Omer Faruk Albayrak

Postdoktor i evolutionen av primordiala magnetfält

Ref nr: SU FV-4638-25-34
Datum för ansökan: 2026-01-20 00:33

Födelsedatum	1992-08-11
E-post	omalbayrak@asu.edu
Kön	Man

Frågor

1. *Nuvarande sysselsättning (ange huvudsaklig sysselsättning)*
Anställd vid lärosäte utanför Sverige

2. *Högsta examen*
Kandidatexamen

3. *Från vilket land har du din högsta examen?*
Turkiet

4. *Har du din högsta examen från Stockholms universitet?*
Nej

5. *Ange datum när du tog din doktorsexamen*
2026-06-12

6. *NUVARANDE ANSTÄLLNING. Ange arbetsplats och jobbtitel samt när anställningen påbörjades..*
Arizona State University
Graduate student
Research assistant (for summers) and teaching assistant (for rest of the year)

7. *REFERENSER. Ange namn, telefon och e-post för 2–3 referenspersoner som kan komma att kontaktas.*
- Tanmay Vachaspati -
Email: Tanmay.Vachaspati@asu.edu
Phone: +1 480-965-3587

- Michael Treacy -
Email: treacy@asu.edu
Phone: +1 480-965-5359

- Cynthia Keeler -
Email: ckeeler1@asu.edu
Phone: +1 480-965-4985

8. *SPRÅKKUNSKAPER. Beskriv kort dina språkkunskaper.*
English - Fluent
Turkish - Native

9. *FORSKNINGSPLAN/PROJEKTPLAN. Bifoga din plan som beskriver det tilltänkta projektet.*
research_statement_n_omer_albayrak.pdf

10. *DOKTORSEXAMEN ELLER MOTSVARANDE. Ange doktorsexamen med ämne och lärosäte.*
Arizona State University
I am currently working towards my doctoral degree in the creation of topological defects with quantum mediation under the supervision of Tanmay Vachaspati.

11. *EXAMENSBEVIS ELLER MOTSVARANDE. Bifoga examensbevis.*
phd_entollment_full.pdf

Eget uppladdat CV

Omer Faruk Albayrak

Department of Physics,
Arizona State University
Tempe, AZ 85287
USA
✉ *omalbayrak@asu.edu*

Dear Members of the Committee,

I am writing to apply for the Postdoctoral Fellow in Primordial magnetic field evolution position at Nordita. I am currently a Ph.D. candidate at Arizona State University, working under the supervision of Prof. Tanmay Vachaspati since Fall 2020, with an expected graduation date of Summer 2026.

My research lies at the intersection of high-energy theory, cosmology, and computational physics, with a specific focus on the production and the non-equilibrium dynamics of topological defects. During my doctoral studies, I developed a robust numerical framework to simulate quantum-mediated defect production in regimes where analytical methods fall short. This work required bridging fundamental field theory with high-performance computing, employing novel parallelization schemes to resolve the complex, nonlinear dynamics that govern defect formation.

Currently, I am expanding this numerical framework to investigate the formation and dynamics of complex topological structures and their signatures in multi-messenger cosmology and high-energy experiments. I am particularly interested in leveraging my background in large-scale numerical simulations and theoretical modeling within the Nordita research environment to problems related to primordial magnetic fields. The COSMOMAG project's focus on early Universe dynamics and simulation-driven studies of magnetic field evolution closely aligns with my interests in non-equilibrium field dynamics and numerical approaches to complex physical systems.

I am confident that my background in both theoretical modeling and large-scale numerical simulations will enable me to make effective contributions to your group. I have enclosed my CV and research statement and would be delighted to provide any additional information.

Thank you for your consideration.

Sincerely,
Omer Faruk Albayrak.

Omer Faruk Albayrak

PhD Candidate in Physics
Arizona State University
Tempe, AZ, USA

omalbayrak@asu.edu
github.com/frkalbayrock
frkalbayrock.github.io
+1(480)-241-5324

Research Summary

Developing numerical simulations for theoretical physics problems with a focus on quantum and classical field interactions, early-universe cosmology and topological defects. Experienced in high-performance computing and large-scale parallel simulations. Combining theoretical modeling with scalable computational methods to study non-perturbative field dynamics and emergent phenomena.
Research Interests: early-universe physics; nonlinear dynamics in field theories; cosmological phase transitions; topological defects; numerical and stochastic methods for quantum and classical fields; large-scale simulations of complex physical systems; astrophysical and cosmological applications of high-performance computing.

