The Cool-Star Spectral Catalog: A Uniform Collection of IUE SWP-LOs

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Abstract. We have assembled an extensive electronically-accessible catalog of low-dispersion far-ultraviolet spectra of chromospheric emission-line stars observed with the International Ultraviolet Explorer.

1. Introduction

Over the past decade and a half of its operations, the IUE satellite has recorded low-dispersion (5 Å resolution) spectrograms in the 1150–2000 Å far-ultraviolet band of more than 800 stars of late spectral type (F–M). The FUV contains a number of emission lines—like O I λ1304, C II λ1335, and C IV λ1549—that are key diagnostics of physical conditions in the high-excitation chromospheres and subcoronal “transition zones” of such stars. Many of the sources have been observed a number of times, and the available collection of SWP-LO exposures in the IUE Archives exceeds 4,000.

With support from the Astrophysics Data Program, we have assembled a subset of the archival material into a catalog. Our goal was to process and measure the FUV spectra in as uniform (and automated) a way as possible, and provide the results in a form amenable to electronic access through the Astrophysics Data System. A brief summary of our efforts follows. A more thorough report will be presented elsewhere (Ayres et al. 1993a).

2. The Sample

We focused on a group of approximately 600 relatively normal F–K stars, that were detected in at least the 12μm survey band of the Infrared Astronomical Satellite. The brightness-limited sample is represented by approximately 3,500 SWP-LO images in the IUE archives. We ordered the SWP raw images from the National Space Sciences Data Center using the automated Mail-Retrieval system, typically a hundred images at a time.
3. Image Processing

3.1. Photometric Linearization, Spectral Extraction, and Calibration

The configuration of the IUE image processing system (IUESIPS) has evolved significantly over the 15-year duration of the mission. In addition, a bug in the system (fully appreciated only recently) has prevented it from properly removing the pixel-to-pixel fixed sensitivity pattern, with the result that production-processed IUE spectra are much noisier than they should be. Thus, in the spirit of applying a uniform reduction to the entire collection of spectra, we devised an independent method for processing the raw vidicon images.

In particular, we first rotate the raw image so that the low-dispersion footprint is parallel to the image “SAMPLE” axis. We then photometrically-linearize the 512 × 48 subimage containing the large-aperture spectrum using an Intensity Transfer Function based on the 1985 recalibration of the SWP camera. The ITF was derived in the rotated frame: the individual pixel sensitivity curves were represented as 4th-order polynomials. We identified, and removed, point-like cosmic-ray hits and other transient defects using an automated procedure. We then filtered the subimage with a 1.5-pixel FHWM Gaussian to suppress “misregistration” noise. Next, we evaluated, and subtracted, the off-spectrum background by spatially-filtering and heavily smoothing the fluxes in reference bands above and below the spectral swath.

We extracted the stellar spectrum using an “Optimal” weighted slit, like that described by Kinney, Bohlin, and Neill (1991), based on the local cross-dispersion profile of the spectral trace and a “noise model” that assigns a photometric uncertainty to each pixel flux according to its intensity. The noise model was derived from the same epoch-1985 UV-Flood flatfield images that were utilized to construct the polynomial ITF (see Ayres 1993). The Optimal extraction explicitly accounts for spatially-extended spectral traces, like trailed or multiple exposures, and is designed to track the small-scale “wiggles” of the spectrum which result from shears in the camera’s fiber-optic coupler.

Finally, we applied an absolute calibration by reference to a series of SWP-LO point-source and trailed spectra of the hot-WD G191-B2B—a fundamental flux standard for the IUE—which were compared with theoretical energy distributions. Prior to applying the absolute calibration, we subtracted a “scattered light” level determined by assessing the apparent fluxes shortward of 1150 Å (where the window of the SWP camera is opaque, so any detected photons must be scattered from longer wavelengths). The wavelength scale was determined by fitting a quadratic relation to the apparent positions of prominent emission lines in the rich spectrum of the bright RS CVn-binary λ Andromedae.

