Fundamentals of Planetary Science I
Course Syllabus – AST 501

General Information:

- Class Times: M/W/F 11:30 – 12:20 pm
- Location: Eastburn Education Room 151
- Instructor: Prof. Tyler Robinson
    - Email: tyler.robinson@nau.edu
    - Office: Physical Sciences 225 B
    - Office Hours: M/WF 12:20 – 1:00 pm (and by appointment)

Course Pre-Requisites: Students should have graduate standing in Physics, Astronomy, Earth Sciences, or a related field. Familiarity with concepts related to mechanics, thermodynamics, and electricity and magnetism at the advanced undergraduate level are required.

Course Description: Physical and chemical processes that are fundamental to the formation, evolution, and habitability of planetary systems are examined using observations and models of molecular clouds, protoplanetary disks, small solar system bodies, solar system planets, and planets around other stars. Key topics include star and planet formation, protoplanetary disks, reservoirs of small bodies in the solar system, solar system planetary interiors and atmospheres, extra-solar planets, and planetary habitability.

Course Objectives: Students completing this course will gain an in-depth understanding of the physics of planet formation, atmospheric evolution, and habitability. Intuition for these subject areas will be built using both observational and theoretical results. Beyond scientific understanding, this course aims to build students into stronger research professionals. Key skills will be developed through group collaboration, re-creating previously-published results, literature reviews, and giving conference- and colloquium-style presentations.

Textbooks: This course does not require any textbook purchases. Useful references include:

- Armitage, P. J. (2007) *Lecture Notes on the Formation and Early Evolution of Planetary Systems*, arXiv:astro-ph/0701485
- Catling, D. C. and Kasting, J. F. (2017) *Atmospheric Evolution on Inhabited and Lifeless Worlds*, Cambridge Univ. Press
- Chamberlain, J. W. and Hunten, D. M. (1989) *Theory of Planetary Atmospheres* (2nd Ed.), Academic Press
- de Pater, I. and Lissauer, J. J. (2010) *Planetary Sciences* (2nd Ed.), Cambridge Univ. Press
- Petty, G. W. (2006) *A First Course in Atmospheric Radiation* (2nd Ed.), Sundog Publishing
- Pierrehumbert, R.T. (2011) *Principles of Planetary Climate*, Cambridge Univ. Press
- Scharf, C. A. (2008) *Extrasolar Planets and Astrobiology*, University Science Books

Course Topics Outline:

WEEK	DATES	TOPIC
1	Aug 23 - Aug 27	Formation; Star Formation and Protoplanetary Disks
2	Aug 30 - Sep 03	Formation; Solar System Constraints and Disk Evolution
3	Sep 06 - Sep 10	Formation; Formation of Terrestrial Planets
4	Sep 13 - Sep 17	Formation; Formation of Giant Planets
5	Sep 20 - Sep 24	Formation; Small Bodies in the Solar System
6	Sep 27 - Oct 01	Formation; Planetary Migration
7	Oct 04 - Oct 08	Evolution; Atmospheric Chemistry
8	Oct 11 - Oct 15	Evolution; Atmospheric/Interior Structure
9	Oct 18 - Oct 22	Evolution; Atmospheric Escape
10	Oct 25 – Oct 29	Evolution; Primary and Secondary Atmospheres
11	Nov 01 - Nov 05	Evolution/Habitability; Long-Term Evolution and Habitability
12	Nov 08 - Nov 12	Habitability; The Habitable Zone and M Dwarf Habitability
13	Nov 15 - Nov 19	Habitability; Loss of Habitability
14	Nov 22 - Nov 26	Group Project Time (no class Wed & Fri)
15	Nov 29 - Dec 03	Group Presentations

Grading: Overall course grades will be determined using the following weights:

- Problem Sets ………………………………………….. 15%
- Problem Sets (writing)* …………………………… 15%
- Theory Project ……………………………………….. 10%
- Friday Paper Presentation/Discussion ………. 10%
- Friday Paper Reading ………………………………. 5%
- Mandatory Office Hours Visit ………………….. 5%
- Final Presentation* …………………………………. 20%
- Final Review Paper* ……………………………….. 20%

Items marked with an '*' are accomplished within small groups, and will be weighted by peer feedback on your level of engagement and collaboration.

