

**Department of Astronomy and Planetary Science
AST 299 Computational Analysis in Astronomy**

2024 Spring

3 Credits Units

Updated February 4, 2024

Modes of Instruction: Primarily Lecture

- Meets in person Mondays and Wednesdays 12:45pm - 2pm in Biological Sciences 021-235, Jan 16 - May 1 or in some cases virtually. Virtual class meetings will be announced ahead of time in class and via Canvas.
 - Final Exam is May 8 12:30pm - 2:30pm.
 - If we meet virtually, use Zoom, <https://nau.zoom.us/j/6032695475> passcode 22.
 - Instructor: Dr. Chad Trujillo
Office: Physical Sciences (#19) 312
Office Hours: by appointment
Availability: Cell response will be typically be within an hour if a voicemail is left or a text is sent, weekday emails will generally be responded to within a day. You can also send class questions or feedback anonymously to Dr. Trujillo at <https://goo.gl/forms/BSvNSPSML7WXMzm22> .
- Email: chad.trujillo@nau.edu
Office phone: 928-523-6007
Cell: 808-756-4393
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Course Purpose: Computational analysis of data is the most fundamental of all skills for students to learn in any science research discipline. Astronomical applications will be the examples focused on in this course, but the techniques and methodologies covered will be broadly applicable to all research science disciplines both in the laboratory or using remote data collection (for example ground-based or space-based telescopes or field data).

The primary analysis platform used in this course will be Jupyter Notebooks (and the associated JupyterLab) which is a free open-source project that supports scientific computing over all computing languages and computing platforms and is commonly used for many science research cases including data-intensive astronomical science. In this course, the primary language will be Python which is an accessible computing language with an extensive suite of community-supported libraries.

Course Student Learning Outcomes: After taking this course, students will be able to do the following:

- Perform scientific analysis of data at a level suitable for undergraduate research in astronomy and other related scientific disciplines.
- Gain a thorough understanding of Python and scientific programming techniques in general to find and utilize publicly available libraries and datasets.
- Understand and practice how to use Application Programming Interfaces (APIs) and other methods to access large databases to retrieve datasets relevant to scientific problems.
- Understand how to assess the significance of astronomical research in the context of professional science and popular culture.

This course provides a number of career-ready competencies (CRCs), which are skills that prepare students for success in the workplace and lifelong career management.¹ In-demand CRCs from the National Association of Colleges and Employers that will be learned in this course include:

- Career and Self-Development: Display curiosity; seek out opportunities to learn.
- Communication: Exchange information and perspectives in a clear manner that others can effectively understand.
- Critical Thinking: Make judgments using sound and inclusive reasoning.
- Professionalism: Act equitably with integrity and accountability; be present and prepared.
- Teamwork: Listen carefully to others, taking time to understand, ask appropriate questions.
- Technology: Use technology appropriate to complete relevant tasks.

Assignments / Assessments of Course Student Learning Outcomes: The majority of the assessments in this course will be through homework assignments. Students will also be assessed based on course attendance and class participation. Additionally, there will be 2 mid-term exams and 1 final exam. Exams are being given because (1) it is primarily an individual effort, which is an important aspect of research to practice, and (2) studies show that course content retention is improved when students are asked to recall information through testing.

¹NACE Career Readiness <https://www.nacweb.org/career-readiness/competencies/career-readiness-defined/>

Health and Safety: If you have symptoms of any kind of sickness, it is up to you to determine if it is appropriate for you to attend class in-person, following any NAU guidelines. If you have a medical excuse or you email me ahead of time, your attendance score will not be impacted. All lecture slides will be made available online if you miss class or not, but live-stream or recorded lectures won't be made unless requested.

Grading System: Letter grades will be assigned as follows: A at 90%, B at 80%, C at 70%, D at 60% and F below 60%. The requirements for grades may be relaxed based on class performance (i.e. a curve), but they will not be made more stringent.

- **Final Exam:** The registrar has set our final exam to take place on **Wednesday May 8 12:30 pm - 2:30 pm**. The final will be worth 20% of the grade.
- **Mid-Term Exams:** There will be two mid-term exams. These will each be worth 7.5% of the grade for a total of 15%.
- **Homework:** There will be a homework assigned most weeks of the semester except for the week before exams (so you don't have homework due on the same week as an exam) and the last week (reading week). These will count for a total of 45% of the grade. As there are 10 homeworks expected, each will count for 4.5% of the grade. These will usually be assigned online on Wednesday and be due the following Wednesday by 11:59pm. This is the largest single part of the grade.
- **Attendance and Participation:** Attendance and Participation will together count towards 20% of the grade. Both will be assessed through online short quizzes during lecture. These quizzes are ungraded (i.e. an incorrect answer still counts as participation) and are used as metrics of class understanding of recently presented material.
- **Extra Credit:** There will be extra credit which will be given with most homeworks. It will generally involve doing something outside the normal scope of the course and involve a more extended essay response than most homework essay questions. These will count as a fraction of a typical homework grade, not more than 1% of total grade and you can still receive a 100% rating in the course without doing them.

