Select Stories on the Influence of QuarkNet on Teachers/Fellows and Former High School Students: Supplement I to the Final Evaluation Report in Support of NSF Grant #2039272

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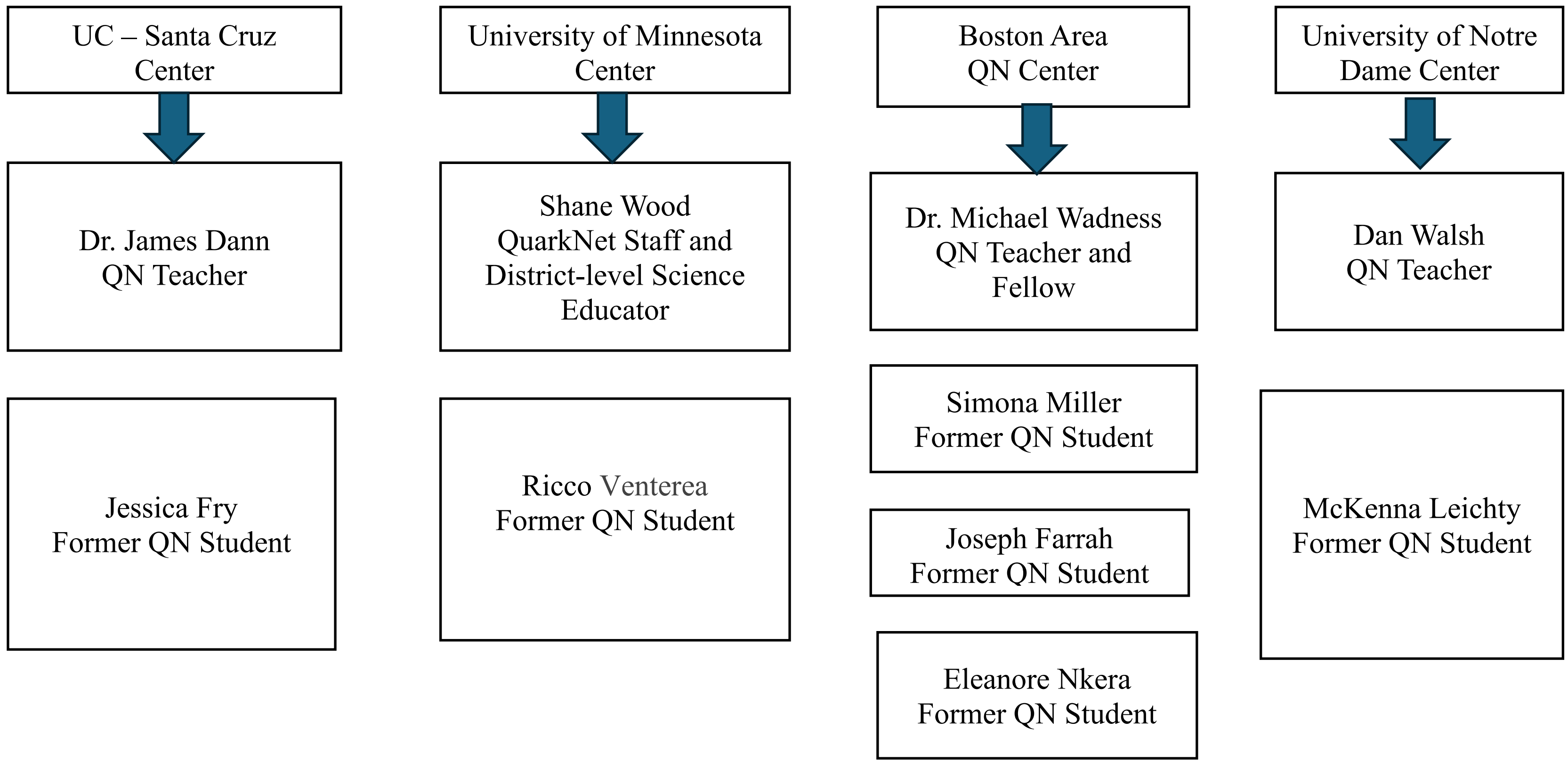
The following document is a supplement to the 2024 QuarkNet Evaluation Report and the Final Evaluation Report (2025) for the National Science Foundation's grant period of 2023-2025. It contains several examples of how QuarkNet engagement has benefited the classroom teaching and instructional practices of QuarkNet teachers and in turn, how these teachers, fellows and staff have influenced QuarkNet. First-hand accounts of how QuarkNet has influenced the academic plans and career choices of former high school students who have engaged in QuarkNet directly and/or through the instructional support of their teachers have been included as well.

Each individual vignette is organized by the QuarkNet Center represented for that individual. In accordance with the Guiding Principles for Evaluators [Guiding Principles (eval.org)] we have sought and received written approval from each individual included in this compilation who has reviewed and approved their story before its inclusion.

As implied by its name, this document is best viewed as a supplement to the final evaluation reports. These evaluation reports (e.g., 2024) present information on the implementation of the program and analyses on the important role that centers play in its implementation. We also look at the engagement level in the program through workshops, masterclasses, and other program events implemented by these centers. These reports provide information about QuarkNet participants and focuses on how QuarkNet influences teacher outcomes and long-term outcomes through this engagement. Center-level portfolios summarize responses to open-ended survey questions by participants over time focused on how teachers plan and have incorporated QuarkNet content and materials in their classrooms; and include proposed implementation plans, teacher work, and student work, when available. Program and evaluation recommendations are proffered as well.

QuarkNet Success Stories: Center Connections, Teacher Connections and Former Students



QuarkNet Center
University of California
Santa Cruz

Dr. James Dann
QuarkNet Teacher
(used with permission)

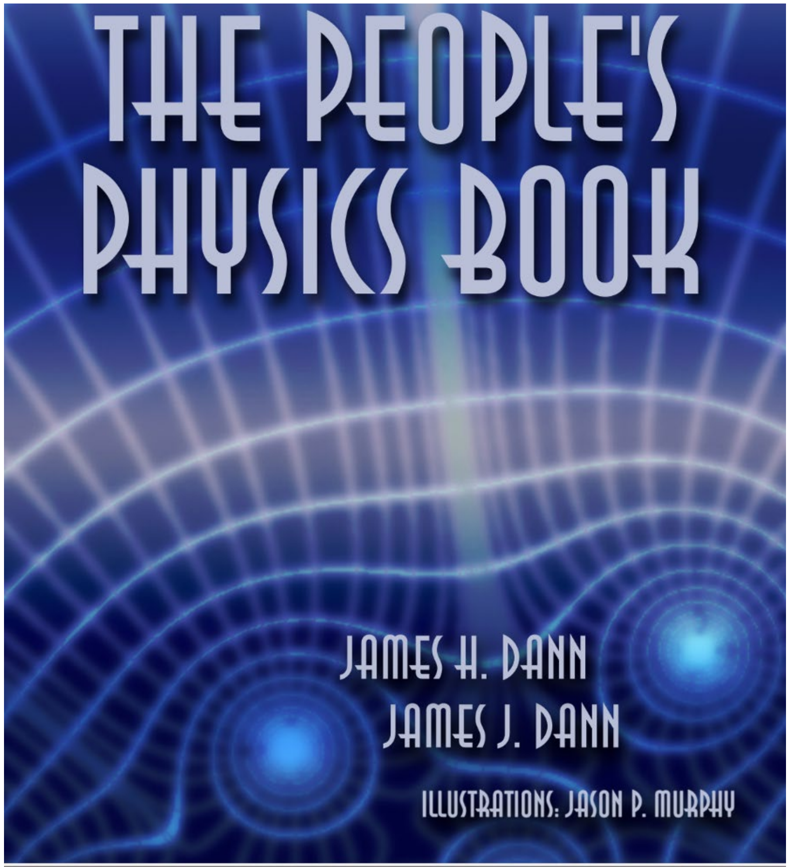
<table>
<tr><td colspan="2">Dr. James Dann, Applied Science and Engineering Teacher, Menlo School Atherton, CA and the Director of their Whitaker Lab. Dr. Dann joined Menlo in 2006. He is an experienced Physics teacher who has taught Physics 1, Physics with Calculus and is currently teaching Sustainable Engineering, Applied Science Research, and AT Physics (Quantum, Relativity and Calculus based Electro-magnetism). He has a BS in Physics from UC Santa Barbara; went to UC Santa Cruz (UCSC) for work on his masters, spent four years doing research at CERN and received a PhD from the University of California, Santa Cruz in Particle Physics. James Dann • Menlo School</td></tr>
<tr><th>QuarkNet Engagement</th><th>Highlighted Responses to Teacher Survey</th></tr>
<tr><td>He had participated in QuarkNet for about 6 years where he attended Data Camp in 2019 and he has participated in ATLAS Masterclasses. In an email to me (dated July 21, 2024), Dr. Dann wrote: “(Dr.) Hartmut Sadrozinski was the UCSC professor that led the QuarkNet group when doing the tethered low altitude balloon launch stuff, this was around 2000 to 2005.” Dr. Dann also wrote that he was able to take this experiment much further noting, “with space launches up to 120,000 feet. I launch four groups each year to take data on the atmosphere.” Finally, he noted that Dr. Jason Nielsen, professor at UCSC led the most recent iteration of the center-led Data Camp and ATLAS Masterclass.

