

2017 SOLID-STATE LIGHTING TECHNOLOGY R&D WORKSHOP
November 8, 2017 • Portland, OR

Panel | Technology Tradeoffs with LED Lighting
- Spectrum -

Steve Paolini, Telelumen LLC

Agenda

- Introduction
- Reflected Spectrum of Objects
- Light Source Spectrum
 - Daylight, fire
 - Vacuum
 - Solid State (LED)
- Daylight data
- Summary
- Demo



The Recording and Playback of Light

- Founded 2007 – Silicon Valley, CA
- Purpose – Replicate any spectral power distribution
 - Products and services to create and playback light
- Privately owned
- Current products:
 - Light Replicator (16 color light player)
 - Octa (8 color light player)
 - LumenScripts (content)
 - Recordings, created, composed digital data

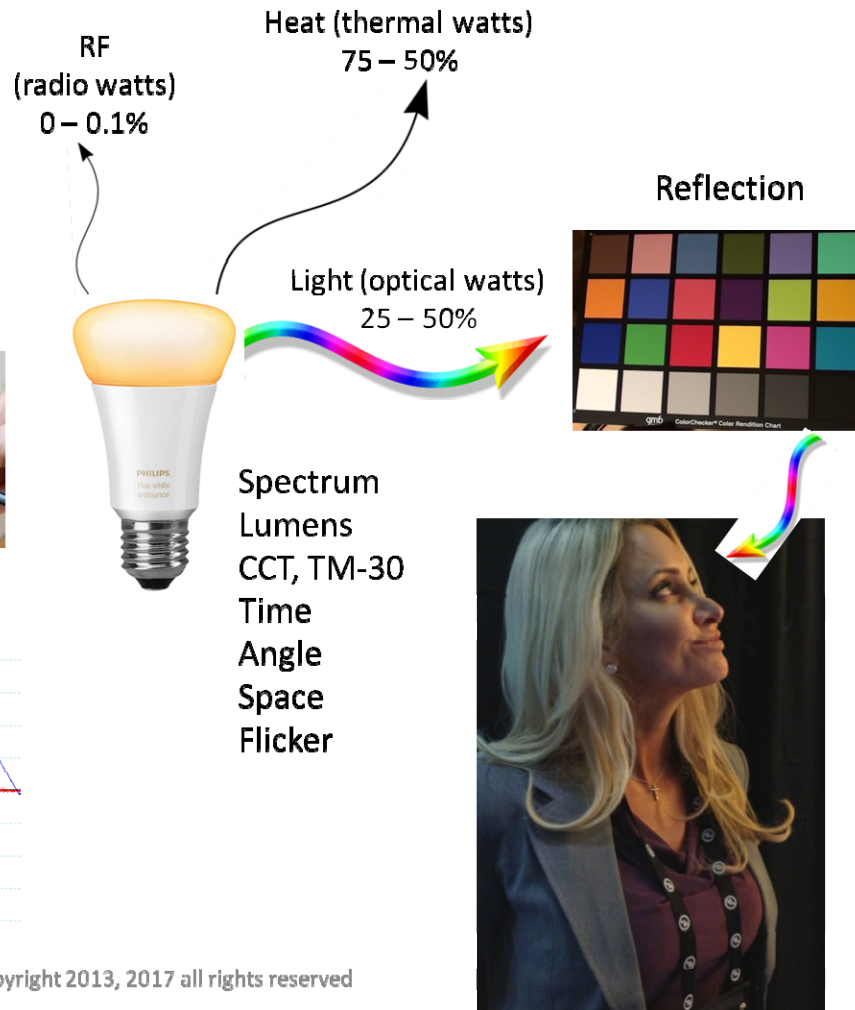
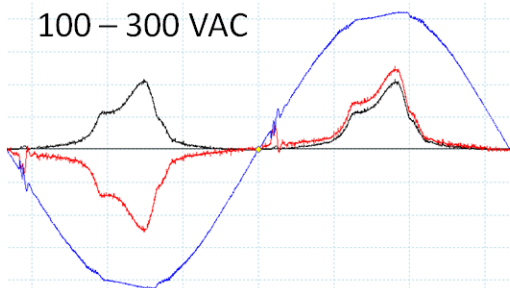
Target Applications

- Healthcare – faster healing, wake/sleep improvement
- Retail – make products more appealing
- Workplace – increase productivity, wellbeing
- Lighting company – designer spectrum, focus group evaluations
- Horticulture – plant growth
- Aquariums – fish, coral
- Sensors (cameras) – firmware development
- Color quality – consistency, metrics, studies
- Movie, TV – outdoor scene and filter replication

SSL Ecosystem

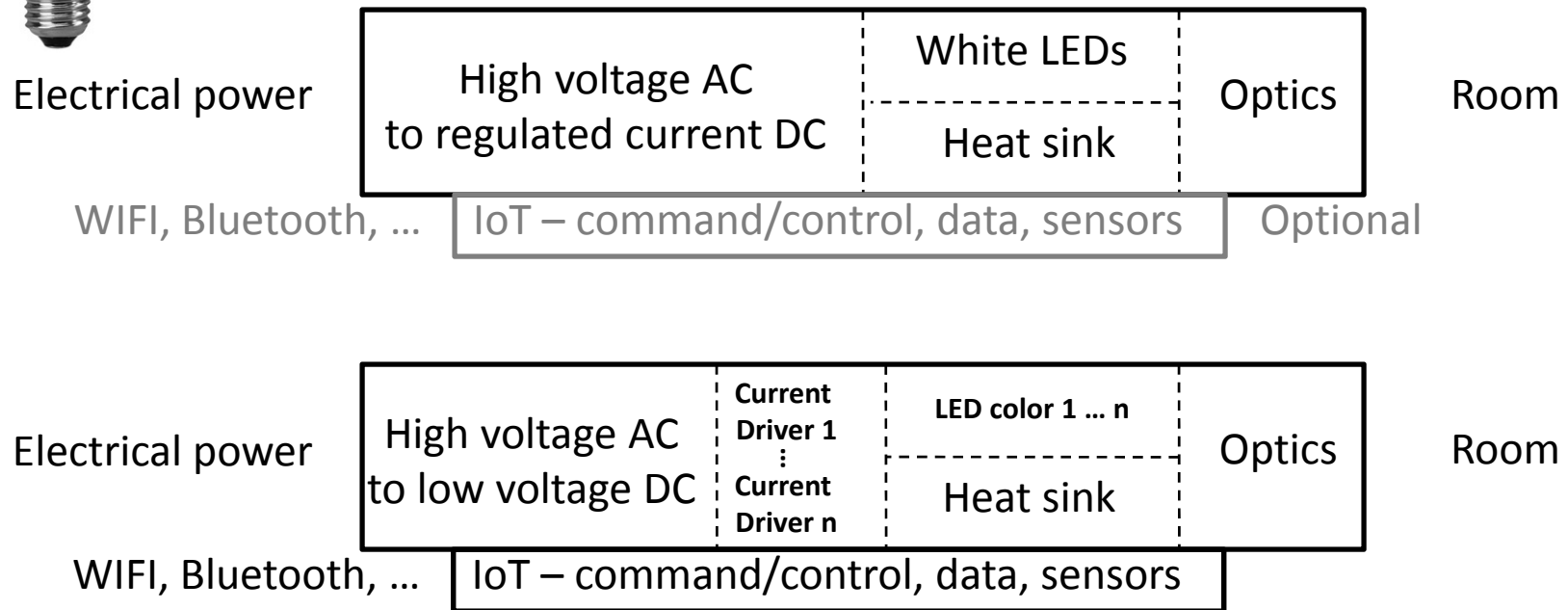


Electrical watts
 Voltage
 Current
 Time
 PF, THD





Fixed color and tunable lamp/luminaires

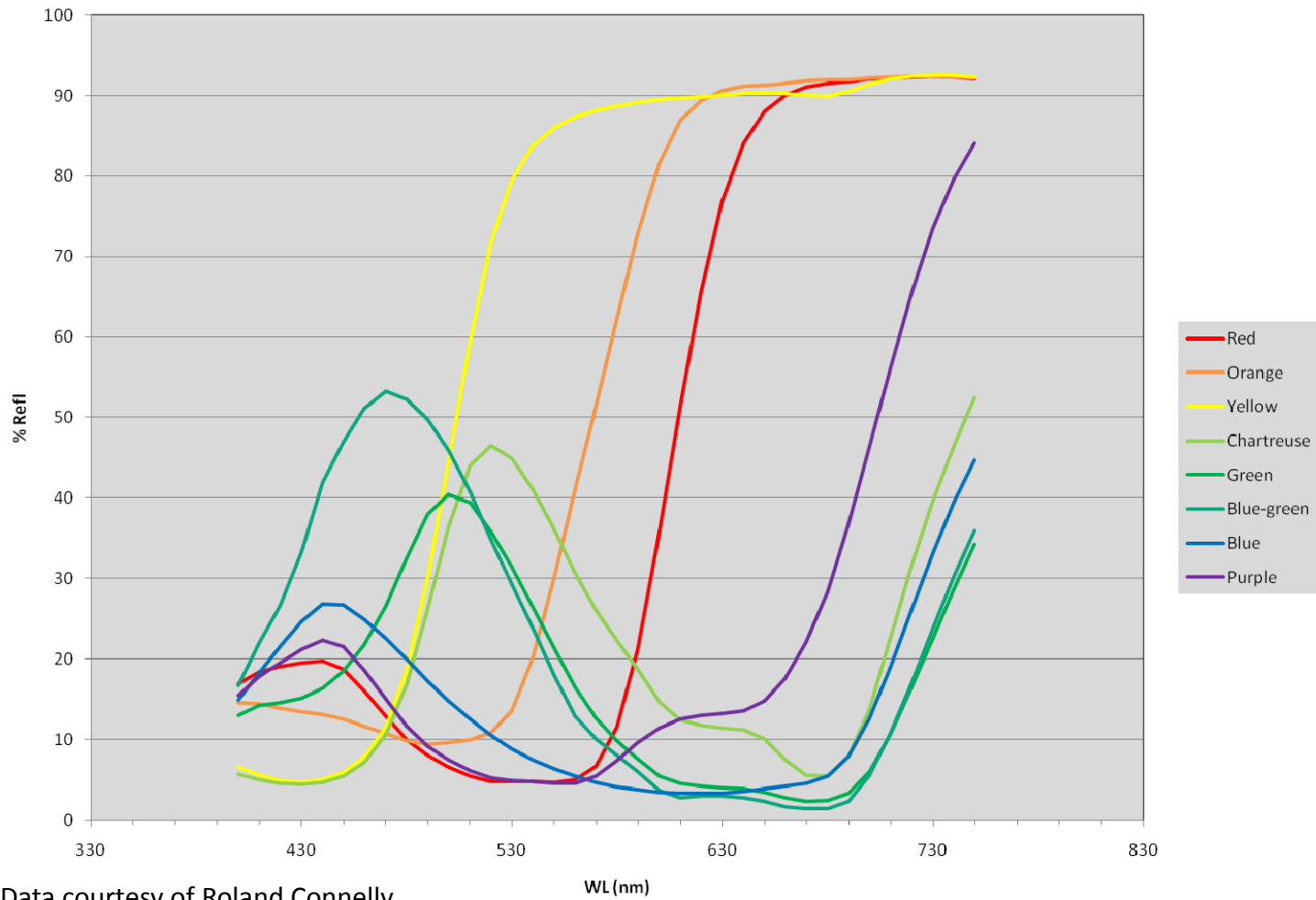


At the top of the LED **value** pyramid
is the ability to
control the **spectrum**
and the **source size**
digitally and efficiently.

