Title:
The quantized black hole as a theoretical laboratory

Long abstract:
Since direct experimental checks are extremely difficult to attain for string theories and other approaches to understand the gravitational force when subject to the laws of quantum mechanics, it was proposed to consider *thought experiments for quantised black holes*.

A black hole is the theoretical final state when a star, or some other heavy concentration of matter, is compressed by its own gravitational field with forces that exceed the limits that any ordinary forms of matter can endure. The stiffness of matter is always limited by the fact that sound in matter cannot propagate faster than the speed of light.
Einstein's theory of gravitation tells us what will happen, and since this theory not only meets with strict demands of internal logic, but has also been tested with many observations, its predictions are generally accepted as being realistic, so that black holes are generally assumed to exist in many parts of the universe.
However, at the atomic scale, matter is described by the equations of quantum mechanics, which are at the basis of all chemical, nuclear, and subnuclear phenomena that have been studied for over a century and are now also well understood.

The question then arises how black holes are to be described when quantum mechanics as well as Einstein's equations for the gravitational force are both acting together. One then notes that several theories produce conflicting, paradoxical or improbable predictions, which implies that they will have to be modified. We simply insist that the resulting equations can be used to obtain unequivocal predictions of their behaviour, while maintaining some basic principles of locality. Thus, the quantum black hole can be used as a laboratory for testing theories; the black hole horizon acts as a formidable particle accelerator as well as an ultramicroscope. On the other hand, black holes should behave as classical black holes in the classical (i.e. non quantum) limit.

When conventional theories are subject to this test, several modifications appear to be necessary. First, one finds that global, additive conservation laws such as baryon number conservation, cannot be exactly valid, as black holes can eradicate unlimited numbers of baryons. Next, one finds that all particles must be directly linked to geometric excitations of space and time, such as gravitons. In this respect, string theory does well. Furthermore, space-time itself is expected to have some bizarre features: it must allow for the existence of non-trivial; closed curves along which not only particles change into mirror-imaged antiparticles, but also the direction of time turns around.

The most important thing our "theoretical laboratory" tells us is that a properly quantized theory of gravity must contain black holes of all sizes and types living peacefully together with fundamental particles. This will be a big departure from the standard picture of particles forming Fock space. Counting of states will have to be in accordance with a holographic principle with consequences that depart more drastically from standard views than is normally assumed.

Literature:
Stephen Hawking, "A brief history of time"
Leonard Susskind, "The Black Hole War, my battle with Stephen Hawking
to make the world safe for quantum mechanics"
G. 't Hooft, "Nature's Book Keeping System", arXiv:1605.00027 [hep-th]

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