How FLAGSTAFF is preserving DARK SKIES

A star party and world-leading community are keeping the hometown of Lowell Observatory in the dark.

by Christian Luginbuhl and Jeffrey Hall

Partygoers and telescope hosts share a star-filled sky near Flagstaff, Arizona, during the city's annual star party. FLAGSTAFF DARK SKIES COALITION

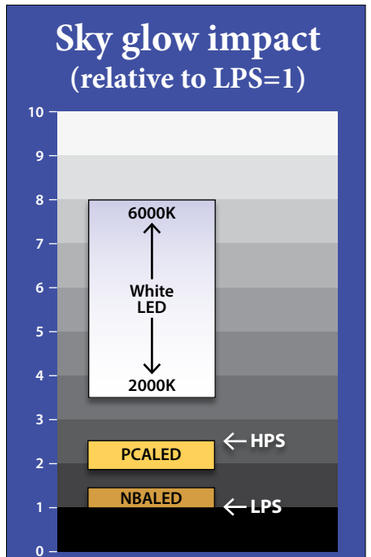
Venus sets among myriad stars above Flagstaff, Arizona, in this view of the sky from Buffalo Park, the site of the annual star party. FLAGSTAFF DARK SKIES COALITION

FLAGSTAFF, ARIZONA, WRAPS picturesquely around the base of the San Francisco Peaks, the state's highest mountain range. At an elevation of 7,000 feet (2,130 meters), the air is thin, and nights are chilly even in summer. The bracing environment, however, doesn't stop thousands of people from coming every September to Buffalo Park, a large open space right in the middle of the city, to peer into the cosmos.

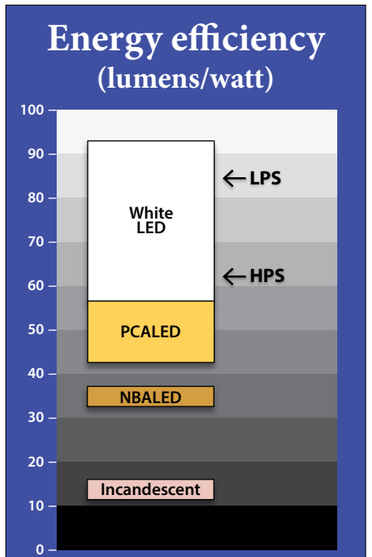
Here at the Flagstaff Star Party, rows of telescopes are hosted by the area's many amateur astronomers, as well as by professionals from Flagstaff's two major observatories: Lowell Observatory and the United States Naval Observatory (USNO). Despite the location less than 2 miles from City Hall, the sky is spectacular. The astronomers trace constellations and stars fainter than 6th magnitude for the partygoers, and the autumn Milky Way rises from the looming peak of nearby Elden Mountain, arcs through the zenith, and dives into the southwestern horizon directly over the center of the city. Even the splendid Sagittarius star clouds find little competition from the sky glow.

The Flagstaff Star Party bills itself as "The World's Most Accessible Dark Sky Star Party," a unique event providing easily accessible viewing under unexpectedly dark skies, within a 10-minute drive of restaurants, hotels, and all the amenities of a college town of 70,000 inhabitants. To the quantitatively inclined, the event boasts Bortle class 4 skies, a zenith sky brightness fainter than 21.2 magnitudes per square arcsecond, and a zenith limiting magnitude of 6.5 or fainter. (The Bortle scale is a nine-level scale of sky darkness created by astronomer John Bortle in 2001. Bortle 9 is a terrible, urban sky, and Bortle 1 is a perfect sky with no terrestrial lights.)

All of this stems from a 59-year tradition of dark-sky preservation in Flagstaff, which in 2001 was given the first "International Dark-Sky City" designation by the International Dark-Sky Association (IDA). Flagstaff shows in brilliant highlights just what can be achieved.



The impact on sky glow from outdoor lights can be huge, as with white LEDs, or minimal, as with low-pressure sodium (LPS) lamps or narrow-band amber (NBA) LEDs. Phosphor-convervted amber (PCA) LED is in between. FLAGSTAFF DARK SKIES COALITION



The energy efficiency of lighting varies widely, from the highly efficient (white LED and low-pressure sodium) to the less efficient (phosphor-converted amber and narrow-band amber LED), to the woefully inefficient (incandescent).

