ABSTRACTS

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PLENARY SPEAKERS

Public Plenary Speaker: **Lisa Fauci**(fauci@tulane.edu)
Tulane University
Title: "Buckling, mixing, swimming, dissolving: adventures with helices at the microscale."
Abstract: The motion of passive or actuated elastic filaments in a fluid environment is a common element in many biological and engineered systems. Examples at the microscale include bacterial flagella propelling a cell body and engineered helical nanopropellers designed to penetrate mucosal tissue for drug delivery. Complex fluid environments and geometries, such as polymeric networks or confinement, can have dramatic effects upon the dynamics of filaments, whether rigid or flexible. In this talk we will present computational models of a few intriguing systems: actin-like fibers in straining flows that spontaneously buckle into helices, flexible helical filaments whose swimming performance improves when confined to a narrow tube, and explorations of rigid helical filaments that penetrate a polymeric network with the ability to remodel the material properties of the network as it moves through it.

Plenary Speaker: **Rachel Ward**(rward@math.utexas.edu)
University of Texas at Austin
Title: "Data-driven forecasting in complex systems: a tale of two approaches using kernels and random projections"

Abstract: Making predictions from snapshots of an unknown nonlinear dynamical system is an important problem in science and engineering. It is becoming increasingly clear that tools from machine learning such as kernel methods, sparse approximation, and randomized embeddings, have significant potential in the design of more efficient and robust algorithms for prediction. We review two recent approaches to data-driven forecasting where inspirations from machine learning have made a clear and theoretically justified impact: sparse identification of nonlinear systems and streaming kernel analog forecasting.

Plenary Speaker: **Alejandro Aceves**(aaceves@smu.edu)
Southern Methodist University
Title: "Modeling climate change: A dynamical systems approach"
Abstract: Addressing climate change from different perspectives is without question an urgent need. Climate research is a complex subject; one where tools from applied mathematics can contribute to its understanding and impact. This talk will concentrate in relatively simple models based on dynamical systems, with particular emphasis on the dynamics of the Atlantic meridional overturning circulation (AMOC) . In turn, I hope to convince the audience that despite its simplicity, such studies can shed light in such an important topic.

1. Advances in Krylov subspaces, preconditioning and analysis.

Organized by: Josef Sifuentes (josef.sifuentes@utrgv.edu), *University of Texas Rio Grande Valley*

Josef Sifuentes (josef.sifuentes@utrgv.edu)
University of Texas Rio Grande Valley
Title: "GMRES Convergence and Spectral Properties of Approximate Preconditioners for KKT matrices"
Joint work with: Mark Embree, Gilbert Ymbert
Abstract: Several important preconditioners for KKT matrix equations lead to GMRES converging exactly 2 or 3 iterations. However, these preconditioners involve inverses of large submatrices. In practice, such inverses are only approximated and more iterations are required before convergence. How many more iterations? We present perturbation analysis results for GMRES that leads to rigorous upper bounds on the number of iterations as a function of the accuracy of the preconditioner to the ideal and spectral properties of the constituent matrices. We also derive a thorough analysis of the spectral properties of these common preconditioners. We demonstrate some numerical computations that verify these results for problems from optimization and fluid dynamics.

Miguel Mascorro (miguel.mascorro01@utrgv.edu)
University of Texas Rio Grande Valley
Title: "The Bridge Between the Field of Values and Systems of Linear Equations"
Joint work with: Josef Sifuentes
Abstract: Since the residual in GMRES can be expressed as a polynomial matrix, to minimize its norm among x in a Krylov subspace is to minimize its norm among a polynomials such that they are 1 at 0. It has been shown that the field of values of a matrix is a complete spectral set, and so we can use it to bound GMRES. However, the restrictions for the polynomial become a problem when dealing with indefinite fields of values, and to overcome this we consider the kth root of the matrix in bounding the optimal GMRES polynomial.

Jesus Saldana (jesus.saldana01@utrgv.edu)
University of Texas Rio Grande Valley
Title: "Preconditioned Iterative Methods for Inhomogeneous Acoustic Scattering Application with Variable Index of Refraction"
Joint work with: Josef Sifuentes
Abstract: We develop and analyze efficient iterative methods for solving the discretization of the Lippmann-Schwinger integral equation for inhomogeneous acoustic scattering with variable index of refraction. Analysis and numerical illustrations of the spectral properties of the scattering problem demonstrate that a significant portion of the spectrum is approximated well on coarse grids for the constant problem. We build preconditioners via restarted GMRES method with adaptive deflation preconditioning over multiple grids for the constant problem and apply

them to the variable problem. The preconditioners are very effective for reducing both the computational time and computer memory required to solve acoustic scattering problems.

2. Advances in theory and applications of composite materials

Organized by: Aaron Welters (awelters@fit.edu), *Florida Institute of Technology*
Organized by: Anthony Stefan (astefan2015@my.fit.edu), *Florida Institute of Technology*
Organized by: Robert Viator (rviator1@swarthmore.edu), *Swarthmore*

Aaron Welters (awelters@fit.edu)
Florida Institute of Technology
Title: "Symmetric determinantal representations of multivariable polynomials and their application in the theory of composites"
Joint work with: Anthony Stefan (Florida Institute of Technology)
Abstract: The HMV Theorem is the statement that every multivariate polynomial has a symmetric determinantal representation, and was first proved in J.W. Helton, S.A. McCullough, and V. Vinnikov, Noncommutative convexity arises from linear matrix inequalities, J. Funct. Anal. 240 (2006), 105-191. In this talk, we discuss our new proof, based only on elementary properties of polynomials, determinants, and Schur complements (inspired by our recent proof of the Bessmertnyi realization theorem). Then we consider the important application of this theorem to realization problems of effective tensors in the theory of composites.

Thuyen Dang (ttdang9@central.uh.edu)
University of Houston
Title: "A simplified model for magnetorheological fluid and its corresponding effective system"
Joint work with: Yuliya Gorb (National Science Foundation) and Silvia Jimenez Bolanos (Colgate University)
Abstract: In this talk, I would like to present the rigorous homogenization of a simplified model of magnetorheological fluids. The model is described mathematically by a one-way coupling between Stokes equation and magnetostatic equation, where the coefficients of the corresponding partial differential equations are locally periodic. First, we obtain an improved gradient estimate for the solution of the magnetostatic equation by compactness method. Then this regularity result is applied to derive the effective response of the suspension. Finally, the mathematical justification of the obtained asymptotics is carried out by two-scale convergence method.

Ornella Mattei (mattei@sfsu.edu)
San Francisco State University
Title: "Bounds on the response of lossy two-phase composites subject to time-varying fields"
Abstract: In this talk, we will discuss bounds on the quasistatic response of lossy composites when subject to applied electromagnetic fields (or antiplane elastic fields), that can have any variation in time, not necessarily a fixed frequency one. Interestingly enough, appropriate choices of the applied field can directly provide the volume fractions of the phases from measurements at specific times. Here we will show how to tailor the applied fields in order to obtain such a result.

Owen Miller (owen.miller@yale.edu)
Yale University
Title: "Photonic and Quantum Design Problems as QCQPs"
Abstract: We show that a wide range of physical design problems can be transformed to quadratically constrained quadratic programs (QCQPs). This leads to a general framework for identifying bounds, or fundamental limits, to possible response. We show applications of this approach across nanophotonics – where we find bounds for perfect absorbers, analog optical computers, and broadband extinction – as well as to quantum optical control.

Robert Viator Jr. (rviator1@swarthmore.edu)
Swarthmore College
Title: "Bloch Waves in 3-dimensional high-contrast photonic crystals"

Abstract: We investigate the Bloch spectrum of a 3-dimensional high-contrast photonic crystal. The Bloch eigenvalues, for fixed quasi-momentum, are expanded in a power series in the material contrast parameter in the high-contrast limit. We achieve this power series, together with a radius of convergence, by decomposing an appropriate vectorial Sobolev space into three mutually orthogonal subspaces which are curl-free in certain subdomains of the period cell. We also identify the limit spectrum in the periodic (zero-quasi-momentum) case. Time permitting, we will describe a wide class of crystal geometries which permit the above described analytic structure of the Bloch eigenvalues.

Ruchira Perera (jperer3@lsu.edu)
Louisiana State University
Title: "Bloch Spectra for High Contrast Elastic Media"
Abstract: Analytic representation formulas and power series are developed to describe the band structure inside periodic elastic crystals made from high contrast inclusions. We use source free modes associated with structural spectra to represent the solution operator of the Lamé system inside phononic crystals. An explicit bound on the convergence radius is given through the structural spectra of the inclusion array and the Dirichlet spectra of the inclusions. Sufficient conditions for the separation of spectral branches of the dispersion relation for any fixed quasi-momentum are identified. New conditions on the symmetry of the inclusions and their Dirichlet spectra are found that are sufficient for the emergence of band gaps.

David Morison (nosiromdivad@gmail.com)
University of Utah
Title: "Order to Disorder in Quasiperiodic Composites"
Abstract: We introduce a class of two-phase composites based on deterministic Moire patterns. As the twist angle varies the microstructural geometry, which is distilled into the spectrum of an operator analogous to the Hamiltonian in quantum physics, switches from periodic to quasiperiodic. The electrical, diffusive, thermal and optical transport properties are then found to transition from those of ordered to randomly disordered materials. Through the lens of random matrix theory, we observe behavior akin to an Anderson transition in wave phenomena, with band gaps and mobility edges - even though there are no wave scattering or interference effects at play.

Matthias Maier (maier@math.tamu.edu)
Texas A&M University
Title: "Optical Phenomena, Resonances, and Homogenization of Layered Heterostructures"
Abstract: Two-dimensional materials with controllable electronic structures have opened up an unprecedented wealth of optical phenomena that challenge the classical picture of electromagnetic wave propagation. They are a promising ingredient in the design of novel optical devices, promising subwavelength optics beyond the diffraction limit. In this talk we present a homogenization theory of plasmonic crystals with two-dimensional material inclusions and a spectral analysis quantitatively describing Lorentz resonances in the effective permittivity tensor. We conclude by demonstrating how our analytical findings can serve as an efficient computational tool to describe the general frequency dependence of periodic optical devices.

Yury Grabovsky (yury@temple.edu)
Temple University
Title: "Exact relations and links for two-dimensional thermoelectric composites"
Abstract: The goal of this talk is to describe all relations and links satisfied by the effective thermoelectric tensors of two dimensional composites. The general theory of such relations and links guides the analysis. As an application we prove that the effective thermoelectric tensor of a polycrystal is uniquely determined by the original crystal and does not depend on the texture, as long as the effective tensor is isotropic. Another application gives explicit formulas for the effective tensors of composites made with two isotropic phases in terms of effective conductivity of composites with the same microstructure.

Andrej Cherkaev (cherk@math.utah.edu)
University of Utah
Title: "Some optimal multi-material composites"

Abstract: The paper discusses optimal structures of multi-material composites and exact bounds for their effective properties. The bounds refine Hashin-Shtrikman bounds in the regions of parameters where the last ones are loose. We show that the fields in the materials within optimal structures vary in restricted domains; taking this into account, we obtain exact bounds and optimal structures. For three-material conducting and elastic composites (one material is void), bounds for the energy are explicitly computed. For isotropic composites, the effective conductivity and effective elastic bulk modulus and are explicitly bounded. Unlike two-material composites, different volume fractions of multi-material mixtures correspond to topologically different types of optimal structures.

Justin Baker (baker@math.utah.edu)
University of Utah
Title: "Optimal Design in Monge-Kantorovich Transportation Problem"
Abstract: The Monge optimal mass transfer problem seeks to optimize rearrangement of a measure by minimizing a cost functional. The problem has applications in image processing, variational analysis, machine learning and models various phenomena arising in biology and engineering. This talk discusses the problem in the relaxed Monge-Kantorovich formulation. Analysis of the constraints in the dual optimization problem reduces it to a partial differential equation for a Kantorovich potential. Optimizing the coefficients of this differential equation can be viewed as an optimal design problem for the structural parameters of a composite medium. The approach results in an efficient computational algorithm.

Daniel Onofrei (dtonofre@central.uh.edu)
University of Houston
Title: "Interior approximate control of heat flow through microstructures separated by a rough interface"
Abstract: In this talk we will present our study on the problem of heat flow and its approximate control through microstructures separated by a rough interface. We will describe the homogenized limit and a constructive strategy for interior approximate controls in the general case of bounded coefficients.

Kenneth M. Golden (golden@math.utah.edu)
University of Utah
Title: "On Thinning Ice: Modeling Sea Ice as a Multiscale Composite Material"
Abstract: Polar sea ice exhibits composite structure on length scales ranging over 10 orders of magnitude. A principal challenge in modeling sea ice and its role in climate is how to use information on small scale structure to find effective properties on larger scales. Well discuss recent results, inspired by statistical physics and theories of homogenization, on fluid and electromagnetic transport through the brine and polycrystalline microstructure, advection diffusion, waves on ice-covered seas, and the fractal geometry of ponds on melting Arctic sea ice. We will also discuss how the microstructure of sea ice influences microbial communities living in the ice.

Elena Cherkaev (elena@math.utah.edu)
University of Utah
Title: "Model reduction for viscoelastic materials: Hidden variables and internal scales in composites "
Abstract: Fields in media with microstructure are often described using internal or hidden variables that model the processes on the microstructural level. The talk discusses model order reduction based on matrix Pade approximation of the spectral measure in the Stieltjes integral representation of the effective response of composite materials. This analytic representation links the microgeometry of the medium to its effective properties; its Pade approximation provides a set of internal variables naturally related to the structure of the material. These hidden variables determine the characteristic internal scales corresponding to the microlevel processes of different characteristic wavelengths.

Kshiteej Deshmukh (kshiteej.jd@gmail.com)
Carnegie Mellon University
Title: "Multiband homogenization of metamaterials in Real-Space"
Abstract: We consider the problem of wave scattering from interfaces between metamaterials and obtain a macroscopic model with effective conditions to be applied at the interface to find the scattering coefficients. Rational function approximations of the exact dispersion relation are used to obtain a multiband homogenized model posed

in real space and time. The homogenized macroscopic model provides predictions of wave transmission that match well with the fine-scale solution. Compared to asymptotic expansions, they are much faster to compute, easy to apply, and valid over a broad range of frequencies, while accounting for the microstructure away from the interface.

Davit Harutyunyan (harutyunyan@ucsb.edu)
University of California Santa Barbara
Title: "On the extreme rays of the convex cone of 3 by 3 quasiconvex quadratic forms "
Abstract: Extreme rays of the convex cone of 3 by 3 quasiconvex quadratic forms plays an important role in applied mathematics and in particular in the theory of composite materials. In this work, we characterize 3 by 3 quasiconvex quadratic forms, the determinant of the acoustic tensor of which is an extremal polynomial, and conjecture/discuss about other cases.

3. Algebraic and Geometric Aspects of Integrable Systems

Organized by: Zhijun Qiao (zhijun.qiao@utrgv.edu), *University of Texas Rio Grande Valley*
Organized by: Erwin Suazo (erwin.suazo@utrgv.edu), *University of Texas Rio Grande Valley*
Organized by: Vesselin Vatchev (vesselin.vatchev@utrgv.edu), *University of Texas Rio Grande Valley*
Organized by: W.A. Zuniga-Galindo (wilson.zunigagalindo@utrgv.edu), *University of Texas Rio Grande Valley*

W.A. Zuniga-Galindo (wilson.zunigagalindo@utrgv.edu)
University of Texas Rio Grande Valley
Title: "p-Adic Neural Networks"
Abstract: We introduce the p-adic cellular neural networks which are mathematical generalizations of the classical cellular neural networks (CNNs) introduced by Chua and Yang. The new networks have infinitely many cells which are organized hierarchically in rooted trees, and also they have infinitely many hidden layers. Intuitively, the p-adic CNNs occur as limits of large hierarchical discrete CNNs. More precisely, the new networks can be very well approximated by hierarchical discrete CNNs. Mathematically speaking, each of the new networks is modeled by one integro-differential equation depending on several p-adic spatial variables and the time. We study the Cauchy problem associated to these integro-differential equations and also provide numerical methods for solving them.

Emer Lopera (edloperar@unal.edu.co)
Universidad Nacional de Colombia, Colombia
Title: "Qualitative behaviour of the solutions to a quasilinear problem from a generalized Pohozaev's Identity"
Abstract: The Pohozaev Identity has been used, since their first apparience in 1940[1], to prove nonexistence results as well as to investigate the properties of the solutions of nonlinear elliptic equations. The aim of this talk is to show a generalized Pohozaev Identity for a semipositone problem and, use this to prove an existence result. Indeed we turned our attention to the radial problem $\Delta_\phi u = \lambda f(u)$ in a ball with homogeneous Dirichlet condition.

Zhijun Qiao (zhijun.qiao@utrgv.edu)
University of Texas Rio Grande Valley
Title: "Integrable high order CH type models with pseudo-peakons"
Joint work with: Dr. Baoqiang Xia, Dr. Mingxuan Zhu, and Dr. Enrique Reyes.
Abstract: In this talk, I will introduce some integrable scalar models which possess peaked solitons (peakons), including the well-known Camassa-Holm (CH), the Degasperis-Procesi (DP), and other new peakon equations developed in recent years. I will take the CH case as a typical example to explain the details and show that the Camassa-Holm (CH) spectral problem yields two different integrable hierarchies of nonlinear evolution equations. In particular, the CH peakon equation is able to be extended to the DP, the b-family, the FORQ, the Novikov, the

[1] R.H. Rellich, "Darstellung der eigenwerte von $\Delta u + \lambda u = 0$ darch ein randintegral", *Math. Z.* **46** (1940), 635-636.

modified CH (MOCH), and other higher order models with peakons or pseudo-peakons. Some open problems will also be addressed for discussion in the end.

Shuxia Li (shuxia.li@utrgv.edu)
University of Texas Rio Grande Valley
Title: "Commutator Representations for a hierarchy of integrable equations"
Abstract: Using the functional gradient approach of eigenvalues, this paper presents a pair of Lenard's operators for the Levi's vector fields and establishes commutator representations for hierarchies of Levi's equations. The relationship between potential and stationary Levi's system is discussed in the end.

Dambaru Bhatta (dambaru.bhatta@utrgv.edu)
University of Texas Rio Grande Valley
Title: "Convective flow analysis in solidification of binary alloys"
Abstract: Here we consider a convective flow arising in the solidification of binary alloys. The solidification process produces an intermediary partly solidified layer known as the mushy layer. During solidification, fluid flow within the mushy layer can trigger vertical chimneys or channels. These chimneys create defects in the final form of the solidified alloy. The flow in the mushy layer is governed by a system of partial differential equations including the continuity equation and the momentum equation governed by Darcy's law. Using the weakly nonlinear approach, various systems of different orders are derived. Computational results for the linear and first order solutions of the flow with constant permeability are presented.

Yufeng Zhang (zhang_yu_f@163.com)
Beijing University of Technology
Joint work with: Jing Li.
Title: "Asymptotical stability of Riemann-Liouville fractional neutral systems with multiple discrete delays"
Abstract: In the talk we will analyze the asymptotical stability of Riemann-Liouville fractional neutral systems with multiple discrete delays by appropriate Lyapunov functionals, numerical examples are used to check the validity and feasibility of the proposed results.

