Pramana – J. Phys., Vol. 37, No. 1, July 1991, pp. 57–58. © Printed in India.

Instantons and the hyperfine splitting of B and B_S mesons

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MS received 13 March 1991; revised 16 April 1991

Abstract. In this short note we wish to point out that the instanton model, which was theoretically fascinating, has recently found application in explaining the hyperfine splitting of mesons and baryons. In particular, the flavour independence of $M_v^2 - M_P^2$ (i.e. the squared mass difference of the vector and the pseudoscalar mesons), known to be constant for the strange and non-strange mesons in the u, d and the charm quark sectors, have recently been shown to be the same for the beauty sector through experiments. This flavour independence and the magnitude of the splitting agrees remarkably well with the instanton model.

Keywords. Instanton model; vector-pseudoscalar meson mass difference; flavour independence of hyperfine splitting.

PACS Nos 12·40; 14·40

In a recent letter, Lee-Franzini *et al* (1990) reported on the average B^*-B meson mass difference to be $46{\cdot}7 \pm 0{\cdot}4$ MeV from data taken by the Columbia–SUNY CUSB–II detector. Analyzing the experiment they find the mass difference for the non-strange and the strange B-s to be $\Delta M_{NS} = 45{\cdot}4 \pm 1{\cdot}0$ MeV, and $\Delta M_S = 47{\cdot}0 \pm 2{\cdot}6$ MeV. This fits with the empirical rule $M_v^2 - M_P^2 = 0{\cdot}54 - 0{\cdot}58\ \mathrm{GeV}^2$ which we refer to as the MR rule [after A Martin who first suggested it in 1981 as stated by Song (1989)]. This rule is flavour independent as it fits the (π, ρ; $0{\cdot}573\ \mathrm{GeV}^2$), ($K, K^*$; $0{\cdot}551\ \mathrm{GeV}^2$), ($D, D^*$; $0{\cdot}547\ \mathrm{GeV}^2$), ($D_s, D_s^*$; $0{\cdot}575\ \mathrm{GeV}^2$) and now ($B, B^*$; $0{\cdot}528\ \mathrm{GeV}^2$), ($B_s, B_s^*$, $0{\cdot}544\ \mathrm{GeV}^2$). It was also pointed out by Lee-Franzini *et al* (1990) that the results disagree with the naive quark model, where the ratio should go as the ratio of quark masses, $m_{u,d}/m_s \cong 0{\cdot}7$. We would like to point out that the MR is expected in the instanton model (Belavin *et al* 1975; 't Hooft 1976) for mesons in the local approximation (Shuryak 1982, 1983; Kochelev 1985).

This model is a variant of the quark potential model where one takes the dressed masses of the valence quarks (antiquarks) of various flavours and adds the additional binding due to the attractive interaction with instanton configurations for the scalar diquark (or $q\bar{q}$) and fits the hadron masses. The model is valid over a wide range of energy scales—from the Goldstone mesons (Shuryak 1982, 1983; Kochelev 1985) to charm and beauty baryons (Shuryak and Rosner 1989; Dey *et al* 1990, 1991). The model has recently been applied also to nucleon-nucleon interaction by Oka and Takeuchi (1989), in order to see whether the naive quark model and this model predicts different results in the six quark case. In the 3 quark case the predictions are indistinguishable.

As discussed by Kochelev (1985) and Shuryak and Rosner (1989), the difference between the masses of the vector and pseudo-scalar mesons $M_v - M_P$ in the model depends only on the instanton density in a lowest order approximation, i.e. on the inverse average volume of the mesons. Assuming this volume depends on the average mass of the mesons, a result which is exact in the MIT bag model of Chodos *et al* (1974), one gets the MR. The remarkable applicability of the MR for all flavours is thus a success of the simple instanton model. It may be that this is another case when the model is distinguishable from the naive quark model through flavour independence—a case which is phenomenologically clearer than the six quark problem considered by Oka and Takeuchi (1989).

Acknowledgement

I acknowledge a grant from DST, Govt. of India. This work was done when the author was in IIT, Kanpur to discuss physics with Prof. H S Mani and Dr Ravishanker.

References

Belavin A A, Polyakov A M, Schwarz A S and Tyupkin Yu S 1975 *Phys. Lett.* **B59** 85
Chodos A, Jaffe R L, Johnson K, Thorn C B and Weisskopf V 1974 *Phys. Rev.* **D9** 3471
Dey J, Dey M and Volkovitsky P 1990 Instantons and charmed baryon mass splittings, Trieste Preprint IC/90/337, *Phys. Lett. B* (in press)
Dey J, Dey M and Volkovitsky P 1991 *Spectroscopy of heavy-flavoured baryons with positive parity.* Paper presented at Whepp-II by Volkovitsky, January 1991, Calcutta, preprint (to be published)
't Hooft G 1976 *Phys. Rev.* **D14** 3432
Kochelev N I 1985 *Sov. J. Nucl. Phys.* **41** 291
Lee-Franzini J, Heintz U, Lovelock D M J, Narain M, Schamberger R D, Willins J, Yanagisawa C, Franzini P and Tuts P M 1990 *Phys. Rev. Lett.* **65** 2947
Oka M and Takeuchi S 1989 *Phys. Rev. Lett.* **63** 1780
Shuryak E V 1982 *Nucl. Phys.* **A203** 93
Shuryak E V 1983 *Nucl. Phys.* **A214**, 237
Shuryak E V 1988 QCD vacuum, hadrons and the superdense matter (Singapore: World Scientific) pp. 180–182
Shuryak E V and Rosner R L 1989 *Phys. Lett.* **B218** 72
Song X 1989 *Phys. Rev.* **D40** 3655