Name: Kyle Felker

Graduate Record Examination

Verification of these scores is required. (Note: Official Graduate Record Examination (GRE) Scores must be sent directly by the Educational Testing Service to the Krell Institute/DOE Computational Science Graduate Fellowship program. The Krell Institute's Institution Code is **6343** and the department code is **5199**)

Your name as it appears on your GRE record:	**Kyle G Felker**
Date test taken/to be taken:	**8/25/12**

GRE Test Results

			Reported from ETS	
Examination	***Score***	***Percentile(%)***	***Score***	***Percentile(%)***
Verbal	167	97	167	97
Quantitative	164	90	164	89
Analytical or Analytical Writing	5.0	92	5	93

References

List at least three persons familiar with your academic preparation and your technical abilities. Please have these individuals mail the reference forms directly to Krell Institute.

	Title	***First name***	***Last name***	***Institution***	***E-mail***	***Status***
1.	**Dr.**	**Andrew**	**Siegel**	**Argonne National Laboratory**	[redacted]	**Notified**
2.	**Dr.**	**Paul**	**Fischer**	**Argonne National Laboratory**		**Notified**
3.	**Professor**	**James**	**Stone**	**Princeton University**		**Submitted**
4.						

Name: Kyle Felker

Academic Status

Current Academic Status: **First Year Doctoral Student**

Have you completed any academic credit towards your computational science/engineering doctoral degree? **No**

If yes, how many terms have you completed? (exclude summer) **----**

Official transcripts from every listed institution are a required component of the application including your Fall 2013 transcript, if applicable. Please see the instructions for more information on where to send the transcripts.

Doctoral Institution (Institution where you plan on completing your computational science and engineering doctorate or first choice doctoral university):

Institution	*Start Date*	*Expected End Date*	*Department*	*Academic Discipline*	*GPA*	*Degree*
Princeton University	09/2013	06/2017	Applied and Computational Mathematics	Applied and Computational Mathematics		PhD

Department Chair at Doctoral Institution:

First Name	*Last Name*	*Email*	*Department*
Peter	Constantin	[redacted]	Mathematics

Other Doctoral Institution Choices (Answer only if not currently at doctoral institution)

Institution	*Department*	*Academic Discipline*

Higher Educational History (All university/colleges attended and degrees obtained with the exception of the doctoral degree listed above):

Institution	***Start Date***	***End Date Expected or Actual***	***Department***	***Academic Discipline***	***Degree***	***GPA***
University of Chicago	09/2009	06/2013	Physical Sciences	Physics and Mathematics	Bachelors	3.62
					None	
					None	
					None	
					None	

Name: Kyle Felker

Graduate Advisor

The graduate advisor is the person from the preferred institution **who views and approves the Program of Study.**

First Name	*Last Name*
Weinan	**E**

Institution	*Title (Dr., Ms., Professor, ...)*
Princeton University	**Professor**

[redacted]

Name: Kyle Felker

Research Statements

This information is vital to the overall evaluation of your application.

1. Field of Interest and the Role of Computational Science

Making sure to describe what contributing role computational science will play, please discuss either
a) your chosen research area of interest, or
b) if you have one, your chosen research plan

My research plan is to develop and implement numerical methods for radiative magnetohydrodynamics (MHD) simulations in fully dynamical spacetimes. This general multiphysics framework will enable astrophysical simulations of compact object mergers and black hole accretion disk formation. Modeling the extreme physics in these events requires the simultaneous solutions for radiative transfer, hydrodynamics, and the Einstein field equations over a vast parameter space of plausible systems.

Under the supervision of Prof. James Stone and Frans Pretorius of the Astrophysics and Physics departments, I have begun to formulate the radiation transfer equation in various spacetime metrics and consider a variety of methods for numerically solving the relativistic pure transfer problem. Once the uniphysics regimes are well understood, we will proceed to the coupled radiative hydrodynamic setting. We will then develop hybrid algorithms capable of efficiently resolving all spatio-temporal scales and implement the methods in a low-level programming language. Finally, the GRMHD code will be tested with compact merger simulations and analyzed. Realizing a fully general relativistic framework for radiative MHD will require a multi-year effort to build on the well-established numerical libraries for numerical relativity and MHD of my advisors.

