Effects of $T=0$ two body matrix elements on $M1$ and Gamow-Teller transitions: Isospin decomposition

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We perform calculations for $M1$ transitions and allowed Gamow-Teller (GT) transitions in the even-even titanium isotopes—^{44}Ti, ^{46}Ti, and ^{48}Ti. We start with the FPD6 interaction. To study the effect of the $T=0$ two-body matrix elements on the $M1$ and GT rates we introduce a second interaction in which all the $T=0$ two-body matrix elements are set equal to zero (A) and a third in which all the $T=0$ two-body matrix elements (B) are set to a constant. For these two interactions the $T=1$ matrix elements are the same as for FPD6. We are thus able to study the effects of the fluctuating $T=0$ matrix elements on $M1$ and GT rates with interactions A and B, and comparing them with the results of using the full FPD6 interaction (C). We find that transition rates are much more sensitive to the details of the $T=0$ interaction than are the spectra of low-lying states of even-even nuclei.

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I. INTRODUCTION

We have previously studied the effects of $T=0$ two-body matrix elements on energy levels. [1,2]. In the former work we used an FPD6 interaction to obtain the energy levels of various fp shell nuclei as well as a second interaction wherein the $T=0$ matrix elements were set to zero while the $T=1$ matrix elements we left unchanged. In a single j shell calculation of ^{44}Ti we found that the energy levels of the yrast even spins $J=2-12$ were very little affected by this apparently severe change. The odd-spin $T=0$ states (not yet found experimentally) were lowered in energy somewhat when this approximation was made (see Fig. 1). Of particular interest in this single j shell calculation many degeneracies appeared, e.g., the $J=\frac{13}{2}^-$ and $\frac{1}{2}^-$ states in ^{43}Sc(^{43}Ti) and $J=3_2^+,7_2^+,9_1^+$ and 10_1^+ states in ^{44}Ti.

In Ref. [1] it was noted that the degenerate states could be labeled by the dual quantum numbers (J_π,J_n). All of the above states contained admixtures of the states $(J_\pi=4,J_n=6)$ and $(J_\pi=6,J_n=4)$. The degeneracies and symmetries required certain $6j$ and $9j$ symbols to vanish and others to be equal. In Ref. [1] it was demonstrated that the use of Regge symmetries for $6j$ symbols showed the nature of the vanishing $6j$ symbols. There are no corresponding Regge relations for $9j$ symbols, but those relations were derived by writing a given $9j$ as a sum of $6j$ symbols.

In a second approach [2] we noted that the $T=\frac{1}{2}$ states of ^{43}Sc(^{43}Ti) and the $T=0$ states of ^{44}Ti broke up into two classes. For one set we found that when the $T=0$ two-body matrix elements were set to zero that degeneracies appeared and a single (J_π,J_n) quantum number could label the state.

For the other set no such symmetries appeared. For ^{43}Sc(^{43}Ti) the members of the first set were $J=\frac{1}{2}$, $\frac{13}{2}$, $\frac{17}{2}$, and $\frac{19}{2}$ while for ^{44}Ti they were $J=3$, 7, 9, 10, and 12. In the second class were the other states, i.e., $J=\frac{3}{2}$, $\frac{5}{2}$, $\frac{7}{2}$, $\frac{9}{2}$, $\frac{11}{2}$, and $\frac{15}{2}$ for ^{43}Sc(^{43}Ti) and $J=0$, 2, 4, 5, 6, and 8 for ^{44}Ti. We thus have a very nice example of a partial dynamical symmetry. Previous examples of such partial symmetries are found in the work of Escher and Leviatan [3].

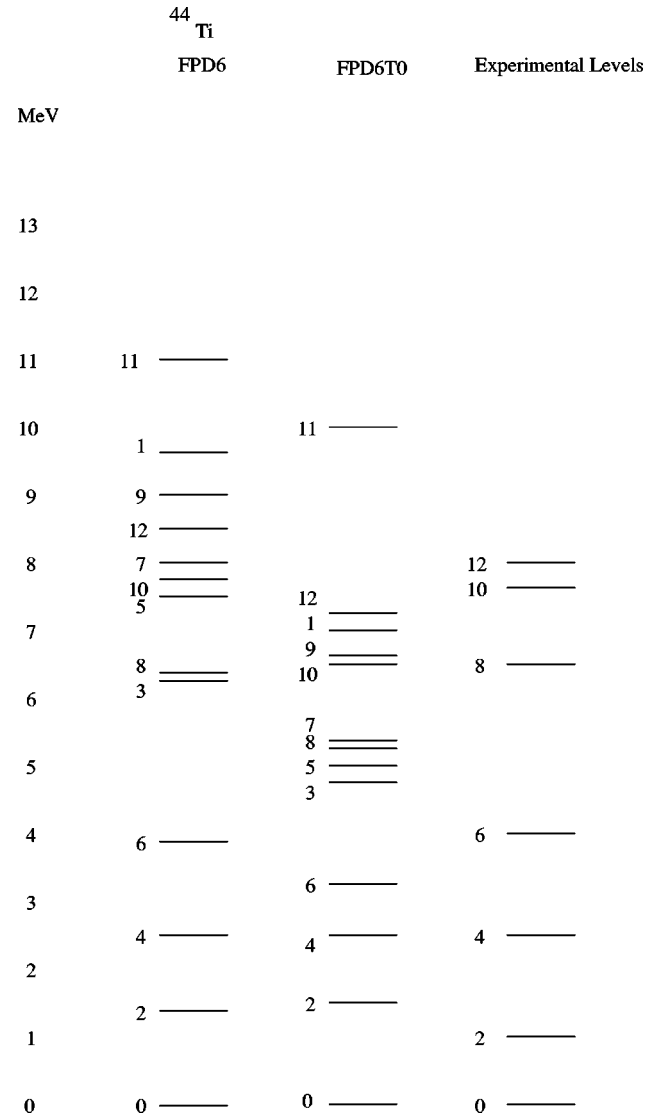

FIG. 1. Spectrum of ^{44}Ti as calculated with FPD6, and FPD6 with T set to zero (FPD6T0) and the known experimental levels.

