Wavelength selection for the spectrometer on Solar Orbiter

P.R. Young, RAL

The choice of wavelength ranges for the spectrometer on Orbiter will have a critical effect on what science can be achieved, and they also play an important role in the design of the instrument. A discussion on wavelength ranges occurred at the Orbiter meeting in Tenerife (Harrison & Vial 2001), and 3 bands were selected: 170-210 Å, 580-630 Å, and another band beyond 912 Å (this latter is based on the requirement for coverage of the chromosphere, whose lines occur above the hydrogen lyman limit). It is not clear yet whether restrictions on the instrument mass will allow 3 wavelength bands.

The present document extends the discussions from the Tenerife meeting, presenting the strengths and weaknesses of key bands in the UV, and making recommendations in the cases of 1, 2 or 3 bands being allowed in the final instrument design.

Instrumental issues

Although science issues should determine the ultimate choice of wavelength bands, there are key facts about the Orbiter mission and instrument technology that must be considered when choosing wavelength bands. These are:

- The spectrometer on Orbiter will likely have a telemetry rate comparable to CDS on SOHO (10's of kilobits per second), yet will have a much higher spatial resolution. Thus if similar sized regions are to be observed with EUS, the quantity of data produced will be much larger than CDS. To have good time cadence, the number of emission lines that can be observed will be very limited, perhaps around 2-5 in typical observing sequences. To maximize the science from EUS it is essential that the strong lines observed cover a wide range in temperature and are unblended.
- For normal incidence reflections on optical surfaces, *multilayer coatings* are required on the optical surfaces (mirror or grating) to achieve useful reflectivities at wavelengths below ≈400 Å. The multilayer coatings enhance throughputs over only a small wavelength range, typically 10-20% of the central wavelength, with highest reflectivity in the centre of the band, and a smooth decrease towards to the edges. In addition, multilayer coatings previously used on space missions severely curtail sensitivity at other wavelengths. This may require the mirror and grating to be partitioned into 2 or 3 sections, each having a different coating (sensitive to different wavelength regions). This would lower the telescope throughput for each band. It may be possible to use a multilayer coating that has two sensitivity peaks (B.J. Kent, EUS Consortium Meeting, Nov. 2001).
- The satellite operations will be autonomous during the key phase of the mission: the perihelion pass, when the satellite is closest to the Sun. Targets have to be chosen ahead of time, and there will be limited opportunities to respond to dynamic events such as flares or CMEs. It would thus be expected a large

proportion of observing time will be devoted to coronal hole, quiet Sun and quiet (non-flaring) active regions. In addition, the spectrometer is unlikely to be an independently-pointed instrument, and so will be forced to point at the same regions on the Sun as the other instruments. Given that a magnetograph and a coronagraph are amongst the expected instrument suite, it is thus likely that most observations with EUS will be on the solar disk.

- The SUMER instrument design whereby a very large spectral area (500-1600 Å) is covered through observing a movable 40 Å window is unlikely to be feasible as it requires an additional mechanism that would add more mass to the instrument.

The latter point means that we are looking to observe fixed wavelength bands in a similar manner to CDS on SOHO. Fixed bands have the advantage that the lines both within a band and in different bands are observed simultaneously. The other points lead to additional considerations that are discussed below.

Strong lines in the EUV/UV

The lines that will be most regularly observed with EUS will be the strongest lines in the wavelength bands, simply because good time resolution is often a key observing requirement. We consider here the strongest lines in the 150-1600 Å range that are unblended, and provide wide temperature coverage. Note that cooler lines generally occur at longer wavelengths, with most coronal lines found below 400 Å, and very few transition region or chromospheric lines below 400 Å.

Since the instrument design of CDS involved the use of wavelength bands, it is worthwhile to consider its bands and their strongest lines. The vast majority of CDS data has been obtained from the normal incidence spectrometer (NIS) of CDS and so we consider this only. NIS covered the wavelength regions 308-381 Å and 513-632 Å, and the strongest lines are He I λ584, O V λ629, Mg IX λ368, Mg X λ624, Si XII λ520, Fe XVI λ360[1]. Since telemetry restrictions are important for CDS (as they will be for EUS), these are the most commonly observed NIS lines, as one can guarantee to obtain useful data from them. For exposure times of 5-10 s, each of these lines will yield a measurable line profile in quiet Sun conditions (except for Si XII and Fe XVI). While Mg IX, Mg X, Si XII and Fe XVI provide excellent coronal coverage, transition region coverage was poorer, particularly between O V and Mg IX (temperature range $5.4 \leq \log T \leq 6.0$). The medium strength Ca X λ557 line was often observed in order to bridge this gap. There also lacked any significant lines formed below $\log T = 5.0$ (He I and He II data are difficult to interpret and are generally not used in analysis).

Considering first the strongest lines in the transition region, Table 1 lists the best lines in the UV and EUV, together with their temperature of formation (T_{max}) and their thermal widths. All lines should be unblended when observed with a medium-to-high resolution spectrometer such as proposed for EUS.

The corona is considered here to fall in the temperature range $5.9 \leq \log T \leq 6.4$ (we do not cover flaring plasmas here) and the strongest lines are listed in Table 2. The lines listed in the two tables are referred to in this document as Class A lines.

