



July 27, 2017 | Newport Beach, CA | Newport Beach Marriott

What is Daylight and How Can it be Reproduced Electronically?

Steve Paolini

Teledumen, President

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Agenda

- Introduction
- What is Human Centric Lighting?
- Daylight Data
- Electronic Illumination
- 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 – firmware development
- Color quality – metrics, studies
- Movie, TV – outdoor scene and filter replication

What is Human Centric Lighting?

- Depends who you ask.
- A fundamental aspect is the daylight experience.
- Daylight is complex. The SPD changes with:
 - time of day
 - the weather
 - time of year
 - place on earth
 - your immediate environment – window, sidewalk, park, ...
- Chromaticity is typically not on the black body or daylight locus and does not define SPD.

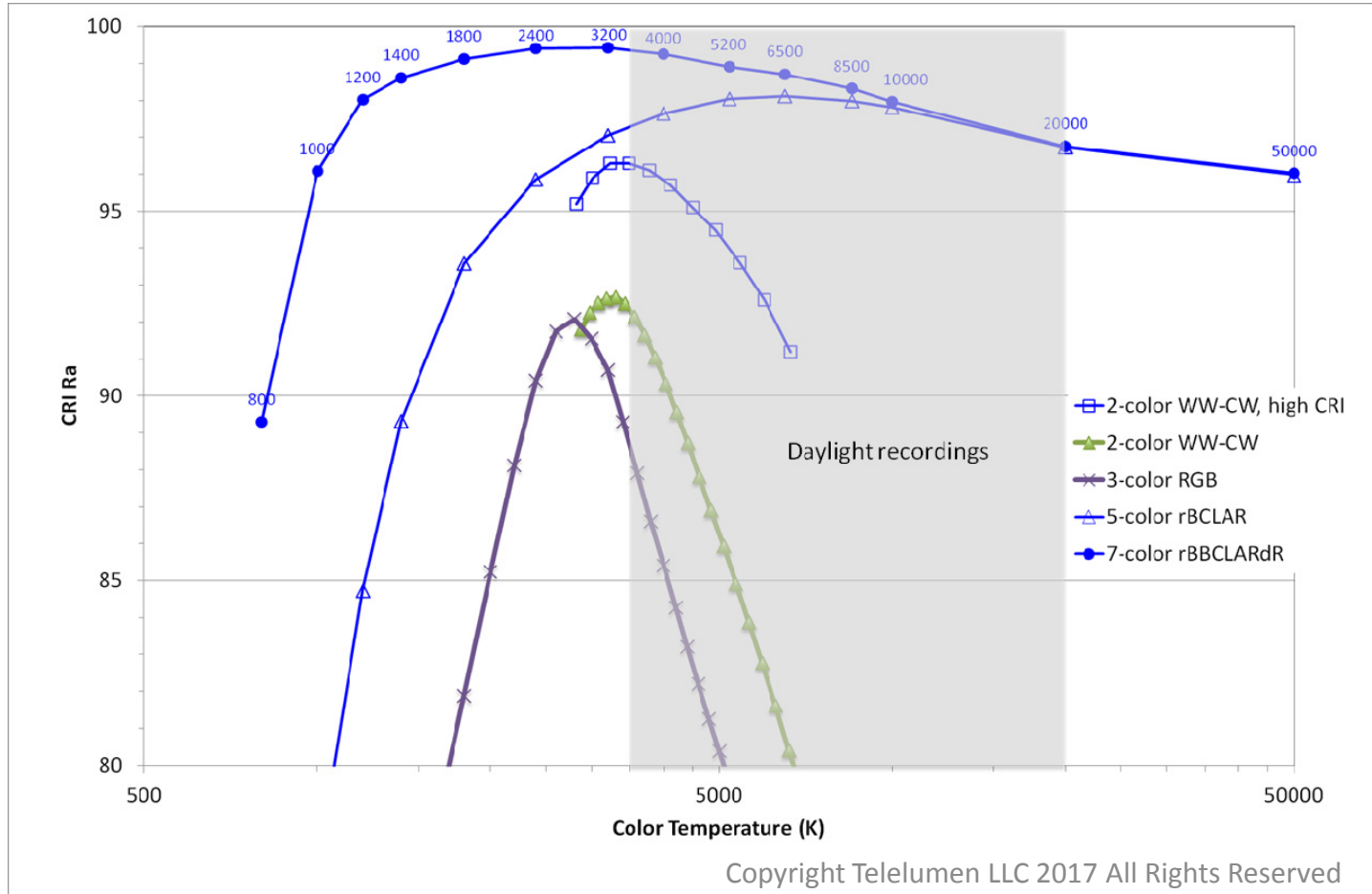
With so many variables, what can be done?

- Record daylight with a spectrometer in many situations.
- Use the recordings as references to produce time varying scripts that replicate the spectral characteristics and timing of actual daylight.
- Playback the scripts on time-based spectrally tunable luminaires.
- Many such scripts are useful because of the wide variety of daylight.

Why go beyond WW-CW and RGB

- Broader CCT range at higher color quality
- Multiple solutions for a given chromaticity
- Larger gamut area

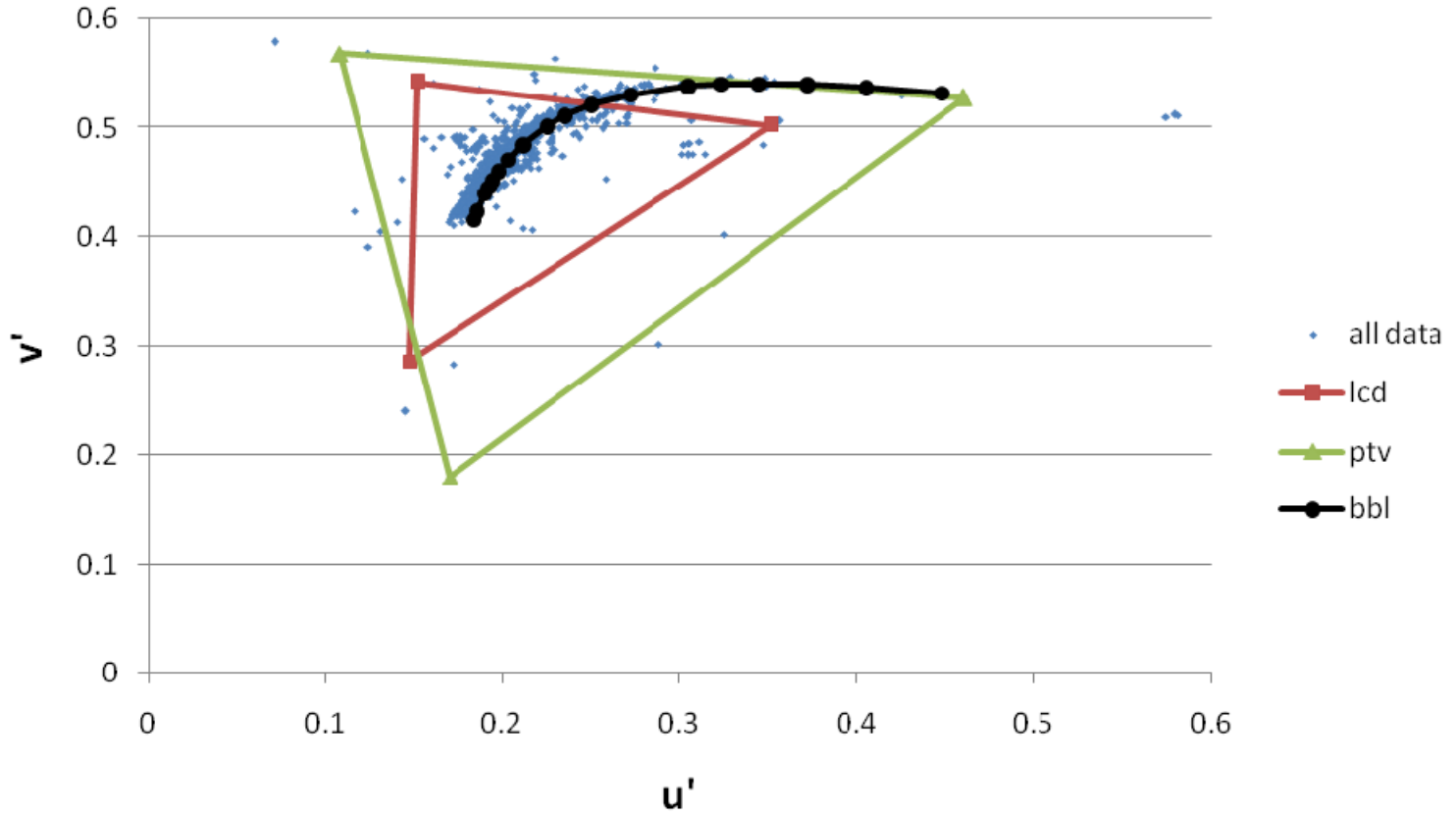
Broader CCT Range and Higher Color Quality



