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Remembering Feynman

Quantum gravity

In the fall of '62 Feynman is all revved up as he tells me about a Quantum Gravity course he is about to teach. Teaching will provide the motivation he needs to create a renormalisable Quantum Theory of Gravity, combining Quantum Mechanics with Einstein's General Theory of Relativity.

In the first lecture Feynman asks, "What if Einstein had never been born, and the General Theory of Relativity had never been created? How would high energy theorists understand gravity?" He argues that since all other forces are created though the exchange of particles, they would assume that particle exchange is also responsible for the gravitational force. That particle Feynman calls the "graviton".

Then he considers its properties. Gravity is very long-ranged, so the graviton must be massless. Gravity acts between objects of the same electrical charge, so it must be neutral. What about its spin? The electrical force between particles of the same charge is repulsive, and the photon has spin one. Since the gravitational force between identical objects is attractive, he argues that the graviton's spin must be even. Naively, the lowest possible spin for the graviton is 0, but the Special Theory of Relativity puts energy and mass on the same footing. Therefore "two tea pots, as they get hotter, feel a stronger attraction," is not possible with a spin-zero graviton. Feynman concludes that the simplest possibility is that the graviton has spin 2, and couples to the 2-indexed energy-momentum tensor.

The next time I go to class Feynman writes down the Feynman rules for "Quantum gravitational dynamics (QGD)" in the upper left-hand corner of the blackboard. This is the first time anyone other than Feynman has proposed these rules. Here is a modern Moses giving us the commandments for gravity, the force that sticks us to the surface of the earth.

I had seen the Feynman rules for Quantum electrodynamics (QED) used to calculate the scattering of positrons off electrons to obtain the energy levels of positronium. Now Feynman uses QGD to calculate the scattering of Mercury off the Sun, as if they were elementary particles, obtaining an advance of the perihelion of Mercury twice that predicted by Newtonian theory, and in agreement with observation. Forget the curvature of spacetime, the geodesic paths of planetary motions, the Ricci tensor and the Christoffel symbols. Just find the motion of Mercury's perihelion! Magic without magic, all in a 50 minute hour.

I had taken a course in General Relativity from one of its masters, Howard Percy Robertson. In 1936 Robertson received a paper by Einstein to review in which Einstein incorrectly claimed that gravitational waves do not exist. In a review longer than the paper, Robertson correctly showed that they do exist. The course I took from Robertson started in September, but it wasn't until the following year that he calculated for us the advance of the perihelion. He needed all that time to teach us what Feynman didn't need. Feynman's lecture was the most brilliant display of intellectual prowess I would ever witness, and I knew it at the time.

Transcribing Feynman

The job of transcribing Feynman's lectures into class notes falls to Bill Wagner, a brilliant graduate student whose office is next to mine on the third floor of the Bridge. Bill drags me into his office to play back the recording he made in class that day. Unlike Julian Schwinger, who speaks in eloquent publishable sentences, Feynman uses colloquial English with a heavy Queens accent, and his speech is all over the place, promising infinitely less intelligence than it delivers. When you hear him talk you are swept away, thinking you understand everything. But the reality is quite different. Bill is beside himself, crying "What should I do with this?" You might remember that it took two Caltech full Professors, Robert Leighton and Matthew Sands, working together for several years to edit Feynman's Lectures in Physics.

Disappointment

The rest of the course was tough going, and did not end on a satisfactory note. Of the 27 lectures distributed as class notes, 17 were not approved for publication, although 5 of these appeared in a later edition, albeit in uncorrected form[1].

The Feynman rules allow one to perturbatively calculate gravitational quantum effects to any order of accuracy, but at each order a measurement is required to determine an unknown 'renormalisation' constant. Feynman was unable to eliminate this complication, which still exists today. In addition, non-perturbative quantum effects that are encountered in the physics of black holes remain incalculable. I think Feynman's inability to create a satisfactory renormalised theory of gravity had a profound effect on him. He loses some of his edge. He throws more of his energies into drawing and other activities unrelated to physics. Feynman is at an impasse. It takes six years for his return[2].

References

[1] R. P. Feynman, F.B. Morinigo, and W.G. Wagner, Feynman Lectures on Gravitation, B. Hatfield ed., Addison-Wesley, (1995).
The lectures are extensively edited to the point where they no longer capture the dynamism of the originals, nor accurately reflect what was said in each lecture.

[2] R. P. Feynman, Phys.Rev.Letters 23, 1415 (1969)