PHYSICS AND ASTRONOMY COLLOQUIUM 04/04/2024

SUPERCONDUCTIVITY AT INTERFACES OF THE QUANTUM PARAELECTRIC KTAO3

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Can ferroelectricity and superconductivity, collective states known to us since more than a century, work in concert? Superconductivity occurs in metals at low temperatures where electrons develop an attractive pairing interaction, typically mediated by phonons. Ferroelectricity occurs in insulators that develop a switchable static polarization, typically due to a lattice distortion that breaks inversion symmetry. Ferroelectric or polar metals are rare, and the collective modes that drive ferroelectric distortions often interact only weakly with conduction electrons. In this colloquium I will discuss a recently discovered superconducting electron gas formed at interfaces of an incipient ferroelectric $KTaO_3$ (KTO), with very unusual properties that point to the role of ferroelectric fluctuations in superconductivity. In its pristine insulating state, KTO is believed to be a 'quantum paraelectric', where the onset of ferroelectricity at low temperatures is thwarted by quantum fluctuations, giving rise to a large dielectric constant ~ 4500. However, a metallic electron gas can be obtained at interfaces of KTO by depositing a variety of insulating oxide overlayers which introduce carriers (electrons) in the conduction band of KTO. Only recently, such electron gases were discovered to be superconducting. Remarkably, the superconducting state is orientation selective, where electron gases formed at the (111) and (110) crystalline interfaces of KTO are robust two-dimensional superconductors, with Tc as high as 2.2 K and 1 K respectively, while electron gases formed at the (001) interface of KTO remain normal down to 25 mK. Based on our findings, we propose an inter-orbital mechanism for pairing mediated by inversion-breaking transverse optical (TO1) phonons. These are the same phonon modes that soften to create incipient ferroelectric displacements in KTO, but were presumed to interact very weakly with conduction electrons. Our proposed mechanism explains several key aspects of superconductivity at KTO interfaces and may provide insights into pairing in incipient ferroelectrics, which has remained an open question for decades. Looking further, the presence of strong spin-orbit coupling and broken-inversion symmetry at KTO interfaces raises the possibility of realizing unconventional (p-wave) superconductivity, though this is not yet established. Superconducting KTO interfaces are also a promising platform for novel devices for quantum information science due to their extremely large kinetic inductance, and I will present some initial results in this direction.

GRAD 2:40 PM STUDENT MEET N' GREET (3049 PHYSICS)

COFFEE: 3:00 PM BARKAS LOUNGE (3049 PHYSICS)

COLLOQUIUM: 3:40 PM WINSTON CHUNG HALL (ROOM 138)

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