Shaotao Zhu (zhushaotao@bjut.edu.cn)
Beijing University of Technology
Joint work with: Jing Li and Ji Zhou.
Title: "Multiple periodic vibrations of auxetic honeycomb sandwich plates with 1:2 internal resonance"
Abstract: In this talk, we will analyze the multiple periodic vibration behaviors of auxetic honeycomb sandwich plates subjected to in-plane and transverse excitation. The effects of transverse excitation on nonlinear vibration behaviors will be discussed in detail. Evolution laws and waveforms of multiple periodic vibrations are obtained to analyze the energy transfer process between the first two order modes.

Mallikarjunaiah Muddamallappa (M.Muddamallappa@tamucc.edu)
Texas A & M University - Corpus Christi
Title: "Phase-field simulation of quasi-static crack propagation in strain-limiting elastic bodies"
Abstract: In this talk, we discuss a phase-field model for quasi-static crack propagation in strain limiting elastic bodies. Our goal is to formulate a diffuse interface approach for the initiation and growth of a single crack in an elastic material that is governed by a special constitutive relationship. Such a setting yield physically reasonable crack-tip fields which are well within the basic assumptions used in the derivation of the model. The quasi-static evolution problem is formulated as a minimization of energy functional based on Griffiths criterion. The coupled system consists of two nonlinear second order elliptic partial differential equations. The discretized coupled system is solved by a monolithic Netwon-Raphon iterative algorithm. The crack propagation is demonstrated by several numerical examples.

Erwin Suazo (erwin.suazo@utrgv.edu)
University of Texas Rio Grande Valley

Title: "On explicit and numerical solutions for stochastic partial differential equations"
Abstract: We will introduce exact and numerical solutions to some stochastic partial differential equations. The solutions are found using a coupled system of deterministic equations and stochastic differential equations.

Vesselin Vatchev (vesselin.vatchev@utrgv.edu)
University of Texas Rio Grande Valley
Title: "On Non-Linear Superposition Principle for Some Classes of Solitons"
Abstract: In the talk we consider approximate two soliton solutions to the Incompressible Euler equations with constant and uniform density obtained via asymptotic expansion. For the two soliton solutions of the KdV and Boussinesq equations we discuss a non-linear superposition principle. For the Boussinesq equation we identify two steady states and an interaction term. Directly from the Euler equations we also derive new two-soliton solutions for solitons traveling in opposite directions that exhibit the same type of interaction. Relations to particle trajectories are presented and discussed in several numerical example.

Julio Cesar Paez (julio.paez01@utrgv.edu)
University of Texas Rio Grande Valley
Title: "Applying the Method of Asymptotic Expansion to Approximate Two-Soliton Solutions for Nonlinear PDEs"
Abstract: In this presentation, we use a method based on Hirota substitution or the Wronskian method to find approximate soliton solutions to the classical Euler equations. This method uses a small parameteras the basis of approximation, a parameter derived from the form of prospective solutions we consider, rather than the standard small parametersand. The L-infinity norm and asymptotic notation are used to measure the accuracy of the approximation rather than finding the error explicitly.

4. Algorithmic Algebra and Geometry

Organized by: Alperen Ergur (alperen.ergur@utsa.edu), *The University of Texas San Antonio*
Organized by: J. Maurice Rojas (jmauricerojas@gmail.com), *Texas A&M University*
Organized by: Frank Sottile (sottile@tamu.edu), *Texas A&M University*

Joe Kileel (jkileel@math.utexas.edu)
University of Texas at Austin
Title: "Recovering group orbits from polynomial invariants, and applications to cryo-EM"
Abstract: In many applied problems, there exists a ground truth signal, one observes various noisy rotated copies of the signal, and the goal is to recover the ground truth. In this talk we abstract such problems to the setup of a compact Lie group acting linearly on a real vector space. We relate the invariant theory of the group representation to computational methods to recover the signal. Degree bounds in invariant theory play a special role. As our main application, we show that solving large systems of polynomial equations can help to recover the 3D shapes of molecules in cryo-EM. This is based on works with numerous coauthors, who will be precisely specified in the talk.

Arpan Pal (arpan@tamu.edu)
Texas A&M University
Title: "Tensors of Minimal Border Rank"
Joint work with: JM Landsberg and Joachim Jelisiejew
Abstract: We know if a collection of square matrices are simultaneously diagonalizable then they commute, however the converse does not hold. It has been a classical problem in linear algebra to classify the closure of the space of simultaneously diagonalizable matrices. This problem is closely related to a problem regarding tensors. In this talk, I shall describe the problem, the relation to the classical question, and recent progress towards classifying minimal border rank tensors.

Runshi Geng (gengrunshi@tamu.edu)
Texas A&M University
Title: "On Geometry of Geometric Rank"
Joint work with: J.M. Landsberg
Abstract: Geometric Rank of tensors was introduced by Kopparty et al. as a useful tool to study algebraic complexity theory, extremal combinatorics and quantum information theory. In this talk I will introduce Geometric Rank and results from their paper, in particular showing the relation between geometric rank and other ranks of tensors. Then I will present recent results based on joint work with J.M. Landsberg, including classification of tensors with geometric rank two and three.

Hang Huang (huanghang1109@gmail.com)
Texas A&M University
Title: "Border Apolarity and Border Rank of 3×3 Permanent"
Abstract: The exponent ω of matrix multiplication is a fundamental constant governing the complexity of the basic operations in linear algebra. The upper bounds on ω of 2.38 and below have been obtained using Strassen's laser method via auxiliary tensors called Coppersmith-Winograd tensors. It has been a long-standing problem to determine the border rank of the Kronecker square of the only Coppersmith-Winograd tensor that could potentially be used to prove $\omega = 2$ (the $q = 2$ small Coppersmith-Winograd tensor). We will discuss how we solve the problem with the recently developed technique called border apolarity and a refined condition we used called flag condition.

Brandilyn Stigler (bstigler@smu.edu)
Southern Methodist University
Title: "Geometric Criteria on Model Spaces of Biological Networks"
Abstract: Biological data science relies on data analysis and modeling to aid in decision making for public policy. As a common issue is that the number of candidate models overwhelms validation processes, a mitigating strategy is to identify data sets with few associated models. We introduce the space of polynomial models for a biological network in terms of a coordinate ring. A key problem is to identify bases of the ring as the basis elements reveal potential network interactions. We describe geometric criteria on the data associated with unique models and highlight upper bounds for the size of the model space.

Elise Walker (elise.walker@tamu.edu)
Texas A&M University
Title: "Homotopies are useful numerical methods for solving systems of polynomial equations."
Abstract: Embedded toric degenerations are one source for optimal homotopy algorithms. In particular, if a projective variety has a toric degeneration, then linear sections of that variety can be optimally computed using the polyhedral homotopy. Any variety whose coordinate ring has a finite Khovanskii basis is known to have a toric degeneration. We provide embeddings for this Khovanskii toric degeneration and use the resulting homotopy to compute general linear sections of the variety.

Thomas Yahl (thomasjyahl@tamu.edu)
Texas A&M University
Title: "Parameter Homotopies in Cox Coordinates"
Abstract: Duff et al. introduced Cox homotopies for solving sparse polynomial systems with solutions lying in a compact toric variety. This takes advantage of the Cox construction of a compact toric variety as a quotient of a quasi-affine space by a reductive group. These Cox homotopies generalize parameter homotopies in projective space and products of projective space while giving more refined information about solutions lying at infinity.

Kalina Mincheva (kmincheva@tulane.edu)
Tulane University
Title: "Hilbert Schemes for non-pinhole cameras"
Abstract: Classically, multiview geometry is the study of two-dimensional images of three-dimensional scenes, and the cameras are linear maps from projective 3-space to the projective plane. Here we consider a more general

set up with cameras being linear maps from $(n+1)$-space to n-space, as well as two-slit cameras: linear maps from projective 3-space to product of projective lines. In those cases, we find a universal Groebner basis for the multiview ideal of k generic cameras. We study the multigraded Hilbert Scheme of k cameras in some of these cases. These results are a generalization of the results on the classical pinhole cameras which are well-understood.

Rupei Xu (rupei.xu@utdallas.edu)
The University of Texas at Dallas
Title: "Beyond Linear Algebra and Euclidean Geometry in 5G and Beyond Networks"
Abstract: Nonlinear algebra provides many surprising new insights into traditional communication networks. For example, the widely used TCP protocol is Max-Plus linear, shortest path routing in switch circuits is related to the Kleene Star of Tropical Matrix Multiplication. The new challenges of 5G and beyond networks motivate to study from matrix to tensor, from complex networks to multilayer and multiplex networks, from ordinary statistics to high-dimensional and algebraic statistics, from Euclidean geometry to Manifolds, from graph theory to sheaf theory. This talk will cover and discuss these computing trends based on our recent research.

Zeyu Guo (zguotcs@gmail.com)
The University of Texas Austin
Title: "Variety Evasive Subspace Families"
Abstract: We consider the problem of constructing explicit variety evasive subspace families. Given a family F of projective or affine subvarieties, a finite collection of projective or affine k-subspaces is evasive for F if for every V in F, some (or most) subspaces intersect V with (at most) the expected dimension. I will show you how to construct polynomial-size k-subspace families that are evasive for varieties of bounded degree. As one application, this gives a derandomization of the Noether normalization lemma for low-degree varieties. We also give an optimal lower bound for the family size in the projective case.

Carlos E. Arreche (arreche@utdallas.edu)
The University of Texas at Dallas
Title: "Mahler residues and telescopers for rational functions"
Abstract: We describe a notion of Mahler discrete residues for rational functions, which comprise a complete obstruction to the Mahler summability problem of deciding whether a given rational function $f(x)$ is of the form $g(x^p) - g(x)$, for some rational function $g(x)$ and integer $p > 1$. We explain the usefulness of this notion in the context of creative telescoping problems. This work extends to the Mahler case the analogous notions, properties, and applications of discrete residues (in the shift case) and q-discrete residues (in the q-difference case) developed by Chen and Singer.

Alperen Ergur (alperen.ergur@utsa.edu)
The University of Texas San Antonio
Title: "Beyond Worst-Case Analysis for Symbolic Real Root Isolation Algorithms"
Abstract: Symbolic computation tradition mostly relies on analyzing algorithms for their worst-case in the Boolean complexity model. This approach yielded many breakthroughs, but also created certain restrictions. One common restriction is the discrepancy between worst-case estimates and the practical performance of algorithms. We aim to develop a more flexible framework for complexity analysis of symbolic algorithms that can delineate the fastest algorithm for a given task. This talk is about the first step of this program, in which we analyzed symbolic real isolation algorithms for polynomials that have integer coefficients that are perturbed by random integer noise. In our semi-random data model Descartes solver (a practitioner's choice) has almost optimal Boolean complexity.

Jordy Lopez Garcia (jordy.lopez@tamu.edu)
Texas A&M University
Title: "Using Macaulay2 To Count Real Roots of Univariate Polynomials"
Joint work with: Frank Sottile, Thomas Yahl and Kelly Maluccio.
Abstract: Since the 19th century, understanding the number of real roots of a polynomial has become ubiquitous in the study of real algebraic geometry. In particular, three theorems by Budan-Fourier, Sylvester and Sturm give us powerful methods to bound and count the number of real solutions of univariate polynomials. I will present a

Macaulay2 package that implements algorithms for studying real roots of univariate polynomials based on such theorems.

Erick Boniface (embonifa@ncsu.edu)
North Carolina State University
Title: "Trinomials and Complexity Limits Over the Reals "
Abstract: Let f in $\mathbb{Z}[x]$ have degree d, coefficients of bit-length h, and exactly t monomial terms. We define solving f over $\mathbb{R}$ as finding, for each real root of f, an approximation z of height $(h \log d)^{O(1)}$ yielding error $O((1/2)^{2^i})$ after i Newton iterations. We give an $(h \log d)^{O(1)}$ algorithm that solves a fraction of $1 - o(1)$ of such input f as d tends to infinity. This also strengthens recent work on deciding the sign of trinomials at rational points of small height.

Weixun Deng (deng15521037237@tamu.edu)
Texas A&M University
Title: "Randomization in Solving and Diophantine Approximation"
Joint work with: Weixun Deng, Alperen Ergur, and Grigoris Paouris
Abstract: A real analogue of Smale's 17th Problem, posed in 2004 by Rojas and Ye, proposes that, on average, approximate real solutions of sparse polynomial systems can be found quickly. However, even the univariate case is open. We show how this problem is connected to linear forms in logarithms, which are a central object of study in diophantine approximation. We then show how the univariate case of the Rojas-Ye Conjecture naturally leads to a randomized version of Baker's Theorem, a workhorse from diophantine approximation.

Joshua Goldstein (jgoldstein345@tamu.edu)
Texas A&M University
Title: "On Extremal Trinomials over the p-adic Rationals"
Abstract: A recent result of Rojas and Zhu shows that the roots of trinomials over the p-adic complex numbers are well-spaced: the valuation of the minimal separation is cubic in the log of the degree, when p is fixed. We consider the existence of trinomials with roots as close as possible and show that valuation of the minimal separation can be linear in the log of the degree. This has implications for the complexity of efficiently approximating roots over the p-adic rationals. We also illustrate how trinomials can currently be solved faster over $\mathbb{Q}_p$ than over $\mathbb{R}$ and show an explicit family of trinomials attaining maximally many roots $(\max\{9, 3p-2\})$ over $\mathbb{Q}_p$ for odd p.

5. Applications of Algebra in Mathematical Physics and Integrable Systems

Organized by: Baofeng Feng (baofeng.feng@utrgv.edu), *University of Texas Rio Grande Valley*
Organized by: Stepehn Anco (sanco@brockc.edu), *Brock University, Canada*
Organized by: Hamidreza Ramezani (hamidreza.ramezani@utrgv.edu), *University of Texas Rio Grande Valley*

Hamidreza Ramezani (hamidreza.ramezani@utrgv.edu)
University of Texas Rio Grande Valley
Title: "Anomalous topological effects"
Abstract: Topological states are known for their robustness against disorder. A well known example is the edge state in Hermitian SSH systems with non-trivial topology where the age states becomes protected against the disorder in the couplings. In my talk I will show how one can get a topologically robust state without having a non-trivial topology.

Hamed Ghaemidizicheh (hamed.ghaemidizicheh@utrgv.edu)
University of Texas Rio Grande Valley
Title: "Asymmetric Localization by Second Harmonic Generation"
Joint work with: Baofeng Feng, Hamidreza Ramezani
Abstract: This talk introduces a nonlinear photonic system that unidirectionally transfers an electromagnetic wave through the second harmonic generation process. To achieve this, we propose a scattering setup consisting of a

non-centrosymmetric nonlinear crystal with nonlinear susceptibility $\chi^{(2)}$ placed to the left of a one-dimensional linear crystal. By embedding a defect in the linear crystal, a left-incident coherent transverse electric wave with frequency $\omega_\star$ exponentially decays through the lattice while a generated second harmonic wave with frequency $2\omega_\star$ localizes into the defect layer. For a right-incident wave, our optical setup acts as a mirror and wholly reflects the incident wave.

Masoumeh (Sara) Izadparast (masoumeh.izadparast@utrgv.edu)
University of Texas Rio Grande Valley
Title: "Modified EP-Based Ring Laser Gyros"
Joint work with: Gururaj Naik, Hamidreza Ramezani
Abstract: Recently there has been an increasing interest in exceptional point-based sensors and gyroscopes due to their ultra sensitivity made of parity-time symmetric double-ring resonators. However, in a practical situation, such gyroscopes are limited by the coupling between the two ring resonators. In this work, we extend the exceptional point-based gyroscopes to the lattice-based gyros. We show that by extending the concept of ring gyros to the lattice systems one can increase the effective coupling at which the exceptional point occurs and thus achieve higher sensitivity.

Baofeng Feng (baofeng.feng@utrgv.edu)
University of Texas Rio Grande Valley
Title: "Discrete KP equation:generating function to integrable systems"
Abstract: It has been known that the discrete KP equation, or the so-called Hirota-Miwa equation, is the master equation of integrable systems. In this talk, I will confirm this by showing the Camassa-Holm equation, modified Camassa-Holm equation and their integrable discretizations can be constructed from a series of transformations of the discrete KP equation.

Stepehn Anco (sanco@brockc.edu)
Brock University, Canada
Title: "New integrable peakon equations"
Abstract: Peakons are peaked travelling waves that were first found as solutions to the Camassa-Holm equation arising in the theory of shallow water waves. The Camassa-Holm equation is an integrable system which possesses multi-peakon solutions. These discoveries started an extensive study of peakon equations, both integrable and non-integrable.

This talk will survey some recent work on a search for new integrable equations:

(1) multi-peakon solutions exist for a wide class of nonlinear dispersive wave equation and does not require integrability;
(2) new integrable peakon equations exhibiting parity-time non-invariance have been obtained
(3) many integrable peakon equations arise as reductions of certain universal multi-component peakon integrable systems

Elena Poletaeva (elena.poletaeva@utrgv.edu)
University of Texas Rio Grande Valley
Title: "Yangians and Finite W-algebras"
Joint work with: V. Serganova
Abstract: Yangians and Finite W-algebras are two classes of associative algebras. Physicists observed a correspondence between Yangians and Finite W-algebras constructed for the general linear Lie algebras. We consider a super analogue of the general linear Lie algebra called the queer Lie superalgebra and show that there exists a relationship between the corresponding Yangian and Finite W-algebra.

Steven Rayan (rayan@math.usask.ca)
University of Saskatchewan
Title: "Integrable systems on Nakajima quiver varieties"
Abstract: It is generally expected that Nakajima quiver varieties, which are manifolds produced from the data of

a directed graph and which are important in various dualities in gauge theory and high-energy physics, support completely integrable Hamiltonian systems. I will report on joint work with L. Schaposnik, where we establish that Nakajima quiver varieties for a certain shape of quiver, called a "comet", admit integrable systems of Gelfand-Tsetlin type. The existence of the system reflects an interesting interplay of algebra (in particular representation theory), geometry, and physics. We will furthermore connect these systems in a natural way to the Hitchin integrable system on the moduli space of Higgs bundles.

Anton Dzhamay (anton.dzhamay@unco.edu)
University of Northern Colorado
Title: "Different Hamiltonians for Painleve Equations and their identification using geometry of the space of initial conditions"
Abstract: It is well-known that differential Painleve equations can be written in a Hamiltonian form. However, a coordinate form of such representation is not unique - there exist different Hamiltonians that reduce to the same equation. We describe a systematic procedure of finding changes of coordinates connecting different Hamiltonian systems. Our approach is based on the notion of Okamoto space of initial conditions and Sakai's geometric theory of Painleve equations. In particular, we consider differential PIV equation and compare five Hamiltonians given by Okamoto, Jimbo-Miwa, Filipuk-Zoladek, Kecker, and Its-Prokhorov and show how to find birational change of coordinates between them.