Daylight Data

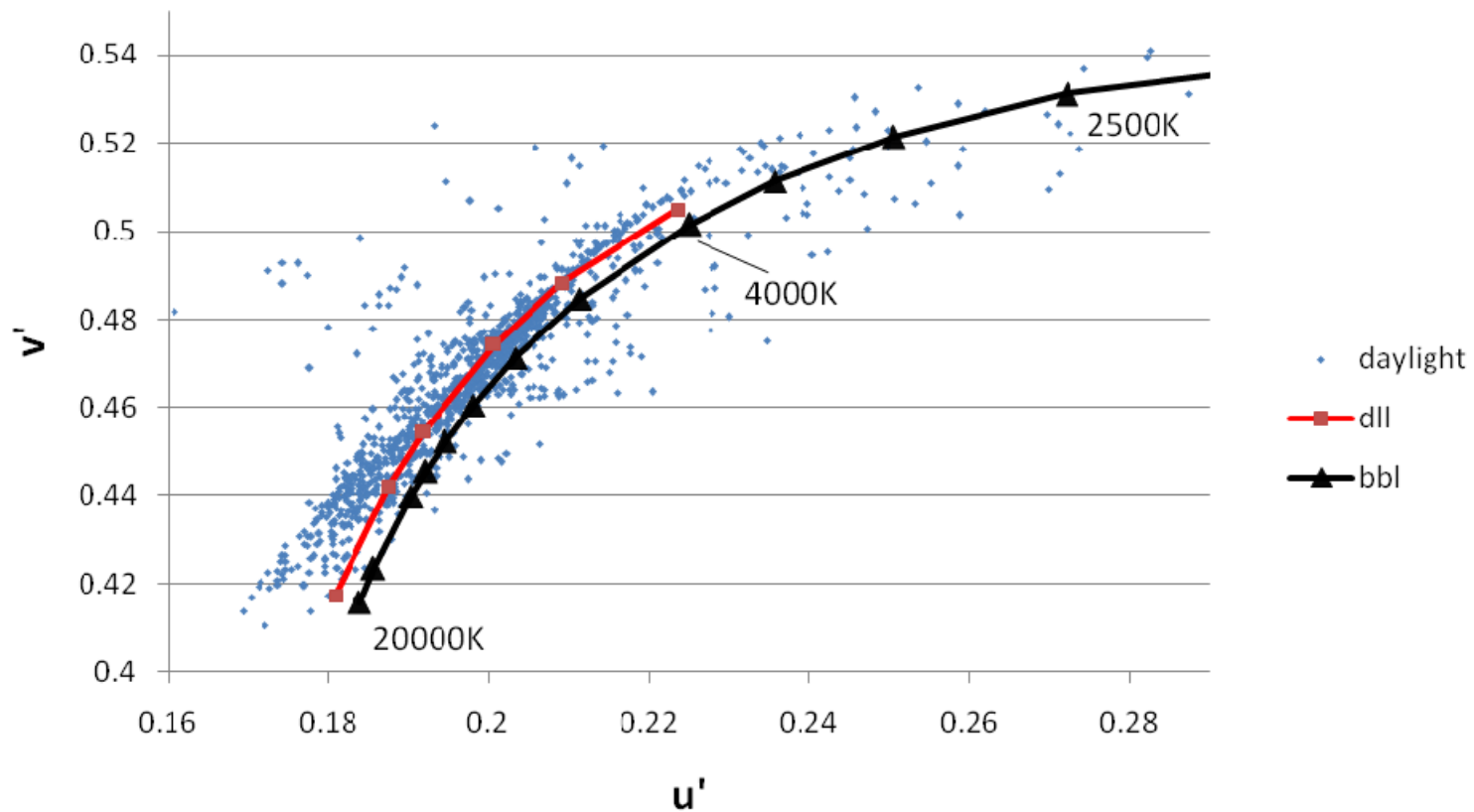
All Data

Aug15 to Jul17 (1600 recordings)



Daylight Data

Aug15 to Jul17 (1400 recordings)

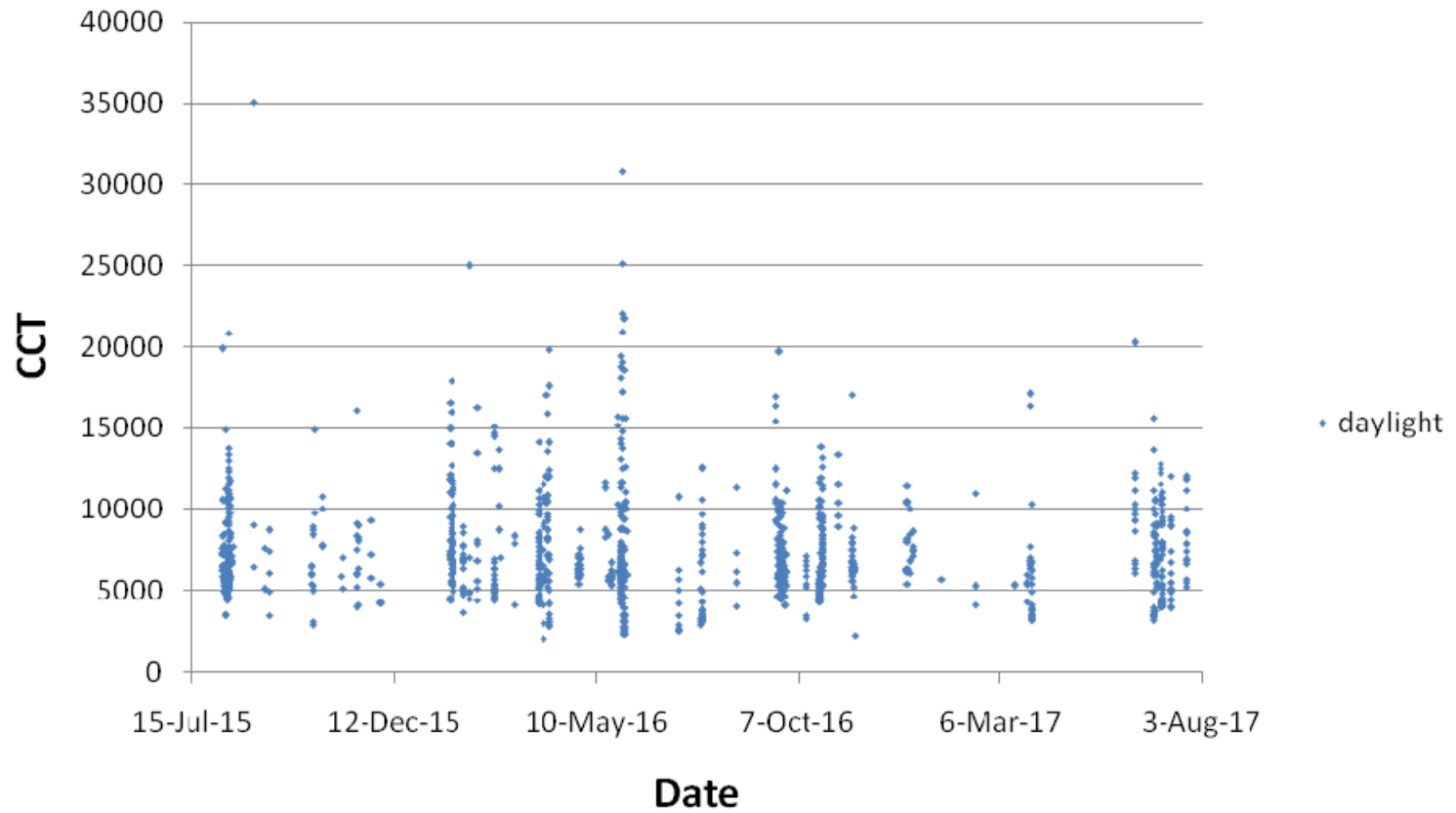


Daylight Recording Locations

Abisko, Sweden	Melbourne, FL	Santa Monica pier, CA
Akihabara, Japan	Millbrae, CA	Saratoga, CA
Bangalore, India	Monterey Bay Aquarium, CA	Shanghai, China
Branno Island, Sweden	Mt. Hamilton, San Jose, CA	Shinagawa, Japan
Bregenz, Austria	Munich, Germany	Shinjuku, Japan
Charlotte, NC	Narita airport, Japan	Singapore
Como, Italy	Newark airport, NJ	Somerset, PA
Deep Creek, MD	Newport Beach, CA	Stockholm, Sweden
Del Garda, Italy	Orlando, FL	Styrso Island, Sweden
Denver, CO	Penang, Malaysia	Sunnyvale, CA
Gaithersburg, MD	Raleigh Durham airport, NC	Taoyuan airport, Taiwan
Garching, Germany	Saltholmen, Sweden	Various airplane windows in route
Göteborg, Sweden	San Diego, CA	Wexford, PA
Irvine NAS, CA	San Francisco airport, CA	Wilmington, NC
Kingsten, Sweden	San Francisco bay bridge, CA	Yokohama, Japan
Kuala Lumpur, Malaysia	San Jose, Giants, CA	Yosemite national park, CA
Lapland, Norway	Santa Clara, CA	

