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Nanoscale Magnetic Resonance Imaging Based on Ultrasensitive Force Detection[1]

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Magnetic Resonance Force Microscopy (MRFM) seeks to dramatically improve the sensitivity and resolution of magnetic resonance imaging (MRI), perhaps ultimately down to the molecular scale. It uses force detection to circumvent the sensitivity limits inherent in conventional inductively-detected MRI. By using an ultrasensitive, single crystal silicon cantilever cooled to 300 mK, we can detect forces smaller than 1 aN, allowing us to sense the magnetism from small ensembles of nuclear spins. We have used tobacco mosaic virus as a test object, detecting the hydrogen signal. Using three-dimensional scans and mathematical deconvolution algorithms, we have made 3D reconstructions of the viruses with resolution down to roughly 4 nm. This represents a $10^8\times$ improvement in minimum detectable volume compared to the best conventional MRI. Advancing the technique further will require reducing the force noise, increasing the achieved magnetic field gradients, and making use of the inherent chemical sensitivity of magnetic resonance.

[1]Work done in collaboration with Christian Degen, Martino Poggio, Charles Rettner, Tjerk Oosterkamp, Mark Sherwood and Dan Rugar