Light pollution at the Roque de los Muchachos Observatory

Pedani, M.¹

INAF-Centro Galileo Galilei, Po Box 565, S/C La Palma - 38700 TF, Spain

Abstract

Sky spectra were obtained from archival science frames taken with DoLoRes at the 3.58m Telescopio Nazionale Galileo with a wavelength range $\sim 3800 - 8000\,\text{Å}$ and resolution of $2.8\,\text{Å/pix}$ and $3.6\,\text{Å/pix}$. Our spectra include all the important Sodium and Mercury light pollution lines and span a wide interval of azimuth and observing conditions, essential to disentangle environmental and seasonal effects. New sodium and mercury lines were also detected for the first time at the observatory. Light pollution from NaD$_{5892-8}$ emitted by the LPS lamps increased by a factor of $1.5 - 2$ with respect to the average values of 1998. At the same time, light pollution from Hg lines decreased by $\sim 40\%$ and reaches the 1998 levels only when observing toward the towns. The contribution of NaD$_{5892-8}$ from LPS lamps to sky background is $0.05 - 0.10\text{mag}$ at V-band and $0.07 - 0.12\text{mag}$ at R-band. Synthetic sky brightness measures calculated from our spectra at V, B and R bands are in good agreement with those of Benn & Ellison (1998) if we take into account that our observations were done during 2003, seven years after the last sunspot minimum. The effects of the application of the Canary Sky Law are directly visible in the spectra as a $50\%$ dimming of the Hg light-polluting lines in the spectra taken after local midnight.

Key words: Light pollution, Nightglow

PACS: 94.10.R

1 Introduction

The Observatorio del Roque de los Muchachos (ORM), located at La Palma in the Canary Islands is actually the largest European Observatory in the northern hemisphere. The site benefits from good sky transparency, and a high fractions of clear ($\sim 70\%$) and photometric nights ($\sim 60\%$) and a mean

¹ E-mail: pedani@tng.iac.es
seeing of 0.76” (Munoz-Tunon et al. 1997). The ORM is located at \( \sim 2300 m \) altitude, close to the summit of a 2426 m volcanic peak at longitude 17.9°W and latitude +28.7° and very close to the rim of a caldera. An inversion layer in the 1300 – 1700 m height range, guarantees (though with many exception in winter) stable observing conditions during 3/4 of the year. The relative proximity (\( \sim 200Km \) Eastward) of the Moroccan coast makes it possible that, especially during the summer, dust from the Sahara desert blows over the island, increasing atmospheric extinction (typically \( \sim 0.09 \text{mag at } r’\text{-band} \)). To our knowledge, after Benn & Ellison (1998, hereinafter BE98), who presented a low-resolution night-sky spectrum taken at WHT in 1991 (see their Fig.1), no other works have been published on light pollution at ORM. Our spectra have about three times greater resolution than that of BE98; they span a wide range of environmental parameters and observing conditions and show all the important light pollution lines. During recent years the island of La Palma underwent a strong development of turistic resources with the construction of new hotels, roads and urban areas. Though a special Sky Law exists which establishes the general rules for public and private illumination, this growth inevitably led to an increase of the outdoor lighting with negative consequences for the light pollution at the observatory. The aim of this paper is to give a comprehensive and up-dated view of the light pollution at ORM during 2003.

The organization of the paper is as follows: the sources of light pollution in La Palma are described in Sect. 2; the observational data are summarized in Sect. 3 and the analysis of the night-sky spectra is described in Sect. 4. Spectrophotometric data are described in Section 5 and conclusions are summarized in Sect. 6.

