TITLE: Y Deflection offsets for Echelle Interorder Measurements

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ABSTRACT

The deflection offsets required for precise measurement of interorder light in the HRS Echelle modes must be calculated for each observation. These offsets are entries in the Observation Control Table, which the flight software uses to execute an observation. This report describes how to calculate the offsets when either the science diodes, or the large corner diodes are to be used to sample the interorder background.
Y DEFLECTION OFFSETS FOR ECHELLE INTERORDER MEASUREMENTS

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I. INTRODUCTION

The removal of background signal level is an important step in the reduction of spectroscopic data. The HRS offers an observer considerable flexibility in the way background light is measured. It is possible to use either the 500 science diodes or the four large corner diodes to sample the background. Data can be accumulated into seven substep bins. Typically one makes either one, two or four substeps with the diode array sampling the spectrum, and two deflections to measure the adjacent background. In the first order modes, the background deflections can be a constant offset from the spectrum for all wavelengths in all modes. In each Echelle mode there are 17 orders present on the photocathode at one time. The location of each order in the Y direction is a function of both wavelength and order number. Furthermore, the spacing of the orders is not uniform. At the short wavelength end (high order number) of each mode, the separation between orders is comparable to the height of the science diodes. The point is that for the Echelle modes a constant deflection offset is not adequate. In order to sample the background properly, the deflection offsets must be calculated precisely for each observation. These offsets, together with their repeat codes define a substep pattern, and must be specified in the Observation Control Table (OCT). This report describes how to calculate the deflection offsets.
II. DISTANCE BETWEEN ORDERS

The general equation for the calibration of $Y$ deflections is

$$Y = A + B\lambda + C\lambda^2 + D \cdot m \lambda \quad (1)$$

In the Echelle modes the quadratic term is negligible, $C=0$. For an observation of wavelength $\lambda$ in order $m$, the initial $Y$ deflection is calculated from

$$Y = A + B\lambda + D \cdot m \lambda \quad (2)$$

The coefficients are determined by fitting equation (2) to an observed set of $Y$, $\lambda$, and $m \lambda$. They define the $Y$ deflection calibration, and will be part of the HRS calibration data base. The values which resulted from the May 1983 laboratory testing are listed in table 1. This table will be updated following the replacement of the detectors.

**Table 1**

<table>
<thead>
<tr>
<th>Echelle A</th>
<th>Echelle B</th>
</tr>
</thead>
<tbody>
<tr>
<td>7244</td>
<td>-3653</td>
</tr>
<tr>
<td>-4.644</td>
<td>+1.854</td>
</tr>
<tr>
<td>0.019</td>
<td>0.017</td>
</tr>
</tbody>
</table>

When wavelength $\lambda$ is observed in order $m$, the wavelengths in the adjacent orders are:

$$\lambda_+ = \frac{m}{m+1} \lambda \quad \quad \lambda_- = \frac{m}{m-1} \lambda$$

Their $Y$ deflections are:

$$Y_+ = A + B \lambda + D \cdot (m+1) \frac{m}{m+1} \lambda \quad (3)$$

$$Y_- = A + B \lambda + D \cdot (m-1) \frac{m}{m-1} \lambda \quad (4)$$

The distances between the orders are therefore:

$$\Delta Y_+ = Y_+ - Y = B\lambda \left( \frac{m}{m+1} - 1 \right) \quad (5)$$

$$\Delta Y_- = Y_- - Y = B\lambda \left( \frac{m}{m-1} - 1 \right) \quad (6)$$

\[
\begin{array}{c|c|c}
    m+1 & \lambda_+ & m \\
    \hline
    m & \lambda & \Delta Y_+ \\
    m-1 & \lambda_- & \Delta Y_- \\
\end{array}
\]
III. "UPPER INTERORDER" AND "LOWER INTERORDER"

The orientation of the orders with respect to the diode array and the deflection coordinates is sketched below.

The UPPER INTERORDER measurement samples the background "above" the order of interest. It is in the direction of DECREASING Y deflection. For Echelle A, if a feature is being measured in order \( m \), the upper interorder samples midway between \( m \) and \( m+1 \). For Echelle B, the upper interorder samples between \( m \) and \( m+1 \).