6. Complex adaptive systems in Life and Social Sciences

Organized by: Lucero Rodriguez Rodriguez (lrodri68@asu.edu), *Arizona State University*
Organized by: Yun Kang (lun.kang@asu.edu), *Arizona State University*
Organized by: Jordy Cevallos-Chavez (jcevall1@asu.edu), *Arizona State University*

Hayriye Gulbudak (hayriye.gulbudak@louisiana.edu)
University of Louisiana at Lafayette
Title: "Differential impacts of contact tracing and lockdowns on outbreak size in COVID-19 model applied to China"
Abstract: By mathematical modeling lockdowns and contact tracing as reactive quarantine measures, dependent on current infection rates, with different mechanisms of action, we analytically derive distinct nonlinear effects of these interventions on final and peak outbreak size. We simultaneously fit the model to provincial reported case and aggregated quarantined contact data from China. Our analysis suggests that altering the cumulative cases in a rapidly spreading outbreak requires sustained interventions that decrease the reproduction number close to one, otherwise some type of swift lockdown measure may be needed.

Zhaosheng Feng (zhaosheng.feng@utrgv.edu)
University of Texas Rio Grande Valley
Title: "Dynamics of a degenerate parabolic system"
Abstract: In this talk, we are concerned with a degenerate parabolic system suggested as dispersion model of biological populations. Dynamical behaviors are presented by virtue of the Abel operator theory and the contraction mapping principle in Banach spaces.

Peter Hinow (hinow@uwm.edu)
University of Wisconsin - Milwaukee
Title: "Tiny Giants - Mathematics Looks at Zooplankton"
Abstract: Zooplankton is a diverse group of organisms. They form a link between autotrophic phytoplankton and higher trophic levels. Changing water temperatures, salinities and decreasing pH values create monumental challenges to their well-being. A significant subgroup of zooplankton are crustaceans of sizes between 1 and 10 mm. They have extremely acute senses that allow them to navigate their surroundings, escape predators, find food and mate. We investigate the visualization of the feeding current of the calanoid copepod Leptodiaptomus sicilis

and the communication by sex pheromones in the copepod Temora longicornis. In these studies, we use tools from optics, ecology, computational fluid dynamics, and computational neuroscience.

Cristina Villalobos (cristina.villalobos@utrgv.edu)
University of Texas Rio Grande Valley
Title: "Optimal control with MANF treatment of photoreceptor degeneration "
Abstract: In many cases vision impairment can be repaired. However, no cure currently exists for blindness due to photoreceptor degeneration. A common cause of photoreceptor degeneration is attributed to apoptosis, or cell death. Experiments in mice have shown that the MANF neurotrophic factor can decrease the number of cells affected by apoptosis. In our study, we model apoptosis into the system that describes the interaction of photoreceptors and the trophic pool along with introducing MANF as a control variable in the system. We show results provided by the optimal control model with those obtained through experimental results.

Md Rafiul Islam (rafiul@iastate.edu)
Iowa State University
Title: "Evaluation of the United States COVID-19 Vaccine Allocation Strategy"
Abstract: To evaluate the U.S. CDC's COVID-19 vaccine prioritization strategy we developed a mathematical model that takes into account various characteristics influencing the spread and severity of the disease (age, profession, comorbidities, and living conditions). We determined the globally optimal vaccine allocation strategy for four outcomes (mortality, cases, infections, and YLL), and verified that the CDC strategy performed well in all outcomes although never optimally. The developed approach can be used to inform the design of future mass vaccine rollouts in the U.S., or adapted for use by other countries seeking to optimize the effectiveness of their vaccine allocation strategies.

Saber Elaydi (selaydi@trinity.edu)
Trinity University
Title: " On some discrete-time epidemic models"
Abstract: In this talk, I will present some discrete-time epidemic models including SEIR and SEIRU models. Here S is the number of individuals susceptible to infection at time t, $E(t)$ is the number of asymptomatic noninfectious individuals at time t, $I(t)$ is the number of asymptomatic but infectious individuals at time t, $R(t)$ is the number of reported symptomatic infectious individuals at time t, and $U(t)$ is the number of unreported symptomatic infectious individuals at time t. The models will be applied to specific diseases, where we compute the basic reproduction number for each disease. Moreover, we will give an estimate of the herd immunity of these diseases.

Carlos Bustamante Orellana (cbustam3@asu.edu)
Arizona State University
Title: "Understanding the dynamics of human reliance and trust on automation"
Abstract: Currently, most of the autonomous vehicles are designed to be used in conjunction with human operators. Since the driving performance of humans can degrade with factors like workload, the decision to assign some tasks to an automation can led to better driving performance. We trained a machine learning model, with data from a previous study on simulated driving with an automated driving assistant, to predict whether a human operator will use the driving assistance at a given time. We obtained the most important features driving human reliance on automation and use them to make associations between reliance and trust.

Lucero Rodriguez Rodriguez (lrodri68@asu.edu)
Arizona State University
Title: "The harvesting effect of Pacific Yew for cancer treatment on the ecosystem: Mathematical modeling approach"
Abstract: The Pacific Yew is a native tree in the United States which is classified as threaten species. The Pacific Yew's bark is mainly used to produce Taxol, a common chemotherapy drug to treat breast, ovarian and lung cancer. The Pacific Yew is unable to survive once its bark has been removed. As a slow growing tree, the Pacific Yew population can easily be destabilized. In this research, we use a system of ordinary differential equations to study

the ecological impact of bark harvesting on the Pacific Yew population, and the impact to breast cancer patients in the United States.

Cameron Browne (cameron.browne@louisiana.edu)
University of Louisiana at Lafayette
Title: "Modeling COVID-19 outbreaks in United States with distinct testing, lockdown speed and fatigue rates"
Abstract: Each state in the United States exhibited a unique response to the COVID-19 outbreak, along with variable levels of testing. In this study, via per-capita testing dependent ascertainment rates, along with case and death data, we fit a minimal epidemic model for each state. We estimate infection-level responsive lockdown/self-quarantine entry and exit rates (representing government and behavioral reaction), along with the true number of cases in first phase of epidemic. We observe a theoretically predicted inverse proportionality relation between outbreak size and lockdown rate, and critical population quarantine "half-life" of 30 days independent of other model parameters.

Tamer Oraby (tamer.oraby@utrgv.edu)
The University of Texas Rio Grande Valley
Title: "Network modeling of Social Learning of Vaccination and Disease Spread"
Abstract: Network modeling of Social Learning of Vaccination and Disease Spread In this work, we use a multiplex network model to investigate the consequences of employing different models of social learning on the resultant vaccine acceptance. In this talk, I will present our research team's work on modeling levels of acceptance of vaccines against childhood diseases and their spread, under some constraints of resources.

Amy Veprauskas (amy.veprauskas@louisiana.edu)
University of Louisiana at Lafayette
Title: "Examining the effect of frequency-dependent and independent selection on the dynamics of a predator-prey system"
Abstract: We apply a Darwinian dynamics framework to study ecological and evolutionary processes occurring on commensurate timescales. Two types of selection are compared: frequency-independent selection in which an individual's fitness depends solely on its own trait, and frequency-dependent selection where their fitness also depends on the traits of others. Our main application is a discrete-time predator-prey system where the prey evolves due to an environmental stressor. Under frequency-independent selection, slow evolution describes a continuous perturbation of the non-evolutionary system, while fast evolution destabilizes dynamics via a period-doubling bifurcation. Meanwhile, frequency-dependent selection may destabilize dynamics, even for slow evolution, via a Neimark-Sacker bifurcation.

Yun Kang (yun.kang@asu.edu)
Arizona State University
Title: "Dynamics of task allocation in social insect colonies: Scaling effects of colony size versus work activities"
Abstract: We propose an adaptive modeling framework on task allocation by incorporating variation both in task performance and task-related metabolic rates. We study the scaling effects of colony size on the resting probability as well as task allocation. We also numerically explore the effects of stochastic noise on task allocation in social insect colonies. Our theoretical and numerical results show that: (a) changes in colony size can regulate the probability of colony resting and the allocation of tasks, and the direction of regulation depends on the nonlinear metabolic scaling effects of tasks; (b) increased response thresholds may cause colonies to rest in varied patterns such as periodicity. (c) stochastic noise can cause work activities and task demand to fluctuate within a range

7. Computational Methods in Wave Theory

Organized by: Thomas Hagstrom (thagstrom@smu.edu), *Southern Methodist University*

Jesse Chan (jesse.chan@rice.edu)
Rice University
Title: "On the entropy projection and the robustness of high order entropy stable discontinuous Galerkin schemes for under-resolved flows"
Abstract: High order entropy stable schemes provide improved robustness for computational simulations of fluid flows. However, additional dissipation shock capturing can still be required for flows with highly under-resolved features. We demonstrate numerically that entropy stable DG methods based on the "entropy projection" do not require additional shock capturing or dissipation for flows with turbulent features, and investigate potential explanations for this observed improvement in robustness.

Stephen Lau (lau@math.unm.edu)
University of New Mexico
Title: "Gauge-preserving boundary conditions for the helically reduced Einstein equations"
Abstract: Computational relativity solves the Einstein equations, often for configurations of two massive objects (binaries). We consider a nonstandard problem in computational relativity, construction of binaries solving the helically reduced Einstein equations as formulated by Beetle, Bromley, and Price. Helically symmetric binaries involve balance of incoming and outgoing radiation. We review a multidomain spectral-tau approach for solving the BBP equations, and describe a new aspect of our work: "gauge-preserving" boundary conditions (BCs) based on those developed by Kreiss, Reula, Sarbach, and Winicour. We report on the extent to which the new BCs yield numerical solutions obeying the harmonic gauge condition.

Judith Munoz-Matute (judith.munozmatute@gmail.com)
University of Texas at Austin
Title: "Time-marching DPG scheme and error representation for transient problems."
Abstract: We present a time-marching scheme based on the Discontinuous Petrov-Galerkin method with optimal test functions for linear transient problems. For that, we employ a ultraweak variational formulation and we show that the scheme is equivalent to exponential integrators for the trace variables. Additionally, it delivers the L^2 projection of the solution in the element interiors and an error representation function for adaptivity in time. We combine our method in time with Bubnov-Galerkin discretization in space. We show the performance of the method and adaptive strategy for 1D and 2D + time linear Partial Differential Equations.

Sue Minkoff (sminkoff@utdallas.edu)
University of Texas at Dallas
Title: "How extended source inversion can aid solution of seismic inverse problems"
Abstract: To illuminate the Earth's subsurface, one sends waves into the ground and records those propagating waves at some distance from the source. The measured seismic data can then be used to work backwards to determine the distribution of mechanical parameters in the Earth through which the waves propagated. Unfortunately, this seismic inverse problem is ill-posed with many models of the subsurface fitting the measured data equally well. The standard least-squares objective function has many local minima which make using local gradient-based optimization difficult. In this talk I will illustrate one technique (source extension) for overcoming this cycle skipping problem.

Lu Zhang (lz2784@columbia.edu)
Columbia University
Title: "Coupling Deep Learning with Full Waveform Inversion"
Abstract: Full waveform inversion (FWI) aims at reconstructing unknown physical coefficients in wave equations using the wave field data collected from different incoming illuminations. In this work, we propose an offline-online computational strategy for coupling classical least-squares based computational inversion with modern deep learning based approaches for FWI to achieve the advantages that can not be achieved with only one of the components. We demonstrate through numerical simulations that our coupling strategy improves the computational efficiency of FWI with offline training on moderate computational resources (in terms of both the size of training dataset and the computational cost needed).

Wei Guo (weimath.guo@ttu.edu)
Texas Tech University
Title: "High order low-rank tensor methods for the Vlasov simulations"
Abstract: In this talk, we present a low-rank tensor approach for solving the Vlasov equation. Among many existing challenges for Vlasov simulations, the curse of dimensionality has been a long-standing key obstacle for realistic high-dimensional simulations. In this work we propose to overcome the curse of dimensionality by dynamically and adaptively exploring a low-rank tensor representation of Vlasov solutions. In particular, we develop two different approaches: one is to directly solve the unknown function, and the other is to solve the underlying flow map, aiming to obtain a low-rank approximation with optimal complexity.

Juntao Huang (huangj75@msu.edu)
Michigan State University
Title: "Structure-preserving machine learning moment closures for the radiative transfer equation: enforcing hyperbolicity and physical characteristic speeds"
Abstract: In this talk, we take a data-driven approach and apply machine learning to the moment closure problem for the radiative transfer equation. Instead of learning the unclosed high order moment, we propose to directly learn the gradient of the high order moment using neural networks, called the gradient-based moment closure. Moreover, we introduce two approaches to enforce the hyperbolicity of our gradient-based machine learning moment closures. A variety of benchmark tests, including the variable scattering problem, the Gaussian source problem and the two material problem, show both good accuracy and generalizability of our machine learning closure model.

Alexander Mamonov (mamonov@math.uh.edu)
University of Houston
Title: "Acoustic velocity estimation with reduced order models"
Abstract: Estimating acoustic velocity from surface measurements is notoriously difficult. Its nave nonlinear least squares formulation leads to an optimization problem with abundant local minima. To address this issue we propose a novel approach that uses reduced order models (ROM). Specifically, a matrix ROM is constructed for the wave equation operator from the measured data. Then, velocity estimation is set up as a minimization of a misfit of operator ROMs, which approximately convexifies the objective thus making the optimization process robust with respect to the choice of initial guess and the presence or absence of low frequency components in the measurements. The performance of the proposed approach is illustrated with a number of numerical experiments.

8. Dispersive Wave Equations with Applications in Optics and Fluids

Organized by: Ross Parker (rhparker@smu.edu), *Southern Methodist University*
Organized by: Brian Choi (choighmath@gmail.com), *Southern Methodist University*

Yannan Shen (yshen@ku.edu)
University of Kansas
Title: "Regularity of a family of water wave equations"
Abstract: In this talk, we consider the Cauchy problem of a family of partial differential equations, named as λ-family equations where λ is the power of the nonlinear wave speed. The λ-family equations include Camassa-Holm equation ($\lambda = 0$) and Novikov equation ($\lambda = 1$) modeling water waves, where solutions generically form finite time cusp singularities. The global energy conservative solution we construct is Hölder continuous with exponent $\frac{2\lambda+1}{2\lambda+2}$. The existence result also paves the way for the future study on uniqueness and Lipschitz continuous dependence.

Akif Ibraguimov (akif.ibraguimov@ttu.edu)
Texas Tech University
Title: "On finite speed of propagation for degenerate Einstein equation"
Abstract: We employ the generalization of Einstein's random walk paradigm for diffusion to derive a class of N-D degenerate nonlinear parabolic equations in non-divergence form. The diffusion coefficient can depend on

both dependent variable and its gradient and it vanishes when either one of the latter does. It is known that solution of such degenerate equations can exhibit finite speed of propagation (FSP). We prove this property using a De Giorgi-Ladyzhenskaya iteration for non-divergence-equations and provided Numerical results via a finite-difference scheme are used to illustrate. Moreover, we provide the construction of 1-D self-similar solution with FSP, in the sense of Kompaneets-Zel'dovich-Barenblatt. We thus show how the FSP quantitatively depends on the model's parameters.

Ross Parker (rhparker@smu.edu)
Southern Methodist University
Joint work with: Alejandro Aceves
Title: "Standing wave solutions in twisted multicore fibers"
Abstract: There has been much recent theoretical and experimental interest in light dynamics in twisted multi-core optical fibers. I consider the existence and spectral stability of standing wave solutions to a model for light propagation with no gain or loss of energy. I prove that for a specific relationship between the number of waveguides and the twist parameter, there are standing wave solutions which exhibit optical Aharonov-Bohm suppression, in which a single waveguide in the fiber remains unexcited. I also explore spectral stability of these solutions, as well as an extension of the model which incorporates a second order dispersion term.

Brian Choi (choighmath@gmail.com)
Southern Methodist University
Title: "Well-posedness of mixed fractional nonlinear Schrödinger equation"
Abstract: Motivated by the recent trend in the study of non-local dynamics, we investigate the well-posedness theory of the 2-D fractional nonlinear Schrödinger equation (NLSE) with a mixed degree of derivatives. It is well understood that the classical NLSE with the Laplacian operator, in the context of optics, describes the light propagation in homogeneous media with the quadratic dispersion profile in the Fourier space. In recent years, the assumption on the quadratic dispersion profile has been relaxed to the fractional-power dispersion. We further relax that assumption and consider the fractional NLSE where the dispersion parameter is non-uniform in different directions.

Michael Hott (michael.hott@math.utexas.edu)
University of Texas at Austin
Joint work with: Thomas Chen
Title: "On the emergence of a quantum Boltzmann equation in the presence of a Bose-Einstein condensate"
Abstract: The mathematically rigorous derivation of a nonlinear Boltzmann equation from first principles is an extremely active research area. In classical physical systems, this has been achieved in various models, based on a variety of fundamental works. In the quantum case, the problem has essentially remained open. I will explain how a cubic quantum Boltzmann equation arises within the fluctuation dynamics of a Bose-Einstein condensate, starting with the von Neumann equation for an interacting Boson gas.

Jacky Chong (jwchong@math.utexas.edu)
The University of Texas at Austin
Title: "Dynamical Hartree–Fock–Bogoliubov approximation of interacting bosons "
Abstract: We consider a many-body Bosonic system with pairwise particle interaction that scales to a positive delta function. Our main result is the extension of the local-in-time Fock space approximation of the exact dynamics of squeezed states proved in the work of Grillakis and Machedon, *Comm. PDEs*, (2017) to a global-in-time approximation. Our work can also be viewed as a generalization of the results in Boccato, Cenatiempo, and Schlein, *Ann. Henri Poincare*, (2017) to a more general set of initial data that includes coherent states along with an improved error estimate.

9. Efficacy and safety statistics of COVID-19 treatment and prophylaxis protocols

Organized by: Eleftherios Gkioulekas (eleftherios.gkioulekas@utrgv.edu), *University of Texas Rio Grande Valley*
Organized by: Leisha Martin (leisha.martin@tamucc.edu), *Texas A&M University-Corpus Christi*

Harvey Risch (harvey.risch@yale.edu)
Yale University
Title: "Hydroxychloroquine and Other Outpatient Treatments for Covid-19, with Critique of Epidemiologic Methods"
Abstract: To most academics and clinicians, the field of epidemiology seems like a no-brainer–you just get some cases and controls, run some regression models if you are a quant, and see what's different. Is there really any science there? Epidemiology is indeed a science but what is scientific about it per se is subtle. The crucial scientific aspect about epidemiology is representativeness: that the patients are generalizable to the disease as a whole, the controls are generalizable to the population of relevance, the exposure measures accurately reflect what the subjects really experienced, and the exposure association is not reflective of some other reason why an association is present. Epidemiologists agonize over these issues in terms of bias and confounding, as well as misrepresentation of studies, cherry picking and other more general corruptions of the scientific method. In this talk, I will discuss how non-scientific factors created aberration of knowledge greater than the scientific evidence itself, and show what the evidence for early treatment really does show.

