Curriculum Vitae of A. Nepomuk Otte

Appointments:

2023-	Professor of Physics	Georgia Institute of Technology, Atlanta, GA, USA
2018-2023	Associate Professor	Georgia Institute of Technology, Atlanta, GA, USA
2012-2018	Assistant Professor	Georgia Institute of Technology, Atlanta, GA, USA

Professional Preparation:

1998-2003	Physics Diploma	University Heidelberg, Germany Diploma thesis in Prof. Uli Lynen's group, GSI, Darmstadt Supervisor: Prof. Herbert Orth
2004-2007	Doctorate	Technical University Munich, Germany Thesis in Prof. Masahiro Teshima's group, MPI for Physics, Munich Supervisor: Dr. Eckart Lorentz
2007-2008	Postdoctoral	Humboldt University, Berlin and MPI for Physics, Munich, Germany Mentor: Dr. Thomas Schweizer
2008-2011	Postodctoral	Santa Cruz Institute for Particle Physics (SCIPP) at the University of California, Santa Cruz, CA, USA Mentor: Prof. David Williams

Recognitions and Awards:

2008-2010	Feodor Lynen Postdoctoral Fellow of the Humboldt Foundation
2016	W. Roane Beard Outstanding Teaching Award

Teaching Experience:

2016	Development of an advanced electronics/detector lab course for undergraduate and graduate physics (at Georgia Tech).
2012-	I am teaching core curriculum courses for undergraduate and graduate students in physics (at Georgia Tech).
2010	Course in experimental techniques in high-energy physics and astroparticle physics for graduate students (at UCSC).
2005	Supervising undergraduate lab courses (at the Technical University, Munich).

Ongoing Research Projects:

Trinity (`https://trinity-observatory.org`) is an instrument I proposed for observing of very-high and ultra-high energy neutrinos. It is most sensitive between 1 PeV and 1 EeV and bridges the observational gap between IceCube/KM3NET and radio detectors. We just completed the first phase of *Trinity* and started taking data with the *Trinity* Demonstrator in October 2023.

POEMMA/EUSO-SPB2 tries to do the same as *Trinity* but from space and sub-orbital altitudes, respectively. My group developed the camera and readout for the EUSO-SPB2 Cherenkov telescope. We had our flight in May 2023 and succeeded in the first observation of cosmic-ray air showers. EUSO-SPB2 was a pioneering experiment. We are currently analyzing the data recorded during the flight.

CTA: The Cherenkov Telescope Array (CTA) is the next-generation very-high-energy gamma-ray observatory. Georgia Tech is a CTA member institute with me as the PI. Within CTA, I am participating in the US-led effort to develop the Schwarzschild-Couder telescope (SCT) as a candidate for the mid-size telescopes of CTA. I co-led the camera development of the camera for the prototype SCT and I am currently the project manager of the camera upgrade. My group at Georgia Tech has designed the focal plane and the front-end electronics of the prototype telescope.

GaN Photodetector Development: In collaboration with colleagues from the electrical engineering department at Georgia Tech, Prof. Dupuis and Prof. Shen, I am developing (V)UV-sensitive photon detectors on GaN basis, with the goal of transfering the SiPM concept onto GaN.

Current Funding

1. **Title:** WoU-MMA: Demonstrating Ultrahigh-Energy Neutrino Observations with Compact Air-Shower Imaging Telescopes
   Source of Support: National Science Foundation
   Total Award Amount: $823,130
   Total Award Period Covered: 9/2021 - 8/2024
   Role: Principal Investigator
   Comments: This award has funded the *Trinity* Demonstrator and its operation. My group has developed the telescope, camera, and readout. We deployed the telescope in Summer 2023.

2. **Title:** UHE-Neutrino Searches with Air-Shower Imaging from EUSO-SPB2
   Source of Support: NASA
   Total Award Amount: $1,645,3639
   Total Award Period Covered: 1/2022 - 1/2026
   Role: Principal Investigator
   Comments: This award funds our activity to search for astrophysical neutrinos with a long-duration balloon flight. The mission is called EUSO-SPB2 and is the precursor for the planned POEMMA space mission. At Georgia Tech, my group developed the camera and readout system for the Cherenkov telescope on EUSO-SPB2. The flight took place in May 2023. We currently analyze the data recorded during the flight.

