The Tunable Challenge from WW-CW to spectrum control

Steve Paolini – Telelumen LLC

29sep20

Agenda

- Levels of control and tuning
- Object colors
- Light source spectrum
- Observers
- Daylight
- Moving outside the box we built
- Summary

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Control and Tuning

- Dimming – intensity control, fixed CCT
- Warm-dim – intensity control, CCT changes
- WW-CW – intensity control, 1D CCT control
- Color change – RGB intensity control, 2D chromaticity control
- Spectral tuning – 4 or more colors, “3D” chromaticity control
  - Many SPD solutions with constant chromaticity
- Daylight tuning – 7 or more colors (ROYGBIV), no gaps, 660nm
  - Deep red is key for attractive skin color and blue sky
    - Typical red is actually orange
  - ROYGBIV – Sir Isaac Newton, Opticks, London, 1704

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Check the Box vs. Walk the Talk

- Dimming – 30-100% vs. 0.1-100%
- Warm-dim – CCT changes vs. blackbody, high Rf
- WW-CW – 3000K/5000K Rf80 vs. 2700K/6500K Rf90
  - Engineered spectrum, “daylight” LEDs
- Color change – RGB vs. RLB or RLBW (L=lime, PC-green)
- Spectral tuning – RGBW vs. 5 non-white channels
- Daylight tuning – 7 or more colors (ROYGBIV), no gaps, 660nm
  - Deep red is key for attractive skin color and blue sky

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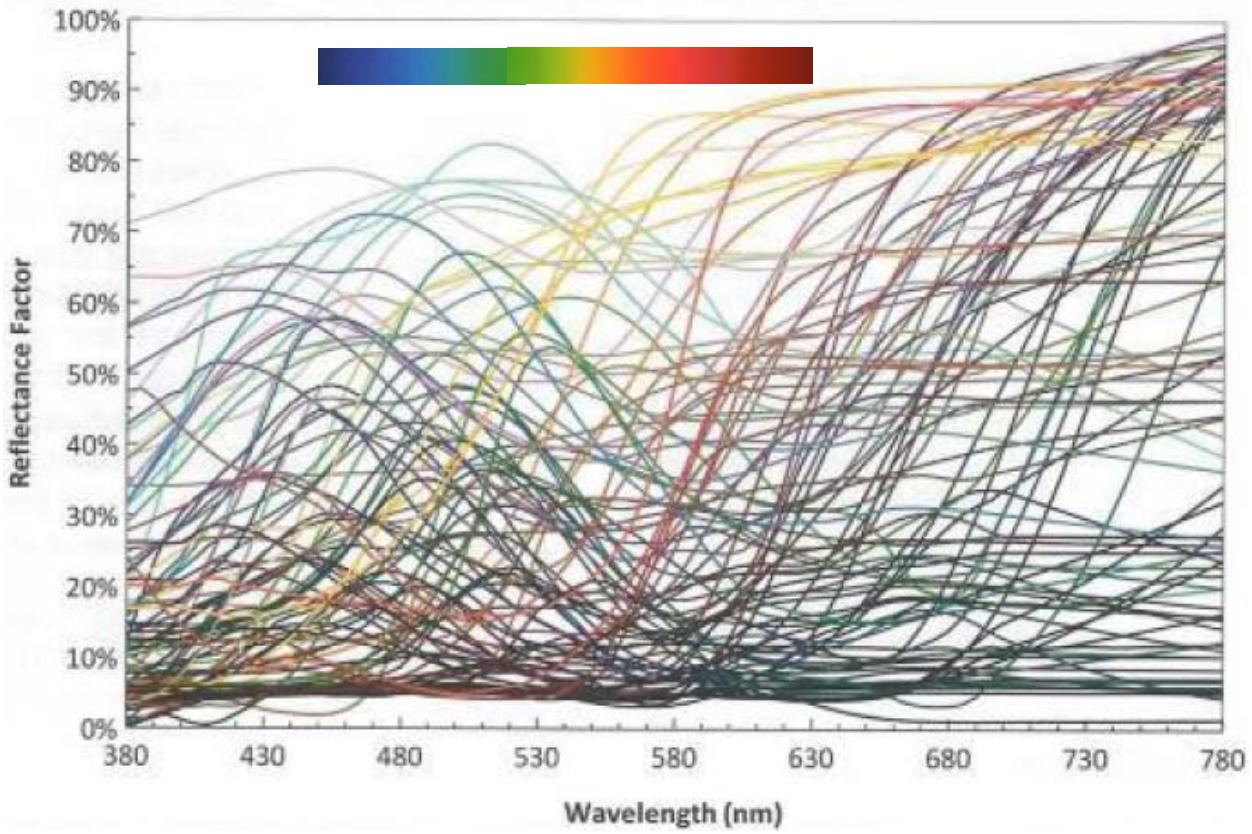
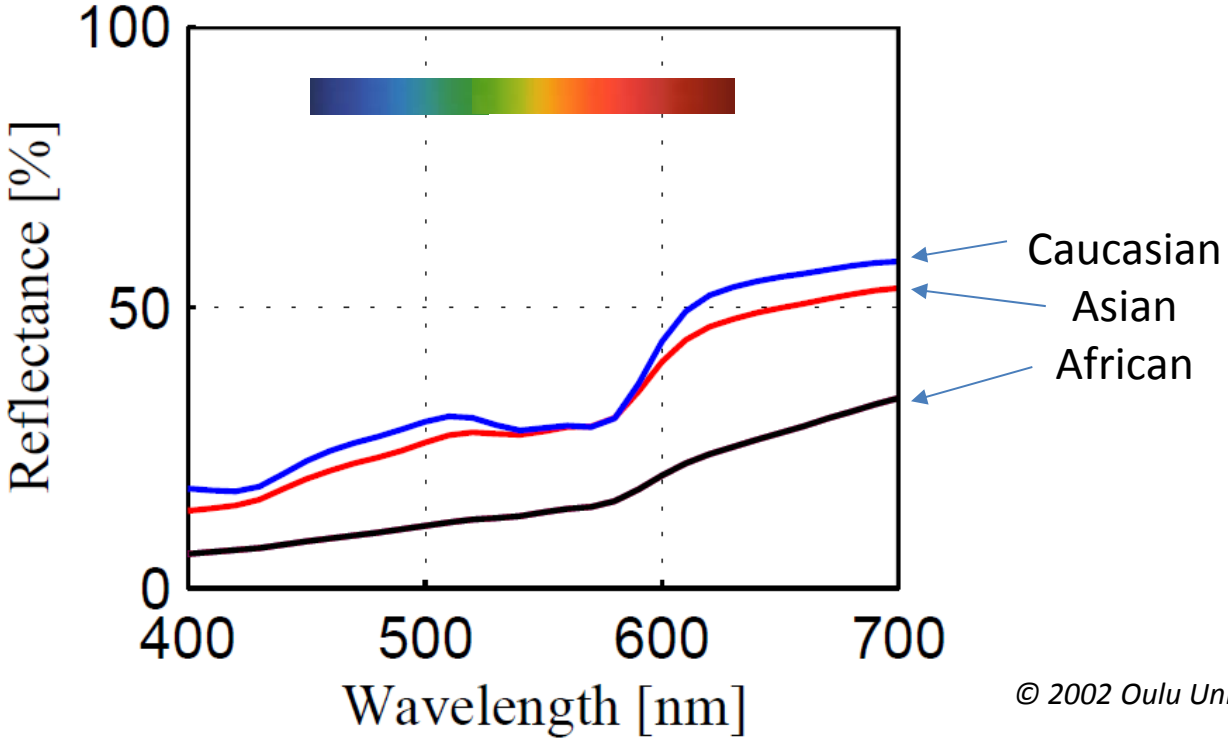
TM-30 Objects



Courtesy of Michael Royer, PNNL

Deep Red is Key to Proper Skin Rendition

About half the response is >600nm



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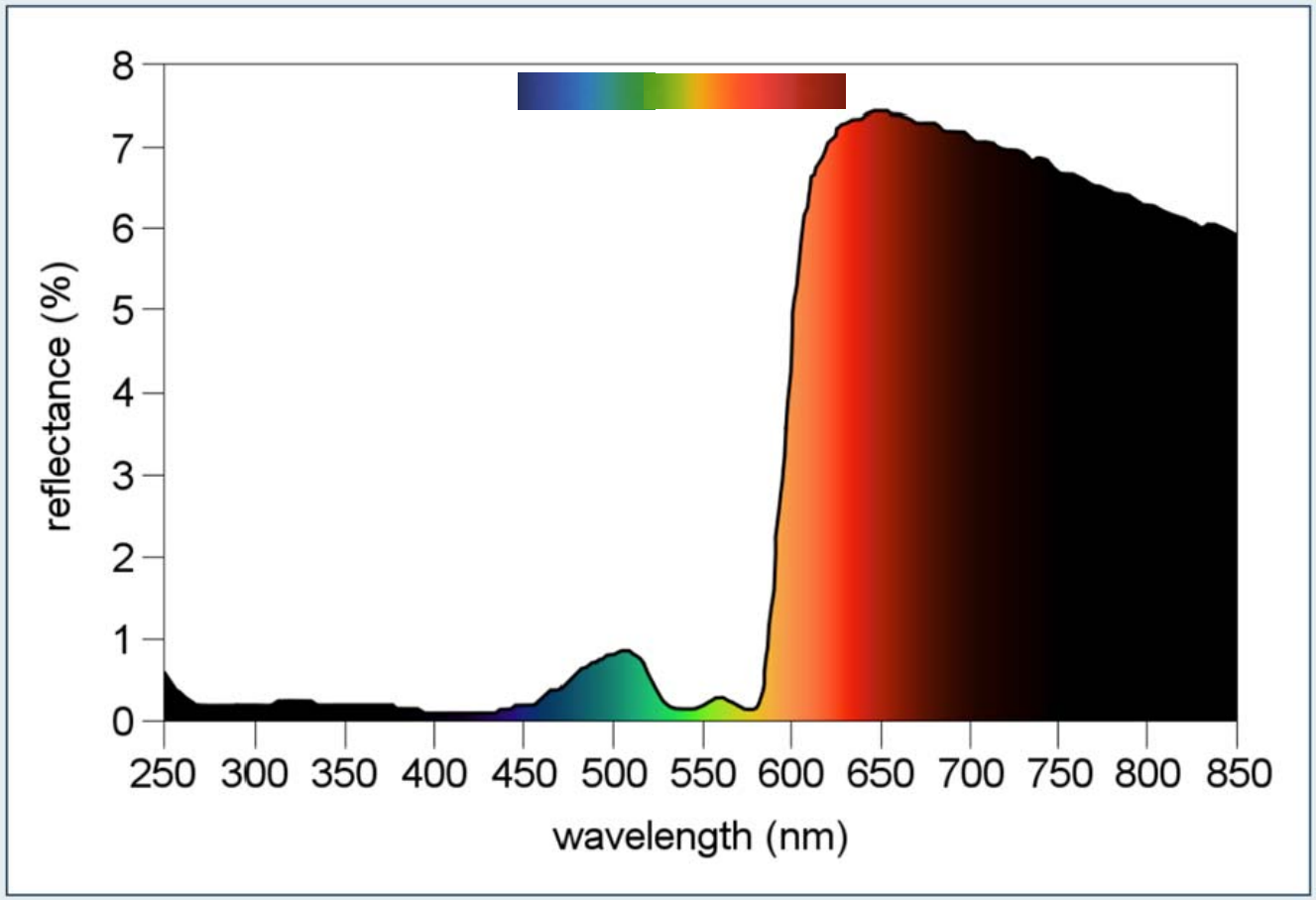
From: ”Face colour under varying illumination”, Chapter. 4; *http://herkules.oulu.fi/isbn9514267885/html/i1030756.html*



Diffuse reflectance of human blood with a hematocrit of 33%, oxygen saturation of 100%, and mean cell volume of 83 femtoliters. Public Domain Image, data source: M. Meinke, image source: Christopher S. Baird.

Daylight refracting through a fish tank on to a wood floor.

NOTE: Some colors in this image are false because they lie outside the camera and display gamut.

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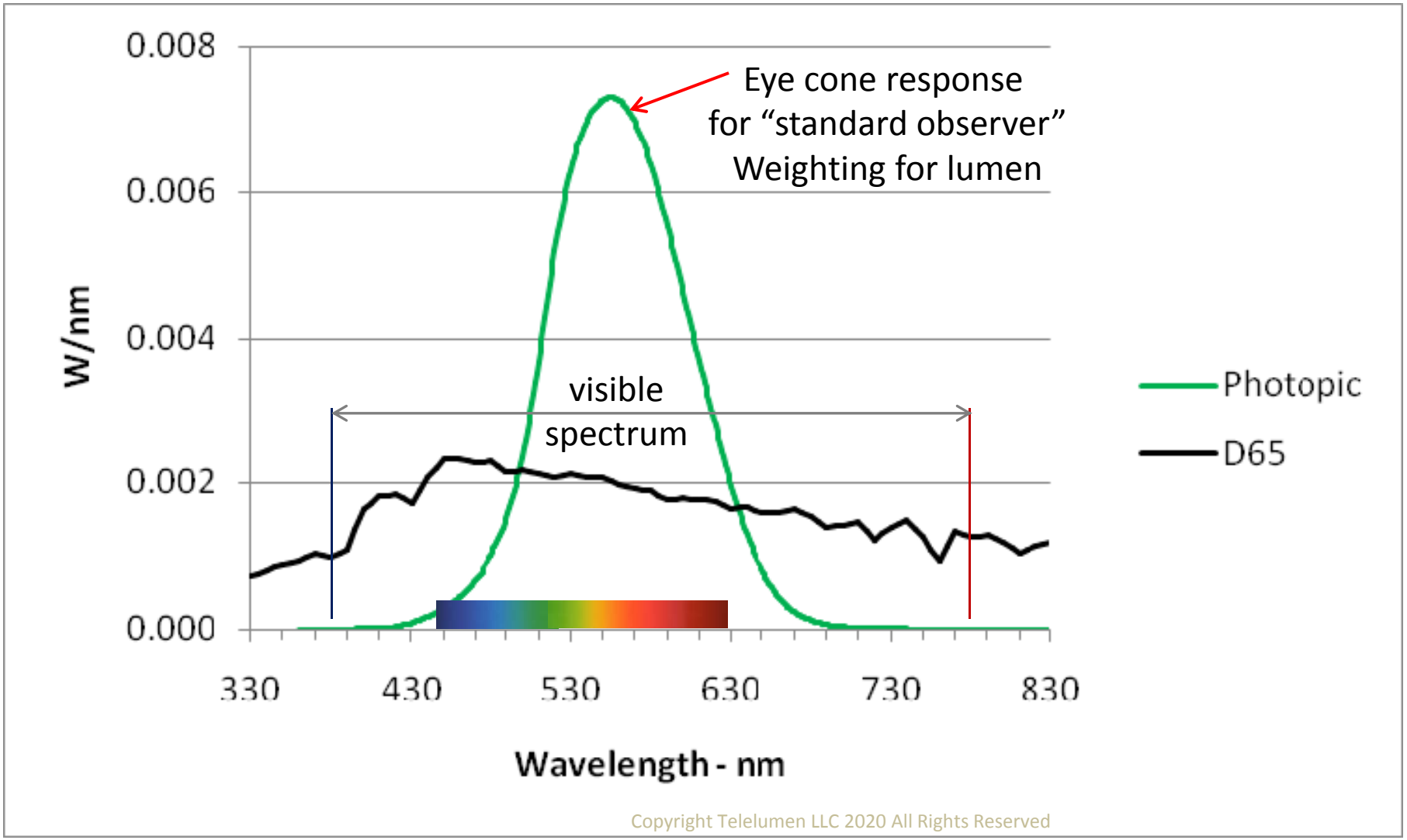

