

The HST/STIS Next Generation Spectral Library

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Abstract. During Cycles 10, 12, and 13, we obtained STIS G230LB, G430L, and G750L spectra of 378 bright stars covering a wide range in abundance, effective temperature, and luminosity. This HST/STIS Next Generation Spectral Library was scheduled to reach its goal of 600 targets by the end of Cycle 13 when STIS came to an untimely end. Even at 2/3 complete, the library significantly improves the sampling of stellar atmosphere parameter space compared to most other spectral libraries by including the near-UV and significant numbers of metal poor and super-solar abundance stars. Numerous calibration challenges have been encountered, some expected, some not; these arise from the use of the E1 aperture location, non-standard wavelength calibration, and, most significantly, the serious contamination of the near-UV spectra by red light. Maximizing the utility of the library

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depends directly on overcoming or at least minimizing these problems, especially correcting the UV spectra.

1. Introduction

A wide variety of astrophysical problems can be addressed only through spectral modeling (see Leitherer et al. 1996), from constraining the turnoff age of ellipticals to deriving the initial mass function in starbursts. In almost all galaxy spectral modeling applications, the limiting reagent is the input spectral library because none of the extant spectral compilations cover luminosity, metallicity, and T_{eff} space sufficiently, especially at UV wavelengths.

To help fill the need for a better stellar library, we have carried out a STIS snapshot program (GO9088, GO9786, GO10222) to construct a “Next Generation” Spectral Library (NGSL). Stellar targets were selected from various metallicity catalogs, and nearly all have $V < 12$ and HIPPARCOS parallaxes. The observations used the low dispersion gratings and CCD detector of STIS to take high S/N spectra of stellar targets distributed over four metallicity groups:

very low	$[\text{Fe}/\text{H}] < -1.5$
low	$-1.5 < [\text{Fe}/\text{H}] < -0.5$
near-solar	$-0.3 < [\text{Fe}/\text{H}] < +0.1$
super-solar	$+0.2 < [\text{Fe}/\text{H}]$

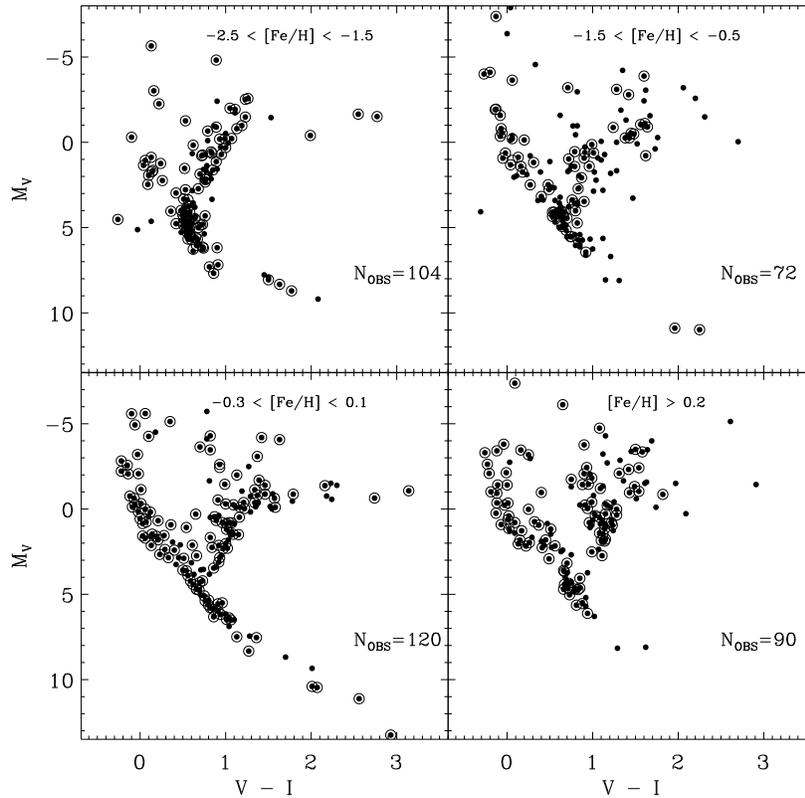


Figure 1: The final NGSL sample: circled points are stars for which we obtained STIS spectra; uncircled are the stars denied fame by the failure of STIS. The super-solar and low metallicity samples are somewhat under-represented because only solar and extremely metal poor stars were done in the first cycle of observing.

