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Origins of anisotropic seismic attenuation of the inner core - intrinsic anelasticity of hcp iron alloy

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Earth's inner core is elastically anisotropic, with seismology showing faster wave propagation along the polar axis compared to the equatorial plane. Some inner core studies report anisotropic seismic attenuation. Attenuation of body-waves has, previously, been postulated to be due to scattering by anisotropic microstructure, but recent normal mode studies also show strong anisotropic attenuation (Mäkinen et al. 2014). This suggests that the anisotropic attenuation is a result of the intrinsic (and anisotropic) anelastic properties of the solid iron alloy forming Earth's inner core.

Here, I consider the origins of inner core anisotropic attenuation. Possibilities include grain boundary relaxation, dislocation bowing/glide, or point defect (alloying element) relaxations. The inner core is an almost perfect environment for near-equilibrium crystallisation, with very low temperature gradients across the inner core, low gravity, and slow crystallisation rates. It is assumed that grain sizes may be of the order of hundreds of metres. This implies vanishingly small volumes of grain boundary, and insignificant grain boundary relaxation. The very high homologous temperature and the absence of obvious deviatoric stress, also leads one to conclude that dislocation densities are low. On the other hand, estimates for light element concentrations are of the order of a few % with O, S, Si, C and H at various times being suggested as candidate elements.

Light element solutes in hcp metals contribute to intrinsic anelastic attenuation if they occur in sufficient concentrations to pair and form elastic dipoles. Switching of dipoles under the stress of a passing seismic wave will result in anelastic mechanical loss. Such attenuation has been measured in hcp metals in the lab, and is anisotropic due to the intrinsic elastic anisotropy of the host lattice. Such solute pair relaxations result in a "Zener effect", which is suggested here to be responsible for observed anisotropic seismic attenuation.

Zener relaxation magnitude scales with solute concentration and is consistent with around 5% light element. Variations in attenuation are expected in a core with spatially varying concentrations of light element, and attenuation tomography of the inner core could, therefore, be employed to map chemical heterogeneity.