# PCGM Talks

- **Gabriel Steffano Bonilla** (California State University, Fullerton)
  *Modeling the Merger in Beyond-GR Waveforms*
  The parameterized post-Einsteinian framework incorporates beyond-GR effects into inspiral waveform models. We extend the existing model into the merger-ringdown regime. The modification introduced here adds a single degree of freedom that corresponds to a change in the binary coalescence time. Other merger properties remain as predicted by GR. We discuss parameter estimation with this model, and how it can be used to extract information from beyond-GR waveforms.

- **Steven Carlip** (UC Davis)
  *Path integrals may suppress non-manifoldlike causal sets*
  Causal set theory offers an interesting discrete model for spacetime. In one direction, the connection is well understood: we know how to approximate a spacetime manifold by a causal set, and how to construct quantities such as curvature from the discrete structure. The other direction, though, is harder: while some causal sets approximate spacetimes, the vast majority are not at all manifold-like. I report on recent progress in showing that large classes of these "bad" causal sets are very strongly suppressed in the gravitational path integral, perhaps allowing us to recover the observed continuum structure of spacetime from the quantum theory.

- (s) **Sean Colin-Ellerin** (UC Davis)
  *Bootstrapping Quantum Extremal Surfaces*
  Quantum extremal surfaces are central to the connection between quantum information theory and quantum gravity and they have played a prominent role in the recent progress on the information paradox. In this talk, I will present a program to systematically link these surfaces to the microscopic data of the dual conformal field theory, namely the scaling dimensions of local operators and their OPE coefficients. I will consider CFT states obtained by acting on the vacuum with single-trace operators, which are dual to one-particle states of the bulk theory. Focusing on $AdS_3/CFT_2$, I will provide a computation of the CFT entanglement entropy to second order in the large c expansion where quantum extremality becomes important and match it to the expectation value of the bulk area operator. I will show that to this order, the Virasoro identity block contributes solely to the area operator.

- (s) **Lucas Daguerre** (UC Davis)
  *Holographic Approach to Irreversibility of the Renormalization Group*
  Using the entanglement entropy of spheres in the vacuum (EE), we study non-perturbative properties of the Renormalization Group (RG) flow of Holographic Quantum Field Theories in the large N limit. The EE has an expansion in powers of the sphere's radius near the fixed points of the RG flow with the leading term being proportional to the area. In the regime of the radius bigger than the IR scale and assuming the Null Energy Condition (NEC), we compute the first three coefficients of this expansion and show that, in absolute value, they are always bigger in the UV than in the IR. Therefore, these first coefficients turn out to be irreversible by means of the RG flow. The irreversibility for the first two coefficients of the expansion has been previously proven in the literature using the strong subadditivity of the EE. On the other hand, the unprecedented irreversibility of the third coefficient for holographic RG flows motivates the search for stronger inequalities involving the EE in generic Quantum Field Theories.

- **Christian Ferko** (UC Davis)
  *Gravitational Memory and Compact Extra Dimensions*
  In this talk, I will describe a general formalism for studying massless fields near null infinity in a spacetime with an arbitrary Ricci-flat compact internal space. In this context, the radiative degrees of freedom decompose into gravitational, electromagnetic, and scalar modes in a way analogous to the usual Kaluza-Klein reduction. Relatedly, the asymptotic symmetry group of such spacetimes is enlarged from the usual BMS group to include extra "supertranslations" which involve isometries of the internal space. This framework can be used to study gravitational memory effects and illustrates that observations made by gravitational wave observatories may be able to probe properties of compact extra dimensions.

- **Temple He** (UC Davis)
  *Momentum diffusion and sound propagation in neutral plasma*
  Planar black holes in AdS, which are holographically dual to compressible relativistic fluids, have a long-lived phonon mode that captures the physics of attenuated sound propagation and transports energy in the plasma. We describe the open

effective field theory of this fluctuating phonon degree of freedom using the Schwinger-Keldysh formalism and compute the stress tensor two-point function of the plasma.

