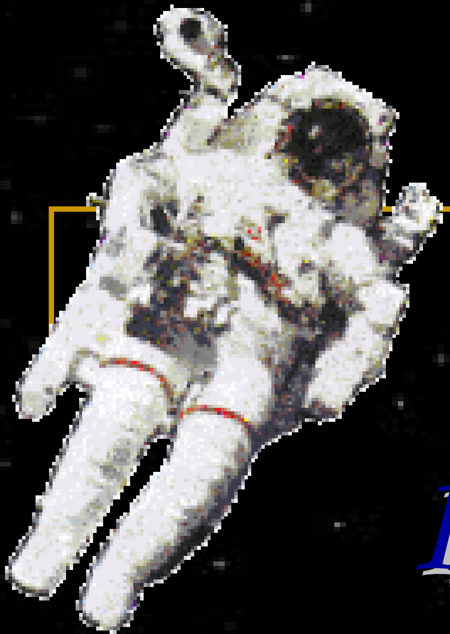
بسم الله الرحمن الرحيم



# *Islamic Astronomy*

# Topics covered

- **Islamic calendar**
- **types of instruments and mathematical methods used**
- **Prayers based on the astronomical position of the sun in the sky**
- **Brief history of *Kaaba***
- **astronomical importance in the structure of *kaaba***
- ***problems in Islamic astronomy***
- ***solutions to problems by astronomers***
- ***Observatories in Islamic astronomy***

# *Islamic Calendar*

# *Islamic Calendar*

## The calendar is called Hijri

- It is first introduced by Umar ibn Al-KHaTTab a close companion of the Prophet in 638 C.E (common era).
- The reason for this introduction was to rationalise the various, at times conflicting, dating systems used during that era.
- HIJRA was the migration of Prophet Mohammad from Mecca to Madina in September 622 C.E. which led to the foundation of the first Muslim city-state, a turning point in Islamic and world history.
- Thus it was finally agreed that the referrence point for the calendar be “HIJRA”.
- The starting date of the calendar was the 1st day of the 1st month of the year of the Hijra. This day corresponds to 16 July 622 C.E of the Julian calendar.

# *Islamic Calendar*

|  |  |
|---|---|
| (1) Muharram | (7) Rajab |
| (2) Safar | (8) Sha`baan |
| (3) Raby` Al-Awal | (9) Ramadan |
| (4) Raby` Al-Thaany | (10) Shawwal |
| (5) Jamadi Al-Awal | (11) Thu Al-Qi` Da |
| (6) Jamadi Al-Thaany | (12) Thu Al-Hijja |

Importance of the calendar

- The calendar has 12 months
- It is a lunar calendar
- Important dates in the Islamic calendar

1st Muharram – islamic new year

27th Rajab – ISRA & Miraj

1st Ramadan – first day of fasting

17th Ramadan – start of revelation: NUZUL AL QURAN

(The last 10 days of Ramadan includes: LAYTAT ALQADER)

1st Shawwal – 1st major festival: Hari Raya Puasa

8-10th Thu Al-Hijja – the Hajj to Makka

10th Thu Al-Hijja – second major festival: Hari Raya Haji

# Islamic Calendar

## Importance of the calendar

- Within each month, there are 7 days per week, similar to the Gregorian Calendar

| | | |
|---|---|---|
| Sunday | al-Ahad | the first (day of the week) |
| Monday | al-Ithnayn | the second (day of the week) |
| Tuesday | ath-Thulatha'a | the third (day of the week) |
| Wednesday | al-Irbi'aa | the fourth (day of the week) |
| Thursday | al-Khamees | the fifth (day of the week) |
| Friday | al-Jumu'ah | From jama'a: to gather. This name was given to the sixth day of the week in Islam because it is the day on which people gather for shalah (prayer). |
| Saturday | as-Sabt (related to the word sabbath) | stoppage or cessasion. This is the seventh day of the week on which no creation occurred. |

# *Islamic Calendar*

## Importance of the calendar

- Though the calendar helps the muslims to keep track of time and to date important religious events, to them it has other religious and historical significance.
- Using the calendar with 12 (purely) lunar months without intercalation was considered to be of divine command as evident from the following verses of the QURAN:

> They ask thee the New Moons Say: They
> are but signs To mark fixed periods of time
> In (the affairs of) men And for Pilgrimage. (II:189)

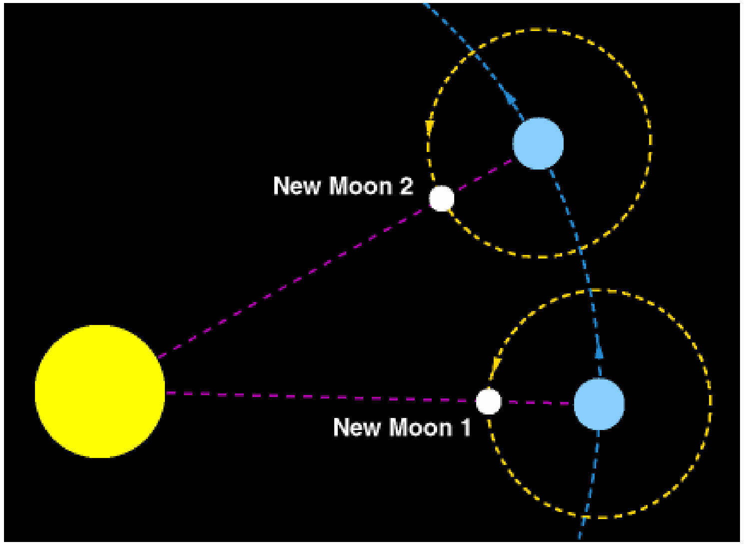
> The number of months In the sight of Allah Is twelve
> (in a year) So ordained by Him The day He created
> The heavens and the earth; Of them four are sacred;
> That is the straight usage So wrong not yourselves
> Therein, and fight the Pagans. (IX: 36)

# *Islamic Calendar*

## The calendar being a lunar calendar

Let us look at the some characteristics of the moon before going into the lunar calendar topic.

- The time it takes for the Moon to go from one New Moon to the next is called a **Synodic Month**, and is 29.530589 days.
- Why then is the **Synodic Month** longer by approximately 2 days to the actual time taken for the moon to revolve round the earth?



As the Moon is orbiting the Earth, the Earth is going around the Sun; and while the Moon is busy completing its orbit of the Earth, the Earth moves a twelfth of the way around the Sun. As shown in the diagram, this means that starting from a New Moon, the Moon has to go around a full orbit and a bit more to get back in between the Earth and the Sun again.

# Islamic Calendar

## The calendar being a lunar calendar

Differences between the Islamic and Gregorian calendar

- One is solar the other lunar.

  The lunar calendar follows the rotation of the moon around the earth whereas the solar calendar follows the rotation of the sun around the earth. (Geocentric point of view)

- Does not follow the seasons

  Due to this 11 days shorter than the Gregorian calendar, the Islamic calendar cannot be used by farmers to predict the coming seasons. This 11 days short character moves the calendar backwards. (For example, 1st Muharram falls on 24th of Oct this year. Then in the coming year, 1st Muharram falls on the 13th of Oct)

# *Islamic Calendar*

The calendar being a lunar calendar

- 11 days shorter than the Gregorian calendar.

  The Islamic calendar has 12 months with approximately 29.5 days each months. In a year it has 12 x 29.5 = 354 days. Subtract the days of both calendars, we'll get 365 – 354 = 11 days shorter.

  Since the Islamic calendar is not in sync with the Gregorian calendar, it means that Muslim festivals which falls in the same Hijri month will fall in different seasons.

- 33 year cycle

  If we take 365 / 11 ~ 33 it is in a 33 year cycle that the lunar months will make a complete turn and fall during the same season again.

# *Islamic Calendar*

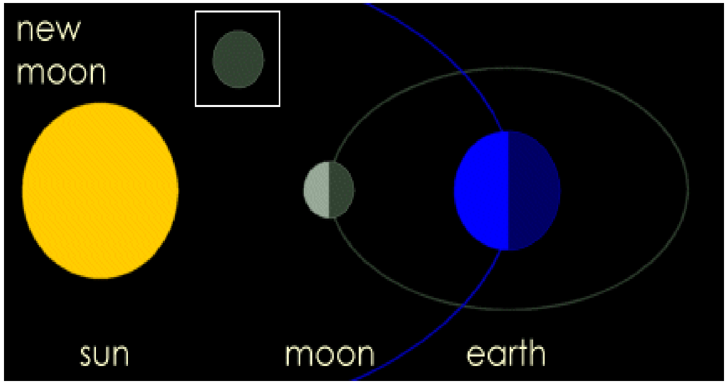
## Hari Raya Puasa and Hari Raya Haji

- Hari Raya Puasa falls on the 1st day of the 10th Islamic month
- Hari Raya Haji falls on the 10th day of the 12th Islamic month.
- Due the the 11 days short cahracter of the calendar, any Muslim festival can occur twice in the same Gregorian year. An example: In 1999, Hari Raya Puasa fell on Jan 19; in 2000, it fell on Jan 8 and Dec 27.
- Since 365/11 =33, this "twice" Hari Raya Puasa per year will occur every 32 or 33 years. Hari Raya Puasa will  also meet up with Chinese New Year for 2-3 years, and then continue on its 33 years cycle backwards through the calendar and meet up with Chinese New Year again after about 30-31 years.

