Predicting the non-visual effects of lighting in buildings

Applied Research Consortium
05.18.2023
Bo Jung

Team

University of Washington

Applied Research Consortium Fellow
Bo Jung

Faculty Advisor
Mehlika Inanici

ZGF Architects

Firm Advisor
Marty Brennen

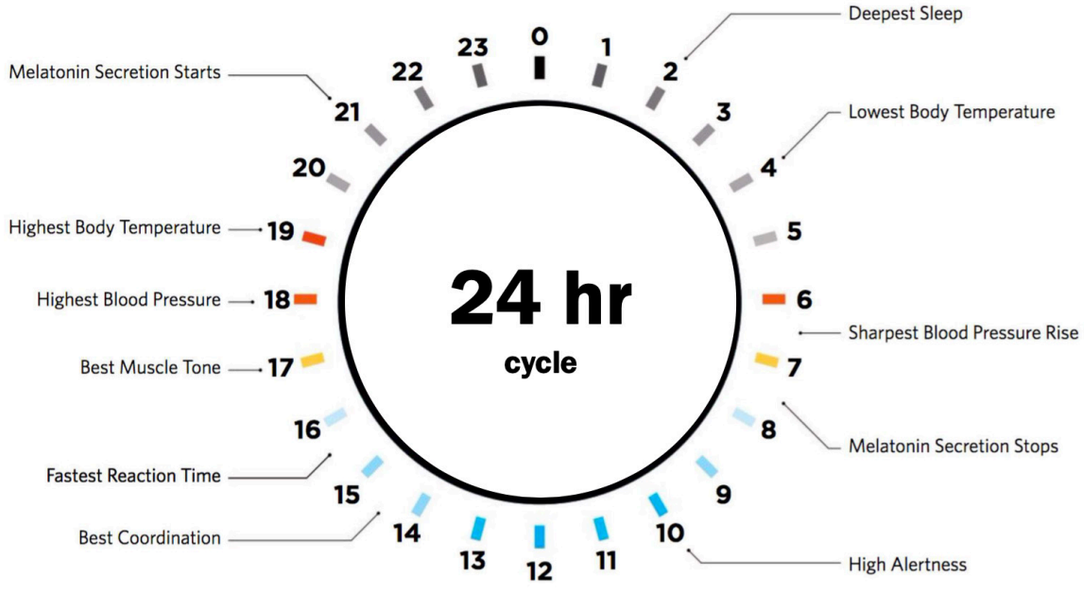
Spectral lighting simulation

Applications of spectral light simulation

- Color appearance of interiors
- Agriculture
- Human health

Research on accurate simulation of color indoors

Project goal to further development of LARK multispectral simulation tool



Contents

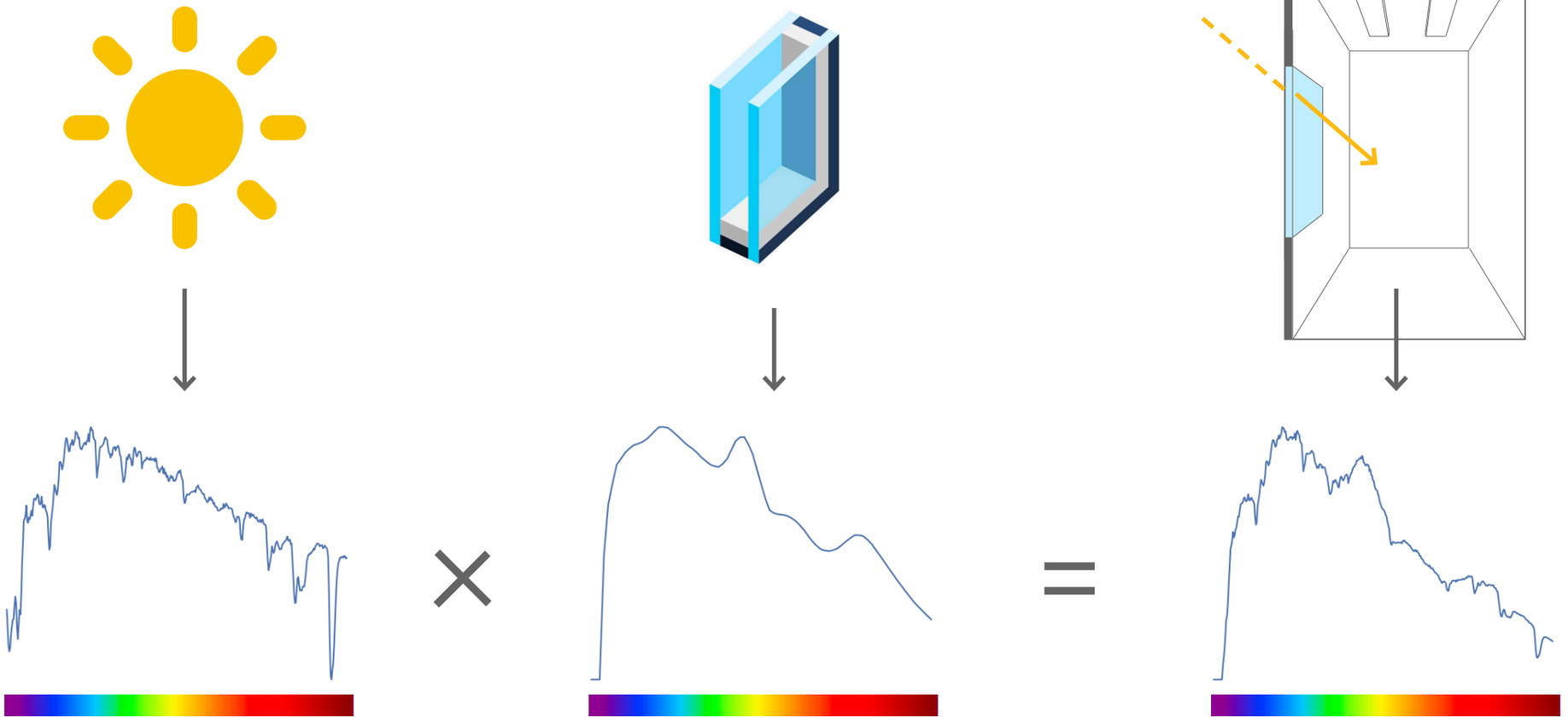
1. Spectral Interaction with daylight

2. How is this implemented in LARK

3. Improvements in LARK and why is it important?

4. Predicting color of the sun

Spectral Interaction with daylight



Spectral Power Distribution (SPD)

Showing energy levels of a light source through a range of wavelengths

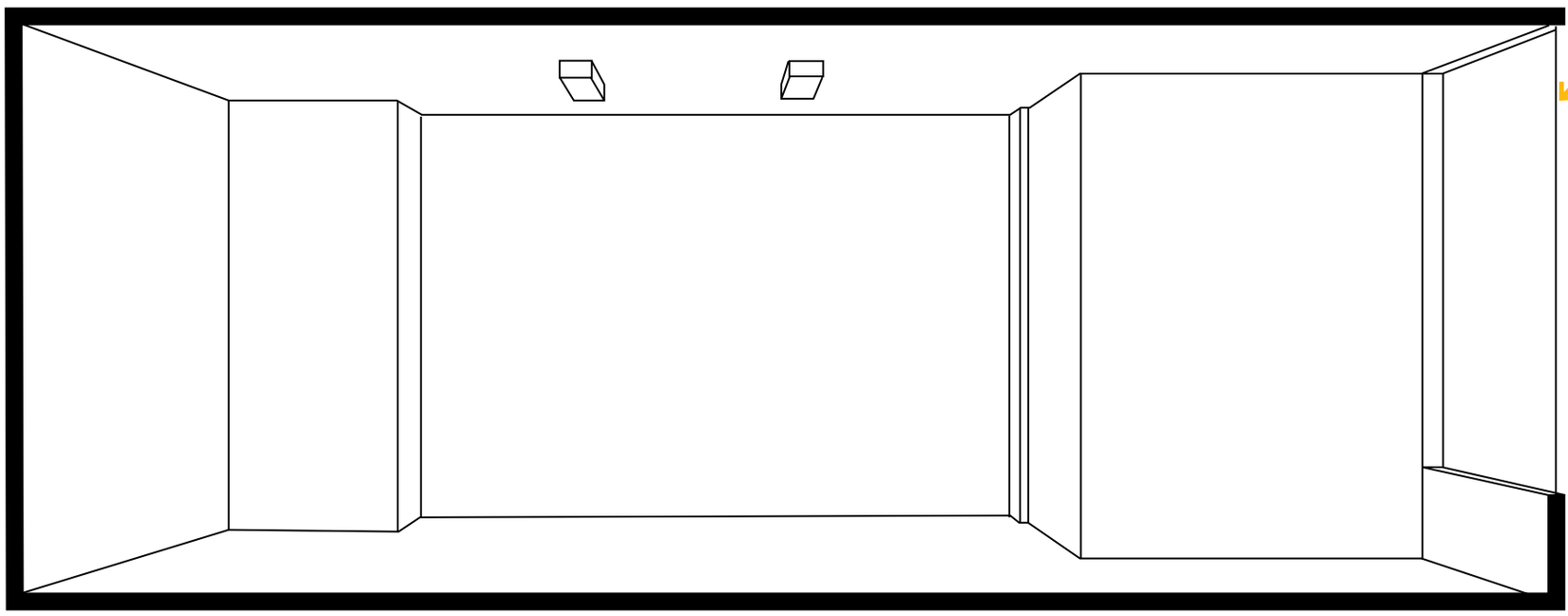
Visible Light Transmittance (VLT)

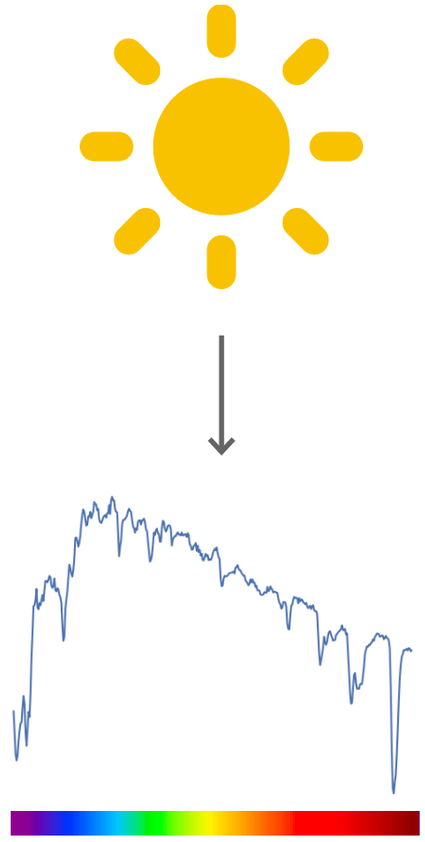
Amount of light in the visible portion of the spectrum that passes through a glazing material

