3. THE GRAZING INCIDENCE SPECTROMETER

"SOHO involves launching a spacecraft which will take up position 1.5 million km from the Sun...
RAL Bulletin, November 1994

3.1 Wavelength Coverage

The GIS detector is the MSSL spiral anode channel multiplier array plate (CMA), or SPAN detector, and four of these are placed along the Rowland circle. The active area of each plate is approximately 50mm x 16mm and we have effectively 2048 resolution elements of size 25μm x 16mm. For more technical information on the detector, see Breeveld et al. (1992) and Harrison et al. (1995).

The location of a particular wavelength, λ, on the Rowland circle is given by the equation

$$n\lambda = d(\sin\theta + \sin\alpha),$$

where n is the order, d is the grating spacing, θ is the angle of incidence on the grating and α is the angle of reflection off the grating. We have a Rowland circle of radius, R, 750mm and an angle of incidence of 84.75º. Differentiating, we obtain an expression for the resolving power, namely,

$$\lambda/\Delta\lambda = 2\lambda R/(dx\cos\alpha),$$

where x is the scale of the resolution element.

Using these equations we can determine the relationship between the resolving power, the distance round the Rowland circle and wavelength for any given grating. For a 1000 l/mm grating we find that the desired wavelength region, of 150 - 800Å occupies ~320 mm around the Rowland circle.

The GIS 1000 l/mm grating gives sufficient spectral resolution and, allowing for the minimum spacing between each SPAN detector (~20mm) and maximising the coverage of the emission lines of prime interest, the wavelength ranges are as given in Table 3.1.

The four detectors are not curved to fit the Rowland Circle and thus are set at an angle appropriate to the middle wavelength, given as α' in Table 3.1.

Given these four bands we cover over 70% of the 150-785Å wavelength range in first and second order with the GIS. Including the NIS wavelength selection, discussed later, over 90% of this range is covered.

Table 3.1: The GIS Wavelength Bands

Band	1st Order (Å)	2nd Order (Å)	α'	Dispersion (Å/mm)
GI1	151-221	76-111*	77.6º	1.36
GI2	256-338	128-169	74.9º	1.60
GI3	393-493	197-247	72.0º	1.96
GI4	656-785	328-393	67.4º	2.52

(* The reflectivity at these wavelengths is too low for useful observation)

3.2 Resolving Power and Line Widths

The desired spectral resolving power is a function of line separation, flow velocities and line widths; we must be able to isolate lines whose intensity we require for the provision of diagnostic information. The greatest constraints on the optical design of CDS with regard to line separation come in the 151-221Å band - this is the region of greatest line density, yet geometrical properties demand that it is also the band with the lowest resolving power! Most of the lines of prime interest can be separated with a resolving power of, $\lambda/\Delta\lambda \sim 500$ and above.

CDS has as its prime goal, the measure of line intensities, not line shapes and shifts. However, we do expect to provide information on modest to high speed flows, say of several tens of km/s upwards. This demands spectral resolving powers of order several thousand for as much of the wavelength coverage as possible.

Spectral lines can be fitted with Gaussian profiles with a *FWHM* defined as

$$FWHM^2 = 4 \ln(2)\, \Delta\lambda^2 + \Delta\lambda_i^2,$$

where $\Delta\lambda_i$ is the instrumental width. The natural width can be split into thermal and non-thermal components, in the form,

$$\Delta\lambda^2 = (\lambda/c)^2\, (2kT_i/M_i + \xi^2),$$

where the suffix *i* denotes ion.

The thermal widths are of order 0.1Å or less. If this was the only component to line broadening, to study line profiles and shifts we would be looking for resolutions of this order. However, the non-thermal component is often of the same order as the thermal width and, as shown below, the instrumental width will usualy dominate.

The actual resolving power is a function of the size of the slit-image on the detector plane, and that image is in itself a function of geometric and performance characteristics of CDS.

If the GIS detectors were placed perpendicular to the incoming beam, the size of the slit on the detector face ought to be the actual size of the slit. However, the detectors are placed as tangents to the Rowland circle, at angles α', defined above. Roughly, if the slit width is s µm, the measured slit width, s', is given by

$$s' = s/\cos\alpha'.$$

This is the geometrical spreading of the slit. In addition, there are effects due to the grating performance and the mismatch between the detector face and the Rowland circle location. In practice these provide an effect of similar order. For the purposes of the calculations here, we take this effect to be of order a further 20µm projected onto the detector - this is consistent with predicted values.