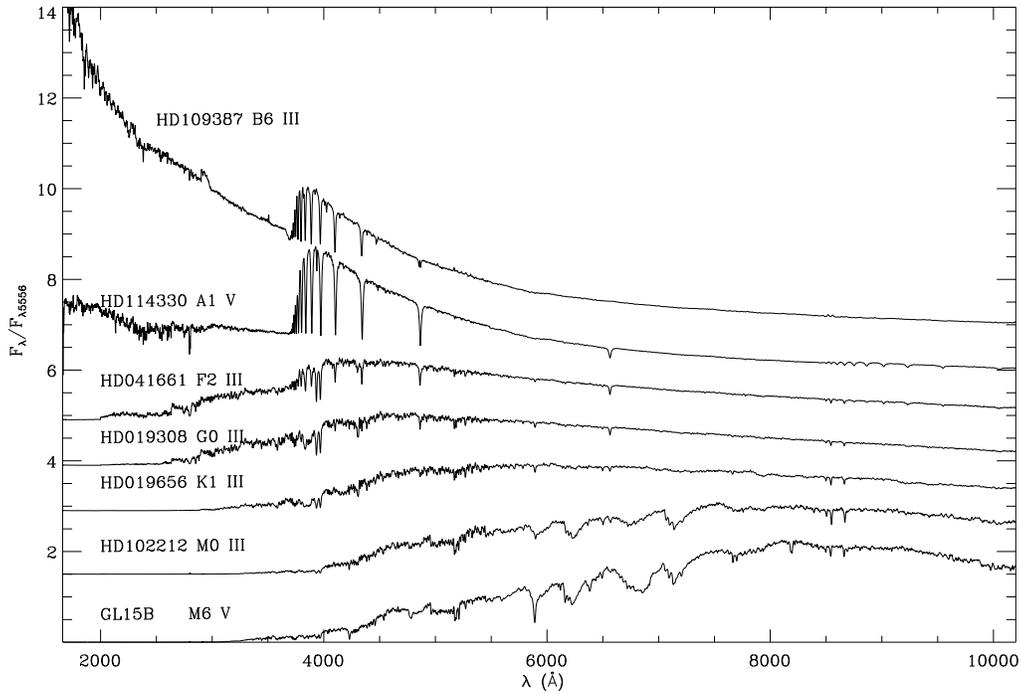


Figure 2: Example flux calibrated STIS NGSL spectra showing the wide range of spectral types covered by the program stars.

The three low dispersion CCD modes of STIS, G230LB, G430L, and G750L, cover the wavelength range 1670–10250Å. The original goal was to obtain 600 stellar spectra covering $T_{eff} - L - Z$ space far better than has been done before. This would have been reached in Cycle 13, but the failure of STIS in August, 2004, halted data collection at 380 stars. Even with the reduced number, the targets sample most of the HR-diagram in each bin (Figures 1, 2). Figure 3 compares two early K giants with different metallicities, demonstrating the need for a wide range of abundance in a stellar library for synthesizing composite populations.

2. NGSL Calibration Challenges

Despite STIS being a relatively mature HST instrument when the project began, several calibration issues immediately arose because of the demands and observing mode of this project.

2.1. Wavelength Scale

The NGSL snapshots were carried out in a somewhat nonstandard fashion. Permission was granted to dispense with automatic wavecal, saving 10 – 15 minutes per snapshot. All of the targets have known radial velocities, so the wavelength scale can be determined *a posteriori*, assuming that grating positioning uncertainties produce only zeropoint shifts. The parameter SHIFTA1 is determined for each grating for each target by cross correlation with a zero velocity template spectrum, then updated so that the X1D extraction produces a spectrum with the published velocity of the target. The X1D spectrum is then deredshifted to the restframe. Some of the metal poor stars have velocities in excess of 300 km s⁻¹, so this extra step is important to obtain the best wavelength scale (Figure 4).

