# PHYSICAL STRUCTURE AND DYNAMICS OF MAGNETIC LOOPS IN THE SOLAR CORONA

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In the recent years important progress has been reached in the investigation of the coronal loop physical structure, evolution and dynamics and a new and more complex scenario is emerging from the present generation of space instruments. However, to get an exhaustive understanding of what constitute the "building blocks" of the outer solar atmopshere, it is important to answer some questions that remain still open:

- What are the detailed profiles of the plasma temperature, density and flow along the magnetic structures, particularly close to the loop footpoints (i.e., in the transition region observable in the VUV), and what is their behaviour as a function of time? The data available up to now are rather scanty to provide a satisfactory picture.
- Can coronal loops be described as single "monolithic" structures, or they are collections of hundreds or even thousands of unresolved strands, each with its own independent dynamics? TRACE observations at high angular resolution (1 arcsec) suggest that they consist of several individual filaments.
- Where and how does the heating deposition occur in the loop plasma? The observed features strongly imply time-variable, non-uniform heating, but the picture of this process determining the loop plasma dynamics is not yet well defined.

To address these issues, key measurements are high spectral and spatial resolution spectroscopic EUV/VUV data, obtained with high temporal cadence (~ 5-10 s), good signal-to-noise ratio, and covering the entire magnetic structures, in order to determine the detailed time-dependent profiles of temperature, density and flow velocity along the observed structures, from the loop footpoints to the apex.

The dimensions of the spatial resolving element provided by Solar Orbiter (100-200 km) are crucial to resolve coronal loops into bundle of several loops. There are good theoretical reasons to suspect that the loop filamentation may go deeper to smaller spatial scales, which may be resolved with a spatial resolution of the order of that reported above

An additional important open question is whether there are significant departures from ionization equilibrium in the loop plasma. On the basis of the observed mass flows through the steep temperature gradients of the transition region and fast temporal variability, it seems inevitable that non-equilibrium should occur, with considerable consequences for the diagnostics and energetics of the plasma confined in the magnetic loops. While there is no simple observational signature for detecting deviations from equilibrium of the emitting ion populations, a study designed to address the three questions listed above, and that therefore exploit at its best the high temporal, spectral, and spatial resolution allowed by EUS, could provide useful constraints to address such an important question as well.

## *EUS instrument requirements*

### 1. Emission line requirements

Bands 7a and 7b, described in the wavelength selection documents, contains strong lines formed at $10^4$ K, $10^5$ K and $10^6$ K plus the C III 97.7/117.6 density diagnostic at transition region temperatures. A selection of lines would include, H I Lyman-α or -β ($2\times10^4$ K, morphology and link with the imager, EUI), C III 97.7 ($8\times10^4$), O VI 103.2 nm ($3\times10^5$), Mg X 62.5 nm ($1\times10^6$ K, in second order). The C III 117.6 nm multiplet should also be included for density diagnostic. Moreover, we could introduce the Si II 126.5 nm (two lines) or the N V 123.8 nm ($1.5\times10^5$), depending on whether we want a better coverage of the chromosphere or of the TR. It might be very useful to consider some *flare* line, such as, for instance, the Fe XVIII 97.5 nm.

### 2. Spectral resolution requirements

Profile needs to be resolved in order to study line shifts and widths. A spectral resolving element of 0.005 nm/pixel is required (2 km/s in 1/7th of pixel at 97.7 nm). Spectral windows must be at least 0.2 nm large (40 pixel with 0.005 nm/pixel). If it will be possible to select spectral windows of variable width, and since the H I Lyman-α line in this study is required only for morphology and alignment with the imager, a smaller window (15 or 20 pixels) for this line could be employed.

### 3. Spatial coverage

The FOV should be large enough to include a whole loop structure of significant size (e.g., active region loop: $L \approx 10\times100$ Mm). Rasters covering an area of ≈700×700" are required (at 0.22 AU).

### 4. Time resolution (incl. Count rates)

The timescales to resolve are of the order of 1-5 s . Required count rates: at least 100 counts in 1 s. On active regions such count-rates are achieved by all the listed lines, with the exception of Mg X 62.5 nm, which requires at least 5 s. The produced data rate (12 bps) would be $6\times700\times40\times1\times12=2016$ kbps, for 1 s exposures, roughly 120 times the available rate. For exposure times of 5 s, the telemetry requirement drops to 24 times what will be available: in any case some amount of data compression may be needed. Exposure time may need to be increased to 10 s.

### 5. Requirements for other instruments

Imaging capability at coronal and transition region temperatures is important for placing the spectroscopic measurements in context and for studying the morphology and evolution of the selected active region. EUI images in Lyman-α and Fe IX 17.1 nm will be required. If available, hotter EUI bands ($T>3\times10^6$ K) would be much useful. We also require VIM magnetograms to allow structures to be related to magnetic features.

### 6. Other requirements

All the collected data must be characterized by a very good signal-to-noise ratio, even for fainter features, which implies high efficiencies (>30%) and dynamic range (~10,000) for the optical systems and detectors.

## *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

Given the role of magnetic loops in the overall structure of the solar transition region and corona, with significant implications for the mass and energy balance in the outer layers of the solar atmosphere, it is important to extend our knowledge of their physical conditions, that is crucial for understanding the mechanisms that produce coronal heating, accelerate the solar wind and trigger transient energetic phenomena such as solar flares, which significantly affect the heliosphere and the terrestrial magnetosphere.

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

The outer solar atmosphere is highly structured by the magnetic flux emerging from the photosphere and the building-blocks of the confined corona are loops with different sizes and lifetimes.

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

N/A