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K. Prema

S.S. Raghavan

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Sekhar Raghavan

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K. Prema **
International Centre for Theoretical Physics, Trieste, Italy

S.S. Raghavan
Physics Department, Regional College of Education
Mysore 570006, India

and

Sekhar Raghavan
Designs and Prototypes, Adyar, Madras 600020, India.

ABSTRACT

Nucleon-Nucleon interaction is studied using a phenomenological potential model called solitary wave exchange potential model. It is shown that this simple model reproduces the singlet and triplet scattering data and the deuteron parameters reasonably well.

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** Permanent address: Department of Physics, Seethalakshmy Ramaswamy College, Tiruchirappalli 620002, India.

Burt and Sebhatu [1)-4)] have in a series of papers developed the $\lambda\phi^4$ and $\lambda\phi^6$ solitary wave exchange potentials (hereafter called SWEP). The advantage with the SWEP potentials is that they require very few parameters and generalizations of one-boson exchange potential are obtained without the introduction of new arbitrary mass meson exchange [4)]. In this note we report a preliminary investigation done in the fitting of the two-nucleon data using SWEP.

Instead of the conventional linear field theory propagator, Burt and Sebhatu [4)] using a solitary wave propagator have shown that in the non-relativistic limit of the direct part of the lowest order, solitary wave exchange N-N interaction amplitude is

$$M_{NN} = \left(\frac{g}{2m}\right)^2 (\vec{\tau}_1\cdot\vec{\tau}_2)(\vec{\sigma}_1\cdot\vec{k})(\vec{\sigma}_2\cdot\vec{k}) \sum_{n=0}^{\infty}\left\{\frac{\Gamma(2qn+2)(2qn+1)^{2qn-2}}{\left[m_{qn}^2+\vec{k}^2\right]^{qn+1}}\left[\frac{Z_q}{V^q}\right]^{2n}\left[C_n^{1/2q}(\varepsilon_q)\right]^2\right\} \tag{1}$$

where $\vec{\tau}$ and $\vec{\sigma}$ are the isospin and spin Pauli matrices, g the Λ-N coupling constant, M the nucleon mass and $\vec{k}$ the exchanged three momentum.

In Eq.(1) Γ_n are the usual Gamma functions

$$m_{qn} = (2qn+1)m$$

$$\varepsilon_q = \lambda_1/4Z_q(q+1)m^2$$

$$Z_q = \left[\frac{\lambda_1^2}{16(q+1)^2m^4} - \frac{\lambda_2}{4(2q+1)m^2}\right]^{1/2} \tag{2}$$

where λ_1 and λ_2 are self interaction coupling constants and m is the mass of the associated linear fields. After some mathematical manipulation [4] the potential is expressed in terms of Legendre and Laguerre polynomials. Using the standard definitions of polynomials the potential is reduced to the form

$$
\begin{aligned}
V^{SWEP}_{\alpha,\gamma}(x) = \frac{g^2}{4\pi}\left(\frac{m}{2m}\right)^2 \frac{m}{3} (\vec{\tau}_1 \cdot \vec{\tau}_2) \Bigg\{ & \left[\vec{\sigma}_1 \cdot \vec{\sigma}_2 + S_{12}\left(1 + \frac{3}{x} + \frac{3}{x^2}\right)\right] \frac{e^{-x}}{x} \\
& + 3\alpha^2 \left[\vec{\sigma}_1 \cdot \vec{\sigma}_2 (3x - 2) + S_{12}(3x + 1)\right] \frac{e^{-3x}}{x} + \frac{75}{4}(2\alpha^2 + \gamma)^2 \\
& \left[\vec{\sigma}_1 \cdot \vec{\sigma}_2 (5x - 3) + S_{12}(5x)\right] e^{-5x} + \frac{735}{4}(2\alpha^3 + \alpha\gamma)^2 \\
& \left[\vec{\sigma}_1 \cdot \vec{\sigma}_2 (49x^2 - 21x - 3) + S_{12}(49x^2)\right] e^{-7x} + \ldots\ldots \Bigg\}
\end{aligned}
\tag{3}
$$

where $x = mR$; $\alpha = \frac{\lambda_1}{8m^3 v}$ and $\gamma = \frac{\lambda_2}{12m^4 v}$

As can be seen from Eq.(3) the potential has only three adjustable parameters. Further, for large distances the experimental terms for higher mass particles drop out leaving behind the one pion exchange contribution alone. On the other hand, for small distances SWEP can be shown to possess a delta function singularity, thus giving the necessary repulsion in the form of hard-core. Hence, these features provided the motivation for using the polynomial SWEP in the N-N problem.

Having found that the SWEP has the necessary characteristics of a phenomenological nuclear potential, it is logical to investigate whether such a potential will be able to fit the two body data.

Using SWEP we have fitted the $^1S_0$ phase shifts and our results are shown in Fig.1. In evaluating the phase shifts we have used the variable phase approach of Calogero [5]. This method is very powerful and is amenable for easy computation. The singlet effective range and the scattering length are also computed and are shown in Table 1.

