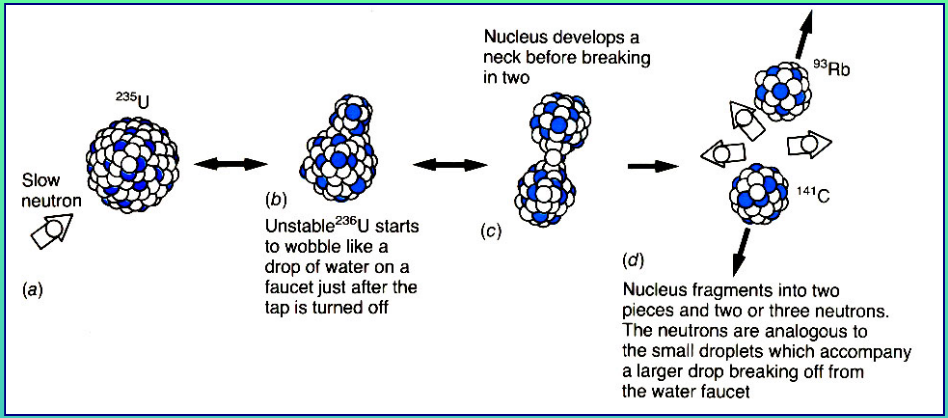
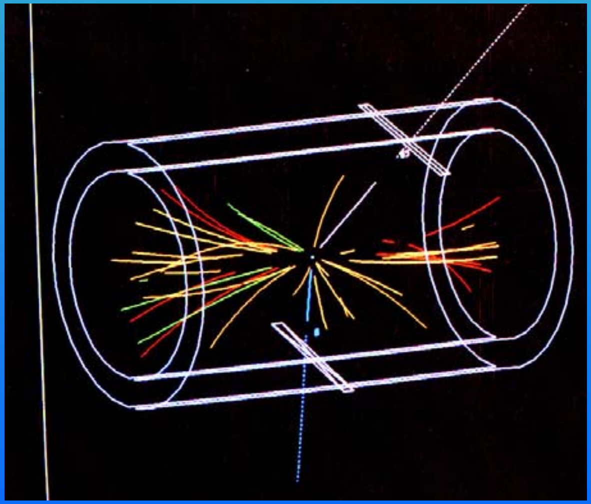
Q.M. on the Small Scale



At the atomic and sub-atomic scales, interference and superposition are everywhere. The physics of the nucleus was unravelled once the existence of the "weak" & "strong" forces was realised- this explained radioactive decay and led to nuclear weapons. In the following years investigations at ever higher energies probed subnuclear processes, culminating in the period 1967-73 with the formulation of the "standard model", which unifies the strong, weak, and EM interactions in a single quantum theory. This allows an explanation of the high-energy processes in astrophysics.

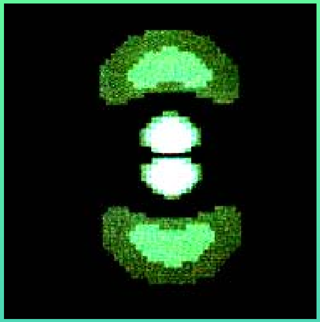
Nuclear fission



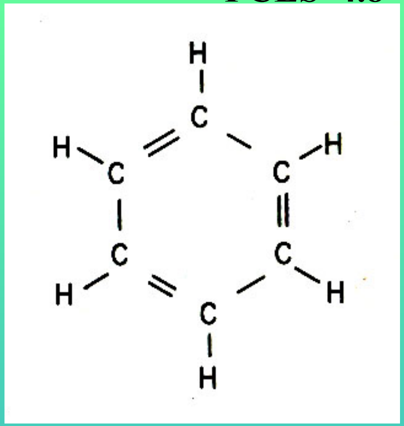
We still have no clear idea how to unify the standard model with gravitation- this is the main goal of modern string theory.

