



Managing lighting applications with three spectral indices

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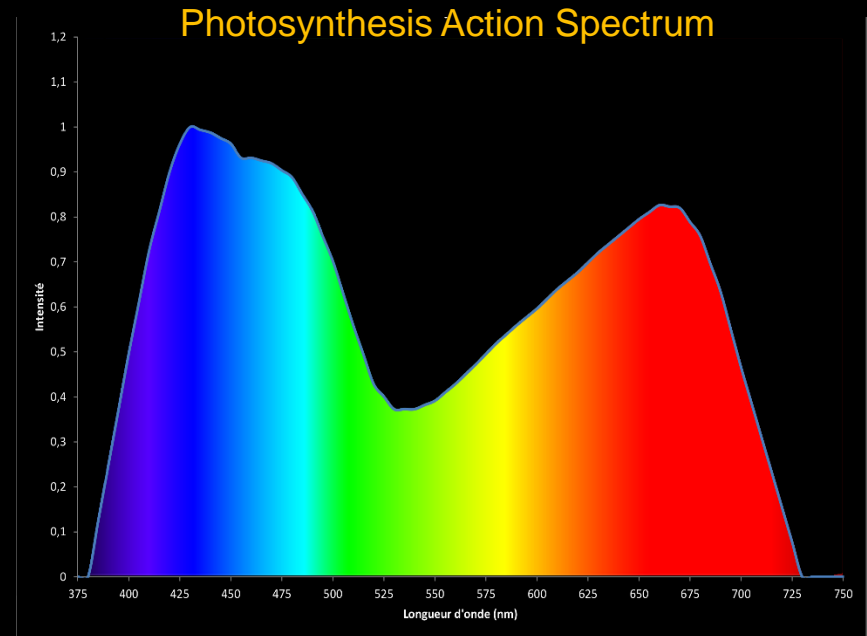
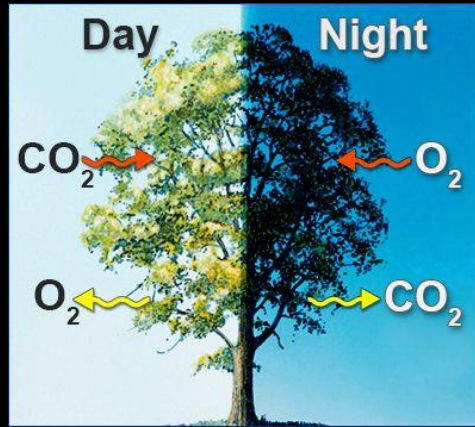
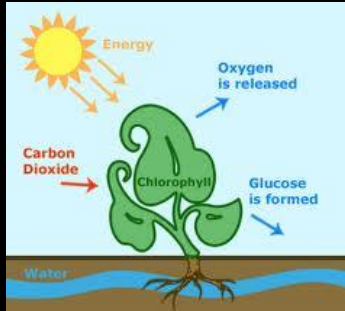
Cégep de Sherbrooke, Québec, Canada

Artificial light at night increases every year....

- In the last ~130 years:
 - The intensity and duration of ALAN are on the rise.
 - The duration of artificial illumination has increased by up to 7h per day.
 - The people spend more time indoors under artificial lights
- ALAN has many impacts on fauna, flora, human health and starry sky.
- How to manage the artificial lighting in order to evaluate the impact on the environment?
- Actual metrics: CCT and CRI

Role of natural light in biological processes

In photosynthesis



- Photosynthesis is a process where a plant transforms solar light into organic compounds.
- Some reactions occur during the day period and some during the night period.
- Chlorophyll is the most important and common in all vegetable species.

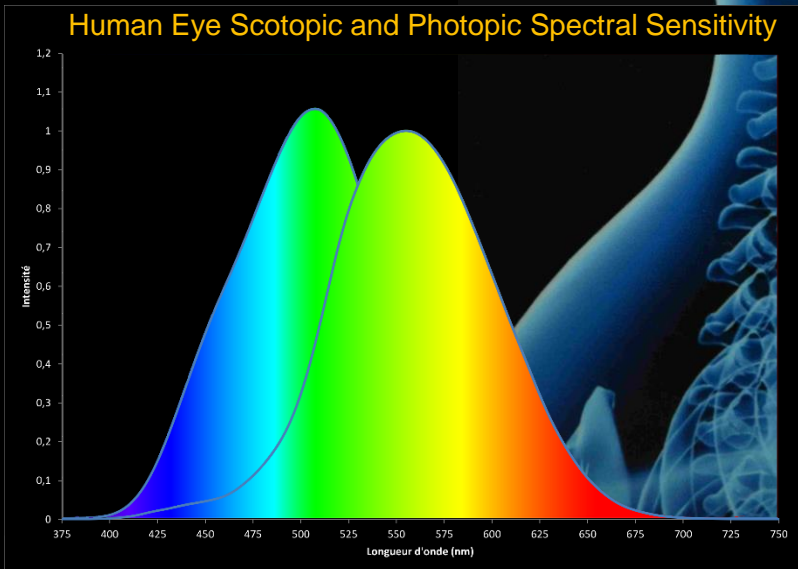
Role of natural light in human biological processes

Light is crucial for visual biological process:

- Photopic vision
- Scotopic vision

Visual fonction

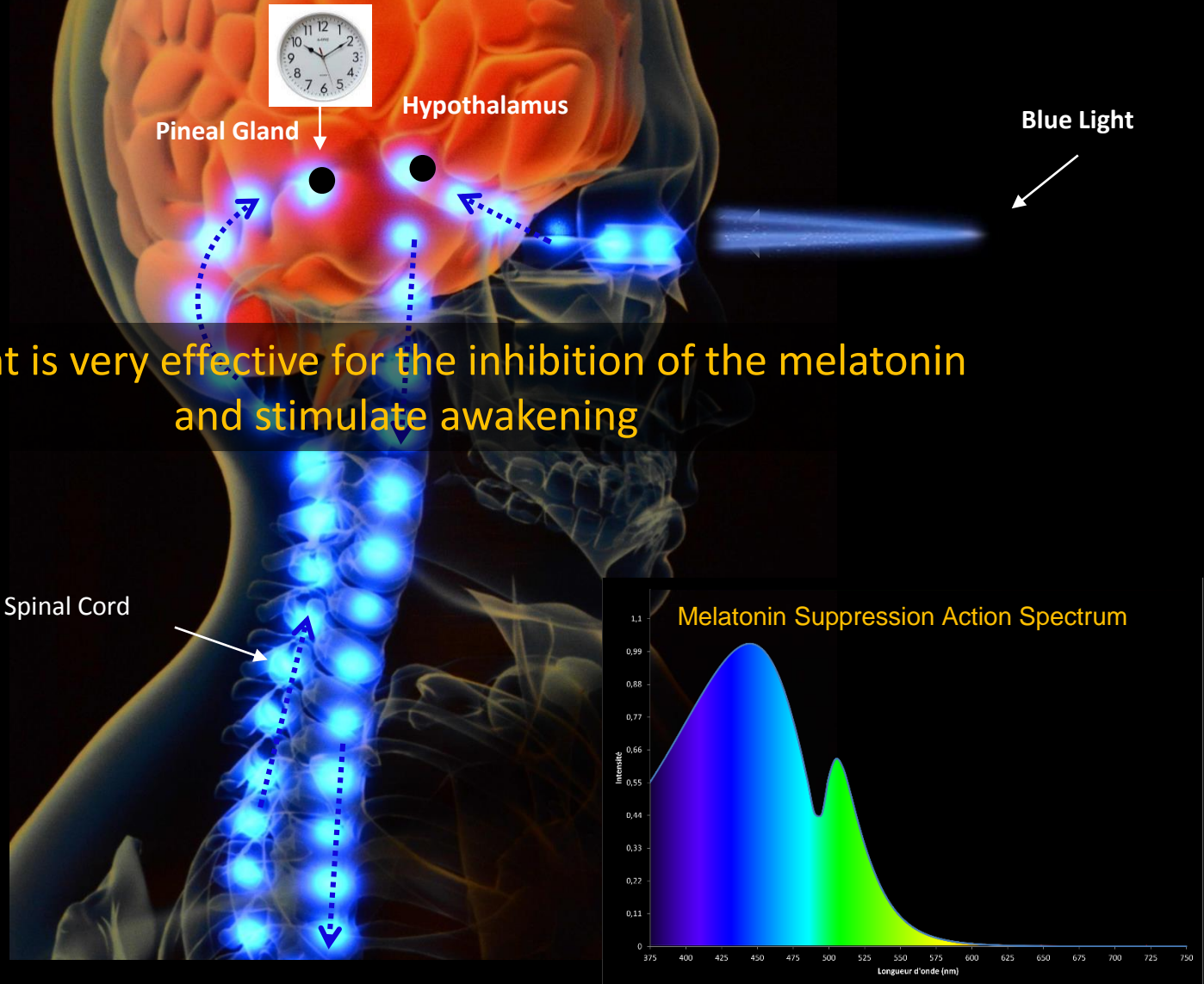
Light



Role of light on the biological processes

Light is crucial for non-visual biological process

- synchronization of the circadian system

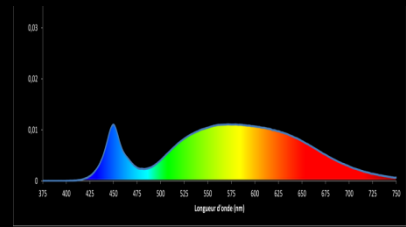
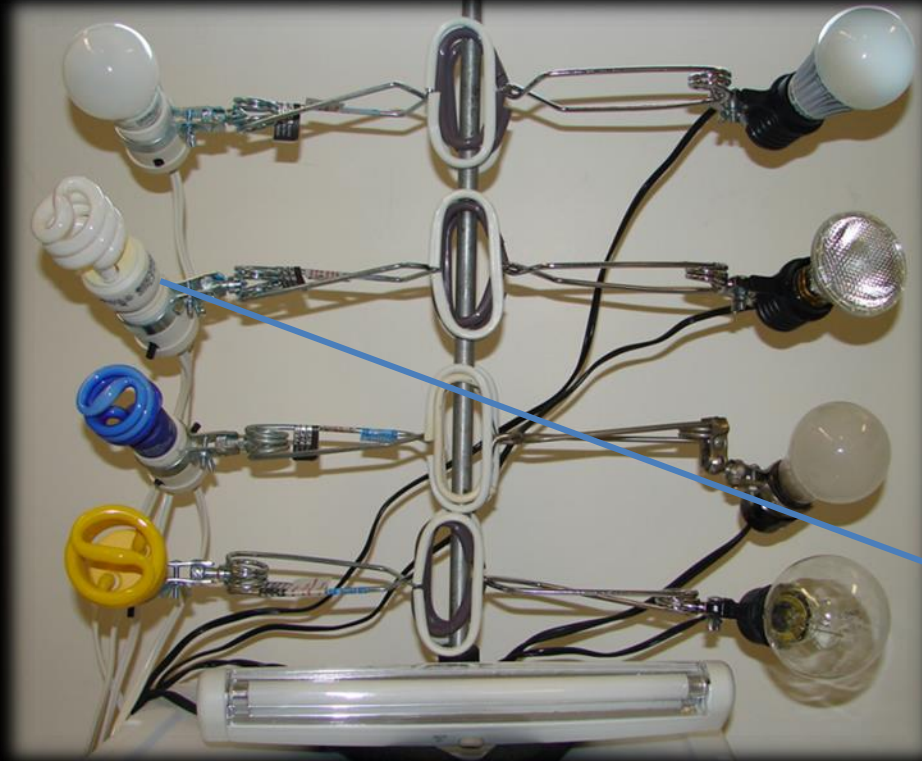
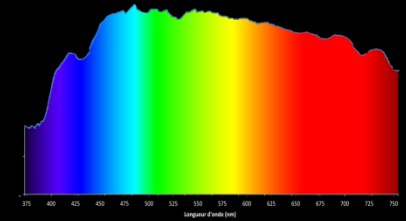


