

**Department of Astronomy and Planetary Science**  
**AST 520 Astroinformatics: Big Data in Astronomy**

2023 Spring 3 Credit Units Prerequisite: Admission to Astronomy and Planetary Science PhD  
Updated January 19, 2023

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**Mode of Instruction: Lecture**

- Meets Tuesdays and Thursdays 11:10am - 12:25pm in 19-111 or in some cases, virtually.
  - If we meet virtually, use Zoom to connect, <https://nau.zoom.us/j/6032695475> passcode 22.
  - Instructor: Dr. Chad Trujillo  
Office: Physical Sciences (#19) 312  
Office Hours: by appointment  
Availability: Phone response will be typically be within an hour if a message 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](mailto:chad.trujillo@nau.edu)  
Office phone: 928-523-6007  
Cell phone: 808-756-4393
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**Course Content:** This course provides training in the fundamentals of astroinformatics: applying “big data” techniques to research topics in astronomy. Course material will include case studies of astroinformatics projects that exist presently and that are coming in the future; tutorials in computational approaches; exposure to relevant statistical approaches; and training in creating informatics research topics. The course will conclude with a term project in which students will apply the skills they have learned to existing data sets.

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**Goals:** The main goal of this course is to prepare you for real-world research in astronomy which is becoming increasingly computationally intensive. Even if you do not do astronomy as a profession in the future, the skills you will learn in this course will help you in almost all STEM-related fields. I believe that the best way to learn is to learn by doing. Therefore, to reach the main goal, we will explore several smaller goals in this course:

In the first 8 weeks of the course, we will review journal publications that are good examples of what astroinformatics is about. We will look at the publications in detail and will identify

and summarize the main methodologies and techniques used. The summaries will be done in writing and/or in oral presentations in class. There will be associated technical exercises (primarily programming) related to the readings with the goal of demonstrating skills associated with these publications.

In the next 3 weeks of this course, we will brainstorm research ideas in astroinformatics and create mock proposals for these ideas. These proposals will be peer-evaluated by us in a blind manner, so nobody knows whose proposal is whose. We will rank the proposals and identify the best proposal for the last third of the course.

In the final 4 weeks of the course, we will take the highest ranked research proposal and implement it. The work effort will be distributed among all the people in the class. The goal is that we will, as a team, first implement the proposal on a small amount of data on a desktop/laptop computer then execute the full analysis using the NAU Monsoon High Performance Computing cluster. We will then write up the results of the research project into a single final paper. The last week there will be short presentations by each person on their aspect of the project.

**Class Outline:** Below is an approximate outline of the topics covered by week. Keep in mind there is the possibility of class cancellation in the event of instructor jury duty, adverse weather such as snow, terrorist threat and/or pandemic. If I deem travel conditions unsafe, I will notify the class by email through NAU's classlists prior to 9am the morning of class and that will say whether we do class online at the normal time or whether it's asynchronous. This is likely to happen if the National Weather Service issues a Winter Weather Warning that warns against travel around class time. And if NAU cancels classes, then of course, we will not have class.

- Week 1: (Jan 17 – 19): Introduction, Syllabus, Astroinformatics Overview, RAID arrays, Catalogs: WISE, 2MASS, Vizier. Monsoon Training.
- Week 2: (Jan 24 – 26): Catalog Queries, Cursor Search, Binary Trees, Python and NumPy, Catalogs: Sloan DSS, Kepler, NEOWISE. Homework 1 Due.
- Week 3: (Jan 31 – Feb 2): Algorithm Optimization, Binary Trees, KD Trees, Fast Fourier Transform, Matched Filters, Convolution/Correlation, Experiment: LIGO, Catalog: Gaia. Homework 2 Due.
- Week 4: (Feb 7 – 9): Fast Fourier Transform, Image Processing, Source Extraction, Catalog Creation, Kernels and Convolution, Source Extractor. Homework 3 Due.
- Week 5: (Feb 14 – 16): NumPy, Evil For Loops, Source Extractor, SCAMP. Homework 4 Due.
- Week 6: (Feb 21 – 23): Citizen Science, Zooniverse Projects, Gaussian Statistics, Bayesian Statistics. Homework 5 Due.
- Week 7: (Feb 28 – Mar 2): Zooniverse Projects, Top Hat, SQL and Relational Databases, Alert Streams and ZTF, Project Proposal Work. Homework 6 Due.

