

# Algebraic models in quantum mechanics

## *Atomic, molecular, nuclear, and subnuclear physics*

### Topical Lecture Week with Prof. Lorenzo Fortunato (Univ. Padova)

Date: 20.-22.11.2024

This theoretical course is aimed at a level suitable for finishing M.Sc. and Ph.D. students in Physics. Its purpose is to put into action the most formal theories of quantum mechanics (second quantization, group theory, Lie algebra) by allowing students to solve practical problems. These skills are of interest to all those interested in atomic, molecular, nuclear, and subnuclear physics and probably for future applications in quantum devices and quantum computers.

The theoretical lectures will be complemented by exercise sessions, where simple codes written in Mathematica will be discussed with the purpose of learning how to run calculations and obtain practical results.

Aim: Develop the ability to write a simple model Hamiltonian for quantum phenomena and run schematic calculations.

#### Wednesday, November 20

**09:00 - 09:30** Introduction

**09:30 - 10:30** Lecture 1: Reminder of basic Lie algebra theory and jargon – Algebra chains and dynamical symmetries.

*Example: The rigid rotor in diatomic molecules.*

**10:30 - 11:00** Coffee break

**11:00 - 12:30** Lecture 2: Spectrum Generating algebras and dynamical symmetry breaking.

*Example: Higher symmetries in the hydrogen atom, Flavour SU(3) in particle physics.*

**12:30 - 12:45** Group picture

**12:45 - 14:00** Lunch

**14:00 - 15:30** Exercise 1: How to build and diagonalize matrix models for simple quantum mechanics problems with  $a/a+$  operators and with  $SO(3)$ .

Mathematica software will be distributed and run with students.

#### Thursday, November 21

**09:00 - 10:30** Lecture 3: Interacting Boson Model and  $U(6)$  and deformation in nuclear models, electromagnetic transitions.

**10:30 - 11:00** Coffee break

**11:00 - 12:30** Lecture 4: Extensions (IBM-2 and IBFM), vibron model for molecules, and examples.

**12:30 - 14:00** Lunch

**14:45 - 16:00** Exercise 2: Visualization of collective shapes (quadrupole, octupole, etc.). Diagonalization of symmetry chains in SU(6) IBM and SU(4) vibron molecular model.

Mathematica software will be distributed and run with students.

**18:30** Social Dinner

**Friday, November 22**

**09:00 - 10:30** Lecture 5: Introduction to  $\alpha$  clustering in nuclei – Physical properties, discrete symmetries.

**10:30 - 11:00** Coffee break

**11:00 - 12:30** Lecture 6: Advanced examples on  $^{12}\text{C}$  in terms of 3- $\alpha$  clusters.

**12:30 - 14:00** Lunch