Apparent Magnitude of a Visible Star under the Hazard of Light Glare Pollution

Naoyoshi NAMEDA

Abstract

Kihoku-cho in Kagoshima prefecture is known as one of the best town in our country for detecting and observing stars.

Kihoku-cho is also selected the place for experimental installation of ideal lighting by the Japanese Environmental Ministry in 1998 fiscal year. For the promotion of the experiment, experts were assembled in a "committee for the best lighting in Kihoku-cho". The author was selected as a member of the committee and its chairman in November 1998. Usually, light pollution is caused by the upwards straying artificial light in urban places. However, in Kihoku-cho town, there is no such artificial lighting. The most hazardous light for observation of stars is the newly installed lighting apparatus itself, especially light beaming in direction of an observer. Hence, a guideline for better lighting without hazard to star observation was developed theoretically and experimentally, and experimental lighting was installed according to the guideline.

Key words : star watching, light polution, sky glow

Introduction

Guidelines for countermeasures against light pollution were issued by the Japanese Environment Ministry in March 1998.

In reference to the guidelines, special types of illumination whose upwards straying light is constrained, were recommended.

If lighting is designed strictly according to the guidelines, light pollution is expected to decrease. The main problem of light pollution in urban areas is that stars are not observed in the brightened sky. This brighter sky effect is called sky glow. Kihoku-cho in Kagoshima prefecture was selected as one of the best location for star observation in Japan. In fiscal year 1998, Kihoku-cho was also selected as the place for the experimenting ideal lighting. For the promotion of the experiment, experts were assembled in a "committee for ideal lighting in Kihoku-cho" an electric specialist, a construction specialist, an employee of the Kyushu electric power company, an anti-pollution authority of the prefecture and so on. I was also selected as a member of the committee and its chairman in November 1998. We had many discussions until October 1999, and carried out many star observations. Kihoku-cho has very little artificial lighting and no sky glow of its area and is sheltered by Sakurajima Volcano from the sky glow of

Computer and Systems Engineering Department, Fukuoka Institute of Technology
3-30-1 Wajirohigashi, Higashi-ku, Fukuoka 811-0214, Japan.

Kagoshima City. The most hazardous light for the observation of stars is newly installed lighting apparatus, especially light emitted in the direction of an observer, not upwards straying light.

According to the guidelines of the Ministry, the most hazardous light is supposed to be the upwards straying artificial light. But, in special cases, when a lamp is set in a lower position, upward straying light exists and can be directed to the eye of observer who looks up at the stars, but the straying light in this case is less hazardous. Actually, in Kihoku-cho low light fixtures were installed.

Then, light pollution in Kihoku-cho could not be properly solved by following the guidelines of the Ministry, and so the author aimed to establish another guideline for lighting to ensure better star observation.

The Threshold Magnitude of an Observable Detectable Star and the Hazard Light Affecting an Observer

The author supposed the degree of hazard is measurable by the threshold magnitude of star, which is observable, detected under the hazard of artificial light. Consequently, the relation between star magnitude and illuminating factors for an observer must be investigated.

First, N.Pogson defined star magnitude in 1850, and on this basis C.F. Zöllner constructed a star visual measurement device which was two nickol prisms able to conduct two light fluxes for two stars (Unzelt, Kodaira K translator, 1968).

Given that its ratio of the two light fluxes is S1/S2, the difference in magnitude (m) of the two stars is follow,

$m1-m2=-2.5\log(S1/S2)$ ・・・・ (1)

If m2=0, S2 becomes one,

where m1 and m2 are magnitudes of the stars whose light fluxes are S1 and S2 respectively.

Then,

$m1=-2.5\log(S1)$ (magnitude)・・・・・・ (2)

On the other hand, its hazard for observation star corresponds to the disability glare problem in illuminating engineering.

The luminance difference (delta L, as listed in the handbook of Japanese Illuminating Engineering Society, 1987) between back ground luminance and objective luminance is increased by the effect of hazard light as following formula,

$Lev=KEv/\theta^n$ ・・・・・・・・・ (3)

Where, Lev is increasing luminance, Ev is the illuminance on an observer's cornea and θ is the arc angles between the glare source and the observer's visual direction. k and n are constants.

If the illuminance on the cornea by a star is Es and the illuminance of the glare

source is Ev, the observable degree of a star is defined as follows
Observation detected degree of a star=
$\log(Es)-\alpha\log(Ev)$ ・ ・ ・ (4)
In formula (4), Es and Ev expressed by logarithmic function are postulated as light sensitive value corresponding to biological measures. Then, the Fechner effect may be considered (Tanaka, 1977).
α is a constant comparing star and glare source smaller than "1".
In formula (2), S1: light flux entering the measurement device, and Es: illuminance on the observer's cornea, are expected to have a proportional relation, as follows:
$S1=CEs$ ・ ・ ・ ・ ・ ・ ・ ・ ・ ・ ・ ・ (5)
Where C is constant.
Combining formula (5) and formula (2),
$\log(Es)=-m1/2.5+\log C$ ・ ・ ・ ・ ・ (6)
Combing (6) and (4), and letting the threshold observably detective degree of a star be zero, then,
observable detective degree of a star=0
$= -m1/2.5+\log C-\alpha\log(Ev)$ ・ ・ (7)
m1 is obtained as follows, then
$m1=2.5\log C-2.5\alpha\log(Ev)$ ・ ・ ・ (8)
Therefore, the threshold logarithmic magnitude of star is inversely proportional to the hazardous light logarithmic illuminance on an observer's cornea.

