Ibn al-Shatir Sundial

Great Mosque Damascus

R T Bailey

BSS Conference

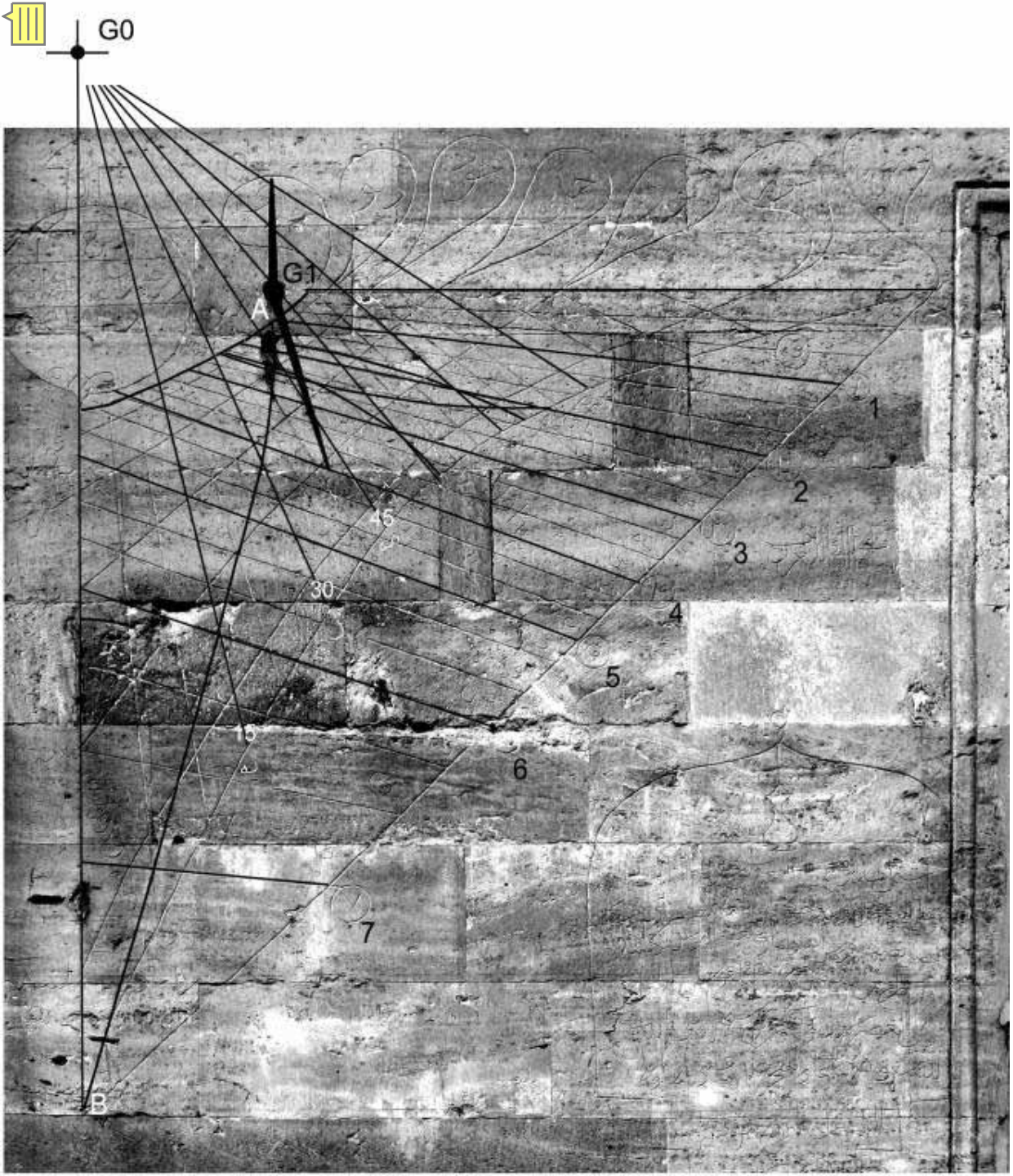
April 2012

Cheltenham

Istanbul: New Mosque *Yeni Camii*

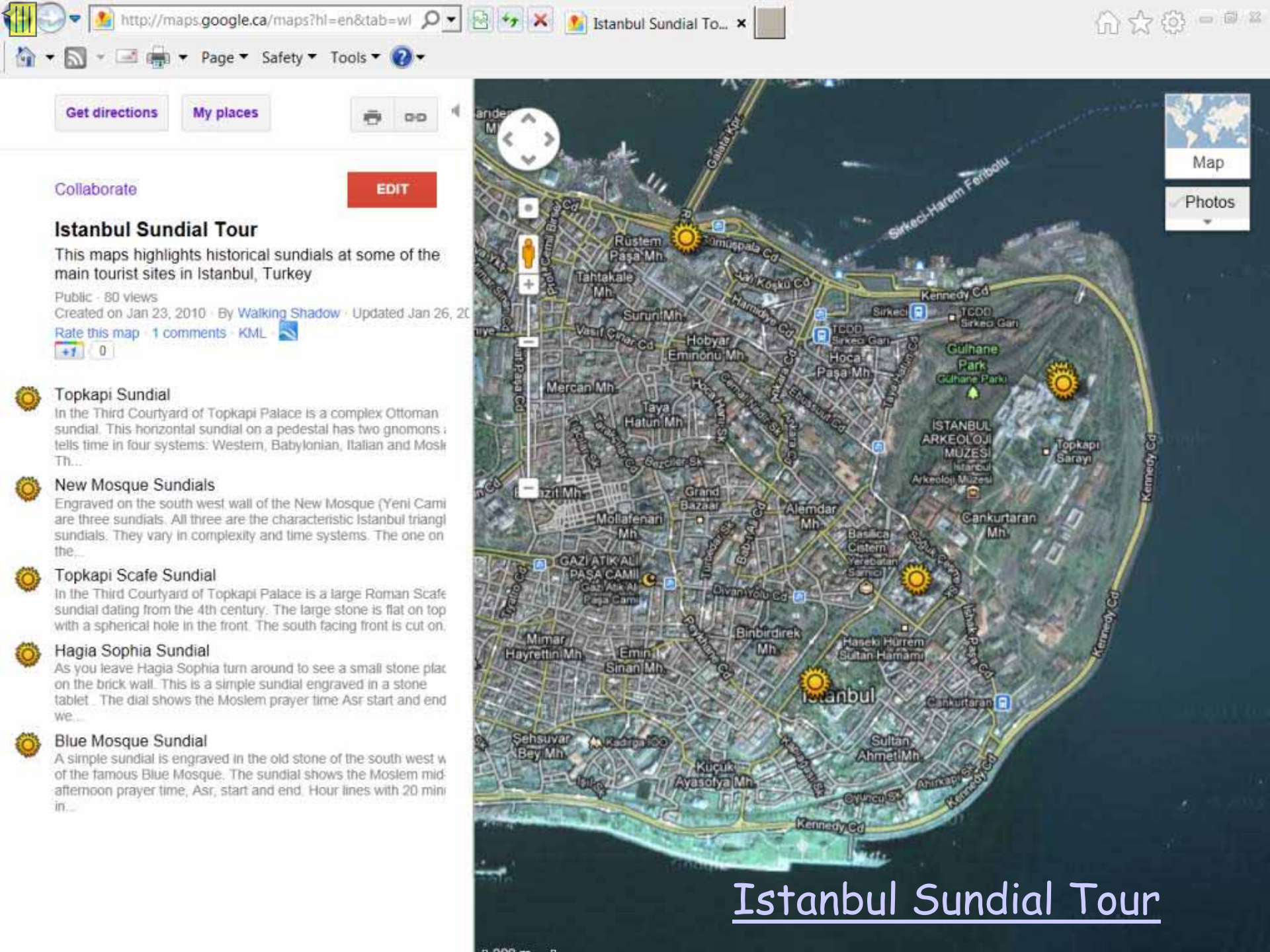
Vertical Declining Sundials

New Mosque
"Yeni Camii" 1
-Local hours 20'
-Italian hours
-Asr 1 & 2
-Declination
-Other curves



Dawn and Dusk Prayers

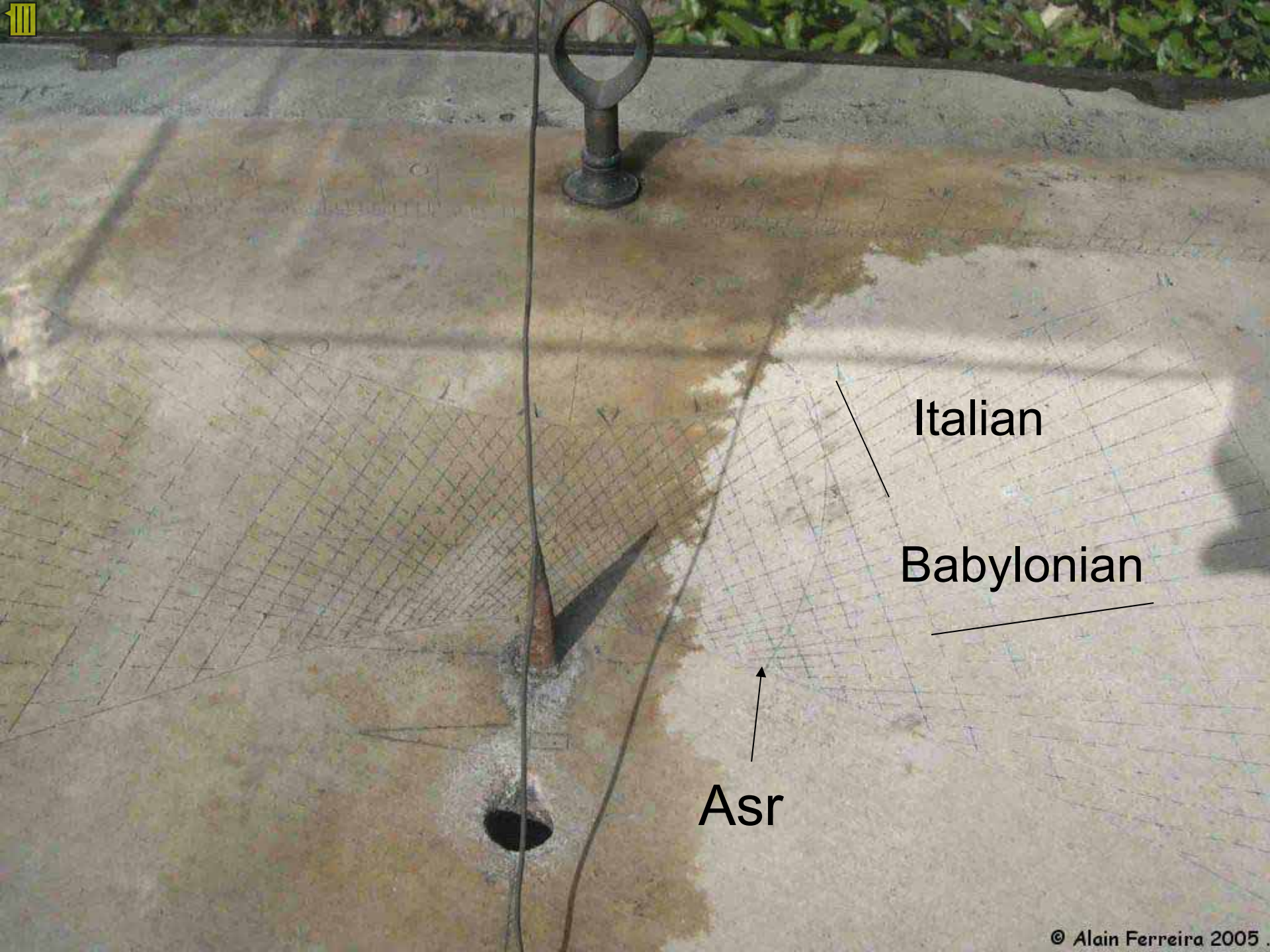
- G. Ferrari found Fajr and Isha prayer reference lines on Yeni Camii pictures
- Sloping down left 14 hours before Fajr (dawn) -19°
- Curving up 4 hours before Isha (dusk) -17°
- All 5 prayer times on this sundial


http://maps.google.ca/maps?hl=en&tab=wl
Istanbul Sundial To...
Page
Safety
Tools
Get directions
My places
Collaborate
EDIT
Istanbul Sundial Tour
This maps highlights historical sundials at some of the main tourist sites in Istanbul, Turkey
Public · 80 views
Created on Jan 23, 2010 · By Walking Shadow · Updated Jan 26, 20
Rate this map · 1 comments · KML ·
+1 0
Topkapi Sundial
In the Third Courtyard of Topkapi Palace is a complex Ottoman sundial. This horizontal sundial on a pedestal has two gnomons ; tells time in four systems: Western, Babylonian, Italian and Mosl Th...
New Mosque Sundials
Engraved on the south west wall of the New Mosque (Yeni Cami are three sundials. All three are the characteristic Istanbul triangl sundials. They vary in complexity and time systems. The one on the...
Topkapi Scafe Sundial
In the Third Courtyard of Topkapi Palace is a large Roman Scafe sundial dating from the 4th century. The large stone is flat on top with a spherical hole in the front. The south facing front is cut on.
Hagia Sophia Sundial
As you leave Hagia Sophia turn around to see a small stone plac on the brick wall. This is a simple sundial engraved in a stone tablet . The dial shows the Moslem prayer time Asr start and end we...
Blue Mosque Sundial
A simple sundial is engraved in the old stone of the south west w of the famous Blue Mosque. The sundial shows the Moslem mid afternoon prayer time, Asr, start and end. Hour lines with 20 mini in...
Map
Photos
Istanbul Sundial Tour

Istanbul

- Topkapi Palace
- Complex sundial in Courtyard
- Asr prayer line
- Italian Hours
- Babylonian
- Equal Hours