Q.M. on the SMALL SCALE

The structure of atoms and molecules is essentially quantum- mechanical- the electrons live in probability amplitude clouds around the central nuclei. As Dirac put it, with the advent of QM, chemistry became a sub-branch of physics- although it is a long way from the QM equations to the structure of, eg., the DNA molecule. Nevertheless QM led to the 20th century revolution in chemistry and biology

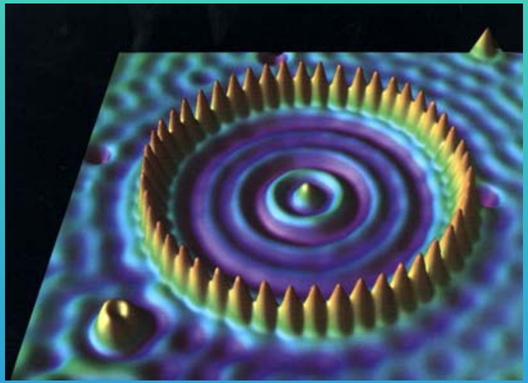


Wave-function for H atom.

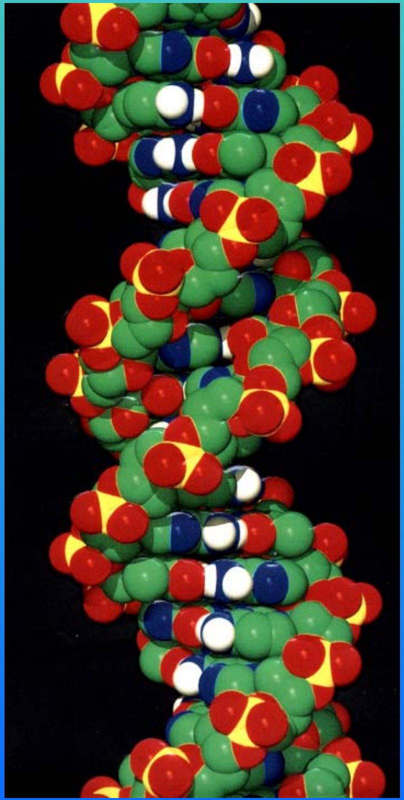


Benzene molecule

C-60 molecule

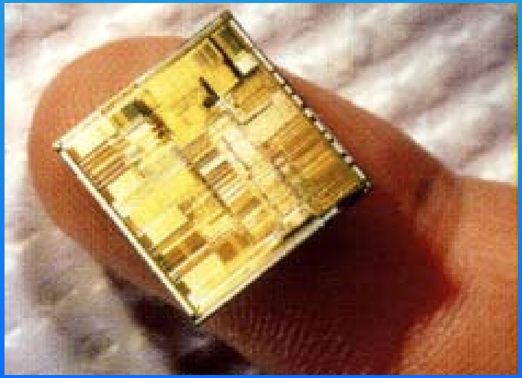


Quantum Corral (Co on metallic Cu surface)



DNA molecule

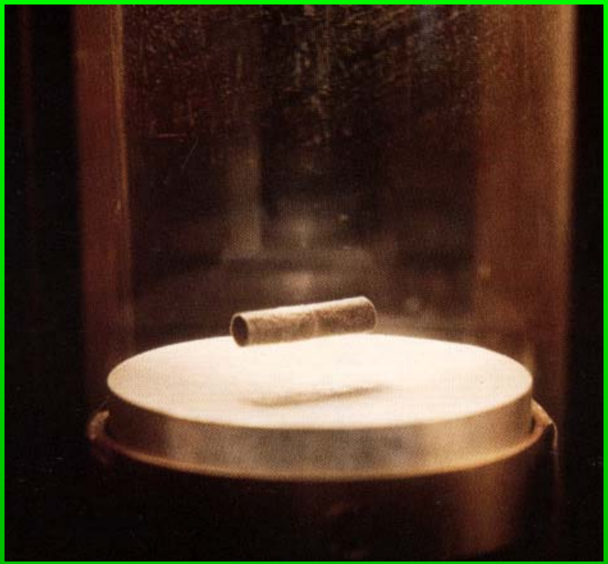
In the same way QM allowed us to understand the electronic structure of solids, including metals, semiconductors, magnets, polymers, etc., and of liquids from water to liquid crystals. Beginning in the 1960's, this has triggered a massive and continuing techno- revolution



