Crystallization dynamos: slow convection and fast rotation

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It has been recently suggested that white dwarfs generate magnetic fields in a process analogous to the Earth. The crystallization of the core creates a compositional inversion that drives convection, and combined with rotation, this can sustain a magnetic dynamo. We reanalyse the dynamo mechanism, arising from the slow crystallization of the core, and find convective turnover times $t_{\rm conv}$ of weeks to months – longer by orders of magnitude than previously thought. With white dwarf spin periods $P \ll t_{\rm conv}$, crystallization-driven dynamos are almost always in the fast rotating regime, where the magnetic field B is at least in equipartition with the convective motion and is possibly further enhanced by a factor of $B \propto (t_{\rm conv}/P)^{1/2}$, depending on the assumed dynamo scaling law. We track the growth of the crystallized core using MESA and compute the magnetic field $B(T_{\rm eff})$ as a function of the white dwarf's effective temperature $T_{\rm eff}$. We compare this prediction with observations and show that crystallization-driven dynamos can explain some – but not all – of the $\sim$MG magnetic fields measured for single white dwarfs, as well as the stronger fields measured for white dwarfs in cataclysmic variables, which were spun up by mass accretion to short P. Our $B(T_{\rm eff})$ curves might also explain the clustering of white dwarfs with Balmer emission lines around $T_{\rm eff} \approx 7500$ K.