Intercalibration of SUMER and CDS on SOHO.
II. SUMER detectors A and B and CDS NIS

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Results of an intercalibration between the extreme-ultraviolet spectrometers Coronal Diagnostic Spectrometer (CDS) and Solar Ultraviolet Measurements of Emitted Radiation (SUMER) on board the Solar and Heliospheric Observatory (SOHO) are reported. The results of the joint observing program Intercal_01 are described, and intercalibration results up to July 2000 of both SUMER detectors A and B and of the CDS Normal Incidence Spectrometer (NIS) are presented. The instruments simultaneously observed radiance of emission lines at the center of the Sun, and three lines have been chosen for intercomparison: He I 584 Å, Mg X 609 Å, and Mg X 624 Å. Initially the same area was observed by both instruments, but, after restrictions were imposed by the scanning mechanism of SUMER in November 1996, the instruments viewed areas of different sizes. Nevertheless, the temporal correlation between the two instruments remained good through June 1998, when contact with the SOHO spacecraft was lost. Until then the CDS instrument measured (33 ± 5)% and (38 ± 7)% ($\pm 1\sigma$) higher intensity than SUMER in the He I 584-Å line on average for detectors A and B, respectively. Data from SUMER detector B agreed well for Mg X 609 Å and Mg X 624 Å with the CDS intensities, showing offsets of (2 ± 10)% and (9 ± 15)%, much less than the data of detector A with offsets of (7 ± 8)% and (16 ± 7)% for the two lines, respectively, relative to CDS. Finally, the intercalibration measurements after the loss and recovery of the SOHO spacecraft are analyzed. The data for observations from November 1998 to July 2000 are compared, and it is shown that, although the responses of the instruments have changed, the CDS and the SUMER still perform well, and their temporal correlation is good. © 2001 Optical Society of America

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1. Introduction

The radiometric intercalibration between the extreme- and far-ultraviolet spectrometers[1] Coronal Diagnostic Spectrometer (CDS) and Solar Ultraviolet Measurements of Emitted Radiation (SUMER) on board the Solar and Heliospheric Observatory (SOHO) was introduced in a previous paper.[2] The results were based on a comparison of simultaneous observations of quiet-Sun regions in the three spectral lines He I 584 Å, Mg X 609 Å, and Mg X 624 Å [Joint Observing Program (JOP) Intercal_01]. They showed that the time series of radiances measured by the two instruments maintained good temporal correlation and stability during the time from March 1996 to August 1996 (Phase I of the intercalibration period). However, CDS generally measured more than 30% greater radiance than SUMER for the He I 584 Å line and 7% and 16% greater radiance for Mg X 609 and Mg X 624 Å, respectively. During the first study the CDS Normal Incidence Spectrometer (NIS)

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longer-wavelength channel (NIS2) and SUMER detector A were involved, and raster scans that recorded one spectral line at each spatial position were performed with both instruments.

In the following period (Phase II), SUMER usually used its detector B. Unfortunately, the raster scanning mechanism of the SUMER instrument failed in its normal-current mode in November 1996. Consequently the SUMER scans were limited to the drift of the solar surface across the slit that was due to solar rotation, whereas CDS still performed raster scans. A pixelwise cross correlation of the images as described in Ref. 2 was no longer possible. Nevertheless, the averages of the images of overlapping target areas simultaneously observed by the two instruments still provided the opportunity for intercalibration of the two instruments for an extended period of time.

In June 1998 contact with the SOHO spacecraft was lost and could not be reestablished for more than a month. In the four months between loss and complete recovery of the spacecraft the payload experienced extreme temperature conditions, which in most cases affected the radiometric response of the instruments. The intercalibration observing program was continued after recovery of SOHO. To investigate the postrecovery performance of the CDS and SUMER instruments, we compare the corresponding data sets, which cover the period from November 1998 to July 2000 (Phase III) and relate them to the earlier results. In August 1999 the O V line at 629 Å was added to the Intercal_01 JOP and has since been monitored together with the other lines.

After a short summary of the data reduction (Section 2) we compare the average absolute radiances for the entire period of the intercalibration observing program (Section 3) from March 1996 until the loss of the SOHO spacecraft in July 1998 as well as the postrecovery data until July 2000. We also investigate how the instruments' behavior changed after the loss and recovery of SOHO. A summary of the results and some conclusions are given in Section 4.

2. Data Reduction

For a description of the CDS and SUMER instruments and their data we refer the reader to the relevant literature, namely, Refs. 3 and 4, respectively. The data preparation applied in this study was performed in close analogy to that for the measurements from March 1996 to August 1996 as described in Ref. 2.