Similarly, the LOWER INTERORDER measurement samples "below" the spectrum, in the direction of INCREASING Y deflection. For Echelle A, the region between \( m \) and \( m+1 \) is measured. For Echelle B the space between \( m \) and \( m-1 \) is measured.
IV. DEFLECTION OFFSETS

A. SCIENCE DIODES: If the observer wishes to sample the interorder background with the 500 science diodes, the following offsets are ADDED to the INITIAL Y DEFLECTION.

Echelle A: UPPER INTERORDER \( \text{DYUPA} = \frac{1}{2} B \lambda \left( \frac{m}{m_{-1}} - 1 \right) \) (7)

LOWER INTERORDER \( \text{DYLOA} = \frac{1}{2} B \lambda \left( \frac{m}{m_{+1}} - 1 \right) \) (8)

Echelle B: UPPER INTERORDER \( \text{DYUPB} = \frac{1}{2} B \lambda \left( \frac{m}{m_{-1}} - 1 \right) \) (9)

LOWER INTERORDER \( \text{DYLOB} = \frac{1}{2} B \lambda \left( \frac{m}{m_{+1}} - 1 \right) \) (10)

Note that \( \text{DYUP} \) is a negative number, so that adding it to the initial \( Y \) deflection decreases the deflection value.

B. CORNER DIODES: The orders crowd together at the short wavelength ends of the Echelle formats, making it difficult to center the science diodes cleanly between the orders. The observer may choose to center the corner diodes instead. The following offsets, when added to the initial \( Y \) deflection, will center the top corner diodes, 1 and 511, in the upper interorder, and the bottom corner diodes, 2 and 512, in the lower interorder.

UPPER INTERORDER \( \text{DYUPA} + 64 \) or \( \text{DYUPB} + 64 \) (11)

LOWER INTERORDER \( \text{DYLOA} - 64 \) or \( \text{DYOLO} - 64 \) (12)
Example: Lyman x in Echelle A

\[ m = 46 \quad \lambda = 1216 \]

2 samples per diode width, science diodes for background

Initial Y deflection from equation 2 = 2660
Upper interorder offset from equation 7 = -63
Lower interorder offset from equation 8 = +60

<table>
<thead>
<tr>
<th>bin</th>
<th>X</th>
<th>Y</th>
<th>(\Delta X)</th>
<th>(\Delta Y)</th>
<th>comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2048</td>
<td>2660</td>
<td>0</td>
<td>0</td>
<td>Initial deflection pair</td>
</tr>
<tr>
<td>2</td>
<td>2052</td>
<td>2660</td>
<td>+4</td>
<td>0</td>
<td>2 substeps on spectrum</td>
</tr>
<tr>
<td>3</td>
<td>2048</td>
<td>2597</td>
<td>0</td>
<td>-63</td>
<td>Upper interorder</td>
</tr>
<tr>
<td>4</td>
<td>2048</td>
<td>2720</td>
<td>0</td>
<td>+60</td>
<td>Lower interorder</td>
</tr>
</tbody>
</table>

to use the background diodes instead

Initial Y deflection = 2660
Upper interorder offset from equation 11 = +1
Lower interorder offset from equation 12 = -1

<table>
<thead>
<tr>
<th>bin</th>
<th>X</th>
<th>Y</th>
<th>(\Delta X)</th>
<th>(\Delta Y)</th>
<th>comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2048</td>
<td>2660</td>
<td>0</td>
<td>0</td>
<td>2 samples per diode width</td>
</tr>
<tr>
<td>2</td>
<td>2052</td>
<td>2660</td>
<td>+4</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>2048</td>
<td>2661</td>
<td>0</td>
<td>+1</td>
<td>Upper interorder 1, 511</td>
</tr>
<tr>
<td>4</td>
<td>2048</td>
<td>2656</td>
<td>0</td>
<td>-4</td>
<td>Lower interorder 2, 512</td>
</tr>
</tbody>
</table>