

# Light and Sound

as serious pollution

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# Pollution: what's that?

- centuries ago: religious notion only
- 
- 60's: toxic additives to the environment
- 
- now: alteration of the natural state
- 
- – if harmful to us or other beings,
- that might be difficult to find
-

# 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.

# 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

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

# What's 1000 Hz?

- and what spectral composition the real sounds have,
- 
- like speech



# 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?

# Ten times, two times, three times..

- 
- How many decibels it amounts to?

# Health effects

- [en.wikipedia.org/wiki/Noise\\_health\\_effects](https://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

# Light as a pollutant

- Light pollution – no heavy issue?

# 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
- 
-

# Day and night alteration: the basic rhythm of our world

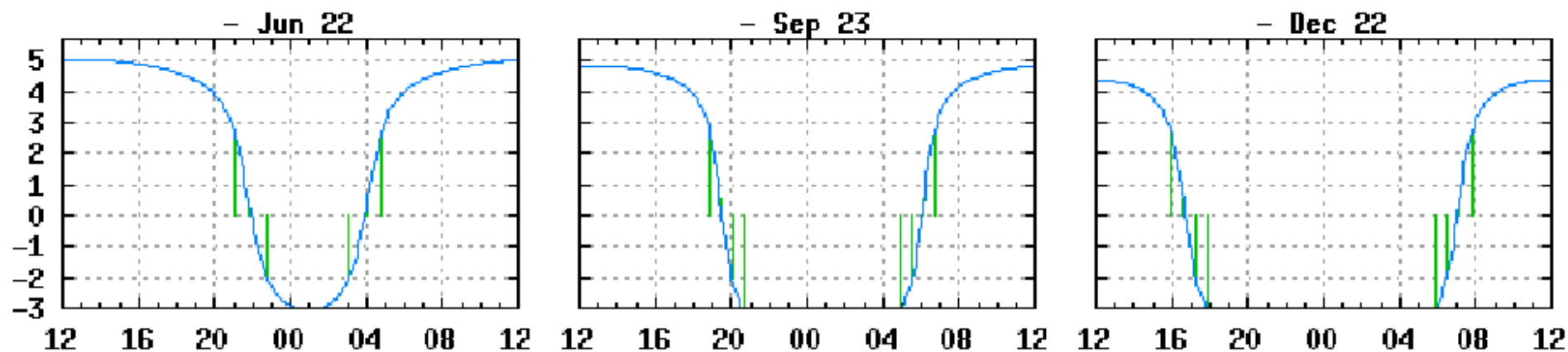
- sunny day 30 thousand to 100 thousand lux
- 1/1000 lx at night
- overcast: 3x to 30x less
- day/night ratio: 3 millions to 1000 millions
- full moon night – 1/10 lx  
(the ratio day/night diminishes 100x)



# What about indoors?

- Orders of magnitude less light than outdoors – originally
- 
- Now, tens or hundreds of lux at night
- 
- Often stronger than in daytime...

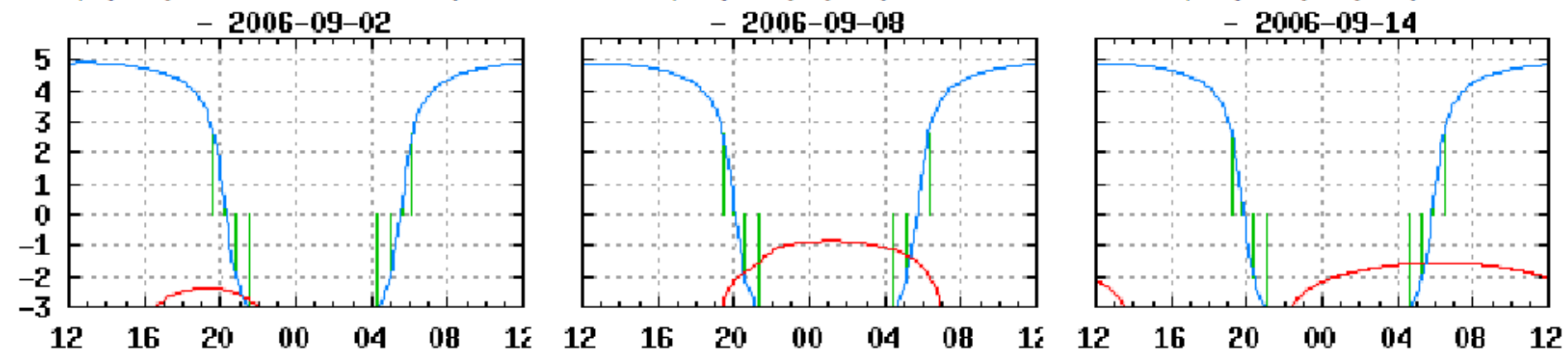
# log (horizontal illuminance / 1 lx) clear sky, with/out Moon



