

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

Panel | Technology Tradeoffs with LED Lighting  
**- Spectrum -**

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# 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

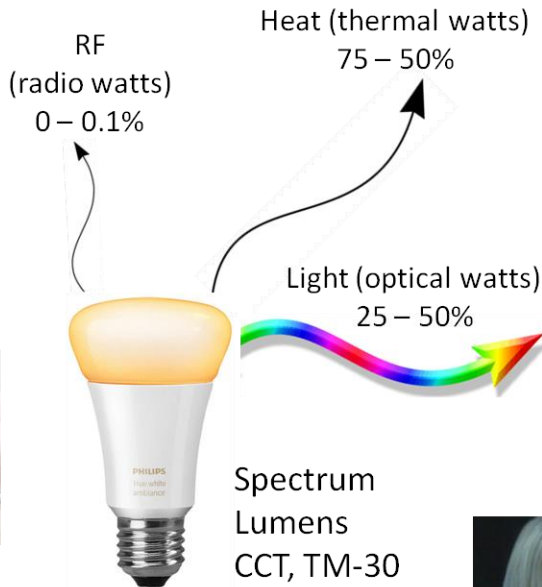
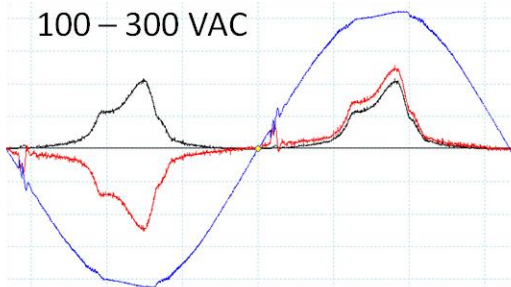
# Target Applications

- 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



Spectrum  
Lumens  
CCT, TM-30  
Time  
Angle  
Space  
Flicker

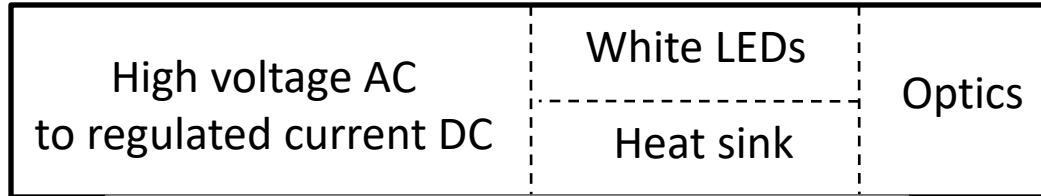
Reflection





# Fixed color and tunable lamp/luminaires

Electrical power



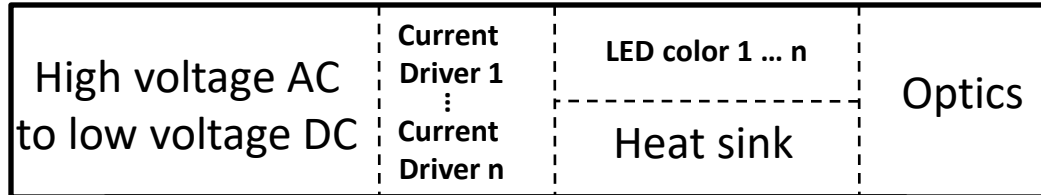
Room

WIFI, Bluetooth, ...

IoT – command/control, data, sensors

Optional

Electrical power



Room

WIFI, Bluetooth, ...

IoT – command/control, data, sensors

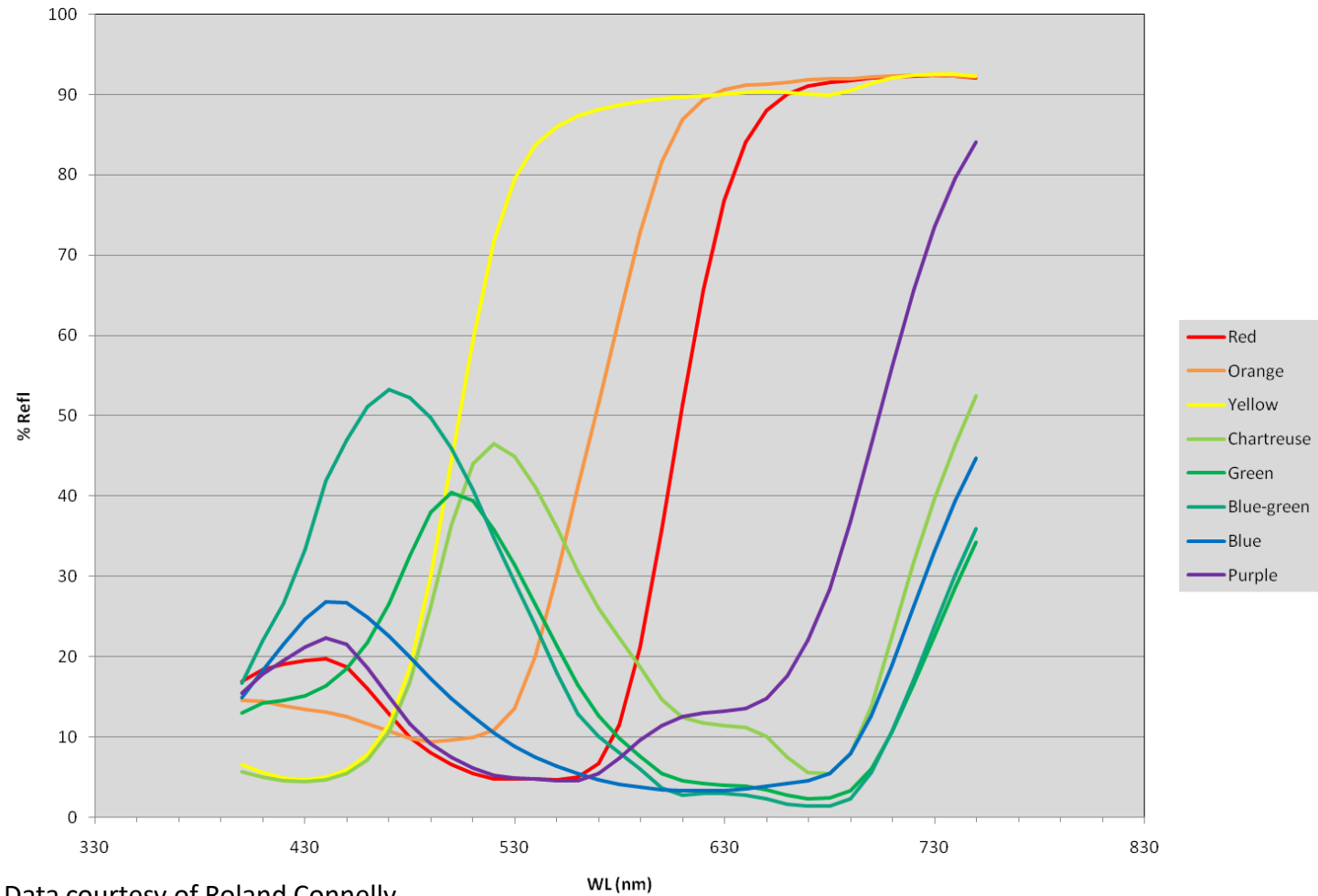
At the top of the LED **value** pyramid  
is the ability to  
control the **spectrum**  
and the **source size**  
digitally and efficiently.

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



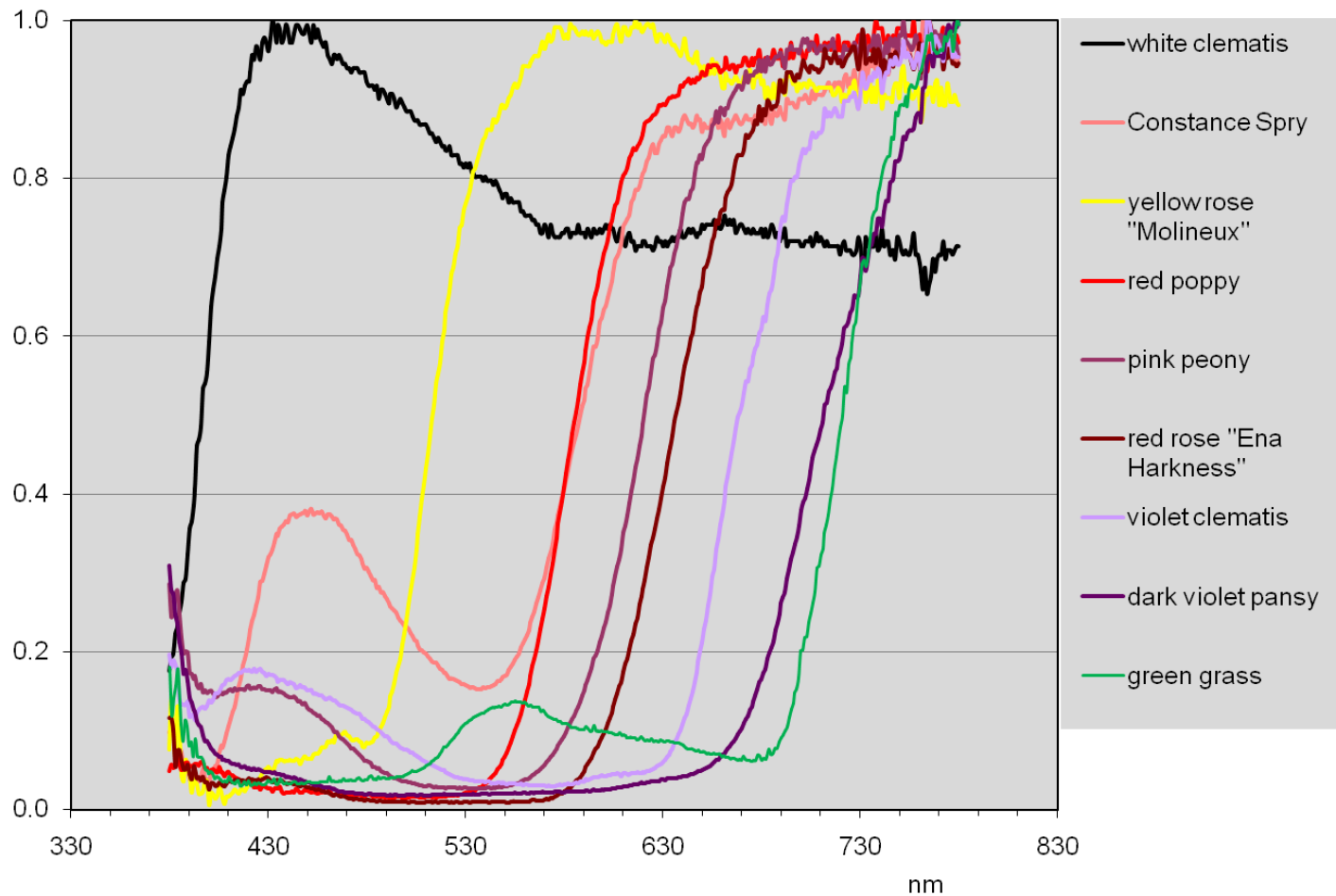
# Spectral Characteristics of Illuminated Objects

