First Name: **Gabriel**	Middle Name:	Last Name: **Casabona**

Doctoral University: **Columbia University**

Univ. Preference 2:

Univ. Preference 3:

Advisor: **Robert Fisher**

Advisor's Institution: **University of Massachusetts Dartmouth**

Academic Status: **Master's Degree Student**

Terms in Doctoral Program: **----**

Date Degree Expected: **05/2025**

Department: **Physics**

Discipline: **Computational Astrophysics**

Applicant Reported Information						**Official Transcript**	
Institutions	*Department*	*Academic Discipline*	*Dates of Attendance*	*Degree*	*Reported GPA*	*Trans Recv'd*	*Trans GPA*
Columbia University	Physics	Computational Astrophysics	08/2019 - 05/2025	PhD			
University of Massachusetts Dartmouth	Physics	Astrophysics	09/2017 - 05/2019	Masters	3.6	Yes	3.63
Florida International University	Physics	Physics	08/2011 - 05/2017	Bachelors	2.9	Yes	2.90
			-	None			
			-	None			
			-	None			

Letters are received either online or by mail.

References	**Institution**	***Email***	***Status - Online***	***Received by Mail***
Robert Fisher	University of Massachusetts Dartmouth	robert.fisher@umassd.edu	Submitted	
Gaurav Khanna	University of Massachusetts Dartmouth	gkhanna@umassd.edu	Submitted	
David Kagan	University of Massachusetts Dartmouth	david.kagan@umassd.edu	Submitted	

DOE CSGF Application - Traditional Track

Name: Gabriel Casabona

Academic Status

Current Academic Status: **Master's Degree 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 2018 transcript, if applicable.

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*
Columbia University	08/2019	05/2025	Physics	Computational Astrophysics		PhD

Department Chair at Doctoral Institution:

First Name	*Last Name*	*Email*
William	Zajc	waz1@columbia.edu

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

			Department Chair Information	
Institution	*Department*	*Academic Discipline*	*Name*	*Email*

Name: Gabriel Casabona

Research Statements

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

Field of Interest and the Role of Computational Science

a. *In terms a general audience would understand, describe an important, outstanding scientific or engineering challenge in your field of interest where computational science can play an important role. (1/3)*
b. *Describe the particular science or engineering problem that you would like to pursue in your research. What would be the impact on the field and/or on science, engineering and/or society in general if this challenge could be successfully addressed? (2/3)*

The recent discoveries of mergers of black hole binary systems (BHBH), beginning with GW150914, and the binary neutron star system (NSNS), GW170817, have broadened our understanding of fundamental questions in physics. These questions include: What are the astrophysical sources of gravitational waves? What are the sites of r-process element production? What are the multimessenger electromagnetic (EM) counterparts to gravitational wave events,and in what bands (optical, infrared, X-ray, gamma ray) do they occur? Although BHBH and NSNS mergers have only been observed to date, black hole-neutron star (BHNS) mergers are also expected to naturally be produced by similar astrophysical production channels. In particular, BHNS are promising candidates for short gamma-ray bursts as well as LIGO sources of gravitational waves.

The primary goal of this proposed research effort is to undertake a detailed and systematic study of self-consistent three-dimensional simulations of BHNS mergers, and predict their expected EM counterparts, nucleosynthetic yields, and gravitational wave forms. A central issue at the heart of the problem is the determination of the quantity and composition of matter ejected from the system, since it is this matter which does not fall into the black hole, and will be observable to astronomers following up on a LIGO-VIRGO trigger. Consequently, I will be modeling all major mechanisms which give rise to the ejecta -- the tidal tail, neutrino-driven winds, as well as magnetized outflows and jets. A key new facet of my proposed research is a novel treatment of the development of the magnetorotational instability (MRI) in the disk using adaptive mesh refinement.

Use of Computational Science in your research

a. *What is the most complex calculation you have run on a high performance machine as part of your research experience? Or if you haven't run a high performance computing system, tell us about the most complex computational problem you've tackled. (1/2)*
b. *Imagine if you were given access to resources 100 times more powerful than what you have had access to. What would that enable you to do, and what do you perceive the mathematical/computer science challenges to be? (1/2)*

In my current research group, focused on Type Ia Supernovae (SNe Ia),
I am a research assistant working in collaboration with Professor Robert Fisher. Research topics range from detonation profiles to nucleosynthetic yields. SNe Ia are thermonuclear explosions believed to occur from the nuclear burning of carbon in white dwarfs.

