Light and Sound

as serious pollutants

Jan Hollan

CzechGlobe –

Global Change Research Institute
(of Acad. Sci. Czech Rep.)

and

Department of Public Health,
Masaryk University, Brno

Pollution: what's that?

- centuries ago: religious notion only

- 60's: toxic additives to the environment
- now:
  - alteration of the natural state by adding anything

- – if harmful to us or other beings,
- that might be difficult to find

Pollutants affecting physics of environment

- radiation
- - electromagnetic waves
- - acoustic waves
- heat
- (like that from thermal power plants)
- particulate matter in the air
- greenhouse gases
- (= gases absorbing and emitting longwave infrared radiation)
- (see more on IS for 3. grade on PM and Climate Change)

Radiation

- at which wavelength ranges
- is the energy flux density around us
- really large?

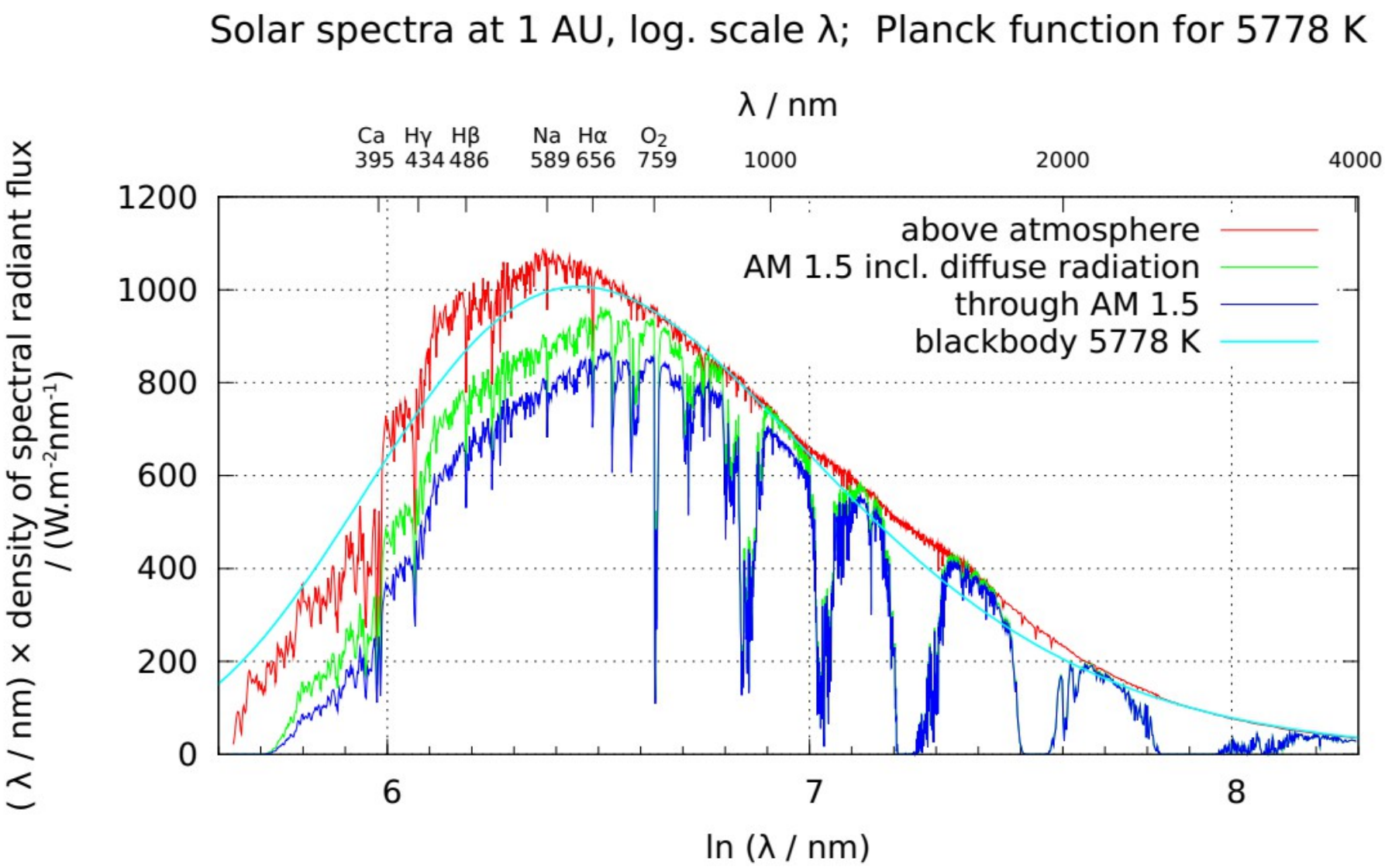
Radiation

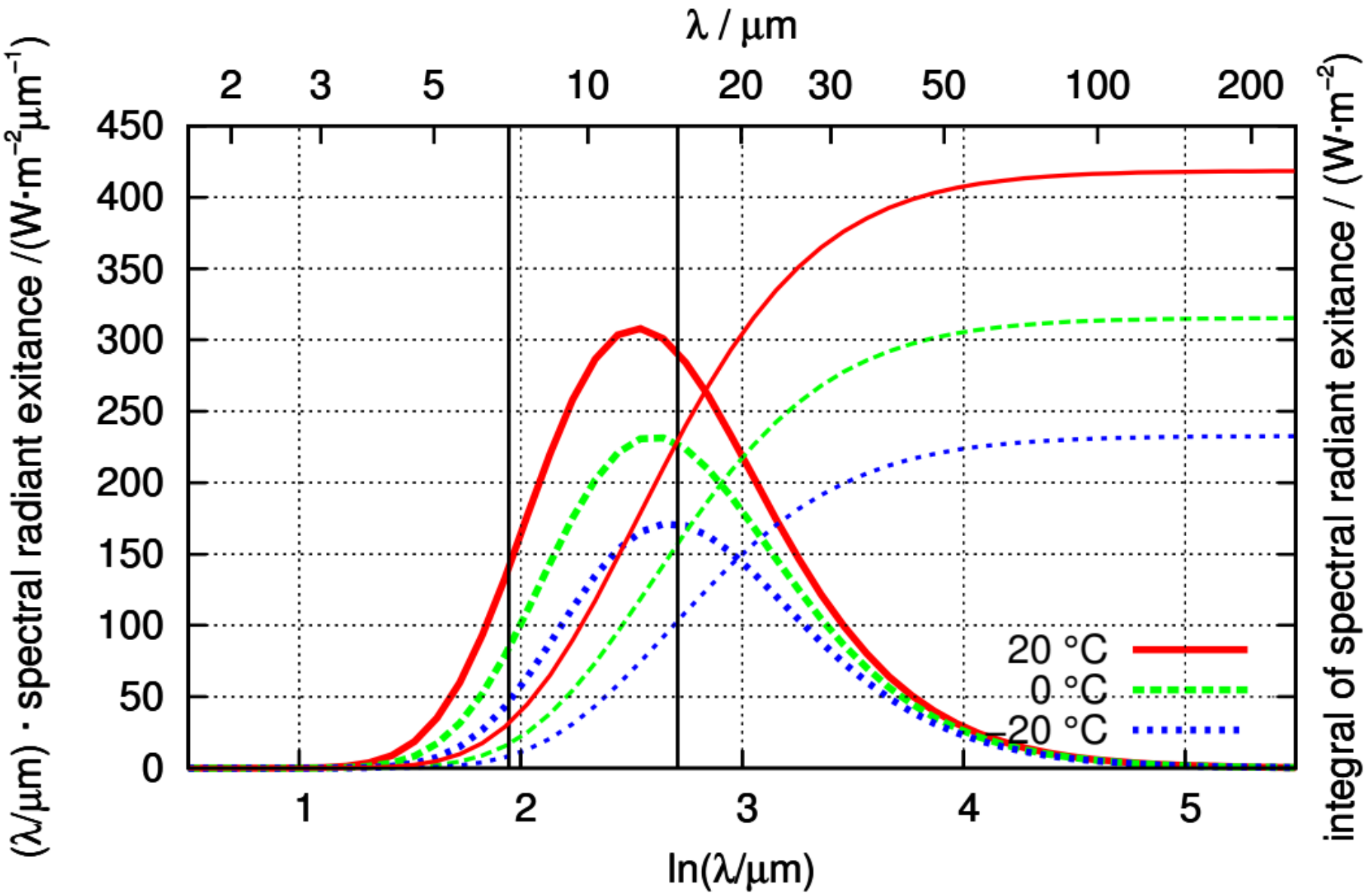
- - at those we feel as heat:

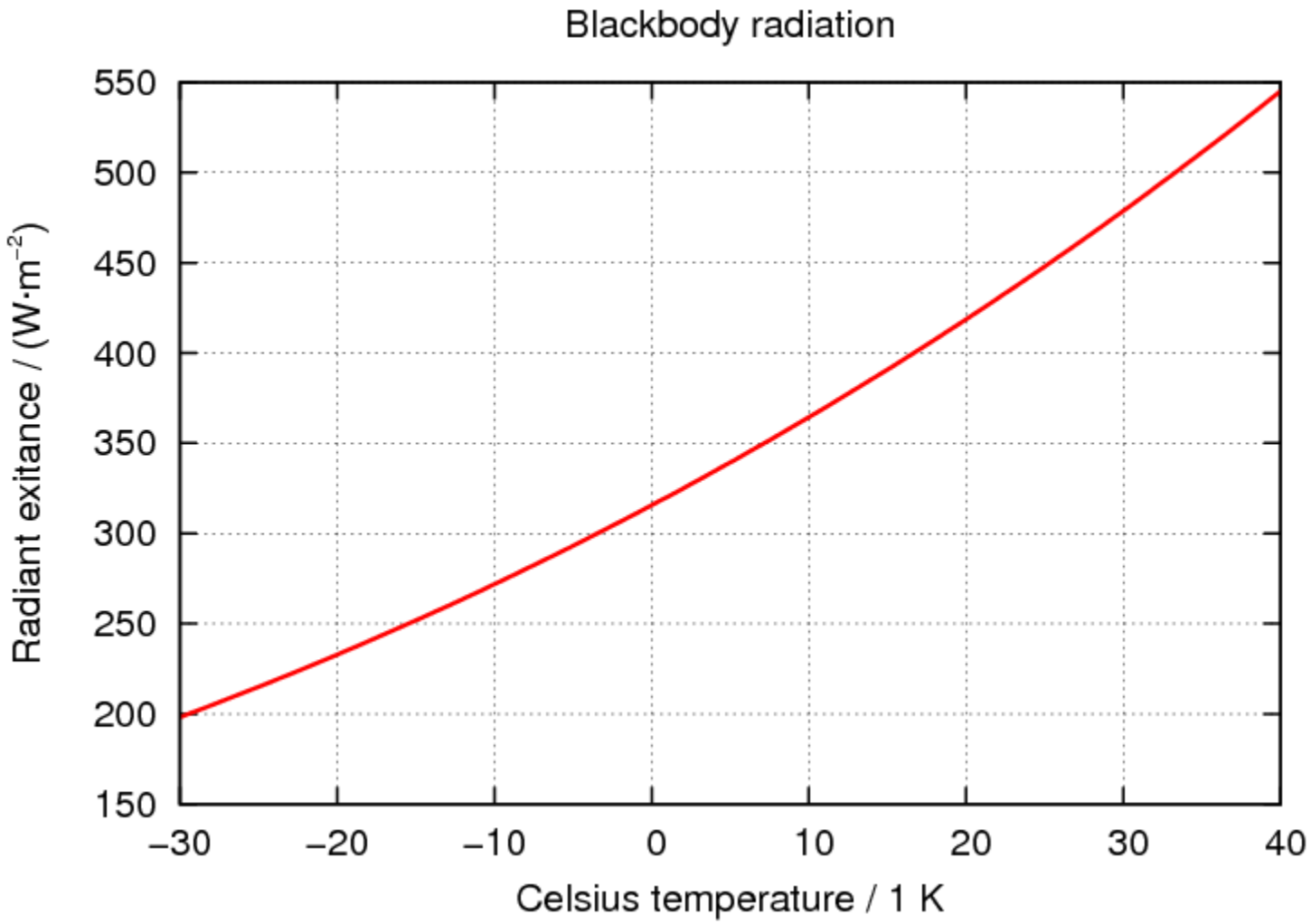
- Solar (tenths of a micrometre to several micrometres):
- up to 1 kW/m^2 - but not all the time

