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COMPARISONS OF IUE & HST ULTRAVIOLET SPECTRA OF EXTRAGALACTIC HII REGIONS[1]

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RESUMEN

Comparamos espectros HST FOS recientemente obtenidos con espectros ultravioleta IUE SWP de dos regiones HII extragalácticas: SBS 0335-052 y 30 Doradus en la Nube Mayor de Magallanes. Los espectros FOS se tomaron usando la configuración G190H/RD y apertura circular de 1.0 segundo de arco; cubren el intervalo de longitud de onda 1570-2310 Å . Los espectros IUE son exposiciones SWP de baja dispersión tomadas con la apertura grande ovalada de ~10″x20″; cubren el intervalo de 1150-2000Å . A pesar de la mucho menor apertura en HST FOS, los espectros HST son superiores a los espectros de baja dispersión IUE SWP (procesados en forma estándar) en cuanto a S/R para las líneas de emisión ultravioletas debido al mayor intervalo dinámico y la mayor resolución en longitud de onda del FOS. Sin embargo presentamos espectros IUE SWP de I Zw 18, procesados mediante NEWSIPS, cuyos datos muestran mejoras en las calidad que sugieren la posibilidad de incrementar de manera importante los resultados científicos mediante el reprocesamiento del acervo de espectros IUE.

ABSTRACT

We compare recently obtained HST FOS and IUE SWP ultraviolet spectra of two extragalactic HII regions: SBS 0335-052 and 30 Doradus in the LMC. The FOS spectra were taken using the G190H/RD configuration and the 1.0 arcsec diameter circular aperture and cover 1570-2310Å . The IUE spectra are low-dispersion SWP exposures taken through the ~10″x20″ oval large aperture and cover 1150-2000Å . Despite the much smaller HST FOS aperture, the HST spectra are superior to the (standard processed) low-dispersion IUE SWP spectra in S/N for the UV emission lines due to the larger dynamic range and wavelength resolution of the FOS. We also present IUE SWP NEWSIPS processed spectra of I Zw 18, which show significant improvements in the data quality, suggesting that reprocessed IUE archival spectra will offer enhanced science for the future.

Key words: **H II REGIONS — GALAXIES: IRREGULAR — ULTRAVIOLET: GALAXIES**

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1. INTRODUCTION

During the past decade, the *International Ultraviolet Explorer* satellite permitted the first comprehensive UV spectral studies of astronomical objects. This decade, the successful launch and operation of the *Hubble Space Telescope* with its FOS and HRS spectrometers provides a new capability for such UV spectral studies. Herein we make the first comparisons between archival IUE SWP ultraviolet spectra of several extragalactic HII regions with HST FOS UV spectra which we have recently acquired as part of the observations in the Cycle 2 HST General Observer Program GO-3840. The objectives of this program were to obtain high S/N UV spectra of several extragalactic HII regions of very low O/H in order to be able to derive C:N:O ratios directly from the UV lines of CIII], NIII], and OIII]. Seven target HII regions were approved for observation with the FOS during Cycles 2 and 3, and spectra of five have been obtained as of the time of writing. Herein we present the results for two objects: SBS0335-052 and 30 Doradus.

The UV spectra of emission nebulae contain lines of various ions of carbon, nitrogen, oxygen, neon, and silicon that are important diagnostics of abundances and physical conditions in the nebulae; and for which there are no visible-wavelength lines observable from the ground. This is particularly true of C and Si, which have prominent lines of CIII]$\lambda\lambda$1907-9 and SiIII]$\lambda\lambda$1883-92 in moderate-excitation HII regions where C^{++} and Si^{++} are the dominant ionization states of C and Si in the ionized volume.

