Making Quantum Gravity Safe

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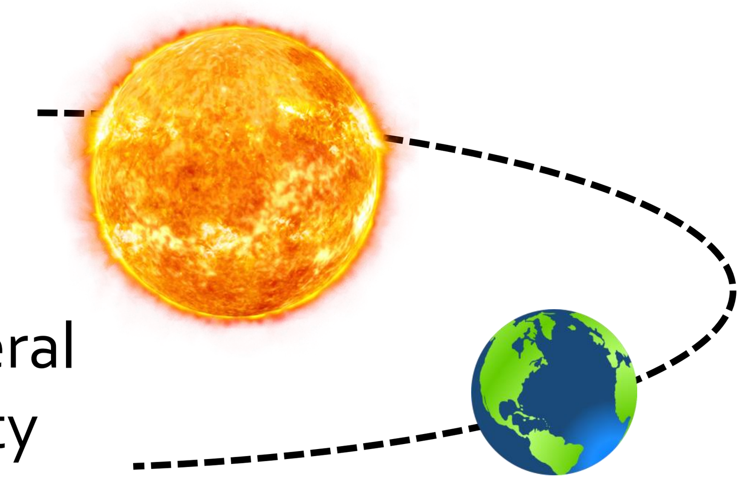
What is Quantum Gravity?

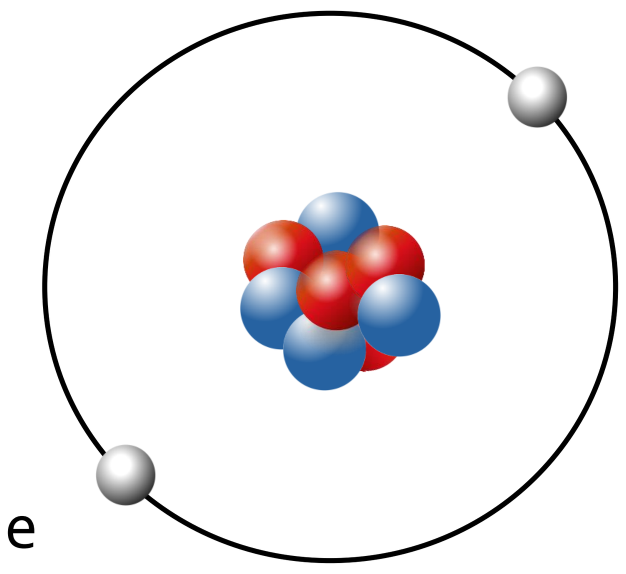
Quantum gravity is an area of theoretical physics which aims to describe the force of gravity according to the laws of quantum mechanics.

General Relativity



Our best understanding of the force of gravity comes from Einstein's theory, general relativity. The force of gravity governs the dynamics of the large-scale structures in the universe, for example the orbits of the planets around the sun.

