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The solar ultraviolet spectrum from 1200 Å to 1560 Å: a radiometric comparison between SUMER/SOHO and SOLSTICE/UARS

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Abstract. After short descriptions of the SUMER (Solar Ultraviolet Measurements of Emitted Radiation) spectrometer onboard SOHO (the Solar and Heliospheric Observatory) and the SOLSTICE (Solar-Stellar Irradiance Comparison Experiment) spectrometer on UARS (the Upper Atmosphere Research Satellite), a radiometric comparison is carried out of solar irradiance spectra measured by SOLSTICE and spectra derived from SUMER radiance observations of quiet-Sun regions in the wavelength range from 1200 Å to 1560 Å. The emission lines N V (λ1238) and C IV (λ1548) are considered in detail. For these lines, irradiance data are also available from full-Sun raster scans of SUMER and deviations of less than 15% are found between SOLSTICE and SUMER results – well within the combined uncertainty margins.

Key words: Sun: UV radiation – Sun: transition region – instrumentation: spectrographs

1. Introduction

The radiometric calibration and stability of EUV and UV spectrometers mounted on spacecraft for solar research have been a matter of concern: Early instruments suffered from major degradation effects (see, e.g., Huber et al. 1973; Lemaire 1991; Woods et al. 1996), before it was fully understood that photo-activated polymerization of hydrocarbon compounds (mainly out-gassing and off-gassing products from organic materials used in the construction of the instrumentation) on optical surfaces was adversely affecting their reflectivity (e.g., Hall et al. 1985; Steward et al. 1989). With the advent of stringent cleanliness control procedures during all phases of the instrument and spacecraft development and operation, the contamination problem could be successfully avoided for the normal-incidence spectrometer SUMER (Solar Ultraviolet Measurements of Emitted Radiation) on SOHO (Solar and Heliospheric Observatory) operating in the vacuum ultraviolet (Schühle et al. 1998). It thus appears to be possible to obtain accurate radiance and irradiance measurements with high spectral resolution of the solar radiation in this wavelength range. The observations are relevant for investigations of the upper atmospheres of both the Sun and the Earth. However, in view of the experimental difficulties, it is important to verify the consistency of results obtained with different instruments using independent calibration sources and diversified techniques for maintaining and tracking the calibration status. In this study, we undertake to demonstrate this for two instruments, which are totally different in nearly all aspects: SOLSTICE (Solar-Stellar Irradiance Comparison Experiment) on UARS (Upper Atmosphere Research Satellite) and SUMER. We restrict our discussions to the wavelength interval from 1200 Å to 1560 Å within the ranges of both instruments. This selection has been motivated by initial comparisons between these instruments, which led to an agreement, in general (Schühle et al. 1998), but showed low irradiance values from SUMER with respect to SOLSTICE for N V (λ1238) of 23% and for C IV (λ1548) of 31% (Wilhelm et al. 1999). Although both results are consistent within the combined uncertainty ranges of the instruments, we want to separate the various contributions to the respective measurements in an attempt to define the calibration status in more detail.

In this context, it is of interest that DeLand & Cebula (1998) performed a comparison between SOLSTICE, the NOAA 11 Solar Backscatter Ultraviolet (SBUV/2) instrument and the Solar Ultraviolet Spectral Irradiance Monitor (SUSIM) (Brueckner et al. 1993) at longer wavelengths from 1700 Å to 4000 Å. The results obtained by the three instruments are consistent with each other with long-term accuracies of better than 1.5%.

