IACHEC 2022

Virtual Workshop
May 2022

NICER
Neutron star Interior Composition ExploreR

Current and Future Tools for Modeling NICER Background

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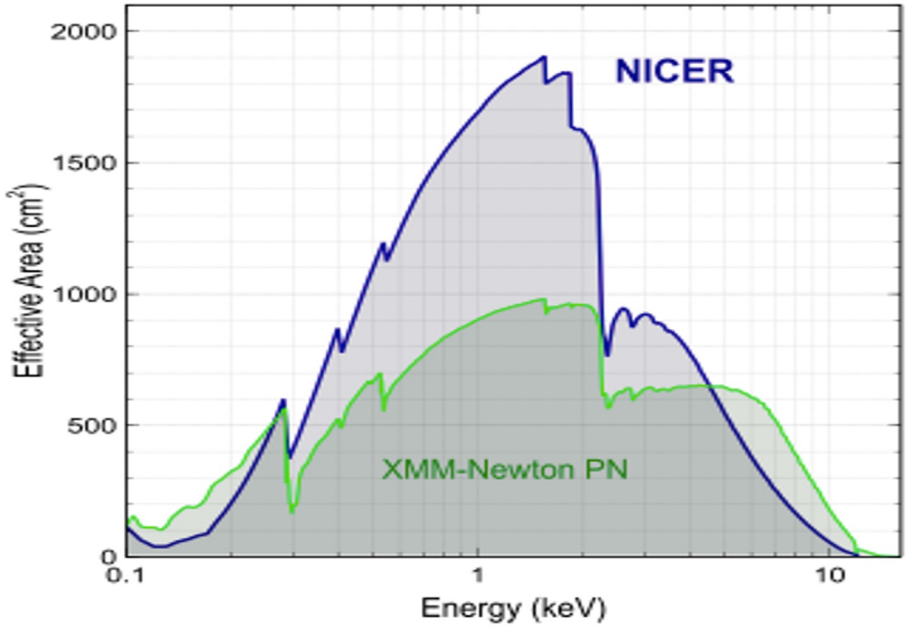
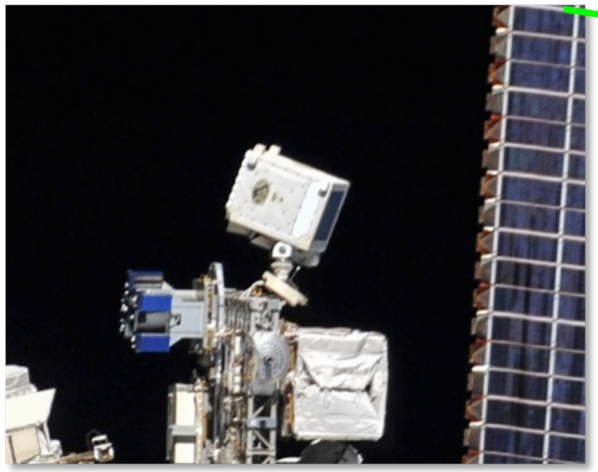
on behalf of NICER Team

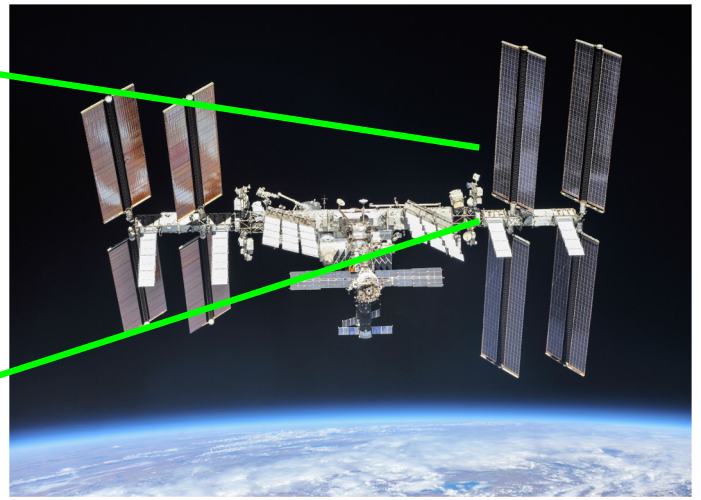
NASA GSFC MIT KAVLI INSTITUTE DTU BROAD REACH MOOG

What is NICER?

