Living Environmental Laboratory for Lighting — A comprehensive study of interactions of artificial lighting and wildlifes

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LIVING ENVIRONMENTAL LABORATORY FOR LIGHTING — A COMPREHENSIVE STUDY OF INTERACTIONS OF ARTIFICIAL LIGHTING AND WILDLIFES

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SZÉCHENYI 2020

MAGYARORSZÁG KORMÁNYA

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BEFEKTETÉS A JÖVŐBE

Recent light pollution projects in Hungary

GINOP 2.3.3 (Strengthening research infrastructures - internationalisation, networking) : “Development of a measurement system based on digital cameras for international monitoring of light pollution and its biological effects” (Mobile Lab)

EFOP 3.6.2 (Thematic research network co-operations) : Development of international research environment for light pollution studies (Living Environmental Lab)

Connection:

National Landscape Strategy for Hungary (2017–26) – necessary action by the government and universities: *National assessment of light pollution (e.g. through the determination of sky luminance distribution) and condition assessment of light pollution.*

Duration: September 2017 – October 2020

Consortium of 3 Hungarian Universities:

Eötvös Loránd University, Savaria Campus – Szombathely

Eszterházy Károly University – Eger

University of Kaposvár – Kaposvár

Eger: Bükk Starry Sky Park

Kaposvár: Zselic Starry Sky Park

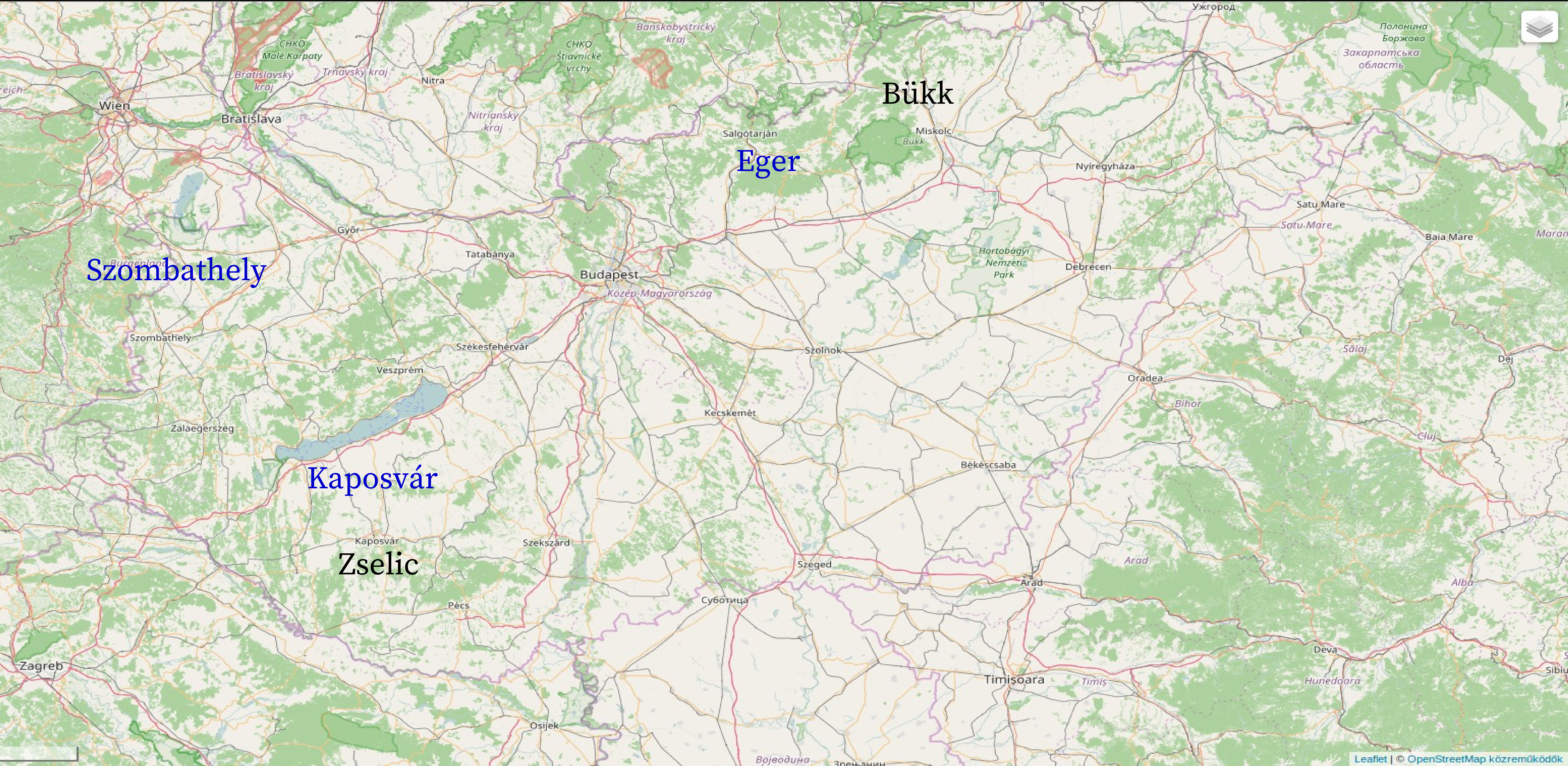
Living Environmental Laboratory for Lighting (LELL)

The ecological and biological impacts of light pollution has recently gain attention to the science community (see e.g. Longcore and Rich 2004). In light of this, we set up the LELL project as an experiment for exploring feasible way of reducing light pollution.

