UNIVERSITY OF MARYLAND

COMPUTATIONAL ASTROPHYSICS

(ASTRONOMY 415 – Fall 2024)

Term: *Fall/2024*
Professor: Massimo Ricotti
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Email: ricotti@umd.edu
Office Hours: TBD
Credits: 3
Course Dates: From Aug 27, 2024 - Dec 5, 2024
Course Times: 2:00 pm – 3:15 pm
Classroom: ATL 2428 or Computer Lab (ATL 0224)

Teaching Assistant: I do not have one this time!
Email: N/A
Office Hours: N/A

Preface

This course does not require previous programming experience but if you never learned a compiled programming language, by the end of this course, you will. I discourage the use of any programming language other than Fortran77, Fortran90, C, C++. The use of python can be discussed. Interpreted programming languages like Matlab, Matematica and IDL can be used for plotting data but not to solve the homework. The reason is twofold:

i) The term "computational astrophysics" typically refers to running computationally intensive applications that require high-level efficiency and parallelization. These codes need to run on supercomputers and are typically written in C or Fortran and are parallelized using OpenMP or MPI. Recently, has also become possible to run supercomputer codes on GPU using CUDA or OpenCL languages (we will touch on that).

ii) The course focuses on understanding the mathematical methods involved in writing efficient numerical algorithms. Your goal is to write these algorithms (almost) from scratch as a learning process. However, several interpreted programming languages have these algorithms already built in: they work like "black boxes" with an input and an output. These are not suited for teaching the numerical methods hidden inside the "black box.

My "mother tongue" is Fortran, but I can also speak C as a second language and, if necessary, I can understand some Java or python. Solutions to the homework will be in C. The level of the class and the topics covered will partially depend on the student's previous familiarity with low-level programming languages. Along the way I may complement the lectures with power point presentations on topics that the class is especially interested in. I will post homework on ELMS but I will also keep the webpage updated and link all the course material there. Laptop computers are allowed and indeed required in class.

Notes on Logistics and Personal Computers:

The number of students in this class is probably too large to fit comfortably in the Astronomy computer lab (we can try and see how it goes). Therefore, it is important that each student in class has its own

laptop personal computer. If you do not have a laptop to bring to class, please let me know ASAP. We will try to solve the problem and get you up to speed.

Course Description

This course will provide students with a basic knowledge of numerical methods commonly used in astrophysics and, more generally, in physics. This process will be motivated by concrete examples of modern problems in astrophysics that demand numerical approaches.

As mentioned above, the material covered will depend on the existing level of computer sophistication among the class participants. However, in broad outline the major course topics will include linear algebra, root finding, least-square fitting, Monte Carlo methods, numerical integration, N-body methods, fluid dynamics, FFTs and time-series analysis.

Learning Outcomes

By the end of the course students should be comfortable working in a Unix environment, compiling and running codes, employing a variety of numerical methods to solve scientific problems and visualization techniques to analyze the results.

Required Resources

There is no required text for this course. The following recommendations may be helpful to you. Note that much of the course material will follow, *Numerical Recipes*, which is available online. Most in-class programming examples will be in C, but you are free to choose from any suitable languages for completing the assignments.

Aarseth, S. J. 2003, "Gravitational -body Simulations: Tools and Algorithms," Cambridge Univ. Press.

Hockney, R. W., and J. W. Eastwood 1988, "Computer Simulation Using Particles," Hilger. [Out of print?]

Kernigan, B. W., and D. M. Ritchie 1988, "The C Programming Language" (2nd ed.), Prentice-Hall.

Peek, J. D., et al. 1997, "Learning the Unix Operating System (Nutshell Handbook)" (4th ed.), O'Reilly.

Prata, S. 1998, "The Waite Group's C Primer Plus" (3rd ed.), Howard W. Sams & Co.

Press, W.H. et al. 1992, "Numerical Recipes in Fortran [or C or C++]" (2nd ed.), Cambridge Univ Press - visit the website at *http://www.nr.com/*.

Yee, H.C. 1989, "A class of High-resolution Explicit and Implicit Shock-Capturing Methods", Tech. Report Lecture Series 1989-04, von Karman Institute of Fluid Dynamics [difficult to find?]