- Platform: International Space Station **(51.6° inclination)**
- Launch: June 2017
- Instrument: X-ray (0.2–12 keV) “concentrator” optics and silicon-drift detectors; GPS position & absolute time tagging
- Spectral band: 0.2–12 keV
  - 52 operating single-pixel silicon detectors
- Energy resolution: < 150 eV @ 6 keV
- Timing resolution: 100 nsec RMS
- **Non-imaging field of view**
  - 6 arcmin diam. (half-max)

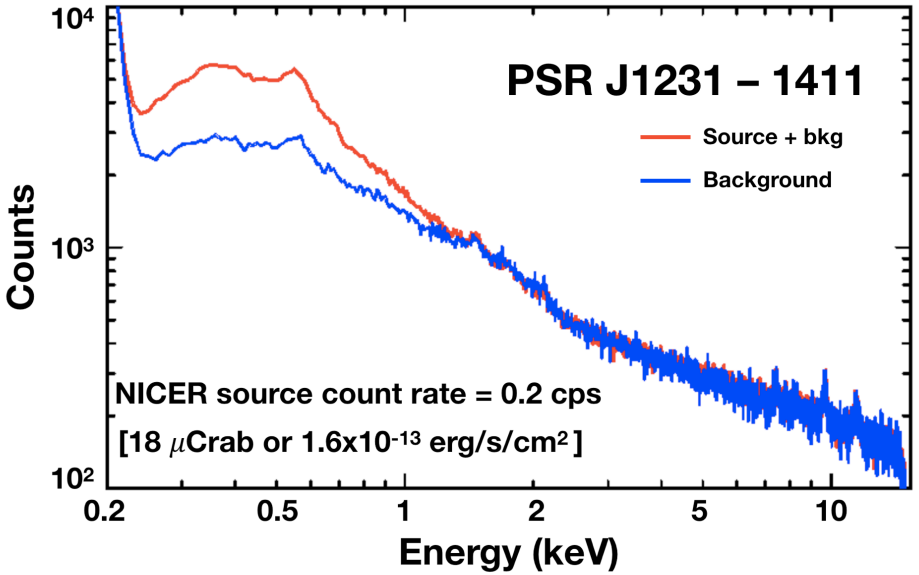




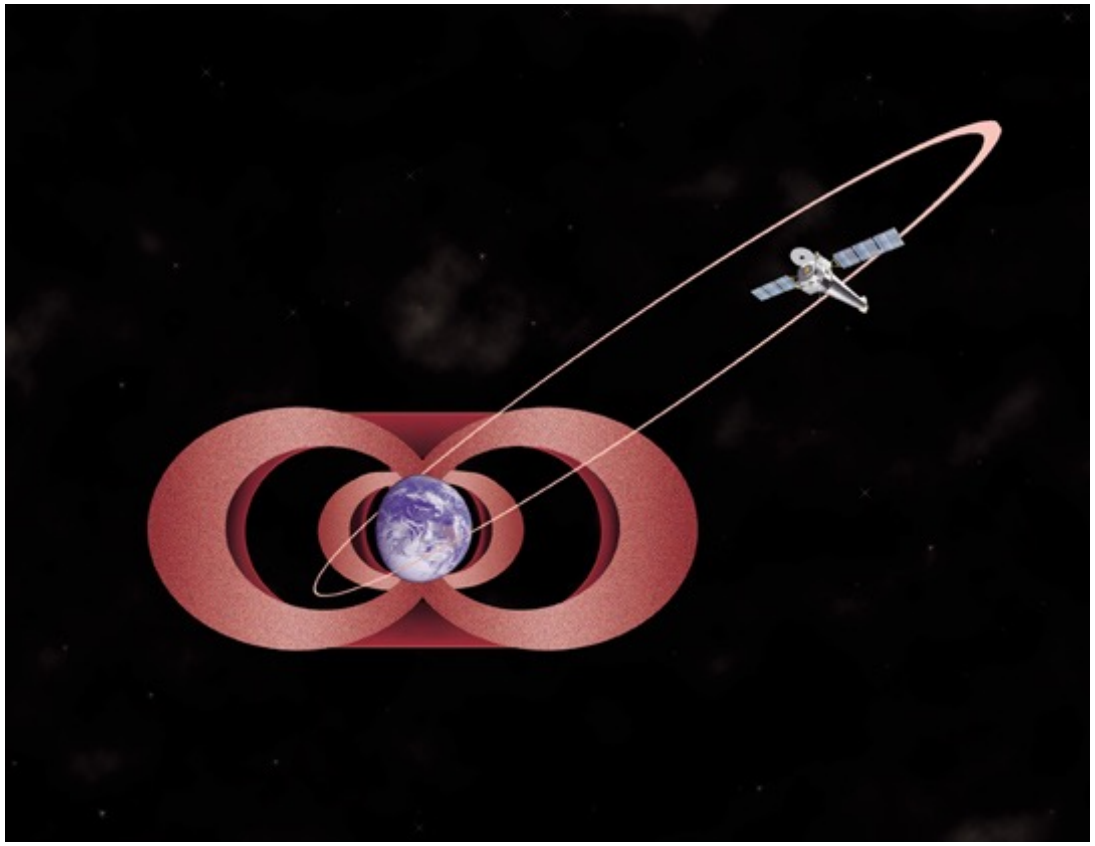


Understanding NICER Background

- NICER is a non-imaging instrument
  - Unlike CCD imagers, “off-source” background events are not available
- NICER is subject to several forms of background
  - Astrophysical (CXB, LHB, Halo, other diffuse or point-like sources in the FOV)
  - Non X-ray Backgrounds (SAA, Trapped Electrons, Precipitating Electrons, Geomag storms, Cosmic Rays)
- **These backgrounds must be modeled**, and there are several background modeling tools available
  https://heasarc.gsfc.nasa.gov/docs/nicer/tools/nicer_bkg_est_tools.html