Transmitted Light

Energy levels of transmitted light

Spectral Interaction with daylight - example

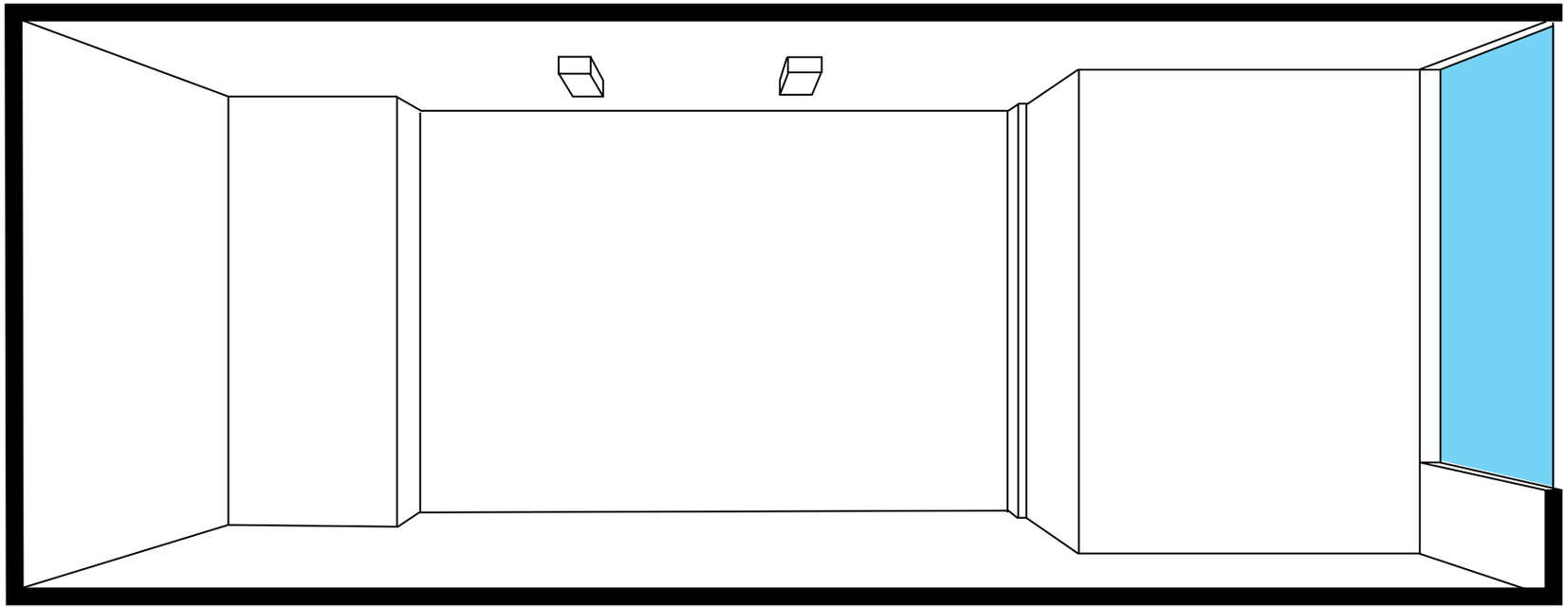


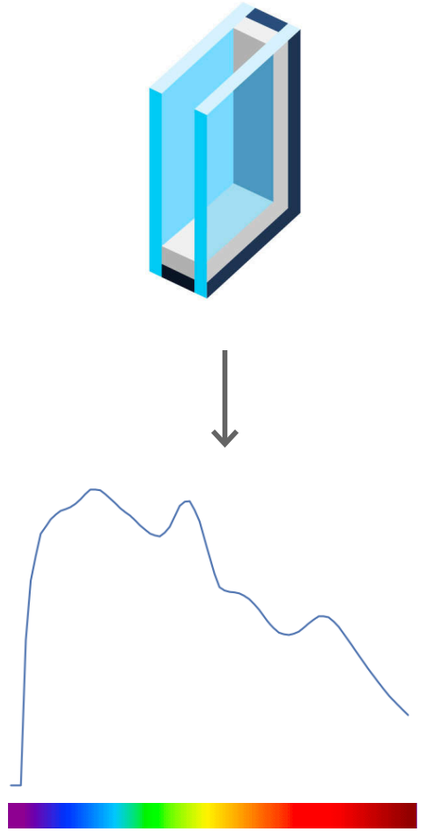


Spectral Power Distribution (SPD)

Showing energy levels of a light source through a range of wavelengths

Spectral Interaction with daylight - example

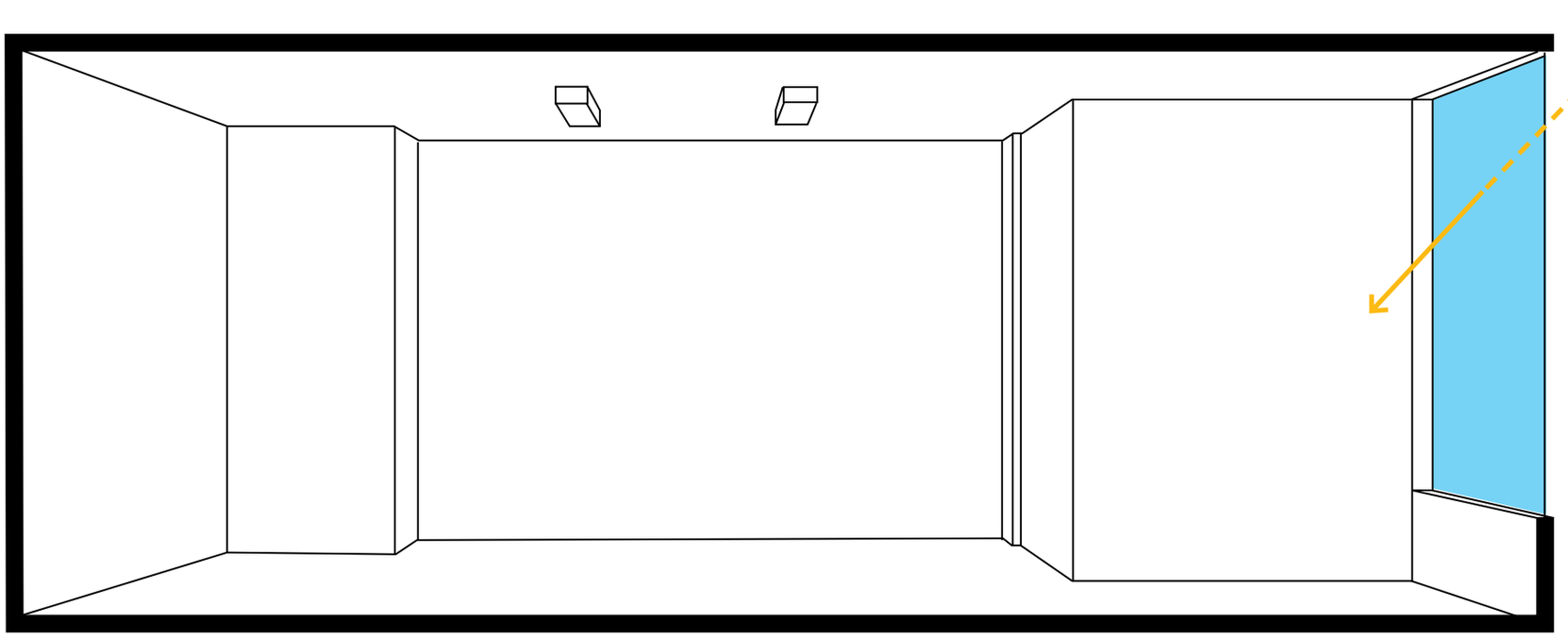


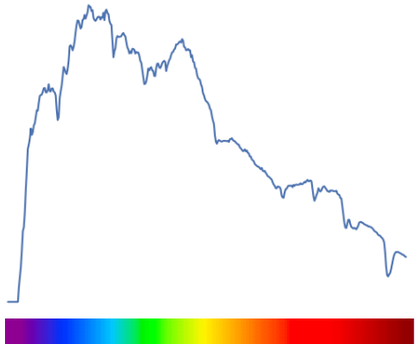


Visible Light Transmittance (VLT)

Amount of light in the visible portion of the spectrum that passes through a glazing material

