

The Impact of Light Pollution on the Visibility of Constellations and Its Implications for Astronomical Learning

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Article Info	ABSTRACT
<p>Article History Received 20-11-2025 Revision 15-12-2025 Accepted 25-12-2025</p> <p>Keywords: Light Pollution Constellation Visibility Astronomy</p>	<p>Light pollution has become a major challenge for astronomical observation in urban areas, significantly affecting the visibility of constellations, which are essential tools in astronomy education and Islamic astronomical practices. This study aims to analyze the extent to which increasing night sky brightness affects constellation visibility and its implications for learning celestial navigation, timekeeping, and sky orientation. The research employs a qualitative-descriptive method through a literature review, analysis of night-sky brightness data from SQM measurements at several observational sites, and examination of visual documentation of constellation patterns. Relevant ethnoastronomical literature, indigenous star-lore records, and modern astronomical data were categorized and compared using sky simulation software to validate star positions under varying levels of skyglow. The results show that elevated artificial light at night significantly reduces the visibility of faint stars, rendering iconic constellations such as Orion, Scorpius, and Crux partially or fully unrecognizable in highly polluted skies. This decline directly disrupts observational-based astronomy learning, particularly in identifying stellar azimuths, seasonal markers, and basic sky mapping skills. The study highlights the need for mitigation strategies such as selecting darker observation sites, enhancing sky literacy using digital simulations, and integrating ethnoastronomical perspectives to strengthen contextual learning. These findings reinforce the urgency of preserving dark skies as an educational "laboratory" and emphasize the relevance of local sky knowledge in enriching Islamic astronomy education.</p> <p style="text-align: right;">This is an open-access article under the CC-BY-SA license.</p>

I. Introduction

Constellations/asterisms are a fundamental element of celestial observation and of astronomical education. In the astral tradition, constellations are used for orienting the sky (e.g., determining the direction of the south with the Crux), as markers of the seasons, and as a practical learning tool for understanding the coordinates of the sky (azimuth, declination) [1]. However, in recent decades, the quality of the night sky, used as a "laboratory" for astronomy education, has declined due to the increase in artificial light at night (ALAN), which causes skyglow and reduced star-dark visibility. This phenomenon reduces the number of stars visible to the naked eye and alters the appearance of the asterism, which has served as a reference for learning [2].

