OPTICA
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Technical Groups

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Vision

WEBINAR

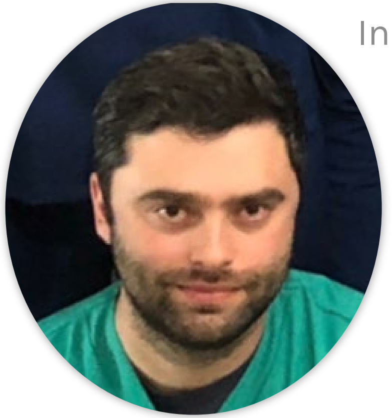
How Life on Planet Earth Has Adapted to Environmental Light

14 December 2022 | 11:00 — 12:00 EST (UTC-05:00)

Technical Group Vision Executive Committee

Vyas Akondi
IISER Berhampur

Alberto de Castro
Instituto de Optica, CSIC



Len Zheleznyak
Clerio Vision, Inc.

Christina Schwarz
University of Tübingen

About Our Technical Group

Our technical group focuses on optics of the eye and of ophthalmic lenses and devices; physiological optics; and mechanisms of transduction, transmission, coding, detection and analysis of visual information.

Our mission is to connect the 1000+ members of our community through technical events, webinars, networking events, and social media.

Our past activities have included:

- Panel Discussion on Approaches for Myopia Control
- Webinar on Grant Writing for Vision Scientists
- Webinar on Color Vision at a Cellular Level
- Color and Vision Annual Data Summer Blast

Connect with our Technical Group

Join our online community to stay up to date on our group’s activities. You also can share your ideas for technical group events or let us know if you’re interested in presenting your research.

Ways to connect with us:

- Our website at www.optica.org/VV
- Email us at TGactivities@optica.org

Today's Speaker

Robert Fosbury
European Southern Observatory
Institute of Ophthalmology, UCL

Optica webinar

14 December 2022

Light and Life

How life on planet Earth adapted to environmental light

Bob Fosbury

European Space Agency (ESA)

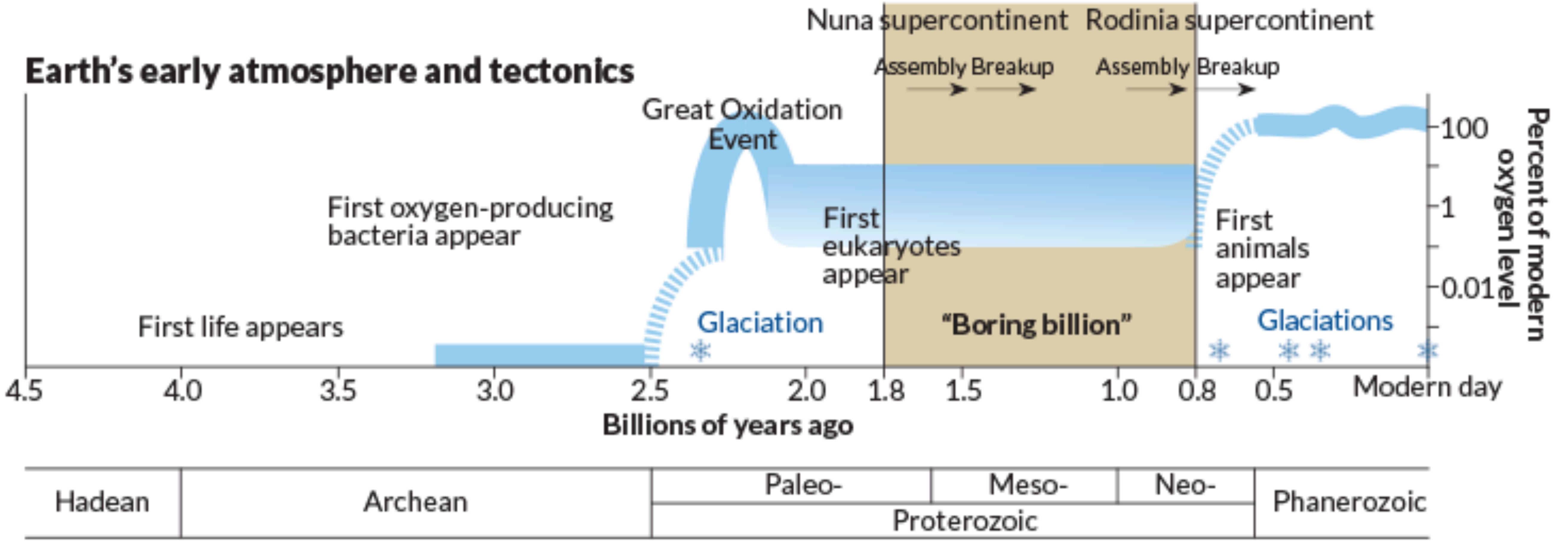
European Southern Observatory (ESO)

Institute of Advanced Study (IAS) — University of Durham

Institute of Ophthalmology — University College London

www.flickr.com/photos/bob_81667/

Clearing the Earth's skies



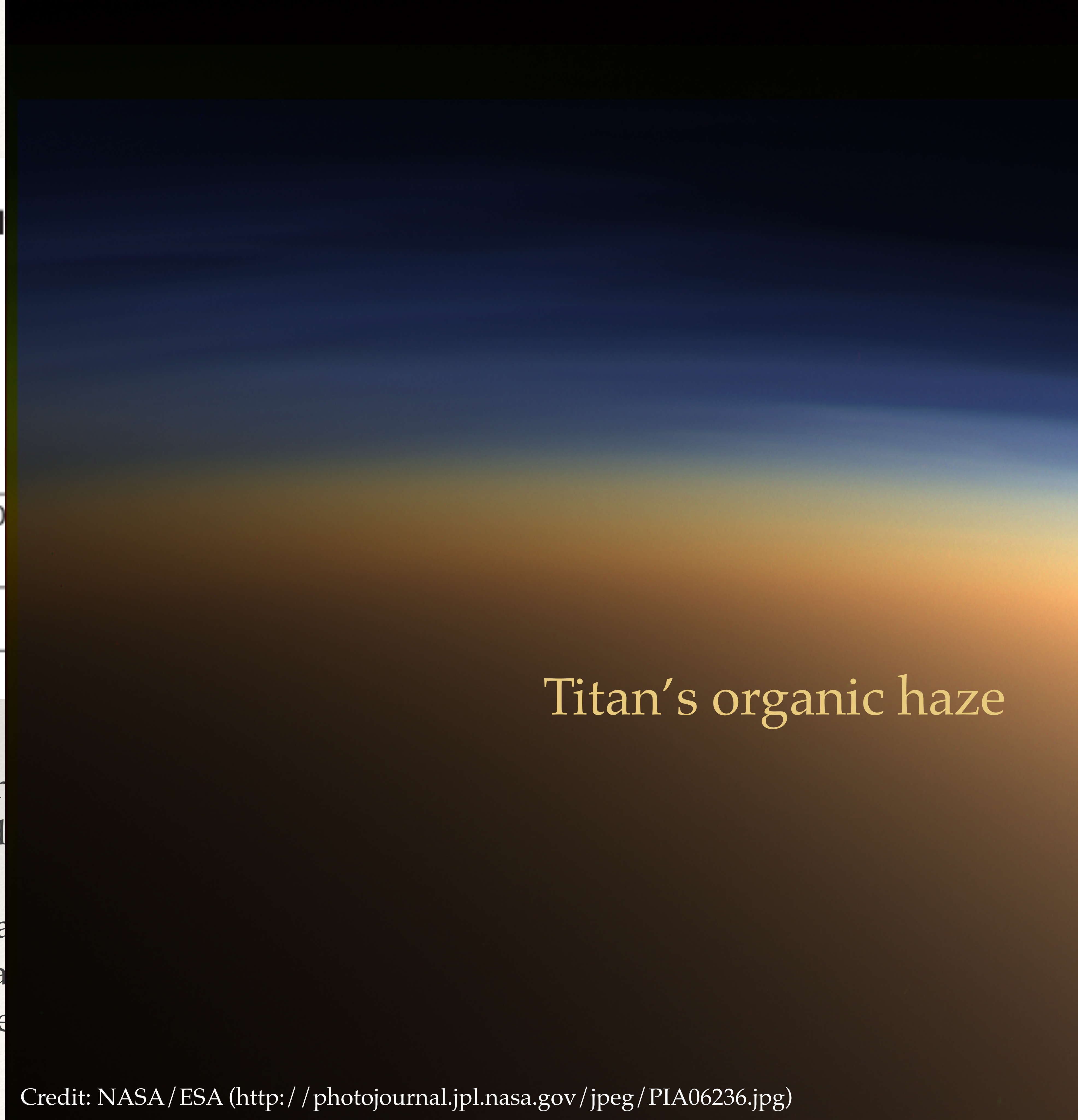
Credit: https://commons.wikimedia.org/wiki/File:Timeline_showing_the_Boring_Billion.png

The Earth's atmosphere would have become transparent as the oxygen content increased between about 2.5 and 2 billion years ago.

Earth's early atmosphere contained methane which, on interaction with Solar UV light, would have produced an orange haze of hydrocarbons (Saturn's moon Titan). The rise in atmospheric oxygen content oxidised the hydrocarbons and gradually cleared the haze.

Earth's earl
First
4.5
4.0
Hadean
100
1
0.01
Percent of modern oxygen level
odern day
zoic

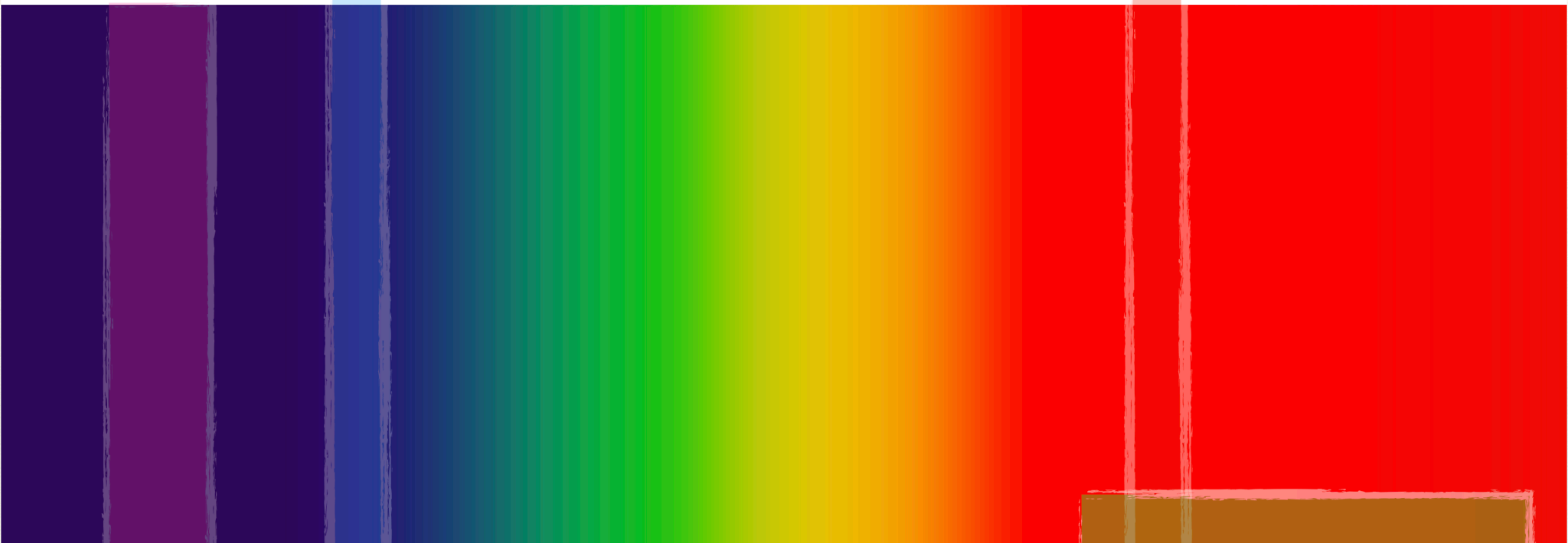
Boring_Billion.png



Credit: NASA/ESA (http://photojournal.jpl.nasa.gov/jpeg/PIA06236.jpg)

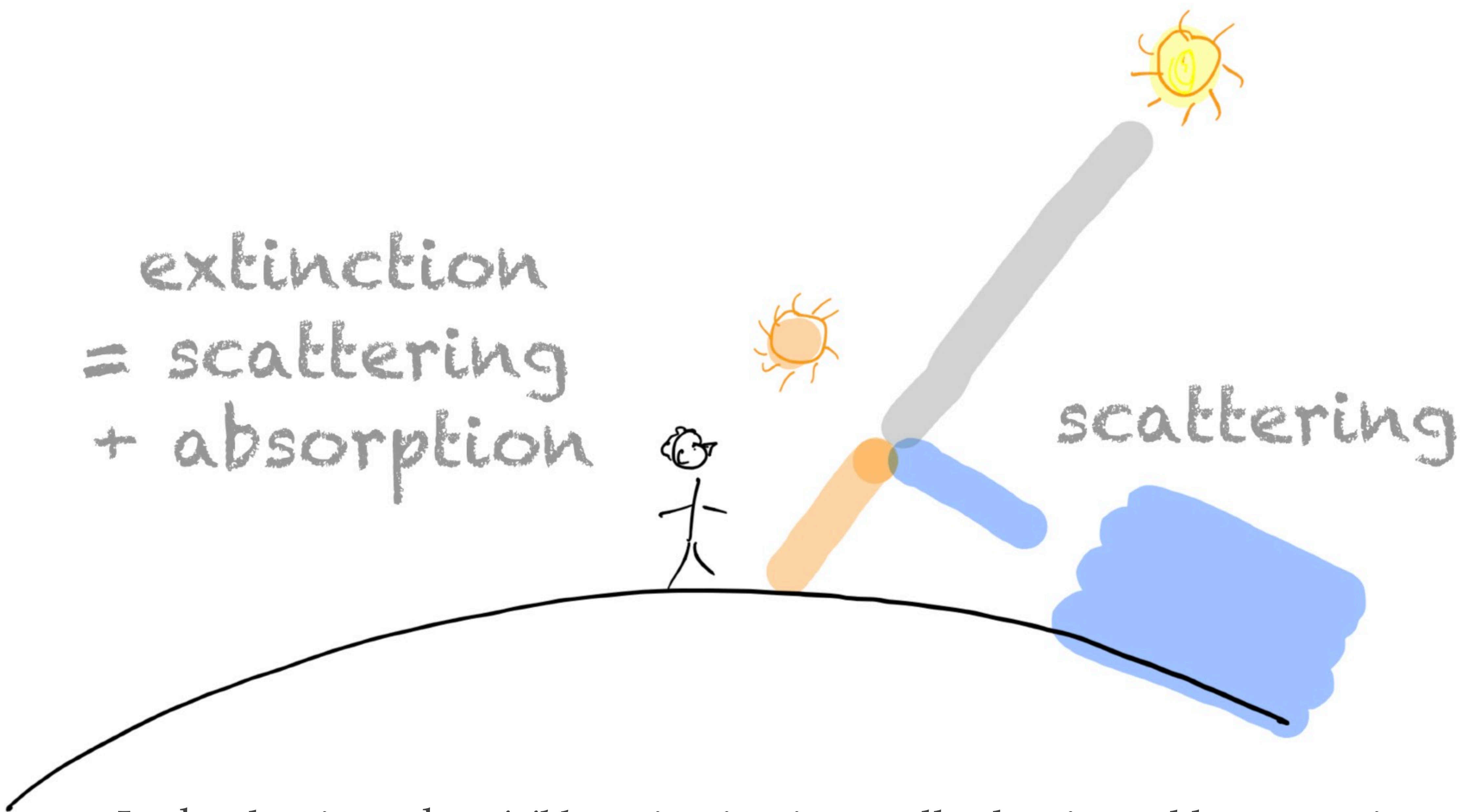
The Earth
increased

Earth's ea V light,
would ha he rise in
atmosphe he haze.



