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Global Qibla Direction Using Stellar Transit at Kaaba Latitude

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Abstract

The global *rashd al-qiblah* is currently considered the most accurate and easily applicable method for measuring the *qibla* direction, as it utilizes the sun's shadow during its transit above the Kaaba. Unfortunately, this event occurs only twice a year, and the sun's disk diameter of 0.5° reduces the accuracy of the method. The global *rashd al-qiblah* method, which utilizes stars with declinations equal to the latitude of the Kaaba, with its higher annual frequency and point-sized stellar disks, is more effective to use. This study employs a library research method with a qualitative and multidisciplinary approach, integrating both religious science and natural science. This study aims to develop an alternative method for determining the global *qibla* direction using stellar transit. Thirty-two stars can be utilized for the worldwide star *rashd al-qiblah* method, each usable for measurements over approximately 177.41 days. This means the global *rashd al-qiblah* method can be applied approximately 2,838 times across multiple countries within one year.

Keywords: *qibla*, stars, transit, accuracy.

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Rashd al-qiblah global saat ini diyakini sebagai metode pengukuran arah kiblat yang paling akurat dan mudah diaplikasikan karena memanfaatkan bayangan matahari saat transit di atas Kakbah. Sayangnya peristiwa ini hanya terjadi dua kali dalam setahun, ditambah diameter piringan matahari yang sebesar 0,5° membuat tingkat akurasinya berkurang. Metode *rashd al-qiblah* global menggunakan bintang yang berdeklinasi sama dengan lintang Kakbah dengan frekuensi dalam setahun dan piringan yang berukuran titik kecil membuatnya lebih efektif untuk digunakan. Metode yang digunakan pada penelitian ini adalah library research dengan pendekatan kualitatif dan multidisipliner antara keilmuan syar'i dan sains. Penelitian ini bertujuan untuk memformulasikan metode alternatif dalam pengukuran arah kiblat dengan menggunakan waktu transit bintang. Terdapat 32 bintang yang bisa dimanfaatkan untuk metode *rashd al-qiblah* bintang global yang masing-masing bisa digunakan untuk pengukuran selama 177,41 hari. Artinya dengan metode *rashd al-qiblah* global bintang ini bisa dimanfaatkan 2838 kali di berbagai negara dalam periode satu tahun.

Kata Kunci: kiblat, bintang, transit, akurasi

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A. Introduction

In general, there is no apparent dichotomy between the schools of *ḥisāb* and *ru'yah* about *qibla* direction.[1] Historically, however, the methods used to determine the *qibla* direction have evolved in line with the advancement of scientific knowledge.[2] Determining the *qibla* direction is a matter of great importance in the performance of Muslim worship, particularly in prayer, where facing the *qibla* constitutes a fundamental condition for its validity. In practice, this determination requires specific expertise to ensure conformity with Islamic ways.[3] The *qibla* direction is established by identifying the nearest path toward the Kaaba that follows a great circle on the Earth's surface.[4]

The factors contributing to inaccuracy in determining the *qibla* direction include the absence of a calculation process, human error, and the use of mobile applications without verification.[5] *Qibla* measurement has become increasingly practical with the availability of various *qibla* applications on smartphones; however, the results are inaccurate, showing an average deviation of 03° 55' 0.05", which is far from the tolerance limit of *iḥtiyāṭ al-qiblah* .[6] Determining the *qibla* direction without the aid of calculation methods or modern applications often results in limited accuracy. This limitation becomes increasingly significant when determination is conducted at night and without the use of navigation aids. Therefore, this study aims to develop an alternative method for accurately determining the *qibla* direction at night. This solution is expected to serve as a practical reference in situations requiring quick *determination of qibla* direction, especially in emergencies, during travel, or outdoor expeditions. According to Shaykh Arsyad Al-Banjari, an authority in fiqh, theology, and astronomy, an individual intending to perform the *salah* prayer in proximity to the Kaaba is obligated to face the physical structure of the Kaaba itself. Conversely, those at a distance are required to undertake ijtihad if they cannot directly sight the Kaaba. Furthermore, they are advised to correct the direction of the *qibla* if the initial determination proves to be erroneous.[7]

In addition to using an instrument, determining the *qibla* direction can also be achieved by observing the azimuth of celestial bodies, such as stars and planets, and noting the shadows of objects.[8] The global *rashd al-qiblah* is currently considered the most accurate method for determining the *qibla* direction, based on natural scientific principles. The natural scientific method is a classification of approaches that begins with scientific calculations, followed by empirical

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[1]Muthmainnah & Fattah Setiawan Santoso, "Pemanfaatan Sains dan Teknologi dalam Pengukuran Arah Kiblat di Indonesia", *Ulumuddin: Jurnal Ilmu-ilmu Keislaman,* 10 no. 2, (December, 2020), 149-162, https://doi.org/10.47200/ulumuddin.v10i2.441.

[2]Ahmad Izzuddin, Fiqih Hisab Rukyah, (Jakarta: Erlangga, 2007), 40.

[3]A. Frangky Soleiman, "Problematika Arah Kiblat". *Jurnal Ilmiah Al Syir'ah*, Vol. 9 No. 1 (2011), 1-2.

[4]Slamet Hambali, *Ilmu Falak I: Tentang Penentuan Awal Waktu Salat dan Penentuan Arah Kiblat di Seluruh Dunia*, (Semarang: Program Pasca Sarjana IAIN Walisongo Semarang, 2011), 167.

