Short Range Structure of QCD

summary

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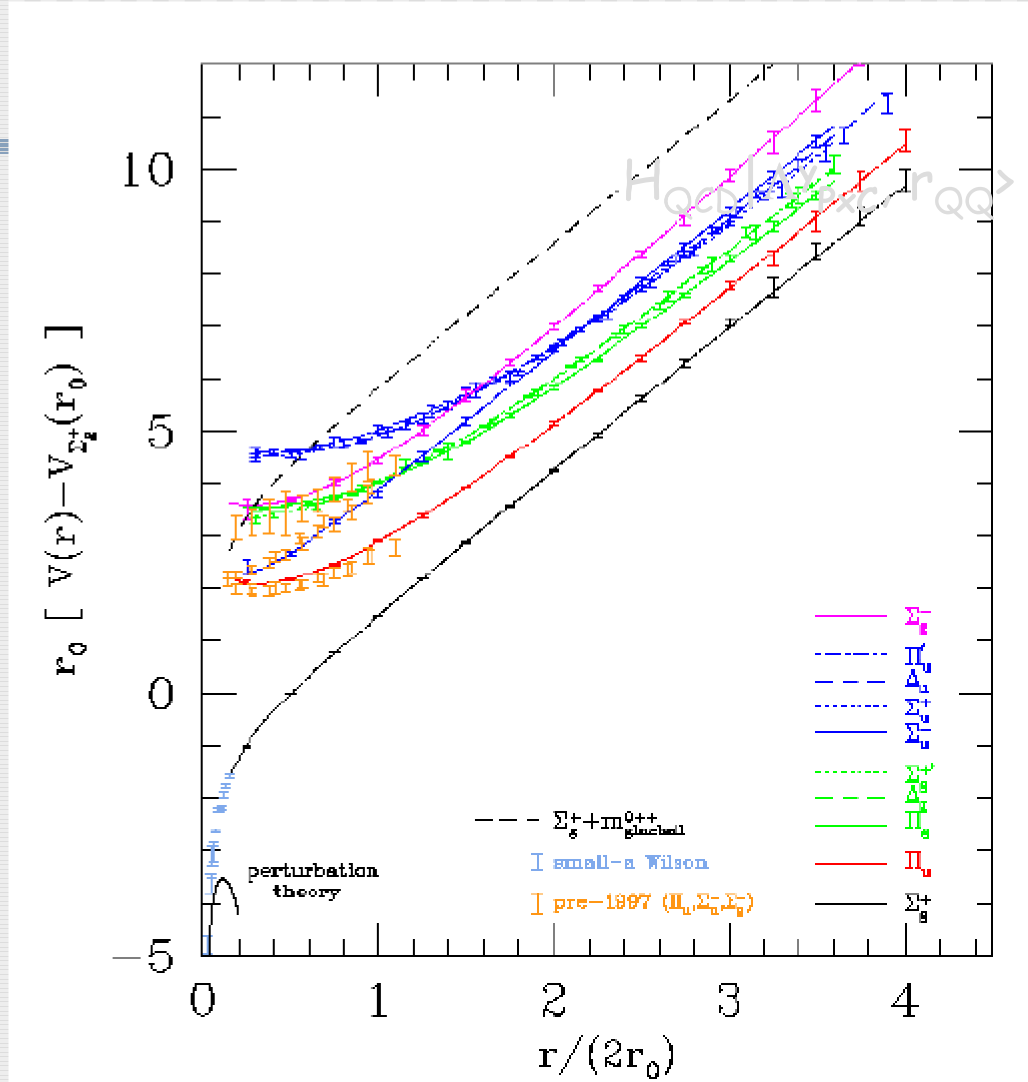
Generic Model Features

- chiral symmetry breaking generates constituent quarks with a dynamical mass; these provide an efficient description of hadrons. For example, a baryon is accurately described as three constituent quarks.

- soft gluonic degrees of freedom are assumed to be static (adiabatic separation of degrees of freedom).

Fast Glue



$H_{QCD} |\Lambda^Y_{PXC}, r_{QQ}\rangle = V(r) |\Lambda^Y_{PXC}, r_{QQ}\rangle$

Generic Model Features

- a potential description is applicable to constituent *u* and *d* quarks.

