INTEGRAL & *RXTE* Power Spectra of Cygnus X-1

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The Broad Picture

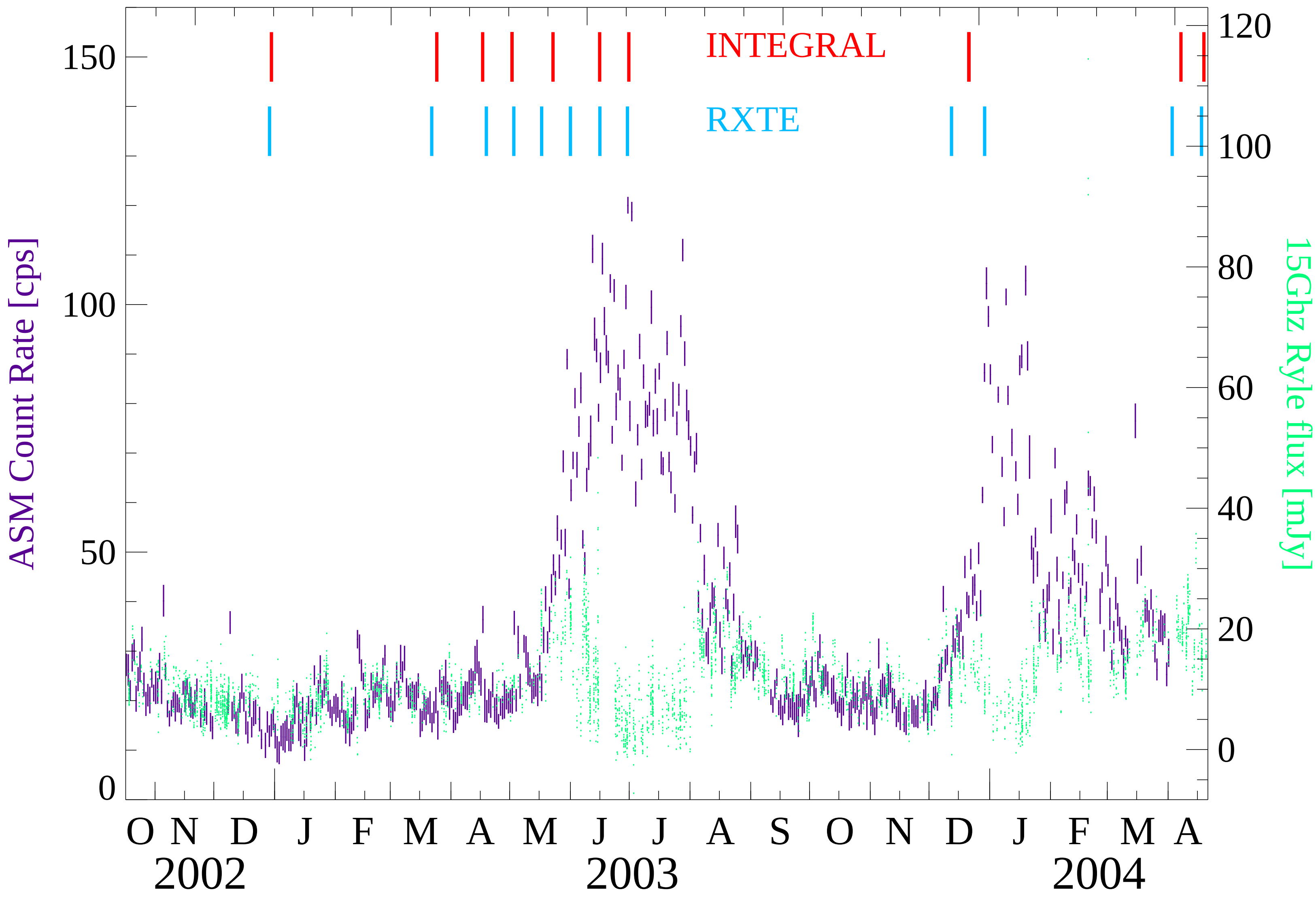

Fig. 1: *Ryle* radio flux (15 GHz) and *RXTE-ASM* count rate (2–12 keV) of Cyg X-1. The red and blue tickmarks denote pointed *INTEGRAL* and *RXTE* observations, respectively.