[5] Kusdiana, Samsudin, Muhammad Wildan Nur Akmal, "Accuracy of *Qibla* Direction Mosque at Rest Area Toll Road on the *Qibla* Jurisprudence Perspective", *Nusantara: Journal of Law Study*, 2 no. 1, (March, 2023), 31-39, https://doi.org/10.5281/zenodo.17388760

[6] Ahmad Husein, Ahmad Izzuddin, Muhammad Said Fadhel. "The Effect of Magnetic Declination Correction on Smartphone Compass Sensors in Determining *Qibla* Direction". *Alhilal: Journal of Islamic Astronomy*, 3 no. 2 (October, 2021), 43-74, https://doi.org/10.21580/al-hilal.2021.3.2.8309

[7] Adi Nugroho, *Qibla* Direction of Syaikh Arsyad Al-Banjari in the Mas'ala Al-*Qibla* fi Batawi's Book, *Al-Hilal: Journal of Islamic Astronomy*, 5 no. 1, (April, 2023), 81-98, https://doi.org/10.21580/al-hilal.2023.5.1.14038

[8]Muhammad Thoyfur, "Digitalization of Local Rashd al-qiblah by *Qibla* Diagram", *Al-Hilal: Journal of Islamic Astronomy*. 3 no. 1, (March, 2021), 75-106, https://doi.org/10.21580/al-hilal.2021.3.1.7697.

validation through observation of natural phenomena.[9] This method utilizes the predictable motion of celestial bodies in precise detail. It occurs only twice a year when the sun's declination equals the latitude coordinate of the Kaaba, meaning the sun is at the zenith point above the Kaaba on that day.[10] This happens because the latitude of the Kaaba is 21° 25' 25" N, while the sun's declination varies periodically throughout the year between approximately -23.5° and +23.5°. Thus, the direction of the shadow cast by an object illuminated by sunlight corresponds to the direction of the qibla. [11] Although it is possible to perform this method daily by waiting for the sun to align with the Kaaba's path[12], the calculations involved become more complex.

The *rashd al-qiblah* method, which utilizes the shadow of the sun, still has a slight margin of error because the sun, as observed from Earth, appears as a luminous disc with a diameter of approximately 0.5°, rather than a point source of light like stars. Consequently, the accuracy limit of the *rashd al-qiblah* method using the sun is inherently 0.5°.[13] This limitation serves as a basis for developing the global *rashd al-qiblah* method using stars, aiming to minimize the influence of the sun's diameter on the precision of *qibla* direction measurements.

The method of determining the *qibla* direction using stars with declination equal to the latitude of the Kaaba addresses one of the several gaps identified in previous *qibla* measurement practices. This research aims to develop a *qibla* measurement method that utilizes natural celestial objects, offering broader spatial and temporal applicability. Consequently, it provides an alternative approach for *qibla* determination under various conditions by formulating the *qibla* direction measurement using the global *rashd al-qiblah* method with stars whose declination matches the Kaaba's latitude, making it a reliable reference for *qibla* orientation worldwide.

B. Method

This study employs a library research design, which involves procedures related to data collection from credible written sources.[14] The literature research is conducted using various materials, including books, notes, and reports from previous studies.[15] This study employs a quantitative research method to model, predict, and measure the transit events of stars above the Kaaba , which can be used to determine the qibla direction across various parts of the world.[16] The study also uses a *scientific-cum-doctriner* approach to integrate both scientific and religious analysis in a *shar'i* manner,[17] namely Islamic astronomy, with its Sharia foundation, conventional astronomy, and geometric mathematics, as scientific instruments.

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[9]Ahmad Izzuddin, "Metode Penentuan Arah Kiblat dan Akurasinya". *Conference Proceedings, Annual International Conference Islamic Studies (AICIS XII)*, 2012, 794-795.

[10]Ahmad Izzuddin, *Ilmu Falak Praktis*, (Semarang: Pustaka Al-Hilal, 2012), 45.

[11]Tina Lestari & Rizal Ramadhan, "Peran Penting Posisi Matahari dalam Penentuan Rashd al-qiblah Lokal dan Global", *El-Falaky: Jurnal Ilmu Falak,* 8 no. 1 (June, 2024), https://doi.org/10.24252/ifk.v8i1.47990

[12]Nurmila, "Metode Azimuth Kiblat dan Rashd Al-*Qibla*t dalam Penentuan Arah Kiblat", *Istinbath,* 15 no. 2 (November, 2020), 191-212, https://doi.org/10.36667/istinbath.v15i2.26

[13]Muh. Ma'rufin Sudibyo, *Sang Nabi pun Berputar*, (Solo: Tinta Medina, 2011), 74.

[14]Mestika Zed, *Metode Penelitian Kepustakaan*, (Jakarta: Yayasan Pustaka Obor Indonesia, 2014), 3.

[15]Iqbal Hasan, *Analisis Data Penellitian dengan Statistik*, (Jakarta: Bumi Aksara Jakarta, 2018), 5.

[16]Sugiyono, *Metode Penelitian Kuantitatif, Kualitatif, dan R&D*, (Bandung: Alfabeta, Cet. 19, 2013), 7-15.

[17]Asep Awaludin, Manzilatul Fadhilah. "*Scientific-Cum-Doctrine*r dalam Studi Islam Menurut Mukti Ali (Studi Analisis Perspektif *Worldview* Islam)". *Al-Banjari*, 21 no. 2 (July-December, 2022), 118-132. https://doi.org/10.18592/al-banjari.v21i2.6431

The numerical coordinate data of stars used in this study were obtained from the Hipparcos and Tycho star catalogues published by the European Space Agency (ESA).[18] These catalogues are among the most popular and widely used star catalogues currently available. The numerical star coordinate data were then filtered according to the criteria for global star-based *rashd al-qiblah* and processed using the mathematical algorithms from the Jet Propulsion Laboratory (JPL) of the National Aeronautics and Space Administration (NASA) with development Ephemeris 440 (DE440)[19] for calculations. The Python programming language was employed to determine the measurement times for *rashd al-qiblah* using stars, providing usable data for various locations.

