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Vector meson dominance and ρ-ω mixing

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The scale of a phenomenologically successful charge-symmetry-violating nucleon-nucleon interaction, that attributed to meson exchange with a $\Delta I=1$ ρ-ω transition, is set by the Coleman-Glashow SU(2)-breaking tadpole mechanism. A single tadpole scale has been obtained from symmetry arguments, electromagnetic meson and baryon measured mass splittings, and the observed isospin-violating ($\Delta I=1$) decay $\omega\to\pi^+\pi^-$. The hadronic realization of this tadpole mechanism lies in the $I=1$ a_0 scalar meson. We show that measured hadronic and two-photon widths of the a_0 meson, with the aid of the vector meson dominance model, recover the universal Coleman-Glashow tadpole scale. [S0556-2813(98)00911-X]

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I. INTRODUCTION

An isospin-violating effective interaction, with the strength of second-order electromagnetic (em) theory and labeled $H_{\rm em}$, has long been invoked to explain the observed $\Delta I_z=1$ meson and baryon diagonal electromagnetic mass splittings, and the observed $\Delta I=1$ off-diagonal transitions ρ^0-ω, π^0-η, and π^0-η'. In particular, it is the effective em ρ^0-ω transition

$$\langle\rho^0|H_{\rm em}|\omega\rangle\approx-4520\ \ {\rm MeV}^2, \tag{1}$$

as found [1] from the observed [2] isospin-violating ($\Delta I=1$) decay $\omega\to\pi^+\pi^-$, which underlies the dominant charge-symmetry-violating (CSV) nucleon-nucleon interaction of Refs. [3,4]. The latter CSV *NN* force is quite successful in explaining the observed charge symmetry violation in nuclear physics. These observations include *NN* scattering and bound state (the Okamoto-Nolen-Schiffer anomaly) differences in mirror nuclear systems, Coulomb displacement energies of isobaric analog states, isospin-mixing matrix elements relevant to the isospin-forbidden beta decays, and precise measurements of the elastic scattering of polarized neutron from polarized protons [5,6]. In addition, the latter CSV ρ^0-ω mixing potential is ''natural'' [i.e., dimensionless strength coefficients are $\mathcal{O}(1)$ in the contact force limit] in the context of low-energy effective Lagrangian approaches to nuclear charge symmetry violation [7]. In spite of the phenomenological success and theoretical plausibility of the CSV potential based upon the effective $\Delta I=1$ Hamiltonian density in Eq. (1), this potential has been criticized in the recent literature on nuclear charge symmetry violation [8].

Alternative approaches [9] based, not on data and physical Feynman amplitudes, but upon a ''mixed propagator'' of field theory, imply a CSV *NN* potential which is neither consistent with the nuclear data nor with the naturalness criterion. One of the misleading conclusions stemming from a focus on the mixed propagator (only an ingredient of a *NN* potential) will be discussed in another paper [10]. In this paper we return to the theory behind Eq. (1): the Coleman-Glashow tadpole picture [11,12] in which both transitions $\langle\rho^0|H_{\rm em}|\omega\rangle$ and $\langle\pi^0|H_{\rm em}|\eta\rangle$ are given by the tadpole graphs of Fig. 1 and the photon exchange graphs of Fig. 2. We reexamine, in the light of current particle data [13], the numerical accuracy of vector meson dominance (VMD) [14], and then use VMD to link measured decays of the $I=1$ scalar meson a_0 to the universality of $\Delta I=1$ meson transitions recently established [15]. We close with a discussion of the implications of our results for recent conjectures about a direct $\omega\to2\pi$ coupling [16–20]; i.e., a decay not based on $\omega\to\rho\to2\pi$, which is a G-parity-violating $\Delta I=1$ transition.