SPD is the definitive description of the CCT and chromaticity (color) properties of a light source and through reflection the rendering of an object.

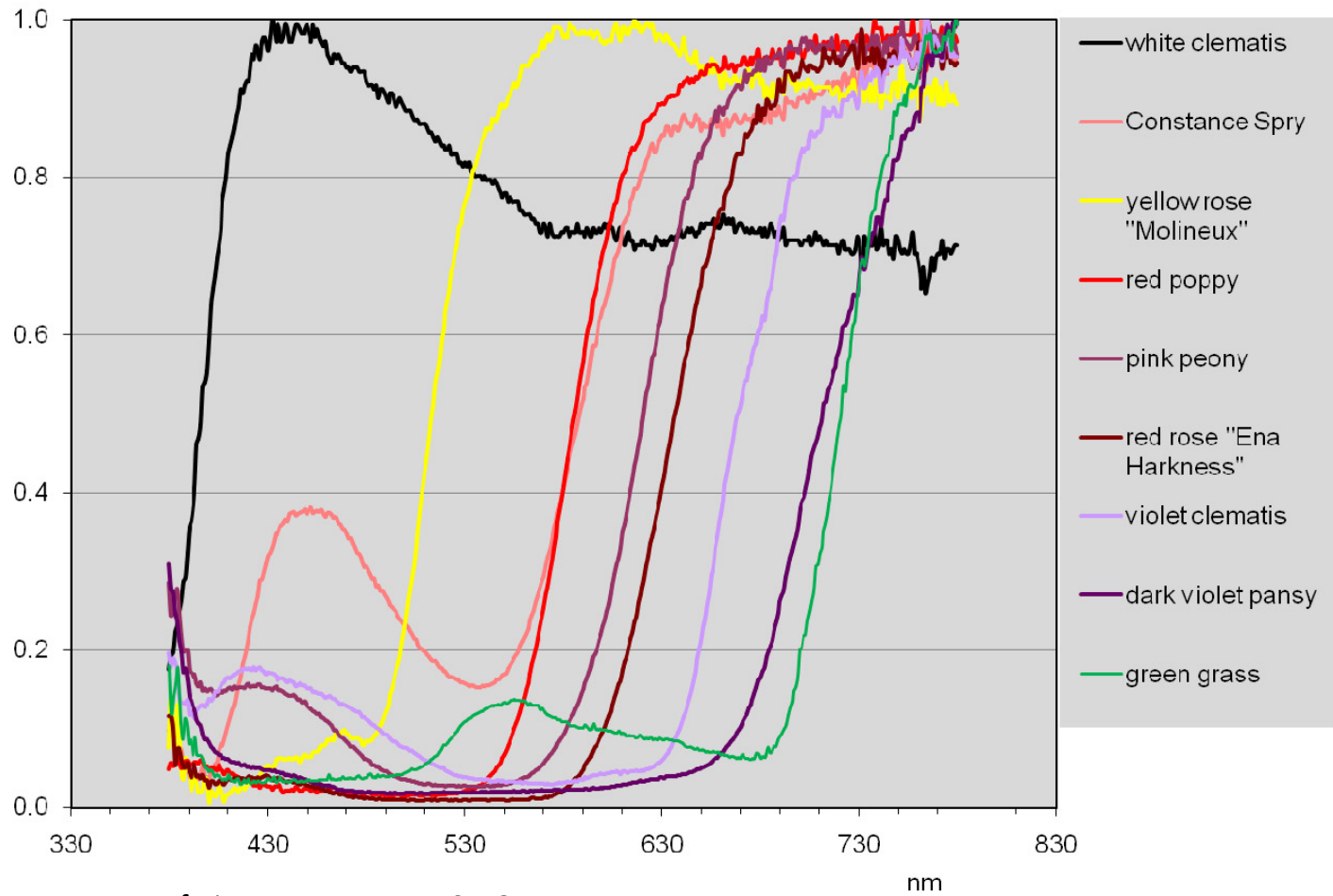
Spectral Characteristics of Illuminated Objects

Textile Reflectance Data



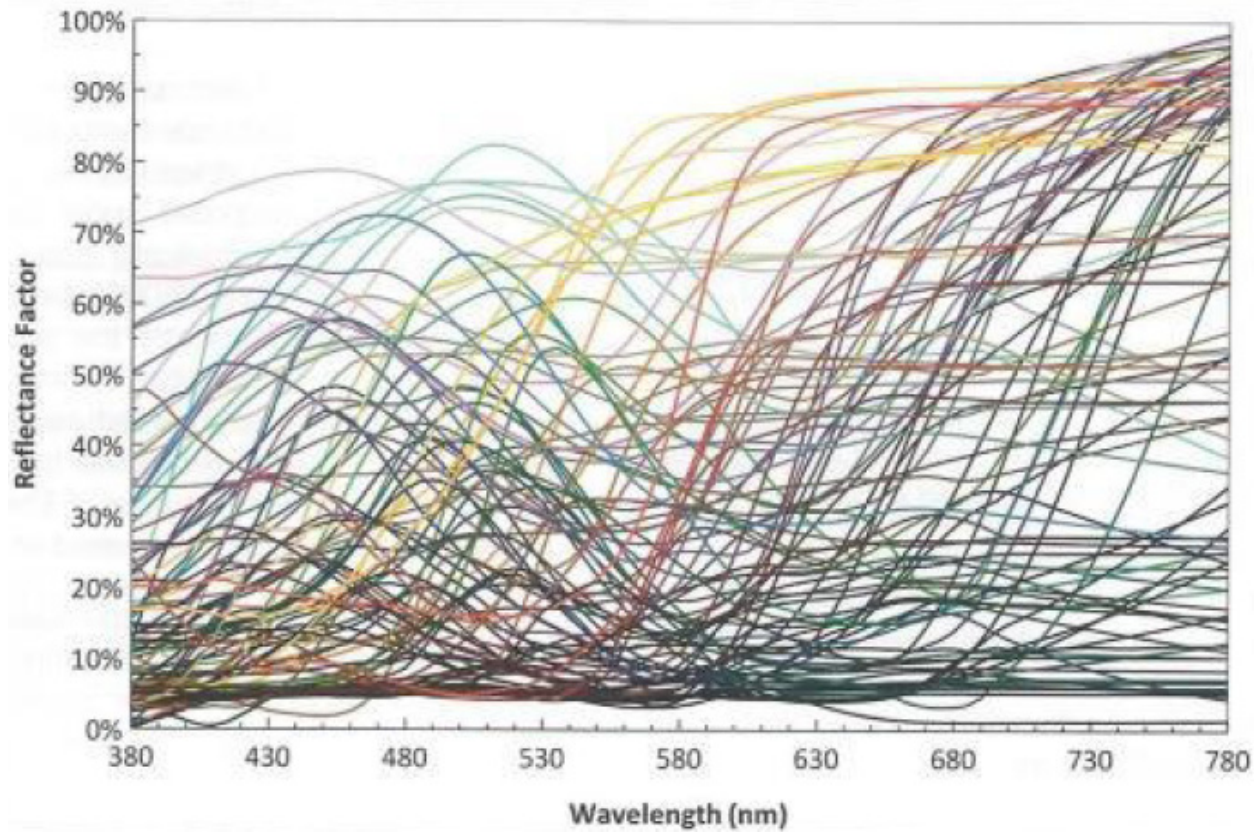
Data courtesy of Roland Connelly

Remission of flowers



Data courtesy of Dieter Lang, LEDVANCE, Germany

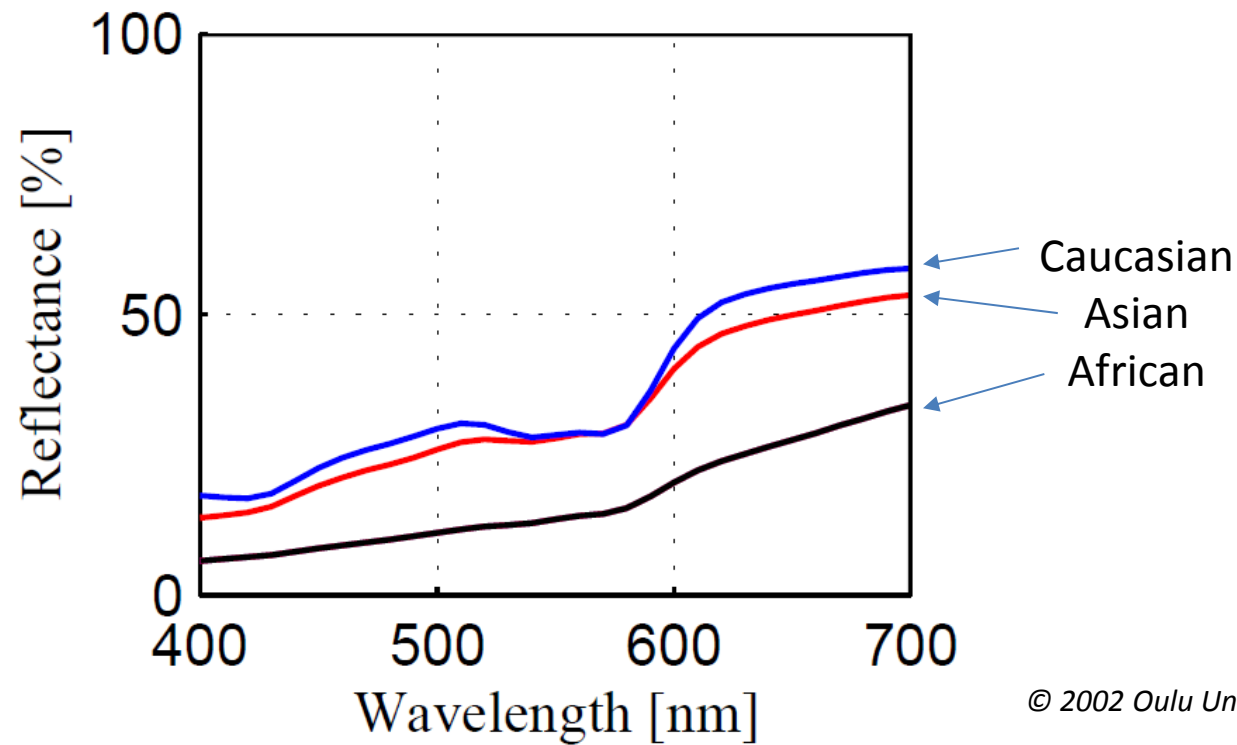
TM-30 colors - 99



Courtesy of Michael Royer, PNNL

Reflectance Spectra of Skin

half is between 600nm – 700nm



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From: "Face colour under varying illumination", Chapter. 4; <http://herkules oulu.fi/isbn9514267885/html/i1030756.html>

Light Source Spectrum

Light Source Spectrum (in the beginning)

- Daylight
- Fire

- **Continuous spectrum**
- Intensity and spectrum **change with time**

Light Source Spectrum (20th century)

- Vacuum sources
 - Incandescent/Halogen – **continuous spectrum**
 - Fluorescent – discontinuous spectrum
 - Other discharge – discontinuous spectrum
 - Metal Halide (higher CRI/TM-30)
 - HPS, LPS, HGV (low CRI/TM-30)

