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The spin liquid ground state of the $S = 1/2$ Heisenberg model on the kagome lattice

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Condensed matter physicists have long sought a realistic two-dimensional (2D) magnetic system whose ground state is a *spin liquid*—a zero temperature state in which quantum fluctuations have melted away any form of magnetic order. The nearest-neighbor $S = 1/2$ Heisenberg model on the kagome lattice has seemed an ideal candidate, but in recent years some approximate numerical approaches to it have yielded instead a valence bond crystal. We have used the density matrix renormalization group to perform very accurate simulations on numerous cylinders with circumferences up to 12 lattice spacings, finding instead of the valence bond crystal a spin liquid, gapped in both the singlet and triplet sectors, with substantially lower energy. [Simeng Yan, David A. Huse, and Steven R. White, *Science* 332, 1173 (2011). *Cover article*] Our results, through a combination of very low energy, short correlation lengths and corresponding small finite size effects, a new rigorous energy bound, and consistent behavior on many cylinders, provide strong evidence that the 2D ground state of this model is a gapped spin liquid. One key feature of this spin liquid is that the predominant valence bond resonances occur on eight site loops rather than the shortest six site loops. The eight site loops allow a greater fraction of the bonds in the lattice to resonate. Our recent studies including a next nearest neighbor interaction J_2 reveal that the $J_2 = 0$ point is near the edge of a substantial spin liquid phase centered near $J_2 = 0.05 - 0.1$.