An Event-based Implementation of Keith's "Space-Weather" Model

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NICER GOF

Background on the Background

Background depends on:

- Sun angle (solar contamination; low energy “undershoots”)
    - increase in low energy background for low sun angles
- Charged particle environment (high energy; “overshoots”)
    - Space Weather environment:
        - COR_SAX
        - KP index (global geomagnetic activity index based on 3-hour measurements from ground-based magnetometers around the world; “planetarische Kennziffer der geomagnetischen Aktivit¤t” - Katja)
    - increase in charged particle background for low COR_SAX, high KP intervals (ISS latitude dependent - polar horns, SAA)
- Other dependencies?

SW Methods:

1. Generate a library of spectra for different parameter values
    - Interpolation can cause issues in predicted background

2. Create combined background events file from “blank sky”
    - extract spectrum (lightcurve) from event file

Caveats:

- KP only measured every 3 hours - varies on faster timescales
- Does not account for differences in cosmic background (generally soft X-ray)
- Coverage of relevant parameter space (SUN_ANGLE, COR_SAX & KP) uneven

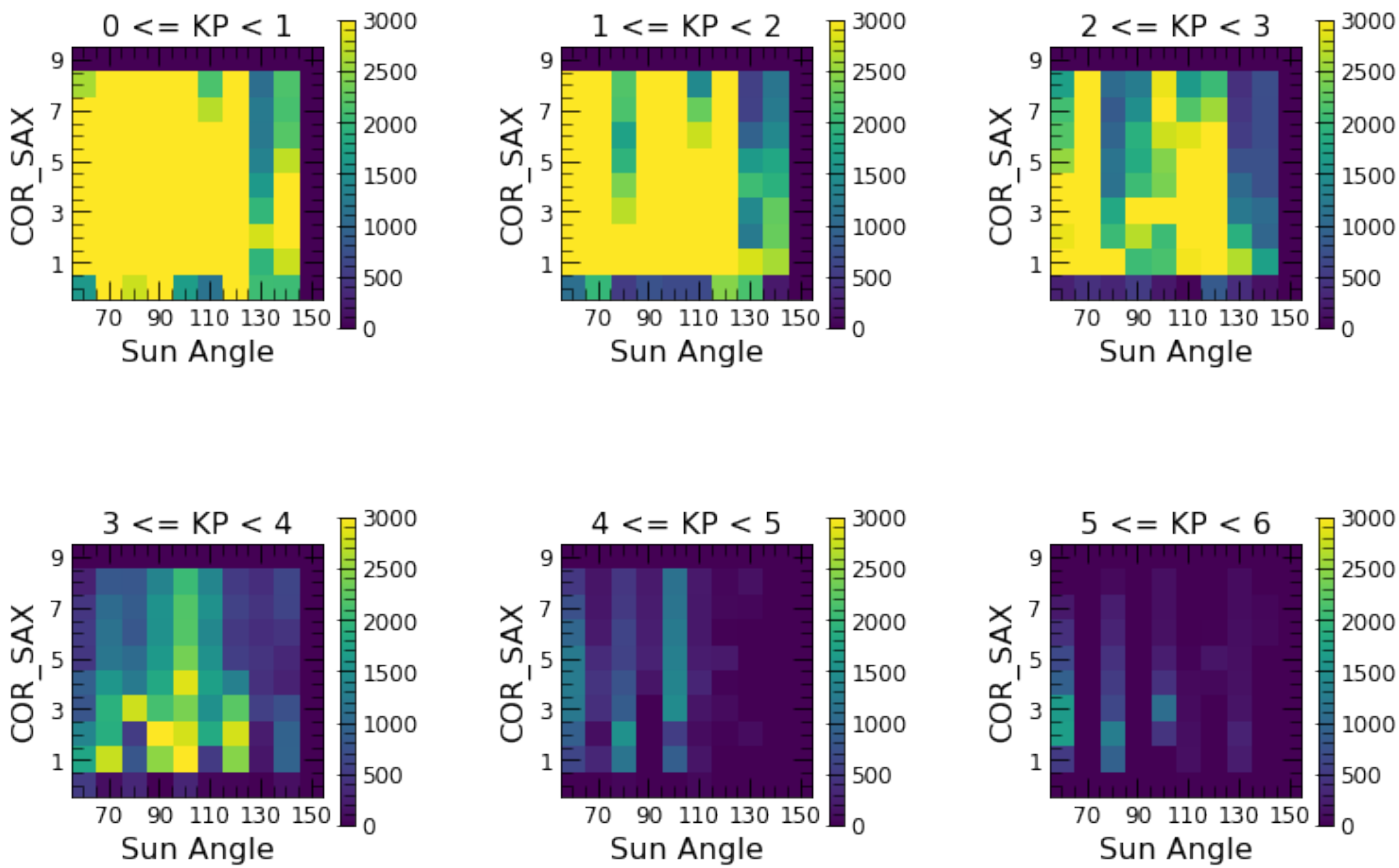
Background Fields

BKGD_RXTE_N fields: (N=1,2,3,4,5,6,8)

- > 1.5 Ms (now > 2.1 Ms)
- ~ 900 obsids (now 1442)
- high galactic latitude (|b| > 36^o)
- Known and unknown issues:
  - RXTE_7 = U Cep, eclipsing binary, 2.5 day period, coronally active). DO NOT USE
  - Other (unknown) variable sources?
  - variations in cosmic X-ray background from field to field

Current Parameter Distribution

Total time (seconds) in COR_SAX, SUN_ANGLE bins for 0<KP<6



Current Implementation

Keith: generated “enhanced background event file” combining data from all background fields (exc. #7) through November 2018

- “enhanced” bkg event files (with KP, COR_SAX, SUN_ANGLE included for each event based on event time)

https://heasarc.gsfc.nasa.gov/FTP/caldb/data/nicer/xti/pcf/30nov18targskc_enhanced.evt