3.2. Measurement of Emission Lines and Continuum Bands

We measured the calibrated SWP-LO spectra using a semi-autonomous algorithm developed originally by Bennett (1987). It establishes a smooth continuum via a specialized numerical filter, and then fits the significant emissions (or absorptions) by means of a constrained Bevington-type multiple-Gaussian procedure. Nineteen separate emission lines and nine continuum bands are measured. The algorithm assigns uncertainties to the fitted fluxes—or upper limits in the
**SWP15292R**

SWP 15292, HD 159181, 30 MIN LGAP & 6 MIN SNAP, LOW DIS

**Observer:** Stencil, Program: CDSDR, Date: 1981.292

<table>
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<tr>
<th></th>
<th>(\lambda) (Å)</th>
<th>FWHM (Å)</th>
<th>(S_0 \pm \sigma) (E–13 ergs)</th>
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<tr>
<td>H I</td>
<td>1216.1</td>
<td>10</td>
<td>76 ± 2</td>
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<tr>
<td>O I</td>
<td>1305.2</td>
<td>8.0</td>
<td>58 ± 1</td>
</tr>
<tr>
<td>C II</td>
<td>1335.6</td>
<td>5.1</td>
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<tr>
<td>C IV</td>
<td>1550.1</td>
<td>7.1</td>
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</tr>
<tr>
<td>Si II</td>
<td>1814.2</td>
<td>7.5</td>
<td>26 ± 2</td>
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\(t_{exp} = 30.00 / \Delta = +0.0 [0 \text{ I}]\)

![Graph](image)

**Figure 1.** Visualization of SWP-LO reduction scheme. Panel (d) illustrates a stretched version of the photometrically-corrected image: the stellar continuum is visible, particularly at \(\lambda > 1700\ \text{Å}\), and a number of prominent emission lines (including diffuse Ly\(\alpha\) sky emission through IUE's large aperture). The sharp-edged dark features are resseau marks. Panel (e) depicts the cross-dispersion profiles of the Optimal extraction: points refer to local profiles; solid curves are the global average. In panel (f), the points are the calibrated fluxes; the solid curve is the fitted spectrum.

absence of a significant detection—according to error prescriptions developed for Gaussian profiles by Lenz and Ayres (1992). The processed data—spectrum, flux errors, continuum fit, tables of line and continuum flux parameters—are stored in a simple ASCII file. The storage file also contains a compressed (one character per pixel) version of the photometrically-corrected, background-subtracted 2-D spectral image, which has been stretched to reveal faint structure. A simple procedure allows one to visualize the contents of the storage files. Figure 1 is an example.

The unified processing and measuring code runs 1 CPU minute per image on a VAXstation 3100/M38 under VMS. The code itself is written in IDL V2, and has been ported to other platforms (e.g., a SUN SPARCstation). Each ASCII storage file occupies 20 kbytes: the entire collection of \(\approx 3500\) spectra is maintained online. A subsample of the images—500 SWP-LOs of about 50 stars—was processed completely many times until the code—and the underlying numerical strategies—stabilized. As a result, we have had to reprocess the full sample only twice (so far!): each reprocessing required roughly a month of
Figure 2. Examples of (mostly coadded) spectra from the test sample. Each calibrated spectrum was divided by the bolometric flux, $f_{bol}$, of the star for display purposes.
background time at a rate of a few-hundred images per night (limited more by available storage than CPU speed: A SPARCstation with 4 Gbytes of disk could reprocess the entire collection overnight).

4. Present Status of the Catalog

We presently are constructing auxiliary tables required by the Astrophysics Data System to permit ready access to the catalog. We also are coadding spectra for those stars for which several suitable SWP-LOs are available (about 20% of the sample), so that we can provide high-quality average spectra. Examples are illustrated in Figure 2 for F-type stars from the "test sample".

5. For the Future

We are developing low-dispersion processing codes for the IUE’s two longwavelength cameras. Specialized high-dispersion software has been devised as well (see Ayres et al. 1993b). Our approach is complementary to that of the IUE Project in its long-term “NEWSIPS” development. In particular, our strategies are devised primarily for late-type emission-line sources, and with the intent to rapidly make available highly-distilled versions of the archival spectra suitable for quick-look analysis and other catalog-style purposes. We feel that our photometric corrections and spectral extractions are comparable in quality to those which will be provided by the NEWSIPS for the majority of IUE images, except perhaps for observations taken at extremes of camera temperature (see discussion in Ayres 1993). However, some types of in-depth analysis projects—particularly those for which high-quality spatial information perpendicular to the dispersion is desired—likely will turn to the Final Archive for the ultimate in S/N and geometrical fidelity, using catalogs like the present one for the initial reconnaissance of the available spectra.

Acknowledgments. We gratefully acknowledge support from NASA’s Astrophysics Data Program. We also thank the participants in the Final Archive Definition Committee and the staff of the IUE Project for helpful advice. The raw SWP frames were provided by the National Space Sciences Data Center.

References