Lecturing at the ISU SSP

Rice University, June 2024

Elizabeth Tasker (ISAS/JAXA)

Elizabeth Tasker

Astrophysicist & science communicator

Based at ISAS since 2016
(Department of Solar System Science)

Research field: extrasolar planets

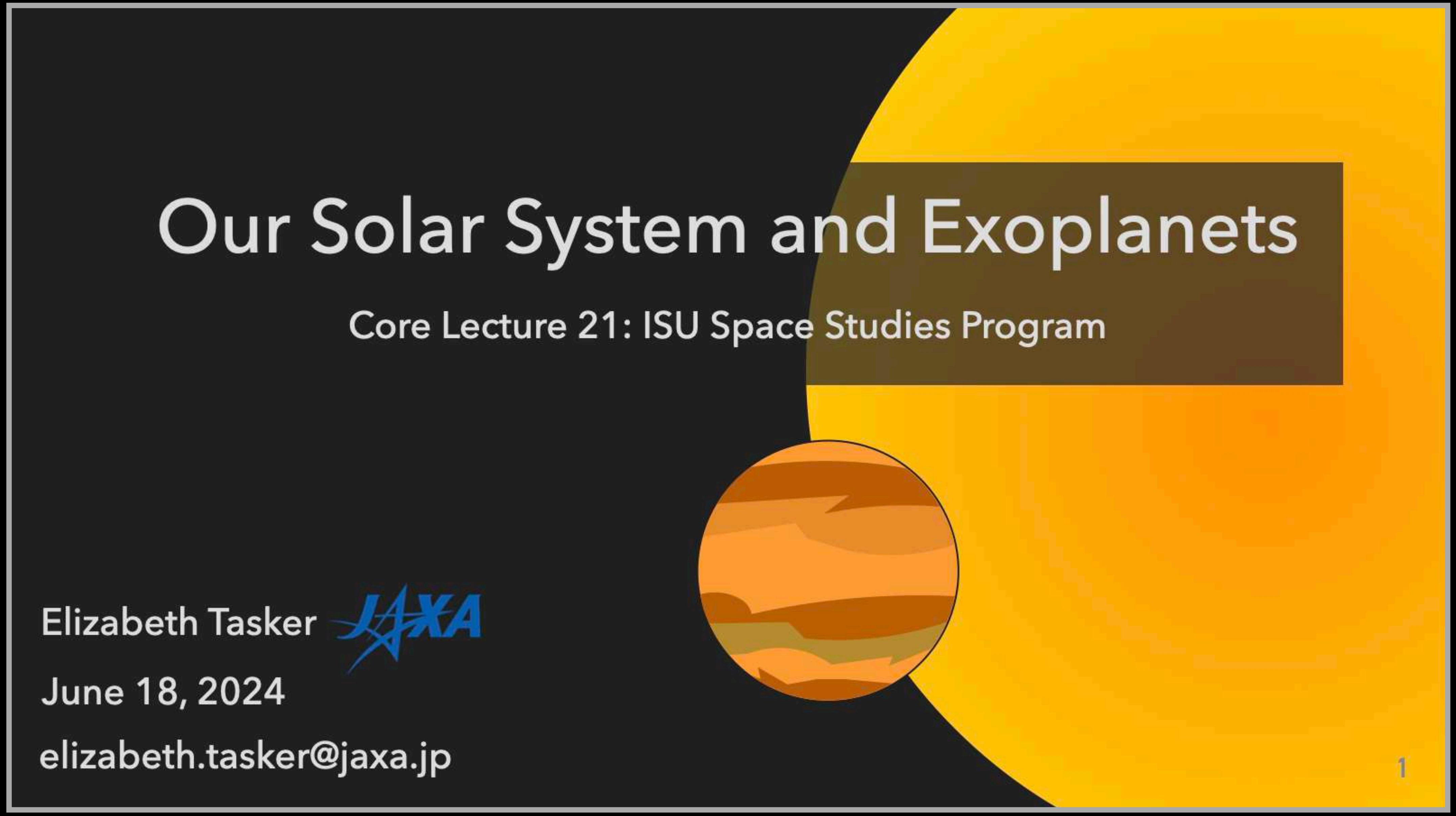
International outreach team for ISAS, and
Hayabusa2 and MMX missions

Whose idea was it…

… to hold the ISU SSP in Houston in June?

(Hurricane 🌀 season)

What was I asked to do?



Give two science lectures with the titles:

"Our Solar System and Exoplanets"

"Moon and Mars"

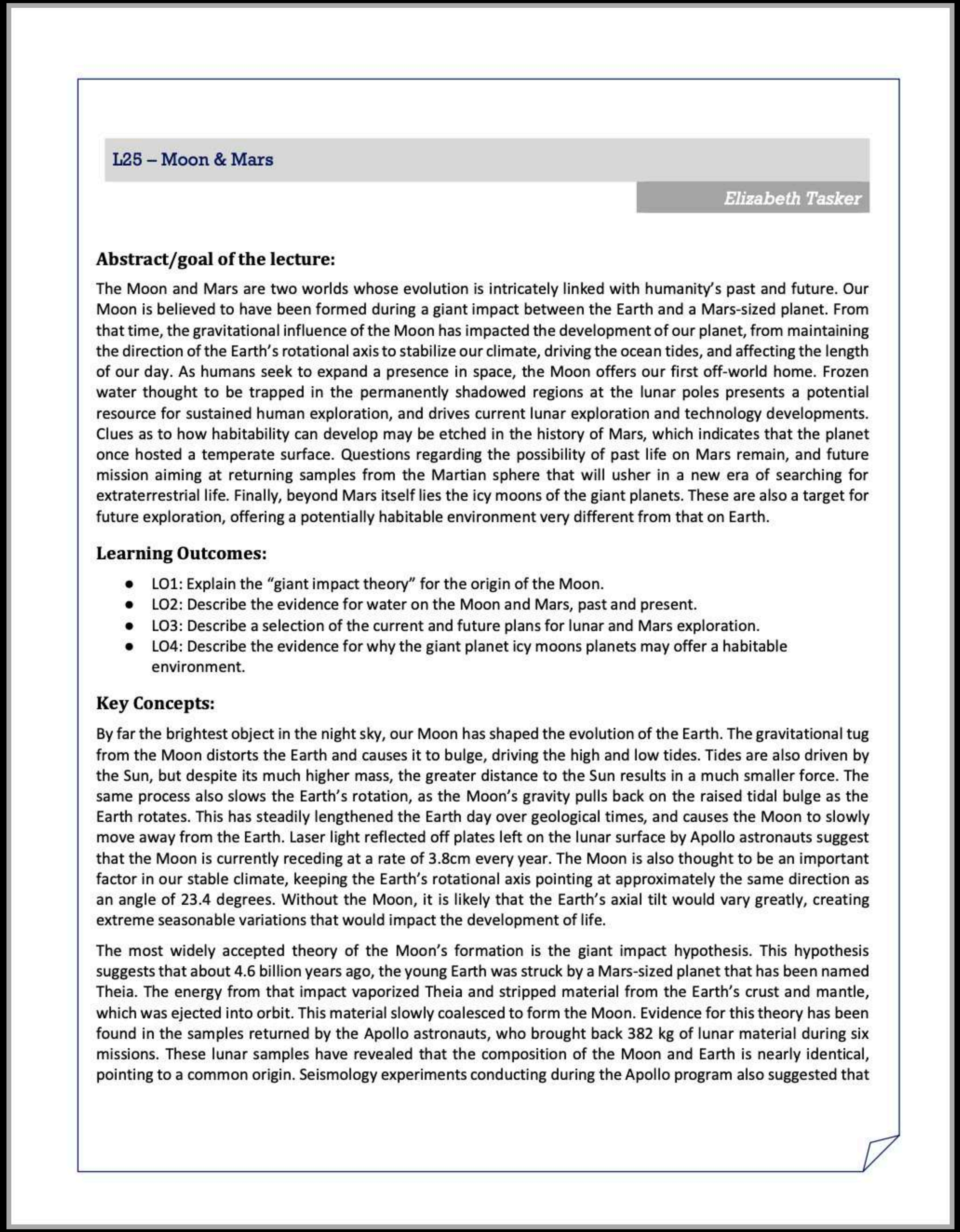
Guidelines:

Accessible and understandable to non-experts and non-native English speakers

50 minute lecture + 10 minute Q&A

Submit slides ~1 month in advance

What was I asked to do?