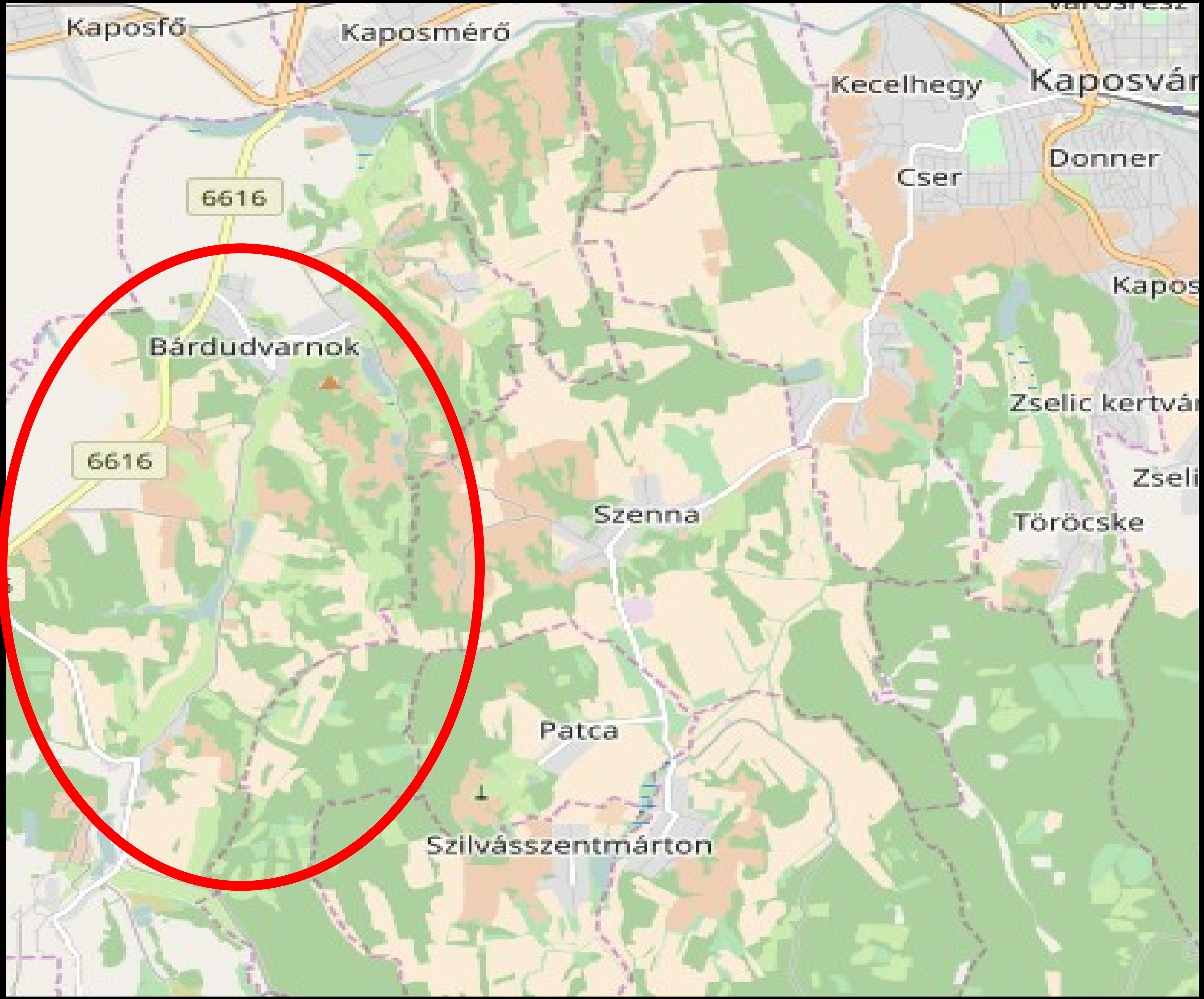
The Two villages involved in the project, one in Zselic and one in Bükk, are both situated in international dark sky parks certified by the International Dark Sky Association (IDA) (in 2009 and 2017 respectively).

Strict requirements for lighting within premises of dark sky parks necessitates complete lighting remodelling, in order to control luminous flux and spectra (warm white or amber, which has lower impact on ecology). During the project, the lighting system can be used to test the effect of colour by light measurements and bio-monitoring. In addition, a third national park, the Hortobágy National Park (certified by IDA in 2011), is also participating the project.

Living Environmental Laboratory for Lighting (LELL)



Living Environmental Laboratory for Lighting (LELL)




ZSELIC


BÜKK


HORTOBÁGY

Living Environmental Lab for Lighting (LELL)

Bárdudvarnok, next to Zselic Starry Sky Park, is the main site of the project.

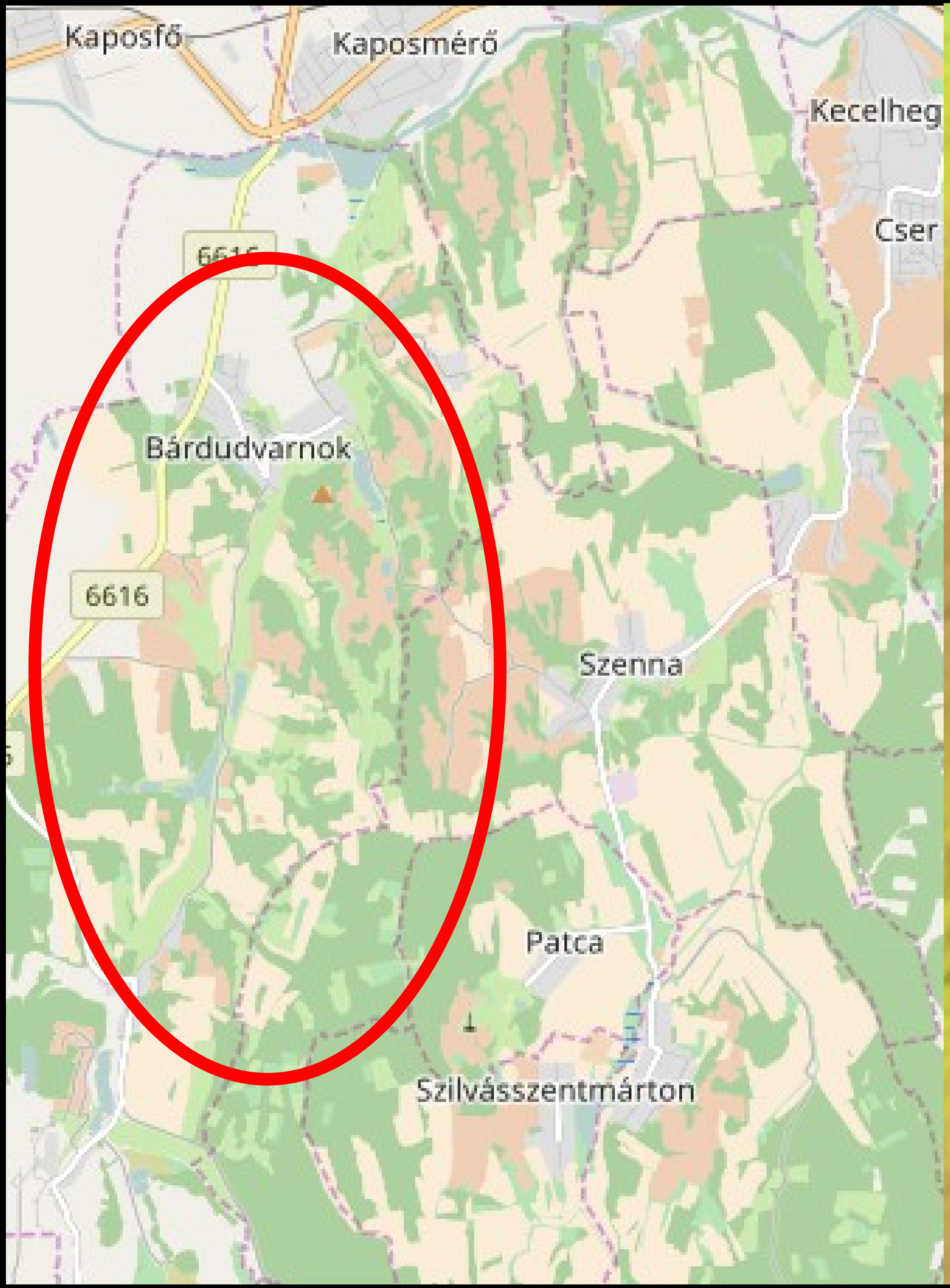
Before Dec 2018, most of the ~290 lighting points used 36W compact fluorescent + 70 and 100 W Sodium lamps. After a year of development and monitoring with the original lighting system, the lighting was remodeled to an LED-based, remotely controllable system. We are currently in a ~ 2-year phase of monitoring with this system.

