SCIENTIFIC FORUM

Forces and Their Particles

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Essay/Commentary · TACI-2026-00008 · Published 10 June 2026 · Volume 1, Issue 1

Keywords — Graviton, Forces, Elementary Particles, LIGO

HOW TO CITE THIS ARTICLE
APA: Hashmi, M. (2026). Forces and Their Particles. TACI Bulletin, 1(1). https://taci-bulletin.taci.com.pk/article.php?id=8

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Every fundamental force in nature has a particle that carries it.

Electromagnetism has the photon.
The strong nuclear force has the gluon.
The weak force has the W and Z bosons.

But gravity stands alone.

The force that keeps planets in orbit, binds galaxies together, and anchors your feet to the Earth has no confirmed quantum particle.

Physicists call this missing particle the graviton.

And its absence is not just an unsolved mystery. It is one of the deepest fractures in modern physics.

Because if the graviton does not exist, then our current understanding of reality may be fundamentally incomplete.

For more than a century, physics has been divided into two extraordinarily successful, yet incompatible, theories.

Quantum mechanics describes the microscopic world of particles and forces with astonishing precision. General relativity explains gravity as the curvature of space-time itself, governing stars, galaxies, and the structure of the universe.

Both theories work beautifully.

But they refuse to work together.

The moment physicists attempt to describe gravity using quantum mechanics, the mathematics collapses into catastrophic infinities. The equations stop producing meaningful physical answers.

This conflict has become one of the greatest unsolved problems in science.

The proposed solution is simple in principle, yet almost impossible to test.

If gravity is fundamentally quantum, then it should also possess a force-carrying particle: the graviton.

A massless spin-2 particle traveling at the speed of light.

Detecting even a single graviton would demonstrate that gravity obeys quantum laws and could open the path toward a unified theory describing all forces of nature.

But gravity is unimaginably weak.

It is approximately 10^{40} times weaker than electromagnetism. For decades, physicists believed detecting a single graviton would be practically impossible. Some estimates suggested it would require a detector the size of Jupiter positioned near a neutron star.

Then experimental physics began changing the rules.

In 2022, physicist Jack Harris at Yale University cooled superfluid helium to its quantum ground state and measured individual phonons, tiny quantum vibrations, within a macroscopic object.

At the same time, the LIGO observatory was routinely detecting gravitational waves produced by colliding black holes and neutron stars, ripples traveling directly through spacetime.

If gravity is quantum, those waves should consist of enormous numbers of gravitons acting collectively.

In 2024, physicist Igor Pikovski proposed a remarkable possibility.

What if a macroscopic quantum system could absorb a single graviton from a passing gravitational wave?

One graviton.

One measurable quantum excitation.

The gravitational equivalent of the photoelectric effect.

His work suggested that single-graviton detection may no longer belong purely to theoretical speculation.

Now, with support from the WM Keck Foundation, researchers are building what may become the world’s first graviton detector.

The experiment is extraordinarily delicate.

A small cylinder of superfluid helium is cooled to temperatures approaching absolute zero, eliminating nearly all thermal motion. When a gravitational wave passes through the detector, theory predicts that a single graviton could transfer one discrete quantum of energy into the helium, creating a measurable phonon.

Laser systems would then attempt to detect that microscopic quantum jump.

To reduce false signals, the detector will operate alongside LIGO. Whenever LIGO observes a gravitational wave, researchers will search for simultaneous quantum excitations inside the helium detector.

If those signals consistently align, it could become the first direct evidence that gravity itself is quantum.

The implications are staggering.

For over a century, physics has operated with two separate rulebooks: quantum mechanics for the microscopic universe, and general relativity for the cosmic one.

The graviton could finally connect them.

But there is another possibility.

If gravitational waves pass through the detector and no quantum signatures ever appear, then gravity may not be quantum at all.

And if that is true, many of the leading attempts to unify physics, including string theory and other quantum gravity models, may require radical reconsideration.

Either outcome changes physics forever.

Right now, in a laboratory in New Jersey, superfluid helium is being cooled to the edge of absolute zero, waiting for a ripple in spacetime to leave behind a single quantum fingerprint.

One phonon.

One signal.

One possible graviton.

If it appears, physics moves one step closer to unification.

If it does not, our understanding of reality may need to be rebuilt from the ground up.

Either way, the universe is preparing to answer one of the oldest and most profound questions humanity has ever asked:

Is gravity truly quantum?

And are we ready for the answer?