“NITEP Condensed Matter Lecture 2025” with Prof. M. Berry and four invited speakers

Program

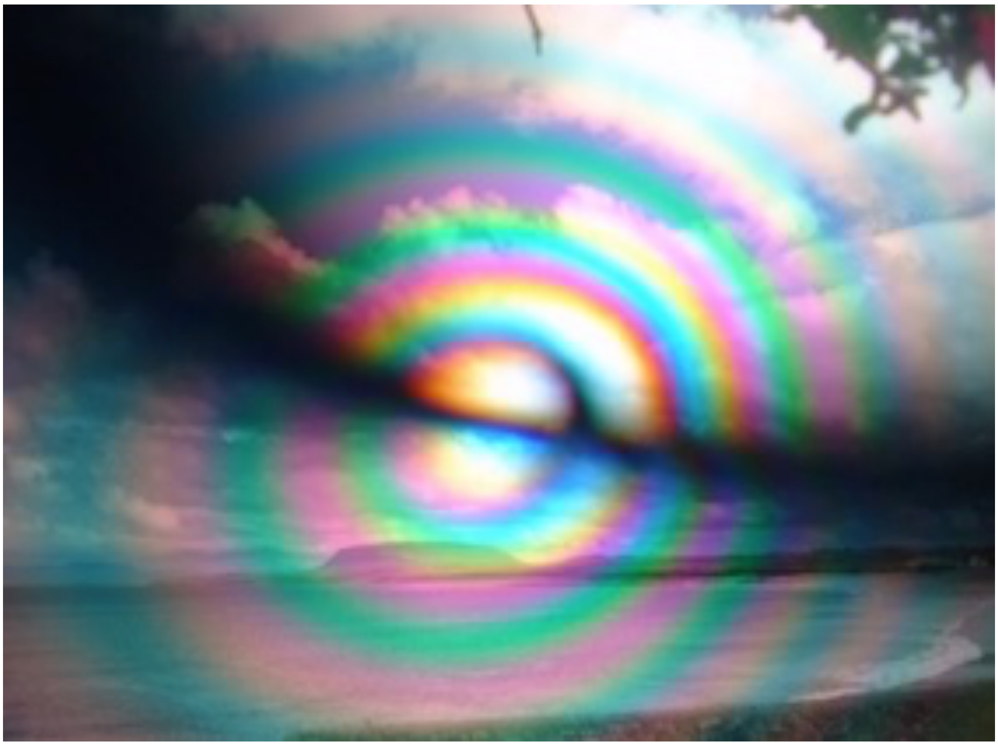
13:20 - 13:30	Opening Remarks
	Session 1 (Chair: N. Maru)
13:30 - 14:30	Michael Berry (University of Bristol) “Geometric phases old and new”
14:30 - 14:40	Break
	Session 2 (Chair: A. Oguri)
14:40 - 15:10	Katsuhiro Nakamura (National University of Uzbekistan) “Fast-forward of adiabatic dynamics: from generation of entangled states to quantum thermodynamics”
15:10 - 15:40	Tsuneya Yoshida (Kyoto University) “Topology of exceptional points”
15:40 - 15:50	Break
	Session 3 (Chair: G. Oohata)
15:50 - 16:20	Masahiro O. Takahashi (RIKEN) “Non-Abelian anyons in the Kitaev spin liquid: stable realization and detectability via lattice defects”
16:20 - 16:50	Satoshi Tanaka (Osaka Metropolitan University) “Quantum geometry of a bosonic system exhibiting a quantum phase transition in terms of frame bundle structure”
16:50 – 17:00	Closing Remarks
	Reception
17:30 – 19:30	@ Metasequoia (Tanaka Kinen Kaikan)

Osaka, August 2025

Geometric phases old and new

Michael Berry
University of Bristol, Europe
https://michaelberryphysics.wordpress.com

The waves that describe systems in quantum physics can carry information about how their environment has been altered, for example by forces acting on them. This effect is the geometric phase. It occurs in the optics of polarised light, where it goes back to the 1820s; it influences wave interference; and it provides insight into the spin-statistics relation for identical quantum particles. The underlying mathematics is geometric: parallel transport, explaining how falling cats turn, and how to park a car. Associated with the geometric phase are the curvature and metric 2-forms. Incorporating the back-reaction of the geometric phase on the dynamics of the changing environment exposes an unsolved problem: how can a system be separated from a slowly-varying environment? The concept has a tangled history.



Contribution ID: **4** Type: **not specified**

Fast-forward of adiabatic dynamics: from generation of entangled states to quantum thermodynamics

Tuesday, 26 August 2025 14:40 (30 minutes)

We review the idea of fast-forward of adiabatic dynamics proposed by Masuda and Nakamura. This idea has been applied to diverse areas of physics. Here we show that the generation of entangled states is fast-forwarded and speeded up by application of a suitable driving protocol. Then we treat a dynamical system coupled with the dissipative environment. The fast-forward evolution of Gibbs state (: canonical distribution) is guaranteed by innovating the detailed balance condition for coefficients of the dissipator, which makes possible the existence of quantum analog of Carnot-like 4-stroke heat engine with arbitrarily finite power.

References:

Original idea of FF theory: S. Masuda and K. Nakamura, Proc. R. Soc. A 466, 1135-1154 (2010).
Review of FF theory: S. Masuda and K. Nakamura, Philosophical Transactions of the Royal Society A 380, 20210278 (2022).

