Human Centric Lighting needs new quantities for light intensity

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Light for life: are we using the right light?

.....too little light in daytime

.....too much light by night

consequences

- circadian misentrainment
  problems with body clock, similar to jet-lag
- problems with sleep & alertness
- compromised mood, functioning, well-being and health....

HUMAN CENTRIC LIGHTING:

designed to benefit human health & wellbeing

the right light, at the right time & place

Human Centric Lighting:
non-visual responses to light

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CONNECTING OPPORTUNITIES FOR INNOVATION

- Increasing light intensity (and blue content):
  increases alertness (all times of day)
- Decreasing light intensity (and blue content):
  supports relaxation (all times of day)
- Light at night must be handled with care:
  not to disrupt sleep and health

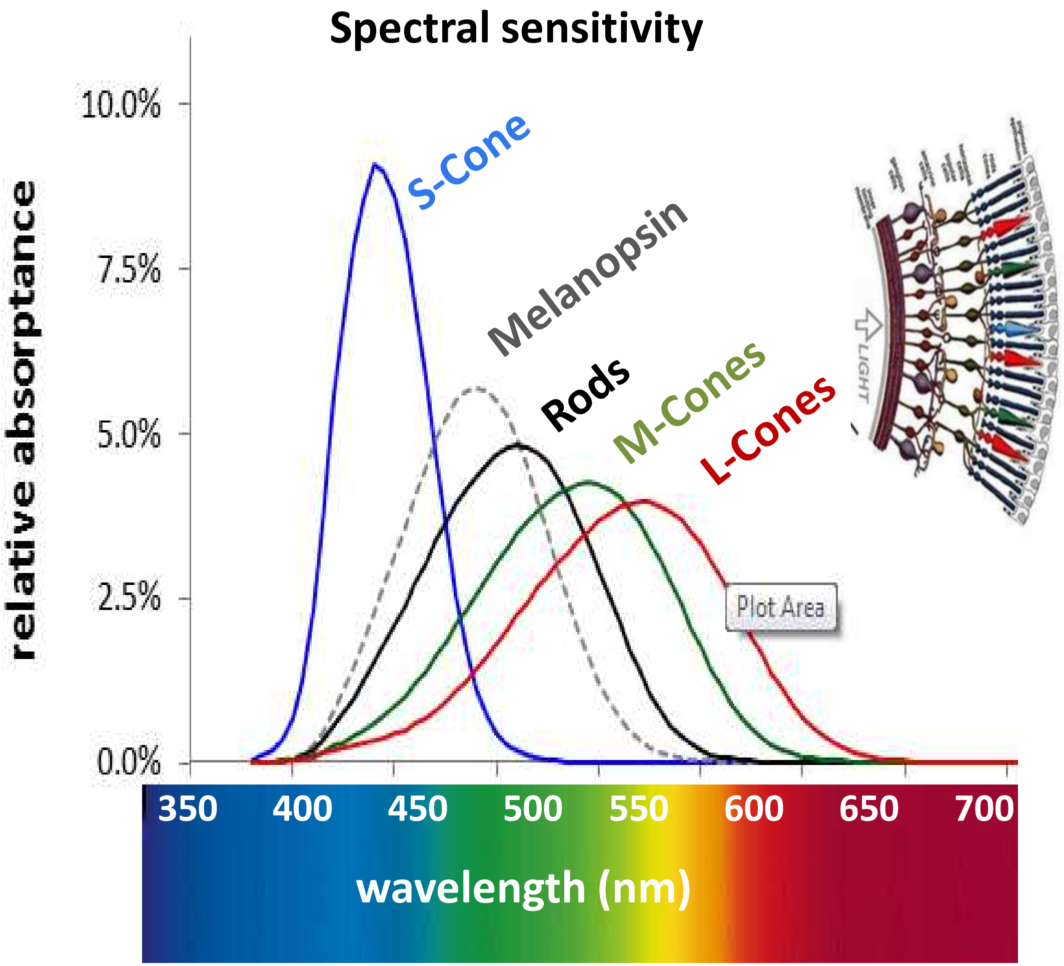
Opportunity: dynamic light solutions; mimic dawn and dusk, create a photoperiod of about 12 hours of sufficient brightness and 12 hours of dim, blue-deprived light, or darkness