- *longwave* infrared (3 μm to over 100 μm):
- 0.4 kW/m^2 - from our environment at 18 ºC, all the time
- 0.5 kW/m^2 - from our face if very warm
- 1/3 kW/m^2 - from the atmosphere to the surface: the average greenhouse effect

solar and terrestrial spectra and fluxes




Blackbody radiation, log scale λ – Planck functions and their integrals
(the LWIR band from 7 μm to 15 μm is marked)
λ / μm
2
3
5
10
20
30
50
100
200
450
400
350
300
250
200
150
100
50
0
1
2
3
4
5
ln(λ/μm)
(λ/μm) · spectral radiant exitance /(W·m⁻²μm⁻¹)
integral of spectral radiant exitance / (W·m⁻²)
20 °C
0 °C
-20 °C


Blackbody radiation
Radiant exitance / (W·m^{-2})
550
500
450
400
350
300
250
200
150
−30
−20
−10
0
10
20
30
40
Celsius temperature / 1 K

Radiation in public view

- something surely dangerous, harmful
- - that from decay of radioactive elements: ionizing radiation

- It is measured in energy terms (J/kg), but its influence is chemical in fact

- even UV radiation affects molecular bonds and is harmful (even if we need it a bit: for D, we may have not enough in winter)

Radiation which matters more

- ionizing radiation: strict rules, good measurement, no real problem for most people
- UV: everybody knows
- Visible radiation (light), audible radiation (noise) have *far more serious impact* to all of us

Noise then and now

- how to get back to harmless levels?

Noise?

-

Noise - various meanings

- strong sound
- sound with no recognizable tones, no melody
- any sound we don't want to hear
- antipode of silence
- Noise – the same root as Nausea

Noise / Sound

- Sound pollution?
- (sound: OK, good, healthy, reasonable...)
- Therefore: Noise pollution
- or, better, *Acoustic pollution*

More noise targeting us

- Natural phenomena
- Anthropogenic sources, preindustrial
- Its new sources in the 20-th century
- … and in the 21-st one...

Lack of silence

and people being addict to it

Physics of Sound

- pressure fluctuation
- energy flux: a square of pressure amplitude

Weber-Fechner law

- what we perceive, is the ratio of inputs
- - i. e., the increment of the
- logarithm

Quantification

- $L_p = 10\ \mathrm{dB} \cdot \log(p^2/p_0^2)$
  - $p_0 = 2 \cdot 10^{-5}\ \mathrm{Pa}$
- $L_I = 10\ \mathrm{dB} \cdot \log(I / I_0)$
  - $I_0 = 10^{-12}\ \mathrm{W/m^2}$
  -
  - That's for 1000 Hz...

What's 1000 Hz?

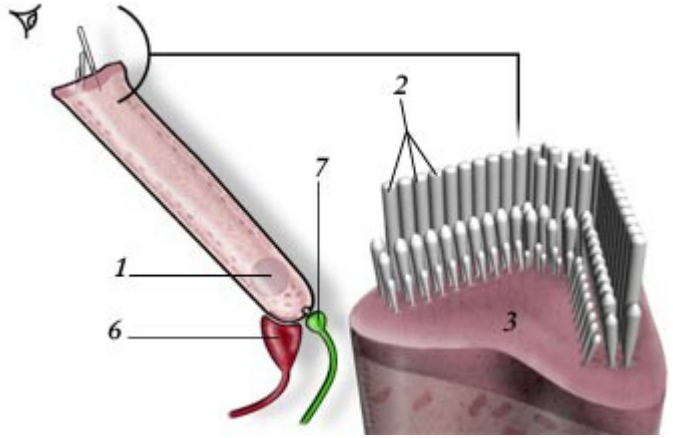
- and what spectral composition the real sounds have,
- like speech
- ...from Voice type on Wikipedia:

What's 1000 Hz?

