RGB radiometry with ordinary cameras as a research opportunity

workshop led by Jan Hollan

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within a project

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EVROPSKÁ UNIE
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OP Vzdělávání pro konkurenceschopnost

INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

Moduly jako prostředek inovace v integraci výuky moderní fyziky a chemie
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Photometry? Who understands it (even if it concerns the only quantities we *see*...)?

- Amounts? The oldest “unit”: candle – so much light sends candle flame in each direction around itself
- Its modern implementation: candela – one of the 7 basic units of SI
- Unit of? Luminous intensity
- Do we see it? No.

What we perceive: ratios of Luminance

of adjacent darker and brighter pieces of a scene before us

- these 'pieces' may be surfaces of opaque bodies
- but generally, they are space angles
- 1 % stronger luminance is perceptible in daylight, 3 % are easy to notice at sharp divides
- 10 % more or less can be noticed at night – this is 0.1 mag

Common luminance ratios are up to 1:30

- Black surface returns almost 10 % of light, a white one about 90 % - ten times more
- Luminance of a surface in shadow is 1/10 of an adjacent sunlit part
- Rather dark surface in a shadow and a rather light sunlit one, that's the span of 1 to 30 in relative luminance, still a comfortable range to look at
- - no more had been around for eons, apart from the Sun at day and Moon and flames at night

Weber-Fechner law

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

  - logarithm

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Luminance itself

- is expressed in units of candela per square metre, cd/m^2
- non-English languages may name it shortly and conveniently: nit, symbol 'nt'
- luminance can be documented by any camera giving raw counts from its CCD or CMOS pixels; knowing the exposure settings, the only parameter to be found is a proportionality constant, valid forever
-

Do we have an instrument, measuring the luminance directly?

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- Yes we have – the SQM
- However, it displays a logarithmic quantity
- - let's call it Darkness: it's a faintness of a “angular square second” expressed in magnitudes (faintness: the more the fainter)
- roughly, 5 mag : 1000 nt, 10 mag : 10 nt, 15 mag: 0.10 nt, 20 mag: 1 mnt, 21.6 mag: 0.25 mnt... (what corresponds to 7.5 mag?)
- (precisely, 1080, 10.8, etc. - neglect 8 %)

A more common instrument is a luxmetre

-
- - we can get some luminances by it too:
- point it toward a large surface of a uniform luminance, keeping it no farther than 1/5 of its size from it
- and divide its reading by π, or simply by 3
- Any camera can be calibrated this way!

  Pointing the sensor away from the surface gives its illuminance, the ratio of the previous reading to this one is the *albedo*. Try this for asphalt or concrete roads!

Day and night alteration of the 'horizontal illuminance' 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 then outdoors – originally
-
- Now, tens or hundreds of lux at night
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- Often stronger than in daytime...
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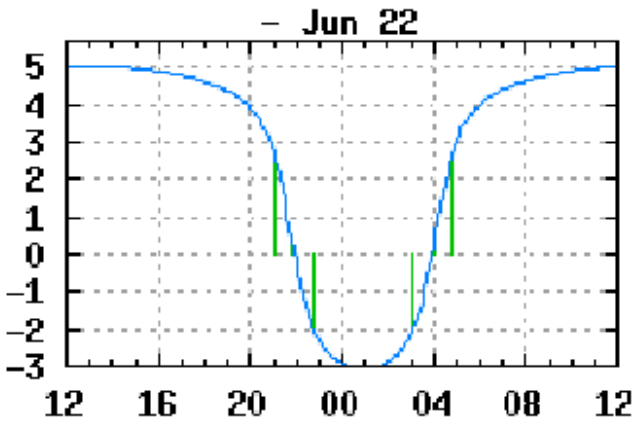
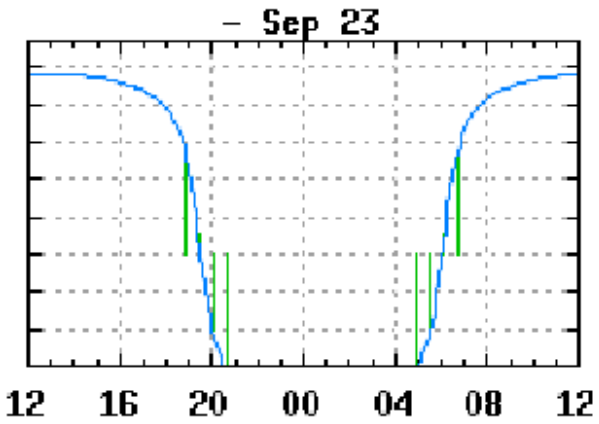
- But traditionally? Vertical illuminance 1 m from a candle is 1 lx.