Blue light is very effective for the inhibition of the melatonin and stimulate awakening

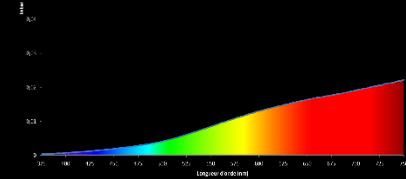
The impact of natural light on many biological processes is highly linked to the spectrum of emitted light

- wavelength color and light intensity

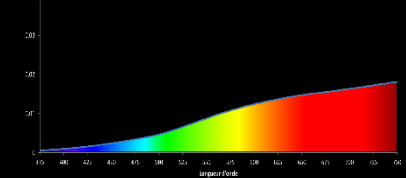
Indoor Artificial Light versus Natural light



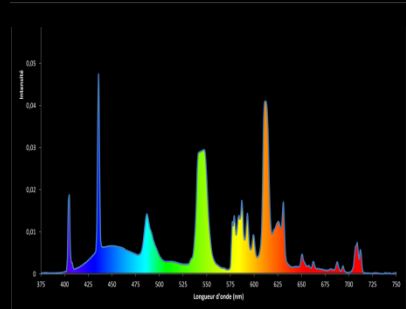
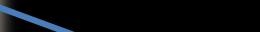
LED