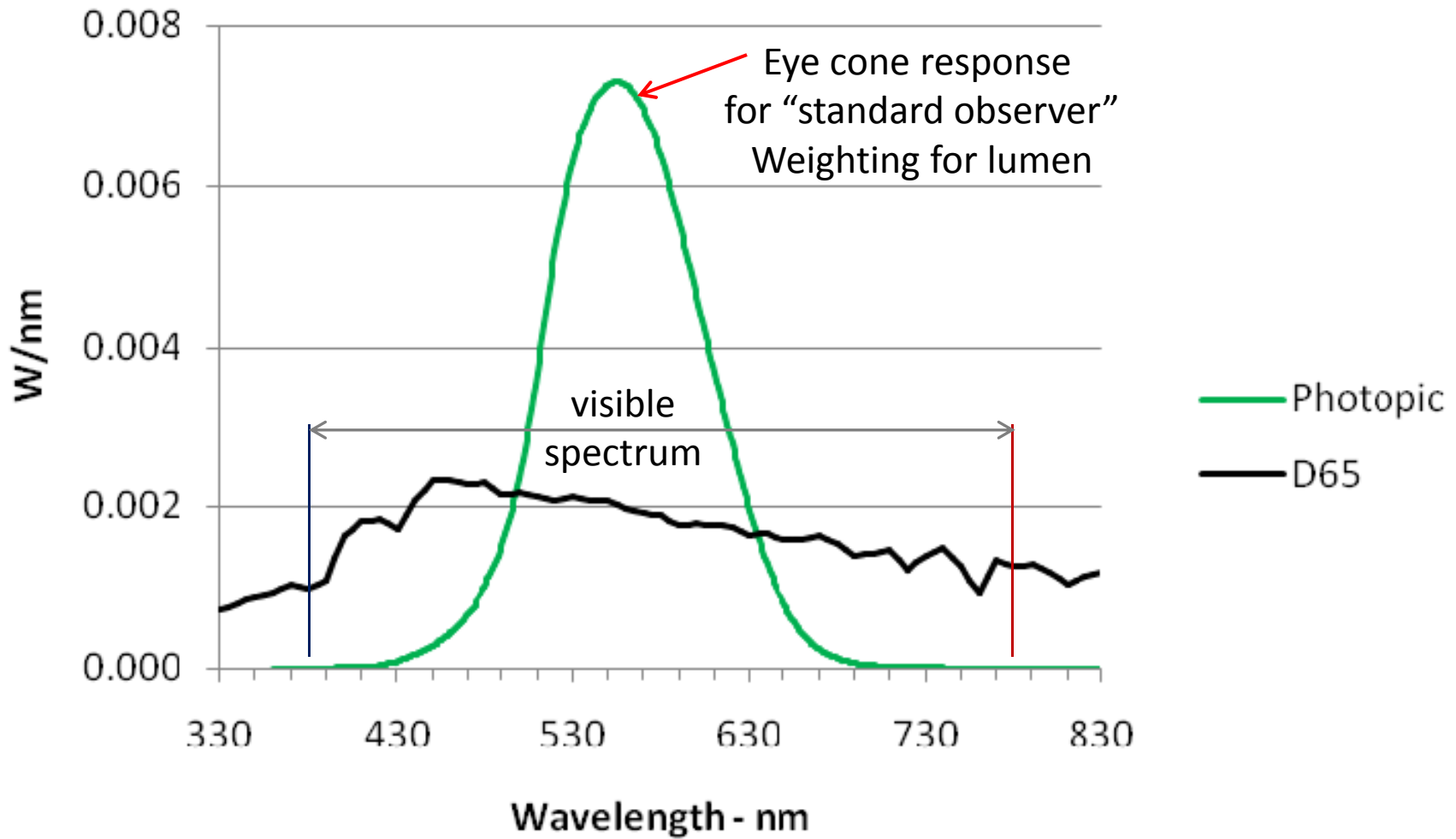
Light Source Spectrum (21st century)

- Solid state sources
 - White LED – continuous but truncated
 - Blue and violet pumps plus phosphor(s)
 - White Laser – continuous but truncated
 - Blue and violet pumps plus phosphor(s)
 - Narrow beam – ex. car headlights
 - Many color LED – continuous and broad
 - 5, 8, 16, 22, 32

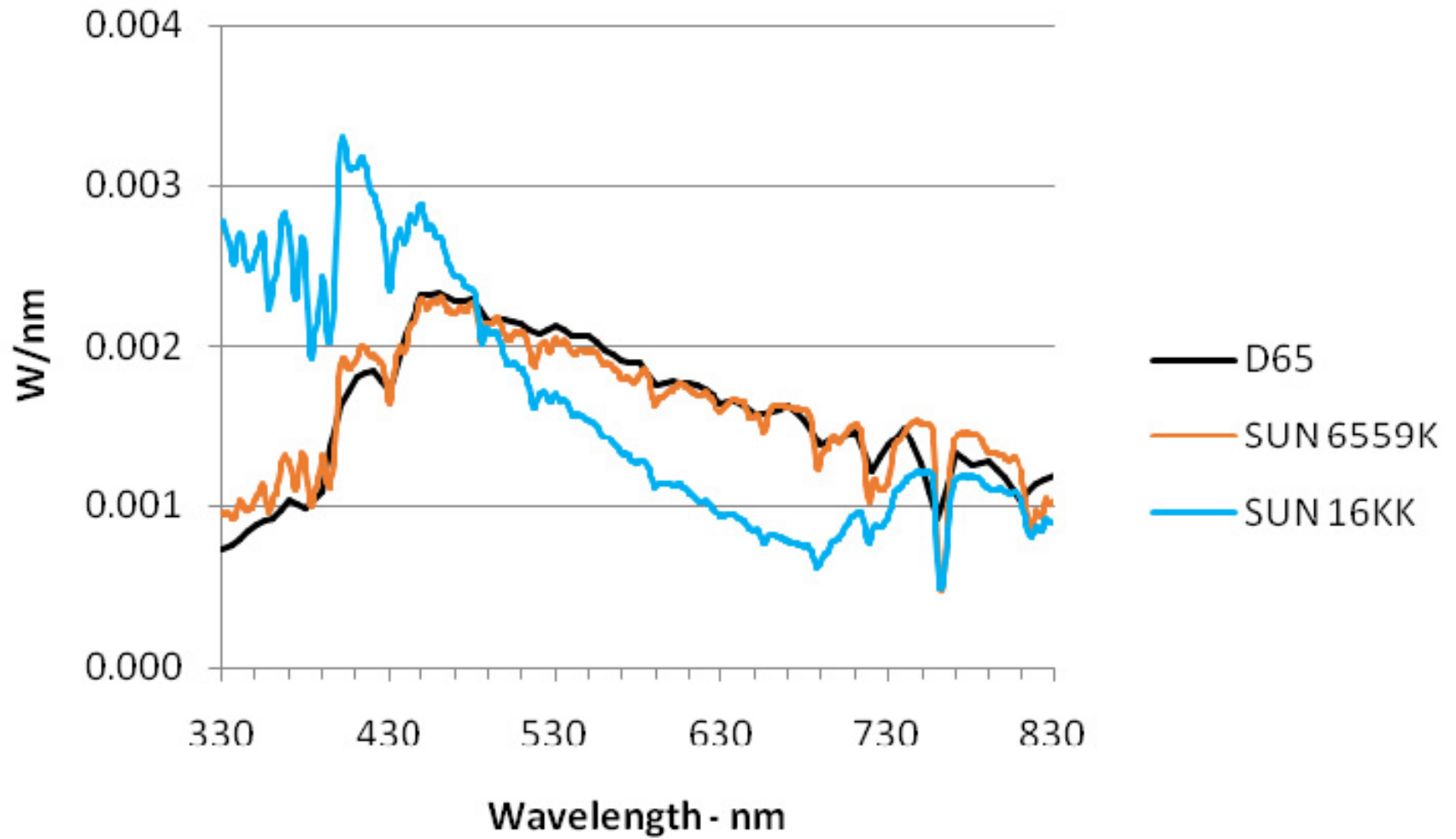
Efficacy vs. Efficiency

- Efficacy = lumens per electrical watt
- Efficiency = optical watts per electrical watt

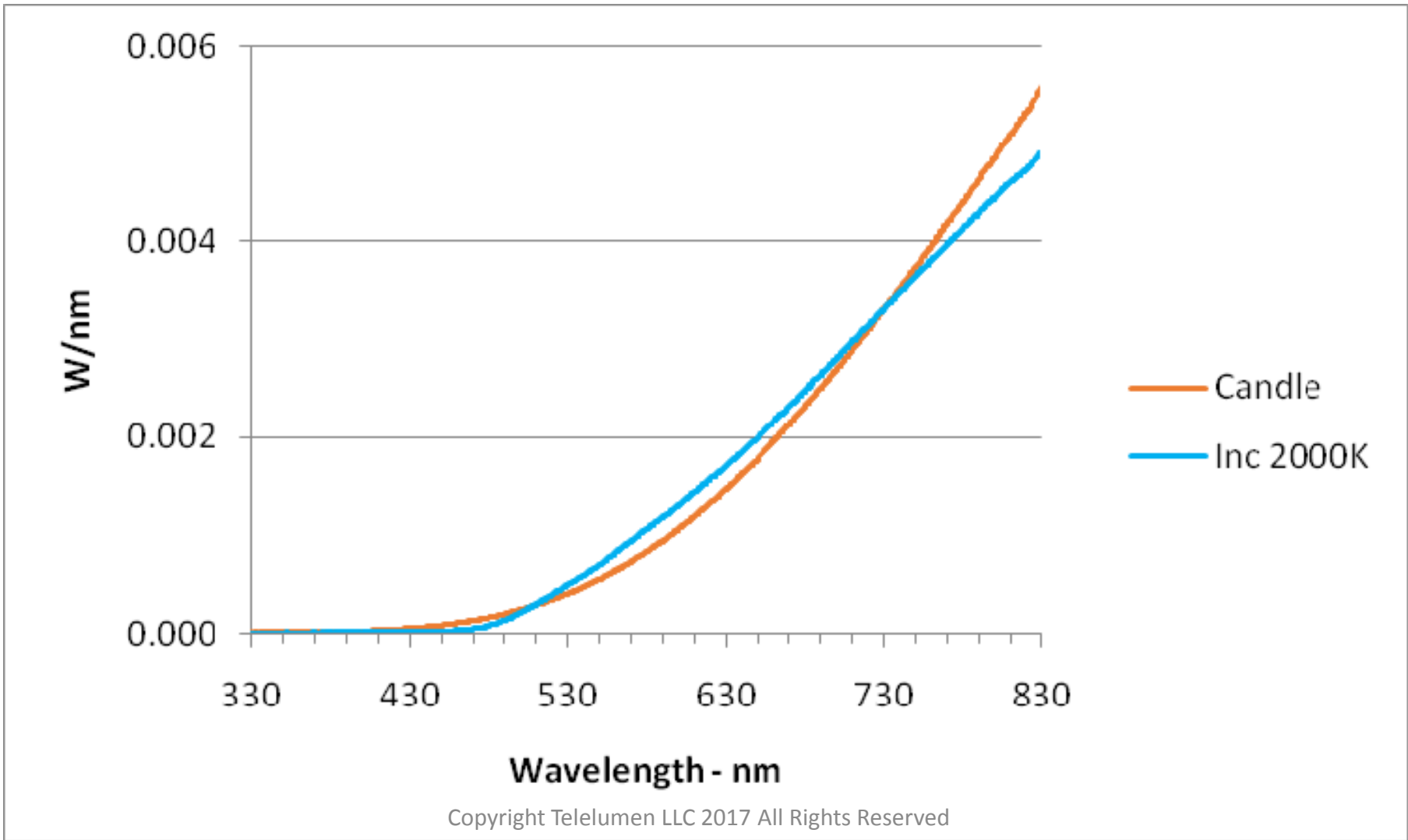
- Lumens are a weighted measure of optical watts with a peak at 555nm (green) and falling off toward red and blue.

