SOLAR ORBITER EUV/UV WAVELENGTH SELECTION AND INSTRUMENTATION – REPORT OF PAYLOAD SPLINTER GROUP 4

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ABSTRACT

We present here a summary of the discussions concerning the extreme ultraviolet (EUV) and ultraviolet (UV) wavelength selection and instrumentation for Solar Orbiter, held at the Tenerife meeting. These issues were assigned to Payload Splinter Group 2 and to the Wavelength Selection Working Group. Concerning the wavelength selection, a number of critical wavelength ranges were highlighted and discussed. Great emphasis was placed on good atmospheric coverage, from the chromosphere to the hottest coronal lines. A number of wavelength ranges were presented but the wide temperature range demands the inclusion of wavelengths longer than 912 Å as well as prime coronal lines in much shorter wavelength ranges, such as 170-250 Å. Regarding the instrumentation, the group agreed that Solar Orbiter should carry both imaging and spectroscopic capability in the EUV/UV and the two strawman instruments were presented and discussed. A number of alternatives were considered as were developments in technology, which could be of use for these instruments.

INTRODUCTION

The ultraviolet and extreme ultraviolet (UV/EUV) instrumentation on Solar Orbiter was the subject of two Working Groups, which met in series at the Tenerife Workshop. The first discussion concerned the selection of wavelengths for the spectrometer and imager, and the second homed in on instrument design and operational issues. These two facets will be discussed separately in this report.

The sessions were quite deliberately set up as brainstorming sessions with no strict agenda. Groups were able to present any material, and most of the time was devoted to open discussion. The sessions are reported on in that spirit.

WAVELENGTH SELECTION

In the introduction to the wavelength selection discussion, it was stressed that the wavelength selections in the strawman payload were just that; all options are open at this time. It was also stressed that the spectrometer (EUS) and imager (EUI) will not be used in isolation, so they had better not be designed in isolation. They must be complementary.

It was obvious from the initial discussions that we all want everything! There is total agreement that it would be ideal to have access to emission lines from the chromosphere, transition region, and corona, in addition to some flare-like lines. How we can make a selection to satisfy that, and how we could possibly design an instrument to achieve such a selection, is where opinions differ.

In his talk to the meeting, Viggo Hansteen (2001, this issue) had made the case for ensuring a good link to the chromosphere. He pointed out that the He I and II lines detected in the SOHO/CDS instrument are not ideal chromospheric lines due to the complexity of the hydrogen emission processes. He made the case for a chromospheric band longward of the hydrogen edge at 912Å.

Werner Curdt (Curdt and Landi, 2001, this issue) presented some discussion on his poster paper. He had studied diagnostic lines in the UV/EUV and had selected a set of critical ranges, each of which has important diagnostic tools. The ranges are 580-630, 690-730, 760-800, 1330-1430 Å. However the different ranges provided different diagnostic capabilities, e.g. the longest wavelength band gave the best temperature coverage, yet the two intermediate bands had the best capability for velocity analyses. His conclusion was that the best compromise was to take the two bands 580-630 Å and 1330-1430 Å.

Massimo Landini (2001, this issue) had also presented an EUV study to the meeting. His study had highlighted the 150-250 Å band as being essential for studies of the hot coronal emission lines. This he regarded as the most important band to include. He pointed out that for cooler plasmas other bands would have to be considered. It was noted that his prime band was out of the wavelength range considered by Curdt.

Richard Harrison reported on a study being undertaken with Ken Phillips. The SOHO and Skylab EUV line lists had been compared with an up to date listing of plasma diagnostic emission lines (principally density sensitive pairs). Only ‘well detected’ lines had been

selected, i.e. those identified with ease in the SOHO and Skylab data. Such an approach provided clusters of prime lines in the bands at 173-197, 240-281, and 333-365 Å. He noted that this did not include good chromospheric coverage, though it did include some high temperature (flare-like) lines. The coronal lines suggested by Landini were included in the selection.

