THE EVOLUTION OF *AL-JALĀLĪ* CALENDAR: INSIGHTS FROM ‘UMAR KHAYYĀM'S CONTRIBUTIONS

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Abstract

The *Al-Jalālī* calendar, developed by ‘Umar Khayyām in the 11th century, has important significance in Islamic history and culture. This study aims to trace the calendar's evolution, focusing on Khayyām's contributions and impact on the development of science and culture. The methods used include literature study, document analysis, and review of astronomical methods used by Khayyām. This journal highlights its scientific significance in the development of the calendar system, describing the journey of the *Al-Jalālī* Calendar from its initial concept to the improvements it obtained. An in-depth analysis of ‘Umar Khayyām's contributions and the development of the *Al-Jalālī* Calendar provides a rich insight into the history, mathematics, and astronomy of the time and its influence on time measurement and administration in Persian society.

Keywords*: Al-Jalālī Calendar; ‘Umar Khayyām; Islamic Astronomy; Contributions*

Abstrak

Kalender *Al-Jalālī* yang dikembangkan oleh ‘Umar Khayyām pada abad ke-11, memiliki signifikansi penting dalam sejarah dan budaya Islam. Penelitian ini bertujuan untuk menelusuri evolusi kalender tersebut, dengan fokus pada kontribusi Khayyām dan dampaknya terhadap perkembangan ilmu pengetahuan dan budaya. Metode yang digunakan mencakup studi literatur, analisis dokumen, dan kajian terhadap metode astronomi yang digunakan Khayyām. Artikel ini menyoroti signifikansi keilmuannya dalam pengembangan sistem kalender, menggambarkan perjalanan Kalender *Al-Jalālī* dari konsep awal hingga peningkatan yang diperolehnya. Analisis mendalam terhadap kontribusi ‘Umar Khayyām dan perkembangan Kalender *Al-Jalālī* memberikan wawasan yang kaya akan sejarah, matematika, dan astronomi pada masa itu, serta pengaruhnya terhadap pengukuran waktu dan administrasi dalam masyarakat Persia.

Keywords: *Kalender Al-Jalālī; ‘Umar Khayyām; Astronomi Islam; Kontribusi*

A. Introduction

In ancient times, man calculated time using natural phenomena. The most natural phenomena for adjusting the rhythm of human activity are the demands of day and night. On a smaller scale, the vertical shadow of the gnomon is used to indicate the position of the Sun in the sky. The moon's phases—from the crescent to the full—are constructive for extended periods. A year is called twelve lunar months because it can be observed that nature returns to its initial place after roughly twelve complete lunar cycles. Nevertheless, historical records indicate that the proper year, or the return of nature to its initial position, is lengthier and is contingent upon the Sun's location against the backdrop of fixed stars.[1]

The calendar was made by those responsible for politics and religion. For example, the Julian calendar was created by Julius Caesar, the Hebrew calendar was created by Hillel II, a Jewish Rabbi, the Gregorian calendar was created by Pope Gregory, and the Islamic calendar was formulated by the Prophet Muhammad and perfected by Caliph Umar Ibn al-Khaṭṭāb, as the successor of the Prophet Muhammad.[2]

The *Al-Jalālī* calendar, devised by ʻUmar Khayyām in the 11th century, was one of the crucial achievements in Islamic astronomy. The calendar has a long history and significant influence on various aspects of Muslim community life. However, an in-depth study of the evolution of this calendar, particularly regarding Khayyām's specific contributions and impact on science and culture, remains to be explored.

This research will reveal ʻUmar Khayyām's specific contribution to the development of the *Al-Jalālī* Calendar as well as how the accuracy and superiority of the *Al-Jalālī* Calendar compared to other calendars such as the Gregorian calendar. This research uses a library method with a qualitative and comparative approach between the *Al-Jalālī* calendar and the Gregorian calendar.

[1] Mohammad Bagheri, "Ancient Iranian Calendars," in *Symposium on Calendars Used in Asia and Oceania*, 2022, 73–76.

[2] Ahmad Musonnif, "Perumusan Kalender Syamsi Hijri Iran dan Ahmadiyah dalam Tinjauan Al-Siyasah Al-Syar'iyyah," *Al-Ahkam* 9, no. 1 (2021): 1–26, https://doi.org/10.21274/ahkam.2021.9.1.1-26.

Some previous studies related to this research are "The institution of the *Al-Jalālī* calendar in 1079 CE and its cohabitation with the old Persian calendar."[3] Written by Johannes Thomann, the similarity of this research with the author's research lies in the discussion of the *Al-Jalālī* calendar. In contrast, the difference lies in the research focus, where previous research discussed how the *Al-Jalālī* calendar developed from the Ancient Persian calendar. In contrast, researchers discuss ʻUmar Khayyām's contribution to the evolution of the *Al-Jalālī* calendar. Then, Mohammad Bagheri's research entitled "Ancient Iranian Calendars."[4] The similarity with the author's research lies in the discussion of the calendar used by the Iranian nation. In contrast, the difference between the authors' research and the research is in the focus of the research. In contrast, the previous research discusses using the ancient Iranian calendar. In contrast, the author discusses the contribution of ʻUmar Khayyām in the evolution of the *Al-Jalālī* calendar.

