SALT HRS Thorium-Argon Spectral Atlas

Introduction

This document provides a brief description of the latest available version of a comprehensive set of Thorium-Argon spectral line identification maps and the corresponding order maps for both the red and blue camera arms for the SALT HRS spectrometer in high-resolution (HR) mode. The atlas includes 41 orders for the blue camera arm and 33 orders for the red camera arm, spanning the wavelength range from 3740 to 8860 Å. Creation of the atlas was performed in Matlab.

Creating the Spectral Atlas

Raw data frames for each detector are first pre-scan bias corrected, trimmed and pixel values are converted from ADU to electrons using the gain values provided in the FITS headers. Each trimmed frame is full-frame bias corrected using a master bias frame created from all available bias frames from the same night or if not available (i.e. semester 2014-1) the next available previous date. Finally, all of the flat frames for the night are median combined into a single image that is later used for defining order locations in the image. For this version of the spectral line atlas no correction for the blaze function or flat-fielding has been performed.

The procedure for spectrum extraction is based on existing methods originally implemented in IRAF, but now carried out with some additional steps required to address unique instrumental challenges in reducing the SALT HRS data.

After performing bias correction, initial aperture locations are determined using a single reference column from a median combined master flat frame, in this case the central column. The pixel coordinate values of the order locations (Y_0) are the centroid positions of the order profiles, as shown in Figure 1. Note the presence of the source and sky fibers in each of the flat frames. With the initial starting values of each spectral order, the aperture centers are traced using the same centroid method described above. Finally, for each order, the X and Y order positions on the detector determined during aperture tracing are well fit by 2nd order polynomials. A total of 41 orders for the blue detector and 33 orders for the red detector have been identified and traced in this manner. The polynomial fits to the aperture centers are over-plotted on the provided order maps for clarification, along with the corresponding order number.

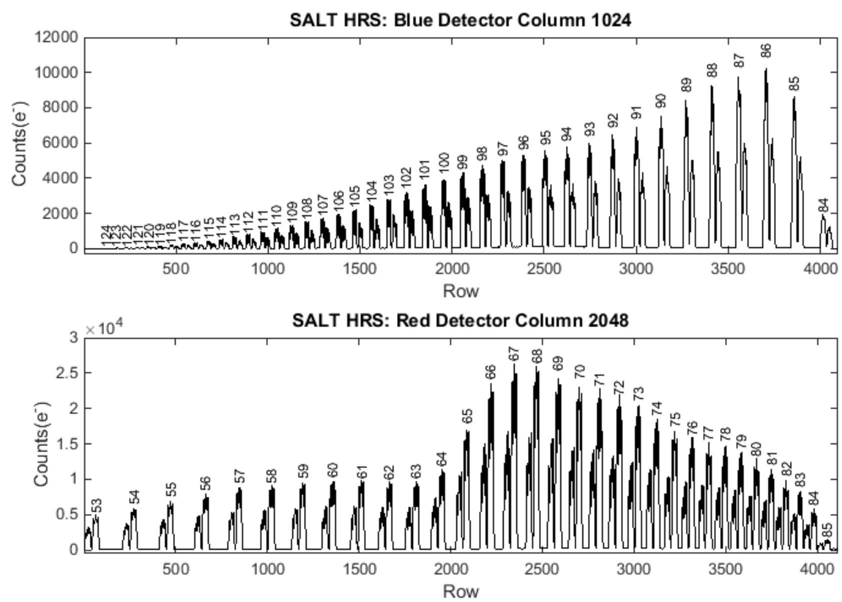

Figure 1: Single reference columns for SALT HRS blue(top) and red(bottom) flat frames. Order numbers are also plotted for clarity.

Upper and lower boundaries for each aperture are defined as the positions at which the flux in the aperture profile drops to a fraction of the peak value. For this atlas, background regions have not been defined and subtracted for reasons pertaining to the observed tilt of the Thorium-Argon lines in the arc calibration frames as explained in the subsequent text. For each order, the upper and lower aperture boundary locations are fit with 2nd order polynomials independently instead of simply defining a constant aperture width in pixels. The plot in Figure 2 shows order 85 in the blue detector traced in this manner. Note the presence of order 85 from the background sky fiber located directly above the primary source fiber

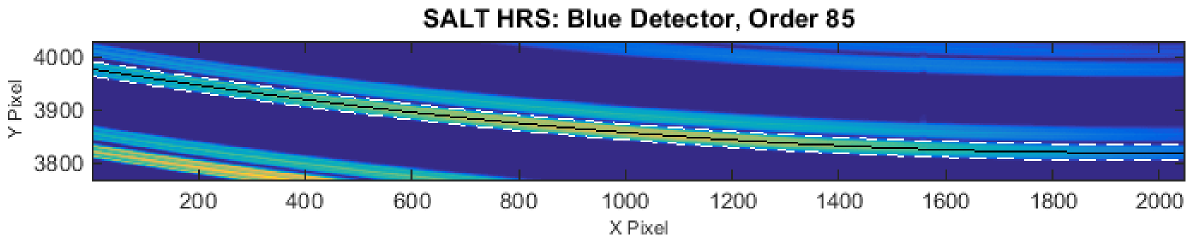

Figure 2: HRS order 85 in the blue detector. The aperture center and upper/lower bounds are over plotted in solid black and dashed white lines respectively. Aperture centers and bounds are all well fit by 2^{nd} order polynomials.

in the image. Care must be taken to not include flux from this feature during extraction since it originates from a different fiber entirely on the sky.

