Effective theories

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Effective theories

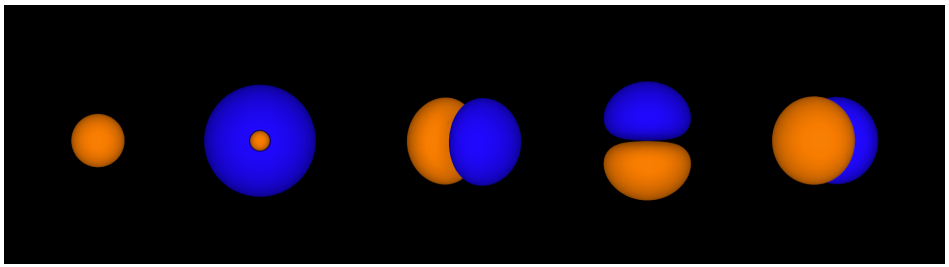
- Particle physicists and cosmologists come up with weird ideas to explain the world ...
- "Theory of everything!"
- but material scientists (or engineers) don't care.

Why?

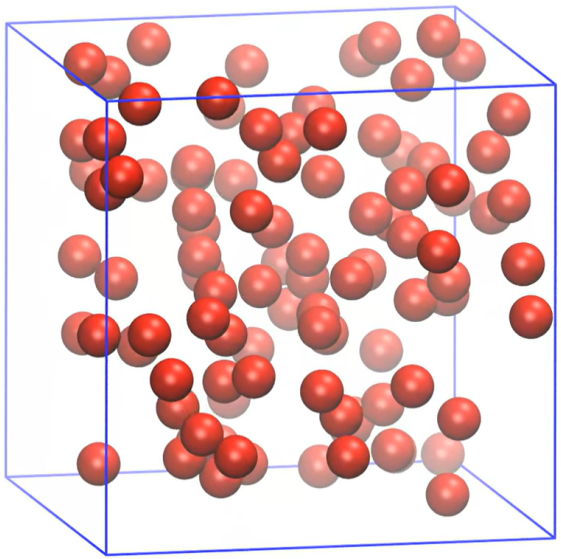
- A phenomenon can be well described by a theory that *fits its scale*
- **Effective theory**

Example 1

We can use quantum theories to predict the behavior of electrons . . . [1]



But the dynamics of molecule doesn't need full information concerning this: Atoms are seen as balls without inner structures.[2]

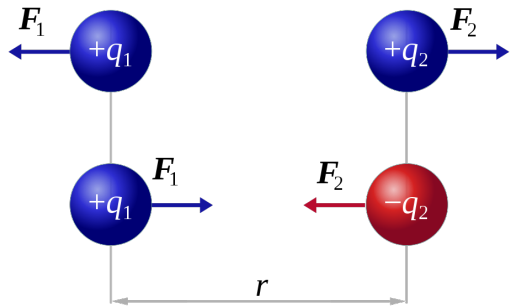


[1] Picture from Wikipedia.

[2] Picture from another Wikipedia page.

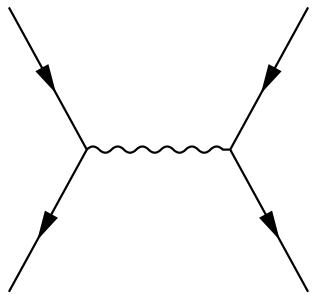
Example 2

Electrons repulse each other – Coulomb interaction[3]



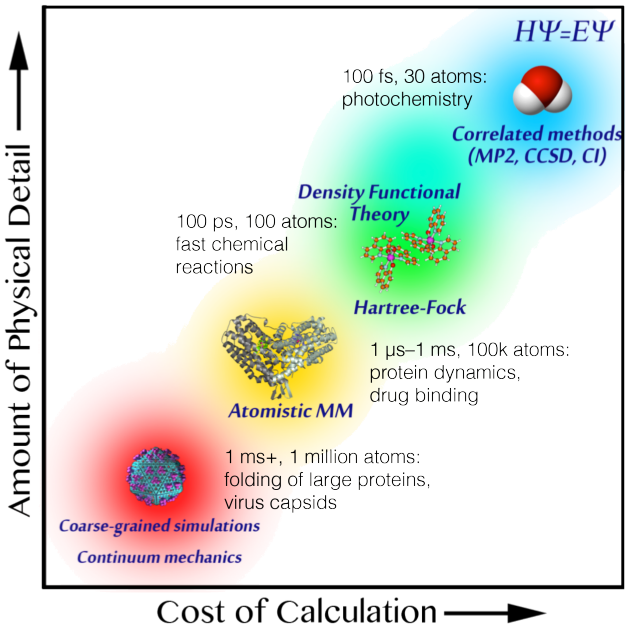
$$|F_1| = |F_2| = k_e \frac{|q_1 \times q_2|}{r^2}$$

But do you know this actually arises from changing photons (i.e. smallest unit of light)?



[3]Picture from Wikipedia.

Effective theories are everywhere



- (Engineers') mechanics is an effective theory of molecular dynamics
- Molecular dynamics is an effective theory of quantum mechanics.
- Coulomb interaction is an effective theory of quantum electrodynamics.
- ...

[3] Picture from here.

Conclusion

- Phenomena happening on different scales require different theories.
- Understanding phenomenon happening on one scale doesn't really require theories on a smaller scale.
- "Learning the rules doesn't make you a chess master!"