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[1] O IV λ554.5 is also a strong line, however it is part of a multiplet that is close in wavelength, and so it was necessary to have a larger than normal wavelength window to observe the full multiplet and enable the measurement of an accurate background for the line.

Table 1. List of the strongest transition region lines in the UV/EUV.

Ion	Line (Å)	Log T_{max} (K)	Thermal width (mÅ)
C II	1335.7	4.6	55
O II	834.5	4.8	37
Si III	1206.5	4.8	41
C III	977.0	4.9	51
Si IV	1393.8	4.9	53
C IV	1548.2	5.0	101
O III	835.3	5.0	47
N IV	765.1	5.2	58
O IV	554.5, 790.2	5.2	39, 56
N V	1238.3	5.3	105
O V	629.7	5.4	56
O VI	1031.9	5.5	104
Ne VII	465.2	5.7	53
Ne VIII	770.4	5.8	98
Fe IX	171.1	5.8	13

Table 2. List of the strongest coronal lines in the UV/EUV.

Ion	Line (Å)	Log T_{max} (K)	Thermal width (mÅ)
Mg IX	368.1	6.0	54
Mg X	624.9	6.0	91
Fe X	174.5	6.0	17
Fe XI	180.4	6.1	19
Fe XII	195.1	6.1	21
Si XI	303.3	6.2	51
Fe XIII	202.0	6.2	24
Si XII	499.4	6.3	95
Fe XIV	211.3	6.3	28
Fe XV	284.2	6.3	38
Fe XVI	360.8	6.4	55

Wavelength pixels and detector size

The size of detector available to an instrument constrains the spectral resolution and wavelength range possible. Current plans are to have a 2048 pixel detector for EUS.

A simple way of working out a wavelength range is to assume a 2048 pixel detector and to set a minimum required pixel size. Now the minimum width of an emission line comes from the thermal width, and the thermal widths of the Class A lines are given in Table 1 and Table 2. Investigations of line broadening with SUMER (e.g., Chae et al. 1998) shows that in the quiet Sun additional line broadening is found for all transition region lines, leading to actual line widths of around 0.15-0.20 Å. The smallest line widths measured by SUMER are around 0.10 Å, for neutral species.

Having wavelength pixels much smaller than the FWHM of emission lines (say 10 pixels across the FWHM) potentially allows one to look for subtle structures in the profile shape (e.g., absorption in the wings of a line). A drawback is that a wavelength window on the detector required to see the whole line requires around 40-50 pixels, and much more if explosive events are to be studied (up to 200 pixels). For a telemetry constrained mission such as Orbiter this would lead to considerable restrictions on spatial coverage, time cadence or the number of lines being studied.

An issue that applies to wavelength ranges below 400 Å is the width of the multilayer bandpass that is typically around 10-20% of the central wavelength. Thus there is no benefit in having a wide wavelength band as the sensitivity outside the central portion would be very small.

Band 1: 170-210 Å

This band will be observed by the EUV Imaging Spectrograph (EIS) on Solar-B. It contains the strongest resonance lines of Fe IX-XIV (all Class A lines), that provide excellent probes of the quiet corona in the temperature region 5.8 ≤ log T ≤ 6.3. In addition, the ions Fe X-XIII have their best density diagnostics in this band. It is essential to use a multilayer coating at these short wavelengths, and for EIS, the multilayer coating is sharply-peaked leading to high sensitivity at 195 Å, but low sensitivity outside of the band ≈180-205 Å. Thus the Fe IX λ171.1 and Fe XIV λ211.1 lines will not be usable, nor will the Fe X λ175.3/ λ174.5 density diagnostic.

The multilayer coating for the Orbiter spectrometer could be modified so that it is sensitive to a broader range of wavelengths at the expense of reducing sensitivity at the central wavelength

If the multilayer peak is shifted towards shorter wavelengths then the cooler Fe IX λ171.1, Fe X λλ174.5, 177.2 and Fe XI λ180.4 lines can be studied in much greater detail than will be possible with EIS. This would be particularly suitable for quiet Sun and coronal hole observations. The Fe X λ175.3/λ174.5 and Fe XI λ182.2/λ180.4 are the best density diagnostics available from these ions and are suitable for active region and quiet Sun conditions.

Summary: Band 1 contains the best set of coronal emission lines, however it is essential to use a multilayer coating at these wavelengths which leads to trade-offs between bandwidth and sensitivity. In addition EIS on Solar-B will cover this region, and so the potential for important new results may be limited, unless the multilayer is shifted to focus on the cooler Fe IX-XI lines.

