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The enigmatic Earth's core: constraints given by seismology

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The Earth's core represents about 1/3 of the mass of the Earth, with a radius of 3480 km for the liquid core and 1220 km for the solid inner core. Its composition is mostly iron with a small percentage of light elements. It is widely accepted that the inner core (IC) grows from the solidification of the liquid core, with release of latent heat and light elements which power the dynamo at the origin of the magnetic field.
A model of slow, radial growth has long been considered. However, simple analyses or sometimes direct observations of seismic waves sampling the core reveal puzzling features, which depart from spherical symmetry. In particular, the inner core is anisotropic, with a fast axis parallel to Earth rotation axis. A strong frequency dependence of the anisotropy is observed for these fast polar paths, but not for those parallel to equatorial plane. Moreover, the anisotropy is not uniform: the upper part of the IC is isotropic and its central part has a different anisotropy. More surprisingly, the IC presents a hemispherical dissymmetry, with distinct properties in the quasi-eastern and quasi-western hemispheres. Attenuation shows a similar hemispherical dichotomy, but the correlation between attenuation and velocity is opposite to that in the mantle. On the other hand, very small scale heterogeneities, with length scales of the order of 1-10 km, are present at the inner core boundary. By contrast, the liquid core appears homogeneous to seismic waves, except close to its boundaries. In particular, the lowermost 100-200 km of liquid core depart from neutral stratification and they also present a weak hemispherical dissymmetry.
These strange features raise many questions, most of them still open, on the nature of the IC and on its solidification mechanism. The form of iron able to explain the anisotropy remains controversial, as well as the mechanisms generating crystal alignment and anisotropy variations inside the inner core. At the inner core boundary (ICB), two models of solidification are opposed: a dendritic growth from the inner core surface, or sedimentation of a slurry layer from the liquid core. The inner core dichotomy also is not yet fully understood. It could be explained either by a thermal forcing by the heterogeneities of the mantle, or by a convection mode of the inner core, of thermal or compositional origin. The dense layer at the base of the liquid core could result from this convection mode.
A better understanding of core processes will require new data, in particular for sampling the ICB, which appears as a key region. Wave scattering in the uppermost inner core may inform on the texture of the newly formed solid and on its compaction, whereas the gradient above ICB may give insight on the fate of the light elements. On the other hand, a better 3D image of inner core anisotropy is hardly accessible with the available seismic source distribution. In a near future, noise analyses will probably open new possibilities for such studies.