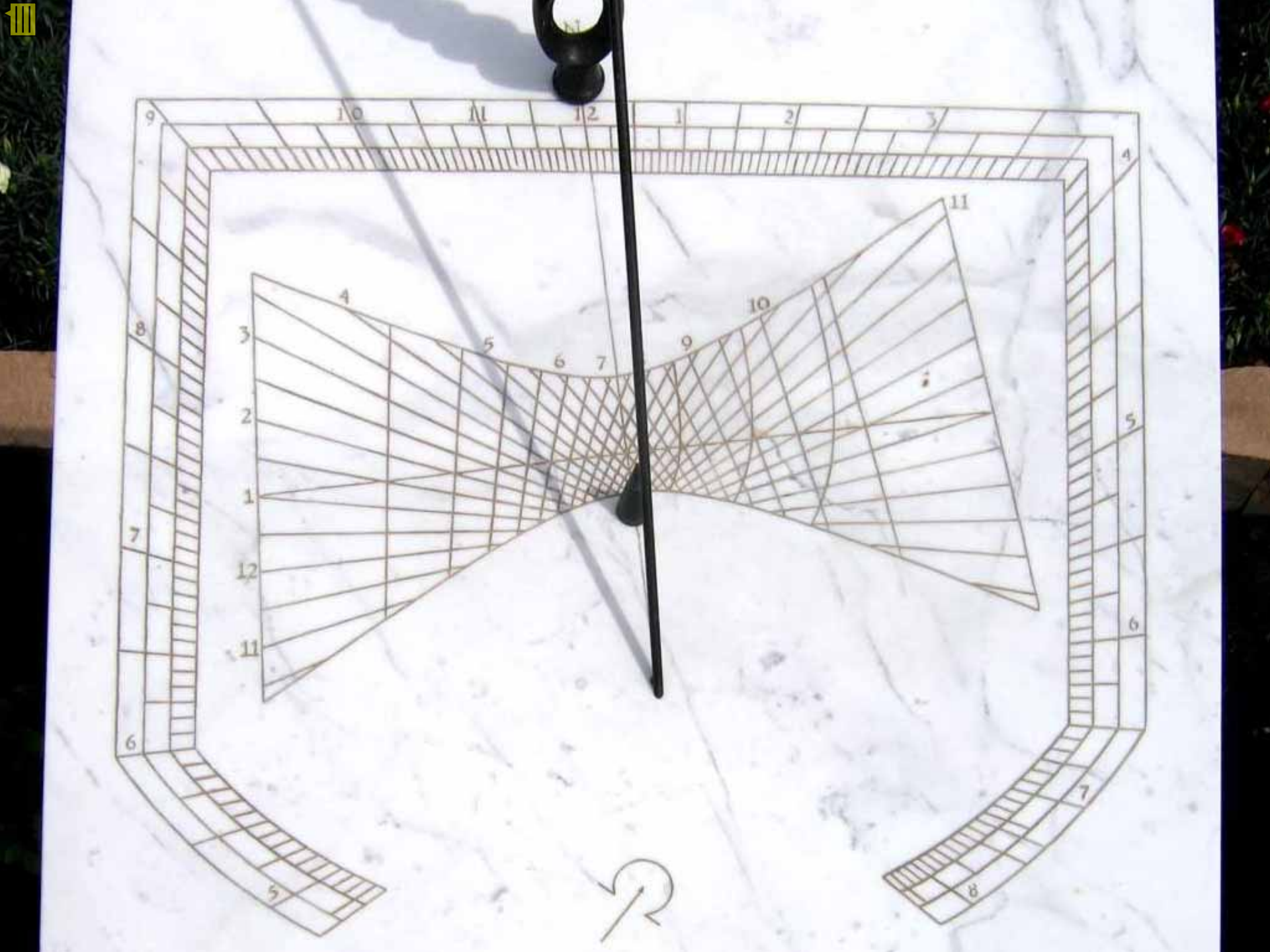
http://perso.orange.fr/cadrans.solaires/cadrans/cadran-istanbul-topkapi.html



© Alain Ferreira 2005

Ottoman Sundial
Missouri Botanical Garden

- Sundial is unique and significant
- Only Islamic dial in public use in America
- Only dial with Italian and Babylonian hours
- Only dial with prayer times or Qibla
- Shows what western civilization gained from the peak of Islamic science and culture
- Appropriate for the Ottoman Gardens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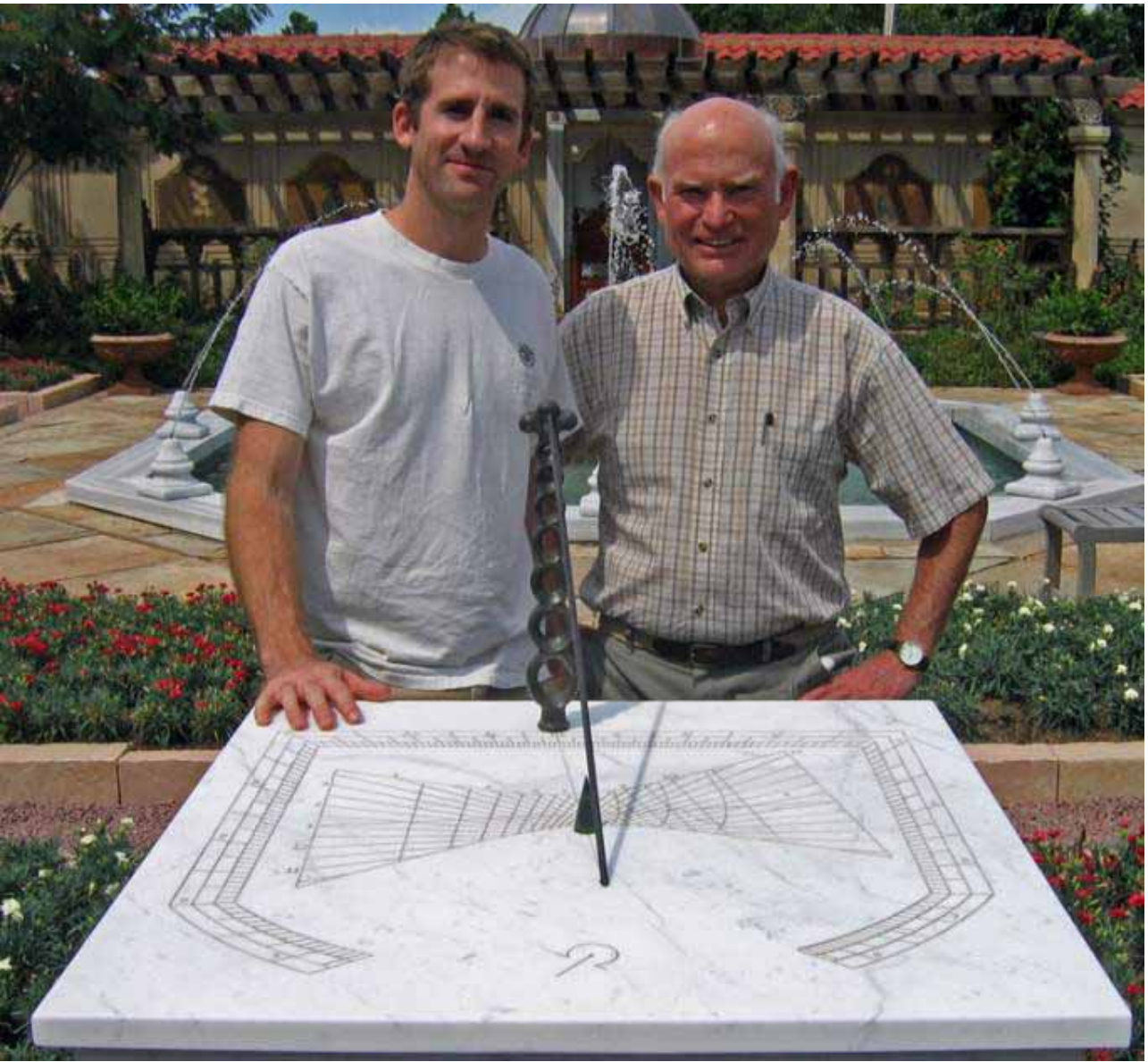
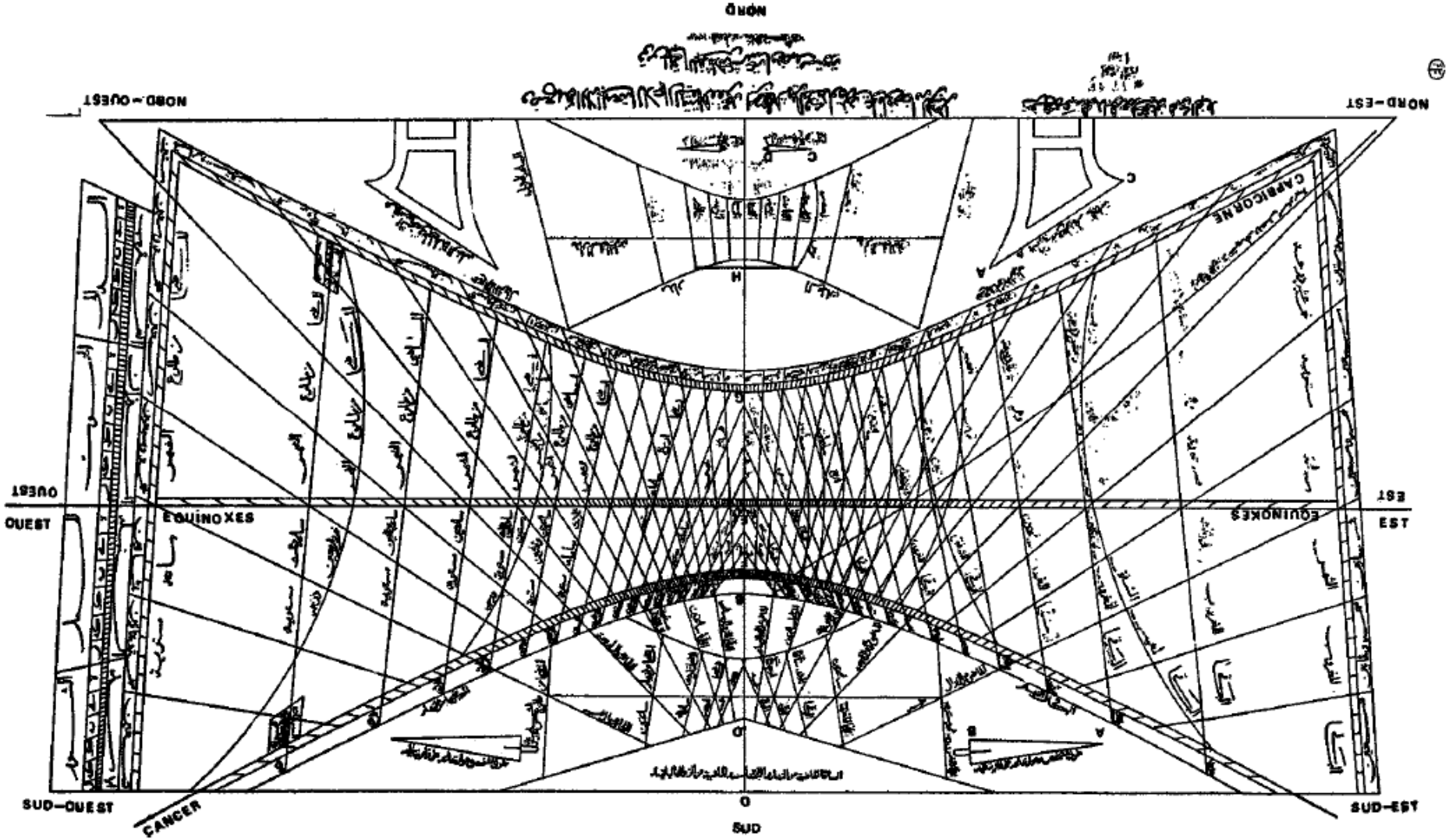
Proud Artisans



Abraham Mohler
Sculptor

Roger Bailey
Designer

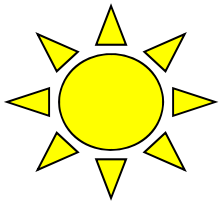
Walking Shadow Designs



Ibn al-Shatir Sundial

Year 1371

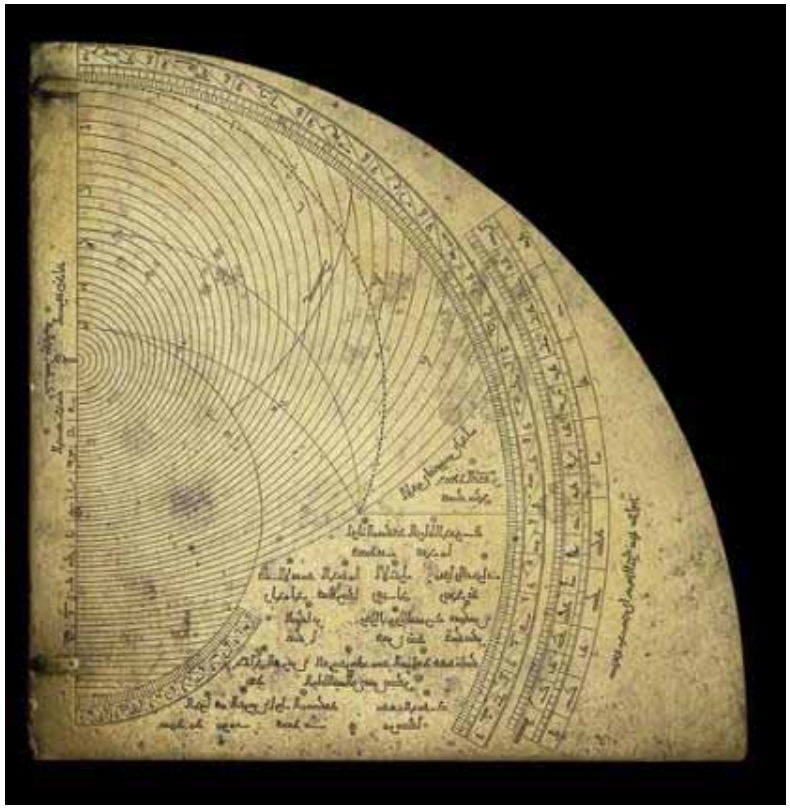
- Europe: After black death, crusades, Cathars, Normans, Magna Carta, cathedrals
- Time of Edward III, Charles V, Charles IV, Hundred Years war, Reconquesta, Chaucer
- Ming Dynasty, after Gengis Khan
- After Golden Age of Islam in Mecca, Cairo and Damascus, from North Africa, Spain, to India
- Damascus attacked by Mongols from the east, Turks from the north, crusaders from the west
- Ottoman Empire growing, Byzantine besieged
- Sundials? Greece, Roman hemispheres, Mass dials, altitude dials, point gnomons, temporal hours
- Many Islamic sundials:planar horizontal, vertical, polar etc were proper instruments with equal hours



Islamic Sundial Concepts

- Mathematics and instrumentation for astronomy and timekeeping was well defined in the east before al-Shatir
- Al-Marrakushi described horizontal sundials with temporal and equal hours about 1275 to 1282 in Cairo
- Najm al-Din al-Misri described over 100 different astronomical instruments: sundials, quadrants, astrolabes, alidades etc about 1330 in Cairo
- Equal hours but no polar gnomons

Damascus School of Astronomy
Great Umayyad Mosque



Al Mizzi Quadrant 1333

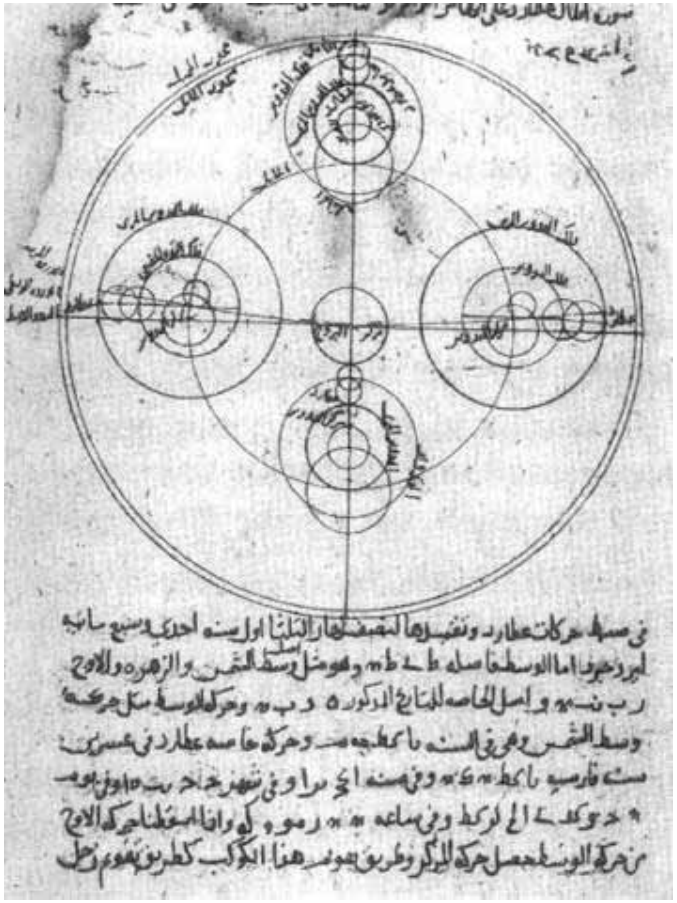
©Trustees of the British Museum

- Damascus was the 14th century world leader in math & astronomy
- Great clock by Al Khurasani, 1146-1169
- Consultants for Frederick II
- Quadrants by Ibn Ahmad Al Mizzi, 1326-1349, astronomer timekeeper
- Ibn al-Shatir the last and perhaps greatest Damascus astronomer, mathematician, craftsman, timekeeper

