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Quantum physics

Black hole paradox solution?

Black holes may not destroy all information about what they were originally made from, which would solve a major puzzle first described by Stephen Hawking, finds **Leah Crane**

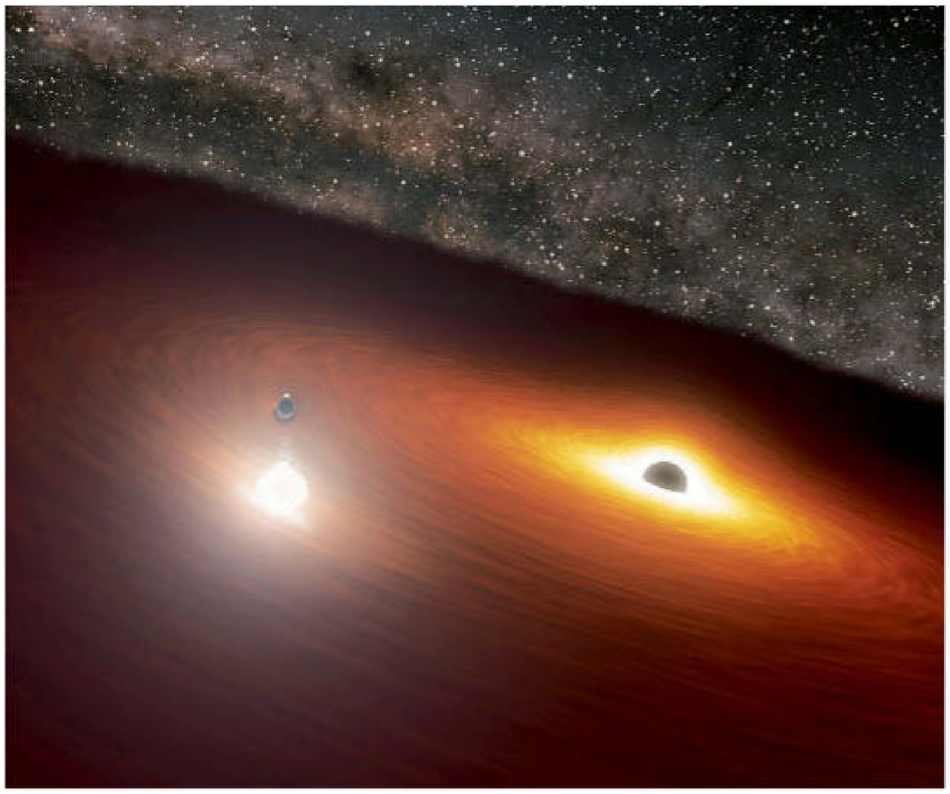
ONE of the biggest paradoxes in astrophysics may finally be solved. The question of what happens to information when it falls into a black hole has vexed physicists for decades, and now a group of researchers claims to have figured it out.

When Stephen Hawking calculated that black holes should slowly evaporate by emitting radiation – now called Hawking radiation – he also created a problem.

His work suggested the radiation should be emitted in a way that depended only on the black hole's current state and not on what previously fell into it. If correct, it would mean that when matter is pulled into a black hole, all the information about the state of that matter would be destroyed.

This isn't allowed in quantum mechanics, the laws of which require that it must be possible to use the state of any closed system at any point in time to extrapolate forward or backward in time. Essentially, it must be possible to mathematically rewind the system in order to understand its past state. However, if information is destroyed, that possibility is lost with it. This problem is called the black hole information paradox.

Xavier Calmet at the University of Sussex in the UK and Stephen Hsu at Michigan State University claim to have solved the paradox. Their work involved using a framework called quantum field theory to explore what happens when quantum mechanics and gravity interact at the edge of black holes.



NASA/JPL-CALTECH

Artist's impression of two black holes in a distant galaxy

When they applied quantum mechanical corrections to calculations of stars evolving into black holes, they found that these modifications required information to escape the system, along with Hawking radiation, once the star had become a black hole (*Physics Letters B*, doi.org/hmqc).

"If I have two black holes and they're made out of completely different things – one is made entirely out of shredded encyclopedias and the other is made of pumpkin pie – if they're the same mass, under classical physics they look exactly the same," says Hsu. "But what we're saying is that there are quantum features that distinguish between the encyclopedia black hole and the pie black hole."

"When you put quantum mechanics into a black hole, it becomes a more mundane object"

The calculations involved comparing two stars of the same mass and radius, one of which had the same density all the way through, while the other was made of shells of different materials with different densities.

In a second paper, Calmet, Hsu and their colleagues found that these two objects look slightly different from one another if gravity is assumed to come in small packets – quanta – in the same way that other physical phenomena, such as light, do (*Physical Review Letters*, doi.org/hmqd).

Each star's collapse into a black hole isn't expected to counteract this effect, nor is the slow evaporation of the black hole via Hawking radiation, says Calmet.

"When you put quantum mechanics into a black hole, strangely enough it becomes a more mundane object and, in principle, you should be able to take everything in the evaporation process, reverse time and build back a black hole and eventually a star," he says. If this is the case, then this extra information contained in the quantum gravitational field of the black hole would solve the black hole information paradox.

However, actually measuring that quantum information is far beyond any of our current capabilities, says Hsu. That makes this theoretical solution nearly impossible to confirm observationally or experimentally.

"It's a potential way out of the black hole information problem, but it would be extraordinarily difficult to find out whether it is the actual way out of the problem," says Neil Lambert at King's College London.

Even if this quantum information were the mechanism by which the information paradox is solved, the vagueness of this solution presents its own problem, says Don Marolf at the University of California, Santa Barbara.

"The real question is, how is this information inside the black hole transferred to the outgoing radiation and where does that happen?" says Marolf. "Noting that the information is correlated to what's going on far away from the black hole doesn't actually tell you how and where that information is transferred to the radiation."

In other words, the question of how exactly information escapes from a black hole when even light remains trapped inside stays unanswered regardless of whether quantum effects allow us to differentiate between an encyclopedia black hole and a pie black hole, he says.

There is more work to be done to dig down into what these quantum corrections really mean for our understanding of black holes and gravity, says Calmet.

But this research takes us one step closer to understanding how quantum gravity works, he says – which is an even bigger mystery than the information paradox. ▮