- **Gary Horowitz** (UCSB)
  *A new type of extremal black hole*
  I describe a family of four-dimensional, asymptotically flat, charged black holes that develop (charged) scalar hair as one increases their charge at fixed mass. Surprisingly, the maximum charge for given mass is a nonsingular hairy black hole with nonzero Hawking temperature. The implications for Hawking evaporation are discussed.

- (s) **Weixuan Hu** (UC Davis)
  *covariant phase space quantization of cosmological models*
  My talk is about the application of the method of the covariant phase space quantization in various models.

- (s) **Molly Kaplan** (UCSB)
  *The algebras of HRT-area and half-geodesic operators*
  We perform direct computations of semiclassical commutators involving Hubeny-Rangamani-Takayanagi (HRT) area operators in pure $2+1$ dimensional Einstein-Hilbert gravity on spacetimes asymptotic to either Poincar'e AdS or an $M > 0$ planar black hole. This result agrees with the HRT-area algebra obtained by considering the action of HRT-area operators on the covariant phase space of classical solutions. We derive this action in general dimensions, taking appropriate care with asymptotically Anti-de Sitter (AdS) boundary conditions. We extend our results to a simple network of intersecting extremal surfaces, and show all "half-geodesics" in such a configuration commute.

- (s) **Yoonsoo Kim** (Caltech)
  *Comparison of shock capturing schemes for the discontinuous Galerkin method in GRMHD*
  Using our open-source code SpECTRE, we present a detailed comparison of various limiting and shock capturing strategies for the discontinuous Galerkin methods proposed in the literature applied to a set of test problems in general relativistic magnetohydrodynamics (GRMHD). We compare the standard minmod/$\Lambda\Pi$N limiter, the hierarchical limiter of Krivodonova, the simple WENO limiter, the HWENO limiter, and a discontinuous Galerkin-finite difference hybrid method. The goal is to evaluate the robustness and accuracy of the different strategies in order to understand which are most likely able to simulate neutron stars.

- (s) **Maciej Kolanowski** (University of Warsaw/UCSB)
  *Almost all extremal black holes in AdS are singular*
  We show that for almost all extremal black holes in the Einstein-Maxwell theory with a negative cosmological constant, tidal forces diverge at the horizon. This singularity is not captured by any curvature polynomial invariant. The result holds for spherical, hyperbolic and (sufficiently large) toroidal black holes. Joint work with Gary Horowitz and Jorge Santos.

- (s) **Henry Leung** (UCSB)
  *Charged shells in black holes and scrambling*
  We study the motion of charged shells in a charged AdS black hole. Due to electromagnetic interaction, there are bouncing shells in addition to shells that enter the black hole. Via holography, these shells are related to perturbations in the thermofield double state in the boundary field theory. It has been shown that chargeless shells have the effect of disrupting the two-sided entanglement structure of the unperturbed state. We find that this scrambling effect occurs also for charged shells that enter the black hole, with corrections due to the charge of the shell. However, scrambling is not observed for shells that bounce outside the horizon.

- (s) **Dongjun Li** (Caltech)
  *An extension of Teukolsky formalism to beyond-GR theories*
  Linear gravitational perturbations of Kerr black holes in general relativity are most efficiently treated by the Teukolsky formalism, which leads to single decoupled equations for Weyl scalars psi0 and psi4. These equations are further separable into radial and angular equations. The standard derivation of the Teukolsky equation in general relativity required the background spacetime to be algebraically special (Petrov type D). In beyond-General-Relativity (bGR) theories, for example, dynamical Chern-Simons (dCS) and Einstein-dilaton Gauss-Bonnet (EdGB) theories, spacetimes of rotating black holes are not type-D, but type-I instead. This lack of symmetry creates potential difficulties computing gravitational waveforms in bGR theories. In this work, for any stationary background spacetime with an order epsilon deviation from a Petrov type-D spacetime, we obtain a single decoupled modified Teukolsky equation for the perturbative psi0 (and psi4) of that spacetime — accurate up to linear order in epsilon. This equation may also have a source term on the right-hand side due

