

Sun Apparent Motion and Salat Times

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Abstract

The knowledge of the starting and ending times for prayers is of fundamental importance to Muslims. This paper discusses the definitions of the five Islamic prayers, which are termed *fajr*, *dhuhr*, *asr*, *maghrib* and *isha* according to the major schools of Islamic jurisprudence. As these times depend on the astronomical positions of the sun in its daily movements, the paper introduces the necessary equations, explaining how to calculate the starting and ending of each prayer time. By using our own observations, we conclude new scientific explanations for the false dawn and the true dawn: our explanations match well with the definitions of *al-fajr al-kathib* and *al-fajr al-sadiq*.

Keywords: false dawn, true dawn, zodiacal light, twilight, meridian, sunrise, sunset.

1. Introduction

The daily prayers are an integral part of a Muslim's life. In order to fulfill their religious obligation, it is important for all Muslims to know the timings of the daily prayers. Knowing the timings of *dhuhr* and *maghrib* prayers has never been a problem; but knowing the timing of *fajr* prayer has not been easy. Previously, in Muslim countries, Muslims used to rely on *athan* (the call to the prayer) of mosques, which would mostly depend on visual senses to determine the time of *fajr* prayer. Nowadays there are timetables, which can be used by all Muslims all over the world. In preparing a timetable, for *dhuhr* and *maghrib* prayers one can easily ask any observatory or astronomical institution for the times of "noon" and "sunset" because the times of "noon" and "sunset" are well defined. The difficulty arises in determining the time for *fajr* (dawn) prayer. How do we define *fajr* in a scientific way? Moreover, how can we explain the difference between the "false" dawn and the "true" dawn?

In this paper, we intend to discuss the definitions of *salat times* in Qur'an and Hadith and see how we can relate them to the existing astronomical terms.

1.1. Salat Times in the Qur'an

Direct or indirect mention of the times of the daily prayers can be found in several parts of the Qur'an, including the following:

Pray at the two ends of the day and in some watches of the night. Lo! Good deeds annul evil deeds. This is a reminder for the mindful. (Hud, 11: 114)

Establish prayer at the setting of the sun until the dark of the night, and the recital of the Qur'an at dawn. Lo! The recital of the Qur'an at dawn is ever witnessed. (Al-Isra, 17:78)

Celebrate the praises of your Lord before the rising of the sun and before its setting. Glorify Him some hours of the night and at the two ends of the day, that you may find acceptance. (Ta-Ha, 20: 130)

1.2. Salat Times in Hadith:

Here, let us start with two well-known hadiths:

Abdullah ibn 'Amr reported that the Messenger of Allah, upon whom be

peace, said: "The time of the noon prayer is when the sun passes the meridian and a man's shadow is the same length as his height. It lasts until the time of the afternoon prayer. The time of the afternoon prayer is until the yellowing of the sun (during its setting). The time of the evening prayer is as long as twilight. The time of the night prayer is to the middle of a night of medium duration. And the time of the morning prayer is from the appearance of the dawn until the time of sunrise. When the sun rises, abstain from praying, as it rises between the horns of Satan." (Muslim, 966)

Jabir ibn 'Abdullah narrated that the angel Gabriel came to the Messenger of Allah and said to him "Stand and pray," and they prayed the noon prayer when the sun had passed its meridian. He then came to him for the afternoon prayer and said, "Stand and pray," and they prayed the afternoon prayer while the length of a shadow of something was similar to the length of the object. Then he came at sunset and said, "Stand and pray," and they prayed the sunset prayer when the sun had just disappeared. Then he came at night and said, "Stand and pray", and they prayed the night prayer when the twilight had disappeared. He came again when dawn broke (and they prayed the morning prayer). Then Gabriel came on the next day at noon and said (to the Messenger of Allah), "Stand and pray," and they prayed the noon prayer when the length of the shadow of something was close to the length of the object. Then he came for the afternoon prayer and said, "Stand and pray," and they prayed when the shadow of something was twice as long as the length of the object. Then he came at the same time (as the previous day) for the sunset prayer, without any change. Then he came for the night prayer after half of the night had passed ("or," he said,

"one-third of the night"). Then he came when the sky was very yellow and said, "Stand and pray," and they prayed the morning prayer. Then Gabriel said, "Between these times are the times for the prayers." (Al-Nasa'i, 523).