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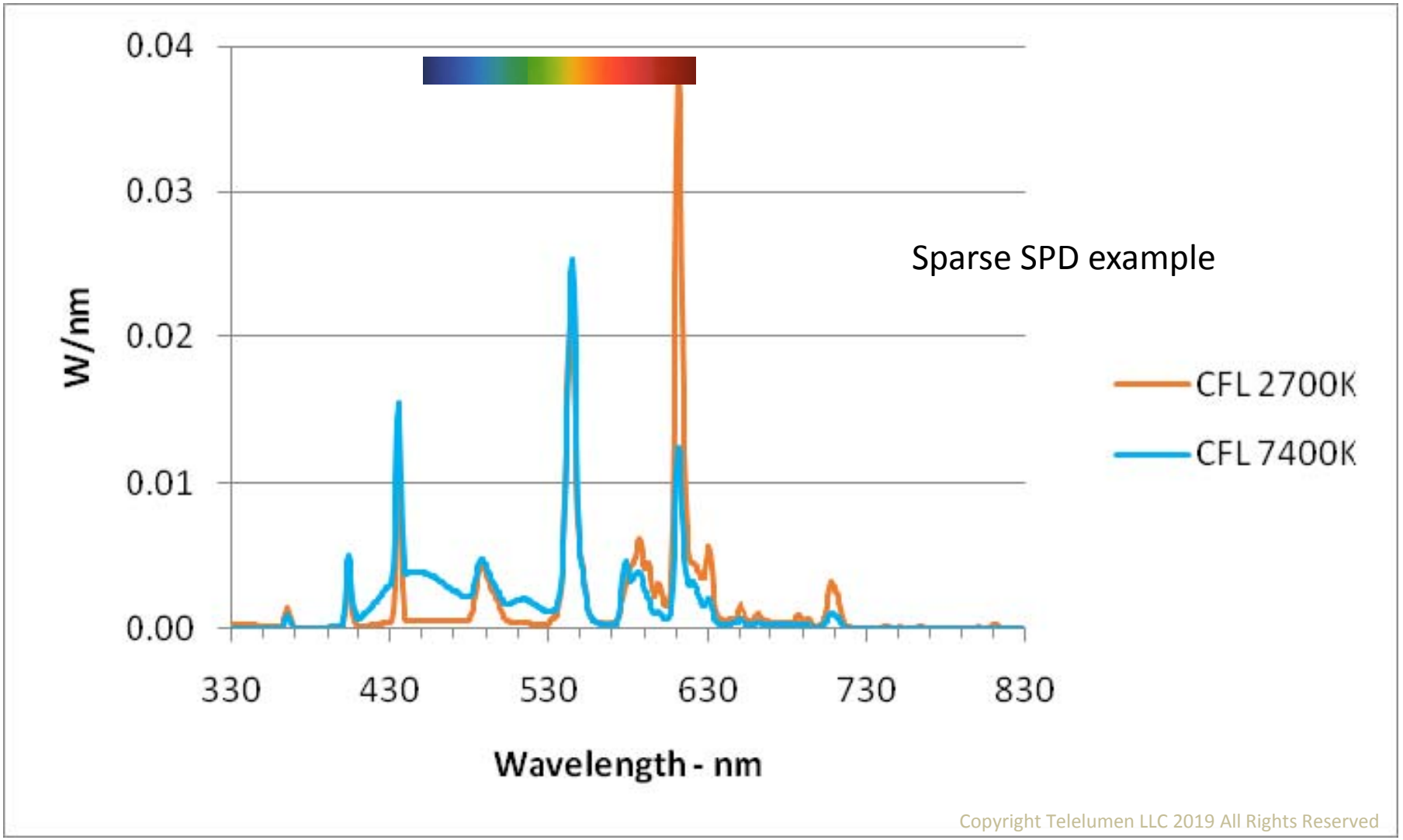

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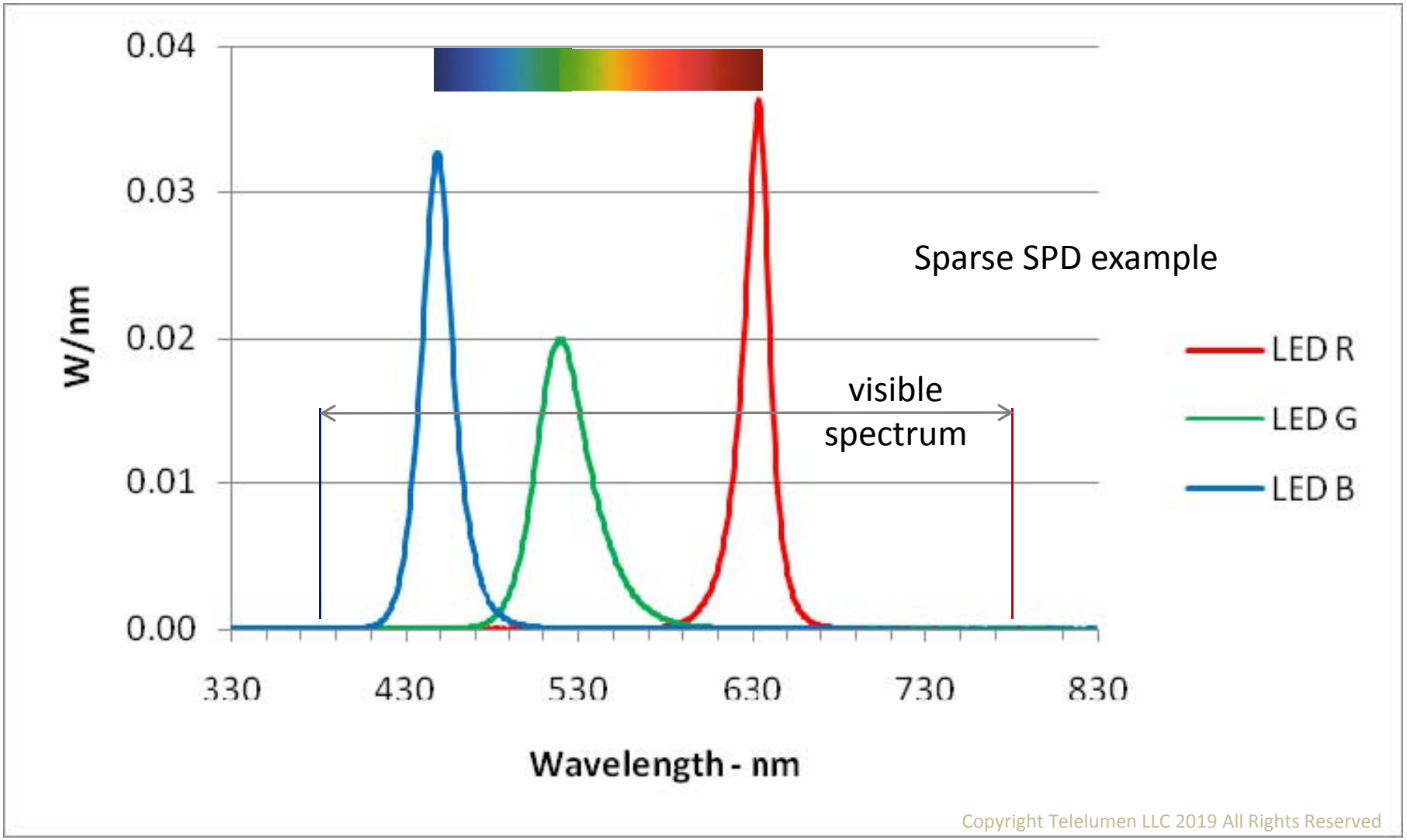

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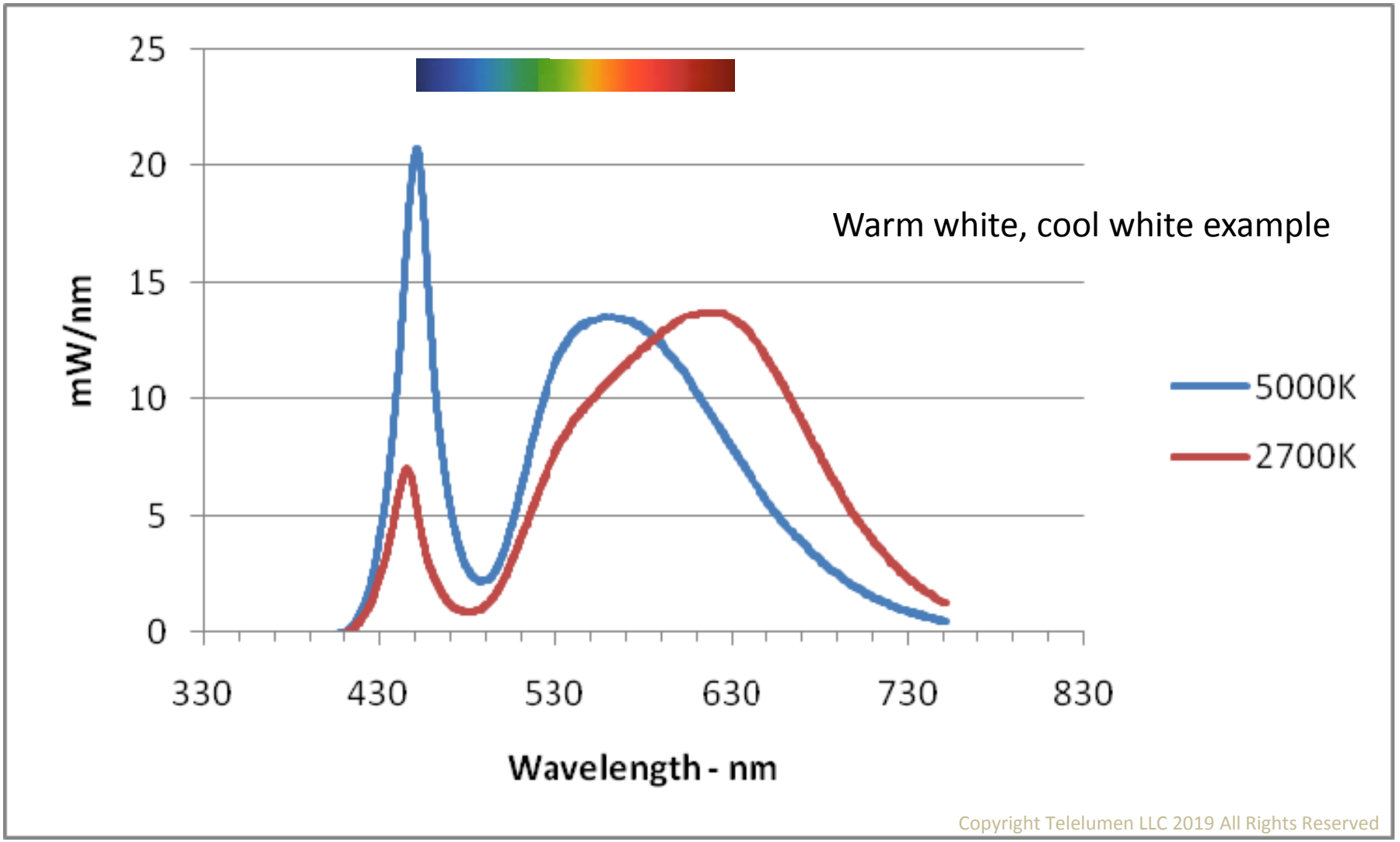

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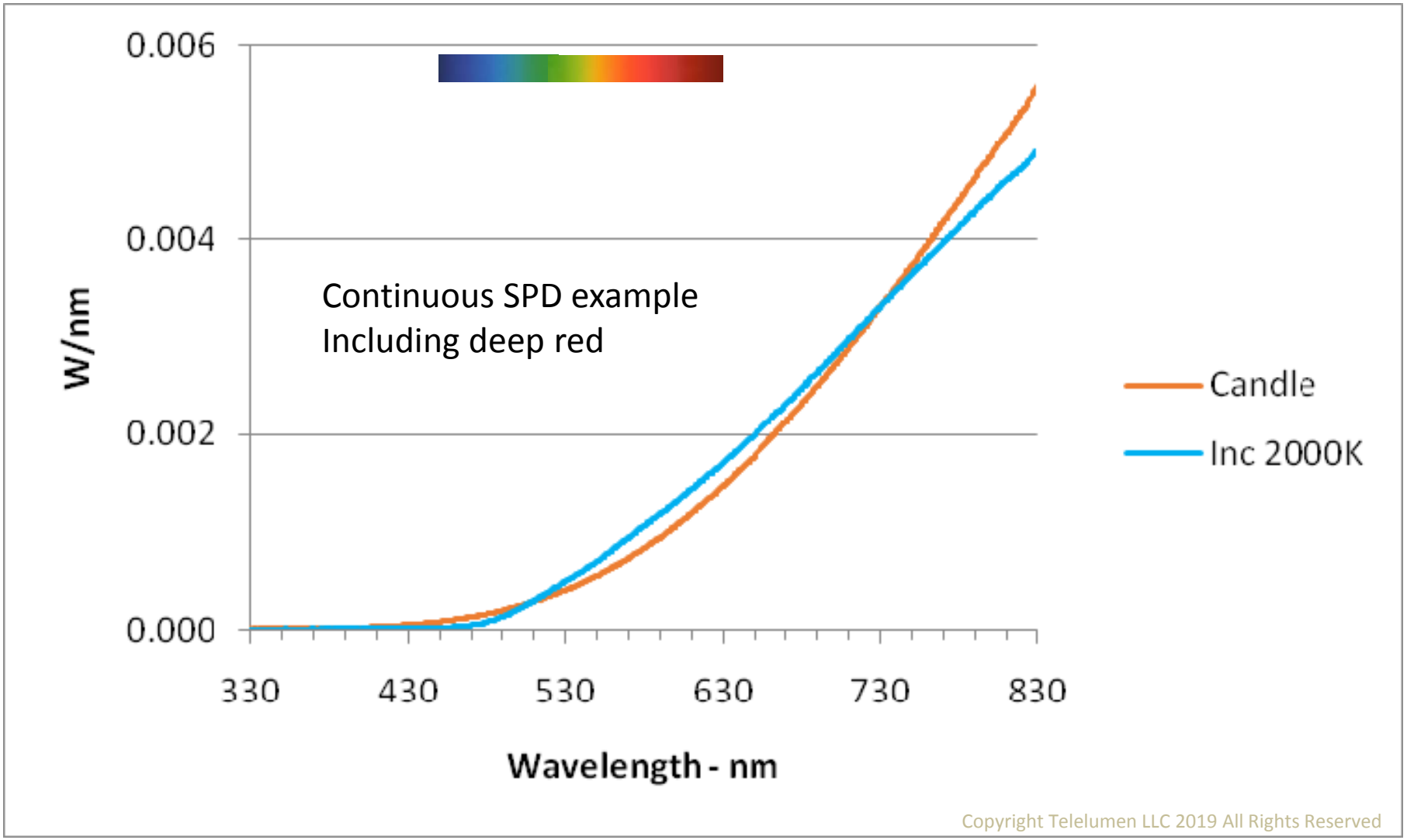