II. PHOTONIC AND TADPOLE COMPONENTS OF $H_{\rm em}$

The effective $\Delta I=1$ Hamiltonian density $H_{\rm em}$ in Eq. (1) was originally thought [11,12] to be composed of a Coleman-Glashow (CG) nonphotonic contact tadpole part (now couched in the language of the u_3 current quark mass matrix $\bar{q}\lambda^3 q$) along with a photonic part H_{JJ} involving in-

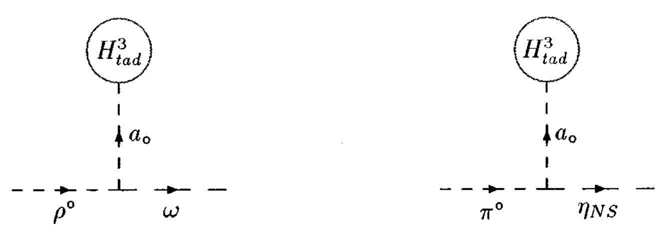

FIG. 1. a_0 meson tadpole diagrams for the CSB $\Delta I=1$ transitions $\langle\rho^0|H^3_{\rm tad}|\omega\rangle$ and $\langle\pi^0|H^3_{\rm tad}|\eta_{\rm NS}\rangle$. According to Coleman and Glashow [11], these are diagrams that can be broken into two parts, connected only by the scalar meson a_0 line, such that one part is the scalar tadpole $\langle 0|H^3_{\rm tad}|a_0\rangle$, represented by the circle, and the other part involves only the SU(3)-invariant strong interactions. The latter interactions, in this case, $a_0\to\omega\rho^0$ and $a_0\to\eta\pi^0$ transitions, are represented by the coupling constants of Eq. (11).

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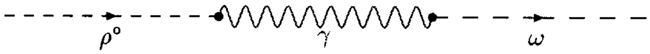

FIG. 2. The current-current contribution $\langle\rho^0|H_{JJ}|\omega\rangle$ to $\langle\rho^0|H_{\rm em}|\omega\rangle$.

termediate photon exchange. This CG tadpole mechanism [11]

$$H_{\rm em}=H_{\rm tad}^3+H_{JJ}\,, \tag{2}$$

with a *single* tadpole scale, in fact explains the 13 ground state pseudoscalar, vector, octet baryon, and decuplet baryon SU(2) observed diagonal mass splittings without the introduction of additional free parameters [15].

For the off-diagonal ρ^0-ω transition, Gatto [21] first showed that the VMD of Fig. 2 predicts the photon exchange contribution

$$\langle\rho^0|H_{JJ}|\omega\rangle=(e/g_\rho)(e/g_\omega)m_V^2\approx 644\ \ {\rm MeV}^2. \tag{3}$$

In Eq. (3) we have used the average ρ^0-ω mass $m_V=776$ MeV along with the updated VMD ratios $g_\rho/e\approx 16.6$ and $g_\omega/e\approx 56.3$, with the latter g_ρ and g_ω couplings found from electron-positron decay rates [13]:

$$\Gamma_{\rho ee}=\frac{\alpha^2}{3}m_\rho(g_\rho^2/4\pi)^{-1}\approx 6.77\ \ {\rm keV}, \tag{4a}$$

$$\Gamma_{\omega ee}=\frac{\alpha^2}{3}m_\omega(g_\omega^2/4\pi)^{-1}\approx 0.60\ \ {\rm keV}, \tag{4b}$$

leading to $g_\rho\approx 5.03$ and $g_\omega\approx 17.05$ for $e=\sqrt{4\pi\alpha}\approx 0.30282$. Note that Eqs. (4a) and (4b) imply the ratio $g_\omega/g_\rho\approx 3.4$, which is reasonably near the SU(3) value $g_\omega/g_\rho=3$. Finally, combining the VMD H_{JJ} prediction (3) with the observed H_{em} transition in Eq. (1), one finds the CG tadpole transition using Eq. (2) is

$$\langle\rho^0|H_{\rm tad}^3|\omega\rangle\approx -4520\ \ {\rm MeV}^2-644\ \ {\rm MeV}^2\approx -5164\ \ {\rm MeV}^2. \tag{5}$$

