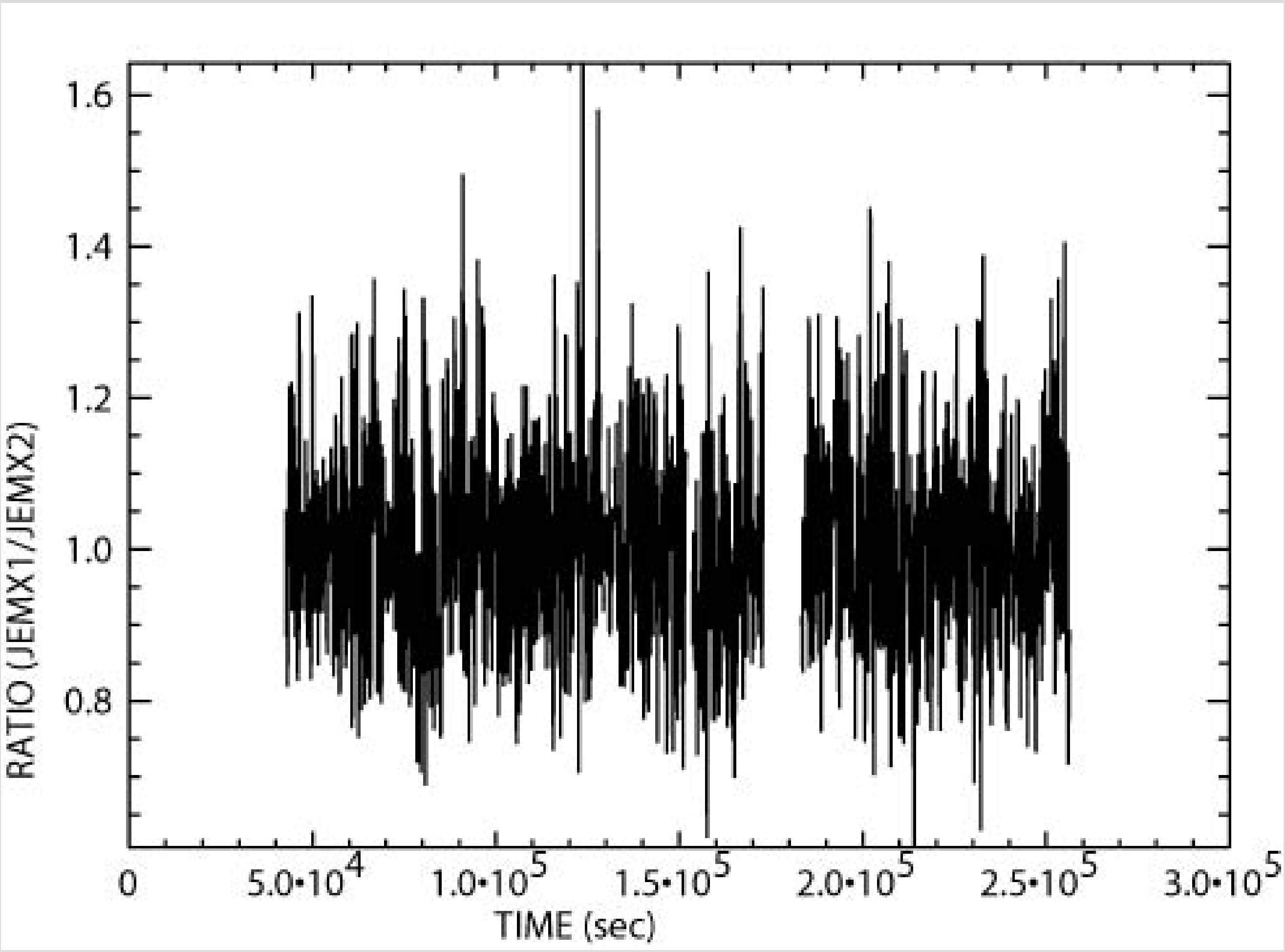
JEMX 1 & 2 light curves (shown shifted relative to each other).

The revolution 15 JEMX light curves plotted on top of each other.

The two light curves obviously track each other quite well.



Ratio of JEMX1/JEMX2 count rates in revolution 15.
No normalization. Count rates are those obtained from JEMX source extraction (OSA 4.2).