2.2. E1 Aperture

The E1 aperture location was introduced in Cycle 10. Placed near the edge of the CCD, it was implemented to minimize charge transfer losses, but added to the flux calibration challenges in at least two ways. Because of flat fielding and vignetting/throughput differences relative to the standard, central STIS aperture, corrections to the flux calibration sensitivities were necessary. Charles Proffitt reports elsewhere in this volume on these efforts (Proffitt 2006), now nearly finalized. The other challenge arises from an error in the initial location of the 52X0.2E1 aperture, which was off by about 0.5 pixels, resulting in additional slit losses. To save precious time, the NGS observations (per the STIS Handbook advice) did not use peak-ups to center targets, so for most of Cycle 10, stars were observed slightly off center in the slit. It is not clear yet just how much this affects the spectral energy distribution shape (which is critical for spectral modeling), but overall throughput is affected at the 5 – 15% level. An example of the typical flux calibration match/mismatch is shown in Figure 5. Even when two gratings do not agree, a simple scaling appears to be enough to correct the discrepancy, but we are comparing the STIS spectra to stellar models to test this.

2.3. Fringing

The STIS CCD is subject to severe fringing at wavelengths redward of 7000Å. Contemporaneous fringe flats were obtained for every target to allow removal of the fringing. Slightly modified versions of the standard IRAF/STSDAS STIS routines are used to divide out the fringes. The results are improved significantly by subtracting a scattered light component; this component is estimated by fitting a smooth curve to the occluded portions of the detector in the fringe flat images. In most cases, the fringes are removed down to the 1-2% level (Figures 2, 4). The flux calibration and useful data overlap between G430L and G750L would be improved by using the flats to take out the high order response/sensitivity variations at the blue end of G750L; presently, these wiggles are removed from the flats using a

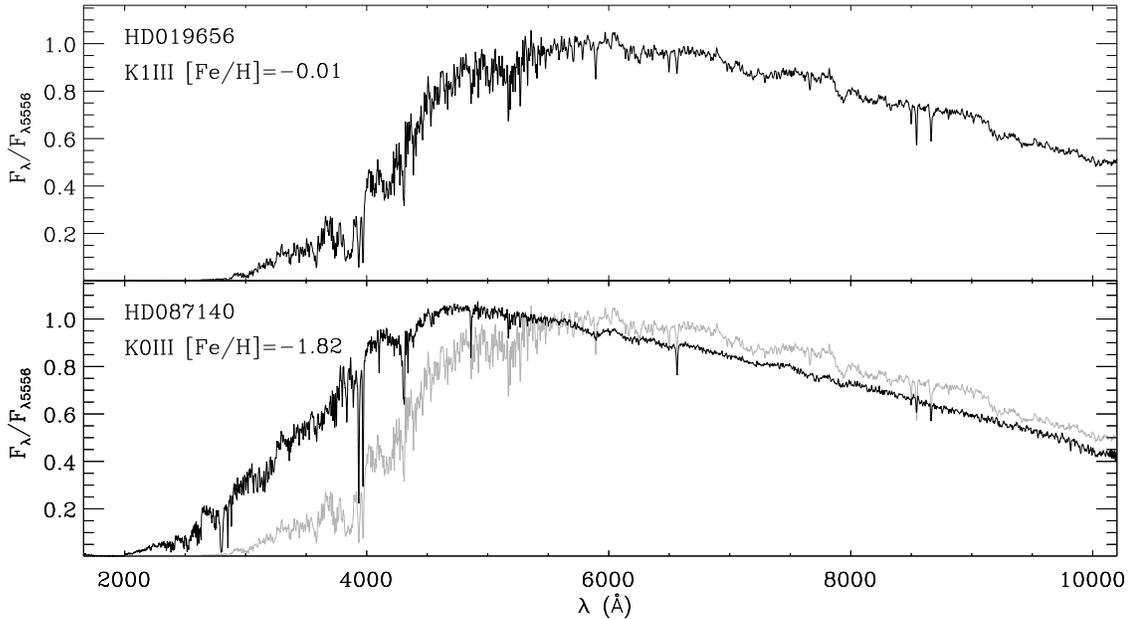


Figure 3: Comparison of STIS spectra of two K giants with very different metallicity. The metal rich star is overplotted as the grey line in the lower panel. This comparison highlights the need for a wide range of not only temperatures but abundances in stellar libraries for proper modeling of composite systems.

