Unified meson-baryon potential

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We study the spectra of mesons and baryons, composed of light quarks, in the framework of a semirelativistic potential model including instanton induced forces. We show how a simple modification of the instanton interaction in the baryon sector allows a good description of the meson and the baryon spectra using an interaction characterized by a unique set of parameters.

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I. INTRODUCTION

The description of the meson and baryon spectra in the framework of nonrelativistic or semirelativistic potential models appears to be a rather successful approach. Many works have been devoted to the study of these observables but generally not in a consistent way: the meson properties (see, for example, Refs. [1–5]) or the baryon properties (see, for example, Refs. [6–9]) are investigated in disconnected approaches. The spectra are generally well reproduced separately; only the understanding of few states remains difficult [radial excitations of kaons or $\Lambda(1405)$, for example]. Nevertheless a unified description of meson and baryon spectra seems to be more problematic. For example, in Ref. [4], the meson spectra are nicely reproduced, but the baryon spectra with the same potential are not so satisfactory. Conversely, the model of Ref. [9] is rather good for baryon spectra, but appears catastrophic if applied, as such, to describe the meson properties. There exist only few complete studies dealing consistently with both meson and baryon spectra. Even if some encouraging results have already been obtained, none is really satisfying.

In a pioneer work, Bhaduri *et al.* have proposed a nonrelativistic model relying on a Cornell potential and a spin-spin interaction [10]. The authors proposed a consistent scheme and used the same set of parameters for mesons and baryons. This model was refined later on by Silvestre-Brac and Semay [11] with interesting successes. However, the main problem arising with these models is the bad description of the radial excitations of mesons and baryons; this is due partly to the use of nonrelativistic kinematics [12]. Most of these excitations are calculated 200–300 MeV above their experimental value. Moreover, pseudoscalar mesons cannot be described in a satisfactory way since the interaction does not allow flavor mixing and thus does not allow a correct description of the mesons η and η'.

Isgur *et al.* have proposed a semirelativistic model relying on a Y junction for a confinement supplemented by spin-spin, spin-orbit, and tensor interactions [13] (denoted CGI model in this paper). A purely phenomenological annihilation term was added to describe the flavor mixing. The authors also proposed to take into account some relativistic effects by replacing the masses of the quarks appearing in the interaction by expressions which depend on quark momenta; this procedure introduces new phenomenological parameters. This leads to a complicated model which, up to our knowledge, has never been used for systems containing more than three quarks. Despite the use of such a complex model, the authors need to choose different values for the slope of the confinement for mesons and for baryons to obtain good theoretical results (some other parameters have also been slightly modified). The meson spectra obtained with this model are good and similar to spectra obtained with more simple models (see, for example, Ref. [14]). The baryon spectra are also in good agreement with experiment (but less good than the meson spectra) and here also similar to spectra obtained with more simple models (see, for example, Ref. [15]). Note that the baryon spectra are clearly less good than that obtained with Goldstone Boson-Exchange models [9], but a unified description of mesons and baryons seems to be difficult within this formalism [16].

Another attempt to get a consistent description of meson and baryon properties with a simple model was performed by Blask *et al.* [17] (denoted BBHMP model in this paper). The authors proposed a nonrelativistic model relying on a confinement supplemented by an instanton induced interaction [18]. The meson and baryon ground states are well described, but the use of a nonrelativistic kinematics leads, here also, to a bad description of radial excitations of mesons and baryons.

These previous works devoted to the description of meson and baryon properties with a unique interaction show clearly that this task is complex, and no satisfying result has already been obtained. Very recently, Löring *et al.* have studied meson and baryon spectra within a relativistic framework based on a covariant Bethe-Salpeter equation [19]. Even with this more sophisticated model an unified description is not possible.

In a previous work [15], we tried such a description using a semirelativistic model relying on a Cornell potential supplemented by an instanton induced interaction. No satisfying result was obtained, but this work [15] and a previous

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one [14] have clearly shown that a separate description of meson and baryon properties was possible within this simple semirelativistic potential. So, a natural question arises: ''which simple modification (if any) of our model could lead to a consistent description of both meson and baryon spectra?''

In this work, we show that, at least one such a modification exists. The one we present consists in adding a simple constant term in the instanton induced interaction in the baryon sector.

II. MODEL

The model used in this work is similar to those introduced in Refs. [14,15], except from the additional mentioned term in the instanton induced interaction (see below). Here, we just recall the main lines of our model.