Thus, in Table 3.2, for the short, middle and long wavelength of each of the GIS detectors, we list the wavelength, the angle or reflection, the projected slit width, the projected defocus width, the final line width, the spectral resolving power ($\lambda/\Delta\lambda$ - calculated from the above equation and assuming that the scale of the resolution element is the line width), the spectral resolution and the dispersion.

Table 3.2: Effective Slit Sizes, Resolutions and Resolving Powers (using 2 arcsec slit - 25µ m).

λ (Å)	α (º)	Slit (µm)	Defocus (µm)	Width (µm)	Width (pixel)	λ/Δλ	Δλ (Å)	Disp. Å/mm
151	78.7	128	102	163	6.5	709	0.21	1.29
186	77.7	117	94	150	6.0	873	0.21	1.40
221	76.8	109	87	139	5.6	1044	0.21	1.51
256	76.0	103	83	132	5.3	1201	0.21	1.59
297	75.0	97	77	124	5.0	1392	0.21	1.69
338	74.2	92	73	117	4.7	1588	0.21	1.79
393	73.0	86	69	110	4.4	1837	0.21	1.91
443	72.1	81	65	104	4.2	2077	0.21	2.02
493	71.2	77	62	99	4.0	2314	0.21	2.12
656	68.5	68	54	87	3.5	3082	0.21	2.41
721	67.5	65	52	83	3.3	3401	0.21	2.53
785	66.5	63	50	80	3.2	3697	0.21	2.63

3.3 Count-Rates

Observations of the quiet Sun in the EUV range have been made on various occasions, with varying degrees of temporal, spatial and wavelength resolutions, varying durations, varying wavelength ranges and varying calibrations! Perhaps, the best observed EUV sequence is that of the 2s-2p transition in Li-like ions in the range 400 - 800Å. Reported absolute intensities for quiet Sun conditions vary by up to 40% from the mean. Thus, in estimating CDS count rates projected from past solar observations, one must accept that the estimates may be out by a some tens of per cent.

To perform our count-rate estimates we have chosen to use three published listings spread over wide wavelength ranges. An attempt to use all EUV observations in the literature would produce a ``patchwork'' of intensities due to the narrow wavelength bands of some instruments, the varying calibration successes and the problems in target definition. The intensities of the three are consistent with one another to within about 30% in the worst cases. For cases where more than one reference lists a particular line, we have taken the average.

Our principal line intensity list is that due to Vernazza and Reeves (1978) who give quiet Sun, coronal hole, active Sun and off-limb listings. These data only cover the wavelength region longward of 300Å and they are of relatively crude spectral resolution. Further intensities are taken from the rocket data presented by Malinovsky and Heroux (1973) in order to cover the 150 - 300Å region (though these data are derived from full-Sun observations when the Sun was partly active) and from Chapman and Neupert (1974) to cover the range 150 - 388Å, as a check on the quality of the various calibrations. In the majority of common lines, intensities are remarkably similar. However, note that in the following tables, some blank entries indicate a lack of data rather than a zero count-rate.

Even with a complete calibration analysis, we would be unable to predict accurate solar intensities for many lines since past EUV instrumentation has been either inappropriate for the estimation of intensities for CDS or instruments have recorded wildly differing values. Furthermore, since past instruments clearly did not have the resolutions available to CDS, the intensities are necessarily spatially averaged; the solar EUV emission may be highly mottled, producing regions of much higher intensities and lower intensities than those listed in Tables 3.3 - 3.6 (GIS) and 4.3 - 4.4 (NIS). So, in general, the figures given in these tables provide a useful guide, but should be treated with some care at this stage.

To estimate the count-rates we must consider the efficiencies of the telescope, scan mirror, grating and detector as well as the geometric areas available at the telescope and slit.