## 2 Light pollution at ORM

About 85,000 people live in La Palma, mainly concentrated in 8 small towns within 15Km of the ORM. Given the altitude of the ORM, the line-of-sight over the sea has a radius of \( \sim 180Km \), enough to intercept the lighting of the major Canary island Tenerife (800000 people and 120Km distant) whose coast is visible to the naked eye on very clear nights. Nevertheless, its contribution to the sky brightness, as well as that of two small islands, (El Hierro and La Gomera, 29000 people and 40Km distant) is negligible. In many cases, the presence of the so called ”sea of clouds” below the thermal inversion layer, greatly reduces outdoor lighting, especially during the coldest months. During summer, the presence of the anticyclone of Azores causes the clouds to be dispersed, so that outdoor lighting can easily escape upward. The most important sources of light pollution in La Palma are listed in Table 1. Though the study of the sky brightness is not the aim of this paper, their contribution to the zenith sky brightness at V-band has been calculated using the model
of Garstang (1989). This model (tested with some U.S. cities) is based on a series of assumptions which do not translate entirely to La Palma.

Though the ground reflectivity and the fraction of aerosols in the atmosphere can be those of a typical high-altitude site in the U.S. (e.g. Mount Graham), the fraction of outdoor lighting escaping upward is much less in La Palma. The relative fraction of lamps installed on La Palma (LPS lamps are much preferred here) is also different from other cities, so that light pollution preferentially arises toward red wavelengths, with different impact on the sky brightness with respect to a site where mercury lamps are predominant. On the other hand, the above model assumes 1000 Lumens/head which approximately agrees with the typical values of La Palma (∼ 1850 Lumens/head before local midnight and ∼ 1000 Lumens/head after).

The Canary Sky Law, introduced in 1992 (McNally 1994) put strict limits on the type of lamps which can be used for outdoor lighting, on their power, and on orientation with respect to the ground and implied that, after local midnight, most of the high-pressure sodium (HPS) and mercury lamps must be extinguished, as well as all the discharge-tube illumination. In general, LPS lamps should be used except in the urban areas where HPS lamps are admitted and a non-negligible fraction of mercury and incandescent lamps still exist (see Table 2).

LPS lamps are the best choice for astronomy because their emission is almost exclusively concentrated in the NaD$_{5890-6}$ doublet, which simply adds to the natural sky glow at these wavelength. No continuum emission arises from these lamps. Other emission lines are Na$_{5683-8}$ and Na$_{6154-61}$, the latter about 4 times weaker than the former. Detecting the above lines in the sky spectra permits the contributions to the NaD$_{5890-6}$ emission from light pollution and the natural sky glow to be disentangled (see Sect. 4.1). Up to now, the only way to measure the natural NaD skyglow at ORM was during an artificial 1hr blackout on the night 24 – 25 June 1995 to celebrate the 10th anniversary of the inauguration of the ORM (see BE98 for details).

The HPS lamps are the second contributor in terms of light output on La Palma (see Table 2). Their emission is characterized by a smooth continuum in the ∼ 5500 to 7000Å range. The NaD$_{5890-6}$ line, is now replaced by a deep void. Other narrow emission line are: Na$_{4665-9}$, Na$_{4979-83}$, Na$_{5149-53}$, Na$_{5683-8}$ and Na$_{6154-61}$.

Mercury lamps, though they contribute with a mere 9% to the total luminous flux of the island are another important source of light-polluting lines, especially in the violet/blue region of the spectrum. There is also a weak continuum emission in the 3200 – 7800Å range. The most important lines observed in our spectra are: Hg$_{4046}$, Hg$_{4358}$, Hg$_{5461}$, Hg$_{5769}$ and Hg$_{5790}$ (see Sect. 4.2).
Table 1
Sources of light pollution at the ORM at different azimuths (North through East). The contributions are calculated according to the model of Garstang (1989) and should be considered as upper limits (see Sect.2).

| Town                     | Azimuth (deg.) | Population (2003) | Distance (Km) | $\Delta mag_V$ |
|--------------------------|----------------|-------------------|---------------|----------------|
| Barlovento               | 50             | 2400              | 10            | 0.03           |
| San Andres y Sauces      | 110            | 5100              | 12            | 0.05           |
| Santa Cruz               | 125            | 18200             | 15            | 0.13           |
| Brena Alta/Baja          | 140            | 10800             | 15            | 0.07           |
| El Paso                  | 180            | 7500              | 12            | 0.08           |
| Los Llanos + Tazacorte   | 200            | 26100             | 12            | 0.32           |
| Puntagorda               | 280            | 1800              | 9             | 0.03           |
| Garafia                  | 325            | 2000              | 9             | 0.03           |

Incandescent lamps are a significant source of light pollution before midnight (see Table 2), though their solely continuum emission is not considered in the present work. Nevertheless, BE98 estimated their contribution to zenith sky brightness at V-band to be 0.01 mag.

