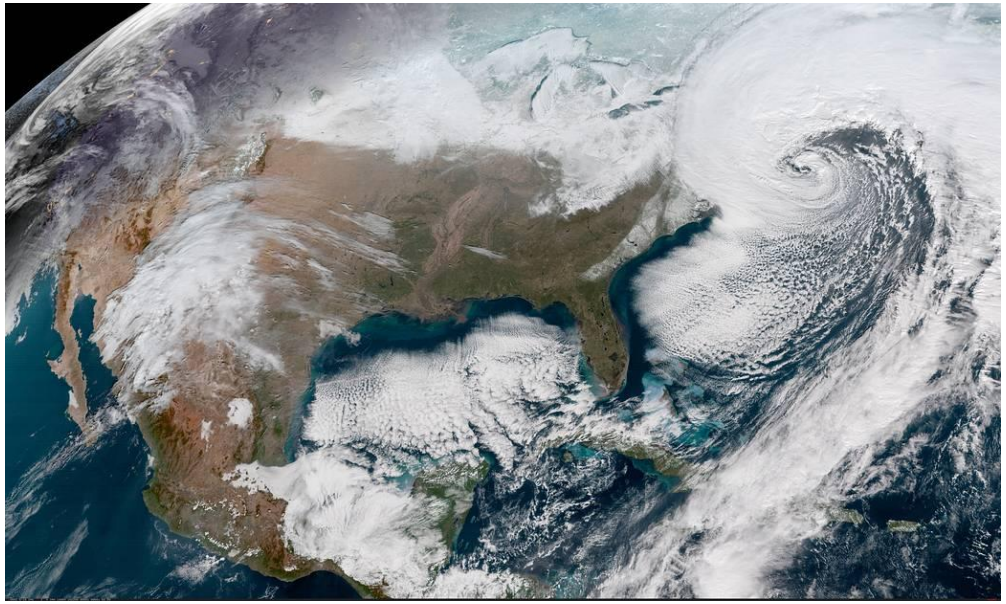
Learning Objectives

- Learn about planets outside of our solar system
- Use scientific methods to investigate what conditions are needed for a planet to have clouds
- Explain how clouds are formed

Clouds In Space

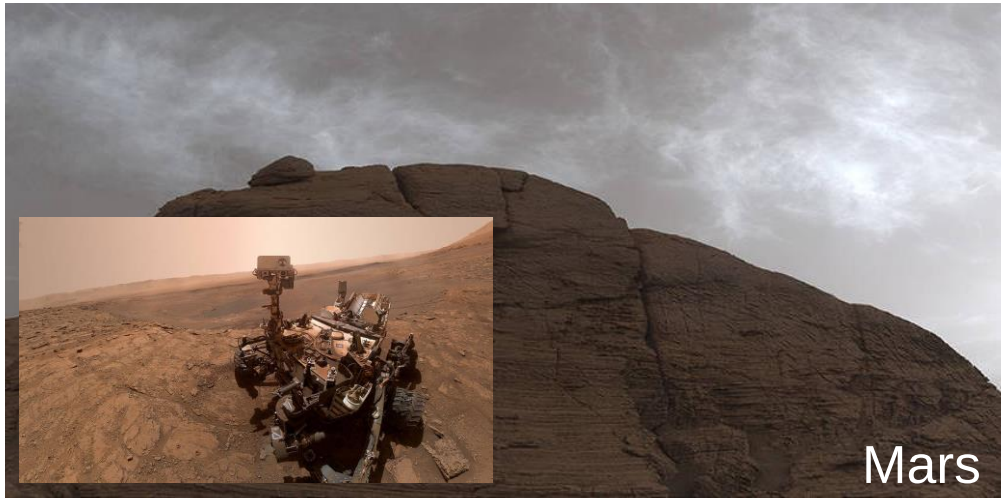
ESA astronaut Alexander Gerst captured this image of Earth from the International Space Station on 21 June 2018.

Where do you think these clouds can be found?



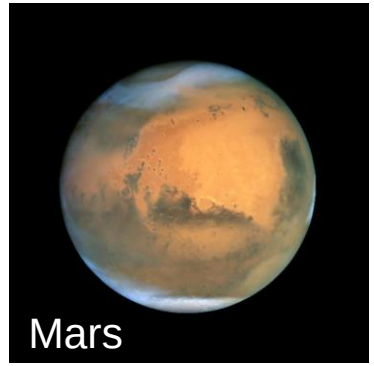
Where do you think these clouds can be found?

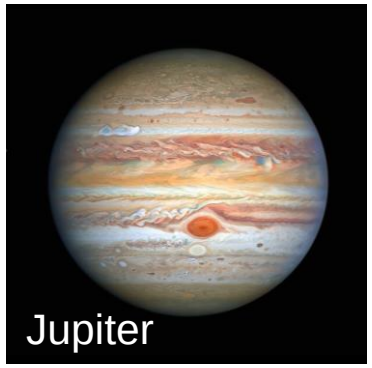
NASA's Juno Spacecraft, NASA.gov

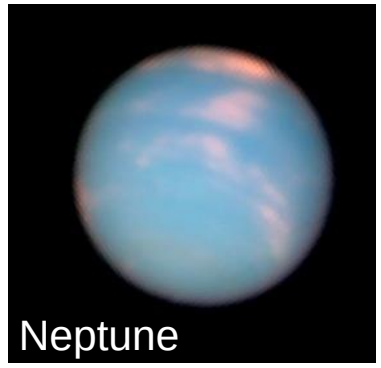


NASA's Mars Curiosity rover 2021, NASA.gov
ESA's Copernicus Sentinel-3 Mission www.ESA.int

Which of the planets in our solar system do you think have clouds?

