HST/WFC3 Flux Calibration Ladder: Vega

Susana E. Deustua, Ralph Bohlin, Nor Pirzkal & John MaKenty. Space Telescope Science Institute (United States)

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Introduction

Vega is the quintessential absolute flux calibrator in Astronomy, and, one of only a few stars calibrated against an SI-traceable blackbody. The majority of experiments made measurements the visible (see Megessier 1995 for a detailed discussion) with uncertainties on the order of a few percent. Equivalent measurements made in the infrared, from the ground, yielded much larger uncertainties (e.g. Blackwell and collaborators), due in large part to atmospheric effects. Hence, accurate measurements made above the atmosphere should reduce the uncertainties

STIS spectral observations of Vega between 3000 angstroms and 1 micron were made by Bohlin and Gilliland (2004, AJ, 127, 3508) in the traditional stare mode. By exploiting the fact that in the STIS CCD saturated charge in one pixel spills over to neighboring pixels, thereby conserving flux, they were able to obtain high signal to noise spectra of this fundamental flux standard.

At wavelengths longer than 1 micron Vega's spectral energy distribution is obtained by extrapolating from the current UVIS data via models. To fill in the crucial gap between 0.9 and 1.7 microns, we started a program to acquire grism spectroscopy of Vega in the near infrared using the two Wide Field Camera 3 (WFC3) infrared grisms, in scanning mode. In principle we should obtain an absolute flux calibration of less than 3%

Spectra of Vega are obtained with spatial scanning in the -1st and, depending on position on the array, the -2nd order.

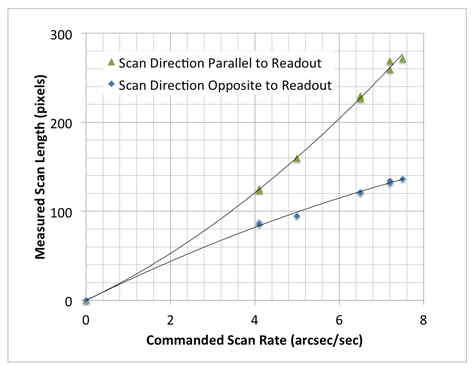
Cautions

-1st order calibrations. Because use of the -1st grism orders was not anticipated, these were not as well calibrated as the +1st and +2nd orders. Therefore, we obtained +1st and -1st spectra of the solar analog flux standard star P330E to check the flux calibration of the -1st order, and observations of the planetary nebula, VY2-2, to check the wavelength calibration.

Upstream/Downstream effects. Scans were made along the columns, either parallel to or opposite the scan direction. The effect is different scan lengths, and therfore different per pixel on source exposure times during one image. The WFC3/IR detector is readout using non destructive reads.

Upstream/Downstream Effect

The measured scan length is a function of the scan rate, the sample time (time between reads) and the time to readout the array. Our spectra were obtained using the RAPID sample sequence which has uniform intervals of 2.93 seconds between reads. The time to readout one quadrant is 2.91 seconds.



Left Figure: Measured length of a scan (in pixels) during one read when the scan direction and the readout direction are the same (parallel), and when the scan and readout direction are opposite each other.

Right Figure: Ratios of measured parallel and opposite scan lengths to expected length if readout time were instantaneous. Best fit lines are forced to include the values at scan rate= 0 arcsec/second.

Vega Infrared Spectra

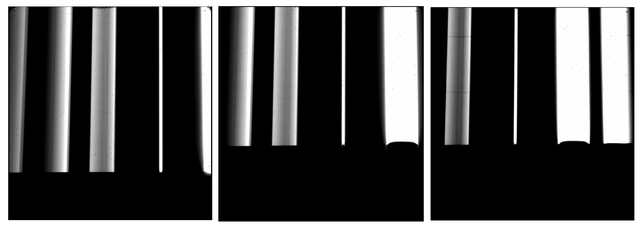


Figure 1. Positions on the detector of the spectral scans. Grism orders from right to left are +2nd, +1st, 0th, -1st and -2nd. Left: 0th, -1st, -2nd. Slivers of the +1st on the right edge, and -3rd on the left edge are visible. Center: +1st, 0th, -1st and -2nd orders. Right: +2nd, +1st, 0th and -1st orders are visible. The 0th, +1st and +2nd orders are saturated

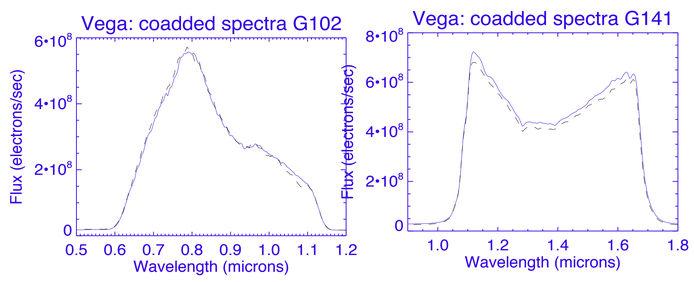


Figure 2 Coadded unfluxed spectra of Vega at each scan rate for the -1st orders of the G141 (top) and G102 (bottom) WFC3 IR grisms. Wavelength scale is in microns, negative numbers indicate negative order. Solid lines are the slow scan rates; dashed lines are the fast scans. Top: Paschen β is the dip at -1.28 microns, and the series of features between 1.6 and 1.7 microns are Br 13,12, 11. Bottom: Pa γ is just visible at 1.09 microns, and Pa δ at 1.05 microns.