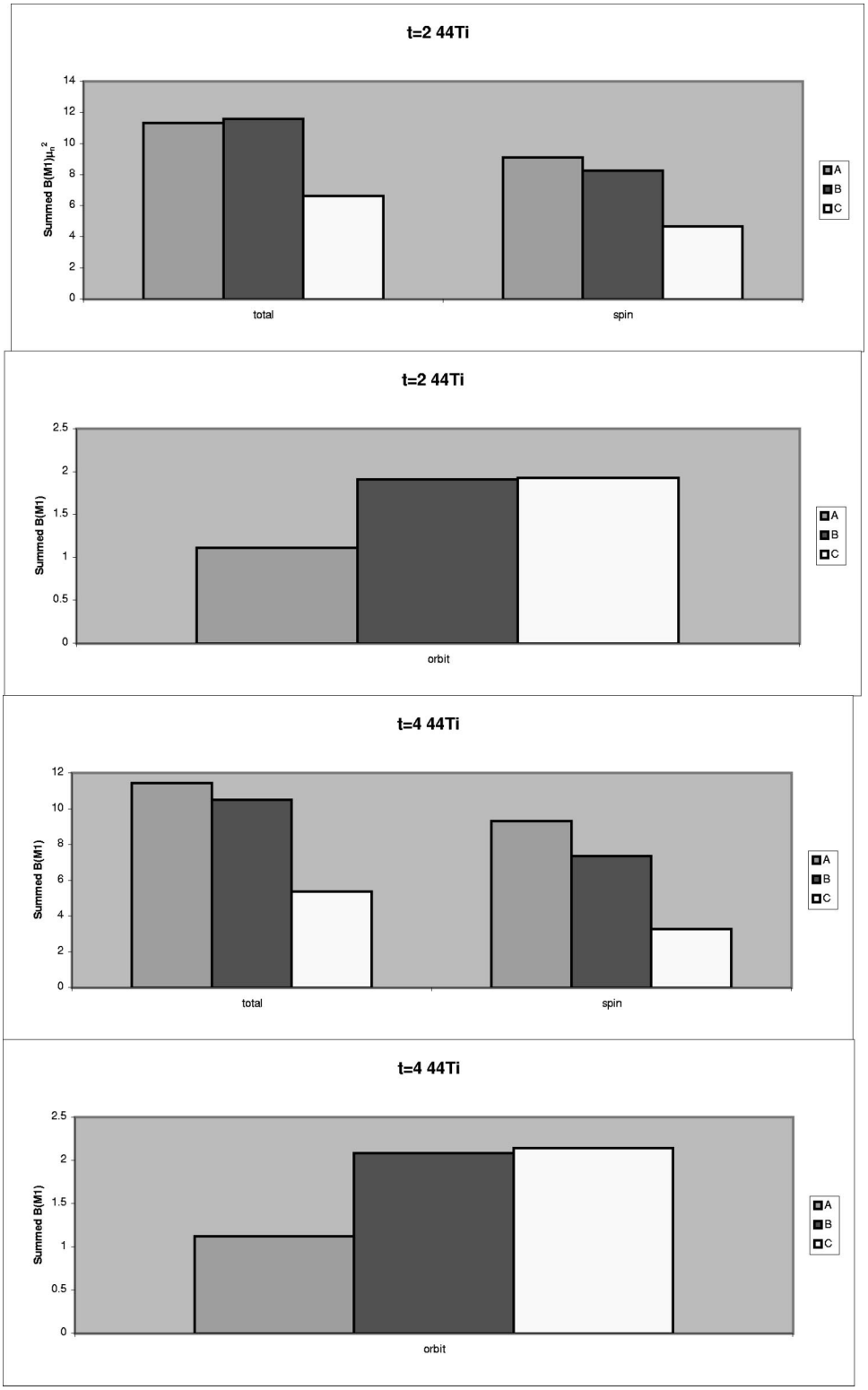

FIG. 2. ^{44}Ti summed $B(M1)$ from $J=0^+$ $T=0$ to $J=1^+$ $T=1$ for $t=2$ and 4.

After spending a long time reflecting on these strange results, we came across the illuminating work by Talmi on coefficients of fractional parentage to states which are forbidden by the Pauli principle. We noted that the states which belonged to the second class (no symmetry) have angular momentum which can occur for the Calcium isotopes in a single j shell model ie for the $T=\frac{3}{2}$ states of ^{43}Ca and for the $T=2$ states of ^{44}Ca. The allowed states for ^{43}Ca are indeed $J=\frac{3}{2}$, $\frac{5}{2}$, $\frac{7}{2}$, $\frac{9}{2}$, $\frac{11}{2}$, and $\frac{15}{2}$, all occuring only once, while for ^{44}Ca the allowed states are $J=0$, for seniority 2 they are $J=2$, 4, and 6, and for seniority 4 they are $J=2$, 4, 5, 6, and 8. We thus have an interesting connection between $T=\frac{3}{2}$ states in ^{43}Ca and corresponding $T=\frac{1}{2}$ states in ^{43}Sc and of $T=2$ states in ^{44}Ca and $T=0$ states in ^{44}Ti.

A simple example will show why such a partial dynamical symmetry occurs. We compare the $J=\frac{13}{2}^-$ and $\frac{15}{2}^-$ states of

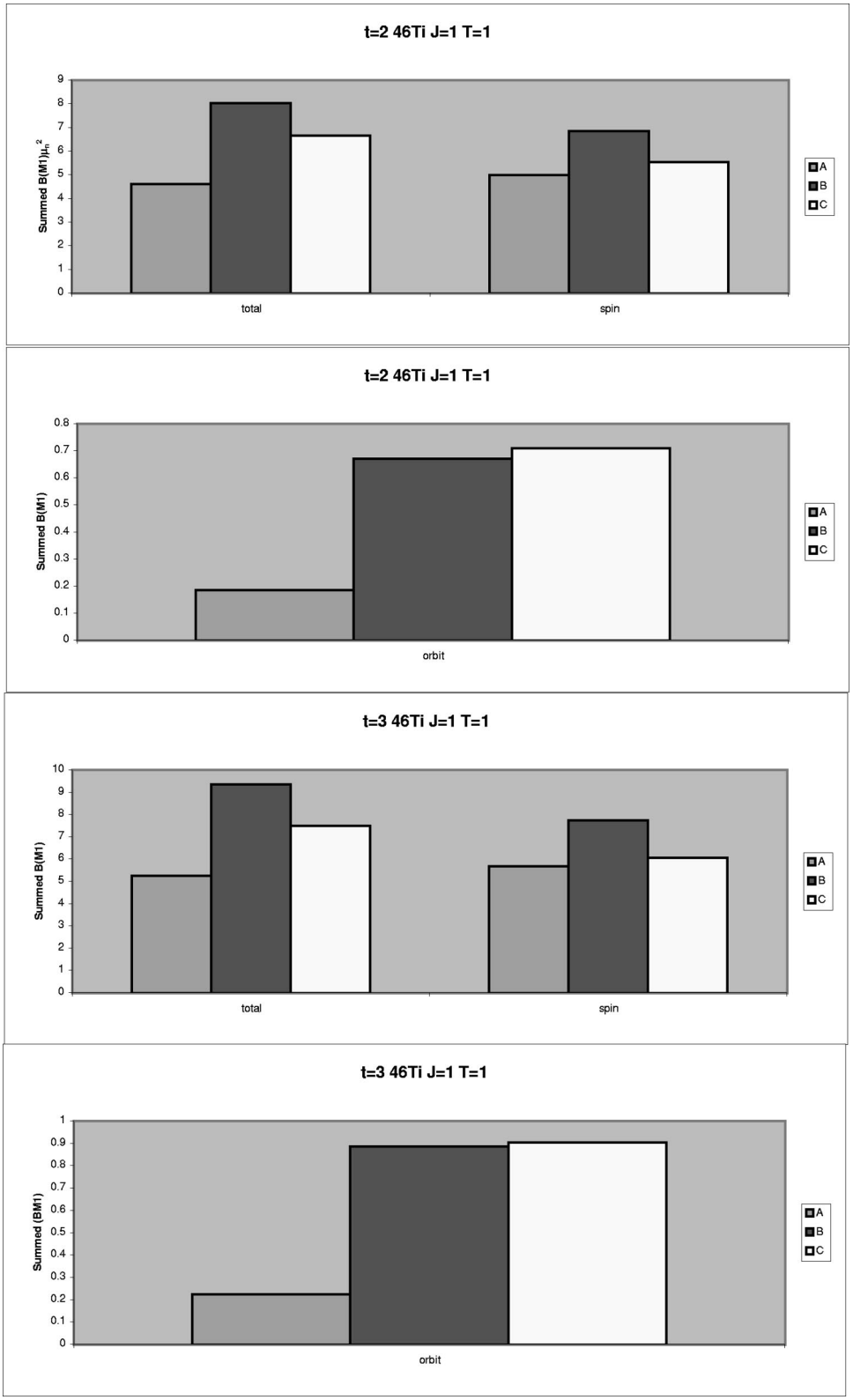

FIG. 3. ^{46}Ti summed $B(M1)$ from $J=0^+$ $T=1$ to $J=1^+$ $T=1$ for $t=2$ and 3.

