**Journal of Information Systems Engineering and Management**
2025, 10(50s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

**Research Article**

# The Effect of the Total Energy of the Stars and the Presence of the Moon Above the Horizon on the Onset of True Dusk and True Dawn

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**ARTICLE INFO**

Received: 28 Dec 2024

Revised: 18 Feb 2025

Accepted: 26 Feb 2025

**ABSTRACT**

This study is concerned with determining the altitude of the sun under the horizon to the morning and the evening of the night sky including the true dawn and dusk in cases moonless and moon light conditions. True dusk and dawn appear only after the total energy of the stars appears or disappears as an inevitable result of twilight light. The measured of the night sky are done for four months (from May to August, 2018) in Malaysia (3.82° N, and 100.8° E). The Sky Quality Meter (SQM) was used to measure the brightness of the night sky. The measurements were taken when the device was directed to the zenith position during the entire monitoring period. The two methods that calculate the threshold for eye visibility are M and M1 in the case of the cloudless conditions. The determination of true dusk and true dawn is based on the concept of the onset of the eye's visual threshold of magnitude (m, mag/arcsec2) as M= Δm = 1.3m (which is the absence or appearance of the total energy of the stars relative to the celestial background), M1 =NELM=6m and the relationship to the sun vertical depression of Do (degree). At the Moonless, the depression of true dusk ranges as 11.2° ≤ Do ≤14.8°, while Do of the true dawn ranges as 12.2˚ ≤ Do ≤14.5˚. In case the full moon, the beginning of distinguishing dusk and dawn light from moonlight is Do ≈ 9.5˚ at 17.3m. The mean values of the light minimum of a full-moon-case, for morning and evening twilight is Do ≈12.5˚ at 17.9m and elongation ≈171˚. The average light level magnitude throughout the night is 20.61m (scotopic vision) and is at Do ≈15˚ in the beginning of night (or ends).

**Keywords:** Zenith direction, evening and morning twilight magnitude, sun vertical depression, moon phase, total energy of stares and SQM.

## I.INTRODUCTION

Zenith sky brightness was in the range $15^m$-$19.25^m$, as a general approximation one can take 21.83m as representative of a truly dark sky, though at a pristine site there may be regions of the sky that are darker than this (Garstang 1989 and Duriscoe 2013). Human vision at normal light levels is photopic, utilizing the trichromatic cone cells whose density is greatest in the foveal region of the retina. In very low light levels vision is scotopic, utilizing the monochromatic rod cells whose density is greatest outside the fovea. There was formerly thought to be an abrupt switch between the two types of vision, though in fact there is a continuous transition at intermediate (mesopic) light levels as cone response lessens and rods become active. Hence it is misleading to speak of `day' and `night' vision. The transition is dependent on the particular visual task and prevailing conditions so cannot be species exactly, but as a working dentition one can take the range of mesopic vision as 0.005 to 5 cd $m^{-2}$ (CIE 2010), i.e., scotopic vision operates in conditions darker than about $18.3^m$.

For astronomical purposes, Puschnig et al (2014) estimated the limit as $18.9^m$. Vision has channels for luminance and chromaticity; contrast can be denned with respect to either, but in scotopic vision only the luminance channel operates. If an observer is able to detect color, then this indicates cone activity, so nocturnal astronomical observation often involves mesopic rather than scotopic vision. Variable star observers generally restrict magnitude estimates to stars at least two magnitudes ($2^m$) brighter than threshold, using direct rather than averted vision, which gives more

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e-ISSN: 2468-4376
https://www.jisem-journal.com/
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reliable estimates since it minimizes rod contribution (Hallett 1998). Schaefer (1996) found from a survey of experienced observers that in telescopic stellar viewing, scotopic vision operates at no more than about one magnitude above threshold. Mesopic photometry would be important for a proper treatment of supra-threshold magnitude estimates or visibility under severe light pollution (including twilight). However, this article is concerned with threshold rather than brightness perception; and although the model will cover achromatic vision across the entire luminance range, the astronomical applications will be restricted to scotopic vision, i.e., targets within about one magnitude of threshold against a background no brighter than about $18.9^m$, to which the observer is assumed fully adapted. The International Dark-Sky association (IDSA 2013) currently recognizes three classes of dark sky: Bronze (SQ$20^m$– $20.99^m$), Silver (SQ $21^m$– $21.74^m$) and Gold (SQ≥$21.75^m$).

When the sun is below the horizon; the sky is illuminated affected by two original sources of light; **Twilight** and **Moonlight** (except the polar region) Ephemeris (1961, pp 400) and Rozenberg (1966). At the times given for astronomical twilight the geocentric zenith distance of the sun is $D_o$ =18°, and the indirect illumination from the sun is approximately equal to that of the night sky.

**(a) Twilight;** it is caused by the scattering of sunlight from the upper layers of the Earth's atmosphere. It begins at sunset (ends at sunrise) and is conventionally taken to end (or begin) when the sun reaches a sun vertical depression of $D_o$ =18°. The variation of the illumination on a horizontal surface, in clear conditions, is shown diagrammatically as a function of the Sun vertical depression $D_o$ (- altitude of the sun); the rapid flattening of the curve from $D_o$ =15° onwards, after an almost linear relationship from $D_o$ =0° to 15°, is noteworthy. At $D_o$ =18°, astronomical twilight, the indirect illumination from the sun on a horizontal surface, is about 6 x $10^{-5}$ foot-candela ($21.803^m$), rather less than the contribution from star light and of the same order as that from the aurora, air glow, and zodiacal light. The actual brightness of the sky depends on direction, as well as on meteorological conditions. In navigational practice, and for some astronomical applications, two intermediate steps in the twilight period are recognized and tabulated: civil twilight ends (or begins) when the sun reaches a Do = 6°; and nautical twilight ends (or begins) when the sun reaches $D_o$ = 12°. The degree of illumination at the beginning and end of civil twilight (in good conditions and in the absence of other illumination) is usually described for navigational purposes as such that the brightest stars are visible and the sea horizon is clearly defined; for the beginning and end of nautical twilight the corresponding statement is that the sea horizon is in general not visible and it is too dark for the observation of altitudes with reference to the horizon. The total illumination from the stars contributes about 2 x $10^{-4}$ foot-candela ($20.496^m$), rather more than the sun at the beginning and end of astronomical twilight.