The results of this study are expected to provide new insights into the history and development of the *Al-Jalālī* Calendar, reveal ʻUmar Khayyām's essential contributions in the field of Islamic astronomy, and highlight the significance of this calendar in the development of Islamic science and culture. In addition, this study is also expected to provide recommendations for the use of the *Al-Jalālī* Calendar in the modern context.

B. Method

This research uses a literature analysis method with a descriptive-analytical approach. The descriptive method provides a comprehensive overview of Khayyām's role and contribution in the context of Islamic history, and the analytical approach allows this study to analyze the impact of Khayyām's contribution to Islamic civilization during the Seljuk dynasty. The data comes from primary sources, namely books and manuscripts that discuss Umar al-Khayyām and his contribution

[3] Johannes Thomann, "The Institution of the Jalālī Calendar in 1079 CE and Its Cohabitation with the Older Persian Calendar," in *Calendars in the Making : The Origins of Calendars from the Roman Empire to the Later Middle Ages*, ed. Sacha Stern (Leiden: University College London, 2021), 210–44, https://doi.org/10.1163/9789004459694_007.

[4] Bagheri, "Ancient Iranian Calendars."

to the formation of the *Al-Jalālī* calendar. The secondary sources used come from journals, articles, and related research.

C. Discussion

C.1. Biography of Umar Al-Khayyāmi

Ghiyāth al-Dīn Abū al-Futūḥ ʻUmar Ibn Ibrāhīm Khayyām was the full name of ʻUmar Khayyām. He was born in the northeast Persian city of Naisabur. As suggested by his name, he may have worked in the tent trade; his family has been there for centuries. Because of its name, Khayyām's association with the Khayyāmi clan, who had Arab descent and lived in Persia (Iran), many assume it originated in Arabia.[5]

Indian scholar Swami Govinda Tirtha first discovered his date of birth, which has long been the subject of speculation. He first realized that the astrological information provided by his earliest biographer, Beihaqi, and rejected by severe scholars as unworthy of their attention, was sufficient to establish the date very precisely, that is, at sunrise on May 18, 1048 AD, a date that happened to meet all the requirements. However, Govinda failed to find an exact date of death, which he set at March 23, 1122 CE.[6]

Most of his young life needs to be documented because little is known. However, it is clear that he lived in Naisabur most of his life and attended school in Samarqand.[7] Political events greatly influenced Khayyām's life journey in the 11th century. In the 11th century, a group known as the Seljuk Turks invaded southwest Asia and eventually established an empire that included Mesopotamia, Syria, Palestine, and most of Iran. Between 1038 and 1040, the Seljuks conquered the northeastern part of Iran, occupying the grazing lands of Khurasan. In 1038, Toghrïl Beg, the Seljuk ruler, became sultan of Naisabur

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[5] Ali Dashti, *In Search of Omar Khayyam*, trans. George Allen and Unwin Ltd, vol. 01 (New York: Routledge Library Editions, 2011).

[6] Swami Govinda Tirtha, *The Nectar of Grace Omar Khayyam's Life and Works* (Hyderabad: Government Central Press, 1941).

[7] "Omar Khayyam: Life and Contributions," IvyPanda, 2022, https://ivypanda-com.translate.goog/essays/omar-khayyam/.

and arrived in Baghdad in 1055. Khayyām grew up in this challenging and unstable military empire, which also faced religious problems while trying to establish an orthodox Muslim state.[8]

Al-Khayyāmī probably became a teacher wherever he was educated. However, teaching will not give him enough free time to study science. At that time, he was the only scholar who was highly talented. He could only do regular education if he were attached to the court with some ruler or essential figure. As a result, his work depended on the attitude of his ruler, court politics, and the war's outcome. At the beginning of his book, *Risāla fī al-Barāhīn 'alā Masā'il al-Jabr wa al-Muqābala*, Al-Khayyāmī narrates the dangers of such an existence. Even under the unfavorable conditions he described, Al-Khayyāmī was still able to flourish and wrote his short work on music theory, *al-Qāwl 'alā Ajnās allatī bi al-Arba'a* (Problems of Arithmetic), and his unfinished treatise on algebra, *Mushkilāt al-Ḥisāb* (Discussion on Genera Contained in a Fourth).[9]