Halo

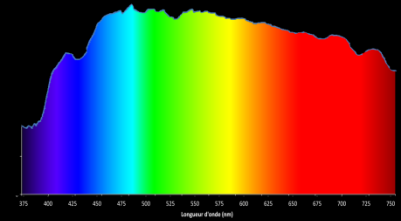


INC

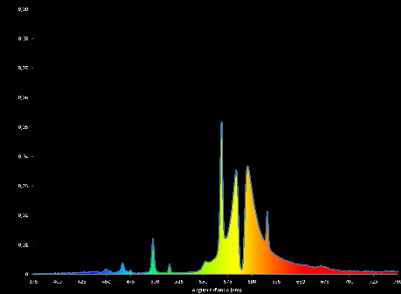


CFL

Outdoor Artificial Light versus Natural light

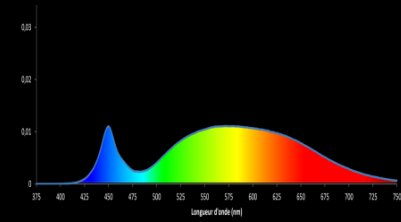


HPS



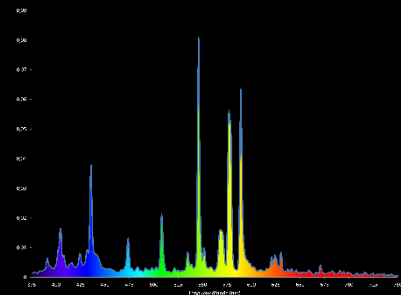
HPS

LED



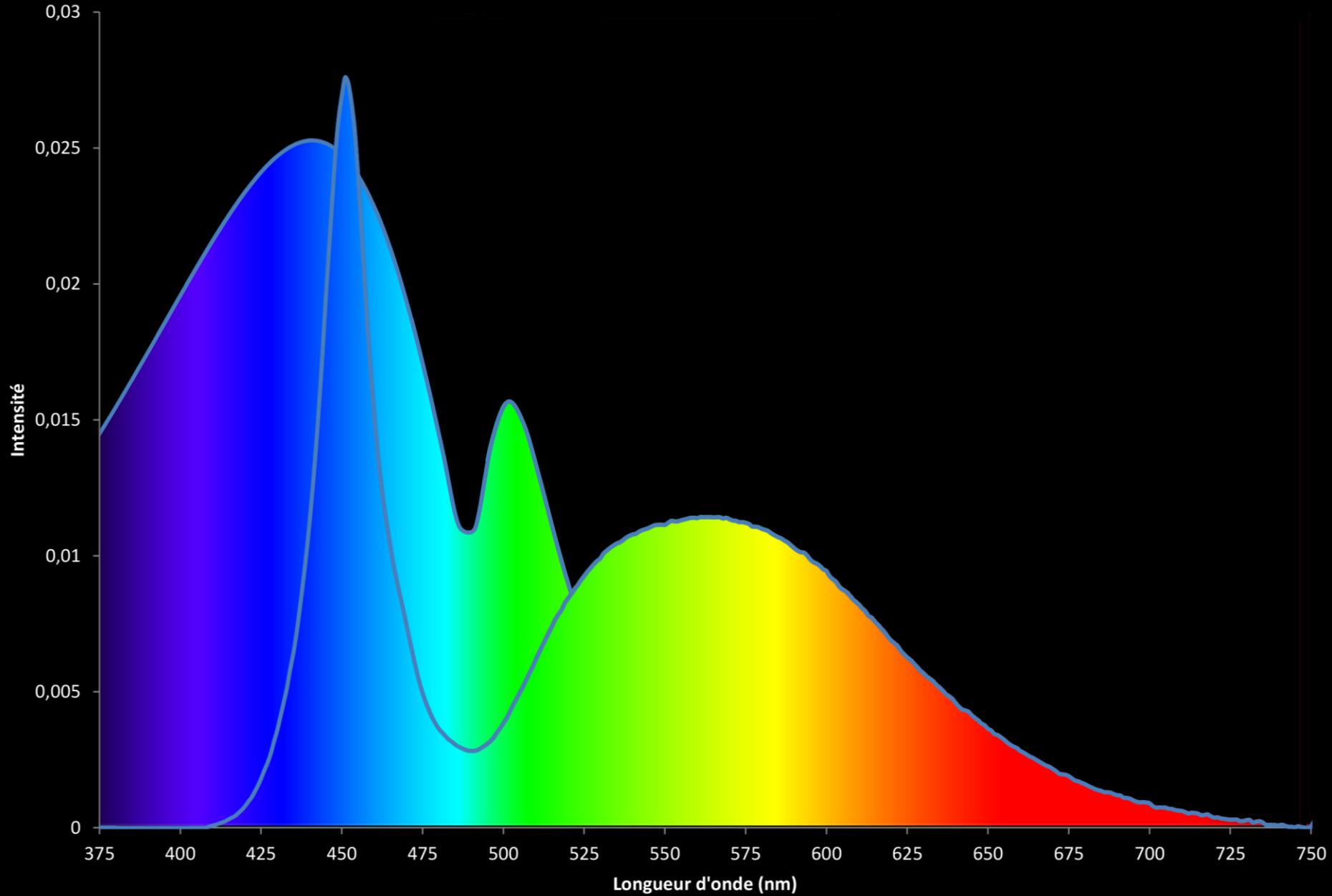
LED

MH



MH

Cool White LED and Melatonin Suppression Action Spectrum



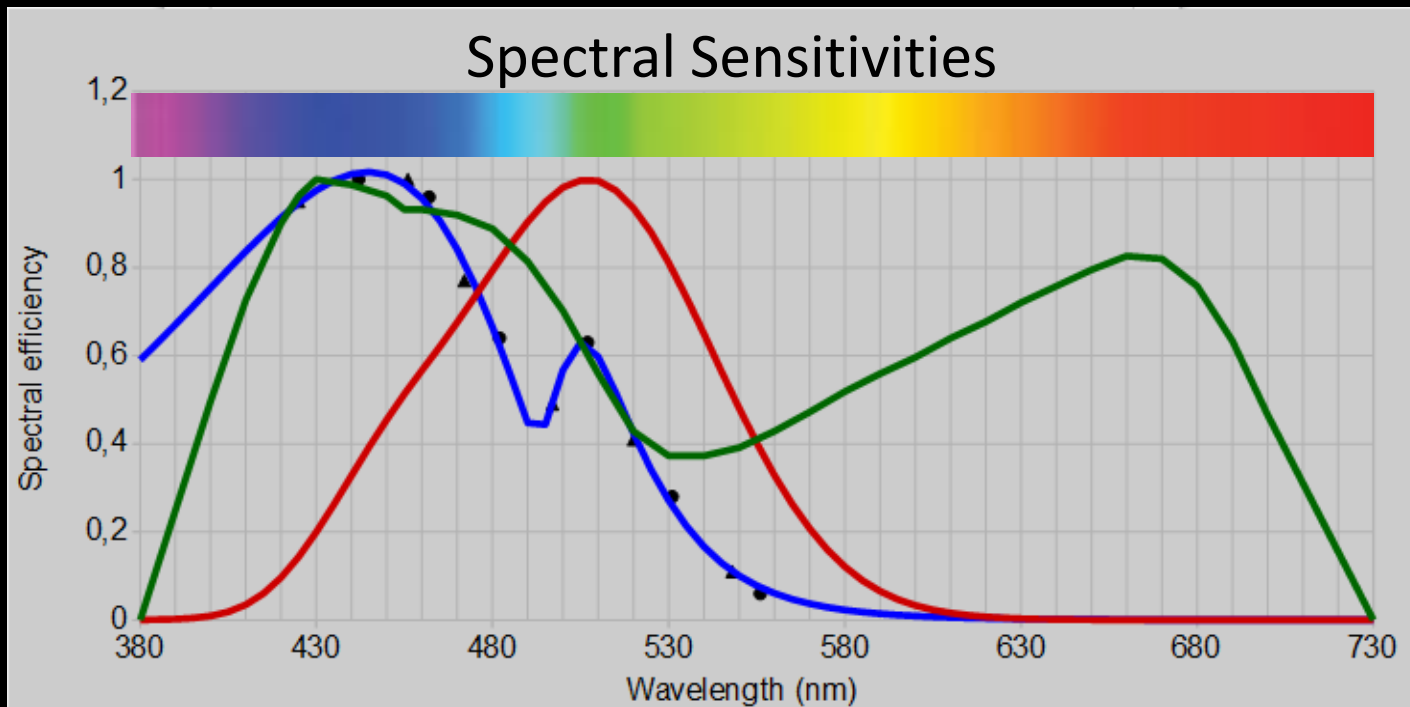
What could we do to manage lighting?



Control:

- The orientation of emitted light (Ex: Cobrahead to Helios);
- The amount of emitted light (diminution of the radiant power);
- The lighting period (closing time, motion detector, etc.);
- The spectrum of emitted light We need good metric for its evaluation