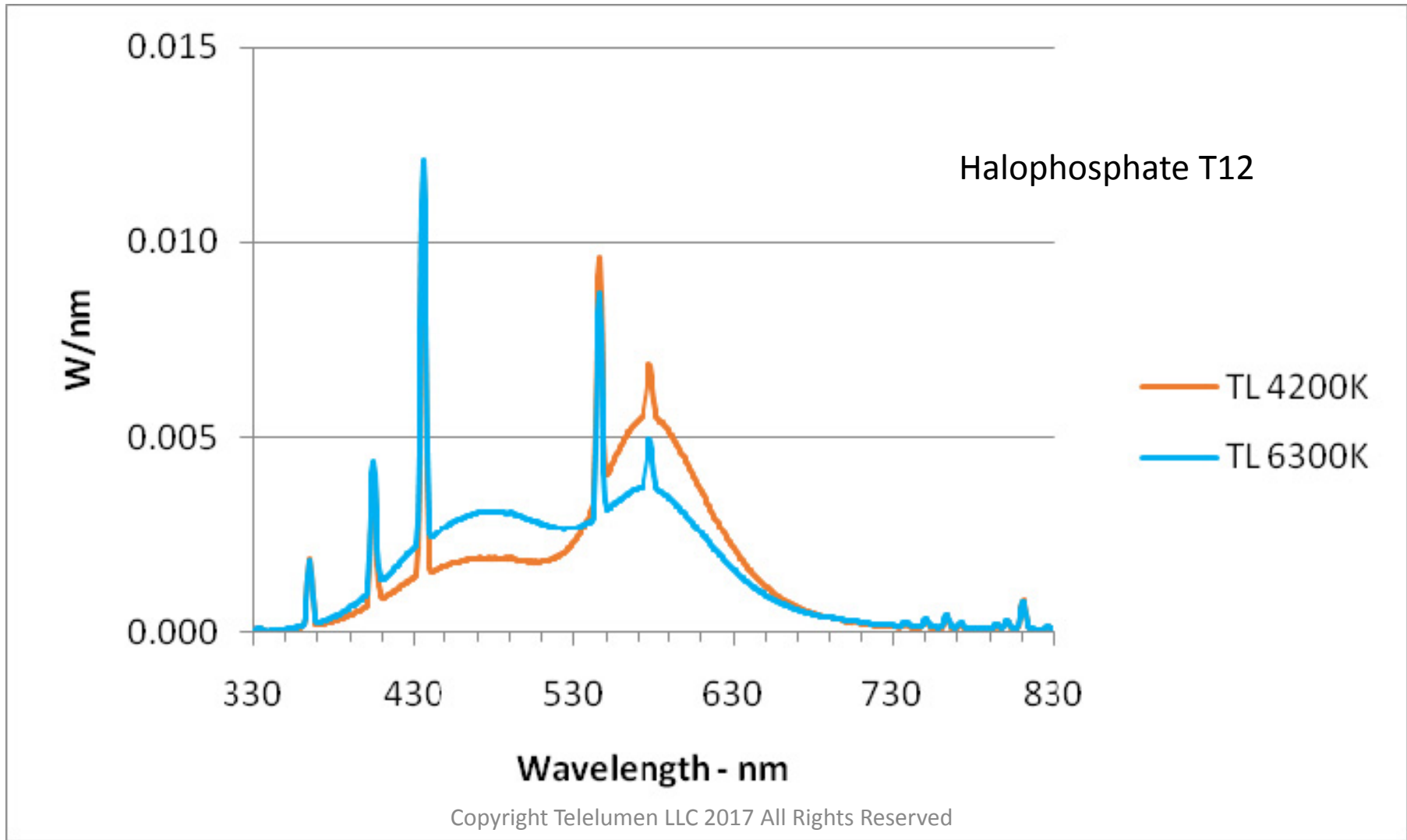


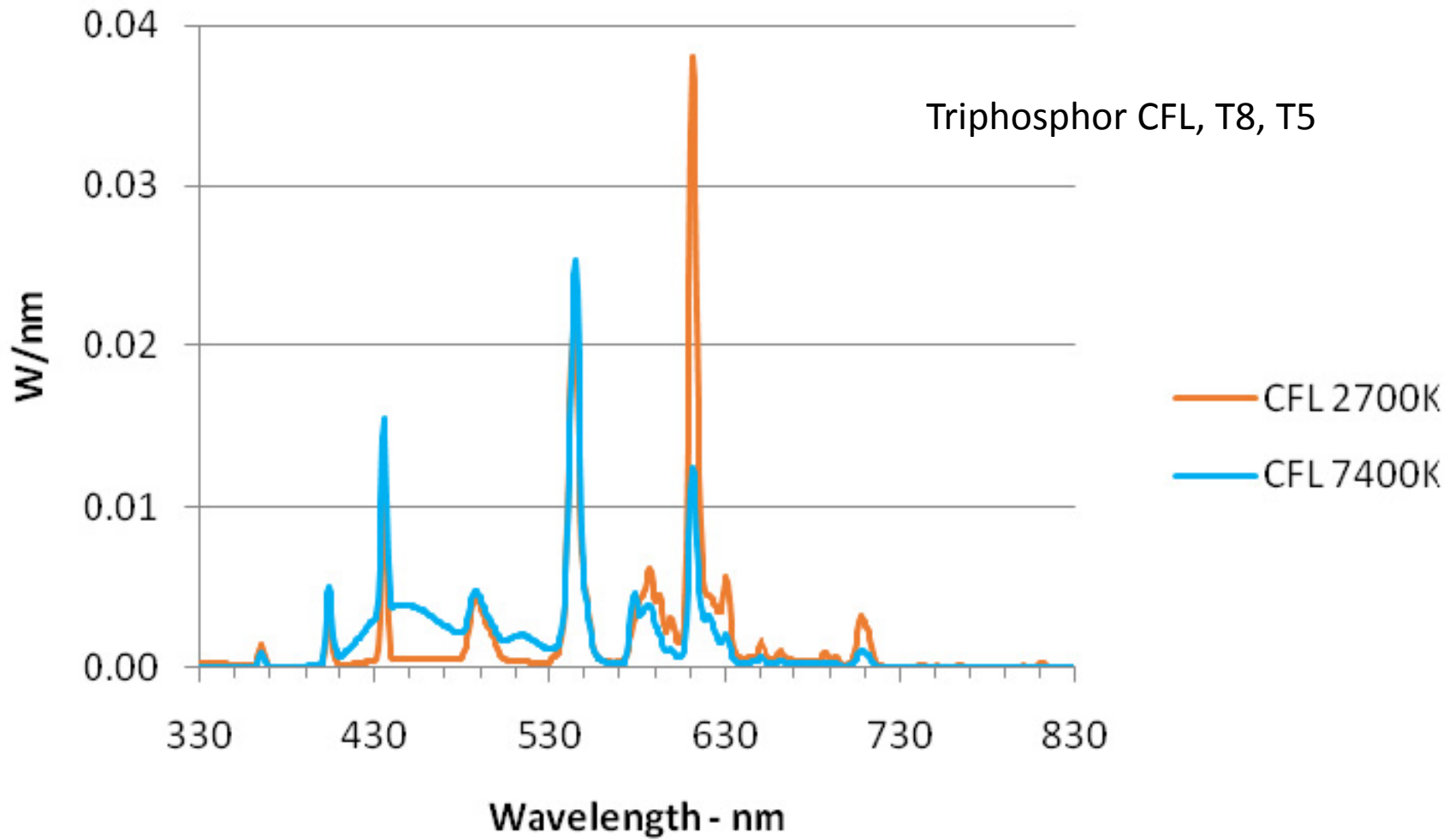
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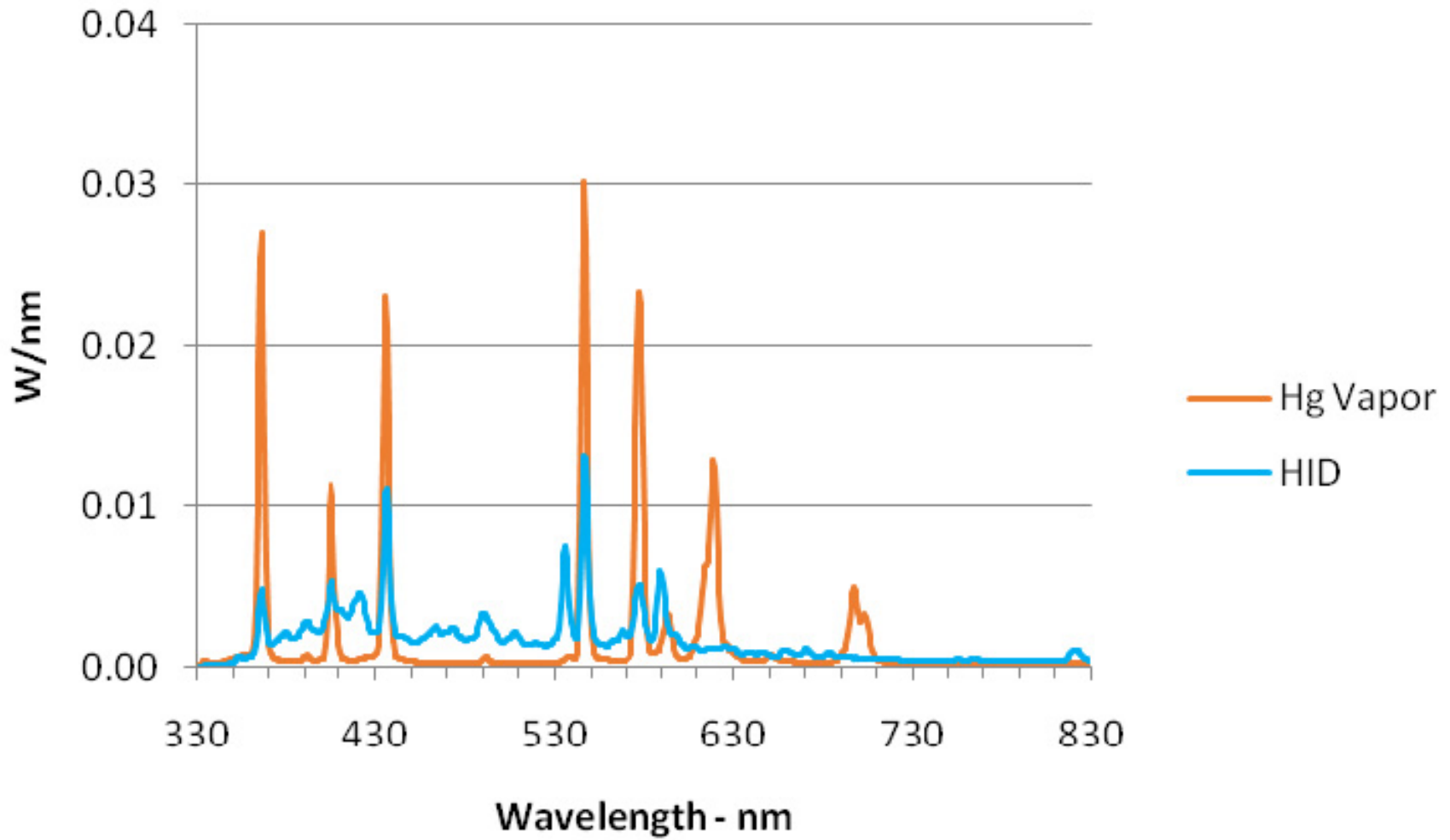
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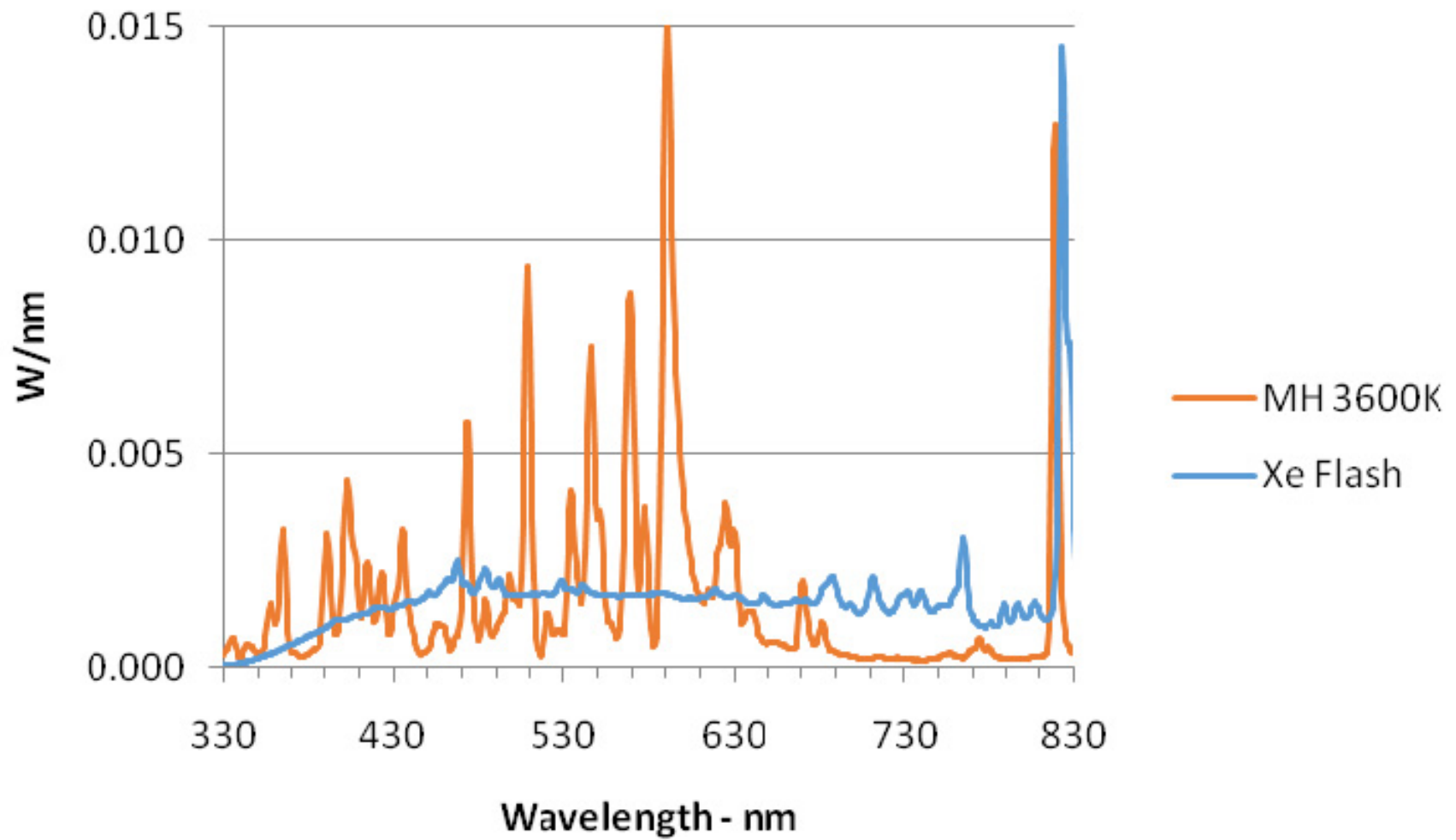




