Solar Orbiter – EUV Spectrometer

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Goals of the Solar Orbiter

Introduction

We need to focus the scientific goals of Solar Orbiter. The mission was proposed using a large set of goals and objectives, and it is timely to refine these to a subset of fundamental issues, the solutions of which really require the unique aspects of the Solar Orbiter mission. This note is an attempt to provide some focus – or at least to fuel the discussion. There is some urgency. We will be considering the detailed design of instrumentation for Orbiter over the next year or so. We do need a refined set of goals in order to provide the scientific requirements for the instrumentation.

What is unique about Solar Orbiter?

The unique features of Solar Orbiter have been highlighted by emphasising the four 'new aspects' in the proposal to ESA. This includes the following:

(i) Proximity to the Sun
(ii) High Latitude Remote Sensing
(iii) Co-rotation
(iv) In-situ measurements in the inner heliosphere

In themselves, though, these are not goals. So, what do they give us?

The 'proximity' aspect gives us the high-resolution capability but we can, in principle, make good high-resolution observations using large instrumentation in Earth orbit, with a MUCH better telemetry rate! Thus, this alone is not a selling point.

The 'high latitude' aspect suffers in that it is rather late in the mission. However, Orbiter will achieve significantly high latitudes in the latter part of the main mission (i.e. pre-extension). This gives us a few major new things, e.g. the 'cosine' is such that we can see the flow patterns using spectroscopic means; the photospheric magnetic and flow patterns of the poles can be seen for the first time; we can view luminosity and mass ejection from more than one vantage point (the only star for which we can view from different angles).

The co-rotation is unique and does offer the chance to link the atmosphere and inner heliosphere - if we can work out how to do it. However, it is a marginal feature of the mission, i.e. a few days per orbit for the first (in ecliptic) orbits. We should use it but not as the principal argument.

The in-situ measurements question is easy to answer. There is no other way to do it other than to go there! It is unique, though we have to sell it carefully to make it look better than a marginal improvement on Helios. Of course, it is closer and with a much more sophisticated and complete set of instruments.

However, there is another location aspect, namely the Sun-spacecraft-Earth angle, which provides us with unique views out of the Sun-Earth line and even of the far-side of the Sun. This aspect was not highlighted in the original proposal to ESA. In addition, unique multiple spacecraft vantage points enable a variety of new opportunities. This multiple vantage point aspect is important.

Thus, we have <u>five</u> new aspects to the mission and their importance in selling the mission, based on their uniqueness can be given in the following order of priority:

1. In situ/exploring the inner heliosphere
2. Co-rotation/linking the corona to the heliosphere
3. Multiple vantage point observations/3D and unique views of solar phenomena
4. High latitude/3D studies of a star
5. Proximity/high resolution observation of the Sun

2. What does this mean for the instrumentation?

2.1 EUV/UV Spectroscopy

We explore here the needs for EUV/UV spectroscopy, in particular, as part of the preparation for the EUS instrument.

EUV/UV spectroscopy should not be flown for its own sake but for its unique uses on Solar Orbiter. Such techniques provide the plasma diagnostic 'tools' for all solar phenomena. The following statements, based on the goals of Orbiter, define the need for such an instrument, <u>given in a rough order of importance (i.e. uniqueness):</u>

(i) *We need to use spectroscopic means to determine the plasma processes and structure of the polar regions, including the generation of the high speed wind streams, the structure and evolution of plume and inter-plume regions and the evolution of coronal hole boundaries.*

(ii) *We can provide plasma diagnostic and evolution characteristics for solar surface and atmospheric phenomena connected directly to the spacecraft, and thus linked to the in-situ instrumentation, for coronal-heliospheric interrelation studies during the co-rotation phases.*

(iii) *Multiple line of sight observation vantage points afforded by Solar Orbiter (with ground-based observatories, near-Earth spacecraft and other heliospheric spacecraft - such as STEREO and Solar Probe) can be used to determine the plasma properties and evolution of a range of solar phenomena which cannot be determined readily from one vantage point. This applies in particular to diagnostic analyses of phenomena best observed at the limb, e.g. eruptive phenomena onsets (CMEs, prominences, sprays and surges, spicules, macrospicules) as well as the detection of far-side phenomena.*