^{43}Sc(^{43}Ti). They are both linear combinations of the $(J_\pi, J_n)=(4,\frac{7}{2})$ and $(6,\frac{7}{2})$. Both the $J=\frac{13}{2}^-$ states have isospin $T=\frac{1}{2}$ (because the j^3 $J=\frac{13}{2}$ configuration in ^{43}Ca does not exist). For $J=\frac{15}{2}^-$ one of the states has isospin $T=\frac{1}{2}$ and the other $T=\frac{3}{2}$. The latter wave function is completely determined by the Pauli principle and is equal to $\sqrt{2/9}(J_\pi=4,\frac{7}{2})^{15/2}+\sqrt{7/9}(J_\pi=6,\frac{7}{2})^{15/2}$. But the $T=\frac{1}{2}$ wave function must be orthogonal to the $T=\frac{3}{2}$ wave function thus becoming $-\sqrt{7/9}(J_\pi=4,\frac{7}{2})^{15/2}+\sqrt{2/9}(J_\pi=6,\frac{7}{2})^{15/2}$. This wave function is *independent* of what interaction is used, and does not therefore display any symmetry when the two-body matrix elements are set equal to zero. However the two $J=\frac{13}{2}$

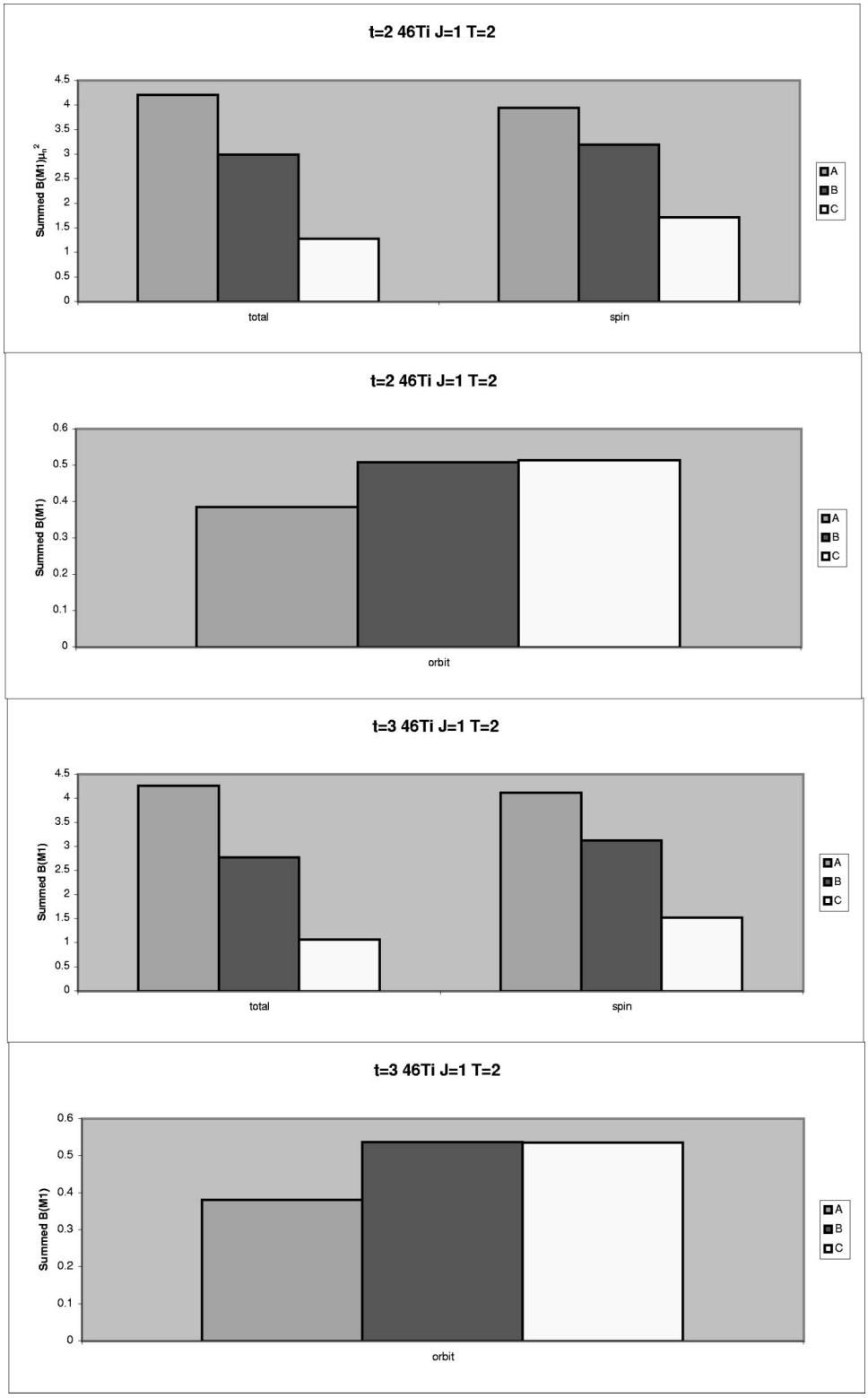

FIG. 4. ^{46}Ti summed $B(M1)$ from $J=0^+$ $T=1$ to $J=1^+$ $T=2$ for $t=2$ and 3.

states, both having $T=\frac{1}{2}$, collapse into $(J_\pi=4,\frac{7}{2})$ and $(J_\pi=6,\frac{7}{2})$ when this happens.

In a full fp calculation the even spin spectrum spread out a bit more—leaning slightly toward a rotational spectrum when the $T=0$ matrix elements were reintroduced (i.e., full FPD6 interaction) but only slightly. It thus appeared that keeping only the $T=1$ matrix elements led to a reasonable spectrum and the $T=0$ matrix elements were only needed for fine tuning. This is of particular note as there is currently an intense interest in the neutron-proton interaction in the nucleus. Several references were given in our first paper [1]. We should add recent contributions by Garrido and coworkers [4,5]

We were astonished that the removal of the $T=0$ matrix

TABLE I. Summed $B(M1)$ strengths and mean excitation energies for the ^{46}Ti transition from $J=0^+$ $T=1$ to $J=1^+$ $T=1,2$.

Final state $J=1$ $T=1$						
$t=0$	A	$\overline{E_A}$	B	$\overline{E_B}$	C	$\overline{E_C}$
Total	0.2384	2.704	0.2384	2.704	1.092	3.380
Spin	0.08892	2.704	0.0889	2.704	0.4073	3.381
Orbit	0.03614	2.704	0.03614	2.704	0.1655	3.381
$t=1$						
Total	7.004	8.905	7.526	9.302	8.695	8.476
Spin	7.707	9.323	7.280	10.204	7.793	9.523
Orbit	0.2504	7.468	0.4501	7.447	0.5865	6.723
$t=2$						
Total	4.604	10.469	8.026	9.348	6.665	9.404
Spin	4.996	10.880	6.840	10.636	5.537	10.466
Orbit	0.1850	8.914	0.6701	7.593	0.7095	9.257
$t=3$						
Total	5.252	9.429	9.350	8.384	7.495	8.275
Spin	5.674	9.811	7.746	9.521	6.057	9.214
Orbit	0.2248	8.007	0.8863	6.810	0.9028	8.584
Final state $J=1$ $T=2$						
$t=0$	A	$\overline{E_A}$	B	$\overline{E_B}$	C	$\overline{E_C}$
Total	1.874	3.882	1.874	5.886	0.8320	9.006
Spin	0.699	3.882	0.699	5.886	0.3103	9.007
Orbit	0.2841	3.882	0.284	5.886	0.1261	9.009
$t=1$						
Total	4.400	7.615	3.209	9.716	1.918	11.413
Spin	4.487	8.703	3.297	11.732	2.688	12.209
Orbit	0.2979	5.498	0.446	8.854	0.3153	2.029
$t=2$						
Total	4.210	8.658	2.992	11.651	1.275	13.027
Spin	3.941	10.056	3.196	13.661	1.717	13.640
Orbit	0.3846	7.057	0.508	10.688	0.5138	14.296
$t=3$						
Total	4.262	8.320	2.775	11.913	1.066	13.302
Spin	4.121	9.427	3.122	13.309	1.522	13.410
Orbit	0.3812	7.109	0.5372	10.889	0.5356	14.253

elements did not have a more profound effect on the spectra that we examined. While there were clearly signs that might have pointed out the differences between the original interaction and the one without the $T=0$ two-body matrix elements, it was a reasonable spectrum that we were obtained. We now examine the $M1$ and Gamow-Teller (GT) transition strengths in ^{44}Ti, ^{46}Ti, and ^{48}Ti to see whether these transition strengths are more sensitive to $T=0$ matrix elements than are the energy levels. The goal is to understand where the effects of the $T=0$ two-body matrix elements can be most clearly seen and the nature of the effect there. (Is it an average effect from simply having a $T=0$ portion of the interaction or does it depend on the detailed nature of the $T=0$ portion of the interaction?) For completeness we also present calculated $M3$ transition strengths.