True if (positronium):

$$E_\gamma = p_\gamma >> K_e \qquad p_\gamma \sim \alpha m \qquad K_e \sim \alpha^2 m$$

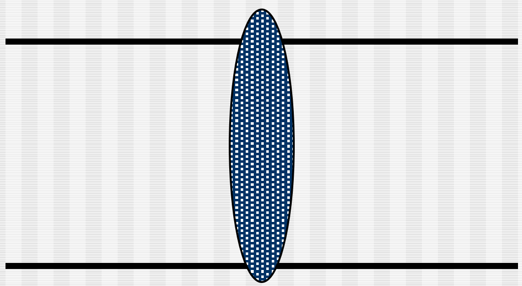
The situation in QCD may be saved via dynamical effects (a fat gluon).

Generic Issues

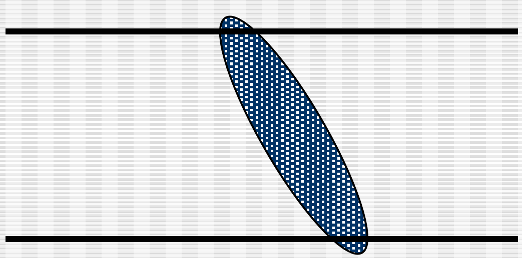
- most models are quenched
- most models do not incorporate spontaneous symmetry breaking in a dynamical way
- are potentials applicable to light quarks?
- most models do not incorporate gluodynamics
- what is the structure of glue in the baryons?
- where does topology (and in general, the QCD vacuum) fit into the picture?
- it is desirable to maintain as close contact to QCD as possible

how do the quarks interact?

It depends on what you mean by ‘interact’



instantaneous



retarded

[configuration mixing: qqq, qqqg, $qqq\bar{q}$, …]

Possible Approaches

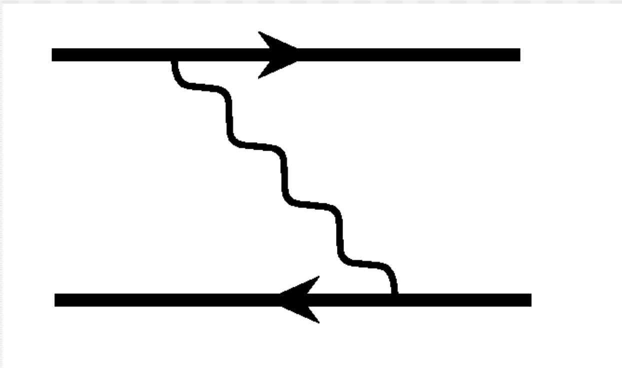
1. Explicitly unquench

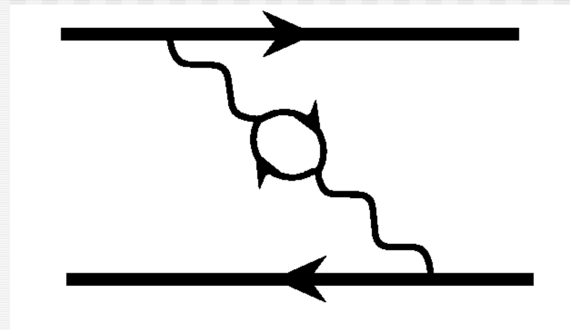
$$H = \int b_x^\dagger \frac{-\nabla^2}{2m} b_x + d_x^\dagger \frac{-\nabla^2}{2m} d_x$$

$$+\frac{1}{2}\int\int (b_x^\dagger b_y^\dagger + d_x^\dagger d_y^\dagger) V(x-y)(b_y b_x + d_y d_x)$$

$$+\gamma \int (b_x^\dagger \sigma \cdot \nabla d_x^\dagger + \text{H.c.})$$

2.





All short distance (Δ E > m a_0 = Λ) behaviour is in the full photon propagator (instantons?)

The long range Fock sector mixing effects are complicated: QQ -> QQg, QQgg, gg, ggg, QQQQ, etc.

Ideally we take these into account with a full coupled channel computation, until then replace these LR contributions with an effective interaction:

$$V_{LR}(x) = \sum_n c_n(\Lambda) v_n(r)$$

Choose a scale Λ, and match the couplings to data.

We require a small parameter at the ½ fm scale: 1/Nc?

Desiderata

- comparison to the spectrum is not sufficient to test models
- exploration of regularities in the higher excitation spectrum is vital
- relativistic quark models are desirable and are likely necessary. For example, relativistic effects are important in nucleon form factors.
- Revisit strong decays in a relativistic framework (boosts!)
- perturbation theory is not acceptable

Desiderata

- strong hadronic couplings need to be understood
- unquenching formalism is required to improve the first order predictions. For example, all models fail to describe the $\Lambda(1405)$.
- do all of this while staying close to QCD!

The lattice will play a vital role.

Dytman: average hours per day