To assist in the establishment of a new observatory under the patronage of Jalāl al-Din Mālik-Shāh, the Seljuk sultan, and his minister Niẓām al-Mulk, Khayyām relocated to Iṣfahān in 1074. Al-Khayyāmi spent over eighteen years of his life in Isfahan, arguably the most tranquil time. The most crucial observatory effort, the development of the Mālikī calendar, or *Al-Jalālī*, was unquestionably made possible by Khayyām. Compared to the present Western Gregorian calendar, which requires corrections every 3,333 years, Khayyām's calendar was more precise, requiring one day's worth every 5,000 years. In addition to the calendar, the Iṣfahān observatory produced the *Zīj Mālik-Shāhī* (covering only a tiny part of the ecliptic coordinate table numbering the 100 brightest stars extant), apparently one of the more critical astronomical handbooks.[10]

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[8] J J O'Connor and E F Robertson, "Omar Khayyam," MacTutor, School of Mathematics and Statistics, University of St Andrews, Scotland, 1999, https://mathshistory.st-andrews.ac.uk/Biographies/Khayyam/.

[9] "Al-Khayyam," Complete Dictionary of Scientific Biography, Encyclopedia.com, 2023, https://www.encyclopedia.com/science/dictionaries-thesauruses-pictures-and-press-releases/al-khayyam.

[10] Mousavian et al., "Umar Khayyam," in *The Stanford Encyclopedia of Philosophy*, ed. Edward N Zalta and Uri Nodelman, Winter Edi (Metaphysics Research Lab, Stanford University, 2023).

Al-Khayyāmī also served as a court astrologer, although Niẓām Samarqandī says that he did not believe in judicial astrology. In 1077, he completed his commentary on Euclid's theory or parallel lines and ratio theory, which was his most important scientific contribution, along with his earlier algebra *Risāla fī al-Barāhīn 'alā Masā'il al-Jabr wa al-Muqābala*. During this period, he also wrote about philosophy. In 1080, he wrote *Risāla al-Kawn wa al-Taklīf* (A treatise on the universe and assignment), which was included with *Al-Jawab 'an Thalāth Masā'il: Dawrāt al-tadadd fī al-Ālam wa al-Jabr wa al-Baqā*. He also wrote *Risāla fī al-Kulliyāt al-Wujũd* for the son of Mu'ayyid al-Mulk, who was vizier from 1095 to 1118 (His other two philosophical works, *Risāla al-Ḍiyā' al-'Aql fī Mawdũ' al-'Ilm al-Kullī* cannot be dated with certainty).

The adversaries of al-Khayyāmī started to pose a threat in 1092. An assassin had assassinated both King Mālik-Shāh and his vizier, Niẓām al-Mulk. Turkān-Khātūn, Mālik-Shāh's wife, held the position of regent for two years before his demise. The observatory lost funding, and its operations stagnated, preventing the completion of calendar reform. Additionally, orthodox Muslims gained significant influence in court, disliking al-Khayyāmī for his independence in his quarrel.

When Sanjar, Mālik-Shāh's third son, took the throne in 1118, al-Khayyāmī fled Isfahān. He was able to compose *Mizān al-Ḥikām* and *Fī al-Qustas al-Mustaqīm* coupled with his pupil al-Khāzinī (who also worked in Merv), together with the writings of another disciple of al-Khayyāmī, al-Muẓaffar al-Isifīzarī. He lived in Merv (now Mary, Turkmen S.S.R.), the new capital of the Seljuks. A purely algebraic solution to the problem of figuring out how much gold and silver is based on weight and variable factors was one of Mizān al-Khayyāmī's works.[11]

There is insufficient information about the final period of ‘Umar Khayyām's life. Some sources state that Khayyām was highly regarded as a mathematician and astronomer for his incitement of a free way of thinking and

[11]Bal'id Humaydi, *Jawanib Min Tathawwur Al-Afkar Al-'Ilmiyah Hatta Al-'Ashr Al-Wasith* (Ribath: Mansyurat Kulliyat al-Adab wa al-'Ulum al-Insaniyah, 2000).

apostasy. Islamic philosophy is at odds with Khayyām's perspective of freedom. At that time, the relationship between the scientist and the priest deteriorated considerably.[12] 'Umar Khayyām was forced to make a long and arduous pilgrimage to Mecca when he was almost old because they took on a dangerous character for him. Al-Qiftī, in his book *Tārikh al-Ḥukamā'*, says, "*When his contemporaries doubted his faith and brought out the secrets he had hidden, he feared his blood and grabbed control of his tongue and pen and performed Hajj out of fear, not out of fear of God...*".[13]

In the end, Khayyām did nothing but write and teach. He lives in Naisabur, has few students, and sometimes goes to Bukhara. According to Tabrizi's book, Khayyām never tended to leave a family and left no descendants. Only quatrains and well-known works on philosophy in Arabic and Persian remain from it. The date of his death is still in doubt. Variations on December 4, 1131 AD, do not contradict the document; it appears to be the most likely date of death.

