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Naked Eye Determination of the Dawn at Tubruq of Libya Through Four Years Observations

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Abstract: Results of unaided eye observations of the morning twilight phenomenon at Tubruq of Libya are recorded. These results are an average of 623 observing twilights carried out at Tubruq (φ = 32° 05′ N, λ = 23° 59′ E) for the desert background in the time interval (2010-2013). The average enabled us to get an average depression of the sun below the horizon of about 13.144° which lies in a range between (11.13° $\leq Do \leq$ 14.7°). The results show that there is about 4° difference between our obtained value and that currently used in Libya which is 18.25°. The azimuthally range of observation in the solar vertical direction ranges from 0° to 10°, while the phenomenon was followed from 0° to 20° along the altitudinal range. The results indicate that the dawn (first light) occurs according to normal eye estimates at Tubruq at sun vertical depression angle D_o = 14.7°.

Key words: Naked eye · Dawn · Sun vertical depression · Twilight

INTRODUCTION

The unaided eye has been used in many astronomical circumstances [1, 2]. The sensation of the normal eye depends on two factors: the wavelength of radiation (i.e. the sensation of color) and the intensity of radiation.

Belikov [3] developed a model for the scattering of solar radiation by the terrestrial spherical atmosphere on the basis of a numerical solution of the radiation transfer equation in the zenith angle range 92-106°. Modeling has been carried out for standard altitude distributions of the molecular number density and ozone absorption coefficient and for the aerosol model of Toon and Pollack [4]. The "excessive" twilight atmosphere brightness at large solar zenith angles, earlier attributed to high turbidity of the upper atmosphere, is completely explained by the effects of multiple scattered light in the atmosphere. The importance of multiple scattering in twilight is shown, in particular, for λ=530 nm, at altitude below 20 km. This model shows that the maximum sun vertical depression in the multiple scattering is 16°.

The normal eye has its highest sensitivity in the yellowish-green range of the visible spectrum. It responds to light intensity logarithmically in such way that the eyes response to intensity is equal to a constant multiplied by the natural logarithm of the change in intensity.

Maximum absolute sensitivity for detection of light is found between 10 and 20° to the side of the fovea, where the density of rods is the highest. The minimum energy that gives rise to light detection in the dark for a young eye is close to the physical limit, namely the simultaneous absorption of a single quantum of light by each of only a few rods. The lowest energy that can be recognized as light in a dark-adapted eye (at 507 nm, at which the rods are the most sensitive) was found to be between 3.3 and 6.6 x 10^{-17} J measured at the cornea [5]. At 507 nm, the energy, E= hυ, of a light quantum is 3.92×10^{-19} J. This means that between about 50 and 150 quanta reach the cornea at absolute threshold. Let us assume that (i) about 50 percent of the light is absorbed in the eye media before it reaches the retina and that (ii) so many of the incoming quanta are lost between the rods that only 20 percent of the quanta reaching the receptor level are absorbed. This means that only between 5 and 15 quanta are actually absorbed at absolute threshold. Early data and statistical methods, based on the comparison of experimentally determined ‘frequency of seeing’ curves and summated Poisson distributions, gave five to seven quanta as the best estimate [6]. With so few quanta absorbed, the likelihood of the same rod being hit by two quanta simultaneously is vanishingly small.

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Trichromatic response of the human eye and the exact mechanics of human color vision are unknown but it has been determined that the response is shared by the eye and the brain. The trichromatic theory holds that the retina of the eye consists of a mosaic of three different receptor elements. Each element responds to specific wavelength corresponding to blue, green and red lights. These three elements, which appear to overlap considerably and responsively, are separately connected through nerves to the brain where the sensation of color is derived by the brain's analysis of the relative stimulus from the three elements. Color is perceived as a conscious sensation in terms of three major subjective attributes, luminance, hue and saturation; primary among these attributes is luminance (often called brightness). The second major attribute, hue, which is the most characteristic of color, is the distinction between redness, yellowness, blueness, etc. The hue of pure colors of the physical spectrum, relates directly to wavelength. The third attribute, which distinguishes strong colors from pale ones, is saturation or chroma. Saturation is related to physical purity, i.e., freedom from diluation by white [7].