very high order spline, necessitating a very high frequency signature in the flux calibration.
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2.4. Red Light Contamination in G230LB

The thorniest problem facing NGSL is the red light contamination in the G230LB mode. Because the CCD is extremely sensitive in the red and relatively insensitive in the ultraviolet, even a miniscule fraction of scattered light from red targets can dominate their UV signal. Using the MAMA detectors, which do not suffer from this problem because they are insensitive to optical wavelengths, was not an option because of the brightness of NGSL targets.

The level of the contamination rises from the short to the long wavelength end of G230LB (Figure 6), showing that the main contribution to the contamination is probably dispersed light from G230LB, though some contribution from the wings of the zero-order

¹Editors' note: Reference files (keyword LFLTFILE) to calibrate large-scale variations in the flats for the CCD L gratings were delivered for use in the pipeline and archive retrieval on 12 December 2005. They provide corrections of up to a few percent at locations beyond the central rows of the detector.

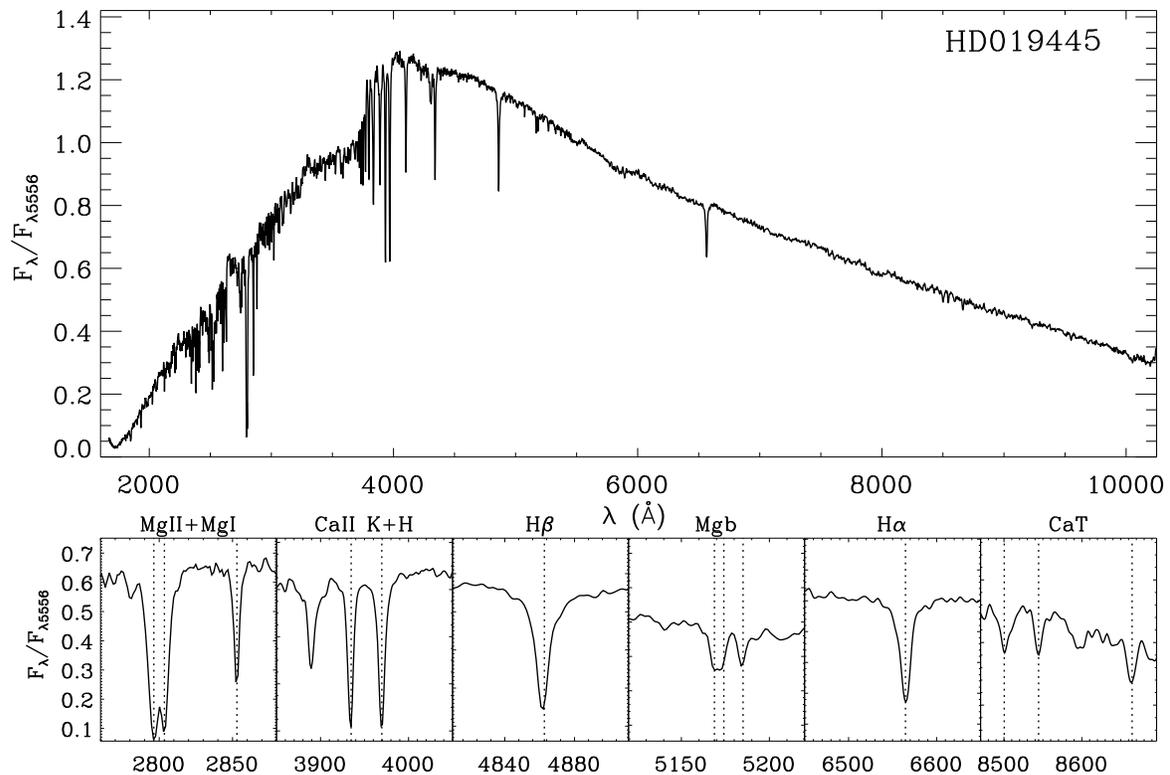


Figure 4: An example NGSL spectrum with all three gratings combined and shifted to restframe wavelengths. The reliability of the wavelength calibration is demonstrated by the relatively good agreement between the absorption features and their expected locations (dotted lines) in the lower panels. The lack of fringing redward of 7000 \AA demonstrates how well the defringing method works.

