

The Power of Night

Interpretive Handbook







Star Trails: European Southern Observatory/A. Santerne



James Webb Telescope Deep Field Image. Photo: NASA

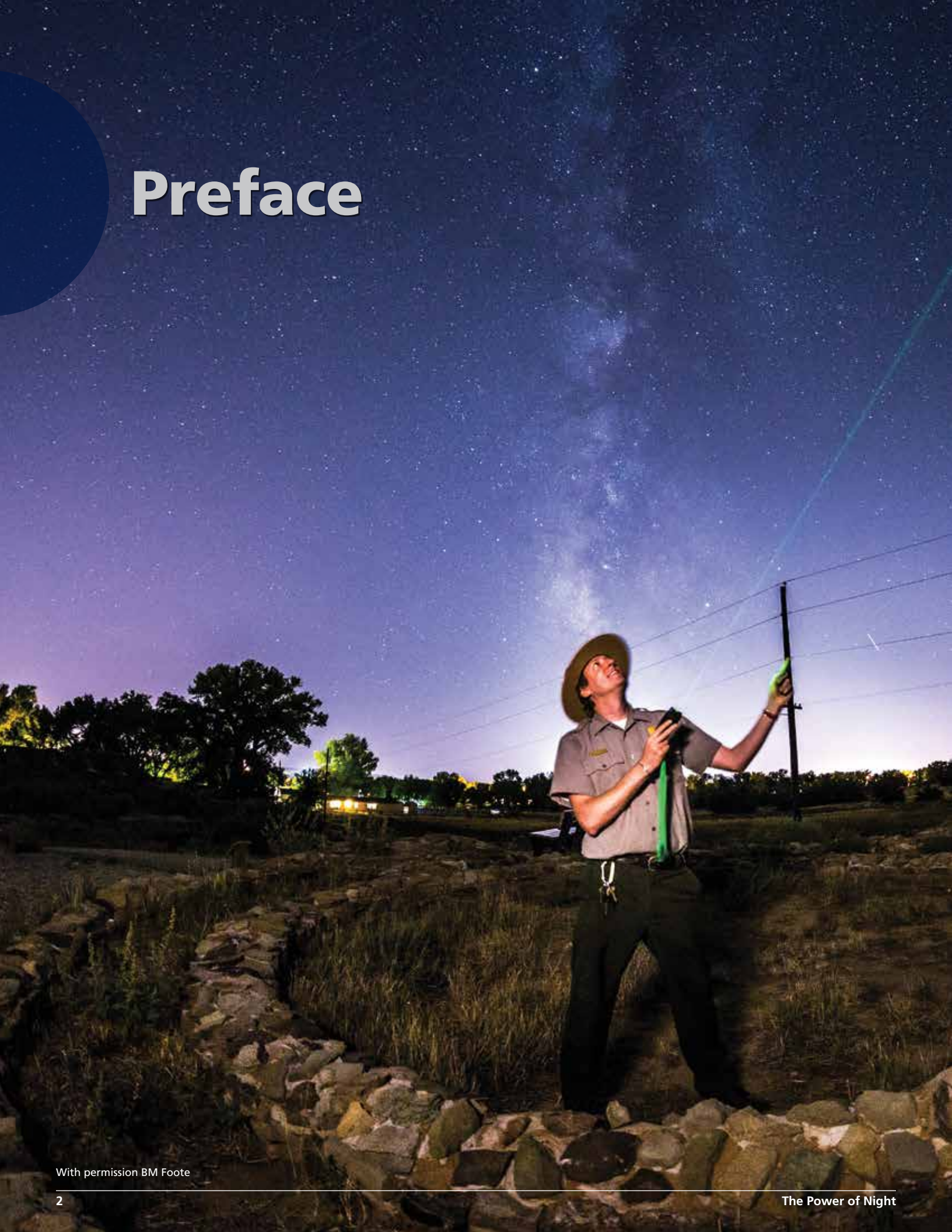


Denali National Park, Aurora Borealis. Photo: NPS

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Preface





Goals

The goal of this handbook is to inspire and empower interpretive rangers to play leading roles in night sky interpretation and protection by increasing understanding of night skies and NPS management.

Contextual Notes

Throughout this handbook, descriptive phrases such as “night sky,” “night sky views,” and similar variations appear. These phrases refer to celestial phenomena, yet are also meant to include broader concepts relating to nocturnal, or nighttime environments. The NPS Natural Sounds and Night Skies Division (NSNSD) considers both night views and nocturnal environments to be interdependent, essential aspects of night sky resource protection. The night sky gives us a cosmic wilderness to ponder, whereas the night environment is needed for healthy functioning of animals and people on the land below.

The word “dark” is often used in the common vernacular to describe the night sky. NSNSD sees this word as both problematic and practical—problematic because a night sky is not dark but filled with numerous sources of celestial light; practical because when night falls, it does get dark. Thus, we recommend using the terms “naturally dark skies” or “natural night skies” to describe night, especially in contrast to a sky brightened by light pollution.

For some people, dark means scary, and reducing light may not be perceived as a good thing. In some cases, the word carries cultural-historic, fear-based associations—of criminals, dangerous animals, and hidden “evils.” For this reason, take care when choosing words to convey the night and as you explore perceptions with visitors. Phrases like “starry nights,” “night views and environments,” or “naturally dark night skies” can be good, alternate choices. NSNSD hopes this book provides concepts sufficient for diffusing fears and inspiring people to embrace the special qualities of night.

Part One

*“Though my soul may set in darkness, it will rise in perfect light;
I have loved the stars too fondly to be fearful of the night.”*

— *“The Old Astronomer” by Sarah Williams*



Natural Cycles of Light and Dark

For millennia, the night sky has been a collective canvas for our stories, maps, traditions, beliefs, and discoveries. From the origins of life, daily cycles of light and dark have shaped the structure of our bodies and behavior. These cycles are ingrained in our DNA. Humans need darkness for sleep and healthy immune functioning. Animals and plants, too, rely on natural dark skies. Bats forage for food, song birds migrate following the stars, and corn grows by moonlight.

Over the course of time, continents have formed and eroded, sea levels have risen and fallen, the chemistry of our atmosphere has changed, while this daily light-dark cycle has remained much the same. . . until the last 100 years. Light pollution is often the most common and pervasive of human influences on the natural world. As sky glow floods across our communities and into wildlife habitat, it disrupts our connection to these light-dark cycles, as well as opportunities for nighttime discovery and wonder. Unlike other conservation challenges, we have the opportunity to restore the night sky. Simple changes in lighting practices can reveal the cosmos as it has been for millennia.

Laws and Policies

The **Organic Act of 1916** directs the National Park Service to “conserve the scenery and the natural and historic objects and the wildlife therein, and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations.”

While scenery is traditionally associated with geologic formations, distant vistas, and sublime landscapes, it also includes the night sky, which is part of a complex ecosystem that supports natural, cultural, and economic resources.

Naturally dark skies allow natural processes and rhythms to progress unimpeded. Many species rely on natural patterns of light and dark to navigate, nest, mate, hide from predators, and cue behaviors. Part Two elaborates on these behavioral connections.



The quality of the night sky and nighttime environments in parks is relevant to every unit in the National Park System, as these conditions affect the quality of many other park resources, such as wildlife, wilderness character, visitor experience, cultural landscapes, and historic preservation.

The NPS Natural Sounds and Night Skies Division is a leader in measuring light pollution and reducing its effects on night sky resources.

Located in Fort Collins, Colorado, the Night Skies team of scientists, engineers, policy experts, and communication staff assess, protect, and restore nighttime views and environments through research, field work, outreach, planning, and partnerships. The division works with national parks, federal agencies, and community organizations to develop guidance, policy, and best practice solutions for reducing light pollution. Data gathered in parks helps park managers evaluate lighting conditions and make improvements, like replacing outdated lighting with sustainable, night sky-friendly lights—simple yet effective changes that reduce glare from washing out celestial light to help conserve ecological integrity and enhance visitor experiences.

Learn more about the role of NSNSD in Part Two.

Night sky over Bristlecone pine trees at Great Basin National Park, Nevada. Photo: NPS / Kelly Carroll

Naturally dark skies also contribute to positive visitor experiences. Millions of people live in urban areas where the night sky is obscured by light pollution. When pristine night skies are visible, visitors experience a vastly different way to see their world.

With interpreters' help in raising awareness about the value of the night sky to park resources, we aim to inspire park visitors to protect and enjoy the same starry views that our ancestors looked upon.

The Wilderness Act of 1964 recognizes wilderness as “an area where the earth and its community of life are untrammelled by man, where man himself is a visitor who does not remain.”

Night sky protection enhances wilderness qualities of solitude, naturalness, and untrammelled, undeveloped character that animals depend on for survival, park visitors seek for connections, and many cultural-historical parks require for preservation. Naturally dark night skies are also considered an air quality related value under the Clean Air Act Amendments of 1977. Air quality can affect the quality of the night sky.

NPS Policy 4.10: Lightscape Management directs the Service to preserve, to the greatest extent possible, “the natural lightscapes of parks, which are natural resources and values that exist in the absence of human-caused light . . .”

NPS Director's Order 50C: Public Risk Management Program requires park superintendents “to identify risks within their jurisdiction and to mitigate these risks within the limits of available resources without compromising the integrity of the environments they are charged to protect.”

Key Messages

Natural night skies and light-dark cycles are critical to wildlife survival, and part of our human experience.



Light pollution interferes with sky quality and the health of wildlife and people.



The NPS uses science-based stewardship to assess, protect, and restore night skies.



Everyone can help protect night skies; actions have immediate benefits.

Photo: Ron Warner, Dark Ranger Telescope Tours

The Role of the Interpreter

Our parks offer some of the nation's best views to near pristine night skies, with diverse opportunities for visitors to experience parks after sunset, from full moon hikes and stargazing programs to candle-lit, battlefield tours and constellation stories. Countless visitors have remarked seeing the Milky Way clearly for the first time in parks, or as they remembered it from childhood.

Park interpreters can introduce visitors to astronomy and the importance of naturally dark night skies to plants and wildlife, explore cultural and historical connections to the night sky, and build a shared sense of stewardship for its protection. The night sky is a common resource. No matter where you are, if you look up at night, you will see the night sky. Increasing your knowledge of this spectacular resource can be valuable no matter where you work or live.

Night sky programs are increasingly popular among visitors. Astronomy programs invite visi-

tors to experience a different aspect of the park and can help them form deeper connections to the park. In addition, visitors can play an active role in preserving the night sky by selecting night sky-friendly choices at their homes and working within their communities to change lighting practices. Unlike many conservation challenges, the night sky exists behind the veil of light pollution. With better lighting practices, both inside parks and cities the natural night sky can be restored and revealed.

Night sky interpreters can reveal a whole new way of experiencing the park and help visitors create lasting memories they can revisit every time they look up.

Part Two

“Most of humanity lives under intersecting domes of reflected, refracted light, of scattering rays from overlit cities and suburbs, from light-flooded highways and factories.”

*— Verlyn Klinkenborg,
author of “Our Vanishing Night”*

Myth

The more light, the better.

Fact

There comes a point when too much light is wasteful and harmful. Excessively bright, numerous, or unshielded lights cause glare and light trespass, and waste energy.

Light pollution also prevents the human eye from fully dark-adapting, meaning that more light does not always equal safer conditions. Sometimes the more light there is at night, the less we can see, as high contrast makes shadows darker.

Skyline night view from Milson Point, Sydney, Australia.
Photo: Pookrook/Adobe Stock



Light Pollution

Outdoor lights are encroaching upon vast regions of what were once supremely dark skies. Light pollution is not limited to urban environments: skyglow produced by the concentration of city lights can be seen as far as 200 miles from its source. Nocturnal habitat is also affected, with consequences for wildlife that depend on natural light-dark cycles.

Untamed by time, the night is a refuge for discovery.

Dark zones on nighttime satellite images are few and far between in urban populated areas, such as the eastern half of the U.S. As populations of people and cities have grown, so, too, has light pollution. Many Americans do not have opportunities to see the Milky Way or a truly dark sky. Light pollution's rapid growth rate over the last 100 years also brings a range of other consequences.

Light pollution washes out the view of the night sky for many Americans, and degrades nocturnal environments. The rising tide of lights is even reaching remote national parks.

Impacts

Light and Wilderness Qualities

Humans seek out the night sky for many reasons, from contemplation to discovery. In the following quote from *The Elegant Universe*, author and Columbia University physicist Dr. Brian Greene expresses that access to a naturally dark night sky gives us perspective on our place in the universe.

"I have long thought that anyone who does not regularly, or ever, gaze up and see the wonder and glory of a dark night sky filled with countless stars loses a sense of their fundamental connectedness to the universe. But a clear night sky and a little instruction allow anyone to soar in mind and imagination to the farthest reaches of an enormous universe in which we are but a speck. And there is nothing more exhilarating and humbling than that."



Myth: People can go out of town to see naturally dark night sky views without light pollution.