In fact this off-diagonal CG tadpole scale of Eq. (5) extracted from $\omega\to 2\pi$ data combined with the VMD scale of Eq. (3) is quite close to the CG tadpole scale predicted from the SU(3) diagonal vector meson mass splittings [22]. If the ω is assumed to be pure nonstrange, the SU(3) prediction becomes

$$\langle\rho^0|H_{\rm tad}^3|\omega\rangle=\Delta m_{K*}^2-\Delta m_\rho^2\approx -5120\ \ {\rm MeV}^2, \tag{6}$$

obtained using the 1996 PDG values, $m_{K*^+}\approx 891.6$ MeV, $m_{K*^0}\approx 896.1$ MeV so that $\Delta m_{K*}^2=m_{K*^+}^2-m_{K*^0}^2\approx -8040\ \ {\rm MeV}^2$. While $m_{\rho^+}\approx 766.9$ MeV, the more elusive ρ^0 mass at [23] $m_{\rho^0}\approx 768.8$ MeV then requires $\Delta m_\rho^2=m_{\rho^+}^2-m_{\rho^0}^2\approx -2920\ \ {\rm MeV}^2$. The difference between Δm_{K*}^2 and Δm_ρ^2 above then leads to the right hand side of Eq. (6).

Since only a slight change of m_{ρ^0} above can shift $\Delta m_{K*}^2-\Delta m_\rho^2$ by more than 10%, it is perhaps more reliable to exploit the SU(6) symmetry between the pseudoscalar and vector meson masses, $m_{K*}^2-m_\rho^2=m_K^2-m_\pi^2$. But because this SU(6) relation is valid to within 5%, it is reasonable to assume the SU(6) mass difference $\Delta m_{K*}^2-\Delta m_\rho^2=\Delta m_K^2-\Delta m_\pi^2$ also holds. Then the ρ^0-ω tadpole transition (6) is predicted to be [15]

$$\langle\rho^0|H_{\rm tad}^3|\omega\rangle=\Delta m_{K*}^2-\Delta m_\rho^2=\Delta m_K^2-\Delta m_\pi^2\approx -5220\ \ {\rm MeV}^2, \tag{7}$$

because pseudoscalar meson data [13] require $\Delta m_K^2=m_{K^+}^2-m_{K^0}^2\approx -3960\ \ {\rm MeV}^2$ and $\Delta m_\pi^2=m_{\pi^+}^2-m_{\pi^0}^2\approx -1260\ {\rm MeV}^2$, leading to the right hand side of Eq. (7). Comparing the similar tadpole scales of $\sim -5200\ \ {\rm MeV}^2$ in Eqs. (5), (6), and (7), we might deduce from this consistent picture that $\langle\rho^0|H_{em}|\omega\rangle$ in turn is predicted to have the scale $\langle\rho^0|H_{em}|\omega\rangle\approx -4500\ \ {\rm MeV}^2$, as was found from the Barkov $\omega\to 2\pi$ data [1,2].

To emphasize that the above tadpole scale (5)–(7) of the off-diagonal $\Delta I=1$ ρ^0-ω transition also holds for the diagonal electromagnetic mass differences as well, we briefly review the well-measured pseudoscalar π and K em mass splittings. It has long been known [24] that Δm_π^2 is essentially due to the photonic self-interaction mass shifts of the charged and uncharged pions [25]. As noted in Ref. [15], this familiar idea takes the form in the tadpole picture $[(H_{\rm em})_{\pi^+}=\langle\pi^+|H_{\rm em}|\pi^+\rangle$, etc]:

$$\Delta m_\pi^2\equiv(H_{\rm em})_{\Delta\pi}\equiv(H_{\rm em})_{\pi^+}-(H_{\rm em})_{\pi^0}=(H_{\rm tad}^3)_{\Delta\pi}+(H_{JJ})_{\Delta\pi}$$
$$=(H_{JJ})_{\Delta\pi}\,, \tag{8a}$$

where the first equality is due to the CG decomposition (2) and the second equality is because $(H_{\rm tad}^3)_{\Delta\pi}=0$ due to SU(2) symmetry. However, $(H_{\rm tad}^3)_{\Delta K}$ does not vanish in the analogous CG kaon mass splitting relation

$$\Delta m_K^2\equiv(H_{\rm tad}^3)_{\Delta K}+(H_{JJ})_{\Delta K}\,. \tag{8b}$$

Then subtracting Eq. (8a) from Eq. (8b) while using the Dashen partially conserved axial vector current (PCAC) observation [26]

$$(H_{JJ})_{\pi^0}=(H_{JJ})_{K^0}=(H_{JJ})_{\bar K^0}=0,\quad (H_{JJ})_{\pi^+}=(H_{JJ})_{K^+}, \tag{8c}$$

which is strictly valid in the chiral limit, one is led [15] to the diagonal pseudoscalar meson tadpole scale

$$(H_{\rm tad}^3)_{\Delta K}\equiv(H_{\rm tad}^3)_{K^+}-(H_{\rm tad}^3)_{K^0}$$
$$=\Delta m_K^2-\Delta m_\pi^2\approx -5220\ \ {\rm MeV}^2. \tag{9}$$