Development of 3 New Spectral Indices

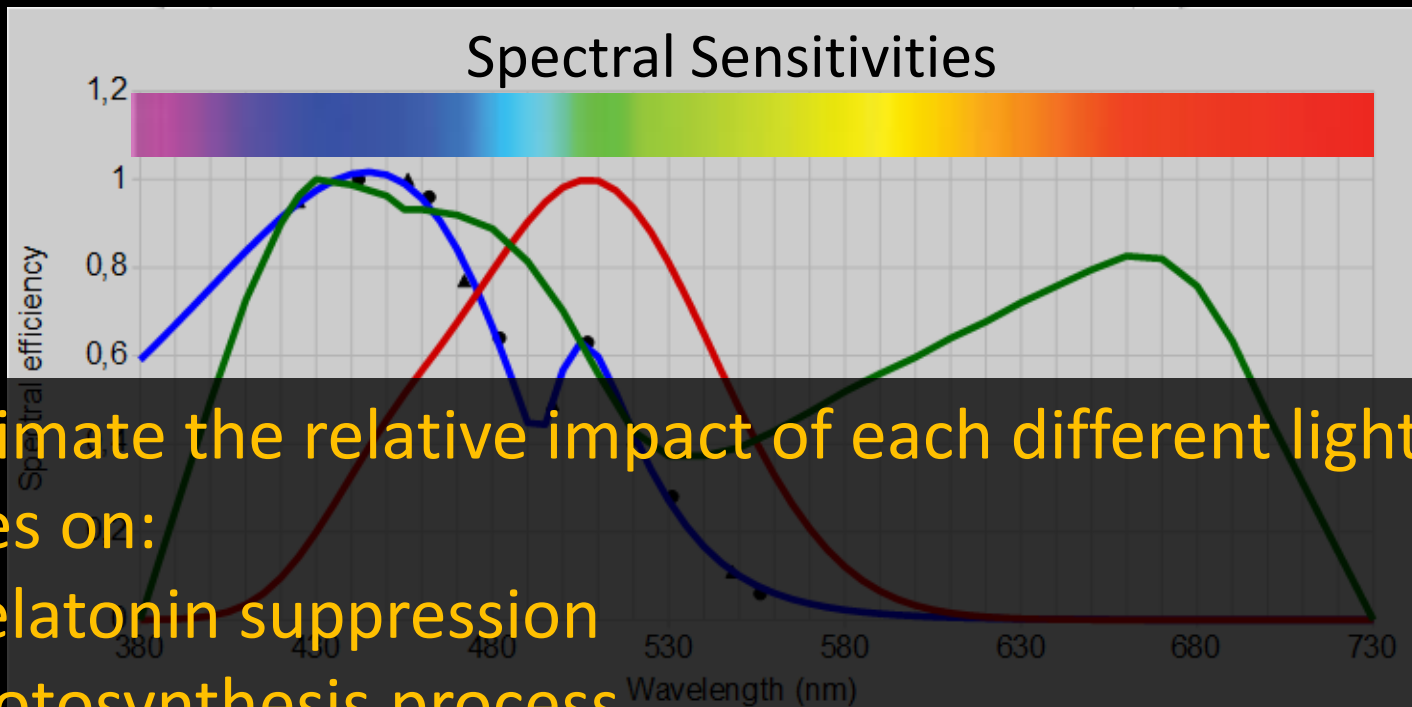


— MSI: Melatonin Suppression Index

— IPI: Induced Photosynthesis Index

— SLI: Star Light Index

Development of 3 New Spectral Indices



To estimate the relative impact of each different lighting devices on:

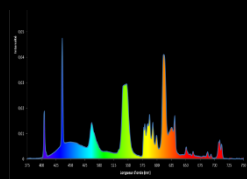
- melatonin suppression
- photosynthesis process
- star visibility

— MSI: Melatonin Suppression Index

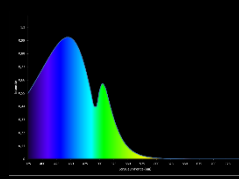
To help authorities and the population manage lighting

— SLI: Star Light Index

Exemple for MSI (Melatonin Suppression Index)

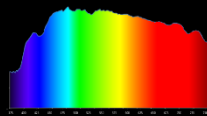


Lamp SPD



Melatonin Suppression Action Spectrum

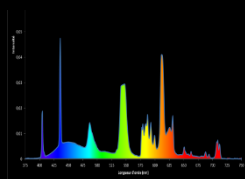
$$MSI = \frac{\int_{380nm}^{730nm} \Phi_{n(lamp)}(r, \lambda) M(\lambda) d\lambda}{\int_{380nm}^{730nm} \Phi_{n(D65)}(r, \lambda) M(\lambda) d\lambda}$$



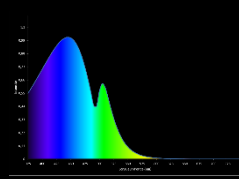
Reference SPD (Sun)

$$MSI = \frac{\text{Sum (Constant lumen spectrum x Melatonin suppression action spectrum)}}{\text{Sum (Constant lumen SOLAR spectrum x Melatonin suppression action spectrum)}}$$

Exemple for MSI (Melatonin Suppression Index)



Lamp SPD



Melatonin Suppression Action Spectrum

$$MSI = \frac{\int_{380nm}^{730nm} \Phi_{n(lamp)}(r, \lambda) M(\lambda) d\lambda}{\int_{380nm}^{730nm} \Phi_{n(incandescent)}(r, \lambda) M(\lambda) d\lambda}$$