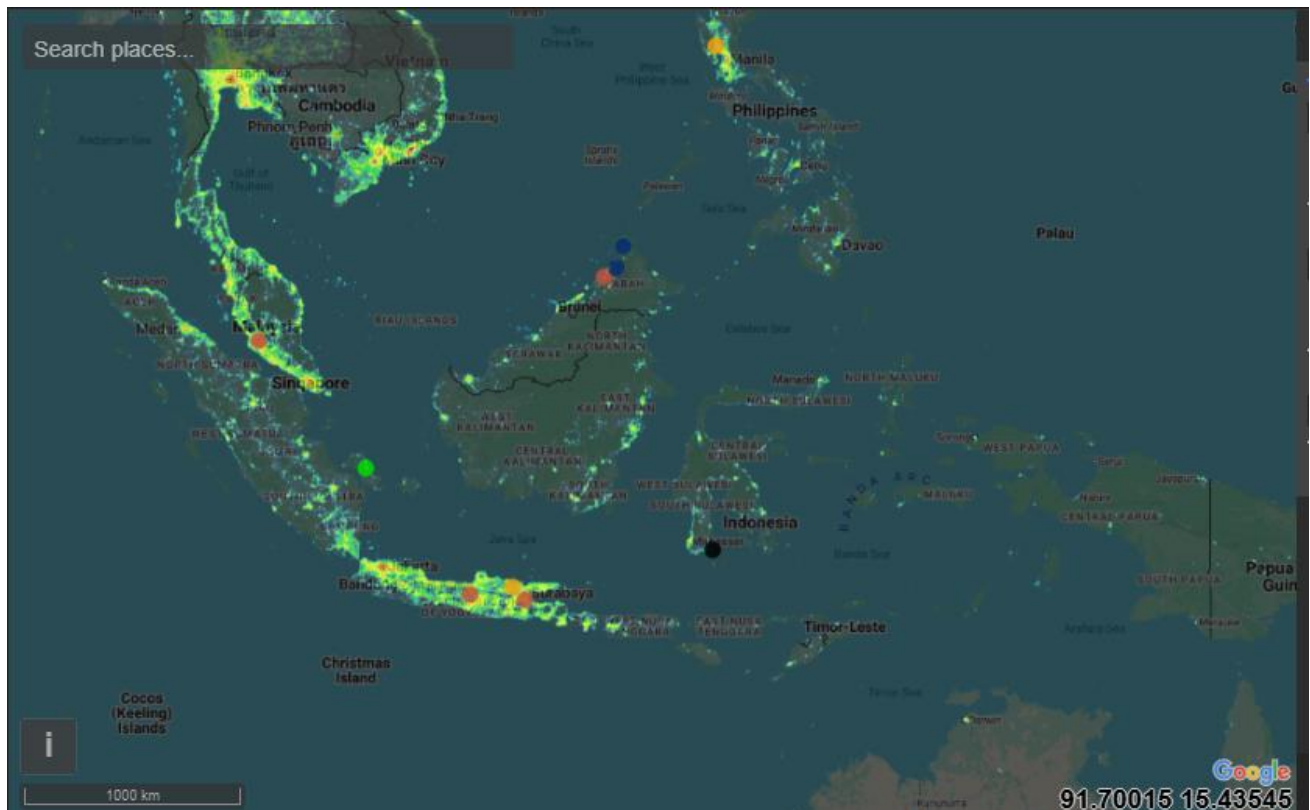


Figure 1. Light pollution in Indonesia from VIIRS 2024

Measurement and monitoring of night sky brightness (NSB) have developed rapidly; instruments such as the Sky Quality Meter (SQM) [3], all-sky camera [4], and photometer [5] use multispectral imaging methods to quantify NSB and skyglow [6]. However, simple devices such as the SQM, while popular, have spectral and viewing-angle limitations that need to be understood when interpreting data, especially as lighting technology evolves and

shifts the spectrum of emitted light, affecting instrument readings [5]. Therefore, the study of measurement and correction methods is particularly relevant for studies that associate quantitative NSB data with constellation visibility [7].

Globally, citizen science data and monitoring networks show an increasing trend in sky brightness over the past decade – a large study based on ~51,000 observational citizen scientists reported a sharp decline in star visibility (equivalent to an average annual NSB increase of $\approx 7\text{--}10\%$ in the period 2011–2022), which has direct implications for public access to star-studded skies and observation-based educational activities [8]. This trend underscores the urgency of studying how light pollution affects the practical aspects of astronomy/astronomy learning.

In addition, nightlight metrology researchers propose new indicators and statistical techniques to make more robust spatial and temporal comparisons, such as the NSB Dispersion Ratio, because single measurements are often affected by meteorological conditions, galaxy position, and sensor drift, as well as factors that must be controlled when using data to quantitatively assess the visibility of constellations [9]. It is important when the purpose of the research is to correlate formal NSB values (mag/arcsec² or radiance conversion) with the ability to identify constellation patterns in the field for educational purposes [10].



Figure 2. Stellar Visibility at Locations with Different Sky Brightness

In the Indonesian context, several local monitoring studies, such as measurements at the Bosscha observatory and other regional studies, show significant variations in NSB between urban, suburban, and highland locations [11]. These results show that important constellations (such as Orion, Scorpius, and Crux) can experience degradation in visibility at many astronomical learning acquisition sites in large cities. Therefore, studies that examine the relationship between NSB measurements (SQM/satellite imagery/camera) and the ability to observe constellations in the field are highly relevant for developing educational and mitigation recommendations [12].

Based on the description above, this study aims to (i) quantify the influence of light pollution on the visibility of constellations that are often used in astronomy learning, (ii) identify the most affected constellations in the Indonesian urban environment, and (iii) formulate practical learning recommendations (location, observation techniques, and integration of digital tools) so that astronomy learning remains effective even in the midst of an increase in ALAN. The research gap to be closed is the lack of a measurable relationship between the values of NSB (SQM/VIIRS/all-sky imaging) and the success rate of constellation pattern recognition by students/beginners in real conditions (not just simulations).

