Abstracts for Condensed Matter Seminars

Hong Ding, July 10, 2014, Abstract:

Iron-based superconductors (Fe-SCs), with their highest transition temperature (Tc) at 57K, have been added since 2008 to the family of high-Tc superconductors which has been solely occupied by copper-based superconductors (Cu-SCs) for more than 20 years. Both Fe-SCs and Cu-SCs, with a transition element playing crucial roles in their superconductivity, share a similar phase diagram where the superconducting phase is adjacent to a magnetic order phase, and are clearly beyond the scope of BCS superconductors. In this talk I will report our extensive and some new ARPES results on Fe-SCs, which demonstrate unequivocally that a strong pairing gap is determined by its location in the momentum space, basically following a coskxcosky function which is likely determined by the local next-nearest-neighboring antiferromagnetic exchange J2, in much the same way that the d-wave gap of cuprates is caused by its nearest-neighboring exchange J1. In an example of Li(Fe,Co)As, the low-energy spin fluctuations, while sensitive to the Fermi surface nesting condition, are found not directly tie to its superconductivity. We conclude that a same pairing mechanism, at least phenomenologically if not microscopically, must be in work for both Fe- and Cu-SCs.

Peng Cai, September 22, 2014, Abstract

One of the key issues regarding the cuprate high temperature superconductors is the evolution of the electronic structure when charge carriers are doped into the parent Mott insulator. We have performed scanning tunneling microscopy studies on the parent Ca2CuO2Cl2 Mott insulator and severely underdoped B2Sr2-xLaxCuO6 in the antiferromagnetic insulating state. The large energy window covered by the tunneling spectroscopy allows us to simultaneously capture the features of the full charge transfer gap and the low energy electronic state at the atomic scale. We show that with increasing hole doping, the high energy spectral weight of the upper Hubbard band is systematically transferred to the low energy electronic state at the atomic scale. We show that this transfer is accompanied by changes in the low energy dynamics, which we interpret as the emergence of a new electronic state with a well defined quasiparticle picture. The implications of these results on the pseudogap phase and charge density order in the cuprates will be discussed.

Patrick Lee, October 27, 2014 Abstract:

The pseudo-gap phase has long been considered a central piece of the high Tc puzzle. I shall review some of the data and show why they are difficult to explain. I then show that by postulating a novel form of pair fluctuation, much of the data can be accounted for. Experiments to test this idea will be discussed.

John Martinis, November 10, 2014, Abstract

Superconducting quantum computing is now at an important crossroad, where “proof of concept” experiments involving small numbers of qubits can be transitioned to more challenging and systematic approaches that could actually lead to building a quantum computer. Our optimism is based on two recent developments: a new hardware architecture for error detection based on “surface codes”, and recent improvements in the coherence of superconducting qubits. I will explain how the surface code is a major advance for quantum computing, as it allows one to use qubits with realistic fidelities, and has a connection to the full charge transfer gap and the low energy electronic state at the atomic scale. We show that with increasing hole doping, the high energy spectral weight of the upper Hubbard band is systematically transferred to the low energy electronic state at the atomic scale. We conclude that a same pairing mechanism, at least phenomenologically if not microscopically, must be in work for both Fe- and Cu-SCs.

Barry Bradlyn, November 11, 2014, Abstract:

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One hallmark of topological phases with broken time reversal symmetry is the appearance of quantized non-dissipative transport coefficients, the archetypical example being the quantized Hall conductivity in quantum Hall states. Here I will talk about two other non-dissipative transport coefficients that appear in such systems - the Hall viscosity and the thermal Hall conductivity. In the first part of the talk, I will start by reviewing previous results concerning the Hall viscosity, including its relation to a topological invariant known as the shift. Next, I will show how the Hall viscosity can be computed from a Kubo formula. For Galilean invariant systems, the Kubo formula implies a relationship between the viscosity and conductivity tensors which may have relevance for experiment. In the second part of the talk, I will discuss the thermal Hall conductivity, its relation to the central charge of the edge theory, and in particular the absence of a bulk contribution to the thermal Hall current. I will do this by constructing a low-energy effective theory in a curved non-relativistic background, allowing for torsion. I will show that the bulk contribution to the thermal current takes the form of an "energy magnetization" current, and hence show that it does not contribute to heat transport.