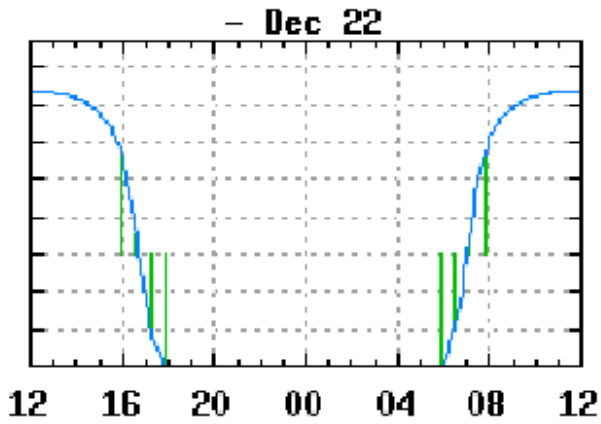
log (horizontal illuminance / 1 lx)
clear sky, with/out Moon



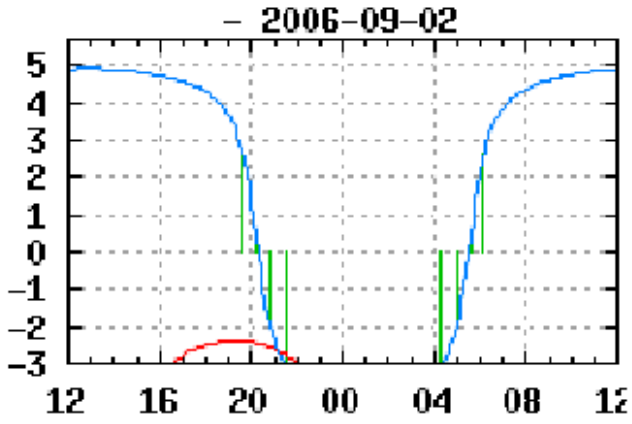
letní slunovrat
*(**6,3** h, astron. nenastává)*