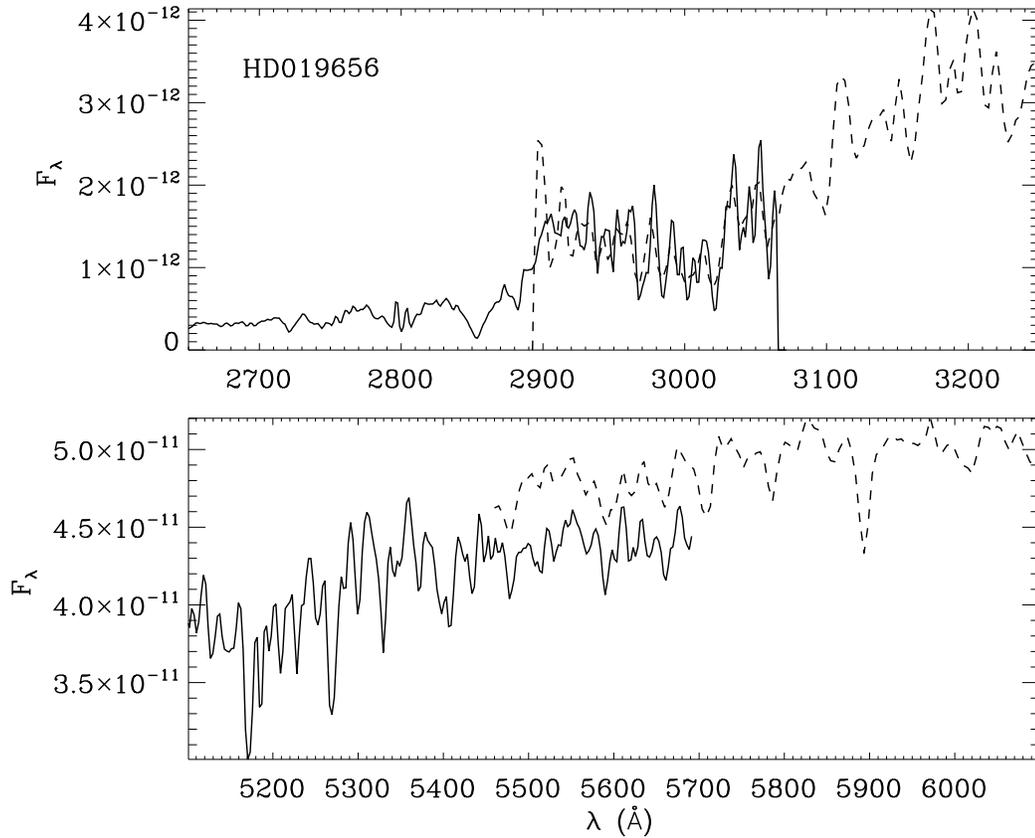


Figure 5: There are sometimes significant mismatches between gratings for the fluxed spectra. For this star, the G430L and G750L spectra differ by 10%, but the G230LB and G430L agree to within a few percent. The disagreement in the red appears to be mainly a scaling or throughput problem and is easily removed, but we have not tested this systematically, nor does this problem occur for all targets. It may be associated with the E1 aperture placement error.

