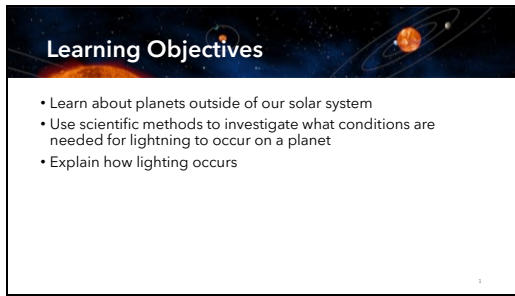


Slide 1




**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 lightning occurs

2

Slide 2



**Lightning in Space**

Lightning captured in a photograph by ESA astronaut Paolo Nespoli from on board the International Space Station. [www.esa.int/ESA\\_Multimedia](http://www.esa.int/ESA_Multimedia)

Activity 1: Introductory 'quiz' – the aim of this is to introduce the students to exoplanets, and to gauge their knowledge on the topic of exoplanets and lightning

Slide 3



**True or False?**

Lightning has only been observed on Earth

3


Slide 4

## False!

Lightning 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/MDS/Carroll Eckstrand

The slide features two images. On the left, a grid of six small images shows lightning flashes on Saturn's night side, captured by the Cassini spacecraft. On the right, a larger image shows an illustration of high-altitude electrical storms on Jupiter, based on data from NASA's Juno mission.

Slide 5

## True or False?

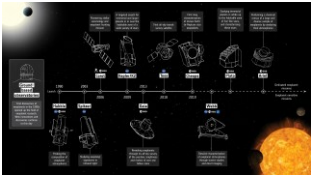
Lightning has only been observed in our solar system

The slide shows a dark, stormy sky with several bright, jagged lightning bolts striking downwards. The text is overlaid on the center of the image.

Slide 6

## True (for now)

Lightning has been predicted on planets outside of our solar system (exoplanets) and scientists are currently in the process of confirming this

A timeline diagram showing various space missions from 1990 to 2020. The missions are represented by icons and text boxes, including: 1990 (Voyager 1 & 2), 1997 (Cassini-Huygens), 2001 (Mars Global Surveyor), 2003 (Mars Express), 2004 (Mars Reconnaissance Orbiter), 2006 (Dawn), 2007 (Rosetta), 2009 (MESSENGER), 2011 (Juno), 2013 (Kepler), 2015 (New Horizons), 2016 (OSIRIS-REx), 2018 (TESS), 2019 (James Webb Space Telescope), and 2020 (Europa Clipper).

This timeline shows all the space missions that are either dedicated to observing exoplanets or that are able to observe exoplanets.  
<https://sci.esa.int/>

Slide 7



Slide 8

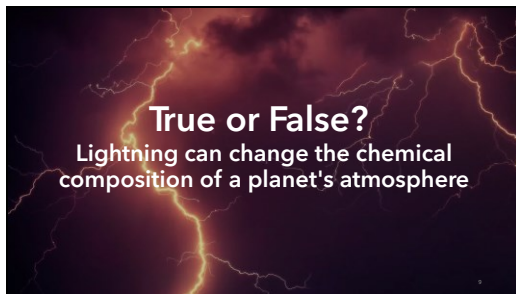
**False! (we think)**

Lightning can occur anywhere with the correct conditions! There are currently exoplanet scientists working on predictions and models for lightning in protoplanetary disks. These are disks of gas and dust that orbit stars and are where new planets are formed.

Protoplanetary Disks in the Orion Nebula  
NASA's James Webb Space Telescope (JWST)

This slide has a white background with a lightning bolt graphic at the top. It contains text and a 2x2 grid of four images showing protoplanetary disks in various colors (green, purple, blue, and orange). A small caption is at the bottom right of the grid.


