

# Eruption Plumes of Io

## Extraterrestrial volcanism

### Welcome to Io

🖼️ Open the **Io** image.

Io is the innermost Galilean satellite of Jupiter. It is slightly larger than Earth's Moon. The densities of the Moon and Io are nearly the same, indicating that they are both made of rocky material. However, the Moon is geologically "dead", while Io is the most volcanically active body in the Solar System.

Io is caught in a gravitational tug-of-war between Jupiter and its other moons. As Io orbits Jupiter, its distance from the planet changes. Io is flexed (stretched) in different directions by the changing tidal forces. The friction created by this flexing produces enough heat to keep parts of Io's interior molten.

At first, the Voyager scientists processed images of Io to bring out surface detail. They were delighted to discover volcanic cones and flows. These signs of recent volcanic activity made headlines around the world.

1. Describe any evidence of active volcanism you see on the surface.

🖼️ Open the **Prometheus** image.

One of the images showed a large, unexpected bubble-like feature above Io's surface. Further examination revealed that the cameras had caught a volcano in the act of erupting. In all, scientists discovered nine active volcanoes on Io. In this activity, you'll measure and study these plumes.

- 🖼️ Adjust the brightness and the contrast of the image to show the surface features as clearly as possible.
- 🖼️ Experiment with different color tables to see which one best shows the structure of the plume.
- 🖼️ Drag the  $\pm$  tool up and down in the **LUT** window. This will help you to visualize the plume material erupting.

Based on the camera's distance from Io, scientists know that the width of each pixel in the image represents a distance of 4.16 km. This scale has been set for you.

- 🖼️ Use the  $\backslash$  to measure the maximum height of the plume (named Prometheus). Magnifying the plume using the  $\times$  tool will make it easier to measure.
2. Record the height you measured for Prometheus.
  3. Use the plume height you measured to calculate the ejection velocity of the material that forms Prometheus. (Remember to convert to meters!)
  4. Prometheus is actually  $5^\circ$  in front of Io's limb instead of right on the edge. Would the actual height of the plume be greater than or less than your measured height? Why?
  5. The true height of Prometheus, corrected for limb geometry, is 77 km. Calculate the ejection velocity again, using the actual height.
  6. Commercial jets fly at about 500 miles per hour. Compare this value to the ejection velocity of the plume material. (Convert units as necessary.)

🔧 File/Open...

🔧 Use the **B** and **C** controls in the **Map** window to adjust the brightness and contrast.

🔧 Options/Color Tables ▶

🔧 Analyze/Measure, Analyze/Show Results

### Ejection velocity

$$v = \sqrt{2gh}$$

$v$  = ejection velocity (m/sec)  
 $g$  = surface gravity (m/sec<sup>2</sup>)  
 $h$  = plume height (m)

• The average surface gravity for Io = 1.79 m/sec<sup>2</sup>.

## Pele

🖼️ Open **the Pele image**.

This image of Io was taken through an ultraviolet filter. It shows Pele, the largest volcanic plume observed on Io.

🖼️ Enhance the image to discover the plume for yourself. Experiment with the contrast and/or color tables to get the best view of the entire plume.

7. The scale of this image has been set to 7.5 km/pixel. Measure the height of Pele and determine the ejection velocity of the volcanic material for this plume.
8. Measure the width of the plume and calculate the total area covered by the fallout from the plume.

## Loki

🖼️ Open **Loki 1**. This is another eruption area, viewed from above.

🖼️ Adjust the brightness and contrast for the clearest view of the area.

Loki is the site of a fissure eruption on Io. It is a long, straight eruption vent with plumes at each end. The fan-shaped, hazy, dark material on the left end of the fissure is Plume 2. Plume 9 is the smaller, less obvious dark area at the right end. Below the fissure, the dark horseshoe-shaped feature is possibly a lake of molten sulfur with solid “sulfurbergs” floating in it.

🖼️ Open **Loki 2** and **Loki 3**.

These images show Loki’s plumes from another angle, above Io’s limb. Voyager 1 took **Loki 2** in March 1979. **Loki 3** was taken about 4 months later by Voyager 2. The viewing angle and scale are *not* the same for each image.

🖼️ Scale and rotate the images to the same size and orientation so that you can compare them more easily.