2. The instruments

2.1. SUMER

SUMER is a high-resolution EUV and UV slit spectrometer covering a wavelength range from 465 Å to 1610 Å (observed in first and/or second order of diffraction). The spectral resolution element is $\approx$ 42 mÅ in first order and the spatial resolution element is close to 1″. Despite this high spatial resolution, scans of the full Sun can be acquired by rastering the slit perpendicular to its long extension across the solar disk, albeit with total sampling times of several hours. Alternatively, a spectrum in the

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SUMER wavelength range can be obtained from a limited solar area by stepping the grating mechanism through its full operational range. Two detectors, A and B, of which detector A is used in this comparison, are equipped with two photocathodes each (potassium bromide in the central portion and the bare micro-channel plate on either side). SUMER was radiometrically calibrated in the laboratory against a secondary transfer-standard source, which had been calibrated at the Physikalisch-Technische Bundesanstalt (PTB) using the primary radiometric source standard of the Berlin Electron Storage ring for SYnchrotron radiation (BESSY I) (Hollandt et al. 1996). This calibration and its stability have been verified with the help of star observations and line intensity ratios based on atomic physics data (Wilhelm et al. 1997a; Schühle et al. 1998). Uncertainty levels of 15% (1 σ) have been determined for wavelengths below 1250 Å, for which a reliable laboratory calibration could be carried out, and 30% in the remaining wavelength range under consideration. Detailed descriptions of this instrument and its performance under operational conditions have been published elsewhere (Wilhelm et al. 1995, 1997b; Lemaire et al. 1997). SUMER is operated on SOHO, which is positioned near the Sun-Earth Lagrange point L1 since early 1996. This point is 1.5 10^6 km from the Earth on the Sun-Earth line. This distance corresponds to $\approx$ 1% of 1 AU (astronomical unit). All irradiance data in this contribution are, however, normalized to 1 AU for both instruments.

2.2. SOLSTICE

SOLSTICE has been designed to study the UV radiation of the full Sun with high accuracy. The primary components of the SOLSTICE instrument are three grating spectrometers that are integrated into a single housing. The spectral bandpass is wavelength dependent. With the SOLSTICE optical design, only one wavelength can be in perfect focus and give the specified resolution of 1.0 Å. Wavelengths near 1300 Å have this resolution and at other wavelengths the bandpass varies between 1.0 Å and 1.5 Å. The instrument, its calibration and operation are described in detail by Rottman et al. (1993) and Woods et al. (1993). Although the spectral range of SOLSTICE is 1190 Å to 4200 Å, only the data from 1200 Å to 1560 Å are presented here in this comparison with SUMER. The radiometric calibration of SOLSTICE is based on pre-flight calibrations at the Synchrotron Ultraviolet Radiation Facility (SURF-II) at the National Institute of Standards and Technology (NIST) and in-flight calibrations using bright early-type stars (Woods et al. 1998). The uncertainty of SOLSTICE measurements in the wavelength range of interest is 3% to 5% (1 σ).

3. Observations, data analysis, and results

Most of the measurements to be discussed were obtained in 1996 when the solar activity was very low, as can be seen from the Penticton 10.7-cm flux levels, $F_{10.7}$, in Table 1. Only the last observation was performed at the beginning of the new activity cycle 23, but a quiet-Sun region near the centre of the disk was selected for this radiance observation, and it will, moreover, only be used to determine the relative intensities of the C IV and Si I lines near 1550 Å. With E_λ we denote the SOLSTICE irradiance spectrum in the wavelength range from 1200 Å to 1560 Å, and with E^*_{1238}, E^*_{1548} the irradiances of the corresponding spectral lines N V and C IV observed by SUMER during full-Sun raster scans. L^*_λ refers to the SUMER radiance spectrum of a quiet-Sun region in our wavelength range, whilst L^*_{1394} and $L^*_{1548,1550}$ represent narrow windows around the Si IV and C IV lines.

Table 1. Dates and types of observations in the wavelength range from 1200 Å to 1560 Å in the context of this study. The SUMER observations are marked with an asterisk (*). The radio flux, $F_{10.7}$, is given in 10^{-22} W m^{-2}Hz^{-1}.

