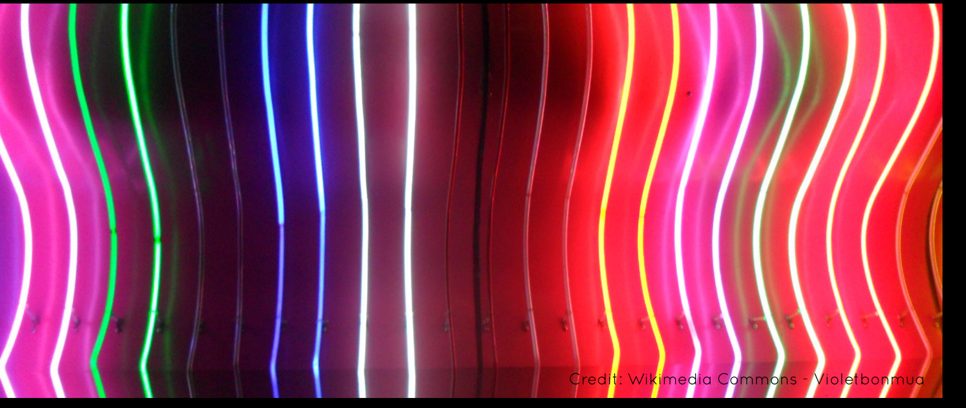
LIGHT
Beyond the Bulb

Whether it comes from the Sun, a distant galaxy or a neon sign around the corner, light is all around us. We use it to communicate, navigate, learn and explore.

INTERNATIONAL YEAR OF LIGHT 2015


Credit: U.S. Navy photo by Cmdr. Ed Thompson


Credit: T.A. Rector / University of Alaska Anchorage and B.A. Wolpa (NOAO / AURA / NSF)


Credit: Wikimedia Commons - Violetbonmua

Light comes in different forms. The light that we see with our eyes is just a fraction of all light. Light also encompasses wavelengths ranging from radio waves to gamma rays in what is called the "electromagnetic spectrum."

Light can be described as a wave, with characteristics and behavior that depends on how far apart the crests from each of its waves are spread (a.k.a. its wavelength"). Alternatively, light can be viewed as composed of a stream of photons, with energies inversely proportional to the various wavelengths of light, so that short wavelengths correspond to high energies.

Nothing in the Universe can travel faster than light. In a vacuum, light travels at about 1.08 billion kilometers (671 million miles) per hour. This means light could circle the Earth 7.5 times in one second.

As light travels, its path can be bent when it goes from one medium to another (such as air to water). It can also be blocked (producing a shadow for example), reflected (as with a mirror), or absorbed (as when a stone is heated by infrared light from the Sun.)

Humans have learned how to harness light and use it in technologies ranging from medical devices to cell phones to giant telescopes.

Together with SPIE (the international society for optics and photonics), the Chandra X-ray Center/Smithsonian Astrophysical Observatory are leading Light: Beyond the Bulb for the International Year of Light 2015 (IYL2015). Light: Beyond the Bulb is a cornerstone project for the International Astronomical Union. IYL2015 was declared by the United Nations and is supported by UNESCO. URL: http://lightexhibit.org/ iyl@cfa.harvard.edu

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When viewed on different scales, things can appear in a whole new light. An optical microscope (also called a "light microscope") uses visible light and a system of lenses to magnify images of very small samples. By taking advantage of various properties of light, including polarization, we can explore the world of single cell organisms, bacteria, and other wonders of the microbial world.

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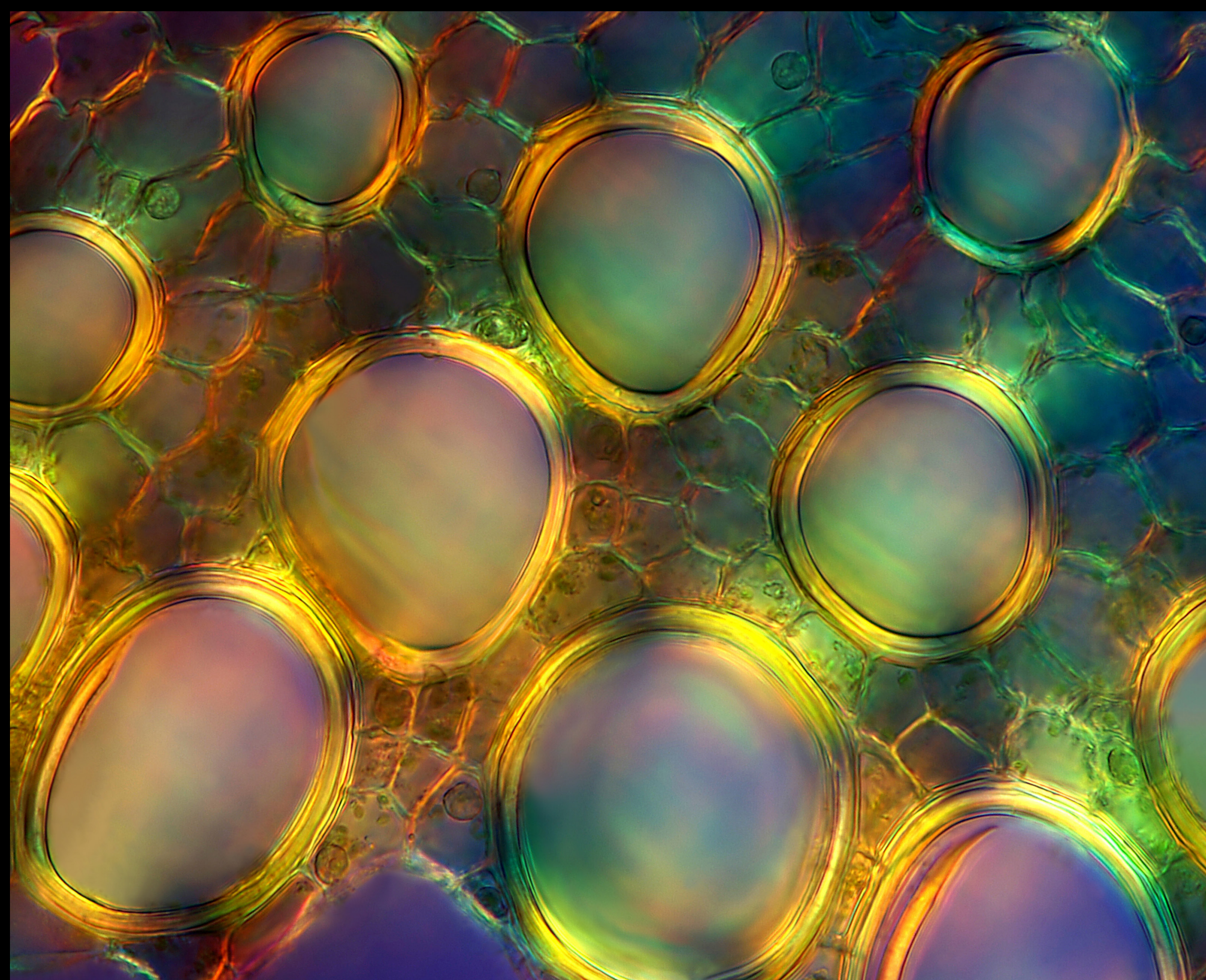