Health and wellbeing (SSL-erate WP3) non-visual effects of light

- Identify non-visual effects for five application domains (education, healthcare, workplaces, homes, cities)
- Create dose-response curves (scientific studies): which non-visual effects occur in what light intensity ranges
- Give guidance on which light metrics to use in practice

Accelerate uptake Solid State Lighting technology

Quantify light via five photoreceptor inputs



Lucas et al. Trends. Neurosci. 2014

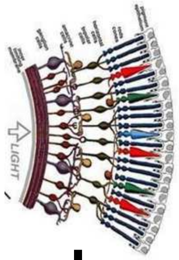
photoreceptors interplay & total spectral sensitivity depends on (non-visual) effect, timing, intensity, adaptation state...

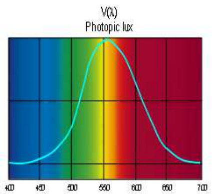
Start including melanopsin activation in our lighting designs, codes & standards

ISO cie DIN cen

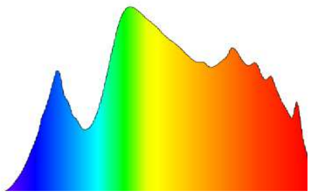
Rethinking light beyond vision and lux…

Visual system





V(λ) - lux
555 nm

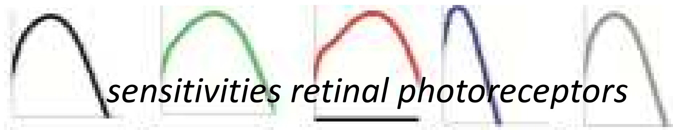


spectrum * V(λ)

Lux

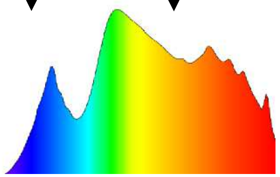
Non-visual system

rod	**G-cone**	**R-cone**	**B-cone**	**Melanopsin**



sensitivities retinal photoreceptors

R 496 nm	MC 530 nm	LC 558 nm	SC 419 nm	M 480 nm



spectrum * sensitivity: (eq.) opic Lux

Lucas et al., TINS 2014

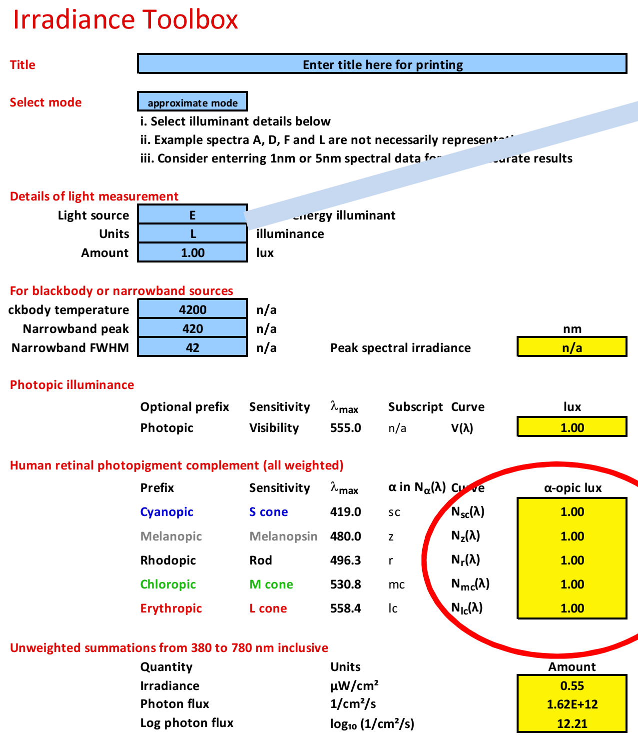
Rhodopic Lux	Chloropic Lux	Erythropic Lux	Cyanopic Lux	Melanopic Lux