In examining $M1$ transitions we shall consider not only the total $M1$ rates but separately the spin and orbital contributions. Concerning the latter we note that they are associated with scissors mode excitations [6], a problem which we have addressed in the past in a shell model approach, as have others [7–11]. There has been considerable work on $M1$ transitions in the *f-p* shell including the scissors mode analyses [12–16]. Some of these studies also included work on the $M3$ transition. [12,13].

II. CALCULATION

Whereas in our previous works we considered only one modification of the basis FPD6 interaction, here we consider two. We denote our three interactions as follows.

Interaction A. Set all $T=0$ two body matrix elements of FPD6 to zero; keep all $T=1$ matrix elements of FPD6 unchanged.

Interaction B. Set all $T=0$ two-body matrix elements of FPD6 to a constant; keep all $T=1$ matrix elements of FPD6 unchanged.

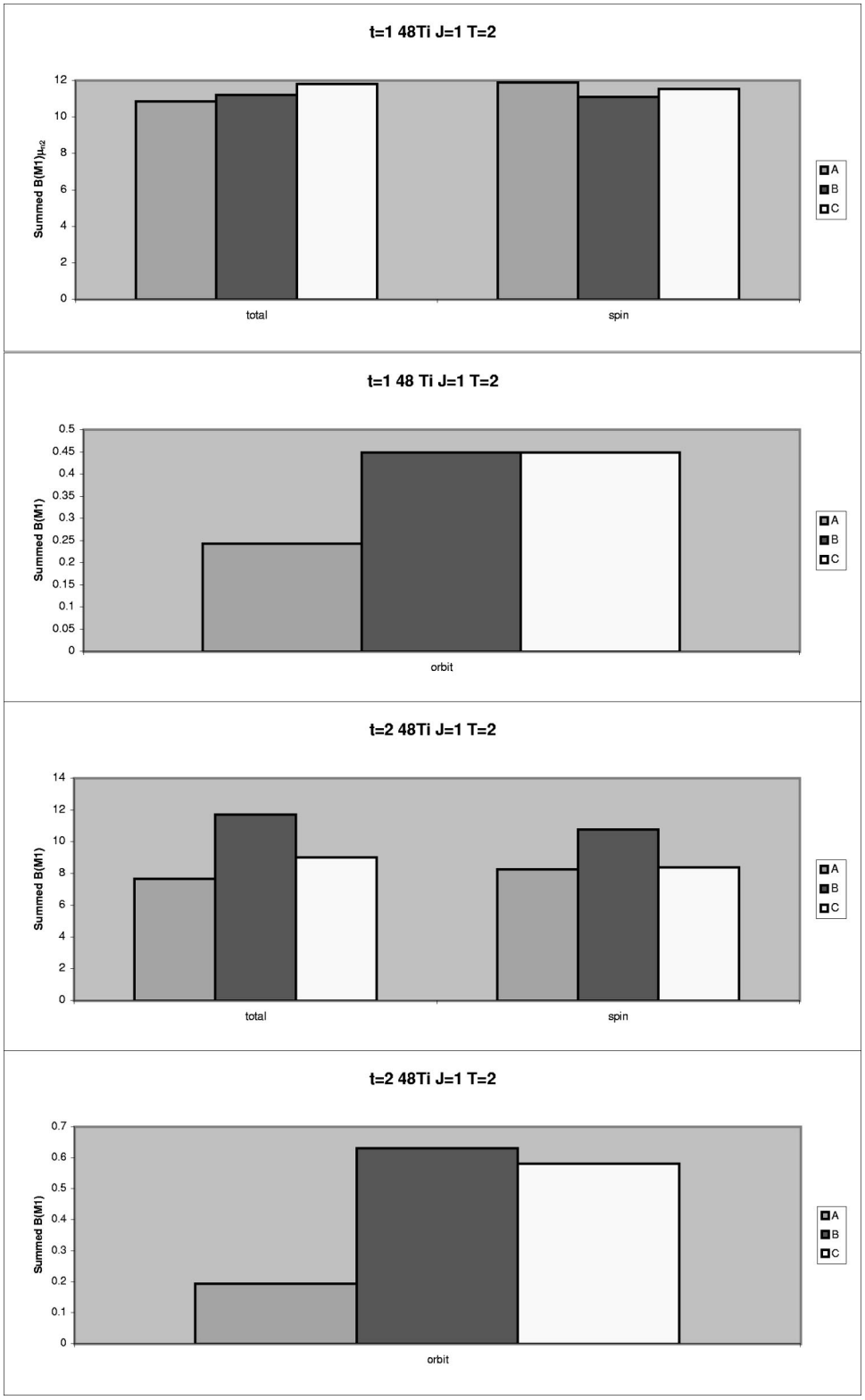

FIG. 5. ^{48}Ti summed $B(M1)$ from $J=0^+$ $T=2$ to $J=1^+$ $T=2$ for $t=1$ and 2.

Interaction C. Unmodified FPD6 interaction.

It should be mentioned that there is no difference in the results for the *spectrum* of the states of a given isospin in a single j shell calculation between interactions A and B. Of course the ground state energy (binding energy) will be affected as will the relative energies of states with different isospins.

However, when configuration mixing is included there will be a difference in the spectrum of states of a given isospin when we progress from interaction A to interaction B. In particular we wish to note there is a difference between setting the $T=0$ matrix elements equal to a constant and introducing a constant $T=0$ interaction $c(\frac{1}{4}-t(1)\cdot t(2))$. With the latter there will be no change in the spectrum of