3. **Title:** MRI Consortium: Development of a Wide Field-of-View Camera for the Schwarzschild-Couder Gamma-Ray Telescope
   Source of Support: National Science Foundation
   Total Award Amount: $347,273 (Georgia Tech Part)
   Total Award Period Covered: 9/2018 - 8/2024
   Role: Co-Investigator
   Comments: Funding supports my group's contribution to the mechanical integration of new silicon photomultipliers in the focal plane of the pSCT camera and the evaluation of preamplifiers. The majority of the funding pays for management professionals at Georgia Tech who helps me and the PI (Prof. Reshmi Mukherjee) with the technical aspects of managing the upgrade project. I am the project manager of the camera upgrade.

4. **Title:** Research and Development of High-Sensitivity UV Solid-State Photon-Counting Devices for High-Energy Physics and Related Fields
   Source of Support: Department of Energy
   Total Award Amount: $420,000
   Total Award Period Covered: 7/2021 – 3/2024
   Role: Principal Investigator
   Comments: This grant pays for the development of single photon counters with III-V compound semiconductors. Our goal is to transfer the silicon photomultiplier concept to GaN and AlGaN an excellent UV and deep UV sensitive detector material. Funding pays for the fabrication and characterization of devices and one graduate student.

Atlanta, GA, December 21, 2023

Statement of teaching philosophy and service goals

A. Nepomuk Otte

Teaching Philosophy

Teaching and mentoring are privileges that I find incredibly gratifying. The satisfaction comes from shaping how students think about a subject and how they will apply their knowledge in their careers. I was unaware of this aspect until a graduating student I taught in my first year at Georgia Tech approached me. She had completed her fourth year and was about to start her first job. She expressed her gratitude and appreciation for what she had learned and how she had learned it in my class, which was her very first course at Georgia Tech. I was startled by her feedback, but it made me reflect on my own student experience and realize that some courses I took still resonate and profoundly impacted my career. In all these courses, the lecturer was always the decisive factor. In essence, every time I enter a classroom, I aspire to engage the students and be a facilitator to equip them with the tools and knowledge they need to succeed in their careers.

My teaching approach is based on establishing a relationship with my students that is built on mutual respect and trust. I create a learning environment where learners feel comfortable making mistakes and are motivated to participate, even in a class with a large number of students. My aim is for students to view me as a facilitator who guides them while they take an active role in the learning process. I consider my goal achieved when students move beyond memorization and start to connect what they are learning with their prior and future learning experiences.

I teach one course per semester, which is the standard teaching load for a U.S. university professor. Over the past twelve years, I have taught introductory physics for non-physics majors seven times, electrodynamics for undergraduate physics majors four times, and introductory particle physics for undergraduate and graduate students twice. Additionally, I have taught lab courses in analog electronics once and digital electronics three times.

At Georgia Tech, students evaluate their instructors through CIOS - The Course Instructor Opinion Survey at the end of each semester. Georgia Tech's benchmark to evaluate instructors' performance for promotion and tenure is the "Instructor: Overall effectiveness" which students rank on a scale from 0 to 5. I consistently rank above 4.5, which is significantly above average.

The most challenging courses to teach at Georgia Tech are the introductory physics courses for non-physics majors with 250 students. Instructors typically evaluate below average. I struggled at first, partly because I needed more teaching experience. Still, I steadily improved and now rank far above average when teaching that course. Georgia Tech awarded my accomplishment in teaching introductory physics with the $12,000 W. Roane Beard Outstanding Teacher Award in 2015, the highest teaching award Georgia Tech awards annually to one non-tenured faculty.

