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Manuscript Title: A computer code for calculations in the algebraic collective model of the atomic nucleus

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Program title: ACM

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Programming language: Maple 18 (or versions 17, 16, 15).

Computer: Any.

Operating system: Any which supports Maple; tested under Linux, Max OSX, Windows 7.

RAM: 500Mb

Keywords: Algebraic collective model, Bohr model of atomic nucleus, SO(5) Clebsch-Gordan coefficients.

PACS: 21.60.Ev, 21.60.Fw, 03.65.Fd, 02.70.Wz.

Classification: 17.20.

Nature of problem:
The calculation of energy eigenvalues, transition rates and amplitudes of user specified Hamiltonians in the Bohr model of the atomic nucleus.

Solution method:
Exploit the model's SU(1,1)xSO(5) dynamical group to calculate analytic (as far as possible) expressions for matrix elements, making use of extensive files (supplied) of SO(5) ⊃ SO(3) Clebsch-Gordan coefficients. Diagonalisation of the resulting matrices (once the entries are converted to floating point) is carried out using the Maple library procedure Eigenvectors. (Maple [1] makes use of the NAG [2] and CLAPACK [3] linear algebra libraries.)

Additional comments:

1. The dimension of the Hilbert space that can be handled is limited only by the available computer memory and the available SO(5)⊂SO(3) Clebsch-Gordan coefficients $(v_1\alpha_1 L_1 v_2\alpha_2 L_2 \| v_3\alpha_3 L_3)$.
2. The supplied data files provide coefficients $(v_1\alpha_1 L_1 v_2\alpha_2 L_2 \| v_3\alpha_3 L_3)$ for $1 \le v_2 \le 6$, and contain all non-zero coefficients for $v_1 < v_3 \le 50$ when $v_2 \in \{1,3\}$, for $v_1 \le v_3 \le 30$ when $v_2 \in \{2,4\}$, and for $v_1 \le v_3 \le 25$ when $v_2 \in \{5,6\}$. (Once calculated, further coefficients can be readily made available to the code without changing the code.) Thus, depending on the model Hamiltonian being analysed, the states in the Hilbert space used are limited in their seniority. For analysis of the more typical types of model Hamiltonian, only the coefficients with $v_2 \in \{1,3\}$ are required, and therefore, with the supplied files, the seniority limit is 50. More exotic Hamiltonians

having terms with seniority $v_2 \in \{2,4,5,6\}$ would have the seniority limited to 30 or 25 accordingly.

3. The code provides lower level procedures that give ready access to the Clebsch-Gordan coefficients and the SU(1,1) and SO(5) matrix elements. These procedures are described in the manuscript and enable extensions to the code and model to be made easily.
4. The accuracy to which Maple performs numerical calculations is determined by the Maple parameter Digits, which specifies the number of significant decimal digits used. The default value of 10 is more than adequate for most ACM calculations. Note, however, that if Digits is increased beyond a certain value (obtained from the Maple command evalhf(Digits), and usually 15 on modern computers) then the code can no longer take advantage of hardware mathematical operations, and is significantly slower.

Documents included

1. The code makes use of SO(5)⊃SO(3) Clebsch-Gordan coefficients which are supplied in zip files, and must be installed by the user.
2. A Maple worksheet that gives various example calculations and tests carried out using procedures from the code is provided.
3. A 162 page PDF file containing everything displayed in the worksheet (input, output and comments, and making use of colour) is also provided.

Running time:

For a fixed value of the parameter Digits, the running time depends on the dimension of the Hilbert space on which the diagonalisation is performed, and this in turn is governed by the number of eigenvalues required and the accuracy required. Note that diagonalisation is performed separately in each L-space. For typical ACM calculations (such as those carried out in [4]), the matrices being diagonalised are usually of dimension at most a few hundred, and often much smaller. On a modest personal computer, the computation for the smallest cases takes at most a few seconds. The worksheet contains a range of examples for which the calculation time varies between a few seconds and 750s. In the latter case, diagonalisation is performed on L-spaces for $0 \leq L \leq 8$, the dimensions of these spaces being between 154 and 616.

References:

[1] Maplesoft, Waterloo Maple Inc., Waterloo, ON, Canada.

[2] NAG, www.nag.com.

[3] CLAPACK, www.netlib.org/clapack.

[4] D. J. Rowe, T. A. Welsh, M. A. Caprio, Phys. Rev. C 79 (2009) 054304.