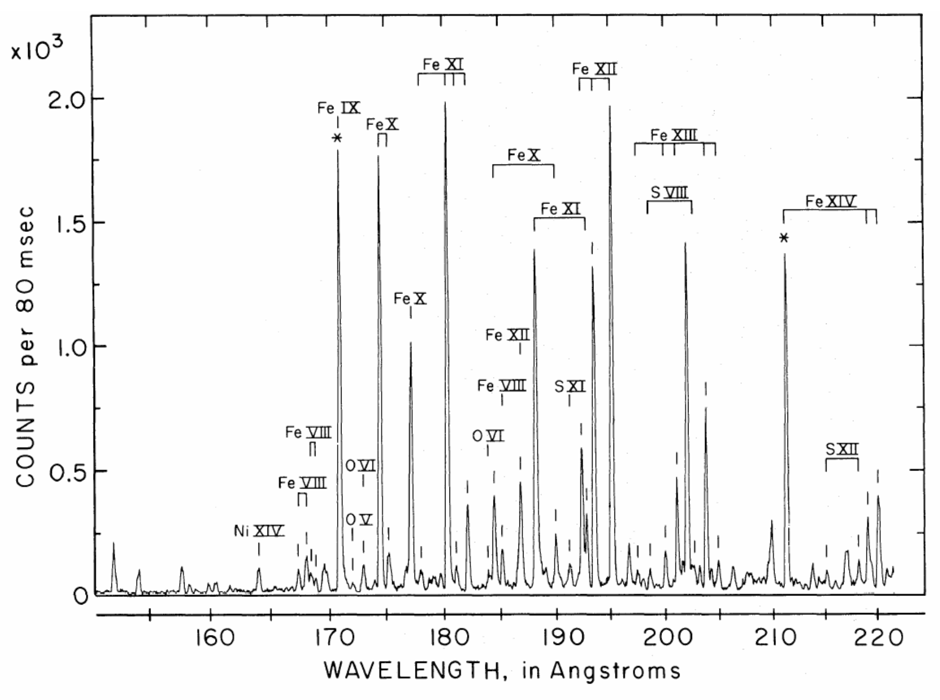

Figure 1. Malinovsky & Heroux (1973) spectrum showing the 170-210 Å region.

Band 2: 220-260 Å

Devoid of the strong coronal transitions of Band 1 (there are no Class A lines in Band 2), this region does have some useful density diagnostics, and a number of coronal sulphur lines that may be useful for understanding the FIP effect in the corona. The strongest line will be He II λ256 (Lyβ of H-like He). Multilayer restrictions mean that the usable wavelength region will be ≈20-25 Å. The 220-250 Å region is relatively unexplored as it has not been observed by the SERTS instrument or CDS, and will not be observed by EIS. It is particularly suited to high spectral resolution as there is a forest of weak-to-medium lines in this region that have not been completely resolved and identified previously.

Several sulphur ions have strong transitions in Band 2: S IX λ224.7, S X λ228.6, S XI λ246.9, λ247.5, S XII λ218.2, λ227.5, S XIII λ256.7. Sulphur is the most useful high FIP element in the corona and could be used for studying the FIP effect in, for example coronal loops.

The Fe IX 244.9/241.7 is an excellent density diagnostic involving two medium strength lines with sensitivity over the range 10^9 cm^{-3} to 10^{12} cm^{-3}. Previous problems with atomic data for Fe IX appear to have been solved now (Storey & Zeippen 2001). The temperature of formation of Fe IX means that the density diagnostic is useful in a wide range of conditions, including polar plumes and coronal loops.

The Si IX λ258.1/λ227.0 is an excellent density diagnostic in active conditions ($9.5 \leq \log N_e \leq 11.5$, however it will be difficult to measure both lines accurately with a multilayer. Preferable is the Si IX λ227.4/λ227.0 ratio, which has the same density sensitivity but the 227.4 lines is around half the strength of the 258.1 line.

Summary: The 220-250 Å region is relatively unexplored and new science can be expected. There are several coronal sulphur lines that would allow the FIP effect to be studied in detail, while there exist several useful density diagnostics. However, the lack of strong lines is a major handicap for this band.

Band 3: 308-381

This is the NIS1 band of CDS. A multilayer coating is necessary to improve the sensitivity in this band, and it will be difficult to achieve high sensitivity over the entire band. A more realistic band is 330-370Å which picks up the strongest transitions (Mg IX λ368, Fe XVI λλ335,360), and the Si IX, Si X, Fe XII, Fe XIII and Fe XIV density diagnostics that have been used with CDS. A multilayer peaking at 350 Å would be very useful in enhancing the reflectivity in the diagnostic lines between 345 and 355 Å. However, the important Mg IX 368 line would be suppressed by the (likely) low reflectivity near the edge of the multilayer bandpass.

Summary: there is a good selection of coronal lines in this band, offering good temperature discrimination, while there are also weak transition region lines (Mg V-VII, Ne IV, V). There are several density diagnostics, although none as good as the Fe XII and Fe XIII diagnostics in Band 1. A multilayer peaking at 350 Å would likely result in low sensitivity for the strong Mg IX λ368 transition resulting in no strong coronal lines in the entire band for quiet Sun conditions. Band 1 is to be preferred.

