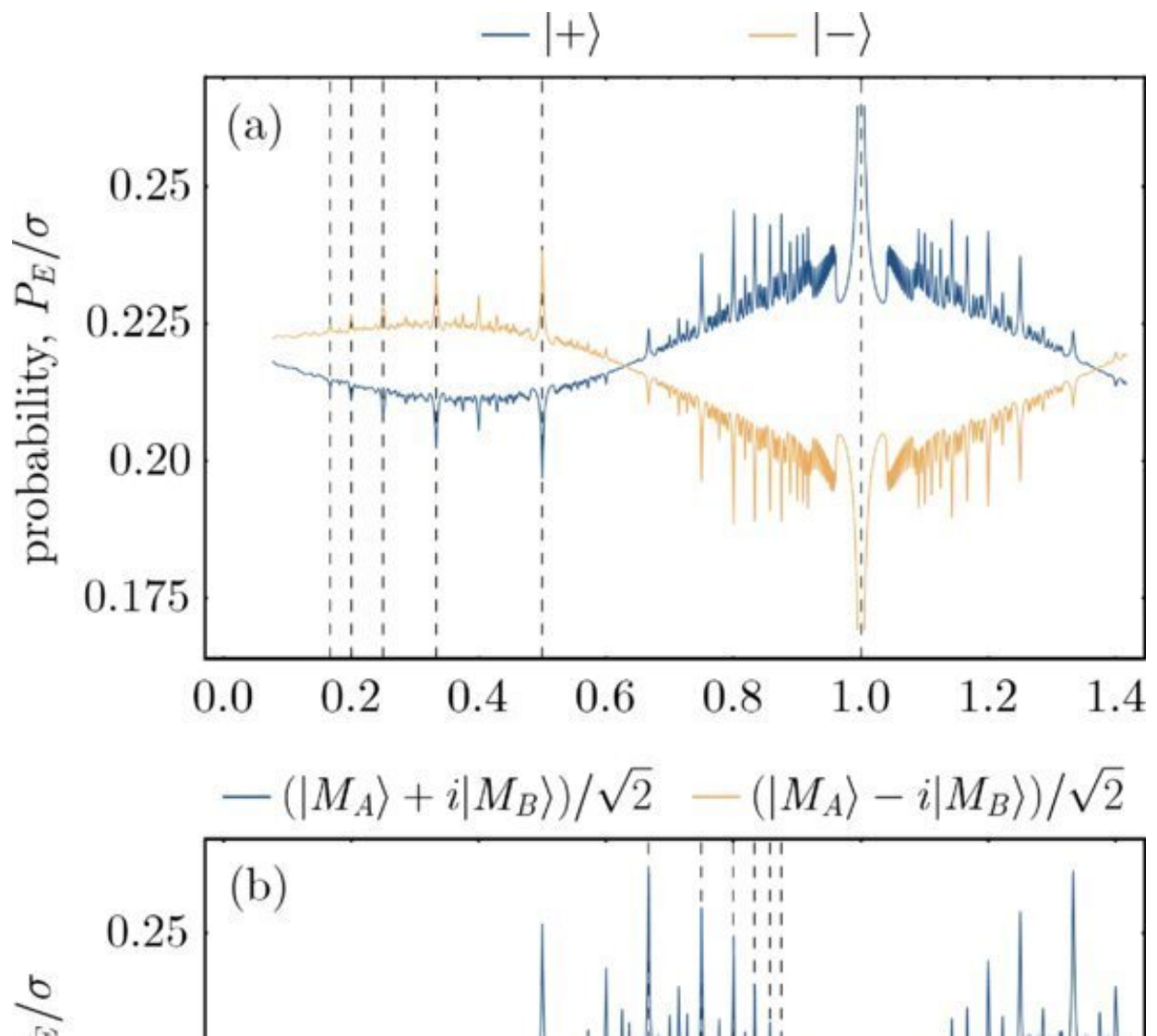


Uncovering the massive quantum mysteries of black holes

October 31 2022



Transition probability of the detector as a function of $\sqrt{M_B/M_A}$. The measurement basis corresponding to the relevant plot is indicated by the legend.

In (a), the dashed lines correspond to $\sqrt{M_B/M_A}=1/n$ where $n=\{1, \dots, 6\}$. In (b), the dashed lines correspond to $\sqrt{M_B/M_A}=(n-1)/n$ where $n=\{3, \dots, 8\}$. Moreover, the oscillating cross term in (b) is $\pi/2$ out of phase with that for the black hole measured in the (anti)symmetric basis. In all plots we have also used $l/\sigma=5$, $R/\sigma=25$, $t_f=5\sigma$, and $MAI^2=2$. Credit: *Physical Review Letters* (2022). DOI: 10.1103/PhysRevLett.129.181301

Bizarre quantum properties of black holes—including their mind-bending ability to have different masses simultaneously—have been confirmed by University of Queensland physicists.

A UQ-led team of theoretical physicists, headed by Ph.D. candidate Joshua Foo, ran calculations that reveal surprising black hole quantum phenomena.

"Black holes are an incredibly unique and fascinating feature of our universe," Mr. Foo said.

"They're created when [gravity](#) squeezes a vast amount of matter incredibly densely into a tiny space, creating so much [gravitational pull](#) that even light cannot escape.

"It's a phenomenon that can be triggered by a dying star.

"But, until now, we haven't deeply investigated whether [black holes](#) display some of the weird and wonderful behaviors of quantum physics.

"One such behavior is superposition, where [particles](#) on a quantum scale can exist in multiple states at the same time.

"This is most commonly illustrated by Schrödinger's cat, which can be

both dead and alive simultaneously.

"But, for black holes, we wanted to see whether they could have wildly different masses at the same time, and it turns out they do.

"Imagine you're both broad and tall, as well as short and skinny at the same time—it's a situation which is intuitively confusing since we're anchored in the world of traditional physics.

"But this is reality for quantum black holes."

To reveal this, the team developed a mathematical framework allowing us to "place" a particle outside a theoretical mass-superposed black hole.

Mass was looked at specifically, as it is a defining feature of a black hole, and as it is plausible that quantum black holes would naturally have mass superposition.

Research co-supervisor, Dr. Magdalena Zych, said that the research in fact reinforces conjectures raised by pioneers of quantum physics.

"Our work shows that the very early theories of Jacob Bekenstein—an American and Israeli theoretical physicist who made fundamental contributions to the foundation of black hole thermodynamics—were on the money," she said.

"He postulated that black holes can only have masses that are of certain values, that is, they must fall within certain bands or ratios—this is how energy levels of an atom works, for example.

"Our modeling showed that these superposed masses were, in fact, in certain determined bands or ratios—as predicted by Bekenstein.

"We didn't assume any such pattern going in, so the fact we found this evidence was quite surprising.

"The universe is revealing to us that it's always more strange, mysterious and fascinating than most of us could have ever imagined."

The research has been published in *Physical Review Letters*.

More information: Joshua Foo et al, Quantum Signatures of Black Hole Mass Superpositions, *Physical Review Letters* (2022). [DOI: 10.1103/PhysRevLett.129.181301](https://doi.org/10.1103/PhysRevLett.129.181301)

Provided by University of Queensland

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