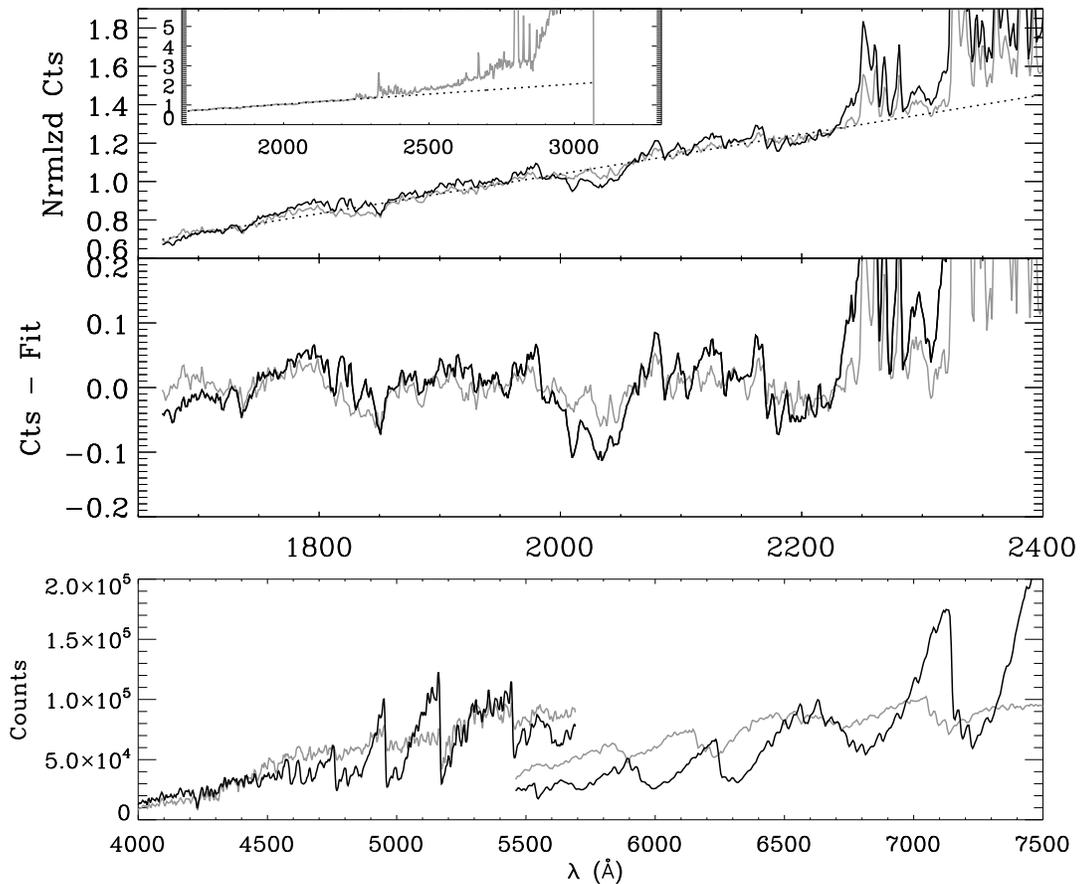


Figure 6: Top panel: Example counts vs. wavelength for two stars to show the rising red light contamination problem for red targets; inset shows the complete G230LB wavelength range. Neither of these stars should generate appreciable counts below 2000Å; all of the detected signal is spurious. Because it rises to the red, the absolute level of contamination is significant at all wavelengths in G230LB. For these stars, normalized to unity at 2000Å, the contamination is remarkably similar in level and slope, allowing removal by a simple linear fit (middle panel). Unfortunately, this breaks down for bluer stars where the correction is still significant but not directly measurable because of actual signal. The bottom panel shows the redder two gratings counts for the two stars.

image may also be present. A simple linear fit and subtraction of the contamination works well over a small range of colors (Figure 7), but the slope of the contamination changes with the temperature of the target and there appear to be periodic features in the red light, with scales of a few hundred angstroms (Figure 6). Though scattered light usually does not contain spectral features, there is at least a hint that the later type stars produce scattered light with deeper residuals, perhaps somehow related to the very wide molecular features in the red (Figure 6).

A correction from first principles, or at least a solid empirical calibration for all stellar temperatures, is needed to be able to correct the data adequately. We are at work trying to produce adequate models, cross checking with IUE fluxes.

