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NEW FAR-ULTRAVIOLET INTRINSIC SPECTRAL FLUXES OF HOT STARS AND THEIR PHOTOSPHERIC TEMPERATURES

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ABSTRACT

We present photometric, far-ultraviolet (FUV) intrinsic spectra of Galactic OB stars that were acquired by the orbital Hopkins Ultraviolet Telescope (HUT) at 2–3 Å resolution in the range $\lambda = 912$–1840 Å. Flux-calibrated by observations of standard white dwarfs to 5% systematic uncertainty, and corrected for extinction to ~15% random uncertainty, the lightly dereddened B-star spectra agree with Kurucz-model atmospheric fluxes at most wavelengths $\lambda > 1000$ Å. The best-fit $T_{\rm eff}$ are within 500–1000 K of $T_{\rm eff}$-values recently derived by others with longer wavelength ($\lambda > 1200$ Å) data. The HUT B-star fluxes near 1000 Å are systematically ~5% higher than the models—just within the systematic uncertainty but yielding FUV color temperatures that are at least 1000–5000 K hotter than models.

Subject headings: atlases — stars: atmospheres — stars: fundamental parameters — ultraviolet: stars

1. INTRODUCTION

Thermal radiation from hot OB stars peaks in the far-ultraviolet (FUV) for temperatures $T \sim 10{,}000$–30,000 K. These stars thus inject the bulk of their radiant energy into the Galactic medium at FUV wavelengths, where dust absorbs most strongly (Buss et al. 1994). In this manner, hot stars profoundly influence their surroundings, so the FUV absolute spectral energy distributions of OB stars are important for studies of hot stars, the interstellar medium (ISM), and star-forming galaxies. Yet, it is unknown just how bright and how hot are OB stars at FUV wavelengths. At $\lambda < 1150$ Å, photometrically calibrated FUV spectra of hot stars currently exist only at low (18 Å) resolution (Chavez, Stalio, & Holberg 1995; Longo et al. 1989), which is insufficient to resolve most photospheric absorption lines. Other useful short-wavelength, high-resolution spectra do not have reliable photometric calibrations (e.g., Snow & Jenkins 1977). Data from *ORFEUS* (Hurwitz & Bowyer 1991) could help remedy this situation but are not yet available.

To provide accurate measurements of the radiative characteristics of hot stars, we observed OB stars at 2–3 Å resolution over the range $\lambda = 912$–1840 Å with the 0.9 m Hopkins Ultraviolet Telescope (HUT; Davidsen et al. 1992) on the Astro-2 and Astro-1 Space Shuttle missions. Kruk et al. (1995a) discuss the modifications and calibration for Astro-2. In this Letter, we present photometric, dereddened spectra for stars that span spectral types A1–O6.5, most of whose ISM transmission corrections are relatively small or well known. These spectra will be useful for comparison with stellar atmospheric models, synthesis of stellar populations, analysis of starburst galaxies, derivation of dust extinctions, radiative modeling of Galactic clouds, and, presumably, other unanticipated future studies.

2. OBSERVATIONS AND REDUCTION

We selected Galactic OB stars to sample a range of spectral types (Table 1) that we determined from the literature, in the SIMBAD stellar database, and subsequently from our HUT observations. The spectral types and magnitudes from the literature yielded reddenings (see Fitzgerald 1970). We later cross-checked the spectral types with those in Heck et al. (1984) by classifying them ourselves with this atlas and by comparing the types with a master catalog of OB stars (K. Garmany 1994, private communication). The types mainly agreed, except for HD 31726 (sometimes B1 V), whose UV spectral lines, notably C III] λ1176, indicate a B1.5 class rather than B2 (Heck et al. 1984). We kept the optical luminosity class of O9 IV(e) for HD 57682 instead of the UV class of O9.5 V because of optical Balmer line emission (Coté & van Kerkwijk 1993), though this may be nebular. Two stars were observed on Astro-1 (Kruk et al. 1995b; Bowers et al. 1995) and are included in Table 1 to provide a range of luminosity classes at O9.5; a B1 IV–Ve spectrum of π Aqr was presented by Buss et al. (1994).

