Learning Objectives

- Learn about planets outside of our solar system
- Use scientific methods to investigate what conditions are needed for lightning to occur on a planet
- Explain how lighting occurs

Lightning in Space

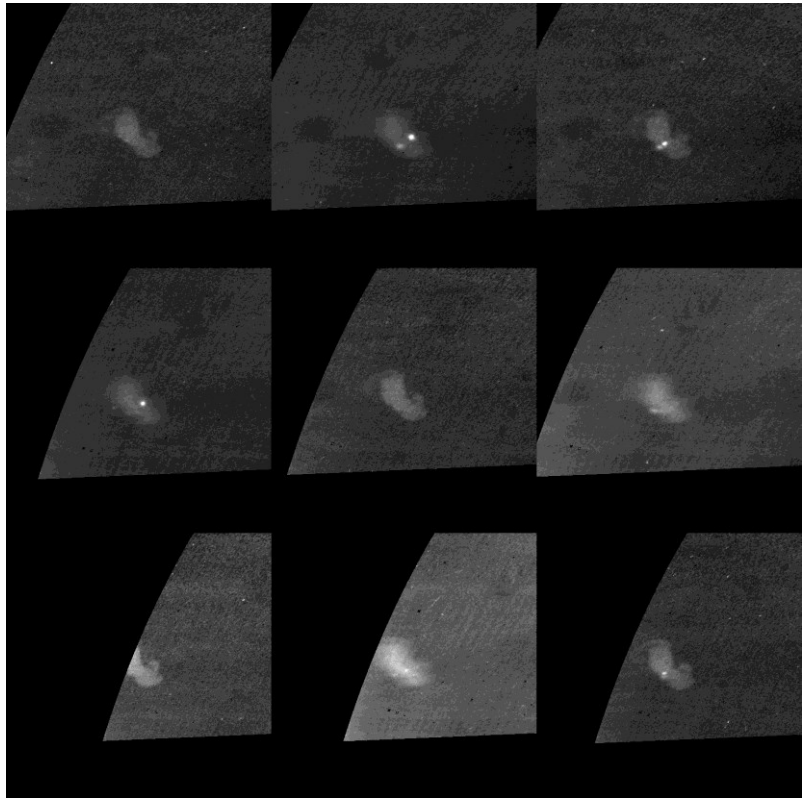
Lightning captured in a photograph by ESA astronaut Paolo Nespoli from on board the International Space Station https://www.esa.int/ESA_Multimedia

True or False?

Lightning has only been observed on Earth

False!

Lighting storms occur on many other planets including Saturn, Jupiter, Uranus, Neptune and Venus! Many of these lightning storms have been observed by NASA and ESA spacecrafts.