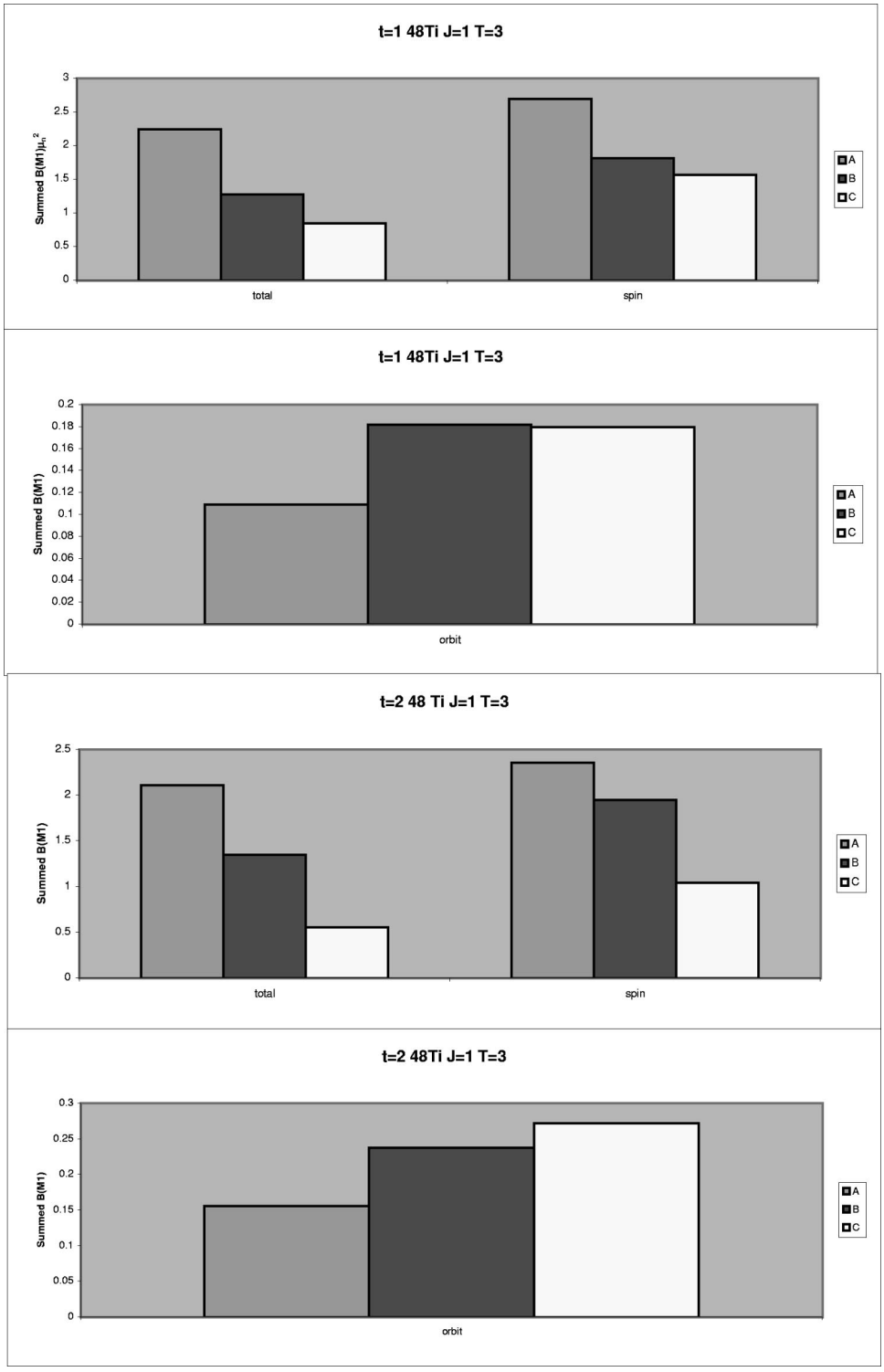

FIG. 6. ^{48}Ti summed $B(M1)$ from $J=0^+$ $T=2$ to $J=1^+$ $T=3$ for $t=1$ and 2.

states of a given isospin when we change the value of c even in a large space calculation. We get the same answer whether c is positive, negative or zero (again the binding energy *will* be affected). With the above constant $T=0$ interaction matrix elements of the form $\langle [j_1,j_2]^{J,T=0} V [j_3,j_4]^{J,T=0} \rangle$ will vanish if $(j_3,j_4) \neq (j_1,j_2)$. However this is different from our interaction B as it will be a constant, the same constant as for the diagonal matrix elements.

We can regard the results for going from interaction A to B to C as, respectively, studying the effects of (A) no $T=0$ interaction, (B) an average $T=0$ interaction, and (C) fluctuations in the $T=0$ interaction with possible $T=0$ pairing.

III. RESULTS

In this section we discuss the effects of changing the interaction from interaction A to B to C for $M1$ (orbital), $M1$ (spin), and B(GT). Note that for the fundamental two-

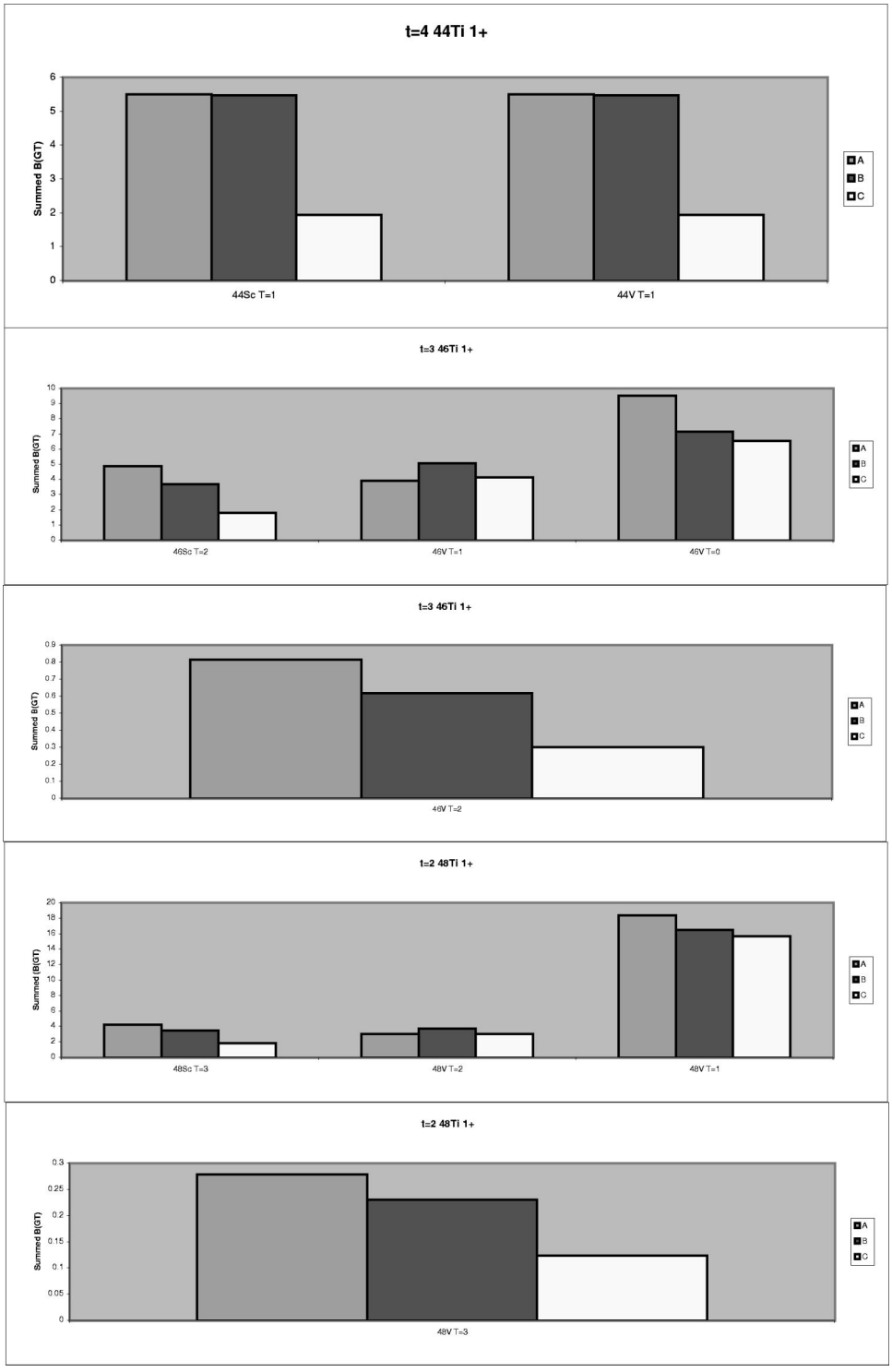

FIG. 7. Summed Gamow-Teller strength for ^{44,46,48}Ti in largest space calculations.

particle transition ^{42}Sc ($J=0$ $T=1$ $\rightarrow J=1$ there will be no change in the summed strength. This is because the ground state is determined by the $T=1$ interaction only, so changing the $T=0$ matrix elements does not change the ground state of ^{42}Sc.

A. *M*1 calculations

We study the summed strength $B(M1)$ for the three interactions A, B, and C. The results for total $B(M1)$, $B(M1)_{spin}$, and $B(M1)_{orbital}$ are examined. The respective g factors are as follows:

$B(M1)$: $g_{s_\pi}=5.586$, $g_{s_\nu}=-3.826$, $g_{l_\pi}=1$, $g_{l_\nu}=0$,

$B(M1)_{spin}$: $g_{s_\pi}=5.586$, $g_{s_\nu}=-3.826$, $g_{l_\pi}=0$, $g_{l_\nu}=0$,

$B(M1)_{orbital}$: $g_{s_\pi}=0$, $g_{s_\nu}=0$, $g_{l_\pi}=1$, $g_{l_\nu}=0$, with effective charges of $e_\pi=1.5$ and $e_\nu=0.5$ being used throughout.