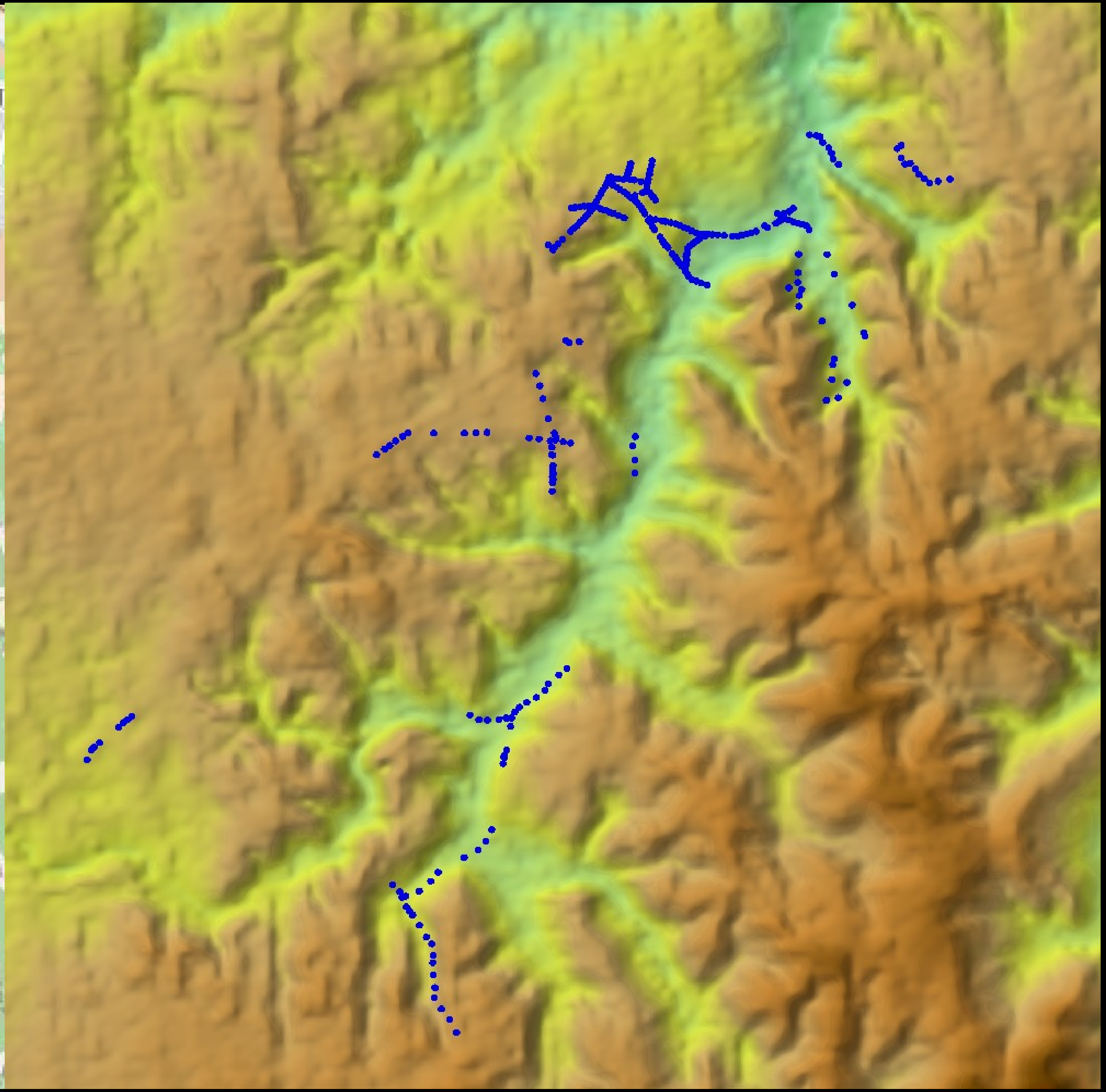
After the 2020 the system works as normal lighting:

In rush hours: warm white

Other part of the night: amber, with reduced flux. Notice the slightly changed color.