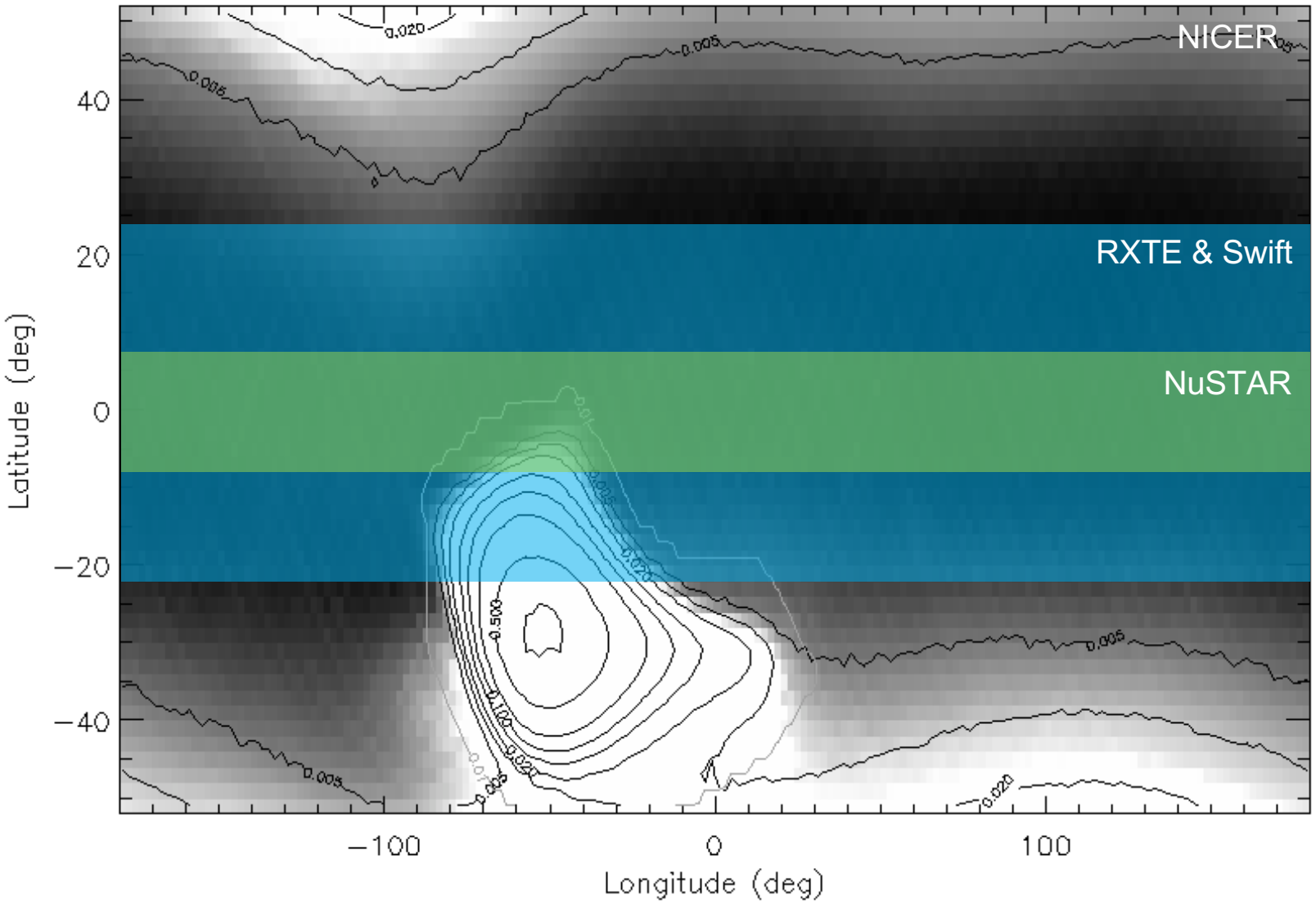


NICER Comparison to Other Missions (HEO)