Quantum Mechanics

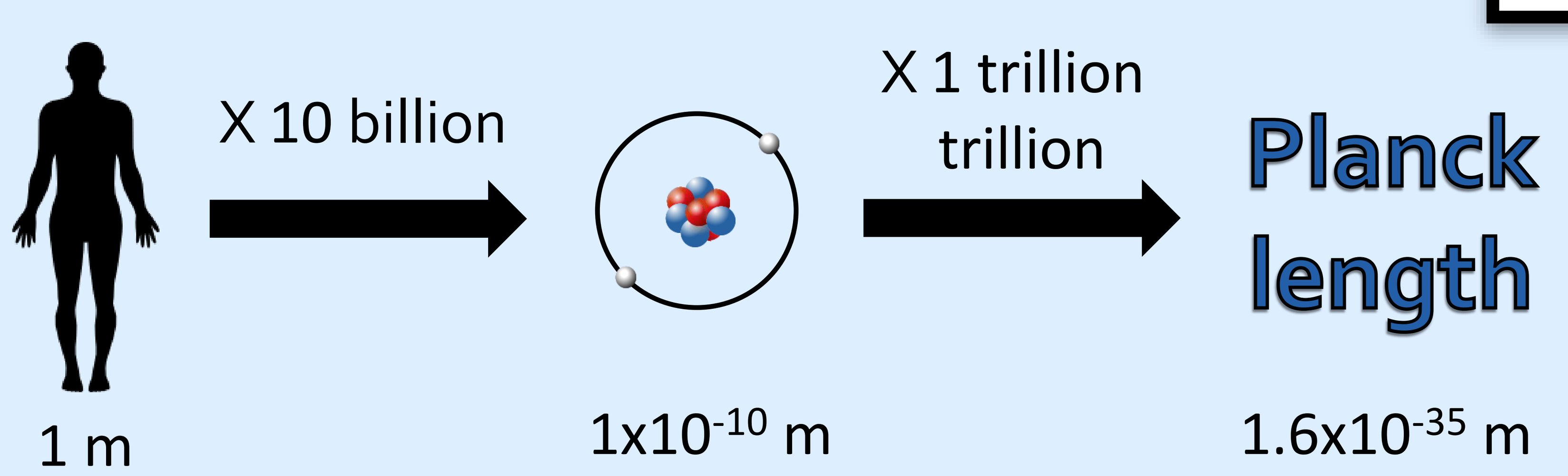


The remaining three fundamental forces of nature are described within the framework of quantum mechanics. Quantum mechanics is our best theory for describing the universe on microscopic scales, for example we use it to understand the behaviour and interactions of particles.

A theory of quantum gravity would bring together these two seemingly disparate pictures of reality. Obtaining such a theory would help us to gain a deeper understanding into curious astronomical objects called **black holes** and even the **beginning of the universe** itself!

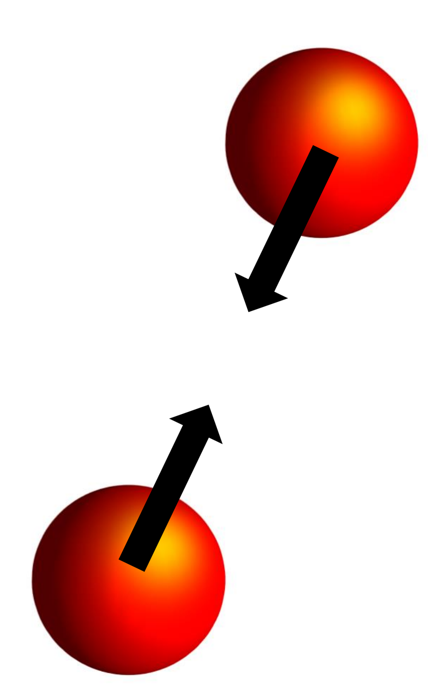
The Trouble with Quantum Gravity

Trying to "quantize" gravity in the usual way is problematic. The resulting theory breaks down if we use it to predict what happens at very small distance scales, giving us un-meaningful **infinite predictions**. The scale around which this happens is called the **Planck length**.



In physics we require our theories to produce finite numbers as predictions which we can ultimately compare to experimental data. Whether or not a theory yields these undesirable infinite predictions is determined by the behaviour of quantities called **coupling constants**.

Coupling constants quantify the strength of the force acting between particles. Different theories will contain different coupling constants depending on the particle interactions they describe.



If the coupling constants of the theory remain finite as we probe increasingly smaller distance scales, then so do the predictions of the theory.

What is Asymptotic Safety?

I work in **asymptotic safety** which is an approach to finding a theory of quantum gravity. It utilizes the mathematics of the **renormalization group** to search for a theory which is safe from infinities.

The renormalization group provides a systematic way to investigate the behaviour of coupling constants as we examine smaller and smaller distance scales.

We can imagine this mathematical apparatus, the renormalization group, to be a bit like a microscope, enabling us to examine how a theory changes when viewing the physical system in question at varying magnifications.

Candidate theories of quantum gravity are difficult to test experimentally. Quantum effects of gravity are only expected to become visible near the Planck scale and this is far beyond that which can be accessed by particle accelerators.

However, there is hope to put constraints on candidate theories or indeed rule them out completely with, for example, data from cosmological observations or the possible existence of extra dimensions.

References: Sun - www.dmf.hr, earth - www.cliparthut.com, red spheres in atom – www.clker.com, blue spheres – http://eceweb.ucsd.edu/courses/ECE15/FA_2015/, grey spheres – www.rosettacode.org, human figure – www.flaticon.com, red particles - http://wallpaper222.com/explore/red-sphere-png/.