Experiment from one of his recent students (Dr. Dann noted): During the 2023-2024 school year, one of his students conducted two experiments using the QuarkNet cosmic ray experiment. She did a day-night experiment that showed the effects of Earth shielding on the data rate of muons. She also determined the lifetime of the muon and got results consistent within error of the accepted value at various altitudes when including the effects of relativity. She attempted to build three small scintillators with mini photo multiplier tubes with the intention of sending up into the stratosphere on a weather balloon with these scintillators and the QuarkNet data board (she successfully launched a weather balloon with me and took data all the way up to 120,000 ft. earlier in the year and wanted to repeat it with this experiment in mind). He noted that unfortunately two 2 out of the 3 photomultiplier tubes purchased from another source did not work so they were not able to do the final experiment.</td><td>In response to a question from the Teacher Survey that asks, Of the QuarkNet Workshops and Programs you participated in which do you think have been most helpful to you in your teaching? Please briefly describe why. Dr. Dann wrote in 2019 (quoted with permission): “ATLAS Masterclass if by per day. Data Camp for overall because more time to dive in deeper. Data Camp was truly valuable and learned a lot. I really enjoyed the masterclass as well, however, and for one day it was a truly excellent learning experience for my students and myself.”

And when asked for final comments he concluded with (again quoted with permission): “The best thing to come out of QuarkNet for me is the weather balloon experiments we developed at UC Santa Cruz in the early 2000's. It has been an amazing project that I spend 6 to 8 weeks on every year, incorporating engineering skills (programming and calibrating a DAQ and sensors) and science research skills (analyzing the data from the sensors) and also getting pictures of Earth from over 100,000 ft. up. No project I have every done excites the students more and gets them to learn as much about physics, science experimentation, engineering and data analysis.” [See link to project: http://asr.menloschool.org/projects/space-launch]

And finally in an email to me (dated July 21, 2024) he wrote: “The cosmic ray stuff has been super energizing and stimulating for certain students who really love physics and see a career in research. It's been fun for me as well to tap into my particle physicist self again.”</td></tr>
</table>

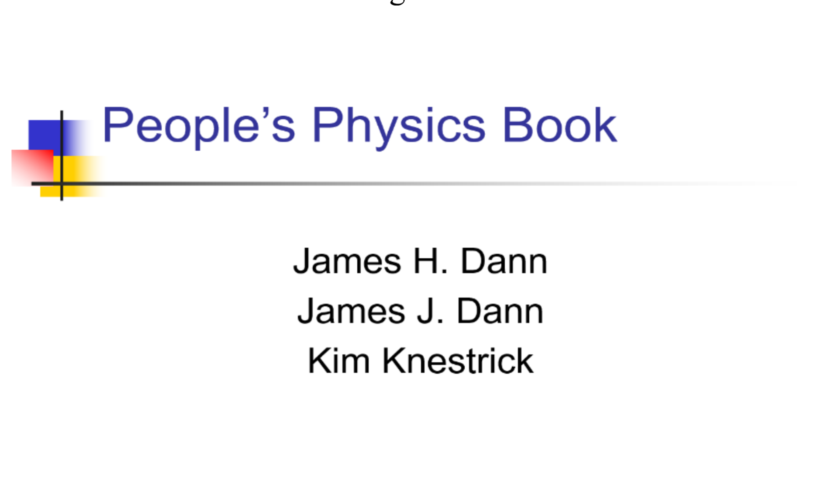
In an email to me (date July 23, 2024), Dr. Dann noted that he had presented at AAPT in 2014 on the balloon launch experiment. And that in 2023, he presented at SOTF on the methodology of inquiry learning among other presentations.

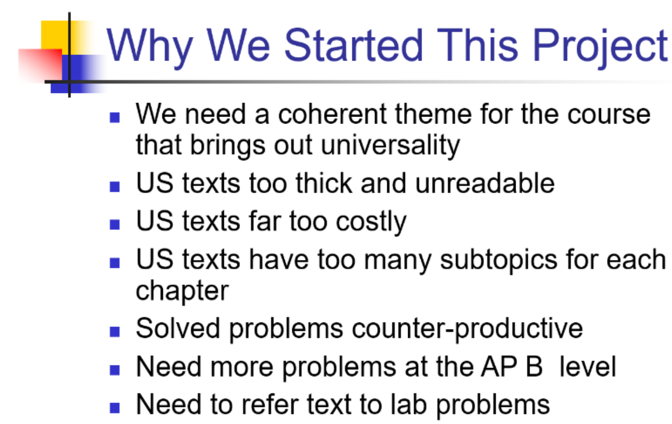


Open-source book authored by Dr. Dann and his father in 2004.
http://scipp.ucsc.edu/outreach/index2.html

He has also created a popular YouTube channel for students:
https://www.youtube.com/user/jamdann21

Presented at an AAPT meeting in 2008.





Jessica Fry graduated from Menlo School in 2015, where she had been a student of Dr. James Dann (a QuarkNet teacher from the University of California Santa Cruz center) in Calculus physics (AP C) and Applied Science Research (ASR) classes (email from J. Dann, 5/7/2024). Menlo School is a private college prep school in Atherton, CA.

As a senior, with another student, she completed her ASR project entitled *Confirming Relativity with a Cosmic Ray Detector*. She told me during our conversation[1] that this project, along with the support and confidence Dr. Dann had in her math and science abilities, sparked her interest in pursuing her undergraduate studies in physics. Dann noted, "She just wrote me a few months ago citing her experiment in my class using the QN equipment as her main inspiration to become a particle physicist." (email from J. Dann 3/28/2024)

As an undergraduate at Stanford, Jessica engaged in research starting in her freshman year. Jessica received a summer grant from Stanford's Physics Department for two years, one spent at CERN where she engaged in an analysis searching for the dark sector in ATLAS data. At the encouragement of her mentor, Jessica participated in research in several labs at Stanford to help crystalize her future graduate studies. Jessica received a BS in Physics, with a minor in Theatre and Performance Studies from Stanford in 2021.[2]

Jessica is currently a Ph.D. candidate at MIT, where she writes:

> I am interested in physics beyond the standard model, discovering the particle nature of dark matter. As an experimentalist, I focus on the application of novel quantum sensors in cryogenic environments to find low-mass axion dark matter. In the Winslow lab, I work on the DMRadio and ABRACADABRA experiments. In particular, I contribute to the calibration software, hardware design, and detector simulations. (Jessica Fry, Graduate Student | Winslow Lab (mit.edu)

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[1] Zoom meeting with Jessica Fry and Kathryn Race May10, 2024. Informaiton used with permission via email from Jessica on 5/20/24.

[2] Jessica writes *Prior to becoming a physicist, I performed on Broadway as a professional dancer, actor and singer. I performed on Broadway, toured with a Broadway company, acted on TV, originated a role , and performed in a principal role at the MUNY.* Broadway | Jessica Fry (jessica-fry.com)

Publications:

PHYSICAL REVIEW D **106,** 103008 (2022)

Projected sensitivity of DMRadio-m^3: A search for the QCD axion below 1 μeV

L. Brouwer,[1] S. Chaudhuri,[2] H.-M. Cho,[3] J. Corbin,[4] W. Craddock,[3] C. S. Dawson,[4] A. Droster,[5] J. W. Foster,[6] J. T. Fry,[7] P. W. Graham,[4] R. Henning,[8,9] K. D. Irwin,[4,3,*] F. Kadribasic,[4] Y. Kahn,[10] A. Keller,[5] R. Kolevatov,[2] S. Kuenstner,[4] A. F. Leder,[5,1] D. Li,[3] J. L. Ouellet,[7,†] K. M. W. Pappas,[7] A. Phipps,[11] N. M. Rapidis,[4] B. R. Safdi,[12] C. P. Salemi,[7] M. Simanovskaia,[4] J. Singh,[4] E. C. van Assendelft,[4] K. van Bibber,[5] K. Wells,[4] L. Winslow,[7] W. J. Wisniewski,[3] and B. A. Young[13]

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(Received 11 May 2022; accepted 17 October 2022; published 8 November 2022)

The QCD axion is one of the most compelling candidates to explain the dark matter abundance of the Universe. With its extremely small mass ($\ll 1$ eV$/c^2$), axion dark matter interacts as a classical field rather than a particle. Its coupling to photons leads to a modification of Maxwell's equations that can be measured with extremely sensitive readout circuits. DMRadio-m^3 is a next-generation search for axion dark matter below 1 μeV using a > 4 T static magnetic field, a coaxial inductive pickup, a tunable LC resonator, and a DC-SQUID readout. It is designed to search for QCD axion dark matter over the range 20 neV $\lesssim m_a c^2 \lesssim$ 800 neV (5 MHz $< \nu <$ 200 MHz). The primary science goal aims to achieve Dine-Fischler-Srednicki-Zhitnitsky sensitivity above $m_a c^2 \approx 120$ neV (30 MHz), with a secondary science goal of probing Kim-Shifman-Vainshtein-Zakharov axions down to $m_a c^2 \approx 40$ neV (10 MHz).

