LEDs: The Future of Street Lighting and their Effect on Astronomy

Britny N. Delp and Stephen M. Pompea
National Optical Astronomy Observatory
Tucson, AZ

Light pollution degrades the night sky.

Light pollution comes in many forms including light trespass, glare and sky glow. Of these, sky glow is of the most concern to the astronomical community as it limits their field of view. Broad spectrum sources exacerbate this problem by providing short wavelength light, which is scattered by Earth's atmosphere via Rayleigh scattering.

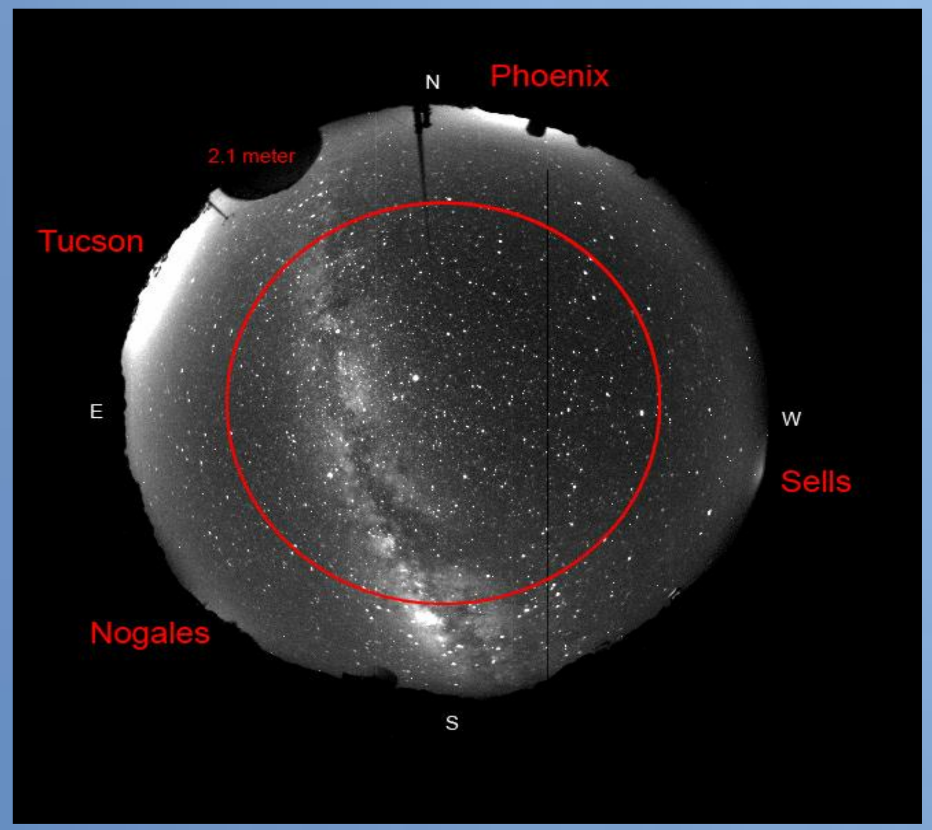

Figure 1. Light pollution at Kitt Peak National Observatory from neighboring cities of Nogales, Sells, Phoenix and Tucson.

Shorter wavelengths produced by broad spectrum lighting scatter more.

This scattering (Rayleigh scattering) of blue and purple light makes white lights with significant short wavelength output very detrimental to astronomers. White LED lights are typically constructed from blue LEDs with a phosphor coating. This causes the white LED to produce a large spectral spike around 460nm. This spike disrupts astronomical measurements directly, and by creating a brighter night sky via sky glow. In addition, research indicates that this wavelength may have a detrimental influence on biological rhythms by influencing melatonin production.