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What do we want?

- What?

  Study the variability of a source not only at a given period, but over a range of time scales, i.e., the continuum of the strength of the variability (power) over a range of frequencies.

- Why?

  Black hole binaries show very characteristic shapes of this continuum depending on the state they are in, timing diagnostics for black hole states are more precise than doing it from spectra.

- Power Spectral Density (PSD): $P_j = A\langle \mathrm{FT}^\star(x_i)\mathrm{FT}(x_i)\rangle$

  $A_{\text{Miyamoto}} : A(R_{\text{bkg}})$ in $[(\text{rms}/\text{mean rate})^2/\text{Hz}]$, i.e., relative lc variance (per frequency interval)

- Such an analysis has to be done much more carefully than period searches!

  ⋆ absolutly necessary to average over PSDs from many lightcurve segments

  ⋆ absolutly necessary that the segments are equally binned

  ⋆ Poisson noise correction

  ⋆ background and/or deadtime correction if necessary (instrument dependent)

- How? . . . to produce equally binned high resolution lightcurves from *ISGRI* data (black holes have power up to a few 100 Hz)?

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How do we get it?

- For a bright source image deconvolution is not necessary & “deconvolved lightcurve extraction” was/is still under development.
- You need a PIF (pixel illumination fraction) file for your source. The canonical way to produce the PIF file is to run OSA up to spectral level (quicker way: see *ISGRI* cookbook).
- Remove all sources but those you are interested in from isgri_sky_res.fits and copy to $workpath/events/$o.res.fits ($o: loop over ScWs).
- Revision 1 data: evts_extract group=“$workpath/$o/obs/$o/og_ibis.fits[1]”
  events=$workpath/events/$o.evts.fits
  sources=“$workpath/events/$o.res.fits[2]” pif=y
  instrument=IBIS gtiname=MERGED_ISGRI barycenter=1

  Produces event file with PIF columns for your sources (optionally with barycentered time column) and a GTI extension (warning: BIG file).
- Use your own software (here: IDL) to:
  - ⋆ select events according to energy range (15–70 keV) and PIF ($>$0.8) values
  - ⋆ bin into lightcurve taking into account the GTI
  - ⋆ produce segments without gaps and of equal length & do your careful PSD analysis