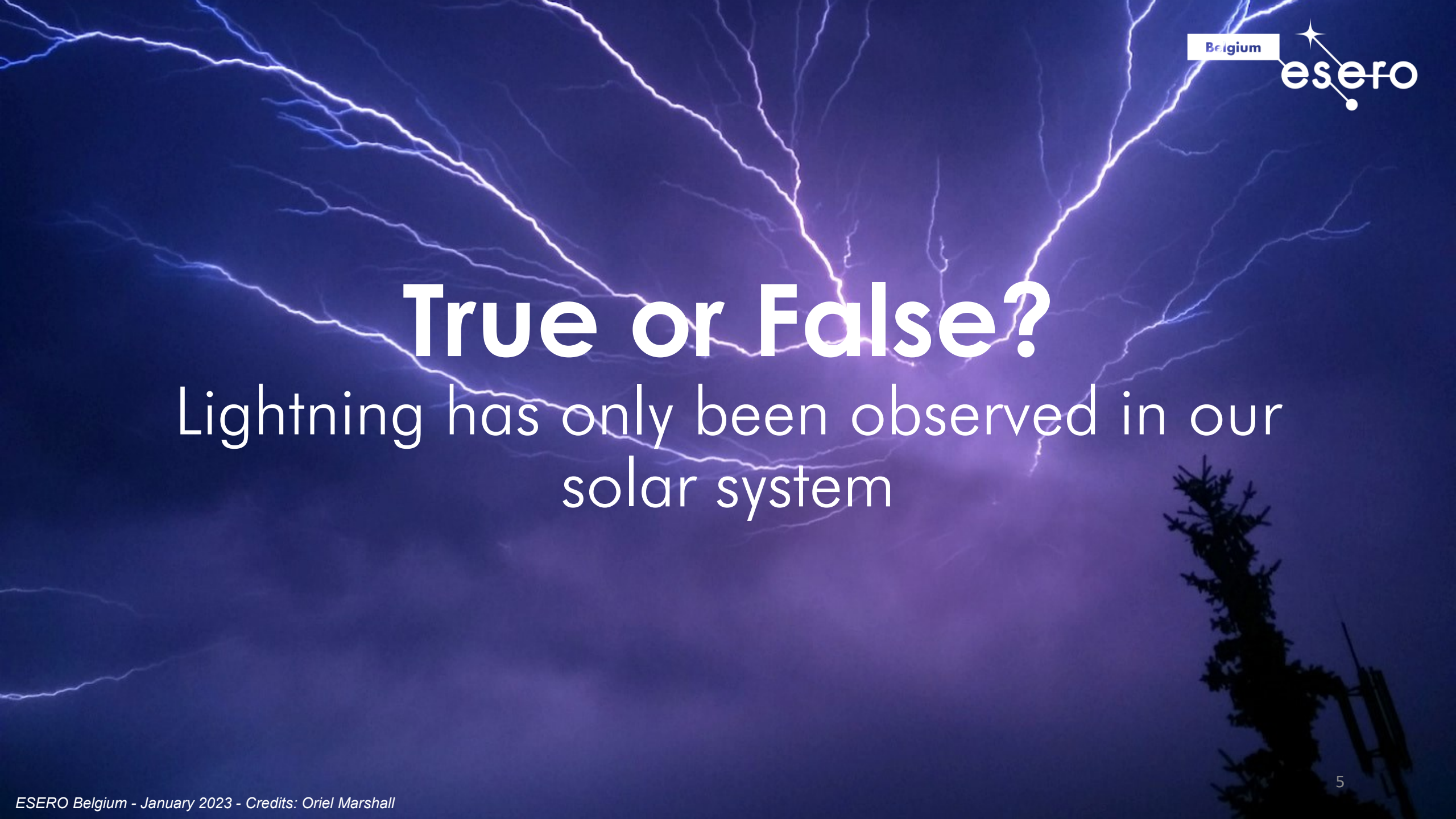


Lightning flashes on Saturn's night side in a cloud illuminated by the light from Saturn's rings. Captured by the Cassini spacecraft

Credit: NASA/JPL-Caltech/Space Science Institute/University of Iowa

An illustration of high-altitude electrical storms on Jupiter using data obtained by NASA's Juno mission.

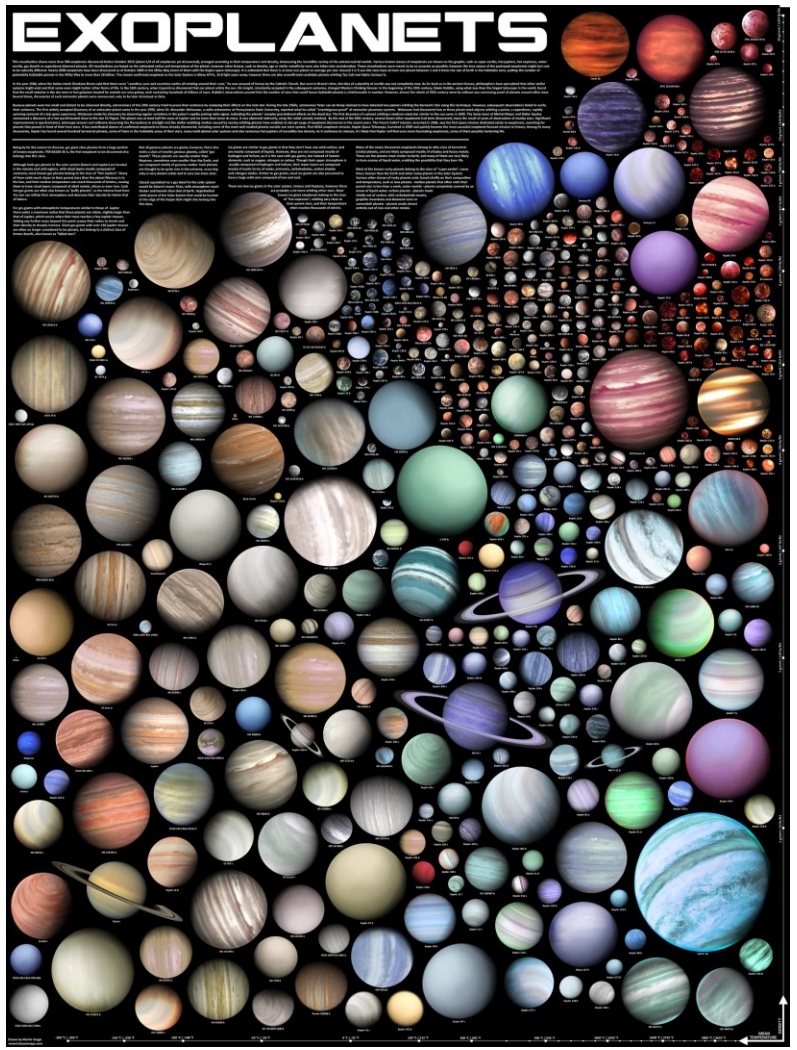
Credit: NASA/JPL-Caltech/SwRI/MSSS/Gerald Eichstädt