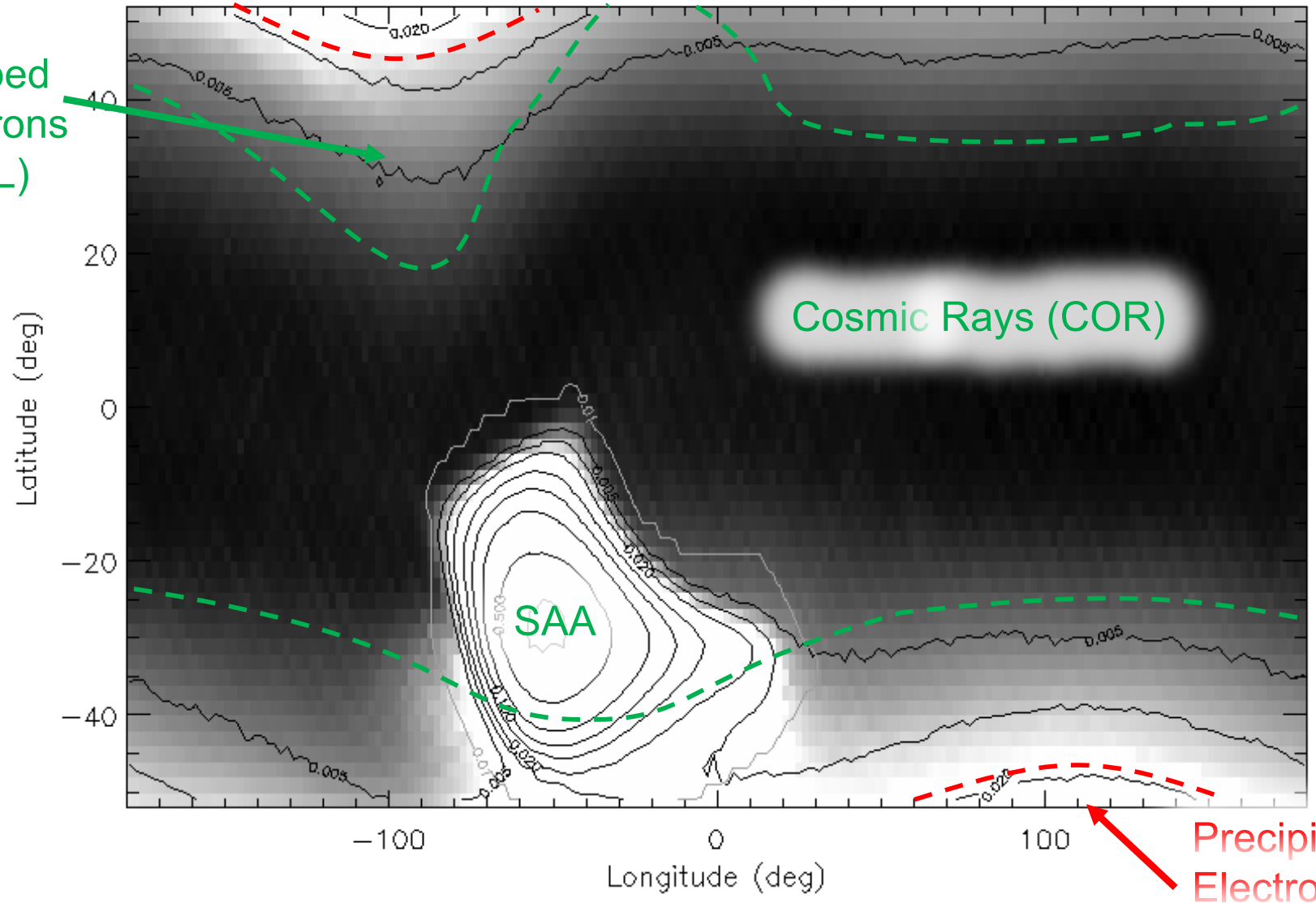
- Chandra, XMM, INTEGRAL: elliptical, high-altitude orbits
- NICER / ISS is circular low earth orbit (< 0.1 Re)

Comparison to LEO X-ray Observatories



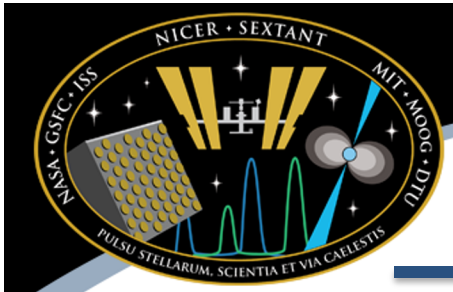
- NICER (ISS) inclination (51.5°) orbit samples greater variety of backgrounds

Geographic Overview of Dominant NICER Background Contributors



NICER Background Modeling Options

- Current
  - **"3C50"** – a library model based on NICER HK developed by Ron Remillard (NICER & MIT)
  - **"Space Weather"** – a library model based on geomagnetic quantities developed by Keith Gendreau and Michael Corcoran (NICER)
  - See "NICER Background Estimator Tools" webpage for more information https://heasarc.gsfc.nasa.gov/docs/nicer/tools/nicer_bkg_est_tools.html
- Future
  - **"SCORPEON"** – a template-based model in development by Craig Markwardt (NICER)
  - Machine learning techniques