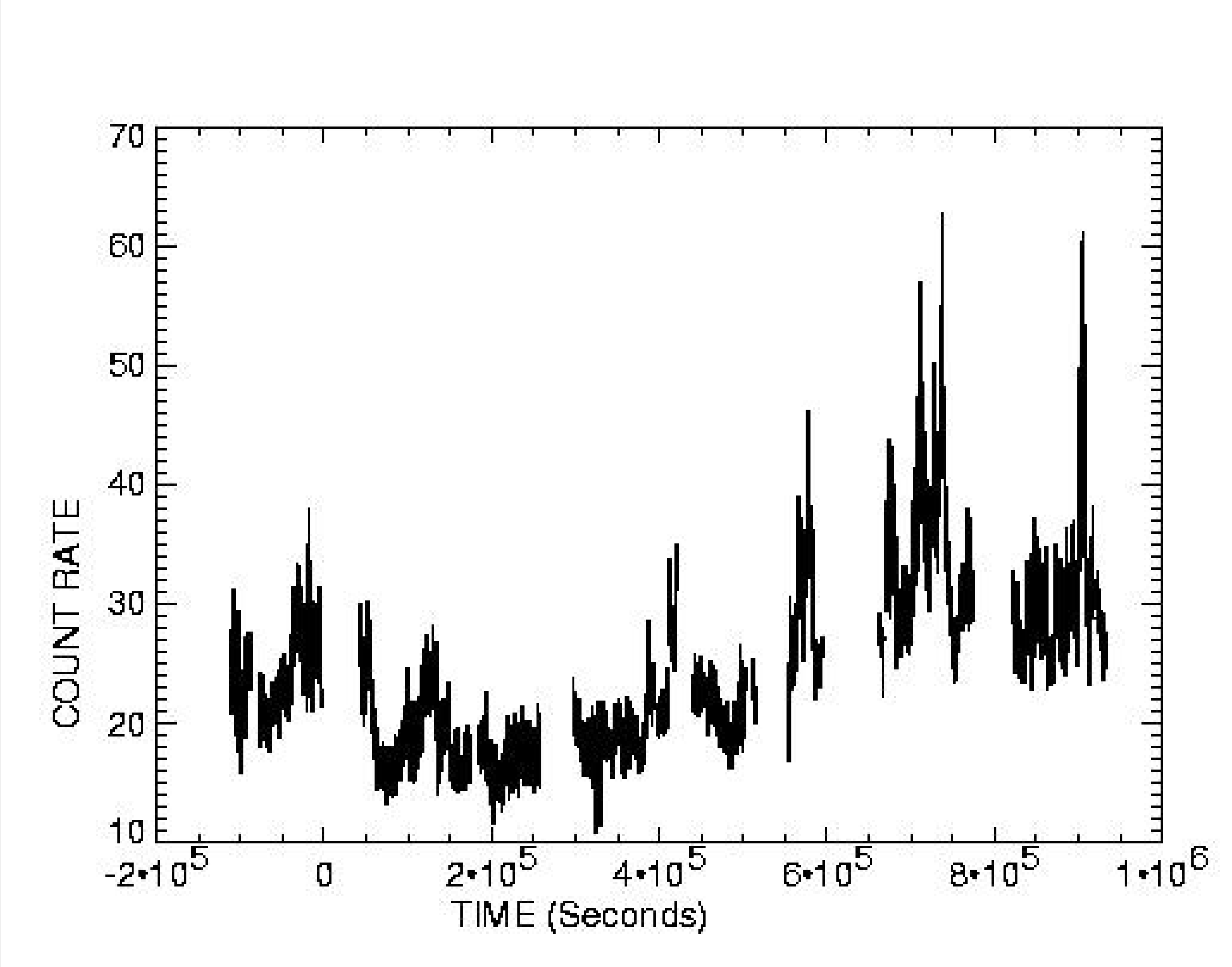


RATIO =

1.001 +/- 0.004

Returning to the JEMX light curve for Cyg X-1, rev. 14 – 18.