The dynamic range of the HUT detector imposes an OB-star FUV brightness limit for observation that corresponds to $V \geq 6.0$ mag, assuming $E(B-V) < 0.04$ mag and a mean FUV extinction for $R_V = 3.05$ (Cardelli, Clayton, & Mathis 1989, hereafter CCM). Thus, this and other secondary observing constraints forced us to observe stars that were *not* the brightest spectral standards. Within this subsample of stars, however, we chose those with the smallest $E(B-V)$ to minimize contamination by foreground dust and gas. In most cases, the corrections for the ISM are relatively minor (Table 1), except for the luminous Galactic O giants that are necessarily distant.

We corrected the spectra for detector dark counts (3.9×10^{-4} counts s^{-1} pixel^{-1}), intensifier pulse-persistence (0.95), dead time (<1.05), and scattered-light, flat-field, and spectrograph second-order ($\lambda > 1824$ Å) reflection. The HUT

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TABLE 1
Stellar and ISM Properties

Name (HD)	Start[a] (days:hours:minutes:seconds)	Stop[a] (days:hours:minutes:seconds)	Type (MK)	V (mag)	$E(B-V)$ (mag)	C_{1000}	$N(H\ \text{I})$ (log cm^{-2})	$N(\mathrm{H}_2)$ (log cm^{-2})	$v \sin i$ (km s^{-1})	T_{eff} (10^3 K)	T_{FUV} (10^3 K)	Notes
94963	65:14:56:06	65:15:11:14	O6.5 IIIe	7.15	0.23	31.9	21.05[b]	20.00[b]	90	...	...	...
30614	...[c]	...	O9.5 Iae	4.30	0.30	78.0	20.90	20.34	95	...	...	α Cam
189957	67:02:11:50	67:02:19:38	O9.5 III	7.82	0.32	124	21.30[b]	19.3[b]	145	...	...	ISM large!
57682	74:02:16:47	74:02:30:35	O9 IV(e)	6.42	0.12	6.09	20.90	18.7[b]	17	>35	...	UV O9.5 V; Oe[d]
93521	62:14:46:05	62:14:57:32	O9.5 Vp	7.04	0.02	1.35	20.11	...	400	...	...	B0 Ib;[e] 32″ slit
2905	...[c]	...	B0.7 Iae	4.16	0.35	161	21.28	20.27	62	...	...	κ Cas; $R_V \approx 3.05$
31726	66:23:25:59	66:23:32:35	B1.5 V[b]	6.15	0.04	1.83	20.43	...	...	24	29	$F_{\lambda 1500}$ scaled to *IUE*
51285[f]	74:22:00:23	74:22:15:33	B2 Ve	8.16	0.06	2.47	20.5[g]	...	...	23	25	Weak Be star
86466	65:15:34:30	65:15:38:56	B3 IV	6.12	0.07	2.87	...	<19.0[b]	30	18	18	$F_{\lambda 1565} \approx F(\mathrm{TD1})$
188665	74:04:54:29	74:05:18:07	B5 V	5.14	0.02	1.35	...	...	145	16	17	...
95418	63:04:00:11	63:04:40:29	A1 V	2.37	0.0	1.00	...	...	39	...	...	β Uma; varies

[a] 1995, GMT: day 61 = Julian day 2,449,779.
[b] Our measure.
[c] 1990, Astro-1.
[d] Coté & van Kerkwijk 1993.
[e] Rapid rotation makes absorption lines like those of B0 Ib (Massa 1995). At high latitude *b*.
[f] Observed courtesy of R. Schulte-Ladbeck & D. Hillier.
[g] Assumed.

wavelength scale was calibrated by use of emission lines from symbiotic stars as a reference grid, with resultant ±0.26 Å uncertainty in λ. Strong airglow emission and photon scrubbing of the detector always contaminates the HUT spectra at H I 1216.7 Å and O I 1304 Å; airglow emissions of H I 1025.7 Å and O I 989 Å are present weakly in HD 189957. For observations through the HUT 50–200 cm^2 doors, scrubbing due to strong emission lines in other bright objects caused cumulative decreases (<20%) in detector sensitivity at N V λ1240, C IV λ1549, and He II λ1640, which were corrected for with 5% uncertainties.