Extending $\Delta m_K^2-\Delta m_\pi^2$ to $\Delta m_{K*}^2-\Delta m_\rho^2$ via SU(6) along with $(H_{\rm tad}^3)_{\Delta K}=(H_{\rm tad}^3)_{\Delta K*}$ also by SU(6) symmetry yields the diagonal vector meson tadpole scale

$$(H_{\rm tad}^3)_{\Delta K*}\equiv(H_{\rm tad}^3)_{K*^+}-(H_{\rm tad}^3)_{K*_0}$$
$$=\Delta m_{K*}^2-\Delta m_\rho^2\approx -5120\ \ {\rm MeV}^2. \tag{10}$$

Thus we see that the off-diagonal ρ^0-ω tadpole scales (5)–(7) together with the diagonal tadpole scales in Eqs. (9) and (10) are indeed universal. This $-5200\ {\rm MeV}^2$ scale also is approximately valid for diagonal baryon masses when one uses quadratic mass formulas for baryons [15].

III. TADPOLE MECHANISM AND THE $a_0(980)$

The $I=1$ a_0 scalar meson is assumed to play a unique role in the Coleman-Glashow $\Delta I=1$ tadpole mechanism which describes SU(2) mass differences and mixing among hadrons [11,12,27]. Furthermore, this meson is also almost unique among the scalar mesons in that it is experimentally well established with known decay parameters. Therefore one can test the universal tadpole scale of the previous section against experimental data from an entirely different sector. We shall see that this confrontation yields yet another consistent pattern of a $\Delta I=1$ universal tadpole scale.

More specifically the $\Delta I=1$ em tadpole graphs of Fig. 1 are controlled by the $I=1$ $a_0(980)$ pole for both $a_0\to\omega\rho^0$ and $a_0\to\eta\pi^0$ transitions. The unknown tadpole $\langle 0|H^3_{\rm tad}|a_0\rangle$ and the a_0 propagator cancel out of the ratio of the two tadpole graphs of Fig. 1:

$$\frac{\tilde{F}_{a_0\rho^0\omega}}{F_{a_0\pi^0\eta_{NS}}}\approx\frac{\langle\rho^0|H^3_{\rm tad}|\omega\rangle}{\langle\pi^0|H^3_{\rm tad}|\eta_{\rm NS}\rangle}, \tag{11}$$

where $\tilde{F}_{a_0\rho^0\omega}\equiv m^2_{a_0}F_{a_0\rho^0\omega}$. The left-hand side of Eq. (11) can be related to the experimental ratio obtained from the PDG rate $\Gamma_{a_0\gamma\gamma}=(0.24\pm0.08)$ keV (assuming $\Gamma_{a_0\pi\eta}$ is overwhelmingly dominant) divided by $\Gamma_{a_0\pi\eta}\approx 75$ MeV, midway between the PDG range (50–100) MeV:

$$r=\frac{\Gamma_{a_0\gamma\gamma}}{\Gamma_{a_0\pi\eta}}\approx\frac{0.24\ \text{keV}}{75\ \text{MeV}}\approx 3.2\times10^{-6}. \tag{12}$$

This relation is again the VMD model turning the vector mesons of Fig. 2 and Eq. (11) into the γ's of Eq. (12), since the ''rate'' for $a_0\to\rho^0\omega$ cannot be directly measured.