# *Islamic Calendar*

## The New or ‘Wane’ moon

- plays a very important role in determining the start of a new month for the Islamic calendar
- The new moon occurs when the moon, Sun and earth lie exactly on the same line.
- Here the sun illuminates the portion of the moon facing it and the other side facing the earth remains dark. (refer to figure)



- We’ll not be able to see the new moon because of the sun’s glare. Note that usually the new moon is above or below the sun. It’s rare of it to be at the same celestial latitude as the sun because if that happens often, we’ll be getting solar eclipses every once a Islamic month.
- For religious reasons, the beginning of a Hijri month is not by the start of the new moon but by the actual human sighting of the waxing crescent at a given location.

# *Islamic Calendar*

The New or ‘Wane’ moon

Here are some guidelines on how to look for the waxing crescent.

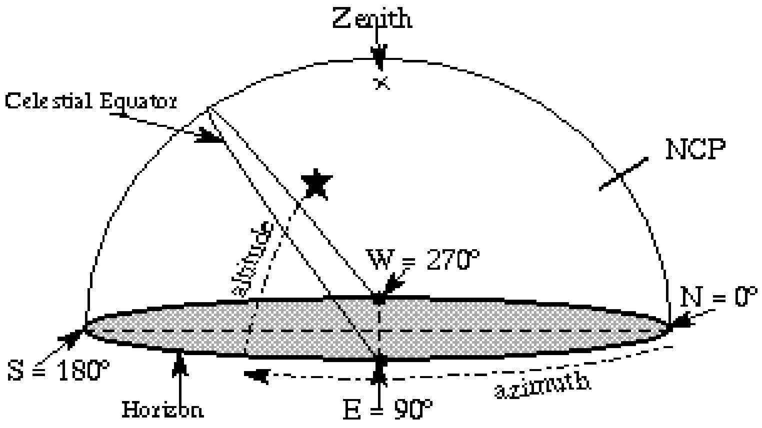
- When to look for the waxing crescent? After sunset. The waxing crescent to our knowledge is near the sun. Visibility of this crescent during the day is about zero due to the twilight glare. The best time is to wait till the glare decreases as when the sun starts to set.
- Where to locate the waxing crescent? The waxing crescent is near the sun, that means that when the sun sets it’ll appear around the setting point of the sun. The sun sets in the west thus we’ll look for the crescent in the west.

Fig shows crescent; moon age:22h 47min
Elevation 2.4 degrees

# *Islamic Calendar*

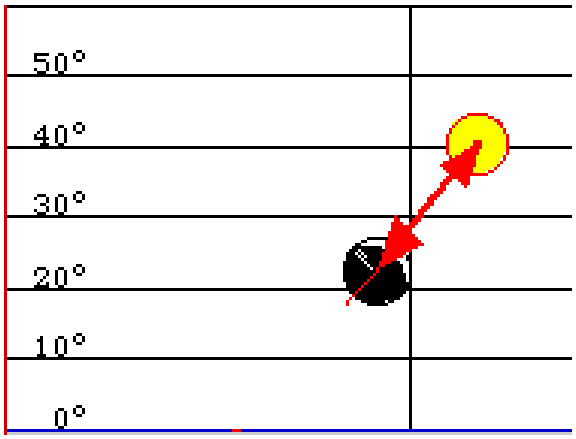
## Factors involving crescent visibility

- Crescent Altitude – The moon's **altitude** is measured upward from the horizon to the bottom edge of the moon, and is 0 degrees at the horizon and 90 degrees overhead.



side view

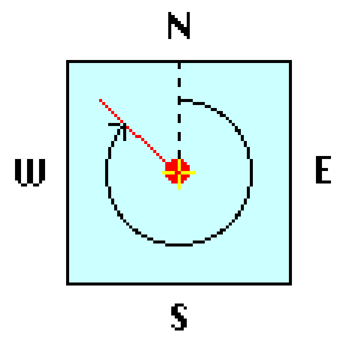
- Angular distance between the centres of Sun and moon – The angular distance is measured between the sun and moon with the Earth being the vertex.

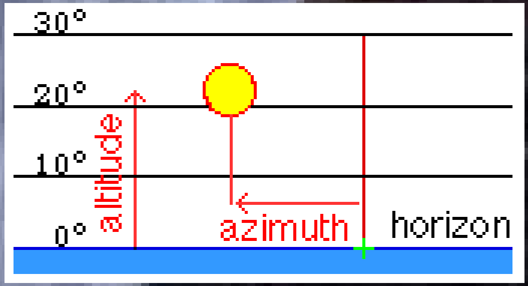


# *Islamic Calendar*

## Factors affecting crescent visibility

- **Interval between sunset and moonset – The longer the interval between sunset and moon setting, the better the crescent visibility. This is because twilight is reduced. The lesser the twilight, the visibility of the crescent increases.**
- **Azimuth difference between sun and moon – the azimuth of a star is how many degrees along the horizon it is and corresponds to the compass direction. The bigger the difference in the azimuth, the better the visibility. This is because the twilight is decreasing as the difference increases. Fig 1 shows the direction of calculating azimuth. Calculation is done clockwise starting from 0 degrees as north then 90 degrees at east.**





# *Islamic Calendar*

**Factors Contributing to Good Sightings:**

- Clear air - low humidity, haze, dust, pollution.
- A clear horizon with no clouds near the predicted position.
- Good eyesight (or eyeglasses).
- Knowing the correct location on the sky.
- Searching first with optical aid, which is correctly focused.
- Higher observer altitude above sea level generally is helpful.
- Darkening of the twilight, requiring at least 15 minutes after sunset.
- Height of the moon's location above the horizon, from several causes.
- Size or brightness of the crescent, from several causes.
- Practice and experience, and avoidance of unnecessary distractions.
- Recording the details immediately such as weather, times of sighting, orientation of the crescent, perceived degree of difficulty. Delayed reports pieced together from memory or from second-hand accounts tend to be highly flawed.
- Remaining on guard against self-deception in the form of imaginary sightings, *particularly in poor conditions*. We emphasize this last point because it is a well-established fact that **OBSERVERS HAVE FREQUENTLY CLAIMED TO SEE THE MOON WHEN IT WAS TRULY INVISIBLE** (e.g. due to overcast conditions or the moon being below the horizon).


Dorling Kindersley

# Instruments and mathematical methods used


Paul Almasy/Corbis


THE BETTMANN ARCHIVE/Corbis

# *Sundial or Shadow Clock*

- The ancients began measuring hours with the use of star positions to tell time at night. This is recorded in Egyptian tombs before 2000 BC.

- The earliest sundials, or shadow clocks, known to us come from Egypt, beginning around 1500 BC.

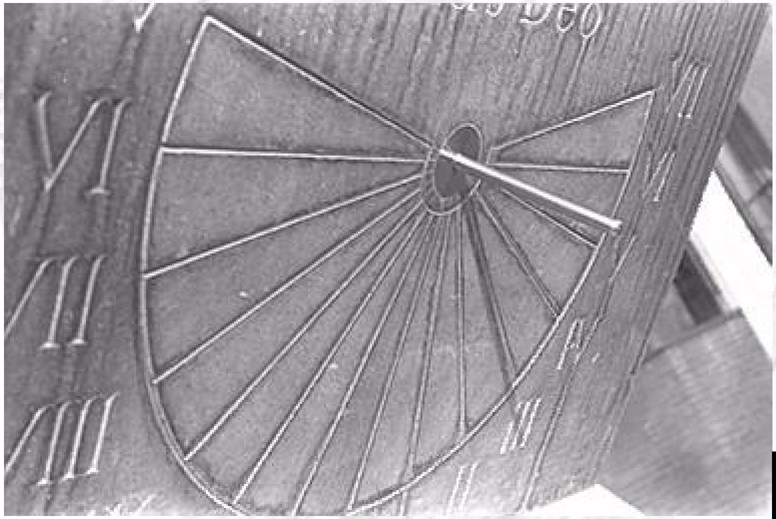
- By 300 BC the Egyptians had a sundial marked to show hours of equal length. (The concept of time flowing uniformly is undoubtedly older; "flowing" time was measured with water clocks.)