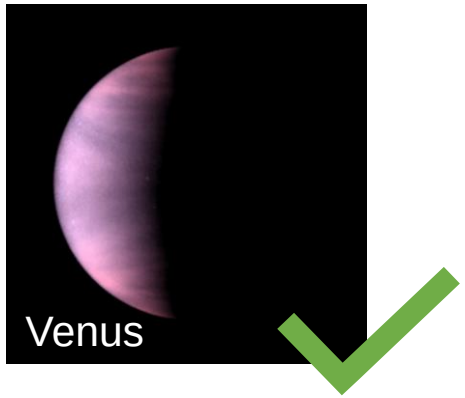


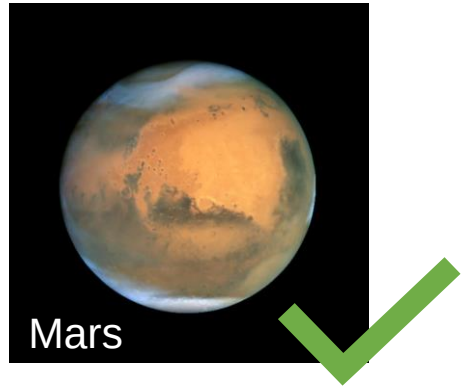


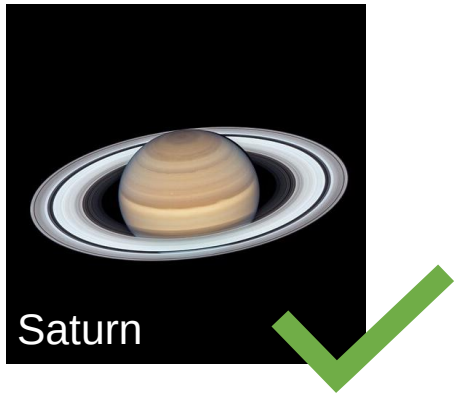


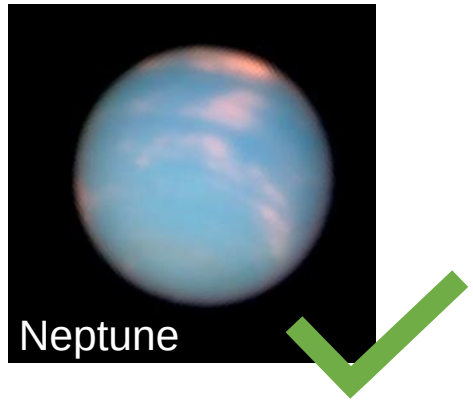
Mercury: NASA Messenger https://solarsystem.nasa.gov/, Earth image ESA Meteosat http://esa.int,
All other images from the Hubble Space Telescope https://esahubble.org/images/

Which of the planets in our solar system do you think have clouds?









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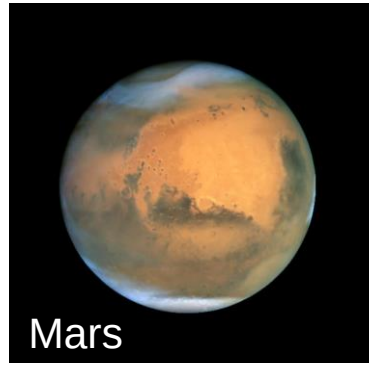
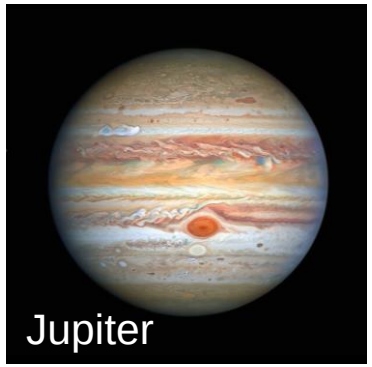
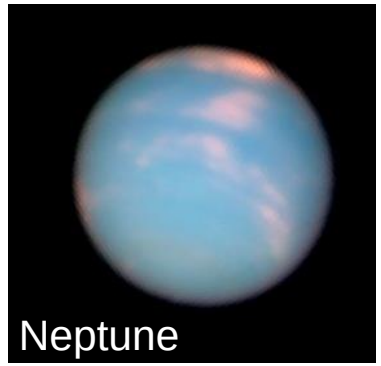
Which of these planets do you think have clouds made of water?







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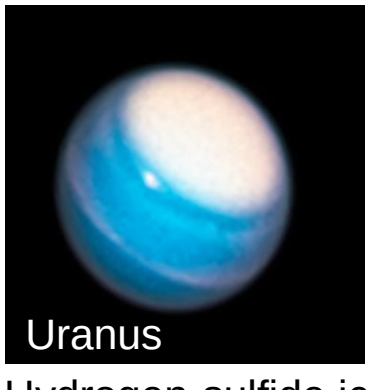
Which of these planets do you think have clouds made of water?