To illustrate the VMD model [14] in this context, we first study $\omega\pi\gamma$ coupling (times the usual Levi-Cività factor $\epsilon_{\mu\nu\alpha\beta}k'^{\mu}k^{\nu}\epsilon^{\alpha}\epsilon^{\beta}$) by comparing it to $\pi^0\gamma\gamma$ coupling (divided by 2 due to Bose symmetry)

$$F_{\omega\pi^0\gamma}=(g_\omega/e)F_{\pi^0\gamma\gamma}/2\approx 0.704\ \text{GeV}^{-1} \tag{13a}$$

by virtue of VMD turning an ω into a γ. Here $F_{\pi^0\gamma\gamma}=\alpha/(\pi f_\pi)\approx 0.025\ \text{GeV}^{-1}$ as found from the axial anomaly or using instead the $\pi^0\gamma\gamma$ rate of 7.6 eV [13]. This VMD prediction (13a) is in excellent agreement with the measured value [13]

$$F_{\omega\pi^0\gamma}=\sqrt{12\pi\Gamma_{\omega\pi^0\gamma}/k^3}\approx 0.704\ \text{GeV}^{-1}, \tag{13b}$$

where the amplitude $F_{\omega\pi^0\gamma}$ is also weighted by $\epsilon_{\mu\nu\alpha\beta}k'^{\mu}k^{\nu}\epsilon^{\alpha}\epsilon^{\beta}$. A similar VMD prediction for $\rho\to\pi^0\gamma$ is also quite good: The VMD amplitude is

$$F_{\rho\pi^0\gamma}=(g_\rho/e)F_{\pi^0\gamma\gamma}/2\approx 0.208\ \text{GeV}^{-1} \tag{13c}$$

using $g_\rho\approx 5.03$ found from Eq. (4a), while the data imply

$$F_{\rho\pi^0\gamma}=\sqrt{12\pi\Gamma_{\rho\pi^0\gamma}/k^3}\approx 0.222\ \text{GeV}^{-1}, \tag{13d}$$

as extracted from the PDG tables in [13].

Given this justification of VMD in Eqs. (13), we follow Bramon and Narison [28] and use VMD to link the CG tadpole mechanism of Fig. 1 with the observed properties of the a_0 meson. We return to Eq. (11) and note that the $a_0\rho^0\omega$ coupling in Eq. (11) is divided by 2 [as it was in Eq. (13a)] when applying VMD to the identical photon transition:

$$F_{a_0\rho^0\omega}\approx(g_\omega/e)(g_\rho/e)F_{\pi^0\gamma\gamma}/2. \tag{14}$$

Since both $F_{a_0\rho^0\omega}$ and $F_{a_0\gamma\gamma}$ are weighted by the covariant form $\epsilon^{*\prime}_{\mu}\epsilon^{*}_{\nu}(k'\cdot kg^{\mu\nu}-k^{\mu}k'^{\nu})$ which squares up to $(k'\cdot k)^2=2(m^2_{a_0}/2)^2$, the desired amplitude $\tilde{F}_{a_0\rho^0\omega}=m^2_{a_0}F_{a_0\rho^0\omega}$ has the same $(\text{GeV})^1$ mass dimension as does $F_{a_0\pi^0\eta\text{NS}}$. The latter is given as

$$F_{a_0\pi^0\eta\text{NS}}=F_{a_0\pi^0\eta}/\cos\phi\approx 1.35F_{a_0\pi^0\eta} \tag{15}$$

for the $\eta'-\eta$ mixing angle $\phi\approx 42^0$ in the NS-S quark basis [29].

On the other hand, the theoretical branching ratio rates become, with VMD [28],

$$r=\frac{\Gamma_{a_0\gamma\gamma}}{\Gamma_{a_0\pi\eta}}=\frac{1}{4}\left|\frac{k_\gamma}{k_\eta}\right|\frac{\tilde{F}^2_{a_0\gamma\gamma}}{F^2_{a_0\pi\eta}}=\frac{4}{4}\left|\frac{k_\gamma}{k_\eta}\right|\left(\frac{e}{g_\omega}\right)^2\left(\frac{e}{g_\rho}\right)^2\frac{\tilde{F}^2_{a_0\rho^0\omega}}{F^2_{a_0\pi\eta}}, \tag{16}$$

where $k_\gamma=492$ MeV, and $k_\eta=321$ MeV, so that $|k_\gamma/k_\eta|\approx 1.53$. The factor of $\frac{1}{4}$ in Eq. (16) corresponds to Feynman's rule of $\frac{1}{2}$ for two identical final-state photons, times the numerator factor of $\frac{1}{2}$ in Eq. (16) coming from the square of the covariant factor $\epsilon^{*\prime}_{\mu}\epsilon^{*}_{\nu}(k'\cdot kg^{\mu\nu}-k^{\mu}k'^{\nu})$ (times $m^2_{a_0}$ which is absorbed into the definition of $\tilde{F}_{a_0\gamma\gamma}$). Finally a factor of 4 in the numerator of the right hand side of Eq. (16) is due to the square of the VMD relation (14).