- Week 8: (Mar 7 – 9): SQL and Relational Databases, Machine Learning. Homework 7 Due. Project Proposal Work.
  - Week 9: (Mar 14 – 16) Spring Break.
  - Week 9: (Mar 21 – 23): Draft Project Proposals Due.
  - Week 10: (Mar 28 – 30): Final Project Proposals Due.
  - Week 11: (Apr 4 – 6): Project Proposal Presentations, Rankings, Choice, Delegate Work
  - Week 12: (Apr 11 – Apr 13): Group Project Work
  - Week 13: (Apr 18 – 20): Group Project Work
  - Week 14: (Apr 25 – 27): Group Project Work
  - Week 15: (May 2 – 4): Last Week of Instruction: Final Project Presentations, Final Project Due
  - Week 16: (May 9 – May 11): Finals Week (no exam, no class)
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**Class Times:** This course meets Tuesday and Thursday from 11:10am – 12:25pm either virtually (see Zoom connection info on the first page) or in 19-111. We all have busy schedules, so please respect the beginning and ending times. Although we meet over most people’s lunchtime, I request that you don’t eat in class unless you absolutely have to and/or if you bring enough food for everyone.

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**Office Hours:** Office hours are by appointment - email or text me so we can figure out a time. I’ve had set office hours in the past and almost nobody attends them, so setting up a specific time seems to have limited utility for everyone.

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**Prerequisites:** This course has a prerequisite of being enrolled in the Astronomy and Planetary Sciences PhD program. I am open to considering enrollment for seniors or those with other degrees depending on their background.

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### Required Materials:

- Computer: You will need a computer to do assignments and experiments which will be computationally intensive.
  - Monsoon Training: The latter part of this course will involve using NAU's Monsoon High Performance Computing cluster. You must register for a Monsoon account and take a self-paced training to use Monsoon. Info about this can be found on the HPC website, currently <https://in.nau.edu/hpc/obtaining-an-account>
  - Textbook: There are no required textbooks for this course because there are none suitable for this course. There will be reading assigned on a case-by-case basis drawn from journal articles and other sources.
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**Attendance:** You are expected to attend every class. This is a small, discussion-style class so having even one person missing can result in a fundamental change in the feel of the class. You may miss 2 classes over the semester without penalty (no excuse needed) if you notify me ahead of time. Institutional excuses and physical or mental health issues do not count towards the 2 classes you can miss. If you cannot attend class for some reason, please let me know and I can run the class in hybrid format or record it. It's probably best to text me (or tell someone else who is attending class in-person) about this especially if the change happens right before class since I might not check email. In terms of points, attending virtually and synchronously counts the same as attending in-person.

### Homework Policy:

- My goal is to give out homework on Thursdays by 11:59pm and collect homework the Thursday a week later by 11:59pm. The point of this is so that you don't have to do homework on the weekend and I don't have to create it or grade it over the weekend either. Homework will be assigned and turned in through NAU's Google Drive File Stream because of the BbLearn-breaking file sizes that may be encountered. Source Code written as part of homework should be turned in as a file AND a PDF version of the code should also be turned in, preferably with color syntax highlighting enabled. This is so I can virtually "write" comments on the PDF to provide feedback. Although most assignments will involve some programming, *this is not a programming class*. I will comment on your program, but we will spend little time in class talking about specifics of programming (syntax, libraries to use, etc.) and more time talking about overall concepts (data sets, algorithms and methodologies that are important and how they are used). In most cases, it is up to you and your cohort to figure out the specific programming methods to use. In fact, this class doesn't have a specific language that we will use pre-decided — this will be determined based on student feedback in the first class meeting.