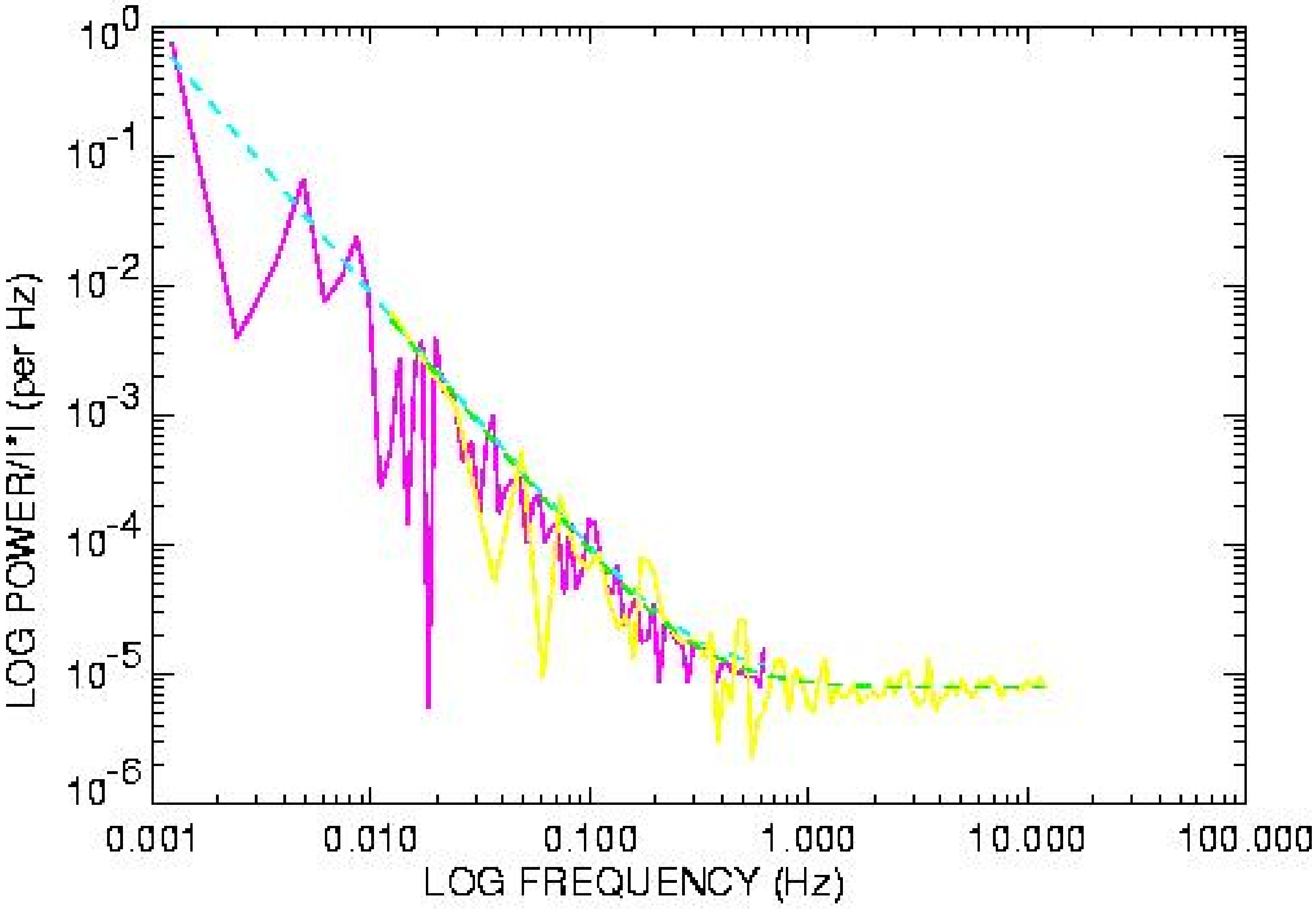
The data gaps may cause distortions of the computed power spectrum, due to leakage and aliasing.



The effects of the time sampling can be modelled.