David Wiseman (synechion@aol.com)
Synechion, Inc.
Title: "Re-analysis of policy-shaping studies on hydroxychloroquine and ivermectin reverses original findings to yield significant benefits. Review in the context of regulatory decisions on vaccines."
Abstract: It was with skepticism about the efficacy of hydroxychloroquine (HCQ) in Covid-19, that we read a paper reported in NEJM that was one of only two substantive papers cited by FDA in its revocation of the EUA for HCQ in June 2020. This was a study of postexposure prophylaxis (PEP) in persons experiencing a high or moderate risk exposure to Covid-19. Subjects enrolled in the study online and received HCQ or a folate placebo with the goal of preventing development of disease. Data presented in the supplemental appendix suggested, surprisingly, that the drug may have some efficacy in certain subpopulations. After contacting the PI, he pointed out a possible benefit of very early intervention. Exploring this observation, an examination of the raw dataset suggested that the intervention lag had likely been underestimated. After further data requests, we established that 52% of subjects had received drug later than the overnight delivery assumed by the investigators. Correcting for this error yielded a 42% reduction ($p = 0.044$) in Covid-19 compatible disease associated with HCQ given ≤ 3 days from exposure. We found a similar problem in a companion study performed by the same team under the same logistical arrangements addressing early symptomatic subjects. We were unable to obtain corrected intervention lag data to determine if effects could be observed that were greater than the 20% reduction of symptomatic Covid-19 reported originally. We also re-analyzed a study of early treatment using ivermectin (IVM) reported in JAMA in March 2021. The paper reported several execution errors or changes, notably the dosing of some placebo subjects with active drug, and the use of different types of placebos in different trial phases. Obtaining the raw dataset, accounting for these issues yielded a 56% reduction ($p = 0.033$) of residual Covid-19. We will discuss these studies in the context of significant decisions made during the pandemic, particularly in light of recent decisions made by FDA and CDC regarding the Covid-19 vaccines.

Leisha Martin (leisha.martin@tamucc.edu)
Texas A&M University-Corpus Christi
Title: "Medical Countermeasures: Analysis and Assessment of COVID-19 Prevention and Early Treatment Approaches and Shortfalls"
Abstract: Over the previous 20 months, COVID-19 research has dominated the primary literature. Numerous clinical trials have been performed, yielding vast amounts of data on vaccines, repurposed drugs, novel drugs, monoclonal antibodies, and nutraceuticals, many with conflicting results. The significant variability in the number of participants, age ranges, co-morbidities, maintenance doses, and the study exclusion criteria may further

complicate conclusions. We present a broad, unbiased comparison of some of the most effective COVID-19 countermeasures to date. Mechanisms of action, convenience of use, cost, and the potential for adverse effects are also considered.

Eleftherios Gkioulekas (eleftherios.gkioulekas@utrgv.edu)
University of Texas Rio Grande Valley
Title: "Frequentist and Bayesian analysis methods for case series data for the early outpatient treatment of COVID-19"
Abstract: Dr. Zelenko proposed an early outpatient treatment for the SARS-CoV-2 pandemic that has evolved into Dr. McCullough's more detailed sequenced multidrug therapy protocol, corroborated with additional case series by Dr. Procter and Dr. Raoult. We introduce mathematical techniques for conducting rapid statistical analysis of these case series data that can be used to make emergency decisions, on whether to deploy these treatment protocols. In particular, we use the Sterne interval and the Bayesian factor to compare the observational case series outcomes on hospitalizations and death with treatment against the expected hospitalization and mortality rates without treatment.

10. Finite element and related methods for challenging problems

Organized by: Todd Arbogast (arbogast@oden.utexas.edu), *University of Texas at Austin*
Organized by: Robert Kirby (robert_kirby@baylor.edu), *Baylor University*

Robert Kirby (robert_kirby@baylor.edu)
Baylor University
Title: "Domain truncation BC for scattering"
Abstract: Numerical resolution of exterior Helmholtz problems requires some approach to domain truncation. As an alternative to approximate nonreflecting boundary conditions and invocation of the Dirichlet-to-Neumann map, we introduce a new, nonlocal boundary condition. This condition is exact and requires the evaluation of layer potentials involving the free space Green's function. However, it seems to work in general unstructured geometry, and Galerkin finite element discretization leads to convergence under the usual mesh constraints imposed by Gårding-type inequalities. The nonlocal boundary conditions are readily approximated by fast multipole methods, and the resulting linear system can be preconditioned by the purely local operator involving transmission boundary conditions.

Chuning Wang (cwangaw@utexas.edu)
University of Texas at Austin
Title: "Direct Serendipity and Mixed Finite Elements on Convex Polygons"
Abstract: We construct new families of direct serendipity and direct mixed finite elements on general planer convex polygons. They have optimal order of accuracy of any order, they are H^1 and $H(\text{div})$ conforming, respectively, and they have a minimal number of degrees of freedom. The finite elements shape functions are defined to be the full spaces of scalar or vector polynomials plus a space of supplemental functions. The direct serendipity elements are the precursors of the direct mixed elements in a de Rham complex. The convergence properties of the elements are shown under a regularity assumption on the shape of the elements.

Jorge Marchena-Menendez (jorge_marchena1@baylor.edu)
Baylor University
Title: "Schwarz methods for serendipity elements"
Abstract: While solving Partial Differential Equations with finite element methods, serendipity elements allow us to obtain the same order of accuracy as rectangular tensor-product elements with many fewer degrees of freedom. We develop some additive Schwarz methods based on solving local patch problems. Adapting arguments from Pavarino for the tensor-product case, we prove that patch smoothers give conditioning estimates independent of the polynomial degree for a model problem. Combining this with a low-order global operator we give an optimal

two-grid method, with conditioning estimates independent of the mesh size and polynomial degree. Numerical experiments using Firedrake and PETSc confirm this theory.

Alan Demlow (demlow@math.tamu.edu)
Texas A&M University
Title: "Maximum norm a posteriori estimates for convection-diffusion problems"
Abstract: Residual a posteriori error estimators for convection-diffusion problems are typically reliable but not efficient for standard norms. Instead a dual norm of the convective derivative must be added to the error notion in order to ensure efficiency of the estimators. These issues are well-understood for energy norms. In this work we explore them instead in the context of maximum norms. We prove reliability of maximum-norm a posteriori estimates for convection-diffusion problems for standard and stabilized continuous Galerkin methods. We also define a suitable dual norm of the convective derivative. When added to the maximum norm, this dual norm yields an error notion for which standard residual estimators are both reliable and efficient.

Jiaqi Li (jiaqi@oden.utexas.edu)
University of Texas at Austin
Title: "DPG in Banach Spaces"
Abstract: The Discontinuous Petrov-Galerkin (DPG) method has many attractive features: guaranteed stability provided the problem is well posed, built-in a posteriori error estimator, as well as the ability to control the norm in which the convergence occurs. DPG is traditionally set in Hilbert space. However, for singularly perturbed problems, we experience Gibbs phenomena near boundary layers. It is known that the projection in a Banach space instead of L^2 can eliminate Gibbs phenomena. We will present a DPG method in Banach space and present numerical results to demonstrate the improvement over the Hilbert method.

Judit Munoz-Matute (judith.munozmatute@gmail.com)
University of Texas at Austin
Title: "Time-marching DPG scheme for linear hyperbolic problems"
Abstract: We present a time integration method based on the Discontinuous Petrov-Galerkin method with optimal test functions for linear hyperbolic problems. For that, we reduce the second order system in time to first order and we consider an ultraweak variational formulation. We compute the optimal test functions analytically and we prove that the resulting method is equivalent to exponential integrators for the trace variables. Our method also delivers an optimal approximation for the element interiors in time. We show the performance of our method for 1D and 2D + time linear hyperbolic problems together with an algorithm to speed up the computation of exponential-related functions.

Jeonghun Lee (jeonghun_lee@baylor.edu)
Baylor University
Title: "Robust numerical methods for fluid and poroelastic structure interaction problems"
Abstract: For poroelasticity problems parameter-robust numerical methods and preconditioning techniques are intensively studied. However, similar studies on the fluid and poroelastic structure interaction (FPSI) problems are not well-known. In this work we present parameter-robust numerical methods for the FPSI problems.

Todd Arbogast (arbogast@oden.utexas.edu)
University of Texas at Austin
Title: "Self-Adaptive Theta Schemes for hyperbolic equations"
Abstract: We develop an implicit self-adaptive theta (SATh) scheme for finite volume approximation of scalar hyperbolic conservation laws. It is based on a discontinuity aware quadrature (DAQ) rule that is accurate when there is a discontinuity in the solution. We prove that SATh is unconditionally stable, satisfies the maximum principle, and is total variation diminishing under appropriate monotonicity and boundary conditions. Compared to solutions of finite volume schemes using Crank-Nicolson and backward Euler time stepping, SATh solutions often approach the accuracy of the former but without oscillation, and they are numerically less diffuse than the later.

11. Geometry of Machine Learning

Organized by: Eliza O'Reilly (eoreilly@caltech.edu), *California Institute of Technology*

Eliza O'Reilly (eoreilly@caltech.edu)
California Institute of Technology
Title: "Stochastic Geometry for Machine Learning"
Abstract: The Mondrian process in machine learning is a recursive partition of space with random axis-aligned cuts used to build random forests and Laplace kernel approximations. The construction allows for efficient online algorithms, but the restriction to axis-aligned cuts does not capture dependencies between features. By viewing the Mondrian as a special case of the stable under iterated (STIT) process in stochastic geometry, we resolve open questions about the generalization of cut directions. We utilize the theory of stationary random tessellations to show that STIT processes approximate a large class of stationary kernels and achieve minimax rates for Lipschitz functions (forests and trees) and C^2 functions (forests only). This works opens many new questions at the novel intersection of stochastic geometry and machine learning. This talk is based on joint work with Ngoc Tran.

Zehua Lai (laizehua@uchicago.edu)
University of Chicago
Title: "Noncommutative positivstellensatz and stochastic gradient descent"
Abstract: Stochastic optimization algorithms have become indispensable in modern machine learning. An important question in this area is the difference between with-replacement sampling and without-replacement sampling — does the latter have superior convergence rate compared to the former? In this talk, We will explain the connection between this problem and the theory of noncommutative Positivstellensatz and polynomial optimization, which allows us to relate the problem to a semidefinite program and the validity of the conjecture to certain bounds for the optimum values. We show that a previous conjecture by Recht and Re is false. This result has been subsequently confirmed by concrete constructions.

Tan Nguyen (tanmnguyen89@ucla.edu)
University of California Los Angeles
Title: "Transformer with a Mixture of Gaussian Keys"
Abstract: Multi-head attention is a driving force behind state-of-the-art transformers which achieve remarkable performance across a variety of natural language processing (NLP) and computer vision tasks. It has been observed that for many applications, those attention heads learn redundant embedding, and most of them can be removed without degrading the performance of the model. Inspired by this observation, we propose Transformer with a Mixture of Gaussian Keys (Transformer-MGK), a novel transformer architecture that replaces redundant heads in transformers with a mixture of keys at each head. These mixtures of keys follow a Gaussian mixture model and allow each attention head to focus on different parts of the input sequence efficiently. Compared to its conventional transformer counterpart, Transformer-MGK accelerates training and inference, has fewer parameters, and requires less FLOPs to compute while achieving comparable or better accuracy across tasks. Transformer-MGK can also be easily extended to use with linear attentions. We empirically demonstrate the advantage of Transformer-MGK in a range of practical applications including language modeling and tasks that involve very long sequences. On the Wikitext-103 and Long Range Arena benchmark, Transformer-MGKs with 4 heads attain comparable or better performance to the baseline transformers with 8 heads.

Oscar Leong (oleong@caltech.edu)
California Institute of Technology
Title: "Learned Generative Priors for Phase Retrieval"
Abstract: Deep generative models, such as Generative Adversarial Networks (GANs), have quickly become the state-of-the-art for natural image generation, leading to new approaches for enforcing structural priors in a variety of inverse problems. In contrast to traditional approaches enforcing sparsity, GANs provide a low-dimensional parameterization of the natural signal manifold, allowing for signal recovery to be posed as a direct optimization problem whose search space is restricted to the range of the GAN. Moreover, the dimensionality of this parameterization can be lower than that of the sparsity level of a particular signal class. In this talk, we investigate the

use of GAN priors in a nonlinear inverse problem known as compressive phase retrieval, which asks to recover a signal from undersampled quadratic measurements. We show that a subgradient descent algorithm on a nonsmooth, nonconvex least squares problem can provably recover a signal in the range of a generative model given an optimal number of measurements with respect to the input dimension of the generator. This overcomes a notorious theoretical bottleneck in phase retrieval, where the best known efficient algorithms under a sparsity prior exhibit a sub-optimal quadratic sample complexity. We corroborate these theoretical results with empirics showing that exploiting generative priors in phase retrieval tasks can significantly outperform sparsity priors.

12. High-order structure preserving techniques for simulating transport phenomena and fluids

Organized by: Bennett Clayton (bgclayto@tamu.edu), *Texas A&M University*
Organized by: Jesse Chan (jesse.chan@rice.edu), *Rice University*
Organized by: Eirik Valseth (eirik@utexas.edu), *The University of Texas at Austin*
Organized by: Eric Tovar (ejtovar1@tamu.edu), *Texas A&M University*

Tarik Dzanic (tdzanic@tamu.edu)
Texas A&M University
Title: "Bounds Preserving Temporal Integration Methods for Hyperbolic Conservation Laws"
Abstract: We will present a modification of explicit Runge-Kutta temporal integration schemes that preserves any locally-defined quasiconvex set of bounds for the solution. These schemes operate on the basis of a bijective mapping between an admissible set of solutions and the real domain to strictly enforce bounds, and they are proven to recover the order of accuracy of the underlying Runge-Kutta method upon which they are built. Within this framework, we show that it is possible to recover a wide range of methods independently of the spatial discretization, including positivity preserving, discrete maximum principle satisfying, entropy dissipative, and invariant domain preserving schemes.

Jean-Luc Guermond (guermond@tamu.edu)
Texas A&M University
Title: "Invariant-domain-preserving explicit Runge–Kutta time stepping"
Abstract: Considering ODE systems with invariant-domain properties, the question addressed in this work consists of constructing explicit and high-order accurate time stepping technique that preserve the invariant-domain property of these systems. One well-known class of methods meeting this goal is composed of the so-called strong stability preserving Runge-Kutta methods. In this work we go beyond the strong stability preserving barrier and develop a time stepping technique that makes every explicit Runge-Kutta method invariant-domain preserving.

Robert Kirby (robert_kirby@baylor.edu)
Baylor University
Title: "Bounds-constrained polynomial approximation using the Bernstein basis"
Abstract: A fundamental problem in numerical analysis and approximation theory is approximating smooth functions by polynomials. A much harder version under recent consideration is to enforce bounds constraints on the approximating polynomial. In this paper, we consider the problem of approximating functions by polynomials whose Bernstein coefficients with respect to a given degree satisfy such bounds, which implies such bounds on the approximant. We frame the problem as an inequality-constrained optimization problem and give an algorithm for finding the Bernstein coefficients of the exact solution. Additionally, our method can be modified slightly to include equality constraints such as mass preservation. It also extends naturally to multivariate polynomials over a simplex.

Madison Sheridan (sheridanm@tamu.edu)
Texas A&M University
Title: "High-order invariant domain preserving approximation of the gray radiation equations"
Abstract: In this talk I will present new results regarding the approximation of the gray radiation equations. This

system of nonlinear conservation equations is composed of the compressible Euler equations augmented with a equation for the conservation of the radiation energy. One important feature of this system is that it contains a highly nonlinear relaxation source term that connects the radiation energy and the fourth power of the temperature. Another key feature is that the radiation energy balance equation contains a non-conservative product. The proposed method is fully discrete. The time stepping mixes explicit and implicit steps. The method can be made accurate to any order in time. The invariant domain property is maintained under the usual hyperbolic CFL condition.

Eirik Valseth (eirik@utexas.edu)
The University of Texas at Austin
Title: "Goal-Oriented Error Estimation for the Shallow Water Equations"
Abstract: We introduce goal-oriented a posteriori error estimates for a weighted first-order least-squares FE method for the shallow water equations (SWE). In the corresponding FE discretization, we use a weighted norm equivalent to the L2 norm and solve an equivalent saddle point system. Error estimates are introduced by considering a linearized SWE and quantities of interest in terms of the solution and solving an adjoint problem. We consider the adjoint PDE itself and subsequently seek weighted least squares FE approximations to it. We present numerical verifications for the error estimator and the resulting error indicators in adaptive mesh refinements.

Eric Tovar (ejtovar1@tamu.edu)
Texas A&M University
Title: "Well-balanced second-order convex limiting technique for solving the Serre equations"
Abstract: In this talk we introduce a numerical method for approximating the dispersive Serre equations with topography using continuous finite elements that is explicit, second-order accurate, and invariant domain preserving. The method is well-balanced, parameter free and an extension of a hyperbolic relaxation technique for the Serre Equations. The numerical method is then verified with academic benchmarks and validated by comparison with laboratory experimental data.

Bennett Clayton (bgclayto@tamu.edu)
Texas A&M University
Title: "Invariant-Domain Preserving Approximation of the Compressible Euler Equations with Tabulated Equations of State"
Abstract: We present a numerical method for solving the compressible Euler equations supplemented with an equation of state that is either analytic or tabulated. A robust first-order approximation technique that guarantees positivity of the density and the internal energy is proposed. A key ingredient of the method is a local approximation of the equation of state using a co-volume ansatz from which upper bounds on the maximum wave speed are derived for every elementary Riemann problem.

Yimin Lin (yiminlin@rice.edu)
Rice University
Title: "A positivity preserving strategy for entropy stable discontinuous Galerkin discretizations of the compressible Euler and Navier-Stokes equations"
Abstract: High order entropy stable discontinuous Galerkin methods for the compressible Euler and Navier-Stokes equations assume the positivity of physical quantities. In this work, we introduce a positivity limiting strategy for entropy stable discontinuous Galerkin discretizations based on convex limiting. The key ingredient in the limiting procedure is the low order positivity-preserving discretization based on graph viscosity terms. Numerical experiments in 2D confirm the accuracy and robustness of the proposed strategy.

Rami Masri (ramimasri14@gmail.com)
Texas A&M University
Title: "Stability and convergence of high order discontinuous Galerkin methods for incompressible flow"
Abstract: Solving the incompressible Navier-Stokes equations presents a challenging computational task primarily due to the coupling of the velocity and pressure by the incompressibility constraint and to the nonlinear convection term. Projection algorithms decouple this nonlinearity from the pressure term. Such algorithms are favorable since, at each timestep, the saddle point problem is replaced by elliptic equations. This is particularly important for

large scale problems in complicated computational domains. In this talk, we formulate and theoretically analyze an unconditionally stable discontinuous Galerkin discretization of the pressure correction approach which features high order spatial accuracy.

Loic Cappanera (lmcappan@central.uh.edu)
University of Houston
Title: "Projection and artificial compression methods for incompressible multiphase flows"
Abstract: We present two numerical methods to approximate the incompressible Navier-Stokes equation with variable density and viscosity. Both methods use the momentum, equal to the density times the velocity, as primary unknown and are made suitable for spectral elements by an adequate treatment of nonlinearities and diffusion operator. The incompressiblity condition is respectively enforced via the use of projection methods and artificial compression methods. Stability and robustness of both methods are compared on a large range of problems involving large ratio of density, surface deformations and magnetohydrodynamics instabilities.