Pentiun 2 chip

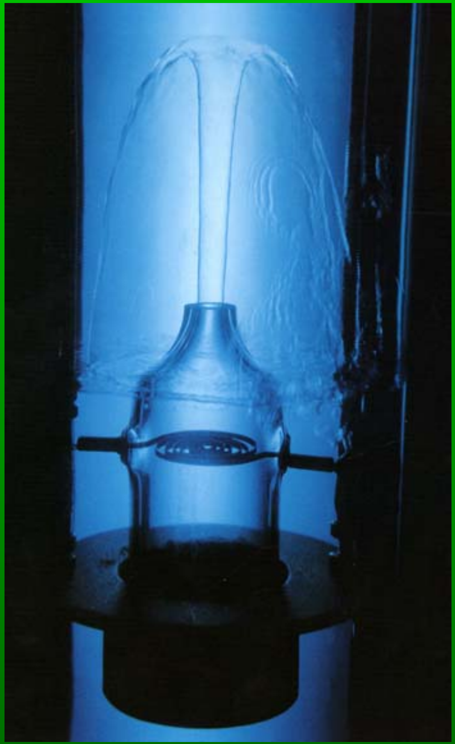
Effect of Q.M. on the Large Scale

Although quantum effects like interference and entanglement were not expected at the macroscopic scale by the founders of Q.M., the indirect effect of Q.M. is clear, at scales from the nanoscopic up to our size. In fact, one can't understand physical processes and structure at the large scale without Q.M.

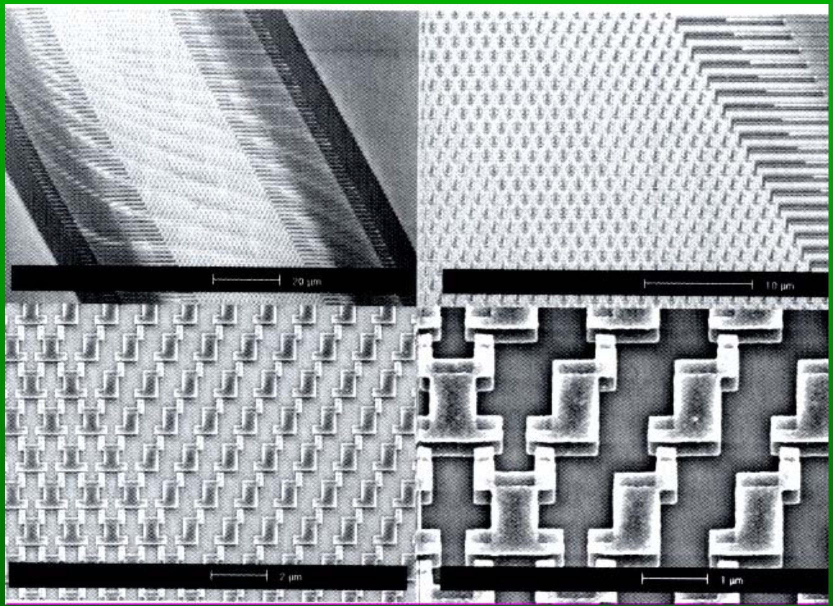


Superconducting levitation effect

However there ARE a few direct effects of QM on the large scale, which are very dramatic (for some, the most dramatic effects of QM anywhere in Nature). These are superfluiditiy and superconductivity, involving the coherent quantum behaviour of huge numbers of particles . These systems can show very strange behaviour.



Superfluid fountain



Large array of Josephson junctions

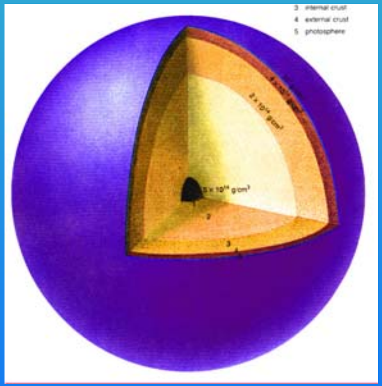
Quantum Mechanics on the Large Scale

Until QM, almost all astrophysical processes were beyond our comprehension. We now have an incredibly detailed understanding of how stars function, from birth to death, and of the physics of objects ranging from comets & planets to nebulae and galaxies. Relativistic quantum field theory has opened up the structure of supernovae, neutron stars & black holes, and exposed the story of the universe back to its beginning.

Zeldovich distribution

M16 (Eagle nebula)

Supernova (bottom left) in NGC 5426



Cross-section inside a neutron star (mass ~1.4 suns, diameter ~10 km)

Section of the Hubble deep space probe.