**(b) Moonlight;** the illumination (%) received from the Moon varies according to phase, altitude, and atmospheric extinction. From a full moon in the zenith (see table 1) the intensity of illumination on a horizontal surface is approximately 0'02 foot-candela ($15.49^m$), which equivalent $D_o$ = 8°. After full moon the illumination falls off rapidly, mean values from several observers (Russell et al., 1926) being as follows:

**Table 1: The elongation (degree) and illumination (%) received from full moon varies in the zenith direction according to phase.**

| **Elongation (degree)** | 180 | 160 | 140 | 120 | 100 | 80 | 60 | 40 | 20 |
|---|---|---|---|---|---|---|---|---|---|
| **Illumination %** | 100 | 65 | 41 | 26 | 15 | 7.5 | 3.2 | 1.0 | 0.1 |

The waxing moon, shortly after first quarter, is some 20% brighter than the waning moon at the corresponding phase. The half-moon gives only one ninth as much light as the full moon. For astronomical observations the position of the moon in the sky, rather than the general illumination, is the most important factor.

The lunar phase had no consistent effect on down welling irradiance until solar elevation was less than $D_o$ = 8°. For lower solar elevations, the effect of the moon increased with the fraction of the illuminated lunar disk until the fraction was approximately 50%. For fractions greater than 50%, the brightness and chromaticity of the down welling irradiance were approximately independent of the fraction illuminated, likely because the greater brightness of a fuller moon was offset by its lower elevation during twilight. This data set, while relatively small, leads to several

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e-ISSN: 2468-4376
https://www.jisem-journal.com/
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conclusions. First, the moon has little effect on either the brightness or the color of down welling irradiance during civil twilight and early nautical twilight (Glenn Palmer and Sönke Johnsen, 2015).

Patat et al. (2006) studied the brightness of the *UBVRI* aurora at Dome C (Kenyon and Storey (2006)) and found that the brightness level of the night sky is reached when the sun is below the horizon in the range $15^\circ \leq D_o \leq 16^\circ$. While the rate of the total spectrum got converted from the positive to negative signs at solar altitude of $D_o = 14.8^\circ$.

Abdel-Hadi and Hassan (2022) studied the evening and morning twilight by the Sky Quality Meter (SQM) at five regions in Malaysia to measure the brightness at night, pseudo and true (for dawn and dusk). The measurements were taken when the device was directed to the position of the east (for morning) and west (for evening) direction toward at the horizontal angle of the sunrise and sunset at five degrees above the horizon during the entire monitoring period. The sun vertical depressions $D_o$ for the true dusk was found to be $D_o = 14.38^\circ \pm 0.91$ and for the beginning of the true dawn it was found to be $D_o = 14.19^\circ \pm 0.52$ (for high confidence $D_o = 14.71^\circ$) The light magnitude of the full night after the pseudo dusk was found to be $20.77^m \pm 0.93$ (scotopic vision), while it was found to be $22.17^m \pm 0.1$ (scotopic vision) before the pseudo dawn. The difference in the light magnitude of the zodiacal light for the pseudo dusk is about one magnitude and for the pseudo dawn is $0.83^m$, the thickness of the false dawn is $\Delta m = 2.34^m$ ($22.53^m$-$20.19^m$) which is equivalent to $\Delta m = m_A - m_B = 2.512^{2.34} = 8.632\%$.

Harry Ramza et al. (2021) studied the evening and morning twilight at five countries; the observation data (465 day) are collected for the dawn and dusk in Indonesia, Malaysia, USA, Egypt, and Turkey. The comprehensive summary of ISRN's research concludes that the average value of the presence of the true dawn is at $D_o = 13.4^o$ and for the true dusk is at $D_o = 13^o$. The main instrument used is a SQM that records the sky brightness data. For quality assurance, ISRN-UHAMKA employed dozens of imaging sensors ranging from an All-Sky Camera, different types of DSLR, and gadget cameras. Naked eye limiting magnitude (NELM), quite often astronomers will refer to a sky by the darkest star they can see, for example a "$6^m$ magnitude sky", in that case you can see $6^m$ magnitude stars and nothing dimmer like $7^m$ magnitude stars. The term "$6^m$ magnitude skies" is very subjective to a person's ability to see in the night, for example an older person might say "$5^m$ magnitude skies" but a young child with better night vision might say "$7^m$ magnitude skies", Bortle (2011).

Ramy Mawad (2024), derive an equation to calculate the height of the lower atmosphere using ground-based observations of morning twilight from the eastbound camera in Aswan, Egypt. It was found that true dawn occurs at a depression of $D_o = 14.9° \pm 0.17$, which is accompanied by a mean angular height of the twilight, is at $2.66° \pm 0.23$. The height of the twilight is estimated to be $303.80 \pm 5.69$ km above sea level.

Table 2 summarizes the important previous published works (22 researches); it represents ten countries distributed over most latitudes and longitudes on the Earth surface, which included the countries; Egypt, Libya, SKA, Yemen, USA, Indonesia, Malaysia and Turkey for determined the sun vertical depressions of $D_o$ (degree) and authors and (Taking into account the chronology). Note that all of these observations were horizontal towards the east in the case of dawn and towards the west in the case of dusk.

Observing tools to determine the illumination of the night sky brightness, which includes true dawn and true dusk are; naked eye (*N.E*), photoelectric (*P. E.*), cameras and SQM through the interval years of 1909– 2022. The final almost results of the $D_o$ (degree) are ranging from $D_o = 13.5^\circ$ (in the sea and agriculture background) and $D_o = 14.7^\circ$ (in the desert background), since it depends mainly on the transparency of the atmospheric conditions, see Rashed et al. (2022). Note that the absolute values without the standard deviation mean that these values are added to the standard deviation (SD) as the highest degree of confidence (mean +1SD).

This research aims to answer two essential questions;

1- To which degree does the sun's vertical dip below the horizon occurs when twilight light overwhelms the total energy of the stars.
2- What is the effect of the presence of the moon in its various phases, especially in case the moonless and the full moon, on the stages of twilight, especially true dusk and true dawn.