At La Palma, light pollution originates from 17166 street lamps (end of year 2000, 23% more than reported in BE98) emitting a total of $1.56 \times 10^5$ KLumens before midnight, reduced to $1.0 \times 10^5$ KLumens after that hour. If we consider that about 50% of the light is emitted by the fixtures and the ground reflectivity is assumed 10%, we calculate that the amount of power emitted upward by the outdoor lighting is $\sim 16$ W/Km² before midnight and $\sim 11$ W/Km² after. It is noteworthy that the typical sky background of $V = 21.9$ mag/arcsec² corresponds to $\sim 9.2$ W/Km².

3 Observational data

Our sky spectra were obtained from archival science frames taken in the period August-December 2003 with the 3.58m Telescopio Nazionale Galileo at La Palma using DoLoRes (Device Optimized for Low Resolution), equipped with a $2048 \times 2048$ pixel thinned back-illuminated CCD with 15$\mu$ pixels. Only spectra taken with the LR-B Grism were considered, with a final wavelength coverage of $\sim 3800 \div 8000$ Å. The slit widths used were 1.0" and 1.3", yielding a resolution of 2.8Å/pix and 3.6Å/pix respectively. Wavelength comparison
Table 2
Type and number of lamps installed at La Palma at the end of year 2000 (Francisco Javier Diaz Castro - private communication). Column 3 gives the total amount of light produced by each class; Column 4 gives the fractional contribution of each class to the total luminic flux of the island.

| Type of lamp          | Number | MLumens | Fraction of total Flux |
|-----------------------|--------|---------|------------------------|
| LPS                   | 11086  | 72000   | 0.45                   |
| HPS                   | 1350   | 35000   | 0.22                   |
| Mercury               | 1040   | 14800   | 0.09                   |
| Incandescent          | 1026   | 30150   | 0.19                   |
| Fluorescent compact   | 560    | 670     | < 0.01                 |
| Tube-discharge        | 2104   | 6312    | 0.04                   |

lines were obtained with a Helium lamp at the beginning of each night. For the present study, only deep exposures taken with airmass < 1.3 during photometric, moonless nights with low extinction were selected. After a careful visual inspection, those spectra showing very similar content of light pollution lines were aligned and co-added to build six template spectra (hereinafter groups). These groups span a wide range in azimuth, epoch of the year and observing conditions, crucial to disentangle environmental and seasonal effects. As reported by BE98, we also found noticeable night-to-night variations in the intensity of the light pollution lines; this could be due to the presence of clouds below the ORM, blocking most of the outdoor lighting. To reduce the errors on the final line fluxes, we decided to include in the same group only those spectra whose NaD$_{5892}$ line fluxes differed by no more than 30%. In particular, the spectra with the highest Na line fluxes (less cloud cover) were considered. Our data were reduced using standard IRAF tasks for long-slit spectra. The final wavelength calibration is accurate to $\sim 0.8$ Å r.m.s. Flux calibration was performed by observing spectrophotometric standard stars (typically one per night); within each group, the individual response functions were averaged to reduce errors introduced by slit losses and the variability of the photometric quality of the nights. The final flux calibration is accurate to $\sim 15%$. 