Course Structure

There will be no exams in this course. Grades will be determined by homework assignments (6 of them) plus one term paper with the following weights:

Homework	70%
Participation	15%
Term paper	15%

There will be no curve on the final grades. There may need to be some adjustment to scores depending on the class average; however, any adjustment will be to lower the percentages given above, never to raise them.

In order to succeed in this course, you should follow the following advises[1] :

1. **Participate.** I invite you to engage deeply, ask questions, and talk about the course content with your classmates. You can learn a great deal from discussing ideas and perspectives with your peers and professor. Participation can also help you articulate your thoughts and develop critical thinking skills.
2. **Manage your time.** Students are often very busy, and I understand that you have obligations outside of this class. However, students do best when they plan adequate time that is devoted to course work. Block your schedule and set aside plenty of time to complete assignments including extra time to handle any technology related problems.
3. **Login regularly.** I recommend that you log in to ELMS-Canvas several times a week to view announcements, discussion posts and replies to your posts. You may need to log in multiple times a day when group submissions are due.
4. **Do not fall behind.** This class moves at a quick pace and each week builds on the previous content. If you feel you are starting to fall behind, check in with the instructor as soon as possible so we can troubleshoot together. It will be hard to keep up with the course content if you fall behind in the pre-work or post-work.
5. **Use ELMS-Canvas notification settings.** Pro tip! Canvas ELMS-Canvas can ensure you receive timely notifications in your email or via text. Be sure to enable announcements to be sent instantly or daily.
6. **Ask for help if needed.** If you need help with ELMS-Canvas or other technology, IT Support. If you are struggling with a course concept, reach out to me and your classmates for support.

Policies and Resources for Undergraduate Courses (UMD Syllabus template)

It is our shared responsibility to know and abide by the University of Maryland's policies that relate to all courses, which include topics like:

- Academic integrity
- Student and instructor conduct
- Accessibility and accommodations
- Attendance and excused absences
- Grades and appeals
- Copyright and intellectual property

Please visit www.ugst.umd.edu/courserelatedpolicies.html for the Office of Undergraduate Studies' full list of campus-wide policies and follow up with me if you have questions.

Use of AI:
I believe that AI tools will become, for better or for worst, an increasingly large part of our daily life. It will be important to learn how to use these tools efficiently and critically to increase your productivity and competitive edge. Hence, I will not forbid the use of AI tools (e.g., ChatGPT) for this course, even though I understand it can be used to write or fix your computer codes. Nevertheless, I warn you that, in order to use AI effectively, you still need to be a smart and competent coder (need to ask the right questions and catch the unavoidable errors). I ask you to disclose in the HW solution whether you used AI or not, and if you did, in which way (e.g., to write the skeleton of the code, to debug the code, to do both).
Group Chats:

[1] Text in gray is standard text taken directly from the UMD Syllabus template.

We are aware that there will likely be a group chat established for this course. We encourage the use of a group chat for discussion of the course material and concepts, as long as that discussion follows the acceptability guidelines listed below. All the rules in this course syllabus also apply to any postings in a group chat or other social media venue.

Acceptable in Group Chats	**Unacceptable in Group Chats**
To use in cases when electronic devices are allowed in the course.	To use during exams or at other times when electronic devices are not allowed.
To discuss the concepts and ideas in the course, on homework assignments, and in other course assignments.	To give out an answer to a homework question, clicker question, or other assignment.
To discuss the mathematical equations in the course, how they work, and to do examples.	To give out numerical answers and exact math work to math problems on a homework assignment or other course assignment.
To report to the instructor any conduct or remarks on the group chat that go against the university's Code of Academic Integrity or Non-Discrimination Policy.	To use to complete an in-class assignment when you are not in class, such as clicker questions or pop quizzes.
To ask about the mechanics of the course, such as when a due date is or where the class is being held.	To facilitate (help) others cheat, such as by passing on answers to assignments or quizzes, or telling others when in-class activities are occurring (i.e., clicker questions or pop quizzes).
To coordinate with other course members on a groupwork assignment.	To actively exclude another student in the course.