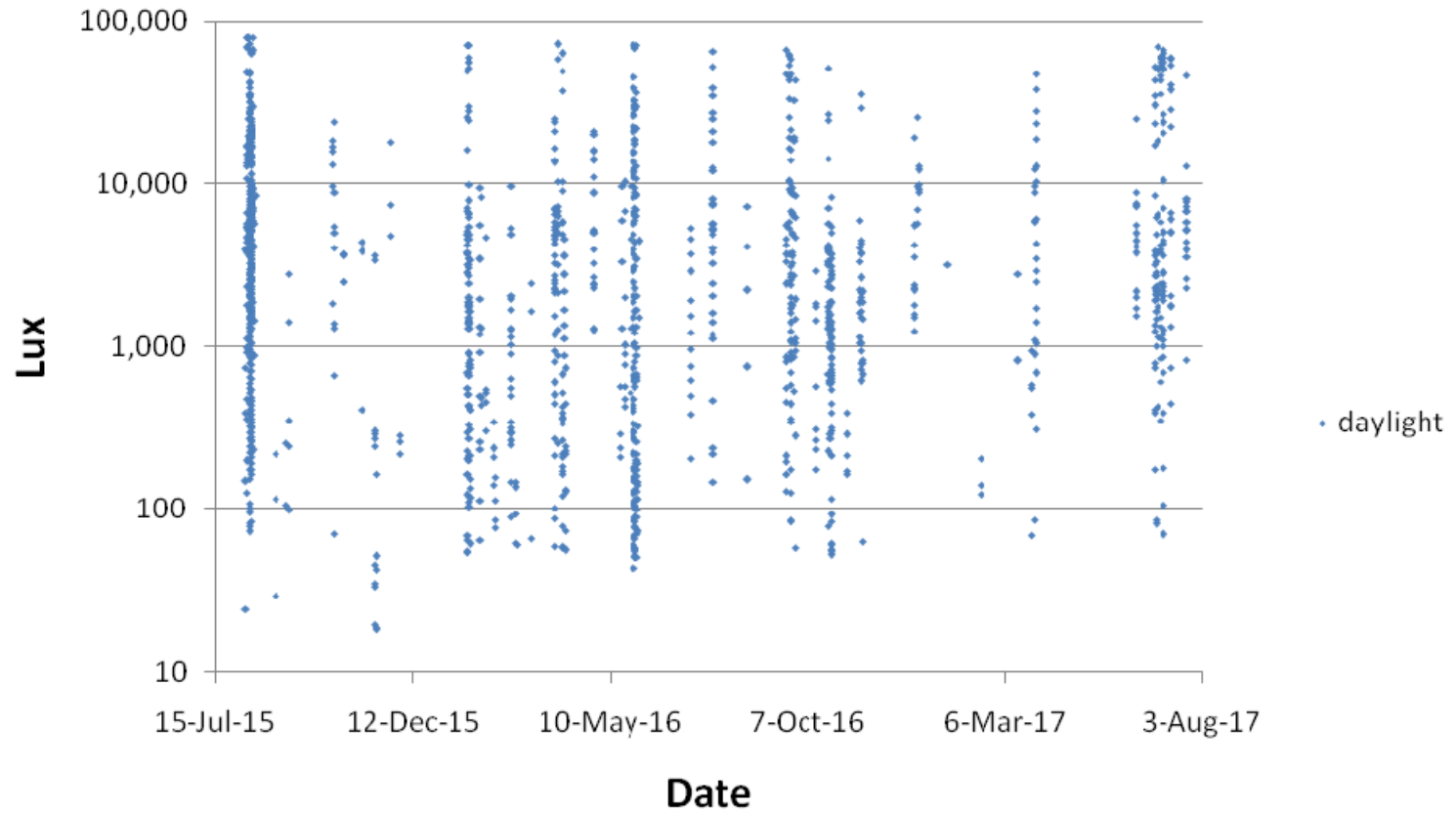
Daylight Data

Aug15 to Jul17 (1400 recordings)



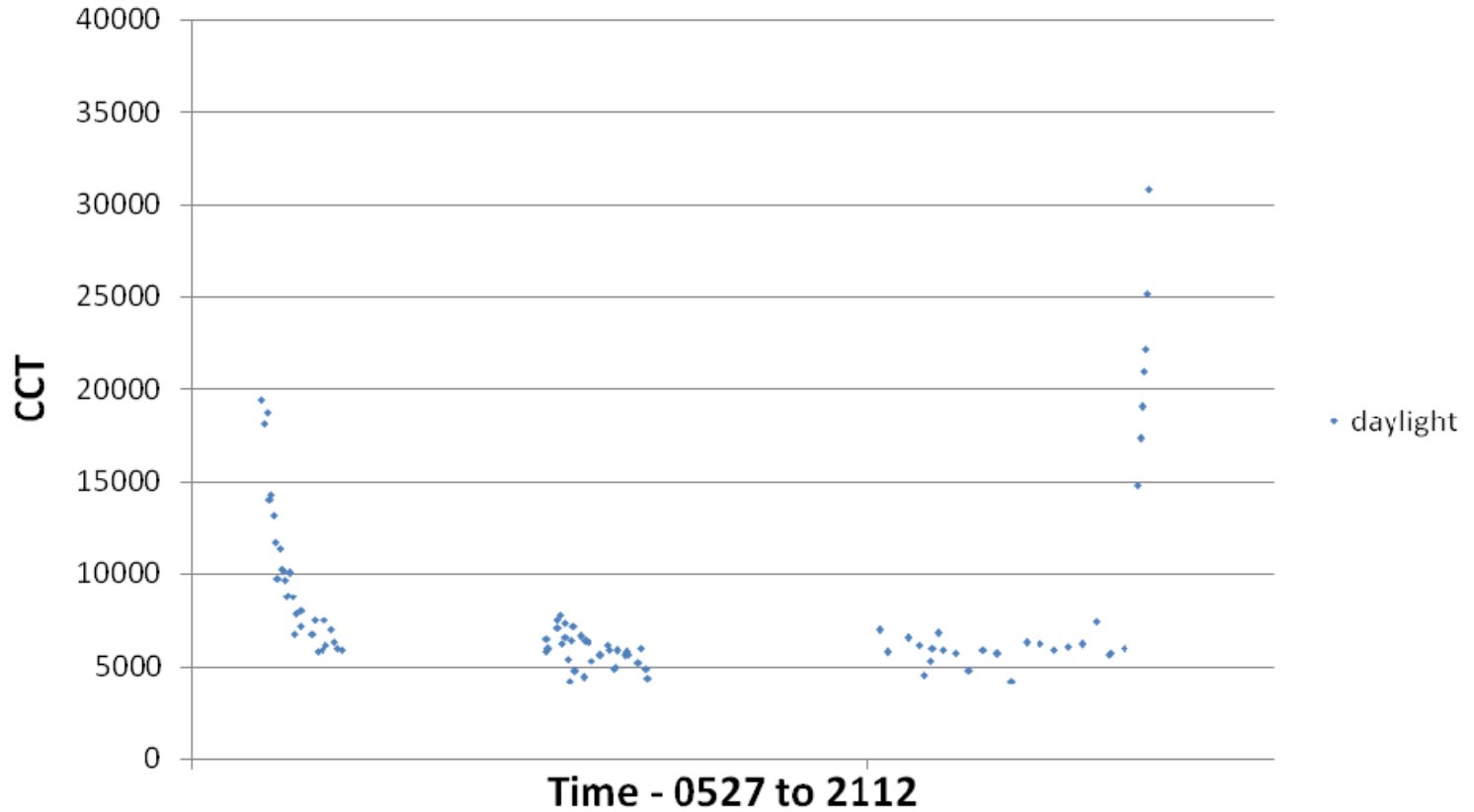
Daylight Data

Aug15 to Jul17 (1400 recordings)