L25 – Moon & Mars

Elizabeth Tasker

Abstract/goal of the lecture:

The Moon and Mars are two worlds whose evolution is intricately linked with humanity's past and future. Our Moon is believed to have been formed during a giant impact between the Earth and a Mars-sized planet. From that time, the gravitational influence of the Moon has impacted the development of our planet, from maintaining the direction of the Earth's rotational axis to stabilize our climate, driving the ocean tides, and affecting the length of our day. As humans seek to expand a presence in space, the Moon offers our first off-world home. Frozen water thought to be trapped in the permanently shadowed regions at the lunar poles presents a potential resource for sustained human exploration, and drives current lunar exploration and technology developments. Clues as to how habitability can develop may be etched in the history of Mars, which indicates that the planet once hosted a temperate surface. Questions regarding the possibility of past life on Mars remain, and future mission aiming at returning samples from the Martian sphere that will usher in a new era of searching for extraterrestrial life. Finally, beyond Mars itself lies the icy moons of the giant planets. These are also a target for future exploration, offering a potentially habitable environment very different from that on Earth.

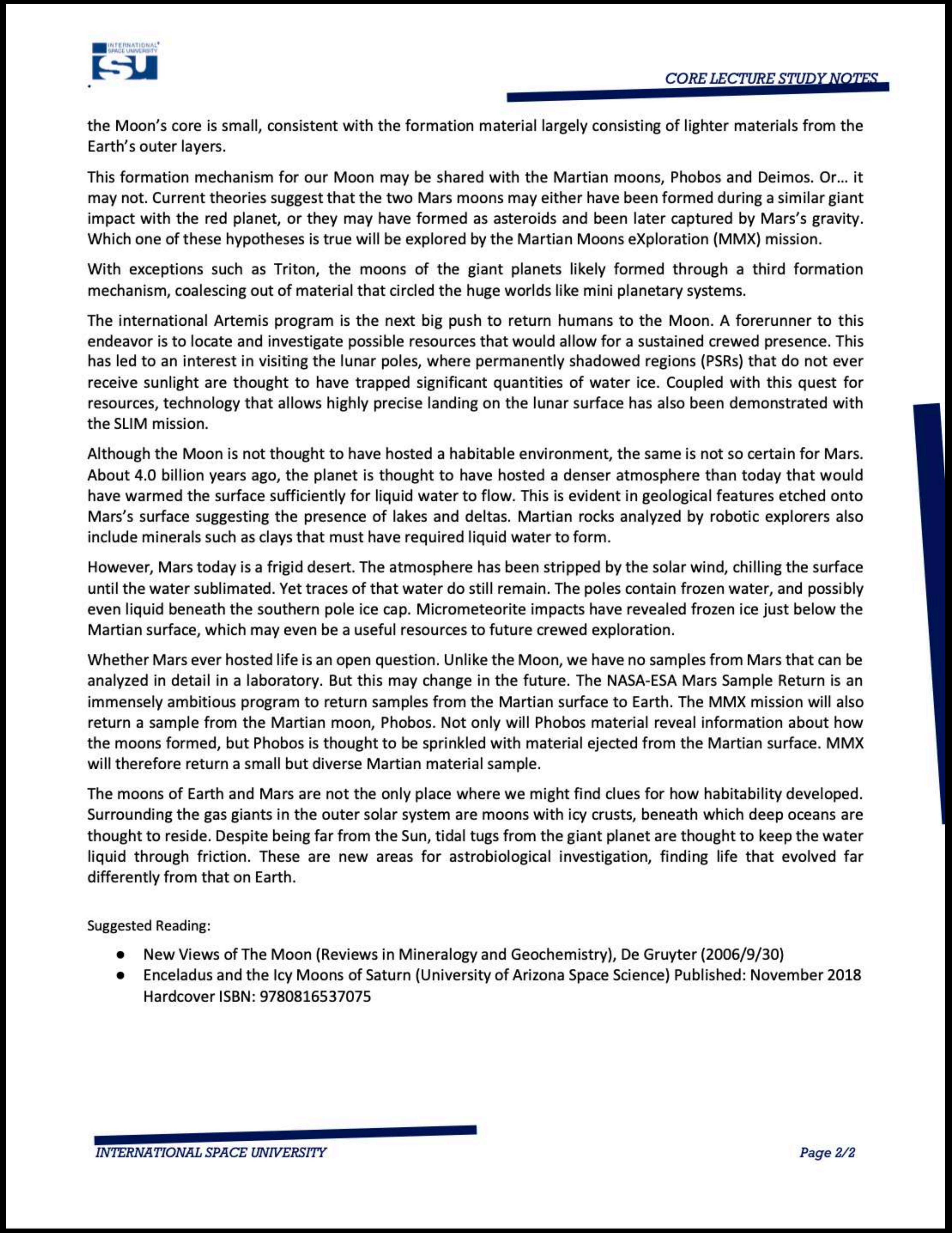
Learning Outcomes:

- LO1: Explain the "giant impact theory" for the origin of the Moon.
- LO2: Describe the evidence for water on the Moon and Mars, past and present.
- LO3: Describe a selection of the current and future plans for lunar and Mars exploration.
- LO4: Describe the evidence for why the giant planet icy moons planets may offer a habitable environment.

Key Concepts:

By far the brightest object in the night sky, our Moon has shaped the evolution of the Earth. The gravitational tug from the Moon distorts the Earth and causes it to bulge, driving the high and low tides. Tides are also driven by the Sun, but despite its much higher mass, the greater distance to the Sun results in a much smaller force. The same process also slows the Earth's rotation, as the Moon's gravity pulls back on the raised tidal bulge as the Earth rotates. This has steadily lengthened the Earth day over geological times, and causes the Moon to slowly move away from the Earth. Laser light reflected off plates left on the lunar surface by Apollo astronauts suggest that the Moon is currently receding at a rate of 3.8cm every year. The Moon is also thought to be an important factor in our stable climate, keeping the Earth's rotational axis pointing at approximately the same direction as an angle of 23.4 degrees. Without the Moon, it is likely that the Earth's axial tilt would vary greatly, creating extreme seasonable variations that would impact the development of life.

The most widely accepted theory of the Moon's formation is the giant impact hypothesis. This hypothesis suggests that about 4.6 billion years ago, the young Earth was struck by a Mars-sized planet that has been named Theia. The energy from that impact vaporized Theia and stripped material from the Earth's crust and mantle, which was ejected into orbit. This material slowly coalesced to form the Moon. Evidence for this theory has been found in the samples returned by the Apollo astronauts, who brought back 382 kg of lunar material during six missions. These lunar samples have revealed that the composition of the Moon and Earth is nearly identical, pointing to a common origin. Seismology experiments conducting during the Apollo program also suggested that



the Moon's core is small, consistent with the formation material largely consisting of lighter materials from the Earth's outer layers.