The Hamiltonian is written

$$H=\sum_{i=1}^{N}\sqrt{\vec{p}_i^{\,2}+m_i^2}+\sum_{i<j=1}^{N}V_{ij}\quad (N=2 \text{ or } 3), \tag{1}$$

with $\vec{p}_i$ the momentum of quark i ($\Sigma_{i=1}^{N}\vec{p}_i=\vec{0}$), m_i being its constituent mass, and V_{ij} is the interaction between quarks (or antiquarks) i and j. The interaction contains the Cornell potential and the instanton induced interaction. The Cornell potential, which depends only on the distance r between two quarks, is given by

$$V_{\mathrm{C}}(r)=-\frac{3}{4}\frac{\lambda_i\cdot\lambda_j}{4}\left[-\frac{\kappa}{r}+ar+C_{\mathrm{M}}+C_{\mathrm{B}}\delta_{N3}\right], \tag{2}$$

The confining part of this potential represents a good approximation of the string junction in a meson and of a Y-shape string configuration in a baryon. As usual, we need two different constant interactions to obtain correct absolute values of the meson and baryon energy levels. C_{M} is the constant for the meson spectra, while C_{B} is the constant that we need to add to C_{M} to obtain the correct absolute value of the energy levels of the baryon spectra. The presence of the C_{B} term could simulate the effect of three-body forces. Obviously, the values of these constants do not influence the structure of the wave function and thus play a minor role: only the relative positions of the energy levels have a physical meaning.

The instanton induced interaction provides a suitable formalism to reproduce well the spectrum of the pseudoscalar mesons (and to explain the masses of η and η' mesons). In the nonrelativistic limit, this interaction between one quark and one antiquark in a meson [17,20] is vanishing for $L\neq 0$ or $S\neq 0$ states. For $L=S=0$, its form depends on the isospin of the $q\bar{q}$ pair

(i) For $I=1$,

$$V_{\mathrm{I}}(r)=-8g\,\delta(\vec{r}); \tag{3}$$

(ii) For $I=1/2$,

$$V_{\mathrm{I}}(r)=-8g'\,\delta(\vec{r}); \tag{4}$$

(iii) $I=0$,

$$V_{\mathrm{I}}(r)=8\begin{pmatrix} g & \sqrt{2}g' \\ \sqrt{2}g' & 0\end{pmatrix}\delta(\vec{r}), \tag{5}$$

in the flavor space $[1/\sqrt{2}(|u\bar{u}\rangle+|d\bar{d}\rangle),|s\bar{s}\rangle]$.

The parameters g and g' are two dimensioned coupling constants. Between two quarks in a baryon, this interaction is written [17,20]

$$V_{\mathrm{I}}(r)=-4(gP^{[nn]}+g'P^{[ns]})P^{S=0}\delta(\vec{r}), \tag{6}$$

where $P^{S=0}$ is the projector on spin 0, and $P^{[qq']}$ is the projector on antisymmetrical flavor state qq' (n for u or d is a nonstrange quark, and s is the strange quark). The operator $P^{[nn]}$ is simply a projector on isosinglet states. A procedure to compute the matrix elements of the projector $P^{[ns]}$ is described in Ref. [15].

The instanton induced forces also give a contribution Δm_q to the current quark mass m_q^0. As this interaction is not necessarily the only source for the constituent mass, a phenomenological term δ_q is also added to the current mass [14]. Finally, the constituent masses in our model are given by

$$m_n=m_n^0+\Delta m_n+\delta_n, \tag{7}$$

$$m_s=m_s^0+\Delta m_s+\delta_s. \tag{8}$$

In the instanton theory, the quantities g, g', Δm_n, Δm_s are given by integrals over the instanton size ρ up to a cutoff value ρ_c [see for instance Ref. [20], formulas (5)–(9)]. These integrals can be rewritten in a more interesting form for numerical calculations by defining a dimensionless instanton size $x=\rho\Lambda$, where Λ is the QCD scale parameter [14].

The quark masses used in our model are the constituent masses and not the current ones. It is then natural to suppose that a quark is not a pure pointlike particle, but an effective degree of freedom that is dressed by the gluon and quark-antiquark pair clouds. The form that we retain for the color charge density of a quark is a Gaussian function

$$\rho(\vec{r})=\frac{1}{(\gamma\sqrt{\pi})^{3/2}}\exp(-r^2/\gamma^2). \tag{9}$$

It is generally assumed that the quark size γ depends on the flavor. So, we consider two size parameters γ_n and γ_s for n and s quarks, respectively. It is assumed that the dressed expression $\tilde{O}_{ij}(\vec{r})$ of a bare operator $O_{ij}(\vec{r})$, which depends only on the relative distance $\vec{r}=\vec{r}_i-\vec{r}_j$ between the quarks i and j, is given by

$$\tilde{O}_{ij}(\vec{r})=\int d\vec{r}\,'O_{ij}(\vec{r}\,')\rho_{ij}(\vec{r}-\vec{r}\,'), \tag{10}$$

where ρ_{ij} is also a Gaussian function of type (9) with the size parameter γ_{ij} given by

$$\gamma_{ij}=\sqrt{\gamma_i^2+\gamma_j^2}. \tag{11}$$

This formula is chosen because the convolution of two Gaussian functions, with size parameters γ_i and γ_j respectively, is also a Gaussian function with a size parameter given by Eq. (11) (for more details, see Ref. [14]).

