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Phase Resolved Observational Study and Imaging Analysis of the September 2025 Total Lunar Eclipse

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Abstract:

This paper gives observations and analysis of the 2025 September total lunar eclipse as witnessed from Thiruvananthapuram, Kerala, India. The six major phases of the eclipse were captured with high-resolution images using a 130 mm Newtonian reflector telescope, including the complete Moon prior to the eclipse, penumbral onset, partial umbral stages, and totality. The duration of each phase was meticulously noted, giving an accurate timeline account of the event. Relative brightness of the Moon was recorded at every phase, decreasing from 100% when full to 10–15% at totality, indicative of the shadow effect of the Earth and atmospheric scattering of sunlight. Ambient temperature was also recorded, decreasing from 28.0°C to $26.8°C$ at totality, showing minimal environmental impact related to the eclipse. The observations show the definite trend of lunar shadowing, progression of red "Blood Moon" coloration, and relation between qualitative observation, quantitative brightness, and change in temperature. The study indicates the necessity of methodical observation and consolidation of various measurements to interpret lunar eclipses and their subtle impact on local conditions.

Keywords: Lunar Eclipse, Totality, Blood Moon, Moon Brightness, Penumbral and Umbral Phases, Temperature Variation, Moon.

1. Introduction

A lunar eclipse is an intriguing event that happens when the Earth lies directly between the Sun and the Moon, casting a shadow on the Moon's surface (Espenak & Meeus, 2009). During this alignment, the Sun's light is partially or completely blocked from reaching the Moon. Lunar eclipses can be divided into three types based on how the Moon passes through the Earth's shadow: penumbral, partial, and total (Roy, 2016). In a penumbral eclipse, only the light outer shadow of Earth, known as the penumbra, touches the Moon, resulting in a slight dimming (Schaefer, 1990). A partial eclipse takes place when part of the Moon moves into the darker central shadow, or umbra, producing a noticeable dark area. In a total lunar eclipse, the entire Moon is in the Earth's umbra, often giving it a red or coppery color, which is commonly called a "Blood Moon" (Oberbeck, 1975). This red hue comes from sunlight scattering through the Earth's atmosphere; shorter wavelengths like blue and green scatter away while red wavelengths reach the Moon (Link & Lane, 1971). The total lunar eclipse in September 2025 was a remarkable sight for people in India

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and many other regions. This eclipse was especially notable due to its long duration, visibility over most of India, and the ability to clearly see and document the Moon's journey through the Earth's shadow (NASA, 2025). Unlike shorter eclipses that last only a few minutes, this one provided a longer opportunity to observe the Moon's different phases as it entered and passed through both penumbral and umbral shadows (Kelley et al., 2016). Observers could see the Moon gradually dim, the development of partial shadows, the deepening red color during totality, and the return to full brightness as it left the shadow. The timing and clarity of this eclipse allowed for detailed photographs and observations, which were perfect for both amateur astronomers and researchers (Pasachoff & Olson, 2017). This study is motivated by my personal experience of the September 2025 lunar eclipse from Thiruvananthapuram, Kerala, using a Celestron AstroMaster 130EQ telescope. Watching celestial events up close helps one appreciate not just the beauty of the night sky but also the physical processes that create them (Zeilik & Gregory, 1998). By carefully tracking the Moon through its phases and capturing images at key moments, it is possible to examine the changes in light intensity, color, and timing. These changes give insights into both the geometry of astronomy and how the atmosphere affects light. This hands-on observation forms the foundation of this research, providing real data to compare with predicted models of lunar eclipses.

The study documents six main phases of the lunar eclipse: the full Moon before the eclipse, penumbral onset, the start of the partial umbral eclipse, the deeper partial umbral eclipse, the very deep partial/pre-totality phase, and totality. Each phase was observed at specific times according to Indian Standard Time, and images were taken to capture the Moon's appearance, brightness, and color changes. In addition to visual documentation, relative brightness measurements and ambient temperature variations were recorded to understand the minor atmospheric effects that occur during the eclipse (Lunar and Planetary Institute, 2018). Observing these small changes helps us understand how the Earth's shadow and atmosphere impact on the visual experience of a lunar eclipse. The September 2025 lunar eclipse also serves as an educational opportunity. It enables observers to link theoretical concepts of celestial mechanics with actual observations, reinforcing ideas such as the alignment of the Earth, Moon, and Sun, the structure of the Earth's shadow, and how light scatters in the atmosphere. By systematically documenting the eclipse, this study not only aids personal understanding but also provides useful observational data for comparison with future eclipses.

