计算物理 project

1.Time Delay in the Kuramoto Model of Coupled Oscillators

URL:https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.82.648

摘要:We generalize the Kuramoto model of coupled oscillators to allow time-delayed interactions. New phenomena include bistability between synchronized and incoherent states, and unsteady solutions with time-dependent order parameters. We derive exact formulas for the stability boundaries of the incoherent and synchronized states, as a function of the delay, in the special case where the oscillators are identical. The experimental implications of the model are discussed for populations of chirping crickets, where the finite speed of sound causes communication delays, and for physical systems such as coupled phase-locked loops or lasers.

2. Localization and multifractal properties of the long-range Kitaev chain in the presence of an Aubry-André-Harper modulation

URL:https://journals.aps.org/prb/abstract/10.1103/PhysRevB.106.024204

摘要:In the presence of quasiperiodic potentials, the celebrated Kitaev chain presents an intriguing phase diagram with ergodic, localized, and multifractal states. In this work, we generalize these results by studying the localization properties of the Aubry-André-Harper model in the presence of long-range hopping and superconducting pairing amplitudes. These amplitudes decay with power-law exponents ξ and α , respectively. To this end, we review and compare a toolbox of global and local characterization methods in order to investigate different types of transitions between ergodic, localized, and multifractal states. We report energy-dependent transitions from ergodic to multifractal states for pairing terms with $\alpha < 1$ and energy-dependent transitions from ergodic to localized states with an intermediate multifractal region for $\alpha > 1$. The size of the intermediate multifractal region depends not only on the value of the superconducting pairing term Δ , but also on the energy band. The transitions are not described by a mobility edge, but instead we report hybridization of bands with different types of localization properties. This leads to coexisting multifractal regimes where fractal dimensions follow different distributions.

3.Quantum Langevin model for nonequilibrium condensation

URL:https://journals.aps.org/pra/abstract/10.1103/PhysRevA.90.023633

摘要:We develop a quantum model for nonequilibrium Bose-Einstein condensation of photons and polaritons in planar microcavity devices. The model builds on laser theory and includes the spatial dynamics of the cavity field, a saturation mechanism, and some frequency dependence of the gain: quantum Langevin equations are written for a cavity field coupled to a continuous distribution of externally pumped two-level emitters with a well-defined frequency. As an example of application, the method is used to study the

linearized quantum fluctuations around a steady-state condensed state. In the good-cavity regime, an effective equation for the cavity field only is proposed in terms of a stochastic Gross-Pitaevskii equation. Perspectives in view of a full quantum simulation of the nonequilibrium condensation process are finally sketched.

4.Fast noise in the Landau-Zener theory

URL:https://journals.aps.org/prb/abstract/10.1103/PhysRevB.67.144303

摘要:We study the influence of a fast noise on Landau-Zener transitions. We demonstrate that a fast colored noise much weaker than the conventional white noise can produce transitions itself or can change substantially the Landau-Zener transition probabilities. In the limit of fast colored or strong white noise we derive asymptotically exact formulas for transition probabilities and study the time evolution of a spin coupled to the noise and a sweeping magnetic field.

5.Brownian yet Non-Gaussian Diffusion: From Superstatistics to Subordination of Diffusing Diffusivities

URL:https://journals.aps.org/prx/abstract/10.1103/PhysRevX.7.021002

摘要:A growing number of biological, soft, and active matter systems are observed to exhibit normal diffusive dynamics with a linear growth of the mean-squared displacement, yet with a non-Gaussian distribution of increments. Based on the Chubinsky-Slater idea of a diffusing diffusivity, we here establish and analyze a minimal model framework of diffusion processes with fluctuating diffusivity. In particular, we demonstrate the equivalence of the diffusing diffusivity process with a superstatistical approach with a distribution of diffusivities, at times shorter than the diffusivity correlation time. At longer times, a crossover to a Gaussian distribution with an effective diffusivity emerges. Specifically, we establish a subordination picture of Brownian but non-Gaussian diffusion processes, which can be used for a wide class of diffusivity fluctuation statistics. Our results are shown to be in excellent agreement with simulations and numerical evaluations.