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Preserving dark skies for astronomy — and more

Dark-sky protection in Flagstaff goes back to 1958, when at the impetus of Lowell and USNO astronomers, the city enacted the world's first law to protect night skies, banning advertising searchlights. Lowell (established in 1894) and USNO (1955) steadily grew, and they now have over $125 million in telescope assets in the area. Preservation of the sky quality necessary for astronomical research is contained in Flagstaff's lighting code and in its engineering standards.

At the heart of these standards is a proverbial three-legged stool for dark-sky preservation: full shielding for outdoor fixtures, limits to the total amount of installed lighting per acre, and spectrum management calling for low-pressure sodium street and area lighting.

Astronomy, however, is only part of the equation. Flagstaff has built the idea of looking up and seeing a star-filled sky into the city's culture. You can find locals sipping a "dark-sky mocha" at Late for the Train Coffee, or unwinding at the end of the day at Dark Sky Brewing Company on Beaver Street. A bit west of downtown, you can turn off Flagstaff Ranch Road and onto Dark Sky Lane. The IDA proclamation of dark-sky city status is found on signs leading into town. The natural night sky — as an environmental quality, as a resource to be enjoyed, as a tourism driver, and as an ecological and health benefit — is part of the ongoing conversations of residents, city planners, and advocacy groups like the Flagstaff Dark Skies Coalition.

SENSIBLE DARK-SKY LIGHTING STANDARDS WOULD REDUCE SKY BRIGHTNESS OVER OUR CITIES BY 90 PERCENT OR MORE.

Decades ago, we all had to think consciously about whether refuse went in the trash or the recycle bin; today it's second nature. For a longtime resident of Flagstaff, it's startling to go to another city and not see the Milky Way from downtown. Seeing the galaxy and faint stars from the middle of a sizable town is second nature.

Unfortunately, it is also easy not to see them unless preserving the dark sky also becomes second nature.

Losing the night

The night sky has been a canvas of human hopes and inspirations since we have been aware enough to raise our eyes from the ground. Yet today, we find night's window closing almost everywhere, veiled by the spread of artificial light.

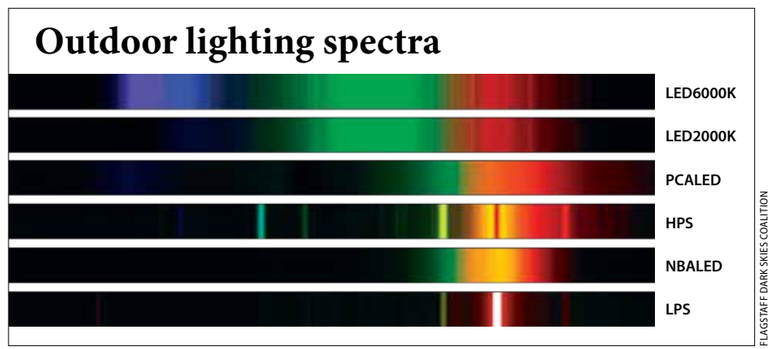
Sensitive individuals noticed this invasion long ago: In 1928, naturalist Henry Beston lamented, "With lights and ever more lights, we drive the holiness and beauty of night back to the forests and the sea" (*The Outermost House*). But in our modern age, the problem has vastly accelerated, with an ever-increasing demand to use more light in more circumstances and at more times. "The New World Atlas of Artificial Night Sky Brightness" (available online at http://advances.sciencemag.org/content/2/6/e1600377), published in the June 2016 issue of *Science Advances*, revealed in beautifully-colored maps the un-beautiful consequences of increased artificial light: None of the land area in Europe or nearly anywhere east of the Great Plains in the United States has naturally dark night skies; 60 percent of Europeans and nearly 80 percent of U.S. residents live where they can no longer see the Milky Way. Increases in the efficiency of lighting technologies (most recently LEDs), always touted as an opportunity to save energy, have instead only contributed to the relentless increases in the amount of light.

How many of us know that this is not necessary?

Recovering the night

It doesn't have to be this way. To examine the options, we return to our three-legged stool.

