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Paradox of solar eclipses

During a total solar eclipse, the moon stands between earth and sun, completely shielding the sun from view on some spots on earth. In contrast, the gravitational forces of sun and moon on earth simply add up; there is no shielding by the moon. In quantum field theories, forces are mediated by virtual particles, more specifically by bosons (even spin). Virtual particles connecting sun and earth would thus not interact at all with the moon in between.

How would a virtual particle mediating the force of gravitation between sun and earth “know” that it should “not stop” at the moon in between?

Let me explain this in more detail. First of all, there is today no quantum field theory of gravitation, but the general argument also works, for example, for electromagnetic forces, where there is a quantum field theory (quantum electrodynamics, QED) that works with fantastic precision.

A Faraday cage is a closed box of a material that conducts electricity. If you apply an electric field outside, such that charged particles outside the cage will be attracted or repelled, there will be no force inside the cage. The cage would thus appear to shield what is inside from the outside world. But this is not what immediately happens. On the surface of the cage, positive and negative charges separate such that they generate an electric field that exactly compensates the one imposed from outside, so that all adds up to zero inside the cage.

Speaking in terms of virtual particles, virtual photons in this case, there would still be virtual photons connecting the source of the electric field with any charge inside the cage, thus exerting an electric force on each such charge, but there would also always be virtual photons connecting the surface of the cage to the same charges inside, so that forces would cancel inside.

What makes this paradox, is that virtual particles interact heavily with matter, but are also able to “travel” completely undisturbed through other matter.

I wrote “travel” in double quotes because virtual particles can “travel” faster than the speed of light “behind the scenes”, which means that which way they “travel” depends on the observer, more precisely, on the relative speed of the observer relative to the setup. This is simply a consequence of special relativity; see e.g. Richard Feynman’s article “The reason for antiparticles” (1987).

Virtual particles remind of the “spooky” actions at a distance that can instantaneously (faster than the speed of light) correlate measurements in quantum mechanics, as first brought up by Einstein, Podolski and Rosen (1935). Or think of the Aharonov-Bohm effect, where there is zero electric field, but a directly unobservable non-zero electric potential, and an observable effect.

A quantum theory of gravitation would presumably feature spin 2 gravitons, implying no negative masses (“charges”), hence not even apparent shielding.