Omar Khayyām was buried in what is now Omar Khayyām's Mausoleum after dying at the age of 83. According to Nizami Aruzi, one of his students, in 1112–1113, Khayyām was in Balkh with Isfizari, one of the scholars he collaborated with on the *Al-Jalālī* calendar. He prophesied that "*my tomb will be buried where the north wind can spread roses on it*."[14] Four years later, Aruzi placed Khayyām's tomb in a large and famous cemetery in the Naisabur area.

C.2. The Development of the Ancient Iranian Calendar

The earliest source of the Iranian calendar tradition dates back to the second millennium B.C. It may even be earlier than the appearance of Zoroaster, a prophet from ancient Persia. The Achaemenids, the 5th century B.C. royal dynasty, were the first fully preserved calendar. Throughout history, Persians have paid attention to the concept and importance of having a calendar. They were

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[12]L I Mukhamadiyeva and E I Dudinova, "Microcosm as Omar Khayyam's Philosophy," *Al-Farabi Kazakh National University*, 2018.

[13]Ibn Yusuf Qifthi, *Tarikh Al-Hukama'* (Leipzig: Dieterich'sche Verlagsbuchhandlung, 1908).

[14]John Andrew Boyle, "Omar Khayyam: Astronomer, Mathematician and Poet," *Bulletin of the John Rylands Library*, September 1969, https://doi.org/https://translate.google.com/website?sl=en&tl=id&hl=id&client=srp&u=https://doi.org/10.7227/BJRL.52.1.3.

among the first countries to use a solar calendar and have long adhered to the solar approach rather than the moon and lunisolar. The Sun has always been a religious and divine symbol in Iranian culture. This is also the origin of the legend about Cyrus the Great.

The year that a dynasty's first monarch took the throne was the definition of an era in ancient Iran. Each monarch set their calendar starting in the first year of their reign. The final pre-Islamic ruler of Iran, Yazdigird, came to the throne in 632 AD. Islam was introduced to Iran during the Hijra era, and in 622 AD, the Prophet Muhammad moved from Medina to Mecca.[15]

The following intercalation method was used before the Achaemenian dynasty, which flourished in the sixth century B.C., to adapt the year to the seasonal changes. There are 360 days in a year (12 months with 30 days each) in eastern Iran. Subsequently, they add a month to account for the five extra days of the solar year (6 x 5 = 30) after each six years and two months (since 120 is a multiple of 6) at the end of each 120-year period to account for the extra quarter day of the solar year.

The Babylonian calendar influenced the lunisolar calendar used in western Iran. A leap year is 383 or 384 days, while a regular lunar year is 354 or 355 days (12 lunar months). Seven months are added every 19 years as part of the intercalation method (19 x 11 = 209 days = seven months), and occasionally three months are added every eight years (8 x 11 = 88 days = three months). The factor of 2,7 (7 x 2,7 = 18,9 = 19 and 3 x 2,7 = 8,1 = 8) is in line with this.

After the conquest of Egypt by Cambyses in 525 BC, the connection between Persian and Egyptian cultures must have attracted the attention of a nation rising from that old and famous civilization. Darius went to Egypt with Cambyses for several years before becoming king of Persia in 517 BC. He loved Egypt and its culture, treated Egyptians well, became popular there, and was considered their lawgiver. He probably brought many Persian nobles, sages,

[15]Reynold A. Nicholson, *A Literary History of the Arabs* (Cambridge: Cambridge University Press, 1966), https://doi.org/10.4324/9780203038956.

and religious figures to Egypt, and he probably summoned the high priest of the famous Sais temple, Uzahor, to Susa (according to an inscription in the Vatican).[16]

It is reasonable to assume that the high authorities of the Zoroastrian community in Persia adopted the Egyptian system of calculating time and introduced their calendar at or around this period due to the growing relations between the two countries, mainly because of Persia's friendly attitude towards Egypt and the two countries' good feelings towards each other. The basis for reconciliation in this area may have been established by the commonality of ideas underlying the theoretical start of the year in both instances (among the Zoroastrian and Egyptian cultures) at or close to Sirius' heliacal ascent. The old Egyptian New Year was determined by timing the rise of the first star in the Sirius constellation, Sopdet, which historically almost corresponded with the start of the Nile floods.[17]

Furthermore, the great Zoroastrians were inspired by the Egyptian system, which had a year with 365 days and no intercalation (for the portion of the erased days), particularly for more straightforward liturgical uses than their own. Consequently, they accepted and integrated the Young-Avestan calendar within the Zoroastrian church and community.[18] After the murder of usurpers who held Magi power and the general massacre of this caste in 522 BC, this community may have been encouraged, and perhaps even considered, to follow Darius' anti-Magi policies.

