Inter-Intercomparison Campaign Chelmos/Greece

September 2015

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Reason

From the Tuscany intercomparison campaign report (2015) it is clear, that sky brightness measurements under stable conditions at a dark place are essential for comparing different measurement methods. The main problems are differences between SQM and astronomical and photometrical measurements.

Chelmos (or Helmos) Observatory/Greece

The observatory on Northern Peleponnese at an altitude of 2340 m near the city of Kalavryta shall be one of the darkest places in Greece and Europe (cited on their webpage: http://helmos.astro.noa.gr/about.html). In Sept. 2013 a zenith-corrected V magnitude of 20.7 mag/arcsec² was measured (1). It is situated at about 130 km west of Athens within the Chelmos-Vouraikos National and Geo Park. The last 8 km from the Chelmos ski resort to the observatory are gravel road where a 4x4 car must be taken, and rental was too expensive for our survey. Chelmos ski resort offers a large parking at about 1700 m altitude, and with a line-of-sight distance to the observatory of only 3-4 km, it can be expected that the sky brightness should not differ much from that at the peak (see Fig. 1). SQM measurements have been taken in 15-08-2014 by Andreas Paplambrou (www.darksky.gr) at the observatory ϕ = 37.985703, λ = 22. 198283, h =2340 m with 21.55 mag/arcsec² and at the ski resort mountain station ϕ = 37.998293, λ = 22.190044, h =1962 m with 21.45 mag/arcsec²:

Therefore it was decided to stay in a hotel in Kalavrita and drive to the high altitude (1760 m) plane Xerokampos where the measurements were taken (ϕ = 38.028118°, λ = 22.218718°, h = 1761 m). Observations were not taken at the parking of the ski resort (ϕ =38.006383°, λ = 22.198202°, h = 1707 m) because the horizon was limited by Chelmos mountain and there were two bright floodlights that would have disturbed the measurements (see Fig. 2.).

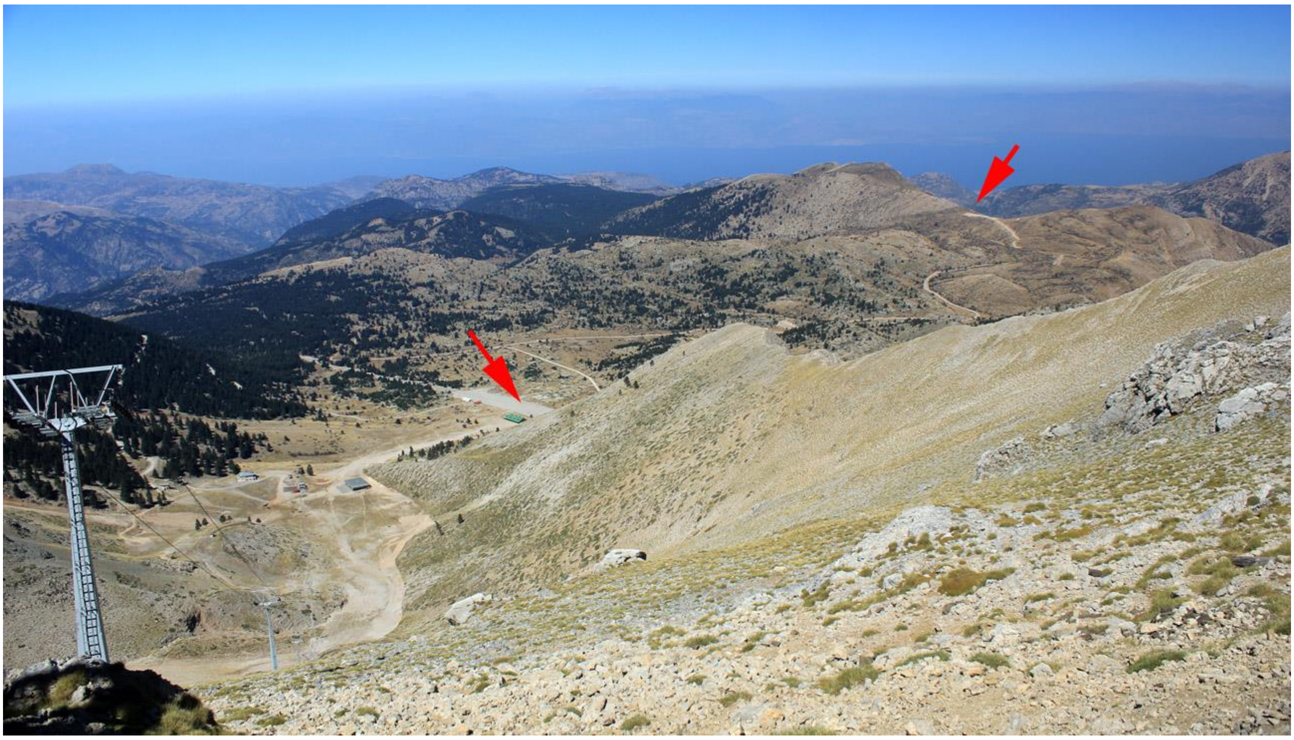


Fig. 1: View from the top of the mountain with the observatory towards the North: left arrow – ski parking, right arrow observing place.

Fig. 2: The illumination of the skiing area as seen from the observing place

Fig. 3 + 4: The illumination of the skiing area as seen from the parking

The following instruments were used for comparison:

- SQM: #3111, firmware V1.17 (BE)
- SQM-L: #2049, firmware V2.17 (AH), #3204 firmware V2.17 (BE); #8037 firmware V2.18 (BE)
- SQM-LU: #1049, firmware V4-3-16 (AH), #2486, firmware V4-3-25 (AH)
- SQM-LR: #933 (BE) modified with a microcontroller interface as described in http://lrt.sagepub.com/content/46/1/67.short
- Filters used with SQM-L devices: Baader green filter (AH), giving a smaller spectral response of about 100 nm for the SQM-L and a peak transmission at about 520 nm, so between the photopic and scotopic sensitivity curve, V-Filter: Custom Scientific Johnson V (BE) used in conjunction with SQM-L CM-500 filter.
- Canon EOS 550D with 85mm f/1.5 (reduced due to a smaller filter diameter) and Baader green filter for stellar photometry.
- Nikon D300 with Samyang 8mm f/3.5 fisheye lens and circular polarizing filter.

The Baader green filter (fig. 5) was chosen because it was readily available at reasonable prices with different diameters. It neither matches the photopic (and astronomical V) nor the scotopic response curve but lies in between. The main reason for using the filter was to reduce the broad bandwidth of the SQM detector to similar bandwidths like the scotopic or photopic eye sensitivity curve. It should be expected that the influence on the astronomical photometry would not be too great, but further tests are necessary.

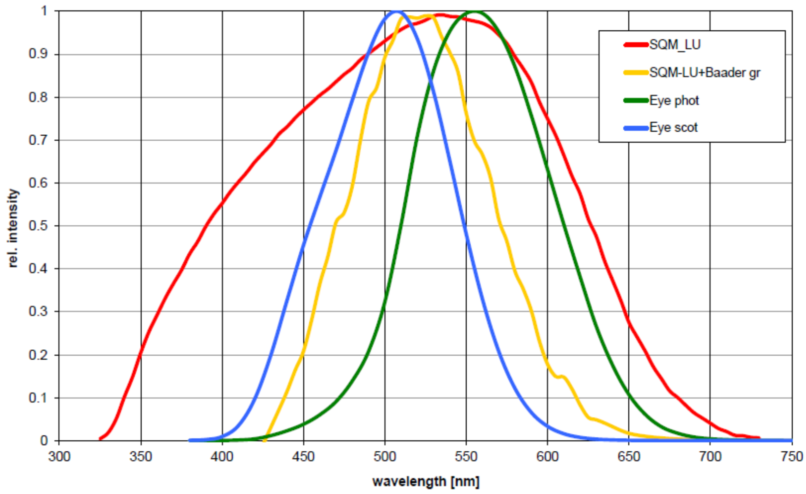


Fig. 5: The sensitivity curves of the photopic (green) and scotopic (blue) eye, the SQM (red) and the Baader green filter (yellow). The passband of the Custom Scientific V band filter is most similar to that of the Baader green filter.