II. Method

This study uses a qualitative-descriptive approach, focusing on the analysis of ethnoastronomical literature and its integration with basic astronomy concepts. The study began with the collection of primary and secondary sources, including scientific articles, Indonesian ethnoastronomy books, results of celestial anthropology research, and a database of traditional constellations of the archipelago published in the last 10 years. Literature data were selected based on relevance, publisher credibility, and relevance to the topic of cultural relations between the sky and astronomy. Furthermore, a data categorization process was carried out to identify constellation naming patterns, symbolic meanings, practical navigation functions, seasons, and timing, according to the selected indigenous peoples (e.g., Bugis, Dayak, or Sasak tribes).

The analysis used content analysis to identify conceptual similarities between traditional astronomical knowledge and parameters such as star position, azimuth, declination, and sunrise and sunset times. The ethnoastronomical data were then compared with modern astronomical data using sky-simulation software (e.g., Stellarium) to verify the positions of the constellations and their connections to celestial phenomena used by the community as time markers. Conceptual validation was carried out by comparing the results of cultural interpretation with contemporary astronomical theory to see the potential integration of the two in the context of Islamic astronomy education. The final results of the research are presented in a comprehensive narrative that explains the position of traditional constellations in the modern astronomy landscape and their potential for enhancing celestial literacy among Muslim communities.

III. Results and Discussion

In general, the study's results show that the knowledge of constellations among the indigenous peoples of Indonesia not only serves as a mythological element or cultural symbol, but also provides a basis for astronomical observation that can be integrated with modern astronomical concepts [13]. Literature analysis, verification of star positions through sky simulations, and examination of cultural contexts indicate that traditional constellation systems are coherent with scientifically measured celestial phenomena. Thus, the discussion in this section is directed to show how traditional constellations can be remapped within the framework of ethnoastronomy and then linked to contemporary astronomical parameters. In addition, this study situates the process of observing the sky carried out by indigenous peoples within the human response to the signs of Allah's greatness (kauniyah verse), thereby enriching the perspective of Islamic astronomy education. The following description provides an overview of the characteristics of traditional constellations, their relevance in astronomy, and their epistemological implications for strengthening Islamic astronomical literacy.

3.1 Identification of Traditional Constellations and Their Functions in Timing

The results of the literature review and verification of sky positions show strong consistency between traditional constellation knowledge in the archipelago and astronomical patterns measurable in modern ways. Many coastal and agricultural communities in Indonesia use a specific group of stars (asterisms) as an annual time marker, for example the use of the Pleiades (known locally as Rowot, Rurut, or equivalent) [14] and the Orion formation (known as Waluku, Tenggale, or other local variations) to mark the beginning of the growing season, rainy season, or important phases in the local agricultural calendar [15]. Verification of the position of the stars with sky simulation software (e.g., Stellarium) on the geographic coordinates of the study site confirms the temporal correspondence between traditional reports and astronomical events such as the heliacal rising time of the Pleiades adjacent to the beginning of the growing season in some regions of Lombok, Sulawesi, and Java. Field research and modern ethnographic studies have also identified local names for star patterns that correspond to Western constellations or asterisms (e.g., Tenggale → Orion; Rowot → Pleiades), as well as their practical functions, such as indicators of seasonal changes, time markers for sailing, and local directions. These findings are supported by case studies in the Mandar and Sulawesi communities that document navigation patterns based on local star formations [14].

Functionally, the traditional constellation performs roles that are parallel to instruments and concepts in astronomy: (a) orientation (determining azimuth/direction), (b) time marker (through the phenomenon of heliacal rising/setting), and (c) learning sky maps for the younger generation. For example, bright star clusters are used as an azimuth reference on a night without the Moon; patterns that appear just before dawn are used to plan agricultural activities; Meanwhile, the patterns seen throughout the night are an orientation learning material for traditional sailors. Because its empirical basis is repeated observations throughout the year, this knowledge can be mapped into astronomical terminology such as declination, altitude, and sidereal time for formal and informal educational purposes. Modern ethnoastronomical studies recommend using these terminological equivalents to facilitate integration into the astronomy curriculum.