to matter (including, e.g., dCS and EdGB scalar-field) perturbations. Our derivation is an extension to Chandrasekhar's alternative derivation of the Teukolsky equation and his metric reconstruction procedure (both originally formulated for the Kerr spacetime). For demonstration, we apply our formalism to perturbations of slowly-rotating black holes in dCS gravity. In this case, psi0 (and psi4) are decoupled from all other space-time degrees of freedom, and only couple to the dCS scalar field, which arises due to the source term of the modified Teukolsky equation.

- (s) **Ziyi Li** (UCSB)
  *Aspects of Holography in Conical AdS3*
  We study the Feynman propagator of free scalar fields in $AdS_3$ with a conical defect, with arbitrary mass for the scalar field and defects of arbitrary strength. The propagator is built by summing over the modes of the field, properly normalized, we then take it to the boundary. We do various consistency checks of the resulting boundary to boundary correlator. In the dual CFT, the operator responsible for the defect creates a highly excited state, and we consider the exchange of the Virasoro identity block to obtain a semiclassical approximation to the propagator, sensitive to the mass of the defect, at short distances. Specializing to quotient spaces $AdS_3/Z_n$, we treat the propagator by the method of images and show that the result we have agrees with the geodesic approximation for heavy correlators. For generic defects, we argue that long-range correlations of the scalar are screened by the defect and decay as it grows more massive. We find, in particular, that the propagator experiences a continuous phase transition as one approaches the BTZ threshold. Finally, we entertain an application of our results to holographic entanglement entropy by proposing that twist fields (objects appearing in the calculation of Renyi entropies via the replica trick) are quasifree. This proposal passes consistency checks in pure AdS3 and in the UV, but encounters an order-of-limits ambiguity in $AdS_3/Z_n$: we find agreement with the Ryu–Takayanagi formula only if the semiclassical limit is taken before one completes the replica calculation.

- (s) **Xiaoyi Liu** (UCSB)
  *Finding complex saddle-point solutions in JT gravity*
  In ArXiv 2012.00828 and 2105.07002, saddle-point geometries with complex metrics are identified in computing Rényi entropies using real-time gravitational path integrals. If we take the gravitational path integral as a contour integral in the (infinite-dimensional) "complex plane" of metrics, then those saddle-point solutions lie away from the original integration contour, i.e. the "axis" of real metrics. In this work, we write down the gravitational path integrals that computes Rényi entropies in two-dimensional Jackiw-Teitelboim gravity, where the path integral is only finite-dimensional, and show that within semiclassical approximation, those complex saddle-point geometries are accessible from deforming the original integration contour.

- (s) **Sizheng Ma** (Caltech)
  *Relativistic effects on neutron star fundamental-mode dynamical tides*
  During the final stage of the coalescence of a black hole-neutron star system, the tidal excitation of the quasi-normal modes of the neutron star can leave significant imprints on gravitational waves. To understand this process and build a robust theoretical model is important for extracting neutron star properties from gravitational-wave data. In this talk, we will discuss how the quasi-normal modes of the neutron star in the binary environment are modified by relativistic effects, including the gravitational redshift and the frame-dragging due to the spin on the black hole. We investigate the impact of these two relativistic effects on gravitational waves by incorporating them in the SEOBNRv4T waveform model. We compare this new model with a few new black hole-neutron star simulations that are performed using a numerical relativity code Spectral Einstein Code.

- (s) **Robinson Mancilla** (UC Santa Barbara)
  *Thermal one-point function from Weyl tensor source.*
  In arXiv:1602.05599 was introduced an interaction between a scalar field and Weyl tensor which sources a thermal one-point function. Their results were numerical in a 3+1 dimensions black brane. In arXiv:2011.01004 was found the analytical result for the one-point function but restricted to conformal dimensions less than 2d. In this work, we extend the analytical result for any conformal dimensions and arbitrary dimension d by founding explicitly the particular solution of the scalar field associated with the Weyl tensor source. Furthermore, we discuss briefly a possible extension of this result for spherical black hole and charged black brane.