Spectral Interaction with daylight - example

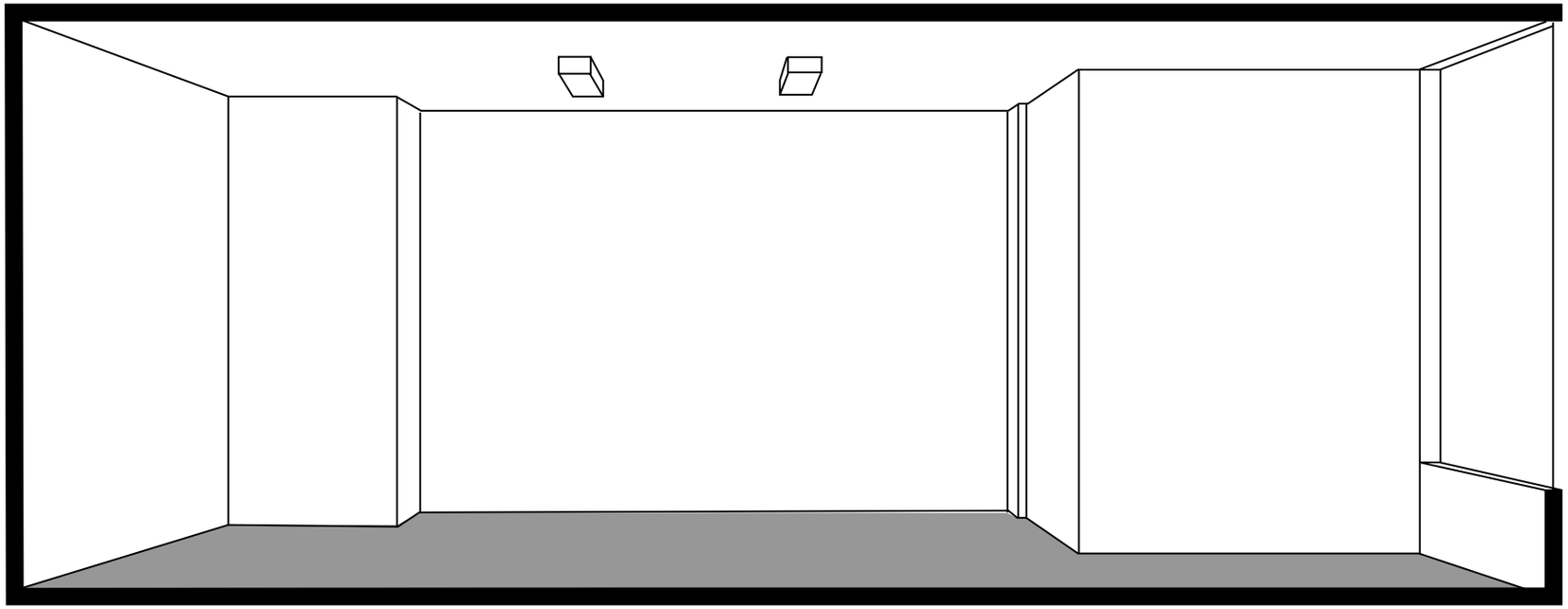


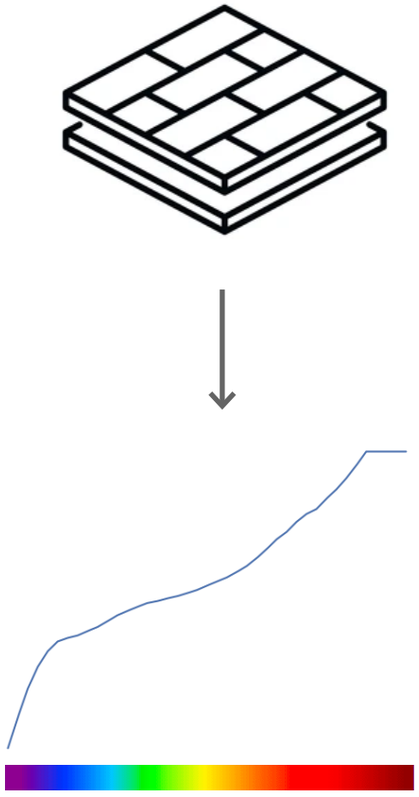


Transmitted Light

Energy levels of transmitted light

Spectral Interaction with daylight - example

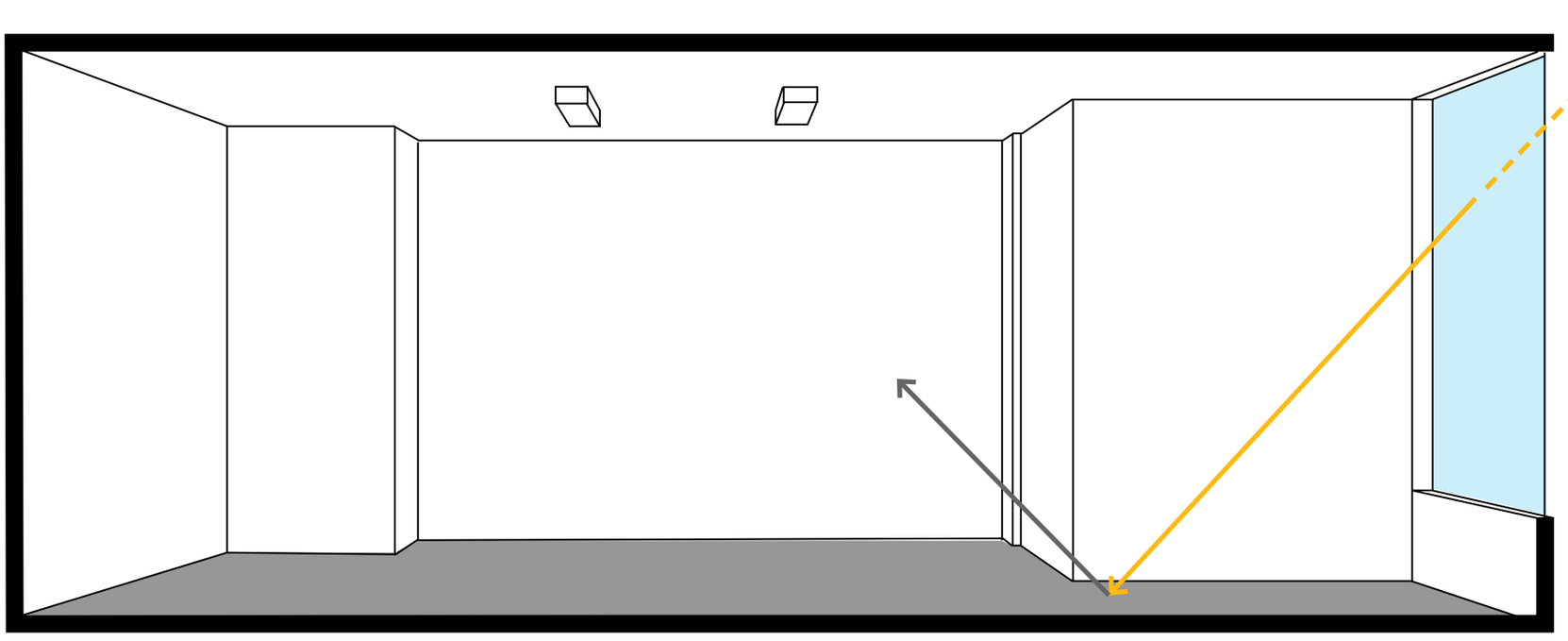


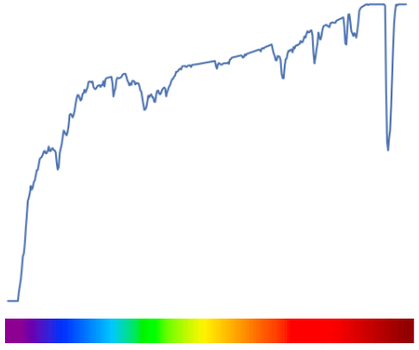


Spectral Reflectance

wavelengths of light that reflect off a surface

Spectral Interaction with daylight - example

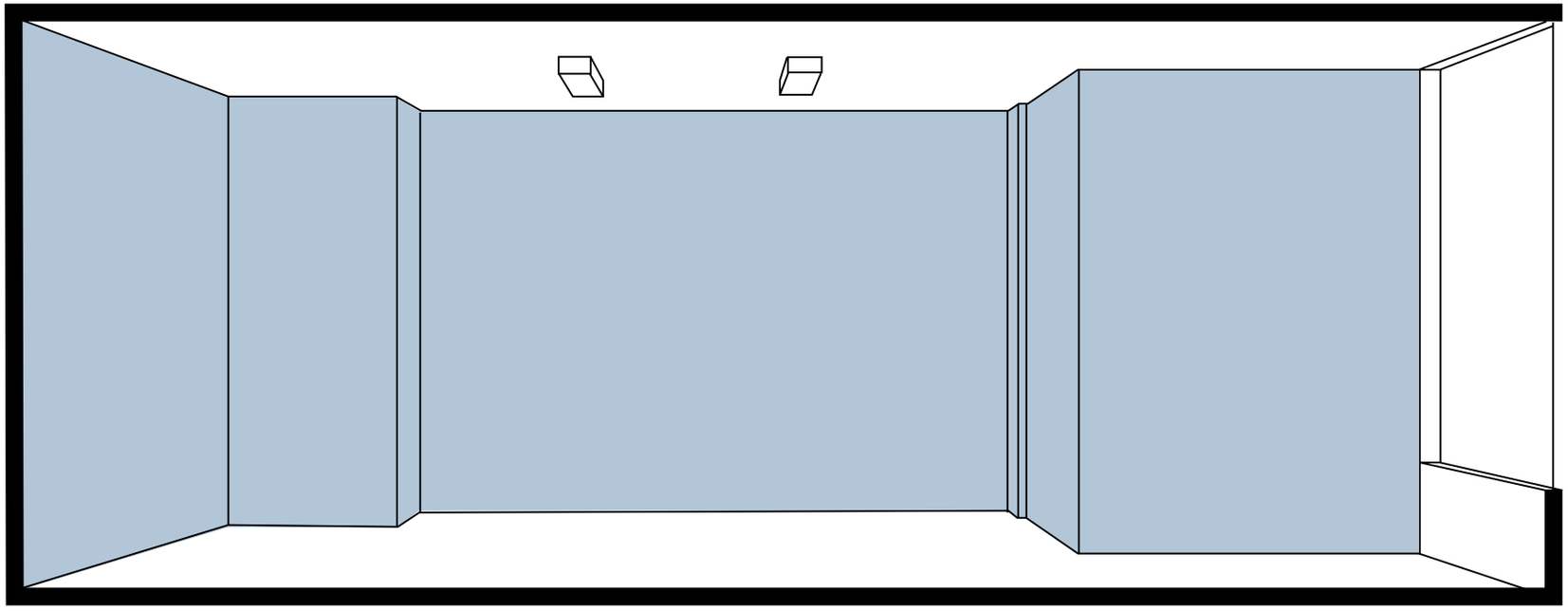


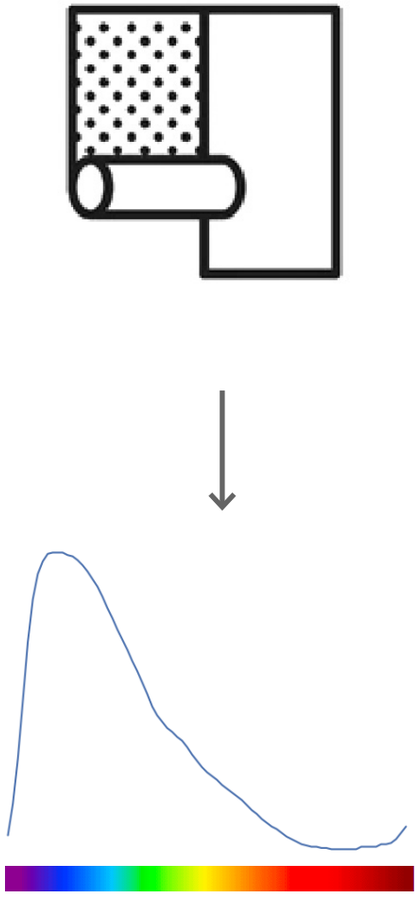


Reflected Light

Energy levels of reflected light

Spectral Interaction with daylight - example

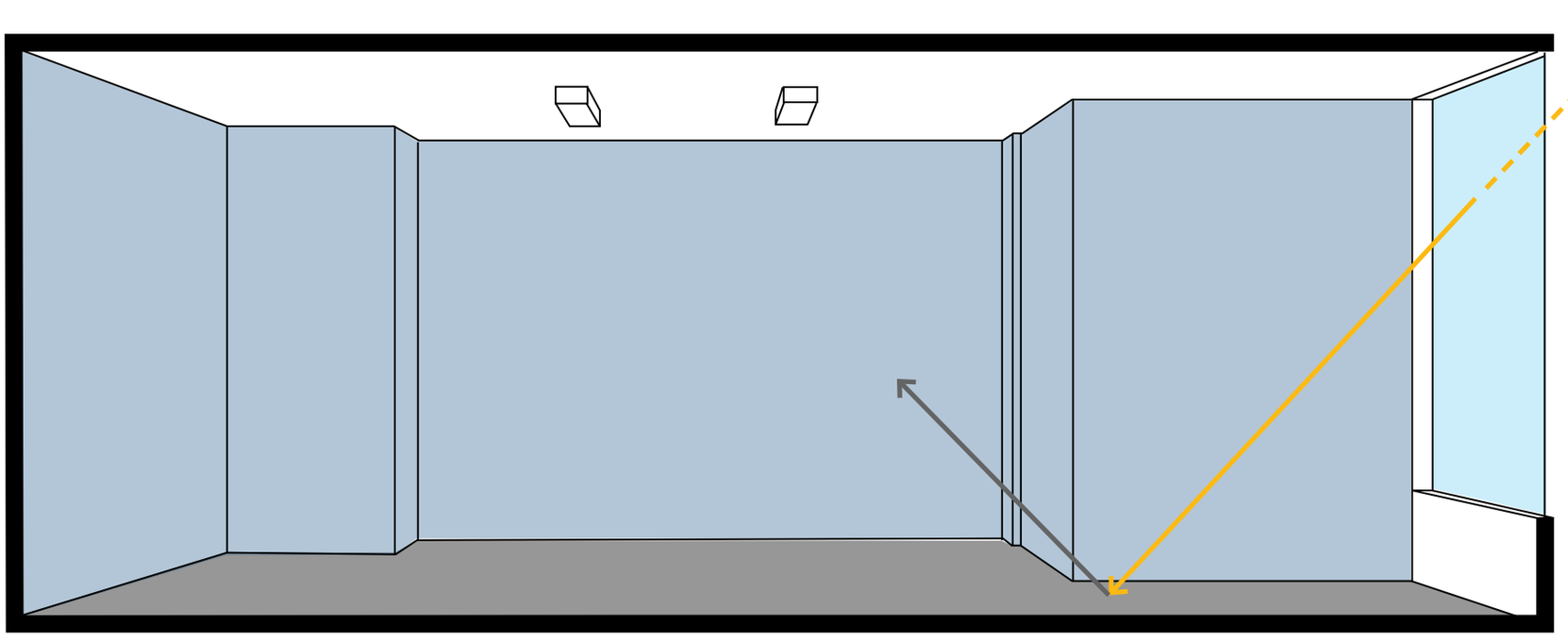




Spectral Reflectance

wavelengths of light that reflect off a surface

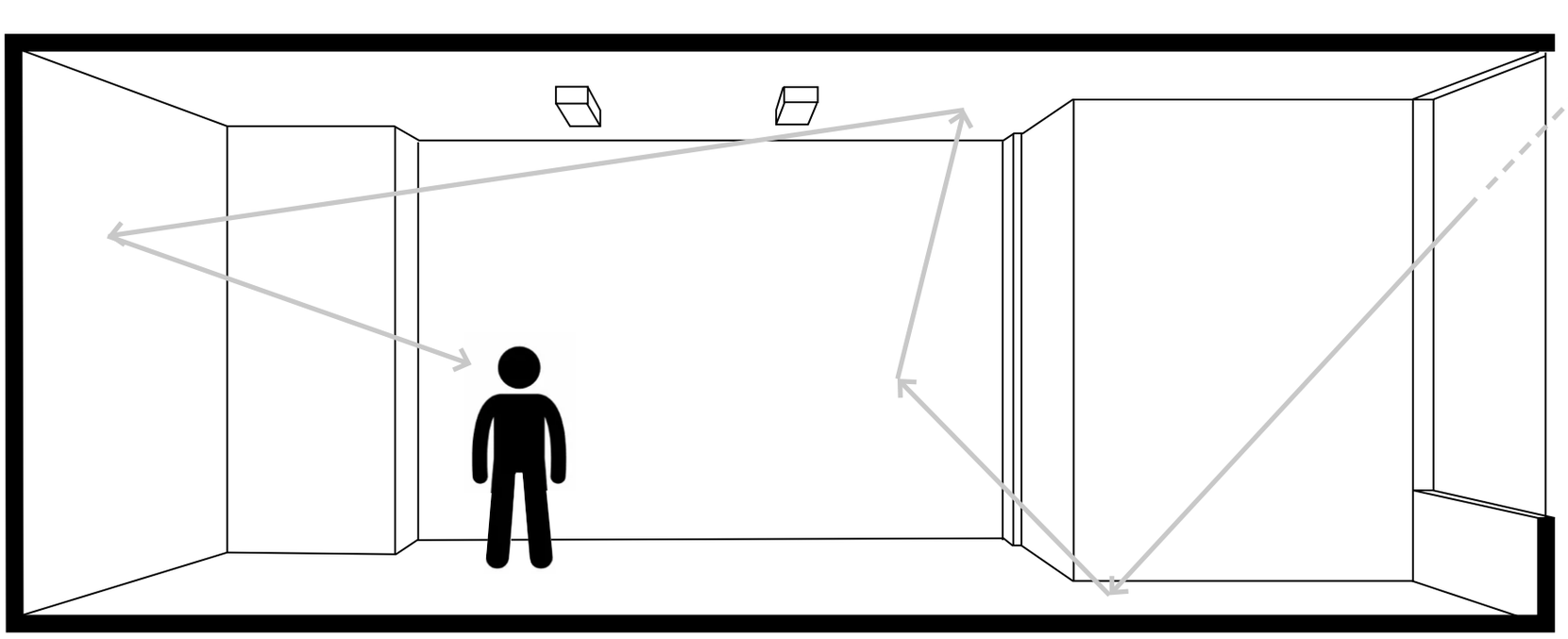