# Textile Reflectance Data



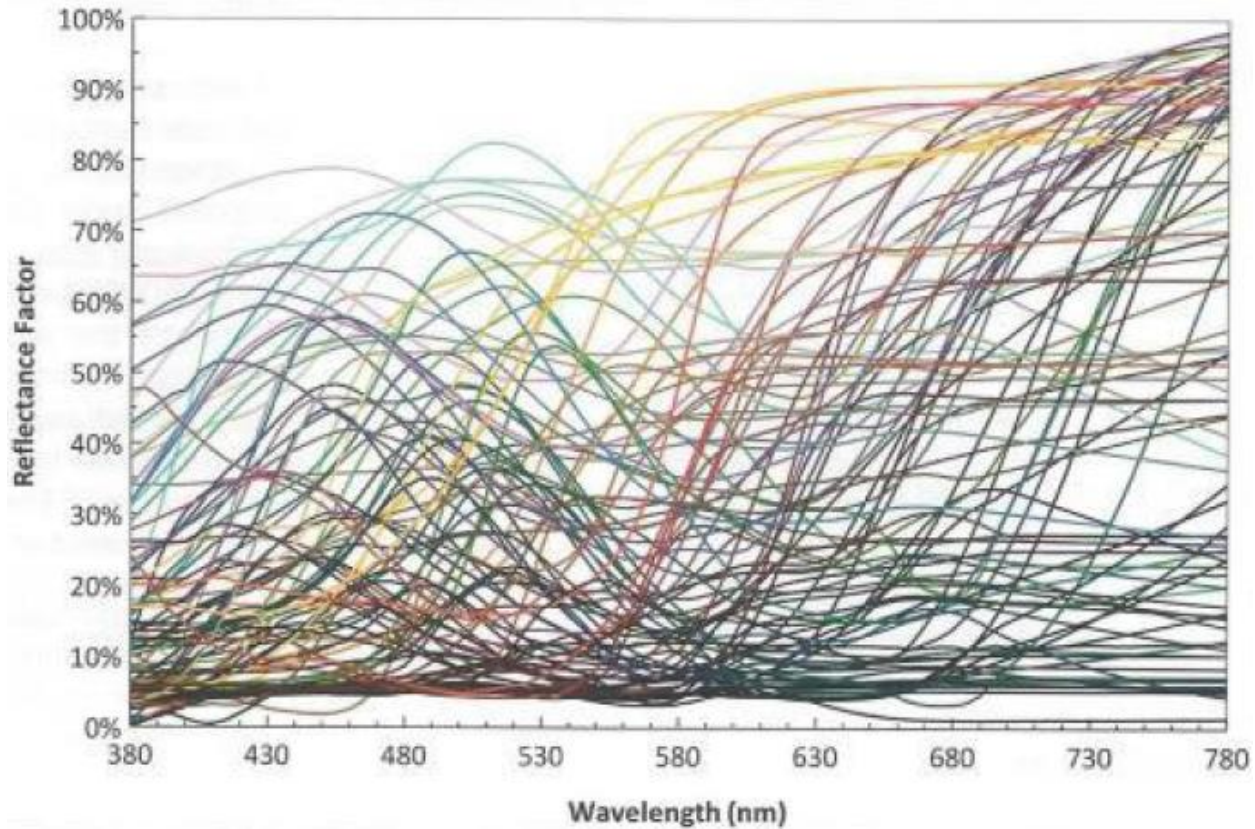
Data courtesy of Roland Connolly

# Remission of flowers



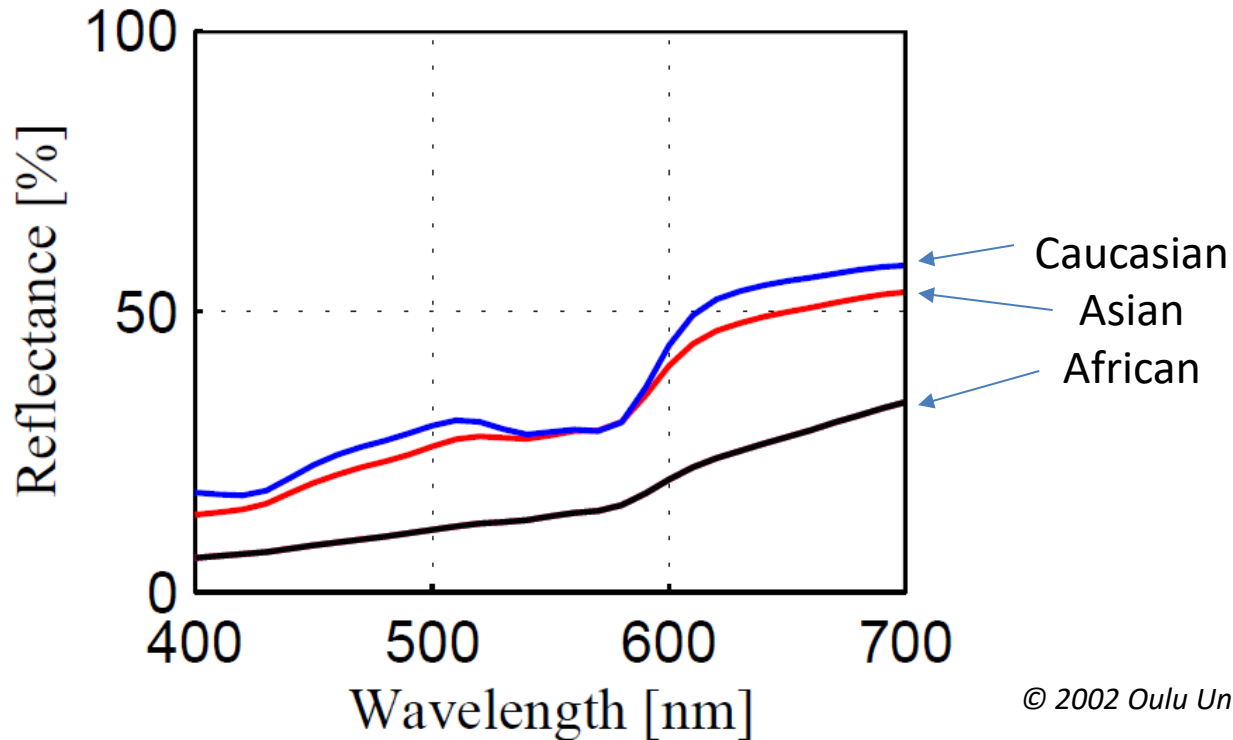
Data courtesy of Dieter Lang, LEDVANCE, Germany