The transit time of the global star-based *rashd al-qiblah* can also be calculated using data from other star catalogs, such as the Henry Draper Catalogues, Yale Bright Star Catalogues, and Bonner Durchmusterung. Similarly, various computational algorithms can be employed, including the astronomical algorithm, the nautical almanac, VSOP87, and others, to determine transit times accurately for measurement purposes. The calculation results were then simulated under various observation conditions using samples from different cities worldwide to evaluate the effectiveness and accuracy of the global star-based *rashd al-qiblah* for universal *qibla* direction measurement.

The accuracy analysis of the testing in this study utilizes a comparative method between the star's azimuth during its transit over the Kaaba and the *qibla* azimuth calculated using conventional spherical astronomy formulas (geographic azimuth) based on city data from various parts of the world. Subsequently, the generated data were analyzed to calculate the mean difference between the outcomes derived from the two respective methods.

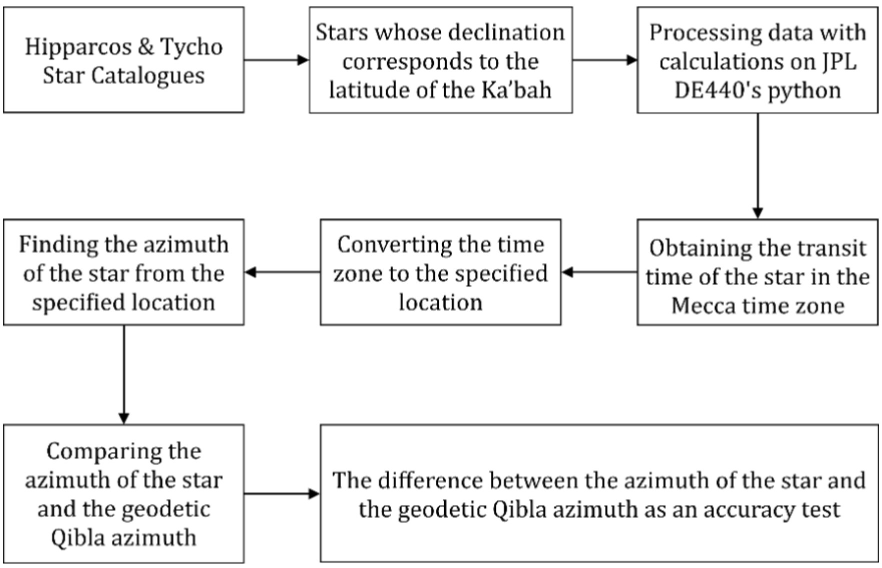

Figure 1: Analytical Data Method

[18] European Space Agency, the Hipparcos and Tycho Catalogues, (Noordwijk: ESA Publications Division, 1997), 1

[19] Jet Propulsion Jet, https://ssd.jpl.nasa.gov/doc/de440_de441.html, accessed May 6, 2025

C. Result and Discussion

1. Global Rashd al-Qiblah Using Stellar Transit

The development of *qibla* direction determination methods has evolved from simple celestial observations to geographic traditions incorporating multi-regional data, and further into scientific approaches using mathematical calculations based on latitude and longitude relative to the Kaaba as a central reference point. This progression enabled the development of more comprehensive and accurate solutions due to the interconnected nature of scientific traditions.[20]

Global star-based *rashd al-qiblah* is a method for measuring the *qibla* direction by utilizing the transit time of a star directly above the Kaaba. At that specific time, all observers facing that star are simultaneously aligned toward the Kaaba. This concept is adapted from the well-known and easily applicable solar *rashd al-qiblah* method, which the general public can use by observing the direction of shadows when the sun is positioned above the Kaaba.[21] According to research, the geodetic approach to calculating the *qibla* direction is considered the most accurate method because it uses the Earth's ellipsoidal shape in its calculations.[22] This approach takes into account the Earth's actual form as an oblate spheroid, rather than a perfect sphere, which enhances the precision of *qibla* determination, especially over long distances.[23] Furthermore, *rashd al-qiblah* provides a solution for determining the *qibla* direction that is independent of the Earth's shape, whether it is flat, ellipsoidal, or spherical.[24]

The measurement of the *qibla* direction using the star-based *rashd al-qiblah* method has spatial coverage limitations, similar to those of the solar *rashd al-qiblah* method. Both global *rashd al-qiblah* approaches rely on the transit event of celestial bodies directly above the Kaaba. However, a limitation arises because not all locations on Earth's surface can observe the celestial body during its transit due to the Earth's curvature.

Ideally, regardless of latitude, the surface area of the Earth that can utilize the transit event is the region with geographic longitudes within 90° of the Kaaba. When the celestial body transits above the Kaaba, it will have already set in locations 90° east of the Kaaba's longitude, while it will just be rising in locations 90° west of the Kaaba's longitude. The illustration is as follows:

[20] Muhammad Thoyfur, "Perkembangan Metode dan Instrumen Arah Kiblat Abad Pertengahan: Studi Kajian Historis Perspektif David A. King", *Al-Afaq: Jurnal Ilmu Falak dan Astronomi*, 3 no. 1, (June, 2021), 41-58, https://doi.org/10.20414/afaq.v3i1.2879.