6.Many-fermion generalization of the Caldeira-Leggett model

URL:https://journals.aps.org/pra/abstract/10.1103/PhysRevA.72.022113

摘要:We analyze a model system of fermions in a harmonic oscillator potential under the influence of a dissipative environment: The fermions are subject to a fluctuating force deriving from a bath of harmonic oscillators. This represents an extension of the well-known Caldeira-Leggett model to the case of many fermions. Using the method of bosonization, we calculate one- and two-particle Green' s functions of the fermions. We discuss the relaxation of a single extra particle added above the Fermi sea, considering also dephasing of a particle added in a coherent superposition of states. The consequences of the separation of center-of-mass and relative motion, the Pauli principle, and the bath-induced effective interaction are

discussed. Finally, we extend our analysis to a more generic coupling between system and bath, which results in complete thermalization of the system.

7.Dynamics of the sub-Ohmic spin-boson model: A time-dependent variational study

URL:https://aip.scitation.org/doi/full/10.1063/1.4792502

摘要: The Dirac-Frenkel time-dependent variation is employed to probe the dynamics of the zero temperature sub-Ohmic spin-boson model with strong friction utilizing the Davydov D_1 ansatz. It is shown that initial conditions of the phonon bath have considerable influence on the dynamics. Counterintuitively, even in the very strong coupling regime, quantum coherence features still manage to survive under the polarized bath initial condition, while such features are absent under the factorized bath initial condition. In addition, a coherent-incoherent transition is found at a critical coupling strength $\alpha \approx 0.1$ for $s = 0.25$ under the factorized bath initial condition. We quantify how faithfully our ansatz follows the Schrödinger equation, finding that the time-dependent variational approach is robust for strong dissipation and deep sub-Ohmic baths ($s \ll 1$) .

8.Quench from Mott insulator to superfluid

URL:https://journals.aps.org/prb/abstract/10.1103/PhysRevB.86.144521

摘要:We study a linear ramp of the nearest-neighbor tunneling rate in the Bose-Hubbard model driving the system from the Mott insulator state into the superfluid phase. We employ the truncated Wigner approximation to simulate linear quenches of a uniform system in one, two, and three dimensions, and in a harmonic trap, in three dimensions. In all these setups, the excitation energy decays like one over third root of the quench time. The -1/3 scaling arises from an impulse-adiabatic approximation—a variant of the Kibble-Zurek mechanism—describing a crossover from nonadiabatic to adiabatic evolution when the system begins to keep pace with the increasing tunneling rate.

9.Many-body dynamical localisation of coupled quantum kicked rotors

URL:https://arxiv.org/abs/1901.09362

摘要:The quantum motion of N coupled kicked rotors is mapped to an interacting N-particle Anderson-Aubry-André tight-binding problem supporting many-body localised (MBL) phases. Interactions in configuration space are known to be insufficient for destroying Anderson localisation in a system in the MBL phase. The mapping we establish here predicts that a similar effect takes place in momentum space and determines the quantum dynamics of the coupled kicked rotors. Due to the boundedness of the Floquet quasi-energy spectrum there exists limitations on the interacting lattice models that can be mapped to quantum kicked rotors; in particular, no extensive observable can be mapped in the thermodynamic limit.

10.Global density equations for interacting particle systems with stochastic resetting: from overdamped Brownian motion to phase synchronization

URL:http://export.arxiv.org/abs/2401.03501

摘要:A wide range of phenomena in the natural and social sciences involve large systems of interacting particles, including plasmas, collections of galaxies, coupled oscillators, cell aggregations, and economic "agents'. Kinetic methods for reducing the complexity of such systems typically involve the derivation of nonlinear partial differential equations for the corresponding global densities. In recent years there has been considerable interest in the mean field limit of interacting particle systems with long range interactions. Two major examples are interacting Brownian particles in the overdamped regime and the Kuramoto model of coupled phase oscillators. In this paper we analyze these systems in the presence of local or global stochastic resetting, where the position or phase of each particle independently or simultaneously resets to its original value at a random sequence of times generated by a Poisson process. In each case we derive the Dean-Kawasaki (DK) equation describing hydrodynamic fluctuations of the global density, and then use a mean field ansatz to obtain the corresponding nonlinear McKean-Vlasov (MV) equation in the thermodynamic limit. In particular, we show how the MV equation for global resetting is driven by a Poisson shot noise process, reflecting the fact that resetting is common to all of the particles and thus induces correlations that cannot be eliminated by taking a mean field limit. We then investigate the effects of local and global resetting on nonequilibrium stationary solutions of the macroscopic dynamics and, in the case of the Kuramoto model, the reduced dynamics on the Ott-Antonsen manifold.