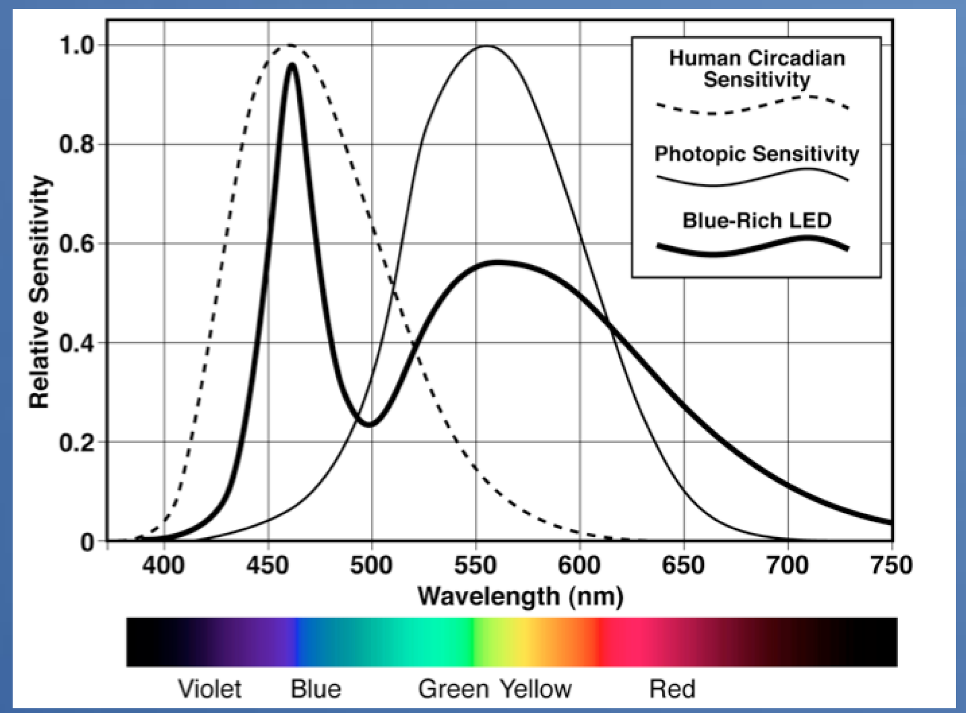

Figure 2. White LED spectrum with human photopic and circadian sensitivity overlay courtesy of IDA.

The project goal was to determine the most useful and dark-skies friendly LED lighting.

Using a Czerny-Turner spectrometer, 45 different types of outdoor lights were categorized. These spectra were used to determine how useful the light is for human vision and how dark skies friendly these lights are. Dark skies friendly lighting means that little to no light shines above a right angle to the light, and should emit as little as possible below 500nm (green) wavelengths to curb scattering. The following criterion were used in selecting the best source for urban and rural lighting: color rendition measured by color rendering index (CRI), percentage of light emitted under 500 nm, and luminous efficiency (lumens/watt).