Date		$F_{10.7}$	Type of observation	
			SOLSTICE	SUMER
02 February	1996	74	E_λ	–
04 February	1996	71	–	C IV: E^*_{1548}
27 March	1996	72	–	Si IV: L^*_{1394}
07 June	1996	75	E_λ	E^*_{1238}, E^*_{1548}
14 June	1996	70	–	N V: E^*_{1238}
16 June	1996	69	E_λ	C IV: E^*_{1548}
12 August	1996	75	E_λ	L^*_λ
08 March	1999	125	–	C IV: $L^*_{1548,1550}$

Before we discuss the irradiance data available for the N V and C IV lines, an overview of the observations, E_λ and L^*_λ, obtained in the full wavelength range is displayed in Fig. 1. In Fig. 1a, the four SOLSTICE irradiance spectra, E_λ, are shown offset by factors of two (for display purposes) with respect to each other and by larger factors relative to the SUMER data. SUMER's high-resolution spectrum was derived from an observing sequence called "reference spectrum" taken at Sun centre with the $1'' \times 120''$ slit and a sampling time of 115 s on 12 August 1996. In addition to the routine SUMER data handling procedures (including, in particular, detector dead-time and local-gain depression corrections) described, for instance, in Wilhelm et al. (1998) with emphasis on calibration aspects, the spectrum has been treated as follows:

- Significant second-order lines superimposed on the first order spectrum (i.e., Mg X ($\lambda\lambda$609,624), O V (λ629), N III ($\lambda\lambda$685,686), O III ($\lambda\lambda$702,703), O V (λ760), N IV (λ765), Ne VIII (λ770), and O V (λ774)) have been removed manually and the gaps have been filled with interpolated data.
- The second-order continuum (H I Lyman continuum), which contributes to the count-rates in first order above 1520 Å, has also been removed. This has been done with the help of a count-rate comparison on both photocathodes. The second-order contribution to the background can be neglected below 1520 Å.
- The radiance spectrum, L^*_λ, has been multiplied by the solid angle of the Sun at 1 AU, $\Omega_\odot$. This transforms the spectrum into an estimate of the irradiance spectrum, E^*_λ, at 1 AU for those lines and continua which exhibit no centre-to-limb variations in their radiances and which do not extend far beyond the photospheric limb into the corona. A discus-