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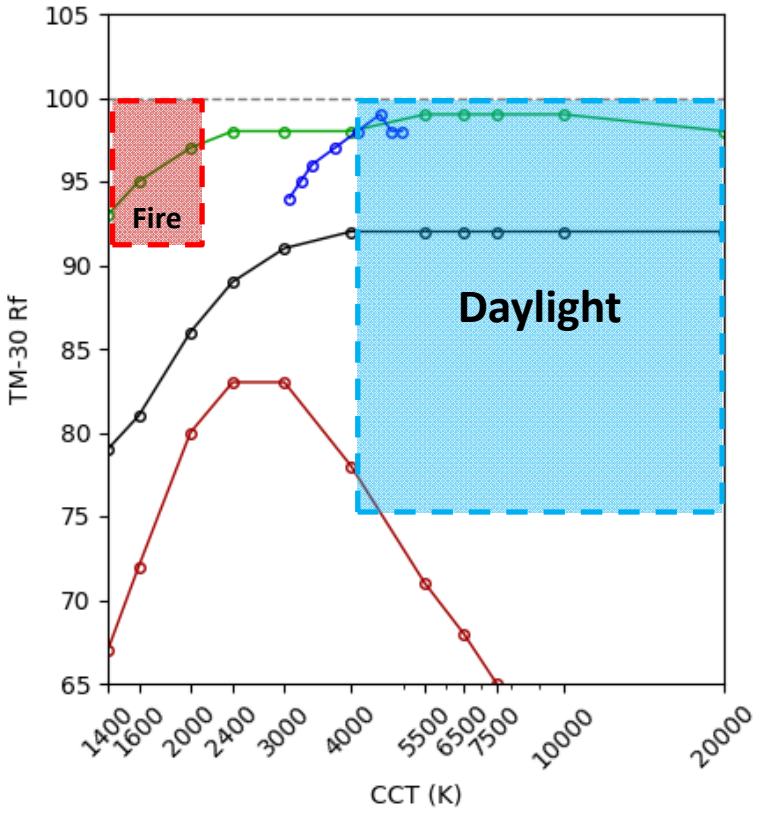
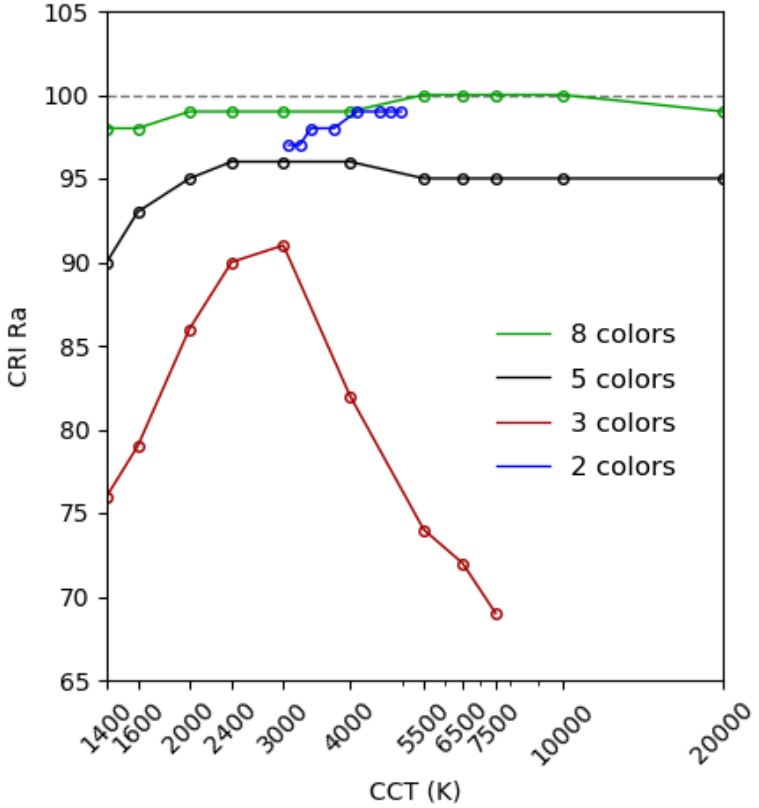
Rf vs. Ra vs. Channels





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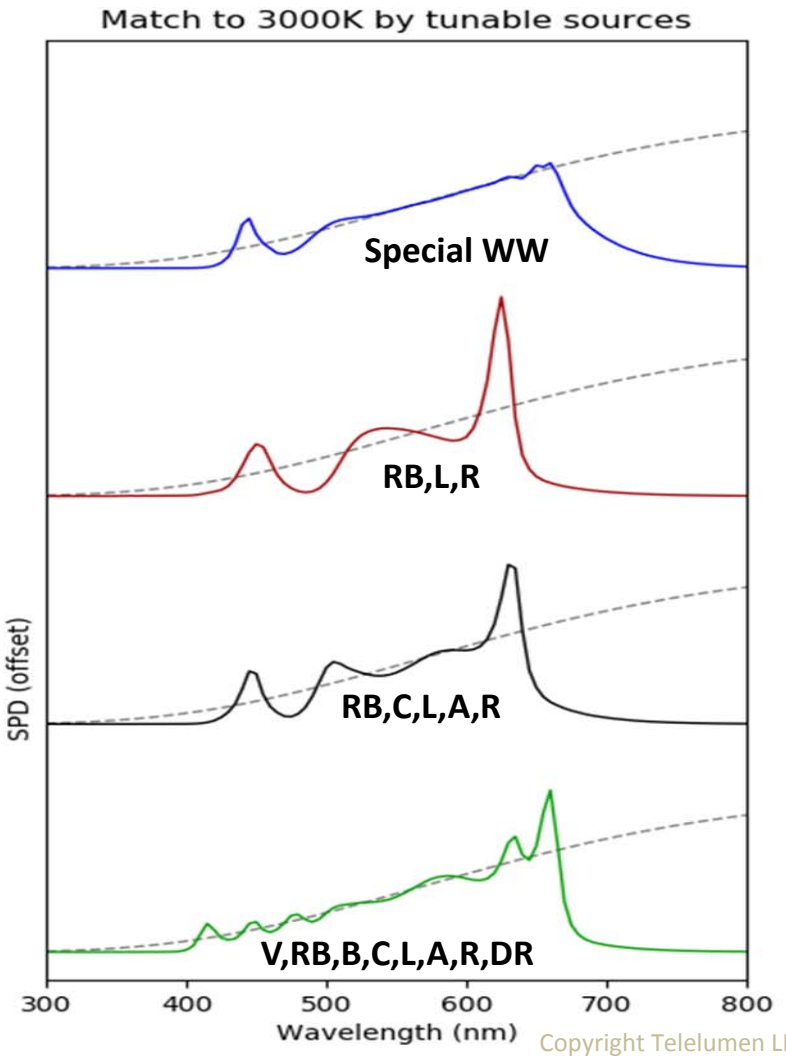

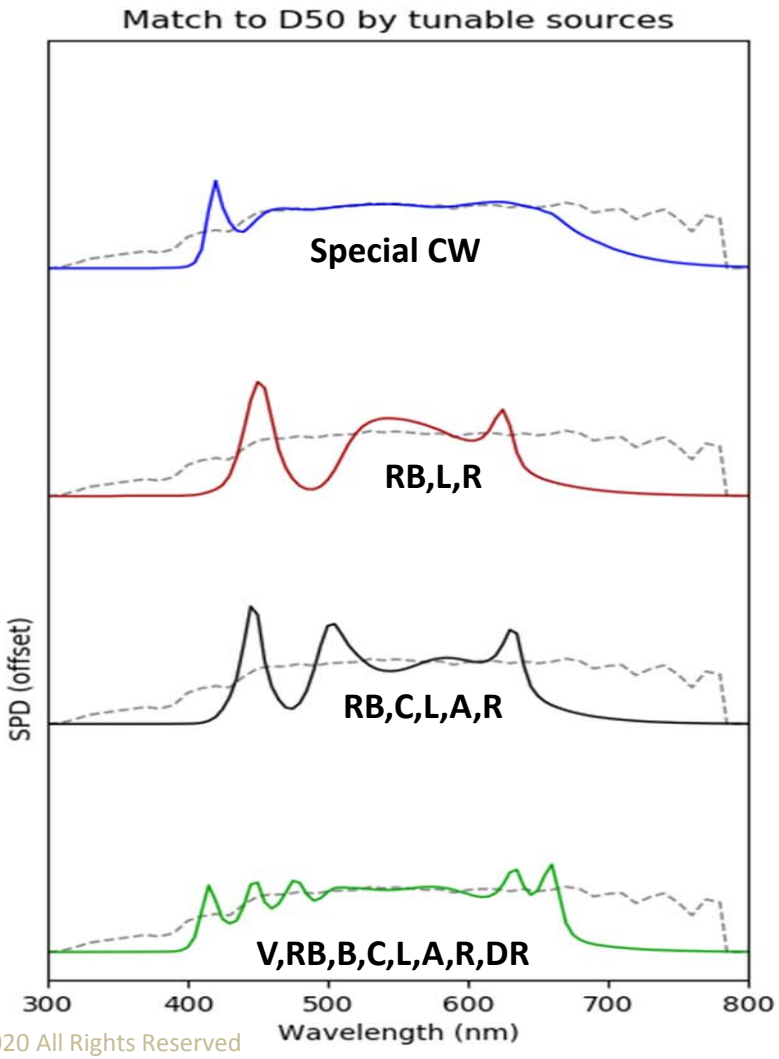

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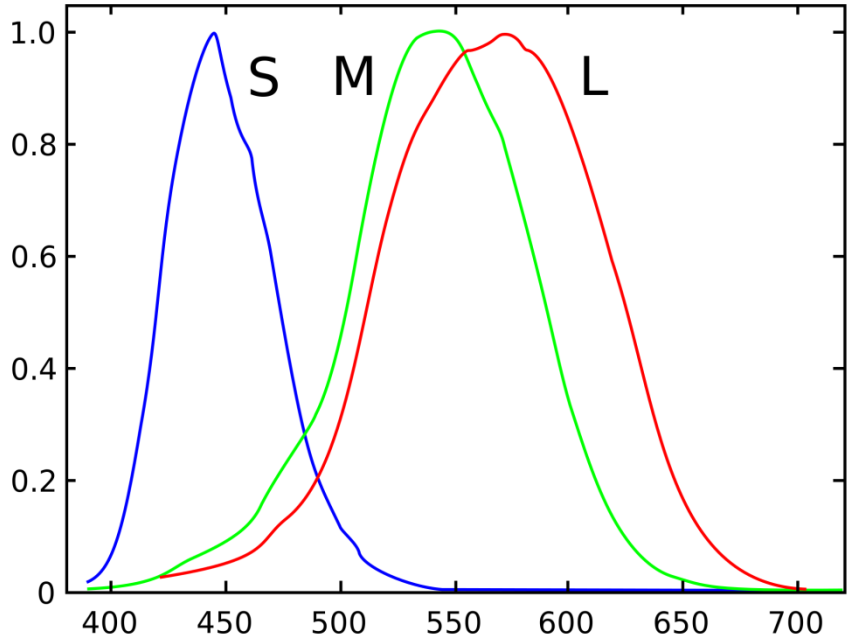
Observers



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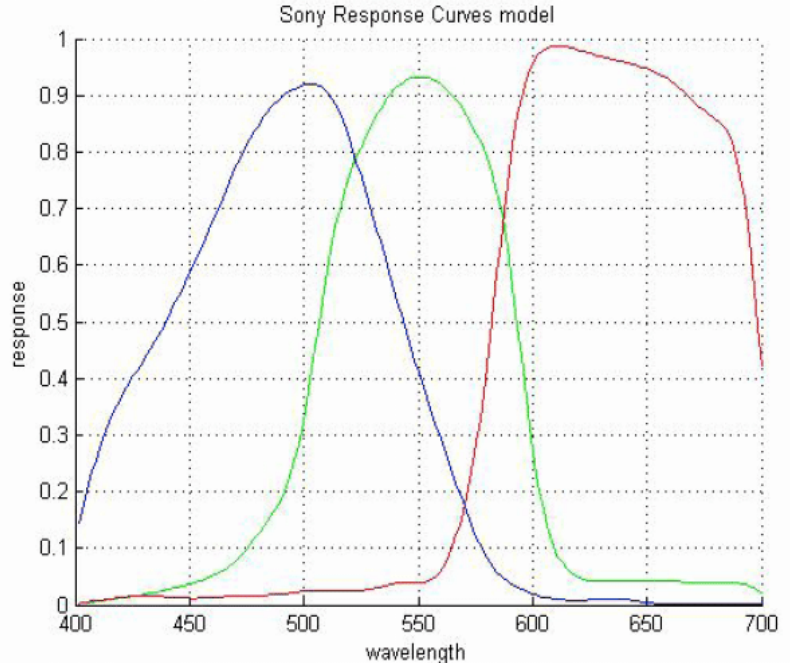

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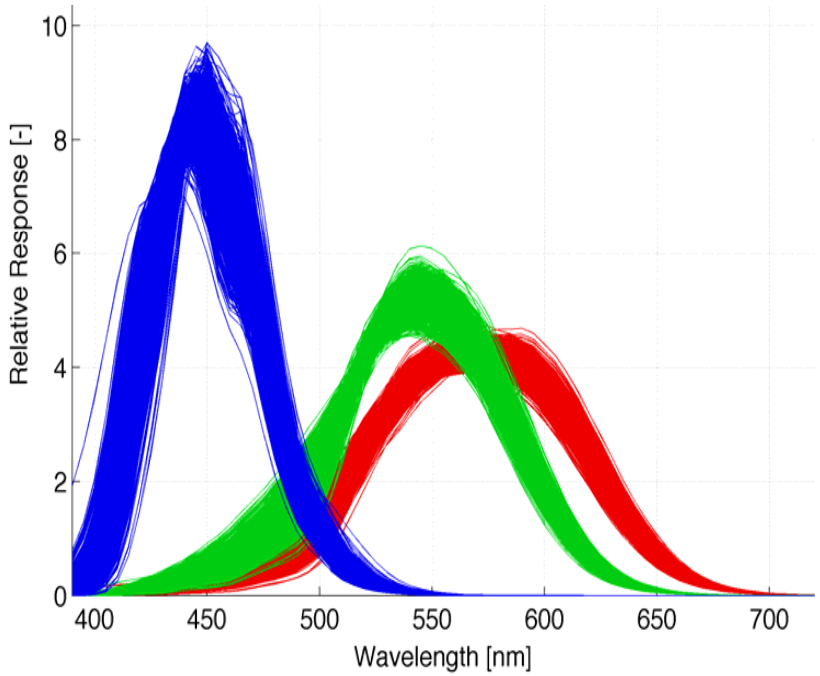
Observers



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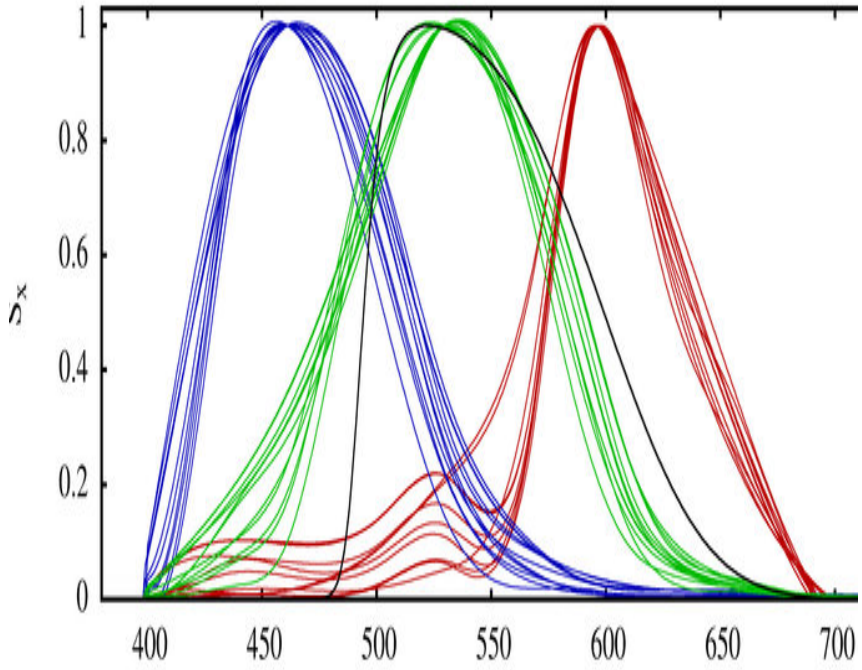

https://www.researchgate.net/figure/Typical-spectral-sensitivity-curves-of-commercial-digital-cameras-with-RGB-bands-The_fig1_342113086

Observers

We have noticed, that if the underlying SPD of two light sources is significantly different, that matching chromaticities may not match for different people.

Some will see white, some a greenish tint, and some a pinkish tint from the same source.

