The renowned and mysterious hidden-order (HO) phase in URu$_2$Si$_2$ is intimately related to the large-moment antiferromagnetic (LMAFM) phase that is induced under pressure or upon iron (Fe) substitution. MagLab users performed electrical resistivity measurements on single crystals of URu$_{2-x}$Fe$_x$Si$_2$ in magnetic fields of up to 45T (Hybrid Magnet) and 65T (Pulsed Magnets). Various phases including HO, LMAFM, HO* (reentrant HO phase), SDW (spin density wave), FL (ordinary Fermi-Liquid metallic phase, recovered at high field), and PM (paramagnetic phase at high temperature) were mapped, along with P1 (a possible new intermediate-field phase), to establish a three-dimensional (3D) field – composition - temperature ($H$, $x$, $T$) phase diagram for this complex material.

The 3D phase diagram establishes a “universal” relationship between the normalized transition temperature $T/T_0$ and the normalized critical magnetic field $H/H_0$ for the HO phase: the $H/H_0$ versus $T/T_0$ data in the lower figure collapses onto a single curve. This curve provides tight constraints on potential models for the order parameter of the HO phase.

Within a certain range of $x$ values, $x \approx 0.17$, the HO phase reenters when magnetic fields suppress the LMAFM phase. This is similar to the behavior observed for pure URu$_2$Si$_2$ crystals within a certain range of pressures.

**Facilities and instrumentation used:** 65 Tesla capacitor-driven magnet at the MagLab’s Pulsed Field Facility, Los Alamos; 45 T Hybrid Magnet at the MagLab’ DC Magnet Facility, Florida State University;

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