DOI: 10.1103/PhysRevD.106.103008

Proposal for a definitive search for GUT-scale QCD axions

L. Brouwer,[1] S. Chaudhuri,[2,*] H.-M. Cho,[3] J. Corbin,[4] C. S. Dawson,[4] A. Droster,[5] J. W. Foster,[6] J. T. Fry,[7] P. W. Graham,[4] R. Henning,[8,9] K. D. Irwin,[4,3] F. Kadribasic,[4] Y. Kahn,[10] A. Keller,[5] R. Kolevatov,[2] S. Kuenstner,[4] A. F. Leder,[5,11] D. Li,[3] J. L. Ouellet,[7] K. M. W. Pappas,[7] A. Phipps,[12] N. M. Rapidis,[4] B. R. Safdi,[13] C. P. Salemi,[7,14,3,†] M. Simanovskaia,[4] J. Singh,[4] E. C. van Assendelft,[4] K. van Bibber,[5] K. Wells,[4] L. Winslow,[7] W. J. Wisniewski,[3] and B. A. Young[15]

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(Received 29 May 2022; accepted 31 October 2022; published 12 December 2022)

The QCD axion is a leading dark matter candidate that emerges as part of the solution to the strong *CP* problem in the Standard Model. The coupling of the axion to photons is the most common experimental probe, but much parameter space remains unexplored. The coupling of the QCD axion to the Standard Model scales linearly with the axion mass; therefore, the highly motivated region 0.4–120 neV, corresponding to a GUT-scale axion, is particularly difficult to reach. This paper presents the design requirements for a definitive search for GUT-scale axions and reviews the technological advances needed to enable this program.

DOI: 10.1103/PhysRevD.106.112003

Electromagnetic modeling and science reach of DMRadio-m^3

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(Dated: March 1, 2023)

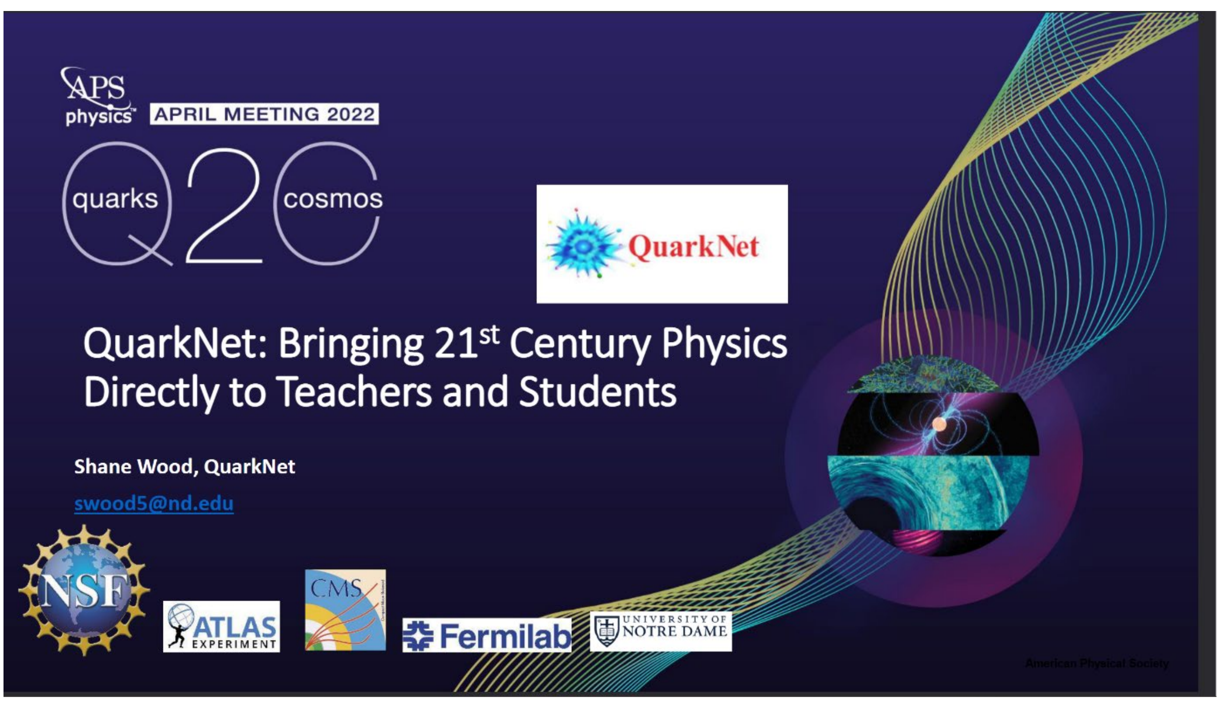
DMRadio-m^3 is an experiment that is designed to be sensitive to KSVZ and DFSZ QCD axion models in the 10–200 MHz ($41\,\mathrm{neV}/c^2$ – $0.83\,\mu\mathrm{eV}/c^2$) range. The experiment uses a solenoidal dc magnetic field to convert an axion dark-matter signal to an ac electromagnetic response in a coaxial copper pickup. The current induced by this axion signal is measured by dc SQUIDs. In this work, we present the electromagnetic modeling of the response of the experiment to an axion signal over the full frequency range of DMRadio-m^3, which extends from the low-frequency, lumped-element limit to a regime where the axion Compton wavelength is only a factor of two larger than the detector size. With these results, we determine the live time and sensitivity of the experiment. The primary science goal of sensitivity to DFSZ axions across 30–200 MHz can be achieved with a 3σ live scan time of 3.7 years.

Electromagnetic modeling and science reach of DMRadio-m3
DMRadio Collaboration Preprint, 2023 arXiv:2302.14084

QuarkNet Center
University of Minnesota

Shane Wood QuarkNet Staff Teacher (presented with permission)

Shane Wood joined the University of Minnesota (UM) QuarkNet in 2002 when it became a new center with Ken Heller as its first mentor. That year, Shane Wood also came to QuarkNet as a lead teacher for this center, participated in Data Camp and engaged in research with Roger Rusack, a CMS physicist, at the University of Minnesota and then at CERN. At that time, Shane was a Physical Science and Earth Science (and later Physics) teacher at Irondale High School in New Brighton Minnesota a suburb of Minneapolis. He continued in his role as one of the lead teachers for the UM Center and expanded his QuarkNet role when in 2007 he became a fellow in the year the QuarkNet Fellows component of the program began. As a classroom teacher, he worked with leadership to help forge the development of instructional support for science teachers at the district level. After serving several years as a part-time teacher and working part-time supporting science teachers at the district level, and as a QN fellow, in 2015 he accepted the role of QuarkNet staff teacher. He continues in this role where he serves part-time as a QuarkNet staff teacher and part-time as a district-level science educator in the Mounds View (MN) Public Schools. At the local school district level, he supports classroom science teachers and science specialists with standards alignment and curricular support. In addition, he provides district teachers and administrators with information and resources on current and cutting-edge research in particle physics and keeps QuarkNet informed of local teacher needs and perspectives. In this capacity, he has also worked with high school students in a research class or through independent study where students engage in the collection and analysis of authentic particle physics data including the use of a comic ray detector. From 2015 on, Wood has gained extensive QuarkNet experience both at the local level and serving the national program working to build relationships through program administration, oversight and coordinating with at least a third of QN centers, as well as implementation and instructional support through workshops, masterclasses and help in the development of Data Activities Portfolio activities. He has shared his experiences and expertise at several professional national and regional meetings; the example below highlights an invited speaker presentation Shane gave at the American Physical Society meeting in April 2022.