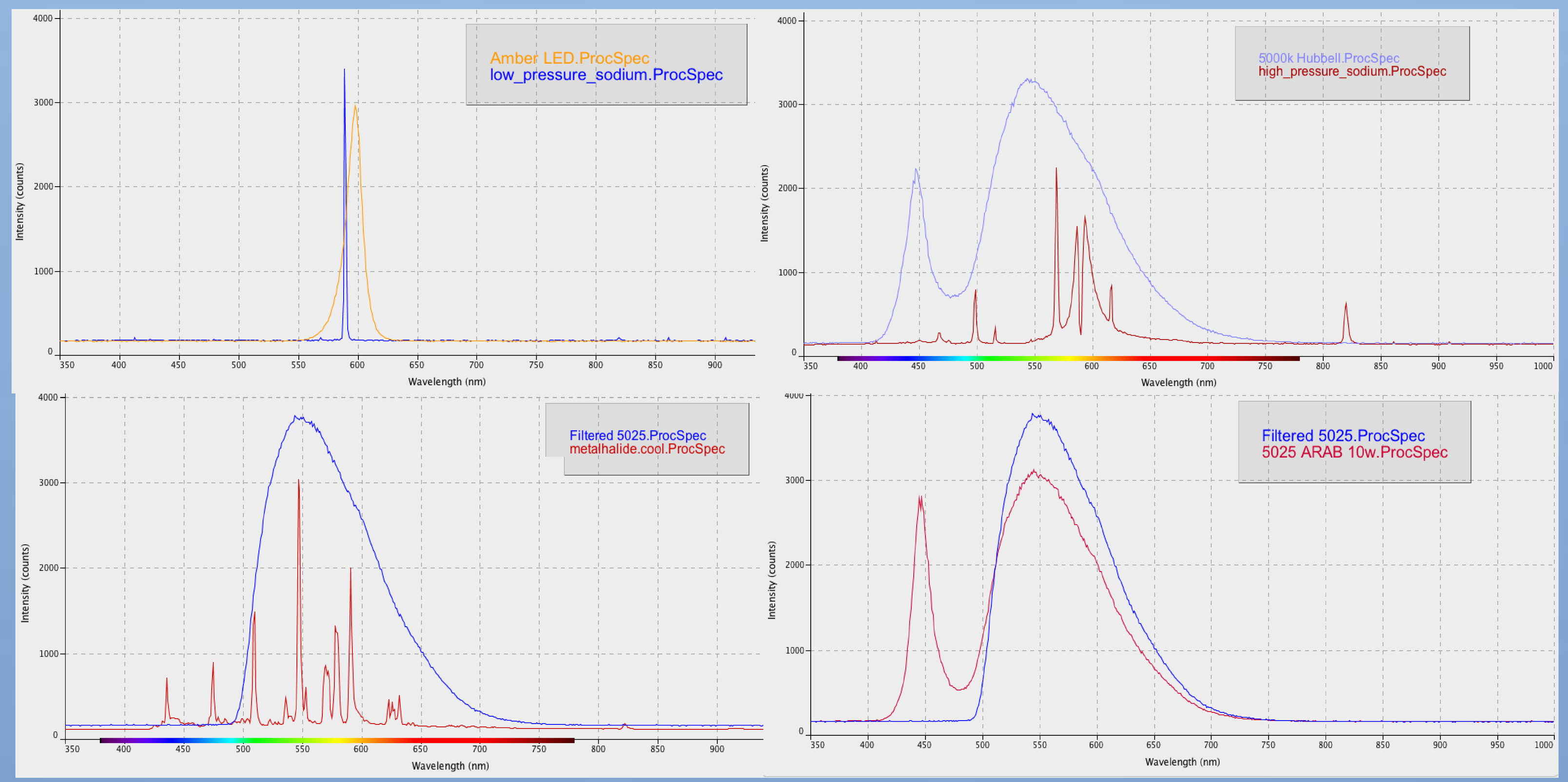

Figure 3. A comparison of spectra: (clockwise from top left) LPS vs. Narrow Band Amber LED, HPS vs. unfiltered LED, Filtered vs. Unfiltered LED, and Metal Halide vs. Filtered LED.

Light Source	Efficiency (Lumens/watt)	% of Light Emitted below 500nm	Color Rendering Index
High Pressure Sodium	70-140	17.3	20-25
Low Pressure Sodium	100-200	0	0
Fluorescent	46-104	21.8	90+
Incandescent	8-17	10.7	100
Tungsten Halogen	14-24	8.5	95-100
Metal Halide	78-120	20	60-70
White LED	75-107	30	70-90+
Filtered White LED	41-75	9.5	55
Narrow Band Amber LED	25-51	0	0

Figure 4. Table of values featuring Lumens per watt (complied from catalogues), color rendering index, and percentage of light emitted below 500nm for various light sources.

The spectra of 45 light sources were compared to human eye sensitivity.

Luminous efficiency (lumens/watt) is typically a good reference for the usefulness and efficiency of a light source. However, claims have been made that some companies have been manipulating this metric by using the scotopic (starlight level) eye response as opposed to the mesopic (outdoor night time lighting) to mislead consumers about the efficiency of their product. Others are working to replace the CRI with the Color Quality Scale (CQS) to better evaluate the usefulness of LEDs.