After convolution with the quark density, a Cornell dressed potential has the following form:

$$-\frac{\kappa}{r}+ar+C\rightarrow-\kappa\frac{\mathrm{erf}(r/\gamma_{ij})}{r}+ar\left[\frac{\gamma_{ij}\exp(-r^2/\gamma_{ij}^2)}{\sqrt{\pi}r}+\left(1+\frac{\gamma_{ij}^2}{2r^2}\right)\mathrm{erf}(r/\gamma_{ij})\right]+C, \tag{12}$$

while the Dirac distribution in $V_{\mathrm{I}}(r)$ is transformed into a Gaussian function

$$\delta(\vec{r})\rightarrow\frac{1}{(\gamma_{ij}\sqrt{\pi})^3}\exp(-r^2/\gamma_{ij}^2). \tag{13}$$

Despite this convolution, we consider, for simplicity, that the instanton induced forces act always only on $L=0$ states.

We have shown in Ref. [15] that this model is not able to describe correctly meson and baryon spectra in a consistent way. We needed to use two different sets of parameters to get a correct description of hadron masses. So, we have performed of series of minimizations, starting with new ranges of parameters and studying only some classes of hadrons. We have then remarked that it was systematically possible to reproduce the masses of all the mesons, as well as the masses of the baryons for which the instanton induced interaction does not act. Consequently, we tried to modify in different ways $V_{\mathrm{I}}(r)$ of Eq. (6) in the baryon sector. We propose below the simplest form that we found, which gives good results:

$$V_{\mathrm{I}}(r)=-4(gP^{[nn]}+g'P^{[ns]})P^{S=0}\tilde{\delta}(\vec{r})+C_{\mathrm{I}}(P^{[nn]}+P^{[ns]})P^{S=0}P^{L=0}. \tag{14}$$

In this formula, C_{I} is a new constant. Due to the presence of the projectors, this additional term will not contribute on an equal footing for all baryon states. The status of this supplementary term is up to now purely phenomenological. Let us note that a three-body instanton induced interaction exists but its contribution is vanishing in baryon [17,20]. So, the new additional term we propose cannot be interpreted as a simulation of such a three-body interaction.

Even if we cannot provide any physical explanation for its presence in the interaction, we believe that such an improvement of both meson and baryon spectra (see Sec. III) is not only a question of chance; a physical process could exist to explain the existence of this supplementary interaction. Investigations in this direction are in progress.

TABLE I. Centers of gravity (c.o.g.) of L and I multiplets for mesons chosen to fix the parameters of the model (the minimal uncertainty is fixed at 10 MeV, see Ref. [14]). The values of the c.o.g. and their corresponding errors are given by formula (33) of Ref. [14]. The symbol ''mf '' means ''mixed flavor.'' A meson name used to represent a multiplet in Figs. 1, 2, and 3 is underlined.