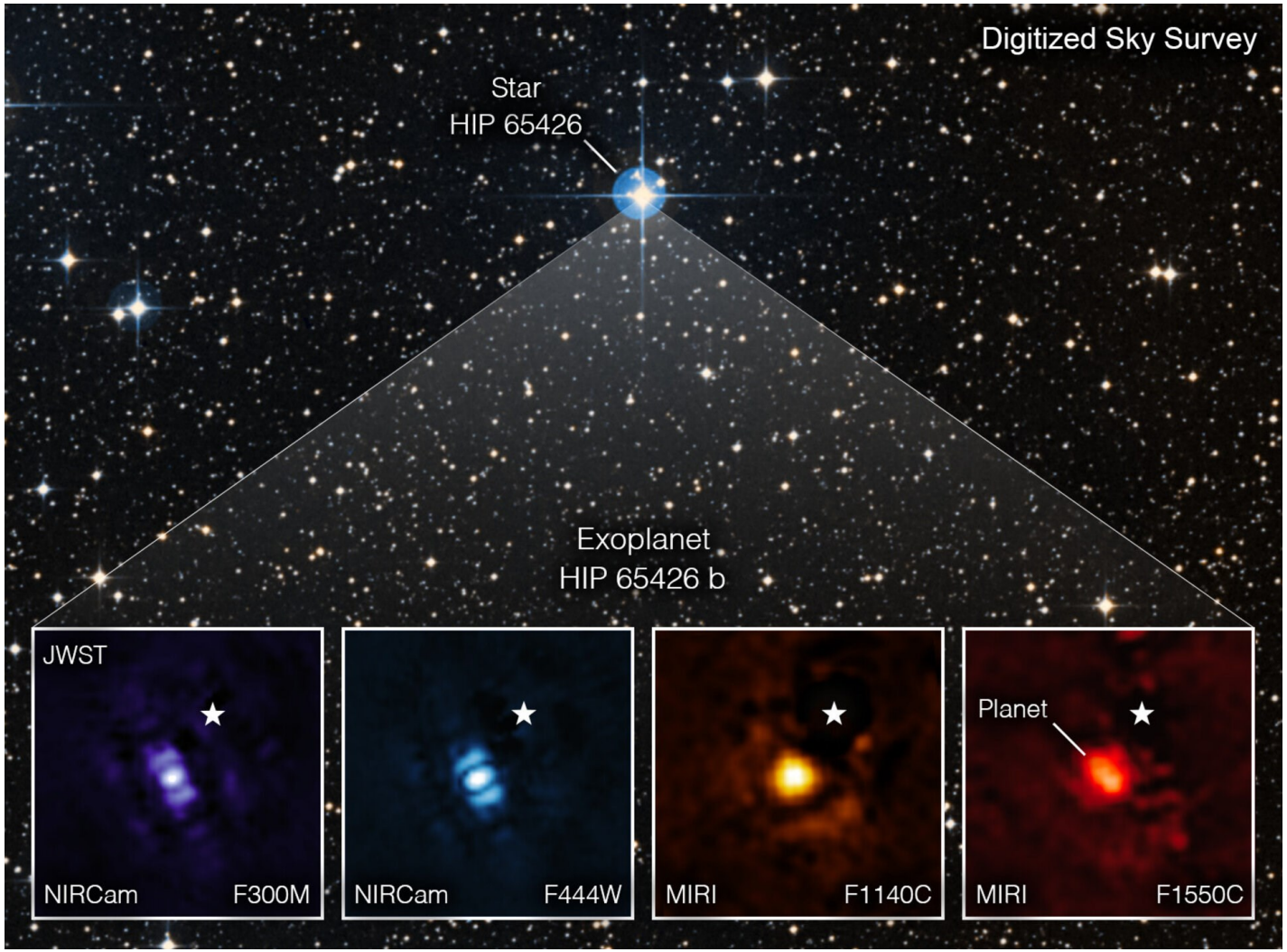


True or False?