# TM-30 colors - 99



# Reflectance Spectra of Skin

half is between 600nm – 700nm



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# Light Source Spectrum

# Light Source Spectrum (in the beginning)

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

# Light Source Spectrum (20<sup>th</sup> 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)

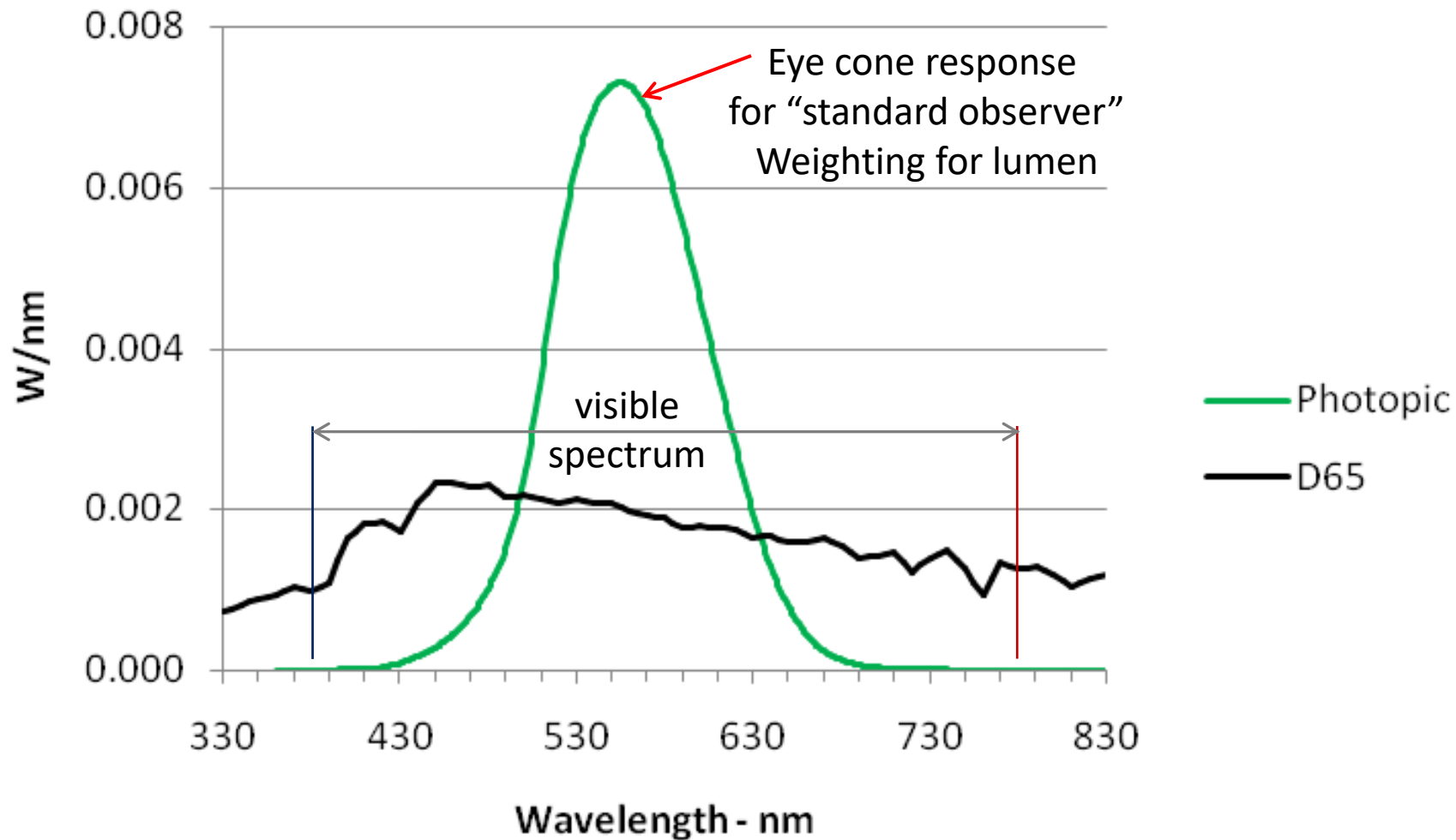


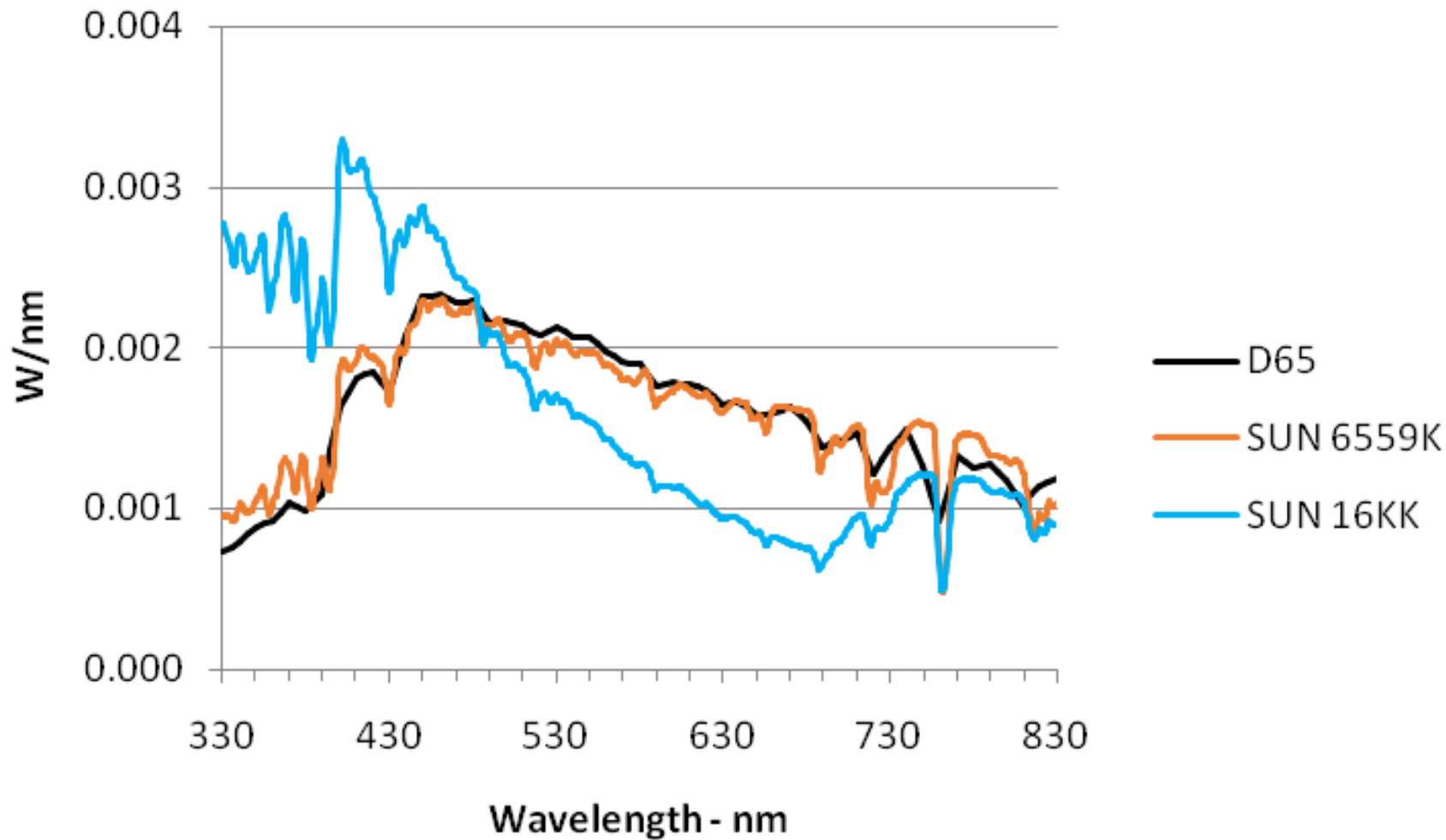
# Light Source Spectrum (21<sup>st</sup> century)

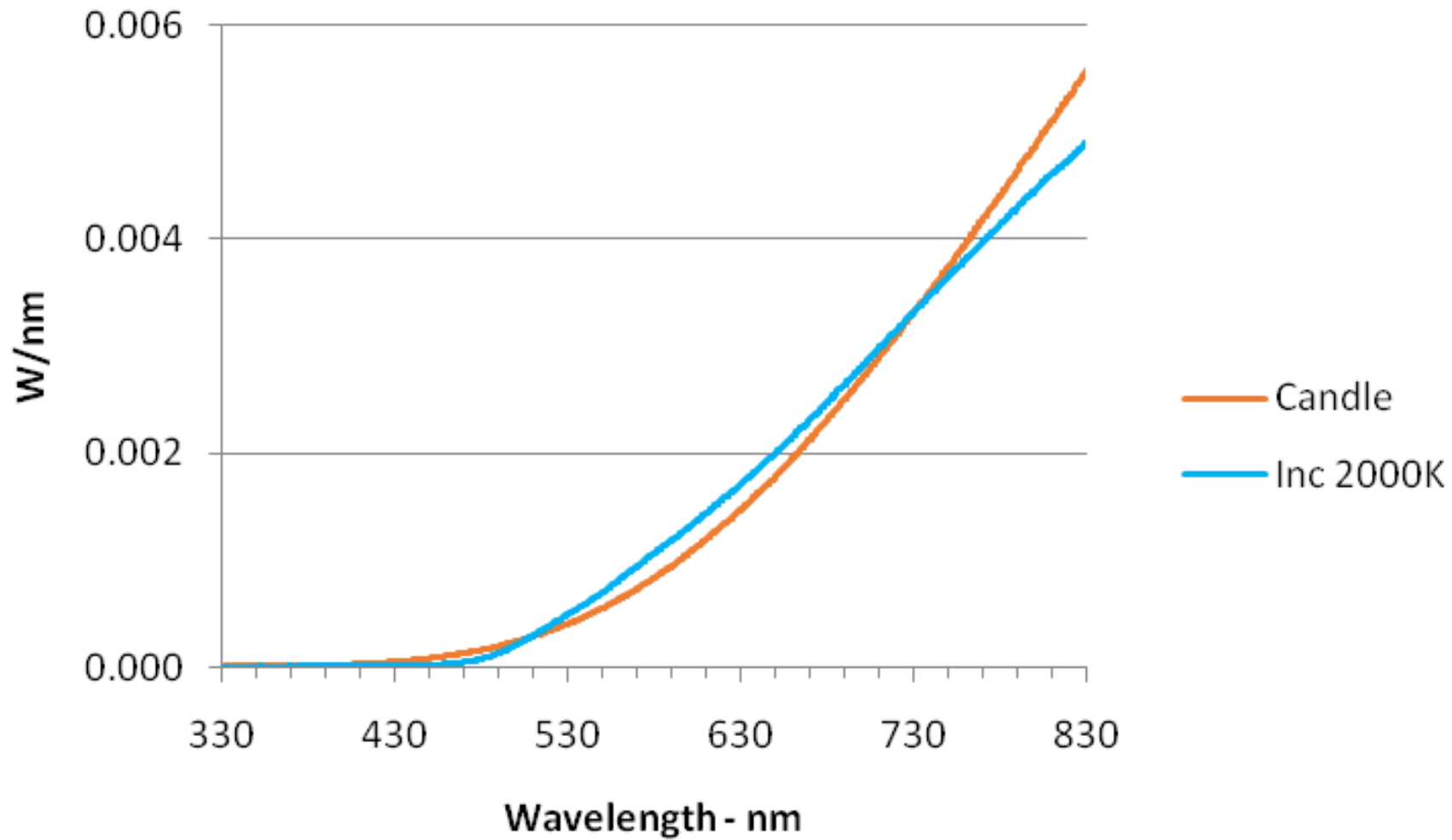
- Solid state sources
  - White LED – continuous but truncated
    - Blue and violet pumps plus phosphor(s)
  - White Laser – continuous but truncated
    - Blue and violet pumps plus phosphor(s)
    - Narrow beam – ex. car headlights
  - Many color LED – continuous and broad
    - 5, 8, 16, 22, 32

# Efficacy vs. Efficiency

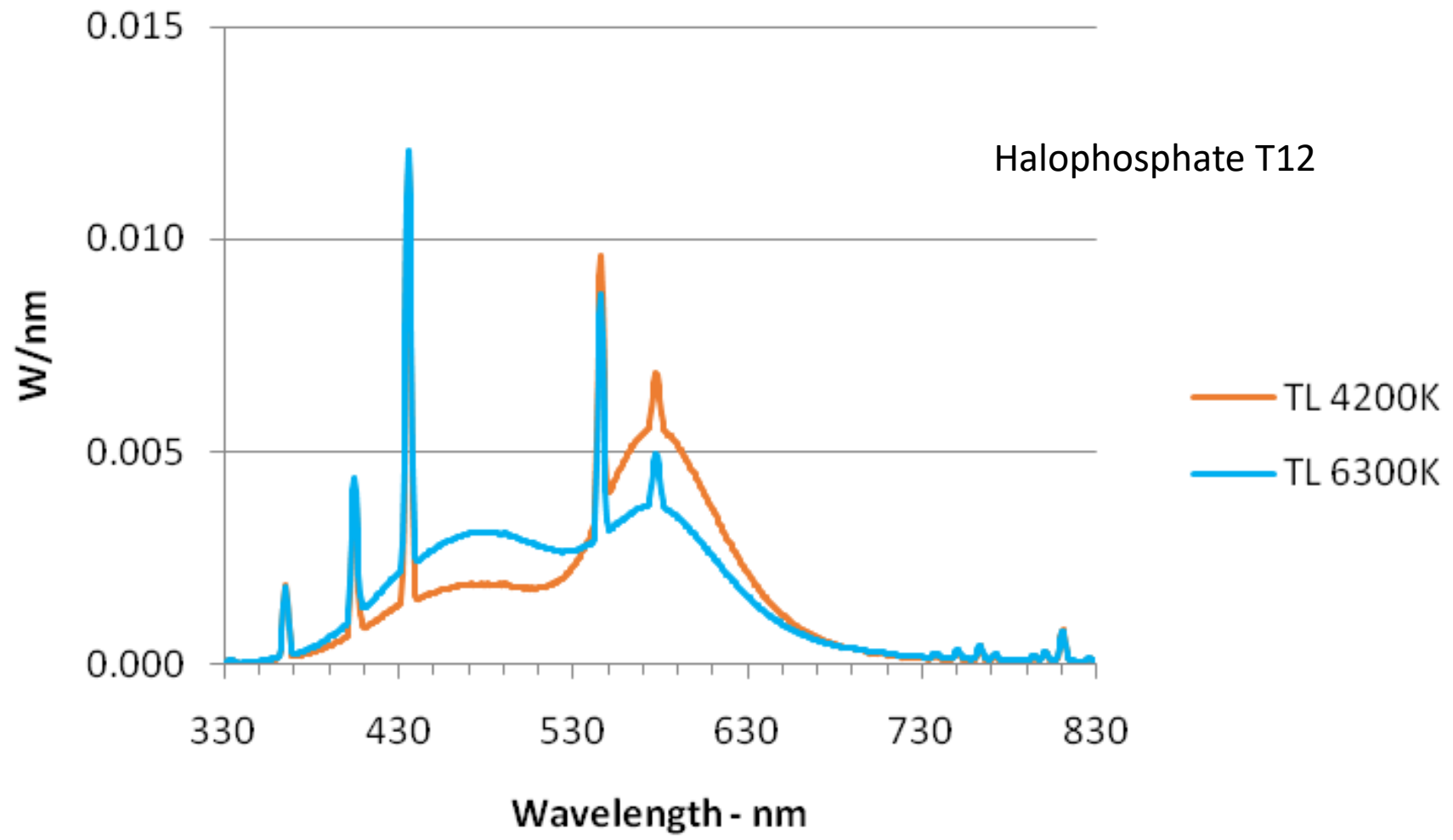
- Efficacy = lumens per electrical watt
- Efficiency = optical watts per electrical watt
  
- Lumens are a weighted measure of optical watts with a peak at 555nm (green) and falling off toward red and blue.