Sulfuric acid

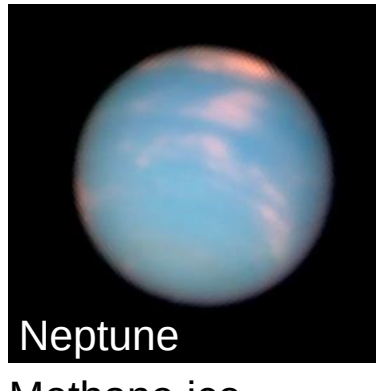
Water

Water ice and some frozen carbon dioxide

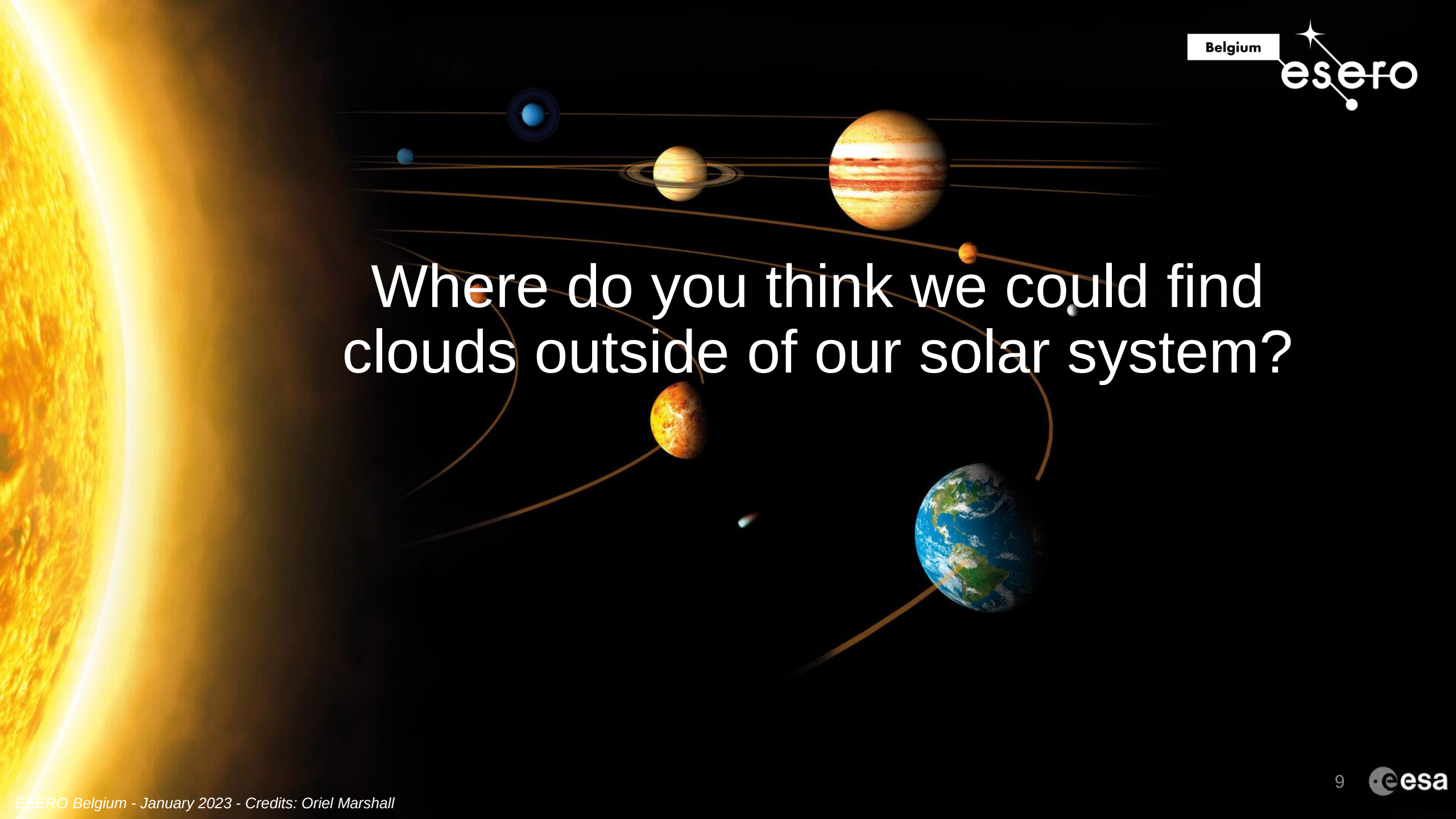
Ammonia ice, ammonium hydrosulfide crystals, possibly water ice and vapour

