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On Sky Brightness Variantion Caused by Annular Solar Eclipse Observed with CCD Cameras

[1]Liu Xin, [1]Guo Jin-Yun, [1]Song Lai-Yong, [1]Dai Jie and [2]Han Yan-Ben
[1]College of Geodesy and Geomatics, Shandong University of Science and Technology, 266590, Qingdao, China
[2]National Astronomical Observatories, Chinese Academy of Sciences, 100012, Beijing, China

Abstract: Annular solar eclipse took place at Jan. 15, 2010 and Qingdao was one of best good places to observe it. We used two CCD cameras to take photos of zenith sky on Dongmen Mt. of Qingdao at Jan. 15 and 16 to study the effect of annular solar eclipse on the sky brightness at the dusk. After image processing, gray curves were constructed based on three primary components of Red (R), Green (G) and Blue (B). The principle component analysis method was used to analyze the variations of sky brightness caused by the annular eclipse comparing with the normal condition at Jan. 16. Curves of R, G, B and gray roughly had the consistent pattern. The annular solar eclipse affected seriously the normal variations of components R, G and B, among which components of R and G were more affected than that of B. Meantime the R component was most sensitive to the annular solar eclipse. The annular solar eclipse affected the mean gray each epoch with a certain time lag by comparing gray curves in Jan. 15 and 16. This influence to gray is up to maximum at 17:15 and tends to stable while relighting.

Key words: Annular solar eclipse, CCD image processing, Sky brightness, Mean gray, Principle component analysis

INTRODUCTION

Eclipse as one astronomical phenomenon will happen while the Moon moves between the Sun and the Earth. Liu Xiang, one famous astronomer in the Western Han Dynasty, ever concluded that the eclipse is caused by the Moon sheltering the Sun. Observation of the eclipse has a long history and the rich record in China. China is the best preserved of the most accurate astronomical phenomena observations and records before the renaissance in Europe and has the world's earliest and most complete records of solar eclipse (Han and Qiao, 2009). Annular solar eclipse is one solar eclipse and China has a long history of observing the eclipse. Since, ancient times many researchers at home and abroad make the research and exploration of the eclipse phenomena and records. Astronomical records in eclipse as a historical clock are used to determine the historical events, Saros (Isaia, 2009; Zhao *et al.*, 2009), visible observation (Li *et al.*, 1997), infrared observation (Bao *et al.*, 2009), corona, planetary (Zhao, 2008), changes in the weather, Earth's rotation changes (Han, 1999; Zhang and Han 1995; Zhang and Han, 1996), unusual activity of plant and animal, communications security, gravity anomaly (Wang and Wang, 1989), magnetic anomaly (Liu and Lin, 2008) and ionospheric anomaly (He and Sun, 2001).

The astronomical telescopes and other professional instrument are used to make optical observations of the solar eclipse, especially for the annular solar eclipse phenomenon (Bao *et al.*, 2009). Now there is no relative study on effects of annular eclipse on sky brightness characteristics. The annular eclipse present in January 15, 2010 is the first annular solar eclipse visible in the 21st century in China. The annular eclipse started from the central Africa, through the Indian Ocean, Sri Lanka, India, Myanmar, Burma border into China and finally at the end of the Shandong Peninsula. In this study, two cameras of Canon EOS 7D are used to observe the sky in different two directions before and after the annular eclipse at Qingdao, China, in January 15 and 16, 2010. The abnormal effect of the annular eclipse on the sky brightness characteristics is explored.

The Dongmen Mountain in Qingdao as one ideal place for observing is located near central region of the annular eclipse. The sun is not recovered and the sunset occurs with the end of the annular eclipse which will make the impact of atmospheric reflection and refraction of sunlight and the twilight phenomenon. In this study, based on CCD camera observations on January 15 and 16, 2010, effects of the annular eclipse on the sky brightness characteristics and the abnormal twilight changes are studied through the image data processing and analysis.

Corresponding Author: Guo Jin-yun, Shandong University of Science and Technology, 266590, QingDao, China

ANNULAR ECLIPSE IMAGE ACQUISITION

We have chosen the Dongmen Mountain top (35.999°E, 120.110°N) at Qingdao as the observing site because Qingdao is located near the centerline of the annular eclipse, where the weather conditions are ideal. Choosing the mountain-top as the observing site can increase the field of view and can effectively avoid the impact of light and the other external environment.

The first contact occurred at local time 15:36:51, the second contact occurred at 16:51:49, the middle of eclipse is present at 16:55:25, the third contact occurred at 16:59:01 and the annular eclipse continued for 432 sec at Qingdao. The sunset time is 17:06:11 and the end of the annular eclipse occurred at 18:01. The sun was below the horizon at the end time of the annular eclipse. Qingdao is not only suitable for the study on the effect of 15 January 2010 annular eclipse on the sky brightness characteristics, but also appropriate to study the effect of the annular eclipse on the twilight.