The interaction of light with biochemistry

Environmental light in a nutshell



In the daytime, the *visible* extinction is usually dominated by scattering

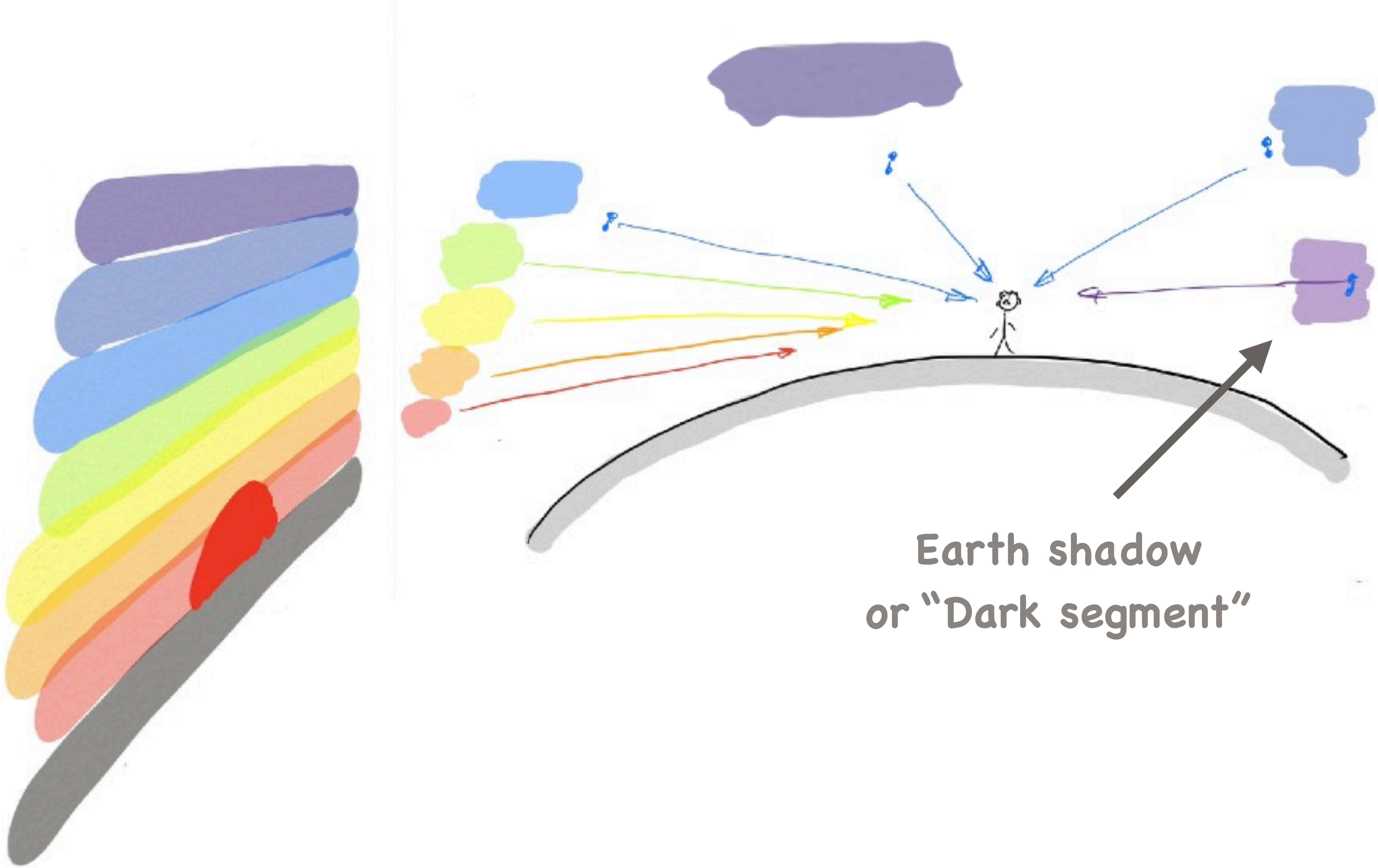


Figure 9. Painting the bands of twilight colour. Light from the low Sun can reach us directly after suffering the extinction arising from a long, almost horizontal path through the atmosphere. It can take many alternative paths, involving a single scattering, from molecules anywhere in the atmosphere that is visible from where we are standing.

Painting the twilights

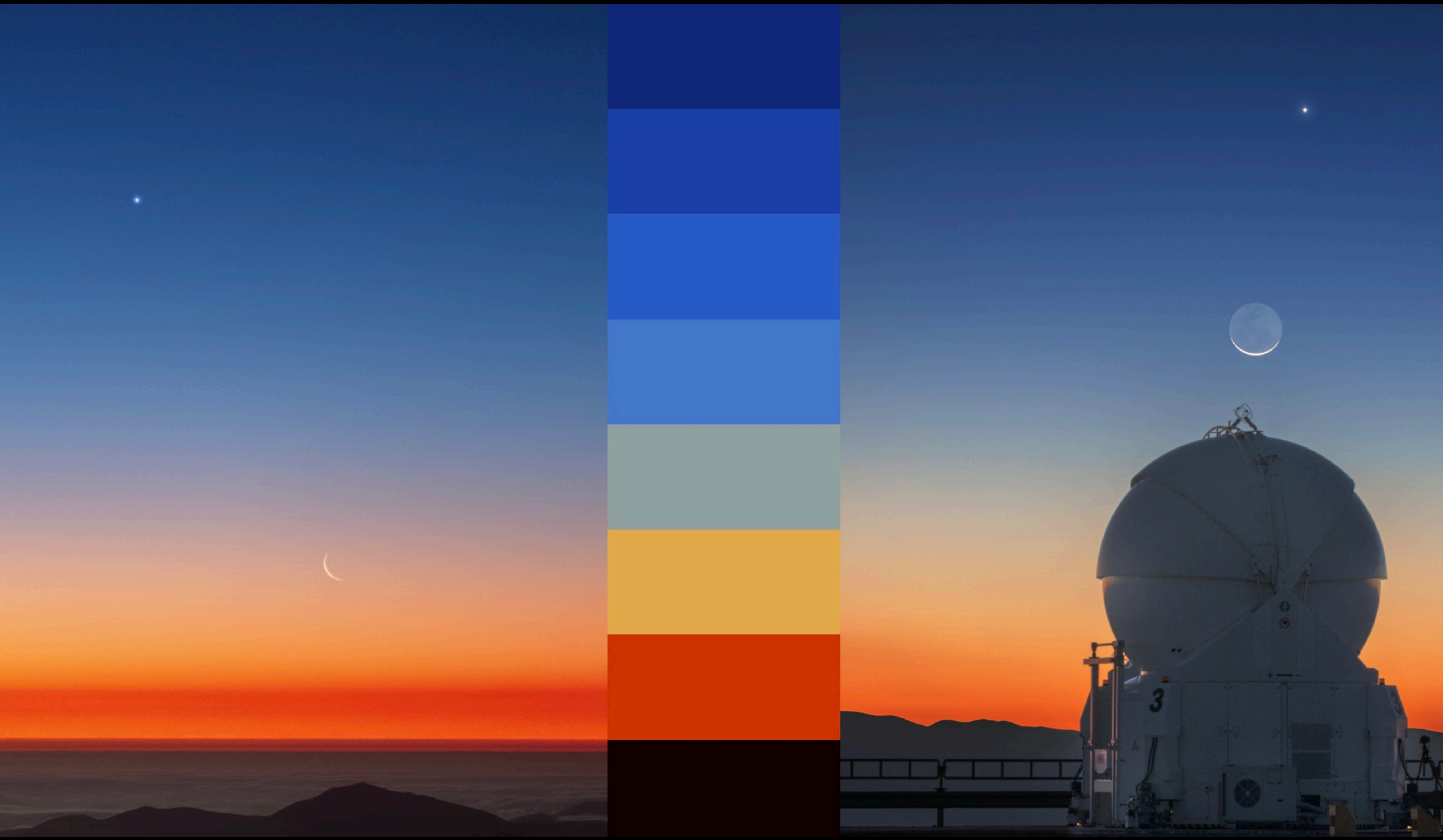


Image credit: Y. Beletsky (LCO)/ESO

Painting the twilights

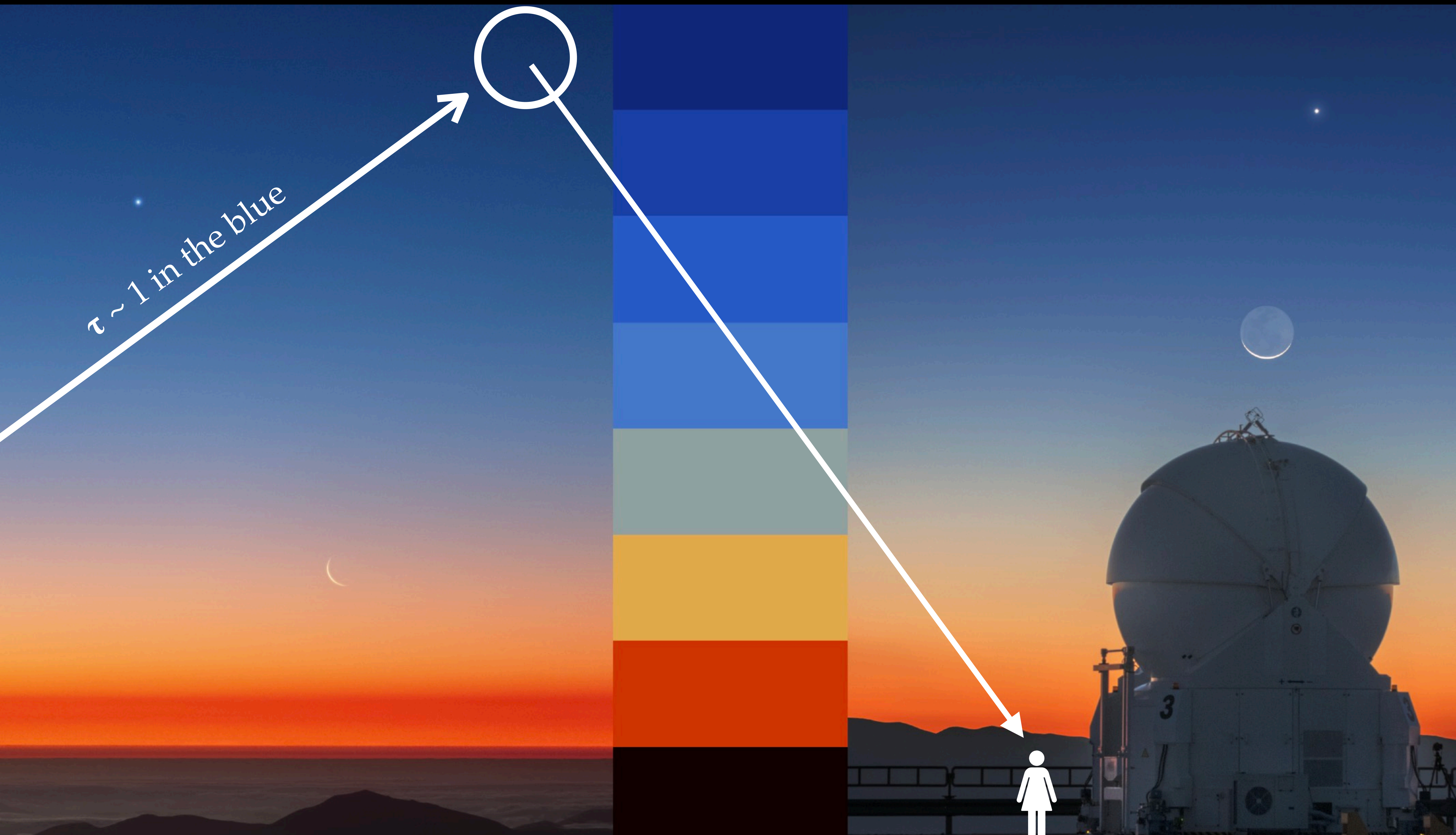


Image credit: Y. Beletsky (LCO)/ESO

Painting the twilights

Image credit: Y. Beletsky (LCO)/ESO

Painting the twilights

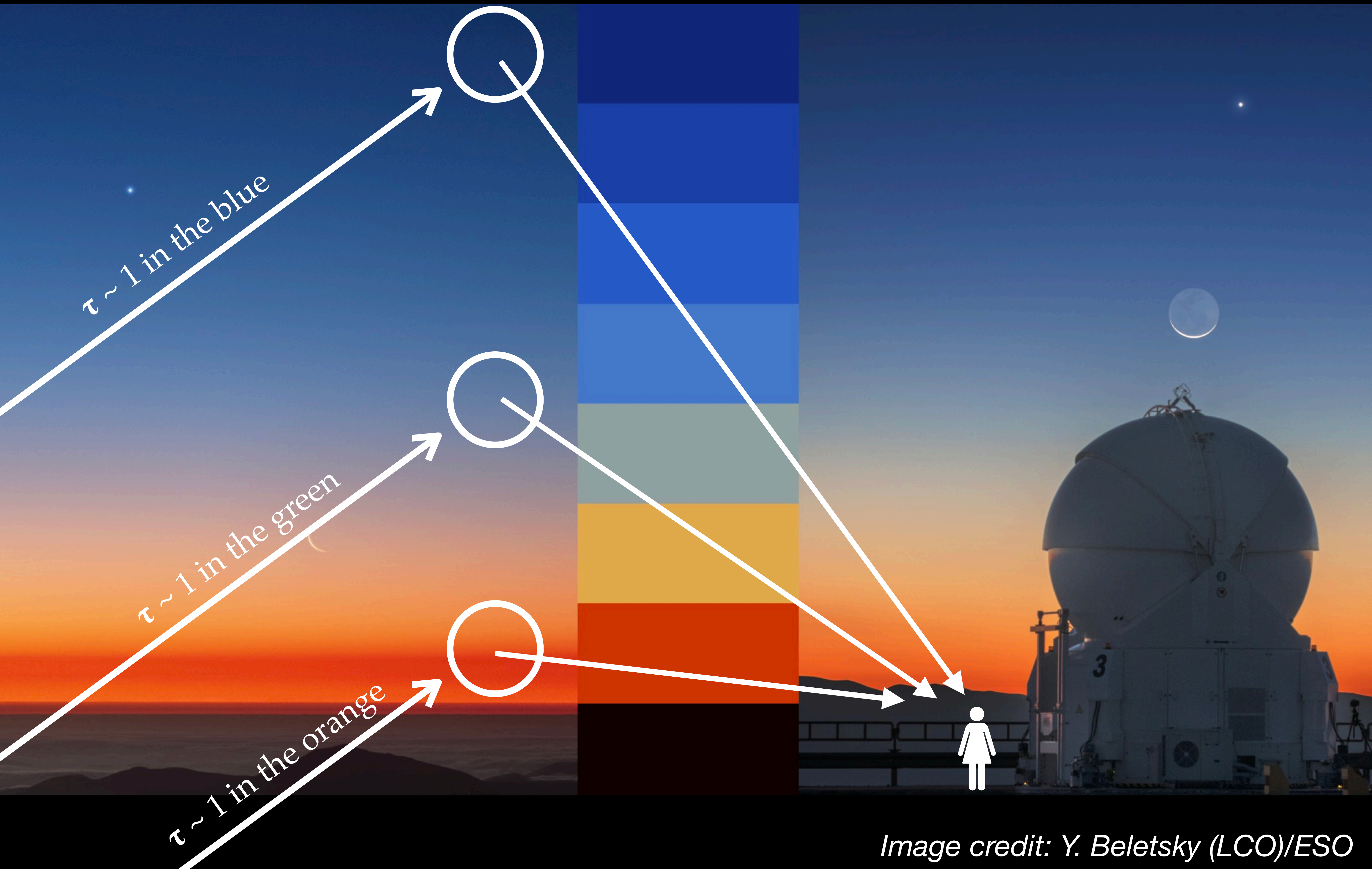


Image credit: Y. Beletsky (LCO)/ESO

E. O. HULBURT, JOURNAL OF THE OPTICAL SOCIETY OF AMERICA VOLUME 43, NUMBER 2 FEBRUARY, 1953
Explanation of the Brightness and Color of the Sky, Particularly the Twilight Sky

What happens at twilight?

