TFM proposals 2021

Cosmology, Relativity, Fields and Particles

Director: **Igor Bandos** (igor.bandos@ehu.eus)

Title: **Modern problems of String/M-theory**

The strategic goal of the research will be to gain new insights in the theory of fundamental interaction and in the structure of the Universe in the framework of String/M-theory. The characteristic predictions of this are supersymmetry, the symmetry between bosons and fermions, and extra spacetime dimensions. The project will deal with supergravity, a supersymmetric generalization of the Einstein General Relativity, which describes the low energy limit of String/M-theory, and with supersymmetric extended objects, supermembrane and higher p-branes in multidimensional spacetime, which appear as non-perturbative states in String/M-theory. As the field is progressing very rapidly and new interesting directions might appear, a more detailed specification of the research project is postponed till fall of this year.

Director: **Mariam Bouhmadi-López** (mariam.bouhmadi@gmail.com)

Title: **Quantum cosmology and classical singularities**

The quantum fate of classical singularities can be addressed in the setup of quantum cosmology: the application of quantum theory to the universe as a whole. This framework has proven that many cosmological singularities (and also gravitational singularities) like the big bang, can be avoided as a result of quantum effects emerging as the universe approaches the classical singularity. In this work, we will further analyze the quantum behavior of some classical singularities beyond the big bang that can be described classically in the framework of general relativity as well as in some extended theories of gravity. For that purpose, we shall focus on the quantum cosmology scheme given by the Wheeler-DeWitt equation and its possible extensions within a quantum geometrodynamics approach.

Directors: **David Brizuela** (david.brizuela@ehu.eus), **Marco de Cesare**

one choice between these two projects:

Title: **Quantum-gravity phenomenology**

The main goal of this project is to compute quantum-gravity effects on a given physical scenario. The setup would be either the primordial universe or a gravitational collapse, and different approaches could be considered. For instance, concerning the early universe, one could analyze certain technical aspects like the possibility of constructing a well-defined Hilbert space by using the PT invariance of the Hamiltonian, or the backreaction due to mode coupling. Concerning the physical scenario of a gravitational collapse, the main goal would be to obtain quantum-gravity corrections to the Hawking radiation. This effect is usually formulated on a Lagrangian framework. Nonetheless, recently a number of approaches have been put forward in order to provide a Hamiltonian formulation. Therefore, one could first perform a literature review of such proposals and then consider the computation of quantum-gravity corrections to the Hawking radiation via certain semiclassical method.

Title: **Conformal invariance in gravitational theories**

In this project we will review existing approaches to conformal gravity, the corresponding geometric framework, and study their Lagrangian and Hamiltonian formulations. The Hamiltonian formulation in particular reveals the existence of an extra first-class constraints (in addition to the scalar and diffeomorphisms constraints of general relativity), which generates Weyl transformations. We will study the problem of the spontaneous breakdown of conformal symmetry and then we will focus on simple cosmological models with a finite number of degrees of freedom in order to study the dynamics of the quantum theory.

Director**: Iñaki Garay** (inaki.garay@ehu.eus)

Title**: Spinor formalism for loop quantum gravity: dynamics and semiclassical limit**

Loop quantum gravity (LQG) is a well established proposal for the quantization of spacetime. Among its main results we find the description of the microscopic origin of the black hole entropy and, within the cosmological version of the theory (known as loop quantum cosmology), the avoidance of the initial singularity. Nevertheless, the implementation of the dynamics and the semiclassical limit are still open problems of the theory. In this project, we will explore the framework given by the so-called spinor formalism for LQG in order to study these issues in carefully constructed models with sensible physical interpretation, such as cosmological models, simple models to implement dynamics on them, or models suitable for coarse-graining procedures in order to look for the semiclassical limit.