Ibn al-Shatir (ابن الشاطر)

- Ala Al-Din Abu'l-Hasan Ali Ibn Ibrahim Ibn al-Shatir (ابن الشاطر) (1304 - 1375)
- Arab Muslim astronomer, mathematician, engineer, instrument craftsman & inventor
- Religious timekeeper (muwaqqit) at Umayyad Mosque in Damascus
- Best known for his planetary theories
- Sundials with equal hours and polar gnomon
- Trig concepts developed earlier by Muhammad ibn Jābir al-Harrānī al-Battānī (858-925) and others

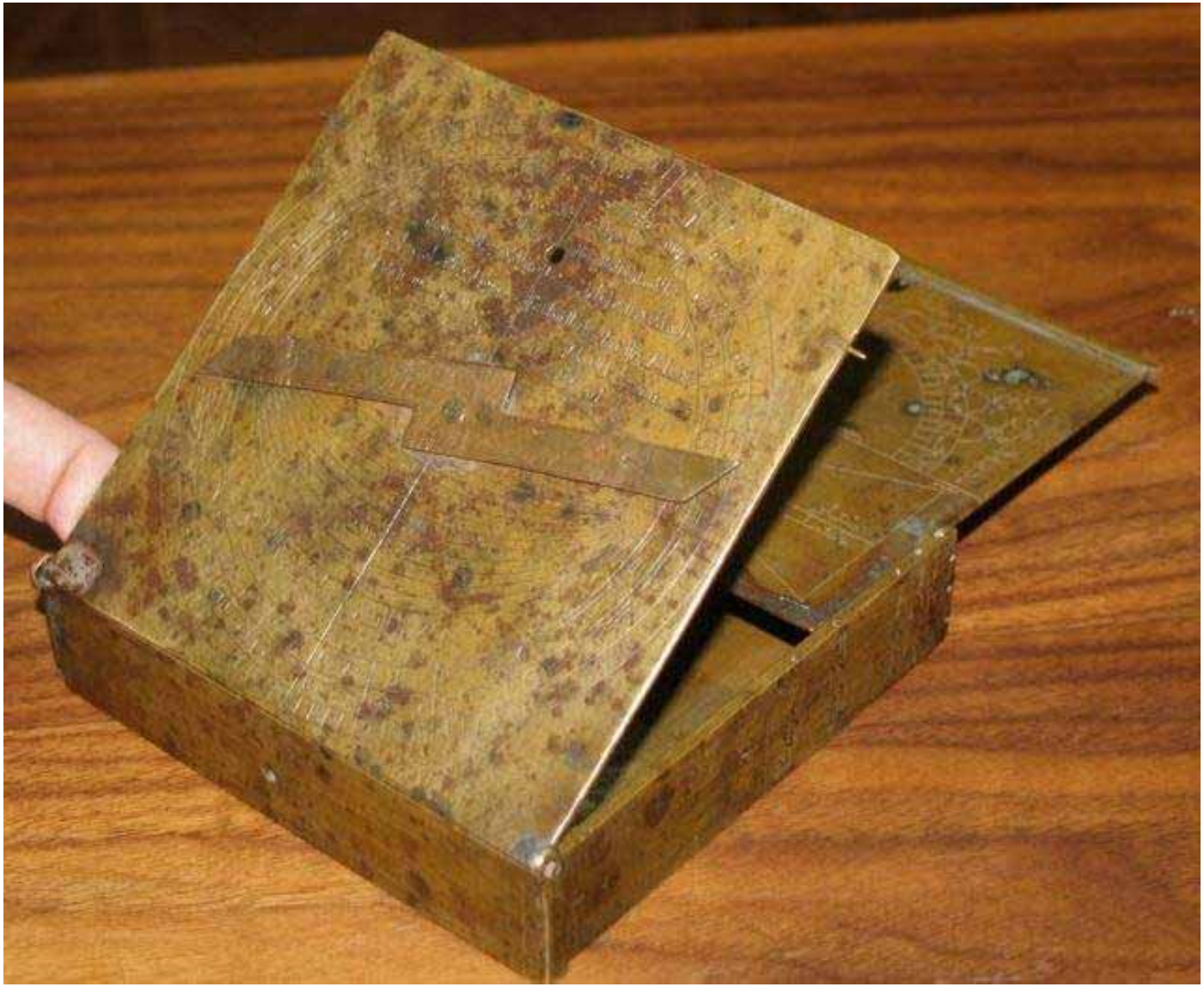
Ibn al-Shatir (بن الشاطر)



- Planetary theories used Tusi Couples
- Eliminated Ptolemy's equant and eccentrics from planetary model
- Better fit for observations & predictions using concentric nested celestial spheres
- Predated almost identical math and drawings by Copernicus almost two centuries later
- Maintained geocentric model like Tyco Brahe

Al-Shatir's Compendium

- Al-Shatir made this Compendium Sundial in ~1360
- Astrolabe style alidade on cover
- Equatorial sundial
- Removable sundial inside
- Library of Awqaf in Aleppo, Syria
- Photo: Rim Turkmani ©



Compendium Slider Plate

Upper part is a 180° Protractor with 10° & 5° = increments

Not a sundial with a polar gnomon but an alidade using a weight on a string.

Also a Qibla showing the direction to Mecca from 10 cities.

Lower part is is a polar sundial at latitude angle with a point gnomon peg, equal hour lines not temporal, and odd curved line

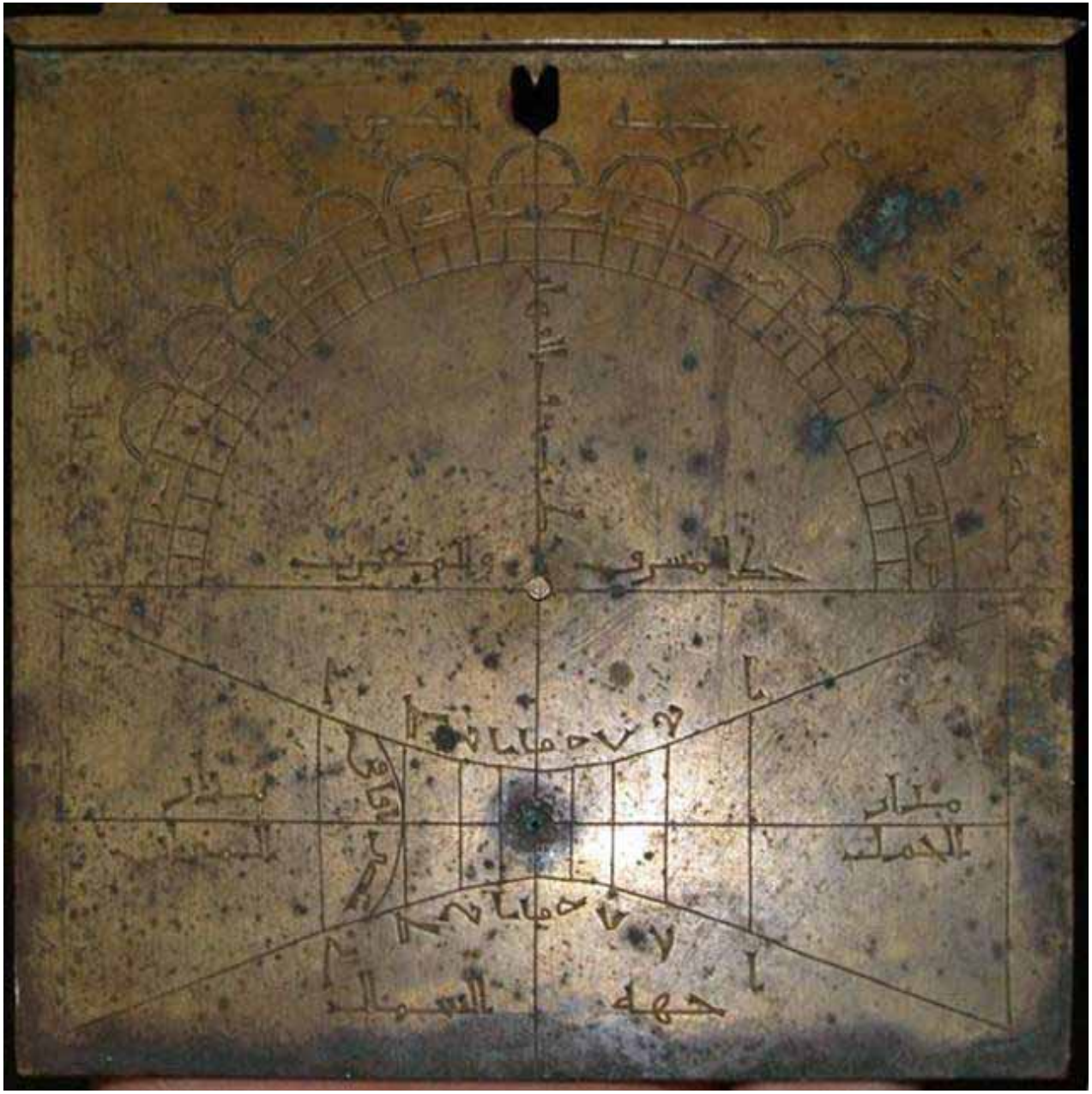


Photo: Rim Turkmani © Library of Awqaf in Aleppo, Syria

Damascus Umayyad Mosque

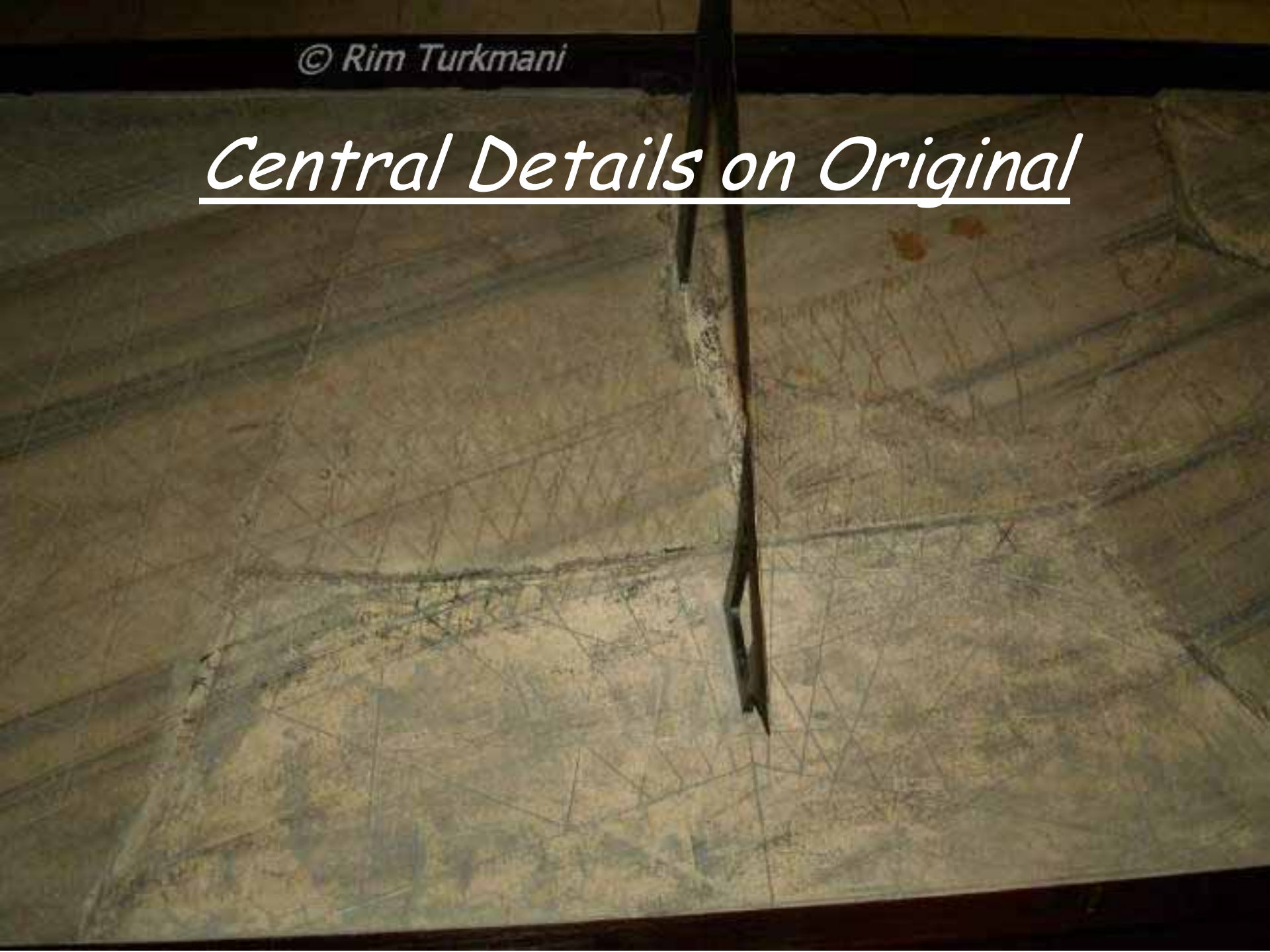
- Mosque built in 715
- Sundial on Minaret
- Ibn al-Shatir made original in 1371
- Dial damaged in 1880 by al-Tantawi
- Replica now in place
- Original is in a museum in Damascus

Great Mosque Damascus Sundial

- al-Shatir sundial 1371
- Large 2 m x 1 m dial
- Engraved in marble
- Polar gnomons for noon based equal hours
- Gap between gnomons is the point gnomon
- Pictures by Dr. Rim Turkmani, Imperial College Astrophysics
- BBC TV "Science & Islam"
- Youtube link