This formation mechanism for our Moon may be shared with the Martian moons, Phobos and Deimos. Or… it may not. Current theories suggest that the two Mars moons may either have been formed during a similar giant impact with the red planet, or they may have formed as asteroids and been later captured by Mars's gravity. Which one of these hypotheses is true will be explored by the Martian Moons eXploration (MMX) mission.

With exceptions such as Triton, the moons of the giant planets likely formed through a third formation mechanism, coalescing out of material that circled the huge worlds like mini planetary systems.

The international Artemis program is the next big push to return humans to the Moon. A forerunner to this endeavor is to locate and investigate possible resources that would allow for a sustained crewed presence. This has led to an interest in visiting the lunar poles, where permanently shadowed regions (PSRs) that do not ever receive sunlight are thought to have trapped significant quantities of water ice. Coupled with this quest for resources, technology that allows highly precise landing on the lunar surface has also been demonstrated with the SLIM mission.

Although the Moon is not thought to have hosted a habitable environment, the same is not so certain for Mars. About 4.0 billion years ago, the planet is thought to have hosted a denser atmosphere than today that would have warmed the surface sufficiently for liquid water to flow. This is evident in geological features etched onto Mars's surface suggesting the presence of lakes and deltas. Martian rocks analyzed by robotic explorers also include minerals such as clays that must have required liquid water to form.

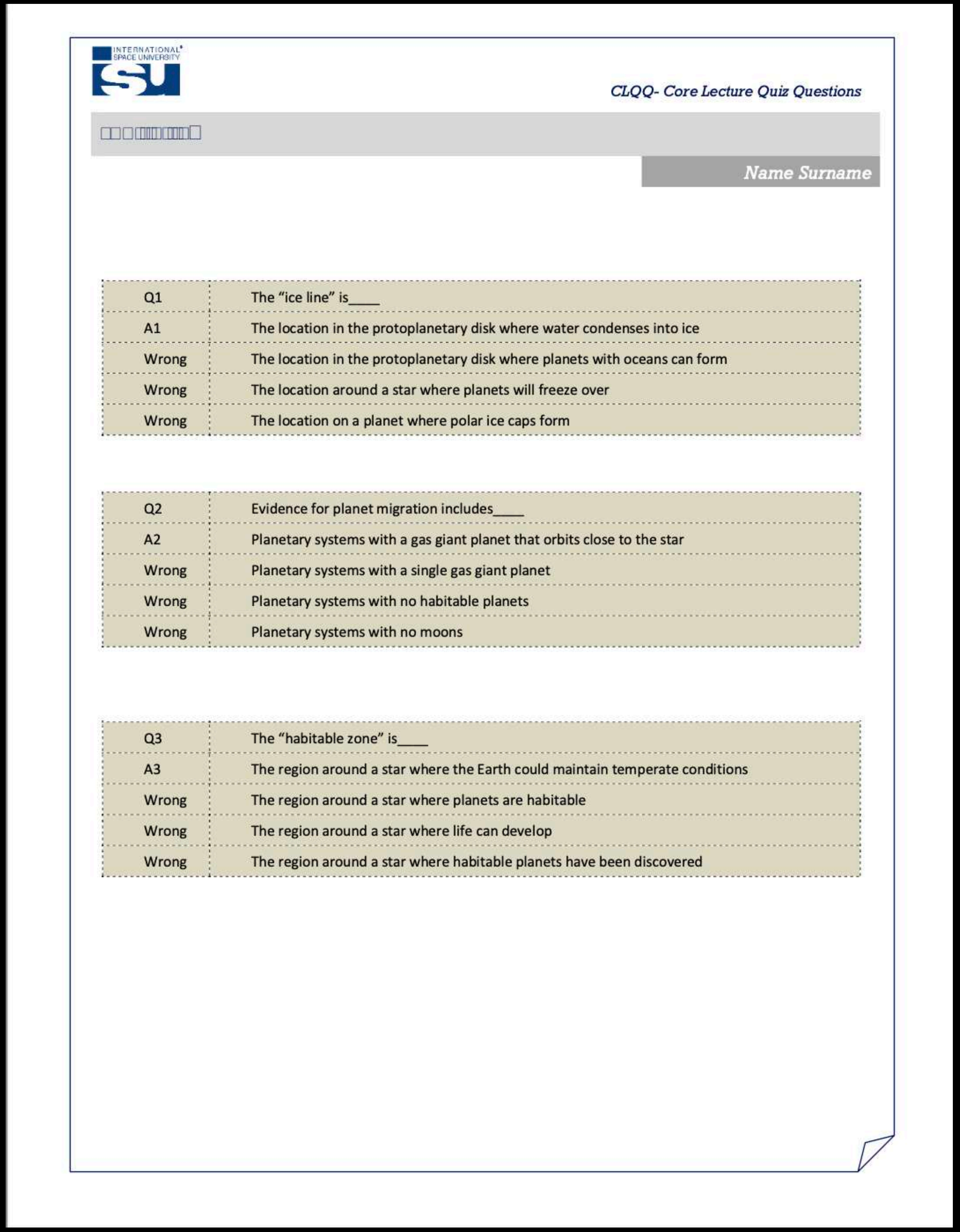
However, Mars today is a frigid desert. The atmosphere has been stripped by the solar wind, chilling the surface until the water sublimated. Yet traces of that water do still remain. The poles contain frozen water, and possibly even liquid beneath the southern pole ice cap. Micrometeorite impacts have revealed frozen ice just below the Martian surface, which may even be a useful resources to future crewed exploration.

Whether Mars ever hosted life is an open question. Unlike the Moon, we have no samples from Mars that can be analyzed in detail in a laboratory. But this may change in the future. The NASA-ESA Mars Sample Return is an immensely ambitious program to return samples from the Martian surface to Earth. The MMX mission will also return a sample from the Martian moon, Phobos. Not only will Phobos material reveal information about how the moons formed, but Phobos is thought to be sprinkled with material ejected from the Martian surface. MMX will therefore return a small but diverse Martian material sample.

The moons of Earth and Mars are not the only place where we might find clues for how habitability developed. Surrounding the gas giants in the outer solar system are moons with icy crusts, beneath which deep oceans are thought to reside. Despite being far from the Sun, tidal tugs from the giant planet are thought to keep the water liquid through friction. These are new areas for astrobiological investigation, finding life that evolved far differently from that on Earth.

Suggested Reading:

- New Views of The Moon (Reviews in Mineralogy and Geochemistry), De Gruyter (2006/9/30)
- Enceladus and the Icy Moons of Saturn (University of Arizona Space Science) Published: November 2018 Hardcover ISBN: 9780816537075



Name Surname

Q1	The "ice line" is____
A1	The location in the protoplanetary disk where water condenses into ice
Wrong	The location in the protoplanetary disk where planets with oceans can form
Wrong	The location around a star where planets will freeze over
Wrong	The location on a planet where polar ice caps form

Q2	Evidence for planet migration includes____
A2	Planetary systems with a gas giant planet that orbits close to the star
Wrong	Planetary systems with a single gas giant planet
Wrong	Planetary systems with no habitable planets
Wrong	Planetary systems with no moons

Q3	The "habitable zone" is____
A3	The region around a star where the Earth could maintain temperate conditions
Wrong	The region around a star where planets are habitable
Wrong	The region around a star where life can develop
Wrong	The region around a star where habitable planets have been discovered

Study notes: 1 ~ 3 pages

Three "test" questions

Advanced reading / study material

Who are the students?