The university's Code of Academic Integrity (https://president.umd.edu/sites/president.umd.edu/files/documents/policies/III-100A.pdf) states that academic dishonesty includes any of the following acts:

1. **Cheating:** attempting to gain an unfair advantage and/or intentionally using or attempting to use unauthorized materials, information, or study aids in any academic course or exercise.
2. **Fabrication:** falsification or invention of any information or citation in any academic course or exercise.
3. **Facilitating Academic Dishonesty:** intentionally or knowingly helping or attempting to help another to violate any provision of this Code.
4. **Plagiarism:** intentionally or knowingly representing the words or ideas of another as one's own in any academic course or exercise.

The university's Non-Discrimination Policy (https://www.president.umd.edu/sites/president.umd.edu/files/documents/policies/VI-1.00B_2.pdf) prohibits discrimination on grounds of race, color, sex, gender identity or expression, sexual orientation, marital status, age, national origin, political affiliation, physical or mental disability, religion, protected veteran status, genetic information, personal appearance, or any other legally protected class. This applies to discrimination, harassment or retaliation "that adversely impacts the education...of a member of the University community regardless of where the conduct occurred."

As you use a group chat for this course, keep in mind that *it is unacceptable to have another person do your own work.* You must write up your own answers in your own words, unless the assignment is a designated group activity. If others post information on the group chat, you should verify that it is correct and complete so that it helps your understanding rather than hinders it. You should never copy the work of another person or other source without quoting it, citing it, and providing a full reference, because otherwise that is plagiarism.

Course Guidelines (UMD Syllabus template)

Names/Pronouns and Self-Identifications:

The University of Maryland recognizes the importance of a diverse student body, and we are committed to fostering inclusive and equitable classroom environments. I invite you, if you wish, to tell us how you want to be referred to in this class, both in terms of your name and your pronouns (he/him, she/her, they/them, etc.). Keep in mind that the pronouns someone uses are not necessarily indicative of their gender identity. Visit trans.umd.edu to learn more.

Additionally, it is your choice whether to disclose how you identify in terms of your gender, race, class, sexuality, religion, and dis/ability, among all aspects of your identity (e.g., should it come up in classroom conversation about our experiences and perspectives) and should be self-identified, not presumed or imposed. I will do my best to address and refer to all students accordingly, and I ask you to do the same for all your fellow Terps.

Communication with Instructor:

Email: If you need to reach out and communicate with me, please email me at ricotti@umd.edu. Please DO NOT email me with questions that are easily found in the syllabus or on ELMS (i.e. When is this assignment due? How much is it worth? etc.) but please DO reach out about personal, academic, and intellectual concerns/questions.
While I will do my best to respond to emails within 24 hours, you will more likely receive email responses from me on Mondays, Wednesdays and Fridays from 8:00am-10:00am EST

ELMS: I will send IMPORTANT announcements via ELMS messaging. You must make sure that your email & announcement notifications (including changes in assignments and/or due dates) are enabled in ELMS so you do not miss any messages. You are responsible for checking your email and Canvas/ELMS inbox with regular frequency.

Communication with Peers:

With a diversity of perspectives and experience, we may find ourselves in disagreement and/or debate with one another. As such, it is important that we agree to conduct ourselves in a professional manner and that we work together to foster and preserve a virtual classroom environment in which we can respectfully discuss and deliberate controversial questions. I encourage you to confidently exercise your right to free speech—bearing in mind, of course, that you will be expected to craft and defend arguments that support your position. Keep in mind, that free speech has its limit, and this course is NOT the space for hate speech, harassment, and derogatory language. I will make every reasonable attempt to create an atmosphere in which each student feels comfortable voicing their argument without fear of being personally attacked, mocked, demeaned, or devalued.

Any behavior (including harassment, sexual harassment, and racially and/or culturally derogatory language) that threatens this atmosphere will not be tolerated. Please alert me immediately if you feel threatened, dismissed, or silenced at any point during our semester together and/or if your engagement in discussion has been in some way hindered by the learning environment.

Major Assignments

In this class there are no Midterms and Final exams. The final exam is replaced by a "Term Project." Below is a description of the main graded assignments.

