Mini black holes that look like atoms could pass through Earth daily

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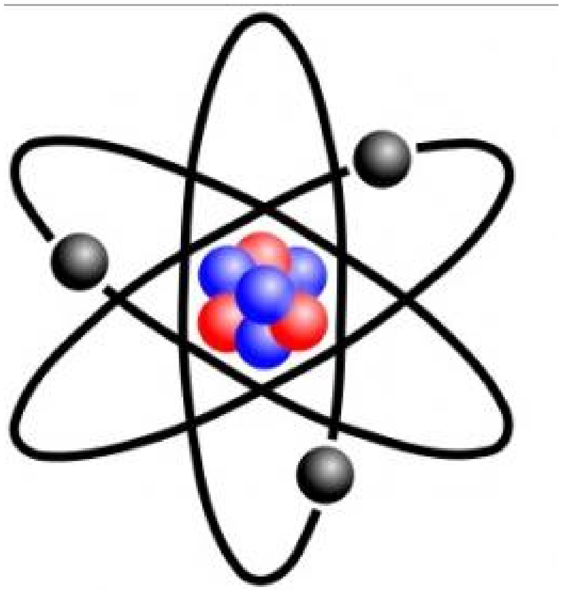

Similar to how electrons orbit an atomic nucleus without collapsing inward, mini black holes below a certain mass may cause surrounding matter to orbit without falling into the black hole. Image credit: Halfdan, Wikimedia Commons.

(PhysOrg.com) -- In a new study, scientists have proposed that mini black holes may interact with matter very differently than previously thought. If the proposal is correct, it would mean that the time it would take for a mini black hole to swallow the Earth would be many orders of magnitude longer than the age of the Universe.

In their paper, which is posted at arXiv.org, Aaron P. VanDevender from Halcyon Molecular in Redwood City, California, and J. Pace VanDevender from Sandia National Laboratories in Albuquerque, New Mexico, wanted to find a way to detect the mini black holes that are thought to exist in nature. Their calculations suggest that mini black holes may be passing through the Earth on a daily basis, and pose a very minimal threat to the planet.

Orbiting matter

Mini black holes are different than the ordinary astrophysical black hole in terms of how they're formed and their size. Whereas astrophysical black holes are formed by the collapse of giant stars, mini black holes are thought to have formed during the Big Bang, which is why they're also called primordial black holes. And while an astrophysical black hole has a minimum mass of 10^{30} kg, the mass of mini black holes range from the tiny Planck mass to trillions of kilograms or more, but are still much smaller than astrophysical black holes. (Although physics should allow for black holes of all sizes, scientists don't yet know of any mechanism that could produce objects in the intermediate range.) The expected mass of laboratory-produced mini black holes is on the small side, about 10^{-23} kg. Because of their extreme density, even the most massive mini black hole is microscopic in size.

The conventional view of a black hole is one of an object that is so dense that its powerful gravity pulls in all nearby matter past a critical point called the event horizon, from where it cannot escape. But the VanDevenders have suggested that something different happens with mini black holes with masses below 10^{12} kg. Instead of absorbing matter, these mini black holes may gravitationally bind matter, so that matter orbits the black holes at a certain distance. Because matter atoms orbiting a black hole due to gravity are reminiscent of the way that electrons orbit a nucleus due to electrostatic forces - both without collapsing inward - the physicists call this theoretical system the

Gravitational Equivalent of an Atom (GEA).

Although this may seem purely theoretical, the concept could provide a way to test the current theory of how mini black holes age and die, called quantum evaporation. In this process, mini black holes lose mass until they eventually disappear. As they lose mass, they should produce X-rays. However, attempts to observe the X-ray signature of the final stages of evaporation have so far been unsuccessful. This lack of evidence suggests that either mini black holes were not created in large numbers as predicted, or that they do not evaporate.