Md Mahmudul Hasan (mhasan5@miners.utep.edu)
University of Texas at El Paso
Title: "A high order compact hybrid variable method with application to inviscid compressible flow problems"
Abstract: Numerical methods for hyperbolic conservation laws have been the driving force for the research in scientific computing for many physical, biological, and engineering systems. In this work, We will present a Compact Hybrid Variable Method(CHVM) based on two major developments in the literature: (1) the compact differencing scheme by S. K. Lele and (2) the hybrid-variable scheme developed by X. Zeng. We conducted rigorous stability and accuracy analysis of the method to show that it is linearly stable and formally sixth-order accurate on uniform grids. Then the study is extended to nonlinear equations for inviscid compressible flow problems.

Ignacio Tomas (nachotet@gmail.com)
Sandia National Laboratories
Title: "Compressible Navier-Stokes: numerical schemes with mathematically guaranteed properties."
Abstract: We present a scheme for the compressible Navier-Stokes equations that: (i) Is invariant domain preserving and satisfies global balance of total mechanical energy. (ii) The scheme runs at the usual hyperbolic CFL $\mathrm{d}t \leq O(h)$ dictated by Euler's subsystem, rather than the technically inapplicable parabolic CFL $\mathrm{d}t <= O(h^2)$. The scheme uses operator splitting in time: key details are related to careful construction of viscous dissipation terms and the choices of space and time discretization used at each sub-stage. The scheme is second-order accurate in space and time and exhibits remarkably robust behavior in the context of shock-viscous-layers interaction.

13. Mathematical foundation of deep learning with the applications to PDE

Organized by: Lizuo Liu (lizuol@smu.edu), *Southern Methodist University*
Organized by: Haizhao Yang (yang1863@purdue.edu), *Purdue University*
Organized by: Senwei Liang (liang339@purdue.edu), *Purdue University*

Richard Tsai (ytsai@math.utexas.edu)
University of Texas at Austin
Title: "Numerical wave propagation and parallel-in-time computation aided by deep learning"
Abstract: We propose a deep learning approach for wave propagation in media with multiscale wave speed, using a second-order linear wave equation model. We use neural networks to enhance the accuracy of a given solver, which under-resolves a class of multiscale wave media and wave fields of interest. Our approach involves generating training data by the given computationally efficient coarse solver and another sufficiently accurate solver, applied to a class of wave media (described by their wave speed profiles) and initial wave fields. We combine the neural-network-enhanced coarse solver with the parareal algorithm and demonstrate that the coupled approach improves the stability of parareal algorithms for wave propagation and improves the accuracy of the enhanced coarse solvers.

Senwei Liang (liang339@purdue.edu)
Purdue University
Title: "Solving PDEs on unknown manifolds with machine learning"
Abstract: Parameterizing manifolds is challenging if the unknown manifold is embedded in a high-dimensional ambient Euclidean space, especially when the manifold is identified with randomly sampled data and has boundaries. In this talk, I will introduce a mesh-free computational framework and machine learning theory for solving elliptic PDEs on unknown manifolds, identified with point clouds, based on diffusion maps and deep learning. The PDE solver is formulated as a supervised learning task to solve a least-squares regression problem that imposes an algebraic equation approximating a PDE (and boundary conditions if applicable).

Lizuo Liu (lizuol@smu.edu)
Southern Methodist University
Title: "A Linearized Learning with Multiscale Deep Neural Network for Stationary Navier-Stokes Equations with Oscillatory Solutions"
Abstract: We present several linearized schemes that accelerate the conver- gences of training for those PDE problems containing nonlinear terms. The stationary nonlinear Navier-Stokes equation is what we study in this paper. To solve the stationary nonlinear Navier-Stokes equation, we introduce the idea of linearization of Navier-Stokes equation and iterative methods to treat the nonlinear convection term. Three forms of linearizations are considered. After a benchmark problem, we solve the highly oscillating stationary flows utilizing the proposed multi- scaled neural network and the linearized ideas in complex domains. The results show that multiscale deep neural network combining with the linearized schemes can be trained fast and accurately

Chunmei Wang (chunmei.wang@ufl.edu)
University of Florida
Title: "Structure probing neural network deflation"
Abstract: The speaker will propose a network-based structure probing deflation method to make deep learning capable of identifying multiple solutions that are ubiquitous and important in nonlinear physical models. First, we introduce deflation operators built with known solutions to make known solutions no longer local minimizers of the optimization energy landscape. Second, to facilitate the convergence to the desired local minimizer, a structure probing technique is proposed to obtain an initial guess close to the desired local minimizer. Together with neural network structures carefully designed in this paper, the new regularized optimization can converge to new solutions efficiently. Numerical experiments also demonstrate that the proposed method could find more solutions than exiting methods.

Wenjing Liao (wliao60@gatech.edu)
Georgia Institute of Technology
Title: "Nonparametric estimation of nonlinear operators between function spaces by deep neural networks"
Abstract: Learning nonlinear operators between function spaces has wide applications, including PDE solving, data-driven PDE identification, forward and inverse scattering, image processing etc. This talk presents a non-parametric estimation theory of deep neural networks for learning Lipchitz operators between Hilbert spaces. A non-asymptotic error bound is derived for the empirical risk minimizer. The error converges as the sample size increases at a fast rate when the given data exhibit low-dimensional structures.

Xiaoliang Wan (xlwan@lsu.edu)
Louisiana State University
Title: "A deep adaptive sampling method for solving PDEs"
Abstract: In this work we present an adaptive strategy for the machine-learning-based approximation of PDEs. The basic idea is to refine the collocation points in the training set adaptively such that the Monte Carlo approximation error will be reduced. More specifically, we treat the residual as an unnormalized probability density function and use a recently developed deep generative model to approximate and sample the residual such that variance reduction techniques can be adopted to reduced the discretization error of the loss.

Tan Nguyen (tanmnguyen89@gmail.com)
University of California, Los Angeles
Title: "Momentum-Based and Fast Multipole Methods for Designing Deep Learning Models"
Abstract: Designing deep learning models is an art that often involves expensive search over candidate architectures and optimization algorithms. We develop novel momentum-based frameworks to facilitate the process of designing deep learning models. In particular, we focus on recurrent neural networks (RNNs), neural ordinary differential equations (NeuralODEs), and transformers. In particular, we establish connections between key components in these models and gradient descent (GD). We then integrate momentum into these frameworks and propose a new family of momentum-based models. We theoretically prove and numerically demonstrate that our momentum-based models alleviate limitations in the baseline models such as the vanishing gradient issue in training RNNs, a large number of function evaluations in NeuralODEs, and the quadratic memory and computational complexity of transformers.

In the case of transformers, we also propose FMMformers, a class of efficient and flexible transformers inspired by the celebrated fast multipole method (FMM) for accelerating interacting particle simulation. FMMformers decompose the attention into near-field and far-field attention, modeling the near-field attention by a banded matrix and the far-field attention by a low-rank matrix. FMMformers only require linear complexity in computational time and memory footprint with respect to the sequence length but achieve similar accuracy as standard transformers, which suffer from quadratic complexity.

Tan Bui (tanbui@oden.utexas.edu)
University of Texas at Austin
Title: "Model-constrained deep learning approaches for forward and inverse problems"
Abstract: Deep Learning (DL), in particular deep neural networks (DNN), by design is purely data-driven and in general does not require physics. This is the strength of DL but also one of its key limitations when applied to science and engineering problems in which underlying physical properties and desired accuracy need to be achieved. Leveraging information encoded in the underlying mathematical models, we argue, not only compensates missing information in low data regimes but also provides opportunities to equip DL methods with the underlying physics and hence obtaining higher accuracy. This talk introduces model-constrained DL approaches that are capable of learning not only information hidden in the training data but also in the underlying mathematical models to solve inverse problems. We present and provide intuitions for our formulations for general nonlinear problems. For linear inverse problems and linear networks, the first order optimality conditions show that our model-constrained DL approaches can learn information encoded in the underlying mathematical models, and thus can produce consistent or equivalent inverse solutions, while naive purely data-based counterparts cannot.

14. Mathematics and Computation in Biomedicine

Organized by: Sebastian Acosta (sebastian.acosta@bcm.edu), *Baylor College of Medicine, Houston TX*

Charles Puelz (charles.puelz@bcm.edu)
Baylor College of Medicine and Texas Children's Hospital
Title: "Immersed boundary methods for pediatric and adult cardiovascular models"
Abstract: This talk will focus on the construction and numerical simulation of cardiac models for the heart, valves, and great vessels. Cardiac anatomy is derived from clinical imaging data. Immersed finite element methods are used to describe the interaction between the structures (including the valves, great vessels, and heart tissue) and the blood. This talk will discuss applications of this approach to pediatric heart disease as well as to modeling the mechanics of the adult heart.

Bryant Wyatt (wyatt@tarleton.edu)
Tarleton State University
Title: "Supraventricular Tachycardia Study Using a Dynamic Computer Generated Atria"
Abstract: Supraventricular Tachycardia (SVT) is when the heart's upper chambers, the atria, beats either too quickly or out of rhythm with the heart's lower chambers. This out-of-step beating of the heart is one of the leading

causes of strokes, heart attacks, and heart failure. The most successful treatment for SVT is catheter ablation. There is a great deal that is not known about what triggers SVT and where to place scar tissue for optimal patient outcomes. Here we present our work on creating a dynamic model of the right atrium that will allow researchers to perform simulated ablations.

Beatrice Riviere (riviere@rice.edu)
Rice University
Title: "Numerical simulations of reduced solute transport"
Abstract: Simulations of blood flow and oxygenation can provide insight on the planning of cardiovascular surgeries. Reduced models have proven to be a computationally efficient alternative to the three-dimensional coupled Navier-Stokes and transport problems in vascular networks. Unknowns in the reduced models are the vessel cross-sectional area, the radially averaged blood momentum and solute concentration. This work presents a generalized reduced model of solute transport in blood vessels of varying cross-section and with arbitrary axial velocity profile. A locally implicit discontinuous Galerkin method is analyzed. Numerical simulations of coupled blood flow and solute transport in a fifty-five vessel network are shown.

Mario Bencomo (mjb6@rice.edu)
Rice University
Title: "Discrete adjoint computations for relaxation Runge-Kutta methods"
Abstract: Relaxation Runge-Kutta (RK) methods reproduce a fully discrete dissipation/conservation of entropy for entropy stable semi-discretizations for nonlinear conservation laws. In this talk, we derive the discrete adjoint for relaxation RK schemes, which are applicable to discretize-then-optimize approaches to optimal control problems. Furthermore, we prove that the derived relaxation RK adjoint preserves time-symmetry when applied to linear skew-symmetric systems of ODEs. Numerical experiments verify these theoretical results while demonstrating the importance of appropriately treating the relaxation parameter when computing the discrete adjoint.

Rahnuma Islam (rahnuma.islam@ttu.edu)
Texas Tech University
Title: "Chemotactic system exhibiting traveling band phenomena based on Einstein Paradigm for Brownian motion"
Abstract: We study the movement of the living organism in a band form towards the limited presence of chemical substrate. We incorporate the Einstein's method of Brownian motion to motivate such equations describing chemotactic system. In addition to considering Chemotactic response of organism and the random motion of organism arising from chemotactic response, we also consider the formation of crowd by living organism via interactions within or between the community. We have shown that under specific compromise on coefficients in our model results in Keller- Segel model in depletion of substrate. Also, under no such adjustment, traveling band has been yield and explained accordingly.

Tahsin Khajah (tkhajah@uttyler.edu)
University of Texas at Tyler
Title: "Phase-reduced isogeometric on surface radiation conditions for high-frequency scattering analyses at dramatically low computational cost"
Abstract: We develop isogeometric on surface radiation condition method to perform high-frequency scattering analyses at dramatically low computational cost. Geometrical features are evaluated accurately even at very course discretization levels. The Pade-type OSRCs was optimized to increase the accuracy of the proposed method. To avoid pollution error and enable dramatically fast analyses at high frequencies, we separate the oscillatory part of the solution and solve for slowly varying amplitude. We demonstrate the performance of the proposed method for two- and three- dimensional acoustic scattering problems and propose a coupling method to increase the accuracy of the proposed method for non-convex scatterers.

Jesse Chan (jesse.chan@rice.edu)
Rice University
Title: "Efficient high order DG methods on moving curved meshes"

Abstract: High order discontinuous Galerkin (DG) methods on moving curved meshes must perform expensive assembly and inversion weighted mass matrices at each time step. We show how to avoid this step by utilizing an easily invertible weight-adjusted approximation. The resulting semi-discrete weight-adjusted DG scheme is provably energy stable up to a term which converges to zero with the same rate as the optimal error estimate.

Greg Morrison (gcmorrison@uh.edu)
University of Houston Dept of Physics
Title: "Modeling stiff biomolecules under spatial constraints"
Abstract: In this talk, we develop an analytical method for determining the statistics of stiff chains accounting for a variety of spatial constraints, relevant for many in vivo and in vitro processes. We determine scaling laws and correlation functions for confined stiff polymers, confirmed by simulations. We further consider a pair of stiff crosslinked filaments (modeling an F-actin bundle), and find a mathematical connection to the confined biopolymer that gives rise to a new length scale. Finally, we determine the response to compression and find a buckling transition akin to Euler buckling, but accounting for the thermal fluctuations in the system.

Andreas Mang (andreas@math.uh.edu)
University of Houston
Title: "CLAIRE: A scalable multi-GPU solver for diffeomorphic image registration in 3D"
Abstract: We present a fast, parallel multi-GPU implementation of a solver for diffeomorphic image registration problems termed CLAIRE. In diffeomorphic image registration, we seek a diffeomorphism that establishes a point-wise spatial correspondence between two views (images) of the same scene. Our contributions are new algorithms and dedicated computational kernels to reduce the runtime significantly. We study the performance of our solver and compare it to the state-of-the-art. As a highlight, we demonstrate that we can solve problems for clinically relevant data of size 256^3 in under 10 seconds. This amounts to a speed-up that is at the order of $20\times$ compared to our current CPU implementation.

Cesar Uribe (cauribe@rice.edu)
Rice University
Title: "Optimal Transport for Federated Biomedical Signal Processing"
Abstract: Machine learning can transform healthcare in the intensive care unit by deriving quantifiable insights from large-scale data generated during healthcare delivery. However, the unprecedented advances in ML are yet to be translated to practical decision support systems. Small samples sizes hinder these methods' potential of becoming a trustworthy clinical adjunct to intensivists. This talk will discuss opportunities for shifting traditional paradigms to a data-based integrative analysis of signals geometry. We focus on recent theoretical advances in Optimal Transport (OT) to aggregate and analyze large-scale medical data and enable monitoring systems based on geometric-driven quantification of physiological signal changes.

Weston Baines (bainesw1@tamu.edu)
Texas A&M University
Title: "The range description of a conical radon transform"
Abstract: In this work we consider the Conical Radon Transform, which integrates a function over shifted copies of a given circular cone. Transforms of this type are known to arise naturally as models of Compton camera imaging and single-scattering optical tomography (in the case of two dimensions). The main results (which differ depending on the parity of the dimension) provide a description of the range of the transform on the space test functions.

Mohammad Latifi (mjlatifi@math.arizona.edu)
University of Arizona
Title: "V-Line transform in 2D vector tomography"
Abstract: We study the problem of reconstructing a 2-dimensional vector field from vectorial versions of the V-Line Radon transform. The longitudinal and transverse V-line transforms of a vector field integrate along V-shaped trajectories the components of that field correspondingly in the direction of the V-line and the normal to the V-line. We show that the vector field can be recovered using longitudinal and transverse data with some interesting

geometric interpretations. We also state a more general inversion theorem for the star Radon transform on vector fields.

Arko Barman (arko.barman@rice.edu)
Rice University
Title: "Leveraging brain symmetry in CT and CTA images for diagnosis and treatment of Ischemic Stroke & Hemorrhage"
Abstract: Spatial symmetry is commonly used by clinicians in the diagnosis and prognosis of diseases in organs such as the brain. Anomalies in symmetry can be indicative of patient-specific disease-related features that are less sensitive to inter-patient variability. However, quantifying these anomalies in symmetry is challenging as the hemispheres in the brain are not exact mirrored copies. We present a novel deep learning architecture, Deep Symmetry-sensitive Network (DeepSymNet), and its variants that are capable of learning anomalies in symmetry from 2D or 3D radiological images for detecting ischemic stroke and brain hemorrhage, and are currently being used at Memorial Hermann Hospital.

Negar Orangi-Fard (norangifard@ggc.edu)
Georgia Gwinnett College
Title: "Prediction of chronic obstructive pulmonary disease"
Abstract: Over 16.4 million adults suffer from Chronic obstructive pulmonary disease (COPD) and over 2.2 million patients are admitted to hospitals annually due to COPD exacerbations in US. Monitoring patients exacerbations could save their life. In this work presents three different models to predict COPD exacerbation using AI and Natural Language processing (NLP) approaches. These models use respiration summary notes, symptoms, and vital signs. To train and test models, we used over 8000 data records from tens of thousands of patients and achieved an Area under the ROC curve of 0.84 and accuracy of 97.0% in predicting COPD exacerbation.

Bo Zhao (bozhao@utexas.edu)
University of Texas at Austin
Title: "Optimized Magnetic Resonance Fingerprinting with Statistical Learning and Inference"
Abstract: Magnetic resonance (MR) Fingerprinting is an emerging quantitative MR imaging technique, who holds a great promise of revolutionizing the existing paradigm of MR imaging. In this talk, I will present our recent research that introduces a novel statistical framework for optimizing this quantitative imaging technique. Specifically, I will present several principled statistical inference and learning approaches developed by my group in optimizing the encoding and decoding processes of MR Fingerprinting. Towards the end, I will discuss the future opportunities of integrating spin physics with statistical inference and learning in advancing quantitative MR imaging for medicine and biology.

Ali Ghafouri (ghafouri@utexas.edu)
University of Texas at Austin
Title: "Inverse modeling in neurooncology"
Abstract: A predictive, patient-specific, biophysical model of tumor growth would be an invaluable tool for causally connecting diagnostics with predictive medicine. For example, it could be used for tumor grading, characterization of the tumor microenvironment, recurrence prediction, and treatment planning, e.g., chemotherapy protocol or enrollment eligibility for clinical trials. Such a model also would provide an important bridge between molecular drivers of tumor growth and imaging-based phenotypic signatures, and thus, help identify and quantify mechanism-based associations between these two. Unfortunately, such a predictive biophysical model does not exist. Existing models undergoing clinical evaluation are too simple–they do not even capture the MRI phenotype. Although many highly complex models have been proposed, the major hurdle in deploying them clinically is their calibration and validation. In this talk, we will discuss the challenges related to the calibration and validation of biophysical models, and in particular the mathematical structure of the underlying inverse problems. I will also present a new algorithm that localizes the tumor origin within a few millimeters.