Lighting points remodeled in Bádudvarnok



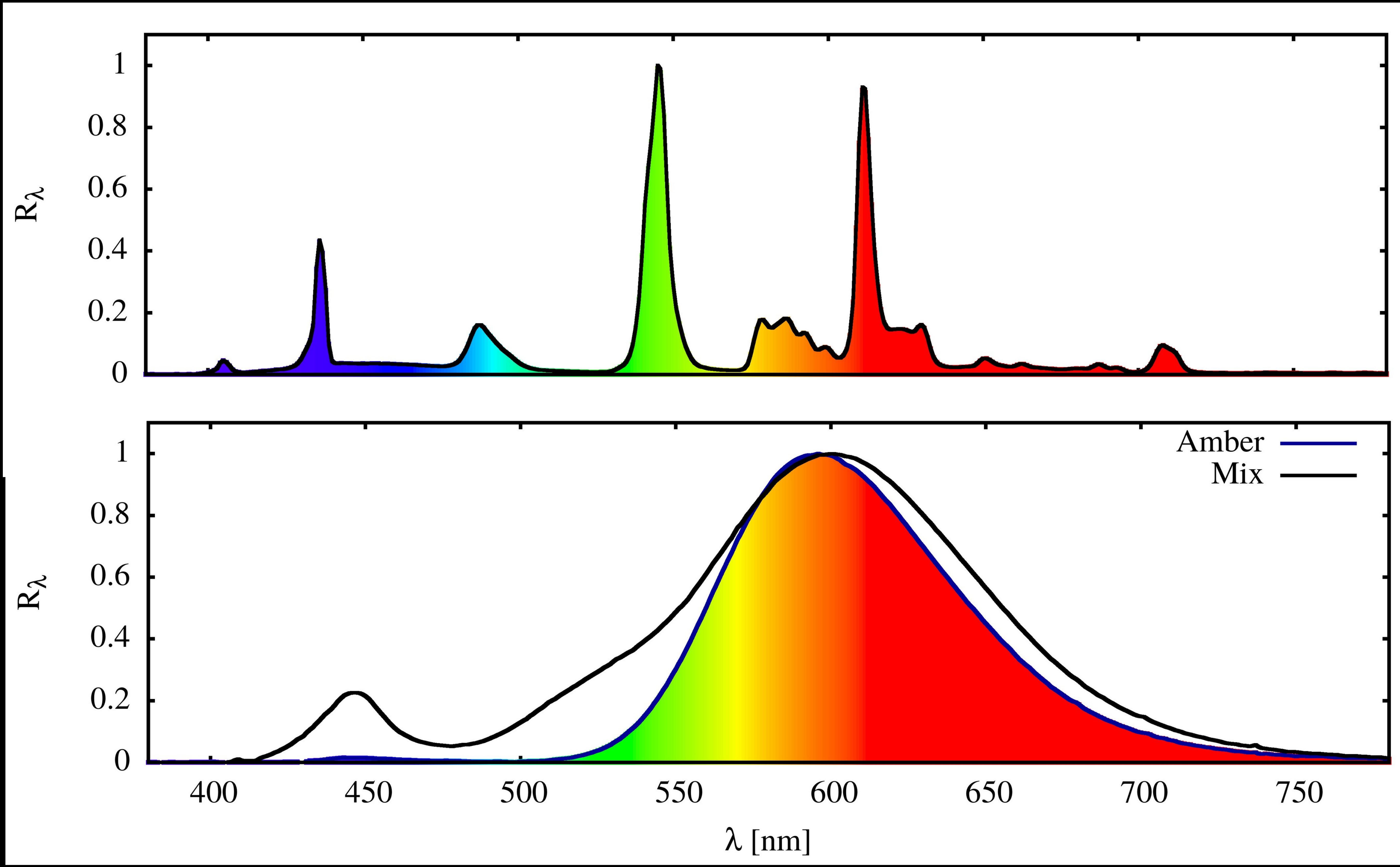


Bárdudvarnok — before and after

Spectral change

Before remodeling: mostly compact flourescent (mostly the green and blue), with some high pressure sodium (mostly the orange and red)

After remodeling: Phosphor converted (PC) amber LED only (~1900K). Blue light emission decreases.



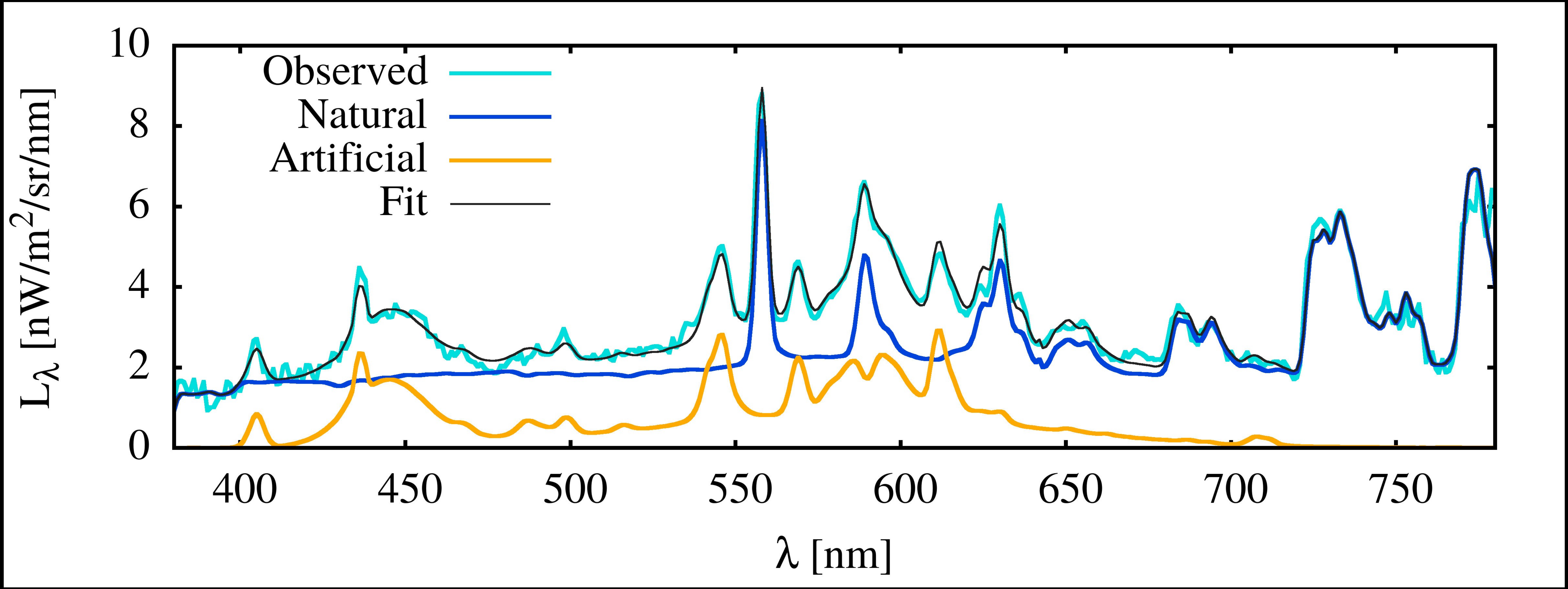
Bárdudvarnok — before and after

Center: defocused images of upper and lower images (taken before and after remodeling, respectively), to show position, intensity and color of light source.

New lighting system emits less uplight and is less bluish.