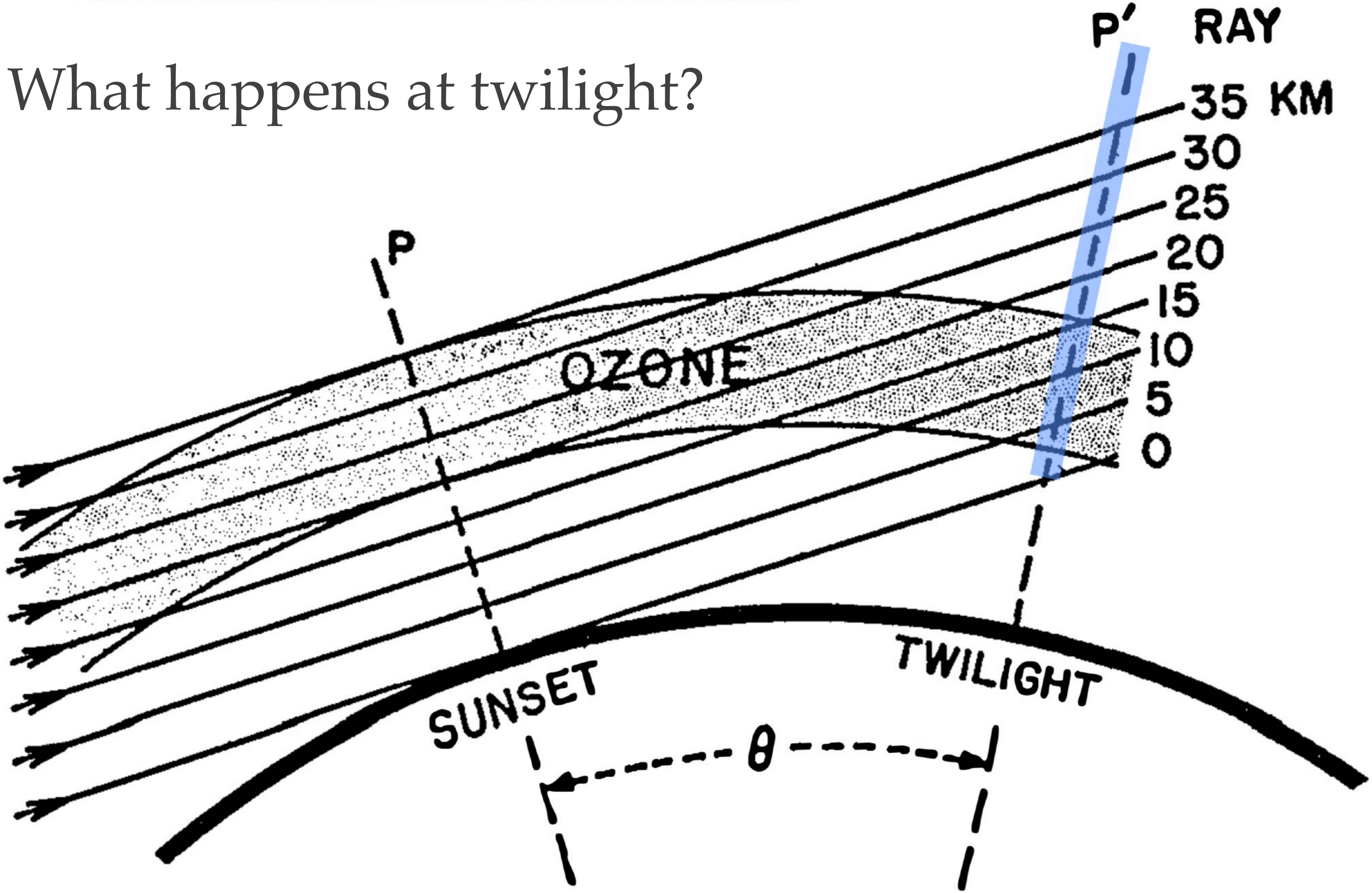
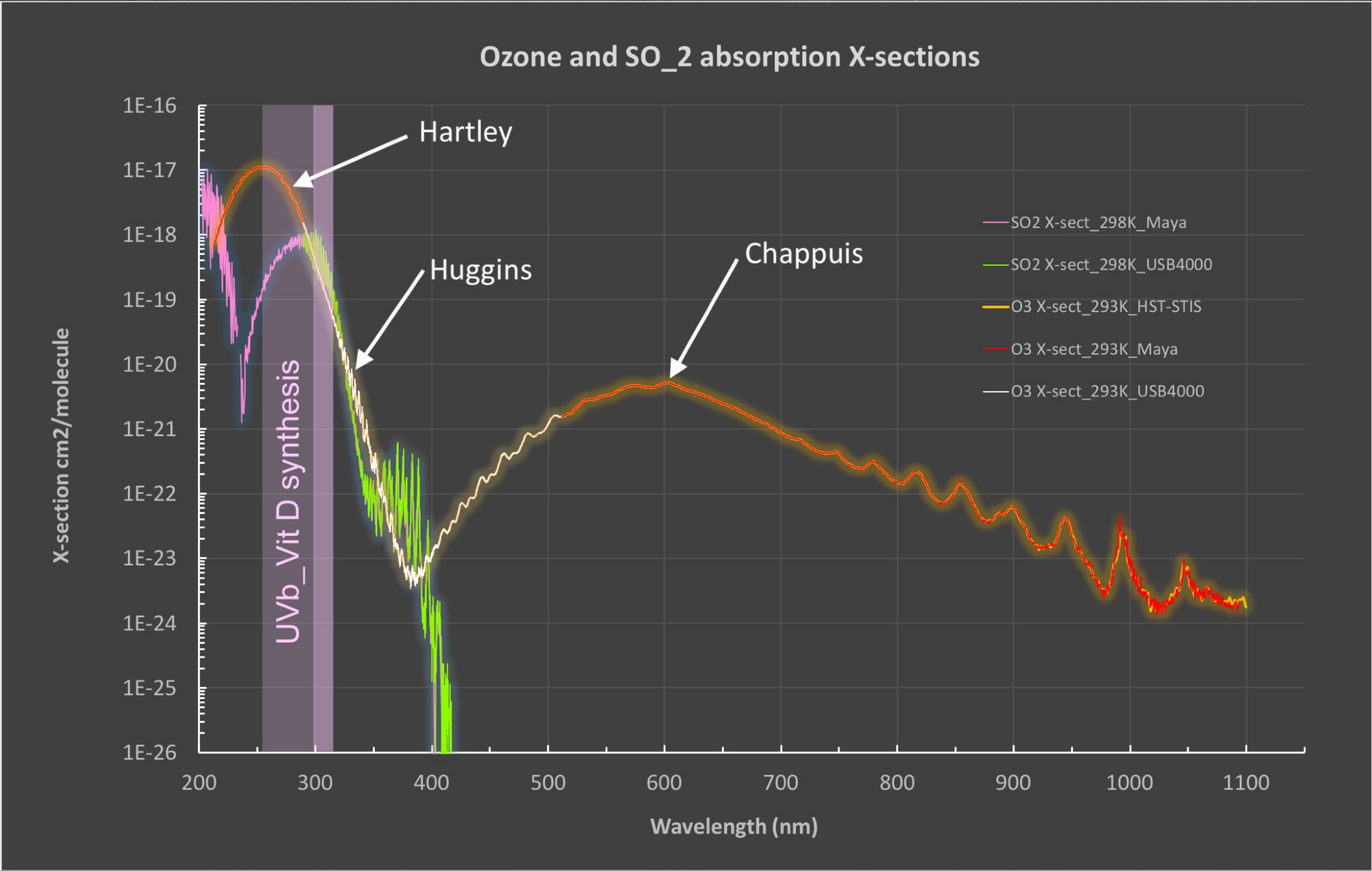


FIG. 6. Geometry of twilight scene with ozone.

Molecular absorption x-sections of interest

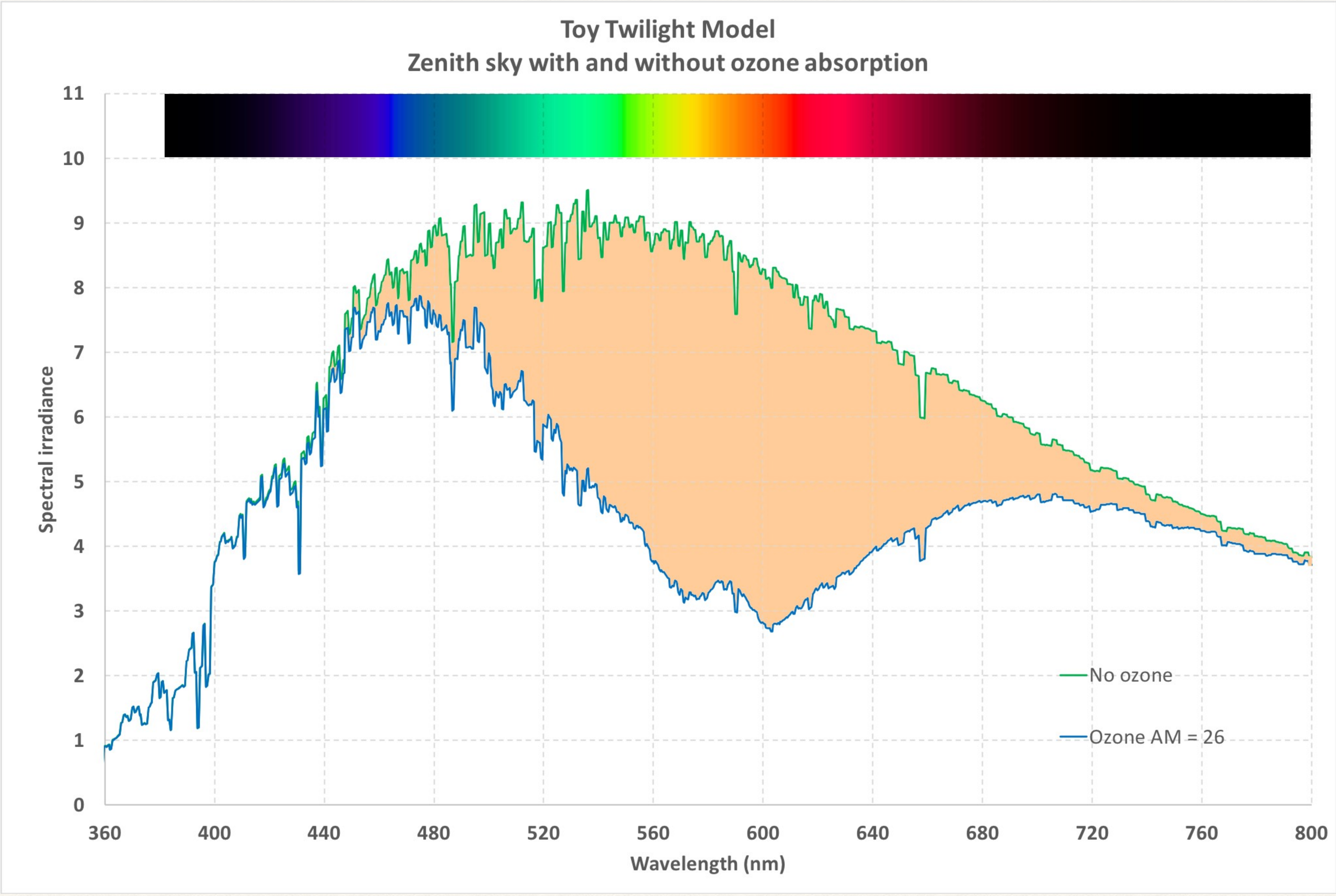
http://www.iup.physik.uni-bremen.de/gruppen/molspec/index.html



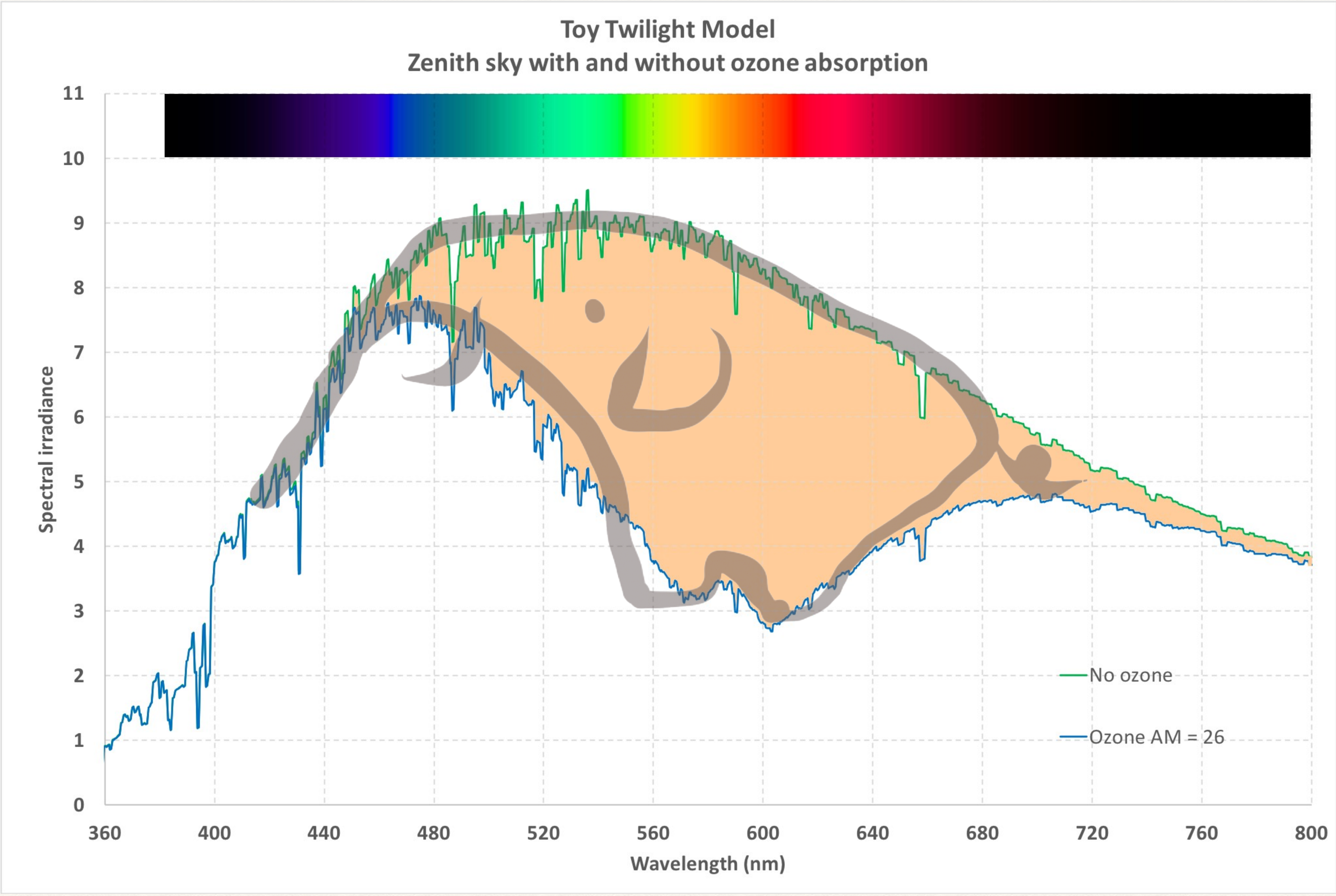
The transition to twilight, cloudy or clear

The transition to twilight, cloudy or clear


Liquified ozone — blue colour caused by the Chappuis band
Ultramarine!
Photograph courtesy of the BIPM (Bureau international des poids et mesures)



Toy Twilight Model
Zenith sky with and without ozone absorption
Spectral irradiance
Wavelength (nm)
0
1
2
3
4
5
6
7
8
9
10
11
360
400
440
480
520
560
600
640
680
720
760
800
No ozone
Ozone AM = 26


Toy Twilight Model
Zenith sky with and without ozone absorption
Spectral irradiance
Wavelength (nm)
No ozone
Ozone AM = 26
0
1
2
3
4
5
6
7
8
9
10
11
360
400
440
480
520
560
600
640
680
720
760
800

How reindeer eyes transform in winter to give them twilight vision

Published: July 1, 2022 11.39am BST

Shutterstock

Reindeer are loved the world over for their dark, expressive eyes, majestic antlers and magical association with Santa Claus. The moment you learn the cold, hard truth of how Christmas presents arrive under the tree is a harrowing one that blights many a childhood. But reindeer are more special than your cynical older sibling or classmates would have had you believe.