Education

Arizona State University, Tempe, AZ — Jan 2017 – Present
Ph.D. in Physics
Advisor: Tanmay Vachaspati

Koç University, Istanbul, Turkey — Sep 2010 – Jun 2016
B.S. in Physics (with honors)
B.S. in Mathematics (with honors)

Research Experience

Graduate Researcher - Vachaspati Lab, Arizona State University — Aug 2020 – Present
Thesis: Developing numerical simulations of quantum and classical field theories to study non-perturbative processes, including the formation and dynamics of topological defects and particle production. Utilizing stochatic methods and classical-quantum correspondence, and exploring a range of theoretical setups, background configurations and parameter regimes. Searching multi-dimensional parameter spaces to identify conditions under which defects, instabilities, or other emergent structures arise.

Graduate Researcher - Adami Lab, Arizona State University — Oct 2018 – Aug 2019
Conducted theoretical research on the black hole information paradox within quantum information frameworks. Integrated gravitational redshift into prior models and analyzed implications for stimulated emission.

Graduate Researcher - Treacy Lab, Arizona State University — Sep 2017 – Dec 2017
Developed numerical simulations of Earth's orbital dynamics including multi-body gravitational effects. Validated results against Milankovitch cycle predictions and produced orbital trajectory visualizations.

Technical Skills

Programming Julia, Fortran, Python, Matlab, Mathematica, Bash
Skills: Field theory simulations, numerical relativity simulations, parallel computing, data analysis, high-performance computing, visualization pipelines
Tools & Libraries: MPI, OpenMP, Julia multi-processing, Git, Jupyter, Linux HPC environments

Publications

Peer-Reviewed

- O. Albayrak and T. Vachaspati, "Creating kinks with quantum mediation", *Phys. Rev. D* **109**, 036001 (2024), 2308.01962

In Preparation

- O. Albayrak and T. Vachaspati, "Global strings production via a quantum bridge", 2601.xxxxx
- O. Albayrak, J. Pereira, and T. Vachaspati, "Stability of SU(2) Electric Fields", 26xx.xxxxx

Conferences & Talks

- **33rd Texas Symposium**, Conference Talk, Tempe, AZ, December 2025
- **APS Four Corners Meeting**, Conference Talk, Northern Arizona University, Flagstaff, AZ, October 2024
- **Solitons at Work**, Invited Virtual Talk, November 2023
- **Cosmology Friday Seminar**, Invited Research Talk, Arizona State University, Tempe, AZ, September 2023

Teaching Experience

Graduate Teaching Assistant, Department of Physics, ASU, AZ — 2017 – Present
Conducted laboratory and recitation sessions, graded assignments, developed instructional material, and held office hours across multiple physics courses.

Lab Co-designer, Physics Instructional Resource Team, ASU, AZ — 2019
Co-designed experiments and laboratory manuals for General Physics II

Teaching Assistant, Koç University, Istanbul, Turkey — 2016
Prepared homework sets and solution manuals, graded assignments and held weekly office hours for Phys 403: Solid State Physics

Funding & Awards

33rd Texas Symposium — 2025
Travel Award, ASU, AZ

U.S. Department of Energy Grant — 2021 – 2025
Award: #DE-SC0019470, ASU, AZ

APS Four Corners Section Conference — 2024
Travel Support, Northern Arizona University and ASU, AZ

Michigan Cosmology Summer School — 2023
Travel Award, University of Michigan, MI
Travel Support, ASU, AZ

Summer Graduate Fellowship — 2018-2023
For summer semesters of 2018, 2019, 2020, 2021, 2023, ASU, AZ

Molecular Imaging Corporation Endowment — 2021
Graduate Fellowship, ASU, AZ

Outreach & Service

Seminar Organizer, Cosmology Friday Seminar Series, ASU — August 2024 – May 2025
Organized weekly seminars, handling speaker invitations and arranging seminar lunches

Guest Scientist, "Beer with Scientists," 39 Alpha Research — Jan 2025

Seminar Organizer, Cosmology Wednesday Seminar Series, ASU — Jan 2024 – May 2024

Organized weekly seminars, handling speaker invitations and arranging speaker lunches

Student Worker, Faculty of Science, Koç University 2011 – 2014
Designed and maintained the Computational Physics webpage and Faculty of Science website.

IT Specialist, Istanbul Otobüs A.Ş. 2010
Built company website (PHP/JS) and provided IT support.

Omer Albayrak - Research Statement

I am a theoretical physicist working at the intersection of high-energy physics and cosmology, motivated by phenomena in the early Universe that link high-energy theories to testable signatures such as defects, particle production, and gravitational signals. My research focuses on nonequilibrium dynamics in quantum and classical field theories, as well as the development of large-scale numerical simulations to study problems where analytic control is limited. I utilize advanced computational frameworks and high-performance computing (HPC) to tackle computationally bound problems. My computational background and experience equip me to work on a wider range of theoretical and large-scale simulation problems, including nonlinear dynamics in the early Universe, particularly in the generation and evolution of primordial magnetic fields, where numerical simulations are essential for understanding their time evolution and potential observable signatures.

