

Curriculum Vitae

Gabriel Herczeg

Research Experience

Brown Theoretical Physics Center

-Gauge/gravity double copy (current, from 2019)

With Gilly Elor, Kara Farnsworth, and Michael Graesser, I developed the “Newman-Penrose map”—a correspondence between exact solutions of general relativity and classical electrodynamics that extends the classical double copy to a new space of solutions and elucidates its geometric significance. Recently, Kara Farnsworth, Michael Graesser and I reformulated the Newman-Penrose map in terms of quantities naturally defined on twistor space. This reformulation is invariant under both spacetime diffeomorphisms and projective transformations on twistor space, and might serve as a powerful theoretical tool for extending the Newman-Penrose map to an even broader class of spacetimes. In ongoing work with Kara Farnsworth and Michael Graesser, I extend the Newman-Penrose map to double Kerr-Schild spacetimes, focusing Plebanski-Demianski family of solutions as an example. In another ongoing project with Kara Farnsworth and Michael Graesser, I study some explicit examples of vacuum Kerr-Schild spacetimes with Petrov type II in the context of the classical double copy using the Newman-Penrose map.

-Aspects of Quantum Cosmology (Current from 2020)

With Stephon Alexander and João Magueijo, I studied a formal expression for a wavefunction of the universe defined as the Fourier dual of the Chern-Simons state. In the minisuperspace approximation, this expression reproduces the Hartle-Hawking state when the integration contour is taken over the real line. We viewed this formal expression as a generalization of the Hartle-Hawking state beyond mini-superspace and used it to produce wavefunctions for anisotropic cosmological models and black holes. Taking the Einstein-Cartan theory as the fundamental classical theory rather than general relativity allows for the possibility of quantum torsion with possibly far-reaching consequences. In a related project with Stephon Alexander, João Magueijo and Emma Albertini, I investigated the effect of quantum torsion on the “probability of inflation.” We found a complete set of solutions to the Wheeler DeWitt equation that are eigenstates of the torsion and that generalize Vilenkin’s tunneling wave function. With respect to this complete set, general solutions can be constructed as linear superpositions in the torsion. In particular, we performed a detailed study of Gaussian wave packets centered around zero torsion.

-Cosmology and black holes in topologically modified gravity (2019-2021)

With Stephon Alexander, Jinglong Liu, and Evan McDonough, I investigated the cosmological implications of a modified gravity model that resolves aspects of the cosmological constant problem by confining quantum corrections to vacuum energy within a “topological sector” of the theory that classically decouples from the gravitational field. By coupling fermions to this model, we obtained a tight relationship between the chiral anomaly and the cosmological constant. The smallness of the

observed cosmological constant can then be explained from the point of view of technical naturalness and chiral symmetry-breaking. In recent work with Stephon Alexander, Steven Clark and Michael Toomey, I extend the model (without fermions) to include a gauge kinetic term, which sources fluctuations of the cosmological constant, with implications for black hole physics and cosmology.

UC Davis

-Quantization of contact structures (2016 – 2021)

With Andrew Waldron, I developed a reformulation of quantum mechanics in terms of the geometry of "phase-spacetime"---an odd dimensional manifold coordinatized by generalized position, momentum and time variables. Classical dynamics is determined by a choice of contact one-form on phase-spacetime. BRST quantization leads to a totally constrained system with elements of the physical Hilbert space satisfying a parallel transport condition. In recent work with Roger Casals and Andrew Waldron, I developed a mathematically rigorous extension of this program that quantizes equivalence classes of contact forms up to local rescaling. We also showed that the quantizations of these equivalence classes on manifolds of dimension $2n - 1$ are closely related quantizations of a fixed contact form on a manifold of dimension $2n + 1$.

-Shape Dynamic Black Holes (2010-2017)

Dissertation research focused on theoretical aspects of black holes in classical and quantum gravity, with a focus on classical black hole solutions in shape dynamics, which agree with the corresponding solutions of general relativity outside the event horizon, but disagree at and within the horizon, and which may therefore circumvent the information loss paradox. This research was conducted under the guidance of Steven Carlip.

