Giant Spin Gap and Magnon Localization in the Disordered Heisenberg Antiferromagnet Sr$_2$Ir$_{1-x}$Ru$_x$O$_4$

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We study the evolution of magnetic excitations in the disordered two-dimensional antiferromagnet Sr$_2$Ir$_{1-x}$Ru$_x$O$_4$. A gigantic magnetic gap greater than 40 meV opens at $x = 0.27$ and increases with Ru concentration, from 40 meV to >150 meV, rendering the dispersive magnetic excitations in Sr$_2$IrO$_4$ almost momentum independent. Up to a Ru concentration of $x = 0.77$, both experiments and first-principles calculations show the Ir $J_{\text{eff}} = 1/2$ state remains intact. The magnetic gap arises from the local interaction anisotropy in the proximity of the Ru disorder. Under the coherent potential approximation, we reproduce the experimental magnetic excitations using the disordered Heisenberg antiferromagnetic model with suppressed next-nearest neighbor ferromagnetic coupling. Ref: Y. Cao et al., arXiv:1608.04640 (2016).