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Relativistic bound state approach to fundamental forces including gravitation

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Abstract. To describe the structure of particle bound states of nature, a relativistic bound state formalism is presented, which requires a Lagrangian including scalar coupling of two boson fields. The underlying mechanisms are quite complex and require an interplay of overlapping boson fields and fermion-antifermion production. This gives rise to two potentials, a boson-exchange potential and one identified with the long sought confinement potential in hadrons. With minimal requirements, two elementary massless fermions (quantons) - with and without charge - and one gauge boson, hadrons and leptons but also atoms and gravitational systems are described by bound states with electric and magnetic coupling between the charges and spins of quantons. No need is found for colour, Higgs-coupling and supersymmetry.

1 Introduction

To investigate fundamental forces, nature provides us with particle bound states, hadrons and leptons, which form the constituents of matter, but also with composite bound states, nuclei, atoms and gravitational objects in form of solar and galactic systems. For the description of these bound states a relativistic theory is needed, since the elementary constituents of these states are relativistic. However, relativistic bound state problems are generally difficult to resolve, see e.g. Salpeter and Bethe [1], and could not be unraveled so far for fundamental systems with quantitative results.

Instead, powerful effective theories have been developed, which are contained (except gravitation) in the Standard Model of particle physics [2] (SM). In this framework hadronic bound states and leptons are included effectively by a number of parameters including nine masses of elementary particles. Generally an excellent description of experimental data is obtained, but the underlying mechanisms leading to particle bound states are hidden. Further, on a fundamental level problems appear: Neutrino masses are non-zero in contradiction to the SM expectation. To respect gauge invariance, the exchange of heavy bosons in weak interactions requires the Higgs-mechanism with the existence of scalar Higgs-bosons, which have not been found. Due to this mechanism, which requires an enormously high energy density of the vacuum, gravitation has not been included in the SM. Furthermore, in an extension of the SM the flavour structure of leptons and hadrons is described [2] by supersymmetry, which should give rise to a new class of particles with masses of several hundred GeV, which also has not been observed experimentally.

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2 Relativistic bound state approach

To study the mechanisms, which lead to particle bound states and to resolve the above problems, a solution of the relativistic bound state problem is discussed, see details in ref. [3], based on a Lagrangian with elementary massless[1] fermions (quantons, q) and gauge bosons. Formally a bound state can be obtained, if a coupling between two boson fields is included in the Lagrangian, which yields contributions only, if the time component of both boson fields is the same. In this case a reduction to three dimensional space is possible and the bound state problem can be solved. However, the underlying mechanisms are rather complicated: a particle bound state as observed in nature can be obtained only, if by an intimate interplay of overlapping boson fields and $q\bar{q}$ production a stabilized fermionic and bosonic system is created. This should lead to a description essentially without free parameters.

It should be realized that the features of the fundamental interactions in such a realistic approach can be different from those of the effective theories in the SM, which may not be unique. Therefore, our strategy was to assume the most restrictive structure of elementary particles, only two elementary quantons (with and without charge) and one gauge boson, with simple interactions given by electric and magnetic coupling to the charges and spins of quantons. If on the fundamental level other symmetries or structures are needed, this should show up in a break down of our approach.

We write the Lagrangian in the form

$$\mathcal{L} = \frac{1}{\tilde{m}^2} \bar{\Psi}\, i\gamma_\mu D^\mu (D_\nu D^\nu) \Psi \; - \; \frac{1}{4} F_{\mu\nu} F^{\mu\nu} \,, \qquad (1)$$

where $\tilde{m}$ is a mass parameter and Ψ a two-component massless fermion (quanton, q) field $\Psi = (\Psi^+, \Psi^o)$ and $\bar{\Psi} = (\Psi^-, \bar{\Psi}^o)$ with charged and neutral part. The covariant derivative is given by $D_\mu = \partial_\mu - igA_\mu$ and the field strength