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**Table 2: The photoelectric, camera instruments and naked eye (N.E.) for true dawn and true dusk using SQM observation, reported by the most important research that reviews the sun vertical depression ($D_o$, degree)**

| Place | $D_o$ (degree) True dawn | $D_o$ (degree) True dusk | Authors |
|---|---|---|---|
| Aswan, Egypt | 14.25 | 14.9 | Miethe and Lehmann, (1909) |
| Sana'a, Yemen | 12° | 15 | Sultan, (2004) |
| Riyadh, SKA | 14.6±0.3 | | Al Mostafa et al. (2005) |
| Hail, SKA | 14.66 | | Khalifa, et al. (2018) |
| Depok, Indonesia | 14±0.6 | | Saksonoa and Fulazzaky, (2020) |
| Tubruq, Libya (2 Research) | 13.5-14.7 | | Hassan, et al.(2015) and (2021) |
| Indonesia, Malaysia, USA, Egypt and Turkey | 13.4 | 13 | Harry Ramza et al. (2021) |
| Egypt, 12 Research (2008-2022) | 13.5-14.7 | | Rashed et al. (2022) |
| Malaysia (4 locations) | 14.71 | 14.38± 0.91 | Abdel-Hadi and Hassan, (2022) |
| Egypt (6 regions) | 14-14.8 | | Marzouk et al. 2024 |
| Aswan, Egypt | 14.9 ± 0.17 | | Ramy Mawad (2024) |

## II.SITE OBSERVATION AND METHODOLOGY

The measurements were taken in Malaysia near the city of Sabak (3.82°N, 100.8°E, 8.3m Elev.) were used, and the observation period was 95 days from 4 May to 7 August 2018 by Sky Quality Meter (SQM)-LE.

The device was zenith toward and recorded every one minute. The calculations of the coordinates of the sun and the moon were done using our programs (Hassan, et al., 2013, 2014, 2016 and we reviewed them by moonc6 (http://www.Monzur@starlight.demon.co.uk). The two methods for determining the true onset of both true dusk and true dawn rely on the eye's visual threshold magnitudes M and M1 to distinguish twilight light from the celestial background. For all measurements, the cloudless nights were selected. The identification codes used in this article are:

- NSB (m, mag/arcsec$^2$); night sky brightness measurements in moonless conditions.
- NSB1 (m, mag/arcsec$^2$); night sky brightness measurements in full moon conditions.
- M= $\Delta m = 1.31^m$ (m, mag/arcsec$^2$), it is the first method to determine the optical threshold for the onset of true twilight (true dusk or true dawn), which represents the total energy of stars appearing in the evening or disappearing in the morning relative to the celestial background (Russell et al., (1926), Ephemeris (1961) and Leinert, C. et al., (1997).
- M1 (m, mag/arcsec$^2$) = NELM, the second way to determine the optical threshold for the onset of true twilight (true dusk or true dawn) and it is expressed as;
- NELM (mag/arcsec$^2$) = $7.93 - 5 \log (10^{(4.316 - (m/5))} + 1)$, m=NSB (1)

To convert units we used, Andreas (2017), Nawar (2020), John C. Barentine (2022) and SQM-LE, Operator's Manual, Version: 20180128, as;

- Foot-candela=10.764 Lux, cd/m$^2$ =Lux/π and foot-candela=3.42 cd/m$^2$
- m (mag/arcsec$^2$) = 12.583559399 -2.5 Log (cd/m$^2$) (2)
- $m_A$= night sky brightness is 6 x $10^{-5}$ foot-candela = $21.803^m$,
- $m_B$= total energy of stars is 2 x $10^{-4}$ foot-candela = $20.496^m$

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- $\Delta m = m_A - m_B = 1.31^m = 2.512^{1.31} = 3.34\%$

Table 3 shows the moon phase during the observation period from May to Augusts 2018, new moon (NM), first quarter (FQ), full moon (FM), and last quarter (LQ), from; *www.Astropixels.com*"https://aa.usno.navy.mil/data/MoonPhases, and L.M.T= 8+UT, which includes the phases of moonlight in the months in which the observations in this article were taken.

**Table 3 The moon phase during the observation period of the L.M.T (8+UT) at 2018 (April to Augusts 2018).**

| New Moon, NM | | First Quarter, FQ | | Full Moon, FM | | Last Quarter, LQ | |
|---|---|---|---|---|---|---|---|
| Day | Time | Day | Time | Day | Time | Day | Time |
| Apr 16 | 09:57 | Apr 23 | 05:46 | Apr 30 | 08:58 | May 8 | 10:09 |
| May 15 | 19:48 | May 22 | 11:49 | May 29 | 22:20 | Jun 7 | 02:32 |
| Jun 14 | 03:43 | Jun 20 | 18:51 | Jun 28 | 12:53 | Jul 6 | 15:51 |
| Jul 13 | 10:48 | Jul 20 | 03:52 | Jul 28 | 04:21 | Aug 5 | 04:18 |
| Aug 11 | 17:58 | Aug 18 | 15:49 | Aug 26 | 19:56 | Sep 3 | 10:37 |

100% moon illumination ($f$=1) throughout the night is not practically achieved on all nights, the full moon sometimes occurs in the middle of the day, before or after noon. Therefore, it is practically difficult to obtain a uniform distribution of moonlight for all nights unless there is a full moon at exactly midnight. The light distribution is usually in the range of 0.99<$f$<0.98 before or after midnight, making sure that these nights are free of clouds, what concerns us here primarily is the effect of moonlight on seeing the true light of dusk and true dawn, especially in case the full moon.

## III.RESULTS AND DISCUSSION

Figure 1 represents the NSB and NELM (m, mag/arcsec$^2$) at moonless condition from the left to the right of evening (13th May 2018, NM) and morning (14th May 2018, NM) with $D_o$ (degree). For the evening, the $D_o$ ≈11.5° at M=Δm=1.31$^m$ (Relative value of sky background) and $D_o$ =15° at M1=6$^m$ (NELM), while for the morning $D_o$ ≈12° at M and $D_o$ =14.5° at M1. The magnitude level of the full night sky brightness (NSB) from $D_o$ =15° to mid-night and statistical weight of the data in this period exceeds 200 points, the magnitude of the evening (13th May) is 20.77$^m$±0.27 and in the morning (14th May) is 20.5$^m$±0.22.

