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The night sky brightness at Potsdam-Babelsberg including overcast and moonlit conditions

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ABSTRACT

We analyze the results of 2 years (2011–2012) of night sky photometry performed at the Leibniz Institute for Astrophysics in Potsdam-Babelsberg. This institute is located 23 km to the southwest of the center of Berlin. Our measurements have been performed with a Sky Quality Meter. We find night sky brightness values ranging from 16.5 to 20.3 mag_{SQM} $arcsec^{-2}$; the latter value corresponds to 4.8 times the natural zenithal night sky brightness. We focus on the influence of clouds and of the moon on the night sky brightness. It turns out that Potsdam-Babelsberg, despite its proximity to Berlin, still shows a significant correlation of the night sky brightness with the lunar phases. However, the light-pollution-enhancing effect of clouds dominates the night sky brightness by far: overcast nights (up to 16.5 mag_{SQM} $arcsec^{-2}$) are much brighter than clear full moon nights (18–18.5 mag_{SQM} $arcsec^{-2}$).

1. Motivation

Astronomers have been monitoring the brightness of the night sky for many decades at several observatories around the world (see, e.g., [1–3]). When it comes to choosing the site of a new ground-based telescope, measurements of the night sky brightness are of crucial importance in order to find sufficiently dark sites with as many clear nights per year as possible. Much less investigations have been devoted, for obvious reasons, to the sky brightness at abandoned astronomical sites and in urban areas both under clear and overcast conditions.

Recently, however, monitoring programmes have been initiated in many places to study the brightness of the clear *and* cloudy night sky as well as during moonless *and* moonlit nights. This is because of the increasing knowledge about the influence of light at night not only on astronomical observatories, but also on ecosystems, on chronobiological rhythms and on our society. In October 2013, the first international conference on artificial light at night – covering all these topics – took place ([4]). The present paper is indeed motivated by the fact that light pollution needs to be monitored continuously due to its implications for astronomy, energy consumption, wildlife and human health (e.g., [5,6], and references therein).

Our study of the night sky brightness (henceforth: NSB) at Potsdam-Babelsberg presents a special case in this context. Potsdam-Babelsberg is located 3 km away from the center of Potsdam (population: 159,500) and 23 km from the center of Berlin (3.375 million inhabitants). During clear nights, the NSB measured at Potsdam-Babelsberg is mainly influenced by the proximity of Berlin with its huge light dome. For those numerous nights, however, in which the sky is covered by clouds – especially clouds lower than cirrus – the sum of the upward directed artificial light from Potsdam is most probably the largest source of the night sky brightness that we measure. A third case is of interest as well: clear nights close to full moon. As Davies et al. [6] did for the first time for Plymouth (UK) and its surroundings, we examined whether or not the dependence of the mean NSB on the phase of the moon is still significant at the observatory of Potsdam-Babelsberg.

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Table 1
Geographical coordinates of our measurement site Potsdam-Babelsberg.

Altitude	Longitude	Latitude
70 m	13° 06′ 06′ E	52° 24′ 18″ N

2. Measurement site and method

All our NSB measurements were performed on top of the “Schwarzschildhaus”, a building that is located 160 m to the west of the Potsdam-Babelsberg observatory. The location of our measurement device is sufficiently high to preclude any *direct* irradiation of artificial light on our detector. Hence, it is indeed only the light scattered by the night sky which we measure. The question of single versus multiple scattering of sunlight during the twilight and the transition from dominant scattering of sunlight to the dominant scattering of artificial light will shortly be addressed in Section 3.

The geographical position of our measurement site is summarized in Table 1.

NSB measurements at Potsdam-Babelsberg were initiated in October 2010. However, we decided to use only the data from the completed years 2011 and 2012 for our analysis.

We used Unihedron′s Sky Quality Meter with an integrated lensing system. The model we used is called “SQM-LE”, but for the sake of brevity, we will refer to it as “SQM” here. The instrument was placed into a weather-proof housing and directed into the zenith, thus detecting the zenithal and near-zenithal sky brightness. The device is connected to a computer via ethernet. The sampling rate we used was 2.1 s.