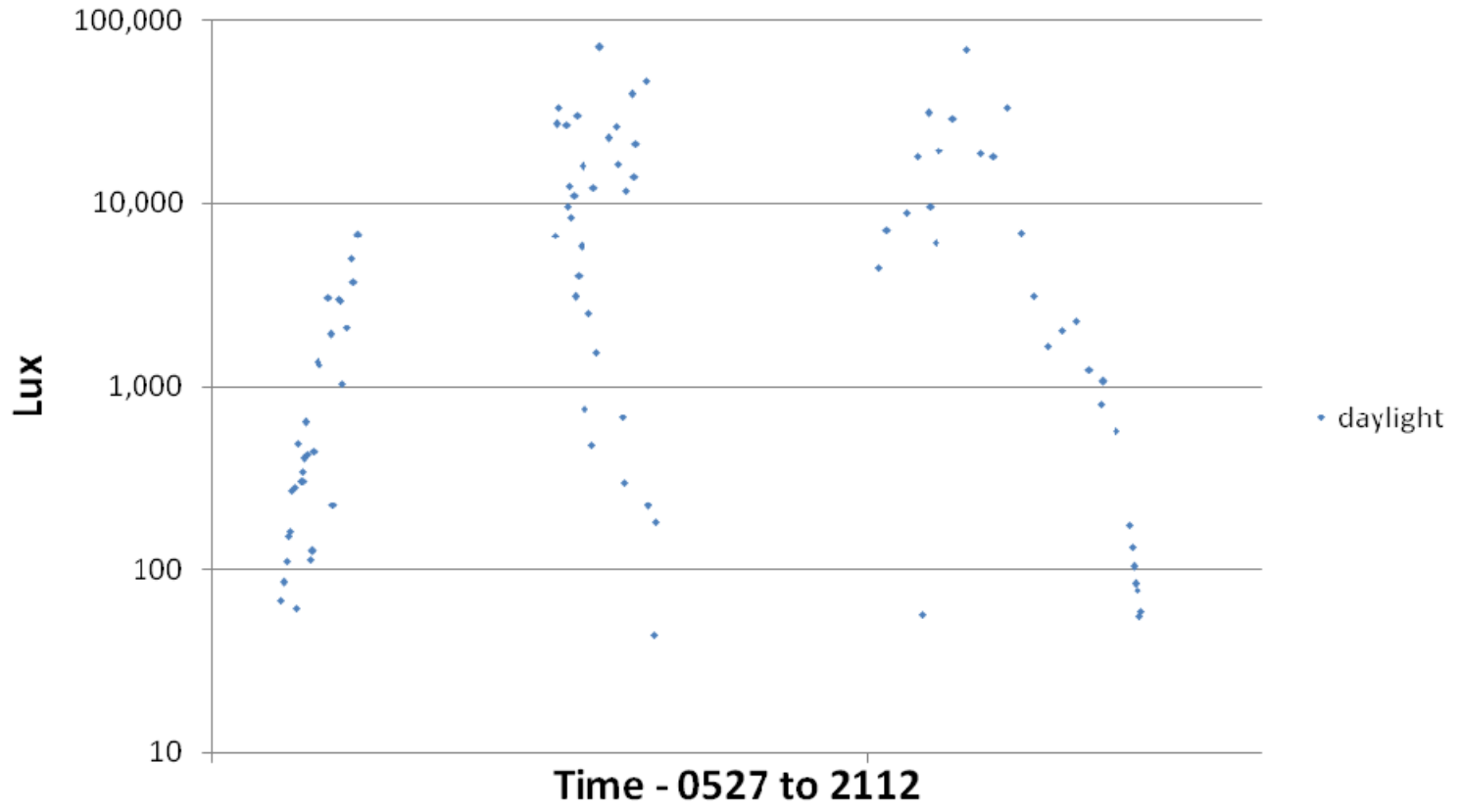
Daylight Data

Como, Italy - 28may16



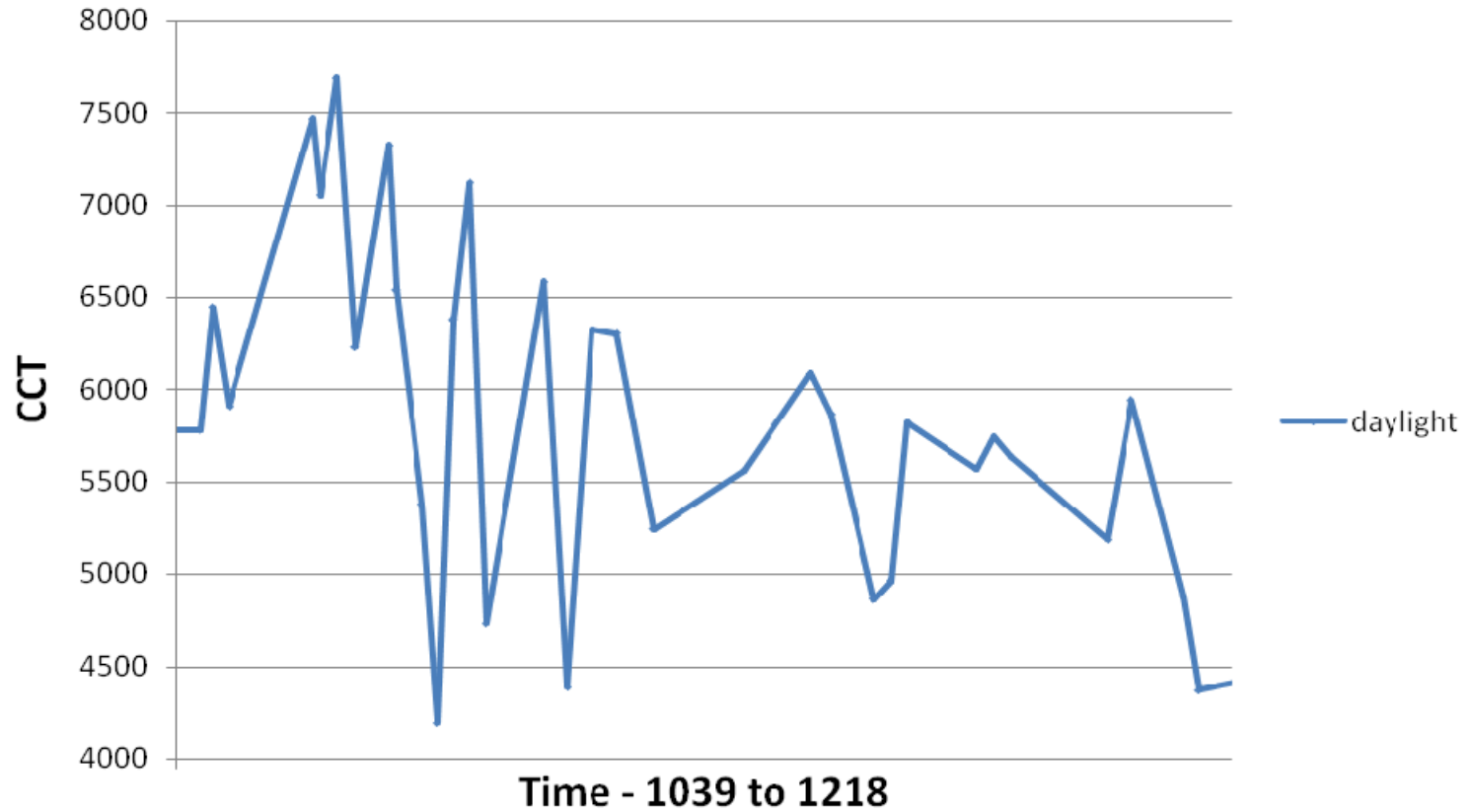
Daylight Data

Como, Italy - 28may16



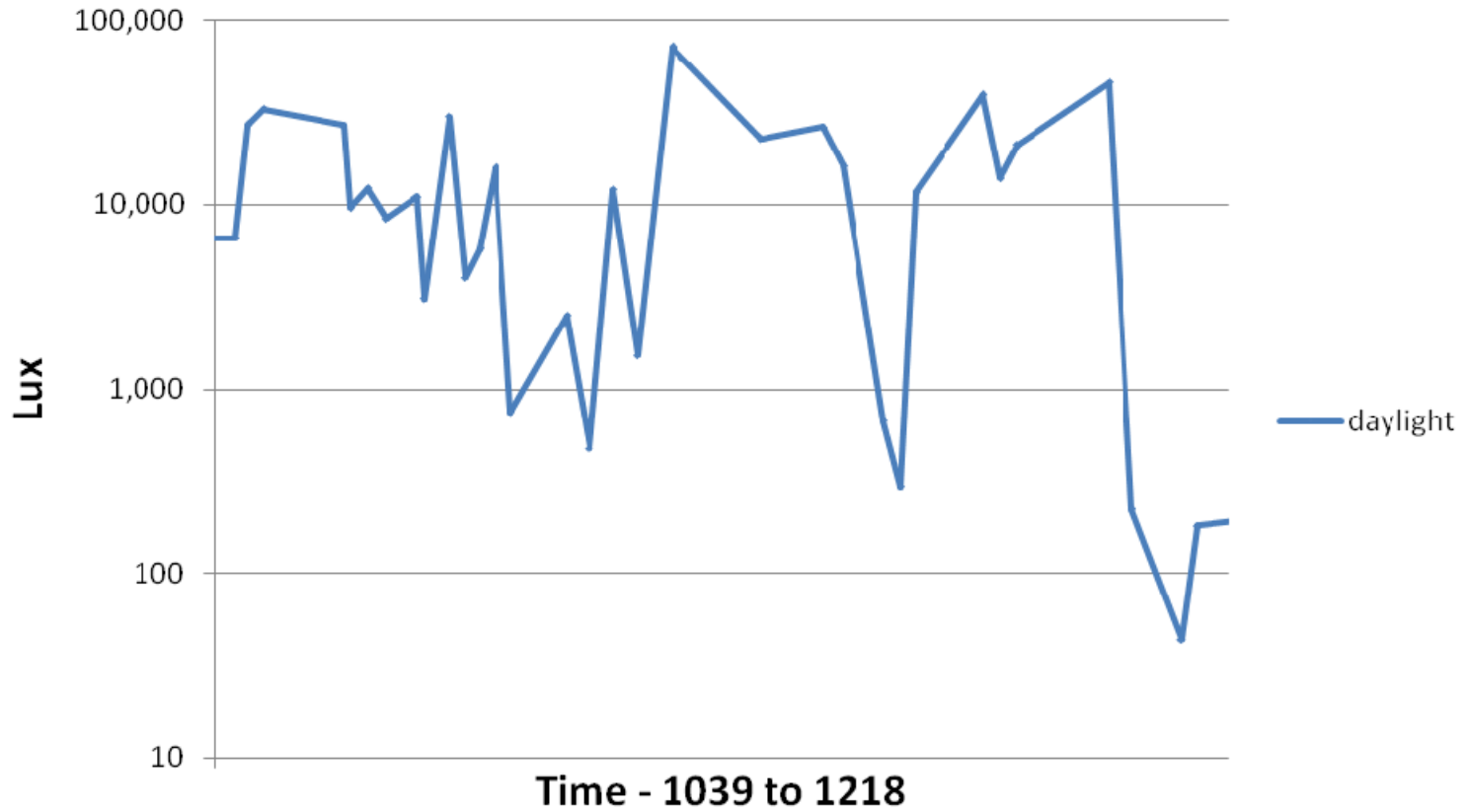
Daylight Data

Como, Italy - 28may16



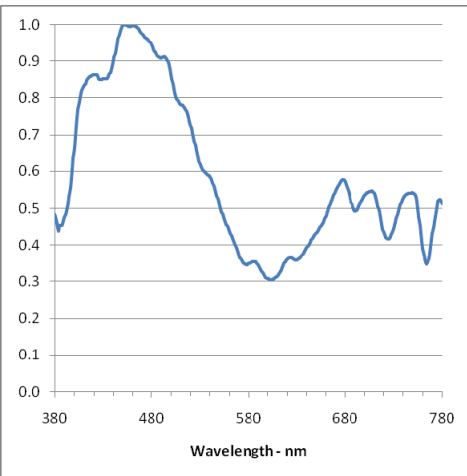
Daylight Data

Como, Italy - 28may16



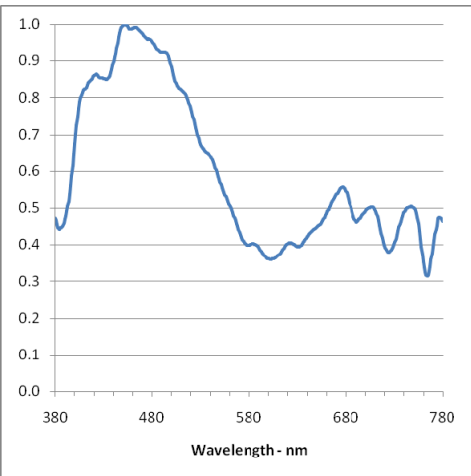
Spectrum and the Experience

Place	Como, Italy
Date	28-May-16
Time	0527
Lux	67
CCT	19459
CRI	91
u	0.175
v	0.421
duv	0.010



