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Zack R. Carson, Ph.D.

Education

University of Virginia — Charlottesville, VA
PhD Physics *(Thesis: Probing Fundamental Physics with Gravitational Waves)* — *Aug. 2014 - May 2020*
- Overall GPA: 3.850

University of Utah — Salt Lake City, UT
BS Pre-Professional Physics, BS Applied Mathematics, Astrophysics minor — *Aug. 2010 - May 2014*
- Overall GPA: 3.820, Major GPA: 3.896, Last 60 credits GPA: 3.860
- Dean's Honor List every semester

Experience

Gravitational Wave Outreach (part-time grant) — Charlottesville, VA
University of Virginia — *March 2022 - Present*

Building an educational outreach video game using **Unity** and **C#** to teach students about orbital mechanics and gravitational waves. Specifically, I focus on gravitational waves generated by orbiting black hole and neutron star binary systems, and navigating a warping spacetime under the influence of such radiation. This work is sponsored by an **NSF** grant co-applied for with Dr. Kent Yagi.

Data Scientist III, Machine Learning — New York City, NY
Dataminr — *March 2021 - Present*

Currently working with NLP (**natural language processing**) and CV (**computer vision**) machine learning models using **Python** and **PyTorch** to detect alertable content for public and private-sector clients using public data streams. This includes analyses with:

* Leading the **Cyber AI** team tasked with the detection and alerting of cyber security threats and vulnerabilities towards clients using NLP and CV machine learning models.
* Analyzing internal usage data (**Postgresql**, **Amazon AWS S3**), to identify patterns and increase efficiency of human-in-the-loop alerting, as well as providing meaningful analyses to external stakeholders.
* Testing, experimenting with, and training various state-of-the-art NLP and CV models, and analyzing their performance on different data sources.
* Designing, creating, and experimenting with annotation tasks on AMT (**Amazon Mechanical Turk**) to collect high-quality labeled data from various sources, to be used for training better models.

Data Scientist, Machine Learning — Boulder, CO
TruU — *June 2020 - March 2021*

Worked on building and optimizing biometric machine learning models in **Python** used for gait recognition, hand recognition, and typing recognition in production as a security measure for clients.

* Implemented a NormUFCPC (Normalized User-Forced Contrastive Predictive Coding) metric learning model and pipeline in **PyTorch Lightning** and **MLFlow** for gait recognition in user identification, reaching an accuracy of 98%.
* Implemented a Siamese machine learning model with **PyTorch** and **Catalyst** for hand recognition in user identification, reaching an accuracy of 96%.
* Implemented a Siamese machine learning model with **PyTorch Lightning** and **MLFlow** for typing recognition in user identification, reaching an accuracy of 98%.
* Built a motion-type recognition model to determine user's motion type (e.g. running, limping, walking, carrying phone, phone in bag, etc.), reaching an accuracy of 94%.

- Used **Postgresql**, **Elastisearch**, and **Kibana** for data management and analysis.

Graduate Research Assistant, Gravitational Wave Physics Charlottesville, VA
University of Virginia, Advisor - Professor Kento Yagi *March 2018 - May 2020*

Under the advisement of Professor Kent Yagi, the PhD research I was involved in consisted of studying various aspects of astrophysics and general relativity via the detection of gravitational waves from the collisions of compact objects using Mathematica, Fortran, C++, and Matlab. This is split into two branches: constraining the supranuclear matter equation of state from the mergers of binary neutron star systems, and testing our current understanding of General Relativity via the collisions of black holes in binary systems.

