Isaac Legred

Postdoctoral Research Associate, University of Illinois Urbana-Champaign
ilegred2@illinois.edu · isaaclegred.github.io
ORCID 0000-0002-9523-9617 · github.com/isaaclegred

Research Interests

Neutron stars and compact-object mergers as laboratories for dense nuclear matter and strong-field gravity, studied through Bayesian inference on astrophysical data, theory, and numerical simulation.

- *Dense-matter equation of state:* nonparametric and semiparametric inference from gravitational-wave, X-ray, and radio observations, from the crust to perturbative-QCD densities.
- *Astrophysics and nuclear theory:* confronting relativistic and chiral mean-field models with astrophysical data; emulator-accelerated Bayesian calibration.
- *Neutron-star structure:* stability and the turnover of stellar sequences; universal relations independent of the equation of state.
- *Gravitational-wave astrophysics:* classifying low-mass mergers, failed supernovae and the black-hole mass spectrum, and dynamical tides in neutron star–primordial black hole binaries.
- *Numerical relativity:* hydrodynamic simulations of neutron stars and their mergers with `SpECTRE`.

Appointments

Postdoctoral Research Associate, University of Illinois Urbana-Champaign 2025–present

Education

Ph.D. in Physics, California Institute of Technology 2025
Thesis: *Neutron Stars: Robust Constraints on Dense Matter from Astrophysics*
Advisor: Katerina Chatziioannou

M.S. in Physics, California Institute of Technology 2024

B.A. in Physics and Mathematics, Cornell University 2020
Magna cum laude in Physics, *magna cum laude* in Mathematics, Distinction in All Subjects
Senior thesis: *Testing the No-Hair Theorem: The Precessing Case*

Honors and Awards

2026	Finalist, Cecilia Payne-Gaposchkin Doctoral Dissertation Award in Astrophysics, American Physical Society
2024	James A. Cullen Memorial Fellowship, Caltech
2020	Wallace L. W. Sargent Fellowship, Caltech
2020	Hans Bethe Senior Thesis Prize, Cornell University

Publications

Newest first. † Student mentored by me.

[1] **Isaac Legred** and Nicolás Yunes. Neutron Star–Primordial Black Hole Binaries: Dynamical Tides, Resonance Locking, and Gravitational Waves. 2026. arXiv:2610.33314

[2] **Isaac Legred**, Mateus Reinke Pelicer, Veronica Dexheimer, Jacquelyn Noronha-Hostler, and Nicolás Yunes. Neural-Accelerated Bayesian Calibration of Chiral Mean-Field Models to Nuclear Saturation and Vacuum Properties. 2026. arXiv:2607.13268

[3] **Isaac Legred**, Jacob Golomb, and Katerina Chatziioannou. Low-mass failed supernovae and the 10 $M_\odot$ peak in the merging black hole mass distribution. *Phys. Rev. D*, 114(10):103023, 2026. doi: 10.1103/mnzq-w1b5. arXiv:2604.01420

[4] **Isaac Legred** and Nicolás Yunes. Why stellar sequences turn over: Fixed points, instability, and equation-of-state universality. *Phys. Rev. D*, 114(6):064006, 2026. doi: 10.1103/y75z-bbyk. arXiv:2603.26973

[5] Sunny Ng, **Isaac Legred**, Lami Suleiman, Philippe Landry, Lyla Traylor, and Jocelyn Read. Inferring the neutron star equation of state with nuclear-physics informed semiparametric models. *Class. Quant. Grav.*, 42(20):205008, 2025. doi: 10.1088/1361-6382/ae1094. arXiv:2507.03232

[6] Eliot Finch, **Isaac Legred**, Katerina Chatziioannou, Reed Essick, Sophia Han, and Philippe Landry. Unified nonparametric equation-of-state inference from the neutron-star crust to perturbative-QCD densities. *Phys. Rev. D*, 112(10):103023, 2025. doi: 10.1103/krc7-kz2l. arXiv:2505.13691

[7] **Isaac Legred**, Liam Brodie, Alexander Haber, Reed Essick, and Katerina Chatziioannou. Nonparametric extensions of nuclear equations of state: Probing the breakdown scale of relativistic mean-field theory. *Phys. Rev. D*, 112(6):063003, 2025. doi: 10.1103/9kh9-xfpd. arXiv:2505.07677

