SUMMARY

This work deals with applications of the spectral distribution methods (SDM) to nuclear physics. These methods examine physical observables in terms of their distribution in model space. Most quantities of interest can be obtained from the smoothed (fluctuation-free) distribution which is examined in terms of its low order moments. Here, we use SDM for the study of binding energies, expectation values of operators and various sum-rule quantities, especially those related to single nucleon transfer reactions.

An attempt is made to study the inverse energy weighted sum-rules which appear as coefficients in a Rayleigh-Schroedinger expansion of perturbed eigenvalues, whenever the hamiltonian H is perturbed by a small operator αK. These expressions are derived in the scalar and configuration spaces. The result is applied to obtain correction to the ground state energy of ^{20}Ne when an effective hamiltonian (PW) is approximated by a set of model hamiltonians constructed by taking different linear combinations of quadrupole and pairing operators. Results involving correction upto second order are presented for the binding energy predictions of five model hamiltonians. Configuration space gives better results for the binding energy than the scalar space.

It is well known that the expectation value of an arbitrary operator K can be expressed as a polynomial expansion in terms of eigenvalues of a known operator. Recently, an expansion involving bivariate polynomials for the expectation value of K as a function of two variables was obtained by Potbhare and Kota. The same result for both univariate and bivariate cases

is derived geometrically in the CLT limit. The expectation value of K is obtained through parametric differentiation of the perturbed eigenvalue x_{α}, resulting due to perturbation of the operator X by a small operator αK. For the univariate case, X is assumed to have a gaussian distribution. In the bivariate case, two operators X and Y are assumed to have a joint bivariate gaussian distribution. The results agree with the univariate and bivariate linear polynomial expectation-value expansions respectively.

A large portion of this work concentrates on the study of various properties related to single nucleon transfer reactions. Single particle properties are studied for a range of nuclei lying in the s-d, f-p and upper f-p-g shells. For s-d shell nuclei, proton and neutron orbit occupancies have been calculated using two standard s-d shell interactions and compared with the experimentally observed values. Both the effective interactions are in good agreement with the experimental results. Centroids and widths of particle removal and addition strengths have been calculated and displayed. The particle removal strength centroids are obtained through two different approaches. It is concluded that the strength function when written as a sum of bivariate gaussians is a good approximation to the extent that the sum-rule quantities so obtained agree well with the polynomial expansion results. Finally, the occupancy dependent single particle energies have been calculated and compared with experimental results. Again, a good comparison is obtained between theory and experiment. These energy values are significant since they are related to SNT strength centroids, and are at times measurable. Theoretically, these single particle energies directly depend upon matrix elements of an effective interaction and therefore provide a sensitive test for the effective interactions. This can be seen by looking at the effective single particle energies for different nuclei in the f-p shell , which are calculated using known occupancy data for four different f-p shell interactions. Some of them are compared with the experimental data with respect to energy positions and with reference to f7/2-p3/2 energy gap. The MWH2 and the MWH effective interactions give a better agreement with experimental data, as compared to other effective interactions. For the upper f-p-g shell, we present results for the proton and neutron occupancies, centroids and widths of particle addition and removal strength for isotopes of Zn, Ga and Ge. Two effective interactions have been used. The occupancies obtained for Bhatt-Ahalpara interaction match well with the experimental results. The strength centroids are displayed and compared with experimental centroids. The widths of the strength function in case of both s-d shell and upper f-p-g shell are much smaller than the average configuration width, indicating the validity of the single particle picture.

In SDM, a statistical approach known as the Ratcliff procedure is adopted to calculate binding energies of different nuclei. Some effective interactions operating in the s-d and f-p shells give a good estimate of binding energies so obtained. It is known that the concept of effective interactions and all calculations done using them fall in the category of shell model calculations. On the other hand, the semi-empirical mass formula which is most commonly used to estimate binding energies of all nuclei follows from the liquid drop model. The liquid drop model parameters in the mass defect formula are known. By least square fit procedure, it is possible to obtain these parameters using binding energies calculated through SDM. Comparison of these values with the actual parameters would provide a test for the effective interactions. It could also provide a link between shell model results and those derived using liquid drop model. This work is being done, and positive results are expected.

We have so far dealt with energy and strength distributions, which are known to have a gaussian and a bivariate gaussian structure respectively. However, if dependence of expectation values on other quantum numbers are sought, we can expect to encounter non-gaussian structures. For example, J^2 is known to have a chi-squared distribution. Bivariate polynomials for different types of marginal distributions may not be easy to construct (they might not exist at all). It therefore becomes necessary to seek another approach, even another expansion. One such approach is indicated by Mardia, who gives a formula for expanding a general bivariate density function, in terms of canonical variables. Following this, we are attempting to construct a bivariate density as a function of E and J^2. At present, the process is under study.