

NICER Summer 2022 Proposal and Science Workshop

August 31-September 1, 2022

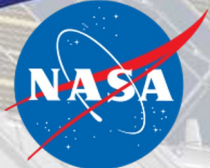
NICER

Neutron star Interior Composition Explorer

NICER Analysis and Calibration Summary for Proposers

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MIT KAVLI
INSTITUTE



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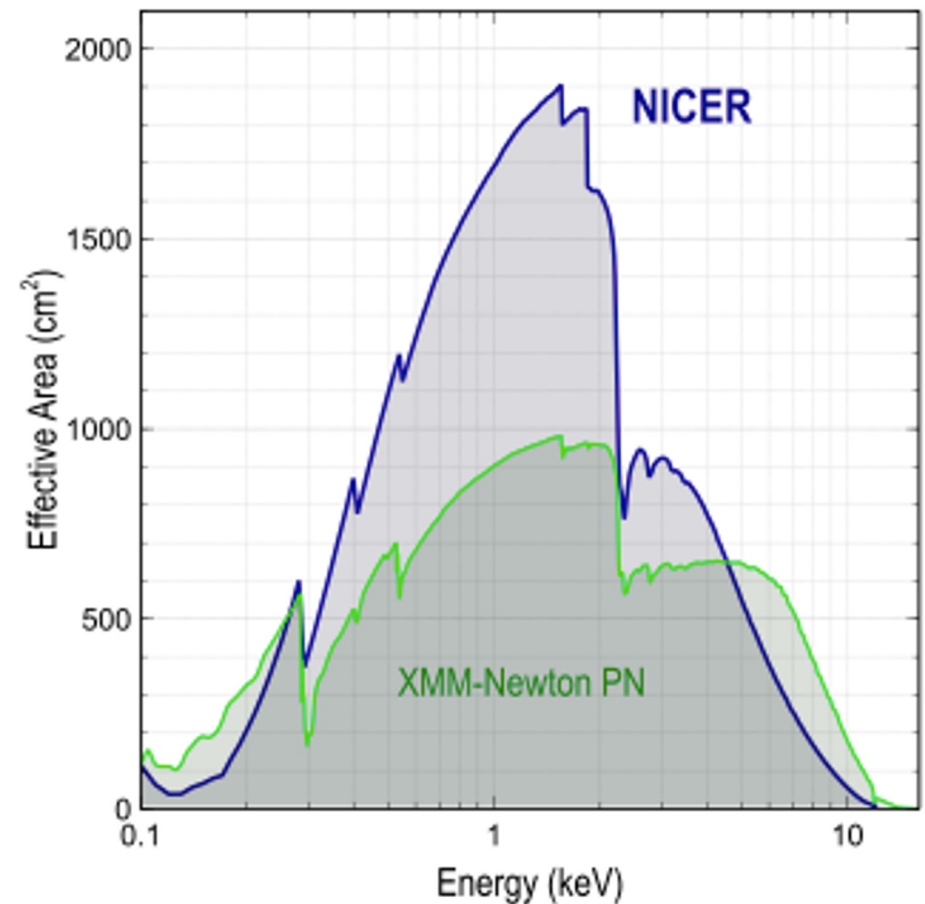
Summary Up Front