The Arctic reindeer, like its main predator the wolf, is incredibly well adapted to its snowy home, where winter conditions can see temperatures drop to -50°C and low levels of daylight. Reindeer

Author

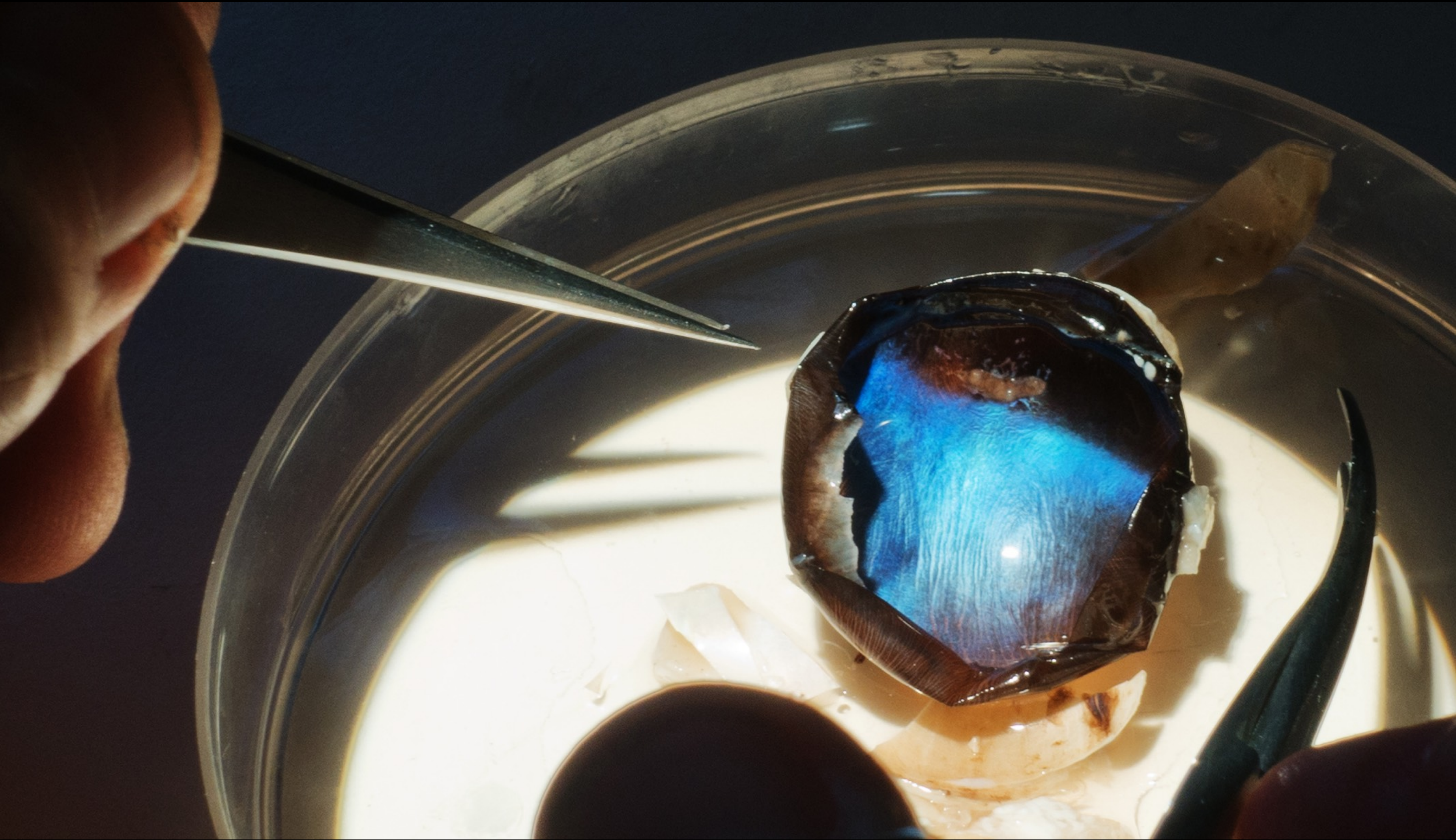
Robert A E Fosbury
Honorary professor, UCL Institute of Ophthalmology, UCL

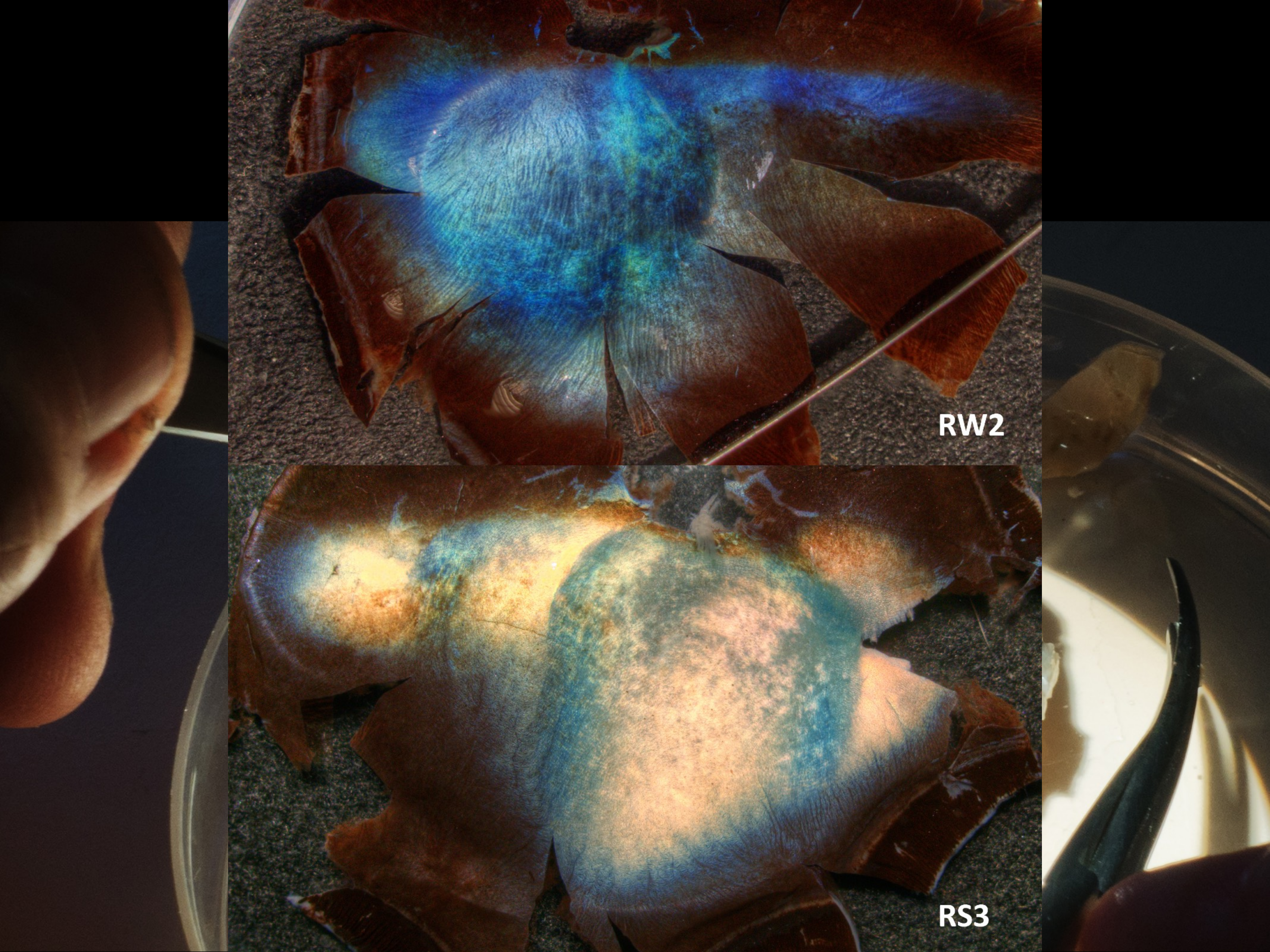
Disclosure statement

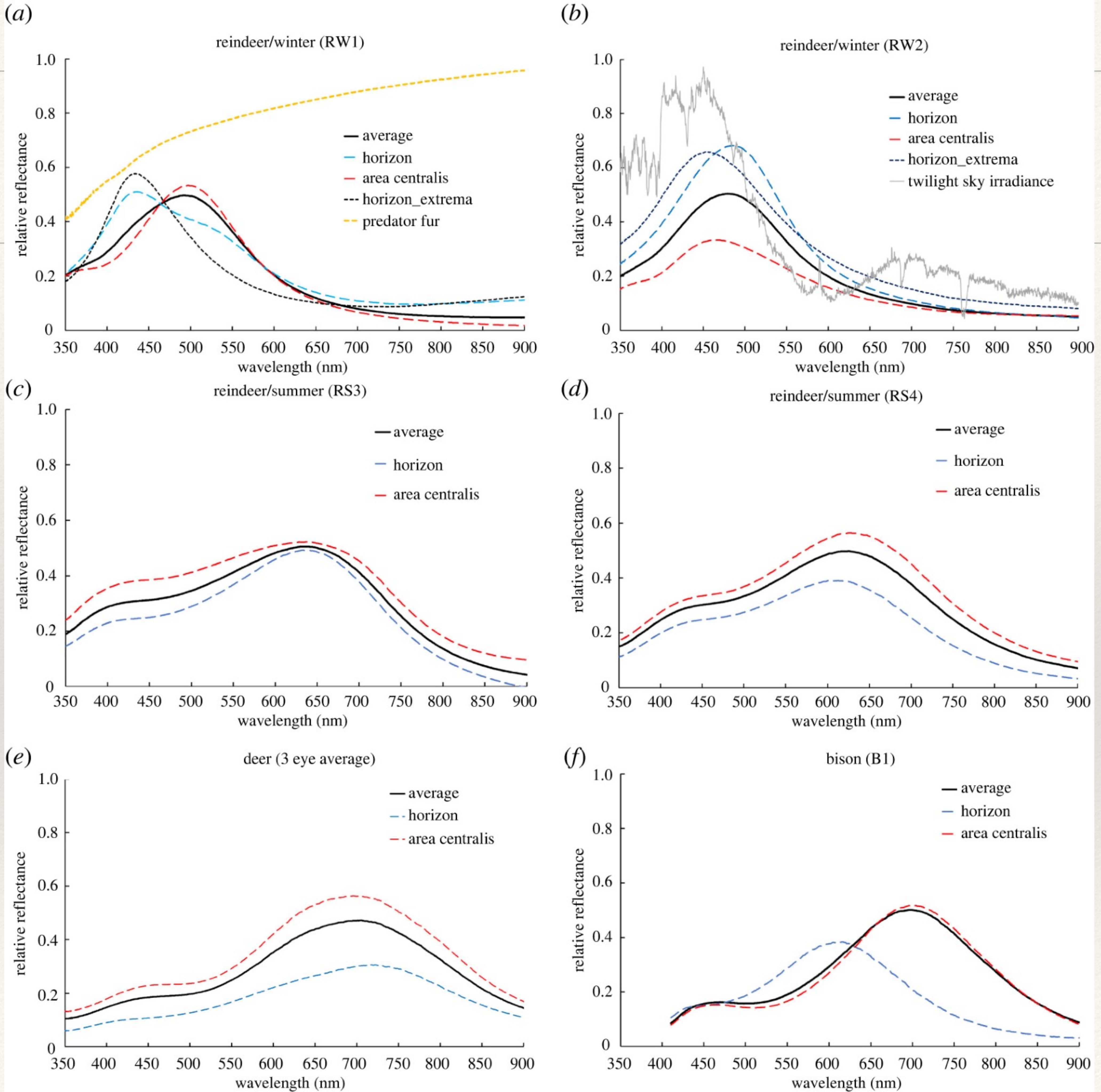
Robert A E Fosbury receives funding from BBSRC, The project was originally funded by BB/F008244/1

