EPIC-pn re-distribution matrix
an update

Frank Haberl

1. Energy resolution at Fe-K energies
2. Re-distribution at low energies
3. Future work

EPIC calibration meeting, ESAC, 2010 March 23-24
1. Energy resolution: On-board calibration source

Single-pixel events
CCD 4, RAWY > 180

592 spectra, revolutions 45-1640
Combined into 27 blocks
Line parameters linked within 1 block
Model powerlaw+gauss+gauss (Mn)
Model powerlaw+gauss (Al)

Current response
On-board calibration source

Single-pixel events
CCD 4, RAWY > 180

592 spectra, revolutions 45-1640
Combined into 27 blocks
Line parameters linked within 1 block
Model powerlaw+gauss+gauss (Mn)
Model powerlaw+gauss (Al)

New response with increased FWHM
On-board calibration source

Single-pixel events
CCD 4, 10 < RAWY < 50

592 spectra, revolutions 45-1640
Combined into 27 blocks
Line parameters linked within 1 block
Model powerlaw+gauss+gauss (Mn)
Model powerlaw+gauss (Al)

Current response

New response
The SNR N132D

Single-pixel events
Model powerlaw+gauss
Current response
Model: egde*pow + gaus + gaus + gaus + gaus

<table>
<thead>
<tr>
<th>Element</th>
<th>Energy (keV)</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe I</td>
<td>6.424</td>
<td>( E_1 = E_3 - 0.275 )</td>
</tr>
<tr>
<td>Fe XXV (f)</td>
<td>6.634</td>
<td>( N_1 )</td>
</tr>
<tr>
<td>Fe XXV (i)</td>
<td>6.699</td>
<td>( E_2 = E_3 - 0.065 )</td>
</tr>
<tr>
<td>Fe XXV (r)</td>
<td>6.699</td>
<td>( N_2 = N_3 \cdot 0.441 )</td>
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<tr>
<td>Fe K-edge</td>
<td></td>
<td>( E_3 )</td>
</tr>
<tr>
<td>Fe XXV Heβ</td>
<td>7.881</td>
<td>( E_4 )</td>
</tr>
<tr>
<td>(blend with Ni XXVII f/i/r)</td>
<td></td>
<td>( N_4 )</td>
</tr>
</tbody>
</table>

\( \sigma_1 = \sigma_2 = \sigma_3 = \sigma_4 \)
## Eta Carinae

Model: egde*pow + gaus + gaus + gaus + gaus

<table>
<thead>
<tr>
<th>Element</th>
<th>Energy (keV)</th>
<th>Equation</th>
<th>N1</th>
<th>N2</th>
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<tbody>
<tr>
<td>Fe I</td>
<td>6.424</td>
<td>(E_1 = E_3 - 0.275)</td>
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<td></td>
<td>(E_4)</td>
<td>(N_4)</td>
</tr>
</tbody>
</table>

### Results

<table>
<thead>
<tr>
<th>FF mode:</th>
<th>SW mode:</th>
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</thead>
<tbody>
<tr>
<td>2000-07-26</td>
<td>2003-06-08</td>
</tr>
<tr>
<td>Rev 0115</td>
<td>Rev 0640</td>
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<tr>
<td>Rev 1126</td>
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</table>

<table>
<thead>
<tr>
<th>Energy (eV)</th>
<th>Revolutions</th>
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</thead>
<tbody>
<tr>
<td>6694 ± 3</td>
<td>1000</td>
</tr>
<tr>
<td>6658 ± 4</td>
<td></td>
</tr>
<tr>
<td>6685 ± 3</td>
<td>500</td>
</tr>
<tr>
<td>6670 ± 4</td>
<td></td>
</tr>
</tbody>
</table>

\[\sigma = 46 ± 5\]  
\[\sigma = 40 ± 8\]  
\[\sigma = 45 ± 3\]  
\[\sigma = 45 ± 7\]
## 2. Re-distribution: Sources and spectral models

Models derived from RGS spectra:

<table>
<thead>
<tr>
<th>Source</th>
<th>Model Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNR 1E0102</td>
<td>continuum + emission lines</td>
</tr>
<tr>
<td>Star Zeta Puppis</td>
<td>continuum + emission lines</td>
</tr>
<tr>
<td>Comet C/2000 WM1</td>
<td>emission lines (unknown spectrum below 300 eV)</td>
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</tbody>
</table>

Other sources for consistency checks:

<table>
<thead>
<tr>
<th>Source</th>
<th>Model Description</th>
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<tbody>
<tr>
<td>INS RXJ0720</td>
<td>bbody + broad absorption line</td>
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<tr>
<td>INS RXJ1856</td>
<td>bbody (+bbody?)</td>
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<tr>
<td>AGN MS1229.2+6430</td>
<td>powerlaw</td>
</tr>
<tr>
<td>AGN H1426+428</td>
<td>broken powerlaw</td>
</tr>
<tr>
<td>AGN PKS2155</td>
<td>broken powerlaw</td>
</tr>
<tr>
<td>SNR G21.5-09</td>
<td>powerlaw</td>
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</tbody>
</table>
1E0102