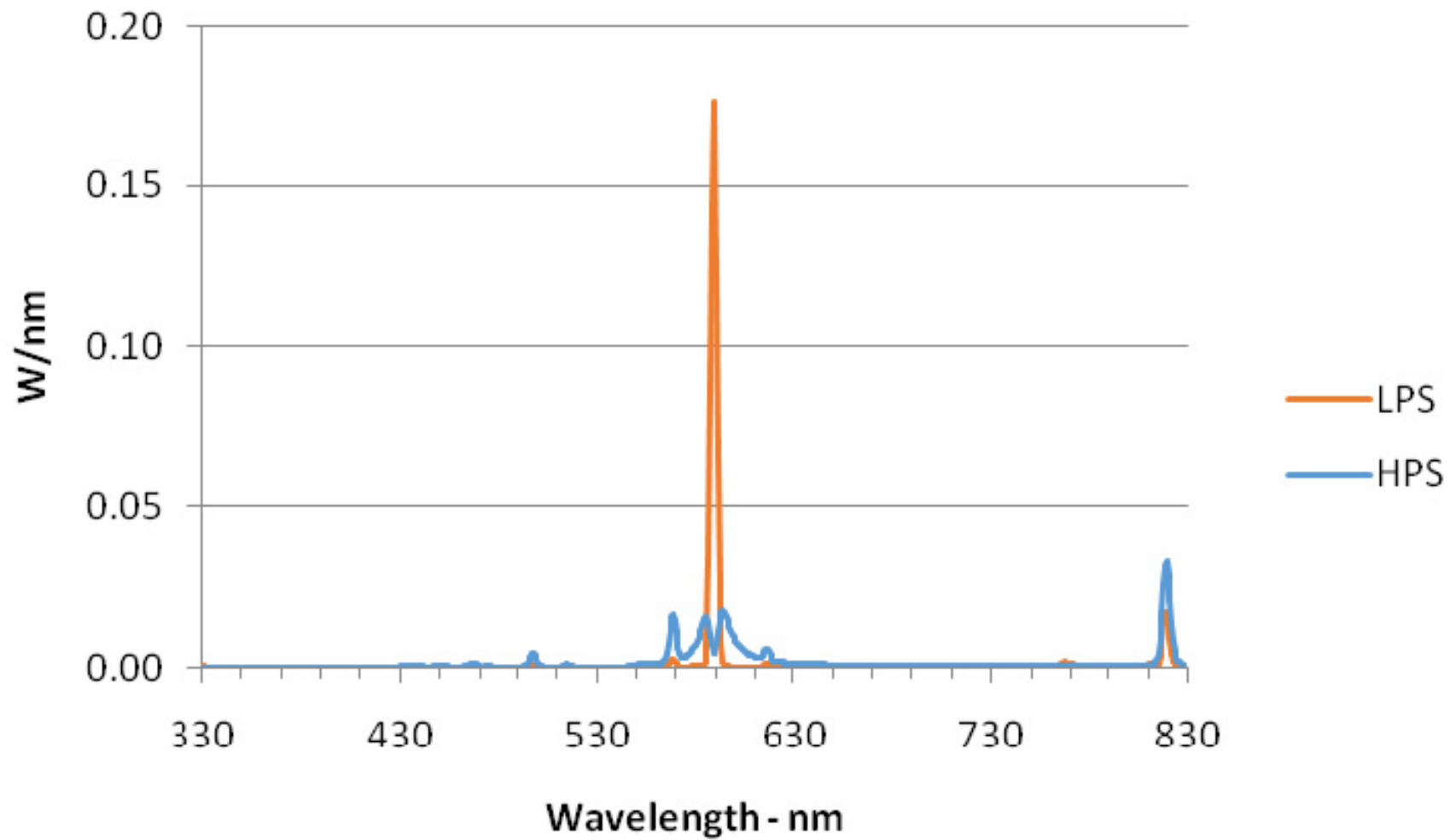
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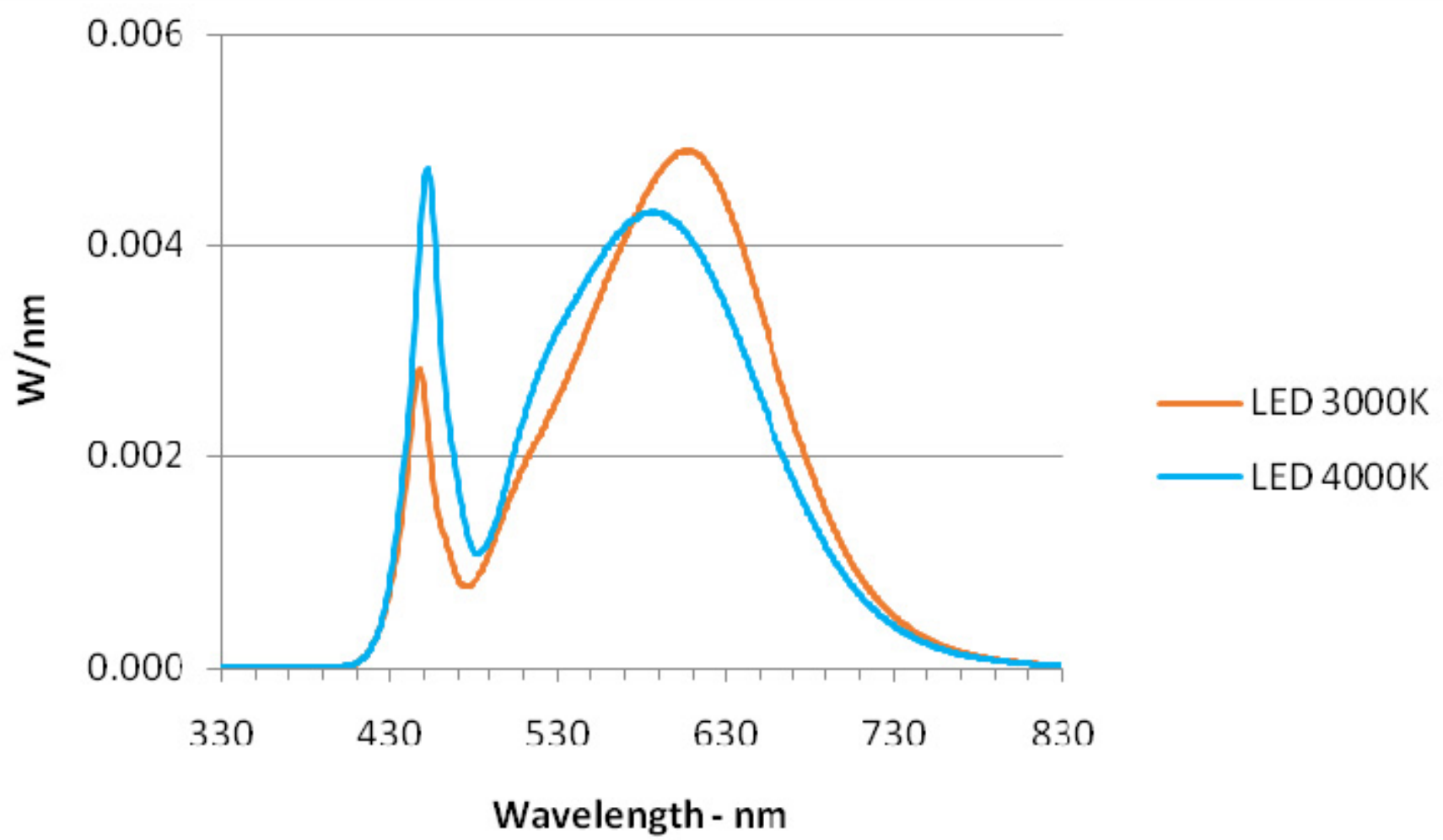
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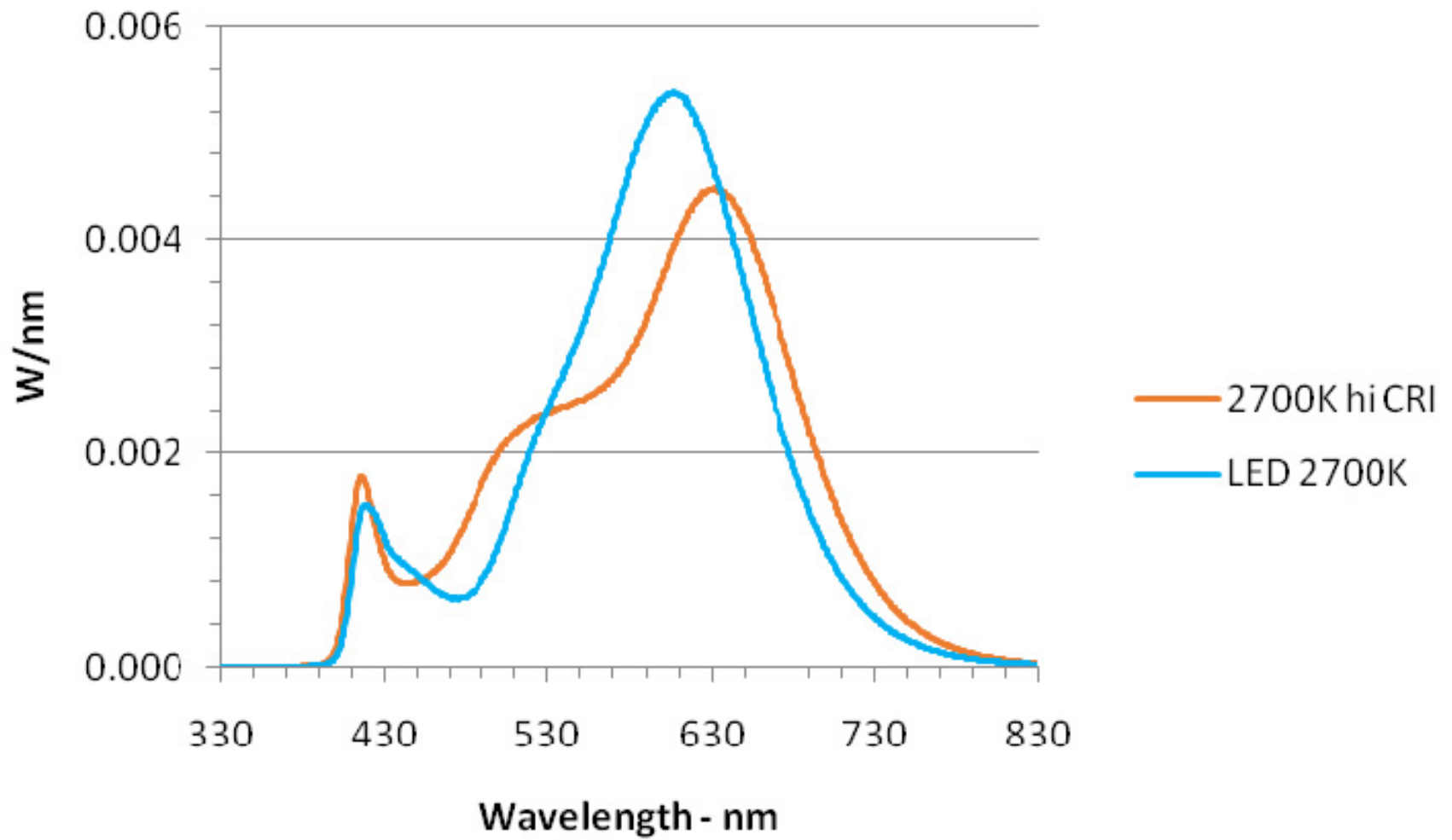
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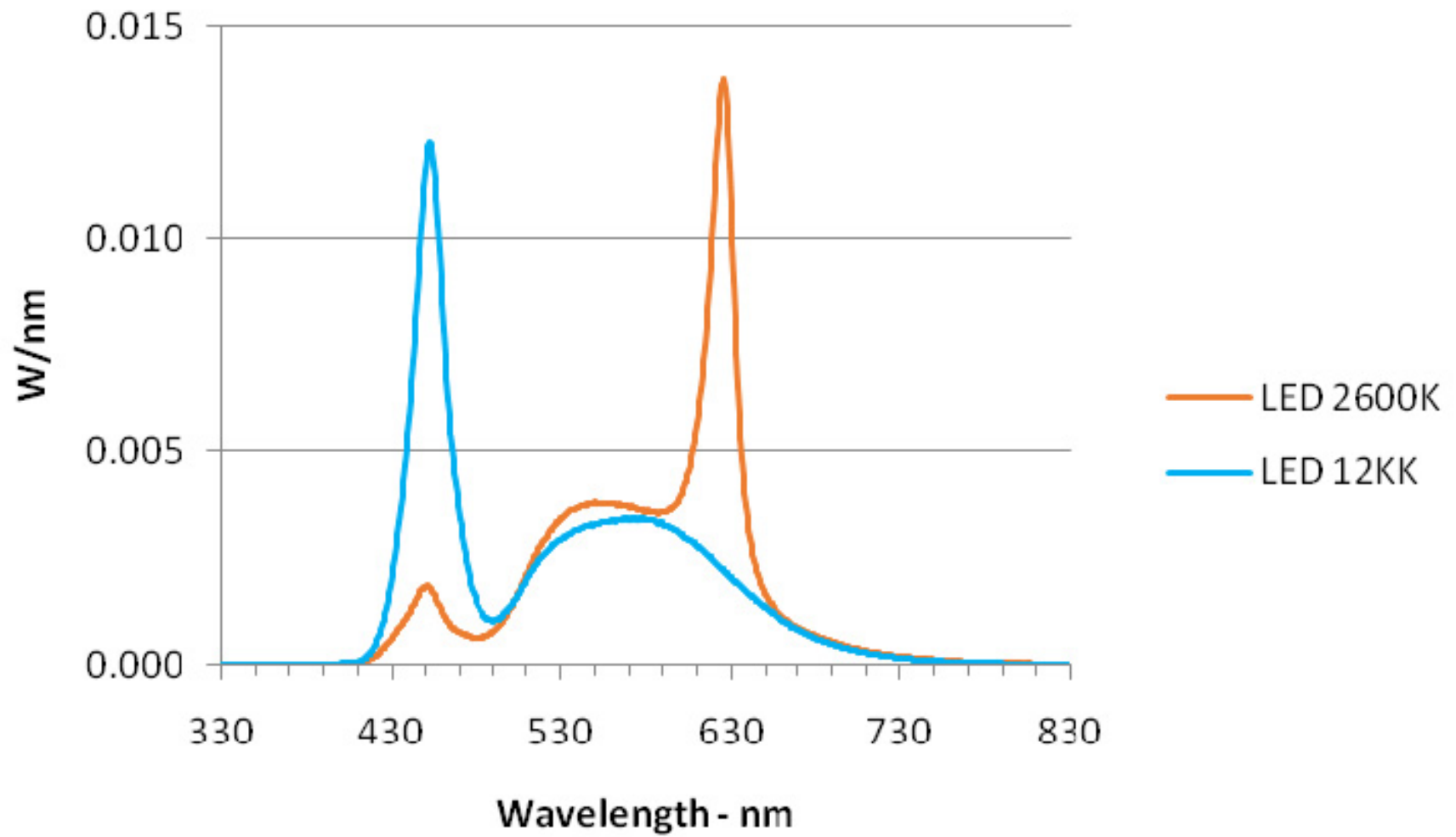