*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)*

# 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 to of the Universe
- tremendous expenditures
- and greenhouse gas emissions
- and health impairment due to lack of 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 thousand persons >15 years

sleep disturbance by 5 %, due to light at night  
penetrating to bedrooms as one of the two  
most serious reasons

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

using night shades with success, further  
20 %

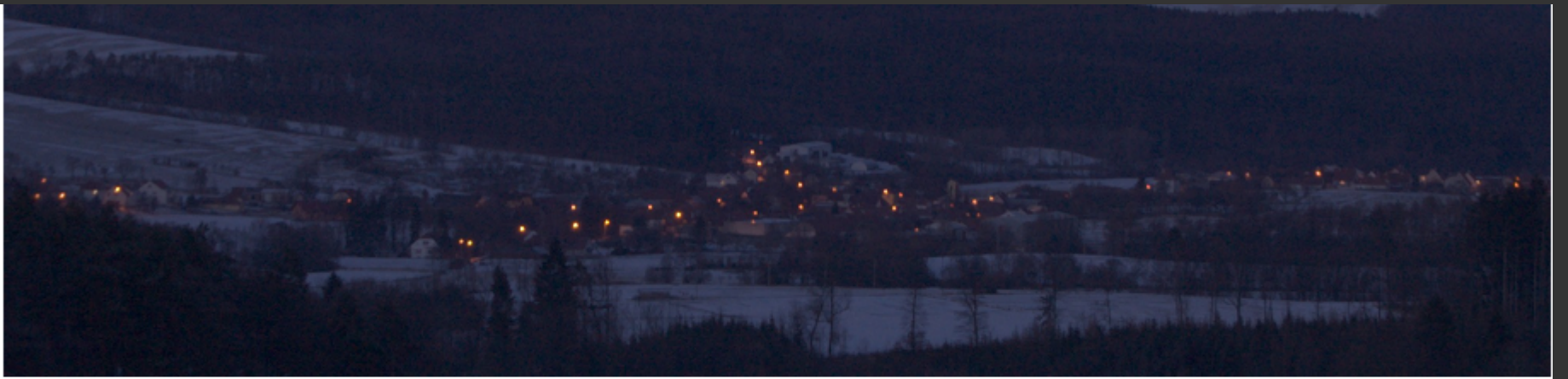
glare perceived as a problem by tens of per cent

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

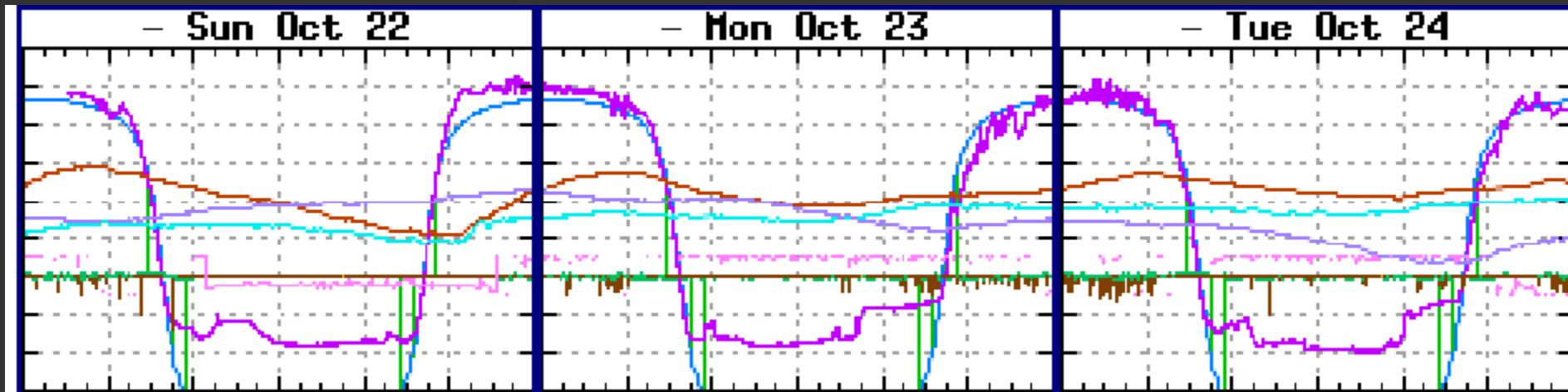
too bright sky even where there is no glare, says quarter of the population.

