National Aeronautics and
Space Administration

ART & THE COSMIC CONNECTION

Elements of Art Inspire Planetary Image Analysis

Created by Monica & Tyler Aiello, Artists & Educators
for NASA's Discovery and New Frontiers Programs

Cool new images arrive from NASA missions to planets, asteroids, comets, moons. What do they tell us? Using the elements of art—shape, line, color, texture, value—make sense of what you see, honing observation skills and inspiring questions. Learners of all ages create a beautiful piece of art while learning to recognize the geology on planetary surfaces. We start with what we know here on Earth and use that awareness to help us interpret features on distant objects in the solar system. *Art & the Comic Connection* offers a terrific bridge between Earth and Space Science, as well as a wonderful dive into the potential of science to inspire art—and art to empower science!

PROGRAM OVERVIEW

For the past three decades, NASA has sent many space missions to the planets, moons and small bodies of our solar system. Spacecraft have acted as robotic explorers, capturing images of mysterious alien landscapes using a range of instruments: spectrometers, gamma ray neutron detectors, cameras. These pictures are studied using a variety of techniques including visual analysis, or "looking to understand." Similarly, visual artists depend on their sense of sight to guide their creativity. Both artists and scientists are keen observers of the natural world and engage in creative problem solving.

Artists utilize a system of concepts to make sense of visual information called the elements of art—line, shape, color, value, and texture. Planetary scientists utilize analogous concepts, and the elements of art can be a valuable tool in planetary image analysis. Fusing art and science education proves an exciting and effective method for inspiring students to explore both disciplines.

PROGRAM FEATURES:

Flexible, can be scaled for K-12 students and informal education settings of all kinds.

***Art & the Cosmic Connection* PowerPoint Presentation**

- Easy to follow presentation notes and science notes for expanded content

- Pastel Art Activity to engage students and reinforce concepts

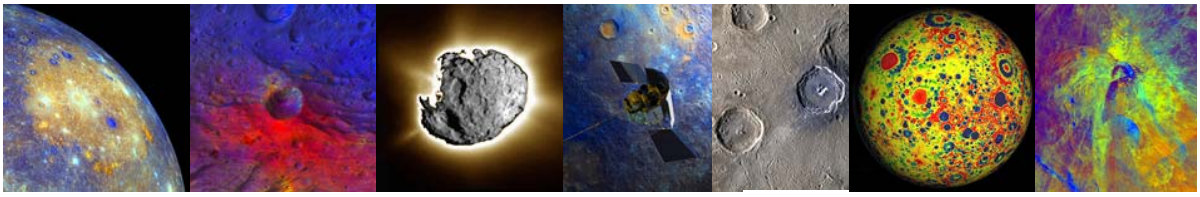
- Beautiful and inspiring NASA images you can print

- **NASA images correlate with current and recent missions to highlight space exploration**
- **Downloadable from the NASA Discovery Program website**

- Program can be a one day or two day activity

-Works with both science and art curricula, providing opportunities for cross-curricular collaboration

-Curriculum has proven success with both youth and adults via schools, universities and museums



Courtesy NASA/JPL

PRESENTATION + ART ACTIVITY

Art & the Cosmic Connection is a 2-part interdisciplinary program developed by artists and educators Monica & Tyler Aiello. Learn more about their work at http://www.studioaiello.net. Designed to engage students in space science education by becoming artist explorers, the project incorporates the use of the elements of art as a tool to investigate and interpret the mysterious surfaces of our celestial neighbors. Students learn to analyze images of planets and smaller bodies such as moons, comets and asteroids with basic art concepts which parallel scientific practice. The project includes a PowerPoint presentation and pastel art activity which teachers can incorporate into their classroom curriculum or out-of-school time program. The project is scalable for different grade levels and blends artistic concepts with the investigation of planetary studies and storytelling. Utilizing art-making as a vehicle for scientific inquiry both inspires and engages students—preparing them for a more rigorous exploration of space science and art theory, while gaining a broader perspective of their own planet, Earth.

MATERIALS & SUPPLIES

- **PowerPoint presentation**
- **NASA image prints**
- **Artist drawing paper**
- **Soft pastels or other drawing media**
- **Gummy erasers**
- **Hand wipes**
- **Q tips**
- **Fixative, either artists' or hair spray (prone to wrinkling the paper) (optional but very helpful)**

LEARNING OBJECTIVES

Space Science

- Explore the basic structure of the solar system
- Appreciate the diverse planets and small bodies within the solar system, including moons, dwarf planets, asteroids, comets, and Kuiper Belt Objects (KBOs are similar to main asteroid belt objects, beyond the orbit of Neptune)
- Introduce current and recent NASA space missions
- Appreciate the concept of remote sensing and how it is used in scientific research
- Apply the Elements of Art (shape, line, color, value, texture) to planetary image analysis and learn how they can be used to recognize geologic processes in Earth science
- Learn about basic geologic processes including impact cratering, volcanism, erosion, and tectonic activity
- Begin to interpret more complex geologic stories
- Create a beautiful piece of artwork inspired by planetary images!

BACKGROUND INFORMATION

CORE CURRICULM CONCEPT: Art Elements Correspond to Geological Features

The elements of art—shape, line, color, value, texture—offer an amazing way to make sense of the geology of planetary surfaces. The core curriculum connects the elements of art to planetary image analysis. This simple concept shows how basic art forms can be sign posts for specific geologic processes – art depicts geology. The Elements of Art can provide a road map for students to interpret planetary images. When there are exceptions to these rules, or if these rules have multiple interpretations, students can learn to use other factors to infer results, just like scientists. As these concepts build, students can combine these elements to understand more complex images, thus discovering geologic narratives and engaging in storytelling.

SLIDE/PRESENTATION RECOMMENDATIONS

GRADES 3-5
Break the presentation into several lessons.

Lesson 1 60 120 min
Introduction to the Solar System: Slides 1-13
- **Have student teams create a KWL chart, and then build one for the entire class.**
- **Explore books to help students develop understanding of celestial bodies**

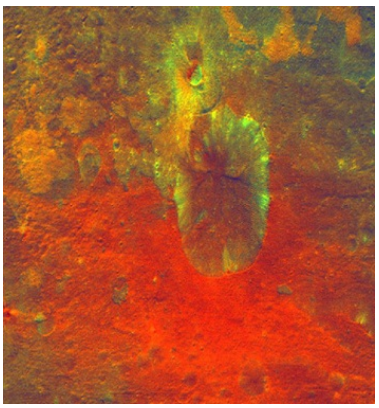
Lesson 2 60 120 min
- **Have each child choose a favorite image. Introduce the elements of art**
- **Choose 2-3 examples of each element of art from Slides 14-58 to illustrate concepts, hiding the rest.**

Pastel Art Activity
- **Suggest a focus on just shape, color, and line to start.**
- **Children are able to appreciate value and texture, too, but try it in context of kids' art creation to keep from overwhelming them with content/talk.**

GRADES 6-10
90-120 min
- **Encourage students to engage actively in the PowerPoint; noting features and writing down ideas are ways to keep participation lively.**
- **Use the PwPt notes to familiarize yourself with the content ahead of the presentation.**
- **Encourage interested students to use the many PwPt links to investigate further.**
- **It is also effective to have small discussions with students about art elements in their particular images in lieu of an extended presentation – the art making leads to rich scientific discourse!**

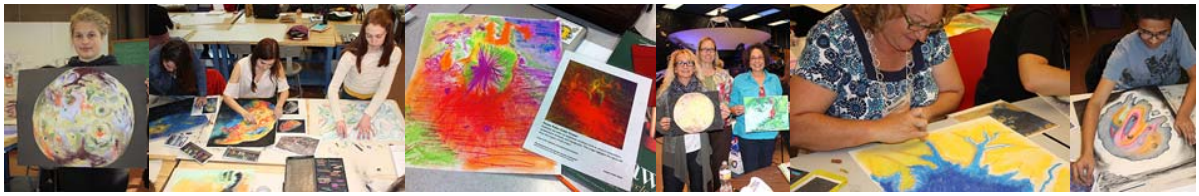
Elements of Art and their Geology Matches

- **Circle:** When circles are viewed on a planetary image, it often indicates an impact feature, a crater. The size, shape, ejecta blanket (stuff thrown away or ejected from the impact site, material from both the impactor and the area impacted) and number of craters give important clues as to the history of a planetary body. Sometimes circular features are volcanic or tectonic in origin, such as volcanic pancake domes found on Venus, for example.
- **Blobs:** Organic shapes, or blobs, can often be interpreted in two ways. Blobs frequently mean that one is viewing volcanic processes and lava flows. Blobby shapes can also indicate existing bodies of surface liquid (rivers and seas) or ancient bodies of liquid that left remnants of dried beds.
- **Straight Lines:** The presence of straight lines on a planetary body is often indicative of tectonic activity, including faults, ridges, cracks and mountains. On Earth tectonic activity is thought of as a land phenomenon; it can also be present in icy worlds.
- **Squiggly Lines:** The presence of squiggly lines on the surface often tells us forces of erosion are at work, including that of liquid and wind.
- **Color:** In addition to visible light, scientists image planetary bodies in many different frequencies of the electromagnetic spectrum (infrared, radio waves, X-ray, ultraviolet, etc.) They also create colorized images, adding and often exaggerating color differences to show subtle differences that the eye cannot detect otherwise, highlighting distinct aspects of a planet: topography, mineral composition, even gravity! Light and color are critical tools in interpreting and understanding planetary surfaces.
- **Value:** Value is the contrast of light and dark. Its scientific counterpart is called *albedo* - the measure of the reflectivity of a surface (think of snow vs. charcoal—which reflects more light?). Value/Albedo is a critical tool for understanding a planetary body.
- **Texture:** Implied texture is the tactile quality of a two-dimensional surface which we can see with our eyes, yet not touch. Images of planetary bodies are replete with various textures corresponding to eons of geologic history. Geologic processes build over time to create complex textures which can be deciphered with the aid of the other art elements.



TEACHING PART 1: Art & the Cosmic Connection PowerPoint Presentation

The presentation uses many beautiful NASA planetary images to illustrate concepts. It is flexible and scalable for various ages, experience levels, and time requirements. To prepare, teachers are encouraged to review the PowerPoint and make appropriate revisions for their particular students (see sidebar page 3), depending on the curriculum you would like to cover. The PowerPoint includes extensive ***Presentation Notes*** to guide teachers through the curriculum. The notes serve as a basic script and also include question prompts to encourage class discussion. There is also a ***Science Notes*** section with links to NASA web resources for educators who wish to expand their lesson plans.



Courtesy McREL

Show the PowerPoint
After reviewing the PowerPoint and the *Presentation Notes*, show the PowerPoint presentation to your students. The PowerPoint has an introduction to the solar system, an overview of remote sensing and space exploration, and the core concept that describes planetary image analysis using the elements of art.

Getting Started: What Do You Know About the Solar System?
Begin by making a KWL (Know, Wonder, Learn) table on the board or chart paper. Take notes (or invite students to) on the chart paper as students answer the following about the solar system:

- What do we ***know***?
- What do we ***wonder*** about?
- What have we ***learned***?

This forms a baseline of classroom knowledge, helps you be aware of your students' prior knowledge, and promotes inquiry. The KWL can be done in pairs or small groups initially to engage participants actively.

- ➢ If a student states something others are uncertain about, or you believe is inaccurate, post it in the Wonder section to return to for verification later.

Avoid major discussion of the structure of the solar system (including the inner terrestrial planets, outer gas giants, and small bodies including moons, asteroids, comets, dwarf planets, and Kuiper Belt Objects [or KBOs]) until after the main presentation. Images there will help support your discussion.

- Make special note that our activity focuses on worlds with visible geology. Thus, the presentation does not focus on the gas giants themselves, but does appreciate their marvelous moons!

Introduction: Science Inspires Art
The beginning of the presentation briefly introduces students to the painting and sculpture of project authors, Monica and Tyler Aiello. The husband and wife artist team collaborate with NASA and the scientific community in the development of their artwork and educational programs. Students are intrigued to view professional artists inspired by science, and are encouraged to become "artist explorers."

Remote Sensing & Space Exploration
A brief discussion of remote sensing incorporated in the PowerPoint explains how NASA sends robotic explorers to planetary bodies and takes pictures of their surfaces. The images used are shown from the aerial or "birds-eye" view. The planetary images provided correlate to recent and current NASA missions to provide an opportunity to build student interest and excitement in space exploration. The beautiful and often unfamiliar images keep students engaged with the content.

Elements of Art & Planetary Image Analysis
The core concept section relates how the Elements of Arts can be used to interpret planetary images. It is useful to have students define (or for the educator to review) the definitions of the Elements of Art. The remainder of the presentation includes sections for each of the Elements of Art and illustrates the how these relate to specific geological processes using examples of gorgeous NASA images.

- Circle – Crater
- Blobs – Volcanoes or Lakes
- Straight Lines – Tectonic Activity
- Squiggly Lines – Erosion
- Color, Value, Texture – Critical Scientific Tools

TEACHING PART 2: Art Activity

The *Pastel Art Activity* is designed to be a simple, yet fun and engaging way for students to explore the concepts they've learned from the PowerPoint presentation. Students enjoy making art in science class or exploring science in art class, depending upon how the project is taught. This reinforces the connections between the arts and the sciences and engages the students in an interdisciplinary learning environment. The art project can be taught during the same session as the presentation or in subsequent sessions.

Time Recommendations

Grades K-5: two or three 45-minute periods
Grades 6-12: one or two 45-60 minute periods

Supplies

- **Drawing paper** – A larger-sized, fine artist drawing paper is recommended, budgets allowing (22"x28" is great, at least 9"x12"). Students enjoy working with fine art materials and tend to take their projects more seriously. The drawing paper should be appropriate for the drawing media.
- **Drawing media** – Soft pastels are recommended for their ease of use and blend-ability. However, they should not be ingested. Water colors, crayons, markers and pencils are more appropriate for K-2 students.
- **NASA Planetary Prints** – Download from the NASA Discovery Program website, http://discovery.nasa.gov. The prints inspire the students' artworks.
    - Images are both in black and white and in color. Slipping them into sheet protectors is essential for future use; laminating them is more costly but more durable.
- **Gummy erasers** – Can be used effectively with soft pastels to lift pigment and create highlights
- **Q-tips** – Are a great blending tool
- **Cleaning or Hand Wipes** – Pastels are messy but easy to clean up, especially with cleaning wipes
- **Fixative (optional)** - A pastel spray fix can be used; however, it is toxic and should only be used by a teacher or with older or experienced students, and by all in a ventilated area. For other students, aerosol hairspray can be used. A light coating will help fix the pastel pigment to the drawing paper.
    - Drawings can also be spray-fixed between layers if they get too heavily loaded with pigment or muddy so that students may work on top of the drawing. This process should be completed or supervised by the educator. A fixative is not necessary.

Implementing the Art Activity

- Have all students select a NASA planetary image to work from; pass out paper.
- Ask students to make pastel drawings inspired by their image.
- Discuss or share images prior to the project, if desired.
- Ask students to pay special attention to the Elements of Art and how they relate to interpreting the geologic history of their image. They may choose to focus on one or two images.
- Explain that students do not have to make their artwork exactly like their image. They are making "art" and should feel free to interpret their image by altering their composition, cropping, color, orientation, etc. This is effectively done using question prompts, such as, *"Do you have to make your artwork black and white like your image? No, feel free to explore color!" or, "Focus on the details that intrigue you."*
- Encourage artists to explain their interpretation. For example, a student may have noticed especially bright areas and picked them out in a certain color.

TIP: Distribute drawing supplies AFTER you explain the assignment above so that students do not work ahead or get distracted. ☺

Artists and activity authors at work, Monica & Tyler Aiello



Wrap Up and Formative Assessment

- At the conclusion of the art activity, display artwork and discuss the project. Here are two possible approaches.
  a) Conduct a **gallery walk**, where student art is hung up, with its inspiring image beside it, and students spend time viewing all. Ask all present, kids and adults, to offer observations about what strikes them about the drawing on sticky notes to leave for the artist.
     - Examples: "Really nice example of texture!" "What is your interpretation of that feature?" "Your blending really made those colors pop out!"
  b) Break students into small groups (mix up the class so kids see others' work). Ask students to do a **think-pair-share**, where they write about their experience for a couple of minutes on a sticky note, share their ideas with a partner, and then with a small group.
     - Reflect on the selected planetary image: interpret the geology of their image, and discuss how they used that image to inspire their artwork.
- Ask students to share something new they have learned from the activity with the entire group.
- Conclude by returning to the KWL chart to record:
  - What have we ***learned***?
  - What do we ***wonder*** – what **new** questions do we have?
- Clean up studio or classroom.

Storytelling & Geologic History

- Interspersed within the Elements of Art sections are images with multiple art elements/geologic features. These examples provide students with the opportunity to combine what they have learned to decipher more complex geologic history *(i.e., circles and blobs might be interpreted as craters and volcanoes)*.

NATIONAL EDUCATION STANDARDS
ART & THE COSMIC CONNECTION
Elements of Art Inspire Planetary Image Analysis

SCIENCE
Source:
http://www.nap.edu/openbook.php?record_id=4962

K-4
Earth and Space Science
- Objects in the Sky
- Changes in the Earth and Sky

History and Nature of Science
- Science as Human Endeavor

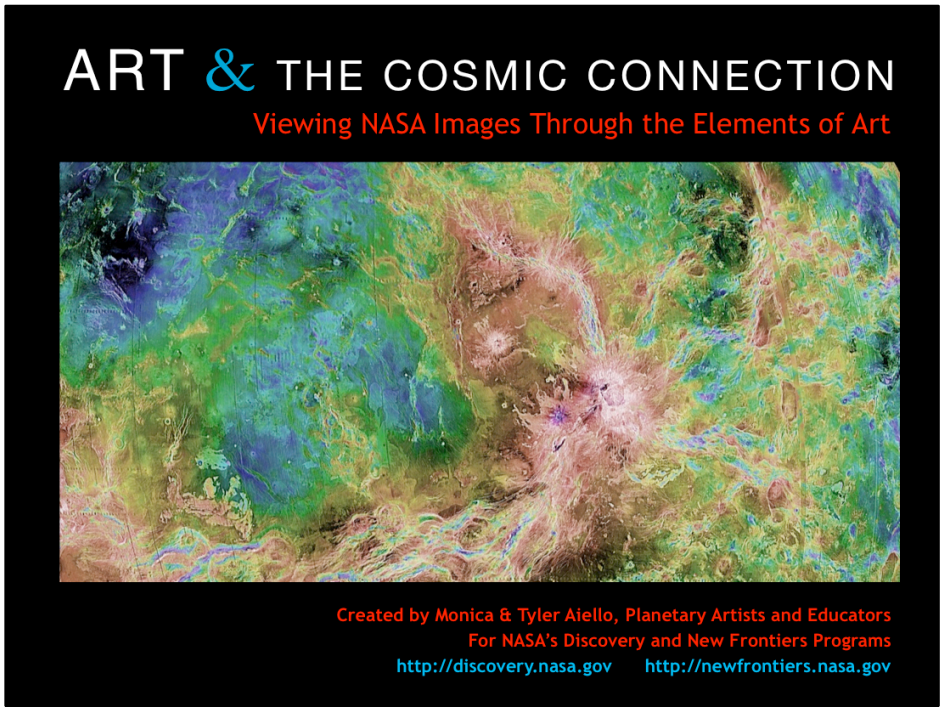
5-8
Unifying Concepts and Processes
- Evidence, models and explanation
- Form and Function

Earth and Space Science
- Structure of the Earth System
- Earth in the Solar System

ART
Visual Arts

K-4 **Source: http://artsedge.kennedy-center.org/teach/standards/standards_k4.cfm**
- Content Standard #1: Understanding and applying media, techniques, and processes
- Content Standard #2: Using knowledge of structures and functions
- Content Standard #5: Reflecting upon and assessing the characteristics and merits of their work and the work of others
- Content Standard #6: Making connections between visual arts and other disciplines

5-8 **Source: http://artsedge.kennedy-center.org/teach/standards/standards_58.cfm#04**
- Content Standard #1: Understanding and applying media, techniques, and processes
- Content Standard #3: Choosing and evaluating a range of subject matter, symbols, and ideas
- Content Standard #5: Reflecting upon and assessing the characteristics and merits of their work and the work of others
- Content Standard #6: Making connections between visual arts and other disciplines



"Art and the Cosmic Connection" is a program that introduces students to the solar system using art concepts. It uses the elements of art to help students understand and analyze beautiful NASA images from space.

The activity was developed by planetary artist and educator Monica Aiello and her husband Tyler Aiello, a sculptor with a background in architecture. Both of the Aiellos are prominent artists whose art is displayed in galleries throughout the west. They also dedicate considerable time to working with students from K through college in schools, afterschool programs and at camp.

The first 13 slides introduce our solar system in its marvelous diversity and the concept of using an artist's eye to make sense of science (and a scientist's eye to deepen one's art!).

PRESENTATION NOTES:

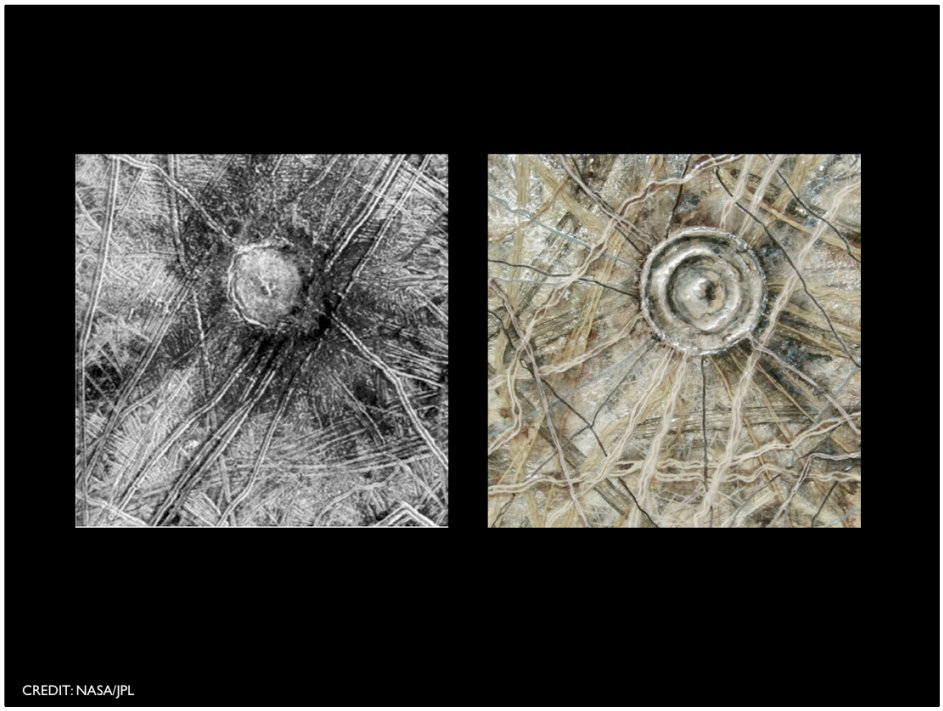
- Today we are going to do something a little different.
- We're are going to do art in science class (or science in art class depending on the course this activity is being taught)
- We are going to learn about our solar system as artist explorers.

SPECIAL NOTE:

The PowerPoint includes animations that relate to the script and question prompts. These are activated by clicking the forward buttons or arrows. They may also be turned off if not desired.

PRESENTATION NOTES:

- You may think that Art & Science are two very different things.
- But the arts & sciences share many things in common
- The activity we'll be doing today was developed by internationally acclaimed artists Monica & Tyler Aiello
    - Their artwork will inspire your artwork!
    - They are a married couple who work closely with the scientific community to create artworks and educational programs inspired by science



PRESENTATION NOTES:

Just to give you some brief illustrations of how science inspires art...

- The image on the left is of a crater called Cilix on Jupiter's icy moon Europa. The image on the right is a painting by Monica Aiello of Cilix made with acrylic, ink, yarn, thread and paper.
- This is essentially what we will be doing today.
    - You will be making art inspired by planetary images, and
    - Your understanding of planet surfaces will deepen by looking at them through art's lens.

PRESENTATION NOTES:

Another example…This is an image of Ganymede, one of Jupiter's four big Jovian moons (the largest and most visible from Earth), and the largest moon in the solar system.

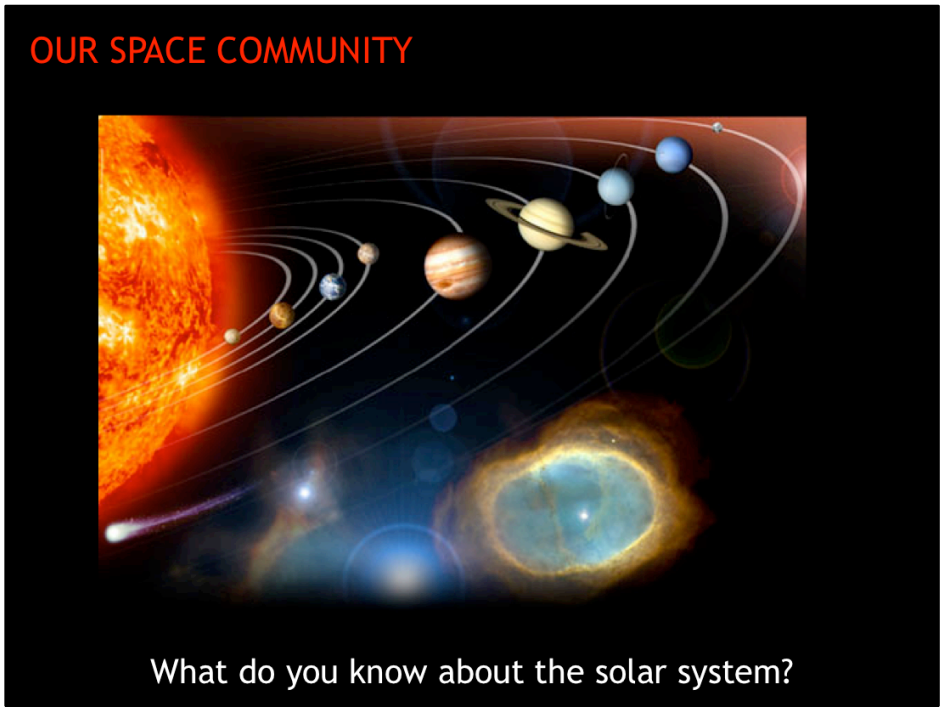
PRESENTATION NOTES:
Here are some artworks by the Aiellos inspired by Ganymede at the Denver Museum of Nature & Science. Monica's painting is 5'x10' and Tyler's steel sculpture is 5' in diameter.

Painting by Monica Aiello:
The Flight of Ganymede
Acrylic, ink, paper, fiber, on panel
5'x10'

Sculpture by Tyler Aiello:
Sphere X
Hand-forged steel
5' diameter

PRESENTATION NOTES:
In the program package, you will receive a host of tools to implement this program in your classrooms:

- **PowerPoint Presentation:** for in class presentation
- **Easy to follow presentation notes and science notes:** for expanded content
- **Correlates with current and recent missions:** to excite students about space exploration
- **Scalable for K-12 students…and beyond**
- **Art Activity to reinforce concepts:** we will be doing this activity later today
- **Beautiful NASA images to print:** for use with the art activity
- **1 day or 2 day program:** program is flexible for age/time requirements
- **In-depth Educator Guide:** walks teachers through the program/activity
- **Works in both art & science class:** as well as general elementary education
- **Proven success with both youth and adults:** iterations of the program have been taught in schools, universities, & museums



PRESENTATION NOTES:

Suggestion: On the board or chart paper, record what the students already know about the structure of the solar system to inform you of their background knowledge and promote discussion. A ***KWL*** *chart can be great here – three columns, what we* ***Know****, what we* ***Wonder****, what we have* ***Learned****. If you have students who are younger or more reticent to speak, having small groups of kids develop their own KWL before opening a larger whole class discussion is an effective way to draw out your students' background knowledge while engaging them in the activity.*

Start by discussing what we already know about our solar system. *Recommendation: Leave this portion of the presentation open-ended, building from wherever the students begin. The subsequent slides can be used as cues, and the notes include question prompts to keep students engaged in the discussion. Feel free to adjust the presentation to make it appropriate for your students. Indicators of the answer categories teachers should be looking for are highlighted in red.*

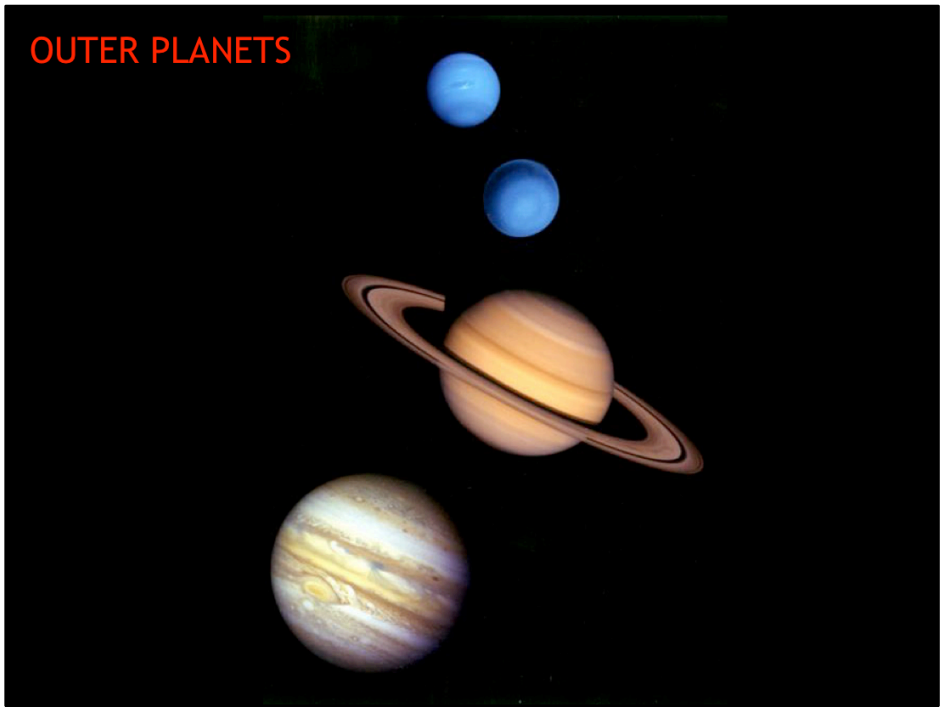
- Ask students what is at the center of the solar system: *The Sun*

[Note: The illustration is an artistic interpretation; scale and distance are not accurate.]

PRESENTATION NOTES:

Possible Question Prompts:

- Anyone recognize these? Give me a name of one of the inner planets. *Mercury, Venus, Earth, Mars*
- Scientists talk about the inner solar system and the outer solar system – have you heard of that? Where do you think the boundary could be – and why?
- Or for older students: What are they called? *Terrestrial Planets*
- Why are the inner planets called "terrestrial" planets? *Because they have rocky surfaces*
- What does "terrestrial" mean – any ideas? Why might they call it that? *Encourage discussion about rocky surfaces and geology*
- What do you notice about their surfaces? *Encourage any answers to get them thinking*
- Do they have geologic processes we can see on their surfaces? *Examples: moving atmosphere, signs of cratering, tectonics – fault lines, etc.*



PRESENTATION NOTES:

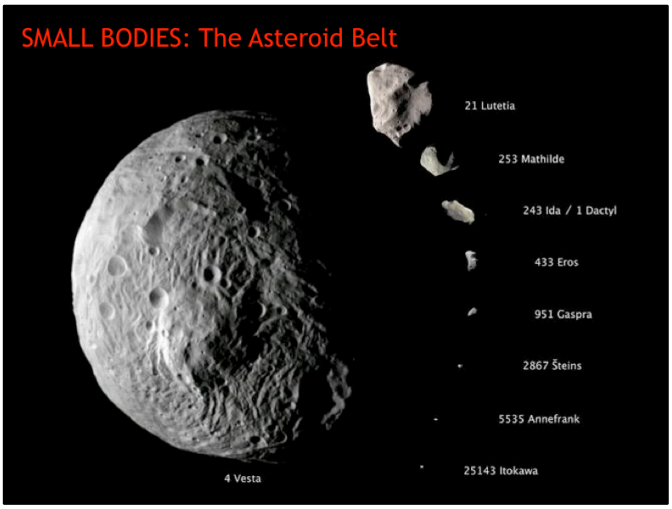
- What are the four large outer planets? *Jupiter, Saturn, Uranus, Neptune*
- Why are these planets called "gas giants"? *Because their surfaces are made of thick atmospheres – they may have a dense, molten, core of rocky materials, but they are mostly hydrogen and helium; Neptune and Uranus are sometimes known as ice giants since they are primarily icy worlds made of water, ammonia and methane.*
- Can we see geologic process at work on their surfaces? *No*
- We are going to be focusing on geologic processes we can see on the surface, so gas giants won't be much in the picture. However, we will be looking at their marvelous moons!

SMALL BODIES: Moons

CREDIT: NASA/JPL

PRESENTATION NOTES:

- Some of the coolest, weirdest bodies in our solar system are the moons of the outer solar system that orbit the gas giants.
    - What defines a moon? *A body that orbits one of the solar system's planets.*
    - Moons are like planets, sometimes as large as planets, with fascinating geology.
- Many current and recent NASA missions are focused on these worlds, and hopefully some future ones. There is so much to learn!



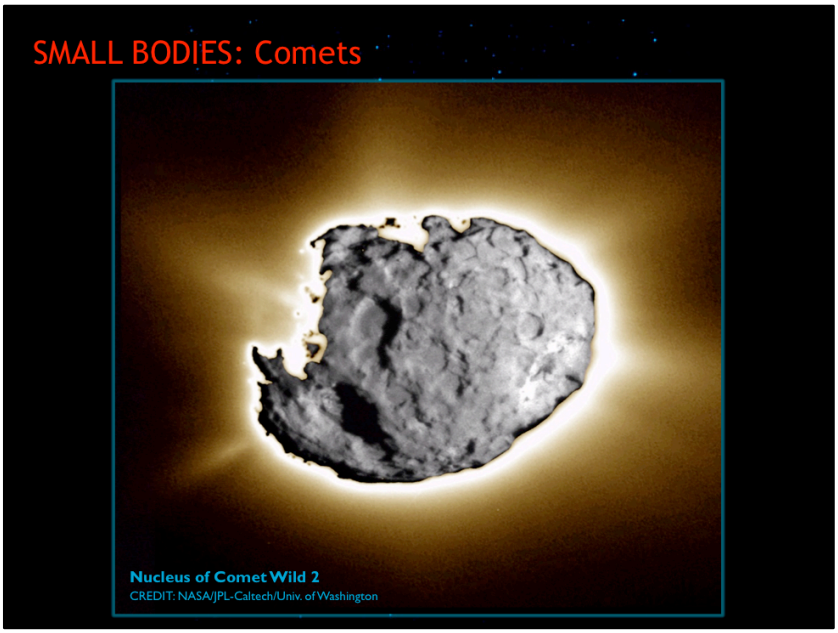
PRESENTATION NOTES:

In addition to the moons of the solar system, there are many other small, interesting bodies to investigate that orbit the Sun, including asteroids, comets and dwarf planets.

- What orbits between the inner and outer solar system? *The main asteroid belt*
- An asteroid is a small body in orbit around the Sun made mostly of rock and metal.
- They are the subject of exciting current NASA missions and research, including the Dawn mission to Vesta and Ceres and the OSIRIS-REx asteroid sample return mission, to name two
- Why is it valuable to study these small bodies?
    - *Understanding their origin helps us understand Earth's origin – visit an asteroid, and you are often stepping back in solar system time!*
    - *Have you heard of the doomsday worries? Well, keeping an eye on asteroids means we can possibly protect Earth from an impact.*

SCIENCE NOTES:

- Asteroids are small, rocky, airless worlds that orbit our Sun, leftover from the formation of the solar system 4.6 billion years ago. Early in the history of the solar system, the formation of Jupiter brought an end to the development of planetary bodies in the gap between Mars and Jupiter and caused the small bodies that occupied this region to collide with one another, fragmenting them into the asteroids we observe today. This region, called the asteroid belt or simply the main belt, may contain millions of asteroids. Because asteroids have remained mostly unchanged for billions of years, studies of them could tell us a great deal about the early solar system.
- The asteroid belt is a vast doughnut-shaped ring between the orbits of Mars and Jupiter. Many asteroids are tiny, but some are quite large. Some are close to planet-size and appear to have "differentiated" as Earth has, with a core, mantle and crust. More than 150 asteroids are known to have one or two moons. Orbits have been determined for more than 300,000 of these space rocks. Asteroids that pass close to Earth are called Near-Earth Objects (NEOs). http://solarsystem.nasa.gov/planets/profile.cfm?Object=Asteroids



PRESENTATION NOTES:

- What's this? *A comet*
    - A comet is a small object made of ice, rocky debris, dust and gas that orbits the Sun. Jets of gas and dust form long tails that can be seen from Earth.
    - They are sometimes called "dirty snowballs"
    - Comets are believed to originate in the Kuiper Belt and even more distant Oort Cloud. There are trillions of comets orbiting our Sun!

SCIENCE NOTES:

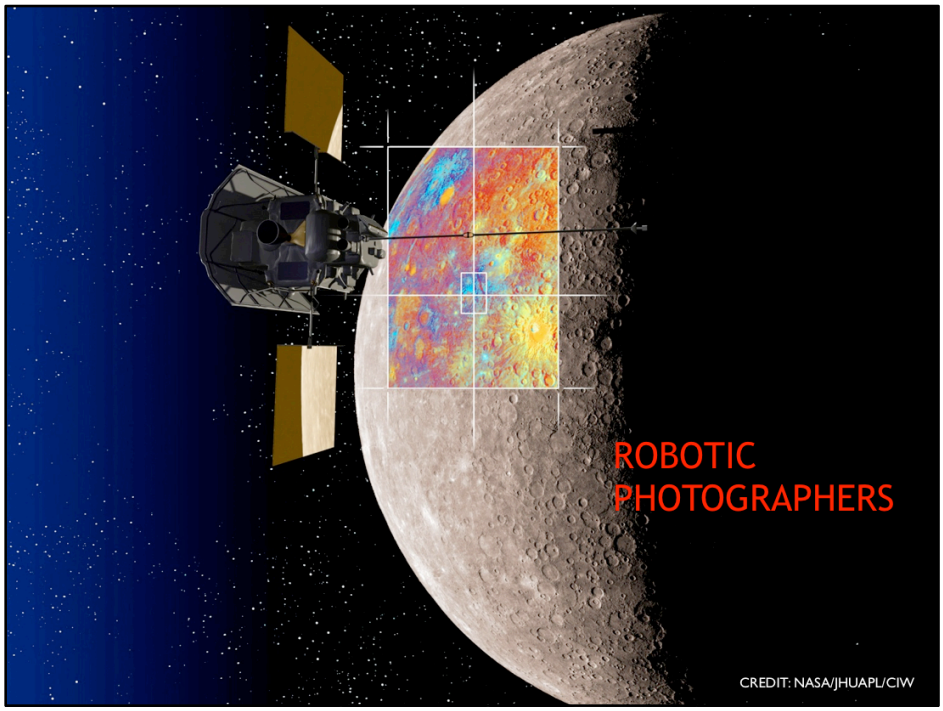
- Comets are part of the solar system. They orbit the Sun, just as planets do, except a comet usually has a very elongated, elliptical orbit. Its orbit starts out very, very far from the Sun but eventually it approaches quite close to the Sun. A comet's **nucleus** is like a dirty snowball made of ice. As the comet gets closer to the Sun, some of the ice starts to sublimate, going straight from a solid to a gas. The ices sort of explode off the surface of the comet, along with particles of dust. These particles and gases make a cloud around the nucleus, called a **coma**. The coma is lit by the Sun. The solar wind pushes this material into the beautiful brightly lit **tail** of the comet. http://spaceplace.nasa.gov/comet-nucleus/redirected/

PRESENTATION NOTES:

- So what happened to Pluto? *It was re-classified as a dwarf planet. Scientists learned more, and that made them rethink Pluto's original classification.*
    - Why do you think this happened?
        - *Generally kids will say because scientists learned new stuff…*
        - *That's right on – we learn new stuff that that makes us reconsider our thinking – here, our classification. Pluto has a lot of odd un-planet like characteristics – an elliptical orbit, an orbit off the planetary plane, and a lot of debris around it, little icy worlds…*
- Beyond the orbit of Neptune, scientists found a large disc-shaped region they named the Kuiper Belt. Pluto is part of the Kuiper Belt.
    - The Kuiper Belt has hundreds of thousands of icy bodies larger than 62 miles across orbiting billions of miles from our Sun.
    - Most objects in the Kuiper Belt are tiny; here are some of the larger, Pluto-sized bodies known so far.
- One of the definitions of a planet is that its mass and therefore gravity are great enough to sweep up all the debris in its orbit. Since Pluto has not swept up all the icy debris in its Kuiper Belt orbit, Pluto's classification changed to "dwarf planet."

For additional information:

- The Kuiper Belt & Ort Cloud
  http://solarsystem.nasa.gov/planets/profile.cfm?Object=KBOs&Display=OverviewLong
- NASA's New Horizons spacecraft will make the first close-up study of Pluto and its moons and other icy worlds in the distant Kuiper Belt. It launched in 2006 and will fly past Pluto in 2015.
  http://sse.jpl.nasa.gov/missions/profile.cfm?Sort=Target&Target=KBOs&MCode=PKB

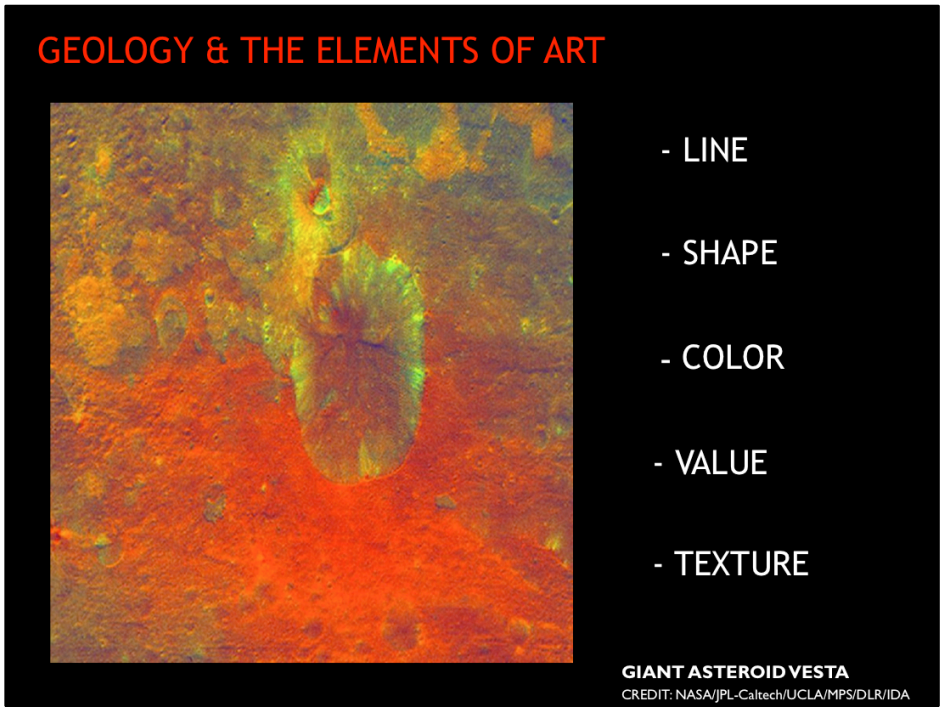


PRESENTATION NOTES:

- So how do we study planets and moons that are very far from Earth?
  - *We use tools like telescopes here on Earth*
  - *We also send telescopes into space where the atmosphere doesn't distort images so much – Hubble Space Telescope, WISE, etc.*
  - *And sometimes, We go there!*
- Can scientists easily travel there themselves?
  - *Not easily – very expensive, much of the technology is not yet developed to support people in such alien (un-Earth-like) environments.*
  - *The only planetary body humans have visited is Earth's moon during the Apollo missions.*
- Instead scientists and engineers build robotic explorers and send them out into the solar system to take images of planets, moons, asteroids and comets.
  - They beam back images for us to explore remotely. These are called Remote Sensing Images.
  - Remote Sensing is the acquisition of information about an object without making physical contact with it. NASA's spacecraft all carry a variety of science instruments to collect different kinds of data, such as spectrometers, altimeters, magnetometers, and the fabulous cameras and imaging systems that send back these amazing images.
  - Remote Sensing Images are often taken from a birds-eye or aerial view.

SCIENCE NOTES:

The MESSENGER spacecraft has been orbiting Mercury since March 2011. It carries seven cool scientific instruments, including wide and narrow-angle cameras with CCDs similar to digital devices. MESSENGER is able to gather images in color as well as monochrome! This is an artist's rendition of the spacecraft over Mercury with a colorized set of images. Scientists often colorize images to help define topographical variations, mineral composition, etc., to help us make better sense of the data.

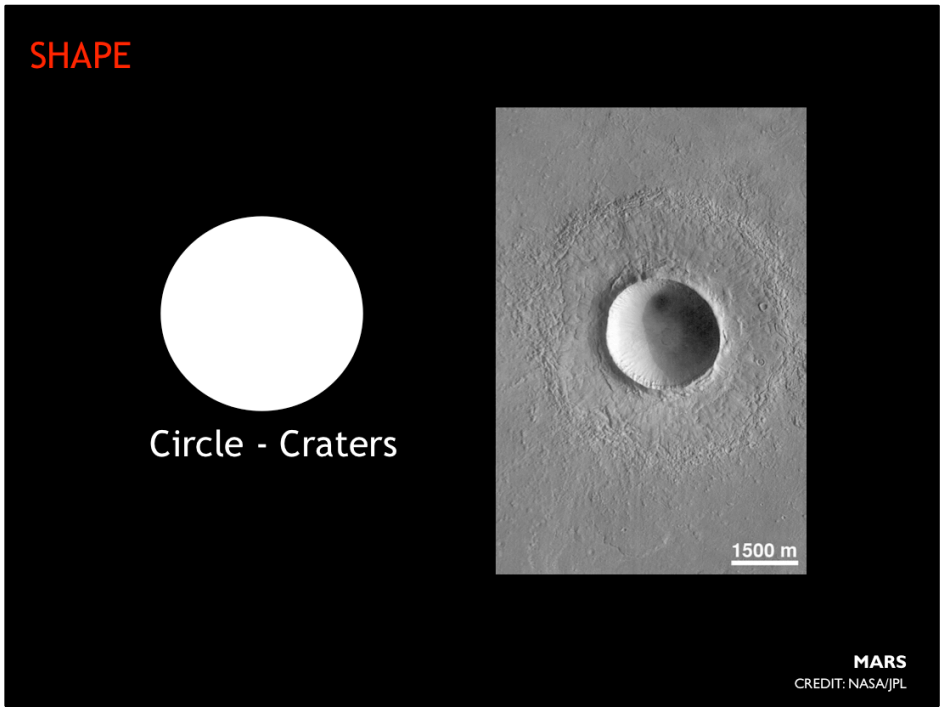


PRESENTATION NOTES:

- When scientists look at remote sensing images of planets, moons and asteroids, they have to try and understand their surfaces by using their eyes.
- The Elements of Art are the foundation artists use to understand visual information.
    - Does anyone know what the five Elements of Art are? *Line, Shape, Color, Value and Texture*
    - *[Includes animation which can be turned off]*
- These art concepts can help us understand the geology of planetary bodies.
- This image of the large asteroid Vesta taken by the Dawn spacecraft during the year it spent in orbit uses "translated" color to distinguish the different materials found on the surface around this crater, translating information that instruments capture and making it visible to our eyes.

THE ELEMENTS OF ART (See Educator Guide for more detailed definitions)
If students have not covered concepts in art class, taking them at face value works very well – students will learn as they go!

SCIENCE NOTES:
This translated color image obtained by the Framing Camera on NASA's Dawn spacecraft shows a crater on the giant asteroid Vesta. The reddish coloring below the crater points to material that was hurled from Vesta's interior during an impact or originated from the impactor itself. This image was obtained at an altitude of 1,700 miles altitude above the surface of Vesta. Image resolution is about 260 meters per pixel.
http://www.nasa.gov/mission_pages/dawn/multimedia/pia14709.html

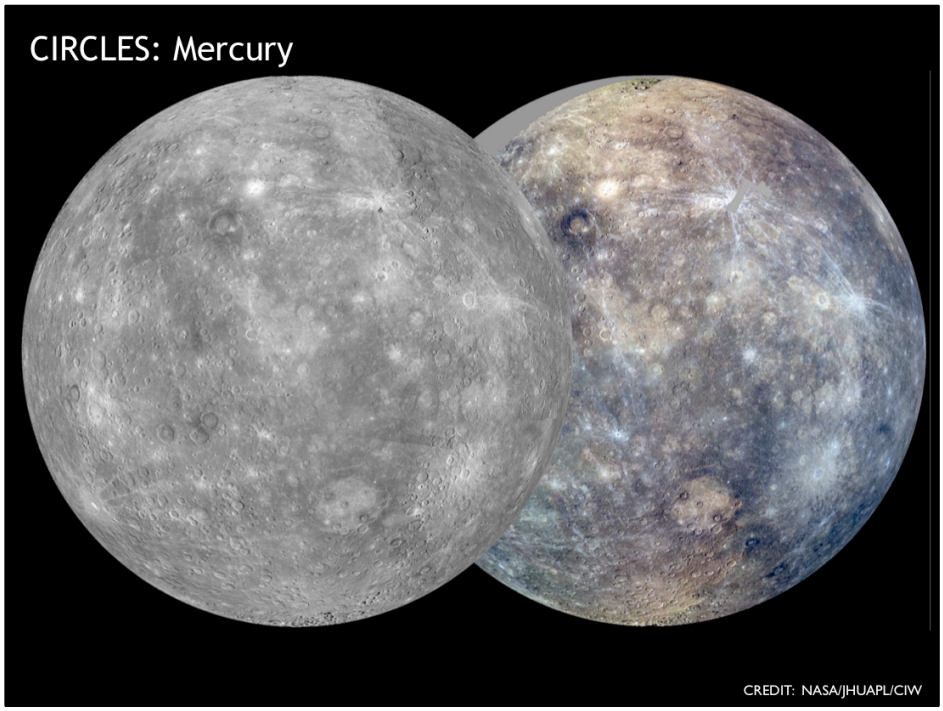


PRESENTATION NOTES:

- Let's discuss shapes first.
- When scientists see circles on the surface of a planet or small body, it often means that there is a crater.
- What is a crater? What might cause one? *A crater is formed when something impacts a planetary body. Note: Students may not be aware that they are found on Earth as well as the Moon and other planetary objects.*
- When an object like a meteoroid, asteroid or comet hits the surface of a planet it leaves a mark typically in the shape of the circle.
    - It also kicks up a lot of debris which is thrown away from the impact site, or "ejected," around the crater. This is called an ejecta blanket.
    - This is a beautiful picture of a crater on Mars.

SCIENCE NOTES:

- This crater on northern Elysium Planitia is a little more than twice the diameter of the famous Meteor Crater in Arizona. It was formed by the impact and subsequent explosion of a meteorite. The image was taken by the Mars Orbiter Camera aboard the Mars Global Surveyor in July, 1998.
  http://pds.nasa.gov/planets/captions/mars/crater.htm



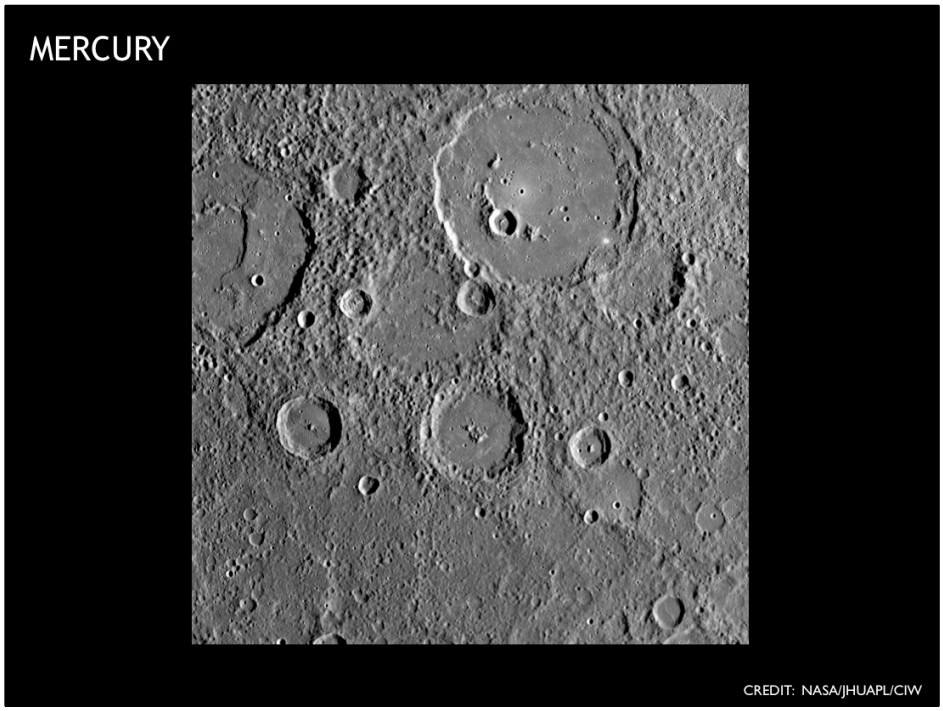
PRESENTATION NOTES:

- Currently NASA has a mission called MESSENGER orbiting Mercury, the planet nearest our Sun, for the first time.
- Here two images of Mercury in monochrome and color.

SCIENCE NOTES:

More on the MESSENGER Mission

- After its first Mercury solar day (176 Earth days) in orbit, MESSENGER has nearly completed two of its main global imaging campaigns: a monochrome map at 250 m/pixel and an eight-color, 1-km/pixel color map. Apart from small gaps, which will be filled in during the next solar day, these global maps now provide uniform lighting conditions ideal for assessing the form of Mercury's surface features as well as the color and compositional variations across the planet.
- http://messenger.jhuapl.edu/gallery/sciencePhotos/image.php?page=9&gallery_id=2&image_id=658

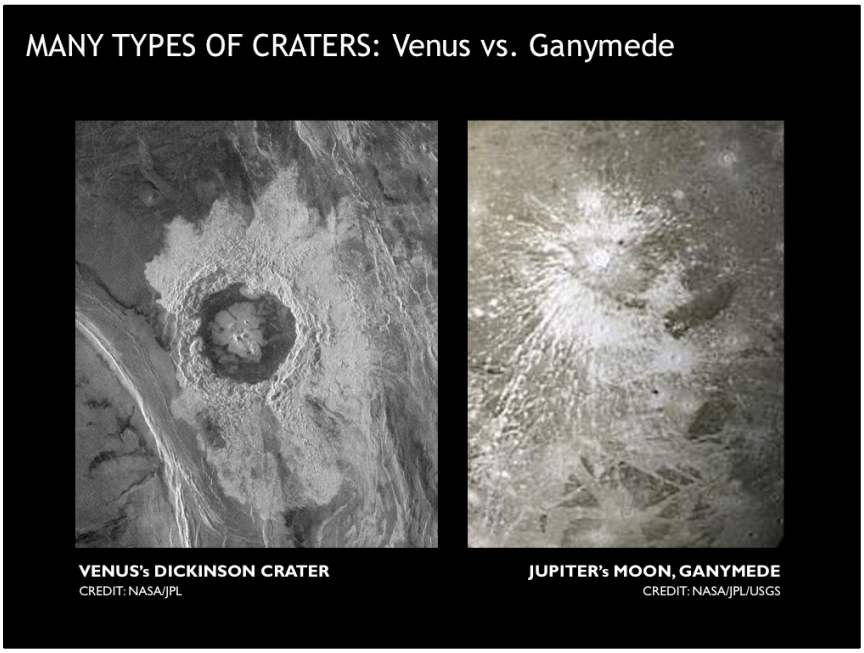


PRESENTATION NOTES:

- What has MESSENGER found on the surface of Mercury?
    - *Lots of circles which means lots of craters.*
- You can have students come up and point to craters – urging them to look, notice little ones, eroded ones, craters in craters, etc.
- Mercury has been bombarded by many impacts.