Measurements 2015-09-15/16

During the first night measurements were taken along the road with the “Roadrunner software” from Kalavrita to the observing place, back over the ski parking to Kalavrita.

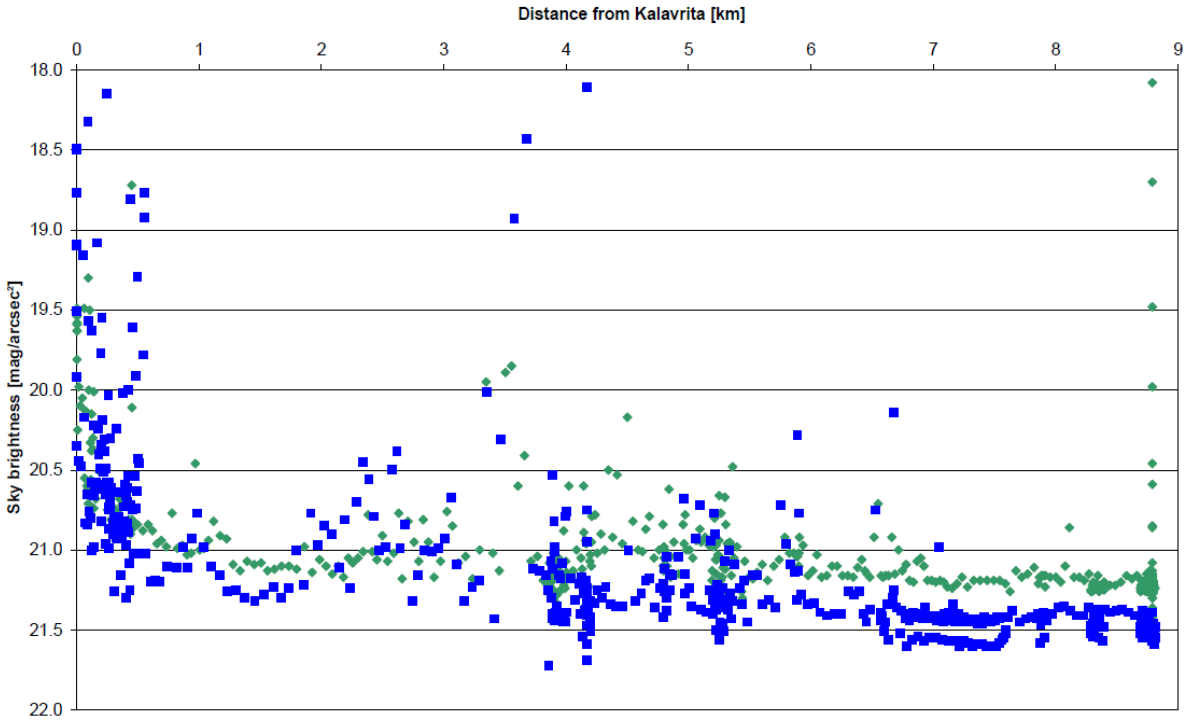


Fig. 6: Sky brightness measurements with the roadrunner software (SQM-LU #1049) against the distance from the center of the village of Kalavrita, green outwards to the observing place, blue back towards Kalavrita. The brightening near 3.5 km is due to some street luminaires at a small settlement.

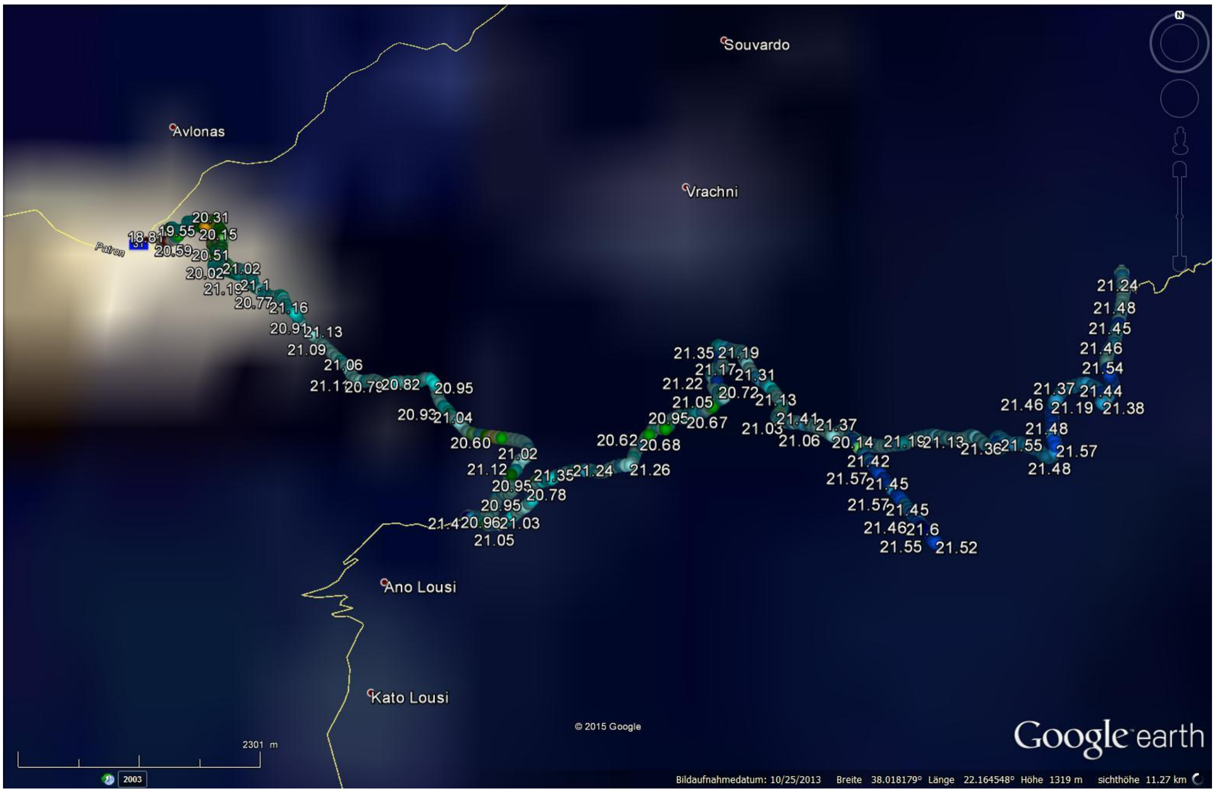


Fig. 7: The same measurements overlaid to the Black Marble data (VIIRS 2012 data) with GoogleEarth.

At the observing place continuous and parallel measurements with the two SQM-LUs #1049 and #2486 were taken with the Unihedron Device Manager. The SQMs were installed on the roof of the car. In front of #2486 was placed the Baader-green filter (1 in fig. 8), while in front of #1049 for a short time a neutral density filter Schott NG4/1mm (transmission 0.30 or +1.307 mag at 530 nm, 2 in fig. 8) filter was placed.