Six different transitions are computed and discussed. The six are as follows:

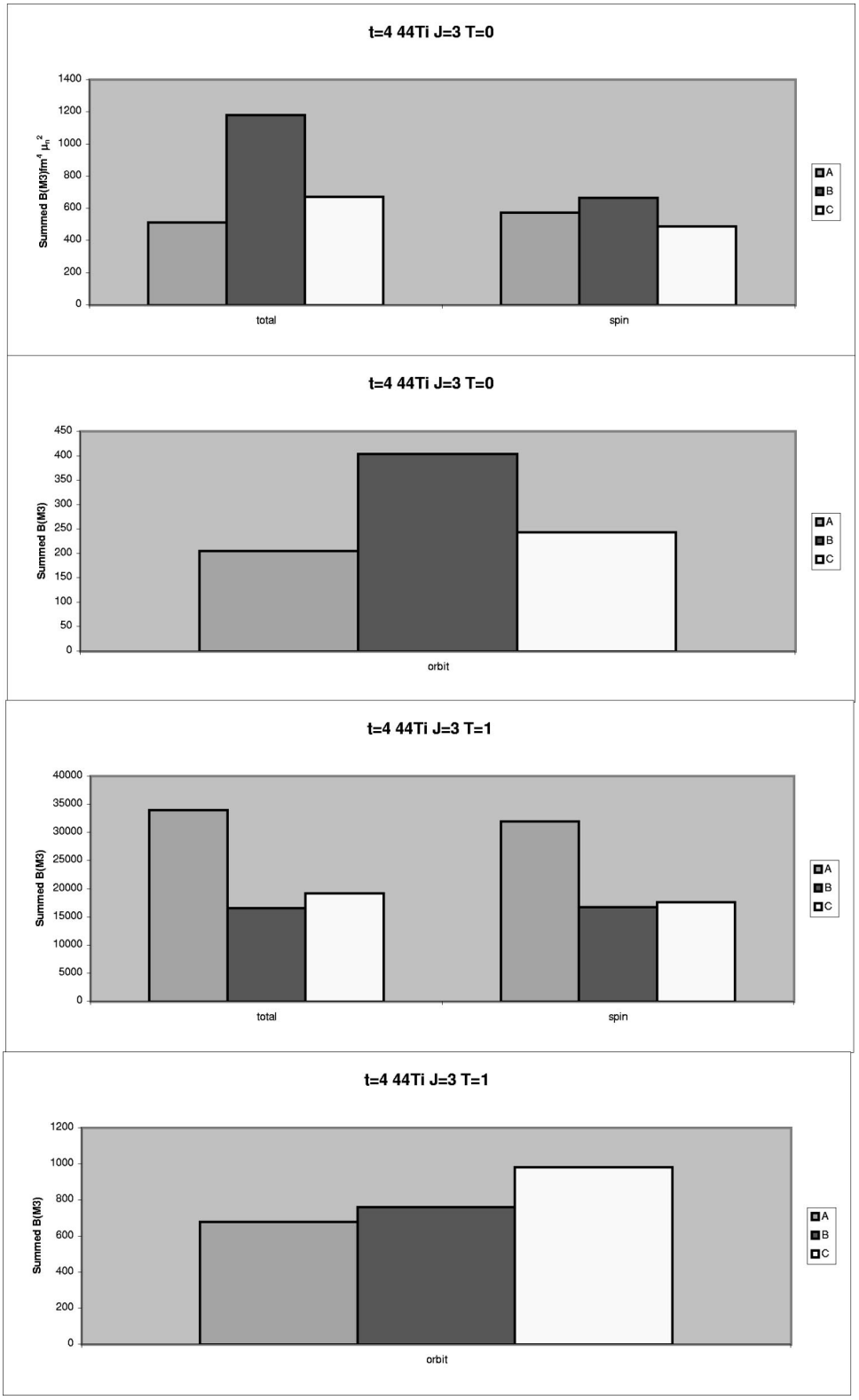

FIG. 8. ^{44}Ti summed $B(M3)$ from $J=0^+$ $T=0$ to $J=3^+$ $T=0,1$ for $t=4$.

(I) ^{44}Ti $J=0$ $T=0\rightarrow J=1$ $T=0$,
(II) ^{44}Ti $J=0$ $T=0\rightarrow J=1$ $T=1$,
(III) ^{46}Ti $J=0$ $T=1\rightarrow J=1$ $T=1$,
(IV) ^{46}Ti $J=0$ $T=1\rightarrow J=1$ $T=2$,
(V) ^{48}Ti $J=0$ $T=2\rightarrow J=1$ $T=2$,
(VI) ^{48}Ti $J=0$ $T=2\rightarrow J=1$ $T=3$.

The case ^{44}Ti $J=0$ $T=0\rightarrow J=1$ $T=0$ is atypical because of the single j result that the $M1$ rates are zero. This is easily understood as arising from the fact that an isoscalar $M1$ operator $\vec{\mu}$ can be replaced by $g\vec{J}$ in a single j shell, and the total angular momentum operator $\vec{J}$ cannot induce $M1$ transitions. We hence expect the computed values to be small

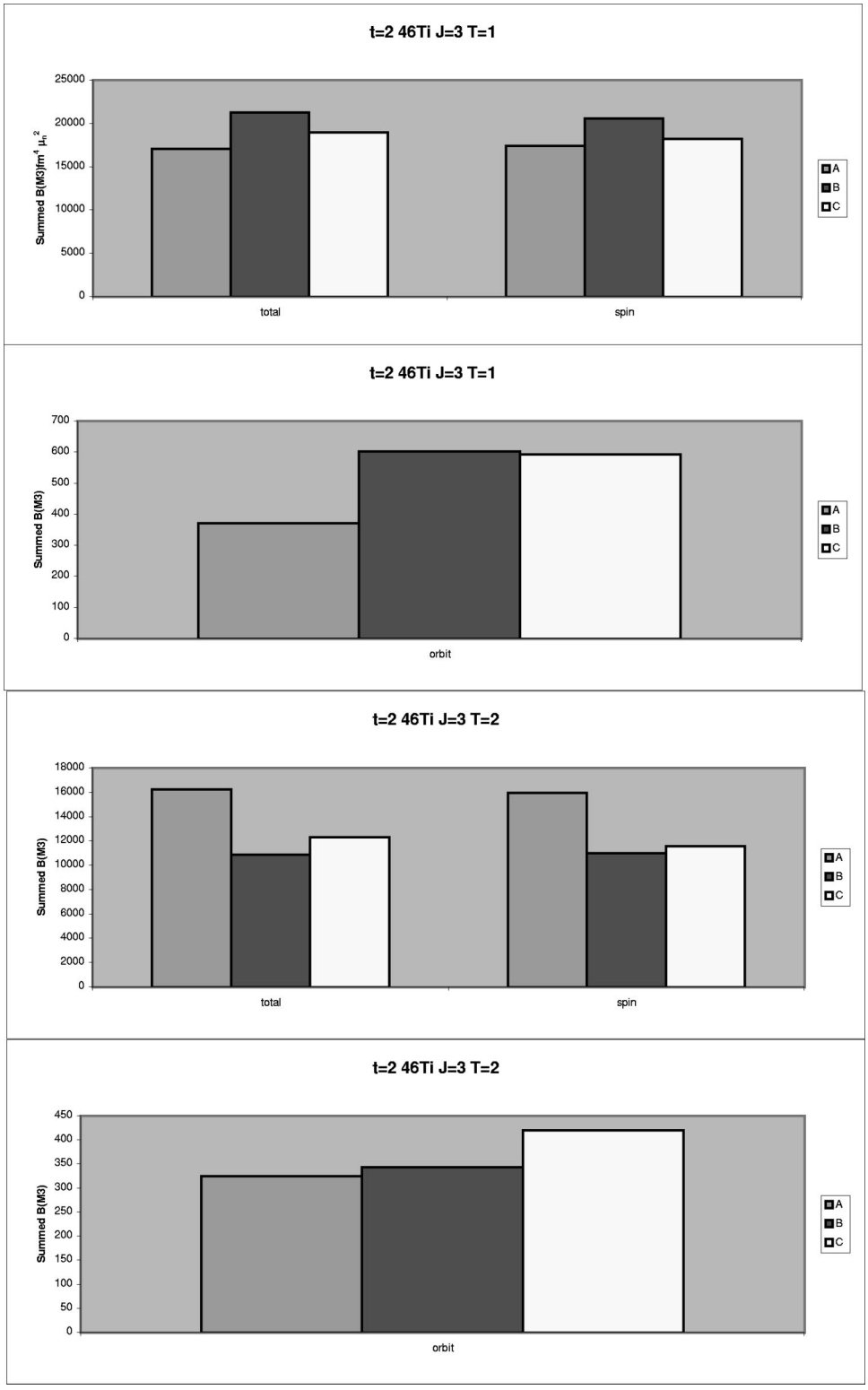

FIG. 9. ^{46}Ti summed $B(M3)$ from $J=0^+$ $T=1$ to $J=3^+$ $T=1$, 2 for $t=2$.

and finding this the case we discuss this transition no further.