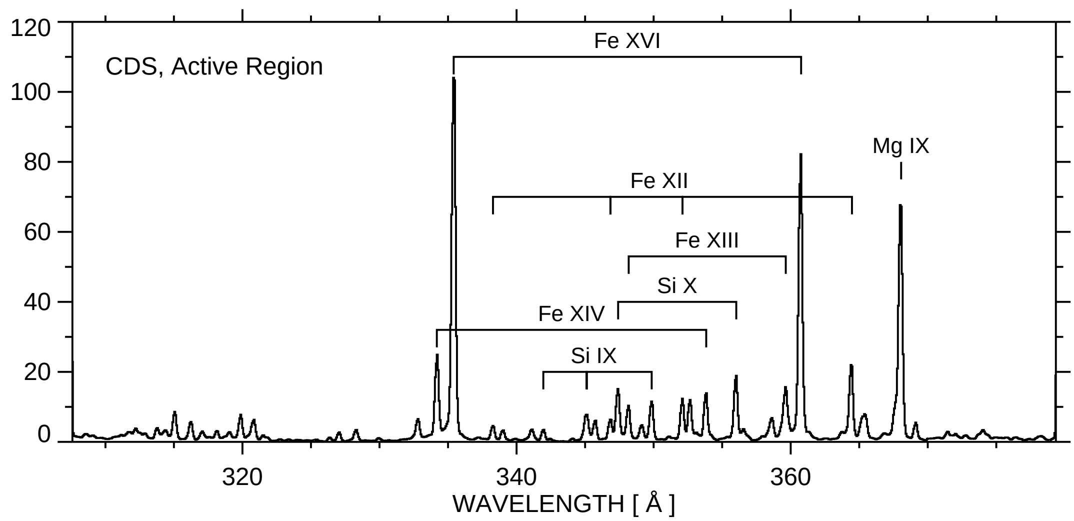

Figure 2. Active region spectrum from NIS/CDS.

Band 4: 460-500 Å

Two Class A lines fall in this band: Ne VII λ465 and Si XII λ499.4. The Ne VII line is formed at log T = 5.7, a temperature not well covered with CDS and SUMER. Obtaining high resolution spectra in this line with EUS will provide important information about the change in morphology from the transition region to the corona. A nearby Ca IX line at 466.2 Å is formed at the same temperature as Ne VII, and the pair of lines will be important for abundance studies.

The Si XII λ499.4 line is the stronger of the Li-like doublet for this ion (the other line occurs at 520.7 Å – see Band 5) and is the hottest of the coronal lines above 400 Å (Table 2). Outside of these two strong lines, there are few useful lines.

Summary: The Ne VII λ465 line is an attractive target, but there are very few other useful lines in this band. Si XII λ499 is an excellent coronal line, but the other member of the doublet could be observed in Band 5.

Band 5: 515-635 Å

This is the NIS2 band of CDS that contains 3 Class A lines – O IV λ554.5, O V λ629.7 and Mg X λ624.9 – as well as Si XII λ520.7 (the weaker, by factor 2, of the Si XII doublet – see Band 4), and the strong He I λ584 line. There are many useful weaker lines, including the coronal species, Al XI and Si XI, and transition region lines, O III, Ca X and the four neon ions Ne IV-VII. In addition, during flares the Fe XIX λ592.2 becomes strong and has been seen many times in CDS observations of active regions.

Curdt & Landi (2001) recommended the restricted wavelength range 580-630 Å, which retains most of the strongest lines in Band 5. If a 2048 pixel detector is assumed, the pixel sizes in this case would be 0.024 Å, compared to 0.059 Å if the 515-635 Å range is covered.

It is to be noted that although there are a large number of transition region lines in this band, the only significant chromospheric line is He I λ584 which is optically thick and not suitable as a fiducial for providing a wavelength calibration. If velocity shifts are to be searched for, it would be necessary to use the coronal lines (Mg X, Si XII) as reference points and assume they have zero velocity.

The NIS2 band of CDS was sensitive to 2nd order lines, with He II λ304 being very prominent. Also seen were the Class A lines Si XI λ303.3 and Fe XV λ284.2. The latter line, however, is blended with Al XI λ568.1 and Ne V λ568.4. With higher spectral resolution it may be possible to deconvolve these components

Summary: This is an excellent band combining coronal and transition region temperatures. There are no strong density diagnostics, however.

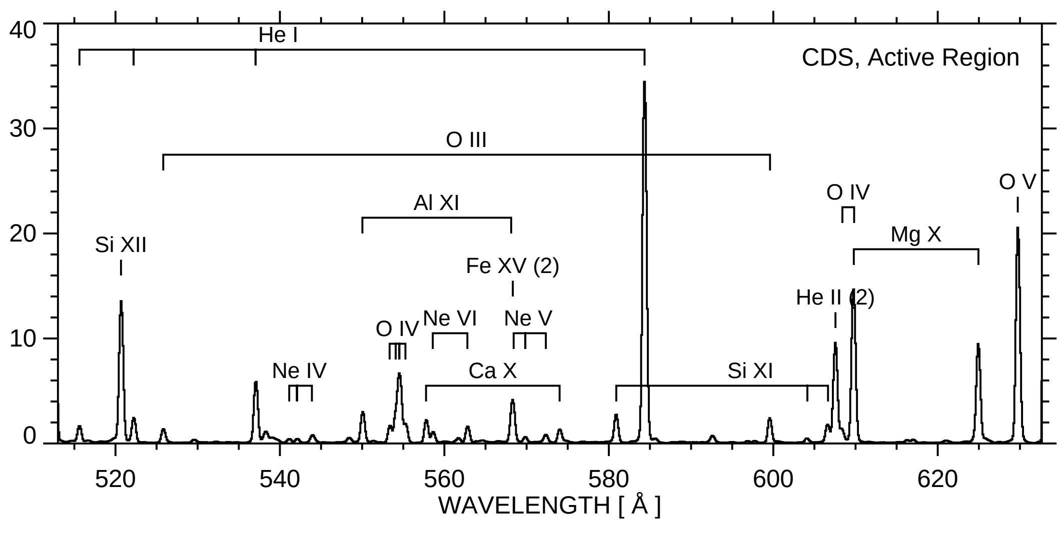

Figure 3. Active region spectrum from NIS/CDS.