Directors: **Iván de Martino**, **Ruth Lazkoz** (ruth.lazkoz@ehu.es)

Title: **Cosmological forecast for the Einstein Telescope**

The main objective of this TFM is to focus on the development of the necessary tools to carry out cosmological forecasting for the Einstein Telescope (ET) in modified gravity ["The Einstein Telescope Project," https://www.et-gw.eu/et /]. ET will be able to detect the GW emission from binary systems up to redshift ~ 5, and provide for each system an estimate of the luminosity distance. Following the methodology in Zhao et al., Phys. Rev. D 83, 023005 (2011), Cai and Yang Phys. Rev. D 95, 044024 (2017), it will be discussed how to simulate luminosity distances as they will be detected by ET , focusing on various aspects, for example, the configuration of the GW telescope, how to simulate noise and error bars, and also on the statistical importance of the methodology. The student must generate a catalog of 10,000 events in modified gravity models that will be used to make a figure of merit exploring the parameter space with Monte Carlo Markov Chain techniques.

Directors: **Joanes Lizarraga** (joanes.lizarraga@ehu.eus), **Jon Urrestilla** (jon.urrestilla@ehu.eus)

Title: **Lattice simulations of Superconducting Cosmic Strings**

Superconducting strings, as predicted by Witten, can be formed in systems with U(1)xU(1) symmetry when only one of the U(1) symmetries is spontaneously broken. This symmetry breaking leads to the formation of stable vortices or strings. The field associated to the unbroken symmetry condensates at the core of those vortices and forms superconducting flux tubes. The formation of superconducting strings is predicted in many supersymmetrical and inflationary cosmological scenarios, thus they could be relevant in some early universe models. Even though they have been studied from different perspectives, e.g. using field theory or approximating to Namgu-Goto strings, the full dynamics of networks of superconducting strings has not been simulated yet. Lattice simulations bring the possibility to explore a wide range of interesting and fundamental properties such as intercommutation, formation of stable superconducting loops, etc. In addition the student will be able to study the evolution of superconducting string in cosmological backgrounds, where some cosmological observables can also be computed. The project will be developed exclusively from a numerical point of view and the student will acquire valuable skills in advanced numerical methods and lattice simulations.

Directors: **Gunar Schnell** (gunar.schnell@ehu.eus)

one choice between these two projects:

Title: **The strange shape of transversely polarized protons**

The novel Sivers effect, characterized by the preference in the transverse momentum direction of quarks in a transversely polarized hadron, has become one of the major topics in hadron physics. Although predicted in the early days of Quantum Chromodynamics to be highly suppressed, various experimental results have since then managed to defy this expectation. The Sivers parton distribution can be accessed among others through the distribution of unpolarized final-state hadrons produced in deep-inelastic scattering of high-energy leptons by transversely polarized nucleons. The dominance of the contributions from up and down quarks to this process makes it difficult, though, to probe anything but those quark flavors without currently overwhelming uncertainties. However, due to the apparently opposite signs of up- and down-quark Sivers distributions as well as the high sensitivity to strange quarks, a different process — namely hyperon polarization — might shed light on the difficult-to-measure strange-quark Sivers effect. In this work, the quark-parton model formalism for polarized hyperon production will be reviewed and current parametrizations for parton distribution and fragmentation functions be used to make predictions for measurements at various facilities in order to estimate the feasibility of such measurements at existing and future experiments, and thus the possibility of accessing the shape of the strange-quark momentum distribution in transversely polarized protons.

