NICER Analysis and Calibration Summary for Proposers
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Summary Up Front

• Now is a great time to submit proposals to NICER
  – Very large effective area, excellent spectral resolution and throughput
  – Calibration is understood
  – Maturing software workflow

• New software release in October will have much improved functionality and simplified workflow
NICER’s Unique Capabilities

• Spectral band: 0.2–12 keV
  • 52 operating single-pixel silicon detectors
• Energy resolution:
  < 150 eV @ 6 keV
  • Comparable to X-ray CCDs
• Timing resolution:
  • 100 nsec RMS absolute
• Non-imaging field of view
  • 6 arcmin diam. (half-max)
  • High throughput (3.5 Crabs with no pileup)
• SUMMARY: large area, fast timing, and excellent spectral performance, but 52 single-pixel detectors
Outline

• Ways to get help
• Calibration summary
• Discussion of background modeling
• Analysis summary and preview of new release
Ways to Get Help

• Consult on-line NICER documentation for analysis issues
  – Software guide overview
  – Analysis “Threads” - procedures for common tasks
  – Analysis tips for specific known problems or issues you may encounter

• Send questions to the NICER helpdesk:
  https://heasarc.gsfc.nasa.gov/cgi-bin/Feedback
NICER Calibration Summary

• NICER brings a very large effective area (>1700 cm$^2$ at 1.5 keV) and large throughput
• Sensitive to modestly faint sources ($\sim 10^{-13}$ erg cm$^{-2}$ s$^{-1}$ 0.5-10 keV)
NICER Calibration Status

- NICER energy scale
  - After calibrations, all event files have “PI” column with common energy scale (“Pulse Invariant”)
    - 1 PI = 10 eV (e.g. PI = 150 means E = 1.50 keV)
    - Estimated error ~5 eV (0-10 keV)
- NICER on-axis response
  - NICER calibrated against Crab nebula as a “smooth” continuum
  - Systematic errors ~1-2% (0.4-10 keV)
  - Total effective area and slope comparable to Madsen et al. 2017 NuSTAR (within ~5%)
  - Often, residuals are due to deficiencies in model, not response
NICER Background Modeling

- NICER is an array of 52 single-pixel X-ray detectors so background must be modeled
- There are three contending background models available
  - 3C50 – popular
  - SCORPEON – new!
  - Space Weather – adjusts to geomagnetic Kp

- Models previously only available as separate download
- GOOD NEWS: all models will be included in forthcoming release in October
- Current performance: systematic errors ~50% remain
• Divide background into physically-motivated components
  — some less predictable than others
• SCORPEON provides a parameterized XSPEC model (not file) which can be adjusted along with your science parameters
  — No over/under-subtraction problems
  — Covariance between background and science uncertainties properly accounted
• Can also estimate a constant background file
- Flux 1-sigma range is $0.87 - 1.15 \times 10^{-13}$ erg/s/cm$^2$ (~4 $\mu$Crab; compare to ~300 $\mu$Crab RXTE PCA sensitivity)
- New SCORPEON model is adjustable to get ultimate fit to your data
**NICER Background Gotchas**

- **Dust scattering halos** can play a significant role for bright sources
  - Modelable with xscat XSPEC model
- **Galactic ridge and bulge** can contribute diffuse emission to the NICER field of view (check ROSAT All-Sky Survey)
  - Modelable as thermal plasma in XSPEC
- **Solar wind charge exchange and neutral oxygen** can be detected and difficult to predict ($\text{O}^\text{VII}$, $\text{O}^\text{VIII}$, $\text{Ne}^\text{IX}$, $\text{O}^\text{K}$)
  - Modelable within SCORPEON model
- **All of these gotchas are applicable to every X-ray observatory**, but may be enhanced because of NICER’s larger field of view (6’ diameter) compared to imagers
Next Software Release

• NICERDAS release date: mid-late October 2022
• Major new capabilities included
  – Standard product generators for spectra and light curves (nicerl3-spect & nicerl3-lc)
  – Background models included in NICERDAS (3C50, SCORPEON, Space Weather)
    • Auto-downloader to retrieve space weather data
  – Improved screening
    • automated screening of individual noisy detectors
    • relaxed overall screening to allow more good exposure
• Existing data: will have to reprocess to take advantage of these features
Current Workflow: Difficult for Beginners

Level 1

NICER Data

nicerl2

Level 2

xselect
extractor
nicerarf
nicerrmf
Background estimation

Level 3

Spectrum
Responses & Bkg

Light Curve
New Workflow: Streamlined

Level 1

NICER Data

nicerl2 (improved screening)

Level 2

nicerl3-spect (extract, responses, bkg, syserr)

nicerl3-lc (extract)

Level 3

Spectrum

Responses & Bkg

Light Curve

NOTE: Existing user-designed workflows continue to work unchanged
Proposal Support Tools

• Please consult NICER Proposal page for more details about proposal content and submission

• Feasibility Simulation
  – HEASARC’s WebPIMMS for count rates
  – HEASARC’s WebSPEC for spectra
  – NICER Analysis Thread “Simulating a NICER Spectrum”
    https://heasarc.gsfc.nasa.gov/docs/nicer/analysis_threads/simulate/

• Summary: now is a great time to submit a NICER proposal!