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Magnetar formation through convective dynamo in protoneutron stars

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Magnetars are isolated neutron stars characterized by a variable X-ray activity powered by the dissipation of strong magnetic fields. Their spin-inferred dipole field strengths range from 100 to 1000 times those of radio pulsars. For many decades now, understanding the origin of these objects has been a theoretical challenge. Thanks to the first 3D MHD direct numerical simulations of thermal convection that develops inside a nascent neutron star, we show that the in situ magnetic field amplification by dynamo action can explain magnetar formation. For sufficiently fast rotation rates, the instability saturates in the magnetostrophic regime with the magnetic energy exceeding the turbulent kinetic energy by a factor up to 10. Our results are compatible with the observational constraints derived from galactic magnetars and also provide strong theoretical support for millisecond protomagnetar models of gamma-ray bursts and superluminous supernovae central engines.

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