Using NDSLIN in EPIC-pn as a proxy for the QPB

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EPIC-pn discarded lines

Number of rejections of a CCD Row or Column (default) due to MIPs (minimum ionizing particle)
- onboard rejection (eFF, FF, LW)
  DLI files present in the odf, per CCD
- software (SAS) rejection (eFF, FF, LW, SW, TI, BU)

Value of discarded lines (NDSLIN) integrated over an exposure
- DLIODF column rejection in DLIMAP extension
- DLISAS column rejection in DLIMAP extensión

Since SASv17 discarded lines available per CCD sampled over 20 frames

Aim

Remove Quiescent Particle Background (QPB) in a given science observation: images and spectra

How

Use full FWC repository for a given EPIC-pn mode (FF)
Use NDSLIN as a proxy to estimate the level of quiescent particle induced background rate
What is the Quiescent Particle Background?

Internal background which is the result of the interaction of High Energy particles (cosmic rays) with the structure surrounding the detectors and the detectors themselves

continuum + instrumental fluorescence

This can be monitored during observations with the filter in the CLOSED position.
What is Filter Wheel Close (FWC) data?

Data gathered from calibration observations with the filter wheel in the closed position.

Repository released in September 2006: stacked collections of FWC data available for MOS (FF) and pn (all modes)

The repository is maintained by the SOC, is updated on a yearly basis and reanalyzed continuously with latest SAS version.

https://www.cosmos.esa.int/web/xmm-newton/filter-closed
What we need to know about the Quiescent Particle Background

Internal background is **Spatial** and **Temporal** dependant

How about the spectrum, is it **Spatial** and **Temporal** dependant?

Do NSDLIN correlate with background rates?
Based on the analysis of 552 **EPIC-pn** science observations taken in **Full Frame** (FF) mode (analysis with SASv17). The observations are randomly chosen over 16 years (2002-2018).

**EPIC-pn Event file including NDSLIN information**

12 extensions **HKAUX01-HKAUX12** (one per CCD)

DSLIN values stored per CCD, but equal within the CCDs in a quadrant

One value every 20xFrametime, -1.46 secs

(FF frametime 73 msec)
NDSLIN vs Time for one observation

Four quadrants represented (CCD#1, CCD#4, CCD#7 and CCD#10)

Obsid. 0782840801

Some Time values set to Null
Four quadrants represented (CCD#1, CCD#4, CCD#7 and CCD#10)

Covered Period:

Rev. 400 – 2002-02-13

Rev. 3369 – 2018-05-02
Mean NDSLIN vs Time

Four quadrants represented (CCD#1, CCD#4, CCD#7 and CCD#10)

Covered Period:

Rev. 400 – 2002-02-13

Rev. 3369 – 2018-05-02

Mean value across each observation
STD NDSLIN vs Time

Four quadrants represented
(CC#1, CC#4, CC#7 and CC#10)

Covered Period:

Rev. 400 – 2002-02-13
Rev. 3369 – 2018-05-02

STD within each observation
(red: STD > 60)
NDSLIN as a proxy for instrumental noise
Analysis of EPIC-pn FF FWC Data

40 EPIC-pn FF FWC exposures

2001-2018

SASv17

Background Filtering of FWC Data (GTI)

#XMMEA_EP && (PI in [200:10000] && PATTERN==0)

100 sec bin Lightcurve

Derive Mean Rate and Error from fit to GTI Rates
FWC: Images / NDSLIN LC / Flaring Background LC

Images: red 8.5-12 keV; green 2-7 keV; blue 0.2-1 keV
NDSLIN LC: rebin to match FL Background LC
FL Background LC: 100 sec bin, XMM_EP && 0.2-10. keV

For each exposure:
Derive Mean Rate and Error from fit to GTI BKG Rates
Derive Mean NDSLIN and Error from fit to GTI BKG Rates
Mean Rate: 2.950 +/- 0.002 cts/sec
RedChi2: 15.813

Mean NDSLIN: 168.122 +/- 0.069
RedChi2: 65.187
Mean BKG Rate = 0.0154 * Mean NDSLIN + 0.3431

(*) Remove points where RedChi2 of fit to Rates > 1.5
Is the FWC spectrum stable with time?
FWC: Images / Spectrum

For each exposure:
Derive HR (2.5-5.0 keV)/(0.4-0.8 keV)

Images: red 8.5-12 keV; green 2-7 keV; blue 0.2-1 keV
FWC Spectra: 0.4-10 keV in 10 eV channels
FLAG==0 and pattern <= 4
Each spectra normalized to exposure time
Mean FWC Spectrum

Normalized Counts

PN
FF

Normalized to counts in 3-7 keV

(*) Mean +/- sqrt(Var)

RMS FWC Spectrum

% Variation

20%
10%

Normalized Counts

Energy (eV)

Energy (eV)

Energy (eV)

Energy (eV)
Average Spectra at 3 Time Epochs

PN
FF

< rev.1200
rev.1200 - rev.2100
> rev.2100

(*) Ratio of epoch spectra / mean spectrum

Change of intensity with time (?)

8 keV
Application to Science data to correct images and spectra
Use science data to define GTI periods from background LC

\[(100 \text{ sec bin, XMMEA_EP \&\& (PI in [200:10000] \&\& PATTERN==0))}\]

Use science data to derive NDSLIN LC within GTI as defined from background LC,

Derive \textit{Mean NDSLIN} \textsubscript{SCIENCE} within GTI

With Mean NDSLIN \textsubscript{SCIENCE} apply the following relation (derived from the FWC data):

\[
\text{Mean BKG Rate} \textsubscript{SCIENCE} (\text{cts/sec}) = 0.0154 \times \text{Mean NDSLIN} \textsubscript{SCIENCE} + 0.3431 \quad \text{EPIC-pn FF}
\]

\[
\text{Scale Factor} \textsubscript{FWC} = \frac{\text{Mean BKG Rate} \textsubscript{SCIENCE} \times \text{Exposure Time} \textsubscript{SCIENCE}}{\text{Mean BKG Rate} \textsubscript{FWC} \times \text{Exposure Time} \textsubscript{FWC}}
\]

\[
\text{Mean BKG Rate} \textsubscript{FWC} = 2.950 \pm 0.002 \text{ cts/sec}
\]

\[
\text{Exposure Time} \textsubscript{FWC} = 5.97e+05 \text{ sec}
\]
0744100501

12.1 ksec

GTI

FWC Cor.

Unfiltered

GTI Filtered

FWC Cor.

Out-of-Field Spectra
Scale Factor 0.0181

In-Field Spectra
Scale Factor 0.0181
Conclusions
As of SASv17 NDSLIN is available on a time scale of 20 x frametime

NDSLIN provides a good trace of the Quiescent Particle Background (QPB)

There is a tight correlation between the QPB rates and NDSLIN as seen in Filter Wheel Close Data

The mean value of the NDSLIN across a science observation derived from periods of GTI can be used to determine the level of QPB to be removed from the science observation: images and spectra
Extra Material
Mean Rate: 2.820 ± 0.002 cts/sec
RedChi2: 10.636

Mean NDSLIN: 433.770 ± 0.176
RedChi2: 36.979
(*) Remove points where RedChi2 of fit to Rates > 1.5

Mean BKG Rate = 0.0055 * Mean NDSLIN + 0.3945

(FF: Mean BKG Rate = 0.0154 * Mean NDSLIN + 0.3431)

(*) Remove points where RedChi2 of fit to Rates > 1.5
SAS evqpb

vs NDSLIN

GTI Filtered

FWC Cor.

Out-of-Field Spectra

Scale Factor 0.0627

NDSLIN