I consider my biggest teaching accomplishment the development of a new lab course, "Electronics II." Electronics II is a required lab course for applied physics majors but was dormant for about ten years. Given my background in hardware and instrumentation, my department chair then asked me to reinstate the course. I took that as an opportunity to set up a syllabus that teaches senior undergraduate and graduate students skills that I consider essential for any graduate student to succeed as an experimental physicist. At least in the U.S., the standard physics curriculum needs to teach more modern detector technologies and electronics. That becomes clear when graduate students start in an experimental physics group and must first learn the essentials. Topics I included in the course are the simulation of analog circuits with SPICE, noise in analog circuits, the design of analog front ends, microcontrollers, FPGAs, embedded systems, and an

LYSO scintillator readout with SiPMs. The course's philosophy is to go broad and give students maximum hands-on exposure to the widest variety of technologies possible. Each student also has to complete a semester project. Faculty members provide the projects based on the needs of their groups. Past examples include a laser lock system, an FPGA-based PLL to stabilize a laser, and a stimulator for heart cells, tracing position and acceleration of a candle-light oscillator, a laser power monitor, and an EKG for one of our biophysics faculty.

I presently supervise four graduate students and mentor two postdoctoral scholars. The standard astroparticle group in the U.S. has one graduate student and one postdoctoral researcher. I have one graduate student who is now a postdoctoral scholar at the University of Delaware, Bartol, and one former postdoctoral researcher who is now a research staff at WIPAC in Madison, WI.

Service Goals

Science is a social activity. Great ideas and discoveries never happen in a vacuum but are built on a foundation of knowledge accumulated over many centuries and through countless human interactions. A conversation over lunch or coffee at a conference has more than once sparked an idea for a great project. Doing groundbreaking science requires inspiring leaders, a stimulating environment, and a sense of belonging. My service goals are to help weave a social fabric encompassing these guiding principles, ensuring the best ideas and minds come to fruition.

I firmly believe that the best ideas and projects are realized only if everyone's voice at the table is heard and valued equally. That is only possible in an environment where everyone feels welcome and can contribute with their ideas, without fear of being judged. Making this happen requires everyone in a leadership position to lead by example, actively listen, and be mindful of each person's background and status.

Just as with good teaching, effective leadership is built on trust and mutual respect. Establishing both takes time, but it is a responsibility that falls on every leader's shoulders. As the new director at WIPAC, I would prioritize getting to know the WIPAC family, understanding their needs and wishes, and building relationships with all its members.

I spend much of my time outside of my research doing service work at the university level, the scientific community, and with funding agencies. I do so because it is again part of creating a social fabric with the best ideas realized irrespective of their origin.

Collaboration Service In VERITAS, a VHE gamma-ray instrument, I was an executive committee member representing collaboration members who were not founding members from 2016-2022. I led the VERITAS simulation group, overseeing the update of the latest detector model and production of the latest VERITAS simulation.

I served on the CTA-US executive committee from 2016 until I stepped down in 2020. I co-led the camera working group to construct the SCT prototype until 2018. Since 2018, I have been the project manager for upgrading the pSCT camera.

For EUSO-SPB2 I managed the development of the camera and its integration into the EUSO-SPB2 balloon payload.

High-Energy Physics and astroparticle community I was co-convener of the ultrahigh-energy neutrino working group in Snowmass 2021, the process through which the U.S. high-energy-physics (HEP) community defines its strategic goals for the next ten years.

I organized ICASiPM, an international conference discussing advancements in silicon photomultipliers in Germany in 2018. More than 100 participants from research institutions and industries from more than 10 countries attended.

Reviewing I regularly review proposals for the NSF particle astrophysics program and the DoE HEP R&D and SBIR programs. I have reviewed single-PI research proposals (APRA) for NASA. I also reviewed proposals for Canadian, South African, and Dutch funding agencies and the European Research Council.

In 2021, 2022, and 2023, I was a panel reviewer for NASA's Mission of Opportunity and Midsize Explorer program, downselecting $80M to $500M missions. Each review was a four-month process involving several site visits and in-person panel meetings.