11.Universality of critical dynamics on a complex network

URL:http://export.arxiv.org/abs/2401.00092

摘要:We investigate the role of the spectral dimension d_s in determining the universality of phase transitions on a complex network. Due to its structural heterogeneity, a complex network generally acts as a disordered system. Specifically, we study the synchronization and entrainment transitions in the nonequilibrium dynamics of the Kuramoto model and the phase transition of the equilibrium dynamics of the classical XY model, thereby covering a broad spectrum from nonlinear dynamics to statistical and condensed matter physics. Using linear theory, we obtain a general relationship between the dynamics occurring on the network and the underlying network properties. This yields the lower critical spectral dimension of the phase synchronization and entrainment transitions in the Kuramoto model as $d_s = 4$ and $d_s = 2$ respectively, whereas for the phase transition in the XY model it is $d_s = 2$. To test our theoretical hypotheses, we employ a network where any two nodes on the network are connected with a probability proportional to a power law of the distance between the nodes; this realizes any desired $d_s \in [1, \infty)$. Our detailed numerical study agrees well with the prediction of linear theory for the phase synchronization transition in the Kuramoto model. However, it shows a clear entrainment transition in the Kuramoto

model and phase transition in the XY model at $d_s \gtrsim 3$, not $d_s = 2$ as predicted by linear theory. Our study indicates that network disorder in the region $2 \leq d_s \lesssim 3$ seems to be relevant and have a profound effect on the dynamics.

12.Algebraic approach to the Kuramoto model

URL:https://journals.aps.org/pre/abstract/10.1103/PhysRevE.104.L022201

摘要:We study the Kuramoto model with attractive sine coupling. We introduce a complex-valued matrix formulation whose argument coincides with the original Kuramoto dynamics. We derive an exact solution for the complex-valued model, which permits analytical insight into individual realizations of the Kuramoto model. The existence of a complex-valued form of the Kuramoto model provides a key demonstration that, in some cases, reformulations of nonlinear dynamics in higher-order number fields may provide tractable analytical approaches.

13.A solvable two-dimensional swarmalator model

URL:https://arxiv.org/abs/2312.10178

摘要:Swarmalators are oscillators that swarm through space as they synchronize in time. Introduced a few years ago to model many systems which mix synchrony with self-assembly, they remain poorly understood theoretically. Here we obtain the first analytic results on swarmalators moving in two-dimensional (2D) plane by enforcing periodic boundary conditions; this simpler topology allows expressions for order parameters, stabilities, and bifurcations to be derived exactly. We suggest some future directions for swarmalator research and point out some connections to the Kuramoto model and the Vicsek model from active matter; these are intended as a call-to-arms for the sync community and other researchers looking for new problems and puzzles to work on.

14.Exact diagonalization of quantum-spin models

URL:https://journals.aps.org/prb/abstract/10.1103/PhysRevB.42.6561

摘要:We have developed a technique to replace hashing in implementing the Lanczös method for exact diagonalization of quantum-spin models that enables us to carry out numerical studies on substantially larger lattices than previously studied. We describe the algorithm in detail and present results for the ground-state energy, the first-excited-state energy, and the spin-spin correlations on various finite lattices for spins S=1/2, 1, 3/2, and 2. Results for an infinite system are obtained by extrapolation. We also discuss the generalization of our method to other models.

15.Quantized fractional Thouless pumping of solitons

URL:https://www.nature.com/articles/s41567-022-01871-x

notes: 这篇文章是实验文章，可以做理论模拟。

摘要:In many contexts, interaction between particles gives rise to emergent phenomena. An example is the fractional quantum Hall effect, where the interaction between electrons leads to fractionally quantized Hall conductance. In photonic systems, the nonlinear response of an ambient medium mediates the interaction between photons, and, in the mean-field limit, these dynamics are described by the nonlinear Schrödinger (also called Gross–Pitaevskii) equation. It was recently shown that at weak nonlinearity, soliton motion in nonlinear Thouless pumps—a dimensionally reduced implementation of a Chern insulator—could be quantized to the Chern number, because solitons track the single-band Wannier function throughout the pumping cycle. Here using arrays of coupled optical waveguides, we show that a sufficiently strong nonlinearity fractionally quantizes the motion of solitons. Specifically, we find that the soliton follows maximally localized multi-band Wannier functions and therefore returns to itself only after multiple cycles of the Thouless pump—but displaced by an integer number of unit cells—leading to a rich fractional plateau structure describing soliton motion. Our results represent an example of emergent behaviour in topologically non-trivial systems in the presence of interactions.