2. SBS 0335-052

The galaxy SBS 0335-052 is of special interest to us because it has an oxygen abundance comparable to that of I Zw 18, the most metal poor HII region known (Terlevich et al. 1992). We note that Izotov et al. (1990) in the discovery paper originally reported an (incorrect) O/H value for it that was about 70% lower than in I Zw 18. As part of a joint US-SERC effort, three long exposure IUE low dispersion spectra of SBS 0335-052 were taken in 1992, across US-Vilspa low radiation shifts, totalling 27.6 hours of exposure time. These spectra were processed with the (old) IUESIPS, but the optimal extraction technique was used to improve the S/N compared to the old boxcar extraction technique. One of the spectra, SWP44070 (400 min exposure), was found to be relatively poor compared to the other two, SWP44075 (646min) and SWP44078 (612min), so we used only the latter two averaged together to produce our final spectrum. Figure 1 shows the combined spectra from the optimal extraction compared to the boxcar extraction. The use of the optimal technique is very important

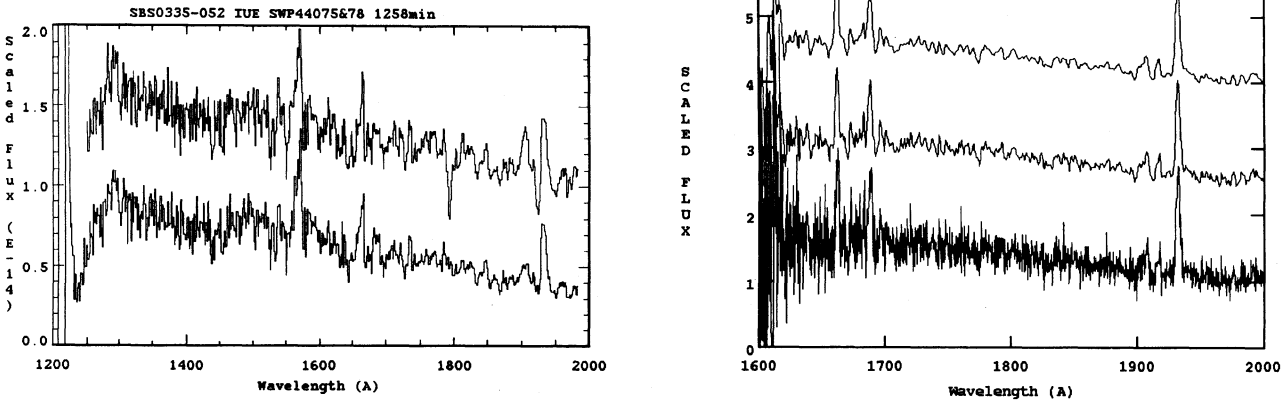

Fig. 1 –IUE (OLDSIPS) spectra of SBS0335-052 as a result of combining two long exposure spectra (SWP44075-646min & SWP44078-612min). The top spectrum is the result of averaging two boxcar extractions and the bottom is an improved spectrum obtained using the slit-weighted optimal extraction scheme. Note the broad CIVλ1549 emission (redshifted by 20Å).

Fig. 2 –HST FOS spectra of SBS0335-052 using the G190H/RD configuration and 1.0 arcsec circular aperture exposing for 5400 sec. The ordinate flux scale is in units of 10^{-15} $ergs$ cm^{-2} s^{-1} with the original spectrum at the bottom. The two upper spectra are with smoothing applied using gaussians of 3 pixel (middle, shifted in flux by 1 unit) and 5 pixel (top, shifted in flux by 2 units) sigmas. For comparison purposes, we show only the 1572-2000Å wavelength range; the original spectrum covers 1572-2312Å.

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near the CIII] line, since it is redshifted 20Å to a point near the 1925Å reseaux mark on the vidicon, and the optimal technique interpolates across the reseaux (thus eliminating the "absorption" line cutting into the shortward side of the CIII] line).