- 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>



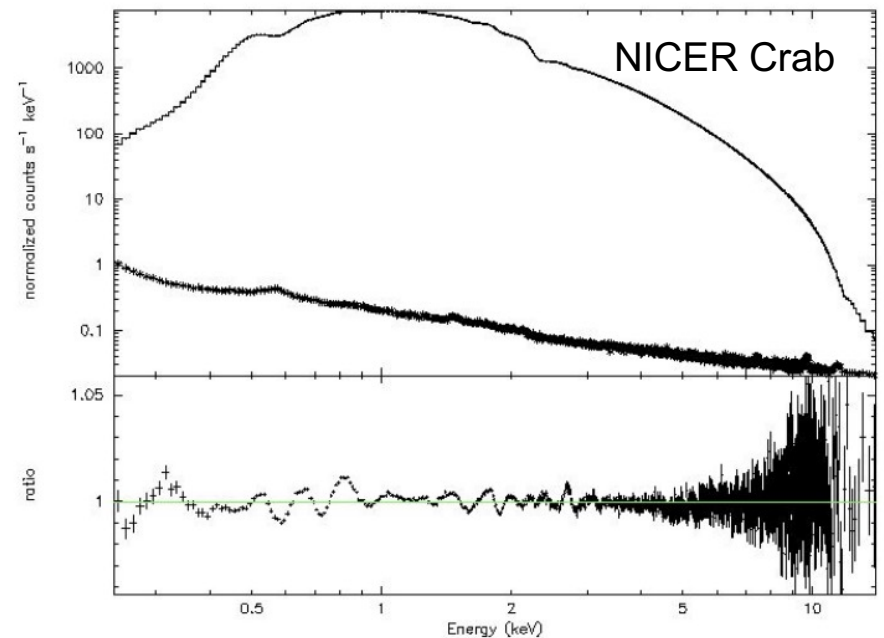
NICER Calibration Summary

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



NICER Calibration Status

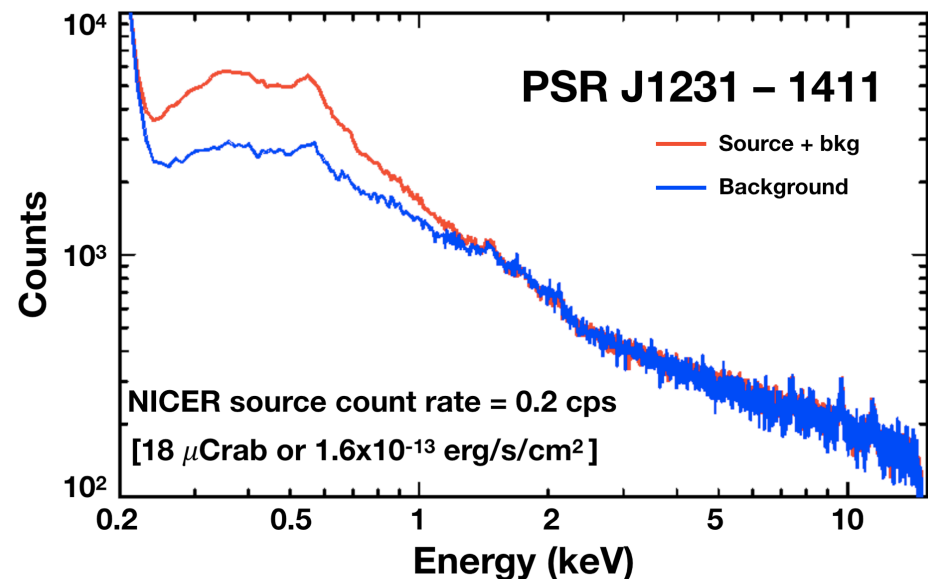
- NICER energy scale
 - After calibrations, all event files have “PI” column with common energy scale (“Pulse Invariant”)
 - **1 PI = 10 eV** (e.g. PI = 150 means $E = 1.50$ keV)
 - Estimated error ~ 5 eV (0-10 keV)
- NICER on-axis response
 - NICER calibrated against Crab nebula as a “smooth” continuum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