new quantities for HCL

Measuring Light

- Tool 1: quantifies photoreceptor input in opic-lux (Lucas et al)

http://dx.doi.org/10.1016/j.tins.2013.10.004



Irradiance Toolbox

Title: Enter title here for printing

Select mode: approximate mode
i. Select illuminant details below
ii. Example spectra A, D, F and L are not necessarily represent...
iii. Consider enterring 1nm or 5nm spectral data fo... ...urate results

Details of light measurement

Light source	E	...nergy illuminant
Units	L	illuminance
Amount	1.00	lux

For blackbody or narrowband sources

ckbody temperature	4200	n/a		
Narrowband peak	420	n/a		nm
Narrowband FWHM	42	n/a	Peak spectral irradiance	n/a

Photopic illuminance

Optional prefix	Sensitivity	λ_{max}	Subscript	Curve	lux
Photopic	Visibility	555.0	n/a	V(λ)	1.00

Human retinal photopigment complement (all weighted)

Prefix	Sensitivity	λ_{max}	α in $N_\alpha(\lambda)$	Curve	α-opic lux
Cyanopic	S cone	419.0	sc	$N_{sc}(\lambda)$	1.00
Melanopic	Melanopsin	480.0	z	$N_z(\lambda)$	1.00
Rhodopic	Rod	496.3	r	$N_r(\lambda)$	1.00
Chloropic	M cone	530.8	mc	$N_{mc}(\lambda)$	1.00
Erythropic	L cone	558.4	lc	$N_{lc}(\lambda)$	1.00

Unweighted summations from 380 to 780 nm inclusive

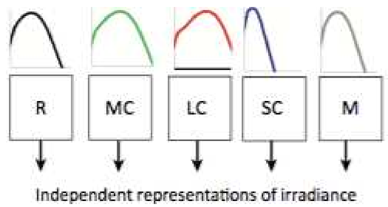
Quantity	Units	Amount
Irradiance	µW/cm²	0.55
Photon flux	1/cm²/s	1.62E+12
Log photon flux	$\log_{10}$ (1/cm²/s)	12.21

INPUT

Light source
A = Illuminant A (incandescent, 2856K)
D = Illuminant D65 (daylight, 6504K)
F = Illuminant F (fluorescent, CCT ~3000K)
L = White LED (blue+phospor, CCT ~4730K)
N = Narrowband, incl monochromatic
B = Blackbody spectra
E = equal energy (for normalisation)
Example: 1 lux of E

OUTPUT

Prefix	α-opic lux
Cyanopic	1.00
Melanopic	1.00
Rhodopic	1.00
Chloropic	1.00
Erythropic	1.00