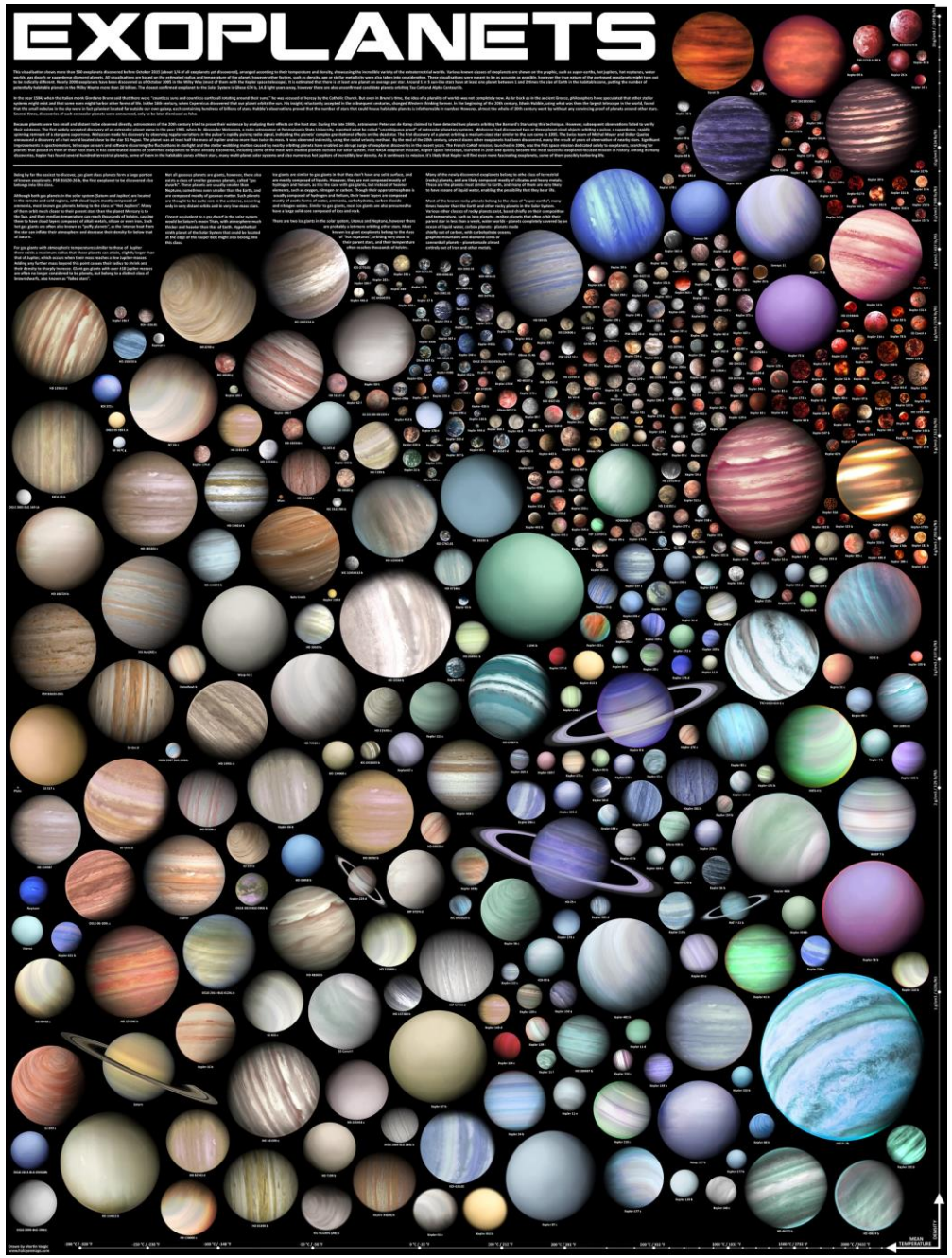


Hydrogen-sulfide ice

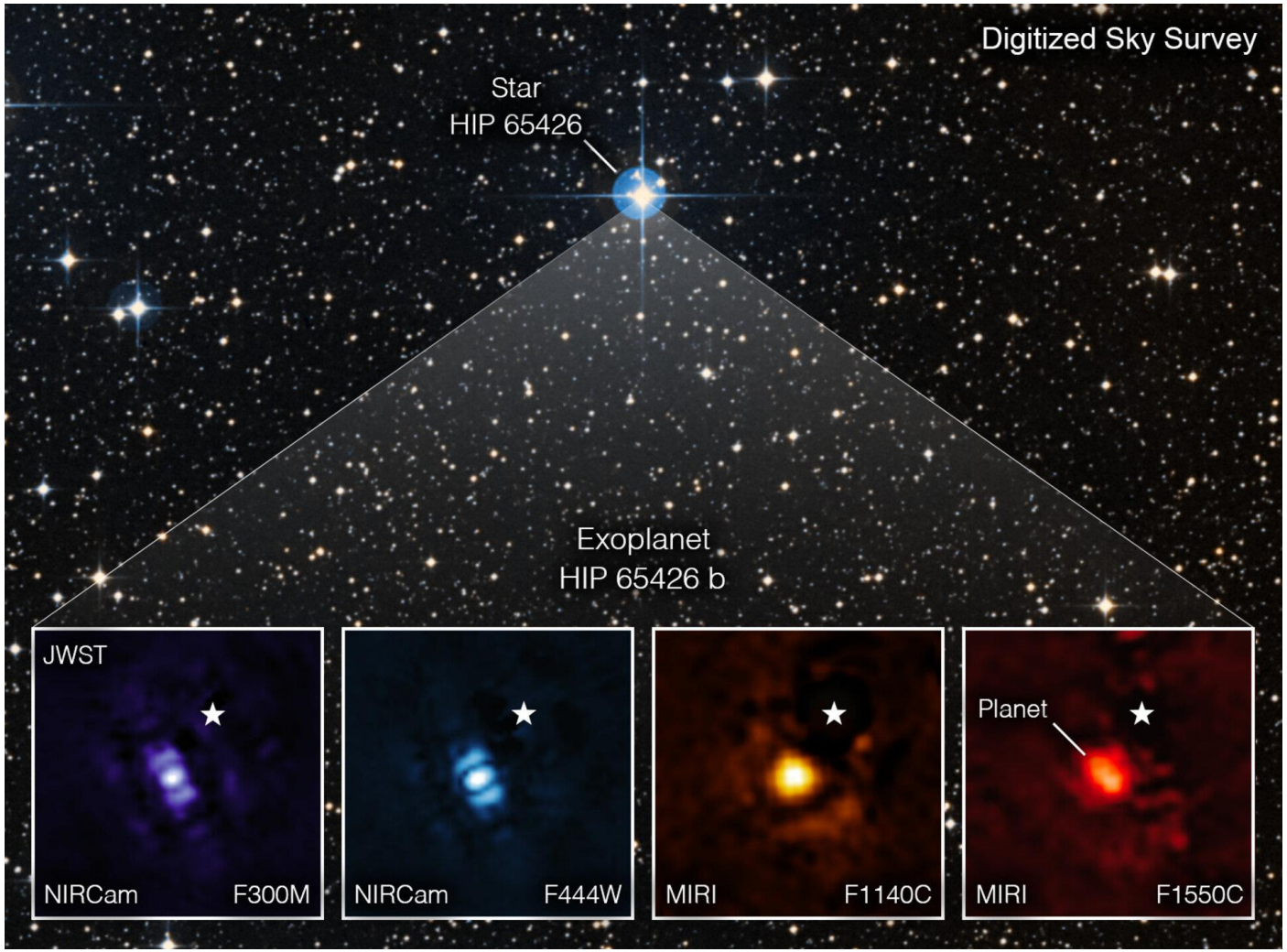


Methane ice


Where do you think we could find clouds outside of our solar system?

