LETGS: A look at the plus and minus orders

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Introduction

- Observation of the Crab Pulsar
  - ObsID 759
  - hrcf00759N003_evt2.fits

- Detailed analysis of the continuum spectrum with plus and minus orders combined completed and documented in paper accepted for publication in ApJ - see astroph/0310332
Analysis restricted to the energy range 0.3-4.2 keV.
The upper energy limit chosen to limit contamination from the zeroth-order nebular image (Fig 1).
The lower energy limit chosen to minimize the degree of contamination from higher orders (Fig 2).
Figure 1

Stretched for clarity. Boxes show regions selected for signal (narrowest) and background.
LETGS spectrum of the Crab Pulsar compared to a model (XSPEC: wilm & tbvarabs with thawed oxygen abundance and fixed amount of dust scattering). The lower solid line shows the model including only the first order response.
Plus and Minus Orders Combined

- Power law fit shown in Figure 1 with plus and minus orders added was excellent with $\chi^2$ of 1539 on 1552 degrees of freedom
Plus and Minus Orders Separated

- Fits do not give same answers (Fig 3)!
Confidence contours for chi-squared minimum plus 1, 2.3, 4.61, 9.21. Left: minus orders ($\chi^2 = 1215$, $\nu = 1142$). Right: plus orders ($\chi^2 = 1168$, $\nu = 1169$).
Next steps

- **Analyze in two energy bands**
  - 0.3-1.5 sensitive to higher orders (see Fig 1)
  - 1.5-4.2 sensitive to first order (see Fig 1)
- If, e.g., problem with higher orders then expect higher energy band to give identical results
- Results in Table 1
## Table 1

**Powerlaw Index**

<table>
<thead>
<tr>
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<th>Plus Order</th>
<th>Minus Order</th>
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<tbody>
<tr>
<td>0.3-1.5 keV</td>
<td>1.54 (0.10)</td>
<td>1.72 (0.09)</td>
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<tr>
<td>1.5-4.2 keV</td>
<td>1.74 (0.11)</td>
<td>1.49 (0.10)</td>
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Other Considerations & Conclusion

- Choice of background region
  - No impact

- Offset of zero order position
  - Yes – but requires huge offsets

- Cross-correlation of plus and minus orders
  - Peaked at zero and appears symmetric

- Conclude problem(s) in response functions used