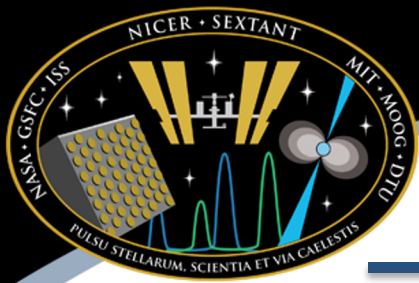




NICER Background Modeling

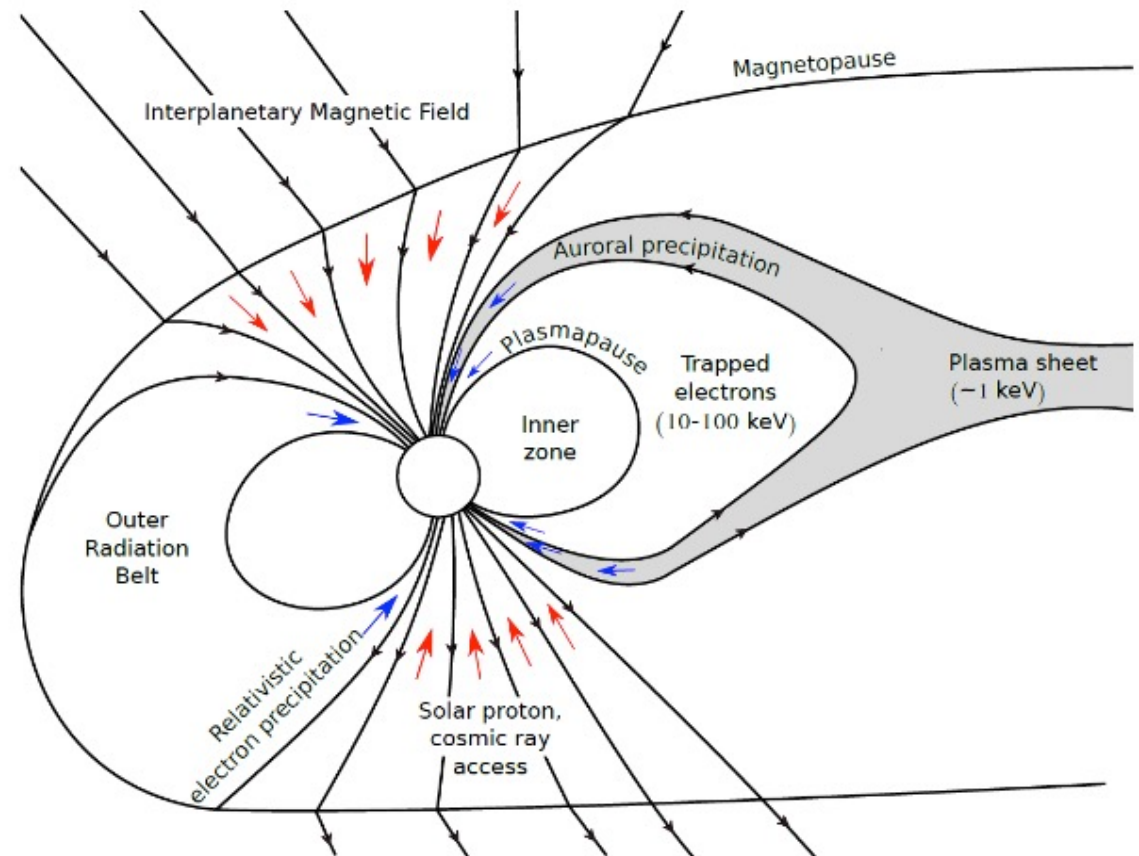
- NICER is an array of 52 single-pixel X-ray detectors so background must be modeled
- There are three contending background models available
 - 3C50 – popular
 - SCORPEON – new!
 - Space Weather – adjusts to geomagnetic Kp
- Models previously only available as separate download
- GOOD NEWS: all models will be included in forthcoming release in October
- Current performance: systematic errors ~50% remain