Experimental determinations have been made by Blackwell [8, 9] of the minimum contrast $(L_o - L_b)/L_b$ of an object with luminance L_o against a background with luminance L_b for 50% probability of detection when both eyes are used and when unlimited time of exposure is available [9]. Patat, *et al*. [10] studied the *UBVRI* twilight brightness at dome C [11] and found that the night sky brightness level is reached at around zenith angle z = 105° -106°.

Al Mostafa *et al*. [12] studied the true dawn in the deep desert 170 km far from Riyadh city in Saudi Arabia (25° 45' 41" N, 74° 12' 10" E and 540 m height over the sea level) by two methods: naked eye observations and camera (of Nikon type) measurements. Both methods were carried out parallel to each other. The observations were recorded during one year twice in every month by four groups consisting of two observers. The results indicated that the dawn can be resolved at sun vertical depression of 14.6° ± 0.3°, where the minimum depression value of resolving the dawn is at 14° and the maximum value is at 15.1°. The applied dawn now (at 19°) is considered to be the pseudo-dawn (zodiacal light).

Accordingly, one of us (A.H. Hassan) was in a situation enabled him to watch the sky quite carefully along 429 twilight skies in 2 years in Tubruq on the Mediterranean coast from two sites. The observations of the first site (S_1) were taken from December 2007 to December 2009, where the prevailing weather is evaporated water vapor [13]. Table 1 summarizes the results of S_1 region. The observations of the dawn phenomenon concluded that the beginning of twilight is at D_o=13.43° (D_o= mean +2 σ).

Table 1: The statistical values of the sun vertical depressions (D_o) for the beginning of twilight on S_1 (Hassan, *et al*. (2009)).

Statistical values of S_1	D_o
Number of twilights, n	429
Minimum	10.52
Maximum	13.5
Mean,	12.351
Median	12.4
Mode	12.5
Rang	2.98
Standard deviation, σ	0.539
Standard error of the mean	0.026
High confidence of D_o	13.43

The authors published many articles in this field, which reported that the beginning of twilight according to the photoelectric measurements at different sites in Egypt is in the range 14° ≤ D_o ≤ 15° [14-19]. By naked eye observations on the four locations in Egypt (Matrouh, Bahria, Kottamia and Aswan, the mean vertical sun depression for observing the dawn was found to be D_o = 14.7° [20]. Table 2 summarizes the results of the published work in the twilight in Saudi Arabia, Egypt and Libya.

The aim of the present work is determining the beginning of twilight (dawn) by the naked eye observations in the large scale of data in another site S_2 in which 623 twilight skies were observed.

MATERIALS AND METHODS

The observations at Tubruq in Libya (φ = 32° 05′ N, λ = 23° 59′ E) were taken to determine the beginning of twilight started in December 2007 until July 2013 by the authors. They included two locations (S_1 and S_2). The observed data of S_1 (from December 2007 To December 2009 [13] were at height of 10 m over the sea level on the Mediterranean coast with water vapor background, while the observed data of the present work were in the second site S_2 (from January 2010 to July 2013) which is far 7 km from S_1 in the south direction and at height 40 m over the sea level with a desert background. The observations were taken in both sites during cloudless nights. The azimuthally range of observation in the solar vertical direction ranges from 0° to 10°, while the phenomenon was followed from 0° up to 20° along the altitudinal range.