State	Flavor	I	$J^{P(C)}$	$N\,^{2S+1}L_J$	c.o.g. (GeV)
$\underline{\pi}$	$n\bar{n}$	1	0^{-+}	$1\,^1S_0$	0.138 ± 0.010
$\underline{\omega}$	$n\bar{n}$	0	1^{--}	$1\,^3S_1$	0.772 ± 0.010
ρ	$n\bar{n}$	1	1^{--}	$1\,^3S_1$	
$\underline{h_1(1170)}$	$n\bar{n}$	0	1^{+-}	$1\,^1P_1$	1.265 ± 0.013
$b_1(1235)$	$n\bar{n}$	1	1^{+-}	$1\,^1P_1$	
$f_1(1285)$	$n\bar{n}$	0	1^{++}	$1\,^3P_1$	
$a_1(1260)$	$n\bar{n}$	1	1^{++}	$1\,^3P_1$	
$f_2(1270)$	$n\bar{n}$	0	2^{++}	$1\,^3P_2$	
$a_2(1320)$	$n\bar{n}$	1	2^{++}	$1\,^3P_2$	
$\underline{\pi_2(1670)}$	$n\bar{n}$	1	2^{-+}	$1\,^1D_2$	1.681 ± 0.012
$\omega(1600)$	$n\bar{n}$	0	1^{--}	$1\,^3D_1$	
$\rho(1700)$	$n\bar{n}$	1	1^{--}	$1\,^3D_1$	
$\omega_3(1670)$	$n\bar{n}$	0	3^{--}	$1\,^3D_3$	
$\rho_3(1690)$	$n\bar{n}$	1	3^{--}	$1\,^3D_3$	
$\underline{f_4(2050)}$	$n\bar{n}$	0	4^{++}	$1\,^3F_4$	2.039 ± 0.022
$a_4(2040)$	$n\bar{n}$	1	4^{++}	$1\,^3F_4$	
$\underline{\pi(1300)}$	$n\bar{n}$	1	0^{-+}	$2\,^1S_0$	1.300 ± 0.100
$\underline{\omega(1420)}$	$n\bar{n}$	0	1^{--}	$2\,^3S_1$	1.454 ± 0.026
$\rho(1450)$	$n\bar{n}$	1	1^{--}	$2\,^3S_1$	
$\underline{K}$	$s\bar{n}$	1/2	0^-	$1\,^1S_0$	0.496 ± 0.010
$\underline{K^*(892)}$	$s\bar{n}$	1/2	1^-	$1\,^3S_1$	0.892 ± 0.010
$\underline{K_1(1270)}$	$s\bar{n}$	1/2	1^+	$1\,^1P_1$	1.382 ± 0.010
$K_0^*(1430)$	$s\bar{n}$	1/2	0^+	$1\,^3P_0$	
$K_1(1400)$	$s\bar{n}$	1/2	1^+	$1\,^3P_1$	
$K_2^*(1430)$	$s\bar{n}$	1/2	2^+	$1\,^3P_2$	
$\underline{K_2(1770)}$	$s\bar{n}$	1/2	2^-	$1\,^1D_2$	1.774 ± 0.012
$K^*(1680)$	$s\bar{n}$	1/2	1^-	$1\,^3D_1$	
$K_2(1820)$	$s\bar{n}$	1/2	2^-	$1\,^3D_2$	
$K_3^*(1780)$	$s\bar{n}$	1/2	3^-	$1\,^3D_3$	
$\underline{\phi}$	$s\bar{s}$	0	1^{--}	$1\,^3S_1$	1.019 ± 0.010
$\underline{h_1(1380)}$	$s\bar{s}$	0	1^{+-}	$1\,^1P_1$	1.482 ± 0.010
$f_1(1510)$	$s\bar{s}$	0	1^{++}	$1\,^3P_1$	
$f_2'(1525)$	$s\bar{s}$	0	2^{++}	$1\,^3P_2$	
$\underline{\phi_3(1850)}$	$s\bar{s}$	0	3^{--}	$1\,^3D_3$	1.854 ± 0.010
$\underline{\phi(1680)}$	$s\bar{s}$	0	1^{--}	$2\,^3S_1$	1.680 ± 0.020
$\underline{f_2(2010)}$	$s\bar{s}$	0	2^{++}	$2\,^3P_2$	2.011 ± 0.080
$\underline{\eta}$	mf	0	0^{-+}	$1\,^1S_0$	0.547 ± 0.010
$\underline{\eta'}$	mf	0	0^{-+}	$1\,^1S_0$	0.958 ± 0.010

III. MESON AND BARYON SPECTRA

In Tables I and II, we give the set of meson and baryon resonances used to fit the parameters of the model (the numerical techniques and the fitting procedure are explained in

TABLE II. Quantum numbers and masses (the minimal uncertainty is fixed at 10 MeV, see Ref. [14]) of the baryons chosen in the fit of parameters.

Baryon	I	J^P	Mass (GeV)
N	$\frac{1}{2}$	$\frac{1}{2}^+$	0.939 ± 0.010
$N(1440)$	$\frac{1}{2}$	$\frac{1}{2}^+$	1.450 ± 0.020
Δ	$\frac{3}{2}$	$\frac{3}{2}^+$	1.232 ± 0.010
$N(1535)$	$\frac{1}{2}$	$\frac{1}{2}^-$	1.537 ± 0.018
Λ	0	$\frac{1}{2}^+$	1.116 ± 0.010
Σ	1	$\frac{1}{2}^+$	1.193 ± 0.010
Σ^*	1	$\frac{3}{2}^+$	1.385 ± 0.010
Ξ	$\frac{1}{2}$	$\frac{1}{2}^+$	1.315 ± 0.010
Ξ^*	$\frac{1}{2}$	$\frac{3}{2}^+$	1.530 ± 0.010
Ω	0	$\frac{3}{2}^+$	1.672 ± 0.010

Refs. [14,15]). This sample is composed of 28 states taken from the most reliable ones [18 centers of gravity (c.o.g.) of meson multiplets and ten baryons] [21].