Shielding. Use of fully shielded fixtures, ensuring no light radiates above horizontal, is simple and effective. Flagstaff does it; other dark-sky communities do it; anyone can do it. Even absent any other



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Spectra of common outdoor lighting types show narrow emission from low-pressure sodium, at bottom, which does little to interfere with night-sky viewing. On the other hand, broad spectrum LEDs, at top, emit light over a wide range of wavelengths, making them destructive to skywatching.

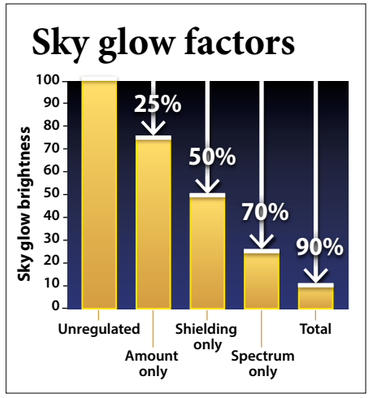
regulations, research shows that simply directing light to the ground where it is needed can reduce artificial sky glow by 50 percent or more.

Appropriate lighting levels. One can find examples of excessive outdoor lighting everywhere, but it can be managed with practical limits on the amount of lighting. Flagstaff's code, for example, specifies anywhere from 25,000 to 100,000 lumens per acre. Implementing these limits will reduce sky glow by another 25 percent in typical communities.

Spectrum. When you take a nighttime flight, you can see the yellowish pinpoints of city lights going by below. Putting aside the point that if you're seeing them at 36,000 feet, they're not doing what they're supposed to be doing, the color, or spectral content, of the light is critical to light pollution impacts.

The yellow color arises from high-pressure sodium (HPS), the predominant technology for outdoor lighting. It's not a terrible dark-sky light, but it's not ideal, either, with broad emission redward of about 550 nanometers and some blue features mixed in. A much better solution is low-pressure sodium (LPS), considered the "gold standard" for dark-sky protection, with nearly monochromatic emission at 590nm, giving rise to its characteristic amber color. Flagstaff has long used LPS for roadway and general area lighting, such as parking lots.

Over the next five to 10 years, many or most of these lights are expected to be replaced with LEDs — and indeed already have been in many cities and towns.



The amount of sky glow reduction one sees results from three factors: reasonable limits to the amount of light, good shielding, and amber light sources. FLAGSTAFF DARK SKIES COALITION

Improved energy efficiency is often touted as a principal reason for this change, but likely an even greater influence is the potential for dramatically reduced maintenance costs, as LED lights have expected lifetimes much greater than lamp-based technologies. But the spectral characteristics of most LED lighting create dramatic increases in sky glow, and any community considering an LED retrofit should consider the many alternative options available.

Sky glow impacts

The worst spectrum choice for sky glow impacts, unfortunately, is the one most often adopted: white LED. LEDs emit light across the entire visible spectrum — that's why they appear white — with dramatically greater emission in the blue and green portions of the spectrum compared with yellow light sources like HPS. Though white lights certainly provide more accurate color perception compared with HPS (and especially LPS), it is at a cost of two to four times more sky glow than HPS (and 3.5 to eight times more than LPS). Often suggested to arise from increased scattering in the atmosphere, the effect actually arises primarily because the night-adjusted eye, the eye that looks at night skies, is most sensitive to blue and green.

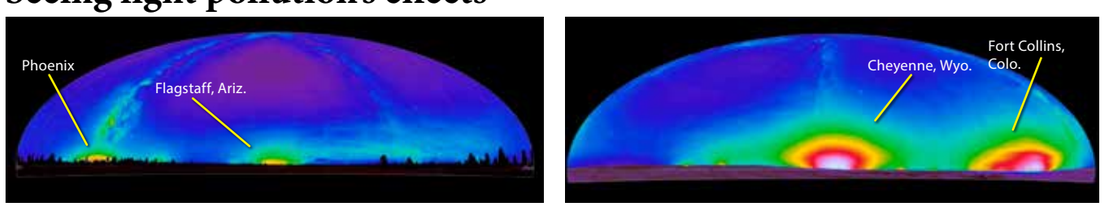
White lights, particularly the "cool white" varieties characterized by high "color temperatures" of 4,000 to 6,000 kelvins with their harsh, bluish-white glare, are ruinous to visual appreciation of the night sky. Some communities are taking notice of how unpleasant the worst of these lights are, and implementing "warmer" (that is, lower color temperature) solutions. Tucson, Arizona, for example, has installed 3,000 K LEDs, and Phoenix, the sixth-largest city in the United States, is installing 2,700 K LEDs.

