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Full Paper

Intensity ratios as derived from the luminosity of the setting Sun: A comparison through photometry principle and Rayleigh theory

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Abstract

We photographed luminosity of the setting Sun at Brahmaputra River by three powerful digital SLR cameras on January 26, 2014 with a view to compare the intensity ratios of the luminosity of the setting Sun using the photometry principle and the Rayleigh scattering theory. The results exhibit a significant deviation in the calculated intensity ratios, suggesting further investigation in this direction.

Key Words

Luminosity; Photometry; Scattering; Blue of the sky.

INTRODUCTION

We photographed luminosity of the setting Sun on January 26, 2014 standing on Brahmaputra River at Guwahati, Assam by monitoring three powerful high resolution digital SLR cameras operated at different angles. The results achieved from the photographic documentations are reported in this paper. Figure 1 shows the photograph of Sunset as viewed from Brahmaputra River, showing that there is a significant change of hour angle with reference to the horizon.

OBSERVATIONAL SITE

A map of Guwahati (26.19^{0}N, 91.73^{0}E), Assam indicating the position of the river Brahmaputra is shown in Figure 2. The location of our observation where we installed the three cameras is also marked in the same Figure.

BACKGROUND

In Maxwell's equations the Mie solution, describes the scattering of electromagnetic radiation by a sphere. The solution takes the form of a systematic infinite problem. The so called Mie theory is ambiguous to some extent because it does not refer to an independent physical theory or law. However, presently, it is also used in broader contexts, for example when discussing solutions of Maxwell's equations for scattering by stratified spheres or by infinite cylinders, or generally when dealing with scattering problems using the exact Maxwell's equations in cases where one can separate for the radial and angular dependence of solutions.

Figure 1 : Photograph of Sunset as viewed from Brahmaputra river on January 26, 2014

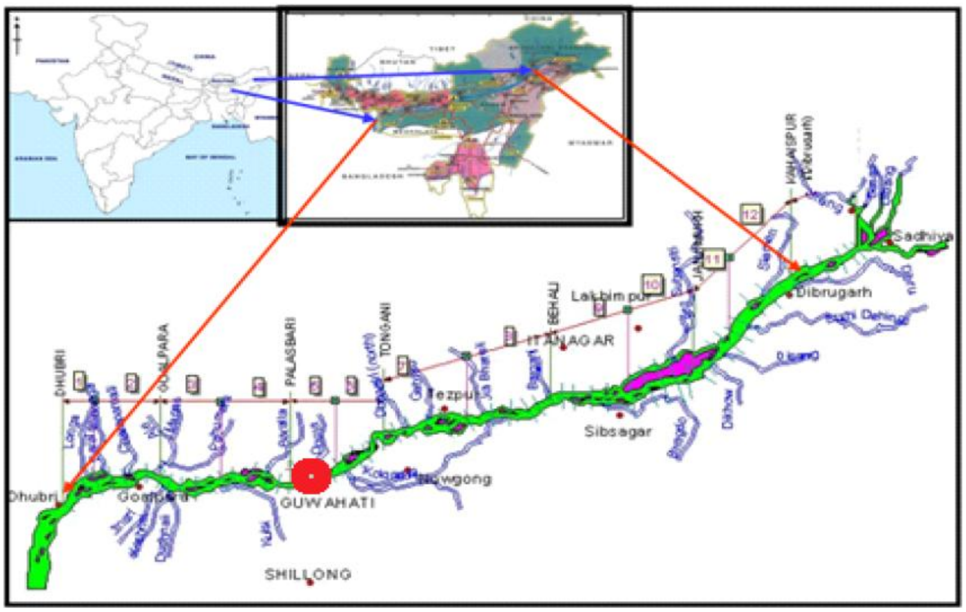

Figure 2 : Map of Guwahati, Assam indicating the position of the river Brahamaputra with the red circle showing the site of observation

TYPE OF CAMERAS USED

We used three very good quality digital cameras of identical type having high resolution and many options of proper recording. The particulars of the cameras used for taking the photographs are given in TABLE 1. The purpose of using the three cameras was to take photograph simultaneously for verifying all the fine points of each individual photograph and also to avoid the risk of missing any important observation due to unavoidable instrumental problem that can be suddenly appeared in course of recording the data.