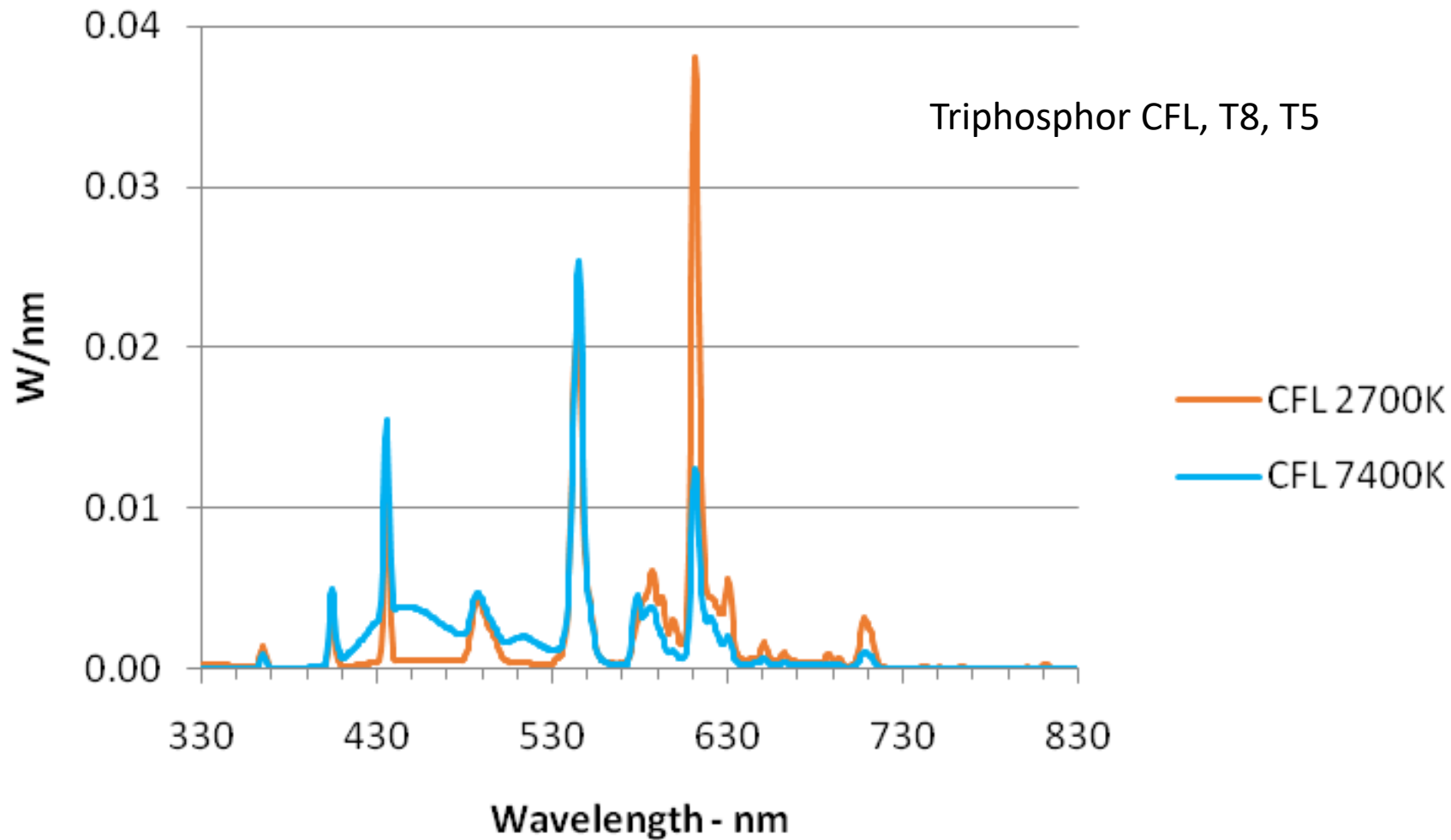


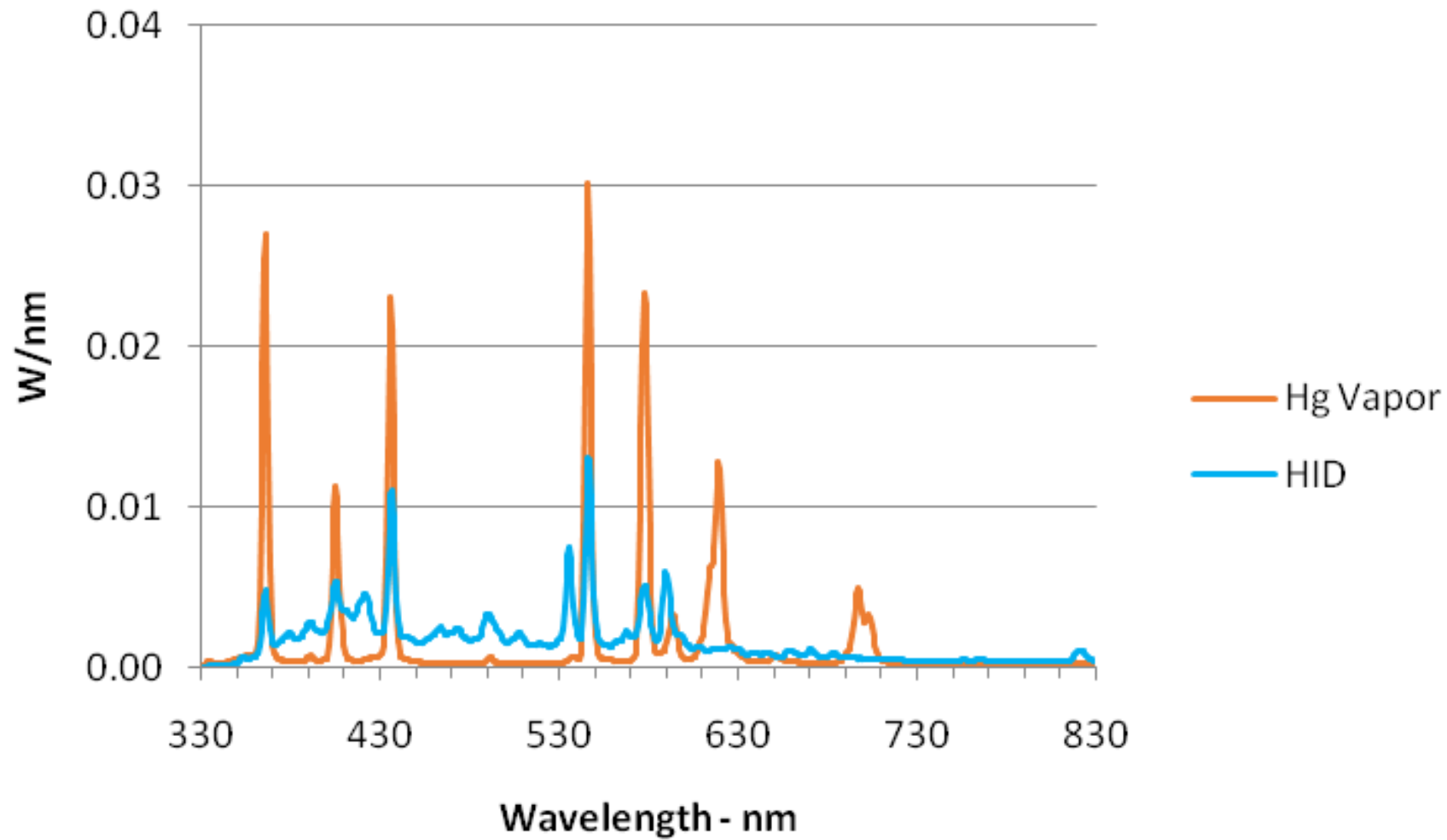




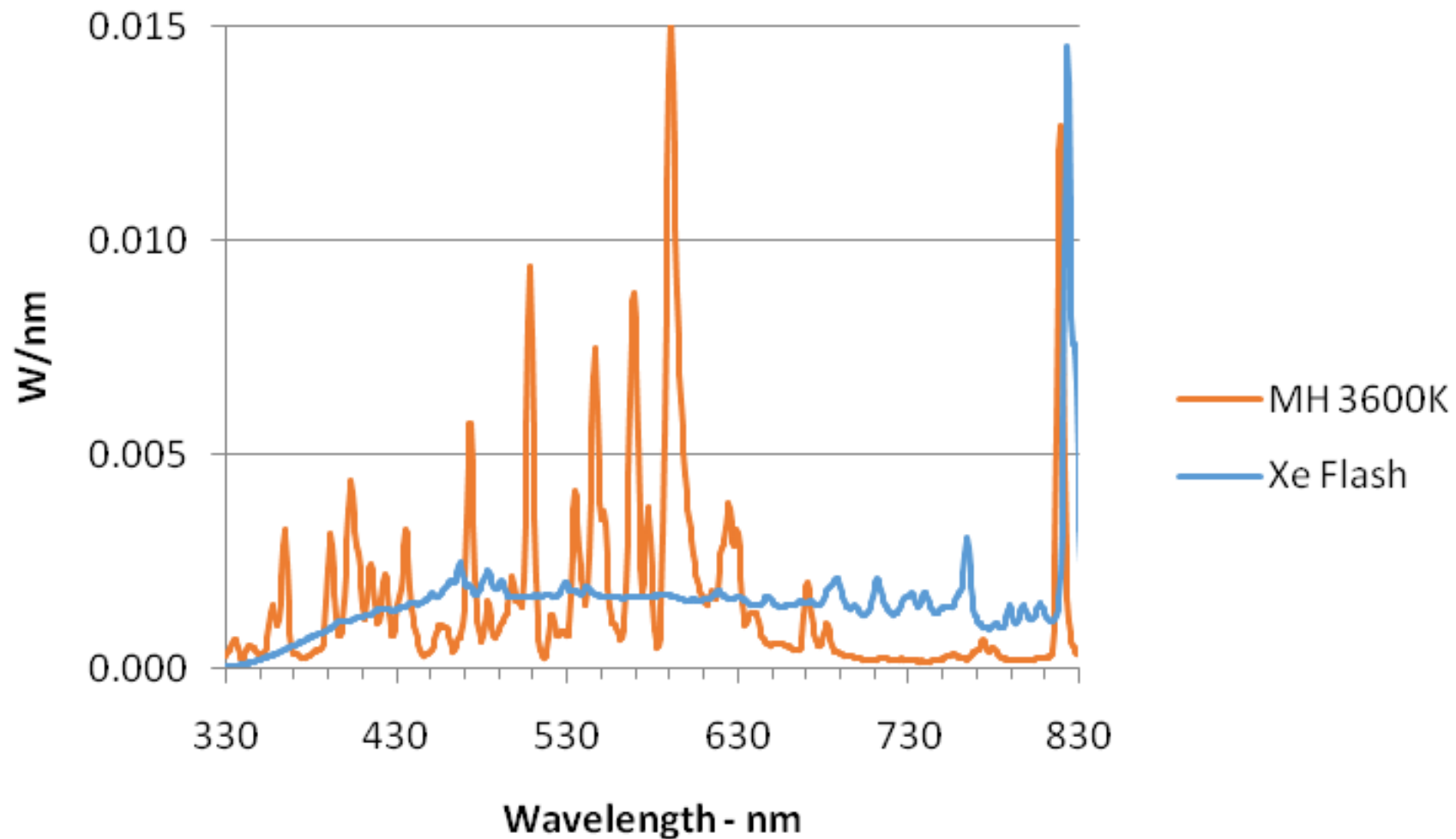
# Halophosphate T12

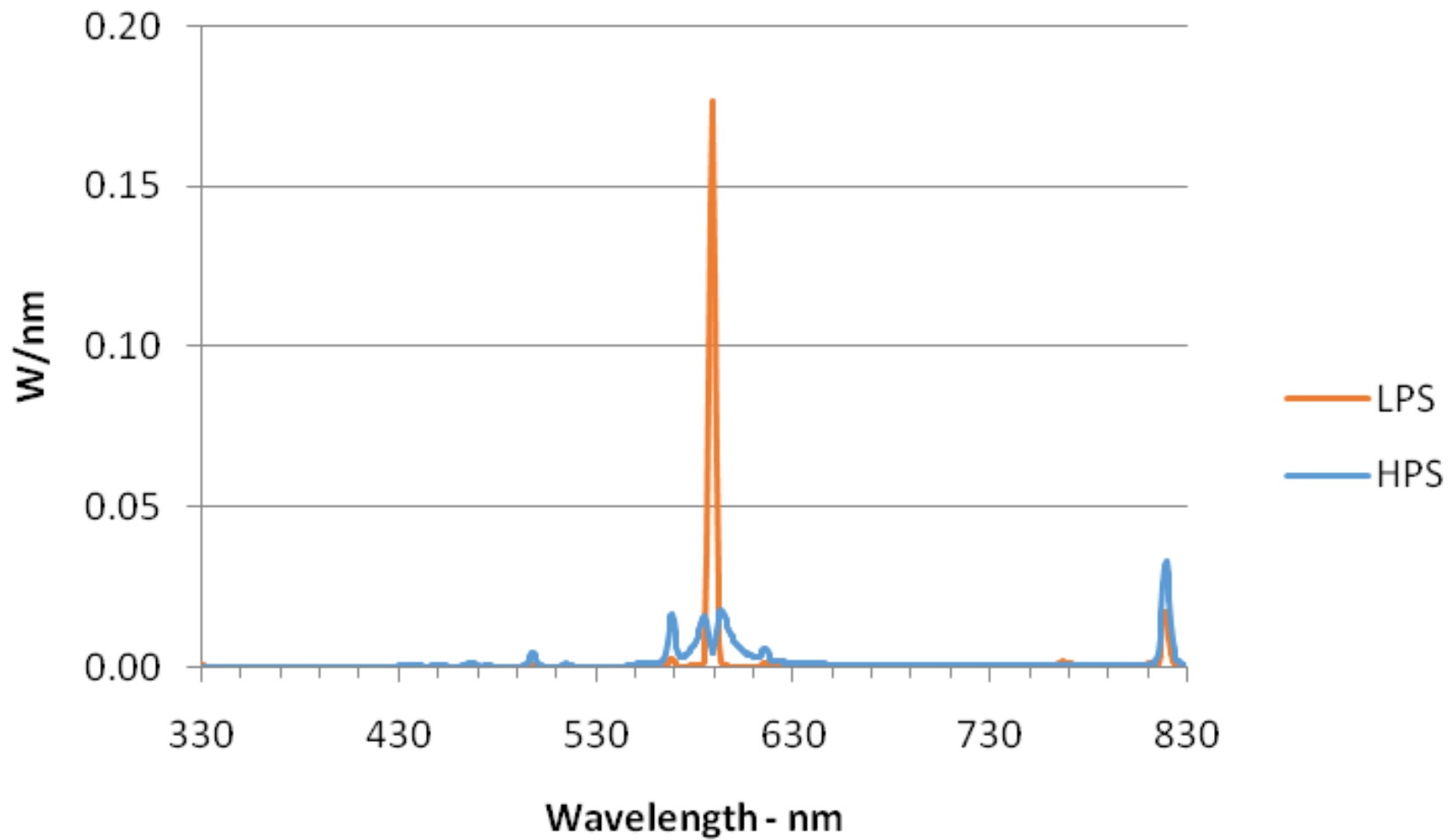