Substituting the observed r from Eq. (12) back into the theoretical ratio (16) and converting to the $\eta_{\rm NS}$ basis using Eq. (15) then leads to the amplitude ratio

$$\frac{\tilde{F}_{a_0\rho^0\omega}}{F_{a_0\pi^0\eta\text{NS}}}\approx 1.0, \tag{17a}$$

a result which stems only from observed properties of the a_0 meson and VMD.

If one goes further and identifies the transition $\langle 0|H_{\rm em}|a_0\rangle$ as the Coleman-Glashow tadpole, the VMD-phenomenological estimate of unity for the ratio (17a) requires the tadpole ratio in Eq. (11) and in Fig. 1 also to be unity

$$\frac{\langle\rho^0|H^3_{\rm tad}|\omega\rangle}{\langle\pi^0|H^3_{\rm tad}|\eta\text{NS}\rangle}\approx 1.0. \tag{17b}$$

This hadronic picture of the CG tadpole is consistent with the universal SU(6) tadpole scale already obtained in Ref. [15] and reviewed in Sec. II.

Implicit in this identification is the conventional $\bar{q}q$ assignment of the a_0. According to Ref. [28], the tadpole mechanism fails to predict the experimental $\Gamma_{a_0\gamma\gamma}$ if the a_0 is considered to be a $\bar{q}q\bar{q}q$ state. Recent K-matrix analyses of meson partial waves from a variety of three-meson final states obtained from $\pi^- p$ and $p\bar{p}$ reactions show rather convincingly that both the $I=1$ $a_0(980)$ and $I=0$ $f_0(980)$ mesons are formed from the bare states which are members of the lowest $\bar{q}q$ nonet [30]. Recent theoretical developments supporting the assignment of the a_0 to the scalar meson $\bar{q}q$ nonet are reviewed in Ref. [31].

The modern identification of the tadpole scale with the mass difference of the up and down current quarks,

$$H^3_{\rm tad}=\frac{1}{2}(m_u-m_d)\bar{q}\lambda_3 q, \tag{18}$$

suggests a parallel treatment of the hadronic and two-photon couplings of the a_0 based on the three-point function method in QCD sum rules. One begins with VMD to express another measured ratio

$$\frac{\Gamma_{a_0\gamma\gamma}}{\Gamma_{\pi^0\gamma\gamma}}\approx\frac{m^3_{a_0}}{m^3_\pi}\,\frac{g_{a_0\rho^0\omega}}{g_{\pi^0\rho^0\omega}} \tag{19}$$

in terms of the strong coupling constants $g_{a_0\rho^0\omega}$ and $g_{\pi^0\rho^0\omega}$. The latter coupling constant ratio is then estimated with the aid of QCD sum rules which bring in the up and down current quark masses. The result is again a reasonable value for $\Gamma_{a_0\gamma\gamma}$ and the ratio r of Eq. (12). This QCD sum rule treatment of the a_0 decays is consistent with, but does not really give new information about, the Coleman-Glashow tadpole. So we do not describe it further and refer to Refs. [28,32] for a detailed account of this QCD sum rule program.