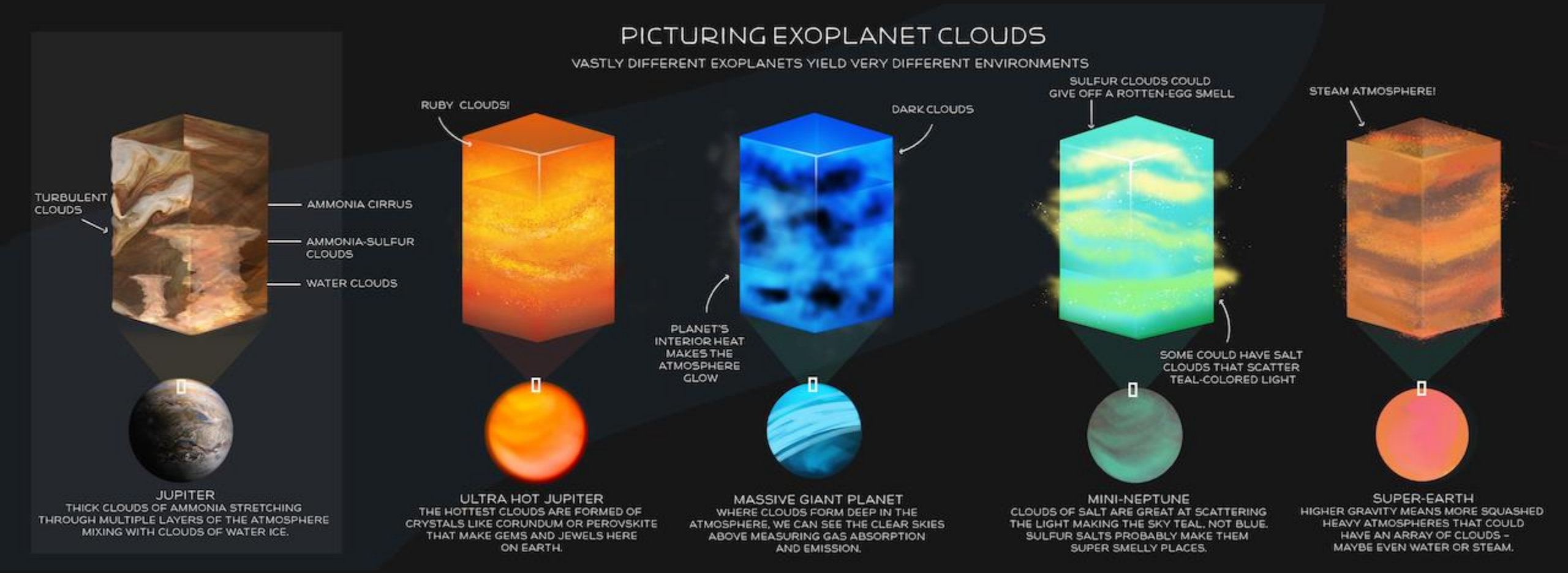


Martin Vargic https://www.halcyonmaps.com/exoplanets

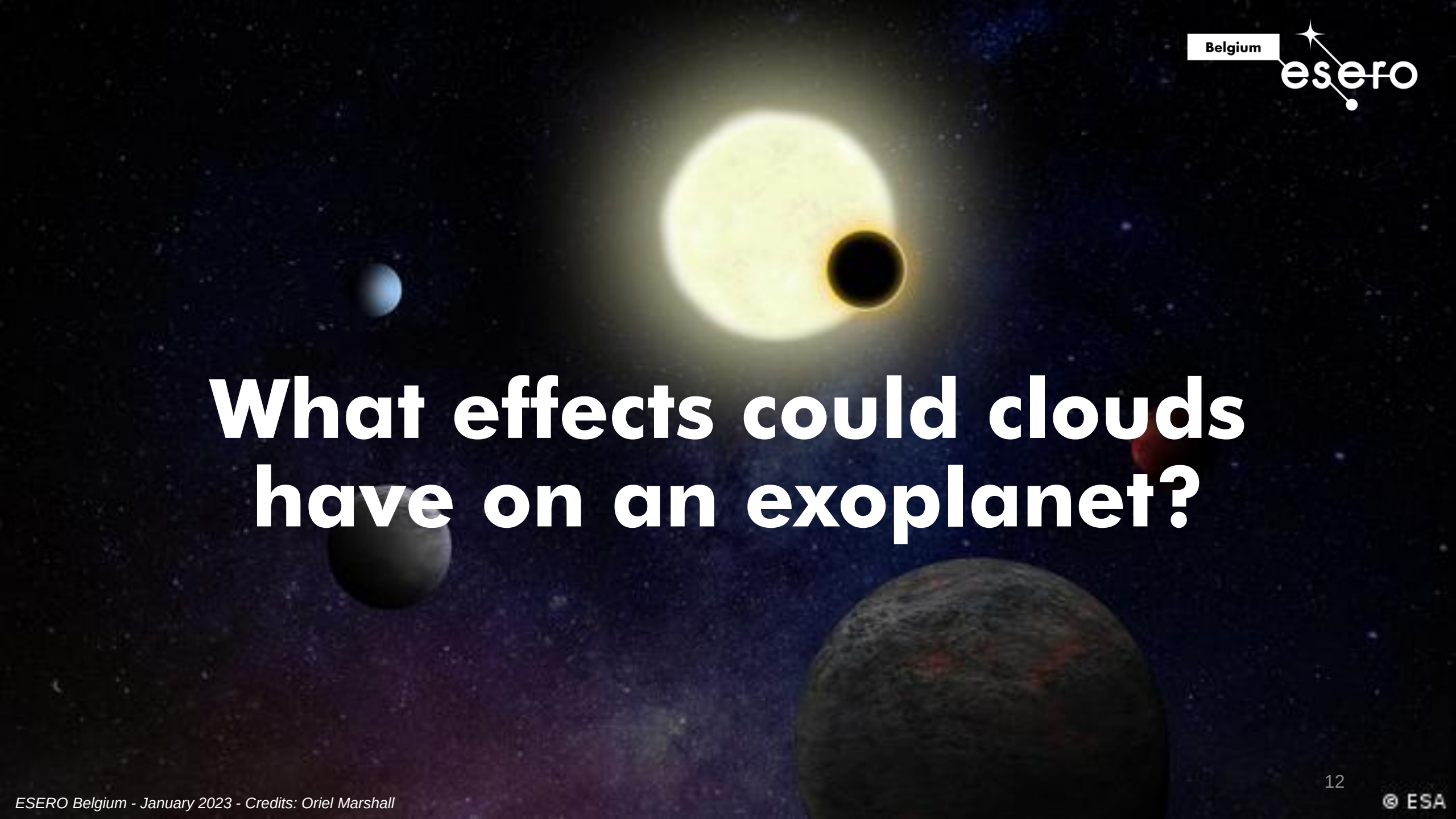


https://www.esa.int/ESA_Multimedia/Images/2022/08/Webb_takes_its_first_exoplanet_image

ESERO Belgium - January 2023 - Credits: Oriel Marshall



https://exoplanets.nasa.gov/news/1709/exoplanet-clouds-jewels-of-new-knowledge/



What effects could clouds have on an exoplanet?

Some possible effects of clouds

- Make it hard for astronomers to see the surface of the planet
- Trap heat and can cause a greenhouse effect
- Reflect and absorb light from their host star
- Change the chemical composition of a planet's atmosphere