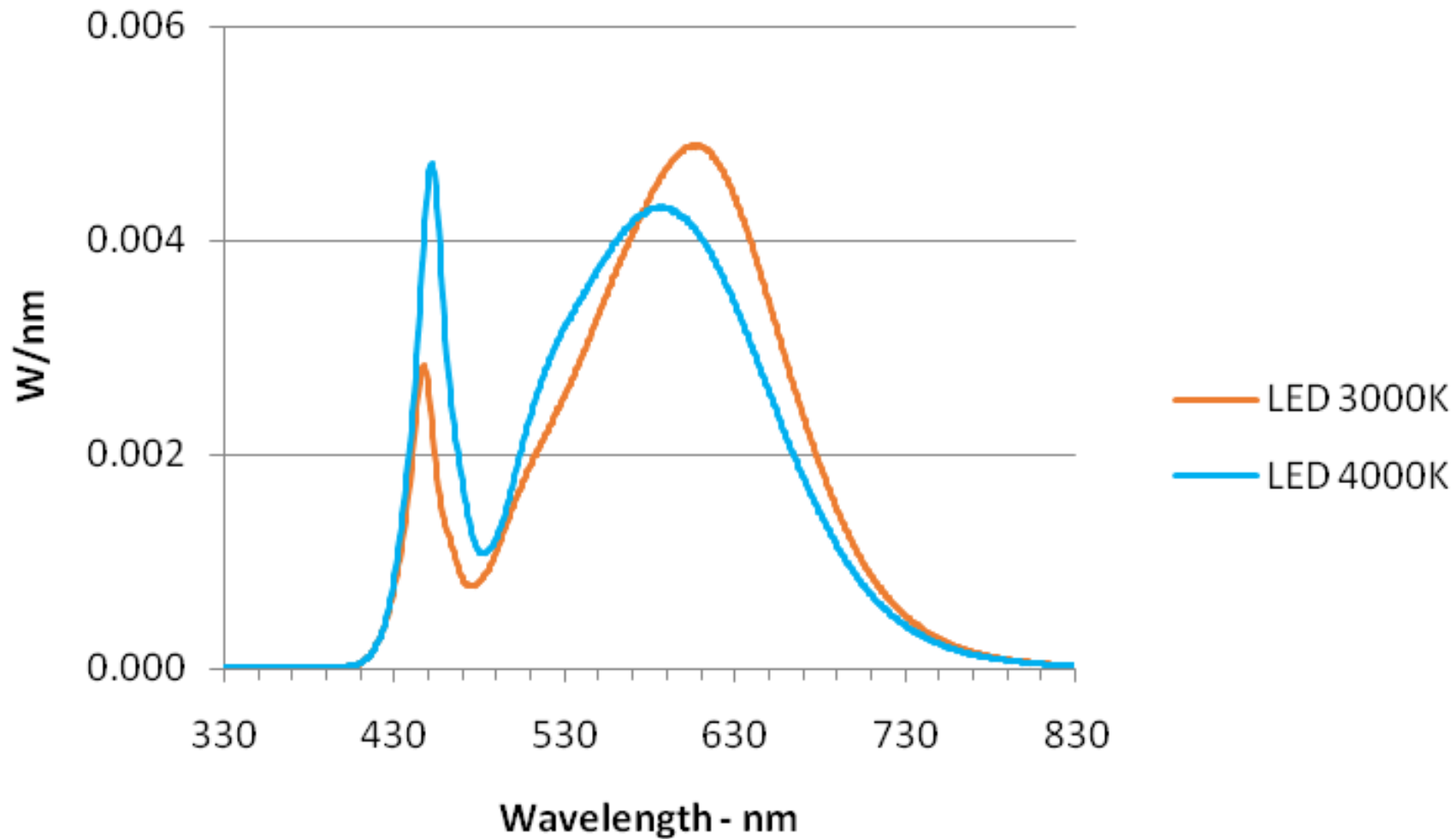


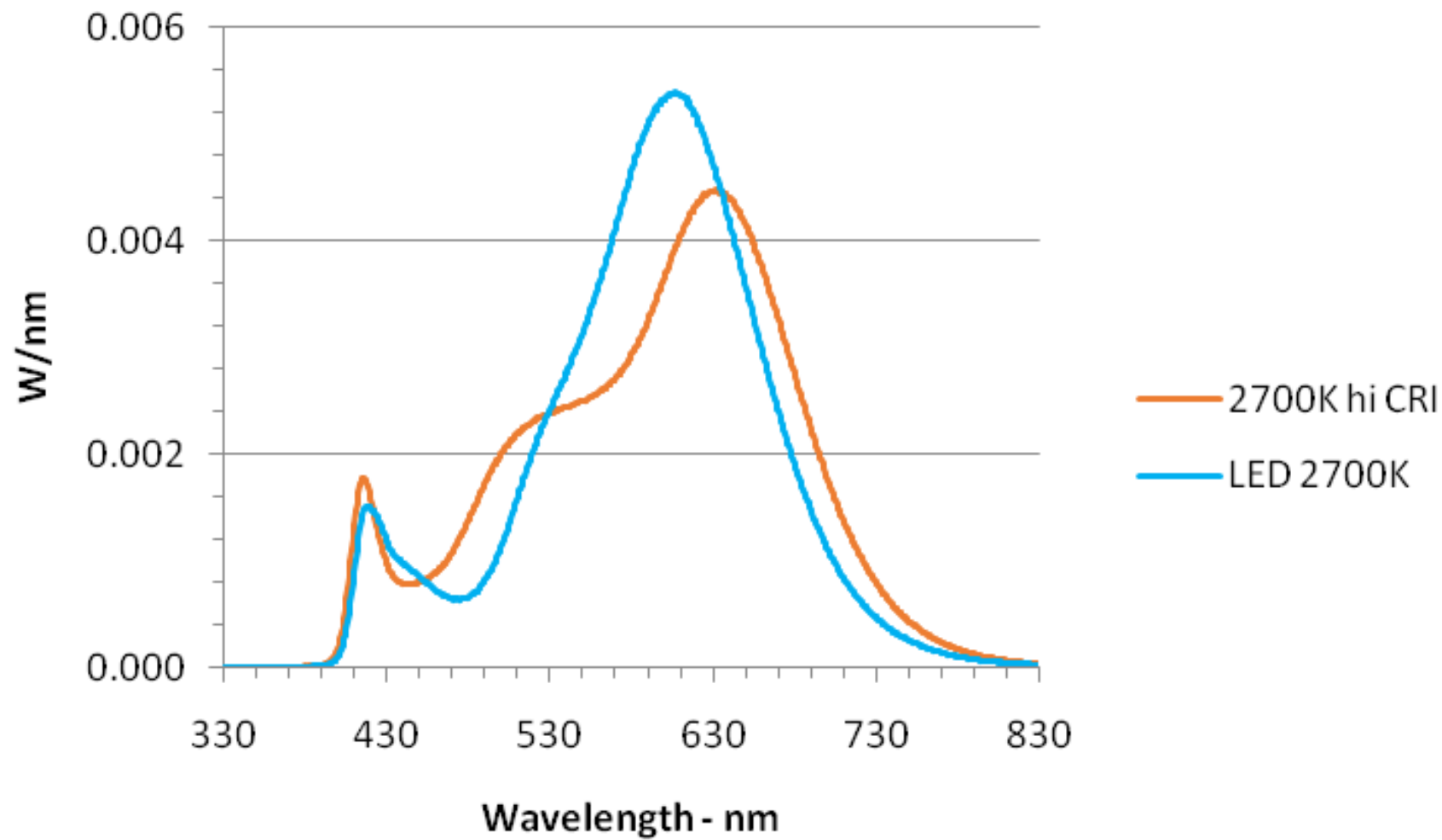


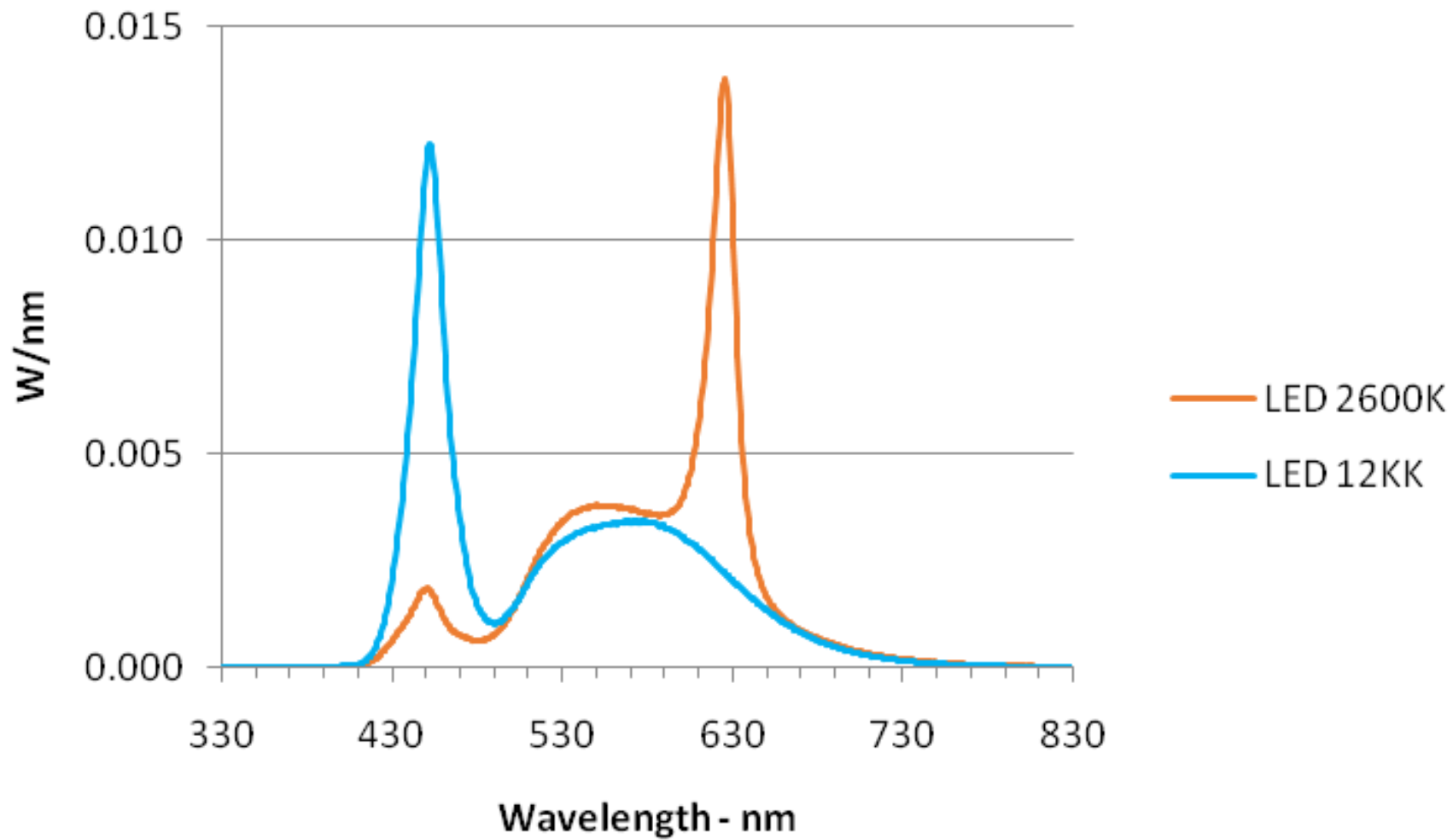


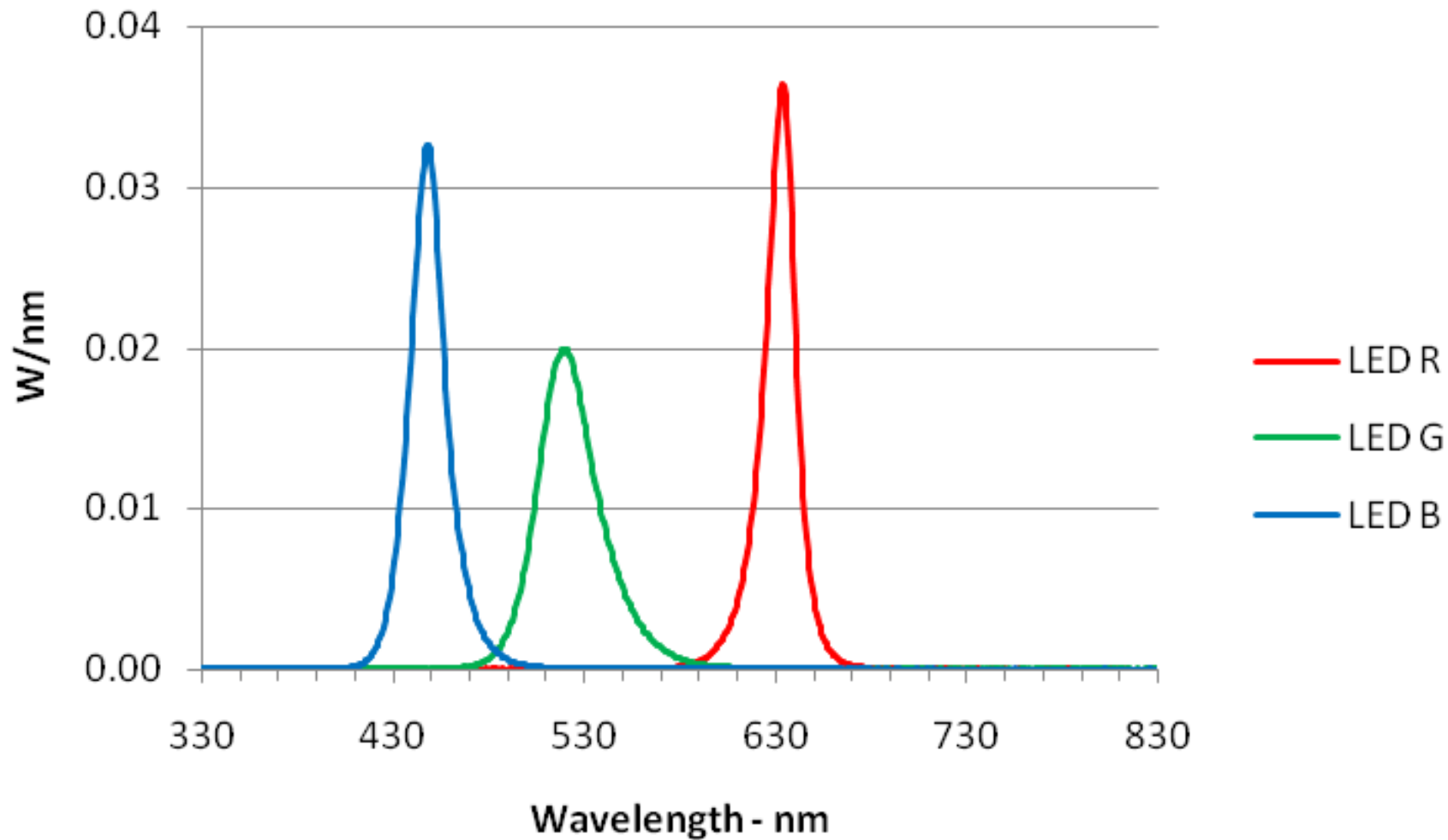


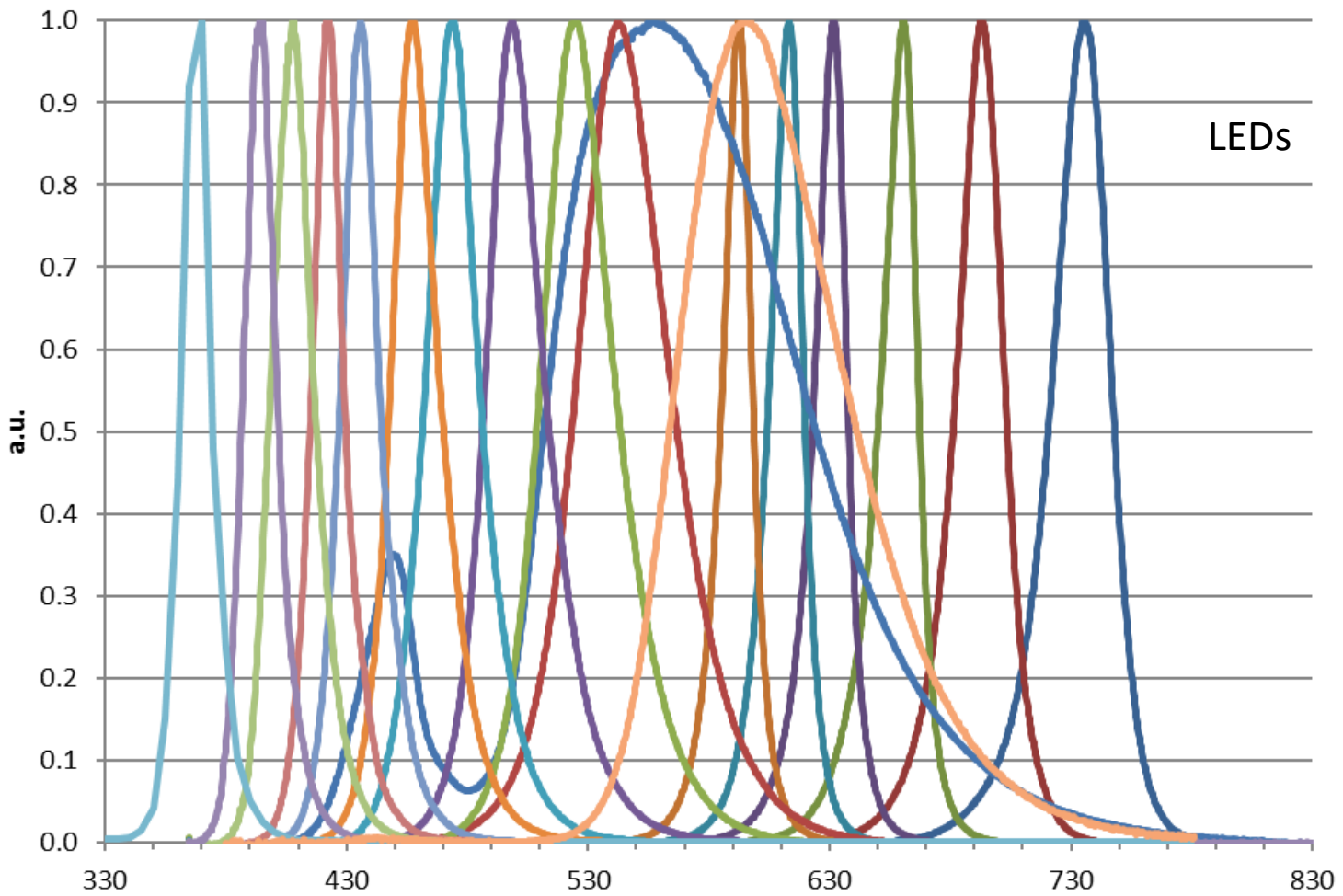