- **Alexey Milekhin** (UCSB)
  *Black holes and cryptocurrencies*
  It has been proposed in the literature that the volume of a black hole interior is equal to complexity at the boundary. Continuing this relation outside the horizon, one might be tempted to propose "complexity=time" correspondence. I argue

that a blockchain, which is the foundation of all modern cryptocurrencies protocols, is an example of "complexity=time" relation.

- (s) **Keefe Mitman** (Caltech)
  *The Importance of BMS Frames for Gravitational Wave Modeling*
  As was realized by Bondi, Metzner, van der Burg, and Sachs (BMS), the symmetry group of asymptotic infinity is not the Poincaré group, but an infinite dimensional group called the BMS group. Because of this, understanding the BMS frame of the gravitational waves produced by numerical relativity is crucial for ensuring that analyses and comparisons with other waveform models are performed properly. Up until now, however, the BMS frame of numerical waveforms has not been thoroughly examined, largely because the necessary tools have not existed. In this talk, I will highlight an improved method for fixing the BMS frame of numerical waveforms. Following this, I will then illustrate how this new scheme of fixing the BMS frame allows for much faster and more correct comparisons between numerical relativity waveforms and either Post-Newtonian or Quasi-normal Mode models, which will prove vitally important for testing Einstein's theory of relativity with observations obtained by gravitational wave observatories.

- (s) **Kellie O'Neal-Ault** (Embry-Riddle Aeronautical University)
  *Spacetime-symmetry breaking via dispersion and birefringence effects of gravitational waves*
  This research bridges the gap between the theory of spacetime-symmetry breaking and the analysis of gravitational waves (GWs): we implement an effective field theory framework that allows for Lorentz and CPT symmetry breaking during the propagation of GWs with an open-source LIGO-Virgo algorithm library suite. We focus on dispersion and birefringence effects beyond General Relativity, using Bayesian inference, and present preliminary results form simulations and sensitivity studies of the measurements of the coefficients for Lorentz and CPT violations.

- **Paul F. OBrien** (none)
  *Defining quantum information with a Schwarzschild - Hawking BH*
  Quantizing Energy, Entropy, quantum information One thing lacking in quantum information theory concerning Black Holes is the value of a quantum bit of information measured at the event horizon. It is my claim that the job of the event horizon is to count exactly every bit of information that crosses the horizon. Without this property one cannot claim a conservation of information, or energy. I will start by defining a Schwarzschild-Hawking BH, which is defined by the Schwarzschild radius ($R_s$), and the Hawking temperature ($T_h$).
  $(R_s)(T_h) = (\hbar c)/(4\pi k)$
  This is a simple BH without charge or angular momentum. I will further derive the meaning for the energy associated with a quantum bit measured at the horizon and its entropy at 1 thermal degree of freedom. Thus, defining our universe as a BH with radius ($R_u$) & temperature ($T_u$)
  $(\hbar c)/(R_u) = (c^2)(L_p^2) = (4\pi k T_u)$
  I will prove for any simple BH having mass,($M$), radius ($R$), and temperature ($T$)
  $2M/((R^2)T) = 4\pi k/(c^2)(L_p^2) = 1/(T_u)$

- **Shruti Paranjape** (UC Davis)
  *Supersymmetrizing Massive Gravity*
  Using a recent on-shell formulation of massive supersymmetric multiplets, we construct candidates for supersymmetrizations of dRGT massive gravity. The R-symmetry structure of the multiplets allows us to make predictions about supersymmetric Galileon theories in the decoupling limit. We find that $N = 4$ picks out special values of the dRGT parameters.