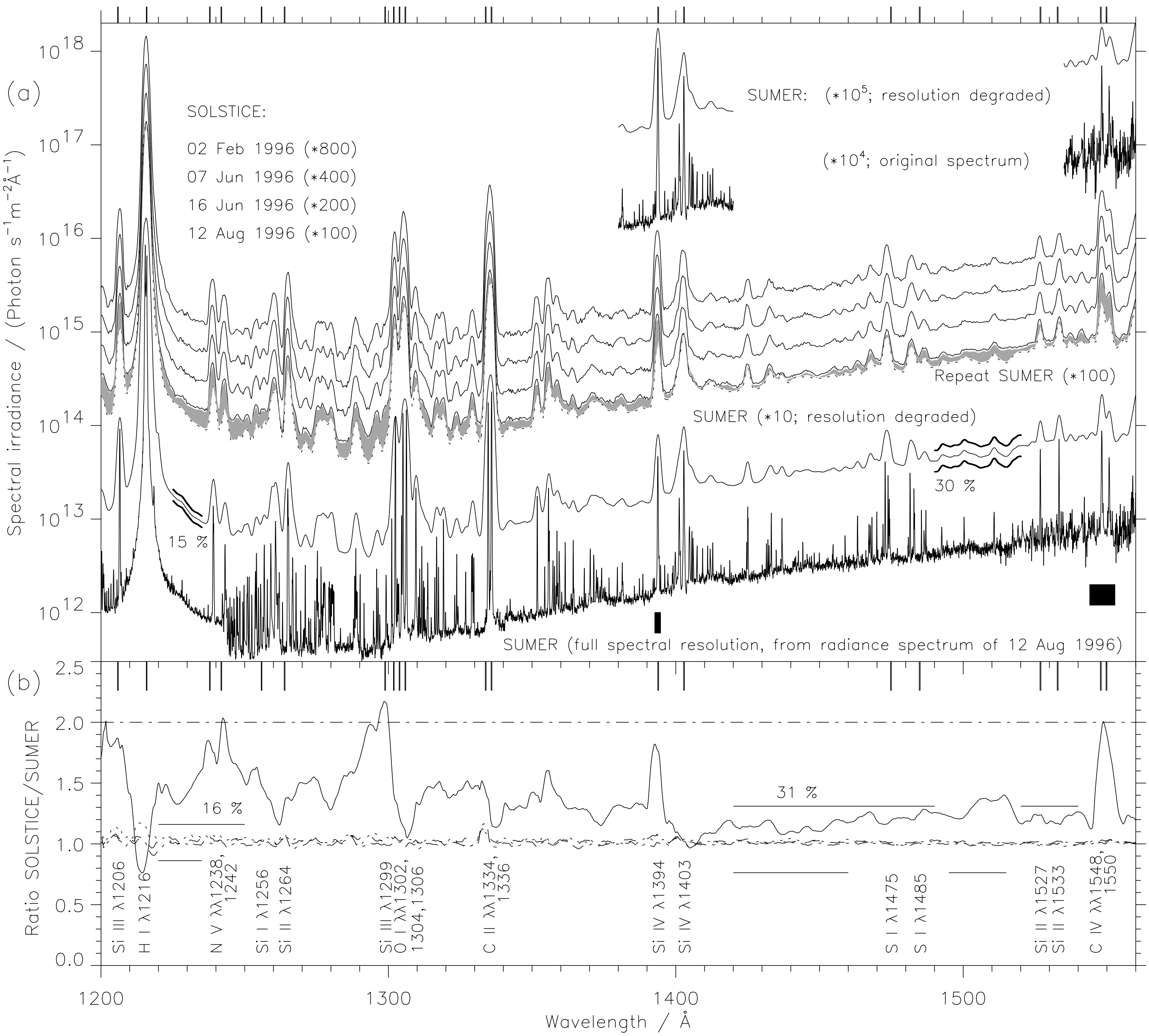

Fig. 1. a Spectra of SOLSTICE and SUMER in the wavelength range from 1200 Å to 1560 Å. The modified high-resolution radiance spectrum of SUMER is shown at the bottom multiplied by the solid angle of the Sun from 1 AU. The spectral resolution was then degraded to match that of SOLSTICE as shown in the next graph, after multiplication by 10 for display purposes. Near 1230 Å and 1500 Å the SUMER uncertainty margins (1 σ) are plotted as well. It is important to note that only the instrumental effects (including the count statistics) are taken into account, but not the solar variations. Four SOLSTICE irradiance spectra are shown over a period of approximately six months. In parallel to the SOLSTICE spectrum of 12 August 1996, the SUMER spectrum multiplied by 100 is repeated and the difference shaded in gray. The original SUMER spectrum and its low-resolution version are shown in the upper portion of panel **a** around those wavelength ranges where the spectrum below had been modified (as indicated by black bars). **b** The ratio SOLSTICE/SUMER is plotted for 12 August 1996 (solid line). Note that most of the wavelength range is dominated by emission lines, which influence this ratio by their different centre-to-limb variations. (For a discussion see Sect. 4.) The ratios of the various SOLSTICE spectra are shown as broken lines. Finally, the combined SOLSTICE/SUMER uncertainty margins (RMS) are indicated and some prominent emission lines are identified.

sion of lines with centre-to-limb variations will be given in Sect. 4, as well as considerations concerning the continuum radiation.

– Data obtained with longer sampling times averaged over larger solar areas (and thus with lower statistical uncertainties as well as a higher significance as far as the definition of a quiet-Sun region is concerned) have been substituted for two sections: L^*_{1394}, from 1392.70 Å to 1394.81 Å and, $L^*_{1548,1550}$ from 1544.03 Å to 1552.91 Å. The original spectrum and its low-resolution format (details will be discussed below) around these wavelength ranges have been included in the upper part of Fig. 1a.