Activity 1: Exoplanet Clouds

If astronomers observe an exoplanet with clouds on it this will tell them that this planet must have the correct conditions for clouds to form.

Ex 1. What do you think is needed for an exoplanet to have clouds?

Activity 2: Demonstration

https://vimeo.com/802277701

ESERO Belgium - January 2023 - Credits: Oriel Marshall

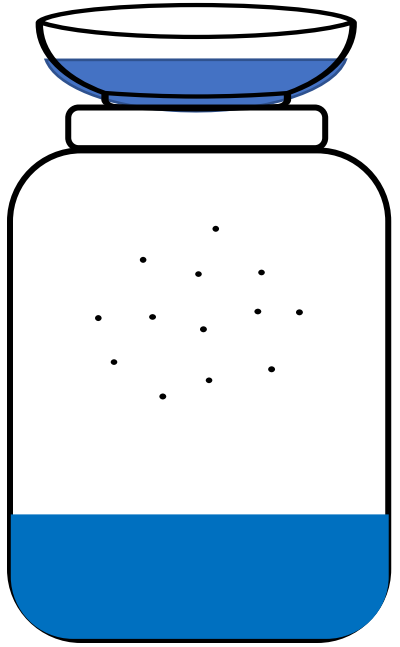
Activity 2: Demonstration

Ex 2. Sketch the experiment set up in your worksheet

Activity 3: Identifying Variables

- What are the variables in this experiment?
- How would each variable relate to an exoplanet atmosphere?