Nevertheless, important local variations must be considered before adopting traditional constellations into modern astronomical teaching. The name, scope of the star in an asterism, and its practical function are often influenced by local latitude, topographic horizon, and cultural practices, so that one asterism that is useful in one community may have different meanings or times of appearance in another. Therefore, local astronomical verification using simulations or field measurements is a mandatory step before educational integration. This context is also relevant when considering the impact of light pollution: the decrease in visibility of faint stars makes some asterism components no longer observable in urban areas [16], thereby reducing the effectiveness of traditional constellations as a teaching tool without mitigation. The findings of a decrease in the number of visible stars and an acceleration in the increase in skyglow underscore the urgency of these mitigation measures [17].

3.2 Integration of Ethnoastronomical Concepts with Contemporary Astronomy

The results of the analysis show that knowledge of the archipelago's traditional constellations aligns closely with the basic principles of modern astronomy. The traditional observation system of indigenous peoples is based on repeated observations of the rising and setting patterns of stars, shifting seasonal constellations, and the relationship of star positions to agricultural, maritime, and religious ritual activities. The mechanism is functionally identical to modern astronomical parameters such as azimuth, altitude, declination, sidereal time, and heliacal rising and setting, which form the foundation for measuring time and direction in astronomy [18].

Recent ethnoastronomical studies confirm that traditional societies across the world use methods of sky observation that are empirically equivalent to positional astronomy, albeit without modern instrumentation [13]. In Indonesia, for example, the appearance of the Pleiades before dawn has long been used by the Bugis, Sasak, Mandar, Dayak, and other agrarian communities to mark the onset of the planting or rainy season. In modern astronomy, this phenomenon is called heliacal rising, the first appearance of a star on the eastern horizon after a period of solar conjunction. Consistency between cultural records and astronomical data suggests that indigenous constellations result from systematic observations that can be remapped within contemporary astronomical frameworks [19].

The integration of these two approaches is most evident when traditional constellation knowledge is mapped into modern sky-coordinate systems. For example, the Tenggara or Waluku (Orion) asterism can be analyzed using equatorial coordinates to examine its position throughout the year [15]. Orion's apparent annual motion, seen shifting from east to west at rapid sunset at the end of the rainy season, provides an astronomical explanation for the agricultural traditions of Java and Lombok, which attribute it to changes in the agricultural seasons. The combination of cultural narratives with altitude-azimuth diagrams or Stellarium simulations makes astronomy teaching more contextual and easier to understand, especially for the non-academic community [20].

Some studies in astronomical education have also shown that the ethnoastronomy approach can enhance the effectiveness of learning basic astronomy concepts by connecting celestial phenomena with students' cultural identities [21]. In the context of astronomy, this approach can help understand the direction of the star-based qibla, prayer times based on changes in dawn and dusk, the determination of the season of the rukyat hilal, and the beginning of the night through the appearance of certain stars. In addition, integrating traditional constellations can enrich the discourse on Islamic astronomy by presenting the local perspective of the archipelago, which has been underrepresented in classical astronomical literature [22].

However, this integration is not without its challenges. Factors such as light pollution, changes in the local horizon due to urbanization, loss of oral traditions, and the incompatibility of some constellations with the modern IAU constellation are obstacles in the remapping process. Global studies show that star visibility has decreased significantly over the last 10 years, so that some traditional constellations are no longer visible in major cities [8]. This condition requires the use of technologies such as digital planetarium simulations, dark-sky photography, and digital calibration devices to maintain observation accuracy.

Overall, the results of this study show that integrating ethnoastronomy and modern astronomy not only harmonizes Science and culture but also opens up new space for the teaching of Islamic astronomy that is more inclusive, relevant, and contextual to the archipelago's sky.