[8] Jacob Golomb, **Isaac Legred**, Katerina Chatziioannou, and Philippe Landry. Interplay of astrophysics and nuclear physics in determining the properties of neutron stars. *Phys. Rev. D*, 111(2):023029, 2025. doi: 10.1103/PhysRevD.111.023029. arXiv:2410.14597

[9] Elias R. Most, Yoonsoo Kim, Katerina Chatziioannou, and **Isaac Legred**. Nonlinear Alfvén-wave Dynamics and Premerger Emission from Crustal Oscillations in Neutron Star Mergers. *Astrophys. J. Lett.*, 973(2):L37, 2024. doi: 10.3847/2041-8213/ad785c. arXiv:2407.17026

[10] Jacob Golomb, **Isaac Legred**, Katerina Chatziioannou, Adrian Abac, and Tim Dietrich. Using equation of state constraints to classify low-mass compact binary mergers. *Phys. Rev. D*, 110 (6):063014, 2024. doi: 10.1103/PhysRevD.110.063014. arXiv:2403.07697

[11] **Isaac Legred**, Bubakar O. Sy-Garcia†, Katerina Chatziioannou, and Reed Essick. Assessing equation of state-independent relations for neutron stars with nonparametric models. *Phys. Rev. D*, 109(2):023020, 2024. doi: 10.1103/PhysRevD.109.023020. arXiv:2310.10854

[12] **Isaac Legred**, Yoonsoo Kim, Nils Deppe, Katerina Chatziioannou, Francois Foucart, François Hébert, and Lawrence E. Kidder. Simulating neutron stars with a flexible enthalpy-based equation of state parametrization in SpECTRE. *Phys. Rev. D*, 107(12):123017, 2023. doi: 10.1103/PhysRevD.107.123017. arXiv:2301.13818

[13] Reed Essick, **Isaac Legred**, Katerina Chatziioannou, Sophia Han, and Philippe Landry. Phase transition phenomenology with nonparametric representations of the neutron star equation of state. *Phys. Rev. D*, 108(4):043013, 2023. doi: 10.1103/PhysRevD.108.043013. arXiv:2305.07411

[14] **Isaac Legred**, Katerina Chatziioannou, Reed Essick, and Philippe Landry. Implicit correlations within phenomenological parametric models of the neutron star equation of state. *Phys. Rev. D*, 105(4):043016, 2022. doi: 10.1103/PhysRevD.105.043016. arXiv:2201.06791

[15] **Isaac Legred**, Katerina Chatziioannou, Reed Essick, Sophia Han, and Philippe Landry. Impact of the PSR J0740+6620 radius constraint on the properties of high-density matter. *Phys. Rev. D*, 104:063003, 2021. doi: 10.1103/PhysRevD.104.063003. arXiv:2106.05313

Theses

[16] **Isaac Legred**. *Neutron Stars: Robust Constraints on Dense Matter from Astrophysics*. Ph.D. thesis, California Institute of Technology, 2025. https://thesis.caltech.edu/17364/

[17] **Isaac Legred**. *Testing the No-Hair Theorem: The Precessing Case*. Undergraduate thesis, Cornell University, 2020. Code: qnm-fitting.

Selected Collaboration Publications and Software

Work done as part of the LIGO-Virgo-KAGRA, SXS, and MUSES collaborations.

[18] Nils Deppe, William Throwe, Lawrence E. Kidder, Nils L. Vu, Kyle C. Nelli, Cristóbal Armaza, Marceline S. Bonilla, François Hébert, Yoonsoo Kim, Prayush Kumar, Geoffrey Lovelace, Alexandra Macedo, Jordan Moxon, Eamonn O'Shea, Harald P. Pfeiffer, Mark A. Scheel, Saul A. Teukolsky, Nikolas A. Wittek, et al. `SpECTRE v2024.09.29`. 10.5281/zenodo.13858965, 2024
Contributor to hydrodynamics modules.