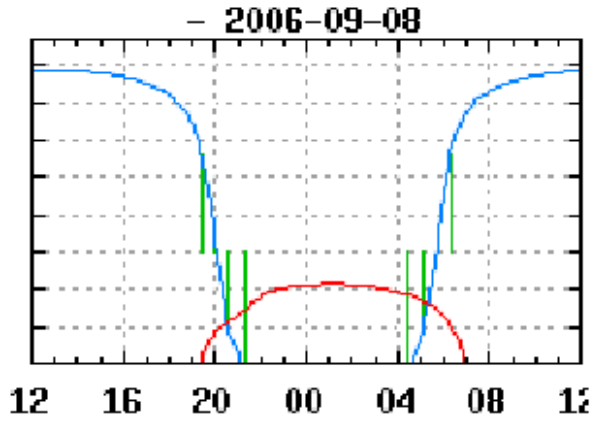
rovnodennost
*(**10,7** h , 8,2 h)*



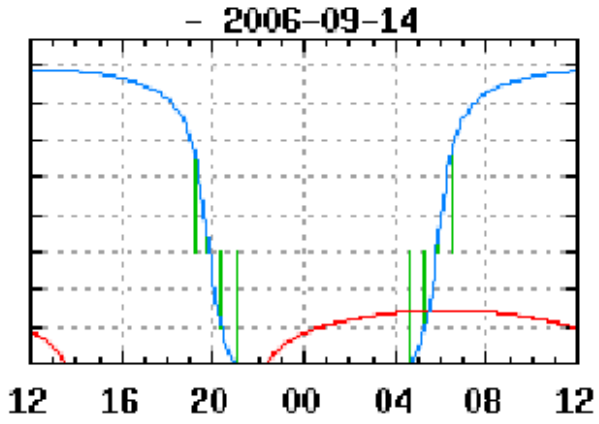
zimní slunovrat
*(**14,5** h , 11,9 h)*



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



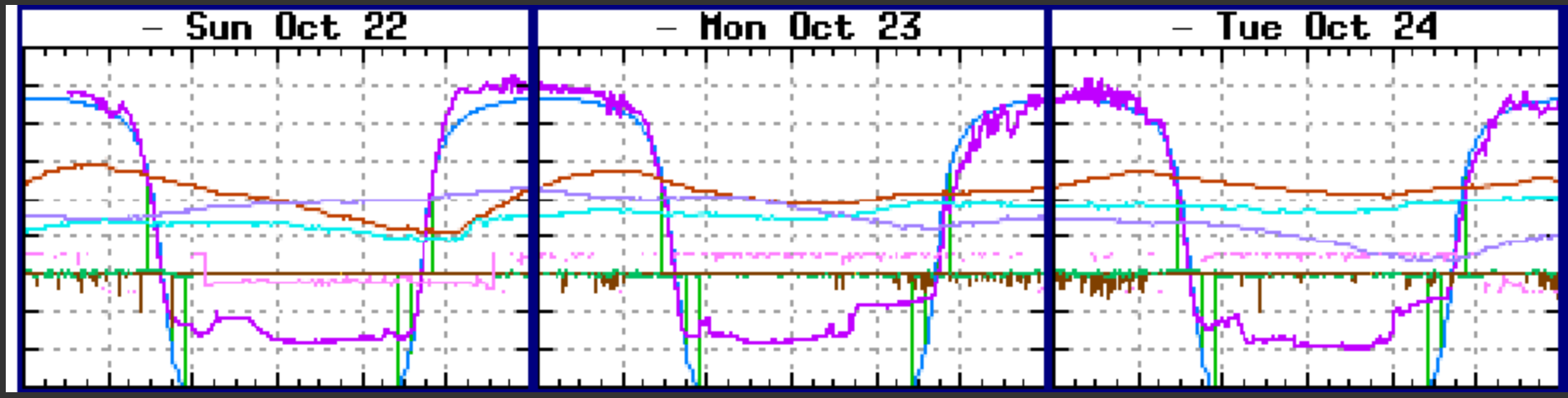
úplněk
(téměř 0,2 lx)



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

Brno, Kuhberg

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



How much is needed to see?

- For most surfaces, their luminance is about tenth of their illuminance, numerically
- (divide illuminance by pi and multiply by albedo)
- under 1 lx to 100 klx we see very well
- just tiny details might need over 10 lx, or even 100 lx
- - often due to improper accommodation; people over 45 need to change glasses to see nearby objects in focus, this is sustainable, unlike contracting eye pupils by strong light

How do we see at night?

- There are no “rods” in retina. Just the imaging receptors (cones) are smaller and more dense in fovea. And their system ceases to report colours below 10 mcd/m^2, concerned with finding contrasts
- (surprised? see James T. Fulton pages)
- If you read at 1 mlx (this is possible for large letters with full contrast), you look directly at them, no sideways
- Ten microlux suffices to find your way indoors