Bárdudvarnok — before and after

Spectrum of the night sky — Zselic; measured by spectroradiometer



Note: Natural and artificial components are fits

Répáshuta near Bükk (photo: Richárd Novák)
During remodelling

Qualifying night sky

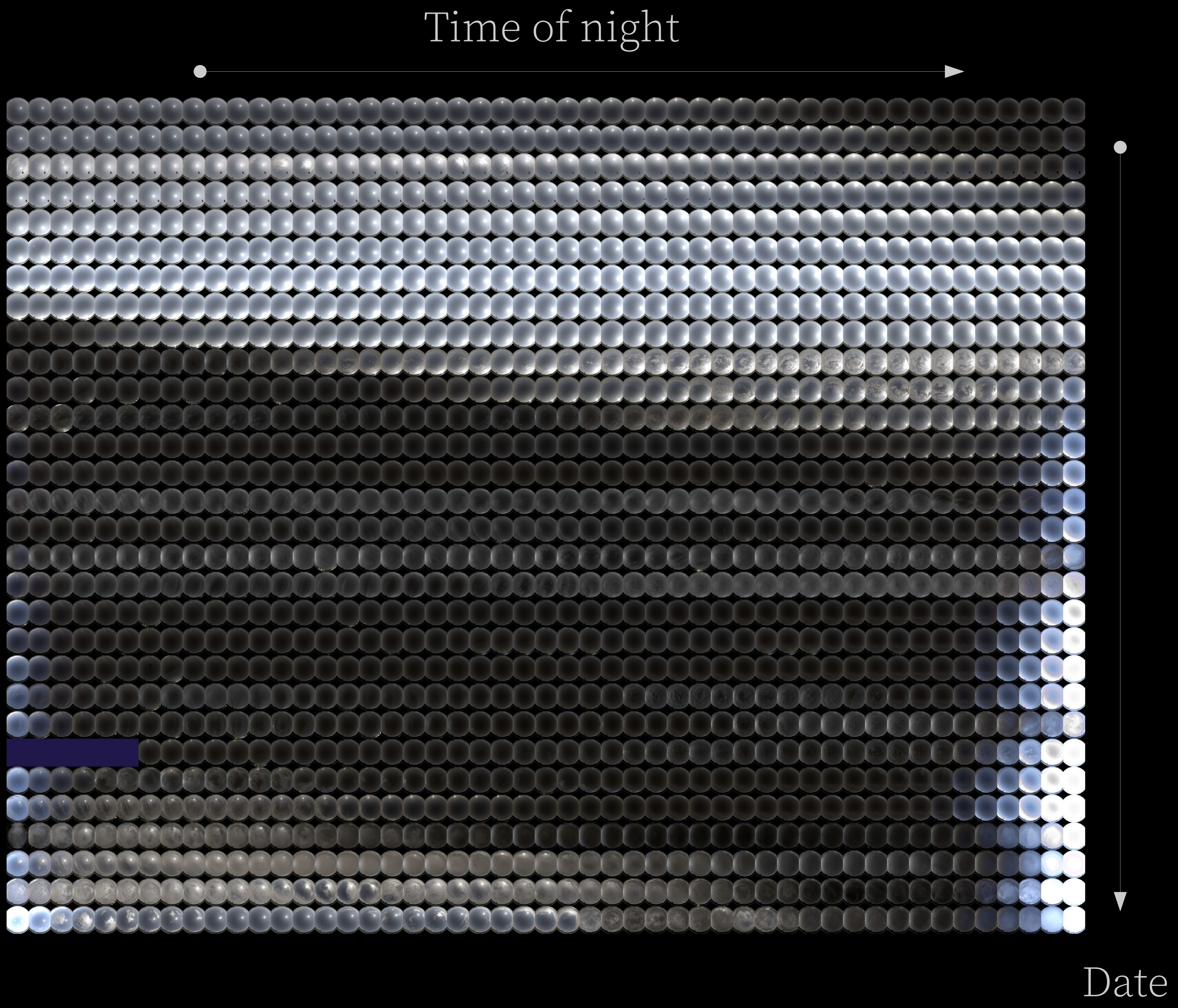
Sky Quality Meter SQM (right), a panchromatic handheld radiometer, has been a common choice in the past, due to low cost, portability and flexibility. It has been used in many light pollution studies (see e.g. Kyba et al. (2015), So et al. (2014)).

However, we later found that the optical system is not metrologically robust for accurate calibration. Therefore we abandoned SQM measurements in this project completely and instead use calibrated commercially available digital cameras and spectroradiometer exclusively.