School and Institute In addition to serving on several school and university-level committees. The Georgia Tech School of Physics (SoP) faculty elected me to the faculty advisory committee (FAC) in 2020. The FAC is the only committee not selected by the department chair but by the SoP faculty. We drafted the bylaws during my tenure in the FAC, which the SoP faculty ratified in 2022. I was a member of the 2021/2022 SoP faculty search committee, which successfully hired three tenure-track faculty.

List of Publications

Adam Nepomuk Otte

A complete list can be found at https://orcid.org/0000-0002-5955-6383

A Selection of Publications

1. Hoon Jeong et al. “Ion-implanted Al0.6Ga0.4N deep-ultraviolet avalanche photodiodes”. In: *Applied Physics Letters* 123.12 (2023). ISSN: 1077-3118. DOI: 10.1063/5.0161953. URL: http://dx.doi.org/10.1063/5.0161953.
2. Hoon Jeong et al. “Low-Temperature Geiger-Mode Characterization of a Gallium Nitride p-i-N Avalanche Photodiode”. In: *IEEE Journal of Quantum Electronics* 59.3 (June 2023), pp. 1–8. ISSN: 1558-1713. DOI: 10.1109/jqe.2023.3266759. URL: http://dx.doi.org/10.1109/JQE.2023.3266759.
3. C. B. Adams et al. “Detection of the Crab Nebula with the 9.7 m prototype Schwarzschild-Couder telescope”. In: *Astropart. Phys.* 128 (2021), p. 102562. DOI: 10.1016/j.astropartphys.2021.102562. arXiv: 2012.08448 [astro-ph.IM].
4. W. Benbow et al. “A Search for TeV Gamma-Ray Emission from Pulsar Tails by VERITAS”. In: *Astrophys. J.* 916.2 (2021), p. 117. DOI: 10.3847/1538-4357/ac05b9. arXiv: 2105.13911 [astro-ph.HE].
5. A.V. Olinto et al. “The POEMMA (Probe of Extreme Multi-Messenger Astrophysics) observatory”. In: *Journal of Cosmology and Astroparticle Physics* 2021.06 (June 2021), p. 007. ISSN: 1475-7516. DOI: 10.1088/1475-7516/2021/06/007. URL: http://dx.doi.org/10.1088/1475-7516/2021/06/007.
6. A. Nepomuk Otte et al. “Development of a Cherenkov Telescope for the Detection of Ultra-High Energy Neutrinos with EUSO-SPB2 and POEMMA”. In: *PoS* ICRC2019.977 (2021), p. 977. DOI: 10.22323/1.358.0977. arXiv: 1907.08728 [astro-ph.IM].
7. A.U. Abeysekara et al. “Demonstration of stellar intensity interferometry with the four VERITAS telescopes”. In: *Nature Astronomy* (2020).
8. A. Archer et al. “A Search for Pulsed Very High-energy Gamma-Rays from 13 Young Pulsars in Archival VERITAS Data”. In: *Astrophysical Journal* 876.2 (2019).
9. A.N. Otte. “Studies of an air-shower imaging system for the detection of ultrahigh-energy neutrinos”. In: *Physical Review D* 99.8 (2019).
10. A.N. Otte, T. Nguyen, and J. Stansbury. “Locating the avalanche structure and the origin of breakdown generating charge carriers in silicon photomultipliers by using the bias dependent breakdown probability”. In: *Nuclear Instruments and Methods in Physics Research, Section A: Accelerators, Spectrometers, Detectors and Associated Equipment* 916 (2019), pp. 283–289.
11. S. Archambault et al. “Gamma-ray observations under bright moonlight with VERITAS”. In: *Astroparticle Physics* 91 (2017), pp. 34–43.
12. A.N. Otte et al. “Characterization of three high efficiency and blue sensitive silicon photomultipliers”. In: *Nuclear Instruments and Methods in Physics Research, Section A: Accelerators, Spectrometers, Detectors and Associated Equipment* 846 (2017), pp. 106–125.

13. Eliza Gazda et al. “Photon Detection Efficiency Measurements of the VERITAS Cherenkov Telescope Photomultipliers after four Years of Operation”. In: *JINST* 11.11 (2016), P11015. DOI: 10.1088/1748-0221/11/11/P11015. arXiv: 1610.01990 [astro-ph.IM].