As important as SNe Ia are, the mechanism of detonation is still unknown. My current research has been in exploring a possible mechanism for detonation motivated by the double degenerate channel. The goal of this research is to determine what role turbulence plays in the detonation of carbon in electron-degenerate matter. This was done by performing 3-dimensional simulations to capture the physics of turbulence. The FLASH4 hydrodynamics code was implemented and the simulations were performed on the XSEDE supercomputer Stampede2. Simulations began with a quiet background of carbon/oxygen fuel being driven to steady-state turbulence, with nuclear burning then activated.

Each simulation saw an increase in temperature by about an order of magnitude before nuclear burning was turned on, caused by Kolmogorov's theory of turbulence. At $t \approx 15$ ms, a hot spot is formed in which nuclear burning develops supersonically, initiating detonation. Analysis of these simulations show that turbulent dissipation dominates nuclear energy generation by over 20 orders of magnitude. This leads to the conclusion that turbulently-driven detonation can occur within the distributed burning regime. These results are outlined in my co-authored peer-reviewed paper submission to The Astrophysical Journal.

Access to a more powerful machine would greatly increase the productivity of my research. More computational cores means a faster run time. The biggest challenge I see facing is in regards to the I/O, since increasing data points also increases the need to better I/O techniques. There can also be some race conditions if the codes are not parallelized properly.

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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: Columbia University

Course number	Course Title	Credit hours	Term and Year	Grade	Academic Level
Science/Engineering					
		S	Fall		G
PHYS G8041	Topics in General Relativity	3S	Fall 2019		G
PHYS GR6011	Astrophysics	3S	Fall 2020		G
Mathematics and Statistics					
MATH GR8255	PDE in Geometry	4S	Fall 2019		G
PHYS G8050	Advanced Mathematical Methods In Physics	4.5S	Fall 2019		G
Computer Science					
EAS 520 *from University of Massachusetts Dartmouth*	High Performance Computing	3S	Fall 2018	B	G
PHYS G6080	Scientific Computing	3S	Fall 2019		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, **Robert Fisher**, 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: **Robert Fisher**
Graduate Advisor's Institute: **University of Massachusetts Dartmouth**
Graduate Advisor signature ___________________________ Date ______________

Krell Institute (Office use only) _________________________________

Krell Institute, Attn: DOE CSGF Coordinator
1609 Golden Aspen Drive, Suite 101, Ames, IA 50010
Phone: 515-956-3696, Fax: 515-956-3699, csgf@krellinst.org

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Course Description

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PHYS G8041: Topics in General Relativity

Topics to be discussed include Hawking radiation and black hole thermodynamics, singularity theorems, and cosmology.

PHYS GR6011: Astrophysics

The basic physics of high energy astrophysical phenomena. Protostars, equations of stellar structure; radiative transfer theory; stellar nucleosynthesis; radiative emission processes; equations of state and cooling theory for neutron stars and white dwarfs, Oppenheimer-Volkoff equation; Chandrasekhar limit; shocks and fluids; accretion theory for both disks and hard surfaces; black hole orbits and light bending.

MATH GR8255: PDE in Geometry

Parabolic flows have become a central tool in differential geometry in recent years. One of the main problems is to understand the formation of singularities. In this course, I will give an introduction to the subject, starting with the simplest example of the curve shortening flow in the plane. We will then discuss the main a-priori estimates for mean curvature flow in higher dimensions, such as the convexity estimate, the cylindrical estimate, and the pointwise gradient estimate. Finally, we plan to present recent results concerning singularity formation for fully nonlinear curvature flows.

PHYS G8050: Advanced Mathematical Methods In Physics

Topics selected on the basis of current research problems.

EAS 520: High Performance Computing *from University of Massachusetts Dartmouth*

Course covers an assortment of topics in high performance computing (HPC). Topics will be selected from the following: parallel processing, computer arithmetic, processes and operating systems, memory hierarchies, compilers, run time environment, memory allocation, preprocessors, multi-cores, clusters, and message passing.

PHYS G6080: Scientific Computing

Computational techniques for scientific problems with emphasis on practical applications and effective programming. Review of computers, programming, floating-point numbers, and numerical stability. Survey of basic numerical algorithms and numerical subroutine libraries and their application to scientific problems.

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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.