1.Homework Assignments

There will be 6 Homework assignments during the semester. All assignments involve programming exercises. To make evaluating your work easier, you must provide me with a *solution in pdf or word format* of the problem as a single "stand-alone" file containing all your work by the beginning of class on the day the assignment is due. In addition, you must provide a working directory containing the source code and instructions to compile and run the codes. Ideally, a Makefile should be provided.

Any static graphical output (plots, etc.) should be embedded in the response document (PDF format is best, as Word has compatibility issues especially with embedded figures).

How to submit the source code and pdf solution (GitHub):

The prefer method to submit all assignments for this class is ***GitHub***. We will learn how to use this web-tool to archive and share software as part of this class curriculum. You will be able to clone and upload your working directory on a repository on GitHub that I have created for this class. If attempting to use GitHub fails, you can submit (by email or ELMS) a gzip tar archive or a zip file containing your working directory that when uncompressed must produce a folder (named by your last name), containing all the files discussed above.

There is no TA assigned to this class. Since the number of students is significant, I will need your help/feedback in grading the homework. My plan is to assign to each student two HW solutions for peer review. We can set this up to be an anonymous and randomized process for each assignment. This effort will give you participation points and it is part of the class learning experience. I will assign the final grade for each HW based on the feedback of the peer reviews in addition to my own assessment of the solution.

I will provide a rubric on how to grade the HW. The standard procedure is to compile and run the code with a set of test parameters to ensure correct functionality and error handling. Toward the end of the course, we will also consider your coding style when evaluating your work. Assignments that are late will automatically incur a 10% penalty unless there are extenuating circumstances. The penalty for late assignment will be commensurate to the number of days the homework is late (e.g., ∼5% per day). Late assignments must be completed before the solutions are handed in to get any credit.

You may work in groups to discuss programming strategies, but you must submit your own solution to each assignment. Note that in the writeup it is necessary to cite the source of any algorithms you use in completing assignments. This includes Numerical Recipes routines that you may decide to use and AI tools (e.g., ChatGPT).

2. In Class Exercises and Participation

This class is based on hands on programming. I will give reading assignments and briefly cover and answer your questions on the reading material during the first half of the class. I plan on devoting the second half of each class for hands-on programming. The in-class activities will include exercises that I will assign during the semester and working on the HW. I will monitor your participation based on the completion of the in-class exercises and assign participation points during each class. I will also assign participation points based on your peer-review of the HW as described above.

3. Term Project

In addition to the homework, I will assign a term project. You can work on the term project in small groups or individually. We will discuss the details and project ideas during the course, but you should expect that you will turn in a writeup of the project and present it in class during one of the last 2 or 3 classes of the semester.

Grading Structure

Assignment	Percentage %
Homework	**70%**
In class exercises/participation	**15%**
Team Project/Paper/Presentation	**15%**
Total	**100%**

Grades

All assessment scores will be posted on the course ELMS page. If you would like to review any of your grades, or have questions about how something was scored, please email me to schedule a time for us to meet and discuss.
Late work will not be accepted for course credit so please plan to have it submitted well before the scheduled deadline. I am happy to discuss any of your grades with you, and if I have made a mistake, I will immediately correct it. Any formal grade disputes must be submitted in writing and within one week of receiving the grade. Final letter grades are assigned based on the percentage of total assessment points earned. To be fair to everyone I must establish clear standards and apply them consistently.

Final Grade Cutoffs									
+	97.00%	+	87.00%	+	77.00%	+	67.00%	+	
A	93.00%	B	83.00%	C	73.00%	D	63.00%	F	<60.0%
-	90.00%	-	80.00%	-	70.00%	-	60.00%	-	

Academic Integrity (UMD Syllabus template)

For this course, some of your assignments will be collected via Turnitin on our course ELMS page. I have chosen to use this tool because it can help you improve your scholarly writing and help me verify the integrity of student work. For information about Turnitin, how it works, and the feedback reports you may have access to, visit Turnitin Originality Checker for Students

The University's Code of Academic Integrity is designed to ensure that the principles of academic honesty and integrity are upheld. In accordance with this code, the University of Maryland does not tolerate academic dishonesty. Please ensure that you fully understand this code and its implications because all acts of academic dishonesty will be dealt with in accordance with the provisions of this code. All students are expected to adhere to this Code. It is your responsibility to read it and know what it says, so you can start your professional life on the right path. **As future**

professionals, your commitment to high ethical standards and honesty begins with your time at the University of Maryland.

