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The Oklo natural fission reactors and dynamical models of dark energy

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Paul Dirac is credited with being the first physicist to speculate in print that fundamental constants like the Newtonian gravitational constant G may change over cosmological intervals. Incongruous though this notion may be, it has gained traction among physicists. Modern theoretical frameworks, which attempt to unify all the fundamental forces, accommodate the possibility of varying fundamental constants, as do dynamical models of dark energy. There are intriguing hints, from absorption spectra of interstellar matter, that the fine structure constant α, which determines the strength of electromagnetic interactions, may vary spatially across the cosmos, the changes found being at the level of about 10 parts per million (ppm). This astrophysical result is in stark contrast to a seminal study (conducted by Thibault Damour and Freeman Dyson) of Oklo neutron capture data which concludes that, in the time since the Oklo natural fission reactors were active (about 1.95 billion years ago), α has changed by less than 0.1 ppm. There is a tendency to take this Oklo bound *cum grano salis* because of the perception that the nuclear physics invoked in its derivation is fraught with substantial unquantifiable uncertainties. I discuss excitation, Coulomb, and deformation corrections, using deformed Fermi density distributions fitted to the output of Hartree-Fock + BCS calculations (with both the SLy4 and SkM* Skyrme functionals), the energetics of the surface diffuseness of nuclei, and thermal properties of their deformation. Although the net correction is uncertain to a factor of 2 or so, it constitutes no more than 25% of the Damour-Dyson estimate. Making allowance for additional uncertainties in the modelling of the Oklo reactors, I conclude that, subject to a weak and testable restriction on the change in light quark masses, the relative change in α over the last 1.9 billion years is less than 0.01 ppm (95% C.L.). This bound reinforces the idea that, of the many dark energy models which predict that fundamental constants do change, only those which suppress the variation of α in the presence of matter are phenomenologically acceptable.