On 1993 December 1 we obtained a 5400 sec FOS UV spectrum of the brightest emission spot in SBS 0335-052. The spectrum was taken with the red digicon and G190H grating through the 1.0 arcsec diameter circular aperture. Figure 2 shows the original and smoothed spectra obtained. The results were excellent, strong lines of HeIIλ1640, OIII]$\lambda\lambda$1660-6, and CIII]λ1909 are all strong with S/N$\sim$12 for CIII] and S/N$\sim$4.5 for HeII and OIII]. The continuum S/N is $\sim$8.4 at 1950Å and $\sim$7.2 at 1700Å. In addition, the weak lines of SiIII]$\lambda\lambda$1883-92 are seen at S/N$\sim$2 above the continuum. However, somewhat disappointing is that the NIII]$\lambda\lambda$1750-54 multiplet is not detected, which would have enabled direct determination of the C^{++}:N^{++}:O^{++} in the nebula.

3. 30 DORADUS

The 30 Doradus nebula in the Large Magellanic Cloud is the most prominent (and among the most complex) HII region complex in this galaxy. It has been extensively studied from the ground (e.g., Rosa and Mathis 1987 and references therein) and with the IUE (e.g., Dufour, Shields and Talbot 1982). Figure 3 shows one of the better SWP low dispersion spectra of this object, SWP8929 (230min exposure), with boxcar and optimal extractions (bottom spectrum). Because the nebula fills the IUE large aperture completely, the S/N of the spectrum is not markedly improved in the optimal extraction, though the effects of a radiation hit at 1600Å and the reseaux "absorptions" at 1790Å and 1915Å are interpolated out of the optimal spectrum. Because the resolution is degraded by the filled slit, the CIII] and SiIII] lines are blended. Also, OIII]$\lambda\lambda$1660-66 is not seen in the IUE spectrum.

Figure 4 gives the FOS spectrum of 30 Doradus acquired on 1992 November 14 (1 hour exposure). Herein we see the improvements afforded by the better resolution of FOS, where now the SiIII] lines are resolved and the OIII] lines are seen. The S/N in the continuum near λ1909 is $\sim$3.9 at 1800Å and $\sim$4.2 at 2000Å. Fitting a gaussian profile to CIII] yields a FWHM=3.8Å and integrated flux of $1.19\text{x}10^{-14}$ ergs $cm^{-2}sec^{-1}$; corresponding to a S/N $\sim$30 for the line. Similar measurements for the SiIII] lines yield S/N $\sim$4.1 for 1883Å and $\sim$2.7 for 1892Å. The blue side of the spectrum has lower S/N due to the drop in the red digicon sensitivity, the S/N in the continuum near 1700Å is only $\sim$2.6 and the OIII]$\lambda\lambda$1660-66 blend is only weakly detected at a S/N $\sim$1.6.