- However, the marks for equal hours work precisely for just two days of the year.

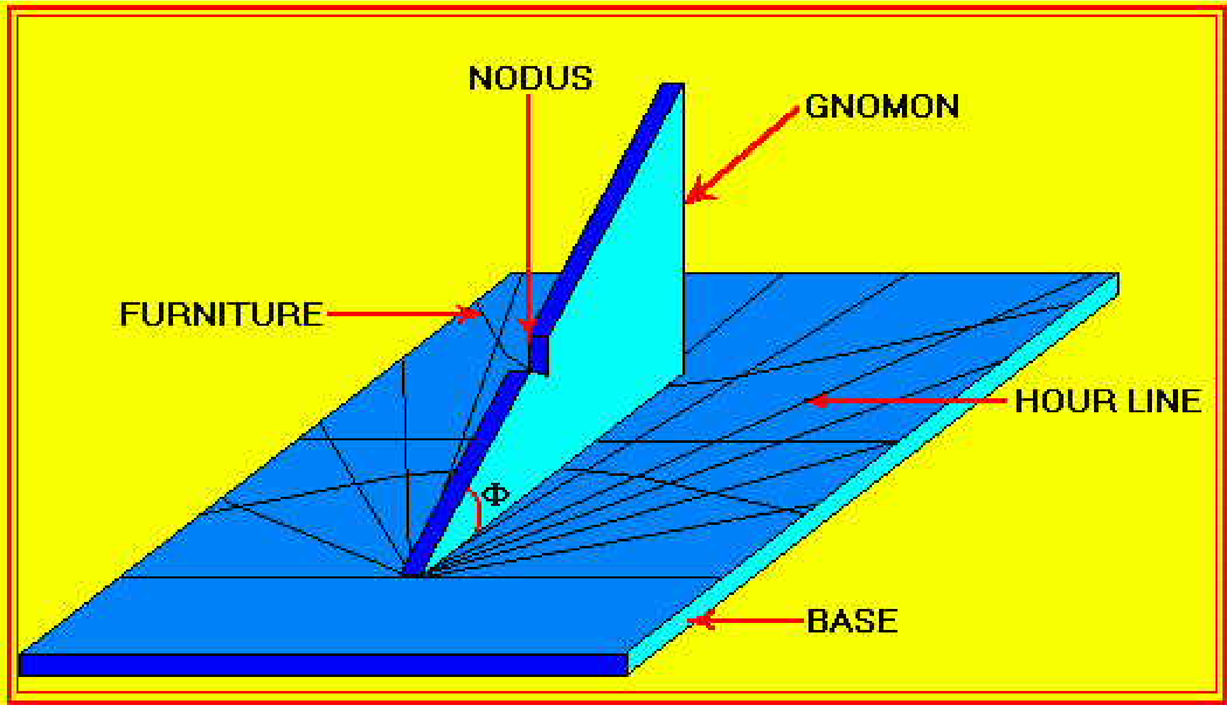
# *Sundials or Shadow Clock*

- secret to marking equal hours in all seasons is to aim the pointer, or gnomon, at the proper angle. The angle should make the gnomon parallel to the earth's axis of rotation.
- the angle is different for different cities.
- Ptolemy used Greek geometry to calculate how to mark out equal hours in all seasons. His theory was later perfected by Islamic scientists.
- Correct alignment of the sundial is essential.

# *Sundials or Shadow Clock*



# Sundials or Shadow Clock



- Gnomon: The shadow caster, in a horizontial dial the angle phi is equal to the Latitude of the location.
- Hour Line(s): The numbered lines that the shadow falls along.
- Nodus: A "marker" along the gnomon to get an exact point on the shadow.
- Furniture: Lines and "functions" other than the Hour lines, usually date lines (this is what the nodus is for).

# *Quadrants*

- is essentially a graduated quarter of a circle, set up to measure the altitude of celestial objects above the horizon.
- graduations from 0 - 90° are on the circumference, or limb of the instrument.
- come in two forms.
- mural quadrants which were fixed to a meridian wall and used to measure meridian altitudes.
- altazimuth quadrants which could be rotated to any bearing, measuring altitude and azimuth simultaneously.

# *Quadrants*

- Mural quadrants were considered the most accurate as movement, wear and flexure were kept to a minimum, although other mountings were devised.
- Observations were restricted to the meridian, but this meant that calculation of declination from the observations was relatively easy.
- One of the earliest examples of a quadrant is the large 'plinth' described in Ptolemy's Almagest and used for measuring the meridian altitude of the Sun.
- The quadrant was the key instrument with which accurate measurements of a stars declination were made.

# *Quadrants*

- The grill is rotated so the star pointers falls on the engraved curve for the altitude angle found by sighting the star.

- Another pointer on the grill shows the correct time of night.

# *Astrolabes*

- both a measuring instrument and a calculating device.
- to find the time at the night by observing bright stars.
- probably invented by the Greeks, and was perfected by Islamic scientists and craftsmen.
- an instrument made of a metal plate or disk with engraving on both sides.
- On the back is a scale for measuring angles, and a rotating pointer for sighting stars.
- The astrolabe is held from a ring on top, so that it hangs vertically like a plumb line. The pointer is adjusted to sight a bright star; its angle above the horizon (altitude) is then found on the engraved angle scale.

# *Astrolabes*

- especially useful during the Islamic holy month of Ramadan, when good Muslims must not eat when there is light in the sky.

- The front of the astrolabe is a computing device which uses both the human viewpoint (the engraved curves of altitude angle), and the stars' viewpoint (the pointers on the grill).

- This movable grill is designed with metal tips or pointers in the positions of about a dozen bright stars.

- After sighting one of these bright stars using the back of the astrolabe, the astronomer turns the astrolabe over and finds its pointer on the grill.

# Spherical Trigonometry

- The shortest distance from one point to another on the surface of the earth is along the shorter arc of the great circle passing through the two points.

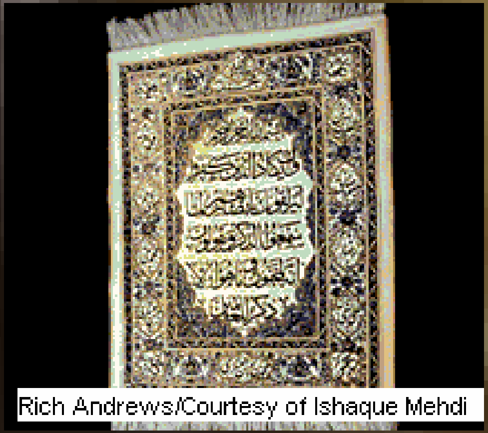
- This direction can be calculated by the spherical trigonometrical equation:

$$\text{Bearing Angle} = Tan^{-1}\left[\frac{Sin(M_p - M_q)}{[Cos(L_p)\cdot Tan(L_q)] - [Sin(L_p)\cdot Cos(M_p - M_q)]}\right]$$

- where: Lp =Latitude of city (North positive, South negative) Mp =Longitude of city (West positive, East negative) Lq =Latitude of Mecca (21° 27' N = 21.45) Mq =Longitude of Mecca (39° 49' E = -39.82)

- This method for Qibla is more accurate than the compass, which involves errors due to the presence of magnetic fields or metallic objects, and magnetic declination which causes compass needle to point some degrees away from True North; how many degrees away depends upon where you are in the world.

# *Prayers*



Rich Andrews/Courtesy of Ishaque Mehdi

# Prayers

- The five prayers (*fajr*,*zuhur*, *asar*, *maghrib*,*isha*) are based on astronomical position of the sun
- prayers are determined using length of the shadow and start and end of twilight ( light from sky when sun is below horizon especially in the evening) during the course of the day
- therefore, prayer times are not the same from one place to another depending on observers’ longtitude and latitude
- Historically speaking the start of the Islamic day used to begin at sunset and not at midnight. Therefore at sunset the Islamic clocks used to register 12:00 however most Muslims now follow the modern midnight starting-day calendar. Therefore many modern prayer timetables often include both the old Islamic timing and the modern timing schedules.
- basic sundials were used to determine the length of shadow

## *FAJR*

- is the first of the Five obligatory prayers of the day.
- It can be performed at any time between the breaking of the dawn or morning twilight till sunrise.

## *ZUHUR*

- Its time begins after the sun declines from its zenith until it is about midway from setting alternatively *zuhur* begins midday when the trailing limb has passed the meridian.
- *zuhur* ends at *asar* (the next prayer after *zuhur*)

# ASAR

- Its time begins soon after the time for *Zuhr* prayer ends and extends to just before sunset.
- *Asar* begins when a length of shadow of an object exceeds the length of an object or the length of shadow is twice the length of the object. In both cases, the minimum length of shadow occurs when the sun passes meridian.

