Activity #3
How Do Atmospheres Change Over Time? The Role of Magnetosphere and Solar Wind *[Adult]*

Adapted from *The Earth as a Magnet:* http://tinyurl.com/2c6kavn; *Planetary Magnetism: How crucial is a planet's magnetic field?* Produced by the Center for Science Education at UC Berkeley's Space Sciences Laboratory, with support from NASA's MAVEN mission and written by Kyle Fricke. Unless otherwise noted, all images are courtesy of SETI Institute.

1. Introduction

In this activity, you will observe the properties of magnets and magnetic fields, and then build a model of Mars and Earth to demonstrate that Mars cannot effectively protect its atmosphere from the solar wind. You will also "Think like a scientist. Be a Scientist!"

2. Science Objectives

You will:

- apply skills learned previously about using models;
- build scale models of Earth's and Mars' magnetic fields; and
- use your new knowledge about the magnetic fields of Earth and Mars to ask questions about the ability of the solar wind to change a planet's atmosphere over time.

3. Materials

For each group of 4 to 6 Cadettes. Prepare materials for each team.

- [1] file or copier paper box lid
- [2] pieces of plain white copy paper to line inside of lid
- [1] 5.1 cm (2 in) diameter paper cup cut off about 1.25 cm (0.50 in) to simulate "Mars." Martian diameter is 52% of Earth's.
- [1] 8.9 to 10.2 cm (3.5 to 4 in) diameter lid or bottom of oatmeal container sufficient to cover 7.6 cm (3 in) bar magnet to simulate "Earth" (see image in Cadette Activity)
- Magnets: 7.6 cm (3 in) bar magnet (Do not use neodymium or rare earth magnets. Handle with care — don't drop or bump.); view bar magnets on Amazon.com: http://tinyurl.com/kjyfa85
- [1] small piece of flexible magnetic sheet (use free advertisements, calendars that are attracted to metallic surfaces); view flexible magnetic sheet on Amazon.com: http://tinyurl.com/lwkrsb3
- iron filings in "salt" shaker container; view iron filings on Amazon.com: http://tinyurl.com/lo832wk
- RSVP 12-piece mini salt and pepper shaker set with rack (for iron filings); view mini shaker set on Amazon.com: http://tinyurl.com/m275z7h. Use one shaker for each group.
- small envelope or paper cup half-filled with paper hole punches
- flexible straws — unique color for each team member
- [1] quart-sized Ziploc® bag (to hold magnets and for cleanup)
- transparent tape for wrapping bar magnets
- small paint brush for cleanup

4. Safety Precautions

4.1. Iron filings can be sharp and irritating if they get under fingernails. Do not handle filings with your bare hands. Keep iron filings away from your eyes, nose, and mouth.

4.2. Do not inhale iron filings through straw. ***Take the straw out of your mouth when you inhale.***

Advance Preparation

a. Wrap, trim, and tape plastic wrap or baggie to cover bar magnets to simplify cleaning the iron filings from the magnets at the end of the experiment.

b. Cut off about 1.3 cm (0.50 in) of the bottom of a 2.5 cm (1 in) diameter paper or plastic cup. Label: **Mars.**

c. Cut off about 1.3 cm (0.50 in) of the bottom of a cardboard oatmeal container or lid. Label: **Earth.**

d. Cut several pea-sized or small pieces of flexible magnetic material from the magnet sheet.

e. Using a pencil, poke a straw-sized hole in the short end of the box lid to accommodate the straw.

f. Fill as many of the mini-shakers as you need with the iron filings. Use a funnel made from paper or plastic if handy to help transfer the filings. Iron filings are a mechanical irritant and should be handled carefully.

g. After you fill the mini-shakers with iron filings, cut a 5 x 5 cm (1.2 x 1.2 in) square of plastic from a Ziploc® bag. Using a pen, poke a hole all the way through the plastic and place it over the opening to the glass shaker and then tightly screw the lid on. The purpose of the plastic is to act as a flow restrictor to the tiny iron filings — otherwise you will have a mess!

h. Optional: assign jobs from "Cooperative Group Responsibilities" (see separate pdf document).