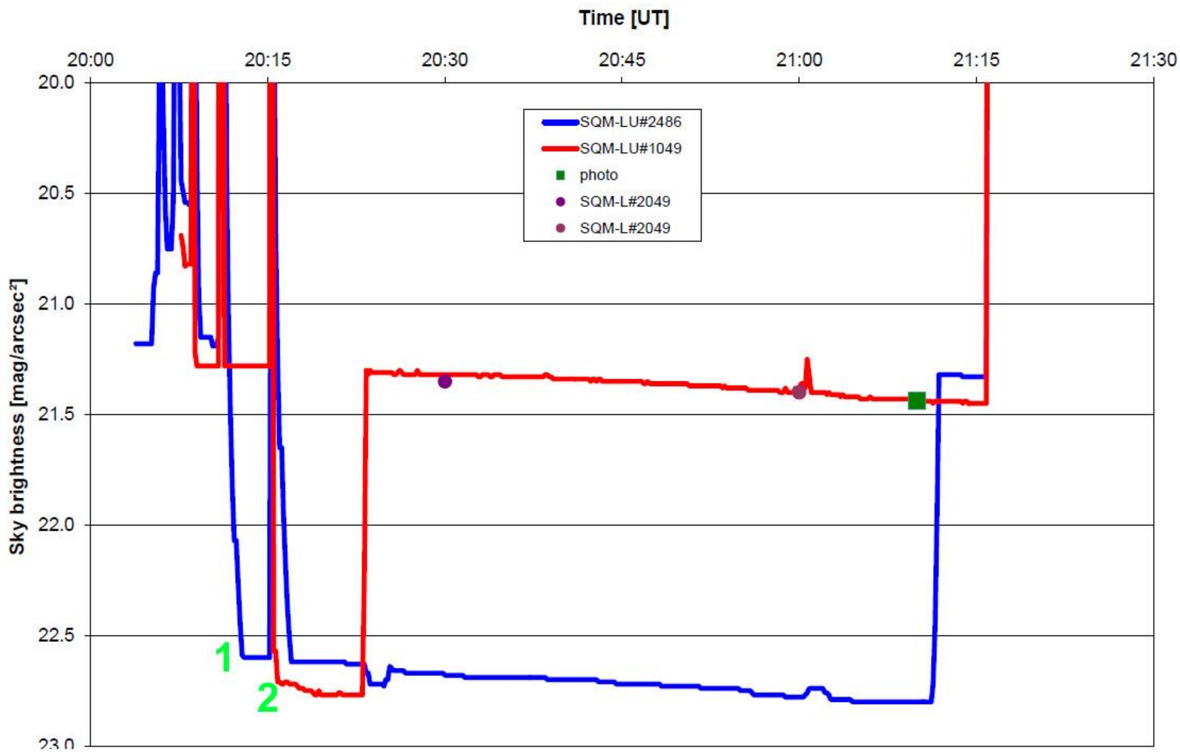


Fig. 8: Measurements with 2 SQM-LUs, at 1 the Baader green filter was put in front of the detector, at 2 the Schott NG/1mm neutral density filter was installed. Dark red circles are measurements with the handheld SQM-L and the green square is the sky background brightness as derived from the photographic photometry.

Several measurements have been taken with the handheld SQM-L #2049 during the time, they varied between 21.35 - 21.4 mag/arcsec².

Fig. 9: A star field photographed with the Baader green filter at the zenith (Frame #5723, 30s, 85mm f/1.5, ISO 800 ASA)

Pictures were taken at several zenith distances with a green filter and the 85mm f/1.5 lens in the Canon RAW format for astronomical photometry. First a picture from the zenith was reduced with the software AstroArt, stellar photometry using the V magnitudes was done with the aperture method. Preliminary reduction of the 30s exposure at zenith (Frame #5723, 22:10 UT) gave a **sky background magnitude** of 21.44 mag/arcsec² (Baader green filter).

Conclusion:

The SQM-LU #2486 measures about 0.12 mag/arcsec² brighter than the #1049.
The SQM-LU with the Baader green filter measures about 1.5 mag/arcsec² fainter, similar to the change when the 1mm thick Schott NG 4 filter is used instead.
During the observing time the zenithal brightness decreased by 0.15 mag/arcsec², which could be explained with the changing position of the Milky Way at the zenith (see also the later section on SQM orientation effects).

Fig. 10: An all-sky photo taken with a modified Canon 700D with extended red bandpass (Astronomik UV+IR). The combined bright light domes of Athens (135 km) and Korinthos (65 km, position 1) dominate the eastern horizon. Patras (50 km, position 2) is partly shielded through the mountain. Relatively prominent is the light dome from Kalavrita (10 km, position 3), the white greenish color is due to the predominant use of fluorescent lamps. Unclear are the different colors near the horizon, towards the north it is green and might be due to airglow, the yellow/orange towards the south looks like light domes but in the direction towards the central Peloponnese are no brighter light domes that extend over such a large azimuthal direction. It might be due to higher dust content.

Measurements 2015-09-16/17

Fig. 11: All-sky pictures taken during the first (15th, left) and the beginning and end of the second night (16th, middle, right), with same exposure conditions, final composed picture contrast enhanced.

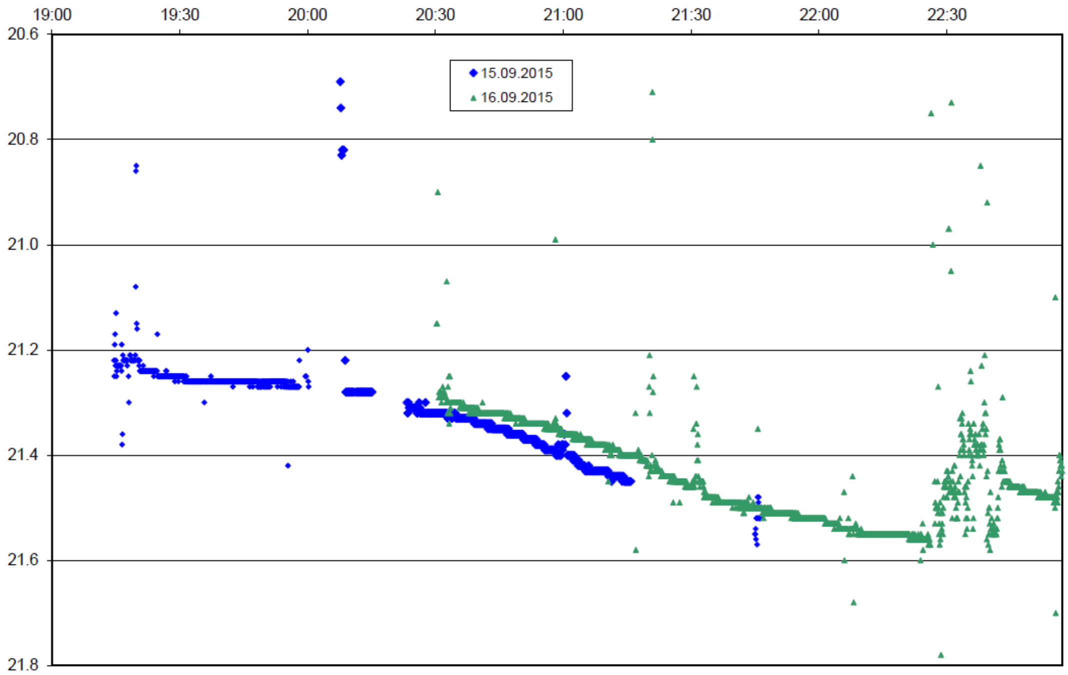


Fig 12: Sky brightness measured with the same instrument (SQM-LU #1049) during the two nights

The all-sky pictures from the two nights look different, in the second night the greenish glow over the picture from the beginning of the night seems to be airglow. The SQM measurements indicate also a higher sky brightness. The decrease in brightness during the night could be due to decreasing airglow activity but also due to an inaccurate alignment of the optical axis of the SQM-L (#1049) towards the zenith. This can also be recognized in fig. 6 at about 7 km distance from Kalavrita. This is the road to the parking of the skiing resort and driving in the two directions could cause slightly different orientations of the SQM-L towards the zenith and therefore different brightness values.