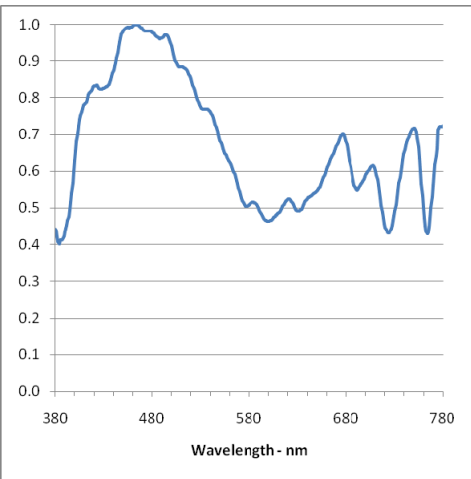
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Place	Como, Italy
Date	28-May-16
Time	0537
Lux	159
CCT	14292
CRI	93
u	0.176
v	0.431
duv	0.010

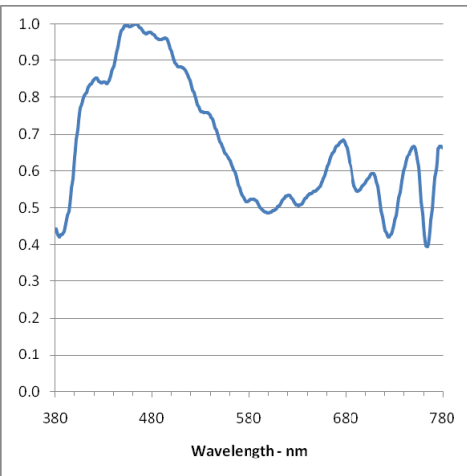


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Place	Como, Italy
Date	28-May-16
Time	0544
Lux	60
CCT	9769
CRI	95
u	0.182
v	0.447
duv	0.009

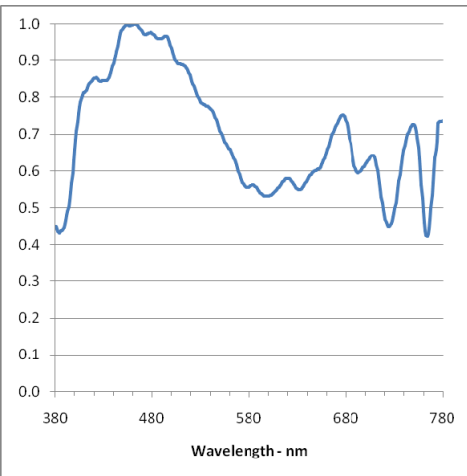


Place	Como, Italy
Date	28-May-16
Time	0551
Lux	304
CCT	9622
CRI	95
u	0.184
v	0.447
duv	0.007

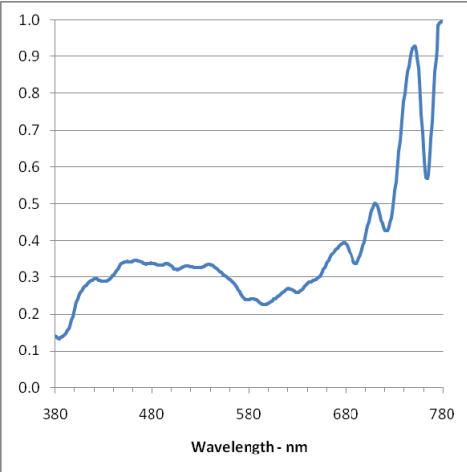


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Place	Como, Italy
Date	28-May-16
Time	0554
Lux	626
CCT	8820
CRI	95
u	0.188
v	0.450
duv	0.005

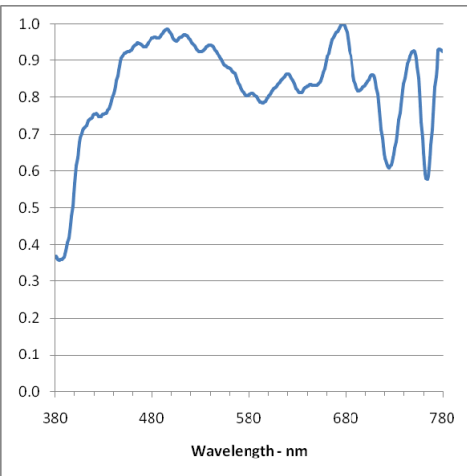


Place	Como, Italy
Date	28-May-16
Time	0602
Lux	125
CCT	6676
CRI	95
u	0.197
v	0.467
duv	0.004



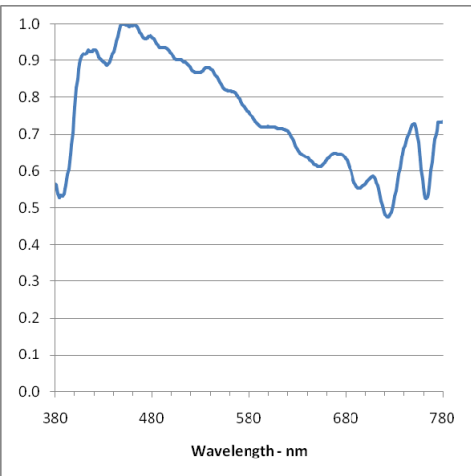
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Place	Como, Italy
Date	28-May-16
Time	0631
Lux	2990
CCT	5868
CRI	97
u	0.202
v	0.475
duv	0.003



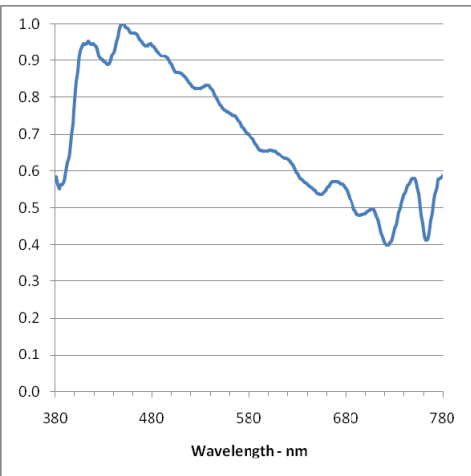
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Place	Como, Italy
Date	28-May-16
Time	1042
Lux	9616
CCT	7052
CRI	99
u	0.196
v	0.462
duv	0.002

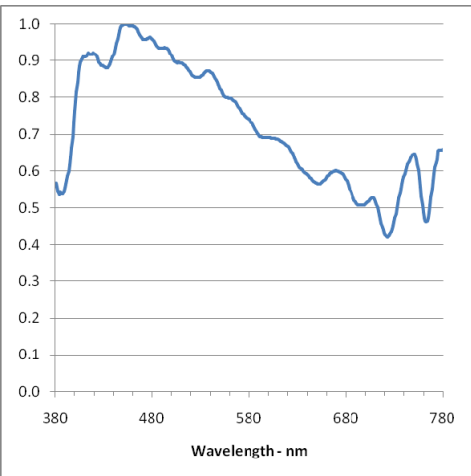


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Place	Como, Italy
Date	28-May-16
Time	1043
Lux	12230
CCT	7688
CRI	98
u	0.193
v	0.457
duv	0.003

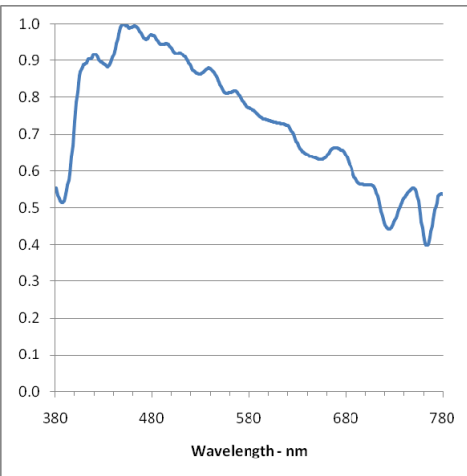


Place	Como, Italy
Date	28-May-16
Time	1049
Lux	11010
CCT	7326
CRI	97
u	0.194
v	0.461
duv	0.004

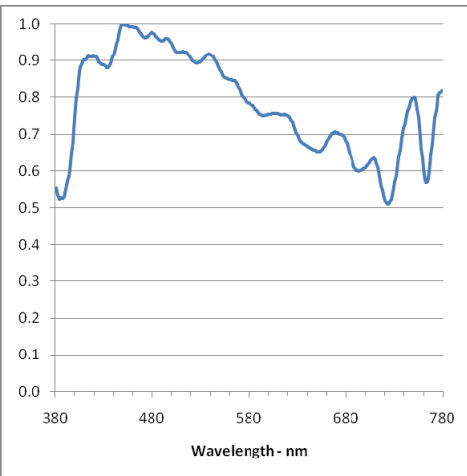


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Place	Como, Italy
Date	28-May-16
Time	1624
Lux	4384
CCT	6912
CRI	99
u	0.197
v	0.463
duv	0.002