Debaleena Nandi, November 13, 2014, Abstract:

Bose-Einstein condensation of excitons is realized in a quantum Hall bilayer at $vT=1$ when the total electron density in the two quantum wells matches the degeneracy of a single spin split Landau level. By decreasing equally the electron density in the two quantum wells and thereby decreasing the effective inter-layer separation between electrons, the system exhibits a phase transition between two independent quantum Hall layers and a phase coherent bilayer. Earlier studies in Hall bar geometry revealed remarkable signatures of the exciton condensate in tunneling and Coulomb drag experiments. The tunneling is reminiscent of the dc Josephson effect [1] and a quantized Hall drag [2] is also observed. However, whether exciton transport is a bulk or edge phenomenon cannot be distinguished in these Hall bar experiments.

Our experiments in Corbino geometry [3,4,5] reveal both tunneling and Coulomb drag as happening throughout the bulk of the $vT=1$ bilayer. Just like all quantum hall states, charge transport through the bulk is activated and suppressed by a quantum hall gap. But the bulk is transparent to the exciton mode of transport. Also, the transmission of bulk excitons is found to be nearly dissipationless. This is consistent with exciton condensation.

To probe the analogy between tunneling in bilayers and the dc-Josephson effect further, we are looking for Shapiro-like steps in the tunneling when the tunnel junction is coupled to microwave radiation. We will briefly also report progress in this effort.

References

Anatoli Polkovnikov, November 17, 2014, Abstract:

I will overview relations between the non-adiabatic response and the geometric tensor. In particular, I will show how the Berry curvature (imaginary part of the geometric tensor) and the topological phase transitions can be engineered and measured using non-adiabatic response and discuss recent experiments in superconducting qubits. The real part of the geometric tensor (Fubini-Study metric) can be measured through noise or imaginary part of the linear response susceptibility. In turn this metric can be used to construct new geometric and topological invariants based on the Euler characteristic. In the last part of the talk I will show that the Newtonian or Hamiltonian dynamics is emergent from the non-adiabatic response and that the notion of the mass is closely related to the metric tensor. I will discuss leading corrections beyond the Hamiltonian dynamics. I will demonstrate general results using simple examples of particles or photons confined to a cavity.

Adolfo Grushin, November 19, 2014, Abstract:

Chern insulators (CI) and fractional Chern insulators (FCI) are zero field lattice analogues of the integer and fractional quantum Hall effects respectively. In this talk we will address the important problem of when and how they are induced by interactions. For the former, we will focus on the existing disagreement between mean field theory results and exact diagonalization/infinite density matrix renormalization group (IDMRG) studies regarding the emergence of the CI state from a semi-metal via short range interactions. For the FCI state I will exemplify its full numerical characterization with the help of IDMRG, a method which will allows us to address, amongst other things, the character of the Metal-FCI phase transition, a possible benchmark for future experiments.

References:
arXiv:1407.6985

Chen Chiu, November 24, 2014, Abstract:

We present a new scheme to engineer the energy-momentum dispersion of atoms in optical lattices. By hybridizing bands, we identify a novel quantum phase transition from the emergence of superfluid domains
Andrey Chubukov, February 2, 2015, Abstract:

Rydberg-based quantum simulation demonstrates a new level of control over long-range interacting spin systems and paves the way for crystalline ground state such as its vanishing susceptibility and local magnetization densities. This work scenario corresponds to the ground state preparation in a quantum magnet. We measure properties of the preparation of Rydberg crystals. Via a mapping to an Ising Hamiltonian with power-law interactions this Combined with the precise shaping of the initial atom pattern in the lattice this allows for the adiabatic Rydberg atom positions we calculate correlation functions and determine the blockade radius. In a second imaging of the former Rydberg atoms after depumping them to the ground state. From the measured technique, which allows to determine the position of individual Rydberg atoms in the lattice by fluorescence temperature many-body states. The spatial configuration of Rydberg atoms is imaged by a novel detection systems and the observation of spontaneous emergence of self-organized ordering. In a first series of experiments we implement time-dependent control of the optical coupling to the Rydberg state. Combined with the precise shaping of the initial atom pattern in the lattice this allows for the adiabatic preparation of Rydberg crystals. Via a mapping to an Ising Hamiltonian with power-law interactions this scenario corresponds to the ground state preparation in a quantum magnet. We measure properties of the crystalline ground state such as its vanishing susceptibility and local magnetization densities. This work demonstrates a new level of control over long-range interacting spin systems and paves the way for Rydberg-based quantum simulation.