We used two cameras of Canon EOS 7D (200 mm F/2L IS lens) to observe respectively the sky in the zenith direction and in the north direction with the zenith distance of 30° with which to calibrate each other. Since, the weather is good for two days before and after January 15, 2010, we also observed the sky at the January 16 with the same period as the January 15. Observing results at January 16 are compared with these at January 15 to investigate the effect of the annular eclipse.. Table 1 lists the information of the annular eclipse observation.

OBSERVING DATA PROCESSING

First the CCD images should be processed to denoise and improve the signal-to-noise ratio. Noises mainly include individual star images, dead CCD pixels and CCD edge distortion. The center of one CCD image region is intercepted as an effective computational domain, the image mutations or the abnormal regions are searched which should be removed. The template-based automatically searching method (Guo *et al*., 2011) is used to process star images after 18:00 to determine star image region and remove them.

The trichromatic components R, G and B of CCD color images are extracted and then the gray-scale processing of color images is made. Data in directions of zenith and zenith distance of 30° are compared and analyzed and the sky brightness features in two days are compared to study the effect of the annular eclipse on the variation of three-components R, G and B. Effects of the annular eclipse on the sky brightness and the twilight are explained by the variations of the three-components R, G and B and gray.

The image gray-scale processing is to convert the CCD color image to grayscale image. The color of each pixel in the color image is determined by the R, G, B three components, each of which has 256 values. A pixel can have more than 256×256×256 color range. Description of grayscale images as well as color images indicates the distribution and characteristics of the image overall and local chrominance and luminance levels.

There are four ways to achieve gray-scale processing of CCD color images. The first is the maximum value method which will take maximum values of R(x, y), G(x, y) and B(x, y) to be the brightness at pixel (x, y) that is:

$$F(x, y) = \max(R, G, B) \quad (1)$$

where, F(x, y) is the gray value at pixel (x, y) on behalf of the pixel brightness. The second is the average method which will take the m ean value of R(x, y), G(x, y) and B(x, y) to be the brightness at pixel (x, y) that is:

$$F(x, y) = \frac{1}{3}(R + G + B) \quad (2)$$

The third is the weight average method. The weights of R, G and B are depended on the sensitivity of the human eye to different colors. The gray value of image can be calculated by averaging the values of R, G and B with different weights that is:

$$F(x, y) = 0.229R+0.587G0.114B \quad (3)$$

The fourth is the HLS model method. HLS model integrates the hue, lightness and saturation based on the visual experience (Cui, 1997; Liu and Jiang, 2003) that is:

Table 1: Essential information of the observation

	Start time		End time		Observing interval		
Direction	Jan. 15	Jan. 16	Jan. 15	Jan. 16	Jan. 15 (sec)	Jan. 16 (sec)	Duration exposure (sec)
Zenith	15:02	14:58	18:27	18:25	60	180	1/100
30°	15:01	14:58	18:26	18:24	60	180	1/100

$$F(x,y)=\frac{2}{3}[\max(R,G,B)+\min(R,G,B)] \qquad (4)$$

ANALYSIS ON RESULTS

The Principal Components Analysis (PCA) can convert multi indexes into a few composite indicators based on the dimensionality reduction. In statistics, PCA is one technique to simplify data set. Linear transformation is used to transform the data into a new coordinate system to make the largest variance of data projector in the first coordinate which is called the first principal component, the second large variance in the second coordinate which is called the second principal component, the third large variance in the third coordinate which is called the third principal component and so. PCA can reduce the dimensionality of the data set by retaining the low-level principal component, ignoring the higher order principal components while can maintain the characteristics of data sets contributing to the variance (He, 2008).

In the observation test, R, G and B are all the random functions of time t under normal conditions. So there is a fixed set of parameters (a, b, c) to meet:

$$aR = bG+cB = z \qquad (5)$$

to maximize the variance of z, in which $a^2+b^2+c^2 = 1$.

In the annular eclipse of the day, under the impact of the annular eclipse there is another group of (a1, b1, c1) to meet Eq. 5.

The relevance of trichromatic components R, G and B to z is relative to the size of a, b and c. Contribution rate changes of the first principal component and the relation of (a, b, c) and (a1, b1, c1) are used to explain reasonably the impact of the annular eclipse.

The R, G and B components and the exposure time are extracted through the CCD image data processing. Four graying methods are compared to process the color images and the weight average method is used to achieve the gray of color images. PCA is used to analyze the impact of the annular eclipse.