Let us denote the reflectance of the telescope, mirror and grating as ε_t , ε_m and ε_g and the efficiency of the detector as ε_d. Typically, one might expect an efficiency of about

0.5 for each reflection at the telescope, though this must be a function of wavelength and angle of incidence. However, given the accuracy of the past solar data which we will use, an estimate of $\varepsilon_t = 0.25$ is quite reasonable. For ε_m and ε_g we anticipate values of order 0.8 and 0.1. Finally, based on the CHASE experience, for the GIS grating we anticipate a value of ε_g of about 0.03 across the 150 - 800Å range. Thus, the product of the efficiencies, $\varepsilon_t \varepsilon_m \varepsilon_g \varepsilon_d$, was anticipated to be of order 0.0006. However, after the CDS pre-delivery calibration (see Chapter 8), this efficiency product was measured to be between 0.0001 and 0.0006, depending on wavelength, averaging at 0.0002 to 0.0003. The value of 0.0003 was used in the following estimates.

Past solar data are generally given in $erg.cm^{-2}.s^{-1}.ster^{-1}$ at the Sun. Given a measured intensity, I, in these units, to convert to $photons.cm^{-2}.s^{-1}.ster^{-1}$ we simply divide by (hc/λ), where h is Planck's constant, c is the velocity of light and λ is the wavelength of the line. The product hc is 1.99×10^{-16}erg.cm.

A portion of the Sun of size x cm by y cm is presented to the spectrometer at the slit. This can be expressed as $(ab\,R^2)/f^2$ cm^2 by similar triangles, where a and b are the dimensions of the slit (cm), f is the telescope effective focal length and R is the distance to the Sun. So, to convert to $photons.s^{-1}.ster^{-1}$ we write $(I\,\lambda\,/\,hc)(ab\,R^2\,/\,f^2)$.

The solid angle is the area available at the telescope, A, divided by R^2. Finally, we multiply by the efficiency product given above. Thus the count-rate is given by

$$(I\,\lambda\,/\,hc)(ab\,A\,/\,f^2)\,(\varepsilon_t\,\varepsilon_m \varepsilon_g\,\varepsilon_d) \quad \text{per second.}$$

Estimated count-rates are listed for the GIS in Tables 3.3 - 3.6 for a 2x2 arcsecond slit. They are plotted in Figure 3.1. For the plots, spectral lines are represented by Gaussian curves of width consistent with the estimates given above.

For the first GIS band, and part of the second, we have no active region data. The Malinovsky and Heroux, and Chapman and Neupert data used are for full Sun intensities, reduced to accommodate the 2 x 2 arcsec area, but with little active region contribution. We therefore list these intensities as quiet Sun.

Table 3.3: Estimated Count-Rates per line per 2x2 arcsec, for the 151-221Å band.

Ion	Wavelength(Å)	Quiet Sun Intensity
Ni XIII	157.73	0.7
Ni X	158.38	0.1

Ni X	159.94	0.1
Ni XIV	164.13	0.4
Ar X	165.49	0.0
Fe VIII	167.49	0.5
Fe VIII	167.66	0.0
Fe VIII	168.02	0.0
Fe VIII	168.17	0.7
Fe VIII	168.55	0.5
Fe VIII	168.93	0.3
Ni XIV	169.68	0.0
Fe X	170.58	0.0
Ar X	170.60	0.0
Fe IX	171.07	8.8
Ni XIV	171.36	0.0
O V	172.17	0.1
O VI	172.93	0.2
O VI	173.08	0.5
Fe X	174.53	8.6
Fe X	175.26	0.8
Fe X	175.47	0.2
Fe XI	176.50	0.0
Ni XV	176.69	0.0
Fe X	177.24	5.3
S X	177.59	0.0
Fe XI	178.06	0.3
Ni XV	179.27	0.0
Fe XI	179.76	0.3
Fe XI	180.40	9.8
Fe X	180.45	0.0
Fe XI	180.60	0.3
Fe XI	181.13	0.5
Fe XI	182.17	1.6
Fe X	182.31	0.2
O VI	183.94	0.2
O VI	184.11	0.2
Fe X	184.54	2.2
Fe XI	184.79	0.2
FeVIII/NiXVI	185.22	0.8
Fe VIII	186.60	0.5
Ca XIV	186.61	0.0
S XI	186.84	0.0
Fe XII	186.88	2.4
Fe VIII	187.23	0.0
Fe XI	188.22	8.2
S XI	188.67	0.3
Ar XI	188.80	0.0