In an email from Ricco Venterea to Shane Wood (4/4/2024), Ricco wrote:

> Hi Mr. Wood,
>
> Today I committed to the University of California, Riverside to obtain a PhD in Astronomy. I am extremely excited for this new stage of my life and can't wait to see what it holds. I also won a Fulbright Award to conduct research in Italy for 9 months. I will be at the University of Perugia starting in October of this year, where I will be doing work in cosmic rays. Thank you so much for inspiring me to pursue physics and for your class in particle physics. After my Fulbright, I will return to the US to attend Riverside in Fall 2025
> My asteroid paper recently got published in *The Astrophysical Journal.* I am continuing work at the University of Minnesota, Twin Cities, and a first draft of our paper can be seen here.
> ….
> Best,
> - Ricco

Ricco Venterea graduated from Irondale High School in June 2020, a public high school in New Brighton, MN that is part of the Mounds View Public Schools district. During the 2019-2020 school year, Ricco participated in a two-semester independent study on physics research; Shane Wood, a QuarkNet staff member, served as his teacher. Ricco noted in a conversation with me,[1] that his hands-on experience with QuarkNet cosmic ray detectors during the first semester of his Independent Study helped him see the meaningfulness and context in the data that he analyzed later that year. (COVID had forced these engagements to happen virtually.) Ricco has gone on to Cornell University where he received a BA degree in astronomy with astrophysics concentration in May 2024. During his undergraduate experiences at Cornell, he participated in a summer research experience at the University of Minnesota, Twin Cities through a grant from Cornell. Ricco mentioned to me that he thought his comic ray research experience was instructional in his applying and received his Fullbright award.

[1] A Zoom conversation with Ricco Venterea and Kathryn Race on 5/6/24.

The Astrophysical Journal, 964:138 (12pp), 2024 April 1 https://doi.org/10.3847/1538-4357/ad21fe

The Atacama Cosmology Telescope: Millimeter Observations of a Population of Asteroids or: ACTeroids

John Orlowski-Scherer[1], Ricco C. Venterea[2], Nicholas Battaglia[2], Sigurd Naess[3], Tanay Bhandarkar[4], Emily Biermann[5], Erminia Calabrese[6], Mark Devlin[4], Jo Dunkley[7,8], Carlos Hervías-Caimapo[9], Patricio A. Gallardo[10], Matt Hilton[11,12], Adam D. Hincks[13,14], Kenda Knowles[15,16], Yaqiong Li[17,18], Jeffrey J McMahon[10,19,20,21], Michael D. Niemack[2,17], Lyman A. Page[7], Bruce Partridge[22], Maria Salatino[23,24], Jonathan Sievers[1], Cristóbal Sifón[25], Suzanne Staggs[7], Alexander van Engelen[26], Cristian Vargas[9], Eve M. Vavagiakis[17], and Edward J. Wollack[27]

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Abstract

We present fluxes and light curves for a population of asteroids at millimeter wavelengths, detected by the Atacama Cosmology Telescope (ACT) over 18,000 deg^2 of the sky using data from 2017 to 2021. We utilize high cadence maps, which can be used in searching for moving objects such as asteroids and trans-Neptunian Objects, as well as for studying transients. We detect 170 asteroids with a signal-to-noise of at least 5 in at least one of the ACT observing bands, which are centered near 90, 150, and 220 GHz. For each asteroid, we compare the ACT measured flux to predicted fluxes from the near-Earth asteroid thermal model fit to WISE data. We confirm previous results that detected a deficit of flux at millimeter wavelengths. Moreover, we report a spectral characteristic to this deficit, such that the flux is relatively lower at 150 and 220 GHz than at 90 GHz. Additionally, we find that the deficit in flux is greater for S-type asteroids than for C-type.

Unified Astronomy Thesaurus concepts: Asteroids (72); Cosmic microwave background radiation (322); Millimeter astronomy (1061)

arXiv > gr-qc > arXiv:2403.18661

General Relativity and Quantum Cosmology

[Submitted on 27 Mar 2024]

A machine-learning pipeline for real-time detection of gravitational waves from compact binary coalescences

Ethan Marx,[1,2] William Benoit,[3] Alec Gunny,[1,2] Rafia Omer,[3] Deep Chatterjee,[1,2] Ricco C. Venterea,[3,4] Lauren Wills,[3] Muhammed Saleem,[3] Eric Moreno,[1,2] Ryan Raikman,[1,5] Ekaterina Govorkova,[1,2] Dylan Rankin,[6] Michael W. Coughlin,[3] Philip Harris,[1] and Erik Katsavounidis[1,2]

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[6] *Department of Physics and Astronomy, University of Pennsylvania, Philadelphia, PA, 19104, USA*
(Dated: March 28, 2024)

The promise of multi-messenger astronomy relies on the rapid detection of gravitational waves at very low latencies ($\mathcal{O}(1\,\mathrm{s})$) in order to maximize the amount of time available for follow-up observations. In recent years, neural-networks have demonstrated robust non-linear modeling capabilities and millisecond-scale inference at a comparatively small computational footprint, making them an attractive family of algorithms in this context. However, integration of these algorithms into the gravitational-wave astrophysics research ecosystem has proven non-trivial. Here, we present the first fully machine learning-based pipeline for the detection of gravitational waves from compact binary coalescences (CBCs) running in low-latency. We demonstrate this pipeline to have a fraction of the latency of traditional matched filtering search pipelines while achieving state-of-the-art sensitivity to higher-mass stellar binary black holes.

QUARKNET

QuarkNet Center
Boston Area
Brown University
Northeastern University

Michael Wadness
QuarkNet Teacher and Fellow
(Used with his permission via email 5/23/24)

<table>
<tr><td colspan="2">Michael Wadness is an experienced Physics teacher at Medford High School, a public school in Medford MA. About one-third of the student body of this school is low income. He teaches 11th/12th Honors Physics, 12th AP C Mech and E&M. Mike came to QuarkNet in 2003 at the Boston area QuarkNet and became a QuarkNet LHC fellow in 2007 (the year the fellow program started) where he was asked to help create the Virtual Center. He became a STEP UP Ambassador in 2019 and Ambassador Lead in 2020. STEP UP. He received his Ed.D. in Science Education from the University of Massachusetts Lowell in 2010. (Dissertation_Final Draft.pdf - Google Drive)</td></tr>
<tr><td>Testimonial
MikeWadness_MA.pdf (quarknet.org)</td><td>QuarkNet Engagement and
Highlighted Responses from Survey</td></tr>
<tr><td>Michael wrote:

Anytime I discuss the impact of QuarkNet on my classroom, I always think of three distinct yet interwoven levels. The first level is the development of my own personal professional knowledge of physics. QuarkNet provides a level of professional development in personal learning of particle physics and inquiry that is not available elsewhere. This standard of quality that QuarkNet is achieved through its model of peer teachers and physicist mentors.

The second level of impact is that QuarkNet provides the knowledge base to discuss comfortably with my students current events in physics. Due to my recent participation in one of QuarkNet's LIGO workshops I was able to engage my students in rich discussions concerning the recent discoveries of gravitational waves and kilonovas!

The third level of impact that QuarkNet has provided is through the inquiry-based activities in their data portfolios. These activities have allowed me to enhance the curriculum by bringing real particle physics data to my students. This involvement ranges from the longterm student use of a Cosmic Ray Muon Detector to foster investigatory skills and scientific habits of mind to using data from the LHC to study traditional topics such as conservation of energy and momentum.

Through the three interwoven levels of impact, QuarkNet has allowed physics to come alive in my classroom. Although the majority of the traditional curriculum is hundreds of years old, QuarkNet allows students to experience the current excitement of today's physics in the 21st century and provides multiple opportunities to enhance many of the Next Generation Science Standards through its emphasis on inquiry based investigations using real particle physics data. QuarkNet has given me the tools to be a relevant student-focused teacher of an evolving physics rather than a mere presenter of ancient, stilted information.</td><td>Michael is a long-term QuarkNet teacher and fellow. Prior to participating in QuarkNet, he was engaged in a CERN summer research program in 2003 where fellow recipients who were involved in QuarkNet suggested he join QuarkNet as well. He has participated in and/or helped lead the following QuarkNet events as examples of his engagement:

• CMS Workshop(s)
• Cosmic Ray e-Lab(s)
• Cosmic Ray e-Lab Advanced
• Neutrino Data Workshop(s)
• ATLAS Masterclass
• CMS Masterclass
• World Wide Data Day
• International Muon Week

How Michael has reported use of QuarkNet materials in his classroom.

In 2021, he wrote: I have incorporated a variety of activities (DAP) when teaching conservation laws. He mentioned these examples: StepUp, Rolling with Rutherford, Particle Cards.

In 2022, he wrote: I will use many of the activities from the data portfolio as after school projects. Some of which will be used while teaching conservation laws and quantum mechanics. He mentioned these examples: Neutrino masterclass, Z Mass, The Case of the Hidden Neutrino. They are fantastic to use to make direct connections to contemporary physics.