The principal conclusion from this discussion is that we must expect to provide multiple wavelength bands in any EUV/UV instrument. The second conclusion is that this is harder said than done, given the wide wavelength range of the lines which have been suggested. However, finally, it is clear that opinions differ wildly as to the value of different groups of lines.

EUV/UV INSTRUMENTATION

To open this discussion, some of the restrictions on instrument design were reviewed. These include the following:

(i) The thermal aspects of the orbit are extreme. Solar Orbiter will have a 149 day orbit with aphelion at 0.8 AU and perihelion at 0.2 AU. The solar flux will range from 2142 W/m² to 34275 W/m² every 75 days. The instruments must be thermally robust.

(ii) The instruments must be autonomous. We will not have the luxury of near real-time control and short-term planning that we have with SOHO. Instrument operation must be pre-planned for the solar passes, each of which covers several tens of days.

(iii) The mass limit for Orbiter is extreme, allowing only a few tens of kg for the largest instruments.

(iv) The telemetry is limited due to the location and the fact that the high gain antenna must be stowed behind the spacecraft during the solar passes. Even with a large on-board memory and data-dumps during the rest of the orbit, we anticipate a telemetry rate (average) of about 20 kbit/s per instrument for the larger instruments.

(v) The power is also restricted to about 25 W for the larger instruments.

(vi) The maximum length of any instrument is of order 2.5m.

(vii) The spacecraft stability may be about 1 arcsec per 15 minutes, demanding independent stabilisation systems for the subarcsec instrumentation.

The two strawman payload instruments were discussed.

The Extreme Ultraviolet Imager (EUI) is a high-resolution (35 km pixel) imager with simultaneous imaging in a range of wavelengths. The heritage for this instrument comes from EIT/SOHO, SXT/Yohkoh and TRACE. The instrument consists of three part-Sun imagers and a full-Sun imager. The wavelengths currently listed are 133 Å (around the Fe XXIII line), 174 Å (Fe X) and 304 Å (He II). The Fe XXIII band allows a high temperature capability which is lacking in SOHO. It was suggested that an intermediate, transition region temperature line, such as O V 629 Å be included since this line displays dramatic dynamic activity and fine structure and is the most requested emission line for the CDS instrument on SOHO.

The Extreme Ultraviolet Spectrometer (EUS) is a high-resolution spectrometer, providing 75 km pixels, 0.01 Å (5 km/s) spectral resolving element and a temporal capability of a few seconds, over a broad range of temperatures. Its basic aim is to provide plasma diagnostic information and its heritage comes from CDS and SUMER on SOHO and the SERTS rocket instrument. The strawman wavelength selection is 580-620 Å and this includes lines such as He I 584, O III 599, Mg X 610, Fe XIX 592 Å. It was noted that this band was very close to one of the bands suggested by Curti. It was also noted that the strawman design had been upgraded to include a variable line spacing grating to improve the off-axis performance.

Before discussing other design options, the group considered some generic issues. Two options for detectors were discussed. This included a presentation by Richard Harrison, on behalf of Nick Waltham (RAL), on APS (Active Pixel Sensor) detectors. These devices include on-chip electronics allowing each pixel to be read-off individually without charge transfer. This reduces the influence of charge trapping which is a great advantage in the harsh particle environment that Solar Orbiter will encounter. In addition, it is a low-mass and low-power option compared to the traditional CCD approach. Back-thinning of such devices for EUV work is being actively pursued by the RAL group, in close collaboration with Marconi (EEV).

Another alternative is the BOLD (Blind to Optical Light Detectors) concept which was presented (see Hochedez et al., 2001, this issue). These are diamond-based detectors specifically aimed at future solar missions and under development by a multinational consortium (Belgium, France, Italy and Germany). The principal advantages of these devices are their visible blindness and radiation hardness.