- (s) **Jude Pereira** (Arizona State University )
  *A New Gauge for Flat Space*
  We present a new gauge for asymptotically flat spacetime that treats future and past null infinities ($I^+$ and $I^-$) democratically. Our gauge is complementary to Bondi and Ashtekar-Hansen gauges, and is adapted to the S-matrix being the natural observable. One new feature is that the holographic directions are null. We present a set of consistent fall-offs in terms of null coordinates at both $I^+$ and $I^-$, with finite BMS± charges. The diagonal BMS0 symmetry of the gravitational S-matrix emerges upon demanding asymptotic CPT invariance. Trivial diffeomorphisms, (absence of) log fall-offs, possible enhancements of BMS algebra, and the possibility of holographic renormalization of data at $I^+_-$ and $I^-_+$, play interesting roles.

- (s) **Julie Perkins** (UCSB)
  *Schrodinger Evolution of Four-Dimensional Black Holes*
  Our goal is to shed more light on the Information Paradox, starting with better understanding local QFT in the vicinity of a Schwarzschild black hole horizon. It has recently been established that Schrodinger evolution of the quantum mechanical

wave function in QFT for a black hole together with its Hawking radiation in the two dimensional case can be described using the ADM formalism with slices which smoothly cross the black hole horizon. The higher dimensional case we consider in this talk is more challenging, but similar techniques are used to characterize the evolving quantum state of the system. Future efforts will focus on investigating modifications needed to restore unitary evolution for black holes.

- (s) **Leonel Queimada** (UCSB)
  *Chaos in Charged Black Holes*
  It has long been recognized that black holes and quantum chaos are deeply tied through the AdS/CFT correspondence. This relationship can many times be understood in the semiclassical limit with the help of shockwave geometries. The presence of charge in a black hole naturally has an important impact in the behavior of shockwaves if the latter also carry a charge. In this talk, we will present ongoing work towards understanding some features of charged shockwave geometries that raise some puzzles for the boundary theory interpretation.

- **Robert Rosati** (NASA - MSFC)
  *Detecting an Early-Universe Stochastic Gravitational Wave Background with LISA*
  In this talk I'll review several possible sources of early-universe stochastic gravitational wave signals (SGWBs) in the LISA band, including some new results for the possible signals from multi-field inflation. I'll then discuss a detection strategy based on matched filtering with stochastic templates, planned to be integrated into the Global Fit in development at Marshall. I will present some promising early results from analysis of the LISA data challenges. The confident identification or exclusion of a primordial SGWB in the LISA band would limit dozens of potential early-universe scenarios, and give new direct constraints on the radiation-dominated era of cosmology.

- **Gh. Saleh** (Saleh Research Centre)
  *Gravitational frequency of stars with their planets and planets with other planets in the same system*
  Usually, gravity is a topic related to stars, planets and their moons. In fact, gravity is the interaction between stars and their planets and also planets and their moons which move in specific orbit with a generally constant speed. It can be said that the relationship between a star and the surrounding planets is through gravitational waves or the force lines or the gravitational flux that separate from the star, enter the planet and return to the star. This cycle causes a permanent effect. It should be noted that the gravity between the planets of a system together and the planets with their moons is due to the gravitational waves of the stars. In this paper, we are going to explain the real structure of gravitational waves and then by using this structure we will calculate the gravitational frequency of the star-to-planet and the planets with each other in the same system. Our results show that the frequencies of the waves which leave the star, enter the planet of that star and return to the star again are between $10^{1}7$ Hz - $10^{2}0$ Hz .On the other hand, the waves that travel from planet to natural satellite or other planets and return to the planet again is lower than the frequency of the planet's main gravitational waves.