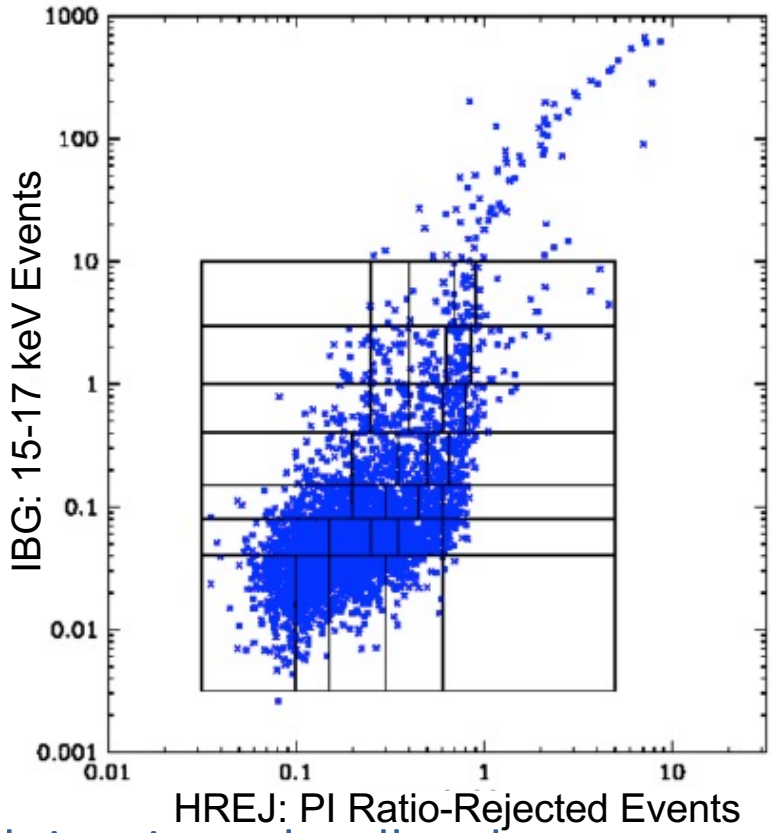


How to Use NICER Background Tools

- Currently available NICER background tools are separate add-on software packages, available from the NICER Background Estimator Tools web page
  - Users must install the tools separately
    - 3C50: more HEASoft-like command-line interface
    - Space Weather model requires Scientific Python
  - Users may also need to re-run the standard pipeline (nicerl2) to add model-specific columns such as geomagnetic Kp
- **Near-term goal for next NICER release is that these tools will be a standard part of NICER's software**

NICER 3C50 Model Example

- 3C50 is a library model that uses two non-source count rates
  - "IBG" 15-17 keV rate (out of optic passband)
  - "HREJ" (events whose slow- and fast-channel pulse heights do not match)
  - Divide this parameter space into cells and measure mean background in each cell based on dedicated background observations



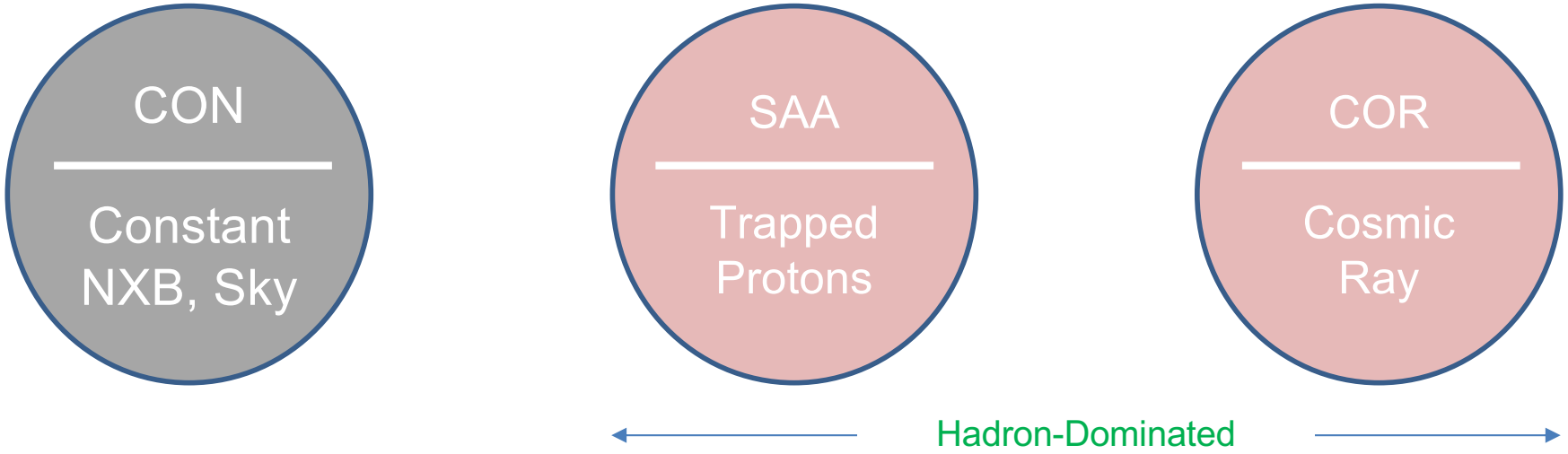
- For a given spectrum, 3C50 tool finds dwell time in each cell and constructs composite spectrum as a weighted sum of library spectra
- Example call

```
nibackgen3C50 rootdir='dataparentdir' obsid='2010100101' \
     bkgidxdir='mybackdir/bg_models_3C50' \
     bkglibdir='mybackdir/bg_models_3C50' gainepoch='2019'
```