Topological defects

As nondissipative and nonperturbative structures in nonlinear field theories, topological defects underpin key phenomena in high-energy physics, ranging from early Universe cosmic strings to the monopoles of grand unified theories. Unlike elementary particles, which are quantized fluctuations of a field, defects are particle-like configurations already present in classical theory. Defect creation processes are of great physical interest in high-energy physics, as defect dynamics are tied to critical open problems, such as sphaleron mediation in baryogenesis and experimental searches for magnetic monopoles at the Large Hadron Collider (LHC) via heavy-ion and proton-proton scatterings [1, 2].

Although well-established classically, a complete quantum description of these defects is hindered by strong-coupling effects and nonlinearities that render perturbative approaches inapplicable. This challenge is compounded by a lack of a unified framework to describe how discrete quantum particles cohere into localized, classical structures. Consequently, while classical scattering models have explored defect production [3], the creation of defects through quantum processes has remained largely unaddressed. To address this, my research employs an analytical-computational framework to simulate the full field dynamics in regimes where analytical solutions are unavailable. One of the primary aims of my doctoral research is to use these simulations to address the question: "How do quantum fluctuations lead to the formation of topological defects from scattering events, and what are the distinct observable signatures of their creation?"

Defect production with quantum mediation

My research provides the first exploration of defect formation with full dynamical quantum degrees of freedom, utilizing a novel "bridge" model within a robust computational framework. Notably, this approach introduces an extra field to separate the nonperturbative classical defect sector from the perturbative quantum sector, which is treated under the Classical-Quantum Correspondence (CQC) framework [4]. The excitation of this quantum field is driven by a third, classically approximated field, where scattering of wave packets is considered. Since this scattering field interacts exclusively with the bridge, any resulting formation is a purely quantum-mediated event.

Z_2 kinks

My early work focused on 1+1-dimensional domain wall production, specifically, Z_2 kinks [5]. A significant outcome of this study was the first successful demonstration of quantum-mediated defect creation. To achieve this, I developed an efficient Fortran-based simulation suite and a novel defect identifier algorithm designed to isolate topological structures within noisy field configurations. These numerical tools have been made publicly available [6].

Utilizing high-performance computing (HPC) clusters and a custom parallelization scheme, I performed an extensive survey of the parameter space to identify the conditions for defect formation. The resulting data revealed a complex, non-linear fractal-like distribution of success and failure regions in the parameter space, with “holes” suggesting that the process is governed by non-trivial resonances. Notably, I found that defect production is favored by high-luminosity wave packets at moderate velocities, whereas high-energy scattering at near-relativistic speeds tends to suppress defect formation. While exploratory, these findings may help constrain the initial conditions for monopoles searches at particle accelerators.

Scaling to 2+1-dimensional global strings

Building on the success of the 1+1-dimensional model, I recently extended this framework to 2+1 dimensions to study the production of global vortex-antivortex pairs. This transition introduces immense computational challenges rooted in both the scaling of the CQC and the complications of higher-dimensional geometry. Two major difficulties arise from this transition. First, because the CQC maps N quantum degrees of freedom to $2N^2$ classical ones per dimension [7], the complexity jumps from $O(N^2)$ to $O(N^4)$. This not only significantly increases the number of equations to be solved, but also places extreme demands on memory and performance. Second, the elegant linear algebra notation leveraged by the CQC for one-dimensional mappings is not directly applicable to higher dimensions, necessitating a fundamental restructuring of the mathematical framework to account for the extra spatial dimension while preserving the formalism’s core strengths.

To address the former challenge regarding the complexity, I conducted extensive benchmarking to balance the high-resolution requirements of the lattice against the available memory and performance of the HPC clusters, ensuring the simulation maintained high physical fidelity within the bounds of the available hardware. To resolve the latter structural challenge, I implemented a numerical scheme to “flatten” the two-dimensional spatial lattice to a one-dimensional one, effectively folding a spatial dimension to recover the powerful linear algebra formalism of CQC.

While this approach preserved the physical rigor of the model, it introduced non-trivial boundary conditions across the flattened lattice that standard parallelization techniques could not reconcile. I developed a novel high-performance parallelization scheme to properly apply the periodic boundary conditions employed in the simulation. I also developed an algorithm that uses the winding number to locate and track the vortex-antivortex pairs within the field configurations.