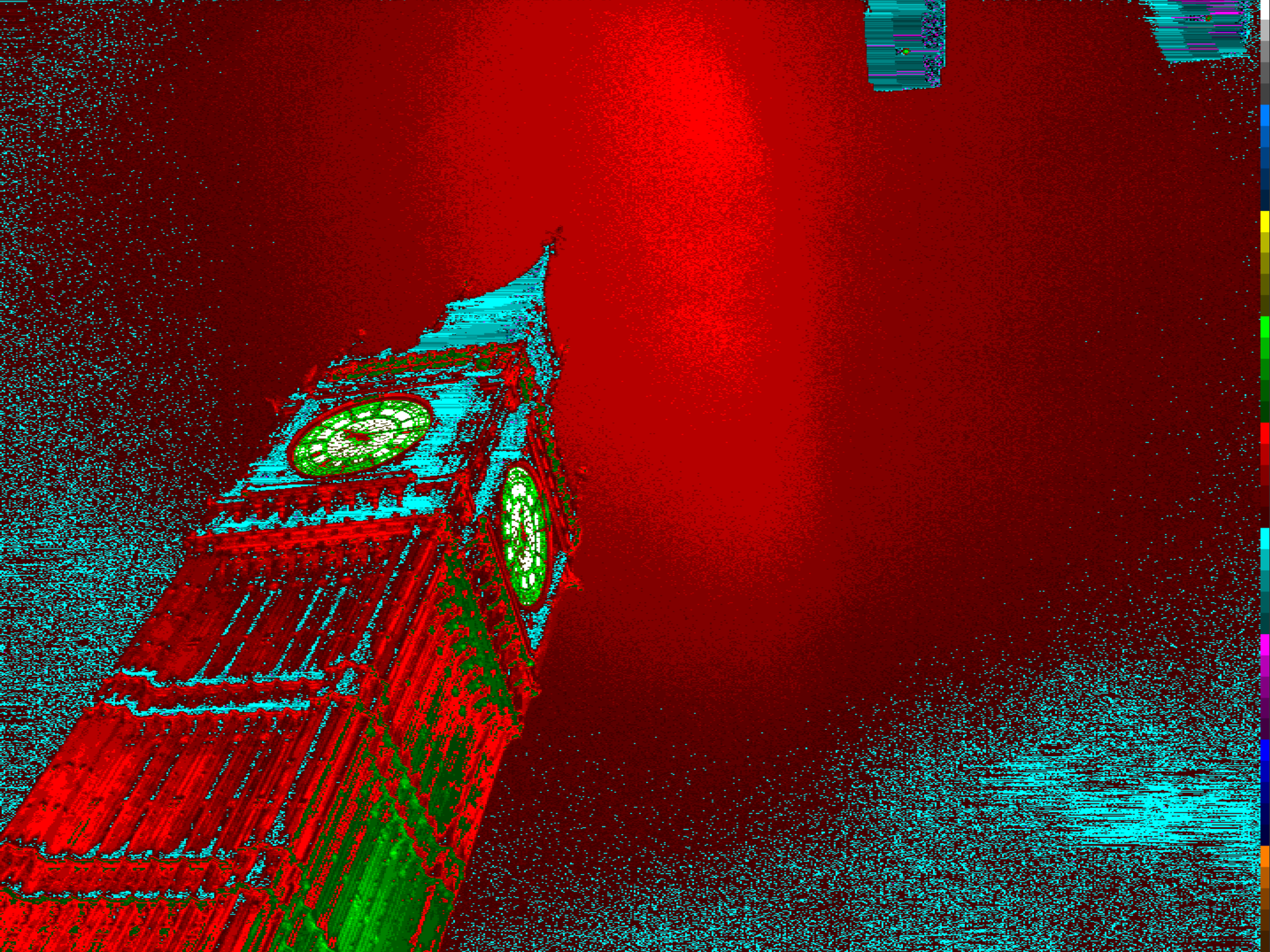
Basic rules for outdoor lighting (like in Slovenia and most of Italy)

No emissions horizontally and upwards

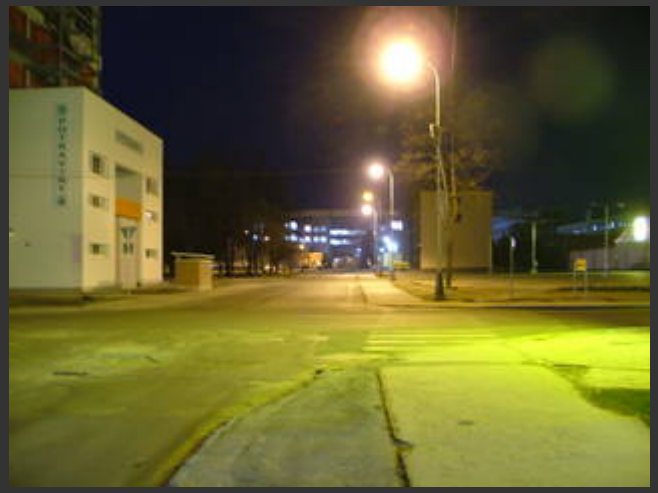
Using just that much light, what's necessary for the task, never more than 1 cd/m^2 or 10 lx

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

a novel one should be: twice full-moon light is too much into bedrooms (so, 0.2 lx man-made addition should be never surpassed)



raw2lum example



What do we need to (be able to) measure:

- http://amper.ped.muni.cz/light/lp_what_is.pdf

Overcast sky at night outdoors, ground and window illuminances, billboard luminances, brightnesses of distant lamps (i.e., luminous flux densities arriving from them)...

Luxmeter, SQM and raw-data cameras enable us to do that all,
we should just learn it...