Slide 9



Slide 10

**True!**

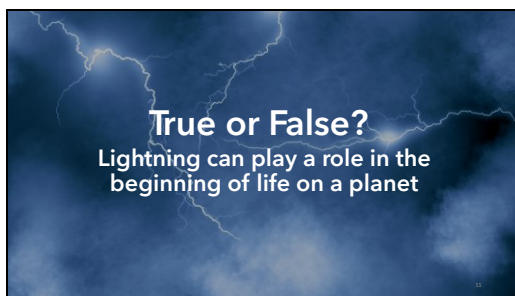
- Lightning flashes are incredibly high energy. This energy can heat up the atmosphere very quickly and to a very high temperature
- This heating of parts of the atmosphere can trigger chemical reactions that would not otherwise occur
- Lightning can significantly alter a planets atmospheric chemical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



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Slide 11

**True or False?**  
Lightning can play a role in the beginning of life on a planet

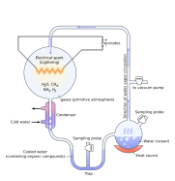


11

Slide 12

**True! (we think)**

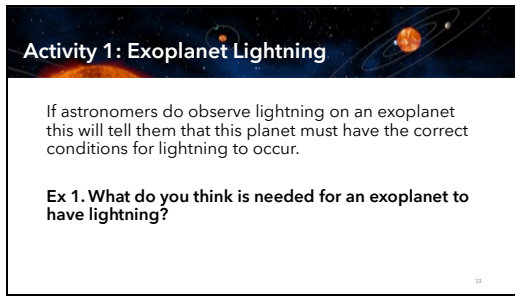
- On the Early Earth it is believed that lightning may have played an important role in the synthesis of prebiotic molecules.
- This was first demonstrated by the Miller-Urey experiments the 1950's.
- This means that lightning could potentially play a role in the origin of life on other planets!



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This is only applicable given the exact correct conditions for the planet, which would be very difficult to find!

Slide 13



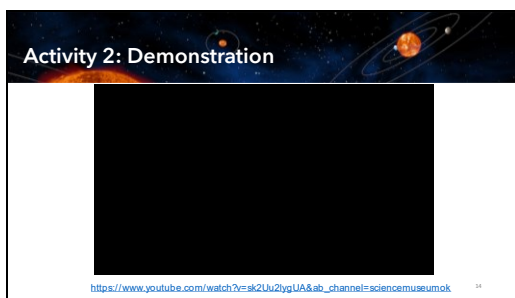
**Activity 1: Exoplanet Lightning**

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?**

This question should be answered by students in their student worksheets. This can be done either individually or using 'think, pair, share'. You may select some students to share their answers with the class. Correct answers will not be given for this question at this stage, as the question should be answered by the students through their experiments during this lesson.

Slide 14

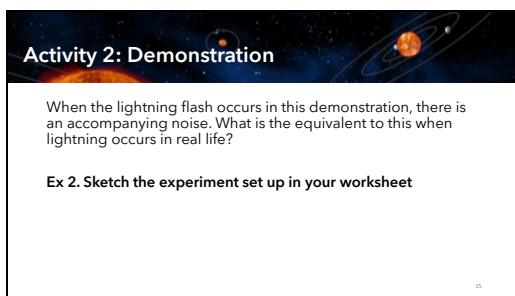


**Activity 2: Demonstration**

[https://www.youtube.com/watch?v=sk2Lu2lygUA&ab\\_channel=sciencemuseumok](https://www.youtube.com/watch?v=sk2Lu2lygUA&ab_channel=sciencemuseumok)

If playing this video from the youtube link, it is important to stop the video at 1:40 (before the scientific explanation) The demonstration shows the creation of lightning. The physics behind lightning is the same on exoplanets as it is on earth. Because we are doing the experiment on earth, we are limited to using materials that work in the conditions we have on earth, on an exoplanet many different materials and chemicals could be used.