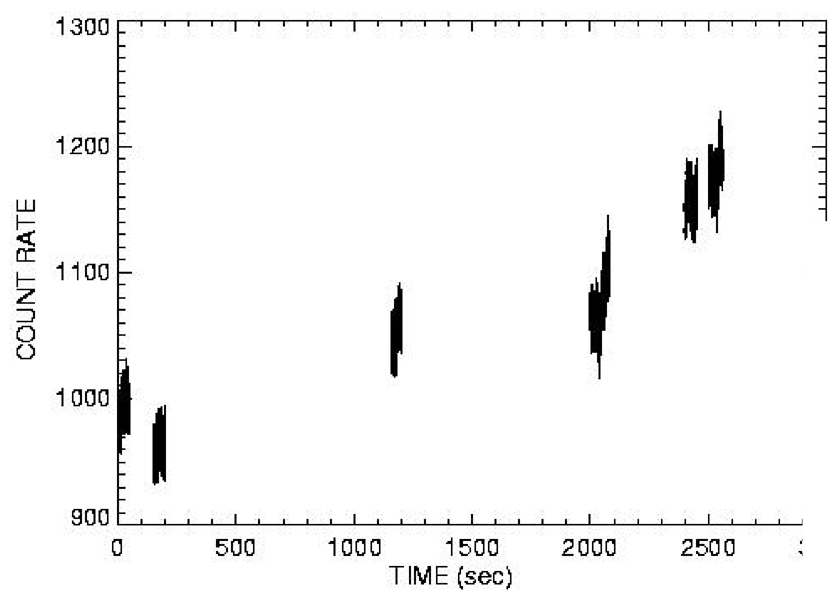
As an example let us consider simulated light curves.

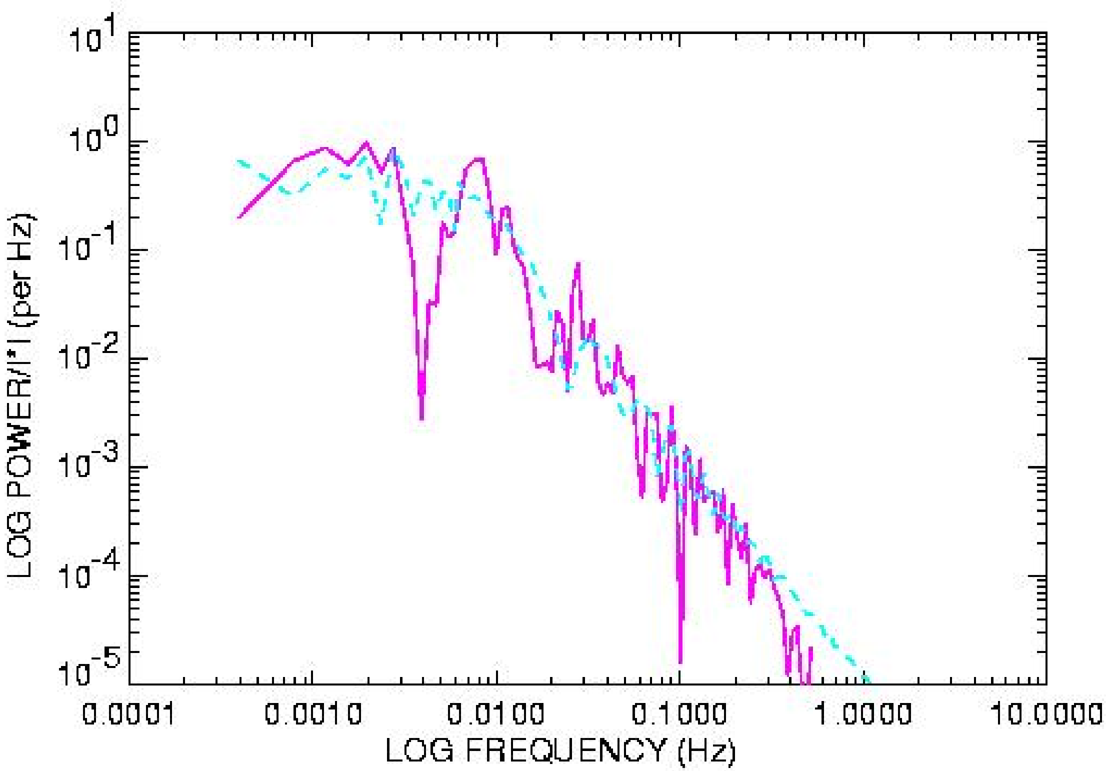
PDS of random walk simulation (evenly sampled).
The solid curves are power spectra of two simulated light curves. Both are realizations
Of the same random walk process but sampled with different time resolution.
The dashed curve is the PDS model, (-2 power law + white noise)



Let us now look at a random walk simulation with data gaps.

The PDS of the simulated data show a flattening below 0.01 Hz in this case. Since the same flattening is exhibited by the model (dashed curve, corresponding to an intrinsic -2 power law) we conclude that this is an effect of the time sampling and not a property of the variability.





(Parameters are slightly different from the previous case and in this case the white noise level was subtracted.)

