Annexe A: New/Revised Course Content in OBTL+ Format

Course Overview

Expected Implementation in Academic Year (New format)	AY2026-2027
Semester/Trimester/Others (specify approx. Start/End date)	Semester 2
Course Author * Faculty proposing/revising the course	Leek Meng Lee
Course Author Email	mlleek@ntu.edu.sg
Course Title	Planetary Astrophysics
Course Code	PH3413
Academic Units	3
Contact Hours	39
Research Experience Components	Not Applicable

Course Requisites (if applicable)

Pre-requisites	PH2401
Co-requisites	
Pre-requisite to	
Mutually exclusive to	
Replacement course to	
Remarks (if any)	

Course Aims

This course aims to follow up on PH2401 Introductory Astrophysics and go deeper into planetary astrophysics. You will apply principles of physics, chemistry, and mathematics to explain the origin and evolution of the Solar System. You will also evaluate the conditions and processes that make planetary environments habitable. You will also distinguish between different scientific approaches in identifying and characterizing of exoplanets.

Course's Intended Learning Outcomes (ILOs)

Upon the successful completion of this course, you (student) would be able to:

ILO 1	Apply knowledge of physics, chemistry, and mathematics such as gravity, kinetics, and composition to explain the origin and evolution of the solar system.
ILO 2	Differentiate between the physical characteristics and processes of terrestrial planets and gas giants.
ILO 3	Explain the differences in surface and sub-surface planetary geology for Venus, Moon, Mars and the icy satellites.
ILO 4	Define the properties and processes that makes a world habitable.
ILO 5	Relate the type of science (modeling surface processes vs identifying objects) to observational methods (modern robotics studies of the solar system vs remote telescopic observations of exoplanet systems)

Course Content

The course has 4 main parts:

- Origins: How do you form a solar system and make planets?
- Planetary geology: Terrestrial Planets
- Gas Giants: Atmosphere, structure and composition
- Searching for other worlds and life: Exoplanets

Reading and References (if applicable)

- "Planetary Sciences" Imke de Pater and Jack J. Lissauer, Cambridge University Press
- "An Introduction to the Solar System" David A. Rothery, Cambridge University Press
- "Exoplanet Atmospheres: Physical Processes" Sara Seager, Princeton University Press
- "Planetary Surface Processes" H. Jay Melosh, Cambridge University Press
- "Planetary Science and Astrobiology Decadal Survey 2023-2032" National Academies https://www.nationalacademies.org/projects/DEPS-SSB-19-17/publication/27209
- Cui, Z. et al. (2024) "A sample of the Moon's far side retrieved by Chang'e-6 contains 2.83-billion-year-old basalt" *Science* 386, 1395-1399.
- Kane, S.R. et al. (2019) "Venus as a Laboratory for Exoplanetary Science" *JGR Planets* 124, 2015-2028.
- Kite, E.S. et al. (2025) "Carbonate formation and fluctuating habitability on Mars" *Nature* 643, 60-66.
- Reynolds, R.T. et al. (1983) "On the habitability of Europa", *Icarus* 56, 246-254.
- Marcy, G.W. et al. (1997) "The Planet around 51 Pegasi", *The Astrophysical Journal* 481, 926.
- JWST Transiting Exoplanet Community Early Release Science Team (2023) "Identification of carbon dioxide in an exoplanet atmosphere", *Nature* 614, 649-652.
- Cockell, C.S. et al. (2024) "Sustained and comparative habitability beyond Earth", *Nature Astronomy* 8, 30-38.

Planned Schedule

Week or Session	Topics or Themes	ILO	Delivery Mode	Activities	Readings
1	Formation and evolution of solar system	1	In-person	In-class activity (pre-test): Sketch the general architecture of the solar system today and explore the varying degrees of details made in each sketch (e.g., presence/absence of asteroid belt, Kuiper belt, Jupiter moons)	Rothery Ch 2.3 Lissauer & de Pater Ch 15.3-15.8
2	Investigating small bodies and meteorites to understand the solar system history	1	In-person	In-class activity: Examine meteorite samples	Rothery Ch 2.4, 9.2
3	Planetary missions to study the solar system planets	5	In-person	In-class activity: Explore NASA eyes on the solar system website and present about your favorite past/current/future missions	Decadal survey Ch 3
4	Volcanism and weathering processes	2, 3	In-person	In-class activity: Gather photos/videos of various types of volcanoes on Earth to compare with volcanoes on Mars and Io	Melosh Ch 5
5	Mercury, Moon, Vesta	1, 2, 3	In-person	In-class activity: Compile locations where there are planned commercial lunar missions. What is so significant about these places?	Decadal survey Ch 2 Cui, Z. et al. (2024) “A sample of the Moon’s far side retrieved by Chang’e-6 contains 2.83-billion-year-old basalt” Science 386, 1395-1399.

