AN INTUITIVE EXPLANATION OF CHIRAL SYMMETRY BREAKING

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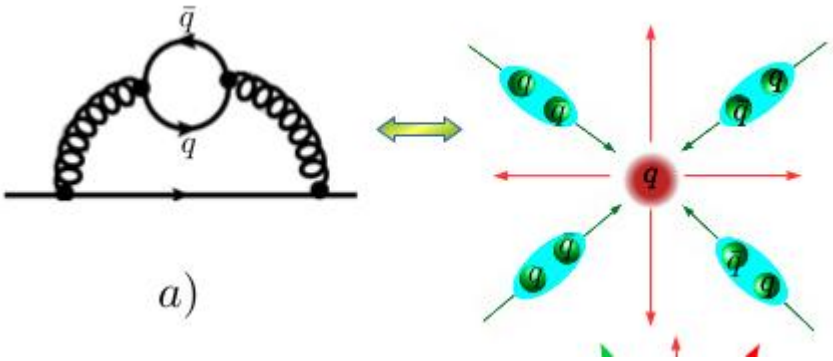
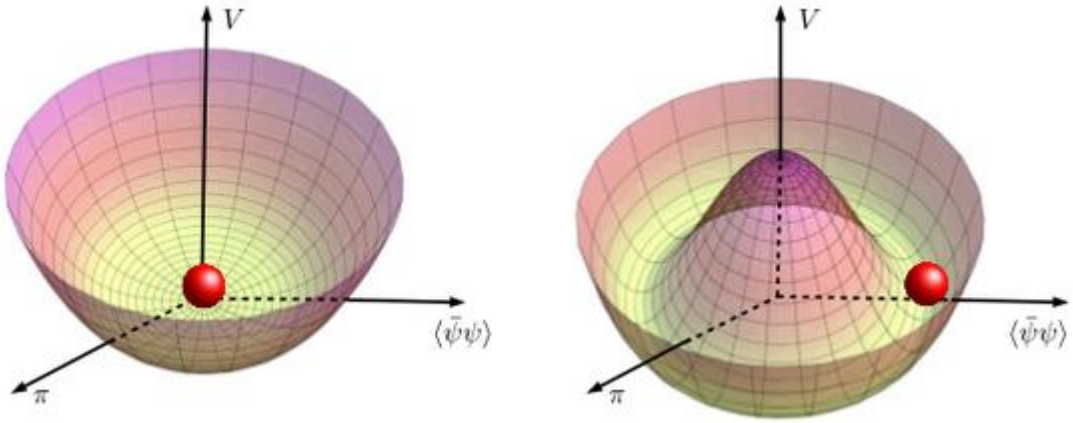
Let's start with this image



which is a quantum effect of short distances or a vacuum polarization (in a)). We say that the symmetry of the QCD vacuum is broken by this kind of quantum fluctuations which meaning is translated intuitively into the appearance of multiple pairs of quark anti-quarks (in b)) , therefore the vacuum is polarized by a formation of a condensate and by a condensate, we mean the infinite pairs of quark -antiquark that populate the vacuum. The probability of the formation of such a pairs is calcuated by the so called chiral condensate .