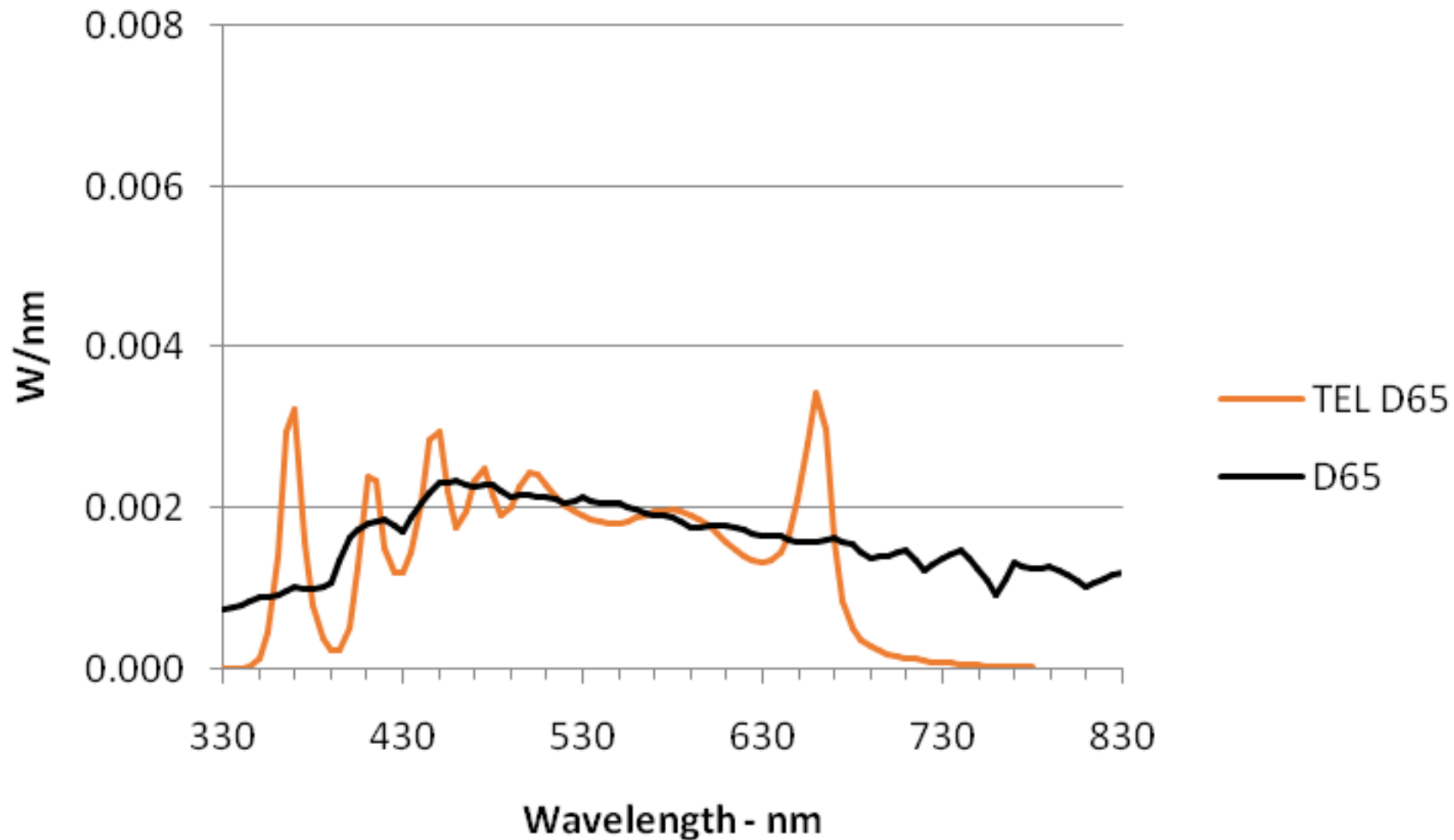




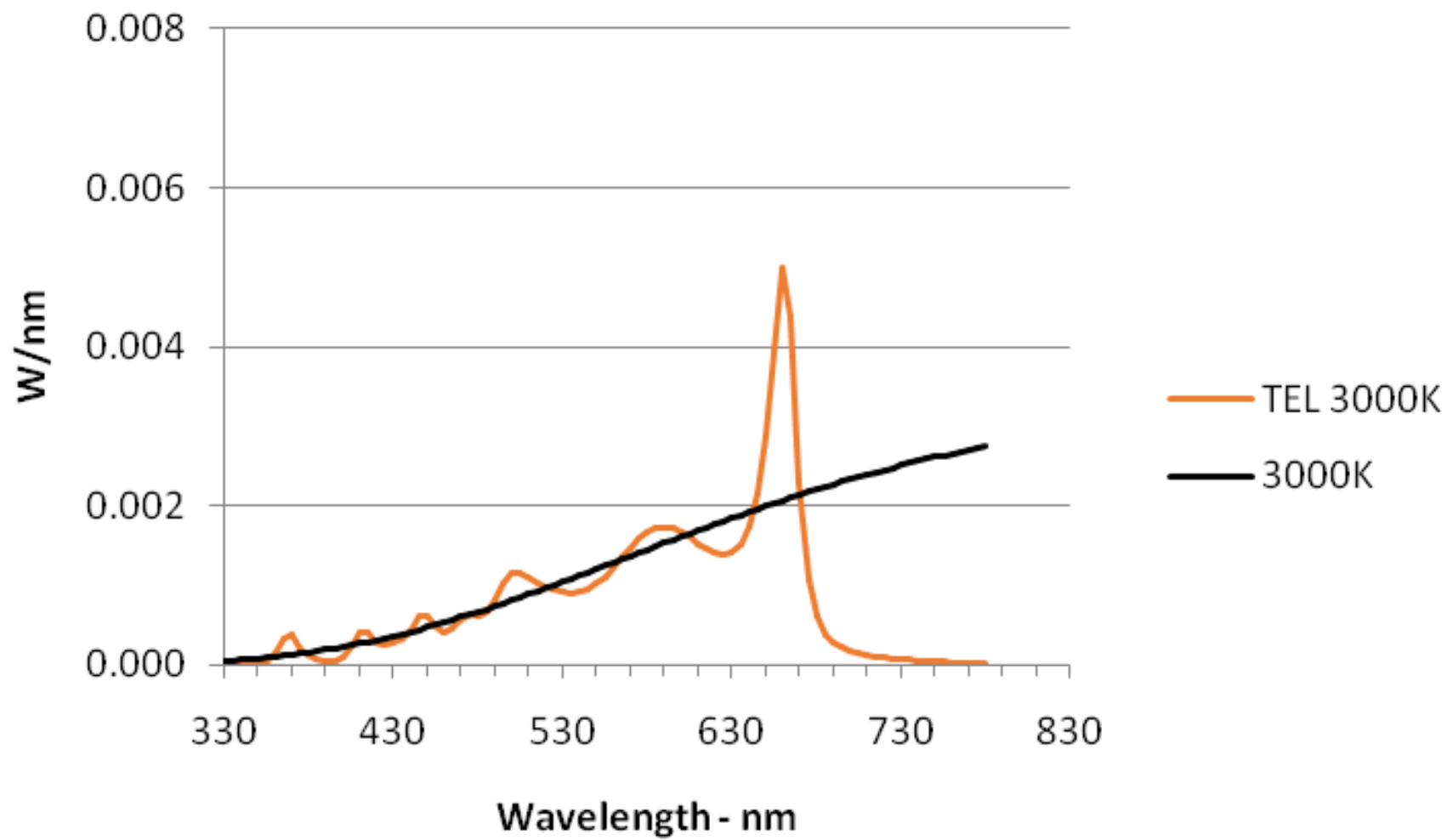












# Specifying Tunable Systems in General

- 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

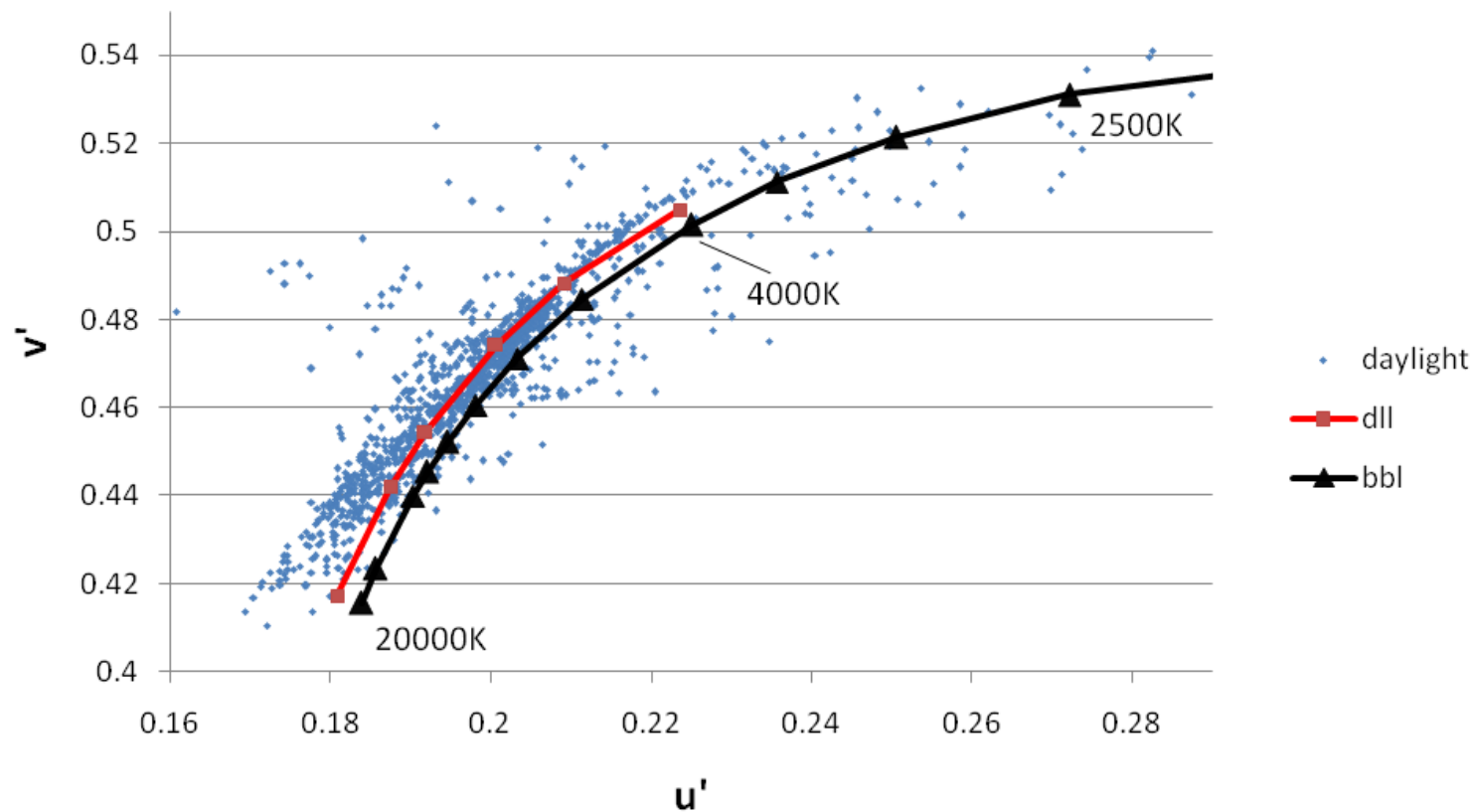
