Magnetic moments of the $N(1535)$ resonance in the chiral unitary model

T. Hyodo[a], S. I. Nam[a,b] D. Jido[a1] and A. Hosaka[a]

[a]*Research Center for Nuclear Physics (RCNP), Ibaraki, Osaka 567-0047, Japan*
[b]*Department of Physics, Pusan National University, Pusan 609-735, Korea*

The study of properties of baryon resonances has attracted continuous attention and is one of the most important topics in hadron physics. The first nucleon resonance with negative parity, $N(1535)$, has a unique feature of its strong coupling to the ηN state, which allows us to take relatively clean data to other resonance by using the eta meson in the final state as a probe of the intermediate $N(1535)$. Recently, the chiral unitary model has been successfully applied to meson-baryon scatterings, where s-wave baryon resonances, such as $\Lambda(1405)$ and $N(1535)$, are described as dynamically generated objects by the ground state mesons and baryons [1]. In Ref. [2], the magnetic moments were calculated for $\Lambda(1405)$ and $\Lambda(1670)$ in the chiral unitary model. Following that paper, here we calculate the magnetic moments of $N(1535)$ in the chiral unitary model. Recently, the resonance magnetic moments were studied also in the quark model [3], and therefore, the present study provides one of the alternative descriptions.

The s-wave scattering amplitudes of the meson and baryon are obtained by the chiral unitary model, where the $N(1535)$ resonance is dynamically generated [4]. This amplitude can be interpreted as the resonance pole term around $N(1535)$ energy region, as shown in the upper diagram in Fig. 1. We then introduce the photon field and electromagnetic couplings based on effective chiral Lagrangian, and we calculate the amplitude for the photon-resonance coupling $-i\tilde{t}_{ij}$ as shown in Fig. 1. Using these two amplitudes, we evaluate the magnetic moments of the resonance. We obtain the results as

$$\mu_{n^*(1535)} = -0.25\mu_N \ , \quad \mu_{p^*(1535)} = 1.1\mu_N \ . \tag{1}$$

where μ_N is the nuclear magneton. For more detail of the formulation, see Ref. [2, 5]

[1]Present address: ECT*, European Centre for Theoretical Studies in Nuclear Physics and Related Areas Villa Tambosi, Strada delle Tabarelle 286, I-38050 Villazzano (Trento), Italy

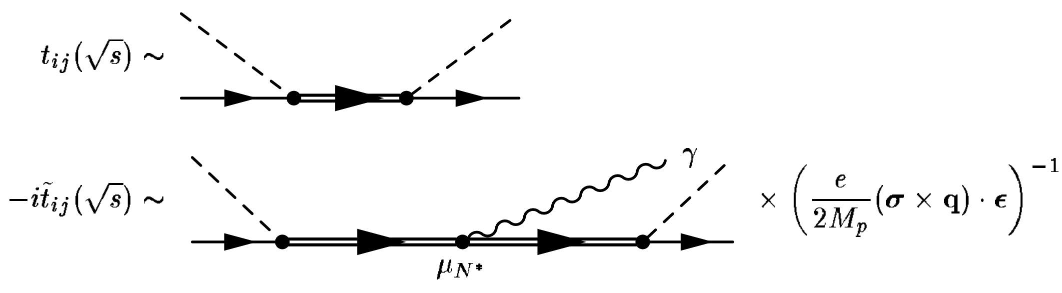

Figure 1: Feynman diagrams of the amplitudes $t_{ij}(\sqrt{s})$ and $-i\tilde{t}_{ij}(\sqrt{s})$ around energy region of the resonance. Solid, dashed, wavy and double lines represent baryons, mesons, photon and baryon resonances, respectively. The baryon resonances are considered as the dynamically generated by summing the meson-baryon loops up to infinite order.

Table 1: Coupling strengths $|g_i|^2$ of $N(1535)$ and $\Lambda(1670)$ in SU(3) basis.

representation	1	8	8	10	$\overline{10}$	27
$n^*(1535)$	–	5.2	6.2	0.17	–	0.58
$\Lambda^*(1670)$	4.0	2.3	7.3	–	–	0.16

Now we study the value of μ_{N*} obtained here in the aspect of the SU(3) flavor symmetry. The magnetic moment of $\Lambda(1670)$ are calculated in the chiral unitary model [2];

$$\mu_{\Lambda^*(1670)} = -0.29\mu_N \ . \tag{2}$$

Since the $N(1535)$ and $\Lambda(1670)$ has the same spin-parity $1/2^-$ and the similar masses, they have been considered to be members of an SU(3) octet. If the SU(3) symmetry is exact, the magnetic moments of the octet should satisfy the Coleman-Glashow relations :

$$\mu_{n^*} = 2\mu_{\Lambda^*} \ . \tag{3}$$

In the present calculation, the signs of the magnetic moments are consistent with this relation, although the absolute values do not agree with Eq. (3). This relation is discussed more clearly by looking at the SU(3) decomposition of the resonance states in terms of the coupling strengths to each channel g_i. The coupling strengths in the SU(3) basis are obtained by a unitary transformation using SU(3) Clebsh-Gordan coefficients. In Table 1, $|g_i|^2$ in SU(3) basis are shown, where we observe that for both $N(1535)$ and $\Lambda(1670)$, octet components are dominant. This fact explains qualitative agreement of the relation between μ_{n^*} and μ_{Λ^*} in the chiral unitary model. Deviation from the relation comes from the large mixture of the singlet component in $\Lambda(1670)$ and SU(3) breaking effects.

We can also extract the anomalous magnetic moments κ in units of $\mu_{N^*} \equiv e/2M_{N^*}$. The results are

$$\kappa_S(1535) = 0.22\mu_{N^*} \ , \quad \kappa_V(1535) = 0.63\mu_{N^*} \ . \tag{4}$$

These numbers may be compared with those of the nucleon (in units of nuclear magneton): $\kappa_S(939) = -0.06\mu_N$ and $\kappa_V(939) = 1.85\mu_N$. Here we see that the strong isovector dominance as in the $N(939)$ magnetic moments is not realized in $N(1535)$.

The present results qualitatively agree with the results of the constituent quark model of Ref. [3]. However, the absolute values of these results are different, so the experimental measurement will bring the information of the structure of the baryon resonances. In Ref. [5], we compute reaction cross section in order to observe the resonance magnetic moments; $\gamma N \to \gamma\eta N$, $\pi^- p \to \gamma\eta n$. The difference in the magnetic moments is, however, not very much reflected in the bremsstrahlung processes.

References

[1] E. Oset and A. Ramos, Nucl. Phys. **A635**, 99 (1998).

[2] D. Jido, A. Hosaka, J. C. Nacher, E. Oset, and A. Ramos, Phys. Rev. **C66**, 025203 (2002).

[3] W.-T. Chiang, S. N. Yang, M. Vanderhaeghen, and D. Drechsel, nucl-th/0211061.

[4] T. Inoue, E. Oset, and M. J. Vicente Vacas, Phys. Rev. **C65**, 035204 (2002).

[5] T. Hyodo, S. I. Nam, D. Jido, and A. Hosaka, nucl-th/0305023.