Sayyid Muhammad Rizvi reported in *The Light* (Dar-es-salaam) in February 1991, the following:

"Ayatullah Sayyid Muhammad Kazim al-Yazdi, writes:

The rising of fajr is known by the appearance on the horizon of a light which ascends towards the sky and resembles a tail of the fox--this is known as al-fajr al-kazib (the false dawn). Then the light spreads on the horizon (and becomes like a white cotton and like the river of Sura') in such a way that whenever you look towards it, it will convince you of its increasing beauty. In other words it [al-fajr as-sadiq, is known by] the spreading of the light on the horizon after it had been ascending towards the sky. (Al-Yazdi, al-'Urwatu 'l-Wuthqa, p. 172)

Ayatullah al-Khu'i also writes:

The al-fajr as-sadiq is the light which spreads horizontally on the horizon and it increases in visibility and clarity. Before this is al-fajr al-kazib: a light which appears vertically on the horizon, ascending towards the sky like a pillar, and it decreases and weakens till it disappears. (Al-Khu'i, Minhaju 's-Salihiyn, vol. 1, p. 132.)"

1.3. Discussing Qur'an verses and Hadiths

From the Qur'anic verses and the hadiths mentioned above, we conclude that the time of the Morning Prayer begins with the true dawn and lasts until sunrise. It is also clear that the noon prayer time begins when the sun

passes the local meridian and it continues until an object's shadow is the same (or double) length as the object itself. The afternoon prayer begins when the shadow of an object is of the same (or double) length as the object itself, and continues until the sun sets. The time for the sunset prayer begins with the disappearance of the sun and lasts until the red twilight ends. The night prayer begins when the red twilight disappears and continues up to half of the night.

Therefore, we can define and calculate easily the exact times for the beginning and the end of dhuhr time, asr time and magrib time.

2. False Dawn and True Dawn

Concerning isha and fajr times, there is absolute agreement among the Muslims on the fact that isha time starts when the evening twilight disappears or when the red twilight ends. All Muslims also agree that there are two dawns: the false dawn (al-fajr al-kathib) which is a vertical white streak of light that appears above the horizon, and the true dawn (al-fajr al-sadiq) which starts when the rays of the sun light change their direction and begin to spread over the horizon.

Sayyid Muhammad Rizvi concludes in his article mentioned above that the disagreement is not in the religious definitions of the true dawn, but it is in applying the phenomenon of al-fajr al-sadiq on a particular time of dawn. We agree with this conclusion, but we do not agree with Rizvi's proposal to consider the astronomical twilight as al-fajr al-kathib!

In trying to find a scientific definition for al-fajr al-sadiq; Rizvi first describes the three known twilights: the astronomical twilight (sun is 18 degrees below the horizon), the nautical twilight: (this occurs when the sun is at 12 degrees below the horizon), and the civil twilight (sun is at 6 degrees below the horizon). He then proposes, "Even in its later stages, the astronomical twilight may, at best, be considered as al-fajr al-kathib (the false

dawn)". His proposal is in contradiction with Ayatullah al-Khu'i definitions of al-fajr al-kathib quoted by Rizvi himself.

Therefore, what is really al-fajr al-kathib?

All Hadith definitions of al-fajr al-kathib (mentioned in this paper or elsewhere) describe it as the light that appears vertically on the horizon, ascending towards the sky like a tail of the fox, a pillar, or a pyramid.

We have studied all celestial phenomena, which may occur at, before, during, or after twilight, and we find that the only astronomical phenomenon, which fit well with Hadith definitions of al-fajr al-kathib, is the phenomenon of Zodiacal Light.

2.1. Zodiacal Light

The zodiacal light is a faint pyramid of light that is associated with the ecliptic and the grouping of stars forming the zodiac. In order to see the zodiacal light, we need to be away from city light. The explanation for the zodiacal light is that meteoric dust particles found in the plane of the solar system scatter sunlight in such a way that it is faintly visible from Earth. This dust mainly comes from asteroids and comets that periodically drop off debris on their way around the Sun.

The diffuse light scattered by the dust particles can only be seen during evening or morning twilight of spring or fall—when the sun rises or sets more abruptly. In the Northern Hemisphere, we can see it best an hour or two before the sunrises in October and November and after the sunsets in February and March. It is possible to see it at other times of the year, but when the sun rises or sets at a more acute angle, this weak light is generally too close to the horizon to be noticeable.

Near the Equator, where the sun appears and disappears at a steeper angle than it does in the mid latitudes or near the poles, the zodiacal light may be observed throughout the year. If the conditions of observation are excellent, that is, on a clear night with no moon, and away from city light, we can see the zo-

diacal light as bright as the Milky Way, and it can be seen 30 to 60 degrees up from the horizon (Fig.1.)