Future Background Developments

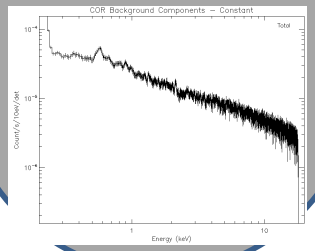
- Machine Learning techniques being attempted with some success (A. Zoghbi)
- SCORPEON: attempt to separate backgrounds into physically-motivated components
  - “template” which are parameterized by housekeeping values
  - Parameterized background, fittable in XSPEC, as well as fixed estimate for spectra & light curve
  - STATUS: in development & testing

Types of Background Components

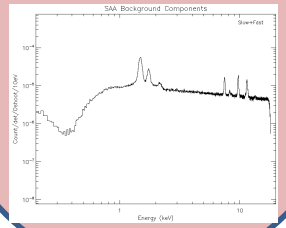


Types of Background Components

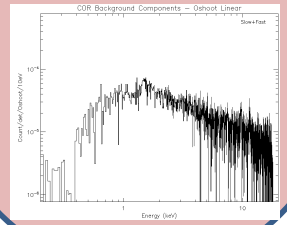
CON



SAA

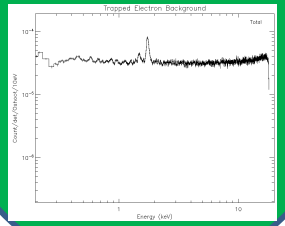


