Hyperbolic and Dispersive Equations on Curved Geometries: Connections to Physics and General Relativity: April 7-11, 2025

Events for:
Monday, April 7th - Friday, April 11th

Monday, April 7th

8:30am **Workshop: Breakfast - SCGP Cafe**

Title: Breakfast

9:30am **Workshop: Wilhelm Schlag - SCGP 102**

Speaker: Wilhelm Schlag

Title: Stability analysis of topological solitons and applications of the distorted Fourier transform

Abstract: We will review some orbital and asymptotic stability results in Hamiltonian equations. A common tool in asymptotic stability proofs is given by the distorted Fourier transform. We will briefly review how this tool is derived and describe some of its applications.

10:30am **Workshop: Coffee Break - SCGP Cafe**

Title: Coffee Break

11:00am **Workshop: Susanna Haziot - SCGP 102**

Speaker: Susanna Haziot

Title: On global regularity theory for the Peskin problem

Abstract: The Peskin problem describes the flow of a Stokes fluid through the heart valves. We begin by presenting the simpler 2D model and investigate its small data critical regularity theory, with initial data possibly containing small corners. We then present the 3D problem and describe the challenges that arise to proving global well-posedness. The first part is joint work with Eduardo Garcia-Juarez, and the second is on-going work with Eduardo Garcia-Juarez and Yoichiro Mori.

12:00pm **Workshop: Lunch - SCGP Cafe**

Title: Lunch

1:00pm **Workshop: Benoit Pausader - SCGP 102**

Speaker: Benoit Pausader

Title: Asymptotic behavior for the Vlasov-Poisson system with a perfectly conducting wall in a convex domain.

Abstract: We consider the 3d Vlasov-Poisson system in an infinite, convex domain (think of generalizations of a half-space), with perfectly conducting wall (Dirichlet for the electrostatic field; particles are absorbed when they touch the boundary). Solutions are global, and we describe their asymptotic behavior based on a correction defined on the asymptotic cone. This is a joint work with W. Huang and M. Suzuki.

2:30pm **Workshop: Birgit Schoerkhuber - SCGP 102**

Speaker: Birgit Schoerkhuber

Title: Stable blowup for supercritical wave maps into perturbed spheres

Abstract: The wave maps equation describes the evolution of maps from (1+d)-dimensional Minkowski space into a target Riemannian manifold and provides a natural geometric generalization of the classical wave equation. We focus on wave maps into d-dimensional warped product manifolds, $d \geq 3$, which corresponds to the energy supercritical case. It is well established that, for a wide range of such target manifolds, the model exhibits finite-time blowup via self-similar solutions. However, little is known about the role of these solutions in the generic time evolution. A notable exception are wave maps into the d-sphere where, in the co-rotational setting, self-similar blowup has been shown to be stable. In this talk, I present recent results that establish stable self-similar blowup for wave maps into warped-product manifolds which arise from small perturbations of the sphere. This is joint work with Alexander Wittenstein (KIT Karlsruhe) and Roland Donninger (University of Vienna).

3:30pm **Workshop: Tea Time - SCGP Cafe**

Title: Tea Time

4:00pm **Workshop: Flash Talks - Istvan Kadar, Gavin Stewart, Leonhard Kehrbeger - SCGP 102**

Speaker: 1) Istvan Kadar, 2) Gavin Stewart, 3) Leonhard Kehrbeger

Title: 1) Construction of multi-soliton solutions for semilinear equations in dimension 3 (Kadar), 2) Modified scattering for 1D cubic NLS with a slowly decaying potential (Stewart), 3) Asymptotics for nonlinear waves from past to future null infinity, with applications to the Einstein vacuum equations (Kehrberger)