CIE: make “opic-lux” approach SI compliant

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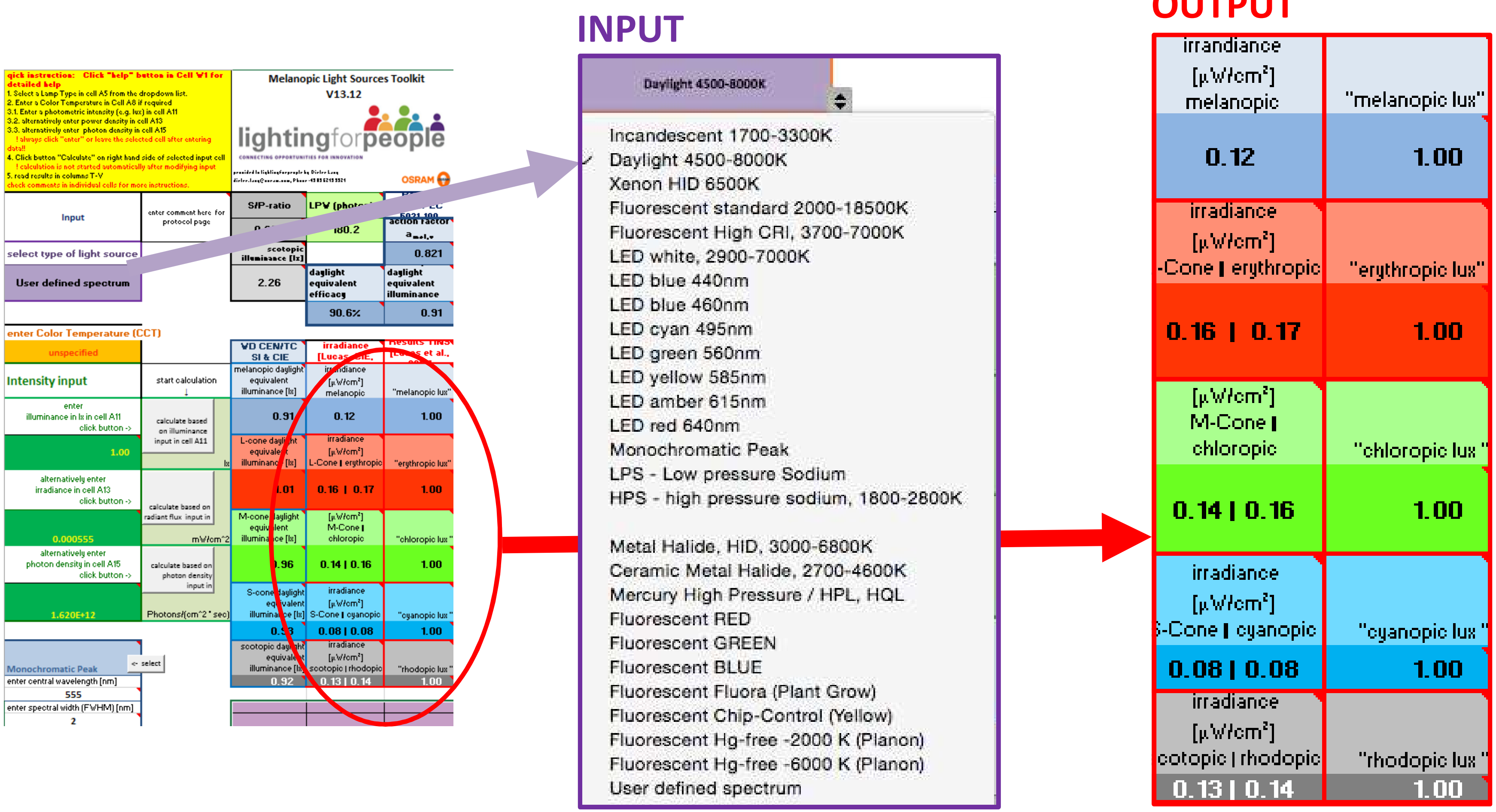
Radiometric	Photometric
(equivalent) “melanopic Lux” × 0.12	(equivalent) “melanopic Lux” × 0.91
⇓	⇓
melanopic irradiance *in μW/cm2*	melanopic daylight-equivalent illuminance *in Lux*

CIE is defining notations, definitions
making “opic lux” SI compliant via multiplication constants
http://div6.cie.co.at/?i_ca_id=611&pubid=490

