Magnetic linkage and reconnection in the TR

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Science case and rationale

To investigate the links between the solar surface and corona and the fine-scale structure of the Sun's magnetized atmosphere on all scales requires the combined observations of VIM and EUI, together with observations of EUS exploring the energetics and dynamics through spectroscopy. The Solar Orbiter mission is needed to do this science because it offers a unique suite of capable instruments and unparalleled set of vantage points at high latitudes and in partial co-rotation.

These conditions will allow us to make high-resolution observations of the vector magnetic field together with plasma emission in the transition region and lower corona, which can not be done on any other ongoing or planned solar space mission. To establish the magnetic linkage, as well as its change by field line reconnection, between the photosphere, transition region and corona for various magnetic structures is a key objective.

It is already known from SOHO and TRACE observations that the main layer to be observed is the **magnetic transition region** (MTR, reaching up to about 10 Mm) that consists of small cool loops and tenuous funnels at temperatures of up to several 10^5 K. Below about 5 Mm the MTR is highly dynamic at scales of one second of arc and below (150 km pixel size of Solar Orbiter is ideal). As numerical simulations have shown, it is from the chromosphere to the middle MTR where reconnection (jets, explosive events) mostly take place as the result of magnetoconvection in the photosphere.

EUS instrument requirements

1. Emission line requirements

To diagnose adequately the MTR a long-wavelength channel is indispensable, which should contain reference lines at rest in the chromosphere for Doppler shift calibration and for co-alignment with the VIM context-magnetograms by means of pattern recognition, and which must provide a broad coverage in temperature from about 5 10^3 K to about 5 10^5 K (line ratios for density diagnostic desirable). A wavelength band > 91.2 nm as envisioned in the SRD is required, but coronal lines at shorter wavelengths can not be used for this study. A possible choice would be the 133-143 nm range (Curdt and Landi, 2001, Tenerife workshop). The 116,3 -126,6 nm range (working paper by Teriaca, Schühle, Curdt, 20/3/2006) would provide a broad range in temperature and contains cold neutral atom lines for wavelength calibration.

Given the relatively broad science theme described above, we do not select here specific wavelengths, the choice of which will depend on the details of the feature under scrutiny. Following the document (version 3) of Young on the EUS wavelength selection, we strongly argue to include the band 7a and/or band 7b in EUS, in order to be able to study the MTR. This range naturally offers neutral-atom lines, for the crucial wavelength calibration (a viable approach as SUMER has demonstrated). Since the VUV spectrometer on Solar-B has poor MTR coverage, high priority should be given to a long-wavelength channel in EUS, to ensure new science and the potential for detections.

2. Spectral and spatial resolution requirements

We need to resolve the lines not only for intensity measurements, but their profiles need to be resolved in order to study the line widths and shift (flows and heating). There is a whole zoo of possible structures in the MTR which should be observed. Typically, for synergy the field of view of the EUI HRI should be covered. Special observations of an individual funnel, a bright point or granule, for example, would only require, say, a 3×3 arcsec^2 field of view. Fast scanning capability of the spectrometer is essential for the study of dynamics.

3. Time resolution (incl. count rates)

Short exposure times (of order seconds) are needed to follow fast reconnection and quick topological changes of the field and the resulting variations in VUV emission in the lower TR.

4. Other requirements

Certainly, simultaneous images from EUI, from the HRI and FSI as well, are required for context and from a global linkage point of view. Of paramount importance are magnetograms from VIM, for magnetic field extrapolation into the MTR, and also visible-light images for a comparison of the MTR structures with convection-induced patterns such as granules and small strong-field flux tubes at the foot points of coronal flux tubes. The TR and coronal magnetic field as obtained by extrapolation from VIM data should routinely be available for the EUS team. To provide those data for general use is requested here from the VIM team.

Relation to Solar Orbiter science goals

1. **Determine the properties, dynamics and interactions of plasma, fields and particles in the near-Sun heliosphere** N/A

2. **Investigate the links between the solar surface, corona and inner heliosphere**

The magnetic transition region, where the field re-organizes itself from the small-scale flux tubes prevailing in the photosphere into the more uniform large-scale structure of the coronal field, is a region of central interest and its study at the heart of this science goal.

3. **Explore, at all latitudes, the energetics, dynamics and fine-scale structure of the Sun's magnetized atmosphere**

The magnetic field in the TR is known to be highly dynamic. It permanently changes, and through reconnection, mostly at heights below 5 Mm and at small scales, its linkage to the coronal and heliospheric field varies strongly. To explore the dynamics of the MRT is of crucial importance for coronal heating and origin of the solar wind.

4. **Probe the solar dynamo by observing the Sun's high-latitude field, flows and seismic small waves** N/A