Fact: It is no simple task to get away from outdoor light. Urban sky glow—the dome of light hanging over almost all cities—extends for many miles. This situation has arisen from a rapid growth in outdoor lighting, as well as population growth. As cities like Flagstaff, AZ and national parks like Big Bend have demonstrated, outdoor lighting can enhance the human outdoor experience without degrading the sky and adjacent landscapes. Bright areas on this nighttime satellite image show concentrations of stray light from outdoor lighting. The image reveals that it is difficult to find places far removed from city lights. NPS scientists and a team of international researchers estimate that light pollution blots out the Milky Way for eight out of ten Americans. An international team of researchers has released the new World Atlas of Artificial Sky Brightness, a paper published in *Science Advances*.¹

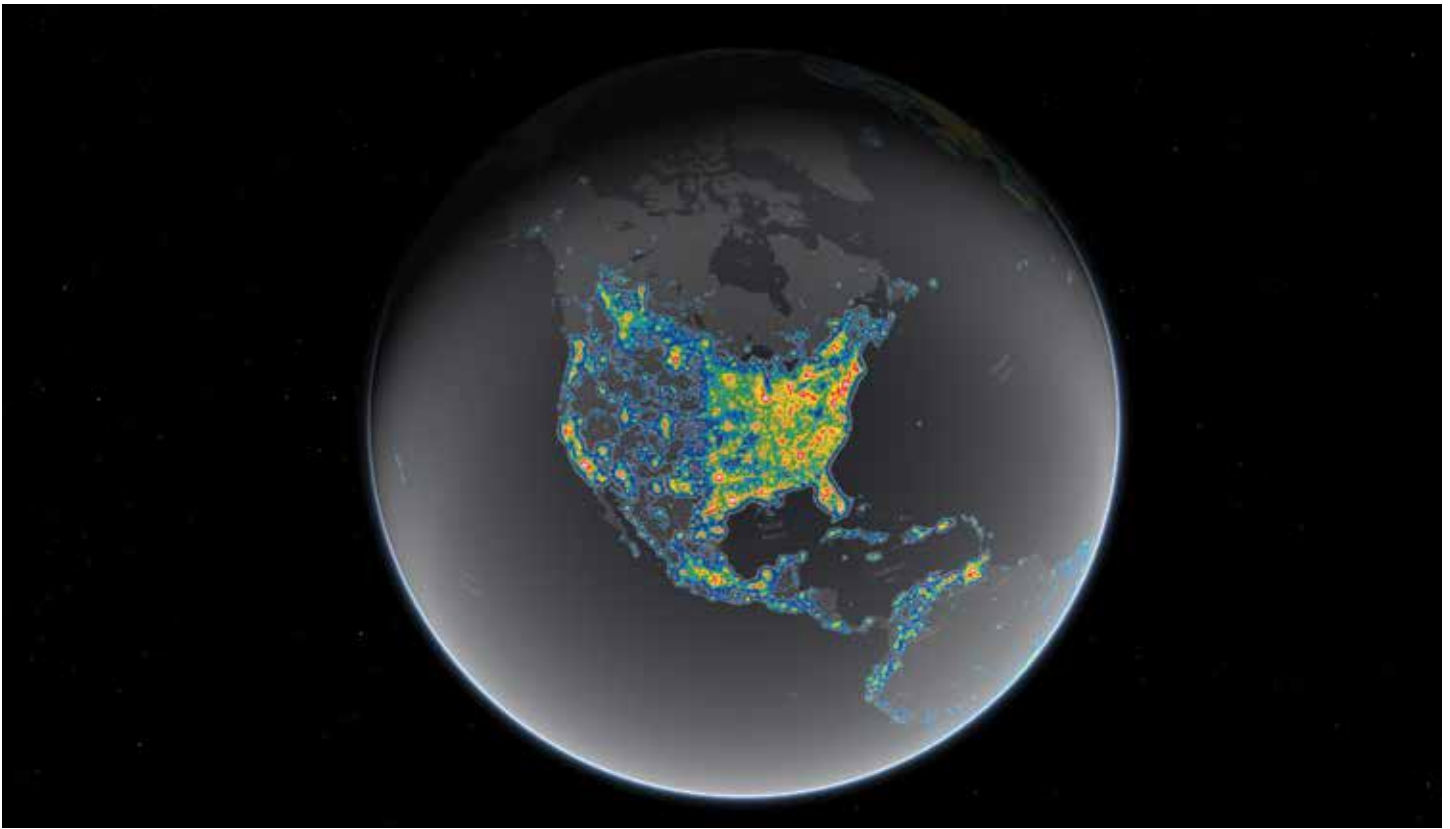
Cultivating citizen stewardship of night sky resources may be the most effective approach to restoring the celestial commons.

Light pollution intrudes upon these connections, reaching the most remote places on earth. Stray light is brightest and presents its greatest impacts near the horizon. Even national parks with excellent night sky views, such as Capitol Reef and Big Bend, experience light pollution.

Lights shining across a dark landscape, or light domes veiling an otherwise starry sky, compromise a visitor's nighttime experience in a park.

Unnatural light obstructs stargazing opportunities and masks faint celestial objects. In wilderness areas, light pollution erodes the primitive, untrammelled, and unconfined qualities of wild places. Such impacts may seem insignificant but consider that exploration in wilderness and other remote settings are opportunities for immersion in the rhythms, smells, sights, and sounds of the natural world far removed from human influences. Scientists and educators are increasingly noting the physiological and psychological benefits of nature, from reduced blood pressure and stress hormones to feeling calm and happy.

One park visitor's experience, recounted here, helps drive this point home.



Bright areas on map show sky glow from artificial light scattering into the atmosphere from North America. Graphic: Falchi et al., including Dan Duriscoe/NPS; Bob Meadows/NPS; Jakob Grothe/NPS, and Matthew Price/CIRES and CU-Boulder, Science Advances

“Years ago I went backpacking in a spectacular and rarely visited national park in Brazil. My Portuguese-speaking guide and I perched on the highest hill to watch the sun set over what appeared to be miles of empty space. But as night time crept across the sky, so too, did a shimmering orb of unnatural light. The ominous glow robbed the place of its other-worldly aspect.

My guide told me about that light and how it had grown every year until it had obliterated the stars in nearly one quarter of the sky. He remembered the sky of his youth, observed from that same perch, and the sense of oneness with the natural world and proximity to the world beyond that it gave him. He lamented that the lights of Rio de Janeiro might one day overtake the entire western hemisphere. His sense of loss hung in the air like a heavy fog and left me missing something I had never known.”

With the encroachment of outdoor lights affecting the remotest places, where will future generations go to experience the twinkling stars, bright planets, and the Milky Way trailing across the night sky?

A hiker can trek deep in the wilderness and still be followed by the glow of distant city lights.

Light and Wildlife Health

Research into the ecological consequences of outdoor lighting is revealing numerous connections between light pollution and species disruption.^{3,4} These disruptions affect species in almost all taxa, from sea turtles and amphibians to insects and migrating birds. Many people have witnessed one of the most widespread effects of outdoor lighting, perhaps without recognizing its ecological significance. How many times have you seen clouds of insects flying around lights or gathered on a lighted wall? You may have also seen toads, bats, or lizards feeding on these artificial concentrations of food. All of those insects had other roles to play in the ecosystem—other places to feed and be fed upon.

Sea turtle hatchlings orient toward the brightest area in their field of view. If you were to visit beaches illuminated only by the moon



Landscape and city lights of northern Utah seen from North Fork Park in Weber County. Photo w/permission from Casey Grimley

Nearly 70% of all mammals are nocturnal.² The darker phases of the moon are crucial activity periods for many species, and nocturnal environments are needed for their survival.

or celestial light during hatchling season, you would see hatchling tracks that head straight from the nest to the ocean. On brightly lit beaches in developed coastal areas, hatchlings become disoriented by multiple sources of light and head in all directions, creating tracks expanding from the nest like bicycle spokes. This

can bring dire consequences. Instead of heading toward waves sparkling with moonlight, they are often drawn toward brightly lit roads and parking lots, where they quickly perish. Hatchlings are born with limited energy reserves. The longer they are on land, the greater their energy deficit and exposure to predators.

Hundreds of migratory bird species use stellar and magnetic cues to guide them while flying at night. Stray, outdoor light from aircraft towers, skyscrapers, and other sources can disorient migrating birds, causing them to lose their way, collide with buildings and structures, or circle tirelessly, expending crucial energy needed for flight and survival. An estimated 100 million



birds die annually in such incidents in North America alone.⁵ A lit night sky can also stimulate birds to sing at atypical times of the night and early morning, which affects mating, nesting, and other seasonally dependent behavioral cues.

Lighting degrades night vision, alters activity schedules, and presents misleading stimuli to wildlife.⁶

Amphibians are able to detect light levels 100x dimmer than humans. Prolonged exposure to bright outdoor light affects their hormones, skin coloration, thermoregulation, and reproduction.

Many organisms have specialized retinal systems to enhance low light vision. Animals active at night have a higher density of rods than humans or diurnal species. A layer of tissue behind the retina—the *tapetum lucidum*—reflects light through the retina twice, which helps them see better in the dark. Highways and skies aglow from outdoor lights hamper this visual advantage, which can affect foraging, mating and dispersal activities of numerous mammals, including mountain lions and other wild cat species. Prolonged exposure to such light is also linked to tumor growth. Mammals you may not think of as being nocturnal, such as elk and deer, still need naturally dark night skies for cover, sleep, and general wellbeing.

Photo: Clark's Nutcracker/U.S. Fish & Wildlife Service



Dung Beetle, Photo: Andy Gentsch/Flickr; w/night sky addition by Dan Duriscoe



Cougar. Photo: w/permission/Ralph Atwood



Swarm. Photo: Rooley202/Flickr

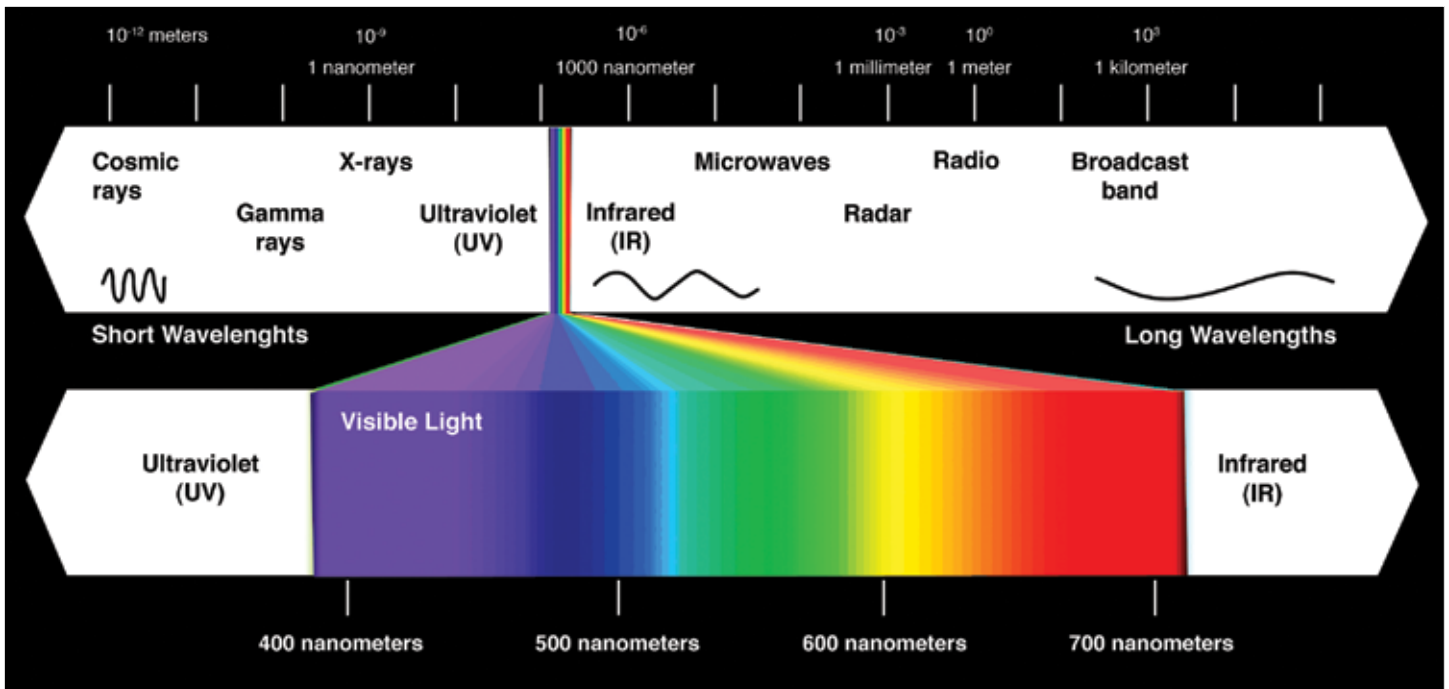


Krill and other zooplankton feed near the surface of water at night, and the bottom of ponds, lakes, and oceans by day to avoid predation. Scientists are discovering that when such water bodies are subject to artificial light, plankton tend to stay at lower depths. This disruption affects their feeding and life cycles, which affects animals up the food chain that subsist on them for food.

An environment devoid of light pollution is not only ideal for viewing the stars, it is vital to all living things. Without natural light conditions, no living thing functions optimally—from insects and aquatic organisms, up to humans.