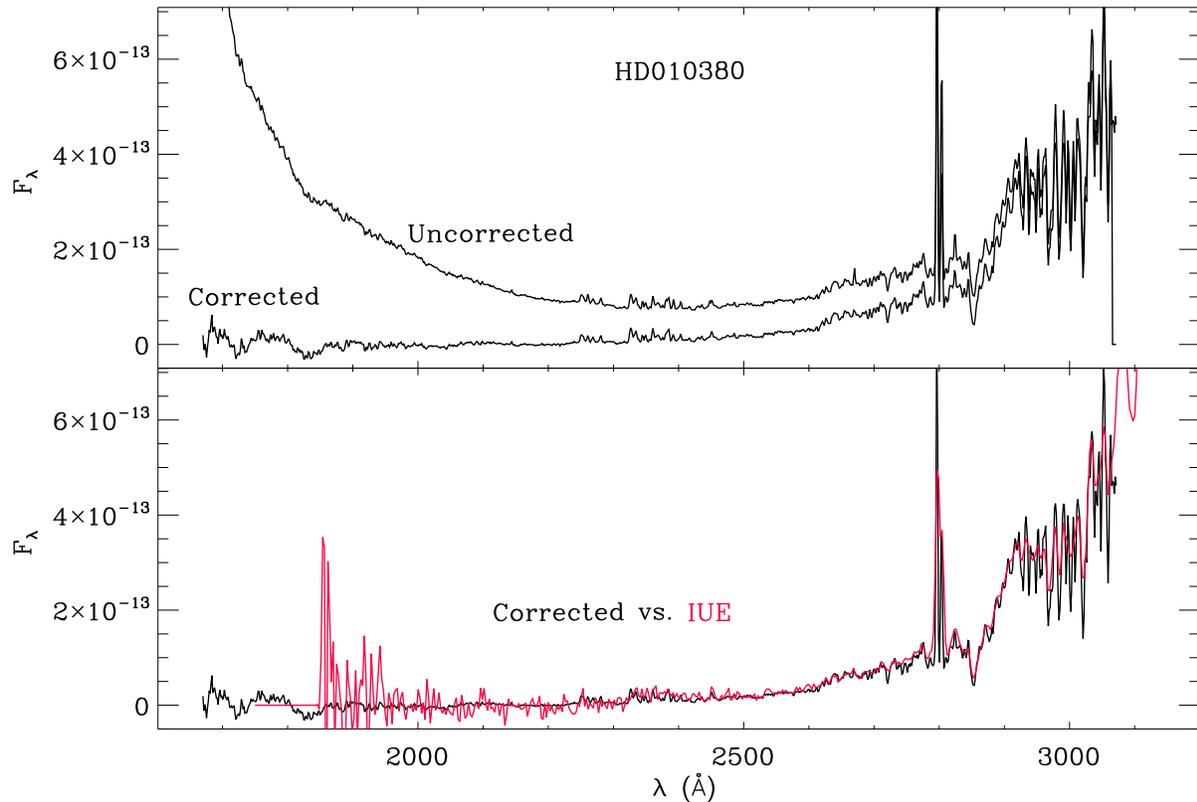


Figure 7: Comparison of IUE and STIS spectra of HD010380 before and after correction for the red contaminating flux. The contamination dominates below 2600Å, and is important at the 5-10% level even at 3000Å.

3. The Future of NGSL

Because the G230LB red light contamination will require more time to model and remove, we are now planning to release the G430L+G750L data on its own by the end of 2005. The UV spectra will be added as soon as a reliable model for the scattered light can be generated. In addition, we plan the following enhancements:

1. Fill out red giant and dwarf color-magnitude space using the HST archive.
2. Extend the wavelength coverage to the far-UV using the HST and IUE archives.
3. We are obtaining echelle resolution spectra using the VLT/UVES instrument. These data will be used to check the atmosphere parameters of the NGSL stars in a consistent manner, plus they will make it possible to work at extremely high resolution over the 3600 – 9000Å window.
4. Similarly, we have begun extending the spectra to $2.5\mu m$ using the SpeX instrument at IRTF.
5. The final goal of NGSL is to be able to interpolate among the observed stars for spectra of arbitrary $Z - L - T_{eff}$. With 380 instead of 600 input stars, such interpolation becomes somewhat less robust, but with contributions from the archives, it may be possible to reach this goal. And there is always the optimistic view that someday STIS will be repaired and reactivated, and NGSL completed.

The NGSL surpasses all extant compilations in terms of metallicity and wavelength coverage. The spectra, once properly calibrated, will be made publicly available via our website, <http://lifshitz.ucdavis.edu/~mgregg/gregg/ngsl/ngsl.html>, and other outlets.

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References

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