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5. Preparation for Activity #3

5.1. Read together *Background Escape of the Atmospheres!* (see page 7) Discuss and answer the following about the images:

5.1.1. Which molecule would more easily escape? Why?

Molecule #1, hydrogen, because it is the smallest/lightest; and gravity is less effective.

5.1.2. Which planet do you think has greater mass? Which planet holds onto an atmosphere more easily?

Based on the image, Earth is larger, therefore has more mass. Based on gravity, Earth would have an easier job of holding onto its atmosphere.

5.1.3. Which planet is least likely to have an atmosphere? Are you surprised that the answer is NOT Venus? Why?

From the information provided in the table and the paragraph, Venus has the highest temperature and is closest to our Sun of the three planets listed. However, Venus has a dense atmosphere now and Mars has a very thin atmosphere. More factors must be involved than distance from the Sun and temperature.

5.1.4. How effective do you think Mars' magnetosphere is compared to Earth's in protecting its atmosphere?

Mars' magnetosphere is relatively ineffective compared to Earth's and therefore is not able to protect the Martian atmosphere.

5.2. Watch this video: [*Raging Solar Wind* (BBC): http://www.seti.org/ggtm](http://www.seti.org/ggtm)

Video Note: This video shows how scientists are using their understanding of solar wind and Mars' distance from the Sun to learn about the history of Mars' atmosphere. Earth's magnetic field is vital for keeping our atmosphere in place. Without a strong magnetosphere, about a third of Mars' atmosphere has been stripped away by the solar wind.

6. Explore

Equipment Manager: check that the necessary materials are in the box.

6.1. Place 1 or 2 sheets of clean white paper inside a copier paper box lid. Place a wrapped bar magnet lengthwise in the center of the paper (see top right image).

6.2. Carefully sprinkle some iron filings over the entire area until you see a pattern develop. Do not remove the filings.

6.2.1. Observe the pattern and briefly sketch it in your Data Sheet. **The lines of iron filings help you see the magnetic field lines produced by the magnets. Where the lines are closest together, the magnetic force is strongest.**

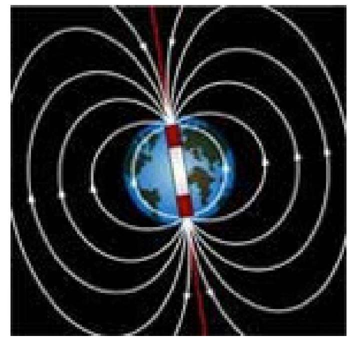


Image credit: NASA

6.2.2. On your sketch, **mark** where the magnet is strongest.

Lines should be close together near the magnet.

6.2.3. Compare the bar magnet lines and the image of Earth (second from top), demonstrating magnetic field lines in the north and south directions.

Does the image look similar to your sketch?

Yes.

6.3. Use the labeled Earth model and cover the bar magnet. Sprinkle more iron filings over the Earth model and the field lines so that they are very apparent (see second image from bottom).

6.4. Add about 1 teaspoon of paper hole punches about 13 cm (5 in) from "Earth" and the end of the magnet.

6.5. Using a straw, ***gently blow*** the hole punches straight towards "Earth" for about 10 seconds and observe what happens to the field lines and hole punches. Note how the straw is held so the bent part is close to the pile of paper hole punches (see bottom right image). Where do the punches end up? What happens to the pattern of iron filing lines? Are field lines disturbed? **Your breath represents the solar wind. The hole punches are tracers for what happens to the solar wind when it reaches "Earth." The iron filings represent the Earth's magnetosphere.**

6.5.1. What happened to the "solar wind" as it reached "Earth"?

"Solar wind" (i.e., hole punches) were deflected away from the model Earth.

