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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

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

Builds text and image based machine learning (ML) models used to detect alertable content for both public and private sector customers utilizing public data streams.

RESPONSIBILITIES:
- Lead the Cyber AI team tasked with the detection of cyber security threats and vulnerabilities towards clients using ML models.
- Develop data streaming pipelines used to support models running 24/7 on live data.
- Collaborate with a team of 22 scientists through pair programming, model planning, and code reviews.
- Collaborate with stakeholders and leadership to design and implement reliable ML models and data storage infrastructures.
- Present complex data, metrics, and visualizations in a digestible way to leadership and stakeholders.

ACCOMPLISHMENTS:
- Collaborated with the team and stakeholders to design and implement live data streaming and reduction pipelines converting upwards of 1 billion raw messages per day into filtered and processed data used in anomaly detection models.
- Collaborated with the team and stakeholders to research, design, collect data, train, test, and implement 6 net new ML models, each currently running with mean accuracies and precisions of 91% and 90% on live streaming data (up to 1 billion messages a day from 100,000 data sources) to produce 1,000+ new alerts per day.
- Designed and implemented a knowledge graph and recurring ingest system containing upwards of 1 million cyber entities from 15 sources (e.g. NIST vulnerability database) used to enrich alerts.
- Promoted from Data Scientist I to Data Scientist III.

RELEVANT SKILLS:
- Python, SQL, Neo4j, Databricks, AWS S3, Snowflake, Airflow, Kibana, Elasticsearch, HTML, git, Bash

Gravitational Wave Outreach (NSF Grant) — Charlottesville, VA
University of Virginia — *March 2022 - Present*

Collaborate with and lead undergraduate and high school students to build educational outreach video games to teach students about orbital mechanics and gravitational waves generated by binary black hole and neutron star binary mergers. This work is sponsored by an NSF grant co-applied for with Dr. Kent Yagi.

RESPONSIBILITIES:

- Design and create engaging and educational video games in Unity using principles of general relativity and gravitational radiation.
- Translate complex information into an easily understandable format to be communicated to laypersons and students around the world.
- Hire, manage, and mentor undergraduate and high school students to plan, design, and create educational video games in Unity.

ACCOMPLISHMENTS:

- Designed and implemented “Gravitational Wave Surfer”, where the player is a lone Hydrogen atom navigating a turbulent space-time due to nearby binary black hole mergers emitting gravitational radiation.

RELEVANT SKILLS:

- Unity, C#

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

Planned and created biometric machine learning (ML) models used by customers as a security measure to verify the identity of their employees while in the office.

RESPONSIBILITIES:

- Collaborated with stakeholders to implement, optimize, and deploy biometric ML models.
- Collaborated with a team of 5 scientists and engineers via pair programming sessions and code reviews.
- Presented visualizations of results, metrics, and data analyses to stakeholders and leadership.
- Designed, managed, and maintained internal databases on company-owned servers.

ACCOMPLISHMENTS:

- Designed, trained, and implemented 4 net new biometric ML models currently running on customer phones and computers with mean accuracies of 92% and precisions of 91% to identify themselves via gait, typing, and hand shape.

RELEVANT SKILLS:

- Python, SQL, Kibana, Elastisearch, git, bash

Graduate Research Scientist Charlottesville, VA
University of Virginia *January 2013 - May 2020*

Graduate level physics researcher focused on the following subjects:

- My primary research focus utilized the gravitational radiation emitted from binary black hole and neutron star mergers detected by LIGO (Laser Interferometer Gravitational-wave Observatory) to probe various aspects of fundamental physics - cosmology, general relativity and the structure of supranuclear matter. See “RESEARCH SUMMARY” below for more details on my primary research
- Earlier in my career I worked in an optics laboratory investigating quantum noise reduction using squeezed qumodes (the continuous-variable counterpart to qubits) of multimodal light, highly useful for gravitational wave interferometers.
- Starting my career I worked with a high energy group investigating the Higgs boson decay modes and microscopic black hole production in collaboration with CERN.