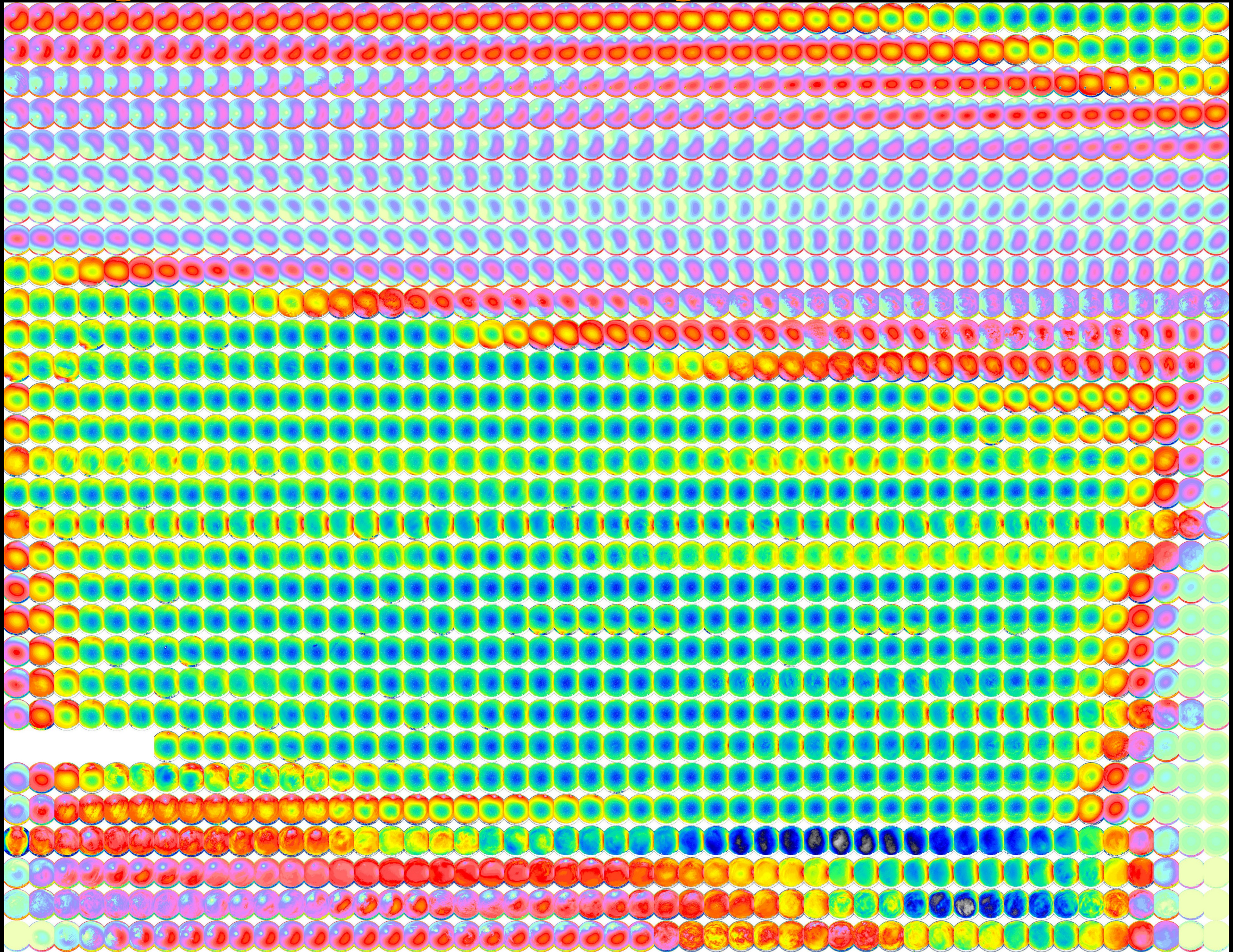
Qualifying night sky

Many light pollution surveys deploy DSLRs or mirrorless interchangeable lens cameras with a fisheye lens.

We recently set up such a system inside a waterproof housing on the roof of a planetarium in Zselic with internet connectivity (details of equipment on next slide). Figure on the right shows a time series of all-sky images in April and May, 2020. Brightening of sky by the moon and the moon phase are apparent in the beginning of April.



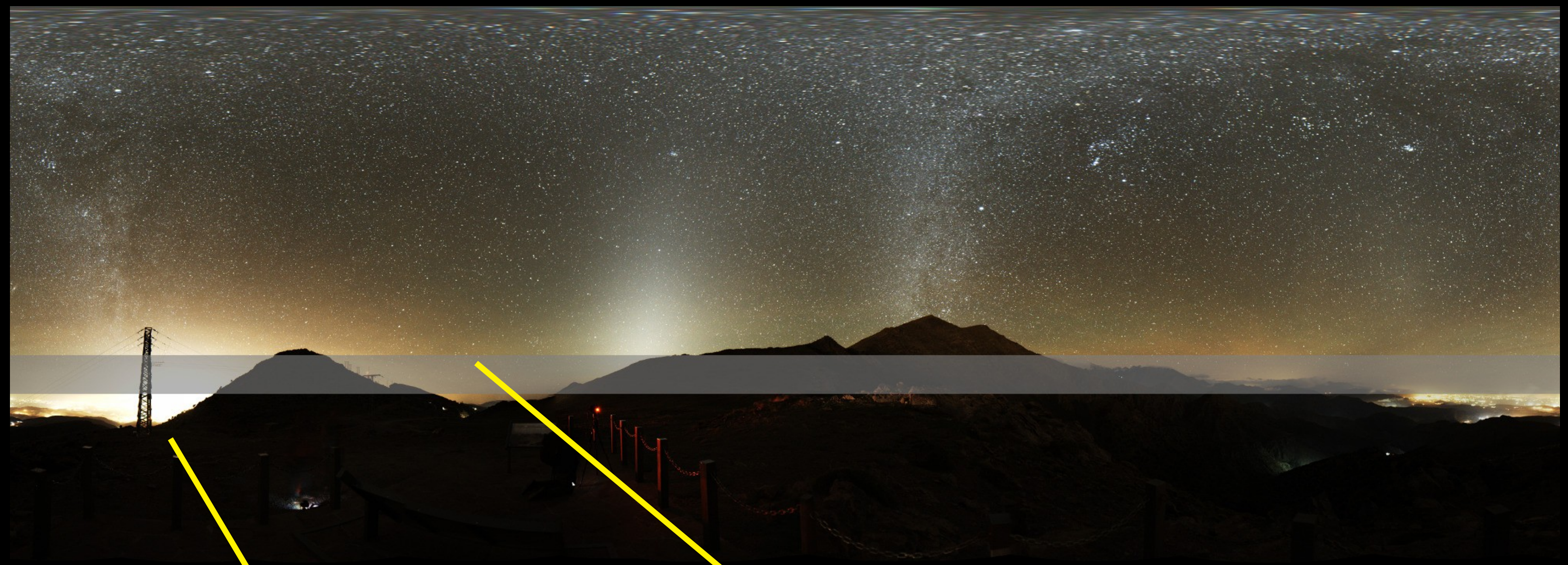
Falsecolor image time series showing radiance values



Problems with DSLR photo/radiometry using fisheye lens

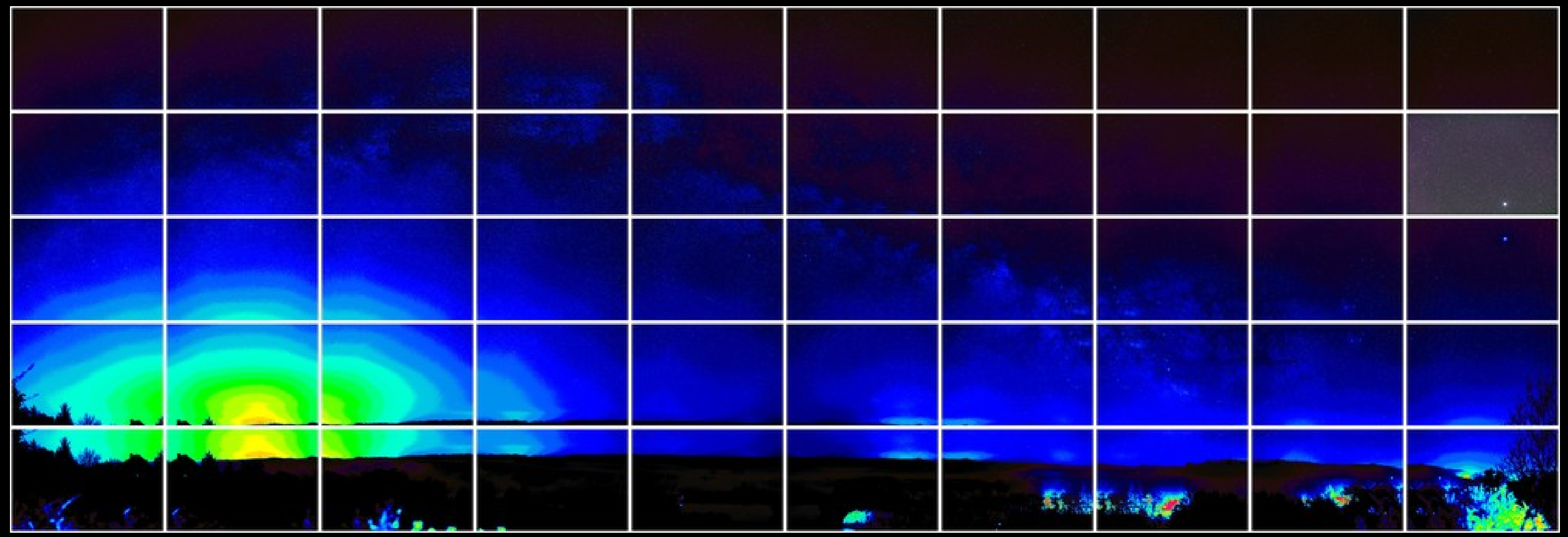
While fisheye lenses are useful for stationary setups and convenient on the field, spatial resolution/quality is considerably reduced close to the horizon. In addition, without taking multiple images it is not possible to cover the terrain below the horizon.