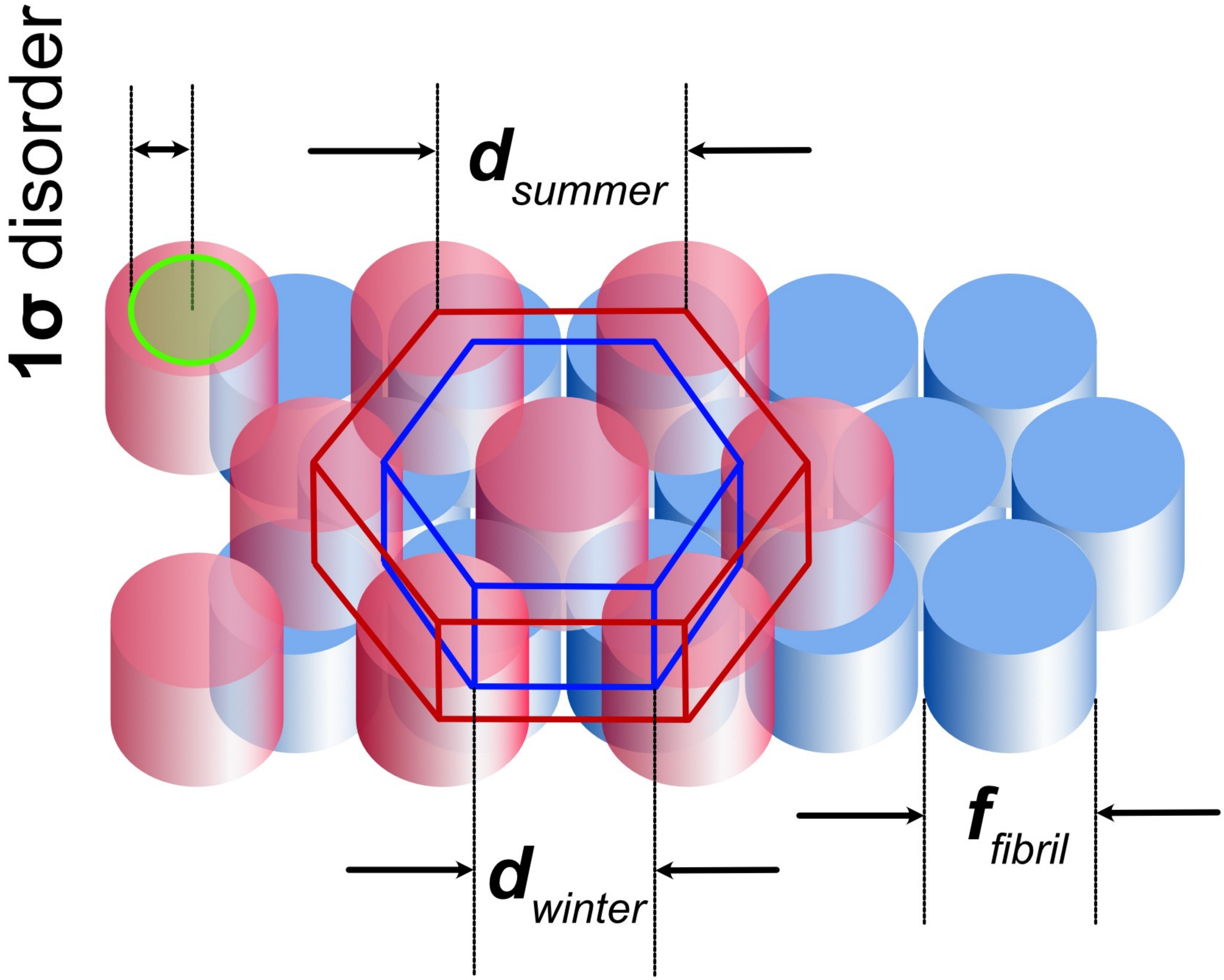
A reindeer tapetum lucidum in winter

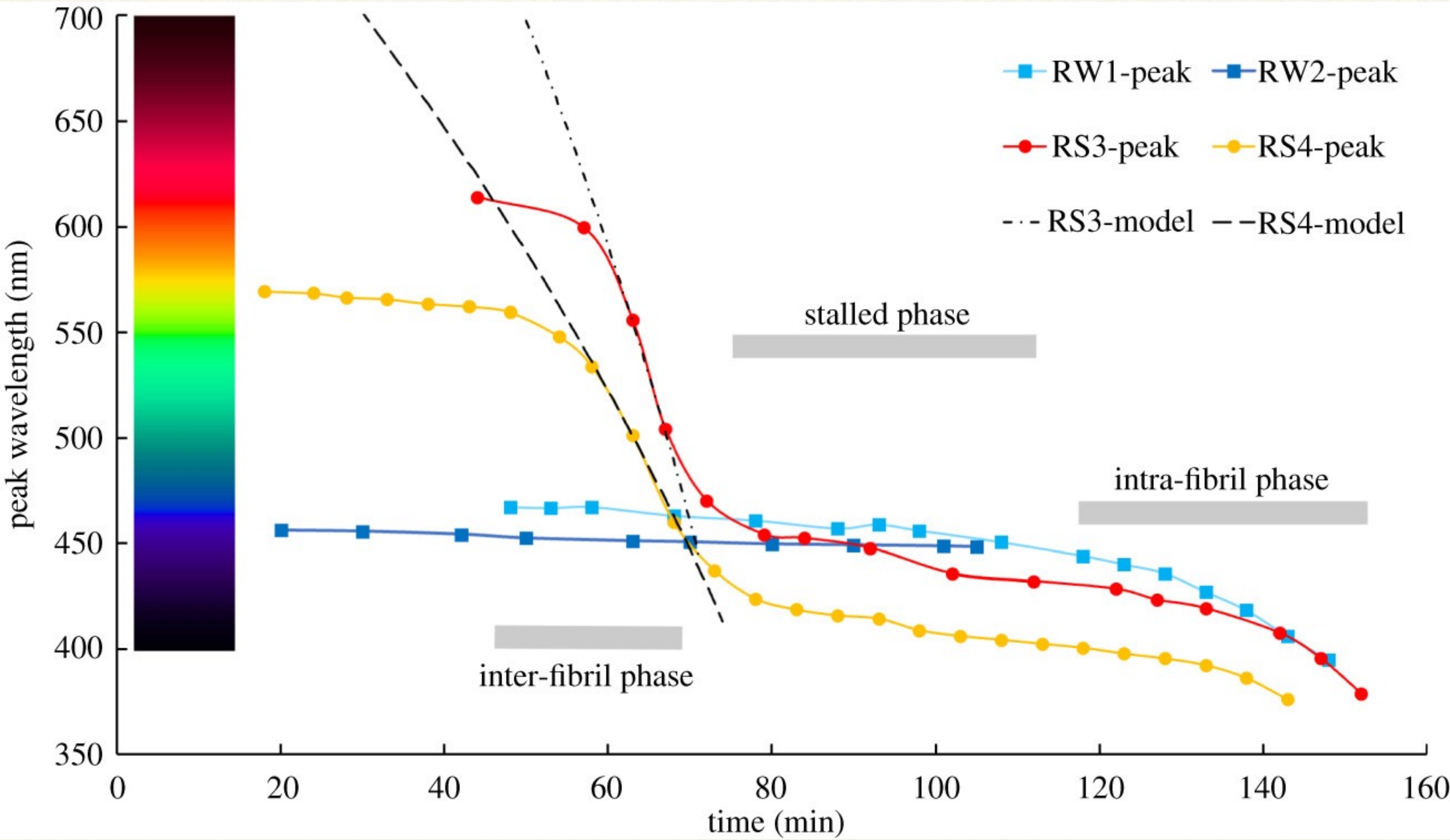
a nano-scale collagen fibre photonic reflector




RW2
RS3


(a)
reindeer/winter (RW1)
relative reflectance
wavelength (nm)
average
horizon
area centralis
horizon_extrema
predator fur
(b)
reindeer/winter (RW2)
relative reflectance
wavelength (nm)
average
horizon
area centralis
horizon_extrema
twilight sky irradiance
(c)
reindeer/summer (RS3)
relative reflectance
wavelength (nm)
average
horizon
area centralis
(d)
reindeer/summer (RS4)
relative reflectance
wavelength (nm)
average
horizon
area centralis
(e)
deer (3 eye average)
relative reflectance
wavelength (nm)
average
horizon
area centralis
(f)
bison (B1)
relative reflectance
wavelength (nm)
average
horizon
area centralis


1σ disorder
d summer
d winter
f fibril



700
650
600
550
500
450
400
350
peak wavelength (nm)
0
20
40
60
80
100
120
140
160
time (min)
RW1-peak
RW2-peak
RS3-peak
RS4-peak
RS3-model
RS4-model
stalled phase
intra-fibril phase
inter-fibril phase

An increase of positional disorder in a 2D natural photonic structure forms a saddle between the first and second order diffraction peaks.

It also transforms the reflection from specular to diffuse

Figure 18 from:

Optical costs and benefits of disorder in biological photonic crystals

Sébastien R. Mouchet, Stephen Luke, Luke T. McDonald and Pete Vukusic

Faraday Discuss., 2020, 223, 9

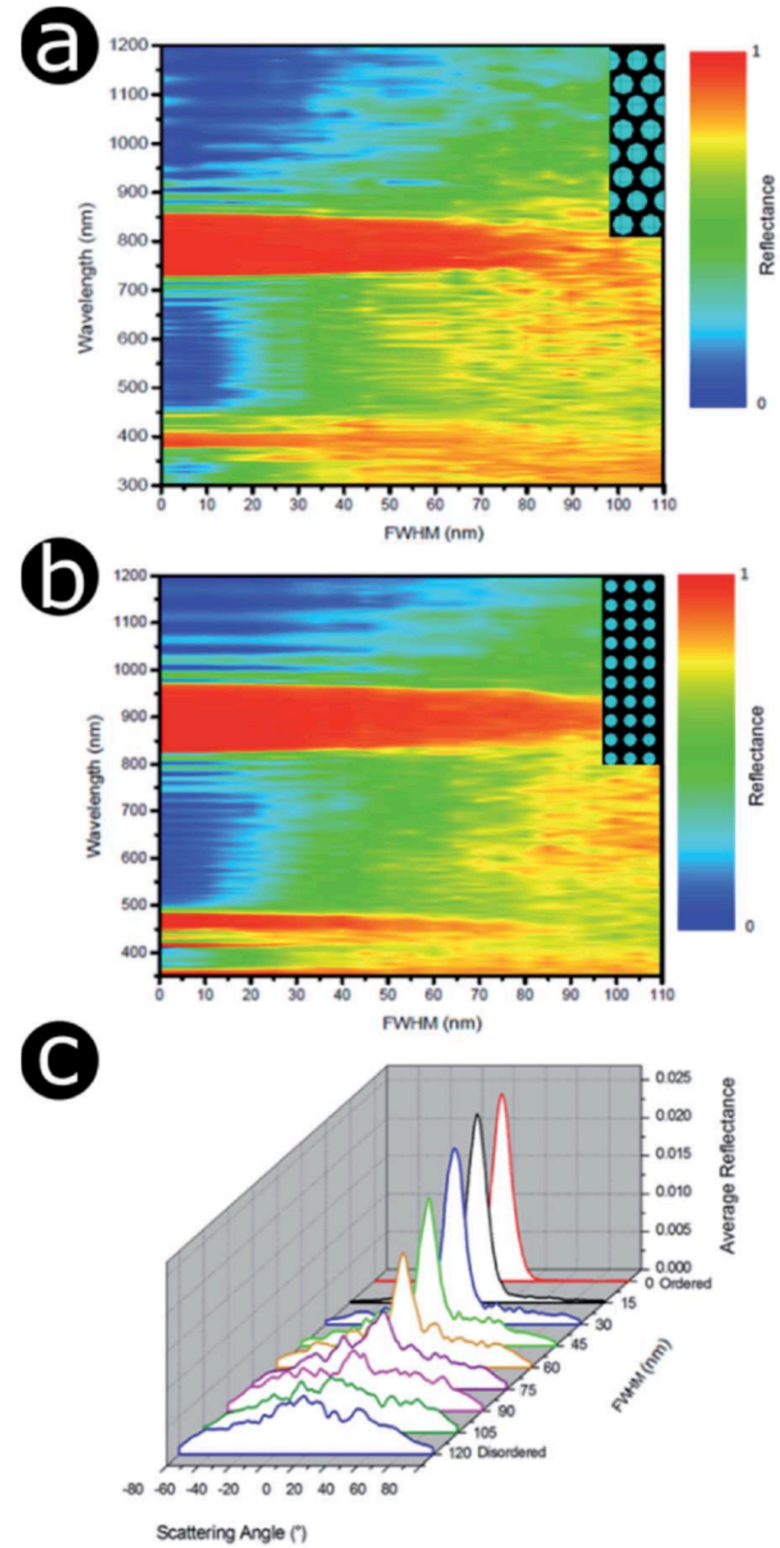
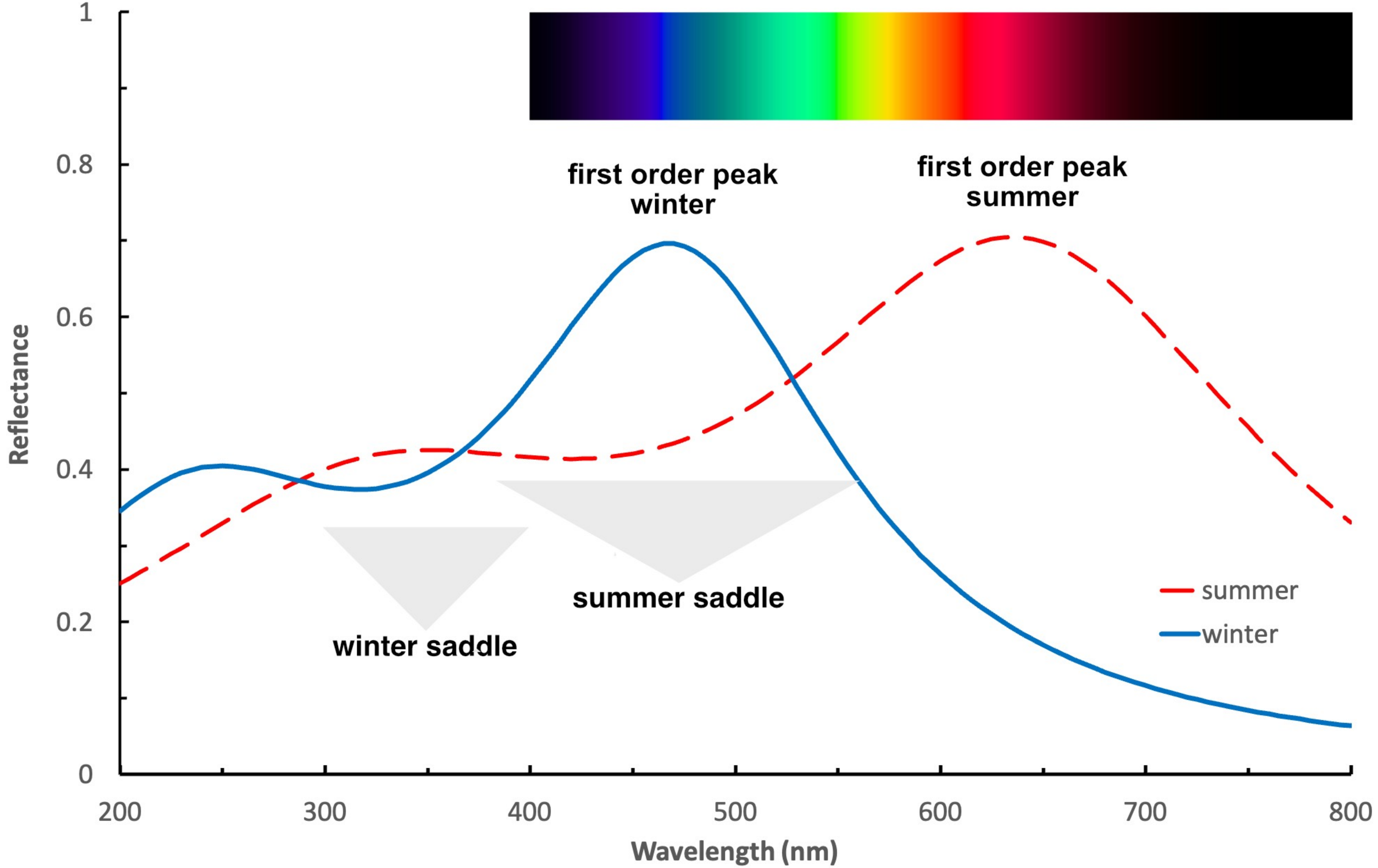
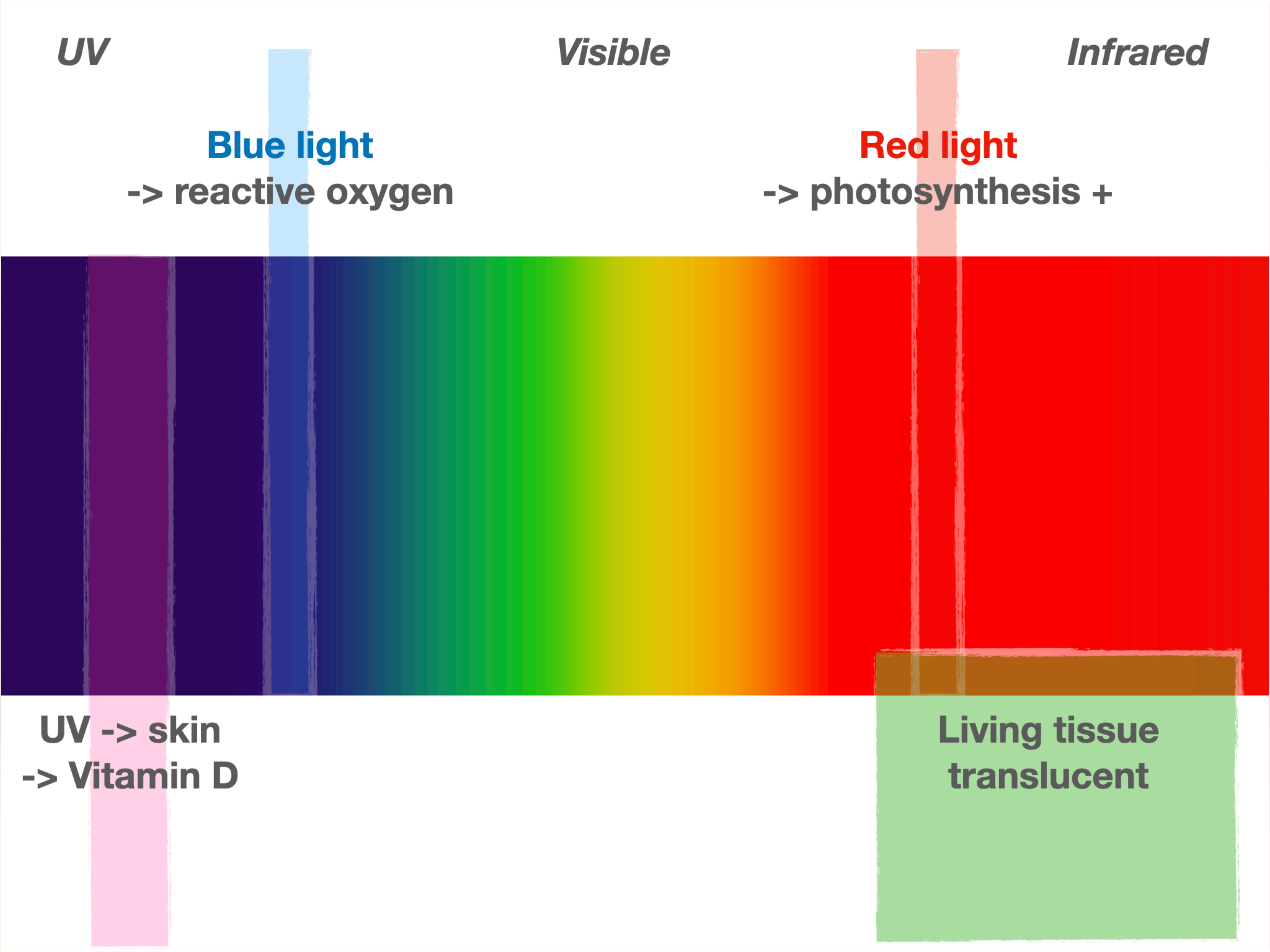