In the triplet state the potential is fitted to the deuteron data and the triplet phase shifts as shown in Fig.2. The deuteron wave functions are obtained by numerical integration of the coupled differential equations. The potential parameters which fit the deuteron data, the triplet scattering length and the triplet effective range are also tabulated in Table 1.

From Table 1, we note that the SWEP potential reproduces the two-body data reasonably well. Thus the SWEP seems to be a simple model without too many adjustable parameters for describing the N-N interactions unlike other potential models. A thorough search for phase shifts of higher partial waves and investigation of the few body problems with this interaction are in progress.

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TABLE 1

SWEP PARAMETERS AND LOW ENERGY RESULT FOR THE n – p SYSTEM

	Potential Parameters					
State	$\frac{g^2}{4\pi}\left(\frac{m}{2m}\right)^2 m$ (MeV)	α	y	Core Radius (F)	Quantity	Experiment *)
Singlet	10.9	0.73	0	0.467	a_s(F) = −23.8	−23.7 ± 0.1
					r_s(F) = 2.36	2.51 ± 0.15
Triplet	10.0	0.50	0	0.55	E_B(Deutron) = −2.223(Mev)	−2.2246(Mev)
					P_D = 7.72%	4 to 7%
					$Q(F^2)$ = 0.2885	0.2860 ± 0.0015
					η = 0.0264	0.0260 ± 0.001
					a_t(F) = 5.29	5.39 ± 0.01
					r_t(F) = 1.86	1.73 ± 0.02

*) L. Petris, J. Phys. G7,309 (1981)

FIGURE CAPTIONS

Fig.1 $^1S_0$ Phase shifts for the interaction as a function of laboratory energy. The experimental results (•) are taken from MacGregor <u>et al.</u>[6].

Fig.2 $^3S_1$ Phase shifts for the interaction as a function of laboratory energy. The experimental results (•) are taken from MacGregor <u>et al.</u>[6].

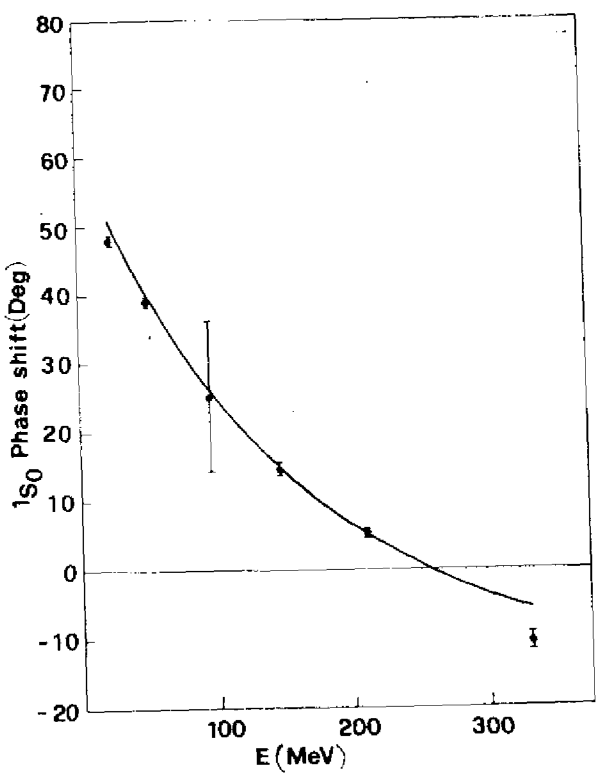

Fig. 1

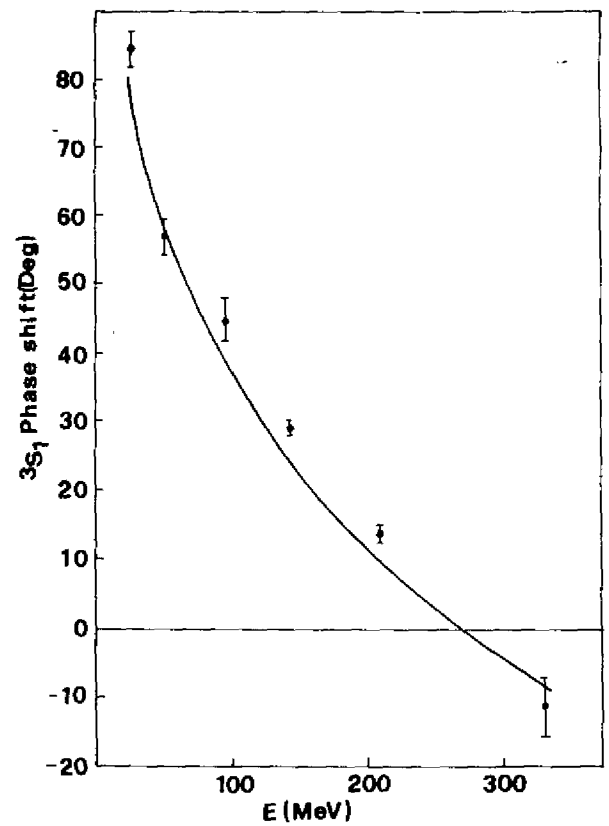

Fig. 2