A. Data Obtained before SOHO's Attitude Loss

From September 1996 to June 1998 the intercalibration measurements involved SUMER's detector B. The SUMER data were corrected for the flat field, the geometric distortion, and detector electronics effects such as dead time and local-gain depression. The radiances were calculated as integrals of Gaussian functions that represent the line profiles. These Gaussians were determined by least-squares fits of single or multiple Gaussian functions and a linear background (i.e., the contributions of the continua) to the observed spectra at every spatial position. Multiple Gaussians were fitted in the case of distortions of the profile of the analyzed spectral line, e.g., owing to secondary peaks caused by blends. Only the area under the Gaussian that represents the main spectral line was considered. The relative uncertainties for the radiometric calibration of SUMER detectors A and B are 15% and 20%, respectively.[5]

The CDS data reduction consisted principally of corrections for burn-in and flat fielding. Gaussian line profiles of the preaccident data were fitted by use of the ADAS (Atomic Data and Analysis Structure).[6] The relative uncertainties of the CDS radiometric calibration are 15% at He I 584 Å and 25% at 609 and 625 Å.[7]

From November 1998 to July 2000, SUMER alternately used its A and B detectors. The data reduction remained the same as before the loss of the SOHO spacecraft. However, the shape of the CDS line profiles changed after the recovery and needs special treatment, as is explained in Subsection 2.B.

B. Postrecovery Data

After the loss of the SOHO spacecraft in June 1998 and because of the subsequent unusual temperature conditions, both instruments suffered changes in their configurations. Assessing the time series of the preloss and postloss image averages for each instrument separately as well as comparing those of the two instruments with each other revealed inconsistencies of the individual instruments. These first comparisons (see Figs. 3–5 below) led us to the following conclusions regarding the postrecovery data: (1) The absolute radiometric calibration of the CDS NIS2 did not change, but all lines were affected by relatively strong burn-in effects. Part of the CDS burn-in stems from the use of the wide (90 arc sec × 240 arc sec) slit of this instrument and is difficult to assess, especially for the postrecovery measurements. (2) The SUMER measurements indicate a smaller responsivity of the instrument but otherwise show the correct trends.

1. CDS

During the loss and during much of the recovery time for the spacecraft, CDS was held at a temperature of ~100 °C, well above the 0–40 °C range over which it had been tested before launch. For the CDS NIS spectrometer the postrecovery line profiles exhibit wings of different strengths on either side of each spectral line. This change is attributed to the prolonged heating, which caused an irreversible distortion in the instrument. Special fitting routines were developed to account for the changed profiles.[8] Examples of fits to the line profile of He I 584 Å before and after SOHO's accident are plotted in Figs. 1 and 2. They confirm that both the original and the modified profile shapes are well modeled.

Even though the absolute radiometric calibration of CDS seems to have remained constant, the instrument showed, in the He I line, relatively high inten-

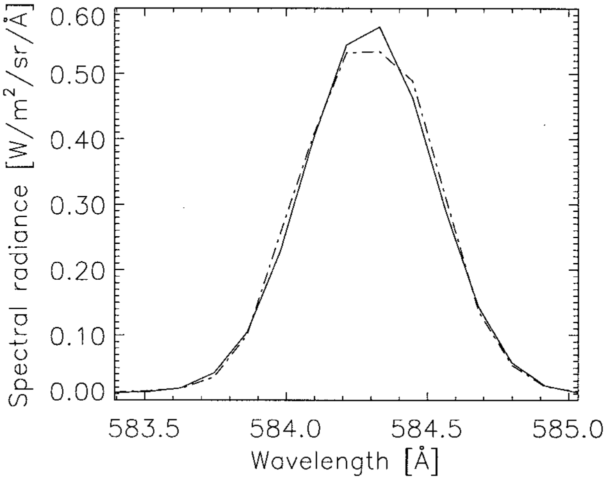

Fig. 1. Sample He I 584-Å preloss line profile measured with CDS (dashed–dotted curve) and corresponding fit of a Gaussian plus a constant background (solid curve).

sity values just after recovery [see Fig. 3(a)]. This behavior is assumed to be the result of initial contamination of the microchannel plate with molecules and their subsequent desorption. Inasmuch as these molecules are loosely bound to the surface, they temporarily increase the responsivity of the detector until they are scrubbed away by the electron avalanches caused by the radiation exposure.

By ~400 days following SOHO's recovery the ratio SUMER/CDS increased owing to an additional burn-in effect that has recently been determined and included in the CDS data-reduction software (SolarSoft version of 15 May 2001). The combined burn-in effects (narrow slit and wide slit) resulted in an additional uncertainty of 10–15% for the He I line and of 15–20% for the Mg X lines, giving a total uncertainty of approximately 20% for the He I line and 30% for the Mg X lines.

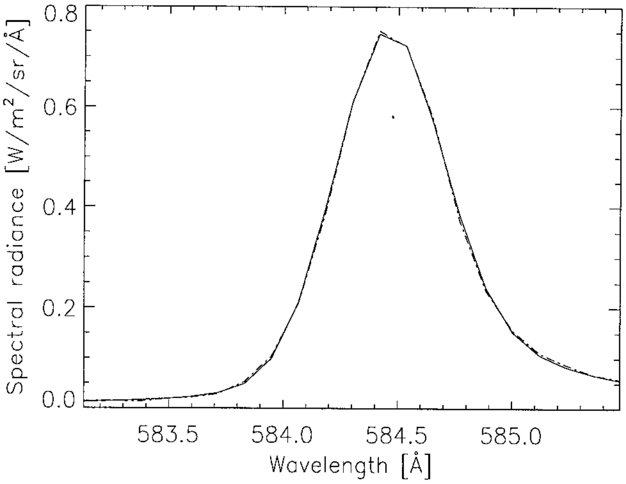

Fig. 2. Sample He I 584-Å postrecovery line profile measured with CDS (dashed–dotted curve) and corresponding fit of a Gaussian with extended tails plus a constant background (solid curve, barely distinguishable).