SCIENCE NOTES:

- The largest impact feature at the top of the image is about 83 miles in diameter and is named Polygnotus, after a Greek painter from the 5th century B.C. This basin has a central peak ring and is embayed with smooth plains material, which is very different in texture from the surrounding terrain. A second, comparably large crater at the top left of the image, named Boethius after the 6th century Roman philosopher, also appears to be almost filled with smooth plains, which were subsequently deformed during the formation of a prominent scarp. http://www.nasa.gov/mission_pages/messenger/multimedia/flyby2_20081007_2.html



PRESENTATION NOTES:

- Craters come in all shapes and sizes. What do you see?
    - *Students' observations can lead to additional info, below.*
    - Their ejecta can give clues as to what type of material the surface is made of.
- The image on the left is of Venus and the image on the right is of Ganymede, a large moon of Jupiter.
    - Venus is very hot and rocky and the flows of ejecta may have been melted by the impact.
    - The Ganymede crater is called a ray crater. It has bright streaks of ejecta which suggest it is a fresh impact on an icy surface

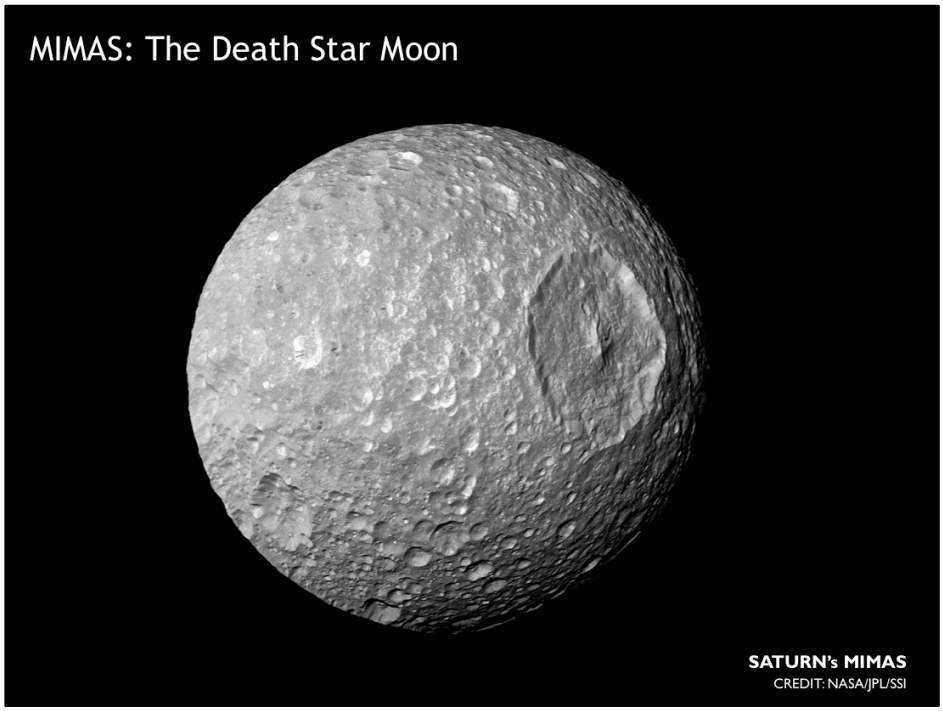
SCIENCE NOTES:

Venus Crater

- This Magellan spacecraft image shows Dickinson crater. The crater is complex, characterized by a partial central ring and a floor flooded by radar-dark and radar-bright materials. Hummocky, rough-textured ejecta extend all around the crater, except to the west. Extensive radar-bright flows that emanate from the crater's eastern walls may represent large volumes of impact melt, or they may be the result of volcanic material released from the subsurface during the cratering event.
  http://photojournal.jpl.nasa.gov/catalog/PIA00479

Ganymede Ray Crater

- This image shows a prominent rayed crater on Jupiter's icy moon, Ganymede. The view shows icy ejecta rays splashed out by the impact.
  http://photojournal.jpl.nasa.gov/catalog/PIA00334

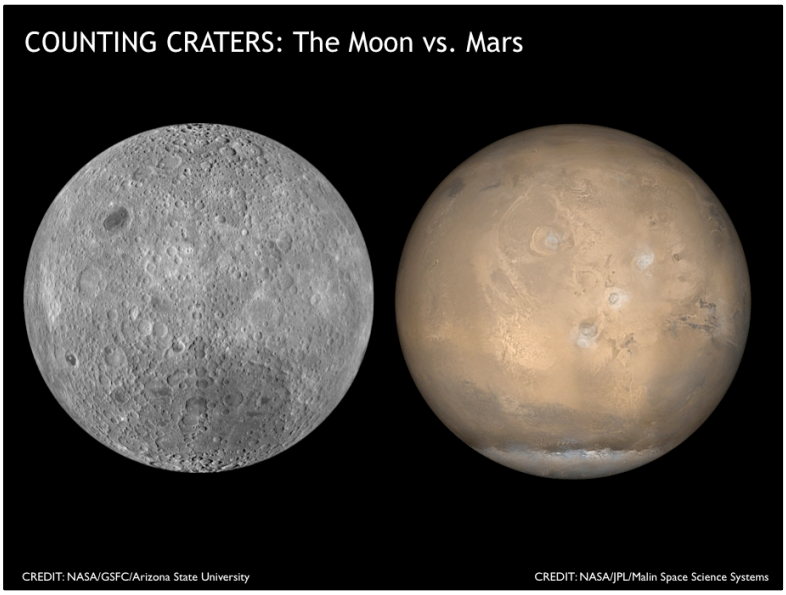


PRESENTATION NOTES:

- Mimas is a small icy moon of Saturn with a larger crater called Herschel.
- What does the size of this circle/crater suggest? *That something very large hit the surface of Mimas.*
- Mimas is often nicknamed the "Death Star" moon because it resembles the fictional moon-sized space station and super weapon from the Star Wars movies.

SCIENCE NOTES:

- In this view captured by NASA's Cassini spacecraft on its closest-ever flyby of Saturn's moon Mimas, large Herschel Crater dominates Mimas, making the moon look like the Death Star in the movie "Star Wars." http://photojournal.jpl.nasa.gov/catalog/PIA12570



PRESENTATION NOTES:

- What do you notice when you compare these two bodies? *Different numbers of circles/craters*
- Scientists count the number of craters on a planetary body to help them understand the ages of their surfaces.
- What surface do you think is older, the Moons or Mars? *The Moon*
- Why does the Moon's surface seem older? *Because there are more circles/craters*
- However, we always have to be careful our interpretations, because there are other possible explanations – resolution of the camera. Scientists have to take all these factors into account.

For deeper questioning/thinking if time allows:

- What might have happened to craters on Mars? *They were erased through geologic process*
- What kind of geology would erase the craters? *Volcanoes, wind erosions, water erosion, tectonic activity.*
- Active geology covers up craters and means a planetary surface is relatively young.

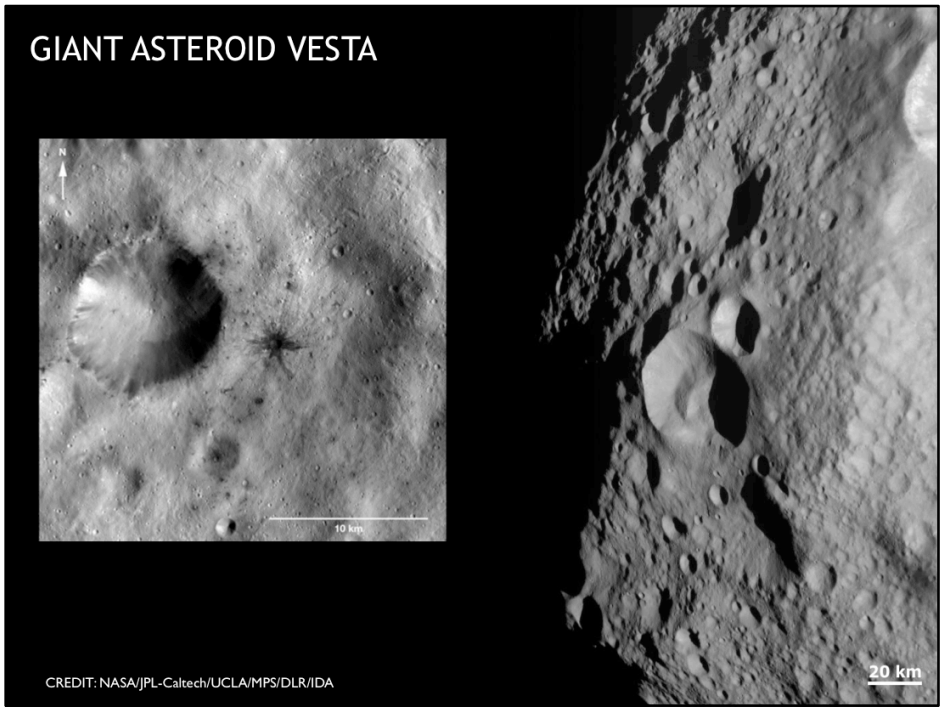
SCIENCE NOTES:

Lunar Reconnaissance Orbiter

- http://lro.gsfc.nasa.gov/

Mars Global Surveyor

- http://mars.jpl.nasa.gov/gallery/global/20020418f_g.html



PRESENTATION NOTES:

- We often think of smaller bodies such as asteroids as causing impacts, and indeed they do, but they are also impacted by other objects as well, as shown in this image of Vesta taken by the Dawn Mission.
- What do you see on Vesta's surface? *Circles/Craters*
    - Vesta is the size of Arizona

SCIENCE NOTES:

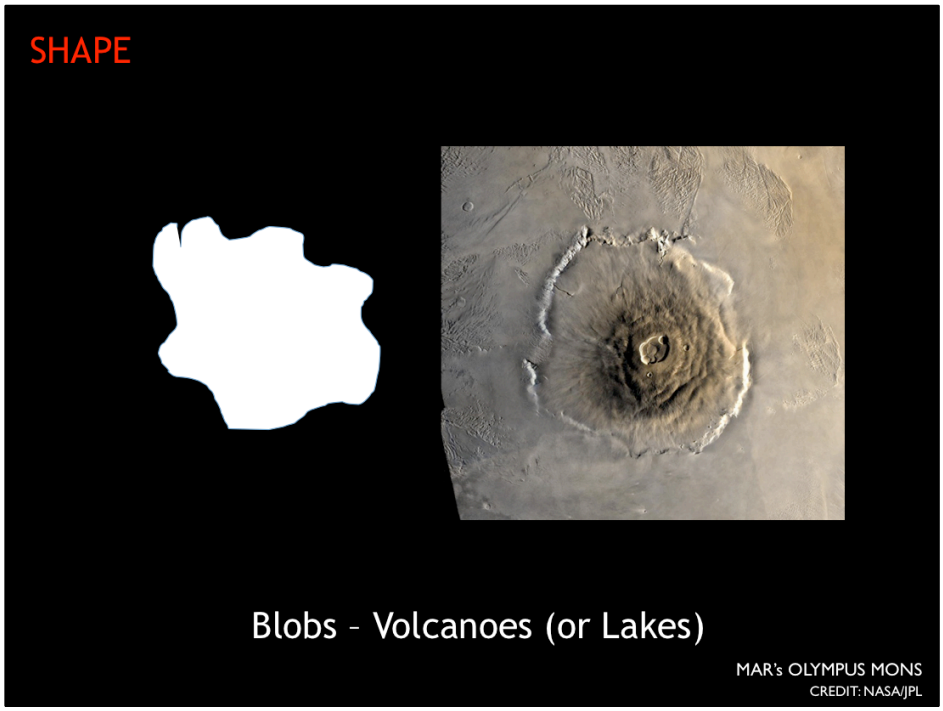
- The image on the left shows a dark-rayed impact crater and several dark spots. The dark materials are located near an older, larger crater in the Sextilia quadrangle of Vesta's southern hemisphere.
- The dark-rayed crater and dark spots may have come from a carbon-rich meteor that broke up and collided with Vesta. Or, the dark-rayed crater could be excavated dark material from under Vesta's surface. Detection of compositional differences among the examples of dark materials will help scientists determine where they came from.
- This image was taken by Dawn's framing camera on January 8, 2012, during the mission's low-altitude mapping orbit (on average 130 miles above the surface). This image covers an area of about 200 square miles.
- http://dawn.jpl.nasa.gov/multimedia/dark_rayed_crater.asp

PRESENTATION NOTES:

- What do you think this image shows? *Circles, craters*
- There are circles, but they are not craters. What do you think this could be? *Encourage any theories*
- As with many things, there are always exceptions to the rules.
- These circular features on Venus are not craters, they are volcanoes.
- They are called "Pancake Domes" and are believed to be volcanoes with very thick lava.
- How do we know this? *Scientists use many other tools to get to the answers.*

SCIENCE NOTES:

- Seven circular, dome-like hills, averaging 15 miles in diameter with maximum heights of 2,475 feet dominate the scene. These features are interpreted as very thick lava flows that came from an opening on the relatively level ground, which allowed the lava to flow in an even pattern outward from the opening. http://photojournal.jpl.nasa.gov/catalog/PIA00215



PRESENTATION NOTES:

- We have talked about circular shapes meaning craters, now let's explore organic shapes, or blobs.
- When scientists see organic shapes (or blobs) on the surface of a planetary body, it often means they are looking at a volcano.
- Recently, that assumption has been expanded by some exciting new discoveries, but we will get to those later.
- This is an image of a giant volcano on Mars called Olympus Mons, and it is roughly the size of Arizona, or 3 times the size of Mt. Everest.

SCIENCE NOTES:

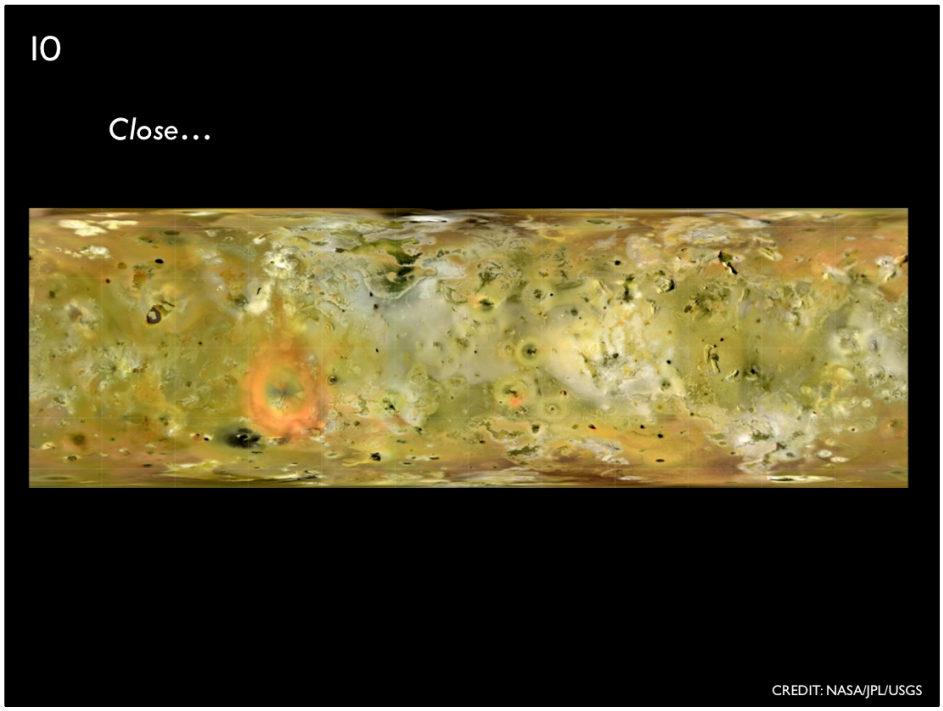
- The largest of the volcanoes in the Tharsis Montes region, as well as all known volcanoes in the solar system, is **Olympus Mons**. Olympus Mons is a shield volcano 374 miles in diameter (approximately the same size as the state of Arizona), 16 miles high, and is rimmed by a 4 mile high scarp. A caldera 50 miles wide is located at the summit of Olympus Mons. To compare, the largest volcano on Earth is Mauna Loa. Mauna Loa is a shield volcano 6.3 miles high and 75 miles across. The volume of Olympus Mons is about 100 times larger than that of Mauna Loa. In fact, the entire chain of Hawaiian islands (from Kauai to Hawaii) would fit inside Olympus Mons!
  http://marsprogram.jpl.nasa.gov/gallery/atlas/olympus-mons.html

PRESENTATION NOTES:

- One of the most fascinating places in our solar system is Jupiter's moon, Io.
- This is about what Io looks like with your naked eye.
- What do you think all of those blobby shapes are? *Volcanoes*

SCIENCE NOTES:

- NASA's Galileo spacecraft acquired its highest resolution images of Jupiter's moon Io on 3 July 1999 during its closest pass to Io since orbit insertion in late 1995. This color mosaic uses the near-infrared, green and violet filters (slightly more than the visible range) of the spacecraft's camera and approximates what the human eye would see. Most of Io's surface has pastel colors, punctuated by black, brown, green, orange, and red units near the active volcanic centers. http://photojournal.jpl.nasa.gov/catalog/PIA02308

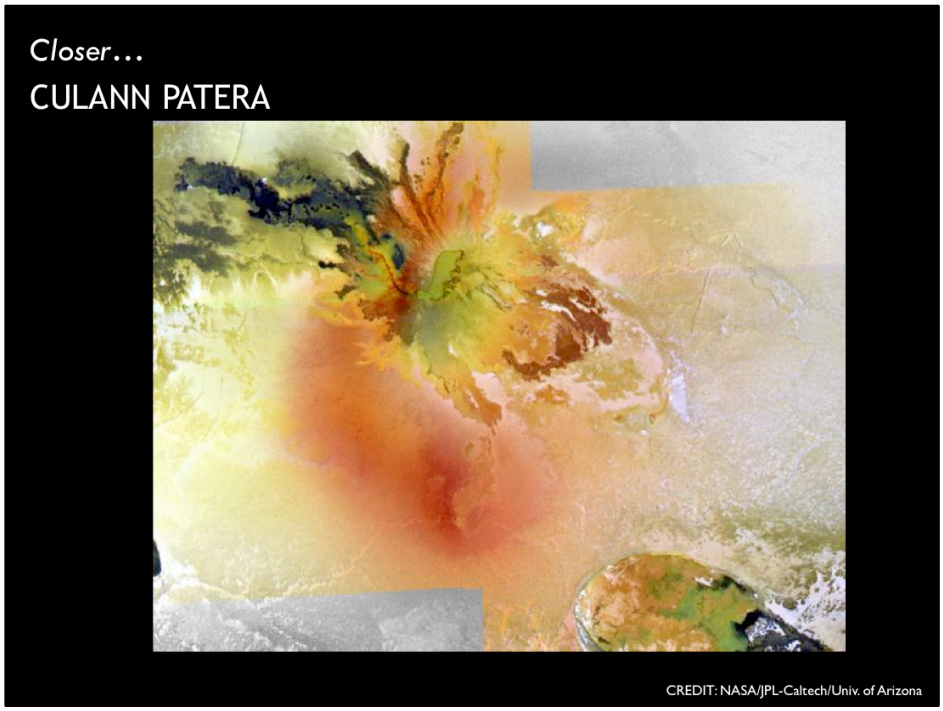


PRESENTATION NOTES:

- What do you see on the surface of Io? *Lots of blobs*
- All these blobs and dark spots on Io are volcanos.
- Io is the most volcanically active in the solar system.
- It is covered with sulphur which makes the amazing colors on the surface.
- Io is stretched and pulled by Jupiter's massive gravity which creates tidal heating and very active geology.

SCIENCE NOTES:

- Volcanoes erupt massive volumes of silicate lava, sulphur and sulphur dioxide, constantly changing Io's appearance.
  http://photojournal.jpl.nasa.gov/catalog/PIA09257

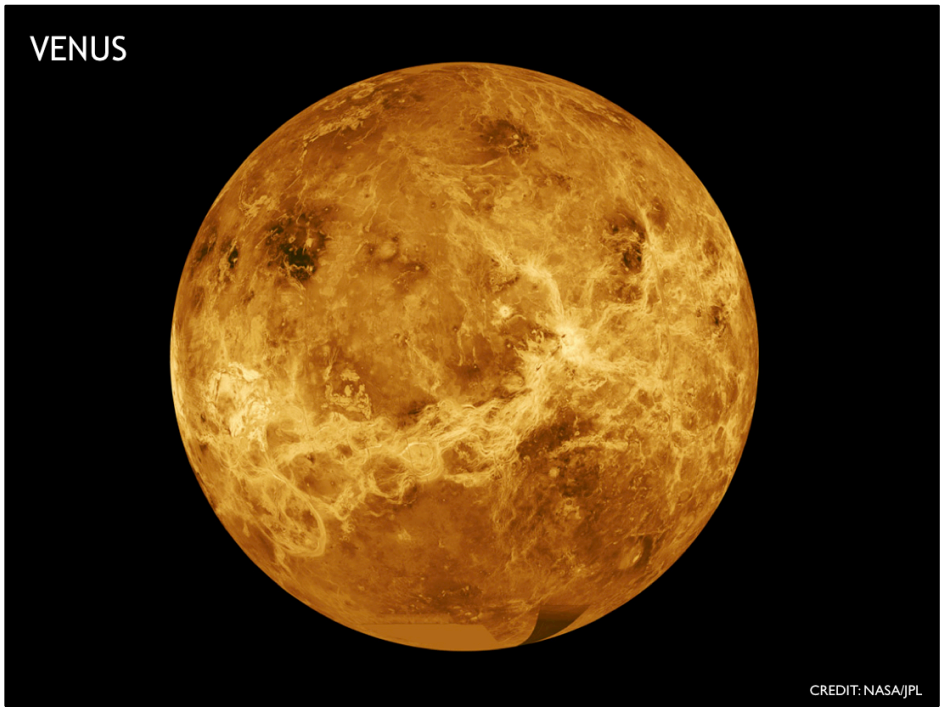


PRESENTATION NOTES:

- One of the most colorful volcanic areas on Io is named Culann Patera.
- What do you see? *Let the audience share their observations*
- The blobby shapes show the different lava flows coming from the volcanic center.

SCIENCE NOTES:

- Culann Patera is the centerpiece of this mosaic of the best high-resolution, color views of Io returned by NASA's Galileo spacecraft. The picture was constructed from images taken through the red, green, and violet filters of the Galileo camera and has been processed to enhance the color variations. The resolution is about 200 per picture element. North is to the top.
  http://photojournal.jpl.nasa.gov/catalog/PIA02535



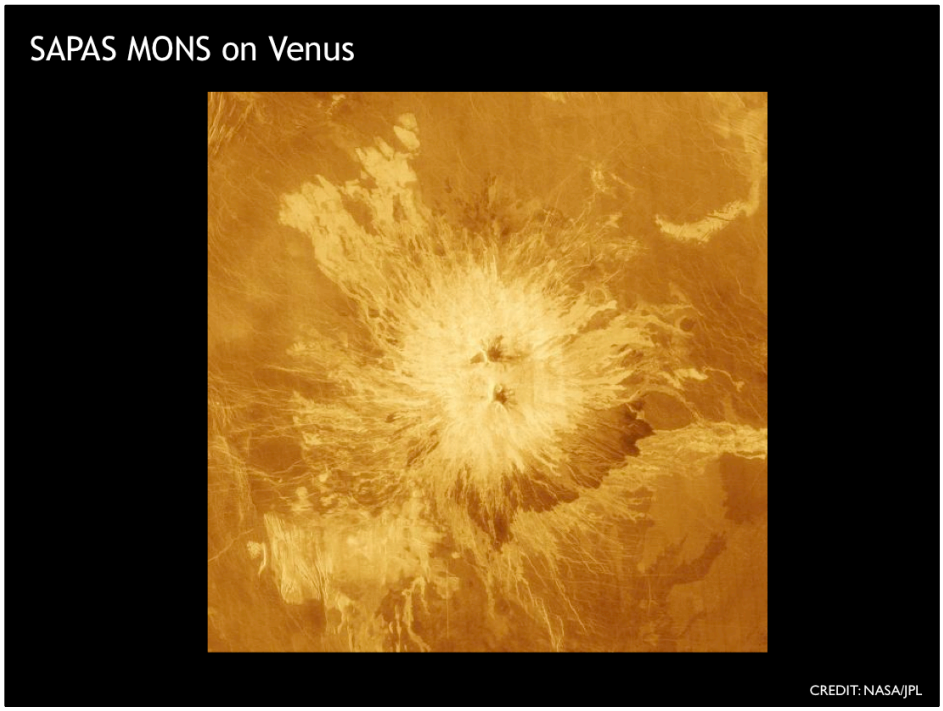
PRESENTATION NOTES:

- Another great place to look for blobs or volcanos in the solar system is Venus.
- Venus is covered with a thick atmosphere and has experienced a runaway "greenhouse effect," making the surface temperatures 800 degrees Fahrenheit.
- We cannot see through Venus' clouds so NASA sent a spacecraft to Earth's neighbor called Magellan which used radar to peer through its thick atmosphere. Another way to see through the clouds would be to use infrared cameras.

SCIENCE NOTES:

For more information on Venus

http://solarsystem.jpl.nasa.gov/planets/profile.cfm?Object=Venus&Display=OverviewLong

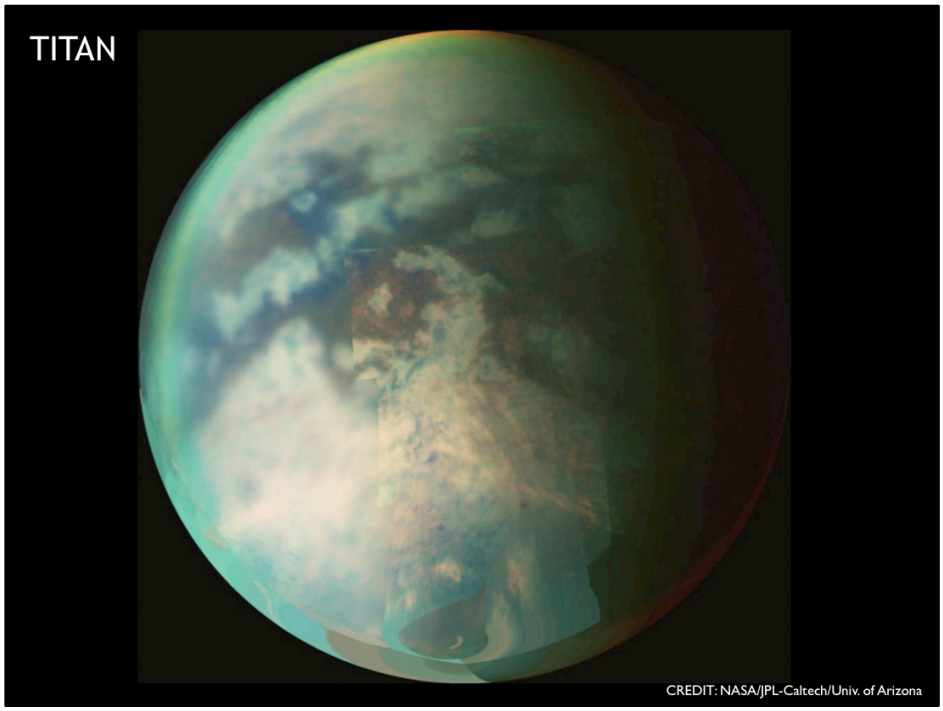


PRESENTATION NOTES:

- When the Magellan spacecraft imaged Venus with radar, it found lots of blobby, organic shapes, giving scientists clues that Venus has experienced a lot of volcanic activity.
- This is an image of a volcano named Sapas Mons.

SCIENCE NOTES:

- This translated-color image shows the volcano Sapas Mons, which is located in the broad equatorial rise called Atla Regio. The area shown is approximately 404 miles on a side. Sapas Mons measures about 248 miles across and 0.9 mile high. Its flanks show numerous overlapping lava flows. The dark flows on the lower right are thought to be smoother than the brighter ones near the central part of the volcano. Many of the flows appear to have been erupted along the flanks of the volcano rather than from the summit. This type of flank eruption is common on large volcanoes on Earth, such as the Hawaiian volcanoes. The summit area has two flat-topped mesas, whose smooth tops give a relatively dark appearance in the radar image. http://photojournal.jpl.nasa.gov/catalog/PIA00203

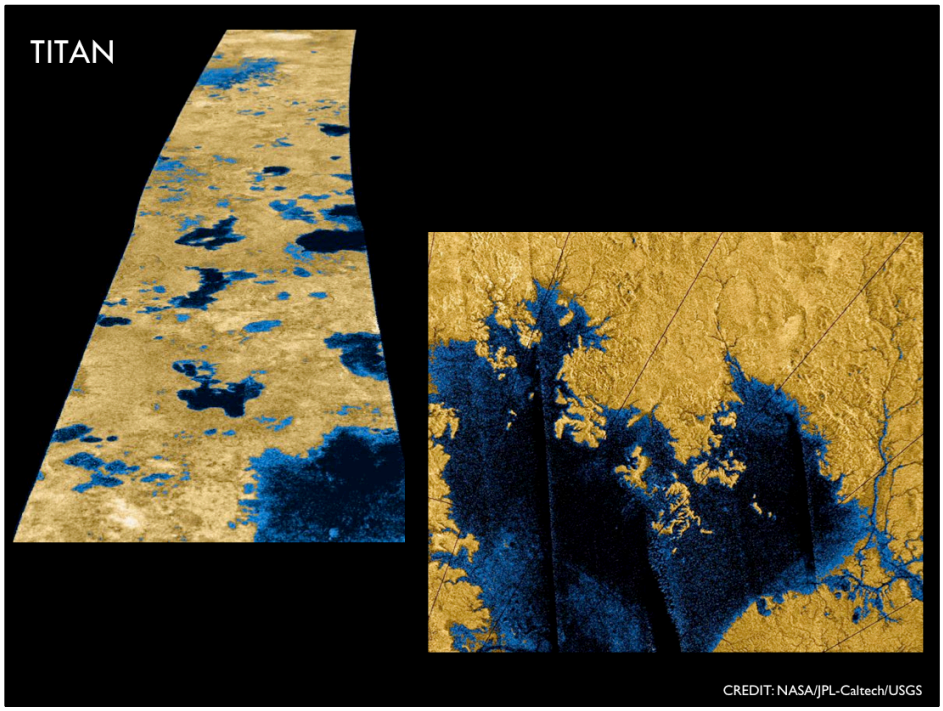


PRESENTATION NOTES:

- There is currently a spacecraft in orbit around Saturn named Cassini.
- Cassini has been studying a fascinating moon of Saturn's called Titan. In many respects, Titan is one of the most Earth-like worlds we have found to date. With its thick atmosphere and organic-rich chemistry, Titan resembles a frozen version of Earth from several billion years ago.
- Titan is the second largest moon in our solar system and is larger than the planet Mercury.
- Titan is covered by a thick atmosphere. Cassini has been studying it using radar and sent a probe called Huygens to its surface in 2005, the first human-made object to land on a body in the outer solar system.

SCIENCE NOTES:

- Titan is of great interest to scientists because it is the only moon in the solar system known to have clouds and a mysterious, thick, planet-like atmosphere. Winds sculpt vast regions of dark, hydrocarbon-rich dunes that girdle the moon's equator and low latitudes.
  http://solarsystem.jpl.nasa.gov/planets/profile.cfm?Object=Sat_Titan

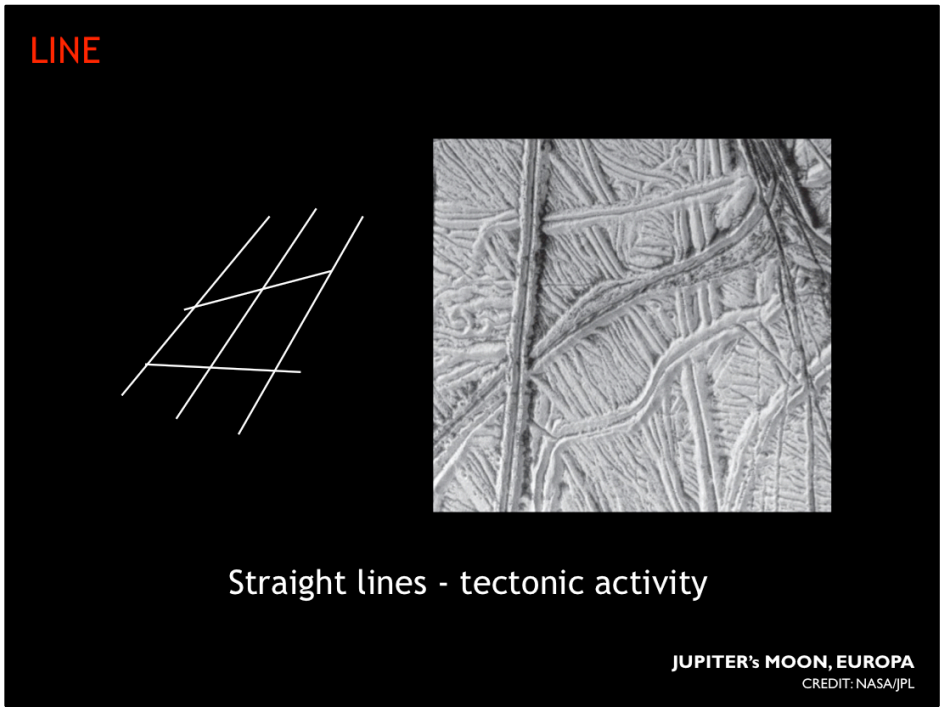


PRESENTATION NOTES:

- When scientist saw the surface of Titan, they saw all these blobby shapes.
- What could they be? Do they remind you of anything on Earth? Volcanoes perhaps?
    - This blobby shapes are in fact lakes.
- Titan is the only place in the solar system other than Earth where we have found liquid on the surface.
- Titan appears to have something like our water cycle with liquid in lakes and streams, clouds and rain.
- However, Titan is extremely cold, so can these lakes be filled with water? *No, water would be in the form of ice.*
- In fact, Titan's lakes, streams, and rain are made of methane!
- Cassini has revealed that Titan's surface is shaped by rivers and lakes of liquid ethane and methane (the main component of natural gas), which forms clouds and occasionally rains from the sky as water does on Earth. Volcanism may occur as well, but with liquid water as the lava.
- Scientists studying Titan have recently discovered that Titan may have a subsurface ocean!
- What we've found on Titan has complete revolutionized our thinking about planetary bodies.

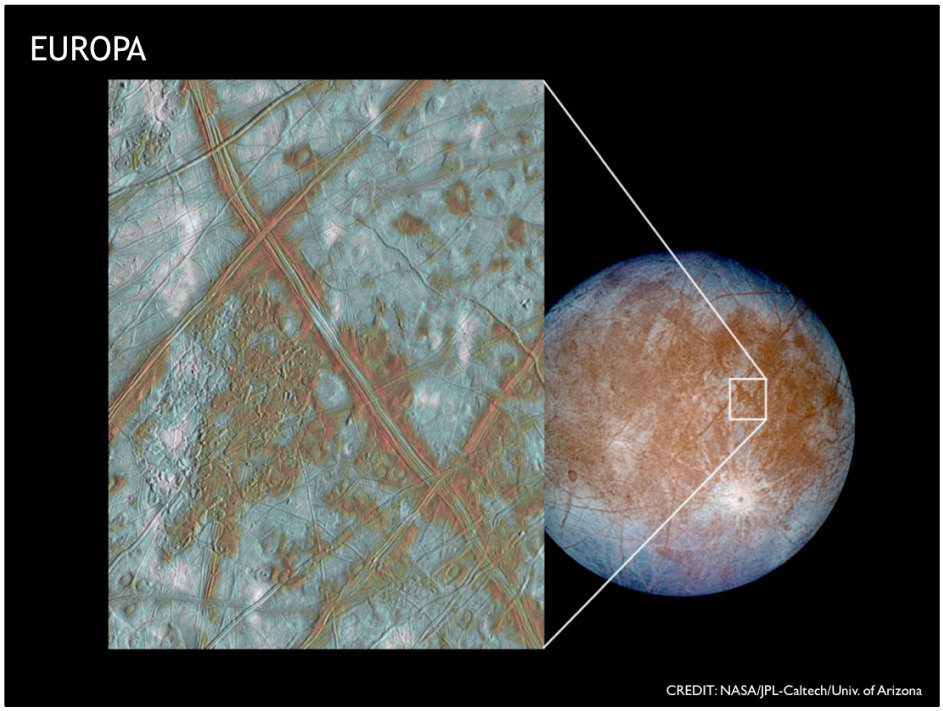
SCIENCE NOTES:

- The existence of oceans or lakes of liquid methane on Saturn's moon Titan was suggested in 1980 from data returned by the Voyager 1 spacecraft. With a dense haze preventing a closer look, it was not possible at the time to confirm their presence. Data from the Hubble Space Telescope in 1995 offered direct evidence of liquid methane on Titan. Observations from the Cassini mission of the northern latitudes showed smooth dark patches dotting the surface near the pole. Based on these observations, scientists announced definitive evidence of of lakes filled with methane on Saturn's moon Titan in 2007. http://photojournal.jpl.nasa.gov/catalog/PIA09102



PRESENTATION NOTES:

- We've explored shapes, so now let's move on to line.
- When scientists see relatively straight lines on a planetary body, it often means there has been some type of tectonic activity.
    - Have you heard of that? What do we know? What are some tectonic processes? *Encourage discussion*
    - Tectonic activity can include fractures, cracks, faults, ridges, mountain building.
- This image of a moon of Jupiter called Europa shows numerous ridges, cracks and fractures.



PRESENTATION NOTES:

- Indeed, one of the best places to look for straight lines and study tectonic activity in the solar system is Europa.
- Icy Europa is one of Jupiter's 4 large moons
    - It is covered in a shell of ice, and scientists think that below the ice is a global ocean.
    - Like Io, Europa is affected by Jupiter's intense gravity and the tidal forces continually re-shape the moon.
    - Europa's surface is covered in cracks, bands and fractures.
- Europa is very exciting to scientists who think it might be one of the best candidates in the solar system to explore to find life in its oceans.
- If we wanted to find out about how ice behaves here on Earth, where could we go?
    - *Arctic, mountains, Antarctica – and indeed, scientists study these places, especially Antarctica, to help them understand icy worlds in our solar system like Europa and dwarf planet Ceres.*

SCIENCE NOTES:

- The image on the left shows a region of Europa's crust made up of blocks which are thought to have broken apart and "rafted" into new positions. These features are the best geologic evidence to date that Europa may have had a subsurface ocean at some time in its past. Combined with the geologic data, the presence of a magnetic field leads scientists to believe an ocean is most likely present at Europa

PRESENTATION NOTES:

- The geology on a planetary surface can help us understand its unique and individual story.
- Now that you have learned some of the basic tools, you can start to piece together the art elements you see to understand a planetary body's history.
- For instance, what is the big feature you see here? *A circle or crater*
- Tell me what else you observe.
    - This circular feature is the impact crater called Tyre Macula on Europa.
    - What do you see going across the impact crater? *Lines or cracks*
    - The lines and cracks show that the surface also has tectonic activity present.
    - What came first, the crater or cracks? *Some cracks are under the crater and came first, then there was an impact that left the large circular feature. Then there are clearly cracks and bands on top of the feature which happened last.*
- So you can use the layers of the art elements you see to uncover the geologic history of a planetary body.

ADDITIONAL SCIENCE NOTES:

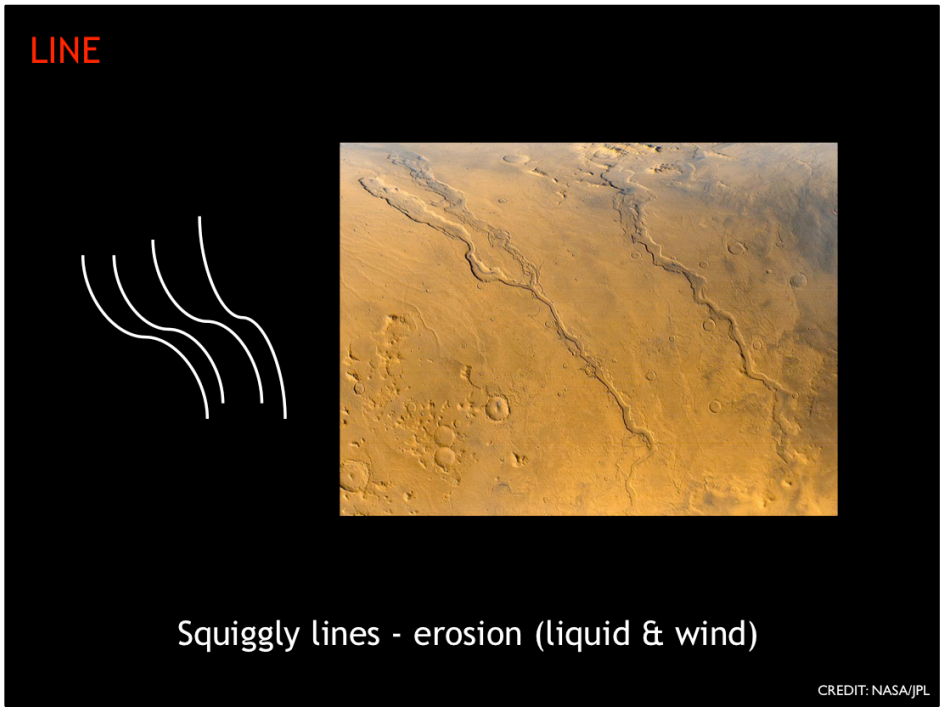
- The "bulls-eye" pattern appears to be an 86-mile-wide impact scar (about the size of the island of Hawaii) which formed as the surface fractured minutes after a mountain-sized asteroid or comet slammed into the satellite. This approximately 132-mile wide picture is the product of three images which have been processed in

PRESENTATION NOTES:

- Let's try it again with this image of Venus.
- What do you see in this image? *Blobs and straight lines*
- This probably means there has been both volcanic and tectonic activity.
- Could the blobs be lakes? *No, because the surface of Venus is too hot for liquid water, so the blobs most likely mean lava.*
- Do you see the break in the straight lines? *Yes*
- Scientists have interpreted this image to mean there was a range of ridges on the left side of the image and the lava broke through to flow to the plains on the right.

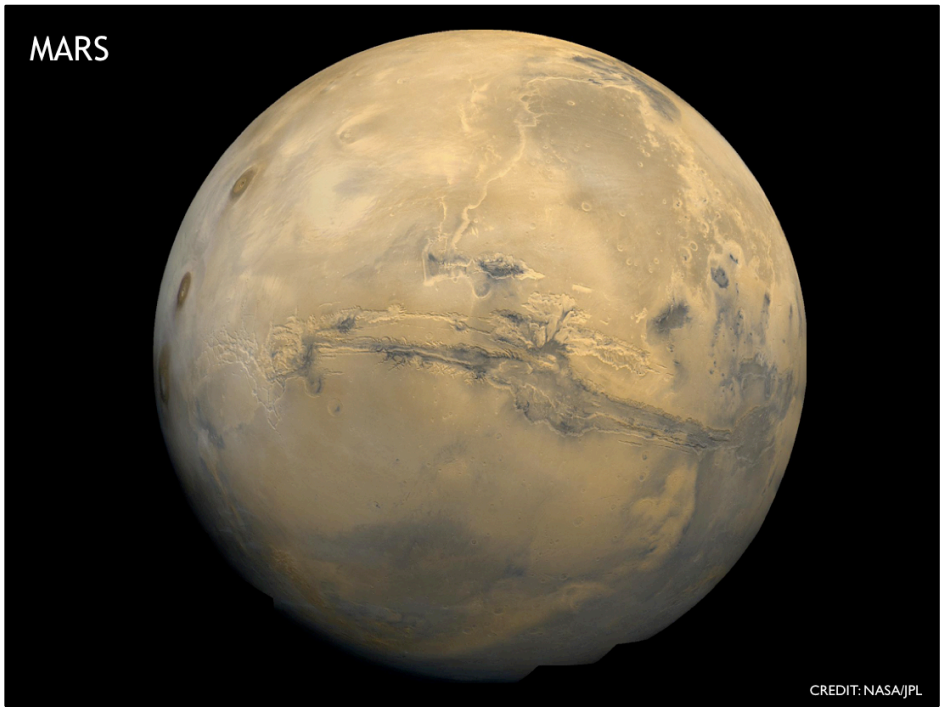
SCIENCE NOTES:

- The mosaic shows a system of east-trending radar-bright and dark lava flows encountering and breaching a north-trending ridge belt (left of center). Upon breaching the ridge belt, the lavas pool in a vast, radar-bright deposit (covering approximately 62,000 square miles [right side of image]). The source caldera for the lava flows, named Ammavaru, lies approximately 186 miles west of the scene. http://photojournal.jpl.nasa.gov/catalog/PIA00486



PRESENTATION NOTES:

- We've discussed straight lines, but scientists also see squiggly lines on the surface of planetary bodies.
    - Hmm, what does this remind you of, if you saw this on Earth…?
    - Squiggly lines often means the surface has experienced erosion… which is most often caused by what? *liquid or wind*
- What type of liquid could cause erosions? *Liquid water as on Earth and Mars, liquid methane on Titan, liquid lava rivers on Venus*
- Can anyone guess what planet this is an image of? *Mars*



PRESENTATION NOTES:

- One of the reasons scientists have been so excited to study Mars is that they see lots of evidence that there has been water on the surface. There are lots of squiggly lines.
- Scientists have not found obvious signs of liquid water currently on Mars, as it is so cold and dry. But they have found lots of clues that it existed in the past.
- What do you see in the center of this image? *A large collection of squiggly lines.*
- Indeed this is a huge canyon system called Valles Marineris, which is 3 times the size of the Grand Canyon on Earth.
- In the 1970's scientists believed this huge canyon was formed by flowing water. But with additional studies, most agree today that Valles Marineris was formed by tectonic activity - rift faults that were made bigger by erosion and collapsing of the rift walls. More than one process likely formed many of the features we are looking at.

SCIENCE NOTES:

More About Mars

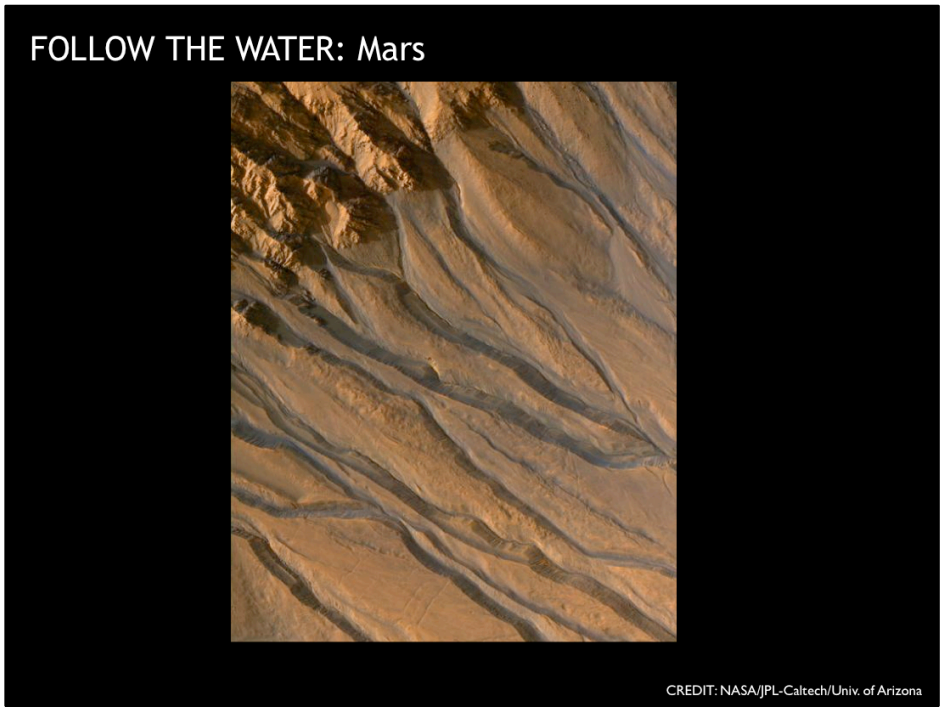
http://www.nasa.gov/mission_pages/mars/main/index.html

PRESENTATION NOTES:

- This is a series of images captured in 2011 that has led some scientists to believe that seasonal flows on Mars today **may** in fact be caused by liquid water. They think that melting and subsequent evaporation of frozen salty water might be the cause of intriguing dark streaks that were observed in images taken during spring and summer on a slope inside Mars' Newton Crater.

SCIENCE NOTES:

- Evidence for the interpretation that this may be an indication of liquid water flowing on Mars today is presented in a report by McEwen *et al.* in the Aug. 5, 2011, edition of *Science*. These images were taken by the High Resolution Imaging Science Experiment (HiRISE) camera on NASA's Mars Reconnaissance Orbiter.
- The features that extend down the slope during warm seasons are called recurring slope lineae. They are narrow (one-half to five meters wide), relatively dark markings on steep slopes at several southern hemisphere locations. Repeat imaging by HiRISE shows the features appear and incrementally grow during warm seasons and fade in cold seasons. They extend downslope from bedrock outcrops, often associated with small channels, and hundreds of them form in rare locations. Liquid brines near the surface might explain this activity, but the exact mechanism and source of the water are not understood.
  http://photojournal.jpl.nasa.gov/catalog/PIA14472

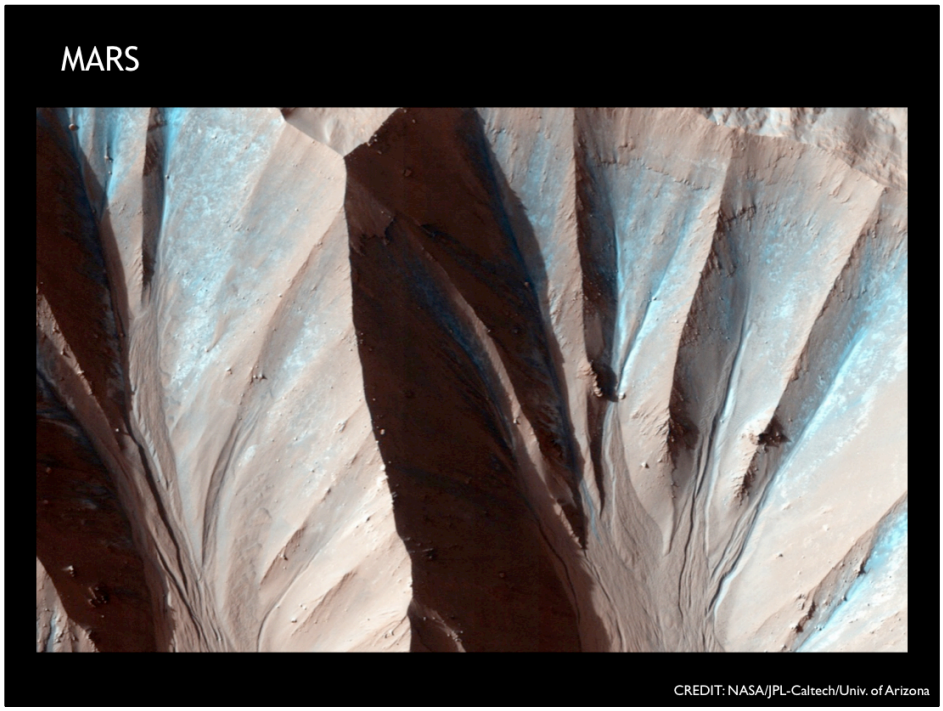


PRESENTATION NOTES:

- This image shows squiggly lines coming from a crater rim.
- Scientists believe these are gullies that have been carved into Mar's surface by water.
- Scientists have a saying, "follow the water". What does this refer to? *They are interested in water because it seems to be necessary for life as we know it.*

SCIENCE NOTES:

- This image shows gully channels in a crater in the southern highlands of Mars, taken by the High Resolution Imaging Science Experiment (HiRISE) camera on the Mars Reconnaissance Orbiter. The gullies emanating from the rocky cliffs near the crater's rim (upper left) show meandering and braided patterns typical of water-carved channels. http://photojournal.jpl.nasa.gov/catalog/PIA10001



PRESENTATION NOTES:

- Gully landforms like those in this image are found in many craters in the mid-latitudes of Mars. Changes in gullies were first seen in images from the Mars Orbiter Camera in 2006.
- Current gully activity appears to be concentrated in winter and early spring, and may be caused by the seasonal carbon dioxide frost that is visible in gully alcoves in the winter.

SCIENCE NOTES:

- This image of landforms on Mars was taken by the High Resolution Imaging Science Experiment (HiRISE) flying onboard the Mars Reconnaissance Orbiter (MRO) mission.
- Learn more about what MRO is finding out about possible water flows on Mars at http://mars.jpl.nasa.gov/mro/.

PRESENTATION NOTES:

- Squiggly lines don't just mean erosion by liquid. What other process can cause erosion? *Wind erosion*
- Indeed, Mars hasn't just had erosion due to liquid water, it also has a lot of wind.
- What do you think this is an image of (think of the desert)? *This is an image of sand dunes.*

SCIENCE NOTES:

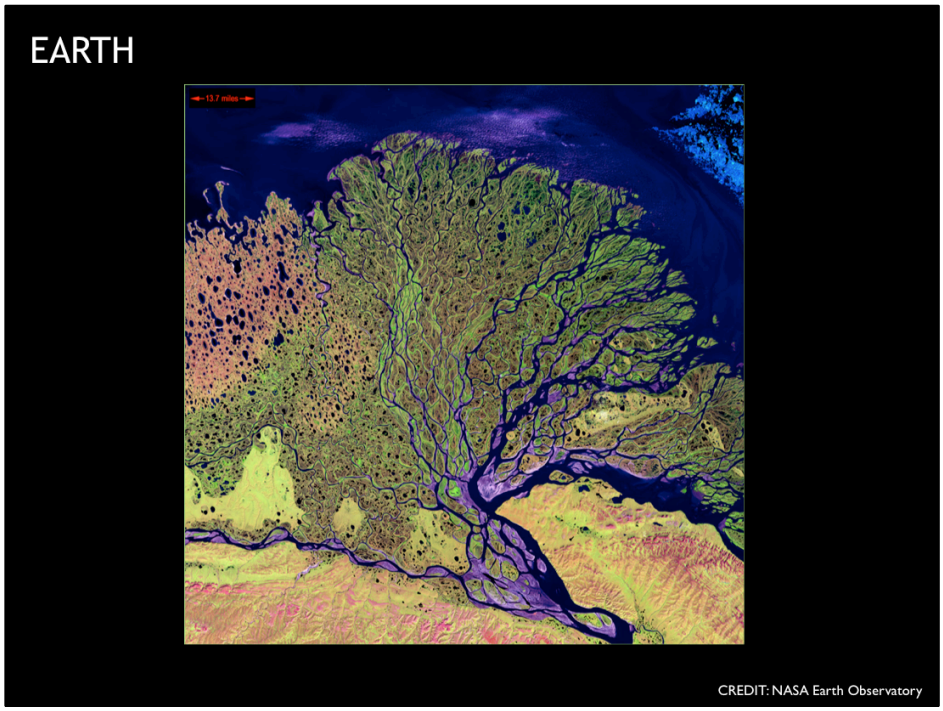
- This view from the High Resolution Imaging Science Experiment (HiRISE) camera on NASA's Mars Reconnaissance Orbiter shows two classes of aeolian bedforms within Proctor Crater. The relatively bright, small ridges are ripples. From their study on Earth and close-up examination by the Mars Exploration Rovers (roving elsewhere on Mars), we know that ripples are composed of fine sand (less than 200 microns in diameter) or fine sand coated with coarser sand and granules. http://photojournal.jpl.nasa.gov/catalog/PIA11833

PRESENTATION NOTES:

- We've talked about how shapes and lines can tell the story of a surface.
- What do you see here? *Circles and squiggly lines*
- Yes, but the circle has a squiggly edge so what has happened? *They have been eroded*
- The circle is a crater called Victoria Crater. Its edges have been eroded and are now irregular. There are sand dunes at the bottom of the crater.
- Do you see the small circles around Victoria crater? *Yes*
- Do you think those are older or younger than the big crater? *They are younger because they are very circular and have not been eroded*

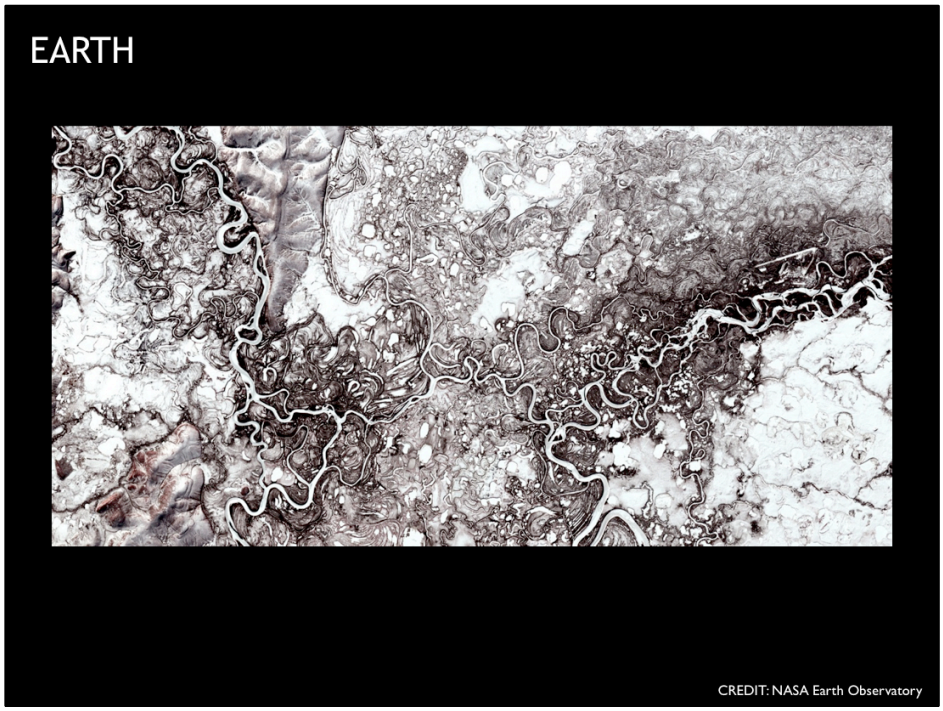
SCIENCE NOTES:

- "Victoria Crater," about one-half mile in diameter, was home ground for NASA's Mars Exploration Rover Opportunity for more than 14 of the rover's first 46 months on Mars. http://photojournal.jpl.nasa.gov/catalog/PIA08813



PRESENTATION NOTES:

- One of the most exciting and beautiful places to look for squiggly lines and erosion is our own planet Earth.
  - Earth is the ONLY planet in the solar system known to have liquid water on the surface.
  - We also have a thick, wet, windy atmosphere so there has been a lot of erosion on the surface of Earth.
  - This image is of the Lena River Delta in Russia taken from space.
- As a reminder, where is the only other solar system body that we know has liquid on the surface? *Saturn's moon, Titan*



PRESENTATION NOTES:

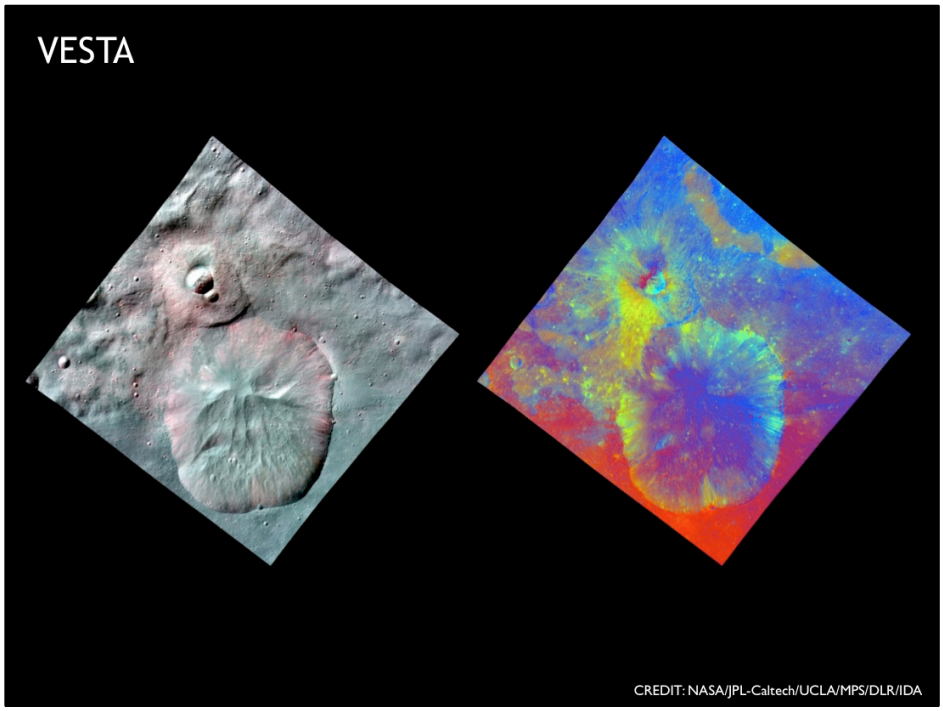
- This is another beautiful image of streams and rivers in Siberia at winter.
- Do you see all the squiggly lines? *Yes*
- What are they? *Rivers and streams covered with snow and ice.*

PRESENTATION NOTES:

- Do you think all the images we've looked at are in "true-color," meaning what your eyes see? *No*
- Scientists use color as an important tool to understand planetary surfaces.
- Sometimes they use different types of light, such as infrared or ultraviolet, to take images.
- Sometimes they use various filters or color schematics to highlight certain features.
- The image of the Moon on the left is in black and white. The image on the right has been colorized to show the differences in surface composition.
- One way to think about this is to call it "translated" color - translated into visible colors that we can see. What else is often translated? *Languages*

SCIENCE NOTES:

- The translated color processing used to create this lunar image is helpful for interpreting the surface soil composition. Areas appearing red generally correspond to the lunar highlands, while blue to orange shades indicate the ancient volcanic lava flow of a mare, or lunar sea. Bluer mare areas contain more titanium than do the orange regions. Mare Tranquillitatis, seen as a deep blue patch on the right, is richer in titanium than Mare Serenitatis, a slightly smaller circular area immediately adjacent to the upper left of Mare Tranquillitatis. Blue and orange areas covering much of the left side of the Moon in this view represent many separate lava flows in Oceanus Procellarum. The small purple areas found near the center are pyroclastic deposits formed by explosive volcanic eruptions.
  http://photojournal.jpl.nasa.gov/catalog/PIA00132

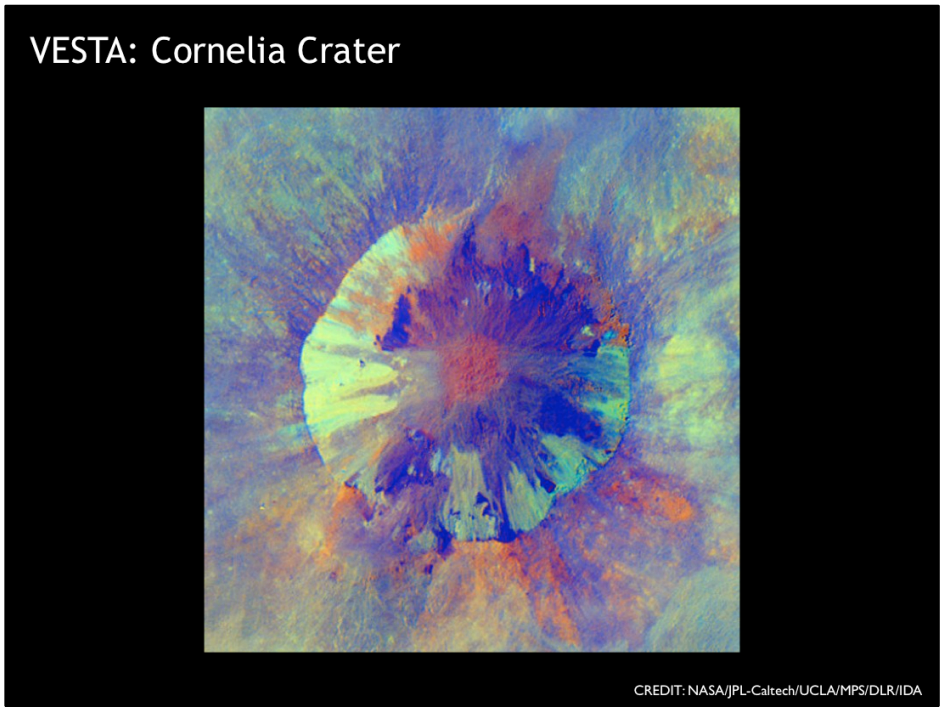


PRESENTATION NOTES:

- Here are two recent images the Dawn spacecraft took of the large asteroid Vesta.
- The image on the left uses infrared filters and the image on the right uses color to represent different types of rock and minerals present.
- What does color help us see when comparing these two images? *Encourage discussion*
- Scientists are using color to better understand the surface.