Peter Schauss, January 6, 2015, Abstract:

In this talk I will present results on the preparation and high-resolution imaging of Rydberg many-body systems and the observation of spontaneous emergence of self-organized ordering. In a first series of experiments we investigate the ordering in the post-selected high-excitation-density components of high-temperature many-body states. The spatial configuration of Rydberg atoms is imaged by a novel detection technique, which allows to determine the position of individual Rydberg atoms in the lattice by fluorescence imaging of the former Rydberg atoms after depumping them to the ground state. From the measured Rydberg atom positions we calculate correlation functions and determine the blockade radius. In a second set of experiments we implement time-dependent control of the optical coupling to the Rydberg state. Combined with the precise shaping of the initial atom pattern in the lattice this allows for the adiabatic preparation of Rydberg crystals. Via a mapping to an Ising Hamiltonian with power-law interactions this scenario corresponds to the ground state preparation in a quantum magnet. We measure properties of the crystalline ground state such as its vanishing susceptibility and local magnetization densities. This work demonstrates a new level of control over long-range interacting spin systems and paves the way for Rydberg-based quantum simulation.

Nicolas Regnault, December 8, 2014, Abstract:

The understanding and simulation of quantum many-body states in one space dimension has experienced revolutionary progress with the advent of the density matrix renormalization group. In modern language, this method can be viewed as a variational optimization over the set of matrix product states (MPS). Due to their perimeter law entanglement, 2-D systems such as the fractional quantum Hall effect are harder to simulate by MPS.

We will show that many fractional quantum Hall states have an exact infinite MPS representation. We will discuss how a controlled truncation can be performed on this representation and we will give a natural interpretation from the entanglement spectrum perspective. Through the MPS, We will give evidences why certain model states related to non-unitary conformal field theories, are pathological. We will also show the direct characterization of the Laughlin quasiholes excitations from their MPS description.

Donna Sheng, December 10, 2014, Abstract

The kagome spin-1/2 model with dominant nearest neighboring (J1) antiferromagnetic coupling had been proposed to host an exotic gapped Z2 spin liquid based on density matrix renormalization group study. Here we report a new finding that small perturbations from the second (J2) and third neighboring (J3) exchange couplings will lead to a time reversal symmetry breaking chiral spin liquid. Searching for the microscopic understanding of the emerging and collapsing of these phases, we study the quantum phase diagram and the interplay of J1-J2-J3 couplings in the kagome lattice model.

For SU2 invariant model, we establish a rich phase diagram where a chiral spin liquid phase emerges between the magnetically ordered antiferromagnetic phase known as q=(\frac{1}{3},\frac{1}{3}) state and a complex non-coplanar ordered state with spins forming the vertices of a cuboctahedron known as a cuboc1 phase. We characterize the spontaneous time-reversal symmetry breaking chiral spin liquid as the Laughlin nu=1/2 bosonic fractional quantum Hall state proposed 20 years ago, based on topological Chern number and modular matrices of the state. The robustness of the chiral spin liquid persists into spin anisotropic model, including the pure XY model (where all the spin exchange interactions are XY interactions).

We explore the nature of quantum phase transitions from chiral spin liquid to time-reversal invariant spin liquid and other magnetic ordered phases, and point to the possibility of the novel continuous transitions in such systems.

We also reveal that there may be a gapless spin liquid state for nearest neighboring dominant spin anisotropic model, with the low energy singlet excitations as magneto-roton minimum of the system. We will also discuss the possible indications of the theoretical results to the experimental relevant frustrated kagome magnets.

James Analytis, December 1, 2015, Abstract:

The physics of quantum critical phase transitions connects to some of the most difficult problems in condensed matter physics, including metal-insulator transitions, frustrated magnetism and high temperature superconductivity. Near a quantum critical point (QCP) a new kind of metal emerges, whose thermodynamic and transport properties do not fit into the unified phenomenology with which we understand conventional metals - the Landau Fermi liquid (FL) theory - characterized by a low temperature limiting T-linear specific heat and a T^2 resistivity. Studying the evolution of the T^- dependence of these observables as a function of a control parameter leads to the identification both of the presence and the nature of the quantum phase transition in candidate systems. In this study we measure the transport properties of BaFe2(As1-xPx)2, at T=T_c by suppressing superconductivity with high magnetic fields. We find an anomalous magnetic field dependence that suggests that not only does magnetic field directly affect the scattering rate (which is unusual for metals), but it does so in a way that is identical to temperature. We suggest that there is a universal phenomenology of scattering near a quantum critical point.