5
Table 3
Overall properties of the night sky spectra. Last column reports when the exposures were taken (either before or after local midnight, when restrictions to the outdoor lighting of La Palma are applied; see Sect.2).

| Name | Exposure Time (h) | Slit Width (arcsec) | Azimuth (degrees) | Airmass | Extinction r-band (mag) | Date & Time                |
|------|------------------|---------------------|------------------|---------|-------------------------|---------------------------|
| Group1 | 4.0              | 1.0                 | +90 ÷ 250        | 1.19    | 0.1                     | Jul-Aug 2003; After h24    |
| Group2 | 2.0              | 1.0                 | +265             | 1.25    | 0.11                    | 29/08/03; Before h24       |
| Group3 | 1.0              | 1.0                 | +215             | 1.30    | n.a.                    | 29/10/03; Before h24       |
|        |                  |                     |                  |         |                         | +thin clouds               |
| Group4 | 1.0              | 1.3                 | +154             | 1.21    | 0.12                    | 27/12/03; Before h24       |
| Group5 | 1.5              | 1.3                 | +170             | 1.30    | 0.12                    | 27/09/03; Before h24       |
| Group6 | 2.0              | 1.3                 | +181             | 1.15    | 0.14                    | 27/09/03; After h24        |

Table 4
Fluxes of the most important emission lines as measured in our spectra. Values are in Rayleigh (see BE98 for some useful conversion formulas). When not detected, a line is labeled with "n.d."; if the line was too noisy/faint or either blended with another line, it is labeled with "n.a.". Contribution to NaD_5890–6 from light pollution is shown in parentheses (see Sect. 4.1 for details).

| Line       | Group 1 | Group 2 | Group 3 | Group 4 | Group 5 | Group 6 |
|------------|---------|---------|---------|---------|---------|---------|
| Hg_4046    | 3.4     | 5.2     | 9.5     | 6.1     | 10.2    | 6.3     |
| Hg_4358    | 5.6     | 7.9     | 22.0    | 17.6    | 14.2    | 4.5     |
| Ni_5199    | 1.5     | 15.4    | 3.2     | 11.2    | 5.1     | 3.1     |
| Hg_5461    | 4.4     | 5.5     | 25.7    | 10.9    | 8.6     | 4.7     |
| OI_5577    | 310     | 256     | 303     | 234     | 447     | 504     |
| NaD_5890–8 | 3.5     | 6.3     | 30.6    | 9.5     | 11.4    | 3.6     |
| Hg_5769    | n.d.    | n.d.    | 7.2     | n.d.    | 1.9     | 1.4     |
| Hg_5790    | n.d.    | n.d.    | 4.7     | n.d.    | 1.7     | 0.7     |
| NaD_5890–6 | 189(156)| 148(89) | 658(431)| 284(134)| 251(162)| 270(161)|
| Na_6154–61 | n.a.    | n.d.    | 9.5     | n.a.    | 9.6     | n.a.    |
4 Analysis of the night sky spectra

4.1 Na Lines - natural and artificial contributions

Given the population of lamps at La Palma, the NaI lines are by far the most important sources of light pollution at ORM. BE98 reported a median equivalent width of NaD of $\sim 100 \, \text{Å} (\sim 100 \, \text{R})$ during summer, of which $\sim 70 \, \text{R}$ due to outdoor lighting and $\sim 30 \, \text{R}$ due to the natural skyglow. The natural NaD skyglow is known to have a strong seasonal variation, going from $\sim 30 \, \text{R}$ in summer to $\sim 200 \, \text{R}$ in winter (Schubert & Walterscheid 2000). A noticeable effect we found in our spectra is the decrease of the Na and Hg lines in the spectra taken after local midnight, when most of the HPS and mercury lamps are switched off, according to the Canary Sky Law (see Sect. 2). To disentangle the natural and artificial contributions to the NaD emission we used our Group5 and 6 spectra taken respectively before and after midnight. Note that no seasonal effect is present since both of them were taken at the end of September 2003. We assumed that all the Na $5683-8$ flux of Group6 is due to LPS lamps while that of Group5 is the sum of LPS and HPS contributions. Thus the fractional contribution of LPS to Na $5683-8$ emission of Group5 is $3.6/11.4 = 0.32$ and that of HPS is 0.68. From the Philips catalog of lamps we derived the ratio NaD $5892-6$ / Na $5683-8$ = 44.6 for the SOX LPS 35W lamps mostly used at La Palma. For Group6 we calculate that light pollution from LPS lamps contributes $\sim 3.6 \times 44.6 = 161 \, \text{R}$ to the NaD $5892-6$ flux; Group5 has an identical value since LPS lamps are never switched off during the night. We deduce that at the end of September 2003 the natural NaD $5892-6$ skyglow at ORM was $\sim 90 - 100 \, \text{R}$.