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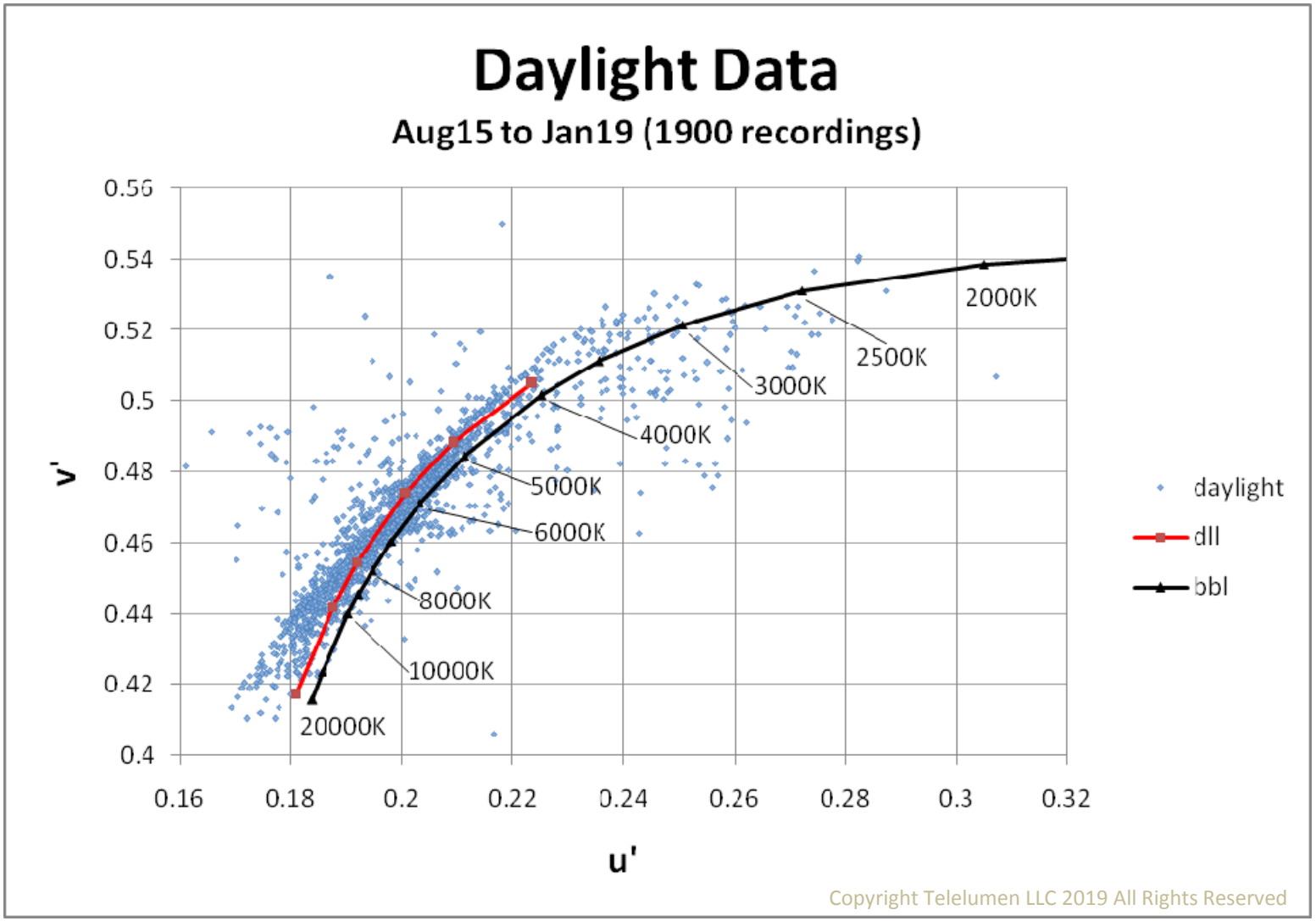

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Recording Locations

Abisko, Sweden	Göteborg, Sweden	Newark airport	Shinagawa, Japan
Akihabara, Japan	Guzhen, China	Newport Beach, CA	Shinjuku, Japan
Banglore, India	Houston airport	Orlando, FL	Singapore
Bolonga, Italy	Irvine, CA	Palo Alto, CA	Sishane, Turkey
Brännö Island, Sweden	Istanbul, Turkey	Panama City	Somerset, PA
Bregenz, Austria	Kingsten, Sweden	Penang, Malaysia	Stockholm, Sweden
Burbank airport	Kuala Lumpur, Malaysia	Point Vicente, CA	Styrsö Island, Sweden
Charlotte, NC	Lapland, Norway	Raleigh-Durham airport	Sunnyvale, CA
Cleveland, OH	Las Vegas, NV	Saltholmen, Sweden	Taipei, Taiwan
Como, Italy	Malpensa airport	San Diego, CA	Taoyuan airport
Dallas, TX	Melbourne, FL	San Jose, CA	Uppsala, Sweden
Deep Creek, MD	Millbrae, CA	Santa Clara, CA	Various airplane windows in flight
Del Garda, Italy	Monterey Bay aqurium, CA	Santa Cruz, CA	Wexford, PA
Delhi, India	Mt. Hamilton, CA	Santa Monica, CA	Wilmington, NC
Denver airport	Munich, Germany	Saratoga, CA	Woodside, CA
Frankfurt, Germany	Narita airport	San Francisco airport	Yokohama, Japan
Gaithersburg, MD	Nashville, TN	San Francisco bay bridge	Yosemite, CA
Garching, Germany	New Market, MD	Shanghai, China	

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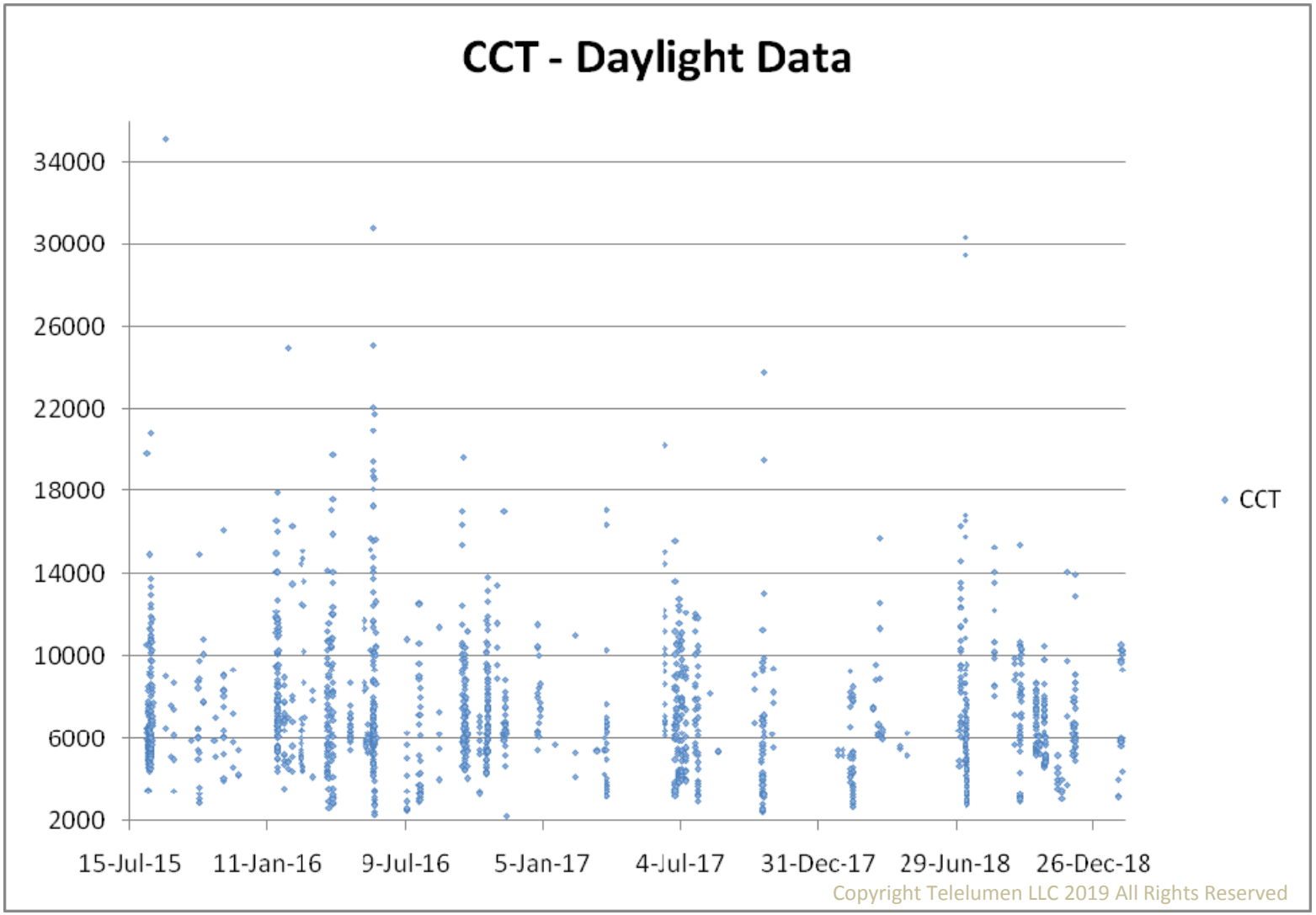

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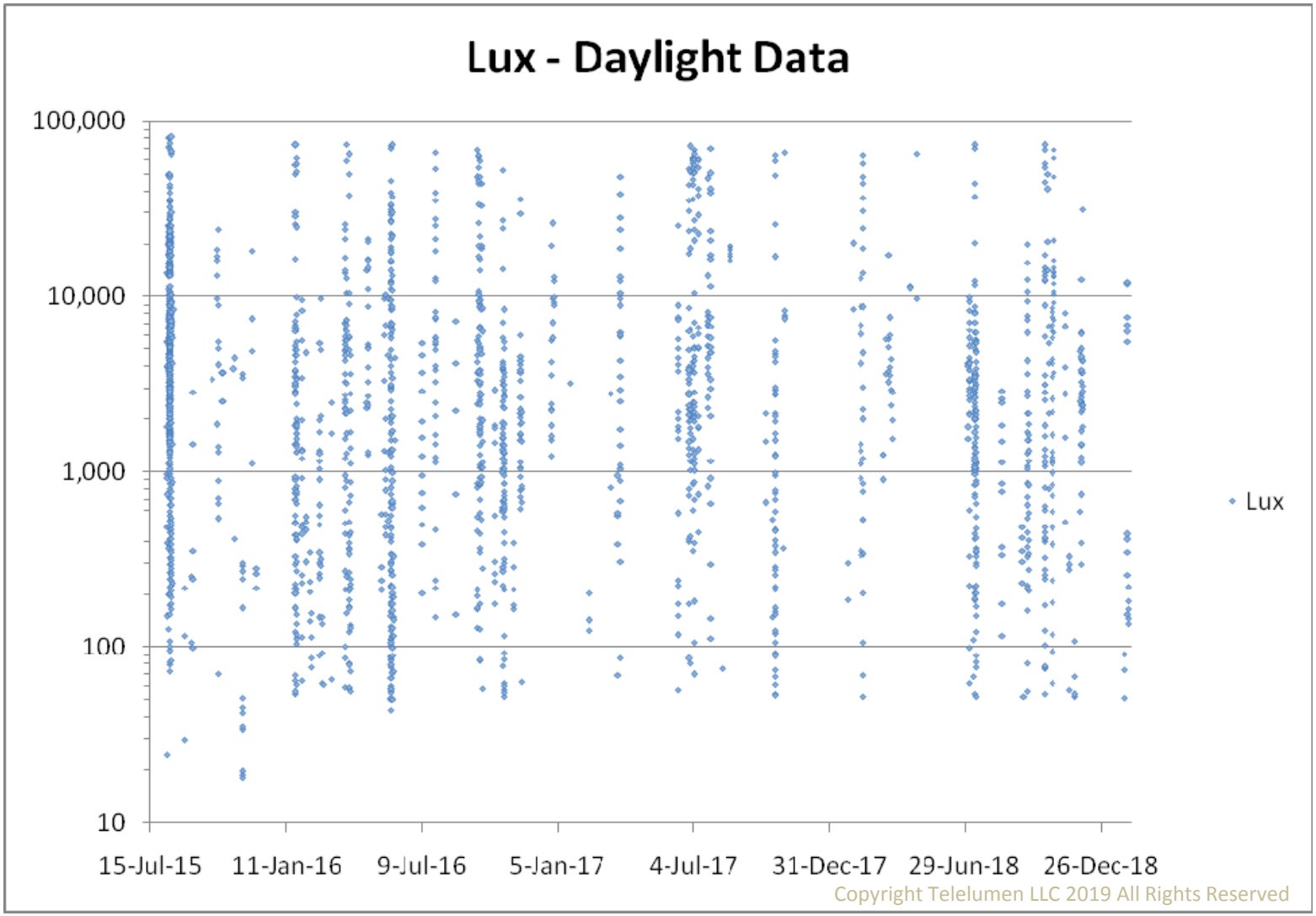

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Como
Bergamo
Milan
Pavia
Turin
Asti
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Parc national des Écrins
Parc national des Cévennes
Parc national du Mercantour
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Genoa
Savona
La Spezia
Nice
Cannes
Marseille
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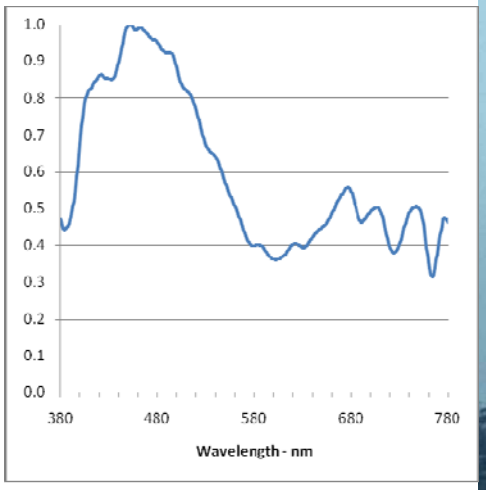
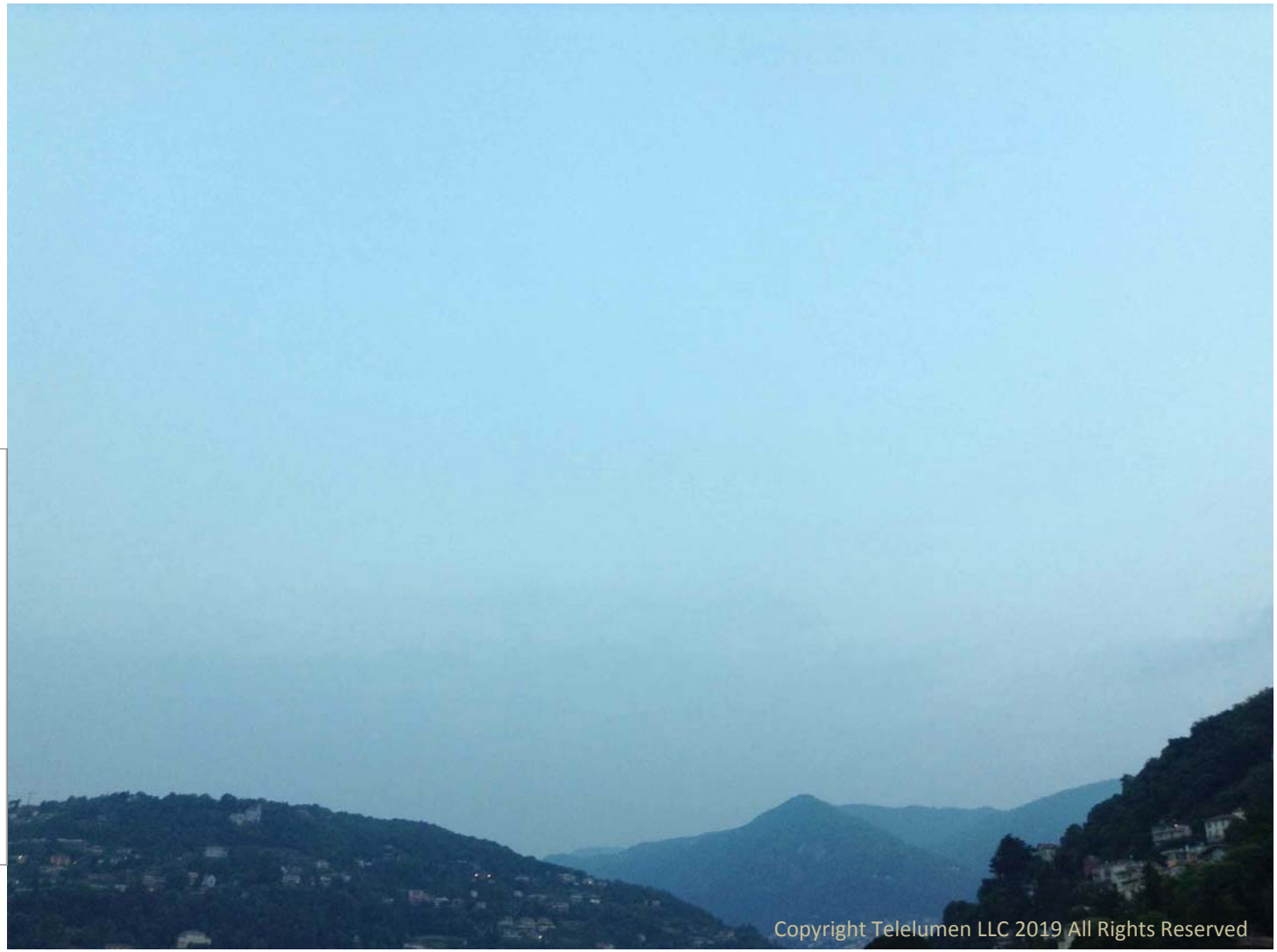
Ascoli Piceno
Terni
Pescara
Chieti
Vasto
Adriatic Sea
Dubrovnik
Kotor
Budva
Rome
Fiumicino
Frosinone
Latina
Foggia
Andria
Bari
Naples
Potenza
Matera
Brindisi
Bastia
Corse
Ajaccio
Porto-Vecchio
Olbia
Sassari
Stintino