TABLE 1 : Particulars of the cameras used

Camera maker	Nikon Corporation
Camera model	Nikon D90
F-stop	f/9 to f/5.6
Exposure time	1/320 sec to 1/125 sec
ISO speed	ISO-200
Focal length	105 mm
Max aperture	5

THEORETICAL APPROACH AND RESULT

According to photometric principle, if two sources produce equal illumination on a surface, then the ratio of the luminous intensity of the two sources is equal to the ratio of the square of the respective distances of the two sources from the surface. In course of our observation all the cameras were so adjusted that successive images were taken during sunset to produce equal illumination for all the snaps taken. If I_1 and I_2 are the luminous intensities of the sources corresponding to the illumination intensities E_1 and E_2 respectively and r_1, r_2 are the corresponding distances from the sources then the principle states:

$$\frac{I_1}{r_1^2} = \frac{I_2}{r_2^2} \qquad [\text{Provided}, E1 = E2] \qquad (1)$$

A Schematic diagram illustrating the principle of our observation is presented in Figure 3. In our observational technique during the snaps of the setting Sun the illuminating surfaces were accommodated by adjusting the camera in such a manner that the two surfaces behave as identical illumination.

Taking into account the positions of the Sun at six different altitudes with appearances of six different colors, *viz*., whitish yellow, light yellow, yellow, dark yellow, orange and red respectively in our case, as indicated in the photographic record, we imposed the principle of photometry for calculating the intensity ratios of varying appearances of the Sun with respect to the appearance of the mean color yellow. These intensity ratios we have presented in TABLE 2 in addition to the result as derived by using Rayleigh scattering theory. The results obtained from the comparison are plotted in Figure 4. It is interesting to note from the figure that there is a significant deviation in the calculated intensity ratios when Rayleigh scattering theory[1,2] is implemented in comparison to that obtained by applying the photometric principle.

Our result is supported by the fact that as we go away from whitish yellow to red taking yellow (mean color) as reference, the deviation becomes greater which is more dominant when we go particularly from orange to red. The large deviation exhibited in the data when the theory of Rayleigh scattering is taken into account conclusively pointed out that a careful study of the intensity-wavelength relation as proposed by Rayleigh should be re-examined with further supporting data of both sunrise and sunset hours with reference to different latitudes[3].

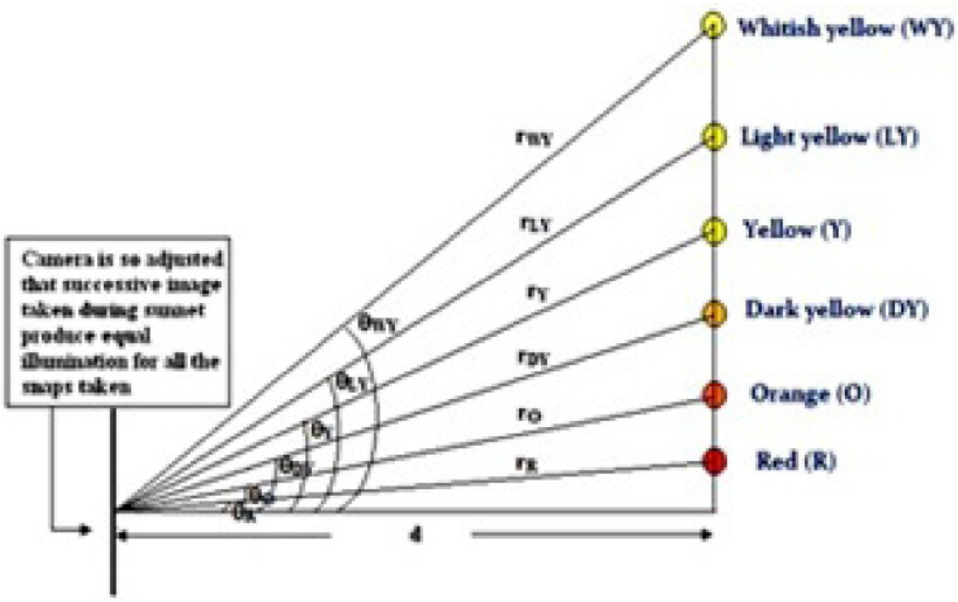

Figure 3 : Schematic diagram showing the principle of observation

TABLE 2 : Recorded visible color of the Sun and the comparison of intensity ratios using the principle of photometry and Rayleigh scattering theory (with respect to yellow)

Color of the last six photographs of sunset	Time (IST)	Altitude angle (°)	Wavelength range (nm)	Average wavelength (nm)	Ratio of different Recorded colors w.r.t. yellow	Intensity ratios corresponding to photographs of the Sun w.r.t. yellow according to	
						Principle of photometry	Rayleigh scattering theory
Whitish yellow (WY)	16:32	20.25	570-590	570	WY:Y	0.991	0.933
Light Yellow (LY)	16:34	19.88	570-590	575	LY:Y	0.995	0.966
Yellow (Y)	16:36	19.5	570-590	580	Y:Y	1.000	1.00
Dark yellow (DY)	16:38	19.13	570-590	590	DY:Y	1.005	1.07
Orange (O)	16:40	18.75	590-620	605	O:Y	1.009	1.18
Red (R)	16:42	18.38	620-750	685	R:Y	1.014	1.94