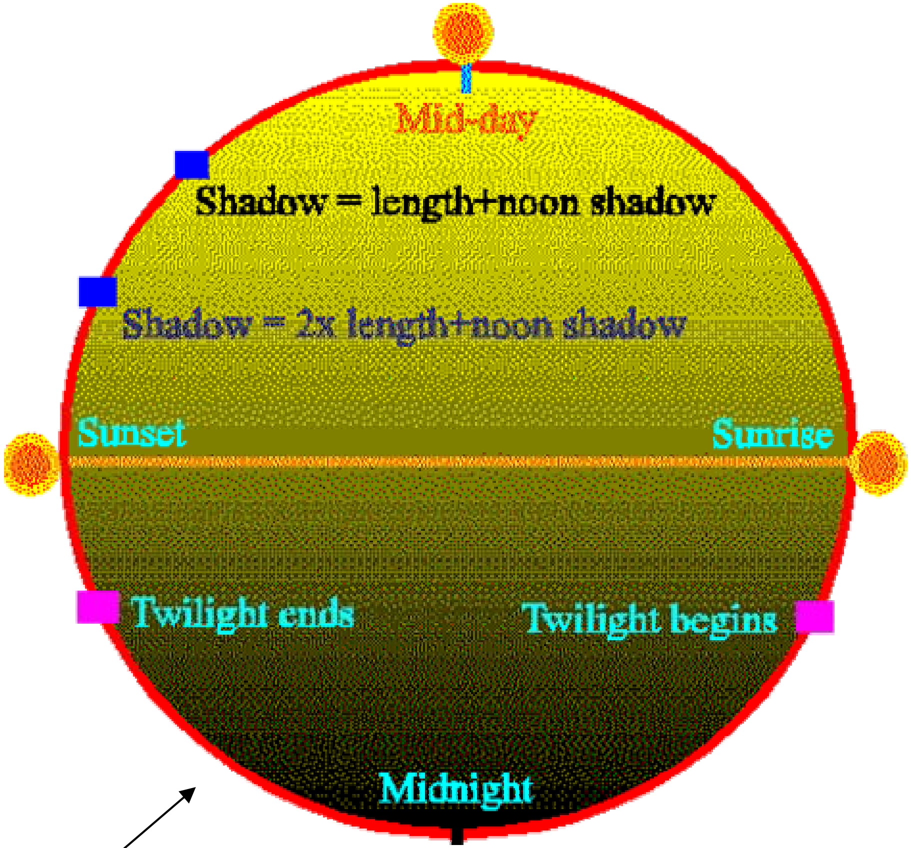

Christine Osborne Pictures

# MAGHRIB

- begins just after sunset and extends to a period of an hour and a half before *isha* (used to be the start of the next day) starts.

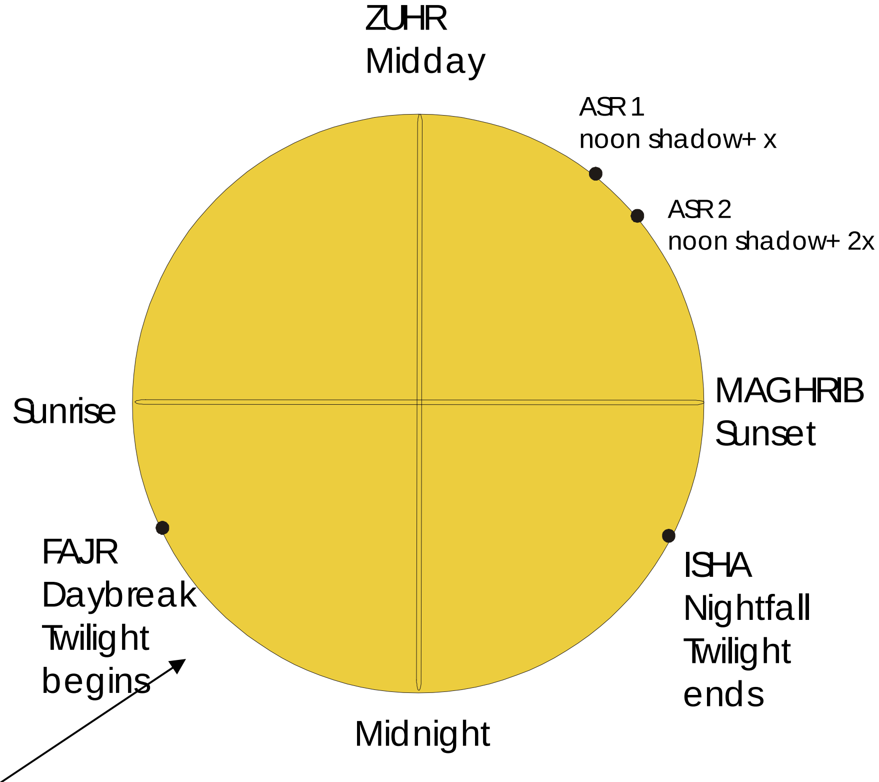
# ISHA

- Starts at dusk when evening twilight disappears.



- picture showing the different length of shadows during the course of the day

Source: http://www.al-kawn.com/Ihsan/applications.htm


ZUHR
Midday

ASR 1
noon shadow+ x

ASR 2
noon shadow+ 2x

Sunrise

MAGHRIB
Sunset

FAJR
Daybreak
Twilight
begins

ISHA
Nightfall
Twilight
ends

Midnight

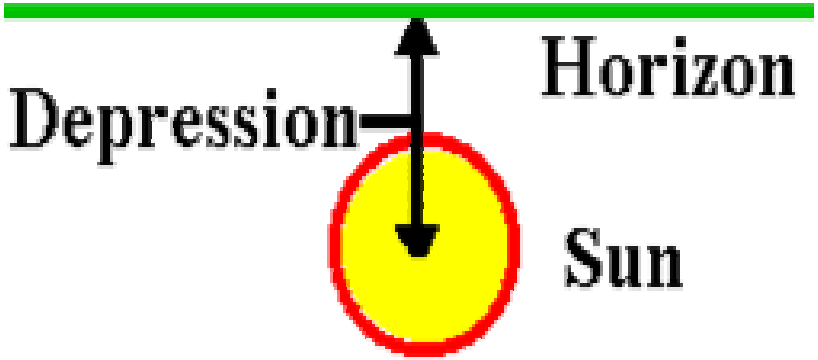
- picture showing the position of shadow as well as the prayer during the course of the day

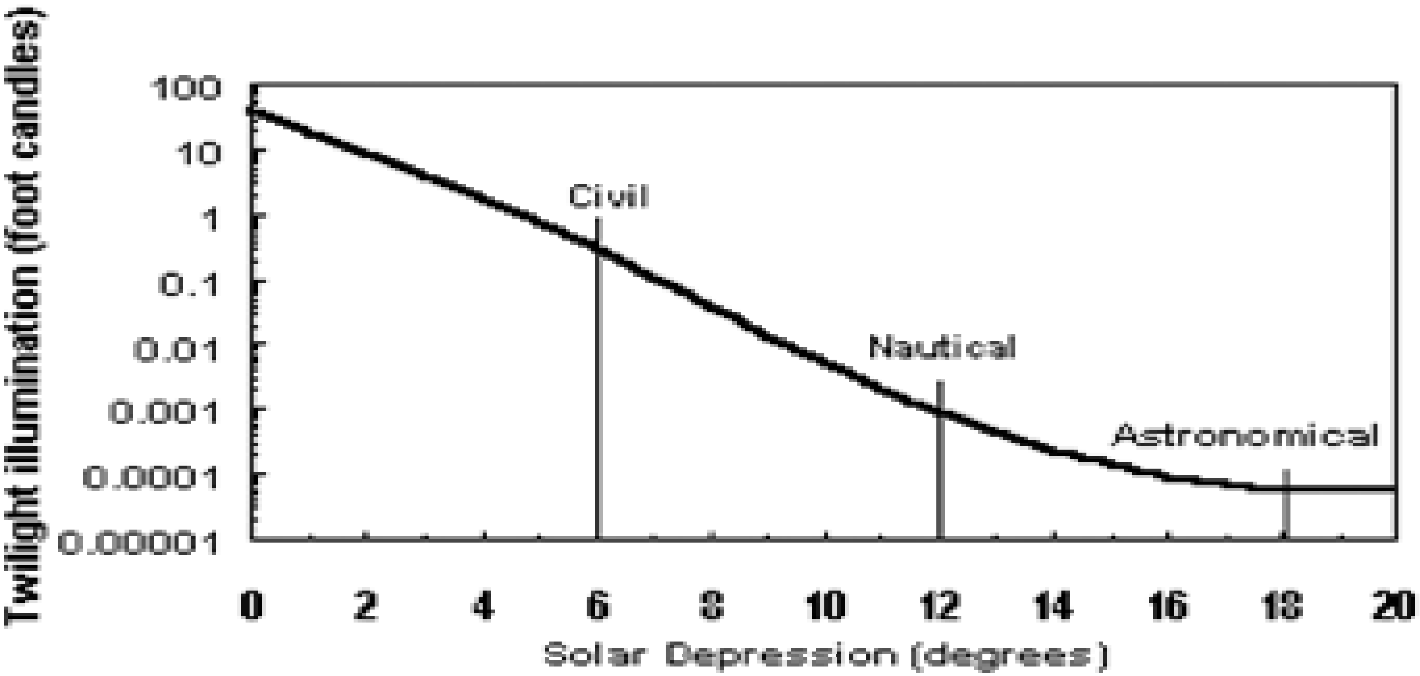
( this picture is flip when compared to the one on the left)