Scientists

Engineers

Educators

Lawyers

Communicators

Graduate students

Postdocs

Professionals

Teachers

Managers

Any field of the space industry

A lecture for a broad audience

Jim Green,
Chief Scientist at NASA (Retired)

An audience of professionals, but with a very broad background.

Cover the basics for non-scientists

With a little "something new" for the experts.

Moon & Mars

Core Lecture 25: ISU Space Studies Program

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June 19, 2024
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Learning outcomes

L01: Explain the "giant impact theory" for the origin of the Moon.

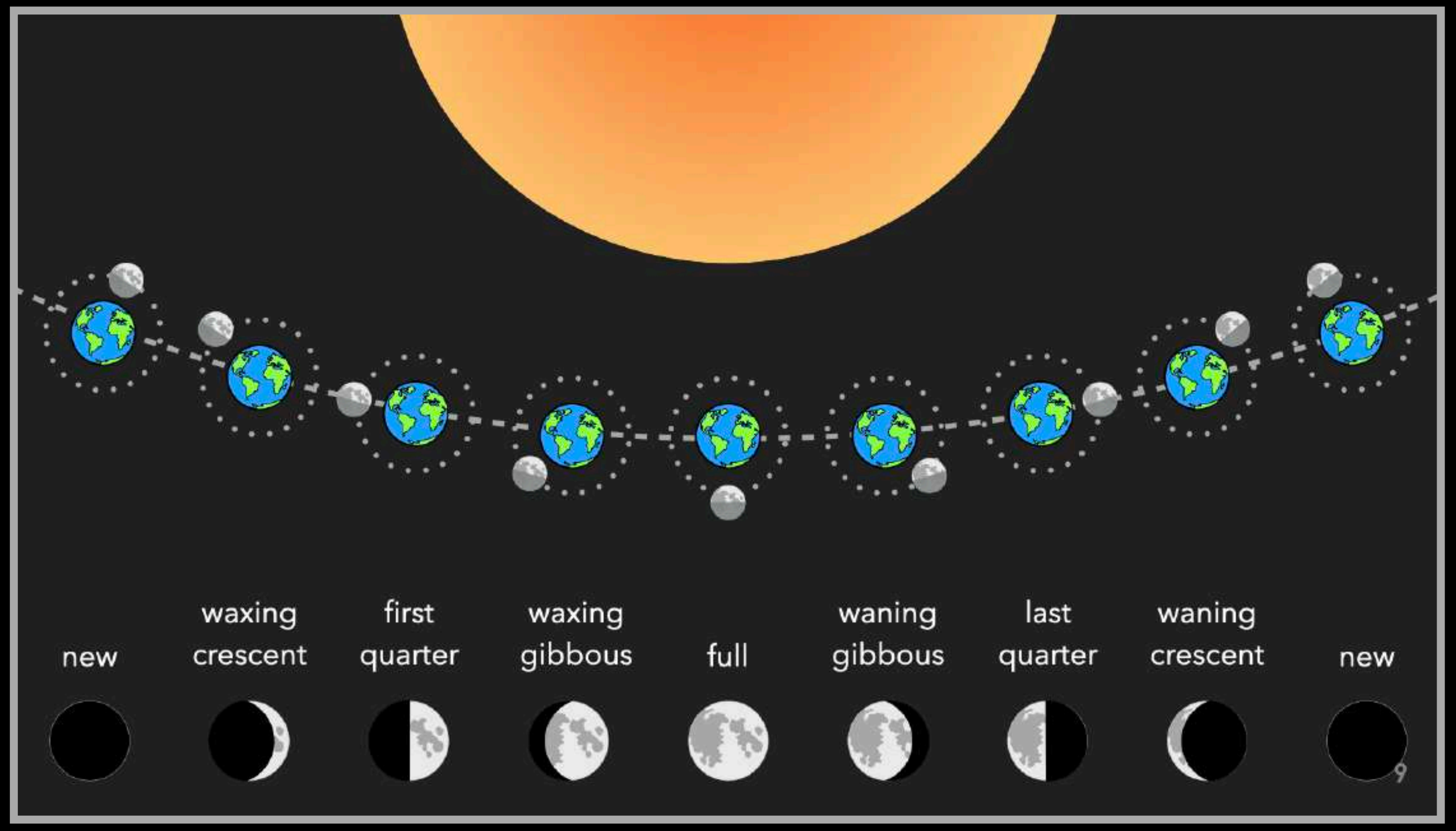
L02: Describe the evidence for water on the Moon and Mars, past and present.

L03: Describe a selection of the current and future plans for lunar and Mars exploration.

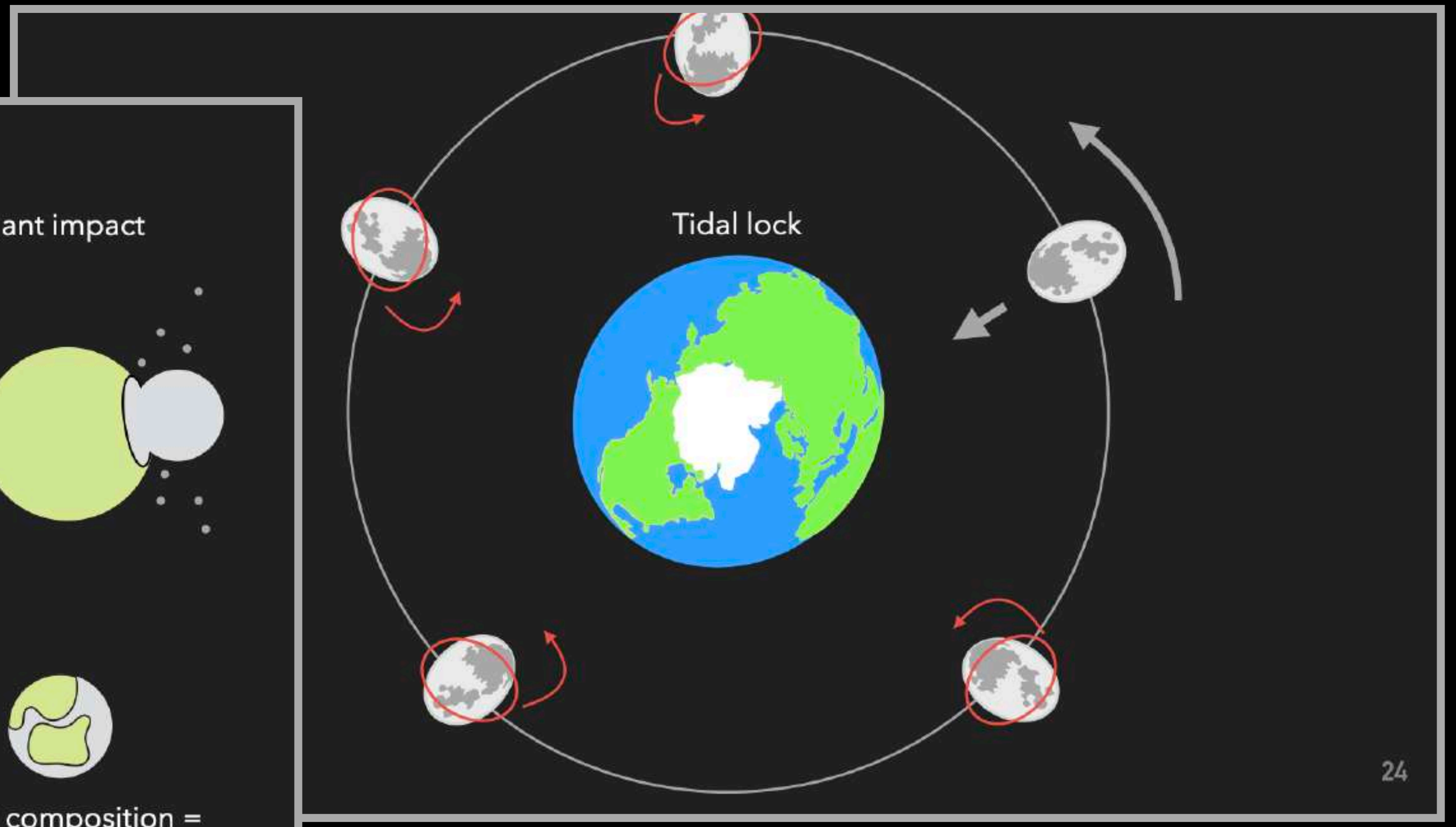
L04: Describe the evidence for why the giant planet icy moons may offer a habitable environment.