Week or Session	Topics or Themes	ILO	Delivery Mode	Activities	Readings
6	Venus	2, 3, 4	In-person	In-class activity: Calculate the runaway greenhouse effect on Venus to understand how Venus became unhabitable.	Decadal survey Ch 2 Optional: Kane, S.R. et al. (2019) "Venus as a Laboratory for Exoplanetary Science" JGR Planets 124, 2015-2028.
7	Mars	2, 3, 4	In-person	Guest lecture from online In-class activity: Watch 7 minutes of terror video and calculate the light travel time between Earth and various planets that have missions to and fro.	Decadal survey Ch 2, 12 Optional: Kite, E.S. et al. (2025) "Carbonate formation and fluctuating habitability on Mars" Nature 643, 60-66.
8	Jupiter and Saturn	1, 2	In-person	Lecture	Decadal survey Ch 2, 10 Lissauer and De Pater Ch 3.2, 3.3 Rothery Ch 6
9	The Galilean moons of the Jupiter system	2, 3, 4	In-person	In-class activity: Compare the images from Voyager, Galileo and Juno of the same objects e.g., Io. What kinds of new science questions can we ask when we see higher resolution images?	Decadal survey Ch 2 Optional: Reynolds, R.T. et al. (1983) "On the habitability of Europa", Icarus 56, 246-254.
10	Exoplanet detections and characterization	5	In-person	Paper discussion: Marcy, G.W. et al. (1997) "The Planet around 51 Pegasi", The Astrophysical Journal 481, 926.	

Week or Session	Topics or Themes	ILO	Delivery Mode	Activities	Readings
11	Exoplanet atmosphere: structure and evolution	2, 5	In-person	Lecture	Seager Ch 2, 3, 4
12	Exoplanet spectroscopy	5	In-person	Guest lecture online	JWST Transiting Exoplanet Community Early Release Science Team (2023) "Identification of carbon dioxide in an exoplanet atmosphere", Nature 614, 649-652.
13	Habitability and the search for life	4	In-person	In-class activity/final presentation project: Create a plan for detecting life outside of Earth (e.g., what bodies will you look at, what instruments will you use, what are the habitability indicators)	Seager Ch 11 Cockell, C.S. et al. (2024) "Sustained and comparative habitability beyond Earth", Nature Astronomy 8, 30-38.

Learning and Teaching Approach

Approach	How does this approach support you in achieving the learning outcomes?
Lectures	Warm-up questions will be raised first, followed by lectures that further explain the physics based on the questions. Then wrap-up questions will also be provided. In-class activities will allow you to discover and understand concepts by yourselves with guidance.
Tutorials	You will review main concepts learned in lectures by doing tutorial questions. This helps you to digest and understand better the concepts learnt.
Homework	These will encourage you to apply what you have learnt and promote deeper understanding. You will also develop the competence and perseverance in solving physics problems. You will also look up readings to aid in solving the problems and broaden your knowledge by going through the readings.

Assessment Structure

Assessment Components (includes both continuous and summative assessment)

No.	Component	ILO	Related PLO or Accreditation	Weightage	Description of Assessment Component	Team/Individual	Rubrics	Level of Understanding
1	Continuous Assessment (CA): Class Participation(The in-class activities involve you to prepare before a lecture and your findings are shared during lecture to help with understanding the concepts to be taught during the lecture in that week.)	1, 2, 3, 4, 5		10		Individual	Analytic	Relational
2	Continuous Assessment (CA): Assignment(This component is made up of several sets of written homework where you will work on problems that enforce and enhance your understanding.)	1, 2, 3, 4, 5		15		Individual	Analytic	Relational
3	Continuous Assessment (CA): Test/Quiz(This component is a written test to access your understanding of the first part of the course.)	1, 2, 3		15		Individual	Analytic	Relational
4	Continuous Assessment (CA): Test/Quiz(This component is a written test to access your understanding of the second part of the course.)	4, 5		20		Individual	Analytic	Relational

No.	Component	ILO	Related PLO or Accreditation	Weightage	Description of Assessment Component	Team/Individual	Rubrics	Level of Understanding
5	Continuous Assessment (CA): Final exam(This is a 2hr written paper assessing your understanding of the entire course.)	All		40		Individual	Analytic	Relational

Description of Assessment Components (if applicable)

Formative Feedback

Formative feedback is given through discussions within tutorial lessons, after the midterms, and an examiner's report for the final exam.