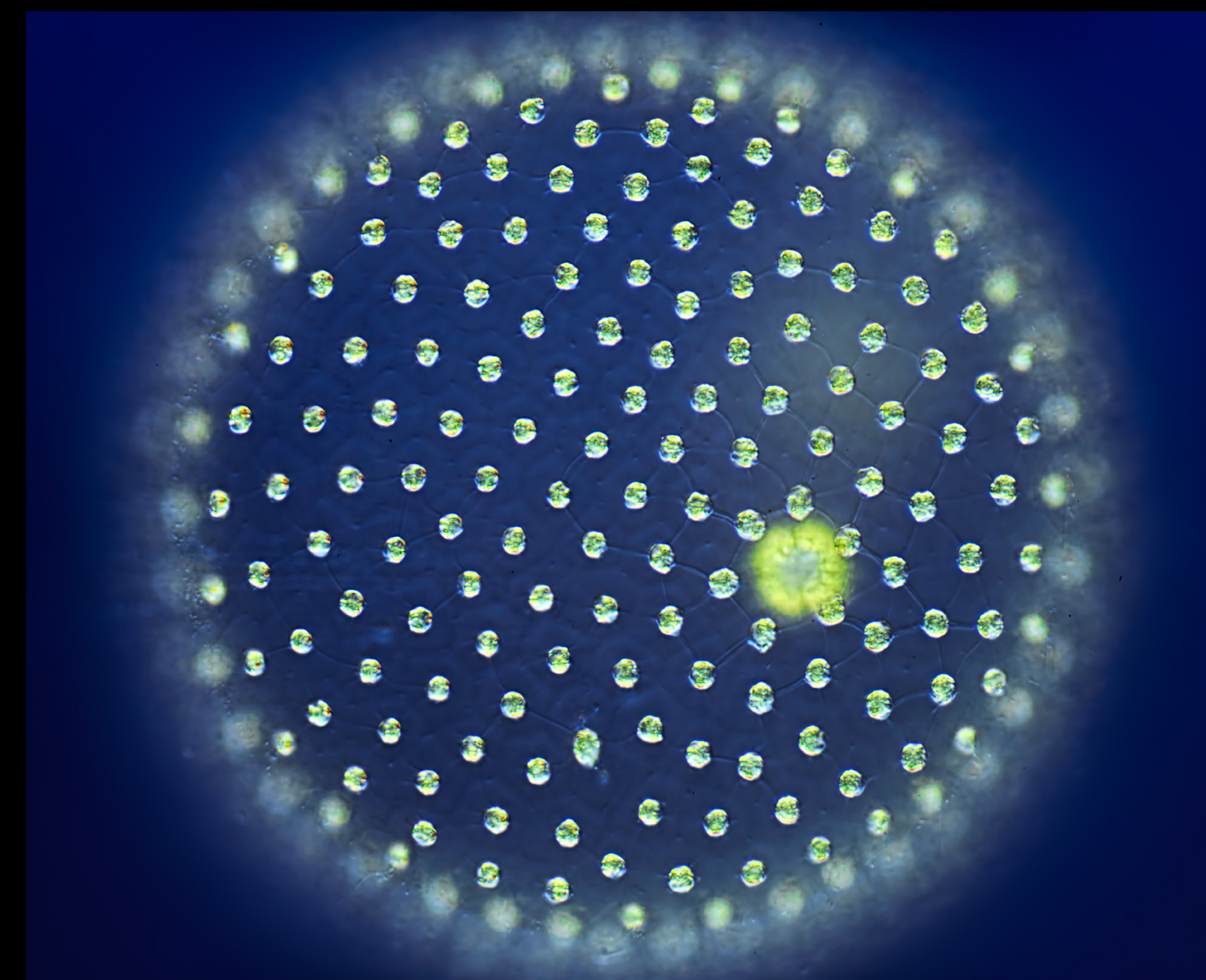

LEVISTICUM

If you come across levisticum in a garden, you will find a tall plant with dark green leaves and greenish-yellow flowers. Under a microscope, however, it looks much different. Here polarized light is used to bring out the details of this plant on the microscopic level. Polarization is used for many things, including sunglasses. These types of sunglasses block most light oriented in a horizontal direction (which often happens when light is reflected from a flat road or smooth water). Under a microscope, polarized light can help us see more by bringing out the contrast between structures and other details otherwise difficult to see in unpolarized light. Credit: Marek Mis

VOLVOX

In this image from an optical microscope, a special technique known as "differential interference contrast" that uses differences in the amount of bending of light by components of the specimen to enhance otherwise undetectable features of these volvox. Volvox are small, colonial green algae that make up a larger spherical colony. The bright green sphere within the colony is a daughter colony, a secondary colony growing on the surface of an older one. Credit: Frank Fox, www.mikro-foto.de

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Light is one of the most important—and non-invasive—tools that doctors and scientists use to learn about the way the body works. The ability to view the internal structures of the brain and eye, as seen in these images, allows researchers to learn about how these critical parts function as well as what happens when things go wrong.