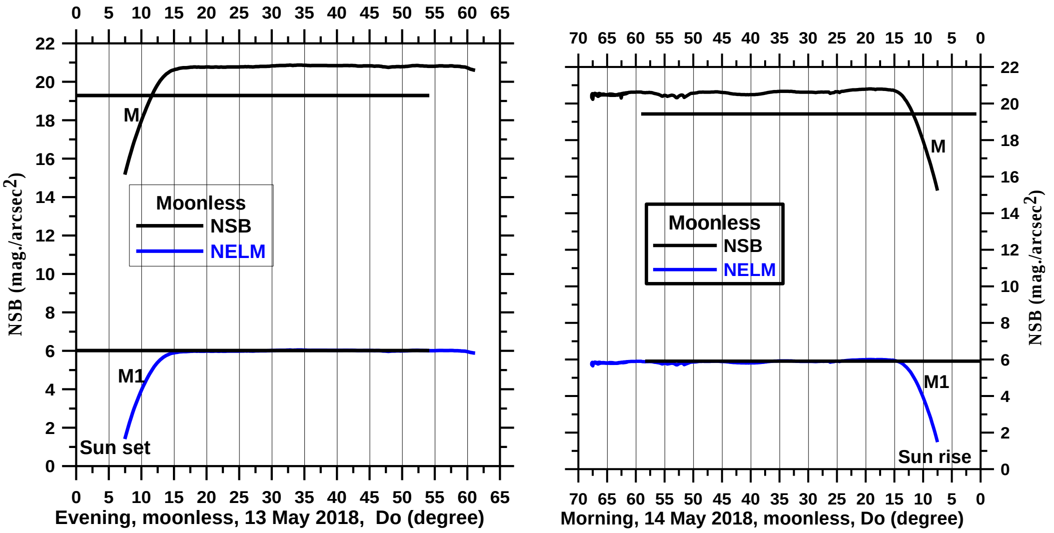


**Fig. 1: The relations of the NSB and NELM (mag/arcsec²) of both M and M1at new moon condition of evening (13th May) and morning (14th May) with $D_o$ (degree).**

**Journal of Information Systems Engineering and Management**
2025, 10(50s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

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Figure 2 represents the NSB and NELM (mag/arcsec²) at moonless condition from the left to the right of evening (10th Jun 2018, NM) and morning (13th Jun 2018, NM) with $D_o$ (degree). For the evening, $D_o \approx 11^\circ$ at $M$=19.23$^m$ and $D_o$ =15˚ at M1=6$^m$, while for the morning $D_o \approx 12.5^\circ$ at $M$ and $D_o$ =14.5˚ at $M1$. The magnitude level of the full night sky brightness (from $D_o$ =15˚ to mid-night), for the evening (13th Jun) is 20.77$^m$±0.27 and in the morning (10th Jun) is 20.5$^m$±0.22.

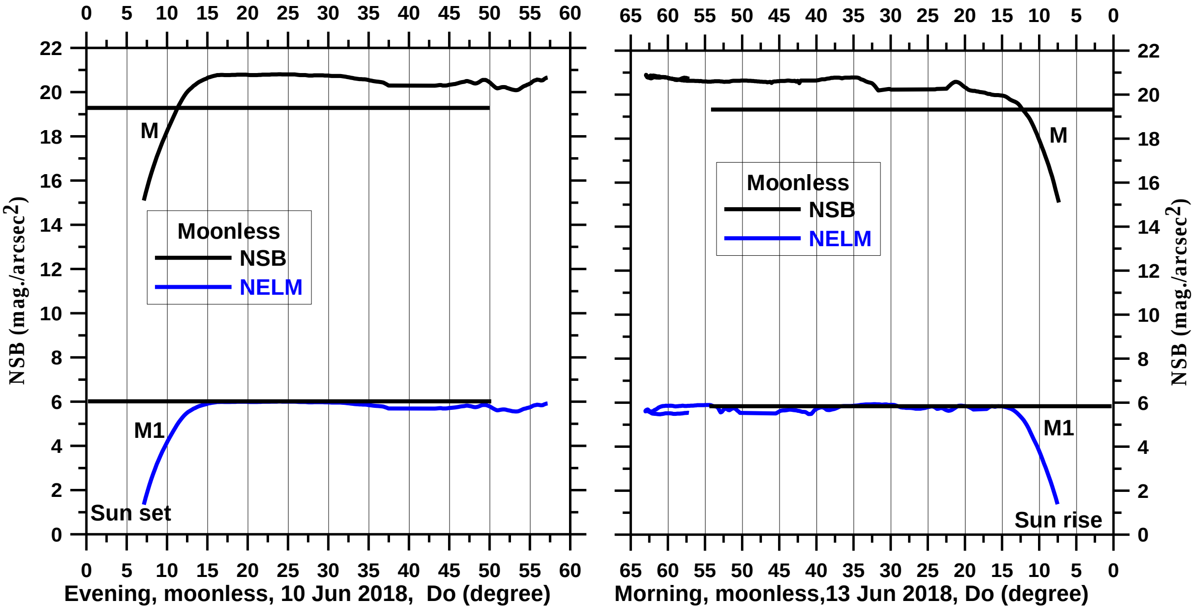


**Fig. 2: The relations of the NSB and NELM (mag/arcsec²) of both the sky brightness at *M* and *M1* for new moon condition of evening (10th June) and in the morning (13th June) with $D_o$ (degree).**

Figure 3 represents the NSB and NELM (mag/arcsec²) at moonless condition from the left to the right of evening (13th Jul 2018, NM) and morning (13th Jul 2018, NM) with $D_o$ (degree). For the evening, $D_o \approx 11^\circ$ at M=19.23$^m$ and $D_o$ =14.8˚ at $M1$=6$^m$, while for the morning $D_o \approx 11.5^\circ$ at $M$ and $D_o$ =14.8˚ at $M1$. The magnitude level of the full night sky brightness (from $D_o$ =15 to mid-night), for the evening (13th Jul) the magnitude is 20.95$^m$±0.11 and for morning (13th Jul) is 20.68$^m$±0.26.

