The University Senate of Michigan Technological University
Proposal 65-21

A New Graduate Certificate: Big Data Statistics in Astrophysics

Submitted by: Department of Physics

Co-sponsored by: Department of Computer Science

1. **Version Date: March 29, 2021**

2. **Proposer Contacts:** Elena Giusarma (egiusarm@mtu.edu), Petra Huentemeyer (petra@mtu.edu), Robert Nemiroff (nemiroff@mtu.edu), Brian Fick (fick@mtu.edu), Ranjit Pati (patir@mtu.edu), Yoke Khin Yap (ykyap@mtu.edu), and Ravi Pandey (pandey@mtu.edu)

3. **Interdisciplinary Program:** Final approvals from the collaborating department and college were obtained in the Deans' Council meetings before forwarding to the Provost's office and the senate. Advising and administrative duties will be housed entirely in the Physics department.

4. **General Description and Characteristics**

General Description: This 9-credit Graduate Certificate in "**Big Data Statistics in Astrophysics**" includes the following objectives:

a) Attract graduate students to our certificate programs who are interested in the statistical analysis of big-data related to astrophysics.

b) Provide training to graduate students who are seeking to refresh their statistical analysis techniques and apply them to real-world big-data.

c) Enhance the credibility and marketability of the graduate students with practical skills and intellectual backgrounds needed for their career in the future.

Catalog Description: The graduate certificate **Big Data Statistics in Astrophysics** allows students to 1) develop a foundation of statistical analysis, data mining, and machine learning; 2) understand how to implement algorithms; how to use databases to manage the data; and how to learn from the data with machine learning tools; 3) develop and implement new machine learning methods to different problems in Astrophysics. Based on these skills, students can explore applications of statistical techniques and machine learning tools to analyze and interpret astrophysical data.

Graduate Learning Outcome (GLO) Assessment

At the time of completion, students will have:

1. GLO 1: Students receiving this certificate will have the ability to solve open-ended problems in Astronomy and Astrophysics through statistical inference, machine learning algorithms, or data mining techniques.
2. GLO 2: Students receiving this certificate will be able to effectively present essential concepts of data analyses in astrophysics.

5. Title of Program: "Graduate Certificate in Big Data Statistics in Astrophysics"

6. Rationale

Astronomy and Astrophysics data are undergoing dramatic growth in size and complexity as detectors, telescopes, and computers become ever more powerful. Modern telescopes produce terabytes of data per observation, and over the next decade, the data volume is expected to enter the petabyte domain. To analyze and interpret those large data sets, the knowledge of existing statistical methods together with the development of new data mining and machine learning tools is crucial. In particular, data mining techniques are important for analyzing and describing structured data, for example, finding patterns in large data sets; while machine learning techniques are important for processing and interpreting data by comparing them to models for data behavior, such as supervised classification methods.

7. Discussion of Related Programs

Our proposed certificate is unique in its requirement of being interdisciplinary and integrating data science (statistics, data processing, artificial intelligence) with the field of astrophysics. There are many certificate programs in astronomy/astrophysics or data sciences for example,

1. ***UC Berkeley –*** Graduate Certificate in Applied Data Science
2. ***University of Michigan -*** Graduate Data Science Certificate Program
3. ***Georgia Tech –*** Certificate in Astrophysics

There are fewer programs that combine the two areas like what we proposed here, for example,

1. ***The University of Minnesota -*** Graduate Minor in Big Data in Astrophysics
2. ***Stanford University –*** Data Science for Astrophysics and Particle Physics

From the information in these links, there is no evidence that these external programs are being offered online.

8. Projected Enrollments

Table 1 shows estimated minimum targets assuming a more aggressive marketing approach is deployed. The enrollment cap depends on the number of sections that can be allocated to each course. The certificate can be offered online in the future when the online versions of the required and elective courses become available.

Table 1. Estimated minimum enrollment by year.

Academic Year	On Campus
2021-2022	2
2022-2023	2
2023-2024	3
2024-2025	3
2025-2026	4

9. Curriculum Design

This 9-credit certificate consists of one required course and other electives. Only three credits may be at the 4000 levels. The required and elective course list with the course descriptions are given below. It is expected that students will work with the program advisor to select courses that fit their interests and prerequisite skills. Course instructors may waive such course prerequisites when deemed appropriate.