We also tried another approach to verify our assumptions about the fluxes of Na $5683-8$ for Groups 5 and 6. From Table 2 the ratio of the illumination contribution of HPS vs. LPS lighting in La Palma is $\sim 0.48$. From the Philips catalog of lamps, as most of the HPS lamps at La Palma are SON-T 70W, we calculate that the flux of Na $5683-8$ emitted by a LPS lamp is 0.38 times that emitted by a HPS lamp. Thus, for Na $5683-8$ of Group5 we obtain that 3.4R are from LPS lamps and 8.0R are from HPS lamps. These values are in very good agreement with those obtained above by simply assuming that all the flux of Na $5683-8$ in Group6 (3.6R) comes from LPS lamps.

Group1 (see Fig.1) is our longest exposure spectrum and well represents the average observing conditions at ORM after midnight when looking at $\pm 5 \, \text{hrs}$ from the meridian. The first important difference from BE98 is that we now clearly detect Na $5683-8$ emission, while Na $6154-61$ is still undetected. Moreover, the Group1 spectrum shows that the average contribution of light pollution to the NaD $5892-8$ flux in the southern regions of sky after midnight is $\sim 150 \, \text{R}$,
about twice the value measured in 1998.

Group2 (see Fig.1) is interesting because it was taken towards the NW, a zone with relatively low light pollution (see Table 1) as confirmed by the lowest contribution of artificial NaD$_{5892-8}$ detected in our spectra (89R). With respect to Group1, the higher flux of Na$_{5683-8}$ is due to the fact that Group2 was taken before local midnight.

Group3 has light pollution lines with abnormally high fluxes (see Fig.1). It was taken looking in the direction of the most polluting towns of the island, before midnight and with thin clouds above the ORM (no data are available for the atmospheric extinction). A direct estimate with the above explained procedure of the artificial contribution to the NaD$_{5892-8}$ gives 431R, which would result in a natural NaD background of 227R, somewhat higher than expected at the end of October. In this case, the presence of high clouds could have played a role in reflecting back light pollution to the observatory.

Group4 is a typical spectrum taken looking toward a moderately polluted region of sky, $\sim$ 2hrs before meridian. Here, the effects of the two urban areas of Brena Alta/Brena Baja and partly of Santa Cruz de La Palma (see Table 1) are evident. The higher-than-average levels of the Na lines (note the Na$_{5683-8}$ flux of 9.5R) are also due to the fact that it was taken before midnight. We estimate the contribution of light pollution to the NaD$_{5892-8}$ to be 134R.

The above discussed Group5 and Group6 are typical spectra taken at the meridian where the line of sight intercepts the town of El Paso (see Table 1). The decrease of the Na lines fluxes is evident in Group6, taken after midnight. The contribution of light pollution to the NaD$_{5892-8}$ is $\sim$ 160R, similar to that of Group4 and Group1.

From Table 4 it is evident that in all our spectra, the fluxes of the NaD$_{5892-6}$ line are always 1.5 – 2.5 times higher than those of BE98. In principle this indicates that light pollution due to LPS and HPS lamps considerably increased in the last 5 years at La Palma, despite the efforts made to control it.

4.2 Hg I Lines

If we consider Group1, the emission of the lines Hg$_{4358}$ and Hg$_{5461}$ is about half that reported in BE98 but our spectrum also shows the line Hg$_{4046}$ detected for the first time at ORM and with intensity comparable to Hg$_{5461}$.

Although the Group2 spectrum was taken in a less polluted region of sky, it has $\sim$ 40% more Hg emission than Group1 and half the Hg emission of Groups 4 and 5 taken toward two towns before midnight (see Tables 3 and 4). This
demonstrates the benefits of the Canary Sky Law; observations made in the less polluted region of sky before midnight imply higher fluxes of Hg lines than those made toward a more polluted region but after midnight.