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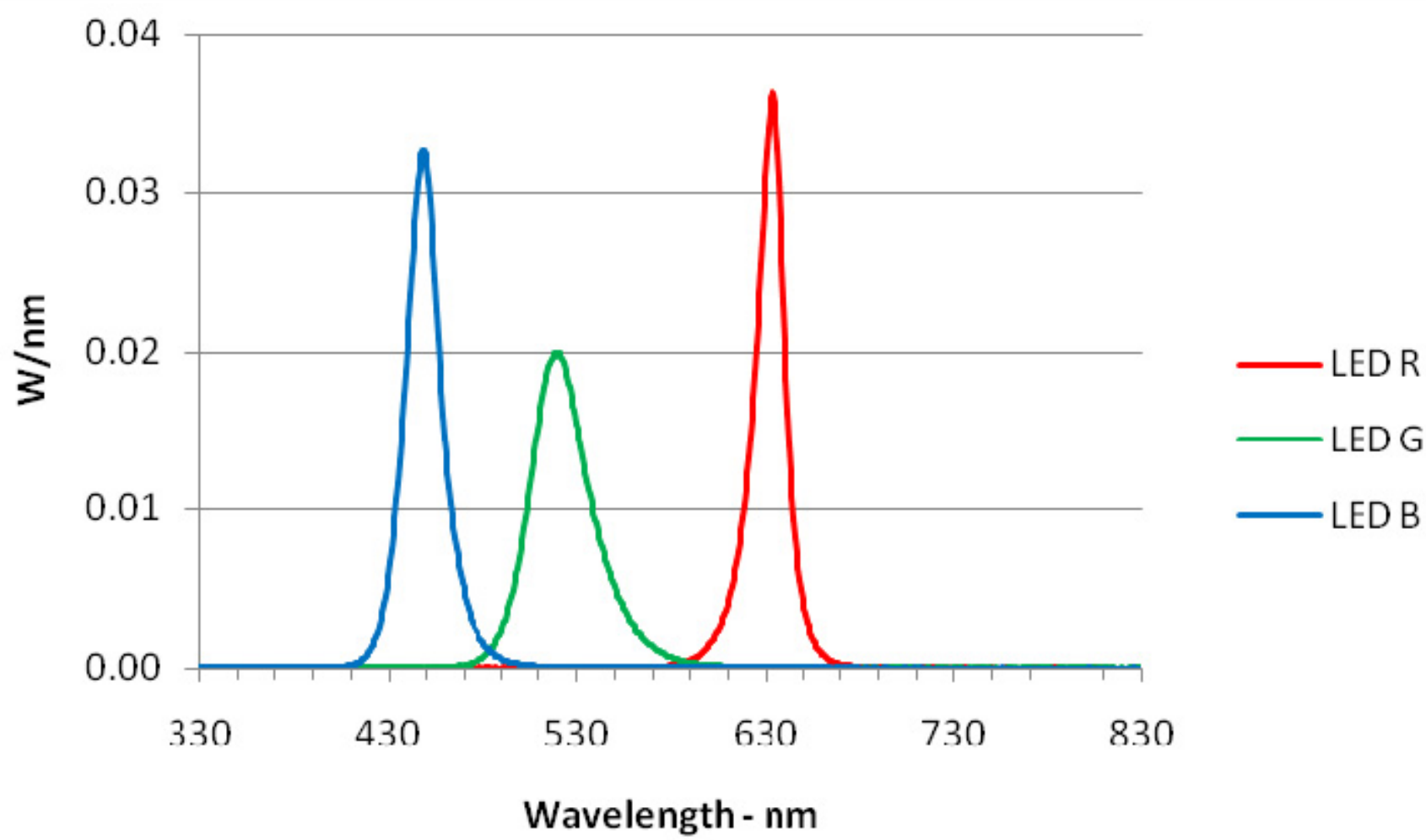
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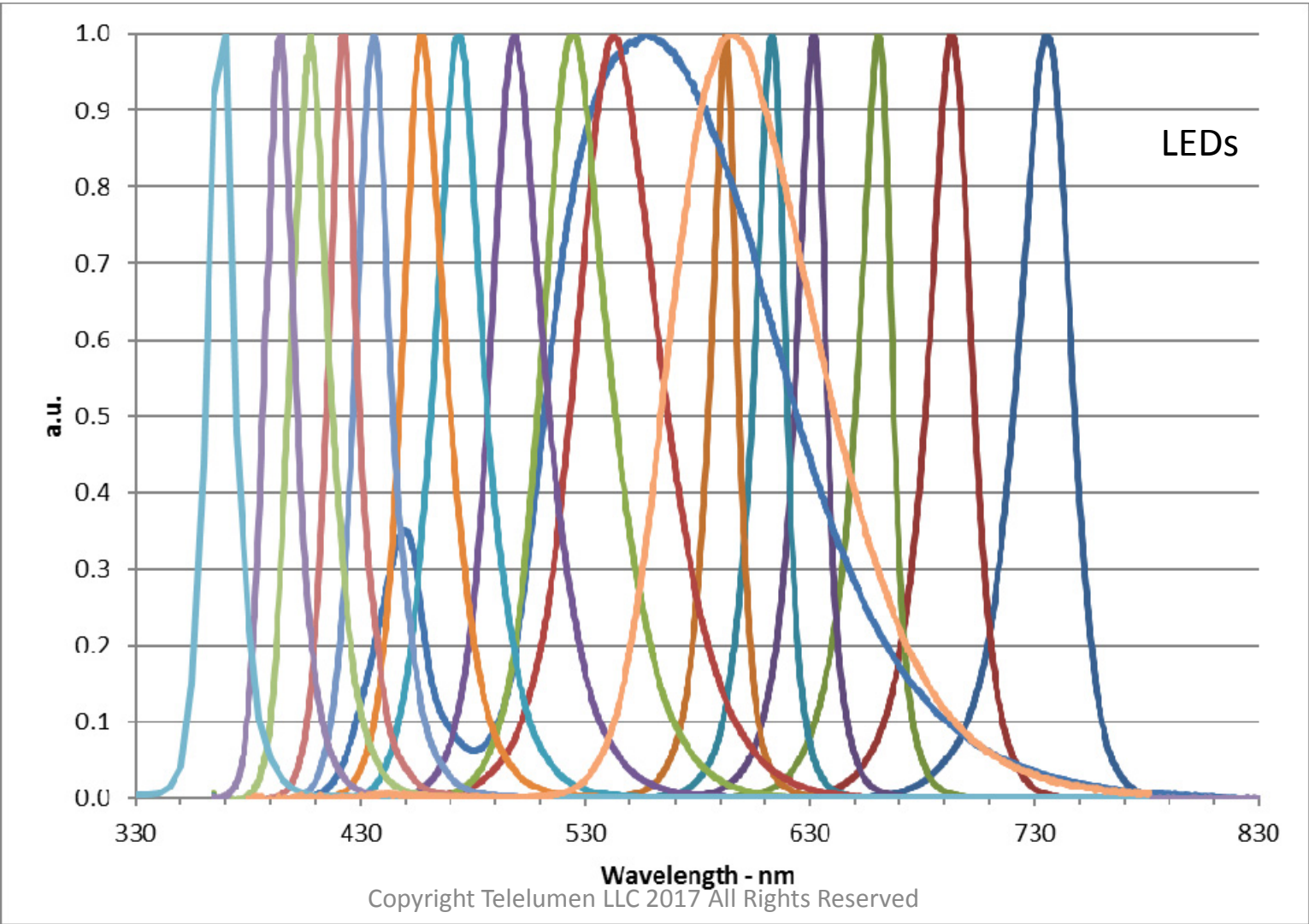
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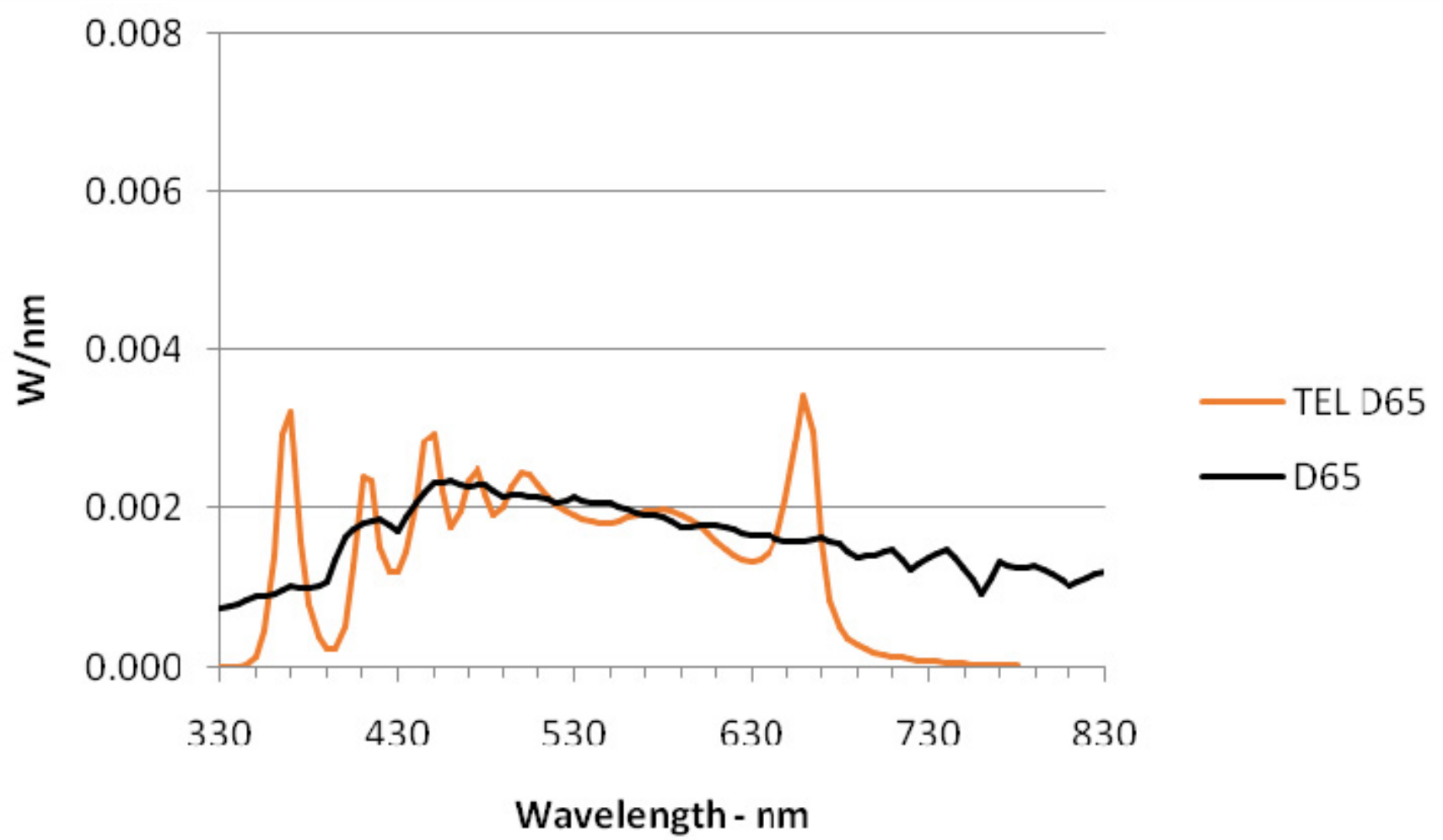