Presenter: NAKAMURA, Katsuhiro (National University of Uzbekistan)

Session Classification: Session 2

Contribution ID: **5** Type: **not specified**

Topology of exceptional points

Tuesday, 26 August 2025 15:10 (30 minutes)

Exceptional points are band-touching points that are unique to non-Hermitian systems[1]. At the exceptional points, two eigenstates coalesce, resulting in square-root dispersion. The emergence of exceptional points is ubiquitous as they are observed for a wide range of systems from quantum systems[2] though meta-materials[3] to geophysical fluid dynamics[4].
In this talk, we discuss topology of exceptional points with/without symmetry[5]. Specifically, we show that symmetry may enrich exceptional points leading to symmetry-protected exceptional rings (surfaces) in two (three) dimensions. We also demonstrate that strongly correlated electrons may host such exceptional points, rings, and surfaces. Furthermore, we extend the analysis to multi-fold exceptional points (i.e., non-Hermitian band touching of three or more bands) which is beyond the periodic table of Bernard-LeClair symmetry classes[6]. Based on resultant of the characteristic polynomial, we clarify the topological aspect of multi-fold exceptional points[7]. Our framework also elucidates the robustness of non-Hermitian band touching reported for acoustic meta-materials.

References:
[1] H. Shen et al., Phys. Rev. Lett. 120, 146402 (2018).
[2] N. Hatano, Mol. Phys. 117 2121 (2019).
[3] W. Tang et al., Science 370, 1077 (2020).
[4] A. Lecleric et al., Phys. Rev. Res. 6, L012055 (2024).
[5] T. Yoshida et al., Phys. Rev. B 99, 121101 (2019).
[6] K. Kawabata et al., Phys. Rev. Lett. 123, 066405 (2019).
[7] P. Delplace et al., Phys. Rev. Lett. 127, 186602 (2021); T. Yoshida et al., Phys. Rev. Res. 7, L012021 (2025); T. Yoshida et al., arXiv:2504.13012.

Presenter: YOSHIDA, Tsuneya (Kyoto University)

Session Classification: Session 2

Contribution ID: **6**

Type: **not specified**

Non-Abelian anyons in the Kitaev spin liquid: stable realization and detectability via lattice defects

Tuesday, 26 August 2025 15:50 (30 minutes)

Non-Abelian anyons in the Kitaev spin liquid: stable realization and detectability via lattice defects

Quantum spin liquids (QSLs) are exotic phases of matter characterized by strong entanglement and the absence of magnetic order even at zero temperature [1]. The spin-1/2 Kitaev model is a unique, exactly solvable example that hosts fractionalized excitations—Majorana fermions and Z_2 fluxes [2]. When time-reversal symmetry is broken, these excitations can give rise to non-Abelian Ising anyons, which are promising candidates for building blocks of topological quantum computation. However, stabilizing such anyons in this system remains challenging, as they are thermal excitations and do not appear in the ground state [2, 3]. Their detection is further complicated by the fact that, in QSLs, charge degrees of freedom are generally frozen, rendering conventional electric techniques—such as those used in fractional quantum Hall systems [4]—inapplicable.
This presentation theoretically investigates various lattice defects in the Kitaev spin liquid—such as higher-S (>1/2) magnetic impurities and spin vacancies—in connection with the stable realization and detection of Ising anyons. Our numerical and phenomenological studies show that spin-3/2 impurities can host stable anyon bound states in the ground state [5], similar to those found at spin vacancies [6]. Furthermore, we demonstrate that Ising anyons trapped at such lattice defects can be detected using local and nonlocal probes, including scanning tunneling microscopy [7] and NV center magnetometry [8], as spectroscopic techniques for observing the low-energy spectrum of fractionalized excitations.

[1] For review, C. Broholm et al., Science 367, 6475 (2020).
[2] A. Kitaev, Ann. Phys. (Amsterdam) 321, 2 (2006).
[3] J. Nasu et al., Phys. Rev. Lett. 113, 197205 (2014).
[4] M. Dolev et al., Nature 452, 829–834 (2008).
[5] M. O. Takahashi et al., npj Quantum Mat. 10, 14 (2025).
[6] A. Willans et al., Phys. Rev. Lett. 104, 237203 (2010).
[7] M. O. Takahashi et al., Phys. Rev. Lett. 131, 236701 (2023).
[8] X. Xiao et al., arXiv:2501.19165.

Presenter: TAKAHASHI, Masahiro O. (RIKEN)

Session Classification: Session 3

Contribution ID: **7** Type: **not specified**

Quantum geometry of a bosonic system exhibiting a quantum phase transition in terms of frame bundle structure

Tuesday, 26 August 2025 16:20 (30 minutes)

We study the quantum geometry of a bosonic system with a quantum phase transition from the perspective of the frame bundle structure. The phase boundary appears in the form of a light cone in the parameter space which is regarded as the exceptional surface. We have obtained the complex eigenmodes which diagonalize the Hamiltonian all over the parameter space, enabling us to study analytical continuation across the entire parameter space. The quantum geometric tensor in terms of the operator algebra space is obtained based on the principal bundle theory. While the symmetric part of the tensor, known as the quantum metric, is a positive-definite Riemannian metric in the stable region, in the unstable region, we found that part of it becomes negative, turning into a pseudo-Riemannian metric. The antisymmetric part representing the Berry curvature experiences the transition from the real phase to the complex phase at the phase boundary. We have found that the operator space holds the Kähler structure in the stable domain as in the Hilbert space, but it transitions to a pseudo-Kähler structure in the unstable domain.

Presenter: TANAKA, Satoshi (Osaka Metropolitan University)

Session Classification: Session 3