Throughout this work we will utilize the parameter t which is the number of nucleons excited from the $f_{7/2}$ shell (t should not be confused with isospin T). Thus $t=0$ corresponds to a single j shell calculation ($f_{7/2}^4$ in ^{44}Ti) while $t=4$ would correspond to all four nucleons free to roam the entire f-p shell. Since the $B(M1)$'s are very small and this case atypical we shall not pursue a discussion of it.

We next consider the transition $J=0$ $T=0 \rightarrow J=1$ $T=1$ in ^{44}Ti. In these data, shown in Fig. 2 we now find a pattern of behavior more typical of what happens in the other nuclei. Comparing interactions A and C (for $t=4$) we find that the reintroduction of the $T=0$ matrix elements causes the spin $B(M1)$ to decrease from $9.296\mu_n^2$ to $3.267\mu_n^2$. The orbital

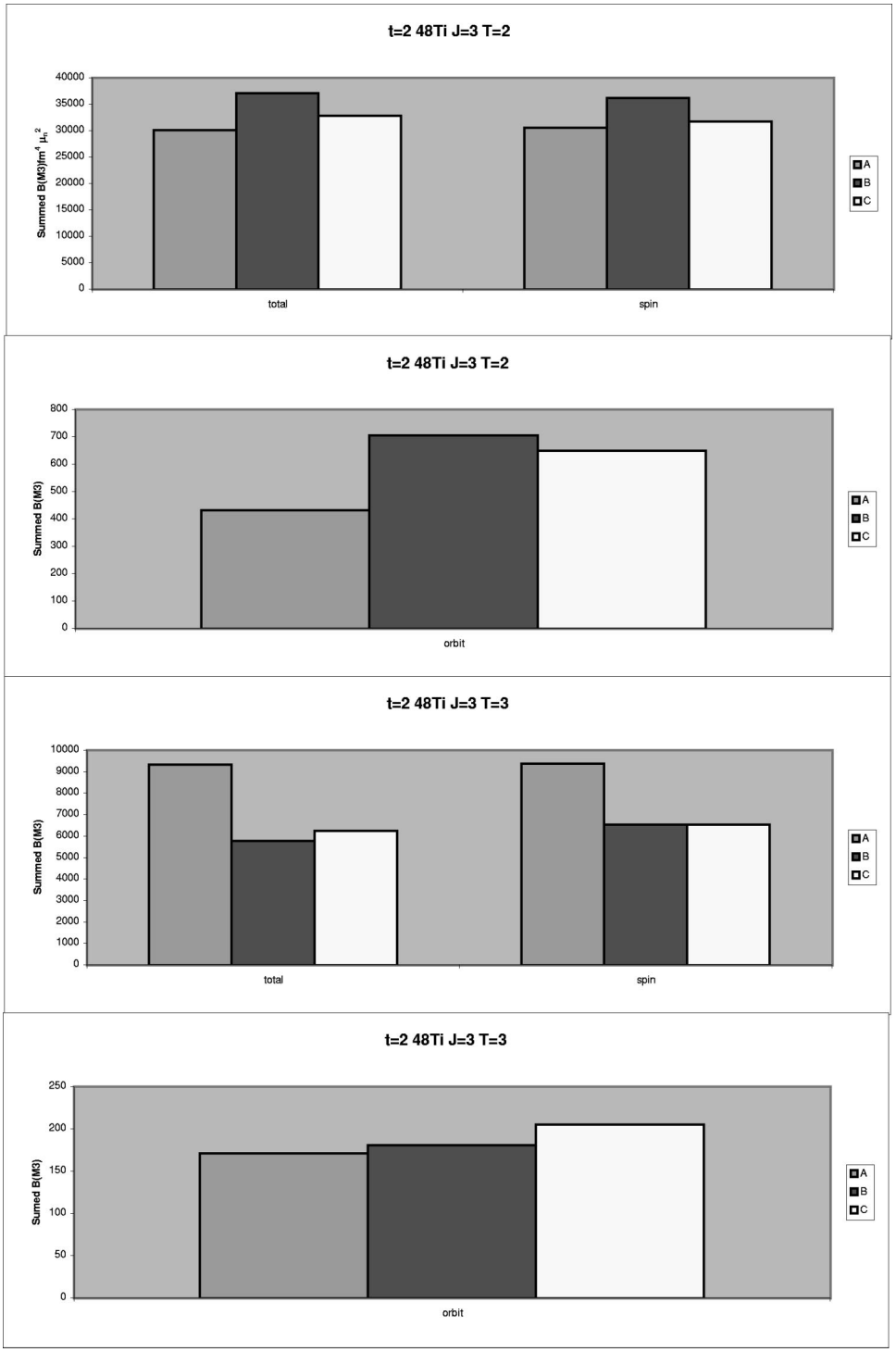

FIG. 10. ^{48}Ti summed $B(M3)$ from $J=0^+$ $T=2$ to $J=3^+$ $T=2,3$ for $t=2$.

$B(M1)$ increases by about a factor of two from $1.121\mu_n^2$ to $2.144\mu_n^2$. Note that in this figure along with the other figures that the orbital $B(M1)$ is shown on a different scale so that the effects of changing interactions is clear. These results are consistent with previous works where it was noted that in the SU(4) limit the orbital $B(M1)$ is large and the spin $B(M1)$ is zero. The SU(4) limit is a case of high collectivity with the other extreme being the single j shell limit. It is clear that reintroducing the $T=0$ matrix elements into the calculation will cause nuclear collectivity to increase.

For the heavier nuclei we only go up to $t=2$ or 3 so it is instructive to compare the $t=2$ and 4 calculations in ^{44}Ti. We will focus on interaction C. Relative to $t=1$ we obtain a reduction in the $t=2$ calculation of $B(M1)_{spin}$ from $8.438\mu_n^2$ to $4.680\mu_n^2$. When we go to $t=4$ the trend continues with $B(M1)_{spin}$ further reduced to $3.267\mu_n^2$. On the other hand the orbital strength increases from $1.317\mu_n^2$ to $1.926\mu_n^2$ to $2.144\mu_n^2$ as we go from $t=1$ to $t=2$ to $t=4$. This means excitation energies also go steadily up. These results are consistent with the fact that as we increase the

configuration mixing we increase the collectivity. In general we find throughout our calculations that the $B(M1)_{orbital}$ increases as the configuration space increases and the $B(M1)_{spin}$ tend to decrease as the configuration space is expanded. We should therefore keep in mind that for the heaviest titanium isotopes where we limit calculations to $t=2$ or 3 we might be underestimating the collectivity present in those nuclei.

Since ^{44}Ti is unstable no $M1$ excitation measurements have been performed on this nucleus. However, the next nucleus that we consider ^{46}Ti (Figs. 3 and 4) has been extensively studied via inelastic scattering by the Darmstadt group [12].

We first consider the summed strength for the $T=1\rightarrow T=1$ $M1$ transitions in ^{46}Ti shown in Fig. 3. We immediately see big changes as we go from interactions A to C. In the largest space calculation that we have done ($t=3$) $B(M1)$ and $B(M1)_{spin}$ both increase from A to C but their is a dramatic increase is in the $B(M1)_{orbital}$. The values there are increasing from $0.2248\mu_N^2$ to $0.9028\mu_N^2$. This is a factor of 4 increase in the orbital (scissors mode) strength. So the $T=0$ matrix elements are vital for the enhanced $B(M1)$.

One sees that most of this increase in orbital strength also occurs with the B interaction. This would suggest that it is mostly an average $T=0$ effect rather than being due to a fluctuation in the matrix elements or $T=0$ pairing.