Abstract: (Kadar) The existence of multi black hole solutions in General Relativity is one of the expectations from the final state conjecture, the analogue of soliton resolution. In this talk, I will present preliminary works in this direction via a semilinear toy model in dimension 3. In particular, I show 1) an algorithm to construct approximate solutions to the energy critical wave equation that converge to a sum of solitons at an arbitrary polynomial rate in (t-r); 2) a robust method to solve the remaining error terms for the nonlinear equation. The methods apply to energy supercritical problems. (Stewart) We consider the asymptotics of the one-dimensional cubic nonlinear Schrödinger equation with an external potential V that does not admit bound states. Assuming that $\langle x\rangle^{2+}V(x) \in L^1$ and that u is orthogonal to any zero-energy resonances, we show that solutions exhibit modified scattering behavior. Our method combines two techniques: First, we prove a new class of linear estimates, which allow us to relate vector fields associated with the equation with potential to vector fields associated with the flat equation, up to localized error terms. The errors are lower order, allowing us to treat the weighted estimates using the same vector field arguments as in the flat case. Second, we derive the asymptotic profile using the wave packet testing method. Again, by taking advantage of improved local decay near the origin, we are able to treat the potential as a lower-order perturbation, allowing us to use tools developed to study the flat problem. (Kehrberger) Consider a quasilinear wave equation that is a perturbation of the Minkowskian wave equation: Given semi-global scattering data along an ingoing cone towards past null infinity and along past null infinity, then what are the asymptotics of the arising solutions towards spacelike and future null infinity? I will give a quick overview of how to resolve this question, explaining in particular the relevance of the number of spacetime dimensions, and discuss consequences on the full Einstein vacuum equations. Based on joint work with Istvan Kadar.

Tuesday, April 8th

8:30am **Workshop: Breakfast - SCGP Cafe**

Title: Breakfast

9:30am **Workshop: Igor Rodnianski - SCGP 102**

Speaker: Igor Rodnianski

Title: TBA

Abstract: TBA

10:30am **Workshop: Coffee Break - SCGP Cafe**

Title: Coffee Break

11:00am **Workshop: Andrew Lawrie - SCGP 102**

Speaker: Andrew Lawrie

Title: Soliton dynamics for classical scalar fields

Abstract: I will present some of my recent work with Jacek Jendrej. We study classical scalar fields in dimension 1+1 with a symmetric double-well self-interaction potential. Examples of such equations are the phi-4 model and the sine-Gordon equation. These nonlinear wave equations admit non-trivial static solutions called kinks and antikinks, which are amongst the simplest examples of topological solitons. We define an n-kink cluster to be a solution approaching, for large positive times, a superposition of n alternating kinks and antikinks whose velocities converge to zero and mutual distances grow to infinity. Our main result is a determination of the leading order asymptotic behavior of any n-kink cluster. We use this information to construct the n-dimensional invariant manifold of n-kink clusters, which plays the dynamical role of the stable/unstable manifold for an ideal "critical point at infinity" given by well separated multi-kink configurations. In this context we also explain the role of kink clusters as universal profiles for the formation/annihilation of multikink configurations.

12:00pm **Workshop: Group Photo - SCGP Lobby**

Title: Group Photo

12:00pm **Workshop: Lunch - SCGP Cafe**

Title: Lunch

1:00pm **Workshop: Fabio Pusateri - SCGP 102**

Speaker: Fabio Pusateri

Title: On Vortices of Ginzburg-Landau evolutions

Abstract: We present some recent results on the (linear) stability of vortices in relativistic Ginzburg-Landau equations.

2:30pm **Workshop: Joachim Krieger - SCGP 102**

Speaker: Joachim Krieger

Title: Finite time bubble trees for the energy critical wave maps

Abstract: I will discuss a recent result, obtained in joint work with Jacek Jendrej(Paris), on finite time blow up solutions for the 2 co-rotational wave maps from \R^{2+1} into S^2 which asymptotically decouple into two distinct bubbles collapsing at different rates and a radiation part. Solutions of this type had occurred in numerous abstract soliton resolution type results, but our construction appears to be the first one giving actual examples.

3:30pm **Workshop: Tea Time - SCGP Cafe**

Title: Tea Time

Wednesday, April 9th

8:30am **Workshop: Breakfast - SCGP Cafe**

Title: Breakfast

9:30am **Workshop: Mihalis Dafermos - SCGP 102**

Speaker: Mihalis Dafermos

Title: Quasilinear wave equations on asymptotically flat spacetimes with applications to general subextremal Kerr black holes

Abstract: I will describe a general method to treat non-linear stability problems for quasilinear wave equations on asymptotically flat background spacetimes, provided the nonlinearities have good structure at infinity of the type present in many physically important examples. The method requires two elements as input, both of which refer only to the linearisation of the equation around the trivial solution: (i) an appropriate integrated local energy decay estimate and (ii) the existence of an energy current possessing certain weak coercivity properties. In addition to unifying many previous results, the method yields the first non-linear stability statement for quasilinear equations on Kerr black holes in the full subextremal range ?a? M. This is joint work with Gustav Holzegel, Igor Rodnianski and Martin Taylor.

