ASTRONOMY 688E
EXOPLANETARY ASTROPHYSICS (Special Topics)
Spring 2022

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Lectures: T/Th 2:00-3:15 PM • ATL 0201

Course Summary & Goals

Our understanding of extrasolar planets has advanced at a remarkable pace — from the first discovery of a planet orbiting a Sun-like star in 1995, we now know of *thousands* of exoplanets orbiting the stars in our galaxy. A key discovery is that exoplanets appear to be ubiquitous, yet most exoplanetary systems discovered to date are nothing like our solar system.

This course will introduce you to the current state of the exoplanet field, at a graduate level. Topics covered will include exoplanet detection, exoplanet demographics, planet formation and evolution, planetary atmospheres and interiors, and habitability. Over the course of the semester you will complete a set of 5 mini research projects in small groups to gain familiarity with techniques of exoplanet observations and theoretical modeling.

Readings

Being still a relatively new field of study, there are no comprehensive pedagogical textbooks on the subject at the graduate level. There is therefore no required textbook for this course. In place of a textbook, to supplement your learning in class, I will provide (via our class ELMS page) a set of readings that are derived from a variety of sources (e.g. published papers, review articles, and book chapters). Because these readings do not follow directly from one another, and some of them can be quite long, I do not expect you to read each one in detail prior to attending class. Rather, the readings should be seen as an additional resource to what is covered in class, if, for example, you would like to get more information or a different take on a topic. I recommend at least doing a thorough skim through each of the readings, to familiarize yourself with what information is conveyed covered. On a related note, the midterm and final exam will focus on material covered *during* class. I will not test you on topics that were only covered in the reading. Below, I provide a list of texts that you may find useful at times during the semester. I have copies

of most of these in my office and would generally be happy to lend them out for limited periods of time.

Various useful texts (not required):
Astrophysics of Planet Formation, **2nd edition**, Philip Armitage, Cambridge University Press, 2020
The Exoplanet Handbook, **2nd edition**, Michael Perryman, Cambridge University Press, 2018
Exoplanets, Editor: Sara Seager, University of Arizona Press, 2011
Exoplanet Atmospheres, Sara Seager, Princeton University Press, 2010

Office Hours

T/Th 3:15 - 4:00 PM • PSC 1111 • First-come-first-served, or by appointment

Class Format

This semester, for as long as class meets in person, class sessions will be conducted in a "mixed media" style. You can expect some standard chalkboard and lecture slide presentations from me, but whenever possible I will engage the class in a more active learning process. This will entail a mix of whole class and small group exercises, in which I will serve as a facilitator, and you and your classmates will engage in "self-discovery" of concepts related to exoplanet detection, properties, modeling, and characterization. I expect all students to come to every class session prepared to engage with the material. For the active learning components of our class to be successful, it is key that we all endeavor to create a supportive classroom environment. Science is done in teams, and when we strive to elevate each member of the team we will all find success. I will make my own notes available to the class following each class session to help synthesize what we covered on a given day. Please make sure to review these notes regularly.

Academic Honesty

Collaboration is encouraged on ***in-class exercises*** and is a required component of the ***group research projects***. Resources consulted when completing your group projects must be correctly cited. When in doubt, cite, and consult with me if you have any questions. It is very important that you do **NOT** collaborate with each other on the ***midterm*** or the ***final exam***. Any suspected violation of the University of Maryland Code of Academic Integrity (https://www.president.umd.edu/sites/president.umd.edu/files/documents/policies/III-100A.pdf) will be forwarded to the Student Honor Council.

Considerations for COVID-19

ASTR-688E will follow all university-issued guidance and regulations with respect to COVID-19. At the start of the semester, this includes wearing an N95 or KN95 over your mouth and nose at all times for all participants in the class, regardless of vaccination status. (As your instructor, I also intend to wear a KN95 mask at all times during class. Please let me know if you have any trouble hearing on comprehending my speech due to my mask wearing.) Students not wearing an appropriate mask will be given a warning and asked to wear one, or will be asked to leave the room immediately. Students who have additional issues with the mask expectation after a first warning will be referred to the Office of Student Conduct for failure to comply with a directive of University officials. These policies may evolve over the course of the semester. We will always defer to university-level rules, which can be found here: https://umd.edu/4Maryland/health-plan

If you are feeling sick or have been exposed to COVID-19 and are waiting on a test result, do not come to class. Please consult with the posted class notes from the day and follow up with me about any concerns about missed material. If you need to be out of class for an extended period of time (more than consecutive 2 lectures) due to a COVID-19 quarantine, please be in touch with me about accommodations for missed work.