Place	Como, Italy
Date	28-May-16
Time	0537
Lux	159
CCT	14292
CRI	93
u	0.176
v	0.431
duv	0.010





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CRI	97
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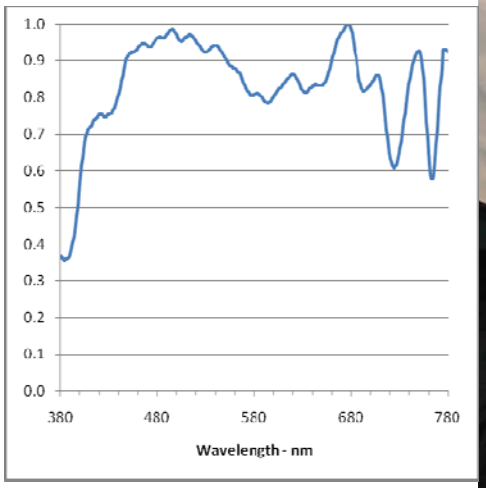
v	0.475
duv	0.003



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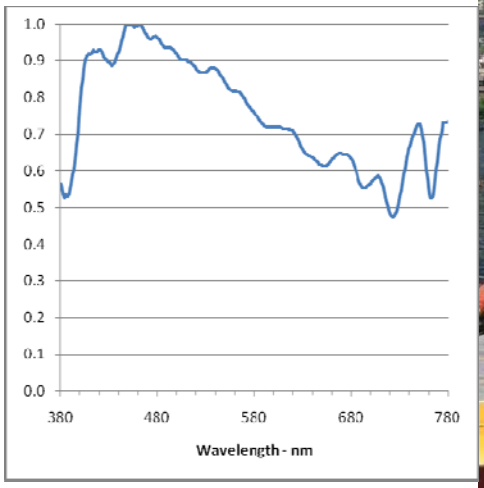

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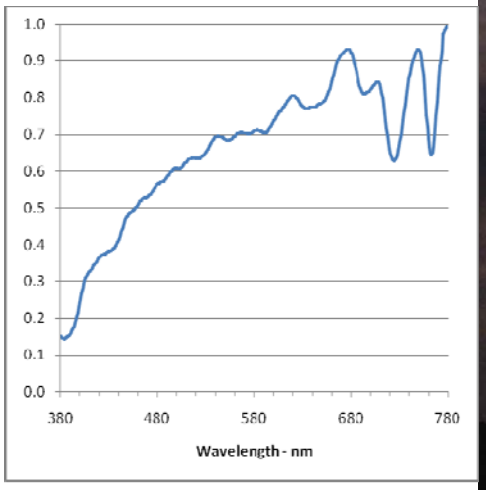

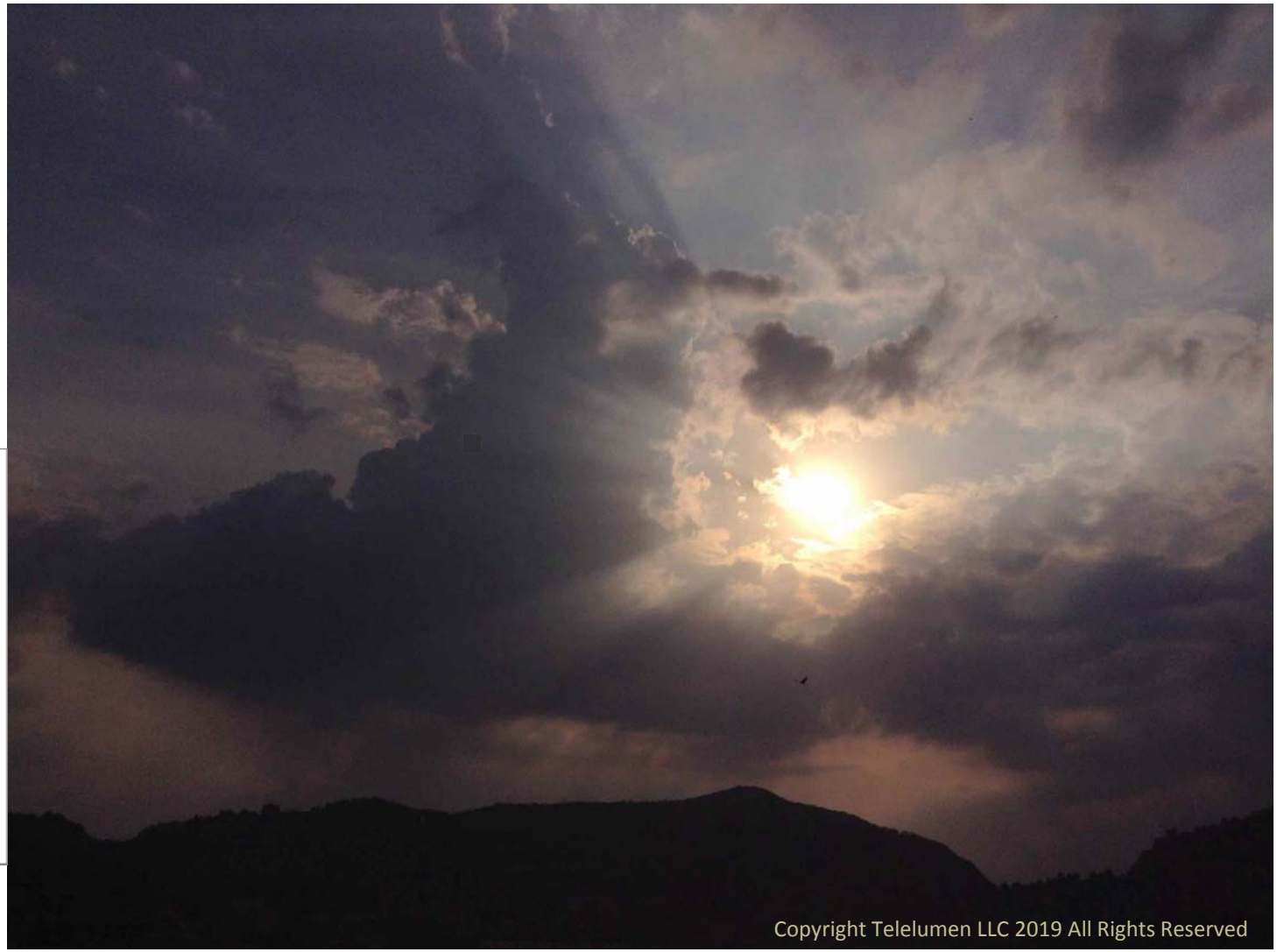

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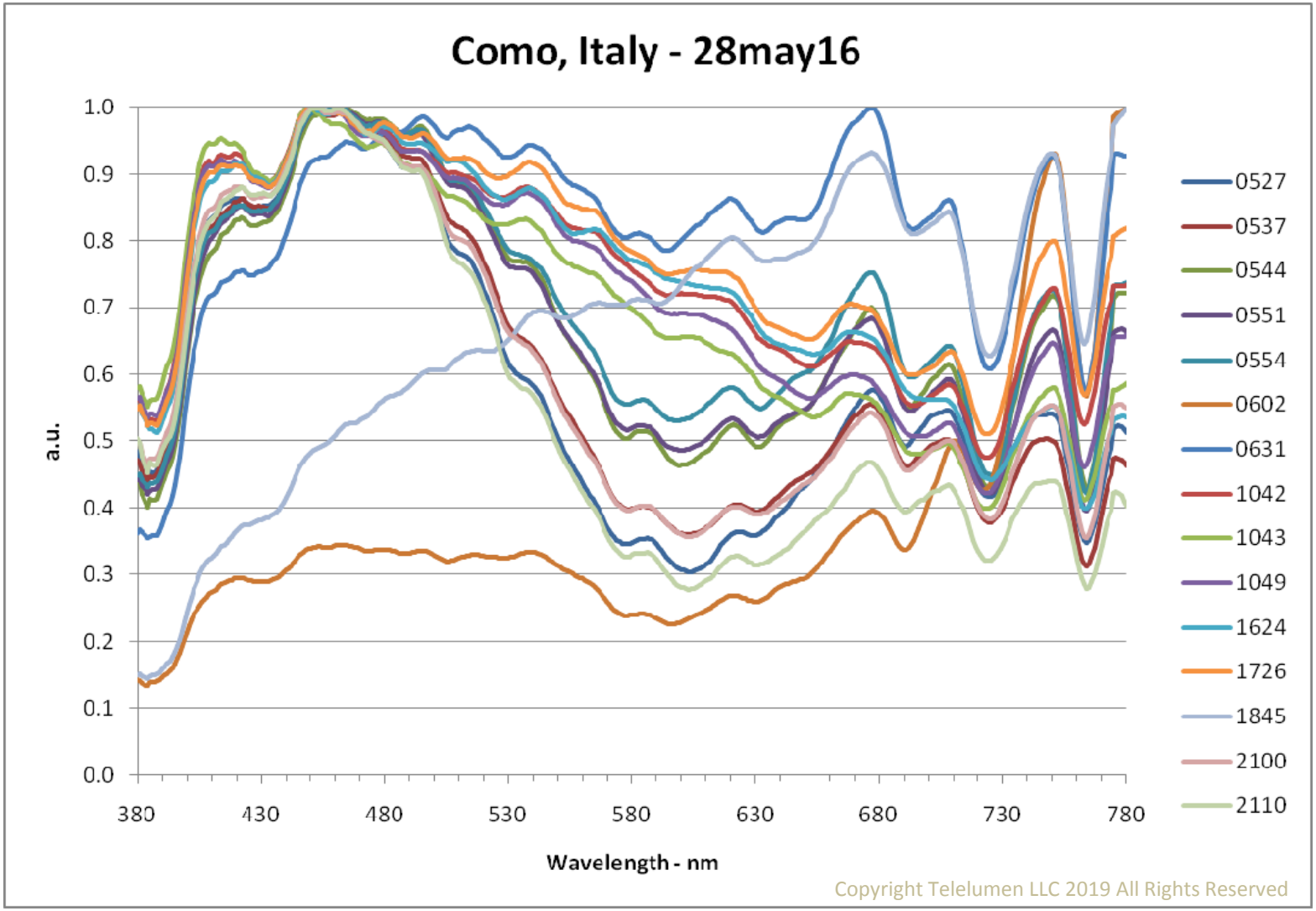

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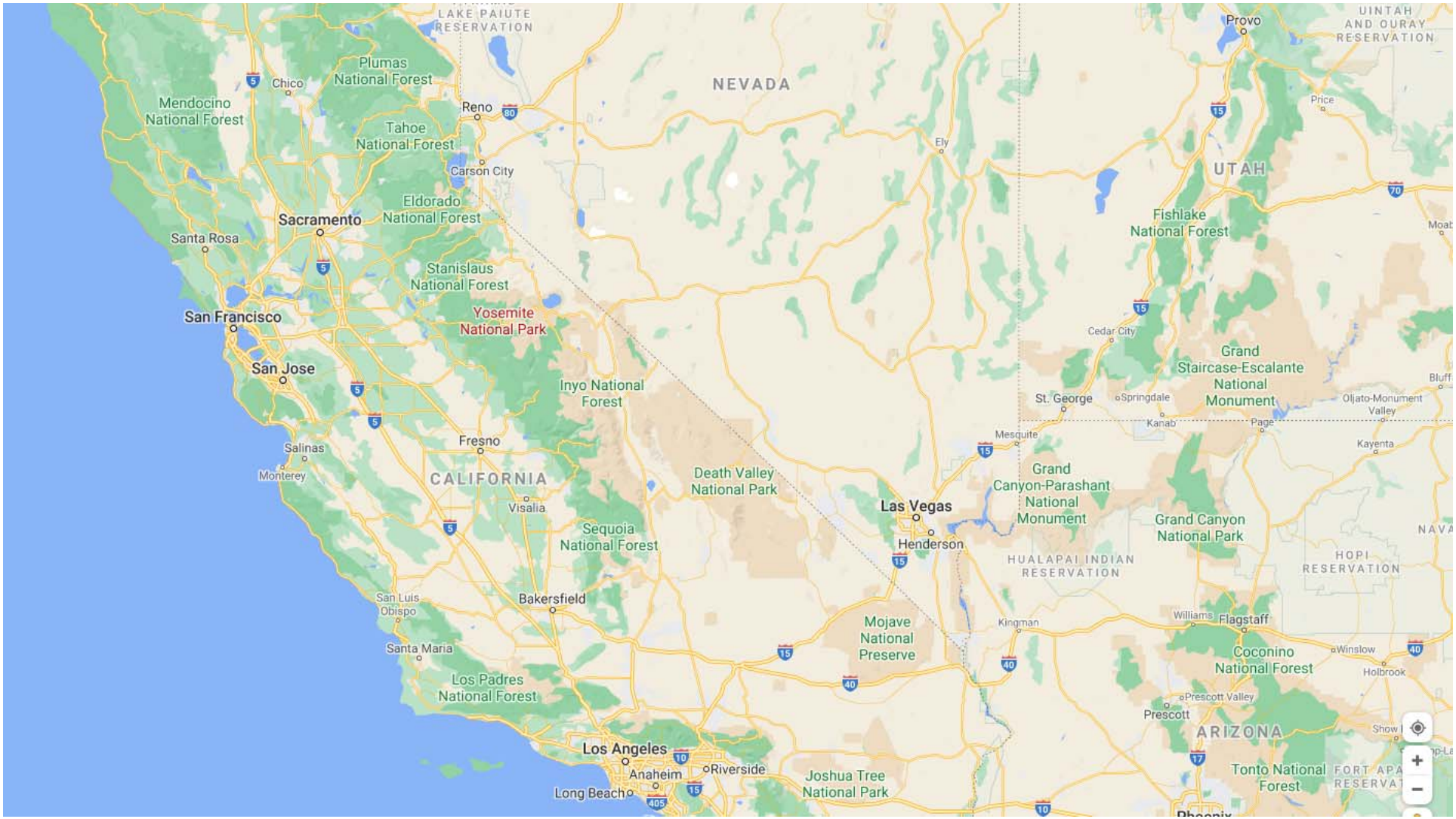
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Eldorado National Forest
Sacramento
Santa Rosa
Stanislaus National Forest
San Francisco
Yosemite National Park
San Jose
Inyo National Forest
Fresno
Salinas
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Visalia
Death Valley National Park
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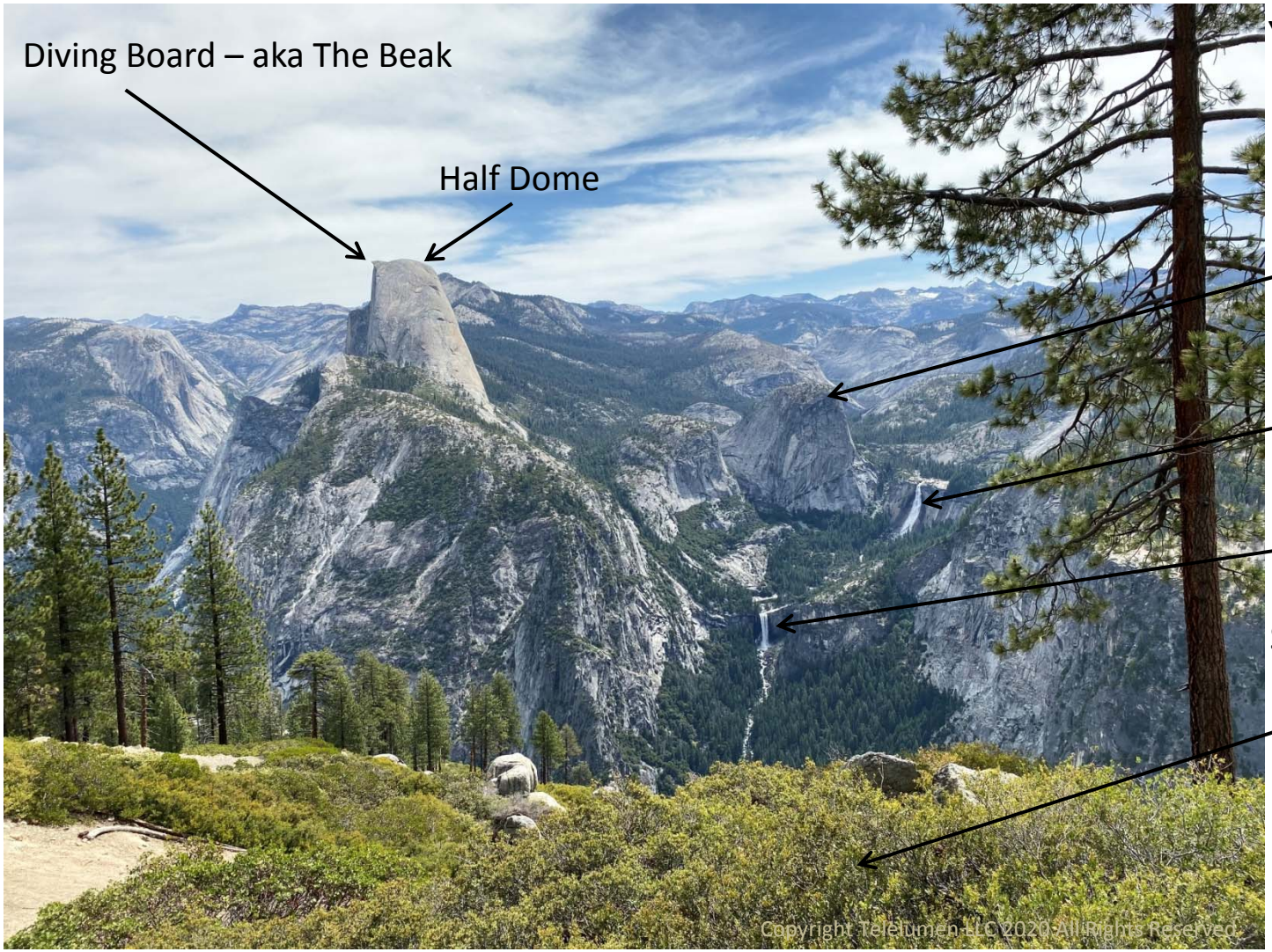