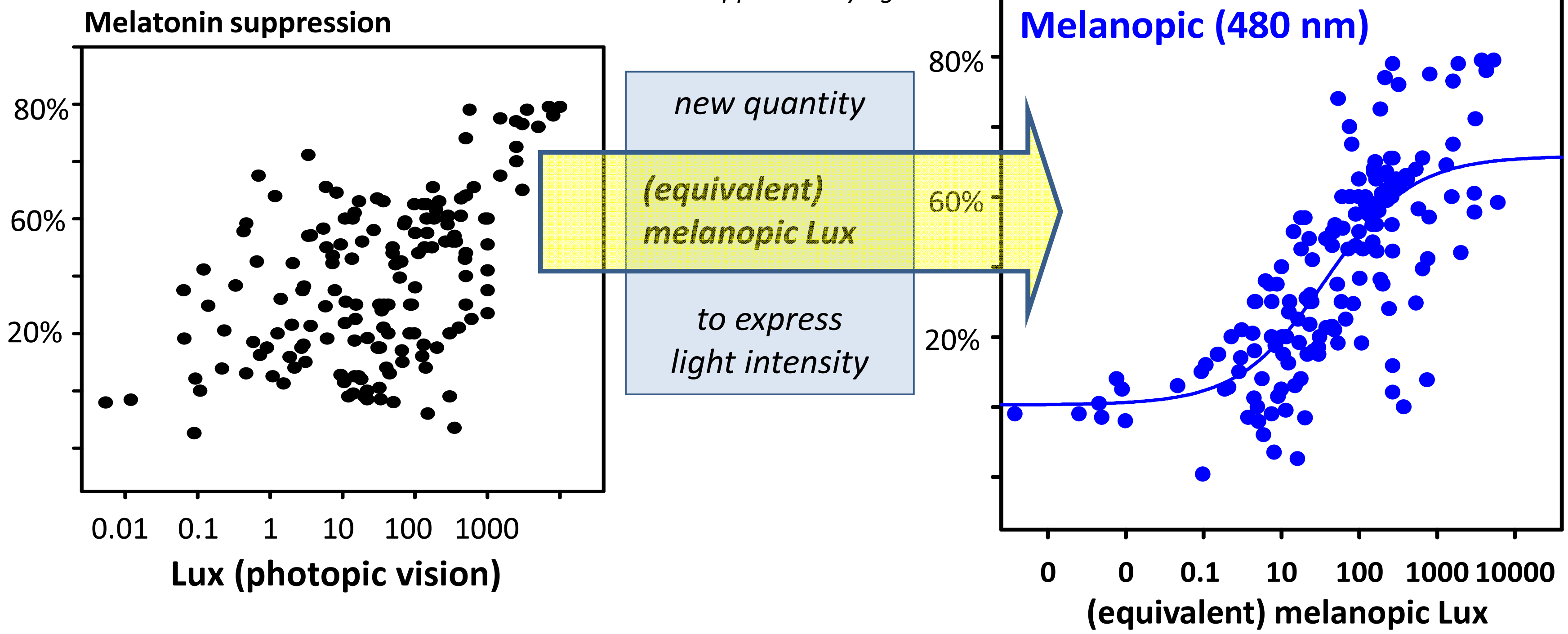
Measuring Light

- Tool 2: extension also quantifies photoreceptor weighted irradiances, daylight equivalents and more light sources (Dieter Lang)