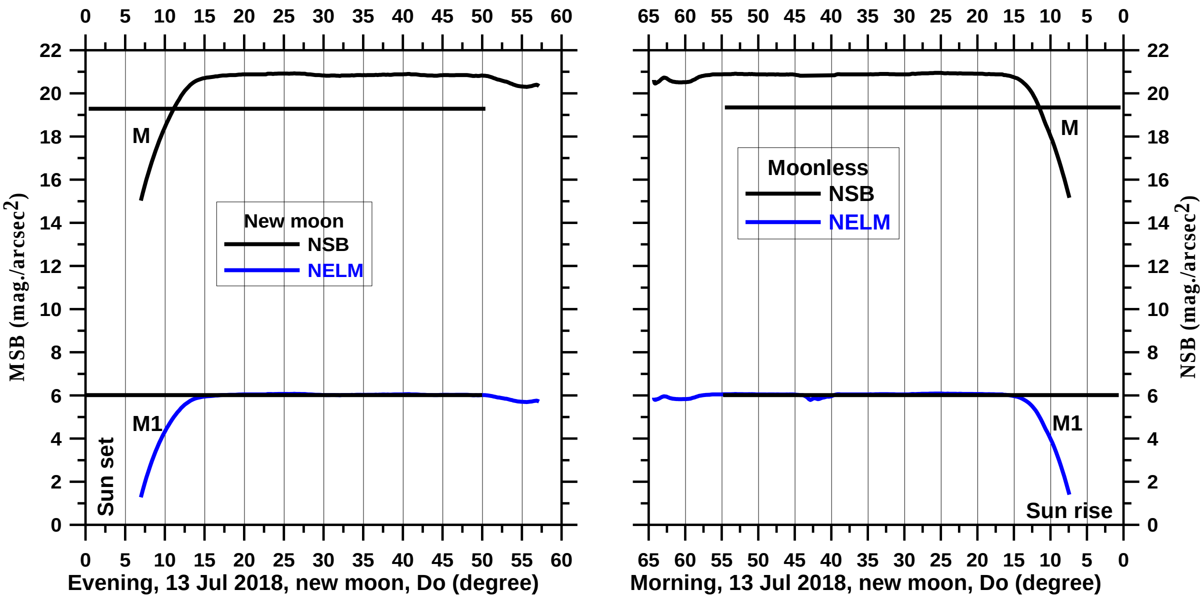


**Fig. 3: The relations of the NSB and NELM (mag/arcsec²) of both the sky brightness *M* and *M1* at new moon condition of evening (13th Jul) and morning (13th Jul) with $D_o$ (degree).**

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2025, 10(50s)
e-ISSN: 2468-4376
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Table 4 summaries the moonless conditions for both NSB and NELM (m, mag/arcsec²) at *M* and *M1* with $D_o$ (degree) for the evening and morning brightness as the results from figures 1-3, which shows the mean values of $D_o$ for the evening is $D_o$ ≈11˚ at *M* and at *M1* is $D_o$ =14.8˚. While for the morning, the mean values of $D_o$ is $D_o$ ≈12˚ at M and at *M1* is $D_o$ = 14.5˚. The mean values of NSB for the evening is $20.74^m$±0.22, for morning is at $20.49^m$±0.20, on average of the whole night for morning and evening is $20.61^m$ at $D_o$ ≈15˚ (as the mean values magnitude from the rang $D_o$ =15˚ to mid night), This means that the morning night is brighter than the evening night by $0.25^m$ or 1.26%. The average values of NSB for the total night (mean of evening and morning) is $20.6^m$.

Therefore, based on the concept of the onset of the eye's visual magnitude of threshold for both M and M1 and that the measurements were taken when the device was zenith toward, the $D_o$ for true dusk is ranging between 11.2˚≤ $D_o$ ≤14.8˚, while the true dawn is ranging between 12.2˚ ≤ $D_o$ ≤14.5˚.

To compared these results with the previous research on 19th Dec., 2019 in Fayum (Egypt), where the observations were taken for the true dawn by two SQM, one in the zenith state and the other in the horizontal direction to the east. We find that the intersection of the vertical and horizontal curves occurred at $D_o$ =12˚ and the difference between them in light magnitude was $1.83^m$ (figure 8, Rashed et al. 2022). The true dawn at this morning was $D_o$ =14˚ eastward directions, based on considering the threshold of eye is $0.83^m$ of the celestial background, which was taken from Abdel-Hadi and Hassan, 2022 (Malaysia, 4 locations). Therefore, the $D_o$ =14.5˚ by NELM method is suitable for both vertical and horizontal cases.

**Table 4: The moonless NSB and NELM (m, mag/arcsec²) for $D_o$ (degree) at M and M1 concept for the evening and morning periods, from figures 3.**

| Fig's | Evening (2018) | | | Morning (2018) | | |
|---|---|---|---|---|---|---|
| | $D_o$˚ (at M) | NSB, m | $D_o$˚ (at M1) | $D_o$˚ (at M) | NSB, m | $D_o$˚ (at M1) |
| Fig.1 | 11.5˚ | $20.77^m$±0.27 | 14.8˚ | 12˚ | $20.5^m$±0.22 | 14.5˚ |
| Fig.2 | 11˚ | $20.51^m$±0.24 | 14.8˚ | 12.5˚ | $20.28^m$±0.27 | 14.5˚ |
| Fig.3 | 11˚ | $20.95^m$±0.11 | 14.8˚ | 12˚ | $20.68^m$±0.26 | 14.7˚ |
| mean | ≈11.2˚ | $20.74^m$±0.22 | 14.8˚ | ≈12.2˚ | $20.49^m$±0.20 | ≈14.5˚ |

Figure 4 represents the night sky brightness at full moon condition (NSB1, m, mag/arcsec²) from the left to the right of evening (28th May 2018), morning (29th May 2018) and the moon altitude (Ma, degree) with $D_o$ (degree). For the evening twilight, the inflection point is $D_o$ = 12˚ at $17.5^m$. And for the morning twilight, the inflection point is $D_o$ = 13˚ at $18.85^m$.

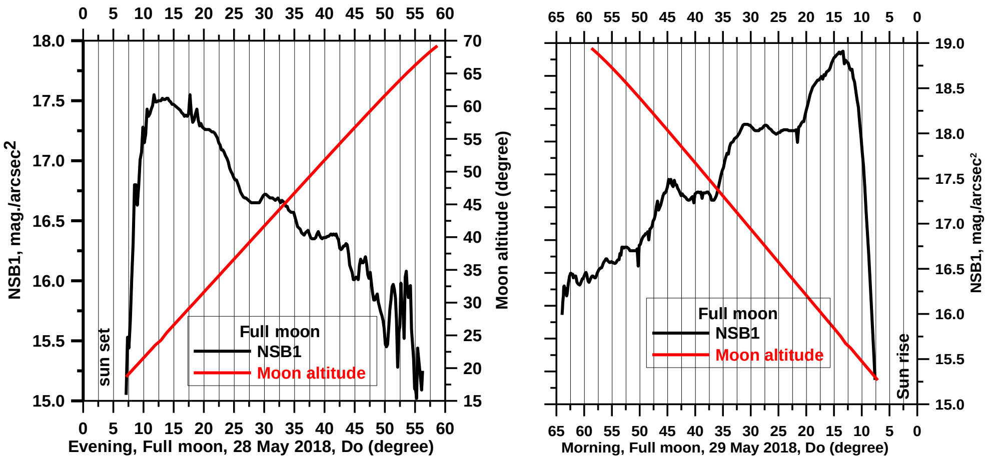


**Fig. 4: The relations of night sky brightness (mag/arcsec²) at full moon condition of evening (28th May), morning (29th May) and the moon altitude with $D_o$ (degree).**

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e-ISSN: 2468-4376
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Figure 5 represents the relations of NSB1 (m, mag/arcsec²) at full moon condition from the left to the right of evening (27th Jun 2018), morning (28th Jun 2018) and the moon altitude (Ma, degree) with $D_o$ (degree). For the evening twilight, the inflection point is $D_o$ = 12° at $17.8^m$ and for the morning twilight, the inflection point is $D_o$ = 12.5° at $18.7^m$.