- (s) **Brian Seymour** (Caltech)
  *Multiband Gravitational Wave Cosmography with Dark Sirens*
  Gravitational waves might help resolve the tension between early and late Universe measurements of the Hubble constant. Recently, there has been enhanced interest in the possibility of gravitational wave detectors in the decihertz band which bridges the gap between LISA and ground-based detectors. Such a detector is particularly suitable for the multi-band observation of stellar-mass black hole binaries between space and ground, which would significantly improve the source localization accuracy thanks to a long baseline for timing triangulation, hence promoting the "dark siren" cosmology. Proposed decihertz concepts include DECIGO/B-DECIGO, TianGO, and others. We consider here the prospects of multi-band observation of dark-siren binaries with a variety of network configurations. We find that this configuration can uniquely identify a black-hole binary to a single galaxy to a cosmological distance, and thus a dark siren behaves as if it had an electromagnetic counterpart. Considering only fully localized dark sirens, we use a Fisher matrix to estimate the error in the Hubble constant and matter density parameter. We find that a decihertz detector substantially improves our ability to measure cosmological parameters because it enables galaxies to be identified out to a larger distance without the systematics from statistical techniques.

- (s) **Rhondale Tso** (Caltech)
  *Constraining Vainshtein Screening with Cosmic Explorer*
  Next generation GW detectors, such as Cosmic Explorer, will allow precision tests of GR at cosmological scales. In some massive graviton theories the graviton mass can be screened within galaxy distributions. This is accomplished through the Vainshtein mechanism. Screening can also hold for gravitational radiation, where the beyond-GR effects are suppressed within matter distributions. Here Cosmic Explorer will allow accurate observations at vast scales to probe this screening

effect. This talk will discuss a framework for Cosmic Explorer to probe fundamental physics in GW propagation screened by multiple galaxy distributions. Using realistic galaxy population models the constraint on the graviton mass and screening radius will also be discussed.

- (s) **Juan Uribe** (Loyola Marymount University)
  *Characterization of EUP Black Holes*
  Black Holes are special objects as they are at the intersection of Quantum Mechanics and General Relativity. These theories have dominated the field for a century and have proved to be correct on many occasions. General Relativity in relation to gravity and massive objects, and quantum mechanics in relation to all other forces and subatomic scales. However, these theories are not compatible and as such we have to look for new ones. The study of black holes is a great place to start because black holes are the most compact objects in the universe but they present quantum properties. A central element of quantum mechanics is the uncertainty principle that dictates we cannot know with complete certainty position and momentum at the same time. However, this principle is not compatible with gravity and therefore it has to be readjusted for general relativity. The Extended Uncertainty Principle takes into account gravity and introduces a position-related uncertainty correction $L_*$. In a previous paper, a black hole metric associated with the Extended Uncertainty Principle was derived, by modifying the metric function of a Schwarzschild black hole. This metric introduces near horizon structures that should produce observable effects, such as love numbers, gravitational wave echoes, quasi-normal modes, and absorption coefficients. Some of these effects could be observed with current or near-term technology such as the Laser Interferometer Gravitational Wave Observatory (LIGO) and the Event Horizon Telescope (EHT). Other than calculating the expected value of the aforementioned observables, this article discusses the magnitude of $L_*$.

- **Julio Virrueta** (UC Davis)
  *Effective description of momentum diffusion in a charged plasma from holography*
  We discuss the physics of momentum diffusion in a charged plasma, modeled holographically in terms of a Reissner-Nordstrom-AdS black hole. We analyze graviton and photon fluctuations about this background and show that their dynamic is captured by a set of designer scalars; in the process, we decouple the long-lived momentum diffusion mode from the short-lived charged transport mode, and construct an open effective field theory for the modes associated to conserved currents.

- (s) **Zhencheng Wang** (UCSB)
  *The Spacetime Geometry of Fixed-Area States in Gravitational Systems*
  The concept of fixed-area states has proven useful for recent studies of quantum gravity, especially in connection with gravitational holography. We explore the Lorentz-signature spacetime geometry intrinsic to such fixed-area states in this paper. This contrasts with previous treatments which focused instead on Euclidean-signature saddles for path integrals that prepare such states. We analyze general features of fixed-area state geometries and construct explicit examples. The spacetime metrics are real at real times and have no conical singularities. With enough symmetry the classical metrics are in fact smooth, though more generally their curvatures feature power-law divergences along null congruences launched orthogonally from the fixed-area surface. While we argue that such divergences are not problematic at the classical level, quantum fields in fixed-area states feature stronger divergences. At the quantum level we thus expect fixed-area states to be well-defined only when the fixed-area surface is appropriately smeared.