Table 2: Summarization of the published work of observing twilight using naked eye and photoelectric (P. E.) instruments

Location	Lat. N	Long. E	Elev. (m)	N. L.	Method	D_o	Authors
Riyadh (Saudi Arabia)	25° 46'	74° 12.16'	540	Desert	Naked eye and Camera	14.7° ± 0.3	Al Mostafa *et al*., (2005)
Bahria, (Egypt)	28° 42.9′	29° 59.82′	150	Desert	P. E.	15.5° ± 0.5	Issa and Hassan (2008) II
Bahria, (Egypt)	28° 42.9′	29° 59.82′	150	Desert	P. E.	$14° \leq D_o \leq 15.5°$	Issa and Hassan (2008) III
Matrouh (Egypt)	31° 0.2′	27° 51′	75	Sea- Desert	P. E.	14.5°	Hassan *et al*., (2009)
Tubruq (Libya)	32° 05′	23° 59′	10	Sea	Naked eye	13.43°	Hassan *et al*., (2009)
Kottamia (Egypt)	29° 55.9′	31° 49.5′	470	Desert	P. E.	14.5°	Issa and Hassan (2010)
Matrouh (Egypt)	31° 0.2′	27° 51′	75	Sea- Desert	P. E.	$14° \leq D_o \leq 16°$	Hassan *et al*., (2013)
Bahria, (Egypt)	28° 42.9′	29° 59.82′	150	Desert	P. E.	$14° \leq D_o \leq 15.5°$	Hassan *et al*., (2014)
Bahria	28° 42.9′	29° 59.82′	150	Desert	Naked eye	$12.6° \leq D_o \leq 15°$	Hassan *et al*., (2014)
Matrouh	31° 0.2′	27° 51′	75	Sea- Desert	Naked eye	$12.3° \leq D_o \leq 14.5°$	Hassan *et al*., (2014)
Kottamia	29° 55.9′	31° 49.5′	470	Desert	Naked eye	$14.46° \leq D_o \leq 14.86°$	Hassan *et al*., (2014)
Aswan	23° 48.22′	32° 29.5′	250	Desert	Naked eye	$12.46° \leq D_o \leq 13.96°$	Hassan *et al*., (2014)

The method was mentioned in details in [13]. Here, we give a brief description of the procedure. We recorded the local time t_o (time of the dawn) corresponding to what we believe to be the first light signal of early twilight. Using MoonCalc© 6.0 by Monzur Ahmed, we converted the time t_o values to the sun vertical depression D_o values.

RESULTS AND DISCUSSIONS

Fig. (1) shows the distribution of the normalized sun vertical depressions D_o with the number of twilight sky observations in S_1 and S_2. The second order polynomial fitting of normalized data for S_1 ranges from -3.084 to 1.9353, while it ranges for S_2 from -3.661 to 2.055.

Fig. (2) gives the distribution of D_o for 1052 observations of S_1 and S_2 as a comparison between them specially for the maximum and the minimum values according to the atmospheric background contents. The visibility in S_2 is relatively higher, where the prevailing weather is dry as the background is desert and the height over the sea level is 40 m.

Table (3) gives the statistical values of sun vertical depressions (D_o) for the beginning of twilight (dawn) on the observations in S_2. It is noticed that, the mean, median and mode are 13.144°, 13.22°, 13.372° respectively, the difference between the mean and the median is 0.076 and the dispersion or the average deviation is 0.6127°.

The skewness coefficient of our data was found to be γ_1= -0.253 which means that the asymmetry is small and can be neglected, while the kurtosis was found to be γ_2 = -0.445 which is approximately coincides with the Gaussian distribution.

The quartiles of a population for our sample of observations are the three values which divide the distribution or observed data into even fourths. So, one quarter of the data lies below the first quartile Q_1=12.62° (near to the nautical twilight), one half of the data distribution lies below the second quartile (Q_2); and three fourths fall below the third quartile (Q_3=13.65°). Half of the values fall above Q_2, one quarter fall above Q_3 and also Q_2 is a synonym for the median. Once the quartiles are defined, it is easy to define the IQR (IQR = Q_3 - Q_1=1.03°).

By definition, half of the values (and specially the middle half, 0.5015°) fall within an interval whose width equals the IQR. If the data are spread out, then the IQR tends to increase and vice versa [20, 21].

In Fig. (3), the width of the bar can be obtained from $W = range / 5Log(n)$, where n is the number of twilight observations. To get more accurate values of D_o, we have to use the high confidence value, which is $D_o = mean+2\sigma$, where σ is the standard deviation. The normalized value of D_o is $Norm. = (D_o\text{-}mean)/ \sigma$.