Again roadrunner measurements were taken from Kalavrita to the observing place and back over the skiing parking to Kalavrita. With the same SQM and software continuous measurements were taken at the observing site.

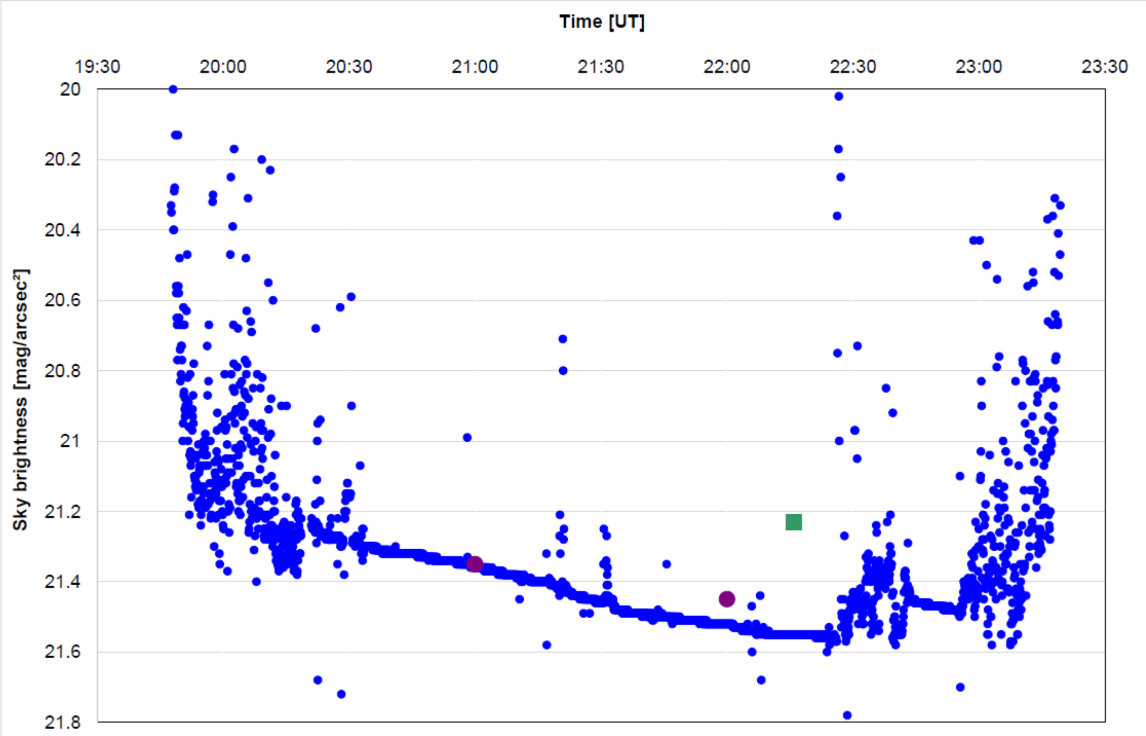


Fig. 13: Sky brightness measurements during the second night with handheld measurements and the sky background brightness value from stellar photometry (green square).

Measurements with the handheld SQM-L #2049 were in the range between 21.35 and 21.45 mag/arcec². Two other SQM-L devices were used for measurements between 20:44 and 21:44 UT (BE's devices #3204 and #8037) and the results were consistent with the variations of #1049, although offset from the latter values by -0.15 magnitudes.

Preliminary reduction of a 30s exposure at zenith (#5810, 22:16 UT) using astronomical photometry gave a sky background magnitude (with Baader green filter) of 21.23 mag/arcsec², therefore considerably brighter than the night before.

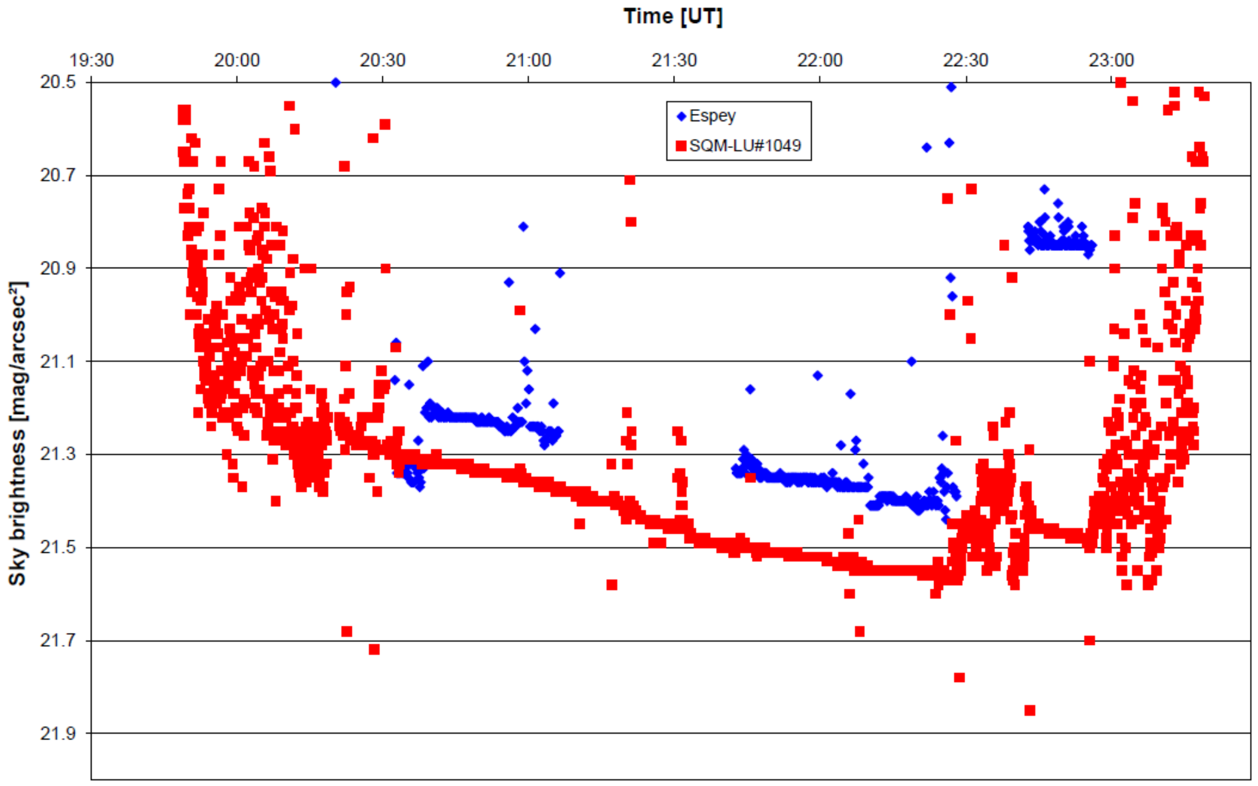


Fig. 14: Continuous measurements with the SQM-LUs #1049 (AH) and a modified SQM-LR unit #933 (BE). The output of the modified unit gave readings that were roughly 1.1 magnitudes brighter than unit #1049, most likely due to a displacement of the lens and/or filter relative to the Taos sensor when this #933 was reassembled after transport.