Examination by eye of the arc lamp exposures reveals that spectral line profiles are not aligned along columns, but instead they are tilted by an average of 5-10 degrees from vertical. The spectral extraction algorithm must take this line tilt into account to minimize spectral contamination. As can be clearly seen in the right panel of Figure 3, simple background definitions and subtractions as typically performed in IRAF will result in incorrect subtraction of flux of a different wavelength if not performed with extreme care. The line tilt as a function of X and Y position has been determined for both cameras. Extraction is performed using "bins" defined by the aperture boundaries and the line tilts. The number of bins per order is set to 2048 and 4096 for the blue and red detectors, respectively. For extraction, each aperture bin is represented by four points in the image, forming the vertices of a polygon. Figure 3 shows seven such aperture bins for order 85 in the blue detector, plotted over a flat frame and an arc frame for comparison. The tilted aperture bins match the tilt of the spectral lines. The extraction code then computes the set of image pixels that intersect this polygonal aperture bin, and sums the flux contribution from each intersecting pixel. After all apertures have been extracted a FITS file containing the Nx2048 or Nx4096 1D spectra is written, where N is the number of extracted orders.

The extracted 1D spectra are then run through a Gaussian weighted peak detection algorithm that returns the positions of peaks with a S/N ratio of 5 or greater for use in wavelength calibration, neglecting all other less significant peaks. An initial user supplied matching of several well-spaced and well-known wavelength spectral lines are specified. An initial 3^{rd} order intensity-weighted polynomial fit is used to iteratively search for additional lines in the NOAO Thorium-Argon line list (http://iraf.noao.edu/specatlas/thar/thar_list). Once all possible lines have been matched to the catalog, the final polynomial fit order is determined as the one that minimizes the root mean squared error with the allowed fit order in the range from three to eight. Fit orders less than three have been empirically determined to be a generally poor fit for all tested orders.

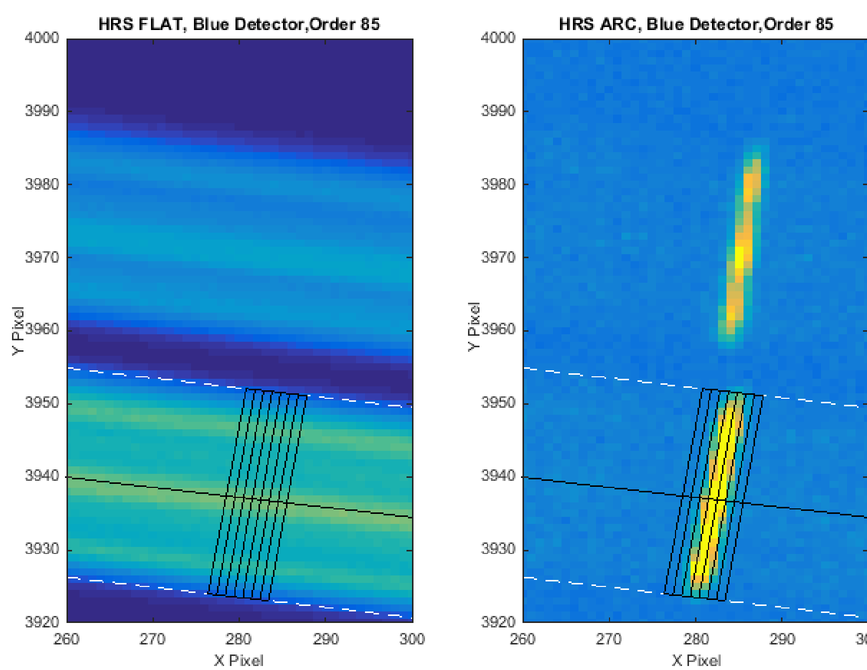

Figure 3: HRS aperture bins used for spectrum extraction. A nightly master flat frame (left) and a nightly master arc frame (right) are shown with aperture center (black) and bounds (white dashed), as well as 7 aperture bins plotted. Note the tilt of the spectral features in the right panel and how the aperture bins are aligned for correct extraction.

The individual line identification maps for each order are annotated in a straightforward manner. Annotations are offset either horizontally or vertically for the purpose of clarity in cases where the peak line intensity is greater than the plot limit or when annotations overlap making them unreadable.

Printable PDF files of the atlas are available in US Letter and A4 paper formats. This version (September 2015) of the SALT HRS Thorium-Argon Line Atlas is a draft and not yet finalized. Updates to this atlas will be provided as they are produced.