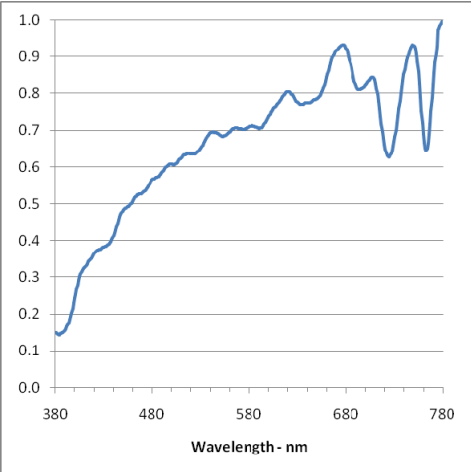


Place	Como, Italy
Date	28-May-16
Time	1726
Lux	6051
CCT	6753
CRI	99
u	0.197
v	0.465
duv	0.003



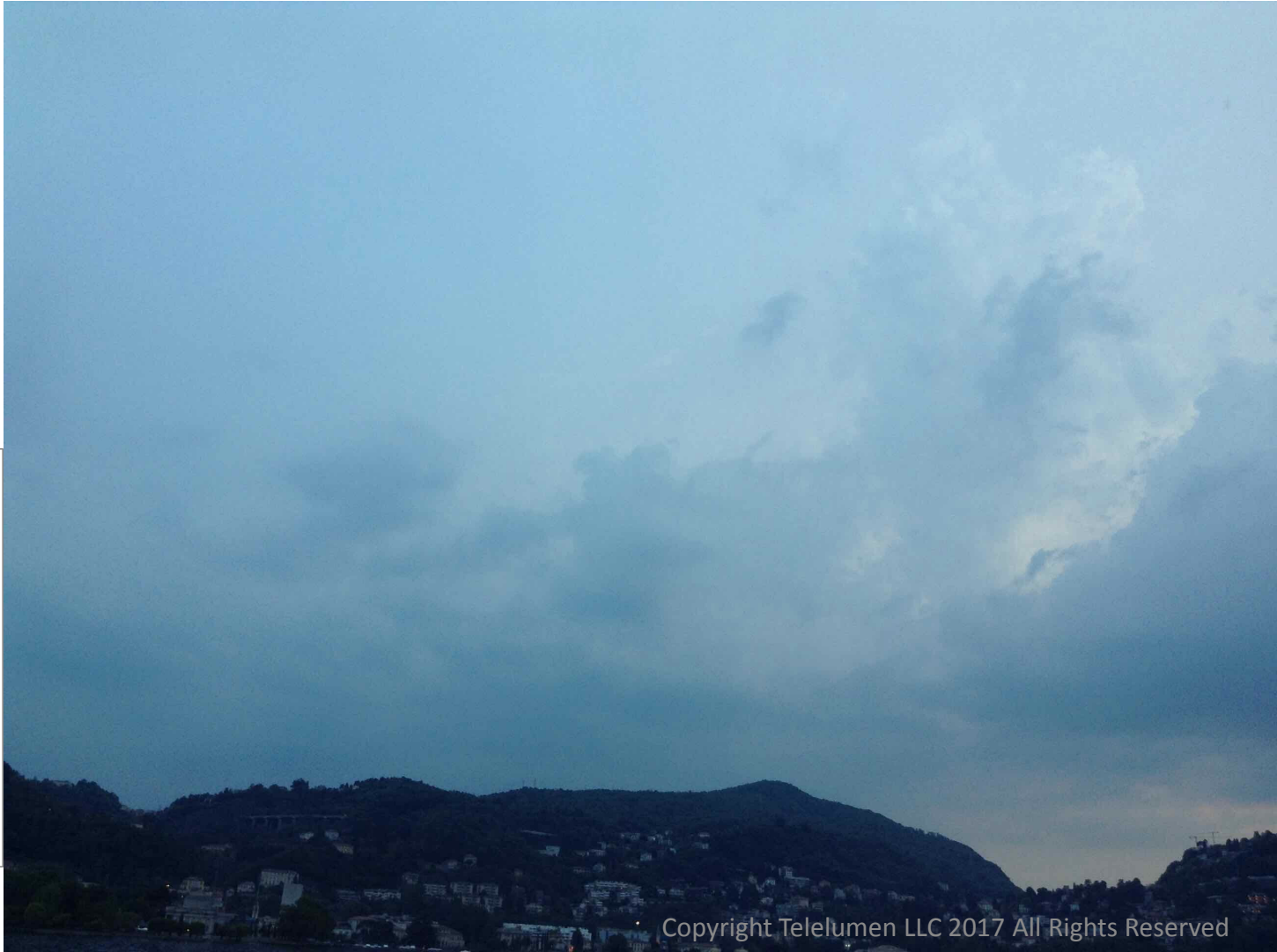
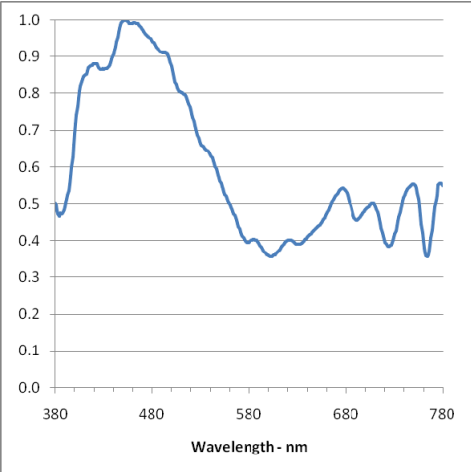
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Place	Como, Italy
Date	28-May-16
Time	1845
Lux	33150
CCT	4188
CRI	98
u	0.222
v	0.498
duv	0.000



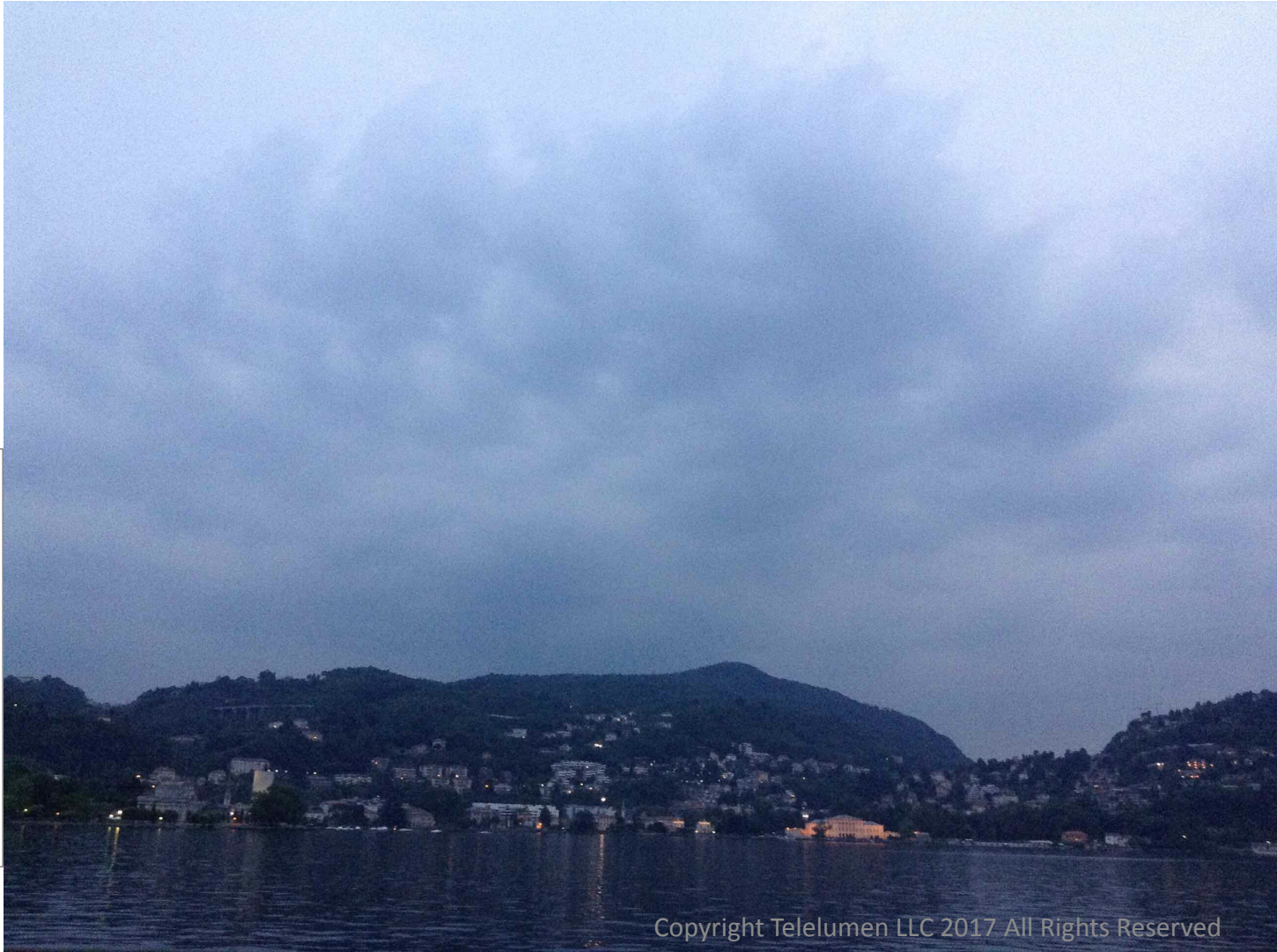
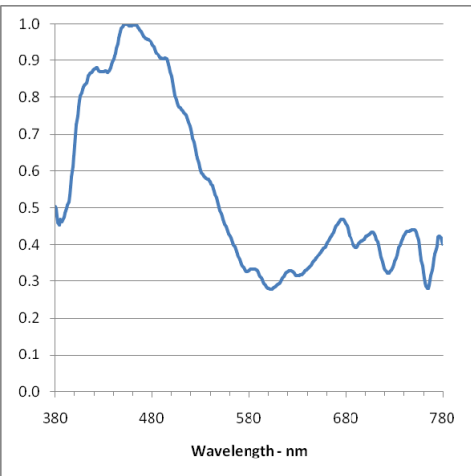
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Place	Como, Italy
Date	28-May-16
Time	2100
Lux	173
CCT	14808
CRI	93
u	0.177
v	0.429
duv	0.009



