A side dish:
Gravity induced quantum interference

Our quantum mechanics = QED, interactions are electromagnetic only.

Physics goal? GUT, in which all (4) interactions are unified.

For example gravitational correspondence for hydrogen atom is neutron + electron bound by gravitation
the potential is similar but nature constants differ

At the same distance, gravitational force between n and e compared to Coulomb force between p and e is 2×10^{39} weaker
$\rightarrow$corresponding Bohr radius would be larger than the size of universe by several orders of magnitude.

It is OKAY for us to neglect other forces (weak and strong in our characteristic distances as well) and study QM of electromagnetics only.

However, it is possible to find way to "see" quantum mechanical effect of gravitation as well.

Elegant example of fruitful scientific procedure:
Gravitationally induced quantum interference
Phys. Rev. Lett. 33,1237
(theory+experiment proposition)
Phys. Rev. Lett. 34,1472
(experimental results)

Thermal neutrons (non-relativistic), choose Hamiltonian

$$H = \frac{\mathbf{p^2}}{2m} + mgy$$

Neutrons propagate through a christal in 2 different but equally long paths (AB=l_1 + BD=l_2) and (AC=l_1 + CD=l_2) and meet afterwards at point D

$\rightarrow$ quantum interference at point D.

If the paths are in the same level with respect to the ground, the particles (wave packets propagating with the speed of the neutrons) are in the same phase.

If system is rotated with respect to axis (AC), particles going through path (AB) suffer phase change compared to particles going through (AC):

$$\exp[\frac{-i\Delta Ht}{\hbar}] = \exp[\frac{-imgyt}{\hbar}] = \exp[\frac{-imgl_2 \sin(\delta)t}{\hbar}]$$

The time they spend at path (AB) in terms of the de Broglie wave length (here expressed with $\hbar$)

$$\lambda = \frac{\hbar}{\mathbf{p}} = \frac{\hbar}{m\mathbf{v}} = \frac{\hbar t}{ml_1}$$

Thus

$$\phi_{ABD} - \phi_{ABC} = \frac{m^2 g l_1 l_2 \lambda \sin\delta}{\hbar^2}$$

Depending on the angle δ, the neutrons (wave packets) meeting at D will interfere either constructively or destructively.

This will be visible in the multiplicity arriving to the detector behind point D.

Plugging in the numbers $l_1 l_2$=10cm^2, $\lambda = 1.42/2\pi$ etc., we get ($\Delta\delta = \pi/2$) $55.6/2\pi \approx 9$ i.e. by turning the apparatus 90 degrees we should see 9 oscillations. Indeed, this was seen in the experiment!

The effect is purely quantum mechanical, since in the classical limit $\hbar \to 0$, $\exp(-i(m/\hbar) \times C) \to 1$ and the interference pattern gets washed out. The fact that the interference pattern depends on the term $(m/\hbar)$ tells us that gravity *is not* purely geometric at the quantum level.

On the other hand, since we were able to predict correctly the interference pattern without making distinction between the gravitational mass and inertial mass supports the Einstein's equivalence principle. In other case

$$\frac{m^2}{\hbar^2} \to \frac{m_{inert} m_{grav}}{\hbar^2}$$

should be made.