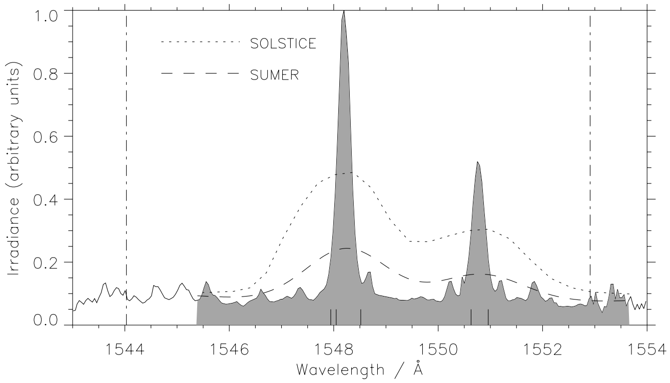

Fig. 2. Details of the wavelength range near the C IV lines are shown as high (solid line) and low resolution spectra (SOLSTICE: dotted line; SUMER: dashed line; not corrected for limb brightening). The irradiances are plotted in arbitrary units, but all three curves to the same scale. The shaded portion of the high-resolution spectrum has been used to determine the Si I line contribution in Table 3. The dashed-dotted lines mark the wavelength range in which the original spectrum in Fig. 1 has been substituted by the March 1999 data. The marks on the wavelength axis indicate those Si I lines which are very near the C IV lines.

The spectral resolution of SUMER has to be degraded before we can perform a comparison between the spectra of SUMER and SOLSTICE, which has a wider bandpass. A trapezoid best describes the SOLSTICE bandpass function for the one wavelength that is in perfect focus. However, a smoothed trapezoid is better for other wavelengths. A Gaussian filter is a reasonable compromise of the SOLSTICE bandpass function over the full range. Consequently, the degrading was done by a convolution of the SUMER spectrum with a Gaussian filter having a standard deviation of 25 resolution elements of SUMER ($\sigma \approx 1.05$ Å), for which we found the best fit. This resulted in an excellent visual correspondence of the SOLSTICE and the SUMER spectra as can be seen from the observations taken on 12 August 1996.

Details of the comparison are shown in Fig. 1b, where the ratio of the SOLSTICE and SUMER spectra from August is plotted as a solid curve. The ratios of the February and June data with respect to the August reference are also given, to demonstrate the small amount of variation between the SOLSTICE observations taken over a time period of half a year. They all are very close to unity, whereas the SOLSTICE/SUMER ratio ranges between 0.75 and 2.18.

We defer any further discussion to Sect. 4 and consider next the SUMER irradiances, E^*_{1238} and E^*_{1548}, of the N V (λ1238) and C IV (λ1548) lines. They are compiled together with the corresponding SOLSTICE observations in Table 2. A comparison of these measurements is not dependent on assumptions about the centre-to-limb variations and thus provides two important data points. The SUMER irradiance data have been published by Wilhelm et al. (1998, 1999) deduced on the basis of the SUMER calibration status at the time of evaluation. A recent re-assessment of the SUMER calibration (available at http://sohowww.nascom.nasa.gov/descriptions/experiments/sumer/radcal.html, 2 June 1999) led to increases of 4% at 1238 Å and of 11% at 1548 Å, which both are, by the way, within the declared uncertainty margins. The SOLSTICE spectra to be compared directly with the SUMER irradiance data have been taken on 2 February 1996 and on 7, 16 June 1996. They are the closest measurements in time available. We performed multi-Gauss fits to the corresponding lines in the SOLSTICE spectra (cf., Fig. 1) in order to obtain the line irradiances and the continuum contributions separately.

The same procedure has been applied to the SOLSTICE spectrum of 12 August 1996 and, in a formal way, to the corresponding degraded SUMER spectrum in the wavelength interval containing the C IV ($\lambda\lambda$1548,1550) lines. In Table 3, the results are presented in the low-resolution section. The SOLSTICE irradiance, $E_{1548,1550}$, is given in a format similar to that in Table 2. The SUMER irradiances have been derived from the observed radiances by multiplication with $\Omega_\odot$, as described above, and, in a second step by taking into account the effect of the centre-to-limb variation found for this line by Wilhelm et al. (1998).