Mike: Python package to generate background spectrum from

- For each GTI in source observation, generate distributions of KP, COR_SAX, SUN_ANGLE
- match the observed KP, COR_SAX, SUN_ANGLE distribution in the source observation with the enhanced bkg events, and accumulate spectrum from bkg events which match the source distribution
- (Craig:) created a FITS formatted file of the Potsdam KP data (updated 8x per day):
    - https://heasarc.gsfc.nasa.gov/FTP/caldb/data/gen/pcf/geomag/kp_potsdam.fits
    - https://heasarc.gsfc.nasa.gov/FTP/caldb/data/gen/pcf/geomag/kp_noaa.fits

    (Potsdam data has finer resolution of KP)

Software Distribution

https://heasarc.gsfc.nasa.gov/docs/nicer/analysis_threads/background/

Download tar file package (current version v0p6):

https://heasarc.gsfc.nasa.gov/docs/nicer/tools/nicer_bkg_estimator_v0p6.tar.gz

- Untar and put in your `$PYTHONPATH` (if you don't have `$PYTHONPATH` defined, you'll need to define it)

- Contains

  - python code (`nicergof.bkg`) to run within a python workflow
  - `bin` directory with scripts (`niaddkp` and `nibkgestimator`) which can be run from the command line
  - test data directory
  - jupyter notebook (:) & other documentation

Usage

2 Steps:

- add KP values to the mkf file from the observation
- determine KP, COR_SAX and SUN_ANGLE from the observation, then extract matching events from the enhanced background events file and create spectrum

EXAMPLE 1: Command-line execution

```
   After placing the executables niaddkp and nibkgestimator in your $PATH with execcute 
permission,
    you can create a nicer background

    a) create the mkf3 file:
        % niaddkp testdata/1200040103/auxil/ni1200040103.mkf2

    b) create the background spectrum:
        % nibkgestimator testdata/test.pha testdata/1200040103/auxil/ni1200040103.mkf3
```

This will create a HEASARC-formatted FITS background PHA file (with .pha replaced by _bkg.pha, i.e. the background file for "./test.pha" is "./test_bkg.pha").

