

Solar flare soft X-ray spectra from Diogeness observations

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Abstract. Diogeness was an uncollimated scanning flat crystal spectrometer observing solar flare X-ray spectra in four narrow wavelength bands in the vicinity of Ca XIX, S XV and Si XIII He-like line ‘triplets’ around 3.18 Å, 5.04 Å and 6.65 Å. In two of the spectral channels, emission lines around the Ca XIX 3.178 Å resonance line were scanned in opposite directions, being diffracted from precisely adjusted identical Quartz crystals mounted on a common shaft in a so-called Dopplerometer (tachometer) configuration. Observations of solar X-ray spectra made by Diogeness provide a direct diagnostic information on plasma characteristics during the impulsive flare energy release. We present a sample of events which occurred during the Diogeness operation time from August 16, 2001 to September 17, 2001.

Keywords. techniques: spectroscopic – Sun: corona, Sun: flares – Sun: X-rays, gamma rays

1. Introduction

In order to obtain a full understanding of the energetics and physical characteristics of solar active regions and the mechanism of flare energy release, reliable measurements of emitted spectra are necessary. For many years crystal spectrometers have been used to obtain soft X-ray spectra of solar emitting regions. The resulting spectra have helped our understanding of the energies and plasma characteristics of the emitting plasma. Additionally, instruments with an accurate absolute intensity calibration have enabled coronal element abundances to be determined. Unfortunately, spectra from crystal spectrometers may sometimes be subject to a confusion of Doppler and spatial shifts, especially during the initial phases of flares, without any means of disentangling the two. This difficulty can be overcome by simultaneous observations using pairs of crystals oriented in such way that the spatial and Doppler displacement shifts are in opposite directions - the ‘Dopplerometer’ mode; a full description is given by (Sylwester *et al.*, 2015).

2. The Diogeness instrument

Details of the Diogeness instrument construction have been given by Płoceniak *et al.* (2002) and Siarkowski *et al.* (2002). Diogeness had four channels covering wavelength ranges around intense resonance lines of He-like ions of silicon, sulphur, and calcium

Table 1. Diogeness instrument channels.

Channel	1	2	3	4
Crystal	Quartz	ADP	Beryl	Quartz
Wavelength range (Å)	3.1436 – 3.3915	4.9807 – 5.3721	6.1126 – 6.7335	2.9601 – 3.2123
Observed principal lines	Ca XIX	S XV	Si XIII	Ca XIX

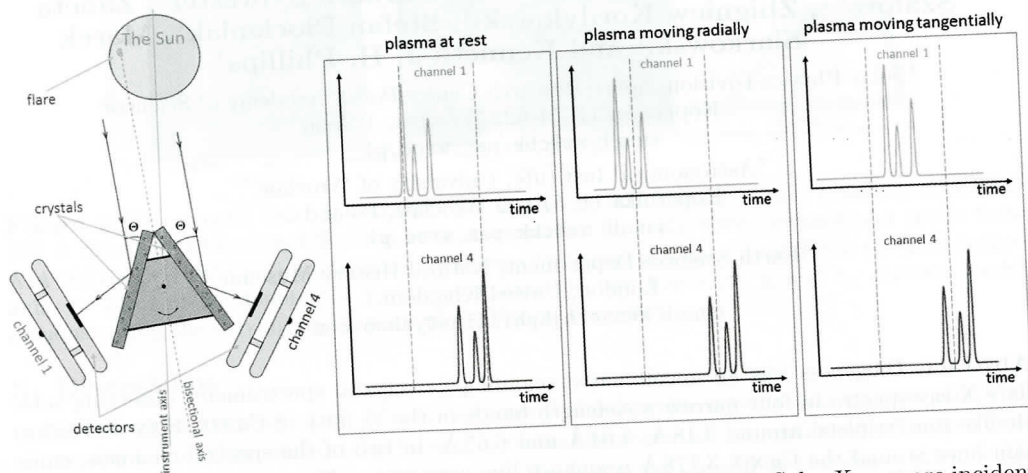


Figure 1. The principle of the Diogeness dopplerometer concept. *Left:* Solar X-rays are incident on two identical quartz crystals oriented as shown. The diffracted photons are detected by proportional counters (labelled 1 and 4). *Right panels:* The resulting spectra. In the left panel the flare plasma is assumed to be at rest and the lines are coincident (for detector 1 wavelength increases to the right, for detector 4 in opposite direction). In the center panel flare plasma is assumed to be in radial motion with respect to the instrument and the lines are shifted in opposite directions. In the right: any tangential motions along crystal dispersion direction are observed as a shifts in identical directions.

emitted during solar flares. Two quartz crystals covered the Ca XIX lines (channels 1 and 4), and ADP and beryl crystals (channels 2 and 3) covered the S XV and Si XIII lines respectively (Table 1).