Spectral Interaction with daylight - example

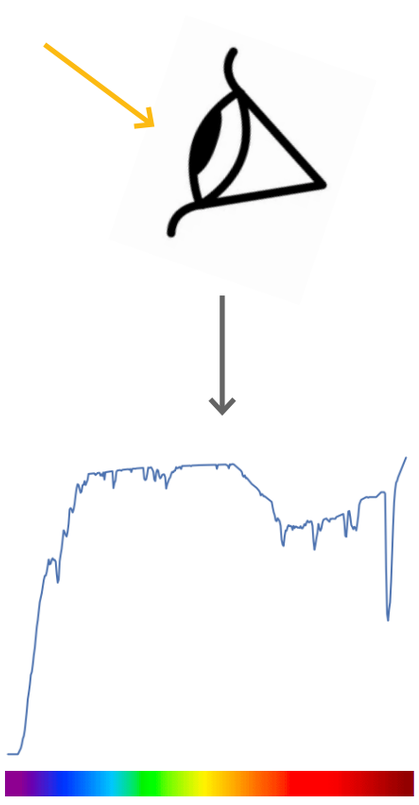


Reflected Light

Energy levels of reflected light

Spectral Interaction with daylight - example

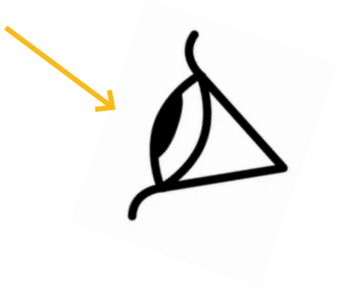




Reflected Light Entering eyes

Energy level of reflected light entering our eyes

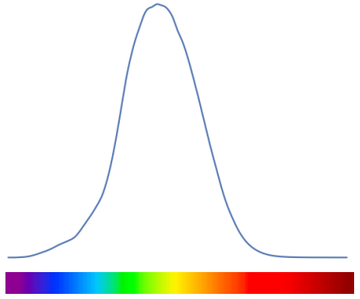
Spectral Interaction with daylight

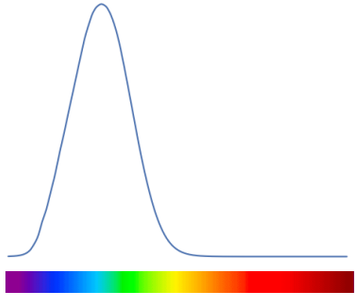


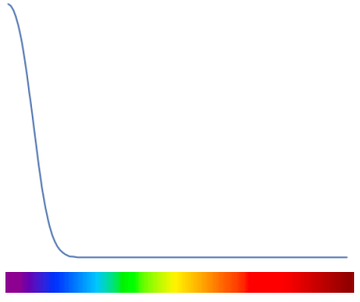
Light entering eyes

Light is processed through light sensitive cells (rods, cones, ipRGCs)

These cells contain proteins that interact with light- sensitive chemicals to enable vision, circadian rhythms, and other light-induced neuro-endocrine responses







Opsin 1 (Photopic)