[1] with negligible mass with respects the mass scale of particle physics

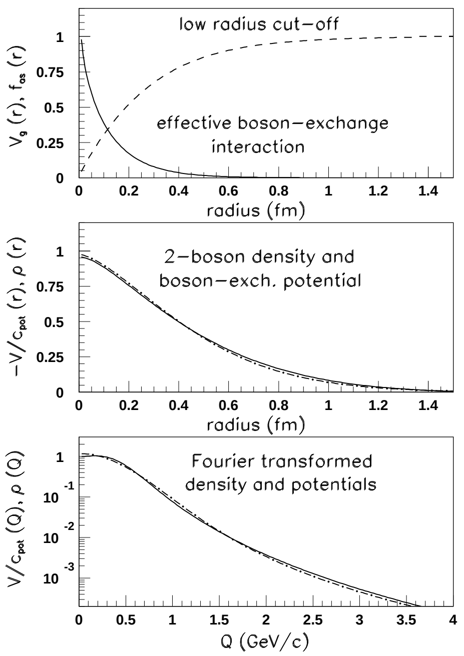

Fig. 1. Solution for a scalar state with a mass of 0.55 GeV. Upper part: low radius cut-off function $f_{as}(r)$ and interaction $\sim f(r)/r$ given by dashed and solid line, respectively. In the lower two parts the two-boson overlap density and the corresponding potential are given by the overlapping dot-dashed and solid lines in r- and Q-space, which are matched by a boundary condition.

tensor by $F^{\mu\nu} = \partial^\mu A^\nu - \partial^\nu A^\mu$. There are two couplings, electric ($g = g_e$) and magnetic ($g = g_m$) to the charge and spin of quantons.

By inserting in eq. (1) $D^\mu = \partial^\mu - igA^\mu$ and $D_\nu D^\nu = \partial_\nu\partial^\nu - ig(A_\nu\partial^\nu + \partial_\nu A^\nu) - g^2 A_\nu A^\nu$ one obtains a Lagrangian, which includes higher derivatives of the fermion fields. This leads to unphysical solutions, see ref. [4], if the Lagrangian is not constrained. By introducing the condition $\partial_\mu(D_\nu D^\nu)\Psi - igA_\mu(\partial_\nu\partial^\nu)\Psi = 0$ on the equation of motion, higher derivative terms of the fermion fields drop out and the first term of $\mathcal{L}$ gives rise to the following terms with 2- and 3-boson coupling (2g) and (3g)

$$\mathcal{L}_{2g} = \frac{-2ig^2}{\tilde{m}^2}\ \bar{\Psi}\gamma_\mu A^\mu (A_\nu \partial^\nu)\Psi \qquad (2)$$

and

$$\mathcal{L}_{3g} = \frac{-g^3}{\tilde{m}^2}\ \bar{\Psi}\gamma_\mu A^\mu (A_\nu A^\nu)\Psi\ . \qquad (3)$$

From these Lagrangians two $q\bar{q}$-potentials can be constructed, see ref. [3], a boson-exchange potential and one, which can be identified with the “confinement” potential known in hadrons. Results from the deduction of these potentials are shown in fig. 1 and fig. 2. Details are given in ref. [3]. It is important to mention that the Lagrangians (2) and (3) give rise to matrix elements without divergencies and thus to solutions in full space.

We can assume a simple structure of the bosonic vacuum with the following properties:
1. Fluctuating boson fields with average energy $E_{vac} = 0$.
2. Creation of $q\bar{q}$-pairs within the overlap of boson fields.
3. Boson-exchange force in the vacuum $V_{vac} \sim 1/r^2$.

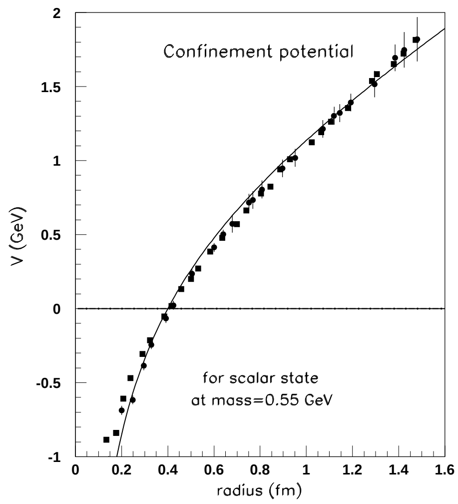

Fig. 2. Deduced ’confinement’ potential $V_{2g}(r)$ in comparison with lattice gauge simulations [5] (solid points).