In 2023, he wrote: World Wide Data Day gives ALL my students a one day exposure to particle physics .. without having to leave my classroom. Examples he gave: StepUp activities to address under representation. The Case of the Missing Neutrino to give an application of vectors, conservation of momentum, and insight into the nature of science. They provide access to particle physics that can be implemented into a traditional curriculum.</td></tr>
</table>

AN EVALUATION OF THE PARTICLE PHYSICS MASTERCLASS AS A CONTEXT FOR STUDENT LEARNING ABOUT THE NATURE OF SCIENCE

By MICHAEL J. WADNESS

ASTRACT OF A DISSERTATION SUBMITTED TO THE FACULTY OF THE GRADUATE SCHOOL OF EDUCATION IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF EDUCATION SCIENCE EDUCATION UNIVERSITY OF MASSACHUSETTS LOWELL 2010

ABSTRACT

This dissertation addresses the research question: To what extent do secondary school science students attending the U.S. Particle Physics Masterclass change their view of the nature of science (NOS)? The U.S. Particle Physics Masterclass is a physics outreach program run by QuarkNet, a national organization of secondary school physics teachers and particle physicists partially funded by the National Science Foundation and the Department of Energy. The Masterclass is a one-day event in which high school physics students gather at a local research institution to learn about particle physics and the scientific enterprise. Student activities include introductory lectures in particle physics, laboratory tours, data analysis, and the discussion of their findings in a conference-like atmosphere. Although the Masterclass has been previously evaluated for students' learning of particle physics content, it was unknown if students' understanding of NOS changed after attending the Masterclass.

This research concerns the problem of science literacy, specifically students' understanding of the nature of science (NOS). Previous research suggests that students do not implicitly acquire a sufficient understanding of NOS through the instruction of science content or through inquiry investigations. The literature suggests that sufficient understanding of NOS will only be successful if it is explicitly taught within a context. Unfortunately, research also suggests that many teachers do not include explicit instruction of NOS due various reasons that include a lack of time, understanding, and resources. Therefore, a need presents itself for curriculum extension programs in which explicit learning of NOS may occur.

Due to the Masterclass explicitly including NOS within its introductory presentations, it was hypothesized that the remaining Masterclass activities may provide a context for student learning of NOS. The design of this study was a mixed methodology utilizing repeated quantitative and qualitative measures. Data collection consisted of a survey instrument consisting of Likert-type and open-response items administered as a pretest prior to the Masterclass, a posttest immediately following the Masterclass, and a second posttest administered two to three weeks after the Masterclass. Additional data were also collected through the use of phone interviews. Three different Masterclasses were evaluated over a two-year period at Fermilab (outside of Chicago) in February 2009 and February 2010 and at U.C. Irvine (outside of Los Angeles) in March 2010.

The results of the combined analyses suggested students' understanding of NOS may have changed after attending the Masterclass, specifically in the NOS tenets regarding: indirect, subjective observations; use of imagination and creativity; collaboration; and the image of a scientist. Students' understanding of NOS did not appear to change in the NOS tenets regarding: tentative yet stable; social and cultural influences; no universal scientific method; and a comprehensive understanding of theory versus law.

Although there are a number of outreach programs involving scientists in K-12 education, very few of them have been formally evaluated to determine if they provide adequate learning of NOS. Therefore, the significance of this study is that it provides data to support the claim that science outreach programs may be designed to address science literacy, specifically as a context for explicit NOS instruction.

Michael told me during a virtual conversation we had on June 10, 2024 that although he had started his doctoral program as a part-time student prior to QuarkNet, QuarkNet was instructional to his dissertation thesis where he focused on the effect of QuarkNet's masterclass has on student's' understanding of the nature of science. QuarkNet provided assistance in scheduling and conducting these masterclass events as well as financial support for Michael's travel.

Example of a presentation given by Michael Wadness at the AAPT 2021: Virtual Winter Meeting (source: abstract book 2021)

A2.11 | Quantum Physics in Introductory
January 9, 2021 | 1:30 PM - 2:45 PM

A2.11-01 | What Heisenberg Knew: A QuarkNet Data-Based Student Activity
Presenting Author **|** *Michael Wadness, Medford High School/QuarkNet*

Many teachers have struggled to connect quantum principles to the traditional high school curriculum. Often these ideas are part of off-topic discussions in which they are simply asserted or partially explained in a hand-waiving manner. This presentation introduces a QuarkNet activity in which high school students analyze simple momentum and position data collected from a 2001 diffraction experiment to empirically discover the famous inverse relationship known as the Heisenberg Uncertainty Principal.

A2.11-02 | Development of Semiclassical Tic-Tac-Toe for Introductory Quantum Mechanics Students
Presenting Author **|** *Joshua Qualls, Morehead State University*
Additional Author | Keaghan Knight, Morehead State University

Quantum tic-tac-toe (QTTT) is an educational tool illustrating novel features of quantum systems. Most versions include states, superposition, collapse, and entanglement. While QTTT can provide a foundation for understanding quantum principles, QTTT can also be overwhelming for students new to quantum mechanics. In this talk, we introduce a simplified version of QTTT that does not include entanglement: semiclassical tic-tac-toe (STTT). As a first step toward a systematic development of interactive quantum computing demonstrations and curriculum, we have designed materials for an STTT lesson plan and pilot study. Materials include a pre- and post-test over basic quantum mechanical ideas, an instructor's guide to STTT and QTTT, and a classroom-ready Python-based program featuring classical tic-tac-toe, STTT, and QTTT. We are implementing a pilot study to explore their effectiveness in communicating scientific content and the extent to which the inclusion of STTT might enhance student knowledge in introductory physics courses.

A2.11-03 | The Qubit and Quantum Computing- A Simulation in the Classroom
Presenting Author **|** *Jorge Kuhne*

After presenting therical evolution and basic entities starting with the qubit it goes to a simple practical demonstration using common components (magnets attraction and repulsion) the six qubit states. Completing these ideas finalizes with a quantum teleportation of one

Simona Miller
Former student of: Michael Wadness
Medford High School Medford,
MA Brown and Northeastern Universities Center
(used with Simona's permission via email 6/20/24)

Testimonial (January 2018) MikeWadness_MA_studentSimonaMiller_MA.pdf (quarknet.org)	Academic Achievements
Simona wrote: *QuarkNet's cosmic ray detectors and masterclass activities are a primary reason that I am pursuing a physics degree in college and aspire to conduct research in astrophysics this upcoming summer and after graduation. QuarkNet's programs provided me with my first opportunity to conduct hands-on modern physics research. Using the cosmic ray detectors, I conducted two research projects for the high school and district-wide science fair in 2015 and 2016. I investigated correlations between weather patterns and muon flux; the following year, I constructed a cloud chamber and compared its findings with those from the scintillator panel system. Through assembling, calibrating, and collecting data with the CR detection system, I discovered a drive to independently explore physics concepts that otherwise wouldn't have ignited until much later in my life. Furthermore, the masterclasses provided me with unique opportunities share data globally, to hear about physics careers, and to connect with other high school students interested in physics. I was excited to learn physics beyond the high-school-classroom curriculum; it felt important and applicable.* *Additionally, my interest in both astrophysics and particle physics piqued during my experiences with QuarkNet's programs. When learning about cosmic rays, I discovered an ongoing fascination with the vastness of the universe and how its pieces fit together and operate on a large scale. I entered college confident that I would study mechanical engineering, which I initially viewed as applied physics. However, I quickly realized that my true interests more closely align with the topics that I was introduced to through the cosmic ray detectors and masterclass activities than to product design. I have now added a physics major and astrophysics minor to my college education. Because I was exposed to particle physics in high school through QuarkNet, I was able to figure out that physics is my passion early-on in college. This has brought me confidence in my career path and will certainly prove an asset in research positions that I plan to hold in the future. Above all, QuarkNet's programs fueled my natural curiosity and drive to understand complicated ideas, which I believe to be my largest asset as a young physicist.*	At Smith College, Simona Miller declared a double major in physics and engineering, The more time Simona spent studying and doing research in physics as an undergraduate, the more interested they became in that field. They told me during a conversation on June 14, 2024 that they weren't aware that one could have a career in physics when they first started at Smith. As a recipient of Smith College's Student Research in Departments (STRIDE) program, they received a 4-year scholarship and the opportunity to serve as a research assistant first in Dr. Joyce Palmer-Fortune's lab focused on educational outreach directed toward introductory Physics classrooms, and then in Dr. Courtney Lannert lab's focused on studying collective quantum-mechanical phenomenon through condensed matter. That early exposure to physics research piqued Simona's interest in physics and demonstrated that careers in physics were possible. In 2018, Simona received an NSF-funded REU Summer Undergraduate Research Fellowship at California Institute of Technology to conduct research at the LIGO, Scientific Collaboration, as they described, *Researched the effect of orbital eccentricity on the gravitational waves produced by binary black hole systems.* In summer 2019, funded by an International REU program from the University of Florida, they worked at the Max Planck Institute for Gravitational Physics in Hannover Germany where they *worked at a gravitational wave detector called GEO 600*. (GEO600 is a key technology development center of the international gravitational-wave research community Home | GEO600 Gravitational-wave Detector.) Simona graduated from Smith College with a BA in Physics in 2020. In January 2021, Simona returned to the Max Planck Institute in Hanover under a Fulbright scholarship conducting research in the group of Dr Maria Alessandra Papa, *studying data analysis methods for detecting gravitational waves from rapidly rotating neutron stars*.