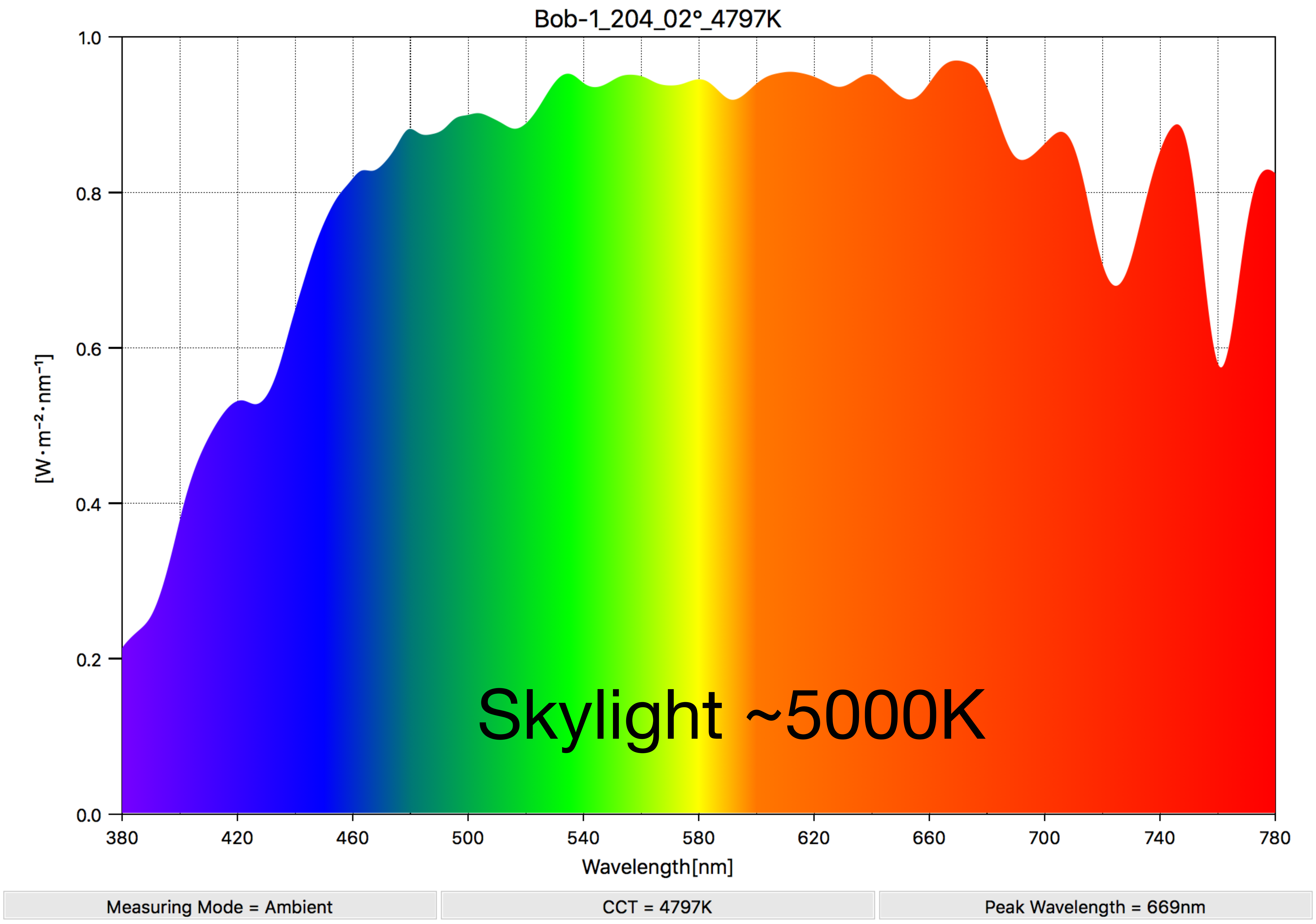
Fig. 18 The 2D natural photonic structures proved to be highly tolerant and resilient to positional disorder, giving rise to apparently constant and stable optical response. Total reflectance spectra were predicted at normal incidence from 2D structure models with hexagonal (a) and square (b) lattices, with increasing levels of positional disorder. The extent of disorder was controlled by the FWHM of the normal distribution of nearest neighbour distances. A FWHM of zero represents perfect order. Angle resolved reflectance intensities were calculated for the hexagonal structure model (c). Light reflection changes from specular to diffuse as positional disorder is increased in the structure model.

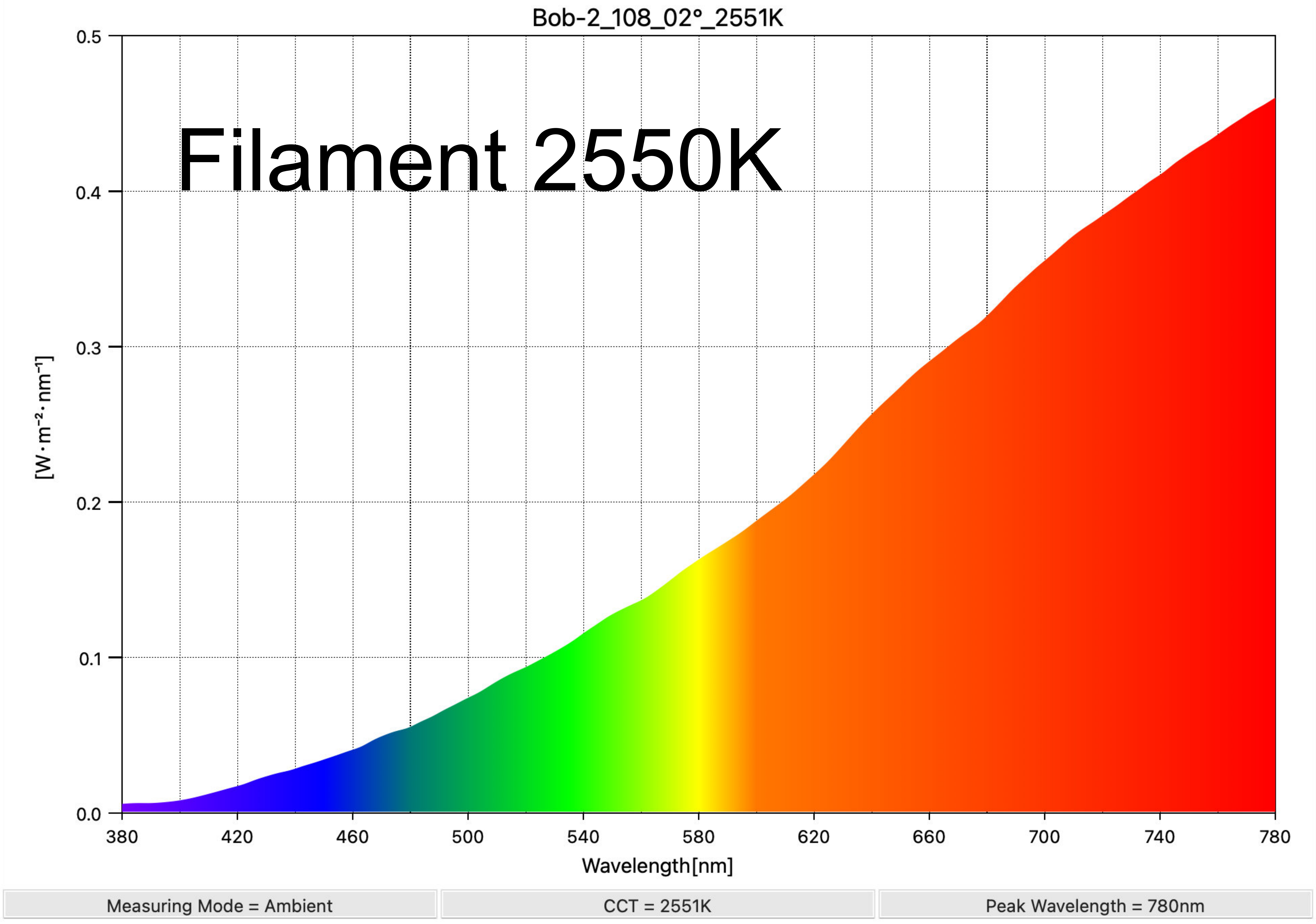

first order peak winter
first order peak summer
summer saddle
winter saddle
summer
winter
Reflectance
Wavelength (nm)
0
0.2
0.4
0.6
0.8
1
200
300
400
500
600
700
800

The wolf seen against snow at the blue/UV end of the spectrum

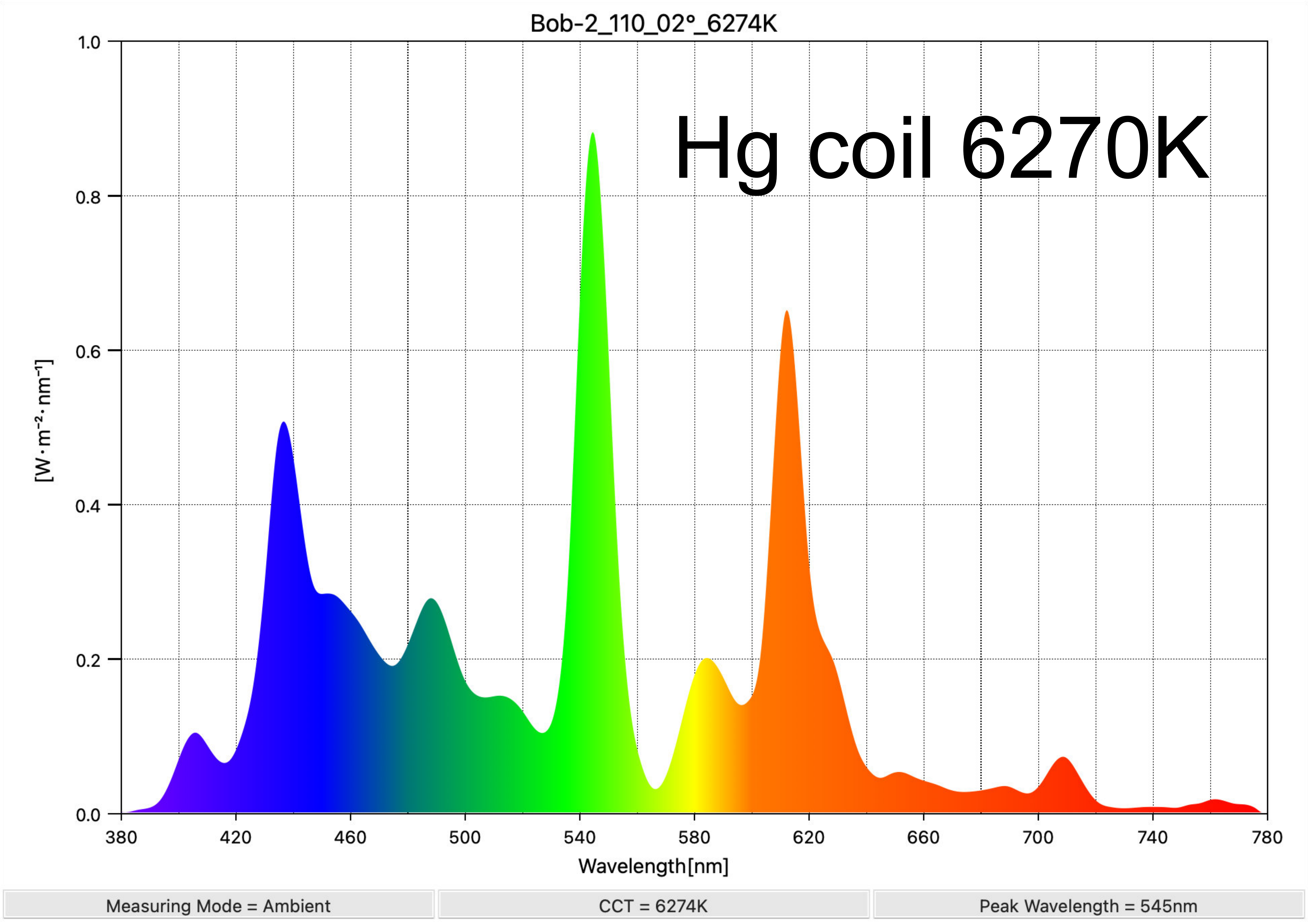
From: BBC EARTH

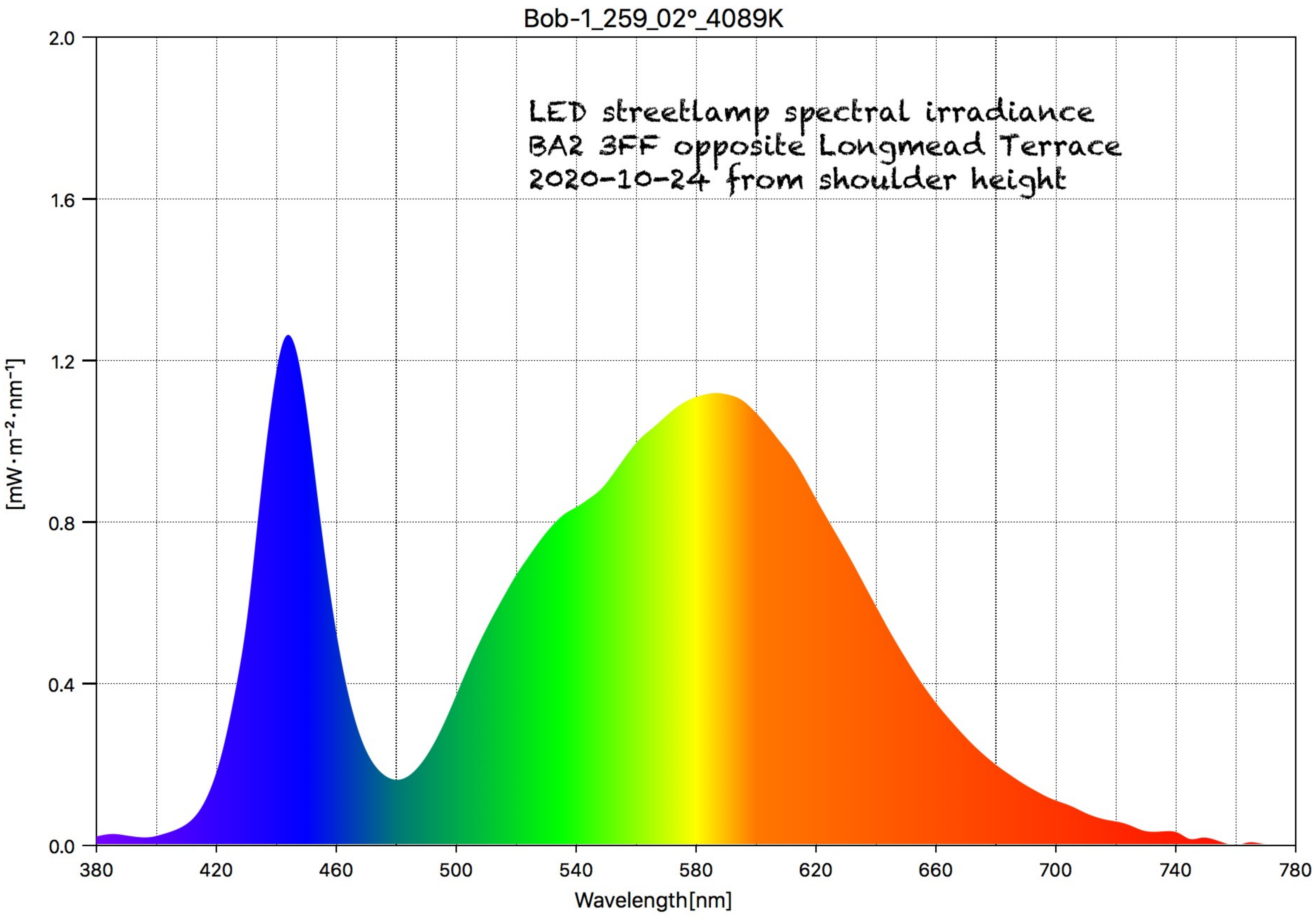

UV
Visible
Infrared
Blue light
-> reactive oxygen
Red light
-> photosynthesis +
UV -> skin
-> Vitamin D
Living tissue
translucent