Readings and Materials:

- **Suggested Textbooks:** Python for Data Analysis: Data Wrangling with pandas, NumPy, and Jupyter 3rd Edition (McKinney) and Python for Scientists 3rd Edition (Stewart and Mommert). There will be some readings from these books, which are available on Amazon for less than \$45 each. Any required reading excerpts will be provided so purchasing them is not required. Although nearly all Python learning information is freely available online, textbooks are useful in that they are both comprehensive (covering a large amount

of information and techniques) and also accessible (providing a readable narrative of how and why things are done).

- Computer: You will need a computer to complete nearly all assignments. If you don't have one, you can use the department computer lab and also the Cline Library rents computers. You must bring a computer or a smartphone to class to respond to in-class polls.
- Top Hat App: NAU is offers Top Hat services through smartphones at no cost to students. This will be used throughout the semester for online polling. Information on how to use the app can be found here:
<https://tophat.com/students/>
- Required supplementary readings will be made available online.

Class Outline: Below is an approximate outline of the topics covered by week. These will be adjusted based on the pace of the class. Also, there is the possibility of in-person class cancellation or move to a virtual class in the event of adverse weather, terrorist threat, or pandemic. If in-person conditions are unsafe, in-person class will be cancelled and students will be notified by email prior to 9:45am the morning of class (3 hours before class) . Anytime NAU is closed, in-person class will not be held.

Week	Date	Topic	Assignments Due
1	Mon Jan 15	Martin Luther King, Jr's Birthday - No Class	
	Wed Jan 17	Overview, Goals, Expectations, "Hello, World!"	
2	Mon Jan 22	Python, Virtual Machines, Jupyter Notebooks/Lab	
	Wed Jan 24	Python Libraries, Lists, Arrays, Tuples	Homework 1
3	Mon Jan 29	Conditionals, Loops, Functions and matplotlib	
	Wed Jan 31	More matplotlib, Avoiding Loops, and NumPy	Homework 2
4	Mon Feb 5	Celestial Coordinates, Magnitudes, Gaussian Statistics	
	Wed Feb 7	Data Outliers (mean, median, standard deviation)	Homework 3
5	Mon Feb 12	Cleaning Data, Outliers	
	Wed Feb 14	Algorithm Optimization	Homework 4
6	Mon Feb 19	No In-Person Class - Washington's Birthday	
	Wed Feb 21	SciPy, Review	Homework 5
7	Mon Feb 26	Mid-term 1 (Covering Homeworks 1-4)	Mid-term 1
	Wed Feb 28	More SciPy and Minimization	
8	Mon Mar 4	Least Squared Fits, Thriving Amid Uncertainty	
	Wed Mar 6	Chi-Squared, Free Parameters and Reduced Chi-Squared	Homework 6
	Mar 11 – 15	Spring Break, No Classes	
9	Mon Mar 18	Corner Plots, Polynomials and Splines	
	Wed Mar 20	Interpolation and Extrapolation	Homework 7
10	Mon Mar 25	Pandas, CSV, Excel	
	Wed Mar 27	Timeseries data, Fast Fourier Transforms	Homework 8
11	Mon Apr 1	Mid-term 2 (Covering Homeworks 5-7)	Mid-term 2
	Wed Apr 3	Matched Filters, Convolution and Correlation	
12	Mon Apr 8	Astropy, Image Processing	
	Wed Apr 10	Source Identification	Homework 9
13	Mon Apr 15	Database Creation and Curation	
	Wed Apr 17	Vizier, APIs and Big Data	
14	Mon Apr 22	Sorting, Binary Trees	
	Wed Apr 24	KD Trees, Citizen Science and Zooniverse	Homework 10
15	Mon Apr 29	Review 1	
	Wed May 1	Review 2 and Contest	
16	Wed May 8 12:30pm - 2:30pm	Final Exam	Final Exam

Fig. 1.— Schedule for lectures and assignments.

Class Policies: Class policies are described below.