Band 6: 700-800 Å

This complete band contains 3 Class A lines: N IV λ765, Ne VIII λ770, O IV λ790. Assuming a 2048 pixel detector the band could be obtained with ≈0.049 Å pixels.

In addition to the strong lines, there are other medium strength lines from O V and S V. The Mg IX λ706 and λ749 lines form a temperature diagnostic that has been used to determine coronal temperatures in off-limb coronal hole regions with SUMER (Wilhelm et al. 1998), however the ratio was not useful for observations on the solar disk.

The O V ^3P-^3P multiplet between 758 and 762 Å can be used to determine the electron density (Doschek et al. 1998), however, the sensitive line is weak and the ratio may only be useful in active conditions.

An issue that may affect interpretation of emission lines from Band 6 is the presence of the Lyman continuum of hydrogen. If there is cool material mixed in with hotter transition region plasma (as suggested by TRACE movies), then the emission lines in Band 6 will be partially absorbed by hydrogen.

Summary: there is an excellent set of lines in this band with good potential for combining lines with other bands (particularly the oxygen ions). Absorption by neutral hydrogen in disk observations may be a problem, however.

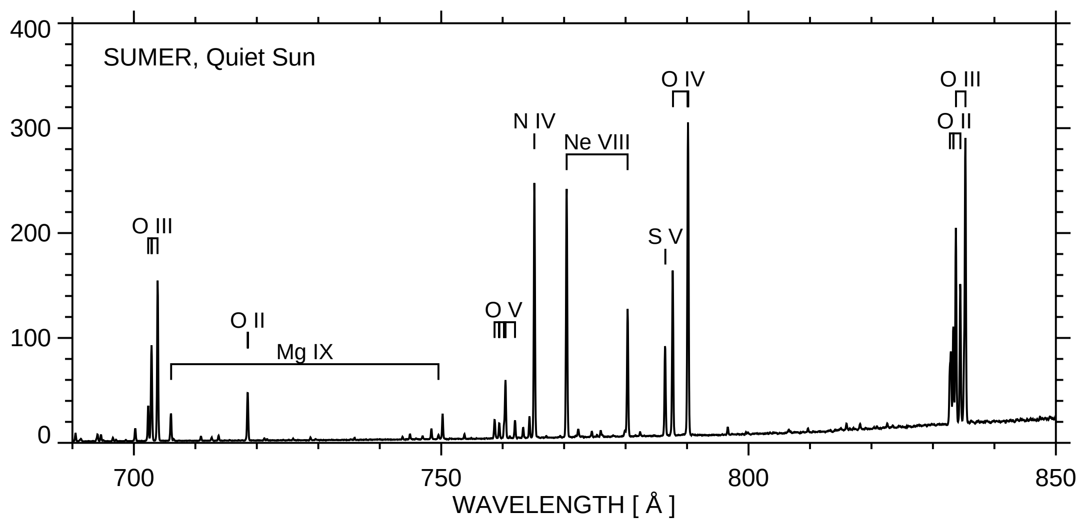

Figure 4. SUMER quiet Sun spectrum between 690 and 850 Å (Band 6).

Band 7a: 970-1040 Å

This band contains the Class A lines C III λ977 and O VI λ1032, as well as the H I Ly-β and Ly-γ lines (972, 1025 Å). A number of chromospheric lines are available, including C II λλ1036.3,1037.0 and O I 1027.4 that can be used both for science and as wavelength fiducials for fixing the wavelengths of the transition region lines. The flare line Fe XVIII λ974.9 will also be seen.

The wavelength region can be extended downwards to pick up other useful lines. Going down to 910 Å gives the complete Lyman series of hydrogen (excepting Ly-α), with pixel sizes 0.064 Å.

Figure 5 shows the SUMER spectrum of the 910-1050 Å region. It is to be noted that the strong lines here (C III λ977, O VI λλ1032, 1038 and H I Lyβ) are much stronger than those in Band 6 (Figure 4). The lower plot of Figure 5 shows the spectrum to the same Y-scale as Figure 4 revealing a large number of other significant lines: N III λλ989, 991, He II λ992, C II λλ1036, 1037, S VI λλ933, 944.