16.Many-body Non-Hermitian Skin Effect for Multipoles

URL:https://arxiv.org/abs/2401.04162

摘要:In this work, we investigate the fate of the non-Hermitian skin effect in one-dimensional systems that conserve the dipole moment and higher moments of an associated global U(1) charge. Motivated by field theoretical arguments and lattice model calculations, we demonstrate that the key feature of the non-Hermitian skin effect for m-pole conserving systems is the generation of an (m+1)th multipole moment. For example, in contrast to the conventional skin effect where charges are anomalously localized at one boundary, the dipole-conserving skin effect results in charges localized at both boundaries, in a configuration that generates an extremal quadrupole moment. In addition, we explore the dynamical consequences of the m-pole skin effect, focusing on charge and entanglement propagation. Both numerically and analytically, we provide evidence that long-time steady-states have Fock-space localization and an area-law scaling of entanglement entropy, which serve as quantum indicators of the skin effect.

17.Quantum logarithmic multifractality

URL:https://arxiv.org/abs/2312.17481

摘要:Through a combination of rigorous analytical derivations and extensive numerical simulations, this work reports an exotic multifractal behavior, dubbed ”logarithmic multifractality”, in effectively infinite-dimensional systems undergoing the Anderson transition. In marked contrast to conventional multifractal critical properties observed at finite-dimensional Anderson transitions or scale-invariant second-order phase transitions, in the presence of logarithmic multifractality, eigenstate statistics, spatial correlations, and wave packet dynamics can all exhibit scaling laws which are algebraic in the logarithm of system size

or time. Our findings offer crucial insights into strong finite-size effects and slow dynamics in complex systems undergoing the Anderson transition, such as the many-body localization transition.

18.Fluctuation spectra of large random dynamical systems reveal hidden structure in ecological networks

URL:https://www.nature.com/articles/s41467-021-23757-x

摘要:Understanding the relationship between complexity and stability in large dynamical systems—such as ecosystems—remains a key open question in complexity theory which has inspired a rich body of work developed over more than fifty years. The vast majority of this theory addresses asymptotic linear stability around equilibrium points, but the idea of ‘stability’ in fact has other uses in the empirical ecological literature. The important notion of ‘temporal stability’ describes the character of fluctuations in population dynamics, driven by intrinsic or extrinsic noise. Here we apply tools from random matrix theory to the problem of temporal stability, deriving analytical predictions for the fluctuation spectra of complex ecological networks. We show that different network structures leave distinct signatures in the spectrum of fluctuations, and demonstrate the application of our theory to the analysis of ecological time-series data of plankton abundances.

19.No complexity–stability relationship in empirical ecosystems

URL:https://www.nature.com/articles/ncomms12573

摘要:Understanding the mechanisms responsible for stability and persistence of ecosystems is one of the greatest challenges in ecology. Robert May showed that, contrary to intuition, complex randomly built ecosystems are less likely to be stable than simpler ones. Few attempts have been tried to test May’ s prediction empirically, and we still ignore what is the actual complexity–stability relationship in natural ecosystems. Here we perform a stability analysis of 116 quantitative food webs sampled worldwide. We find that classic descriptors of complexity (species richness, connectance and interaction strength) are not associated with stability in empirical food webs. Further analysis reveals that a correlation between the effects of predators on prey and those of prey on predators, combined with a high frequency of weak interactions, stabilize food web dynamics relative to the random expectation. We conclude that empirical food webs have several non-random properties contributing to the absence of a complexity–stability relationship.

20.Predicting the stability of large structured food webs

URL:https://www.nature.com/articles/ncomms8842

摘要:The stability of ecological systems has been a long-standing focus of ecology. Recently, tools from random matrix theory have identified the main drivers of stability in ecological communities whose network structure is random. However, empirical food webs differ greatly from random graphs. For example, their

degree distribution is broader, they contain few trophic cycles, and they are almost interval. Here we derive an approximation for the stability of food webs whose structure is generated by the cascade model, in which ‘larger’ species consume ‘smaller’ ones. We predict the stability of these food webs with great accuracy, and our approximation also works well for food webs whose structure is determined empirically or by the niche model. We find that intervality and broad degree distributions tend to stabilize food webs, and that average interaction strength has little influence on stability, compared with the effect of variance and correlation.