Light and Human Health

Like all of life, humans have adapted to natural cycles of light required for physiological, psychological, and emotional, well-being. We sleep more soundly in darkness, and our health suffers without it. With daily exposure to LED light from cell phones and laptops, the human eye absorbs unnaturally large doses of light from human-made sources. Whereas exposure to blue-white light is considered to be beneficial for human physiological functioning during the day, the same is not true for night. The science supports that primitive photoreceptors in the human eyes govern light's influence on our behavior and circadian rhythms.⁷ Excess, cool blue-white light at dusk and night from sources such as LEDs, and fluorescent and metal halide lights interferes with the body's circadian rhythms—natural, restorative biological processes needed for sound sleep and good health. Such light suppresses melatonin and increases cortisol, a brain chemical released when we are stimulated or excited. High levels of cortisol make it difficult to fall asleep, experience deep sleep vital for healthy immune systems, and fight illness and disease. Research also links exposure to artificial light at



Properties of Light

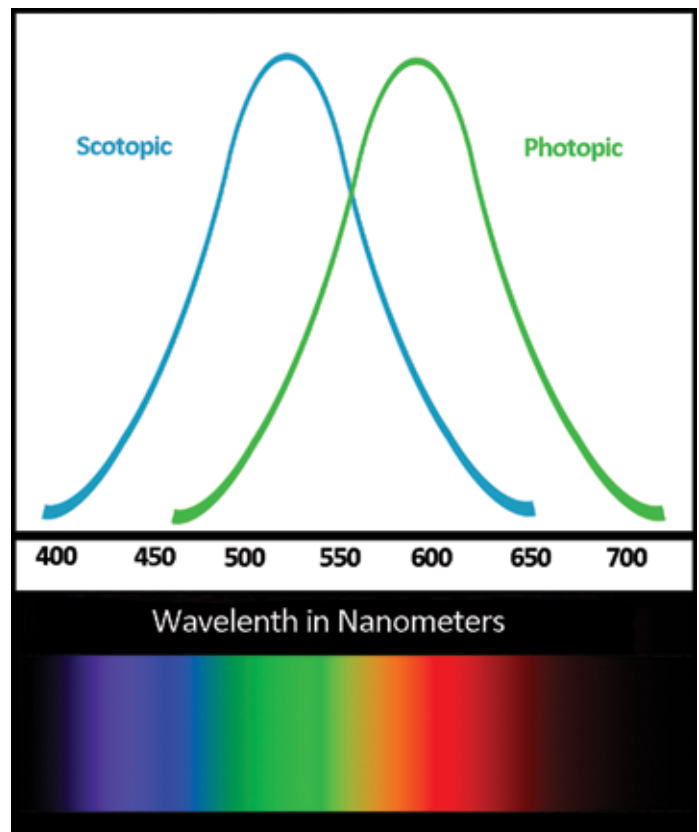
Learning about the science of light will help us understand the effects of outdoor lighting on humans, wildlife, and the environment.
Illustration: Google Classroom

night with higher rates of obesity, heart disease, diabetes, and cancer.⁸

From zooplankton to birds to human beings, from the depths of the sea to the sky, every living creature on the surface of the earth is affected by artificial lighting to some degree. Such information makes it increasingly difficult to deny that the hand of humankind reaches to nearly every corner of the earth, and reminds us of our profound interconnectedness with even the minutest of creatures. The NPS ethos seeks to minimize the impacts of outdoor lighting on wildlife and dark-dependent, natural biological processes in parks.

The Human Eye-Brain Connection

Light behaves both as waves, with measurable wavelengths and frequencies, and as particles, or discrete “packages” of energy called photons. Visible light waves comprise a fraction of the full electromagnetic spectrum, which includes radio waves, microwaves, infrared radiation, X-rays and gamma rays. The human eye perceives visible light as discrete wavelengths ranging in colors from violets to reds using two types of photoreceptors: rods and cones.



The two visual functions of the human eye, scotopic and photopic, are plotted here, showing sensitivity by the color of light received.
Illustration: NPS

The abundance of available daylight activates our cone photoreceptors, producing high acuity and color vision. Using *photopic* vision by day, we see objects with greater sensitivity to light in the



Halogen light from an unshielded fixture creates glare, bathing the area in light and escaping into the night sky. Photo: NPS/Julie West

yellow-green wavelength range. With so much light signal, the eye is not sensitized to every photon. At night we see with *scotopic* vision, with high sensitivity to the blue end of the visual spectrum. The rod photoreceptors in the retina are activated, which adapt our eyes to dark conditions and enhance contrast. It takes longer for the eye to respond to signals, and colors are not as prominent. In low light, transitional times between day and night, *mesopic* vision activates both rods and cones to prime the eyes to see in situations that are neither dark nor bright.

Light Measurements

Photometry is the measurement of light based on photopic detection. Light meters use an optic filter that appears green and mimics the photopic response of the human eye. This light is measured as a photon flux—the number of photons striking the human eye or light meter per second. The amount of visible light illuminating a surface area is measured in units of lux and is known as illuminance.

How does this information relate to the apparent brightness of celestial objects and light sources as perceived by an observer on the ground?

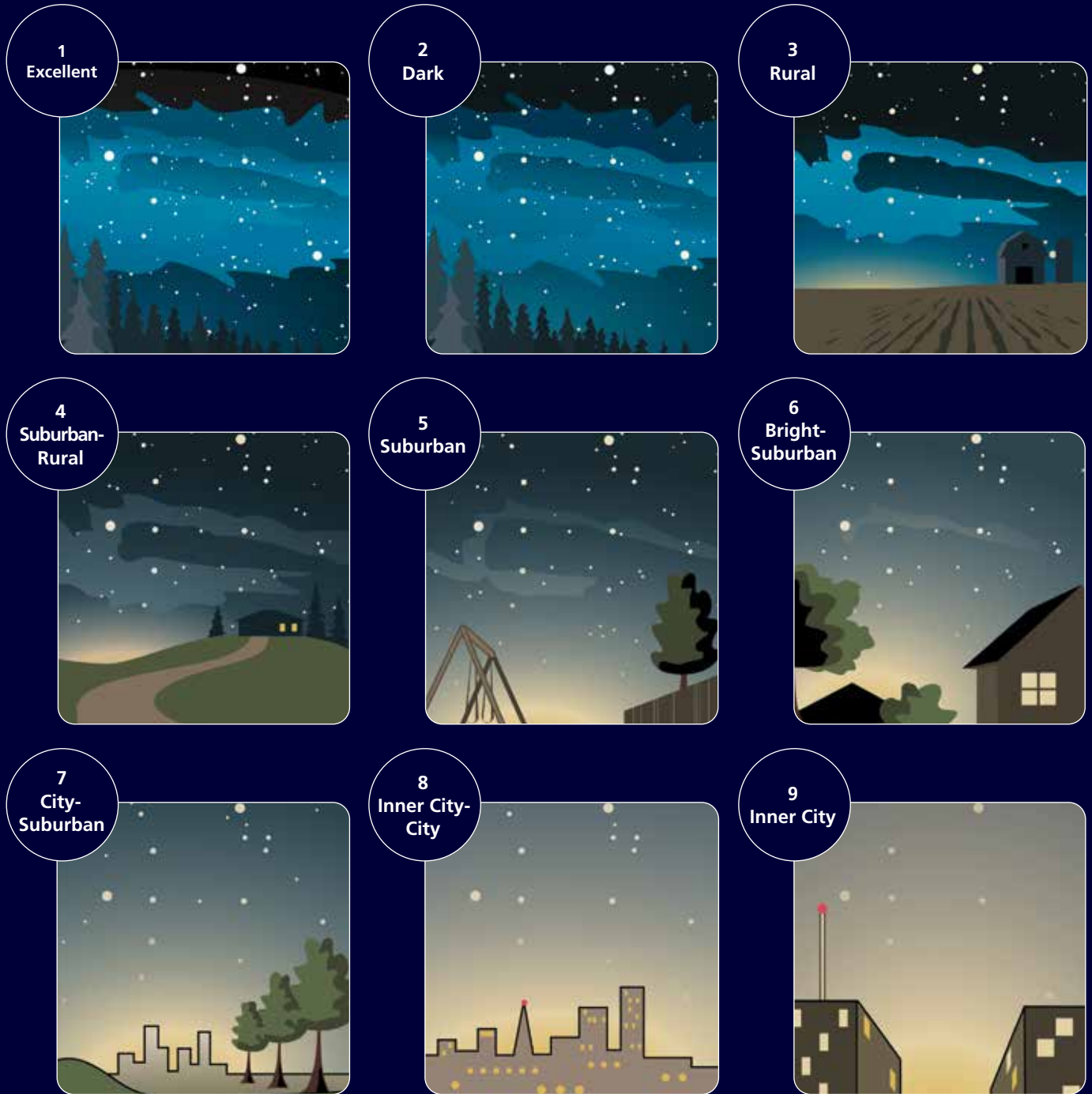
The reason unshielded lights are a concern in national parks and around the world is that light is broadcast into areas where light is not needed or wanted.

The faintest stars visible to the human eye without optical aid yield an illuminance of .000000003 lux. The planet Venus at its brightest produces .0001 lux. The crescent moon produces only .01 lux, and the full moon produces approximately 0.1 to 0.3 lux. The bright sun measures 108,000 lux.

Streetlamps and other light sources on Earth comparatively produce much more illuminance because observers can be closer to them. A typical

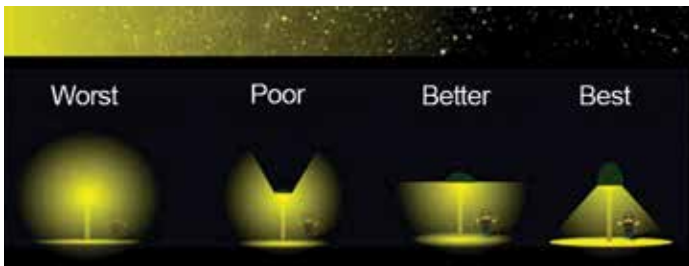
Bortle Dark Sky Scale

The Bortle Dark Sky Scale rates sky quality in intervals from 1 to 9, where 1 is pristine dark and 9 represents a sky dominated by anthropogenic light in which only the very brightest dozen or so stars and planets may be seen. Only a few areas in the United States display class 1 or 2 skies. The sky quality in many western national parks has degraded to class 3 or 4. Class 5 and higher skies are observed in parks in or near large metropolitan areas.



Myth: Security lights, streetlights and parking lot lights always prevent crime.

Fact: In short, nobody knows the answer. Our cities are more brightly lit than ever, yet the crime rate soars. Research shows that, in some cases, lighting does seem to deter crime, but in other cases lighting increases crime because it draws attention to a house or business that might otherwise escape attention. If the lights are overly bright with excessive glare, they can make it easier for a criminal to hide in the deep shadows they cast.



Photograph shows four streetlights at night—two unshielded (left), and two fully shielded (right). Note that there is a person standing beneath each light, but glare from the unshielded streetlights renders the person invisible. Photo courtesy of Illinois Coalition for Responsible Outdoor Lighting



Using special camera equipment, an NPS scientist measures the brightness of light from outdoor and celestial sources across the entire night sky. Photo: NPS

streetlamp produces an illuminance of anywhere from 5 – 50 lux immediately beneath it and in the area of intended illumination. If the lamp is unshielded and light escapes, it will be noticeable to the human eye from a great distance. For example, under a moonless sky, even the light equivalent of a candle flame at approximately 1.2 lux is visible up to 1.6 miles away from the source.

Skyglow is the unintended consequence of poorly designed and ill-suited artificial lighting.

In a vacuum, light travels at a constant speed of $\sim 3 \times 10^8$ meters per second, or 186,000 miles per second. When light passes through any medium other than a vacuum, it is subject to reflection, refraction, and absorption. Particles in the atmosphere such as moisture, dust, and aerosols cause light to scatter in various directions. Light pollution from cities is naturally intensified by the atmosphere, creating sky glow. Natural sources of light can also increase sky brightness, including the Milky Way, integrated starlight, zodiacal light, airglow, the moon, and planets of our solar system. But it is sky glow from light pollution that degrades the quality of the night sky.

Advancing Understanding of Light Pollution and Sky Quality

Improper outdoor lighting can impede night sky views and visitor enjoyment. Sky glow from collective sources of outdoor lights reduces our ability to view the night sky, as both near and far sources combine to unnaturally illuminate the area and inhibit our eyes from adjusting to the dark. Direct glare from light fixtures intrudes on camping, hiking, and other recreation experiences, which further compromises the visitor’s park experience. NPS is working to manage lighting conditions in our parks to give visitors safe, quality, nighttime experiences.

NPS Policy 4.10: Lightscape Management states: “The Service will preserve, to the greatest extent possible, the natural lightscapes of parks, which are natural resources and values that exist in the absence of human-caused light... Improper outdoor lighting can impede the view and visitor enjoyment of a natural dark night sky. Recognizing the roles that light and dark periods and darkness play in natural resource processes and the evolution of species, the Service will protect natural darkness and other components of the natural lightscape in the parks...”