- *Supranuclear matter equation of state:* Neutron stars in a binary system emit radiation in the form of gravitational waves as they lose energy and inspiral into each other. As the stars approach one another, they develop a tidal deformation in response to the companions' strong tidal field, which affects the resulting orbital trajectory. Information regarding this tidal deformation depends strongly on the underlying supranuclear equation of state, and becomes encoded within the gravitational waveform. By extracting such tidal information (from events similar to GW170817 detected by the LIGO collaboration), we place bounds on the nuclear matter parameters descriptive of the equation of state. We similarly use such tidal information to reduce the systematic uncertainties found in universal relations between various neutron star observables, allowing more accurate parameter extraction from future gravitational wave detections.
- *Testing general relativity:* By instead studying the mergers of binary black hole systems (similar to GW150914 detected by the LIGO collaboration), we test the accuracy of Einsteins' General Relativity. By utilizing Fisher Analysis techniques, we estimate the extraction efficiency of Parameterized Post-Einsteinian (PPE) parameters, which describe deviations from the General Relativity gravitational waveform entering at various orders of orbital velocity. By placing bounds on such parameters, we map them to the characteristic coupling parameters of various theories of modified gravity. By taking such an agnostic view, we can constrain the size of non-General Relativity effects relevant in the high-field, high-curvature regime of black hole mergers.

Graduate Research Assistant, Quantum Optics Charlottesville, VA
University of Virginia, Advisor - Professor Olivier Pfister *March 2016 - March 2018*

Under the advisement of Professor Olivier Pfister, exploring the experimental side of quantum optics and quantum computing. Rather than utilizing "qubits" (the quantum analog of classical bits), we studied the use of their continuous-variable counterpart qumodes. By utilizing the multi-mode nature of ultra-fast lasers, we leveraged manufactured qumodes into highly entangled states with large (record-holding) levels of quantum squeezing (the quantum noise reduction of bosonic fields below their minimum uncertainty level). This reduction of quantum noise is a crucial quantum computing resource and also important for future upgrades to the LIGO gravitational wave interferometer.

Graduate Research Assistant, High Energy Physics Charlottesville, VA
University of Virginia, Advisor - Professor Chris Neu *Dec. 2014 - March 2016*

Under the advisement of Professor Chris Neu, using machine learning algorithms (boosted decision trees) and programming in C++ and ROOT to analyze data concerning Higgs $\rightarrow$ Top-Top decay and Microscopic Black Hole Production at the LHC (Large Hadron Collider, CERN).

Graduate Teaching Assistant: Lead TA Charlottesville, VA
University of Virginia, Professors Maksim Bychkov, Stefan Baessler *Aug. 2014 - May 2017*

- Instructed mechanics and electromagnetism labs for scientists and engineers for three years. My last year was spent as a Lead TA where along with teaching, I oversaw training and teaching the teaching assistants.

- Worked with Professor Maksim Bychkov to develop a new teaching curriculum to produce more viable, confident, and motivated teaching assistants. This included the development of a week-long training program with teaching simulations, think-tanks, and more at the beginning of each semester. Presented the results of this research – “Team Based Design of Science Laboratory” at the *Innovation in Pedagogy Summit* in Charlottesville, VA, 2016
- Also taught Electricity and Magnetism II discussion sections to undergraduate physics majors for one semester.

Graduate Graderships: Charlottesville, VA
University of Virginia *Aug. 2014 - May 2016*

- Advanced General Relativity
- General Relativity
- Graduate Quantum Computing
- Graduate Quantum Theory I
- Graduate Optics
- Graduate Classical Mechanics
- Graduate Electromagnetism
- Modern Physics
- Nuclear and Particle Physics
- Introduction to Quantum Computing
- Physics of the Human Body

Astronomy Outreach Teaching Assistant Salt Lake City, UT
University of Utah, Advisor - Professor Tabitha Beuhler *Jan. 2011 - May 2014*

- As an undergraduate student I worked on the University of Utah’s observatory to foster astronomy education outreach to the general public. This included traveling to K-12 schools, boy scouts, and other organizations to run demos, teach astronomy, and use telescopes. We also hosted on-campus “star-parties” where the general public was allowed to use the observatory and learn about astronomy.