For the program OB stars in Table 1, we observed HD 189957 and HD 51285 through the 200 cm^2 HUT door aperture and the remainder through the 50 cm^2 door. Because of miscentering and consequent vignetting of HD 31726 through a 12″ slit, we corrected the HD 31726 HUT spectrum by normalizing it to match the *IUE* spectrum SWP 8165 at 1500 Å (Heck et al. 1984), using the new white dwarf–based *IUE* flux calibration (González-Riestra et al. 1994). Stable pointing at the other HUT stars with a 20″ diameter slit gives photometric, ~2.0–3.0 Å resolution (through 50 cm^2 doors) spectra with signal-to-noise ratio $S/N \gg 5$ per 0.5 Å pixel. Within a few Å of the Lyman 911.5 Å limit, $S/N \rightarrow 0$ in most cases. Cross-checks at 1500 Å with *IUE* (Heck et al. 1984; *IUE* archives) verify the long-wavelength photometry of the HUT spectra to within 5%. For HD 86466, however, the broadband TD-1 atlas is the only independent flux check. From the magnitude of the corrections and agreement in flux levels, we estimate an ~5% calibration uncertainty in the observed stellar fluxes and ~7% at N V λ1240, C IV λ1549, and He II λ1640.

3. ANALYSIS

3.1. *Corrections for Galactic-Medium Extinction*

From the observed stellar flux density F_λ^0, we derive the intrinsic stellar flux density F_λ by removing the dust extinction [optical depth $\tau_\lambda(d)$] and H absorption [$\tau_\lambda(\mathrm{H})$] of the Galactic medium:

$$F_\lambda = F_\lambda^0 \exp\left[\tau_\lambda(d) + \tau_\lambda(\mathrm{H\ I}) + \tau_\lambda(\mathrm{H_2})\right], \qquad (1)$$

where $\tau_\lambda(d) = 0.4(\ln 10)(A_\lambda/A_V)R_V E(B-V)$, $\tau_\lambda(\mathrm{H}) \propto N(\mathrm{H})\phi_\lambda f\lambda^2$, and $N(\mathrm{H})$ is the column density, ϕ_λ the line profile, and f the transition oscillator strength. Because the mean diffuse ISM extinction A_λ/A_V when $\lambda > 1000$ Å is characterized well by an $R_V = A_V/E(B-V) = 3.1$ parameter (CCM), we use the CCM A_λ/A_V curve at all wavelengths to deredden the spectra of stars with $E(B-V) > 0.1$ mag. For these stars, IR photometry (Thé et al. 1989; Aiello et al. 1988) confirms that $R_V = 3.1$. For HD 2905 (κ Cas), however, the polarization $\lambda_{\max}$ indicates a smaller value, $R_V \approx 3.05$, than HD 30614 (α Cam; Clayton et al. 1995). In addition, for stars for which $E(B-V) < 0.1$ mag (Table 1), we assume $R_V = 3.05$ because grain sizes are probably smaller in these less shielded, diffuse regions (Buss et al. 1994). The mean ISM dust extinction when $\lambda < 1000$ Å, however, is extrapolated from longer wavelengths, having been checked versus R_V in one case (Buss et al. 1994). Assuming $E(B-V) = 0.07$ mag, typical of our B stars, the measured $A_{\lambda<1000}/A_V$ extinction yields 9% lower intrinsic fluxes at 960 Å than given by the extrapolated mean FUV extinction (CCM), which corresponds with $R_V \sim 3.0$–3.15.