[21] Abu Sabda, *Ilmu Falak Rumusan Syar'i dan Astronomi Seri 1*, (Bandung: Persis Pers, 2020), 122.

[22] Moelki Fahmi Ardiansyah, "Korelasi Fikih dan Sains dalam Penentuan Arah Kiblat", *Mashlahah,* 8 no. 1, (May, 2017), 13-30, https://doi.org/10.33558/maslahah.v8i1.37.

[23] Rahman Helmi & H. Badrian, "Evaluation of *Rashd Al-Qibla*h Method Accuracy: Spherical Plane and Ellipsoid Approach in *Qibla* Direction Determination", *Indonesian Journal of Religion and Society,* 6 no. 2, (2024), 100-112, DOI: https://doi.org/10.36256/ijrs.v6i2.491.

[24] Reza Akbar & Riza Afrian Mustaqim, "Problematika Konsep Bentuk Bumi dan Upaya Mencari Titik Temunya dalam Penentuan Arah Kiblat", *Shar-E: Jurnal Kajian Ekonomi Hukum Syariah*, 6 No. 1 (January 2020), 43-52, https://doi.org/10.37567/shar-e.v6i1.17.

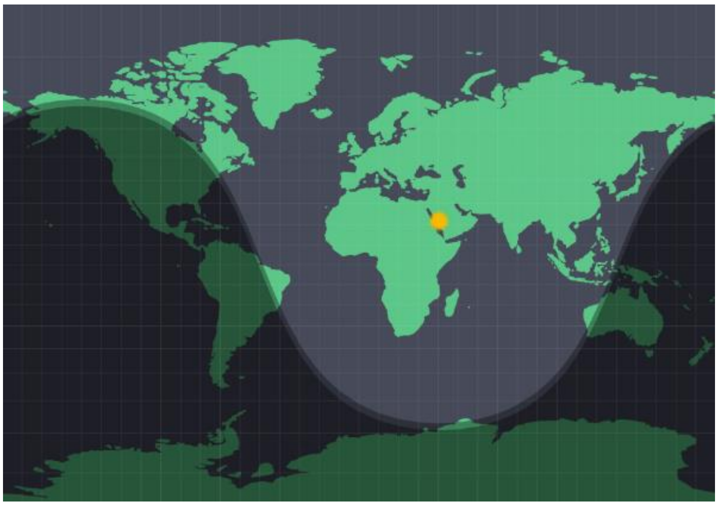

Figure 2. Illustration of a celestial body transiting above the Kaaba. The illuminated area represents the region that can utilize the *rashd al-qiblah* method.

The measurement of the *qibla* using stars with declination equal to the latitude of the Kaaba (global *rashd al-qiblah* stars) involves a series of procedures. The process begins with preparing the calculation data according to the observer's location. Next, the transit time of the global *rashd al-qiblah* star above the Kaaba is calculated. The obtained transit time is then converted to the local time zone. Afterward, the observer locates the global *rashd al-qiblah* star in the night sky and waits until the predetermined transit time. At that moment, the observer aligns their body toward the star, thereby indirectly facing the *qibla* (the Kaaba). This transit time is effectively valid for only about four minutes to maintain accuracy without significant angular deviation. The planned output of this research is a star-based global *rashd al-qiblah* almanac, which will be published to ensure it is widely accessible and utilized by the public. This almanac will serve as an alternative method for determining the *qibla* direction during specific times.

2. The Classifications of Global *Rashd al-qiblah* Stars

Global *rashd al-qiblah* stars are stars whose declination coordinates coincide with the latitude coordinate of the Kaaba (21°25'21.17"). This means that stars within this range lie on the same declination circle and will successively transit above the Kaaba each night, making them usable as references for determining the *qibla* direction in various regions worldwide. The stars used for the global *rashd al-qiblah* must be identifiable by observers at the predetermined calculated times.

Two factors serve as criteria for classifying a star as a global *rashd al-qiblah* star, which Muslims can utilize in certain parts of the world to determine the *qibla* direction using this method; *first,* the declination of the star (δ☆) must be approximately equal to the latitude coordinate of the Kaaba (21°25'21.17"), with a correction of ±1°. This is mathematically expressed as 21°25'21,17" – 1° > δ☆ < 21°25'21,17" + 1°. With this declination range, the global *rashd al-qiblah* stars can be observed up to a maximum latitude of -67°34'38.83" S northward. Note that the southernmost country in the world, Chile, has its southernmost territory at approximately -55°50' S. This means that the global *rashd al-qiblah* stars can be seen from all countries worldwide, provided it is nighttime in the respective country when the stars transit above the Kaaba.

Second, the apparent magnitude (Mv) of the star must be above the minimum threshold visible to the naked human eye (Mv < 6). Astronomers describe stellar brightness by apparent magnitude, which measures how bright a star appears in the night sky. Apparent magnitude does not distinguish between stars that appear bright due to proximity or their intrinsic luminosity. The lower the magnitude, the more colorful the star, with the scale being logarithmic; each magnitude is approximately 2.51 times brighter than the next.[25] The visible brightness detectable by the human eye is around a wavelength of 550 nm.[26] Usually, the naked eye can identify stars up to a magnitude of 6.[27]

Based on the above classification and using the Hipparcos & Tycho star catalogues, 32 stars meet these criteria. These stars are as follows:

Table 1. List of global *rashd al-qiblah* stars using the Hipparcos & Tycho Star Catalogues