4. Discussion and conclusions

First we have to consider the model dependence (i.e., the centre-to-limb variation) of the conversion of the SUMER radiance measurements into irradiances. Fig. 1b provides an important clue. N V, for instance, displays a ratio $\kappa \approx 2$. Withbroe (1970) gives an optical thickness of the formation region of this line of τ = 0.03. For such a case, the disk-averaged radiance, $\overline{L}$, is expected to be twice the mean radiance at disk centre, $\overline{L}$(0). A factor $\kappa_{\rm N\,V}$ = 2.08 has previously been observed by SUMER (Wilhelm et al. 1998). We thus may conclude that there is good agreement for the N V line both in the spectra and in the line irradiances. We also find ratios of $\kappa \approx 2$ for the Si III, Si IV and C IV lines and, by the same token, might conclude that they stem from optically thin regions, too. However, it should be pointed out that it is not easy to establish the mean radiance of transition region lines for the quiet Sun. In SUMER reference spectra we have found, for instance, intensity variations of the Si IV line by a factor of 3. Consequently, it is required to average over large areas with long sampling times. The difficulty can be exemplified by the Si IV ($\lambda\lambda$1394, 1403) line pair. In the original SUMER spectrum of 12 August 1996, shown in the upper portion of Fig. 1a, the intensity ratio of the lines was ≈ 2 as it should be for these lines from optically thin regions. Yet, the ratio SOLSTICE/SUMER in Fig. 1b was close to one for both lines. Only after substituting the brighter line at 1394 Å by a mean profile obtained over $1'' \times 300''$ with a total exposure time of 660 s, we find a SOLSTICE/SUMER ratio representative of optically thin emission regions. The bright O I and C II lines originate from opaque regions and their SOLSTICE/SUMER ratios are close to one, as expected. Many other lines, for which the effects of the centre-to-limb variation are between $\kappa \approx 1$ and ≈ 2, are present, in particular, in the short-wavelength range. They lead to an increase of the SOLSTICE/SUMER ratio. A quantitative study would require detailed information on the centre-to-limb variations on all lines, which is not readily avail-

Table 2. Solar irradiance observations of SOLSTICE and SUMER in the lines N V (λλ1238,1242) and C IV (λλ1548,1550) (in units of 10^{12} photon $s^{-1}m^{-2}$) as well as relative contributions[a] of lines and continua (in percent) to the flux in the wavelength windows around N V and C IV.

Observation	02 Feb 1996	04 Feb 1996	07 Jun 1996	14 Jun 1996	16 Jun 1996	Mean value	Instrument
E^*_{1238}	–	–	5.73 ± 1.15	5.61 ± 1.12	–	5.67	SUMER
E_{1238}	6.53 ± 0.33	–	7.03 ± 0.35	–	6.22 ± 0.31	6.59	SOLSTICE
E_{1238}	26.1%		28.4%		26.1%		
E^{b}_{1242}	19.2%		23.0%		20.8%		
Continuum[c]	53.9%		47.9%		52.3%		
Total[c]	25.0	–	24.8	–	23.8	24.5	SOLSTICE
E^*_{1548}	–	63.3 ± 20.3	58.0 ± 18.6	–	59.4 ± 19.0	60.2	SUMER
E_{1548}	79.2 ± 4.0	–	79.2 ± 4.0	–	77.2 ± 3.9	78.5	SOLSTICE
E_{1548}	41.2%		39.7%		41.7%		
E_{1550}	15.5%		18.3%		18.3%		
Continuum[d]	42.2%		41.1%		39.1%		
Total[d]	192	–	199	–	185	192	SOLSTICE

[a] The multi-Gauss fits led to small residua of typically less than 1%.
[b] Blended with Fe XII (λ1242) and other lines.
[c] In the wavelength window from 1235.96 Å to 1245.94 Å.
[d] In the wavelength window from 1545.03 Å to 1553.84 Å.

Table 3. Comparison of the SOLSTICE and SUMER irradiances near C IV (λλ1548,1550) both observed on 12 August 1996 (in units of 10^{12} photon $s^{-1}m^{-2}$ or in percent).

