The new *hilaal* visibility criterion for tropical region

J A Utama¹*, F M Simatupang² and Amsor¹

¹Department of Physics Education, Faculty of Mathematics and Natural Sciences Education, Universitas Pendidikan Indonesia, Bandung, Indonesia
²Astronomy Research Division, Faculty of Mathematics and Natural Sciences, Institut Teknologi Bandung, Bandung, Indonesia

*Corresponding author’s email: j.aria.utama@upi.edu

Abstract. We propose a new *Hilaal* (lunar crescent formed immediately after conjunction) visibility criterion apply to tropical region utilizing modified mathematical model of near-sun objects visibility. By using only naked eye positive sightings of *Hilaal*, then we are calculating the Moon and Sun observation parameters to obtain the visibility function for each case. Moon – Sun altitude difference (ARCV – Arc of Vision) and elongation (ARCL – Arc of Light) at the first observable moment have been chosen as parameters and used in developing new visibility criterion. The data show that the minimum ARCV and ARCL value for naked eye observation at the moment of *Hilaal* is observed are 8.4° and 7.1°, respectively. Our results can be proposed as a scientifically criterion for constructing Hijri calendar for tropical region (including Indonesia) as an alternative to Jakarta Recommendations criterion.

1. Introduction

The study of *Hilaal* visibility (the first lunar crescent formed after conjunction) has long lasted since Babylonian period. Various physical parameters are used [1], such as the age of the Moon since the conjunction to the sunset time, the interval time between sunset and moonset, the altitude and elongation of the Moon at sunset, the relative azimuth between the Moon and the Sun and the crescent width, as a visibility indicator to determine the lunar calendar in several cultures and religions.

At sunset time, the sky will not darken immediately. The scattering of sunlight by the particles contained in the atmosphere makes the twilight bright enough to dominate the illuminance of *Hilaal*. Thus, to be able to observe *Hilaal*, observers need a darker sky condition but at the same time the Moon remain at a considerable altitude above local horizon. In extreme case where moonset time is very close with sunset time, the brightness of the twilight can dominate until the Moon sets.

Actually, the Ministry of Religious Affair of the Republic of Indonesia and some ASEAN countries member of MABIMS already have *Hilaal* visibility criterion that have been referred since 1980’s [2]. Based on scientific suggestions from astronomers in Indonesia and international community regarding the clauses of this criterion which are too low in value to allow *Hilaal* to be observed, the revision of existing criterion into Jakarta Recommendations (Djamaluddin, private communication) had been proposed as new *Hilaal* visibility criterion to determine Hijri calendar, not in Indonesia only but regionally and internationally also. However, the clauses [minimum altitude of *Hilaal* is 3° and minimum elongation (ARCL – Arc of Light) between *Hilaal* and the Sun is 6.4°; all at sunset time] in the Jakarta Recommendation (see also [3]) as a revised criterion is still considered scientifically
doubtful. This is also based on the argument that no criteria apply universally to all latitudes [4]. Thus, this work focuses on testing the validity of the criterion adopted in the Jakarta Recommendations by utilizing naked eye (used as benchmark of observation modes) accurate positive sighting to produce scientific visibility criterion for tropical region. Furthermore, we also consider contrast parameters [5] in addition to geometric factors to predict Hilaal visibility in this work.

2. Methods

We use data available in [1], Hilaal observation reports from around the world on the page https://moonsighting.com, observational data published by Rukyatul Hilal Indonesia (RHI) and data documented by Ministry of Religious Affairs of Republic of Indonesia. Only data come from tropical regions (geographical latitude ± 23.5°) and conducted by naked eye observations are used. We test all selected data with mathematical model of twilight sky brightness from [6], meanwhile we follow the procedure found in [7] to calculate Hilaal visibility function. Claims of positive sighting (Hilaal can be observed) are tested thoroughly whether during the “observational window” the illuminance of Hilaal can overcome the brightness of the twilight sky. Theoretically Hilaal can only be observed if its illuminance greater than the brightness of the twilight sky, i.e. when contrast (ratio of Hilaal’s illuminance to the sky’s brightness) value is positive.

We choose as a reference the first moment when contrast between Hilaal and twilight sky has a positive number for the first time to obtain the physical parameter values of the Moon and the Sun (topocentric and airless, after [1]). Then we plot all the physical parameters data in altitude – elongation and use the minimum values found as our proposed new Hilaal visibility criterion.

