Structure and dynamics of the solar atmosphere

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Current models based on MHD provide 3D numerical experiments of magneto-convection of the photosphere, chromospheric dynamics and coronal processes more or less separately, because it is not yet possible to resolve the required small scales of the inter-granular dynamics in the photosphere in a simulation box that fully encloses a large active region complex. With increasing computing capabilities even a conservative estimation suggests that at the time the Solar Orbiter will be flying models including the whole atmosphere from the sub-photospheric convection all the way into the hot corona will be possible. At the time, we can also hope to consider non-equilibrium processes such as ionization in the models. Progress in the combination of kinetic physics and MHD might then also allow detailed predictions on the presence of plasma processes and particle acceleration when heating even the quiet corona.

This implies that in order to provide solid tests for the future models, the instruments on-board the Solar Orbiter have to cover the whole solar atmosphere, from the photosphere to the corona, and provide information of energetic particles originating in the coronal heating process(es). As VIM will be restricted to photospheric diagnostics and EUI will be capable of only a small number of selected wavelength bands, it will be of pivotal importance that EUS can provide the link from the photosphere to the corona.

Observations at high spectral, spatial and temporal resolution covering continua and emission lines formed from chromospheric to flare temperatures will be needed to test the future models. For the comparison with the models time series of spatial maps with full spectral coverage will be needed.

EUS instrument requirements

1. Emission line requirements

To compare the results of the future forward models to observations, one needs access to:

(1) EUV continua formed in the low chromosphere, also for co-alignment with photospheric observations.

(2) Diagnostics of lines from neural and singly ionized species to investigate the dynamics, i.e. Doppler shifts and widths, of the low chromosphere.

(3) Lines from the interface to the corona, i.e. the transition region, which are most important to study the reaction of the atmosphere to the heating processes. They are so valuable, because the intrinsic time-scales of the transition region are very short.

(4) Coronal lines formed at 10^6 K and well above to be able to directly see the plasma heated to very high temperatures.

The band that best suits theses needs seems to be the **band 7b (1160-1280 Å)**. If a second band would be possible, **band 6 (690-850 Å)** is a very good choice, as it includes the Ne VIII lines, which are the only suitable lines to investigate the plasma on open field lines (such as in coronal holes), as Ne VIII is formed just around the maximum temperature of these structures at logT=5.8. (Fe IX in Band 1 formes at similar temperatures, but at the short wavelength the spectral resolution would not be sufficient to resolve velocities down to a km/s).

2. Spectral resolution requirements

In order to have access to the intrinsic dynamics of the atmosphere, it will be necessary to resolve line shifts of a few km/s, as the net line shifts at low and high temperatures are around 5 km/s. Individual shifts during e.g. explosive events can be higher, but it will be also of importance for future models to be confronted with the dynamics in the quiet atmosphere.
With increasing spatial (and temporal) resolution one can also expect to see highly non-Gaussian spectral profiles, so the spectral resolution should be well below the FWHM.

3. Spatial coverage

For a high resolution mission it would be illusory to cover a whole active region. At least several granules would have to be covered, and preferable a full super-granular cell. One could use a slit covering some 40 Mm along the slit and raster a map of some 40 Mm x 10 Mm. Larger context raster maps should be possible for comparison with imagers.

4. Time resolution (incl. count rates)

One should allow for sit-and-stare mode and for raster maps of various sizes. To see the dynamic evolution strong lines should allow for a few seconds cadence. The large maps (40 Mm x 10 Mm) would then require some 2-3 minutes, which might be sufficient to track the evolution in the future models.

5. Requirements for other instruments

VIM and EUI observations for the magnetic field and the coronal evolution will be very important. Also the in-situ observations of energetic particles might be very useful, especially in the co-rotation phase.

6. Other requirements

For observations on the hemisphere visible from Earth, support from ground-based observatories would be very helpful. At the time when the Orbiter will fly we can expect ground-based photospheric observations matching the resolution of the Orbiter providing complementary information.

Relation to Solar Orbiter science goals

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

Future models of atmospheric heating will (hopefully) include production of energetic particles, even on the quiet Sun, and thus also be of interest for this science goal.

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

This study aims at a treatment of the whole solar atmosphere as an integrated system. Thus it directly aims at this science goal.

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

The comparison of Orbiter observations with future models will provide new insight into the structure and dynamics of the atmosphere and its interaction with the magnetic field.

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

N/A