Skills

Languages: Python, C#, Mathematica, Matlab, C++, SQL, ROOT, Fortran, HTML, R

Relevant software: UNIX (Ubuntu), LaTeX, git, XMgrace, Windows, Airflow, Databricks, Unity, MacOS

Academic Services and Research Mentoring

- Referee for the Physical Review letters and D (PRL, PRD) and the Monthly Notices of the Royal Astronomical Society (MNRAS) academic journals
- Associate member of the Laser interferometer space antenna (LISA) consortium, where I completed analyses contemplating tests of General Relativity using various configurations of the LISA interferometer.
- Co-advised undergraduate students Josef Zimmerman and Kristen Schumacher on projects dealing with probing the neutron star structure with multi-messenger gravitational/electromagnetic wave observations

Honors

- University of Virginia department of Physics Research Fellowship Award 2020
- University of Virginia Distinguished Graduate Teaching Award for STEM fields (single recipient) 2019
- University of Virginia Physics Department Poster Competition, 2nd place. 2019
- Google PhD Fellowship Program nominee (one of two from University of Virginia) 2018
- Graduate Physics Students Association Vice President - University of Virginia 2016
- Eugene Loh “Fly’s Eye Cosmic Ray” Scholarship - Awarded for Physics academic merit 2010-2014
- Alsco Scholarship - Awarded for academic merit 2010-2014
- Joseph Turner Crockett Memorial Scholarship - Awarded for science academic merit 2012-2013
- Questar Scholarship - Awarded for academic merit 2011

Conferences and Presentations

1. "Probing beyond-Kerr spacetimes with the IMR consistency tests of gravitational waves" (Contributed Speaker) *– APS April Virtual Meeting, April 2020*

2. "Multi-messenger probes of the neutron star equation of state" (Invited Speaker) *– Southeastern Section of the American Physical Society (SESAPS) meeting, Wrightsville, NC, November 2019*

3. "Universal relations after GW170817" (Contributed Speaker) *– APS April Meeting, Denver Colorado, April 2019*

4. "Constraining nuclear matter parameters and improving Universal Relations after GW170817" (Web seminar invited speaker, https://www.youtube.com/watch?v=Xt_9D931lyw) *– Nuclear Theory Group (hosted by Dr. Bharat Kumar, University of Tsukuba, Japan), March 2019*

5. "Universal relations after GW170817" (Poster presentation) *– GWPAW, University of Maryland, December 2018*

6. "Team based design of science laboratories" *– Innovation in Pedagogy Summit, University of Virginia 2016*

Publications

1. **Carson, Zack**. (2020). *Probing fundamental physics with gravitational waves* (Doctoral dissertation, University of Viginia). Retrieved from https://doi.org/10.18130/v3-pxdw-2144

2. **Carson, Zack**, & Yagi, K. (Eds.). (2021). *Testing General Relativity with Gravitational Waves*, submitted as a chapter of the *"handbook of gravitational wave astronomy"* by C. Bambi, S. Katsanevas and K. Kokkotas; Springer Singapore.

3. **Carson, Zack**, & Yagi, K. (2020e). Probing string-inspired gravity with the inspiral-merger-ringdown consistency tests of gravitational waves. *Class. Quantum Grav.*. Retrieved from https://doi.org/10.1088/1361-6382/aba221

4. **Carson, Zack**, & Yagi, K. (2020d). Probing einstein-dilaton gauss-bonnet gravity with the inspiral and ringdown of gravitational waves. *Phys. Rev. D*, *101*, 104030. Retrieved from https://link.aps.org/doi/10.1103/PhysRevD.101.104030

5. **Carson, Zack**, & Yagi, K. (2020a). Asymptotically flat, parameterized black hole metric preserving Kerr symmetries. *Phys. Rev. D*, *101*, 084030. Retrieved from https://link.aps.org/doi/10.1103/PhysRevD.101.084030