Experimental Results and Discussion

Observation of stars was carried out twice in Kihoku-cho, once in December 1998 and again in August 1999. The experiment in December, was done in the garden of town office. The observers were six Kihoku-cho officials- three aged 30 years old, and three aged 50 years old. Their visual acuity was more than 1 value by the Randolt ring test chart after accommodation adjustment. They were tasked to approach towards a glare source and declare the limit criteria, which a particular star was. At this position, illuminant values were measured on the surface of observers eye by an IM-3 illuminance meter made by Topcon Co., Ltd. in Japan. The experimental scheme is shown in Fig. 1. The magnitude of the star is confirmed by a star constellation chart which depicts the 4th magnitude of a star (Specially issue Newton, 1995).

Fig. 2 shows the relation between the illuminance and the magnitude of particular stars. Their axes are plotted as logarithmic measures. The former experimental results are indicated as solid circles. Latter experiment was implemented in August 1999. Usually the atmosphere contains moisture in summer in Japan, but the sky at Uwaba-park located on a hill in Kihoku-cho, was

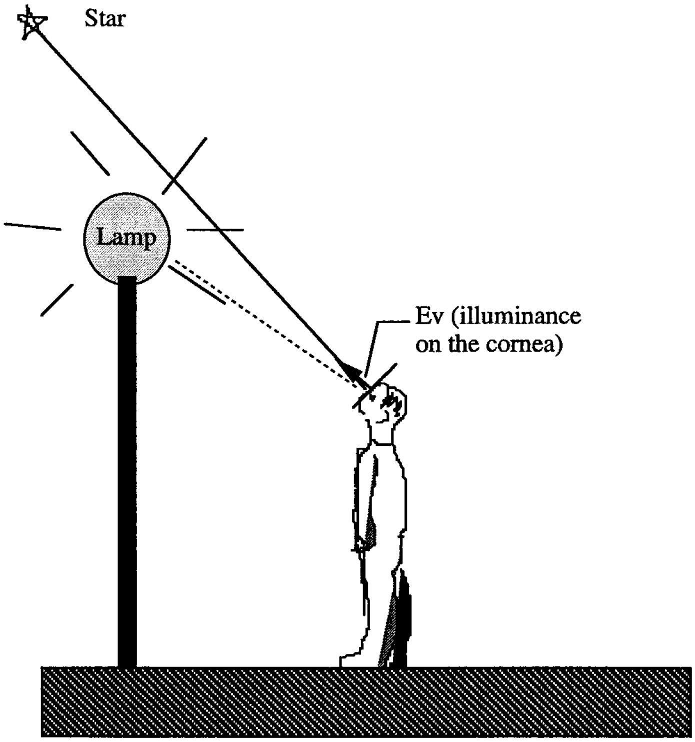

Fig. 1 Experimental scheme

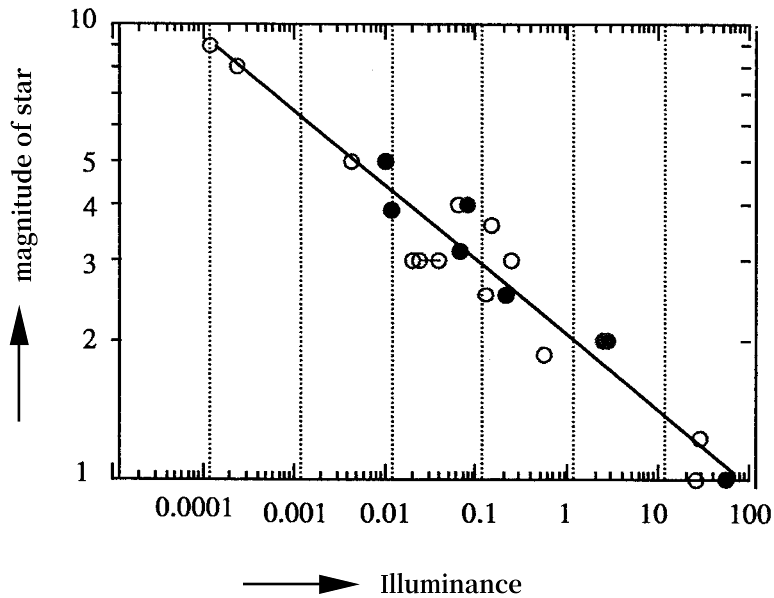

Fig. 2 Illuminance on the cornea and magnitude of star

Solid circles are 6 SB of 30-50 age of years and open circles are 5 SB of 20 age of years.

clear. The experimental observers were five students in Kagoshima University. They are all 21 years old and their visual acuity was also over 1 value after accommodation. The obtained data are plotted in the open circle in Fig. 2. The data of the two groups is put in a straight line which shows the relation predicted by formula (7). In Fig. 2, C and α of formula (8) are calculated as 6.3, and 0.4, respectively.

The author proposes this formula is as valid for estimating of the light hazards of artificial lamps before new lighting installation.

References

Invitation to a star twinkling sky 1995. Specially issue Newton, kyouiku-sha, 72-77pp. in Japanese

Japanese illumination engineering society ed 1978. Lighting Handbook, Ohm-sha, 349pp. in Japanese

TANAKA Y. 1977. Psychological Measurement Method, Tokyo Daigaku shuppan-kai, 143pp. in Japanese

UNZELT A.: Kodaira K translator 1968. Modern Astronomy, Iwanami-shoten, 113pp. in Japanese

(Accepted 4 January, 2000)