Couple taking in the view at Joshua Tree National Park, California/NPS

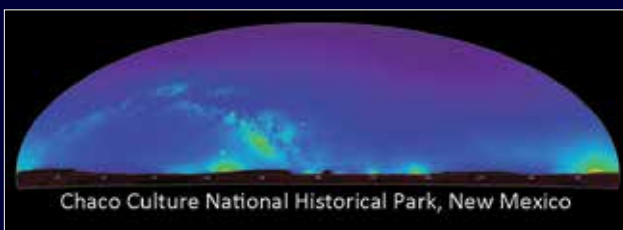
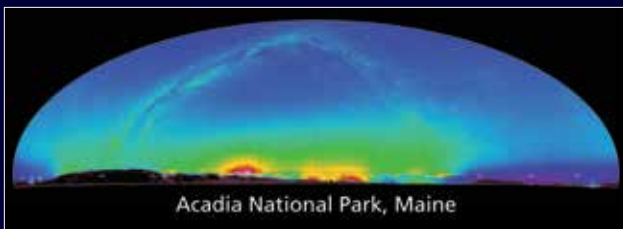
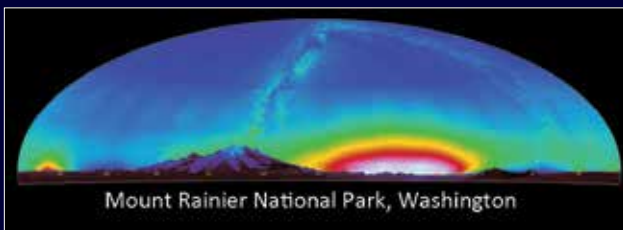
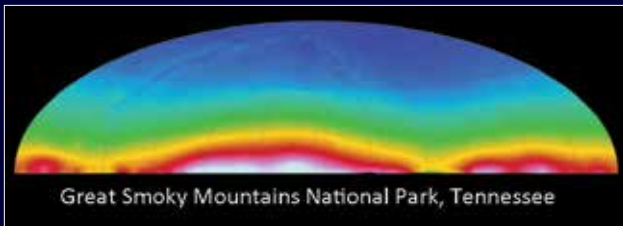
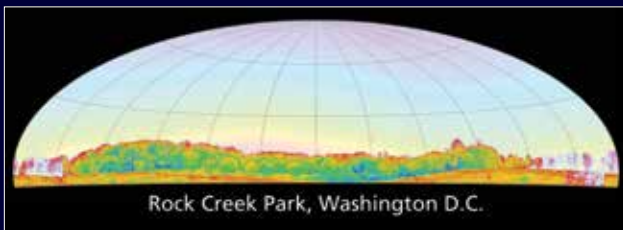
The Work of the NPS Natural Sounds and Night Skies Division (NSNSD)

NSNSD is a leader in understanding and reducing the effects of outdoor lighting. The night skies team works to identify sources of light pollution, measure sky brightness in protected areas, and recommend sustainable, best practices. They apply a suite of instruments and scientific methods to measure light impacts and protect the nighttime environment:

- Night sky scientists use research grade, calibrated camera equipment to inventory the night sky from one or more park locations. The photographs record sky quality across the entire celestial hemisphere—from horizon to zenith (directly overhead)—based on the intensity, or brightness, of both natural starlight and light pollution from sources near and far.
- The resulting high-resolution photos are processed to yield panoramas that contain 36 million light measurement points used to create a precise map of all light sources, or “all sky brightness” within the hemisphere.
- Natural light data from sources like the Milky Way are then subtracted to reveal the amount of outdoor light from human sources.
- The assessment provides baseline conditions of the quality of the night sky and helps park managers identify sources of light pollution and devise guidelines for mitigating impact.

This NPS, peer-reviewed method, based on all sky brightness, offers more information than traditional zenith brightness measurements, which only consider light from the top of the sky. By analyzing the *entire* sky, the NPS approach produces actionable data of relevance to parks by identifying exactly where light pollution originates, and recommending how it could be mitigated.

Managers interested in assessing the quality of light and dark in their parks may solicit assistance from the team for these services using Technical Assistance Requests.



Light domes from large cities can be visible up to nearly 200 miles away. Full resolution panoramas from six national parks show variations in the intensity of light pollution. The scale shows relative, night sky brightness from brightest to darkest conditions. Photos: NPS

Parks Do Their Part

Sky quality information provides park managers with highly accurate, baseline data about the quality of their night skies. Future monitoring of the same site will reveal changes in the amount of sky glow and sources of light pollution. Night sky conditions in parks vary due to a combination of factors, including elevation, proximity to cities, particulates, and moisture content in the air. In this way, the sky above a park in a mountainous area will be different from the sky above a park in a desert or prairie location.

Many national parks have sought NPS night sky guidance and incorporated night sky conservation into their planning.

By understanding the characteristics of a park's natural lightscape and the threats to this environment, park managers can make improvements that will reduce impacts on visitors, wildlife, and cultural resources, and help restore natural dark in our parks.

NPS lighting strategies are designed to enhance naturally dark conditions and the park experience. Effective solutions for reducing outdoor light include replacing lighting fixtures with those that shield and direct light down, and using smart motion sensors that switch on or off as needed.

NSNSD encourages interdisciplinary approaches and alternative lighting strategies where feasible, such as high contrast or luminescent paint for curbs and steps instead of traditional light fixtures. Small red lights or reflectors at curbs and along paths are other options that reduce light while providing markers for safe navigation. Visitor centers, parking lots, campgrounds, and park housing are examples of lighting locations that parks can address.

NPS Director's Order 50C: Public Risk Management Program requires park superintendents "to identify risks within their jurisdiction and to mitigate these risks within the limits of



Outdoor lighting at the Stovepipe Wells Village Hotel in Death Valley National Park before (top) and after (bottom) a lighting retrofit. Following this thoughtful retrofit, the park saw improved resource conditions, as well as positive environmental and economic benefits. Photos: NPS

available resources without compromising the integrity of the environments they are charged to protect." In the case of nighttime views and environments, managers must keep parks dark while also keeping visitors safe. Examples include accommodating visitors' ability to find their way after dark, or reducing a hazard by adding light where needed, without negatively impacting protected resources.

NPS follows a sustainable lighting concept that considers economic, environmental, and social-utility needs for national parks.

Located in southwest Texas along the border of Mexico, Big Bend National Park improved the natural darkness of its Chihuahuan desert ecology by taking stock of its outdoor lighting infrastructure and replacing outdated lights with new, shielded fixtures. Yellowstone National Park has championed reduced lighting in its park since the early 1990s. Some parks have even achieved International Dark Sky Place certification as a result of their night sky protection efforts. However, parks can set the standard for protecting the natural night sky regardless of their certification standing.



NPS/Benjamin Banet

Considerations for visitor wayfinding and lighting in historical-cultural sites are important factors for managing a park’s nighttime environment.

Nighttime lighting may be an intrinsic part of the park or significant to the visitor experience. The grandeur of a memorial or magnitude of a historical event can be enhanced by nighttime lighting. In such cases, parks should assess how the lights affect resources in the park, and whether the timing, amount, color spectra, and direction of the lighting are appropriate, both to protect the surrounding natural environment, and to retain the appropriate, cultural lightscape.

The NPS continues to develop its methods and work with stakeholders to understand the effects of lighting on park resources, and the options for reducing those impacts.

NSNSD also raises awareness of night skies issues through outreach and education, and provides technical assistance to parks working with surrounding communities that value dark skies for their natural beauty, their role in preserving ecological integrity, and the benefits night sky programs bring to local economies.

Light pollution results from excessive light levels or stray light that never reaches its target but scatters into the environment where it isn’t intended.

Best Practices: Guide for Minimizing Light Pollution

We need light. No one is advocating a return to the Dark Ages. Light helps us accomplish what we need to do.



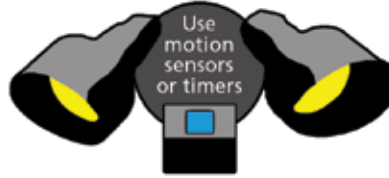
You Make a Difference

The National Park Service recommends this six-step process for evaluating outdoor lighting:

1 Light only **if** needed



2 Light only **when** needed



3 Light only **where** needed

(Shield and direct down)



4 Use **warm-white** or amber light
(Avoid blue-white light)



5 Use the **minimum** amount of light needed



6 Use **energy-efficient** lights



A little effort makes a big difference in protecting the night environment. You, too, can reduce light pollution by improving outdoor lighting at home. **Now go polish those stars!**

“However, just like everything else in life, it’s very easy for too much of a good thing to suddenly become a very bad thing.”

— Kevin “The Dark Ranger” Poe

Excess light comes from any number of sources—industries, city buildings, and even park facilities. The biggest culprits of excess light are unshielded outdoor lights that allow light to emit upward and scatter backwards, and lights that are too bright or stay on for longer periods of time than is necessary.

Fortunately, light pollution is a relatively easy environmental problem to resolve. There are simple remedies for reducing and eliminating wasteful light and bright, outdoor glare. Solutions are immediate, effective, and often save money. You, your family, friends, neighbors, and park visitors can all make a difference in conserving our night sky heritage. Even small efforts have immediate benefits.

Navigate to the NPS night sky community of practice on Teams, Sharepoint, or equivalent platforms for detailed information on best practices.

Notes

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A night sky filled with stars, with a dark silhouette of a rock formation in the foreground. The stars are densely packed, creating a bright, glowing band across the sky. The foreground is dark, with the silhouette of a rock formation on the right side. The overall scene is a clear, dark night sky with a prominent starry band.

Part Three



Cultural, Historical, and Technological Connections

Cultural-Historical Heritage

Every culture has gained knowledge and insight from the night sky, and expressed its mystery and wonder through stories, traditions, and inventions. The night sky's imprint on civilizations is everywhere, from the cosmic myths of ancient Greece, to the architectural celestial alignments of ancient monuments at Chaco Canyon and Chichén Itzá, to the oceanic navigation methods of Polynesian voyagers, and to our greatest scientific discoveries and works of art.

All park visitors bring their own cultural-historic associations about the night sky. Stories shared among interpreters and visitors enhance our collective understanding of how the night sky is valued around the world, and how it continues to inspire imaginations and broaden our knowledge of the universe.

This handbook highlights some of the notable examples that speak to this connection, with additional links and resources provided in the *Useful Resources* section.

Mythology and Time

Many ancient cultures saw connections between the orbiting bodies above with the drama of humans below.

The drama of life plays out in Greek constellations.

The Scorpius constellation is said to shine in the sky thanks to Gaia, the earth goddess and mother of animals. Alarmed by Orion's boasts that he could kill all the wild beasts on Earth, Gaia sent a scorpion to stop him and save the animals from harm. The legend plays out in the Orion constellation, where the scorpion's bite appears as the star Rigel. Scorpius never shares the same night sky with Orion but lives in the opposite hemisphere, as if perpetually chasing Orion across the night sky.

Native American stories are rich with creation myths about our galaxy.

The Shoshone Tribe tells the story of a great bear from Earth wanting to visit the sky. The bear's journey was long and took him over many cold mountains. By the time he arrived, his fur was covered in snow and ice. As he moved across the night sky, the ice melted, leaving behind what we know today as the Milky Way.

Ancient Hindu figures enact the great mystery.

From Shiva's cosmic dance to the Navagrahas—nine deities symbolizing the nine planets—India's cosmology conveys the search for truth and nature of the universe. Representations of Shiva show him dancing in a ring of fire. The dance represents the cyclical orbit of planets and celestial bodies. The circle of fire symbolizes the cosmos, or consciousness. To contemplate Shiva is to contemplate the divine mystery.

Mesoamericans believed that human fate was written in the stars.

The Mayan calendar is among the most sophisticated and accurate in the world—testament to an advanced understanding of astronomy and celestial events. The El Castillo pyramid at Chichén Itzá (also known as the Temple of Kukulcan), c. 600 AD, is a world heritage site that embodies this awareness through its architecture. The monument's 365 steps correspond to

the 365-day calendar; and at the March equinox, a shadow-light “serpent” slides down the walls and steps to illustrate the seasonal shift.

Celestial alignments guided Puebloan culture.

The architecture of Chaco Canyon, c. 850 AD, a UNESCO world heritage destination in New Mexico, expresses the ancestral Puebloan people's advanced knowledge of complex astronomy, engineering, and math. The geometry of their buildings and roads were oriented to solar and lunar cycles. Rock art on the walls of dwellings, such as the Sun Dagger site petroglyph, were used to mark the passage of time based on the alignment of sunlight on its spiral. Park visitors at Chaco Culture National Historical Park today can learn about these celestial relationships.

Medieval clock keeps time to the stars. In Prague, Czech Republic, the legendary Prague Orloj, c. 1410, the third-oldest astronomical clock in the world, tracks the motion of earth and the stars, and enacts the zodiacal position of celestial bodies throughout the weeks, months and years while telling time. The moving figures of saints, skeletons and other figures add visual interest to this one-of-a-kind instrument.

Big Horn Medicine Wheel circles the stars.

Native Americans who lived in the Bighorn Range of Wyoming (circa 1200 AD) built a circular construction of stone cairns to predict seasons and celestial events, such as the rising and setting of stars, the sun, and solstice. The sacred site, consisting of stone spokes within a medicine wheel that align with points on the horizon, is accurate today.¹

The Arts and Traditions

Poets and artists through time have sought the night sky as a muse for their creations, and numerous ancient and contemporary traditions center on the night sky, from harvest and planting festivals to equinox traditions to our own stargazing celebrations.