2. *SUMER*

After recovery of the SOHO spacecraft, SUMER detectors A and B were used alternately so they could be cross calibrated and any changes that might have occurred during the SOHO loss period determined. The two detectors showed a similar response, but the SUMER instrument experienced an overall loss of sensitivity, possibly as a result of captured permanent contamination on various optical parts of the instrument. The SUMER instrument was on the cold side of the spacecraft during most of the time when SOHO's attitude was not controlled. The telescope mirror, which was held at elevated temperatures during the nominal mission to prevent contaminant deposition, was estimated to have dropped to −80 °C during the accident[9] (compared with nominal temperatures of 80 °C in its operational and 40 °C in its nonoperational mode), whereas many other parts of the spacecraft reached extremely high temperatures. The changes in responsivity are attributed to deposition of contaminants and subsequent polymerization on the optical surfaces. To compensate for this loss of efficiency, a correction factor between preloss and postloss efficiency needs to be determined.

Starting from the preloss radiometric calibration (as given in the SolarSoft program radiometry.pro with the keyword /before) we estimated this correction factor in two ways: (A) Separate linear least-squares fits were made to the time series of radiance values before and after the accident. The correction factor was determined from the requirement that the two linear fits intersect during the time that SOHO was lost. This assumption draws on the analysis of Ref. 10, which, by admitting gradients, suggests that the quiet-Sun radiance in selected extreme-ultraviolet spectral lines has increased with increasing solar activity. This technique resulted in a correction factor for the radiometric calibration of 1.36–1.65, depending on the spectral line. For the lines under study here, the correction factors were 1.36 for He I 584 Å, 1.40 for Mg X 609 Å, and 1.30 for Mg X 624 Å as well as for O V 629 Å. (B) We obtained a different estimate by requiring that the mean values before and after the loss of SOHO be equal. This approach yielded smaller correction factors of 1.10–1.55 for SUMER wavelengths within the range 584–1238 Å. Taking the averages of both estimates suggested corrections of 1.20–1.60. We then varied the correction factor from 1.10 to 1.70 and each time computed the cross correlation between the SUMER and CDS time series (corrected as described above) for the three common wavelengths. This cross correlation was maximized for values of approximately 1.38 in Mg X 624 Å, 1.40 in Mg X 609 Å, and 1.60 in He I 584 Å. This procedure ensured consistency between preaccident and postaccident data (Table 1) in this wavelength range.