21.The feasibility and stability of large complex biological networks: a random matrix approach

URL:https://www.nature.com/articles/s41598-018-26486-2

摘要:In the 70’ s, Robert May demonstrated that complexity creates instability in generic models of ecological networks having random interaction matrices A. Similar random matrix models have since been applied in many disciplines. Central to assessing stability is the “circular law” since it describes the eigenvalue distribution for an important class of random matrices A. However, despite widespread adoption, the “circular law” does not apply for ecological systems in which density-dependence operates (i.e., where a species growth is determined by its density). Instead one needs to study the far more complicated eigenvalue distribution of the community matrix $S = DA$, where D is a diagonal matrix of population equilibrium values. Here we obtain this eigenvalue distribution. We show that if the random matrix A is locally stable, the community matrix $S = DA$ will also be locally stable, providing the system is feasible (i.e., all species have positive equilibria $D > 0$). This helps explain why, unusually, nearly all feasible systems studied here are locally stable. Large complex systems may thus be even more fragile than May predicted, given the difficulty of assembling a feasible system. It was also found that the degree of stability, or resilience of a system, depended on the minimum equilibrium population.

22.Numerical analysis of the master equation

URL:https://journals.aps.org/pre/abstract/10.1103/PhysRevE.65.047701

摘要:Applied to the master equation, the usual numerical integration methods, such as Runge-Kutta method, become inefficient when the rates associated with various transitions differ by several orders of magnitude. We introduce an integration scheme that remains stable with much larger time increments than can be used in standard methods. When only the stationary distribution is required, a direct iteration method is even more rapid; this method may be extended to construct the quasistationary distribution of a process with an absorbing state. Applications to birth-and-death processes reveal gains in efficiency of two or more orders of magnitude.

23.Landau-Zener transitions in the presence of harmonic noise

URL:https://arxiv.org/abs/1303.1864

摘要:We study the influence of off-diagonal harmonic noise on transitions in a Landau-Zener model. We demonstrate that the harmonic noise can change the transition probabilities substantially and that its impact depends strongly on the characteristic frequency of the noise. In the underdamped regime of the noise process, its effect is compared with the one of a deterministic sinusoidally oscillating function. While altering the properties of the noise process allows one to engineer the transitions probabilities, driving the system with a deterministic sinusoidal function can result in larger and more controlled changes of the transition probability. This may be relevant for realistic implementations of our model with Bose-Einstein condensates in noise-driven optical lattices.

24.Landau-Zener Transition in the Dynamic Transfer of Acoustic Topological States

URL:https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.126.054301

摘要:Topological notions in physics often emerge from adiabatic evolution of states. It not only leads to fundamental insight of topological protection but also provides an important approach for the study of higher-dimensional topological phases. In this work, we first demonstrate the transfer of topological boundary states (TBSs) across the bulk to the opposite boundary in an acoustic waveguide system. By exploring the finite-size induced minigap between two TBS bands, we unveil the quantitative condition for the breakdown of adiabaticity in the system by demonstrating the Landau-Zener transition with both theory and experiments. Our results not only serve as a foundation of future studies of dynamic state transfer but also inspire applications leveraging nonadiabatic transitions as a new degree of freedom.

25.Numerical study of scars in a chaotic billiard

URL:https://journals.aps.org/pre/abstract/10.1103/PhysRevE.55.5376

摘要:We study numerically the scaling properties of scars in stadium billiard. Using the semiclassical criterion, we have searched systematically the scars of the same type through a very wide range, from ground state to as high as the 1 millionth state. We have analyzed the integrated probability density along the periodic orbit. The numerical results confirm that the average intensity of certain types of scars is independent of $\hbar$ rather than scales with $\sqrt{\hbar}$. Our findings confirm the theoretical predictions of Robnik (1989).