Filter effects

At 21:40, measurements with SQM-L units #3204 and #8027 with the Custom Scientific V filter placed over the lens (and also with the internal Hoya CM500 filter in place) gave readings which were +1.10 mag/arcsec² fainter than without the filter. A similar comparison with SQM #3111 (a non-lensed SQM, also with the internal CM500 filter in place), gave a smaller offset of +0.60. The V band measurements with SQM unit #3111, and SQM-L units #3204, #8037 were 22.36, 22.50, and 22.44, respectively.

SQM orientation effects

On both nights there was a change in SQM magnitude during the night. To estimate the effect of the Milky Way on SQM magnitudes, a test was performed to ascertain the effect of differences in the orientation of the optical axis of the SQM relative to the plane of the Milky Way. For the SQM-L units, with the observer facing the SE and the display facing the observer (i.e. with the width of the SQM-L unit lying parallel to the Milky Way) readings were roughly +0.20 magnitudes larger than when facing NW. Observations taken with the observed facing NW (i.e., with the width of the meter perpendicular to the plane of the Milky Way) gave similar results to when facing SE.

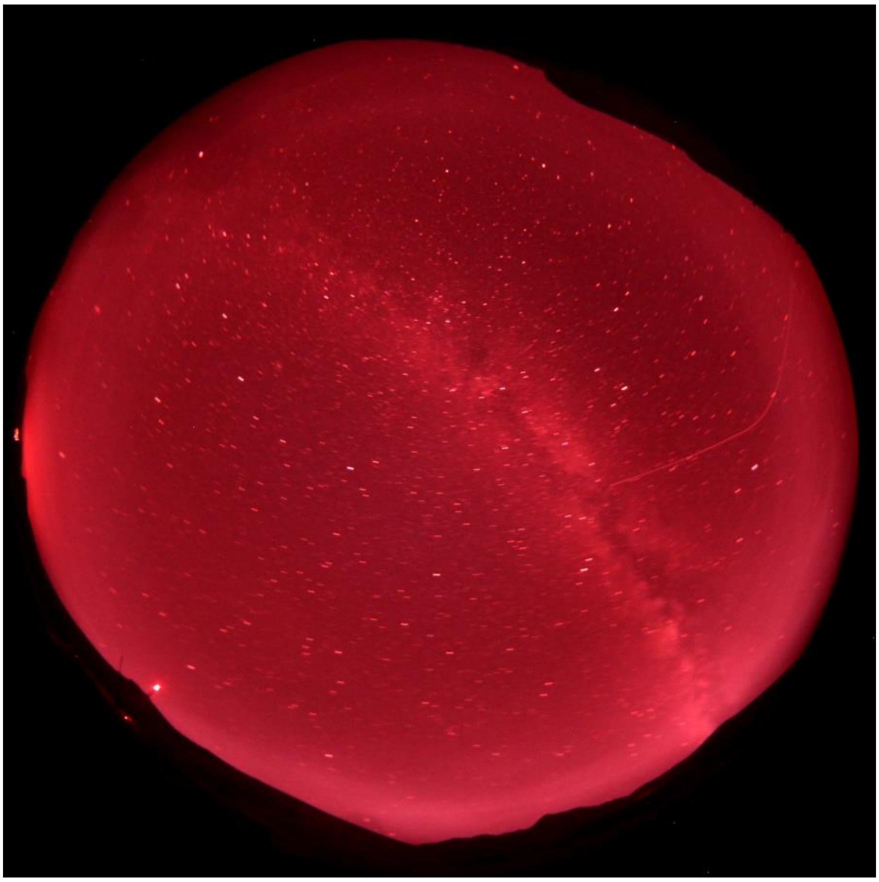


Fig. 15: A near infrared all-sky picture taken during the first night, where the dust near the southern horizon can be better seen. The curved track at the right-hand side is due to the lights of a passing aircraft.

Conclusions and recommendations:

The night sky quality at the observing place is relatively dark, on the horizon light domes from Athens/Korinthos and Patras are remarkable. The weather conditions during the two nights were very stable and undisturbed. For comparison, measurements at the higher observatory site with at least one SQM would have been desirable.

The sky brightness during the second night seems to be a bit higher than in the first, perhaps due to increased levels of airglow.

Measurements with the SQM under changing sky colors (e.g. during twilight) were not possible. These should be done during the next campaign.

The orientation of the optical axis (identical to the mechanical axis of the housing?) of the SQM-Ls towards the Milky Way seems to be very important. Comparable measurements should be tried on a sky without Milky Way (in spring).

Although small changes are seen in the SQM magnitudes with orientation relative to the plane of the Milky Way, there was a similar decrease in brightness detected by the monitoring SQM units (#933 and #1049) although the lenses of the two units were orientated roughly perpendicularly. Hence it may be that the decrease in brightness is due to a decrease in airglow over the night, which could be recognized in fig. 11.

The comparison with the astronomical photometry during the two nights gives very different results: in the first night it was in perfect agreement, in the second night it was brighter by 0.3 mag/arcsec^2 brighter. Therefore a more detailed study of the astronomical photometry is necessary. It is planned to try to derive the extinction.

Unfortunately under these excellent conditions no further comparison with astronomical or V(λ) photometry was possible as the instruments were not available.

2015-09-17

Thanks to the administration of the National Park we made an excursion to the observatory at the top of Mount Chelmos with a ranger in a 4x4 car. A visit inside the observatory building itself was unfortunately not possible.

The day sky at the mountain top was much darker than at the lower altitude and the haze at lower altitudes was very well visible. Therefore the night sky brightness could have been reduced compared with lower altitudes.

Fig. 16: The extreme blue sky and happy excursionist on Mt. Chelmos

In the evening it was planned to map the brightness profile from Korinthos towards Athens. However most of the motorway was illuminated that no representative sky brightness values could be derived.

Fig. 17: The sky brightness measurements are shown overlaid on a composite picture taken from the ISS (ISS026-28873) and Google Earth (https://www.google.com/earth/). ISS image courtesy of the Earth Science and Remote Sensing Unit, NASA Johnson Space Center http://eol.jsc.nasa.gov