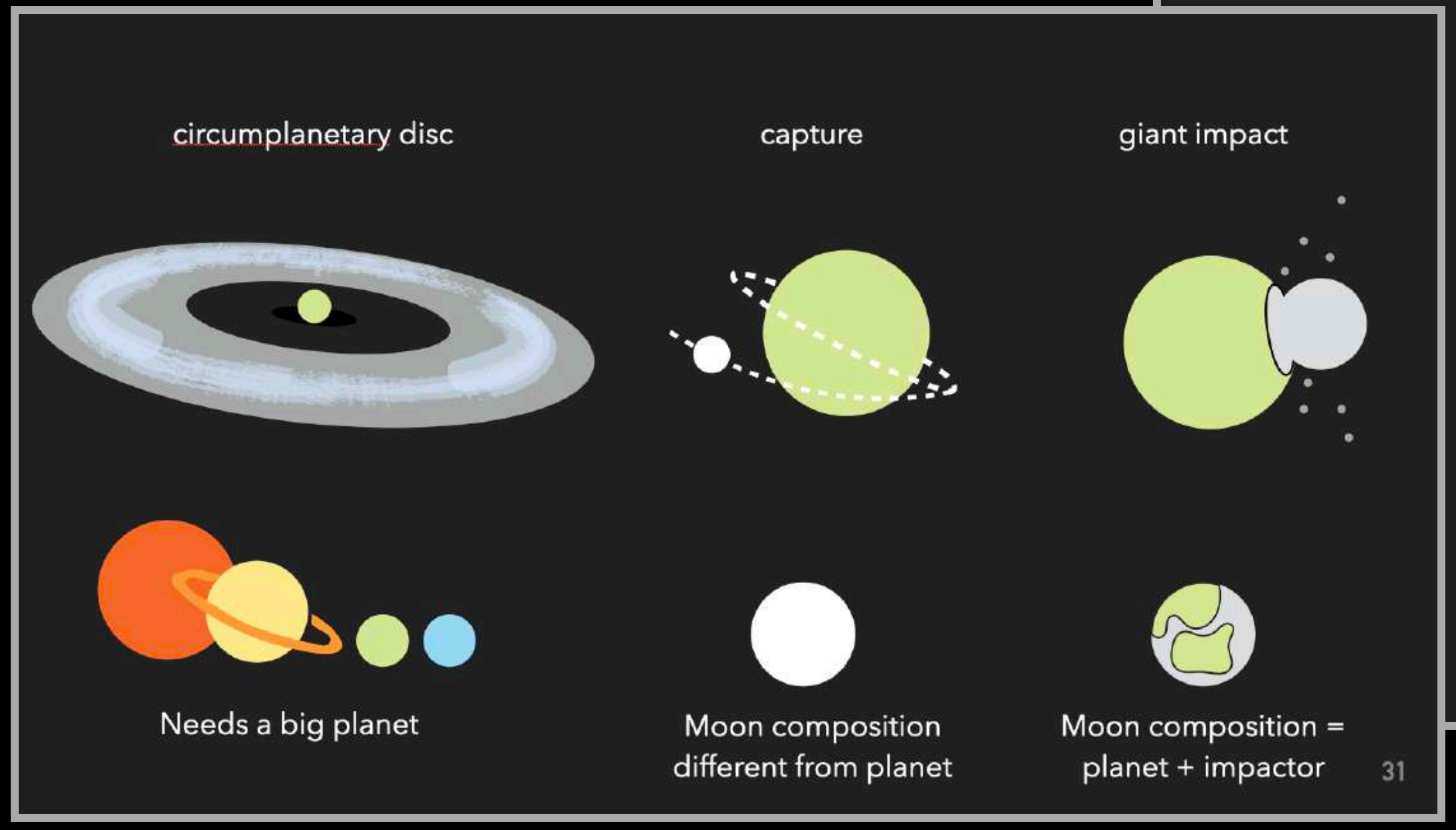
Example

"Basics" — phases of the Moon

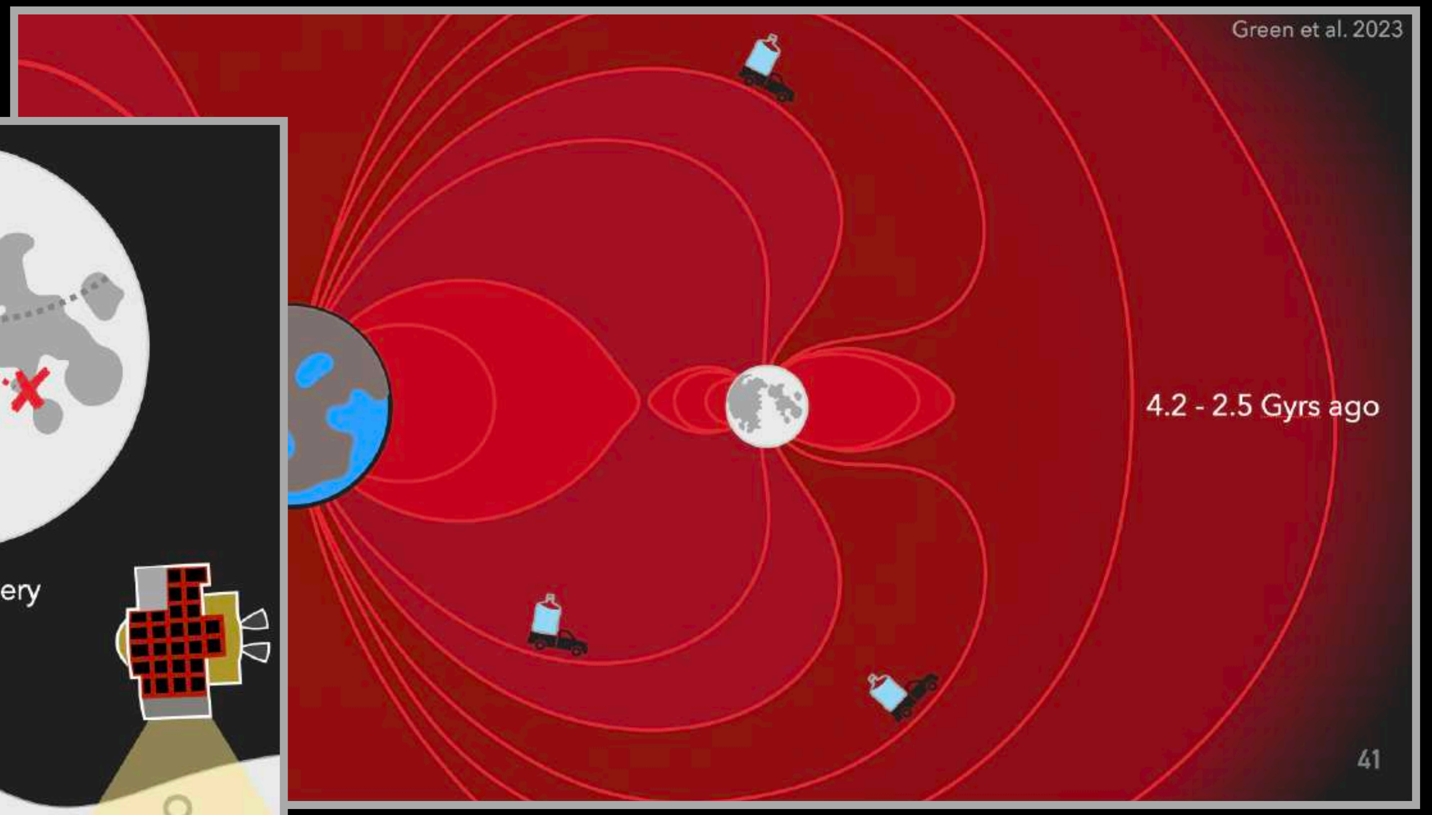


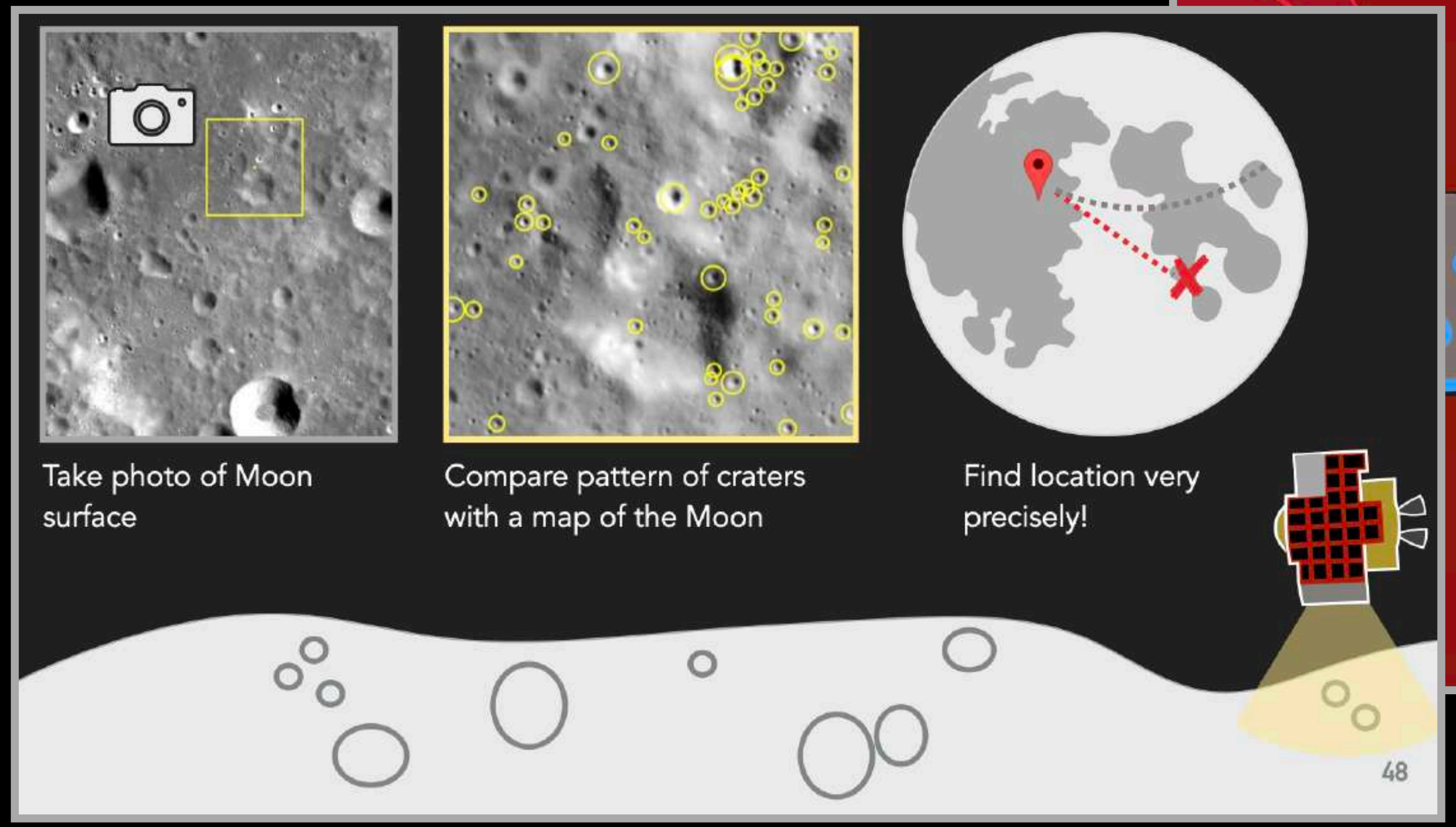
"Mid-level" (Most material) — tidal locking, how moons are formed





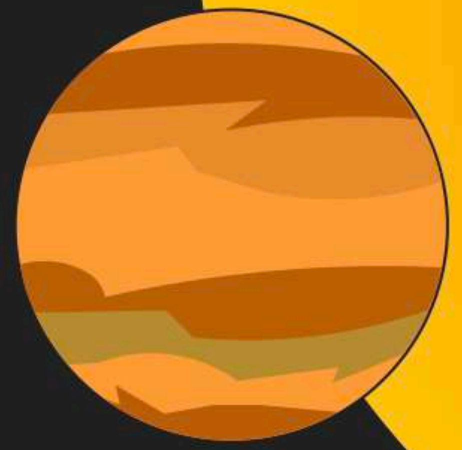
"New research" — the lunar magnetic field, JAXA's SLIM mission





Our Solar System and Exoplanets

Core Lecture 21: ISU Space Studies Program



Elizabeth Tasker JAXA
June 18, 2024
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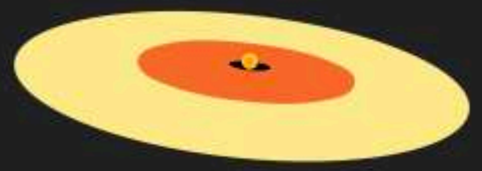
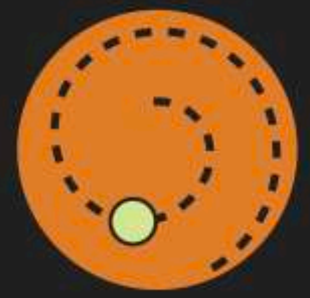
Learning outcomes



L01: Describe our current understanding of how planets form, and explain how this produced the characteristics of our Solar System.