Comparison of ISGRI & PCA Power Spectra, I

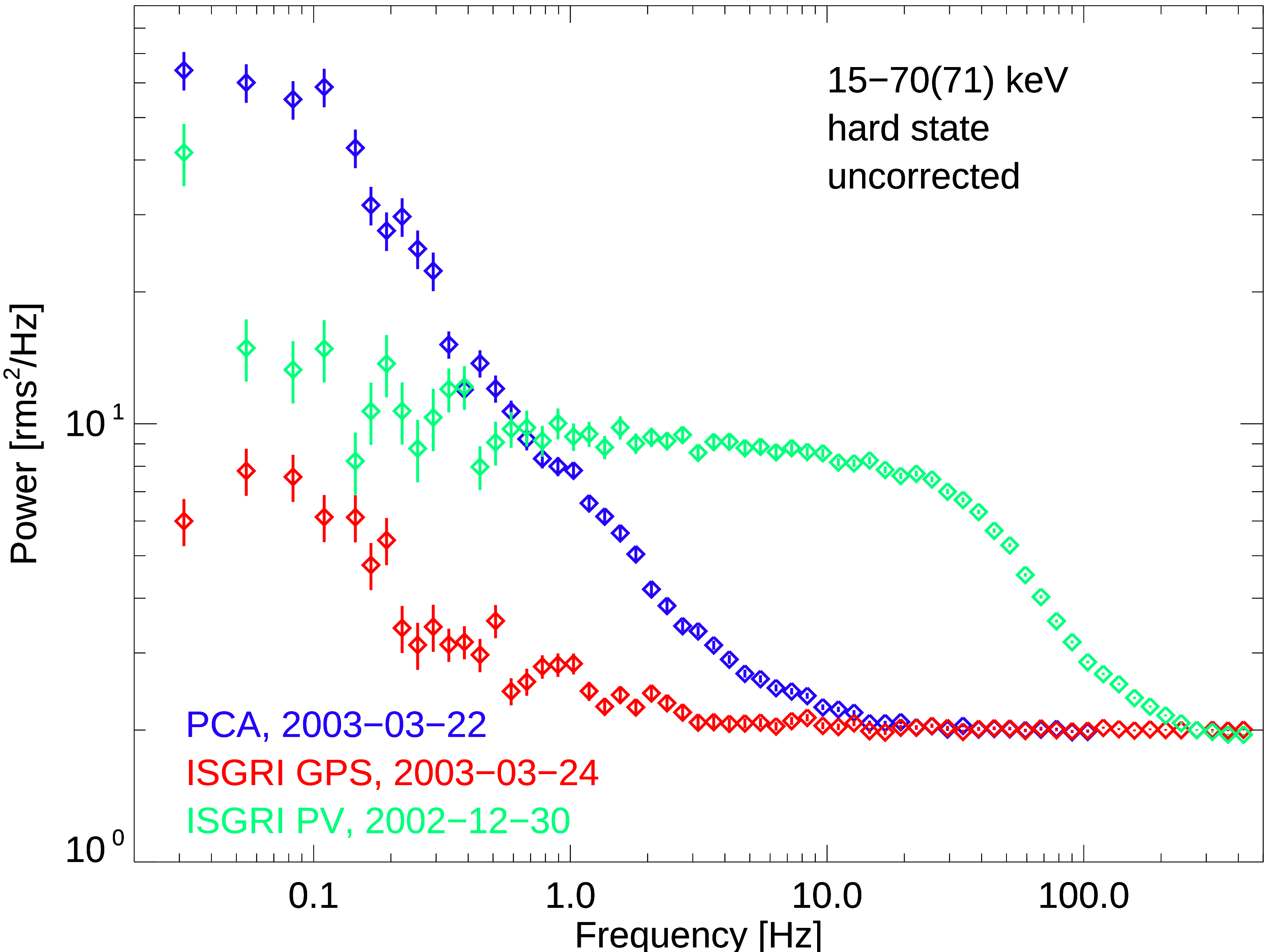

Fig. 2: *INTEGRAL-ISGRI* and *RXTE-PCA* power spectra of Cyg X-1 in the 15–70 keV range. Poisson noise has not been subtracted and corresponds to a power level of 2 (Leahy norm).

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Comparison of ISGRI & PCA Power Spectra, II