15. Numerical methods for multi-phase flows in porous media

Organized by: Loic Cappanera (lmcappan@central.uh.edu), *University of Houston*

Maria Vasilyeva (maria.vasilyeva@tamucc.edu)
Texas A&M University - Corpus Christi
Title: "Learning macroscopic parameters in multiscale simulations of multi-phase flows in porous media"
Abstract: We present the nonlinear upscaling method for problems in heterogeneous and fracture media. We construct an upscaled coarse grid model using a machine learning technique. The proposed upscaled model is based on the solution of the local problem in the oversampled domain up to fine grid resolution that used to create an accurate dataset for the training of the neural networks. We present numerical results for several applications in heterogeneous and fractured media: (1) unsaturated flow, (2) two-phase flow, and (3) poroelasticity problem. Our numerical results show that the proposed approach can provide good accuracy with fast calculations.

Mohammad Sarraf Joshaghani (m.sarraf.j@rice.edu)
Rice University
Title: "A discontinuous Galerkin method with bound-preserving limiters for two-phase immiscible flow"
Abstract: We focus our attention on the study of immiscible, (in)compressible two-phase flow in porous media taking into account gravity, anisotropy, and heterogeneity effects. The goal is to develop a stable discontinuous Galerkin (DG) solver for this system that is accurate, respects maximum principle for saturation solution, and is locally mass conservative. On the computational front, we propose a DG formulation equipped with sequential flux limiter and slope limiter at the post-processing level. We solve benchmark problems to investigate the performance of solver and particularly the impact of the implemented limiting strategies on local mass conservation.

Chenyu Tian (chenyu@ices.utexas.edu)
Oden Institute, University of Texas at Austin
Title: "Simulation of Multiphase Flow and Transport in Partially Melted Materials"
Abstract: Partial melting is an important geological process that occurs in multiple tectonic settings, e.g., at mid-ocean ridges and subduction zones. We describe the mechanical Stokes-Darcy flow problem coupled to an advection-diffusion transport system for energy and chemical component mass. A modified Bernardi-Raugel space and a variant of the lowest order reduced $H(\text{div})$-approximation AC space are used to discretize the Stokes-Darcy equations. Second order accuracy is achieved in the velocity field with a piece-wise constant pressure approximation. This mixed finite element formulation is adjusted to be locally mass conservative. For the transport part, implicit WENO-AO methods will be used.

Giselle Sosa Jones (ggsosajo@central.uh.edu)
University of Houston
Title: "Existence and convergence of a DG method for three phase flows in porous media"
Abstract: In this talk we present and analyze a discontinuous Galerkin method for the compressible three phase black oil problem in porous media. We use a first order time extrapolation which allows us to solve the equations implicitly and sequentially. We show that the discrete problem is well-posed, and obtain a priori error estimates. We present different configurations of the problem, such as variable density and gravity effects, and numerically demonstrate the first order convergence of our scheme.

16. Numerical methods for problems with interfaces and surface PDEs

Organized by: Maxim A. Olshanskii (maxim.olshanskii@gmail.com), *University of Houston*

Andrea Bonito (bonito@math.tamu.edu)
Texas A&M University
Title: "Numerical Approximations of Curved Origamis"
Abstract: The folding of thin elastic sheets along a prepared curved arc is considered. The resulting curved origamis find applications in many areas. Telescopes, self-deployable structures, flapping and flytrap mechanisms,

shields, airbags are a few examples. We start from a thin three-dimensional hyper-elastic model and include a material defect favoring folding. We then justify that in the vanishing thickness limit, the plate deformations satisfy a two-dimensional fourth order problem with interface along with a nonlinear constraint expressing the fact that the plate cannot sustain shear nor stretch. We present a local discontinuous Galerkin method, discuss its properties and conclude the talk by exploring numerically the features of this new model.

Maxim Olshanskii (molshan@math.uh.edu)
University of Housto
Title: "A finite element method for two-phase surface fluids and modeling of multicomponent lipid membranes"
Abstract: This talk reviews a continuum-based model for the process of phase separation in multicomponent lipid membranes exhibiting lateral fluidity. We further introduce a finite element method for solving surface fluid and surface phase-field equations. The models and methods are combined to deliver a finite element method for a thermodynamically consistent phase-field model for surface two-phase fluid. A stable linear splitting approach is introduced and available numerical analysis results are presented. We finally discuss successes and failures of the model to reproduce in vitro experiments with multicomponent vesicles of different lipid compositions.

Abner J. Salgado (asalgad1@utk.edu)
University of Tennessee
Title: "Analysis and approximation of fluids under singular forcing"
Abstract: Motivated by applications, like modeling of thin structures immersed in a fluid, we develop a well posedness and approximation theory for Newtonian and some non-Newtonian fluids under singular forcing in Lipschitz domains, and in convex polytopes.

Alan Demlow (demlow@math.tamu.edu)
Texas A&M University
Title: "Quasi-trace mixed surface finite element methods"
Abstract: In standard trace (or cut) finite element methods for surface PDE, a three-dimensional bulk mesh is approximately intersected with the given surface in order to obtain a highly unstructured anisotropic surface mesh. The surface finite element method is taken to be the restriction of a bulk finite element space to the surface mesh. This methodology works well for H1-conforming spaces, but it is not clear how to extend it to other fundamental finite element settings such as H(div)-conforming spaces. In this talk we explore the idea of using a trace mesh, but then defining a mixed finite element space directly on the trace mesh rather than as the trace of an bulk space. We prove basic error estimates, including for superconvergent postprocessed approximations to the scalar variable.

Alexander Zhiliakov (alex@math.uh.edu)

Title: "Stability and convergence of trace finite element methods for surface fluid flows"
Abstract: We present a geometrically unfitted finite element method (FEM), known as trace FEM or cut FEM, for the numerical solution of the (Navier-)Stokes system posed on a closed smooth surface. A trace FEM based on standard Taylor-Hood bulk elements is proposed. The key result is an inf-sup stability with the constant uniformly bounded with respect to the discretization parameter and the position of the surface in the bulk mesh. Optimal order convergence follows from this new stability result and interpolation properties of the trace FEM. Numerical examples include evolving surface case.

Diane Guignard (dguignar@uottawa.ca)
University of Ottawa
Title: "Large deformation of prestrained plates: reduced model and numerical simulation using an LDG approach"
Abstract: We study the elastic behaviour of prestrained plates relevant for instance in plastic deformation or manufactured polymer gels. In the bending regime, the reduced model consists of a fourth order minimization problem with a nonlinear constraint. We propose a local discontinuous Galerkin method for the discretization: up to stabilization terms, the discrete energy is obtained by simply replacing the Hessians by a weakly converging

reconstructed Hessians. In this talk, we introduce the reduced mathematical model, present the discretization strategy and the gradient flow designed to minimize the energy, and illustrate the performances of the proposed methodology through several numerical experiments.

17. Operator Splitting Methods and Adaptive Schemes for Systems of Nonlinear Evolution Equations

Organized by: Bruce Wade (bruce.wade@louisiana.edu), *University of Louisiana at Lafayette*

Zhaosheng Feng (zhaosheng.feng@utrgv.edu)
University of Texas Rio Grande Valley
Title: "Implicit-explicit wave solutions of a class of nonlinear evolution equations"
Abstract: In this talk, we are concerned with implicit-explicit wave solutions of a class of nonlinear evolution equations. Equivalence transformations are applied for exploring the principal Lie symmetry. By means of the associated equivalence algebra and the Abel operator theory, explicit-implicit wave solutions are presented.

Qin Sheng (qin_sheng@baylor.edu)
Baylor University
Title: "A Second-Order Semi-Discretized Scheme for Solving Stochastic Quenching Models on Arbitrary Spatial Grids"
Abstract: Reaction-diffusion-advection equations provide precise interpretations for many important phenomena in complex interactions between natural and artificial systems. In this talk, we shall study a second-order semi-discretization for the numerical solution of reaction-diffusion-advection equations from numerical combustion applications. Our investigations particularly focus at cases where nonuniform spatial grids are utilized. Detailed derivations and analysis are accomplished. Easy-to-use and highly effective second-order schemes are acquired. Computational experiments are presented.

Olaniyi Iyiola (oiyiola@clarkson.edu)
Clarkson University
Title: "Dynamical systems and iterative schemes with inertial and adaptive step size"
Abstract: Developing robust numerical schemes for solving systems of differential equations and the construction of the fixed-point iterative schemes for solving variational inequality problems (VIP) are active research areas for many decades. In this talk, overview of the relationship that exists between dynamical system and several fixed point iterative schemes will be presented. Furthermore, our recent results on the subgradient-extragradient method with inertial extrapolation terms and self-adaptive step sizes for solving VIP will be discussed. This version is more relaxed with easy to implement conditions on the inertial-factor and relaxation parameter. Examples are provided for implementation and comparison purposes.

E. Macias-Diaz (jemacias@correo.uaa.mx)
Autonomous University of Aguascalientes
Title: "Numerical solution of a space-fractional Fermi-Pasta-Ulam-Tsingou regime"
Abstract: In this work, we consider a fractional extension of the Fermi–Pasta–Ulam–Tsingou chains. The mathematical model has a Hamiltonian which is conserved when damping is equal to zero, and dissipated otherwise. We propose a finite-difference method to approximate the solutions of the continuous model. A discretized form of the Hamiltonian is also proposed in this work, and we prove analytically that the method is capable of conserving or dissipating the discrete energy. Solutions of the discrete model exist and are unique under suitable conditions. We establish rigorously the properties of consistency, stability and convergence of the method.

Brian Moore (brian.moore@ucf.edu)
University of Central Florida
Title: "Exponential discrete gradient schemes for linearly damped-driven Poisson systems"
Abstract: Conservative systems have properties (such as energy and Casimirs) that are desirable to preserve in

numerical simulations. In the presence of damping and driving forces those conservative properties inevitably break down, but when the forcing and/or damping is linear, with coefficients that depend on time, dynamic changes in those properties may sometimes be preserved through discretization. In particular, using discrete gradient methods for the conservative/nonlinear part and the exact flow for the nonconservative/linear part, provides methods that preserve symmetries as well as dynamic changes in energy and quadratic Casimirs. Theoretical and numerical results illustrate the advantages of these methods.

Joshua Lee Padgett (padgett@uark.edu)
University of Arkansas
Title: "Structure-preserving nonlinear operator splitting methods for singular partial differential equations"
Abstract: In recent years, there has been a large increase in interest in numerical algorithms which preserve various qualitative features of the original continuous problem. In this talk, we propose and investigate a numerical algorithm which preserves qualitative features of certain singular partial differential equations. In particular, we propose an implicit nonlinear operator splitting algorithm which allows for the natural preservation of solution positivity and monotonicity. Furthermore, we present a convergence analysis of the algorithm in which the explicit dependence on the singularity is quantified in a nonlinear setting.

Bruce Wade (bruce.wade@louisiana.edu)
University of Louisiana at Lafayette
Title: "Dimensional Splitting with Exponential Time Differencing Schemes for Advection-Diffusion-Reaction Systems"
Abstract: Dimensional splitting formulation for Exponential Time Differencing (ETD) schemes is advantageous for advection-diffusion-reaction systems. These methods are introduced and analyzed for their effectiveness, including smoothing properties when applied to systems with nonsmooth or mismatched data. Several dimensional splitting strategies are presented, with an analysis of speedup. Robust performance under a variety of types of problems is empirically developed.

Emmanuel Asante-Asamani (easantea@clarkson.edu)
Clarkson University
Title: "Exponential time differencing with real distinct poles for simulating chemotaxis problems."
Abstract: Collective migration of cells in response to a chemical gradient (chemotaxis) is important for many biological processes such as tumor angiogenesis and aggregation of unicellular organisms. Mathematical models of these processes fall under the class of advection-diffusion-reaction equations posed in 2D or 3D, having nonlinear advection, stiff linear diffusion and possibly stiff nonlinear reaction kinetics. In this work, we apply a second order exponential time differencing scheme (ETD-RDP) to solve chemotaxis problems. I will discuss the preservation of order, positivity of ETD-RDP and the efficiency of a dimensional splitting variant of the scheme (ETD-RDP-IF) compared with IMEX methods.

Julienne Kabre (jkabre@nova.edu)
Nova Southeastern University
Title: "A preservative operator splitting approximation of the solution of a variable coefficient quenching problem"
Abstract: A physics preserving numerical solution of a two-dimensional adjoint reaction-diffusion equations with nonlinear singular forcing terms over rectangular domains is studied. The equations considered may generate strong quenching singularities. The investigation focuses on a variable time step Peaceman-Rachford splitting method. The time adaptation is implemented based on arc-length estimations of the first time derivative of the solution. The two-dimensional problem is split into several one-dimensional problems to significantly reduce computational cost. The monotonicity and localized linear stability of the variable step scheme are investigated. Numerical examples illustrate our results, and demonstrate the viability and efficiency of the method over existing ones.

Jacob Moore (jacob_moore5@baylor.edu)
Baylor University

Title: "Locally mass conservative partitioned numerical methods for poroelasiticy"
Abstract: In this work we propose a new finite element method for poroelasticity problems. A new enriched Galerkin method is used for spatial discretization, so local mass conservation is satisfied. For time discretization we use a partitioned scheme which solve the elasticity equation and the porous media equation sequentially. In this partitioned scheme the matrices of linear systems are symmetric positive definite, so efficient iterative solver algorithms can be used.

Yanzhi Zhang (zhangyanz@mst.edu)
Missouri University of Science and Technology
Title: "Numerical methods for the tempered fractional Laplacian and its applications"
Abstract: In this talk, I will present an new finite difference method to discretize the tempered integral fractional Laplacian and apply it to study the tempered effects on the solution of problems arising in various applications. Compared to other existing methods, our method has higher accuracy and simpler implementation. Error analysis will be discussed along with numerical experiments. Since our method yields a (multilevel) Toeplitz stiffness matrix, one can design fast algorithms via the fast Fourier transform for efficient simulations. Finally, we apply it together with fast algorithms to study the tempered effects on the solutions of various tempered fractional PDEs, including the Allen-Cahn equation and GrayScott equations.

Yixuan Wu (ywx7c@mst.edu)
University of Missouri System
Title: "Unified Meshfree Pseudospectral Methods for Solving Classical and Fractional PDEs"
Abstract: Fractional partial differential equations have been well recognized for their ability to describe anomalous diffusion phenomena in many complex systems. However, the existing numerical methods have to solve classical and fractional problems separately. In this talk, I will present a novel meshfree pseudospectral method based on the generalized inverse multiquadric or Gaussian radial basis functions. Our method unifies the discretization of classical and fractional Laplacians and also bypasses numerical approximation to the hypersingular integral of fractional Laplacian, and simple and easy when handling complex geometries and local refinements, and its computer program implementation remains the same for high dimension.

18. Optimal measures and point configurations

Organized by: Alexey Glazyrin (Alexey.Glazyrin@utrgv.edu), *University of Texas Rio Grande Valley*

Dmitriy Bilyk (dbilyk@math.umn.edu)
University of Minnesota
Title: "Positive definiteness and energy minimization"
Abstract: While the connection between positive definiteness of kernels and minimization of energy integrals and discrete energies is well known, we explore this topic more extensively and find that, under certain standard conditions (existence of an invariant measure), many (more than ten) natural conditions are, in fact, equivalent.

Ryan Matzke (matzke@math.tugraz.at)
TU Graz
Title: "Estimates for energies on projective spaces"
Abstract: We use the theory of determinantal point processes to give upper bounds for the minimal Green and Riesz energies on the real, complex, and quaternion projective spaces, and the Cayley Plane.

Alexey Garber (alexey.garber@utrgv.edu)
University of Texas Rio Grande Valley
Title: "Substitution tilings with transcendental inflation factor"
Abstract: Classical substitution schemes or tilings use finite alphabets or finitely many prototiles. The Perron-Frobenius theory in these settings implies that the (natural) inflation factor in this case must be an algebraic number as it is given as the largest eigenvalue of the substitution matrix. In the talk I plan to describe a framework for

construction of substitution families on infinite alphabets with arbitrary (sufficiently large) inflation factors, including transcendental inflation factors. Moreover, these families generate subshift dynamical systems that share many properties with classical dynamical systems originating from substitutions on finite alphabets. The talk is based on a joint work with Dirk Frettloh and Neil Manibo (Bielefeld University).

Josiah Park (j.park@tamu.edu)
Texas A&M University
Title: "Optimal energy for hard-spheres and equiangular lines"
Abstract: How does one spread lines (through the origin), or points on a sphere so as to minimize energy? We recently observed peculiarities in limiting problems of the above type, proving through linear programming methods that tight designs appear as discrete minimizers for "frame-like" continuous energies. These observations are an extension of a type of "universality" property of configurations now well studied. I will talk about recent developments in this area where we extend some of these universality properties to the setting where we require an energy minimizer to satisfy a minimal separation condition on the support.

Oleksandr Vlasiuk (oleksandr.vlasiuk@vanderbilt.edu)
Vanderbilt University
Title: "Clustering phenomena for short-range interactions"
Abstract: We will discuss the recent applications of short-range interactions to computing the asymptotics of optimal covering and packing for compact subsets of the Euclidean space. We will also outline the impact that the k-nearest neighbor truncation has on the clustering phenomena in weakly repulsive interactions.

Alexey Glazyrin (Alexey.Glazyrin@utrgv.edu)
University of Texas Rio Grande Valley
Title: "Price of SDP relaxations for spherical codes"
Abstract: In order to analyze spherical codes, oftentimes exact descriptions of codes are substituted by linear and semidefinite conditions. Although convenient in many situations, such substitution may lose some information about the code. We study the price one has to pay when utilizing it. As the main result, we show that semidefinite relaxations imply the rank condition for dimension 2 but not for higher dimensions. We also determine a large set of scenarios when linear conditions in dimension 2 are sufficient as well.

19. Recent advances in Image processing and Data Sciences

Organized by: Mujibur Rahman Chowdhury (mujib@smu.edu), *Southern Methodist University*

Yifei Lou (yifei.lou@utdallas.edu)
University of Texas Dallas
Title: "Graph Regularized Models for Blind Hyperspectral Unmixing"
Abstract: Blind hyperspectral image unmixing is the process of identifying the spectra of pure materials (i.e., endmembers) and their proportions (i.e., abundances) at each pixel. I will talk about a graph total variation (gTV) regularize the abundance map. To further alleviate the computational cost, we apply the Nystrom method to approximate a fully-connected graph by a small subset of sampled points, and adopt the Merriman-Bence-Osher (MBO) scheme by decomposing a grayscale image into a bit-wise form. A variety of numerical experiments on synthetic and real hyperspectral images are conducted, showcasing the potential of the proposed method.

Asim Kumer Dey (adey@utep.edu)
University of Texas at El Paso
Title: "Topological anomaly detection in a temporal transportation network"
Abstract: The past two decades have seen increasing interest in the application of network analysis to improve our understanding of transportation systems. Such complex transportation systems are vulnerable to failure from various hazards including hurricanes, earthquakes, and intentional attacks such as terrorism. In this study, we introduce a novel approach to identify anomalies in temporal transportation networks employing the tool of topological data

analysis (TDA). The proposed TDA based method systematically tracks the evolution of the network and detects changes in the underlying network topology and geometry. We demonstrate the new topological anomaly detection framework on the Texas transportation network during Hurricane Harvey.