Scale Value for Indices: 0 to 1

MSI 0 = no impact on melatonin suppression = use lamp in the evening

1 = strong impact on melatonin suppression = use lamp in the morning

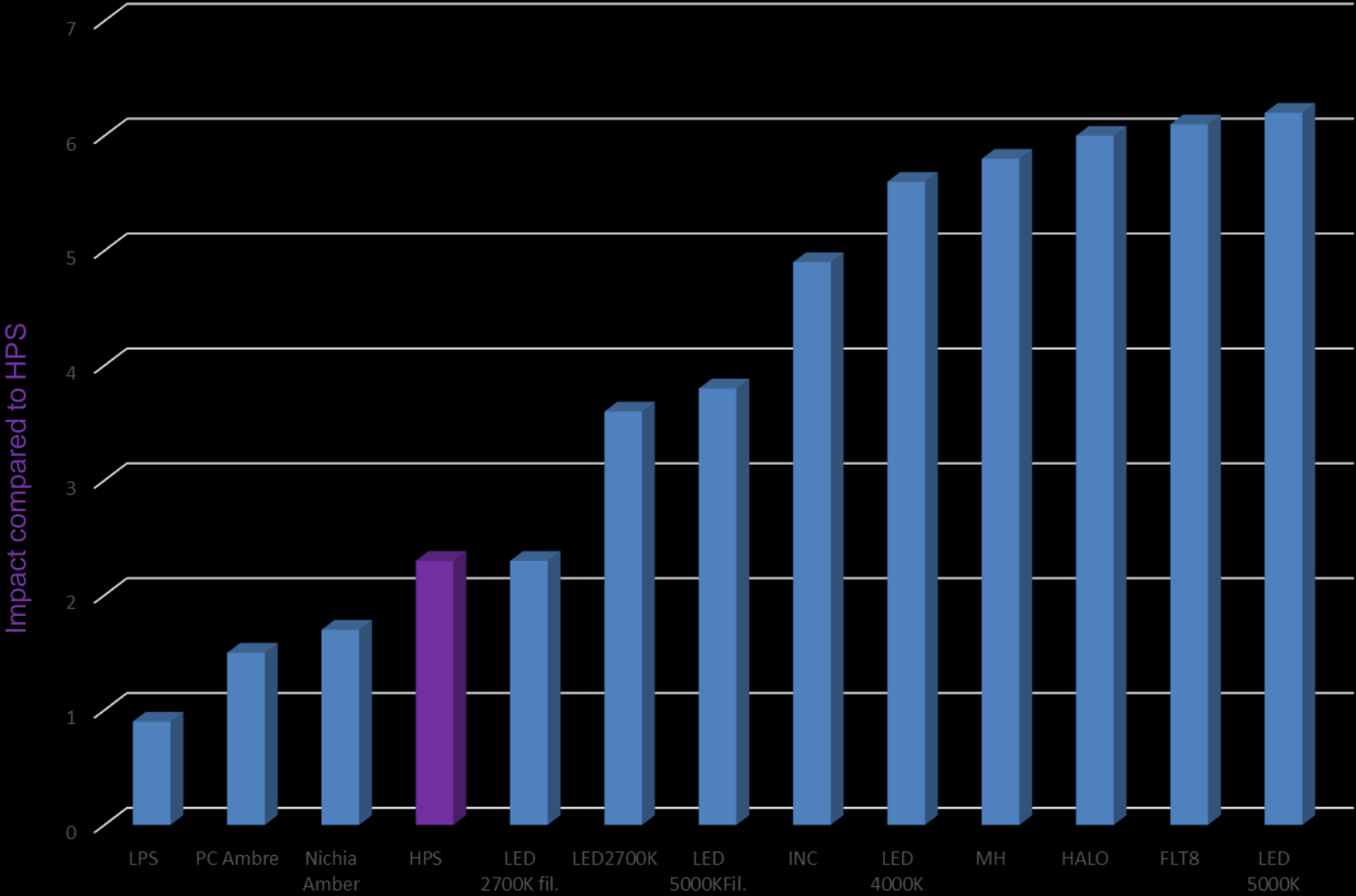
IPI 0 = no impact on photosynthesis processes

1 = strong impact on photosynthesis processes

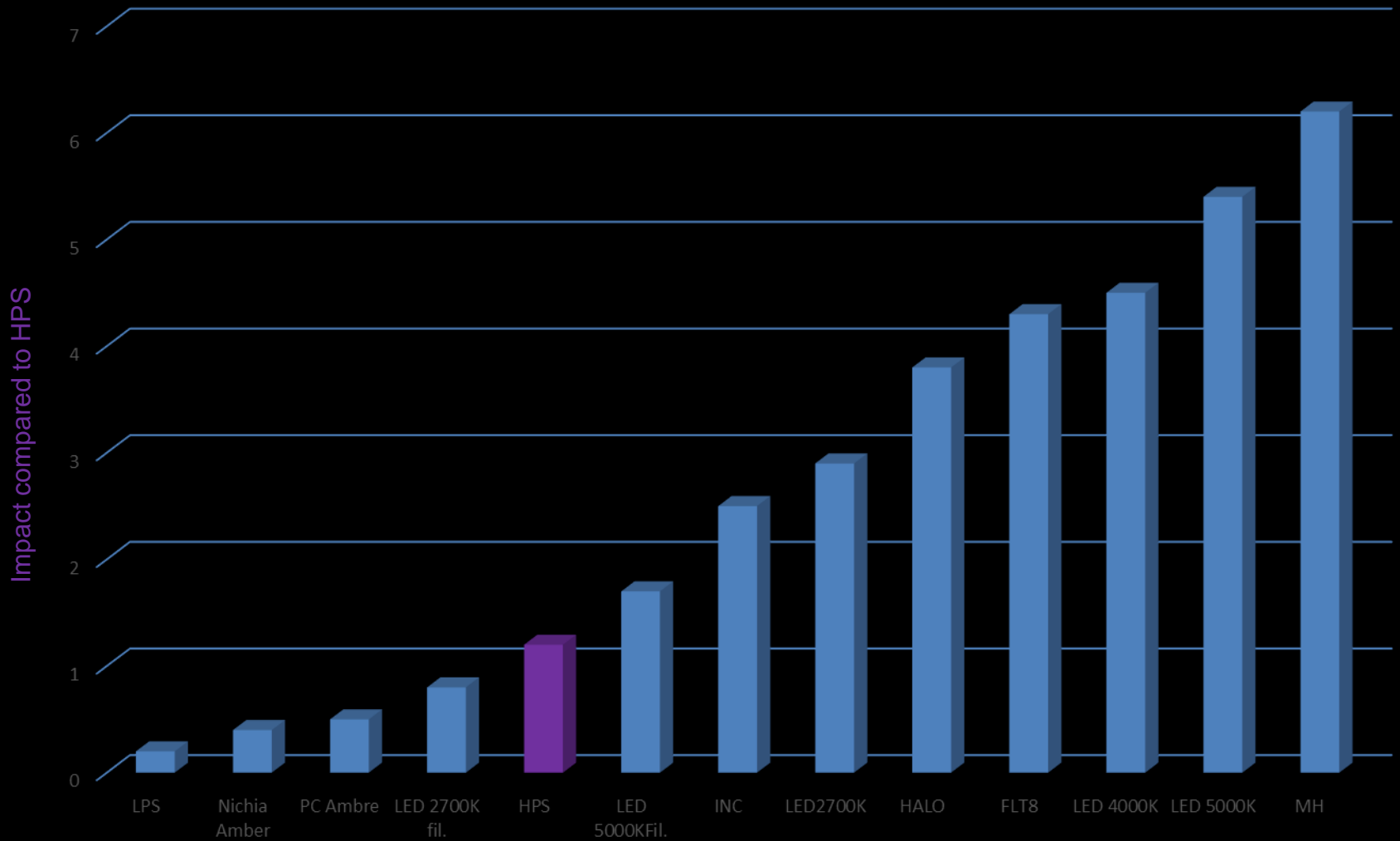
SLI 0 = no impact on the starry sky

1 = strong impact on starry sky = alterate the observation of the sky = our naturel Heritage