No.	Stars	Catalogues Number	Coordinate (J 1991,25) δ ° ' "	α h m s	Mv
1	55 Pisces	HIP 3138	**21 26 18,8**	00 39 55,55	**5,36**
2	ψ1 Pisces A	HIP 5131	**21 28 23,6**	01 05 40,93	**5,33**
3	χ Pisces	HIP 5571	**21 02 04,8**	01 11 27,19	**4,66**
4	Sheratan	HIP 8903	**20 48 29,9**	01 54 38,35	**2,64**
5	η Aries	HIP 10306	**21 12 39,5**	02 12 47,98	**5,23**
6	υ Aries	HIP 12332	**21 57 41,2**	02 38 49,00	**5,45**
7	Al-Butain III	HIP 13914	**21 20 25,6**	02 59 12,73	**4,63**
8	Al-Butain IV	HIP 15110	**21 02 40,7**	03 14 54,11	**4,87**
9	τ Aries	HIP 15627	**21 08 49,7**	03 21 13,61	**5,27**
10	51 Taurus	HIP 20087	**21 34 45,8**	04 18 23,14	**5,64**
11	53 Taurus	HIP 20171	**21 08 32,7**	04 19 26,08	**5,5**
12	ι Taurus	HIP 23497	**21 35 24,2**	05 03 05,70	**4,62**
13	105 Taurus	HIP 23883	**21 42 17,4**	05 07 55,43	**5,84**
14	ο Taurus	HIP 25539	**21 56 13,1**	05 27 38,08	**4,88**
15	ζ Taurus	HIP 26451	**21 08 33,3**	05 37 38,68	**2,97**
16	d Gemini	HIP 32921	**21 45 40,4**	06 51 33,05	**5,28**
17	Wasat	HIP 35550	**21 58 56,4**	07 20 07,39	**3,50**
18	63 Gemini	HIP 36238	**21 26 44,0**	07 27 44,39	**5,2**
19	μ Cancer	HIP 41909	**20 26 28,6**	08 32 42,52	**5,33**
20	Asellus Borealis	HIP 42806	**21 28 06,9**	08 43 17,21	**4,66**
21	92 Leo	HIP 56975	**21 21 10,2**	11 40 47,11	**5,26**
22	35 Coma Berenices	HIP 62886	**21 14 42,1**	12 53 17,77	**4,89**

[25] The Diagram Group, *Space and Astronomy: An Illustrated Guide to Science*, (New York: Chelsea House Publishers, 2006), 12.
[26] Mitchell Beazley, *Philip's Astronomy Dictionary*, (London: Philip's, 2002), 432.
[27] Sir Patrick Moore, *Atlas of the Universe*, (London: Philip's, 2005), 166.

23	e Bootes	HIP 67480	**21 15 50,6**	13 49 42,82	**4,92**
24	10 Bootes	HIP 68276	**21 41 46,8**	13 58 38,93	**5,76**
25	Kornephoros	HIP 80816	**21 29 22,7**	16 30 13,26	**2,78**
26	95 Hercules	HIP 88267	**21 35 44,5**	18 01 30,40	**4,26**
27	109 Hercules	HIP 90139	**21 46 13,2**	18 23 41,77	**3,85**
28	112 Hercules	HIP 92614	**21 25 30,6**	18 52 16,43	**5,43**
29	1 Vulpecula	HIP 94703	**21 23 25,6**	19 16 13,04	**4,76**
30	29 Vulpecula	HIP 101867	**21 12 04,2**	20 38 31,29	**4,81**
31	25 Pegasus	HIP 109240	**21 42 11,1**	22 07 50,33	**5,79**
32	Helvetios	HIP 113357	**20 46 07,3**	22 57 27,85	**5,45**

3. Formulation of the Global *Rashd al-Qiblah* Algorithm Using Stars

Determining the *qibla* direction using the global star-based *rashd al-qiblah* requires precise accuracy to obtain the transit time of a *rashd al-qiblah* star exactly above the Kaaba, to be used by observers worldwide. Various algorithms can be employed to calculate this transit time, one of which is the Jet Propulsion Laboratory (JPL) algorithm developed by NASA. The JPL is a division of NASA in the United States of America specializing in robotic space exploration.[28] NASA JPL produces an astronomical almanac algorithm called the Development Ephemeris, which comprises a series of high-precision mathematical models of the solar system widely used for spacecraft navigation and astronomy.[29] This study uses the Development Ephemeris 440 (DE440s) for calculations.

The star data were obtained from the Hipparcos and Tycho star catalogues, which are primary products of the astrometric mission initiated by the European Space Agency (ESA) named "Hipparcos (High Precision Parallax Collecting Satellite)". The satellite operated for four years, processing high-quality scientific data from November 1989 to March 1993.[30] The mission's objective was to produce highly accurate astrometric data, including star positions, proper motion, and absolute trigonometric parallax, with an accuracy level of approximately 2 arcseconds for about 118,218 stars.[31] The Tycho star catalog (TYC) provides data with less accuracy than the Hipparcos catalog (approximately 0.05 arcseconds), but it contains a larger number of stars, approximately 1,058,332, up to magnitude 11.5, along with two-color photometric measurements. The Tycho star catalog was published in 1997, followed by the Tycho-2 catalog in 2000, which is used in astrometric catalogs to obtain very accurate proper motion data for stars. The Tycho-2 catalog comprises positions, proper motions, and photometric data for approximately 2.5 million of the brightest stars in the sky, providing enhanced precision due to improved data reduction techniques compared to the original Tycho catalog. This makes it a significant resource for astrometry despite being less precise than the Hipparcos catalog.[32]

[28]Jet Propulsion Laboratory, https://www.nasa.gov/who-we-are, accessed on June 10, 2025.
[29] Jet *Propulsion* Laboratory, https://ssd.nasa.gov/horizon, accessed on June 10, 2025.
[30] National Aeronautics and Space Administration (NASA), "Hipparcos - Hipparcos Main Catalog". heasarc.gsfc.nasa.gov/W3Browse/all/hipparcos.html. 2022. Accessed June 10, 2025.
[31] European Space Agency, the Hipparcos and Tycho Catalogues, (Noordwijk: ESA Publications Division, 1997), 1
[32] Mitchell Beazley, *Philip's Astronomy Dictionary*, (London: Philip's, 2002), 182.