A Clear Midnight

This is thy hour O Soul, thy free
flight into the wordless, Away from
books, away from art, the day erased,
the lesson done, Thee fully forth
emerging, silent, gazing, pondering
the themes thou lovest best, Night,
sleep, death and the stars.

— *Walt Whitman*



Painting: The Starry Night, by Vincent Van Gogh, 1889.

The Starry Night

With textured, sweeping brushstrokes, the Dutch post-impressionist painter Vincent Van Gogh (1853–1890) memorialized the essence of night in masterpieces such as *The Starry Night*, 1889 (above), *Starry Night Over the Rhone*, and *Cypresses in Starry Night*.

Art patrons have contemplated these starry scenes in distinguished museums around the world, including the Museum of Modern Art, New York, and the Musée d’Orsay, Paris, France.

When You Wish Upon a Star ...

“... makes no difference who you are, anything your heart desires, will come to you.” Some of our most cherished works commemorate the

profundity of the cosmos. From verses in the Bible to the writings of Shakespeare, Walt Whitman and Walt Disney song lyrics, the night sky has inspired the language we use to describe the human experience. Both celebrated and feared, the celestial heavens are a source for soulful contemplation, and an unknown, endless well of mystery.

**Memorializing the night
is not limited to ancient
traditions and inventions.**



Telescopes at Rocky Mountain National Park/NPS.

Autumn Moon Festivals

Moon festivals in Japan and other parts of Asia are celebrated when the moon is at its brightest and fullest. The millennia-old tradition is a time when people of all ages gather for moon appreciation parties and a night of festivities under the stars. Children look for the “moon rabbit” that, according to folklore, lives on the moon.

Let the Traditions Continue!

What better tradition to celebrate the wonder of night than our very own national park, night sky festivals and programs?! National parks are natural locations for astronomy enthusiasts to converge for night sky stargazing and community connections. There’s always a night sky to ponder, whether at the coast, in a desert, on a mountain, or in an urban setting. The NPS is proud to evolve these cultural traditions. More information for building your park’s night skies program is given in Part Four.

Wayfinding and Navigation

Seafaring Traditions

Without modern instruments, and guided only by the sun, sea and stars, the ancient Polynesians were known for long distance, oceanic enterprise using double-hulled vessels and traditional

wayfinding. Today, crew members with the Polynesian Voyaging Society, are carrying this ancestral tradition forward with worldwide voyages that raise awareness about indigenous knowledge of astronomy, oceanography, meteorology, and related sciences.²

Ancient Methods, Modern Use

Since the launch of the satellite Sputnik by the Russians in the late 1950s, Global Positioning Systems (GPS) tools steadily replaced traditional sextants and charts. With the rise of hacking and signal jamming that could compromise U.S. communications security, U.S. Navy officials are reviving the ancient but true star-finding methods and now use celestial navigation alongside GPS and computers to monitor their fleet.

Song Maps to the Stars

African American cultural history tells how fleeing slaves found their way north by following the “Drinking Gourd”—an asterism of stars within the Ursa Major constellation. Coded directions in the form of “map songs” helped slaves identify the star patterns. The name refers to the gourd slaves commonly used for dipping and drinking water. The asterism references the Big Dipper, whose stars in the bowl point to the North Star—a helpful guide for those without maps!

Could you find your way across unknown bodies of land or water guided only by the stars?

**From ancient to modern times,
people have charted their
destinies to the map of night.**

Advancing Astronomy

On December 24, 1968, the Apollo 8 lunar mission captured one of the most iconic images of the century: Earth rising over Moon's surface.

With Earth's image, for the first time we saw ourselves from afar. The mission marked the dawn of our planetary self-awareness. The blue face of our planet helped launch the environmental movement, gave our species an accurate portrayal of our fragile home, sparked our collective curiosity, and became a hallmark of space exploration. It is curious that perhaps the most memorable aspect of our journey outward into space was looking back upon our home.

This image of Earth gave us new insights into the clockwork of the Universe, both the recognition of our relative insignificance amidst the greater whole and fathomless depth of time, and our unique place within it. We learned that "we are stardust"—that the elements in interstellar clouds from star explosions billions of years ago are the building blocks of our bodies: carbon, calcium, sulfur, sodium, iron and oxygen. We pondered the possibility of, and, indeed, discovered, numerous worlds somewhat like our own planet spinning at their own pace and revolving around different stars. Earth was one of many participants in the cosmic dance.

Night Sky Pioneers

Newton nudged us along the way, as did Galileo, Kepler, and Copernicus. Many luminaries number among these scientists, observers, and inventors. We herald some of these cosmic champions here.



Galileo Galilei (1564-1642)

We attribute the invention of the telescope to the Italian astronomer Galileo Galilei. Applying sophisticated mathematics and technical brilliance, Galileo significantly improved upon the spyglass invention of his day to bring us the forerunner of our modern telescopes. More than the tool itself, it was Galileo's astute observations of celestial bodies that launched the field forward, from recording the pitted surface of the Moon and Saturn's rings to the four moons of Jupiter, phases of Venus, and sunspots. His findings supported Copernicus' theory that Earth and all other planets revolve around the Sun and shook up religious and scientific communities alike. Deemed a heretic, he was sentenced to life imprisonment in 1633. His legacy endures.

**The journey to understand
the night sky stretches
back through the ages.**

Johannes Kepler (1571-1630)

Considered to be the founder of celestial mechanics, Kepler furthered astronomical knowledge by advancing understanding of the heliocentric laws governing planetary motion and positions. His first law, for example, asserts that planets move in ellipses with the Sun at one focus. His writings, together with inventions such as the Platonic solid model of the Solar System circa 1596, influenced countless successors,

including Newton, whose law of gravitation is based on Kepler's discoveries.

Henrietta Leavitt (1868-1921)

How brightly do the stars shine at night? Women astronomers, though often unrecognized, have substantially influenced the field, including American astronomer Henrietta Swan Leavitt. Nicknamed the "Lady of Luminosity," Leavitt researched star brightness and their luminous variability over time while employed at Harvard College Observatory. Her work measuring, cataloging, and standardizing star brightness laid a foundation of knowledge about the natural

"Consider again that dot. That's here. That's home. That's us. On it everyone you love, everyone you know, everyone you ever heard of, every human being who ever was, lived out their lives. The aggregate of our joy and suffering, thousands of confident religions, ideologies, and economic doctrines, every hunter and forager, every hero and coward, every creator and destroyer of civilization, every king and peasant, every young couple in love, every mother and father, hopeful child, inventor and explorer, every teacher of morals, every corrupt politician, every "superstar," every "supreme leader," every saint and sinner in the history of our species lived there - on a mote of dust suspended in a sunbeam."

— *Carl Sagan*

brightness of celestial bodies that well known astronomers like Edwin Hubble used in his work, and that NPS scientists build on today.

Carl Sagan (1934-1996)

"We are a way for the Cosmos to know itself," said Sagan, a well-known and brilliant astronomer, cosmologist, and science educator. Sagan made significant contributions to the scientific understanding of planets and cosmic phenomena, and played an important role in shaping the direction of the American space program. Through his acclaimed television series, *Cosmos*, he brought the universe into the living rooms of millions of people around the world, awakening awe and curiosity, and inspiring new generations of scientists.

Nancy Roman (1925-present)

Orbiting high above Earth's atmosphere, the Hubble Space Telescope, named after astronomer Edwin Hubble, is recognized for capturing breathtaking photos and data of entire new galaxies, and expanding our understanding of the universe. But you may not know that astronomer Nancy Roman is considered the "Mother of the Hubble Space Telescope." Hired as NASA's first female, chief astronomer in 1961, it was Roman who persuaded NASA of the benefits of having an orbiting telescope at a time when the space race, not astronomy, was getting attention. Her passion convinced Congress to fund its creation. Fifty years later, the telescope is globally recognized as one of America's greatest achievements. Now in her early 90's, Roman is still active as an astronomy educator and speaker.

NASA

From missions to the Moon, Mars, and beyond, the National Aeronautics and Space Administration is a world leader in space research and discovery. Since its inception in 1958, the agency continues to transform our understanding of the universe and ignite our imaginations with facts and footage about the world beyond our homes. Since the launch of the first U.S. satellite, Explorer 1, and the iconic Apollo 8 mission, NASA's hallmark achievements include the Apollo 11 Walk on



Photo: NPS / Li-Wei Hung

the Moon; Mars Pathfinder; Hubble Space Telescope; Pioneer 10's Flight to Jupiter; and the International Space Station, which curious park visitors and people around the world can spot in the night sky thanks to the "Spot the Space Station" website. The NPS partners with NASA to share data, outreach materials, interpretive strategies, and scientific expertise to advance understanding of the cosmos and forge meaningful connections with parks and their visitors.

NPS also partners with other federal agencies, and conducts its own astronomical research to advance night sky scholarship, educate the public, and provide opportunities for night sky observation.

USA Observatories

The NPS has worked with some of the nation's most distinguished astronomical observatories to share expertise on night sky research and com-

municate these findings to the public. These include Palomar (California), Mauna Kea (Hawaii), Kitt Peak and Lowell (Arizona), Apache Point Observatory (New Mexico), and the McDonald Observatory (Texas).

Chaco Culture National Historical Park Observatory

The Chaco Culture National Historical Park Observatory gives the public exceptional views of the night sky from its New Mexico location. Astronomy is an integral part of the park's interpretive programming that connects park resources to the celestial knowledge of the ancestral Puebloan people who settled the area. Park lighting is retrofitted to keep skies dark and reduce light pollution, and star programs are anticipated attractions.



Photo credit Dave Lane Astrophotography

Great Basin Observatory

Did you know that NPS has its own astronomical research observatory? Inaugurated in 2016, the Great Basin Observatory is the first NPS research-grade observatory to be based in a national park. Located in one of the darkest areas of the country at the border of Utah and Nevada, the observatory offers near pristine, unpolluted views of the night sky. The NPS observatory works with astronomy researchers across the country to advance our understanding of cosmic phenomena. Its telescopes can be remotely programmed to focus on any cosmic body or event, from little known debris clouds and planets to the Milky Way and solar eclipses.

Glacier National Park Observatory

The Observatory opened in 2019 and was funded by the Glacier National Park Conservancy. The observatory is utilized by the park's astronomical activities. Located at the St. Mary Vis-

itor Center, astronomers use the park's Dusty Star Observatory to help explore the cosmos. This observatory features a 20-inch telescope and astronomy camera to share views of the night sky with visitors watching on exterior television monitors. Traditional telescope viewing is available at both east and west sides of the park during the ranger-led astronomy programs in the summer.

Rock Creek Park Planetarium

The NPS Rock Creek Park Planetarium is another park venue that educates people about night sky phenomena and light pollution issues. Located within the Nature Center, it uses high-tech Spitz software to project the image of the night sky onto a large, dome-shaped ceiling. Rangers lead visitors on a journey of exploration into the solar system, galaxy, and beyond. Monthly, evening stargazing programs are also offered and give information about the seasonal night sky.

Celestial Features

The Milky Way

The Milky Way is the quintessential cosmic expression of our galaxy. Classified as a barred spiral galaxy and composed of our sun and vast numbers of stars and planets, including Earth, it is seen in the sky as a whirlpool band of light encircling the celestial sphere. Its position and orientation in the sky varies with the seasons and nightly motion of the sky. Its “milky” glow owes to the light blended from billions of stars residing in the plane of our galaxy. Scientists estimate the Milky Way to be between 100,000 and 180,000 light-years in diameter, and contains more than 100 billion stars. Our Solar System is located halfway from the center on the Orion Arm of the disk. The Milky Way’s central black hole, Sagittarius A*, is said to have a mass four million times greater than the Sun.

The Moon’s Phases

The brightest and largest object that appears in our night sky, Earth’s moon was likely formed from debris left over after a Mars-sized body collided with Earth. It is the fifth largest moon in the solar system, and the only place beyond Earth where humans have set foot. Earth’s climate is relatively stable because the moon moderates our planet’s wobble on its axis. It also causes tides, creating a rhythm that has guided humans for thousands of years. We see the moon because sunlight reflects from its surface.

As the moon circles Earth, the amount of light we see on its surface changes throughout the days and weeks of the month. These changes, known as the moon’s phases, repeat each month—from the new moon, which we don’t see as readily because the unlit side of the moon faces us, to the waxing moon, when the moon seems to grow larger due to the amount of visible light from the sun on its surface, and to the waning moon, when the moon appears to grow thinner as it completes its journey and again approaches the new moon phase.

Aurora Borealis (Northern Lights)

What more magical display in the night sky could there be than the transient, dynamic Northern Lights? Even though auroras are best seen at night, they are caused by the Sun. The Sun sends us more than heat and light; it sends lots of other energy and small particles our way. The protective magnetic field around Earth shields us from most of the energy and particles, and we don’t even notice them. But the Sun doesn’t send the same amount of energy all the time. There is a constant, streaming, solar wind and there are also solar storms. During one kind of solar storm called a coronal mass ejection, the Sun burps out a huge bubble of electrified gas that can travel through space at high speeds. When a solar storm comes toward us, some of the energy and small particles can travel down the magnetic field lines at the north and south poles into Earth’s atmosphere. There, the particles interact with gases in our atmosphere resulting in beautiful displays of light in the sky. Oxygen gives off green and red light. Nitrogen glows blue and purple.³ The Northern Lights can be viewed in the night sky from locations in the Northern Hemisphere. National parks that offer great views of this magical phenomenon include all Alaska parks, Glacier National Park, Katahdin Woods & Waters National Monument, Voyageurs National Park, and Isle Royale National Park. The Southern Lights, a comparable occurrence in the southern hemisphere, are known as the Aurora Australis.