Sundial High on Minaret

Original Sundial in Museum



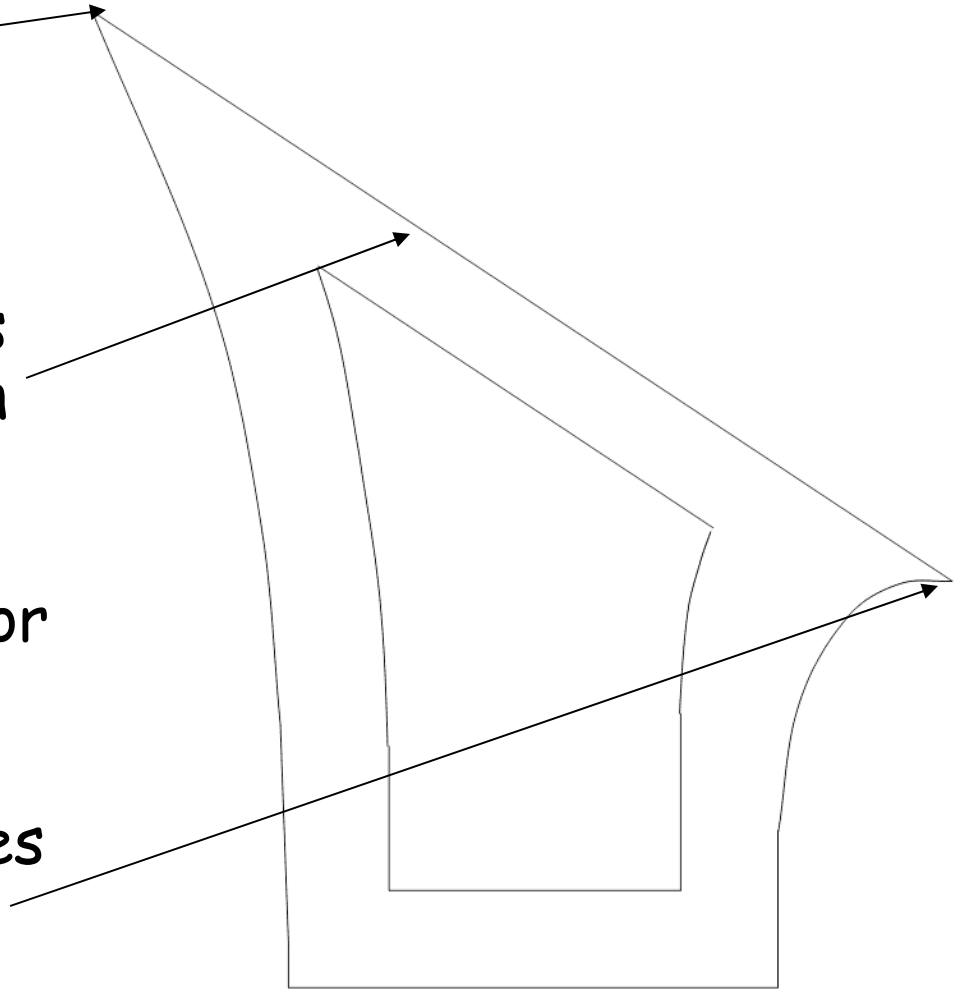
Central Details on Original

Polar / Point Gnomons

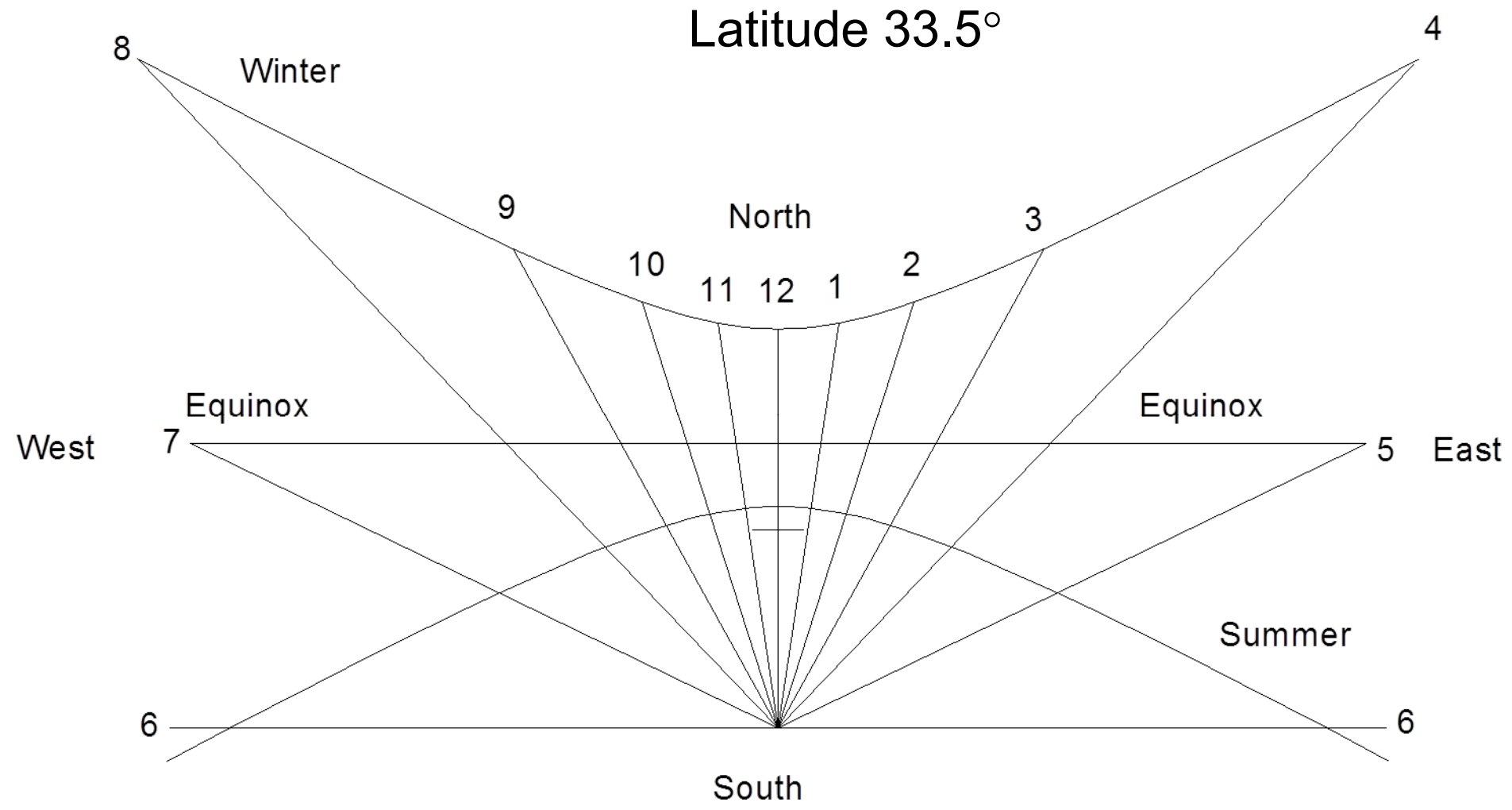
- Al-Shatir's innovation was the use of a Polar Gnomon
- Damascus sundial has two Point & Polar gnomons
- Small gnomon with 2 points is important
- Lower point is for an auxiliary sundial
- Larger gnomon shows long hour lines and form a gap, the true point gnomon

Polar Point Gnomons

- Point gnomon shows declination, hours from noon, sunrise, sunset and prayer times
- Al-Shatir's innovation was the use of a Polar Gnomon at the latitude angle
- Polar gnomon gives clear shadow plane hour lines for distant viewing of equal hours through the year
- Small auxiliary sundial uses the lower point gnomon

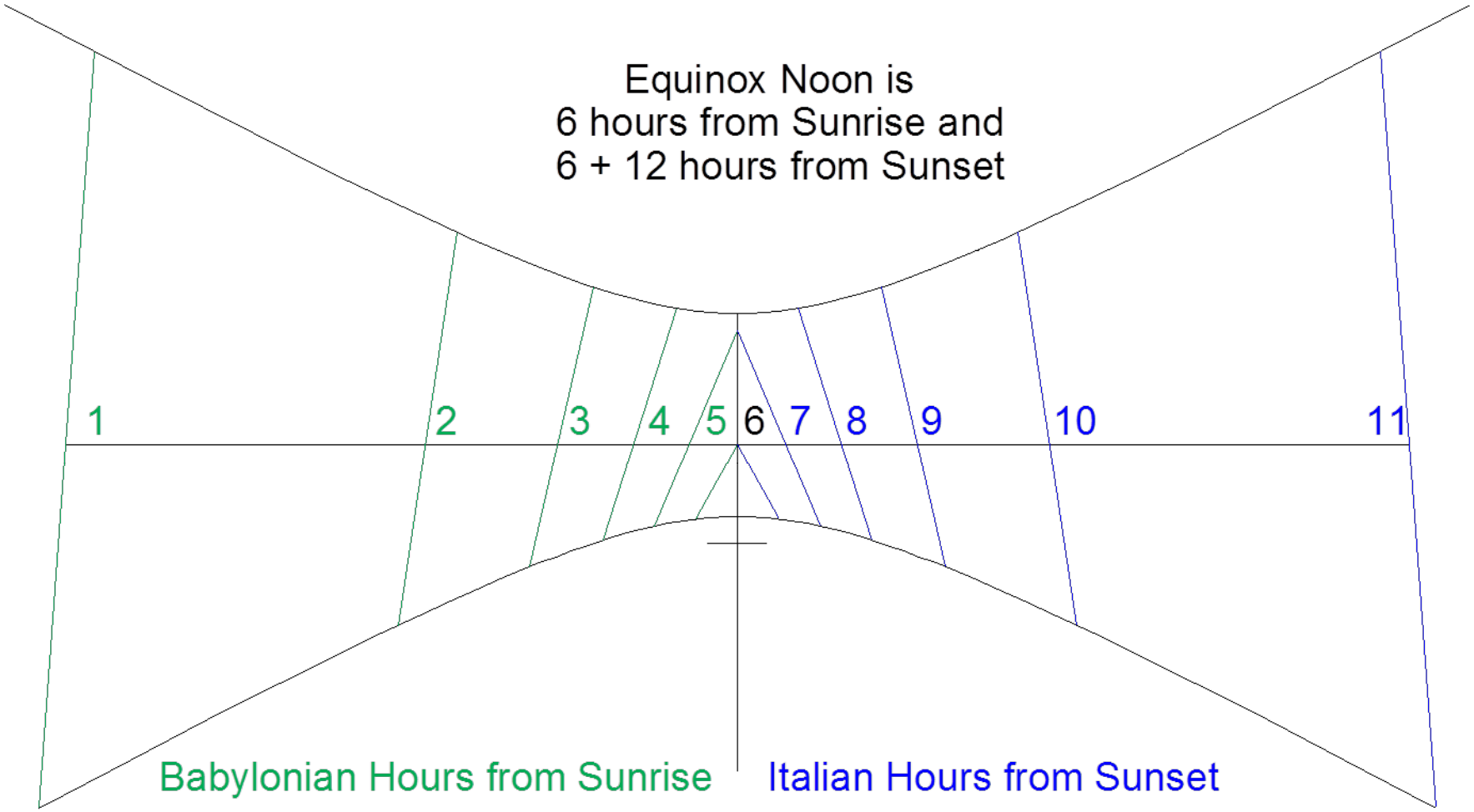


al-Shatir's Sundial

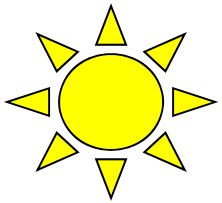


Polar Gnomon Noon Based Hours

al-Shatir's Sundial

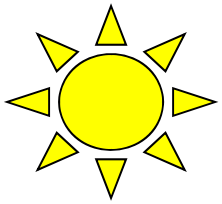


Point Gnomon: Sunrise Sunset Hours



Why? Islamic Sundials

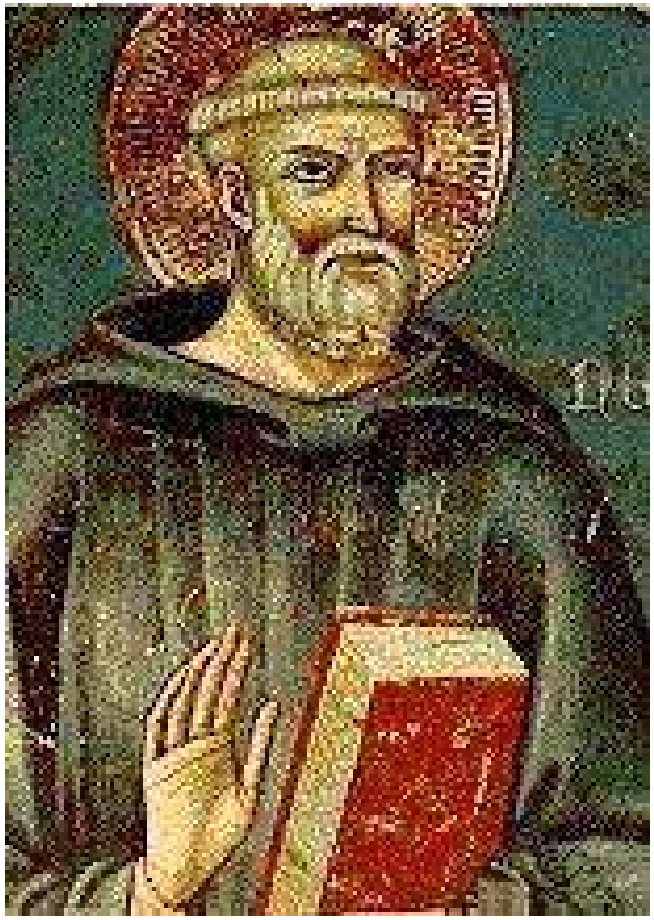
- Question? When do we pray?
- Astronomers = Mosque timekeeper (muwaqqits)
- Sundial were complex and difficult to read but impressive scientific instruments
- Five time systems:
  - Time systems with equal hours based on noon, sunrise, sunset, unequal temporal hours and prayer times
- All Moslem prayer times referenced to the sun
  - Zuhr: Noon meridian
  - Asr: shadow length = noon + gnomon height
  - Maghrib: sunset shadow disappears
  - Twilight: Fajr daybreak, Isha nightfall



Prayer Times: Canonical Hours

- Often shown on Mass or scratch dials on old churches
- Seven times (tides) defined by St. Benedict's Rule (6th Century)
  - Matins (Lauds): midnight to dawn
  - Prime: sunrise (first)
  - Triece: mid-morning (third)
  - Sext: noon (sixth)
  - Nones: midafternoon
  - Vespers: sunset
  - Compline: sunset to midnight