The dereddening multiplication factors at 1000 Å (C_{1000}) are listed in Table 1. Note that a range in R_V of 3.0–3.15 results in only minor (<3%) flux uncertainties at 1000 Å. Random errors caused by photometric [$\delta E(B-V) = \pm 0.01$ mag] and spectral-type color uncertainties [$\delta E(B-V) = \pm 0.01$ mag] give only 20% flux uncertainty at 1000 Å for $E(B-V) \approx 0.07$ mag. For the B dwarfs, repeated measures and careful classifications would seem to lower this to ~10%. Diffuse sight lines generally have smaller deviations from the R_V mean extinctions than H^+ or dense cloud regions. Thus, while the little-reddened B stars will have negligible UV-flux errors due to unknown and known extinction deviations (Savage et al. 1985), the O (super)giants could theoretically have large deviations in the FUV. Actually, the measured 1500 Å extinction deviations from a CCM UV extinction predicted by $R_V = 3.15$ (Savage et al. 1985) for HD 30614 and HD 2905 (κ Cas, at $R_V = 3.05$) translate into flux differences of less than 2%. However, because HD 189957 has some UV-extinction deviation [$\delta(A_{1500}/A_V) = 0.19$ mag] and because we *assume* $R_V = 3.1$ for this star, the HD 189957 dereddened FUV continuum should be taken with caution, particularly because this O9.5 III spectrum rises more steeply than that of the O6.5 III star! An $E(B-V) = 0.30$ mag gives HD 189957 an FUV shape more like that of the other O9 stars.

Stars with substantial *stellar* Lyα absorption (B3 and later; see Savage & Panek 1974) and small reddenings have little *interstellar* H I absorption (see Bohlin, Savage, & Drake 1978) compared to photospheric H I. In contrast, for stars with little stellar Lyα absorption (Table 1, O–B2), we correct for interstellar H I absorption in the Lyman series for quantum $n \leq 48$, using model Voigt line profiles ϕ_λ of $b = 10$ km s^{-1} Doppler width smoothed to the HUT resolution. If $b = 5$ km s^{-1}, systematic errors become greater than 10% for $\lambda < 920$ Å. We measure the ISM H I column density $N(\mathrm{H\ I})$ by restoring the Lyα continuum in the Lorentzian-profile wings in the HUT spectra (see Buss et al. 1994) or by using a column density from the literature (see Diplas & Savage 1994; Fruscione et al. 1994) at ±0.05–0.10 dex cm^{-2}. In most cases, airglow and detector dead time render the corrected Lyα 1215.7 ± 5 Å cores unreliable as intrinsic stellar flux. The corrections for higher Lyman lines, however, are generally small and reliable, and the B2 and earlier stars will have accurate intrinsic fluxes at H I. The B3 and later stellar spectra will have some minor uncorrected contribution from ISM H I.

The HUT spectra of stars with $E(B-V) < 0.08$ mag have negligible $\mathrm{H_2}$ columns (see Bohlin et al. 1978). For the remaining O stars with higher reddenings, however, we correct for $\mathrm{H_2}$ absorption between 912 and 1120 Å by modeling the absorption with 420 Voigt line profiles for $\mathrm{H_2}$ Lyman ($\nu' = 0$, $\nu'' = 0$–20) and Werner ($\nu' = 0$, $\nu'' = 0$–7) rotational j levels (Morton & Dinerstein 1976) that depend on ISM density, excitation, and velocity dispersion b. At the HUT 2.0–3.0 Å resolutions, the $\mathrm{H_2}$ lines often blend with stellar features and each other. For HD 30614 and HD 2905, however, we use the measured, reliable high-dispersion $\mathrm{H_2}$ columns (Savage et al. 1977) and rotational excitations (Jura 1975), $T_{\mathrm{rot}}(j = 0, 1) = 85$ and 100 K at $b = 5$ km s^{-1}, respectively, and the HD 30614 nonthermal population ratios ($2 \leq j \leq 7$; Jura 1975) to correct accurately the HUT spectra at the Astro-1 3.0 Å resolution. Since such data are lacking for HD 94963, HD 189957, and HD 57682, we divide them by various $\mathrm{H_2}$ single-component model spectra, smoothed to 2.0–2.5 Å resolution, to find the model that best restores the observed 965, 1009, 1077, or 1092 Å absorptions to the apparent continuum level. We define the continuum by flux peaks in regions free of $\mathrm{H_2}$

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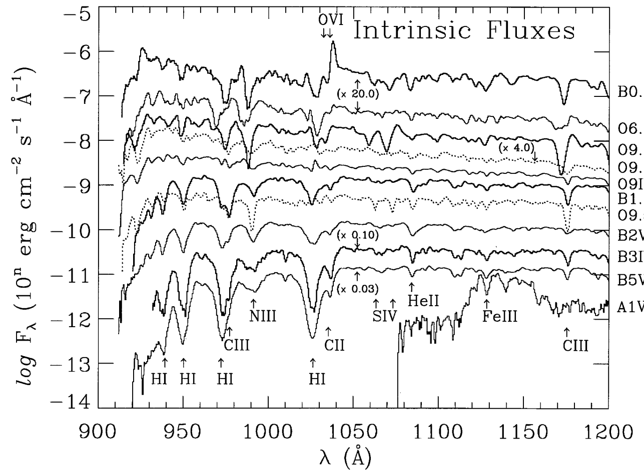