10:30am **Workshop: Coffee Break - SCGP Cafe**

Title: Coffee Break

11:00am **Workshop: Noa Zilberman - SCGP 102**

Speaker: Noa Zilberman

Title: Semiclassical Backreaction on Black Hole Interiors

Abstract: In the semiclassical framework of General Relativity, matter fields are treated as quantum fields propagating on a classical curved spacetime, governed by the semiclassical Einstein field equations. In previous works, we computed the semiclassical energy fluxes on 4-dimensional black hole backgrounds, specifically at the inner horizon (IH), where these fluxes were found to be either positive or negative. In this talk we will feed these non-trivial energy fluxes back into the semiclassical Einstein equations and explore their backreaction on the near-IH geometry of a spherical charged black hole. For simplicity, we consider the homogeneous case, where T_{uu}? =T_{vv}? (with u and v being the standard null Eddington coordinates). The sign of the energy flux at the IH plays a crucial role in determining the resulting spacetime geometry, which, in both cases, deviates significantly from the classical one.

12:00pm **Workshop: Lunch - SCGP Cafe**

Title: Lunch

1:00pm **Workshop: Andras Vasy - SCGP 102**

Speaker: Andras Vasy

Title: Stability of the expanding region of Kerr-de Sitter spacetimes and smoothness at the conformal boundary

Abstract: Based on joint work with Peter Hintz, I will discuss the nonlinear stability of the expanding region of Kerr–de Sitter spacetimes as solutions of the Einstein vacuum equations with positive cosmological constant in a modification of a generalized harmonic gauge introduced by Ringström; in a different type of gauge such a result was obtained recently by Fournodavlos and Schlue. Due to the hyperbolic character of the gauge, the stability result is local near points on the conformal boundary. I will also discuss that in yet another gauge, the conformally rescaled metric is smooth down to the future conformal boundary, with the coefficients of its Fefferman–Graham type asymptotic expansion featuring a mild singularity at future timelike infinity of the black hole.

2:30pm **Workshop: Helvi Witek - SCGP 102**

Speaker: Helvi Witek

Title: On hairy black holes in extensions of General Relativity

Abstract: Black holes are among the most intriguing predictions of general relativity, composed of the fabric of spacetime itself. Observations of black holes offer unique access to extreme gravity, and they enable us to address puzzles in fundamental physics ranging from dark matter to the very nature of gravity itself. I will first give an overview of recent black hole observations, including gravitational wave detections. I will discuss recent progress in mathematical numerical relativity that has been crucial to simulate black-hole mergers in effective field theories of gravity. Finally, I will show new results of hairy black holes in axi-dilaton gravity, their dynamical formation and simulations of their coalescence.

3:30pm **Workshop: Tea Time - SCGP Cafe**

Title: Tea Time

4:00pm **Workshop (Special Lecture): Robert Wald - SCGP 102**

Speaker: Robert Wald

Title: Special Lecture - Quantum Field Theory in Curved Spacetime

Abstract: Quantum field theory in curved spacetime is a theory wherein matter is treated fully in accord with the principles of quantum field theory but gravity is treated classically in accord with general relativity. It is not expected to be an exact theory of nature, but it should provide a good approximate description in circumstances where the quantum effects of gravity itself do not play a dominant role, and it has provided us with fundamental insights into phenomena such as those involving black holes. This talk will give an introduction to quantum field theory in curved spacetime, with emphasis on the mathematical issues arising in the formulation of the theory.

6:00pm **Workshop: Banquet Dinner - SCGP Cafe**

Title: Banquet Dinner

Thursday, April 10th

8:30am **Workshop: Breakfast - SCGP Cafe**

Title: Breakfast

9:30am **Workshop: Gigliola Stafillani - SCGP 102**

Speaker: Gigliola Stafillani

Title: A curious phenomenon in wave turbulence theory

Abstract: In this talk I will use the periodic cubic nonlinear Schrödinger equation to present some estimates of the long time dynamics of the energy spectrum, a fundamental object in the study of wave turbulence theory. Going back to Bourgain, one possible way to conduct the analysis is to look at the growth of high Sobolev norms. It turns out that this growth is sensitive to the nature of the space periodicity of the system. I will present a combination of old and very recent results in this direction.