Lightning has only been observed in our solar system

True (for now)





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

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

True or False?

Lightning can only occur in the atmosphere around a planet

False! (we think)

Lightning can occur anywhere with the correct conditions!
There are currently exoplanet scientists working on predictions and models for lightning in protoplanetary disks.

True or False?

Lightning can change the chemical composition of a planet's atmosphere

True!

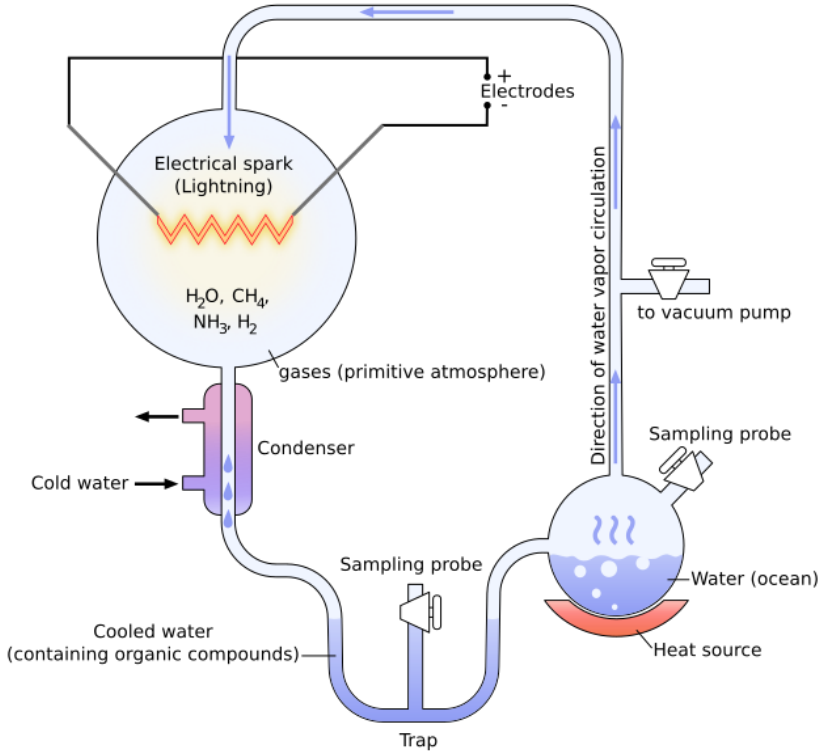
- Lightning flashes are incredibly high energy.
- This energy can heat up the atmosphere very quickly and to a very high temperature
- This heating of parts of the atmosphere can trigger chemical reactions that would not otherwise occur

True or False?

Lightning can play a role in the beginning of life on a planet

True! (we think)

- On the Early Earth lightning may have played an important role in the synthesis of prebiotic molecules.
- This means that lightning could potentially play a role in the origin of life on other planets!



The Miller-Urey experiments from the1950's.

Activity 1: Exoplanet Lightning

If astronomers do observe lightning on an exoplanet this will tell them that this planet must have the correct conditions for lightning to occur.

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

Activity 2: Demonstration

https://www.youtube.com/watch?v=sk2Uu2lygUA&ab_channel=sciencemuseumok

Activity 2: Demonstration

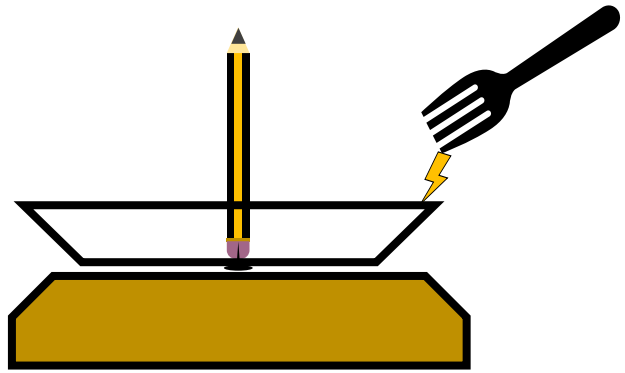
When the lightning flash occurs in this demonstration, there is an accompanying noise. What is the equivalent to this when lightning occurs in real life?