3. Results and Discussion

In the proposed new criterion, the physical parameters for Hilaal visibility are reduced to only Moon – Sun altitude difference (ARCV – Arc of Vision) and elongation (ARCL – Arc of Light). The altitude difference is used as an indicator for the darkness of the sky; the higher the position of the Moon above local horizon the easier for observers to observe it in the relatively darker part of the sky. Meanwhile, the elongation parameter is related to the moon's crescent width. The greater the elongation the thicker Hilaal which has implication for greater value of its illuminance. Thus, the correct combination between altitude difference and elongation is expected to make the illuminance of Hilaal be able to exceeds the brightness of the twilight sky.

The minimum values for altitude difference and elongation found from current data and adopted as our new criterion are 8.4° (Hilaal is 3.5° above local horizon) and 7.1°, respectively. The distribution of selected data is shown in Figure 1. Based on this value, the relative azimuth of the moon and the sun at the time of observation can be 0°. This means that the values required for Hilaal to be observed can be reduced when the relative azimuth between the moon and the sun is greater than 0°. These values do not vary significantly at sunset time.

It seems that our results are not significantly different from the clauses in the Jakarta Recommendations, namely the minimum altitude and elongation for Hilaal is 3° (compare with 3.5° as our finding) and 6.4° (compare with 7.1° as our finding), respectively. Indeed, the minimum altitude and elongation adopted in Jakarta Recommendations are values from two different cases of Hilaal observation with different observation mode. The minimum altitude of 3° is an extrapolation data and is adopted from [4] when the Moon – Sun azimuth difference > 20°, while the minimum elongation of 6.4° comes from Stamm's observation using a telescope from high elevation (2210 m above sea level) on October 13, 2004 when the Moon – Sun azimuth difference is only 0.4° [1]. This is very different from what we did, namely obtaining the pair of minimum values from all selected data with the same observation mode. Furthermore, our values are obtained at the moment of the first visibility of Hilaal not at the moment of sunset time as in Jakarta Recommendations. If we move backward to the sunset time, the minimum values for altitude and elongation are 7.4° and 7.1°, respectively. Indeed, the values adopted in Jakarta Recommendations are obtained when the contrast between Hilaal and sky brightness
is positive (i.e., does not correspond to the sunset time) but it is forced to be used as a criterion at the moment of sunset. Our higher values at sunset time for tropical region than those in Jakarta Recommendations is consistent with [8] who obtain minimum altitude difference greater than 9.3° and minimum elongation of 8.8° as a new accurate criterion for Saudi Arabia (20° North ≤ φ ≤ 29° North).

Figure 1. The distribution of altitude of the moon and elongation at the moment of first positive contrast value.

4. Conclusion
The *Hilaal* visibility criterion by naked eye observation has been obtained. This value is 8.4° and 7.1° for altitude difference and elongation, respectively. We propose our result as the new criterion for tropical region to determine Hijri calendar.

5. References
[1] Odeh M S 2004 New criterion for lunar crescent visibility *Experimental Astronomy* **18** 39-64
[2] Nawawi M S A M Man S Zainuddin M Z M 2015 Origin of the criteria for the visibility of the lunar crescent in Malaysia *International Journal of Arts and Sciences* **1** 1-4
[3] Maskufa 2017 Advances in Social Sciences *Education and Humanities Research* **162** 188-192
[4] Ilyas M 1988 Limiting altitude separation in the new moon’s first visibility criterion *Astronomy and Astrophysics* **206** 133-135
[5] Sultan A H 2007 First visibility of the lunar crescent: beyond danjon’s limit *The Observatory* **127** 53-59
[6] Schaefer B E 1993 Astronomy and the limits of vision *Vistas in Astronomy* **36** 311-361
[7] Kastner S O 1976 Calculation of the twilight visibility function of near-sun objects *The Journal of the Royal Astronomical Society of Canada* **70** 153-168
[8] Alrefay T, Alsaab S, Alshehri F and Alghamdi A 2018 Analysis of observations of earliest visibility of the lunar crescent *The Observatory* **138** 267-291

Acknowledgments
The author would like to thank the administrator of https://moonsighting.com, Rukyatul Hilal Indonesia and Ministry of Religious Affairs of Republic of Indonesia for data provided.