## In general - SPD

- 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

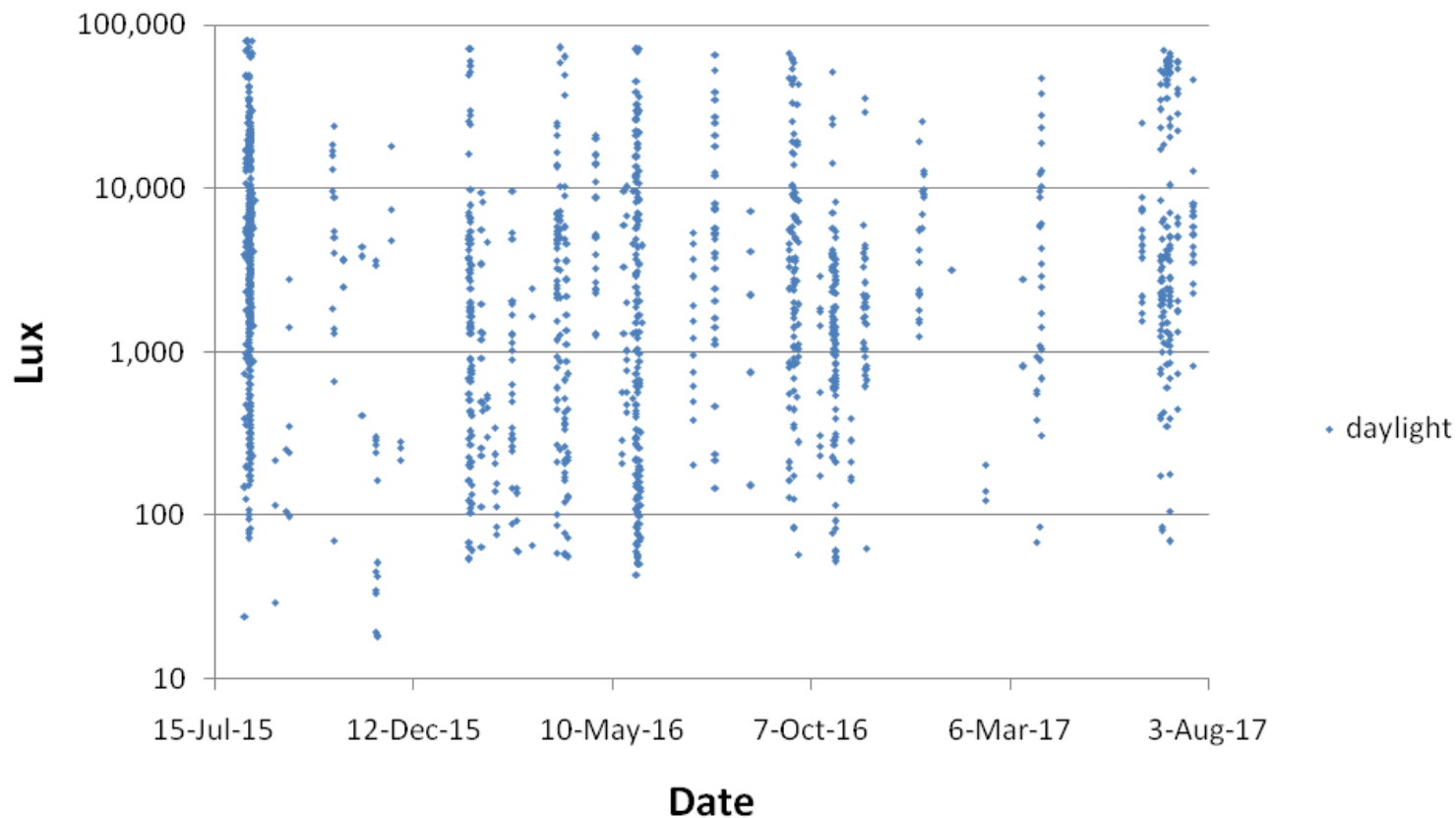
# Daylight Data

Aug15 to Jul17 (1400 recordings)

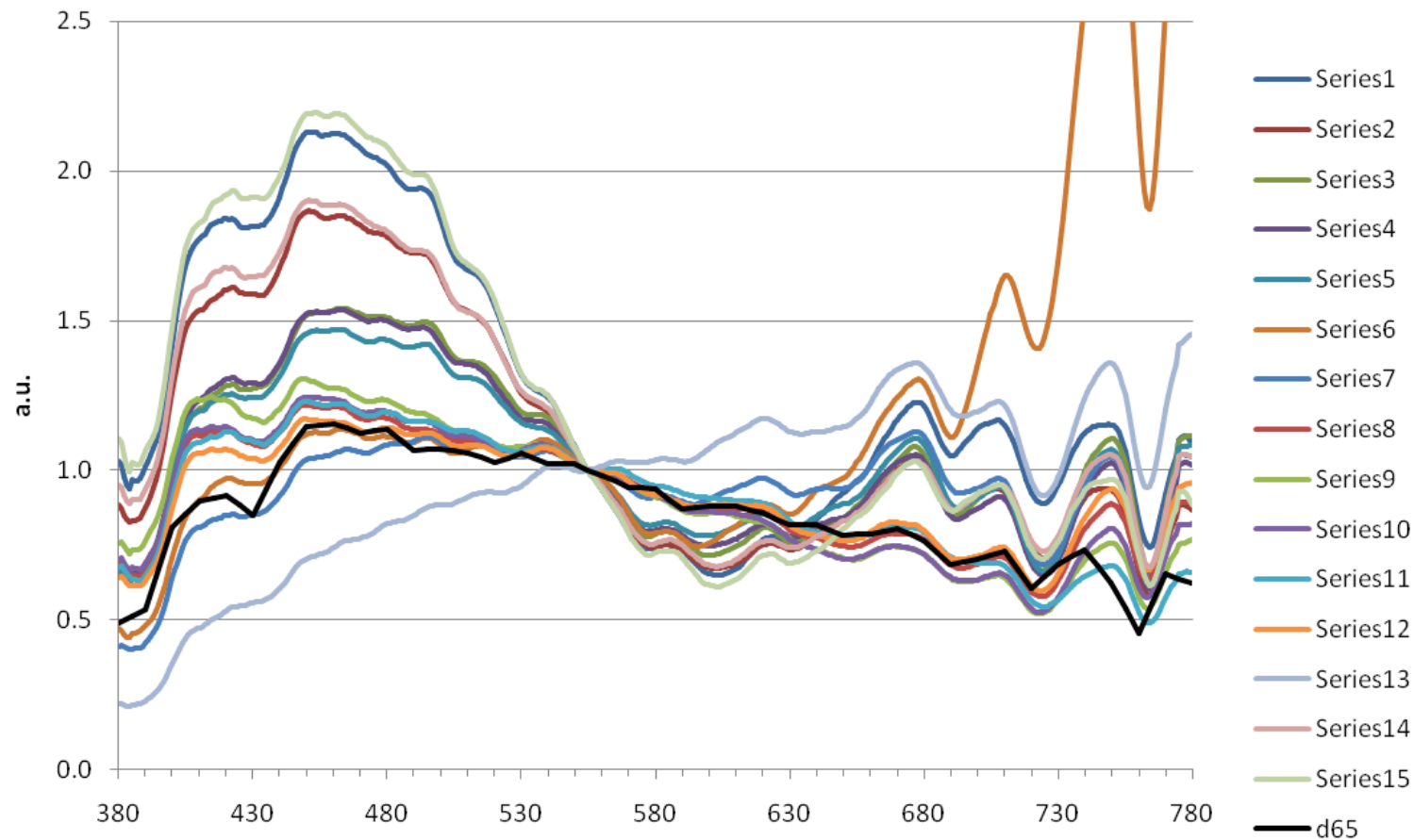


# Daylight Data

Aug15 to Jul17 (1400 recordings)



# Como, Italy - 28may16





# 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.









# Thank You

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