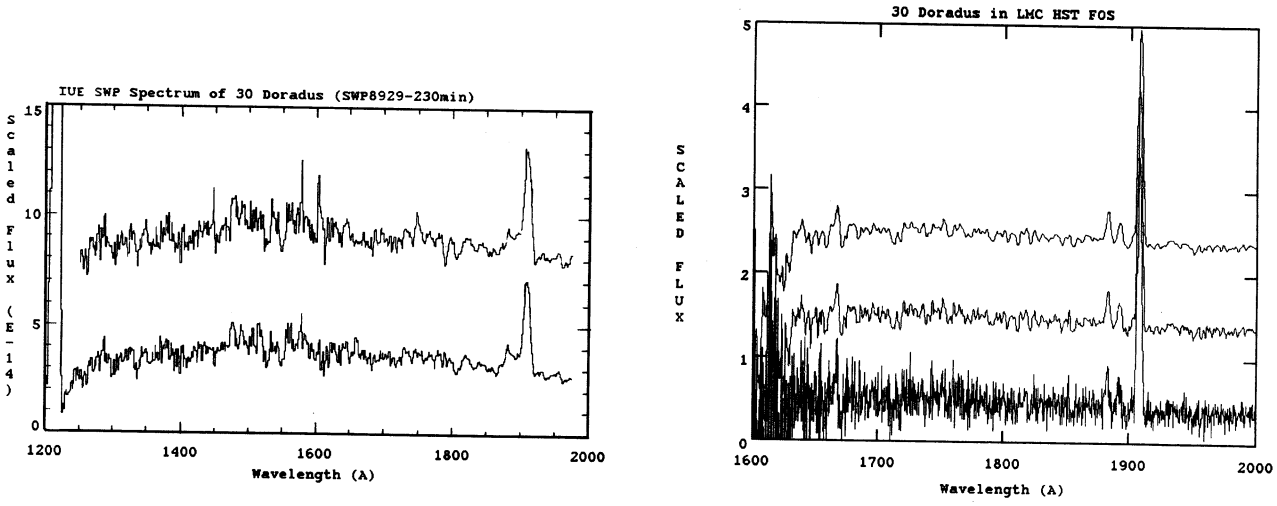

Fig. 3 –IUE SWP spectrum of 30 Doradus (SWP8929, 230min exp, α(1950)=$05^h39^m\ 14^s.3$ & δ(1950)=-69°06′30″). Both spectra are from IUESIPS processing with the bottom one corresponding to optimal extraction and the top is with the standard boxcar extraction. The S/N in the optimal spectrum is again better than the boxcar, both in the removal of artifacts, as well as in the general smoothness of the continuum.

Fig. 4 –HST FOS spectra of 30 Doradus corresponding to a 1 hour exposure with the 1″ circular aperture centered at α(1950)= $05^h39^m08^s.8$ & δ(1950)=-69°06′45.″5). Aside from the CIII] line, note that OIII]$\lambda\lambda$1660-66 is seen blended, but the SiIII] doublet is clearly resolved.

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By comparison, the S/N of CIII]λ1909 on the optimal SWP8929 spectrum is only ~5 and that of the blended SiIII] lines only ~2.

4. IUE NEWSIPS PROCESSED SPECTRA OF IZW18

After 15 years of operations, the IUE has obtained over 75,000 spectra with its SWP and LWP/R vidicon cameras at both low and high resolution (echelle) modes of operation. The SWP low dispersion spectra cover 1150-1950Å wavelength range with a resolution between 3-8Å, depending on how the source fills the 10x20 arcsec oval large aperture. Despite its small light collecting power, the ~200 arcsec^2 area of the IUE large aperture has enabled it to successfully obtain UV spectra of many faint extended sources. However, due to limitations in the dynamic range of its vidicon detectors and to the data processing (limited geometrical registration between spectral images and ITFs resulted in the presence of detector fixed pattern noise), the S/N on IUE spectra has been limited to ~20. Currently a major effort is underway to reprocess all existing IUE spectra with new software, called NEWSIPS, which improves the S/N via more accurate geometrical registration of the ITF and removal of fixed noise patterns that existed in the old (called IUESIPS or herein OLDSIPS) spectral processing. It is anticipated that all of the low resolution SWP spectra obtained by IUE will be reprocessed by the end of 1993 and be available in FITS format through the NSSDC (Nichols-Bohlin 1993).

An example of the improvements on low S/N IUE SWP spectra by NEWSIPS can be illustrated in the IUE SWP spectra of the very metal-poor irregular galaxy I Zw 18 previously analyzed by Dufour, Garnett and Shields (1989). In that study, five long exposure SWP spectra were obtained totalling 36 hours net exposure time. As part of the science evaluation of the NEWSIPS processing, these were reprocessed and provided to Dufour. A comparison of the combined spectra processed with NEWSIPS and OLDSIPS is shown in Figure 5. Two improvements in the NEWSIPS spectra are evident: (a) the S/N in the continuum on the NEWSIPS spectra is improved by a factor of about 1.5 (particularly in the 1200-1600Å region) and (b) reseaux marks (i.e., "absorption lines" near 1790Å and 1925Å) are absent in the NEWSIPS spectra. Part of the S/N improvements in the NEWSIPS spectra are due to the use of the OPTIMAL slit-weighted extraction scheme in the new processing, which interpolates over reseaux marks and radiation hits compared to the old boxcar extractions. Finally, another important factor in the NEWSIPS processing of SWP spectra is that the spectra are processed to near 2000Å, compared to being truncated near 1950Å in the old processing (such is very important for measurements of CIII] in slightly redshifted galaxies as studied here).