RESPONSIBILITIES:

- Performed astrophysics research utilizing observational data in various formats from ground-based (LIGO) and space-based (LISA - in development, theoretical work/analysis) gravitational wave interferometers.
- Worked as an associate member of the LISA (Laser Interferometer Space Antenna) consortium, supporting the space-based observatories' development via detector configuration and data manipulation analyses for future scientific use-cases.
- Traveled to conferences as both invited and contributing speakers to present my research to audiences with all levels and fields of physics experience.
- Wrote and published the results of my research in peer-reviewed journals.
- Co-advised undergraduate students on gravitational wave research.

ACCOMPLISHMENTS:

- 13 publications as lead author, and 4 as a supporting author submitted and accepted to leading peer-reviewed journals.
- Awarded the 2020 University of Virginia Distinguished Research Fellowship Award.
- 2 conference talks given as an invited speaker, and 4 as a contributing speaker.
- Produced code that was widely used in research among the CERN community in simulating the Higgs — Top+Top decay mode.
- Successfully designed, built, and tuned a custom Optical Parametric Oscillator and the accompanying optical setup used to produce and study frequency–entangled, "qumodes" of light, with 3.2 dB of squeezing achieved.
- Awarded the 2018 Google PhD Fellowship Program Nominee slot for the University of Virginia.
- 2nd place awarded in the 2019 University of Virginia Graduate Poster Competition.

RELEVANT SKILLS:

- Scientific laboratory equipment, High precision machining, Electronics, Optics, Mathematica, Matlab, C++, Python, Fortran, LaTeX, git, Bash, XMgrace

RESEARCH SUMMARY:

My primary research focus working with Professor Kent Yagi was split into two distinct branches: constraining the supranuclear matter equation of state from binary neutron star mergers, and testing our current understanding of General Relativity via binary black hole mergers. These paths are summarized below:

- 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 placed 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.
- 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 statistical 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.

Lead Graduate Teaching Assistant Charlottesville, VA
University of Virginia *Aug. 2014 - May 2017*

Lead Teaching Assistant ("Super TA") involved with teaching, training, and grading.

RESPONSIBILITIES:

- Lead and managed the training of the physics lab TAs.
- Collaborated with Professor Maksim Bychkov to develop a new teaching curriculum to produce more viable, confident, and motivated teaching assistants.
- Instructed mechanics and electromagnetism labs and discussion sessions.
- Served as the official grader for several graduate level physics courses:
  - Advanced General Relativity, General Relativity, Quantum Computing, Quantum Theory I, Optics, Classical Mechanics, Electromagnetism, Modern Physics, Nuclear and Particle Physics, Introduction to Quantum Computing, Physics of the Human Body

ACCOMPLISHMENTS:

- University of Virginia Distinguished Graduate Teaching Award for STEM fields awarded in 2019.
- Implemented a new training program including mock teaching simulations and think-tanks at the beginning of each semester - successfully training 15-20 new teaching assistants per year.
- Presented the results in "Team Based Design of Science Laboratory" at the Innovation in Pedagogy Summit in Charlottesville, VA, 2016.

RELEVANT SKILLS:

- Scientific laboratory equipment

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

Worked at the University of Utah observatory to foster astronomy education outreach to the general public both locally and across the state of Utah.

RESPONSIBILITIES:

- Traveled to various K-12 schools, boy scout groups, and other organizations to run demos, teach astronomy, and use telescopes.
- Hosted weekly "Star Parties" at the observatory, where the general public came to learn about astronomy and use the various telescopes.

RELEVANT SKILLS:

- Telescope operation and maintenance

Skills

Technical Skills: Scientific laboratory equipment, Electronics, Optics, Telescope operation and maintenance, High precision machining, bash, git, XMgrace, Airflow, Unity, AWS S3, Snowflake, Kibana, Elasticsearch

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

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

- Linear Automatic Control Systems
- Advanced General Relativity
- General Relativity
- Quantum Field Theory
- Computational Physics
- Nuclear and Particle Physics
- Quantum Information and Optics
- Quantum Computing
- Photonics