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Light and the mystery of its mass

In a mutinous 1905 paper, Albert Einstein, a somewhat unknown theoretical Physicist, put forward the idea that light consists of localised packets of energy (quanta), giving it a particle like property, challenging the then current reign of 'light-wave' belief. Despite evoking uproar amongst the physics community and facing initial rejection, the idea was eventually realised as an epoch in scientific discovery, earning Einstein a Nobel Prize and challenging the previously accepted 'Newtonian orchestrated' Universe.

Consider for now, the particle-like nature of light, in the form of photons. If light were to retain a small but measurable mass, it could potentially violate several laws of physics. We know from general relativity that nothing can breach the universal speed limit – the speed of light, due to the exponential increase in mass preventing further acceleration. If light however has no mass, how can phenomena such as radiation pressure be accounted for? As I sit here, illuminated by my PC monitor, I feel no such force imparted upon my face from the photons leaving the screen, and nor do I feel faster running in the dark.

Take for example a black hole, a region of space formed from a dying star so massive that the internal pressure of its neutrons cannot counterbalance its own gravity. This in turn, causes it to compress into an infinitely small density, giving it a gravitational field so strong that nothing can escape from it, not even light. Using Newtonian physics, space is perfectly uniform and fills the Universe like a rigid framework. In this rigid, concrete perspective, a gravitational field is defined as "the force acting per unit mass", which would suggest if light experiences the forces due to a black hole's gravitational field, it must therefore have some mass, otherwise it would continue to move on in a straight line.

In contrast to Newton's views, Einstein proposed that instead of gravity being created by the masses themselves, it was the curvature of space-time that the masses caused which was responsible for bodies, including light, experiencing forces near large masses – a concept known as the equivalence principle. The corollary of this was that close to black holes, space-time became so curved and folded that light could not escape from the black hole as it followed the curvature of space the black hole had created, an outcome that did not depend on light having mass.

Imagine two parallel monochromatic lasers, each firing a single photon out into uniform flat space, away from any masses. If these photons have mass, they will bend the fabric of space-time, eventually converging towards one another. Yet if they do not, they will continue moving parallel to one another for infinity. Assuming the rest mass of a photon to be zero, this would imply that its energy is equal to the product of its speed and momentum. It seems however paradoxical that a body can have no mass but still retain momentum - a property that light has been demonstrated to have using solar sails, ultra thin mirrors propelled by the force due to photons. For now, the behaviour of light remains shrouded in mystery. The mystery of light and its mass still remains inconclusive, although strong evidence points towards a massless 'particle', mankind still has work to do to unveil the truth about this enigma.

Words: 552 (excluding title)

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