Usage (see the Readme)

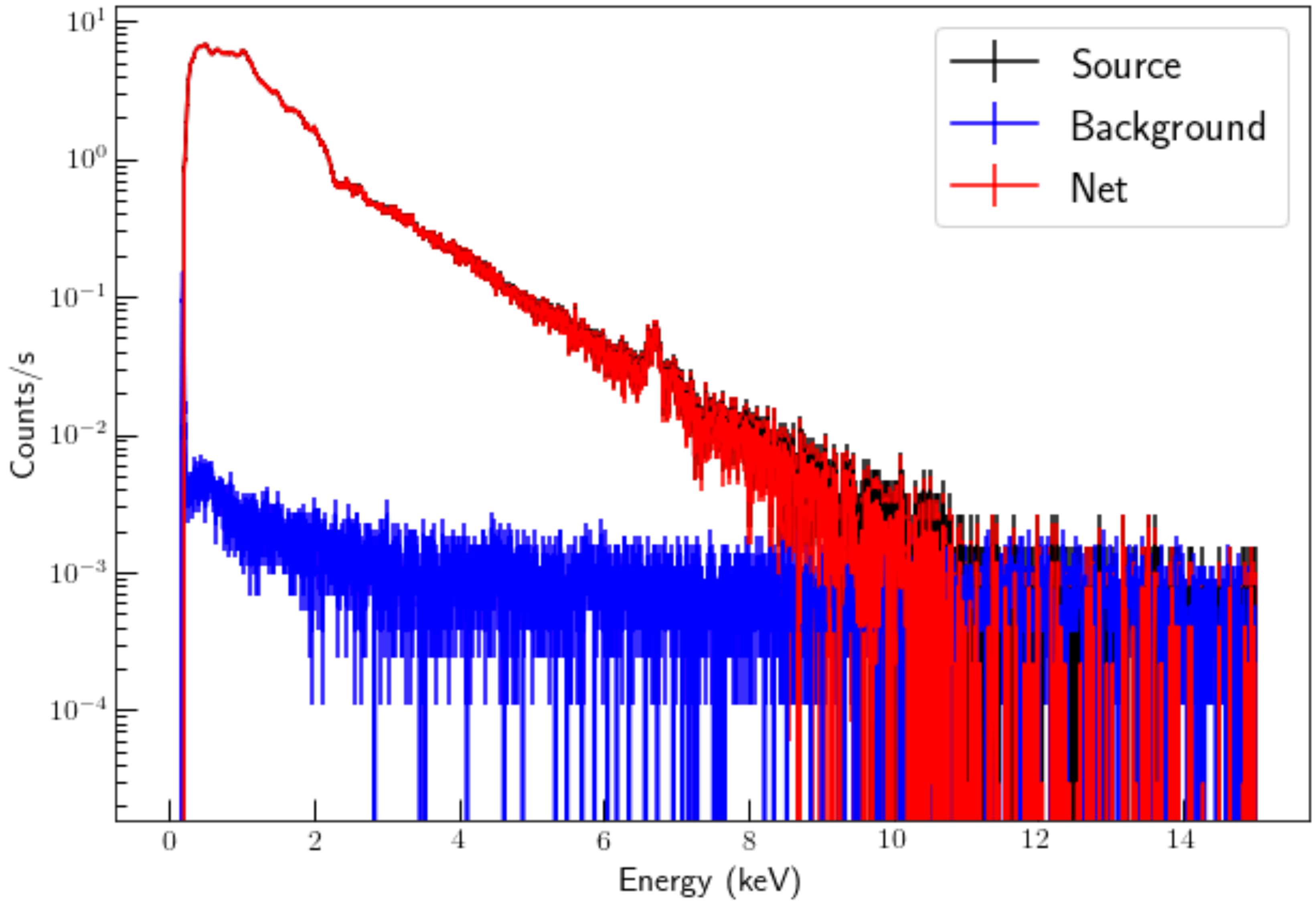
EXAMPLE 2: Python usage

```
    1) import the package:

        >>> from nicergof.bkg import bkg_estimator as be

    2) update the .mkf2 file to include the KP values:

        >>> status = be.add_kp("testdata/1200040103/auxil/ni1200040103.mkf2")

    This will create a ".mkf3" file in the 11200040103/auxil directory

    3) use the mk_bkg_spec_evt function to create the background spectrum:

        >>> bkg_chan, bkgspectot, btotexpo = be.mk_bkg_spec_evt('testdata/test.pha', 
mkf3file='testdata/1200040103/auxil/ni1200040103.mkf3')
```