Myth

Light pollution mainly affects astronomers.

Fact

Light pollution affects everyone, including astronomers who rely on dark sky conditions to gather data about our universe. Light pollution blots out stars and other celestial objects, and robs us of a view of the stars, planets, and natural night sky

Nebulae

Photographed by NASA's Spitzer Space Telescope, and residing 650 light-years away in the constellation Aquarius, the Helix Nebula belongs to a class of objects called planetary nebulae—dying stars. Stars like our sun thrive due to the process of nuclear fusion, which draws energy by converting hydrogen to other gases. When hydrogen runs out, the star turns to helium for fuel and slowly loses mass. When helium is depleted, the star dies, and its dusty, gaseous layers dissipate, illuminated by an infusion of ultraviolet radiation emitted from its remaining “white dwarf” core. This fate awaits our sun one day, too.

Meteor Showers (“Shooting Stars”)

Meteors are chunks of ice or rock in space ranging in size from a grain of sand to a boulder. Asteroids are much bigger, from the size of a garage to miles-wide! What we call a *shooting star* is a streak of light from the burning dust of meteors or asteroids entering Earth's atmosphere at high speeds and vaporizing. Single meteors occur in the night sky all the time, but the best times to see them are during *meteor showers*, which occur when many of these celestial bodies hit the atmosphere in a short period of time, producing brilliant trails that illuminate the night sky. These showers are predictable and intensify when the Earth's orbit passes through streams of debris left behind from comets. Famous ones include the Perseids, which peak around August 12 each year, and Leonids, which peak around November 17. A *fireball* is a meteor that burns brighter than the planet Venus! *Meteorites* are pieces of meteors that don't vaporize but fall to the ground.

Comets

NASA defines comets as “cosmic snowballs of frozen gases, rock and dust roughly the size of a small town.” As comets orbit near the sun, their mass heats, creating a head of spewing dust and gas, and a tail that stretches behind it for hundreds of thousands of miles. Scientists believe that comets may have brought water and organic compounds—the building blocks of life—to early Earth and other parts of the solar system.

Astro-photography of Halley's Comet, visible from Earth every 75-76 years, revealed its nucleus and other new data about this and other comets' compositions.

Eclipses

There are total and partial solar eclipses, and there are total and partial lunar eclipses. A total solar eclipse occurs when the new moon comes between the Earth and the Sun, temporarily and fully blocking the Sun's light except for the corona, the thin ring of light visible around the rim. This exact alignment is referred to as *syzygy*—a Greek word that means paired together. In an annular or partial solar eclipse, the Earth, Sun and Moon do not perfectly align, and so the Moon only partially obscures our view of the Sun. During a total lunar eclipse, which occurs during the full moon phase, the Earth blocks the Moon from the Sun and casts its umbra, the darkest part of its shadow, on the Moon's surface. Similarly, in a partial lunar eclipse, the Earth partially moves between the Sun and Moon, and only part of its shadow is observed on the Moon's surface.

The Planets: Did you know?

Although not a planet, the **Sun** is the brightest, largest, and heaviest celestial body in our solar system. Its gravity is what creates the orbital cycles of planets. The sun converts 4 million tons of matter into pure energy every second. It has enough nuclear fuel to glow strong for another 5 billion years.

Mercury* is the smallest planet and orbits closest to the sun. It is best seen at twilight in spring. “Wrinkles” on its surface, formed when its iron core cooled and contracted, are up to a mile high and hundreds of miles long.

Venus* is brighter and hotter than any other planet. It has the longest rotation cycle of any planet in the solar system, and, along with Uranus, spins east to west instead of west to east like the other planets. It is known as the morning/evening star for its visibility right after sunset and before sunrise.

Earth is unique from other planets for having oxygen, liquid water, an atmosphere that protects from the sun, and a variety of life forms.

Mars* is known as the “Red Planet” for the iron-rich, red dust that covers its surface. Its thin atmosphere is mostly composed of carbon dioxide. Pieces of Mars have fallen to Earth as meteorites.

Jupiter* is the largest planet, with a mass 300 times that of Earth. Its gravity helps divert incoming comets and debris from approaching Earth. Jupiter has 69 moons—more than any other planet. Its size and silvery brightness make it especially visible spring through fall.

Saturn* is known for its rings of water and ice—the most extensive ring system in our Solar System. Its composition of helium and hydrogen give it a yellowish glow and makes it the least dense of the planets. If it could fit in a bathtub, it would float!

Uranus was the first planet found with a telescope. The cold and windy ice giant appears to spin on its side as it orbits the Sun with a 90-degree tilt. Methane gas tints the planet bluish-green. Located in the Pisces constellation, it is at its brightest in the night sky from October to March.

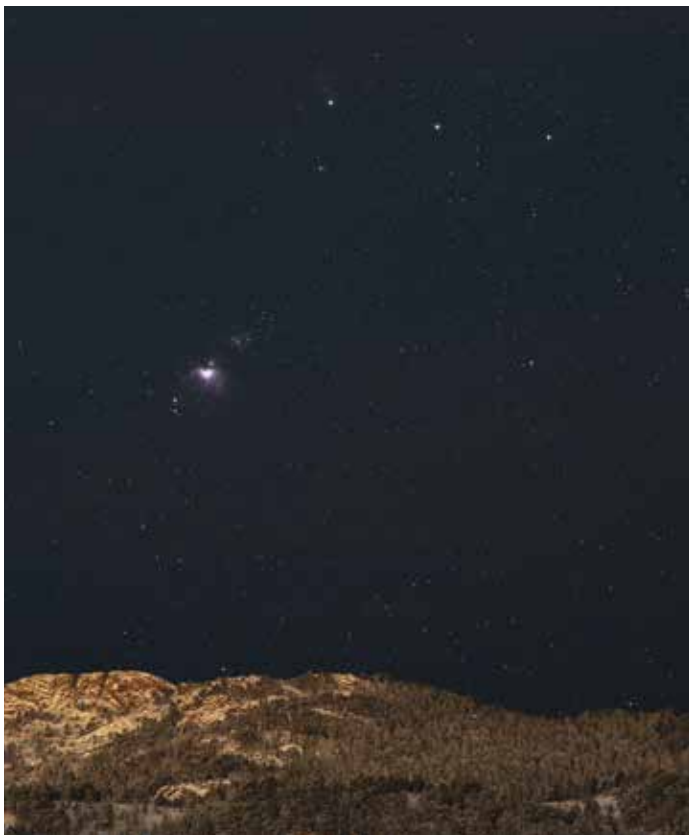
Neptune experiences large storms and high winds, which appear as dark spots on its surface. Neptune owes its vivid blue color to its methane composition. It is 80,000 times dimmer than Venus. It is the first planet discovered based on mathematical predictions and not direct observation.

Formerly considered the ninth planet, **Pluto** is now categorized as a dwarf planet along with other planetary bodies such as Eris and Ceres. Although it orbits the sun, and its mass gives it a near round shape like other planets, it is not the dominant gravitational body in its orbit, and it is not a satellite of another object. It shares its orbital path with other planetary objects. It was named after the Roman God of the Underworld.

*Visible to the naked eye.



Planet Photos: NASA



The constellation Orion, NPS/Damon Joyce

“When one tugs at a single thing in nature, he finds it attached to the rest of the world.”

— John Muir

Constellations

A constellation is a group of stars that form a recognizable pattern within a certain area of the sky. Ancient cultures named these forms and created stories based on their understanding of astronomical phenomena, thus preserving this knowledge for successive generations. Hundreds of constellations have been documented over time. They include a cast of mythological figures and other characters, from insects, land animals, and water creatures to men and women, serpents and centaurs. In 1922, the International Astronomical Union finalized the list at 88.

The summer and winter seasons are the best times to identify some of these constellations in the Northern Hemisphere, as there are more bright stars located in the sky at these times. Even so, constellations do not always look like the figures they are supposed to represent, which can frustrate beginning stargazers. Fortunately, finding them is made easier with asterisms—observed

patterns or groupings of stars. Learn a few asterisms, and you’ll be on your way to identifying constellations.

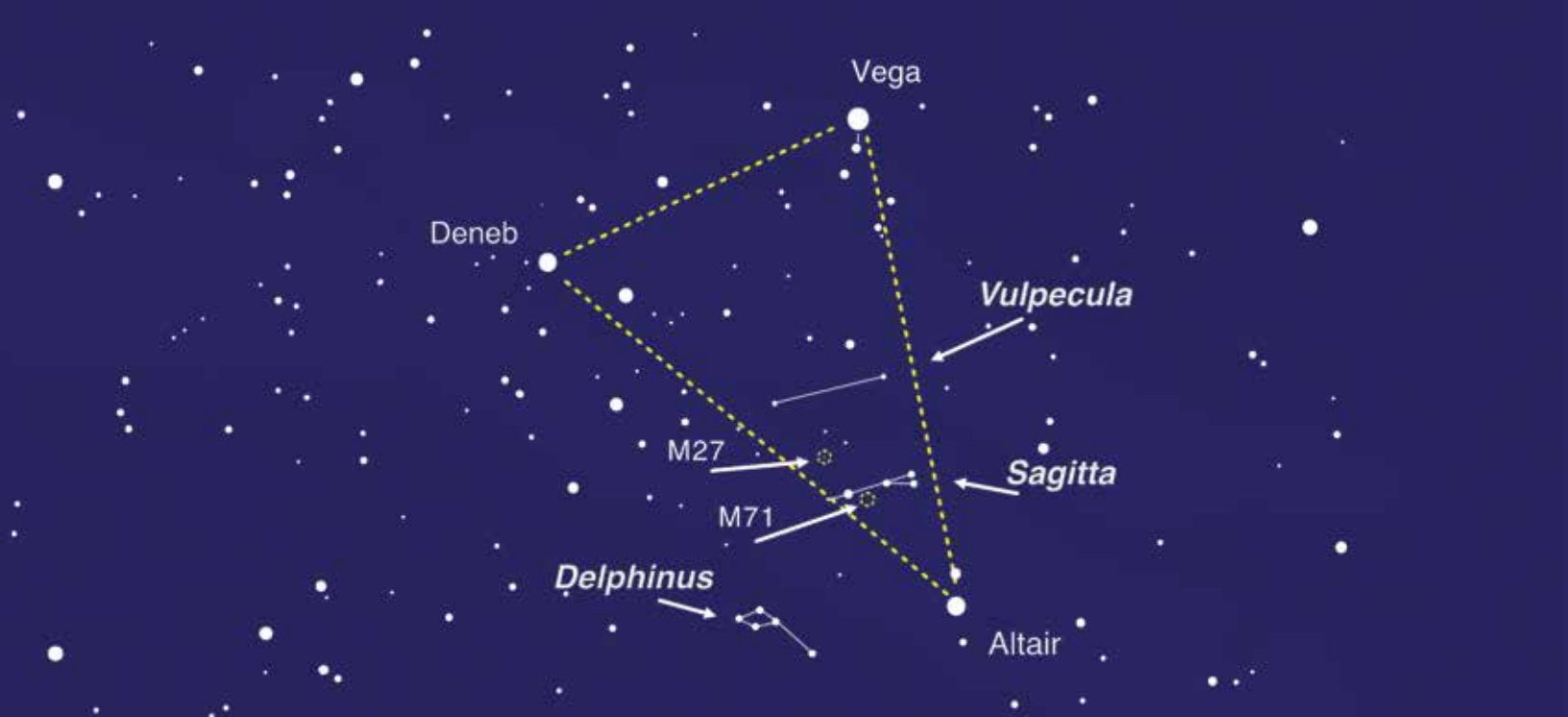
The Night Sky By Season

Winter

Winter is one of the best times to stargaze, as the winter night sky contains some of the brightest stars in the galaxy. Located high in the night sky, the hunter constellation, **Orion** (photo, left), is distinguished by its three-star belt—an asterism at its center. Orion is the key to the winter night sky for being bright and easy to find. Rigel, the brightest star in its constellation, is known as the spot where Scorpius stung Orion’s ankle. Rigel is 50,000 times brighter than the sun and 30 times its diameter. Betelgeuse, one of the largest known stars in the night sky, appears red and is positioned opposite Rigel on Orion’s shoulder (B).

Betelgeuse will lead you to the twin stars Pollux and Castor in the constellation **Gemini**. Draw a line from Rigel through Betelgeuse, and extend it approximately three times the distance between them. Pollux appears more bright and golden-colored than Castor, which is fainter and white in color. Betelgeuse is also the apex star that forms an equilateral triangle of stars known as the **Winter Triangle**. Anchoring the triangle to the right is Sirius, the brightest star at night in the Northern Hemisphere. Sirius is located at the tip of the dog’s nose within the constellation **Canis Major**, “The Greater Dog.” To the left side of the triangle is Procyon, part of the constellation **Canis Minor**, “The Lesser Dog.”