3 Application to fundamental interactions

The formalism discussed in Sect. 2 has been applied to different stationary systems bound by fundamental interactions. In all cases a good description is obtained with the simple couplings discussed above. The general structure of the solutions can be seen in figs. 1 and 2, which displays results for a scalar state with a mass of 0.55 GeV. The upper part of fig. 1 shows the interaction $\sim f(r)/r$, which is finite for $r \to 0$ due to a low radius cut-off in $f(r)$. In the lower parts the two-boson overlap density and corresponding boson-exchange potential are given in r- and Q space, which should match. This is possible only by assuming massless quantons. The derived ’confinement’ potential compared to lattice gauge data [5] is given in fig. 2.

3.1 Hadrons and the strong interaction

By including in the present approach a vacuum potential sum rule, see paper cited in ref. [3], a satisfactory description of the flavour structure of hadrons (including top-states) is obtained with essentially no free parameters. The various flavour states observed are understood in our approach by different fundamental states exhausting a vacuum potential sum rule. Results on the lowest flavour states in comparison with experimental masses are given in table 1.

In our approach there is no colour degree of freedom as in QCD. Therefore, the uniqueness of QCD was studied by comparing the running coupling α_{QCD} and the gluon propagator from lattice QCD with related quantities in the present approach. The results, see paper cited in [3], indicate that both quantites are equally well described in our approach with a weighting of the different flavour contributions i by $V_i(Q)/Q_i$, where $V_i(Q)$ and Q_i are bound state potential and average momentum of each flavour component, respectively. This indicates that QCD is not a unique theory of the strong interaction and that the colour degree of freedom is not really needed to understand the hadronic interacton.

Table 1. Deduced masses (in GeV) of scalar and vector q^+q^- states compared to the lowest 0^{++} and 1^{--} mesonic systems [2].

Solution	(meson)	M_{vec}	M_{scal}	$M_{exp}^{1^{--}}$	$M_{exp}^{0^{++}}$
1	$-$ σ		0.55		0.60±0.2
2	ω f_o	0.78	1.70	0.78	1.70±0.2
3	Φ f_o	1.02	3.28	1.02	–
4	J/Ψ –	3.10	12.7	3.097	–
5	Υ –	9.46	40.4	9.46	–
6	(Z^o) top	~91	370	91.2	~370

3.2 Neutrino masses

The observation of neutrino oscillations indicates clearly that neutrons are massive. They are described in the present bound state approach by a three quanton structure $q^o\overline{q}^oq^o$ with a binding given entirely by magnetic coupling between quanton spins. Detailed calculations [6] indicate that absolute neutron masses can be derived consistent with the neutrino mass square differences derived from neutrino oscillation experiments. An important point is that from this analysis the absolute strength of the magnetic spin-spin coupling g_m could be deduced, which is many orders of magnitude smaller than the electric coupling g_e: $g_m/g_e \sim 3\ 10^{-8}$. It was found that the strength of the spin-spin force is consistent with Newton's gravitational coupling G_N at macroscopic distances [6]. Therefore, a unified description of all fundamental forces appears possible.

3.3 Rotation and mass of galaxies

The formalism discussed above has been applied also to gravitation with a description of the motion of galaxies. Different from hadrons and leptons, recoil effects have to be taken into account for composite systems. This leads to a good description of the lightest atoms, hydrogen and positronium, see article cited in ref. [3]. The magnetic spin-spin coupling between quantons is responsible for gravitation, yielding a cumulative interaction between many quantons.