Required Courses - 3 credits

PH5396 Statistics, Data Mining and Machine Learning in Astronomy (Credits: 3.0) (new course - new course form attached to end of proposal)

Elective Courses - 3 credits (4000 levels)

PH4610 Stellar Astrophysics (Credits: 3.0)
PH4620 Galactic Astrophysics (Credits: 3.0)
PH4630 Particle Astrophysics (Credits: 3.0)

Elective Courses - 3 credits (5000 levels)

PH5610 High Energy Astrophysics (Credits: 3.0)
MA5761 Computational Statistics (Credits: 3.0)
PH5395 Computer Simulation in Physics (Credits: 3.0)
CS/EE 5841 Machine Learning (Credits: 3.0)
CS/EE 5821 Computational Intelligence - Theory and Application (Credits: 3.0)

Course Descriptions

PH5396 Statistics, Data Mining and Machine Learning in Astronomy: The course focuses on modern solving problems in Astronomy and Astrophysics using statistical inference, machine learning and data mining methods.

PH4610 Stellar Astrophysics: The course includes an overview of observational astrophysics, stellar atmospheres, stellar structure, atomic properties of matter, radiation and energy transport in stellar interiors, and stellar evolution to and from the main sequence.

PH4620 Galactic Astrophysics: The course is devoted to the study of the composition and dynamics of our galaxy, dynamics of stellar encounters, spiral density

wave theory, clusters of galaxies, theoretical cosmology, physics of the early universe, and observational cosmology.

PH4630 Particle Astrophysics: The course is an introduction to the twin fields of elementary particle physics and high energy astrophysics. Topics include an overview of particles and interactions, the expanding universe, conservation laws, dark matter and dark energy, large scale structure, and cosmic particles.

PH5610 High Energy Astrophysics: The course describes the physical processes which are important in the structure and emission of light from extreme astrophysical sources.

MA5761 Computational Statistics: The course is an introduction to computationally intensive statistical methods. Topics include resampling methods, Montes Carlo simulation methods, smoothing technique to estimate functions, and methods to explore data structure. This course will use the statistical software S-plus.

PH5395 Computer Simulation in Physics:
Computational research is an integral part in physics, materials science, and engineering. This course is geared for advanced undergraduate students and graduate students interested to work in research fields such as condensed matter physics, astrophysics, biophysics, atmospheric physics, chemical engineering, mechanical engineering, electrical engineering, and other related fields.

CS/EE 5841 Machine Learning: This course will explore the foundational techniques of machine learning. Topics are pulled from the areas of unsupervised and supervised learning. Specific methods covered include naive Bayes, decision trees, support vector machine (SVMs), ensemble, and clustering methods.

CS/EE 5821 Computational Intelligence - Theory and Application: This course covers the four main paradigms of Computational Intelligence, viz., fuzzy systems, artificial neural networks, evolutionary computing, and swarm intelligence, and their integration to develop hybrid systems. Applications of Computational Intelligence include classification, regression, clustering, controls, robotics, etc.

10. New Course Descriptions

PH5396 Statistics, Data Mining and Machine Learning in Astronomy: The course focuses on modern solving problems in Astronomy and Astrophysics using statistical inference, machine learning and data mining methods.

11. Model Schedule Demonstrating Completion Time

The minimum completion time is two semesters. A typical schedule is shown below.

Fall Semester	***Spring Semester***
PH4610	PH5396

PH5610	

12. Library and Other Learning Resources
No additional library or other learning resources are required.

13. Description of available/needed equipment
No additional equipment is needed.

14. Program Costs
No additional program costs are anticipated.

15. Accreditation Requirements
None

16. Planned Implementation Date
This program has an anticipated start in Fall 2021. The certificate program will be extended into an online program as soon as it is established and practical to do so.

Additional Information for New Programs:

1. Program-Specific Policies, Regulations and Rules.
This program will follow Senate Policy 411.1 for Graduate Certificates. No additional program-specific policies apply besides the curricular requirements described above.

2. Scheduling Plans
On-campus sections will not require changes in class schedule, while online sections can be implemented asynchronously.