However, as the CDS postrecovery data have un-

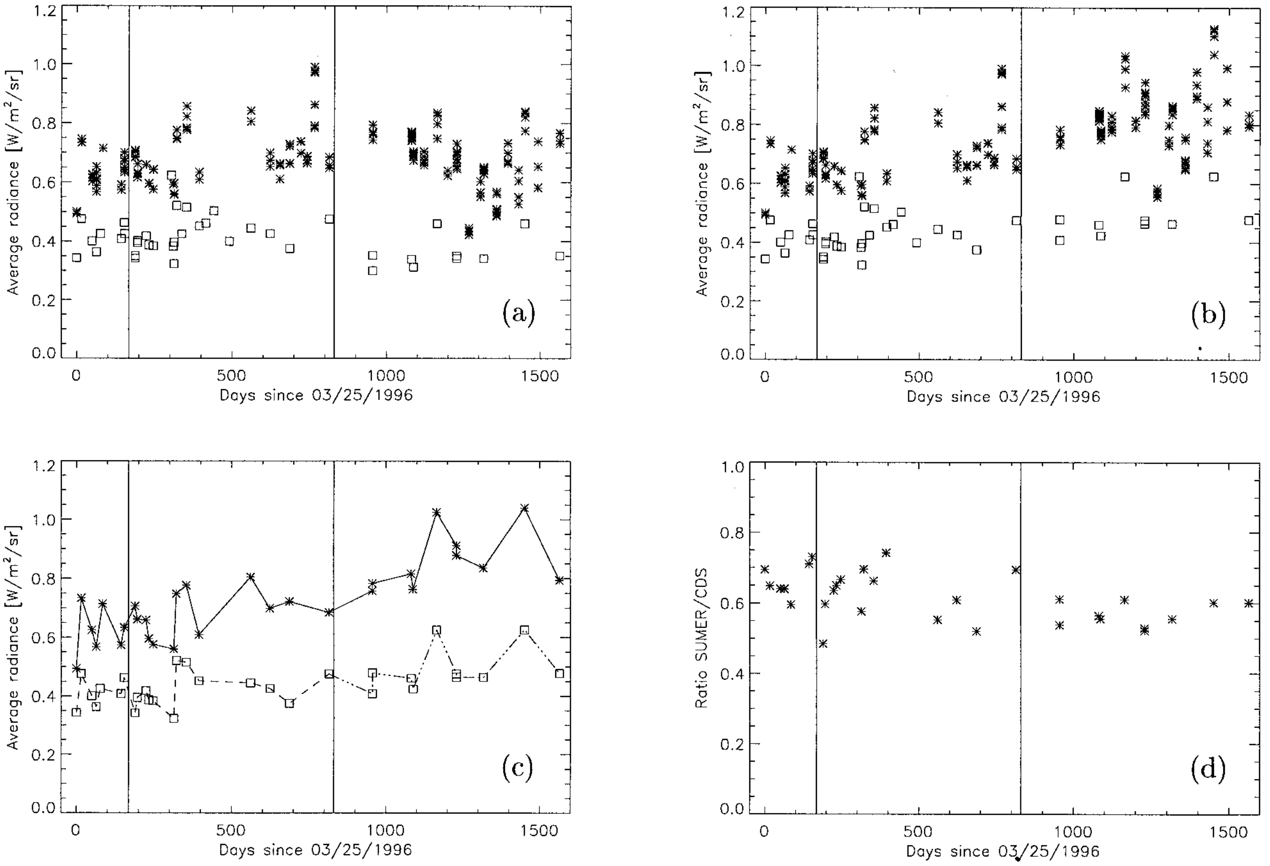

Fig. 3. Spatially averaged radiances in the He I 584-Å line measured with CDS (stars) and SUMER (squares). The three phases of the intercalibration record (SUMER detector A, SUMER detector B, postrecovery) are separated by vertical lines. (a) All available data, with uncorrected postrecovery data. (b) All available data, with postrecovery data corrected as described in Subsection 2.B (SUMER corrected with procedure A). (c) Simultaneous measurements of SUMER and CDS: postrecovery data corrected according to Subsection 2.B. (d) Ratio of the averages of the radiances of SUMER relative to CDS. Here and in Figs. 4 and 5, dates are in numerical order month/day/year.

certainties in the postrecovery burn-in effects and there might be instrumental trends in either time series, it seemed more reasonable to calculate the SUMER correction factors independently of the CDS data. From the preloss values of 15% and 20% for detectors A and B, respectively, and the additional uncertainty of ~30% in determination of the correction factor, we estimated the total uncertainties to be 33% for detector A and 36% for detector B. In this comparison we used the different individual correction factors for the different lines (procedure A). The wavelengths measured in the Intercal JOP program (i.e., 584, 609, 624, 770, and 1238 Å) are the only wavelengths that were monitored continuously and therefore are best suited for the determination of a correction factor. At this stage it does not seem possible to give a wavelength-dependent correction factor that is valid for the entire SUMER range. SUMER's radiometry program, radiometry.pro in SolarSoft (as of 24 May 2001), therefore uses an average

Table 1. Average Relative Differences between the CDS and the SUMER Time Series (%)

	Measurement Period (Phase Number)				
			November 1998–July 2000 (III)		
Wavelength (Å)	March–August 1996 (I)	September–June 1998 (II)	Procedure A	Procedure B	SUM[a] Factor 1.45
584	33 ± 5	38 ± 7	43 ± 5	33 ± 5	39 ± 5
609	7 ± 8	2 ± 10	0 ± 18	0 ± 18	−7 ± 18
624	16 ± 7	9 ± 15	5 ± 12	0 ± 12	−6 ± 13
629	–	–	−4 ± 15	−8 ± 15	−15 ± 15

[a] The SUM factor is the average of the wavelength-dependent individual correction factors.

