IUE Calibration Progress Report

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5 April 1991

This report summarizes the highlights of recent calibration work.

I. Wavelength Calibration for the Final Archive

• Low-dispersion Wavelength Linearization

A correction scheme has been implemented in the prototype Final Archive processing system which removes the recently discovered non-linearities in the dispersion relations for low-dispersion images. The form of the correction was determined by analyzing many low-dispersion wavelength calibration (wavecal) spectra for each camera. Because the non-linear terms are roughly constant as a function of time and camera temperature, a fixed correction can be applied for a given camera. The correction is applied at the resampling stage of the Final Archive system, which produces a geometrically-corrected and rotated image similar in format to the current line-by-line files. Removal of the non-linear terms results in improved wavelength assignments as compared to the current production processing system.

• Large-to-small Aperture Offsets

The resampled low-dispersion (SILO) images produced by the Final Archive system contain spectral data for both the large and small apertures and have the spectral format rotated so that the dispersion direction is parallel to one image axis (analogous to the current line-by-line files). Due to the physical layout of the entrance apertures, a small offset in the dispersion direction exists between the centers of the large and small entrance apertures in this image format. This physical offset results in a corresponding offset in the zero-point terms of the dispersion solutions for the large and small aperture data. So that a single dispersion solution may be applied to the data for both apertures, we have introduced a shift to the data in the resampling step for either the large or small aperture (depending on the camera) to compensate for this offset. The size of the offset for each camera has been determined through measurements of the locations of emission lines in wavecal images containing data for both apertures simultaneously.

• Aperture Tilt

In the rotated SILO image format produced by the Final Archive system, the major axis of the large aperture is not exactly perpendicular to the dispersion axis, but is tilted by about 9 degrees. Left as is, extracted spectra for extended sources could have incorrect wavelength assignments as well as artificially broadened spectral features. The tilt angle of the large aperture has been remeasured in each camera format and a "tilt-correction" procedure has been added to the resampling stage of the Final Archive processing system to remove this problem. For extended sources, the spectral data from the large aperture are appropriately shifted as a function of position along the major axis of the aperture so that data of intrinsically constant wavelength lie along a corresponding line of constant wavelength in the SILO image.

II. Flux Calibration for the Final Archive

Recent work by Finley, Basri, and Bowyer (FBB: 1990, ApJ, 359, 483) suggests that there may be systematic errors of up to 15% in the current IUE absolute calibration flux scale. They base their results on detailed comparisons of the IUE spectra of several hot DA white dwarfs to model atmosphere calculations. The SWP wavelength region appeared to show the greatest discrepancies from the model calculations.

The current basis of the IUE flux calibration is the standard (B3V) star Eta UMa (Bohlin et al. 1980, A&A, 85, 1), which was observed by several rocket and ultraviolet (OAO-2 and TD1) satellites. The often quoted 10% accuracy of the IUE flux calibration scale essentially represents the uncertainty in the Eta UMa flux scale due to the scatter in the various rocket and satellite calibrations. The largest flux differences between the various UV instruments occurred in the SWP wavelength region and thus may be one source of the FBB flux errors.

A meeting was held at VILSPA on December 11-12, 1990 to discuss the basis of the flux calibration for the IUE Final Archive. A number of experts in the modeling of white dwarf, subdwarf and main sequence stars attended the meeting (Finley, Koester, Massa, Weidemann, Husfeld, etc). Several lines of evidence presented at the VILSPA meeting tended to confirm the results of FBB. Models of white dwarfs (Finley and Koester), subdwarfs (Husfeld), main sequence stars (Massa), and BL Lac objects (FBB) all tended to show similar wavelength-dependent discrepancies from the current IUE flux scale. The exact details of the discrepancies, of course, differed somewhat from star-to-star. However, the overall similarity of the various models were remarkable given the wide range in type of object, composition and physics.

It was therefore recommended that white dwarfs models should form the basis of the Final Archive IUE flux calibration instead of the traditional flux standards. DA white dwarfs between temperatures of about 20,000 to 70,000 degrees were considered to be the best choice for flux "standards" because the models for these objects are the simplest and best understood. The atmospheres are thought to be essentially pure Hydrogen. The slope in the flux distribution from 1500A to 2800 Å is believed to be known with an accuracy of 2% and the average vertical level is known to an accuracy of $\sim$ 5–8% (ref. Koester). Thus it was felt that these objects could be used to define the wavelength response of the camera but a flux standard, like Eta UMa, may be needed to determine the overall level. The two white dwarfs, G191B2B (m_V = 11.8, T_{eff}=57838) and CD -38 10980 (m_V=10.9, T_{eff}=23903) were given first priority because they are bright and span a wide range of temperature. Several other white dwarfs, sub-dwarfs and main-sequence stars were selected as secondary checks of the IUE flux calibration.