14. E. Aliu et al. “A search for pulsations from geminga above 100 GeV with veritas”. In: *Astrophysical Journal* 800.1 (2015).

15. A.N. Otte et al. “Silicon photomultiplier integration in the camera of the mid-size Schwarzschild–Couder Cherenkov telescope for CTA”. In: *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment* 787 (July 2015), pp. 85–88. ISSN: 0168-9002. DOI: 10.1016/j.nima.2014.11.026. URL: http://dx.doi.org/10.1016/j.nima.2014.11.026.

16. E. Aliu et al. “A search for enhanced very high energy gamma-ray emission from the 2013 March Crab Nebula flare”. In: *Astrophysical Journal Letters* 781.1 (2014).

17. Maxim Lyutikov, Nepomuk Otte, and Andrew McCann. “The very-high energy emission from pulsars: a case for inverse Compton scattering”. In: *Astrophys. J.* 754 (2012), p. 33. DOI: 10.1088/0004-637X/754/1/33. arXiv: 1108.3824 [astro-ph.HE].

18. J. Aleksic et al. “Observations of the Crab pulsar between 25 GeV and 100 GeV with the MAGIC I telescope”. In: *Astrophys. J.* 742 (2011), p. 43. DOI: 10.1088/0004-637X/742/1/43. arXiv: 1108.5391 [astro-ph.HE].

19. E. Aliu et al. “Detection of Pulsed Gamma Rays Above 100 GeV from the Crab Pulsar”. In: *Science* 334.6052 (Oct. 2011), pp. 69–72. ISSN: 1095-9203. DOI: 10.1126/science.1208192. URL: http://dx.doi.org/10.1126/science.1208192.

20. R. Ogul et al. “Isospin-dependent multifragmentation of relativistic projectiles”. In: *Physical Review C* 83.2 (Feb. 2011). ISSN: 1089-490X. DOI: 10.1103/physrevc.83.024608. URL: http://dx.doi.org/10.1103/PhysRevC.83.024608.

21. Adam Nepomuk Otte et al. “Prospects for GRB Observations With CTA from a Phenomenological Model”. In: 2011.

22. V.A. Acciari et al. “Discovery of very high energy gamma rays from PKS 1424+240 and multiwavelength constraints on ITS redshift”. In: *Astrophysical Journal Letters* 708.2 PART 2 (2010).

23. Michael Rissi et al. “A new sum trigger to provide a lower energy threshold for the MAGIC telescope”. In: *IEEE Trans. Nucl. Sci.* 56 (2009), pp. 3840–3843. DOI: 10.1109/TNS.2009.2030802.

24. J. Albert et al. “VHE γ-Ray Observation of the Crab Nebula and its Pulsar with the MAGIC Telescope”. In: *The Astrophysical Journal* 674.2 (Feb. 2008), pp. 1037–1055. ISSN: 1538-4357. DOI: 10.1086/525270. URL: http://dx.doi.org/10.1086/525270.

25. E. Aliu et al. “Observation of Pulsed γ-Rays Above 25 GeV from the Crab Pulsar with MAGIC”. In: *Science* 322.5905 (Nov. 2008), pp. 1221–1224. ISSN: 1095-9203. DOI: 10.1126/science.1164718. URL: http://dx.doi.org/10.1126/science.1164718.

26. A. Biland et al. “First detection of air shower Cherenkov light by Geigermode-Avalanche Photodiodes”. In: *Nucl. Instrum. Meth. A* 595 (2008). Ed. by Andrea Bressan et al., pp. 165–168. DOI: 10.1016/j.nima.2008.07.097.

27. J. Albert et al. “Constraints on the steady and pulsed VHE gamma-ray emission from observation of PSR B1951+32/CTB 80 with the MAGIC Telescope”. In: *Astrophys. J.* 669 (2007), pp. 1143–1149. DOI: 10.1086/521807. arXiv: astro-ph/0702077.