Lecture Attendance: You are expected to attend every Lecture if it is safe to do so. You may miss 3 Lectures over the semester without penalty (no excuse needed) if you notify Dr. Trujillo **before class starts**. Institutional or medical excuses do not count towards the classes you can miss. Additional absences are allowed for research-related matters (conferences, field work, etc.) provided advance notice is made.

Lecture and Homework Policy:

- Homework: All homework will be done through Canvas. For all homework, as in life, you may work together. However, understand that solving problems by yourself is a core skill in academic inquiry. The submitted homework you must create yourself and any images submitted of paper copy work should be taken by you - in other words, you cannot copy and distribute content to other students. You must also reference other people and/or artificial intelligence that helped you with the homework. The reason for this is because in the real world, not attributing your sources does help a disservice at best and at worst is plagiarism, which is one of the greatest sins in academia.
 - Response Depth: There will be exercises where a calculation or a readable, written response is required. In these problems, you must show your work **in enough depth that a typical student in the class could follow your reasoning**. This is because (1) if you make a mistake in computing the final answer of a response, you can still get partial credit for the approach you use and (2) when doing example problems in real life (such as in a published paper or dissertation), you will have to show your work so that others can follow.
 - Late policy: you can turn in 3 Lecture Homework assignments in this course 3 days late (usually due on Saturday at 11:59pm) for full credit if you notify me **prior** to the original deadline. No other excuse is needed. You cannot “bank” this time (turning in 1 assignment 9 days late) or “gift” your late assignment quota to others. The reason for this is that since you normally have a week to do each assignment, and it takes a few days to grade it after all assignments are turned in, a more lenient late policy delays timely return of the homeworks to all students which makes it difficult to prepare for exams. **No homework will be accepted beyond the 3 day extension**. If you have a significant life event that prevents you from turning in assignments on time, talk to me and we can work something out.
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Exam Policy:

- All exams through Canvas. There will be a time limit, usually at least 24 hours. Exams will be open note and open internet because restricting this is basically impossible. That said, you will be much better off studying for the exam ahead of time rather than trying to find solutions on the internet due to the complexity of the problems. Any required physical constants will be supplied as will fundamental formulae but relevant programming code will not be provided. One week ahead of each exam, the exam policy will be announced, and an opportunity for feedback will be given.
- Exams are designed to test individual knowledge. However, there will be opportunities for group work on tests, but these will be clearly announced ahead of time. In the absence of such an announcement, working together (or with artificial intelligence) on a test, even virtually, is considered cheating.
- As in the homework, all exam work must be shown for full credit.

Plagiarism and Cheating: Plagiarism is using someone else's work or ideas and passing them off as your own (and in fact, you can even self-plagiarize, but that's probably not relevant to this class). **Plagiarism is considered the most serious breach of scientific integrity.** Evidence of this is work suspiciously similar to other's work (exact same wording, or very similar wording) with no attribution. This is considered cheating in this course. All people involved in cheating and/or plagiarism will be given a zero on the assignment / exam and the Department Chair will be informed, regardless of who cheated off whom. Repeat offenses will be escalated to the Dean following the NAU Academic Integrity Policy.

Use of Artificial Intelligence: NAU has put out some guidelines for the use of Artificial Intelligence (AI) in academic work. These are <https://in.nau.edu/academic-affairs/genai/> and some sample statements for syllabi are here <https://in.nau.edu/academic-affairs/genai/syllabus/>. This course adopts "All use of generative AI is permitted, with acknowledgment", as described below.

In these guidelines, we've used ChatGPT as an example, but the behavior is similar across many AI platforms.

What's wrong with ChatGPT?

ChatGPT is specifically designed to obfuscate its sources. If it gives you information, it will never tell you where the information comes from, so you cannot know what influenced it in creating its output or if the information is trustworthy or not.

This is against the fundamental scientific principle that you always cite your sources. In this course, if you get significant help from someone (or something) else, you must cite that source.

Can I use ChatGPT (or other AI) in this course?

Yes. It is probably best used to create the basic framework and syntax for programs and to identify code libraries that might be useful to you. Many people do this today and this is generally considered acceptable use.

Keep in mind that ChatGPT code is not your code - it is akin to asking a Teaching Assistant or a friend for advice on a problem in a course, so you must say that you used ChatGPT (or other AI resource) and how extensively you used it. Also be aware that usually ChatGPT-created code will not run properly to solve our problems in the way they are asked and will need to be modified.

Use of AI-generated code without attribution to the AI platform itself is considered plagiarism or cheating in this course and will be treated similarly to “copying” another person’s work.

