

Using Light to Study Planets

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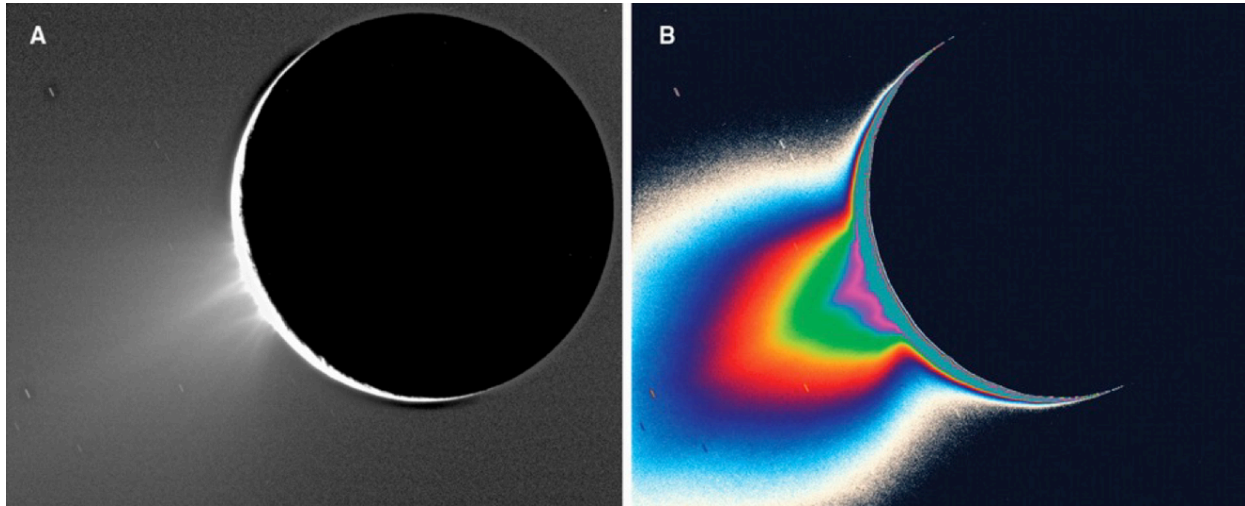


Background

NASA scientists often use a technique called “remote sensing” to study the composition of different elements and structures on planets. Remote sensing refers to making measurements without directly touching the object being measured. These images are one kind of remote-sensing measurement. But what we can see with the naked eye only tells us part of the story.

When we look out into the solar system and beyond, we use remote sensing to see things far beyond what we can see with our naked eye. For example, using remote sensing we’re able to

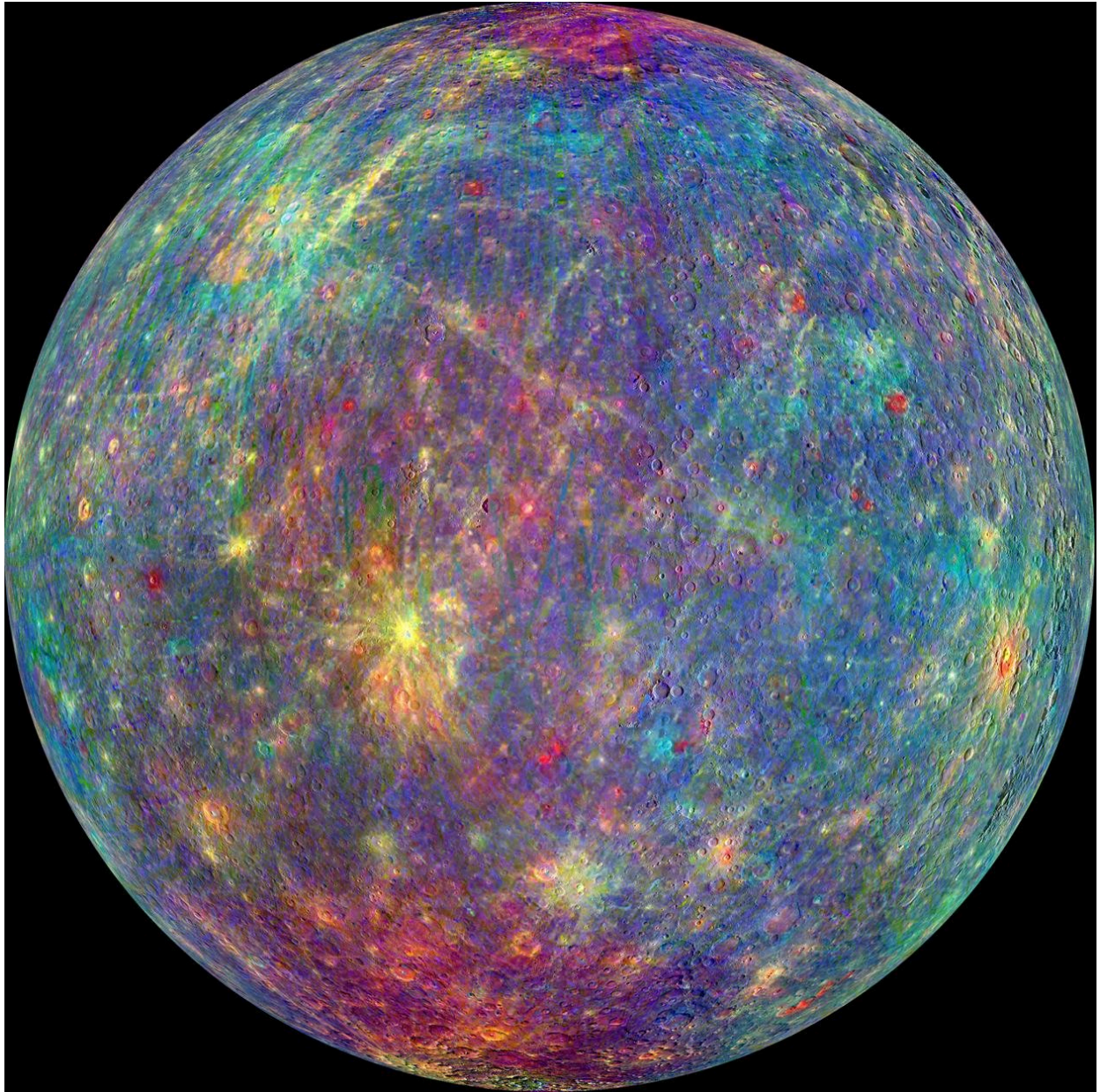
detect the jets of water shooting out from Saturn's moon Enceladus nearly 900 million miles away.



These images captured by NASA's Cassini spacecraft of Saturn's moon Enceladus show plumes shooting out from the moon's south pole. The image on the right was colorized to show details not visible to the naked eye in natural light.

In space exploration, NASA uses remote-sensing tools that are capable of seeing deeper into the electromagnetic spectrum than we can with our eyes. Because wavelengths in the electromagnetic spectrum are so fine, these tools allow us to quantify the amount of light as it moves. These movements are called reflection, absorption and re-emission spectra and they happen at very specific wavelengths. Further, because reflectance spectra come in myriad colors and at a finer resolution than what we can see, we can use these spectra to learn much more about how our planet is changing and the composition of other planets.

Upon its arrival at the Jovian system, the [Europa Clipper](#) spacecraft will use remote sensing as it studies Jupiter's icy moon Europa. It will collect ultraviolet light in the onboard UV spectrograph to determine the composition of Europa's atmospheric gases and surface materials. It will also gather infrared light with an IR spectrometer to map the composition and distribution of ices, salts, organic compounds, and the warmest hotspots on Europa.

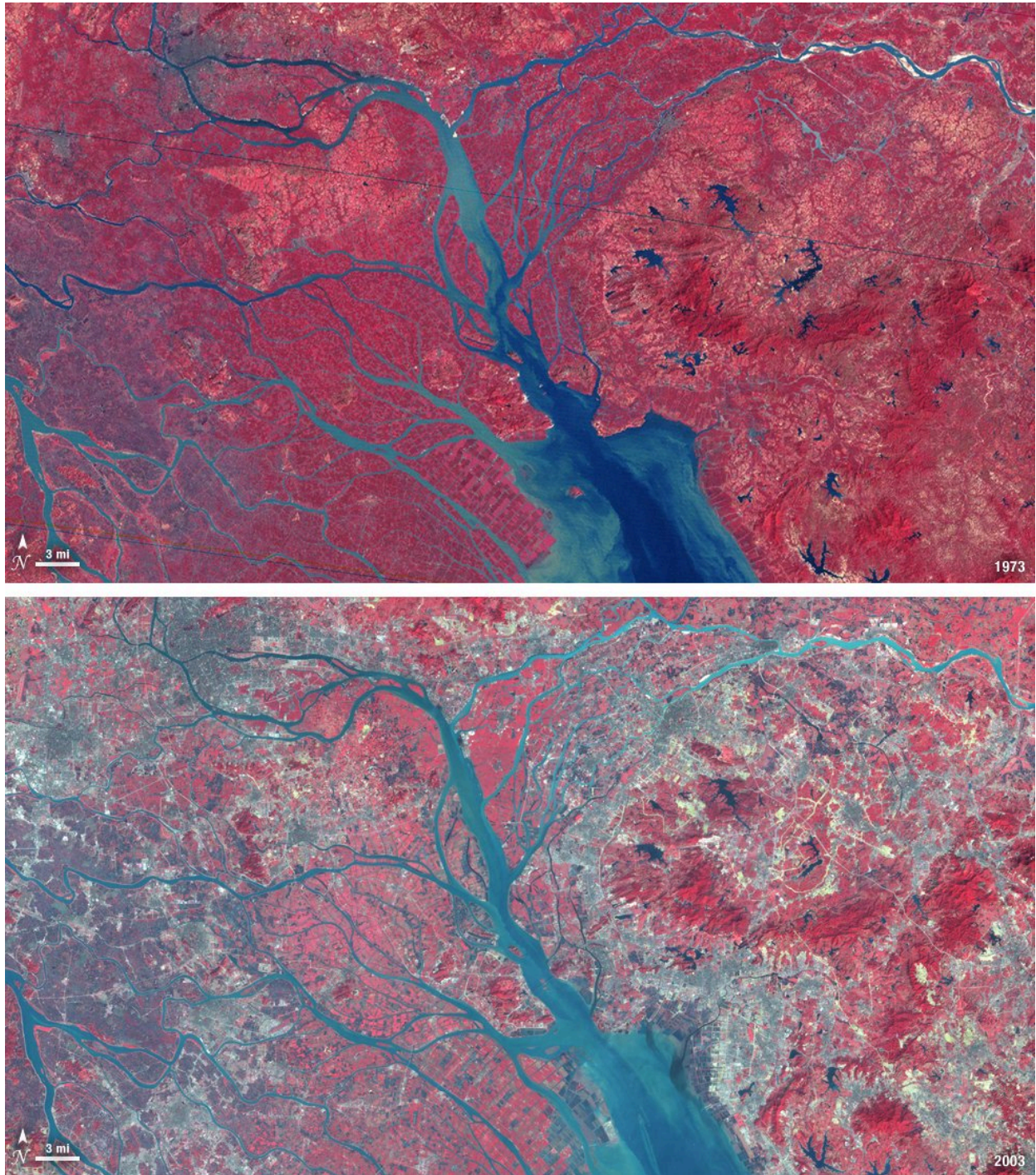


This image from NASA's MESSENGER spacecraft uses spectral data to highlight various minerals, features and properties on Mercury. Credit: NASA/Johns Hopkins University Applied Physics Laboratory/Carnegie Institution of Washington

Another way scientists are interested in using spectra is to develop techniques to measure how life on Earth is changing as a result of climate change. For example, one major player in climate change is carbon dioxide. We know that plant

photosynthesis drives the global carbon cycle and ultimately provides energy for life on Earth. Because of a changing climate and increased human impact on our planet's ecosystems, it is critical that we improve our capability to make highly resolved measurements related to photosynthesis and ecosystem health. Over the past few decades, NASA scientists and engineers have aimed to develop new – and validate current – remote sensing approaches that are responsive to vegetation changes around the world. Ultimately, we want to understand, for example, how the rainforest is responding to deforestation, or how the Arctic tundra might be greening as a result of melting permafrost and increasing temperatures. In general, two remote sensing techniques can be used to measure the changing pulse of the planet (i.e., our terrestrial ecosystems).

The first and most widely used set of information that comes from satellite imagery is measuring the colors of plants on the planet, most commonly in near-infrared (which is highly reflected by plants) and in red (which is highly absorbed by plants for photosynthesis). The difference between near-infrared and red parts of the spectrum can give us an idea of our planet's "greenness" and tell us where and how much plant life there is. This technique is commonly done using NASA's Landsat satellites and Moderate Resolution Imaging Spectrometer (MODIS) instrument.



This pair of infrared images from NASA's Landsat satellite shows China's Pearl River Delta in 1973 (top) and 2003 (bottom). Industrialization has replaced much of the area's vegetation, shown in red. Credit: NASA/USGS

Another technique that effectively measures a leaf's "pulse" uses solar-induced chlorophyll fluorescence, or SIF. SIF is

re-radiated light energy emitted at longer wavelengths of the electromagnetic spectrum than were initially absorbed. It is measured using portions of the light in the electromagnetic spectrum that are absorbed by the sun's atmosphere, then re-emitted, creating a very slight glow. Because the fluorescent glow is so faint, it cannot be measured using traditional reflectance. Until recently, measuring a plant's glow using SIF had been too difficult simply because the light from cities was so much greater than this tiny amount of light. As we get more advanced at detecting this glow, NASA hopes to match data from older satellites with newer ones, such as the Orbiting Carbon Observatory, or OCO-2, to map this glow as a measure of actual photosynthesis. This would ultimately reduce uncertainties in not only the when and where, but also the why and how of land-atmosphere CO₂ exchange. By coupling physics and biology in technology, we can measure the health of plants on Earth.

SPECTRA

Continuous spectra, also called thermal or blackbody spectra, are emitted by any object that radiates heat. As shown in Figure 1, light is emitted from the sun in a continuous band of colors with every wavelength having some amount of electric and magnetic radiation. For example, when sunlight is passed through a prism, its light is spread out into its component colors.



Figure 1: A continuous visible light spectrum. Image credit: Spitzer Science Center.

Credit: Spitzer Science Center.

If you use a more precise spectrometer to look at the sun's spectrum, you will notice the presence of dark lines, as shown in Figure 2 below. These lines are caused by gaseous elements in the sun's atmosphere absorbing light at these wavelengths, so this type of spectrum is called an absorption spectrum. The atoms and molecules in a gas will absorb only certain wavelengths of light. The pattern of absorption is unique to each element and tells us what elements make up the sun's atmosphere. Compare Figure 3, the absorption spectrum of hydrogen, with Figure 2. There are dark bands in the same part of both spectra, indicating the presence of hydrogen in the sun.



Figure 2 and 3: The absorption spectrum of the Sun and hydrogen. Image credit: Spitzer Science Center. Credit: Spitzer Science Center.

An emission spectrum occurs when the atoms and molecules in a hot gas emit light at certain wavelengths, causing bright lines to appear in a spectrum. As with absorption spectra, the pattern of these lines is unique for each element. We can see emission spectra from comets, nebula and certain types of stars.



Figure 4: The emission spectrum of hydrogen. Image credit: Spitzer Science center. Credit: Spitzer Science center.

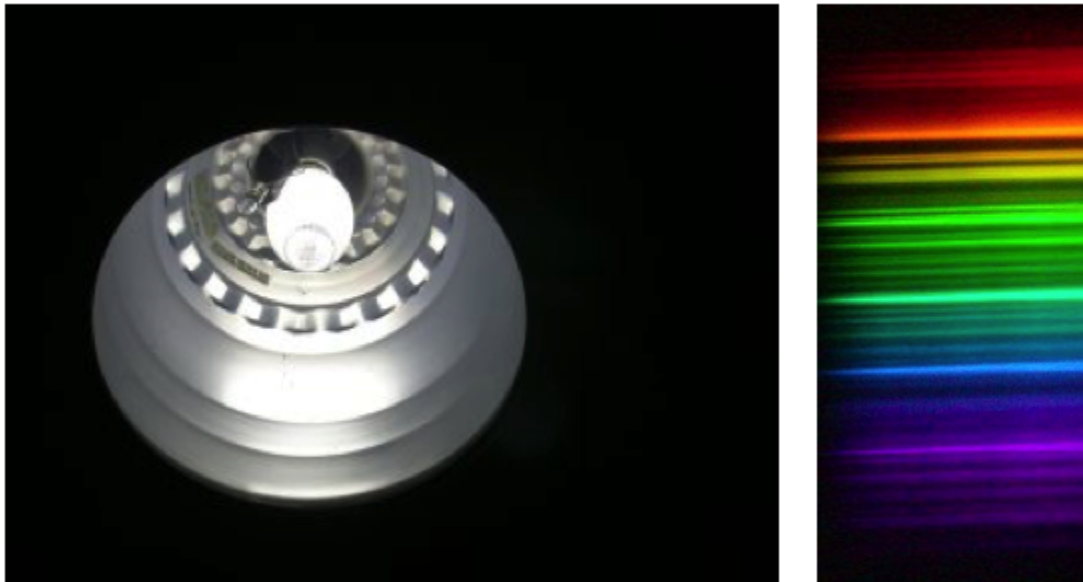


Figure 5: Light source and view through the spectrometer. Image credits: Spitzer Science Center and Jerry Zhu

As a Pair, Summarize:

How we are analyzing the atmosphere and composition of the moon, Europa.

How we are using light to estimate plant coverage here on Earth.

Use the IR image of China's Pearl River above, to estimate what percent of trees were chopped down between 1973 and 2003.

In what ways do the three different types of spectra look different, and how are the three spectra created.