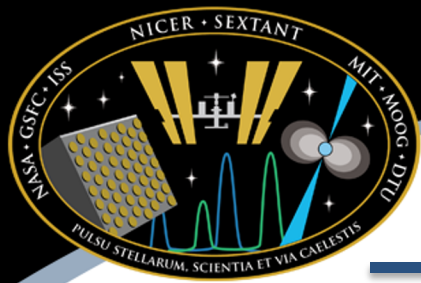


New SCORPEON Background Modeling

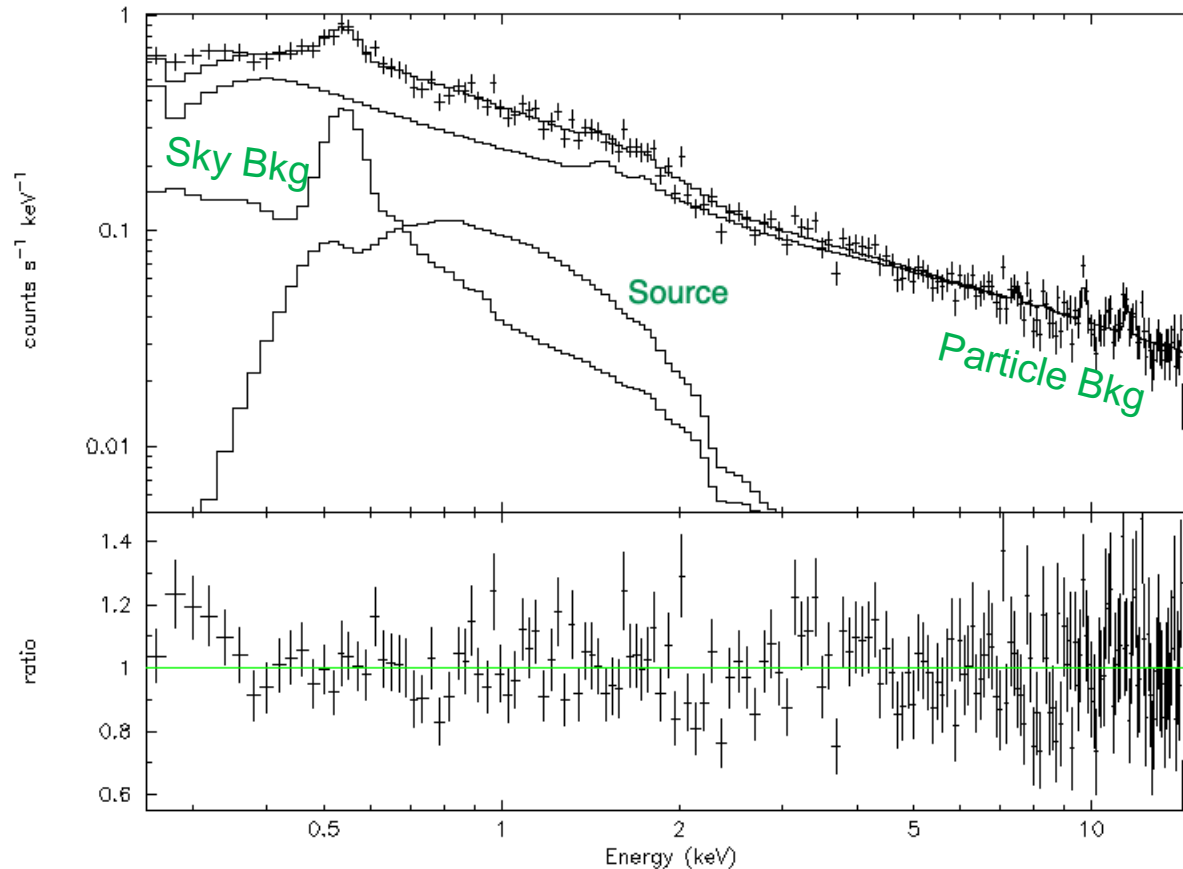
- Divide background into physically-motivated components
 - some less predictable than others
- SCORPEON provides a parameterized XSPEC model (not file) which can be adjusted along with your science parameters
 - No over/under-subtraction problems
 - Covariance between background and science uncertainties properly accounted
- Can also estimate a constant background file



*Thorne et al 1980
Tyssoy presentation*



NICER Example Faint Source



- Flux 1-sigma range is $0.87 - 1.15 \times 10^{-13}$ erg/s/cm² (~4 μ Crab; compare to ~300 μ Crab RXTE PCA sensitivity)
- New SCORPEON model is adjustable to get ultimate fit to your data



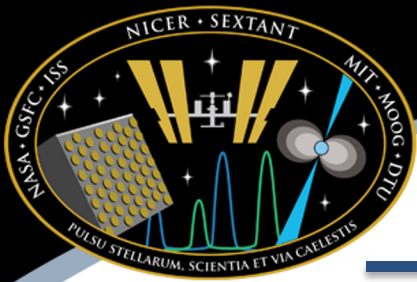
NICER Background Gotchas

- **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 (Ovii, Oviii, Ne ix, O 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

