（ 続紙 1 ）

京都大学	博 士（ 理 学 ）	氏名	道下 佳寛
論文題目	Non-Hermitian Aspect of Strongly-Correlated Electron Systems （強相関電子系に創発する非エルミート物性）		

（論文内容の要旨）

During his Ph.D. course, Mr. Michishita mainly focused on the analysis of non-Hermitian effects occurring in the equilibrium state of strongly correlated materials. Non-Hermitian phenomena are recently widely studied because of novel phenomena, such as unidirectional visibility, enhanced sensitivity, and novel topological phenomena, which cannot be observed in Hermitian systems. In particular, non-Hermitian effects have been studied in open systems, where the coupling between system and environment induces gain and loss, resulting in an effective non-Hermitian Hamiltonian. On the other hand, in strongly correlated materials, non-Hermitian effects have been described in the single-particle Green's function, where the non-Hermiticity arises due to the self-energy induced by correlations. The relationship between the effective non-Hermitian Hamiltonian in open systems and correlated systems was unknown.

Motivated by this, Mr. Michishita analyzed the connection between non-Hermiticity in open systems and strongly correlated systems. Mr. Michishita came up with a novel concept of understanding the appearance of non-Hermitian phenomena in correlated materials using techniques from open-quantum systems. He described a single quasi-particle in the correlated system by Master equations demonstrating that the effective non-Hermitian Hamiltonian of the open system and the effective non-Hermitian Hamiltonian describing the Green's function are identical. He has unified the understanding of non-Hermitian phenomena in both systems with his idea. Thus, known non-Hermitian phenomena in open systems can also be observed in correlated systems and vice versa.

Next, Mr. Michishita examined the appearance of exceptional points in strongly correlated materials. Exceptional points are degeneracies in the spectrum due to non-Hermiticity leading to exciting phenomena such as increased sensitivity. Mr. Michishita has found that exceptional points emerge at or close to the Fermi energy during the crossover between localized and itinerant *f* electrons in Kondo-lattice systems. In particular, the crossover between a Kondo insulator at low temperatures and metal at high temperatures occurs through exceptional points in the single-particle Green's functions. Exceptional points are directly connected to this crossover and thus to the Kondo effect occurring in these materials.

Last, Mr. Michishita has extended the formalism of calculating nonlinear conductivities to correlated materials at finite temperatures using Green's functions. As the single-particle Green's function includes correlation effects via the self-energy, his extension makes it possible to calculate nonlinear responses of strongly correlated materials if the single-particle

Green's function is known. For example, Mr. Michishita has shown that nonlinear response is enhanced by the renormalization of the band structure originating in correlation effects. This idea was used to explain the giant nonlinear Hall effect, which has been measured in a strongly correlated Weyl-Kondo-semimetal. Furthermore, because the single-particle Green's function is described by a non-Hermitian matrix, non-Hermitian effects can become important in the nonlinear response. Mr. Michishita has shown that non-Hermiticity can further enhance the nonlinear response.

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（論文審査の結果の要旨）

During his Ph.D. course, Mr. Michishita's conducted groundbreaking research. It is the first time that non-Hermitian phenomena in open systems and equilibrium correlated systems have been related. This interdisciplinary relation opens up a new path to use methods and results of correlated systems in open systems and vice versa. Furthermore, the formulation using Green's functions to calculate the nonlinear response in correlated materials makes it possible to study and calculate the effects of interactions on nonlinear response, such as the nonlinear optical responses. Mr. Michishita's research of correlation effects on nonlinear response has shown that the renormalization of the band structure and non-Hermiticity occurring in the Green's functions have a pronounced effect on the response.

Besides his Ph.D. thesis, his results have been published in international academic journals.

Based on these results and the Ph.D. defense on 24.01.2022, where Mr. Michishita adequately explained his research and answered related questions, we judge that Mr. Yoshihiro Michishita has sufficiently demonstrated his academic abilities to obtain a Ph.D. (Physics) at Kyoto University.

よって、本論文は博士（理学）の学位論文として価値あるものと認める。また、令和4年1月24日、論文内容とそれに関連した事項について試問を行った結果、合格と認めた。

要旨公表可能日：　　　　　年　　　月　　　日以降