NTU Graduate Attributes/Competency Mapping

This course intends to develop the following graduate attributes and competencies (maximum 5 most relevant)

Attributes/Competency	Level
Curiosity	Basic
Problem Solving	Intermediate
Sense Making	Basic

Course Policy

Policy (Academic Integrity)

Good academic work depends on honesty and ethical behaviour. The quality of your work as a student relies on adhering to the principles of academic integrity and to the NTU Honour Code, a set of values shared by the whole university community. Truth, Trust and Justice are at the core of NTU's shared values. As a student, it is important that you recognize your responsibilities in understanding and applying the principles of academic integrity in all the work you do at NTU. Not knowing what is involved in maintaining academic integrity does not excuse academic dishonesty. You need to actively equip yourself with strategies to avoid all forms of academic dishonesty, including plagiarism, academic fraud, collusion and cheating. If you are uncertain of the definitions of any of these terms, you should go to the academic integrity website for more information. On the use of technological tools (such as Generative AI tools), different courses / assignments have different intended learning outcomes. Students should refer to the specific assignment instructions on their use and requirements and/or consult your instructors on how you can use these tools to help your learning. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

Policy (General)

You are expected to complete all assigned readings, activities, assignments, attend all classes punctually and complete all scheduled assignments by due dates. You are expected to take responsibility to follow up with assignments and course related announcements. You are expected to participate in all project critiques, class discussions and activities.

Policy (Absenteeism)

In-class activities make up a significant portion of your course grade. Absence from class without a valid reason will affect your participation grade. Valid reasons include falling sick supported by a medical certificate and participation in NTU's approved activities supported by an excuse letter from the relevant bodies. There will be no make-up opportunities for in-class activities.

Policy (Others, if applicable)

Diversity and inclusion policy

Integrating a diverse set of experiences is important for a more comprehensive understanding of science.

It is our goal to create an inclusive and collaborative learning environment that supports a diversity of perspectives and learning experiences, and that honours your identities; including ethnicity, gender, socioeconomic status, sexual orientation, religion or ability.

To help accomplish this:
- If you are neuroatypical or neurodiverse, have dyslexia or ADHD (for example), or have a social anxiety disorder or social phobia;
- If you feel like your performance in the class is being impacted by your experiences outside of class;
- If something was said in class (by anyone, including the instructor) that made you feel uncomfortable;

Please speak to your teaching team, our school pastoral ofcer or a peer or senior (either in-person or via email)

about how we can help facilitate your learning experience.

As a participant in course discussions, you should also strive to honour the diversity of your classmates. You can do this by: using preferred pronouns and names; being respectful of others opinions and actively making sure all voices are being heard; and refraining from the use of derogatory or demeaning speech or actions.

All members of the class are expected to adhere to the NTU anti-harassment policy. if you witness something that goes against this or have any other concerns, please speak to your instructors or a faculty member.

Technical Skills To Be Developed

All skills to be developed for this course:

Physics Concepts Application
Analysis of Research Data
Data Analytics and Computational Modelling
Data and Statistical Analysis

Appendix 1: Assessment Criteria for Homework/ Assignments

Each homework assignment consists of a variety of questions relevant to the lecture content. They will be mostly technical questions designed to assist students assimilate various concepts presented in lectures. There will also be a few short reading assignments designed to invite students to critically respond to technical articles written by planetary astrophysicists. The mark percentages for each question will be indicated and the points given to each question will be based not only on the precision of the final answer but also on the validity of the approach.

By mark range

Marks	Criteria
> 90%	Demonstrates very complete understanding of the various conceptual and technical aspects of planetary astrophysics; be able to solve relevant questions reflecting understanding of the topic at the level of being able to apply and process large data sets in planetary astrophysics (as described in the intended learning outcomes)
75% to 89%	Demonstrates ability to solve a variety of questions in planetary astrophysics and a sound awareness of data processing. In other words, you have demonstrated the achievement of the learning outcomes in a comprehensive way.
65% to 74%	Able to solve most elementary questions with partially consistent and valid attempts in applying course content to unfamiliar questions. In other words, you have demonstrated the potential to achieve the learning outcomes in time.
50% to 64%	Able to solve only the most basic questions relevant to the course content. Has difficulty in applying ideas to new contexts. Lack of clarity in physical interpretations. In other words, you have demonstrated an achievement of some of the learning outcomes and have some way to go with the others.
< 50%	Unable to solve most basic questions relevant to the course content, and lack of basic mathematical and data analytical techniques to apply concepts presented in lectures to new data sets and problems.

Appendix 2: Assessment Criteria for Midterm Tests

Two midterm tests each planned to be 90 minutes, consisting of questions similar in rigor and style to tutorial questions, and the range of questions to appropriately reflect the content coverage of the lectures. Point-based marking will be used to grade the midterm tests.

Appendix 3: Assessment Criteria for Final Exam

The final exam has a duration of 2 hours, consisting of questions similar in rigor and style to tutorial questions, and the questions covers the entire range of learning outcomes with varying levels of difficulties. Point-based marking will be used to grade the final exam.