It is important to note that course assistance websites, such as CourseHero, or AI-generated content are not permitted sources unless the instructor explicitly gives permission. Material taken or copied from these sites can be deemed unauthorized material and a violation of academic integrity. These sites offer information that might be inaccurate or biased and most importantly, relying on restricted sources will hamper your learning process, particularly the critical thinking steps necessary for college-level assignments.

Additionally, students may naturally choose to use online forums for course-wide discussions (e.g., Group lists or chats) to discuss concepts in the course. However, collaboration on graded assignments is strictly prohibited unless otherwise stated. Examples of prohibited collaboration include: asking classmates for answers on quizzes or exams, asking for access codes to clicker polls, etc. Please visit the **Office of Undergraduate Studies' full list of campus-wide policies** and reach out if you have questions.

If you ever feel pressured to comply with someone else's academic integrity violation, please reach out to me straight away. Also, ***if you are ever unclear*** about acceptable levels of collaboration, ***please ask***! To help you avoid unintentional violations, ***the following table*** lists levels of collaboration that are acceptable for each graded exercise. Each assignment will contain more specific information regarding acceptable levels of collaboration.

						
Homework Assignments	✓	✓	✓	✓	---	✓
Team Project	✓	✓	✓	✓	✓	✓

Tentative Course Outline

Date	Lecture	Reading	(NRiC)	HW due date
#1	Aug 27	Introduction to the course and survey	–	
#2	Aug 29	Computer architecture	–	
#3	Sep 03	Introduction to UNIX	tutorial	
#4	Sep 05	Introduction to C	1.1-1.2, tutorial	
#5	Sep 10	Examples in C and debugging	1.1-1.2, tutorial	
#6	Sep 12	Parallel Computing (CPU and GPU)	tutorial	
#7	Sep 17	Data representation	1.3	
#8	Sep 19	Linear algebra, part 1 (Gauss-Jordan)	2.0-2.3	HW1 due
#9	Sep 24	Linear algebra, part 2 (LU & SVD dec.)	2.4-2.6	
#10	Sep 26	Root finding in 1-D	9.0-9.1, 9.4, 9.6	
#11	Oct 01	Root finding in multi-D, num. derivative	5.7	HW2 due
#12	Oct 03	Statistics and the K-S test	14.0-14.3	
#13	Oct 08	Least-squares fitting	15.0-15.2, 15.4-15.5	
#14	Oct 10	Random numbers and cryptography	7.0-7.2	HW3 due
#15	Oct 15	Numerical integration	7.6, 4.0-4.4, 4.6	
#16	Oct 17	Integration of ODEs, part 1 (IVPs)	16.0-16.1	
#17	Oct 22	Integration of ODEs, part 2 (leapfrog)	–	HW4 due
#18	Oct 24	Integration of ODEs, part 3 (stiff ODEs)	16.6, 17.0	
#19	Oct 29	Integration of ODEs, part 4 (2-pt BVPs)	16.6, 17.0	
#20	Oct 31	N-body techniques, part 1	–	HW5 due
#21	Nov 05	N-body techniques, part 2 (PP)	–	
#22	Nov 07	N-body techniques, part 3 (PM and tree)	19.0, 19.4-19.6	
#23	Nov 12	Integration of PDEs, part 1 (ell & hyp)	19.0-19.1	
#24	Nov 14	Integration of PDEs, part 2 (hyp & par)	19.2	HW6 due
#25	Nov 19	Fluid dynamics, part 1 (eqns)	19.3	
#26	Nov 21	Fluid dynamics, part 2 (methods)	–	
#27	Nov 26	(TBD: Term project presentations or catch up with material)	–	Project due
--	Nov 28	no class (Thanksgiving)	–	
#28	Dec 03	Term project presentations	–	
#29	Dec 05	Term project presentations	–	

Note: This is a tentative schedule, and subject to change as necessary – monitor the course ELMS page for current deadlines. In the unlikely event of a prolonged university closing, or an extended absence from the university, adjustments to the course schedule, deadlines, and assignments will be made based on the duration of the closing and the specific dates missed.