The most striking feature in our spectra is the line detected in Group3 (see Fig.1) at 5355.5 Å which we identified as ScI (tabulated lambda is 5356.09 Å, see Table 6 of Slanger et al. 2003). Scandium is used as an additive to high-pressure metal halide lamps. Since on La Palma these are used only in the soccer stadiums (to be extinguished after 23:00), our detection could have coincided with some nocturnal sporting activity. The line at 5351.1 Å detected in Group4 (see Fig.2) can also be identified as ScI emission (tabulated lambda 5349.71 Å). The Group3 shows other two lines never detected before at ORM: Hg5769 and Hg5790, only observed at Mount Hamilton (Slanger et al. 2003) and Kitt Peak (Massey et al. 1990). Though very faint, these lines also appear in our Groups 5 and 6, with a clear dimming after midnight evident in the latter spectrum (see Table 4).

To conclude, the average fluxes of the Hg lines detected in our spectra are \( \sim 50\% \) fainter than those reported in BE98. When observing toward a town, the Hg lines have about the same intensities as in 1998. Our directional spectra show for the first the effect of the application of the Sky Law after midnight but it is evident that mercury lamps are never completely extinguished after that hour, since Hg lines are present in all our spectra. For a typical town like El Paso (see Group5-6), we infer that only half of the mercury lamps are extinguished after midnight.

5 Spectrophotometry

Synthetic night sky brightness measures at B, V and R bands were also calculated from our spectra. The advantage of using spectra is that both natural airglow (OI\(_{5577}\)) and artificial (NaD\(_{5892-8}\)) lines can be eliminated by replacing them with the average continuum. It is noteworthy that the OI\(_{5577}\) line typically contributes 0.16 mag arcsec\(^{-2}\) to the broadband \( V \) (Massey and Foltz 2000). The values presented in Table 5 were obtained as in Massey and Foltz (2000) and reported to zenith as in BE98. The contribution (in mag arcsec\(^{-2}\)) of the NaD\(_{5892-8}\) emitted by LPS lamps to the \( V \) and \( R \) magnitudes is also reported in Table 5.

The sky brightness values in Table 5 are consistent with those of BE98 if we take into account that our observations were made about seven years after the 1996.5 solar minimum (sky is \( \sim 0.4 \) mag darker at solar minimum). From Table 5 it is evident a significant increase of light pollution from the NaD\(_{5892-8}\) line emitted by LPS lamps in La Palma (BE98 reported a 0.05 mag contribution).
Table 5
Synthetic sky brightness measures (mag arcsec\(^{-2}\)) as obtained from our spectra (see Section 5). The natural OI\(5577\) and artificial NaD\(5892\)–8 emission were replaced by the average continuum. LPS-V and LPS-R indicate the contribution of NaD\(5892\)–8 (in mag arcsec\(^{-2}\)) emitted by low-pressure sodium lamps to the V and R magnitudes respectively.

| Spectrum | B    | V    | R    | LPS-V | LPS-R |
|----------|------|------|------|-------|-------|
| Group1   | 22.48| 21.66| 20.74| 0.09  | 0.11  |
| Group2   | 22.46| 21.74| 20.79| 0.05  | 0.07  |
| Group3   | 22.34| 21.48| 20.47| 0.26  | 0.31  |
| Group4   | 22.40| 21.58| 20.69| 0.08  | 0.10  |
| Group5   | 22.40| 21.64| 20.72| 0.10  | 0.12  |
| Group6   | 22.42| 21.67| 20.77| 0.10  | 0.12  |