IV. DISCUSSION

In Sec. III, vector meson dominance was used to link measured decays of the $I=1$ scalar meson a_0 to the universality of $\Delta I=1$ meson transitions $\langle\rho^0|H_{\rm em}|\omega\rangle$ and $\langle\pi^0|H_{\rm em}|\eta\rangle$ recently established [15]. One element of this universality is the value of the effective *em* ρ^0-ω transition found [1] from the observed [2] isospin-violating ($\Delta I=1$) decay $\omega\to\pi^+\pi^-$. To obtain this value, the decay is analyzed as $\omega\to\rho\to2\pi$ [4]. It has recently been asserted [16] that a direct $\omega\to2\pi$ coupling is not only necessary on general principles, but that a significant coupling is supported by a theoretical QCD sum rule analysis of an isospin-breaking correlator of vector currents. This assertion has prompted reanalyses of the data on $e^+e^-\to\pi^+\pi^-$ [17,18] and the modeling of this putative contact $\omega\to2\pi$ term in two quark based models of $\rho^0-\omega$ mixing [19,20]. The results of these three investigations are somewhat mixed. Here they are given as the ratio $G=g_{\omega_I\pi\pi}/g_{\rho_I\pi\pi}$, where ω_I and ρ_I are the basis states of pure isospin $I=0$ and $I=1$, respectively. The data analysis of Ref. [18] suggests $G\approx0.10$, the coupled Dyson-Schwinger equations approach [20] finds a value 5 times smaller ($G\approx0.017$), and the generalized Nambu–Jona-Lasinio model [19] predicts a value which is a further factor of 4 smaller ($G\approx0.004$). The last very small ratio would make direct ω decay a relatively unimportant contribution to the calculation of ρ^0-ω mixing from the data. On the other hand, the isospin breaking from direct ω decay suggested by the data analysis [18] is a huge 10% rather than the few percent usually found for isospin breaking (cf. the 2% Coleman-Glashow ratio reviewed in the Appendix of Ref. [15]). This in turn drives the value of $\langle\rho^0|H_{\rm em}|\omega\rangle$ up to ≈-6830 MeV^2, rather far from the value of ≈-4520 MeV^2 [quoted in Eq. (1)] obtained from the same data when this putative contact term is ignored. It is the latter value which was shown in Secs. 2 and 3 to be consistent with the universality discussed there. The most recent extraction of a ρ^0-ω mixing parameter from the data eschews such a separation into a contact $\omega\to\pi^+\pi^-$ and mixing $\omega\to\rho\to2\pi$ term on the grounds that it is model dependent [33,34]. As we have seen, a significant contact G-parity-violating $\omega\to2\pi$ coupling would increase in magnitude the value of $\langle\rho^0|H_{\rm em}|\omega\rangle$ to such an extent that it would not be consistent with the off-diagonal ρ^0-ω tadpole scales (6) and (7), nor with the diagonal tadpole scales in Eqs. (9) and (10), nor with the diagonal tadpole scales obtained from the baryon mass differences [15]. Furthermore, such a large value of $\langle\rho^0|H_{\rm em}|\omega\rangle$ is not consistent with the $\Delta I=1$ universal tadpole scale obtained in Eq. (17) with the aid of the vector meson dominance model. In view of the inconsistency with the global Coleman-Glashow picture and the limited support from quark-based models [19,20] for a contact $\omega\to2\pi$ which violates G parity, it is instructive to look at the analog four-point contact term in the *strong* decay $\omega\to3\pi$. This term was introduced on general grounds some time after the suggestion [35] that $\omega\to\rho\pi\to3\pi$ will dominate the $\omega\to3\pi$ transition. This dominance of this VMD $\omega\rho\pi$ pole diagram model has been confirmed by the experimental study of the $e^+e^-\to3\pi$ reaction [36]. In fact, a contact term large enough to satisfy a low-energy theorem [38] in the pseudoscalar sector [the axial-vector-vector-vector (AVV) anomaly] spoils agreement with this data. The history of the fate of the contact $\omega\to3\pi$ term can be traced in Ref. [37], which concludes that ''nowadays the existence and magnitude of the contact term can be extracted neither from theory, nor experiment.''

We suggest that a similar fate may be in store for the proposed G-parity-violating $\omega\to2\pi$ contact term. While its effects cannot be cleanly isolated from data [17,18], in contrast to the proposed strong interaction $\omega\to3\pi$ contact term, nevertheless the introduction of this G-parity-violating $\omega\to2\pi$ contact term is inconsistent with the SU(6) prediction (7), the universal CG tadpole scale [15], and, as shown in Sec. III, the measured decay properties of the a_0 meson.

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