COR

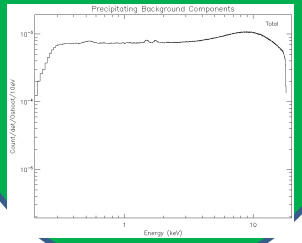


Hadron-Dominated

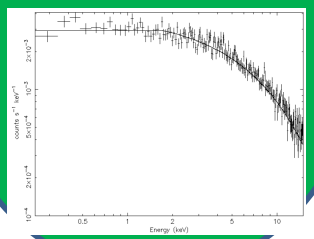
TREL



PREL

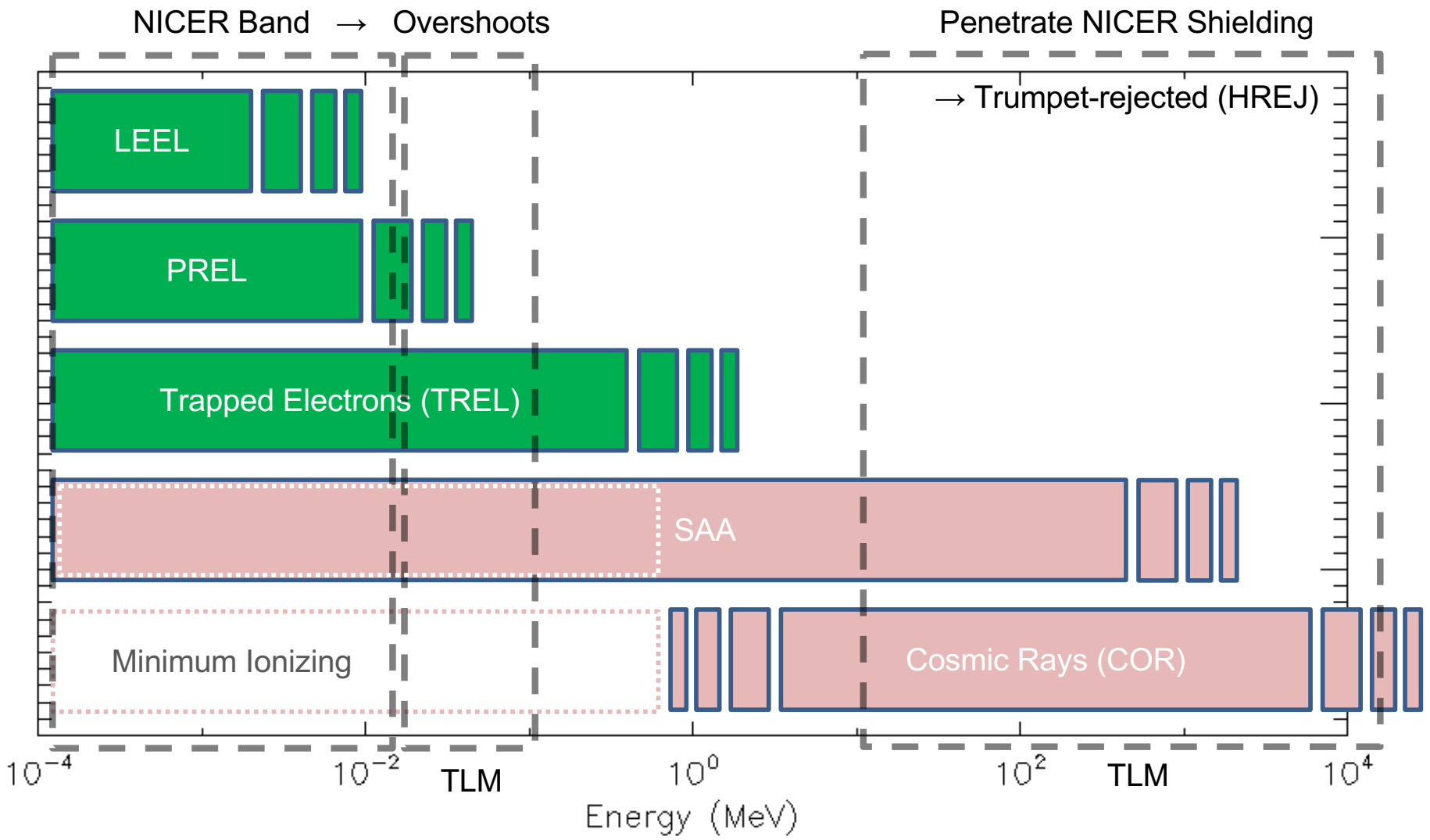


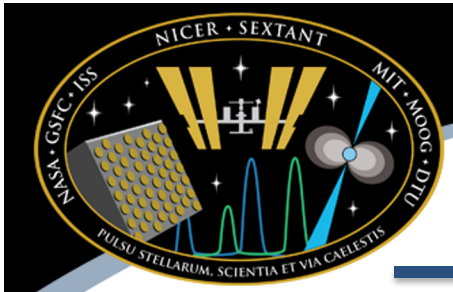
LEEL



Electron-Dominated

Energy Ranges of Components





Summary

- NICER background models are available today as separate downloads
  (See “NICER Background Estimator Tools” webpage for more information https://heasarc.gsfc.nasa.gov/docs/nicer/tools/nicer_bkg_est_tools.html)
- These estimator tools will be part of the next NICER standard software release
- There are new background modeling concepts in development