# Experimental Constraints on the Concentration of Dirac Magnetic Monopoles in Primordial Material returned from Asteroid Ryugu by JAXA's Hayabusa2 Mission

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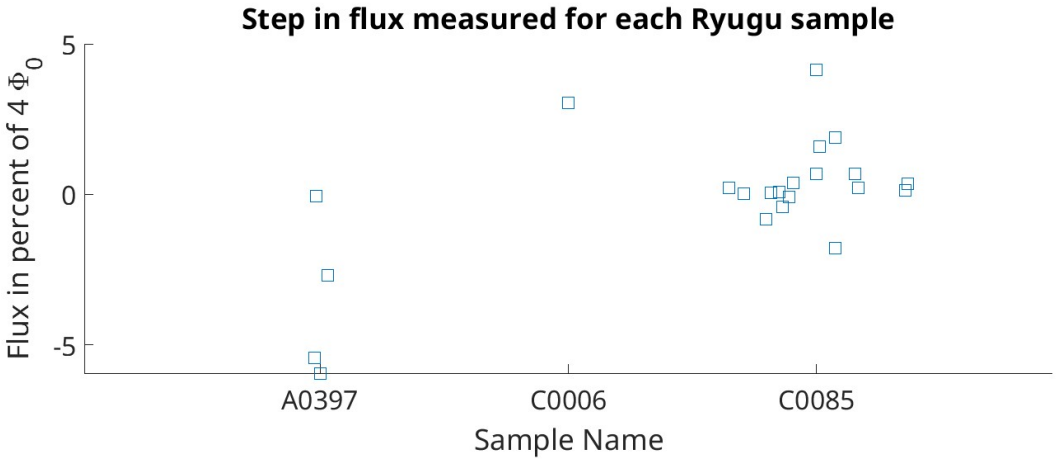
In 1931, Dirac postulated the existence of elementary particles with quantized magnetic charge as an explanation for the observed quantization of electric charge. If found, Dirac magnetic monopoles (DMMs) would require a re-evaluation of electromagnetism and all related theories. However, DMMs have not yet been empirically discovered. Their predicted magnetic charge, multiples of $2\mathbf{\Phi}_0$ (where $\mathbf{\Phi}_0$ is the magnetic flux quantum: ~2.07 fWb), would be detected easily with modern superconducting quantum interference device (SQUID) magnetometers. If cosmic DMMs were trapped on ferromagnetic grains in pre-solar materials, then a promising place to search for them would be in material sampled from primitive small bodies, preferably returned by spacecraft on low-acceleration trajectories, since intense accelerations experienced by meteorites could strip them of DMMs as they enter Earth's atmosphere. By passing material through a 2G SQUID rock magnetometer, a theoretical DMM trapped within ferromagnetic grains would return a change in measured magnetic flux ($\Delta\Phi$) by multiples of $4\mathbf{\Phi}_0$, or ~8.23 fWb. We performed this experiment on three Hayabusa-2 samples returned from the asteroid Ryugu: samples collected from the sites TD1 (A0397) and TD2 (C0006 and C0085), with a combined mass of 18.7 mg. We measured $\Delta\Phi$ as -0.3 ± 0.2 fWb for A0397, 0.3 ± 0.5 fWb for C0006, and 0.4 ± 1.1 fWb for C0085. Although our numbers were not significantly different from zero and are well below the expected magnetic charge for DMMs, we only sampled 18.7 mg of the ~5g of primitive asteroidal material returned from Ryugu, which is in turn an infinitesimal fraction of the solar system. Due to their importance for all of science, we argue that all primitive materials returned from space missions should be screened routinely for DMMs as part of their initial characterization in the sample receiving laboratories.




Summarized results of 22 pass-through experiments conducted on returned Ryugu samples A0397, C0006, and C0085. Here, $\Delta\Phi$ is expressed as a percentage of 4Φ0 – the minimum quantized change in flux expected by a Dirac magnetic monopole. Since $\Delta\Phi$ of all samples is much lower than $4\mathbf{\Phi}_0$, we have not yet detected a magnetic monopole.