28. A. Biland et al. “First detection of Cherenkov light from cosmic-particle-induced air showers by Geiger-mode avalanche photodiodes”. In: *Nucl. Instrum. Meth. A* 581 (2007). Ed. by Josef Hrubec et al., pp. 143–146. DOI: 10.1016/j.nima.2007.07.050.

29. Jelena Ninković et al. "The avalanche drift diode—A back illumination drift silicon photomultiplier". In: *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment* 580.2 (Oct. 2007), pp. 1013–1015. ISSN: 0168-9002. DOI: 10.1016/j.nima.2007.06.060. URL: http://dx.doi.org/10.1016/j.nima.2007.06.060.

30. Adam Nepomuk Otte, E. Lorenz, and A. N. Otte. "A design study for a 12.5 m Imaging Air Cherenkov Telescope for ground-based γ-ray astronomy". In: *Astronomische Nachrichten* (2007).

31. V C Spanoudaki et al. "Use of single photon counting detector arrays in combined PET/MR: Characterization of LYSO-SiPM detector modules and comparison with a LSO-APD detector". In: *Journal of Instrumentation* 2.12 (Dec. 2007), P12002–P12002. ISSN: 1748-0221. DOI: 10.1088/1748-0221/2/12/p12002. URL: http://dx.doi.org/10.1088/1748-0221/2/12/P12002.

32. A.N. Otte et al. "A test of silicon photomultipliers as readout for PET". In: *Nuclear Instruments and Methods in Physics Research, Section A: Accelerators, Spectrometers, Detectors and Associated Equipment* 545.3 (2005), pp. 705–715.

Atlanta, GA, December 12, 2023

Multi-Messenger Astrophysics with Neutrinos, Towards a Bright Future

Statement of Research

A. Nepomuk Otte

Exploring the extremes of the Universe has never been more exciting. With the full suite of cosmic messengers – photons, gravitational waves, and cosmic rays – at our disposal, we are on the verge of witnessing a plethora of fireworks. The results of the present generation of multi-messenger instruments already give us a glimpse of the transformative impact we can expect in future years.

Driving the golden era we live in are constant instrumentation improvements that ultimately have opened these new windows to the universe. In gamma rays, we have access to photons up to 100 TeV. We detect gravitational waves on an almost daily basis. IceCube has opened the high-energy neutrino band from TeV to PeV. And yet, with all this progress, it is clear that we are still only scratching at the surface. A whole new universe is waiting for us to explore if we can push instrument sensitivities further.

I am an experimental astroparticle physicist who specializes in instrumentation. My long-term motivation is to find new physics beyond the standard model of particle physics and do exciting astrophysics along the way. I am involved in three astroparticle experiments: The very-high/ultra-high energy neutrino detectors *Trinity* and POEMMA and the very-high-energy gamma-ray Cherenkov Telescope Array (CTA). In addition, I collaborate with colleagues from Georgia Tech to develop novel single-photon detectors based on the III-V semiconductors GaN and AlGaN. Of all these projects, my long-term activity is *Trinity*, which is my brainchild.

In the following, I detail my group's activities in all three research areas - neutrinos, VHE gamma-rays, and GaN photodetector developments.

Neutrinos

With IceCube's detection of astrophysical neutrinos and the compelling evidence of neutrinos from NGC 1068 and TXS 05060+056, neutrinos have come center stage. For years, they will play an essential role in multi-messenger astrophysics and neutrino physics. My interest is to push neutrino observations above 10^6 GeV to explore the extreme energies of cosmic-ray accelerators and neutrino physics. The intellectual challenge as an experimentalist is to overcome the extremely small neutrino detection rates by instrumenting vast volumes of ice, water, or, in the case of Trinity and POEMMA, atmosphere.

Trinity and POEMMA are air-shower imaging Cherenkov telescopes pointing at the horizon, taking images of air-showers that develop after a VHE/UHE tau neutrino interacts in the Earth, and the resulting tau decays in the atmosphere.