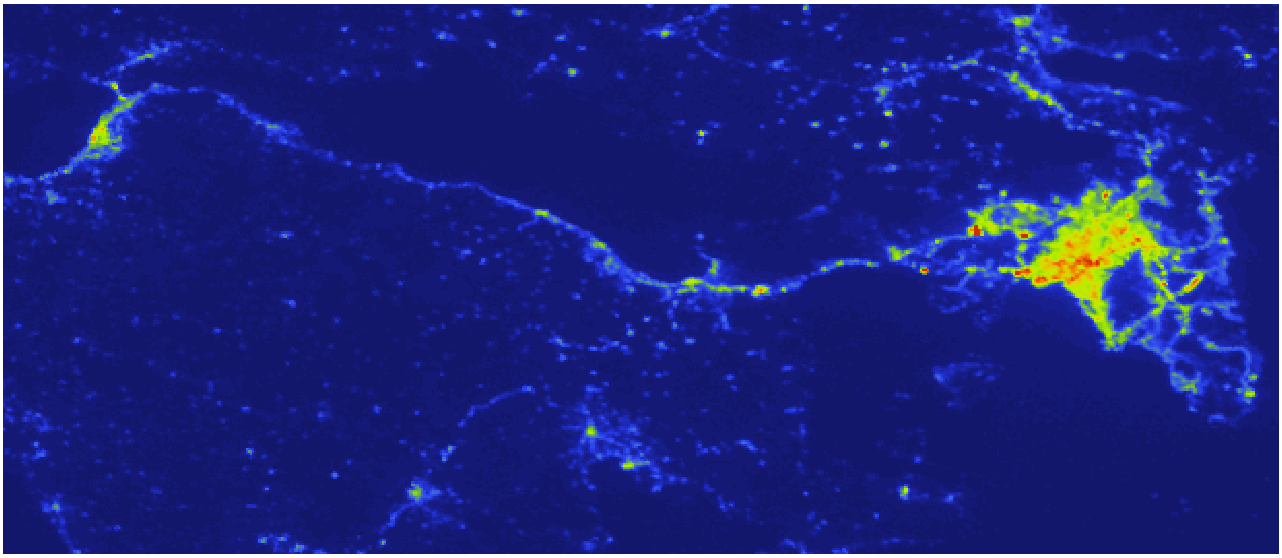
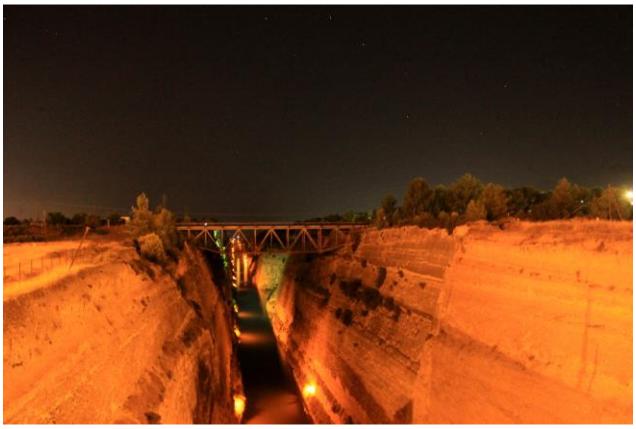


Fig. 18: The VIIRS DNB data for the night of Sept. 16th.



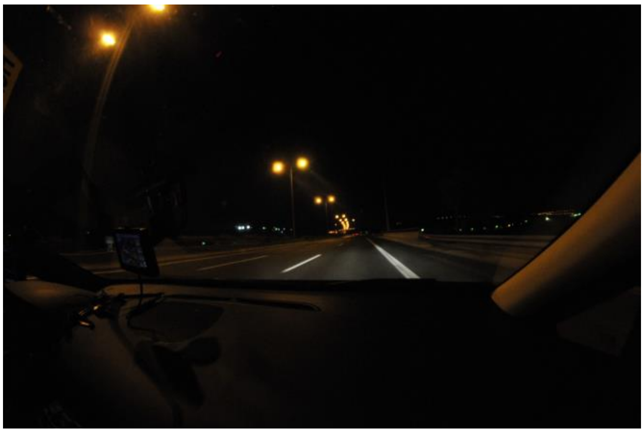


Fig 19: Isthmus of Korinthos illuminated by scattered street lighting

Fig. 20: The illuminated motorway from Korinthos to Athens.

Many thanks to:

COST LoNNe for financing
COST LoNNe scientific members for stimulating discussions
National Astronomical Observatory (Dr. Dimitris Sinachopoulos, Dr. Panayotis Boumis)
Special thanks to the National Park administration in Kalavrita for information and especially for providing transport up the mountain

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Appendix A: Chelmos-Vouraikos National and Geo Park as Star Park

The Greek National Astronomical Observatory is situated in the National and Geo Park Chelmos-Vouraikos in the northwest of the Peloponnese peninsula.

The total area is about 544 km² and 4 Natura 2000 regions and one Special Protected Area (partially overlapping) belong to the National Park.

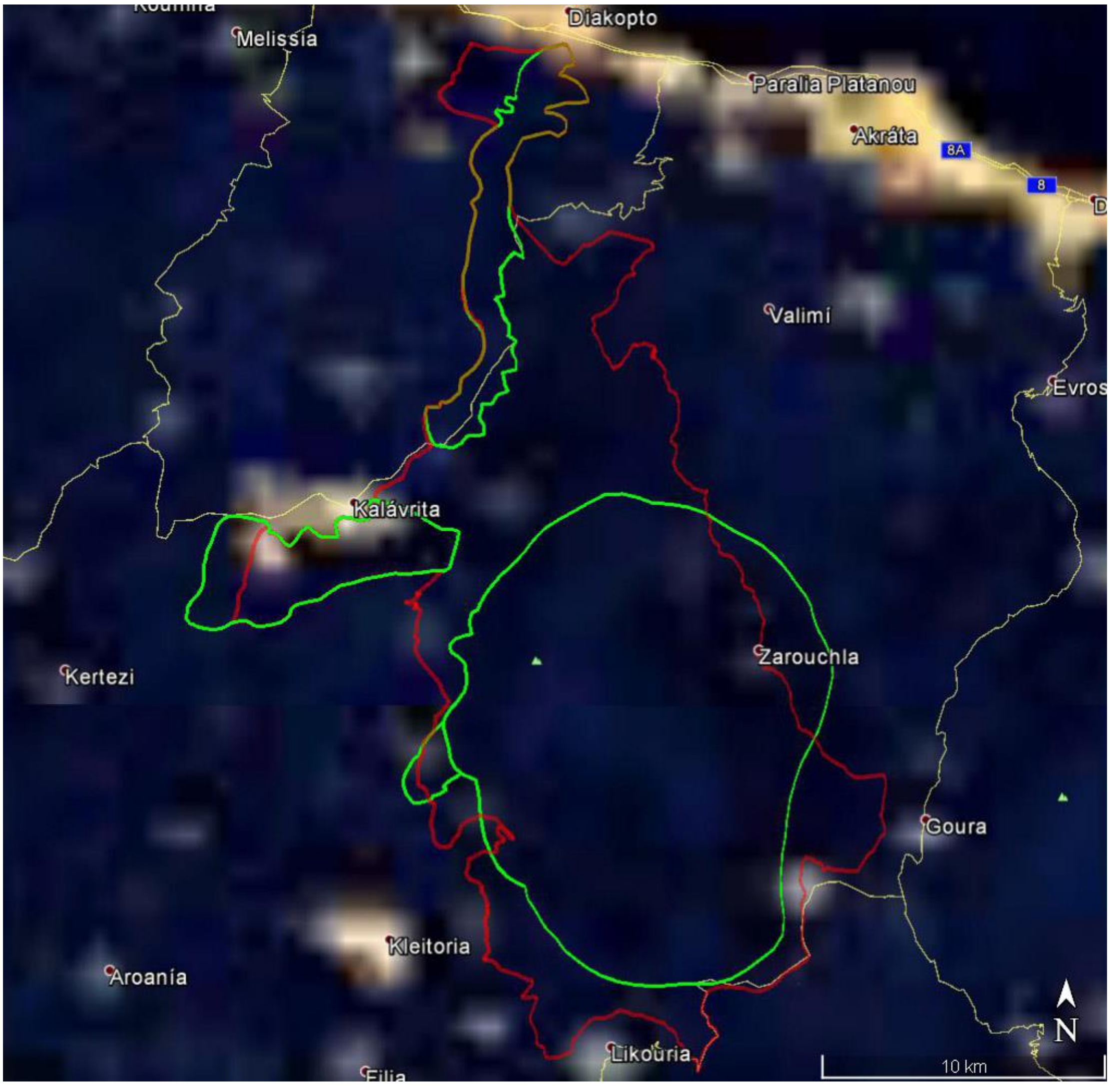


Fig. A1: Boundaries of NATURA2000 areas (red: SPA, green Habitats Directive Sites) which are within the Geopark / National Park overlaid on the Black Marple data

The overlay of the boundaries on the Black Marple map shows (fig. A1) that the region is relatively undisturbed through artificial light. The main light sources are Kalavrita, Kleitoria and the villages along the coast of the Gulf of Korinth.

