Helioseismic and spectroscopic evidences for acoustic wave sources beneath a sunspot umbral photosphere

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Using a high cadence imaging spectropolarimetric observations, made with the IBIS (Interferometric BI-dimensional Spectrometer) instrument at National Solar Observatory of USA at Sac Peak, of a sunspot and its surroundings we study interations between quiet-Sun acoustic waves and the sunspot magnetic field. We map the wave phases and helioseismic travel times as a function of height within the formation region of the photospheric magnetically sensitive Fe I 6173 A and insensitive Fe I 7090 A lines, through a direct spectroscopic and time-distance helioseismic analyses, respectively. We show evidences for acoustic wave sources beneath the umbral photosphere from the observation height dependent changes in the travel times of out-going waves from the sunspot. We discuss the possible origin of these sources in field free convection beneath the umbra of the spot and its implications for sub-surface structure of sunspots. We also discuss the implications of this finding for helioseismic inferences on flows beneath sunspots based on travel time asymmetries between the in- and out-going waves to and from a sunspot.

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