Yifeng Gao (yifeng.gao@utrgv.edu)
University of Texas Rio Grande Valley
Title: "Efficient Frequent Pattern Mining in Large-Scale Time Series "
Abstract: Time series is one of the most commonly encountered data types, touching almost every aspect of human life, including areas such as environmental science, meteorology, and medicine. With the widespread use of sensor networks, many different massive time series have become ubiquitous in both industrial processes and research applications. The detection of frequent patterns, namely time series motif, is a fundamental task in time series data mining. Time series motifs play an important role in many downstream data mining tasks such as dimension-reduction, anomaly detection, classification, prediction, and clustering. They also can be used to compress data, remove noise and visualize large-scale data.

In this talk, I will first discuss the key challenges for motif discovery. Then I will briefly introduce recent advances in the recent motif discovery research. Specifically, I will present the high-level idea of two time- and space-efficient motif discovery algorithms to tackle the challenges and enable the detection of high-quality motifs in large-scale time series. Finally, I will also explain how the detected motifs can be used to solve the research problems in real-world applications.

Sachith Eranga Dassanayaka (sachith-eranga.dassanayaka@ttu.edu)
Texas Tech University
Title: "Classifying the Actors of the Information Operation Networks through a Machine Learning Technique"
Abstract: The information operation networks pose a significant threat to democratic processes. Building on existing scholarship on social media, we suggest a new probabilistic approach to map those types of operations. Using Twitter content identified as part of the Russian influence network, we classify accounts type based on their authenticity function for a sub-sample of accounts. Our predictive model attains 88% accuracy for the test set. We validate our predicted results by comparing with 3 million Russian troll tweets and Russian-language tweets datasets, and the accuracy scores indicate 90.7% and 90.5%, respectively. The validation results suggest that our model can use to identify the tweets actors.

20. Recent developments in finite element methods

Organized by: Cuiyu He (cuiyu.he@utrgv.edu), *University of Texas Rio Grande Valley*

Xu Zhang (xzhang@okstate.edu)
Oklahoma State University
Title: "A High-Order Immersed C0 Interior Penalty Method for Biharmonic Interface Problems"
Joint work with: Yuan Chen
Abstract: We introduce a high-order immersed C0 interior penalty method is for solving biharmonic interface problems on unfitted mesh. The P2 and P3 immersed finite element (IFE) spaces are constructed to accommodate biharmonic interface conditions in the least-squares sense. Basic properties of the new IFE spaces such as unisolvence and partition of unity are analyzed. A C0 interior penalty scheme with the new IFE space is proposed to solve the biharmonic interface problems. We proved the well-posedness of the discrete problem. Extensive numerical experiments show optimal convergence in L_2, H_1 and H_2 norms.

Ruchi Guo (ruchig@uci.edu)
University of California, Irvine
Title: "An Immersed Virtual Element Method for Solving H1 and H(curl) Interface problems"
Abstract: Due to the lower regularity, the finite element computation of H(curl) equations are in general sensitive to the conformity of approximation spaces. However, most of unfitted mesh methods in the literature are based

on non-conforming spaces which may cause loss of accuracy for H(curl) interface problems. In this talk, we will present our recent progress on this problem by developing a novel immersed virtual element method. The fundamental idea is to combine the conformity provided by newly constructed virtual functions solved from local interface problems and robust local approximation capabilities of existing IFE spaces. The new method guarantees the optimal accuracy of solving both the H1 and H(curl) Interface problems.

Natasha S Sharma (nssharma@utep.edu)
University of Texas at El Paso
Title: "First-Order Time Stepping schemes for sixth-order Cahn-Hilliard type equations modeling microemulsions "
Abstract: We consider a continuous interior penalty finite element approximation of a sixth order Cahn-Hilliard type equation which models the dynamics of phase transitions in ternary oil-water-surfactant systems. The temporal discretization is chosen so that a discrete energy law can be established leading to unconditional energy stability. Additionally, we show that the numerical method is unconditionally uniquely solvable. We conclude the talk with several numerical experiments demonstrating the unconditional stability and first order accuracy of the proposed scheme.

Lin Mu (linmu@uga.edu)
University of Georgia
Title: "Pressure robust scheme for incompressible flow"
Abstract: In this talk, we shall introduce the recent development regarding the pressure robust weak Galerkin finite element method (FEM) for solving incompressible flow. Weak Galerkin (WG) Method is a natural extension of the classical Galerkin finite element method with advantages in many aspects. For example, due to its high structural flexibility, the weak Galerkin finite element method is well suited to most partial differential equations on the general meshing by providing the needed stability and accuracy. In this talk, the speaker shall discuss the new divergence preserving schemes in designing the robust numerical schemes. Due to the viscosity independence in the velocity approximation, our scheme is robust with small viscosity and/or large permeability, which tackles the crucial computational challenges in fluid simulation. We shall discuss the details in the implementation and theoretical analysis. Several numerical experiments will be tested to validate the theoretical conclusion.

Cuiyu He (cuiyu.he@utrgv.edu)
University of Texas at Rio Grand Valley
Title: "Cut Finite Element Method and its Application to Shape Optimization"
Abstract: In this talk, we will firstly give a brief introduction to cut nite element methods (CutFEM). The motivation of CutFEM is to circumvent the meshing and remising procedure which is computational costive and challenging for (time dependent) problems with (moving) complex domain and interfaces. Moreover, the optimal accuracy of the method is guaranteed by enriching certain penalty terms. The remaining of the talk will focus on the application of CutFEM to an inverse free boundary Bernoulli problem. Note that the general framework can be extended to other shape optimization problems. The currently considered severely ill-posed inverse problem takes the form where only the Dirichlet condition is given on the free (unknown) boundary, whereas both Dirichlet and Neumann conditions are available on the fixed (known) boundary. We follow the classical shape optimization method in which a shape dependent cost functional is minimized among the set of admissible domains. The position of domain is represented implicitly by the level set function. The steepest descent gradient (shape derivative) method is applied for the level set evolution. CutFEM is involved to solve the PDE system arisen in the optimization analysis. *This talk is accessible to graduate students.*

Son-Young Yi (syi@utep.edu)
University of Texas at El Paso
Title: "A locking-free enriched Galerkin method for linear elasticity."
Abstract: In this talk, we propose a new locking-free enriched Galerkin method for solving the linear elasticity problem. The method is based on the discontinuous Galerkin formulation, but its approximation space is a continuous piecewise linear vector-valued function space enriched by some discontinuous piecewise linear functions. An a

priori error estimate of optimal order in the energy norm is independent of a Lame parameter l, hence the proposed method is free of volumetric locking when modeling incompressible materials. We provide several numerical examples to confirm the accuracy and the robustness of the new method and demonstrate a good performance of the preconditioner.

21. Redistricting: Mathematical and Political Perspectives

Organized by: Andrea Barreiro (abarreiro@smu.edu), *Southern Methodist University*

Joaquin Gonzalez (joaquin@texascivilrightsproject.org)
Texas Civil Rights Project
Title: "Where the Rubber Meets the Road: Introducing Political, Historical, and Legal Complexities into the Equation"
Abstract: TBA

Scott Cook (scook@tarleton.edu)
Tarleton State University
Title: "Improved Recombination MCMC with 2020 Census Results For Texas Redistricting"
Abstract: Recombination MCMC (Recom) developed by Tufts/MIT Metric Geometry and Gerrymandering Group improves convergence and coverage properties of Single-Flip MCMC redistricting. However, the Gerrychain implementation of Recomb was not able to accommodate extreme population imbalances created by 2020 Census results, the need to create 2 new US Congressional districts in Texas, nor the Texas House's "county-line" rule. We present modifications to Recomb MCMC that solved all three problems simultaneously and allowed real-time mathematical analysis of newly-proposed Texas redistricting plans. We also contrast statistical and visual properties of county-contraction rules used to keep low-population counties whole.

Anne Egelston (egelston@tarleton.edu)
Tarleton State University
Title: "Validating Mathematical Assumptions: A political science perspective"
Abstract: In Computational Redistricting and the Voting Rights Act, Becker et al (2021) present methodology to assess compliance with the Voting Rights Act (VRA) under MCMC ensemble redistricting methods implemented in GerryChain. However, this approach significantly simplified voter preferences by assuming that minority voters always prefer Democratic candidates at the precinct level. This presentation compares this assumption to 2020 presidential exit polling that estimate that 40% of Texas Hispanics voted for Trump, including a majority of voters in three Hispanic majority counties, and presents options to reconcile this discrepancy to produce more defensible VRA-analyses.

Betseygail Rand (brand@tlu.edu)
Texas Lutheran University
Will Hager (whager@tlu.edu)
Texas Lutheran University
Title: "Residential Segregation Patterns and Single Member Voting Districts: When is a fair district plan available?"
Abstract: We create 4200 synthetic cities which vary in percent minority population and their residential segregation patterns. Of these, 1200 are modeled on existing cities, and 3000 are rectangular grid cities. Each city is summarized by three traits: minority percent, a measure of segregation, and availability of a fair district plan. We find that when the minority population is around 25%-33%, there is a strong correlation between the degree of segregation and the availability of proportional district plan. When the minority population is under 20%, it is nearly impossible to generate a district plan that yields proportional representation.

22. Reproducibility, reliability, and robustness: confronting models from across mathematical biology with data

Organized by: Joshua Caleb Macdonald (joshua.macdonald1@louisiana.edu), *University of Louisiana at Lafayette*
Organized by: Juan B. Gutierrez (juan.gutierrez3@utsa.edu), *University of Texas at San Antonio*

Hana Dobrovolny (h.dobrovolny@tcu.edu)
Texas Christian University
Title: "Testing density-dependent infection rates for modeling of influenza"
Abstract: Standard ODE models of viral infection assume a constant infection rate that does not accurately reflect viral dynamics. Early in the infection, virus and target cells are not well-mixed, with high viral concentrations near cells that are actively producing virus and low viral concentrations elsewhere. ODE models assuming a density-dependent infection rate can better capture this effect. We examine several density-dependent infection rate models and compare their ability to reproduce in vitro influenza infection data.

Zhuolin Qu (zhuolin.qu@utsa.edu)
University of Texas at San Antonio
Title: "Network modeling the impact of male-screening on the Chlamydia trachomatis prevalence in women"
Abstract: Chlamydia trachomatis (Ct) is the most commonly reported bacterial sexually transmitted infection in the US and causes important reproductive morbidity in women. Despite three decades of screening women, the chlamydia prevalence remains high among young African Americans. Untested and untreated men can serve as a reservoir of infection in women. To quantify the effectiveness of the male-screening strategy, we create a stochastic network-based model to capture the assortative mixing among the targeted population. Our findings indicated that male-screening can reduce the prevalence among women in high-prevalence communities.

Brian Pidgeon (bdpidgeon@gmail.com)
Georgia State University
Title: "The Doubling Time Analysis for Modified Infectious Disease Richards Model with Applications to COVID-19 Pandemic. "
Abstract: In the absence of reliable information about transmission mechanisms for emerging infectious diseases, simple phenomenological models could provide a starting point to assess the potential outcomes of unfolding public health emergencies, particularly when the epidemiological characteristics of the disease are poorly understood or subject to substantial uncertainty. We employ the generalized Richards model to analyze the evolution of an epidemic in terms of the number of times cumulative cases double and the rate at which the intervals between consecutive doubling times increase. Our theoretical analysis of doubling times is combined with rigorous numerical simulations and uncertainty quantification using synthetic and real data for COVID-19 pandemic.

Amanda Laubmeier (amanda.laubmeier@ttu.edu)
Texas Tech University
Title: "Identifying importance of predator traits and behavior from prey abundance data"
Abstract: Predator-prey interactions form the basis for a range of ecosystem functions and services. However, predator effects on prey are determined by a multitude of traits and behaviors. We fit a predator-prey model based on traits and behaviors to experimental data from a controlled greenhouse. Experiments used fully factorial treatments using two prey species and four predator species in pairs and isolation. Preliminary model parameterization was not designed to distinguish between different model formulations. In subsequent work, we used aggregate data instead of replicate-based parameterization. Although this neglects some richness in the data, it highlights average differences and facilities comparison.

Joshua Caleb Macdonald (joshua.macdonald1@louisiana.edu)
University of Louisiana at Lafayette
Title: "Infectious disease dynamics necessarily operate across biological scales"

Abstract: We investigated within-host dynamics and among-host transmission of three strains of highly contagious, directly transmitted foot-and-mouth disease viruses (FMDVs) in their wildlife reservoir host, African buffalo. We combined data on viral dynamics, immune responses of buffalo experimentally infected with southern African territories serotypes of FMDV (SAT1, 2, 3) with non-linear ODE models to ask (i) How does the route of infection affect within-host dynamics? (ii) How do viral and immune dynamics vary among FMDV strains?; and (iii) Which viral and immune parameters determine viral replication within and transmission among hosts?

Ming Zhong (mingzhong@tamu.edu)
Texas A&M University
Title: "Machine Learning for Discovering Effective Interaction Kernels between Celestial Bodies from Ephemerides"
Abstract: Building accurate and predictive models of the underlying mechanisms of celestial motion has inspired fundamental developments in theoretical physics. We use a data-driven learning approach to a derive stable and accurate model for the motion of celestial bodies in our Solar System. Our model is based on a collective dynamics framework, and is learned from the NASA Jet Propulsion Lab's development ephemerides. By modeling the major astronomical bodies in the Solar System as pairwise interacting agents, our learned model generate extremely accurate dynamics that preserve not only intrinsic geometric properties of the orbits, but also highly sensitive features of the dynamics, such as perihelion precession rates.

Juan B. Gutierrez (juan.gutierrez3@utsa.edu)
University of Texas at San Antonio
Title: "Maximizing the Accuracy of COVID-19 Forecasting via Data Rectification"
Abstract: During the early stages of an epidemic, forecasting is particularly difficult. In this talk I present a novel method to rectify daily case counts reported in public databases in the context of COVID-19, so that they match the variable case count emerging from case tracing. Concomitantly, a choice of the objective function for parameterization can greatly simplify the complexity of model calibration. This analysis was conducted with a comprehensive data set of hospitalizations and cases in the metropolitan area of San Antonio through collaboration with local and regional government agencies, a level of data seldom studied in a disaggregated manner. The results obtained show a high level of agreement with data. An automated analysis pipeline guarantees reproducibility.

Quiyana Murphy (Qmurphy@vt.edu)
Virginia Tech
Title: "TCDD alters follicular homeostasis and aggravates autoimmunity in adult lupus mice"
Abstract: Although the precise cause of Systemic lupus erythematosus (SLE), a chronic autoimmune disease, is unknown, a number of environmental factors and immune abnormalities, have been identified as contributing factors. To investigate the effects of exposure to the prototypical ligand 2,3,7,8-tetrachlordibenzo-p-dioxin (TCDD) on SLE, we developed a deterministic mathematical model describing interactions between T follicular helper (Tfh) and T regulatory (Treg) cells, cytokines, and alpha-dsDNA antibody for which experimental data was collected after injection with TCDD or CH-223191, a ligand-selective antagonist of the AhR. Theoretical solutions were fitted to experimental data at three timepoints and used to predict SLE severity.

23. Robust methods for computational fluid dynamics

Organized by: Matthias Maier (maier@math.tamu.edu), *Texas A&M University*

Tarik Dzanic (tdzanic@tamu.edu)
Texas A&M University
Title: "FIXME"
Abstract: We will present a modification of explicit Runge-Kutta temporal integration schemes that preserves any locally-defined quasiconvex set of bounds for the solution. These schemes operate on the basis of a bijective mapping between an admissible set of solutions and the real domain to strictly enforce bounds, and they are proven to

recover the order of accuracy of the underlying Runge-Kutta method upon which they are built. Within this framework, we show that it is possible to recover a wide range of methods independently of the spatial discretization, including positivity preserving, discrete maximum principle satisfying, entropy dissipative, and invariant domain preserving schemes.

Loic Cappanera (lmcappan@central.uh.edu)
University of Houston
Title: "FIXME"
Abstract: We present two numerical methods to approximate the incompressible Navier-Stokes equation with variable density and viscosity. Both methods use the momentum, equal to the density times the velocity, as primary unknown and are made suitable for spectral elements by an adequate treatment of nonlinearities and diffusion operator. The incompressibility condition is respectively enforced via the use of projection methods and artificial compression methods. Stability and robustness of both methods are compared on a large range of problems involving large ratio of density, surface deformations and magnetohydrodynamics instabilities.

Bojan Popov (popov@math.tamu.edu)
Texas A&M University
Title: "Invariant domain preserving ALE approximation of the Euler equation"
Abstract: A second-order continuous finite element technique for solving hyperbolic systems in the arbitrary Lagrangian Eulerian framework (ALE) will be presented. The main property of the method is that the approximate solution produced by the algorithm is second-order accurate in space, conservative and preserves the invariant sets of the hyperbolic system desired by the user. The time stepping is explicit and the approximation in space is done with continuous finite elements. The mesh optimization strategy is based on a high order reconstruction of the Lagrangian velocity and a smoothing of the mesh.

Rami Masri (ramimasri14@gmail.com)
Rice University
Title: "Stability and convergence of high order discontinuous Galerkin methods for incompressible flow"
Abstract: Solving the incompressible Navier-Stokes equations presents a challenging computational task primarily due to the coupling of the velocity and pressure by the incompressibility constraint and to the nonlinear convection term. Projection algorithms decouple this nonlinearity from the pressure term. Such algorithms are favorable since, at each timestep, the saddle point problem is replaced by elliptic equations. This is particularly important for large scale problems in complicated computational domains. In this talk, we formulate and theoretically analyze an unconditionally stable discontinuous Galerkin discretization of the pressure correction approach which features high order spatial accuracy.

Yimin Lin (yiminlin@rice.edu)
Rice University
Title: "A positivity preserving strategy for entropy stable discontinuous Galerkin discretizations of the compressible Euler and Navier-Stokes equations"
Abstract: High order entropy stable discontinuous Galerkin methods for the compressible Euler and Navier-Stokes equations assume the positivity of physical quantities. In this work, we introduce a positivity limiting strategy for entropy stable discontinuous Galerkin discretizations based on convex limiting. The key ingredient in the limiting procedure is the low order positivity-preserving discretization based on graph viscosity terms. Numerical experiments in 2D confirm the accuracy and robustness of the proposed strategy.

Ignacio Tomas (nachotet@gmail.com)
Sandia National Laboratories
Title: "Compressible Navier-Stokes: numerical schemes with mathematically guaranteed properties."
Abstract: We present a scheme for the compressible Navier-Stokes equations that: (i) Is invariant domain preserving and satisfies global balance of total mechanical energy. (ii) The scheme runs at the usual "hyperbolic CFL" $\mathrm{d}t \leq O(h)$ dictated by Euler's subsystem, rather than the technically inapplicable "parabolic CFL" $\mathrm{d}t \leq O(h^2)$. The scheme uses operator splitting in time: key details are related to careful construction of viscous dissipation

terms and the choices of space and time discretization used at each sub-stage. The scheme is second-order accurate in space and time and exhibits remarkably robust behavior in the context of shock-viscous-layers interaction.

