NICER CALIBRATION: Spectral Systematic Error

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Summary and Release History

This document briefly describes the release of the NICER systematic error vector for spectra. This vector is used to apply a SYS_ERR column to NICER spectra by the task niphasyserr.

Released Files

Public Release	NICER CALDB Ver	ID String	Comments
2022-10-20	xti20221001	20170601v001	Initial release

Table Notes: All files appear in NICER Calibration Database as `nicer/xti/bcf/syserr/nixtisyserr.fits`, where *<S>* is the ID String above.

Introduction

A proper NICER spectral analysis requires one to assign representative errors to the spectrum. While standard analysis applies statistical errors to a spectrum, there is also the question of whether systematic errors should be applied.

Are all NICER spectra systematics dominated? It's difficult to make a blanket statement for all possible combinations of NICER analysis, but generally, yes, one can assume that most NICER spectra are systematics dominated.

For bright targets (>100 ct/s observed in ~1000 seconds), systematic errors are dominated by the response matrix (~1% in the 0.4-10 keV band). As noted on the NICER Calibration Recommendations analysis thread, one cannot achieve better than the spectral response systematic limit.

For faint targets, systematic errors are dominated by inaccuracies of the background model subtraction, which can be ~5% or more.

Thus, regardless of source type, most NICER spectra are dominated by systematics, and not statistics.

Therefore, the NICER team has developed a systematic error vector. This vector can be applied to a spectrum using the niphasyserr tool. This tool will append the SYS_ERR column to a given spectrum. When used within XSPEC, this systematic error will more appropriately weight the data so that the least-understood portions of the spectrum are not overemphasized.

The file is indexed with the following CALDB indexing keywords

- CCNM = 'SYS_ERR'
- Boundary keyword DETNAM(99) - applies to all detectors
- Boundary keyword CHANTYPE(PI) - applies to slow channel

The table contains two columns, CHANNEL and SYS_ERR, and these are used to interpolate onto the desired spectrum.

Development of the Systematic Error Vector

The development of this vector is a bit more of art than science. The NICER team has used its experience to emphasize which portions of the spectrum are better or worse known. These can be divided into three energy ranges as shown in Figure 1.

Note that all values are listed as percentages since the systematic error applies as a fractional value of the model, and not as an absolute count rate.

In-band. This is most of the NICER energy range from 0.3 - 10 keV. The systematic error of 1.5% is applied here. This is consistent with the 1-2% recommendation that was previously provided informally to scientists in the 0.4-10 keV range.

Low Energy. Below 0.3 keV, the uncertainty in spectra is dominated by uncertainty in the NICER team's knowledge of the trigger efficiency function (labeled as "Trigger Efficiency" in Figure 1). In principle this function is well determined, but in reality, the function shifts somewhat depending on optical loading and thermal conditions.

The systematic error values shown here are essentially a "shifted" version of the trigger efficiency function. An erf() function was used to simulate the efficiency function, offset by 50 eV.

High Energy. Above 10 keV, the throughput of NICER's X-ray concentrators is less well understood (labeled as "ARF" in Figure 1). At these energies, the classic and simple models of

X-ray reflection and scattering break down, and a hefty phenomenological correction has been applied in generating the ARF to match the Crab spectrum.

The systematic errors shown here grow quadratically with energy beyond 10 keV until they reach 50% at 15 keV. In reality, the strong gold L edges between 11.5 and 13.5 keV should add some more complicated structure to this energy range, but most scientific users will be well-served by this systematic error extension.
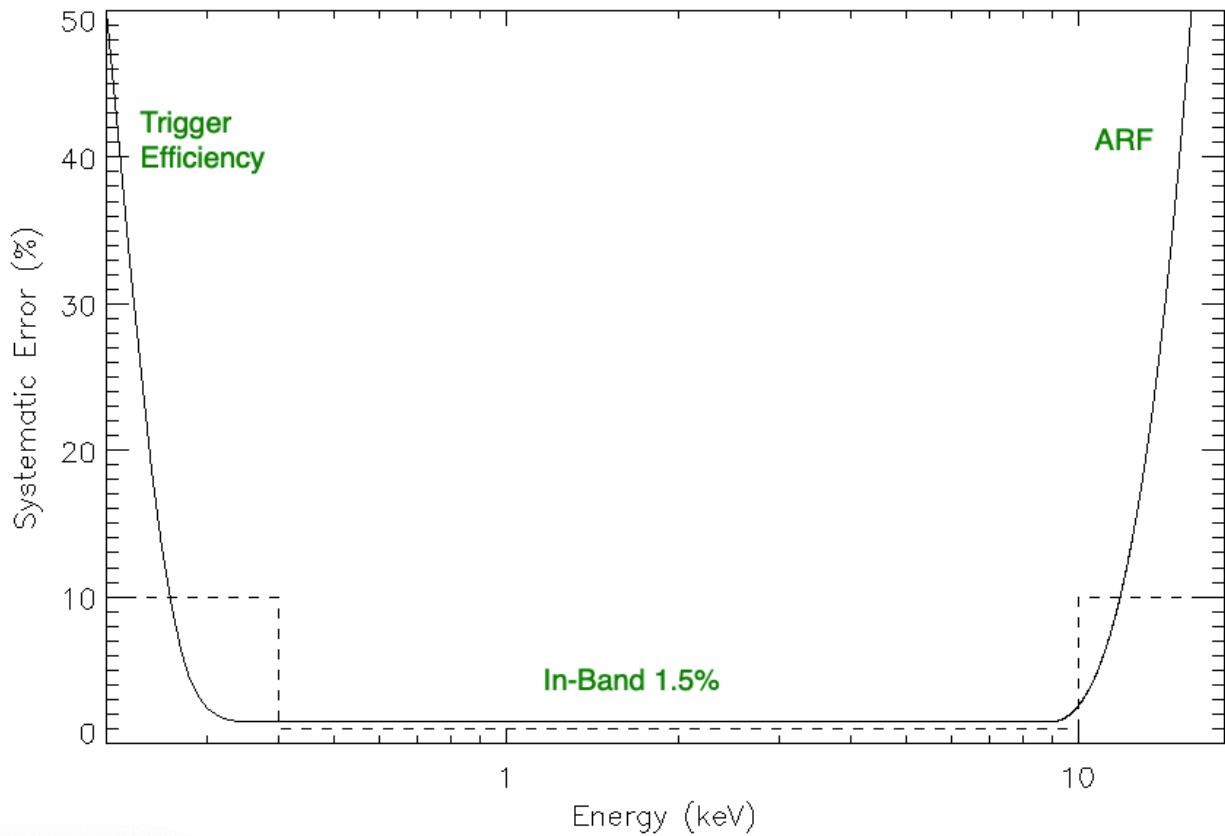

Figure 1. NICER systematic error vector (black solid line). The previous systematic error recommendations (not released via CALDB) are shown as a dashed line.