The spectral sensitivity of the SQM, which has been studied by Cinzano [7]) differs from the transmittance of a Johnson V filter in three respects:

- The peak of the SQM sensitivity is at 540 nm.
- While the Johnson V filter largely cuts off radiation with a wavelength smaller than 470 nm, the SQM detects light down to wavelengths smaller than 400 nm.
- Beyond 550 nm, the SQM sensitivity and the Johnson V transmittance are fairly similar, but the SQM has a broader transmittance window also at these wavelengths.

These differences motivate us to use the unit “mag_{SQM} arcsec^{-2}”, which has also been proposed by Biggs et al. [8]. The difference between mag_{SQM} arcsec^{-2} and mag_V arcsec^{-2} is color-dependent and lies between 0.2 and 0.5 mag according to Cinzano [7].

However, a more systematic investigation of the influence of detector temperature, detector aging, zero-point-differences between individual SQMs, etc. still needs to be done in future.

2.1. Data storage and web interface

All data presented and analyzed in this paper can be found as plots on the website http://verlustdernacht.aip.de. The plots of the zenithal NSB shown on this website will be called ‘scotograms’ in the following, derived from the Greek word ‘skotos’=dark.

3. Data analysis

3.1. Comparison to literature values for the twilight sky brightness

As a ‘reality check’ for our data, we compared them both to a table of twilight sky brightness values published in the 1965 edition of the ‘Landolt-Börnstein’ (LB) encyclopaedia and to the single-scattering model of the twilight sky brightness published by Patat et al. [2]. Both the LB data set ([9]) and the paper by Patat et al. refer to the brightness of the twilight and night sky without light pollution. Another goal of our comparison was thus to find out for which depth of the Sun below the horizon the anthropogenic contribution to the measured NSB becomes noticeable or even dominant.

We converted the LB zenithal luminance data into zenithal sky brightness data in mag arcsec^{-2} by using the equation:

$$\text{NSB}\ [\text{mag}_V\ \text{arcsec}^{-2}] = 12.6 - 2.5\log\left(\text{luminance}\ [\text{cd/m}^2]\right) \quad (1)$$

We refer to Cinzano [10, p. 112] and Garstang [11, Eq. (19)] for the derivation. Note that this relation has been derived for the NSB measured in mag_V arcsec^{-2}, while it is only an approximation for the NSB measured in mag_{SQM} arcsec^{-2}.

Fig. 1 shows a scotogram measured at Potsdam-Babelsberg during a very clear night close to the summer solstice, namely from 26th to 27th of June 2012, compared to the NSB which was expected based on the LB data. It can be seen that for an NSB larger (darker) than 18 mag_{SQM} arcsec^{-2}, the measured values begin to deviate from the LB values due to the influence of light pollution. This zenithal sky brightness is reached when the Sun reaches a depth of 10.2° below the horizon. The darkest NSB recorded during this night was 20.1 mag_{SQM} arcsec^{-2}. This in turn corresponds to the natural NSB predicted for $h_{sun,\ equiv} = -12.7°$ in the case of a light-pollution-free sky, while the real value was $h_{sun,\ real} = -14.3°$ at midnight at our location.

Given that an NSB of 20.1 mag_{SQM} arcsec^{-2} is rarely being surpassed at Potsdam-Babelsberg even during clear, moonless nights, our results can also be expressed in the following way: The skyglow at Potsdam-Babelsberg corresponds to permanent nautical twilight. The sky luminance range of astronomical twilight is barely reached at this location.

In Fig. 1, we also compare our selected clear-night scotogram to a linear approximation to the single-scattering model used by Patat et al. [2]. Patat et al. have pointed out that the brightness of the clear twilight sky in the V band is dominated by contributions of single scattering until $h_{sun} = -5°$. For larger depths of the Sun, the contribution of multiple scattering becomes much more significant, which is reflected in Fig. 1 by the deviation of the measured and LB curves from the *lower*