These data were then processed using a program on *colab.research.google.com* with the Python programming language as follows:

a) Package Installations

```
!pip install skyfield
```

b) Import Library

```
import math
from math import sin, cos, asin, degrees, radians, atan2
import pandas as pd
from pytz import timezone, utc
from datetime import timedelta
from skyfield.api import load, Topos, Star
from skyfield.data import hipparcos
from skyfield.almanac import meridian_transits, find_discrete
```

c) Data Loaded

```
ts = load.timescale()
eph = load('de440s.bsp')
earth = eph['earth']
with load.open(hipparcos.URL) as f:
 df = hipparcos.load_dataframe(f)
daftar_bintang = [
 {"nama": "55 Pisces", "katalog": "3138"},
 {"nama": "ψ1 Pisces A", "katalog": "5131"},
 {"nama": "χ Pisces", "katalog": "5571"},
 {"nama": "Sheratan", "katalog": "8903"},
 {"nama": "η Aries", "katalog": "10306"},
 {"nama": "υ Aries", "katalog": "12332"},
 {"nama": "Al-Butain III", "katalog": "13914"},
 {"nama": "Al-Butain IV", "katalog": "15110"},
 {"nama": "τ Aries", "katalog": "15627"},
 {"nama": "51 Taurus", "katalog": "20087"},
 {"nama": "53 Taurus", "katalog": "20171"},
 {"nama": "ι Taurus", "katalog": "23497"},
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 {"nama": "ο Taurus", "katalog": "25539"},
 {"nama": "ζ Taurus", "katalog": "26451"},
 {"nama": "d Gemini", "katalog": "32921"},
 {"nama": "Wasat", "katalog": "35550"},
```

```
  {"nama": "63 Gemini", "katalog": "36238"},
  {"nama": "μ Cancer", "katalog": "41909"},
  {"nama": "Asellus Borealis", "katalog": "42806"},
  {"nama": "92 Leo", "katalog": "56975"},
  {"nama": "35 Coma Berenices", "katalog": "62886"},
  {"nama": "e Bootes", "katalog": "67480"},
  {"nama": "10 Bootes", "katalog": "68276"},
  {"nama": "Kornephoros", "katalog": "80816"},
  {"nama": "95 Hercules", "katalog": "88267"},
  {"nama": "109 Hercules", "katalog": "90139"},
  {"nama": "112 Hercules", "katalog": "92614"},
  {"nama": "1 Vulpecula", "katalog": "94703"},
  {"nama": "29 Vulpecula", "katalog": "101867"},
  {"nama": "25 Pegasus", "katalog": "109240"},
  {"nama": "Helvetios", "katalog": "113357"}
 ]
```

d) Function

e) This process involves multiple data sessions, such as decimal-to-degree conversion, Gregorian date conversion, and Julian Day (JD) conversion, which support its primary functions. However, due to the large number of lines and their general date conversion functions, these are not displayed in this section.

f) Main Function

g) This session serves as the data input phase according to the observer's conditions and the *rashd al-qiblah* star whose transit time is to be calculated. The customizable inputs include the star index, day, month, year, and time zone. Meanwhile, the latitude and longitude data remain fixed, following the latitude and longitude of the Kaaba in the city of Mecca.

```
def Transit_Stars(index, tanggal, bulan, tahun, lokasi, timezone=0):

  stars = Star.from_dataframe(df.loc[int(star_df['katalog'][index])])
  t0 = ts.utc(tahun, bulan, tanggal)
  t1 = t0 + timedelta(days=1)
  f = meridian_transits(eph, stars, lokasi)
  t, y = find_discrete(t0, t1, f)
  return t[1].ut1
```

```
indeks_bintang = 4
tanggal = 24
bulan = 10
tahun = 2025
lon = 39.8255483
lat = 21.4225092
zona_waktu = 7
lok = Topos(latitude_degrees=lat, longitude_degrees=lon)
transit = Transit_Stars(indeks_bintang, tanggal, bulan, tahun, lok)

print(f"Waktu  Transit  Bintang  {daftar_bintang[indeks_bintang]['nama']}:
{caldat(float(transit), zona_waktu, "JAM").result}")
```

After executing this session, the transit time results of the desired *Rashd al-qiblah* star, converted to the time zone according to the input, will be obtained, for example:

```
Waktu Transit Bintang η Aries: 04:20:51.56
```

4. Calculation Results and Accuracy of Global *Rashd al-qiblah* Using the JPL Algorithm

Accuracy in measuring the *qibla* direction is paramount. The measurement method using a global star-based *rashd al-qiblah* is a novel approach that requires accuracy testing to ensure its validity for both practical and academic applications. The accuracy of the global star-based *rashd al-qiblah* is tested by comparing the azimuth of the global *rashd al-qiblah* star at the observer's location during the star's transit above the Kaaba with the verified and trusted *qibla* azimuth at the observation site. This comparison method is employed because, to date, no method exists for directly correlating star transit times with *qibla* direction.