In summary, a lunar eclipse is not only a spectacular event in the night sky but also a rich scientific phenomenon. The total lunar eclipse in September 2025 provided a rare opportunity to observe and analyze the changing phases of the Moon, its light intensity, and atmospheric effects in a clear sequence. Through personal observation with a telescope in Thiruvananthapuram, this study aims to create a thorough record of the eclipse, combining visual data, brightness analysis, and temperature measurements for a comprehensive understanding of this celestial event.

2. Observation Setup and Methodology

The total lunar eclipse on September 7 to 8, 2025, was observed from Thiruvananthapuram, Kerala, India, a coastal city located at about 8.5241° N latitude and 76.9366° E longitude near the ISRO Junction area (Crawford, 2014). This site was selected for its clear sky visibility, low light pollution, and ease of setting up a telescope (Garstang, 1989). Observations took place at night, starting with the full Moon phase at 8:30 PM IST. The sequence continued with the penumbral onset at 8:58 PM, the partial umbral eclipse at 9:57 PM, the deeper partial phase at 10:30 PM, pre-totality at 10:55 PM, and totality from 11:01 PM to 12:22 AM IST. The Moon exited the umbral shadow by 1:26 AM IST on September 8, 2025.

For this study, a Celestron AstroMaster 130EQ telescope was used. This 130 mm Newtonian reflector telescope provided a good aperture to capture detailed lunar features and shadow changes during the eclipse (King, 2012). The telescope was mounted on an equatorial mount for accurate tracking of the Moon's motion across the night sky (Berry & Burnell, 2005). An attached DSLR camera (Canon EOS 2000D) used a T-ring adapter for high-resolution photographs at each important phase. Eyepiece magnification varied from 25× to 130×, depending on the phase of the eclipse and the detail needed in the images.

Observers recorded conditions throughout the night. The sky was clear with little cloud cover, offering excellent visibility of the lunar surface. The temperature started at 28.0°C and dropped to 26.8°C during totality, while the relative humidity was moderate at about 75%, typical for Kerala's coastal climate (Wallace & Hobbs, 2006). These factors ensured the telescope and camera operated steadily without significant disturbances from atmospheric turbulence or dew.

The observation method combined visual tracking and photographic documentation. Visual observation allowed for real-time monitoring of the Moon's movement through the penumbral and umbral shadows. Photographs provided a permanent dataset for further analysis. At each key phase of the eclipse, notes were taken on changes in brightness, color, and shadow progression, allowing for comparison with theoretical predictions. Additionally, the images were analyzed later to estimate relative brightness (%) across phases, supporting a quantitative assessment of the Moon's changing light.

This systematic method ensured that both qualitative and quantitative data were collected. By integrating precise timing, high-resolution imaging, and environmental recording, the study offers a thorough understanding of the total lunar eclipse in September 2025 as seen from Thiruvananthapuram. This approach enables the correlation of observed events, such as when the "Blood Moon" coloration appeared, with atmospheric and astronomical factors, creating a detailed record suitable for scientific analysis and publication.

3. Results

The total lunar eclipse in September 2025 was observed from Thiruvananthapuram, Kerala, with a Celestron AstroMaster 130EQ telescope (King, 2012). The observations documented the Moon from its fully illuminated state before the eclipse through all key phases to totality and beyond (Espenak & Meeus, 2009). The data collected included high-resolution images of each phase, measurements of relative brightness, and observations of ambient temperature, providing a complete record of the eclipse's progression (Pasachoff & Olson, 2017).