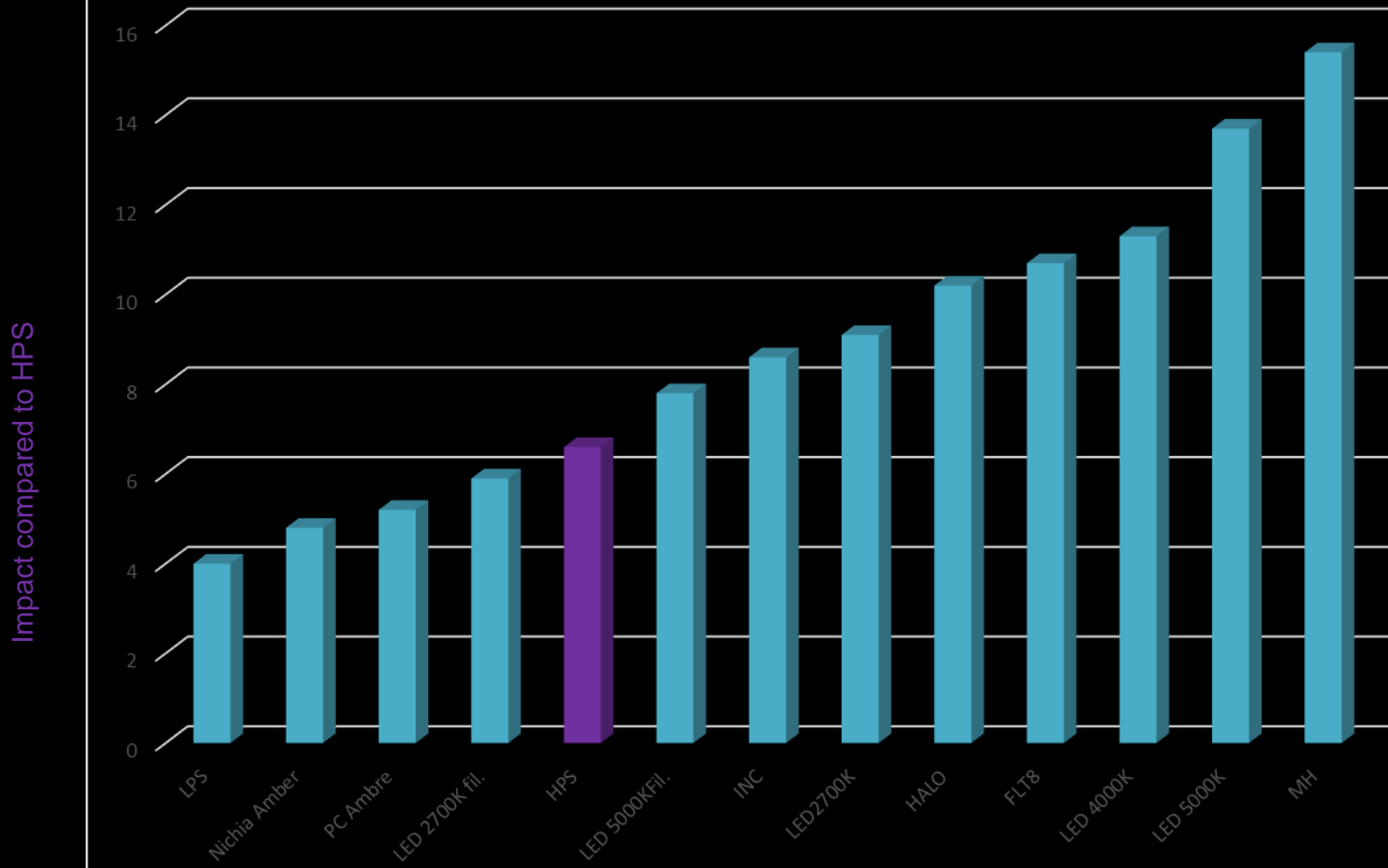
Lamp Impact on Star Light (SLI)



Lamp Impact on Melatonin suppression (MSI)



Lamp Impact on Induced Photosynthesis (IPI)