FIG. 1.—Intrinsic stellar FUV fluxes, smoothed by 3 pixels, show strong absorption lines from abundant elements and continua that generally become steeper with increase in spectral type. Uncertain or peculiar stars are marked with dotted lines. For clarity, we scaled a few spectra by the indicated factors. Most spectra truncate near the 912 Å Lyman limit; for the B3 and B1.5 stars, respectively, we truncate noisy HUT data shortward of 920 and 930 Å, as well as 1075 Å for the cool A1 star.

absorption (on either side of the lines, as well as throughout 1120–1150 Å). The best-fit model parameters for these stars are $b = 5 \pm 2$ km s^{-1}, $T_{\rm rot} = 80 \pm 10$ K, and $N(\rm H_2)$ as in Table 1 for $j < 2$, except that $T_{\rm rot} = 60$ K for HD 57682. For $N(\rm H_2)$ in $j > 2$ toward HD 94963, we scale the high-j column-density ratios of HD 30614 (see above) to the HD 94963 $j = 1$ level, whereas for HD 189957, which may contain multiple components, we find log $N(j > 2) = 18.5$ cm^{-2}, assuming $T(j > 2) = 1000$ K.

3.2. *Comparison of Intrinsic Fluxes with Stellar Model Atmosphere Fluxes*

The intrinsic stellar fluxes, obtained by the above ISM corrections, are displayed in Figure 1 with 3 pixel smoothing. These spectra exhibit the expected strong stellar absorption lines from abundant elements, such as C, N, H, He, and Fe—with H becoming ionized and weaker at earlier types. The C III strengths are most sensitive to the temperature in the dwarfs, decreasing in strength away from B1.5 (see Rountree & Sonneborn 1993; Walborn, Nichols-Bohlin, & Panek 1985), except for the strong 1175 Å line in the peculiar HD 93521 O9.5 Vp star and the weak line in the emission-line B2 Ve star. The $\lambda < 1100$ Å *continuum* fluxes of the dwarfs (Fig. 1) show a monotonic and dramatic decrease relative to F_{1100} as the spectral type decreases (the O9.5 III fluxes have large errors). Since the surface gravity log g and temperature $T_{\rm eff}$ mainly determine the appearance of the absorption lines and continua (rotation can additionally affect the spectra of O stars), the MK type continues *in the FUV* to track systematic changes in the fundamental stellar parameters of OB stars. Also, as the luminosity increases among the O9–O9.5 stars, the C III and S IV (1063 and 1073 Å) lines (Fig. 1) increase in strength, and the strong absorption lines become blueshifted as a result of high-velocity winds. In contrast, the strong absorptions in HD 93521 are caused by rapid rotation (Massa 1995) and lie at rest λ. Finally, O VI emission components are present just longward of Lyβ 1025.7 Å in the O9 IV and B0.7 Ia spectra.

We now determine the FUV atmospheric temperatures ($T_{\rm FUV}$) of the OB IV/V stars by forming a ratio of the observed 1000 and 1400 Å fluxes at 995–1075 Å (excluding ±10 Å at Lyβ) and at 1315–1475 Å and by then comparing this ratio with the same flux ratio in the model atmospheric spectra of Kurucz (1992). We define $T_{\rm FUV}$ for a star by equating it with the $T_{\rm eff}$ of a Kurucz model that has same F_λ ratio as the star (Table 1). Because of known inadequacies (Kurucz 1992) in the LTE line-blanketed models, we exclude O III and I stars (Table 1) and the rapid rotator HD 93521 from this analysis. The models vary with $T_{\rm eff}$ and log g at solar abundance and 2 km s^{-1} microturbulent velocity. The $T_{\rm eff}$ are of the Kurucz model that best fits the observed spectrum after binning it to the 10 Å model resolution. The lowest reduced χ^2_ν, best-fit Kurucz model (often log $g = 4.0$) is found by normalizing the models to the observed fluxes from 1000 to 1700 Å (excluding data with likely systematic errors at Lyα, N V, and O I from 1150 to 1350 Å, and at Lyβ λ1026 and C IV λ1550). Because the mean Galactic extinction at $\lambda < 1000$ Å is not well determined, perhaps with 5%–10% systematic error, we omit the less than 1000 Å stellar fluxes from the model fitting.