Model from the cross-calibration work (Plucinsky et. al 2008, SPIE 7011E, 68)
Derived from combined RGS spectra of 23 observations (+EPIC-pn for higher energies)
rgspn_mod_tbabs_tbvarabs_2apec_line_ratios_jd_v1.9.xcm

Fit to pn spectra:
  only constant factor allowed to vary
  gain fit with slope==1.0 and shift as fit parameter

O VII f 561 eV
O VII i 567 eV
O VII r 574 eV
O VIII Lyα 654 eV
O VII Heß 666 eV

RGS1 708 ks
RGS2 680 ks
The current response:
Problems with energy resolution and re-distribution of O-lines
Zeta Puppis

Model similar to that of 1E0102
Derived from combined RGS spectra (+EPIC-pn for higher energies)

Fit to pn spectra:
only constant factor allowed to vary
gain fit with slope==1.0 and shift as fit parameter

| N VI f    | 420 eV |
| N VI i    | 426 eV |
| N VI r    | 431 eV |
| N VII Lyα | 500 eV |

RGS1 663.6 ks
RGS2 668.8 ks
Zeta Puppis

To avoid pile-up and optical loading:
Use SW mode with thick filter!

The current response:
Problems with energy resolution
and
re-distribution of N-lines
(the shoulder is too narrow)
Comet C/2000 WM1

A pure line spectrum with no continuum
The current response:
Unknown spectrum below 300 eV

C VI Lyα  368 eV
O VII f  561 eV
New response matrix:
Adjustment of energy resolution
and
re-distribution below ~700 eV

**FF old**
\[ \chi^2 = 1495 \]

**FF new**
\[ \chi^2 = 902 \]
New response matrix:
Adjustment of energy resolution and re-distribution below ~700 eV

LW old
$\chi^2 = 1585$

LW new
$\chi^2 = 1315$
New response matrix:
Adjustment of energy resolution
and
re-distribution below ~700 eV

**SW old**
\[ \chi^2 = 1668 \]

**SW new**
\[ \chi^2 = 1112 \]
Zeta Puppis

New response matrix:
Adjustment of re-distribution between 400 eV and 700 eV

SW old
\[ \chi^2 = 1140 \]

SW new
\[ \chi^2 = 896 \]
## Chi-squared comparison

<table>
<thead>
<tr>
<th>old</th>
<th>new</th>
</tr>
</thead>
<tbody>
<tr>
<td>epn6.8</td>
<td>11.19</td>
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### Data Table

<table>
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<tr>
<th>Code</th>
<th>Type</th>
<th>old</th>
<th>new</th>
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<tr>
<td>E0102</td>
<td>FF</td>
<td>489.5</td>
<td>532.3</td>
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<td>FF</td>
<td>728.0</td>
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<td>P0123110301FNS002</td>
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<td>P0135720901FNS001</td>
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<td>P0412980301FNS001</td>
<td>SW</td>
<td>1074.2</td>
<td>1023.6</td>
</tr>
</tbody>
</table>

### Notes

- Zeta Puppis thick
- Comet
  - rgs+pn_sY9(sys) FF 678 667

### Summary

- **Chi-squared comparison**
  - **old (epn6.8)**: 11.19
  - **new**: 11.19

### Additional Data

- **41979 29570**
MS1229.2+6430

Powerlaw fits
singles

FF old
$\chi^2 = 387$
dof = 329

FF new
$\chi^2 = 321$
MS1229.2+6430

Powerlaw fits
singles+doubles

FF old

\[ \chi^2 = 473 \]

\[ \text{dof} = 395 \]

FF new

\[ \chi^2 = 407 \]
**H1426+428**

Broken-powerlaw fits
NH fixed at 1.36 \(10^{20}\) (phabs-wilms)
singles+doubles
Rev. 278: no break

**SW old**
\[ \chi^2 = 5027 \]
dof = 3313

**SW new**
\[ \chi^2 = 4503 \]

Allow break for Rev. 278:
\[ \chi^2 = 4145 \]
Index 1.89/1.78
RX J1856.5-3754

Blackbody fits
singles
NH, kT, norm linked
free constant

$\chi^2 = 2115$
dof = 1403

$\chi^2 = 2118$

$N_H = 5.2 \times 10^{19}$
kT = 61.5 eV

$N_H = 6.8 \times 10^{19}$
kT = 62.3 eV
3. Problems for future work

Time dependence of energy resolution
Not seen in point source spectra?
Requires time dependent CCFs or software+CCF update
Zeta Puppis double pixel events

SW old
\( \chi^2 = 621 \)

SW new
\( \chi^2 = 558 \)
1E0102 double pixel events

FF old
\( \chi^2 = 2898 \)

FF new
\( \chi^2 = 2278 \)
1E0102 double pixel events

LW old
\( \chi^2 = 3190 \)

LW new
\( \chi^2 = 2744 \)
1E0102 double pixel events

Different re-distribution for single/double pixel events?
Actually a threshold effect?
Needs software+CCF update

SW old \( \chi^2 = 2625 \)

SW new \( \chi^2 = 2370 \)