The thermal aspects of the instruments were discussed after some people expressed concern that this issue is not being catered for fully. The current instrumentation on Solar Orbiter makes use of occultation, radiators, light rejection and heat-resistant materials, in a number of ways to cope with this. For example, the EUS has three radiators dedicated to the primary mirror,
secondary mirror and the detector. It also has a 'reduced' secondary mirror, which allows much of the incoming light to be rejected back through the aperture. The SiC mirrors are gold-coated and can run at the calculated temperatures of 70-80 degrees C, and the light stops result in only a small fraction of the incoming radiation passing to the grating and detector.

Several design options were presented in the discussion. These are now summarised.

Pino Tondello and Luca Poletto presented a design option for the spectrometer (see Poletto and Tondello, 2001, this issue). This involved including a second light path inside the (slightly enlarged) existing EUS structure, i.e. the Ritchey-Chretien design of the strawman EUS was unaffected but a double grazing incidence telescope feeding a cylindrical variable line spaced-grating spectrometer was included. This allows 1-2 bands with stigmatic spectra at bands less than about 350 Å. Such wavelengths can only be obtained with the normal incidence strawman using multilayer technology, but this will limit the wavelength range. It was thought that the new approach could enable us to obtain the multiple yet widely-spaced wavelength choices discussed above.

Roger Thomas (Goddard Space Flight Center, USA) presented details on the upgrade of the EUV SERTS rocket payload. It now consists of two single off-axis paraboloid mirrors feeding toroidal gratings. The system uses multilayer technology tuned to the two wavelength bands of 170-205 Å and 300-370 Å. The spatial resolution is 2 arcseconds. This approach, of course, is one way of producing multiple-wavelength bands. This design prompted a discussion about the resolution requirements, i.e. what is the 'cost' of demanding a requirement of spectral resolution elements of 0.01 Å? The general response was that we had better obtain such high resolution in order to tackle the question of flows in particular but the difficulty in obtaining such a resolution was noted. A similar question about the spatial elements of 1 arcsecond generated a unanimous call to maintain the current target.

Regarding the imager, Jean-Pierre Delaboudiniere (Inst. d’Astrophysique Spatiale, France) suggested that it may be worth revisiting the slitless spectrograph concept. He discussed a multilayer slitless spectrograph where the overlapping spectra were limited by the narrow spectral ranges allowed by the multilayers. His suggested scheme centred on bands at 170 and 350 Å. He also suggested that the full-Sun imager of the EUI could be a simple pin-hole camera. This was an interesting option, which raised much discussion.

Following on from Jean-Pierre’s suggestions, Charles Kankelborg (Montana, USA) described the MOSES (Multi-Order Solar EUV Spectrograph) slitless spectrograph rocket experiment (see Kenkelborg and Thomas, 2001, this issue). In the slitless concept, the spatial and spectral information are not readily separated. In the MOSES design this is achieved through the use of two different orders within the optical system. Comparing the two orders allows a greater ability to identify the spectral and spatial components of the data.

Most spectroscopic instruments require rastering, through the use of exposures using a slit, interlaced with mechanism movements, to build up images. A reminder of the limitations of this approach was given in a demonstration by Robert Walah (University of Central Lancashire, UK). He showed a single-loop simulation model in which random heating events occurred. He showed a movie of the actual loop density, temperature and velocity profile with time and compared it to movies of the same parameters produced when the loop is scanned using a rastering spectrometer. The comparison of the observed activity with the true activity was an eye opener and stressed the need for rapid rastering, and careful operation and analysis concepts to reduce the difference between ‘actual’ solar activity and ‘observed’ solar activity.

DISCUSSION

It is clear that the community is not short of novel ideas. The merits of a number of options for Solar Orbiter instruments were discussed and are being studied. However, we were continually reminded that we must keep sight of reality; the instrument sizes, masses and telemetry are severely limited. The instruments must be fairly autonomous and the thermal and particle environments are extreme. There is no doubt that the construction of instruments for this mission will be a real challenge.