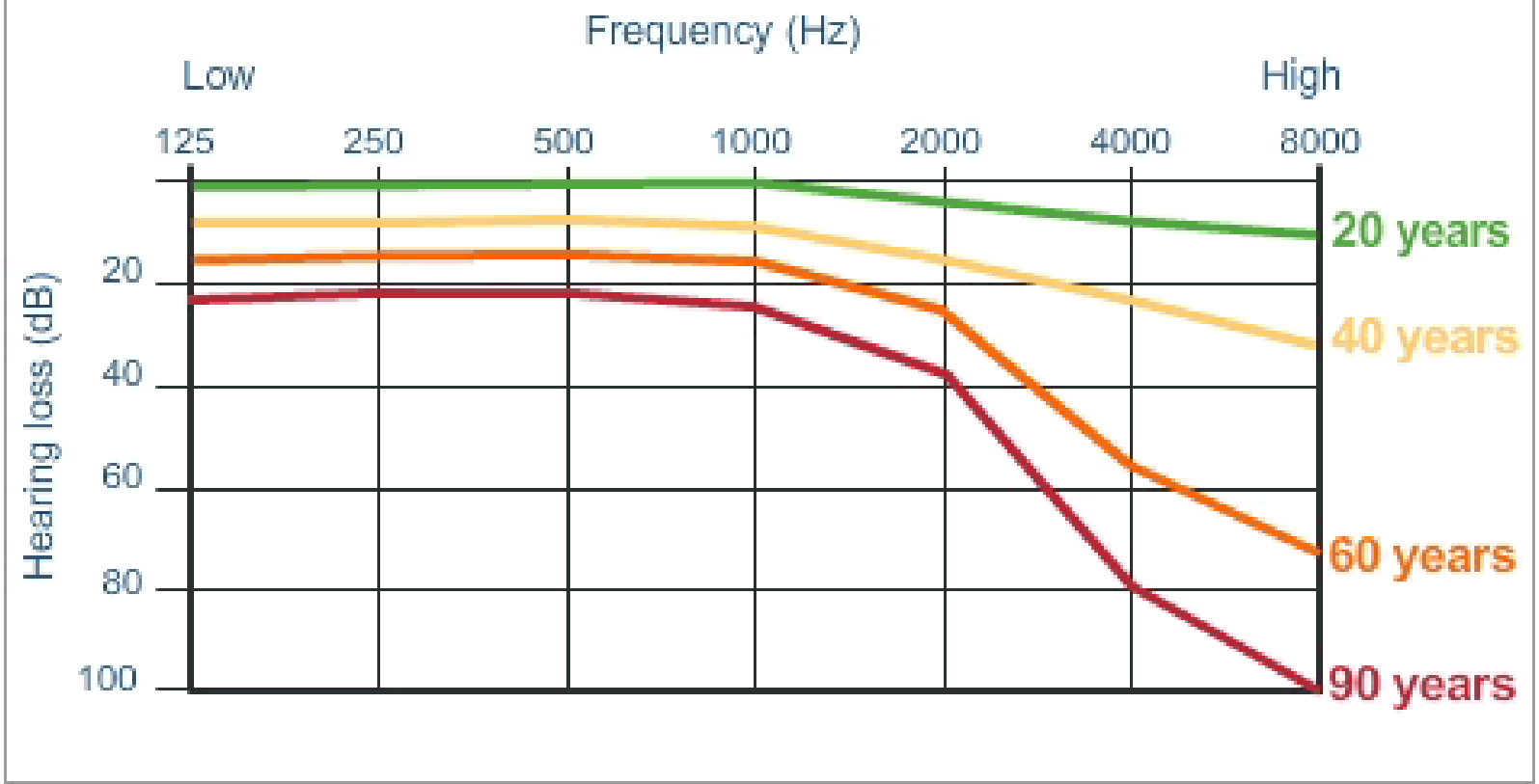
from http://onlinetonegenerator.com

Damage of “hairs”

- that is, of amplification 10^5 times (50 dB), esp. for high frequencies:
- http://www.cochlea.org/en/noise
- http://www.cochlea.eu/en/pathology/presbycusis
- (on hair cells: http://www.cochlea.eu/en/hair-cells)



Presbycusis



Some loudness levels

- pneumatic chipper at 1 metre 115
- hand-held circular saw at 1 metre 115
- power lawn mower at 1 metre 92
- diesel truck 50 km/h at 20 metres 85
- passenger car 60 km/h at 20 metres 65
- conversation at 1 metre 55
- quiet room 40
- … and what about less?
- - we don't really measure silence

Ten times, two times, three times..

-
- How many decibels it amounts to?

5 dB, that is some ratio of energy fluxes

- and further 5 dB the same ratio
- together, it is 10 dB, that is 10x more
- so, 5 dB is a square root of that, or roughly
- 3:1 ratio:
- 5 dB more means (just a bit more than) 3x more
-
- and 3 dB, 6 dB, 9 dB?

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- 3:1 ratio:
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-
- and 3 dB, 6 dB, 9 dB?
- **2x, 4x, 8x**
- (now you'll be able to read logarithmic scale...)

Health effects

- en.wikipedia.org/wiki/Noise_health_effects
-
- hearing impairment – over the aging-dependent one
- (high frequencies most affected, loss of speech recognition)
- tinnitus
- hypertension
- cardiovascular
- discomfort, anger
- sleep disturbance
-

Sleep well?

- Darkness
- and silence
- are a *must*

Technical measures against noise

-
- barriers to its propagation
-
- emission reduction
-
- protect yourself

Light as a pollutant

- Light pollution – no heavy issue?
-
- Outdoors: **any light added artificially**
- (at night) alters its natural state
-
- Indoors? It has no natural state, being artificial itself. As long as we light it on purpose:
    - light which could harm our health...

Darkness: a basic attribute of night

- Darkness, what's that?
-
- Less light than short ago
  - or in adjacent area.
- Common in daytime too...
-
- There is light outdoors in nature at night,
- but less of it below a roof or in a forest.
-
- No light: just totally enclosed spaces.

Darkness unwanted

- a symbol of ugliness
- source of anxiety and fear
- …but no real danger
- just a necessity to move with more caution

- we see at night: night is not black, just gray

Darkness wanted

- for rest
- contemplation or prayer
- storytelling
- privacy
- and for the nature, of course
-
-

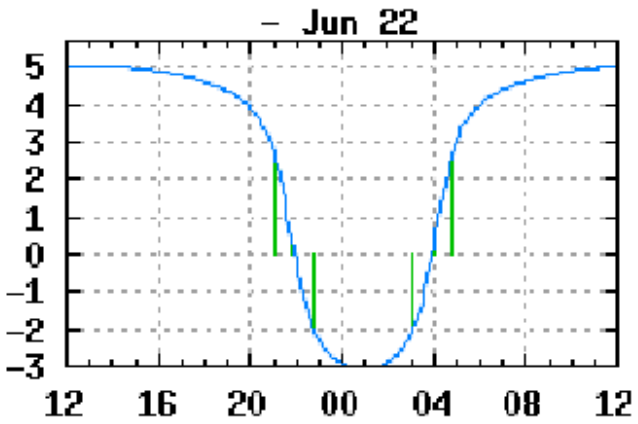
Light themes

- *discussion: do you have enough darkness for sleep? How do you protect yourselves from light if it disturbs you?*
- *How long do you sleep in various situations (response on leaflets)*
- Why the sleep is so important, even for studying...
- light measurement below the table, by the wall, by the window, outside, to the eyes
- yellow glasses influence