Slide 15



**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**

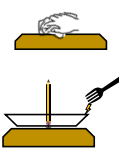
Answer: Thunder. The flash of lightning heats up the air around it so quickly that it causes a shockwave to travel through the air.

Slide 16

**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



The students should be given a few moments in groups to come up with variables. You may use **think, pair, share for this.** You will then write the variables and their equivalent in an exoplanet atmosphere up on the board. Suggested answers for this can be found in the teacher guide. Students may identify variables that are present in the demonstration that are not present in an exoplanet atmosphere and vice versa, this is because the demonstration has limitations, as many scientific models do.

Slide 17

**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.

It is suggested to schedule approximately 25 minutes for the planning and conduction of the experiments, with no more than 10 minutes of this being spent on the planning. You may wish to set a timer for this so student can plan their time accordingly.

Slide 18

**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

When each group is sharing their findings you may wish to write a few brief notes of the findings of each up on the board. At this point you may wish to point out that often in scientific experiments, the results may not align with our expectations or things may not go as expected but this is an important part of the scientific process and helps us to learn more. Science is a continuous process of questioning, testing and learning.

Slide 19

**Activity 5: Share your findings**

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

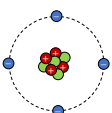
- Your hypothesis
- What you tested
- What results you got
- Did this align with your hypothesis?
- What did you learn

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

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Being able to share your findings is an important part of the scientific process. By explaining their findings to peers this will help students not only practice this skill, but also make sure they understood the content.

Slide 20



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.

20

We will now introduce some important scientific concepts. These are a common ground between earth and exoplanets.

Slide 21

Equal number of electrons and proton = **Neutrally** charged atom  
 $\ominus = \oplus \Rightarrow$  Neutral

More electrons than protons = **Negatively** charged atom  
 $\ominus > \oplus = -$

More protons than electrons = **Positively** charged atom  
 $\oplus > \ominus = +$

Slide 22

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 charge 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.

This is important for astronomers because static charge can cause lots of issues inside spacecrafts or telescopes. Static charge within the international space station can cause electrical problems which can be very dangerous!

Slide 23


Negative charges are attracted to positive charges and visa versa.

Two of the same charges will repel each other.




Slide 24

**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.

24

Conductivity is an important concept for astronomers because it helps them to choose the correct materials for any instruments.

Slide 25

**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.

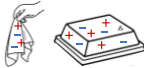


25

Slide 26

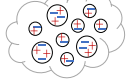
**Triboelectric Charging**

**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.


26

We will now apply what we have learned to both the experiment and what is occurring in clouds on an exoplanet.

Slide 27


### Trieboelectric 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.

Slide 28

### Separation of Charge

**Experiment**



Aluminium has  
high conductivity

Polystyrene has  
low conductivity


**Exoplanet Clouds**

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

Slide 29

### Separation of Charge


**Experiment**



Aluminium has  
high conductivity

Polystyrene has  
low conductivity

**Exoplanet Clouds**



Air currents ↑      ↓ Gravity

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.


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

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

Slide 30

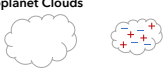
### Potential Difference

**Experiment**



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


**Exoplanet Clouds**



Slide 31


### Potential Difference

**Experiment**




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

**Exoplanet Clouds**




What will happen to the charge in these objects as they are brought together?  
6.4 Draw your answer in your worksheet




Slide 32

### Potential Difference

**Experiment**



**Exoplanets**



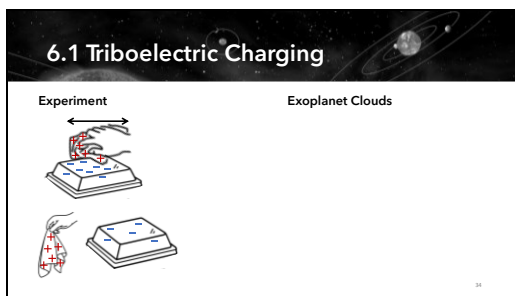
Where do you think lightning would occur in both of these cases?  
6.4 Draw your answer in your worksheet