Source: http://www.al-kawn.com/Ihsan/applications.htm

# *Twilight*

- If the earth did not have an atmosphere, the sky would become dark immediately after sunset. The earth's atmosphere causes scattering of sunlight so that light reaches the observer before sunrise and after sunset. This scattered light is called twilight.
- After sunset, as the depression of the sun increases, the sky gets darker and darker until no scattered light reaches the observer. Conversely, in the morning light starts to appear in the sky even before sunrise. The morning twilight is called dawn whilst the evening twilight is known as dusk.
- In astronomy the twilight period is divided into civil, nautical and astronomical twilight corresponding to solar depressions of 6, 12 and 18 degrees respectively.





- **Civil twilight zone is where the brightest stars are visible and at sea level the horizon is clearly visible**
- **Nautical twilight zone is where the horizon at sea level ceases its visibility and it is not possible to determine altitudes with reference to the horizon**
- **Astronomical twilight zone is where there is no light and is dark and there is no perception of twilight**

Source:http://www.al-kawn.com/Ihsan/applications.htm

# Twilight in relation to prayers

( Note: only *fajr* and *isha* uses twilight wherelse the other three prayers- *margarib*, *asa*r, *zuhur* uses the sun position for timings)

- *Fajr* starts in the morning twilight and *Isha* starts at the end of the evening twilight
- There are some debate as to which twilight should be used for *Fajr* and *Isha*
- Using smaller twilight angles will cause Fajr to be later and isha to be earlier

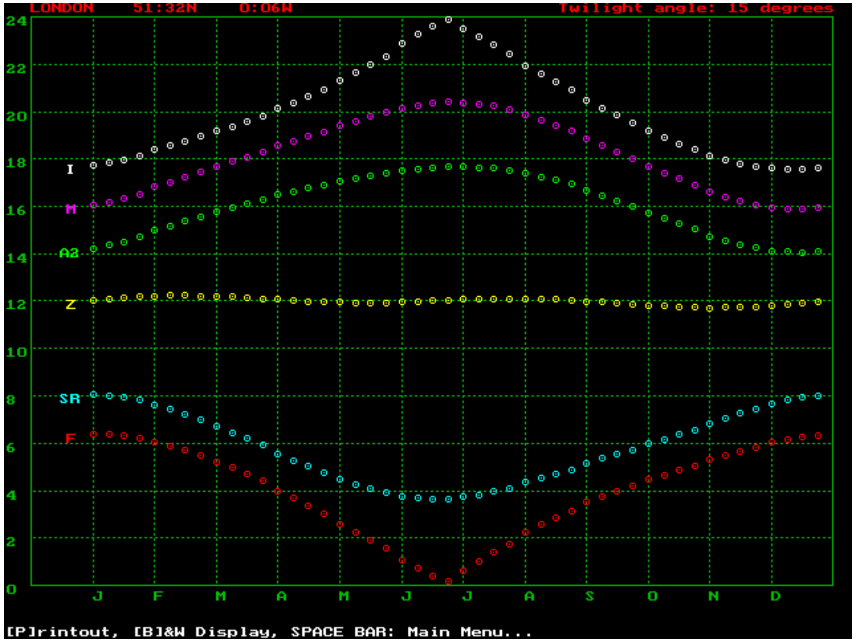
Here is an example for the city of London (51:32N, 00:06W, Time zone 0), On 1st January 1996:

| | FAJR | ISHA |
|---|---|---|
| 18 degrees | 6:02 | 18:04 |
| 15 degrees | 6:22 | 17:43 |

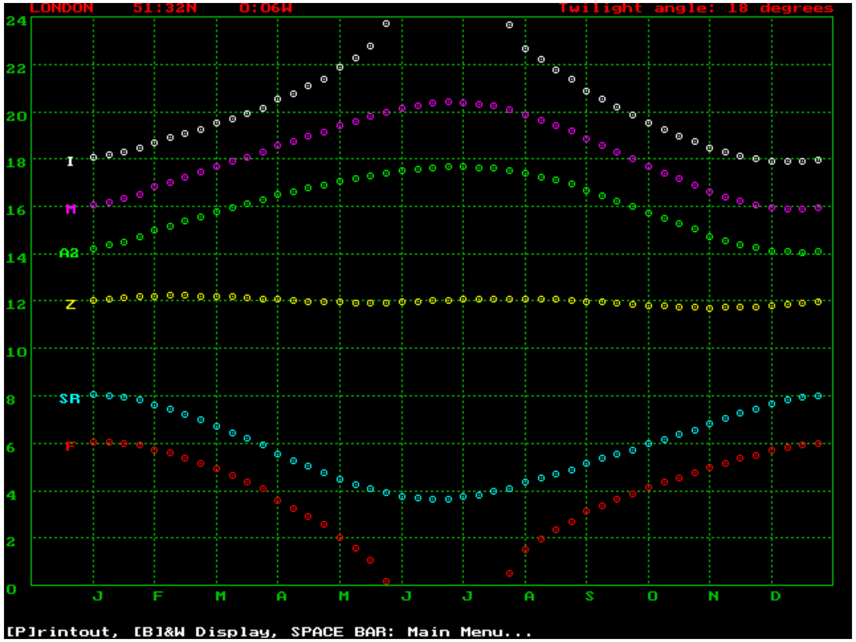
Source:http://www.al-kawn.com/Ihsan/applications.htm

The two graphs below show the change in the timing of the prayer times during the year is shown for London below: (F= Fajr, Z=Zuhr, A2=Hanafi Asr, M=Maghrib, I=Isha).

15 degrees used to calculate *fajr* and *isha* time



18 degrees used to calculate *fajr* and *isha* time



Source:http://www.ummah.net/astronomy/saltime/

- Several conventions for the calculation of FAJR and ISHA are already in use in various countries.
- FAJR and ISHA times are usually calculated using fixed twilight angles as discussed above but some countries also use a method involving adding/subtracting a fixed interval of time to sunset/sunrise respectively.
- Below are some twilight angles adopted by some countries

| **Organization** | **FAJR- Twilight angle** | **ISHA- Twilight angle** | **Region** |
|---|---|---|---|
| University of Islamic Sciences, Karachi | 18 | 18 | Pakistan, Bangladesh, India, Afghanistan parts of Europe. |
| Islamic Society of North America (ISNA) | 15 | 15 | Parts of USA & Canada, parts of UK |
| World Islamic League | 18 | 17 | Europe, Far East, parts of USA |
| Um AL QURA - MAKKA | 19 | 90 min. after MAGRIB, 120 min. during RAMADAN | Arabian Peninsula |
| Egyptian Gen. Organization of Surveying | 19.5 | 17.5 | Africa, Syria, Iraq, Lebanon, Malaysia, parts of USA |

# Summary of prayer times

| **Prayer Times** | **Start** | **End** |
|---|---|---|
| ***Fajr*** | When whitishness begins to appear on the horizon (dawn) | At beginning of sunrise |
| ***Zuhr*** | After sun's trailing limb crosses meridian | Start of *Asar* |
| ***Asar*** | When length of shadow =2x length of object + noon shadow or<br>When length of shadow = length of object + noon shadow | Before sunset |
| ***Maghrib*** | Sunset | Reddishness in the sky |
| ***Isha*** | After reddishness in sky (dusk) ends | Midnight |

# Determination of prayer times

- we need to know the latitude (B) and longitude (L) of the location and its reference longitude (R). B and L may be obtained from an atlas and R may be calculated by multiplying 15 by the difference between local time and GMT (i.e. 15 x Time Band).

- We also need to know two astronomical measures called the declination angle of the sun (D) and the real time-mean time difference, also known as the equation of time (T).