Visual Sensitivity to Light

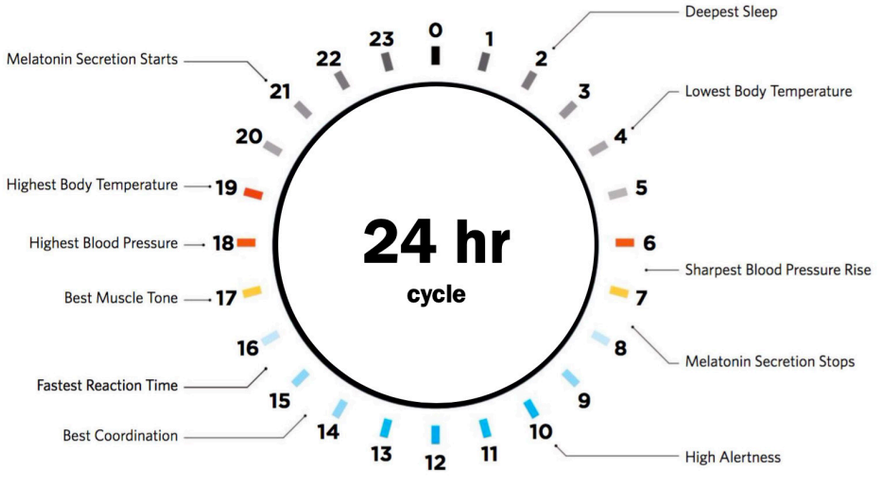
Opsin 4 (Melanopic)

Non-visual Sensitivity to Light

Regulates sleep-wake cycle & Alertness

Opsin 5 (Neuropic)

Regulates temperature and metabolic rate



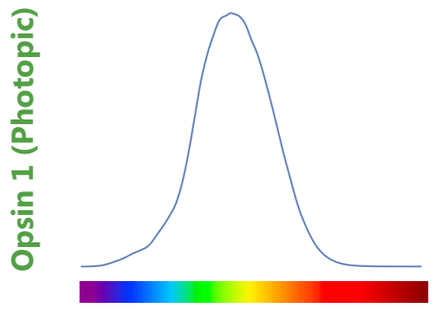
Together, inputs from opsins regulate neuro-endocrine responses in our body

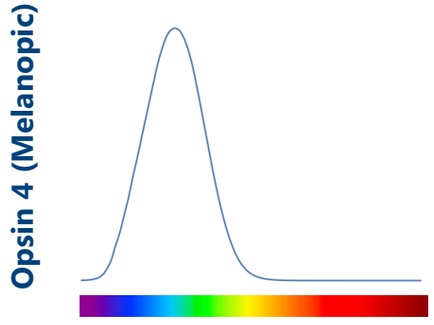
Spectral Interaction with daylight

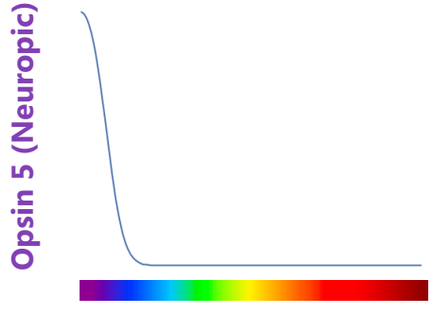
Reflected Light Entering eyes

Energy level of reflected light entering our eyes

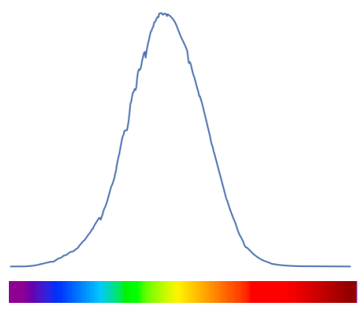
×



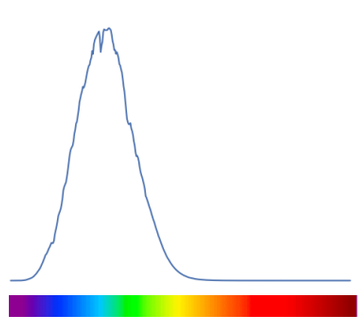




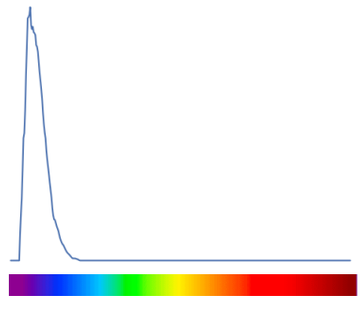
=



400 lux

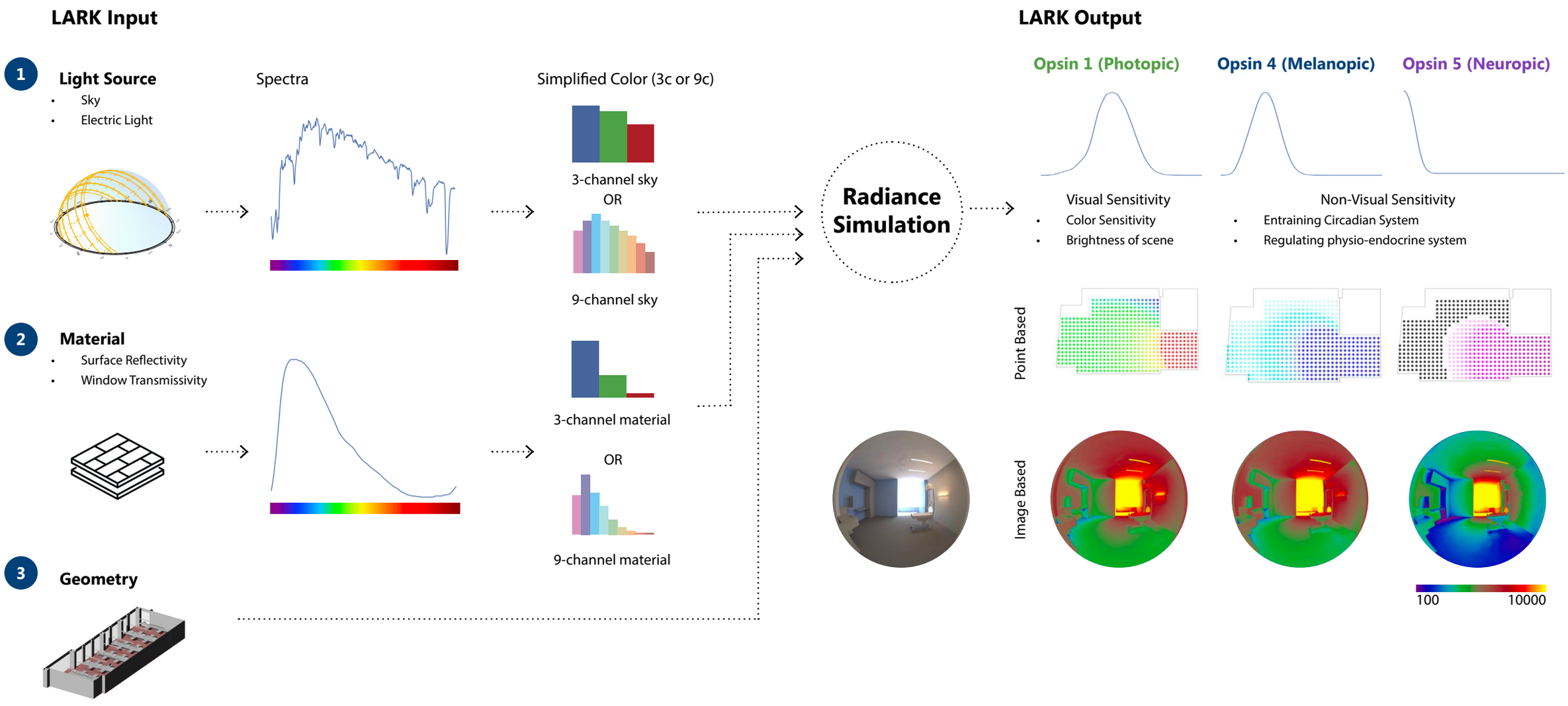


300 lux



100 lux

LARK



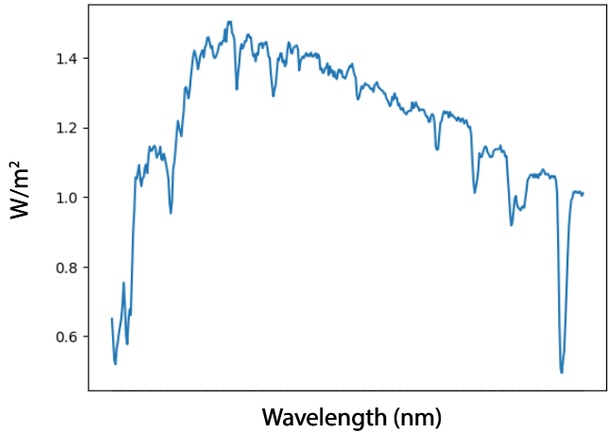
LARK Input
1
Light Source
Sky
Electric Light
Spectra
Simplified Color (3c or 9c)
3-channel sky
OR
9-channel sky
2
Material
Surface Reflectivity
Window Transmissivity
3-channel material
OR
9-channel material
3
Geometry
Radiance Simulation
LARK Output
Opsin 1 (Photopic)
Opsin 4 (Melanopic)
Opsin 5 (Neuropic)
Visual Sensitivity
Color Sensitivity
Brightness of scene
Non-Visual Sensitivity
Entraining Circadian System
Regulating physio-endocrine system
Point Based
Image Based
100
10000

LARK v1.0

Correlated Color Temperature in K (Kelvin)