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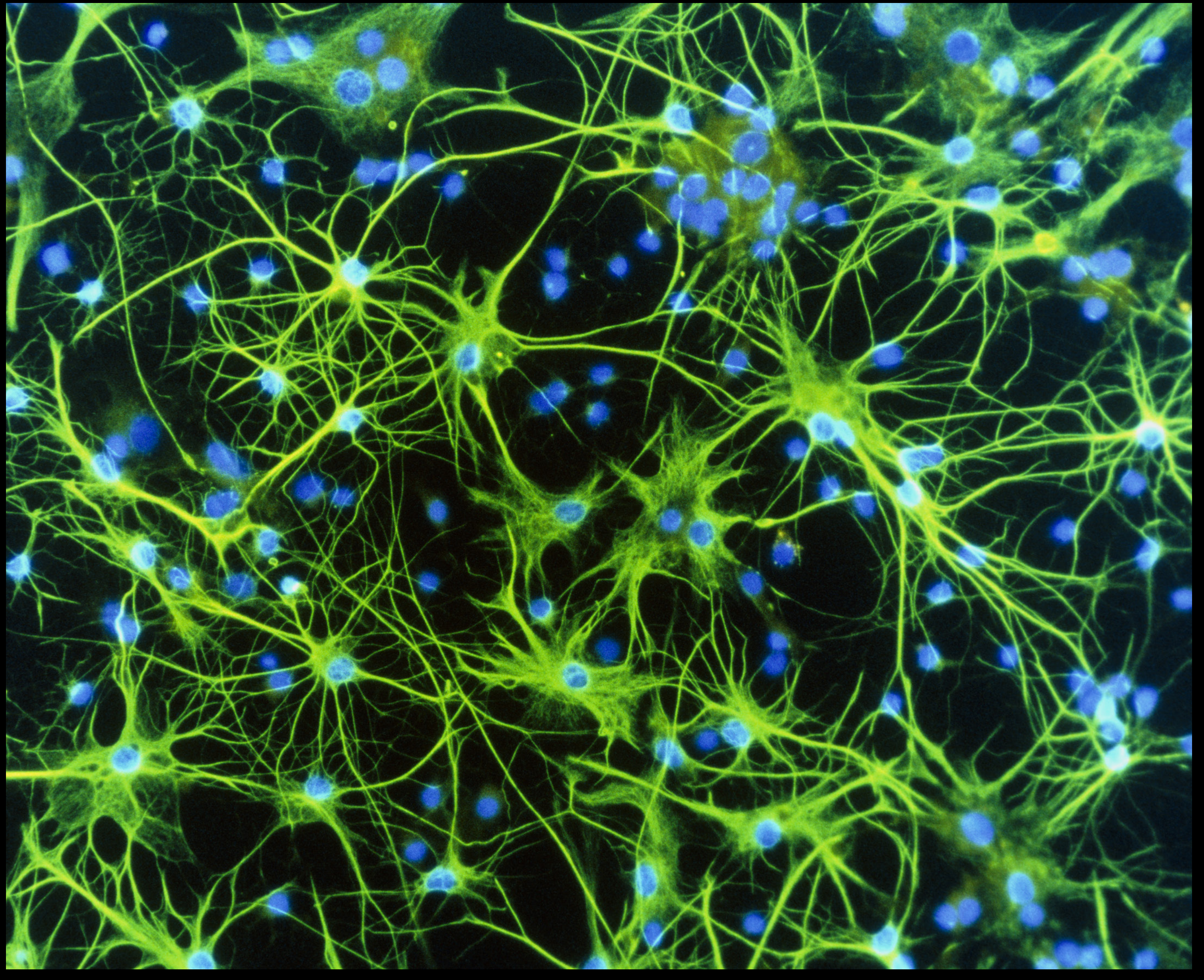
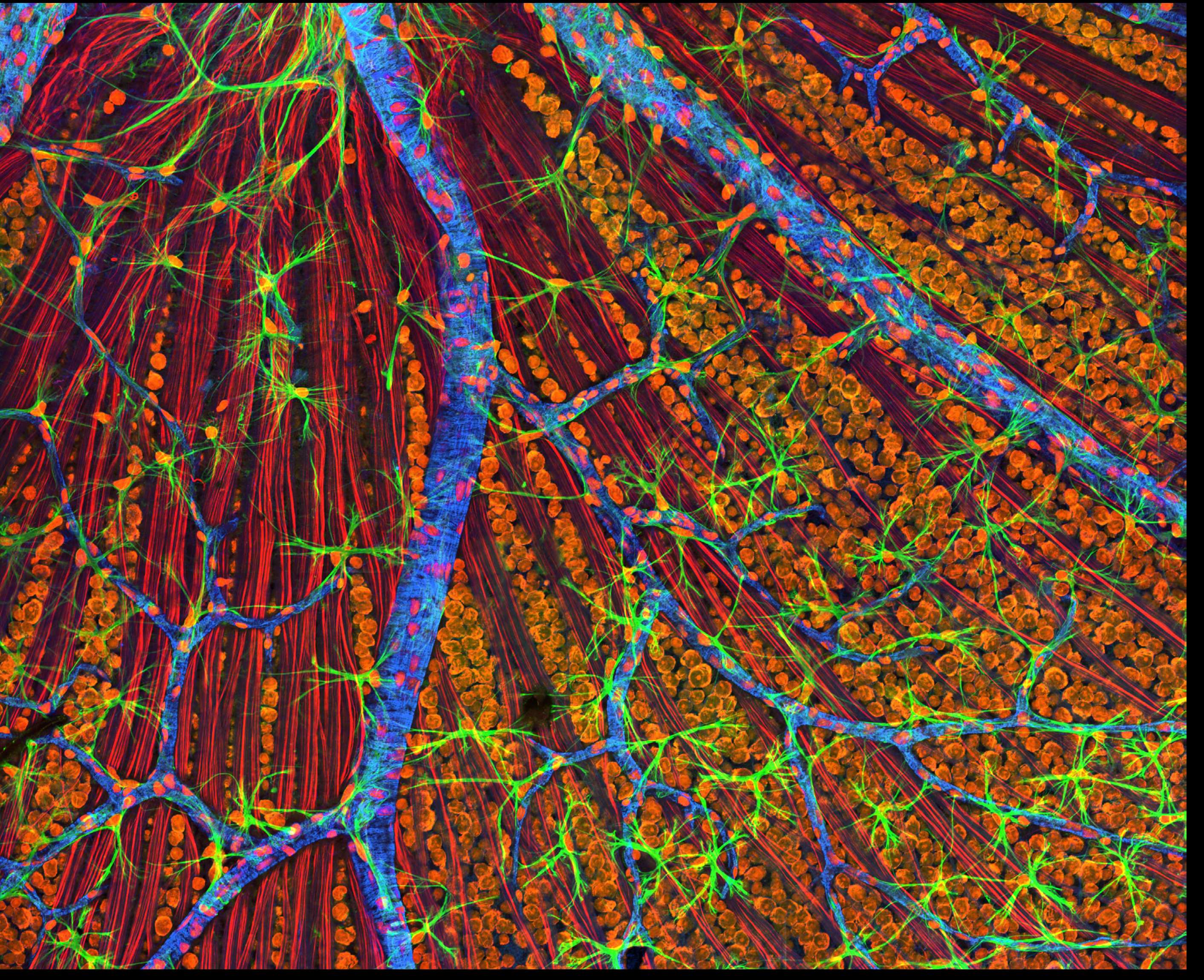


ASTROCYTE BRAIN CELLS

Astrocytes are the star-shaped cells found in spinal cord and the brain. In fact, they are the most abundant cells in the human brain. In this image of astrocytes, the nucleus of each cell has been stained blue while the cytoplasm (the fluid that fills the cell) has been colored green. To achieve this, the process of immunofluorescence was used. Immunofluorescence is a staining technique that uses antibodies to attach fluorescent dyes to specific tissues and molecules in the cell. Credit: Nancy Kedersha / Science Photo Library



MOUSE RETINA

A laser scanning, or "confocal," microscope scans a sample point-by-point or line-by-line at once, assembling the pixel information to generate one image. This allows for a very high-resolution and high-contrast image in three dimensions. The image shown here is from a laser scanning microscope of a mouse retina, where the cells have been stained with fluorescent dye to show different features. By studying the microscopic structure of both diseased and normal retina and optic nerves through this innovative light-based technique, scientists hope to better understand the biology of these tissues and the prospects of developing therapeutic interventions. Credit: National Institute of General Medical Sciences (NIGMS)

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When a light wave strikes an atom or molecule, it can be absorbed. Absorption can occur everywhere and in all types of objects: organic, inorganic, near, and far. The efficiency of absorption depends on the wavelength of the light and the absorbing material.

