ASTR-, PTYS-450/550 — Spring 2025
The Origin of the Solar System and Other Planetary Systems

This class is scheduled to be taught in the in-person modality.

Meeting time: Tuesday & Thursday 11am–12.15pm

Location for in-person classes: Space Sciences 312

Instructor: Dr. Ilaria Pascucci (ilariapascucci.com)

Office hour: Tue 3-4pm (by appointment)

Course Description

This course will review the physical processes related to the formation and evolution of the protosolar nebula and of protoplanetary disks. In doing that, we will discuss the main stages of planet formation and how different disk conditions impact planetary architectures and planet properties. We will confront theoretical models of disk evolution and planet formation with observations of circumstellar disks, exoplanets, and the planets and minor bodies in our Solar System.

Course Objectives and Topics:

Upon completion of this course, students will know which physical processes shape planetary systems, understand observations of disks and exoplanets, and be able to place the Solar System into context. Topics covered in class include:

– The Solar System vs Discovered Planetary Systems: similarities and differences between the planets in our Solar System and exoplanets
– The Solar Nebula Theory: collapse of rotating clouds, the angular momentum problem, viscously accreting disks, irradiated disks, theoretical vs observed disk properties
– Disk Evolution and Disk Dispersal Mechanisms: viscous evolution, internal and external photoevaporation, disk and stellar winds, planet formation, theoretical vs observed evolutionary pathways
– Condensation and Growth of Solids: predicted and observed timescales for grain growth in the solar nebula and in protoplanetary disks, dust settling, radial drift of solids and the meter-size barrier to form planetesimals
– Main Planet Formation Scenarios: core accretion, disk gravitational instability and pebble accretion, observations testing these scenarios

– Planetary Systems vs Stellar Masses: stellar-mass-dependent disk properties imprinted in planetary architectures and planet properties. Discussion on the potential of forming terrestrial planets in the habitable zone of A- down to M-dwarf stars

Expected Learning Outcomes. All students will be able to:

1. Summarize the key physical processes involved in the formation of rocky and gaseous planets
2. Use those key physical processes to explain the observations of disks and exoplanets
3. Place the planets in our Solar System in the context of extrasolar planets

Graduate students will be also able to:
5. Quantitatively describe how planet formation scales with stellar mass

Pre-requisites: All students enrolled in the astronomy, physics, planetary science, and optical science PhD programs can take this class. Students in other PhD programs should contact the instructor for approval. Undergraduate students who have taken Calculus ("Math 129: Calculus II" or equivalent) and two upper division science classes are also eligible to take this class.

Grades for both graduate and undergraduate students will be based on **class participation (10%)**, **in-class problem sets (20%)** and **two in-class individual exams (a midterm and a final, 35% each)**. This course uses absolute grading.

The correspondence between points scored and course grade for **graduate and undergraduate** students is:
A: ≥ 90% — **B**: 80–89%; **C**: 70–79%; **D**: 60–69%; **E**<60%

Class participation

Although attendance will not be formally taken in this class, class participation will be evaluated through engaging in discussions, asking questions, and in-class problem sets. For **graduate students**, class participation will include an oral presentation about a review chapter related to material discussed in class.

In-class problem sets

In-class problem sets are designed to reinforce key concepts and deepen the students' understanding. They can be completed in collaboration with other students. **Graduate students** are expected to offer guidance to undergraduate students. As in-class problem sets are essential to prepare for the individual exams, students should ensure they fully understand the material. Solutions to the problem sets will be reviewed and discussed in class to address any questions.

Individual exams (graduate vs undergraduate)

There will be a midterm and a final exam covering material discussed in class and in the problem sets. The exams will take place in Space Sciences 312 at the same time for graduate and undergraduate students. **Graduate exams** will include more advanced and quantitative questions than undergraduate exams.

The **midterm exam** is scheduled for Thursday, February 27 (the instructor has verified that there are no religious holidays) between 11am – 12.15pm

The **final exam date** is set by the University of Arizona (see the Office of the Registrar website) for Tuesday, May 13 between 10:30am – 12:30pm.

Makeup Exams

Makeup exams are only allowed for the following reasons and must be taken within 1 week of the exam date:

4. University approved activity (dean's approval required);
5. Religious holidays (you must provide information on the holiday);
6. Medical emergency, for which you can provide a doctor's note;
7. Jury duty.

Preliminary lesson schedule

Week	Date	Topic	Activity
1	Jan 16	Introduction to Course and Syllabus	Lecture
2	Jan 21, 23	Solar System main properties, the snowline, mean molecular weight	Lecture
3	Jan 28, 30	Kepler's laws, basic radiative transfer	Lecture & in-class problem-set
4	Feb 4, 6	Exoplanet detection techniques	Lecture & graduate student presentation on the solar neighborhood
5	Feb 11, 13	Exoplanet properties	Lecture & in-class problem-set
6	Feb 18, 20	Formation of protoplanetary disks	Lecture & graduate student presentation on exoplanet architectures
7	**Feb** 25, **27**	Properties of planet-forming disks (I) and **Midterm on Feb 27**	Lecture & **Midterm** (no religious holidays)
8	March 4, 6	Properties of planet-forming disks (II)	Lecture & in-class problem-set