Title: **Hadronization models for high-energy experiments**

Most high-energy physics experiments to date observe among others final-state hadrons that stem from the elementary interactions of the various physics processes. However, our present-day tools of describing the formation of color-neutral hadrons from colored partons (quarks and gluons) within Quantum Chromodynamics (QCD) are still rather limited and insufficient for first-principle calculations and the description of this color-confining process. A multitude of tools have been developed to lessen the dependence on such first-principle calculations, albeit all with their own short-comings. One of the more successful approaches presently available in high-energy physics is the application of Monte Carlo event generators, which employ perturbative methods where possible and parametrizations as well as modeling where perturbative methods cannot be used. One example is the widely used PYTHIA event generator, incorporating the JETSET hadronization model. It is used for a number of processes, from lepton-nucleon scattering, electron-positron annihilation, to hadron collision as, e.g., done at the Large Hadron Collider at CERN. Indeed, it is often the only way of evaluating the Standard Model background in searches for physics beyond the Standard Model. In this work, comparisons of previous PYTHIA tunes with the latest reincarnation of PYTHIA as well as to real data will be performed, in particular for observables relevant to electron-positron annihilation with the goal of establishing a framework to coherently fit model parameters for a better reproduction of annihilation data for the recently started Belle II experiment, the luminosity frontier of particle physics.

Quantum matter, simulations, and technologies

Director: **Dario Bercioux** (dario.bercioux@dipc.org)

Title: **Spectral properties of a non-Hermitian diamond chain**

This project will investigate the spectral topological properties of a non-Hermitian Hamiltonian system. Specifically, we will focus on the diamond chain, a quasi- one-dimensional lattice system characterized by three sites in the unit cell. In the Hermitian case, we have shown that two possible topological phases can describe this system: a half-integer and an integer pseudo-spin. The former can be mapped precisely into the well-known case of the Su-Schrieffer-Heeger model [5], and the latter presents topological properties only in the presence of adiabatic pumping. In the same spirit as in Bercioux *et al.*, Ann. Phys. (Berl.) **529**, 1600262 (2017), we are interested in understanding how the two possible dimerization of the diamond chain are extended to the non-Hermitian case. We will search for possible implementation in the contest on optical fibres.

Directors: **Aitor Bergara** (a.bergara@ehu.eus), **Aritz Leonardo** (aritz.leonardo@ehu.eus)

Title: **Molecular dynamics study of Calmodulin**

The complete resolution of the sequence of the human genome in 2016 has been a huge milestone that continuously reveals causal relations among pathologies and gene signaling. Moreover, the latest advances of experimental techniques, such as nuclear magnetic resonance, provide a direct access to 3D maps with atomic resolution of the proteins that form cell membranes. This new accessible structural information has become a revolution in biological sciences for the design of new drugs that improve the well-being of humans. Remarkably, 60% of the commercial drugs act precisely on the proteins located at the cell membranes. With this scenario in mind, physical models that mimic atomic interactions within the proteins and their posterior time evolution through molecular dynamics provide a very powerful tool for the prediction and comprehension of membrane phenomena. Theoretical simulations of proteins serve as a guidance for the design of new drugs and help understanding the enormous amount of experimental information available. In this Master Thesis we shall consider the Kv7.2 channel of neuron membranes — a potassium voltage-gated channel located in human neurons — whose functioning relies in a potential difference induced by calmodulin (CaM). By means of All-atom simulations, molecular dynamics and coarse grain models, we would like to validate two claims regarding the behavior of the secondary structure of the IQ motiv of the channel: 1) Both wild type and mutant can form stable helices without the ribosome; 2) Wild type can form an alpha helix at the ribosome whereas the mutant cannot.

Director: **Jorge Casanova** (jcasanovamar@gmail.com)

Title: **Quantum detection and control of radioisotopes**

Advanced quantum information processing methods such as those based on machine learning and Bayesian inference would be of great help for dealing with nuclear spin systems with vanishing properties that we aim to accurately estimate. Among them we have those including ensembles of unstable nuclei that could transmute to other nuclear isotopes (thus, effectively changing their magnetic moment). In this case, the repetition of the experiment needed to compute average values according to quantum mechanical laws is not possible, while acquired data from the nuclear system have to be continuously harvested and, afterwards, properly handled. We will tackle this problem by combining suited microwave and radiofrequency radiation patterns over a quantum sensor (such as the nitrogen vacancy center in diamond) with advanced data processing methods of the continuously collected data. This would lead to schemes in which, e.g., one can estimate nuclear decay times of different radioisotopes in challenging time-windows as well as in different environmental conditions such as low/room temperatures and at different magnetic field strengths. Results in this line would have important interdisciplinary applications in fields ranging from nuclear physics to medicine. This is a theoretical project that requires knowledge in quantum mechanics, as well as an open attitude of the candidate to investigate and incorporate different programing paradigms (such as machine learning) to the burgeoning field of quantum computing.