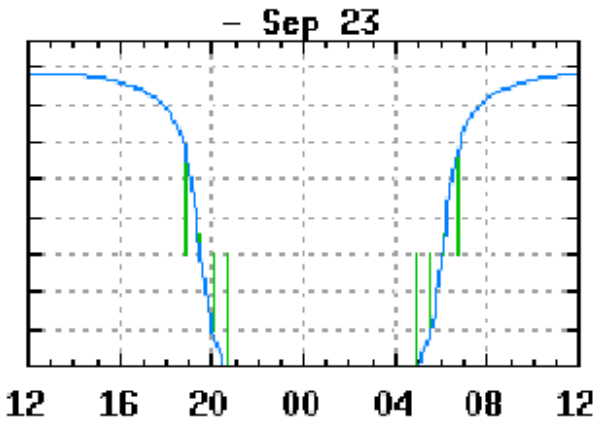
Day and night alteration: the basic rhytm of our world

- sunny day 30 thousand to 100 thousand lux
- 1/1000 lx at night
- overcast: 3x to 30x less
- day/night ratio: 3 millions to 1000 millions
- full moon night – 1/10 lx
  (the ratio day/night diminishes 100x)
-

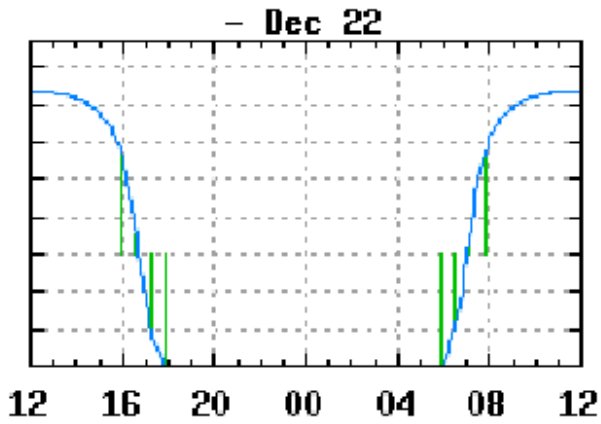
log (horizontal illuminance / 1 lx)
clear sky, with/out Moon



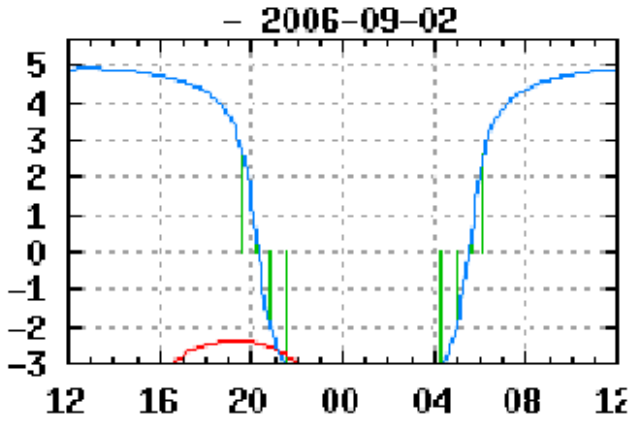
letní slunovrat
*(**6,3** h, astron. nenastává)*



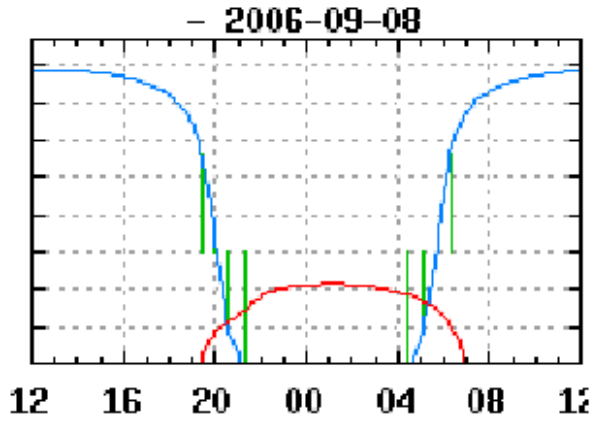
rovnodennost
*(**10,7** h , 8,2 h)*



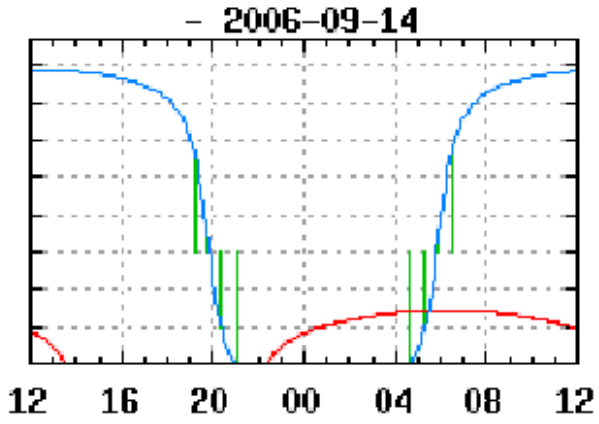
zimní slunovrat
*(**14,5** h , 11,9 h)*



půl dne po první čtvrti
(max. 0.004 lx, ve dne...)



úplněk
(téměř 0,2 lx)



0,5 d před poslední čtvrtí
(až 0,03 lx)

And indoors?

- Orders of magnitude less light then outdoors - originally
- Now tens to hundreds lux at night
- Often more than during daylight...

Artificial lighting

- originally, just flames (wood, fat), not easy and not everywhere

- then enhanced flames

- then electricity, everywhere, whole night

- 24 / 7 ...

Its advantages

- people out of nature don't like darkness, even adults
- darkness is full of ghosts
- today, no ghosts, but: murderers, robbers...
- seeing your way makes walking or riding easier
- but no crime reduction, on the contrary...

and disadvantages

- loss of natural habitat (species disappear, ecosystems, culture, quality of life)
- people don't know night environment any more
- visibility and orientation impairment due to glare
- loss of touch of the Universe
- tremendous expenditures
- and greenhouse gas emissions
- health impairment due to lacking darkness

The first awareness that a problem exists – the 60's

some astronomers

- before the discharge lamps began to replace old bulbs and before the superstition that

“everything is to be lit” became common

but:

Squires WA, Hanson HE. 1918. The destruction of birds at the lighthouses on the coast of California. Condor 20: 6–10.