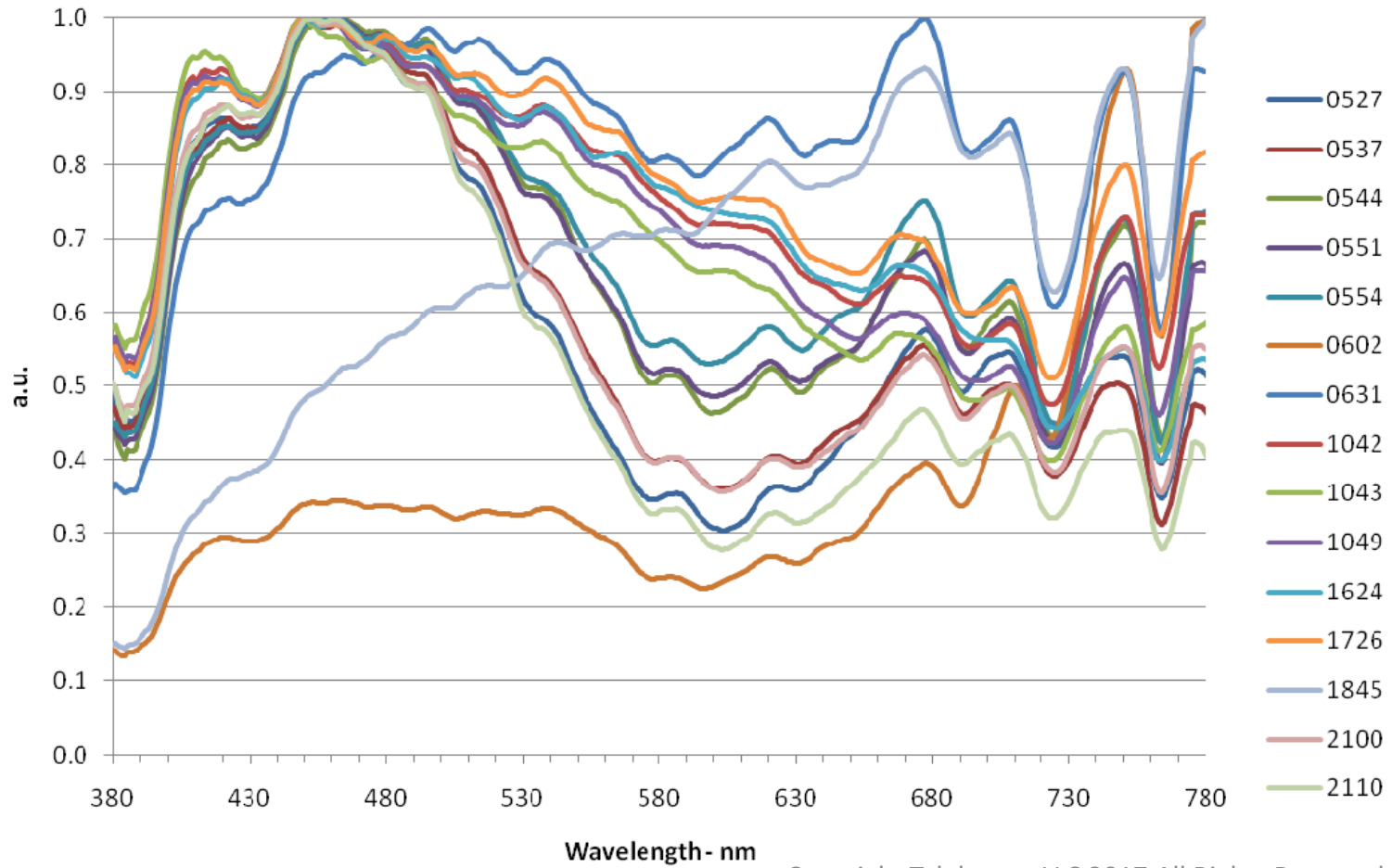
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Place	Como, Italy
Date	28-May-16
Time	2110
Lux	55
CCT	25127
CRI	91
u	0.171
v	0.417
duv	0.013



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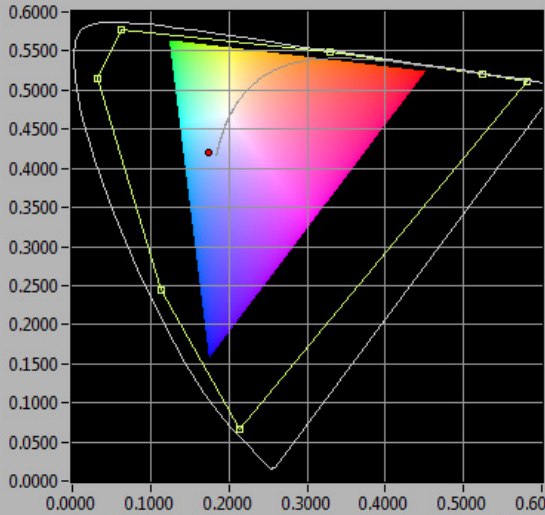
Como, Italy - 28may16



Electronic Illumination



CIE 1976 CIE 1931 CIE Lab NIST CQS CCT-Duv



u' 0.174 v' 0.421 u' 0.174 v' 0.421

CCT	CRI Ri	CCT	CRI Ri
19469	92	19488	92
0 Watt		0 Watt	
19.33	CQSi	3.17	CQSi
Lumen	88	Lumen	90
744		744	
TM30-Rg	TM30-Rf	TM30-Rg	TM30-Rf
100	90	95	85

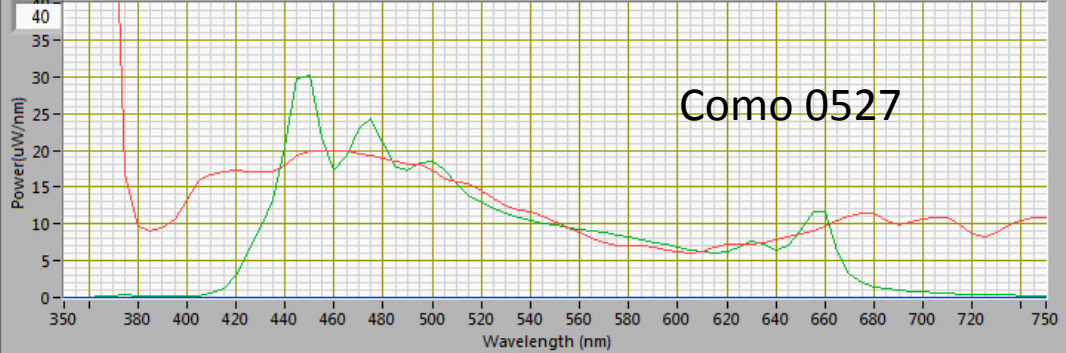
Reference SPD

Simulated SPD

0.000



Log Auto Exp Int T. (ms) 15 Snap Simulate Calibrated Match Palette Spectrum Quick



Synthesizer Recorder Sequencer Cue Editor Flicker Test Luminaire Config Luminaire Control Add To Cue Replace Cue

Reset Default 445 475 500 525 540 595 630 660

8064	20	13.015	15.579	13.905	0.3769	33.185	3.3513	1.5003	4.7015	0	0	0	0	0	0	0
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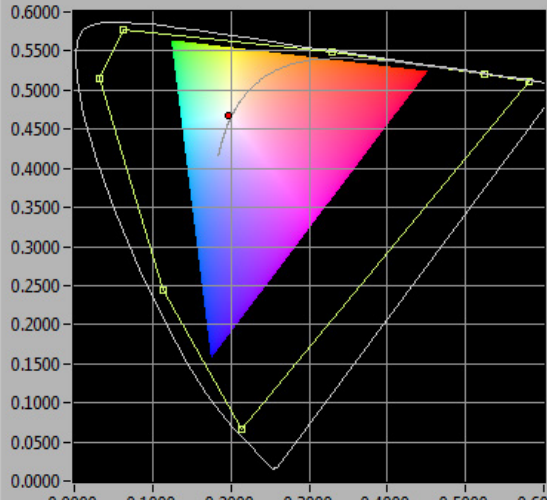
100k 100- 1k- 1- Hold Lumen Output Constant