26.Landau-Zener transitions in a superconducting flux qubit

URL:https://journals.aps.org/prb/abstract/10.1103/PhysRevB.80.012507

摘要:We report an experimental measurement of Landau-Zener transitions on an individual flux qubit within a multiqubit superconducting chip. The method used isolates a single qubit, tunes its tunneling amplitude Δ into the limit where Δ is much less than both the temperature T and the deconerenceinduced

energy level broadening, and forces it to undergo a Landau-Zener transition. We find that the behavior of the qubit agrees to a high degree of accuracy with theoretical predictions for Landau-Zener transition probabilities for a double-well quantum system coupled to a nonMarkovian $1/f$ magnetic flux noise.

27.Synchronization of chaotic systems: A microscopic description

URL:https://journals.aps.org/pre/abstract/10.1103/PhysRevE.98.052204

摘要:The synchronization of coupled chaotic systems represents a fundamental example of self organization and collective behavior. This well-studied phenomenon is classically characterized in terms of macroscopic parameters, such as Lyapunov exponents, that help predict the system's transitions into globally organized states. However, the local, microscopic, description of this emergent process continues to elude us. Here we show that at the microscopic level, synchronization is captured through a gradual process of topological adjustment in phase space, in which the strange attractors of the two coupled systems continuously converge, taking similar form, until complete topological synchronization ensues. We observe the local nucleation of topological synchronization in specific regions of the system's attractor, providing early signals of synchrony, that appear significantly before the onset of complete synchronization. This local synchronization initiates at the regions of the attractor characterized by lower expansion rates, in which the chaotic trajectories are least sensitive to slight changes in initial conditions. Our findings offer an alternative description of synchronization in chaotic systems, exposing its local embryonic stages that are overlooked by the currently established global analysis. Such local topological synchronization enables the identification of configurations where prediction of the state of one system is possible from measurements on that of the other, even in the absence of global synchronization.

28.Boundary Chaos: Spectral Form Factor

URL:https://arxiv.org/abs/2312.12452

摘要:Random matrix spectral correlations is a defining feature of quantum chaos. Here, we study such correlations in a minimal model of chaotic many-body quantum dynamics where interactions are confined to the system's boundary, dubbed *boundary chaos*, in terms of the spectral form factor and its fluctuations. We exactly calculate the latter in the limit of large local Hilbert space dimension q for different classes of random boundary interactions and find it to coincide with random matrix theory, possibly after a non-zero Thouless time. The latter effect is due to a drastic enhancement of the spectral form factor, when integer time and system size fulfill a resonance condition. We compare our semiclassical (large q) results with numerics at small local Hilbert space dimension (q=2,3) and observe qualitatively similar features as in the semiclassical regime.

29.Numerical method for the nonlinear Fokker-Planck equation

URL:https://journals.aps.org/pre/abstract/10.1103/PhysRevE.56.1197

摘要:A practical method based on distributed approximating functionals (DAFs) is proposed for numerically solving a general class of nonlinear time-dependent Fokker-Planck equations. The method relies on a numerical scheme that couples the usual path-integral concept to the DAF idea. The high accuracy and reliability of the method are illustrated by applying it to an exactly solvable nonlinear Fokker-Planck equation, and the method is compared with the accurate K -point Stirling interpolation formula finite-difference method. The approach is also used successfully to solve a nonlinear self-consistent dynamic mean-field problem for which both the cumulant expansion and scaling theory have been found by Drozdov and Morillo [Phys. Rev. E 54, 931 (1996)] to be inadequate to describe the occurrence of a long-lived transient bimodality. The standard interpretation of the transient bimodality in terms of the "flat" region in the kinetic potential fails for the present case. An alternative analysis based on the effective potential of the Schrödinger-like Fokker-Planck equation is suggested. Our analysis of the transient bimodality is strongly supported by two examples that are numerically much more challenging than other examples that have been previously reported for this problem.

30.Generalized synchronization of chaos in directionally coupled chaotic systems

URL:https://journals.aps.org/pre/abstract/10.1103/PhysRevE.51.980

摘要:Synchronization of chaotic systems is frequently taken to mean actual equality of the variables of the coupled systems as they evolve in time. We explore a generalization of this condition, which equates dynamical variables from one subsystem with a function of the variables of another subsystem. This means that synchronization implies a collapse of the overall evolution onto a subspace of the system attractor in full space. We explore this idea in systems where a response system y(t) is driven with the output of a driving system x(t), but there is no feedback to the driver. We lose generality but gain tractability with this restriction. To investigate the existence of the synchronization condition y(t)= (x(t)) we introduce the idea of mutual false nearest neighbors to determine when closeness in response space implies closeness in driving space. The synchronization condition also implies that the response dynamics is determined by the drive alone, and we provide tests for this as well. Examples are drawn from computer simulations on various known cases of synchronization and on data from nonlinear electrical circuits. Determining the presence of generalized synchronization will be quite important when one has only scalar observations from the drive and from the response systems since the use of time delay (or other) embedding methods will produce ''imperfect'' coordinates in which strict equality of the synchronized variables is unlikely to transpire.