As an understanding of hardware realities is essential to achieving this computational challenge, I will work closely with HPC resources throughout algorithmic development. Fortunately, the Princeton Institute for Computational Science and Engineering (PICSciE) offers supercomptuers equipped with GPUs and Intel Xeon-Phi coprocessors that are ideal for optimizing our code for the heterogeneous architectures found in many of the world's fastest supercomputers. Eventually, we will seek a compute-time allocation at a national laboratory to leverage petascale resources to probe the most complex parameter-regimes whose demand may exceed millions of core-hours per simulation. The practicum component of the CSGF would be an invaluable experience to help accomplish this task.

2. Research Using High-Performance Computing and/or Large Data Analysis

What new science or engineering would high performance computing or large data analysis and management enable in your area of interest and why do you think this is the case? In particular, what are the HPC challenges that need to be addressed to make this advancement?

For a recent discussion of potential impact on a number of important applications, see http://www.ipd.anl.gov/anlpubs/2012/11/72183.pdf

Max words is 300

The merger scenarios that are the subject of our simulations comprise the most extreme environments in the universe, and understanding these events requires novel computational methods and substantial computing power. The dense regions of matter associated with black holes and neutron stars produce a spacetime curvature that invalidates the assumptions of many existing MHD libraries. Additionally, during the accretion phase of black hole formation, the accretion disks may be radiation pressure dominated. Accurately modeling the coupling of radiation and matter in a dynamically curved spacetime is an essential component of the dynamics often neglected in numerical relativity codes. Creating and implementing numerical methods that capture both of these considerations in a fully general framework is necessary to model the high energy density physics of compact object mergers.

While the primary HPC challenge of this project will be to develop novel numerical methods, efficient implementation on emerging architectures will be a crucial obstacle to success. While numerical GR and radiative MHD independently are computational daunting, when combined they constitute a petascale or larger challenge necessitating the use of the largest heterogenous computers. Ensuring the feasibility of the simulations requires a grand vision of the overall project and an attention to detail on all levels of development.

High performance computing will enable a plethora of investigations of open astrophysics questions and promises to yield tangible scientific dividends. Merger simulations may explain possible connections to the mysterious occurrences of short gamma ray bursts, the most energetic events in the universe. Computational radiative GRMHD will empower ground based detection of gravitational wave and electromagnetic/neutrino signatures of these events. More generally, such simulations will help us understand the behavior of matter under extreme conditions not available on Earth, and the creation of advanced numerical methods can lead to advances for other computational applications.

3. Program of Study

The fellowship program of study requirement is designed to give you a breadth of competency in fields outside your own that will enhance your ability to perform computational science research. Please describe (in no more than 300 words) how you expect that the courses listed in your planned program of study outside your chosen discipline will contribute to your own research in the future. Describe why you chose these courses and how they will impact your research plans.

Given my years of experience in HPC research and applied mathematics, my program of study is primarily designed to broaden my knowledge of the mathematics and physics of radiative GRMHD. The courses "Introduction to Relativity" and "General Plasma Physics I" will augment my undergraduate knowledge in these fundamental physics subjects. The mathematics topics course "Geometric Analysis and General Relativity" will provide a topological approach to relativity and a new mathematical perspective to my application

field. I anticipate that this course will be especially valuable for visualization work in the nascent field of numerical relativity as the project matures. While my role is primarily that of an applied mathematician, fortifying my theoretical background in these subjects will help me develop an intuition to guide the development of numerical algorithms.

Aided by three years of teaching experience in numerical methods courses, I have developed a strong foundation in the algorithms necessary to model the partial differential equations for my research. However, I have limited formal education in the science of data analysis and post-processing. My Program of Study was designed to fill this educational gap with the courses "Analytics and Systems of Big Data" and "Mathematical Analysis of Massive Data Sets". The classes will equip me with the applied skills and mathematical theory, respectively, for comprehending the sizeable results of petascale-level calculations. Knowledge of large data analysis will be essential to comprehend the exotic, multiscale physics for which we have limited empirical data.