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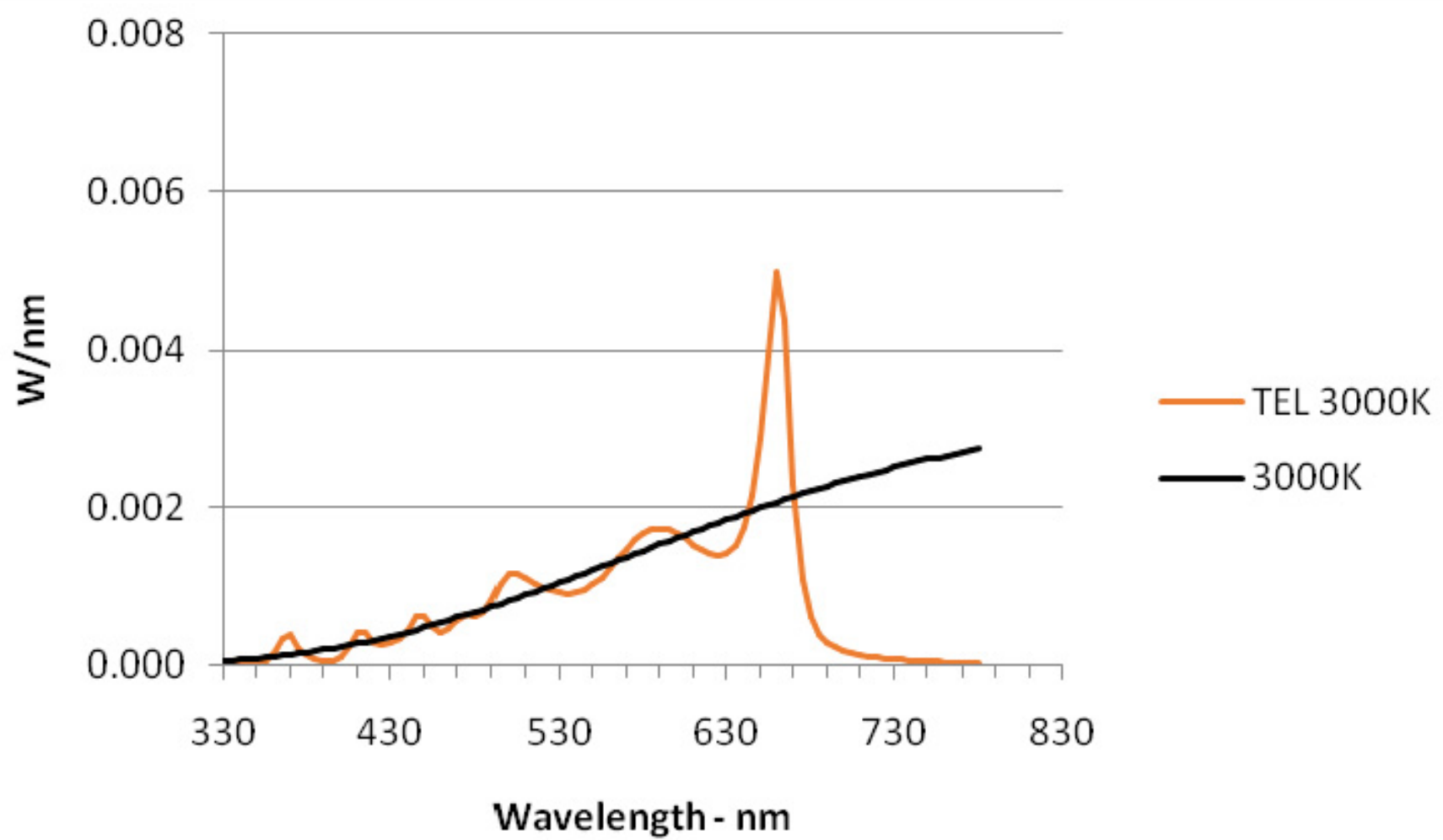