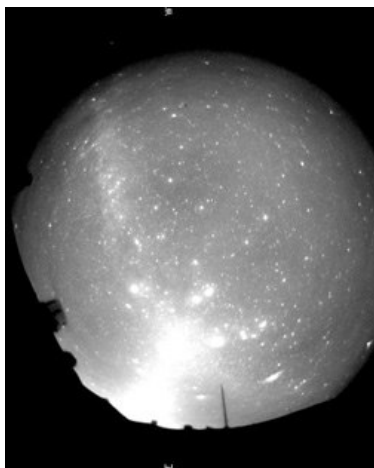


Fig. 1. Zodiacal Light and False Dawn

Note: An unusual triangle of light will be particularly bright near the eastern horizon before sunrise in October and November during the next two months for observers in Earth's northern hemisphere. Once considered a false dawn, this triangle of light is actually zodiacal light, light reflected from interplanetary dust particles. The triangle is clearly visible on the left of the above frame, taken from Mauna Kea in Hawaii on August 30, 2001. (Courtesy: <http://antwrp.gsfc.nasa.gov/apod/ap010912.html>.)

2.2 Our Observations of Zodiacal Light

In winter, the skies of Sana'a, the capital city of Yemen (15.4 degrees N, 44.2 degrees E), are usually clear with dry sunny days and very clear nights. However, Yemen lies on the Tihama—the edge of one of the world's great sand seas, Rubh-al-Khali—and dust clouds are blown from the Tihama up to the Highlands in the direction of Sana'a. Sana'a has two periods of dust annually; the first from March to May and the second from July to September. At the same time, the rainy seasons, which clean the lower troposphere, occur during these two periods of dust. Thus, according to Sultan (2004), excellent conditions for observation - better than those of winter - are occa-

sionally possible during spring and autumn after the air is cleaned by a rainstorm. In the autumn of 2003, we got these excellent conditions during the period 23-28 November after the heavy rain of the previous season.

On November 24, 2003 (the last day of Ramadan), in Bani-Hoshiesh, 30 km east of Sana'a, our observation team started looking for the zodiacal light 3 hours before sunrise. Only 2 hours before sunrise, at 4:01 local time, we had the first chance to see the faint zodiacal light column rise steeply from the eastern horizon en parallel with the Milky Way, which was descending in the south.

No much later, the light column became a triangular glow of light extending up to 50 degrees from the horizon, tilting slightly to the right. Its base near the horizon was around 20 degrees wide. The zodiacal light got brighter and brighter as time was progressing; just before the astronomical twilight it was very bright, brighter than the Milky Way.

Seventy-one minutes before sunrise, at 4:50 we noted that the eastern horizon starts to glow faintly, and the zodiacal light merged into a bright white area on the horizon: it was the sign of the beginning of the astronomical twilight.

Twenty-five minutes later, at 5:15 (calculations show that sun altitude at this time was -13.2 degrees), we noticed that the developing twilight starts to show colors. It became very pale red at the horizon, and yellow just above it: it was the sign of the beginning of the nautical twilight (due to our site elevation 2200 m above sea level, the nautical twilight starts earlier than at sea level).

Fifteen minutes later, at 5:30, it was still too dark to read our written notes, but noticeably getting lighter, The Milky way faded away, and the zodiacal light was still visible higher up along the sky.

Twenty-six minutes before sunrise, at 5:35 (calculations show that sun altitude at this time was -8.6 degrees), the zodiacal light faded, to make place for a deep orange twilight arch stretching almost from north to south.

Eighteen minutes before sunrise, at 5:43 the twilight arch at the point where the sun rose, started to glow with a purple spot which expanded few minutes later into a large part of the eastern sky: it was the sign of the beginning of the civil twilight.

Twelve minutes before sunrise, at 5:49, we had seen the crepuscular rays spanning the entire sky and converging to the west. At exactly 6:01, we stopped gazing; the upper edge of the sun disc emerges with intense flash of light that blurred the scene.

Therefore, we agree with Rizvi's other proposal of considering the nautical twilight as the best candidate for al-fajr al-sadiq (which corresponds, in our observations, to the instant when twilight starts to show colors).

Now, we come back to Rizvi's paper: the followings are the last three lines of his paper:

Following the basis of precaution, the astronomical twilight should be considered as the beginning of fasting; the nautical twilight should be considered as the beginning of the subh prayer time.

However, following our basis of precaution, which depends on observations, we propose the following: the nautical twilight should be considered as the beginning of both fasting and fajr prayer time, by this, and only this, consideration we are sure that Muslims are not fasting before the beginning of al-fajr as-sadiq.