Note that the $B(M1)_{spin}$ also gets some enhancement ($5.674\rightarrow 6.057$) but it is not so dramatic. For the channel $0_{T=1}\rightarrow 1_{T=2}$ in Fig. 4 the $B(M1)_{spin}$ is substantially quenched ($4.121\rightarrow 1.522$) as one goes from interaction A to C, but again the orbital summed strength gets enhanced [$0.3812\rightarrow 0.5356\mu_N^2$]. We show the results for ^{46}Ti in greater detail in Table I.

The behavior for ^{48}Ti (Figs. 5 and 6) is similar to that of ^{46}Ti. In going from the A to C interactions the values of $B(M1)_{orbital}$ increases substantially from $0.1931\ \mu_N^2$ to $0.5816\ \mu_N^2$ for $J=0\ T=2\rightarrow J=1\ T=2$ and from $0.1555\ \mu_N^2$ to $0.2719\ \mu_N^2$ for $J=0\ T=2\rightarrow J=1\ T=3$. We again see the orbital enhancement is also well described by interaction B. This continues to imply that it is mostly an average $T=0$ effect rather than being due to any individual fluctuation in the matrix elements or $T=0$ pairing.

We also see in ^{48}Ti $J=0\ T=2\rightarrow J=1\ T=3$ that there is a repression in the $B(M1)_{spin}$ going from interaction A to C (2.356 vs 1.042). While in $J=0\ T=2\rightarrow J=1\ T=2$ the $B(M1)_{spin}$ is relatively stable with a slight spike in interaction B as compared to interactions A and C. This is in accordance with the trends observed in ^{46}Ti.

B. Gamow-Teller transition

For the isovector $B(M1)$ we have the relation

$$\frac{B(GT)_{(T,-T)\rightarrow(T',-T+1)}}{B(M1)_{(T,T)\rightarrow(T',T)}} = \text{const}\frac{\begin{pmatrix} T' & T & 1 \\ T-1 & -T & 1 \end{pmatrix}^2}{\begin{pmatrix} T' & T & 1 \\ T & -T & 0 \end{pmatrix}^2} \tag{1}$$

$$= \begin{cases} \text{const}(1) & \text{if } T'=T \\ \text{const}\dfrac{1}{(2T+1)} & \text{if } T'=T+1 \end{cases} \tag{2}$$

For the GT transition there is one channel that is never present for $M1$'s, $J=0\ T\rightarrow J=1^+T-1$. The results of the GT calculations are displayed in Fig. 7. Do note that the ^{46}V $T=2$ and ^{48}V $T=3$ final states are shown on a different scale so that their behaviors are more obvious.

For ^{46}Ti we found even at the $t=0$ level a large change in the rate when comparing interaction A to the full FPD6 interaction C ($0.828\rightarrow 0.361$). At the $t=2$ level the change between interactions A and C is now 4.666 to 2.033, more than a factor of 2 reduction. This difference continued to expand as the configuration space was enlarged to $t=3$. A similar reduction is present in the ^{48}Ti GT transition. This large of a difference does not occur with the interaction B. This suggests that for this channel pairing effects (alternatively deviations from the average $T=0$ interaction) are important.

There is a relationship between $A=B(\text{GT})_{(T,-T)}\rightarrow B(\text{GT})_{(T+1),(-T+1)}$ and $B=B(\text{GT})_{(T,-T)}\rightarrow B(\text{GT})_{(T+1),(-T-1)}$, i.e., $B(\text{GT})_{Ti\rightarrow V(T+1)}$ and $B(\text{GT})_{Ti\rightarrow Sc(T+1)}$.

The ratio A/B is equal to

$$\frac{\begin{pmatrix} (T+1) & T & 1 \\ -(T+1) & T & 1 \end{pmatrix}^2}{\begin{pmatrix} (T+1) & T & 1 \\ (T-1) & -T & 1 \end{pmatrix}^2} = (2T+1)(2T+2). \tag{3}$$

Thus

$$\frac{B(GT)_{^{46}Ti\rightarrow{}^{46}Sc(T=2)}}{B(GT)_{^{46}Ti\rightarrow{}^{46}V(T=2)}} = 6$$

and

$$\frac{B(GT)_{^{48}Ti\rightarrow{}^{48}Sc(T=3)}}{B(GT)_{^{48}Ti\rightarrow{}^{48}V(T=3)}} = 15.$$

In principle, then, one should get the $3(N-Z)C_{GT}^2$ sum rule without doing the (n,p) reaction on ^{46}Ti. For example the ^{46}Ti sum rule reads

$$B(\text{GT})_{^{46}Ti\rightarrow{}^{46}V(T=0)} + B(\text{GT})_{^{46}Ti\rightarrow{}^{46}V(T=1)} + B(\text{GT})_{^{46}Ti\rightarrow{}^{46}V(T=2)} - B(\text{GT})_{^{46}Ti\rightarrow{}^{46}Sc(T=2)} = 3(N-Z)C_{GT}^2. \tag{4}$$

We can write this as

$$B(\mathrm{GT})_{^{46}Ti\rightarrow{}^{46}V(T=0)}+B(\mathrm{GT})_{^{46}Ti\rightarrow{}^{46}V(T=1)} -5B(\mathrm{GT})_{^{46}Ti\rightarrow{}^{46}V(T=2)}=3(N-Z)C_{GT}^{2}. \quad (5)$$

We fail to achieve this relation when the full configuration space is not used. However, we do have over 90% of the sum rule in all cases. For those nuclei where a full fp shell calculation proves feasible we find this identity maintained.

C. $M3$ transitions

We also computed $M3$ transitions (the results of which are shown in Figs. 8–10 where again the orbital contribution is separated on a different scale for clarity and insight) from the ground states of ^{44,46,48}Ti. The relative contribution of orbit to spin for $B(M3)$ is much less than for $B(M1)$. As configuration space was increased the normal response of the computed $B(M3)$'s was to be quenched to various degrees. In general progressing from interaction A to C causes the orbital $M3$ to be enhanced. For the spin case these are mixed results sometimes there is a quenching others an enhancement. The enhancements tend to be somewhat weak but for the instances of quenching the effect is a noticeable one.

The appearance of these trends is to a reasonable extent reproduced by the interaction B. This again intimates that this is in large part an average $T=0$ effect not overly sensitive to the particulars of the $T=0$ interaction.

IV. SUMMARY

We have built on our previous work [1,2] and expanded our investigation of the effects of $T=0$ two-body matrix elements into the realm of nuclear transitions. In the recent past we emphasized that one could obtain fairly good *spectra* of states of a given isospin by setting all the $T=0$ two-body matrix elements to zero [1,2]. But is this true of transitions as well? To answer this question we present calculations of $B(M1)$, $B(M3)$, and $B(GT)$. In our previous works we used the FPD6 interaction and a copy of the FPD6 interaction with the $T=0$ two-body matrix elements set to zero. For this work we added an additional copy of FPD6 now changing all the $T=0$ two-body matrix elements to -1.000. This allows us to see not only when effects are due to $T=0$ matrix elements but if they are essentially an average $T=0$ effect or an effect of the varied fluctuations in the $T=0$ portion of the interaction.

Our work has unveiled the fact that the behavior of $B(M1)$'s, especially of the orbital (scissors) mode excitations is highly dependent on the $T=0$ two-body matrix elements but appears to be an average $T=0$ effect and not one dependent on individual fluctuations in the matrix elements. For example, in our best calculation for ^{46}Ti ($t=3$) the summed orbital strength for the $T=1$ to $T=1$ transitions changed from 0.2248 μ_N^2 to 0.8863μ_N^2 to 0.9028μ_N^2 as we change from interaction A, where all $T=0$ two-body matrix elements were set to zero to interaction B where they were set to a constant to interaction C, the full FPD6 interaction. This contrasts with the situation for $B(GT)$'s where the individual fluctuations play a very important role in determining the behavior of these transitions. Thus the Gamow-Teller transition could well be a most fruitful area to explore further in an effort to understand the inner workings of the $T=0$ portion of the nuclear interaction and in particular the question of $T=0$ pairing. In general in order to study the effects of $T=0$ two-body matrix elements it is not enough to look at spectra—one must also carefully examine the transition rates.

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