10:30am **Workshop: Coffee Break - SCGP Cafe**

Title: Coffee Break

11:00am **Workshop: Sung-Jin Oh - SCGP 102**

Speaker: Sung-Jin Oh

Title: Integral formulas for under/overdetermined differential operators and applications to general relativistic initial data sets

Abstract: Underdetermined differential operators arise naturally in diverse areas of physics and geometry, including the divergence-free condition for incompressible fluids, the linearized scalar curvature operator in Riemannian geometry, and the constraint equations in general relativity. The duals of underdetermined operators, which are overdetermined, also play a significant role. In this talk, I will present recent joint work with Philip Isett (Caltech), Yuchen Mao (UC Berkeley), and Zhongkai Tao (UC Berkeley) that introduces a novel approach to constructing integral solution/representation formulas (i.e., right-/left-inverses) for a broad class of under/overdetermined operators. They are optimally regularizing and have prescribed support properties (e.g., produce compactly supported solutions for compactly supported forcing terms). A key feature of our approach is a simple algebraic condition on the principal symbol that implies the applicability of our method. This condition simplifies and unifies various treatments of related problems in the literature. I will also discuss some applications of our approach to the study of the flexibility of initial data sets in general relativity.

12:00pm **Workshop: Lunch - SCGP Cafe**

Title: Lunch

1:00pm **Workshop: Yakov Shlapentokh-Rothman - SCGP 102**

Speaker: Yakov Shlapentokh-Rothman

Title: Polynomial Decay for the Klein-Gordon Equation on the Schwarzschild Black Hole

Abstract: We will start with a review of previous instability results concerning solutions to the Klein-Gordon equation on rotating Kerr black holes and the corresponding conjectural consequences for the dynamics of the Einstein-Klein-Gordon system. Then we will discuss recent work where we show that, despite the presence of stably trapped timelike geodesics on Schwarzschild, solutions to the corresponding Klein-Gordon equation arising from strongly localized initial data nevertheless decay polynomially. Time permitting we will explain how the proof uses, at a crucial step, results from analytic number theory for bounding exponential sums. The talk is based on joint work(s) with Federico Pasqualotto and Maxime Van de Moortel.

2:30pm **Workshop: Flash Talks - Weihao Zheng, Tristan Leger, Serban Cicortas - SCGP 102**

Speaker: 1) Weihao Zheng, 2) Tristan Leger, 3) Serban Cicortas

Title: 1) Mode solutions to the Klein—Gordon equations on the Reissner—Nordström-AdS spacetimes and hairy black holes, 2) Spectral projection bounds on hyperbolic surfaces, 3) Nonlinear Scattering Theory for Asymptotically de Sitter Vacuum Solutions

Abstract: (Zheng) In this talk, I will present the construction of both stationary and growing mode solutions to the charged and uncharged Klein–Gordon equations on the Reissner–Nordström-AdS spacetimes with reflecting boundary conditions. Our results apply to a range of Klein–Gordon mass above the Breitenlohner--Freedman bound, including the conformal mass case. One of the novel mechanisms we exploited in our construction is the "near-extremal instability", which already manifests itself for the uncharged Klein—Gordon equations. As an application of the stationary solution construction, I will then discuss the construction of the hairy black hole solutions to the Einstein–Maxwell–(charged) Klein–Gordon equations. (Leger) In this talk I will present recent and upcoming results on the boundedness of spectral projectors for hyperbolic surfaces. The main focus will be on the case of spectral window with small width. In this setting the bounds become sensitive to the global geometry of the manifold. This is based on joint and upcoming work with J.-P. Anker and P. Germain. (Cicortas) We will talk about recent work establishing a quantitative nonlinear scattering theory for asymptotically de Sitter solutions of the Einstein vacuum equations in $(n+1)$ dimensions with $n\geq4$ even, which are determined by small scattering data at future infinity and past infinity. We will also explain why the case of even spatial dimension n poses significant challenges compared to its odd counterpart and was left open by the previous works in the literature.

3:30pm **Workshop: Tea Time - SCGP Cafe**

Title: Tea Time

4:00pm **Workshop: Georgios Moschidis - SCGP 102**

Speaker: Georgios Moschidis

Title: Type II blow-up solutions for the Einstein--massless Vlasov system

Abstract: In his celebrated proof of the weak cosmic censorship conjecture for the spherically symmetric Einstein-scalar field system, Christodoulou exploited the following property of that specific matter model: Naked singularities, when they arise, exhibit infinite blue-shift along the null geodesics terminating at the singularity. This behaviour is consistent with self-similarity: Even for more general spherically symmetric matter models, it can be shown that self-similar (i.e. of Type I) naked singularities must exhibit infinite blue-shift. Whether, for these more general models, all naked singularities have the infinite blue shift property (and hence are potentially subject to an instability mechanism analogous to that introduced by Christodoulou) still remains an open question. In this talk, we will present the construction of a spherically symmetric solution to the Einstein-massless Vlasov system which contains a locally naked singularity with finite total blue-shift along its past null cone. The initial data giving rise to this solution have finite differentiability, but belong to a regularity class above the scale invariant threshold.