A group of highly brilliant Zoroastrian priests from Sistan, a region in southeast Iran, went to India in the first century A.D. Their sun worshipers are called Sistanis or Mugh-Brahmins. They arrived in India with their religion,

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[16]Cf E Meyer, "Darius," in *The Encyclopedia Britannica : A Dictionary of Arts, Sciences, Literature and General Information*, 11 Edition, vol. 7 (New York: The Encyclopaedia Britannica Company, 1910), 832, https://doi.org/10.1525/aa.1911.13.4.02a00150.

[17]F K Ginzel, *Handbuch Der Mathematischen Und Technischen Chronologie* (Leipzig: J. G. Hinrichs'sche Buchhandlung, 1914).

[18]S Hossein Taqizadeh, "The Old Iranian Calendars," CAIS : The Circle of Ancient Iranian Studies, accessed January 2, 2024, https://www.cais-soas.com/CAIS/Celebrations/calendar.htm#n42.

customs, and wisdom, which they shared and blended with native customs. In Sanskrit, they are called Shak-Dipy, referring to their ethnicity (Shaka or Saka) and their status as a minority. The radix is March 3, 78 A.D. They employed the Shaka calendar, which is still used today. The Vikrami calendar was adopted as India's official calendar in 1950, the country's independence. A change was made to the same calendar system on February 23, 57 B.C.

Between 226 and 651 A.D., the Sassanid dynasty reigned over Egypt using the same calendar system. The names of the days of the month are taken from the Zoroastrian religious angel in this Iranian adaptation of the Egyptian calendar. There's a celebration every time the names of the day and month coincide. At the year's conclusion, five extra days are called after the Avesta, the title of a Zoroastrian scripture. This calendar included an intercalation month at the end of each 120 years to compensate for the additional days in an actual solar year (120 x 1/4 = 30). Due to the long intercalation period, this rule is used sparingly. Moreover, this intercalation was not used after the Arabs conquered Iran because the royal authorities established it.

The seventh and eighth centuries A.D. are known as the "two centuries of silence" in Iranian history because Iranians defended their land and religion against Arab invaders. As a result, due to the war of resistance that has been going on throughout Iran for two centuries, cultural activity has plummeted or stopped. No treatises were compiled or retained during this period. To save themselves, Arabs or Iranians themselves burned manuscripts at this time. Therefore, our knowledge of Iran for the past two centuries is minimal. Luckily, the calendar of fourteen countries—Arab, Jewish, Macedonian, Roman, Athenian, Greek, Egyptian, Ethiopian, Syrian, Bithynian, Cappadocian, Georgian, Albanian, and Persian—was well-known and contributed valuable information by the 7th-century Armenian scholar Anania from Shirak, who was regarded as the most outstanding scholar in Armenia during the Middle Ages.

The Arabic lunar calendar, along with the Hijra period, became famous after Islamic rule in Iran had appeared. However, for agriculture, the Iranian solar calendar is still necessary. Due to restrictions on intercalation, the solar calendar underwent a slow shift, so several reforms were suggested to resolve this inconsistency. The spring and summer months have six days each, followed by five months with thirty days each, and a final month with 29 days (or 30 days in leap years) in this calendar. Astronomical calculations on the Sun's average ecliptic motion were used to make this layout. They observed that when the Sun is near the apogee (geocentric), it moves more slowly, taking longer to cover 30 degrees of the zodiac sign.

In 1925, the Iranian parliament adopted a new calendar derived from the *Al-Jalālī* calendar. This calendar, however, was modified to coincide with the Prophet Muhammad's arrival in Mecca in 622 AD. The month's name in this solar calendar is derived from its pre-Islamic origin in Persia. This calendar is currently Iran's official, even if the Hijra and Christian calendars are utilized for religious and foreign affairs.[19]

C.3. Systematics of *Al-Jalālī* Calendar Dating

After Islam developed rapidly, Muslim leaders felt the need to create the basis for repeated religious celebrations. This simple calendar had to be changed and supplemented to meet the need for a more sophisticated recording of events and transactions as the Islamic community grew. Finally, after various conquests and liberations, it was clear that systematic administration, especially tax and tribute collection, would be necessary to run a vast territorial empire properly. Anomalies such as using multiple calendars simultaneously for different purposes indicate an awareness of these increasingly complex demands. Some calendars used during the Islamic period modified Iran's ancient system. In Iran, these calendars were not only influenced by foreigners but also constantly adapted to the customs and needs of the indigenous people.

The *Al-Jalālī* calendar also referred to as Mālik-Shah and Mālikī,[20] It was created during the reign of Jalāl al-Dīn Mālik-Shah I of the Seljuks at the behest of Niẓām al-Mulk. It used observations made in Isfahan (the Seljuk capital), Rey,

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[19]Bagheri, "Ancient Iranian Calendars."