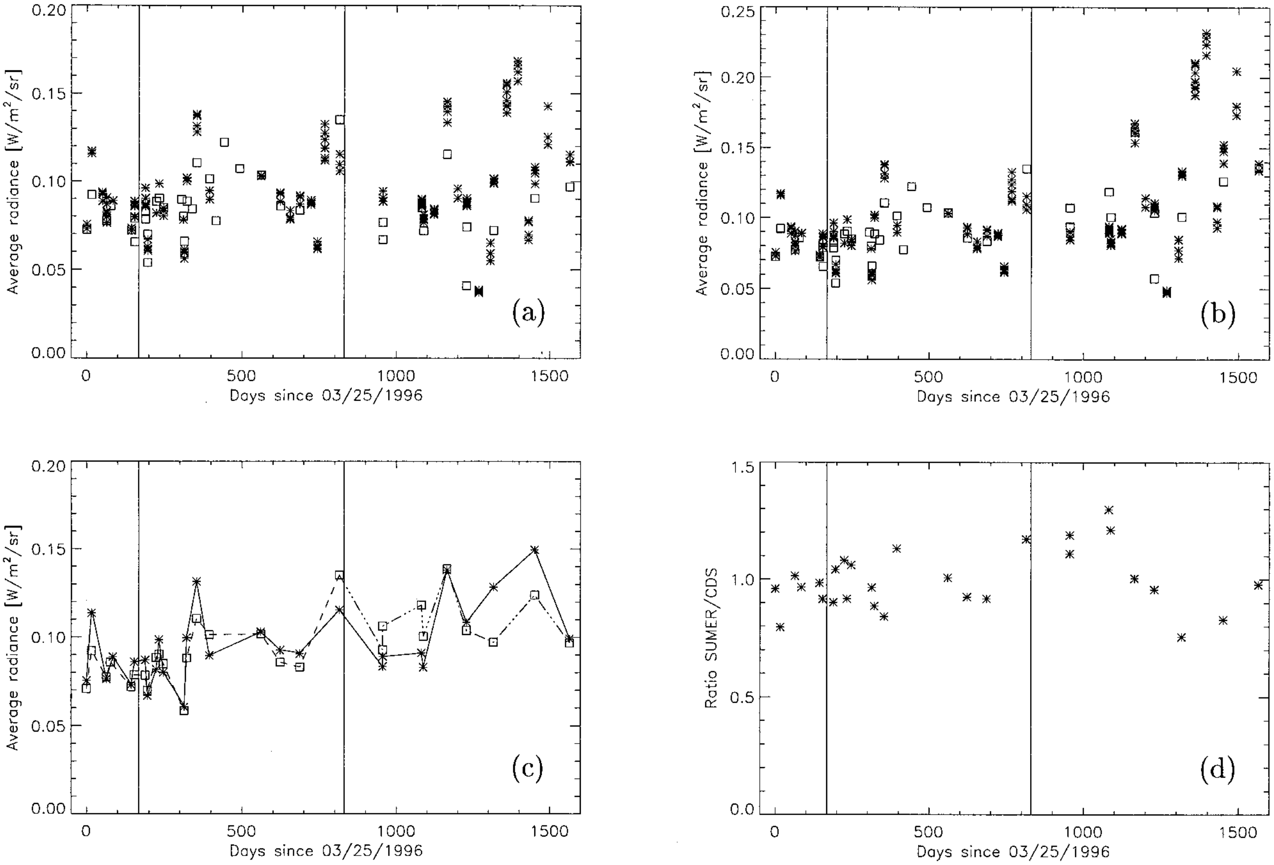

Fig. 4. Radiances in Mg x 609 Å; see Fig. 3 for details.

of the individual values as the correction factor [namely, 1.45. Keywords /epoch_7 (default), /after] that resulted from a mean loss of responsivity of 31% as determined in Ref. 11.

3. Comparison of the Radiances

For the CDS–SUMER intercomparison we have to distinguish among three time periods with different conditions. For Phase I (March 1996–August 1996) we can compare quasi-simultaneous measurements of overlapping areas on the Sun. For Phase II (September 1996–June 1998), only averages of the total radiances in the respective scanned areas can be compared. The postrecovery measurements (Phase III, November 1998–July 2000) form a peculiar data set, as both instruments behave somewhat differently from before SOHO's loss of altitude. This difference introduces a relatively large uncertainty into our estimates for this period. Also, for most of the time (Phases II and III) the CDS instrument scanned a much larger portion of the Sun and consequently observed different features from those observed by SUMER and thus could record different radiances. Another source of uncertainty is the fact that as the solar activity maximum approaches, it becomes increasingly more difficult to find truly quiet-Sun areas.

A. Long-Term Comparison of the Averaged Radiances

Figures 3–5 display the time series of all available radiances averaged over the rasters made by the two instruments as part of the Intercal_01 campaign. The three phases of the intercalibration campaign (March 1996–August 1996, September 1996–June 1998, November 1998–July 2000) are separated by vertical lines. Figure 3(a) depicts the averaged radiances in He I 584 Å without the application of any correction to the postrecovery data. Figure 3(b) shows the same but with the modifications described in Section 2 made to the postrecovery data. For SUMER we used, in all the calculations that follow, the individual correction factors from procedure A outlined in Subsection 2.B. Figure 3(c) shows the same data as Fig. 3(b) but is restricted to the measurements that are obtained simultaneously by both instruments. We use only these data for the comparisons of the two instruments to keep the influence of the inhomogeneity and the intrinsic variability of the solar radiation to a minimum. Finally, Fig. 3(d) depicts the ratios of the averaged radiances SUMER/CDS for the entire time period. In Figs. 4 and 5 the same quantities are depicted for the Mg x 609-Å line and the Mg x 624-Å line, respectively. The measurements of day 1165 (June 1999) and day 1565 (July 2000) have been made off disk center and interpo-