[19] `lwp`: LVK collaboration inference of the dense-matter equation of state from gravitational waves. *Lead developer.*

[20] Johannes Jahan et al. Studying the QCD Matter produced in Heavy-Ion Collisions using the MUSES Calculation Engine. 2026. arXiv:2606.26326

[21] A. G. Abac et al. GWTC-4.0: Population Properties of Merging Compact Binaries. *Astrophys. J. Lett.*, 1005(2):L51, 2026. doi: 10.3847/2041-8213/ae771e. arXiv:2508.18083

[22] A. G. Abac et al. Observation of Gravitational Waves from the Coalescence of a 2.5–4.5 $M_\odot$ Compact Object and a Neutron Star. *Astrophys. J. Lett.*, 970(2):L34, 2024. doi: 10.3847/2041-8213/ad5beb. arXiv:2404.04248

[23] Nils Deppe et al. Binary neutron star mergers using a discontinuous Galerkin-finite difference hybrid method. *Class. Quant. Grav.*, 41(24):245002, 2024. doi: 10.1088/1361-6382/ad88cf. arXiv:2406.19038
Developed infrastructure for hydrodynamic simulations.

[24] R. Abbott et al. The population of merging compact binaries inferred using gravitational waves through GWTC-3. *Phys. Rev. X*, 13(1):011048, 2023. doi: 10.1103/PhysRevX.13.011048. arXiv:2111.03634

[25] Nils Deppe et al. Simulating magnetized neutron stars with discontinuous Galerkin methods. *Phys. Rev. D*, 105(12):123031, 2022. doi: 10.1103/PhysRevD.105.123031. arXiv:2109.12033
Developed infrastructure for hydrodynamic simulations.

Invited Talks

May 2026	T-2 Seminar, Los Alamos National Laboratory
Apr. 2026	Princeton Gravity Initiative Seminar, Princeton University
Mar. 2026	Payne-Gaposchkin Dissertation Award finalist talk, APS Global Physics Summit, Denver (thesis)
Oct. 2024	Theoretical Astrophysics Seminar, Cornell University
Sep. 2024	Nuclear Physics Seminar, University of Illinois Urbana-Champaign
Feb. 2024	MUSES Seminar
June 2023	Nuclear Matter Workshop, Institute for Nuclear Theory (INT)
Oct. 2022	Physics Colloquium, Perimeter Institute
June 2022	Nuclear Matter Workshop, Institute for Nuclear Theory (INT)

Nov. 2021 LIGO Laboratory Seminar

Contributed Presentations

2024 *Using equation of state constraints to classify low-mass object mergers*, APS April Meeting

Distinguishing subsolar mass neutron stars from black holes using information from the nuclear equation of state, LVK Spring Meeting (poster). Best Poster Award (Data Analysis)

2023 *Implicit correlations in the phenomenological models of the dense-matter equation of state*, APS April Meeting

Likelihood weighing protocol of inferring the equation of state of dense matter, LVK Spring Meeting (poster)

2022 *Impact of the radius measurement of J0740+6620 on the equation of state of high-density matter*, APS April Meeting

Teaching

Teaching Assistant and Section Leader, Ph 1b–c, Caltech Winter–Spring 2021

Introductory special relativity and electromagnetism.

Undergraduate Teaching Assistant, Cornell University 2017–2020

Six semesters: Introductory Quantum Mechanics; Waves and Thermal Physics; Electromagnetism (lab); Engineering Waves and Quantum Physics.

Mentoring

Caltech LIGO Summer Undergraduate Research Fellowship (SURF) students, 2021–2025:

- Celine Wang: Optimal settings for BNS skymaps
- Oscar Sy-Garcia: Assessing EoS independence under nonparametric models (publication [11])
- Carter Anderson: Simulating head-on collisions of neutron stars with SpECTRE
- Lana Alabbasi: Distinguishing neutron star postmerger from black hole ringdown with gravitational waves

Postdoctoral Mentoring of Graduate Students, 2025–present:

- Brook Burbridge: Observables of thermal neutron stars
- Kaitlyn Prokup: Simultaneous sampling of neutron star properties and the equation of state
- Emily Dillingham: Understanding neutron star maximum mass dependence on microphysics with emulators

Service

2026–27 Co-organizer, Student and Postdoc Seminar, Simons Collaboration on Black Holes and Strong Gravity

2025–26 Co-organizer, MUSES seminar series

Referee *The Astrophysical Journal*, *Physical Review D*, *Physical Review Letters*