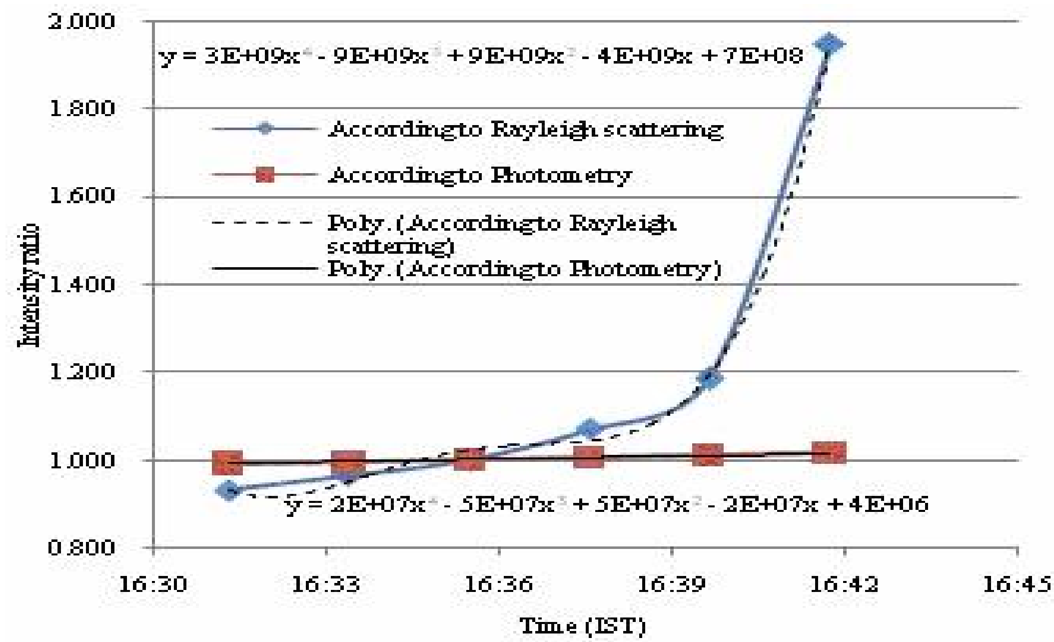

Figure 4 : Plot of intensity ratios with respect to yellow following (a) Rayleigh scattering theory and (b) principle of photometry

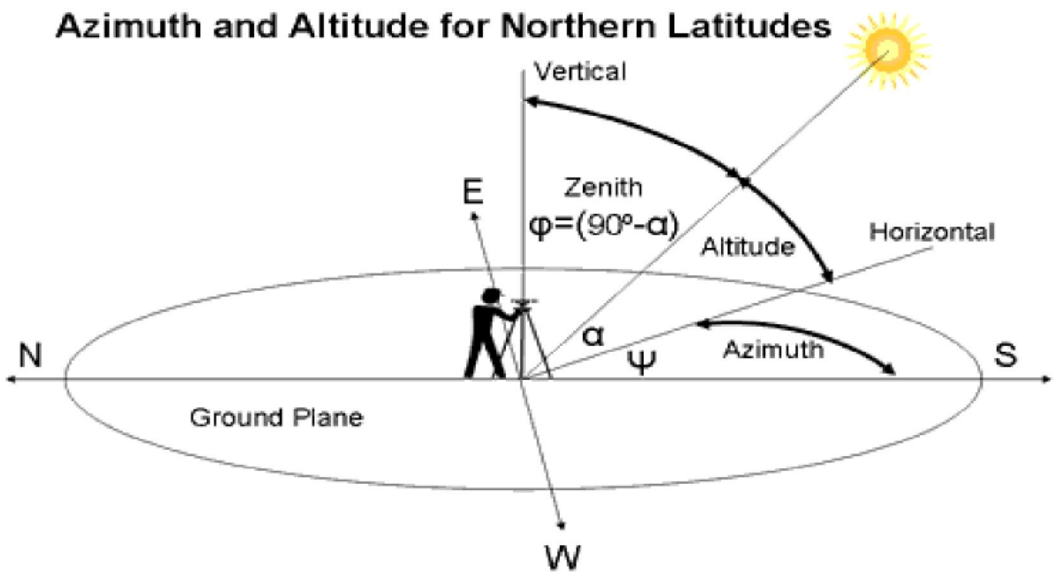

Figure 5 : Schematic diagram for a visibility of azimuths and altitudes for northern hemisphere

Figure 5 shows a schematic diagram for a visibility of azimuth and altitudes for northern hemispheres utilized in our analysis, particularly for calculating the hour-angle.

