Science with the Extreme Ultraviolet Spectrometer for Solar Orbiter

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Wavelength bands

• Wavelength bands covered by a spectrometer strongly affect the science

• From the 1st Solar Orbiter Workshop three spectral bands were identified:
  – 170-210 Å
  – 580-630 Å
  – some band above 912 Å

• This decision has been re-assessed
  – science cases were submitted by the science community (35 received)
  – an EUS Science Working Group was set up to review the science cases
Selected bands

- The following wavelength bands were identified as best representing the science cases:
  
  700 – 800 Å  
  970 – 1040 Å  
  1163 – 1265 Å 

- The additional bands 485 – 520 Å and 581 – 633 Å are observed in second spectral order superimposed on the first order spectrum.

- All three bands are required to achieve the science goals.
Key features

- Strong lines from a wide range of temperatures

<table>
<thead>
<tr>
<th>Region</th>
<th>Lines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chromosphere/low transition region</td>
<td>H I Ly-α, He I λ584, C II λ1036</td>
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<tr>
<td>Transition region</td>
<td>Si III λ1206, C III λ977, N IV λ765, O V λ629, O VI λ1032</td>
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<tr>
<td>Corona</td>
<td>Ne VIII λ770, Mg X λ624.9, Si XII λ520.7</td>
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<tr>
<td>Flaring corona</td>
<td>Fe XVIII λ974.9, Fe XIX λ592.2</td>
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</tbody>
</table>

- C III λ1176/λ977 and O V λ760/λ629 density diagnostics
- Lines from consecutive ion stages (O I-VI, C I-III, N III-V)
- Cool lines allow wavelength calibration accurate to 1-2 km s⁻¹
- Continuum for VIM co-alignment
Solar Orbiter science goals

- A UV spectrometer is critical for two of the four Orbiter science goals

2. Investigate the links between the solar surface, corona and inner heliosphere
   - EUS will simultaneously observe plasma from the chromosphere, transition region, corona and flaring corona
   - Velocity measurements yield plasma flow speeds into heliosphere

3. Explore, at all latitudes, the energetics, dynamics and fine-scale structure of the Sun’s magnetized atmosphere
   - Density and line width measurements essential for studying energetics of plasma
   - Accurate centroiding and line widths give dynamics
   - Emission line coverage suitable for coronal holes
Quiet Sun structure


C III 977.02 Å 29-Jan-1996 7s

Visible G-band

Dynamic events

• UV instruments have revealed a wealth of dynamic events in the quiet Sun transition region
  – explosive events, blinkers, (macro)spicules, bursts, …

• EUS will provide a unified picture of these events
  – spectral resolution comparable to SUMER
  – simultaneous coverage of several transition region lines
  – spatial resolution will resolve structure
  – co-alignment with VIM for magnetic structure
Coronal holes, solar wind

- The contribution of plumes to the fast solar wind is still controversial (Teriaca et al. 2003; Gabriel et al. 2003)
  - high latitude coronal hole observations required
  - EUS will measure outflow velocities in source regions

- Source region of the slow solar wind
  - suggested to be coronal hole/quiet Sun boundary (Fisk et al. 2005)
  - reconnection can be spectroscopically identified through line broadening
  - in situ measurements may detect heliospheric consequences
Waves and seismology

- Waves provide a means of heating the corona, and also of diagnosing the atmosphere (density, magnetic field)

- The solar atmosphere is magnetically coupled to the surface, and oscillations triggered by convective motions
  - wave physics requires simultaneous photospheric, chromospheric, TR, coronal observations
  - De Pontieu et al. (2004) have demonstrated leakage of photospheric oscillations into chromosphere

- Velocity or line width oscillations reveal wave modes ‘invisible’ to imaging instruments (e.g., Alfvén waves)
Active regions

- The transition region is crucial for understanding coronal loop heating
  - the TR responds to coronal heating through chromospheric evaporation
  - EUS will provide density and velocity measurements in the footpoints
  - high spatial resolution is required for resolving footpoints

- Recent nanoflare models (see Klimchuk 2006 review) suggest emission lines at 6-8 MK are the best diagnostics of the heating parameters
  - EUS will measure Fe XVIII $\lambda 974$ and Fe XIX $\lambda 592$ (6, 8 MK)
  - high spectral resolution yields plasma dynamics
Links to other instruments

- **VIM**
  - Photospheric features can be matched to transition region features through cool EUS lines
  - EUS continuum images allow accurate co-alignment

- **EUI**
  - Imaging *essential* for interpretation of spectroscopic data
  - EUI bands must complement EUS wavelengths

- **STIX**
  - EUS will have sensitivity to flare temperatures (Fe XVIII, Fe XIX)

- **COR**
  - H I Lyα will be observed by both instruments
Summary

- EUS is *essential* to achieve the Solar Orbiter science goals

- Proposed wavelength bands are:
  - 700 – 800 Å
  - 970 – 1040 Å
  - 1163 – 1265 Å

- Spatial resolution of 1” (150 km at perihelion)
- Spectral resolution around 100 mÅ (comparable to SUMER)