Andrey Chubukov, February 2, 2015, Abstract:

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I analyze charge order in hole-doped cuprates. I argue that magnetically-mediated interaction, which is known to give rise to d-wave superconductivity, also gives rise to charge-density-wave instabilities with momenta $Q_x=(Q,0)$ and $Q_y=(0,Q)$, as seen in the experiments. I show that the emerging charge order with $Q_x/Q_y$ is of stripe type and that a stripe CDW order parameter by itself has two components: one is incommensurate density variation, another is incommensurate current. Both components are non-zero in the CDW-ordered state, with the relative phase $\pm \frac{\pi}{2}$. Such an order breaks time reversal and mirror symmetries and give rise to a non-zero Kerr effect. I further show that, before a true incommensurate CDW order sets in, the system develops a pre-emptive composite order which breaks lattice rotational symmetry and time-reversal symmetry but preserves a translational $U(1)$ symmetry. I discuss the interplay between our CDW order and pair density-wave order (superconducting order with a finite total momentum of a pair) and present the phase diagram of underdoped cuprates.

Dmitry Abanin, February 9, 2015, Abstract:

Periodic driving of quantum systems provides a natural experimental tool for probing and modifying their properties. In particular, periodic driving has been recently used to realize topologically non-trivial band structures in optical lattices. Yet, theoretically relatively little is known about the general properties of driven interacting systems.

In this talk, I will present a theory of many-body localized, periodically driven many-body systems [1,2]: I will show that many-body localization persists under periodic driving at high enough driving frequency. The Floquet operator (evolution operator over one driving period) can be represented as an exponential of an effective time-independent Hamiltonian, which is a sum of local terms and is itself MBL. The Floquet eigenstates in this case have area-law entanglement entropy, and there exists an extensive set of local integrals of motion. I will further argue that at sufficiently low frequency, there is always delocalization, owing to a large number of many-body level crossings and non-diabatic Landau-Zener transition between them. I will propose a phase diagram of driven MBL systems. Our results provide new experimental signatures of many-body localization, and indicate breakdown of the linear-response theory and classic Mott formula for AC conductivity in localized systems.

N. Peter Armitage, Feb. 23, 2015

Although typically we regard optical spectroscopies as probes of electronic degrees of freedom in materials, light's time-varying magnetic field allows one to couple to magnetic degrees of freedom. This talk will review recent advances in the area of time-domain THz spectroscopy and its application to "quantum" magnets. Our high signal to noise, routinely excellent energy resolution, and unique ability to measure complex response functions gives unique insight into the magnetic response of quantum materials and gives several distinct advantages in these matters over neutron scattering. I will give examples of the use of the technique on quantum magnet systems as diverse as 1D Ising spin chains, quantum spin ices, and spin-orbital liquids.

SuYang Xu, February 26, 2015, Abstract:

Research on topological insulators and Dirac materials have opened the door to search for related topological states of quantum matter. Superconductivity involving topological Dirac electrons has recently been proposed as a platform between concepts in high-energy and condensed-matter physics. It has been predicted that SUSY (supersymmetry), Weyl fermions, or Majorana fermions, all of which remain elusive in particle physics, may be realized through emergent particles in topological insulator based magnets or superconducting systems [1,2]. Using artificially fabricated 3D topological-insulator–superconductor heterostructures, we present direct spectroscopic evidence for the existence of helical Cooper pairing in a half Dirac gas [3]. Our experimental studies reveal that 2D topological superconductivity (TSC) in a helical Dirac gas is distinctly different from that in an ordinary superconductor in terms of the spin degrees of the Dirac electrons. We further show that the pairing of Dirac electrons can be suppressed by time-reversal symmetry-breaking impurities, thereby removing the distinction. Our first demonstration and momentum-space imaging of Cooper pairing in a half-Dirac-gas 2D topological superconductor serve as a critically important platform for future testing of fundamental physics predictions such as emergent SUSY (supersymmetry) and topological quantum criticality (QCP) [3-5].

