Day 1 Abstracts

Topological effects in the interacting Fibonacci chain (G. Rai)

I will discuss the case of the interacting Fibonacci chain when the Fermi level is tuned within one of the gaps of the Fibonacci chain. The Fibonacci chain is known to be topologically non-trivial and its countably infinite gaps can be assigned a unique integer according to the gap labeling theorem. We find that the charge density profile of the Fibonacci chain in perpendicular space shows a clear signature of the gap label corresponding to the Fermi level. This is a direct demonstration of a relation between a bulk, integrated property (the charge density) and a boundary property (the energy of edge states) in the Fibonacci chain. I will show that similar results hold true for other important observables such as the entanglement entropy. Finally, I will discuss the robustness of this phenomenon to disorder and finite temperature.

Intrinsic Superconductivity in the Fibonacci Chain (C. Matsumura)

The discovery of superconductivity in an Al-Zn-Mg quasicrystal by Kamiya et al. in 2018 has resulted in renewed efforts by the quasicrystal community to characterize the properties of superconducting phases in quasiperiodic materials. As a step in that direction, we apply the Bogoliubov-de Gennes approach to the Fibonacci Chain, where the simplicity of the 1D case allows for more straightforward interpretation. We will show how the superconducting gap and the resonant peaks evolve as a function of increasing interaction strength V. We will also show the spatial dependence of the local order parameters. As is well-known, the quasicrystal can be derived from a higher dimensional periodic system. We will use perpendicular space to show that the order parameter depends on the local environments in a simple and systematic way. When the Fermi level is tuned into an intrinsic gap of the Fibonacci Chain, whether we observe superconductivity depends on the size of the gap vs. the interaction strength. This results in an interesting phase diagram where superconductivity may be suppressed when the Fermi level is tuned to a gap.

Quasiperiodic superconductors (N. Takemori, S. Sakai, R. Arita)

Strong correlations in quasiperiodic systems have attracted much interest since the observation of quantum critical behavior in the Tsai-type quasicrystal compound Au51Al34Yb15 in 2012 [1]. Possible long-range electronic orders in such systems have also been widely debated. In this talk, we review our theoretical investigations on correlation effects in the quasiperiodic system especially the superconductivity [2,3]. We found unconventional weak-coupling superconductivity formed by the Cooper pairs deviating from those of Bardeen-Cooper-Schrieffer superconductivity in periodic systems [2]. This deviation can be seen in the real-space distribution of the superconducting order parameter, jump of specific heat, and current-voltage characteristic curve due to the absence of Fermi surface [3]. These results indicate that superconductivity in quasiperiodic systems is qualitatively different from that in periodic and random systems. In particular, the results are consistent with the superconductivity recently discovered in an Al-Mg-Zn quasicrystal [4] and
provide a clue to understanding its mechanism and property.

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Plasmon modes and EELS spectra in 1D and 2D structures (H. Schlömer)

Collective electronic excitations, i.e., plasmons, have gained renewed attention with the rise of 2D materials and topological insulators, yielding large tunability effects and possible applications in the field of e.g. plasmonics. Indeed, it has been shown that spatially confined collective excitations can be stabilized in topological insulators in 1D [Jiang et al. PRB 101, 045106] and 2D [Schloemer et al. PRB 103, 115116], originating from the mid-gap topological edge states appearing in topologically non-trivial phases. Electronic models of quasicrystallic tilings feature intriguing single-particle physics, such as higher order topological phases and therein going edge modes, fractal energy spectra, and electronic states that are strongly confined within the system. This, in turn, suggests a rich phenomenology also in collective excitation sectors.
We here compute the electronic energy loss spectrum (EELS) within the random phase approximation (RPA), and analyze the induced charge density distributions for 1D Fibonacci chains and 2D Penrose tilings, where we find large spatial confinement of collective modes in certain energy regimes. I will briefly address the underlying theory, the numerical challenges arising from studying large scale quasiperiodic systems in real space, as well as discuss the collective spectra and future directions.