SCIENCE NOTES:

- This image combines two separate views of the giant asteroid Vesta obtained by NASA's Dawn spacecraft. The images were taken by Dawn's framing camera. The far-left image uses near-infrared filters where red is used to represent 750 nanometers, green represents 920 nanometers and blue represents 980 nanometers. The image on the right is an image with colors assigned by scientists, representing different rock or mineral types on Vesta. The data reveal a world of many varied, well-separated layers and ingredients. The reddish color suggests a steep visible spectral slope, and areas of fresh landslides in the inner walls of the crater show deeper green colors. http://dawn.jpl.nasa.gov/multimedia/vesta_terrains.asp



PRESENTATION NOTES:

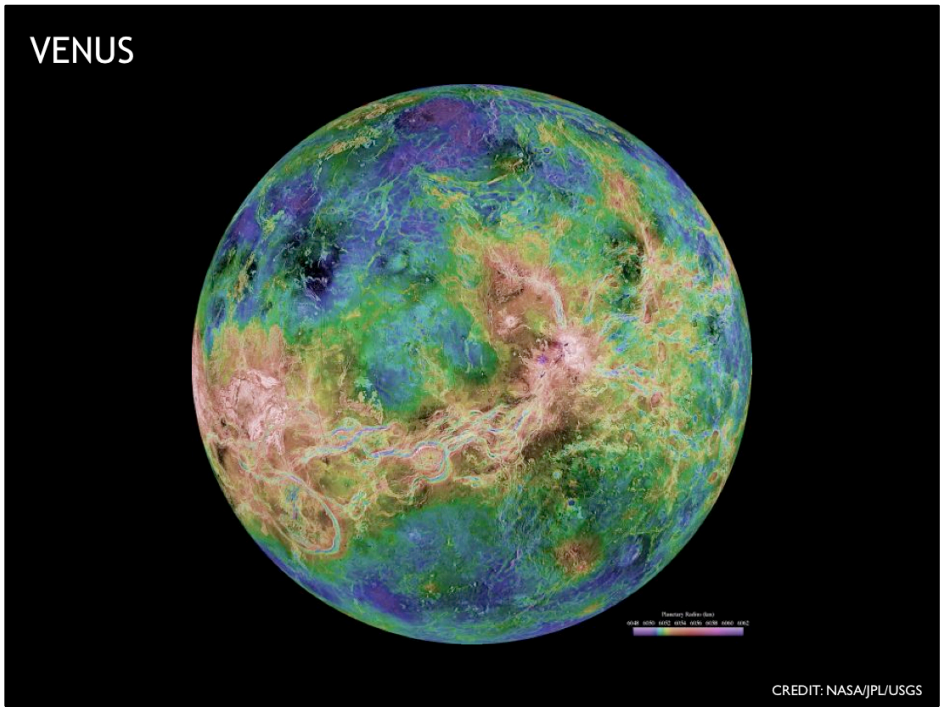
- In this case, the color represents minerals. The pitted terrain in the bottom of the crater contains hydrated, carbon-rich minerals - evidence that water once existed on the giant asteroid!

SCIENCE NOTES:

This enhanced-color view from NASA's Dawn mission shows an unusual "pitted terrain" on the floor of Cornelia crater on the giant asteroid Vesta. A comparison with other craters shows that the physical properties or composition of the material in which these pits form is different from crater to crater.

Scientists think low-speed collisions with carbon-rich meteorites left hydrated minerals on Vesta's surface. It is thought that heat generated during later, high-speed collisions with asteroid belt rocks released water that was previously bound within the hydrated minerals. This water is thought to have explosively degassed into space, leaving behind pothole-like depressions as it escaped.

- http://dawn.jpl.nasa.gov/multimedia/pitted_terrain_in_color.asp

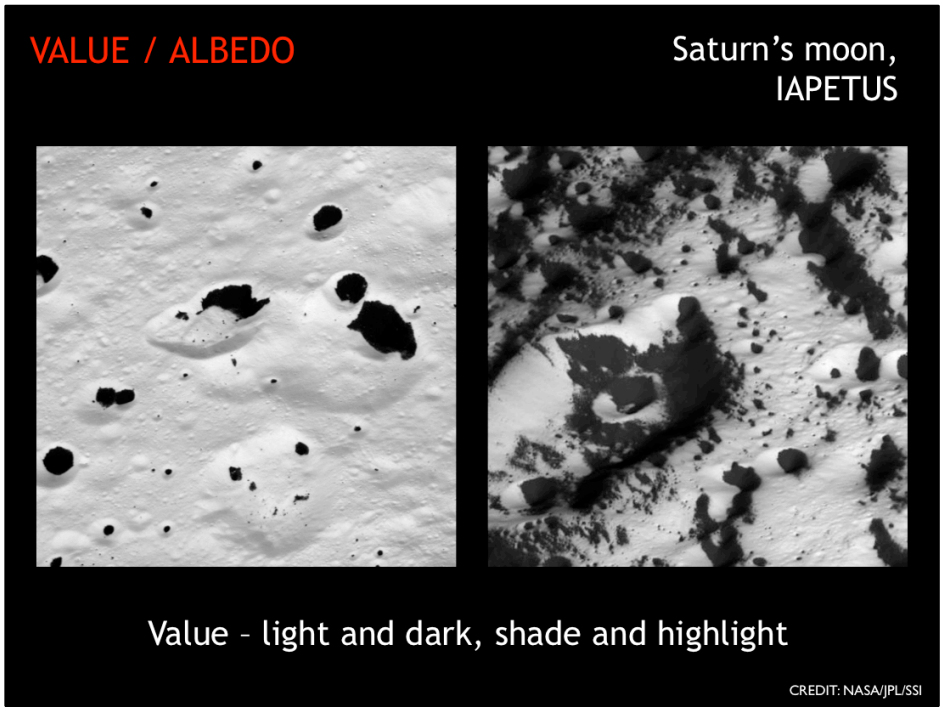


PRESENTATION NOTES:

- Here is an image of Venus that has been color-coded to represent the elevation of different parts of the surface.

SCIENCE NOTES:

- The composite image was processed to improve contrast and to emphasize small features, and was color-coded to represent elevation.
- http://photojournal.jpl.nasa.gov/catalog/PIA00159



PRESENTATION NOTES:

- Can anyone give me a definition of Value? *Value means the contrast between light and dark.*
- Scientists use a similar concept called "albedo," which is the measure of the reflectivity of a surface.
- These two images are details of the surface of Iapetus, a strange icy moon of Saturn.

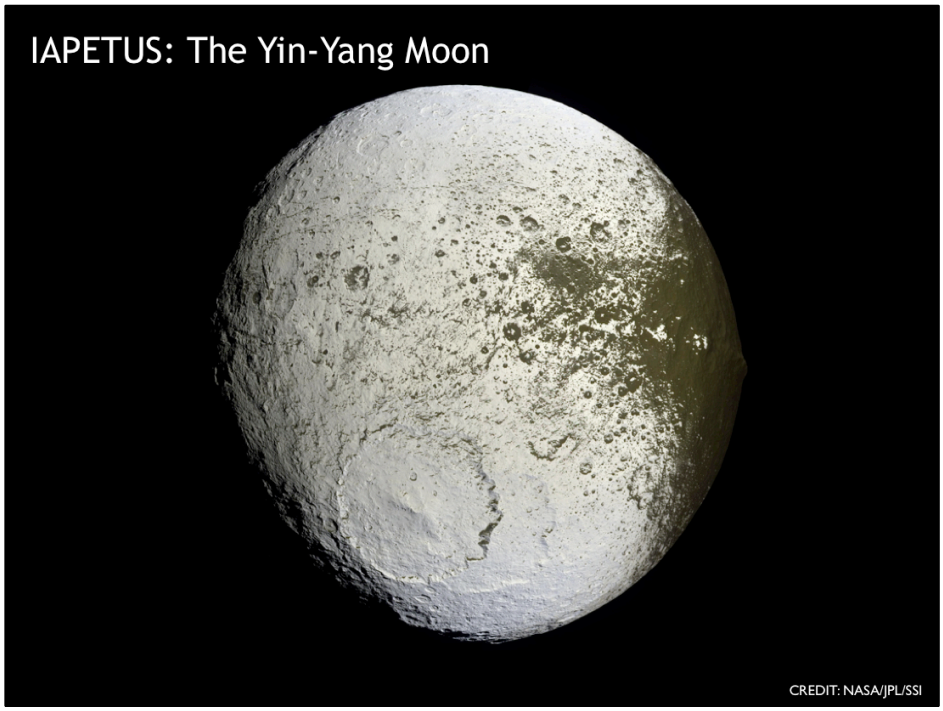
SCIENCE NOTES:

Left Image

- Dark material splatters the walls and floors of craters in the surreal, frozen wastelands of Iapetus. This image shows terrain in the transition region between the moon's dark leading hemisphere and its bright trailing hemisphere. The view was acquired during Cassini's only close flyby of the two-toned Saturn moon. http://photojournal.jpl.nasa.gov/catalog/PIA08374

Right image

- Cassini surveys a bright landscape coated by dark material on Iapetus. This image shows terrain in the transition region between the moon's dark leading hemisphere and its bright trailing hemisphere. The view was acquired during Cassini's only close flyby of the two-toned Saturn moon. http://photojournal.jpl.nasa.gov/catalog/PIA08373

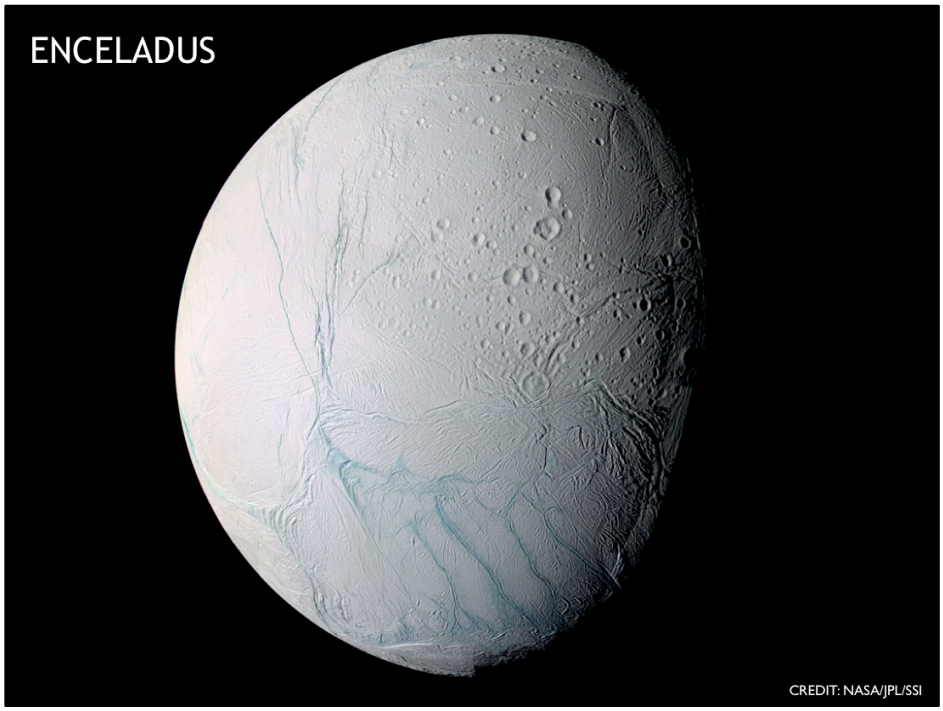


PRESENTATION NOTES:

- Iapetus has the most intense value contrast in the solar system.
    - Half of its surface is bright white the other half is as dark as black velvet.
- Things that are bright white are very reflective; this often means they are composed of ice.
- Iapetus is still a mystery, and scientists are currently studying it and developing theories to explain its unusual terrain.
- What else do you see in Iapetus' southern hemisphere? *A large circle/crater meaning a large impact*

SCIENCE NOTES:

- In many places, the dark material--thought to be composed of nitrogen-bearing organic compounds called cyanides, hydrated minerals and other carbonaceous minerals--appears to coat equator-facing slopes and crater floors. The distribution of this material and variations in the color of the bright material across the trailing hemisphere will be crucial clues to understanding the origin of Iapetus' peculiar bright-dark dual personality. http://photojournal.jpl.nasa.gov/catalog/PIA08384

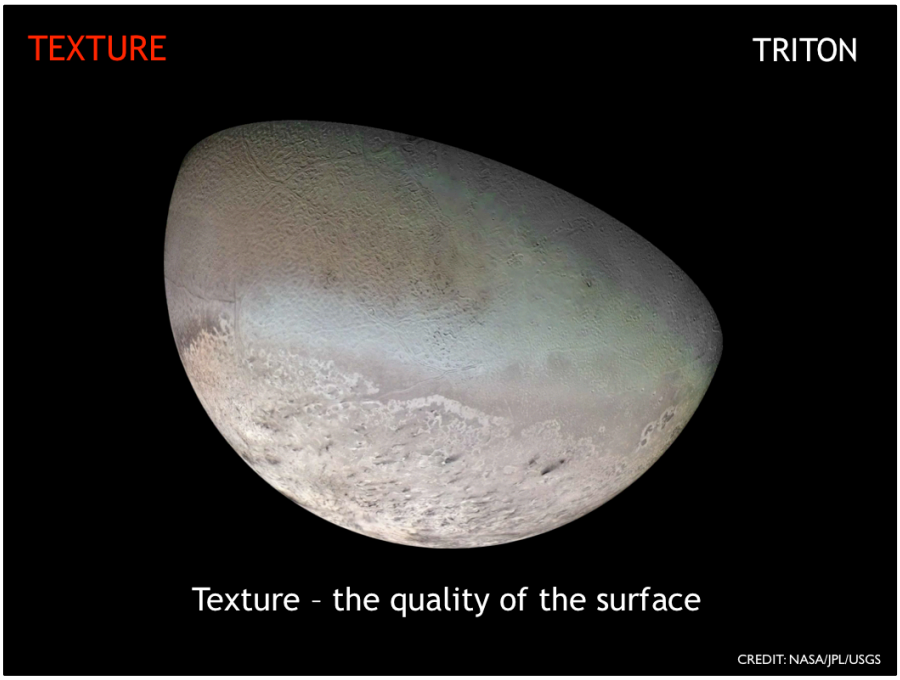


PRESENTATION NOTES:

- Enceladus is a small icy satellite of Saturn. It is the brightest body in our solar system other than the Sun.
- It is bright white, so what do you think its surface is made of? *Ice*
- Yes, It is made of almost pure water ice.
- What else do you see at the bottom of Enceladus? *Lines or cracks, tectonic features*
- These are tectonic features called Tiger Strips. They are faults from which water geysers are erupting.

SCIENCE NOTES:

- A masterpiece of deep time and wrenching gravity, the tortured surface of Saturn's moon Enceladus and its fascinating ongoing geologic activity tell the story of the ancient and present struggles of one tiny world. The enhanced color view of Enceladus seen here is largely of the southern hemisphere and includes the south polar terrain at the bottom of the image. Ancient craters remain somewhat pristine in some locales, but have clearly relaxed in others. Northward-trending fractures, likely caused by a change in the moon's rate of rotation and the consequent flattening of the moon's shape, rip across the southern hemisphere. The south polar terrain is marked by a striking set of `blue' fractures and encircled by a conspicuous and continuous chain of folds and ridges, testament to the forces within Enceladus that have yet to be silenced.
  http://photojournal.jpl.nasa.gov/catalog/PIA07800

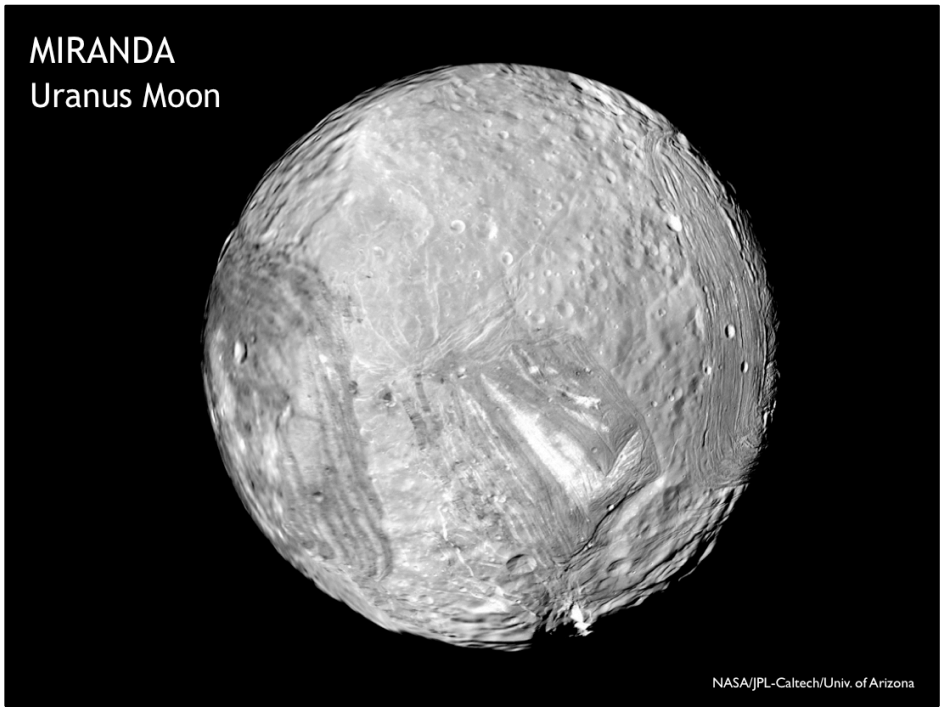


PRESENTATION NOTES:

- Looking at the texture of a planetary surface can give scientists clues as to its geologic story.
- This is Triton, a small icy moon of Neptune.
    - Scientists figured something this far from the Sun and so cold would not have a lot of geologic activity.
    - However, when they got images of Triton they saw this weird texture.
- What does Triton remind you of? *A cantaloupe*
    - The presence of this weird cantaloupe terrain, combined with a lack of craters, suggested that Triton was geologically active.
- And indeed scientists have found evidence of geysers and cryo-volcanoes -- ice volcanoes!

SCIENCE NOTES:

- The surface of Triton is very rugged, scarred by rising blobs of ice, faults and volcanic pits and lava flows composed of water and other ices. The surface is also extremely young and sparsely cratered and could be geologically active today. http://photojournal.jpl.nasa.gov/catalog/PIA12186
- The pinkish deposits constitute a vast south polar cap believed to contain methane ice, which would have reacted under sunlight to form pink or red compounds. The dark streaks overlying these pink ices are believed to be an icy and perhaps carbonaceous dust deposited from huge geyser-like plumes, some of which were found to be active during the Voyager 2 flyby. http://photojournal.jpl.nasa.gov/catalog/PIA00317

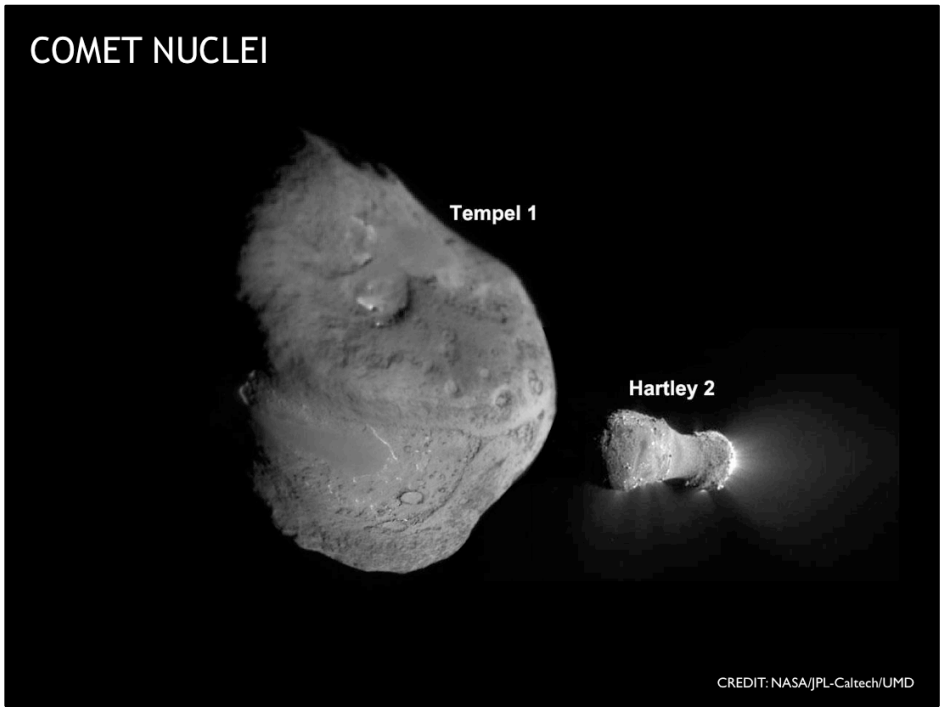


PRESENTATION NOTES:

- One of the strangest most varied surfaces in all of the solar system is present on Uranus' small moon Miranda.
- What do you see in the bottom of this image? *Huge straight lines, cracks, tectonics*
- Scientists think Miranda was smashed apart in some collision and then came back together.

SCIENCE NOTES:

- Like Frankenstein's monster, Miranda looks like it was pieced together from parts that didn't quite merge properly. At about 500 km in diameter, it's only one-seventh as large as Earth's moon, a size that seems unlikely to support much tectonic activity. Yet Miranda sports one of the strangest and most varied landscapes among extraterrestrial bodies, including three large features known as "coronae," which are unique among known objects in our solar system. They are lightly cratered collections of ridges and valleys, separated from the more heavily cratered (and presumably older) terrain by sharp boundaries like mismatched patches on a moth-eaten coat. Miranda's giant fault canyons are as much as 12 times as deep as the Grand Canyon. Due to Miranda's low gravity and large cliffs, a rock dropped off the edge of the highest cliff would take a full 10 minutes to reach the foot of the cliff.
- http://solarsystem.nasa.gov/planets/profile.cfm?Object=Miranda



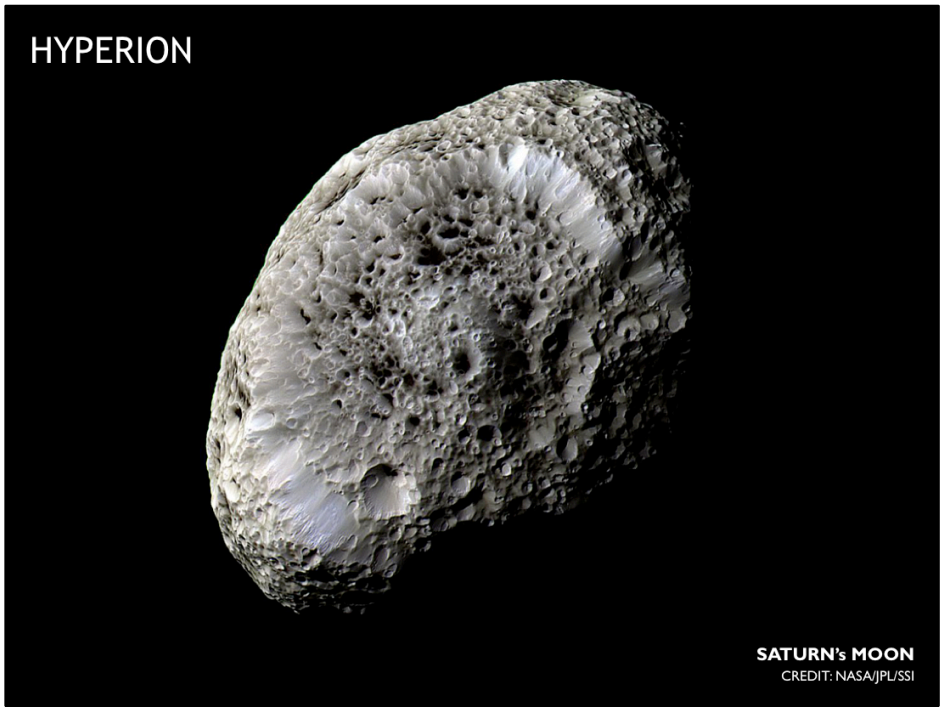
PRESENTATION NOTES:

- Recent and ongoing NASA missions have given us a close up look at the nucleus of comets.
- The surfaces of comets are fascinating and constantly changing. As they approach the Sun, they heat up and shoot jets of ice, dust, and gases from their surfaces.

SCIENCE NOTES:

The Deep Impact/EPOXI Mission

- This image shows the nuclei of comets Tempel 1 and Hartley 2, both imaged by NASA's Deep Impact spacecraft. After its primary mission to impact Tempel 1, the spacecraft continued on to Hartley 2 as part of an extended mission known as EPOXI.
- http://www.nasa.gov/mission_pages/epoxi/index.html

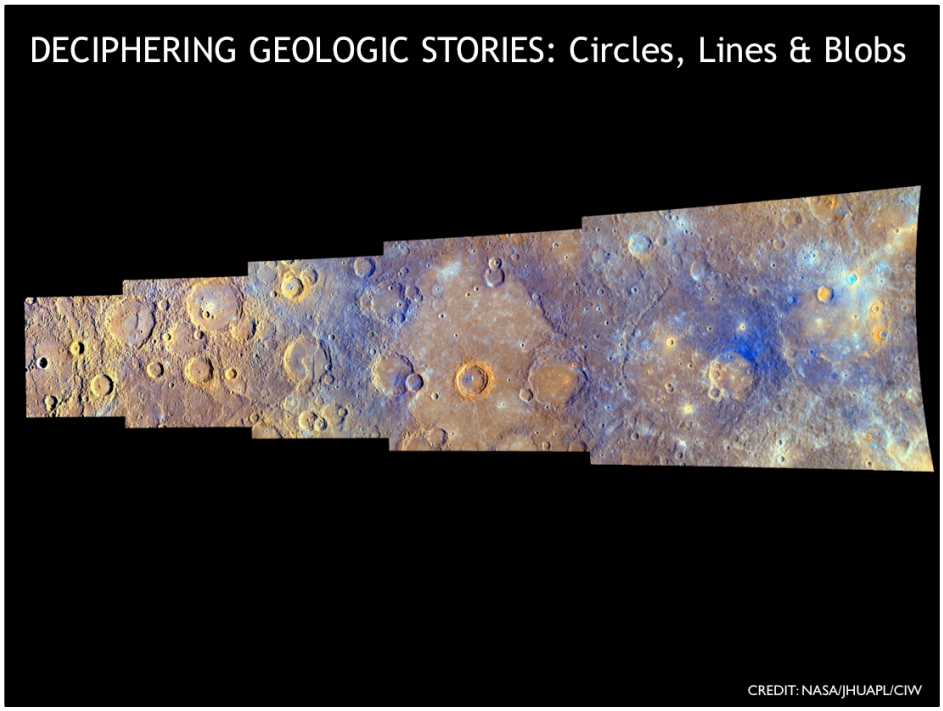


PRESENTATION NOTES:

- A moon with one of the strangest textures in the solar system is Saturn's small icy moon Hyperion.
    - What does it look like to you? *A sponge, loofa*
    - Finding unusual things helps scientists to develop new theories as to how a world is formed. Scientists are still trying to understand Hyperion.
    - Why is Hyperion lumpy and not shaped like a ball? *It does not have enough mass to pull itself into a spherical shape.*

SCIENCE NOTES:

- Cassini mission scientists think that Hyperion's unusual appearance can be attributed to the fact that it has an unusually low density for such a large object, giving it weak surface gravity and high porosity. These characteristics help preserve the original shapes of Hyperion's craters by limiting the amount of impact ejecta coating the moon's surface. Impactors tend to make craters by compressing the surface material, rather than blasting it out. Further, Hyperion's weak gravity, and correspondingly low escape velocity, means that what little ejecta is produced has a good chance of escaping the moon altogether.
  http://photojournal.jpl.nasa.gov/catalog/PIA07740

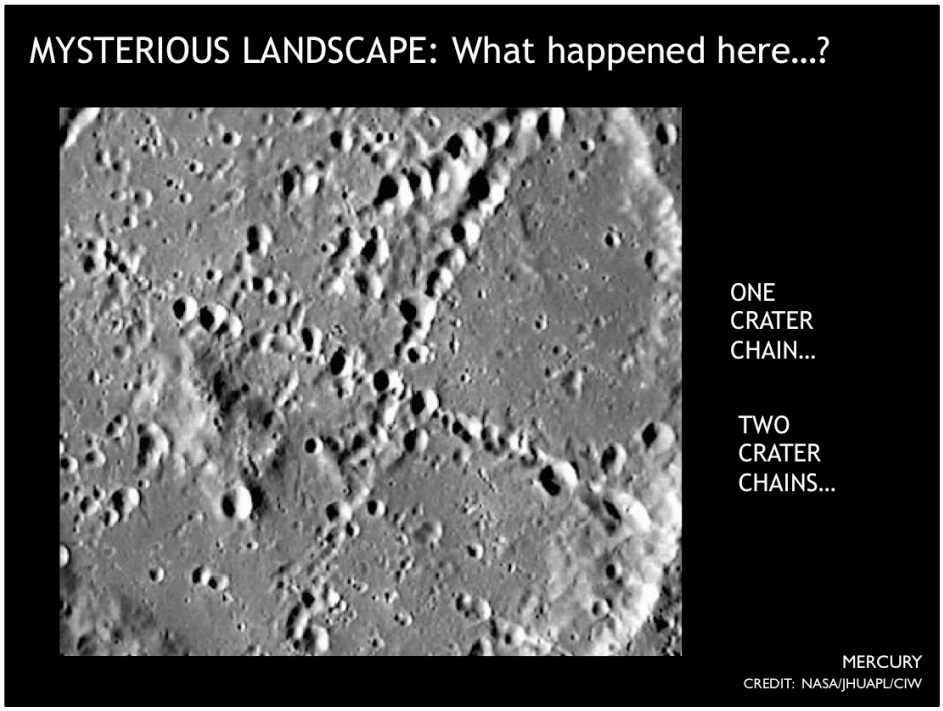


PRESENTATION NOTES:

- We can combine what we know about the Elements of Art to start to understand complex geologic stories.
- What do you see here? *Encourage all discussion*
    - Lots of **impact craters**, some old, some newer, as indicated by what is on top and bottom.
    - Large **blobby shape** in the middle of the image is an old **volcanic basin**. You know it's older because it is covered in subsequent craters.
    - **Young ray craters** have fresh bright ejecta.
    - Lines on the image indicate tectonic activity. These are **scarps** or cliffs that formed when Mercury's interior shrank in its past and its surface buckled.

SCIENCE NOTES:

- During MESSENGER's second flyby of Mercury, the Mercury Dual Imaging System acquired a strip of high-resolution images using each of the Wide Angle Camera's 11 different color filters. There is a detailed graphic and key located on the NASA site: http://photojournal.jpl.nasa.gov/catalog/PIA13823



PRESENTATION NOTES:

- Indeed, the thing that propels science and makes it so exciting are the things we DON'T know.
- For instance, what do you see in this image? *A cross of circles*
- What could have caused this? *Encourage discussion even if theories are wrong*
- Scientists do exactly what you just did. When they see something they don't understand, they come up with ideas and theories to explain what they are seeing. Many ideas end up being tossed aside as new evidence arises, but it is through the process of asking questions that we come up with answers.
- This feature on Mercury was probably formed by a set of orbiting impactors (broken up asteroid or comet) hitting the planet one after another, or one big impactor "skipping" across the surface a little like a stone across water.

SCIENCE NOTES:

X Marks the Spot

This image was taken using the Mercury Dual Imaging System (MDIS) pivot and Narrow Angle Camera (NAC) on April 24, 2011.

- http://www.nasa.gov/mission_pages/messenger/multimedia/messenger_orbit_image20110428_1.html

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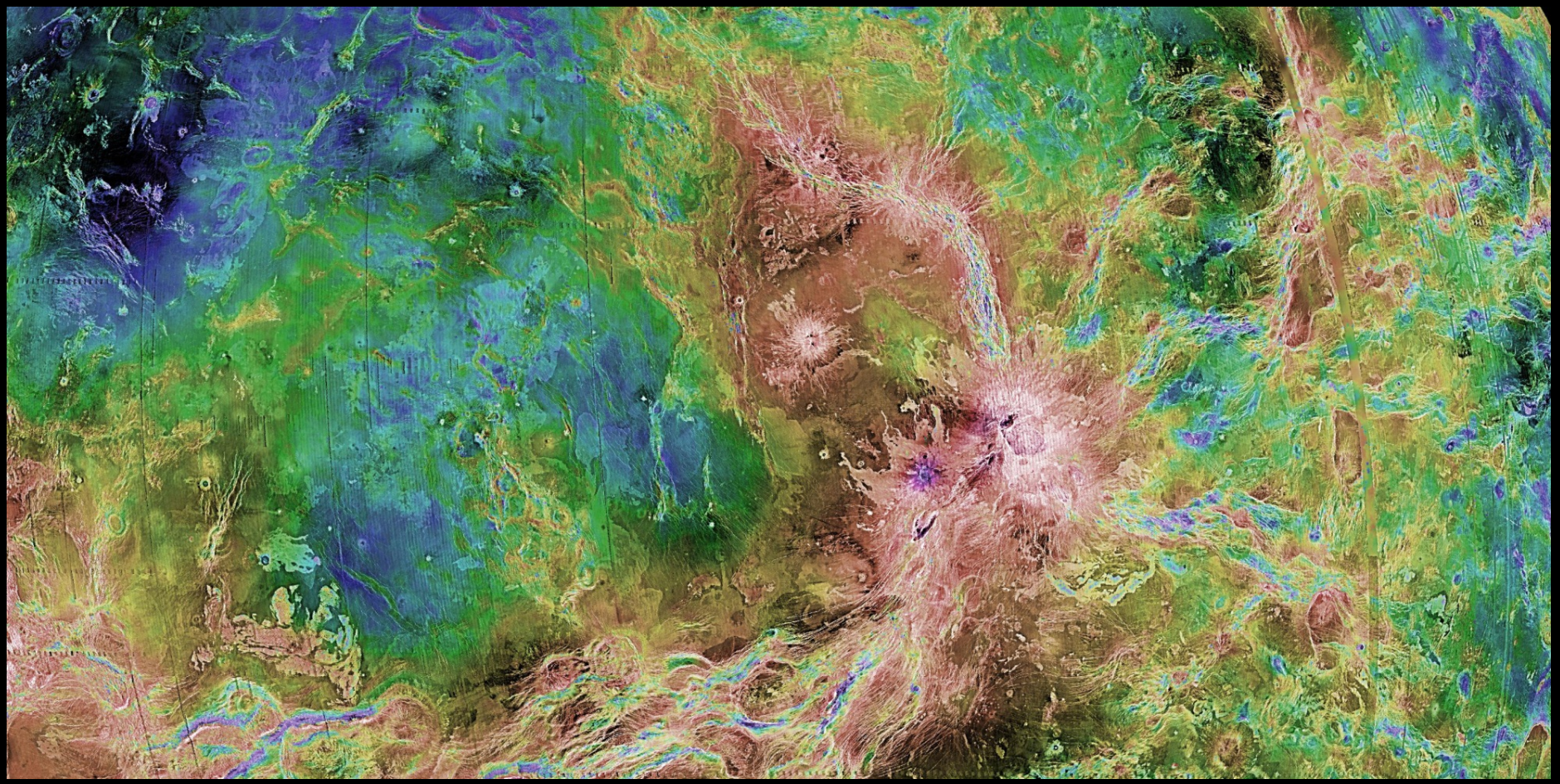
ART & THE COSMIC CONNECTION

Viewing NASA Images Through the Elements of Art



Created by Monica & Tyler Aiello, Planetary Artists and Educators
For NASA's Discovery and New Frontiers Programs

http://discovery.nasa.gov http://newfrontiers.nasa.gov

SCIENCE INSPIRES ART

MONICA & TYLER AIELLO

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DENVER MUSEUM OF NATURE & SCIENCE - Gates Planetarium

PROGRAM HIGHLIGHTS

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- Easy to follow Presentation and Science Notes
- Correlates with current and recent missions
- Scalable for K-12 students…and beyond
- Art Activity to reinforce concepts
- Beautiful NASA images for printing
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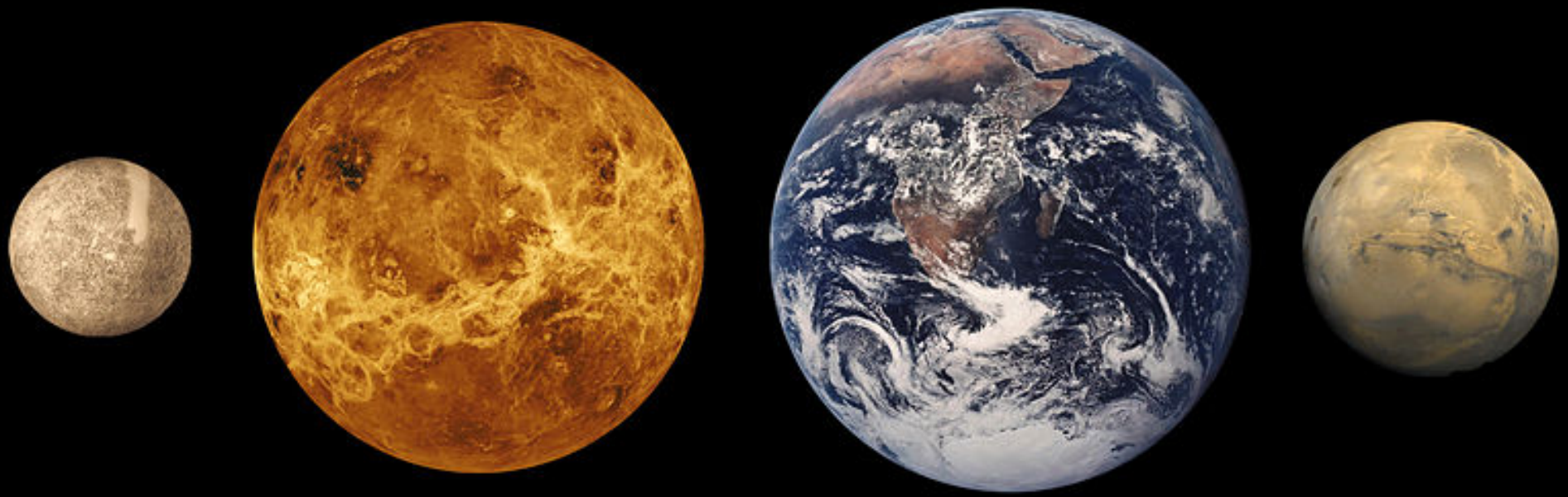
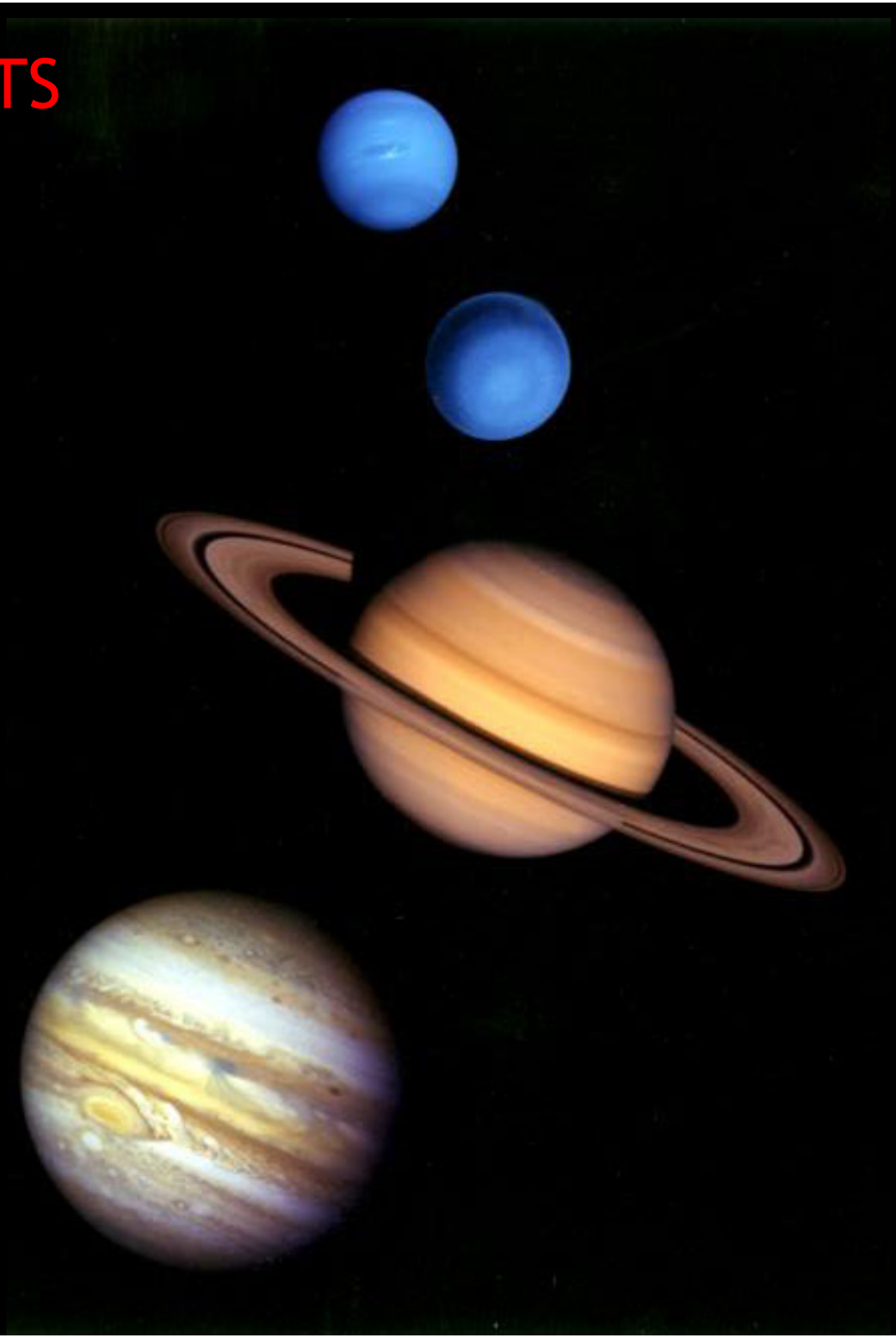
OUR SPACE COMMUNITY

What do you know about the solar system?

INNER PLANETS



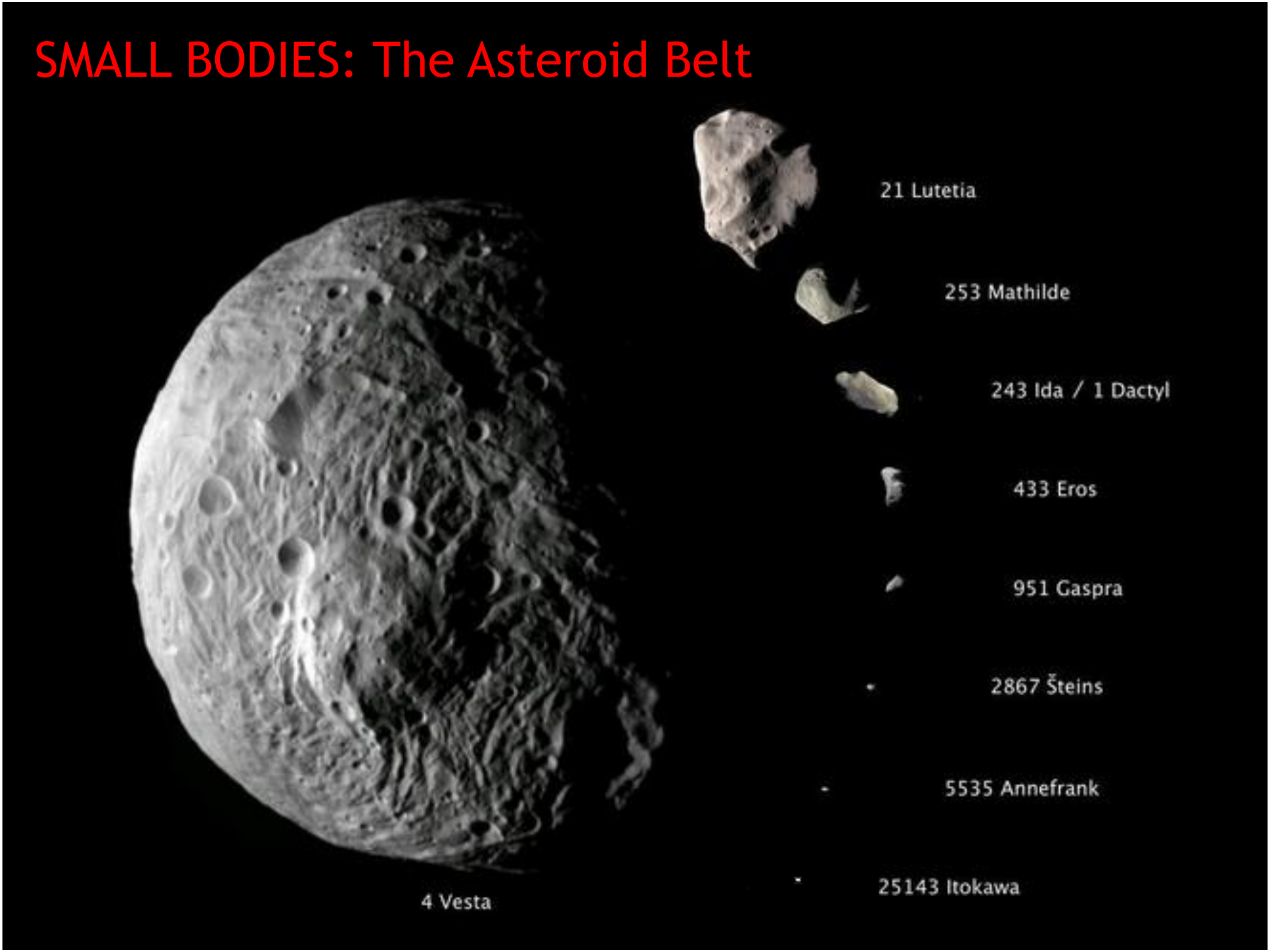
OUTER PLANETS



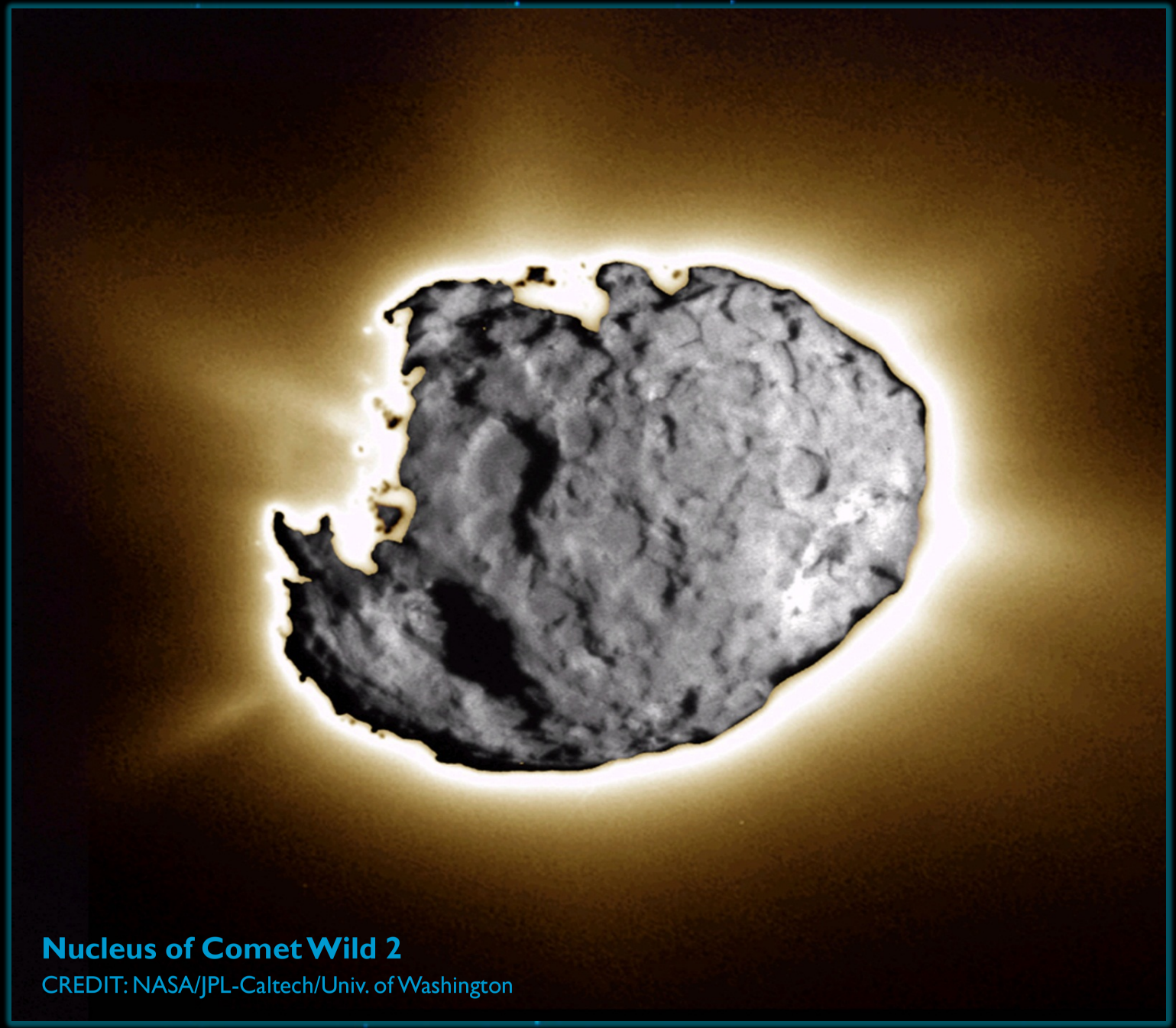
SMALL BODIES: Moons

CREDIT: NASA/JPL

SMALL BODIES: The Asteroid Belt



SMALL BODIES: Comets

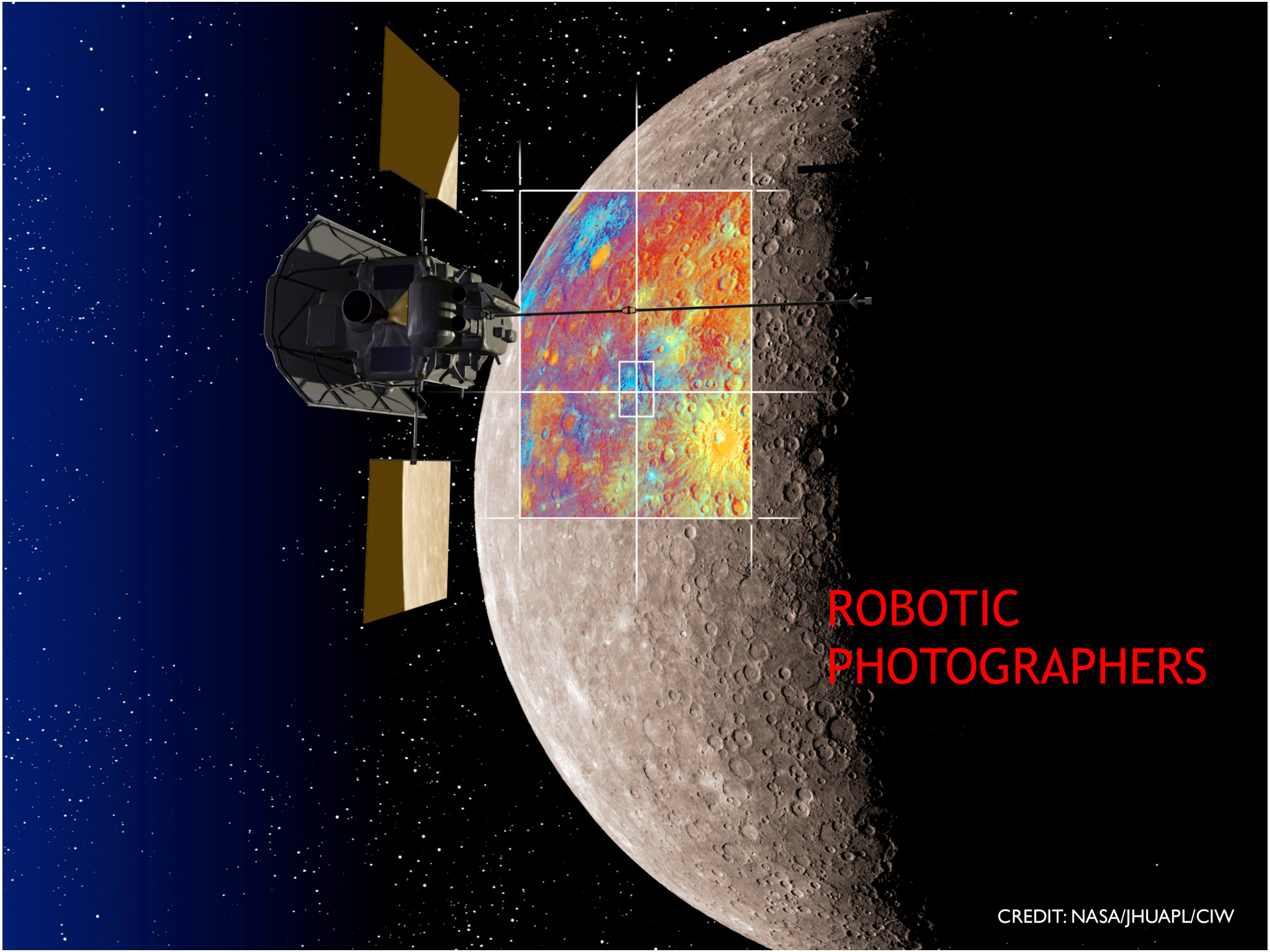


Nucleus of Comet Wild 2

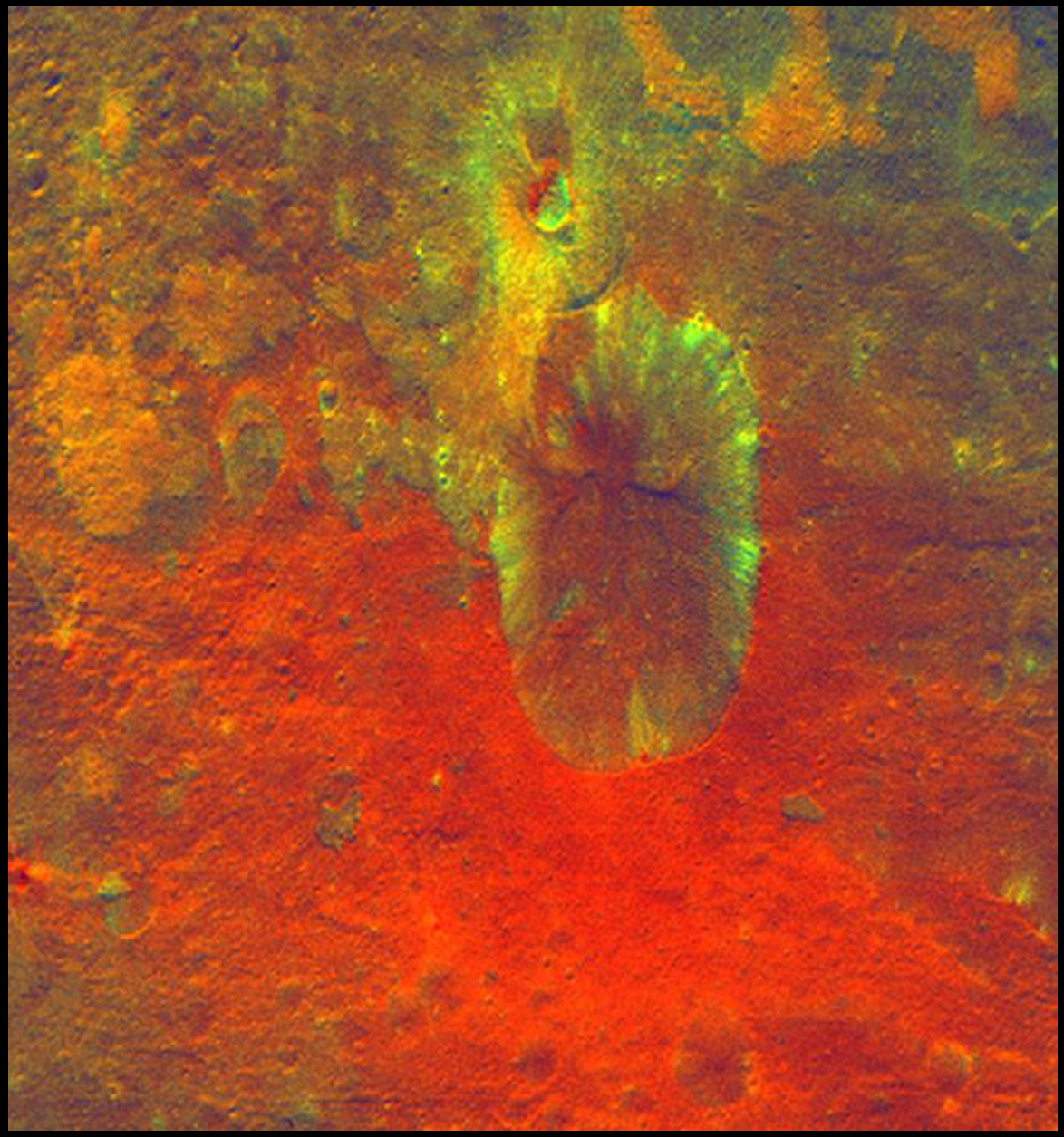
CREDIT: NASA/JPL-Caltech/Univ. of Washington

What happened to Pluto?

