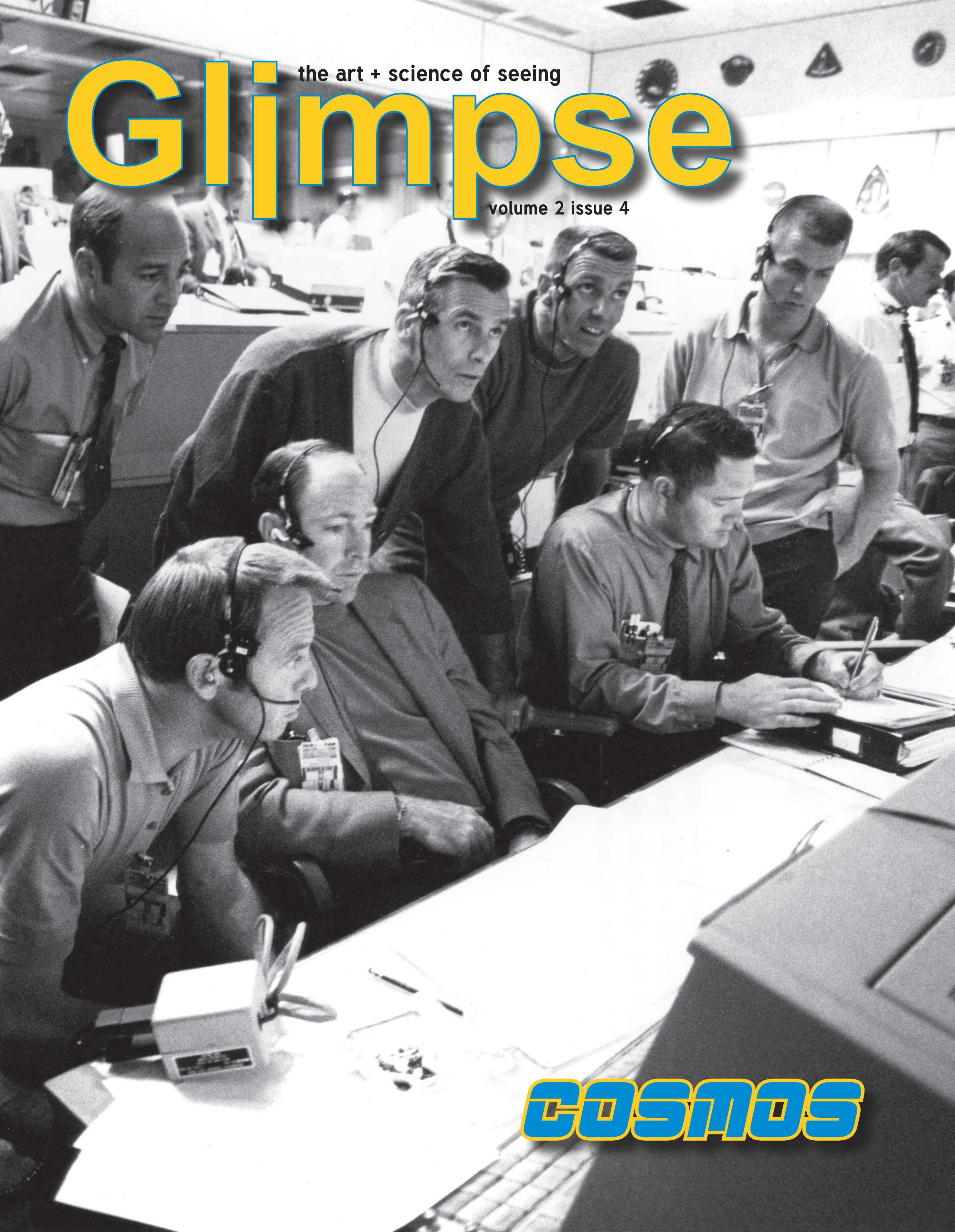
Glimpse

the art + science of seeing

volume 2 issue 4



COSMOS

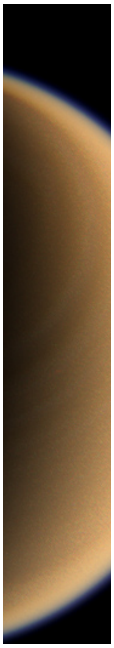
Glimpse™
volume 2 issue 4
the art + science of seeing™

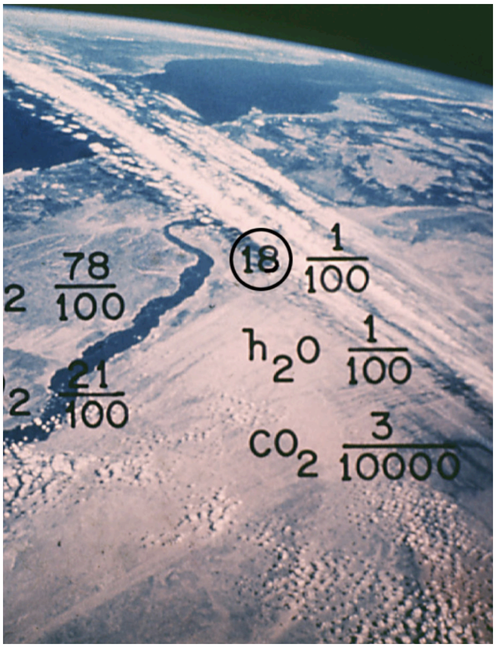
vol 2.4 COSMOS

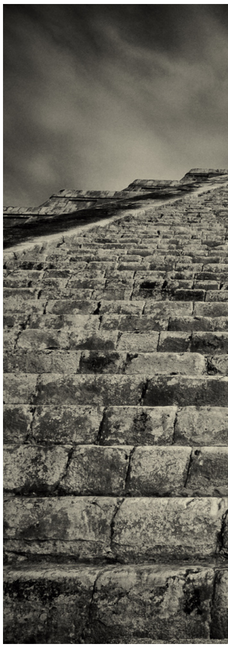
Glimpse is an interdisciplinary journal that examines the functions, processes, and effects of vision and vision's implications for being, knowing and constructing our world(s). Each theme-focused journal issue features articles, visual spreads, interviews and reviews spanning the physical sciences, social sciences, arts and humanities.

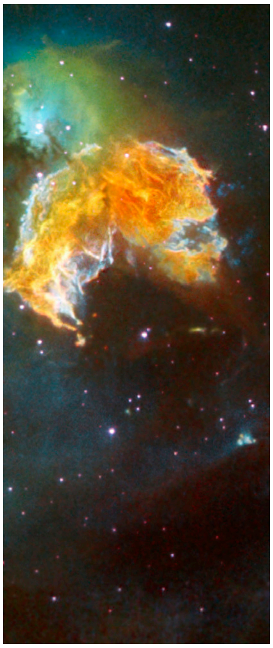
CONTENTS

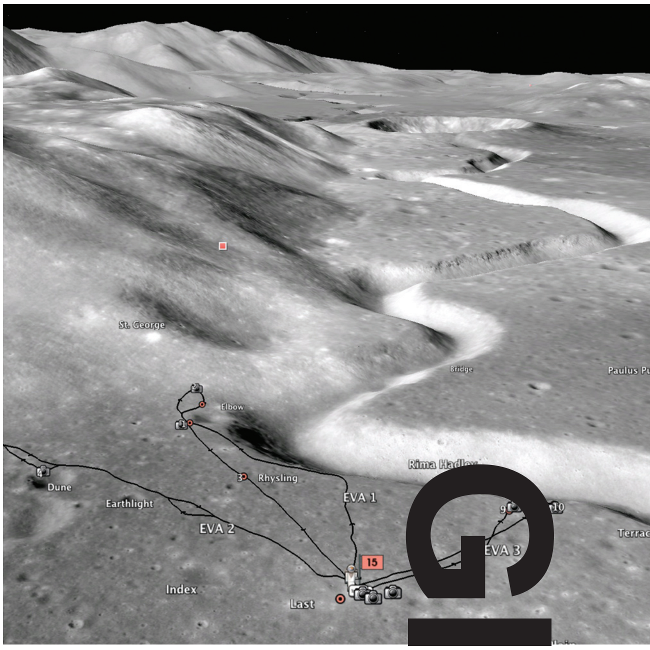
The COSMOS Issue











Glimpse™

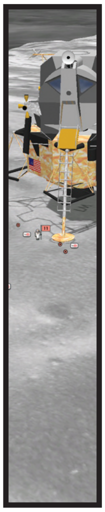
online

THE *COSMOS* ISSUE PLAYLIST

CONTRIBUTORS

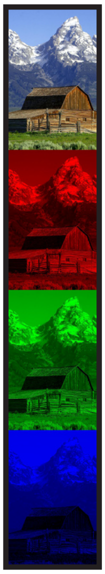
JASON W. BARNES

Jason W. Barnes is an assistant professor of physics at the University of Idaho. After growing up in St. Louis, Missouri, he received a BS degree in Astronomy from Caltech in 1998 and a Ph.D. in Planetary Science from the University of Arizona in 2004. Prior to starting at the University of Idaho he worked as a postdoc for the Kepler mission at NASA's Ames Research Center in Moffett Field, California. He has worked closely with the Cassini VIMS science team since the spacecraft's arrival into the Saturn system in 2004.



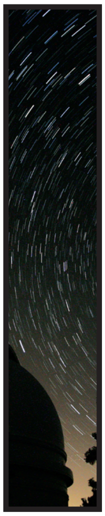
ROSS A. BEYER

Dr. Beyer is a planetary scientist with the Carl Sagan Center at the SETI Institute. He carries out his research in the Space Science and Astrobiology Division (Planetary Systems Branch) at the NASA Ames Research Center. He is also a Research Fellow with the Center for the Origin, Dynamics and Evolution of Planets at the University of California, Santa Cruz. He studies surface geomorphology, surface processes, remote sensing and photogrammetry of the solid bodies in our Solar System—if you can stand on it, he's interested in what it's like and how it got that way. Beyer also serves on the science teams of several active spacecraft.



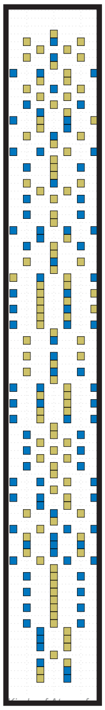
KIMBERLY A. JAMESON

Kimberly A. Jameson is a cognitive scientist conducting research at the Institute for Mathematical Behavioral Sciences, at the University of California, Irvine (http://aris.ss.uci.edu/~kjameson/kjameson.html). Color plays a prominent role in her empirical and theoretical work, which includes research on the mathematical modeling of color category evolution among communicating artificial agents; individual variation and universals in human color cognition and perception; the genetic underpinnings of color perception; and comparative investigations of the ways the worlds' cultures name and conceptualize color in the environment. She also collaborates with Nancy Alvarado on the cognitive processing of emotion.



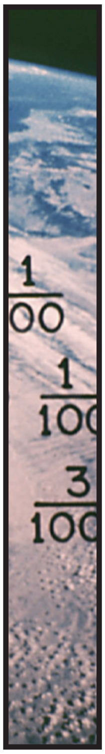
SCOTT KARDEL

Since 2003 Scott Kardel has been the Public Affairs Coordinator for Caltech's Palomar Observatory. There he directs the observatory's public outreach program. He has been a featured speaker across the United States giving talks on general astronomy, light pollution, and the history of Palomar Observatory. He holds a Masters degree in astronomy from the University of Arizona and a Bachelor's degree in physical science/secondary education from Northern Arizona University and is a lifetime member of the International Dark-Sky Association.



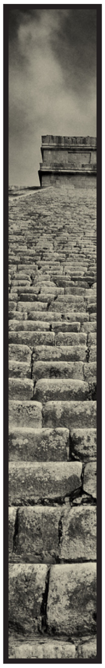
KATHARINA LODDERS

Katharina Lodders is a research professor in the Department of Earth & Planetary Sciences and the McDonnell Center for the Space Sciences at Washington University in Saint Louis, Missouri. She received her doctorate in 1991 at the Johannes-Gutenberg University and Max-Planck-Institute for Chemistry in Mainz, Germany. Her current research focuses on chemistry in stellar environments and in planets inside and outside the solar system. Lodders has (co-)authored more than 80 papers in scientific journals and two books; *The Planetary Scientist's Companion* (Oxford Univ. Press 1998). A new book on the *Chemistry of the Solar System* for the Royal Chemical Society will appear in 2010. More about her research is at http://solarsystem.wustl.edu



JON LOMBERG

For 25 years Jon Lomberg was astronomer Carl Sagan's principal artistic collaborator in books, magazines, television, and film projects including the film *CONTACT* and the TV series *COSMOS*, for which the artist won an EMMY Award. His portrait of the *Milky Way Galaxy*, commissioned by the National Air and Space Museum, remains the iconic image of the galaxy for this generation of astronomers. He has worked in interdisciplinary partnership with prominent astronomers, physicists, and psychologists of perception. As Design Director of NASA's *Voyager* Interstellar Record, Lomberg designed the cover and pictorial contents of the Record, with an estimated lifetime of 1000 million years. Also, three message artifacts of his design are now on the surface of Mars aboard 3 NASA spacecraft. An asteroid near Mars has been officially named Asteroid Lomberg in his honor.



SUSAN MILBRATH

Dr. Susan Milbrath is Curator of Latin American Art and Archaeology at the Florida Museum of Natural History, and an Affiliate Professor of Anthropology at the University of Florida. She received her Ph.D. from Columbia University in Art History and Archaeology, and has curated a number of major exhibits including an NEH-funded traveling exhibit featuring her research that opened at the American Museum of Natural History. For the past 20 years Milbrath has been a curator at the Florida Museum of Natural History where she has continued working on exhibits, including several exhibits that toured nationally. Her recent research focuses on the archaeology and ethnohistory of Mayapan, the last Maya capital in Mexico, and astronomical imagery in Mesoamerican art.

MICHAEL R. MOLNAR

Retired astronomer Michael R. Molnar now makes violins to accompany the music of the spheres. More about the Star of Bethlehem can be learned from his website: www.michaelmolnar.com.

C.J. WALLINGTON

C.J. Wallington is (as far as he knows) the world's first university space tourism development teacher. After two sessions at NASA's Johnson Space Center as a summer faculty fellow, he returned to the Rochester Institute of Technology (RIT) and the next year initiated a course called *Space Tourism Development*. All of this was prior to Dennis Tito's trip to the International Space Station, Zero-Gravity's commercial weightlessness flights, and years before Burt Rutan won the X-Prize. He currently teaches in RIT's School of Hospitality and Service Management, and has even taught the course in Croatia, leading to a Croatian student's Master's thesis about selected consumers' interests in space tourism. If he had the money (college professors don't make that much), he would be on a Zero-G flight or in line for Virgin Galactic's suborbital flights (blatant hint for funding). Wallington has a Ph.D. from the University of Southern California and blames all this on George Lucas who was in cinema school at about the same time making *THX-1138*.

Glimpse Team

Megan Hurst
Founder, Managing Editor

Carolyn Arcabascio
Acquisitions Editor

Nicholas Munyan
Art Director

Christie Marie Bielmeier
Contributing Science Writer

Rachel Sapin
Editorial Assistant

Angie Mah
Editorial Intern

Wayne Kleppe
Design Intern, Illustrator

Ivy Moylan
Contributor, Film Reviews

Arto Vaun
Staff Poet, Contributing Poetry Editor

Adjunct + Alumni

Christine Madsen
Co-Founder, Editor (Europe)

EmComm
Marketing + Communications

Matthew Steven Carlos
Editorial Advisor

Anthony Owens
Photographer

Jamie Ahlstedt
Logo Design

Glimpse
PO Box 44
Salem, MA 01970
ISSN 1945-3906
www.glimpsejournal.com

Copyright and Acknowledgements

Glimpse acknowledges creators' copyright, and encourages contributors to consider Creative Commons licenses for their works. Many of the images used in this issue are Creative Commons licensed images from Flickr.com members, and others are public domain images courtesy of private collectors. The font used in this issue is Tuffy, a freely available font.

From the Editor

Humans have always looked up. The sky's constellations might have been the first text to which humans ascribed meaning, long before written language emerged. This issue, *Cosmos*, is by and about those among us that look intently upwards, and what they've learned by looking.

Four hundred years ago this month, in March 1610, Galileo Galilei published *Sidereus Nuncius*, the first printed treatise on telescopic observations of celestial objects. If Galilei could witness the power of telescopy and digital imaging technology today, he might be awestruck, and then we suspect he would quickly busy himself collaborating with the Glimpse vol 2.4 issue contributors. He might be lobbying with Scott Kardel for dimmer earthly lights so their observatories could get a clearer picture of the sky. He might promote Dr. Katharina Lodders' re-framing of the Periodic Table to better reflect the chemical elements of and beyond terrestrial Earth. He might join Dr. Jason W. Barnes in infrared imaging of Titan's surface. He might virtually fly over the surface of the Moon and Mars in the latest versions of Google Earth™ described in detail by Dr. Ross A. Beyer. Perhaps Galilei would even angle for a $25 million space vacation (heeding Dr. C.J. Wallington's best advice).

We see more clearly by looking to the past. Our telescopes and cameras, stationed on Earth's high points or floating in space, lenses open, record ancient light (both visible and invisible) that tells us stories of long, long ago, from very, very far away. Astronomy is inextricably linked with technologies of seeing. Whether allowing for greater magnification or the visualization of invisible light, advances in digital imaging technologies have enabled astronomers to probe deeper, to the edges of the known universe.

Skills of acute observation serve astronomers just as well when looking at human history. Two contributors to this issue piece together ancient civilizations' customs and practices as they relate to the patterns of the stars. Dr. Michael R. Molnar and Dr. Susan Milbrath devote their inquiry to an understanding of the cultural context of celestial events during the times of Christ and the Maya, respectively.

This issue's cover features an image of Mission Control that typifies the 20th-century lore of space exploration. While we couldn't resist this image, we advise you to look beyond this cover where you will find that the stereotype of men wearing headsets and pocket-protectors is tempered by a much deeper and broader representation of human engagement with the observable universe over millennia.

Megan Hurst, *Editor*
editor@glimpsejournal.com

Seeing Titan

Mapping Saturn's moon with infrared technology

by Jason W. Barnes

It seems incredible now, but at the dawn of the Space Age, equipping interplanetary spacecraft with cameras was not a foregone conclusion. NASA planned no cameras for its first Venus mission, Mariner 2 in 1962, because astronomers inferred from images collected by Earth-based telescopes that a camera wouldn't see anything through the planet's thick clouds. Carl Sagan, a planetary scientist perhaps best known for co-writing the PBS television series *Cosmos: A Personal Voyage* in the early 1980s, lobbied to have a camera installed despite this anticipated futility. The camera's purpose, Sagan mused, would not be to image the clouds that we knew were there, but rather to be on the lookout for the "unexpected."

Carl Sagan lost the Mariner 2 battle. Instruments were sent to test previously existing hypotheses instead. But his approach of using cameras to discover new phenomena and processes—in essence, to look for the questions that we did not know enough to ask—won out in the long run. Over the past fifty years, imaging has developed into a critical tool for planetary exploration. These pictures of planets, asteroids and moons are more accessible and more easily interpreted scientifically than other datasets, in part because they piggyback on the human brain's built-in hardware for assimilating information from images.

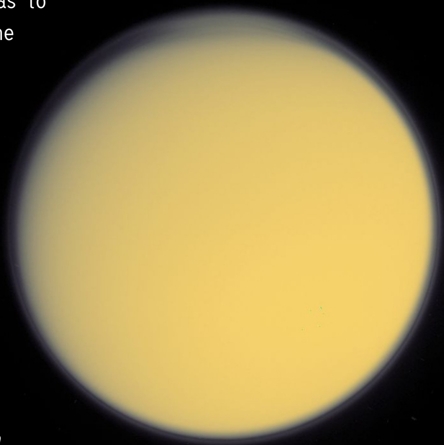


Figure 1. *A true-color image of Titan, like what human eyes would see. Scattering off of atmospheric smog particles smears out all light from the surface, leaving Titan looking like a featureless grapefruit. This image is from* Cassini's *Imaging Science Subsystem (ISS), but* Voyager 1's *cameras from 1980 showed much the same picture. All images courtesy of the author.*

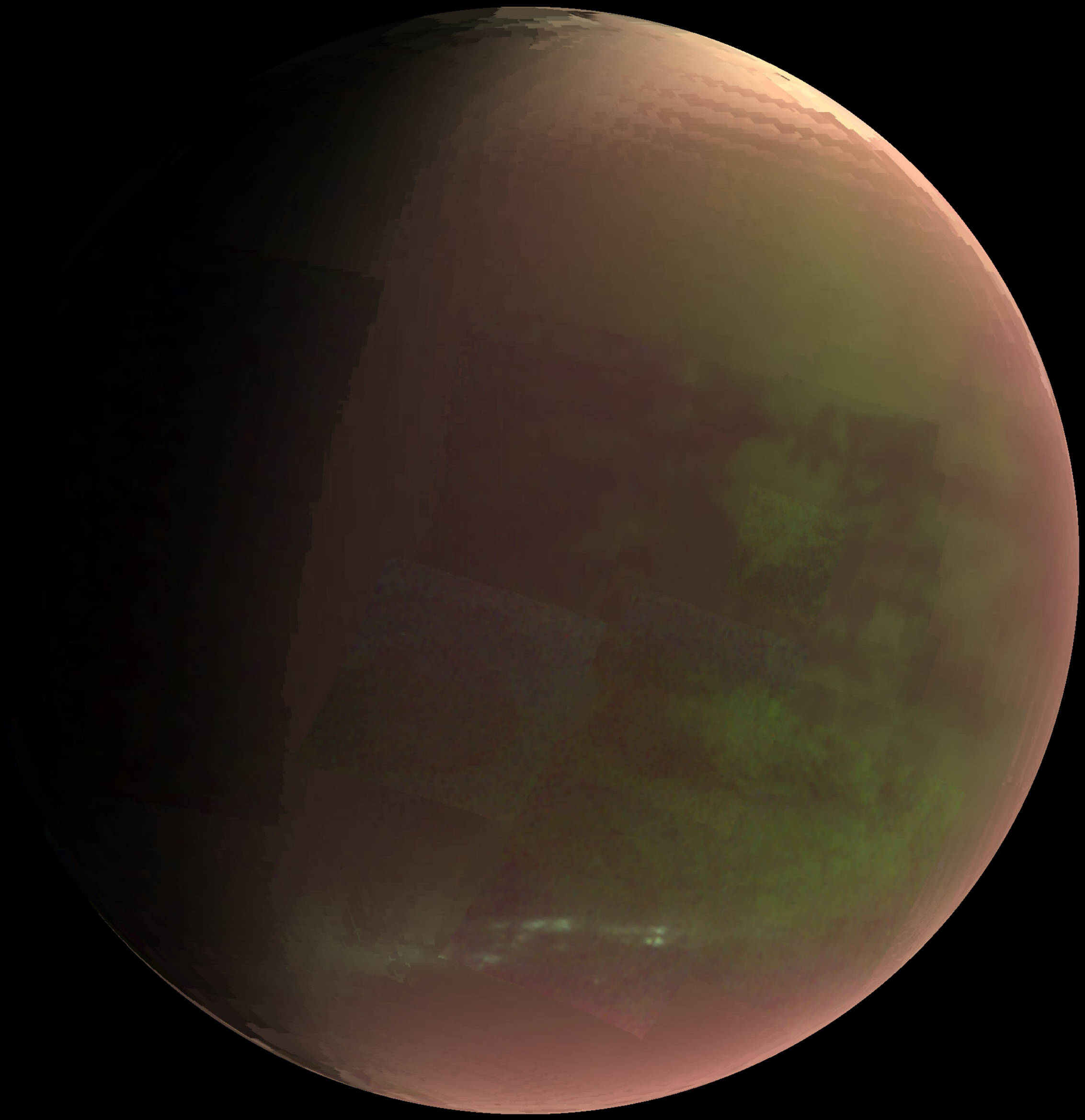


Figure 2. *This color scheme emphasizes Titan's atmospheric features. In this view from the VIMS instrument on* Cassini's *T34 fly-by on July 19, 2007, surface features look green. The pinkish color near the limb shows scattering off of the smoggy haze particles. The bright bluish-white patches near the south pole are methane storm clouds.*

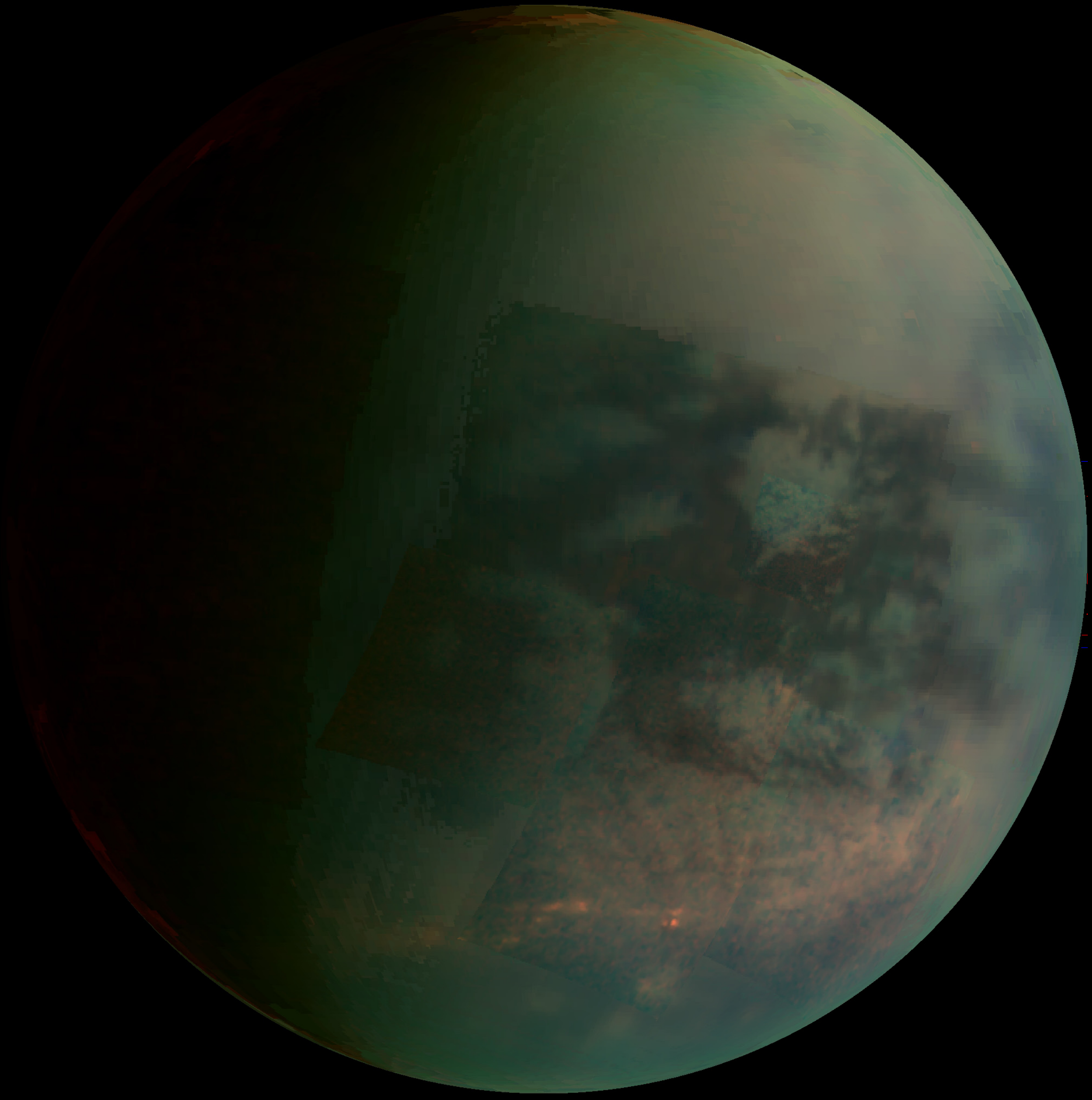


Figure 3. *This is the same VIMS image cube from Figure 2, but it uses images from different wavelengths to bring out the surface instead of the atmosphere. The dark brown areas near the center show where the sand dunes are located; the composition of the brighter areas has not yet been definitively identified. Areas that look bluer have more water ice.*

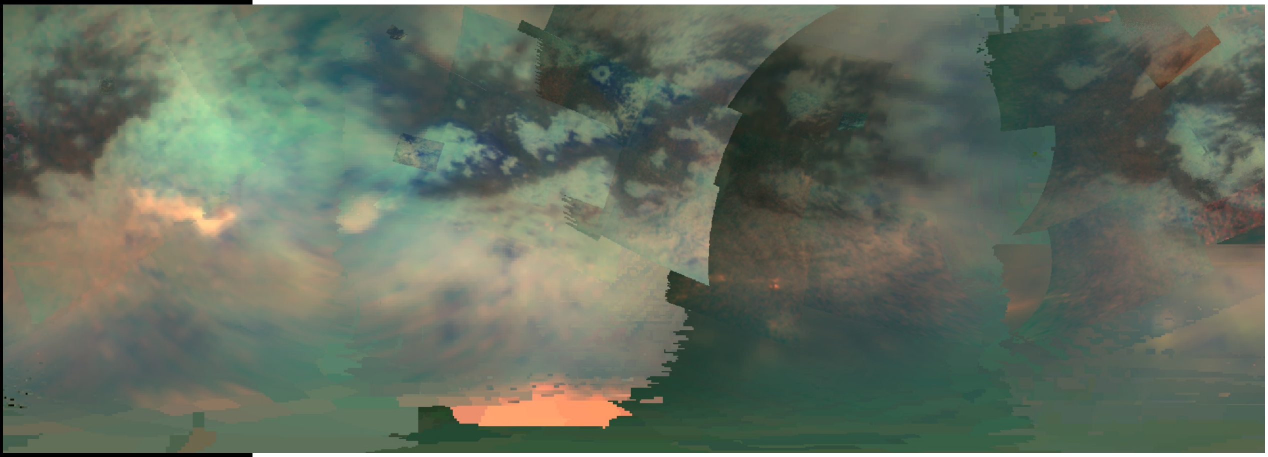


Figure 4. *Global map of Titan at near-infrared wavelengths. This is a simple cylindrical projection with 90 degrees north (the north pole) at the top, 90 degrees south (the south pole) at the bottom, and the equator running from left-to-right through the middle of the image. The center of the image corresponds to 0 degrees longitude on Titan (the point that always points toward Saturn, because Titan is tidally locked just like our moon), while the edges are 180 degrees longitude.*

Figure 5. *This 1.4 kilometer-per-pixel VIMS view from the T4* Cassini *fly-by on March 31, 2005 shows Titan's sand dunes as long, linear features within the dark brown areas.*

Figure 6. *In this VIMS view from the T9 fly-by on December 26, 2005 you can see dark blue linear markings within the bright green terrain that correspond to dry river channels.*

The two *Voyager* spacecraft (*Voyager 1* and *Voyager 2*) that were launched to the outer planets in 1977 were equipped with now-obsolete Vidicon cameras. These instruments were pre-CCD (charge coupled device) cameras with old photomultiplier detectors. They acquired color from taking multiple images with differently colored filters out in front of the main aperture. These cameras made the initial reconnaissance of the four giant planets (Jupiter, Saturn, Uranus and Neptune) and their more than fifty moons. Of the two spacecraft, *Voyager 2* flew by Jupiter and Saturn, using the planets' gravity to fling itself on to Uranus and Neptune as well.

Voyager 1 could have done the same tour. Instead, it was tasked with the only close-up exploration of a single world-Saturn's moon, Titan. Almost as big as the planet Mercury, Titan is the only moon in the solar system with a thick atmosphere. And it was this blanket of air that drew the attention of the Voyager scientists.

photons bounce around endlessly as if in a giant... pinball machine

Ironically, the atmosphere also frustrated *Voyager 1*'s exploratory efforts. In a development similar to that on Venus back in 1962, the spacecraft's 1980 close-up, high-resolution pictures showed Titan to be a nearly featureless, orange billiard ball (Figure 1). Titan looks smooth in these images because they show only the atmospheric haze that obscures its surface, and not the surface itself. The haze is made up of complex organic molecules–consisting of carbon, oxygen, hydrogen and nitrogen–created by the Sun's ultraviolet light in Titan's cold, methane-rich atmosphere. The result is not unlike the smog that infests Mexico City and the Los Angeles basin.

Like L.A.'s smog, Titan's haze inhibits visibility by blocking photons that are smaller in wavelength to the haze particles themselves. Because photons are quantum mechanically both particles and waves at the same time, when the wavelength of light is longer than the particle diameter, the waves are able to pass through the particle without being deflected at all. The shorter wavelengths, however, encounter particles larger than themselves and are either absorbed or deflected in a different direction. The average diameter of a particle in Titan's haze is around 1 micron–one millionth of a meter, or fifty times smaller than the diameter of a human hair. Hence, visible-light wavelengths of around 0.5 microns (like *Voyager 1* used) are deflected off of the ubiquitous haze particles instead of passing through and directly illuminating the surface. Instead of allowing us to view Titan's surface directly, photons bounce around endlessly as if in a giant three-dimensional pinball machine. Information about the surface properties gets lost in the hubbub.

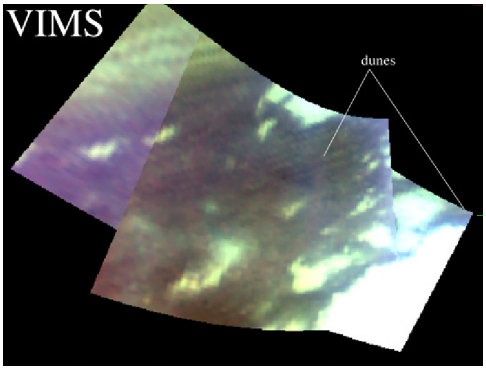
In designing a follow-up mission, named Cassini, after the Italian astronomer who discovered Titan in 1655, spacecraft engineers and planetary scientists sought a mechanism to see through the haze and glimpse the enigmatic moon's elusive surface. The best global and regional views for this mission, which was launched in the mid-1980s and is ongoing today, would come from cameras that see at near-infrared wavelengths, since photons with wavelengths larger than the size of Titan's haze particles pass right through them. Hence, the way to see through Titan's haze is similar to the way that a photographer on Earth might get a clear view of distant mountains by using a near-infrared filter. Cassini has two different instruments that use this technique.

The Imaging Science Subsystem (ISS) is a conventional visible-light camera with a 1024x1024 pixel CCD array for its detector (like the one used in digital cameras that you can buy today). ISS uses a narrow-band color filter at 0.938 microns wavelength that rejects other wavelengths of light in order to penetrate the haze. While the haze is partially invisible at this wavelength, some deflection off of atmospheric haze particles smears the resulting pictures. The best spatial resolution on the surface is no better than one kilometer, and the contrast is only a few percent.

We can only see the surface at wavelengths that methane does not absorb. These wavelengths are called "atmospheric windows."

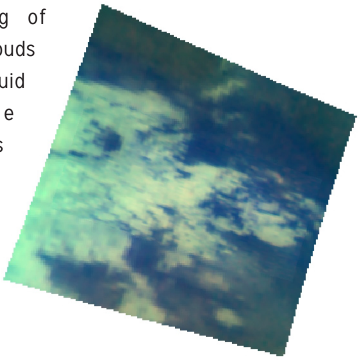
Cassini's other near-infrared instrument is the Visual and Infrared Mapping Spectrometer (VIMS). VIMS is not a normal camera. Instead, VIMS acquires spectra from 0.3-5.2 microns wavelength of a single spot at a time. Then it uses a programmable mirror to focus on different spots on the surface, building a 64x64 image over the course of a few minutes. The resulting data cube looks like 352 different images, each corresponding to a different wavelength between 0.3 and 5.2 microns. Earth observers call this type of imaging data "hyperspectral," but planetary scientists call it "spectral mapping."

Color information is the real power that we get from spectral mapping. Although the haze interference diminishes as we view Titan at longer and longer wavelengths, the atmospheric gases themselves block the surface as well. In particular, gaseous methane, present in Titan's atmosphere at the 5 percent level, absorbs light at most near-infrared wavelengths. We can only see the surface at wavelengths that methane does not absorb. These wavelengths are called "atmospheric windows."



Creative use of the windows can highlight aspects of the atmosphere in a way that helps to delineate its various attributes (Figure 2). Looking outside the windows yields only haze (red/pink); looking within the windows shows mostly surface (green); and then, looking at the edges of a window, you can see clouds that are above the surface (blue/white). These clouds are giant convective thunderstorms, like those on Earth.

Instead of consisting of water though, the clouds are made out of liquid methane. The temperature in Titan's lower atmosphere is near the triple point of methane, similar to the way that water is near its



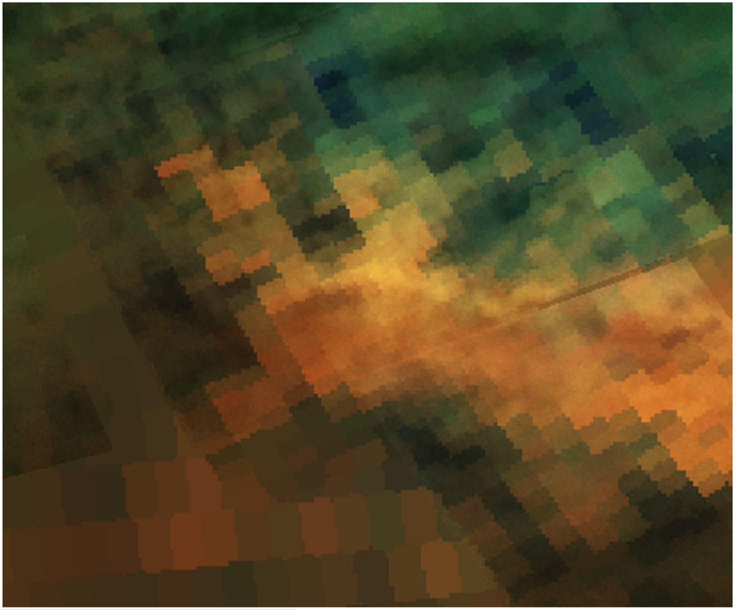


Figure 7. *The bright and unusual spectrum of this area, along with its shape, has lead Titan scientists to think that it might be a cryovolcano. Volcanoes on Earth are places where liquid rock bubbles up from the interior to cover the surface. Since it is so cold on Titan that water behaves like rock, when liquid water is forced up and out onto the surface there we call it a cryovolcano.*

triple point on Earth and can be present in solid (ice), liquid and gaseous (vapor) form. Methane therefore plays a similar role on Titan that water does on Earth- it evaporates into the air, forms clouds and rains on the surface. The effects of methane make Titan the place in the solar system that looks most like Earth.

By looking in different windows, all from the same VIMS observation, we can build up a color image of Titan's surface. This is not true color, of course. True-color is defined as what your eyes would naturally see. Your eyes cannot see near-infrared—and remember that in the visible, all you would see would be haze. But the resulting colors are real, if invisible to the human eye, and they help to tell us about Titan's surface properties. There are ten atmospheric windows total due to the specifics of how the methane molecule absorbs light, and they can be combined in many different ways, each of which tells a different story about Titan's composition and history.

Ten atmospheric windows... can be combined in many different ways, each of which tells a different story about Titan's composition and history

Figure 3 shows a particularly useful color combination. The green channel, at 2 microns, contains the cleanest view of Titan's surface albedo features. Albedo is what planetary scientists call the reflectivity of a surface—hence coal has a very low albedo, while freshly fallen snow has a very high albedo. The red channel, at 5 microns, has the least atmospheric scattering from haze, and shows the best contrast to 2 microns, revealing compositional variations across the surface, only some of which we understand. The blue channel is assigned to 1.3 microns, where areas that are richer in water ice are brighter. Because Titan is so cold, the light we see is always reflected sunlight, and not thermal emission.

As you can see from Figure 3 and from the map in Figure 4, Titan's surface as revealed by this color scheme changes markedly with latitude. Near Titan's equator, dark and bright areas alternate. On Earth, our areas near the equator are hot, wet tropical rainforests. But on Titan, most of the dark areas, spectral units that Titan scientists call "dark brown," correspond to huge fields of sand dunes (Figure 5). Though there are methane rainstorms and clouds on Titan- it evidently must not rain much in these equatorial deserts!

Our best resolution imaging of the dunes, taken when Cassini was closest to Titan in the course of its mission, showed that they are around 70 meters high with 2 kilometers between dune crests. The spectrum of the dunes indicates that they are made of organic compounds, and not water ice like most of Titan's crust. A mental analog for these might be mountains of coffee grounds almost as tall as a football field is wide. The areas between dunes are free of sand; hence, the dunes are probably still actively moving sand around today.

In other near-equatorial areas, we see long, sinuous, dark albedo markings that designate the location of channels (Figure 6). Liquid methane must have carved these, as they show branching patterns just like rivers and streams on the Earth. The channels show that, like Earth, but like no other planet that we know, erosion on Titan is dominated by rainfall runoff.

The geology of Titan has some fundamental differences from a rocky planet like Earth, though. Instead of Earth's silicate rock crust, the crust of Titan is made out of water ice. On Earth, heat from the planet's interior melts rock, which is then extruded onto the surface and spewed out of volcanoes. The equivalent of lava spewing forth on Titan, then, would be interior heat melting crustal ice and spewing out water. We call this "cryovolcanism." The near-infrared imagers on Cassini have shown tantalizing evidence of possible cryovolcanism in a few places on Titan (Figure 7). The shape of the albedo patterns shows finger-like structures that resemble terrestrial lava flows. These still need further study, but if proven genuine, would show that Titan's interior remains active today.

At Titan's north and south poles, Cassini found one of the most exciting discoveries in the space program's history- lakes of liquid methane. Liquid water is ubiquitous on Earth, but no liquid had been seen anywhere else before. Figure 8 shows a combined VIMS and ISS view of the lake called Ontario Lacus near Titan's south pole. The lake is around the same size as Lake Ontario of North America's Great Lakes on Earth. A mixture of liquid ethane and methane fills the lake.

Surrounding the lake are two rings: the inner dark and the outer bright. They seem to be remnants from when the lake level was higher in the past. The inner ring looks like mudflats that are inundated seasonally. Titan's seasons are about as strong as those of Earth since its axis tilt is similar, but the seasons there last twenty-eight years instead of one here on Earth. The outer ring may be evaporite deposits, like salt flats on Earth, from higher lakestands in the geologic past. It is clear that the methane cycle on Titan is active and dynamic, and will be of great interest for future studies.

Because Titan is so cold, the light we see is always reflected sunlight, and not thermal emission.

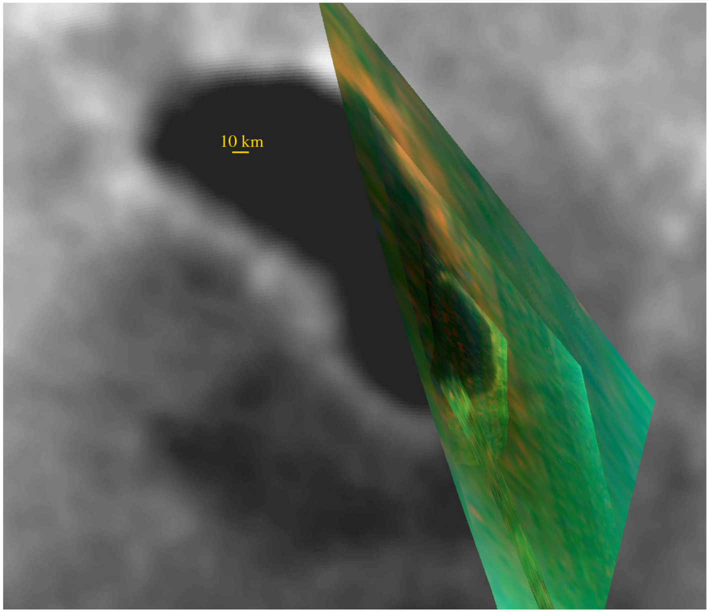


Figure 8. *Here is a closeup view of a liquid methane- and ethane-filled lake named Ontario Lacus near Titan's south pole. The background black-and-white view is from ISS; the color view in the southeast corner is from VIMS. This view starts to show shoreline features that may be similar to mudflats and salty playas on Earth.*

The Cassini mission will continue until the end of this Titan season in 2017. Near-infrared imaging provides an opportunity for many new discoveries when we look into unexplored territory. Several exciting follow-ons have been proposed for when Cassini's remarkable mission ends. The next Titan mission may be an orbiter capable of global 25-meter resolution imaging, or a lander to sploosh into one of the northern lakes, or a propeller-driven airplane to take license-plate scale pictures of the surface. With any luck, what we find will continue to exemplify the kind of flexible science that an imaging system can do. With the detailed information gleaned from Cassini's imaging exploration in particular, most people would now agree that Carl Sagan was right all along.