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BLUELINE SNAPPER – Andaman Sea, Thailand
This spectacularly colorful school of fish contains blueline snappers, a species native to certain parts of the Indian Ocean. The fish themselves do not possess the color we see in this image. Rather, the color is in the light that shines onto them from the Sun above. The atoms and molecules in the fish—as in every object— absorb some wavelengths of light and reflect others. We do not see that particular slice of color corresponding to wavelengths of light that are absorbed. Instead, it is the wavelengths and their respective colors that reflect back to us that allow us to see the dramatic appearance of these fish. Credit: Georgette Douwma/Science Photo Library

BLUEBELLS – Buckinghamshire, England
When light reaches a green plant, many different reactions take place to store the energy from light into sugar (aka, carbohydrate) molecules. The plant doesn't use all of the light that it receives. Plants absorb mainly the red and blue parts of visible light from the Sun. The green color we see most often in plants is there because it is a color that the plant reflects rather than absorbs. The green leaves and grasses in this photograph, found amid this field of bluebell flowers, reflect the green range of light, whereas the bluebells reflect blue light. Credit: Sue Vincent

LIGHT
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Most objects, including living things, do not emit their own visible light. (Many do, in fact, give off other types of light such as infrared.) Rather, a vast majority of things reflect light from the Sun or some other external source. Exceptions to this are those animals and organisms that can produce bioluminescence. The light emitted by bioluminescence is produced by energy released from chemical reactions.

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FLIGHT PATH OF FIREFLIES – Outside Okayama City, Japan

When a living organism produces its own light, scientists call it "bioluminescence." Fireflies, also called lightning bugs, are some of the best-known examples of this process. Fireflies produce light when an organic compound in their abdomen, called luciferin, interacts with oxygen from the air. When this happens, light with a wavelength of between 510 and 670 nanometers—the color of pale yellow to reddish green—is generated. The special cells that hold the luciferin also contain uric acid crystals that help reflect the light away from the fireflies, making them even brighter for other fireflies and humans to admire. Credit: Tsuneaki Hiramatu

BIOLUMINESCENCE – Gippsland Lakes, Australia

Bioluminescence is light produced by a chemical reaction inside a living organism. There are many bioluminescent life forms on land, including different kinds of fungus and insects. Most bioluminescence, however, occurs in water, particularly in the depths of Earth's oceans where sunlight cannot reach. Here we see the bioluminescent glow of marine plankton in the Gippsland Lakes in southeastern Australia. Above the spectacular light of the Milky Way and star trails from a long exposure are also visible. Credit: Phil Hart

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Reflection is a common behavior of light. Here we see visible light from the Sun being reflected off the smooth surface of the lake, but light from radio waves to X-rays can also be reflected. Another shared trait by many types of light is the process of refraction, where light is bent as it passes from one medium to another. This happens in optical light as seen in rainbows like this, but also with light that is invisible to the human eye.

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LAKE REFLECTIONS – Tso Moriri Lake, India
Most objects do not emit light. Rather, they reflect it from a source like a light bulb or sunlight. This common process allows us to see these things that are all around us. In fact, one of the fundamental laws of the physics of light involves reflection. All reflected light obeys the rule that says the reflected ray bounces off the surface at the same angle that the incident ray strikes it. In the case of a smooth surface like a mirror or, in the case of the photograph, the calm top of a lake, a clear identical image is produced. Credit: Prabhu B Doss

SANDSTONE MESAS WITH RAINBOW – Utah, USA
When a ray of light enters a raindrop, its path is bent and it comes out in a different direction on the other side. At the same time, the light is separated into multiple colors as each wavelength of light is bent slightly differently. Part of the light does not simply pass through the raindrop, rather it is reflected back to the front of the raindrop. As it exits the raindrop, the colors of the sunlight are spread out even more. A person viewing this light from the viewpoint where the light has been reflected is treated to the spectacular view of a rainbow, like the one seen here above the mesas in Utah. Credit: David Parker/Science Photo Library

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The simple act of electricity flowing from one point to another is responsible for many phenomena in our lives here on Earth and beyond. The process of "electric discharge" can occur whenever there is a large build up of electric charge. When this happens, many types of light may be generated, including visible light but also more energetic ultraviolet, X-rays and gamma rays.

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LIGHTNING STRIKES – Dubai, United Arab Emirates

In massive storm clouds, the friction between particles composed of many atoms builds up a large separation of electric charge. This, in turn, creates voltages approaching 100 million volts. When the voltage becomes this large, it can cause an explosive electric discharge that heats the gas around it to more than ten thousand degrees, causing a bright glow observed as a lightning bolt. The heat from the lightning bolts also produces sound waves, causing the clap of thunder associated with lightning. The delay we experience between seeing lightning and hearing thunder is due to how much faster light can travel (300 million meters per second) compared to sound waves in air (300 meters per second). Credit: Michael Shainblum

AURORA BOREALIS – Iowa, USA

Some of the most famous light shows in the world are called auroras or, more commonly in the Northern Hemisphere, the "Northern Lights." What causes these spectacular displays? Streams of particles with electric charge are continually leaving the Sun and traveling through the Solar System. As these particles approach the Earth, some of them are channeled by the planet's magnetic field toward the North and South Poles. When these particles collide with atoms in the Earth's atmosphere, the atoms in the atmosphere are excited give off light of a particular color tied to that type of atom. Credit: Stan Richard. nightskyevents.com

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The Earth's atmosphere greatly affects our interaction with light from beyond our planet. It can act as a shield to many types of light, blocking incoming X-rays and gamma rays. The atmosphere can also behave as a lens to the light that does make it through, such as the visible light emitted by the Sun. Here we see two examples of how the atmosphere plays a role in changing the appearance of sunlight to those of us on the planet's surface.