Notice some have moons - We now know of 5 moons orbiting Pluto!


ROBOTIC
PHOTOGRAPHERS
CREDIT: NASA/JHUAPL/CIW

GEOLOGY & THE ELEMENTS OF ART

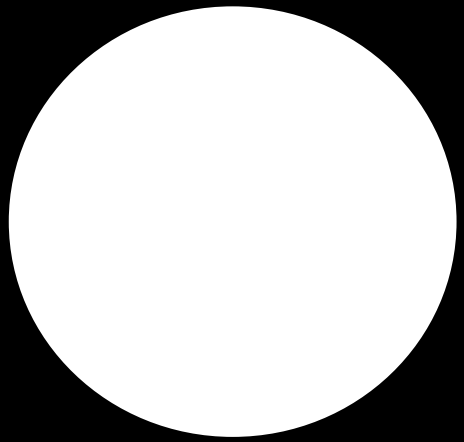


- LINE
- SHAPE
- COLOR
- VALUE
- TEXTURE

GIANT ASTEROID VESTA

CREDIT: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA

SHAPE

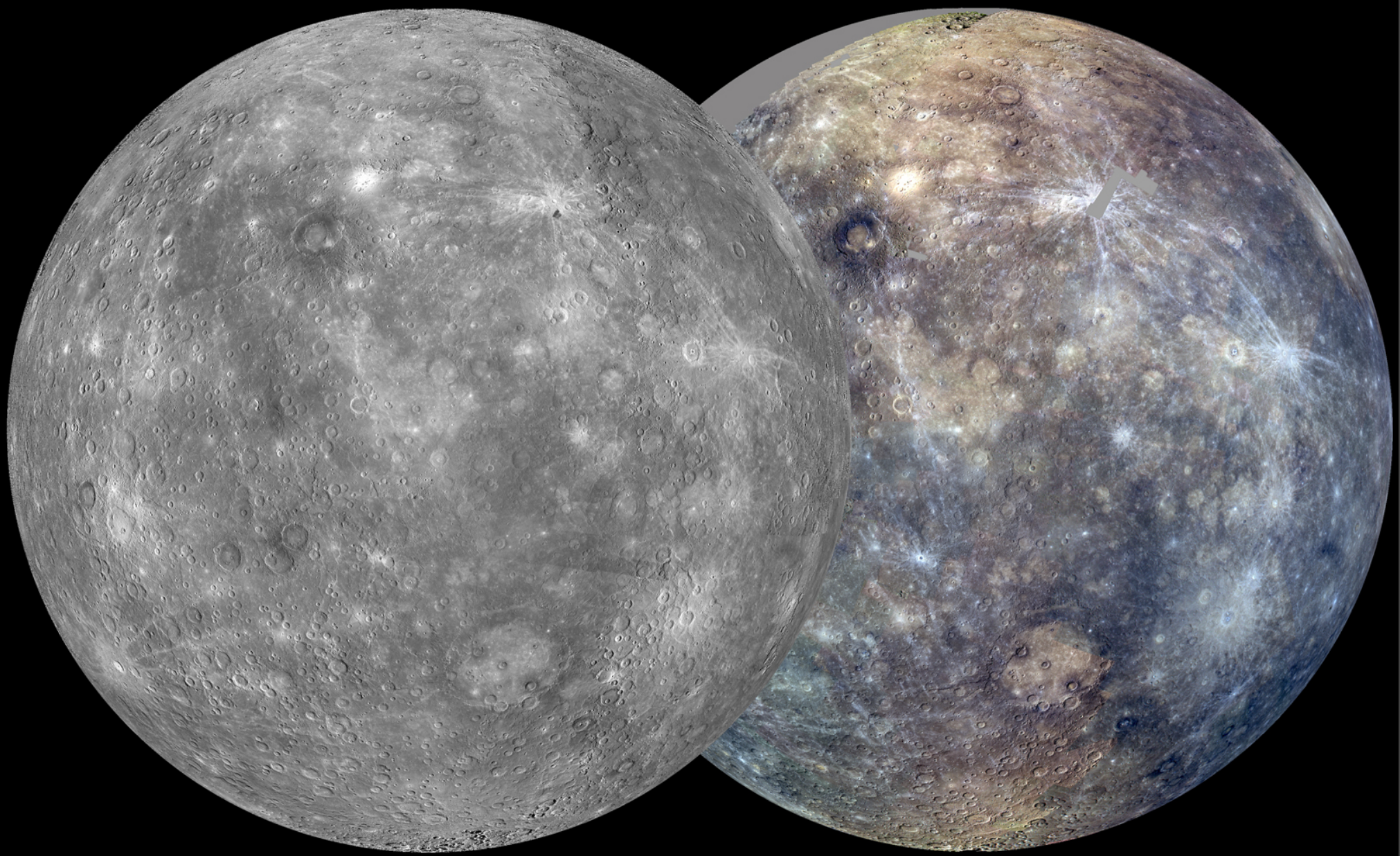


Circle - Craters

MARS

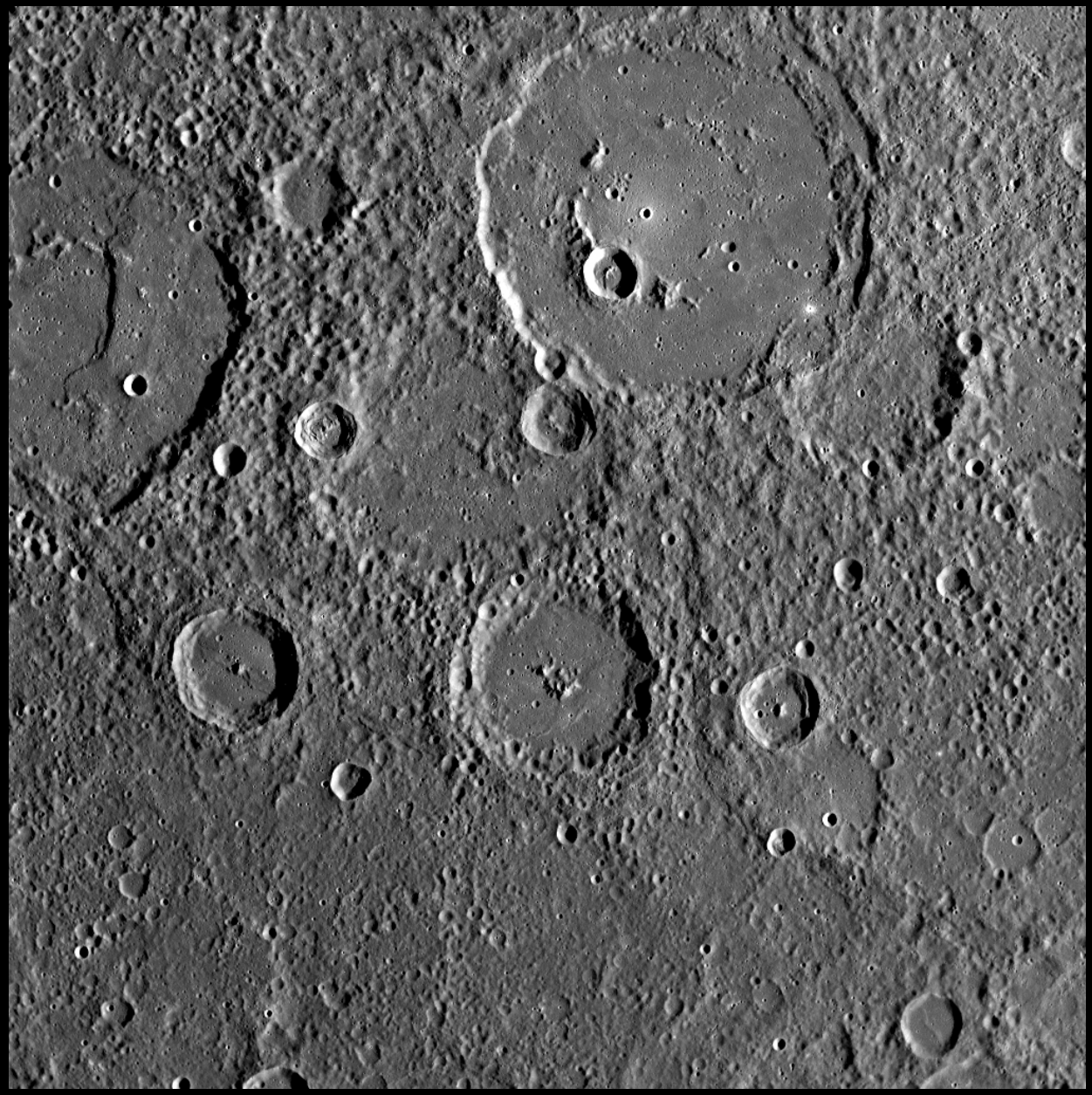
CREDIT: NASA/JPL

CIRCLES: Mercury



CREDIT: NASA/JHUAPL/CIW

MERCURY



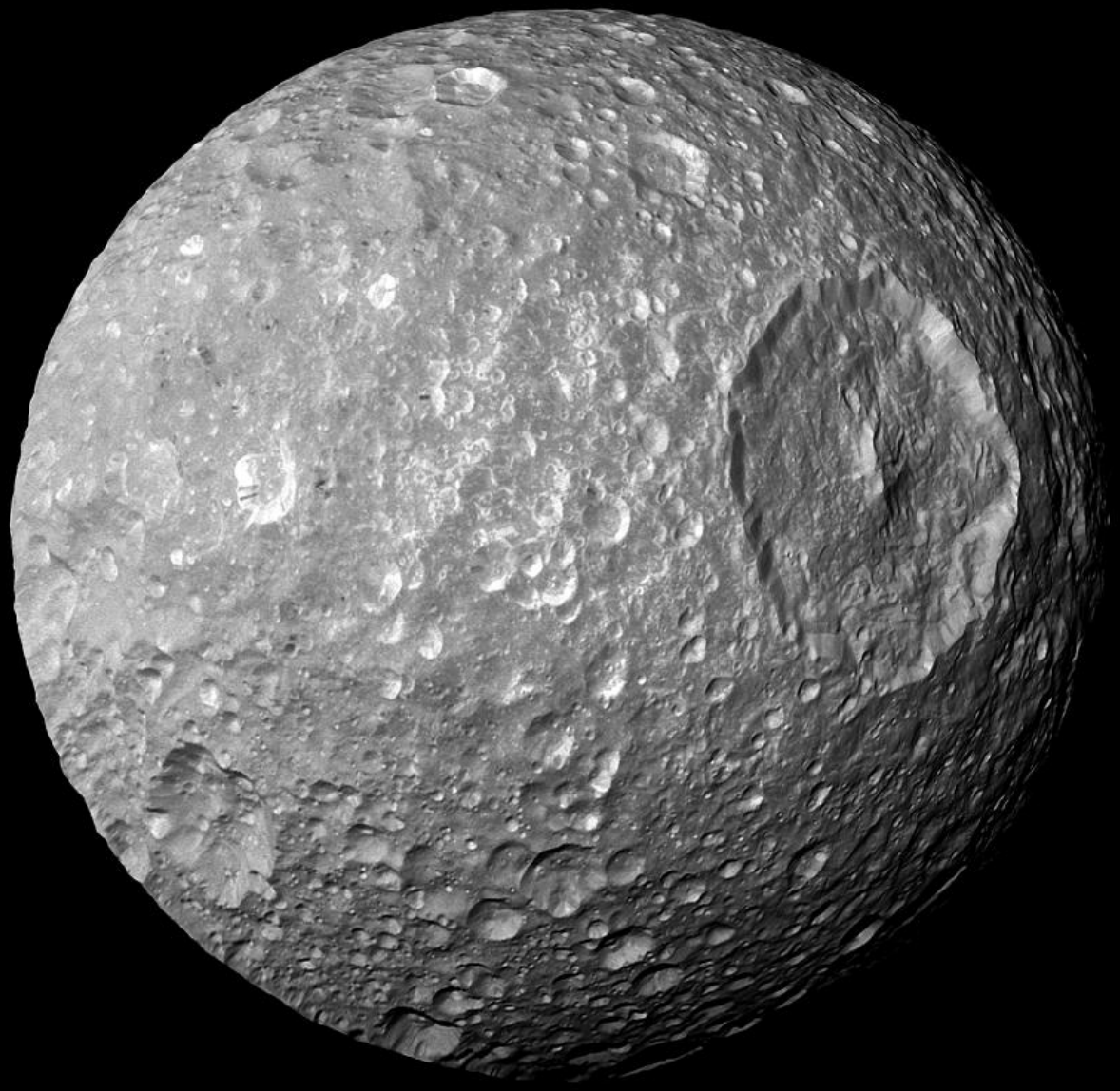
CREDIT: NASA/JHUAPL/CIW

MANY TYPES OF CRATERS: Venus vs. Ganymede

VENUS's DICKINSON CRATER
CREDIT: NASA/JPL

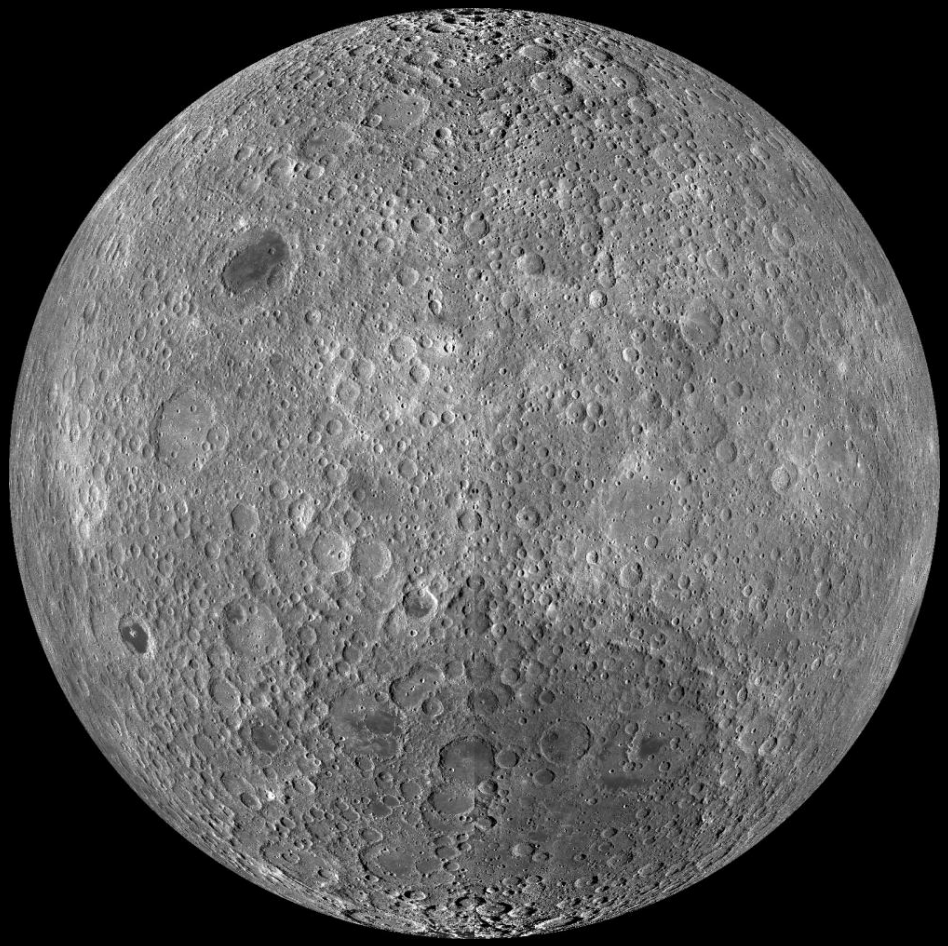
JUPITER's MOON, GANYMEDE
CREDIT: NASA/JPL/USGS

MIMAS: The Death Star Moon

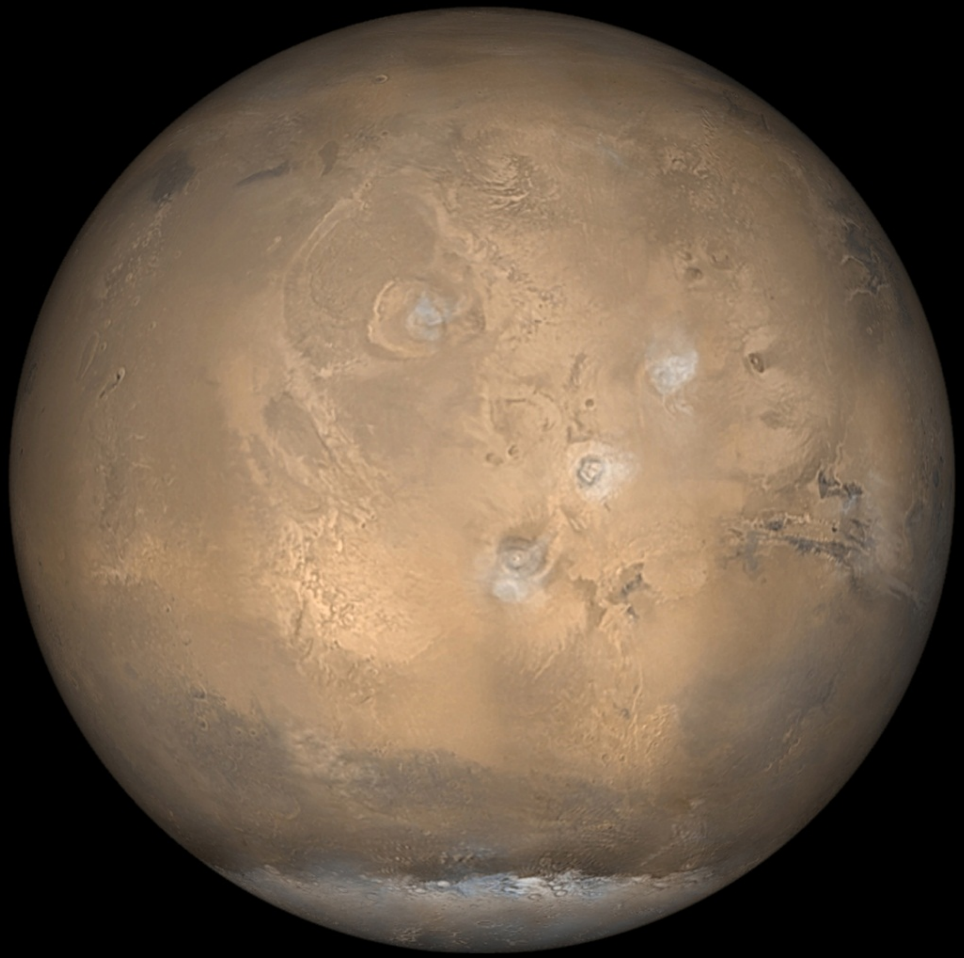


SATURN's MIMAS
CREDIT: NASA/JPL/SSI

COUNTING CRATERS: The Moon vs. Mars

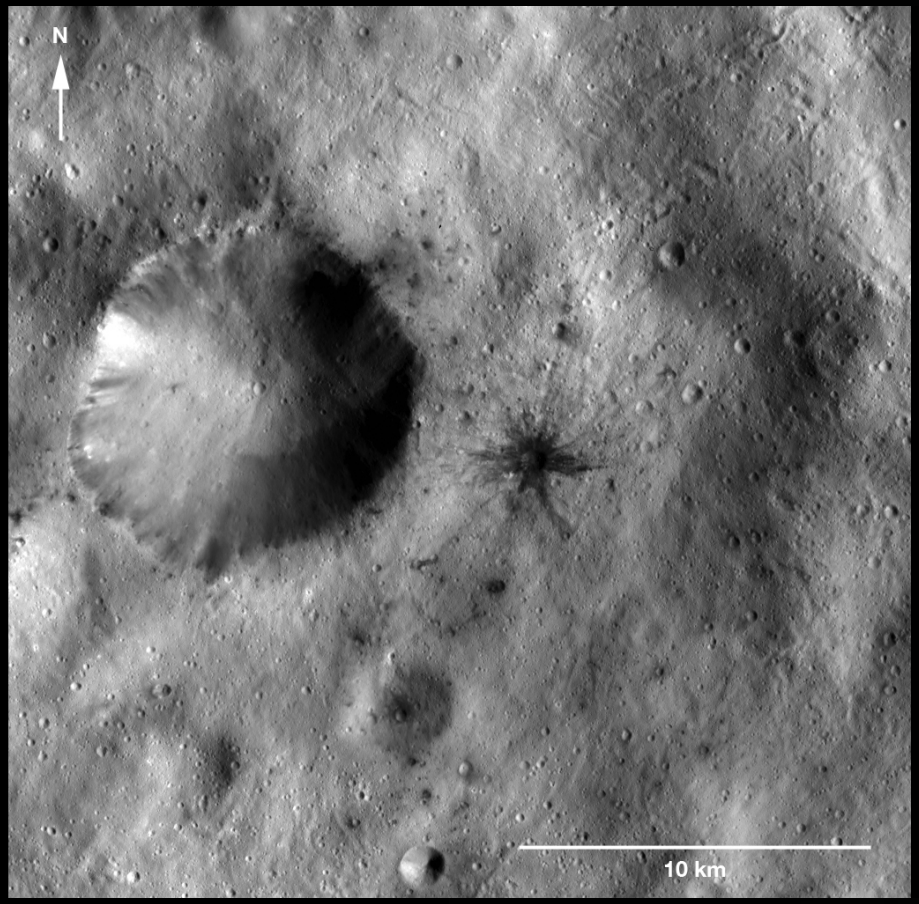


CREDIT: NASA/GSFC/Arizona State University



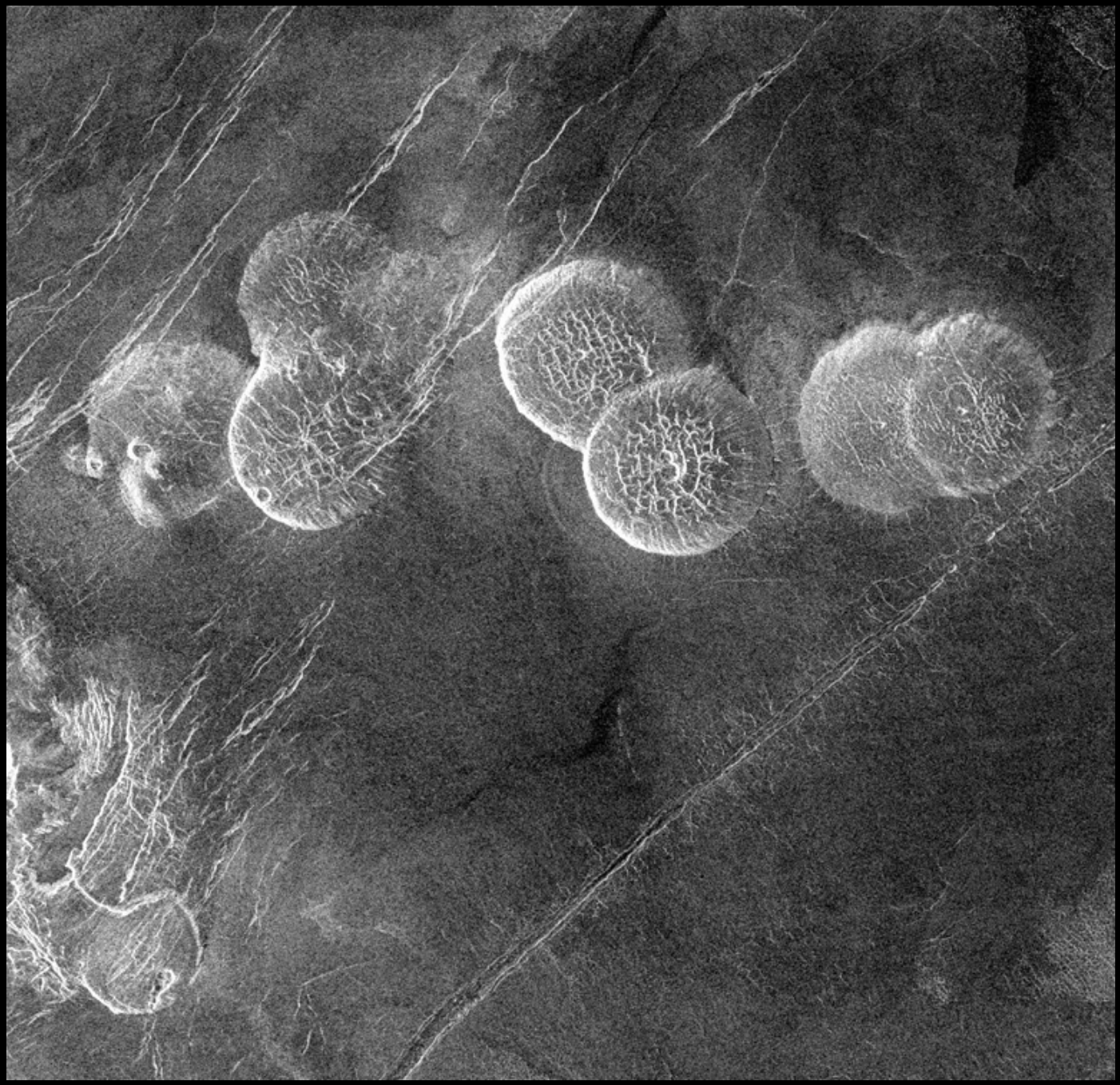
CREDIT: NASA/JPL/Malin Space Science Systems

GIANT ASTEROID VESTA



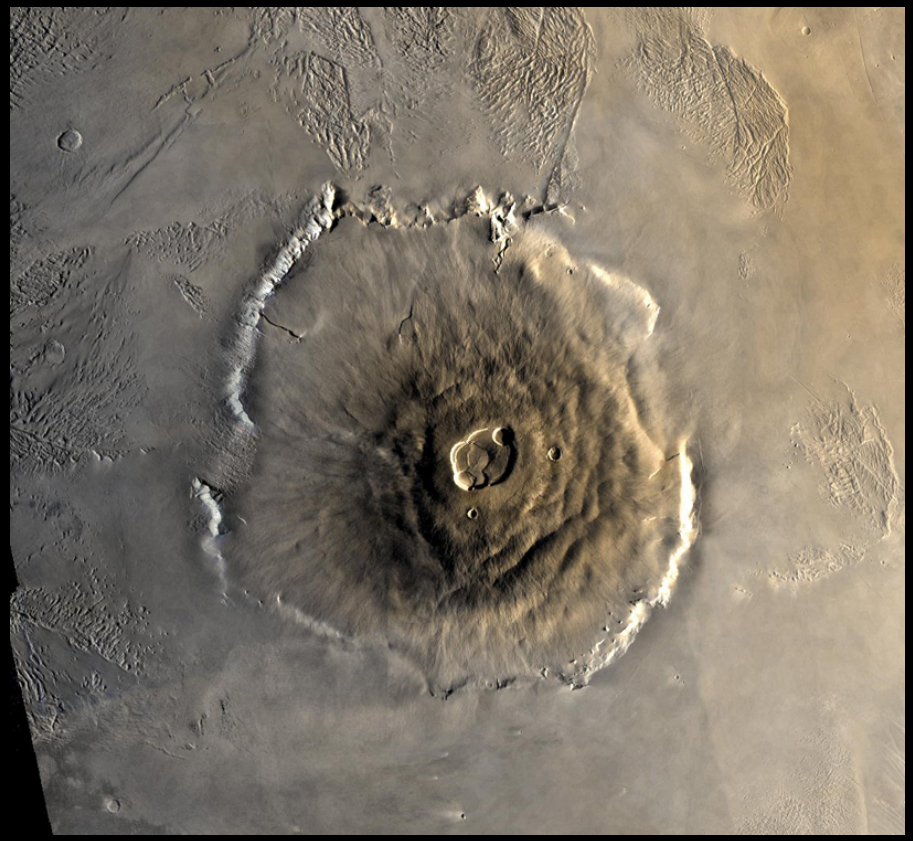
CREDIT: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA

VENUS



CREDIT: NASA/JPL

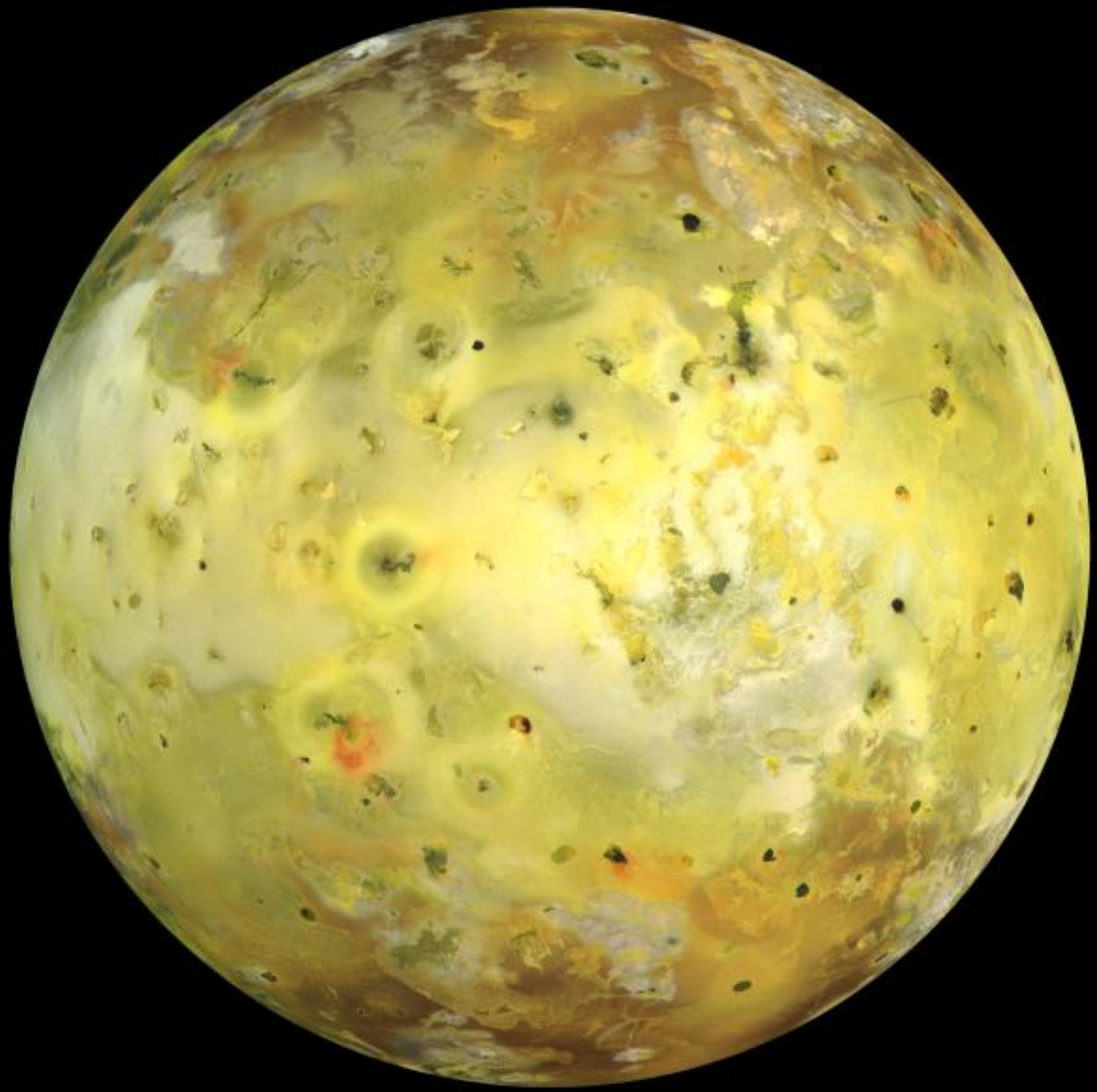
SHAPE



Blobs – Volcanoes (or Lakes)

MAR's OLYMPUS MONS
CREDIT: NASA/JPL

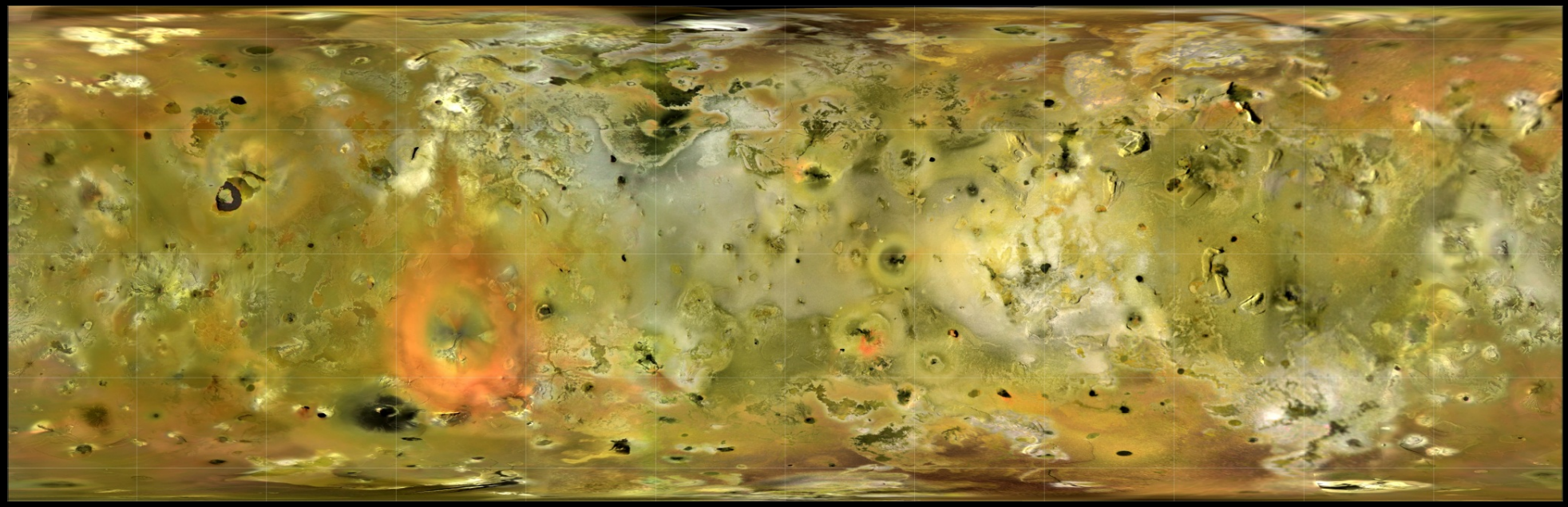
Jupiter's moon, IO



CREDIT: NASA/JPL-Caltech/Univ. of Arizona

IO

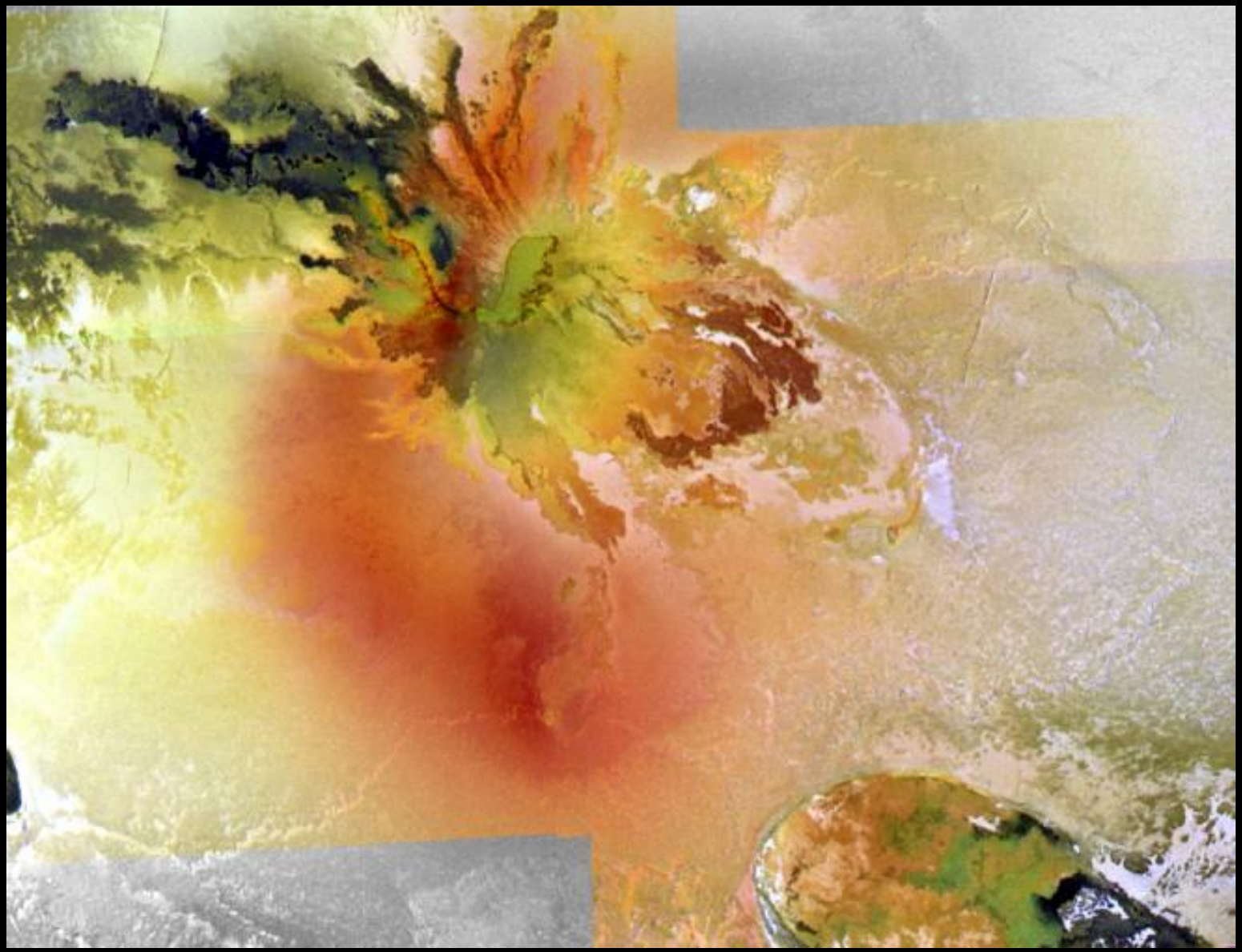
Close…



CREDIT: NASA/JPL/USGS

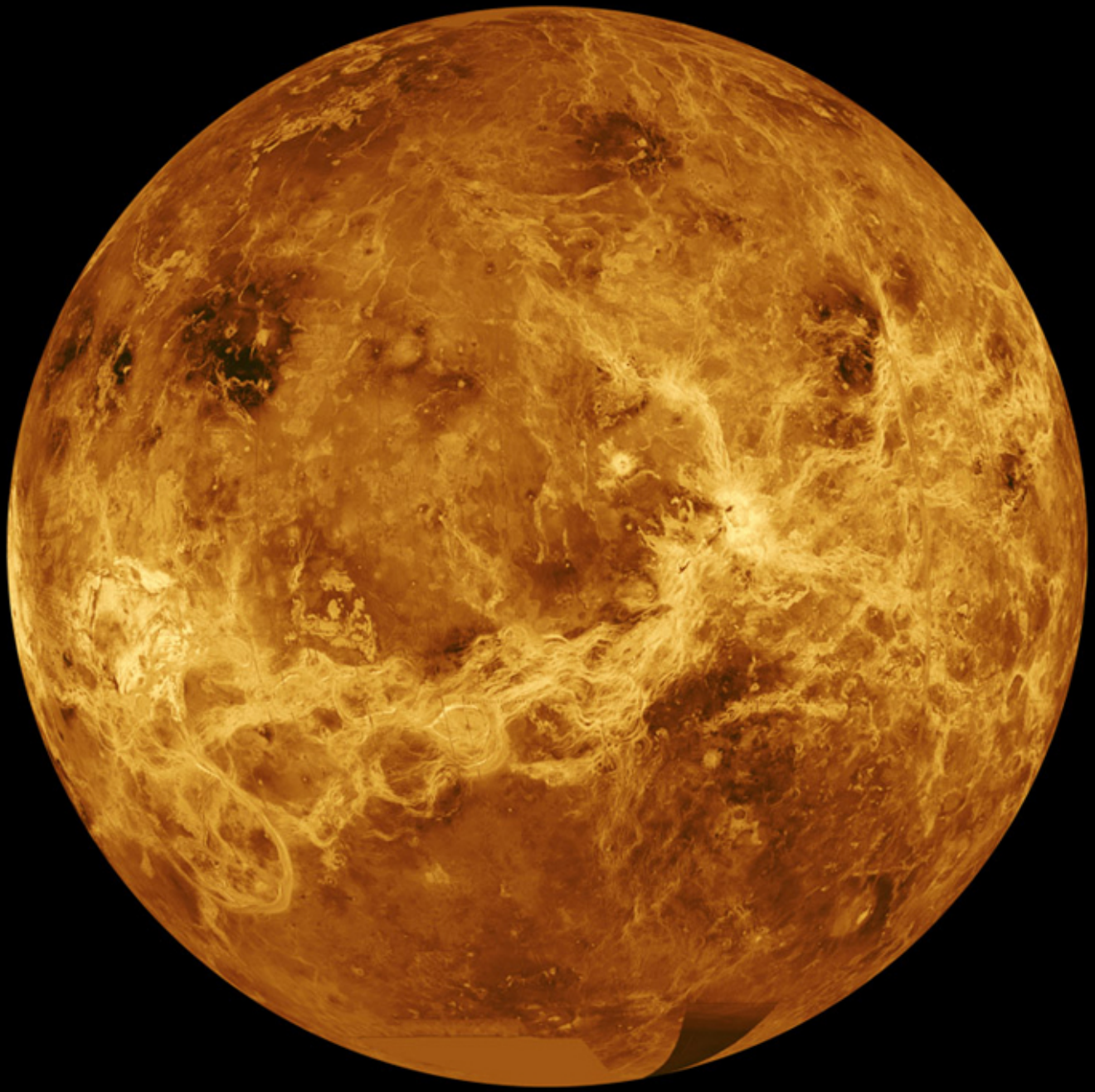
Closer…

CULANN PATERA



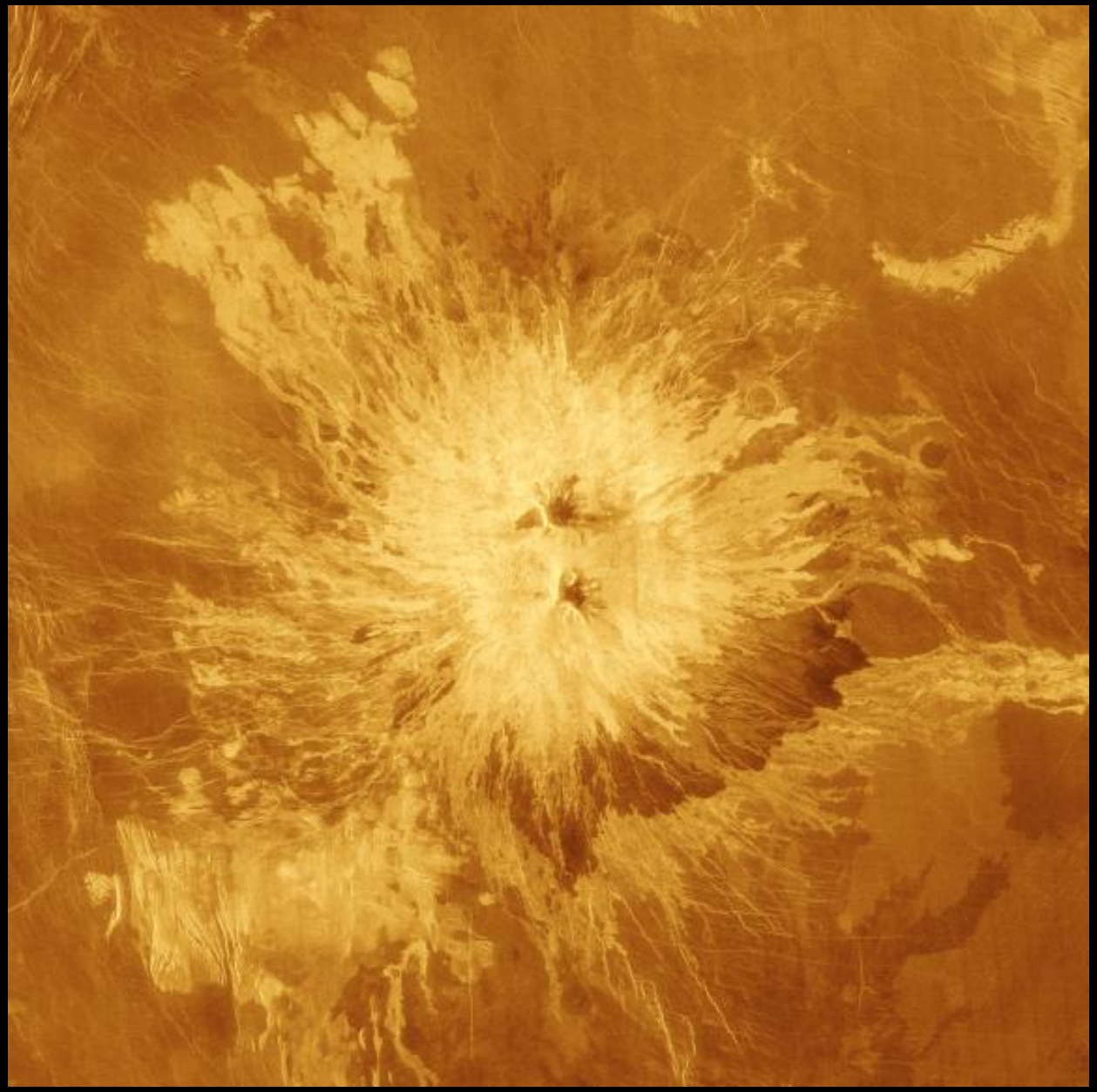
CREDIT: NASA/JPL-Caltech/Univ. of Arizona