Outdoor lighting impacts, Czechia, 2003, one thoudand persons >15 years

5 % have serious sleep problems and mention light as one of the two principal reasons

unwanted, not enough reduced light into bedrooms, affecting another 10 %

using night shades with success, further 20 %

glare perceived as a problem by tens of per cent

replacement of true nighttime landscape by lamps themselves – almost half of the population complains,

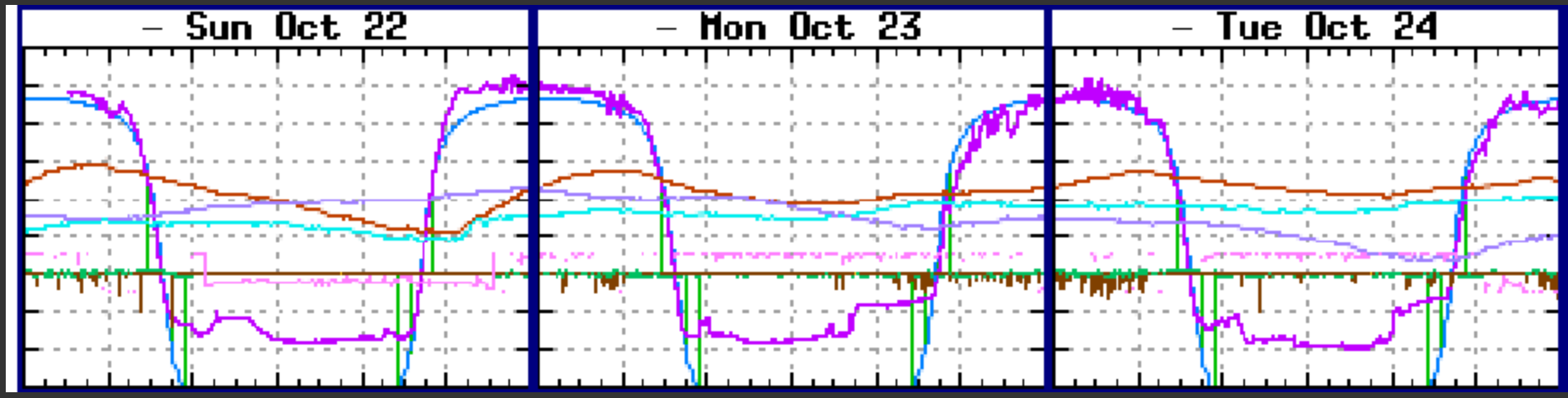
diminished visibility of stars due to glare, says almost half of the population

too bright sky even where there is no glare, says quarter of the population.

... loss of heavens may be more serious than we might guess...

Brno, Kuhberg

- Clear sky: 1 to 2 centilux instead of 1 millilux
- Overcast: decilux levels



Life in nature

- most animals active at night
- darkness is the basic protection
- alteration of light environment is fatal for them
-
- The points or areas of super-high luminance are the worst,
- but
- even the mere absence of natural darkness is a problem

Some impacts

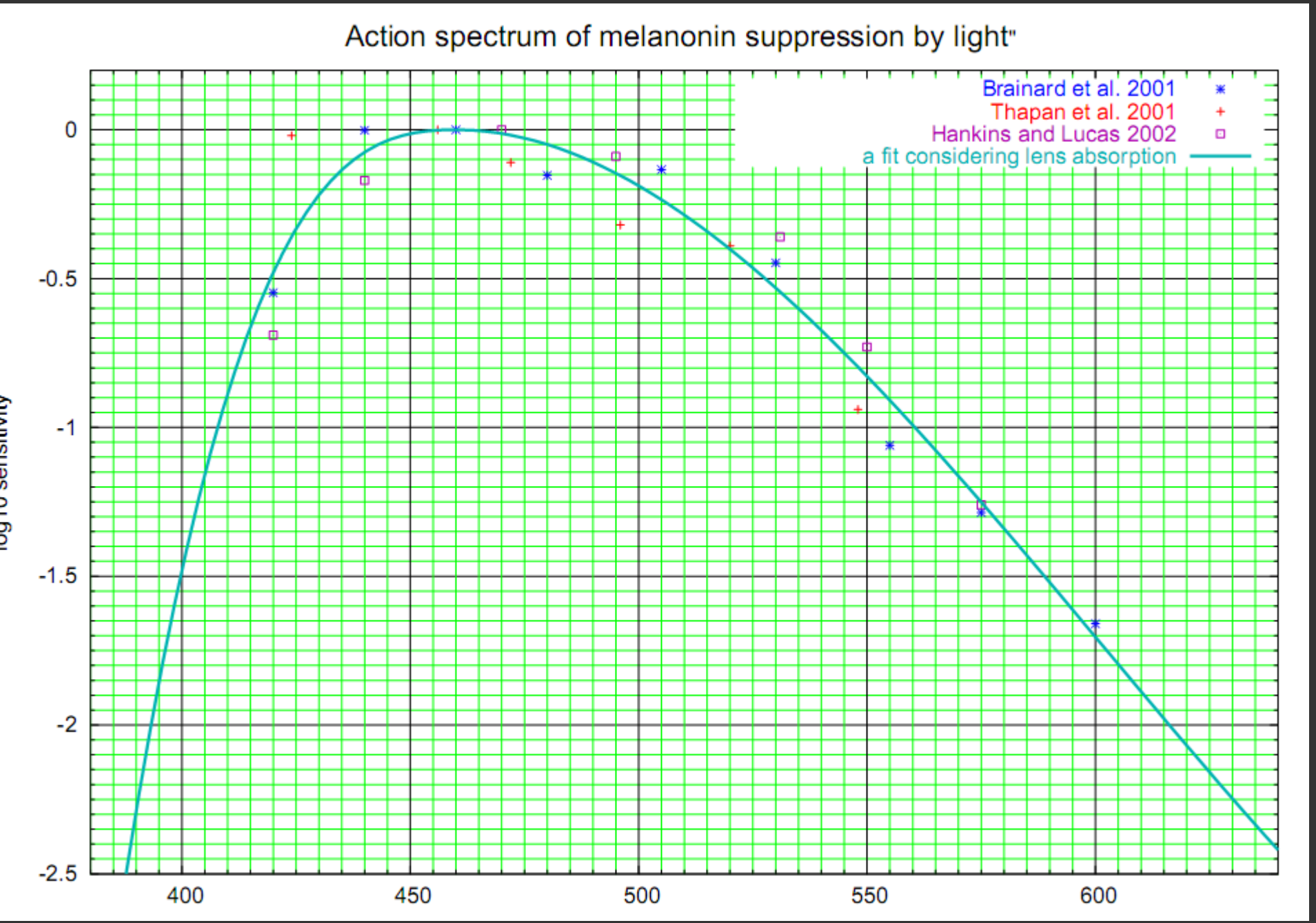
- turtles going away from sea instead towards
- confused, injured, dead birds
- eutrophicated freshwaters
- decimated insect populations, influencing whole ecosystems (mayflies 100 years ago, now...)
- stress for coral reefs (added to temperature, acidity, chemical pollution)
- where are the fireflies?