Since December 1990, a significant amount of the NASA maintenance observing time has been dedicated to the low-dispersion monitoring of the white dwarfs selected as primary and secondary standards. It was determined that a minimum of 21 images (12 optimum and 9 overexposed) would be an acceptable number of exposures for each primary standard. This monitoring effort has been completed for the two primary standards. In addition, all the other six secondary white dwarf standards have also been observed although their monitoring is still being completed as they become observable for IUE. Up to now, 94 low- and 2 high-dispersion images have been secured in both cameras, using an approximate total of 81 hours of observing time for this program.

The VILSPA calibration staff is now concentrating on obtaining a complete set of LWP and SWP observations of some of the "traditional" flux calibration standards [Eta Aur (B3V), Zeta Dra, Lambda Lep (B0.5IV), 10 Lac (O9V), HD 60753 (B3IV), BD +75 325 (subdwarf), BD +28 4211 (subdwarf)]. Both optimum and 2–3 times overexposed large aperture point-source spectra have been included in this program. These observations will be used for comparison with the white dwarf flux scale.

III. Photometric Calibration of the New FES Reference Point

After the implementation of a new FES reference point (FES UNITS: -144, -176) on January 22, 1990 at NASA and on July 23, 1990 at VILSPA a preliminary photometric calibration based on "first principles" has been obtained. By accurate FES data of 17 UBV standard stars we have determined a new zero point for overlap stars. Similarly, by measuring 27 bright stars we have determined a zero point for underlap stars. A new improvement of this calibration is that the FES photometric accuracy can be greatly increased by removing the focus dependency on the counts. The importance of this effect has become more noticeable with the increasing power constraints on IUE as the spacecraft ages. We have estimated the mean focus steps from the 59 single measurements of the 17 stars used for the zero point determination and used it as a "focus zero point." This mean focus step was of -2.653. In addition, we have determined that the mean slope of the focus dependency against focus step to be 0.022 (2.2%) yielding to the following correction equation.

$$CTS(corr) = CTS(obs)[1 + 0.022 \times (-2.653 - focus\ step)]. \qquad (1)$$

And by using the same *Color* correction determined for the previous reference point (Imhoff and Wasatonic 1986, *IUE NASA Newsletter*, No. 29, p45), namely,

$$Color = -0.271087 \times (B - V) - 0.063880 \times (B - V)^2 + 0.137764 \times (B - V)^3, \qquad (2)$$

The final equation of interest is;

$$m_V = -2.5 * log[\frac{CTS(corr)}{1 - 1.2 \times 10^{-4} * CTS(corr)^{0.781}}] + Color + K, \qquad (3)$$

which includes the photomultiplier dead-time correction and where $CTS(corr)$ are the corrected FES counts and K is 16.350 ± 0.063 for overlap stars and 10.995 ± 0.078 for underlap stars. The RDAF procedure FESCALC has been updated to include this calibration for the new reference point for observing dates after January 22, 1990 for NASA and July 23, 1990 for VILSPA. We report that no degradation with time of the measured counts was detected for the first 13 months of usage of the current reference point. The present calibration is not valid for FES data taken during the 'FES anomaly' experienced after January 22, 1991, where additional background scattered light was detected in the FES mainly at high beta attitudes. Currently this background has been reported to decrease substantially since its initial detection.

IV. VAX (Current) Processing of Wavecal Images

Processing of wavecal images on the VAX system at the IUE Greentec facility has begun. Output dispersion constant data files for each image are being stored on a temporary disk area until the software needed to append them to the master dispersion constant files, which were successfully copied over from the Sigma-9 computer, has been generated. The mean dispersion constants and the time and temperature dependent coefficients as used in current IUESIPS production processing will be updated in the near future. This rehosting effort was made necessary by the fact that processing of wavecals on the Sigma-9 computer had become increasingly time consuming and difficult. The VAX wavelength calibration processing and analysis procedures should improve the speed and reliability of the process and help to relieve staff frustrations.