References:
1 M.Z. Hasan & C. L. Kane; Rev. Mod. Phys. 82, 3045 (2010) and Qi & Zhang, RMP 83, 1057 (2011)

T. Kronos, March 30, 2015, Abstract:

Electron spins and photons are complementary quantum mechanical objects which can be used to carry, manipulate and transform quantum information. Combining them into a scalable architecture is an outstanding challenge. In this context, the coherent coupling of a single spin to photons stored in a superconducting resonator is an important milestone. Using a circuit design based on a nanoscale spin-valve, we implement an artificial spin-orbit interaction and coherently hybridize the individual spin and charge states of a double quantum dot made in a single wall carbon nanotube while preserving spin coherence. This scheme allows us to increase by five orders of magnitude the natural (magnetic) spin-photon coupling, up to
frustration. Such frustrated systems exhibit cannot find an orientation that fully neighbors

Nayoon Woo, April 17, 2015, Abstract:

Antiferromagnets are characterized by interactions between spins that favor configurations with nearest neighbors pointing anti-parallel. In some systems, the topology of the spins produces a situation where spins cannot find an orientation that fully satisfies all of the interaction constraints. This is known as geometrical frustration. Such frustrated systems exhibit macroscopically large ground state degeneracy. As a result of

Allan MacDonald, April 6, 2015, Abstract:

Electronic systems can have a type of order in which coherence is spontaneously established between two distinct groups of electrons. So far this (particle-hole or exciton condensate) type of order has been found only in double-layer two-dimensional electron gas systems, and only in certain strong magnetic field limits. I will review some of the surprising superfluid transport effects that have been observed in double-layer exciton condensates, and speculate on the possibility of realizing similar effects at room temperature either by enhancing the stability of bilayer exciton condensate states using two-dimensional materials, or by designing ferromagnetic materials with appropriate properties.

Abhinav Kandala, April 9, 2015, Abstract:

The mass domain wall of a 2D Dirac system has been long predicted to carry a chiral 1D mode. More recently, magnetic perturbations to the Dirac surface states of 3D topological insulators have created a practical route for the experimental realization of such 1D dissipation-less modes, and created a rich playground for a host of other exotic quantum phenomena. I present two different schemes for probing these effects in electrical transport devices – interfacing with insulating ferromagnets [1], and bulk magnetic doping [2,3]. Our experiments with chromium-doped topological insulator thin films detect these 1D chiral modes via the recently discovered quantum anomalous Hall effect. In addition, we demonstrate a magnetization-tilt driven crossover between a gapped quantum anomalous Hall insulator and a gapless, ferromagnetic topological insulator [3]. This crossover manifests itself in an electrically tunable, giant anisotropic magneto-resistance effect, which serves as a quantitative probe of the interplay between the 1D chiral modes and dissipative channels.

Chunhui Du, April 10, 2015, Abstract:

Generation and manipulation of spin is of central importance in modern physics. This intense interest is driven in part by exciting new phenomena such as spin Hall effects and spin transfer torque as well as by the growth in new tools enabling microscopic studies. Ferromagnetic resonance (FMR) is a powerful technique to study both macro and nano-scale spin ensembles, and also an effective method to generate pure spin currents. In the first part of my talk, we use FMR spin pumping technique to characterize the spin Hall angles for a series of 3d, 4d, and 5d transition metals with widely varying spin-orbit coupling strengths and demonstrate that both atomic number Z and d-electron count play important roles in spin Hall physics. We have systematically studied spin transport in a series of six Y3Fe5O12/insulator/Pt trilayers where the inserted insulators have different magnetic properties: diamagnetic (one), paramagnetic (one) and antiferromagnetic (AF) (four, having a wide range of magnetic ordering temperatures). We observe remarkably robust spin transport in the AF insulators and a clear linear relationship between the spin decay lengths in the insulators and the damping enhancements in the Y3Fe5O12, suggesting the critical role of magnetic correlations in magnetic insulators for spin transport. I will then describe our experiment using spin wave modes confined into microscopic volumes in a ferromagnetic film by the spatially inhomogeneous magnetic field of a scanned micromagnetic tip of a ferromagnetic resonance force microscope (FMRFM). We have measured local spin transfer from the resonance region to surrounding areas within an insulating ferrimagnetic Y3Fe5O12 thin film, and we image the local magnetic texture variations in patterned ferromagnetic permalloy structures. Micromagnetic simulations accurately reproduce our FMRFM spectra allowing quantitative understanding of the spin dynamics and transport phenomena across various interfaces. I will also show strong coupling of FMR excitation to spins in Nitrogen Vacancy (NV) center in diamond, suggesting NV center is a promising candidate to image the spin dynamics.