4. List of publications

Please include a list of publications authored or co-authored by the applicant.

K. Felker, A. Siegel, K. Smith, "The energy band memory server algorithm for parallel Monte Carlo transport calculations", Joint International Conference on Supercomputing in Nuclear Application + Monte Carlo, Cite des Sciences et de I'ndustrie de la Villete, Paris, October 2013

A.R. Siegel, K. Smith, K. Felker, P.K. Romano, B. Forget, "Improved cache performance in Monte Carlo transport calculations using energy banding", Accepted for publication Computer Physics Communications, July 2013

A.R. Siegel, K. Smith, P.K. Romano, B. Forget, and K.G. Felker, "Multi-core performance studies of a Monte Carlo neutron transport code", International Journal of High Performance Computing Applications, first published online on July 14, 2013

A.R. Siegel, K. Smith, P.K. Romano, B. Forget, K. Felker, "The effect of load imbalances on the performance of Monte Carlo algorithms in LWR analysis", Journal of Computational Physics, February 2013, 235: 901-911

K.G. Felker, A.R. Siegel, and S.F. Siegel, "Optimizing Memory Constrained Environments in Monte Carlo Nuclear Reactor Simulations", International Journal of High Performance Computing Applications, May 2013 27: 210-216

Name: Kyle Felker

Program of Study

Listed are the courses in science and engineering, applied mathematics, and computer science that you agreed to take on your proposed Program of Study.

University: Princeton University

Course number	Course Title	Credit hours	Term and Year	Grade	Academic Level
Science/Engineering					
AST551	General Plasma Physics I	100S	Fall 2014		G
PHY523	Intro to Relativity	100S	Spring 2014		G
Mathematics and Statistics					
MAT526	Topics in Geometric Analysis and Relativity: Introduction to general relativity	100S	Spring 2015		G
MAT585	Mathematical Analysis of Massive Data Sets	100S	Spring 2015		G
Computer Science					
COS598D	Advanced Topics in Computer Science - Analytics and Systems of Big Data	100S	Spring 2015		G
ELE580A	Advanced Topics in Computer Engineering - Parallel Computation	100S	Fall 2014		G

I have read this program of study and affirm that, in my opinion, it satisfies the fellowship program requirements. This POS has been approved by my advisor, **Weinan E**, and I understand that, if offered a fellowship, my advisor and I are required to sign this page and send it to the Krell Institute.

Student's signature ____________________________ Date _______________

Graduate Advisor: **Weinan E**

Graduate Advisor's Institute: **Princeton University**

Graduate Advisor signature ____________________________ Date _______________

Krell Institute (Office use only) __________________________________

DOE Computational Science Graduate Fellowship Program
Krell Institute
1609 Golden Aspen Drive, Suite 101
Ames, IA 50010
Phone: 515-956-3696
Fax: 515-956-3699
csgf@krellinst.org

Name: Kyle Felker

Course Description

AST551: General Plasma Physics I

An introductory course to plasma physics, with sample applications in fusion, space and astrophysics, semiconductor etching, microwave generation, plasma propulsion, high power laser propagation in plasma; characterization of the plasma state, Debye shielding, plasma and cyclotron frequencies, collision rates and mean-free paths, atomic processes, adiabatic invariance, orbit theory, magnetic confinement of single-charged particles, two-fluid description, magnetohydrodynamic waves and instabilities, heat flow, diffusion, kinetic description, and Landau damping. The course may be taken by undergraduates with permission of the instructor.

PHY523: Intro to Relativity

This course gives an introduction to Einstein's theory of general relativity. No prior knowledge of general relativity will be assumed, and an overview of the differential geometry needed to understand the field equations and spacetime geometries will be given. Beyond this, topics covered will include black holes, gravitational waves, and cosmological spacetimes.