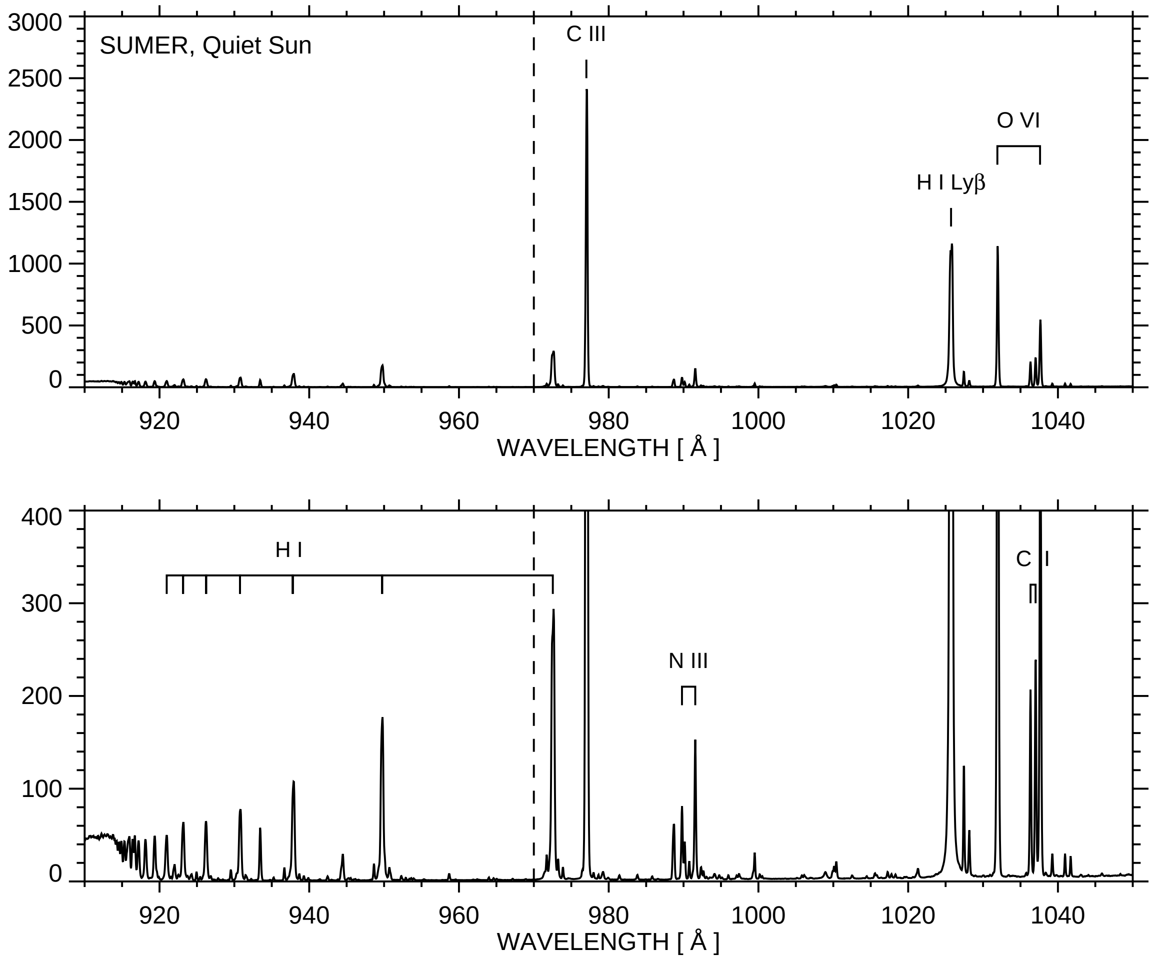

Figure 5. SUMER spectrum of the 910-1050 Å region. Both plots show the same spectrum but with different Y-scales, allowing the weaker lines to be seen more clearly. A dashed line is placed at 970 Å indicating where the boundary of the reduced range 970-1040 Å occurs.

Although the very interesting Ne VII λ465 line is potentially measurable in this band in second order, its wavelength of 930.44 Å places it very close to H I Lyζ at 930.75 Å, and even closer to the weaker O I 930.26 and He II 930.32 lines. It may be possible to suppress 1st order lines in this particular wavelength region (see discussion on Band 7b) which would allow the Ne VII line to be studied.

Summary: This wavelength band contains strong lines of C III, O VI and H I, yielding good temperature coverage. The presence of a number of neutral species in the band will allow the wavelength scale to be determined, vital for interpreting velocity shifts in the C III and O VI lines.

Band 7b: 1163-1265 Å

For maximum usefulness, this band requires good sensitivity to 2^{nd} order lines. The first order lines include the Class A lines Si III 1206.5, N V λ1238, H I Ly-α (the strongest emission line from the Sun), and the C III λ1176 multiplet. The 2^{nd} order lines are those of the important 580-630 Å region: He I 584, Fe XIX 592, Mg X 624.9 and O V 629.7.

If both band 7a and 7b are selected then they will give access to the C III λλ1176/λ977 density diagnostic – the best diagnostic available for the quiet Sun transition region. Important new science could be expected from observing this ratio.

Given the importance of the 580-630 Å lines, it is vital that they be free of contamination from 1^{st} order lines. Information on how the relative $1^{st}/2^{nd}$ order sensitivities can be adjusted in different wavelength regions is provided in a document distributed by the Lindau group.

The Ly-α line is considerably stronger than any other line in the solar UV spectrum. In order for it to be successfully measured on the detector together with the other lines in this wavelength band, the detector sensitivity around 1216 Å must be suppressed by a factor of around 100. This provides an additional technology constraint for this band.