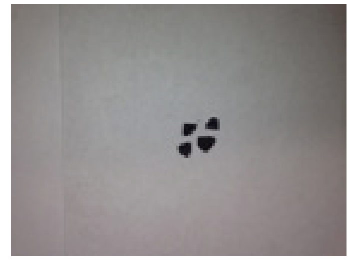
6.5.2. Were the iron filings representing the magnetosphere disturbed by the "solar wind"?

If the Cadettes blew gently the filings were not disturbed.

6.5.3. Make a brief sketch on your Data Sheet page of the iron filings and hole punches after the "solar wind."

6.6. Pick up the Earth model and bar magnet. Return them to the Ziploc® bag. Carefully tilt the box lid so that iron filings and hole punches slide over to the corner of the box.

6.7. Select 4 or 5 pea-sized pieces of flexible magnetics. Group them so they are in a 2.5 cm (1 in) circle on the white paper in the box lid (see top right image).



6.8. Sprinkle a small amount of additional iron filings over the magnets. What does this pattern of iron filings look like? Does Mars show a pattern similar to Earth's? Briefly sketch what you observe on your Data Sheet.

Mars' pattern will not look like Earth's. The small pea-sized magnets will have a disorganized pattern and will not demonstrate the magnetic field lines observed with the bar magnet.

6.9. Leave the iron filings in place. Cover the flexible magnets with the labeled Mars model (see second image from top).

6.9.1. Based on your observations in Step 6.5, **predict** what might happen when you gently blow hole punches at your Mars model.

With the disorganized magnetic field lines, the hole punches should travel directly into Mars' model and not be deflected by the iron filings.

6.9.2. Will the iron filings remain close by? Where will the hole punches go?

Iron filings will be more easily disrupted by the hole punches.

6.9.3. Does Mars have a magnetosphere that behaves like Earth's magnetosphere? Discuss your predictions with your team.

Mars' magnetosphere does not appear to have an organized global magnetic field but has many random less effective surface magnetic fields.

6.10. Now do it. Put a small pile of hole punches about 13 cm (5 in) from your Mars model. Using a straw, ***gently blow*** toward Mars for about 10 seconds.

6.10.1. Was your **prediction** correct? What happened to the iron filings and the hole punches?

Check Cadette outcomes.

6.10.2. Sketch in your Data Sheet the iron filings and hole punches after the "solar wind."

6.10.3. How do the results of this Mars model differ from the Earth model when you blew the hole punches?

Hole punches were not deflected by the iron filings which were also moved.

6.10.4. What does this tell you about Mars' magnetosphere? Is it weak or strong?

Mars' magnetosphere appears weak when compared to Earth's because the hole punches and breath moved the filings.

6.10.5. Do you think Mars' magnetosphere is able to adequately protect its atmosphere?

No.

6.11. The bottom-right image depicts Mars' magnetic fields (circled in white) on the surface rather than coming from the core as observed with Earth's.

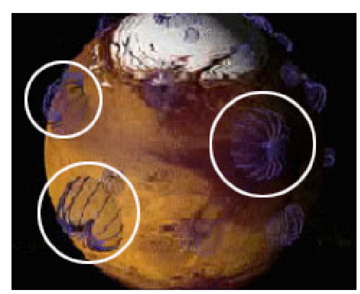


Image credit: NASA JPL

7. Cleanup

7.1. Pick up the Mars model and the flexible magnets. Put them in the Ziploc® bag along with the Earth model and the bar magnet. Use the small paint brush to sweep the hole punches and iron filings into a pile. Pick up the paper and form a funnel. Put the Ziploc® bag in the lid of the box and dump the iron filings and punches inside.

7.2. Tightly close the bag and return it to your equipment box.

8. Data Sheet

Go to Work

Sketch pattern of magnet + iron filings: Can you mark where magnet is strongest?

Earth-like	Mars-like

Complete the table below comparing Mars and Earth following experiment directions

Question	Earth?	Mars?
Make a sketch of iron filings and hole punches after solar wind:		

Questions to think about and to further explore.

8.1. How might a magnetosphere protect a planet's atmosphere?

A magnetosphere acts as a shield to keep the solar wind from damaging the atmosphere by stripping away some of the gas molecules.