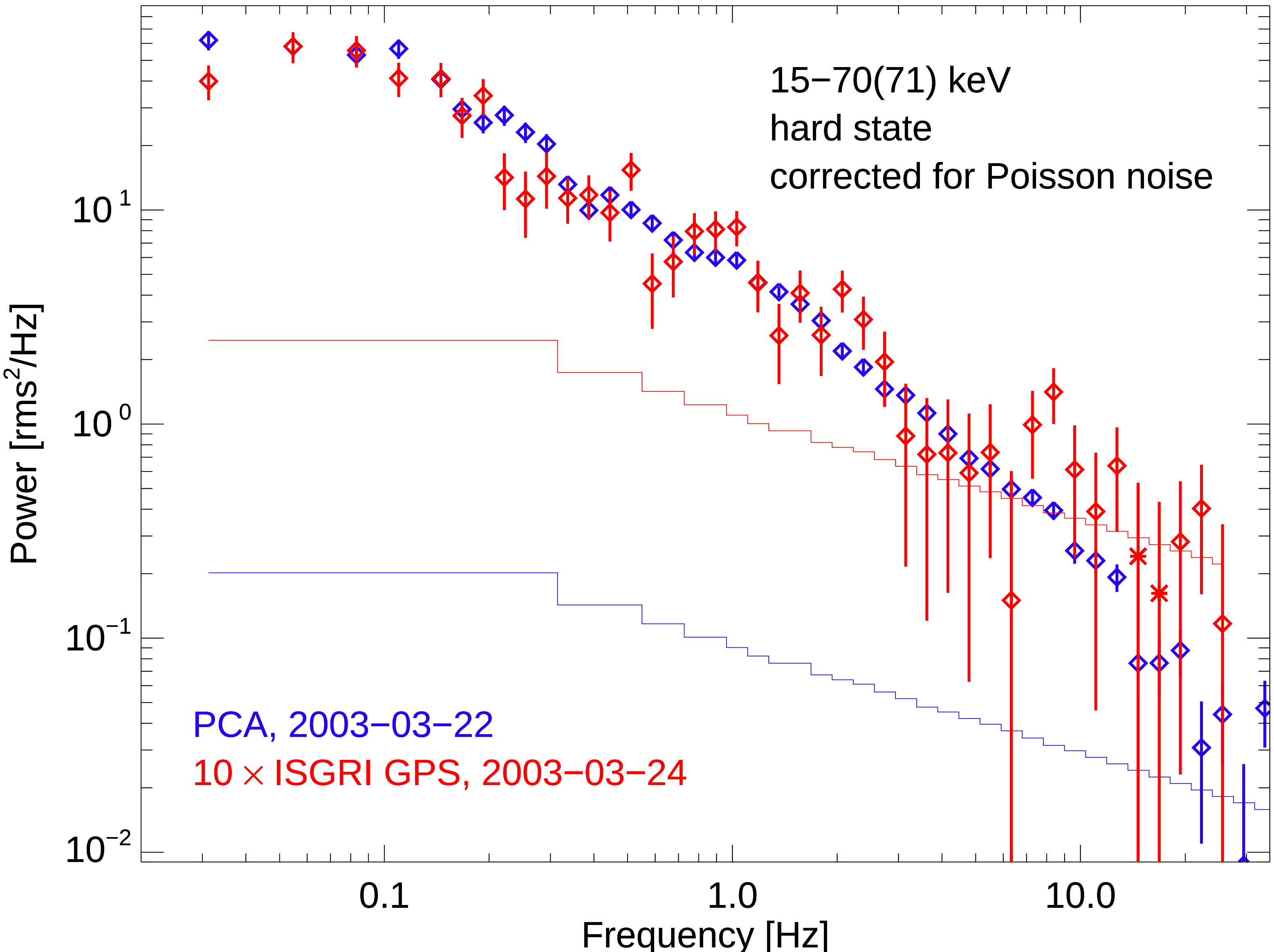

Fig. 3: *INTEGRAL-ISGRI* and *RXTE-PCA* power spectra of Cyg X-1 in the 15–70 keV range, corrected for Poisson noise. Here and in the following figures histograms show the **effective noise level** corresponding to the uncertainty of the Poisson noise correction (Nowak et al., 1999).