Robert Kirby (robert_kirby@baylor.edu)
Baylor University
Title: "Bounds-constrained polynomial approximation using the Bernstein basis"
Abstract: A fundamental problem in numerical analysis and approximation theory is approximating smooth functions by polynomials. A much harder version under recent consideration is to enforce bounds constraints on the approximating polynomial. In this paper, we consider the problem of approximating functions by polynomials whose Bernstein coefficients with respect to a given degree satisfy such bounds, which implies such bounds on the approximant. We frame the problem as an inequality-constrained optimization problem and give an algorithm for finding the Bernstein coefficients of the exact solution. Additionally, our method can be modified slightly to include equality constraints such as mass preservation. It also extends naturally to multivariate polynomials over a simplex.

24. Spectral theory of discrete and continuous models in quantum mechanics

Organized by: Rui Han (rhan@lsu.edu), *Louisiana State University*
Organized by: Stephen Shipman (shipman@lsu.edu), *Louisiana State University*

Giorgio Young (giorgio.young@gmail.com)
Rice University
Title: "Ballistic transport for limit-periodic continuum Schrödinger operators in one dimension"
Abstract: In this talk, I will discuss recent work examining the transport properties of the class of limit-periodic continuum Schrödinger operators whose potentials are approximated exponentially quickly by a sequence of periodic functions. For such an operator H and $X_H(t)$ the Heisenberg evolution of the position operator, we show the limit of $\frac{1}{t}X_H(t)\psi$ as $t \to \infty$ exists and is nonzero for $\psi \neq 0$ belonging to a dense subspace of initial states which are sufficiently regular and of suitably rapid decrease. This is viewed as a particularly strong form of ballistic transport, and this is the first time it has been proven in a continuum almost periodic non-periodic setting.

Wencai Liu (wencail@tamu.edu)
Texas A&M University
Title: "Fermi isospectrality for discrete periodic Schrodinger operators"
Abstract: Let $\Delta + V$ be the discrete Schrodinger operator, where Δ is the discrete Laplacian on $\mathbb{Z}^d$ and the potential $V : \mathbb{Z}^d \to \mathbb{R}$ is periodic. We prove two rigidity theorems for discrete periodic Schrodinger operators in any dimension $d \geq 3$: (1) if two Γ-periodic potentials V and Y are Fermi isospectral, and Y is a separable function, then V is separable; (2) if two Γ-periodic potentials V and Y are Fermi isospectral and both $V = \bigoplus_{j=1}^r V_j$ and $Y = \bigoplus_{j=1}^r Y_j$ are separable functions, then, up to a constant, lower dimensional decompositions V_j and Y_j are Floquet isospectral, $j = 1, 2, \cdots, r$.

Jake Fillman (fillman@txstate.edu)
Texas State University
Title: "Spectral approximation for quasiperiodic Jacobi operators"
Abstract: Quasiperiodic Jacobi operators arise as mathematical models of quasicrystals and in more general studies of structures exhibiting aperiodic order. Such operators can be approximated by periodic ones, the spectra of which can be computed via two finite dimensional eigenvalue problems. Since long periods are necessary for detailed approximations, both computational efficiency and numerical accuracy become a concern. We describe a simple method for numerically computing the spectrum of a period-K Jacobi operator in O(K^2) operations.

Ethan Gwaltney (ewg3@rice.edu)
Rice University
Title: "Stahl-Totik Regularity for Dirac Operators"

Joint work with: Benjamin Eichinger and Milivoje Lukic.
Abstract: We introduce a theory of regularity for Dirac operators with uniformly locally square-integrable operator data. This is motivated by Stahl-Totik regularity for orthogonal polynomials and by recent developments for continuum Schrödinger operators, but contains significant new phenomena. In contrast with regularity in the contexts of orthogonal polynomials or Schrödinger operators, regularity for a Dirac operator will be characterized by not just one scalar equality, but a family of equalities. We will discuss how such complications arise and consider applications to Dirac operators with ergodic and decaying operator data.

Rodrigo Matos (matosrod@tamu.edu)
Texas A&M University
Title: "Irreducibility of the Bloch Variety for Finite-Range Schrdinger Operators"
Joint work with: Jake Fillman and Wencai Liu
Abstract: We study the Bloch variety of discrete Schrdinger operators associated with a complex periodic potential and a general finite-range interaction, showing that the Bloch variety is irreducible for a wide range of lattice geometries in arbitrary dimension. Examples include the triangular lattice and the extended Harper lattice.

Frank Sottile (sottile@math.tamu.edu)
Texas A&M University
Title: "Toric compactifications and discrete periodic operators"
Abstract: Toroidal compactifications of Bloch varieties and Fermi surfaces for operators on discrete periodic graphs were used in the 1990's, for certain classes of graphs. The theoretical foundations for toroidal compactifications—toric varieties has advanced considerably since then. I will explain how to associate a pair of projective toric varieties to any discrete periodic graph such that the Bloch variety and Fermi surfaces of any operator are naturally hypersurfaces, providing a uniform construction of compactifications. These toric varieties admit a non-standard structure as real algebraic varieties. When the operator is self-adjoint, the Bloch variety and Fermi surfaces are real hypersurfaces.

Matthew Faust (mfaust@math.tamu.edu)
Texas A&M University
Title: "The number of critical points of discrete periodic operators"
Joint work with: Frank Sottile
Abstract: The spectral gap conjecture is a well known and widely believed conjecture in mathematical physics concerning the structure of the Bloch variety (dispersion relation) of periodic operators. The Bloch variety of a discrete operator is algebraic, inviting methods from algebraic geometry to their study. Motivated by this conjecture, this talk will introduce a bound on the number of critical points of the dispersion relation for discrete periodic operators, and provide a general criterion for when this bound is achieved. We also present a class of periodic graphs for when this criteria is satisfied for Laplace-Beltrami operators.

Jorge Villalobos (jvill38@lsu.edu)
Louisiana State University
Title: "Reducibility of the Fermi surface for magnetic Schrdinger graph operators"
Abstract: Reducibility of the Fermi surface for a periodic operator is a key for the existence of embedded eigenvalues caused by a local defect. We consider a bilayer combinatorial graph as a model for a quantum system subject to a perpendicular magnetic field, and its application to AA-stacked graphene. Some techniques from non-magnetic operators extend to magnetic ones, but the magnetic case is more complex because a typical magnetic operator on a periodic graph is merely quasi-periodic.

Jonathan Stanfill (jonathan_stanfill@baylor.edu)
Baylor University
Title: "Spectral zeta functions for singular Sturm–Liouville operators and the generalized Bessel equation"
Joint work with: Guglielmo Fucci, Fritz Gesztesy, and Klaus Kirsten
Abstract: We employ a recently developed unified approach to the computation of traces of resolvents and zeta

functions to compute spectral zeta functions associated to singular (three-coefficient) self-adjoint Sturm–Liouville differential expressions. We discuss how this approach can be used to efficiently compute positive integer values of the spectral zeta function. As an application we end by discussing the generalized Bessel equation on a finite interval including computing the sum of the inverse even powers of certain Bessel function zeros.

Selim Sukhtaiev (szs0266@auburn.edu)
Auburn University
Title: "Asymptotic perturbation theory for extensions of symmetric operators"
Abstract: This talk concerns asymptotic perturbation theory for varying self-adjoint extensions of symmetric operators. First, we will discuss a symplectic version of the celebrated Krein formula for resolvent difference. Then we will switch to an asymptotic analysis of resolvent operators via first order expansion for the path of Lagrangian planes associated with perturbed operators. This asymptotic perturbation theory yields an Hadamard–Rellich-type variational formula for multiple eigenvalue curves bifurcating from an eigenvalue of the unperturbed operator. Applications will be given to quantum graphs, periodic Kronig–Penney model, elliptic second order partial differential operators with Robin boundary conditions, and heat equations with thermal conductivity.

Fan Yang (yangf@lsu.edu)
Louisiana State University
Title: "Sharp analysis of localization with two types of arithmetic resonances: Maryland model for all parameters"
Joint work with: Rui Han and Svetlana Jitomirskaya
Abstract: Maryland model is a family of 1D quasiperiodic Schrodinger operator with tangent potential function. It is known to have a sharp (in all parameters) spectral transition line between purely singular continuous spectrum to pure point spectrum. In this talk I will first present a new proof of Anderson localization in the sharp regime using the Green's function method. Then we will discuss the advantages of the Green's function proof, which allows us to obtain asympotitcs of quasiperiodic eigenfunctions.

Cosmas Kravaris (cosmaskravaris@tamu.edu)
Texas A&M University
Title: "On the density of the pure point spectrum of periodic difference operators"
Abstract: Using the Hilbert basis theorem, we show that a difference operators on $\mathbb{Z}^d$-periodic graphs has finitely many finite support eigenfunctions up to translations and linear combinations. We show that this property can be used to calculate the density of elements of the pure point spectrum (i.e. eigenvalues) and illustrate the techniques on the Kagome lattice. Next, we provide a formula for the density of eigenvalues on $\mathbb{Z}^d$-periodic graphs using syzygy modules. If time permits, we generalize the claims to G-periodic graphs whose acting group G is virtually polycyclic.

25. Recent Advances in Model Order Reduction and Applications in Inverse Problems

Organized by: Alexander Mamonov (mamonov@math.uh.edu), *University of Houston*
Organized by: Maxim Olshanskii (maolshanskiy@uh.edu), *University of Houston*

Traian Iliescu (iliescu@vt.edu)
Virginia Tech
Title: "ROM Closures and Stabilizations for Convection-Dominated, Under-Resolved Flows"
Abstract: I will survey closures and stabilizations that tackle the reduced order model (ROM) inaccuracy in the convection-dominated, under-resolved regime, i.e., when the number of DOFs is too small to capture the complex underlying dynamics. I will present regularized ROMs, which are stabilizations that employ spatial filtering to alleviate the spurious numerical oscillations generally produced by standard ROMs. I will also survey ROM closures, i.e., correction terms that increase the ROM accuracy: (i) functional closures, based on physical insight; (ii) structural closures, developed by using mathematical arguments; and (iii) data-driven closures, which leverage

available data. Throughout my talk, I will highlight the impact made by data on classical numerical methods over the past decade.

Vladimir Druskin (vdruskin@wpi.edu)
Worcester Polytechnic Institute
Title: "Lippmann-Schwinger-Lanczos algorithm for inverse scattering problems"
Abstract: Data-driven reduced order models (ddROMs) are combined with the Lippmann-Schwinger integral equation to produce direct and iterative nonlinear inversion methods. The ROM is viewed as a Galerkin projection and is sparse due to Lanczos orthogonalization. Embedding into the continuous problem, a data-driven internal solution is produced. This internal solution is then used in the Lippmann-Schwinger equation, in direct or iterative framework. The new approach allows us to process non-square matrix-valued data-transfer functions, i.e., to remove the main limitation of the earlier versions of the ddROM inversion algorithm.

Jorn Zimmerling (jzimmerl@umich.edu)
University of Michigan
Title: "Imaging and inverse scattering using ROM estimates of internal waves"
Abstract: In this talk we consider inverse scattering of a wave equation in a reduced-order modelling framework. We show how a data-driven reduced-order model, constructed from observations of scattered waves, can be used to estimate the Greens function inside an unknown medium. Subsequently, we shown how this estimation can be used for fast imaging and to solve inverse scattering problems.

Ruhui Jin (rhjin@math.utexas.edu)
University of Texas Austin
Title: "Tensor-structured sketching for constrained least squares"
Abstract: Constrained least squares problems arise in many applications, including electrical impedance tomography and inverse problems. Their memory and computation costs are expensive in practice. We employ the so-called "sketching" strategy to project the least squares problem onto a space of a much lower "sketching dimension". Tensor structure is often present in the data matrices of least squares. In this work, we utilize a general class of row-wise tensorized sub-Gaussian matrices as sketching matrices in constrained optimizations for the sketching design's compatibility with tensor structures. We provide theoretical guarantees on the sketching dimension in terms of the geometric complexity of the underlying problems.

Alexander Mamonov (mamonov@math.uh.edu)
University of Houston
Title: "Interpolatory tensorial reduced order models for parametric dynamical systems"
Abstract: We introduce a novel projection based model order reduction technique for dynamical systems depending on multiple parameters. We search for a projection basis in a parameter-specific way to emphasize the tensor-product structure of the parameter space. Hence, we utilize tensor decomposition techniques such as canonical polyadic, high order SVD, and tensor train to compress a tensor of solution snapshots. We refer to this process as an offline stage as it is performed only once for a given dynamical system. At the subsequent online stage we compute a reduced order model for particular values of system parameters using interpolation and fast linear algebra algorithms. Numerical results comparing the proposed method to conventional POD-ROM are presented.

Poster presentations

Isanka Garli Hevage (Isankaupul.Garlihevage@ttu.edu)
Texas Tech University
Title: "On Einstein - Brownian flow between porous media and fracture with local and non-local conditions on the fracture."
Joint work with: Akif Ibragimov

Aaron Welters (awelters@fit.edu)
Florida Institute of Technology
Title: "Bessmertnyi Realization Theorem for Rational Functions of Several Complex Variables with Symmetries"

Adam Shaker (shaker42751@gmail.com)
University of Texas at Dallas
Title: "Interactions of Matrix Shape, Coherence, and Rank"

Ali Irfan Khan (ali.irfan2136@gmail.com)
University of Western Ontario
Title: "Analyzing Global Life Expectancy using Multi-Linear Regression"

Andre Martins Rodrigues (andre02@ucsb.edu)
University of California
Title: "The buckling load of cylindrical shells under axial compression depends on the cross-section geometry parameters"

Gilbert Ymbert (gymbert@collin.edu)
Collin College
Title: "Advances in Krylov subspaces, preconditioning and analysis"

Jesus Saldana (jesus.saldana01@utrgv.edu)
University of Texas Rio Grande Valley
Title: "Advances in Krylov subspaces, preconditioning and analysis"

Miguel Mascorro (miguel.mascorro01@utrgv.edu)
University of Texas Rio Grande Valley
Title: "The Bridge Between the Field of Values and Systems of Linear Equations"

Anthony Stefan (astefan2015@my.fit.edu)
Florida Institute of Technology
Title: "Symmetric determinantal representation of polynomials: Applications in realizability theory of effective tensors"

Asha Barua (asha.barua01@utrgv.edu)
University Of Texas Rio Grande Valley
Title: "Maxwell's equation for Radar Image Processing"

Aurod Ounsinegad (Aurod.Ounsinegad@go.tarleton.edu)
Tarleton State University
Title: "Dynamics of Eastern Equine Encephalitis Infection Rates: A Mathematical Approach"

Avery Campbell (avery.campbell@go.tarleton.edu)
Tarleton State University
Title: "Supraventricular Tachycardia Study Using a Dynamic Computer Generated Atria"

Bilyana Tzolova (bmt3@rice.edu)
Rice University
Title: "Automated Vessel Segmentation in the Liver Organ"

Brenda Lee Garcia (brenda.garcia01@utrgv.edu)
University of Texas Rio Grande Valley
Title: "Locally Modeling Signals by Constant Coefficient Linear and Nonlinear ODE's"

Christina Taylor (cgt3@rice.edu)
Rice University
Title: "A Reservoir Based Model for Measuring Physical Exertion"

Chunyang Liao (liaochunyang@tamu.edu)
Texas A&M University
Title: "Learning/Recovering a unknown function from given data"

Cody Drolet (Cody.drolet@go.tarleton.edu)
Tarleton State University
Title: "Making unbiased maps to pass the ""eyeball test"" via MCMC redistricting"

Diana Sanchez (disanchezm@unal.edu.co)
Universidad Nacional de Colombia, Colombia
Title: "Qualitative behaviour of the solutions to a quasilinear problem from a generalized Pohozaev's Identity"

Jerry Luckenbaugh (jvl170030@utdallas.edu)
University of Texas at Dallas
Title: "Coupled Oscillators and Hysteresis in Spare Networks"

John Zweck (zweck@utdallas.edu)
University of Texas at Dallas
Title: "The essential spectrum of breathing pulses in a femtosecond laser"

Karl Habig (kth180000@utdallas.edu)
University of Texas at Dallas
Title: "Applying and Refining the CAD algorithm to Neuronal Cell Assemblies"

Kaylee Terrell (kaylee.terrell@go.tarleton.edu)
Tarleton State University
Title: "A mathematical model for Onchocerciasis and Resistance in Treatment"

Kenneth Lathrom (klathrom2014@my.fit.edu)
Florida Institute of Technology
Title: "The Z-problem in the Theory of Composites: Beyond Definite Operators"

Maria del Rosario Valencia (mariadelrosario.valenciaarevalo01@utrgv.edu)
University of Texas Rio Grande Valley
Title: "Matrix Representation of Differentiation Algorithm with respect to a suitable pair of points"

Radoslav G. Vuchkov (rvuchkov@ucmerced.edu)
Los Alamos National Laboratory
Title: "Challenging the curse of dimensionality in multidimensional numericalintegration by using a low-rank tensor-train format"

Alain Bensoussan (subas@utdallas.edu)
University of Texas at Dallas

Title: "Free Boundary Problem with Optimal Control"

Tong Wu (tong.wu@utsa.edu)
University of Texas at San Antonio
Title: "Well-Balanced Positivity Preserving Adaptive Moving Mesh Central-Upwind Schemes for the Saint-Venant System"

Trang Dinh (tndinh@crimson.ua.edu)
University of Alabama
Title: "A predictor-corrector method in quantized tensor train format for the equilibrium of the chemical master equation"

Weihua Geng (wgeng@smu.edu)
Southern Methodist University
Title: "A Cartesian FMM-Accelerated Galerkin Boundary Integral Poisson-Boltzmann Solver"

William Golding (wgolding@utexas.edu)
University of Texas at Austin
Title: "Unconditional Uniqueness of Small BV Solutions for the Isentropic Euler Equations with $\Gamma = 3$"

Yiran Shen (shenyiran91@utexas.edu)
University of Texas at Austin
Title: "Multi-parameter Full Waveform Inversion and Optimal Transport"

Nicholas Niako (nicholas.niako01@utrgv.edu)
University of Texas Rio Grande Valley
Title: "Firearm fatalities in the northern part of Ghana. "

Md Salman Rahman (mdsalman.rahman01@utrgv.edu)
University of Texas Rio Grande Valley
Title: "Combining Machine Learning and Satellite Imagery to Improve Landslide Susceptibility Prediction"

Swetank Mohan (sweetank.mohan01@utrgv.edu)
University of Texas Rio Grande Valley
Title: "Categorical Data Analysis based on Heart Failure clinical data obtained from the Kaggle website."

Amir Targholizadeh (amir.targholizadeh01@utrgv.edu)
University of Texas Rio Grande Valley
Title: "Robust Higher Harmonic Generation at Exceptional Points"

Prosanta Barai (prosanta.barai01@utrgv.edu)
University of Texas Rio Grande Valley
Title: "Determining the Factors Associated with Child Underweight"

Pablo Aldame (pablo.aldama01@utrgv.edu)
University of Texas Rio Grande Valley
Title: "Regression trees modeling of Bodyfat"