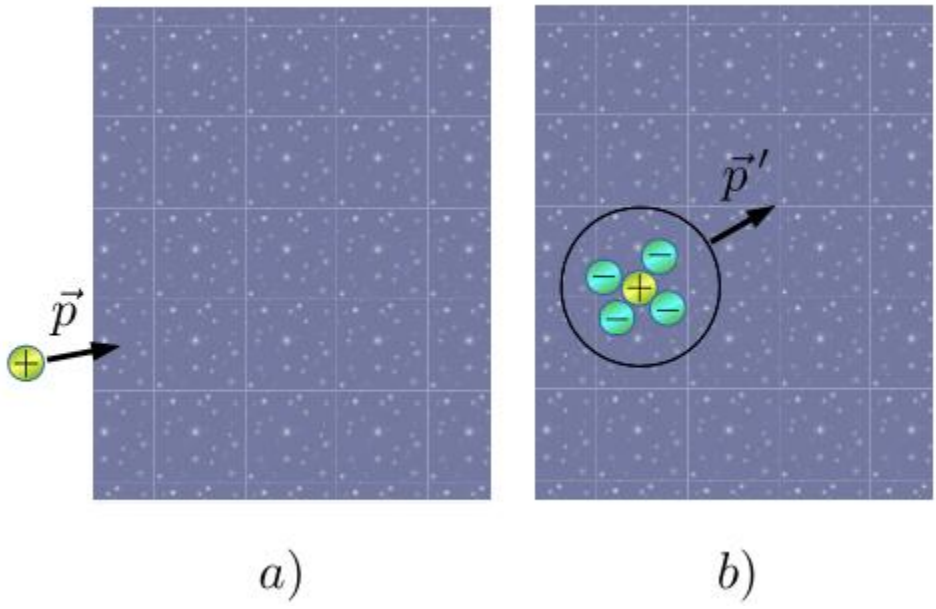
$$\langle \bar{\psi}_L \psi_R \rangle \sim \Lambda^3_{QCD}$$

It is said then, that the chiral symmetry is spontaneously broken. It means that the interaction potential is symmetric but vacuum (ground state) is not. This is usually illustrated by the two classical potentials:



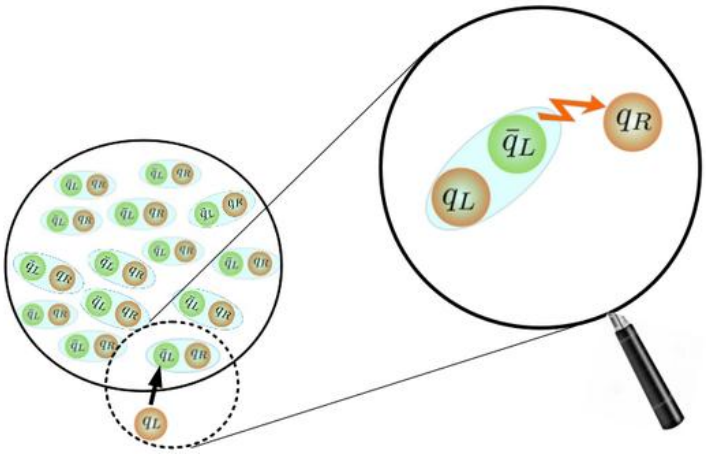
Both potentials are rotationally symmetric, but for the potential on the right the ground state is located at a certain distance from the center. In fact, the ground state is not unique, there exist an infinite set of ground states trough the valley (a "chiral" condensate). We have to choose a particular point as the ground state and any point of the ground state is not rotational invariant (unlike the potential in the left, as you can see in the plot). This analogy serves to illustrate the fact that the condensate breaks

the chiral symmetry. This is the case of the conditions of our everyday lives, where the u & d quarks that make us, have masses of around 300 MeV and that is a direct consequence of we be living in a world where the chiral symmetry is broken. Most of our mass and the mass of the planets and stars come from the interaction with this chiral condensate. Think for example in the system illustrated in this drawing



In a), a particle with with momentum $P = mv$ enter an homegeneus condensate of charged particles, and as the particle propagates in the condensate its momentum changes to $P'=Mv'$ due to the cloud of particles of opposite sign that bind to it. You could fairly say that the particle acquires its new mass M, because of interactions with the condensate.

Well, in quantum field theory is almost the same. Dirac told us that the mass of the particles depends somewhat on the rate on which they change their chirality. As shown in the first graph, the vacuum is populated by a condensate of quarks and anti-quarks; as a particle propagates in that condensate, it can change its chirality as illustrated by the following drawing:



Where a left quark enter the condensate, then is absorbed by the condensate and re-emitted by the condensate as a right quark to continue its propagation, so that, it is equivalent to say that the original quark propagates changing its chirality and therefore getting an effective mass that brakes chiral symmetry as a consequence.