Bob-1_204_02°_4797K
1.0
0.8
0.6
0.4
0.2
0.0
[W·m⁻²·nm⁻¹]
380
420
460
500
540
580
620
660
700
740
780
Wavelength[nm]
Skylight ~5000K
Measuring Mode = Ambient
CCT = 4797K
Peak Wavelength = 669nm

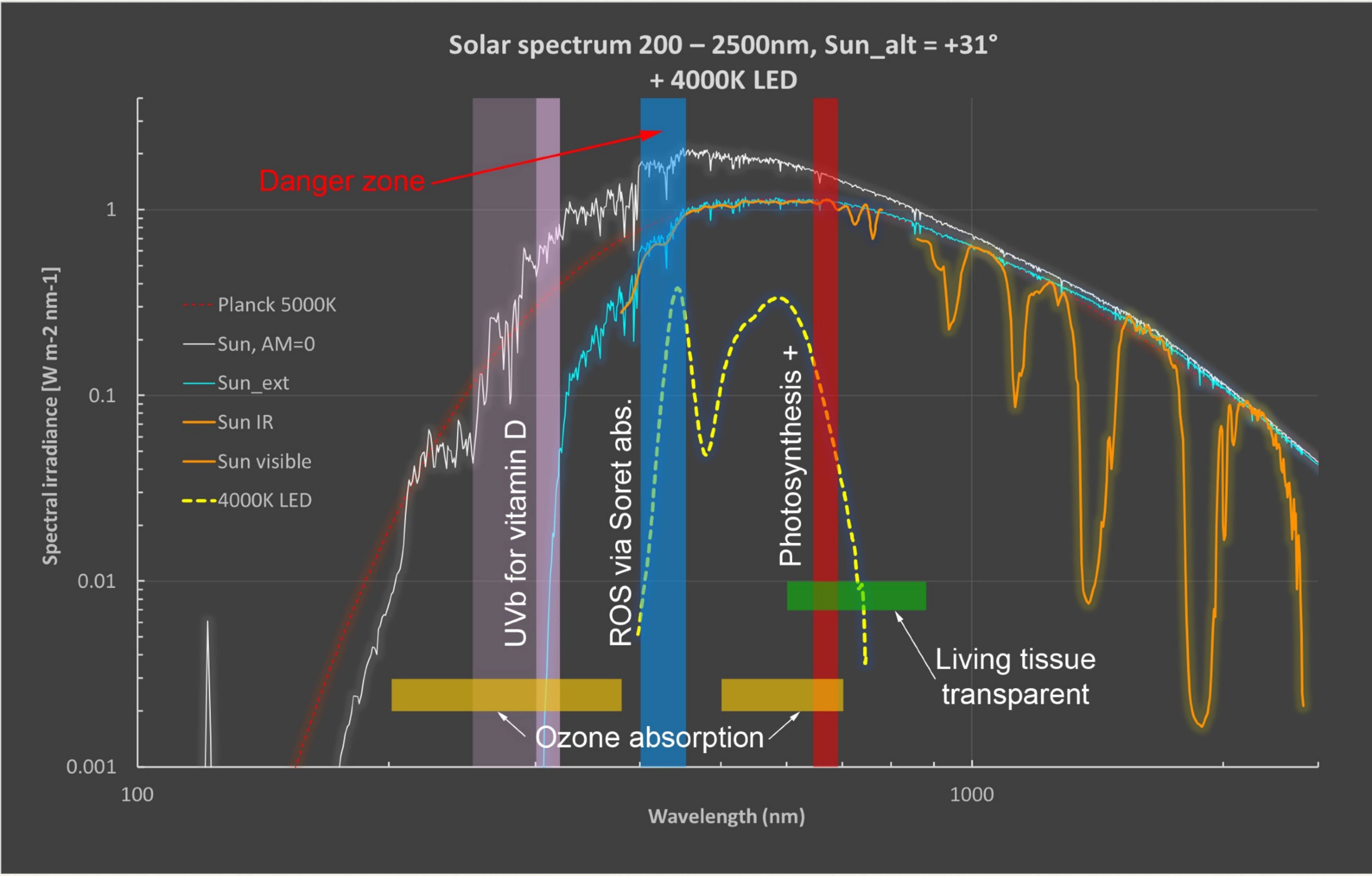


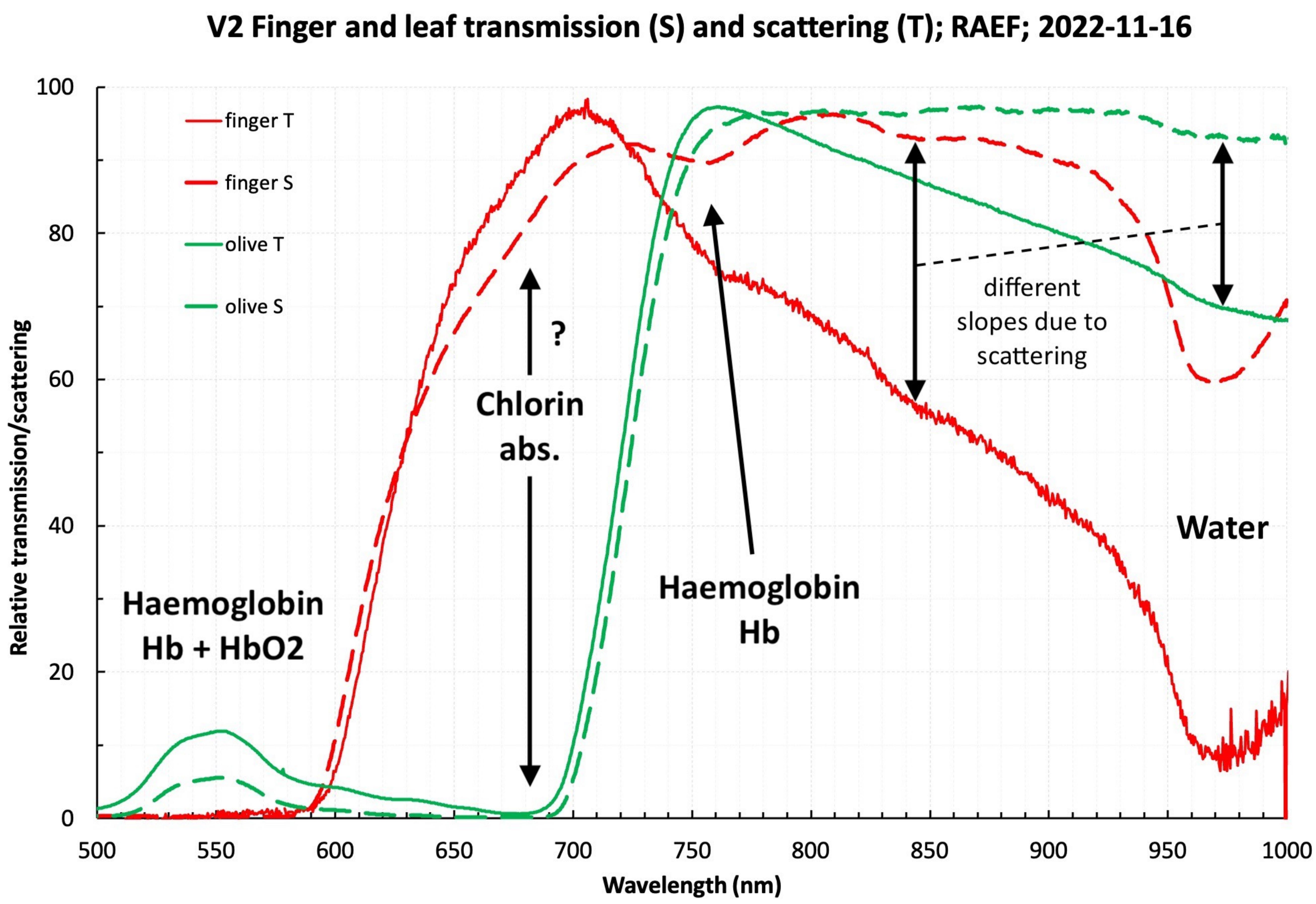
Bob-2_108_02°_2551K
Filament 2550K
[W·m⁻²·nm⁻¹]
0.0
0.1
0.2
0.3
0.4
0.5
380
420
460
500
540
580
620
660
700
740
780
Wavelength[nm]
Measuring Mode = Ambient
CCT = 2551K
Peak Wavelength = 780nm

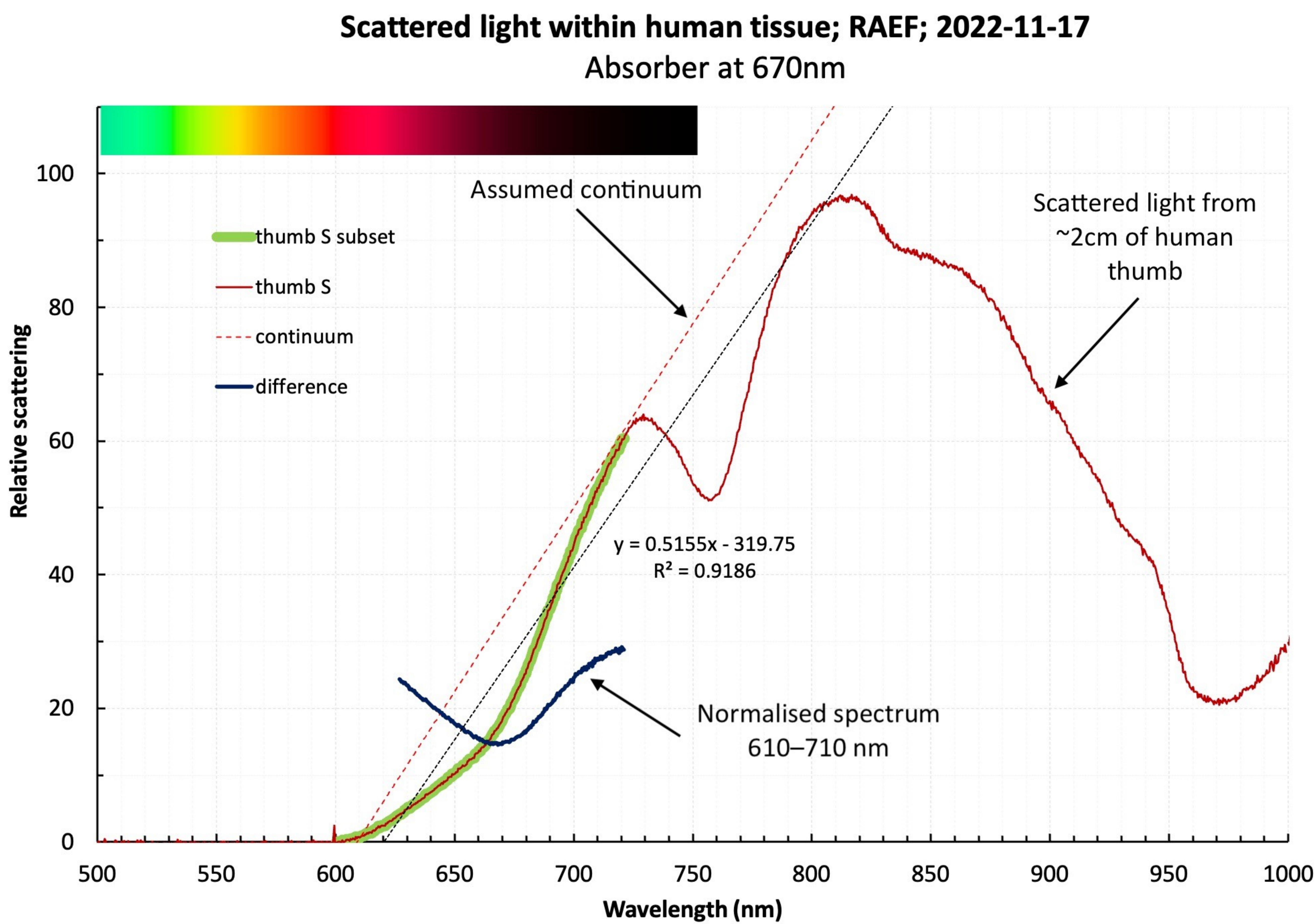

Bob-2_110_02°_6274K
Hg coil 6270K
[W·m⁻²·nm⁻¹]
1.0
0.8
0.6
0.4
0.2
0.0
380
420
460
500
540
580
620
660
700
740
780
Wavelength[nm]
Measuring Mode = Ambient
CCT = 6274K
Peak Wavelength = 545nm



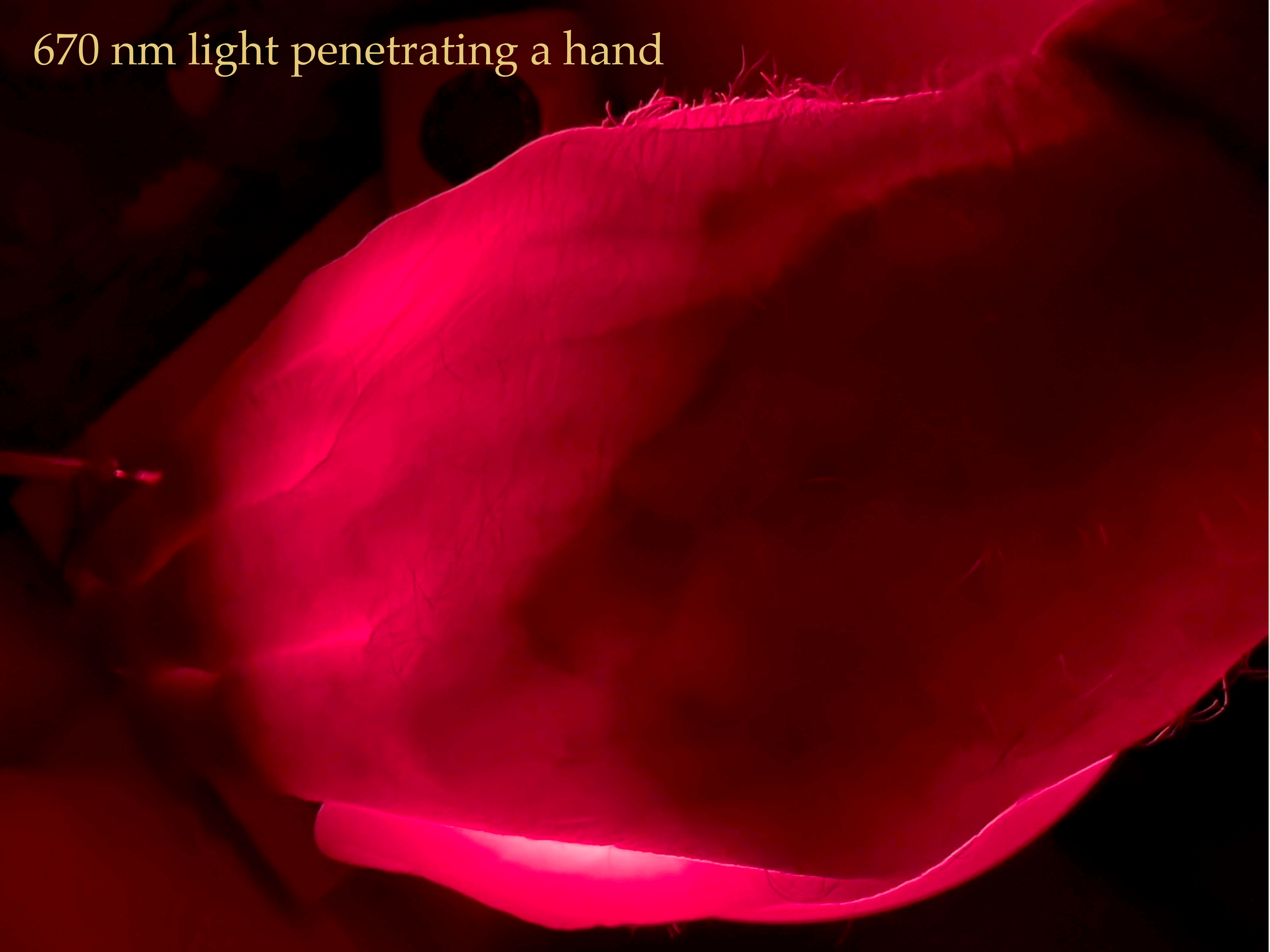
Measuring Mode = Ambient | CCT = 4089K | Peak Wavelength = 444nm