Director: **Xi Chen** (xi.chen@ehu.eus)

Title: **Shortcuts to adiabaticity for digital-analog quantum simulation**

Shortcuts to adiabaticity are well-known methods for controlling the quantum dynamics beyond the adiabatic criteria, where counter-diabatic driving provides a promising means to speed up quantum many-body systems, with the applications in quantum computing for solving the combinatorial optimization problems. On the other hand, the analog-digital quantum simulation of the quantum Rabi and Dicke models has been also proposed by using circuit quantum electrodynamics and other physical platforms. The ultrastrong coupling and other physical regimes can be simulated via unitary decomposition into digital steps. In this project, we are aiming to investigate the shortcuts to adiabaticity for digital-analog quantum simulation of Rabi and/or Dicke modes in in trapped ions or superconducting circuits., We will discuss the possible merge of digital and shortcuts to adiabaticity concepts, onto digital-analog quantum simulations, to reach quantum supremacy in current quantum technologies.

Directors: **Asier Eiguren Goienetxea** (asier.eiguren@ehu.eus), **María Blanco Rey** (maria.blanco@ehu.eus)

Title: **Perturbative Approach to the Dzyaloshinskii-Moriya Interaction with Wannier Functions**

The spin-orbit interaction (SOI) is at the origin of the antisymmetric exchange interaction between spins, known as Dzyaloshinskii-Moriya Interaction (DMI). As this interaction type favours canted spins with a determined chirality, i.e. handedness, it is fundamental in the stabilization of spin spirals and skyrmions. Moriya formulated the interaction as a has spin-orbit correction of the Heisenberg hamiltonian as a first order perturbation in the atomic SOI strength parameter. This is a single-ion multiplet picture, where the DMI is obtained from the orbital quantum numbers of the excited states. The first task in this Master Thesis is to extend this formalism to systems with hybrid dispersive bands making use of Wannier wavefunctions within the density-functional theory. DMI energies in periodic systems are usually calculated by generating a magnetic superstructure (a spin spiral) of a certain wavevector q, which is then solved by the generalized Bloch theorem. The second task is to implement this formalism, also making use of Wannier wavefunctions. The advantage of this strategy over existing codes is that it will allow to perform spectral and real-space analyses of DMI in a natural manner.

Director: **José A. Fernández** (josea.fernandez@ehu.eus)

Title: **Structural determination of molecular aggregates using mass-resolved laser spectroscopy and DFT methods**

Intermolecular interactions are weak forces of pure quantum nature. Despite their small module, they are of paramount importance for life on Earth, due to their influence in the environment. In addition, life makes extensive use of such forces. They are used to control fundamental processes such as docking of a ligand into a protein, or molecular recognition. Thus, having a deep knowledge of such forces is required to understand such processes, and therefore, there is a strong demand for high-quality experimental data from systems attached by intermolecular forces. In the "Grupo de Espectroscopía", we form molecular aggregates using supersonic expansions, which cool the molecules to a few Kelvin, preparing them to be probed by means of a combination of UV and IR lasers. Using several mass-resolved spectroscopic techniques, important structural information is extracted from the aggregates, which is afterwards interpreted on the light of quantum-mechanical calculations.