Light is a serious pollutant

- **Photopollution:**
- degradation of photic habitat
- by artificial light
- (Verheijen, 1985)
-
- Darkness is a biological imperative
-
- **Scotobiology**

Circadian rhythm, melatonin

- natural night and melatonin production is 11 h in average (more in winter, less in summer)
-
  our electric culture shortened it to the sleeptime
-
- breast and prostate cancer, obesity, diabetes


Action spectrum of melanonin suppression by light"
Brainard et al. 2001
Thapan et al. 2001
Hankins and Lucas 2002
a fit considering lens absorption
log10 sensitivity
0
-0.5
-1
-1.5
-2
-2.5
400
450
500
550
600

Stevens, R.G. Electric power use and breast cancer: a hypothesis. *Am. J. Epidemiol.* **125**, 556 (1987).

Stevens, R.G. Light-at-night, circadian disruption and breast cancer: assessment of existing evidence. *International Journal of Epidemiology* **38**, 963 -970 (2009):

Background Breast cancer incidence is increasing globally for largely unknown reasons. The possibility that a portion of the breast cancer burden might be explained by the introduction and increasing use of electricity to light the night was suggested >20 years ago.

Methods The theory is based on nocturnal light-induced disruption of circadian rhythms, notably reduction of melatonin synthesis. It has formed the basis for a series of predictions including that non-day shift work would increase risk, blind women would be at lower risk, long sleep duration would lower risk and community nighttime light level would co-distribute with breast cancer incidence on the population level.

Results Accumulation of epidemiological evidence has accelerated in recent years, reflected in an International Agency for Research on Cancer (IARC) classification of shift work as a probable human carcinogen (2A). There is also a strong rodent model in support of the light-at-night (LAN) idea.

Conclusion

If a consensus eventually emerges that LAN does increase risk, then the mechanisms for the effect are important to elucidate for intervention and mitigation. The basic understanding of phototransduction for the circadian system, and of the molecular genetics of circadian rhythm generation are both advancing rapidly, and will provide for the development of lighting technologies at home and at work that minimize circadian disruption, while maintaining visual efficiency and aesthetics. In the interim, there are strategies now available to reduce the potential for circadian disruption, which include

- extending the daily dark period,
- appreciate nocturnal awakening in the dark,
- using dim red light for nighttime necessities,
- and unless recommended by a physician, not taking melatonin tablets.

Epidemiology evidence

Kloog, I., Haim, A., Stevens, R.G., Barchana, M. & Portnov, B.A.

Light at Night Co-distributes with Incident Breast but not Lung Cancer in the Female Population of Israel.

Chronobiology International **25**, 65-81 (2008).

Kloog, I., Haim, A., Stevens, R.G. & Portnov, B.A.

Global Co-Distribution of Light at Night (LAN) and Cancers of Prostate, Colon, and Lung in Men.

Chronobiology International **26**, 108-125 (2009).

Kloog, I., Portnov, B.A., Rennert, H.S. & Haim, A.

Does the Modern Urbanized Sleeping Habitat Pose a Breast Cancer Risk? (see also its Scholar Google citations)

Chronobiol Int **28**, 76-80 (2011):

(its abstract:)

Due to its disruptive effects on circadian rhythms and sleep deprivation at night, shiftworking is currently recognized as a risk factor for breast cancer (BC). As revealed by the present analysis based on a comparative case-control study of 1679 women, exposure to light-at-night (LAN) in the “sleeping habitat” is significantly associated with BC risk (odds ratio [OR]=1.220, 95% confidence interval [CI]=1.118–1.311; p<.001), controlling for education, ethnicity, fertility, and alcohol consumption. The novelty of the present research is that, to the best of the authors' knowledge, it is the first study to have identified an unequivocal positive association between bedroom-light intensity and BC risk. Thus, according to the results of the present study, not only should artificial light exposure in the working environment be considered as a potential risk factor for BC, but also LAN in the “sleeping habitat.”

Gooley, J.J. et al. Exposure to Room Light before Bedtime Suppresses Melatonin Onset and Shortens Melatonin Duration in Humans. *J Clin Endocrinol Metab* (2010) doi:10.1210/jc.2010-2098

Millions of individuals habitually expose themselves to room light in the hours before bedtime, yet the effects of this behavior on melatonin signaling are not well recognized. Objective: We tested the hypothesis that exposure to room light in the late evening suppresses the onset of melatonin synthesis and shortens the duration of melatonin production. Design: In a retrospective analysis, we compared daily melatonin profiles in individuals living in room light (<200 lux) vs. dim light (<3 lux). Patients: Healthy volunteers (n = 116, 18-30 yr) were recruited from the general population to participate in one of two studies. Setting: Participants lived in a General Clinical Research Center for at least five consecutive days. Intervention: Individuals were exposed to room light or dim light in the 8 h preceding bedtime. Outcome Measures: Melatonin duration, onset and offset, suppression, and phase angle of entrainment were determined. Results: Compared with dim light, exposure to room light before bedtime suppressed melatonin, resulting in a later melatonin onset in 99.0% of individuals and shortening melatonin duration by about 90 min. Also, exposure to room light during the usual hours of sleep suppressed melatonin by greater than 50% in most (85%) trials. **Conclusions:** These findings indicate that room light exerts a profound suppressive effect on melatonin levels and shortens the body's internal representation of night duration. Hence, chronically exposing oneself to electrical lighting in the late evening disrupts melatonin signaling and could therefore potentially impact sleep, thermoregulation, blood pressure, and glucose homeostasis.