E-learning Resources Policy: Much of our course work will take place electronically, including (but not limited to) out-of-class communication, presentation of reading materials, distribution of homework and any virtual lectures. It is the responsibility of the student to check email and Canvas regularly. The student must also allow ample time prior to deadlines at the northwest corner of building nineteen there is a reward in a rock to navigate any technological issues that may arise such as computer crashes, internet outages, software version mismatches, etc. Students are also strongly encouraged to back up all data. ITS has an excellent support network and students having issues with online learning are encouraged to contact them.

Academic Contact Hour Policy: The Arizona Board of Regents Academic Contact Hour Policy (ABOR Handbook, 2-224) states that for a 3 credit course such as this one, a student should expect to spend a **minimum** of 9 hours per week on average. Class time is 2.5 hours per week. Therefore, at least 6.5 hours per week should be spent outside of class on homework, studying, and preparation.

Financial Hardship: If you are experiencing financial hardship that makes it difficult for you to meet the class requirements, please communicate with me and we will find an accommodation.

Disability Resources: If disability accommodations would benefit you, please contact me and/or the Disability Resource office at NAU. Many services and accommodations are available at no cost to NAU students and I fully support any such solution.

University Policies: The following pages contain the NAU Policy Statements for Course Syllabi. They take precedence over anything earlier in this document.

SYLLABUS POLICY STATEMENTS

ACADEMIC INTEGRITY

NAU expects every student to firmly adhere to a strong ethical code of academic integrity in all their scholarly pursuits. The primary attributes of academic integrity are honesty, trustworthiness, fairness, and responsibility. As a student, you are expected to submit original work while giving proper credit to other people's ideas or contributions. Acting with academic integrity means completing your assignments independently while truthfully acknowledging all sources of information, or collaboration with others when appropriate. When you submit your work, you are implicitly declaring that the work is your own. Academic integrity is expected not only during formal coursework, but in all your relationships or interactions that are connected to the educational enterprise. All forms of academic deceit such as plagiarism, cheating, collusion, falsification or fabrication of results or records, permitting your work to be submitted by another, or inappropriately recycling your own work from one class to another, constitute academic misconduct that may result in serious disciplinary consequences. All students and faculty members are responsible for reporting suspected instances of academic misconduct. All students are encouraged to complete NAU's online academic integrity workshop available in the E-Learning Center and should review the full *Academic Integrity* policy available at <https://policy.nau.edu/policy/policy.aspx?num=100601>.

ARTIFICIAL INTELLIGENCE

Artificial intelligence (AI) technologies bring both opportunities and challenges. Ensuring honesty in academic work creates a culture of integrity and expectations of ethical behavior. The use of these technologies can depend on the instructional setting, varying by faculty member, program, course, and assignment. Please refer to course policies, any additional course-specific guidelines in the syllabus, or communicate with the instructor to understand expectations. NAU recognizes the role that these technologies will play in the current and future careers of our graduates and expects students to practice responsible and ethical use of AI technologies to assist with learning within the confines of course policies.

COPYRIGHT INFRINGEMENT

All lectures and course materials, including but not limited to exams, quizzes, study outlines, and similar materials are protected by copyright. These materials may not be shared, uploaded, distributed, reproduced, or publicly displayed without the express written permission of NAU. Sharing materials on websites such as Course Hero, Chegg, or related websites is considered copyright infringement subject to United States Copyright Law and a violation of NAU Student Code of Conduct. For additional information on ABOR policies relating to course materials, please refer to ABOR Policy 6-908 A(2)(5).

COURSE TIME COMMITMENT

Pursuant to Arizona Board of Regents guidance (ABOR Policy 2-224, *Academic Credit*), each unit of credit requires a minimum of 45 hours of work by students, including but not limited to, class time, preparation, homework, and studying. For example, for a 3-credit course a student should expect to work at least 8.5 hours each week in a 16-week session and a minimum of 33 hours per week for a 3-credit course in a 4-week session.

DISRUPTIVE BEHAVIOR

Membership in NAU's academic community entails a special obligation to maintain class environments that are conducive to learning, whether instruction is taking place in the classroom, a laboratory or clinical setting, during course-related fieldwork, or online. Students have the obligation to engage in the educational process in a manner that does not interfere with normal class activities or violate the rights of others. Instructors have the authority and responsibility to address disruptive behavior that interferes with student learning, which can include the involuntary withdrawal of a student from a course with a grade of "W". For additional information, see NAU's *Disruptive Behavior in an Instructional Setting* policy at <https://nau.edu/university-policy-library/disruptive-behavior>.