Directors: **Aran Garcia-Lekue** (wmbgalea@ehu.eus), **Daniel Sánchez-Portal**

Title: **Towards spin qubits in graphene nanostructures**

The recent discovery of stable spin-polarized states in graphene nanostructures has paved the way for their potential use as spin qubit elements for quantum computation. In this project, density functional theory (DFT) and model calculations will be employed to unravel the basic mechanisms giving rise to spin polarized states in selected graphene nanostructures, with special focus on the evolution of the spin arrangement and spin- spin interactions from 1D chains to 2D networks. Our results would be very useful towards developing spin-qubits in carbon-based 2D materials, and could guide future experiments in this direction.

Director: **Julen Ibañez** (julen.ibanez@ehu.eus)

Title: **Understanding the flexo-photovoltaic effect with a two-band model Hamiltonian**

In condensed matter physics, simple band model Hamiltonians can often provide an intuitive understanding of complex physical processes. In this project we propose working with a two-band model expanded in momentum-space; the objective is to describe a novel photovoltaic effect discovered very recently, the so-called flexo-photovoltaic effect. It consists of a light-absorption process that is quadratic in the electric field of light, and takes place in distorted semiconductors. The underlying physics are governed by the Berry connection and its k-space derivatives, which enter the transition matrix elements via Fermi's golden rule. Our goal is to understand how the distortion-induced breaking of inversion symmetry affects the nonlinear light absorption properties of the material. For this, we will identify the relevant parameters that describe the process and assess their importance within the two-band model. The project involves analytic work using quantum theory of solids, combined with numerical calculations.

Directors: **Juan Luis Mañes Palacios** (wmpmapaj@lg.ehu.es), **Maia García Vergniory** (maiagv@gmail.com)

Project: **Fermi arcs in chiral photonic crystals**

Topological insulators and topological semimetals have caused a paradigm shift in our understanding of phases of matter. They exhibit a remarkable symbiosis between elegant mathematical theories, accurate material prediction, and technological applications. Photonic crystals are periodic dielectric structures that are designed to obtain energy bands for photons, which either allow or forbid the propagation of electromagnetic waves of certain frequency ranges, making them ideal for light harvesting applications. The formalism needed to treat the propagation of light waves in these synthetic materials is very similar to that of electrons in a crystal, as one can cast Maxwell's equations into an ordinary eigenvalue problem in the components of the magnetic field, giving a Hermitian operator (in the absence of absorption) that resembles the single-particle Hamiltonian of electron band theory. The space group of a chiral photonic crystal contains only proper operations, and within the right energy window it should display robust unidirectional surface states protected by a topological order. Our goal in this project will be to study the topology of chiral photonic crystals and the existence of surface states in these systems. As a first step we will develop a mathematical model to study chiral photonic crystals.

Director: **Gonzalo Muga** (jg.muga@ehu.eus)

Title: **Control of quantum system dynamics for quantum technologies**

Quantum dynamics offers a vast potential of applications but they are hindered by decoherence. A general way to mitigate decoherence is to implement "Shortcuts to adiabaticity" (STA), a set of techniques developed by the group to speed up the processes without residual excitations. STA work by inverse engineering the time-dependent external controls. They have been applied to a broad range of systems such as qubits in different physical platforms (trapped ions, superconducting circuits, neutral atoms in optical lattices,...) for motional control or to implement interferometry, metrology or quantum information processing. STA extend as well beyond quantum mechanics, to make optical devices or mechanical systems more compact and robust. In this project we would address some application of STA in one of the many systems or operations in which they are useful. Examples in the context of quantum technologies could be to design: a) state transfer between two oscillators b) transport operations robust with respect to noise for quantum information platforms using trapped ions; c) robust particle focusing processes.