VENUS



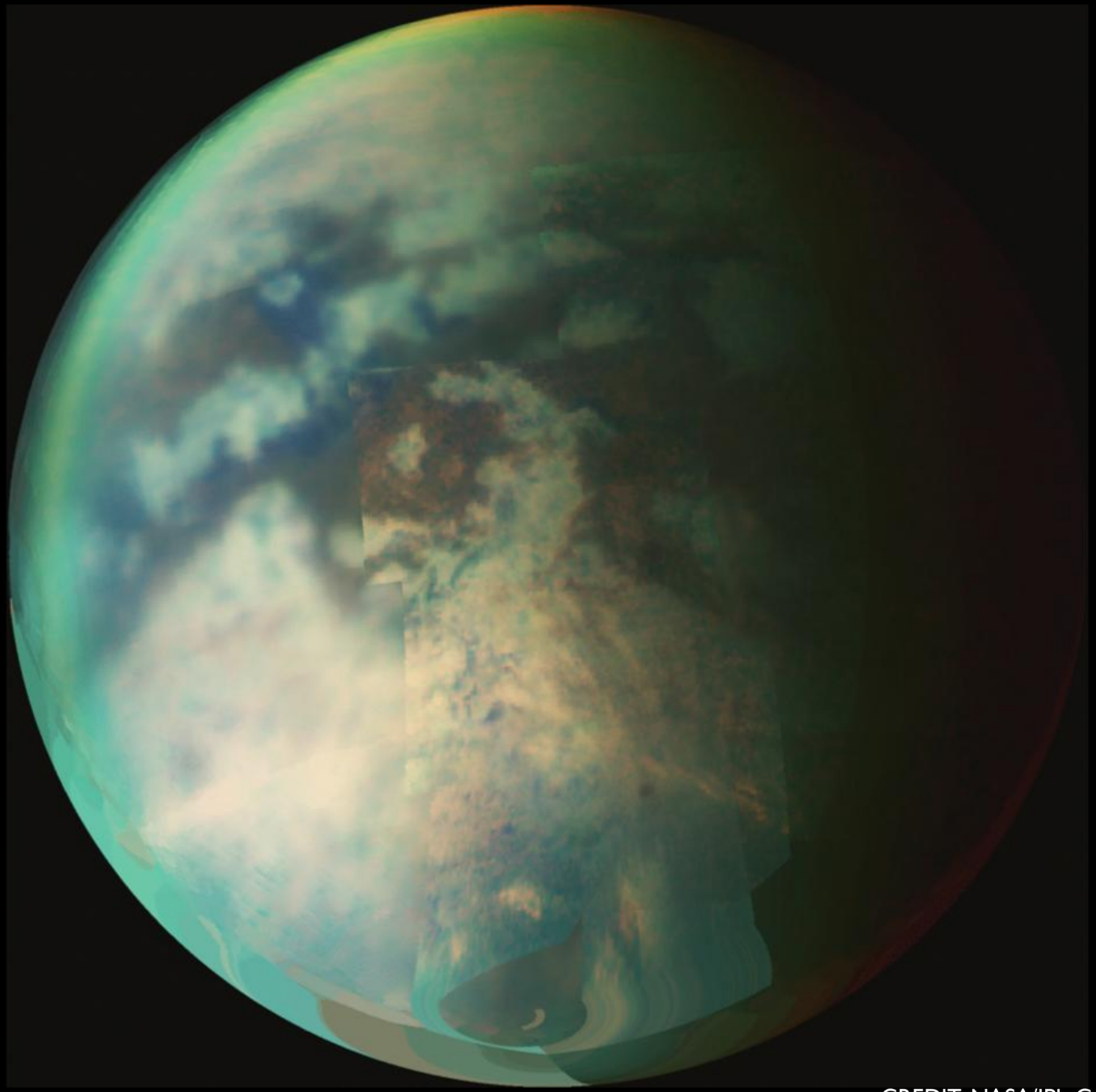
CREDIT: NASA/JPL

SAPAS MONS on Venus



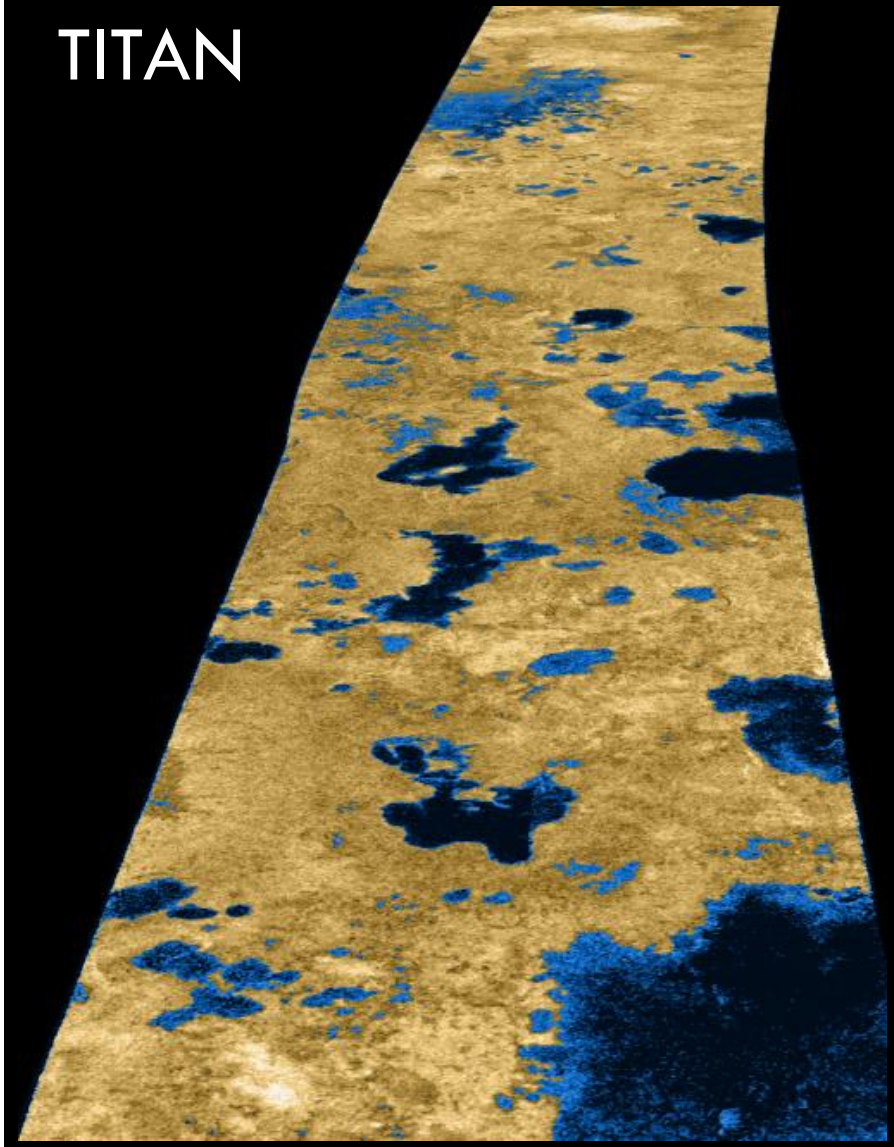
CREDIT: NASA/JPL

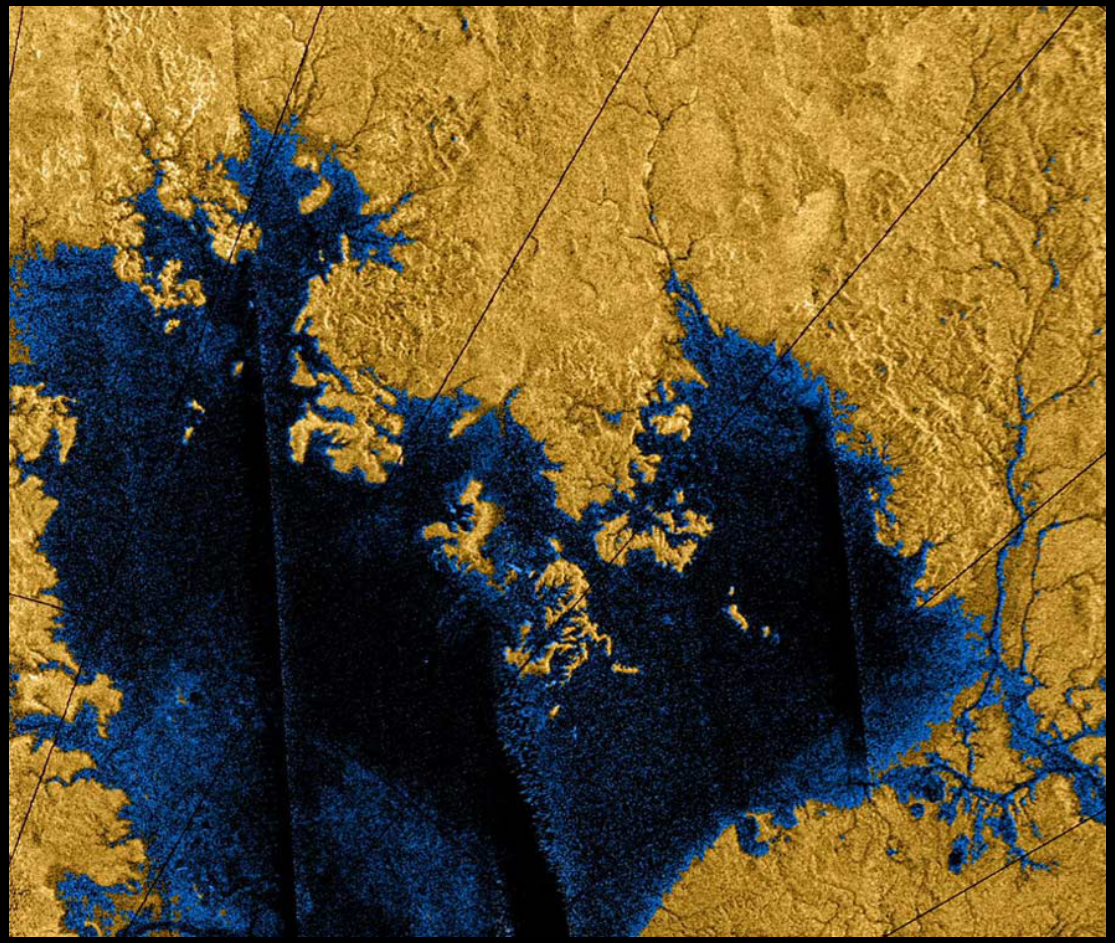
TITAN



CREDIT: NASA/JPL-Caltech/Univ. of Arizona

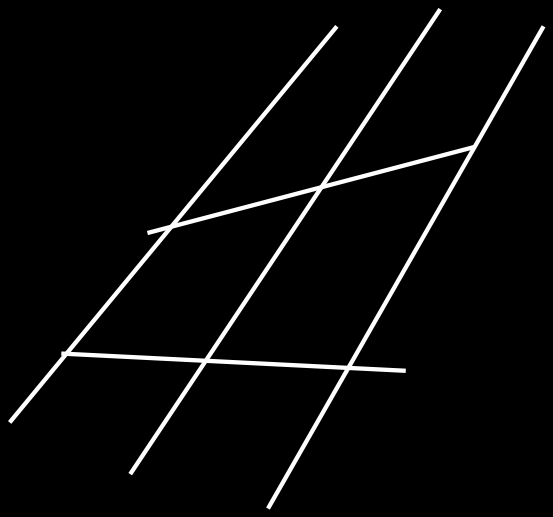
TITAN





CREDIT: NASA/JPL-Caltech/USGS

LINE

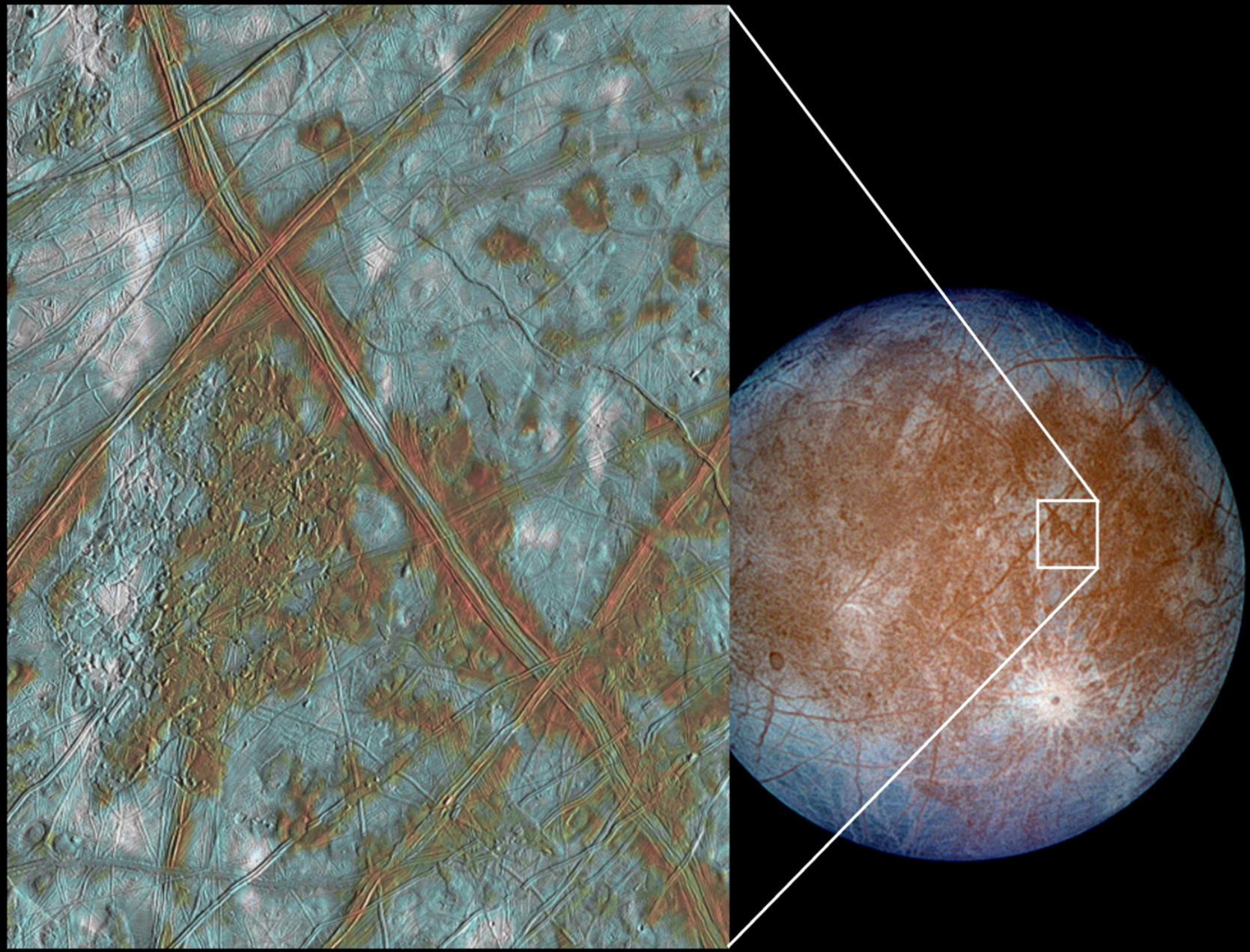


Straight lines - tectonic activity

JUPITER's MOON, EUROPA

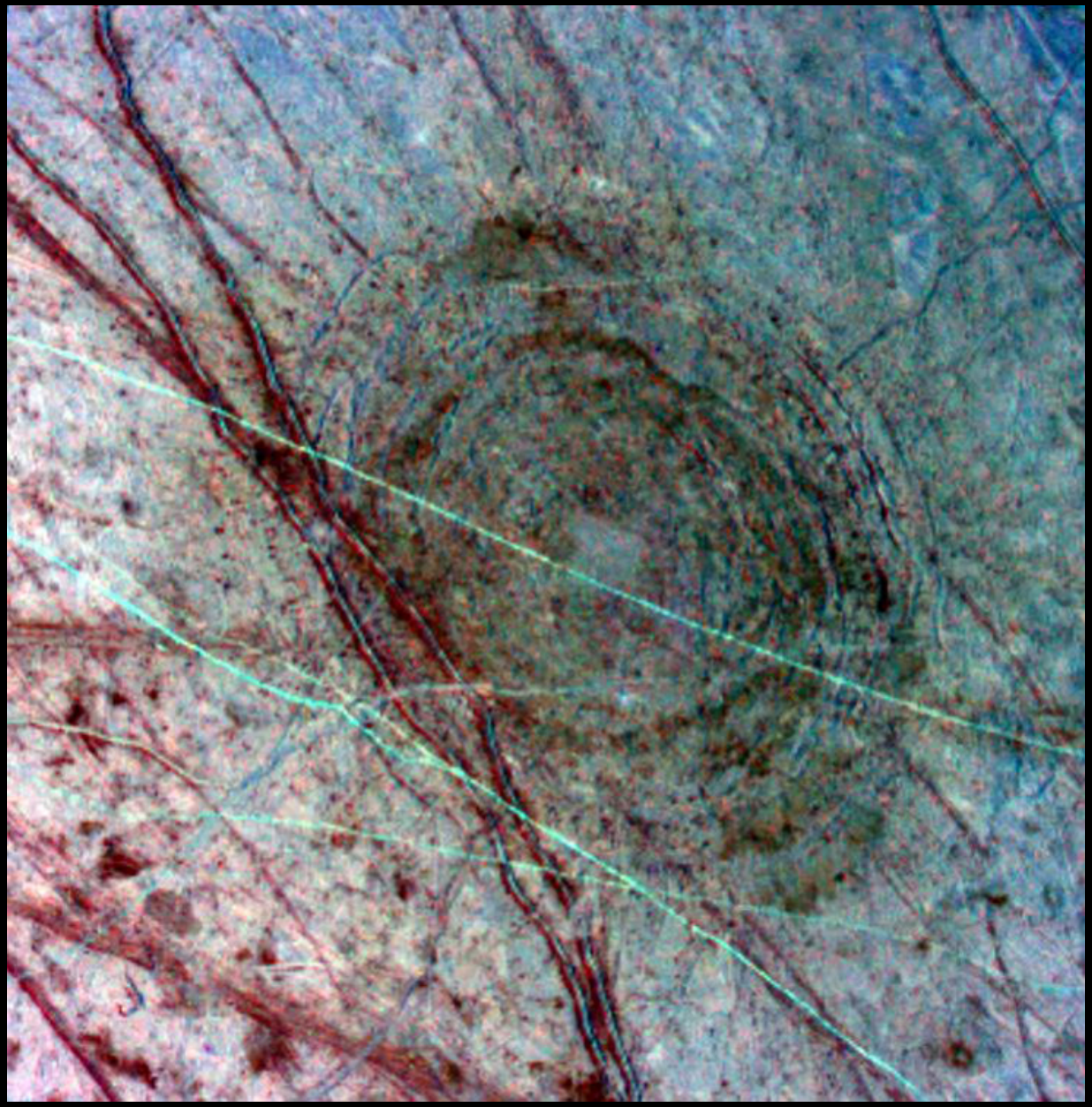
CREDIT: NASA/JPL

EUROPA



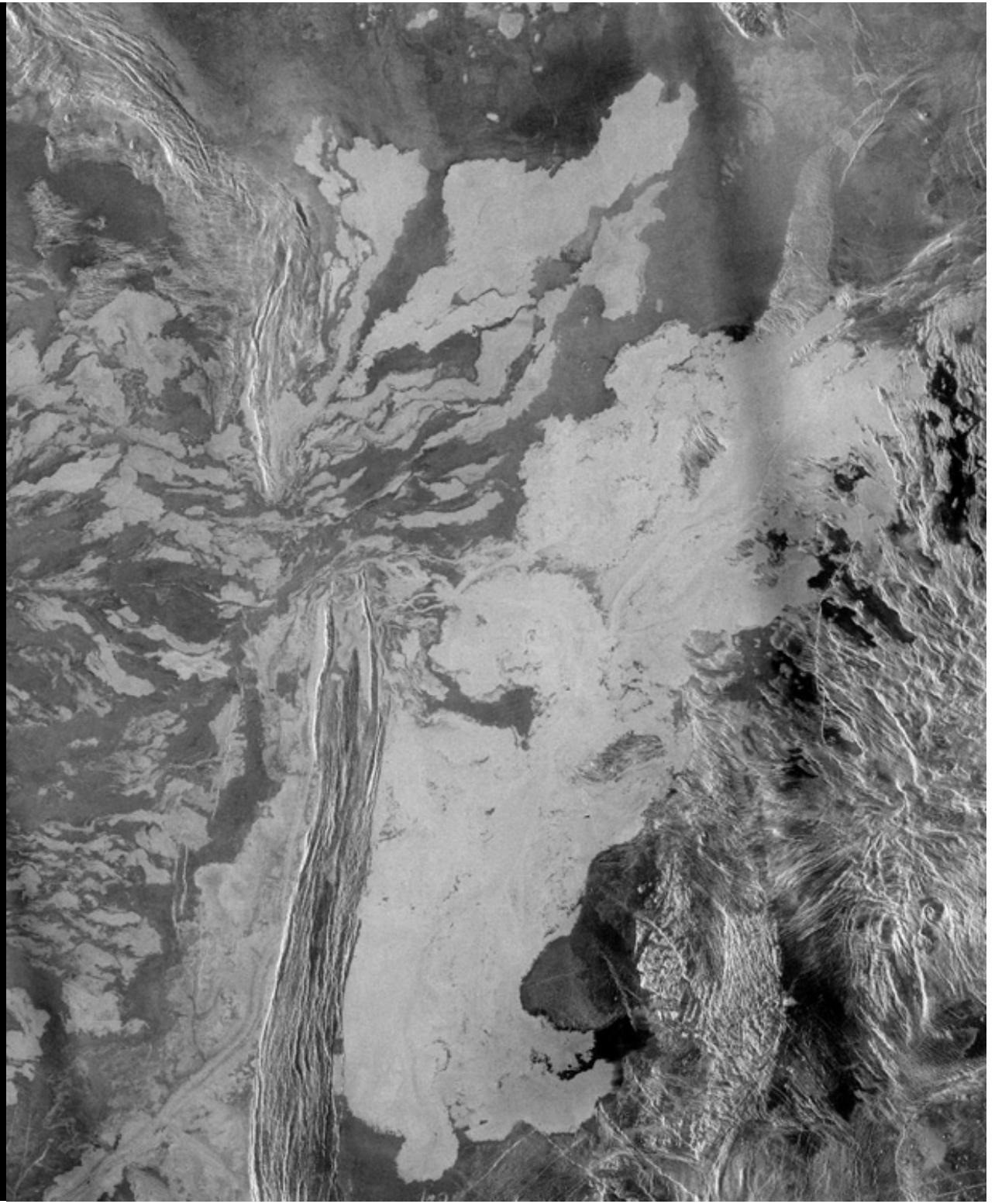
CREDIT: NASA/JPL-Caltech/Univ. of Arizona

EUROPA: Geology & Storytelling



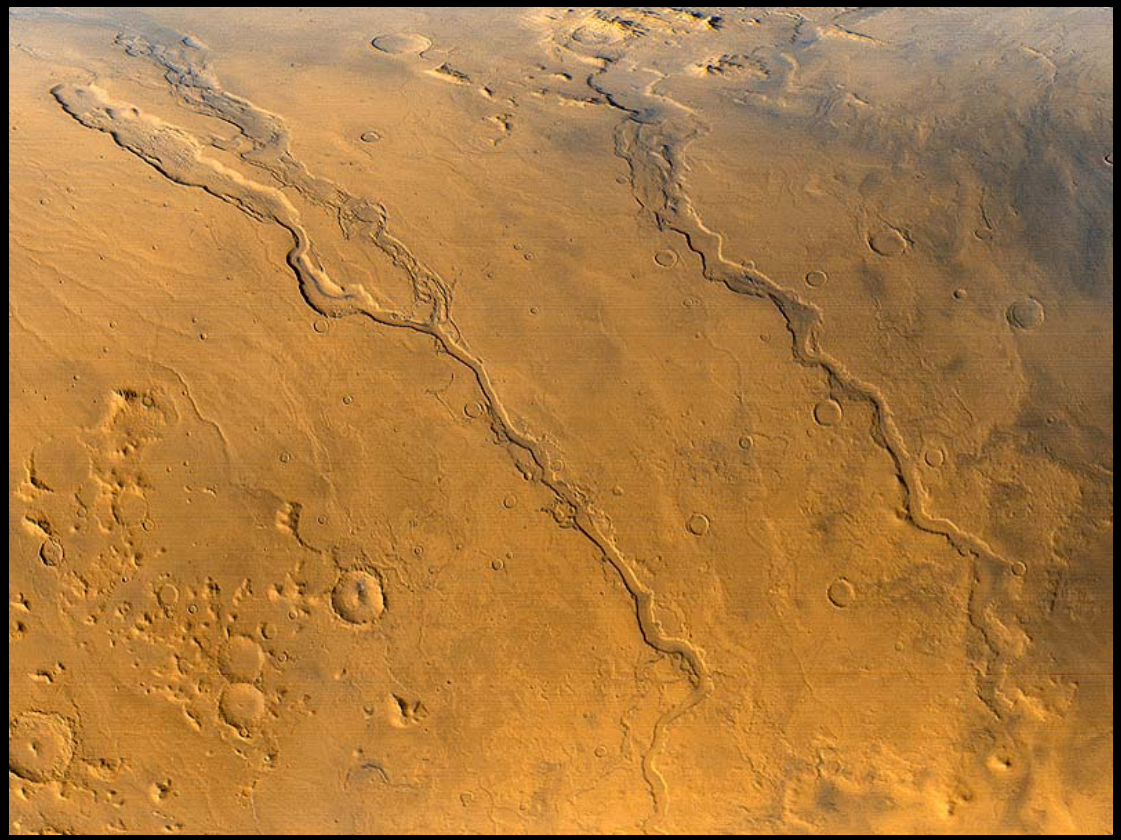
CREDIT: NASA/JPL-Caltech/Univ. of Arizona

VENUS:
Geology & Storytelling



CREDIT: NASA/JPL

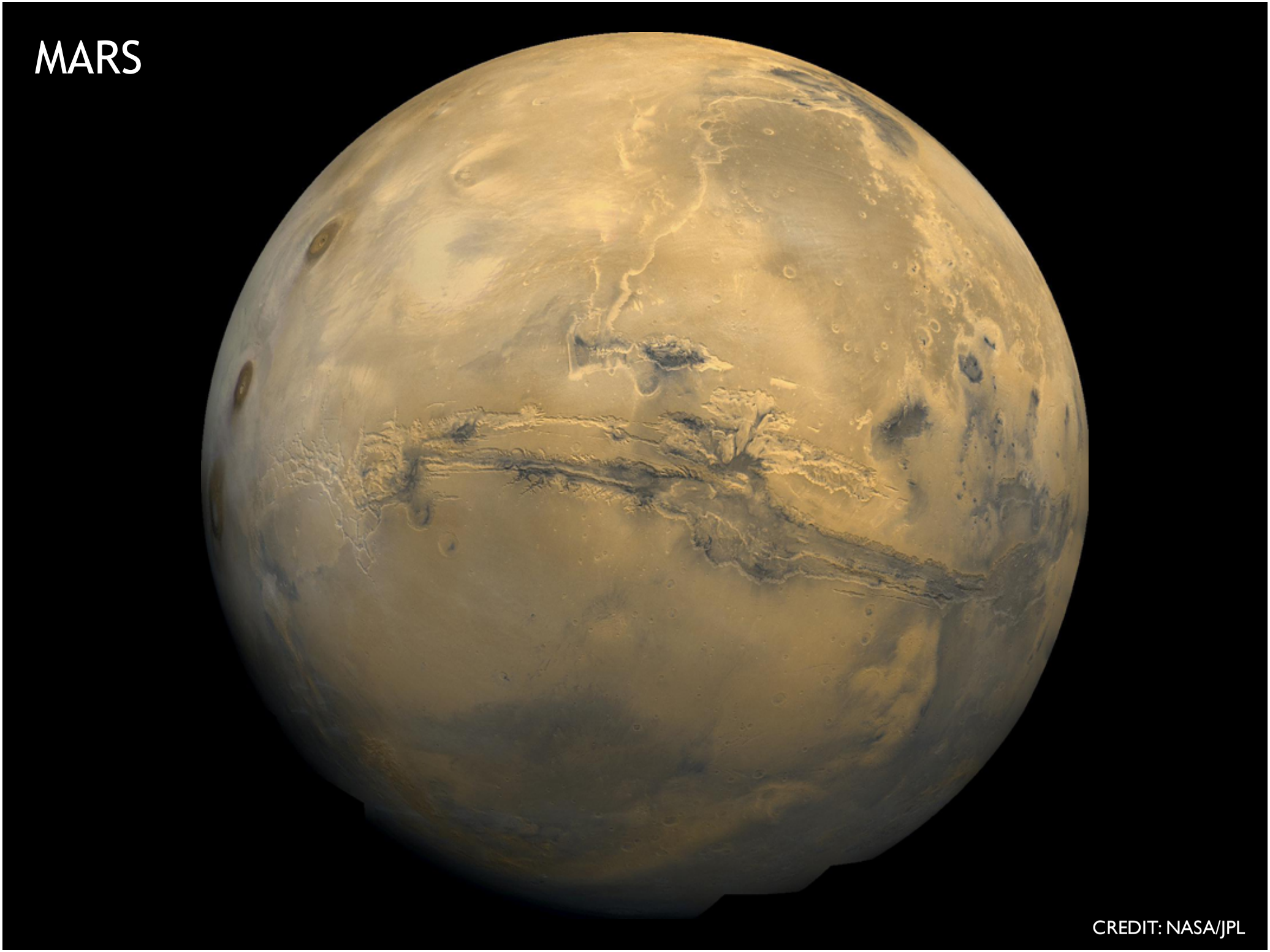
LINE



Squiggly lines - erosion (liquid & wind)

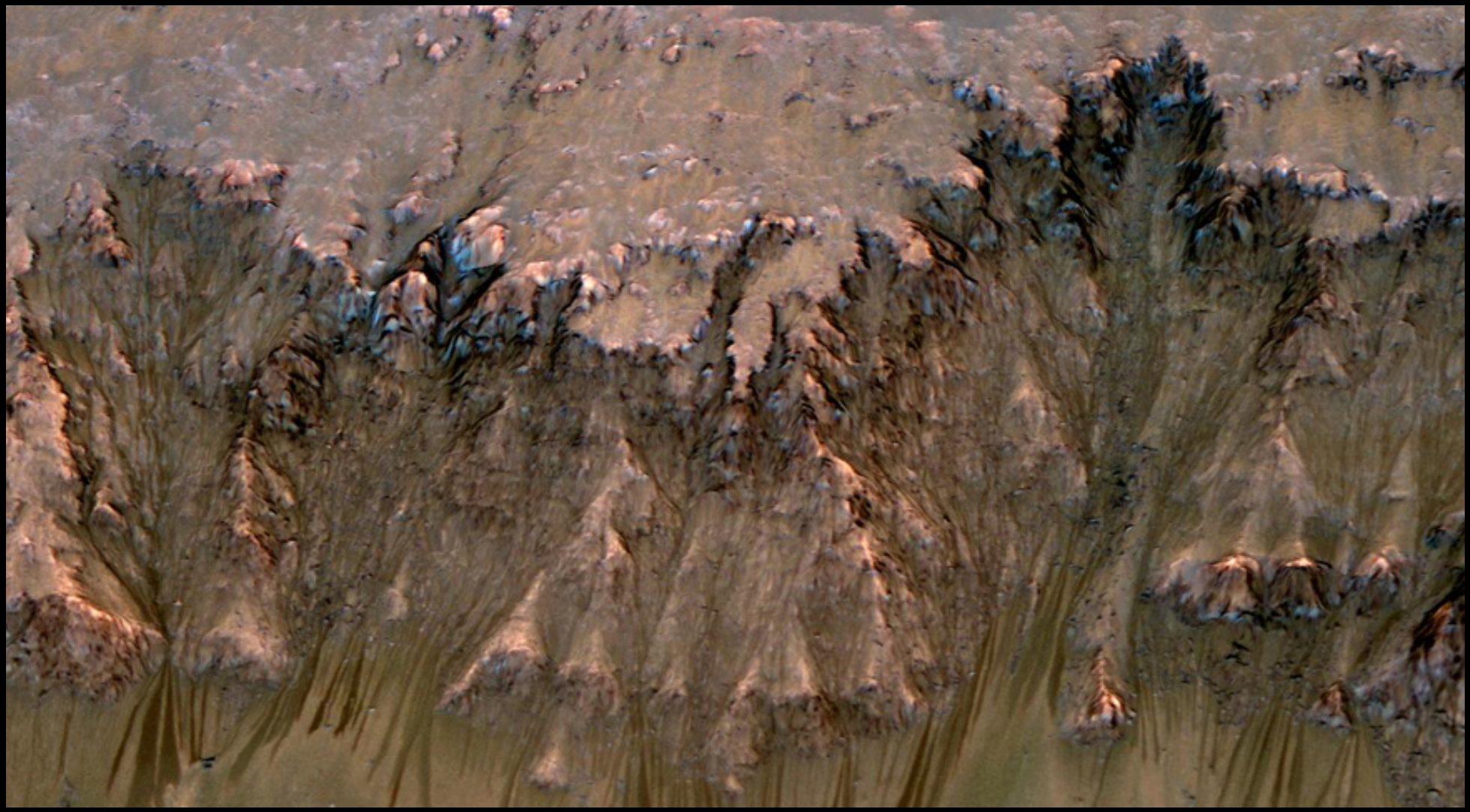
CREDIT: NASA/JPL

MARS



CREDIT: NASA/JPL

MARS

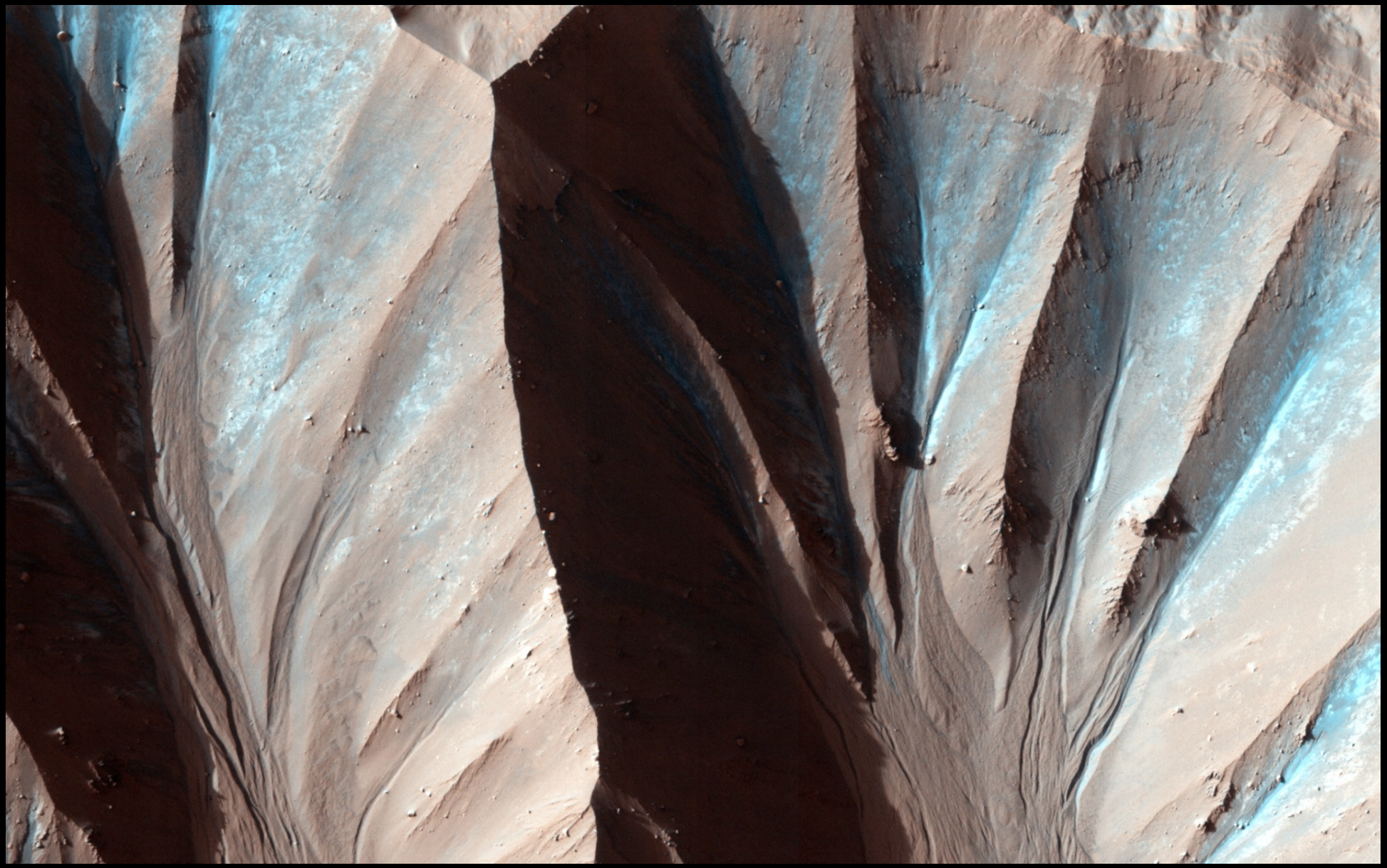


CREDIT: NASA/JPL-Caltech/Univ. of Arizona

FOLLOW THE WATER: Mars

CREDIT: NASA/JPL-Caltech/Univ. of Arizona

MARS



CREDIT: NASA/JPL-Caltech/Univ. of Arizona

MARS

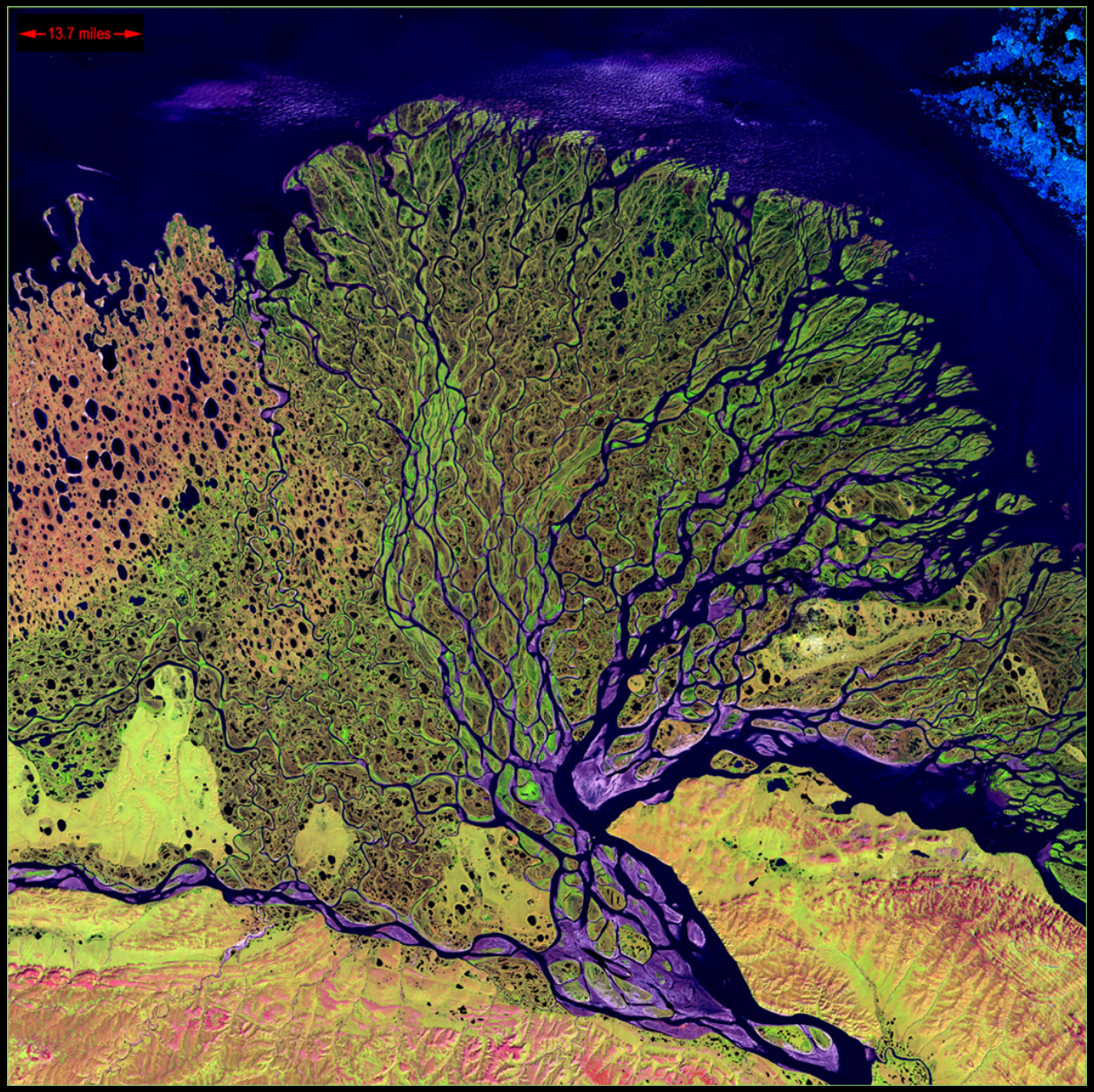
CREDIT: NASA/JPL-Caltech/Univ. of Arizona

What's the Story?

Victoria Crater on Mars

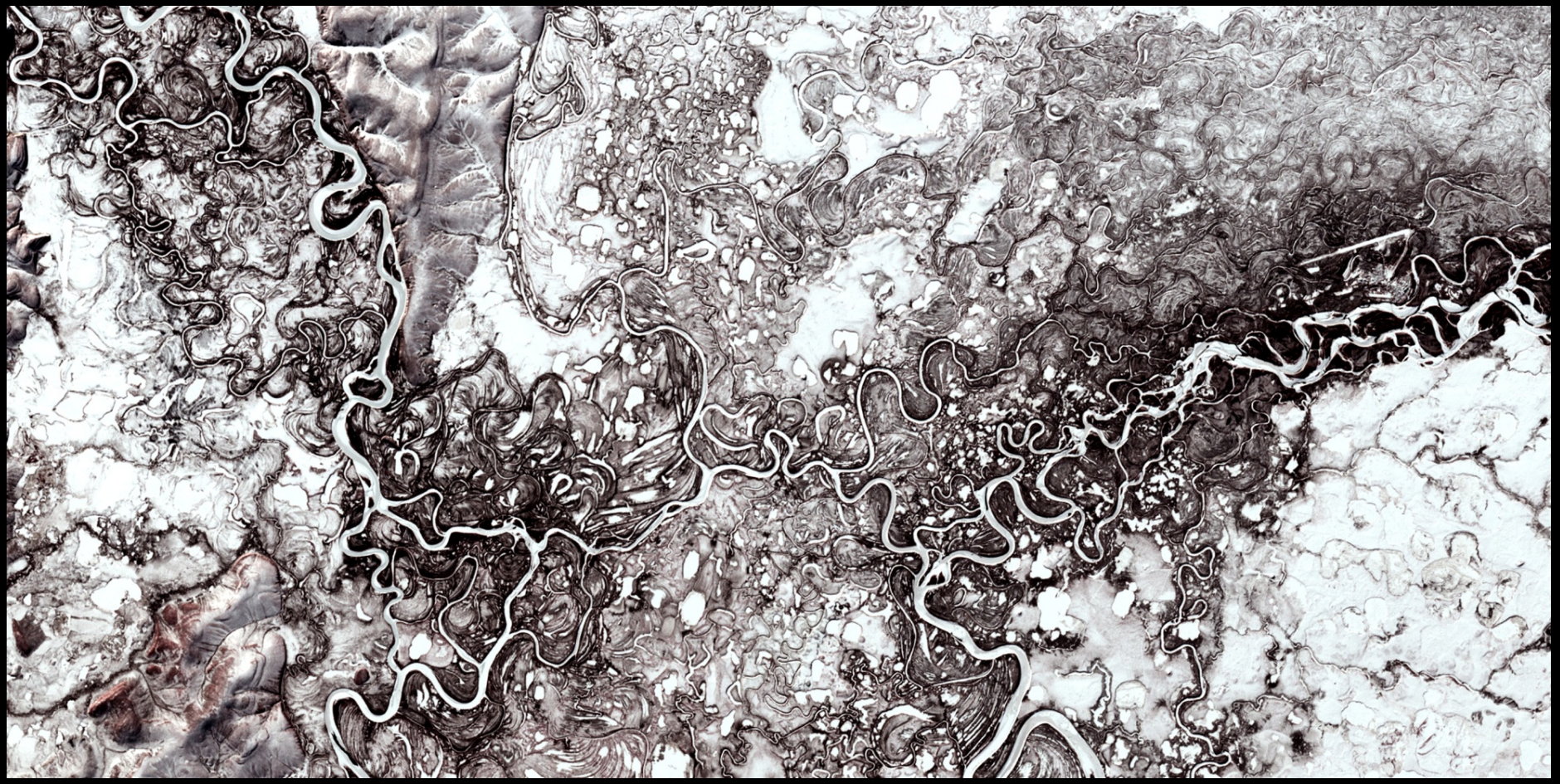
CREDIT: NASA/JPL-Caltech/Univ. of Arizona/Cornell/Ohio State Univ.

EARTH



CREDIT: NASA Earth Observatory

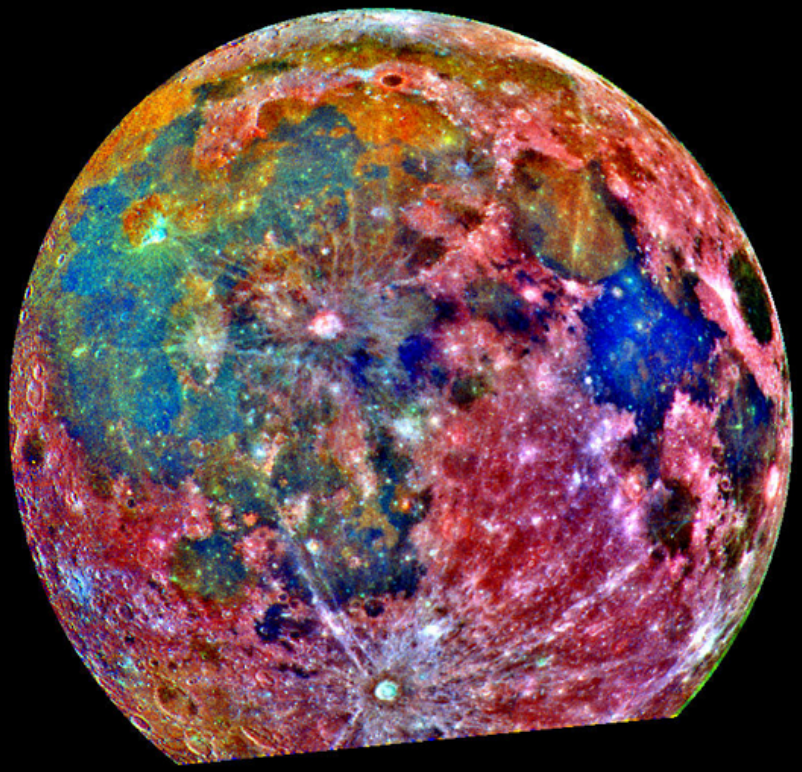
EARTH



CREDIT: NASA Earth Observatory

COLOR

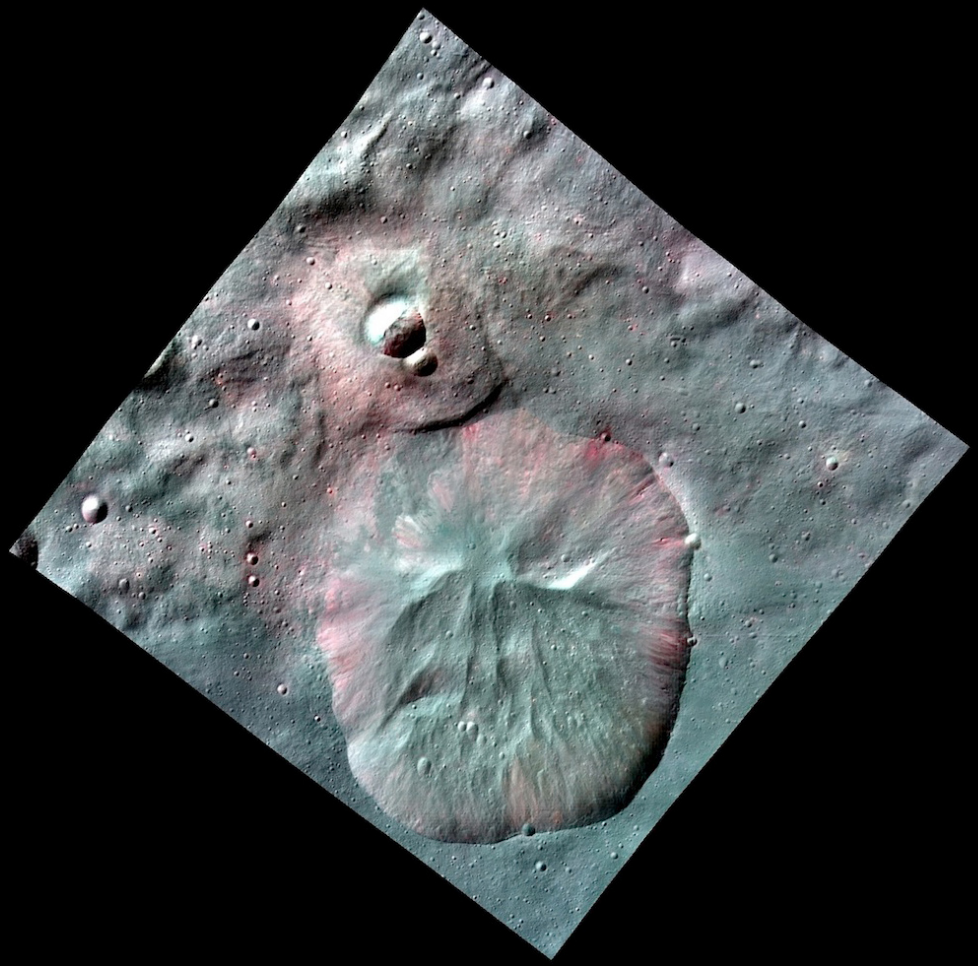
MOON

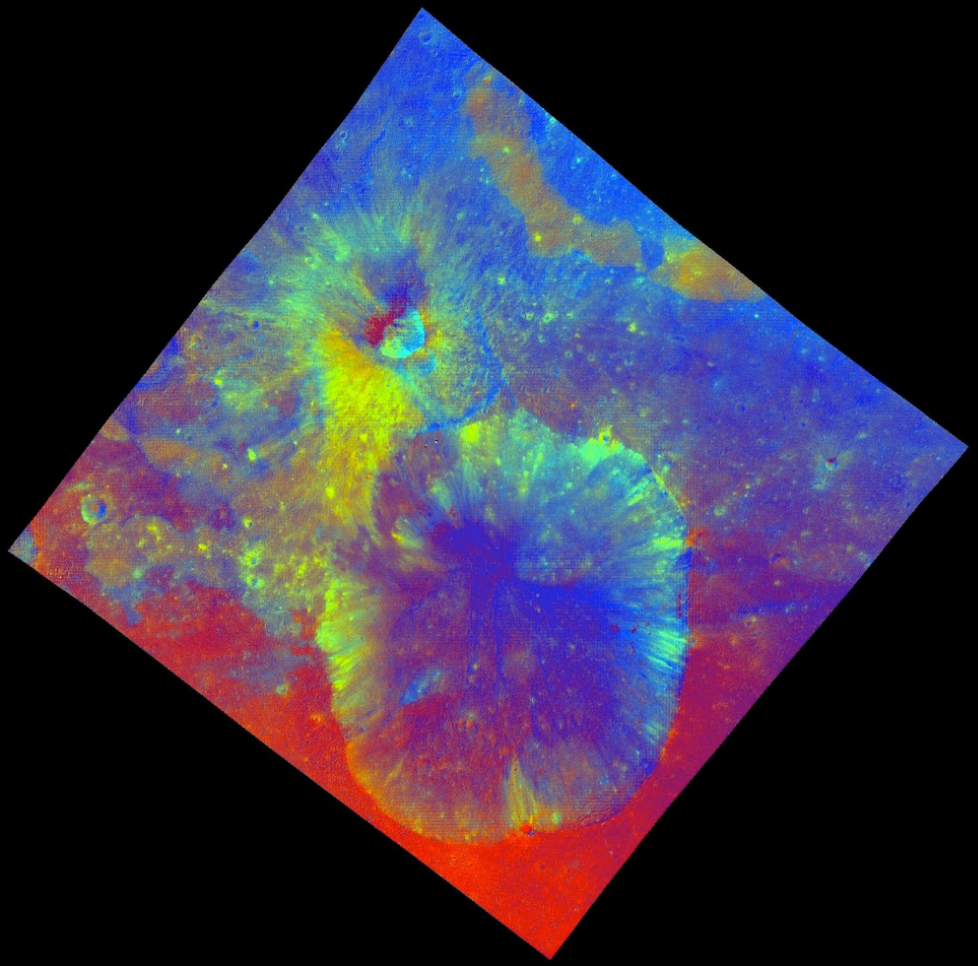


Color – true and added

CREDIT: NASA/JPL

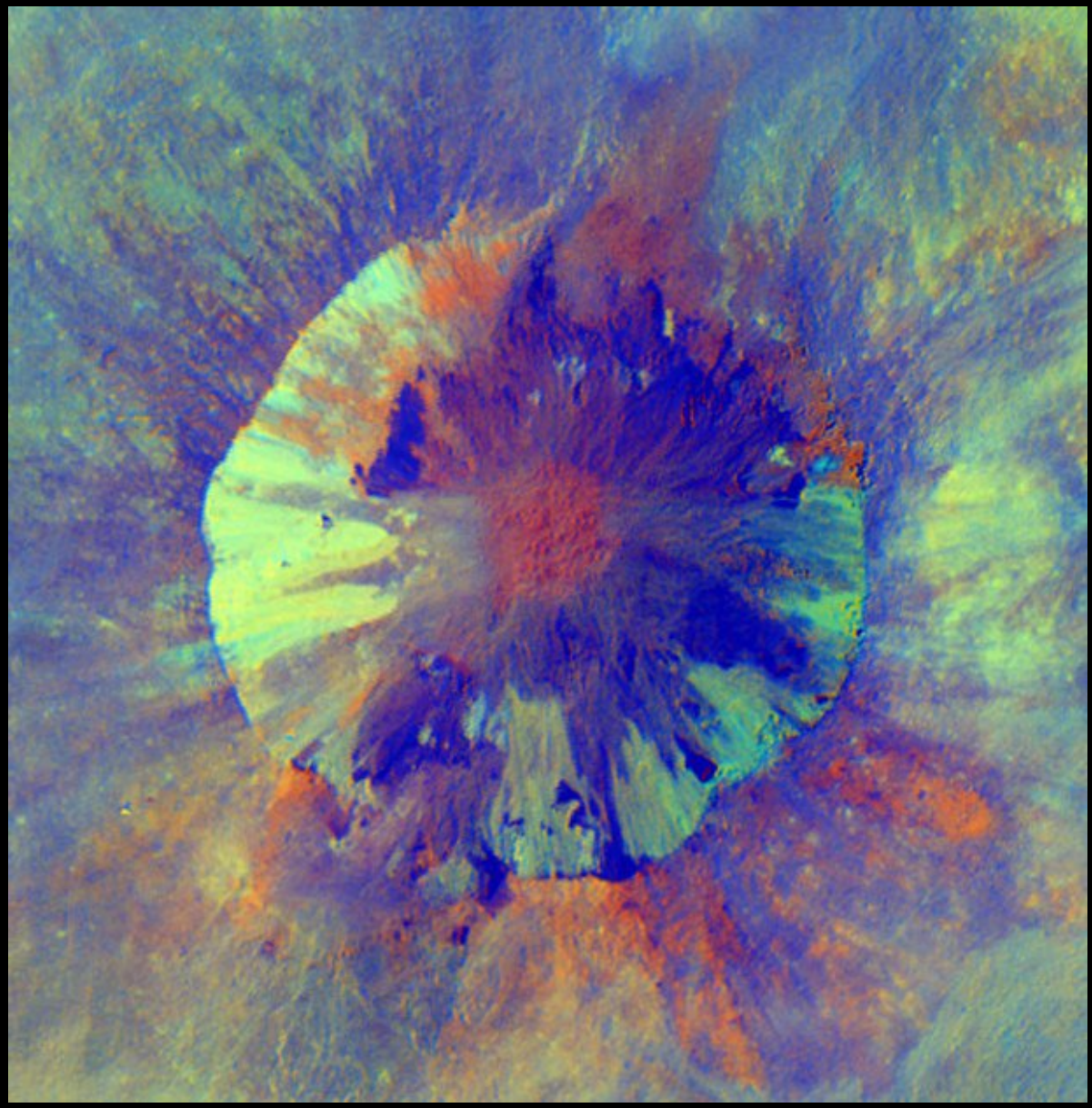
VESTA





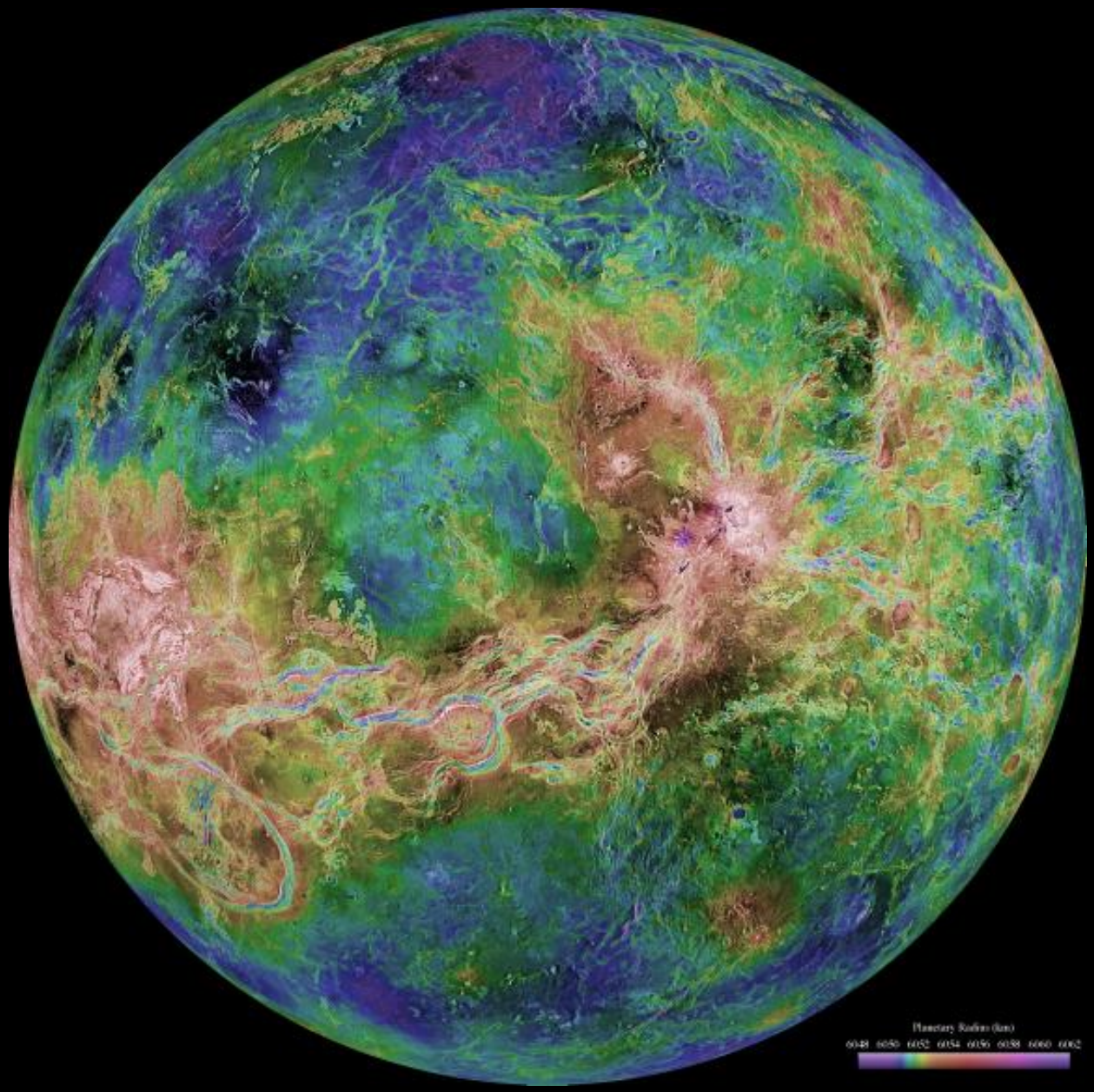
CREDIT: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA

VESTA: Cornelia Crater



CREDIT: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA

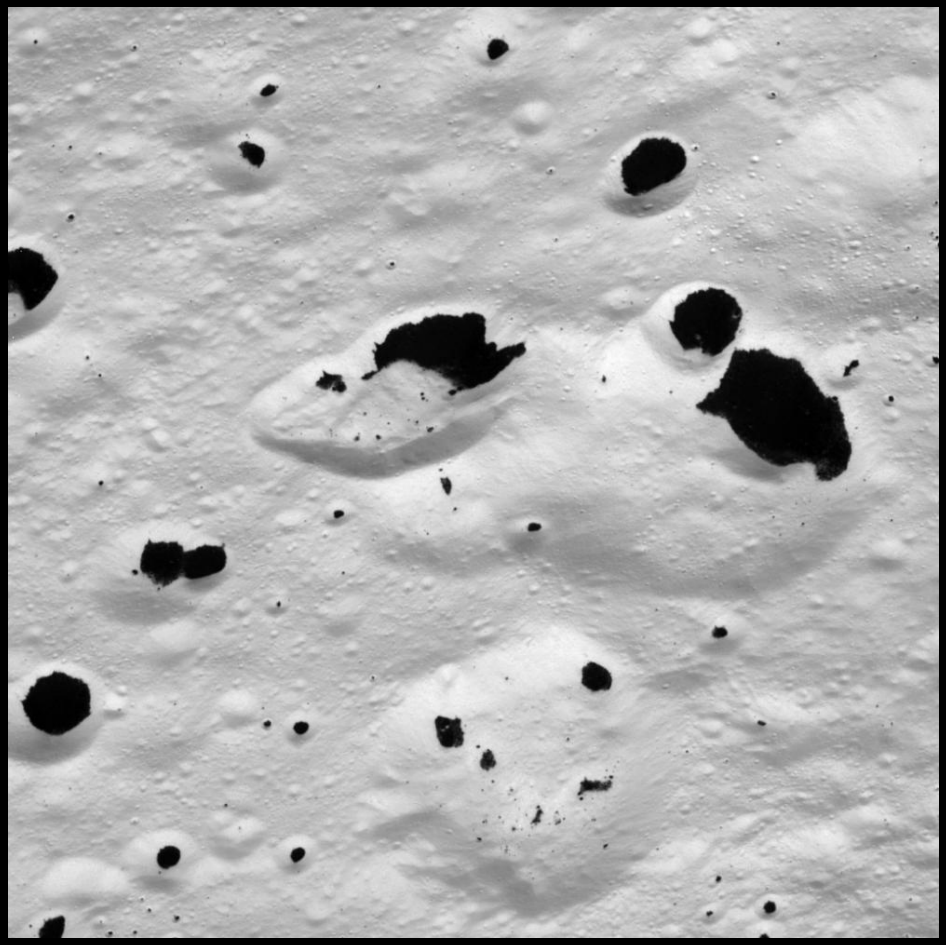
VENUS

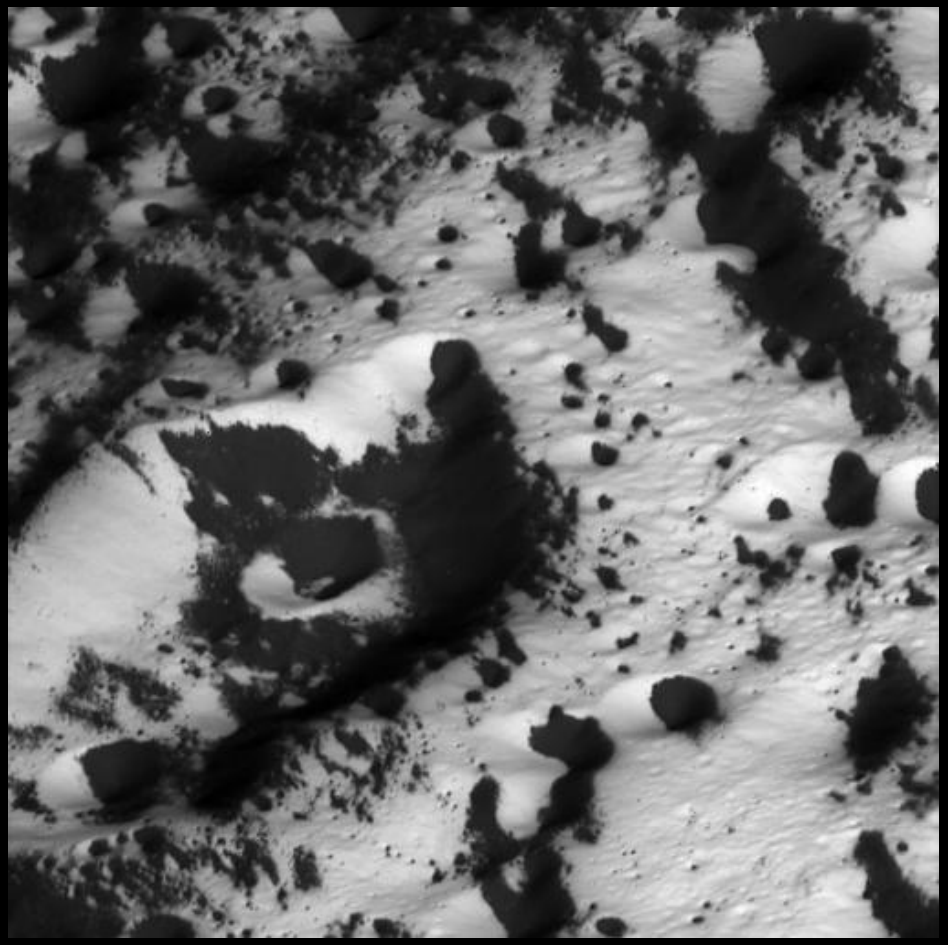


CREDIT: NASA/JPL/USGS

VALUE / ALBEDO

Saturn's moon,
IAPETUS

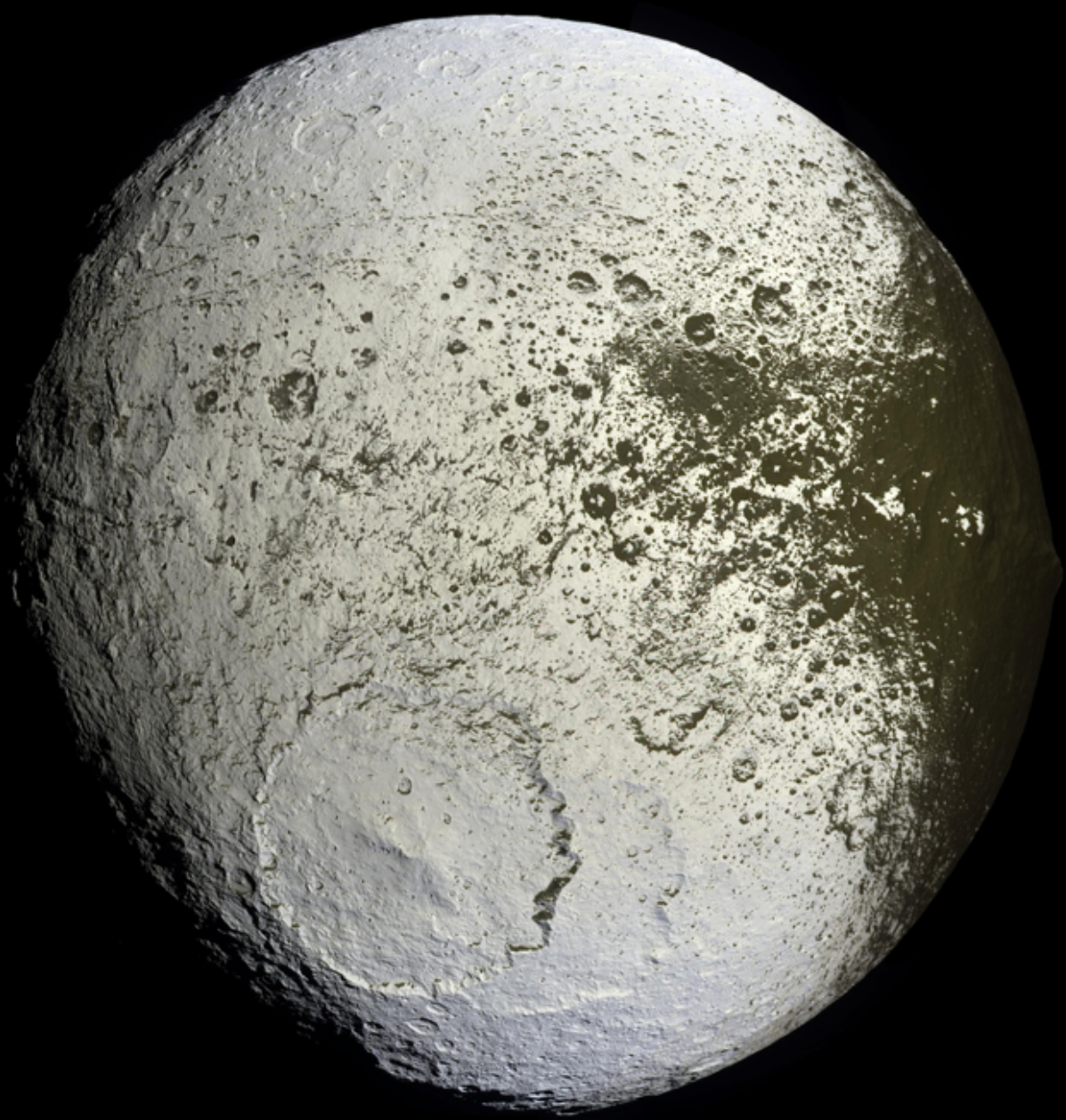




Value – light and dark, shade and highlight

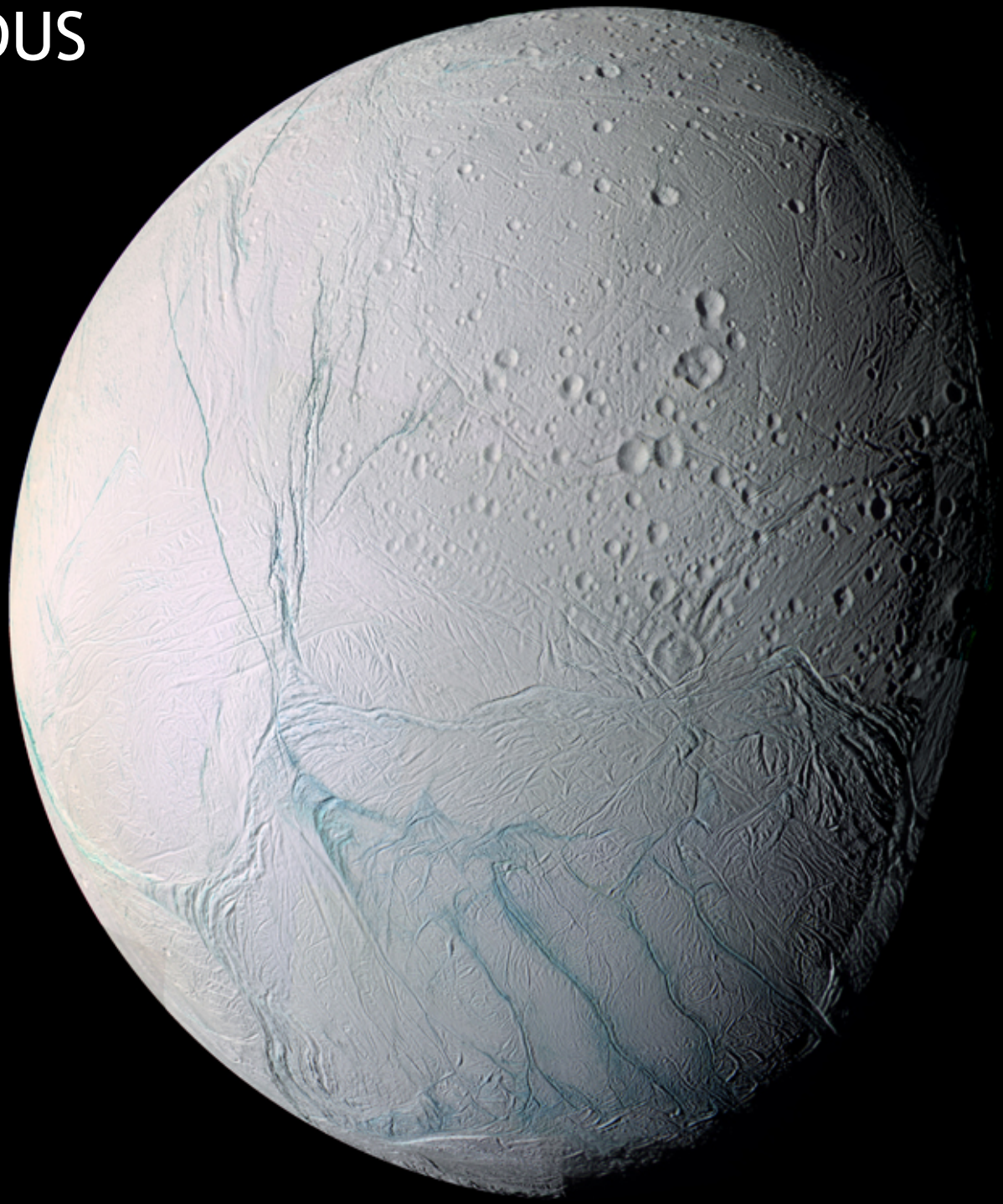
CREDIT: NASA/JPL/SSI

IAPETUS: The Yin-Yang Moon



CREDIT: NASA/JPL/SSI

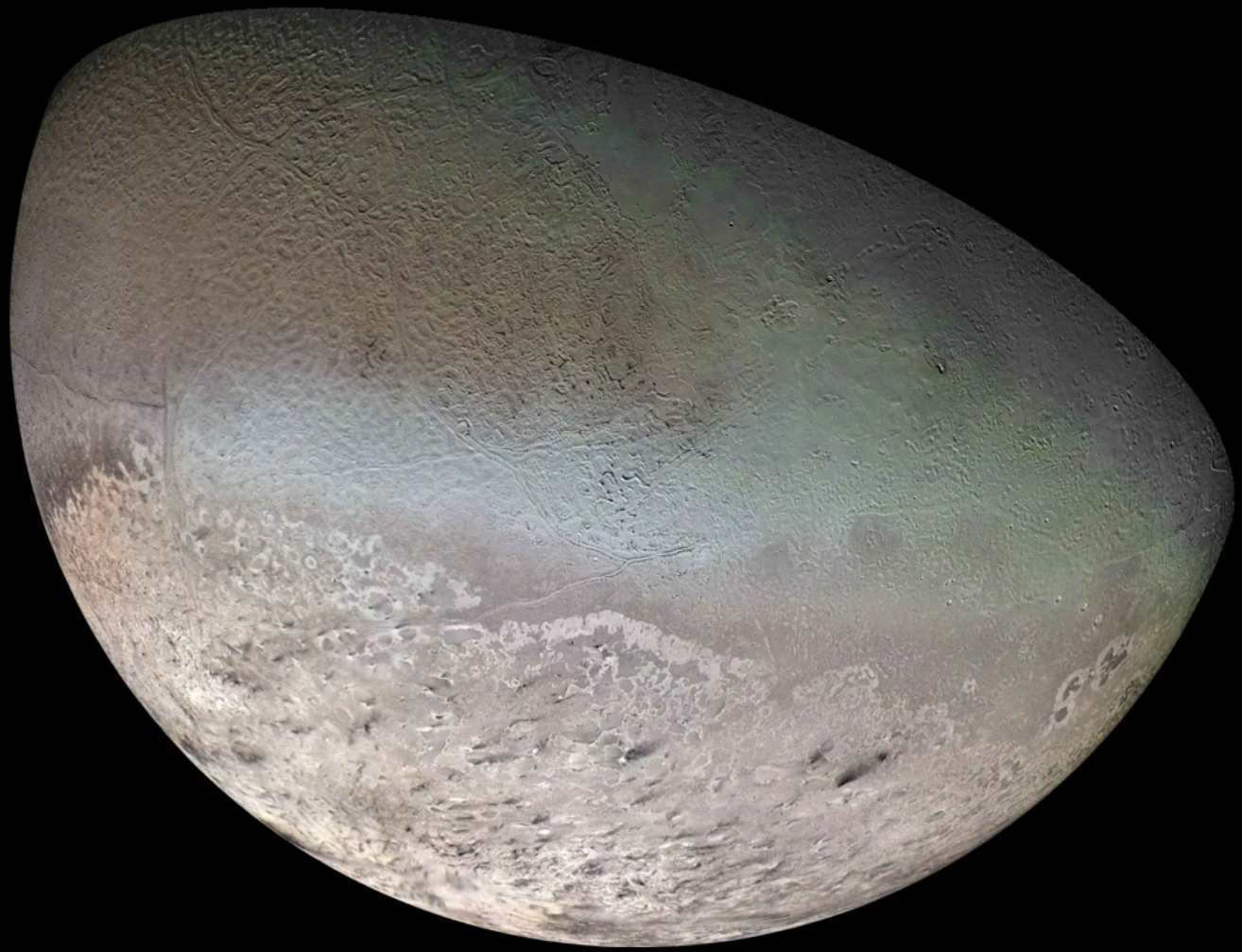
ENCELADUS



CREDIT: NASA/JPL/SSI

TEXTURE

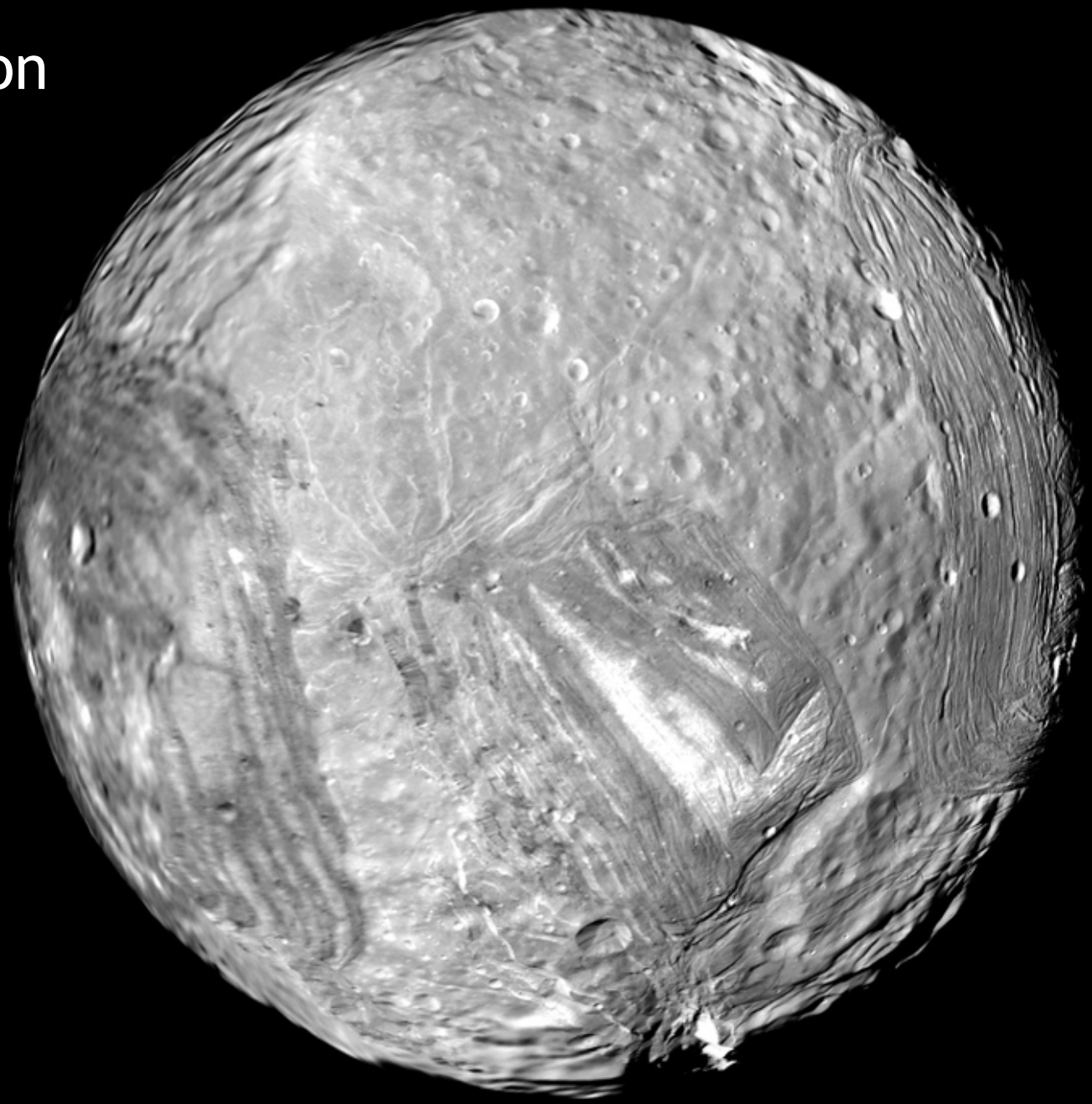
TRITON



Texture – the quality of the surface

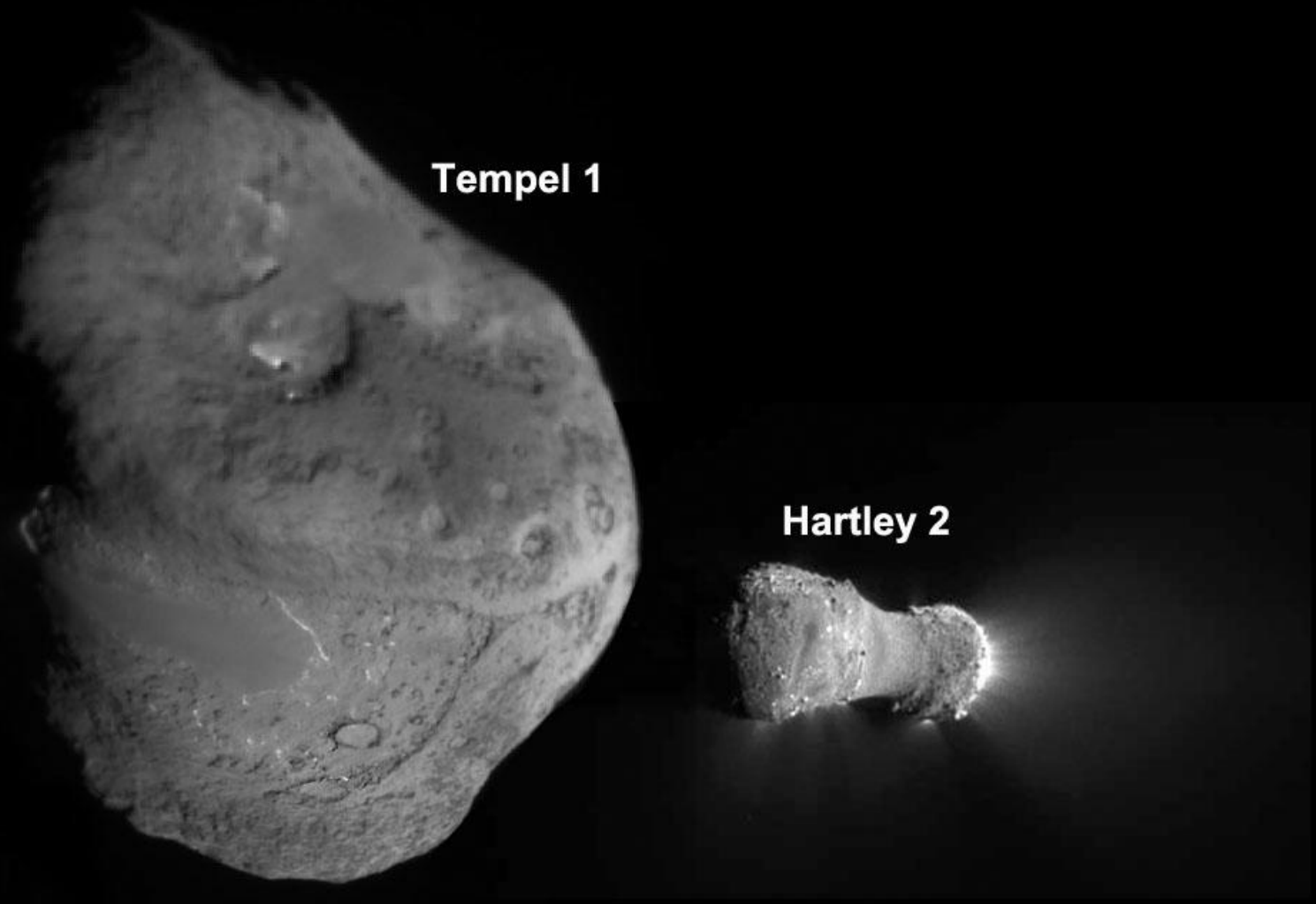
CREDIT: NASA/JPL/USGS

MIRANDA
Uranus Moon



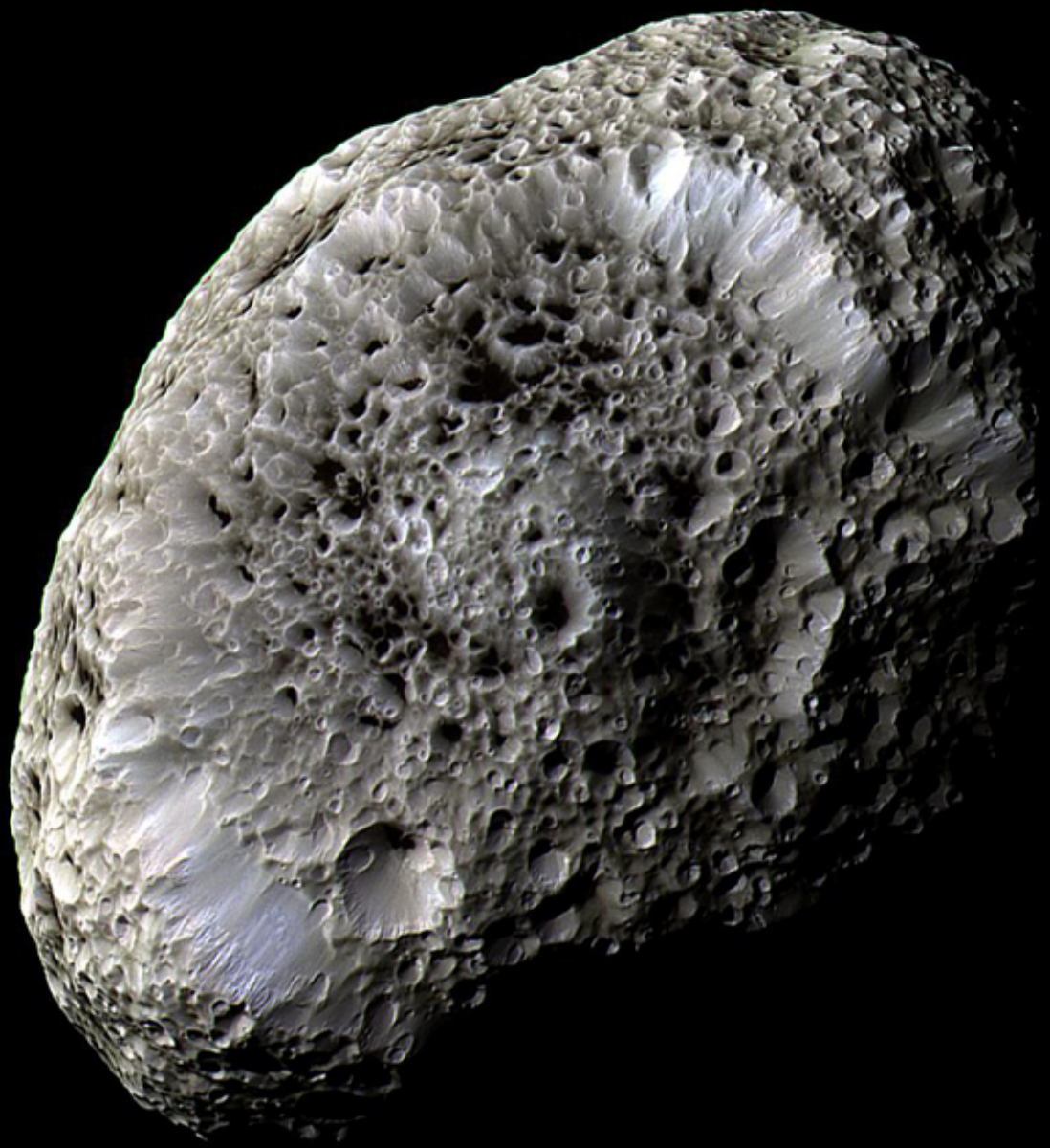
NASA/JPL-Caltech/Univ. of Arizona

COMET NUCLEI



CREDIT: NASA/JPL-Caltech/UMD

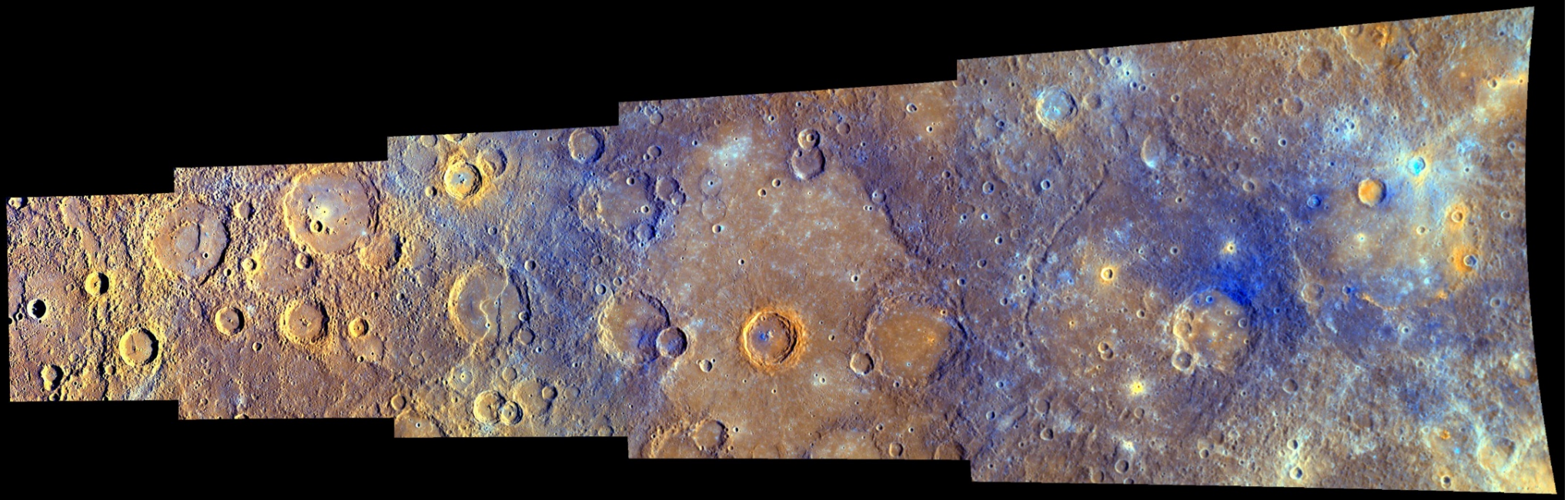
HYPERION



SATURN's MOON

CREDIT: NASA/JPL/SSI

DECIPHERING GEOLOGIC STORIES: Circles, Lines & Blobs



CREDIT: NASA/JHUAPL/CIW

MYSTERIOUS LANDSCAPE: What happened here...?

ONE
CRATER
CHAIN...

TWO
CRATER
CHAINS...

MERCURY

Learn more

NASA's Discovery Program
http://discovery.nasa.gov

Shari Asplund
shari.e.asplund@jpl.nasa.gov

ART & THE COSMIC CONNECTION

NASA Space & Earth Images

Print these images and ask students to select one they would like to draw.

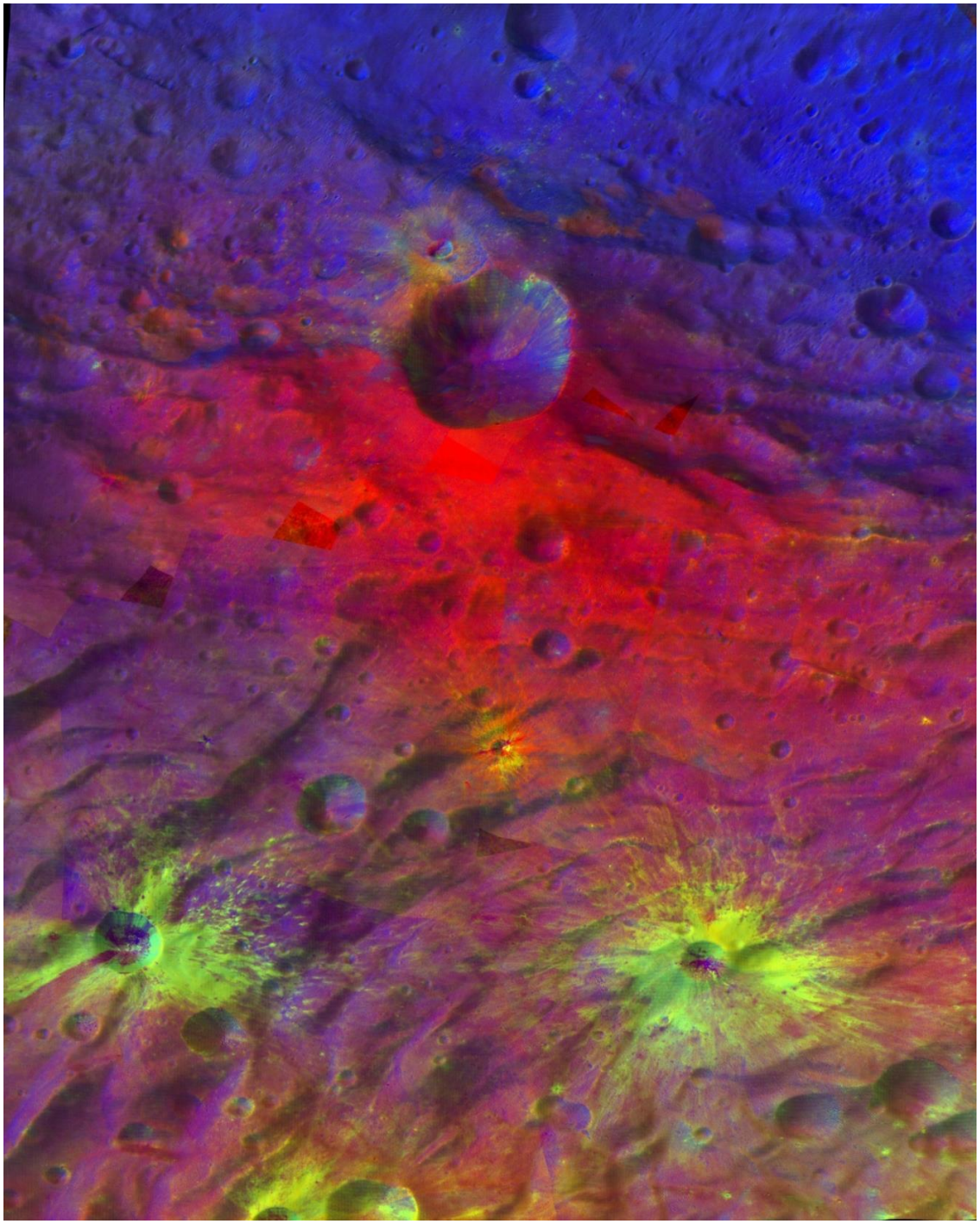
Students should feel free to interpret their image by cropping it or altering the colors. Encourage students to pay attention to the elements of art as they draw and think about the stories the surface features are revealing.

(Laminating or putting the printed images in sheet protectors will help them to last for multiple uses.)

The Color of the Moon

Earth’s Moon is normally seen in subtle shades of grey or yellow. This dramatic image uses small color variations to exaggerate the real differences in the chemical makeup of the lunar surface.

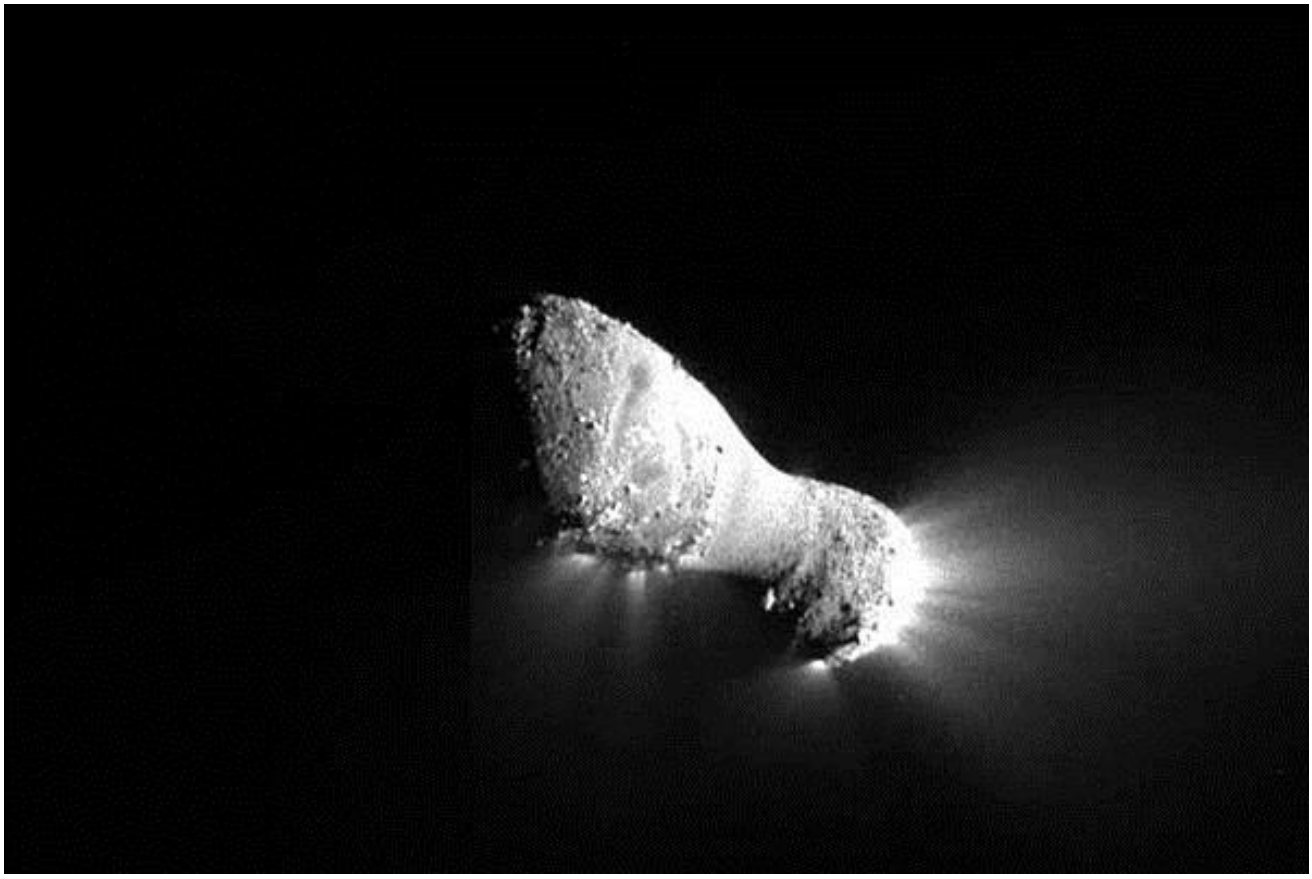
Credit: Johannes Schedler (Panther Observatory)



False Color image of Oppia Crater on giant asteroid Vesta

This is a composite image that has been wrapped on a topographical model to illustrate depth.

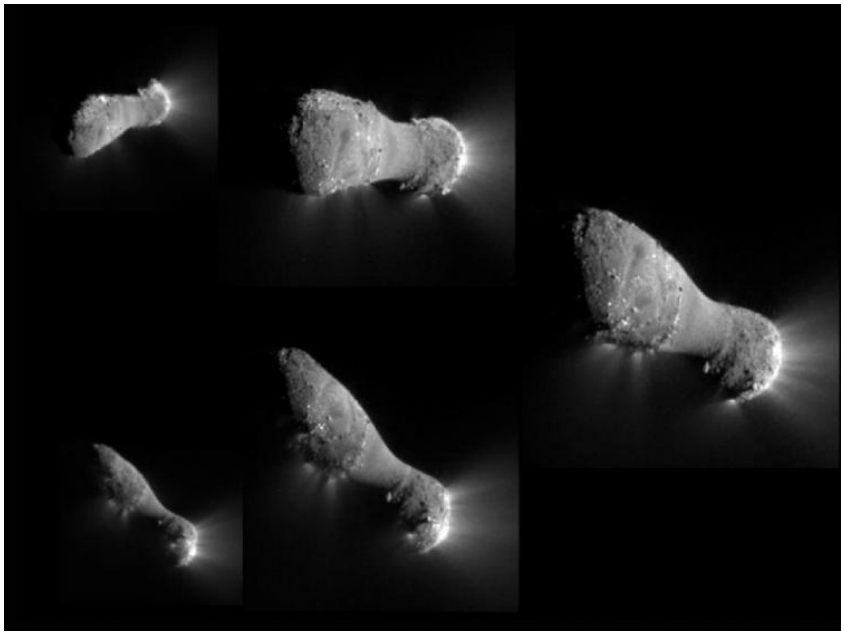
Credit: NASA/JPL-Caltech/UCLA/MS/IDA



Comet Hartley

The comet’s nucleus can be seen in glorious detail in this set of images from NASA's EPOXI mission.

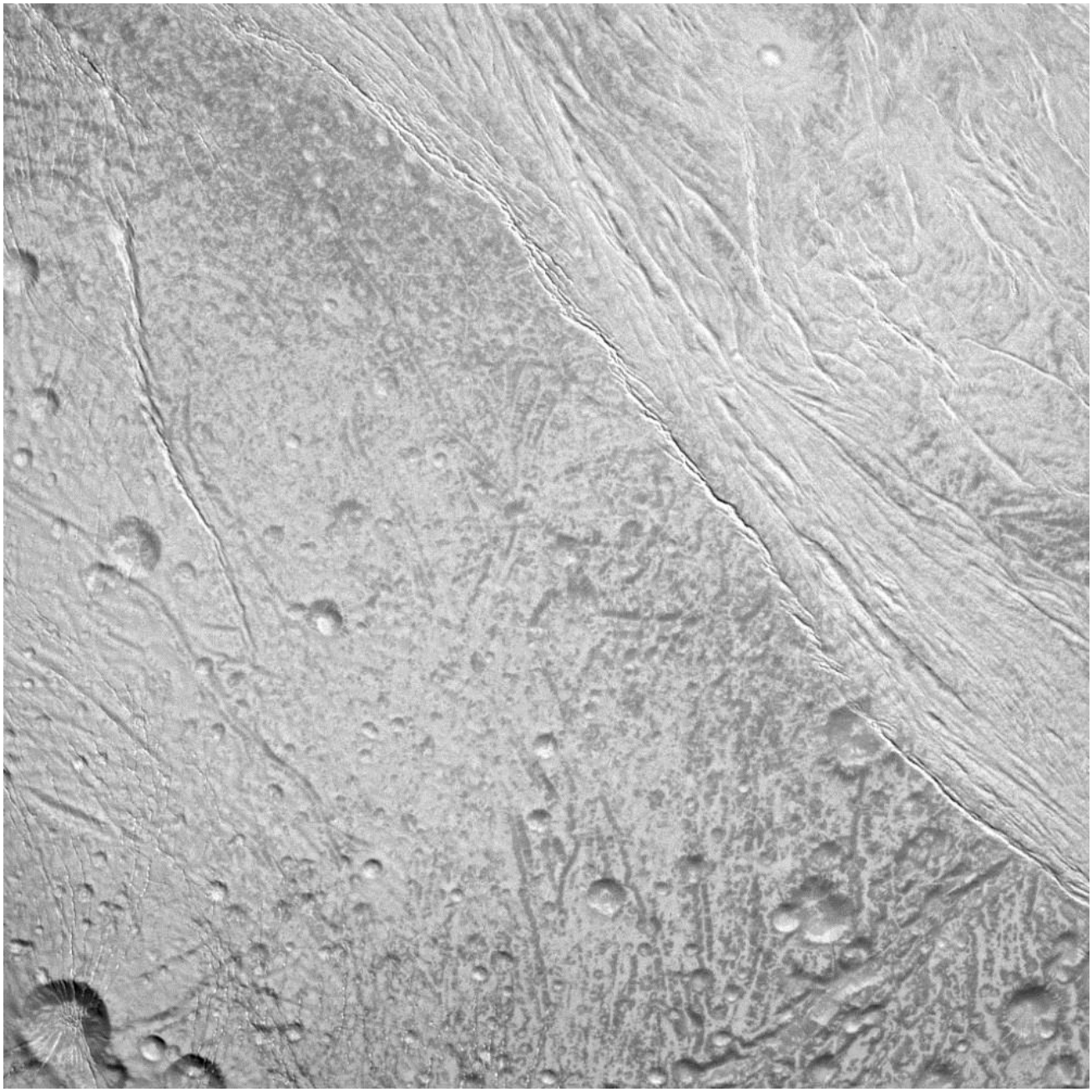
Credit: NASA/JPL-Caltech/UMD



Comet Tempel 1

The Deep Impact mission’s flyby spacecraft captured this image 67 seconds after the impactor slammed into the comet.

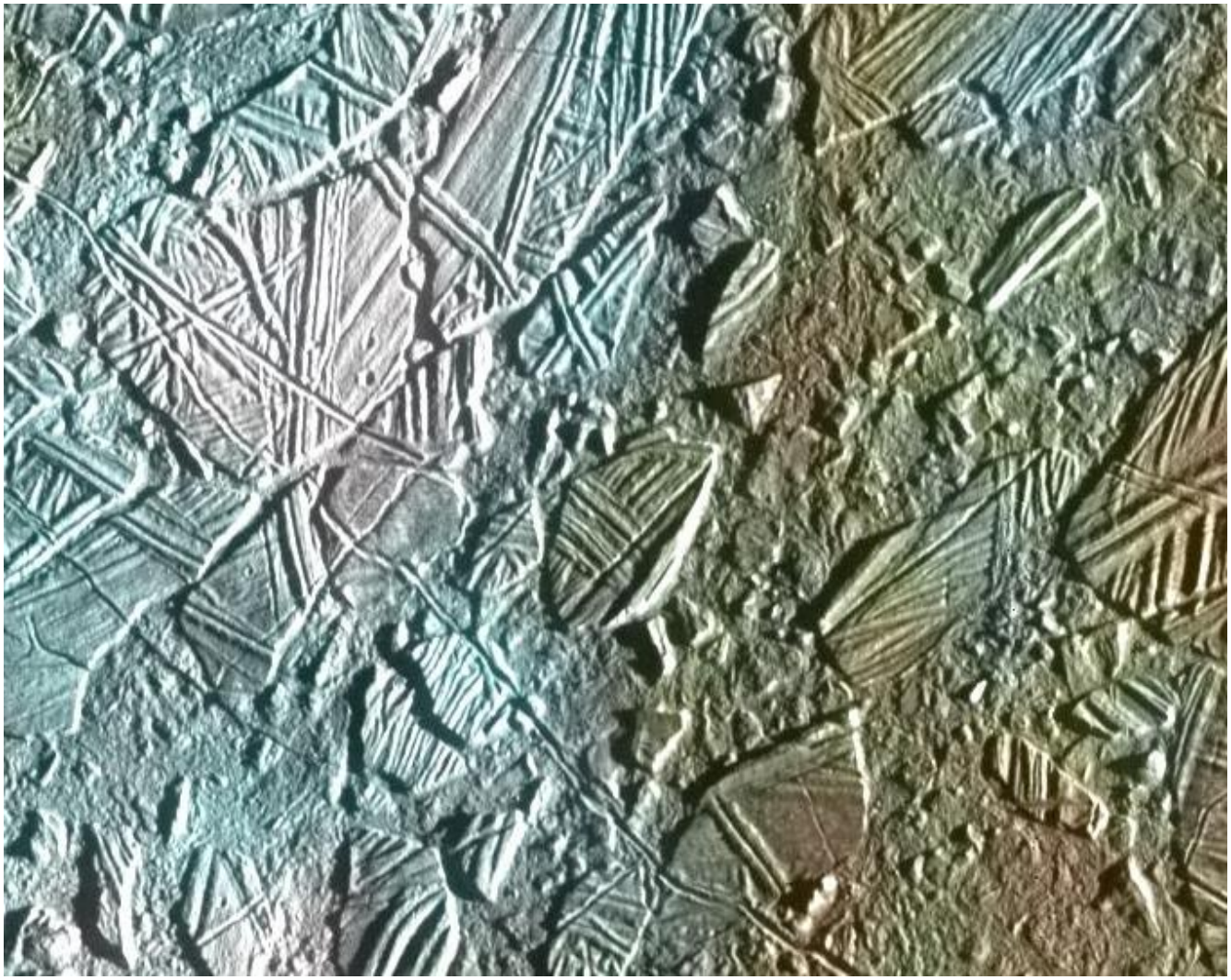
Credit: NASA/JPL-Caltech/UMD



Enceladus’ Icy Surface

The cryovolcanoes (jetting ices) on Saturn's moon Enceladus are responsible for the largest of Saturn’s rings!

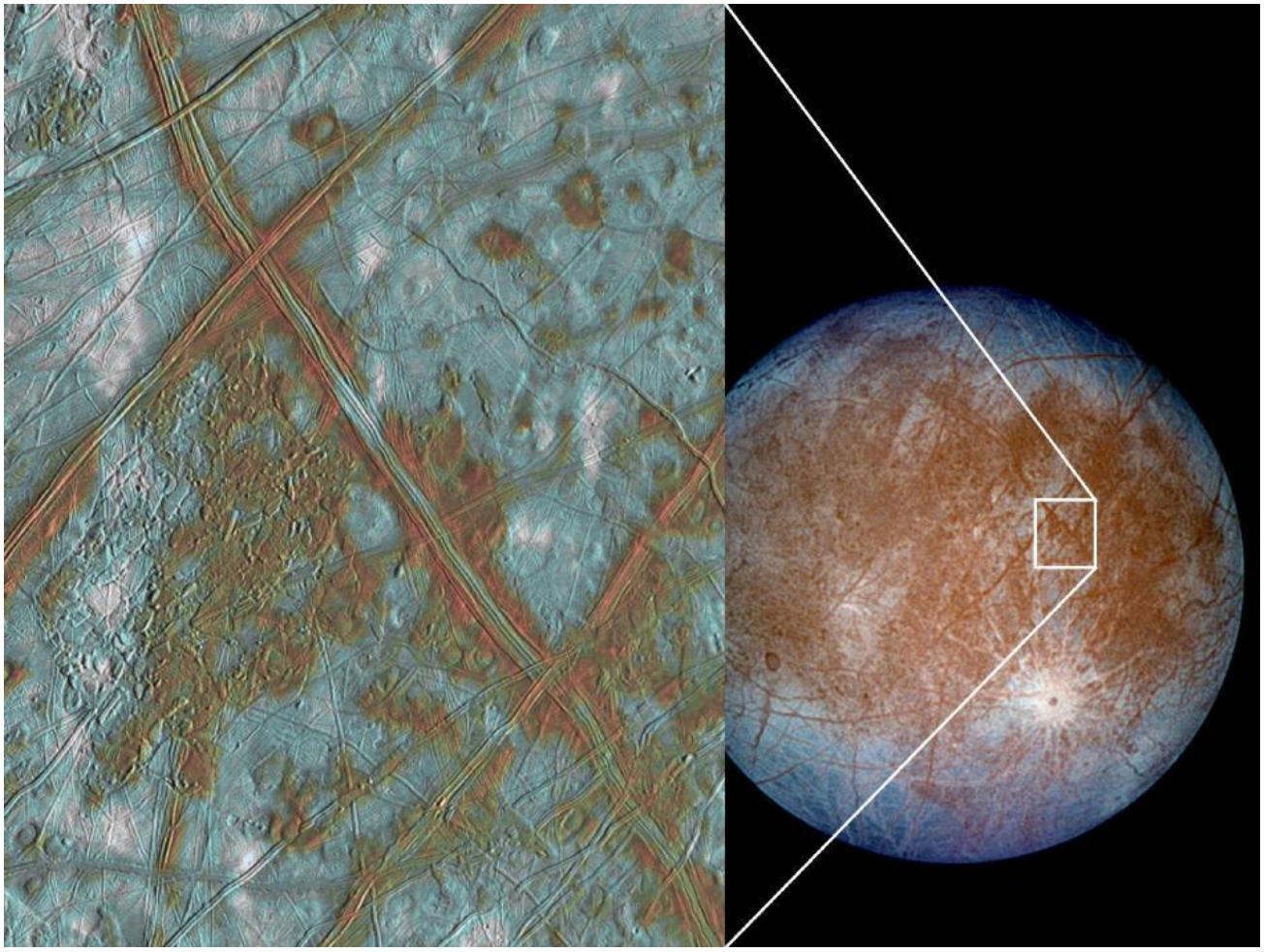
Credit: NASA/JPL-Caltech



Jupiter’s Moon Europa: Chaos

The cracks and fault lines and fissures on the icy surface of Europa resemble activity we observe on our own North and South poles.

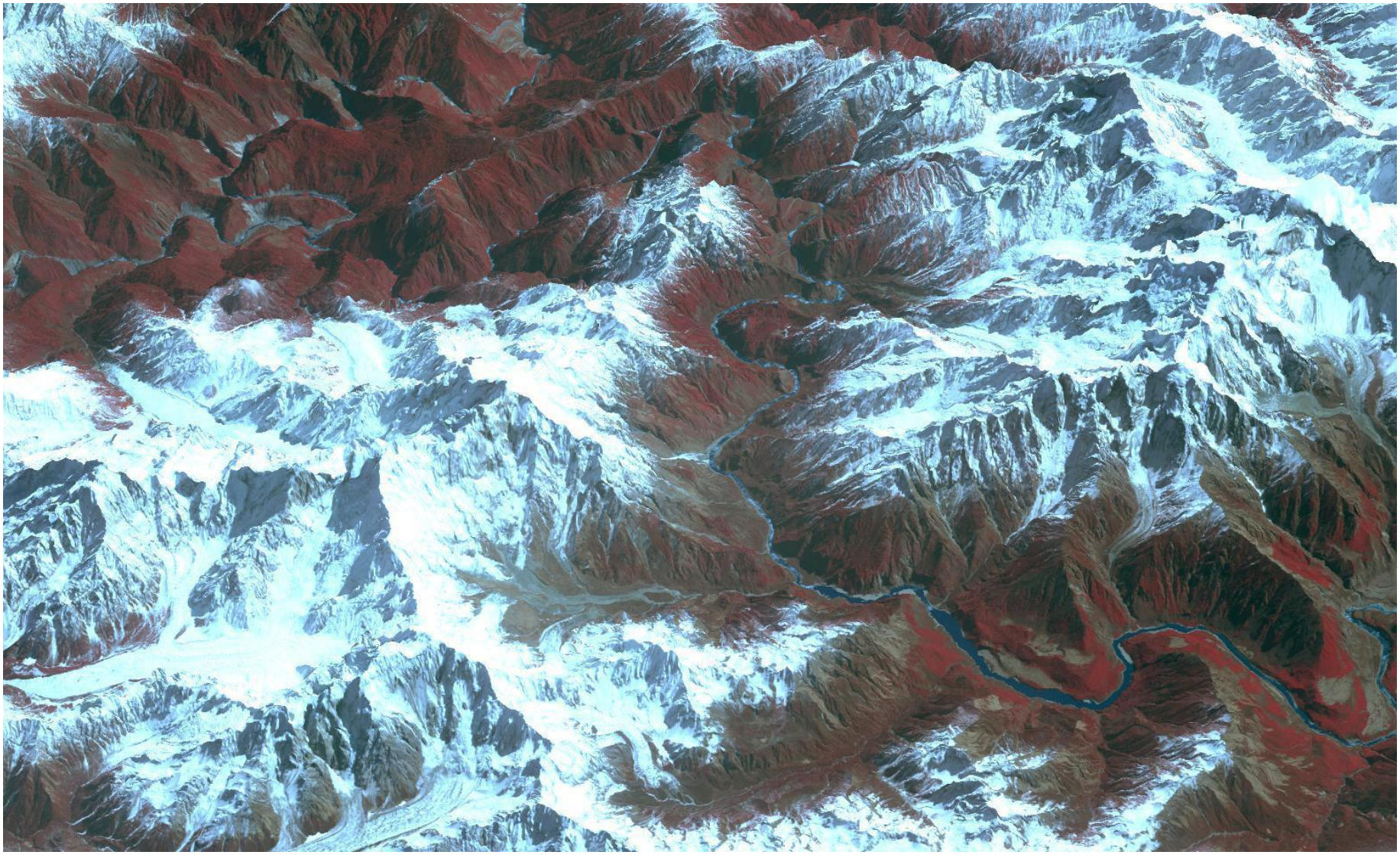
Credit: NASA/JPL-Caltech



Jupiter’s Moon, Europa

Faults in the moon’s icy surface.

Credit: NASA/JPL-Caltech



Yarlang Zangpo Grand Canyon, Tibet

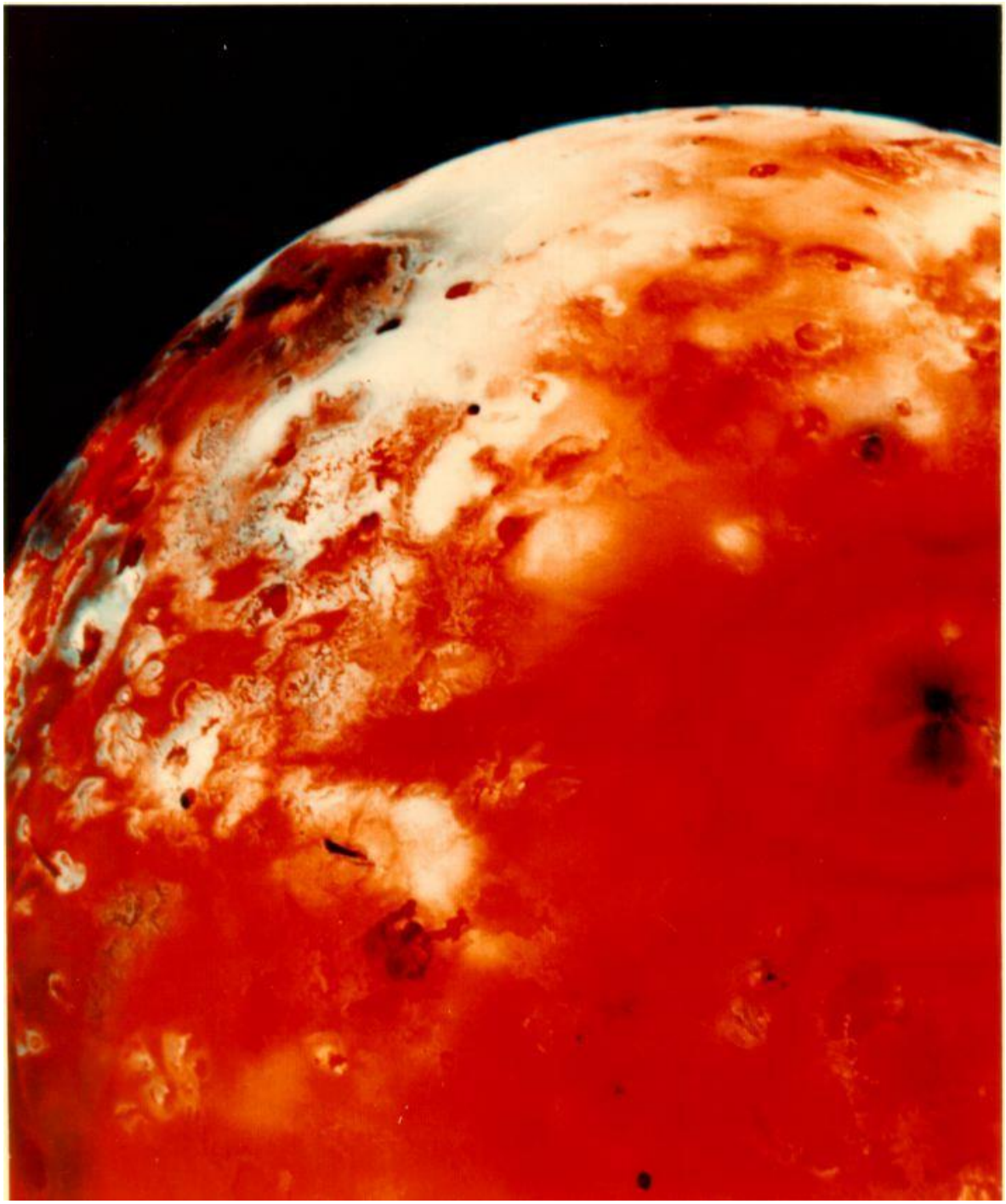
Astronomers and geologists look at topographical features (craters, volcanoes, mountains, patterns left by water) on Earth to help them understand distant planets, moons, comets and asteroids. This image was captured by the ASTER instrument on the Terra satellite.

Credit: NASA/GSFC/METI/ERSDAC/JAROS and U.S./Japan ASTER Science Team

Saturn’s moon, Iapetus

Brown is the actual color of the surface of this intriguing moon, while the black areas are in shadow. Iapetus has extreme values, among the brightest and darkest surfaces in the solar system.

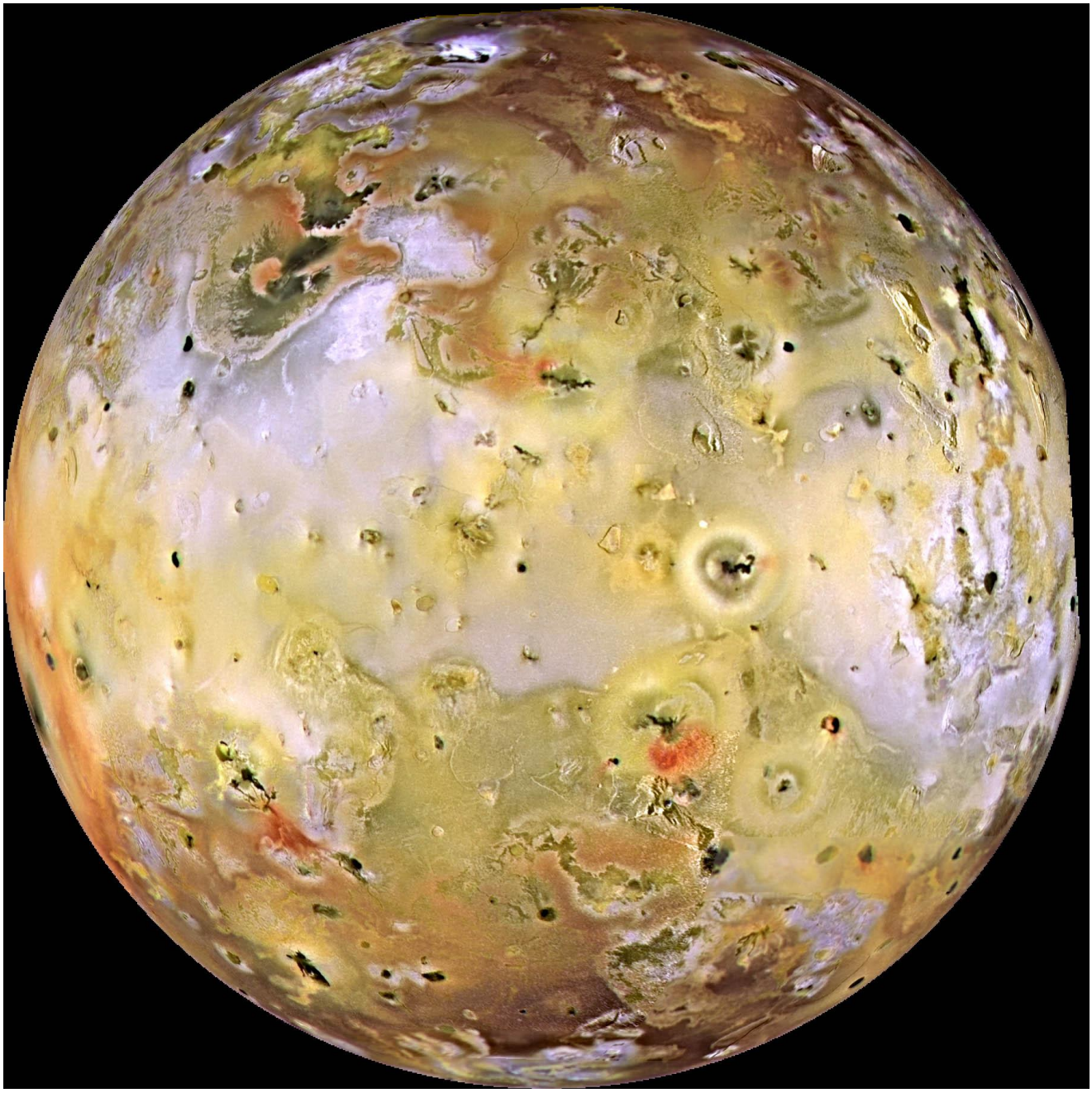
Credit: NASA/JPL-Caltech



Jupiter’s moon, Io

Io is the most volcanic solar system body. Io’s volcanoes continually resurface it, so that any impact craters have disappeared.