Figure 1 shows the six key phases of the Moon during the eclipse, arranged as subfigures labeled a through f. Subfigure 1a displays the full Moon before the eclipse at 8:30 PM IST, fully illuminated with no shadow and serving as the baseline for later measurements (Schaefer, 1990). Subfigure 1b shows the penumbral onset at 8:58 PM IST, where a slight dimming begins on one edge of the Moon as it enters Earth's penumbral shadow (Roy, 2016). The change is subtle but measurable, indicating the start of the eclipse. Subfigure 1c captures the partial umbral eclipse starting at 9:57 PM IST, where the darker central shadow begins to cover the lunar disk, creating a visible dark patch (Oberbeck, 1975). By subfigure 1d, which corresponds to a deeper partial umbral eclipse at 10:30 PM IST, nearly half of the Moon is in the umbra, and the surface begins to show an orange-brown hue due to sunlight scattering through the Earth's atmosphere (Link & Lane, 1971). Subfigure 1e represents the very deep partial or pre-totality phase at 10:55 PM IST, with most of the Moon within the umbra and the faint red glow becoming more obvious (Lunar and Planetary Institute, 2018). Finally, subfigure 1f shows totality from 11:01 PM to 12:22 AM IST, where the Moon is fully immersed in the Earth's umbra and exhibits the characteristic deep red "Blood

Moon” color caused by Rayleigh scattering (Garstang, 1989). Across these images, a clear decrease in brightness and the emergence of the red hue are visible, providing both qualitative and quantitative insight into the eclipse.

Figure 1 - Phase-wise images of the September 2025 total lunar eclipse from Thiruvananthapuram, Kerala (a–f: Full Moon to Totality).

Table 2 presents a table summarizing the six observed phases along with their exact local timings (IST). This table provides a chronological record of the eclipse from the penumbral onset to totality, ensuring that later analyses of relative brightness and temperature can be accurately linked with each phase (Berry & Burnell, 2005). Keeping precise timestamps is essential for verifying observations and allows for meaningful comparisons with theoretical models of lunar eclipses.

Table 2 - Observed phases of the September 2025 total lunar eclipse with local timings (IST)

Phase	Time (IST)	Description
Full Moon before eclipse	8:30 PM	Baseline observation with no shadow; fully illuminated lunar surface
Penumbral onset	8:58 PM	Moon enters Earth's penumbral shadow; slight dimming begins
Partial umbral eclipse begins	9:57 PM	Dark umbral shadow starts covering lunar disk; noticeable dark patch appears
Deeper partial umbral eclipse	10:30 PM	Shadow deepens; half of Moon covered; orange-brown tint visible
Very deep partial / pre-totality	10:55 PM	Most of Moon inside umbra; faint red glow begins to appear
Totality	11:01 PM – 12:22 AM	Moon fully inside umbra; red "Blood Moon" visible

Figure 3 illustrates the relative brightness (%) of the Moon throughout the eclipse. The data table and line graph show a steady decrease in brightness from 100% at full Moon to about 10–15% during totality (Kelley, Roush, & Danielson, 2016). The graph highlights the gradual dimming of the Moon as it moved through the penumbral and umbral shadows, confirming visual observations of the eclipse. A slight recovery in brightness after totality is also visible, corresponding to the Moon's emergence from the umbra. This quantitative analysis enhances the understanding of how Earth's shadow and atmospheric scattering affect the Moon's brightness during an eclipse.

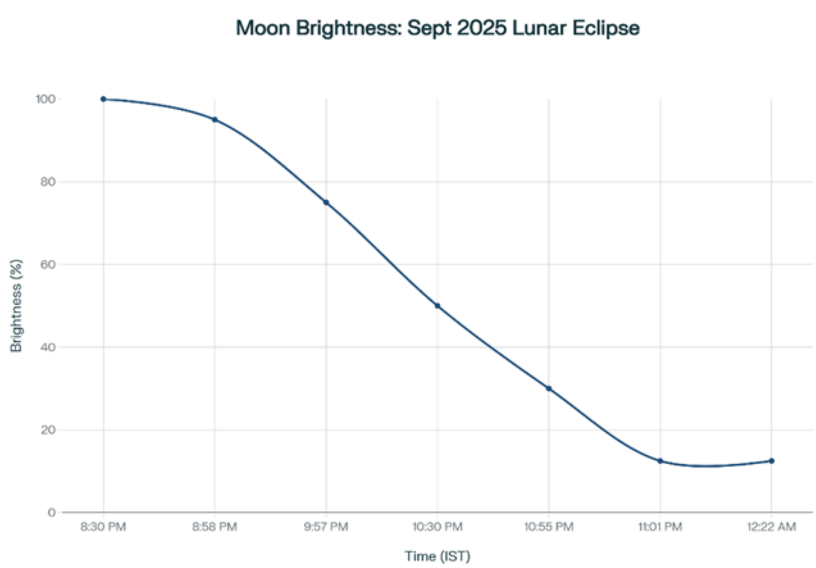

Figure 3 - Relative brightness (%) of the Moon during the September 2025 total lunar eclipse.