Quantity	C IV (λ1548) line	C IV (λ1550) line	Si I lines	Continuum	Instrument
Low-resolution case:					
$E^{a}_{1548,1550}$	75.5	33.7		77.6	SOLSTICE
	40.1%	18.6%	–	41.2%	
$L^{*b}_{1548,1550}\ \Omega^{c}_{\odot}$	26.0	13.4		62.4	SUMER
	25.5%	13.1%	–	61.2%	
$\kappa^{d}_{C\,IV}\ L^{*b}_{1548,1550}\ \Omega_{\odot}$	57.7	29.9		62.7	SUMER
	38.4%	19.9%	–	41.7%	
High-resolution case:					
$L^{*b}_{1548,1550}\ \Omega_{\odot}$	24.4	12.3	12.1	51.5	SUMER
	24.3%	12.3%	12.1%	51.3%	
$(\kappa_{C\,IV}, \kappa_{Si\,I})^{d}\ L^{*a}_{1548,1550}\ \Omega_{\odot}$	54.2	27.3	18.6	55.9	SUMER
	34.7%	17.5%	11.9%	35.8%	

[a] In the wavelength window from 1545.03 Å to 1553.84 Å.
[b] In the wavelength window from 1545.37 Å to 1553.66 Å.
[c] $\Omega_{\odot}$ = 6.80 10^{-5} sr (solid angle of Sun at 1 AU).
[d] The ratio between the mean radiance of C IV (λ1548) and its averaged radiance near disk centre was found to be $\kappa_{C\,IV}$ = $\overline{L}_{C\,IV}$/ $\overline{L}_{C\,IV}(0)$ = 2.22 for quiet-Sun conditions. The corresponding value for Si I was $\kappa_{Si\,I} = 1.44$.

able. In summary, we find agreement between the spectra not only for prominent lines, but also for the general shape - with the above qualification.

A special note is required on the H I Lyα line: The line is too bright for the unprotected SUMER detectors and, consequently, has to be observed through a 1:10 mechanical attenuator very close to the edge of the detectors. Under these conditions, the radiometric calibration of this line is not so well established as for other lines, and the observed SOLSTICE/SUMER ratio of 0.75 seems to be compatible with the assumption that the ratio has, in fact, a value of 1. Additional SUMER observations of the H I Lyα line have been performed and are discussed in detail by Lemaire et al. (1998).