[20]Sacha Stern, *Calendars in the Making: The Origins of Calendars from the Roman Empire to the Later Middle Ages*, 1st Edition (Brill, 2021).

and Naisabur. Today, Iran and Afghanistan still use the *Al-Jalālī* calendar. Names derived from the zodiac are used in Iran, while month names in native Arabic are used in Afghanistan. Both cover 12 Months, but each country chooses a different name for each month. Both date back to the year when the Prophet of Islam began his migration to the city of Medina. There was an unsuccessful attempt to start it at the first Persian Coronation 25 centuries ago.

Table I
Month names in Hijri, *Al-Jalālī*, and Gregorian calendars[21]

Hijri Calendar	***Al-Jalālī* Calendar**	**Gregorian Calendar**
Muharram	Dey	January
Safar	Bahman	February
Rabi'ul Awwal	Esfand	March
Rabi'ul Akhir	Farvardin	April
Juamadal Awwal	Ordibehesht	May
Jumadal Akhir	Khordad	June
Rajab	Tir	July
Sya'ban	Mordad	August
Ramadhan	Shahrivar	September
Syawwal	Mehr	October
Dzulqo'dah	Aban	November
Dzulhijjah	Azar	December

According to Ismail Sama'i's book *'Ilm al-Tārikh-Dirāsāt fī al-Manāhij wa al-Maṣādir*, Khayyām created what is now known as the *Al-Jalālī* calendar. It is a Persian calendar attributed to the Seljuk Sultan Jalāl al-Dīn Shah, Sultan of Khurasan, who ordered it to be created in 468 AH/1075 A.D. Eight Muslim astronomers designed it under Khayyām's leadership,[22] It is very accurate when compared to the Gregorian calendar. However, he predates the Gregorian calendar by 500 years. The *Al-Jalālī* calendar is still used in Afghanistan to this day. In Iran, the Hijri calendar replaced it in 190, with the first beginnings of Libra showing a tropical year in Persia.[23]

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[21] M. Noshadi and A.R. Sepaskhah, "Application of Geostatistics for Potential Evapotranspiration Estimation," *Iranian Journal of Science & Technology, Transaction B, Engineering* 29, no. B3 (2005): 133–42.

[22] Isma'il Sama'i, *'Ilm al-Tārikh-Dirāsāt fī al-Manāhij wa al-Maṣādir* (Markaz al-Kitāb al-Akādimī, 2016).

[23] Muhammad Abdurrahman, "Al-Taqwīm al-Jalālī..Waḍa'ah 'Umar Al-Khayyām Musajjalan Tafawwuqah 'ala 'Gregorian,'" al-Yawm al-Sābi', 2019, https://www.youm7.com/story/2019/5/19/التقويم-الجلالى-وضعه-عمر-الخيام-مسجلا-تفوقه-على-الجوريجورى/4247611.

The current Iranian calendar began on Friday, March 22, 622 CE. It ended on September 22, 7 Rabi'ul Awwal, when the Prophet of Islam moved to Medina. But when ‘Umar Ibn al-Khaṭṭāb, the second Caliph, accepted the lunar calendar system in 638 A.D., he chose to begin the Islamic lunar calendar two months and eight days later, on July 19, 622 A.D., which was the start of the Arabic month of Muḥarram. On the other hand, since the lunar calendar's movement dates were determined by the solar cycle and its months were not correlated with the seasons, it was not appropriate for civil administration duties like planning farms and filing harvest taxes. As a result, four centuries later, during the reign of Jalāl al-Dīn Mālik-Shah of the Saljuks, the problems of the lunar calendar became very pronounced in Iran.

Khayyām established Isfahan as the prime meridian, or *nasf*.[24] The calculation of the moon is based on how the Sun moves through the zodiac. For eighty years, it is still used. This is due to dissatisfaction with seasonal shifts in the Islamic calendar because that calendar uses the moon as a benchmark instead of the Sun. A 354-day lunar year, although acceptable to desert nomadic peoples, proved inapplicable to sedentary agricultural societies. The Iranian calendar is one of the few non-lunar calendars settled Muslims use for agricultural purposes. However, adopting the Persian year will not bring total stability into the calendar because the beginning of the Persian year is aligned with tax collection and pension payments.[25]

At its discovery in 1079 AD, the *Al-Jalālī* calendar was the most accurate calendar that calculated the length of one solar year (One complete turn around the Sun). They calculated the length of one solar year to be 365.24219858156 times the duration of Earth's rotation around it (aka one day). The most important feature of the *Al-Jalālī* year is the beginning of the March equinox. The longest day in the northern hemisphere coincides with the

[24]Abbas Amanat, *Iran: A Modern History* (New Haven: Yale University Press, 2017).