Concerning the beginning of isha time, we propose the -15 degrees of sun altitude; by this consideration, we are sure that the colors of twilight have disappeared.

According to our previous discussion, we can precise the astronomical definitions for prayer times as the following:

Fajr time: It starts with the true dawn (the beginning of nautical twilight), when the sun altitude is -12 degrees—taking into consideration that the nautical twilight—starts earlier on the high mountains and ends just before

sunrise, when the apparent sun altitude is -0.5 degree.

Dhuhr time: It begins after mid-day, when the eastern edge of the disk of the sun has passed the local meridian and ends at the start of asr time.

Asr time: It starts when the shadow of an object exceeds its height, plus the shadow of object at noontime or when the length of the shadow exceeds the double of the height of the object, plus the shadow of the object at noon, and ends at the start of maghrib time.

Maghrib time: It starts at sunset, when the upper edge of the disk of the sun is on the horizon, that is, when the apparent sun altitude is -0.5 degree, and ends at the start of isha.

Isha time: It starts when the red of sunset leaves the sky, that is, when sun altitude is -15 degrees, and ends at midnight.

3. Salat Times Equations

The following section This section contains the essential equations for calculating the prayer times. It is essentially for those who interested in astronomy and mathematics. We shall try to simplify and explain these equations in further studies, in the near future.

To calculate the instant of rising or setting of the sun, whose right ascension α and declination δ are known, we have first to calculate the hour angle H at the moment of rising or setting by the fundamental formula of spherical trigonometry, Smart (1977):

$$\cos H = \frac{\sin(h_0) - \sin(\delta) \sin(\varphi)}{\cos(\delta) \cos(\varphi)}$$

where φ is the observer's latitude and h_0 ; the sun altitude has the following general expression (reference 1):

$$h_0 = -R - 0.5D - \eta_1$$

where R is the refraction at the horizon ($\approx 34'$) D is the diameter of the sun ($\approx 32'$), and $\eta_1 = 1' 56'' \sqrt{A}$ (A is the observer's elevation in meters).

The sidereal time (in degrees) at noon (dhuhr time) is given by:

$$T1 = \alpha \dots\dots\dots (1)$$

Since sun altitude at noon ($h_o = 90 - (\varphi - \delta)$) then, the hour angle of asr time (with same-size shadow) will be:

$$\cos H2 = \frac{\sin\{\cot^{-1}(1 + \tan|\varphi - \delta|)\} - \sin(\delta)\sin(\varphi)}{\cos(\delta)\cos(\varphi)}$$

The sidereal time (in degrees) for asr (with same-size shadow):

$$T2 = \alpha + H2\dots\dots\dots(2)$$

We can get the Hour Angle of Asr time (with double-size shadow) by putting $(2 + \tan|\varphi - \delta|)$ instead of $(1 + \tan|\varphi - \delta|)$ in the previous equation of asr hour angle.

The hour angle of magrib time will be:

$$\cos H3 = \frac{\sin(-0.83 - 1'56''\sqrt{A}) - \sin(\delta)\sin(\varphi)}{\cos(\delta)\cos(\varphi)}$$

And the sidereal time (in degrees) of Maghrib will be:

$$T3 = \alpha + H3\dots\dots\dots(3)$$

The hour angle of isha time will be:

$$\cos H4 = \frac{\sin(-15) - \sin(\delta)\sin(\varphi)}{\cos(\delta)\cos(\varphi)}$$

And the sidereal time (in degrees) of isha will be:

$$T4 = \alpha + H4\dots\dots\dots(4)$$

The hour angle of fajr time will be:

$$\cos H5 = \frac{\sin(-12) - \sin(\delta)\sin(\varphi)}{\cos(\delta)\cos(\varphi)}$$

And the sidereal time (in degrees) of fajr will be:

$$T5 = \alpha - H5\dots\dots\dots(5)$$

4. Conclusions

The conclusions of this research can be summarized in four points:

(1) We have studied all celestial phenomena, which may occur before, during or after twilight, we found that the only astronomical phenomenon, which matches the hadith definitions of al-fajr al-kathib, is the phenomenon of zodiacal light.

(2) Following the basis of precaution, which depends on observations, we propose that the nautical twilight should be considered as the beginning of both fasting and for fajr prayer time; by this consideration we are sure that Muslims are not fasting before the beginning of al-fajr al-sadiq.

(3) The beginning of the nautical twilight on high mountains needs further studies.

(4) The paper gives the essential equations for calculations of the prayer times.

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