The star azimuth at the measurement location is calculated using the JPL algorithm, as done previously, with the following code:

```
def calculate_altitude_azimuth(star_index, tahun, bulan, tanggal, jam_utc,
lokasi):
star = Star.from_dataframe(df.loc[int(star_df['katalog'][star_index])])
t = ts.utc(tahun, bulan, tanggal, jam_utc)
alt, az, distance = astrometric.apparent().altaz()
return alt.degrees, az.degrees

indeks_bintang_hitung = 4
tahun_hitung = 2025
```

```
bulan_hitung = 10
tanggal_hitung = 24
jam_utc_hitung = (4+20/60+51.56/3600)-7

lon = 110 + 20/60 + 53/3600
lat = -(6 + 59/60 + 30/3600)
zona_waktu = 7
lok = earth+Topos(latitude_degrees=lat, longitude_degrees=lon)

alt, az = calculate_altitude_azimuth(indeks_bintang_hitung, tahun_hitung,
bulan_hitung, tanggal_hitung, jam_utc_hitung, lok)

print(f"Ketinggian                                                Bintang
{daftar_bintang[indeks_bintang_hitung]['nama']}: {konversi(alt).result}")
print(f"Azimut  Bintang  {daftar_bintang[indeks_bintang_hitung]['nama']}:
{konversi(az).result}")
```

With the following example results;

```
Ketinggian Bintang η Aries: 16° 11' 47.38"
Azimut Bintang η Aries: 294° 39' 52.95"
```

The accuracy testing of the global star-based *rashd al-qiblah* was conducted with four stars at different times. Each star was tested using coordinates from several major cities worldwide under varying conditions to demonstrate the scope and limitations of this method. The results are as follows:

Table 2. Accuracy test of the global star-based *rashd al-qiblah* with simulation of full coverage areas, able to observe the stars

Star (Date)	Cities	*Qibla* Time	Star Azimuth	*Qibla* Azimuth	Difference
Wasat (January 10, 2026)	**Mecca**	**00:20:46,04**	-	-	-
	Recife	18:20:46,04	66° 52’ 45,74”	67°12’ 19,10”	0° 19’ 33,36”
	Madrid	23: 20:46,04	103° 24’ 27,39”	104° 01’ 24,87”	0° 36’ 57,48”
	Cape of Hope	23: 20:46,04	22° 59’ 33,56”	23° 12’ 00,28”	0° 12’ 26,72”
	Istanbul*	00: 20:46,04	152 `13’ 56,90”	151° 37’ 21,23”	0° 36’ 35,67”
	Semarang*	04: 20:46,04	295° 16’ 02,07”	294° 31’ 05,08”	0° 44’ 56,99”
	Makassar*	05: 20:46,04	293° 07’ 57,76”	292° 28’ 48,21”	0° 39' 9,55."
	Ternate*	06: 20:46,04	291° 55’ 35,56”	291° 24’ 33,75”	0° 31' 1,81."

The data in the table above represent the ideal conditions of the star *Wasat* for *qibla* direction measurement using the global star-based *rashd al-qiblah* method. When a *qibla* star transits above the Kaaba close to midnight in Mecca, the coverage area of the worldwide star *rashd al-qiblah* reaches its maximum. All regions east and west of the Kaaba within the global *rashd al-qiblah* coverage can utilize the transit of that *rashd al-qiblah* star. Conversely, when a *rashd al-qiblah* star transits above the Kaaba around midday (12:00 PM), that star cannot be used as a *qibla* directional reference on that day.

Table 3. Accuracy test of the global star-based *rashd al-qiblah* with simulation of coverage area west of the Kaaba. Unable to observe the stars, while east of the Kaaba can observe the stars

Star (Date)	Cities	*Qibla* Time	Star Azimuth	*Qibla* Azimuth	Difference
Asellus Borealis (April 21, 2026)	**Mecca**	**19:06:32,04**	-	-	-
	Monteiro	13:06:32,09	Not rise yet	66° 41’ 38,55”	-
	Manchester	17:06:32,09	Not rise yet	118° 23’ 11,57”	-
	Marrakesh	17:06:32,09	Not rise yet	91° 23’ 08,78”	-
	Kyiv	20:06:32,09	162° 27’ 33,62”	162° 26’ 13,06”	0° 01’ 20,56”
	Mumbai	21:36:32,09	280° 13’ 19,88”	280° 19’ 01,36”	0° 05’ 41,48
	KualaLumpur	23:06:32,09	292° 31’ 21,42”	292° 34’ 38,24”	0° 03’ 16,82”
	Tokyo	23:06:32,09	292° 59’ 44,02”	293° 02’ 03,42”	0° 02’ 19,40”

The data conditions above illustrate the case when the star *Asellus Borealis* transits above the Kaaba around sunset. Under this condition, the star *Asellus Borealis* has not yet risen in the area east of the Kaaba, making it unusable as a *qibla* directional reference there, whereas the area west of the Kaaba can utilize the star as a *qibla* directional guide.