Fig. (3) and table (4) represent the distributions of the 14 bar interval band widths, where the width of the bar is $W = (3.57 / N)\ 0.255°$ where ($N = 5\ Log\ 623$) in the total range of data (D_o=11.13°-14.7°). The average calculated depression and accordingly standard deviation are D_o = 13.144 and σ = 0.757° respectively. As we see, the most abundance of data for D_o from 1° to 14°) is in D_9, where the value of the mode is 13.372° which lies in the range (13.14°-13.39°) with percent 14.61%. Then the beginning of twilight (dawn) with the high confidence is at sun vertical depression D_o= 14.666° according to D_o= 13.144° + 2(0.757°) = 14.666° ˜ 14.7°, which represents the 99.77% from the total data.

Fig. (4) and Table (5) represent the distribution of the 7 interval bands (of width D_o=0.1º). The relative abundance of $D_o = DD_i$ (i=1→7) is in the range (14°-14.7º) with step 0.1°, which represents the most interesting values of D_o with respect to the critical time of the dawn. These values occurred in 91 twilight sky observations (14.767% from the observations taken in the site S_2).

Table 3: Statistical values of sun vertical depressions (D_o) for the beginning of twilight on the S_2 (623 twilight sky observation)

Statistical Values of S_2 (Jane 2010 To July 2013)	D_o
Number of values, n	623
Minimum	11.13
Maximum	14.7
Range	3.57
Mean	13.144
Median	13.22
Mode	13.372
First quartile (25th percentile), Q1	12.62
Third quartile (75th percentile), Q3	13.65
Standard error of the mean	0.0303
95% confidence interval for the mean	0.0596
99% confidence interval for the mean	0.0784
Variance	0.5736
Average deviation, dispersion, spread	0.6127
Standard deviation, σ	0.7574
Coefficient of variation, σ/mean	0.0576
Coefficient of Skewness, γ_1	-0.253
Coefficient of Kurtosis, γ_2	-0.445