Yosemite National Park,
California
14jun20

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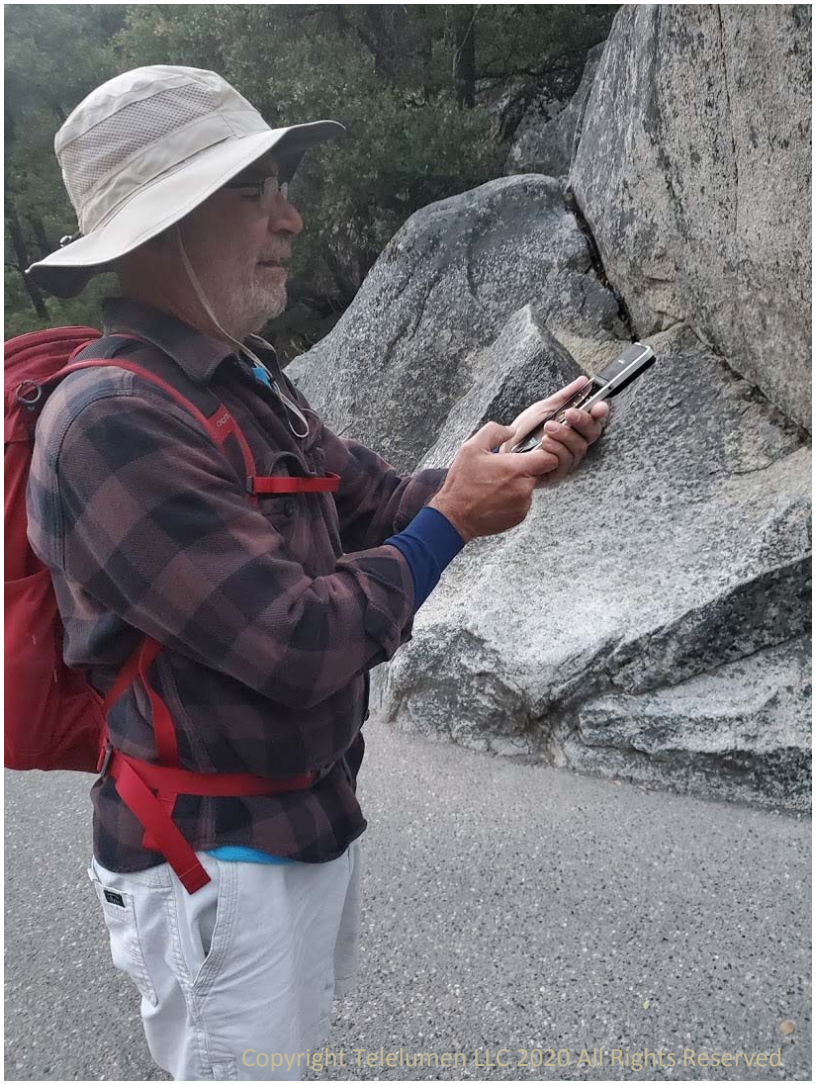
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0526 – Typical recording posture.

Lighting Passport Spectrometer

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0921 – Mighty tall trees.

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0944 – Taking it in.

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1051 – Need to gather courage.

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1054 – Out on the beak.

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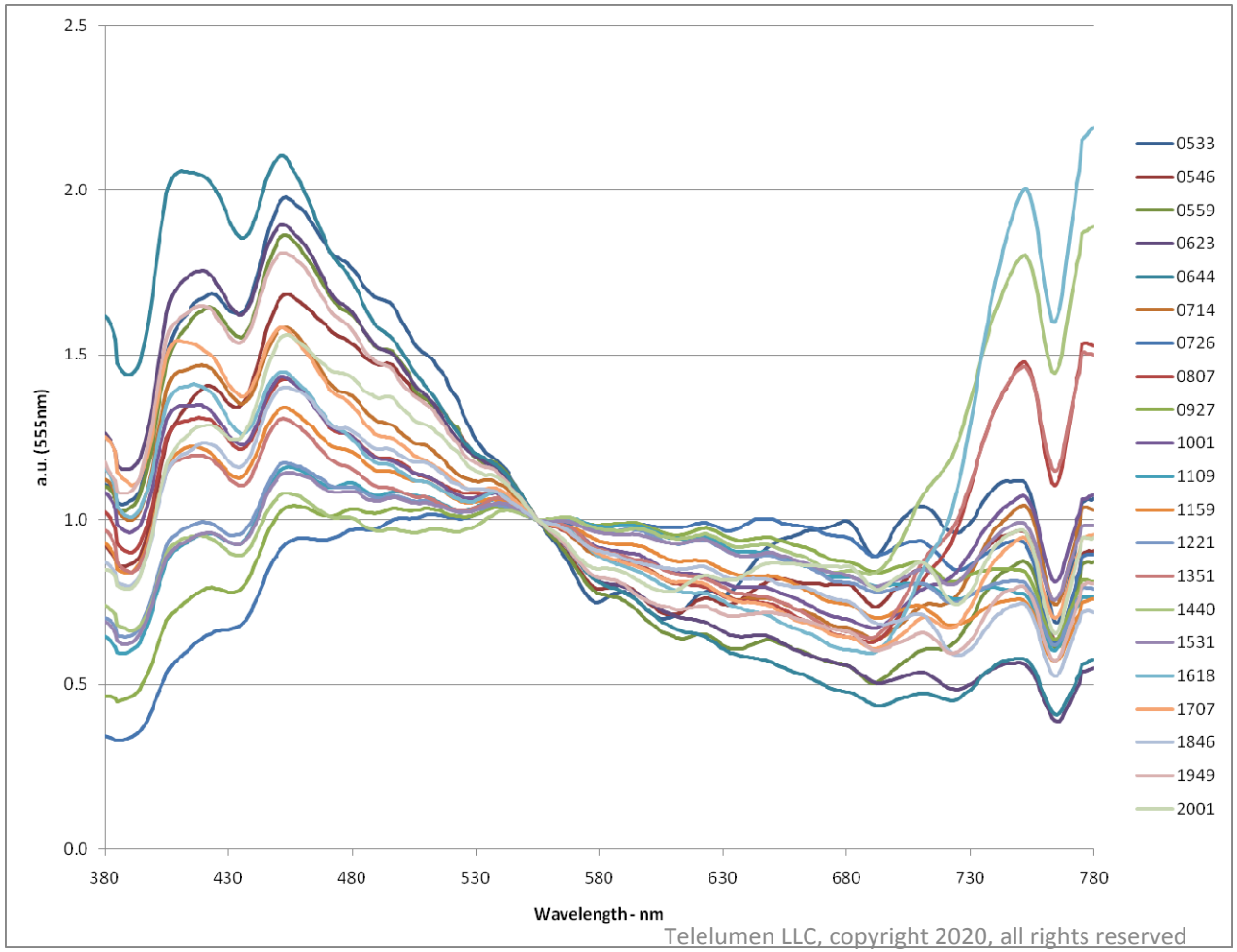
1212 – Light at the top.

Yosemite National Park, Half Dome Hike, 14jun20



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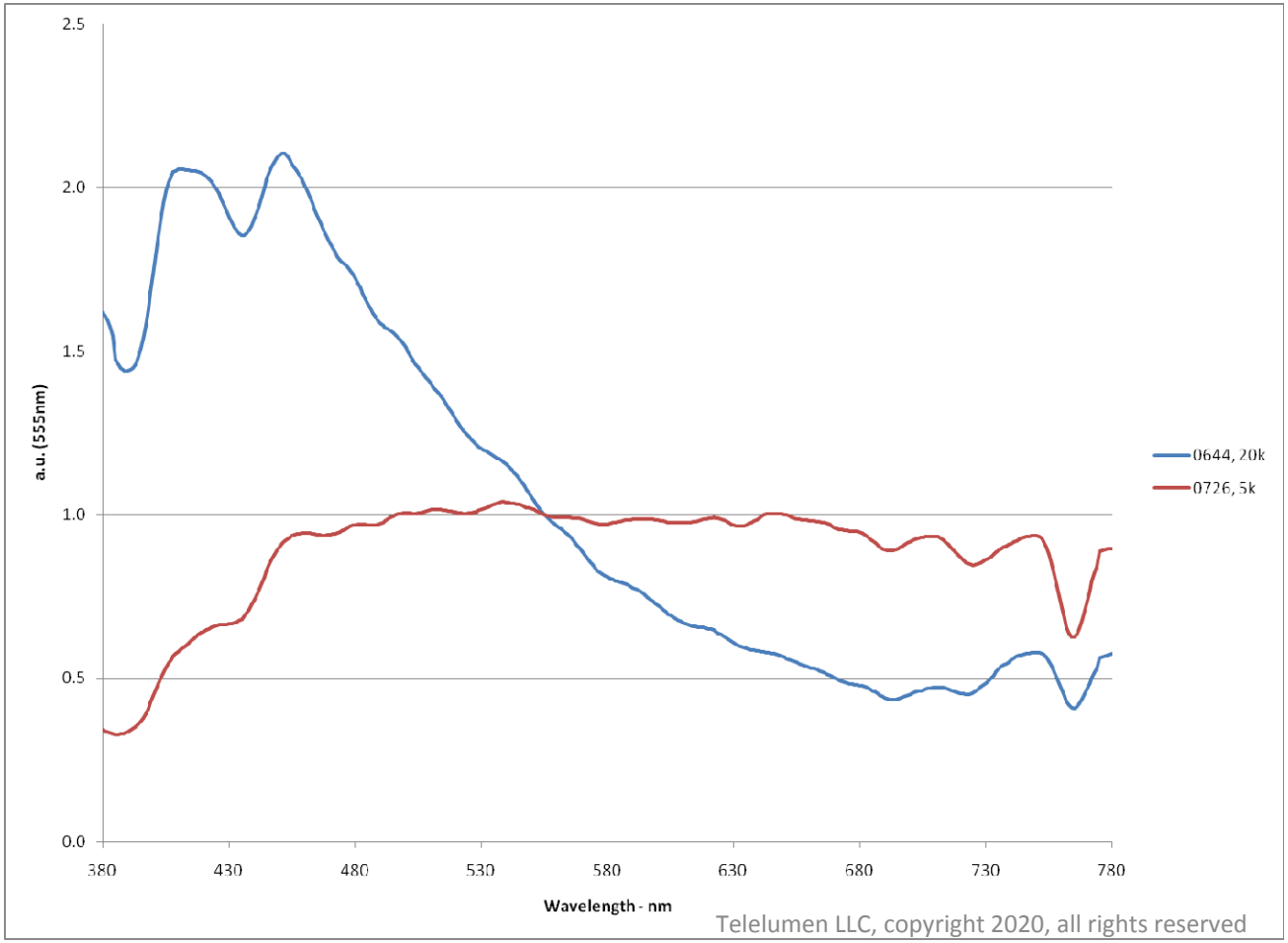
Max, Min CCT – 14jun20



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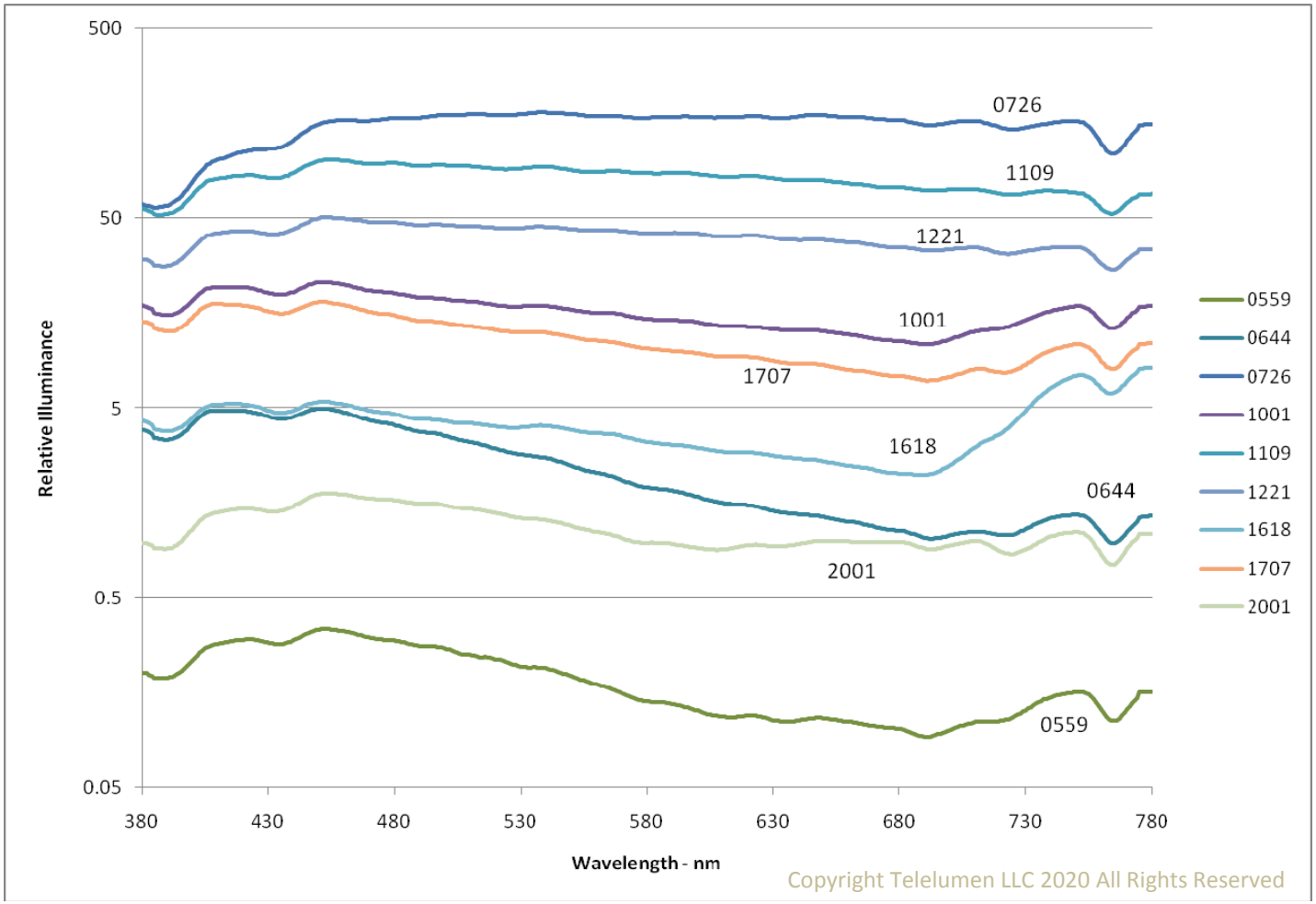
21,600K, 0644