... 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 superhigh 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

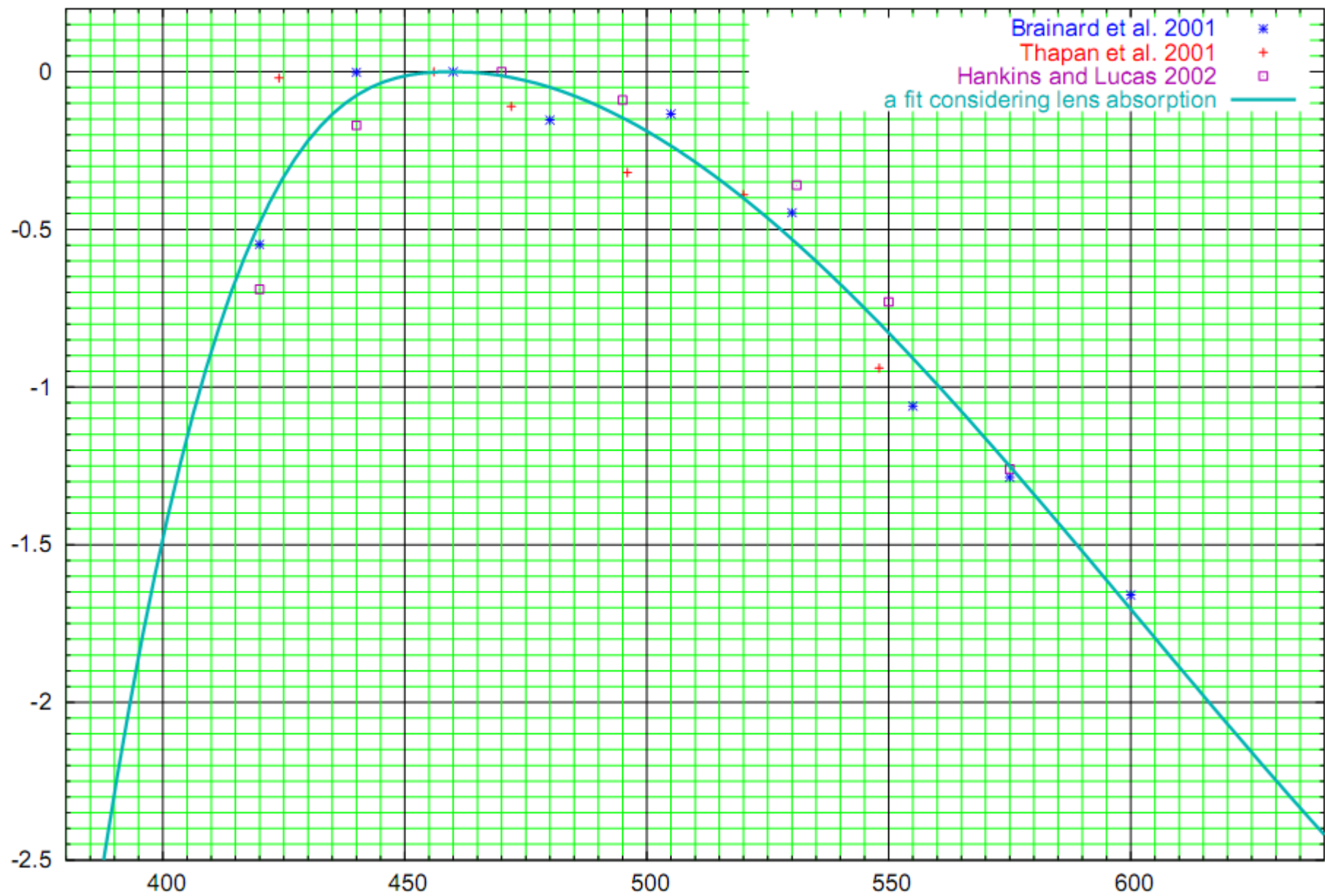
- **Photopollution:**
  - degradation of photic habitat
    - by artificial light
    - (Verheijen, 1985)
- -
- Darkness is a biological imperativ
  -
- **Scotobiology**

# 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"



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.