The entire winter triangle is located within the **Great Hexagon** of the winter night sky. The hexagon can be found by tracing Sirius up through Procyon, continuing on through the twin stars Pollux and Castor to Capella in the north (part of the constellation **Auriga**), then down to Aldebaran (part of the constellation **Taurus**), through Orion’s Rigel, and back to Sirius and Canis Major.



Summer triangle. NASA, with assistance from Stellarium.

Beginning with the Big Dipper asterism, you now know eight constellations!

Spring

Asterisms and constellations are least visible during spring except for the Big Dipper, which appears highest in the night sky during this season. You can use the Big Dipper to find the **Spring Triangle**, composed of the stars Arcturus in the Boötes constellation, Spica in Virgo, and Regulus—the bottom star of the inverted question mark that forms the constellation **Leo**.

The Pleiades, known in Greek mythology as the seven sisters, is a “young” cluster of stars and prominent celestial feature in winter through early spring. Whereas older stars are dispersed with gas around them, newly born stars are clustered close together and have not yet dissipated. Literary references to Pleiades are abundant, with the oldest dating to China circa 2350 BC. Find the sisters by tracing Orion’s belt East through the Taurus constellation.

Summer

The summer night sky brings wonderful views to three star attractions: Vega, Deneb, and Altair. Together these stars form the **Summer Triangle**

(see above). Vega, the brightest of the three, forms the constellation **Lyra**, the harp. Altair is associated with **Aquila**, the Eagle constellation. Deneb brightly tops the constellation **Cygnus**, the swan—also known as the **Northern Cross**.

Fall

Because it’s harder to see the Big Dipper in the fall, many people use Polaris, the North Star, to locate constellations, including Cassiopeia and Perseus. These constellations never set below the horizon, and they circle around Polaris. They are best seen in autumn. Cassiopeia is found by its W, or M, star formation. Perseus follows Cassiopeia across the night sky.

The Andromeda Galaxy (photo, above) is a spiral galaxy like our Milky Way. It is highest in the night sky in autumn, and the only object outside of our galaxy that is visible to the naked eye. It is projected that Andromeda will eventually collide with the Milky Way. After merging, the two will form an elliptical shape.

Notes

1. <https://www.fs.usda.gov/detail/bighorn/home/?cid=fseprd521531>
2. www.hokulea.com/education-at-sea/polynesian-navigation/
3. What Is an Aurora? | NASA Space Place –NASA Science for Kids

A night sky filled with stars and the Milky Way, with a campfire and people in the foreground.

Part Four

Photo: Stargazing at Lassen Volcanic NP/NPS



Night Sky Programs

Interpretation

Many of our national parks provide outstanding opportunities for seeing starry night skies—some, dazzlingly so. On clear nights, visitors to Bryce Canyon and Death Valley, for example, are rewarded with unfettered views of the Milky Way. In Denali National Park, the northern lights dance across the sky, undimmed by city lights. The NPS is proud to point a telescope skyward for them or guide them on a nighttime walk. Even parks in highly urbanized areas like Rock Creek Park in Washington, D.C. can connect visitors to the nighttime environment. Though these parks might not offer equally high-quality night sky views, they are still a respite from the city's incessant glare, providing relatively dark areas that serve as important natural preserves, and the clearest locally-available night sky conditions for large numbers of people.

Public enjoyment and understanding of the night sky are critical ingredients in the restoration of natural darkness.

Park interpreters can help stargazers make sense of the night sky and enhance the experience with connections to their lives and the world around them. Just as you interpret your park's terrestrial resources, you can interpret the night sky by engaging visitors in its role in shaping civilizations, its critical function in nocturnal environments and the ecosystem, and the work of the NPS in protecting this resource and inspiring visitors to be voices for night sky preservation in their own communities. Night sky activities also attract many visitors and benefit local communities. In this way, interpretive rangers are night sky ambassadors.

You don't have to be a Galileo to help people connect to the wonder of night!

There are numerous ways that night sky interpreters can creatively engage park visitors in the night sky through activities, stories, and associated themes. The idea behind night sky activities is to reacquaint visitors (and perhaps yourself) to



Rocky Mountain National Park/NPS

the night's charismatic qualities, and help people feel more at ease in low light settings. Gaining an appreciation for the qualities of the natural world at night can lead not only to a curiosity about the cosmos, but a desire to protect and preserve it in as natural a state as possible. Exploration of the cosmos gives park visitors and interpreters alike another mechanism for understanding the night sky in relation to other park resources such as geology, ecology, biology, and archeology, and comprehending universal themes such as time, space, connectivity, beauty, wilderness, and creation.

There is a lot more to the night sky than stargazing. The night is full of things to discover, whether a star filled sky in the darkest regions of Nevada, a park's nocturnal environment, or a cultural-historic site in an urban location like New York City. In short, there's a whole other world operating under the night sky that has been an integral part of the human experience.

In thinking about your approach to the subject, embrace *all* night sky-related topics, not just

astronomy. Many parks and park interpreters already offer a range of night sky activities. To see how other parks are connecting visitors to night sky events, reach out to the NPS night sky community of practice, through Teams, Sharepoint, or equivalent platforms. We hope the following activities will spark your imagination, boost your confidence, and propel you into the universe of nighttime interpretation!

Activities

Hosting Night Sky Events

Night sky events are a lot of fun and can create lasting memories for park visitors. Some parks are pros at hosting large festivals with telescope viewing opportunities for visitors. If your park is interested in building a program, reach out to other parks with established night sky programming to get advice and standard operating procedures. You can also search for Astronomy programs on the NPS Event Calendar. You don't need telescopes to provide fun experiences. Start small, and you'll grow your park's reputation over time. With a little research, mentoring, and planning, you'll be on your way to organizing your event.

A Night Sky Ambassador's Toolbox

Recommended:

- Dim red flashlight to preserve your night vision
- Green laser ("tuned" to 4-5 milliwatt, with fresh batteries, a momentary button or click switch, and lanyard strap) for pointing out sky features
- Planisphere (star wheel or star chart)
- Almanac and/or cell phone constellation app of where to find planets and other celestial events (e.g. meteor showers, moonrise and moonset times, International Space Station passes)
- A place free of glare from outdoor lights
- Plan B activities should the sky be cloudy
- Warm clothes - even in the desert, when the sun goes down it can get cold

Optional:

- Binoculars / visitors could also bring their own
- Telescope
- Volunteers to assist with skygazing
- A nearby smooth trail for nighttime walks
- Visual aids (e.g. iPad, photographs of celestial objects, diagrams, Junior Ranger Night Explorer guidebooks for children. etc.)
- See “Useful Resources” for more ideas

Stargazing with the Naked Eye

Telescopes are wonderful instruments for peering deeply into the night sky, but you don’t have to have one to experience and share the beauty of the night.

Seeing stars, planets, meteors, the aurora borealis, and other celestial bodies with the naked eye yields its own reward.

If your park’s location provides reasonable views of the night sky, then plan an evening of stargazing in a comfortable outdoor setting, such as a park amphitheater or open lawn. If needed, have visitors bring chairs or blankets. Prepare them in advance to wear warm clothing, as it could get windy and cold at night. Incorporating a few stargazing tips and activities into a standard night hike or talk can pique the interest of your visitors and doesn’t require a lot of expertise on your part. Refer to Part Three for information on cultural stories, celestial phenomena and constellations. Reach out to other parks to learn how they are engaging visitors with annual astronomical events.

Telling Constellation Stories

Constellation stories go a long way in creating memories and wonder and connecting us to other cultures. You don’t have to memorize every constellation! Presenting an evening of star lore is a great way to explore the night sky. There are many ways to explore the night sky through the lens of different cultures, experiences, and advancements



NPS Jeff Zylland

in technology. There are many indigenous explanations of the night sky to explore. Enslaved people followed the Drinking Gourd constellation to freedom. Sailors used celestial navigation to sail across vast oceans prior to GPS or accurate maps. How else have people used stars to navigate? What constellations or night sky stories relate to your park, seasonal event, or part of the country?

Reach out to your local Tribe(s) and other historically connected communities for your park and invite them to share stories of the night sky from their perspective. You can also encourage international visitors to share cultural heritage night sky stories from their region. We see many of the same constellations, although the night sky looks different in North America from locations in the Southern Hemisphere. The multicultural stories emphasize what’s unique about our experiences, and what we have in common.

**The next time they look up,
there’s a story to be found!**

Taking a Night Walk

Those who experience the park at night may be treated to dramatic scenes unique from views by day.

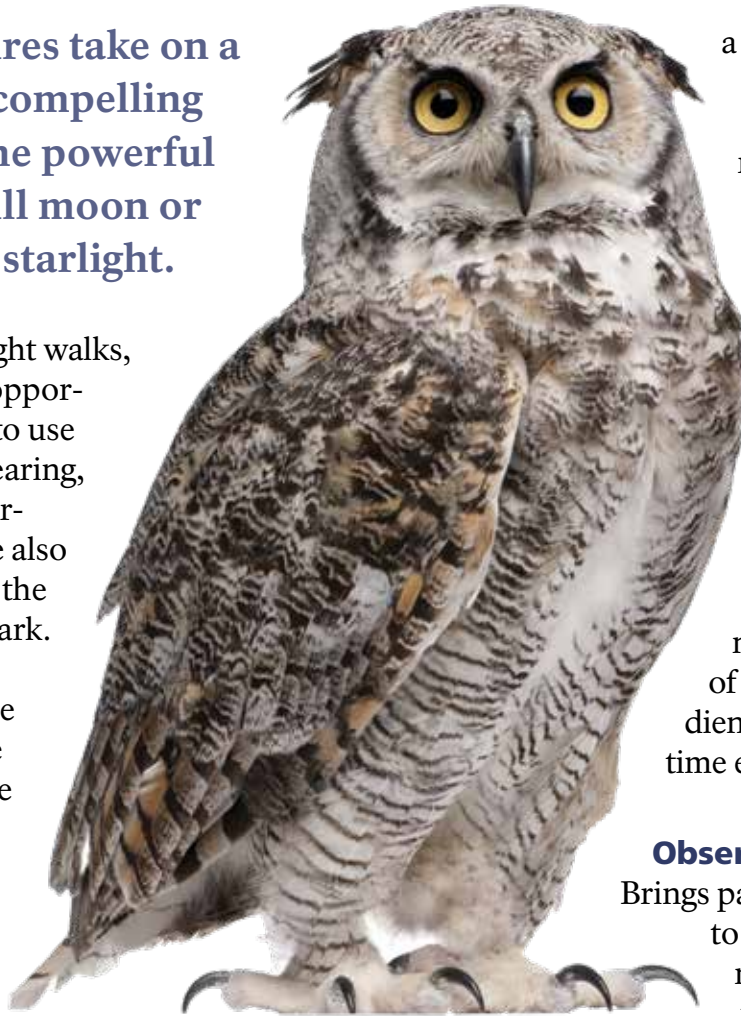
Natural features take on a unique and compelling glow under the powerful light of a full moon or twinkling starlight.

Full moon hikes, night walks, and talks are great opportunities for visitors to use other senses, like hearing, to tune into their surroundings. They are also opportunities to let the eyes adapt to the dark. We learned that the cones in our eyes are activated during the day, and the rods are activated at night. But did you know it takes at least 45 minutes for the eyes to fully adjust to the dark? Even a quick peek at a cell phone screen will interfere with this process. Encourage park visitors to allow their eyes to fully adjust to fully appreciate the night ambience.

Meet or walk your visitors to a park trail or area that provides relatively open terrain, without significant obstacles such as rocks and roots, or sudden drops and climbs.

The temptation to use a flashlight will be great, but once the eyes adjust, it's amazing what you can see that you did not previously think was possible.

Ask visitors to engage all the senses and consider the following questions: What sounds do you hear? Can you recognize the smells of certain trees and plants? Do you see any animals? Is there



a glow of lights on the horizon or from within the park? If so, does this disturb your experience? How might it disturb wildlife? Can you find the Big Dipper? What other constellations do you know?

Notice how the terrain looks different at night. How does the experience make you feel — worried, exhilarated, calm? What phase is the moon? How does moonlight shape your experience? What else do you notice? Include a few moments of silence to immerse your audience even further in their nighttime experience.

Observing with telescopes.

Brings park visitors that much closer to “Wow!” Many parks host night sky festivals and star programs with telescopes for people to experience dark, star-filled night skies up close throughout the year. Can your park accommodate?

Most parks don't own telescopes, but plenty of amateur astronomers do, and many are happy to share their gear and knowledge of the night with park staff and visitors.

Park staff can work with these astronomers to better understand the night sky, and build astronomy knowledge. With training, equipment, and support, these local experts can empower park staff to share the awe-inspiring scenery of the night, and messages of its protection. Observing the night sky with telescopes alongside amateur astronomers or professional scientists provides a platform for discussing science and humanities concepts, from constellation myths

and cultural stories to astronomical advancements and concepts of time and space.

Does your park already have a relationship with local astronomy organizations such as Sidewalk Astronomers or AAS ambassadors? This group of volunteers has branches in cities and towns across the USA. Find out how these volunteers can help you plan your next stargazing program. University astronomy departments and high school science clubs are also resources for connecting with astronomers and other educators who can provide scientific information about our galaxy and scale of the universe.