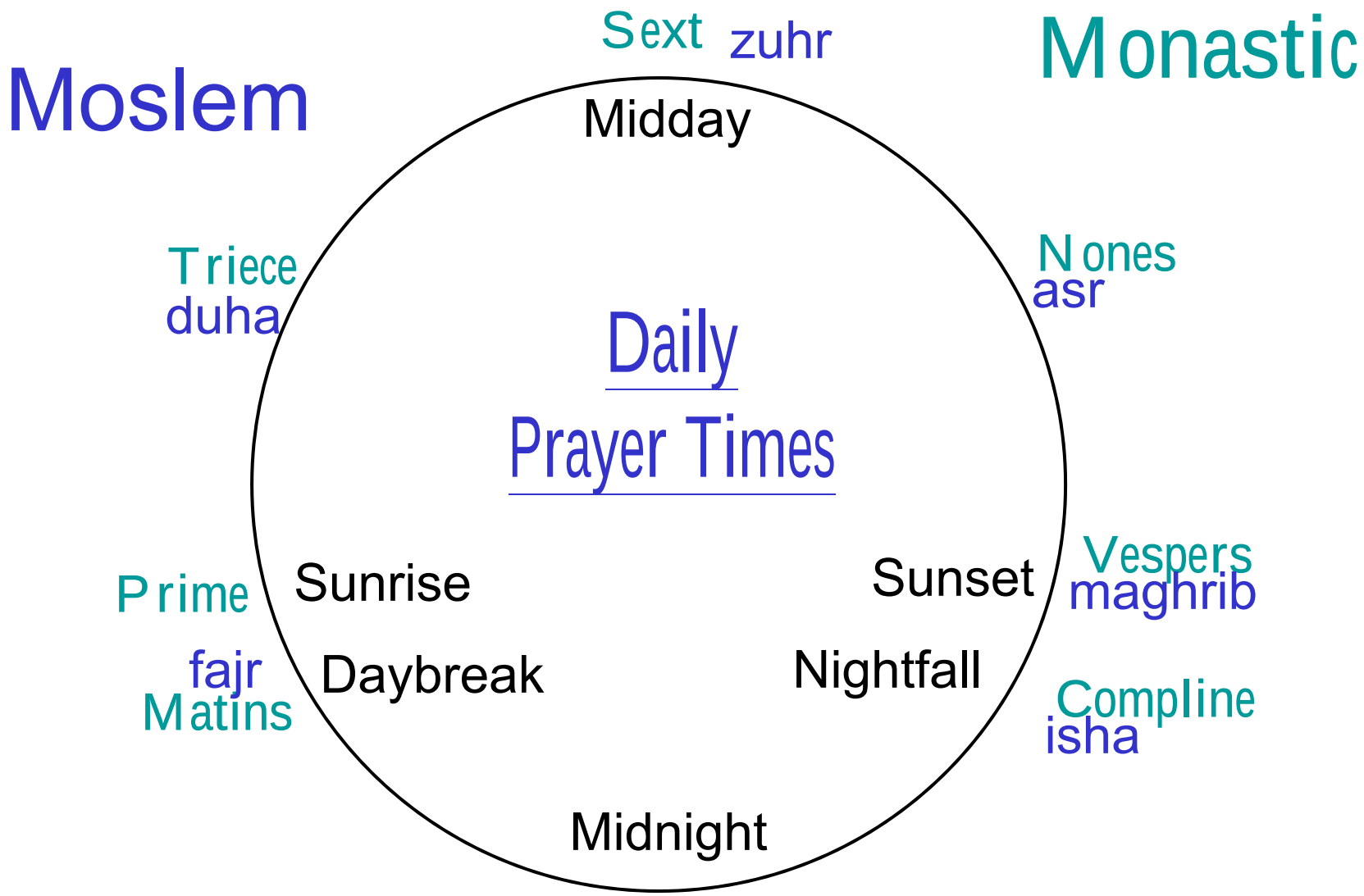
Rule of St. Benedict



- CHAPTER XVI

How the Work of God Is to Be Performed during the Day

As the Prophet saith: "Seven times a day I have given praise to Thee" (Psalms 119:164), this sacred sevenfold number will be fulfilled by us in this wise if we perform the duties of our service at the time of Lauds, Prime, Tierce, Sext, None, Vespers, and Complin;


Moslem
Monastic
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Prayer Times
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fajr
Matins
Daybreak
Nightfall
Compline
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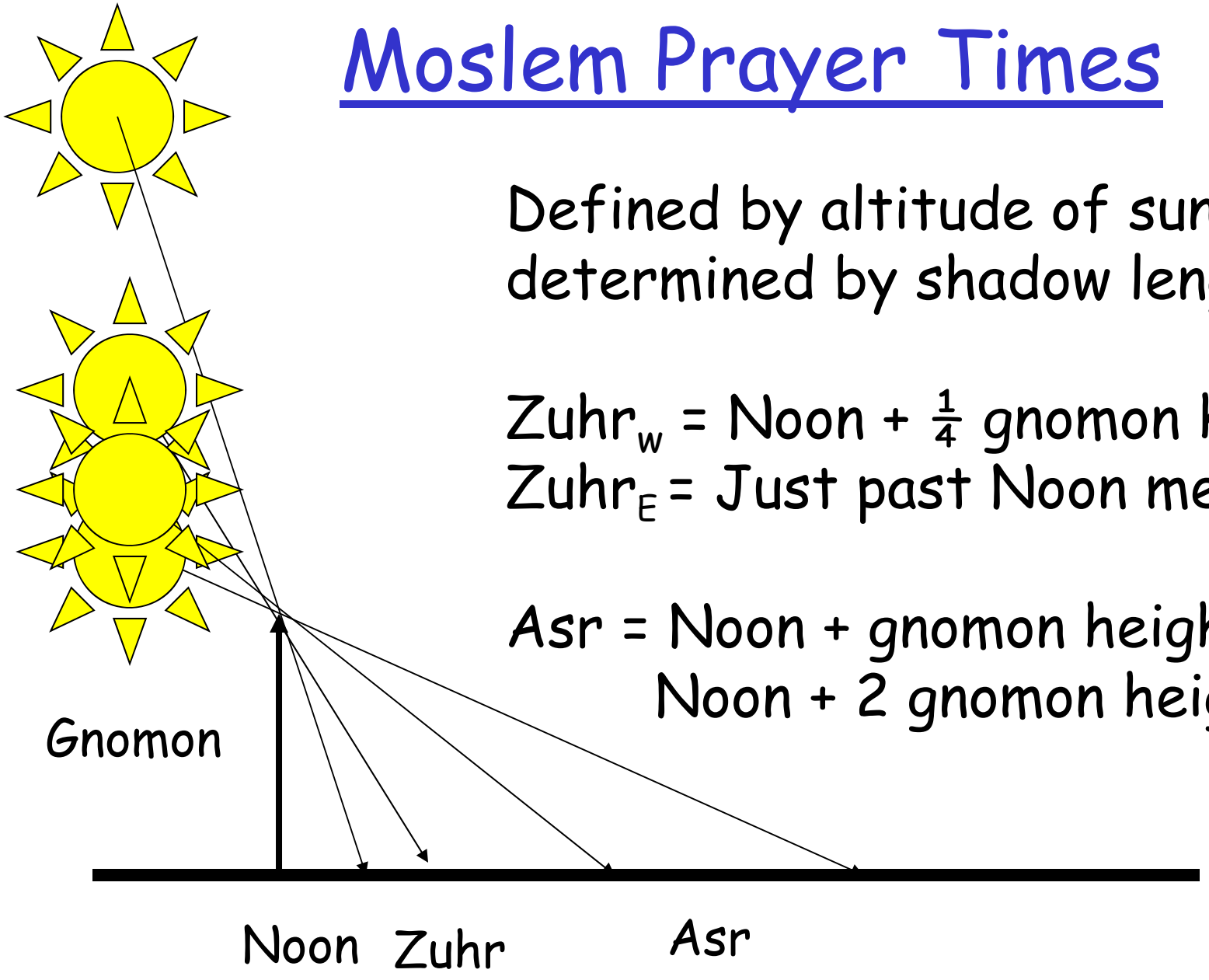
Midnight