[25]S Hossein Taqizadeh, “Various Eras and Calendars Used in the Countries of Islam,” *Bulletin of the School of Oriental and African Studies* 9, no. 4 (1939): 903–22, https://doi.org/10.1017/S0041977X00135049.

last day of the third month, and the longest day in the southern hemisphere occurs precisely on the last day of the ninth month.[26]

The *Al-Jalālī* calendar contains a basic thirty-three-year intercalation cycle, which is determined by multiplying 33 by 0.2424 to get 7.9992. This yields eight leap years for 366 days and 25 ordinary years for 365 days. Leap years are of two varieties. After three regular (quadrennial) years, the first leap year occurs; following four regular (quinquennial) years, the second leap year occurs. Over four years, the vernal equinox happens twice a year, once in the afternoon and once before. But every 33 years, the vernal equinox—which falls between the two pairings and establishes the quinquennial period—occurs close to midnight. It occurs more frequently every 33 years and only occasionally, but much less frequently, after a 29-year interval.

In the 33-year cycle, the first leap year is quinquennial, and the other seven are quadrennial. Thus, the intervals of intercalation are used in years 5, 9, 13, 17, 21, 25, 29, and 33. The total cycle amounts to 25 x 365 + 8 x 366 = 12053 calendar days. For comparison, the current duration of solar time is 33 x 365,242362 = 12052,99795 days, which means a 33-year cycle advances 0,00205 days, or about 3 minutes, from solar time. For this reason, the rigorous 33-year cycle requires changes at a later date. The progress would add up to one day if the vernal-equinox year had a constant length of about 500 cycles or 16,000 years. However, after the +3000 epoch, the year's duration decreases and reaches a value of about 365,24182 days at the +8000 epoch; a shorter period is needed to get a full day.[27]

The astronomer Khāzeni, who probably belonged to the reform group, later wrote *Zij Sanjari* (astronomical observations and tables) during the reign of Mālik-Shah's son. It was written using four-year or five-year intercalations,

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[26]Xoigel, "What Is the Difference between Gregorian, Persian, and Julian Calendars?," Quora, 2018, https://www-quora-com.translate.goog/What-is-the-difference-between-Gregorian-Persian-and-Julian-calendars?_x_tr_sl=en&_x_tr_tl=id&_x_tr_hl=id&_x_tr_pto=tc.

[27]Mohammad R Sayyad, "The Sequence of Quadriennial and Quinquennial Intercalations in the Jalâli Calendar (in Persian)," in *12-Th Mathematics Conference, Isfahân University* (Isfahan, 1981), 33.

most likely derived from the work of Khayyām's reform group. Khāzeni calculated 53 intercalations, eight quinquennial, and 45 quadrennial for the 220-year period of the *Al-Jalālī* calendar.

Two centuries later, astronomer and mathematician Nāṣir al-Dīn al-Tūsī (1201–1274) was the head of the Maragha observatory, which produced *Zij Ilkhani*. He is renowned for his insightful criticisms of Ptolemaic astronomy, novel mathematical models of planetary motion, and succinct but crucial explanations of *Al-Jalālī*'s reforms. He makes it quite evident in his Ilkhani Zij that intercalation occurs every four years, making a year consist of 366 days. Quinquennial intercalations are carried out via induction following seven or eight quadrennial intercalations.

The celebration of the new year in the *al-Jalālī* calendar is called *Nowrooz*, where the festivals and rituals continue for 13 days. Jamshid chose *Nowrooz* because the Sun moves every 365 quarters of days until the constellation Aries returns. When he finds the day, Jamshid calls it *Nowrooz* and celebrates it. After that, the Persian kings followed suit. When they found a date to celebrate the Sun, they made it a symbol and told everyone worldwide about it. Everyone who celebrates *Nowrooz* will have fun until the following year.[28] *Nowrooz* celebrations are celebrated in Iran and Afghanistan. However, they are celebrated in almost all neighboring countries, by different ethnicities, and by diasporas worldwide. Thus, the *Al-Jalālī* calendar system is considered one of the secular calendars.

According to a long-standing Iranian custom, the first day of the *Al-Jalālī* calendar year starts at midnight (real Tehran time) since it cannot begin precisely at the moment of the summer equinox. Accordingly, the first day of the year is the one on which the vernal equinox occurs before noon, while the first day of the calendar year is the one on which it occurs after noon. Thus, The year starts at midnight on the day closest to the equinox. This was accom-

[28]Farhad Javadi, “Finding the Roots of Nowrooz in History,” in *Eclipses of History Book*, 2012.

plished by tracking the Sun's height during the day and determining that *Nowrooz* was the first day on which the Sun's height rose over the celestial equator.[29]

C.4. Comparison between *the Al-Jalālī* Calendar and the Gregorian Calendar

The *Al-Jalālī* Calendar and the Gregorian Calendar have fundamental differences in their calculation of time and historical background.