So how is this modelling achieved?

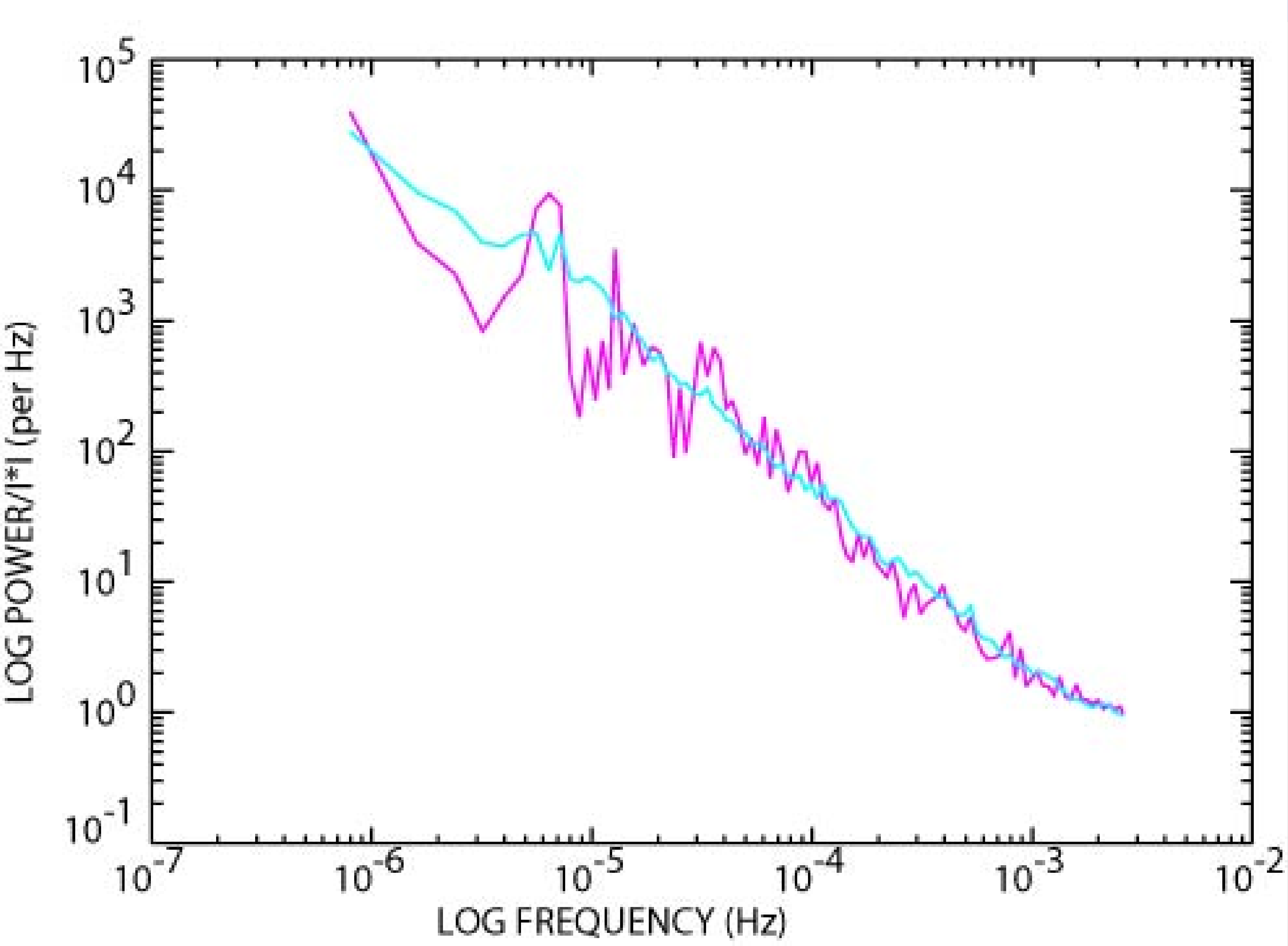
The principle is similar to spectral fitting (XSPEC)
The PDS is modelled by folding through a response (matrix)

For a given time sampling:

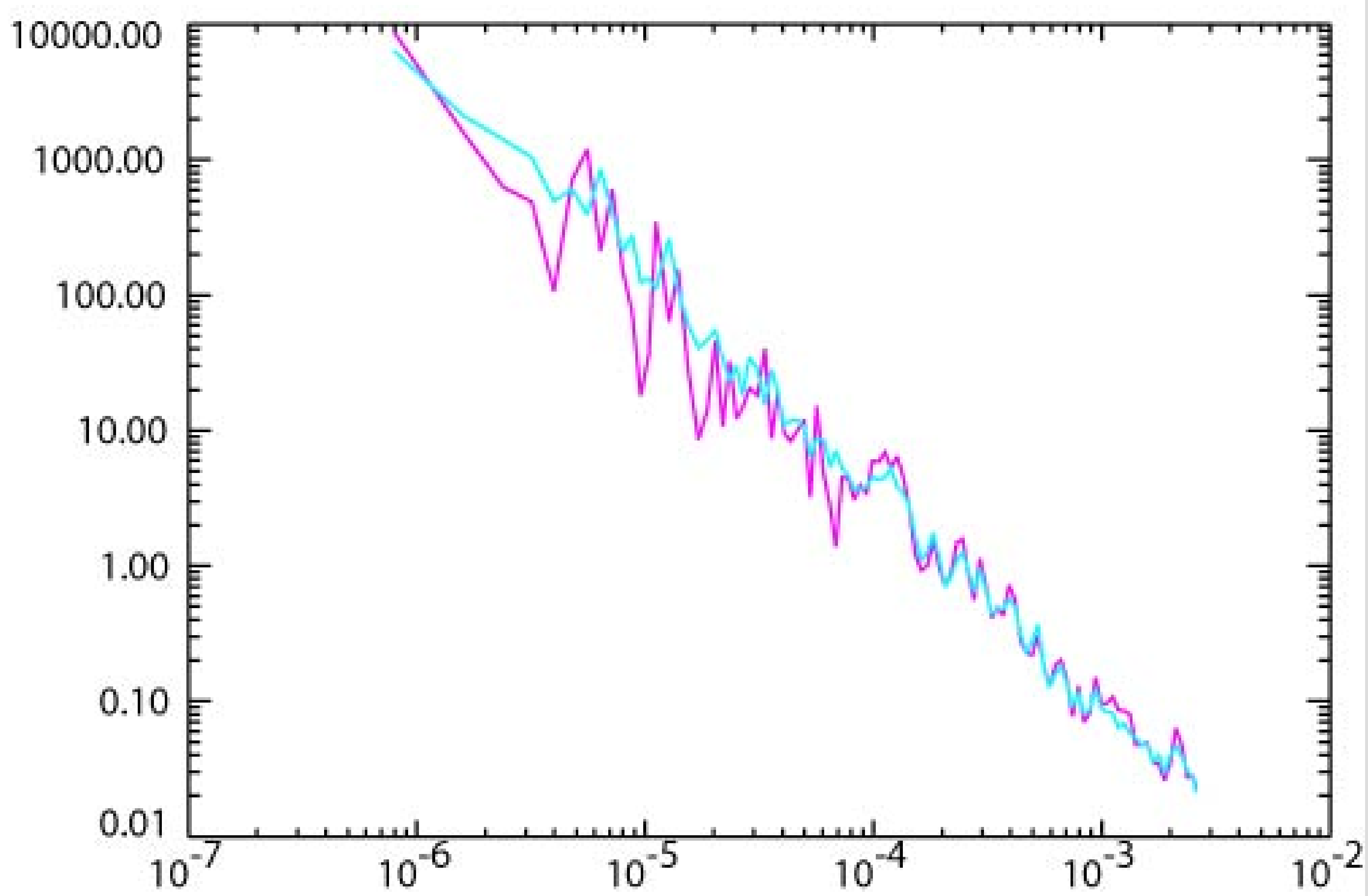
1. compute a response matrix
2. Fold a model PDS through the response
3. Fit the model to the observed PDS

Idea: Done et.al. (1992)
Developed further (e.g. goodness of fit) by Uttley et.al. (2002)