The Trinity Neutrino Observatory with PeV Threshold

I proposed *Trinity* (`http://trinity-observatory.org`) to detect VHE/UHE neutrinos by placing Cherenkov telescopes on the top of mountains [Otte 2019,Wang et al. 2021]. The idea of detecting Earth-skimming tau neutrinos has been around for some time, but only now do we have the technology to realize that concept within a reasonable budget. With a $20M investment, it is possible to build an observatory with a PeV energy threshold and the sensitivity to do detailed studies of astrophysical neutrinos, cosmogenic neutrinos, and point sources in a wide – $-70°$ to

70° – range of declinations. Trinity is complementary to IceCube because it is sensitive to higher energy neutrinos and observes different sky regions. Trinity will contribute to the neutrino and multi-messenger communities before IceCube Gen2 comes online.

Conceived in 2016, I obtained funding in 2021 to build the Trinity Demonstrator, a one-square-meter-class Cherenkov telescope, to prove the concept. This summer we completed construction and deployed the Demonstrator on Frisco Peak, UT. My group has been operating the telescope from Atlanta since October.

What is exciting about the Demonstrator is its sensitivity to detect neutrino fluxes that IceCube measures from the direction of TXS 0506+056 extrapolated into the Demonstrator's energy range. That is why we pointed the Demonstrator in the direction where NGC 1068 and TXS 0506+056 are setting below the horizon. With some luck, the Trinity Demonstrator will be the second instrument after IceCube to detect PeV neutrinos and confirm NGC 1068 and TXS 0506+056 as neutrino sources.

The second stage of *Trinity* will be the construction of the *Trinity* Prototype, one full *Trinity* telescope on Frisco Peak, UT. With collaborators from three countries - Italy, the UK, and the United States- we plan to start construction in 2025 with funding from an NSF MRI award we will apply for in 2024. The standalone *Trinity* Prototype will be the most sensitive VHE neutrino point-source instrument and crucial infrastructure for the multimessenger community. In addition, it will be the second instrument to detect astrophysical neutrinos.

Starting in 2030, we anticipate scaling *Trinity* up by installing 18 telescopes on three different sites. While improving *Trinity*'s point source sensitivity three times, this final stage will mostly benefit *Trinity*'s diffuse neutrino flux sensitivity, improving it 18 times.

Trinity does not happen in a vacuum. Among the many ongoing efforts in radio detection, Prof. Stephanie Wissel's Beacon project also aims at Earth-skimming neutrinos by placing radio detectors on mountaintops. It is thus natural to seriously think about a joint *Trinity*-Beacon array that would deliver a flat sensitivity from PeV to ZeV with overlapping energy range and benefit from the same infrastructure needs.

Funded Personnel: postdoctoral researcher Dr. Mariia Fedkevych, graduate students Sofia Stepanoff, Jordan Bodgan

The EUSO-SPB2 Neutrino Telescope

Much more challenging than *Trinity* is the POEMMA idea of detecting Earth-skimming neutrinos with Cherenkov telescopes from space instead of mountain tops [Olinto et al. 2021]. While not being competitive in detecting diffuse neutrino fluxes, POEMMA might have a competitive edge in detecting short transient events like tidal disruption events (TDEs) or GRBs.

The POEMMA PI, Prof. Angela Olinto, invited me to develop the camera and readout for the Cherenkov telescope on the EUSO-SPB2 long-duration balloon mission. The purpose of EUSO-SPB2 is to establish the feasibility of deploying a Cherenkov telescope at a sub-orbital altitude and study the ambient light levels and possible background sources while searching for neutrinos. Joining EUSO-SPB2 provided me with the opportunity to get funding to develop a camera system that I could also use for the *Trinity* Demonstrator.

I have successfully applied for NASA funding separate from Olinto's EUSO-SPB2 funding, and with it, my group has developed and built the camera and the readout for the one-square-meter Cherenkov telescope. We flew in May 2023, and despite a disappointing short flight of only 2 out of 50 days due to a leaking balloon, our instrument performed as expected. In addition, we could demonstrate air-shower imaging for the first time from 35 km above the ground, pointing our telescope below and above the horizon and recording images from horizontally developing air showers.

My involvement in POEMMA will end after my graduate students Eliza and Oscar have successfully completed their Ph.D.