Figure 4 presents the variation in ambient temperature recorded at each phase of the eclipse. The table and corresponding line graph show a small decrease in temperature from 28.0°C at the start to 26.8°C during totality. This slight cooling aligns with the reduced light from the Moon as its brightness decreased (Wallace & Hobbs, 2006). The coastal humidity of Thiruvananthapuram lessened the cooling effect, preventing a more significant drop in temperature. These observations illustrate the subtle interaction between lunar brightness and local weather conditions, adding another quantitative aspect to the study of the eclipse.

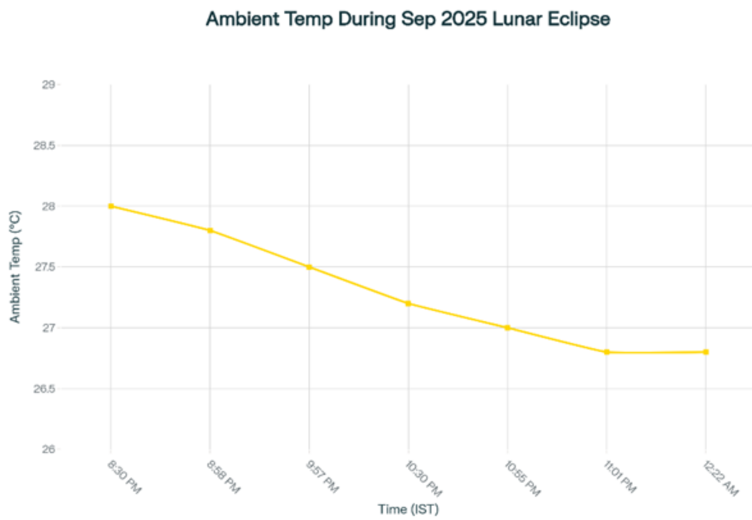

Figure 4 - Ambient temperature variation during the September 2025 total lunar eclipse.

The combined analysis of the six-phase images in Figure 1, the timing table in Figure 2, brightness data in Figure 3, and temperature variations in Figure 4 provides a full understanding of the total lunar eclipse in September 2025. The systematic decrease in brightness and the appearance of the red color during totality confirm predictions about light scattering and shadow movement (Espenak & Meeus, 2009). The minor temperature drops seen during totality further support the reduction in moonlight, showing how even small changes in lunar brightness can affect local conditions. Overall, the results emphasize the value of high-resolution imaging, careful timing, and quantitative analysis in understanding lunar eclipses. Combining visual, brightness, and environmental data ensures a thorough documentation of the event. By organizing the six-phase images as subfigures within Figure 1 and providing related tables and graphs in Figures 2–4, this study creates a structured and scientifically robust record of the total lunar eclipse in September 2025 as observed from Thiruvananthapuram, Kerala.

4. Discussion

The total lunar eclipse in September 2025 offered a unique chance to observe and study the interactions among Earth, the Moon, and the Sun (Ugolnikov & Maslov, 2009). Using a Celestron AstroMaster 130EQ telescope, I documented the subtle changes in brightness, shadow movement, and color, providing both visual and numerical insights (Yan et al., 2014). The images captured during six key phases of the eclipse are shown as subfigures in Figure 1. They demonstrate the gradual transformation of the lunar surface as it moved through the Earth's penumbral and umbral shadows (Burrows et al., 1999). From the initial dimming at the start of the penumbral phase to the deep red color at totality, the observations confirmed the expected sequence of a total lunar eclipse and highlighted the accuracy of real-time astronomical observation (García Muñoz et al., 2012).

