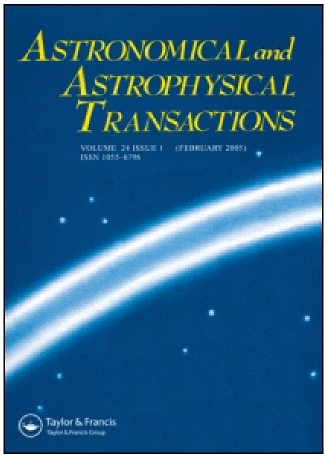

Astronomical & Astrophysical Transactions
The Journal of the Eurasian Astronomical Society
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713453505

Photovisual observation of twilight

O. Ugolnikov [a]
[a] Sternberg Astronomical Institute, Moscow, Russia

Online Publication Date: 01 November 1996
To cite this Article: Ugolnikov, O. (1996) 'Photovisual observation of twilight', Astronomical & Astrophysical Transactions, 11:2, 107 - 110
To link to this article: DOI: 10.1080/10556799608205459
URL: http://dx.doi.org/10.1080/10556799608205459

Astronomical and Astrophysical Transactions, 1996,
Vol. 11, pp. 107–110
Reprints available directly from the publisher
Photocopying permitted by license only

PHOTOVISUAL OBSERVATION OF TWILIGHT

O. UGOLNIKOV

Sternberg Astronomical Institute, Moscow, Russia

(Received May 25, 1995)

In the first approximation, the brightness of twilight sky is a function of the coordinates of a sky point and the position of the Sun at a particular instant. The objective of this work is to determine how does the sky brightness depend on these parameters from the photographic observations in V system. Besides that, the relation of the sky brightness upon limiting magnitude of visible stars is investigated. The knowledge of these dependencies helps a lot in preparing observing programmes to be done at twilight time.

KEY WORDS Twilight: sky brightness

1 INTRODUCTION

Twilight is the time interval when the sky brightness changes very rapidly, decreasing by a factor of millions in the evening and increasing by the same amount in the morning. The theoretical models of twilight phenomena (Fesenkov, 1923; Rosenberg, 1963) do not give direct formulae of the twilight sky brightness. However, the knowledge of at least approximate formulae would be very helpful in many cases.

Let us choose a horizontal system of celestial coordinates, connected with the Sun (i.e. the Sun's azimuth in the system is always zero). The coordinates A and z of a sky point in this system are connected with the usual horizontal coordinates A_0, z_0 with the following obvious relationships:

$$A = A_0 - A_\odot$$

$$z = z_0$$

where $A_\odot$ is the azimuth of the Sun.

If we leave alone the climate factors that influence the twilight, the sky brightness J depend on A, z, and also on h – the depth of the Sun under the horizon. For simplicity, we may ignore refraction since h completely determines the Sun's position.

From the observations of V. G. Fesenkov and many others, it is clear that in any given sky point the decrease of logarythm of J is almost linear as h grows (for $h < 12°$).

Therefore, if we take a magnitude of a sky area

$$M_J = -\log_{2.512} J + \text{const},$$

then

$$M_J(A, z, h) = M_0(A, z) + K(A, z) * h.$$

The objective of our observations was to determine the functions K and M_0. (The observations were relative, therefore M_0 is determined to an arbitrary constant).

2 OBSERVATIONS AND RESULTS

On the 7-th of May, 1993, the brightness of 66 different sky points $(A,\ z)$ was measured photographically approximately in V system (the effective wavelength was equal to 5600Å). The panchromatic emulsion and "ZhS-18" and "SZS-21" filters were used. The measurements were carried out for values of h from 1° to 7°.

The observations were carried out at Sternberg Asronomical Institute. ZENIT cameras were used; only points falling in the linear range of the characteristic curve of the photographic emulsion and the curve gradient was estimated using the least squares method. This allowed to increase the accuracy of the measurements.

The value of M_0 different greatly for different sky areas, as expected. The difficulties in estimating M_0 were caused by different characteristic curves of different photographic films (even with the same film brand and the same development time) and different optical conditions at the center and near the edge of a frame. After taking these factors in account it was necessary to find a function that could be some approximation of $M_0(A, z)$, such that A and z are trigonometric function arguments within it.

These results showed that M_0 = max (i.e. J = min) at zenith and decreases in any direction proportional to z^2 (or $(1 - \cos z)$). The proportion coefficient is approximately constant for large A values and rapidly increases at $A = 0°$ (in the dawn area). This leads to the formula:

$$M_0(A, z) = \text{const} - (P + L \operatorname{sinc}^4 A)(1 - \cos z),$$

where $\operatorname{sinc} A = \frac{\sin A}{A}$ (A in radians) P, L were estimated using the least squared method:

$$P = 1.64 \pm 0.15,$$

$$L = 3.41 \pm 0.14.$$

$K(A, z)$ was estimated later for various sky areas.