Ex 2. Sketch the experiment set up in your worksheet

Activity 3: Identifying Variables

- What are the variables in this experiment?
- How might each variable relate to a variable in 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 physical models to explore the occurrence of lightning on other planets.

Ex 4. Plan an experiment to investigate the effect of one of these variables on the lightning created.

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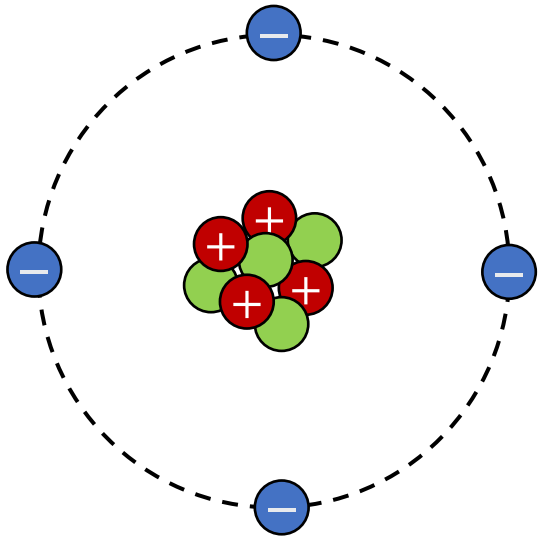
Ex 5. In a short paragraph, write up your class findings as if you are explaining it to a student in another class

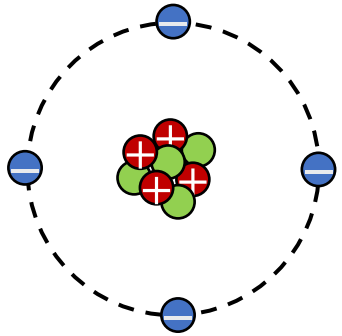


All objects are made up of atoms.

Atoms are made up of three types of particles:

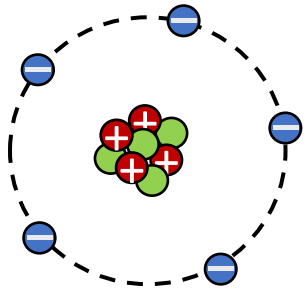
- Protons (positively charged)
- Neutrons (neutral)
- Electrons (negatively charged)

Usually, an atom will have same number of protons and electrons and so are neutrally charged.



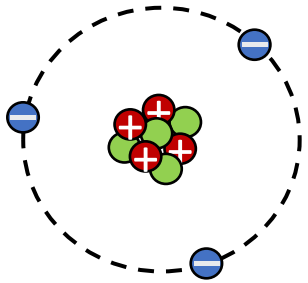
Equal number of electrons and proton **= Neutrally** charged atom

− = + => Neutral



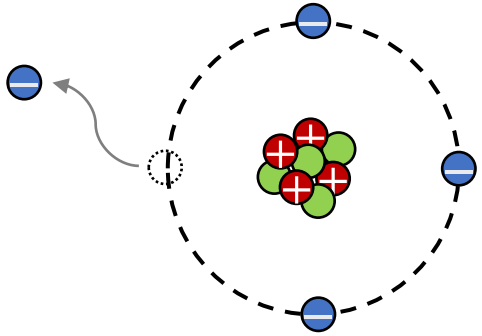
More electrons than protons **= Negatively** charged atom

− > + = −

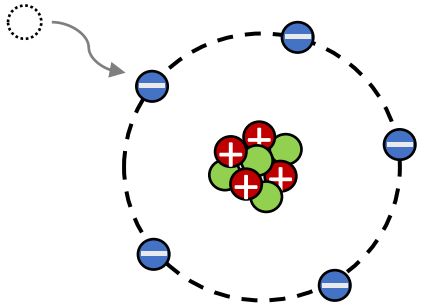


More protons than electrons **= Positively** charged atom

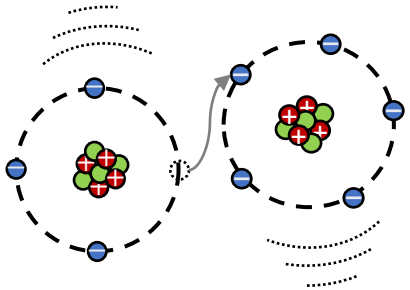
+ > − = +



Certain materials (such as wool and hair) tend to easily give up electrons.