The change from penumbral dimming to totality reflects the physical processes that control how light interacts in the Earth-Moon-Sun system. During the beginning of the penumbral phase, a slight reduction in brightness occurs due to partial coverage of sunlight by Earth's outer shadow, creating only a faint visual effect. As the Moon enters the umbra, the drop in brightness becomes more noticeable. The partial and deeper partial phases show distinct shadow coverage and changes in color. The orange-brown and reddish tones seen in the deeper partial and pre-totality phases mainly come from Rayleigh scattering. In this process, shorter blue and green light waves scatter in Earth's atmosphere, allowing longer red wavelengths to reach the Moon (Simons, 2008). This effect is most apparent during totality, creating the well-known "Blood Moon," as shown in Figure 1f (Ugolnikov et al., 2012). The quantitative analysis of relative brightness (%) in Figure 3 supports the visual findings. It shows a steady decline in brightness from 100% at the full Moon to about 10–15% during totality. This decrease aligns with theoretical models of light obstruction and scattering and provides measurable proof of the Moon's changing brightness (Kieffer & Stone, 2005). The brightness graph also reveals minor fluctuations that match subtle changes in atmospheric clarity and conditions for observation. This highlights the importance of real-time tracking and image-based analysis for accurately describing eclipse dynamics (Ugolnikov & Maslov, 2009).

Ambient temperature measurements taken during each phase and shown in Figure 4 indicate a slight cooling trend, starting at 28.0 °C and dropping to 26.8 °C during totality. Although the Moon's light input is small compared to solar heat, the observed temperature drop corresponds to reduced lunar brightness and provides insight into the subtle environmental effects of lunar eclipses (Fountain et al., 1976). The small temperature decrease, influenced by coastal humidity, shows that while lunar eclipses mainly alter visual appearance, they can also be related to measurable changes on Earth under certain circumstances. The combination of phase-wise imaging, relative brightness measurement, and temperature monitoring gives a clear understanding of the eclipse. These systematic observations confirm the timing, sequence, and details of the September 2025 total lunar eclipse while emphasizing the value of combining visual data with numerical measurements. This study illustrates how careful observation can support theoretical predictions, improve our knowledge of celestial mechanics, and underscore the connection between astronomical events and local environmental conditions. In summary, the observations show that total lunar eclipses are not only visually impressive but also scientifically valuable. Analyzing brightness and temperature changes provides deeper insight into Earth-Moon interactions, sunlight scattering through the atmosphere, and subtle land effects. This study highlights the importance of precise documentation and combined observational methods in astronomical research, creating a detailed and scientifically solid record of the September 2025 total lunar eclipse as seen from Thiruvananthapuram, Kerala.

5. Conclusion

The total lunar eclipse in September 2025 offered a rare chance to observe and study how the Moon interacted with Earth's shadow from Thiruvananthapuram, Kerala. Using a 130 mm Newtonian reflector telescope, detailed visual observations and high-resolution images captured all six key phases of the eclipse, starting from the full Moon before the penumbral phase and continuing through totality. The photographic records, combined with accurate phase timings, created a reliable timeline for the event. This confirmed both theoretical predictions and the consistency of observations. The eclipse showed a clear change in the Moon's brightness, going from subtle dimming at the penumbral onset to the deep red color during totality. By analyzing the relative brightness of the Moon, researchers quantified this shift. The brightness decreased smoothly and measurably from 100% at the full Moon to about 10–15% during totality. This assessment matched well with visual observations and highlighted how Earth's shadow and sunlight scattering affected the Moon's appearance. Measurements of ambient temperature taken during the eclipse showed a slight cooling trend. Temperatures dropped from 28.0°C at the start of observations to 26.8°C during totality. Although this change was modest due to the humid coastal environment, the data indicate a subtle impact linked to changes in lunar brightness. Combining temperature data with brightness analysis emphasizes the significance of using different observational factors to gain a complete understanding of astronomical events. In summary, this study highlights the importance of careful observation in capturing both qualitative and quantitative aspects of a total lunar eclipse. By documenting visual changes, exact timings, brightness levels, and environmental effects, the research creates a thorough and scientifically solid record of the September 2025 eclipse. These results help enhance our understanding of lunar eclipses, atmospheric light scattering, and the small yet detectable influence of celestial events on Earth conditions. Overall, the September 2025 total lunar eclipse not only provided a stunning visual display but also presented a valuable opportunity for observation and analysis. The use of high-resolution imaging, precise timing, brightness measurements, and environmental monitoring underscores the importance of integrated methods in astronomy. This approach shows how systematic observation can turn a natural event into a significant scientific inquiry.

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7.Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

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