6. **Carson, Zack**, & Yagi, K. (2020c). Probing beyond-Kerr spacetimes with the inspiral-ringdown signals of gravitational waves. *Phys. Rev. D*, *101*, 084050. Retrieved from https://link.aps.org/doi/10.1103/PhysRevD.101.084050

7. **Carson, Zack**, & Yagi, K. (2020b). Parameterized and inspiral-merger-ringdown consistency tests of gravity with multiband gravitational wave observations. *Phys. Rev. D*, *101*, 044047. Retrieved from https://link.aps.org/doi/10.1103/PhysRevD.101.044047

8. Zimmerman, J., **Carson, Zack**, Schumacher, K., Steiner, A. W., & Yagi, K. (2020). Measuring Nuclear Matter Parameters with NICER and LIGO/Virgo. *Phys. Rev. Letters (under review)*. Retrieved from https://arxiv.org/abs/2002.03210

9. **Carson, Zack**, & Yagi, K. (2019a). Multi-band gravitational wave tests of general relativity. *Classical and Quantum Gravity Letters*. Retrieved from https://iopscience.iop.org/article/10.1088/1361-6382/ab5c9a

10. **Carson, Zack**, & Yagi, K. (2019b). Parameterized and Consistency Tests of Gravity with Gravitational Waves: Current and Future. In *Proceedings, Recent Progress in Relativistic Astrophysics: Shanghai, China, May 6-8, 2019* (Vol. 17(1)). Retrieved from https://doi.org/10.3390/proceedings2019017005

11. **Carson, Zack**, Seymour, B. C., & Yagi, K. (2020). Future Prospects for Probing Scalar-Tensor Theories with Gravitational Waves from Mixed Binaries. *Class. Quant. Grav*, *37*(6), 065008. Retrieved from https://doi.org/10.1088%2F1361-6382%2Fab6a1f

12. Tahura, S., Yagi, K., & **Carson, Zack**. (2019). Testing Gravity with Gravitational Waves from Binary Black Hole Mergers: Contributions from Amp. Corrections. *Phys. Rev.*, *D100*(10), 104001. Retrieved from https://doi.org/10.1103/PhysRevD.100.104001

13. **Carson, Zack**, Chatziioannou, K., Haster, C.-J., Yagi, K., & Yunes, N. (2019). Equation-of-state insensitive relations after GW170817. *Phys. Rev.*, *D99*(8), 083016. Retrieved from https://doi.org/10.1103/PhysRevD.99.083016

14. **Carson, Zack**, Steiner, A. W., & Yagi, K. (2019a). Constraining nuclear matter parameters with GW170817. *Phys. Rev.*, *D99*(4), 043010. Retrieved from https://doi.org/10.1103/PhysRevD.99.043010

15. **Carson, Zack**, Steiner, A. W., & Yagi, K. (2019b). Future Prospects for Constraining Nuclear Matter Parameters with Gravitational Waves. *Phys. Rev.*, *D100*(2), 023012. Retrieved from https://doi.org/10.1103/PhysRevD.100.023012

16. Zang, J., ..., **Z. Carson**, ..., & Campbell, J. C. (2017). High quantum efficiency uni-traveling-carrier photodiode. *IEEE Phot. Tech. Letters*, *29*(3), 302-305. Retrieved from https://doi.org/10.1109/LPT.2016.2647638

17. Zhu, X., **Carson, Zack**, Alexander, R., & Pfister, O. (n.d.). Leveraging qumode scalability: high squeezing and entanglement from redistributed multitudinous-mode squeezing. *(in progress)*.

Relevant Coursework

- PHYS 8240: Advanced General Relativity
- PHYS 5240: General Relativity
- PHYS 8630: Quantum Field Theory
- PHYS 5630: Computational Physics
- PHYS 5720: Nuclear and Particle Physics
- PHYS 8880: Quantum Optics and Quantum Information
- PHYS 5880: Introduction to Quantum Computing
- PHYS 8220: Photonics
- ECE 6851: Linear Automatic Control Systems