NONDISCRIMINATION AND ANTI-HARASSMENT

NAU prohibits discrimination and harassment based on sex, gender, gender identity, race, color, age, national origin,

religion, sexual orientation, disability, veteran status and genetic information. Certain consensual amorous or sexual relationships between faculty and students are also prohibited as set forth in the *Consensual Romantic and Sexual Relationships* policy. The Equity and Access Office (EAO) responds to complaints regarding discrimination and harassment that fall under NAU's *Nondiscrimination and Anti-Harassment* policy. EAO also assists with religious accommodations. For additional information about nondiscrimination or anti-harassment or to file a complaint, contact EAO located in Old Main (building 10), Room 113, PO Box 4083, Flagstaff, AZ 86011, or by phone at 928-523-3312 (TTY: 928-523-1006), fax at 928-523-9977, email at equityandaccess@nau.edu, or visit the EAO website at <https://nau.edu/equity-and-access>.

TITLE IX

Title IX of the Education Amendments of 1972, as amended, protects individuals from discrimination based on sex in any educational program or activity operated by recipients of federal financial assistance. In accordance with Title IX, Northern Arizona University prohibits discrimination based on sex or gender in all its programs or activities. Sex discrimination includes sexual harassment, sexual assault, relationship violence, and stalking. NAU does not discriminate on the basis of sex in the education programs or activities that it operates, including in admission and employment. NAU is committed to providing an environment free from discrimination based on sex or gender and provides a number of supportive measures that assist students, faculty, and staff.

One may direct inquiries concerning the application of Title IX to either or both the Title IX Coordinator or the U.S. Department of Education, Assistant Secretary, Office of Civil Rights. You may contact the Title IX Coordinator in the Office for the Resolution of Sexual Misconduct by phone at 928-523-5434, by fax at 928-523-0640, or by email at titleix@nau.edu. In furtherance of its Title IX obligations, NAU promptly will investigate or equitably resolve all reports of sex or gender-based discrimination, harassment, or sexual misconduct and will eliminate any hostile environment as defined by law. The Office for the Resolution of Sexual Misconduct (ORSM): Title IX Institutional Compliance, Prevention & Response addresses matters that fall under the university's Sexual Misconduct policy. Additional important information and related resources, including how to request immediate help or confidential support following an act of sexual violence, is available at <https://in.nau.edu/title-ix>.

ACCESSIBILITY

Professional disability specialists are available at Disability Resources to facilitate a range of academic support services and accommodations for students with disabilities. If you have a documented disability, you can request assistance by contacting Disability Resources at 928-523-8773 (voice), 928-523-8747 (fax), or dr@nau.edu (e-mail). Once eligibility has been determined, students register with Disability Resources every semester to activate their approved accommodations. Although a student may request an accommodation at any time, it is best to initiate the application process at least four weeks before a student wishes to receive an accommodation. Students may begin the accommodation process by submitting a self-identification form online at <https://nau.edu/disability-resources/student-eligibility-process> or by contacting Disability Resources. The Director of Disability Resources, Jamie Axelrod, serves as NAU's Americans with Disabilities Act Coordinator and Section 504 Compliance Officer. He can be reached at jamie.axelrod@nau.edu.

RESPONSIBLE CONDUCT OF RESEARCH

Students who engage in research at NAU must receive appropriate Responsible Conduct of Research (RCR) training. This instruction is designed to help ensure proper awareness and application of well-established professional norms and ethical principles related to the performance of all scientific research activities. More information regarding RCR training is available at <https://nau.edu/research/compliance/research-integrity>.

MISCONDUCT IN RESEARCH

As noted, NAU expects every student to firmly adhere to a strong code of academic integrity in all their scholarly pursuits. This includes avoiding fabrication, falsification, or plagiarism when conducting research or reporting research results. Engaging in research misconduct may result in serious disciplinary consequences. Students must also report any suspected or actual instances of research misconduct of which they become aware. Allegations of research misconduct should be reported to your instructor or the University's Research Integrity Officer, Dr. David Faguy, who can be reached at david.faguy@nau.edu or 928-523-6117. More information about misconduct in research is available at <https://nau.edu/university-policy-library/misconduct-in-research>.

SENSITIVE COURSE MATERIALS

University education aims to expand student understanding and awareness. Thus, it necessarily involves engagement with a wide range of information, ideas, and creative representations. In their college studies, students can expect to encounter and to critically appraise materials that may differ from and perhaps challenge familiar understandings, ideas,

and beliefs. Students are encouraged to discuss these matters with faculty.

Last revised November 28, 2023