The protection of the quality of the night sky around the national observatory should be important. Due to the fact that artificial light can reach far in the atmosphere (the light dome of Athens at 135 km distance is very dominant) the protection should be far reaching and extend at least over the National Park. Even the light dome of Kalavrita is easily visible from the observing place (fig. A2) and could be more disturbing from the observatory from where it is directly visible (fig. A3).

Fig. A2: the light dome (white, left) of Kalavrita as seen from the observing place.
Fig. A3: View of Kalavrita from the observatory, at night it should be brightly visible.

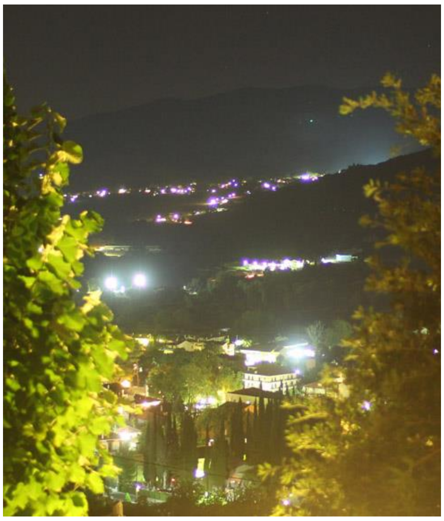


Fig. A4: Kalavrita as seen from the hotel above the village
Fig. A5: The illuminated memorial for the massacre by the German army in 1943

Fig. A6: The luminaires in Kalavrita are very old, inefficient and not very well shielded and waste a lot of light.

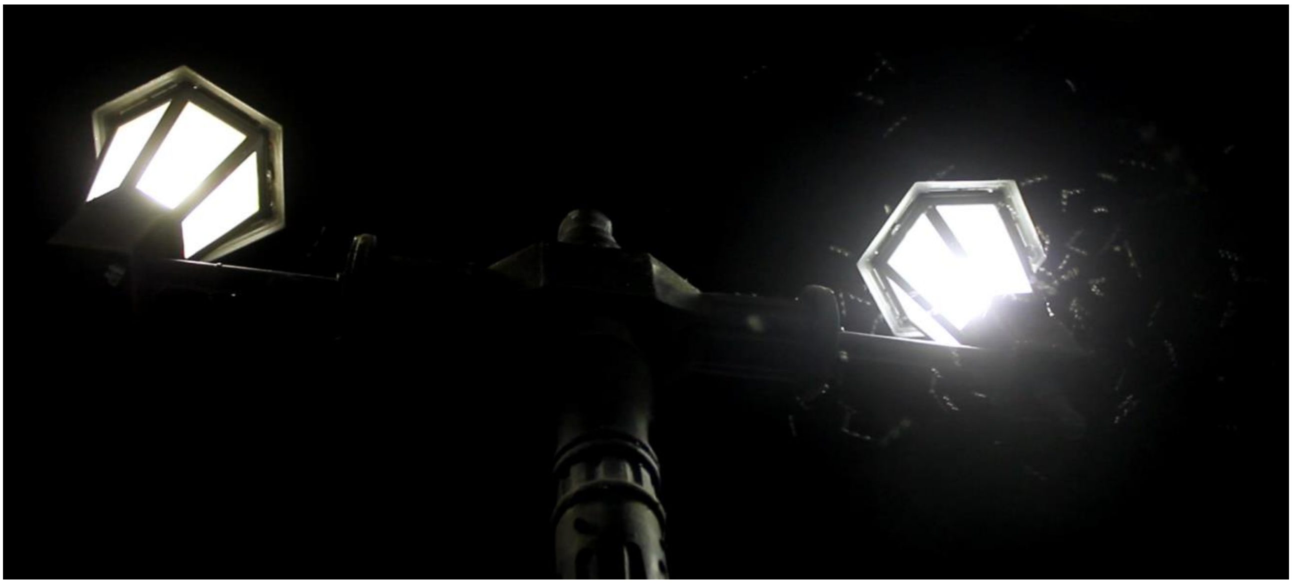


Fig. A7: These luminaires in Kalavrita show the influence of artificial light: left a warm white lamp with low blue content and nearly no insect activity. Right a cold white lamp with high blue content and many insects flying around (screen-shot from a video)

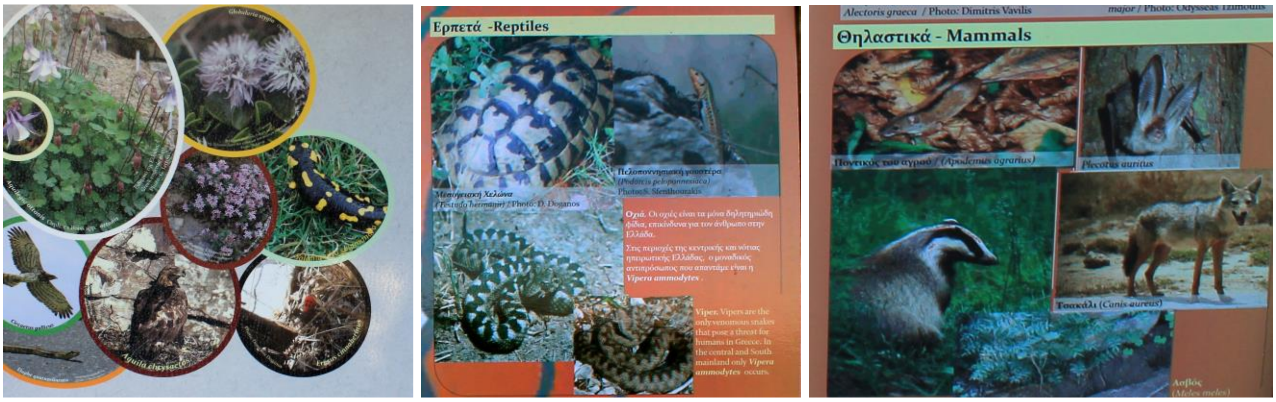


Fig. A8: Some animals living in the National Park that might be influenced by artificial light: amphibians, reptiles, bats (taken from information panels in the National Park)

Fig. A9: Residents close to the observatory with not very well shielded lighting. They could be ideal places for astronomical observations when light would be changed or switched off.

Fig. A10: Flashlights at wind mills are flashing at night with intensive white light – these should be changed during night to less disturbing red lights – like in many other countries.


Fig. A11: Wrongly oriented floodlights shine senseless into the landscape which is illuminated in large distances.

