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Calculation of effective seismic properties of untextured crystal aggregates and application to inner crystallisation

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The top of Earth's inner core behaves as a strongly scattering, statistically isotropic body. This is evidenced simultaneously by the existence of a prominent backscattered coda of the reflected core phases, and by the isotropic behaviour and strong attenuation of P waves that bottom at shallow depth in the inner core. To interpret these observations, we propose to model the superficial part of the solid core as an untextured aggregate of iron "patches", each patch being characterized by the anisotropic properties of individual iron crystals. To calculate the seismic response of such a body we have developed a formalism based on the Dyson equation, that takes into account all the physics of the problem: arbitrary anisotropy of individual grains, mode conversions, multiple scattering. The solutions of the Dyson equation yield effective velocities and scattering attenuation lengths for both P and S waves. We use our theory to test existing models of elastic properties of iron at core conditions obtained from ab-initio calculations or laboratory experiments. We find that for all the models proposed in the literature, the scattering attenuation of S waves is larger by more than one order of magnitude than the attenuation of P waves. This may explain why S waves propagating through the core have been so difficult to observe. In addition we show that models with similar effective velocities can have more than one order of magnitude difference in attenuation. By comparing observed P wave attenuations with our theoretical predictions, we put new constraints on the possible stable phases of iron at core thermodynamical conditions.