- (s) **Wayne Weng** (UCSB)
  *A Tale of Two Butterflies: An Exact Equivalence in Higher-Derivative Gravity,*
  Chaos is prevalent in nature: small changes in initial conditions can lead to drastic variations in the outcome. This is commonly known as the butterfly effect. In chaotic many-body systems, the so-called "butterfly velocity" characterizes the speed at which the effect of local perturbations spreads. In this talk, I will describe two methods of computing the butterfly velocity in holography, one using the shockwave spacetime and the other based on entanglement wedge reconstruction. I will then present computations which show the two butterfly velocities match in all $f$(Riemann) theories, thus establishing an exact equivalence of the two methods. Along the way, I will mention some general results on shockwave spacetimes.

  This talk is based on the recent paper 2203.06189 with Xi Dong, Diandian Wang and Chih-Hung Wu.

- (s) **Erik Wessel** (University of Arizona)
  *NR simulations of PPI-unstable BH-disk systems: Effect of magnetization at late times*
  Non-axisymmetric features in BH accretion disks are a sparsely-explored potential GW source. A natural channel for generating such features is the hydrodynamic Papaloizou-Pringle Instability (PPI). Previously, we conducted the first-ever study of the PPI around spinning BHs ($a/M = 0.7$), finding that BH spin can extend the signal lifetime and improve detection prospects by third-generation GW observatories. However, in a realistic scenario the material of these disks is

likely to be magnetized. Prior studies have shown that the magneto-rotational instability (MRI) out-grows and surpresses the PPI during the early growth phase. Here we model a complementary scenario, where the PPI grows to its non-linear saturation state, and then the disk becomes magnetized in an MRI-suceptable configuration. This allows us to investigate, in full GR, a realistic non-axisymmetric configuration of magnetized matter which may concievably result from a number of formation channels. We find that the MRI once again attacks the non-axisymmetry and strongly reduces GW signal amplitude and lifetime.

- **Jordan Wilson-Gerow** (Caltech)
  *Aspects of the Correlated Worldline theory: formalism and signatures*
  We give an introduction to the central ideas, and early predictions, of the Correlated WorldLine (CWL) theory. It is a fully covariant model in which one has GR in the classical limit, standard QM for microscopic objects, but gravitation serves to violate the superposition principle of quantum mechanics for macroscopic objects. The main idea is to generalize the standard path-integral such that different paths for a single matter system may be correlated via gravitational interactions. We will briefly outline the theoretical framework before discussing expected experimental signatures. The scale at which CWL predictions deviate from conventional QM is currently out of experimental reach, but within the near-term goals of many "macroscopic quantum objects" experiments in the field of quantum optomechanics.

- (s) **Xiaohua Ye** (UCSB)
  *Phases of Holographic CFTs on a Product of Spheres*
  We study quantum phase transitions of holographic CFTs on a product of spheres such as $S^2 \times S^3$ as the ratio of two spheres is varied. Moreover, we find the critical temperatures at which the black hole solution experiences a phase transition to a non-black hole solution, which turns out to depend on the ratio of the sphere sizes, thus generalizing the Hawking Page phase transition to a one-parameter family of them.

- (s) **Cem Yetişmişoğlu** (Koç University)
  *Scale covariant theories of gravity and a three dimensional example*
  I will be discussing locally scale covariant generalizations of gravitational theories using Riemann-Cartan-Weyl space-times in arbitrary dimensions. I will demonstrate the procedure for obtaining the scale covariant version of three dimensional topologically massive gravity and show a non-trivial solution which cannot be obtained from any solution to the original topologically massive gravity model.