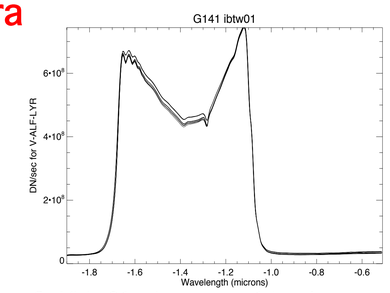


Figure 3. Visit 01; slow scan, -1st order spectra in G141 coadded at each scan position, after dark subtraction, flatfielding, dispersion correction and rectification. Note the 10% variation in the counts rates at wavelengths longer than 1.2 microns (left side of the plot). This is likely due to flat field

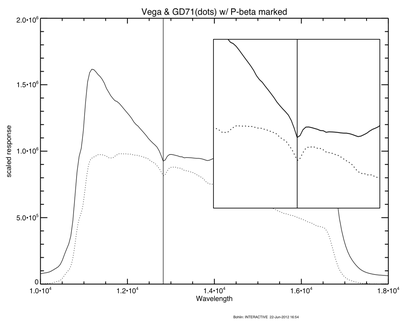


Figure 4. Comparison of GD71 and Vega spectra showing the wavelength calibration of the -1st order is comparable to the +1st order (inset).

Calibration of -1st orders

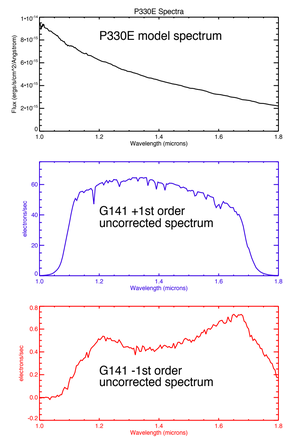


Figure 1. Top panel: P330E model spectrum in the IR extended from STIS spectra. Middle and Bottom panels show coadded WFC3/IR G141 spectra after flat fielding, sky subtraction, and dispersion correction. Flux units are electrons/second.

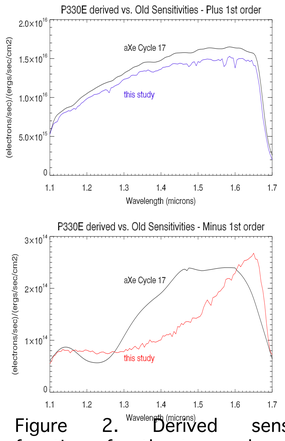


Figure 2. Derived sensitivity functions for the two orders. Black curves are the values at launch.

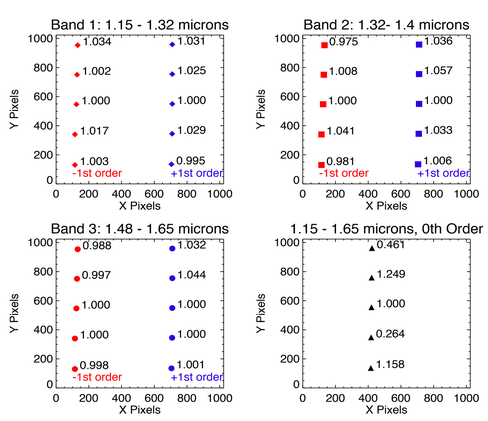


Figure 3. Variation in sensitivity in 3 wavelength ranges over the array with respect to the spectra in the middle position. Red points are obtained from the -1st order spectrum, blue points are from the +1st order. These are consistent with the results from Lee et al 2013

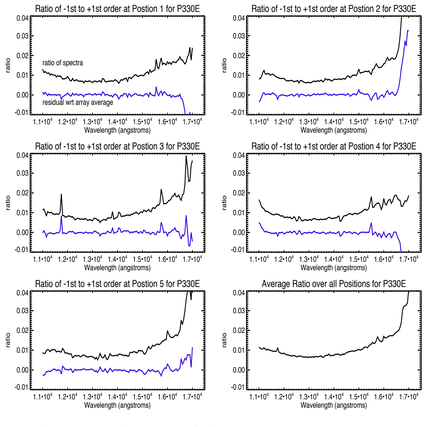


Figure 4. Ratios of the -1st to +1st spectra at each of 5 positions, with residuals (blue curves) with respect to the average shown in the lower right panel. On average, the throughput of the -1st order is 100 times less sensitive.