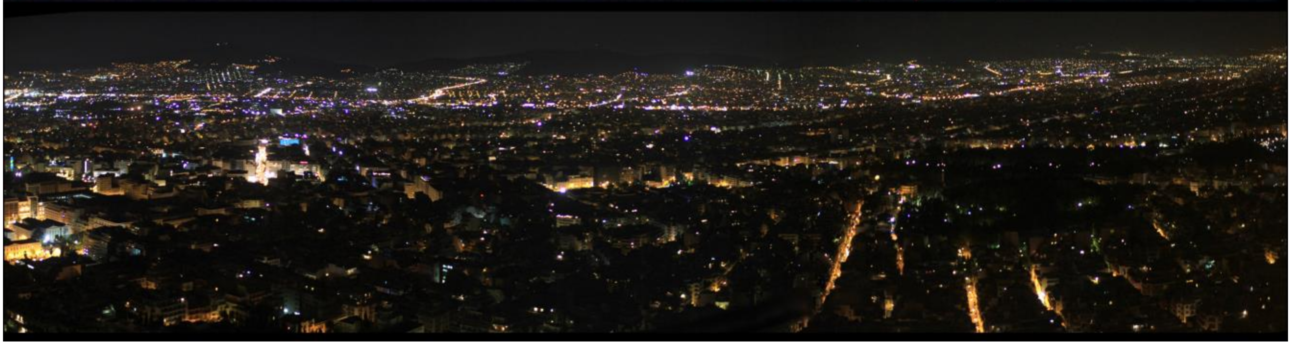
Developing the National Park to a star park (e.g. according to the IDA criteria) would:

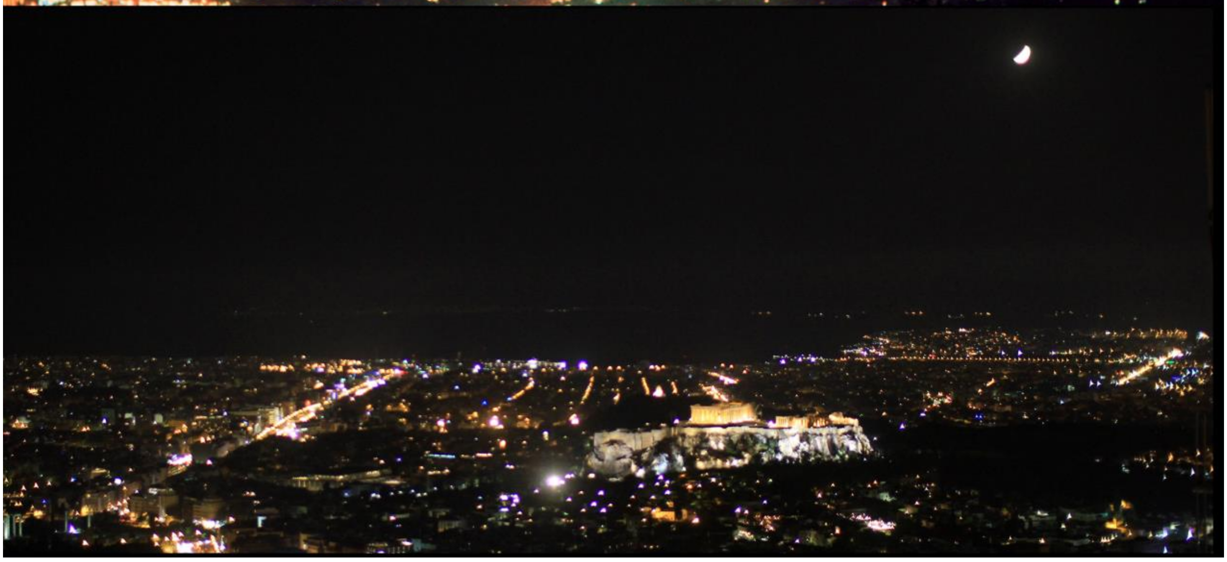
- Protect the astronomical dark sky for the Chelmos observatory
- Protect the nocturnal environment in the National Park for animals and human beings
- Lead to a sustainable lighting (shielded, adaptive, qualitative) that protects nocturnal nature and reduces energy waste
- Increase touristic attraction during seasons when few tourists come to the region (spring and especially fall) and which could be especially interesting for amateur astronomers.
- By this the National Park could become an example of best practice in a sustainable artificial lighting for other regions

Appendix B: Athens: changing lights 1977 - 2015

Analogue slides have been taken from Mount Lykavitos in Athens in September 1977. These have been digitized and compared with digital photos in September 2015.
The direction of the photo shots are indicated in a photo taken from the International Space Station (ISS026_E_28873).
Due to the different techniques with different sensitivities and color renditions a comparison is limited and it will be difficult to remark a general change of the amount of light. However the changes of new settlements or removal of illuminated areas, lighting colors (from greenish mercury high pressure to yellow sodium high pressure), shielding can be detected.

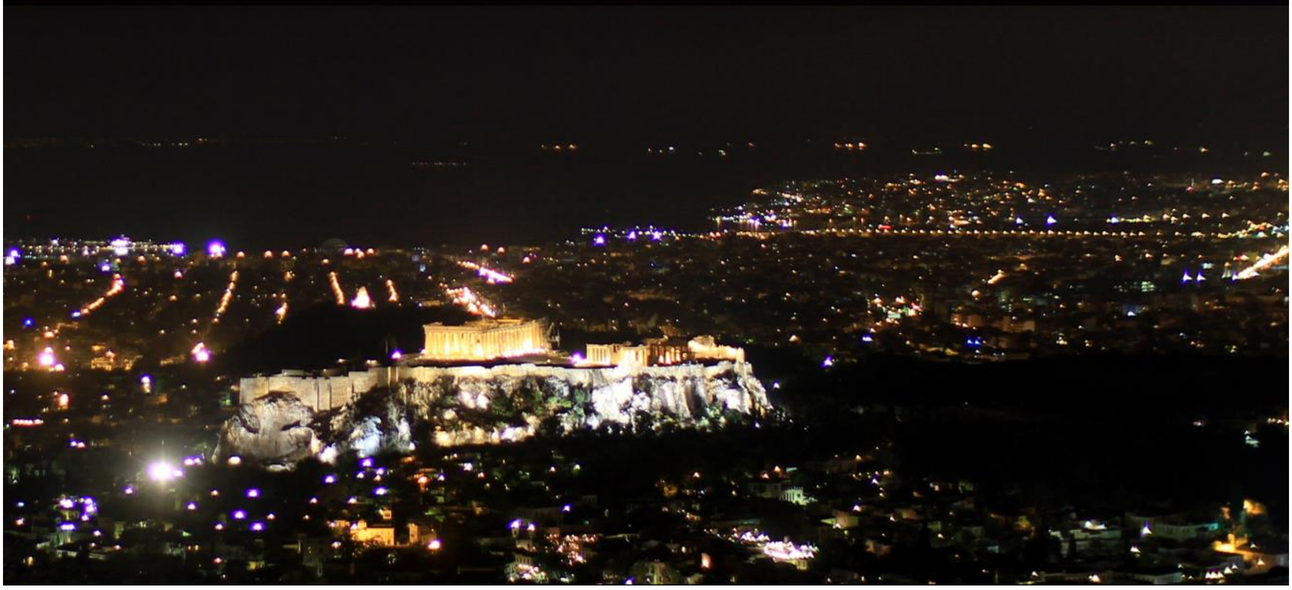
View towards the North-West with Omonia being a bright light source





View towards Piraeus and the Acropolis:

The Parthenon temple was not illuminated during the shot of old photo as there were “Sound and Light” shows that changed the illumination.
The main street Leof. Andrea Siggrou as a main axis from Athens to Piraeus can be detected as a bright band.



More detailed view towards Piraeus and the Acropolis:

The Parthenon temple was illuminated during the shot of old photo while the rocks were not illuminated. The chain of lights to the right might be the (not well shielded) illumination of the motorway.