Summary. This band contains an excellent selection of 1^{st} and 2^{nd} order lines. Care must be taken to ensure that important lines are not adversely affected by blending from the different spectral orders. The high intensity of the H I Ly-α line will require the detector sensitivity to be suppressed at this wavelength

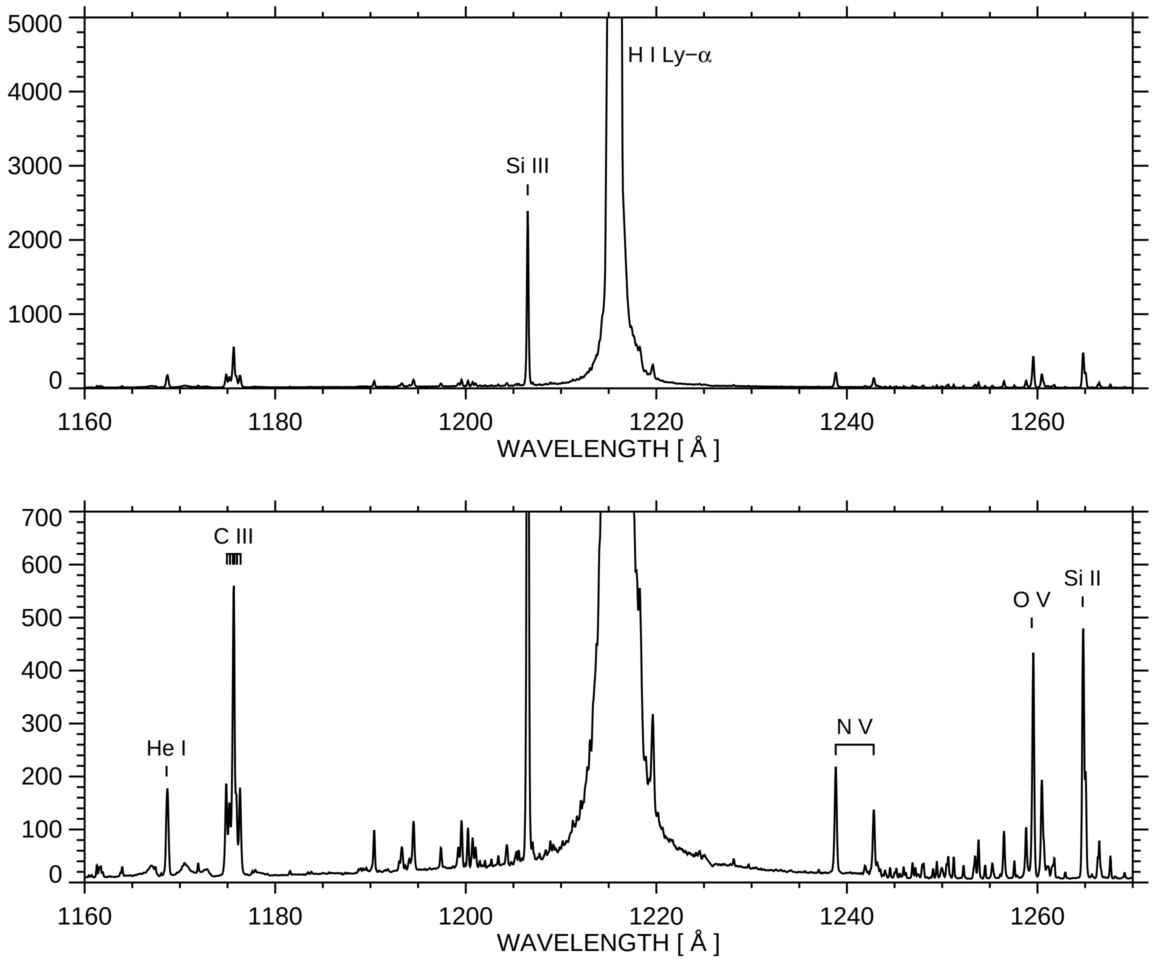

Figure 6. SUMER spectrum of the region 1160-1270 Å. The lower panel shows the spectrum, but with a different intensity scale, allowing weaker lines to be seen.

Band 8: 1330-1450

Feldman et al. (1998) have recommended this band as it contains a wide variety of species, although many of the hotter lines are seen in 2nd order. There are two Class A lines: C II λ1335 and Si IV λ1393. The coronal lines are all rather weak – the strongest line in Table 1 of Feldman et al. (1998) is Mg IX λ706.1 that is only a weak line in Figure 4. If a 2048 pixel detector is assumed the entire band could be obtained with ≈0.059 Å pixels.

The two Si VIII lines at 1440 and 1445 Å form an excellent off-limb density diagnostic (Banerjee et al. 1998), however they are not usable in on the solar disk.

Intercombination lines of O IV provide density diagnostic potential, with the λ1399/λ1401 ratio being sensitive to densities in the range 10^{10}-10^{12} cm^{-3} (Teriaca et al. 2001). The lines are, however, weak compared to resonance lines of O IV.

Summary: only two strong lines are present in this band. In addition, to observe this band simultaneously with a band containing strong coronal lines (below 600 Å) may cause problems for the instrument design.

Band 9: 1480-1600 Å

This band features an important group of lines from Band 6 that will be seen in 2nd order, notably the Class A lines N IV λ765, Ne VIII λλ770, 780 and O IV λ790. A crucial feature is that by seeing them in 2nd order, 1st order chromospheric lines, unavailable in Band 6, can be used for wavelength calibration (e.g., Dammasch et al. 1999). The main first order line is the Class A transition C IV λ1548.