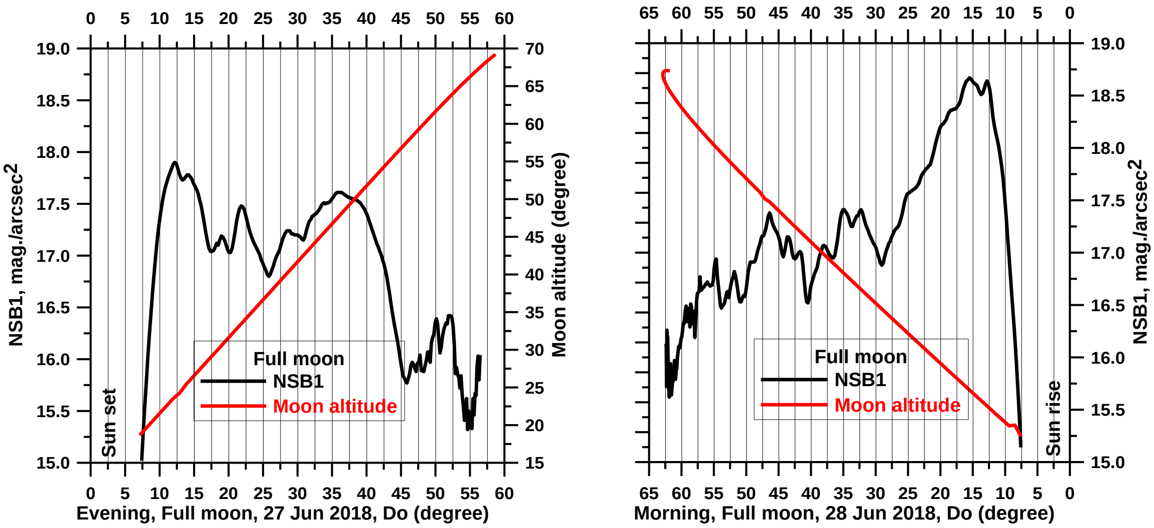


**Fig. 5: The NSB1 (mag/arcsec²) at full moon condition of evening (27th Jun), morning (28th Jun) and the moon altitude with $D_o$ (degree).**

Figure 6 represents the NSB1 (mag/arcsec²) at full moon condition from the left to the right of evening (27th Jul 2018), morning (29th Jul 2018) and the altitude of the moon (Ma, degree) with $D_o$ (degree). For the evening twilight, the inflection point is $D_o$ = 13.5° at $17.9^m$ and for the morning twilight, the inflection point is $D_o$ = 12° at $17.5^m$.

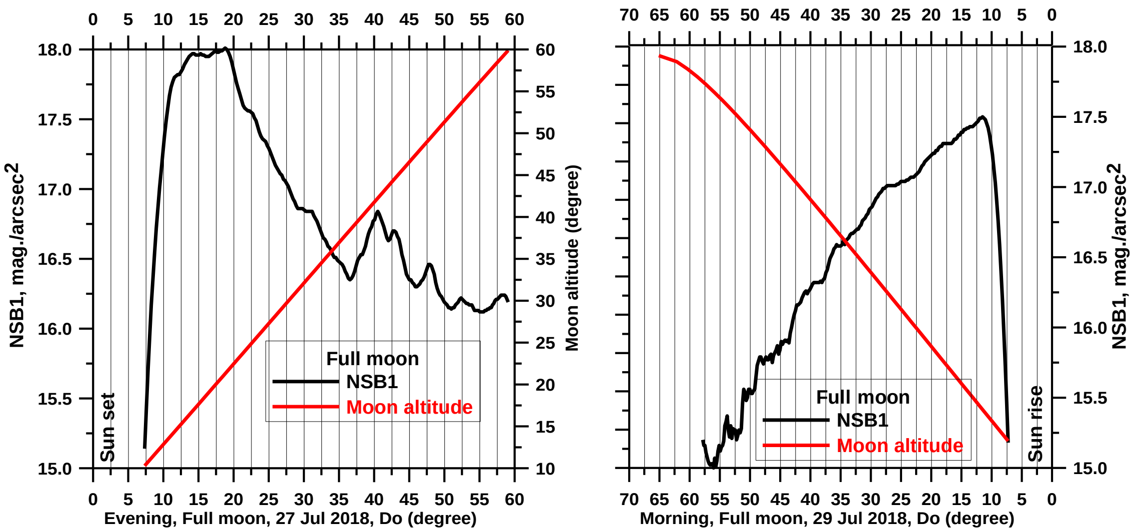


**Fig. 6: The NSB1 (mag/arcsec²) at full moon condition of evening (27th Jul), morning (29th Jul) and the moon altitude (degree) with $D_o$ (degree).**

Table 5 summarizing values of NSB1 (m, mag/arcsec²) and the moon characteristics at $D_o$ (degree) values with the coordinate of the moon (Ma, Maz and elongation (Elong.)) from figures 4-6. For the evening twilight, the mean of inflection point is $D_o$ = 12.5° at $17.7^m$ and the coordinate of the moon are; Ma=19.2°, Maz=110.7°, Elong. = 172.4°. For the morning twilight, the mean of inflection point is $D_o$ = 12.5° at $18.35^m$ and the coordinate of the moon are; Ma=12.8°, Maz=250.6°, Elong. = 171.5°. The mean values of the minimum of light on a full moon ($0.99 \leq f \leq 0.98$) cases for morning and evening twilight is around $D_o$ =12.5° at $17.9^m$.

