Observing Prominences with EUS

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Prominences (filaments when observed against the disk) hold the key to the structure and dynamics of those parts of the coronal and chromospheric field that store huge amounts of energy and helicity and, hence, determine the occurrence and properties of solar eruptions, i.e., the major space weather events. Both the structure and dynamics of prominences and of the magnetic fields which they partly outline are highly debated issues. Models that rely upon a sheared arcade topology compete with models that rely on flux rope topology. This is the case for quiescent as well as for erupting prominences (see, e.g., DeVore & Antiochos 2000 vs. Aulanier & Démoulin 1998 and Lionello et al. 2002 for the quiescent phase and Antiochos, DeVore & Klimchuk 1999 vs. Lin & Forbes 2000, Török & Kliem 2005, Fan 2005 for the eruptive phase). Some of the central issues in the research on prominences and solar eruptions are the questions whether, when and how a transformation from a sheared arcade topology to a flux rope topology might occur and whether or not this marks the onset of an eruption. Some authors prefer the view that such a transformation happens extremely gradually in the long, more or less quiescent phase of a prominence's life (e.g., Mackay & van Ballegooijen 2006), others suppose a more dynamic transformation and associate it more or less closely with the onset of eruptions (e.g., Amari et al. 2003 a,b). The supposed transformation involves magnetic reconnection, which yields two types of clear spectroscopic signatures: localized heating and localized reconnection outflows. If the transition occurs dynamically, especially if it is directly associated with the onset of an eruption and its flaring components, then very high temperatures in the 10 MK range and high outflow velocities of several 10^2 km/s are to be expected. If the transition occurs gradually, the effects will remain moderate, but are nevertheless expected to occur as a succession of many small "events", due to the fibril nature of the magnetic field and due to the bursty nature of reconnection in a highly conducting plasma. Only the high spatial resolution provided by the Orbiter may permit the detection of such gradual topology transitions with a spectrometer like the EUS, which provides high spectral resolution in a very wide temperature range.

I propose to select monitoring observations of quiescent and active-region prominences/filaments in raster mode with simultaneous coverage of a couple of lines (3-10) in a very wide temperature range (ideally from below 10^4 K to at least 10^7 K) as an important science goal for the EUS instrument project.

By combining such observations with high-resolution vector magnetograph observations on the Orbiter and with field extrapolation and MHD modelling, essential progress in the understanding of both, the structure and the dynamics of current-carrying fields and plasmas in the corona and chromosphere will be achieved. There are good prospects that main components of the structure and dynamics can be understood.

Monitoring prominences for extended periods of time (days, up to two weeks) will be a convenient science target, due to the limited short-term flexibility of observing with the instruments on the Orbiter.

EUS instrument requirements

1. Emission line requirements

The key requirement will be that lines in a very wide temperature range can be observed simultaneously. This extends from nominal temperatures of quiescent prominences below 10^4 K to hot flare temperatures of 10-30 MK. A good choice may be bands 6, 7a or 7b, which cover the chromospheric and transition region temperature range, but where we have also the 721 Fe XX, the 974 Fe XVIII or the 592 Fe XIX /2 as hot component.

2. Spectral resolution requirements

A spectral resolution similar to that of SUMER (of order 40 mA/px in 1^{st} order), or perhaps even somewhat better, is desirable in particular to resolve flows (30-50 km/s) and detect broadenings (~15 km/s) in the activation phases of prominences.

3. Spatial coverage

Complete active region prominences and sections of quiescent prominences spanning a few supergranule cell need be covered. A slit length and raster size of no less than 10^5 km on a side should be attempted. A larger size (slit twice as long) would be advantageous.

4. Time resolution (incl. count rates)

Timescales of 0.5-1 hour for a complete raster (~10^5 km) should be OK for prominences in quiescence or slow motion. Eruptions cannot be simultaneously resolved in time, whole spatial extent, and wavelength anyway.

5. Requirements for other instruments

On-disk observations should be supported by vector magnetograms (highest priority) and by EUV images; supporting coronagraph observations will be valuable. Limb observations should be supported by EUV images (highest priority) and by the coronagraph.

6. Other requirements

None.

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

Prominences constitute the principal link between the solar surface, corona and inner heliosphere for major space weather events (CMEs). Exploring the physical mechanisms of prominence activations and eruptions at the greatly increased resolution of the Orbiter bears a high potential to discover basic processes that link the different layers in these "magnetically most sensitive" structures and may be important in linking other structures as well.

Also, those aspects of the mass flow between the photosphere, chromosphere and corona that are related to prominences will be explored in greater detail, as will be the thermodynamics (condensations) of the coronal plasma, which is closely related to the physics of the transition zone.

See also Item 4 for the transport of magnetic helicity through these layers.

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

EUS prominence observations will represent an essential, basic contribution to this Orbiter science goal: (1) the significantly sheared or twisted magnetic fields that shape prominences constitute those fields in the solar atmosphere that store the largest amounts of energy; (2) both the structure of quiescent prominences and their activations and eruptions represent fundamental puzzles of solar MHD (sheared arcade vs. flux rope topology and dynamics); (3) the detailed linking between fine-scale prominence threads and the magnetic field, especially in the barb extensions to parasitic polarity patches, is not understood.

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

EUS prominence observations will represent an essential contribution to this Orbiter science goal: A widely adopted hypothesis is that prominence eruptions and CMEs constitute the necessary final step in the outward flow of small-scale magnetic helicity, which is thought to be imparted on the field by helical motions in the convection zone, probably in the dynamo region proper. Monitoring the evolution of active-region prominences till their eruption will directly probe this hypothesis, since much of the helicity of the region's field should be accumulated in the prominence before it erupts. Combining such EUS observations with magnetic field extrapolation and modelling will determine much of the flow of small-scale magnetic helicity from the the dynamo region into the active region belts and further into the solar wind. Monitoring the evolution of high-latitude (polar crown) prominences will likely capture some of the remaining helicity, which drifts with trailing-polarity fields from the active region belts to the poles in the course of the cycle. It will also likely provide new insights into the details of the polar field reversal, since polar crown prominences form at the interface between the polar field of the “old” and the “new” cycle.