Magnetic orders induced by the RKKY interaction in Tsai-type quasicrystal Approximants (T.Sugimoto)

Recent experimental studies on Tsai-type quasicrystalline approximants including rare-earth ions have shown various magnetic orders and successive variation in the Curie-Weiss temperature [1]. In particular, a Tsai-type 1/1 approximant Au-Al-Gd exhibits several phase transitions among ferromagnetism, anti-ferromagnetism, and spin glass, as the Au concentration changes. In this compound, magnetic moments of Gd ions located at vertices of icosahedra in the Tsai clusters, are coupled via the so-called Ruderman—Kittel—Kasuya—Yosida (RKKY) interaction [1,2]. The Gd ions have no orbital angular momentum, so that the single-ion anisotropy due to the spin-orbit interaction should be suppressed [2]. Therefore, the Friedel oscillation of magnetic exchange energy in the RKKY interaction is supposed to play the key role to exhibit such the interesting phenomenon. Here we theoretically investigate effects of the RKKY interaction on magnetic orders in an effective spin model based on the Tsai-type 1/1 approximant. We assume that the primary effect of the Au concentration on the magnetic system is a shift of the Fermi wavenumber. Classical Monte-Carlo simulations at zero temperature successively reproduce several phase transitions among ferromagnetic, anti-ferromagnetic, incommensurate, and cuboc ordered phases [3]. Moreover, we have also performed a preliminary calculation in a 2/1 approximant, resulting in a qualitatively equivalent behavior to the 1/1 approximant. In real materials, there is always randomness, e.g., chemical disorder and defects of the lattice. Thus, we consider the incommensurate state as the experimentally-observed spin glass state because of the randomness in the real compound. Furthermore, we find the cuboc state, which is defined by twelve-sublattice magnetic order (Fig. 1), with large Fermi wavenumbers. This phase is expected to be found in an untrodden region of the Au concentration for Au-Al-Gd. Furthermore, to understand the qualitative equivalence between 1/1 and 2/1 approximants, we have analyzed an icosahedral magnetic cluster [4] and effective interactions between clusters. Based on this analysis, we conclude that in the experimental region of atomic constitution favoring commensurate states, our cluster model gives a good physical picture to understand the magnetic orders.

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DAY 2 ABSTRACTS

Magnetic structure of an aperiodic 6-fold tiling (Sam Coates)

I will discuss the formal definition of a 2-dimensional 3- (or 6-) fold aperiodic tiling directly related to the 3D Amman-Kramer-Neri tiling. I will briefly show its construction using the dual-grid method, and show its inflation properties. Then, I will show its magnetic phase diagram considering a simple XY J1-J2-J3 model, simulated by the Monte Carlo/Metropolis algorithm method.

Aperiodic □□flux and Haldane model (Rasoul Ghadimi, Takanori Sugimoto and Takami Tohyama)

We generalizes the π-flux and topological Haldane-likes models for two dimensional (2D) Ammann-Beenker and Penrose lattices. We first generalize the π-flux model using the directional Ammann-Beenker and Penrose graph, where staggered π flux passed through the tiles. We obtain the energy spectrum of all possible π-flux models, which some of them [in Ammann-Beenker lattice] host flat or confine state beyond the non-flux model. Next, we generalize the Haldane model to aperiodical system by including staggered diagonal hopping for the all possible π-flux models. We confirm the establishment of the topological phases using the Bott index and observing edge modes. Furthermore, these topological phases persist by relaxing π-flux to other flux strength.

Itinerant Magnetism in 2D quasi-approximants - An atomistic random-phase approximation (RPA) approach (Ammon Fischer)

Since the experimental discovery of antiferromagnetic order (S. Yoshida et. al, PRB 2019) and bulk superconductivity (Kamiya et. al, Nature Communications, 2018) in quasicrystals and quasi-periodic approximants, systems that lack translational symmetry have emerged as a versatile platform to study strongly correlated phases of matter beyond the paradigm of periodic crystals. In particular, the lack of translational symmetry requires a pure real-space description of the electron-electron correlations effects, which drastically increases the computational demands to study electron-electron correlation beyond the mean-field level (Hauck et. al, arXiv:2008.13667).

In this talk, I will outline how itinerant magnetism between the electrons arises in the presence of a repulsive Hubbard-U interaction and is captured by the magnetic susceptibility within the random-phase approximations (RPA). This not only allows to study magnetic instabilities for various parameter regimes, but is also essential for the description of RKKY interactions between magnetic impurities or spin-fluctuations mediated superconductivity (FLEX) from atomistic grounds. I will exemplify this method using different quasi-periodic approximants of the 2D penrose tiling and show how magnetic order develops in these systems and how its spatial structure is influenced by phason flips.

Effect of electron-electron interactions in quasicrystalline metals (S. Sakai)

Considering Hubbard-type models on quasiperiodic tilings, we numerically study the effects of electron-electron interactions in the metallic state of quasicrystals. I will specifically discuss the effects on charge distributions and multifractality. If time allows, I would also discuss the results of doped Mott insulators in quasiperiodic systems.