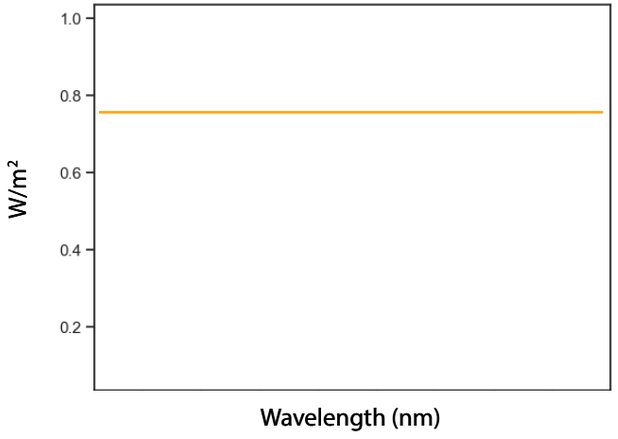
2000 3000 5000 6500 25000

1 Sky (Diffuse horizontal)

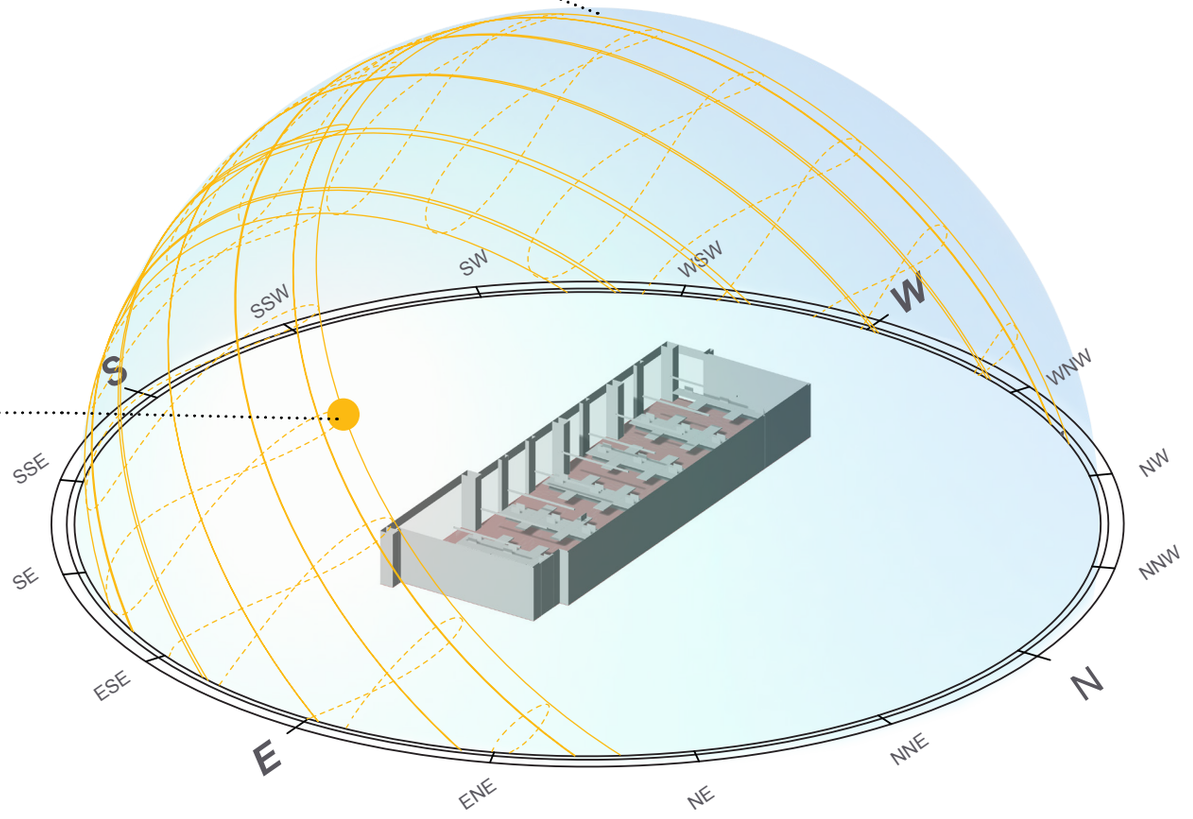


5600 K

2 Sun (Direct Solar)



5500 K

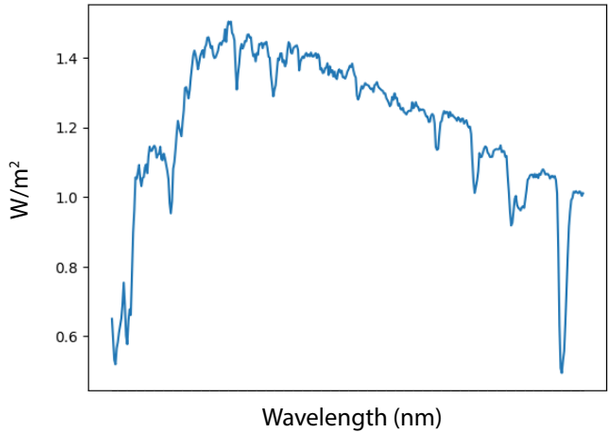


LARK v3.0

Correlated Color Temperature in K (Kelvin)

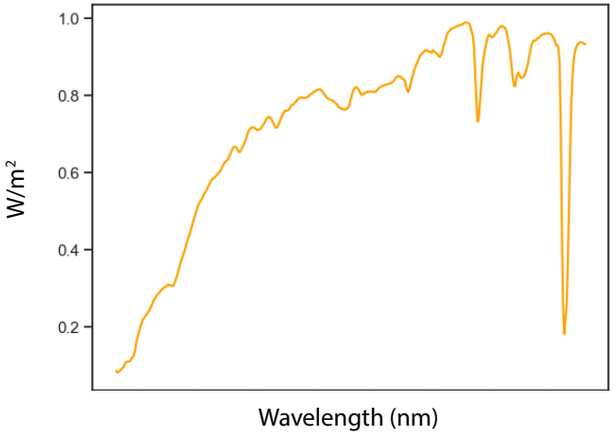
2000 3000 5000 6500 25000

1 Sky (Diffuse horizontal)

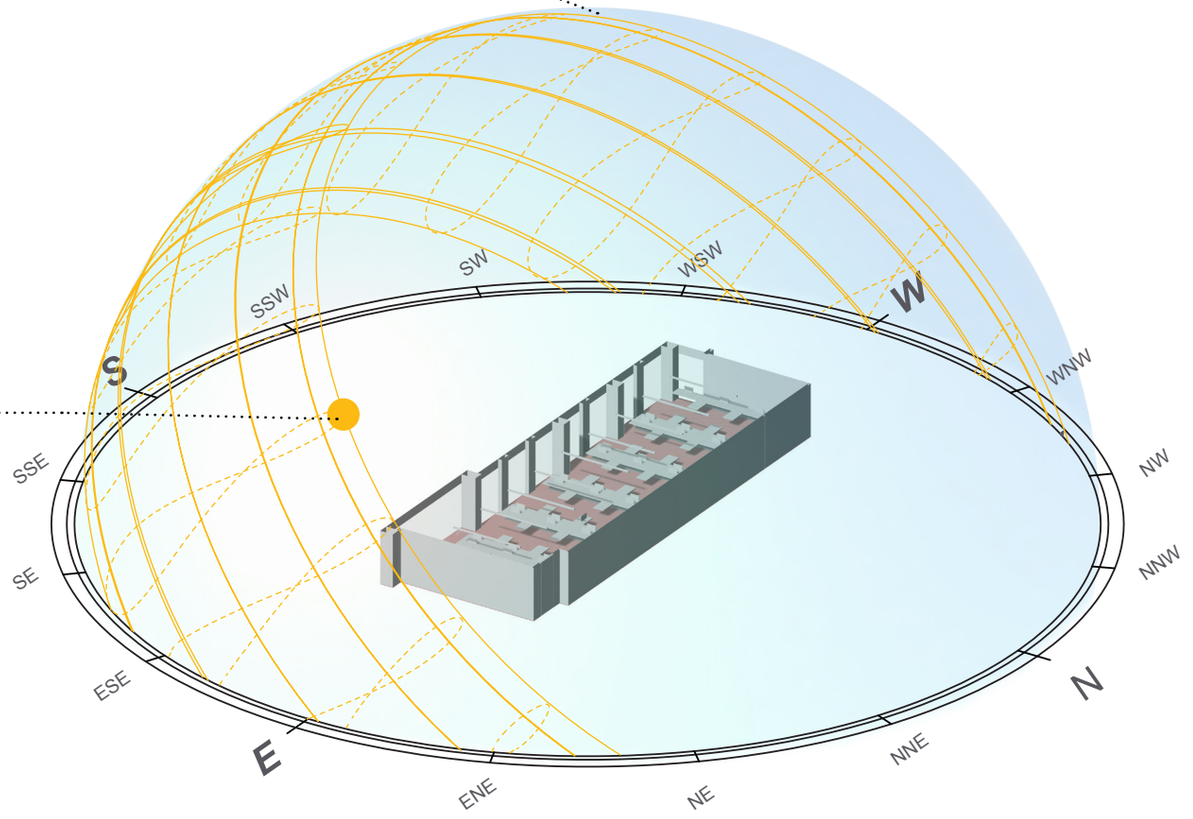


5600 K

2 Sun (Direct Solar)



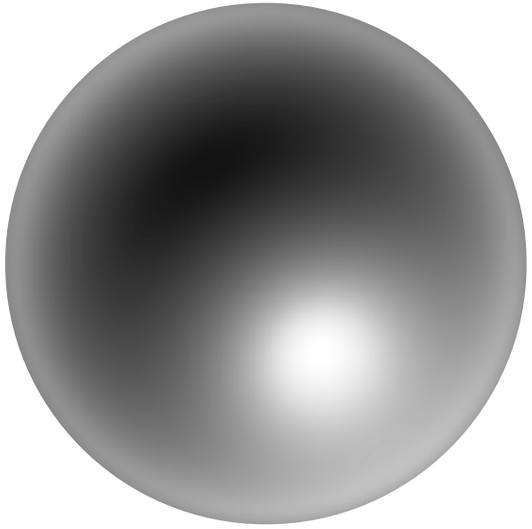
4250 K



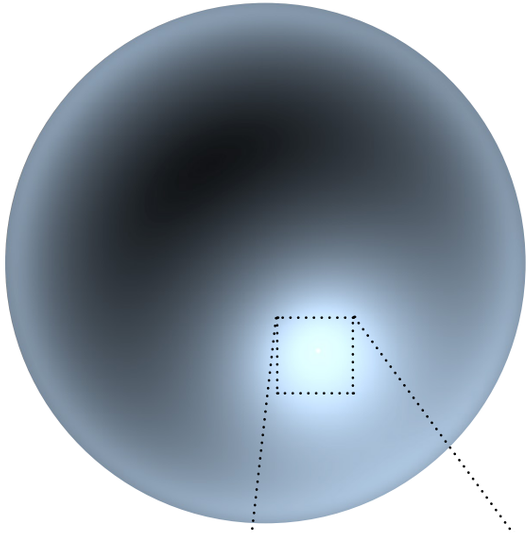
Spectral Sky + Sun - why is it important?