PARK HOURS
OPEN FROM:
SUNRISE UNTIL
1/2 HOUR AFTER
SUNSET
NO
TRESPASSING
AT OTHER
TIMES

Pollution of the enviroment by man-made light

still increases, quickly

The rise should be stopped and reversed, so that we get to a sustainable course

Similar to fossil carbon emissions

Both pollutants considred harmless 40 years ago,

both are very harmful.

Solution:

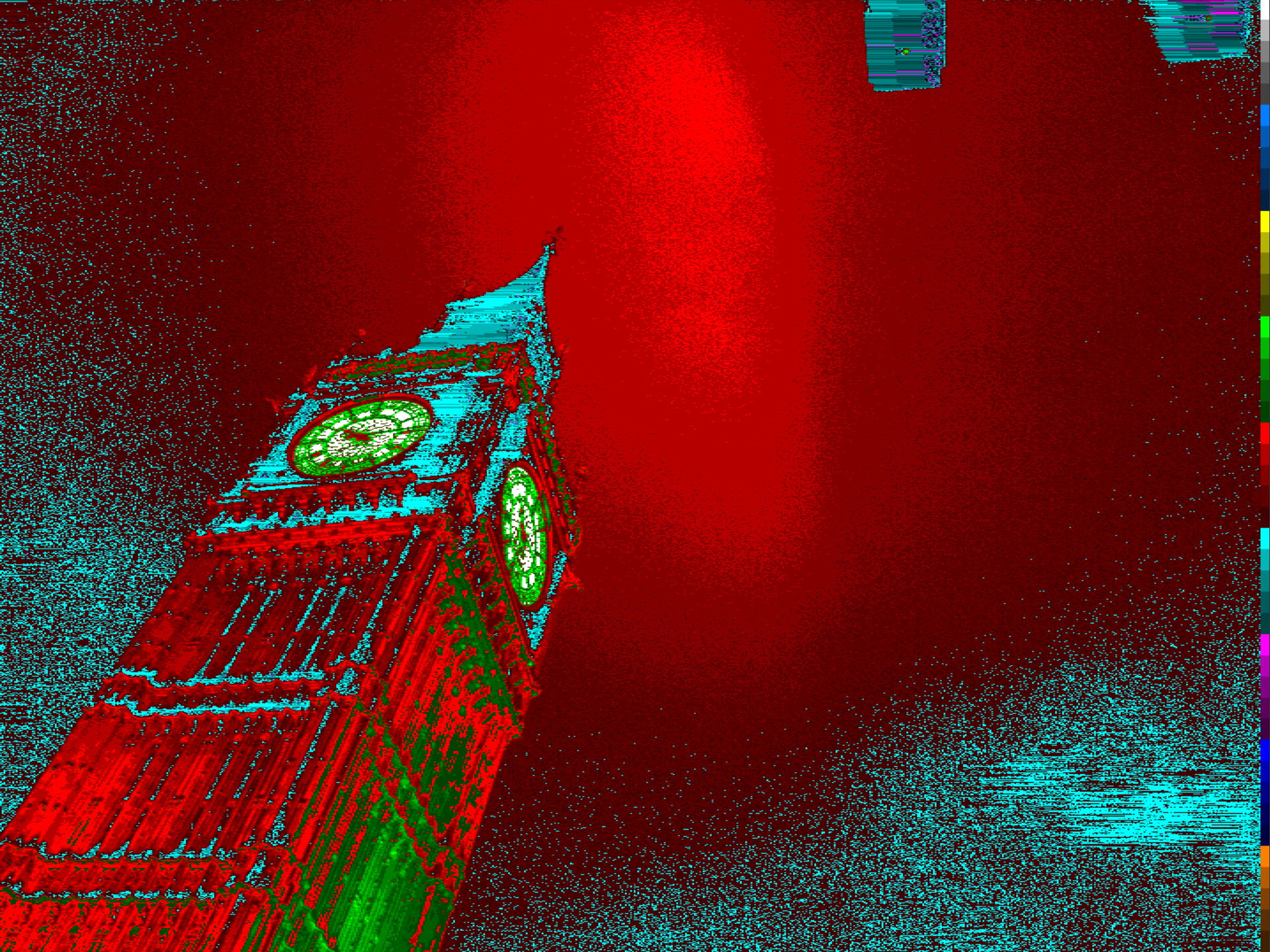
don't waste so much, be careful

Basic rules for outdoor lighting (like in Slovenia and most of Italy)

No emissions horizontally and upwards

Using just that much light, what's necessary for the task, no more than 1 cd/m^2 or 10 lx

Ads max. 10 x more luminance than surroudings (3 x is enough)



Yellow, faint light (lux to dekalux)

for night work

and just centilux/millilux levels

for moving during sleeptime

should become a norm

Technical measures

- replacing old lamps with new, fainter, better directing their light
- dimming
- filtering

  shielding
-
- ...

Can you spoil your eyes by *faint* light?

- Did you ever hear „*light up! don't damage your vision*“?
- What physiology mechanism could do that?
- All creatures, do they have their vision spoiled? Do just the happy people supplied with electricity see really well when old?
- Faint light does not contract eye pupils, so the vision is to be properly in focus. *People over 50 have to use various glasses*, cheap ones are OK, but more than 1 or 2 are needed.
- Very faint light implies more effort for the brain only, so we are tired and go to sleep sooner – OK!

Light is a good servant, but a bad lord!

http://amper.ped.muni.cz/light/declaration/