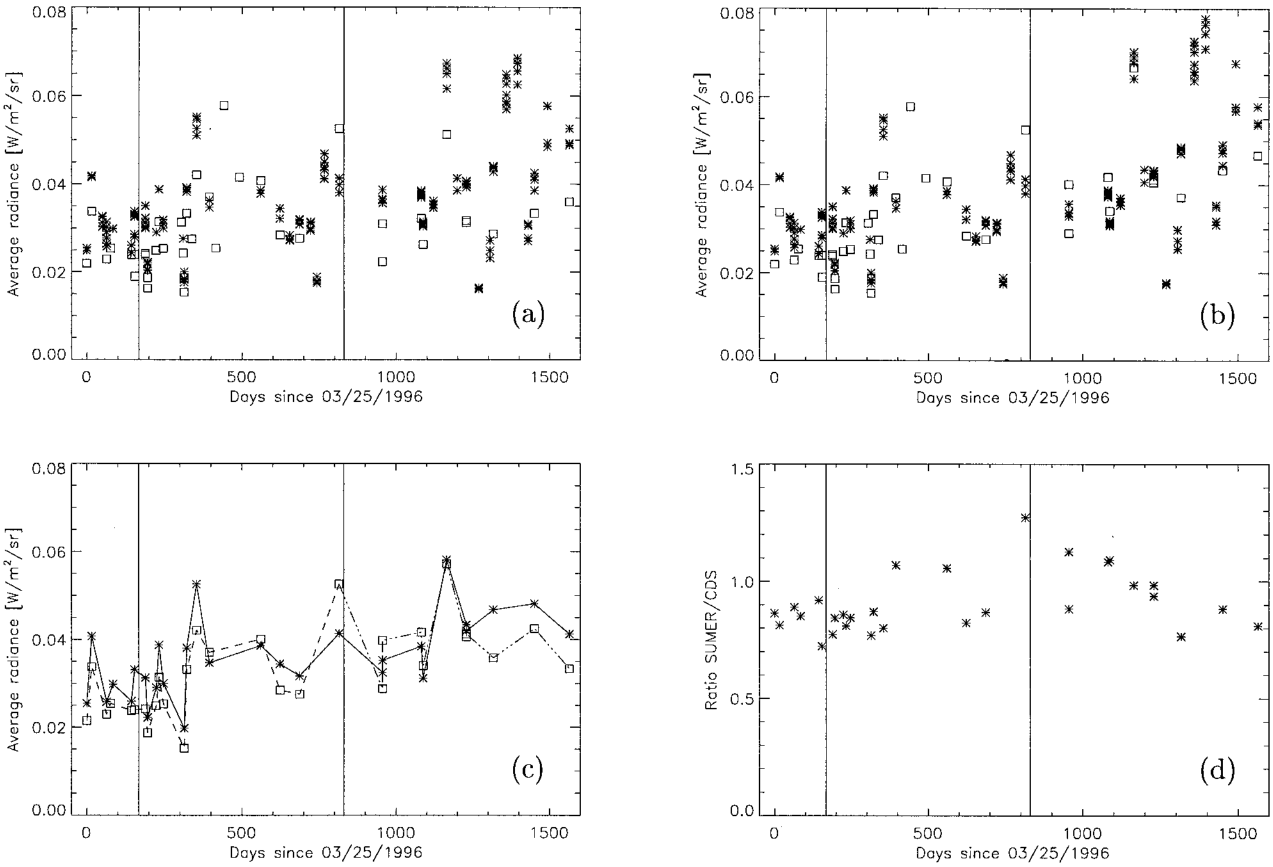

Fig. 5. Radiances in Mg x 624 Å; see Fig. 3 for details.

lated to center values, according to the center-to-limb variation described in Ref. 12. Figures 3(c) and 3(d) show that the He I 584-Å data give consistent trends over the three time periods for each instrument individually, although the absolute radiance differs by 40%. The ratio SUMER/CDS shows no exceptionally large variation over the whole time period. Similarly, the ratio SUMER/CDS of the two Mg x lines varies mainly within a range of ±20%. Especially in the coronal lines, the variability increased significantly during Phase III, and at least the measurements of days 1165 (June 1999) and 1451 (March 2000) contain parts of active regions.

B. Correlation of the Time Series

To determine whether the time variability of the signals is solar or instrumental, we calculated the correlation of the two time series of the simultaneous measurements. High correlation indicates that the variability is solar rather than instrumental. For the He I 584-Å line the correlations of the time series of the CDS and SUMER simultaneously measured radiances (averaged over the corresponding rasters) were 84%, 57%, and 92% for the three phases independently (after correction of the postrecovery data). The correlations for the Mg x 609-Å line were 94%, 84%, and 76%, whereas for Mg x 624 Å they were 92%, 84%, and 87%. The correlations for Phase III are independent of the procedure with which the SUMER correction factor was determined. As described in Ref. 2, during the measurements of Phase I, raster scans over an area of 60 arc sec × 300 arc sec (SUMER detector A) and 60 arc sec × 240 arc sec (CDS) were made, and a common field of view was determined for the comparison. During Phase II, when the SUMER detector B was used, and later, the conditions for a comparison were not so good as they had been because SUMER's field of view was restricted to an area of approximately 3.5 arc sec × 300 arc sec. This difference explains the lower correlation of the two time series over this period. Especially for the He I line, which shows the network quite clearly, the correlation of the SUMER and the CDS averaged radiances drops significantly during the second half of Phase II. In postrecovery Phase III, SUMER was also not scanning most of the time, except during two days when its scanning mechanism was operated in a high-current mode. Although in Phase III the conditions of both instruments changed considerably, the correlation of the two instruments remained surprisingly high. The correlations between the two time series (corrected as described above) for the entire period of intercalibration measurements (Phases I–III) were 81%, 83%, and 89% for He I 584 Å, Mg x 609 Å, and Mg x 624 Å, respectively.