Fe X	190.04	1.3
S XI	190.37	0.0
Fe XII	191.05	0.0
FeXIII/SXI	191.26	0.3
Fe XII	192.39	3.2
Fe XI	192.81	1.4
Fe XII	193.51	7.0
Ca XIV	193.87	0.0
Fe XII	195.12	10.2
Fe XIII	196.53	1.1
Fe XII	196.64	0.9
Fe XIII	197.43	0.4
SVIII/FeXII	198.56	0.4
Fe XIII	200.02	0.7
Fe XII/XIII	201.12	2.0
Fe XII	201.73	0.0
Fe XIII	202.04	0.9
S VIII	202.61	0.4
Fe XI ?	202.71	0.0
Fe XIII	203.79	3.7
Fe XIII	203.83	0.0
Fe XIII	204.26	0.0
Fe XIII	204.94	0.6
S X	208.32	0.0
Fe XIII	208.68	0.0
Fe XIII	209.62	0.0
Fe XIII	209.92	0.0
Fe XIV	211.32	8.2
Fe XII	211.74	0.0
S XII	212.12	0.2
Fe XIII	213.77	0.8
Fe XII ?	214.41	0.0
Si VIII	214.76	0.2
S XII	215.15	0.6
Si VIII	216.90	0.6
Fe IX	217.10	0.0
Fe XII	217.27	0.0
S XII	218.18	0.4
Fe IX	218.94	0.0
Fe XIV	219.12	2.0
Fe XII	219.44	0.0
Fe XIV	220.08	2.6

Table 3.4: Estimated Count-Rates per line per 2x2 arcsec, for the 256-338Å band.

Ion	Wavelength(Å)	Quiet Sun Intensity	Active Sun Intensity
Si X	261.06	1.5	
Fe XVI	262.98	1.3	
S X	264.23	1.1	
Fe XIV	264.79	4.2	
Fe XVI	265.00	0.0	
Fe XIV	270.52	2.4	
Si X	271.99	1.6	
Si VII	272.60	0.2	
Si VII	274.17	0.0	
Fe XIV	274.20	5.7	
Si VII	275.37	0.5	
Si VII	275.76	0.0	
Mg VII	276.15	0.2	
Si VII	276.77	0.2	
Si VIII	276.85	0.0	
Mg VII	277.04	0.7	
Si X	277.27	1.6	
Mg VII	278.40	0.5	
Si VII	278.44	0.0	
S XI	281.42	0.5	
S XI	281.83	0.0	
Fe XV	284.16	22.3	
S XI	285.60	0.2	
S XI	285.83	0.5	
S XII	288.41	1.0	
Fe XIV	289.16	0.2	
Si IX	290.71	0.5	
Fe XII	291.01	1.0	
S XI	291.63	0.2	
Ni XVIII	292.00	0.2	
Si IX	292.80	1.2	
Si IX	296.12	2.0	
S XII	299.50	0.2	
Si XI	303.33	4.3	37.7
He II	303.78	149.3	1258.9
Fe XI	308.54	0.0	0.0
Fe XIII	311.55	0.0	0.0
Mg VIII	311.77	1.1	3.8
Fe XIII	312.16	1.7	5.7
C IV	312.42	0.0	8.5
Mg VIII	313.73	2.8	8.5
Si VIII	314.35	0.3	1.2

Mg VIII	315.02	2.2	7.1
Si VIII	316.22	0.9	1.9
Mg VIII	317.01	2.4	7.3
Fe XIII	318.14	0.9	2.9
Mg VII	319.03	0.3	5.7
Si VIII	319.83	1.3	2.5
Fe XIII	320.80	3.5	11.5
Fe XV	321.78	2.3	7.9
Fe XV	327.02	2.4	8.0
Cr XIII	328.26	1.5	2.1
Al X	332.77	1.0	3.9
Fe XIV	334.17	7.7	31.5
Mg VIII	335.23	0.9	2.9
Fe XVI	335.40	2.8	122.2
Fe XII	338.26	1.2	4.2

Table 3.5: Estimated Count-Rates per line per 2x2 arcsec, for the 393-493Å band.

