Topological Lamb-like waves propagate in the Sun

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Our nearest star, the Sun, has been the subject of extensive study over many years, contributing significantly to our understanding of stellar structure and evolution. For a long time, however, our knowledge of its internal structure was limited. Thanks to the detection of global oscillation modes since the early 1960's, we now have the means to directly probe the solar interior. This is because the properties of these modes - such as amplitude, frequencies, and lifetime - depends on the internal structure and dynamics of the Sun. They've allowed us to precisely measure properties such as rotation, composition, and sound speed profiles.

These oscillation modes fall into three main categories: p-modes, g-modes, and f-modes. P-modes and g-modes, arising from acoustic and internal gravity waves respectively, have been extensively studied in the fields of helioseismology and asteroseismology. The f-mode, which represents the n = 0 mode of the star, occupies an intermediate position in terms of frequency but lacks a clear definition, sometimes referred to as either a fundamental p- or g-mode or a surface mode.

Observationally, only p-modes have been detected in the Sun, primarily probing its outer layers, and leaving uncertainties about the innermost regions. Efforts have been made to detect g-modes, which are believed to exist in the radiative core and could offer vital insights into these inaccessible regions, but to date, no confirmed detections have been made. As for the f-modes, clear detections at high angular degrees (small scales) have been identified as surface modes, but their inability to probe the Sun's interior has led to less attention.

This presentation aims to demonstrate that the low angular degrees (large scale) portion of the f-mode branch is not a surface mode but rather a Lamb-like wave. The origin of this wave lies in topological principles of the wave equation. However, its low angular degree and n=0 nature has led to its analytical oversight in widely used approximations like JWKB. The Lamb-like wave lacks vertical velocity and is vertically trapped, yet it exhibits horizontal velocity within the star, particularly in its deeper layers. This could offer an alternative to g-modes to probes the solar core. Recently hypothesized by Leclerc et al., we validate the existence of this topological oscillation mode using hydrodynamical simulations of a solar model. We use the MUSIC code, which is fully compressible, a necessary condition for the propagation of the Lamb-like wave.

In conclusion, we confirm the prediction that the physical nature of the f-mode is a Lamb-like wave at low angular degrees using hydrodynamical simulations of the solar interior. Moreover, the frequency range associated with these Lamb-like waves may soon become accessible through observational data, potentially offering unprecedented insights into the Sun's innermost layers.