Friday, April 11th

8:30am **Workshop: Breakfast - SCGP Cafe**

Title: Breakfast

9:30am **Workshop: Jonathan Luk - SCGP 102**

Speaker: Jonathan Luk

Title: Sharp asymptotics for quasilinear wave equations satisfying a weak null condition

Abstract: We study the sharp asymptotics for a class of quasilinear wave equations satisfying a weak null condition but not the classical null condition in three spatial dimensions. We prove that the asymptotics are very different from that for the equations satisfying the classical null condition. In particular, at leading order, the solution displays a continuous superposition of decay rates. Moreover, we show that any solution that decays faster than expected in a compact spatial region must vanish identically. The talk is based on joint work in progress with Sung-Jin Oh and Dongxiao Yu.

10:30am **Workshop: Coffee Break - SCGP Cafe**

Title: Coffee Break

11:00am **Workshop: Christoph Kehle - SCGP 102**

Speaker: Christoph Kehle

Title: Nonlinear stability of extremal Reissner–Nordström black holes in spherical symmetry

Abstract: I will present a proof of the codimension-1 nonlinear stability of the family of extremal Reissner-Nordström black holes to the Einstein-Maxwell-neutral scalar field system in spherical symmetry. While the metric decays to a member of the extremal Reissner-Nordström family, I will also show that for 'generic' initial data on the stable manifold, specific components and transverse derivatives of the scalar field and Ricci tensor exhibit non-decay and growth phenomena along the horizon, reflecting the celebrated Aretakis instability for extremal black holes. This is joint work with Yannis Angelopoulos and Ryan Unger.

12:00pm **Workshop: Lunch - SCGP Cafe**

Title: Lunch

1:00pm **Workshop: John Anderson - SCGP 102**

Speaker: John Anderson

Title: Viscosity and the formation of shocks

Abstract: Despite the small scales involved, the compressible Euler equations seem to be a good model even in the presence of shocks. Introducing viscosity is one way to resolve some of these small scale effects. In this talk, we examine the vanishing viscosity limit near the formation of a generic shock in one spatial dimension for a class of viscous conservation laws which includes compressible Navier Stokes. In a nutshell, we recover the inviscid (singular) solution in the limit, and we uncover universal structure in the viscous correctors. The proof involves matching approximate solutions constructed in regions where the viscosity is perturbative and where it is dominant. This is joint work in progress with Sanchit Chaturvedi and Cole Graham.

2:30pm **Workshop: Flash Talks - Jaydeep Singh, Jingbo Wan, Xiaoxu Wu - SCGP 102**

Speaker: 1)Jaydeep Singh, 2)Jingbo Wan, 3) Xiaoxu Wu

Title: 1) Quantifying the blue-shift instability on naked singularity backgrounds, 2)Hyperbolic Estimates for Nonlinear Stability of Subextremal Reissner-Nordström, 3) Decomposition of global solutions for a class of nonlinear wave equations

Abstract: (Singh) Quantifying the blue-shift instability on naked singularity backgrounds Abstract: An important problem in general relativity is the formation and instability of naked singularities, a class of singular spacetimes which lack an event horizon. In this talk we introduce the family of k-self-similar spacetimes constructed by Christodoulou, which are known to exhibit a blue-shift instability. We then survey various results which aim to quantify the strength of this instability, identifying regimes in which these spacetimes transition between stability and instability. (Wan) We establish a key hyperbolic estimate for the nonlinear positive-spin Regge-Wheeler system in perturbations of subextremal Reissner-Nordström spacetimes. Building on Dafermos-Rodnianski's linear analysis on blackhole and Klainerman-Szeftel's framework of nonlinear stability, we address new challenges from gravitational-electromagnetic coupling, which introduces worse nonlinear terms than in the vacuum case. Key improvements in quadratic terms via Einstein-Maxwell equations play a crucial role in our nonlinear analysis. This work is part of the speaker's PhD thesis. (Wu) We study the scattering problem for a general class of nonlinear wave equations. Under appropriate assumptions on the nonlinearity, we establish the existence of the free channel wave operator for initial data that give rise to global solutions. Furthermore, when the interaction term is spatially localized, we prove that the global solution of the full nonlinear equation can be decomposed into a 'free' part and a 'localised' part. This is based on a joint work with Georgios Mavrogiannis and Avy Soffer.

3:30pm **Workshop: Tea Time - SCGP Cafe**

Title: Tea Time