June 21 10am - Clear Sky

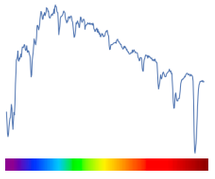
No Color



Colored Sky (V.0)

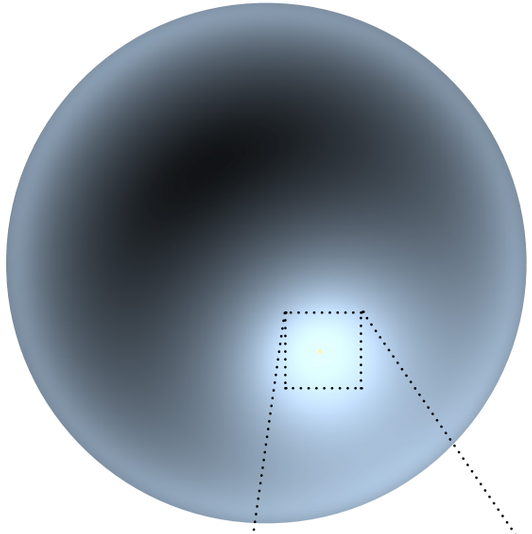


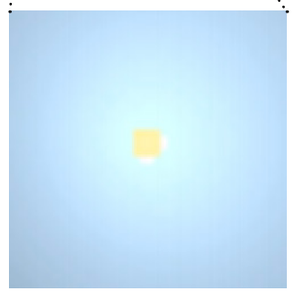
Sun

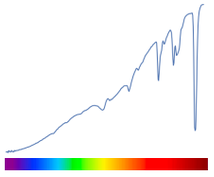


Sky

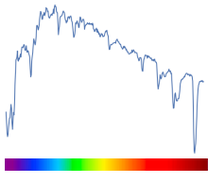
Colored Sky + Colored Sun (V.3)







Sun



Sky

Intensity of the sky:

167 W/m2

X5 intensity

Color of the sun has large impact in the amount of light received

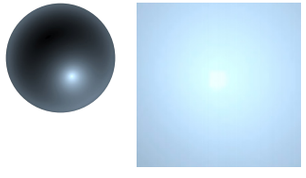
Intensity of the sun:

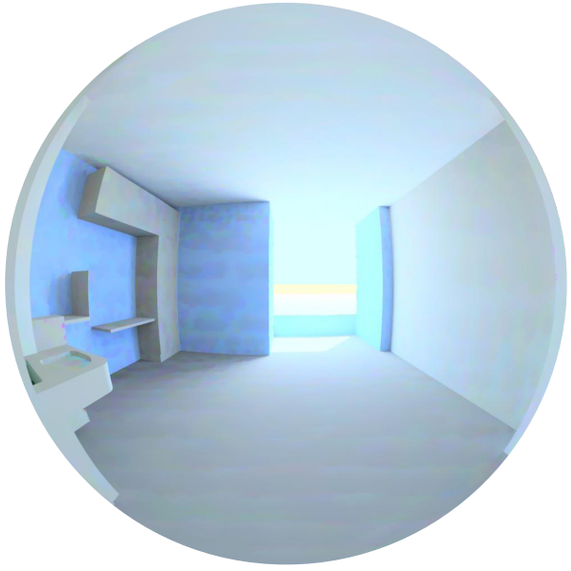
863 W/m2

Spectral Sky + Sun - why is it important?

7000K sun + 9000K sky

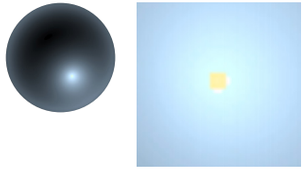
June 21 10am

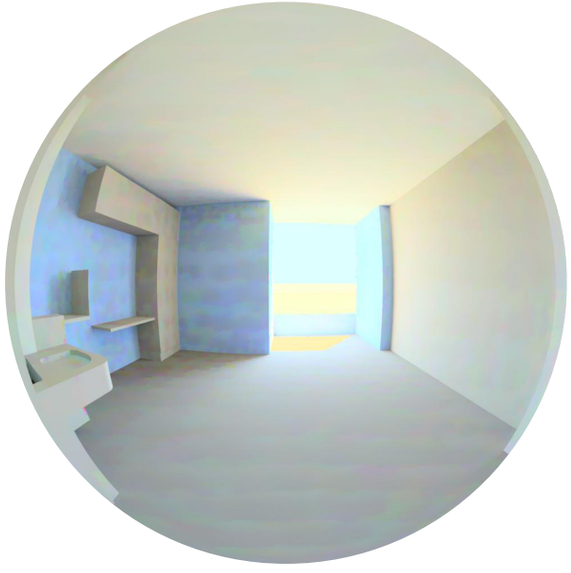




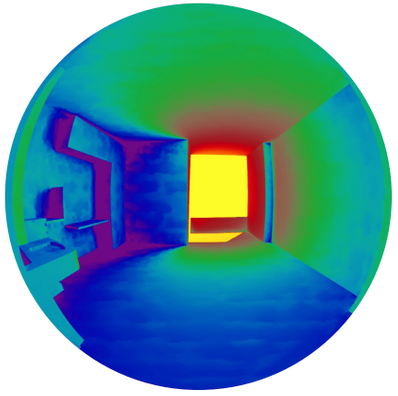
3000K sun + 9000K sky

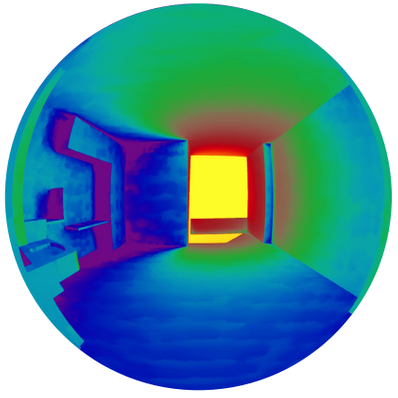
June 21 10am





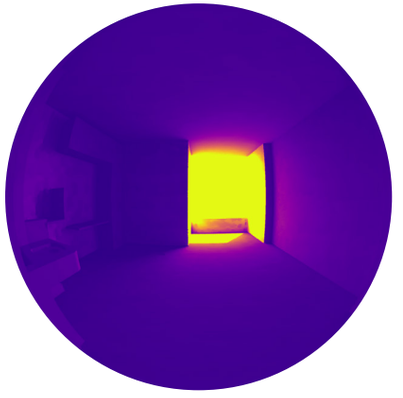
Photopic





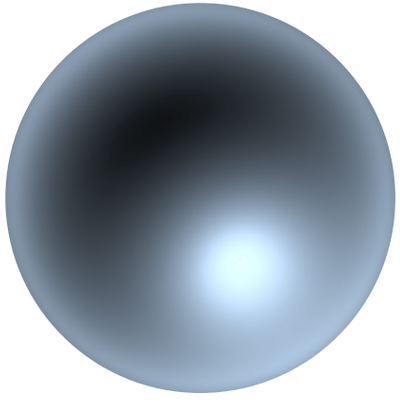
Melanopic

Neuropic

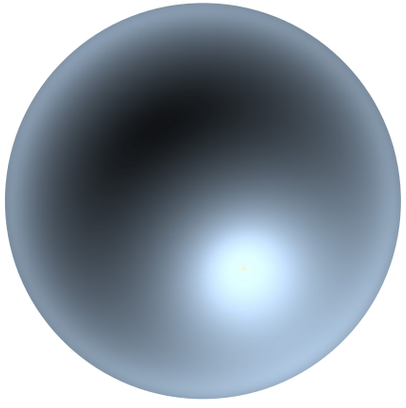


cd/m²

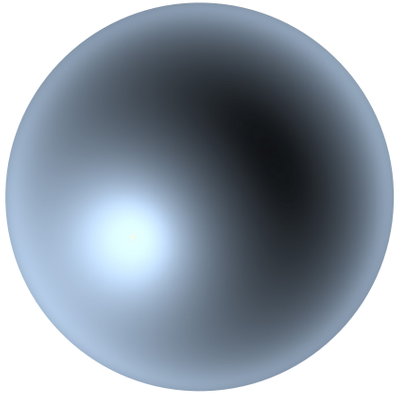
Spectral Sky + Sun - why is it important?



