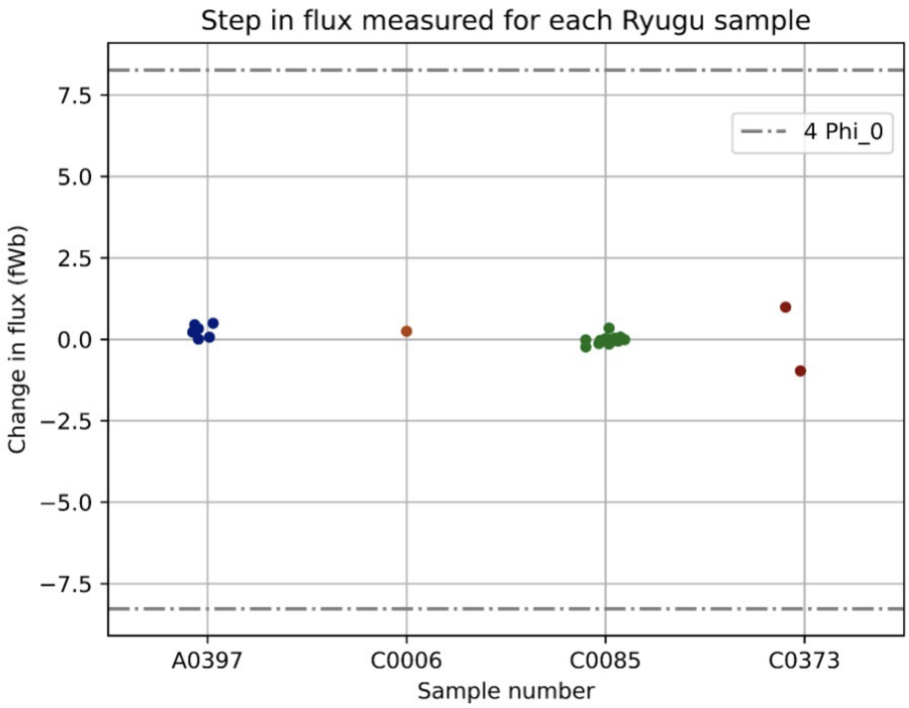
Updates on the Search for Dirac Magnetic Monopoles within Returned Ryugu Samples

Joseph Kirschvink[1, 2], Michael Sowell[1], Chisato Anai[2], Atsuko Kobayashi[1, 2], Yuhji Yamamoto[2], Elias Mansbach[3], Eduardo A. Lima[3], Masahiko Sato[4], Chie Kato[5], Hirosi Ooguri[1], Tadayuki Takahashi[6], Thomas Melia[6], Alexander Kusenko[7], Volodymyr Takhistov[8] and Tomohiro Usui[9]

[1]California Institute of Technology, Pasadena, CA, USA; [2]Marine Core Research Institute, Kochi University, Kochi, Japan, [3]Massachusetts Institute of Technology, Cambridge, MA, USA, [4]Tokyo University of Science, Tokyo Japan, [5]Kyushu University, Fukuoka, Japan, [6]University of Tokyo, Kavli IPMU, Kashiwa, Japan, [7]University of California Los Angeles, USA, [8]High Energy Accelerator Research Organization (KEK), and [9]JAXA Astromaterials Science Research Group, Sagamihara, Japan

In modern physics, the absence of Dirac magnetic monopoles remains a mystery. Magnetic monopoles are expected to arise in any theory that unifies the strong and electroweak forces, and their existence would explain the observed quantization of electric charge in the universe. So far, no magnetic monopole has ever been experimentally confirmed to exist. Assuming that the pre-Solar nebula can decelerate cosmic magnetic monopoles to a point where they can then be bound to ferromagnetic minerals, monopole searches in matter should be performed on primitive material that has experienced as little acceleration upon atmospheric entry as possible. Thus, returned asteroidal samples are the best candidate for monopole searches.

We have tested for the presence of Dirac magnetic monopoles in material returned from the asteroid Ryugu by the Hayabusa2 mission. By passing material through the superconducting Helmholtz coils of SQUID rock magnetometers, a quantized Dirac magnetic monopole trapped within a sample's ferromagnetic grains would return a change in measured magnetic flux ($\Delta\Phi$) by an integer multiple of $4\Phi_0$, or ~8.23 fWb. As of last year, we had performed this experiment on three Ryugu samples (A0397, C0006, and C0085) with a combined mass of 18.7 mg, detecting no magnetic monopoles. We have recently performed the pass-through experiment on the aggregate sample C0373, which nearly doubles the amount of asteroid matter screened to ~37 mg. For this sample, we measured a north charge of $\Delta\Phi$ = +0.987 ± 0.003 fWb during the downward pass-through, and a south charge of $\Delta\Phi$ = -0.969 ± 0.003 fWb during the upward pass-through. While the steps in flux measured in the two experiments are statistically significant, this is likely not a positive confirmation for the presence of a Dirac magnetic monopole. The measured $\Delta\Phi$ is less than the expected $4\Phi_0$ by almost an order of magnitude, and the two tests give equal but opposite results. We suspect that this inconsistent step function might be due to a slight miscalibration in the flux- counting feedback loop of the SQUID sensor used on sample C0373. Additional pass-through experiments on sample C0373 were halted by its swift return to JAXA Sample Curation. We hope to extend these studies to additional samples from Ryugu and Bennu.



Summarized results of 24 pass-through experiments conducted on returned Ryugu samples A0397, C0006, C0085, and C0373. Here, $\Delta\Phi$ is expressed in terms of fWb. The dotted-dashed line represents $\Delta\Phi o$ = 8.23 fWb, which is the minimum quantized charge in flux expected by a Dirac magnetic monopole. Since $\Delta\Phi$ of all samples is much lower than $4\Phi o$, we have not yet detected a magnetic monopole.