In Table III, we present the optimal values found for the parameters of our model. We see that all the parameters of the instanton induced interaction as well as the slope of the confinement have values in agreement with the expected values. The constant C_{B} is very small with respect to C_{M}. The origin of these constants is not clear; several attempts to explain the presence of these quantities can be found in the literature [1,22–24]. Nevertheless, as mentioned in the introduction, the physical meaning of these constants is not crucial since their values do not influence the wave functions of the systems, hence the values of other observables. The values of other parameters (κ, quark sizes, constituent masses) are less constrained but there are close to values found in the literature. As we have already noticed in our previous works [14,15], the instanton induced interaction cannot explain alone the renormalization of the current quark masses. Its contribution is 45 MeV for the quark n and 26 MeV for the quark s, values that are relatively small as compared to the constituent masses of these quarks.

TABLE III. List of parameters of the model. The column ''Meson-baryon'' contains the parameter values used to compute the meson and baryon spectra presented in Figs. 1–6. When available, the expected value of a parameter is also given in the column ''Exp.'' The values of the quantities m_n, m_s, g, and g' computed with these parameters are also indicated at the end.

Parameters	Unit	Meson-baryon	Exp.
m_n^0	GeV	0.005	0.001–0.009 [21]
m_s^0	GeV	0.167	0.075–0.170 [21]
Λ	GeV	0.216	$0.208^{+0.025}_{-0.023}$ [21]
$\langle \bar{n}n \rangle$	GeV^3	$-(0.225)^3$	$(-0.225 \pm 0.025)^3$ [28]
$\langle \bar{s}s \rangle / \langle \bar{n}n \rangle$		0.800	0.8 ± 0.1 [28]
ϵ		0.000	0–1 [14]
a	GeV^2	0.210	0.20 ± 0.03 [29]
κ		0.525	
C_{M}	GeV	−0.691	
C_{B}	GeV	−0.033	
C_{I}	GeV	−0.065	
γ_n	GeV^{-1}	0.779	
γ_s	GeV^{-1}	0.566	
δ_n	GeV	0.186	
δ_s	GeV	0.279	
m_n	GeV	0.236	
m_s	GeV	0.472	
g	GeV^{-2}	2.906	
g'	GeV^{-2}	1.710	

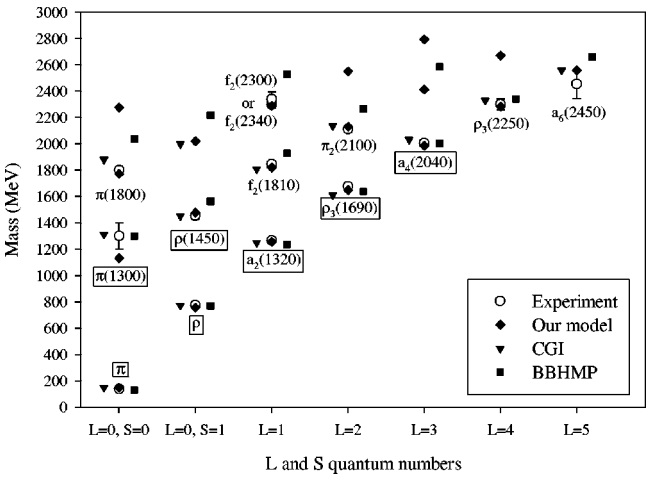

FIG. 1. Masses of $n\bar{n}$ mesons as a function of total orbital angular momentum and total spin. Framed names indicate centers of gravity of multiplets used in the fit of parameters.

In our previous work concerning only mesons [14], we have found several samples of parameters giving similar spectra (see, for instance, models I to V in this reference). The same situation occurs for the baryons [15]. On the contrary, when mesons and baryons are considered together, all the minimizations that we performed produced only very similar sets of parameters. It seems that masses of both mesons and baryons put more severe constraints on the parameters of the model.

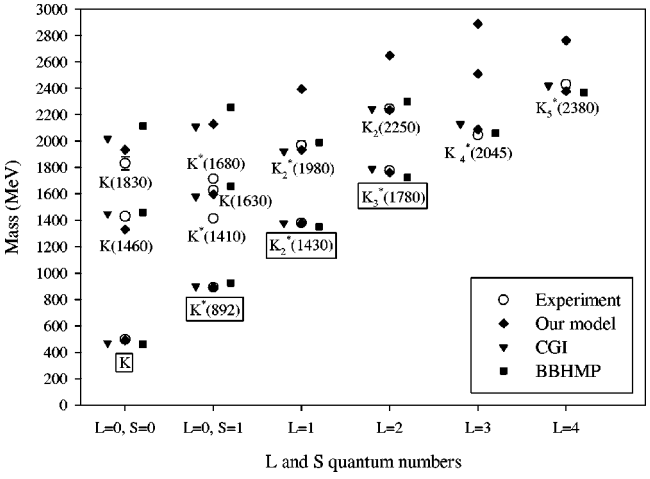

FIG. 2. Same as Fig. 1 but for $n\bar{s}$ mesons.