Vignetting of the lenses and spectral sensitivity of cameras can also be problems for quantitative analysis of images, both for fisheye and rectilinear lenses, but otherwise correction is a straightforward task. We carry out this in our GNU Octave code, DiCaLum (compatible with MATLAB), which will be released in an open-source license.



The solution — image mosaic with rectilinear lenses

By taking multiple images with a rectilinear lens, the whole sky can be covered in high resolution, together with the terrain close to the horizon. Fast lenses and high sensitivity cameras, together with a robotic panorama head, can reduce the image acquisition time to the order of 5 minutes.



High resolution measurements — stitiched from Raw images

High resolution measurements — in lograithmic gain

Our equipment

Our main measurement system consists 8 sets of camera system:

- Sony A7S II (35 mm format sensor with 12Mpx, high signal to noise ratio, electronic shutter…)
- Fixed focus lenses for the range f=8–200mm (40 lenses)
- Tripods, batteries
- 4 sets with robotic panorama heads — to obtain high resolution full sky panoramas

We usually use 24 mm lens for all sky measurements (28 images total)

In addition, we have fixed all sky cameras in most of the national parks used for long term monitoring. Same model of camera and fisheye lenses as in the mobile lab are used for comparable results.

What metrics to use?

The multidisciplinary nature of light pollution research leads to chaos in the choice of metrics, since researchers use different sensitivity and action curves for a wide range of instruments depending on research problem at hand. e.g.

- **μmol/m²/s** (PAR by botanists…)
- **mag/arcsec²** (used by astronomers with Vega as zero point)

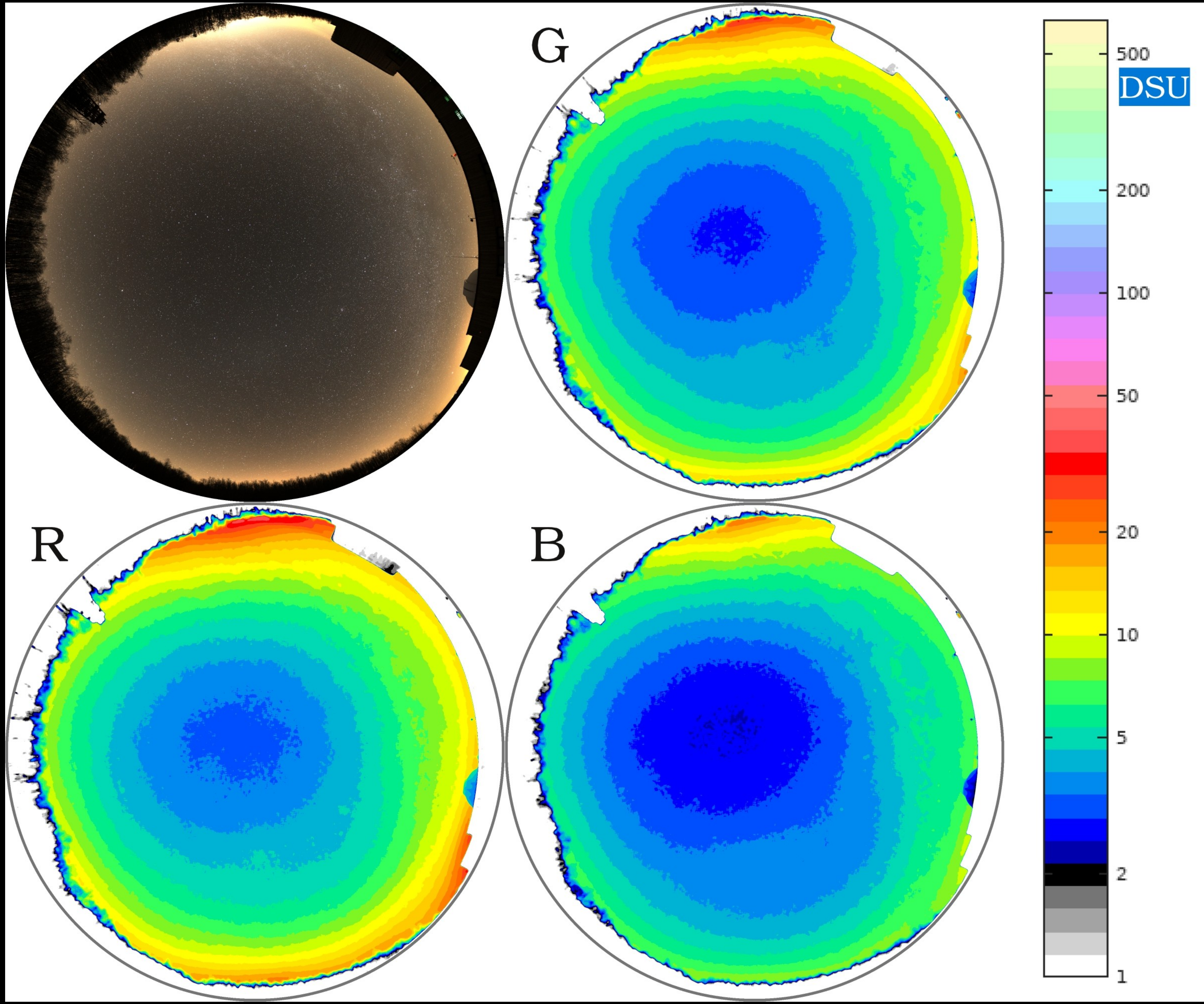
In addition, precise night sky measurements need spectral data.