Through calculation and analysis, the first principal component contribution rate is 99.91% for the CCD images in the zenith direction in January 16. The principal component coefficient matrix M and the eigenvalues of the diagonal matrix D of the eigenvalues are:

$$M=\begin{pmatrix} 0.5920 & 0.5597 & 0.5799 \\ -0.7828 & 0.2282 & 0.5789 \\ 0.1917 & -0.7967 & 0.5732 \end{pmatrix}$$

and:

$$D=\begin{pmatrix} 1 & 0 & 0 \\ 0 & 33 & 0 \\ 0 & 0 & 37234 \end{pmatrix}$$

The first principal component contribution rate is 99.39% for the CCD images in the zenith direction in January 15. The principal component coefficient matrix M1 and the eigenvalues of the diagonal matrix D1 of the eigenvalues are:

$$M1=\begin{pmatrix} 0.4834 & 0.6807 & 0.5505 \\ -0.8095 & 0.1081 & 0.5771 \\ 0.3333 & -0.7246 & 0.6032 \end{pmatrix}$$

and:

$$D1=\begin{pmatrix} 1 & 0 & 0 \\ 0 & 137 & 0 \\ 0 & 0 & 22504 \end{pmatrix}$$

The first principal component contribution rate is 99.92% for the CCD images in the direction of zenith distance 30° in January 16. The principal component coefficient matrix N and the eigenvalues of the diagonal matrix D of the eigenvalues are:

$$N=\begin{pmatrix} 0.5890 & 0.5630 & 0.5797 \\ -0.7840 & 0.2241 & 0.5789 \\ 0.1960 & -0.7955 & 0.5734 \end{pmatrix}$$

and:

$$D=\begin{pmatrix} 1 & 0 & 0 \\ 0 & 28 & 0 \\ 0 & 0 & 37501 \end{pmatrix}$$

The first principal component contribution rate is 99.49% for the CCD images in the direction of zenith distance 30° in January 15. The principal component coefficient matrix N1 and the eigenvalues of the diagonal matrix D1 of the eigenvalues are:

$$N1=\begin{pmatrix} 0.4750 & 0.6910 & 0.5449 \\ -0.8102 & 0.1017 & 0.5773 \\ 0.3435 & -0.7157 & 0.6081 \end{pmatrix}$$

and:

$$D1=\begin{pmatrix} 1 & 0 & 0 \\ 0 & 123 & 0 \\ 0 & 0 & 24172 \end{pmatrix}$$

Comparing the third rows of M and M1 and N and N1 which are the coefficients of the first principal component, we can find that the first principal component coefficients of R, G and B are all very large in which The relation of R primary color component to the gray sample data is weakest and the relation of the green component to the gray sample data is strongest. Due to the influence of the annular solar eclipse, the contribution rates of the first principal components in the zenith direction and the direction of zenith distance 30° in January 15 are slightly weaker than those in January 16. The linear transformation coefficient of component R is largest and that of component B is smallest.

According to the relation of color and gray variation, we choose the weight average method to calculate the gray data of the color images because the results are most consistent with PCA's results.

Under impact of the annular eclipse, grayscale variations of CCD observations in the zenith direction and in the direction of the zenith distance 30° have the similar laws. The annular eclipse produces a relatively large impact on the R, G and B trichromatic components and the normal trend of the average gray scale changes, in which the impact on R and G components is largest and the affect on the B component is less. The R component is most sensitive to the annular eclipse. The annular eclipse impacts on the average gray with a lag. The abnormal changes of the CCD image data in January 15 are analyzed by five periods as following.

In the period of the first contact at 16:36 to the second contact at 16:51, R, G and B components and the average gray compared with the same time in January 16 have the similar trend that they are declining rapidly and the difference of the average gray relative to the data in January 16 rapidly increases. R component declines rapidly at first and is affect by the first contact. Component B is finally affected by the first contact and the changes are smallest in this time period.

In the period of the second contact at 16:51 to the middle of eclipse at 16:55, Components of R and G and the average gray F appear a significant rebound and decrease after increasing. Differences of components R and G and the average gray level relative to those in January 16 firstly decrease and then increase. B component still continues to decline and the corresponding gray difference to that in January 16 continues to increase.

In the period of the middle of eclipse at 16:55 to the third contact at 16:59, Components R, G and B and the average gray F have similar trends and decline rapidly. Components R, G and B, the average gray F and the gray difference relative to that in January 16 all rapidly increase.