Declination is the angular distance between a celestial object and the celestial equator.The Declination and the Right Ascension are used together to give the position of a star with reference to the celestial equator and the vernal equinox respectively.

The equation of time is a correction to be added to apparent solar time, as read on a sundial, to obtain mean solar time, as commonly used. D and T vary according to the time of year and can be obtained accurately from The Star Almanac or calculated approximately.

# *Determination of prayer times*

$$Z = 12 + \frac{(R-L)}{15} + \frac{T}{60} \qquad ........1$$

$$U = \frac{1}{15} \arccos \frac{\{\sin(-0.8333-0.0347(H)^{0.5})\}-\sin D.\sin B}{\cos D.\cos B} \qquad ........2$$

# *Determination of prayer times*

- 1 -sinG-sinD.sinB
- V= -- arccos --------------- ........3
- 15 cosD.cosB

- 1 sin{arccot(1+tan(B-D)}-sinD.sinB
- W= -- arccos -------------------------------- ........4
- 15 cosD.cosB

# *Determination of prayer times*

$$X = \frac{1}{15}\arccos\frac{\sin\{\operatorname{arccot}(2+\tan(B-D))\}-\sin D.\sin B}{\cos D.\cos B} \qquad ........5$$

Where:

B= latitude of place

L= longitude of place

R= reference longitude (i.e. TIME BAND x 15)

H= height above sea level in meters

D= declination angle of sun from celestial equator (-vernal equinox in southern hemisphere)

T= equation of time

G= twilight angle

# *Determination of Prayer times*

- FAJR = Z-V
- Sunrise = Z-U
- ZUHR  = Z
- ASR1 (SHAFI) = Z+W
- ASR2 (HANAFI) = Z+X
- MAGHRIB/Sunset = Z+U
- ISHA = Z+V

# Determination of Prayer times

- **At extreme latitudes the twilight may persist between sunset and the next sunrise for certain months of the year. In these months the sun does not go below the horizon by a sufficient amount to abolish twilight.**

- **Hence there is no true night.**

- **Under these circumstances, FAJR and ISHA times may be calculated using one of four agreed principles:**

# *Determination of Prayer times*

- Nearest latitude - add the interval between sunset and ISHA for a location on latitude 48 degrees to the local sunset time to obtain time for local ISHA. Similarly the interval between FAJR and sunrise for a location on latitude 48 degrees is

  subtracted from local sunrise to obtain local FAJR time.

- Nearest day - use FAJR and ISHA times from the last day when it was possible to calculate these times in the normal way for that location.

# *Determination of Prayer times*

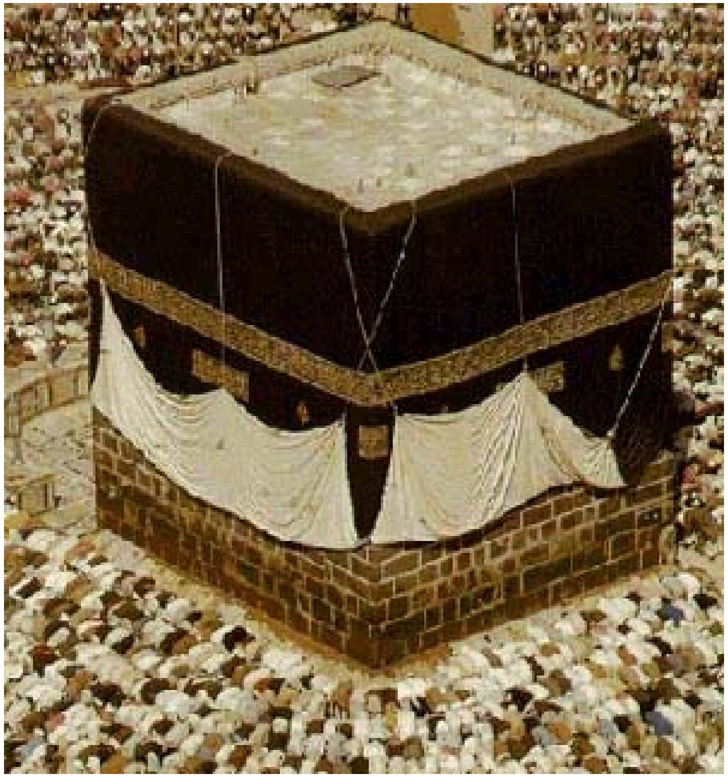
- Middle of night - split interval between sunrise and sunset into two halves. IISHA is offered before the midpoint (e.g. 15 minutes before) and FAJR is offered after the midpoint.

- One seventh of night - split interval between sunset and sunrise into seven segments. ISHA is offered after the first segment and FAJR is offered after the sixth segment.

# Brief History of Kaaba

# *Introduction to the “Kabaa”*

- The “Kabaa” is located in Mecca, Saudi Arabia.
- It is the central shrine of Islam and considered the holiest and most sacred place built for the worship of “Allah”.



# *Description*

The Black Stone mounted in a silver frame

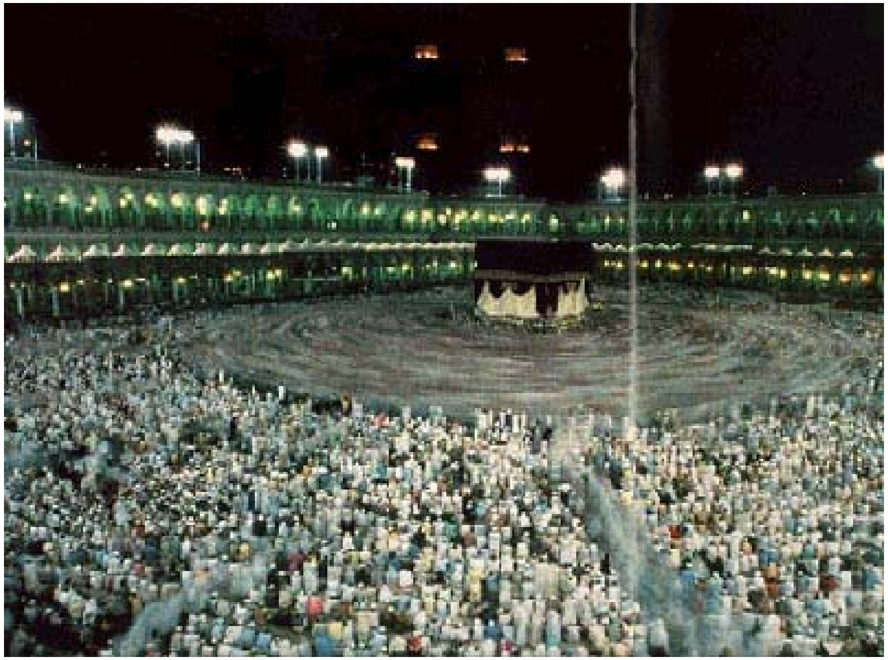
- It is a one-roomed rectangular structure made of inter-layers of wood and stone.
- The Black stone is mounted on the wall of the “Kabaa”
- People are rarely allowed to enter the inside of the “Kabaa”

# *Building the “Kabaa”*

- Some historians believe that it was the Prophet Adam that first built the “Kabaa”. Others believe that it was the Prophets Ibrahim and Ishmael.
- The “Kabaa” had been reconstructed many times.

# *Importance of the "Kabaa"*

- Muslims have to face the direction of the "Kabaa" in their five daily prayers as well as in other rituals.
- The "Tawaf" part of the annual "Hajj" is performed on the grounds of the "Kabaa".



A night scene of the "Hajj"

# Astronomy & the "Kabaa"

- The major axis is $30^0$ anticlockwise from the N-S meridian
- The major axis points towards the rising point of the star, Canopus.
- The minor axis points towards the summer sunrise and winter sunset.

# Foreign Influences on Islamic Astronomy

- Foreign sciences were not easily accepted
- Astronomy and astrology were viewed as branches of the same science
- Astrological statements directly infringe on Islam as a religion and culture
- 2 main foreign influences on Islamic astronomy: Hellenistic and Indo-Persian astronomy

# *Indo-Persian Astronomy*

- In AD760s, the caliph al-Munsur assigned men to translate the astronomical text, *Sindhind (siddhanta)*.
- Soon after, many other astronomical texts based on the *Sindhind* appeared.
- However, this foreign science was quickly forgotten due to introduction of the more sophisticated methods of Hellenistic Greek knowledge.

# *Hellenistic Astronomy*

- Hellenistic astronomy is represented mostly by the spread of Ptolemy’s *Almagest*.
- It was first translated under the support of Yahya ibn Khalid the Barmacid between the late eighth and early ninth century.
- This first translation was subjective so another two more translations was made within the next 60 years.