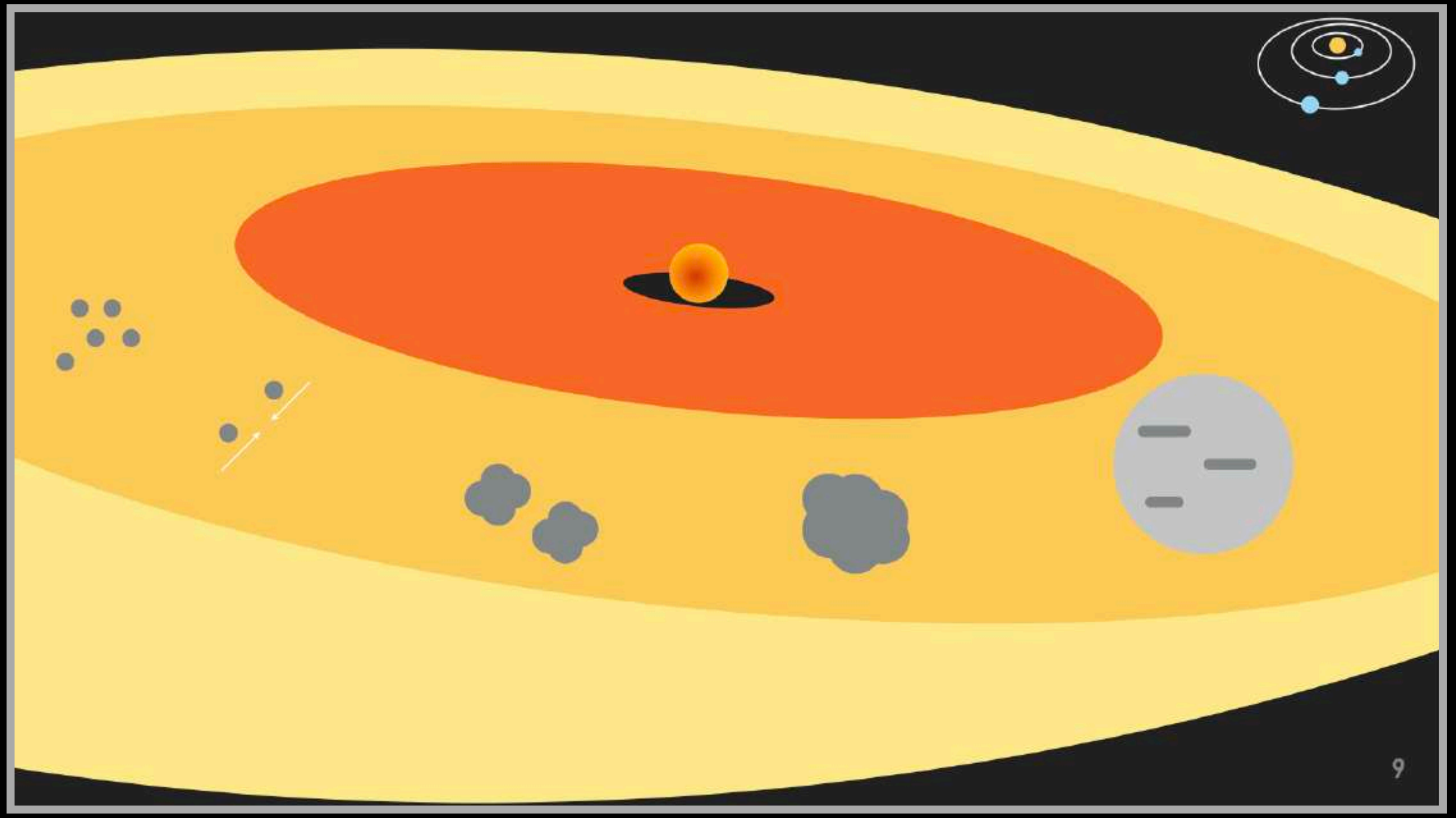


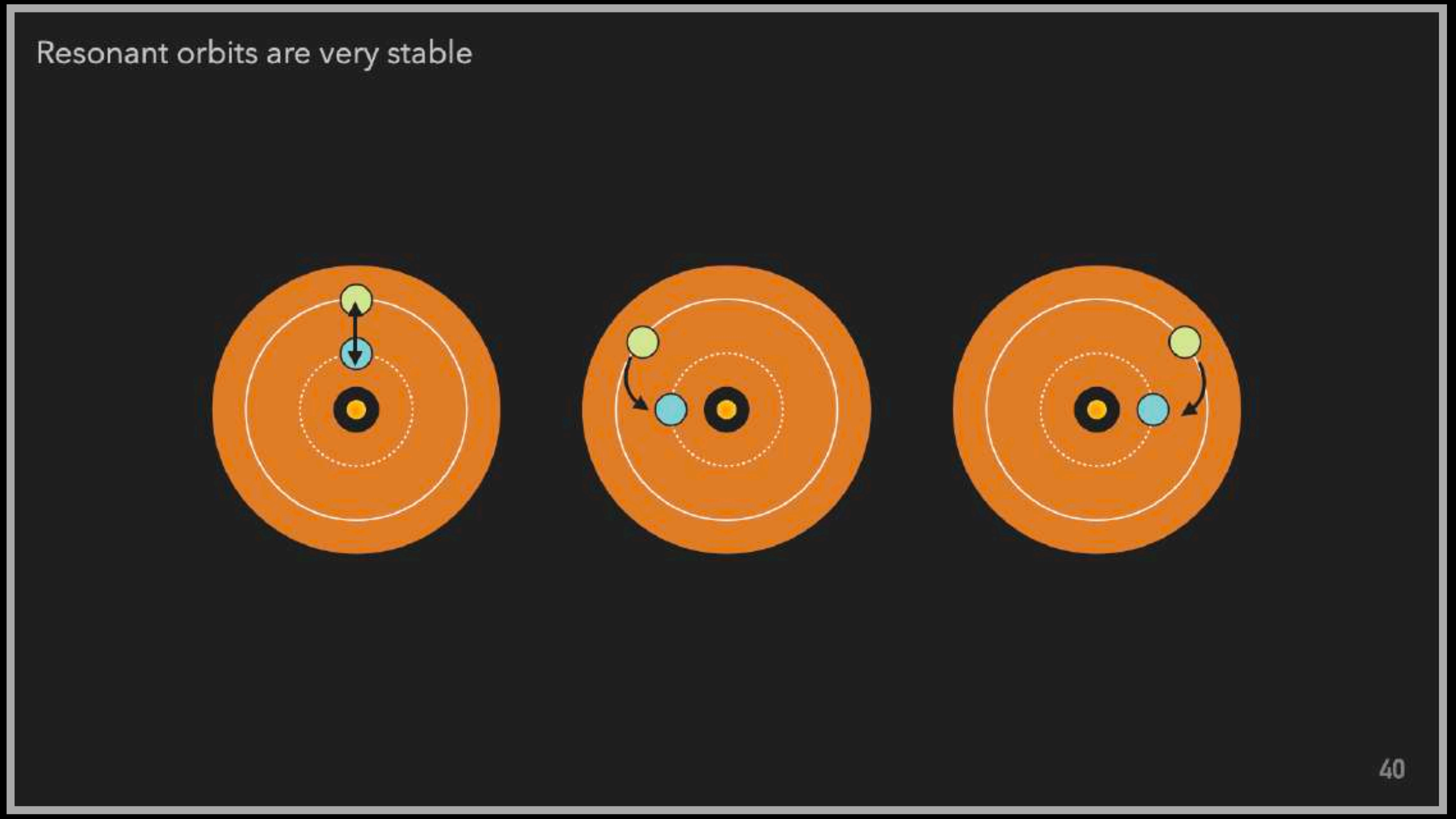
L02: Describe how a planet's orbit can change, and list examples of evidence that this occurred.