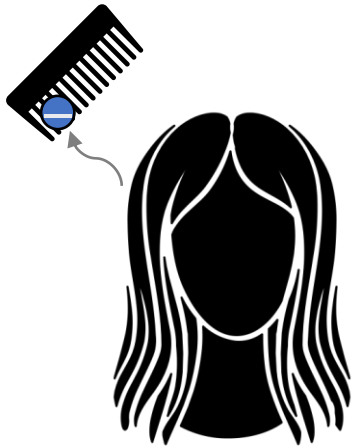


Other materials (such as polystyrene and silicone) tend to easily collect electrons.



If two of these materials are rubbed together then change is transferred from one material to the other. This is called Triboelectric charging.

You might have experienced this when taking clothes out of the dryer, or combing your hair.

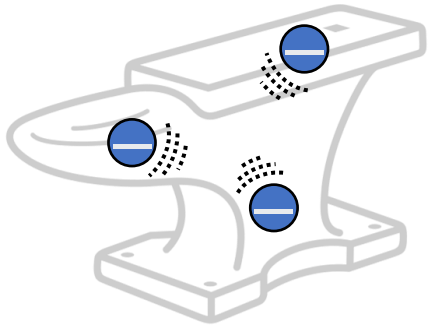


Negative charges are attracted to positive charges and visa versa.

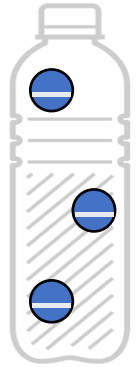
Two of the same charges will repel each other.

Conductivity

Electrical conductivity is a measurement of how easily a material allows electric current to flow through it.



Materials with a high conductivity (such as metals) are called **conductors**.
Electrical charge **moves freely** within these materials.



Materials with a low conductivity (such as plastics) are called **insulators**.
Electrical charge **does not move** within these materials.

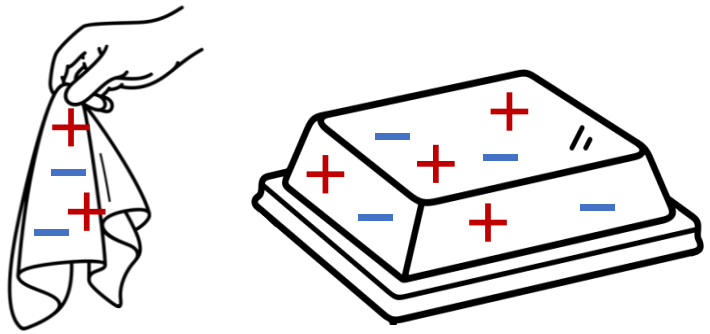
Potential difference is the electrical potential between two points.

Lightning occurs when there is a very large potential difference across a (semi)non-conductive medium (for example: air).

If the potential difference is large enough, electrons will discharge across the gap with a huge release of energy in the form of light, heat and sound. This is lightning.

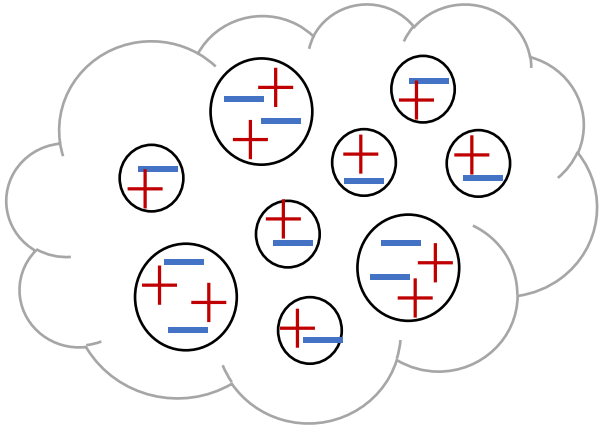
Triboelectric Charging

Experiment



All of the equipment for the experiment begins with an equal amount of negative and positive charge. This makes the items neutrally charged.

Exoplanet Clouds

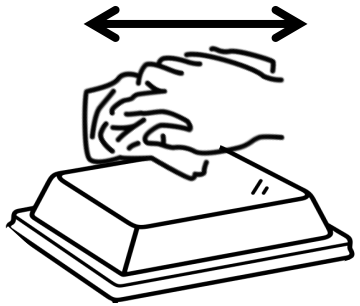


Exoplanet clouds are made up of small, light ice crystals and large, heavy, soft hail.

Each of these particles begin neutrally charged.