- The *Almagest* was warmly received and created its own tradition, replacing that of the *Sindhind*.
- The first few centuries after its introduction, astronomical texts produced appeared to be unions of the *Almagest* and *Sindhind*. Later, this became more Islamic in identity.
- Some of the important types of texts created then were the *anwa'* texts, *hay'a* books, the *'azyaj* and other works dedicated to observational astronomy, instruments, timekeeping for religious purposes and uranography.

# Contributions to Astronomy

- Islamic astronomers perfected the astrolabe to become sophisticated enough to be used at any latitude.
- Quadrants were developed by Muslims from their work on the astrolabe.
- In AD800s, Al-Kwarizimi’s astronomical tables based on *Sindhind* were published.
- The tables were used to calculate phases of the moon, rising and setting times of the moon, sun and planets as well as prediction of eclipses.

# *Ptolemy VS Muslim Astronomers*

- Ptolemy’s planetary models assumed the existence of a mathematical point—the equant, where the planetary epicycles revolve around at constant speed

- Ptolemy’s theory that the solar apogee occurred at a fixed point.

- Abu al-Raihan Biruni observed that the solar apogee had its own precession motion

# More Contributions

- Mu’ayyad al-Din al’Urdi wrote a full discourse on corrections to Ptolemy’s *Almagest*
- Nasir al-Din Tusi wrote two books arguing against Ptolemy’s astronomy, also suggesting substitutes
- In his discussion of the lunar model, he introduces a mathematical theorem—Tusi-couple derived using the Hindu sine function and Menelaus' theorem.
- Al-Tusi also invented new instruments to observe stars accurately, azimuth quadrant  and torquetum, for computing star positions.

- In 14th century, Ibn al-Shatir produced the first realistic model of the motions of the moon
- Copernicus was also motivated by the same errors the Muslim astronomers noticed.
- Recent research showed the Copernican model for upper planets uses the same techniques al-‘Urdi.
- Copernican’s model of the motions of the moon was the same as that of Ibn al-Shatir.
- Copernicus’ and Ibn al-Shatir’s Mercury model shared many similarities.

Copernican system of upper planets

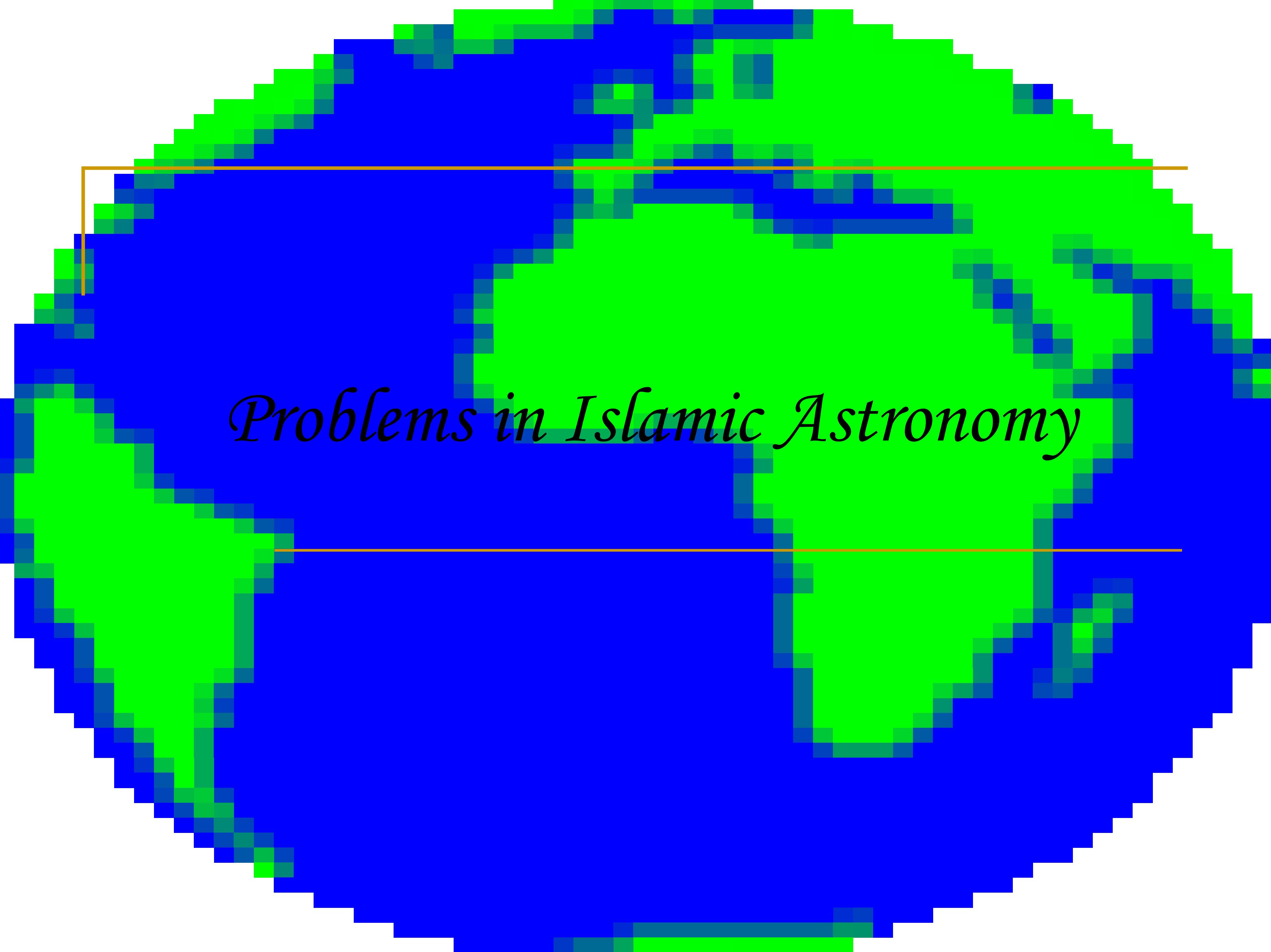
# *Other Famous Muslim Astronomers*

- Al-Farghani or Alfraganus (Latin name), was a celebrated astronomer known for his treatise ' Elements of Astronomy’.
- Thabit ibn Qurrah formed the theory of Oscillatory motion of equinoxes and was involved in the reform of the Ptolemaic system by purporting the addition of the ninth sphere to the eight spheres in Ptolemaic astronomy.

- Al-Battani or Albategnius discovered the increase of the suns apogee and was also responsible for the discovery motion of the solar apsides. He was best known for his treatise ' On the Science of Stars ‘.
- Al-Biruni was the best-known Muslim scientist of his time; he was responsible for the determination of latitudes and longitudes as well as geodetic measurements. ‘Canon’, is his most comprehensive study on astronomy.

- Al-Hazen was known for his treatise ' Resume of Astronomy ' which described the motion of the planets.
- Ibn Yunus solved the problems of spherical trigonometry and was the first to study the isometric oscillatory motion of a pendulum.
- Al-Zarqali, invented the instrument “Sahifah“ and was responsible for proof of the motion of the apogee of the sun with respect to the fixed stars.

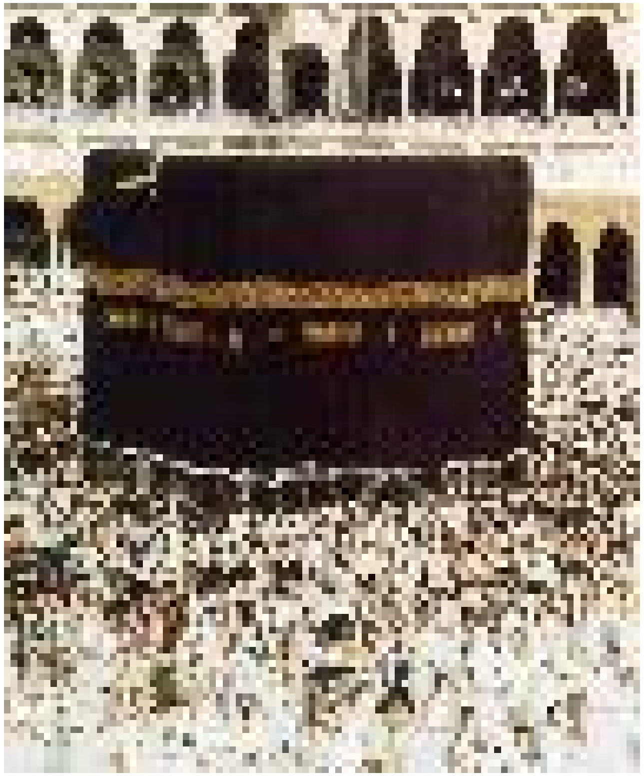
- Ibn Tufail, known to the Occident as Abubacer, was an authority on the theory of the system of homocentric spheres