Publications

Generalized Newman-Penrose Map and the Plebanski-Demianski Family (2022 *expected*)

K. Farnsworth, M. Graesser, G. Herczeg

In preparation

Type II Kerr-Schild Spacetimes and The Classical Double Copy (2022 *expected*)

G. Herczeg

In preparation

Torsion and the Probability of Inflation (2022)

E. Albertini, S. Alexander, G. Herczeg, J. Magueijo

Classical and Quantum Gravity (under review)

arXiv:2203.12640

Black Hole and Cosmological Analysis of BF Sequestered Gravity (2021)

S. Alexander, S. J. Clark, G. Herczeg, M. W. Toomey

Physical Review D

arXiv:2110.09503

Twistor Space Origins of the Newman-Penrose Map (2021)

K. Farnsworth, M. Graesser, G. Herczeg

SciPost Physics Core (under review)

arXiv:2104.09525

Dynamical Quantization of Contact Structures (2021)

R. Casals, G. Herczeg, A. Waldron

Communications in Mathematical Physics (under review)

arXiv:2103.16645.

A Generalized Hartle-Hawking Wavefunction (2020)

S. Alexander, G. Herczeg, J. Magueijo

Classical and Quantum Gravity

arXiv:2012.08603.

The Newman-Penrose Map and the Classical Double Copy (2020)

G. Elor, K. Farnsworth, M. Graesser, G. Herczeg

Journal of High Energy Physics

arXiv:2006.08630.

Chiral Symmetry and the Cosmological Constant (2020)

S. Alexander, G. Herczeg, J. Liu, E. McDonough

Physical Review D

arXiv:2006.08630.

Contact Quantization: Quantum Mechanics = Parallel Transport (2018)

G. Herczeg, E. Latini, A. Waldron

Archivum Mathematicum (Brno).

arXiv:1805.11731.

Contact Geometry and Quantum Mechanics (2018)

G. Herczeg, A. Waldron

Physics Letters B

arXiv:1709.04557.

A Tour Through Shape Dynamic Black Holes (2017)

G. Herczeg

Dissertation

arXiv:1709.04557.

Parity Horizons in Shape Dynamics (2016)

G. Herczeg

Classical and Quantum Gravity

arXiv:1508.06704.

Towards Black Hole Entropy in Shape Dynamics (2015)

G. Herczeg, V. Shyam

Classical and Quantum Gravity

arXiv:1410.4248.

A Rotating Black Hole Solution for Shape Dynamics (2014)

H. Gomes, G. Herczeg

Classical and Quantum Gravity

arXiv:1310.6095.

Selected Invited Talks

Wavefunctions of the Universe and Quantum Torsion

May 7th, 2022 (planned)