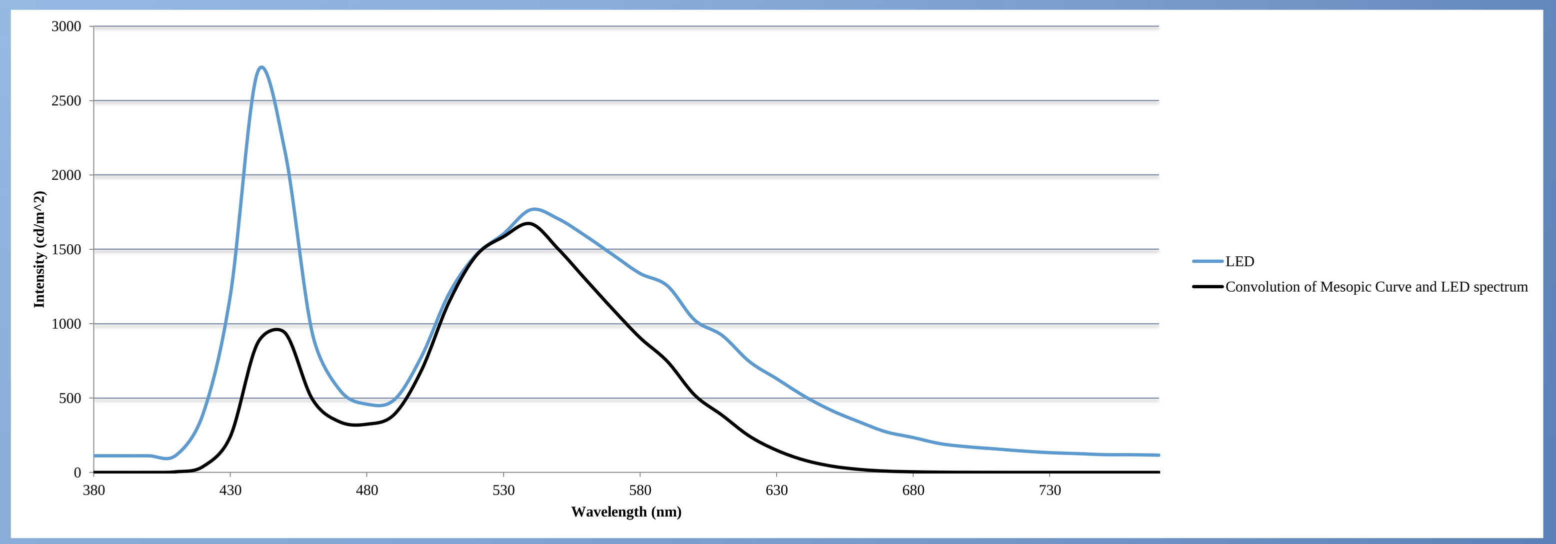

Figure 5: The black line demonstrates that the short wavelength light produced by an LED is mostly unused by the eye, negating the claims of many LED companies that blue light is advantageous.

The most astronomy-friendly LED light source currently available for cities is the filtered LED.

Other possible solutions include the narrow band amber for dark areas like national parks and observatories, as well as the development of a new white LED consisting of amber, green, and red; omitting blue light completely. LED technology is among the fastest growing industries today. As costs decrease, LED street lighting will become more cost effective and efficient. In order to preserve dark skies, we must ensure that these lights are free of mostly useless and detrimental blue light.

Acknowledgements:
I would like to thank my advisor, Stephen Pompea, as well as Chris Monrad of Monrad Engineering and Matthew Root of the international Dark Skies Association for their patience and guidance throughout the project

References

International Dark-Sky Association. "Visibility, Environmental, and Astronomical Issues Associated with Blue-Rich White Outdoor Lighting." 4 May 2012. Web. 26 July 2012. <Visibility, Environmental, and Astronomical Issues Associated with Blue-Rich White Outdoor Lighting>.
Monrad, Christian K., James Benya, and Dr. David L. Crawford. *Rosemont Copper Project Light Pollution Mitigation Recommendation Report*. Rep. Tucson: 2012. Print.

This material is based upon work supported by the S.D. Bechtel, Jr. Foundation and by the National Science Foundation under Grant No. 0952013 and Grant No. 0833358 (check funding spreadsheet if needed). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the S.D. Bechtel, Jr. Foundation or the National Science Foundation. This project has also been made possible with support of the National Marine Sanctuary Foundation.
The STAR program is administered by the Cal Poly Center for Excellence in Science and Mathematics Education (CESaME) on behalf of the California State University (CSU).

Grant No. 0952013

This work was supported by a grant from the National Science Foundation Astronomy Division. NOAO is operated by the Association of Universities for Research in Astronomy (AURA), Inc. under cooperative agreement with the National Science Foundation.