Course number	Course Title	Credit hours	Term and Year	Grade	Academic Level
Science/Engineering					
MTH 551	Differential Geometry	3S	Spring 2019		G
PHY 510-01	Stellar Astrophysics	2S	Spring 2019		G

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Course Description

MTH 551: Differential Geometry

Analysis of curves and surfaces. Frenet-Serret formulae. Fist and second fundamental forms for surfaces, Gaussian and mean curvature, theorems of Meusnier and Rodriques and the Gauss-Bonnet theorem are also studied.

PHY 510-01: Stellar Astrophysics

An advanced treatment of a special topic in physics with an emphasis on recent developments. The subject matter varies according to the interests of the instructor and the students.

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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
EAS 520	High Performance Computing	3S	Fall 2018	B	G
PHY 521	Computational Physics	3S	Fall 2017	B+	G
PHY 565	General Relativity	3S	Fall 2017	A	G

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Course Description

EAS 520: High Performance Computing

An advanced treatment of a special topic in physics with an emphasis on recent developments. The subject matter varies according to the interests of the instructor and the students.

PHY 521: Computational Physics

Application of computational techniques to computer simulations in physical science and engineering. The course covers physical concepts such as realistic projectile motion, planetary systems, nonlinear dynamics, chaos and fractals, and electromagnetic and quantum systems. The course exposes students to numerical algorithms and methods such as solutions to optimization, quadrature, fast Fourier transform, and boundary value problems, and gives hands-on experience in programming and computer simulations.

PHY 565: General Relativity

General Relativity for beginning graduate and advanced undergraduate students. This course covers the basic principles an applications of Einstein's General Relativity, the preeminent theory of gravitation. Topics include: Tensor analysis in flat and curved spacetime; Einstein's Equivalence Principle; geodesic and field equations; black hole, gravitational wave and cosmological spacetimes.

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Program of Study

Describe how the courses listed in your planned program of study would help prepare you to address the challenges you have described in questions 1 and 2. Discuss your rationale for choosing these courses.

The courses in my planned program of study, along with the courses taken at my current institution, are chosen specifically to help me in computation. There are many pieces to being a computational physicist that are not taught in traditional physics courses. By learning these topics from leaders in the field, I will have the advantage of having a higher set of problem solving techniques compared to my peers.

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Programming Languages and Models

List (four at most) the programming languages and programming models with which you have experience. Provide a sentence that describes how you use them.

1. Programming Language/Model: **Python**
Python is used for data analysis and visual representation.

2. Programming Language/Model: **Fortran**
Fortran is used in the main code base I use, FLASH.

3. Programming Language/Model: **C**
In my HPC course, all problems were solved using C99.

4. Programming Language/Model:

What are the programming languages that you intend to use in your research?

Python, Fortran, C

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List of Publications

Papers

Mozumdar, P., Fisher, R., & Casabona, G (Jul 2018). Carbon Detonation Initiation in Turbulent Electron-Degenerate Matter. arXiv:1807.03786 (in submission to ApJ)

Talks

Casabona, G (Mar 2019). Detonation Initiation in Type Ia Supernovae. APS March 2019. Boston, Massachusetts Casabona, G (Nov 2018). Carbon Detonation Initiation in Turbulent Electron-Degenerate Matter. APS New England 2018. University of Massachusetts Dartmouth Casabona, G (Apr 2018). Carbon Detonation Initiation in Turbulent Electron-Degenerate Matter. APS April 2018. Columbus, Ohio

Posters

Casabona, G (Jan 2019). Detonation Initiation in Type Ia Supernovae. 223 rd Meeting of the AAS. Seattle, Washington Casabona, G (Nov 2018). Carbon Detonation Initiation in Turbulent Electron-Degenerate Matter. APS Bridge/NMC Conference 2018. Stanford University Casabona, G (Jul 2018). Carbon Detonation Initiation in Turbulent Electron-Degenerate Matter. IHPCSS. Technical University of Ostrava, Czech Republic

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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.

University of Massachusetts Dartmouth, Physics Department, 07/2018 - 05/2019, Research Assistant

Academic Awards and Honors - *Include undergraduate and graduate honors (if applicable).*

FIU Dean's List: Spring 2013, Spring 2016

Extracurricular Activities - *Include technical societies and service organizations.*

Society of Physics Students
Physics Honors Society (ΣΠΣ)
American Astronomical Society
National Society of Black Physicists

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Additional Comments