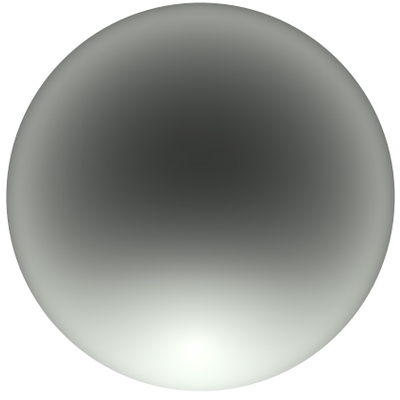
clear
9000k sky + 3000k sun



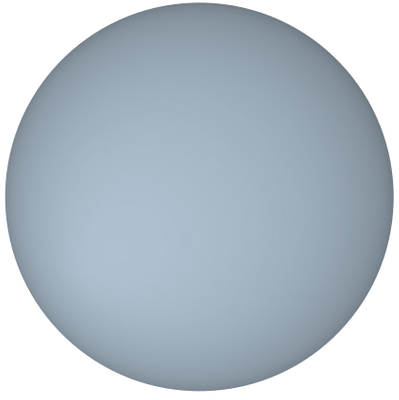
clear
9000k sky + 7000k sun



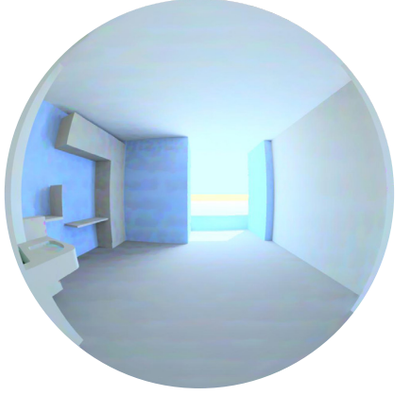
clear
9000 sky + 5000k sun

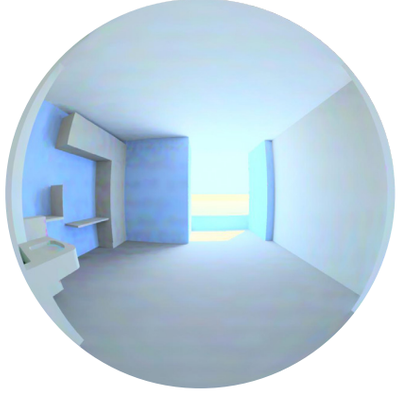


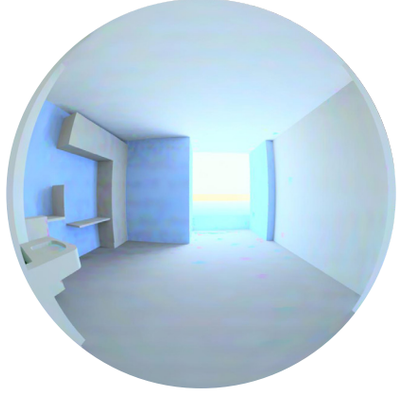
intermediate
5000k sky + 5500k sun

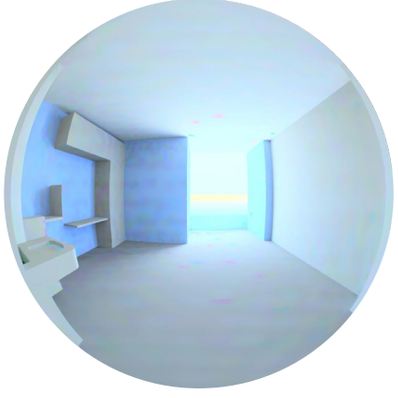


overcast
7000k sky + 3000k sun









Color of the Sun

2020 Solar Spectra Data

↓

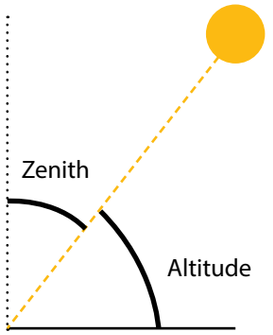
Clean Data
Cull Night Time
Cull measurement Erros

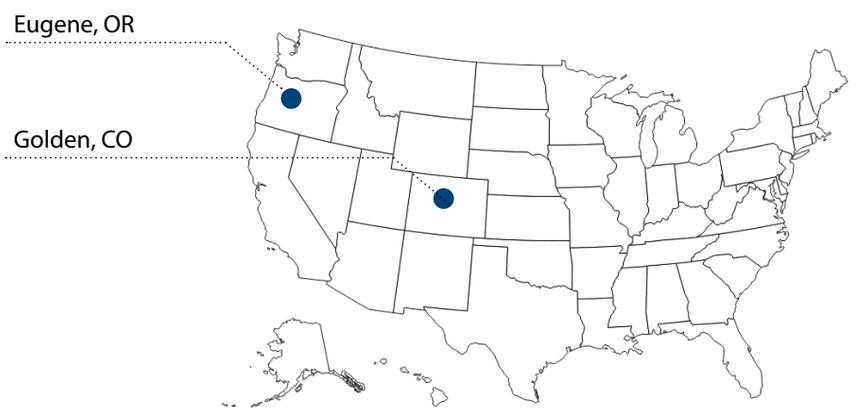
↓

Categorize Data
Overcast
Intermediate
Clear Turbid
Clear

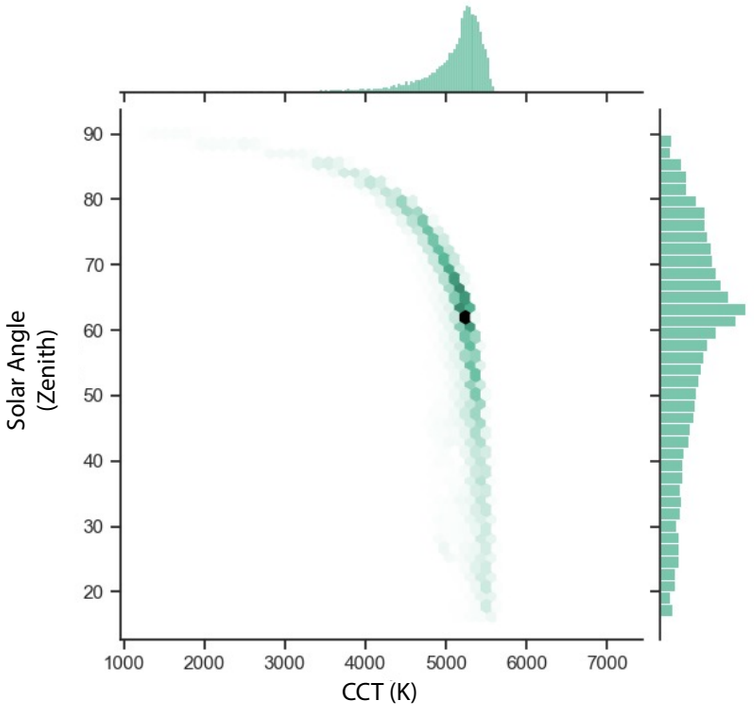
↓

Relationship with Sun Angle

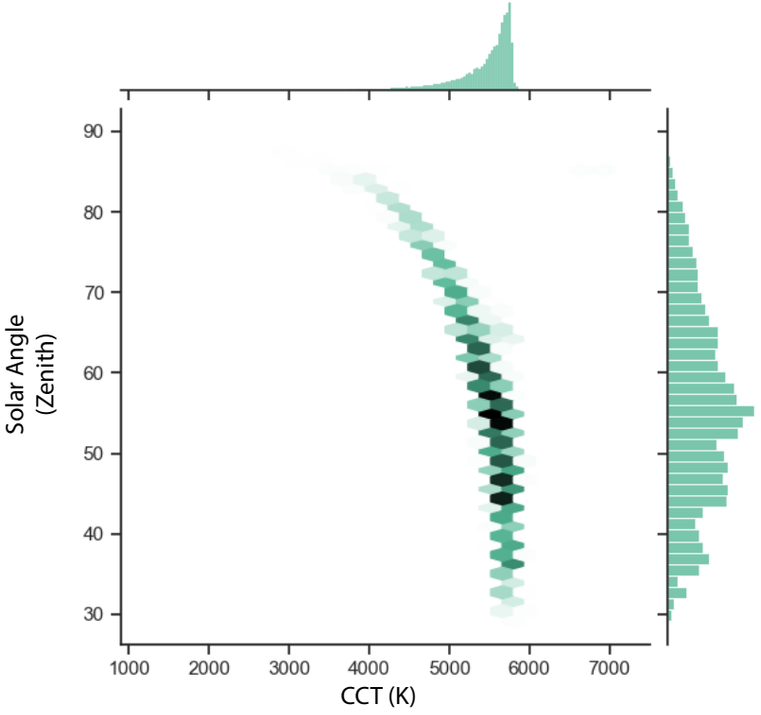




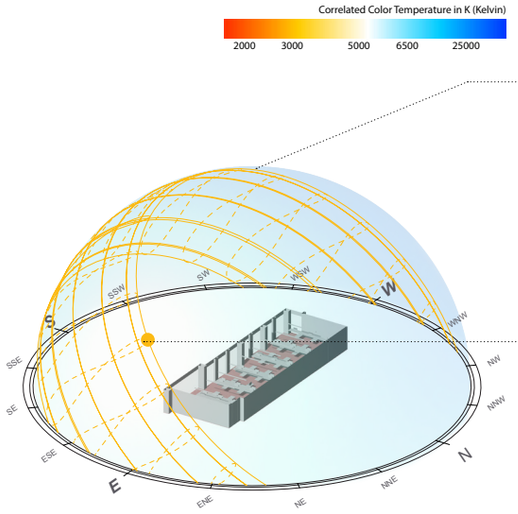
Golden, CO



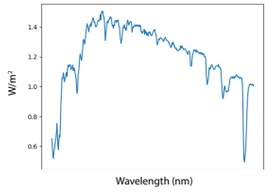
Eugene, OR



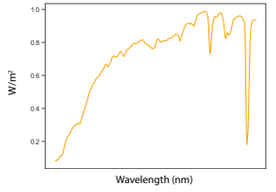
How to put in Sky + Sun in LARK



1 **Sky (Diffuse horizontal)**

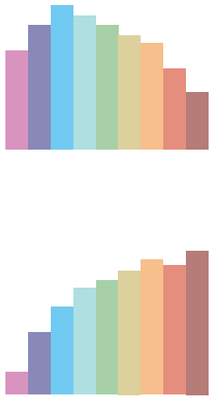


2 **Sun (Direct Solar)**

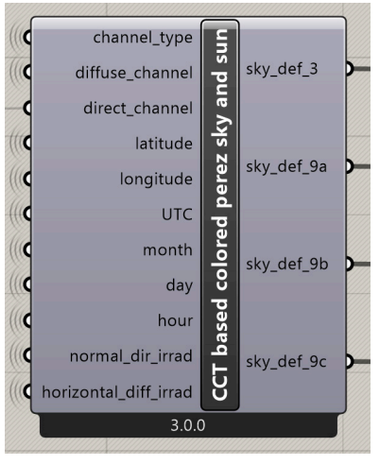


Full spectrum

- Measured (user input)
- Default values

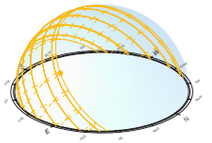


Simplified
9C color representation



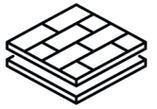
1 **Light Source**

- Sky
- Electric Light

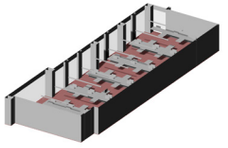


2 **Material**

- Surface Reflectivity
- Window Transmissivity



3 **Geometry**



Radiance Simulation

Conclusions

- LARK v3.0 scheduled to be realised by June 15th
- Conference paper for IBPSA
  (Jung BY, Cheng Z, Brennan M, Inanici M. Multispectral Lighting Simulation Approaches for Predicting Opsin-driven Metrics and their Application in a Neonatal Intensive Care Unit. Paper presented at: 18th International IBPSA Conference and Exhibition; 2023 Sept 4-6; Shanghai, China.)
- Color of the sun largely impacts quality of light and finding the variability of sunlight is a major contribution to the scientific community
- This finding is going to be submitted for publication in LEUKOS -Journal of Illuminanting Engineering Society
  (Jung BY, Brennan M, Inanici M. Variability of sun spectra: findings from collected data. Leukos, the Journal of the Illuminating Engineering Society)
- Acknowledgement - sky spectra data collected on Gould Hall funded by UW & ARC
- Continuing this research for my PhD

Next Steps

- Add sample database for sun spectra based on CCT
- Create LARK tutorial videos

LARK

SPECTRAL LIGHTING

v3.0