As far as the line irradiance data in Table 2 are concerned, the revised SUMER calibration for N V now leads to a mean SUMER irradiance of $\overline{E^*_{1238}}$ = 5.67 10^{12} photon $s^{-1}m^{-2}$ (9.09 μW m^{-2}), which is only 14% lower than the mean SOLSTICE irradiance of $\overline{E_{1238}}$ = 6.59 10^{12} photon $s^{-1}m^{-2}$ (10.6 μW m^{-2}). Whereas the N V line is well isolated in the spectrum, and can be fully resolved both in low and high resolution in Fig. 1a, the C IV doublet at 1548 Å and 1550 Å is blended at the low spectral resolution. Moreover, many Si I lines are crowding this spectral range. It might therefore be appropriate to study the C IV situation more closely by utilizing the radiance spectrum of 12 August 1996 in order to determine the various relative radiation contributions in certain wavelength ranges. It is also evident from Fig. 1a that the SUMER spectrum is rather noisy above 1520 Å as a consequence of the low count-rates for a single spectrum (integrated along the short slit of 120″ and with an exposure time of 115 s). From Fig. 13 of Wilhelm et al. (1998), we get a statistical uncertainty of $\pm$ 7% (1 σ) at 1550 Å for the determination of the level of the continuum under these conditions. In order to determine the relative intensities of the C IV and Si I lines, we study a spectrum from 1545.37 Å to 1553.66 Å in Fig. 2, where the wavelength range from 1544.03 Å to 1552.91 Å is averaged over 50″ × 300″ of a quiet-Sun region near disk centre on 8 March 1999 (Exposure time for each of the 50 frames: 150 s). It has a statistical uncertainty of $\pm$ 0.5% (1 σ) at background level. We do not use the absolute radiometry of this observation, because (1) even the radiance of quiet-Sun regions might vary with the solar cycle (see indications of such an effect in Schühle et al. 1998) and (2) the SUMER instrument probably suffered a decrease of its radiometric sensitivity by ≈ 40% during the period when SOHO had lost its Sun-pointing capability in 1998 (Schühle et al. 1999). By employing multi-Gauss fits to model the C IV and all 20 Si I lines seen in the shaded portion of Fig. 2, we find the contributions listed in Table 3 in the first line of the high-resolution section. We could marginally separate the five Si I emission lines marked in Fig. 2 at 1547.943 Å, 1548.048 Å, and 1548.518 Å from C IV (λ1548.202), and at 1550.630 Å and 1550.958 Å from C IV (λ1550.774). Wavelengths are taken from Kelly (1987). The effect of the centre-to-limb variation has been determined for the C IV (λ1548) line. We adopt the same value for C IV (λ1550) and no centre-to-limb variation for the continuum. At 1550 Å no variation of the centre-to-limb radiance has been found for quiet-Sun regions and a slight limb darkening in polar coronal holes (Wilhelm et al. 1998), although Brekke & Kjeldseth-Moe (1994) determined a stronger limb darkening of 0.933 at 1553.62 Å in terms of the averaged disk radiance to the radiance at disk centre. The prominent Si I (λ1256) line was characterized by $\kappa_{\rm Si\,I} = 1.44$. If we assume this value for the weaker Si I lines in our range as well, we can only underestimate the Si I contribution to the irradiance. With these assumptions, and taking into account the exact wavelength ranges of our comparison (≈ 6% less for SUMER, which can be approximately corrected for by increasing both the continuum and the Si I contributions accordingly), we obtain the relative contributions of the irradiances as shown in the last rows of Table 3 (as discussed above, the absolute radiometry data of this observation will not be used here). We see that at least ≈ 12% of Si I have to be accounted for, which should reduce the SOLSTICE continuum contribution from 41.2% (2nd row) to 35.8% (last row) and the sum of C IV ($\lambda\lambda$1548,1550) from 58.7% to 52.2%. For C IV (λ1548) alone, we estimate a reduction from 40.1% to 34.7%.

If we then reduce the mean $\overline{E_{1548}} = 7.85\ 10^{13}$ photon s^{-1} m^{-2} of SOLSTICE in Table 2 accordingly (by a factor of 34.7/40.1), we arrived at 6.79 10^{13} photon s^{-1} m^{-2} (87.1 μW m^{-2}) and find that the mean SUMER value of $\overline{E^{*}_{1548}} = 6.02\ 10^{13}$ photon s^{-1} m^{-2} (77.2 μW m^{-2}) is 11% smaller. A larger $\kappa_{\rm Si\,I}$ will decrease the difference even further; for $\kappa_{\rm Si\,I}$ = 2 the difference would be 8%. Consequently, we can state that SOLSTICE and SUMER observe the same N V (λ1238) and C IV (λ1548) irradiances within the combined uncertainty margins of both instruments. Since, on the other hand, the SUMER irradiances observed for N V and C IV are outside the narrow SOLSTICE uncertainty range, and, in addition, the continuum seen by SUMER near 1450 Å, where Brekke & Kjeldseth-Moe (1994) did not find a significant center-to-limb variation, is ≈ 15% less than the SOLSTICE result, it is reasonable to conclude that the SUMER calibration in the wavelength range from 1238 Å to 1550 Å gives radiance and irradiance data which are probably too low by 10% to 15%. In order to maintain an independent SUMER calibration, no automatic correction will be applied to the standard SUMER radiometric calibration procedure, but a note will be added to advise potential users on the conclusion drawn from this comparison.

The SUMER data used in this analysis are available for further investigations in the public domain of the SOHO archive at http://sohowww.nascom.nasa.gov/data/ catalogues/main.html. The SOLSTICE level 3BS data can be obtained from http://daac.gsfc.nasa.gov/data/ dataset/UARS.

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