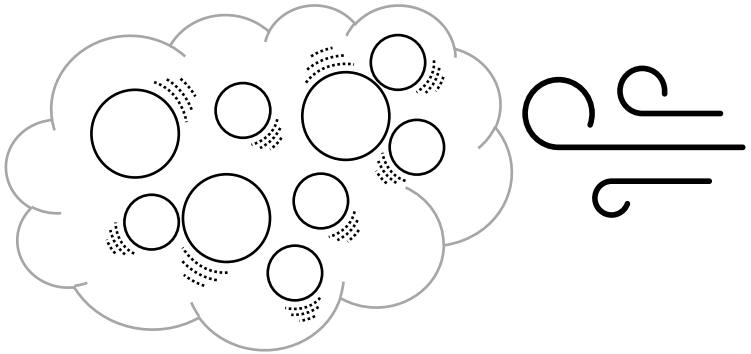
Triboelectric Charging

Experiment



Wool tends to give up electrons, polystyrene tends to collect electrons.

Exoplanet Clouds



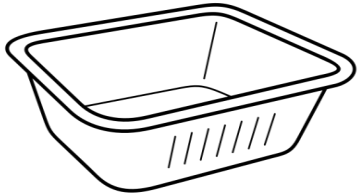
Small ice crystals tend to give up electrons, Large hail particles tend to collect electrons.

Turbulence and wind within the cloud make the particles collide together.

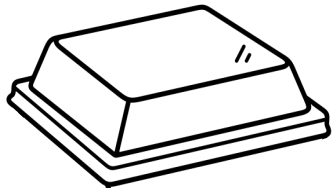
What will happen to the charge on these objects when they are rubbed together?
Ex 6.1 Draw the charge onto the diagrams in your worksheet.

Separation of Charge

Experiment



Aluminium has high conductivity



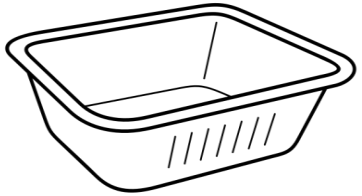
Polystyrene has low conductivity

What do you think will happen to the charges in these objects when they are brought together?

Exoplanet Clouds

Separation of Charge

Experiment



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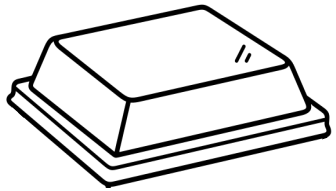

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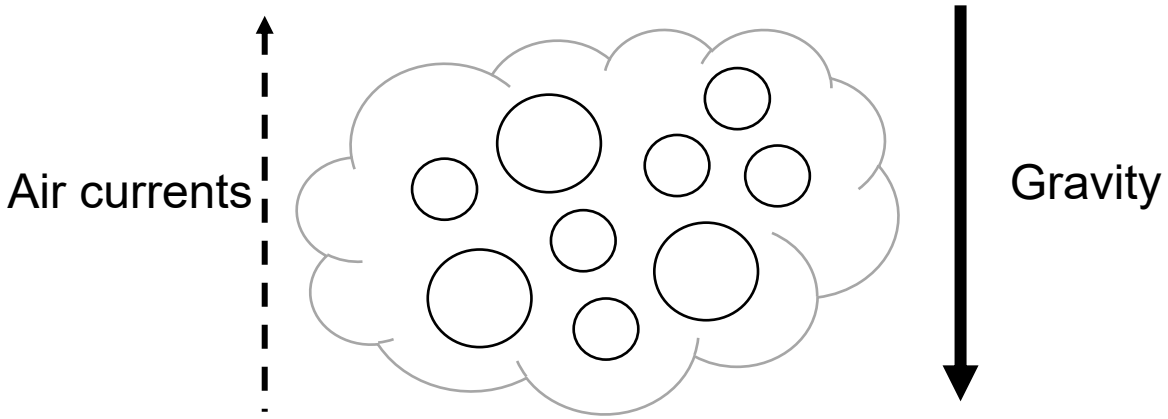
Exoplanet Clouds

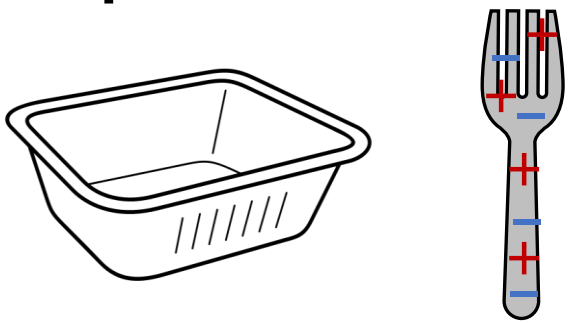


In an exoplanet atmosphere we can not bring in an external object to separate the charge within a cloud. The separation of charge instead is due to gravity and air currents.