Ex 3. Discuss these questions as a class and write your answers up on the board



Activity 4: Experimentation

- Exoplanet scientists often rely on different types of models (for example computational models or laboratory experiments) to help them understand processes on other planets
- In this activity, you will use a physical model to explore exoplanet cloud formation.

Ex 4. Plan and conduct an experiment to investigate the effect of one of these variables on the clouds that form in your mini-exoplanet atmosphere

Activity 5: Share your findings

Share with the rest of your class what you learned from your experiments. This should include:

- Your hypothesis
- What you tested
- What results you got
- Did this align with your hypothesis?
- What did you learn

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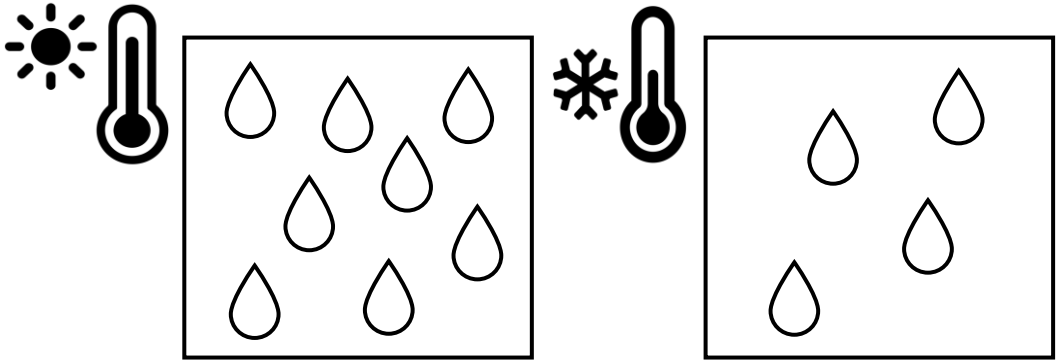
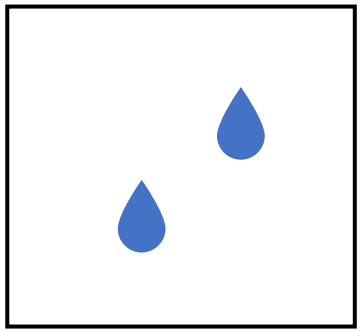
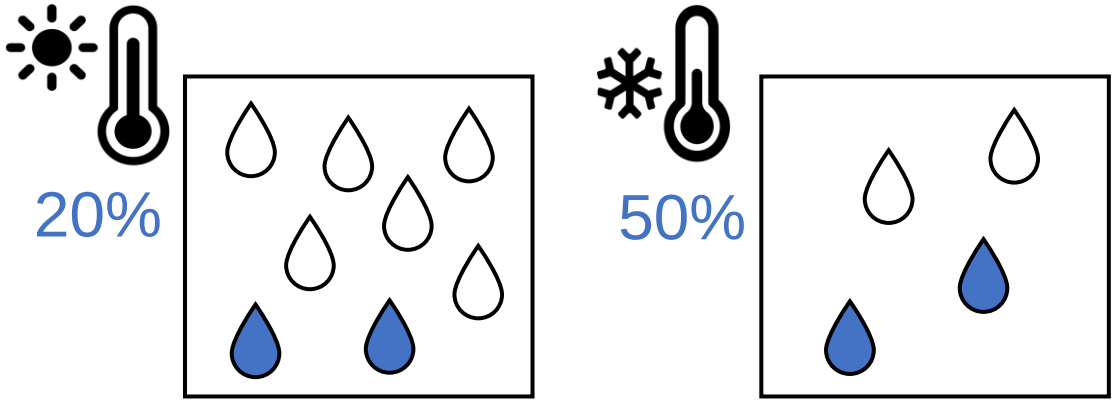
Ex 5. In a short paragraph, write up your class findings as if you are explaining it to a student in another class



The maximum amount of moisture air can hold depends on its temperature. Hotter air can hold more moisture.

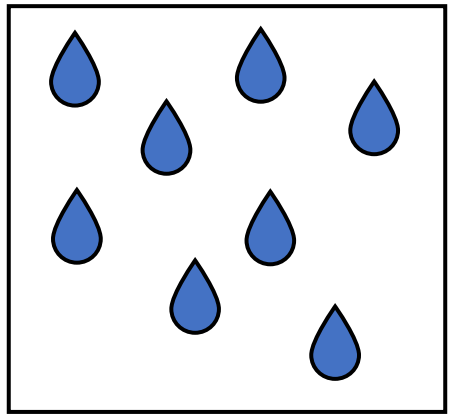


The **absolute humidity** of a pocket of air is the total amount of moisture in the air



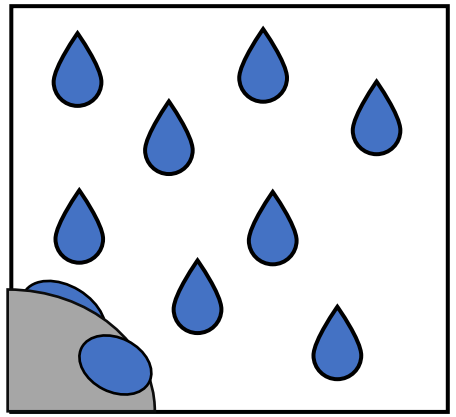
The **relative humidity** of a pocket of air is the amount of moisture in the air as a percentage of the maximum amount of moisture it could hold at that temperature