Slide 33



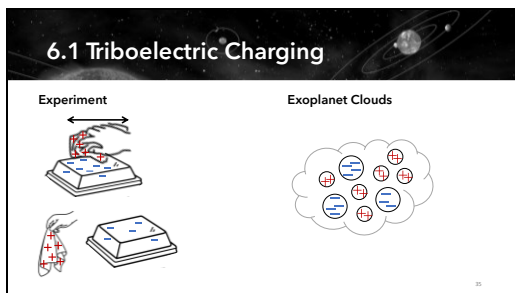
These slides may be useful to show students the answers but it is preferable to have students draw their answers in their worksheets and optionally up on the board.

Slide 34



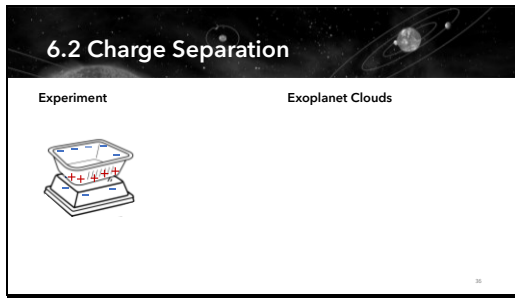
Wool tends to give up electrons, polystyrene tends to collect electrons.

Slide 35



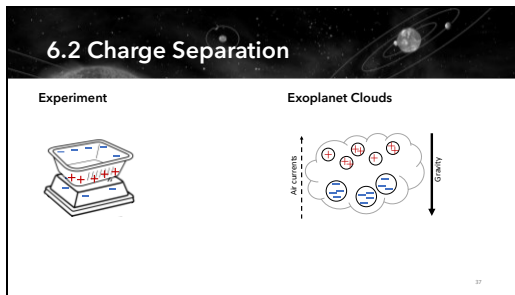
Small ice crystals tend to give up electrons, Large hail particles tend to collect electrons.

Slide 36



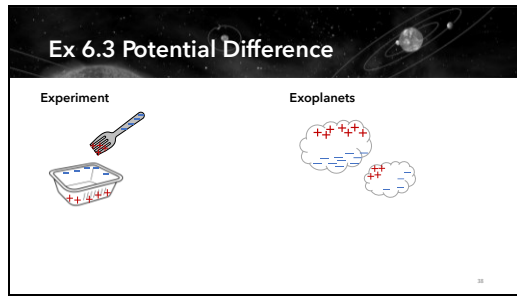
The charges in the metal tray will move because metal is a conductor. The charges in the polystyrene tray will stay where they are because plastic is an insulator. The positive charges in the metal tray will be attracted to the negative charge in the polystyrene tray, the negative charge in the metal tray will be repelled. The top of the metal tray now has a large negative charge.

Slide 37



The air currents will blow the particles up (away from the centre of the exoplanet) Gravity will pull the particles down towards the centre of the exoplanet. The lighter particles will be less effected by gravity than the heavy particles and the heavy particles will be less effected by the air currents. This results in the top of the cloud being positively charged and the bottom of the cloud being negatively charged.

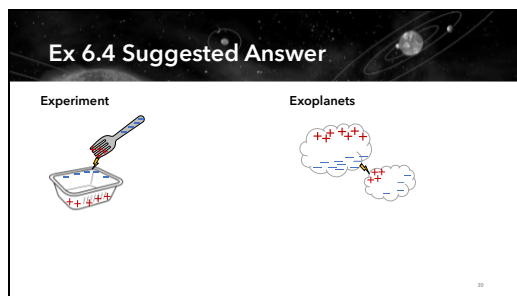
Slide 38



The external objects that are brought in are conductive, so the charge will move freely in them.

The opposite charges are attracted to each other, and like charges are repelled.

Slide 39



Lightning will occur at the closest point between the two objects.