a. In the eleventh century, a group of astronomers led by Omar Khayyām developed the *Al-Jalālī* calendar, commonly known as the Persian calendar or the Solar Hijri calendar. It is a Shamsiah (solar-based) calendar. It was formally accepted in Iran and Afghanistan. It employed precise astronomical calculations to establish the duration of the solar year, which is 365,24219 days. On the other hand, the Julian Calendar was deemed erroneous, and Pope Gregory XIII corrected it in 1582 by creating the Gregorian calendar. Today, the Gregorian calendar is extensively used worldwide, particularly for international trade and communication, and it sets the duration of the solar year at 365,2425 days.[30]

b. According to the *Al-Jalālī* Calendar, the new year begins at the vernal equinox which usually falls on March 21, while the Gregorian Calendar begins the new year on January 1.

c. The New Year in the Gregorian calendar is celebrated at midnight, wherever one is. *Nowrooz*, or the beginning of the year in the *Al-Jalālī* calendar, occurs around the world at the same time at different hours, which is based on the meridian of Tehran at exactly 00:00.[31] For example, the city of Jakarta will celebrate the new year in the early morning at 03.30 WIB because it has a time zone difference of 3 and a half hours, and

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[29]M Heydari and Malayeri, "A Concise Review of the Iranian Calendar" (Paris, 2004), http://arxiv.org/abs/astro-ph/0409620.

[30]"Kalender," Ensiklopedia Dunia, Universitas Stekom, accessed January 1, 2024, https://p2k.stekom.ac.id/ensiklopedia/Kalender.

[31]Javadi, "Finding the Roots of Nowrooz in History."

the city of Cairo will celebrate the new year at 22.30 with a difference of 1 and a half hours.

d. On the principles of calculating years and setting leap years. The Gregorian calendar calculates the year by adjusting the period of the Earth's orbit around the Sun. In contrast, the *Al-Jalālī* calendar is based on calculations that follow the solar cycle, making it very accurate in adjusting the year to the tropical year. Leap years are also different; The Gregorian calendar uses a more straightforward leap year rule every four years, but the *Al-Jalālī* calendar uses more complicated rules.[32]

e. The primary purpose of the *Al-Jalālī* calendar is to accurately regulate the calendar with the Sun's movement for the benefit of agriculture, the determination of the seasons, and religious celebrations associated with the seasons. Meanwhile, the Gregorian calendar aims to correct miscalculations in the Julian calendar so Easter celebrations fall in the right season. The *Al-Jalālī* calendar is one of the most precise solar calendars because it is based on exact astronomical calculations. This accuracy helps farmers determine the right time for planting and harvesting, increasing agricultural productivity. This facilitates long-term agriculture planning, such as land management and crop rotation. A proper calendar can help manage natural resources such as water, especially in countries with arid climates such as Iran.[33] Determining the right time for activities such as irrigation can reduce water wastage and improve resource use efficiency. The *Al-Jalālī* Calendar can be integrated with contemporary weather forecasts and information technology to provide farmers with more accurate and timely information. This can help determine the best time to plant and manage the land.

[32]Rinto Anugraha, "Kalender Julian, Kalender Gregorian Dan Julian Day," 2016, https://rintoanugraha.staff.ugm.ac.id/kalender-julian-kalender-gregorian-dan-julian-day/.

[33] Milad Nouri et al., "Water Management Dilemma in the Agricultural Sector of Iran: A Review Focusing on Water Governance," *Agricultural Water Management* 288, no. May (2023): 108480, https://doi.org/10.1016/j.agwat.2023.108480.

D. Conclusion

This research implies that the *Al-Jalālī* Calendar, created by ‘Umar Khayyām in the 12th century, is one of the most accurate calendars based on the Sun. Studying these calendars can provide a deeper understanding of the astronomical techniques used at the time and how precise calculations of time could be achieved. In addition, the study emphasized the role of ‘Umar Khayyām in mathematics and astronomy. Besides being known as a poet, Khayyām was an adept mathematician and astronomer. The study shows how his expertise helped create a highly accurate calendar. The Al-Jalālī Calendar demonstrates scientific discoveries in the Islamic world in the Middle Ages. The study helps uncover the history of culture and science. It shows how culture and science are interconnected to produce significant innovations.

With the author's limitations in accessing the object of research, the author advises the next researcher to cooperate with international researchers and institutions so that they can get easier access to manuscripts and related documents. Working together makes it easier to access the resources needed. Then, support the project to digitize manuscripts and historical documents related to the *Al-Jalālī* Calendar. This will make the document more accessible to researchers around the world. Subsequently, it formed a network of specialized researchers concentrating on calendar investigations and contributions of medieval Muslim scientists. The network can be used to share resources, results, and research techniques.

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