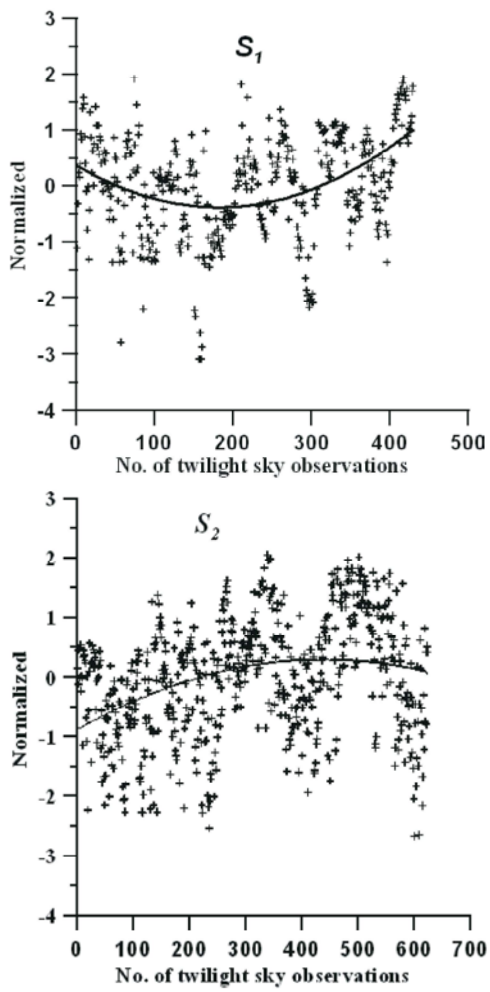

Fig. 1: Distribution of the normalized D_o for S_1 and S_2 sites at Tubruq

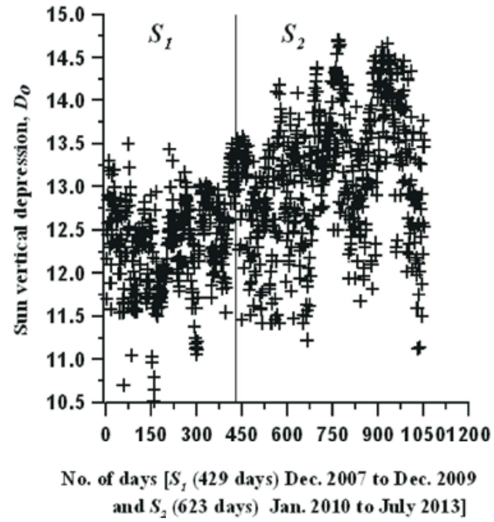

Fig. 2: Distribution of two sites S_1 and S_2

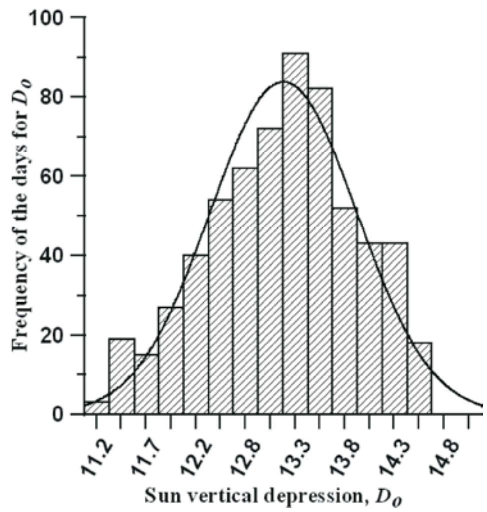

Fig. 3: Distribution of the 14 bars of D_o

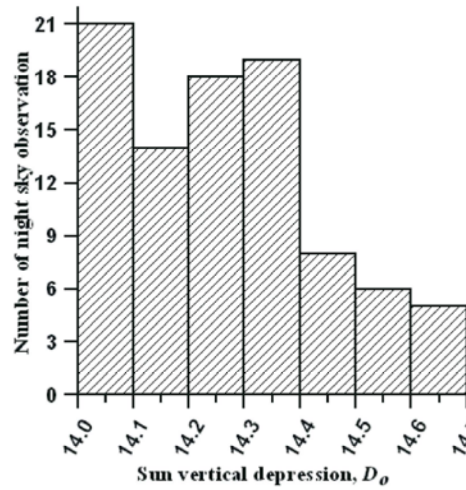

Fig. 4: Distribution of 7 interval bands (of width D_o=0.1°)

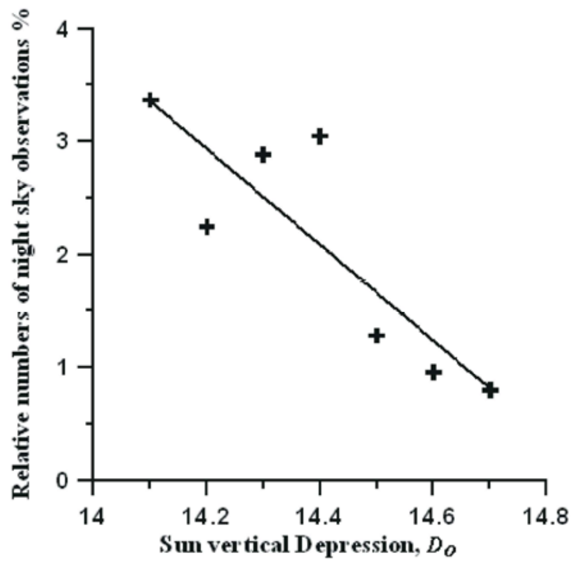

Fig. 5: Rate of decrease of abundance for twilight sky observation in the range D_o=14°-14.7°

Table 4: Percentages of 14 interval bands (of width W=0.255°) and the relative abundances of $D_o = D_i$ (i=1→14) for S_2