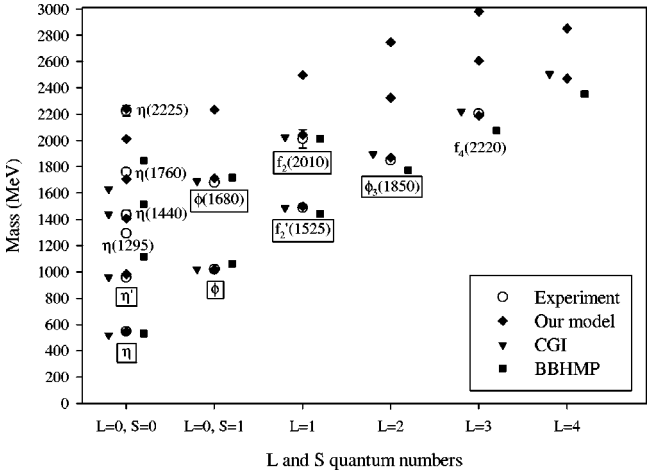

FIG. 3. Same as Fig. 1 but for $s\bar{s}$ and mixed flavor mesons.

Figures 1–3 show a comparison between the meson spectra obtained with the model proposed in Sec. II, the data and the results obtained with the CGI and the BBHMP models (we do not present any comparison with the work of Bhaduri *et al.* because the spectra obtained with this model have roughly the same characteristics than the results of the BBHMP model). It is worth noting that the spectra obtained with our model are as good as that obtained in our previous work [14], where the model was designed to describe only the light mesons. Our energy levels present the same characteristics than those found with the CGI model, but they are clearly better than those obtained with the nonrelativistic BBHMP model compared to experimental data. As mentioned in the introduction, the main difficulties that appear with nonrelativistic models are the correct description of radial excitations. Note that the pseudoscalar mesons π-K-η-η' are very well described with a unique interaction (namely, the instanton induced interaction) while in the CGI model a purely phenomenological annihilation interaction was introduced to describe only the η and η' mesons. There still exist problems concerning radial excitations. Contrary to other works, our model reproduces nicely the $\pi(1800)$ resonance but gives a too low value for the $\pi(1300)$ state, which nevertheless has a very large width. Moreover, the kaon radial excitations (K and K^*) also present some deficiencies. Lastly, the $\eta(1295)$ meson seems to not fit in this scheme. One must seriously wonder whether the explanation can be searched from a description in terms of tetraquarks or other exotic possibilities.

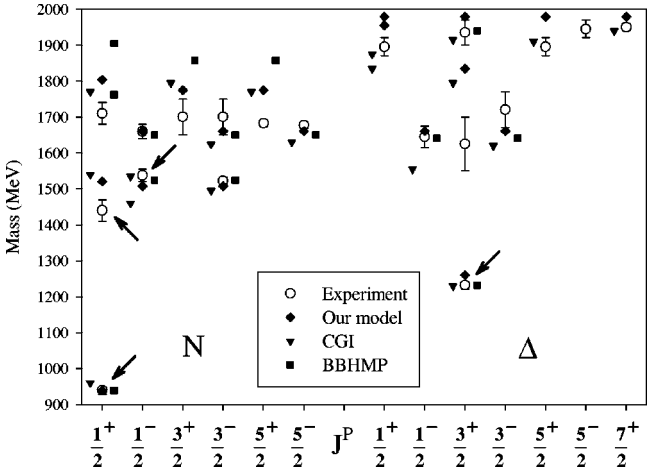

FIG. 4. Masses of the N and Δ baryons (status ★★★★ and ★★★) as a function of total angular momentum and parity J^P. The arrows indicate baryons used in the fit of parameters.

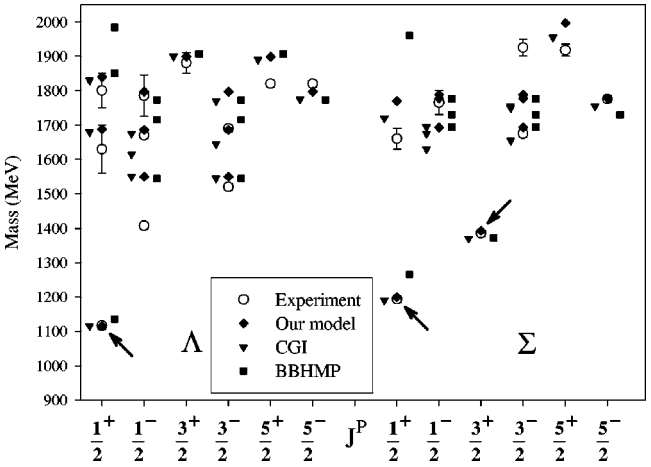

FIG. 5. Same as Fig. 4 but for the Λ and the Σ baryons.