MAT526: Topics in Geometric Analysis and Relativity: Introduction to general relativity

This is a fast moving introductory course in General Relativity with the goal of presenting some recent important results in the field. The following will be covered: quick introduction to general relativity, break-down criterion, a discussion of bounded L2 curvature conjecture, formation of trapped surfaces, and uniqueness of black holes.

MAT585: Mathematical Analysis of Massive Data Sets

This course focuses on spectral methods useful in the analysis of big data sets. Spectral methods involve the construction of matrices (or linear operators) directly from the data and the computation of a few leading eigenvectors and eigenvalues for information extraction. Examples include the singular value decomposition and the closely related principal component analysis; the PageRank algorithm of Google for ranking web sites; and spectral clustering methods that use eigenvectors of the graph Laplacian.

COS598D: Advanced Topics in Computer Science - Analytics and Systems of Big Data

Study of recent papers on analytics and systems of big data. In analytics, we plan to read papers in mining, search and exploration techniques for images, audio, video and network data. In systems for big data, we plan to study recent developments in scale-out systems including storage systems and search systems. Students taking this course for credit are required to present a selected paper and work on a small course project.

ELE580A: Advanced Topics in Computer Engineering - Parallel Computation

Course covers advanced parallel computer architecture and parallel programming. Multicore, many core and large multi-machine architecture and programming will be covered. Discussion-oriented class focuses on in-depth analysis of research papers and primary sources. Final project/paper required. Juniors, seniors, and graduate students from ELE, COS, and related fields welcome.

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Other Planned Courses

Listed are the other courses you plan to take that you believe are particularly pertinent to your proposed or current research in the areas of Mathematics, Science and Engineering, and Computer Science.

No courses have been added.

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Course Description

No courses have been added.

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Completed Courses

Please list up to six courses you have completed that are particularly pertinent to your proposed or current research in the areas of Mathematics, Science and Engineering, and Computer Science. Please do not list entry level science/engineering or mathematics courses like Calculus I.

Course number	Course Title	Credit hours	Term and Year	Grade	Academic Level
CSPP51085	Applied Parallel Programming	100Q	Winter 2011	A	G
CSPP58001	Numerical Methods	100Q	Spring 2011	A	G
PHYS22700	Intermediate E&M II	100Q	Spring 2012	A	U
PHYS23800	Modern Atomic Physics	100Q	Winter 2012	A-	U
PHYS25000	Computational Physics	100Q	Fall 2010	A	U
STAT31100	Numerical Methods for PDEs	100Q	Spring 2013	A	G

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Course Description

CSPP51085: Applied Parallel Programming

The goal of the course is to give students experience in developing efficient, scalable parallel algorithms for both distributed and shared-memory architectures. Assignments will be designed with some flexibility to allow students to explore applying parallel techniques to applications in their own field of interest. After an introduction to MPI and OpenMP, some of the topics covered will include: parallel solutions of linear equations, sorting, interpolation, and integration of ODE's and PDE's.

CSPP58001: Numerical Methods

This is a practical programming course focused on the basic theory and efficient implementation of a broad sampling of common numerical methods. Each class of numerical methods will be introduced conceptually followed by detailed exercises focused on both prototyping them (using MATLAB) and programming them efficiently on modern (serial) architectures. The ideal student in this course would have a strong interest in the use of computer modeling as predictive tool in a range of disciplines -- for example risk management, optimized engineering design, safety analysis, etc. The numerical methods studied in this course underlie the modeling and simulation of a huge range of physical and social phenomena, and are being put to increasing use in a range of industrial applications.

PHYS22700: Intermediate E&M II

Topics include electrostatics, magnetostatics, electromagnetic induction, electric and magnetic fields in matter, plane electromagnetic waves, reflection and refraction of electromagnetic waves, and electromagnetic radiation. Winter, Spring.

PHYS23800: Modern Atomic Physics

This course is an introduction to modern atomic physics. Topics include atomic structure, fundamental symmetries in atoms, interactions of atoms with radiation, laser spectroscopy, trapping and cooling, Bose-Einstein condensates, and quantum information.