# Problems in Islamic Astronomy

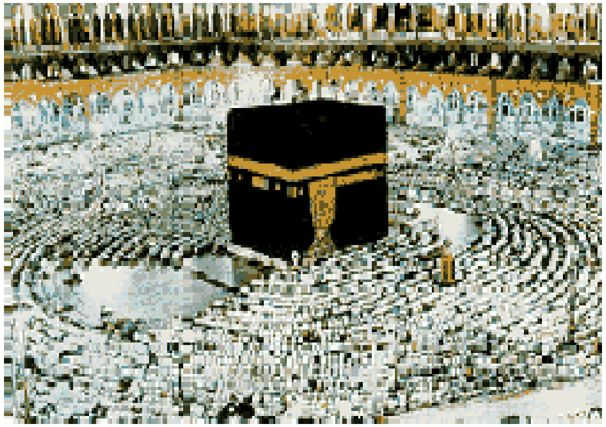
# *Qibla Directions*

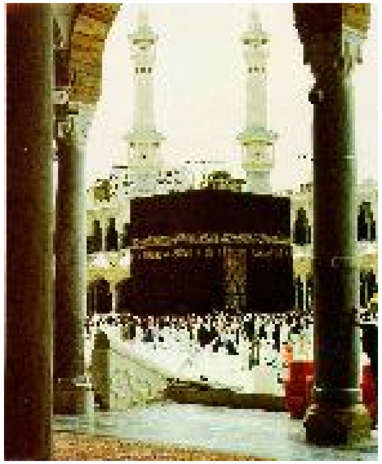
- The main problem in Islamic astronomy is the accuracy of *Qibla* (the position of facing the ‘*kaaba*’ during prayers)
- There were no accurate method in finding the *Qibla*
- Muslim astronomers and geographers starting from the 8th century took up for best methods of *Qibla* direction using the techniques of measurement of geographical coordinated and trigonometry that they have acquired from the Greeks.



Source:http://moonsighting.com/qibla.html

# *Solutions for finding accurate qibla directions*





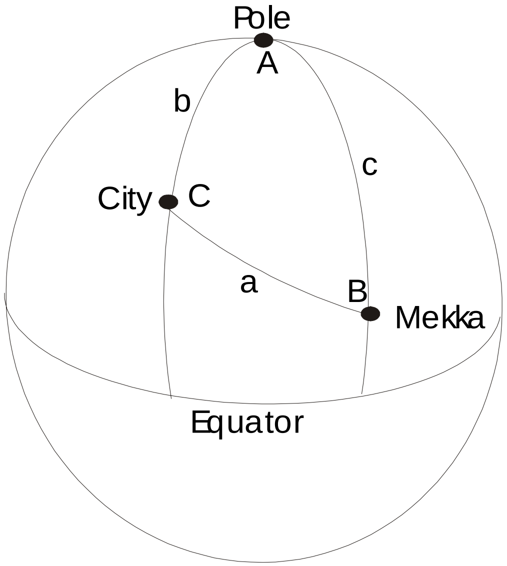
- During the 9th century many observations were made to find the coordination of Mecca and Baghdad to find accurate *qibla* directions.
- The early Muslim scientists tried to come up with solutions to find accurate *qibla* directions.
- Scientists AL-Biruni in the 11th century and AL-Khalili in the 14th century wrote very perfect *qibla* directions for each degree of latitude from 10 to 56 degrees and longitude from 1 to 60 degrees which were based on exact formulae.
- The formula was derived from spherical trigonometry

Note: people in the picture are praying facing the *qibla*

Source:http://www.al-kawn.com/Ihsan/applications.htm

# Spherical trigonometry

- Spherical trigonometry is used because it makes uses of the latitudes, longitudes, and the cardinal directions- North (N), South (S), East (E), and West (W) which are all defined on an equivalent sphere surrounding the earth. The equivalent radius of the Earth is 6,378.14 kilometers.
- Longitudes are vertical lines running from north to south forming great circles. The equator is also a great circle. When two great circles meet at a point, the angle between the tangents of the two circles, at the point of intersection, is then referred to SPHERICAL ANGLE. In a Spherical Triangle, three points on the surface of a sphere are joined by three lines on the surface of this sphere. Each of these lines (shortest distance) joining any two of the three points are on a great circle (example is given in next slide), These lines or sides are curves on the spherical surface of the sphere. Spherical Trigonometric formulae exist in relation to the sides and angles of Spherical Triangles. One of these formulas is called ‘THE FOUR PART FORMULA’.



$$\cos b \;\; \text{COS A} = \sin b \;\; \cot c - \text{SIN A} \;\; \text{COT C}$$

When we rearrange the terms we get,

$$C = \text{TAN}^{-1} \left[ \frac{\text{SIN A}}{\sin b \;\; \cot c - \cos b \;\; \text{COS A}} \right]$$

Note: The upper case letters angles and the lower case letters are sides.

Source:http://www.al-kawn.com/Ihsan/applications.htm

# *Observatories- A scientist who made the difference*

**Nasir al-Din Tusi (1201-1274)**

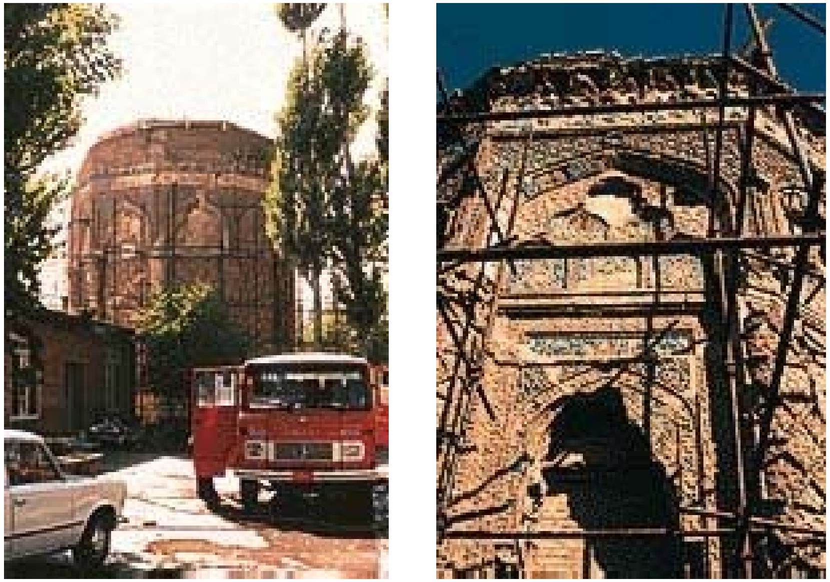
# Nasir al-Din Tusi (1201-1274)

- Tusi, a scientist who was responsible for the creation of Maragha observatory
- construction of Maragha observatory began on 1259
- Let us look at some of the features in the observatories

Source:http://ismaili.net/~heritage/mirrors/29_al-Tusi/42_maragha.html

A star globe from the Observatory in Maragha made in 1279 and is now preserved in Dresden, Germany. It is a rare example of a decorative art from 13th century. The globe is made up of bronze, in laid with silver and gold.

source: file:///E|/melimelo/29_al-Tusi/42_maragha.html



**Part of the Maragha Observatory Complex that still stands today.**

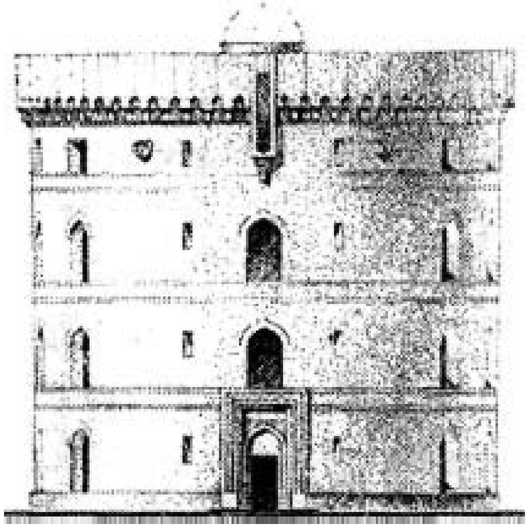


**Photo: An architect's rendition of the Maragha**

- The observatory has provided an exceptionally large library and a school for practicing scientists. Tusi gathered scientists to be involved in the construction of the instruments as well as the actual observations. Many other nationalities, in addition to Azerbaijanis( people of Azerbaijan- later became the empire of Persian), were involved with the work including the Chinese astronomers, Georgians, Mongolians, Turks (people of Turks and Cairo islands), Persians, Arabs and Jews.

source: file:///E|/melimelo/29_al-Tusi/42_maragha.html

Done By: Chen Minghui Jessica
Soh Wei Jing
Tan Jia Ping
Tahira Bee

# *The End*