5,100K, 0726

Yosemite National Park, Half Dome Hike, 14jun20



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Time

- Time is fundamental to life
- Time is fundamental to daylight and fire
- Electronic illumination systems need a time base

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Day of sunlight

- Illuminance sensor pointed up at a mostly blue sky in Saratoga, California
- Starts: 28JUN18 at 05:48
  Ends: 28JUN18 at 20:48
- Lux range in actual recording: 10,000:1
- Color temperature range: 5,700K to 70,000K

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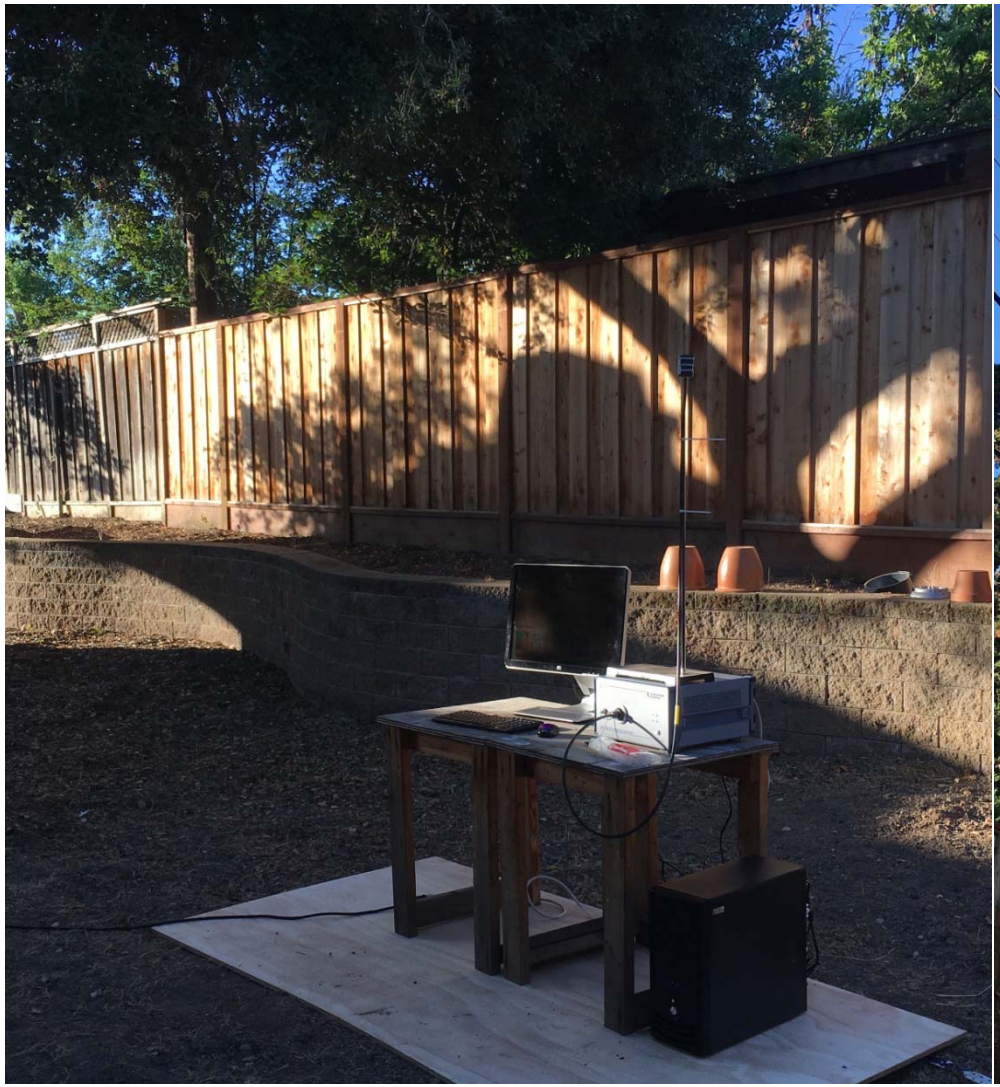

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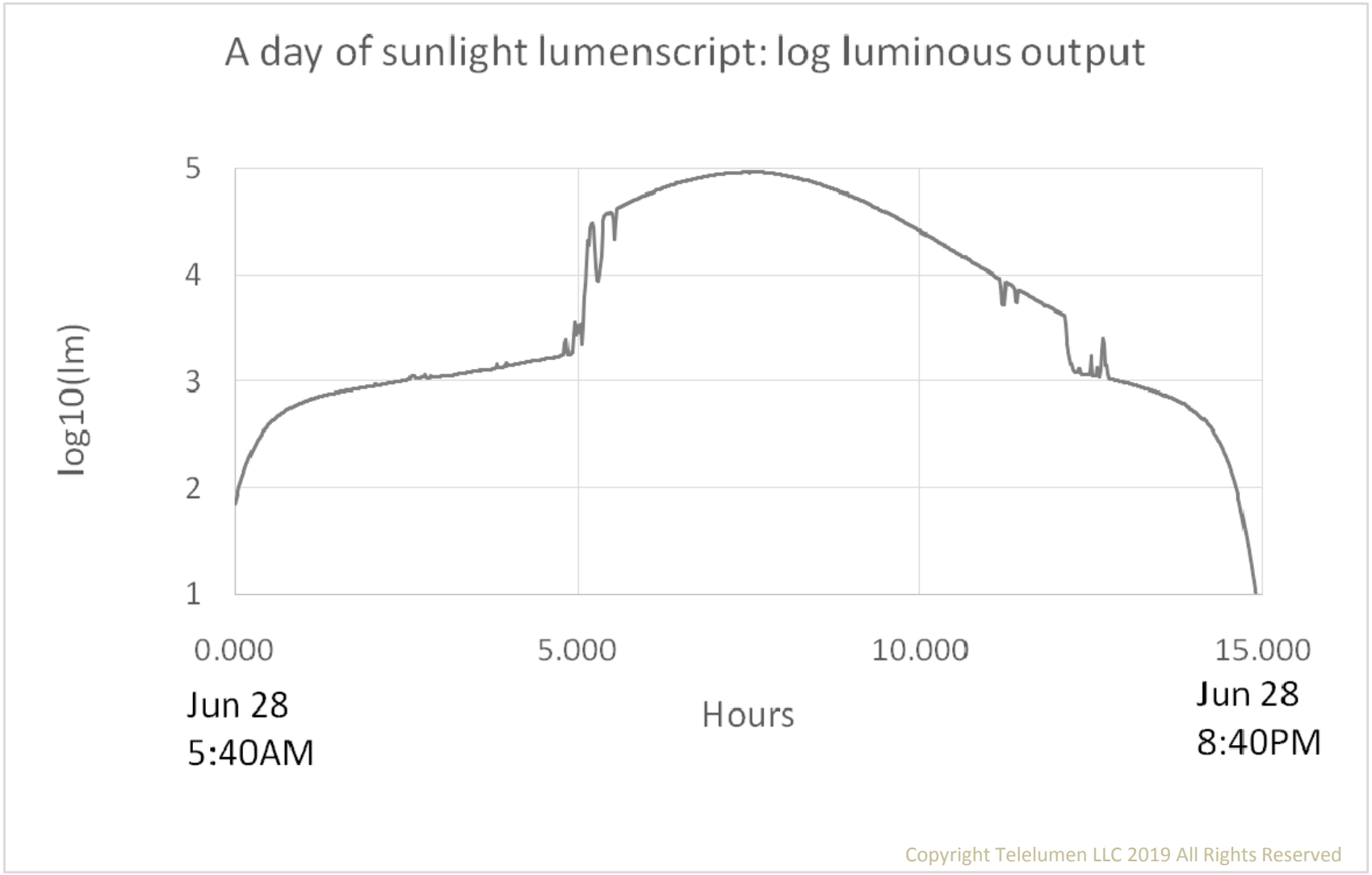

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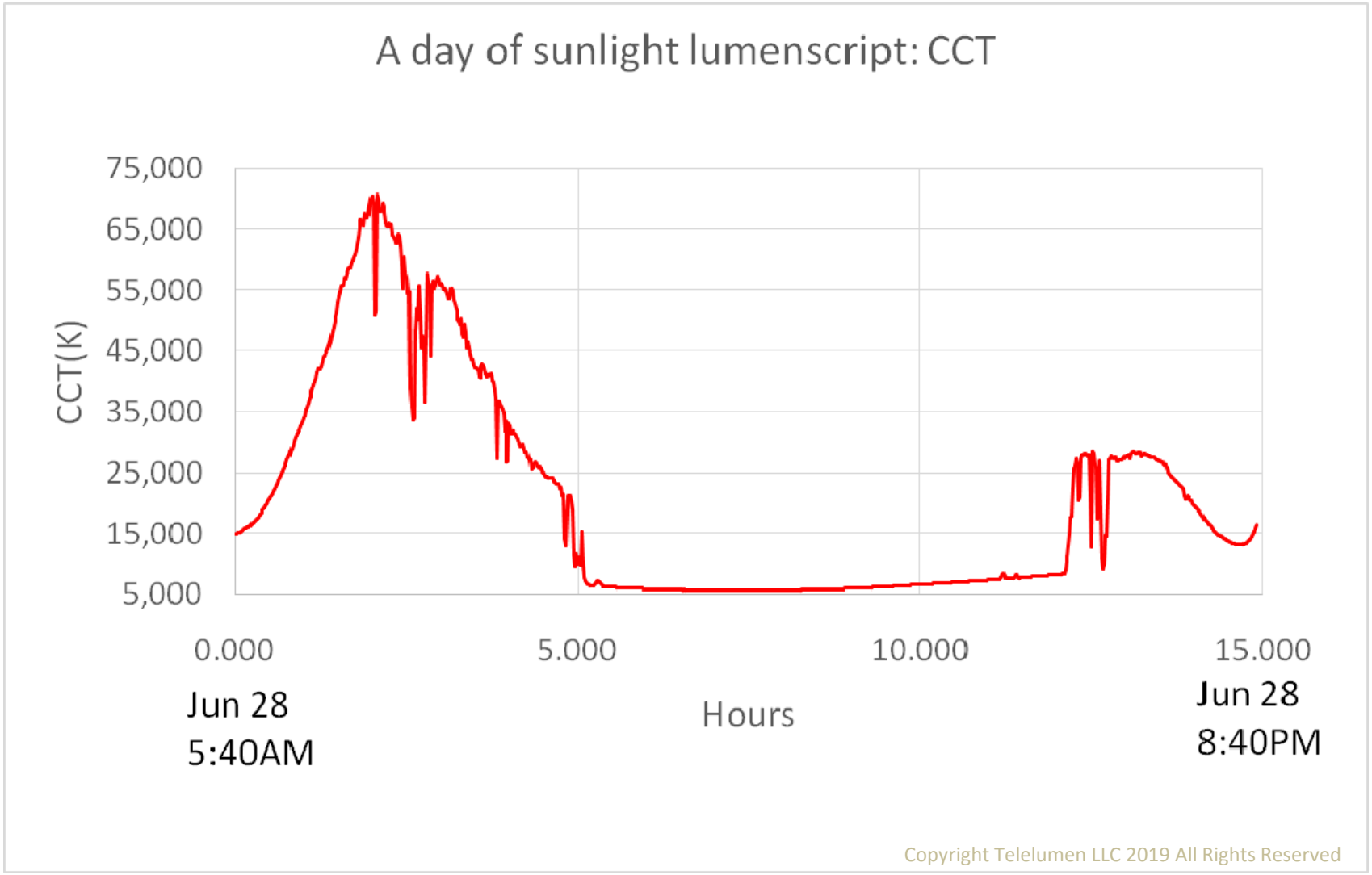

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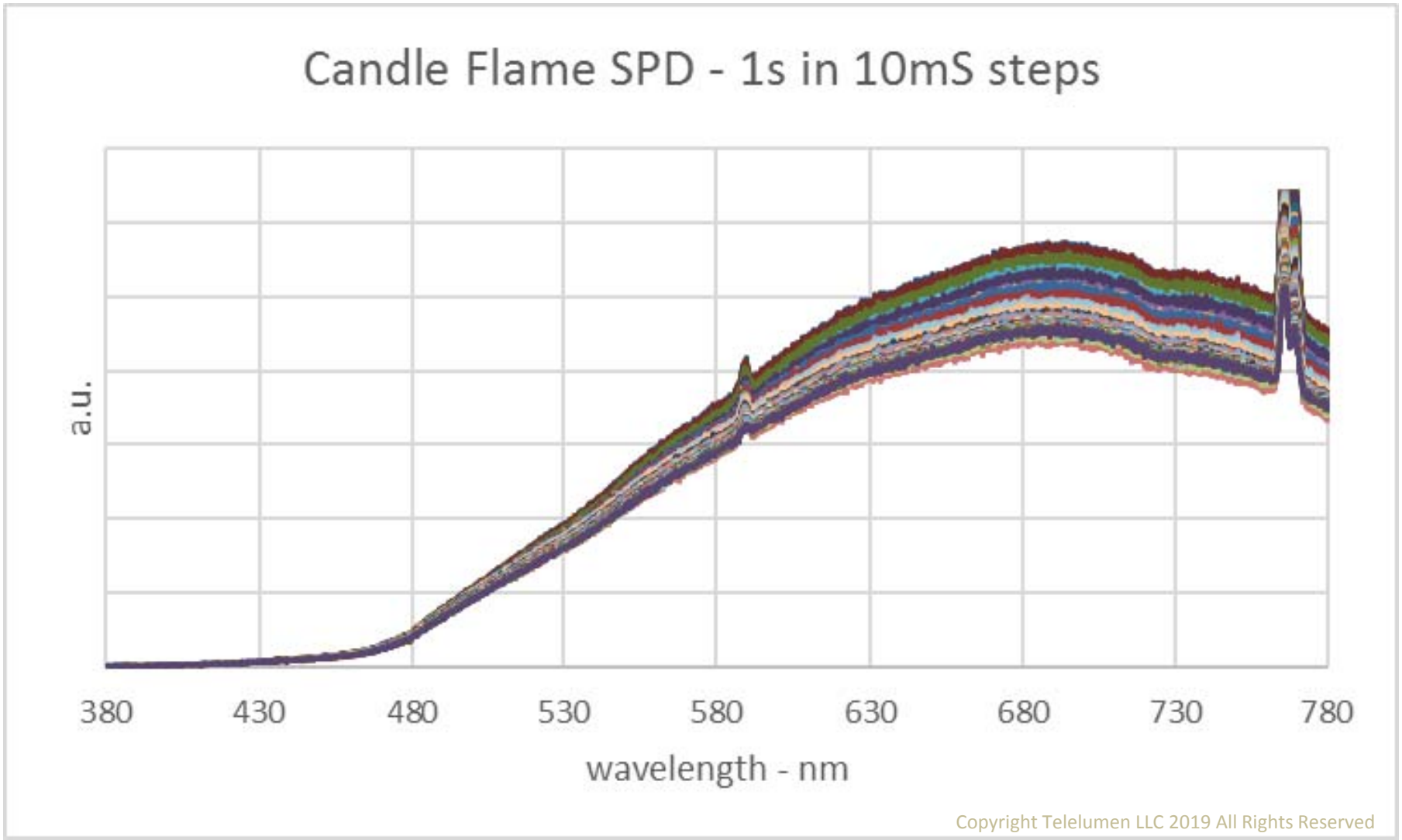