Workshop on Chern-Simons gravity and quantum gravity

Institute for Computational and Experimental Research in Mathematics

Brown University

The Newman-Penrose Map and the Classical Double Copy

March 25th, 2022

Nexus/Simons workshop

Flatiron Institute

The Newman-Penrose Map and the Classical Double Copy

December 3rd, 2021

High energy theory seminar

Brown University

The Newman-Penrose Map and the Classical Double Copy

November 2nd, 2021

Center for Quantum Mathematics and Physics math seminar

UC Davis

The Newman-Penrose Map and the Classical Double Copy

October 29th, 2021

High energy theory seminar

Case Western Reserve University

Panelist

Golden Webinar in Astrophysics

October 8th, 2021

Main Speaker: Julian Barbour

Copanelists included Roger Penrose and Ted Jacobson

Institute of Astrophysics of Pontificia Universidad Católica de Chile

The Newman-Penrose Map and the Classical Double Copy

July 21st, 2020

New England Theoretical Cosmology Gravity and Fields Workshop
Dartmouth College

Contact Quantization: Quantum Mechanics = Parallel Transport

August 19th 2018

Perimeter Institute for Theoretical Physics

Black Holes and the Shape of Space

November 24th 2015

Brooklyn College Physics Department Colloquium

Parity Horizons and Chronology Protection in Shape Dynamics

June 25th 2015

SD @ Convergence Workshop

Perimeter Institute for Theoretical Physics

Other Selected Talks

Algebraically Special Spacetimes and the Goldberg-Sachs Theorem

February 20th 2020

Brown Theoretical Physics Center Journal Club

Unimodular Gravity, BF Theory, and the Cosmological Constant Problem

October 16th 2019

Brown Theoretical Physics Center Journal Club

Parity Horizons in Shape Dynamics

April 13th 2016

American Physical Society, April Meeting

Parity Horizons in Shape Dynamics

July 7th 2015

Friedrich Alexander Universität

Institute for Quantum Gravity

CPT Horizons and Chronology Protection in Shape Dynamics

March 14th 2015

31st Pacific Coast Gravity Meeting

University of Oregon, Eugene

Rotating Black Holes in Shape Dynamics

November 1st 2013

American Physical Society, Far-West Section Meeting

Sonoma State University

Education

Doctor of Philosophy (2017)

Physics

UC Davis

Master of Science (2012)

Physics

UC Davis

Bachelor of Science, Honors (2010)

Physics

City University of New York, Brooklyn College

Bachelor of Science, Honors (2010)

Mathematics

City University of New York, Brooklyn College

Awards and Distinctions

Featured (2015)

Centennial anniversary of general relativity

Special issue of Scientific American

Spring Travel Award (2015)

Graduate Student Association

UC Davis

Spring Travel Award (2014)

Graduate Student Association

UC Davis

FQXi Minigrant MGA-1404 (2014)

Foundational Questions Institute

TA Smits Memorial Award (2009)

City University of New York, Brooklyn College

TA Smits Memorial Award (2008)

City University of New York, Brooklyn College

Ida and Philip Klein Scholarship (2008)

City University of New York, Brooklyn College

Teaching Experience

Instructor, Brown University, (Fall 2021)

Department of Physics

Co-instructed Physics 40, algebra-based introductory electricity and magnetism course for students concentrating on technical disciplines other than physics and engineering (primarily pre-med students).

Mentor for Undergraduate Independent Study, Brown University (2019 – 2020)

Brown Theoretical Physics Center

Provided guidance and mentorship for an undergraduate student exploring the fundamentals of differential geometry in the context of an independent study. Met weekly with the student to discuss weekly readings and exercises.

Lecturer, Sierra College, Rocklin (2018 – 2019)

Department of Physics

Developed curriculum and materials for introductory Physics II, including electricity and magnetism, optics, waves. Prepared and presented lectures and labs, organized all aspect of the course. Sierra College, Rocklin is a community college, and my responsibilities included working closely with students to help them balance their educational and career goals with their often significant personal and family responsibilities. (Class size ~20).

Lecturer, UC Davis (2017 – 2018)

Department of Mathematics

Developed curriculum and materials for various introductory calculus courses, as well as linear algebra and introduction to abstract mathematics. Prepared and presented lectures, managed TAs, organized all aspect of the course. (Enrollment varied from ~80 – 275).

Associate Instructor, UC Davis (2016 – 2017)

Department of Physics

Developed curriculum and materials including lecture slides, problem sets and exams for introductory algebra-based mechanics course. Prepared and presented lectures, managed TAs, organized all aspect of the course. (Enrollment ~175).

Teaching Assistant, UC Davis (2010 – 2016)

Department of Physics

Served as a teaching assistant for a wide range of courses, including several quarters of experience with introductory physics courses for both STEM and non-STEM majors in both lab and discussion. Also served as a teaching assistant for some upper division undergraduate courses and graduate courses in general relativity and quantum gravity.

Service and Leadership

Referee for Classical and Quantum Gravity (Since 2015)

<https://publons.com/researcher/1720860/gabriel-herczeg/peer-review/>

Referee for Annals of Physics (2018)

Organizer (2016)

Entanglement Entropy Journal Club

Organizer (2015)

Black Hole Evaporation Journal Club

Member (Current from 2013)

American Physical Society

Member (2016 – 2017)

Diversity and Inclusion in Physics, Graduate Student Group