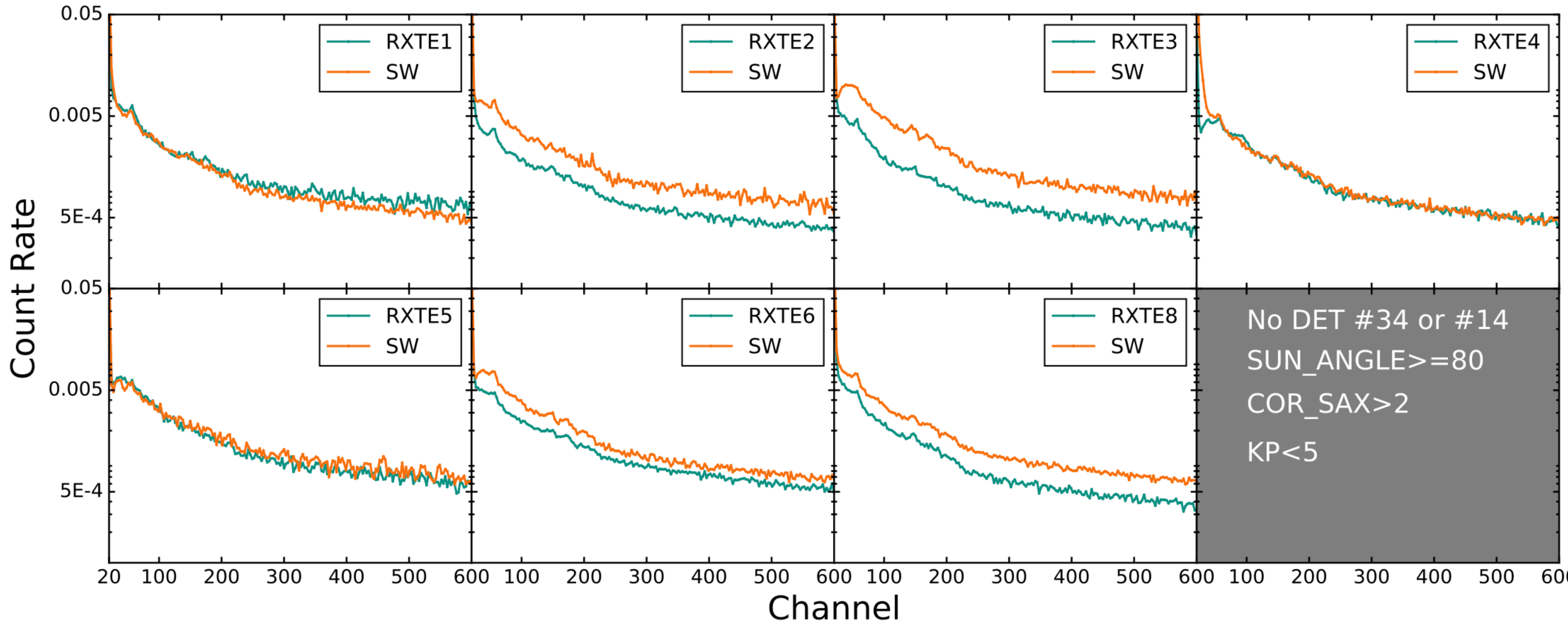
This will create a HEASARC-compliant background PHA file (with .pha replaced by _bkg.pha, i.e. the background file for "./test.pha" is "./test_bkg.pha"). It will also return the background channels, spectrum and exposure as the python arrays bkg_chan, bkgspectot, btotexpo, which can be plotted or manipulated using standard python tools.