Moslem Prayer Times

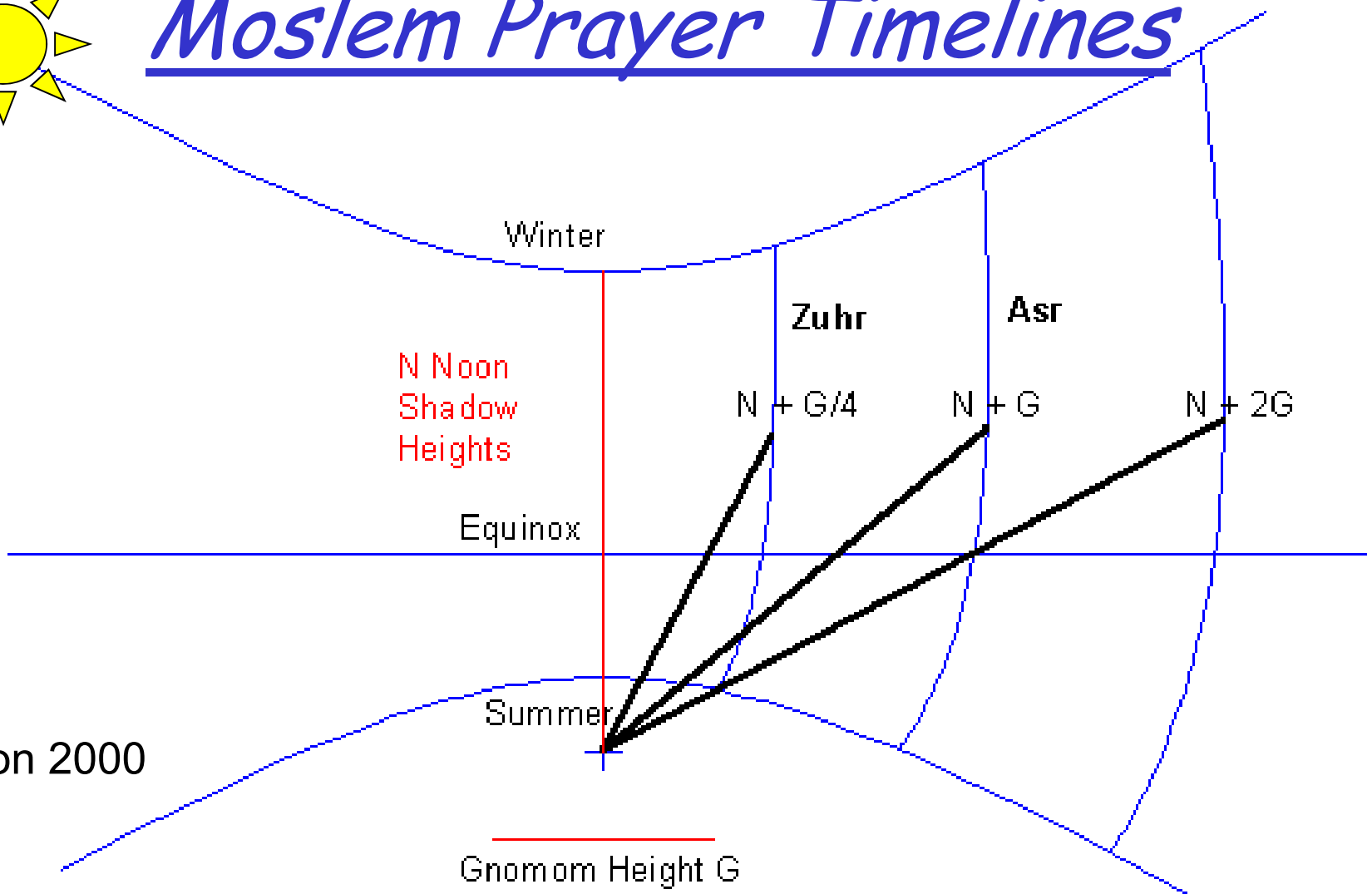


Defined by altitude of sun
determined by shadow lengths

$Zuhr_W$ = Noon + $\frac{1}{4}$ gnomon height
$Zuhr_E$ = Just past Noon meridian

Asr = Noon + gnomon height to
Noon + 2 gnomon heights

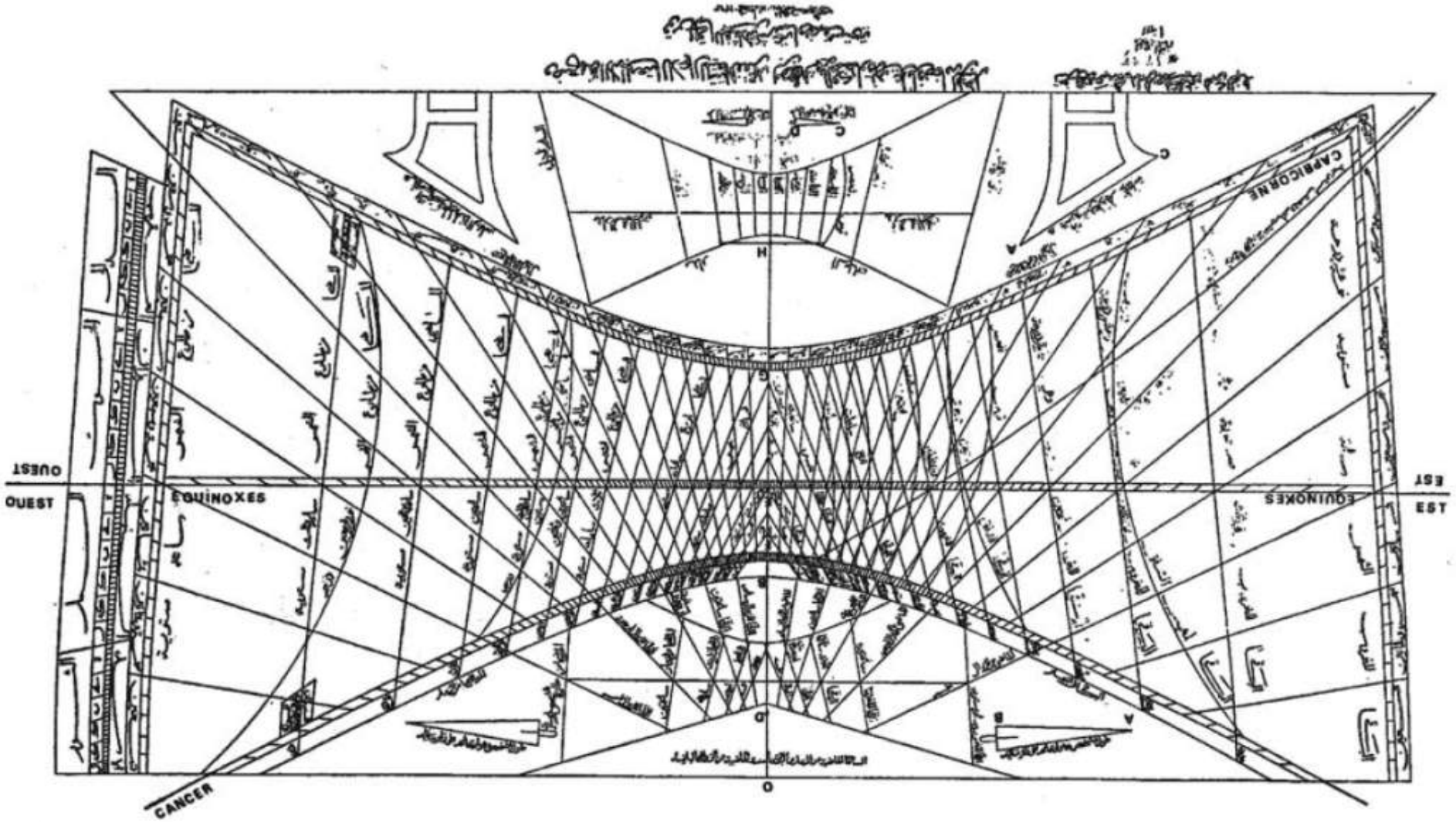
Moslem Prayer Timelines



Zon 2000

Istanbul: Latitude 41° N

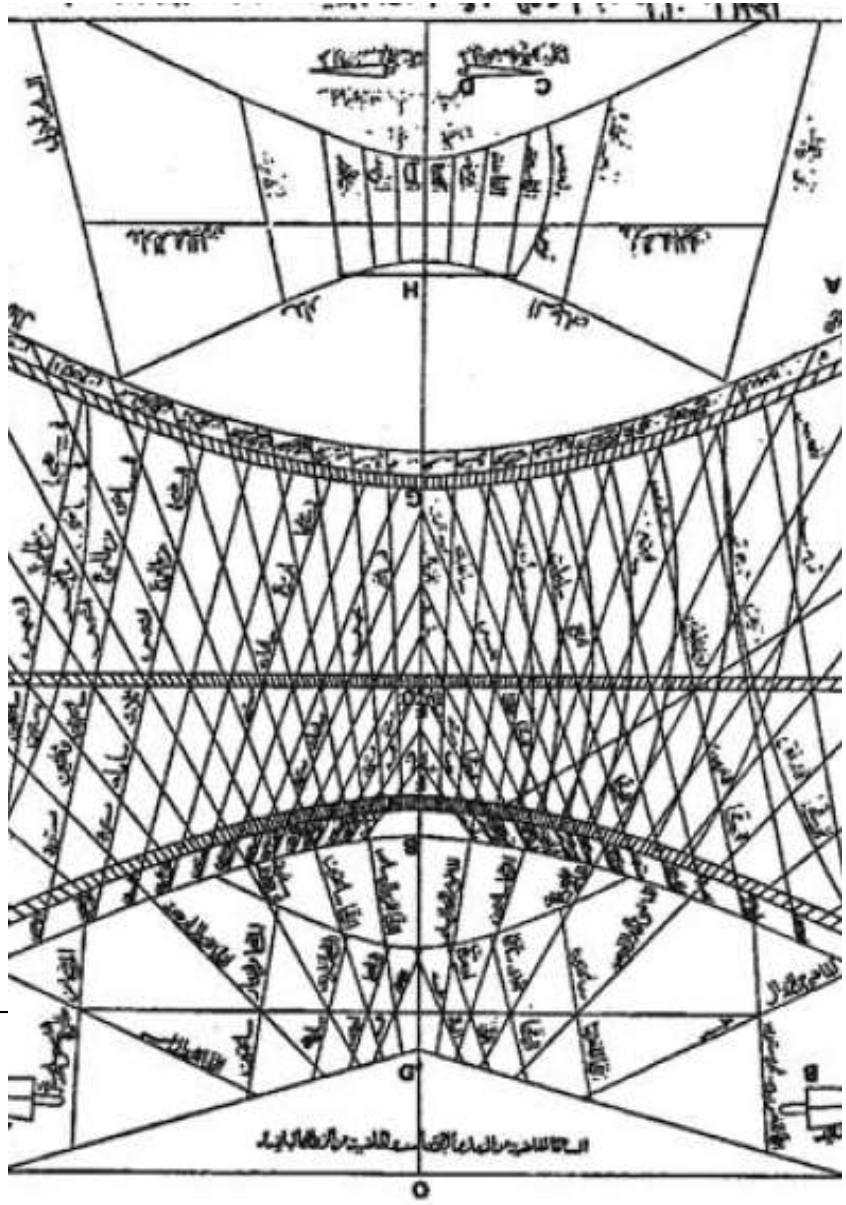
Horizontal with Vertical Gnomon



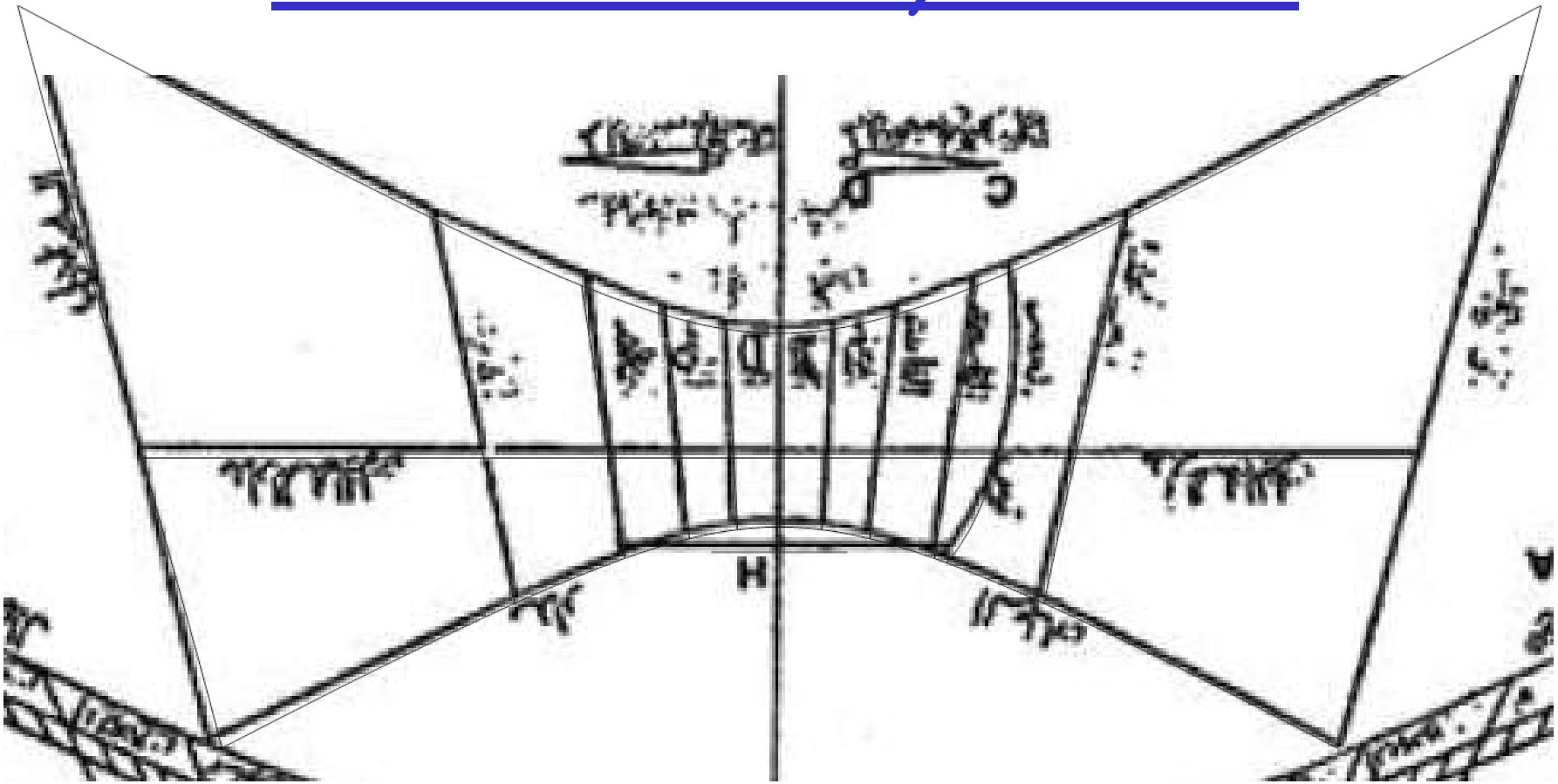
Ibn al-Shatir Sundial

Auxiliary Sundials

- North auxiliary sundial uses a vertical point gnomon to show temporal hours, 12 unequal hours &Asr
- South auxiliary sundial uses the lower point of the polar gnomon to show equal hours from noon, sunrise and sunset

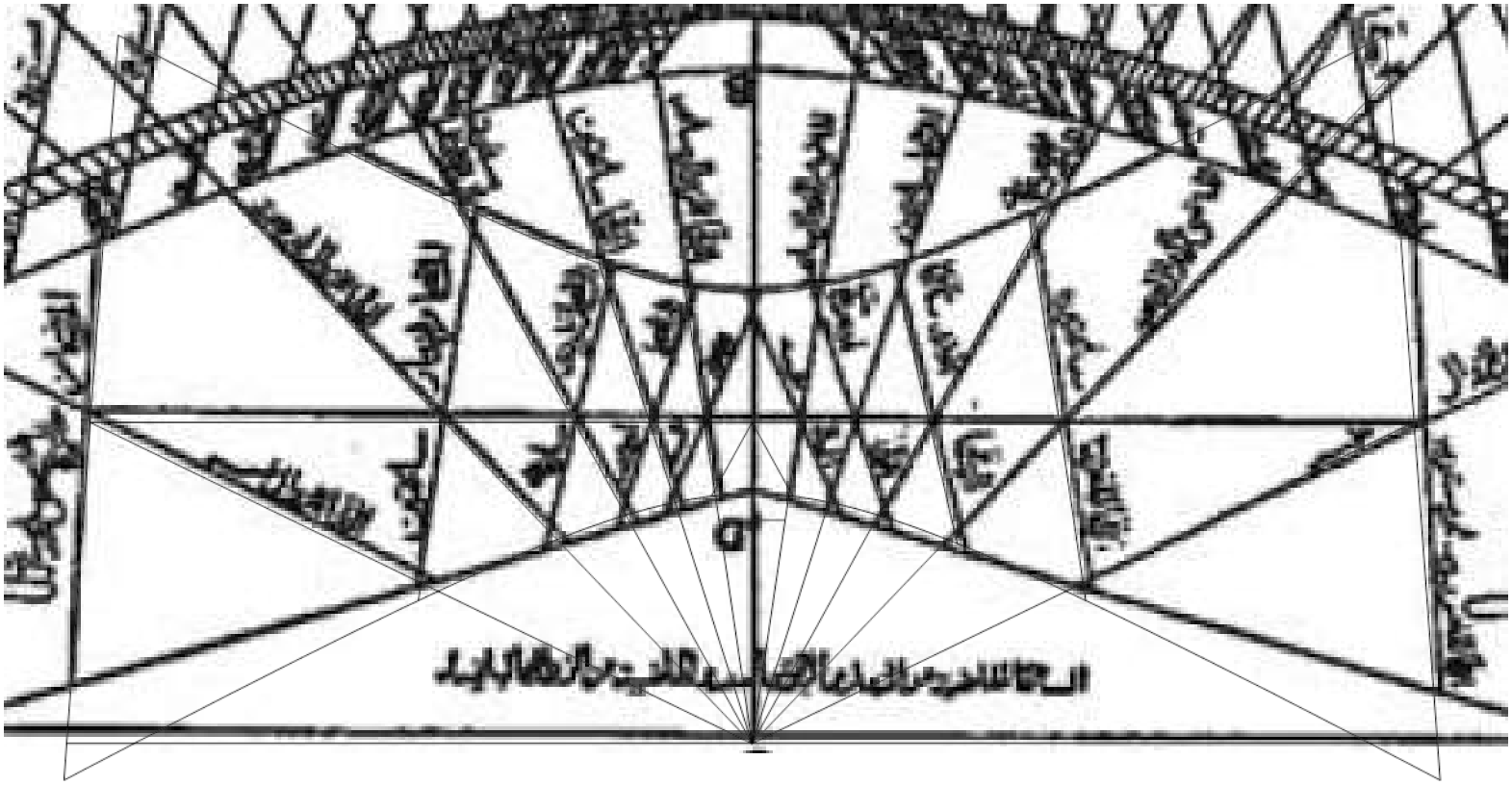


North Auxiliary Sundial

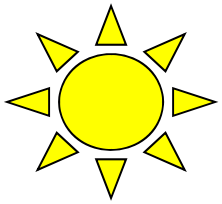


- Damascus Lat 33.5°
- Vertical Point Gnomon, height 42%
- Temporal hour lines, 12 unequal hours, 1 to 11
- Asr Prayer line

South Auxiliary Sundial



- Damascus Lat 33.5°
- Lower Point Gnomon, height 42%
- Sunrise Sunset & Noon based hour lines



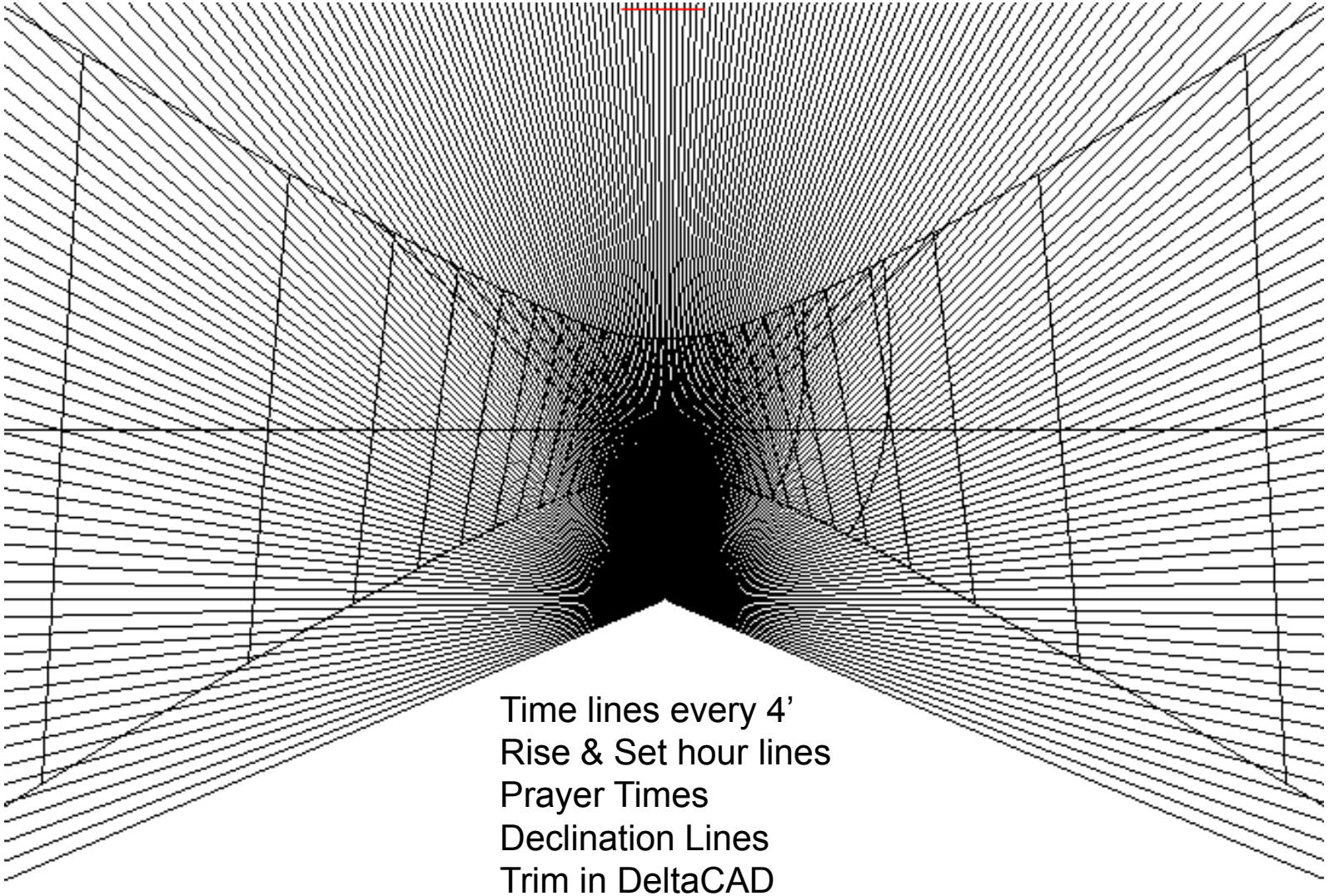
Analemma Society

- The Analemma Society operates an educational and scientific facility at Observatory Park at Turner Farm, near McLean VA
- Charles Olin, President, Analemma Society
- Sundial Garden Project proposes sixty sundials to interpret the cosmos as used in different countries, cultures and times
- Commissioned a replica of Al-Shatir's sundial for their location, Latitude 39°

Replicate al-Shatir's Sundial

- Latitude 39° Analemma Park, Virginia
- Design a horizontal sundial with:
  - Declination lines for solstices and equinox
  - Hour lines every 20 minutes, every 4 minutes
  - Babylonian (Sunrise) hour lines every 20 minutes
  - Italian (Sunset) hour lines every 20 minutes
  - Moslem Prayer Times: Asr and Zuhr
  - Prayer Reference Lines: Fajr and Isha
- Use Fer de Vries Zon 2000 for the lines
- Use DeltaCAD to plot and trim the lines
- Use Excel spreadsheet to calculate the reference lines