The Figs. 4–6 present the same analysis but concerning baryon spectra. Here also, the spectra obtained with our model are as good as that obtained in our previous work [15], where the parameters of the model were fitted to describe only the light baryons. Globally, the features of our spectra as compared to those obtained with the CGI and the BBHMP models can be summarized as follow. We have an improvement of the positive-parity states as compared to the corresponding ones obtained with the BBHMP model, while the negative-parity states are close in both models. Conversely, we have an improvement of the negative-parity states as compared to the those obtained with the CGI model while the positive-parity states are close in both models. Although a semirelativistic kinetic energy operator substantially improves the various Roper resonances, there still re-

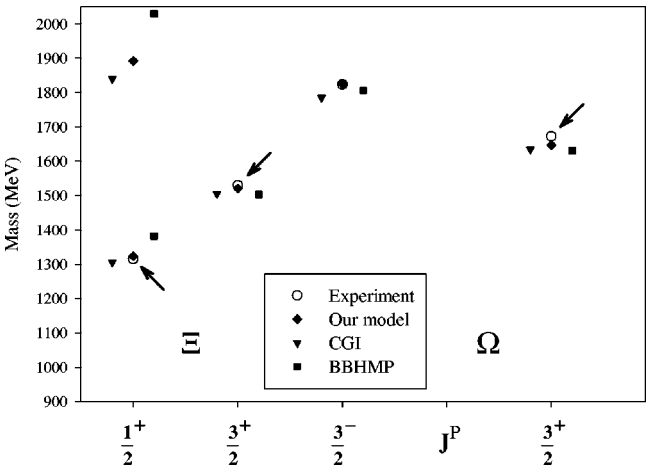

FIG. 6. Same as Fig. 4 but for the Ξ and the Ω baryons.

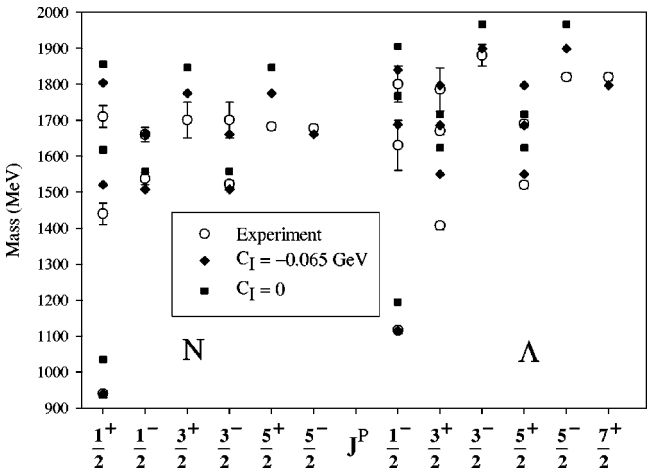

FIG. 7. Effect of the additional term C_I in the instanton induced interaction in the baryon sector for the N and the Λ baryons. The two samples of masses presented are obtained with the same parameters, except the value of C_I.

mains a noticeable disagreement with experimental data. Moreover, the $\Lambda(1405)$ seems to resist to any description in the framework of potential models. It is worth mentioning that the contribution of $q^4\bar{q}$ configurations could be large in the nucleon Roper resonance and the $\Lambda(1405)$ [25,26]. In this case, these two states could not be described by a simple q^3 model as that studied here.

The Fig. 7 gives an illustration of the action of C_I on the energy levels of the N and Λ families (where it plays a major role). For instance, with $C_I=0$, the Δ and Ω baryons are well reproduced, but the masses of the N and Λ sectors are tens of MeV too high. When $C_I=-65$ MeV, these last baryons are more nicely described while the states of the Δ and Ω sectors remain at the same place.

IV. CONCLUDING REMARKS

In Ref. [14], we showed that a simple semirelativistic model based on the spinless Salpeter equation with a Cornell potential supplemented by instanton induced forces is able to describe correctly light meson spectra, provided the quarks are considered as effective degrees of freedom with a finite size and a constituent mass. The wave function was partially tested by calculating the electromagnetic mass splitting.

In Ref. [15], we showed that this simple semirelativistic model extended to treat three constituent quarks leads to a rather good description of the light baryon spectra. However, this model does not provide a correct unified description of both meson and baryon spectra. Two different sets of parameters were necessary for such a calculation; the natural link between meson and baryon was then broken.

In this work, we present a simple extension of these models which allows a good consistent description of both meson and baryon spectra. An interaction with one free parameter is added to the instanton induced interaction in the baryon sector solely. This is, up to now, a purely phenomenological constant term with the same projector structure than the leading term of the instanton induced interaction in the baryon sector.