Evolution Over the Flare, I

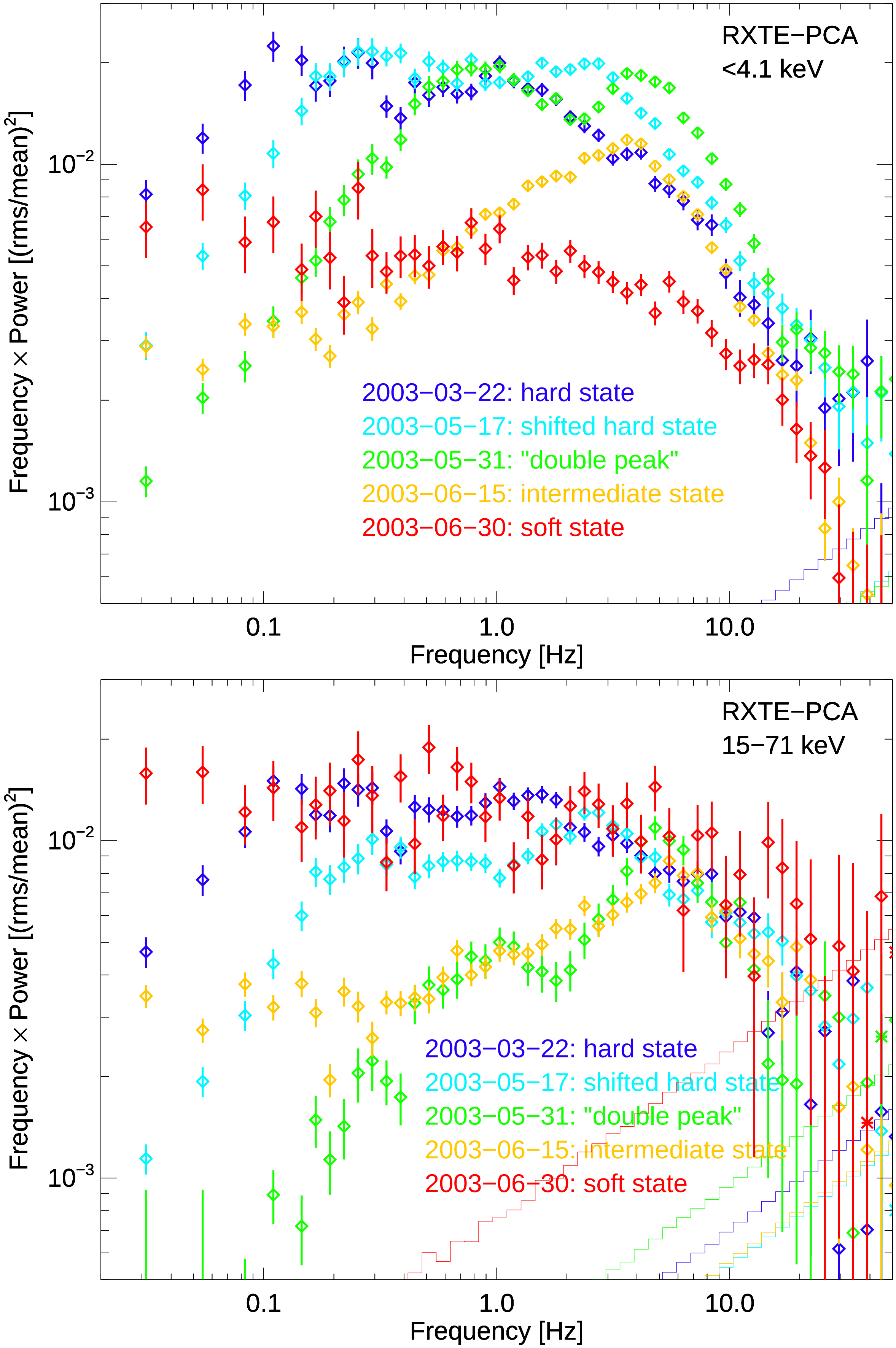

Fig. 4: Evolution of the *RXTE-PCA* power spectrum of Cyg X-1 over the fi rst half of the 2003 flaring episode. Here and in the following the normalization according to Miyamoto et al. (1992) is used. **a:** For energies $<$ 4.1 keV. **b:** For energies between 15 and 71 keV.