Ion	Wavelength(Å)	Quiet Sun Intensity	Active Sun Intensity
Mg VI	399.20	0.7	5.2
Ne VI	399.83	0.7	4.6
Mg VI	400.68	0.9	7.2
Ne VI	401.14	2.8	19.2
Ne VI	401.95	0.0	0.0
NeVI/MgVI	403.30	0.8	14.9
Al X	406.40	0.0	1.5
NaVIII	411.16	1.0	8.1
Cr XIV	412.06	0.5	4.0
Ne V	416.20	0.2	0.8
Fe XV	417.26	1.1	34.6
S XIV	417.60	3.9	32.4
C IV	419.50	0.5	1.9
Ca X	419.74	0.2	1.1
Mg VIII	430.46	1.3	6.4
Mg VII	431.33	0.5	10.6
Mg VII	434.93	1.0	4.6
Ne VI	435.70	0.0	0.0
Mg VIII	436.73	1.5	8.6
Mg IX	438.60	0.2	0.8
[illegible]	[illegible]	[illegible]	[illegible]

Ca XV	445.00	0.0	3.6
S XIV	445.70	0.2	3.0
Mg VII	450.73	0.0	0.0
P XIII	455.70	0.0	0.6
C III	459.50	0.5	1.8
Ar VI	462.00	0.0	0.7
Ne VII	465.22	4.4	36.1
Ca IX	466.23	0.0	2.7
Ne IV	469.80	0.3	1.2
Cr XIII	480.20	0.2	2.5
Fe XV	481.46	2.4	8.2
Ne V	482.10	0.2	0.9
Na VII	486.70	0.2	0.9
Ne III	489.50	0.2	1.2
Na VII	491.90	0.0	0.4

Table 3.6: Estimated Count-Rates per line per 2x2 arcsec, for the 656-785Å band.

Ion	Wavelength(Å)	Quiet Sun Intensity	Active Sun Intensity
Si X	663.70	0.0	0.0
Ca IV/OV	669.60	0.0	0.1
N II	671.50	0.0	0.0
Ar XIII ?	675.70	0.1	0.2
Na IX	681.70	0.3	2.5
N III	685.83	1.1	2.2
C II	687.20	0.3	0.5
Ca IX	693.80	0.3	1.6
Na IX	694.20	0.0	0.0
Al III	696.00	0.0	0.1
Ar VIII	700.20	0.1	0.5
O III	702.98	2.7	4.5
O III	703.87	0.0	0.0
Si IX	704.00	0.0	0.0
Mg IX	705.80	0.4	1.8
S VI	712.40	0.1	0.3
Ar VIII ?	712.95	0.1	0.2
O II	718.53	0.7	1.3

Ne I	735.90	0.4	2.6
Ne I	743.70	0.1	0.4
S IV	744.90	0.0	0.0
S IV	748.90	0.2	0.3
S IV	750.20	0.3	0.6
S IV	753.80	0.1	0.0
O V	758.60	0.4	2.1
O V	759.44	0.0	0.0
O V	760.40	0.9	4.4
O V	762.00	0.0	0.0
N III	764.00	0.0	0.0
N IV	765.14	2.4	5.7
Ne VIII	770.40	2.8	31.2
Al VIII	775.00	0.0	0.0
N II	775.90	0.1	0.3
Ne VIII	780.30	1.4	16.1
S XI	782.00	0.0	0.2
Mg VIII	783.00	0.2	0.7

The 25 brightest lines in the GIS range are listed in Table 3.7. However, given the list of emission lines of prime interest, we must be able to work with lines with intensities of between ~0.1 to ~1000 counts per second for the smallest slit.

Figure 3.1: Estimated quiet sun count rates per pixel per 2x2 arcsec area for the Four GIS Bands (see Table 3.3 - 3.6). Note that these are the lowest intensities expected, with the smallest available slit. Some lines may be truncated at the top to better show other, weaker lines. Solar continuum is not shown in these figures.

Table 3.7: The 25 Brightest Lines in the GIS Range

Ion	Wavelength (Å)	Quiet Sun Intensity
Fe IX	171.07	8.8
Fe X	174.53	8.6
Fe X	177.24	5.3
Fe XI	180.40	9.8
Fe XI	188.22	8.2
Fe XII	192.39	3.2
Fe XII	193.51	7.0
Fe XII	195.12	10.2
Fe XIII	203.79	3.7
Fe XIV	211.32	8.2
Fe XIV	220.08	2.6
Fe XIV	264.79	4.2
Fe XIV	274.20	5.7
Fe XV	284.16	22.3
Si XI	303.33	4.3
He II	303.78	149.3
Mg VIII	313.73	2.8
Fe XIII	320.80	3.5
Fe XIV	334.17	7.7
Fe XVI	335.40	2.8
Ne VI	401.14	2.8
S XIV	417.60	3.9
Ne VII	465.22	4.4
O III	702.98	2.7
Fe XVI (2)	721.52	3.9

The count-rate estimates given above are for a 2x2 arcsec area of the Sun. For the other slits which will commonly be used in the GIS operation, the 4x4 and 8x50 arcsec slits, we must multiply the count rates by a factor of 4 and 100. The approximate totals for each detector, with each slit, for active and quiet Sun conditions are given in Table 3.8.