Some quantitative comparisons of the NEWSIPS and OLDSIPS spectra are relevant. The S/N of the continuum at 1400Å is (NEWSIPS,OLDSIPS)=(10.7, 6.6) and at 1800Å it is (17.2, 13.5). Gaussian fits to the CIII]λ1909 line yield FWHM (in Å) of (9.8, 8.2) and integrated fluxes of (3.74, 2.63) x 10^{-14} ergs cm^{-2} sec^{-1}.

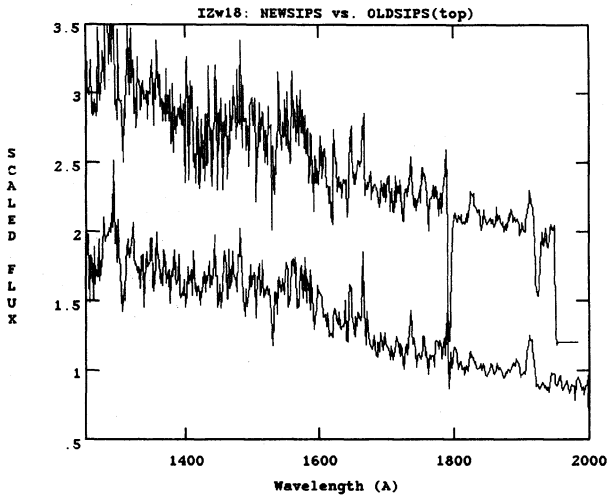

Fig. 5 –IUE SWP low dispersion spectra of IZw18 made by combining 5 spectra processed by NEWSIPS (bottom) and OLDSIPS(top). The ordinate flux scale is in units of $10^{-14} ergs\ cm^{-2}\ s^{-1}$ with the OLDSIPS spectrum shifted upward by a value of 1.2 in flux units.

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These result in S/N for the 1909Å line of ~7.6 with NEWSIPS and ~4.7 with OLDSIPS. Therefore, we conclude that the NEWSIPS processing of low S/N long exposure extended source spectra result in S/N improvements of approximately a factor of 1.5 to almost 2, largely depending on the wavelength range in question (i.e., shorter wavelengths show the highest improvements due to the better vidicon "focus"). Finally, we note that the CIII]λ1909 flux from the NEWSIPS spectrum is almost twice that originally measured in Dufour et al. (1988) and, if correct, would result in a significantly higher C/O in the galaxy than previously reported.

5. SUMMARY

We are finding that using the FOS G190H/RD on the Hubble Space Telescope for UV spectroscopy of metal-poor extragalactic HII regions is resulting in much improved spectra across the important 1600-2000Å region where the most important C-N-O-Si abundance diagnostic lines exist. Despite the small apertures afforded by the FOS, adequate S/N is obtainable in exposures of ~one hour to be able to obtain high (>10) S/N of CIII]λλ1907-9 and, for the higher excitation objects, adequate S/N (2-5) for the lines of OIII]λλ1660-6 and SiIII]λλ1883-92. The initial results indicate that we will be able to derive much improved C/O ratios in several metal-poor galaxies than previously possible. In addition, we will be able to evaluate the variation of Si/C/O in the galaxies as well.

We also point out that, while the IUE spectra of similar objects have lower S/N, the reprocessing of the SWP low dispersion spectra in the archives results in significantly improved S/N for the UV emission lines. Therefore, the UV spectra of the 100-odd extragalactic HII regions (as well as numerous Galactic nebulae) previously observed by IUE should be restudied when the NEWSIPS processed data become available. We expect that these data will afford important new information on C and Si abundances in galaxies of various chemical evolutionary epochs by virtue of the large numbers observed, the improved S/N, and the increase in the supporting ground-based imagery and spectroscopy that has become available in the last few years.

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