Credit: NASA/JPL-Caltech



Jupiter’s Moon, Io

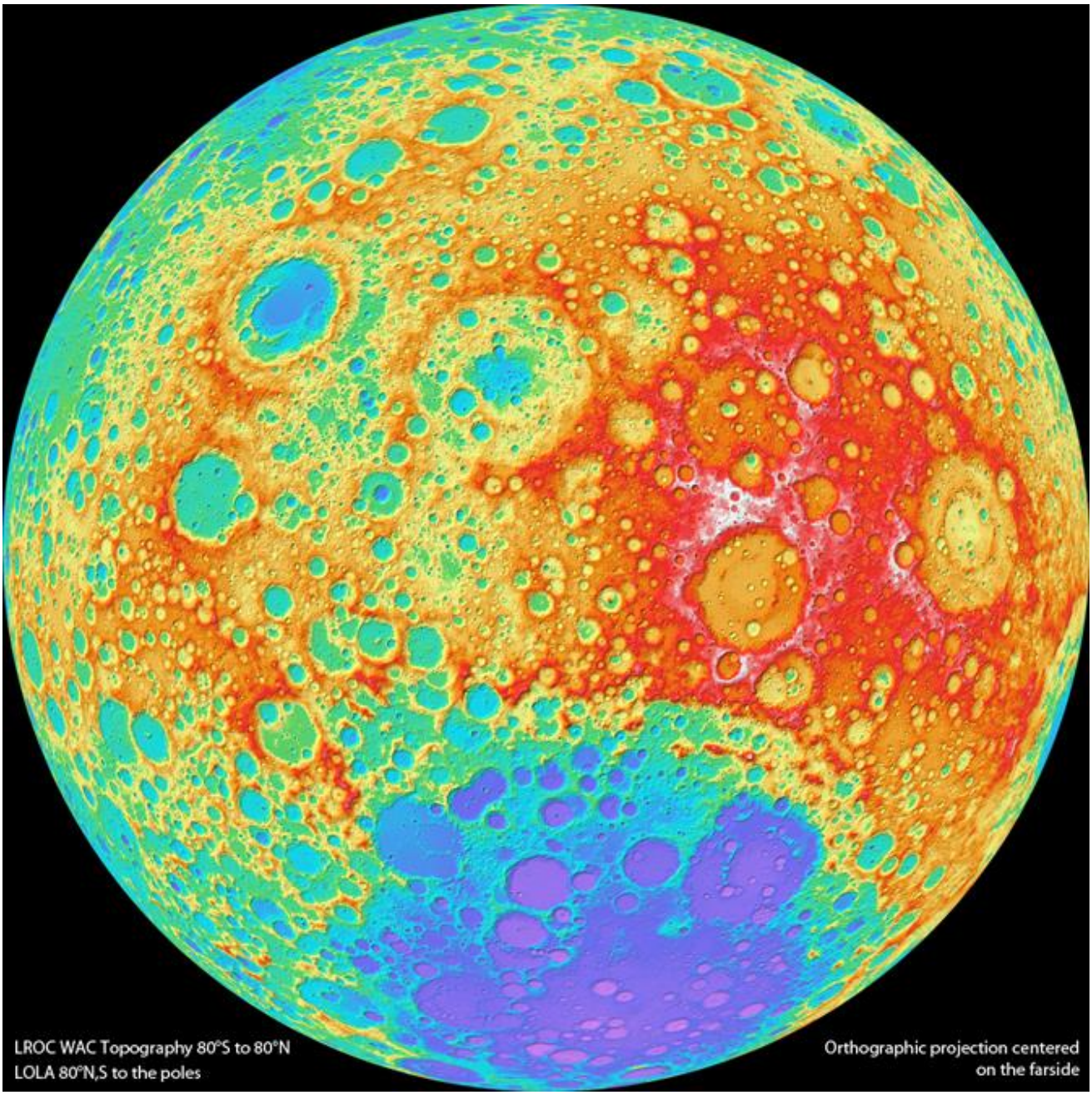
The most volcanic solar system body, Io is so close to Jupiter that the land is pulled 15 meters daily, like our Earth’s ocean tides! This is a true color image.

Credit: NASA/JPL-Caltech

Mercury’s vast crater, Kalidasa

Taken by the MESSENGER spacecraft… check out the crater in the crater!

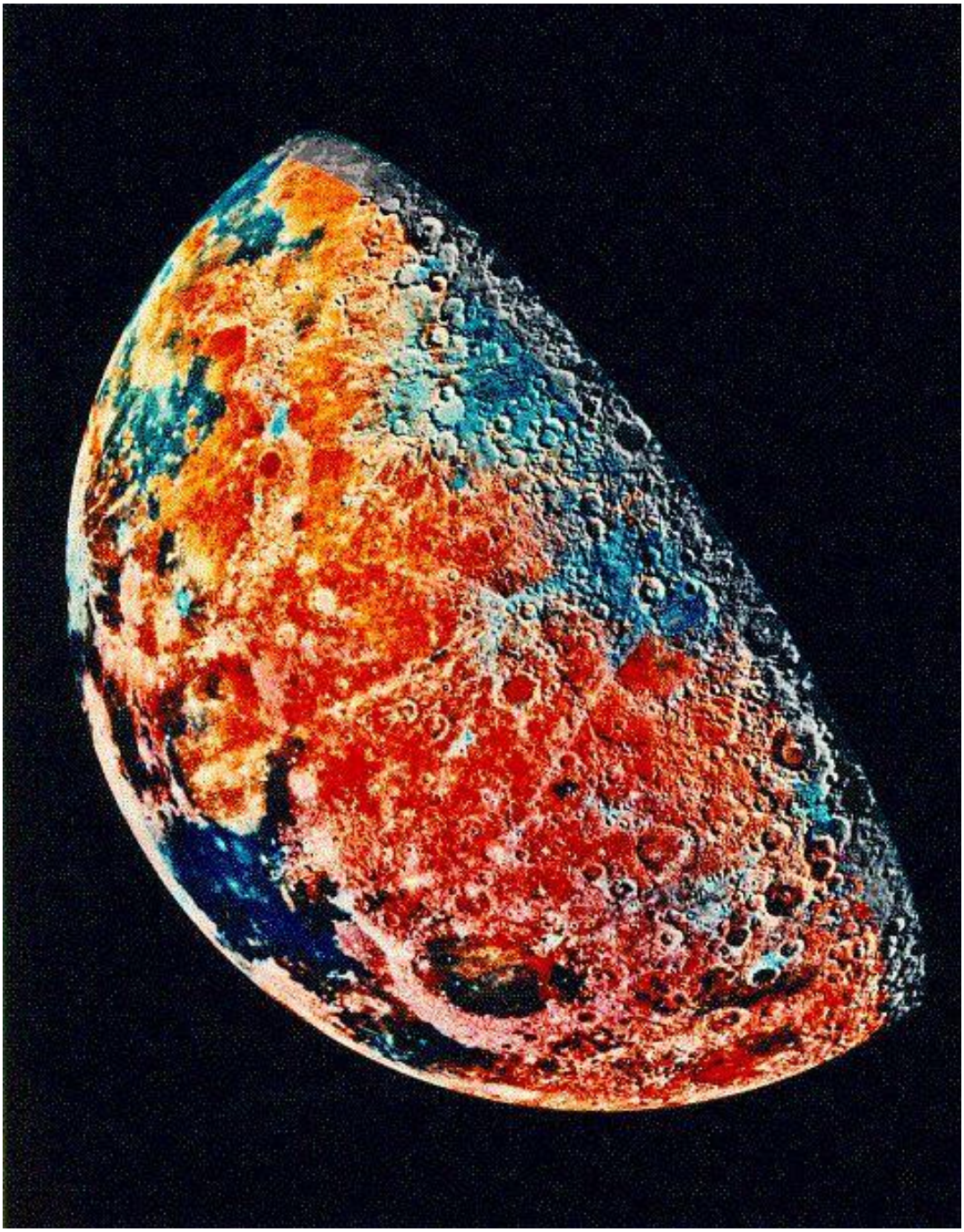
Credit: NASA/Johns Hopkins University Applied Physics Laboratory/Arizona State University/Carnegie Institution of Washington



Far Side of the Moon

Thanks to Lunar Reconnaissance Orbiter, this is the highest resolution composite topographical map of the Moon.

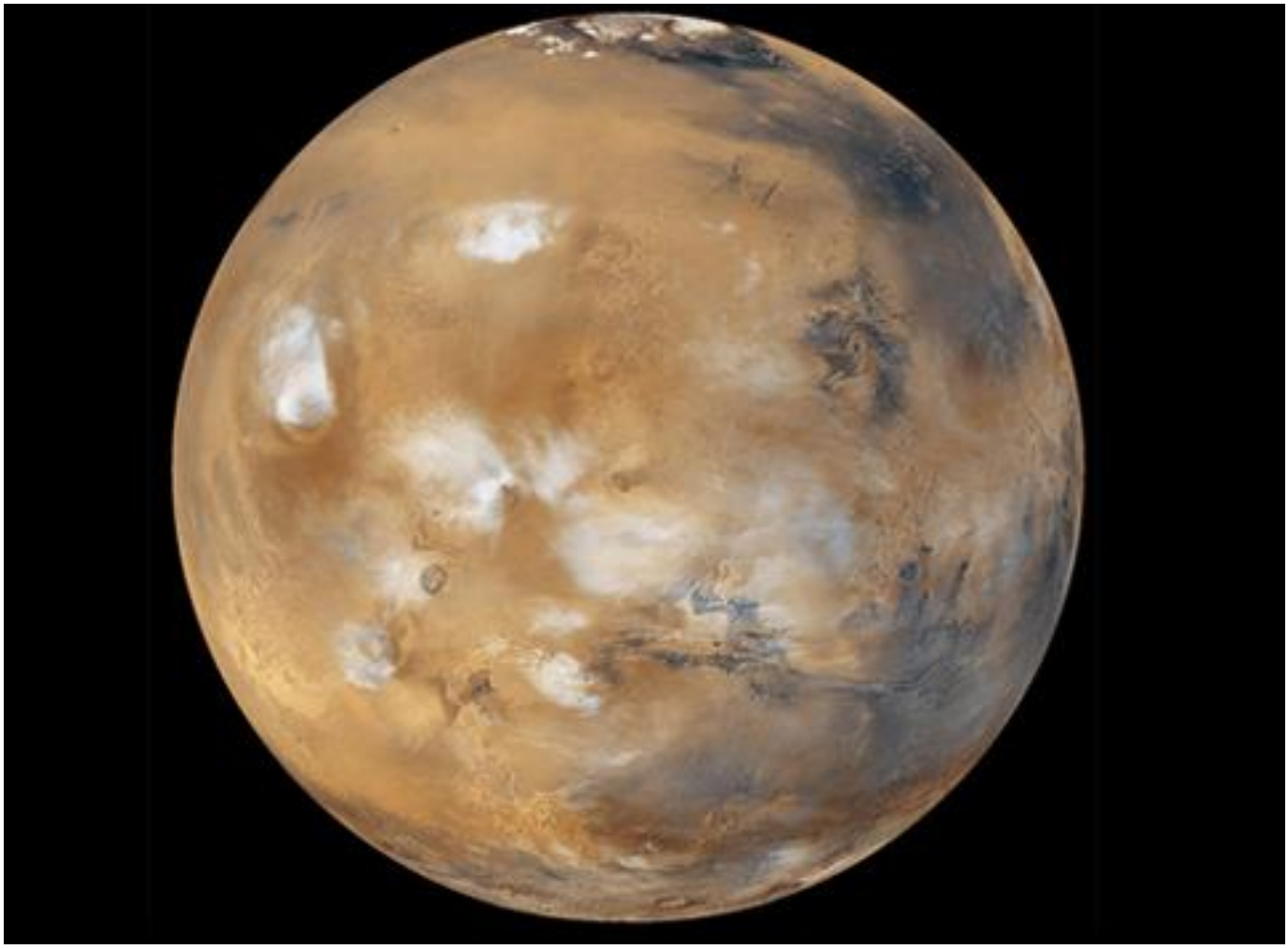
Credit: NASA/JPL/University of Arizona



Earth’s Moon

This false-color mosaic was constructed from 53 images taken by the Galileo spacecraft. It shows compositional variations in the northern hemisphere.

Credit: NASA/JPL-Caltech



Mars

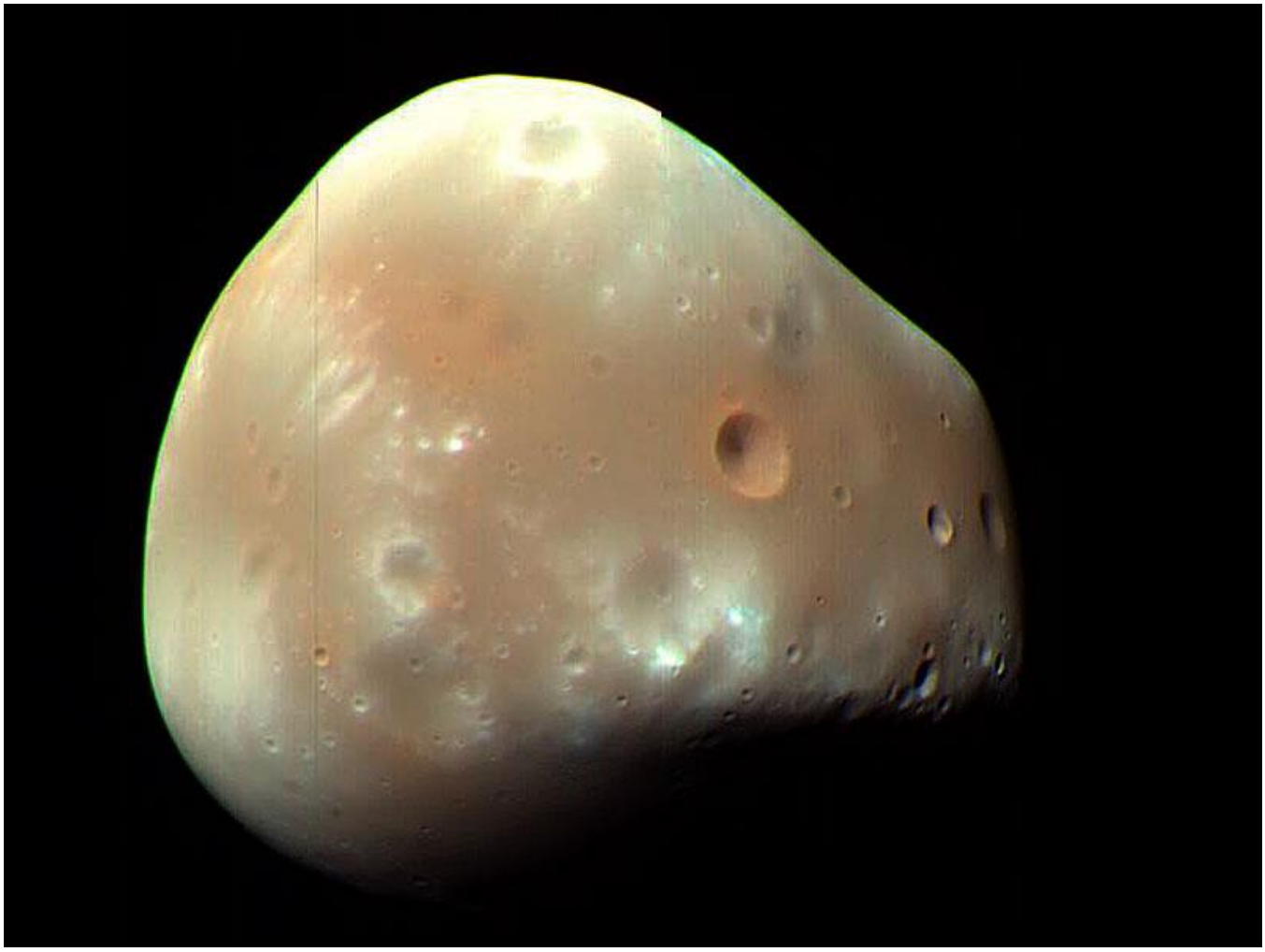
Twelve orbits a day provided the Mars Global Surveyor wide angle cameras a global snapshot of Martian weather patterns. Bluish-white water ice clouds hang above the Tharsis volcanoes.

Credit: NASA/JPL-Caltech/MSSS

Mars: Merged Color Image

This mosaic of the Coprates region of Mars shows moderately cratered and faulted highland ridged plains cut by the prominent, vast Valles Marineris canyon. This image was captured by Viking spacecraft using a combination of filters.

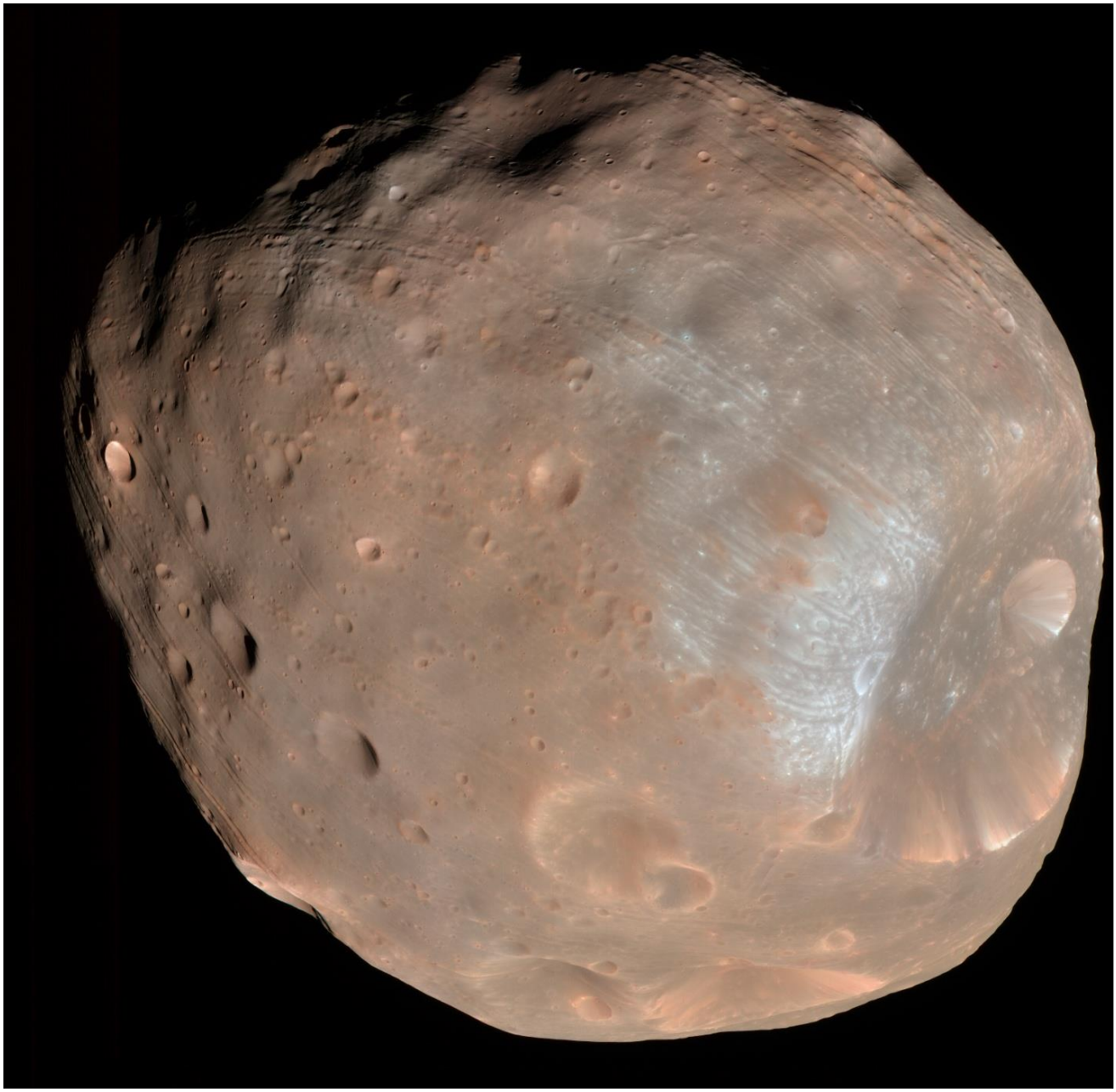
Credit: NASA/JPL-Caltech/ USGS



Mars' Moon, Deimos

Did Mars' gravity capture it from the main asteroid belt?

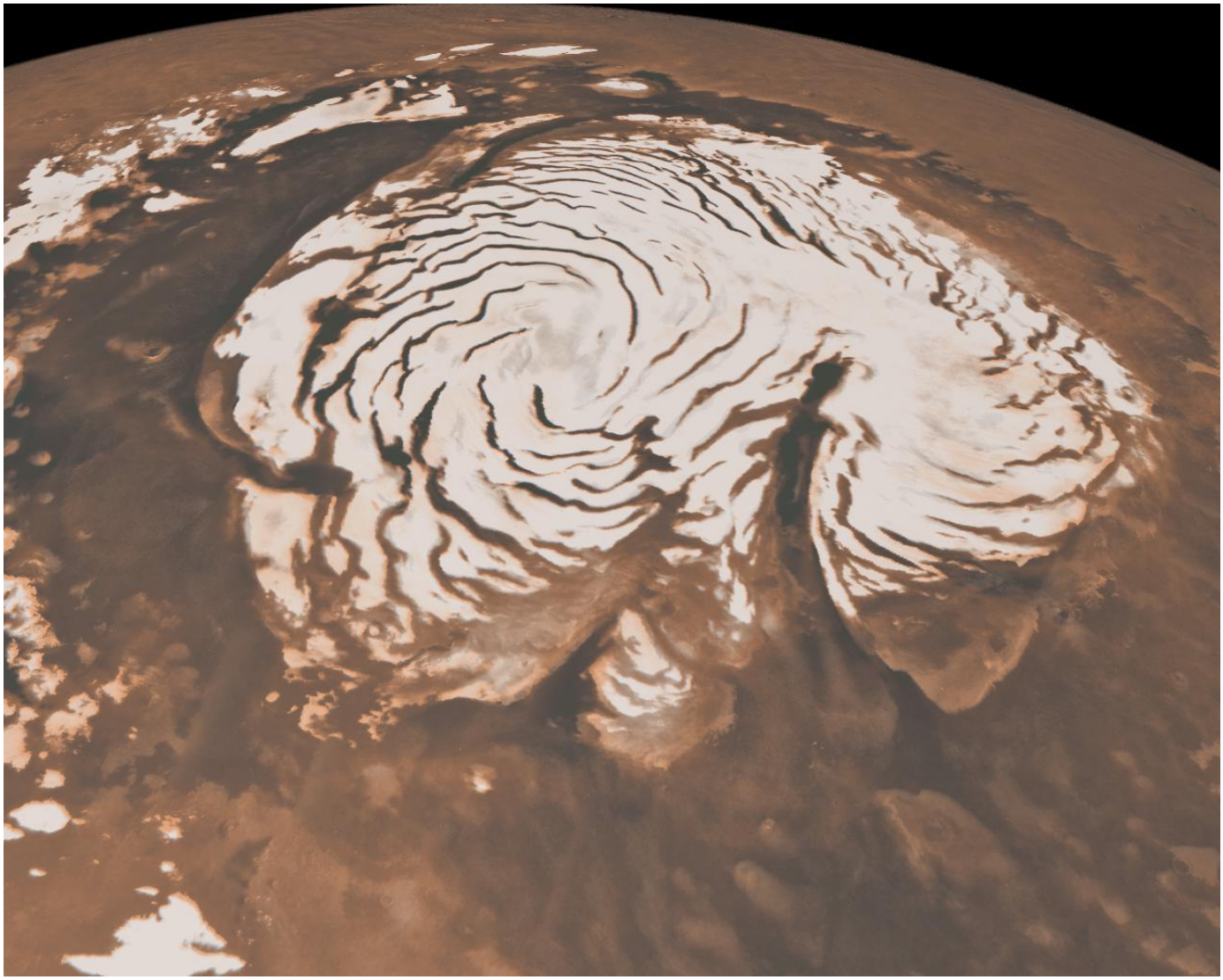
Credit: NASA/JPL-Caltech/HiRISE/U of Arizona (LPL)



Mars' Moon, Phobos

Did Mars' gravity capture it from the main asteroid belt?

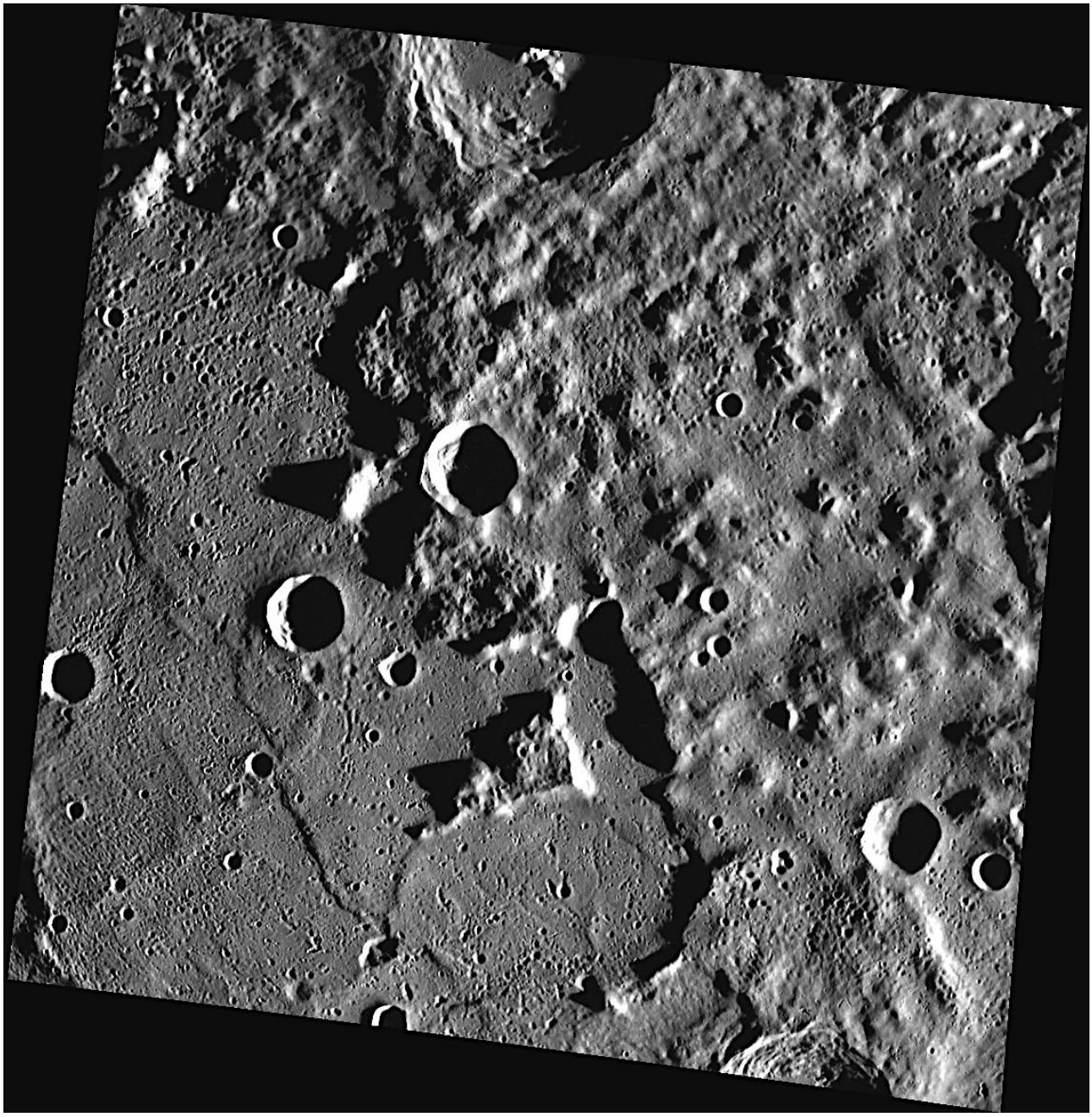
Credit: NASA/JPL-Caltech/HiRISE/U of Arizona (LPL)



Mars’ North Pole

The two-mile-tall, Texas-sized ice cap at the north pole of Mars was a mystery for forty years until Mars Global Surveyor data helped scientists determine that the spiral troughs and giant canyon were formed by katabatic winds, which blow down from the top of the ice cap.

Credit: NASA/JPL-Caltech/MSSS



Mercury Up Close

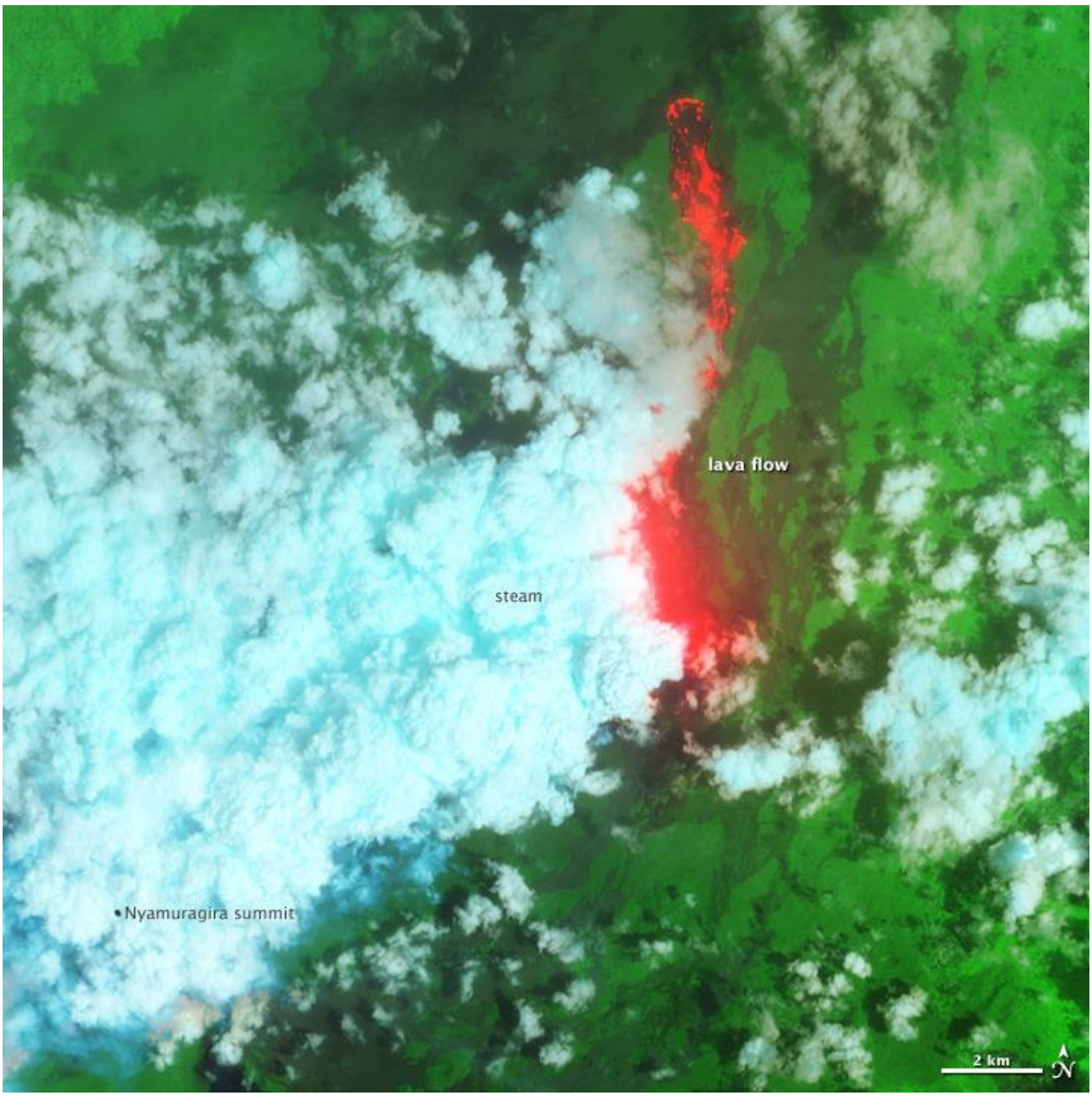
The floor of Mercury’s Caloris basin is filled with volcanic plains, while a ring of mountainous peaks is found along the basin's rim. Near the edge of the huge impact basin, "islands" of rough terrain are surrounded by smooth volcanic plains.

Credit: NASA/Johns Hopkins University Applied Physics Laboratory/Carnegie Institution of Washington

Mercury Crater Trails

What might cause the crater chains shown in this image, taken by the MESSENGER spacecraft? Scientists think these features form when ejecta from a primary impact is thrown outward. As chunks of ejecta fall back to the surface, they can form chains of secondary craters that often overlap.

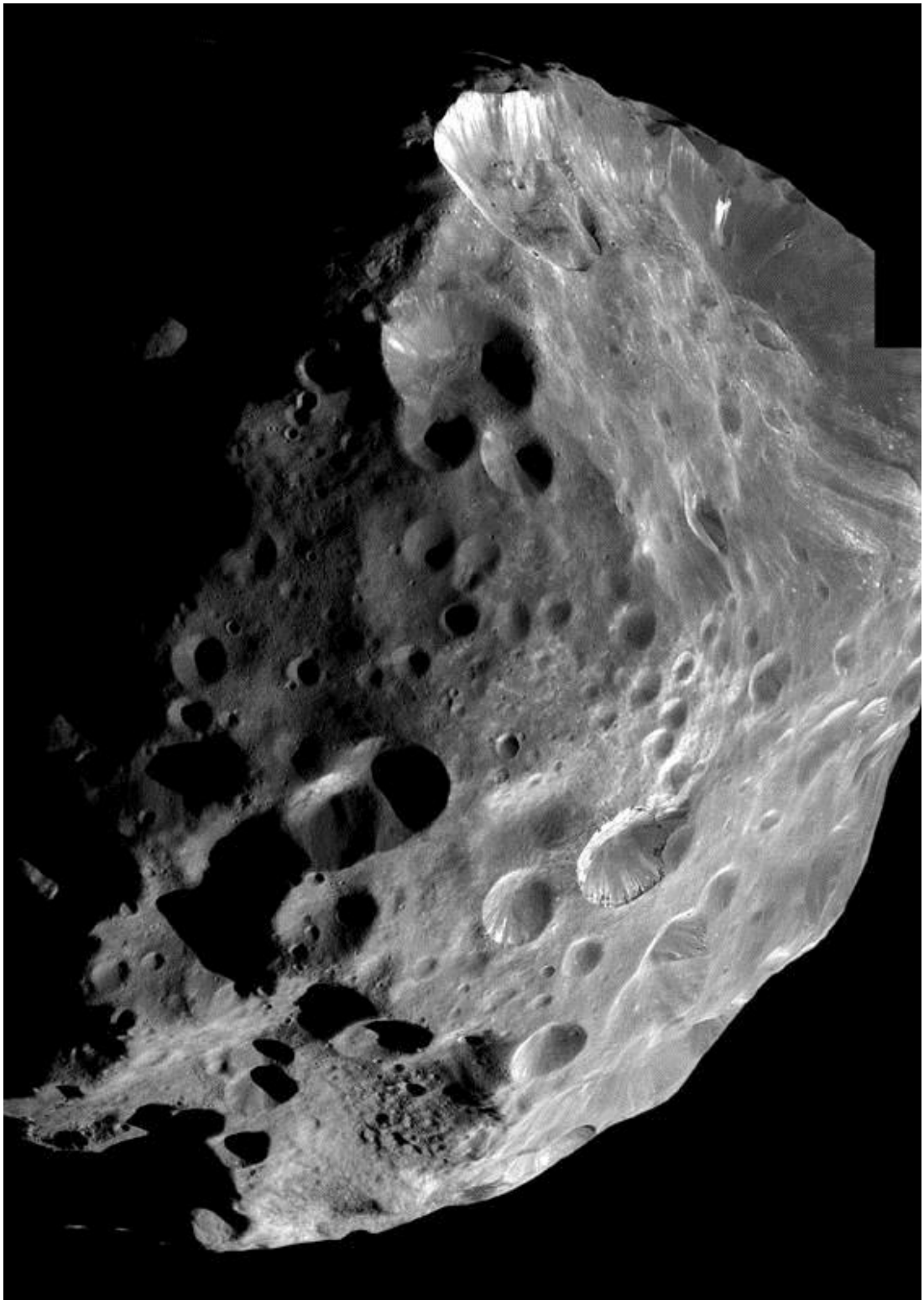
Credit: NASA/Johns Hopkins University Applied Physics Laboratory/Carnegie Institution of Washington



Nyamuragira Eruption, Africa

Nyamuragira is one of the world's most active volcanoes. It erupts roughly every two years, producing large fluid lava flows. This photo from NASA's Earth Observatory shows fresh lava in red.

Credit: NASA



Phobos

Mars' moon Phobos taken by the Cassini spacecraft on its way to Saturn.

Credit: NASA/JPL-Caltech

Pine Island Glacier:
huge ice stream flowing into Hudson Bay in northern Canada.

Astronomers and geologists look at topographical features (craters, volcanoes, mountains, patterns left by water, etc.) on Earth to help them understand patterns on distant planets, comets, asteroids.

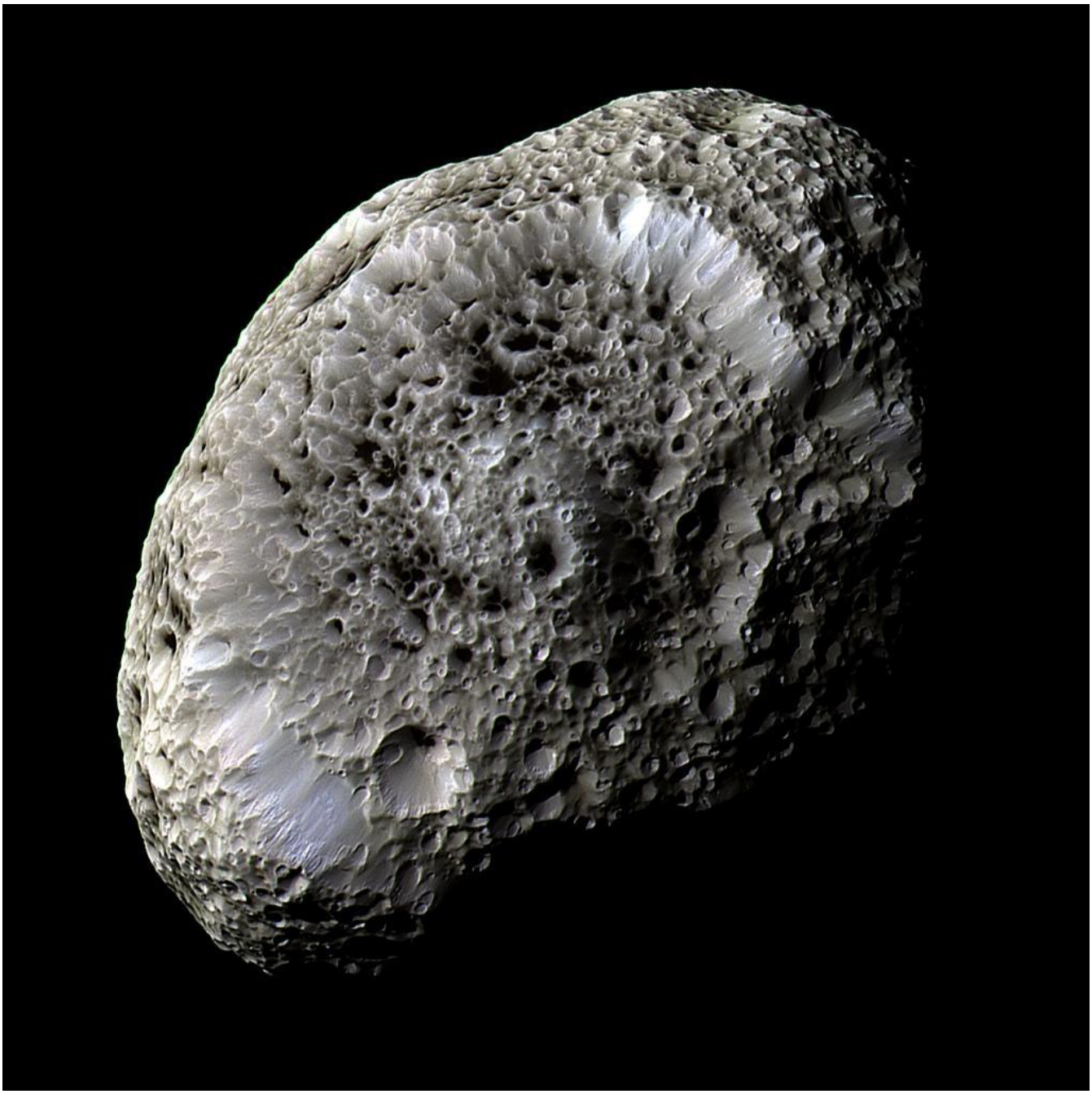
This section of the 260 km glacier is about 80 m (260 ft) wide and 29 km (18 miles) long

Credit: NASA

Saturn’s Odd Moon, Hyperion

Check out the unusual surface topography of Hyperion. Can you think of something that looks like that on Earth? Why might its craters look like that?

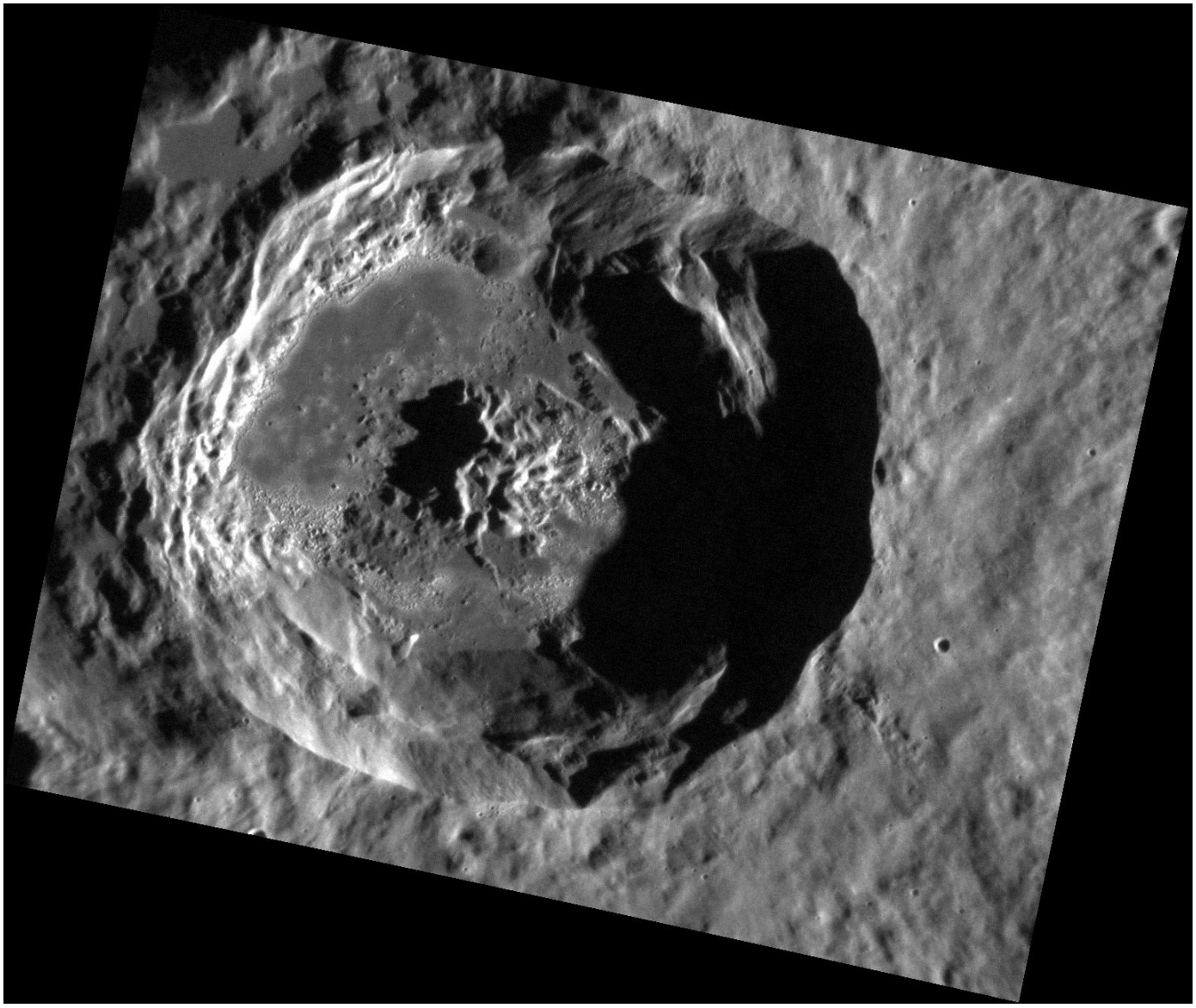
Credit: NASA/JPL-Caltech



Storms over the Gulf of Mexico and the Atlantic, 11/22/11

Astronomers and geologists look at topographical features (craters, volcanoes, mountains, patterns left by water, etc.) on Earth to help them understand patterns on distant planets, comets, asteroids.

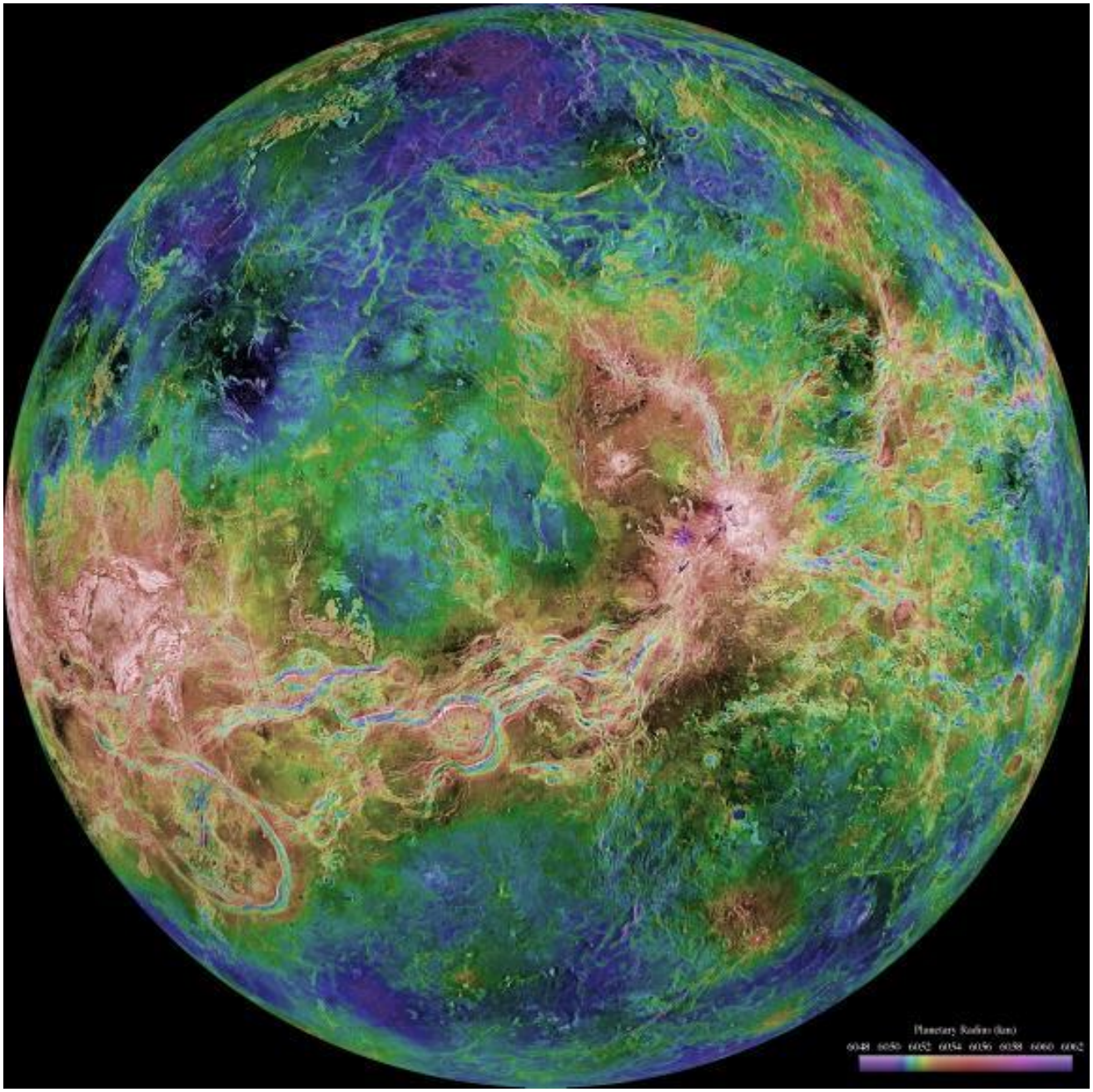
Credit: NASA



Mercury: Unnamed Hollows

MESSENGER took this image… is it a depression or a dome? Don’t let your eyes deceive you!

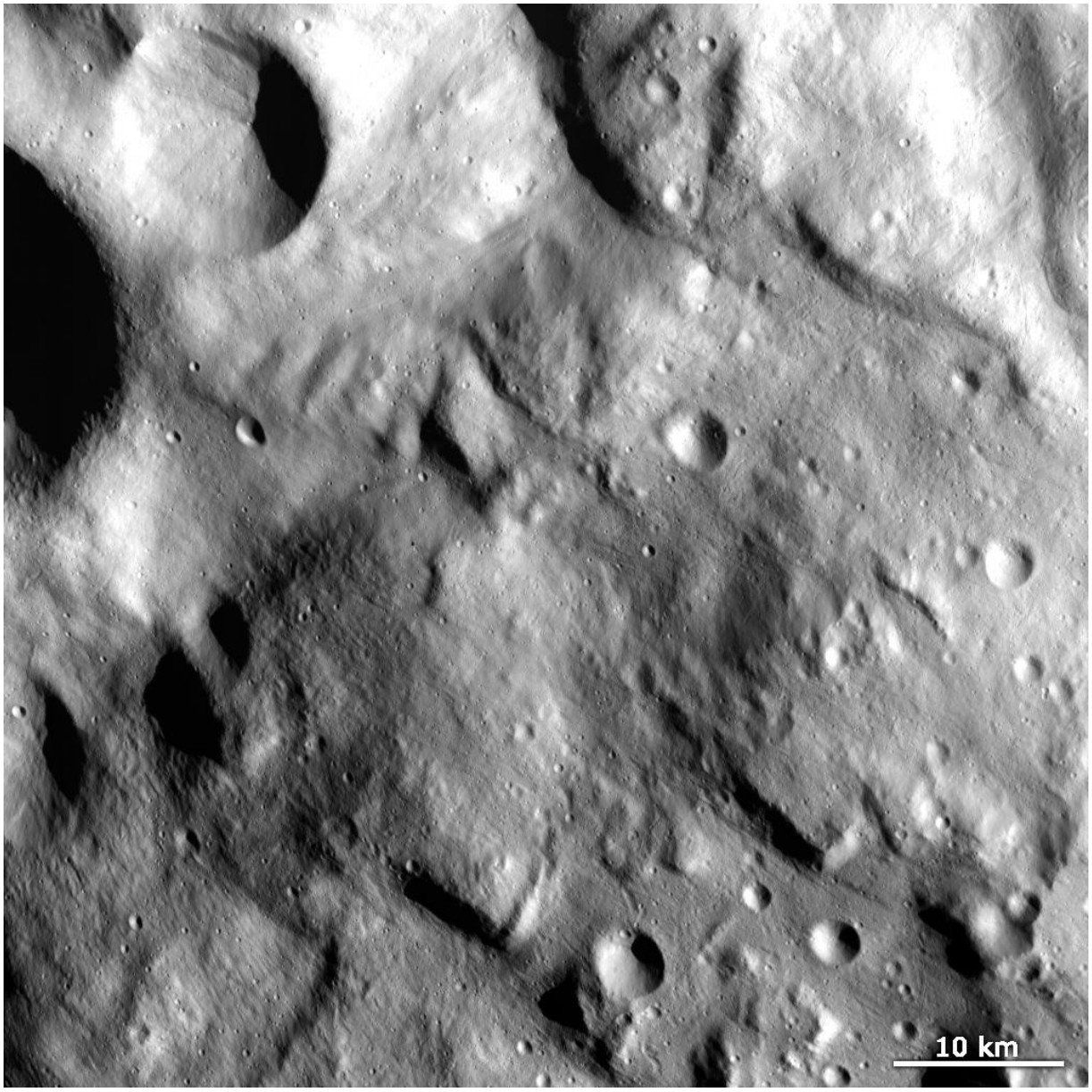
Credit: NASA/Johns Hopkins University Applied Physics Laboratory/Carnegie Institution of Washington



Venus Colorized

Scientists use color to emphasize variations such as mineral composition, temperature variation, and topography.

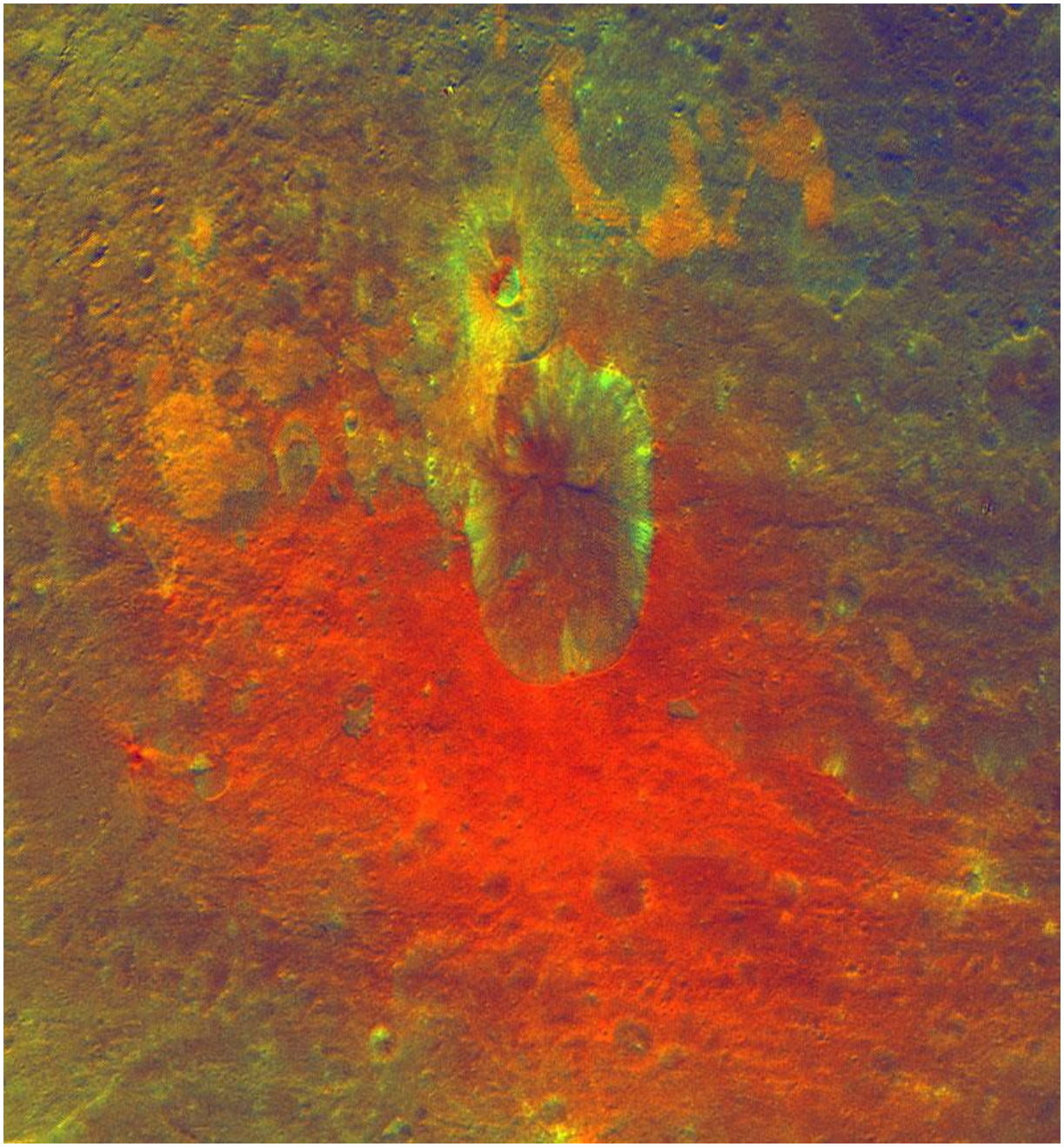
Credit: NASA/JPL-Caltech



Vesta Close Up

The Dawn spacecraft took this detailed image of giant asteroid Vesta during its year-long orbit.

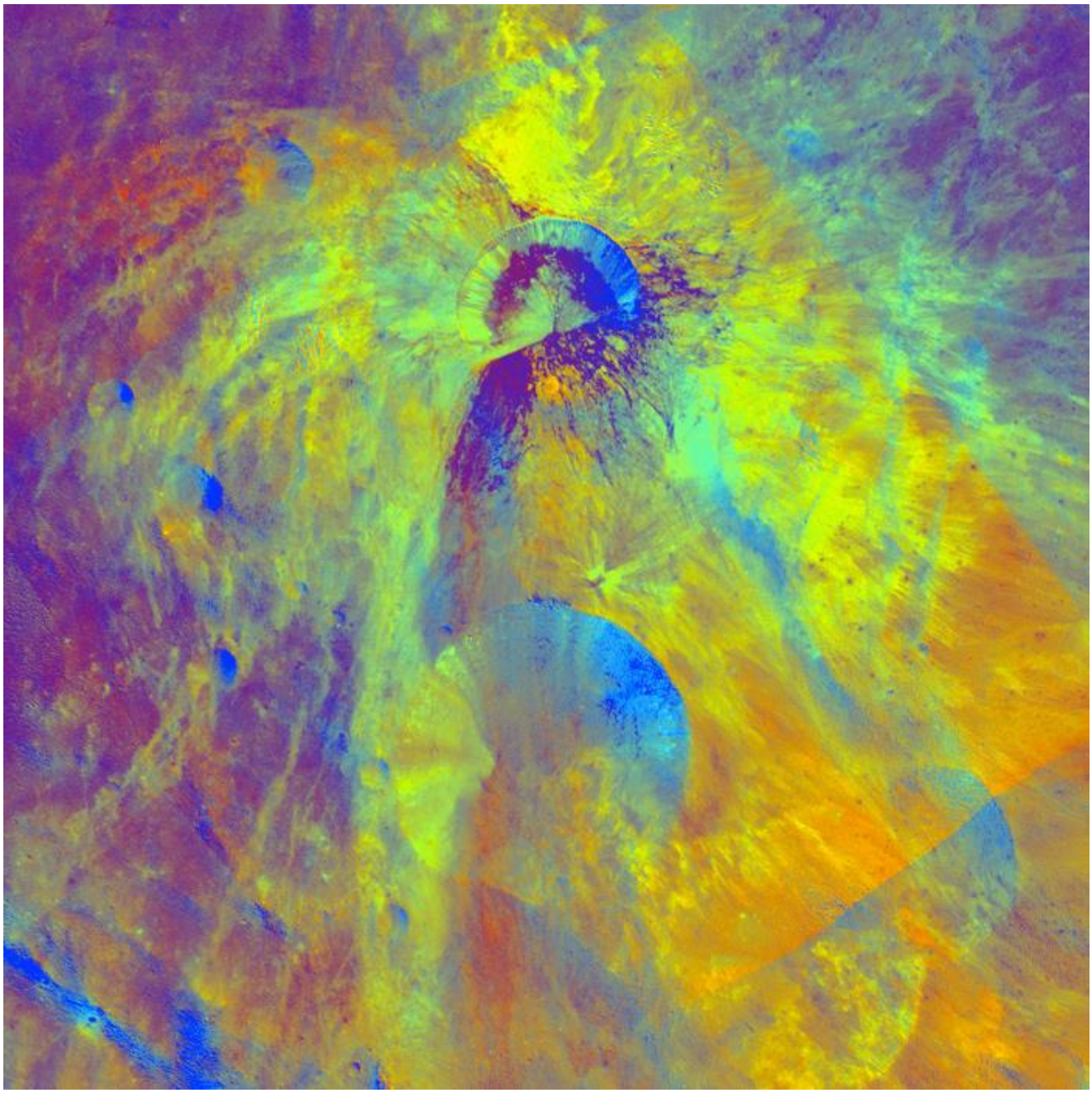
Credit: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA



Vesta: False Color Crater

Scientists use color to emphasize variations such as mineral composition, temperature variation, and topography. This image highlights the ejecta left from the impact of the crater.