Table 1 contains the data for 15 sky areas (h in degrees). The table shows that K rapidly increases near the zenith (however, as we shall below, the value of $K = 1.47$ is slightly overestimated).

In order to clarify the behavior near the zenith, further observations were required. In summer 1993, K was measured again photographically, in a system close to V (5600Å) and in the red color area ($\lambda = 6200$Å – panchromatic emulsion and "KS-11" filter). This was done to find out the sky color change with the increase of h.

The observations was carried out at Valentinovka, 20 km to North–East from Moscow.

The results of observations are given in Table 2. Based on these results, the average values of K at the zenith were obtained:

$K = 1.31 \pm 0.12$ in V system (taking into account the results from the 7th of May),

$K = 1.27 \pm 0.03$ in the red area.

The given errors characterize data scatter. The error of average values is equal to 0.02 in both color regions.

This shows that at $h < 7°$ the sky becomes slightly red as the sun falls deeper. More precise observation (Rosenberg, 1963) show that the sky gets slightly red at $h <$ 4–5° and then gets slightly blue.

The resultant dependence $K(A, z)$ is as follows: Slight variations near 1.0 over the most part of the sky, increase in the dawn area, and rapid increase at the zenith.

Knowing $M_0(A, z)$ and $K(A, z)$, the required dependence $J(A, z, h)$ can be determined using the formula:

$$J = J_0 \times 10^{0.4((P+L sinc^4 A)(1-\cos z)-K(A,z)\cdot h)}.$$

where J_0 is the sky brightness at the zenith at sunset.

3 ONE OF THE POSSIBLE USES OF THE ESTABLISHED RELATIONS

Knowing J, we can determine its relation with the limiting visible magnitude of stars for a given sky area.

From visual observations of star appearance on the evening sky (August 1992, February–March 1993), it was obtained that the limiting magnitude m at 50–80° above the horizon, towards South–East, is related to h as follows:

$$m = a + bh,$$

where the average coefficients were equal to:

$$a = -1.40 \pm 0.05,$$

$$b = 0.719 \pm 0.007$$

(h in degrees).

This shows that the human eye sees bright point with intensity I on the background with brightness J if:

$$I \geq I_{\min} = \mathrm{const} \cdot J^{\alpha},$$

where $\alpha = b/K \approx 0.6$ (obviously, K taken same sky area as b).

It is not possible to determine α exactly for two reasons: first, because of large variations of K in the specified sky area (z from 10° to 40°); second, because of the influence of brightness distribution of the stars in the sky on b (there are relatively few bright stars in the sky, and the observer finds them late). This effect increases the value of b and, therefore, the value of α. If there were no such effect, α would be close to 0.5 which means that $I_{\min} \sim \sqrt{J}$.

Knowing α, $M_0(A,z)$, $K(A,z)$, the expression for the limiting visible magnitude can be obtained for the specified sky point (A,z) at arbitrary h:

$$m = a + \alpha(M_0(A,z) + K(A,z)h.$$

As the visual observations were done close ti the zenith, the arbitrary constant in the formula $M_0(A,z)$ may be assumed close to zero.

In a similar way, the limiting visible magnitude for telescopic visual observations is determined:

$$m = a + 5\log(D/d) + \alpha\left[M_0(A,z) + K(A,z)h - 5\log\left(\frac{D}{d \cdot \Gamma}\right)\right].$$

where D is the telescope lens diameter,

d is the eye pupil diameter,

Γ is the telescope eyepiece magnification ($\Gamma \geq D/d$).

If the magnification exceeds 50–60, the star will be seen as a turbulent disk and the last formula will be wrong.

Finally, I would like to thank T. N. Nazarova, G. V. Sokol, T. V. Avakyan, G. V. Moshkin, S. V. Korobkin, A. N. Burlak, T. V. Vorobiev for their help in observations and preparation of results.

References

Fesenkov, V. G. (1923) On the Atmosphere Structure (Photometric Analysis of Twilight), *The Works of the Head Russian Astrophysical Observatory.*

Orlova, L. N. (1993) Radiational Model of Cloudless Atmosphere in the Optical Part of the Spectrum, *Svetotechnika* **2**.

Pyaskovskaya–Fesenkova, E. V. (1957) *The Investigations of Light Scattering in the Earth Atsmosphere*, Acad. of Sci. Publishers, USSR.

Rosenberg, G. V. (1963) *Twilight*, Phys.-Math. Publishers.