PHYS25000: Computational Physics

Knowledge of computer programming not required. This course introduces the use of computers in the physical sciences. After an introduction to programming basics, we cover numerical solutions to fundamental types of problems, techniques for manipulating large data sets, and computer simulations of complex systems. Additional topics may include an introduction to graphical programming, with applications to data acquisition and device control.

STAT31100: Numerical Methods for PDEs

This course examines computational methods for challenging partial differential equations having a strong hyperbolic component. There will be a short introduction to review some basic concepts that arise when PDE's are discretized. The first part of the course focuses on Riemann solvers based methods that are typically used to treat flows with discontinuities and shocks. In the second part, we develop high-order weighted residual discretizations (spectral element methods) designed to minimize numerical dispersion. In the final segment, we consider alternative approaches for these problems (e.g., discontinuous Galerkin, WENO, and method of characteristics). Relevant background material, particularly regarding timestepping, stability, and linear solvers, is provided throughout the course.

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Laboratory and Research Experience/Other Employment

Begin with current or most recent employment. Please include employer, dates employment started and ended, position, and nature of work.

Assistant in Instruction, Princeton University
September 2013 - Present
- Currently assisting graduate-level course, APC 523 Numerical Algorithms for Scientific Computing
- Developed and graded computer programming assignments requiring the use of high performance computers

Department of Energy Intern, Argonne National Laboratory
June 2011 - August 2013
Advisor: Dr. Andrew Siegel, Mathematics and Computer Science Division
- Researched parallel algorithms for computational neutron transport for the Center for Exascale
Simulation of Advanced Reactors
- Designed, wrote, and deployed scientific applications on thousands of processors of IBM
Blue Gene supercomputers
- Carried out multiphysics simulations with computational fluid dynamics (CFD) and nuclear physics libraries

Teaching Assistant, University of Chicago
January 2012 - June 2013
- Assisted in grading and instruction for three masters-level courses over two years: C Program-
ming, Numerical Methods, High Performance Computing
- Delivered several guest lectures during instructor absences
- Successfully applied for and managed an educational allocation on open-science cluster at Argonne National Laboratory

NSF Intern, Universidad de Chile
July 2010 - September 2010
- Conducted granular mechanics simulations in the computational physics group

Academic Awards and Honors

Include undergraduate and graduate honors (if applicable).

University of Chicago Careers in Higher Education Fellow
University of Chicago Dean's list of Distinguished Students, 2009-2013
AMS/IEEE Supercomputing 2012 "HPC for Undergraduates" invitee

Extracurricular Activities

Include technical societies and service organizations.

Varsity competitor, University of Chicago Debate Society 2009-2013 **Member of Society for Industrial and Applied Mathematics**

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Additional comments

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Demographics (Optional)

Applicant data is important in assessing the effectiveness of our efforts to solicit applications from a diverse population. Your completion and submission of this form will assist us in this regard. Providing the information on this form is voluntary; omission of information will not affect any decision about your application. We appreciate your cooperation.

Race: ---- ***Gender:*** ----

Physical/mental disability: ----

Fellowship Survey

The information that you provide will allow us to target our advertising more effectively. This information is confidential and is not used in review of the fellowship application.

1. How did you find out about the program?

- [x] DOE CSGF Poster
- [ ] DEIXIS, DOE CSGF annual publication
- [ ] Attended DOE CSGF talk
- [ ] Advertisement:

  Please name the source:

- Word of mouth from

  - [x] faculty
  - [ ] student
  - [ ] administrator

- [ ] Laboratory Staff
- [ ] Institutional Announcement
- [ ] Conference or Meeting

  Name:

- [ ] World Wide Web

  List URL:

- [ ] Other

  Explain:

2. Have you applied to other fellowship programs?

- ☑ DOE NNSA SSGF
- ☐ NSF
- ☑ DOD
- ☐ University-Sponsored

  Names of fellowships:

- ☐ Other

  Names of fellowships: