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How Astronomy Caught the Infrared Wave

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We understandably lament all that we're missing. Dogs hear a far greater range of frequencies than we do. Other animals see things we don't. Some snakes, amphibians, and insects rely on their ability to detect infrared light, but our eyes are insensitive to all but the shortest infrared wavelengths.

Anything with a temperature above absolute zero emits at least some infrared light, and anything at room temperature emits mostly infrared light. So, we never see a lot of radiant energy around us. It's easy to be disappointed about this, but we should be grateful. Warm-blooded creatures miss out on infrared vision because they are too hot to permit infrared detectors to work effectively. We are blinded by our modestly elevated temperature but benefited by the autonomy our independent temperature regulation delivers.

We have compensated for our limitations and created infrared instruments to detect what our eyes cannot see. Dr. John Miller describes this month how infrared astronomy has taken advantage of that technology and revealed unseen cosmic wonders. That couldn't happen without the discovery that there is infrared light, and Dr. Miller starts by reminding us it was first disclosed by an astronomer…more than 200 years ago.

Dr. Miller has spent professionally more than 40 years in the infrared. Although he holds degrees in physics from the University of Southern California and graduate courses and degrees from California State University, Long Beach; the University of Hawai'I; and Regis University, Dr. Miller started his astronomical career at Griffith Observatory, as a Museum Guide and as a back-up Telescope Demonstrator. He then joined those who have helped us warm-blooded organisms see things in a new light—at Mount Wilson and Palomar Observatories, at Rockwell International on the Space Shuttle and a classified infrared space telescope, at Mauna Kea's Infrared Telescope facility, at Lockheed Martin, and as the chief technology officer of FLIR systems, from which he retired. He continues to consult for governments, universities, industry, and United Nations agencies. He has authored more than a hundred papers and five books on infrared and photonic technology and is now developing a proposal for PBS NOVA. He sheds light on the infrared via his consulting firm Cascade Electro-optics LLC, as noted above.

—E.C.K.

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Dateline Feb 11, 1800, Slough England: The Court Astronomer William Herschel, famed discoverer of the planet Uranus, now finds another type of light. On this date, by trying to unify two fields of "Natural Philosophy" (now called "science"), our genius ties thermodynamics to photonics. In a brilliant experiment, he repeats Sir Isaac Newton's experiment of sending sunlight through a prism. He does more than Newton, however. He positions a thermometer to measure the temperature of the light's colors.

In one story, I heard, Hershel flipped his thermometer to the right and removed it from the red light to make notes. Retrieving his thermometer, he found the temperature actually increased just beyond the reddest part of the spectrum and realized there is "invisible" light. He called this new light "Calorific Rays." In the late nineteenth century it was renamed "infrared." Herschel clearly discovered infrared radiation—by accident or on purpose, we don't know. This was the first-time light was discovered outside of the visible spectrum and the first time two fields of science were unified. It was one of two tectonic discoveries by William Herschel.

Today we know that infrared light has wavelengths from just beyond visible to sub-

The constellation Gemini the Twins is the backdrop in an 1814 portrait of astronomer William Herschel by Frederick Refberg. Herschel discovered the planet Uranus in Gemini on 13 March 1781, and a telescopic view of the planet, here still called Georgium Sidus, is included in the scene with the crescent moon. (Wellcome Collection. Attribution 4.0 International, London, U.K.)

FRONT COVER

Below the Red

The longest waves our eyes can see are red, and in 1800, when William Herschel with a thermometer discovered invisible light beyond the red, he called it "calorific rays." By 1875, this radiation was known as infrared light, but whoever originated that term remains unknown. *Infrared* means "below red," but infrared light is actually redder than red with wavelengths longer than the wavelength of red light. It's not clear how infrared is below red. Red, after all, is at the top of the arc of a natural rainbow. Any infrared that gets through the raindrops would appear, if not invisible, above the red. So, as far as rainbows are concerned infrared is above the red. Nonetheless, the name has stuck. All of the colors of the rainbow, from radio waves to gamma rays, are showcased at Griffith Observatory in the Jack C. and Ann Marie Wilder Hall of the Eye, where an image in each kind of light of the center of the Milky Way Galaxy appears in the "Beyond the Visible" exhibit. Cloaked with dense clouds of interstellar dust that absorbs visible light, the center of the Galaxy is blocked from view. Infrared light emitted by what is in those clouds can pass through the dust, however, and infrared telescopes collect it. That infrared light lets us see clusters of stars throughout the Galaxy's core. For more below the red, please see Dr. John Miller's article this month, "How Astronomy Caught the Infrared Wave." (photograph E.C. Krupp, cover design Robert Smith, Griffith Observatory)

— Dr. E.C. Krupp

Astronomer William Herschel was the first person we know by name who discovered a planet, but he also put a thermometer beyond the red in a tabletop spectrum and discovered infrared light. (portrait by Lemuel Francis Abbott, 1785, National Portrait Gallery, London, Wikimedia Commons)

Caroline Herschel collaborated on astronomical projects with her brother William and also conducted independent research. She discovered eight comets and lived to 97, but this portrait, by Melchior Gommar (aka Maerten Freanz Tieleman), captured her when she was 78, in 1828. (from Hoskin, Michael. *Discoverers of the Universe: William and Caroline Herschel*, from Herschel Family Archives, Wikimedia Commons)

millimeter. It is generally defined to fall between one micron and 100 microns. *The Hubble Space Telescope* observed the universe from the ultraviolet to the short-wave infrared. The *James Webb Space Telescope* observes entirely the infrared. Most terrestrial infrared sensors work in the short-wave infrared (1 to 2.5 microns), the mid-wave infrared (3 to 5 microns) or the long wave infrared (8 to 14 microns). The atmosphere absorbs other wavelengths above 16 microns but allows some narrow (albeit important) bands until the sub-millimeter wavelengths. Space-based infrared telescopes obviously have no such limitations.

Permit me to dispel two incorrect common notions about infrared light. First, infrared is not "heat rays" as there is no such thing, and it is a misnomer. Infrared is not the shivering that you see above a hot stove burner or fire. That is the atmosphere heating and cooling. If it were, it would not be detected over the vacuum of space, and infrared astronomy could not exist. Infrared is part of the electromagnetic spectrum, a color (wavelength) of light longer than the visible. Period.

Like ultraviolet and visible light, infrared does follow the Planck function. As an object gets hotter, it glows with more energy, and its peak energy shifts to the shorter wavelength. People are at 98 degrees F and radiate in the long-wave infrared. Their skin emissions peak at about 10.8 microns. The sun's surface is

much brighter. With a temperature of about 5600 degrees Kelvin, it peaks at a yellow visible wavelength. Infrared cameras can be programmed to display temperatures based on the Planck function. Not all radiation follows the Planck function, however. Some chemical reactions emit more in some particular wavelength, and some absorb more in a given wavelength. Dark matter does not follow this function, and that is its defining property.

Second, you will never see an "infrared image," and there are none in this article. Human eyes simply can't see in the infrared. Common printers and projectors cannot project in the infrared. So, every infrared "image" or "video" that you perceive in the visible wavelengths that your eyes can sense are interpretations of the actual infrared image that the sensor detects. All such "infrared images" and "infrared videos" are false-color (or intensity black-and-white) interpretations of the actual infrared scene. There are expensive infrared scene generators that can project infrared images to infrared sensors, but our eyes cannot see their projected content.

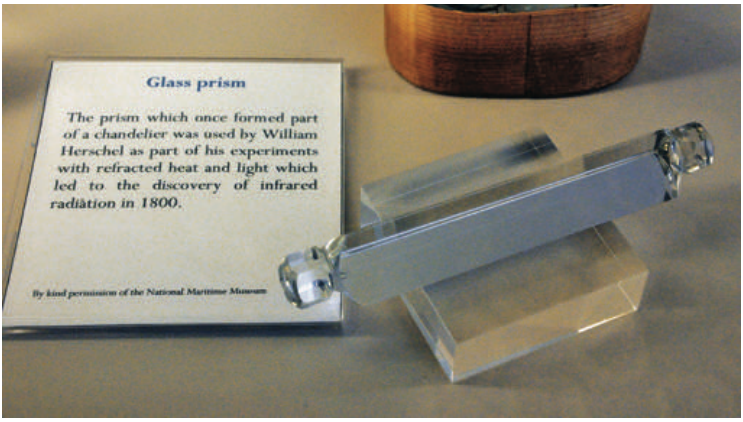
Herschel, infrared's discoverer, was born on November 15, 1738, in Hanover, Germany. He moved to England in 1757. With a dual career,

Herschel's home in Bath, England, at 19 New King Street, is next to the home of Admiral Horatio Nelson, the British naval hero commemorated with the column in London's Trafalgar Square. (photograph John Lester Miller)

William and Caroline Herschel, polishing a metal mirror they have cast in the Bath workshop, are imagined in an 1896 lithograph by Alfred Richard Diethe. Caroline is "adding lubricant." ((Wellcome Collection, London, U.K., Wikimedia Commons)

The cracked and stained flooring stones in Herschel's optics manufacturing facility at his home in Bath is evidence of spilled liquid metals. (photograph John Lester Miller)

Some of the optical elements William Herschel and his younger sister Caroline fabricated survive and are displayed at Herschel House in Bath. (photograph John Lester Miller)

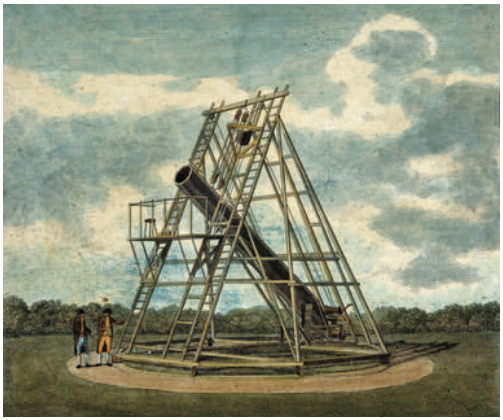


This cut glass prism from the chandelier King George III gave William Herschel may have been what Herschel used to disperse light into the spectrum that allowed him to discover infrared light. (photograph John Lester Miller)

Hershel's residence in Bath included a shop for melting, pouring, casting, and cooling metal for speculum mirrors. (photograph John Lester Miller)

Herschel discovered Uranus from the back courtyard of his home in Bath. (photograph John Lester Miller)

William Herschel catalogued many nebulae and galaxies. He discovered the Fireworks galaxy (NGC 6946, in Cepheus the King) in 1798, but he didn't see it like this. It earned its name by hosting ten observed supernovae in the last hundred years. (ESA/Hubble & NASA, A. Leroy, K.S, Long)



Five years after the discovery of Uranus, Herschel established a home in Slough—about 20 miles west of London and 80 miles east of Bath—and assembled there his largest telescope, the 40-foot-focal-length reflector. The mirror for the instrument was nearly 50 inches in diameter. In this illustration from 1877, Herschel appears in eighteenth-century clothes. (Wellcome Collection, London, U.K., Wellcome Library no. 46257i)

Understanding that high-altitude may permit more astronomical access to the infrared, Gerard Kuiper examined the infrared potential of the summit of Mauna Kea on Hawai'i, the big island in the Hawaiian chain. His discovery of the mountain's astronomically high performance eventually led to the establishment of the Mauna Kea observatories, including the NASA Infrared Telescope Facility, which is on the far right. It is accompanied in this view by the Suburu telescope on the left and the Keck Observatory telescopes in the middle. (photograph Vadim Kurland, 23 December 2007, Wikimedia Commons)

he was an astronomer and a musician. In fact, he wrote approximately 135 pieces for organ, harpsichord, and other instruments.

While in Bath, England, Herschel began to make telescopes. His designs and manufacture pushed the state of the art for those times. He once burnt himself and his sister with liquid metal, and the stains and cracks in the stone lab floor can be seen to this day. Herschel's telescopes were reflectors. The mirrors were made of speculum metal. Speculum is an alloy, approximately two-thirds copper and one-third tin, with some secret ingredients, such as arsenic. He made several that were from four to 12 inches in diameter, in Bath, and his largest, 1.2 meters, was part of his 40-foot Telescope in Slough. He worked with his sister Caroline to make telescopes and accomplish profound astronomical achievements:

1. cataloged nebulae (Herschel's catalogs are still the basis for the current NGC catalog. He was greatly helped by his sister Caroline.)
2. separated gas nebulae from clusters of stars in the Messier catalog. (This was not considered fully understood until Edwin Hubble showed that some nebulae are gas structures in our Galaxy and that others are actually external galaxies.)
3. discovered that the Martian polar caps vary seasonally
4. discovered two moons of Uranus (Titania and Oberon)
5. discovered two moons of Saturn (Enceladus and Mimas)
6. used a microscope to prove coral is not a plant
7. made his most famous discovery, the

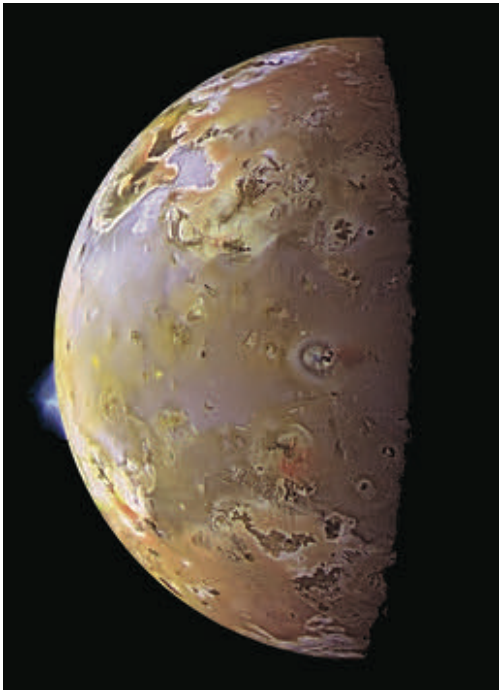
In the mid-1970s, Infrared astronomy took wing with the Kuiper Airborne Observatory, a modified Lockheed C-141A Starlifter jet transport. Retired in 1995, the mission was eventually succeeded in 2007 by the Stratospheric Observatory for Infrared Astronomy (SOFIA). The Boeing 747SP has a large aft door that opens for the 8.9-foot-diameter mirror visible here. (NASA/DLR)

planet Uranus (He did this in his back courtyard on March 13, 1781. Discovering Uranus was Herschel's other tectonic discovery. Uranus was the first planet discovered by a known person. All of the other planets were known from antiquity and cannot be attributed to a single person.)

8. discovered infrared light in Slough, not Bath (Infrared is probably the most important of Herschel's discoveries.)

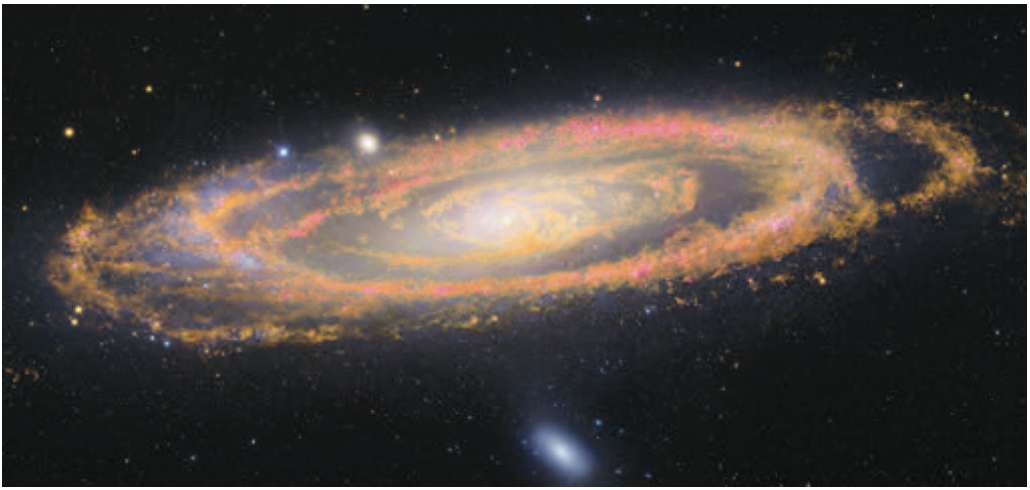
Herschel's sister Caroline helped him with most of his work (including the discovery of Uranus), but she did not participate in the discovery of infrared. She was jealously protective of her close relationship with her brother and moved away from Slough when he married. She also independently discovered several comets and nebulae. She was the first woman to be granted an official title and salary as an astronomer.

Herschel's discovery of Uranus made him famous. The British king, George III, appointed him Court Astronomer, moved him to Slough (near Windsor Castle and London), and gave him an expensive and fancy chandelier with fused silica glass prisms. This type of glass can actually transmit short-wave infrared (like radiation the *Hubble Space Telescope* can view).



Volcanoes on Io, one of Jupiter's Galilean moons, were discovered by Linda Morabito, a *Voyager 1* spacecraft scientist, in 1979. Infrared observations of Io from earth had earlier suggested these active hotspots are present. The 86-mile-high plume on Io's limb here is an eruption of the Prometheus ice volcano. (NASA/JPL/University of Arizona *Galileo* spacecraft image, 28 June 1997)

The difference between what is seen by the *Hubble Space Telescope*'s Wide Field Camera 3 (WFC3) in visible light (left) and in infrared light (right) is striking. These towering columns of interstellar matter are part of the Eagle nebula (M16) in Serpens the Serpent, and in visible light, the object came to be known as the "Pillars of Creation," a place of very active star formation. Light from background stars behind the curtain of gas and dust is blocked in the optical view, but infrared light is not obstructed by the dust. In the infrared, the number of background stars is astronomically greater, and more of the very young stars inside the nebula's "elephant trunks" are also evident. (NASA, ESA/Hubble, and the Hubble Heritage Team, 2015)



M31, the Andromeda galaxy, is just up the street from us as galaxies go, and the optical images of it, especially in black-and-white, are classics. In this visible light-infrared light composite, however, it looks a little less familiar. Infrared light is represented in peach and pink here, and in infrared light, the galaxy's arms are far more distinct. (Suburu Mauna Kea telescope, Mayall 4-meter telescope (Kitt Peak National Observatory), Digitized Sky Survey, and *Spitzer Space Telescope*—image assembly and processing by Robert Gendler)

The Carina nebula also looks very different in visible light (top) and in infrared (bottom). Infrared permits a look inside the chaotic cloud to see the star that is producing an energetic jet of explosively ejected material. (NASA, ESA and the Hubble SM4 ERO Team, 24-30 July 2009)

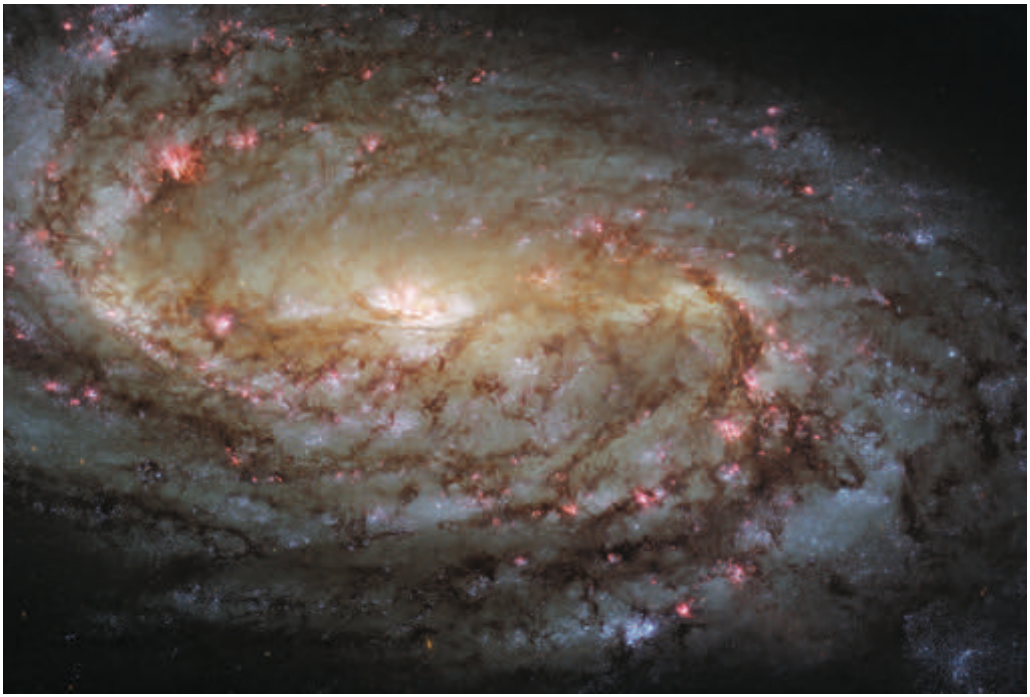
William got on a ladder and pulled some prisms from his chandelier to disperse sunlight as Newton had done and discovered infrared by measuring the light's temperature.

In Slough, he built a 40-foot telescope, the largest in the world at that time. Nothing much came of this, however. Most believe the metering (or support) structure that held the primary and secondary mirrors was made of wood and so was not thermally or mechanically stable. Perhaps it was too large for its time.

Sir William Herschel died on August 25, 1822, and is buried near Slough. His memorial in Westminster Abby is near Newton's tomb. After Herschel's death, his son (John Herschel) also had a career in music and astronomy, but not with the successes that his father experienced. John Herschel is, however, credited with inventing the blueprint.

With the discovery of infrared rays, William Herschel discovered a branch of science and technology that allowed us to explore what infrared is and does. This has added to and changed chemistry, astronomy, military, intelligence, surveillance, process monitoring, integrated circuit development, and now self-driving cars and forest-fire prevention. The benefits are incredibly diverse and valuable.

Infrared imaging, developed as a military and intelligence technology, grew since the Vietnam



A *Hubble Space Telescope* Wide Field Camera 3 image of NGC 2903, a barred spiral galaxy 30 million light-years away in Leo the Lion, combines ultraviolet, visible, and infrared light. Together, these wavelengths indicate the galaxy's extraordinary complexity and the structure that suggests its central bar. William Herschel was the first to chart this galaxy, on 16 November 1784. Our own Milky Way Galaxy may be similar to NGC 2903. (ESA/Hubble, NASA, and L. Ho, J. Lee, and the PHANGS-HST Team).

War. Today, the U.S. Army likes to say, "We own the night," and will almost always initiate any operation at night (such as the operation to remove Osama bin Laden). Military uses include heat-seeking missiles, night vision, pilotage, detecting and tracking ICBM launches from space, surveillance, targeting, and others. For example, all fielded laser-guided weapons use short-wave infrared technology.

Infrared imagery sensors are becoming ubiquitous in all forms of life: From home electrical and heat leak detection to firefighting, security cameras, and, likely, self-driving cars. Integrated circuit manufactures use infrared images, as do many breweries and coffee roasters. It has allowed weather satellites to save countless lives through hurricane and storm prediction. The latter is claimed with ending the mystery of the "Bermuda Triangle," as all those ships and aircraft were lost to unpredictable hurricanes prior to weather satellites. Infrared imaging can monitor CO_2 and methane emissions (from space or the earth) for monitoring compliance to control climate change, as well as veterinary diagnoses, nocturnal-wildlife monitoring, and poaching prevention (I have worked on the latter two pro bono.). These and other valuable contributions create a large demand for these products, and the market value of non-military infrared imagery is about three billion dollars

per year. It is over ten billion dollars for earth-based military markets and maybe another five to ten billion per year for military and commercial space assets.

Infrared astronomy is a rich and active field. Because the wavelength is longer than the wavelengths for visible light, it penetrates smoke, dust, and some gases better than visible light. This provides researchers with clearer views of galaxies and nebulae. It is key to modern understanding of stellar formation and galactic evolution.

This branch of astronomy started in the 1960s with some ground-based single-detector elements displayed at existing observatories. Gerard Kuiper, Carl Sagan, and others pioneered these studies. Kuiper did some early tests on Mauna Kea and established it as an excellent observatory site. The '70s saw the development of specialized infrared ground-based telescopes (including one where I worked) and the Kuiper Airborne Observatory, which sampled infrared from an aircraft at high altitude and first spotted signs of the rings around Uranus, a suitable tribute to Herschel, who first speculated that he saw evidence of rings. This airborne telescope was followed by the SOFIA (Stratospheric Observatory For Infrared Astronomy), a Boeing 747 that is still in operation. Gerard Kuiper's early atmospheric measurements on Mauna Kea led to the installation of major telescopes including an infrared telescope. In the Canary Islands, Tenerife became another ground-based infrared observatory facility. Recently China announced a plan to develop a large observatory in Tibet, on Mount Saishiteng, with several telescopes including an approximately 12-meter infrared telescope. Finally, many other space infrared telescopes: IRTF, Spitzer, WMAP, COBE, and others—all have added to our knowledge of the universe.

These observations not only contribute to our knowledge but also supply spectacular images. The Carina nebula in the infrared is revealed to be a birthplace of stars. Gas and dust obscure its visible light. Infrared observations provide scientists a kind of cosmic clarity.

Infrared observation excels with the detection of objects with low solar reflection (either because of small size or low reflectivity) because their thermal emission peaks in the infrared bandpass. Infrared has been used to discover and track numerous asteroids, including potentially dangerous earth-crossing asteroids. Infrared observations discovered the volcanoes on Io, the first known volcanoes off of the earth. It also provides images of various gases on the gas giants and atmospheric constituents on the rocky planets and large moons.

Molecules tend to vibrate with frequencies that cause emission and absorption features in the infrared spectrum. This allows infrared spectroscopy to identify chemicals on objects in the solar system and in galaxies on the other side of the universe. They include molecules like chlorophyll and other biological markers which may identify life beyond earth.

The recently launched *James Webb Space Telescope* operates entirely in the infrared. It has cooled optics and instrumentation to reduce noise and enhance its sensitivity. Plans call for observing X-ray phenomena that are so red-shifted, their features are in the infrared. Other planned observations include exo-planets and viewing back to when the universe became transparent (about 300,000 years after the big bang). This is much further back in time than the *Hubble Space Telescope* and ground-based telescopes) can manage.

Following the *James Webb Space Telescope* will be the Grace Telescope, approximately the size of the *Hubble Space Telescope*, and other space and ground telescopes to explore this amazing region of the optical infrared spectrum. Hold on to your hats for the amazing discoveries in the next few decades in Infrared Astronomy. It will define our understanding of the universe and ourselves. The next William Herschel may be reading this right now!

The Rabbit on the Moon

Jennifer Wong

Griffith Observatory

Before the Deep Thought supercomputer from Douglas Adams's *The Hitchhiker's Guide to the Galaxy* generated the "Answer to the Ultimate Question of Life, the Universe, and Everything" (The answer is 42, by the way.), people looked for meaning everywhere—from tea-leaf formations to the shape of natural rock outcrops—in order to understand life and its mysteries. They also looked to the heavens. From this search emerged myths, folktales, and other narratives that would answer the questions "How?" or "Why?" One of those myths originates with the moon. You may have heard about the "man in the moon," but have you heard about the rabbit in the moon?

Pareidolia: Making Sense of the Senseless

On 25 July 1976, *Viking 1 Orbiter* took several pictures of the surface of Mars, and the world went wild. As exciting as pictures of the Red Planet were, one image of the Cydonian mesa received special attention. Later called the "Face on Mars," this image still commands attention over four decades later, and despite almost immediate dismissal by NASA, many people still claim it's proof of extraterrestrial life. After all, how else could a sculpture of a human face appear on another planet?

This turned out to be one of many examples of pareidolia, a phenomenon which prompts an observer to see or hear patterns in otherwise random data. In the psychological world, pareidolia is a subcategory of apophenia, in which the onlooker tries to perceive connections and meaning in unrelated stimuli. Historically, psychologists encouraged these traits in patients subjected to Rorschach tests in an effort to gauge a patient's character, emotional stability, or overall mental health. In theory, it sounded like an easy method to assess patients by

Proof of aliens or just a lucky shot? By the way, see "Losing Face" in the August, 1978, the *Griffith Observer* and the back cover of the February, 1977, issue of *Griffith Observer*. We dealt with this before NASA. (NASA *Viking Orbiter 1* photograph, NASA/JPL)

Contrary to Joni Mitchell's song, clouds don't only block the sun. Watching them provides a fine way to pass the time. With a little imagination, you may see them take on familiar shapes. During Jennifer Wong's grand day out, she snapped this picture of the elusive sky-alligator as it opens its jaws. (photograph Jennifer Wong)

having them stare at inkblots and describing to doctors what they see. It was a way to let the unconscious mind speak. Rorschach test results were even used in criminal cases. The practice, however, has been dismissed as unreliable for court trials, although it is still used in some aspects of mental-health evaluations.

According to evolutionary anthropologists, the ability to recognize patterns is a requirement for survival. In an eat-or-be-eaten world, both predators and prey have evolved to succeed to survive, and that includes the use of camouflage. According to anthropologist Matteo Meschari, "recognizing without delay prey or a predator in the indistinct foliage constitutes a selective advantage, even in the case of error." For a predator, the visual suggestion of prey hiding in tall grass before the prey perceives it's in danger means ensuring the next meal. For prey, early detection of a predator means securing a few precious seconds to make an escape. This seems to indicate that this ability is learned at a later stage in life because some animals—mammals, in particular—must be taught how to hunt or forage for their food. Famed American astronomer and science communicator Carl Sagan, however, posited that pareidolia develops in humans much earlier in life:

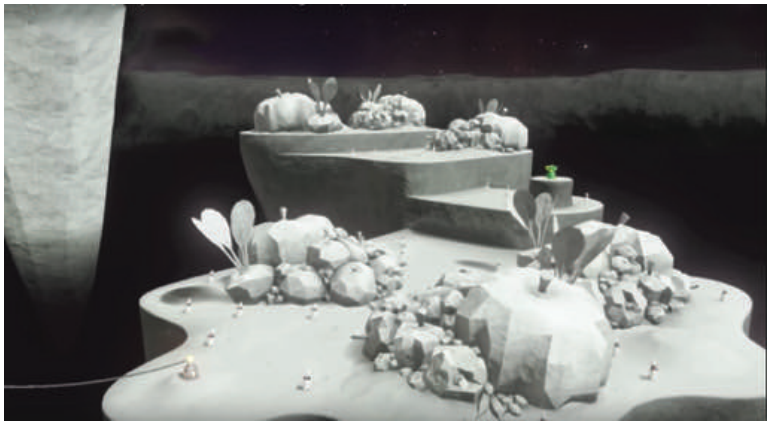
"As soon as the infant can see, it recognizes faces, and we know that this skill is hard-wired in our brains. Those infants who a million years ago were unable to recognize a face smiled back less, were less likely to win the hearts of their parents, and less likely to prosper . . . As an inadvertent side effect, the pattern-recognition machinery in our brains is so efficient in extracting a face from a clutter of other detail that we somehow see faces when there are none." (*The Demon-Haunted World: Science as a Candle in the Dark* 1996)

According to this explanation, the ability can't be turned on and off like a light switch, and people don't grow out of it. So when the people of early civilizations looked up in sky, whether during the day or night, they were, of course, affected by pareidolia.

In the night sky, there are a few sights reliably visible to the unaided eye: The stars, the occasional planet, and the moon. Were your eyes to linger on the moon you would see that it's not a smooth, white surface but a complex

Although the animated film *Wallace and Gromit: A Grand Day Out* accurately depicts the moon as having a textured surface, the moon is not made of cheese. (https://wallaceandgrommit.com/films)

A bat? A butterfly? A face? What do you see in the first inkblot of the Rorschach test? (Wikimedia commons, source credit Bryan Derksen)



The Moon Rabbit legend does not escape popular culture. In *Super Mario Odyssey*, a video game, the level called Rabbit Ridge requires traveling to the moon, which is inhabited by rabbits. (screenshot taken from *Super Mario Odyssey* wiki via The Mansion)

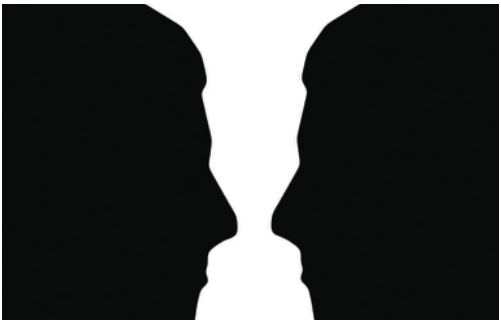
Somehow China's Mid-autumn Moon Festival and its moon-dwelling rabbit made their way into the lobby of the Chumash Casino Resort on the reservation of the Santa Ynez Band of Chumash Indians in southern California. Rabbits and eggs are symbols of fertility, renewal, and spring in several cultures worldwide. In the West the secular Easter Bunny is affiliated with a sacred holiday celebrating Christ's resurrection and eternal life. Traditional China's moon rabbit is an agent of immortality, which is reflected in the moon's monthly cycle of renewal. These two traditions merge at the casino where an Easter display incorporates a lunar landscape. (photograph Jennifer Wong, 16 April 2022)

blend of light to dark gray shadows caused by uneven surfaces and basaltic plains. These plains are called lunar *maria* because early astronomers mistook them for seas on the moon. *Maria* means "seas." Stare at the lunar *maria* long enough, and your mind will start to look for a pattern.

The Chinese traditionally saw a rabbit in the moon, but this concept is not exclusive to Chinese fables. Given the amount of people in the world, it would make sense that many of them—across civilizations and continents—might share similarities in what they saw. The moon rabbit is found in Japanese, Aztec, Hindu, Cree, and African myths, to name a few. Even within the same culture, you'll soon learn there are variations on who the rabbit is and how it got there. Here, we'll explore one aspect of moon-rabbit lore.

The Moon Rabbit Legend

"The living is a passing traveler;
The dead, a person come home.
One short journey between heaven and earth,
Then, alas! We are the same old dust of ten thousand ages.
The rabbit in the moon pounds out the elixir in vain;
Fu-sang, the tree of immortality, has crumbled to kindling wood.
Man dies, his white bones are dumb without a word
While the green pines feel the coming of spring.



Rubin's vase is an example of using negative space to create an illusion. Your eyes may see a vase or two faces staring at each other. (Wikimedia commons, source credit Brocken Inaglory)

Looking back, I sigh; looking in front of me,
I sigh again.
What is there to value in this life's vaporous glory?"
"The Old Dust" by Li Po (701 CE to 762 CE)

In Chinese legend, there is one person who has titles which could rival Daenerys, the exiled heir from *Game of Thrones*. It's the Jade Emperor, supreme deity, Ruler of All Heavens, first god, and first emperor of China.

One day, the Jade Emperor determined he needed additional help to prepare the elixir of life for his fellow immortals. He looked around at his options and wasn't impressed. People, he decided, could not be trusted with such an important task. After all, the potion of immortality could be too tempting for their greed. That meant it would be necessary to obtain aid from the animal kingdom, but how could he determine which is the most worthy animal? To investigate, he disguised himself as a frail old man and set off to the mortal realm on earth.

The Jade Emperor ended up at the outskirts of a forest and encountered there a fox, a monkey, and a rabbit relaxing by a campfire. Playing up his act, he asked them if he could warm himself by their fire and have something to eat because he was weak with hunger. The three animals were moved by this pitiful figure before them, and the fox and monkey immediately set off to find food for him. The rabbit, sensing the urgency of the situation, realized its companions' efforts would take too long and threw himself into the fire in a sacrifice of his own life to become food for the man.

The rabbit, however, landed on cold sticks, not in the roaring flames and smoke. The fire had been mysteriously extinguished. Confused, the rabbit looked around. The Jade Emperor then threw off his disguise and revealed his true self. The monkey and fox, having returned from their fruitless search, stood in awe along with the rabbit. The Jade Emperor explained that he appreciated the monkey's and fox's efforts, but he was profoundly moved by the rabbit's selfless act. The Jade Emperor granted the rabbit immortality. He became the Jade Rabbit and was whisked away to his new home on the moon, where he would work to prepare the elixir of life and later accompany Chang'e, the moon goddess.

The Symbol Is in the Eye of the Beholder

This is but one iteration of the story. In others, the rabbit already resided on the moon and Chang'e was the newcomer, or the rabbit simply wished to hitch a ride on earth's natural satellite. According to some, the rabbit is not the only animal to reside in the moon. The perception of negative space seems to be what permits a toad to be seen just below the rabbit.

In European tradition, on the other hand, a man gazes down upon earth from the moon. While each is entertaining, it's the observer who has the final say. So when you next look up at the moon, ask yourself, "What do I see?"

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Sky Calendar for August, 2022

David Nakamoto
Griffith Observatory

Observers located outside of the Pacific Time zone should apply these corrections to Sky Calendar times where appropriate:

Mountain	Time	add 1 hour
Central	Time	add 2 hours
Eastern	Time	add 3 hours
Universal	Time	add 7 hours

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SUN

The sun moves from Cancer the Crab to Leo the Lion on the 11th. Its noontime elevation decreases from 74 degrees on the 1st to 64 degrees on the 31st, while the point where it rises in the morning moves southward from 22 degrees north of east to 11 degrees north of east on the same dates. On the 15th, sunrise is at 6:15 a.m., PDT, and sunset is at 7:40 p.m., PDT. The day in Los Angeles is 13 hours 25 minutes long.

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MOON

Lunation No. 1232			
First Quarter	August	5	4:07 a.m., PDT
Full Moon	August	11	6:36 p.m., PDT
Last Quarter	August	18	9:36 p.m., PDT
Lunation No. 1233			
New Moon	August	27	1:17 a.m., PDT
Perigee	August	10	10:16 a.m., PDT
	223,594 miles		
Apogee	August	22	2:59 p.m., PDT
	251,896 miles		

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PLANETS

Mercury (mag. +0.0) sets at 8:47 p.m., PDT, and the sun sets at 7:54 p.m., PDT, on the 1st. Mercury is 85-percent illuminated and 5.3 arcseconds in width. On the 31st, Mercury sets at 8:15 p.m., PDT, and the sun sets at 7:20 p.m., PDT. Mercury's disk is 46-percent illuminated and 7.8 arcseconds in width. A telescope with a magnification of 150x is needed to see the disk. Do not observe any planet when it comes close to the sun, for the danger to the eyes is great.

Venus (mag.-3.8) rises at 4:20 a.m., PDT, on the 1st, and the sun rises at 6:05 a.m., PDT. The planet's disk is 93-percent illuminated and 11 arcseconds wide. On the 31st, Venus rises at 5:18 a.m., PDT, and the sun rises at 6:26 a.m., PDT. Venus is 97-percent illuminated and ten arcseconds wide. Venus decreases in size and becomes more fully illuminated as it journeys to the far side of its orbit. Powerful binoculars or a small telescope will reveal the planet's disk.

Mars (mag.+0.0) crosses from Aries the Ram to Taurus the Bull on the 9th. Mars rises at 12:31 a.m., PDT, on the 1st and at 11:32 p.m., PDT, on the 31st. The disk is 85-percent illuminated and increases in size from 8.3 arcseconds on the 1st to 9.7 arcseconds on the 31st. A telescope with a magnification of 150x is needed to see the disk.

Jupiter (mag -2.8) is in Cetus the Sea Monster. Jupiter rises at 10:38 p.m., PDT, on the 1st and at 8:36 p.m., PDT, on the 31st. Jupiter is 47 arcseconds wide. On the 15th, Jupiter is two degrees north of the moon. The Red Spot is visible at a magnification of 50x. The four bright Galilean moons move back and forth, roughly in a line centered on Jupiter.

Saturn (mag.+0.3) is in Capricornus the Sea Goat. It rises at 8:35 p.m., PDT, on the 1st and

at 6:30 p.m., PDT, on the 31st. Saturn is 19 arcseconds wide. The rings and its largest moon Titan may be seen with a small telescope with a magnification of 50x.

Uranus (mag +5.8) is in Aries the Ram. Uranus rises at 12:27 a.m., PDT, on the 1st and at 10:29 p.m., PDT, on the 31st. On the 15th, Uranus is located at Right Ascension $3^h\ 4^m\ 53^s$ and declination +16° 59' 54". Uranus is 3.6 arcseconds wide, and so a magnification of 150x is needed to show the disk.

Neptune (mag. +7.8) is in Pisces the Fishes. Neptune rises at 10:02 p.m., PDT, on the 1st and at 8:02 p.m., PDT, on the 31st. On the 15th, Neptune is at Right Ascension $23^h\ 41^m\ 57^s$ and declination -3° 16' 48". Neptune is 2.4 arcseconds wide, and so a magnification of 150x is needed to show the disk.

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SPECIAL EVENTS

The Perseid meteor shower is active from July 14th to September 1st. The Perseids peak from the evening of August 12 to the morning of the 13th. Rates will range from 50 to 75 meteors per hour from a dark location. Unfortunately, the moon will be full and will interfere with observation. The Perseids are particles released from comet 109P/Swift-Tuttle during its numerous returns to the inner solar system. They are called Perseids because they seem to come from near the constellation Perseus the Hero. The warm summer nights make the Perseids a popular shower to observe.

There is a chance that comet C/2017 K2 (PanSTARRS) can be viewed in the evening sky with binoculars and small telescopes.

Date	Rise time	Right Ascension	Declination
8/1	5:34 p.m., PDT	$17^h\ 26^m\ 05^s$	+01° 54' 39"
8/15	5:34 p.m., PDT	$16^h\ 57^m\ 08^s$	-03° 33' 18"
8/31	3:13 p.m., PDT	$16^h\ 28^m\ 41^s$	-10° 19' 49"

Griffith Observatory normally provides free public sky observing day and night–weather permitting–through a variety of telescopes. To plan a visit to the Observatory, please see our website (www.griffithobs.org) for the latest information. The Sky Report, also available on the website, provides monthly observing information.

BACK COVER

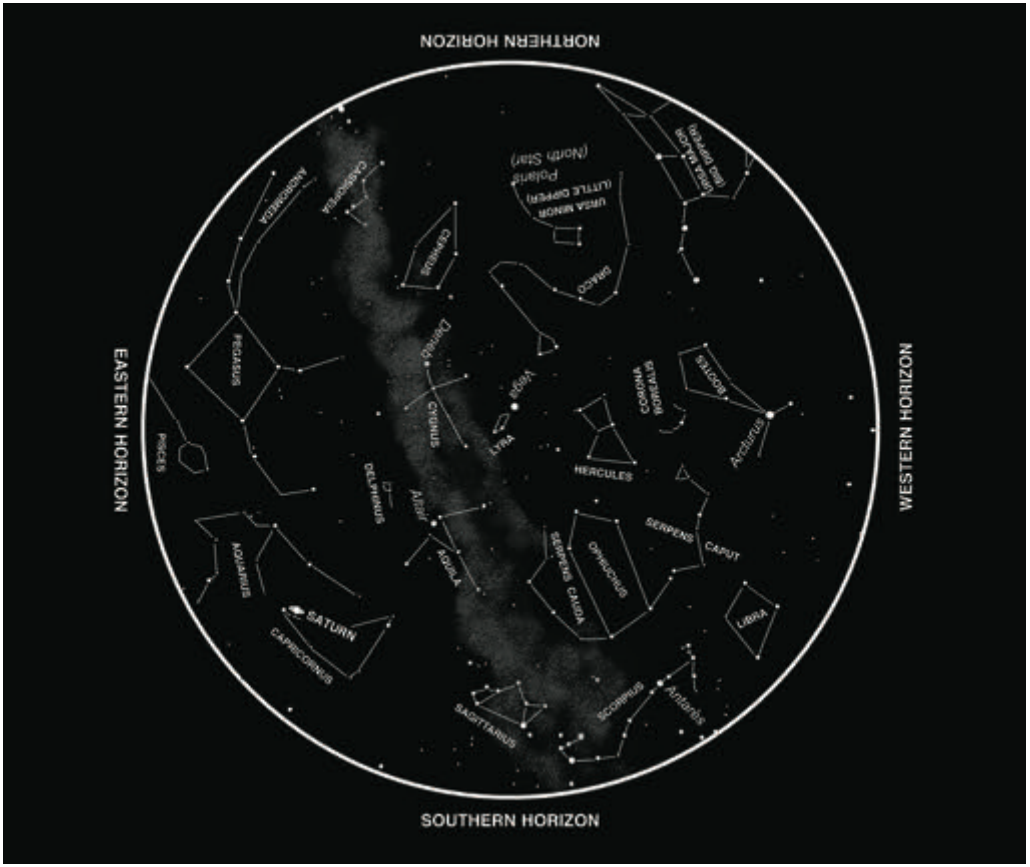
Opening the Gate for Every Color of the Rainbow

Any normal material with a temperature above absolute zero radiates energy in every color there is, and the color it sheds the most is determined by its temperature. The Planck function, developed by German physicist Max Planck in 1900, tells in detail how much energy of a given wavelength is radiated each second by a defined surface area into a defined angle of three-dimensional space. Dr. John Miller shares his preoccupation with infrared light elsewhere in this issue in "How Astronomy Caught the Infrared Wave." Dr. Miller is understandably aligned with the Planck function, which tells us what to expect in the infrared realm, and so he keeps the formula close at hand. It is inscribed on the back gate of his home in Bend, Oregon. (photograph John Lester Miller)

— Dr. E.C. Krupp.
Griffith Observatory

Evening Sky In August

Patrick So
Griffith Observatory



EVENING SKY IN AUGUST

To use: Hold the chart over your head and orient it so that the directions on the outside of the chart match the directions on the ground. The chart shows the entire sky from horizon to horizon at the time indicated.

This chart is set for the latitude of Los Angeles (34° north), but it is useful through out the continental United States and around the world at a similar latitude.

Planet positions are plotted for the 15th of the month. Sidereal times are: Evening chart, $18^h\ 45^m$; Morning chart, $00^h\ 42^m$.

Chart Times

Evening Sky

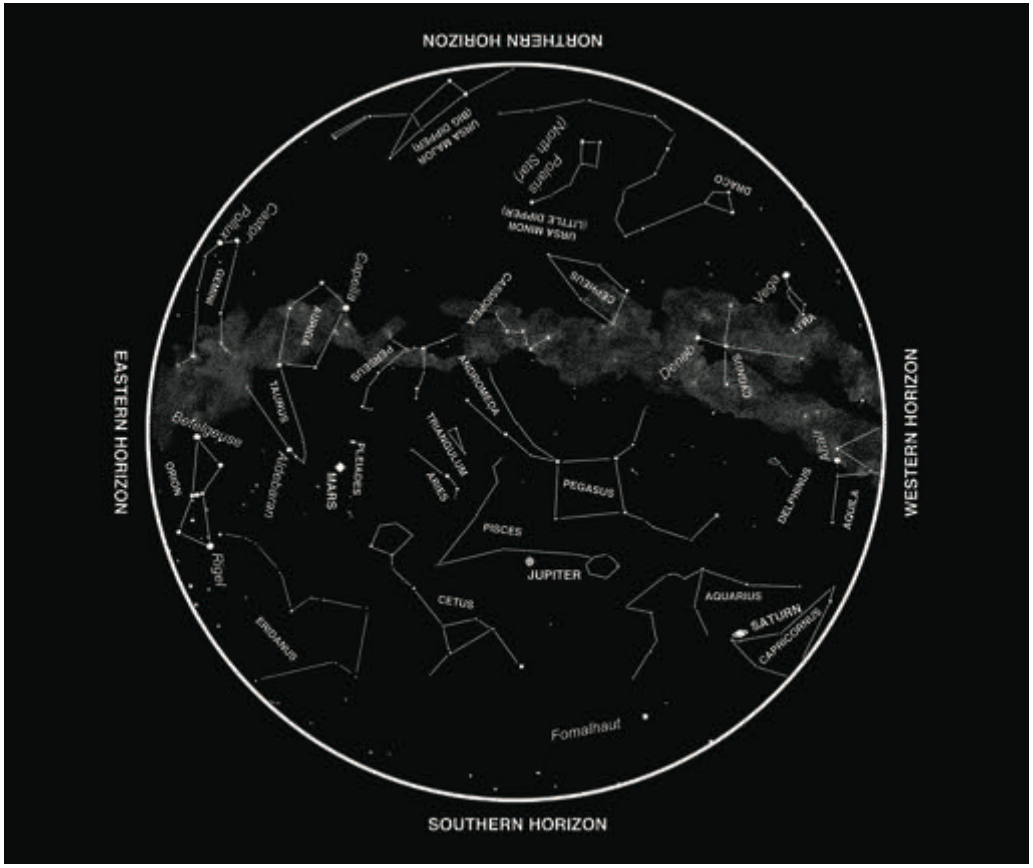
11:00 p.m.	PDT	August	1
10:00 p.m.	PDT	August	15
9:00 p.m.	PDT	August	31

Morning Sky

5:00 a.m.	PDT	August	1
4:00 a.m.	PDT	August	15
3:00 a.m.	PDT	August	31

Morning Sky In August

Patrick So
Griffith Observatory



MORNING SKY IN AUGUST

City of Los Angeles
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