Solar spectrum 200 – 2500nm, Sun_alt = +31°
+ 4000K LED
Danger zone
Planck 5000K
Sun, AM=0
Sun_ext
Sun IR
Sun visible
4000K LED
UVb for vitamin D
ROS via Soret abs.
Photosynthesis +
Living tissue transparent
Ozone absorption
Spectral irradiance [W m-2 nm-1]
1
0.1
0.01
0.001
100
1000
Wavelength (nm)


V2 Finger and leaf transmission (S) and scattering (T); RAEF; 2022-11-16
finger T
finger S
olive T
olive S
Relative transmission/scattering
Wavelength (nm)
100
80
60
40
20
0
500
550
600
650
700
750
800
850
900
950
1000
?
Chlorin
abs.
Haemoglobin
Hb + HbO2
Haemoglobin
Hb
different
slopes due to
scattering
Water

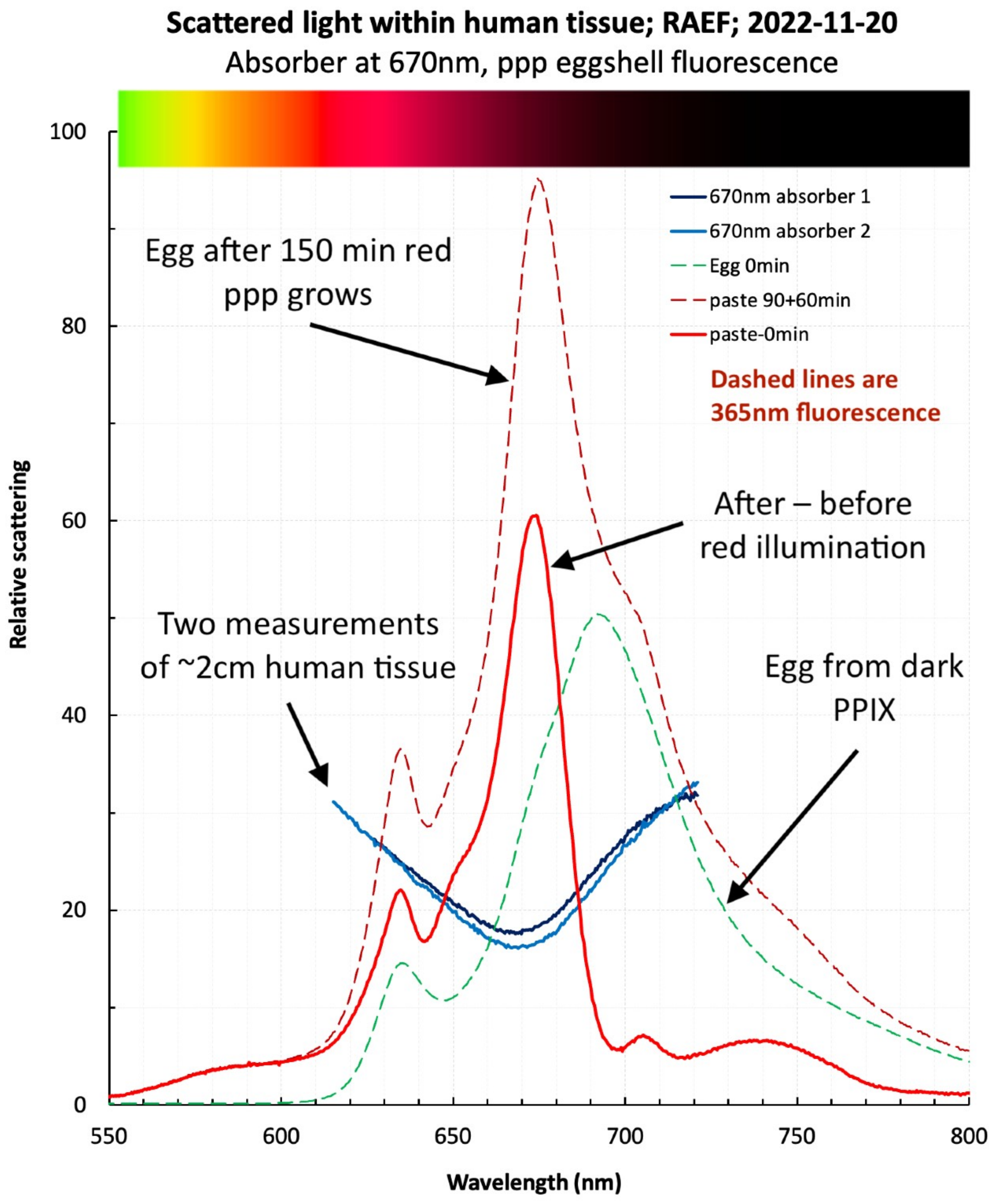


Scattered light within human tissue; RAEF; 2022-11-17
Absorber at 670nm
Assumed continuum
Scattered light from ~2cm of human thumb
thumb S subset
thumb S
continuum
difference
y = 0.5155x - 319.75
R² = 0.9186
Normalised spectrum 610–710 nm
Relative scattering
Wavelength (nm)
0
20
40
60
80
100
500
550
600
650
700
750
800
850
900
950
1000


670 nm light penetrating a hand

Hand transmission at 850nm using a lamp with 850 and 660nm diodes

Full spectrum camera with long-pass filter to remove 660nm emission


Scattered light within human tissue; RAEF; 2022-11-20
Absorber at 670nm, ppp eggshell fluorescence
100
80
60
40
20
0
550
600
650
700
750
800
Wavelength (nm)
Relative scattering
670nm absorber 1
670nm absorber 2
Egg 0min
paste 90+60min
paste-0min
Dashed lines are
365nm fluorescence
Egg after 150 min red
ppp grows
After – before
red illumination
Two measurements
of ~2cm human tissue
Egg from dark
PPIX

M. B. Ericson Æ S. Grapengiesser Æ F. Gudmundson A-M. Wennberg Æ O. Larko¨ Æ J. Moan Æ A. Rose´ n

A spectroscopic study of the photobleaching of protoporphyrin IX in solution

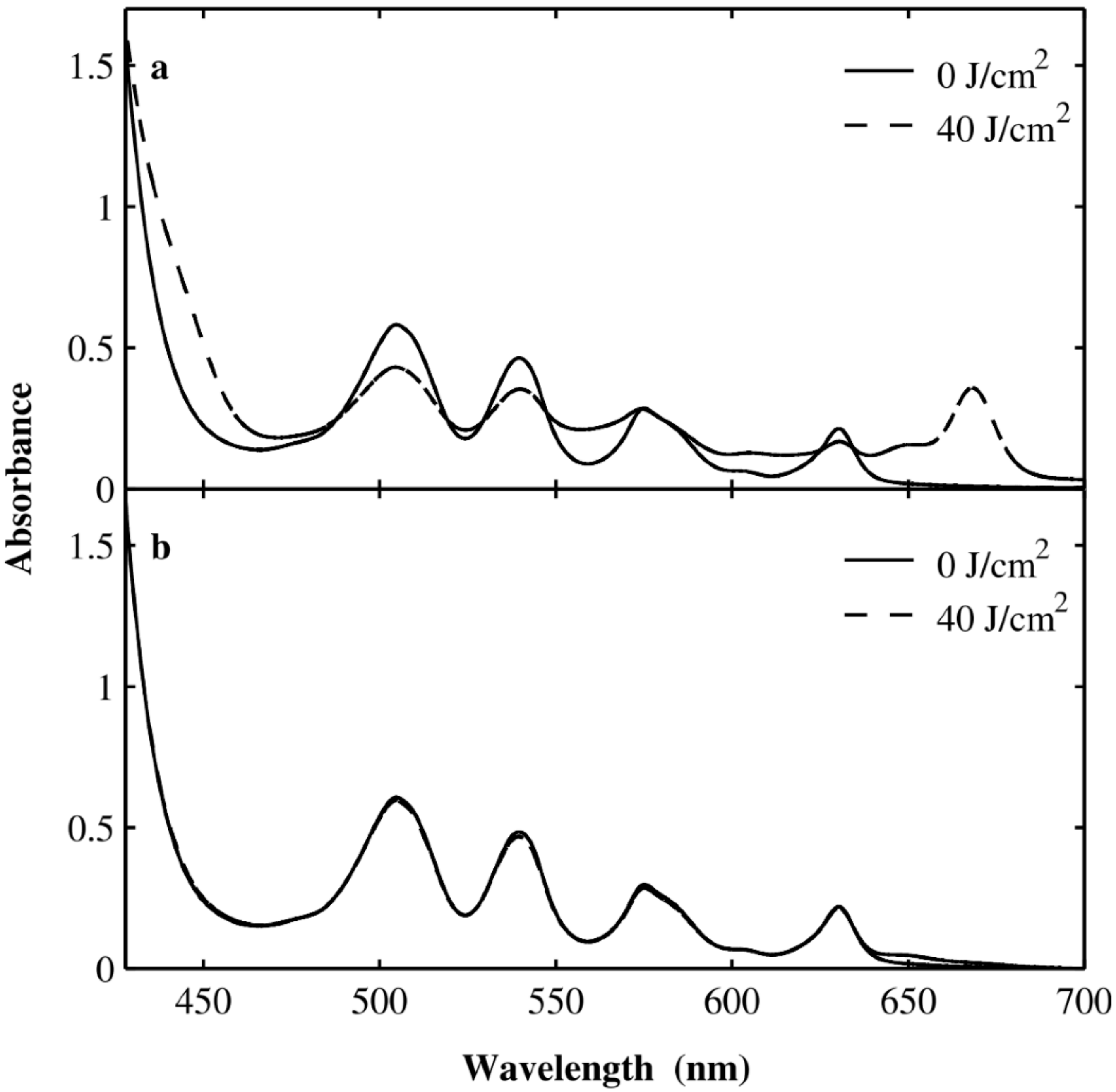


Fig. 2 Absorption Q bands of Pp IX before and after irradiation. **a** Air present; **b** deoxygenated sample

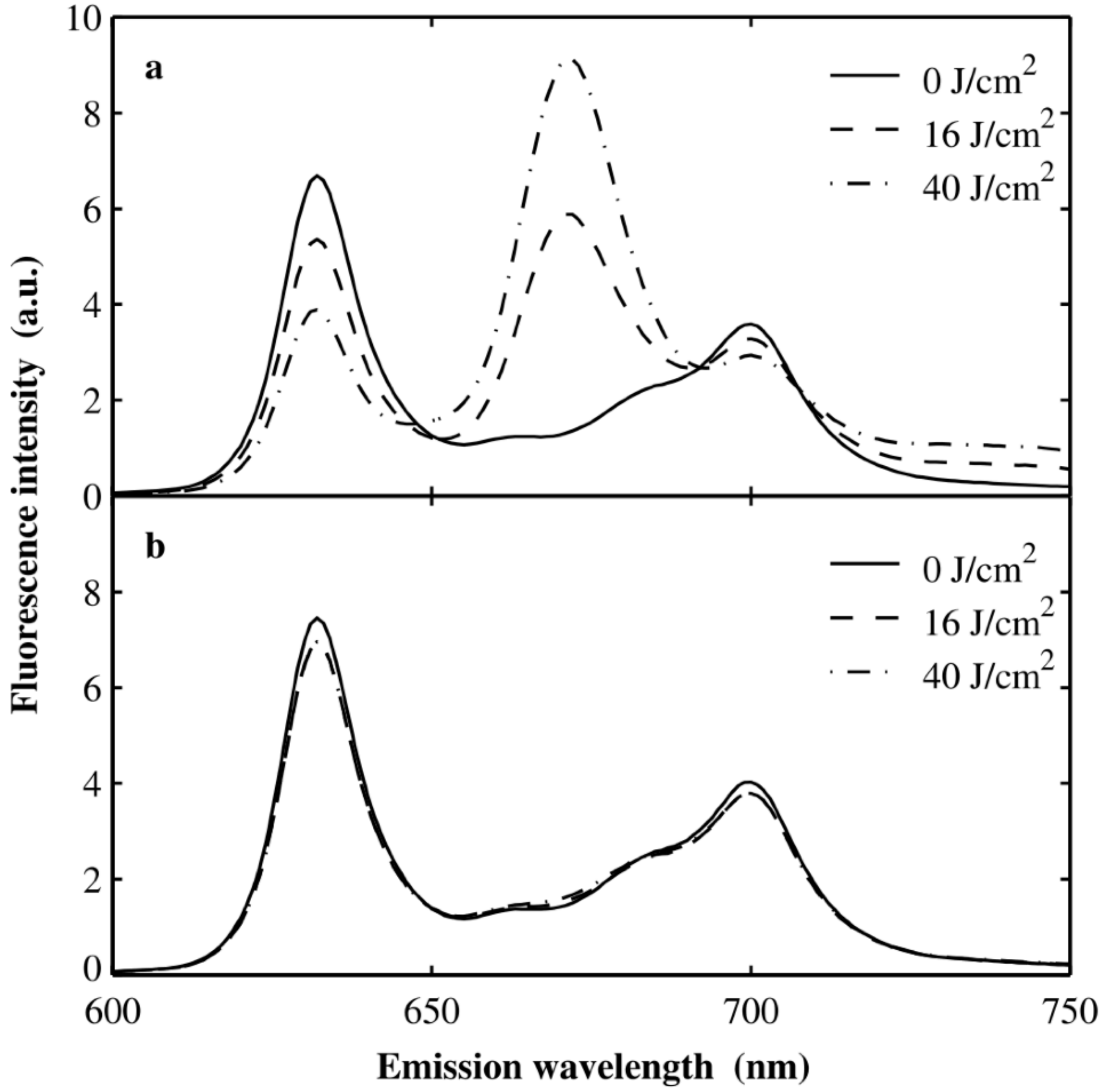


Fig. 5 Fluorescence emission spectra of Pp IX before and after irradiation. **a** Air present; **b** deoxygenated sample. (Excitation at 428 nm)

Access to the reindeer paper and commentary

Paper:
https://royalsocietypublishing.org/doi/10.1098/rspb.2022.1002

Commentary:
https://royalsocietypublishing.org/doi/10.1098/rspb.2022.1528

Article: “How the Sun Paints the Sky”

http://herschelsociety.org.uk/wp-content/uploads/2021/01/How-the-Sun-Paints-the-Sky_v9_med-res.pdf