Unit Test: Sigma Gem

```
bkg_chan, bkgspec_tot, bexpotot = be.unit_test(pha='test.pha', obsid=1200040103,root='testdata', numfpms = 52,
        bevt="https://heasarc.gsfc.nasa.gov/FTP/caldb/data/nicer/xti/pcf/30nov18targskc_enhanced.evt")
```



Comparison to Reality: Caution



Courtesy Renee Ludlam

Significant overestimates for some background fields

- variations within GTIs for a single field
- discrepancies from combining the events from different fields in the event library?
- better matching of cleaning criteria required?
- exclusion of “hot” FPMs (14 & 34)

Next Steps

- Create new enhanced bkg events file with OBSIDs/field names for issue tracking
- allow field selection in background estimates to provide estimate of systematics
- allow for future gain updates & other calibration updates
- Improve efficiency of code
- Provide reliable background lightcurve estimator

Unadvertised Special

Creating BKG lightcurves

The nicergof.bkg package also includes a (PRELIMINARY) lightcurve background estimator

```
mk_bkg_lc_evt(srclc, mkf3file)
```

which can be run from the python command line

Inputs:

- source lightcurve (extracted with `xselect`, for example)
- source mkf file (with KP column added - using `niaddkp`, for example)

Method

- Assumes each time bin is its own GTI and calculates the predicted background from SW conditions

Output: A background lightcurve FITS file

Unadvertised Special

Creating BKG lightcurves: Example

```
In [5]: from nicergof.bkg import bkg_estimator as be

In [6]: be.mk_bkg_lc_evt?
Signature:
be.mk_bkg_lc_evt(
    srclc,
    mkf3file,
    bevt='https://heasarc.gsfc.nasa.gov/FTP/caldb/data/nicer/xti/pcf/30nov18targskc_enhanced.evt',
    verbose=True,
    clobber=True,
    chanrange=None,
)
Docstring:
DEVELOPMENT VERSION OF A lightcurve background generator
:param srclc: source lightcurve file
:param mkf3file: enhanced mkf file (with KP values added)
:param bevt: background events file
:param verbose: if True print diagnostic messages
:param clobber: if True overwrite existing file
:param chanrange: 2-element list giving the upper and lower channel range
:param nrows: if None, use all rows, otherwise use rows 0 to nrows in GTI table
:return: bklctab, an astropy table of background times and rates; also writes a HEASARC-formatted
RATE fits file
File:      ~/software/github/nicergof/bkg/bkg_estimator.py
Type:      function
```

Unadvertised Special

Creating BKG lightcurves: Example

```
In [13]: be.add_kp('3591011901/auxil/ni3591011901.mkf2')
In [17]: bklctab = be.mk_bkg_lc_evt('ni3591011901_0mpu7_cl.lc', mkf3, bevt=bevt)

           Writing ni3591011901_0mpu7_cl_bkg.lc
```

Alpha release: Needs testers and testing!

Advertised Special

SciServer

Sciserver (www.sciserver.org) is a collaborative science platform for server-side analysis with extremely large datasets

The HEASARC has partnered with SciServer to host entire HEASARC archive along with HEASoft (6.28), python, Jupyter, JupyterLab and other tools

Users can set up an account on SciServer and have instant (local) access to all NICER data (and other data - Chandra, XMM, NuSTAR, ROSAT, MAXI…) for large (or small) data processing and analysis tasks

see https://heasarc.gsfc.nasa.gov/docs/sciserver/ for instructions on setting up an account.

See David Espinoza’s talk Thursday afternoon for an example of NICER analysis with SciServer