8.2. What happens when the solar wind strikes a magnetosphere? What might happen if a planet has a magnetosphere that is weak or has holes in it?

Solar wind can be deflected by the magnetosphere. If the magnetosphere is weak, then the solar wind can strip away parts of the atmosphere.

8.3. Can an atmosphere be changed by the solar wind?

Yes.

9. Connection to the Leadership Journey *Breathe. It's Your Planet — Love It!*

Add to your Air Log.

Activity #3: BACKGROUND *Escape of the Atmospheres!*

<table>
<tr><th>Why do gases leave the scene?</th><th>Evidence</th></tr>
<tr><td>

a. Atmosphere composition:

Some molecules of gas are small and lightweight, and they can more easily get away.

Which molecule would most easily escape?

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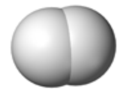
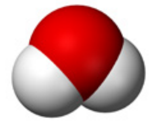
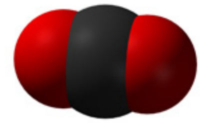


#1 hydrogen



#2 water



#3 carbon dioxide

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b. Planetary mass:

Gravity is a force of attraction that acts between all objects with mass, including between atmospheric gases and planets.

If a planet has a higher mass, it has stronger gravity. This gravity makes it harder for molecules to get away — to reach "escape velocity."

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Earth vs. Mars

Which planet do you think has greater mass?

Which planet do you predict would do a better job of "holding onto" an atmosphere?

Image credit: NASA

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c. Distance from the Sun:

Think about Activity #1 Scale Model of the Solar System — where were Venus, Earth, Mars, and the Sun relative to each other?

A planet closer to the Sun has a hotter atmosphere, with more molecules moving faster and, therefore, more likely to escape.

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Which planet is least likely to have an atmosphere?**

<table>
<tr><th>Planet</th><th>Distance from Sun</th><th>High Surface Temp.</th></tr>
<tr><td>Mars</td><td>228,000,000 km</td><td>20°C</td></tr>
<tr><td>Earth</td><td>150,000,000 km</td><td>58°C</td></tr>
<tr><td>Venus</td><td>108,000,000 km</td><td>465°C</td></tr>
</table>

** Predict: **Venus**. Evidence shows **Mars** has very little atmosphere. **Clearly factors other than distance are involved too.**

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d. Solar wind:

The solar wind flows in all directions and blasts every planet in its way. Some planets have a way to protect their atmospheres. They generate a magnetic field from their molten iron core that acts like a shield. Scientists call the region surrounding Earth where its magnetic field is located, the **magnetosphere**. Not all planets have a strong magnetosphere and that may cause their atmosphere to be more open to attack by the solar wind.

How effective do you think Mars' magnetosphere is compared to Earth's in protecting its atmosphere?

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Earth's Magnetosphere and Solar Wind (drawing)

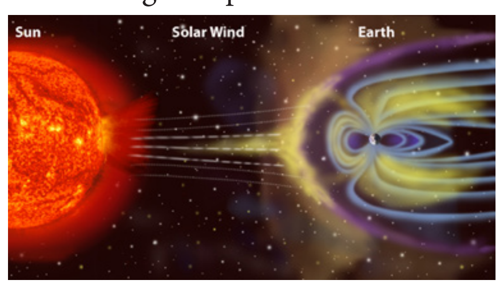
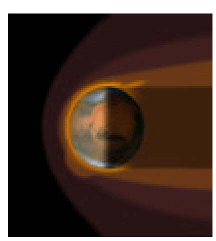


Image credit: NASA



Artist's conception of Mars' magnetosphere

Image credit: ESA

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Other Factors:

Planets lose atmosphere to meteorite impacts and to the capture of gas molecules into rocks.

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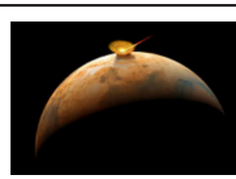

Meteorite impact on Mars (artist's conception)

Image credit: NASA

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