Don't dismiss the power of binoculars for exploring bright star clusters, the Moon, planets, and other celestial bodies.

Though they do not provide the same level of magnification possible with telescopes, they still give excellent views, and the ability to see more of the night.

Tuning into Wildlife.

What animals in your park come out after dark? Why might animals be nocturnal? Where would you likely find them — on the ground, in a tree or in the sky? Near a water source? A rocky cliff or prairie? Look to the environment for clues. Perhaps you spied an owl's nest in a cottonwood or juniper tree, or found its undigested pellets on the trail. You might have seen raccoon tracks by the stream, or marveled at the swooping silhouettes of bats at dusk.

If possible, meet or lead visitors to appropriate habitat to investigate, or simply watch and wait in a convenient location removed from noise.

Before you begin, let your eyes adjust to the dark. Use all your senses.

Many animals are nocturnal. Some animals come out at night to escape the heat of the day. Others need the night to hunt, mate, or avoid predators. Animals such as cats, owls, and rodents have developed keen hearing, smell, and dark-adapted vision to navigate at night.

There is a natural fascination for creatures that are awake and moving about when most people are in bed at night. Engaging park visitors after hours can yield rewarding opportunities to observe nocturnal wildlife in their natural habitat. Dawn and dusk are other good times to observe animals.

Animals are sensitive to sounds. Remind visitors to be as quiet as possible so as not to disturb them. Being quiet may increase visitors' chance of sightings.

Can you hear animals' calls? If so, can you guess the nature of their sounds? Are they used for warning, mating, or foraging? Are there sounds or lights in the area that might be affecting your ability to see or hear them?

North American nocturnal animals include:

- Aardvark
- Armadillo
- Badger
- Barn owl
- Bat
- Coyote
- Firefly
- Gray Wolf
- Luna moth
- Mink
- Mountain Lion
- Mouse
- Opossum
- Raccoon
- Red Fox
- Scorpion
- Skunk



Bring the Night Indoors.

If you are unable to lead park visitors to wildlife, perhaps you can bring the wildlife to visitors! Many parks have live webcams. If yours does, and if it has an infrared or low light setting, see if it could be installed in an area likely to have nocturnal activity, such as in a tree by a raptor's nest. Visitor center auditoriums are good venues for viewing webcam footage. Do scientists in your park use camera traps? These motion-triggered tools capture a range of roving critters at night. A slide presentation is a great way to introduce them.

Echo locators are a fun and effective way to amplify and show the acoustic activity of bats. Find

out if your park has or could obtain one. These instruments entertain curious kids and adults of all ages while educating about the threats of White Nose Syndrome and the unique contributions these creatures make to the ecosystem.

If you can't get outside under the sky due to rain or other reasons, there are still ways to connect visitors to concepts of light and dark environments.

This simple, indoor "looking" exercise can be done during the day or night, possibly as an interlude to or following a presentation on lightscaapes, nocturnal animals, or constellations. It reinforces an understanding of light, and the impact small amounts of light can have on dark environments.

Assemble and seat visitors in a room with no exposure to daylight. Shut the door and turn off the lights. Give the group five to fifteen minutes for their eyes to adjust to the dark while you give your presentation. During this time, unexpected patterns and images will emerge. Beams of light from outside may filter in through cracks in the door. Objects in the room will be distinguished from the surrounding darkness or may cast "shadows" of illumination that glance off the ceiling and reflective surfaces. Subtle variations in shades of darkness may appear, ranging from light gray to deep black.

Have visitors share observations. Introduce your own. How might this exercise shape observations in their own night surroundings?

Other indoor ideas:

Create a presentation that orients visitors to key stars, planets, asterisms, constellations, or other astronomical phenomena. Visitors can apply this information the next time they are under a night sky.

Introduce the concept of time travel! All the light we see at night was emitted from minutes

Myth

It's too late to do anything about light pollution.

Fact

Protecting natural night skies is as easy as changing your outdoor lighting. Yes, the problem is enormous and, in many areas, growing. However, with increasing scientific research and media articles, public awareness of light pollution has also increased, as has access to simple and effective solutions for lighting upgrades. Equipped with awareness, education, and determination, we can reverse our impact and reduce light pollution to restore natural night sky conditions in many areas of the country.

You doubt? Consider this: Bald eagles, once nearly extinct, are on the rebound; "recycling" and "sustainability" are everyday words. Or, research the state of U.S. air and waterways prior to the Clean Air and Clean Water Acts in the 1970's. It only takes you and the will to act.

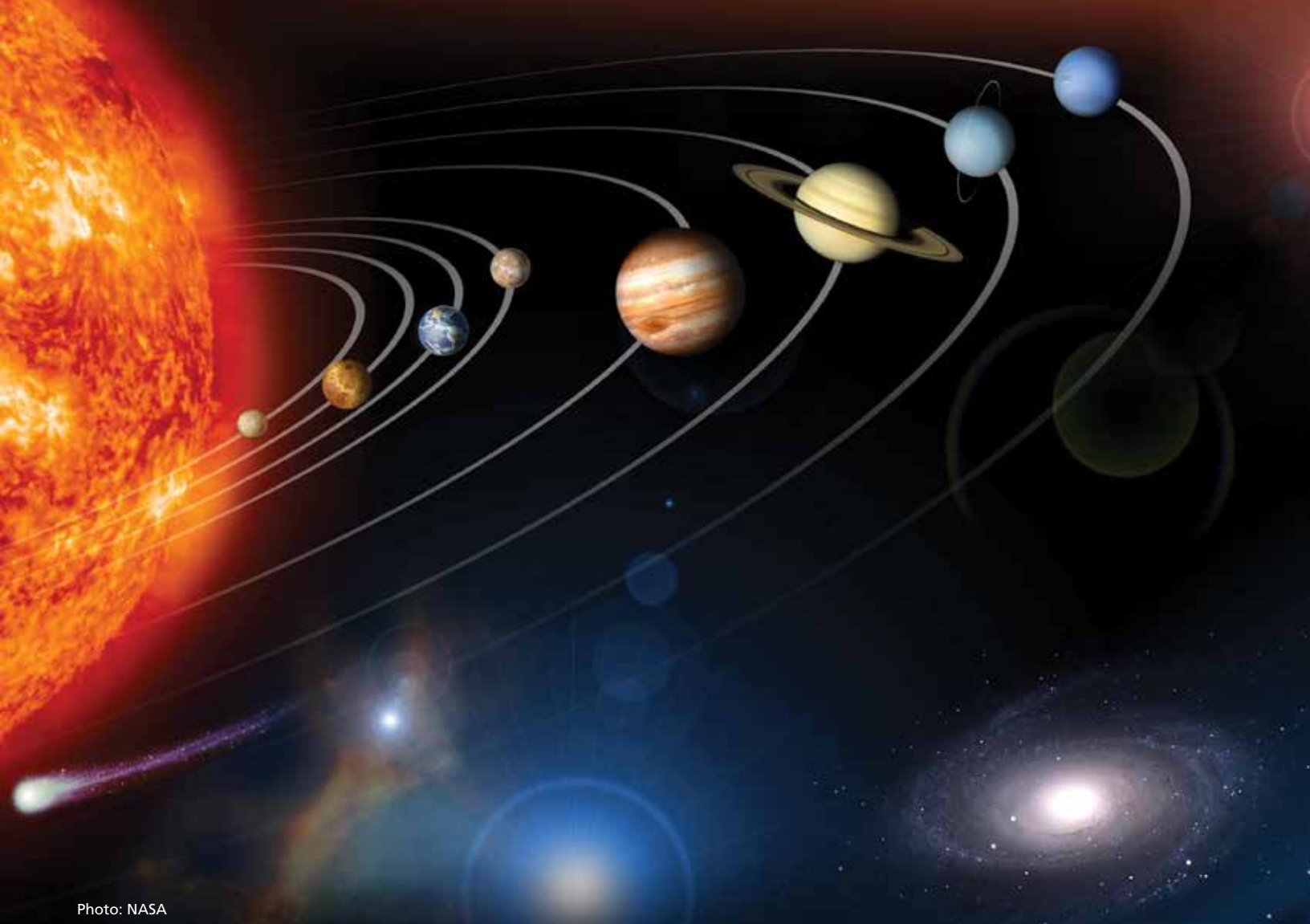


Photo: NASA

ago to millions of years ago. Connect the age of light seen in the night sky to what was going on in your park during the time when the light was first emitted. The Orion nebula is located 1345 light years away from Earth. For example, the light we see from Orion today was first emitted when most of the giant sequoias in Sequoia and Kings Canyon National Parks were just saplings.

Fathoming the Solar Scale

The universe is vast. Just how vast, no one knows. What directions would you give an alien to get to your house? Sure, you know your street address, city, state and country, but do you know your cosmic address? You might know that Earth is the third planet from the sun — located in the solar system within the Orion Arm of the Milky Way Galaxy. What else do you know? Could you chart a path from distant galaxies to Earth?

Planet	Distance from Sun (Miles)	Distance from Sun (Feet)
Mercury	35,983,610	.39 ft (4.68 in)
Venus	67,232,360	.75 ft (9 in)
Earth	92,957,100	1 ft
Moon	93,205,678	1.03 ft
Mars	141,635,000	1.53 ft
Jupiter	483,632,000	5.23 ft
Saturn	888,188,000	9.56 ft
Uranus	1,783,950,000	19.19 ft
Neptune	2,798,842,000	30.11 ft
Pluto	3,670,000,000	39.48 ft

This exercise may not help you with aliens, but it will put the scale of the solar system in perspective for visitors and can be integrated into other night sky lectures/activities. Get a 50 ft. length of twine or rope. Make knots based on figures given in the chart. Have park visitors hold the different knots and stretch out. For a more dramatic appreciation of scale, double the units of

Pillars of Creation. Photo: NASA





measurement and use a 100 ft. rope. Afterwards, encourage visitors to share their preconceptions and other insights of the solar scale.

Integrating Content

You play an important role in encouraging night sky conservation. As people are losing opportunities to see the night sky, interpretive activities are a great way to connect visitors to the wonder and value of nighttime environments. Without a personal connection, there is little motivation to protect. It is also important to raise understanding around the issues that drive the NPS to protect night sky resources. Providing this context will help compel park visitors to care and become night sky stewards.

Providing night sky experiences, coupled with educating the public about light pollution causes and solutions, will create recognition and a sense of pride and heritage for this endangered resource — tools that evoke action.

You've read that natural darkness is as much a part of the ecosystem as light and air. You get that gazing at a star filled sky can be inspiring. You now have a better idea of how wildlife, humans, and cultural resources are affected by the lack of darkness. You know, too, that it is a rapidly diminishing resource with a not-too-difficult fix. The night sky is a springboard for exploring questions about exploration, survival, and our role on earth. We hope you appreciate it as much as we do and will share that interest with our visitors.

Glossary of Night Sky Terms

Airglow is naturally occurring light emitted from the photochemical luminescence of gases in the upper atmosphere. It often appears as a vague and smooth light in the sky that is brighter toward the horizon as compared to the zenith; however, it can sometimes have a banded or wispy character. Also known as the “night glow.”

All sky brightness refers to measured light from both anthropogenic and natural light sources.

Asterism a prominent pattern or group of stars, typically having a popular name but smaller than a constellation.

Anthropogenic light is human-caused light.

Constellation a group of stars forming a recognizable pattern that is traditionally named after its apparent form or identified with a mythological figure. Modern astronomers divide the sky into eighty-eight constellations with defined boundaries.

Glare is caused by a source of light that is much brighter than the scene luminance to which the eye is adapted, the effect of which can hamper visibility.

Integrated starlight is the combined brightness of stars in the Milky Way Galaxy that are too faint or too close together to be resolved.

Light pollution is excess or inappropriate artificial light outdoors. Light pollution occurs in three ways: glare, light trespass, and skyglow.

Light trespass is light that directly shines beyond the area intended to be lit.

Luminance is the amount of light emitted or reflected from the source, and **illuminance** is the amount of that light that shines on an object from a source. Luminance doesn't vary with distance from the source, but illuminance does.

Lux is one lumen per square meter and is the unit of measurement that quantifies illuminance.

Natural nighttime environment refers to naturally occurring light conditions from integrated celestial sources such as the stars, Moon, Milky Way, and planets without the presence of anthropogenic light.

Photometry refers to methods of measuring light levels and distribution in terms of perceived brightness, or the interaction of light with the human eye. In this regard it differs from **radiometry**, which measures light energy in purely physical terms.

Sky glow refers to the scattering of escaped light by the atmosphere back to the ground. Sky glow creates “light domes” over bright cities.

Zenith is a point in the sky directly “above” an observer in a particular location. The atmosphere is thinnest at the zenith, which helps astronomers observe celestial objects.

Zodiacal light is the glow of light that scatters off dust particles in the solar system and extends upwards from the horizon after sunset (false dusk) and before sunrise (false dawn). It lasts about 90 minutes after astronomical twilight or before the start of dawn before it fades away.



National Park Service
U.S. Department of the Interior
Natural Resource Stewardship and Science Directorate
Natural Sounds and Night Skies Division