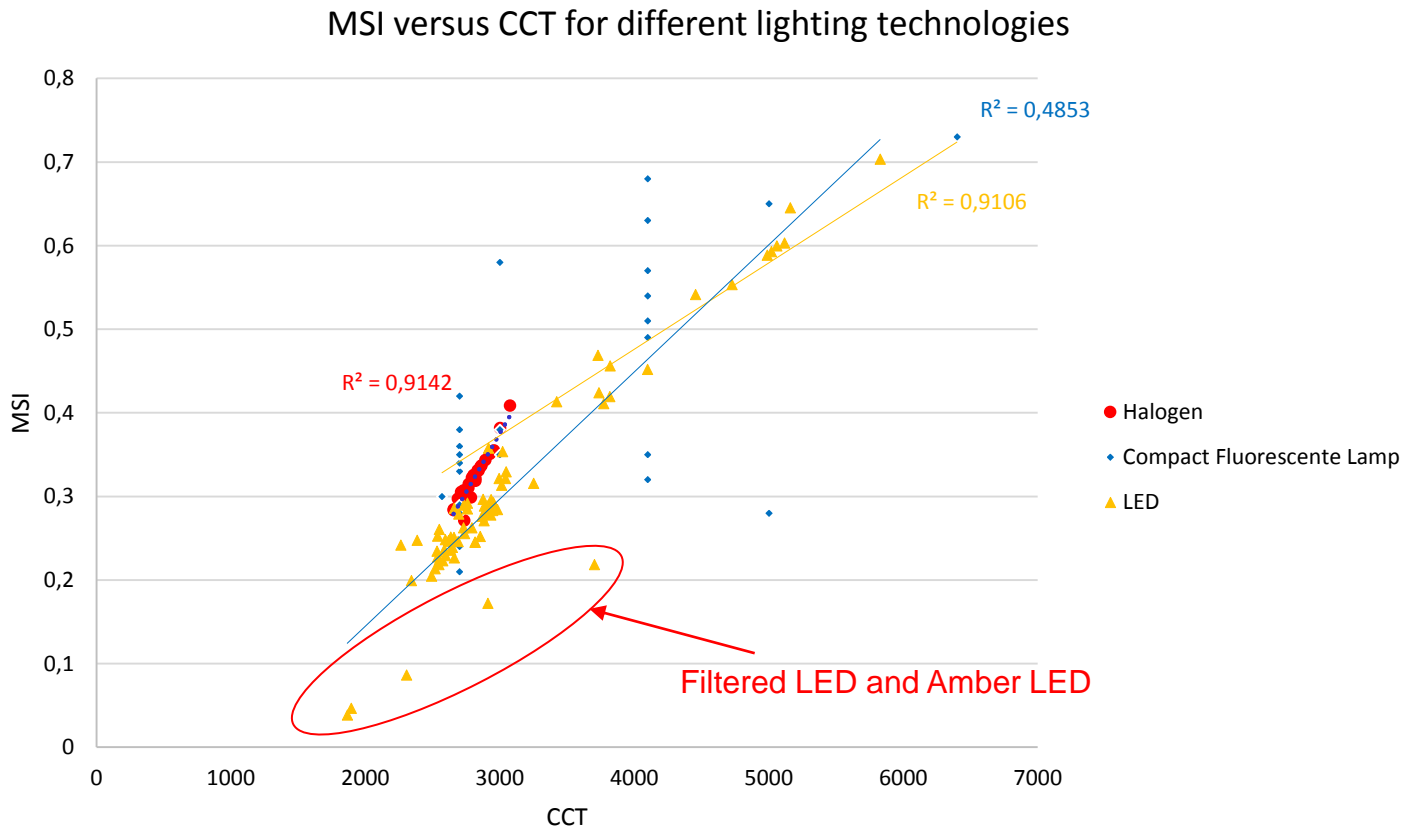


Is CCT is a good metric to manage lighting and evaluate the impact of artificial light on biological processes?

Using our lamps spectral power distribution database (lspdd.org), we evaluate:

- The correlation between different type of devices, CCT, spectral indices and % of short wavelength

Correlation of Indices with CCT for different technologies

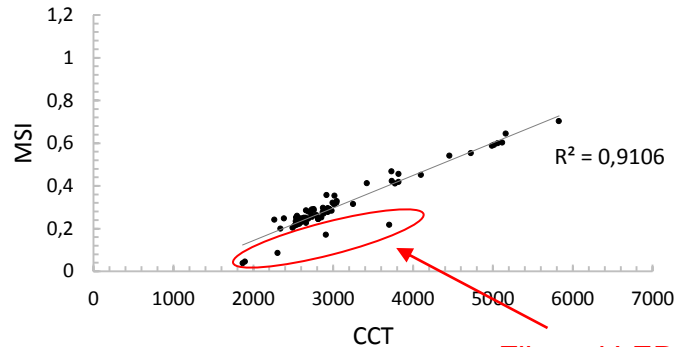


CFL: no significant correlation

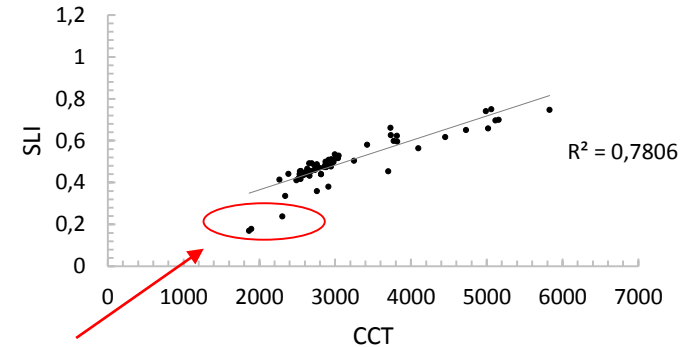
HALO and LED: significant correlation

LED: Correlation of Indices, %Blue with CCT

LED: MSI versus CCT

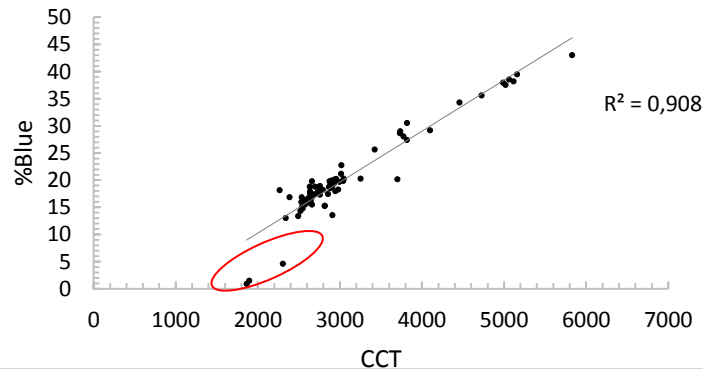


LED: SLI versus CCT



Filtered LED and Amber LED

LED: % Blue* versus CCT



For MSI, SLI: significant correlation
If we modify the technology: correlation changes
For % short wavelength (Blue): significant correlation

*% Blue = $\frac{405\text{nm}-530\text{nm}}{380\text{nm}-730\text{nm}} \times 100$

Conclusion

- We introduced three new indices to characterize lighting devices using the Spectral Power Distribution Data.
- These indices have been designed to allow a quick estimation to evaluate the lighting devices.
- Melatonin Suppression Index (MSI), Star Light Index (SLI) and Induced photosynthesis (IPI) Indices are good metrics to evaluate the impact on biological processes, whereas CCT is not a appropriate metric.
- The correction between CCT and Indices are unclear.
 - We found significant correlation between Indices and CCT for some lighting technologies.