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SUN DOGS AND HALO AROUND SETTING SUN – Iowa, USA

The term "sun dog" refers to a pair of bright lights seen on either side of the Sun, typically when it is setting. Sun dogs belong to a large class of atmospheric phenomena caused by the bending of sunlight by small ice crystals in the air. The crystals act as prisms, bending the light rays. If the crystals are randomly oriented in the atmosphere, a complete ring around the Sun–a halo–is seen, as is the case with this photograph. The best time to see sun dogs is during the winter when the Sun is close to the horizon. Credit: Thomas DeHoff

SUNSET (LENSING) – Iowa, USA

When the path of a light ray is bent, the image of the light source becomes distorted. This is what happens when light is bent as it passes from the air into the lenses of eyeglasses, producing a magnified image. Another commonly seen example of this is at sunset. When sunlight is deflected as it travels through different layers of the Earth's atmosphere, the Sun can appear flattened. This is because the atmosphere acts as a lens. Light from the bottom of the Sun is being bent more than from the top because the light must pass through more of the atmosphere the closer we look to the horizon. The result is that the Sun appears oval in shape. Credit: Thomas DeHoff

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Light affects us every day. From the moment we wake up, we can see and feel the light from the Sun. Today, people are looking to light from our Sun as an energy source that may one day provide power to billions of people across the planet. Humans have also learned how to use light from the cosmos in its many forms to explore the Universe.

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SOLAR PANELS – Colorado, USA

Solar panels allow us to harness some of the vast energy that is provided to us every day from the Sun. Photovoltaic cells within the solar panels generate electrical power by converting light from the Sun into electricity using semiconducting material such as silicon. Solar panels may be used on individual homes or buildings or in large "farms" of networked panels that can provide electricity for large numbers of people and businesses. Many people consider solar power as one of the most promising sources of renewable energy. Credit: Dennis Schroeder / NREL

LASERS – Atacama Desert, Chile

From applications in fields of manufacturing to medicine to the military, lasers are all around us. While there are many different types of lasers, there are some commonalities among them. All lasers are based on enhancing, or stimulating, the emission of light from a specific type of atom in the laser so as to produce a powerful, directed beam. This image shows one innovative use of lasers. By beaming a laser into the sky, astronomers can measure and then compensate for the blurring effects of the Earth's atmosphere, allowing for clearer images of distant cosmic objects. Credit: ESO / B. Tafreshi

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LIGHT
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Light illuminates our homes and roads and powers industries and businesses in many parts of the world. Scientists and engineers around the globe continue to investigate ways to make lighting more efficient, preserving the beauty of dark skies for present and future generations.

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CAR HEADLIGHTS – Belfort, France

While the first headlights on cars were fueled by kerosene or acetylene, today's versions are far safer and more effective. Many car headlights these days are powered by running electricity through a gas that causes it to glow brightly. Technology has led to new innovations in the bulbs, with newer cars using halogen or light-emitting diodes (LEDs) instead of incandescent bulbs. In the future, reflected lasers may power more of our headlights, providing a more powerful and energy-efficient (yet still safe) beam that lights our way through the night. This photo combines 8 photos, each lasting for 30 seconds. Credit: Thomas Bresson, https://www.flickr.com/people/36519414@N00

WELCOME TO THE GRID – Utah, USA

There are many different ways cities can produce light. Streetlights glow either through traditional sodium lamps or by newer and more efficient light-emitting diodes (a.k.a., LEDs). Headlights in cars use sophisticated lamps that shine their light directly ahead yet are diffused enough to not interfere with the vision of oncoming drivers. Through the collisions of electrons and atoms, neon signs glow with their distinct look. Taken together, light defines our modern cities in many ways, as seen here in this photograph of Salt Lake City, Utah taken by astronauts aboard the International Space Station. Credit: NASA

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Artificial lighting has brought many benefits to humanity, but it can also have negative consequences. The term "light pollution" refers to light that is wasteful or excessive and disrupts ecosystems, wastes energy, and disconnects us with the night sky. There are many people worldwide who are working to address issues related to light pollution, including improving the efficiency of lighting to keep the skies as dark as possible.

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EARTH LIGHTS FROM THE SPACE STATION

While moving at 17,000 miles per hour at an altitude of 240 miles above the Earth's surface on the International Space Station, NASA astronaut Don Petit was able to capture the lights from our planet in a unique way. His time-lapse photographs—taken from this unusual vantage point—feature star trails, terrestrial lights, and auroras. This image and others like them show how much artificial light from technology leaks into our shared night sky. Efforts are being made around the world to limit this so-called light pollution and keep the night skies dark for everyone to enjoy. Credit: NASA/JSC

THE EARTH AT NIGHT

Without the light from the Sun shining upon it, our Earth appears like a dark disk. This shroud of darkness falls every 24 hours as the Earth spins on its axis. The Sun's light rises in the east and eventually fades below the horizon in the west, ushering in night. There are still many places around the globe where our view of the night skies is unimpeded. However, in many urban, suburban, and even rural areas, artificial lighting and industrial development drown out the light from distant cosmic objects. Credit: NASA

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In certain circumstances, our most familiar celestial objects, the Sun and Moon, can appear much differently. A lunar eclipse can cause the surface of the Moon to appear to change colors due to reflected light traveling through the Earth's atmosphere. Likewise, if we look at the Sun in ultraviolet light through a telescope in space, it no longer looks like the yellow disk we see from the ground.