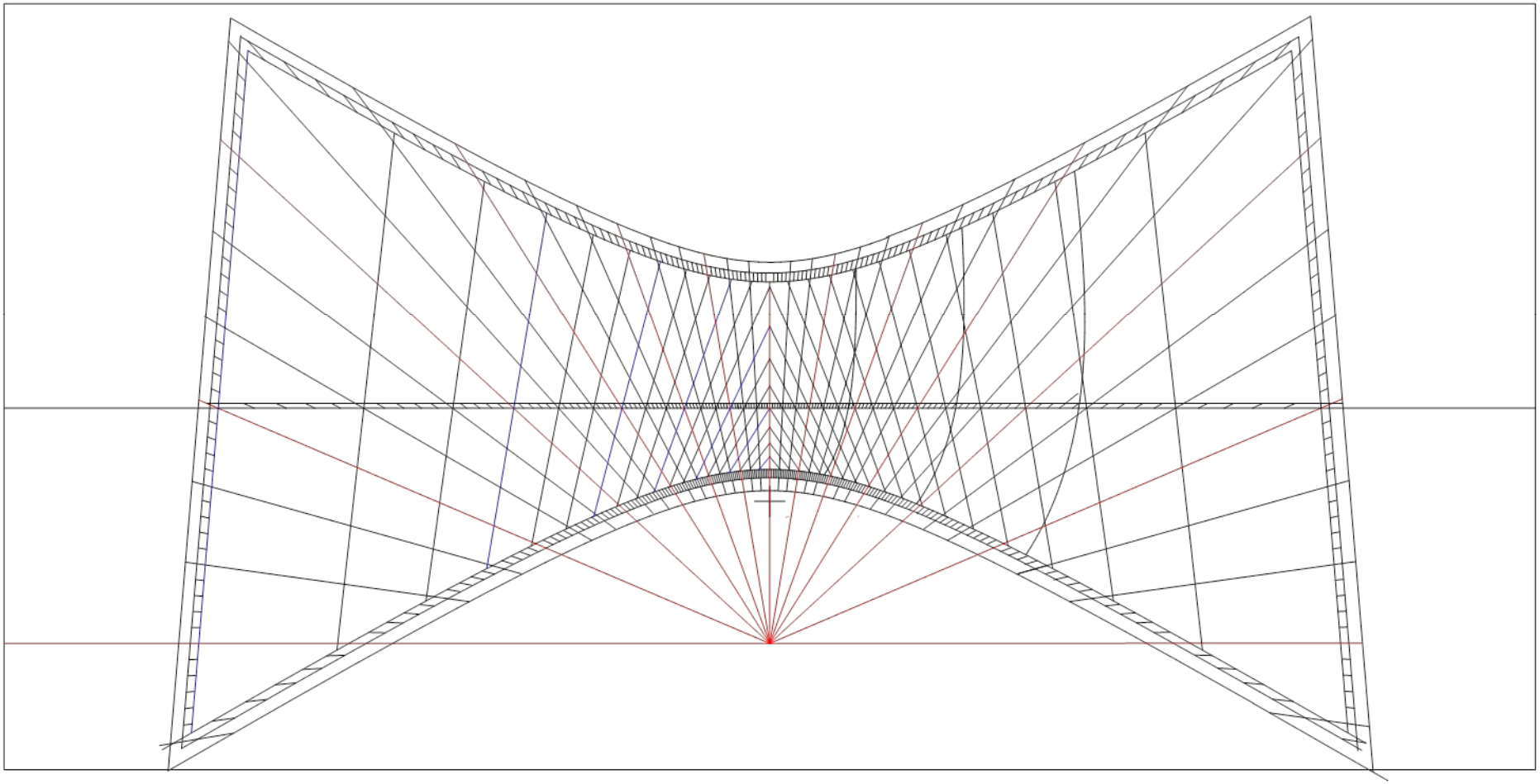
Zon 2000 Raw Output



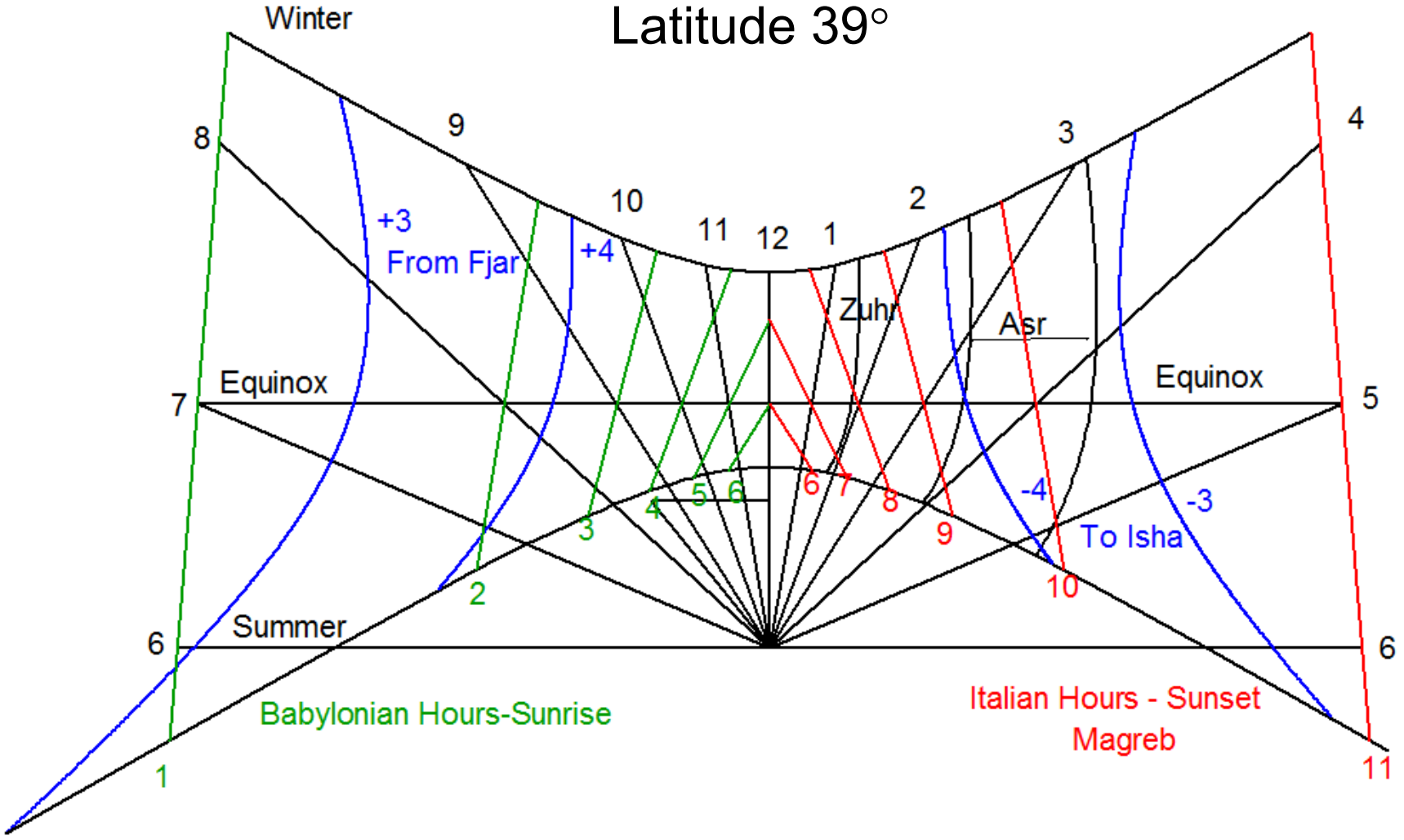
Time lines every 4’
Rise & Set hour lines
Prayer Times
Declination Lines
Trim in DeltaCAD

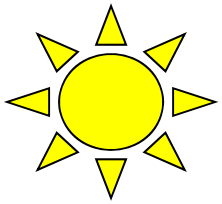
DeltaCAD Trimmed Version

Declination, Hour, Sunrise, Sunset & Three Prayer Lines



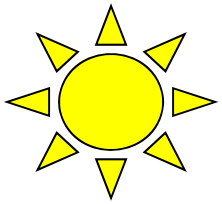
Replicate al-Shatir's Sundial





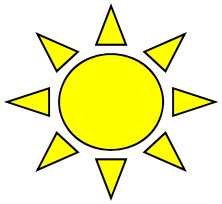
Twilight: Modern and Ancient

- Twilight?
  - How far below the horizon is the sun ?
- Modern Twilights:
  - Civil 6°, Nautical 12°, Astronomical 18°
- Ancient: (Moslem)
  - Equivalent to astronomical twilight
  - Nightfall 17°, Daybreak 19°
  - Why? Dark adaptation



Sundial Reference Lines

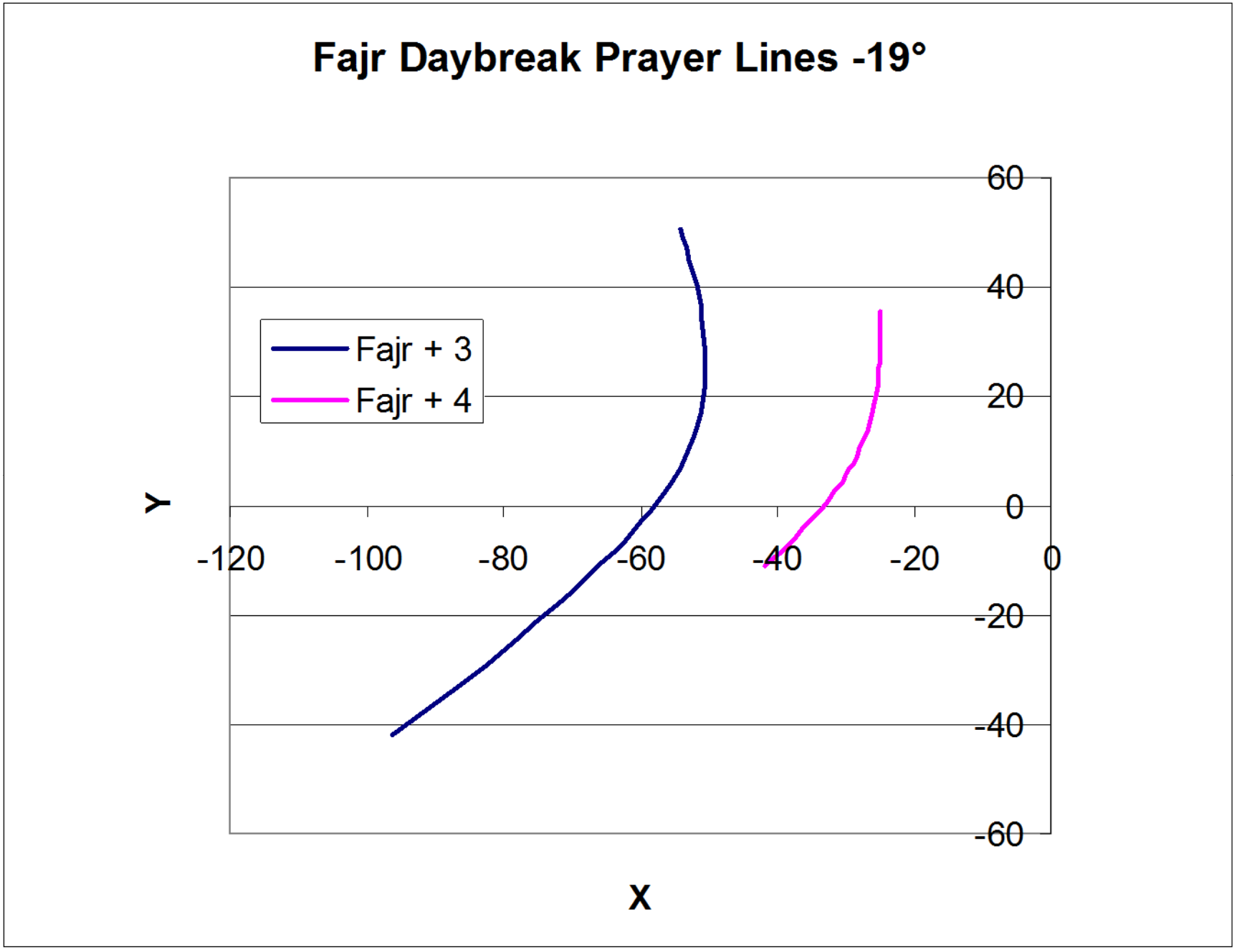
- Moslem sundials have reference lines for daybreak and nightfall prayers
  - Damascus Mosque,
  - Istanbul: Topkapi, Mosques
- Nightfall (Isha):
  - 3 and 4 hours before, 45°and 60°
- Daybreak (Fajr):
  - 13:20 or 14 hours before, 200° or 210°
  - 3 and 4 hours after