The spectra calculated with the model defined in Sec. II are globally better than those obtained with other models built to describe both mesons and baryons. Obviously, better spectra can be found in the literature but they are obtained with models dedicated to only one of these hadron families. These encouraging results incite to perform further tests of our model by calculating other observables, for example, electromagnetic mass splittings, electromagnetic form factors, and decay widths. Such a work is in progress [27]. The model could also be extended to heavy mesons and baryons, but in this case another spin-dependent interaction is needed since the instanton induced interaction does not act in these sectors.

[1] W. Lucha, F. F. Schöberl, and D. Gromes, Phys. Rep. **200**, 127 (1991).
[2] Junchen Su, Yubing Dong, and Shishu Wu, J. Phys. G **18**, 1347 (1992).
[3] L. P. Fulcher, Phys. Rev. D **50**, 447 (1994).
[4] C. Semay and B. Silvestre-Brac, Nucl. Phys. **A618**, 455 (1997).
[5] L. A. Blanco, F. Fernández, and A. Valcarce, Phys. Rev. C **59**, 428 (1999).
[6] B. Silvestre-Brac and C. Gignoux, Phys. Rev. D **32**, 743 (1985).
[7] F. Stancu and P. Stassart, Phys. Rev. D **41**, 916 (1990).
[8] B. Desplanques *et al.*, Z. Phys. A **343**, 331 (1992).
[9] L. Ya. Glozman, W. Plessas, K. Varga, and R. F. Wagenbrunn, Phys. Rev. D **58**, 094030 (1998); for more recent calculations see R. F. Wagenbrunn, L. Y. Glozman, W. Plessas, and K. Varga, Nucl. Phys. **A663&A664**, 703c (2000); **A684**, 284c (2001).
[10] R. K. Bhaduri, L. E. Cohler, and Y. Nogami, Nuovo Cimento **65**, 376 (1981).
[11] B. Silvestre-Brac and C. Semay, internal report, ISN Grenoble, preprint ISN 93-69, 1993; C. Semay and B. Silvestre-Brac, Z. Phys. C **61**, 271 (1994); B. Silvestre-Brac, Few-Body Syst. **20**, 1 (1996).
[12] F. Brau, Phys. Rev. D **62**, 014005 (2000).
[13] S. Godfrey, Phys. Rev. D **31**, 2375 (1985); S. Godfrey and N. Isgur, *ibid.* **32**, 189 (1985); S. Capstick and N. Isgur, *ibid.* **34**, 2809 (1986).
[14] F. Brau and C. Semay, Phys. Rev. D **58**, 034015 (1998).
[15] C. Semay, F. Brau, and B. Silvestre-Brac, Phys. Rev. C **64**, 055202 (2001).
[16] N. Isgur, Phys. Rev. D **62**, 054026 (2000).
[17] W. H. Blask, U. Bohn, M. G. Huber, B. C. Metsch, and H. R. Petry, Z. Phys. A **337**, 327 (1990).
[18] Edward V. Shuryak and Jonathan L. Rosner, Phys. Lett. B **218**, 72 (1989).
[19] U. Löring, K. Kretzschmar, B. C. Metsch, and H. R. Petry, Eur. Phys. J. A **10**, 309 (2001); U. Löring, B. C. Metsch, and H. R.

Petry, *ibid.* **10**, 395 (2001); **10**, 447 (2001).
[20] C. R. Münz, J. Resag, B. C. Metsch, and H. R. Petry, Nucl. Phys. **A578**, 418 (1994).
[21] Particle Data Group, D. E. Groom *et al.*, Eur. Phys. J. C **15**, 1 (2000).
[22] D. Gromes, Z. Phys. C **11**, 147 (1981); **14**, 94(E) (1982).
[23] J. Carlson and V. R. Pandharipande, Phys. Rev. D **43**, 1652 (1991).
[24] C. Semay and B. Silvestre-Brac, Phys. Rev. D **52**, 6553 (1995).
[25] Masahiro Kimura *et al.*, Phys. Rev. C **6**, 015206 (2000).
[26] O. Krehl, C. Hanhart, S. Krewald, and J. Speth, Phys. Rev. C **62**, 025207 (2000).
[27] F. Brau, Thesis, Université de Mons-Hainaut, 2001.
[28] L. J. Reinders *et al.*, Phys. Rep. **127**, 1 (1985).
[29] C. Michael, in *Proceedings of the 17th International Conference on Lepton-Photon Interactions, LP95, Beijing, 1995*, edited by Zheng Zhi-Peng and Chen He-Sheng (World Scientific, Singapore, 1996), p. 626.