Table 4. Accuracy test of the global star-based *rashd al-qiblah* with simulation of coverage area west of the Kaaba, able to observe the stars, while east of the Kaaba is unable to observe the stars

Star (Date)	Cities	*Qibla* Time	Star Azimuth	*Qibla* Azimuth	Difference
τ Aries (August 23, 2026)	**Mecca**	**05:35:51,79**	-	-	-
	Dakar	02: 35:51,79	74° 08' 09.62"	73° 57’ 46,88”	0° 10’ 22,74”
	Lisbon	03: 35:51,79	97° 38' 02.47"	97° 55’ 18,63”	0° 17’ 16,16”
	Turin	04: 35:51,79	120° 35' 37.76"	121° 12’ 16,31”	0° 36’ 38,55”
	Tashkent	08: 35:51,79	Already set	240° 17’ 24,61”	-
	Moskow	05: 35:51,79	Already set	176° 14’ 50,70”	-
	Bangkok	09: 35:51,79	Already set	286° 53’ 33,27”	-
	Beijing	10: 35:51,79	Already set	278° 53’ 47,56”	-

In contrast to the previous condition, the data above show a simulation when one of the *rashd al-qiblah* stars (τ Aries) transits above the Kaaba around sunrise. As a result, the region east of the Kaaba cannot use this star as a *qibla* directional reference because it has already set, whereas the area west of the Kaaba can utilize it as a *qibla* guide since the star is still above the horizon.

Table 5. Accuracy test of the global star-based *rashd al-qiblah* with simulation of all regions unable to observe the stars

Star (Date)	Cities	*Qibla* Time	Star Azimuth	Star Altitude	Annotation
Al Butain III (December 27, 2026)	**Mecca**	**20:56:33,08**	-	-	-
	Honolulu	07:56: 33,08	336° 55' 40.71"	-43° 53' 33.49"	Below Horizon
	Los Angeles	10:56: 33,08	23° 44' 08.28"	-30° 51' 55.07"	Below Horizon
	Bogota	12:56: 33,08	65° 05' 49.01"	-20° 15' 30.72"	Below Horizon
	Buenos Aires	14:56: 33,08	76° 15' 22.42"	-18° 29' 17.03"	Below Horizon
	Jayapura*	02:56: 33,08	291° 22' 01.45"	-11° 03' 59.68"	Below Horizon
	Sydney*	04:56: 33,08	277° 30' 33.51"	-29° 03' 49.96"	Below Horizon
	Wellington*	06:56:33,08	256° 25' 38.73"	-47° 21' 05.70"	Below Horizon

Regions with a longitude difference of more than 90° from the longitude of the Kaaba are not included within the global *rashd al-qiblah* coverage zone; therefore, the star-based *rashd al-qiblah* method cannot be applied in these areas. This is due to their position being directly on the opposite side of the Earth from the Kaaba, causing the *rashd al-qiblah* star in those regions to remain below the horizon when it transits above the Kaaba.

The conditions in tables 3 and 4 represent simulations of a single star, while in one night, more than one *Rashd al-Qiblah* star transits above the Kaaba. Each day, the 32 of *rashd al-qiblah* stars successively transit above the Kaaba. To be applicable for observers in multiple regions around the world, the observer only needs to select the transit time of the *rashd al-qiblah* star that is above the horizon during nighttime in their area.

A rashd al-qiblah star transiting above the Kaaba at times other than midday can still serve as a *qibla* directional reference in specific regions, taking into account their time zone differences. For example, when a *rashd al-qiblah* star transits above the Kaaba at 14:30, regions with astronomical time zones UTC +7, +8, and parts of UTC +9 can utilize the star because it is already nighttime there.

Based on the calculation results for *qibla* determination, using data from various cities worldwide as reference points, the average difference between the star azimuth and the geographic *qibla* azimuth was found to be 0° 22' 5.73''. This azimuth difference value does not exceed the scientifically accepted tolerance limit for *qibla* deviation. Therefore, it can be concluded that the global star-based *rashd al-qiblah* method meets the requirements to serve as an alternative for *determining the qibla* direction under specific conditions. Each *rashd al-qiblah* star remains observable during nighttime for approximately 5 months, 24 days, and 21 hours before rising and setting concurrently with the sun. This means observers can use each *rashd al-qiblah* star for about 177.41 days. With 32 stars alternating transit above the Kaaba, the *rashd al-qiblah* method using stars with declination equal to the latitude of the Kaaba can be applied approximately 5677 times per year. Compared to the global *rashd al-qiblah* method using the sun's shadow, this number increases by 2,838,500 times, representing an incremental percentage of 2,838,500 %.

D. Conclusion

The global star-based *rashd al-qiblah* method offers an efficient alternative for *determining the qibla* direction, particularly at night. This method calculates the transit time of one of 32 *rashd al-qiblah* stars above the Kaaba and adjusts it based on the observer's local time zone. Observers facing the *rashd al-qiblah* star at transit time are effectively aligned with the *qibla* direction. In testing the accuracy of this method, the mean deviation of the *qibla* azimuth was found to be 0° 22' 5.73''. This value meets the minimum tolerance requirement for *qibla* direction deviation widely accepted within the scientific community. The method is applicable within 90° longitude east and west of the Kaaba; regions outside this range cannot use it because the stars remain below the horizon during transit. The star-based *rashd al-qiblah* method can be utilized approximately 5677 times annually, with each star transiting about 177.41 days per year. This allows the phenomenon to be applied roughly 15 times daily worldwide. In comparison, the conventional solar shadow *rashd al-qiblah* method can only be used twice per year, making the star method's frequency 2838.5 times greater. The higher precision is due to stars appearing as point sources, in contrast to the sun's disk, which has a diameter of 0.5°, making the star method more precise and filling the gaps of the conventional approach. The application of the global star-based *rashd al-qiblah* method in this study is limited to regions with a maximum longitudinal difference of 90° from the longitude of the Kaaba. Consequently, further validation is essential through subsequent research utilizing transit time data from other stars at the Kaaba's antipodal point. Furthermore, as this method is relatively novel as an alternative for determining the *qibla* direction, a comparative analysis with the established method of calculating stellar transit times at the Kaaba is necessary to corroborate its degree of accuracy.

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