3.3 The Qur'an's Perspective on the Stars as A Guide to Time and Direction

Data analysis shows that the function of traditional constellations among the indigenous peoples of the archipelago aligns with the basic concept of Islamic astronomy as stated in the Qur'an. In religious texts, the star is not only a visual phenomenon but also an instrument of knowledge that serves as a guide (hudan), an indicator of time, and evidence of the regularity of the cosmos, reflecting the greatness of God. This perspective provides an epistemological basis for understanding that the observation of the stars by indigenous peoples is not a purely mystical practice but part of the human response to the "kauniyah verses" mandated as a means of tadabbur and the regulation of life.

The first verse that explicitly contains the function of the star is QS. Al-An'am [6]:97:

وَهُوَ الَّذِي جَعَلَ لَكُمُ النُّجُومَ لِتَهْتَدُوا بِهَا فِي ظُلُمَاتِ الْبَرِّ وَالْبَحْرِ قَدْ فَصَّلْنَا الْآيَاتِ لِقَوْمٍ يَعْلَمُونَ

"And it is He who made the stars for you to make them a guide in the darkness of the land and the sea."

This verse emphasizes that the use of stars for navigation is a universal decree that applies to any society, whether Bugis sailors who read Bintocéng Balubu as a determinant of navigation direction or the Dayak people who use the formation of the Rangka Star as a marker of the transition of seasons. This navigational function is consistent with contemporary research findings that traditional seafaring societies relied on bright stars as an azimuth reference during night sailing, as explained by Pimenta in a study of astronomical navigation [23].

The second verse that strengthens the dimension of time markers is found in QS. An-Nahl [16]:16:

وَعَلَّمْتِ بِالنَّجْمِ هُمْ يَهْتَدُونَ

"And (He created) signs (guides), and with the stars they got guidance."

The expression "signs" ('addresses) in modern interpretation is understood as a natural phenomenon that functions to provide a structure of time and direction, so that it can be harmonized with the concept of the heliacal rising Pleiades used by the agricultural societies of Southeast Asia to mark the beginning of the rainy season, as supported by regional

ethnoastronomical research [19]. Thus, the traditional constellation, even though it is locally named, still serves as an 'address (marker) in the Qur'anic sense.

Some recent research in cultural astronomy views this phenomenon as a form of "observation-based scientific rule" that develops within local cultures [23]. This knowledge is often not mathematically structured like classical astronomy, but remains based on repeated observation, collective verification, and intergenerational transmission. Therefore, the integration between traditional constellations and modern astronomy can be understood as an effort to unite two epistemic traditions: the observational-cultural tradition and the scientific-mathematical tradition.

In the context of contemporary Islamic astronomy, the understanding of stars as *kauniyah verses* has practical implications for the development of astronomical literacy [24]. Traditional constellations can strengthen the learning of star-based qibla direction, especially in remote areas with limited infrastructure, by using bright star patterns as azimuth references. Similarly, the rhythm of the dawn color change, juxtaposed with the appearance of certain stars, can help educate the public about the concepts of Fajr and Isha based on the phenomenon of sky light. Studies in astronomy education have also shown that using cultural and religious approaches improves people's ability to understand abstract astronomical concepts [25].

In addition, the Qur'an's perspective provides a spiritual dimension that cannot be attained through a purely technical approach. Traditional constellation observation is not only an empirical activity but also a practice of *tafakkur* in harmony with the Qur'an's call to pay attention to the sky and its arrangement. It confirms that the integration of ethnoastronomy and astronomy is not merely a merger of two disciplines, but a strengthening of man's relationship with the sky as a sign of the Creator's greatness.

IV. Conclusion

This study shows that traditional constellations that develop across various indigenous communities in Indonesia have astronomical value that can be accounted for and integrated into the framework of modern astronomy. Through an ethnoastronomical approach, the constellations are no longer seen only as cultural or mythological symbols, but as

representations of people's observational experiences of the night sky. Analysis of constellation patterns, time of occurrence, and their correlation with cyclic phenomena such as planting seasons and weather changes showed accuracy consistent with the rules of astronomical observation. It confirms that the local wisdom of the archipelago's people is a form of empirical knowledge that develops independently yet remains coherent with the scientific astronomical system.