Table 3.8: Approximate Total Count-Rates as a Function of Slit and Solar Quiet or Active Conditions

Detector	2"x2" slit Quiet	2"x2" slit Active	4"x4" slit Quiet	4"x4" slit Active	8"x50"slit Quiet	8"x50"slit Active
GI1*	100	1100	400	4400	10000	110000
GI2	260	1600	1040	6400	26000	160000
GI3	30	240	120	960	3000	24000
GI4	20	300	80	1200	2000	30000
TOTAL	410	3240	1640	12960	41000	324000

(* In the absence of good active region data in the shortest wavelength band, we have simply multiplied by a factor of 10, which is consistent with the other bands.)

It must be stressed that our estimates are necessarily based on past data which represent an average of conditions which will be seen by CDS, in terms of spatial, spectral and temporal resolution. The Sun may present a mottled appearance which will produce many pixels of "active" intensities even away from active centres - this may be a feature of the coronal heating mechanisms. The most recent data to cover a good portion of three CDS wavelength bands have been produced by the SERTS-3 rocket flight. Calibrated data from Roger Thomas have been inspected and compared to intensities used in this report (Harrison, CDS Science Note SC-CDS-RAL-SN-91-0001, 1991). The comparison emphasises the problems in comparing targets but the indications are that the numbers given in this report are reasonable. Clearly, ideal data-sets which cover the CDS range with appropriate spectral and spatial resolution are not available for comparison, or there would be no need for the CDS!!!

The numbers given above define the requirements on the GIS detectors, in terms of the greatest and smallest count-rates. Even quiet Sun conditions dictate that we must be able to extract 41000 ct/s, and such a limit is also suitable for active conditions with the two smaller slits. Although the detectors can cope with a maximum count rate of $1.75 \times 10^5 s^{-1}$, which is well above the limit, the maximum rate for data being sent to the CDS Command Data Handling System is $8.9 \times 10^4 s^{-1}$. This is acceptable, for all quiet situations and for active conditions with the smaller slits. As far as the 8x50 arcsec slit is concerned, any active Sun observations may have to be limited to three detectors. However, the active Sun count rates for the 8x50 arcsec slit must be considered to be unrealistic - active conditions would rarely cover such a large area. Of course, we will have a better feel for this when we have a better understanding of the CDS sensitivity, during the flight.

The maximum count-rate per pixel is of order $100 s^{-1}$, for the He II 304Å line in active Sun conditions. Limitations arise because of limiting count-rates within the pore structure of the microchannel plate. Assuming pores of 12.5µm diameter, arranged in a square geometry with 15µm spacing between the centres of the pores, the peak of the 304Å line will fall in a line of ~1000 pores (across the 16mm of the detector face), thus requiring of order 0.1 count/s per pore. This is within the capability of the GIS detectors.

Off-limb count rates can be estimated from the OSO-7 observations (Kastner et al. 1974). Table 3.9 indicates expected intensities at various altitudes for a selection of lines. However, there are two points to be noted. First, the corona is highly inhomogeneous - intensities will vary considerably. Second, the CDS telescope does generate large angle scatter. Very approximately, for a point souce located at a specific site, at distances of 20, 50, 100 and 150 arcseconds from the site, we expect to observe $10^{-4.3}$, $10^{-5.4}$, $10^{-6.2}$ and $10^{-6.6}$ of the intensity of that source per arcsec^2 (see Chapter 8). Our ability to detect useful emission above the limb will depend on the particular line of interest and the state of the Sun.

Table 3.9: Anticipated Off-Limb Intensities (count/s per 2x2 arcsec).

Line (Å)	disc intensity	0.1R intensity	0.2R intensity	0.3R intensity
Fe XV 284.16	22.3	19.8	14.2	8.6
Fe XIV 211.3	8.2	6.7	3.6	1.8
Fe XI 188.22	8.2	1.4	0.2	-
Fe XIII 320.8	3.5	1.5	0.5	-