All white sources however, even at 2,700 K, have substantial blue and green emission not present in HPS or LPS. Filtered LEDs exist that remove all light blueward of 500nm, but they still emit substantial green and have notably greater sky glow impacts than yellow sources. Phosphor-converted amber (PCA) LEDs closely resemble HPS, and narrow-band amber (NBA) LEDs take one more step toward a truly dark sky-friendly LED solution, creating a reasonable approximation to LPS.

For its own LED streetlight solution, Flagstaff is considering options favoring NBA LEDs for most roadway lighting. A practical disadvantage to any of these yellow LED solutions is their lower energy efficiency relative to white LEDs, but technology steadily improves and, year by year, these options are becoming more viable.

Combined, these practices can dramatically reduce sky glow. With conservative estimates of the reductions likely from each of these three critical aspects, sky glow in many communities can be reduced by 90 percent! In a town of 70,000, a night sky populated with a paltry 500 stars can be amped to one with 2,000, 3,000, or more.

Seeing light pollution's effects



Sky brightness measurements show how startlingly dark Flagstaff is compared with a similar city at a similar distance. The all-sky map at left shows sky glow from Flagstaff (near center) measured from a distance of 17 miles (27 kilometers). Flagstaff's population is 70,320. Sky glow from Phoenix, far more distant, appears at left. The right-hand map shows sky glow from Cheyenne, Wyoming, from a distance of 19 miles (31km). This city has a similar population — 63,335. The sky glow at right in this map is from Fort Collins, Colorado. Lighting ordinances can really work! U.S. NATIONAL PARK SERVICE

The setting Big Dipper looms just over the horizon from the site of the Flagstaff Star Party, just 2 miles (3km) from the city center. Star-filled skies would shine over much more of the United States if effective lighting ordinances required better lighting. FLAGSTAFF DARK SKIES COALITION

THE INSPIRATION OF STAR-FILLED SKIES CAN RETURN TO MILLIONS OF OUR BACKYARDS IF WE MANAGE OUTDOOR LIGHTING SENSIBLY.

Your mileage may vary

Astronomy readers hail from all over the world, and your community may well not have two major observatories right at the city limits. The narrow-band emission of LPS or NBA LEDs is vital to maximum dark-sky preservation for 4-meter telescopes, but as described above, many other options exist, both in the type of lighting as well as where and how much of it is applied, to greatly reduce sky glow for both telescopes and human observers.

We encourage all readers to look at Flagstaff, and at other communities that have adopted dark-sky practices (especially those with IDA dark-sky community or dark-sky place status), and to think about — and work to implement — the optimal solution for your area. This discussion shows the range of options available, and how much could be gained. Flagstaff shows that all the solutions are within reach if the community sets its priorities to achieve the best for dark skies.

It can be done

Let's look at what happens when all three legs of the stool are applied.

During one September evening at the Flagstaff Star Party, we overheard a pair of visitors from Phoenix who had journeyed to Flagstaff for an evening of telescope viewing. It was the first night of the star party, and the locals were disappointed with some scattered clouds, given that September is usually reliably clear. With the clouds reflecting such light as Flagstaff does emit, the sky was looking as bright and unappealing as it ever does to Flagstaff natives. "Wow," remarked one of the visitors. "It really is dark here!"

With relatively simple measures, we can all ensure statements like that become more common. Nights when the Milky Way is so bright it looks three-dimensional, when vast numbers of faint stars peek out of the darkness alongside the bright ones, and when the light from the Andromeda Galaxy reaches our eyes after its 2½ million-year journey are moments of inspiration and deep connection to the cosmos for all of us, not just astronomers. Let's make sure we hold on to those moments — for ourselves, and for those who will follow us — and that there is darkness in the light. For more information on the Flagstaff Star Party, visit Flagstaffstarparty.org.

The myriad stars still come to Flagstaff, Arizona. Let's see them everywhere.

Christian Luginbuhl, *a retired astronomer who spent many years at the U.S. Naval Observatory in Flagstaff, is a dark night sky activist.* **Jeffrey Hall** *is director of Lowell Observatory in Flagstaff.*