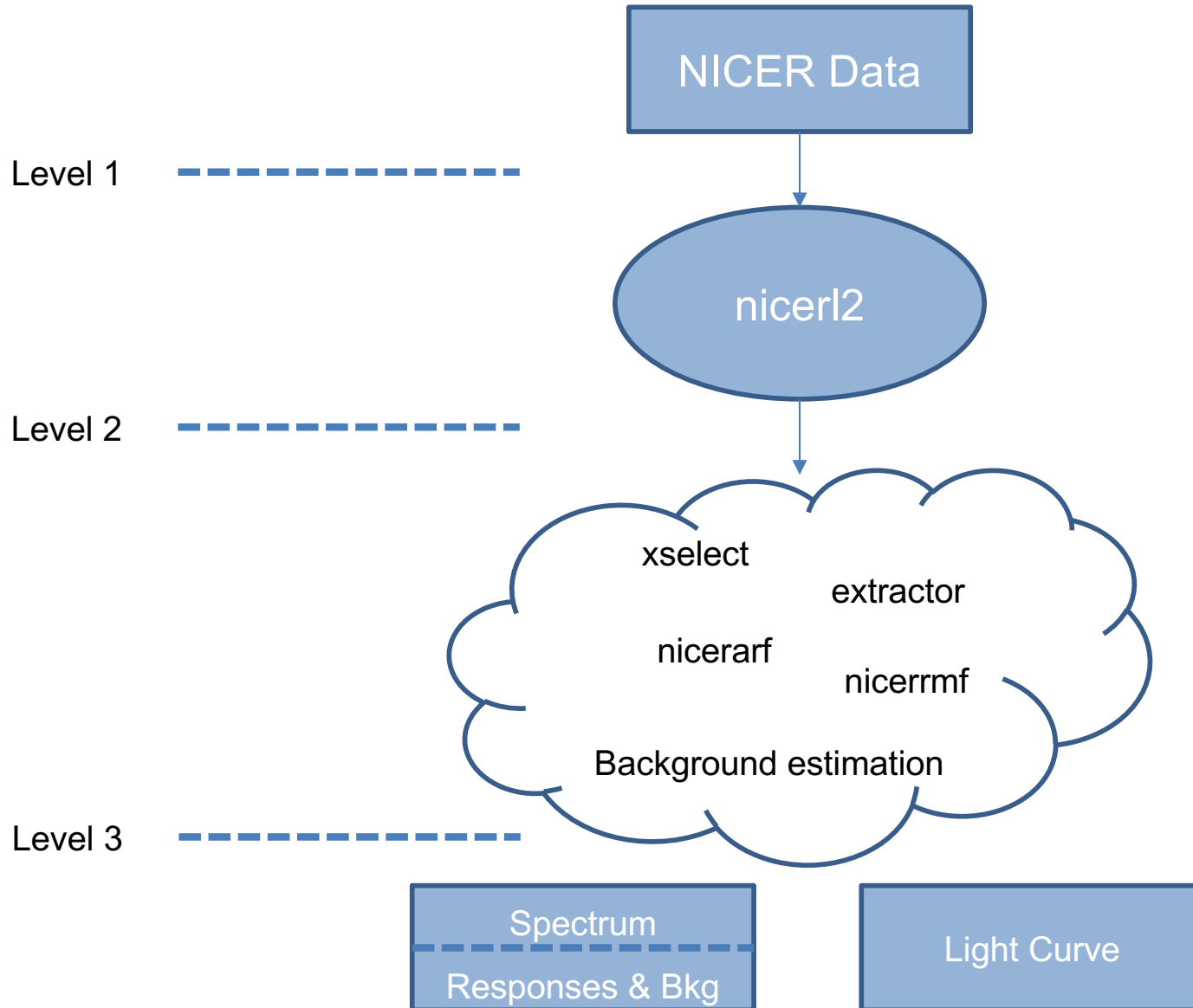


Next Software Release

- 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

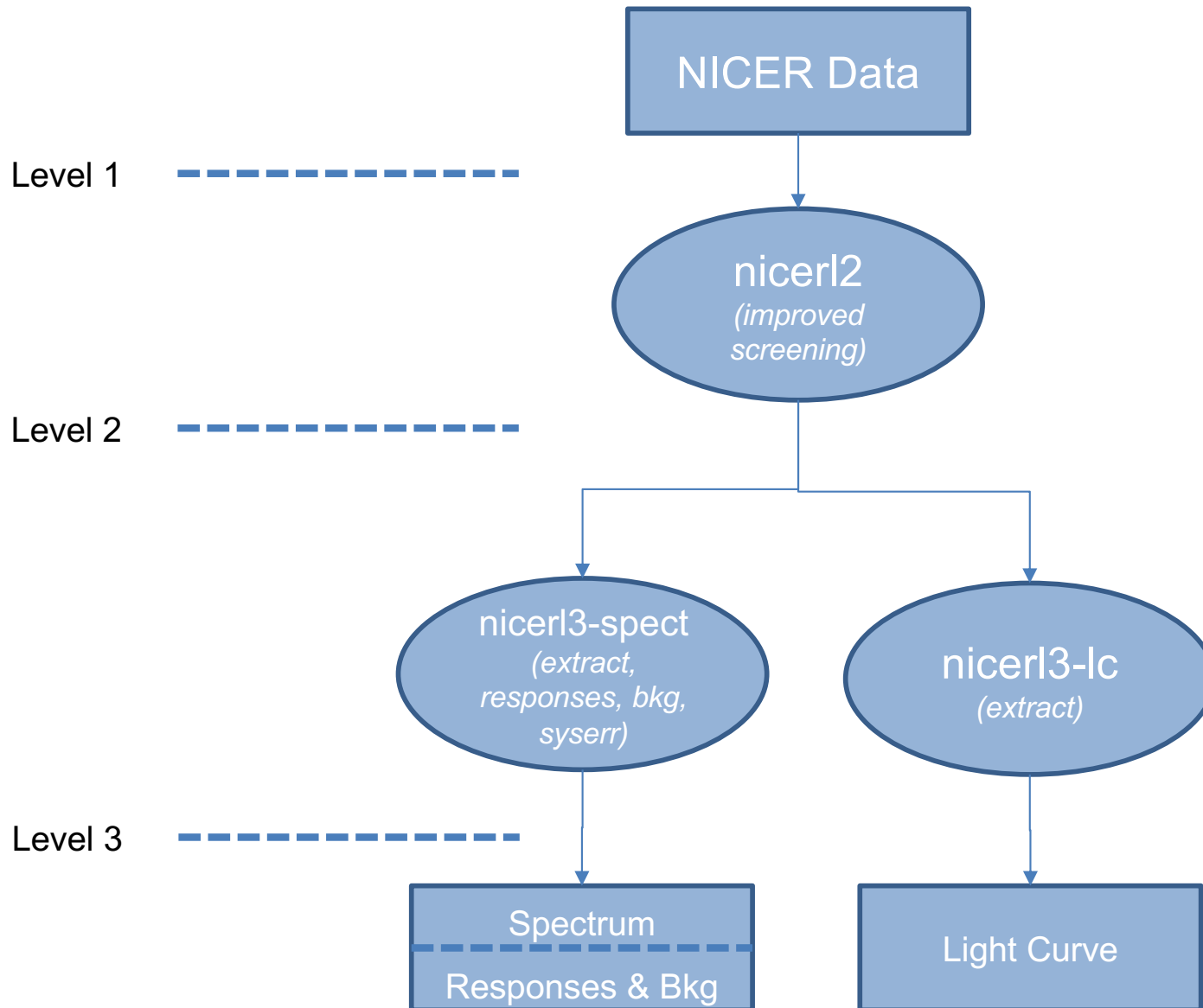


Current Workflow: Difficult for Beginners

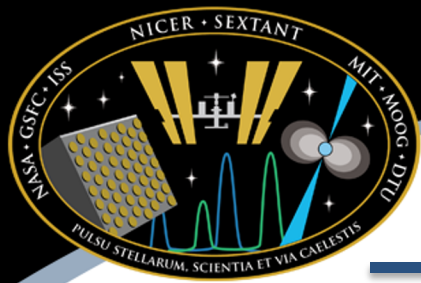




New Workflow: Streamlined



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!