We find that for gravitation the confinement potential derived from $\mathcal{L}_{2g}$ is of large significance and leads to confinement of galactic systems. This potential together with the deduced density for the low surface brightness galaxy F583-1 (a typical galaxy for which a large dark matter halo has been assumed) is shown in the upper part of fig. 3. In the lower two parts the velocity curve calculated from the kinetic energy of the gravitational bound state is shown. With a radius adjustment indicated by the vertical lines good agreement with the experimental data [7] is obtained.

The absolute magnitude of the rotational curve and the mass of the galaxy is obtained by scaling the single quanton bound state energies by more than 60 orders of magnitude, which yields a mass of 2.4 10^{10} solar masses. This is in agreement with the usual mass estimate $M_{gal} \sim v_{rot}^2 R/G_N$, in which v_{rot} is the maximum rotational velocity and R the radius at highest velocity, which gives 2.5 10^{10} M_{sol}. A similar quantitative description has been obtained for three other rather different galaxies, Draco, Fornax and NGC 3379. This indicates that there is no need for additional dark matter contributions, as deduced from phenomenological studies.

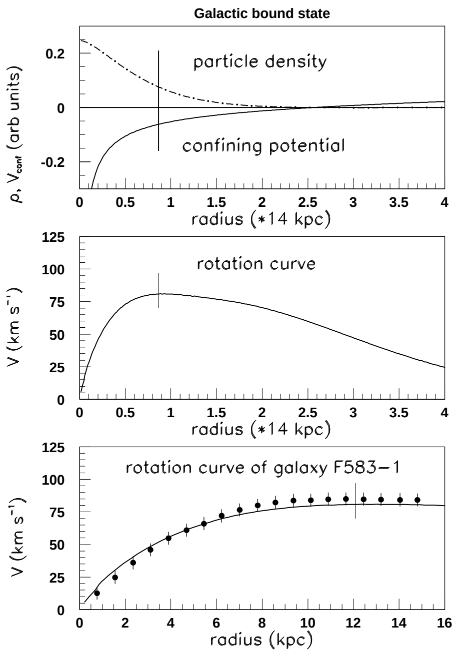

Fig. 3. Upper part: density (dot-dashed) and confining potential of a galactic bound state. Lower two parts: deduced velocity distribution, with a radius fitted to that of the galaxy F583-1 shown in the lower part, which is compared to the data of ref. [7].

4 Summary

The relativistic bound state approach discussed above leads to a unified description of all fundamental forces of nature with essentially no free parameter. Only the relative strength of the magnetic spin-spin force between quantons g_m/g_e has been determined from the description of neutrino masses. With $g_m/g_e \sim 3\ 10^{-8}$ the relative masses of electron and ν_e and the gravitational coupling are well understood. This leads to a quantitative description of bound states of nature with radii from $\sim 10^{-20}$ up to $\sim 10^{20}$ m without need for Higgs-bosons, supersymmetric particles and dark matter.

References

1. E.E. Salpeter and H.A. Bethe, Phys. Rev. 84, 1232 (1951)
2. Review of particle properties, K. Nakamura et al., J. Phys. G 37, 075021 (2010); http://pdg.lbl.gov/
3. H.P. Morsch, arXiv 1112.6345 [gen-ph]; and other publications cited therein
4. J.Z. Simon, Phys. Rev. D 41, 3720 (1990); A. Foussats, E. Manavella, C. Repetto, O.P. Zandron, and O.S. Zandron, Int. J. theor. Phys. 34, 1 (1995); V.V. Nesterenko, J. Phys. A: Math. Gen. 22, 1673 (1989); and refs. therein
5. G.S. Bali, K. Schilling, and A. Wachter, Phys. Rev. D 56, 2566 (1997)
6. H.P. Morsch, arXiv 1104.2576 [hep-ph], with comments as in ref. [3].
7. S.S. McGaugh and W.J.G. de Blok, Astrophys. J. 499,41 (1998) and 499,66 (1998) (arXiv:astro-ph/9801102 and 9801123)