31.Synchronization of chaotic systems and their machine-learning models

URL:https://journals.aps.org/pre/abstract/10.1103/PhysRevE.99.042203

摘要:Recent advances have demonstrated the effectiveness of a machine-learning approach known as "reservoir computing" for model-free prediction of chaotic systems. We find that a well-trained reservoir computer can synchronize with its learned chaotic systems by linking them with a common signal. A necessary condition for achieving this synchronization is the negative values of the sub-Lyapunov exponents. Remarkably, we show that by sending just a scalar signal, one can achieve synchronism in trained reservoir computers and a cascading synchronization among chaotic systems and their fitted reservoir computers. Moreover, we demonstrate that this synchronization is maintained even in the presence of a parameter mismatch. Our findings possibly provide a path for accurate production of all expected signals in unknown chaotic systems using just one observational measure.

32.Quantum synchronization in an optomechanical system based on Lyapunov control

URL:https://journals.aps.org/pre/abstract/10.1103/PhysRevE.93.062221

摘要:We extend the concepts of quantum complete synchronization and phase synchronization, which were proposed in A. Mari et al., Phys. Rev. Lett. 111, 103605 (2013), to more widespread quantum generalized synchronization. Generalized synchronization can be considered a necessary condition or a more flexible derivative of complete synchronization, and its criterion and synchronization measure are proposed and analyzed in this paper. As examples, we consider two typical generalized synchronizations in a designed optomechanical system. Unlike the effort to construct a special coupling synchronization system, we purposefully design extra control fields based on Lyapunov control theory. We find that the Lyapunov function can adapt to more flexible control objectives, which is more suitable for generalized synchronization control, and the control fields can be achieved simply with a time-variant voltage. Finally, the existence of quantum entanglement in different generalized synchronizations is also discussed.

33.Inter-layer synchronization in multiplex networks of identical layers

URL:https://pubs.aip.org/aip/cha/article-abstract/26/6/065304/322470/

摘要:Inter-layer synchronization is a distinctive process of multiplex networks whereby each node in a given layer evolves synchronously with all its replicas in other layers, irrespective of whether or not it is synchronized with the other units of the same layer. We analytically derive the necessary conditions for the existence and stability of such a state, and verify numerically the analytical predictions in several cases where such a state emerges. We further inspect its robustness against a progressive de-multiplexing of the network, and provide experimental evidence by means of multiplexes of nonlinear electronic circuits affected by intrinsic noise and parameter mismatch.

34.Dynamic Simulation of Structural Phase Transitions in Magnetic Iron

URL:https://arxiv.org/abs/1706.07635

摘要:The occurrence of bcc-fcc ($\alpha-\gamma$) and fcc-bcc ($\gamma-\delta$) phase transitions in magnetic iron stems from the interplay between magnetic excitations and lattice vibrations. However, this fact has never been proven by a direct dynamic simulation, treating non-collinear magnetic fluctuations and dynamics of atoms, and their coupling at a finite temperature. Starting from a large set of data generated by ab initio simulations, we derive non-collinear magnetic many-body potentials for bcc and fcc iron describing fluctuations in the vicinity of near perfect lattice positions. We then use spin-lattice dynamics simulations to evaluate the difference between free energies of bcc and fcc phases, assessing their relative stability within a unified dynamic picture. We find two intersections between the bcc and fcc free energy curves, which correspond to $\alpha-\gamma$ bcc-fcc and $\gamma-\delta$ fcc-bcc phase transitions. The maximum fcc-bcc free energy difference over the temperature interval between the two phase transition points is 2meV , in agreement with other experimental and theoretical estimates.