Assuming the latter explanation, the VanDevenders propose that, instead of searching only for evaporation effects, researchers should search for evidence of the actual existence of the mini black holes, as well. If their theory of mini black holes as GEAs is correct, then the gravitationally bound matter in a GEA should produce emissions that could be detected with current detectors, even though the chance of detecting these emissions would be slim.

“Quantum evaporation has been a major cornerstone of quantum gravity theories for three decades, yet it has never been experimentally confirmed,” Aaron VanDevender told *PhysOrg.com*. “Our study asks, ‘what if small back holes do not evaporate?’ We have shown that if they do not evaporate, they may interact with matter and be detected. If we are able to observe such objects, it will have a significant impact on our understanding of black hole evaporation, and quantum gravity in general.”

How a GEA works

In their paper, the researchers mathematically describe how a black hole can exist on Earth without consuming all of the surrounding mass. Such a mini black hole has constraints on its Schwarzschild radius, which is the closest an object can be to a black hole before it is absorbed, never to escape. Any object smaller than its Schwarzschild radius is a black hole. But because mini black holes with masses below 10^{12} kg are so small, they can have a Schwarzschild radius that is much smaller than the orbit of the gravitationally bound matter particles. As long as these matter particles stay beyond the mini black hole's Schwarzschild radius, they will orbit rather than be absorbed. (Black holes with masses of 10^{12} kg have a Schwarzschild radius that equals the ground state radius at which the nearest matter particles orbit, so this mass is the upper limit for a GEA.) The researchers compare the GEA's risk of collapse with that of real atoms.

"The concern that a terrestrial GEA might absorb the earth is similar to the early 20th century expectation that electrons orbiting a nucleus should radiate their energy away and fall into the nucleus," the researchers wrote in their study. "Since the electron energy levels are quantized and the expectation value of the radius of the ground state is much larger than the radius of the nucleus, the probability of an electron being captured by the nucleus is vanishingly small. Similarly, particles of mass m are unlikely to fall into the black hole at the center of a GEA; however, those few that do could, in principle, provide energy for observable emissions."

Up close

The scientists calculated that mini black holes with a mass of about 100,000 kg may be of particular interest, since they could be candidates for dark matter. They estimated that, if dark matter is composed primarily of mini black holes and is evenly distributed throughout the galaxy, then about 40 million kg of mini black holes should pass through the Earth every year. The researchers calculated that about 400 mini black holes per year could be detectable through their strong electromagnetic emissions from their gravitationally bound matter.

If a particle on Earth approaches a GEA while it's passing through the planet, the particle could either scatter off, be captured in orbit, or strip an already bound particle off. Due to the mini black hole's high velocity compared to the binding energy required to capture a particle, the researchers predict that the mini black hole would quickly be stripped of its particles as it passes through the Earth. Therefore, the search for the emissions should be focused on space-based sources.

"It would be difficult, but not impossible [to detect one of the mini black holes passing through the Earth]," Aaron VanDevender said. "The available power of a GEA to emit detectable radiation is small but not negligible. It would likely be substantially easier to observe a GEA in orbit around the Earth, rather than one that is passing through at a tremendous velocity. Also, the larger GEA will likely be much easier to detect, so it is worth focusing our observational efforts on objects in the range of 10^4 to 10^6 kg."

The researchers also noted that black holes created at the LHC would be too small and not have sufficient binding energy to bind matter into quantum orbitals that might emit detectable radiation.

In any case, according to this theory, mini black holes of any size would not absorb large amounts of matter very quickly. The scientists calculated that, for a black hole with a mass of 1 kg, it would take 10^{33} years to swallow the Earth. For comparison, the Universe is about 13.7 x 10^9 years old. And for smaller black holes like those that might be formed at the LHC, the time it would take to absorb the Earth would be even longer.

More information: A. P. VanDevender and J. Pace VanDevender. "Structure and Mass Absorption of Hypothetical Terrestrial Black Holes." arXiv:1105.0265v1 [gr-qc]