Ex 6.2 Draw in what will happen to the charge onto the diagrams in your worksheet.

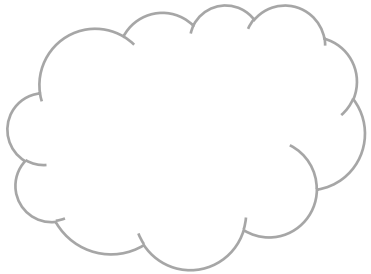
Potential Difference

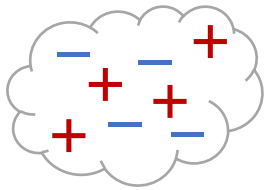
Experiment



We now bring in an additional, neutrally charge, conductive object

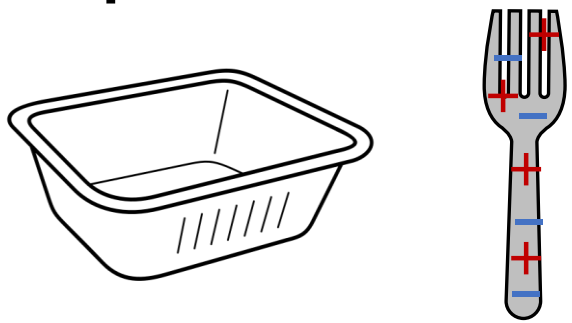
Exoplanet Clouds





Potential Difference

Experiment

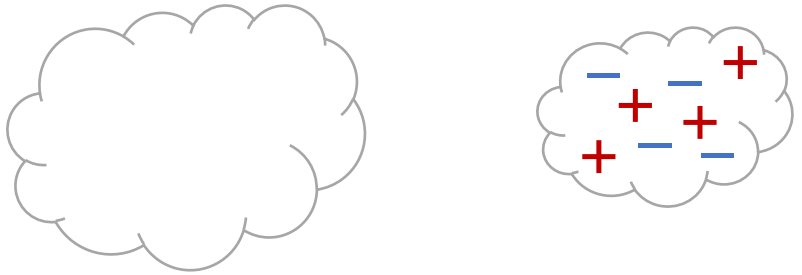


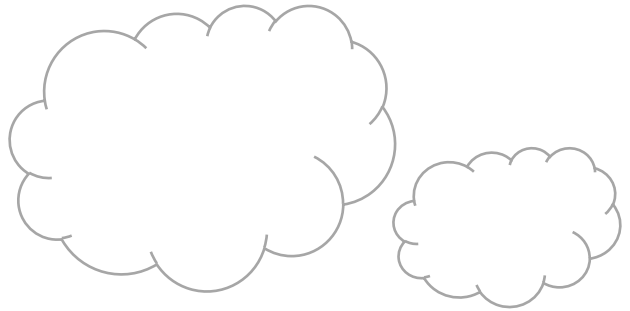
We now bring in an additional, neutrally charge, conductive object

What will happen to the charge in these objects as they are brought together?

6.4 Draw your answer in your worksheet

Exoplanet Clouds

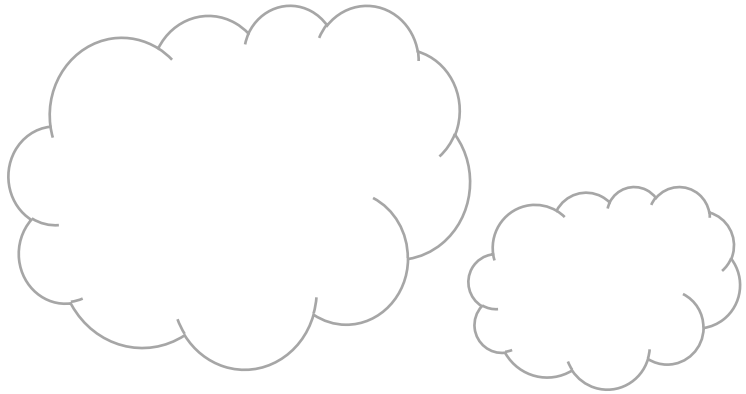




Potential Difference

Experiment

Exoplanets



Where do you think lightning would occur in both of these cases?

6.4 Draw your answer in your worksheet