SYLLABUS – Spring 2023 – PTYS 595B – Planetary Collisions

Instructor Information

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Office hours – Drake 114H or phone or zoom, by appointment

Course Description

This is a one-semester graduate-level lecture-discussion course about collisions and how they shape the formation and evolution of planets, from the original pile-ups of pebbles to the giant impacts that created the Earth and Moon. These formation hierarchies and events, and the subsequent pummeling by objects of all sizes, are governed by basic physics that are the subject of the lecture half of the course: The size and velocity distribution, from dust to similar-sized bodies at mm to km per second. Gravitational potential, multi-body effects and angular momentum. Impact cratering and its associated geology and potential for astrobiology. Material strength, porosity, temperature, and equation of state. Irreversible material responses under intense loads and rates. These are topics of astrophysics and geophysics, and centuries of laboratory physics and space exploration, so there will be an ongoing introduction to the history of these ideas.

Course Prerequisites or Co-requisites

Students must be in good standing in PTYS, ASTR, GEO, AME or a related science or engineering graduate program. Senior undergraduates may enroll if approval is granted by the instructor.

Course Format and Teaching Methods

This course will be live in person. The first 6 weeks will be mostly lectures, then an interruption (LPL Field Trip and LPSC Conference). The next 8 weeks will be mostly student-led discussions, on the topic of their final project, with the occasional lecture by the instructor. The course website is at http://d2l.arizona.edu/d2l/home/1273109.

Course Objectives

The objective is to provide a foundational understanding of the role celestial collisions play in planet formation and evolution. This requires a basic knowledge of diverse processes at many scales, so students will be introduced to the topic from the perspectives of geophysics, astrophysics, field research, laboratory studies, and exploration.

Expected Learning Outcomes

Upon completion of this course, students will be able to describe the physics of plantetary collisions and the historical development of these ideas from the 1500s to the present. Students will identify and summarize some of the major early papers on this topic and the role those papers played in the relatively new science of planet formation and astrobiology. Students will be able to describe the controversies in the modern literature and will demonstrate their knowledge by delivering a short lecture on a quantitative topic and by guiding scientific discussions.

Required Texts and Materials

Required: Melosh, *Impact Cratering: A Geologic Process* (1989). A copy is on reserve in the LPL Library.

Recommended: de Pater and Lissauer, *Planetary Science* (2015), available for free download at http://new.library.arizona.edu/.

Other reading materials will be available on the d2l website.

Schedule of Topics and Activities

Specific readings and lecture topics are subject to revision. Make-up activities will be coordinated to account for conference/field trip dates.

- Week 1 Discussion of syllabus; current events; project topic ideas and interests
  Readings: Shoemaker (1963); Melosh 1 & 2
- Week 2 Lecture: Planet formation; hierarchies of growth
- Week 3 Lecture: from Shockology notes
  Readings: Armstrong et al. "Rummaging…" (2002); Melosh 3
- Week 4 Lecture: Shockology continued; elastic solids, fragmentation and friction; seismic effects
  Reading: Melosh 5 & 7
- Week 5 Lecture: Scaling of crater dimensions and disruptions
  Reading: Asphaug "Global Scale Impacts"; TBD
- Week 6 Lecture: Impact structures on the Moon and planets
- Week 7 LPL Graduate Student Field Trip – NO CLASS
- Week 8 LPSC Conference – Class tag-ups via zoom
- Week 9 Lecture: Giant impacts and planetary dynamics
- Week 10 Lecture: Collisions in other planetary systems
- Week 11 Student-led discussions
- Week 12 Student-led discussions
- Week 13 Student-led discussions
- Week 14 Student-led discussions
- Week 15 Lecture: upcoming spacecraft missions – Psyche and Hera

Assessments

Final Project

Beginning in week 8 students will take turns leading a discussion on their topic, and will then submit a short research paper. Topics can be anything closely relevant to the study of planet-forming collisions at any scale. You can review a topic in depth, or can present your original research. If you try something new, you certainly won't be penalized for naivete and we would all learn something. If you present your thesis research, that is fine, but the expectation will be proportional.

Examples include:

- Hemispheric-scale collisions and geophysical consequences
- Shock thermodynamics of rocks, ices and/or oceans
- Impact research facilities, technologies and capabilities
- Weapons programs; e.g. a research summary of Rodionov et al. 1963 "peaceful purposes"
- Collisional formation of asteroid families and delivery of meteorites
- Does pebble accretion allow giant impacts?
- Angular momentum evolution during a collision
- Ostwald or 'late stage' ripening and other statistics of population growth
- Martian moons formation and evolution
- Signatures of giant impacts on various bodies
- Collisional processes recorded in meteorites
- Shock levels in iron meteorites
- Kuiper Belt collisions
- Numerical methods of computational hydrodynamics
- Impacting space missions (e.g. Ranger/Apollo, Deep Impact, LCROSS, Hayabusa2, DART)
- Microphysics of particle coalescence in the nebula
- Lunar or terrestrial impact basins
- Impact hazards to spacecraft and habitation modules
- Mixing, or not, in collisions (instability analysis)
- The Late Veneer and the Late Heavy Bombardment

The project will have the following components for a total of 65% of the course grade:

• 2x20% – Leadership of two 1-hour discussions, where the student is responsible for providing the relevant reading(s) and a brief summary of each, <u>at least five days in advance</u> of the discussion, and for delivering a <u>short topical lecture</u> to the class at the start of each discussion. Assessment is based on the student's preparation for and management of their discussions, the rigor of the scientific approach, the quantitative basis of the analysis, the completeness of the presented background materials, and the student's ability to field questions about their topic.

• 25% – A <u>short research paper due on the last day of class</u> that includes: a summary of the scientific topical background (3 pages), a narrative of what you learned or concluded from the discussion sessions you led (1-2 pages), and the most relevant citations (1 page).

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.

University Policies

All university policies related to a syllabus are available at: https://academicaffairs.arizona.edu/syllabus-policies.

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

Further graduate student resources may be found here: http://basicneeds.arizona.edu/index.html.