Week	Date	Topic	Activity
9	March 11,13	No classes – Spring recess	
10	March 18, 20	Midterm review	Lecture & graduate student presentation on initial conditions for star formation
11	March 25, 27	Disk evolution	Lecture & in-class problem-set
12	April 1, 3	Disk dispersal	Lecture & graduate student presentation on disk structures
13	April 8, 10	Planetesimal formation 1	Lecture & in-class problem-set
14	April 15, 17	Planetesimal formation 2/ Terrestrial planet formation 1	Lecture & graduate student presentation on disk kinematics
15	April 22, 24	Terrestrial planet formation 2	Lecture & in-class problem-set
16	April 29, May 1	Giant planet formation	Lecture & graduate student presentation on planet formation theory (in the in the era of ALMA and Kepler)
17	May 6 last day of classes	Review of topics/concepts (students' choice)	
19	**May 13 from 10.30am to 12.30pm**		**Final Exam**

Suggested textbooks:
There are no required textbooks for this class. The following textbooks are suggestions as to where students might look for extra information on the topics covered in class. These books will be put on reserve at the LPL library (Space Sciences 409):

"Accretion Processes in Star Formation" by L. Hartmann (Cambridge Astrophysics)
"Astrophysics of Planet Formation" by P. Armitage (Cambridge University Press)
"Protoplanetary Dust" by D. Apai and D. Lauretta (Cambridge University Press)
"Planetary Sciences" by I. de Pater and J. Lissauer (Cambridge University Press)

Classroom Participation Policy and Attendance: Participating in the course and attending lectures and other course events are vital to the learning process. As such, attendance is required at all lectures and discussion section meetings. If you

anticipate being absent, are unexpectedly absent, or are unable to participate in class activities, please contact me as soon as possible. A student's request for reasonable religious accommodations will be granted, please see http://policy.arizona.edu/human-resources/religious-accommodation-policy for details.

However:
– If you feel sick, or may have been in contact with someone who is infectious, stay home. Except for seeking medical care, avoid contact with others and do not travel.

If you will be missing a course meeting or an assignment deadline, notify me immediately. Non-attendance for any reason does not guarantee an automatic extension of due date or rescheduling of examinations/assessments. If you must miss the equivalent of more than one week of class, you should also contact the Dean of Students Office DOS-deanofstudents@email.arizona.edu to share documentation about the challenges you are facing.

Academic advising: If you have questions about your academic progress this semester, please reach out to your academic advisor (https://advising.arizona.edu/advisors/major). Contact the Advising Resource Center (https://advising.arizona.edu/) for all general advising questions and referral assistance. Call 520-626-8667 or email to advising@.arizona.edu

Life challenges: If you are experiencing unexpected barriers to your success in your courses, please note the Dean of Students Office is a central support resource for all students and may be helpful. The Dean of Students Office can be reached at (520) 621-2057 or DOS-deanofstudents@email.arizona.edu.

Physical and mental-health challenges: If you are facing physical or mental health challenges this semester, please note that Campus Health provides quality medical and mental health care. For medical appointments, call (520) 621-9202. For After Hours care, call (520) 570-7898. For the Counseling & Psych Services (CAPS) 24/7 hotline, call (520) 621-3334.

Nondiscrimination and Anti-harassment Policy

The University of Arizona is committed to creating and maintaining an environment free of discrimination. In support of this commitment, the University prohibits discrimination, including harassment and retaliation, based on a protected classification, including race, color, religion, sex, national origin, age, disability, veteran status, sexual orientation, gender identity, or genetic information. For more information, including how to report a concern, please see: http://policy.arizona.edu/human-resources/nondiscrimination-and-anti-harassment-policy

Code of Academic Integrity

Students are encouraged to share intellectual views and discuss freely the principles and applications of course materials. However, graded work/exercises must be the product of independent effort unless otherwise instructed. The use of generative artificial intelligence (AI) is allowed for learning purposes (but be aware that AI is not trained in the topic of this course!). Note that incorporating any part of an AI-written response in an assignment is not allowed as it will be considered a violation of the Code of Academic Integrity. Students are expected to adhere to the **UA Code of Academic Integrity** as described in the UA General Catalog. **The code clearly states that cheating, fabrication, facilitating academic dishonesty, and plagiarism are prohibited**. **See: https://deanofstudents.arizona.edu/policies/code-academic-integrity for more details including actions that the faculty member of record for the course needs to take if a violation occurs**.

Safety on Campus and in the Classroom

For a list of emergency procedures for all types on incidents, please visit the website of the Critical Incident Response Team (CIRT): https://cirt.arizona.edu/case-emergency/overview

Also watch the video available at https://arizona.sabacloud.com/Saba/Web_spf/NA7P1PRD161/common/learningeventdetail/crtfy000000000003560

University Policies

For other university policies please see:
https://academicaffairs.arizona.edu/syllabus-policies

Students with Disabilities:

If you anticipate barriers related to the format or requirements of this course, please meet with me so that we can discuss ways to ensure your full participation in the course. If you determine that disability-related accommodations are necessary, please register with Disability Resources (621-3268; drc.arizona.edu) and notify me of your eligibility for reasonable accommodations. We can then plan how best to coordinate your accommodations.

Subject to Change Notice

Information contained in the course syllabus, other than the grade and absence policies, may be subject to change with reasonable advance notice, as deemed appropriate by the instructor of this course.

Graduate Student Resources: http://basicneeds.arizona.edu/index.html