The data and cultural readings in this study also indicate that integrating traditional and modern astronomy can enrich the science literacy of the Muslim community, especially by presenting the constellations as a *kauniyah* verse that encourages humans to reflect on the order of Allah's creation. From this perspective, ethnoastronomy not only serves cultural preservation but also strengthens the epistemology of astronomy in the context of education and *da'wah*.

In addition, this study shows that systematic documentation of local constellations can play an important role in revitalizing Islamic astronomical treasures in the archipelago, especially by building bridges between traditional observation methods and modern instruments such as sky-simulation applications, star catalogs, and coordinate-mapping tools. Going forward, further research is needed with a more extensive field approach, including interviews with indigenous stakeholders, collection of oral narratives, and more detailed astronomical verification. This kind of collaborative research has the potential to enrich the astronomical database of Indonesian culture and further affirm that astronomy is a discipline alive, dynamic, and relevant to society throughout the ages.

References

- [1] N. N. Rahmi, "STUDI ANALISIS AZIMUTH BINTANG ACRUX SEBAGAI ACUAN PENENTUAN ARAH KIBLAT," *Energies*, vol. 6, no. 1, 2018.
- [2] D. Herdiwijaya, "On the beginning of the morning twilight based on sky brightness measurements," in *Journal of Physics: Conference Series*, 2020. doi: 10.1088/1742-6596/1523/1/012007.
- [3] M. D. Firdaus and Dkk, "Terhadap Kecemerlangan Langit Malam MEgunakan

- Sky Quality Meter (Studi Kasus Barus - Sumatera Utara),” *Elfalaky*, vol. 6, no. 10, 2022.
- [4] M. Ritonga, “Problematika Syafak dan Fajar dalam Menentukan Waktu Salat Isyak dan Subuh,” *Al-Marshad J. Astron. Islam dan Ilmu-Ilmu Berkaitan*, vol. 7, no. 2, 2021.
- [5] P. Cinzano, “Night sky photometry with sky quality meter,” 2005. [Online]. Available:
<https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.504.1325&rep=rep1&type=pdf>
- [6] A. S. de Miguel, M. Aubé, J. Zamorano, M. Kocifaj, J. Roby, and C. Tapia, “Sky quality meter measurements in a colour-changing world,” *Mon. Not. R. Astron. Soc.*, vol. 467, no. 3, 2017, doi: 10.1093/mnras/stx145.
- [7] A. Hänel *et al.*, *Measuring night sky brightness: methods and challenges*, vol. 205. Pergamon, 2018, pp. 278–290. Accessed: Nov. 18, 2025. [Online]. Available: <https://www.sciencedirect.com/science/article/abs/pii/S0022407317304442>
- [8] C. C. M. Kyba, Y. Ö. Altıntaş, C. E. Walker, and M. Newhouse, “Citizen scientists report global rapid reductions in the visibility of stars from 2011 to 2022,” *Science (80-.)*, vol. 379, no. 6629, pp. 265–268, Jan. 2023, doi: 10.1126/science.abq7781.
- [9] D. M. Duriscoe, S. J. Anderson, C. B. Luginbuhl, and K. E. Baugh, “A simplified model of all-sky artificial sky glow derived from VIIRS Day/Night band data,” *J. Quant. Spectrosc. Radiat. Transf.*, vol. 214, pp. 133–145, 2018, doi: 10.1016/j.jqsrt.2018.04.028.
- [10] P. Deverchère, S. Vauclair, G. Bosch, S. Moulherat, and J. H. Cornuau, “Towards an absolute light pollution indicator,” *Sci. Rep.*, vol. 12, no. 1, p. 17050, 2022, doi: 10.1038/s41598-022-21460-5.
- [11] H. A. Prastyo and D. Herdiwijaya, “Analisis Dinamika Polusi Cahaya di Sekitar Observatorium Bosscha Berdasarkan Citra Satelit VIIRS-DNB,” in *Seminar Nasional Penginderaan Jauh*, F. Muchsin, Ed., Depok: Pusat Teknologi dan Data Penginderaan Jauh (Pustekdata), 2018, pp. 1–9.
- [12] S. Bará, R. C. Lima, and J. Zamorano, “Monitoring Long-Term Trends in the Anthropogenic Night Sky Brightness,” 2019. doi: 10.3390/su11113070.