However, after the loss and recovery of the space-

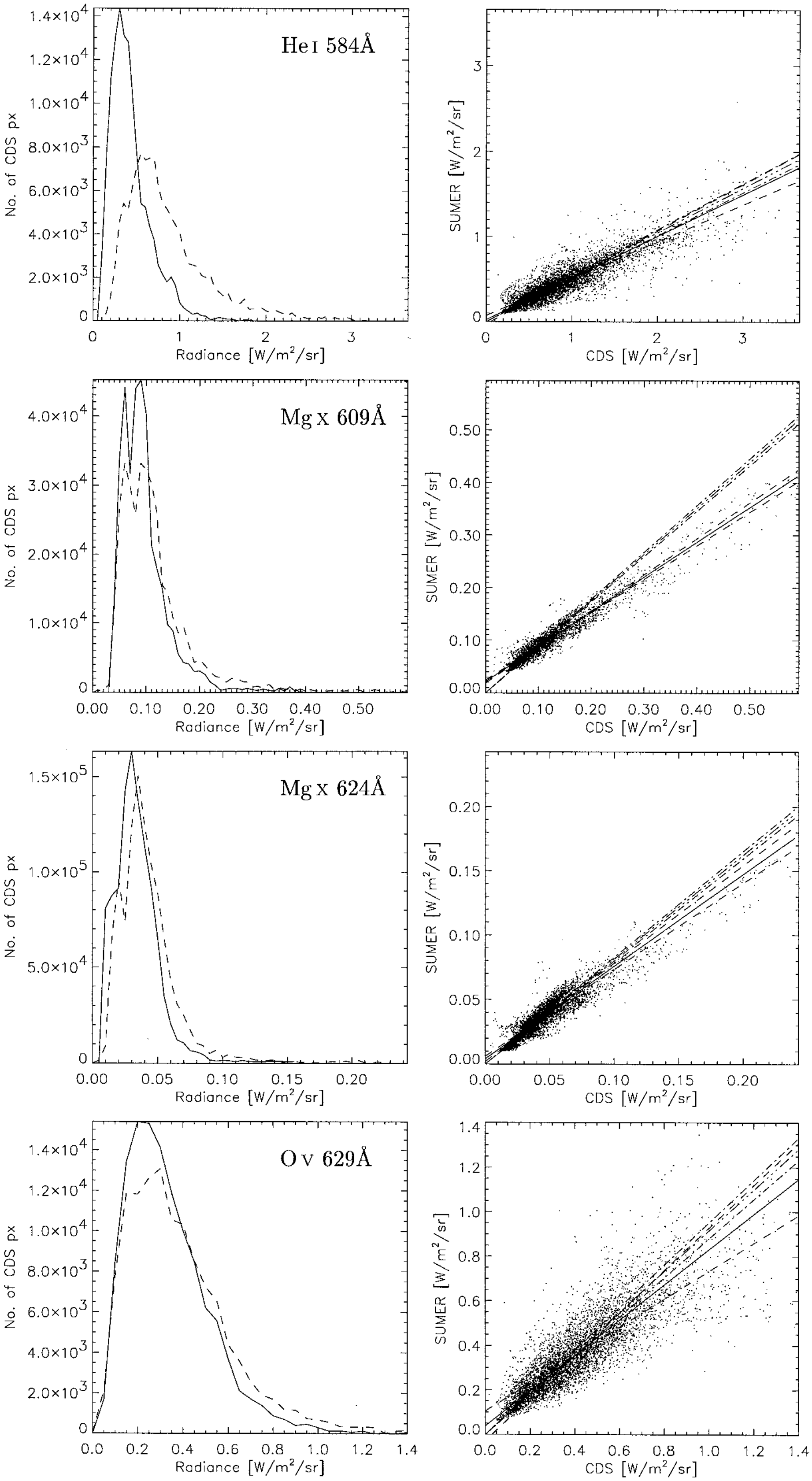

Fig. 6. Left, histograms of the radiances of the overlapping fields of view for the measurements of 6 August and 2 November 1999. (CDS, dashed curves; SUMER, solid curves) Right, scatter plots and linear regressions for the same data sets; see Subsection 3.B for details.

craft there is a considerable difference in the radiometric calibration of the two instruments, depending on the chosen correction, which implies a significantly larger uncertainty. This can be seen from Figs. 3–5 as well as from Table 1, in which the average relative differences $[\text{av(CDS)}]_{\text{phase}_i} - \text{av(SUMER)}_{\text{phase}_i}]/\text{av(CDS)}_{\text{phase}_i}]$ of the three time periods are listed. (For Phase III we have included in the last three columns of Table 1 the values for the several SUMER postrecovery correction factors. Throughout this comparison, procedure A was used.) In the Mg x lines and in the O v line the uncertainty of this average difference is rather large. The small differences from the earlier paper[2] for Phase I result from our use here of calibrations that meanwhile have been slightly improved (e.g., improved burn-in correction for CDS). Although it has been accounted for, possibly the burn-in correction for the CDS NIS is still not fully sufficient, or the factors that adjusted the SUMER postrecovery data might be different. It is also noticeable that after the measurements of Phase I there is no persistent offset between the SUMER and CDS measurements for the Mg x lines. The average difference in the radiances in these lines falls well within the uncertainty range.

