中里　研究活動　2018 年度報告

出版された論文

[1] Time evolution of a pair of distinguishable interacting spins subjected to controllable and noisy magnetic fields,
R. Grimaudo, Yu. Belousov, H. Nakazato and A. Messina,
Ann. Phys. **392** (2018, May) 242–259.

[2] Classes of exactly solvable Generalized semi-classical Rabi Systems,
R. Grimaudo, A. de Castro, H. Nakazato and A. Messina,
Ann. Phys. (Berlin) **530** (2018, November) 1800198 (8 pages).

[3] Analytic estimation of transition between instantaneous eigenstates of quantum two-level system,
T. Suzuki, H. Nakazato, R. Grimaudo and A. Messina,
Sci. Rep. **8** (2018, November) 17433 (7 pages).

Research summary in 2018

1 A new strategy to construct exactly solvable models of quantum two-level systems with time-dependent Hamiltonians, proposed in 2014, has been applied to a few physical systems.
First, it is applied to a system of two coupled spins under controllable or fluctuating time-dependent magnetic fields that preserve the total spin. In this case, each eigenspace of total spin is dynamically invariant and the Hamiltonian of the total system restricted to any one of such eigenspaces possesses the SU(2) structure of the Hamiltonian of a single fictitious spin under the same total magnetic field. Such a reducibility has been shown to hold regardless of the time dependence of the externally applied field as well as of the statistical properties of the noise. The time evolution of the joint transition probabilities of the two spins between two prefixed factorized states is analytically estimated, bringing to light peculiar dynamical properties. When the noise-induced non-unitary dynamics of the two coupled spins is properly taken into account, analytical expressions for the joint Landau–Zener transition probabilities are obtained.
Second, the exact quantum dynamics of a single spin-1/2 in a generic time-dependent classical magnetic field are investigated and compared with the quantum motion of a spin-1/2 studied by Rabi and Schwinger. The possibility of regarding the scenario studied here as a generalization of that considered by Rabi and Schwinger is discussed and the notion of a time-dependent resonance condition is introduced and carefully legitimated and analyzed. Several examples help to disclose analogies and departures of the quantum motion induced in a generalized Rabi system.
時間に陽に依存するハミルトニアンを持つ量子 2 準位系の可解模型を構成するための新たな手法を，いくつかの物理系に適用した．
まず，制御された，あるいは揺らいだ外部磁場下に置かれ，全スピンの大きさを保ちながら互いに相互作用する 2 個のスピンからなる系を考えた．この場合，全スピンの各固有空間は力学的に不変となり，同じ磁場下に置かれた仮想的な 1 個のスピンに対するハミルトニアンの SU(2) 構造を持つ．このような既約可能性が，外場の時間依存性や揺らぎの統計的性質とは無関係に成立することを示した．また，与えられた 2 つの積状態間の結合遷移確率を解析的に求め，特異な力学的振る舞いを明らかにした．さらに，ノイズにより引き起こされる非ユニタリー的時間発展を適切に取り込むことで，結合 Landau–Zener 遷移確率を解析的に求めた．
次に，時間変化する一般の古典的磁場下におかれた 1 個のスピン 1/2 粒子の厳密な量子ダイナミクスを調べ，いわゆる Rabi 模型と比較した．まず，ここで考える模型が Rabi 模型の一般化と見なせる可能性を議論し，時間に依存した一般化された共鳴条件を導入してその有効性を注意深く検証した．また，いくつかの具体例を通して，Rabi 模型と一般化された Rabi 模型のダイナミクスの類似性あるいは差異を明らかにした．

2 Transition amplitudes between instantaneous eigenstates of a quantum two-level system are evaluated analytically on the basis of a new parametrization of its evolution operator, which has recently been

proposed to construct exact solutions. In particular, the condition under which the transitions are suppressed is examined analytically. It is shown that the analytic expression of the transition amplitude enables us, not only to confirm the adiabatic theorem, but also to derive the necessary and sufficient condition for quantum two-level system to remain in one of the instantaneous eigenstates.
厳密解を構成するために近年導入された，量子 2 準位系の時間発展演算子に対する新しいパラメータ表示に基づいて，量子 2 準位系の瞬時固有状態間の遷移振幅を解析的に評価した．特に，遷移が抑制される条件を解析的に調べ，遷移振幅の解析的な表式から，断熱定理を確認しただけでなく，量子 2 準位系がひとつの瞬時固有状態に留まるための必要十分条件を導出した．