Simona is a Ph.D. student as Caltech in the Division of Physics, Mathematics and Astronomy. They are a member of the LIGO scientific collaboration; and their advisor is Dr. Katerina Chatziioannou. Simona wrote in an email to me (6/19/2024), *I study gravitational waves from merging binary black hole systems, with a focus on making the measurements of their spins as robust as possible at all points in LIGO's data analysis pipeline.* And they noted, *I recently was awarded the James A Cullen Memorial Fellowship Prize.* The Fellowship is a fund awarded annually to a graduate student or students who have demonstrated outstanding academic achievement in physics. James A. Cullen Memorial Fellowship Fund Recipients | The Division of Physics, Mathematics and Astronomy (caltech.edu).

Recent publication https://journals.aps.org/prd/abstract/10.1103/PhysRevD.109.104036

PHYSICAL REVIEW D **109,** 104036 (2024)

Gravitational waves carry information beyond effective spin parameters but it is hard to extract

Simona J. Miller,[1,2,*] Zoe Ko,[3,†] Tom Callister,[4,‡] and Katerina Chatziioannou[1,2,§]

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[2]*LIGO Laboratory, California Institute of Technology, Pasadena, California 91125, USA*
[3]*Department of Physics, University of California Berkeley, Berkeley, California 94720, USA*
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(Received 12 January 2024; accepted 13 March 2024; published 10 May 2024)

Gravitational wave observations of binary black hole mergers probe their astrophysical origins via the binary spin, namely the spin magnitudes and directions of each component black hole, together described by six degrees of freedom. However, the emitted signals primarily depend on two effective spin parameters that condense the spin degrees of freedom to those parallel and those perpendicular to the orbital plane. Given this reduction in dimensionality between the physically relevant problem and what is typically measurable, we revisit the question of whether information about the component spin magnitudes and directions can successfully be recovered via gravitational-wave observations, or if we simply extrapolate information about the distributions of effective spin parameters. To this end, we simulate three astrophysical populations with the same underlying effective-spin distribution but different spin magnitude and tilt distributions, on which we conduct full individual-event and population-level parameter estimation. We find that parametrized population models can indeed qualitatively distinguish between populations with different spin magnitude and tilt distributions at current sensitivity. However, it remains challenging to either accurately recover the *true* distribution or to diagnose biases due to model misspecification. We attribute the former to practical challenges of dealing with high-dimensional posterior distributions, and the latter to the fact that each individual event carries very little information about the full six spin degrees of freedom.

DOI: 10.1103/PhysRevD.109.104036

Joseph Farah, PhD candidate at UC Santa Barbara
Former Student of Dr. Michael Wadness Medford High School Medford MA
Boston Area QuarkNet Center
(Used with permission 7/5/2024)

Testimonial (January 2018) MikeWadness_MA_studentJosephFarah.pdf (quarknet.org)	QuarkNet's Influence and Academic Accomplishments
When I walked into Dr. Michael Wadness' classroom for the first time in 2015, I wasn't expecting to emerge with a completely different outlook on physics. As a budding sophomore, I was experimenting with interests and passions, mostly in science. For my science fair project that year, I decided to explore special relativity, and I took some of the questions I had about the subject to Dr. Wadness. Despite the fact that I wasn't his student, he graciously took the time to answer my elementary questions. His explanations and answers were thorough, simple, and generally fantastic—something I found to be consistently true of his teaching when I eventually took his AP Physics class. But my curious eye was drawn to what some of his students were doing in the back of the room. I watched quietly as they assembled a large, stacked structure, attached to enough tape, wires, and circuit boards to intrigue my younger self. Dr. Wadness and his students explained that what they were building was called a "cosmic ray detector", and it was capable of measuring the quantity and velocity of hundreds of thousands of invisible particles that pass through the atmosphere, our bodies, and the Earth. These particles originated in outer space, far, far away, and ended their enormous journey by smacking into electrons inside of the detector. As I watched the LCD counter rocket upwards, I felt the stirrings of an immense fascination with the physics of the very small, the very fast, and the very far away. *A year later, when I had taken that fascination and turned it into an astrophysical science fair project, I approached Dr. Wadness once more with my eagerness to learn more about the mysterious world of particle physics. Despite a complete lack of preparation, he welcomed me into a group of students learning rudimentary particle physics, practicing for the annual QuarkNet Masterclass at Northeastern. Needless to say, the class doubled my interest in the subject. Despite knowing that the class remained essentially the same from year to year, I decided to go my senior year as well, just to recapture that magical rush that comes from characterizing the invisible and collaborating with people from around the world. The feeling never got old, and it inspired me to firmly declare a physics/math double major before I had even begun my first semester in college. It inspired me to jump head first into real-world particle physics research. Thanks to QuarkNet and the science faculty at Medford High, I went from learning about leaders in particle physics to working side by side with them in just a few short months.*	When we spoke on July 1, 2024, Joseph noted that his enthusiasm for science goes back as far as he can remember. He spoke of watching an episode on NOVA (PBS series), when he was very young, that talked about the Mars Rover. That ignited an interest and enthusiasm for science that has not waivered as he got older. He told me that he valued his opportunity to participate in local science fairs during high school and that his engagement with QuarkNet helped him improve his science projects; Joseph received local, regional and state science fair awards. He credits QuarkNet with helping him see and appreciate the rigor of science as well as opportunities to talk with mentors and researchers as to career opportunities in science, and specifically in astrophysics. Prior to his high school graduation, he was a Summer Research Intern at Tufts University in the Astrophysics Department in 2015 mentored by Dr. Anna Sajina. He held an additional Summer Research Internship at Harvard John A. Paulson School of Engineering and Applied Science where he worked with a team to create a robotic glove to help in the development of an algorithm to support a robotic hand. Joseph graduated from Medford High School in 2017. During the summer between his high graduation and the start of his freshman year as an undergraduate, Joseph was a Research Intern working on ATLAS at the Harvard Laboratory for Particle Physics and Cosmology. Joseph received a full scholarship to attend the University of Massachusetts, Boston where he graduated *summa cum laude* with distinction with a BS in Physics Astrophysics in 2021. As an undergraduate, he was a Research Intern with the QBism Research Group at UMass and *Joseph worked on the Event Horizon Telescope (EHT) project as a Smithsonian Fellow at the Harvard-Smithsonian Center for Astrophysics under the supervision of Michal Johnson*. He was the recipient of the Breakthrough Prize in Fundamental Physics (co-received with the EHT Collaboration).

Joseph Farah is a Ph.D candidate in Astrophysics at UC Santa Barbara studying supernovae under Dr. Andy Howell as part of the Las Cumbres Observatory (LCO) and the Global Supernova Project. Joseph Farah | Department of Physics | UC Santa Barbara (ucsb.edu). He is the recipient of the National Science Foundation Graduate Research Fellowship (2021-2026) and the recipient of the LeRoy Apker Award (2021). He describes his research interests, in addition to supernovae, as: *Astrophysics, radio astronomy, black holes, dark energy, very long baseline interferometry, theoretical cosmology, strong gravity, Bayesian modeling and magnetohydrodynamics.* He completed his MA in Physics from UC Santa Barbara in 2023. He is the author or co-author of approximately 100 publications. He has given numerous outreach invited talks including one at Medford High School to Honors and AP Physics classes in 2022.

The Astrophysical Journal, 900:77 (9pp), 2020 September 1 https://doi.org/10.3847/1538-4357/aba59a

CrossMark

On the Approximation of the Black Hole Shadow with a Simple Polar Curve

Joseph R. Farah[1,2,3], Dominic W. Pesce[1,2], Michael D. Johnson[1,2], and Lindy Blackburn[1,2]
[1] Center for Astrophysics, Harvard-Smithsonian, 60 Garden Street, Cambridge, MA 02138, USA; joseph.farah@cfa.harvard.edu
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Abstract

A black hole embedded within a bright, optically thin emitting region imprints a nearly circular "shadow" on its image, corresponding to the observer's line of sight into the black hole. The shadow boundary depends on the black hole's mass and spin, providing an observable signature of both properties via high-resolution images. However, standard expressions for the shadow boundary are most naturally parametrized by Boyer–Lindquist radii rather than by image coordinates. We explore simple, approximate parameterizations for the shadow boundary using ellipses and a family of curves known as *limaçons*. We demonstrate that these curves provide excellent and efficient approximations for all black hole spins and inclinations. In particular, we show that the two parameters of the limaçon naturally account for the three primary shadow deformations resulting from mass and spin: size, displacement, and asymmetry. These curves are convenient for parametric model fitting directly to interferometric data, they reveal the degeneracies expected when estimating black hole properties from images with practical measurement limitations, and they provide a natural framework for parametric tests of the Kerr metric using black hole images.