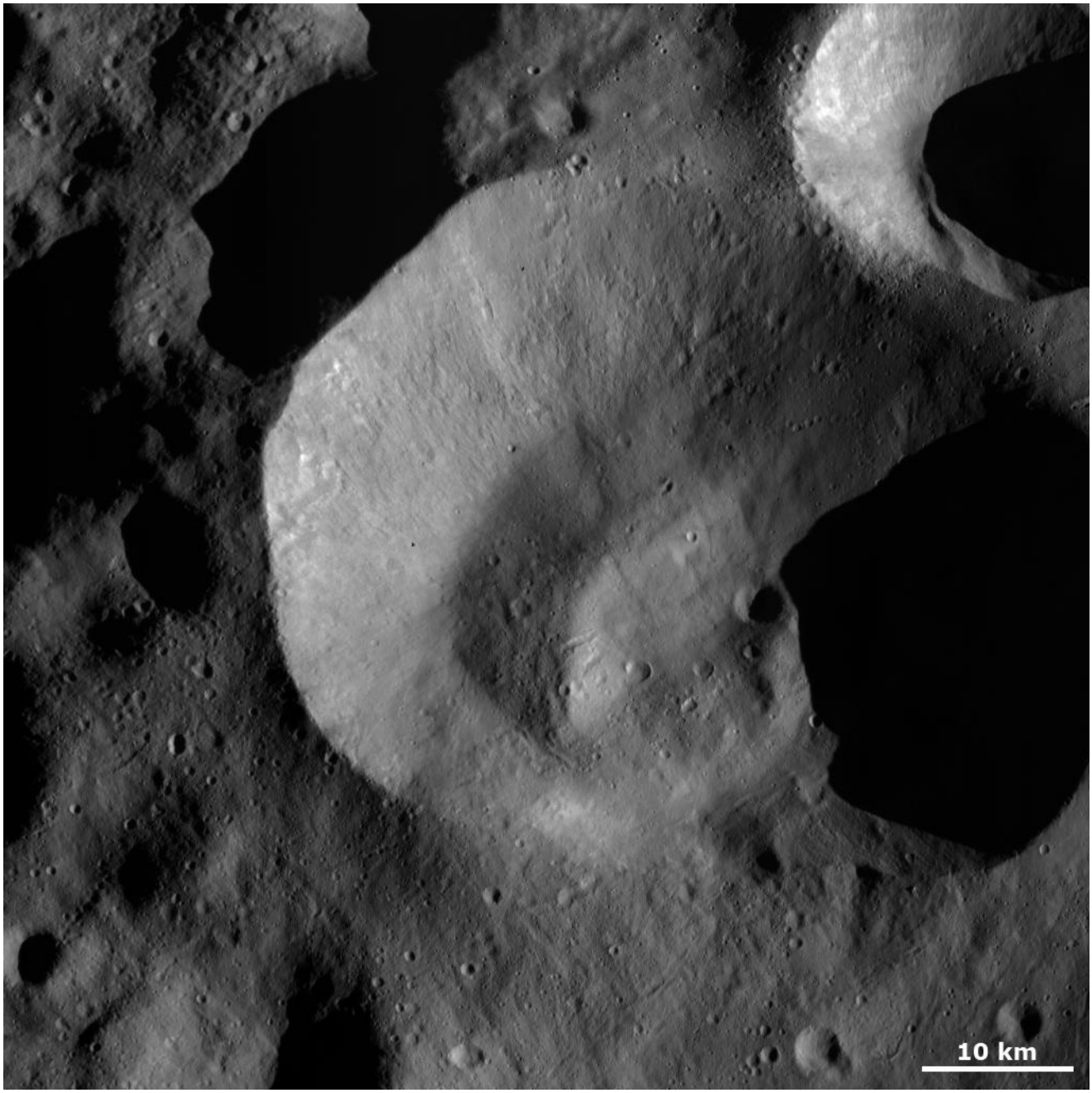
Credit: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA



Antonia Crater on Vesta

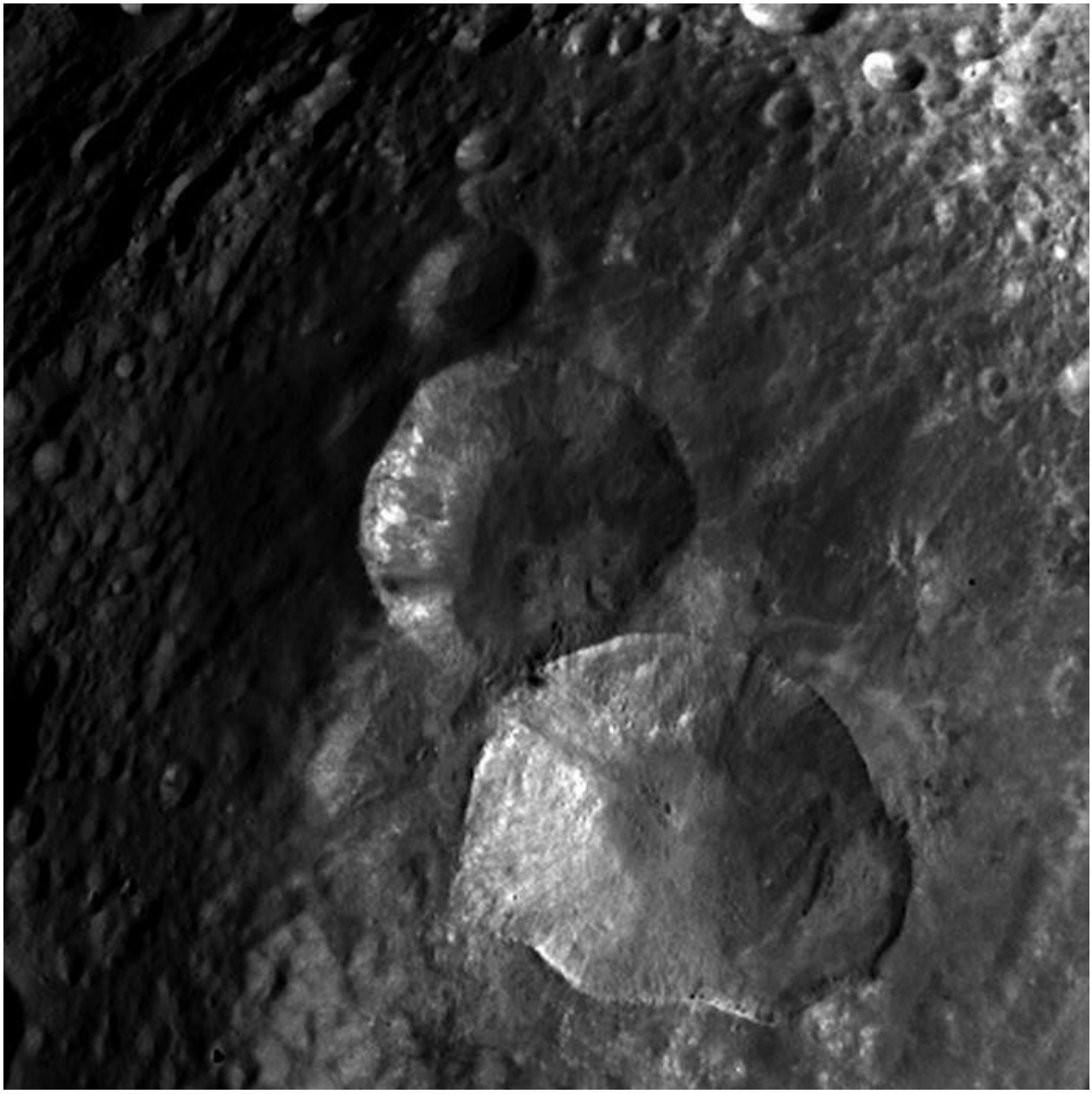
Scientists use color to emphasize variations. This image, take by the Dawn mission's framing camera, uses red, blue and green filters to show the spectacular spectral diversity of the crater and the area around it.

Credit: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA



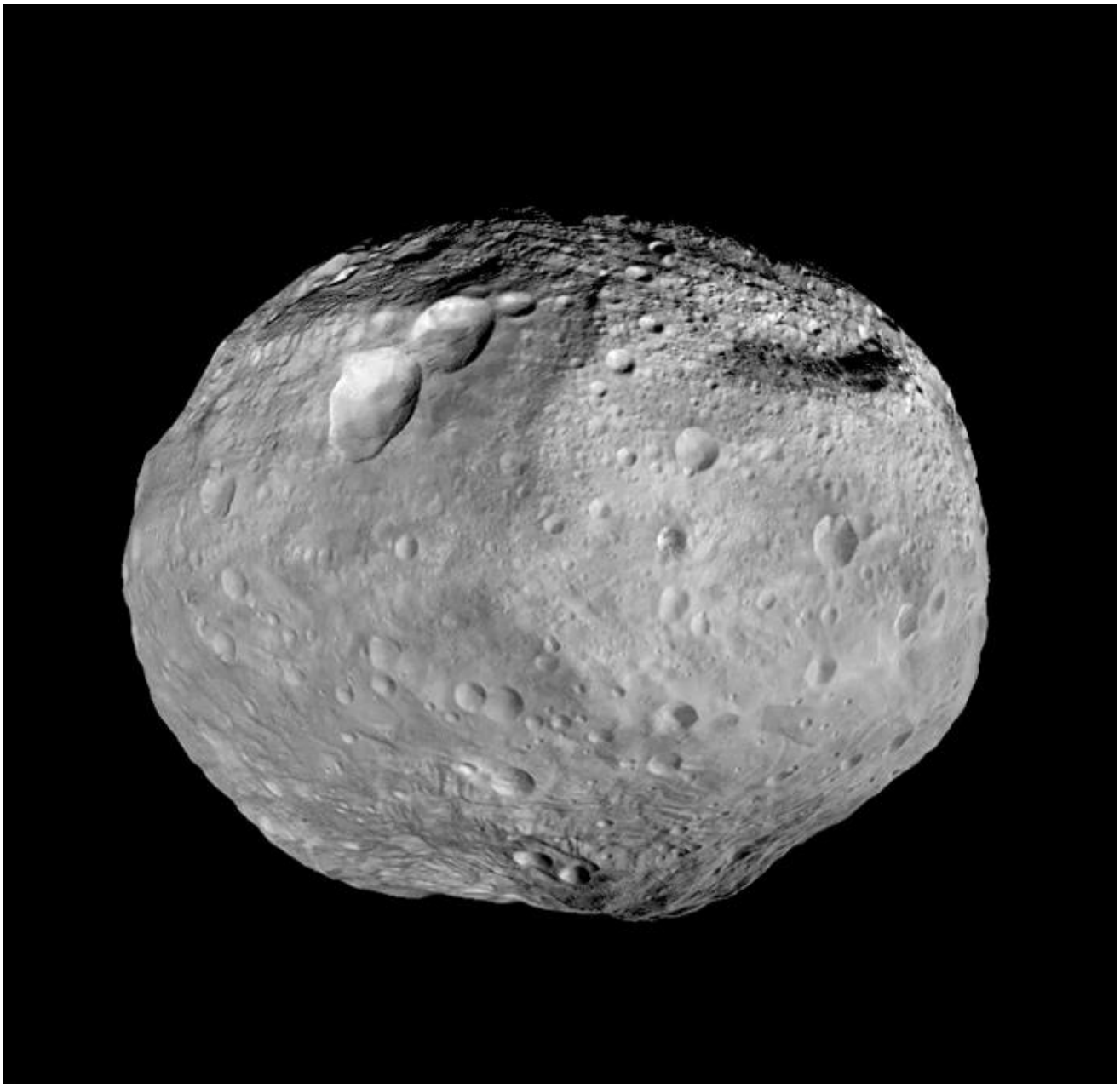
Caparronia Crater on giant asteroid Vesta

Credit: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA



“Snowman” craters on giant asteroid Vesta

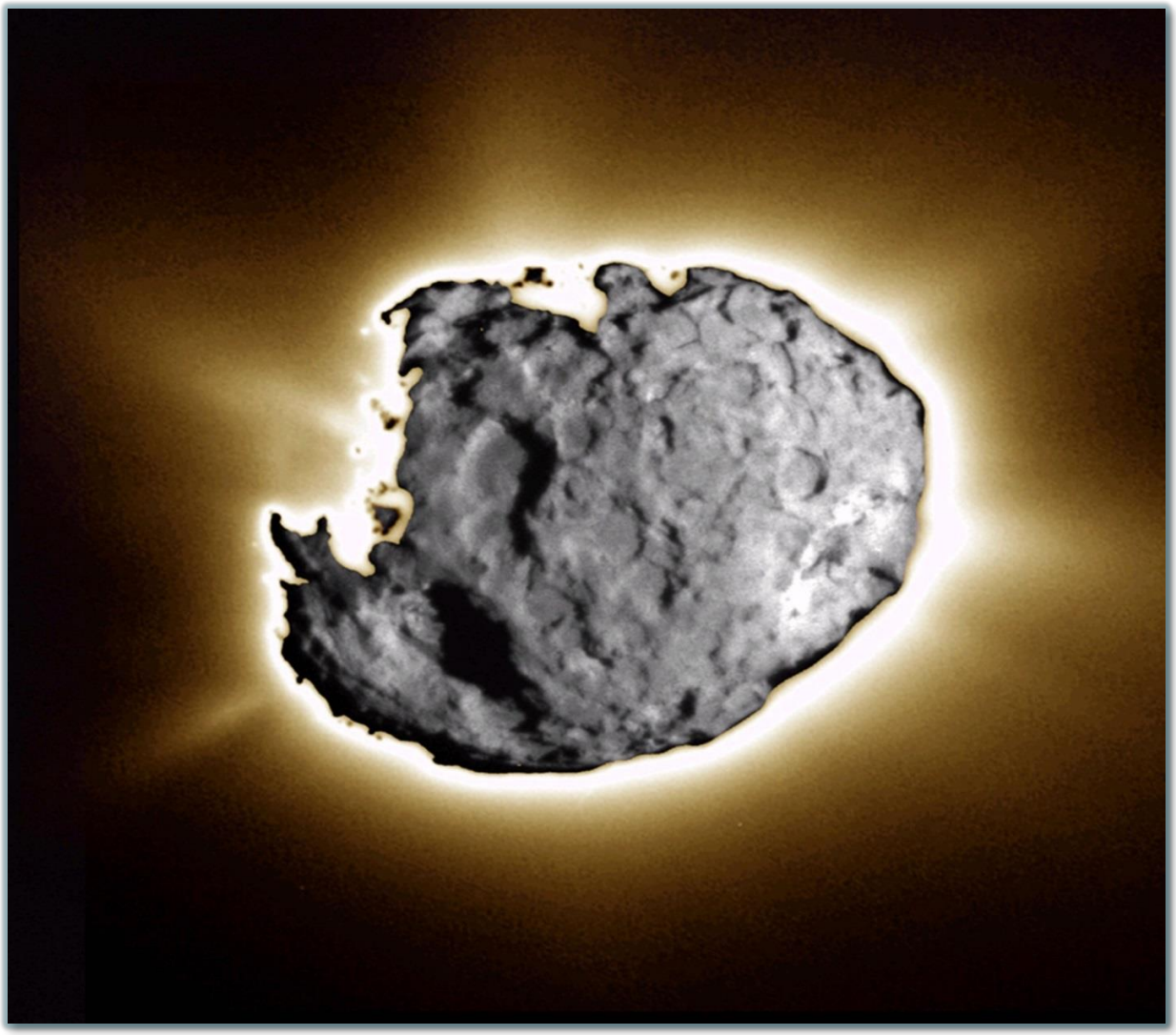
Credit: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA



Global View of Vesta

This beautiful mosaic combines some of the best views that the Dawn spacecraft captured of the giant asteroid. The mountain at the south pole is more than twice the height of Mount Everest.

Credit: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA



Comet Wild 2

Nucleus of comet Wild 2 imaged during the Stardust mission flyby to collect samples of comet dust and return them to Earth.

Credit: NASA/JPL-Caltech/University of Washington

Yukon Delta, Alaska

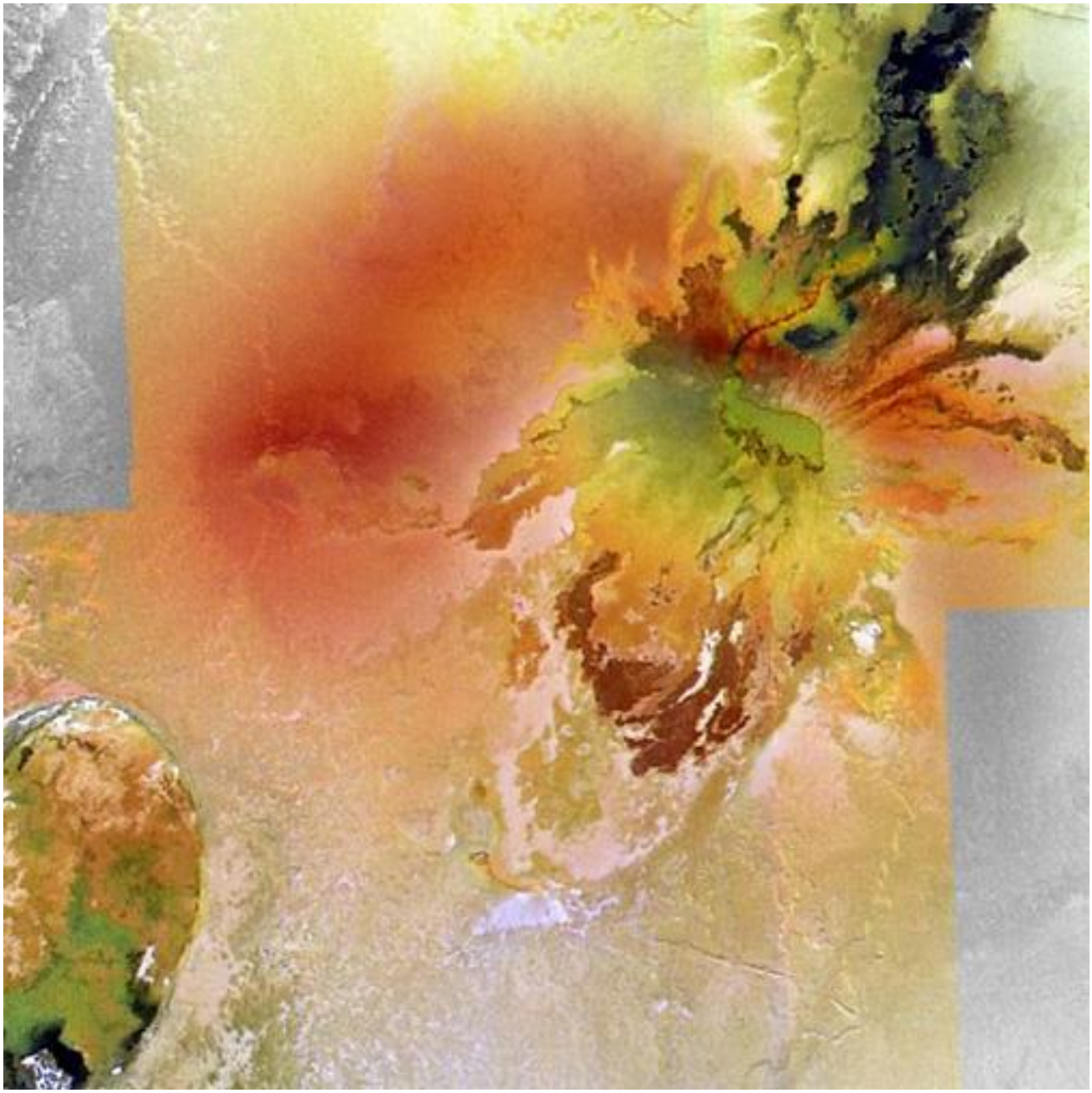
Astronomers and geologists look at topographical features (craters, volcanoes, mountains, patterns left by water, etc.) on Earth to help them understand patterns on distant planets, comets, asteroids.

Credit: NASA

Jupiter’s moon, Ganymede

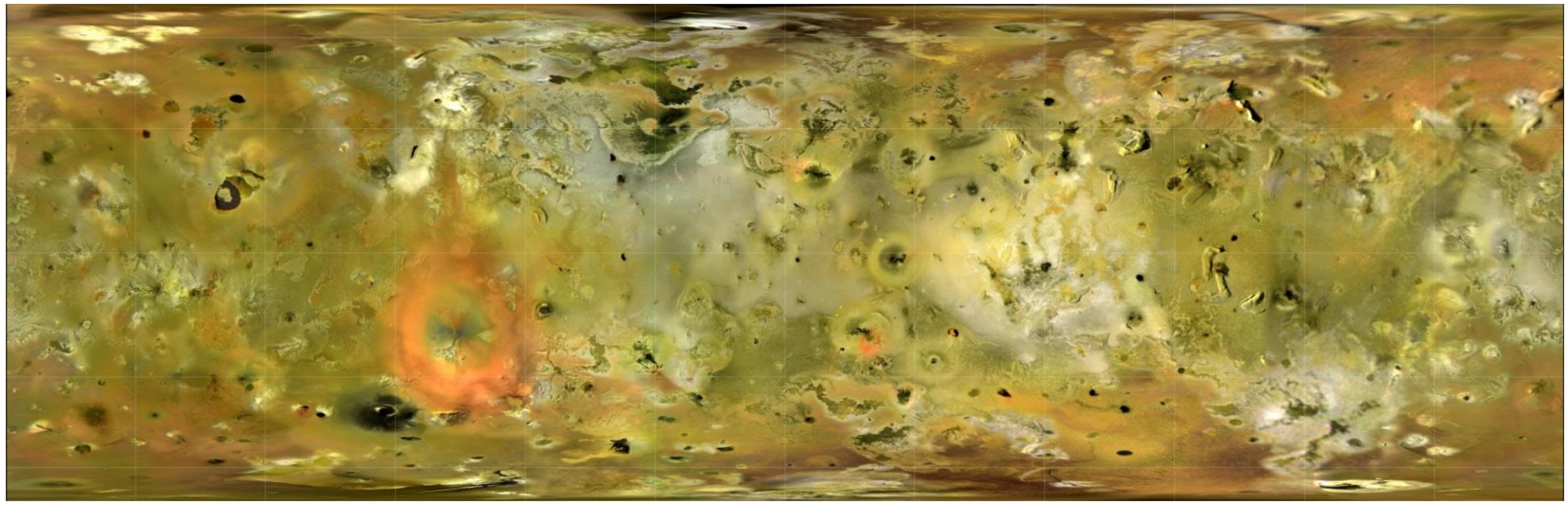
This Galileo image reveals frosty polar caps in addition to the two predominant terrains on Ganymede: bright, grooved terrain and older, dark furrowed areas. Many large craters are visible as well.

Credit: NASA/JPL-sDLR



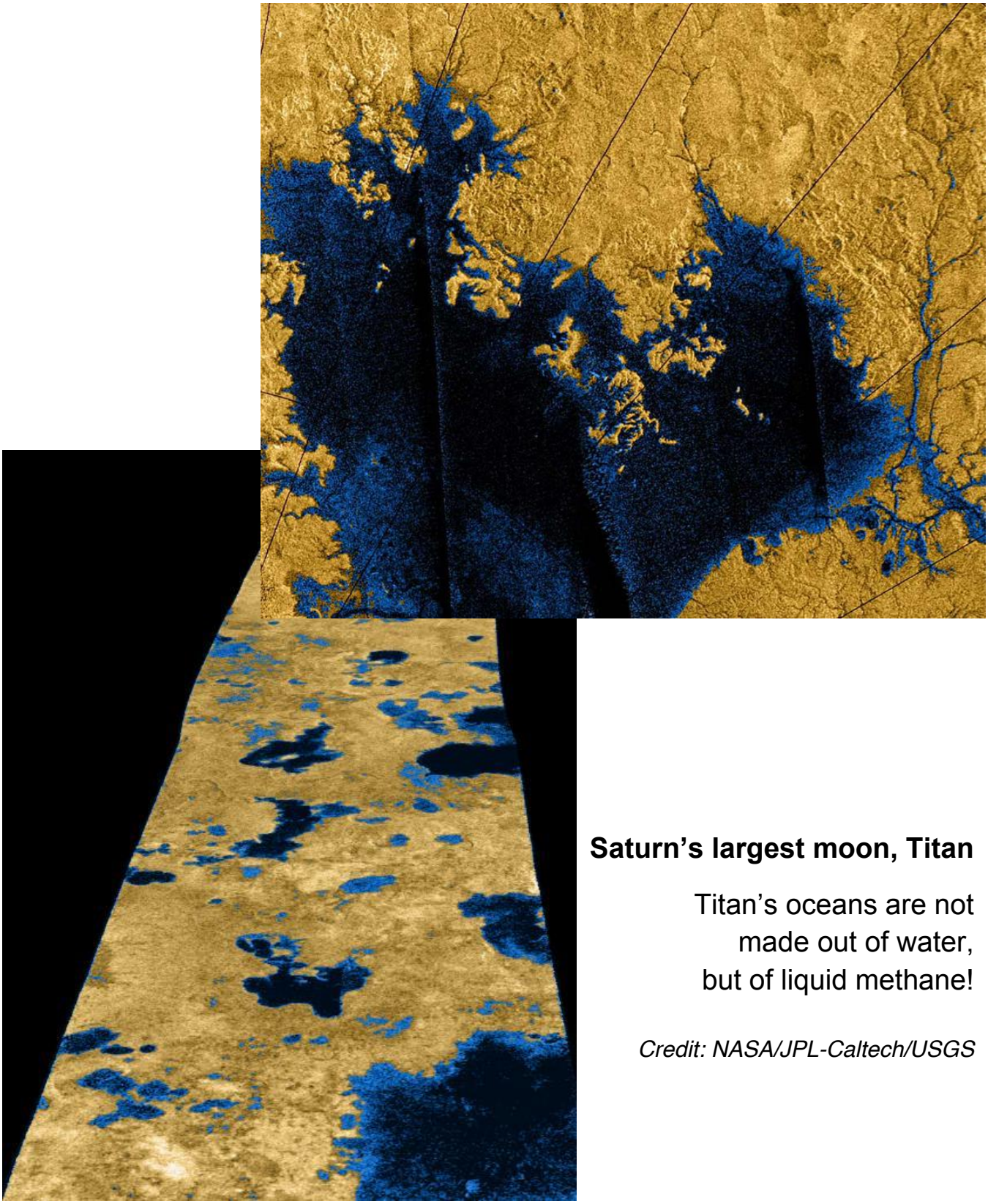
Close-up: Active Volcano Culann Patera on Jupiter's moon, Io

Credit: NASA/JPL/University of Arizona



Active Volcano Culann Patera on Jupiter's moon, Io

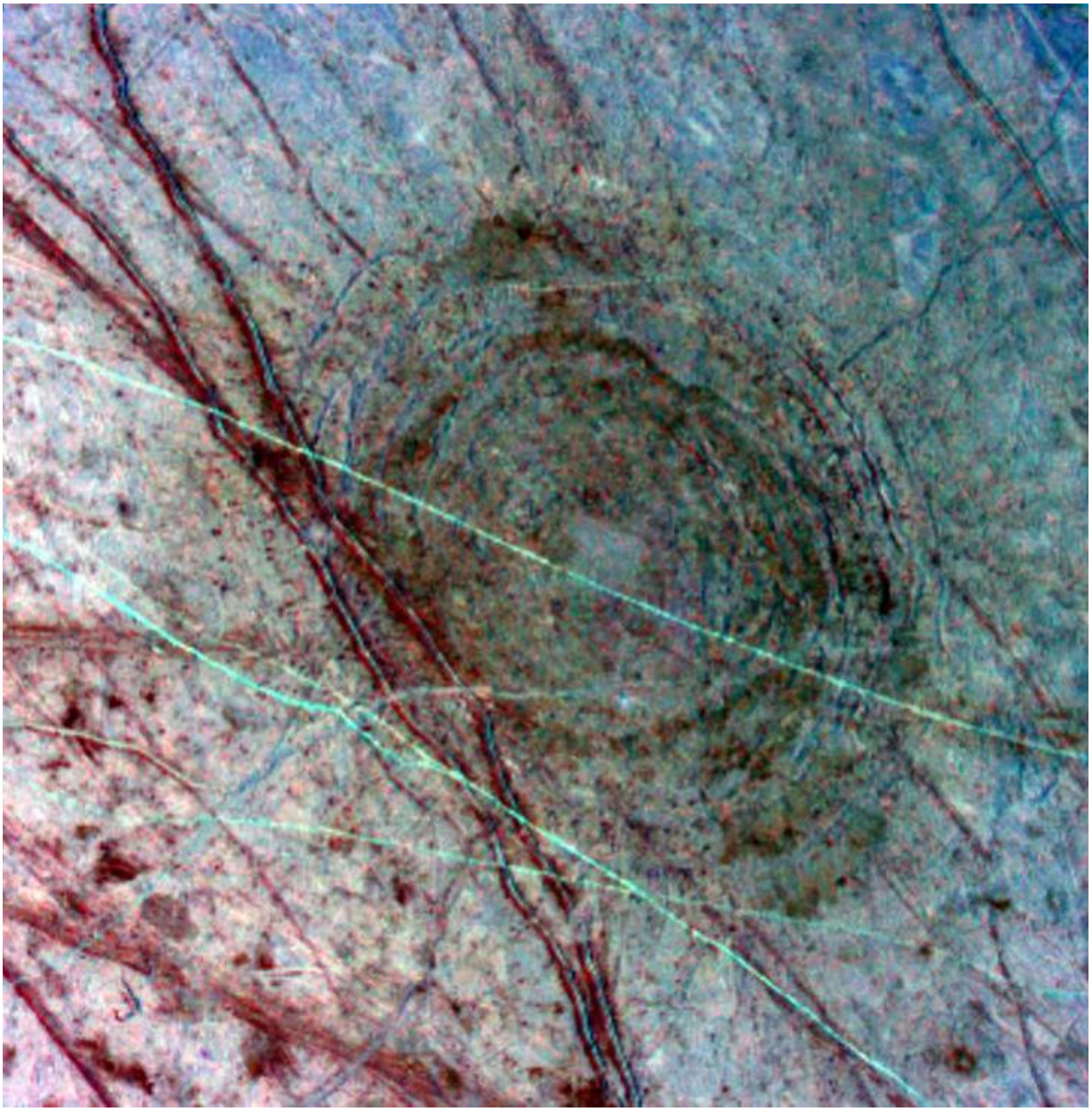
Credit: NASA/JPL/University of Arizona



Saturn’s largest moon, Titan

Titan’s oceans are not
made out of water,
but of liquid methane!

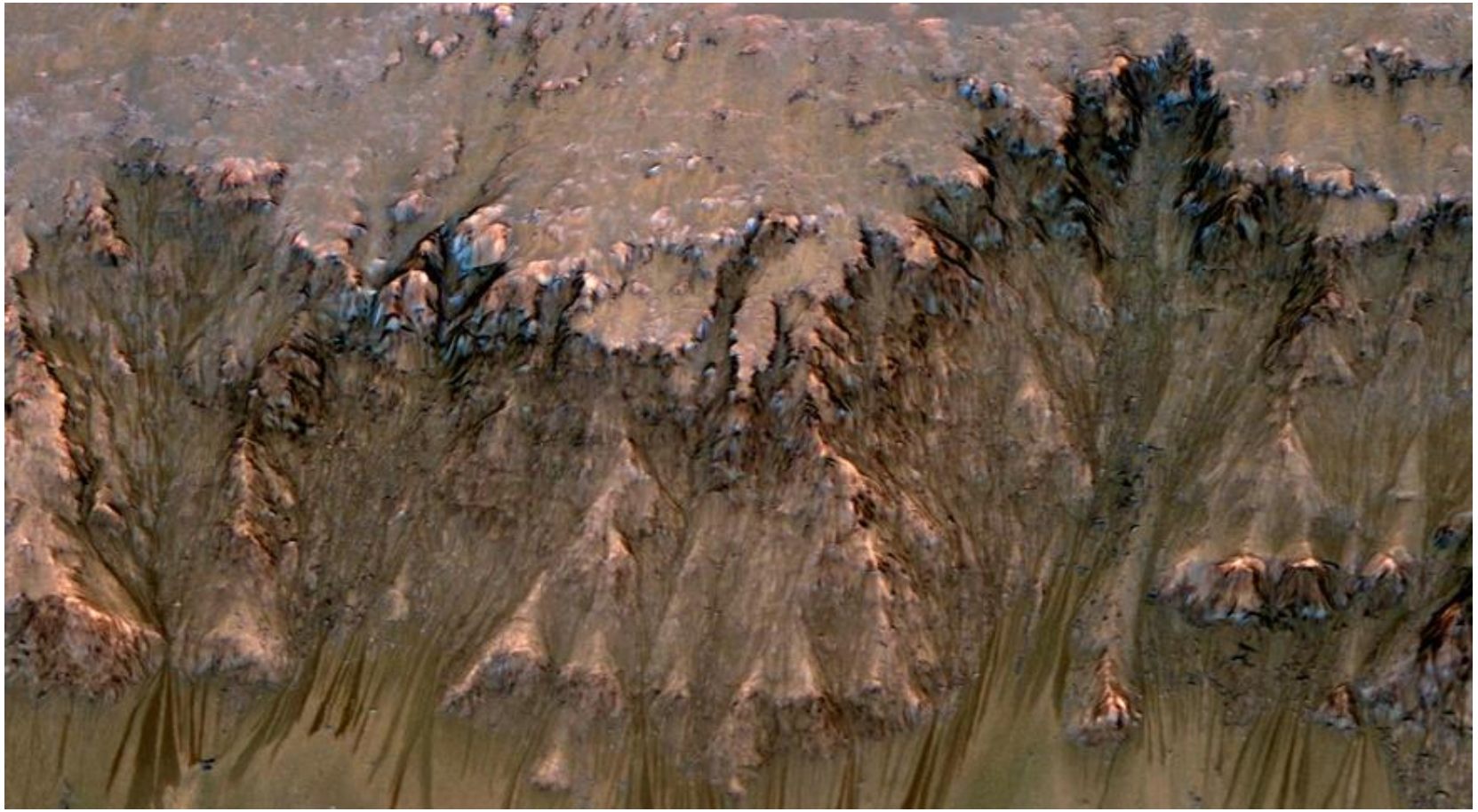
Credit: NASA/JPL-Caltech/USGS



Europa, moon of Jupiter

This is an impact feature called Tyre Macula on Europa’s icy surface.

Credit: NASA/JPL/University of Arizona



Mars

Might there be seasonal water flowing on Mars today? These features that extend down the slope during warm seasons are called recurring slope lineae. They appear and grow on steep slopes during warm seasons and fade in cold seasons.

Credit: NASA/JPL-Caltech/University of Arizona

Gullies on Mars

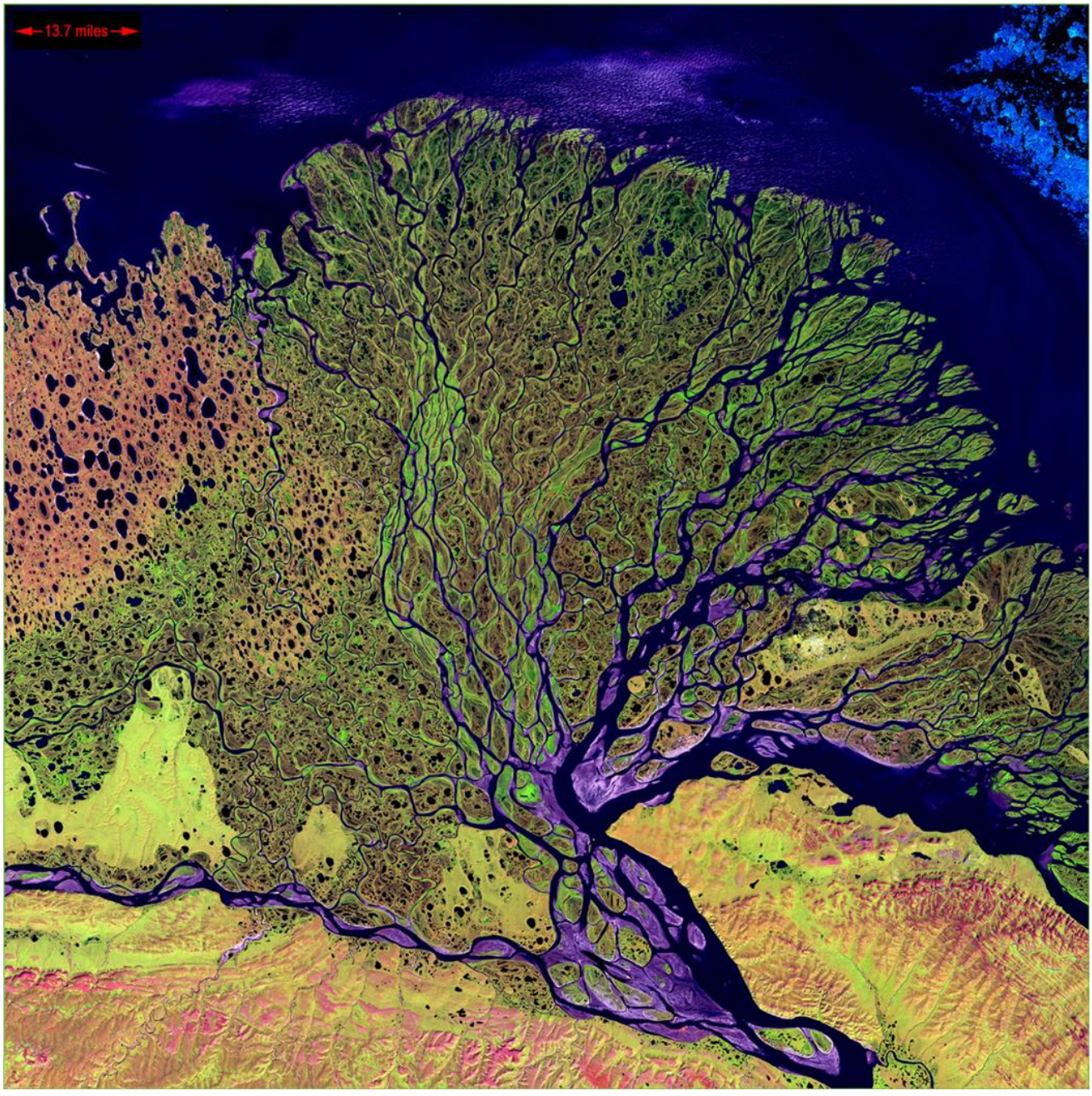
Theses gully landforms are found in many craters in the mid-latitudes of Mars. Current gully activity appears to take place in winter and early spring, and may be caused by the seasonal carbon dioxide frost that is visible in gully alcoves in the winter.

Credit: NASA/JPL-Caltech/University of Arizona

Sand Dunes on Mars

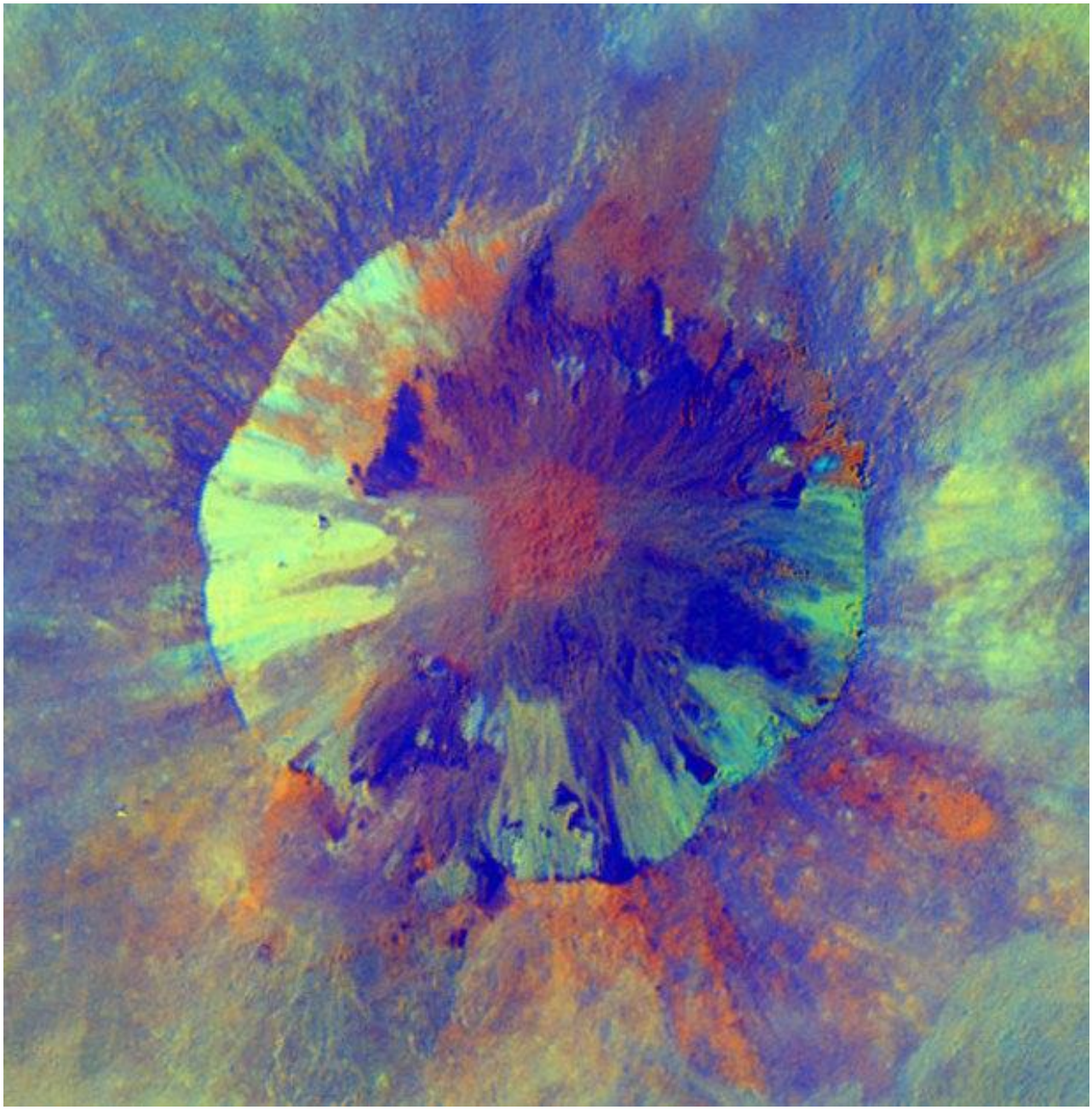
These bright, small ridges are ripples, composed of fine sand coated with coarser sand and granules.

Credit: NASA/JPL-Caltech/University of Arizona



Lena River Delta, Russia

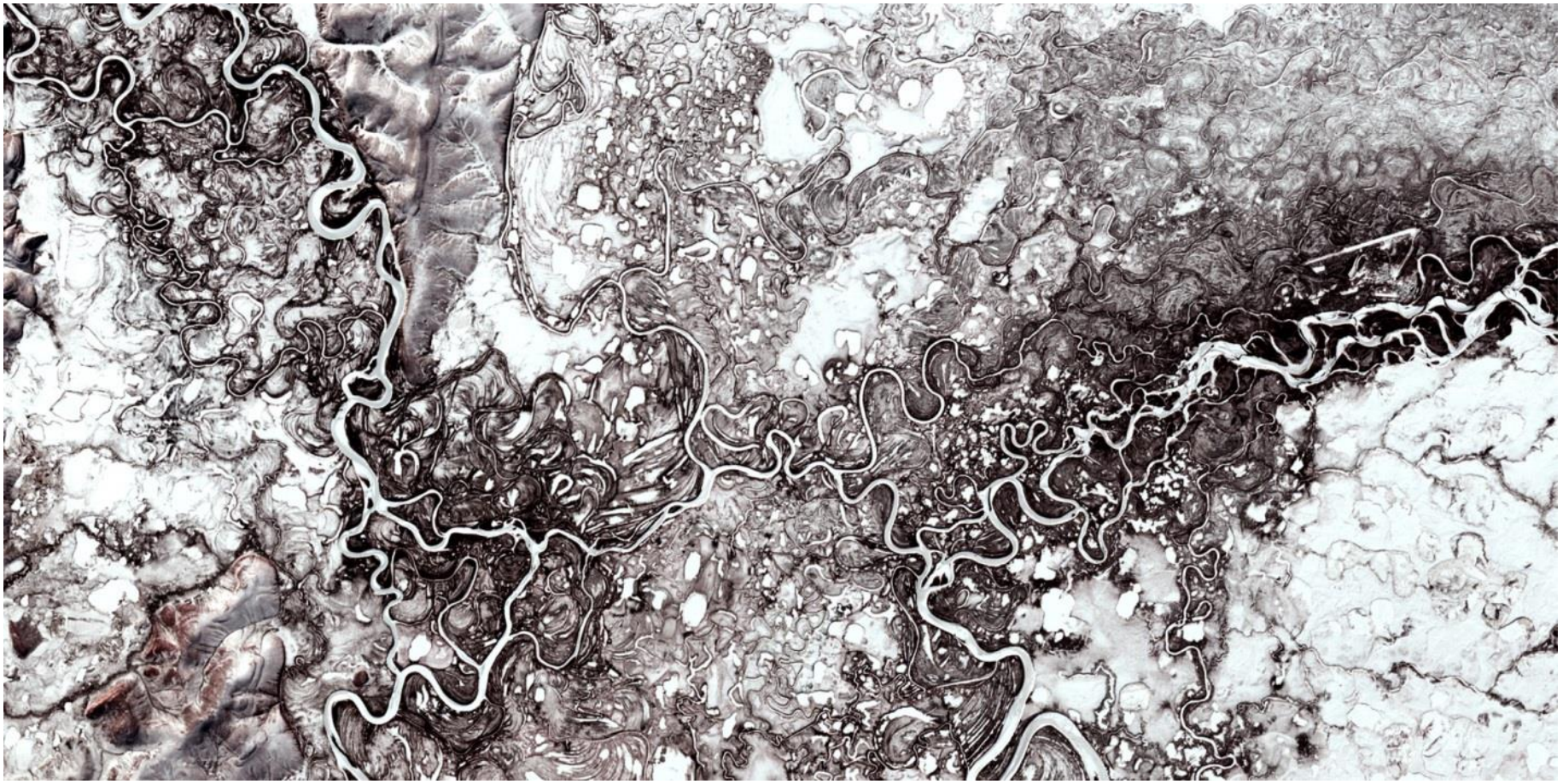
Credit: NASA Earth Observatory



Giant Asteroid Vesta

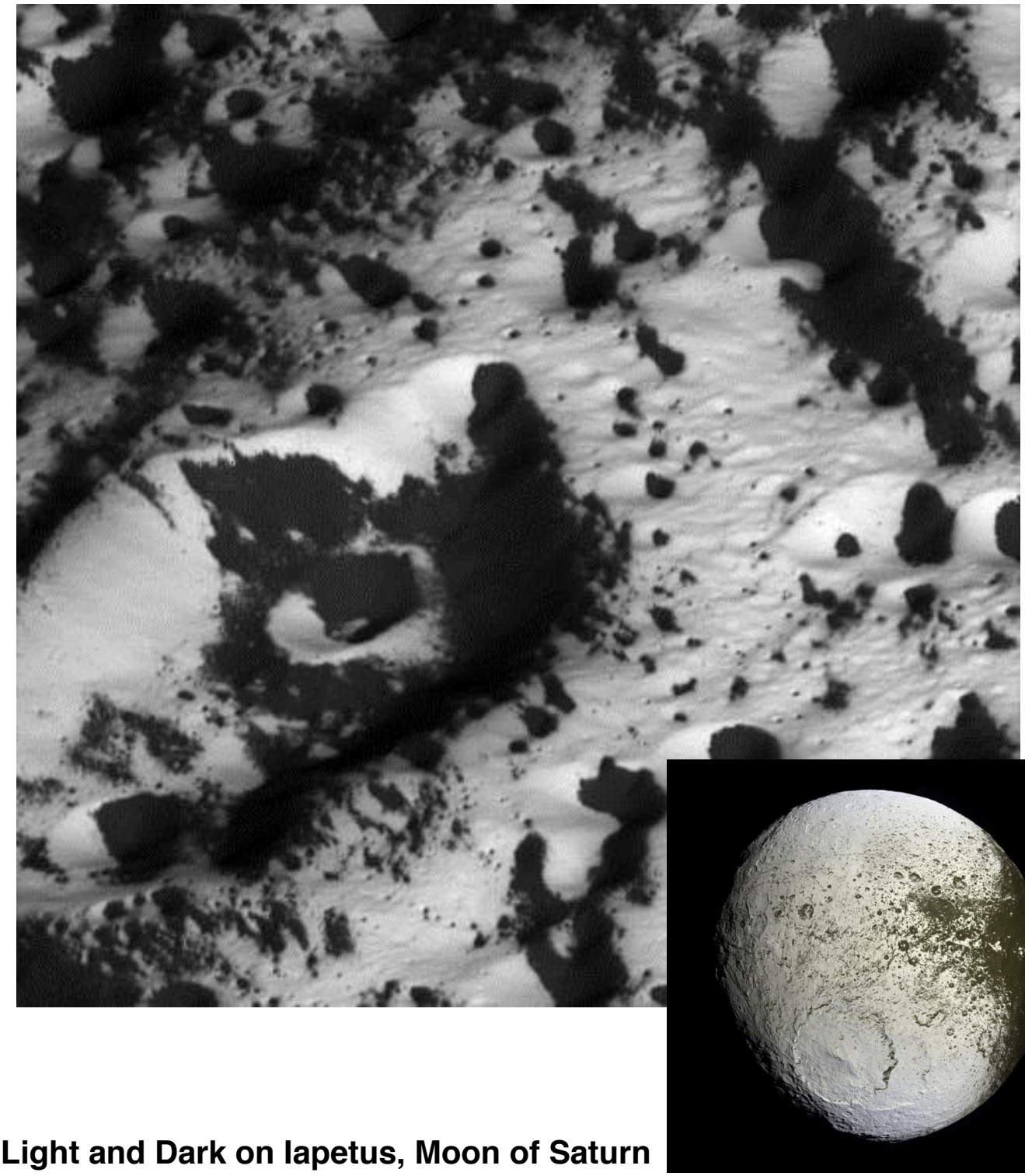
This enhanced-color view from NASA's Dawn mission shows an unusual "pitted terrain" on the floor of Cornelia crater.

Credit: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA



Mayn River, Siberia, Earth

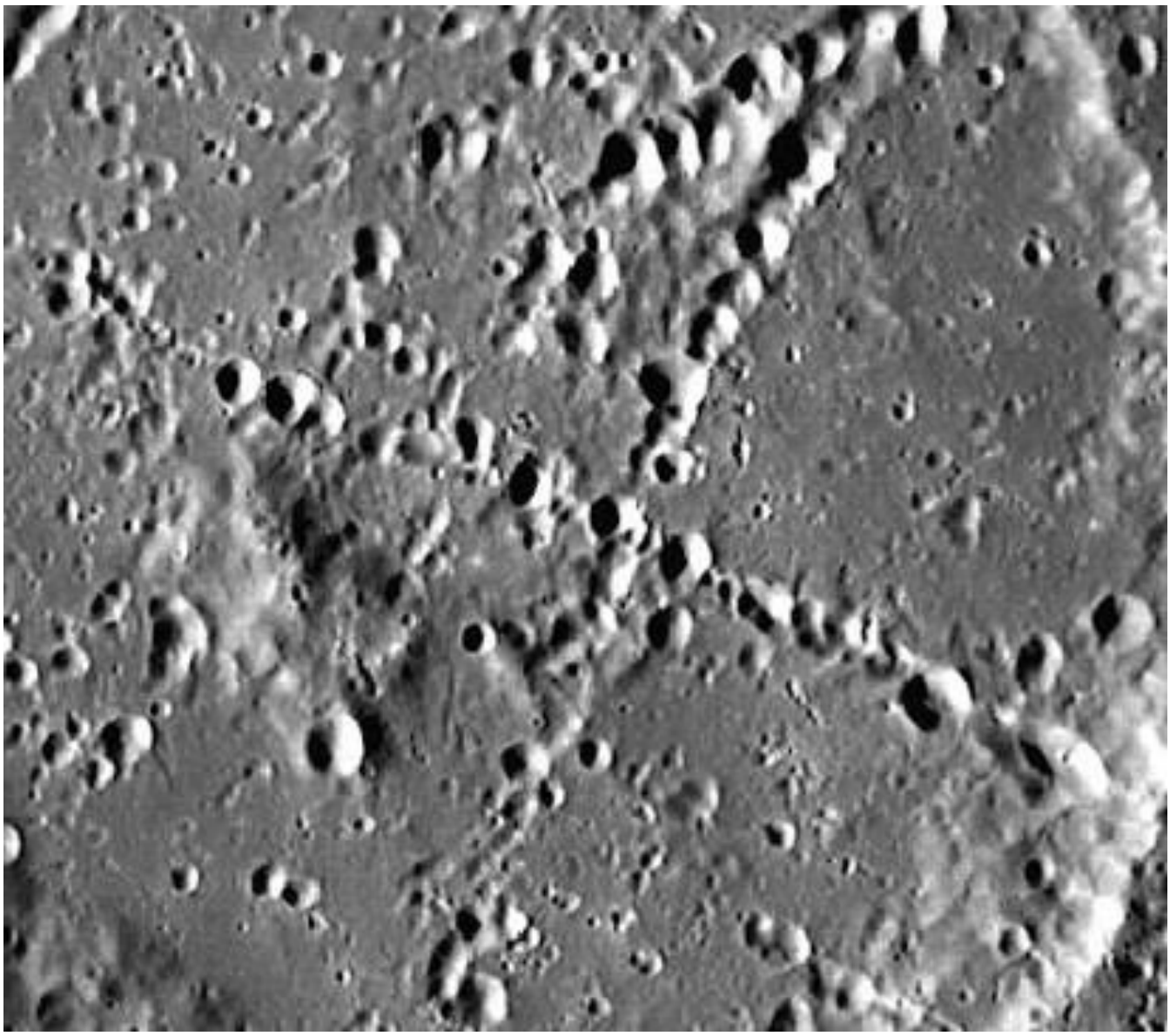
Credit: NASA/Landsat7



Light and Dark on Iapetus, Moon of Saturn

The most dramatic value extremes observed so far in the solar system are on Iapetus.

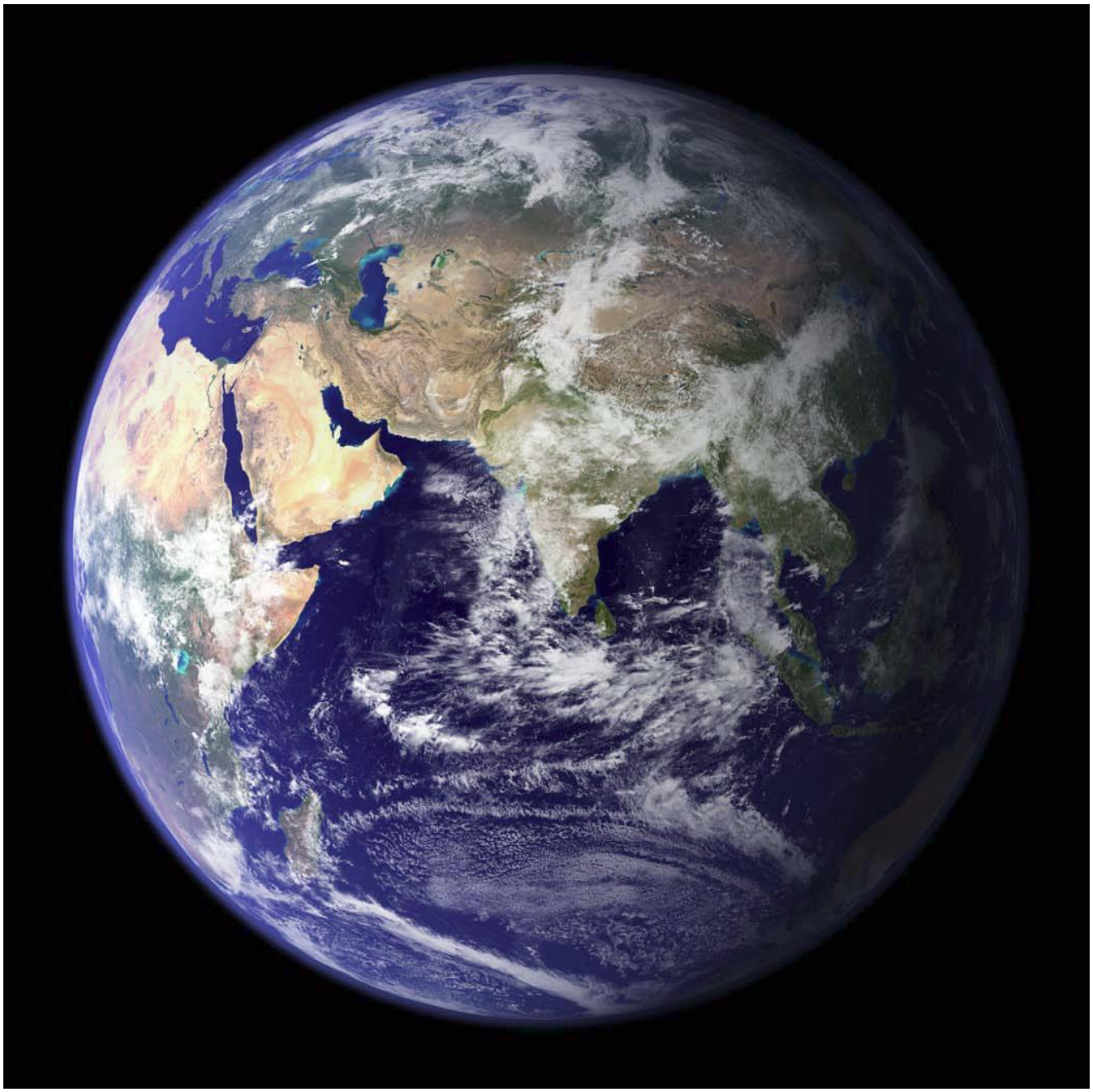
Credit: NASA/JPL/Space Science Institute



Crater Chains on Mercury

Taken by NASA’s MESSENGER mission, what do you think happened here?

Credit: NASA/Johns Hopkins University Applied Physics Laboratory/Carnegie Institution of Washington



Earth from space: Astronomers and geologists look at topographical features (craters, volcanoes, mountains, patterns left by water, etc.) on Earth to help them understand patterns on distant planets, comets, asteroids. This image is in true color.

Earth’s Moon

The colors added to this lunar image reveal the surface soil composition. Red areas generally correspond to the lunar highlands, while blue to orange shades indicate the ancient volcanic lava flow of a lunar sea. Blue areas contain more titanium. Small purple areas found near the center are deposits from volcanic eruptions.

Credit: NASA/JPL-Caltech