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Quantum mechanics displays Devil's crevasse

A new connection between quantum mechanics and chaos theory was found at the National Institute of Informatics (Director General: Masaru Kitsuregawa) in Tokyo, Japan.

Quantum mechanics is the study of microscopic objects and states that matter can have wave-like properties. This allows objects to be in two places at once – a principle that allows for famous paradoxes such as Schrodinger's cat.

Chaos theory, the study of complex classical systems, has given the world iconic images such as the Mandelbrot set (Figure 1). Such fractals are interesting as they possess a property called self-similarity – zooming in on an image gives an infinite amount of fine structure.

In the new work led by Assistant Professor Tim Byrnes, it was found that the entanglement between two clouds of atoms displays entanglement with fractal characteristics.

Entanglement is the purely quantum mechanical phenomenon where particles mysteriously show correlation with each other. This was an effect described by Einstein as a "spooky action at a distance", as the particles can be separated by large distances.

Byrnes found that when the time of interaction between the two clouds of atoms is varied, the amount of entanglement shows very rapid fluctuations. A closer analysis of the entanglement showed that it had a fractal nature, where it showed sharp drops every time the interaction time was a rational number (Figure 2).

Such fractal structures occur only occasionally in physical models. The closest effect is the "Devil's staircase" which occurs in antiferromagnetic materials.

The current effect has been coined the "Devil's crevasse" in analogy to the antiferromagnetic case. Between any two points on the curve, there are an infinite number of drops. If one

were to try and move across the landscape, one would have to negotiate an infinite number of crevasse-like features.

The discovery is anticipated to be useful for quantum information applications. An understanding of the entanglement could be applied to using the atomic clouds as quantum memories.

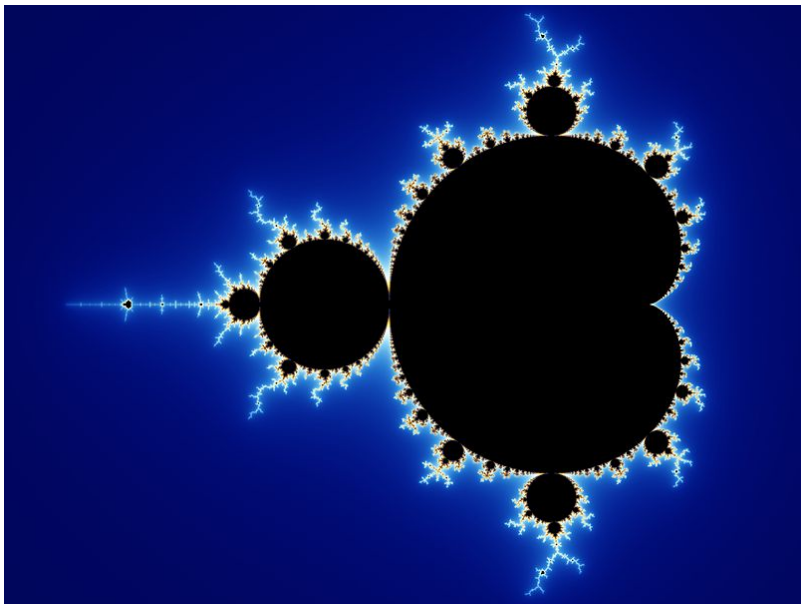

Figure 1 The Mandelbrot set, the most well-known example of a fractal structure

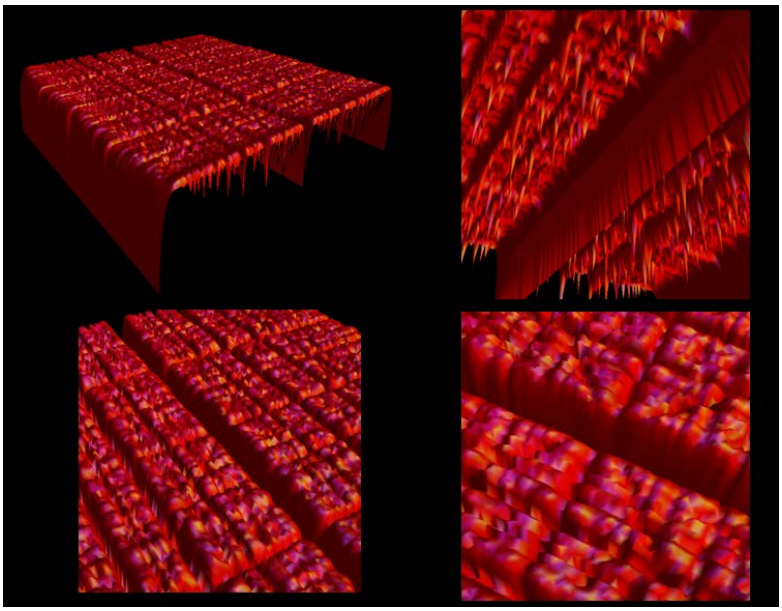

Figure 2 The Devil's crevasse entanglement as found in the new results. The plot shows the amount of entanglement between two atomic clouds as they interact.

Journal paper: "Fractality and macroscopic entanglement in two-component Bose-Einstein condensates", to appear in *Physical Review A.*

Preprint paper: http://arxiv.org/abs/1305.5095

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