6 Conclusions

Light pollution lines at the Roque de los Muchachos Observatory (ORM) - La Palma were studied with archive low-resolution spectra taken with DoLoRes at the 3.58m Telescopio Nazionale Galileo during 2003. Our spectra cover the wavelength range \(\sim 3800 \div 8000\) Å, and have resolution of 2.8Å/pix and 3.6Å/pix (slit width 1.0" and 1.3" respectively). Only deep exposures taken with airmass < 1.3 during photometric, moonless nights with low extinction were selected, resulting in six deep spectra which span a wide range in azimuth, epoch and observing conditions. We showed in Sect.4.1 how the detection of Na\(5683\)–8 permits the artificial and the natural contributions to the NaD\(5892\)–8 line to be disentangled. The average intensity of the NaD\(5892\)–8 line emitted by LPS lamps increased by a factor of 1.5 – 2 over the last 5 years on La Palma and its contribution to the sky background is 0.05 – 0.10mag at V-band and 0.07 – 0.12mag at R-band, depending on the region of sky and the time when observations are made. The IAU’s recommendation that NaD\(5892\)–8 emission should not exceed in intensity the natural background, is definitely no longer met in La Palma. Sodium lines such as Na\(5683\)–8 and Na\(6154\)–61 were also detected in our spectra for the first time. Light pollution from mercury lamps is \(\sim 50\%\) lower than in 1998, except when observations are made looking toward the towns, before midnight; in this case we found very similar levels. Our spectra also show the Hg\(4046\) and, in two cases, the Hg\(5769\) and Hg\(5790\) lines, never detected before at ORM. Though in non-optimal atmospheric conditions, we detected in Group3 one strong line which was identified as Scandium (ScI). This element is used as an additive in high-pressure metal halide lamps which, to our knowledge, are only used in the soccer stadiums.
on La Palma. The presence of this type of lamp on La Palma is confirmed by another line at 5351.1Å detected in the Group4 spectrum which can also be identified as ScI emission. Synthetic sky brightness measures were derived from our spectra at V, B and R bands (see Section 5). Our values are in good agreement with those of BE98 if we take into account that our observations were done at 2003, about seven years after the last sunspot minimum (sky is $\sim 0.4$mag darker at solar minimum).

7 Acknowledgments

The author is particularly grateful to Dr. Javier Francisco Diaz Castro, of the O.T.P.C. (Oficina tecnica para la Proteccion del Cielo-IAC) for providing updated data of the outdoor lighting of La Palma and for useful hints for the manuscript. The author is also grateful to Dr. Chris Benn (Isaac Newton Group-La Palma) and Dr. William Cochran (McDonald Observatory) for their helpful suggestions and discussions. Based on observations made with the Italian Telescopio Nazionale Galileo (TNG) operated on the island of La Palma by the Centro Galileo Galilei of the INAF (Istituto Nazionale di Astrofisica) at the Spanish Observatorio del Roque de los Muchachos of the Instituto de Astrofisica de Canarias.

References

[1] Benn, C.R., Ellison, S.L. 1998, La Palma Technical Note, 115
[2] Garstang, R.H. 1989, PASP, 101, 306 (1989PASP.101.306G)
[3] Massey, P., Gronwall, C., Pilachowsky, C.A. 1990, PASP 102, 1046 (1990PASP.102.1046M)
[4] Massey, P., Foltz, C.B., 2000, PASP 112, 566 (2000PASP.112.566M)
[5] McNally, D. 1994 ed., "The Vanishing Universe - Adverse Environmental Impacts on Astronomy", Cambridge University Press.
[6] Munoz-Tunon, C., Vernin, J., Varela, A.M. 1997, A&AS, 125, 183 (1997A&AS.125.183M)
[7] Schubert, G., Waltersheid, R.L., 2000, in Allen’s Astrophysical Quantities, ed. A.N. Cox (New York: AIP Press; Springer), 4th edition.
[8] Slanger, T.G., Cosby, P.C., Osterbrock, D.E. et al. 2003, PASP, 115, 869 (2003PASP.115.869S)
Fig. 1. The night-sky spectra (see Table 3). The Group1 (4hrs total exposure) is the average of 8 spectra and best represents the average observing conditions at ORM; The Group2 spectrum was taken towards the NW, the least light-polluted zone at ORM. The Group3 spectrum was taken towards the most light-polluted region of sky at ORM, before midnight. The presence of thin clouds could explain the abnormally high fluxes of the light polluting lines (see Sect.4.1).
Fig. 2. The night-sky spectra (see Table 3). The Group4 spectrum was taken toward a moderately polluted region (see Table 1) before midnight; The Group5 spectrum was taken toward the meridian before midnight; The Group6 spectrum was taken toward the meridian after midnight.