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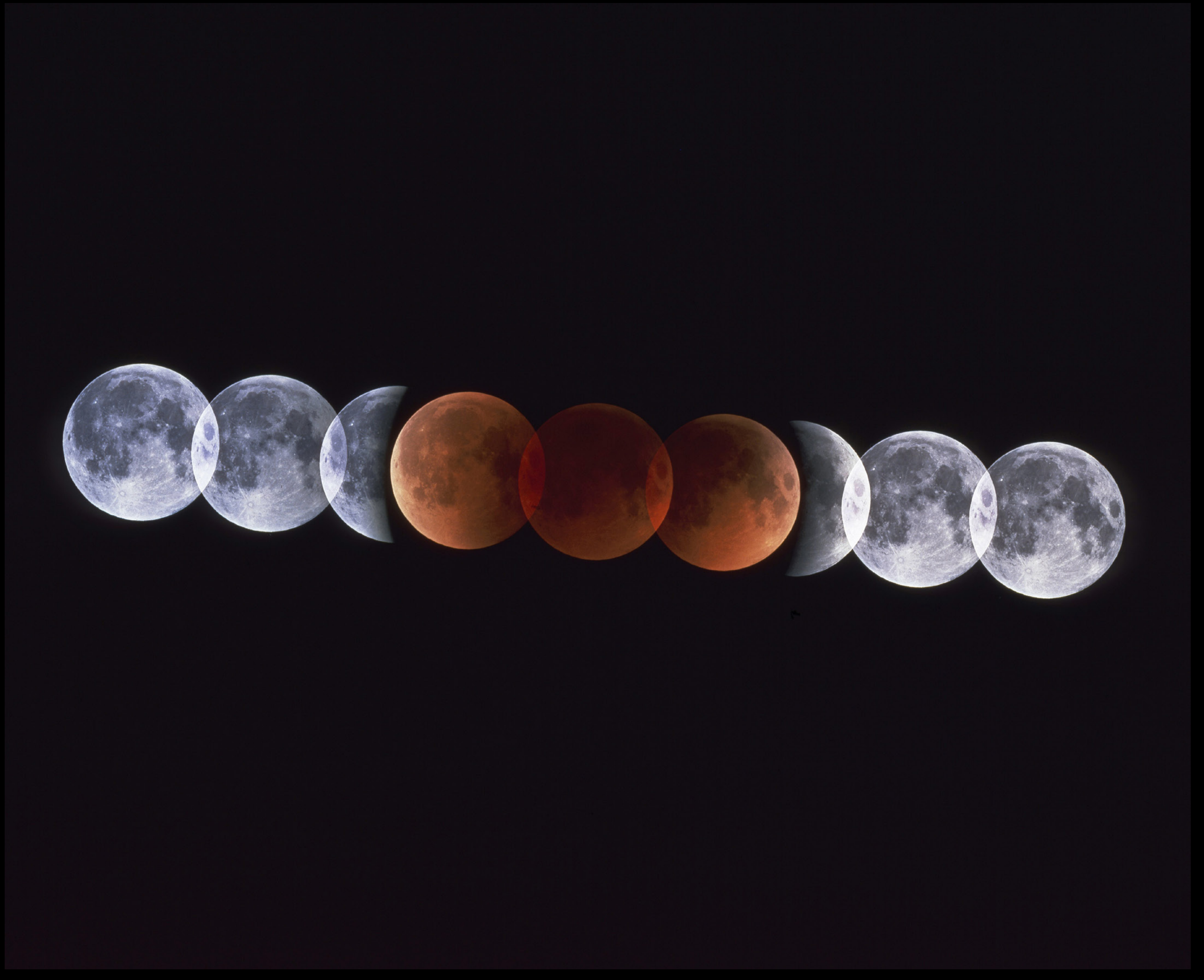
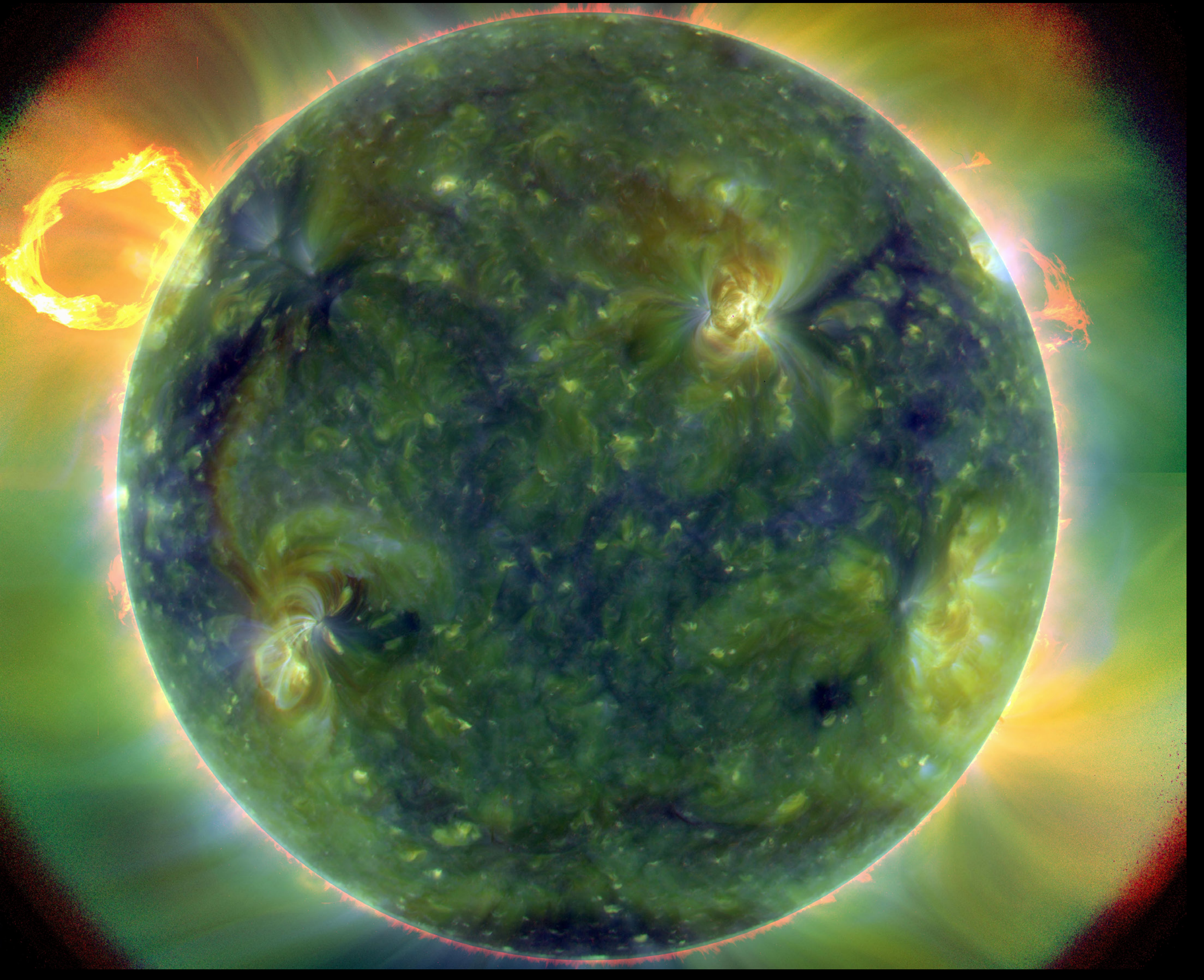


LUNAR ECLIPSE – 1.25 light seconds from Earth

When the Moon passes through the shadow of the Earth, a lunar eclipse occurs. During such an event, light from the Sun still reaches the Moon. However, before sunlight reaches the Moon, it must pass through dense layers of the Earth's atmosphere. When this happens, the light is scattered by molecules of air and other small particles in the atmosphere. The shorter, or bluer, wavelengths of light are scattered more, so mainly only the red part of sunlight reaches the Moon. This is why the Moon appears to be orange or red during a lunar eclipse. This multiple-exposure image was taken during a lunar eclipse on July 16, 2000. Credit: Akira Fujii/Ciel et



SUN IN ULTRAVIOLET LIGHT – 8.3 light minutes from Earth

When we look at the Sun from the surface on the Earth, it typically looks yellow to us because it gives off its most intense radiation in that color of visible light. However, if we observe the Sun in the "other" types of light that it emits, we are exposed to an entirely different looking object. Here we see the Sun in ultraviolet light through a telescope with better resolution than the most sophisticated high-definition television. This telescope, called the Solar Dynamics Observatory, gets these amazing views of our closest star in an orbit high above the Earth's atmosphere. This gives it access to ten different wavelengths of sunlight. Credit: NASA/SDO

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Objects in the Universe frequently give off many types of light. By detecting this variety of light through different telescopes and instruments, scientists can learn about the physical properties that govern these objects and reveal their nature. Whether it is from a radio telescope on the ground or an X-ray satellite in space, scientists use every tool at their disposal to improve our knowledge of the cosmos.

