Magnetoseismology – Resonant Coupling of Helioseismic Modes to the Lower Solar Atmosphere

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Helioseismic observations suggest that the global *f* (fundamental) and *p* (pressure) mode oscillations are not completely trapped in the solar interior but they partially penetrate into the atmosphere (De Pontieu, Erdelyi, James, Nature, 430, 536, 2004).
The atmospheric magnetic fields have fundamental effects on the solar structures and dynamics above the photosphere. One group of them is predicted by magnetohydrodynamic (MHD) modelling of the Sun, that is, slow and Alfvén waves, with spatially varying frequencies, can propagate basically along the magnetic field lines.
The *f* and *p* modes penetrated through the photosphere from the interior have small amplitudes, by which they are currently undetectable with the available instruments. However, these *f* and *p* mode oscillations, with global frequency resonantly interact with local slow and Alfvén waves at regions where the global frequency of these acoustic modes matches the local frequency of the slow or Alfvén oscillation. This resonant interaction, according to results of intensive and extensive MHD modelling, can strongly increase the amplitudes of the *f* and *p* mode oscillations, and by that they are observable (Erdelyi, Phil. Trans. Roy. Soc A, 364, 351, 2006).
The observation of the presence of global helioseismic modes in the lower (or upper!) solar atmosphere will be a real scientific discovery event for itself, notwithstanding for its diagnostic implication. As seismology has become the Rosetta stone to the deeper understanding of the solar interior, extending this method into magnetically dominated plasmas, it can become a similar important diagnostic tool for the lower (and upper) solar atmosphere.
The aim of this case is to observe global *f* and *p* modes coupled into the lower (or possibly even upper) regions of the atmosphere, which is basically the chromosphere (and transition region to lower corona), demonstrate that resonant interactions between global helioseismic and local slow and Alfvén waves do occur *well above* the photosphere.
For that, we propose to measure intensity and Doppler shift in a small, magnetically active region of the chromosphere and transition region for long enough time that frequencies and line widths can be studied in the Fourier spectrum of the observed data. The Solar Orbiter, observing the Sun from the unprecedented small distances, can meet these requirements, and by that it will be able to contribute to number one discoveries in the rapidly emerging magnetoseismology in solar physics by observing resonant coupling of oscillation modes.

EUS instrument requirements

1. **Emission line requirements**

Diagnostics in the chromosphere, transition region and low corona are required.

2. **Spectral resolution requirements**

The line profile from EUS observations has to be resolved in order to study temporal variations of line widths.

3. **Spatial coverage**

A small part (of the lower atmosphere) of an active region with a typical spatial size of around 50 Mm x 50 Mm should be covered.

4. **Time resolution (incl. count rates)**

Sit-and-stare exposures can be repeated on timescales of seconds. 100 counts in 5 seconds are required for the key emission lines.

5. **Requirements for other instruments**

Vector magnetograms from VIM and EUI images at around 1MK temperature are required for magnetic measurements.

6. **Other requirements**

No.

Relation to Solar Orbiter science goals

Indicate how your science fits in with the four Orbiter science goals. Simply type “N/A” if it’s not applicable to a science goal.

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**

Finding evidence for resonant interaction between global helioseismic oscillations and atmospheric slow and/or Alfvén waves would provide an unprecedented insight into the coupling of the solar interior and photosphere to the atmosphere.

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

The observation of the *f* and *p* modes in the solar atmosphere would provide a strong tool for local magnetic diagnostics. According to preliminary modelling studies, a sophisticated method of data analysis, developed from the so-called ring-diagram analysis, would provide measurements of strengths and directions of local magnetic fields (Pintér, Erdélyi, Goossens, A&A, submitted).

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

N/A