35.Longitudinal magnetic fluctuations in Langevin spin dynamics

URL:https://journals.aps.org/prb/abstract/10.1103/PhysRevB.86.054416

摘要:We develop a generalized Langevin spin dynamics (GLSD) algorithm where both the longitudinal and transverse (rotational) degrees of freedom of atomic magnetic moments are treated as dynamic variables. This removes the fundamental limitation associated with the use of stochastic Landau-Lifshitz (sLL) equations, in which the magnitude of magnetic moments is assumed constant. A generalized Langevin spin equation of motion is shown to be equivalent to the sLL equation if the dynamics of an atomic moment vector is constrained to the surface of a sphere. A fluctuation-dissipation relation for GLSD and an expression for the dynamic spin temperature are derived using the Fokker-Planck equation. Numerical simulations, performed using ferromagnetic iron as an example, illustrate the fundamental difference between the two- and three-dimensional dynamic evolution of interacting moments, where the three-dimensional GLSD includes the treatment of both transverse and longitudinal magnetic excitations.

36.Langevin equation for a particle in magnetic field is inconsistent with equilibrium

URL:https://www.researchgate.net/publication/329413894_Langevin_equation_for_a_particle_in_magnetic_field_is_inconsistent_with_equilibrium

摘要:We study the stochastic motion of a particle subject to spatially varying Lorentz force in the small-mass limit. Using existing literature on the small-mass limit of Langevin equations, we obtain the over-damped equation of motion of a Brownian particle in a spatially varying magnetic field. We show analytically that the the equation is inconsistent with thermal equilibrium: unphysical steady-state fluxes are present in a bulk homogeneous system. We perform Brownian dynamics simulations of the over-damped equation of motion, measure the fluxes and show that they are in quantitative agreement with

the analytical predictions. The problem of the correct overdamped equation of motion thus remains unsolved. However, the corresponding Fokker-Planck equation for the position variable is obtained by an independent route and is shown to be consistent with thermal equilibrium.

37.Nonlinearly driven Landau-Zener transition in a qubit with telegraph noise

URL:https://journals.aps.org/prb/abstract/10.1103/PhysRevB.77.014514

摘要:We study Landau-Zener-like dynamics of a qubit influenced by transverse random telegraph noise. The telegraph noise is characterized by its coupling strength v and switching rate γ . The qubit energy levels are driven nonlinearly in time, $\propto \mathrm{sgn}(t)|t|^{\nu}$, and we derive the transition probability in the limit of sufficiently fast noise, for arbitrary exponent ν. The level occupation after the transition depends strongly on ν , and there exists a critical ν_c with qualitative difference between $\nu \langle \nu_c$ and $\nu > \nu_c$. When $\nu < \nu_c$, the final state is always fully incoherent with equal population of both quantum levels, even for arbitrarily weak noise. For $\nu > \nu_c$, the system keeps some coherence depending on the strength of the noise, and in the limit of weak noise, no transition takes place. For fast noise $\nu_c = 1/2$, while for slow noise $\nu_c < 1/2$and it depends on γ. We also discuss phase coherence, which is relevant when the qubit has a nonzero minimum energy gap. The qualitative dependency on ν is the same for the phase coherence and level occupation. The state after the transition does, in general, depend on γ. For fixed v , increasing γ decreases the final state coherence when $\nu < 1$ and increases the final state coherence when $\nu > 1$. Only the conventional linear driving is independent of γ .

38.Classical synchronization indicates persistent entanglement in isolated quantum systems

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摘要:Synchronization and entanglement constitute fundamental collective phenomena in multi-unit classical and quantum systems, respectively, both equally implying coordinated system states. Here, we present a direct link for a class of isolated quantum many-body systems, demonstrating that synchronization emerges as an intrinsic system feature. Intriguingly, quantum coherence and entanglement arise persistently through the same transition as synchronization. This direct link between classical and quantum cooperative phenomena may further our understanding of strongly correlated quantum systems and can be readily observed in state-of-the-art experiments, for example, with ultracold atoms.

39.Chaos, Strange Attractors, and Fractal Basin Boundaries in Nonlinear Dynamics

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摘要:Recently research has shown that many simple nonlinear deterministic systems can behave in an

apparently unpredictable and chaotic manner. This realization has broad implications for many fields of science. Basic developments in the field of chaotic dynamics of dissipative systems are reviewed in this article. Topics covered include strange attractors, how chaos comes about with variation of a system parameter, universality, fractal basin boundaries and their effect on predictability, and applications to physical systems.