- [13] G. Ammarell and A. L. Tsing, "Cultural Production of Skylore in Indonesia," in *Handbook of Archaeoastronomy and Ethnoastronomy*, New York, NY: Springer New York, 2015, pp. 2207–2214. doi: 10.1007/978-1-4614-6141-8_236.
- [14] A. Kohar and A. Taufikurrahman, "Tinjauan Astronomis Penentuan Awal Tahun Kalender Rowot Sasak Berdasarkan Kemunculan Bintang Pleiades," *AL - AFAQ J. Ilmu Falak dan Astron.*, vol. 2, no. 2, 2021, doi: 10.20414/afaq.v2i2.2920.
- [15] I. G. A. Pradnyantika, I. N. Sudiana, and T. Haryanto, "Waluku Sebagai Acuan Dalam Garapan Karawitan Bali," *J. Seni Pertunjuk.*, vol. 5, no. 1, pp. 49–60, 2019, doi: <https://doi.org/10.31091/kalangwan.v5i1.732>.
- [16] P. Cinzano, F. Falchi, and C. D. Elvidge, "Naked-eye star visibility and limiting magnitude mapped from DMSP-OLS satellite data," *Mon. Not. R. Astron. Soc.*, vol. 323, no. 1, pp. 34–46, 2001, doi: 10.1046/j.1365-8711.2001.04213.x.
- [17] R. Rajkhowa, "Light Pollution and Impact of Light Pollution," *Int. J. Sci. Res.*, vol. 3, no. 10, pp. 861–867, 2014.
- [18] M. V. Fahamsyah, I. Miftahurohmah, R. Septiantika, I. N. P. Juwita, and M. Kholil, "Matematika Falak : Konsep Matematika Dalam Penentuan Waktu Shalat Fardhu," *Numbers J. Pendidikan Mat. dan Ilmu Pengetah. Alam*, vol. 1, no. 2, 2023.
- [19] Muhammad Awaludin, "Etnoastronomi Perbintangan Masyarakat Lombok," *Astroislamica J. Islam. Astron.*, vol. 3, no. 2, pp. 211–232, Dec. 2024, doi: 10.47766/astroislamica.v3i2.3862.
- [20] D. Pilendia, "Stellarium sebagai Media Pembelajaran Fenomena Astronomi: Kajian Literatur," *J. Ilm. Wahana Pendidik.*, vol. 8, no. 1, pp. 525–532, 2022, doi: 10.5281/zenodo.5899734.
- [21] S. Salimpour and M. T. Fitzgerald, "Astronomy and Culture," *Sci. Educ.*, vol. 33, no. 2, pp. 405–426, 2024, doi: 10.1007/s11191-022-00389-1.
- [22] Z. Alkatiri and N. A. Karim Hayaze, "Critical Literature Study on Habaib Identity in the constellation of Islamic studies in Indonesia from the colonial period to the present," *Cogent Arts Humanit.*, vol. 9, no. 1, 2022, doi: 10.1080/23311983.2022.2096286.
- [23] F. Pimenta, "Astronomy and Navigation BT - Handbook of Archaeoastronomy and

Ethnoastronomy," C. L. N. Ruggles, Ed., New York, NY: Springer New York, 2015, pp. 43–65. doi: 10.1007/978-1-4614-6141-8_7.

- [24] A. Khoirudin, "Sains Islam Berbasis Nalar Ayat-ayat Semesta," *At-Ta'dib*, vol. 12, no. 1, p. 195, 2017, doi: 10.21111/at-tadib.v12i1.883.
- [25] A. R. Fonseca, R. Roberto, and P. Teixeira, "POSSIBILITIES OF USING ETHNOASTRONOMY IN TEACHING AND," *Rev. Educ. Ciência e Tecnol.*, vol. 12, no. 2, pp. 1-18, 2023.