Melatonin suppression and light intensity

Melatonin @ night promotes good sleep
and is suppressed by light

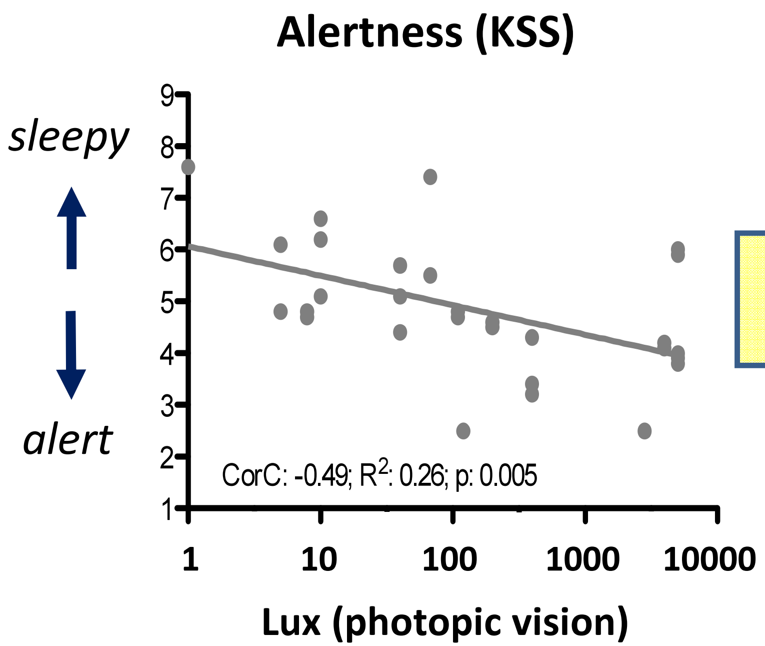


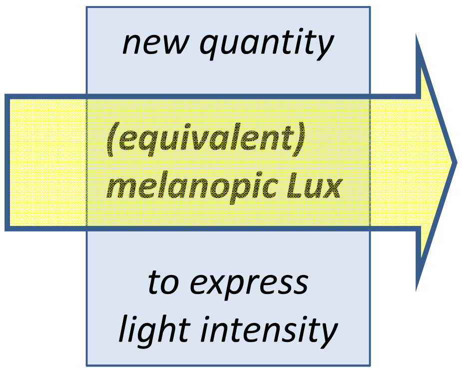
Lux does not predict
melatonin suppression

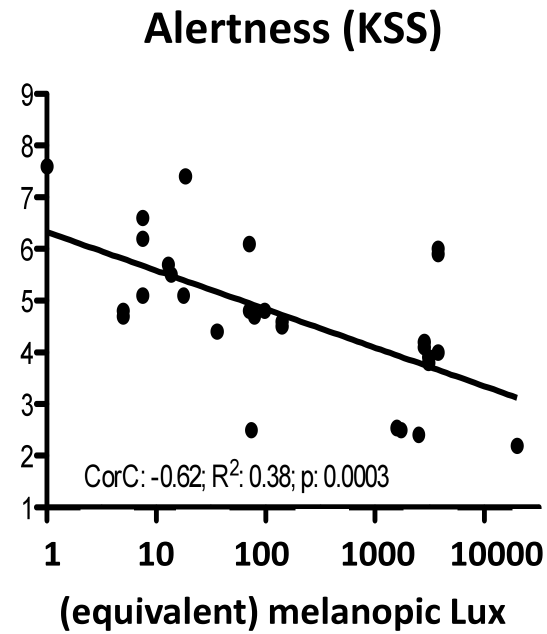
“melanopic Lux” predicts
melatonin suppression

CIE: make “melanopic Lux” approach SI compliant

Alertness and light intensity







Alertness correlates with log(lux)

Alertness correlates more strongly with log("melanopic lux")

Errors, depression scores and light intensity

- How does performance (errors) depend on light intensity?

- How do depression scores depend on light therapy?

statistics & time frame (light intensity & therapy duration)

Work in progress……..

Conclusions

- Melatonin suppression: lux (photopic vision) is not predicting the response

- α-opic irradiances are expected to be useful predictors for non-visual effects of light in HCL, especially for narrow spectral bands, mixed colors or special whites

- The lighting practice needs SI compliant metrics:
  - unit "α-opic lux" is not SI-compliant
  - α-opic irradiance & α-opic daylight-equivalent illuminance
    (multiplication factors, definitions & notations pending in CIE)

- Start using α-opic irradiances to design light conditions that achieve, or avoid, certain non-visual effects.

- Application example for dynamic light solutions:
  - offer high melanopic irradiances during daytime
  - and minimize melanopic irradiance during the night

This is the result of collaborative efforts by

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Thank you for your attention!

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