



INTERNSHIP PROPOSAL



Laboratory name: Laboratoire de Physique et Modélisation des Milieux Condensés
CNRS identification code: UMR 5493

Internship director's surname: Pierre NATAF

e-mail: pierre.nataf@lpmmc.cnrs.fr

Phone number: 04 76 88 79 84

Web page: <https://lpmmc.cnrs.fr/spip.php?auteur78>

Internship location: LPMMC, Av. des Martyrs, 38000 Grenoble, France

Internship codirector's surname: Loïc HERVIOU

e-mail: loic.herviou@lpmmc.cnrs.fr

Web page: <https://lherviou.github.io/index>

Thesis possibility after internship: YES

Potential funding: EDPHYS Grenoble, Quant-EDU, QuantAlps

Efficient representations of $SU(N)$ spin chains and ladders

Large-spin models have recently gained significant attention due to experimental breakthroughs in cold atom systems. These setups enable highly controlled experiments that simulate complex theoretical models. However, large-spin models present considerable challenges for numerical modeling. The large spin dimensions and intricate symmetries of these systems make simulations extremely difficult, and standard methods often fall short, failing to access certain experimental regimes of interest.

In this context, an alternative approach based on advanced group theory concepts was recently proposed by one of the project supervisors[1,2]. It avoids the traditional bottleneck of computing Clebsch-Gordan coefficients by directly implementing the $SU(N)$ algebra in its most efficient mathematical basis: the basis of (semi-)standard Young tableaux (SYT). This breakthrough has already enabled simulations of systems at unprecedented scales with an exact implementation of all symmetries.

This internship aims to explore and extend this new framework. The successful candidate will investigate one of the following research avenues, according to their interests and skills:

1) generalization to other symmetry groups. The success with $SU(N)$ relies on its deep connection to the symmetric group. This project will explore extensions to other Lie groups, such as $SO(N)$ or $Sp(N)$, which possess similar but more complex mathematical structures. This is a fundamental research direction at the intersection of group theory and computational physics.

2) Monte-Carlo simulations of $SU(N)$ models. While the SYT basis is highly efficient, the Hilbert space of large systems remains vast. This project will focus on developing and applying advanced computational techniques, such as Stochastic Series Expansion (SSE) Monte Carlo or modern machine learning approaches, to perform simulations within this new basis.

[1] Wan et al, Phys. Rev. B 96, 115159 (2017)

[2] Botzung et al, Phys. Rev. Lett. 132, 153001 (2024)

Condensed Matter Physics: YES

Soft Matter and Biological Physics:

NO

Quantum Physics: YES

Theoretical Physics:

YES