**Journal of Information Systems Engineering and Management**
2025, 10(50s)
e-ISSN: 2468-4376
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**Table 5: The moonless NSB and NELM (m, mag/arcsec²) for $D_o$ (degree) at M and M1 concept for the evening and morning periods, from figures 3.**

| Figure | Evening, NSB1 | | | Morning, NSB1 | | |
|---|---|---|---|---|---|---|
| | Date | $D_o$° at mag/arcsec² | Ma, Maz, Elong. Degree | Date | $D_o$° at mag/arcsec² | Ma, Maz, Elong. Degree |
| **Fig.4** | 28th May | 12°at 17.5$^m$ | 23.5°, 107.5°, 167.4 ° | 29th May | 13° at18.85$^m$ | 6.34°, 253.8°, 170.4° |
| **Fig.5** | 27th Jun | 12° at17.8$^m$ | 19.27°, 113.1°, 172.6° | 28th Jun | 12.5° at 18.7$^m$ | 9.15°, 248.3°, 175.2° |
| **Fig.6** | 27th Jul | 13.5° at 17.9$^m$ | 14.81°, 111.5°, 177.2° | 29th Jul | 12° at 17.5$^m$ | 23.1°, 249.9°, 169° |
| **mean** | | 12.5° at 17.7$^m$ | 19.2°, 110.7°, 172.4° | | 12.5° at 18.35$^m$ | 12.8°, 250.6°, 171.53° |

Figure 7 represents the NSB and NSB1 (mag/arcsec²) of evening at moonless (13th May 2018), full moon (28th May 2018) and for morning moonless (14th May 2018), and full moon (29th May 2018) with $D_o$ (degree). For the evening twilight, the point of divergence between the two curves (moonless and full moon) is $D_o$ = 9° at 17$^m$. For the morning twilight, the point of divergence between the two curves is $D_o$ = 10.5° at 18.2$^m$.

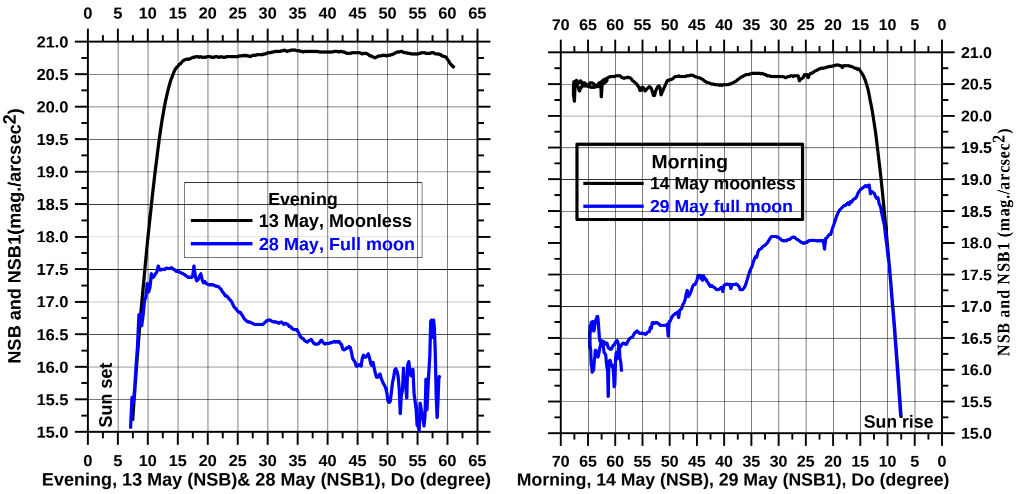


**Fig. 7: The night sky brightness of NSB and NSB1 (mag/arcsec2) in the evening when the moonless sky (13th May) and full moon conditions (28th May), and in the morning (moonless, 14th May and full moon, 29th May) with $D_o$ (degrees).**

Figure 8 represents the NSB and NSB1 (mag/arcsec²) of evening at moonless and full moon (14th Jun 2018, 27th Jun 2018) and for morning at moonless and full moon (14th Jun 2018, 28th Jun 2018) with Do (degree). For the evening twilight, the point of divergence between the two curves (moonless and full moon) is $D_o$ = 9° at 17$^m$. For the morning twilight, the point of the divergence between the two curves is $D_o$ = 11° at 18$^m$.

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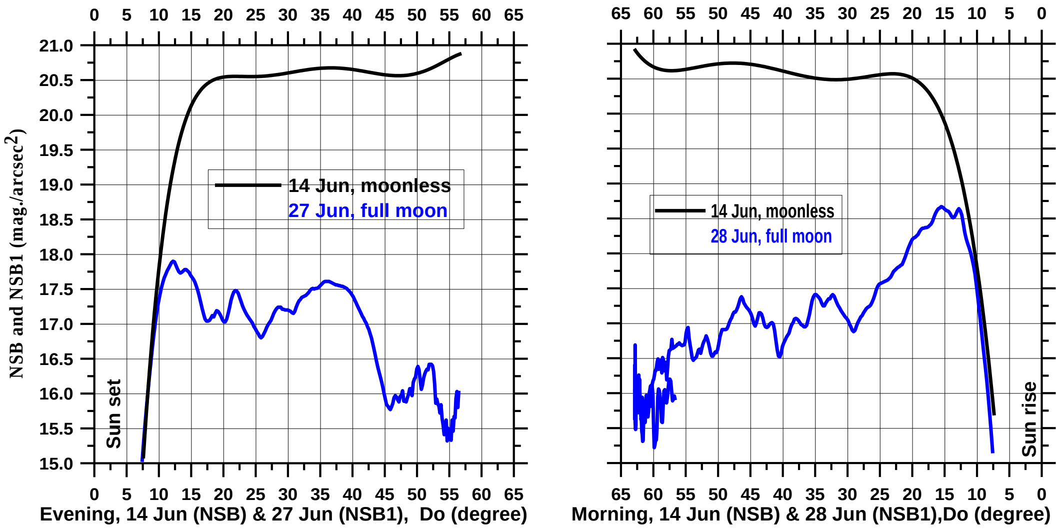


**Fig. 8: The NSB and NSB1 (mag/arcsec²) of evening at moonless and full moon at 14th Jun, 27th Jun and for the morning of moonless and full moon at 14th Jun, 28th Jun with $D_o$ (degree).**

Figure 9 represents the NSB and NSB1 (mag/arcsec²) of evening for moonless and full moon at 13th Jul, 27th Jul 2018 and of morning for moonless and full moon at 13th Jul, 29th Jul 2018 with $D_o$ (degree). For the evening twilight, the point of divergence (moonless and full moon) between the two curves is $D_o$ = 8° at 16.5$^m$. For the morning twilight, the point of divergence between the two curves is $D_o$ = 9° at 17.2$^m$.