Currently, we are proposing a new, band-averaged spectral radiance unit for night sky radiometry, the *dark sky unit* (dsu):

$$1\ \text{dsu} = 1\ \text{nW/(m}^2\text{/sr/nm)}$$

As such, results of measurements are SI unit-traceable.

Zselic Planetarium mosaic image, RGB + false color in DSU



Preliminary results

Before: upward light output ratio (ULOR) > 10%

P(<550 nm) / P(total)   46% → 2× the IDA allowed

After: ULOR=0

Main period (warm WLED + PC Amber LED):

P(<550 nm) / P(total)   19%

CCT 2400K

S/P = 0.9

22:00 – 04:00 (PC Amber LED):

P(<550 nm) / P(total)   5%

CCT 1900K

S/P = 0.44

Investigation with satellite data

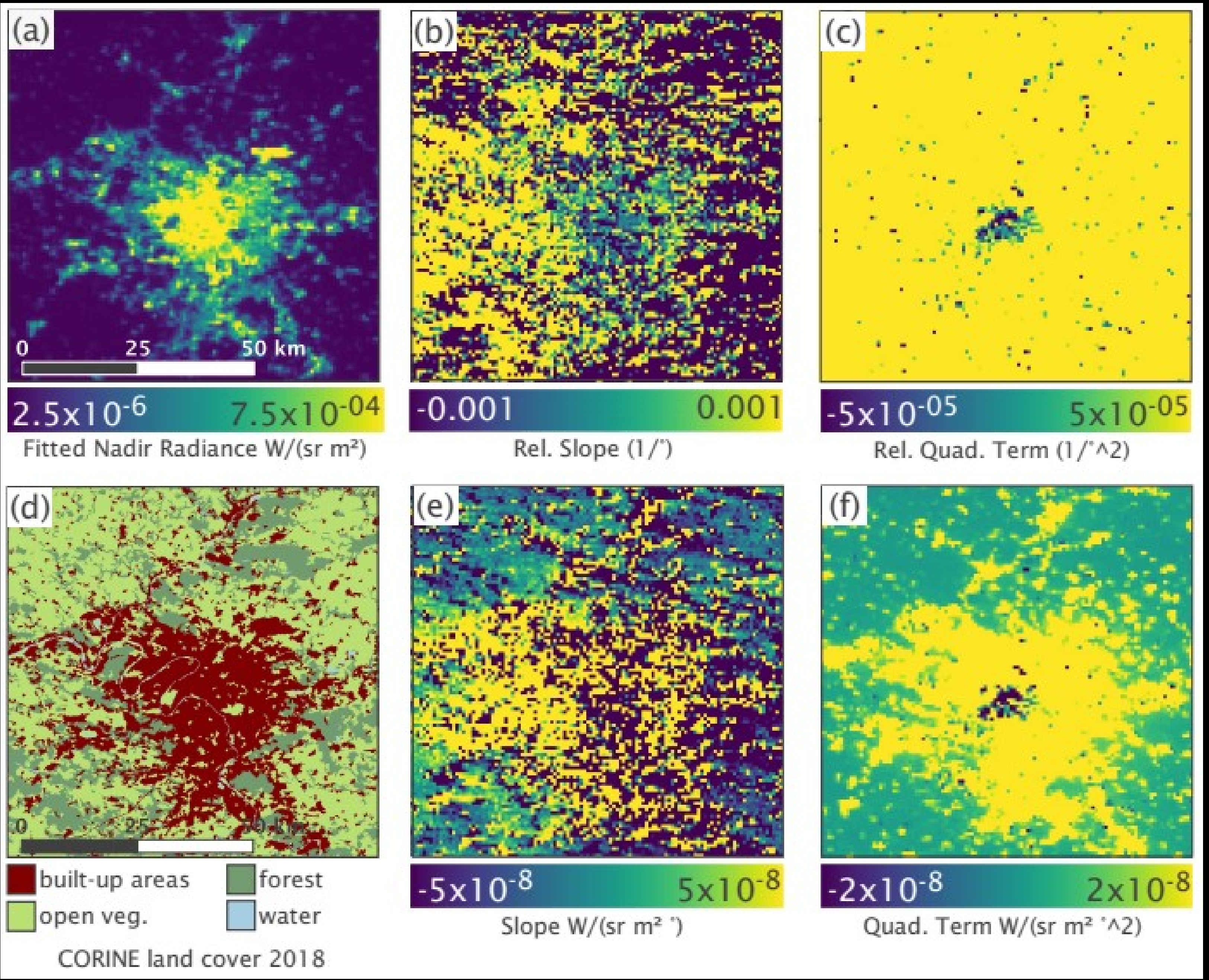
Suomi NPP (Launched 2011) carries a panchromatic sensor sensitive enough for night time light sources (from cities, forest fires, gas flares etc.)

We analyzed the angular distribution of European upwelling light using 2018 overflights data.

Rural or suburban areas emit more light sideways, whereas city centers shine light upwards, likely due to obstacles.

Data can be useful for modeling new sites without existing ground-based measurements.

More on Tong et al. (2020): http://dx.doi.org/10.1016/j.jqsrt.2020.107009



References

D. Száz, Z. Kolláth, F. Szabó and P. Csuti. Dark sky park and environmental friendly luminaires with adjustable light distribution, color and luminous flux: light pollution reduction in Hungarian settlements. In press.

Z. Kolláth, A. Cool, A. Jechow, K. Kolláth, D. Száz, K.P. Tong: Introducing the "Dark Sky Unit" for multi-spectral measurement of the night sky quality with commercial digital cameras. In preparation.

K.P. Tong, C.C.M. Kyba, G. Heygster, H.U. Kuechly, J. Notholt and Z. Kolláth (2020). Angular distribution of upwelling artificial light in Europe as observed by Suomi–NPP satellite. *J. Quant. Spectrosc. Radiat. Transf.*, 249, 107009. doi:10.1016/j.jqsrt.2020.107009

C.C.M. Kyba et al. Worldwide variations in artificial skyglow. *Scientific Reports*, 5:8409. doi:10.1038/srep08409

C.S.J. Pun, C.W. So, W.Y. Leung and C.F. Wong. Contributions of artificial lighting sources on light pollution in Hong Kong. *J. Quant. Spectrosc. Radiat. Transf.*, 139: 90–108.

T. Longcore, C. Rich. Ecological light pollution. *Frontiers in Ecology and the Environment* 2(4): 191–198.


Thank you for your attention!