Resources & Accommodations (UMD Syllabus template)

Accessibility and Disability Services

The University of Maryland is committed to creating and maintaining a welcoming and inclusive educational, working, and living environment for people of all abilities. The University of Maryland is also committed to the principle that no qualified individual with a disability shall, on the basis of disability, be excluded from participation in or be denied the benefits of the services, programs, or activities of the University, or be subjected to discrimination. The **Accessibility & Disability Service (ADS)** provides reasonable accommodations to qualified individuals to provide equal access to services, programs and activities. ADS cannot assist retroactively, so it is generally best to request accommodations several weeks before the semester begins or as soon as a disability becomes known. Any student who needs accommodations should contact me as soon as possible so that I have sufficient time to make arrangements.

For assistance in obtaining an accommodation, contact Accessibility and Disability Service at 301-314-7682, or email them at **adsfrontdesk@umd.edu**. Information about **sharing your accommodations with instructors, note taking assistance** and more is available from the **Counseling Center**.

Student Resources and Services

Taking personal responsibility for your own learning means acknowledging when your performance does not match your goals and doing something about it. I hope you will come talk to me so that I can help you find the right approach to success in this course, and I encourage you to visit **UMD's Student Academic Support Services website** to learn more about the wide range of campus resources available to you.

In particular, everyone can use some help sharpening their communication skills (and improving their grade) by visiting **UMD's Writing Center** and schedule an appointment with the campus Writing Center.

You should also know there are a wide range of resources to support you with whatever you might need (**UMD's Student Resources and Services website** may help). If you feel it would be helpful to have someone to talk to, visit **UMD's Counseling Center** or **one of the many other mental health resources on campus**.

Notice of Mandatory Reporting

Notice of mandatory reporting of sexual assault, sexual harassment, interpersonal violence, and stalking: As a faculty member, I am designated as a "Responsible University Employee," and I must report all disclosures of sexual assault, sexual harassment, interpersonal violence, and stalking to UMD's Title IX Coordinator per University Policy on Sexual Harassment and Other Sexual Misconduct.

If you wish to speak with someone confidentially, please contact one of UMD's confidential resources, such as CARE to Stop Violence (located on the Ground Floor of the Health Center) at 301-741-3442 or the Counseling Center (located at the Shoemaker Building) at 301-314-7651.

You may also seek assistance or supportive measures from UMD's Title IX Coordinator, Angela Nastase, by calling 301-405-1142, or emailing titleIXcoordinator@umd.edu.

To view further information on the above, please visit the Office of Civil Rights and Sexual Misconduct's website at ocrsm.umd.edu**.**

Basic Needs Security

If you have difficulty affording groceries or accessing sufficient food to eat every day, or lack a safe and stable place to live, please visit **UMD's Division of Student Affairs website** for information about resources the campus offers you and let me know if I can help in any way.

Veteran Resources

UMD provides some additional supports to our student veterans. You can access those resources at the office of Veteran Student life and the Counseling Center. Veterans and active duty military personnel with special circumstances (e.g., upcoming deployments, drill requirements, disabilities) are welcome and encouraged to communicate these, in advance if possible, to the instructor.

Participation

- Given the interactive style of this class, attendance will be crucial to note-taking and thus your performance in this class. Attendance is particularly important also because class discussion will be a critical component for your learning.
- Each student is expected to make substantive contributions to the learning experience, and attendance is expected for every session.
- Students with a legitimate reason to miss a live session should communicate in advance with the instructor, except in the case of an emergency.
- Students who miss a live session are responsible for learning what they miss from that session.
- Additionally, students must complete all readings and assignments in a timely manner in order to fully participate in class.

Course Evaluation

Please submit a course evaluation through Student Feedback on Course Experiences in order to help faculty and administrators improve teaching and learning at Maryland. All information submitted to Course Experiences is confidential. Campus will notify you when Student Feedback on Course Experiences is open for you to complete your evaluations at the end of the semester. Please go directly to the **Student Feedback on Course Experiences** to complete your evaluations. By completing all of your evaluations each semester, you will have the privilege of accessing through Testudo the evaluation reports for the thousands of courses for which 70% or more students submitted their evaluations.

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