- Code comments: It is very important to comment your code, to remind yourself of the decisions you made when writing it, for other people who might be working with you, or in this class, so I can understand what you are doing. Please include many comments in your code.
- For all homework, as in life, you may work together. However, the submitted homework you must create yourself. You must also reference other people that helped you with the homework. The reason for this is because in the real world, not attributing your sources does them a disservice at best and at worst is plagiarism, which is one of the greatest sins in academia.
- Reading assignments with feedback: we will have reading assignments from journal publications and other sources. You will usually have to create some kind of feedback, which may be a written summary of the article or you may have to lead a discussion in class. The purpose of this is because studies show that if you write/discuss an article (rather than just reading it), knowledge of the subject and retention is greatly increased.
- Technical assignments: most assignments will involve computational exercises that will include creating code for data analysis. In these cases, you may discuss computational techniques with people, but you should write your code yourself using your own style.
- Calculations: there will be exercises where a calculation is required. In these problems, you must show your work in enough depth that someone else can follow your reasoning. This is because (1) if you make a mistake in computing the final answer, you will still get partial credit for the approach you use and (2) when doing example calculations in real life (such as in a published paper or thesis), you will have to show your work so that others can follow.
- Writing assignments: being able to communicate effectively in writing is one of the most important skills in the sciences. There will be writing assignments where not only the content but the clarity of your work will be assessed.
- Late policy: you can turn in 2 assignments in this course 4 days late (nominally Monday at 11:59pm for homeworks normally due Thursday) for full credit if you notify me *prior* to the deadline. No other excuse is needed. This is because stuff happens in life and sometimes you cannot make the deadline. The four days is because that deadline still lets me talk about the homework on Tuesday after the assignment is normally due. This late policy doesn't apply to the group project work since that affects everyone in the course quite a bit.

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### Exam Policy:

- In this class you will generally be allowed to use anything at your disposal to take an exam (if there is an exam) including notes, books or the web. Do *not* assume that this means you shouldn't study the course material.

- As in the homework, all work must be shown for full credit.
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**Grading:** 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.

- Final Exam: This is a project-based research-oriented class, as such there will be no final exam, although this is something we will discuss the first class session.
  - Homework: There will be about 6 homeworks assigned for the first 2/3 of the class. These will primarily be reading / response and will count towards 35% of your grade.
  - In-Class Presentation: You will also be asked to give a short (5 minute) in-class presentation about a reading assignment. This will count for 5% of your grade (similar to a single homework assignment).
  - Final Project: There will be a writing project where mock research proposals will be written. These are individual works and will count for 20% of your grade. The final third of the class will be a group exercise where we will conduct an actual astroinformatics project. This will also count for 20% of your grade.
  - Attendance: Attendance and in-class participation will each count towards 10% of the grade for a total of 20% .
  - Extra Credit: There is extra credit for attending the Astronomy and Planetary Science Colloquium. Attend and write two paragraphs with the speaker's name and describe (1) the instrumental setup the speaker used, (2) one of the main conclusions, and (3) what the speaker might be doing in the future along this line of research. One colloquium is equivalent of 12.5% of a single homework, so if you attend 8 colloquia, it is the equivalent of 1 homework assignment.
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**Plagiarism and Cheating:** Plagiarism is using someone else's work or ideas and passing them off as your own. It 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, regardless of who cheated off whom. Repeat offenses will be escalated to the Dean following the NAU Academic Integrity Policy.

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**E-learning Resources Policy:** Some course work will take place electronically, including (but not limited to) out-of-class communication, presentation of reading materials, distribution of homework and virtual lectures. It is the responsibility of the student to check email and BbLearn

regularly. The student must also allow ample time prior to deadlines 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.

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**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.

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**Disability Resources:** If disability accommodations would benefit you, please talk to me and/or the Disability Resource office at NAU. Many services and accommodations are available at no cost to NAU students.

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

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## **COVID-19 REQUIREMENTS AND INFORMATION**

Additional information about the University's response to COVID-19 is available from the **Jacks are Back!** web page located at <https://nau.edu/jacks-are-back>.

## **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>.

### **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](mailto: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](mailto: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](mailto: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](mailto: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](mailto: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 August 4, 2022