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

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 environment 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 considered 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  $1 \text{ cd/m}^2$  or  $10 \text{ lx}$

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



























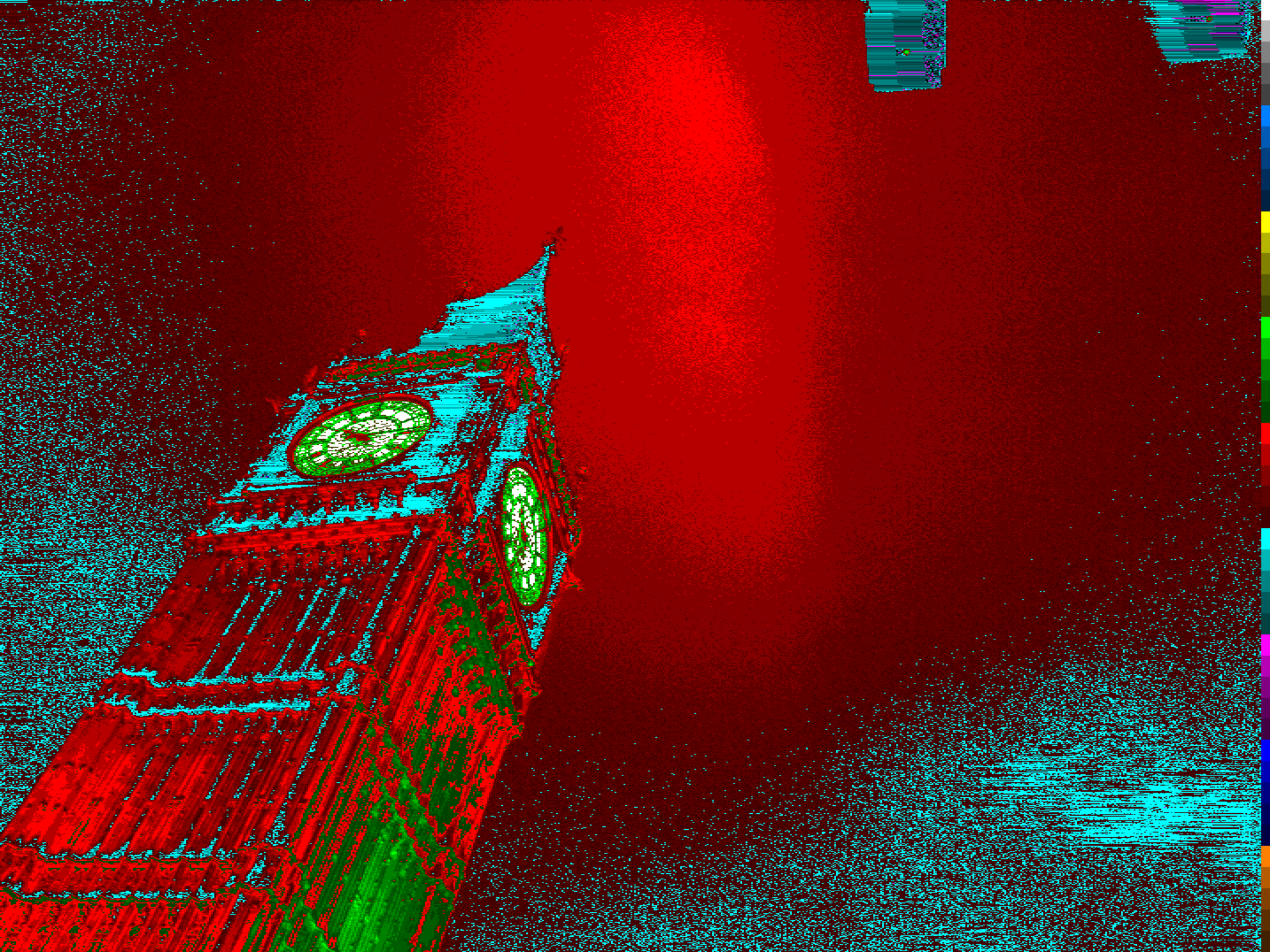












**Yellow**, faint light

for night work (who objects?)

and just centilux/millilux levels

for moving during sleeptime

should become a norm



Light is a good servant, but a  
bad lord!

<http://www.astro.cz/darksky>

# Technical measures

- replacing or alternating old bulbs
- 
- dimming,
- 
- filtering,
- 
- shading
- 
- ...