This robust framework made the 2+1-dimensional simulations viable, enabling the observation of vortex production [8]. As part of this ongoing work, the current results confirm that the fractal resonance patterns observed in 1+1 dimensions persist in this higher-dimensional landscape, demonstrating the versatility of the “bridge” model across different topological sectors.

Towards the production of monopoles in high-energy experiments

The simulation suite I developed for 2+1-dimensional vortex dynamics has paved the way for my current expansion into 3+1 dimensions and monopoles. This transition poses a significant challenge, as the complexity scales to $O(N^6)$ and requires moving the CQC beyond its current limitations. Ongoing work focuses on broadening the applications of the CQC method to include more complex interactions and field dynamics.

A key focus of my future research, in line with this work, is the production mechanisms of 3+1-dimensional topological defects, specifically monopoles. I am particularly interested in examining these production scenarios in the context of future experimental searches and cosmological settings.

Future Outlook

My research has centered on the intersection of high-energy theory and computational physics, providing me with a broad foundation in the high-energy phenomena instrumental for understanding the early Universe. Because many high-energy phenomena involve nonlinearities that are difficult to capture through purely analytical means, investigating these processes often relies on a rigorous integration of theory and numerical simulations. My experience in developing specialized numerical methods and high-performance computing frameworks positions me to tackle a broad range of challenges, from non-equilibrium dynamics to their applications in early Universe magnetohydrodynamics. Looking ahead, I am interested in applying large-scale numerical simulations, along with analytical insight, to study the generation and evolution of primordial magnetic fields and in connecting these results to potential observational signatures.

References

[1] Vasiliki A. Mitsou. First search for magnetic monopoles through the Schwinger mechanism. *J. Phys. Conf. Ser.*, 2375(1):012002, 2022.

[2] B. Acharya et al. Search for Magnetic Monopoles with the MoEDAL Forward Trapping Detector in 13 TeV Proton-Proton Collisions at the LHC. *Phys. Rev. Lett.*, 118(6):061801, 2017.

[3] Henry Lamm and Tanmay Vachaspati. Numerical exploration of soliton creation. *Phys. Rev. D*, 87:065018, Mar 2013.

[4] Tanmay Vachaspati and George Zahariade. Classical-quantum correspondence and backreaction. *Phys. Rev. D*, 98(6):065002, 2018.

[5] Omer Albayrak and Tanmay Vachaspati. Creating kinks with quantum mediation. *Phys. Rev. D*, 109(3):036001, 2024.

[6] Omer Albayrak. Github repositories. `https://github.com/frkalbayrock`, 2025.

[7] Tanmay Vachaspati and George Zahariade. Classical-Quantum Correspondence for Fields. *JCAP*, 09:015, 2019.

[8] Omer Albayrak and Tanmay Vachaspati. Production of global vortices with quantum mediation, 2026. arXiv:2601.xxxxx.

Omer Faruk Albayrak

Department of Physics,
Arizona State University
Tempe, AZ 85287
USA
✉ *omalbayrak@asu.edu*

Dear Members of the Committee,

I am currently a Ph.D. candidate in Physics at Arizona State University, enrolled in the doctoral program working under the supervision of Prof. Tanmay Vachaspati. My doctoral studies are in their final stage, and I expect to complete all degree requirements by Summer 2026, prior to the start date of the advertised postdoctoral position.

As my doctoral degree has not yet been formally awarded, I am submitting this letter in place of a final PhD degree certificate. Attached to the following page is an official enrollment verification document from Arizona State University, confirming my current doctoral status and expected graduation date.

I am happy to provide any additional documentation upon request.

Sincerely,
Omer Faruk Albayrak

PhD Candidate, Physics

Arizona State University

Arizona State University
University Registrar Services
P.O. Box 870312
School Code: 001081
Tempe, Arizona 85287-0312
(480) 965-3124

Enrollment Verification as of 01/19/2026

Name: Omer Faruk Albayrak

ID Number: 1211649761

Current Program of Study

Career	Academic Program
Graduate	The College of Lib Arts & Sci

Academic Plan	Degree	Acad Level	Antic Grad Term
Physics PHD	PHD	Graduate	August 2026

Enrollment History

Term	Career	Begin Date	End Date	Units	Status
2026 Spring	GRAD	01/12/2026	05/11/2026	1.00	Less 1/2

Arizona State University is accredited by the Higher Learning Commission. The enrollment status listed on this document is for academic load purposes. Enrollment status reported for loan servicing is done in accordance with federal financial aid load status requirements, which is full-time: 9+ hours, half-time: 5 - 8.5 hours. Visit registrar.asu.edu/enrollment-verification for more information.

Louise A. Denny
University Registrar