100%



When a pocket of air is holding as much vapour as is possible at a given temperature it has reached **saturation point**, e.g. the air is **saturated**

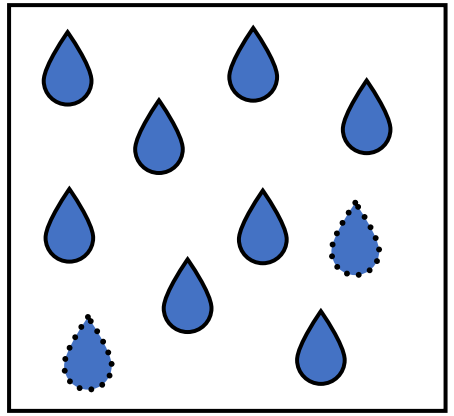
100%



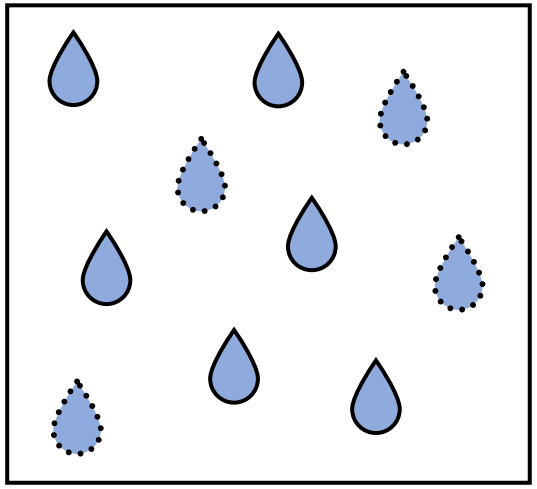
Any extra vapour added past saturation point will condense onto any surface possible to remain at saturation point

You can see this in action when there is a car full of people breathing out water vapour and it starts to condense onto the windows

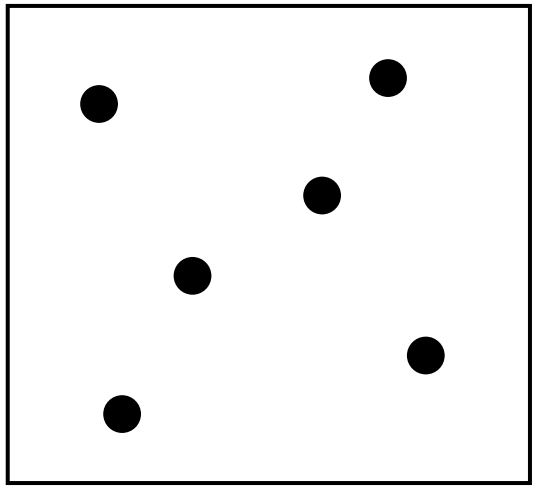
125%



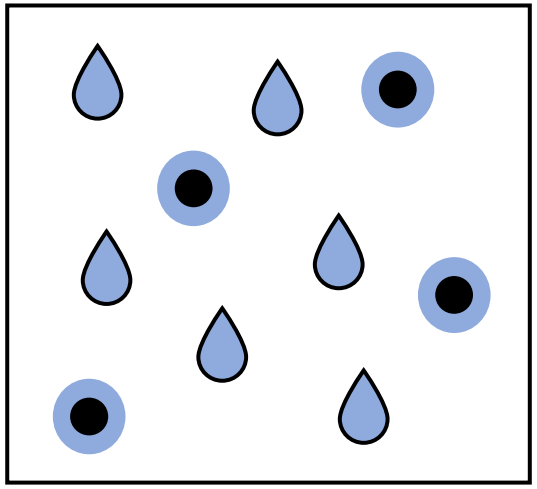
If there is no surface for the extra vapour to condense onto then the vapour must stay in the air and the air will be **super saturated**



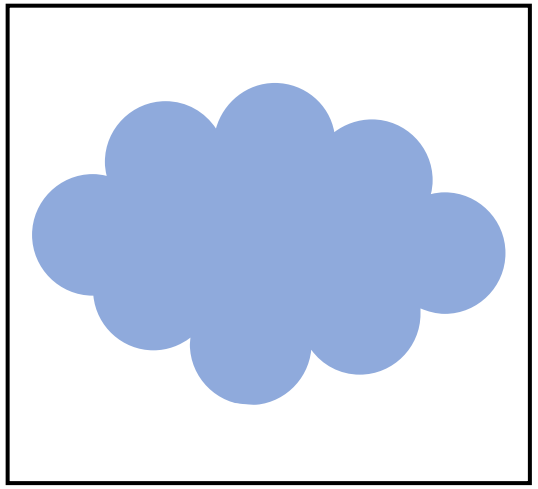
Super saturated air will condense onto any surface available.



Aerosols are small solid particles in the air.



Aerosols can act as a surface for vapour to condense onto.



These droplets will join together and form clouds.

Aerosols in the atmosphere are **cloud condensation nuclei**, also called '**cloud seeds**'. Some examples of aerosols on exoplanets are: dust, tiny pieces of rock or other minerals, and smoke from volcanoes.

Activity 6: Applying your knowledge

The science behind cloud formation is the same both in your experiment and on exoplanets.

Because your experiment has a solid surface, in this activity we will compare it to a terrestrial exoplanet

Ex 6.1 Complete the table in your worksheet