Evolution Over the Flare, II

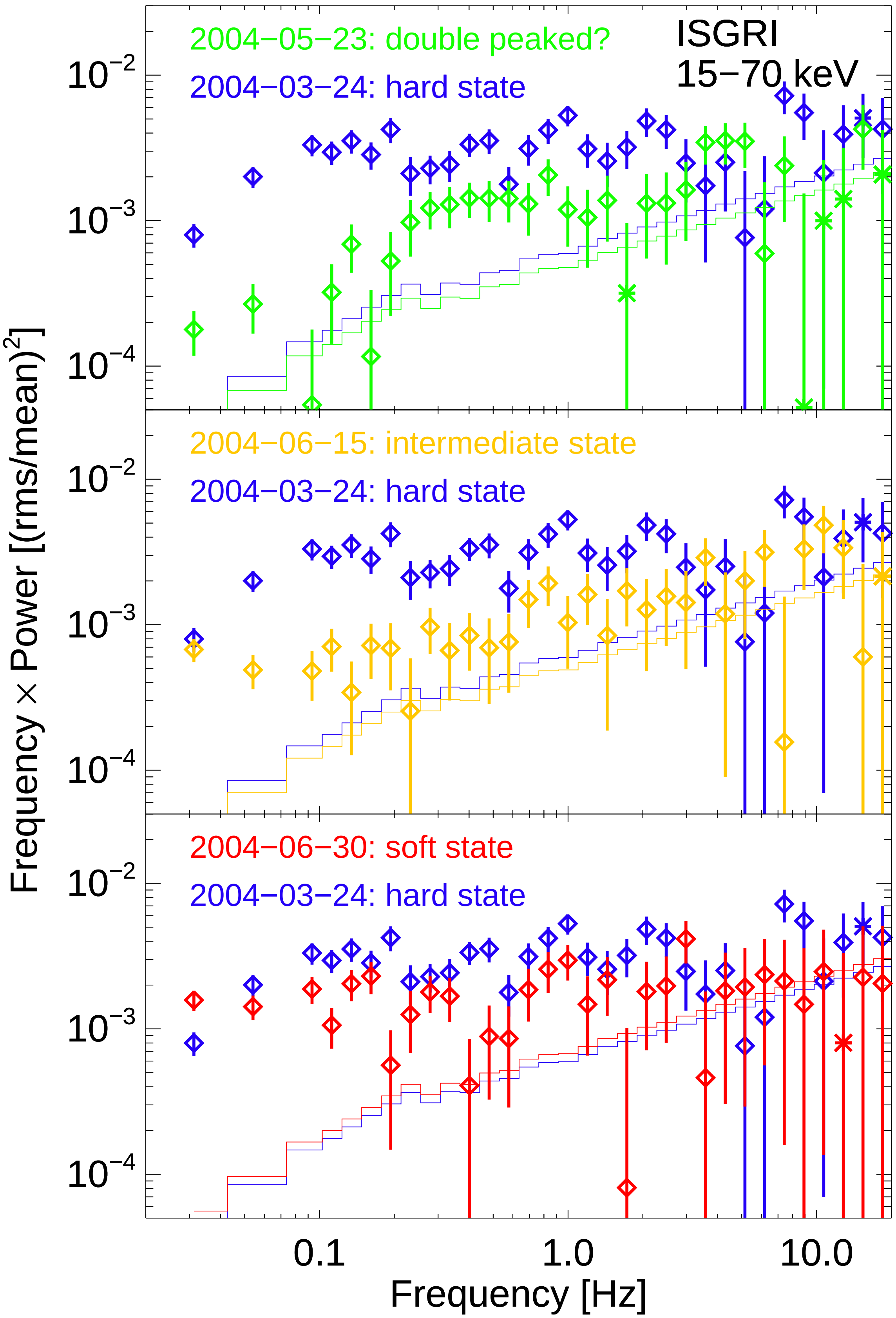

Fig. 5: Evolution of the *INTEGRAL-ISGRI* power spectrum of Cyg X-1 over the fi rst half of the 2003 flaring episode for energies between 15 and 70 keV.

Conclusions

- Contemporary *ISGRI* and *RXTE* 15–70 keV power spectra of Cyg X-1 are consistent in shape (data from the PV phase and the following few months are not usable).
- For the *ISGRI* power spectra a background correction is required. In the case of Cyg X-1 the uncorrected power is an order of magnitude too low.
- This is one of only a few studies effectively accessing energies above the *RXTE-PCA* range. The fact that the same power spectral shape is observed for both instruments means that it does not change much between 20 and 40 keV and is clearly attributed to coronal emission. Even higher energies will be accessible with future *INTEGRAL* observations.
- The peak at 4–8 Hz dominates the transitional states at all *PCA* energies while other components only play a role in the soft band. The additional association with radio flaring speaks for an origin in or near the jet forming region.