Funded Personnel: postdoctoral researcher Dr. Mahdi Bagheri, graduate students Eliza Gazda and Oscar Romero Matamala

The Cherenkov Telescope Array

I received my Ph.D. and training with the MAGIC Cherenkov telescope, a very-high-energy gamma-ray telescope with a 25 GeV energy threshold. In collaboration with four other MAGICians, I developed a trigger system that lowered the trigger threshold from 100 GeV to 25 GeV. With it, we detected the first pulsar in gamma rays above 25 GeV, which unequivocally placed the gamma-ray emission region in the boundary of the pulsar magnetosphere [Aliu 2008]. I then transitioned to the US-based VERITAS collaboration where, among other work, I was responsible for the VERITAS pulsar program that I established. With VERITAS, I extended the Crab pulsar measurements to 400 GeV, which was entirely unexpected, causing a paradigm shift in how we think about VHE gamma-ray emission in pulsar magnetospheres [Aliu 2011].

All of the existing second-generation VHE instruments have exhausted their sensitivity, and major progress requires a new-generation VHE gamma-ray instrument. The Cherenkov Telescope Array (CTA) will be that instrument. It will be ten times more sensitive, reach lower and higher energies, and achieve all-sky coverage with an array of Cherenkov telescopes in each hemisphere. CTA has a very broad and rich science program. It will be a critical instrument in the multi-messenger community, search for indirect dark matter signatures, and be sensitive to physics beyond the Standard Model by looking for Lorentz Invariance violation.

The U.S. Cherenkov community has rallied behind the Schwarzschild-Couder Telescope (SCT) concept as the U.S. contribution to CTA. The CTA-US group has constructed the prototype SCT (pSCT), for which I was co-lead of the camera-working group. My group integrated the photosensors – silicon photomultipliers – and designed the preamplifier. The pSCT saw its first light in January 2019.

Following pSCT construction, we received an NSF's Major Research Instrumentation (MRI) award to upgrade the camera with better silicon photomultipliers and electronics. Prof. Reshmi Mukherjee (Barnard) is the PI, and I am the project manager. My group is responsible for integrating the photosensors and front-end electronics in collaboration with INFN groups in Italy. We expect to complete the upgrade in 2024.

When moving to WIPAC, I would join forces with Prof. Vandenbroucke on CTA and maintain a footprint within the SCT project.

Funded Personnel: graduate student Alasdair Gent (graduated in 2022); GTRI professional project-management support Gabriel Buddenbrock

Gallium-Nitride Photon Detector Developments

Any progress in physics depends on advances in sensor technologies. That is why I always maintain some activity in detector development. Since receiving tenure in 2018, I have collaborated with Professors Dupuis and Shen from the Georgia Tech Electrical Engineering Department to develop UV-sensitive, single-photon sensitive GaN photon detectors. Both are world experts in fabricating III-V semiconductors, and I bring the expertise of photon detector characterization and applications to the table. Together, we develop gallium-nitride (GaN) photon detectors that can operate in Geiger mode. We hope that the project eventually culminates in a sensor based on the same principle as the silicon-photomultiplier but with much better sensitivity in the UV, higher radiation hardness, and tailorable spectral response.

I have co-supervised graduate student Hoon Jeong, who graduated in 2022. Together, we characterized GaN photodiodes in Geiger-mode for the first time. Based on his results, we are now developing a new generation of GaN structures, with improved breakdown characteristics and lower dark currents.

Funded Personnel: graduate student Hoon Jeong (graduated in 2022)

Summary Statement

The future looks bright for groundbreaking discoveries in VHE neutrino astrophysics. Trinity is a promising concept that could provide a sensitivity that will greatly enhance our understanding of VHE neutrinos. The idea of implementing Trinity at WIPAC in parallel with the ongoing IceCube Gen2 efforts is exciting. Trinity's smaller scale and complementary nature to IceCube could offer a unique opportunity for WIPAC to establish a world-leading VHE neutrino observatory and conduct impressive research before IceCube Gen2 becomes operational.