Unified Astronomy Thesaurus concepts: Black hole physics (159)

As described by Joseph:

On the Approximation of the Black Hole Shadow with a Simple Polar Curve: this paper presented an elegant new formalism for calculating the shadows of black holes, an alternative to the exact but far more unwieldy full Boyer-Lindquist expression. It presented several key discoveries about black hole shadow behavior and has been cited 30+ times (8x higher than the field average), including in some new texts on general relativity.

The Astrophysical Journal Letters, 930:L18 (21pp), 2022 May 10 https://doi.org/10.3847/2041-8213/ac6615

CrossMark

Selective Dynamical Imaging of Interferometric Data

Joseph Farah[1,2], Peter Galison[3,4,5], Kazunori Akiyama[3,6,7], Katherine L. Bouman[3,8,9], Geoffrey C. Bower[10], Andrew Chael[11,12], Antonio Fuentes[13], José L. Gómez[14], Mareki Honma[15,16,17], Michael D. Johnson[3,8], Yutaro Kofuji[15,17], Daniel P. Marrone[18], Kotaro Moriyama[6,15], Ramesh Narayan[3,8], Dominic W. Pesce[3,8], Paul Tiede[19,20], Maciek Wielgus[21], Guang-Yao Zhao[13]
The Event Horizon Telescope Collaboration,

Abstract

Recent developments in very long baseline interferometry (VLBI) have made it possible for the Event Horizon Telescope (EHT) to resolve the innermost accretion flows of the largest supermassive black holes on the sky. The sparse nature of the EHT's (u, v)-coverage presents a challenge when attempting to resolve highly time-variable sources. We demonstrate that the changing (u, v)-coverage of the EHT can contain regions of time over the course of a single observation that facilitate dynamical imaging. These optimal time regions typically have projected baseline distributions that are approximately angularly isotropic and radially homogeneous. We derive a metric of coverage quality based on baseline isotropy and density that is capable of ranking array configurations by their ability to produce accurate dynamical reconstructions. We compare this metric to existing metrics in the literature and investigate their utility by performing dynamical reconstructions on synthetic data from simulated EHT observations of sources with simple orbital variability. We then use these results to make recommendations for imaging the 2017 EHT Sgr A^* data set.

Unified Astronomy Thesaurus concepts: Astrophysical black holes (98); Very long baseline interferometry (1769); Aperture synthesis (53); Interferometry (808)

As described by Joseph:

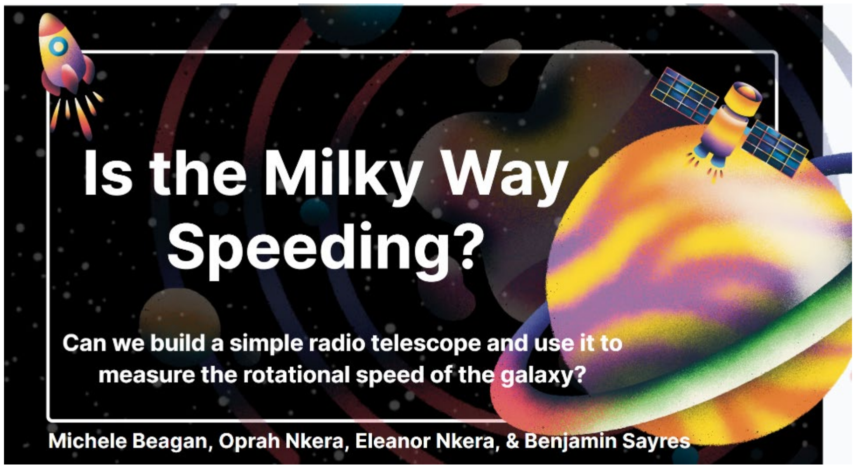
Selective Dynamical Imaging of Interferometric Data: this paper was Paper VII of the 10 papers published by the EHT in May 2022 reporting the second ever image of a black hole. It presents a novel method for imaging rapidly varying radio sources with sparse interferometric coverage, and is heavily cited in our imaging analysis (Paper III in the series). It's been cited ~30 times (15x higher than the field average) and downloaded 7000+ times. I received the LeRoy Apker award and the NSF GRFP for the work I did as lead author on this paper.

Eleanor Nkera (former student of Dr. Michael Wadness)
Salutatorian, Class of 2024
Medford High School, Medford, MA
(used with her permission 6/27/2024)

<table>
<tr><td colspan="2">Eleanor’s Engagement in QuarkNet and the Program’s Influence</td></tr>
<tr><td>In her junior and senior years Eleanor took Physics and AP Physics classes respectively, both taught by Dr. Wadness. Eleanor participated in QuarkNet included:

• Masterclass (twice)
• World Wide Data Day
• Cosmic Ray Detector use (as part of classroom engagement)

Eleanor mentioned to me (in our conversation on June 22, 2024) how valuable her QuarkNet Masterclass(es) and World Wide Data Day experiences were, giving her an opportunity to engage with and analyze authentic data. She also noted that Masterclasses provided her with the opportunity to collaborate with other students many of whom she did not know. She noted that these were experiences she’d likely have in her future academic and research pursuits. Eleanor also mentioned that a tour of a laboratory at MIT gave her a real world idea of how particle physics data are collected.</td><td>In her AP Physics class, Eleanor, with three other students, built a radio telescope in “an attempt to calculate the rotational velocity of the Milky Way” for their capstone project.


</td></tr>
<tr><td>Eleanor’s Thoughts about Her Salutatory Message</td><td>Where She’s Headed</td></tr>
<tr><td>Regarding her salutatory message (see an excerpt of her speech below), Eleanor wrote to Dr. Wadness in an email (June 6, 2024), Thank you Dr. Wadness! I knew I wanted to speak about high school friendships and reconnecting, but I decided to include physics because of how big of a role it has had in my life these last two years. Thanks for being a great teacher and showing up for your students. We appreciate it even if we don’t say so. Hope next year’s AP Physics class is as good as ours!</td><td>In our conversation, Eleanor told me when applying to colleges and universities, she had a two-part strategy “safe schools,” and “reach schools.” She was accepted into all of the top-tier universities where she applied.

She will start Harvard in the fall of 2024. She picked Harvard, where she intends to focus on bio-tech. She described to me that bio-tech offers her an opportunity to match her interests in math, computer science, science and engineering. She selected Harvard, in part, as it and the greater Boston area will provide many opportunities for her to pursue summer research internships closest to her academic interests.</td></tr>
</table>

Portion of Eleanor's Salutatory Message, Medford High School Graduation Class of 2024:

….. Speaking of faculty,
After I was assigned to write and perform this salutatory speech, I visited my physics teacher, Dr. Wadness for insight. What could I possibly say that would hopefully have an impact on every one of the thousands of attendees here? "Teach them an important lesson," he said. So, I'm taking his advice literally. Brace yourselves for a minute of Physics.

A quark, Q-U-A-R-K, is a simple elemental particle, and the building block of all visible matter in the universe. The radius of a quark is smaller than 43 billion billionths of a centimeter, about a million times smaller than a grain of sand. Now what physicists do with these particles is they accelerate them to 99.999% the speed of light, in huge 17-mile long machines made of superconducting magnets, called particle accelerators.

You're probably wondering, what does this quark nonsense have to do with me? Truth be told, every one of us here acts as a particle. What I haven't told you about these quarks is that while they bounce around at amazing speeds, some, a very small percentage, happen to collide. United for a brief millisecond, they interact. Imagine two glass marbles smashing into each other. Now multiply that collision by 150, leaving us with 300 marbles, each of them representing one of us.

Like these particles, we are all united by chance. Several graduates have families, like mine, who immigrated across the globe in hopes of a better future. Many students have gone through the Medford Public School system and followed this path to Medford High.
Others moved from city to city, and finally decided to settle in Medford, which they now proudly call home.

Regardless of where we come from, we are united by our shared collisions within the walls of our school. We have experienced the highest of highs and lowest of lows together. We forged connections as we bounced from class to class, bonding over the struggles of finding open bathrooms, and having to layer up when walking through B-building during the winter. We made friends we'll never forget at the black lab tables in our science classes, and discovered a newfound love for playing pingpong in the senior cafe. We have made memories that will last a lifetime at prom, homecoming, and formals, shimmying to Party in the U.S.A. and Mr. Brightside like our lives depended on it.