Directors: **Mikel Palmero** (mikel_palmero@hotmail.com), **Sofía Martínez-Garaot** (sofia.martinez@ehu.eus)

one choice between these two projects:

Title: **From quantum control to dynamical control of classical systems**

We have developed a set of analytical and numerical tools called shortcuts to adiabaticity (STA), that help dynamically manipulate quantum systems for a myriad of applications in quantum optics and quantum information. Most notably, these methods can help in the implementation of quantum technologies such as quantum computers by dramatically improving fidelities limited by the state-of-the-art technology. Interestingly enough, many classical systems that need to be dynamically manipulated can be explained by similar Hamiltonians as the quantum systems we have been studying so far, so the same techniques can be applied there. Mechanical systems are particularly suitable for this, including examples such as cranes, drones carrying a load, or water wells. For this master's thesis, we propose extensively exploring other disciplines with complex dynamical problems that could potentially benefit from applying these imported quantum STA techniques, and proposing a set of concrete applications that could be improved by applying specific STA methods. These disciplines may include aerospace industry, chemical industry, life sciences and med- ical devices, material science, quantitative finances, hydrodynamics, et cetera. Depending on the available time, the student will also choose one of the potential applications and dig deeper into it.

Title: **Machine learning to optimize quantum control**

We have developed a set of analytical and numerical tools called shortcuts to adiabaticity (STA), that help dynamically manipulate quantum systems for a myriad of applications in quantum optics and quantum information. Most notably, these methods can help in the implementation of quantum technologies such as quantum computers by dramatically improving fidelities limited by the state-of-the-art technology. For this project, the student will develop a machine learning algorithm as an alternative, or even as a complement, to these STA techniques. We will first apply the machine learning algorithm to dynamical problems that have already been treated with other STA techniques, and compare the performance of the different methods. Specially interesting is the comparison with optimal control theory, another purely numerical optimization method that has been extensively used for control of dynamics in quantum systems. After this, the student can move forward to apply the method to more difficult (and meaningful) problems, where analytical solutions are not applicable, and numerical methods like this acquire more strength.

Directors: **Marisa Pons** (marisa.pons@ehu.eus)

Title: **Heat rectification in a chain of trapped ions**

A thermal rectifier, when connected to two thermal baths at different temperatures, conducts heat asymmetrically if the temperatures of the baths are interchanged. These devices are crucial components to manipulate heat currents and construct phononic devices. Up to now, though, no efficient and feasible devices have been found and the manipulation of heat fluxes is far from being completely controlled. In all the proposals that have been studied the same difficulties arise: scalability and efficiency. We have made several proposals in order to improve their performance based on chains of atoms and trapped ions. Also, we have been interested in analyzing the criteria in order to obtain rectification. Still there is still much room for further work on possible systems that would enhance the rectification and act also as thermal transistors, and allow for larger systems. In this project we would study simple models with trapped ions, that can be treated analytically and show heat rectification, and extend the model to larger systems.

Directors: **Enrique Rico** (enrique.rico@ehu.eus)

one choice between these two projects:

Title: **Symmetry protected qubit in an open quantum system**

We will consider a particular limit of a very light particle on a circle, in the presence of half of the flux quantum. With this flux, the ground state of the system is doubly degenerate and the rest of the spectrum is separated by large energy gaps from the ground state. At low- temperatures, we can neglect contributions of all states except for the ground state. The ground state space coincides with the one for a spin-1/2. We will consider a superconducting circuit implementation, considering any source of noise, that must be described by an open quantum system. Problems to be addressed: (1) Discuss the symmetry and topological aspects of the problem and characterise the symmetry protected subspace that realises a qubit. Check how is changing in the presence of noise. (2) Couple two protected qubit and study any interaction that respects the symmetries of the combined system. (3) Study the quantum computational power of the proposed qubit. (4) Analyse a particular implementation of a single and two protected qubits in terms of superconducting circuits. (5) Propose a minimal quantum circuit realisation for a set of symmetry protected qubits in realistic scenario, i.e., described by an open quantum system.

Title: **Quantum simulation of particle physics**

We will consider the simplest gauge model, a Z(2) lattice gauge model, and we will study in detail how to implement in a quantum simulator any possible gauge invariant expectation value, including real-time dependent quantities which are essential to describe physical processes like scattering of particles. Problems to be addressed: (1) Study and get familiar with the physics of lattice gauge models in the case of a Z(2) gauge model. (2) Propose a physical realizable implementation of a quantum simulator with all the degrees of freedom and interaction terms of the gauge model. (3) Understand how to measure gauge invariant quantities that depend on real-time. (4) Analyse all the previous steps in the description of scattering of particles.