Pablo Jarillo-Herrero, April 13, 2015, Abstract:

Over the past decade, the physics of low dimensional electronic systems has been revolutionized by the discovery of materials with very unusual electronic properties where the behavior of the electrons is governed by the Dirac equation. Among these, graphene has taken center stage due to its ultrarelativistic-like electron dynamics and its potential applications in nanotechnology. Moreover, recent advances in the design and nanofabrication of heterostructures based on van der Waals materials have enabled a new generation of quantum electronic transport experiments in graphene. In this talk I will describe our recent experiments exploring electron-electron interaction driven quantum phenomena in ultra-high quality graphene-based van der Waals heterostructures. In particular I will show two novel realizations of a symmetry-protected topological insulator state, specifically a quantum spin Hall (QSH) state, characterized by an insulating bulk and conducting counterpropagating spin-polarized states at the system edges. Our experiments establish graphene-based heterostructures as highly tunable systems to study topological properties of condensed matter systems in the regime of strong e-e interactions and I will end my talk with an outlook of some of the exciting directions in the field.

Nayoon Woo, April 17, 2015, Abstract:

Antiferromagnets are characterized by interactions between spins that favor configurations with nearest neighbors pointing anti-parallel. In some systems, the topology of the spins produces a situation where spins cannot find an orientation that fully satisfies all of the interaction constraints. This is known as geometrical frustration. Such frustrated systems exhibit macroscopically large ground state degeneracy. As a result of
this large degeneracy, a perfectly frustrated system does not settle into any particular configuration and hence does not form an ordered state at any finite temperature. However, the ground state degeneracy is very fragile, and can be broken by effects such as quenched disorder and thermal and quantum fluctuations. These effects can relieve the frustration, allowing the formation of ordered states, a phenomenon known as “order by disorder.”

We studied the effects of disorder in the archetypal frustrated magnet Gadolinium Gallium Garnet (Gd₃Ga₅O₁₂) by introducing controlled amounts of a magnetic dopant. Measurements of the ac magnetic susceptibility in the low-field linear-response regime found an onset of a short-range ordered state at T~90 mK, which is suppressed to below 30 mK with the introduction of a 1% dopant concentration. Doping actually seems to reduce the effective disorder and increase the degree of frustration. Nonlinear susceptibility measurements excite and probe coherent clusters of hundreds of spins. We find similarly that the introduction of dopants acts to reduce the effective degree of disorder of these spin clusters.

Joel Moore, April 20, 2015, Abstract:

An electron moving through a crystal ceases to be a featureless point particle and acquires structure within the unit cell, with far-reaching consequences. Although the forces acting on the electron are electromagnetic and hence described by a simple (Abelian) gauge theory, the internal structure gives Berry gauge fields that are non-Abelian in the same sense as the fields of quantum chromodynamics (QCD). The Berry gauge fields give the most compact description of the 3D topological insulator phase and lead to a general theory of orbital magnetoelectricity. Recent work suggests that long-standing experiments on natural optical activity (NAO) also probe these Berry gauge fields. Taking the topological insulator phase and adding superconducting correlations is one of several experimentally promising routes to create particles with non-Abelian statistics, such as an emergent Majorana fermion excitation. We explain non-Abelian statistics briefly and discuss recent work on how quantum quench dynamics can show universal power laws characterizing various non-Abelian particles. These power laws can be observed in optical absorption, similar in spirit to the classic orthogonality catastrophe in X-ray absorption.

Inna Vishik, May 4, 2015, Abstract:

Carlos Sa De Melo, May 20, 2015, Abstract:

We investigate the Berezinskii-Kosterlitz-Thouless (BKT) transition in a two-dimensional (2D) Fermi gas with spin-orbit coupling (SOC), as a function of the two-body binding energy and a perpendicular Zeeman field [1]. By including a generic form of the SOC, as a function of Rashba and Dresselhaus terms, we study the evolution between the experimentally relevant equal Rashba-Dresselhaus (ERD) case and the Rashba-only (RO) case. We show that in the ERD case, at fixed non-zero Zeeman field, the BKT transition temperature TBKT is increased by the effect of the SOC for all values of the binding energy. We also find a significant increase in the value of the Clogston limit compared to the case without SOC. Furthermore, we demonstrate that the superfluid density tensor becomes anisotropic (except in the RO case), leading to an anisotropic phase-fluctuation action that describes elliptic vortices and anti-vortices, which become circular in the RO limit. This deformation constitutes an important experimental signature for superfluidity in a 2D Fermi gas with ERD SOC. Finally, we show that the anisotropic sound velocity exhibit anomalies at low temperatures in the vicinity of quantum phase transitions between topologically distinct uniform superfluid phases.