C T K e l v i n R e f . P e a k



Light Replicator

CIE 1976 CIE 1931 CIE Lab NIST CQS CCT-Duv

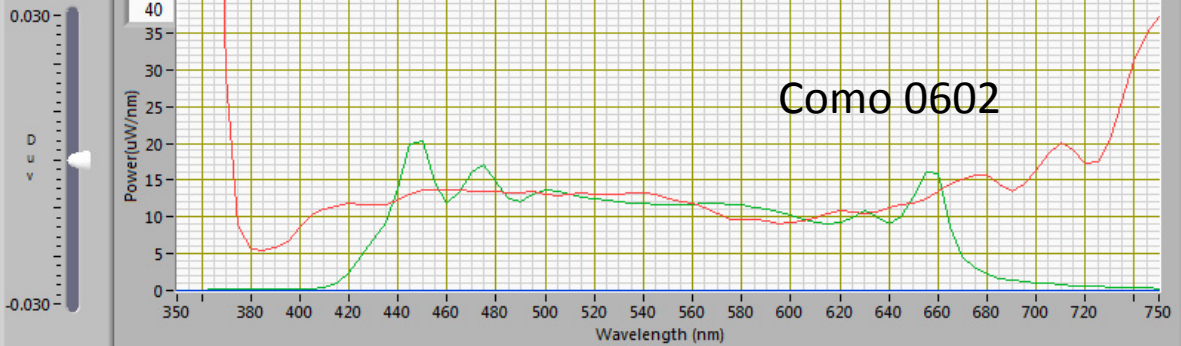


Reference Spectrum Working Spectrum
 u' 0.197 v' 0.467 u' 0.196 v' 0.467

CCT	CRI Ri	CCT	CRI Ri
6678	93	6679	97
O Watt		O Watt	
11.62		3.09	
Lumen	CQSi	Lumen	CQSi
847	95	847	97
TM30-Rg	TM30-Rf	TM30-Rg	TM30-Rf
103	94	98	93

Reference SPD Simulated SPD

0.000 Log Auto Exp Int T. (ms) 15 Snap Simulate Calibrated Match Palette Spectrum Quick

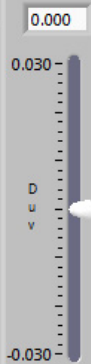
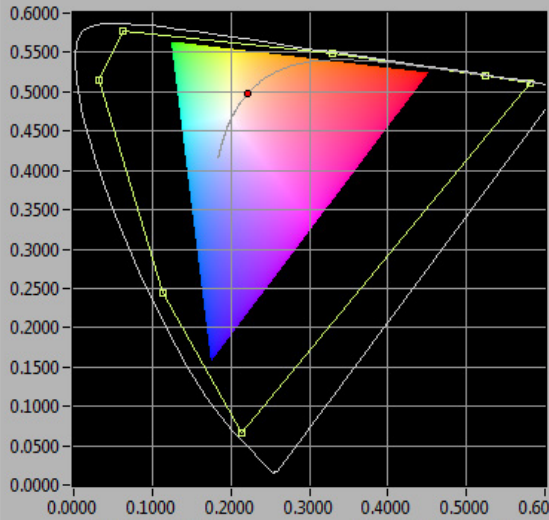


Synthesizer Recorder Sequencer Cue Editor Flicker Test Luminaire Config Luminaire Control Add To Cue Replace Cue

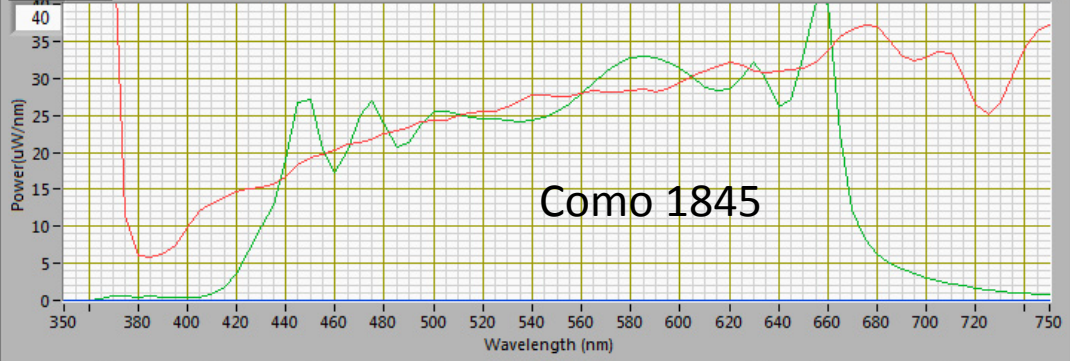
Reset Default	44%	47%	50%	53%	54%	59%	63%	66%									
8064	40	8.5424	11.017	8.8435	0	39.271	6.2964	1.9039	6.2698	0	0	0	0	0	0	0	0
100k	100-																
C T	R e f																
K e l	l v																
1k-	1-																
Hold Lumen Output Constant																	



CIE 1976 CIE 1931 CIE Lab NIST CQS CCT-Duv



Log Auto Exp Int T. (ms) 15 Snap Simulate Calibrated Match Palette Spectrum Quick



Synthesizer Recorder Sequencer Cue Editor Flicker Test Luminaire Config Luminaire Control Add To Cue Replace Cue

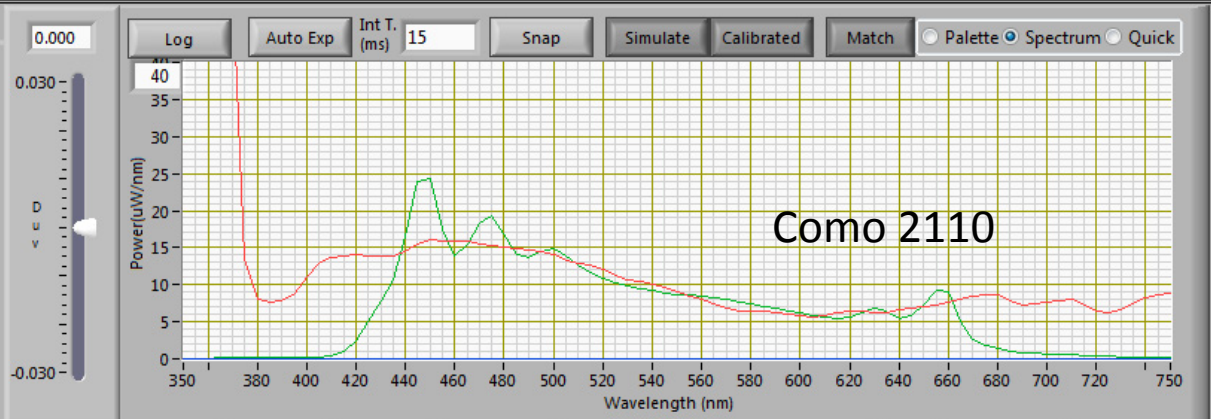
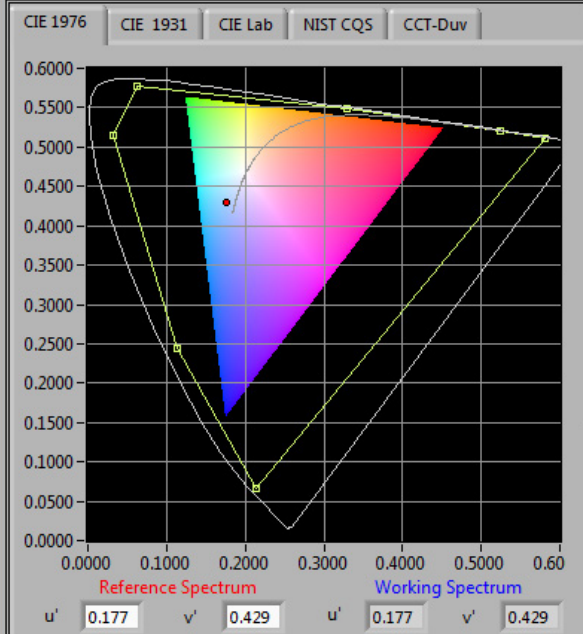
Reset Default 445 475 500 525 540 595 630 660

8064	40	10.937	17.231	16.531	1.9993	78.746	44.77	5.3844	14.758	0	0	0	0	0	0	0
------	----	--------	--------	--------	--------	--------	-------	--------	--------	---	---	---	---	---	---	---

100k 100-
C T
K e l
l i v i n
1k 1-
Hold Lumen Output Constant.

CCT	CRI Ri	CCT	CRI Ri
4189	0 98	4191	0 94
O Watt		O Watt	
22.76		6.74	
Lumen	0 99	Lumen	0 94
2019		2019	
TM30-Rg	TM30-Rf	TM30-Rg	TM30-Rf
100	0 98	96	0 91

Reference SPD Simulated SPD



Synthesizer Recorder Sequencer Cue Editor Flicker Test Luminaire Config Luminaire Control Add To Cue Replace Cue

Reset Default 449 475 500 525 540 595 630 660

8064	16	10.478	12.46	10.784	0	29.979	0	1.4444	3.5963	0	0	0	0	0	0	0
------	----	--------	-------	--------	---	--------	---	--------	--------	---	---	---	---	---	---	---

100k- 100-
C T
K e l v i n
P e a k
1k- 1-
 Hold Lumen Output Constant.

CCT CRI Ri CCT CRI Ri

14808	0	95	14810	0	93
O Watt			O Watt		
15.76			2.65		
Lumen	0	91	Lumen	0	92
645			645		
TM30-Rg			TM30-Rg		
100	0	92	95	0	87

Reference SPD Simulated SPD

Summary

- Human centric lighting is rooted in our daylight experience.
- Daylight is complex and changes with time.
- Spectrometer recordings of daylight capture this complexity.
- Recordings and other data can be composed into Lumenscripts.
- Lumenscripts become illumination on a Light Player.
- The player interface (channel change and volume) enable intuitive controls.

A few questions and
then a short demo.

Thank You

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