IUE FAR-ULTRAVIOLET SPECTRA OF CAPELLA AND $\gamma$ DRACONIS FOR COMPARISON TO HST/GHRS GTO OBSERVATIONS

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Abstract. I present reference spectra from the IUE Archives to compare with recent HST/GHRS observations of Capella and $\gamma$ Draconis. The comparison demonstrates graphically the enormous increase in sensitivity and spectral resolution afforded by the GHRS. At the same time, the HST tracings reveal that much of the faint structure in coadded IUE spectra is genuine: structure that seasoned IUE observers would tend to dismiss as noise.

1. INTRODUCTION

A previous paper (Linsky, Brown, & Carpenter 1991: this volume) reported the results of low-, moderate-, and high-dispersion spectroscopy of two bright late-type stars using the GHRS of HUBBLE during Science Verification and early GTO activities. The two targets – Capella ($\alpha$ Aurigae A [G9 III + G0 III]) and $\gamma$ Draconis (K5 III) – present very different energy distributions in the vacuum ultraviolet. Capella – the archetype “active-chromosphere” giant – is dominated by bright, high-excitation emissions (like C IV $\lambda$1548,50). In contrast, $\gamma$ Dra – a typical “non-coronal” giant – is dominated by low-excitation species (like the O I 1305 Å multiplet), and its high-excitation spectrum is quite weak (in fact, thought to be entirely absent prior to HST). The observational work described by Linsky and collaborators consisted of G140L low-resolution spectra of both stars, covering the range 1150–1750 Å; medium-resolution (G140M, G160M, & G200M) spectra of selected intervals of Capella containing diagnostically-important emission lines; and ECH-A & ECH-B spectra of the bright chromospheric emissions of H I ($\lambda$1215 Ly$\alpha$) and Mg II ($\lambda\lambda$2795,2802 doublet) of Capella. The low-dispersion GHRS spectra have a factor of $\approx$ 5 higher spectral resolution than the comparable SWP-LO mode of the IUE; the medium gratings of the GHRS are comparable in spectral resolution (through the LSA) to the IUE echelle (“HI”) mode; and the GHRS echelles have a factor of $\approx$ 8 higher resolving power (through the SSA) than the IUE SWP-HI or LWP-HI modes. Furthermore, the HST/GHRS is considerably more sensitive than the IUE by virtue of its 25x larger collecting area, high-throughput spectrometers, and low-noise detectors. Nevertheless, the IUE has been accumulating spectrograms of a diverse set of cosmic targets for nearly a decade and a half. Thus, a comparison between HST/GHRS and IUE spectra is useful not only to demonstrate the extraordinary advance represented by the new Great Observatory, but also as an independent validation of the data quality of the aging but prolific Explorer.

$^{1}$Guest Observer, International Ultraviolet Explorer.
2. LOW-DISPERSION IUE SPECTRA

There are a large number of SWP-LO, SWP-HI, and LWP-HI spectra of Capella in the IUE Archives. I selected 4 representative SWP-LO images for the present work, with exposure times of 0.5–2.5M (5M total) to increase the effective dynamic range. For γ Dra, there are 4 SWP-LOs in the Archives: the 3 reliable spectra total 500M. Fig. 1 illustrates the coadded SWP-LO spectra of the two stars. These tracings should be compared with Figs. 1–4 from the Linsky et al. paper: the G140L exposure times were of order 0.5M for Capella and 10M for γ Dra. The difference in sensitivity of the two low-resolution modes is much greater than the simple ratio of the exposure times, because the S/N is higher in the HUBBLE spectra, and the noise refers to pixels that are 5x smaller in wavelength than those of the IUE. Encouragingly, the overall spectral structure in the 1150–1750 Å is qualitatively the same in the GHR and IUE tracings. Nevertheless, a seasoned IUE observer would certainly hesitate to identify the 3σ feature near 1550 Å in the IUE coadded spectrum of γ Dra as C IV; whereas the feature is highly significant in the GHR spectrum, and the identification as C IV is made all the more secure because both components of the doublet are present, in the expected intensity ratio, at the higher dispersion of the G140L mode.

3. HIGH-DISPERSION IUE SPECTRA

I reduced a series of IUE SWP and LWP echelle spectra of Capella, taken near opposite radial-velocity extrema in the orbit. The original observations were conducted using a number of techniques (including pseudo-trailing, multiple Offset Reference Points, and graded exposures) to push the S/N and dynamic range of coadded spectra beyond the usual limits.

Fig. 2 illustrates the Mg II h and k lines observed near the opposite orbital quadratures.
The S/N in these spectra is high (> 50:1): each tracing represents the sum of at least three independent pseudo-trailed spectra, and 10M of total integration time. Also shown is a simple model of the relative contributions of the active G0 III secondary ("F"), the less-active G9 III primary ("G"), and the interstellar Mg II absorption components ("LISM"). The solid curve depicts the sum of the three model contributions: it is similar (at phase 0.29) to the HST/GHRS ECH-B spectra (see Fig. 10 in Linsky et al.) and schematically illustrates the origins of the distinct spectral structure in the high-resolution profiles. While the GHRS ECH-B spectrum also required about 10M of integration, the S/N (and the noise characteristics) are better than the coadded IUE spectrum; again the noise refers to smaller wavelength steps; and the factor of \( \approx 8 \) better resolution permits a whole new regime of scientific inquiry unavailable to the IUE.

Fig. 3 illustrates several intervals in the sub-2000 Å IUE spectrum of Capella coinciding with the medium-resolution (or ECH-A in the case of Lyα) GHRS spectroscopy reported by Linsky et al. Here, the IUE tracings represent the coaddition of two or more independent pseudo-trailed SWP-HII's with a total exposure time of 400M (\( \lambda < 1800 \) Å) or \( \geq 60M \) (Lyα & \( \lambda > 1800 \) Å). The solid curves refer to phase 0.29 (similar to that of the GHRS work), while the dashed curves refer to the opposite orbital quadrature. The overall shift of the high-excitation emissions between the opposite velocity extrema is clear: they follow the fast-rotating chromospherically-active secondary star. Panel (a) should be compared with Figs. 11 and 9 of Linsky et al.; panel (b) with Figs. 8 and 5; panel (c) with Fig. 7; and panel (d) with Fig. 6. Aside from the stunning GHRS echelle spectrum of Lyα, the medium-resolution spectra of Capella are comparable in resolution to those of the IUE, although the S/N is clearly higher in most of the HUBBLE observations (in about 1/50-th the equivalent IUE exposure time!). This is particularly true of the fainter emissions in each interval: compare, for example, the diagnostically-critical O IV] lines in the 1400 Å region.
Figure 3: Coadded SWP high-dispersion spectra of Capella in selected wavelength intervals near opposite quadratures in the binary orbit. Crosses flag reseau marks or saturation.

4. CONCLUSIONS

Space limitations prevent a more exhaustive comparison than this. Nevertheless, one can safely conclude the following: (1) A large-aperture space telescope with a modern spectrograph and detectors produces beautiful (dare I say, solar-quality) vacuum-ultraviolet spectra; and (2) even so, the quality of the IUE spectrograms is surprisingly good, at least with respect to the preconceptions of this all-too-knowledgeable observer. Thus, the HST/GHRS presents not only a powerful new spectroscopic tool for the nineties, but also a critical validation of the quality of the spectral material in the extensive archives of the IUE, the workhorse UV space observatory of the eighties.

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