Most importantly, we are all in this together. It is key that you look out for our own health and that of your classmates. In this time of uncertainty, I ask you all to please be flexible. Our class format may change at any time, either due to university-imposed restrictions or because we find we need to adapt to changing circumstances. I pledge to be open an honest with all of you about the status of our class as it relates to the pandemic, and I hope that you can each do the same. Please let me know if you have any concerns about any of the COVID regulations.

Grading

Class Participation 10%

While I can present material, I cannot make you learn, and without your help this class will not be a success. Because of this, I will be grading on participation. Students who receive an "A" in participation will do the following things:

- Attend class
- Ask questions (before, during, or after class)
- Answer questions (being correct is not important)
- Work at the board when called upon to do so, and support classmates when it is their turn for this role
- Work effectively and collegially with their fellow classmates

Homework Group Projects 50%

Over the course of the semester, you will complete **5** mini research projects in small groups. These project are intended to give you experience handling exoplanet data, interpreting observational results, and performing theoretical calculations. The 5 research projects will cover the following topics and are due as indicated on the course schedule:

- Project #1: Transit (or radial velocity) dataset fitting
- Project #2: Determining exoplanet occurrence rates from survey data
- Project #3: Modeling protoplanetary disk SEDs
- Project #4: Determining mass-radius relations from interior structure calculations
- Project #5: Observations and theory of exoplanet atmospheres (open-ended)

Each project submission will be in the form of a LaTeX document, shared via the Overleaf platform (https://www.overleaf.com/), which covers your motivation, methods, results, and conclusions. Your projects will be graded via a rubric that will be shared near the start of the semester. Each project will be worth 10% of your final grade.

Midterm Exam 15%

The in-class midterm exam will occur on Thursday 3/15. It will cover material from the first 6 weeks of class, through exoplanet demographics. All students are expected to take this exam. I will allow for alternate arrangements only in exceptional circumstances, and such arrangements must be made well in advance of the exam date.

Final Exam 25%

The final exam will occur on Monday 5/16 at 10:30 AM. The exam will be 2 hours in duration. It will be a cumulative final exam, covering all course content from the semester with a weighting toward new material that was not covered on the midterm.

Grading

The course will be graded on an absolute scale, with the following letter grade assignments. I reserve the right to revise the dividing line between letter grades downward. I will not revise them upward.

90-100%: A (+/-)
78-89%: B (+/-)
66-77%: C (+/-)
56-65%: D (+/-)
55% or less: F

Approximate Course Schedule

Date	Topic (approximate)	Reading
1/25	Introduction; Historical context	
1/27	Detection techniques: transits I	arXiv:1001.2010 (Winn)
2/1	Detection techniques: transits II	
2/3	Detection techniques: radial velocities I	Lovis & Fischer handout
2/8	Detection techniques: radial velocities II	
2/10	Combined inferences from transits & RVs; Transit timing	arXiv:1706.09849 (Agol & Fabrycky)
2/15	Detection techniques: astrometry	Perryman Exoplanet Handbook Ch 3 (handout)
2/17	Detection techniques: microlensing; ***Group Project #1 due***	arXiv:1002.0332 (Gaudi)
2/22	Detection techniques: direct imaging	Traub & Oppenheimer handout
2/24	Comparison & future of detection techniques	arXiv:1210.2471 (Wright & Gaudi), Sections 1-3
3/1	Exoplanet demographics I	arXiv:2011.04703 (Gaudi et al.)
3/3	Exoplanet demographics II	Choose an occurrence rate paper…
3/8	Planet formation: solar system context; ***Group Project #2 due***	TBD
3/10	Planet formation: protoplanetary & debris disks	arXiv:1509.06382 (Armitage), Sections 1-3
3/15	**Midterm Exam**	
3/17	Planet formation: Formation of terrestrial & gas giant planets	TBD
	**** Spring break ****	
3/29	Orbital evolution	TBD
3/31	Equations of planetary (& stellar) interiors; ***Group Project #3 due***	TBD
4/5	Terrestrial planet interiors	Sotin et al. handout
4/7	Giant planet interiors & evolution	arXiv:0911.3154 (Fortney et al.)

Date	Topic (approximate)	Reading
4/12	Exoplanet atmospheres: basic theory	Seager Exoplanet Atmospheres Ch 9 (handout)
4/14	*No class* (tentative)	
4/19	Exoplanet atmospheres: 1-D structure; ***Group Project #4 due***	
4/21	Exoplanet atmospheres: 3-D structure	Seager Exoplanet Atmospheres Ch 10 (handout)
4/26	Exoplanets atmospheres: observations I	arXiv:1810.04175 (Deming & Sheets)
4/28	Exoplanets atmospheres: observations II	
5/3	Habitability & biosignatures	Meadows & Barnes handout
5/5	The future of exoplanet science	NAS Exoplanet Report (handout)
5/10	Review / catch up; ***Group Project #5 due***	
5/16	**Final Exam: 10:30 AM - 12:30 PM**	