Directors: **Mikel Sanz** (diracmatrix@gmail.com)

Title: **Mathematical aspects of quantum computing and quantum algorithms**

Quantum computation employs quantum resources to speed up certain algorithms and tasks. This field has blossomed during the last years due to the advances in quantum platforms and algorithmics, but there are still multiple open problems which must be addressed. Some examples are the generation of efficient methods for data loading in quantum processors, the design of efficient classical-quantum interfaces, or a proof of speedup in variational quantum algorithms, just to mention a few. In this thesis, we will develop mathematical tools to address some of this questions.

Director: **Evgeny Sherman** (evgeny.sherman@ehu.eus)

one choice between these two projects:

Title: **Electron motion in solids with isotopic disorder**

Disorder is the key element that determines electron transport in solids. Usually disorder is produced by charged impurities or other lattice defects. However, another type of disorder is possible and is of real interest. Chemical elements have various isotopes, having different atomic masses with all other absolutely equivalent electronic properties. Isotopes are randomly distributed in crystals and, thus, produce a disorder in the mass distribution. At zero temperature this disorder can considerably influence conductivity of the system due to randomness in the zero-point quantum oscillations of the atoms. The proposed project will be focused on the studies of the effects of the isotopic disorder on the electron transport in solids.

Title: **Driven motion of solitons**

Solitons (self-localized objects) in nonlinear systems play an important role in modern physics, from optics to spin systems and cold atomic gases. Understanding of the motion of solitons is important in all these branches of quantum physics. As localized objects, solitons strongly interact with the impurities and other defects in their host systems. Therefore, motion of solitons can be initiated and controlled by the motion of these defects. In this project, we will study motion of solitons driven by controlled displacement of the defects the solitons are pinned to. Thus, we will understand their dynamics and also formulate new rules for design of properties of dynamical nonlinear quantum systems.

Director: **Jens Siewert** (jens.siewert@ehu.eus)

Title: **Bell inequalities and the Bloch representation of two-qubit quantum states**

The Bloch representation (that is, the description of density operators in terms of a matrix basis) is a powerful tool to solve quantum mechanics problems. This is because its language is deeply rooted in geometry and therefore its concepts are amenable to geometric intuition. However, the mathematical techniques of this representation are not well developed and present considerable difficulties. Recently we have found methods to geometrically visualize the space of two-qubit correlations. A fascinating (and, at the same time, challenging) problem is to ask whether so-called nonlocal states (that is, states that violate a Bell inequality) are geometrically special compared to other entangled states. In order to find an answer we will study the simplest Bell inequalities (Clauser-Horne type inequalities with two measurement settings) in terms of the Bloch formalism. A necessary ingredient for this research is to develop simple techniques to treat also measurements in the Bloch representation.

Director: **Lianao Wu** (lianaowu@gmail.com)

Title: **Trotterization to simulate adiabatic evolution and adiabatic quantum computation**

In 2002, we proposed to use Trotterization to simulate adiabatic evolution of a time-dependent driving Hamiltonian in our paper, Phys. Rev. Lett. **89**, 057905 (2002). The experimental test of this BCS simulation was done by Massachusetts Institution of Technology. Now the idea have become a new type of quantum computation, the Trotterized (or digitized) adiabatic quantum computation [Nature **534**, 222 (2016)]. Along this line, we recently propose a static version of this technique to perform the optical simulation of the adiabatic evolution if an arbitrarily given Hamiltonian. The dynamical process of the adiabatic evolution is mapped to a static linear optical array which is robust to the errors caused by dynamical fluctuations. We plan to mimic different physical systems with the static adiabatic evolution using the idea in Phys. Rev. Lett. 89, 057905 (2002).