Depression, D_o	No of data	Percentage (%) according to 623 observations
$D1$=11.1-11.355	5	0.802
$D2$=11.355-11.61	19	3.05
$D3$=11.61-11.865	17	2.729
$D4$=11.865-12.12	28	4.494
$D5$=12.12-12.375	40	6.42
$D6$=12.375-12.63	53	8.507
$D7$=12.63-12.885	61	9.791
$D8$=12.885-13.14	72	11.557
$D9$=13.14-13.395	91 (mode)	14.607
$D10$=13.395-13.65	83	13.323
$D11$=13.65-13.905	52	8.3467
$D12$=13.905-14.16	42	6.741
$D13$=14.16-14.415	42	6.741
$D14$=14.415-14.67	18	2.889
Summations	623	100

Table 5: The interval of depressions and the relative abundances of $D_o = DD_i$ (i=1→7) in the range 14°-14.7°

Depression, D_o degrees	No of data in the range 14°-14.7°	Percentage (%) according to 623 observations
DD_1=14-14.1	21	3.371
DD_2=14.1-14.2	14	2.247
DD_3=14.2-14.3	18	2.889
DD_4=14.3-14.4	19	3.05
DD_5=14.4-14.5	8	1.284
DD_6=14.5-14.6	6	0.963
DD_7=14.6-14.7	5	0.802
Total	91	14.4%

Table 6: The difference between the observations of the beginning of twilight (D_o=14.7º) and the applied of twilight now in Tubruq (D_o=18.25º)

Date	18.25° hh:mm	14.7° hh:mm	Δm mm
21 Mar.	5:03	5:21	18
21 June	3:36	3:59	23
21 Sep.	4:48	5:06	18
21 Dec.	5:52	6:10	18

The rate of decrease of the percentages of depressions in this region is given by the slope of the line in Fig. (5) which is equal to 4.24. This means that the percentage of the values of depressions in ranges DD_6 and DD_7 is 1.76% of the 91 twilight observations. This agrees with the results obtained by many researchers who used the photoelectric observations which decided that the dawn shows itself at 14° ≤ D_o ≤ 15° [14- 19]. Table (6) represents the difference in the sun vertical depression of D_o between the values obtained from the observations of the beginning of twilight (14.7°) and the considered values of twilight now in Tubruq (18.25°). This difference is found to be 3.55°. As we see, the difference in the time ranges accordingly between 18 and 23 minutes.

CONCLUSION

The results indicate that the dawn (first light) occurs according to an average of the normal eye observations at Tubruq taken in S_2 (623 twilight sky observations) at desert background at sun depression angle D_o = 14.7° (D_o=13.144° + 2σ) with a standard deviation of 0.757°. The maximum value of the depression D_o is 14.7°, while the minimum value is 11.13°.

This result of S_2 agrees exactly with the results from the naked eye observations (D_o = 14.7°) for the four locations in Egypt (Matrouh, Bahria, Kottamia and Aswan) which have the same climatologically and environmental conditions like Tubruq. These all results also agree with the observations by the photoelectric technique (14° ≤ D_o ≤ 15°. Similarly, they also agree with Al Mostafa *et al.* in Saudi Arabia which indicates that the dawn shows itself at sun vertical depression angle of D_o= 14.6°±0.3.

The comparison between S_1 and S_2 shows that the visibility in S_1 (where the dawn shows itself at D_o=13.43°) is less than S_2 (where the dawn shows itself at D_o= 14.7°) because of the high water vapor contents on the sea surface as the background in S_1. On the other hand, the weather is dry and the height over the sea level is 40 m in S_2, which is at least 7 km apart from the coast.

Also, our results agree with Patat *et al*. in dome C which reported that the night sky brightness level is reached at zenith angle z between 105° and 106°. According to this study, we believe that the beginning of twilight (dawn) occurs at z = 105° (at sun vertical depression D_o = 15°) and the end of twilight is at z = 106° (at sun vertical depression D_o = 16°). The thickness of the atmospheric layers in the evening twilight is bigger than the thickness of the atmospheric layers in the morning twilight because the temperature in the evening is normally 5 °C higher than the temperature in the morning twilight especially in the latitudes lower than 45°.

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