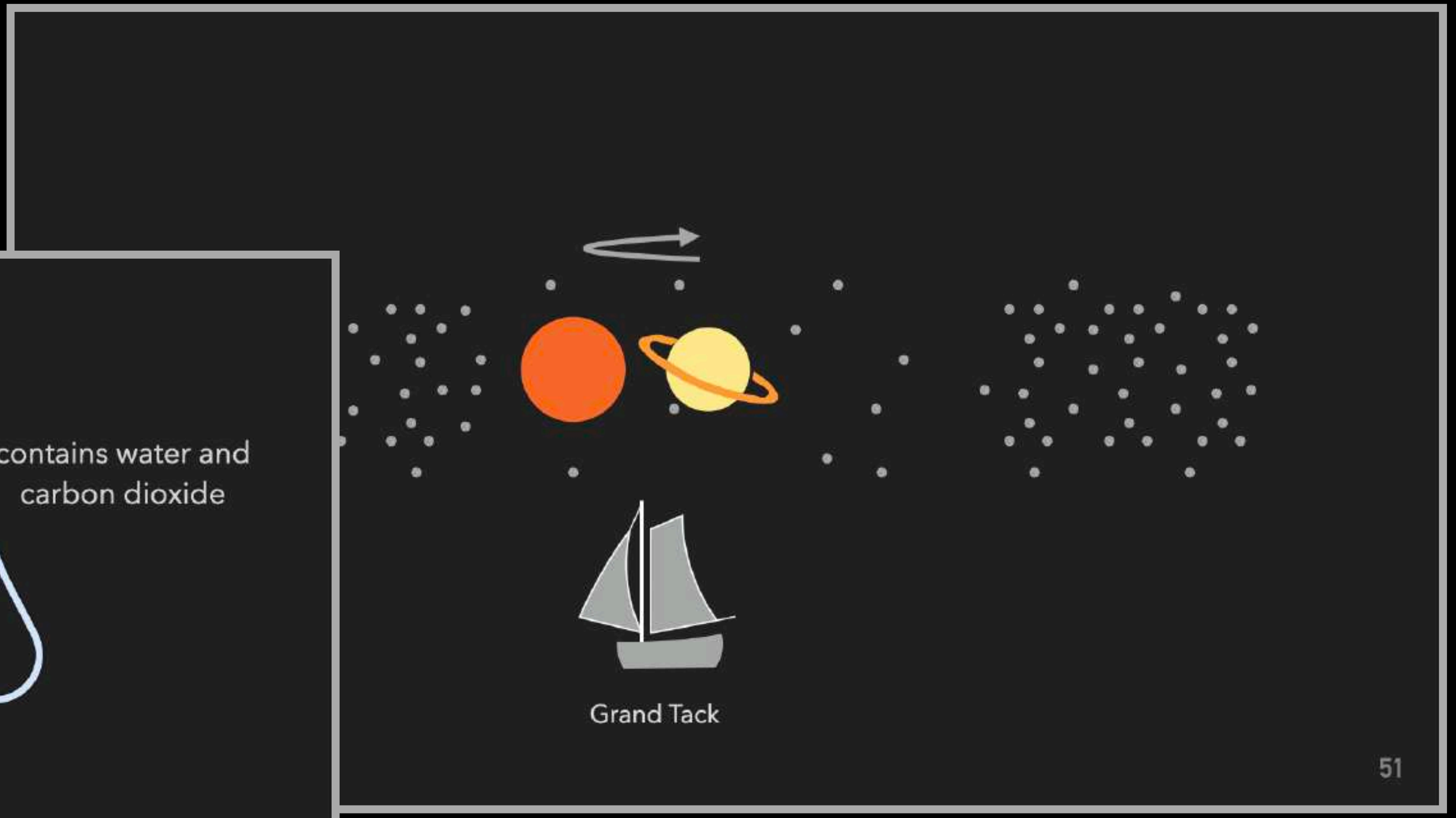
L03: Describe how the Earth may have acquired water.

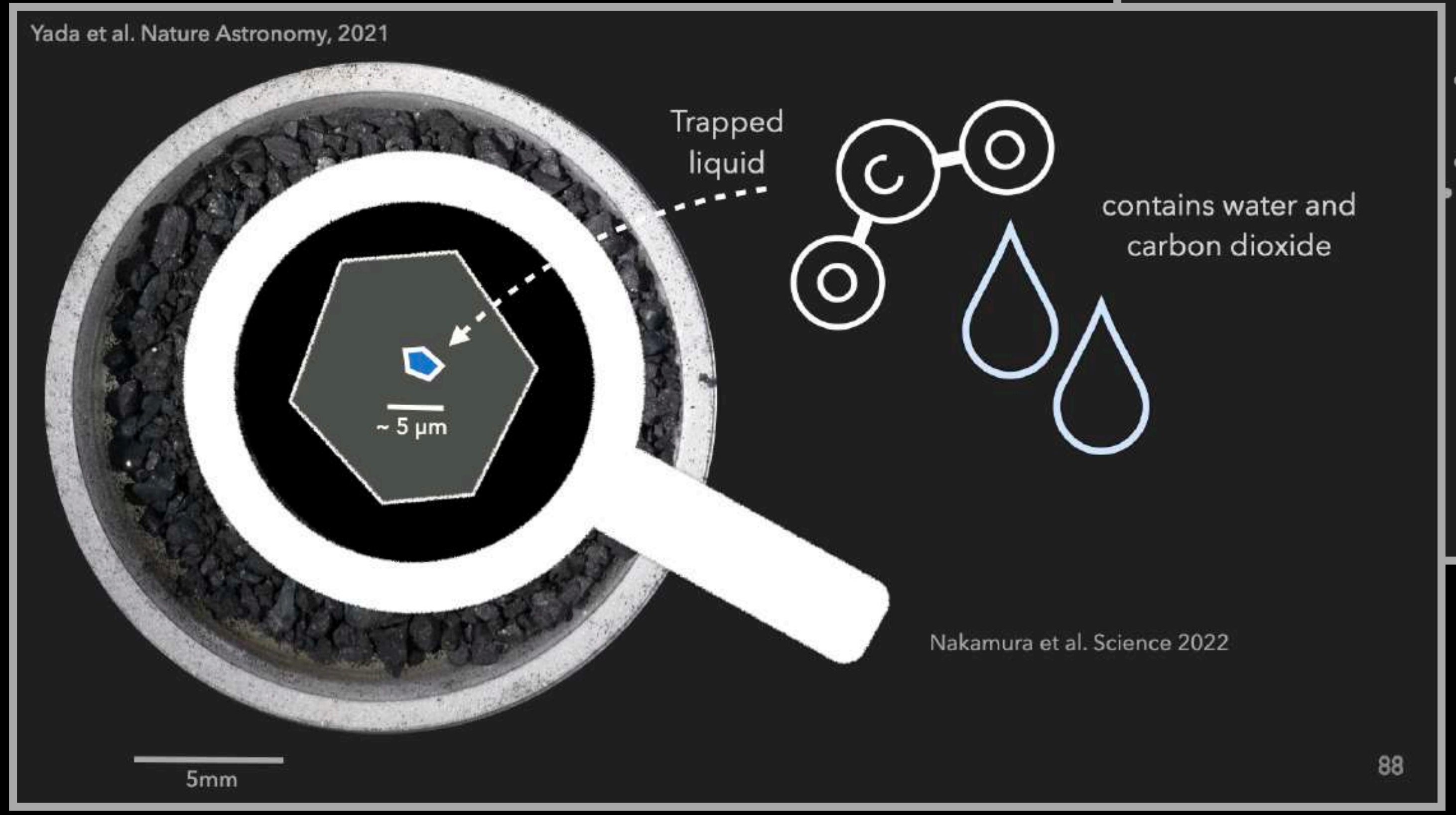
L04: Explain the concept of the "habitable zone" and describe how we can probe the environment on exoplanets.

	Example
“Basics”	Dust collision
“Mid-level” (Most material)	Resonant orbits
“New research”	The ‘Grand Tack model”
	Hayabusa2 mission and asteroid Ryugu analysis









The experience

Lots of questions!

VERY varied

e.g. can we terraform Mars?

Students and lecturers eat together in the dining hall

The schedule is very busy. So this is a good opportunity to chat with the lecturers!

Lecturers did have to attend on-site (no online option).

TA:

Meritxell Lorber