But what happens after the collision? What happens after we clean out our lockers and say goodbye to the teachers who have taught many of the things we now know? What happens after we commit to college, or start the job search, or pack suitcases for gap year travel? After we wave goodbye to our friends and fellow classmates, some will move across the state, the country, or even the world, at the end of the summer, after four years together. It feels like a long time, but four years is less than 5 percent of our lives. Comparable to the blink of an eye, or to the time that particles interact before rebounding just as fast as they met, never to cross paths again.

Yet, there is good news. The good news is that humans are made of quarks, but we do not have to act like them. After we disperse from Medford High, we will not disappear into the nothingness of the universe. Our relationships do not only exist in the time vacuum that was high school. We have the power to control our trajectories. So take charge of your future courses. Stay connected. Spend holidays together. Grab lunch at the Tavern, and an ice cream cone at Colleen's. Put the mini computers you carry in our pockets to use and remember that each one of us here is only a phone call away.
Graduates, make sure that the goodbyes you impart today are not forever, *but temporary. Congratulations, graduates, and don't be a stranger.*

Eleanor and her identical twin sister Oprah were featured in a article in the Boston Globe Meet the Medford twin sisters graduating as valedictorian and salutatorian, then heading to Harvard - The Boston Globe and on local Boston news Twin sisters from Medford graduate at top of their class, plan to attend Harvard - Boston News, Weather, Sports | WHDH 7News.

QUARKNET

QuarkNet Center
University of Notre Dame

Dan Walsh
QuarkNet Teacher
(used with permission)

<table>
<tr><td colspan="2">Dan Walsh is an experienced science teacher at Elkhart High School, a public school in Elkhart Indiana. He holds a BS in Mechanical Engineering from the University of Notre Dame, a BS in Professional Aeronautics, Embry-Riddle Aeronautical University, and a MS in Manpower Systems Analysis from the Naval Postgraduate School and a MS in Educational Leadership from Indiana University.</td></tr>
<tr><th>Teaching Experience</th><th>QuarkNet and Outreach Engagement</th></tr>
<tr><td>Dan Walsh, a retired P-3C Orion Naval flight officer, is a science teacher at Elkhart High School. He was previously at Adams High School where he taught science and served as the Science Department Chair for 10 plus years. He is also a commander of a school squadron in the Indiana Wing (John Adams High School Civil Air Patrol Cadet Squadron in South Bend).

He was named the John Adams High School Teacher of the Year in 2015. He was also received an Outstanding Teacher Award from the Indiana Department of Education in 2023.
He has taught:

• AP/IB/Dual Credit Physics
• Aeronautical Engineering
• Astronomy, Meteorology
• Earth Science
• Integrated Chemistry
• Technology Education

He also directs a Civil Air Patrol Squadron. He is passionate about aviation and STEM education, encouraging students to explore career opportunities in these fields.</td><td>Dan Walsh started his involvement in QuarkNet in 2013 and has participated in numerous QuarkNet program events, such as participating:

• Notre Dame's QuarkNet Research Experience for Teachers (RET) Program
• ATLAS Masterclass(es)
• CMS Masterclass(es)
• World Wide Data Day
During the summer of 2019 when he participated RET, he helped create along with Ken Cecire and in collaboration with Dr. Arielle Phillips, an Astro-Physics Masterclass. This class was used to introduce students like McKenna Leichty to Exoplanet detection calculations and was the impetus for her participation in the 2019 Summer Research Experience for High School Students (REHS) also at Notre Dame.

In 2023 Dan was selected by NASA, the American Society of the Pacific and the National Science Teachers Association as a Solar Eclipse Ambassador. As this ambassador, he and McKenna Leichty in 2023/2024 conducted outreach events at locations such as: Elkhart Community schools, their community library and Adult Education center. Together they distributed more than more than 15,000 solar eclipse glasses reaching (directly or indirectly) more than 25,000 students, teachers, parents and community with information about the Partial (2023) and total (2024) Solar Eclipses as well as the concept of Citizen Science through the NASA Solar Eclipse App.</td></tr>
</table>

McKenna Leichty (used with permission via email 6/21/24)

As a junior and senior at John Adams High School (2019 and 2020), McKenna Leichty enrolled in IB Physics classes taught by Mr. Dan Walsh. Mr. Walsh started participating in QuarkNet in 2013 where since then he has engaged in numerous QuarkNet program events, such as participating in the CERN summer program, Atlas Masterclass(es), CMS Masterclass(es), and World Wide Data Day.

During the summer of 2019 Dan Walsh participated in a research project at the University of Notre Dame. As did McKenna under Dan's recommendation. As part of his QuarkNet summer research, in collaboration with Ken Cecire and Dr. Arielle Phillips, he helped create an Astrophysics Masterclass that McKenna also participated in. During her QuarkNet summer research internship, McKenna (as noted in LinkedIn) *Used the program Astrometrica to analyze astronomical photographs for unidentified asteroids or near Earth Objects. Analyzed light curve data on TZ Cyg to develop evidence that it is a mira variable star.* In our conversation on June 13, 2024, McKenna credits Mr. Walsh for sparking her interest in physics, helping to merge her interests in math, how things are made, and her fascination with space. (In her senior year, Ms. Leichty was also named South Bend Tribunes Student-Athlete of the Month --January, 2020-- and won Kiwanis Athletic and Most Improved awards.) (South Bend Adams - Team Home South Bend Adams Eagles Sports (johnadamsathletics.com).

She graduated from John Adams High School with a Full International Baccalaureate Diploma in 2020. In his college letter of recommendation Mr. Walsh wrote: *McKenna will be responsible for solving some of the world's most difficult scientific problems.* Recently he's added, *I think we're in good shape with her as part of the next generation of researchers* (email message to me on 6/14/2024).

As she approached the end of her freshman year as an undergraduate student at the University of Notre Dame, McKenna began working in Dr. Peter Garnavich's lab in spring of 2021. She credits Dr. Garnavich for fueling and solidified her interest in physics where she had the opportunity to engage in numerous research projects, including her most recent discovery of a probable planet. Undergraduate McKenna Leichty discovers probable planet with help from Krizmanich Telescope atop Jordan Hall | News | News & Media | College of Science | University of Notre Dame She plans to continue this research with Dr. Garnavich as she moves on to Michigan State University.

During the summer of 2021, McKenna participated in Notre Dame's REU program for physics students. She described this experience where she *Studied and analyzed data for 49 confirmed cataclysmic variables to determine any stars that entered low states and possible models that might explain these low states.*

McKenna was accepted into the NSF-funded REU program at Michigan State University during the summer of 2023. As she wrote, *I have been working with Dr. Megan Donahue and Dr. David Turner on the X-ray analysis of the Local Volume Complete Cluster Survey (LoVoCCS). This survey observed about 143 local galaxy clusters, and I am using this survey to work on two different projects. So far, I have written Python software to identify possible background emissions that contaminate the X-rays coming from the LoVoCCS clusters. I have also started writing Python code to fit ellipses to the 2D projections of these clusters. Doing so will allow us to calculate morphological parameters such as the centroid shift and power ratios which determine whether a cluster is relaxed. Relaxed clusters are used in cluster cosmology to determine universal constants such as the dark energy density of the universe and the mass density of the universe. These numbers are what tell us how much dark energy, dark matter, and normal matter there are!*

McKenna Leichty graduated from the University of Notre Dame in 2024 with a BS in Physics. She is now a Ph.D. student at Michigan State University where she plans on earning her Ph.D. in astrophysics. She writes, *I am most passionate about learning how our universe works and where we stand in the middle of it all.*

And, oh by the way, she likes rock climbing.

Recent publication by Leichty, Garnavich, et. al.
https://iopscience.iop.org/article/10.3847/1538-4357/ad3bac

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An Eccentric Planet Orbiting the Polar V808 Aurigae

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Abstract

We analyze 15 yr of eclipse timings of the polar V808 Aur. The rapid ingress/egress of the white dwarf and bright accretion region provide timings as precise as a few tenths of a second for rapid cadence photometric data. We find that between 2015 and 2018, the eclipse timings deviated from a linear ephemeris by more than 30 s. The rapid timing change is consistent with the periastron passage of a planet in an eccentric orbit about the polar. The best-fit orbital period is 11 ± 1 yr and we estimate a projected mass of $M \sin(i) = 6.8 \pm 0.7$ Jupiter masses. We also show that the eclipse timings are correlated with the brightness of the polar with a slope of 1.1 s mag^{-1}. This is likely due to the change in the geometry of the accretion curtains as a function of the mass transfer rate in the polar. While an eccentric planet offers an excellent explanation to the available eclipse data for V808 Aur, proposed planetary systems in other eclipsing polars have often struggled to accurately predict future eclipse timings.

Unified Astronomy Thesaurus concepts: Cataclysmic variable stars (203); AM Herculis stars (32); Exoplanet detection methods (489); Eclipsing binary minima timing method (443); Stellar magnetic fields (1610)

Supporting material: machine-readable table