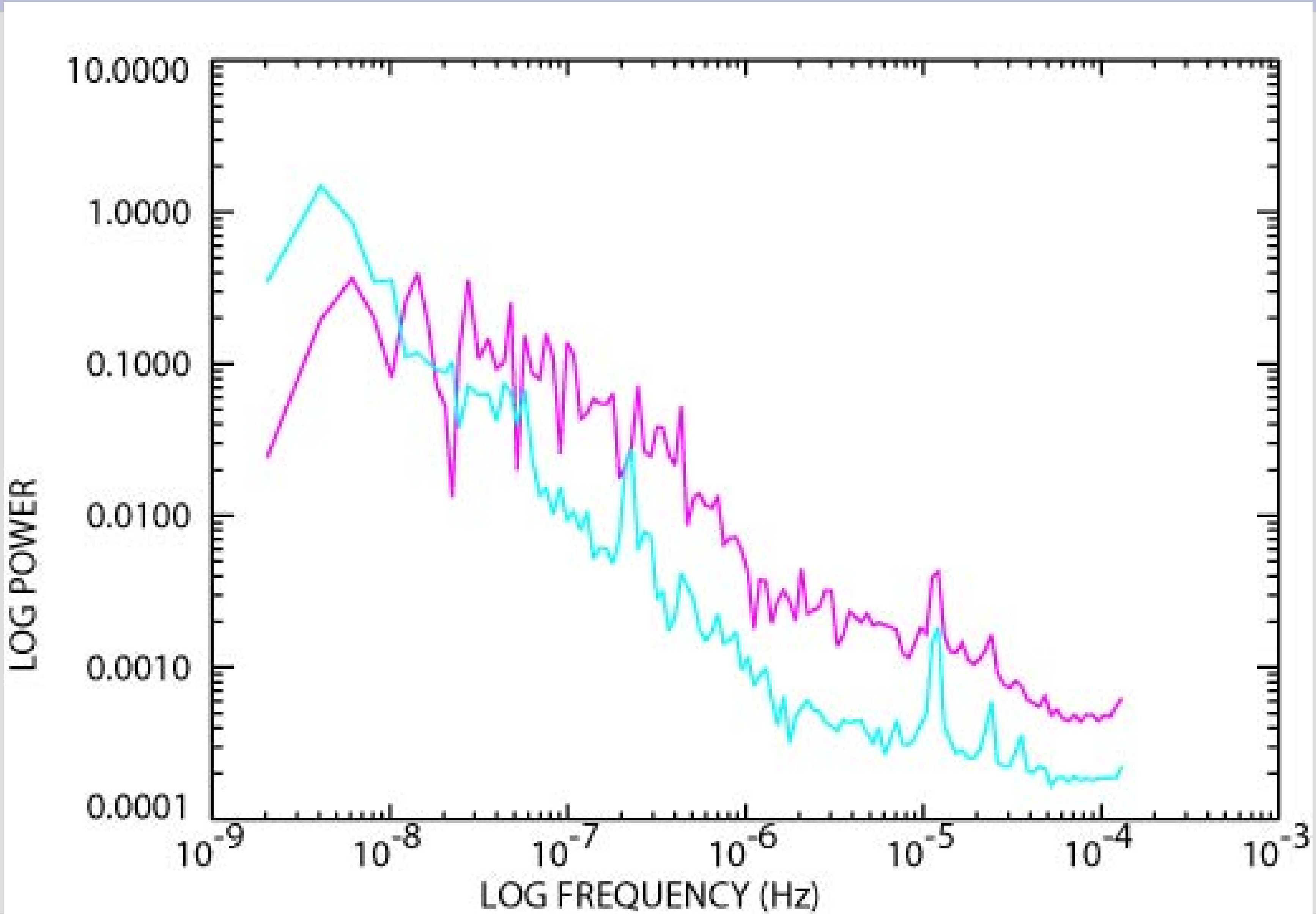
Cyg X-1 JEMX PDS (violet curve) with model (-1.5 power law)



Test case: Random walk simulation sampled at the same time values as the Cyg X-1 observation.
The PDS model (blue curve) is a -2.0 power law model.



PDS for all ASM low/hard state data (violet curve) compared with a -1.0 power law model. This is not a quantitative fit but it suggests a flattening in the observational data at low frequencies. Above a few times 10^{-6} Hz the uneven sampling becomes more and more important and leakage cause a flattening of the spectrum. At those frequencies the ASM spectrum is consistent with the -1.5 power law of the JEMX PDS.



Combined ASM (all states) + JEMX + PCA power density spectrum. Our preliminary model fit suggest a change in power law slope from -1.0 to -1.5 at about 10^{-5} Hz. (The full quantitative analysis with proper goodness of fit estimation is not yet completed).