For the reliable data between 1000–1700 Å, the models provide reasonable overall continuum matches that are not always statistically acceptable ($0.6 < \chi^2_\nu < 7.4$). At ±500 K uncertainty the derived $T_{\rm eff}$ values in Table 1 agree with those measured by Gulati, Malagnini, & Morossi (1989). For HD 57682 at $T_{\rm eff} > 35{,}000$ K, only a lower limit could be derived at the edge of the model grid. Nevertheless, at each $T_{\rm eff}$, the observed FUV flux ratios are higher than the model ratios as a result of systematically higher (~5%) observed 1000 Å fluxes in four of the five stars and lower 1400 Å fluxes in HD 188665 and HD 57682 than in the models. Thus, the color temperatures $T_{\rm FUV}$ are *hotter* than the $T_{\rm eff}$ values, except for the B3 IV star HD 86466, whose Kurucz model fits throughout the FUV. The actual $T_{\rm FUV}$ for a star is given by the value of the observed ratio that matches the ratio for a particular model. Even at log $g \approx 4.5$, the inferred $T_{\rm FUV}$ for the observed B stars are 1000–5000 K hotter than the best-fit $T_{\rm eff}$.

4. DISCUSSION AND CONCLUSIONS

We have derived intrinsic stellar fluxes of a sample of Galactic OB stars that are photometrically accurate to ~16% at $\lambda > 1000$ Å (see §§ 2, 3), mainly from random 15% uncertainties in the extinction corrections (except for HD 189957). For $\lambda < 1000$ Å, an additional possible 5%–9% systematic uncertainty in extinction could result in total flux errors of ~16%–20%. The OB-star 912–1100 Å continua become progressively bluer (hotter) as the type increases (Table 1), and the absorption-line strengths, particularly at H I and C III, vary systematically by depending sensitively on the spectral type and luminosity class. Thus, the MK types continue in the FUV to be good systematic indicators of the stellar properties, and the accurate intrinsic fluxes can currently provide the most sensitive flux tests of model spectra in the FUV.

We find that the Kurucz stellar models that best fit the observed B5–B1.5 star spectra from 1000 to 1700 Å yield $T_{\rm eff}$ values similar to those of Gulati et al. (1989) and ~500 K hotter than those of Chavez, Stalio, & Holberg (1995), both derived from $\lambda > 1200$ Å data. Using $\lambda = 1050$ Å fluxes, Chavez et al. found generally good agreement (cf. Longo et al. 1989) with Kurucz models, but at B3 and earlier, the observed 1050 Å fluxes (relative to V) of their stars are higher, within a factor of 2, than the models'. Using only FUV fluxes, we find a similar trend: Kurucz-model continua that generally match the observations but with stellar 1000 Å fluxes ~1.05 times higher than the models—too systematic to be likely to result from random $E(B-V)$ errors. Thus, the HUT flux-calibration might be 5% too high near 1000 Å, the CCM mean A_{1000}/A_V extinction could be too high by 0.25 units, or the inferred color temperatures of B stars could be hotter by $\delta T_{\rm FUV} = 1000$–$5000$ K than the LTE models (Kurucz 1992). If the latter, then the stellar temperature structure might have a hotter layer and higher FUV fluxes, because of nonequilibrium heating in the upper atmosphere, similar to but less than the observed EUV flux excesses for a B2 II star, which are 30 times higher than expected (Cassinelli et al. 1995). Hence, at present, flux differences between models and observations from 912 to 1000 Å, where some ISM extinctions have been measured (Snow et al. 1990; Longo et al. 1989), would be a useful check. Measurements of deviations from the CCM *mean* diffuse-medium extinction below 1000 Å, however, are scarce (Buss et al. 1994), so unknown systematic errors in the $\lambda < 1000$ Å ISM extinction might be larger than the total known 16% spectral flux uncertainty or mask any 15% flux deviations from the models. Detecting an FUV flux excess or $T_{\rm FUV}$ excess awaits a large survey measurement of the mean Galactic extinction near the Lyman limit.