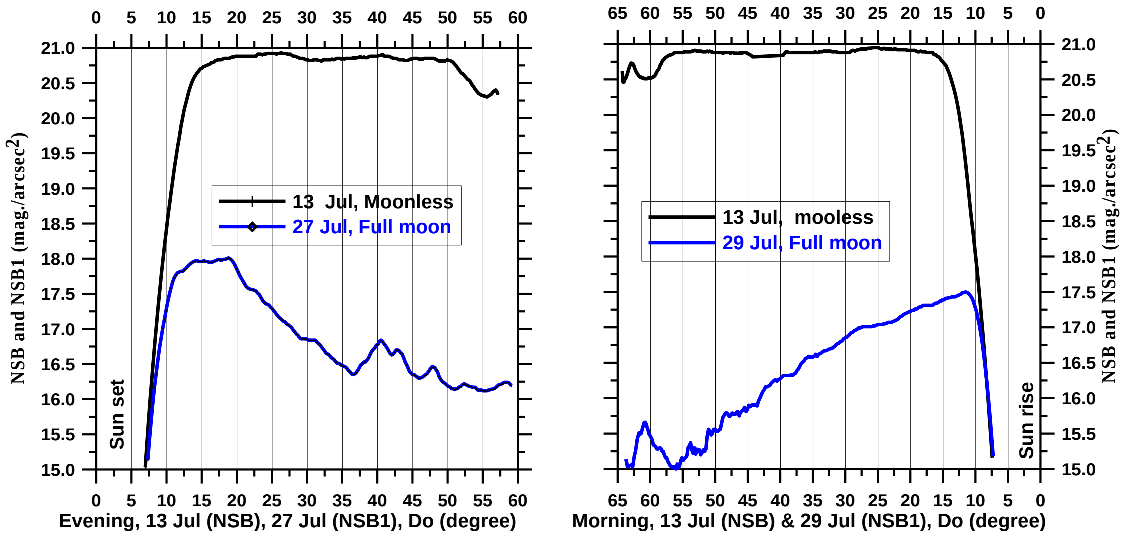


**Fig. 9: The NSB and NSB1 (mag/arcsec²) of evening (moonless of 13th Jul and full moon of 27th Jul 2018) and morning (moonless at 13th Jul and full moon at 29th Jul 2018) with $D_o$ (degree).**

Table 6 summarizes the evening and morning (2018) results for the intersection of two curves, NSB and NSB1 (m, mag/arcsec²) at $D_o$ values and the degree of lunar coordinates (Ma, Maz and elongation, Elong.) from figures 7-9. For the evening twilight, the mean values of the divergence point between the two curves at full moon are; $D_o \approx 8.7°$ at 17$^m$, Ma≈16°, Maz≈110°, Elong.≈170°. While these values for the morning twilight are $D_o \approx 10.3°$ at 17.7$^m$, Ma≈10.7°, Maz≈251°, Elong.≈171.5°. Therefore, when the SQM is in the zenith direction and in case of a full moon, the beginning of distinguishing dusk and dawn light from moonlight is $D_o \approx 9.5°$ at 17.3$^m$ ($D_o$ =8° at 14.23$^m$ at horizontal service, Russell (1926)).

**Table 6: Results of the evening and morning (2018) of moonless and full moon conditions for the NSB and NSB1 (m, mag/arcsec²) at $D_o$° values* and the degree of the moon coordinate, Ma, Maz and Elong.**

| Fig. | Evening (2018), NSB and NSB1 | | | Morning (2018), NSB and NSB1 | | |
|---|---|---|---|---|---|---|
| | Date of Moonless, Full moon (FM) | FM, $D_o$° at mag/arcsec² | Ma, Maz, Elong., degree | Date of Moonless, Full moon (FM) | FM, $D_o$° at mag/arcsec² | Ma, Maz, Elong., degree |
| **Fig.7** | $13^{th}$ ,$28^{th}$ May | 9° at $17^m$ | 20.5°, 106.8°, 167.3° | $14^{th}$ ,$29^{th}$ May | 11° at $18^m$ | 4.5°, 254°, 170.4° |
| **Fig.8** | $14^{th}$ ,$27^{th}$ Jun | 9° at $17.5^m$ | 16.4°, 112.5°, 164.7° | $14^{th}$ ,$28^{th}$ Jun | 11° at $18^m$ | 7.6°, 248.5°, 175.3° |
| **Fig.9** | $13^{th}$ ,$27^{th}$ Jul | 8° at $16.5^m$ | 10.9°, 110.8° , 177° | $13^{th}$ ,$29^{th}$ Jul | 9° at $17.2^m$ | 20°, 250.6° , 168.9° |
| **mean** | | 8.7° at $17^m$ | 15.9°, 110°, 169.6° | | 10.3° at $17.7^m$ | 10.7°, 251°, 171.5° |

***As the point of divergence between the two curves**

## IV.FUTURE WORK

We need to increase the number of observation nights in the event of a full moon for consecutive months to know the effect of the presence of the moon in distinguishing the beginning of true dusk and true dawn in a desert area where the percentage of clouds is almost non-existent, in order to confirm or modify the results we obtain. The focus should be mainly on the time period from $D_o$ =6° to 15°, which the most important light changes and interference between moonlight and morning or evening twilight light occur.

## V.ACKNOWLEDGMENT

Many thanks to Prof. Dr. Mohamed Mahmoud Sabry (M.Sabry, mohamed.ma.sabry@gmail.com from NRIAG) for the final review, especially the linguistic one.

## VI.CONCLUSIONS

When the SQM is in the zenith direction; Based on the concept of the onset of the eye's visual threshold of light for both the magnitude of M=Δm =$1.31^m$ (m, mag/arcsec²) with respects the celestial background (absence or appearance of the total energy of stars) and M1 (NELM=$6^m$) with the sun vertical depression ($D_o$, degree). The $D_o$ at true dusk are 11.2°≤ $D_o$ ≤14.8° as the ranging between the two threshold eye methods M and M1, while for the true dawn its 12.2° ≤ $D_o$ ≤14.5°. In case the full moon (0.99≤$f$≤0.98), the beginning of distinguishing dusk and dawn light from moonlight is $D_o$ ≈ 9.5° at $17.3^m$. The mean values of the light minimum of a full moon cases, for the evening and morning twilight are; $D_o$ =12.5° at $17.9^m$ and elongation ≈171°. The average of the night sky brightness (NSB) values in the evening is $20.74^m$ ± 0.22, while in the morning it is $20.49^m$ ± 0.20, so the thick of the night sky in the morning is Δm ≈ $0.25^m$ (which means that the sky in the morning is 1.26 % brighter than in the night sky in the evening). There is a correspondence around the $D_o$ =12° of true dawn in case of the horizontal or vertical toward compared to previous research (Rashed et al., 2022 in Fayum, Egypt). The $D_o$ =14.5° by NELM method is suitable for both vertical and horizontal cases.

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