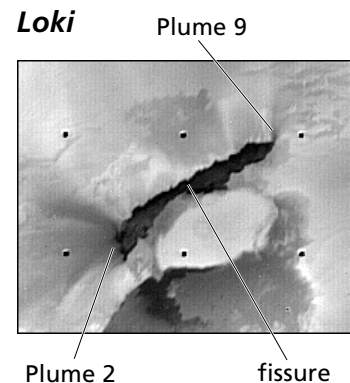
🖼️ Adjust the brightness and contrast of both images to view and compare the plumes, seen above Io’s limb.

9. Describe any changes in the size of each plume between the two Voyager encounters.
10. Do you think these changes are due to differences in *ejection velocity* or changes in the *amount of material erupted*? Why?

## More exploration

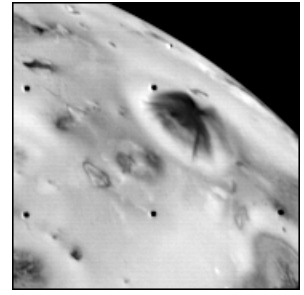
- If you have other Voyager images of Io available, look for more plumes.
- The activity **Io Physics** covers the behavior of the plumes in more detail.

- Area of circle =  $\pi R^2$



### 🔧 Options/Scale and Rotate...

- Scale **Loki 2** by a factor of **0.52** (horizontal and vertical), with **0°** rotation. Scale **Loki 3** by a factor of **1.4** and rotate it **-123°**. For best results, set **☑ Bilinear** and check **☑ New Window**.



# Teaching Notes

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## Extraterrestrial volcanism

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### Subjects

- Earth & Space Science
- Physics

### Topics

- Volcanology
- Ballistics
- Comparative geology

### Goal

The student will develop a basic understanding of the cause, distribution, and dynamics of volcanic features on Jupiter's moon Io.

### Science Objectives

The student will:

- locate and identify volcanic features on Io.
- calculate ejection velocities of volcanic plumes.
- compare and contrast volcanic features over time and location.

### Image Processing Skills

- Enhancing images
- Measuring
- Labeling features
- Scaling and rotating

### Background

This activity is most valuable after students have been introduced to the outer planets and their satellites. Basic algebra is required for calculations.

### Notes

The full equation for ejection velocity is shown at the right. It can be simplified to  $v = \sqrt{2gh}$  because the ejection angle for the highest plume material is approximately  $90^\circ$ , and  $\sin^2 90^\circ = 1$ .

### Acknowledgments

Activity developed by Robert Strom, LuAnn Dahlman, and Larry Kendall, Image Processing for Teaching Program, University of Arizona, Tucson, Arizona

Images courtesy of NASA

### References

Strom, R. G. & N. M. Schneider (1982) Volcanic Eruption Plumes on Io, *Satellites of Jupiter*, David Morrison, ed. University of Arizona Press: Tucson.

### Suggested Grades

K	1	2	3	4	5	6	7	8	9	10	11	12	C

### IP Skill Level

Novice	Expert

### Ejection velocity

$$v = \frac{\sqrt{2gh}}{\sin^2 \theta}$$

- v = ejection velocity (m/sec)
- g = surface gravity (m/sec<sup>2</sup>)
- h = plume height (m)
- θ = ejection angle (°)

## Answers

- Answers will vary. Surface coloration, circular features, absence of craters all suggest volcanic or other surface processes.
- Height of Prometheus  $\approx 70\text{--}85$  km
- $v = \sqrt{2(1.79\text{ m/s}^2)(70\text{ km})(\frac{1000\text{ m}}{\text{km}})} = 500\text{ m/s}$
- The actual height of the plume would be greater than that measured, because it is being viewed at a slightly oblique angle.
- $v = \sqrt{2(1.79\text{ m/s}^2)(77\text{ km})(\frac{1000\text{ m}}{\text{km}})} = 525\text{ m/s}$
- $\frac{500\text{ miles}}{1\text{ hour}} \times \frac{1585\text{ meters}}{1\text{ mile}} \times \frac{1\text{ hour}}{3600\text{ sec}} = 220\text{ m/s}$   
The speed of commercial jets is less than half the ejection velocity of Io plume material.
- Height  $\approx 260$  km,  $v = \sqrt{2gh} = \sqrt{2(1.79\text{ m/s}^2)(260,000\text{ m})} \approx 965\text{ m/s}$
- Diameter  $\approx 1100$  km, so Area  $= \pi R^2 = \pi(550\text{ km})^2 \approx 950,334\text{ km}^2$ .
- Answers will vary. Overall, the plumes appear to have increased in size over time. Specifically, Plume 9 appears to have increased relative to plume 2 since the first image was taken.
- Answers will vary. Look for reasonable arguments.