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REFERENCES

Aiello, S., et al. 1988, A&A, 73, 195
Bohlin, R. C., Savage, B. D., & Drake, J. F. 1978, ApJ, 224, 132
Bowers, C. W., Blair, W. P., Long, K. S., & Davidsen, A. F. 1995, ApJ, 444, 748
Buss, R. H., Jr., Allen, M., McCandliss, S., Kruk, J., Liu, J.-C., & Brown, T. 1994, ApJ, 430, 630
Cardelli, J. A., Clayton, G. C., & Mathis, J. S. 1989, ApJ, 345, 245 (CCM)
Cassinelli, J. P., et al. 1995, ApJ, 438, 932
Chavez, M., Stalio, R., & Holberg, J. B. 1995, ApJ, 449, 280
Clayton, G. C., Wolff, M. J., Allen, R. G., & Lupie, O. L. 1995, ApJ, 445, 947
Coté, J., & van Kerkwijk, M. H. 1993, A&A, 274, 870
Davidsen, A. F., et al. 1992, ApJ, 392, 264
Diplas, A., & Savage, B. D. 1994, ApJS, 93, 211
Fitzgerald, M. P. 1970, A&A, 4, 234
Fruscione, A., Hawkins, I., Jelinsky, P., & Wiercigroch, A. 1994, ApJS, 94, 127
González-Riestra, R., et al. 1994, in Calibrating *Hubble Space Telescope*, ed. J. C. Blades & S. J. Osmer (Baltimore: STScI), 427
Gulati, R. K., Malagnini, M. L., & Morossi C. 1989, A&AS, 80, 73
Heck, A., Egret, D., Jaschek, M., & Jasheck, C. 1984, *IUE* Low-Dispersion Spectral Reference Atlas (ESA SP-1052) (Noordwijk: ESA)
Hurwitz, M., & Bowyer, S. 1991, in Extreme Ultraviolet Astronomy, ed. R. F. Malina & S. C. Bowyer (Elmsford, NY: Pergamon), 442
Jura, M. 1975, ApJ, 197, 581
Kruk, J. W., Durrance, S. T., Kriss, G. A., Davidsen, A. F., Blair, W. P., Espey, B. R., & Finley, D. S. 1995a, ApJ, 454, L1
Kruk, J. W., et al. 1995b, ApJ, 454, in this issue: L5428
Kurucz, R. L. 1992, in IAU Symp. 149, The Stellar Popoulations of Galaxies, ed. B. Barbuy & A. Renzini (Dordrecht: Kluwer), 225
Longo, R., Stalio, R., Polidan, R. S., & Rossi, L. 1989, ApJ, 339, 474
Massa, D. 1995, ApJ, 438, 376
Morton, D. C., & Dinerstein, H. L. 1976, ApJ, 204, 1
Rountree, J., & Sonneborn, G. 1993, Spectral Classification with the *International Ultraviolet Explorer* (NASA RP-1312)
Savage, B. D., Bohlin, R. C., Drake, J. F., & Budich, W. 1977, ApJ, 216, 291
Savage, B. D., Massa, D., Meade, M., & Wesselius, P. R. 1985, ApJS, 59, 397
Savage, B. D., & Panek, R. J. 1974, ApJ, 191, 659
Snow, T. P., Allen, M. M., & Polidan, R. S. 1990, ApJ, 359, L23
Snow, T. P., Jr., & Jenkins, E. B. 1977, ApJS, 33, 269
Thé, P. S., De Winter, D., Arens, M., Heijblok, M., & Nieuwland, E. R. 1989, A&AS, 81, 114
Walborn, N. R., Nichols-Bohlin, J., & Panek, R. J. 1985, *International Ultraviolet Explorer* Atlas of O-Type Spectra from 1200 to 1900 Å (NASA RP-1155)