3. Space
No additional space requirements are necessary for this certificate.

4. Faculty Resumes
The associated faculty who have taught or can teach the related courses are given below. Examples of faculty webpages are embedded with the faculty names.

Brian E. Fick mtu.edu/physics/department/faculty/fick
Petra H. Huentemeyer https://www.mtu.edu/physics/department/faculty/huentemeyer/
Elena Giusarma https://www.mtu.edu/physics/department/faculty/giusarma/
Robert J. Nemiroff https://www.mtu.edu/physics/department/faculty/nemiroff/
Issei Nakamura https://www.mtu.edu/physics/department/faculty/nakamura/
Xiaoyong Yuan https://www.mtu.edu/computing/about/faculty/yuan/
Timothy Haven https://www.mtu.edu/computing/about/faculty/havens/

Approval Process
Department approval: January 22, 2021
College of Sciences and Arts: February 15, 2021

Graduate Faculty Council: March 2, 2021
Provost's Office and Deans' Council: March 15, 2021
Approval by the Senate:
Approval by the President:

Michigan Tech

— Course Add Proposal —

PLEASE COMPLETE THIS FORM IN RED

A guide for completing this form is located at http://www.mtu.edu/registrar/faculty-staff/course-proposal/

1) Course Information

Is this a **half-semester course proposal?** ☐ Yes ☒ No

NOTE: All half-semester courses must follow rules set in Faculty Senate Proposal 4-00. See Senate website for details: http://www.sas.it.mtu.edu/usenate/propose/03/10-03.htm

Course Prefix/Number *(i.e. MEEM 2110)*: PH5396

Course Title *(abbreviated; used on transcript - Up to **30** characters including spaces)*

Stat.,Data Mining & ML in Astr

Alternative Title for Catalog *(Up to **100** characters including spaces)*

2) Credits

Number of credits assigned to this course 3

OR

Range of credits if **variable** ☐ to ☐ *(Number of credits to be taken in a given semester)*

3) Schedule

Contact Hours per Week *(Lec & Rec: 1 credit =1 contact hour; Lab: 1 credit =1-3 contact hours. (i.e. a 3-credit course may be 2 contact hours of lecture or recitation and up to 3 contact hours of lab OR 1 contact hour of lecture or recitation and up to 6 contact hours of lab)*

2	0	3
Lecture	Recitation	Lab

OR

Research Course? ☐ Yes ☐ No

OR

Special Topics Course? ☐ Yes ☐ No

4) Additional Credits

May students receive **additional credits** by taking and passing this course more than once?

☒ No

☐ Yes, for a maximum of_____credits. *(Must be a multiple of the course credits, i.e. Research or Special Topics)*

☐ Yes, for an unlimited number of credits. *(i.e. Music, Varsity sports, etc.)*

5) Pass/Fail

Will this course be offered as a **pass/fail option ONLY**? *(grade of S or E)* ☐ Yes ☒ No

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6) Cross/Dual Listed Course

Cross Listed: Is there an identical course offered in a different subject? ☐ Yes ☐ No

If yes, what is the other subject and course number? _____

Dual Listed: Is there a course offered at a different level? ☐ Yes ☐ No

If yes, what is the other course number? _____

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7) Equivalent Course: Does this course replace a dropped course with no change in course content for degree requirements, prerequisites, and repeating purposes? ☐ Yes ☒ No

If yes, what is the subject and course number of the dropped course? _____

8) Corequisites and Prerequisites

Corequisites are courses that are **REQUIRED to be taken at the SAME TIME** as this course (courses MUST be offered during the same term):

Required corequisite course(s):

_____

_____

Prerequisites are courses that are **REQUIRED to be taken PRIOR** to enrollment in this course.
Select appropriate box and use parentheses where needed.

Required prerequisite course(s):

1_PH4390

☐ And ☐ Or 2_____

☐ And ☐ Or 3_____

☐ And ☐ Or 4_____

☐ And ☐ Or 5_____

☐ And ☐ Or 6_____

A **concurrent prerequisite** is a defined prerequisite course (from list above) that **MAY** be taken **EITHER** simultaneously in the same semester **OR** in a prior semester. Indicate below applicable courses.