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Specifying Tunable Systems in General

- SPD for all color channels is required.
- Upper CCT at color quality – ex. 20kK, $R_f > 90$
- Lower CCT at color quality – ex. 1200K, $R_f > 90$
- Color gamut and fluorescence may also be important.

Going forward - animation

- Tunable systems facilitate changes with time
 - Warm dim, sweep CCT, fire
 - Increase/decrease saturation while holding chromaticity constant
 - Add/subtract fluorescence

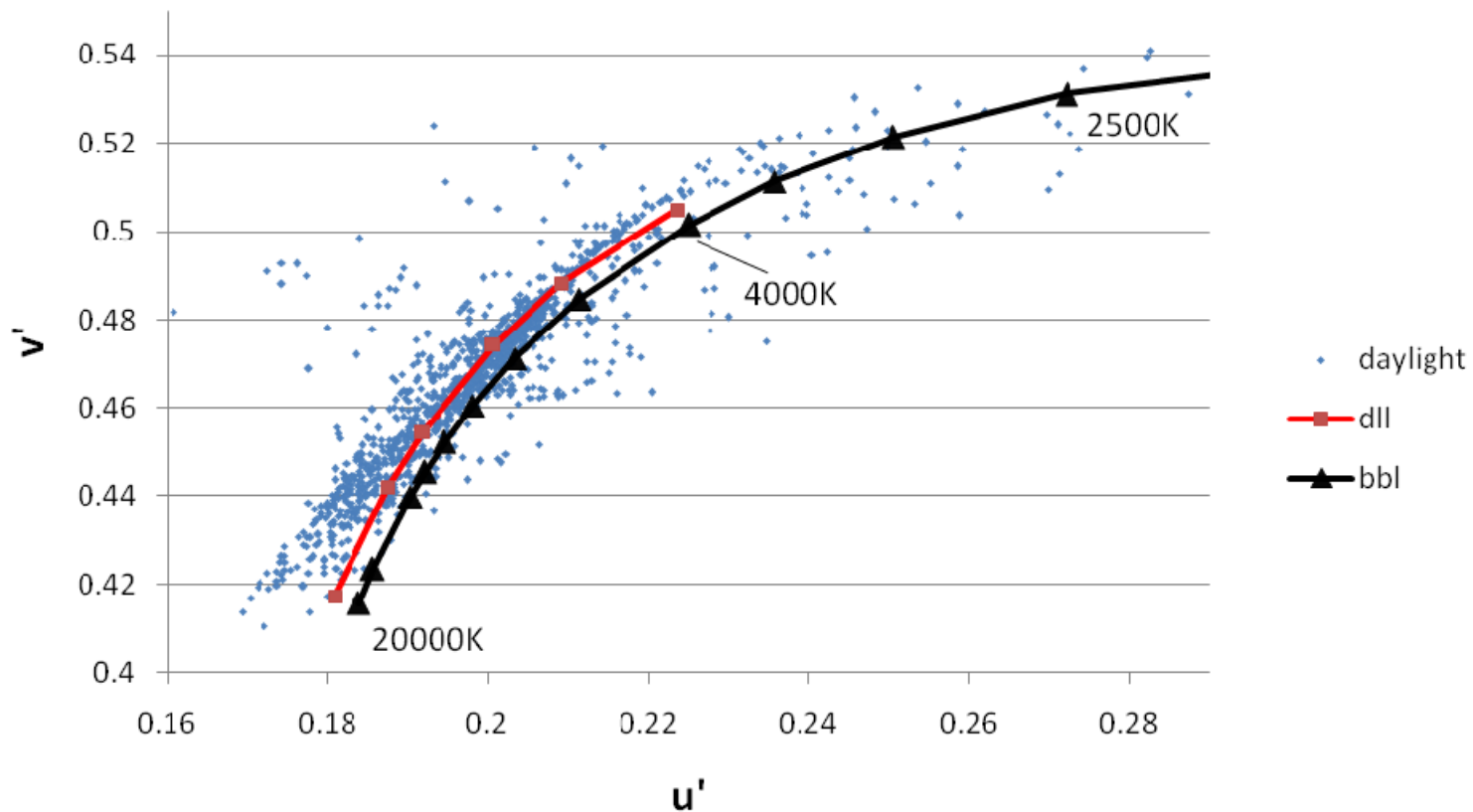
In general - SPD

- A more continuous spectrum and wider range of wavelengths produce higher color quality light sources. (more \$)
- A less continuous spectrum and truncated range of wavelengths are often more efficient. (less \$)

Daylight Data

Daylight Data

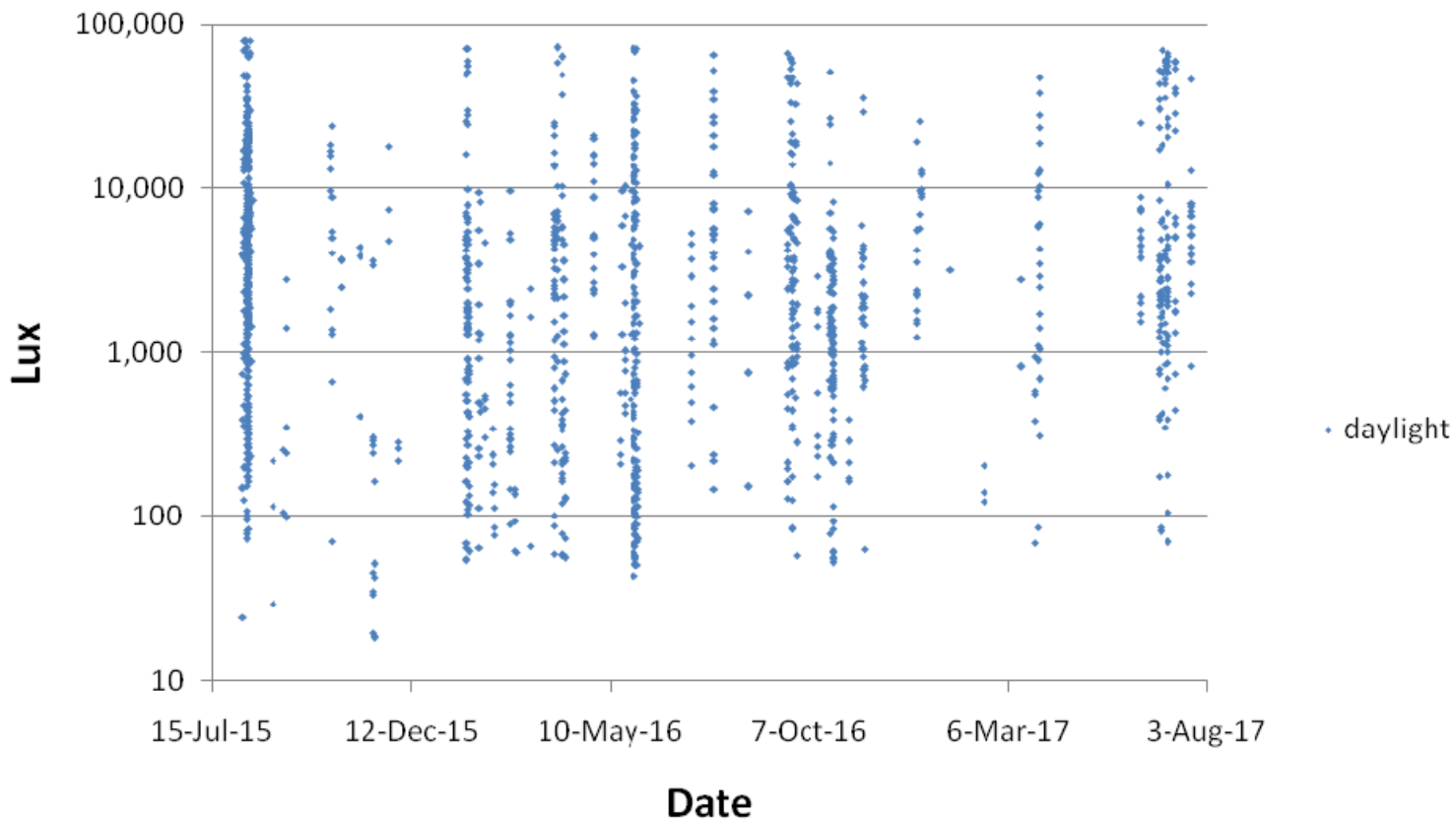
Aug15 to Jul17 (1400 recordings)



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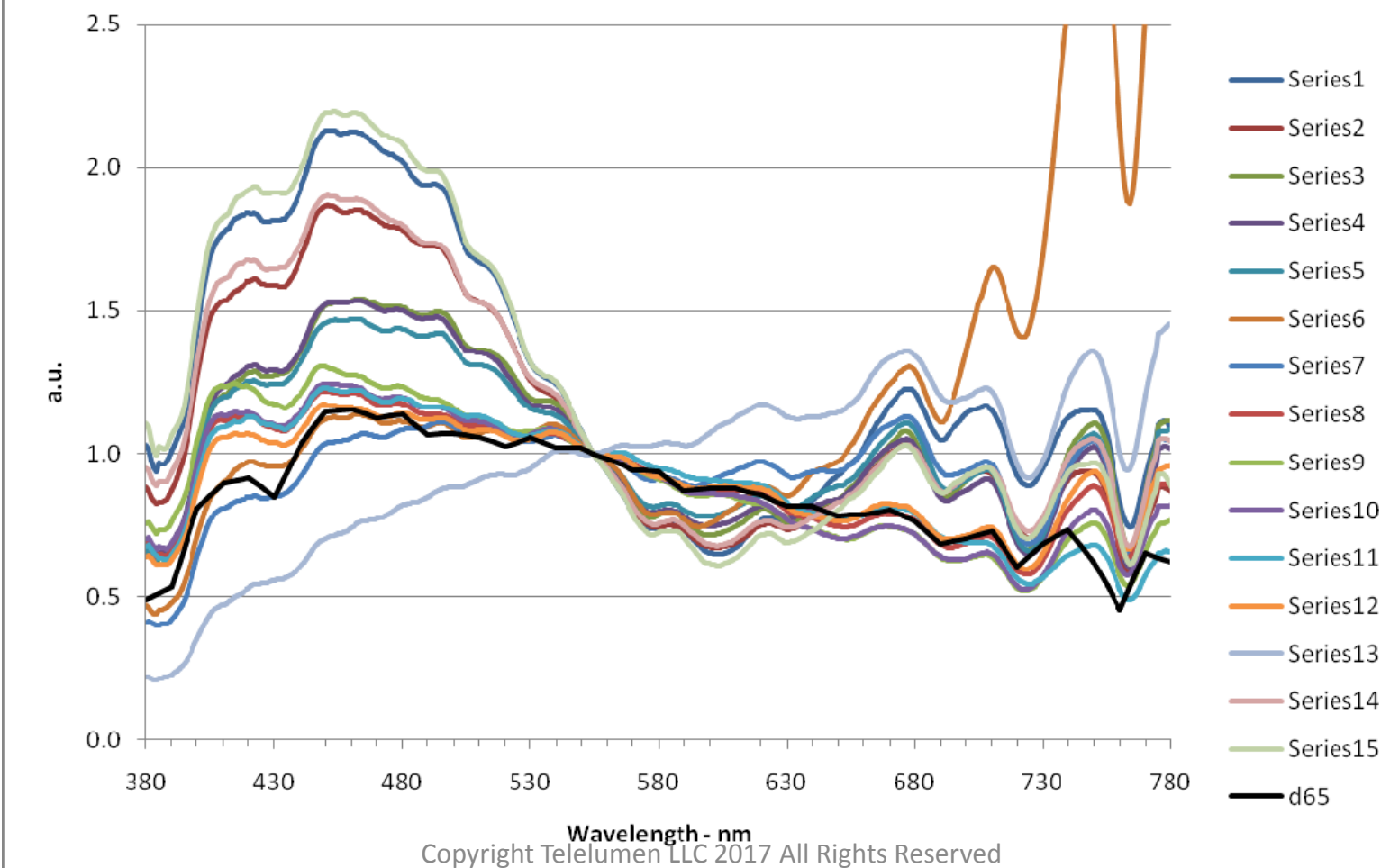
Daylight Data

Aug15 to Jul17 (1400 recordings)



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Summary and Demo Introduction

- Spectrum is important for fidelity and preference.
- Broader wavelength range and less dropout in the SPD increases color quality and impact.
- Natural light sources have broad variable spectrum.
- Get a copy of the SPD for all sources.



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Thank You

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