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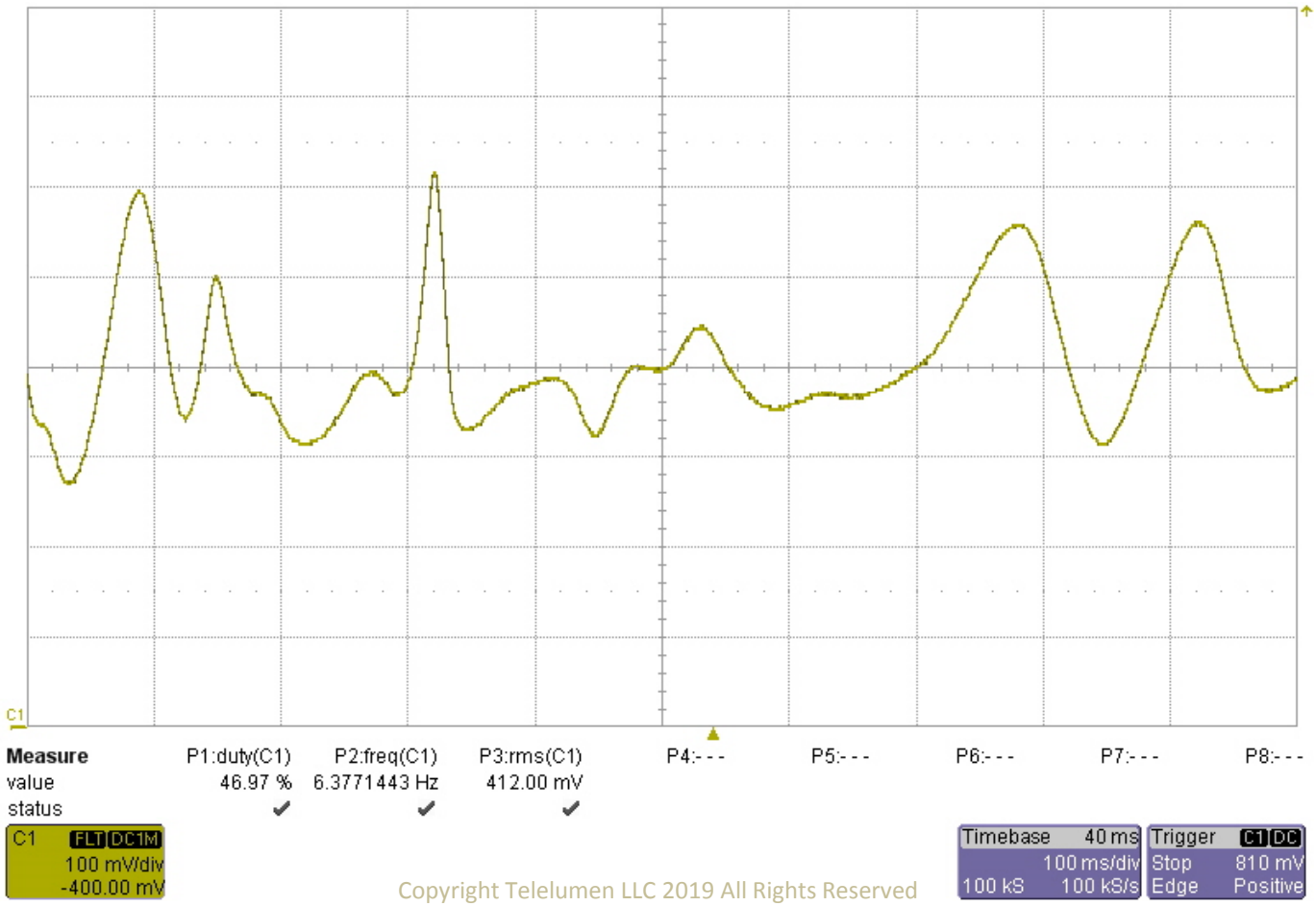
Candle Flame from Photometer – 1 sec



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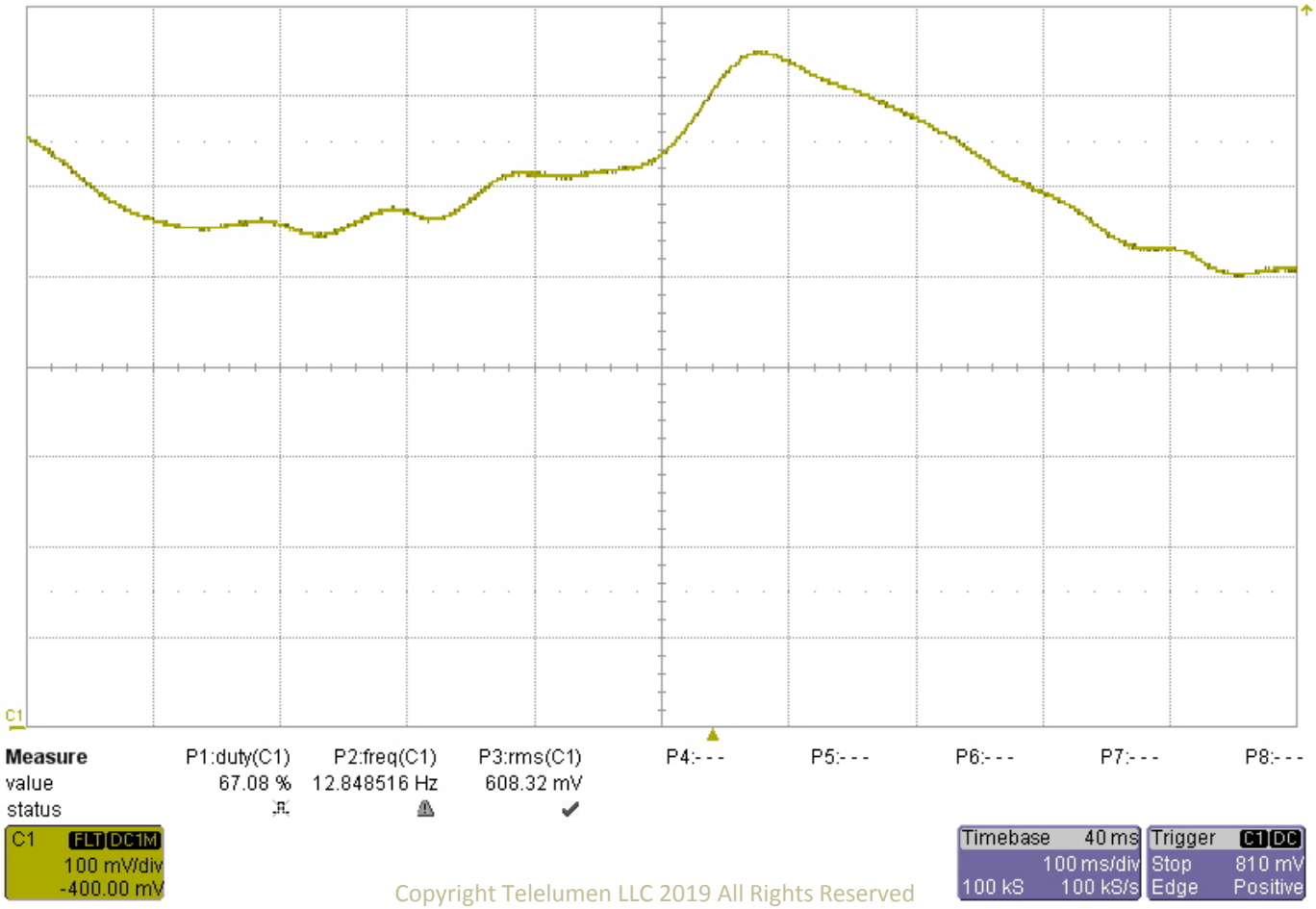
Candle Flame from Photometer – 1 sec



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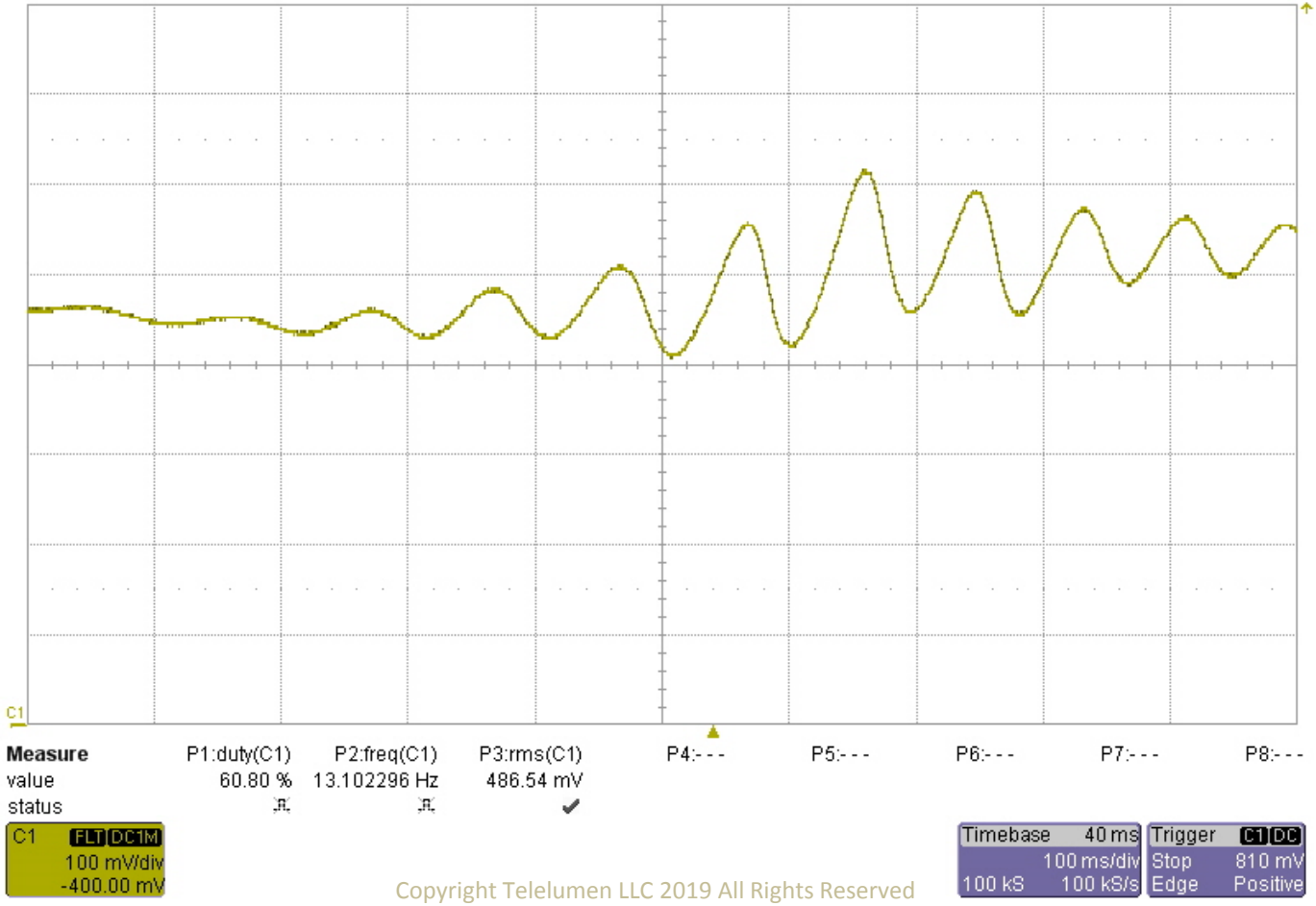
Candle Flame from Photometer – 1 sec



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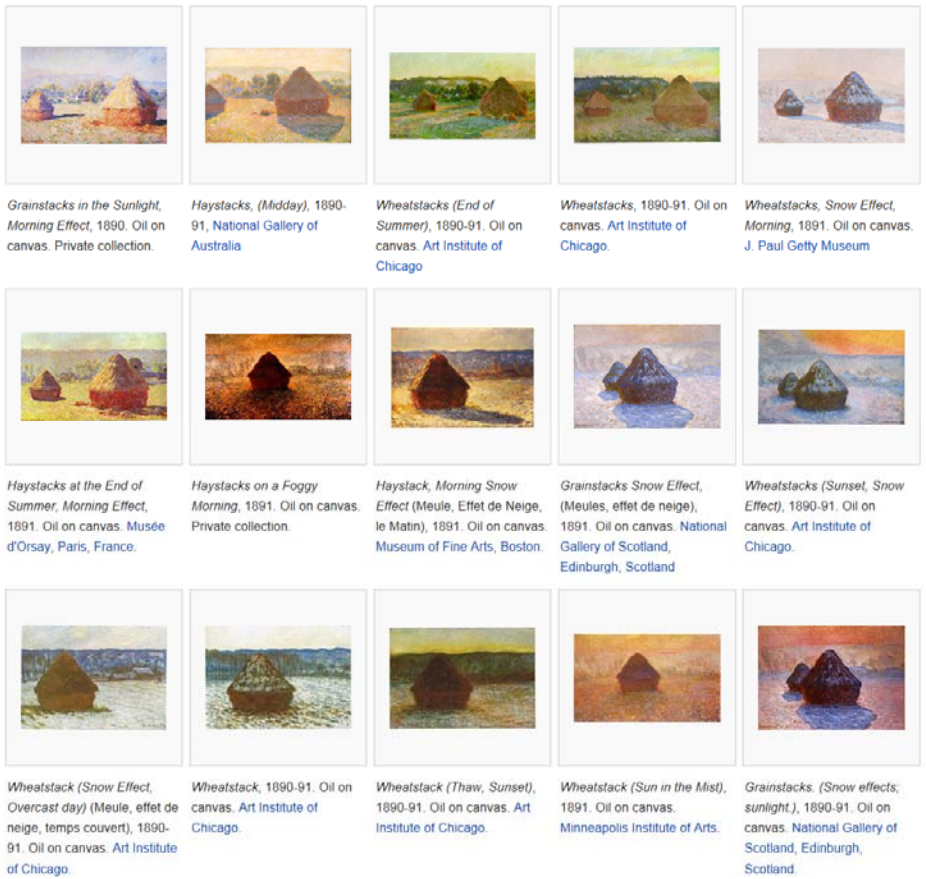
Claude Monet – “Haystacks”

The series shows differences in perception of light across various times of day, seasons, and types of weather.

http://en.wikipedia.org/wiki/Haystacks_(Monet)

1890-1891 series [edit]



Grainstacks in the Sunlight, Morning Effect, 1890. Oil on canvas. Private collection.

Haystacks, (Midday), 1890-91, National Gallery of Australia

Wheatstacks (End of Summer), 1890-91. Oil on canvas. Art Institute of Chicago

Wheatstacks, 1890-91. Oil on canvas. Art Institute of Chicago.

Wheatstacks, Snow Effect, Morning, 1891. Oil on canvas. J. Paul Getty Museum

Haystacks at the End of Summer, Morning Effect, 1891. Oil on canvas. Musée d'Orsay, Paris, France.

Haystacks on a Foggy Morning, 1891. Oil on canvas. Private collection.

Haystack, Morning Snow Effect (Meule, Effet de Neige, le Matin), 1891. Oil on canvas. Museum of Fine Arts, Boston.

Grainstacks Snow Effect, (Meules, effet de neige), 1891. Oil on canvas. National Gallery of Scotland, Edinburgh, Scotland

Wheatstacks (Sunset, Snow Effect), 1890-91. Oil on canvas. Art Institute of Chicago.

Wheatstack (Snow Effect, Overcast day) (Meule, effet de neige, temps couvert), 1890-91. Oil on canvas. Art Institute of Chicago.

Wheatstack, 1890-91. Oil on canvas. Art Institute of Chicago.

Wheatstack (Thaw, Sunset), 1890-91. Oil on canvas. Art Institute of Chicago.

Wheatstack (Sun in the Mist), 1891. Oil on canvas. Minneapolis Institute of Arts.

Grainstacks. (Snow effects; sunlight.), 1890-91. Oil on canvas. National Gallery of Scotland, Edinburgh, Scotland.

Controls

- Physical wall switch, slider dimmer (reference control)
  - Intuitive, instant-on
- In general – non-intuitive, slow, proprietary
  - avoided, disabled, frustrated

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Controls

- Problems are magnified with tunable systems
- In general we are asking to much from the customer
  - It's like having to create your own music and movies
- A few pre-programmed choices is one solution
- Player model is another solution
  - channel change and volume control

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A Path Forward

- Move beyond photometrics
  - Not sufficient to define daylight
- Move outside the built environment
  - Detachable power, batteries
- Use the entire visible spectrum
  - use efficiency vs. efficacy
- Adopt a time base (frames per second)
- Facilitate illumination content creation by artists

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Summary

- CCT, color, and spectrum control are fundamentally different
- The number independent color channels and the wavelength range matter
- Most objects have a continuous reflectance spectrum
- Light sources with wide continuous spectrum tend to be better
- Daylight is complex – wide continuous spectrum changes continuously
- Daylight CCTs are much higher than typical electric lights but include deep red
- Photometrics are not sufficient to capture the daylight experience
- Consider the player model for spectrally tunable controls
- There's a solution for every budget. Check the box or walk the talk.

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Thank You

steve@telelumen.com