DISCUSSION

Rayleigh scattering occurs from individual molecules where the scattering is due to the molecular polarizability, which describes the amount of the electrical charges on the molecule for the purpose of moving in an electric field. The amount of Rayleigh scattering from a single particle can usually be expressed as a cross section. As for example, the major constituent of the atmosphere, nitrogen, has a Rayleigh cross section of 5.1×10^{-31} m^2 at a wavelength of 532 nm (green light) which means that at atmospheric pressure, about a fraction 10^{-5} of light will be scattered for every meter of travel. In Figure 6 the greater proportion of blue light scattered by the atmosphere relative to red light has been shown, which clearly indicates that the Rayleigh scattering provides the atmosphere with its blue colour.

The strong wavelength dependence of the scattering ($\sim\lambda^{-4}$) suggests that shorter (blue) wavelengths are scattered more strongly than longer (red) wavelengths. The present findings in the indirect blue light coming from all regions of the sky supports strongly the principle of the scattering phenomena but at the same time revealing some interesting characteristics changes with reference to horizon and hence will be able to provide further information when careful observation of the characteristic variations

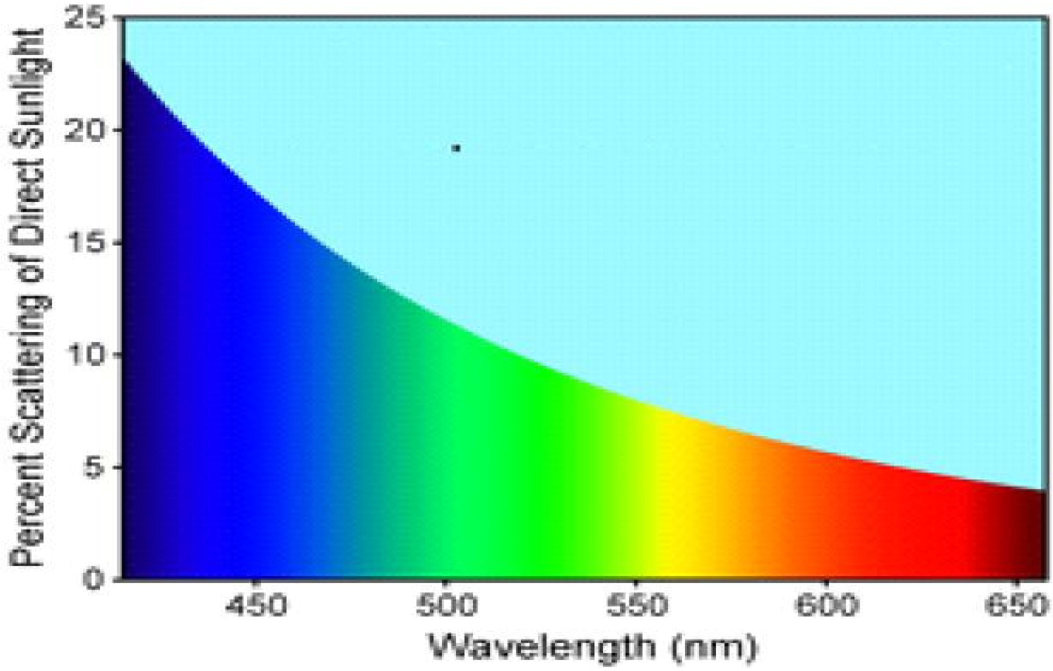

Figure 6 : The greater proportion of blue light scattered by the atmosphere relative to red light

will be taken into consideration. Rayleigh scattering is, in fact, a good approximation of the manner in which light scattering occurs within various media for which scattering particles have a small size parameter. A portion of the beam of light coming from the sun scatters off molecules of gas and other small particles in the atmosphere. Rayleigh scattering basically occurs through sunlight's interaction with randomly located air molecules.

Sun, like any star, has its own spectrum and falls away in the violet. In addition the oxygen in the Earth's atmosphere absorbs wavelengths at the edge of the ultra-violet region of the spectrum. The resulting color, which appears like a pale blue, actually is a mixture of all the scattered colors, mainly blue and green[4,5]. On the other hand, glancing toward the Sun, the colors that were not scattered away, the longer wavelengths such as red and yellow light, are directly visible giving the sun itself a slightly yellowish hue. However, when observed from space, the sky is black and the sun is white.

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