Final letter grades will be assigned according to:

A = 90 – 100 : B = 80 – 89 : C = 70 – 79 : D = 60 – 69 : F = 0 – 59

Student grades may be scaled up (but never down) based on overall class performance.

Course Policies: Collaboration with peers on assignments is encouraged. Credit should be given to all collaborators, either through co-authorship or by citing personal communications. Plagiarism in written work will be not be tolerated, resulting in a failing grade for the assignment and, potentially, referral to the University. See policy.nau.edu/policy/policy.aspx?num=100601 for NAU's policies on academic integrity. Late work may be accepted at the instructor's discretion. Please contact me as early as possible if you learn you will miss a due date or presentation.

Key Due Dates:

DATE	ITEM
SEP 23	Group-written problem #1
SEP 27	Select theory paper
OCT 04	Pitch review paper topic
OCT 08	First problem set due
NOV 04	Group-written problem #2
NOV 12	Theory project due
NOV 15	Review paper outline due
NOV 19	Second problem set due
NOV 29 – DEC 03	Group presentations
DEC 06	Group review paper due

Group-Written Problems: Two homework problems will be designed by you and your group partners. These will fall under the general themes of planetary system formation, planetary evolution, and habitability. Your group is free to decide the specific sub-topic addressed by your problem. The goal for writing these problems within your group is to build a strong understanding of the particular sub-topic. The collection of homework problems designed by all groups, once vetted by the instructor, will be ranked by the class. The top three ranked homework problems will be assigned to the class as a problem set. Thus, problems should be written to help your classmates understand a new subject area. Problems most likely to pass vetting will be multi-part, will include physics-based theory and/or observational data, and will include an opportunity to synthesize new ideas into an understanding of the broad topics covered in this course. Along with the question, a separate answer key must be provided to the instructor.

Theory Project: "Pen and paper" theory is accessible to all advanced students and scientists. To prove this point, and to demonstrate reproducibility in the research process, students are expected to find a theory paper on any sub-topic of interest within the areas of planet formation, planetary evolution, and habitability. Once the selected paper is vetted by the instructor, the student will read the paper, reproduce (in a theory-based write-up) the key working expression from the paper, and will also re-create a key figure/plot from the paper.

Paper Presentations: Each week (roughly) we will read a recent paper from the fields of planet formation, planetary evolution, and habitability. Each student is expected to select one of these papers (ideally from high-impact journals like *Nature*, *Science*, or *PNAS*) to give a 10-minute conference-style presentation on that manuscript. The student will also field questions from the audience. Following the presentation and Q&A, the entire class will discuss the paper.

Paper Reading: To encourage students to read papers in advance of the weekly student presentations, each student must show (either in person or via email) a marked-up version of every weekly paper. Also, each student must bring (on a slip of paper, with your name) one question they have regarding the paper or its findings to each class when a presentation occurs.

Mandatory Office Hour Visit: Students are expected to attend at least one office hours session. This visit (around late September) will be to discuss the paper selected for the "theory project."

Final Projects: Students, working in their small groups, will select a topic of interest related to planet formation, planetary evolution, and habitability. The selected topic will be pitched to the class in a brief presentation (no slides) on Oct 4. Students will perform a literature review on this topic, and will produce a (minimum) 15-page (double-spaced, not including figures or references) review paper on the topic. This material will then be distilled into a 20-minuted colloquium-style review talk given to the class at the end of the semester.

A few ideas for topics include:

- The Nice Model: Successes and Challenges
- *Kepler* and Exoplanet Systems
- Reservoirs of Small Bodies in the Solar System and their Origins
- Origin of Earth's Oceans
- A History of the Atmospheres of Earth, Venus, and/or Mars
- Atmospheric Chemistry of Jupiter: Origin and Composition of Chromophores
- The Cosmic Shoreline: Atmospheric Retention in the Solar System and Beyond
- Atmospheric Loss and Evolution of Mars: Results from *MAVEN*
- Gaia Theory and the Co-Evolution of Earth and Life
- Habitability in the TRAPPIST-1 Planetary System

Feedback: Unsolicited feedback, either positive or negative, is welcome at any time. I want students to feel safe and secure in my classroom. Additionally, students should feel confident in the material they are being taught and shouldn't feel over-burdened by course requirements. If you are ever feeling concerned, please either: (1) speak to me in person, (2) send me an email, or (3) send me anonymous comments at bit.ly/2wR1aU6.