Flat mono-crystals were mounted on a common rotatable shaft, so back-and-forth scanning motions of the shaft allowed spectra to be viewed. Silicon and sulphur lines (channels 2 and 3) were scanned repeatedly during the development of flares in the direction of alternately increasing and decreasing wavelengths. Figure 1 shows the arrangement for channels 1 and 4 with an identical pair of quartz crystals (cut from the same mono-crystal) oriented in the dopplerometer configuration.

3. Diogeness observations

The Diogeness instrument had a lifetime of only a few weeks, but during that time spectra from nine substantial flares with GOES classes ranging from C to X were recorded. Table 2 gives details of these flares including times, standard IAU flare notation, GOES and H α importance, and heliographic locations. More than 200 spectra were obtained in the four channels for these events. Example spectra for the M1.5-class flare on August 30, 2001 are shown in Figure 2.

Table 2. Solar flares observed by Diogenesis.

Flare	GOES	H α	Location
SOL2001-08-25T09:28	M1.2	-	S18E31
SOL2001-08-25T16:45	X5.3	3B	S17E34
SOL2001-08-30T17:57	M1.5	2N	S21W28
SOL2001-09-02T06:02	M1.3	1F	S17W66
SOL2001-09-02T13:48	M3.0	2N	S21W56
SOL2001-09-03T01:58	C9.0	-	~E90S15
SOL2001-09-03T17:16	M1.1	-	N10W06
SOL2001-09-03T18:41	M2.5	-	~E90S28
SOL2001-09-16T03:53	M5.6	2N	S29W54

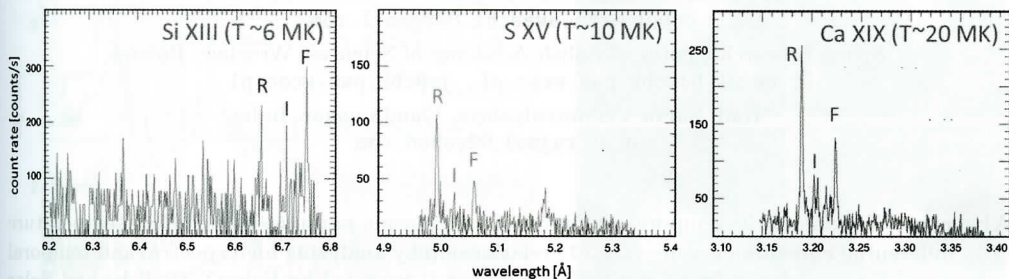


Figure 2. Spectra during the M1.5 class solar flare from August 30, 2001 observed at 17:52 UT by three of the Diogenesis channels. In each channel, triplet lines emitted by He-like S, Si, and Ca are observed (they are labelled resonance – R, intercombination – I and forbidden – F). The temperatures at which lines are formed are also indicated. For measurements of Si XIII spectral range, the Beryl crystal has been used. Beryl ($\text{Be}_3\text{Al}_2\text{Si}_6\text{O}_{18}$) incorporate Si atoms in the crystal lattice and therefore its X-ray reflectivity has absorption jump just left to the forbidden line (F). This causes that on the recorded spectrum the intensity of R line is less than the F line. This effect will be corrected on the Level.2 reduced spectra.

4. Summary

Some 200 high-resolution X-ray spectra have been obtained with the Diogenesis instrument during nine large solar flares in 2001. Analysis is proceeding of these spectra which cover the triplet of lines due to He-like S, Si, and Ca ions to give temperature and other information about the emitting plasmas. Of particular interest are the Ca XIX spectra in the dopplerometer mode which will allow Doppler and spatial shifts to be disentangled. The same principle will be used for the ChemiX instrument which will be on board the forthcoming *Interhelioprobe* Mission (Sylwester *et al.*, 2015).

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References

- Płoceniak, S., Sylwester, J., & Kordylewski, Z., *et al.* 2002, *ESA SP*, 506, 963
 Siarkowski, M., Sylwester, J., & Płoceniak, S. *et al.* 2002, *ESA SP*, 506, 753
 Sylwester, J., Kordylewski, Z., & Płoceniak, S. *et al.* 2015, *Solar Physics*, 239, 149