The fine structure of solar prominences and filaments

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Prominences are structures of great scientific interest because of the complexity of the physical processes involved in their forming and disappearance. It is still not understood how solar prominences and filaments reach a state of equilibrium, allowing cold and dense plasma to remain in the hot and tenuous corona for up to a few solar rotations. One of the important aspects for the understanding of the physics of solar prominences is the characterization of the region of transition to the surrounding corona (PCTR). In the PCTR, the emitting plasma (which contains different ions coexisting in several excitations states) seems to flow primarily along magnetic field lines. However, despite the magnetic field being mostly horizontal, we do also observe vertical motions. The determination of the vector velocity of the plasma, obtained from spectroscopy, provides us with some information about the geometry of this magnetic field. In order to characterize physically the structure of prominences, it is important to determine the distribution of plasma density with temperature (Differential Emission Measure). Cirigliano et al. (2004) have made such a study using SUMER and CDS and have shown that the minimum of the PCTR DEM is at a lower temperature than for other structures like the quiet sun, a coronal hole, or an active region. This aspect has to be further investigated with the Solar Orbiter instruments in order to understand heat transfer within the prominence. Cirigliano et al. also made an attempt to calculate the filling factor of their observed prominence, but the spatial resolution of the SOHO instruments is too low. Furthermore they found a discrepancy between filling factors inferred from electron density and EM diagnostics, and from mass flows.
To answer these and other questions, accurate measurements of the fundamental plasma parameters across the whole structure are necessary. It is crucial to get a detailed picture of the energy budget within the prominence. To study the fine structure and the geometry of the PCTR, observations with high spatial and spectral resolutions are necessary. This is made possible thanks to the high spatial and spectral resolutions of EUS and HRI / EUI. In particular the size of the plasma threads composing the PCTR is beyond the spatial resolution of the current instruments.

EUS instrument requirements

1. Emission line requirements

EUS will allow the determination of the plasma parameters from the EUV line profiles. While optically thin lines are the easiest to interpret in terms of thermodynamic plasma parameters, integration along the line of sight prevents the derivation of their variation across the structure. We need specific lines to probe the transition region between the central body of the prominence and the surrounding corona, which plays a critical role in the energy equilibrium of the structure. EUV optically thick lines such as the H Lyman lines, and the He I 584 Å and He II 304 Å resonance lines are formed in this region and bring unique information on the most important elements that are hydrogen and helium (the major drivers in prominence dynamics). The difficulty lying in the fact that the plasma is out of local thermodynamic equilibrium can be overcome with the help of radiative transfer codes (Labrosse & Gouttebroze, 2004, ApJ 617, 614). Other lines with formation temperature between 10^4 and

~7 10^5 K will be used for further diagnostics, from the core of the prominence to the interface with the corona.
We recommend the following two bands, based on a 2048 pixels detector and a pixel size of 0.044 Å. **1)** 545 Å - 635 Å, which includes among other lines He I, He II, O III, O IV, Ne IV, O V, Ne V, Ne VI, Ne VII, Mg X, and Ca X; **2)** 950 - 1040 Å, with H I, O I, C II, He II, C III, N III, O VI, Na VI, Si XII. If a **third** band is available, we suggest the band 1162 - 1252 Å, which includes H I, He I, N I, Si II, Si III, C III, N V, O V, Mg X, S X, Fe XII lines. We have good temperature coverage for DEM studies, density diagnostic with the C III line ratio (to be compared with our radiative transfer modelling), and several lines from H, He I, and He II.

2. Spectral resolution requirements

The line profiles need to be resolved in order to study line widths and line shifts (to study mass flows), thus SUMER resolution should be good enough (though better spectral resolution should be targeted to resolve lines which are blended in SUMER spectra). Instrumental resolution better than 90 mÅ to look for self-reversed line profiles of optically thick lines with small peak-to-peak distance which are sometimes predicted by models (Labrosse & Gouttebroze, 2001, A&A 380, 323).

3. Spatial coverage

We would like to see the environment of the structure simultaneously with the structure itself. A coverage of 240" x 240" at 1 AU (similar to CDS fov) should be acceptable, with resolution better than 100 km.

4. Time resolution (incl. count rates)

Time-scale between a few seconds to a few 10s seconds should be enough, depending on whether a filament or a prominence is observed. In raster mode it should not last longer than ~30 minutes.

5. Requirements for other instruments

Simultaneous EUI images will provide the information on the spatial structure: a series of images at different wavelengths to get a picture of the repartition of the 'multi-temperature' plasma in the region observed. For example, images taken at 304 Å will give us an insight on relatively cold plasma compared to images at shorter wavelengths. Images taken in the hydrogen Lyman alpha line would be useful as the description of the plasma would be more complete. These images will also serve as a context information for the analysis of the spectral line profiles. Therefore we request that there is at least one line that can be jointly observed by the imager and the spectrometer (HE II 304 or H Ly-alpha).

6. Other requirements

N/A

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

N/A

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

Our objective is to explore and understand the energetics, dynamics and fine-scale structure of solar prominences, how the plasma is confined by the magnetic field, and look for spectroscopic signatures of destabilisation that could lead to coronal mass ejections.

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

N/A