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NGC 602, A.K.A. THE SMALL MAGELLANIC CLOUD – 180,000 light years from Earth

The Small Magellanic Cloud, a dwarf galaxy that is one of Milky Way galaxy's nearest neighbors, is so bright in the southern night sky that navigators for centuries—including Ferdinand Magellan, for whom it is named—have used it to help guide them across the ocean. Modern telescopes reveal there is much more to this object than just being a bright cloud seen from the sea. This image combines three different types of light to give us this spectacular view. X-ray light is purple, infrared light is red, and optical light is red, green, and blue. Together, these different slices of light give us a more complete picture of a stellar nursery where stars like our Sun are being born.

Credit: X-ray: NASA/CXC/Univ. Potsdam/L. Oskinova et al.; Optical: NASA/STScI; Infrared: NASA/JPL-Caltech

ANTENNAE GALAXIES – 45 million light years from Earth

The Antennae are two galaxies in the process of merging. They were once spiral galaxies like our Milky Way, but they have been interacting and colliding for hundreds of millions of years and are morphing into a new object. Infrared and visible light captured in this image from the Hubble Space Telescope give us clues about the cosmic chaos going on. Clouds of gas are shown in pink and red, while the cores of the galaxies, where some of the older stars remain, are yellow. The blue-colored points and regions are where star formation, triggered by the galactic merger, are happening at a furious rate. Astronomers think this light-filled cosmic postcard is a preview of what will happen to our Galaxy when the Milky Way and its neighbor, the Andromeda Galaxy, collide in a few billion years.

Credit: NASA/ESA/Hubble Heritage Team (STSCI/AURA)-ESA/Hubble Collaboration

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Even when objects do not give off light, we can still learn much about them from the indirect impressions they make in light. Take, for example, dark matter. This mysterious substance makes up a majority of matter in the Universe, but it does not emit or absorb light. Yet we can see its gravitational effects imprinted in cosmic light.

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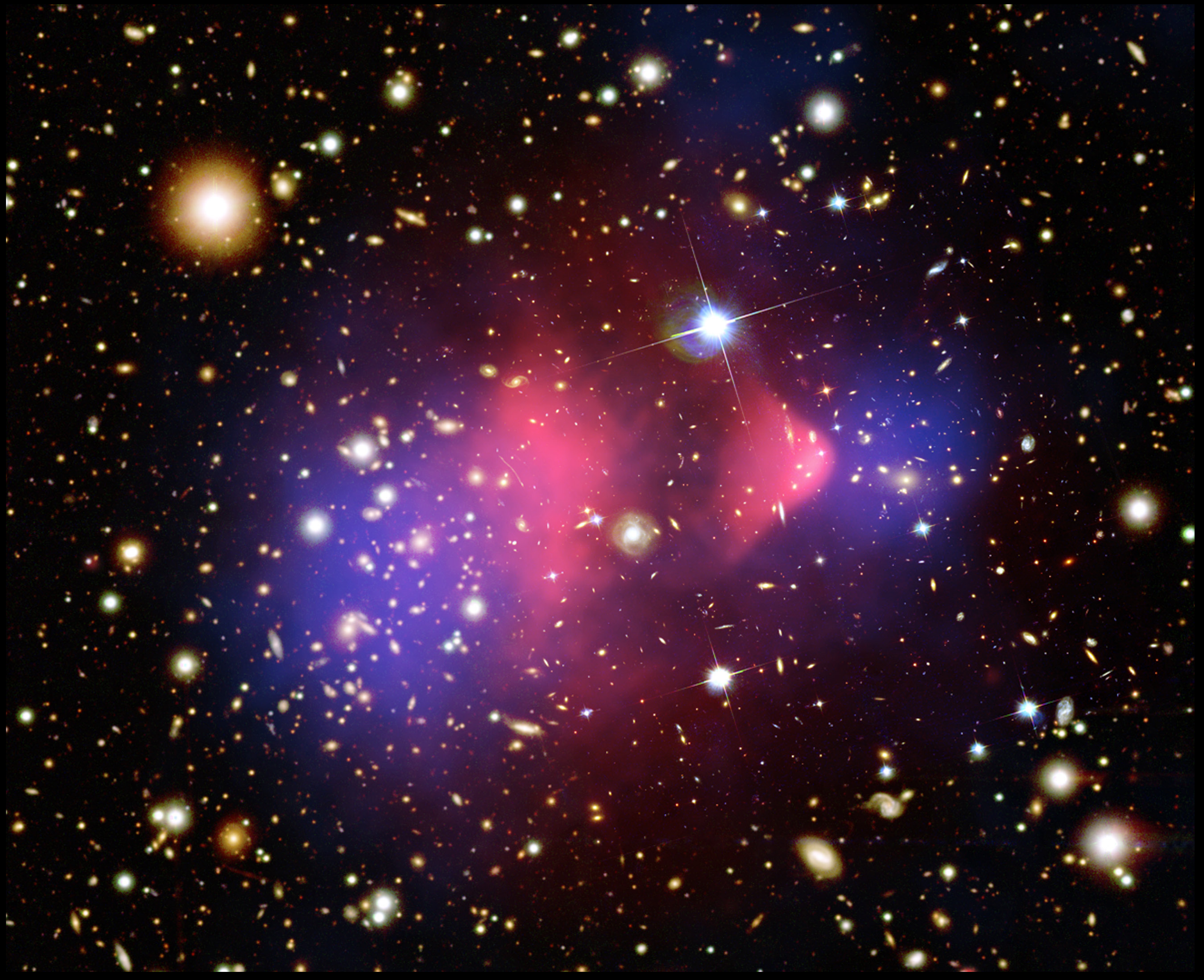
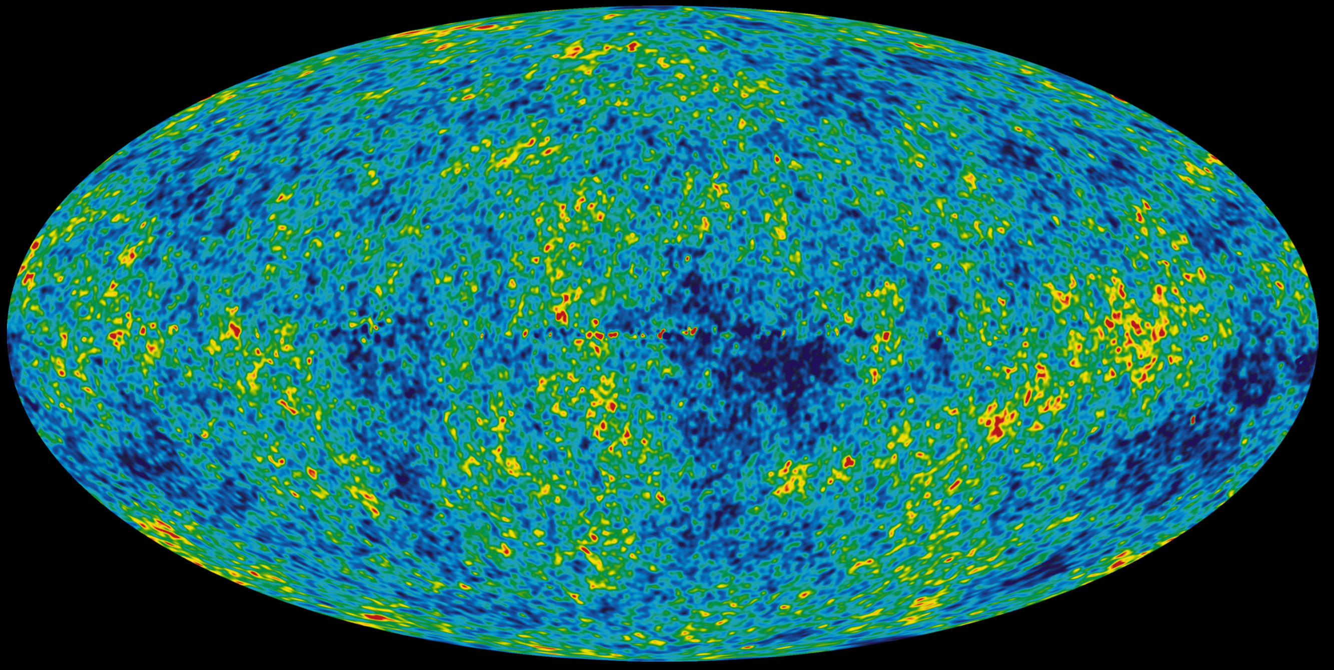