Concurrent prerequisite course(s):

_____

_____

_____

9) Catalog Course Description

The traditional catalog style description for a course is limited to **350 characters including spaces**. If course is proposed as a half-semester course, please include that information in the description. **Please refer to the Course Proposal Guide for examples and suggestions on developing a course description.**

The course focuses on modern problem solving in Astronomy and Astrophysics through statistical inference, machine learning algorithms and data mining techniques. Students will be presented with data sets and research problems in astrophysics and will learn how to formulate solutions.

10) Registration Restrictions

- If permission is **always required** for registration purposes (a student cannot enter the course without department or instructor signature)**,** please select the appropriate permission.

  Do not select unless EVERY STUDENT must get "SIGNED INTO" the class.

  ☐ Department **OR** ☐ Instructor

- Students who register for this course may be restricted by their **College/School OR** their **Major**. Please indicate if any college or major restrictions should be applied to this course. If there are no restrictions please indicate in the check box provided.

☐ **No College/School Restrictions**

Colleges/Schools who MAY NOT enroll (EXCLUDE)

_____

-OR-

Colleges/Schools who MAY enroll (INCLUDE)

_____

☐ **No Major Restrictions**

Majors that MAY NOT enroll (EXCLUDE)

_____

-OR-

Majors that MAY enroll (INCLUDE)

_____

-- Restrictions continued on next page --

- A restriction may also be placed on **Class Standing** (freshman, sophomore, junior, senior, graduate). Please indicate if any class restrictions should be applied to this course. If there are no restrictions please indicate in the check box provided.

☒ **No Class Restrictions**

Class of students who MAY NOT enroll (EXCLUDE)
_____
-OR-
Class of students who MAY enroll (INCLUDE)
_____

11) Semester(s) Offered

☐ Fall ☒ Spring ☐ Summer *(Check all that apply)*

OR ☐ On Demand

If offered in a specific semester, will the course be offered only in alternate years? ☐ Yes ☐ No

If yes, what will be the starting academic year? *(i.e. 2014-15 or 2015-16)*_____

12) General Education

Is this course being proposed for General Education? ☐ Yes ☐ No

Proposal forms are available at: http://www.mtu.edu/registrar/faculty-staff/course-proposal/.

13) Course Computing Lab and Expendables Fees

DO NOT RECORD FEE INFORMATION HERE. Submit new course fee information on the New Course Fees Form available at: http://www.mtu.edu/registrar/faculty-staff/course-proposal/.

14) Course Learning Objectives (Required)

Upon successful completion of this course, students will be able to:

o Demonstrate basic programming skills
o Construct different computer models.
o Describe and utilize linear and nonlinear functions to model data. Visualize empirical. data and the fitting function using a computational tool.
o Visualize data and analyze modeling .
o Discuss methods for reviewing models, their verification and validation. Discuss the differences between the predictions and the data.
o Demonstrate problem solving and critical thinking skills.
o Demonstrate professional scientific communication skills .

15) Degree Programs which this course will affect

List the degrees, minors, and certificates in which this course will be required or used as an elective: ***

Degree Program(s):

Graduate Certificate in Big Data Stat. in

PhD program in Physics/Applied Physic

MS program in Physics/Applied Physic

***** Be sure to adjust the appropriate degree audits in sections 7 and 8 in your department's binder.**

***16)* Course Rationale** *(Required)*

Astronomy and Astrophysics data are undergoing dramatic growth in size and complexity as detectors, telescopes, and computers become ever more powerful. Modern telescopes produce terabytes of data per observation, and over the next decade, the data volume is expected to enter the petabyte domain. To analyze and interpret those large data sets, the knowledge of existing statistical methods together with the development of new data mining and machine learning tools is crucial.
This course is geared for advanced undergraduate students and graduate students interested to work in the research field of astrophysics. The course is not offered by the Physics Department.

17) Faculty Contact

Faculty proposing this course *(please print)*: Name Elena Giusarma

Email egiusarm@mtu.edu

DID YOU USE RED INK TO COMPLETE THIS FORM?

IF NOT, PLEASE HIGHLIGHT YOUR ANSWERS SO NOTHING IS MISSED IN PROCESSING.