(iv) *We can produce high-resolution spectral observations, for plasma diagnostic analyses, of all solar features, with a spatial and spectral capability an order of magnitude better than currently available.*

Item (i) we cannot do with SOHO - the Don Hassler solar wind/network image is as near as we get. Thus, the principal measurement here, in many ways, is VELOCITY. However, this must be across a broad range of temperatures preferably from chromosphere to corona and flare-like lines. The density may come in a poor third but as with the CDS NIS2 band, we can retain some density capability almost as a by-product (e.g. the O IV in the Mg X wing) and the weakness of the lines may not be such a problem if we sum images on the ground to obtain the statistics - as long as the density is not the driver. This we do for CDS in the CME onset studies, for example, with short exposure times. HOWEVER, we must ensure that the sensitivity is such that the exposure times are consistent with the temporal needs for such high resolution. However, as stated, the bottom line is the new ability to explore the polar regions and we do not need to get that far out of the ecliptic to make significant advances here.

Item (ii) is not straightforward, but provides a unique opportunity to study the source plasma and its subsequent signature in situ.

Item (iii) certainly provides unique opportunities with observations in combination with near-Earth and ground-based systems, as well as with other spacecraft such as STEREO and Solar Probe. More than one vantage point is a major advantage for a number of phenomena, such as CME onsets. Note that STEREO does NOT carry a spectrometer.

Item (iv) is a major advance but not unique enough to be higher in the list.

2.2 Other Instruments

The coronagraph observations are also only really new from the out of ecliptic point of view. The out of Sun-Earth line would be new if STEREO did not exist! Out of the ecliptic observations (again, we don't need 70 degrees plus) can provide an insight to CME distribution, directions and widths, as well as making statements about global CME activity, sympathetic CMEs etc, etc… The global mass loss picture would certainly be clearer because we can see the equatorial belt from above, and the ecliptic <u>and</u> out-of-ecliptic view can only be done for one star – the Sun! In effect, we are studying a star in 3D for the first time. However, the strength of this is in the late phase of the mission.

The in-situ instrument advantage is obvious - we can sample the innermost heliosphere for the first time.

The radiometer is also obvious. To sample a star (the only one) from more than one vantage point is a key to understanding the luminosity question. How else could we do it?

The comments about the EUV/UV spectroscopy also apply to any oscillations/magnetic device. We lack knowledge of the polar regions and a few tens of degrees would do it! The magnetic and flow information in the polar regions are critical to an understanding of the dynamo, for example.

3. Suggested Focused Goals

So, given all of the above, it is suggested that the focused goals should be listed as below. For each there is a 'uniqueness rating', α, where the values are given in the table:

Uniqueness Rating (α)	Definition
0	Not unique. Goal can be addressed effectively by existing instrumentation.
1	Not unique. Goal can be addressed by existing

	instrumentation, but expected improvement does represent a step forward.
2	Unique? Could, in principle, be done by other means, but plans do not exist for this, and the expected improvement is extremely significant.
3	Unique. Cannot be done by any other planned instrument or mission.

(i) To ***explore the innermost heliosphere*** for the first time using in-situ measurement. **[α = 3]**

(ii) To ***investigate the linkage between the solar surface and atmosphere to the inner heliosphere***, using remote sensing and in-situ instrumentation in a co-rotating orbit. **[α = 3]**

(iii) To provide the ***first 3-D view of the luminosity and global mass ejection processes of a star***, using a combination of low and high latitude remote sensing oservations. **[α = 3]**

(iv) To investigate for ***the first time the true nature of the Sun's polar regions using a combination of imaging and spectroscopy from high latitude***. This includes studies of (a) the nature of the polar flow and magnetic fields (critical for understanding the solar dynamo); and (b) the generation of the high speed solar wind and the structure and evolution of coronal holes, including the plume/inter-plume regions and coronal hole boundary structure and evolution. **[α = 3]**

(v) To investigate a range of solar phenomena through ***multiple vantage point observation***, enabling a unique view of Earth-observed limb events and structure, and far-side activity, which will provide critical information on event onsets, and the structure and evolution of a range of solar features. **[α = 2/3]**

(vi) To investigate the fine-scale fundamental processes in the solar atmosphere through ***close-up, high-resolution imaging and spectroscopy***. **[α = 2]**

[Based on an original note by R. Harrison, 22 May 2001]