BULLET CLUSTER – 3.4 billion light years from Earth

This image of two colliding clusters of galaxies is a special snapshot that contains X-ray light, visible light, and the inferred presence of dark matter, the mysterious substance that pervades the Universe. The pink areas are where hot, X-ray emitting gas is found. The bending of light from distant background galaxies by the massive clusters shows astronomers the location of unseen dark matter (blue). The combined image shows that hot gas has been ripped apart from the dark matter by the force of this colossal collision. Therefore, even though it does not emit light itself, clues about the amount and distribution of dark matter can be obtained from the effect it has on light from cosmic sources. Credit: X-ray: M.Markevitch for NASA / CXC / CfA and visible light by D. Clowe for NASA / STScI; Magellan / U. Arizona and ESOh



COSMIC MICROWAVE BACKGROUND – 13.7 billion light years from Earth

The cosmic microwave background is the oldest light in the Universe, the afterglow of the Big Bang. This ancient light arrives to us not as the type of light we can see with our eyes, but in the form of microwaves, a type of light with wavelengths between radio and infrared light. This image was made by the WMAP satellite and shows the whole sky unfolded onto a flat image. The different colors show tiny variations in temperature that existed when the Universe was about 380,000 years old, and had cooled enough after the Big Bang for light to travel large distances without absorption. These fluctuations are thought to be the structures that eventually formed into galaxies. Credit: NASA / WMAP Science Team

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Since ancient times, humans have sought to understand and utilize light. Over the centuries, some of the greatest minds have taken on this quest. Today our lives have been enriched by what we have learned about light.

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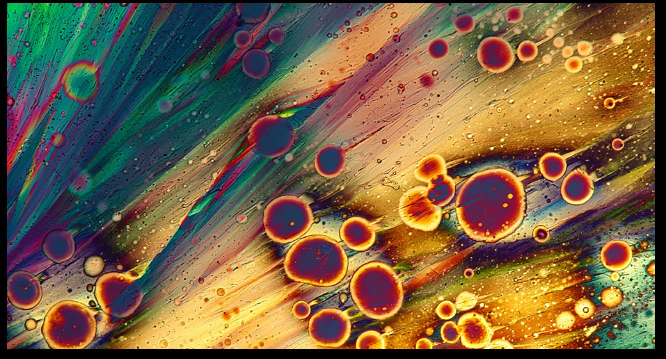


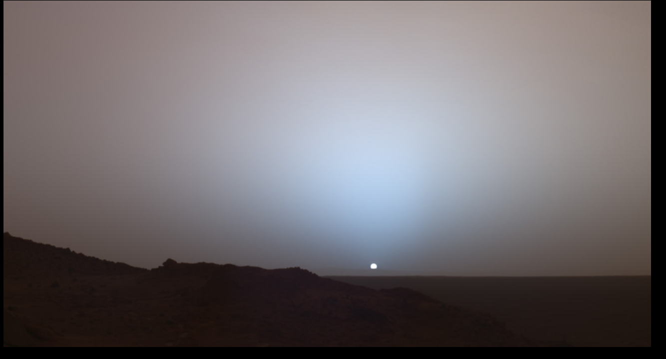
Polarized Photomicrograph
Credit: Marek Mis

Sunflowers North Dakota, USA
Credit: USDA

Lenticular Clouds
Credit: Serge Ouachée

Stardust Santa Barbara, California, USA
Credit: Michael Shainblum

Comet Hale-Bopp
Credit: Dan Schechter



Sunset On Mars
Credit: NASA/JPL/Texas A&M/Cornell

Our Galaxy in Many Kinds of Light
Credit: X-ray: NASA/CXC/UMass/D. Wang et al.; Optical: NASA/ESA/STScI/D.Wang et al.; IR: NASA/JPL-Caltech/SSC/S.Stolovy

Helix Nebula
Credit: ESO

In all of its different forms, light enhances our lives. We rely on light—both natural, and sources made by humans—to brighten our world. Scientists and engineers around the globe continue to investigate ways to make our use of light ever more efficient. Simultaneously, people are looking to light from our Sun as an energy source that may one day provide power to billions of people across the planet.

We use light to monitor our climate and forecast our weather. We use observations of light from extraterrestrial sources to explore distant galaxies and learn more about our own planet. We use light to build better industry and manufacturing, which helps drive our global economy.

Light comes to us in a myriad of ways, from X-rays from deep space, to the beauty of a rainbow, to important calls made and received through radio waves in our cell phones.

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