Summary: This band has strong transition region coverage, and by picking up some of the Band 6 lines in 2nd order has the advantage of allowing wavelength calibration through chromospheric lines. There are no strong coronal lines in this band, however, and it may be difficult to have an optical design that is able to cover this long wavelength band with a shorter wavelength band necessary for satisfactory coronal coverage.

Recommended bands (Personal view)

It is argued here that the principle driver for selecting wavelength bands for EUS is the number of strong lines available and their usefulness for temperature discrimination. Since the EUV Spectrometer on Solar-B will have weak transition region and chromosphere coverage, it should be a high priority for EUS to observe strong transition region and chromospheric lines in order to provide more opportunities for new science to be achieved. Observations with CDS and SUMER have demonstrated the huge potential for new science in the lower layers of the solar atmosphere, but limitations of both instruments have prevented the emission lines from being fully exploited. In addition the very high spatial resolution that will be possible with Solar Orbiter is particularly suited to the small-scale structures seen in the chromosphere and transition region.

Of the wavelength bands described in this document, three of them (Bands 1-3) can only be observed with multilayer coatings on the optical surfaces, which provide restrictions on the wavelength ranges that can be observed. Bands 1-3 also have poor coverage of the transition region. Band 1 is the best of the three for coronal coverage but is already going to be observed with the Solar-B/EIS instrument. For these reasons I do not place a high priority on these bands.

Bands 4 and 5 contain both strong coronal and strong transition region lines. Beyond the Ne VII and Si XII lines, Band 4 contains very few useful transitions, and the other (admittedly weaker) of the Si XII Li-like doublet is found in Band 5. The combination of strong coronal and transition region lines, makes Band 5 very attractive and the only question would be whether to observe in 1st or 2nd order (Band 7b for the latter).

Bands 8 and 9 are both at long wavelengths and it may be difficult to observe both bands and Band 5 simultaneously with a single grating. Both bands require high 2nd order sensitivity and the presence of 1st and 2nd order lines together in the spectrum may lead to confusion in disk observations.

Band 6 has a number of strong transitions giving excellent coverage of the transition region. Other, weaker lines also provide good diagnostics. The effects of the hydrogen Lyman continuum in absorbing the emission lines must be considered, however.

Band 7a is the shortest wavelength band to contain neutral species that could be used for wavelength calibration. It contains the important transition region lines C III λ977 and O VI λ1032 and H I Ly-β. Band 7b picks up the 580-630 Å region in 2nd order, and adds important 1st order lines, in particular H I Ly-α, N V λ1238 and C III λ1176 as well as numerous cool lines that can be used for wavelength calibration.

The opinion of the author is that, if technical studies allow 3 wavelength bands to be observed, then these should be Bands 5, 6 and 7a. Swapping Band 5 for Band 7b is an option that has to be assessed both technically and scientifically, as there are advantages and disadvantages in both cases.

If only 2 wavelength bands are possible, then it is recommended to go for Band 5 and Band 7a.

Wavelength calibration

The majority of observations that will be performed with EUS will be of the handful of strong lines that the spectrometer sees. As with CDS and SUMER we can expect much of the scientific analysis to focus on line profile changes and velocity shifts in the response to dynamic events on the Sun. A major issue for interpreting such observations is the absolute wavelength calibration. Neither CDS nor SUMER had an onboard calibration lamp. For SUMER, calibration was performed using emission lines of neutral elements formed in the chromosphere. These were observed to show only very small velocity shifts during long time series and so they were often set to be at rest velocity and so fixed the wavelength scale for interpreting transition region lines (which show much larger velocity shifts). For CDS, the wavelength scale is set by either assuming the average velocity shift over a raster is zero, or by assuming that a coronal line has no net velocity shift and so this is used as a reference. None of these methods is satisfactory, and particularly those employed for CDS. The SUMER method requires lines of neutrals to be observed and these are not found below 912 Å (He I lines are found at shorter wavelengths but they are optically thick and their formation mechanism is not understood).

A key issue to be determined for EUS is thus the importance of a wavelength calibration lamp. Should, for example, a wavelength band be sacrificed in order to add a lamp?

1 or 2 bands

Restrictions on the mass and power of the spectrometer may lead to only 1 or 2 wavelength bands being observed. We consider Band 5 to be the highest priority, and should be chosen if only 1 band is available. If 2 bands are allowed, then Bands 5 and 7 are preferred (Band 6 has the risk that the Lyman continuum may hamper analysis).

Unique features of recommended bands

This document has recommended Bands 5, 6 and 7. Some benefits of obtaining these three bands simultaneously are listed below.

- Detailed, simultaneous coverage of the transition region in strong resonance lines from logT=4.5 to logT=5.8.
- Complete, simultaneous coverage of oxygen from O I to O VI, with the strongest resonance lines available for O II to O VI.
- Complete, simultaneous coverage of nitrogen from N II to N IV, with the strongest resonance transitions available for each ion.
- Transition region density diagnostics sensitive to densities between 10^9 and 10^{12} through C III 1176/977 and O V 761.1/760.4. Possibly also O V 760/629 although this requires accurate inter-band calibration.

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