In the period of the third contact at 16:59 to the sunset at 17:06, Components R, G and B and the mean gray F changes relatively slow, firstly increase faintly and then decrease slowly. Differences of components R, G and B and the average gray F relative to those in January 16 are relatively stable. This is because the early time of the third contact to the end of eclipse and the sunset have time coincidence. Components R, G and B and the average gray F increase in the period of the third contact to the end of eclipse. The sun gradually disappears under the ground plane in the sunset process which causes components R, G and B and the average gray-scale F gradually decrease.

In the period of sunset at 17:06 to 17:42, components R, G and B and the average gray F all have the similar trend and rapidly decrease. Component R is close to zero earlier than components B and G. Differences of components R and B and the average gray F relative to those in January 16 rapidly increase and have rapid increase to the maximum in 17:15 and then decrease. Clearly, the annular eclipse affects the twilight phenomenon in which the R component is most seriously affected and has the rapid decreasing speed and component B has the slowest reducing speed.

Comparing the gray data change curve and the result of PCA, we can find the results are consistent for the two methods. The annular eclipse can produce a relatively large impact on the three primary color components R, G and B, in which components R and G are more seriously affected and component B is less affected. We can find that component R is most sensitive to the annular eclipse.

CONCLUSION

Color images were took in both directions of the zenith and the zenith distance 30° in January 15 and 16, 2010 while the annular eclipse was present in January 15. Variations of components R, G and B and the average gray are studied by the gray change curve and PCA in the image processing. We compare and analyze the impact of annular eclipse on components R, G and B and the twilight. The results indicate that the annular eclipse produced a relatively large impact on components R, G and B in which components R and G are seriously affected and component B is less affected. Meantime component R is most sensitive to the annular eclipse. The annular eclipse has also affected the twilight phenomenon in which component R rapidly decreases and component B reduces slowly. The annular eclipse with a lag affects the difference of average gray at the same epoch in January 15 and 16. The difference stabilizes at the third contact and the annular eclipse has the maximum impact on the difference at 17:15.

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REFERENCES

Bao, X.M. Z.Y. Zhang, J. Deng, K.L. Hu and W.J. Xuan *et al*., 2009. Near infrared spectral and polarization imaging observation of coronal emission lines during the 2008 total solar eclipse. Sci. China Ser. G: Phys. Mech. Astron., 52: 1794-1798.

Cui, Y., 1997. Digital Image Processing and Applications. Electronic Industry Press, Beijing, China.

Guo, J.Y., 2011. Improved two-dimensional moment method for positioning sub-pixel of CCD star image in digital zenith camera. Acta Geodaetica et Cartograph. Sinica, 40: 679-683.

Han, Y.B. and Q.Y. Qiao, 2009. Records of solar eclipse observations in ancient China. Sci. China Ser. G: Phys. Mech. Astron., 52: 1639-1645.

Han, Y.B., 1999. Records of ancient central solar eclipses in China and variation of the Earth's rotation. Chinese J. Geophys., 42: 18-23.

He, X.Q., 2008. Multistatistics. People's University of China Press, Beijing, China.

He, Y.W. and H.L. Sun, 2001. The acoustic-gravity wave effects of the solar eclipse. Chinese J. Radio Sci., 16: 93-97.

Isaia, I., 2009. Saros cycle in meteorology. Present Environ. Sustainable Dev., 3: 217-224.

Li, W., Q. Li, J. Dun and S. Zhao, 1997. Optical observation of the partial solar eclipse at Kunming on March 9, 1997. Publ. Yunnan Observatory, 4: 91-96.

Liu, Q.X. and T. Jiang, 2003. Technique of obtaining image in the intelligent vehicle plate recognization system. J. Wuhan Univ. Technol., 27: 127-130.

Liu, Y. and H. Lin, 2008. Observational test of coronal magnetic ?eld models: I. Comparison with potential ?eld model. Astrophys. J., 68: 1496-1507.

Wang, Z. and Y.Q. Wang, 1989. The analysis of observation gravitational during the annular solar eclipse. J. Xinjiang Univ., 6: 47-52.

Zhang, P.Y. and Y.B. Han, 1995. The timing solar eclipses recorded in China and the secular changes in the Earth's rotation before the 8th century. Acta Astron. Sinica, 36: 314-320.

Zhang, P.Y. and Y.B. Han, 1996. Variation of the Earth's rotation derived from timing records of solar eclipse in ancient China. Chinese Sci. Bull., 41: 525-526.

Zhao, H.B., H. Lu, G.T. Zhaori, J.S. Yao and Y.H. Ma, 2009. The search for vulcanoids in the 2008 total solar eclipse. Sci. China Ser. G: Phys. Mech. Astron., 52: 1790-1793.

Zhao, J.L., 2008. Basic laws of the solar and lunar eclipse. Chinese J. Nat., 30: 151-155.