C. Radiances of Individual Pixels

After recovery of SOHO, SUMER's scanning mechanism was employed for dedicated measurements. It was used for the intercalibration data sets of 6 August and 2 November 1999, where also the O v 629-Å line was included in the intercalibration program. It is interesting to compare the radiances for the two instruments point by point for these postrecovery data after the common field of view of the two instruments has been determined by cross-correlation of the corresponding images. A comparison with Fig. 10 of Ref. 2 then reveals whether there are changes in the relative responsivity of the two instruments that go beyond what can be deduced from the spatially averaged data. In Fig. 6 we show curves and scatter plots of the combined measurements of 6 August and 2 November 1999 for all four wavelengths. (These were the only dates after November 1996 when the SUMER scanning mechanism was enabled during the intercalibration JOP.) A more-detailed statistical description of the preloss data can be found in Ref. 13. The SUMER measurements have been corrected by use of the factors of procedure A. To match the CDS spatial resolution we reduced the resolution of the SUMER data, using a point-spread function and sampling according to the CDS spatial grid (see Ref. 2), so the images of both instruments resembled the CDS pixel pattern. On the right-hand side of Fig. 6 the dashed lines represent the best fits that resulted from the two regressions (one applied to the CDS radiances as a function of SUMER values; the other, vice versa), and the solid line between represents their average. As both variables contain uncertainties, and one usually applies a linear regression to investigate the relation between a dependent and an independent variable, it is useful to carry out both fits with dependent and independent variables interchanged. (If the modulus of the regression coefficient is 1, the two fits are identical; but the larger the scatter, the larger the difference between these two fits.) The dashed–dotted curves depict the results from the corresponding one-parameter fits through the origin. As in the earlier data (see Ref. 2), CDS measures higher values than SUMER in the He i 584-Å line for the data set shown. The differences are rather small in both Mg x lines and in the O v 629 Å line. The O v line is of particular interest because it is the only transition-region line in the sample. It shows a much larger scatter between the two instruments than do the other lines. This transition-region line is also by far the most variable of the lines analyzed.[14] We believe that the extra scatter is of solar origin and is due to the fact that no given part of the solar surface was observed strictly simultaneously by both instruments. (Though the observations were simultaneous, the measurements of the individual spatial points were not exactly cotemporal, owing to the different slit sizes and raster speeds of SUMER and CDS.)

Table 2. Regression Coefficients from the Scatter Plots of Fig. 4

Wavelength (Å)	Slope	Constant	One-Parameter Fit
584	0.500 ± 0.078	0.023 ± 0.069	0.524 ± 0.150
609	0.663 ± 0.033	0.021 ± 0.004	0.878 ± 0.040
624	0.717 ± 0.064	0.004 ± 0.003	0.810 ± 0.030
629	0.791 ± 0.232	0.039 ± 0.094	0.915 ± 0.110

The parameters of the fits shown in Fig. 4 are listed in Table 2. The two-parameter fits are a considerable improvement over the one-parameter fits for the Mg x 609-Å and the O v 629-Å lines, indicating that a small offset in the background or the continuum treatment of the instruments would bring their intercalibration into reasonable agreement. For the He i 584-Å and the Mg x 624-Å lines, however, the two-parameter fits only marginally improve the agreement between the instruments. This discrepancy is negligible within the uncertainty margins of these measurements for the Mg x 624-Å line, but it is substantial for the He i 584-Å line.

4. Summary and Conclusions

The intercalibration of the CDS and the SUMER, instruments for the first 6 months of operations, which was described in a previous paper,[2] has been continued here to cover a period of more than 4 years. The earlier results for the stability of the CDS and SUMER instruments have been confirmed for the years up to the loss of the SOHO spacecraft. Although a comparison of the corresponding CDS and SUMER measurements is less straightforward for the data obtained since September 1996 than for the first phase of the intercalibration (when the SUMER instrument was scanning and common fields of view could be determined), the correlation between the two time series is still high. The SUMER detector B measurements show no difference in radiometric calibration from those obtained with detector A. The decrease in correlation in the second period might be due to the large difference between the fields of view of the instruments, with CDS still covering 60 arc sec in an east–west direction during the 21-min scanning time and SUMER covering just 3.5 arc sec. Finally, the SOHO accident caused several changes in the instruments, which had been exposed to large temperature differences during the SOHO's loss of contact.

In the He I line at 584 Å, the CDS instrument measured (33 ± 5)% to (38 ± 7)% higher values than the SUMER for the first two periods of the intercalibration record. The differences were much lower in the two Mg X lines and amounted to approximately 7% and 2%; they were 16% and 9% for 609 and 624 Å, respectively, with the corresponding 1σ uncertainties approximately the same or much greater than these mean differences. For the postrecovery period, the relative differences of the data sets, which have been corrected as described in Section 2 (with individual wavelength-dependent factors to correct SUMER's postrecovery efficiency), amount to (43 ± 5)%, 0%, and 5.0% for He I 584 Å, Mg X 609 Å, and Mg X 624 Å, respectively. For O V 629 Å the relative difference of the average radiance during the last period of measurements is −4%. Again all values except for He I are much smaller than their corresponding 1σ uncertainties. It has to be noted that the postrecovery radiance values are affected by larger uncertainties than those in the initial comparison, i.e., of the order of 36%, and that this period of the comparison was also subject to increased solar activity.

The radiometric in-orbit comparison showed that the ratio between the responsivities of the two instruments remained constant with time until the SOHO accident. Variations in solar radiance (be they due to long-term changes in the solar output or to residual solar activity in what was thought to be quiet solar regions at the time of the observations) clearly dominate over instrumental changes. The responsivity degradations that plagued some earlier solar space telescopes after exposure to solar irradiation in space are absent so far from these two instruments on the SOHO mission after nearly 5 years. Even after the loss and recovery of the spacecraft, when the instruments had been exposed to extreme temperature conditions, the radiometric calibration of both instruments could be maintained, although with higher uncertainty. However, some of the differences in the radiometric calibrations of the two instruments as well as the consequences of SOHO's temporary failure for data analysis need further investigation. Ongoing and planned studies involve comparisons of irradiance measurements as well as comparisons with other instruments and calibrations that use stars.

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