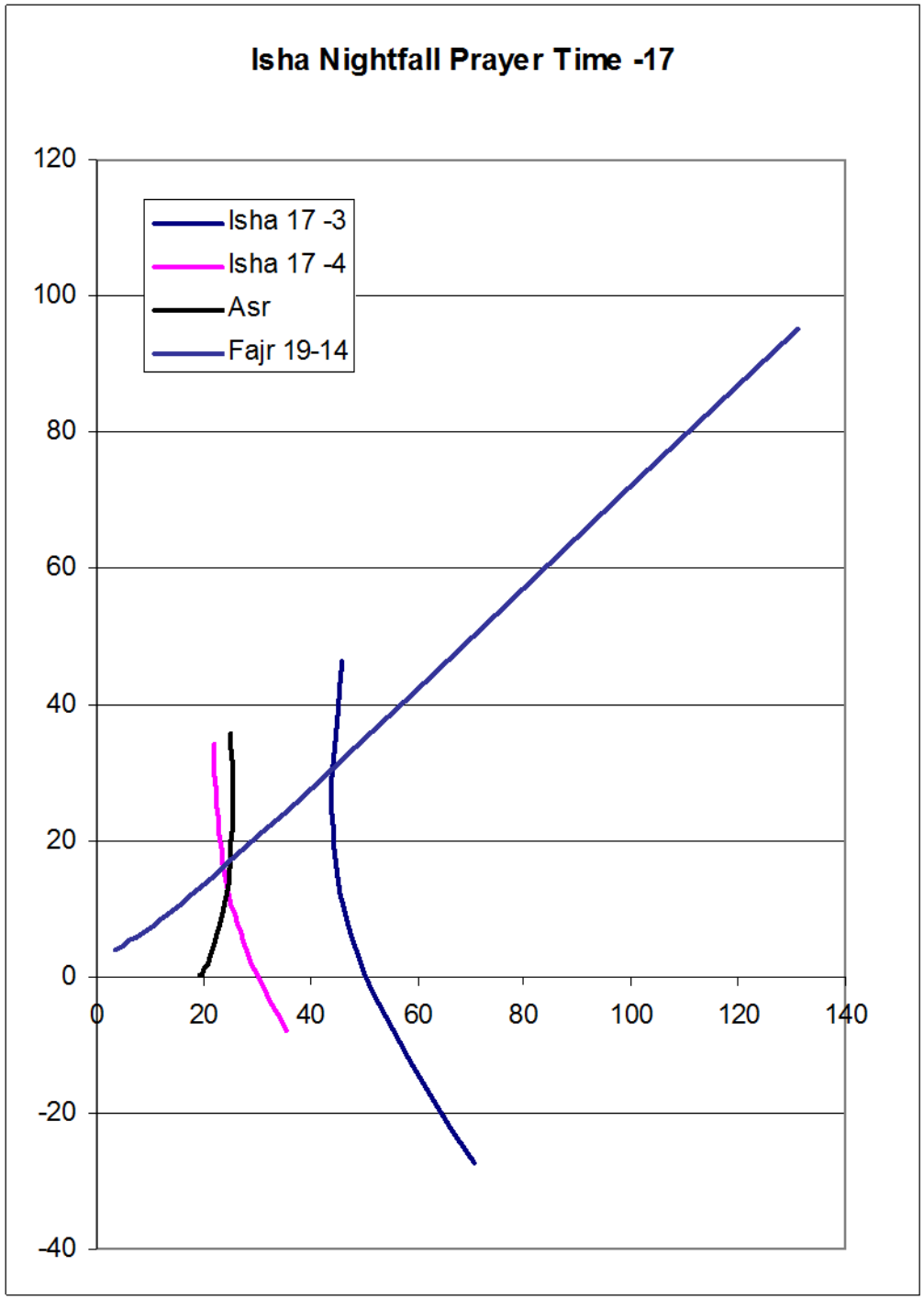


Sundial Reference Lines

- Solve for time t_w at twilight altitudes

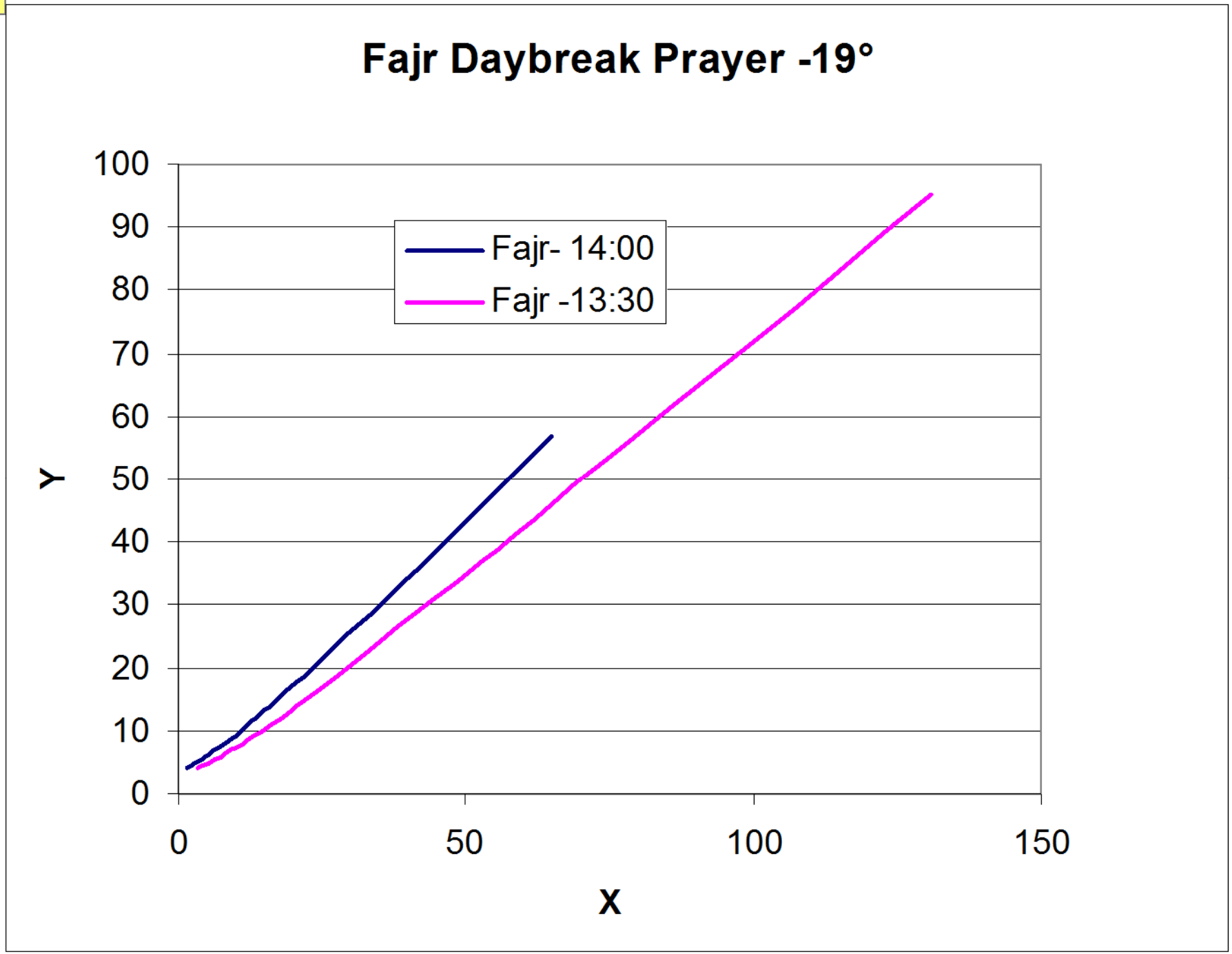
  Sin Alt = Sin Dec x Sin Lat +Cos Dec x Cos Lat x Cos t_w
- Subtract reference time angle from twilight
- Solve for Altitude and Azimuth for the ref time
  - Sin(Az)=Cos(Dec)xSin(t_r)/Cos(Alt)
- Project gnomon tip onto sundial plane
  - Distance: g = G/Tan Alt
  - Solve for x,y coordinates: x = g Sin Az, y = g Cos Az
- Repeat for different declinations and times
- Plot x,y coordinates as a spline

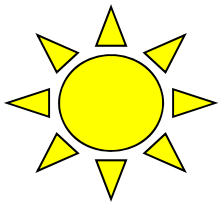

Fajr Daybreak Prayer Lines -19°
Fajr + 3
Fajr + 4
60
40
20
0
-20
-40
-60
-120
-100
-80
-60
-40
-20
0
Y
X



Afternoon Prayer Times

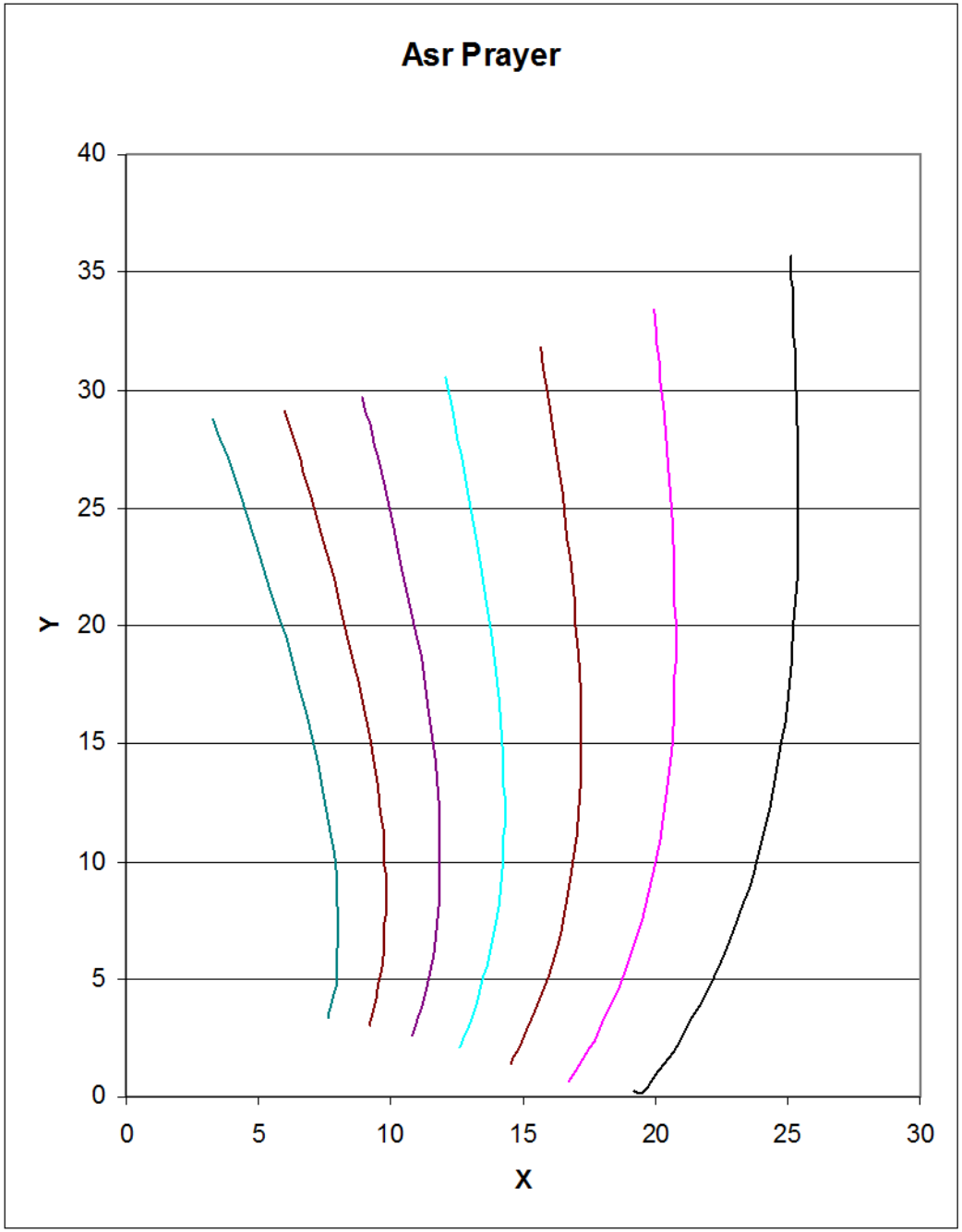
- Asr afternoon prayer
- Isha Nightfall prayer
  - 17° below horizon
  - 3 & 4 hours before
- Fajr Daybreak prayer
  - 19° below horizon
  - 14 hours before
- Fajr line is on the al-Tantawi 1880 replica, not the al-Shatir original


Fajr Daybreak Prayer -19°
100
90
80
70
60
50
40
30
20
10
0
Y
Fajr- 14:00
Fajr -13:30
0
50
100
150
X



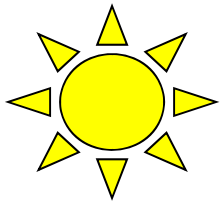
Asr Reference Lines

- Solve for Asr Prayer Time
  - Shadow Length = Noon Shadow + Gnomon Height
  - Sin Alt = Sin Dec x Sin Lat +Cos Dec x Cos Lat x Cos t
- Subtract reference time angle from Asr time
- Solve for Altitude and Azimuth as above and as
  - Sin Az = Sin Alt x Sin Lat/ Sin Dec
- Project gnomon tip onto sundial plane
  - Distance: g = G/Tan Alt
  - Solve for x,y coordinates: x = g Sin Az, y = g Cos Az
- Repeat for different declinations
- Plot x,y coordinates as a spline



Time Before Asr

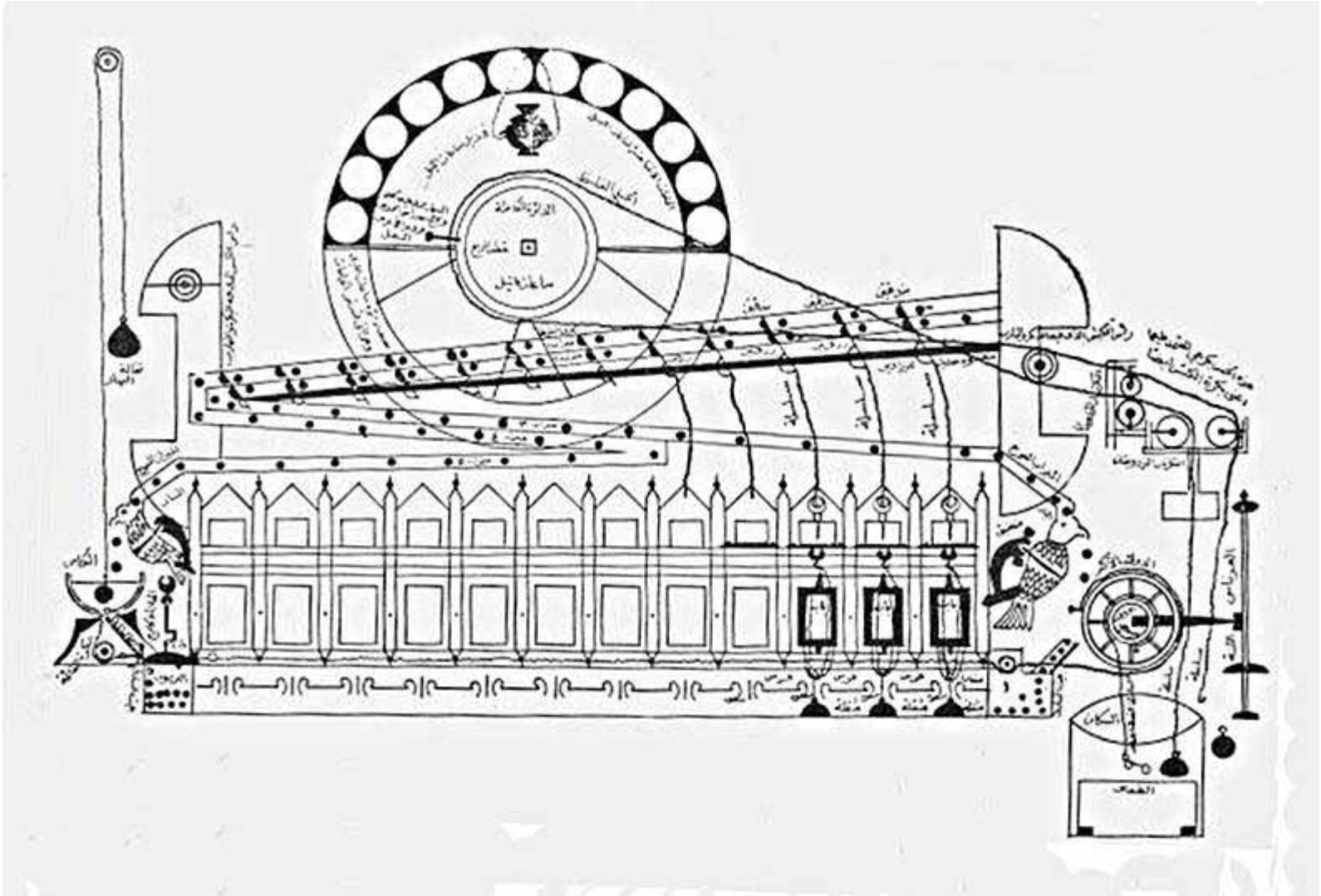
- Asr is defined by the shadow length
- Noon shadow + gnomon height
- 20 minute intervals for 2 hours before Asr afternoon Prayer
- All time references after noon meridian and Zuhr Prayer



al-Shatir Sundial Lines

- Prayer reference lines require a clock
- Sundial shows equal hours:
  - Noon based equal hour lines with polar gnomon
  - Sunrise and sunset based equal hours from point
  - Prayer reference lines use equal hours
  - Auxiliary sundial shows (temporal) unequal
- Clocks show equal hours
- A sophisticated mechanical clock existed at the Great Mosque in Damascus

Bab Jayrun Clock, Damascus



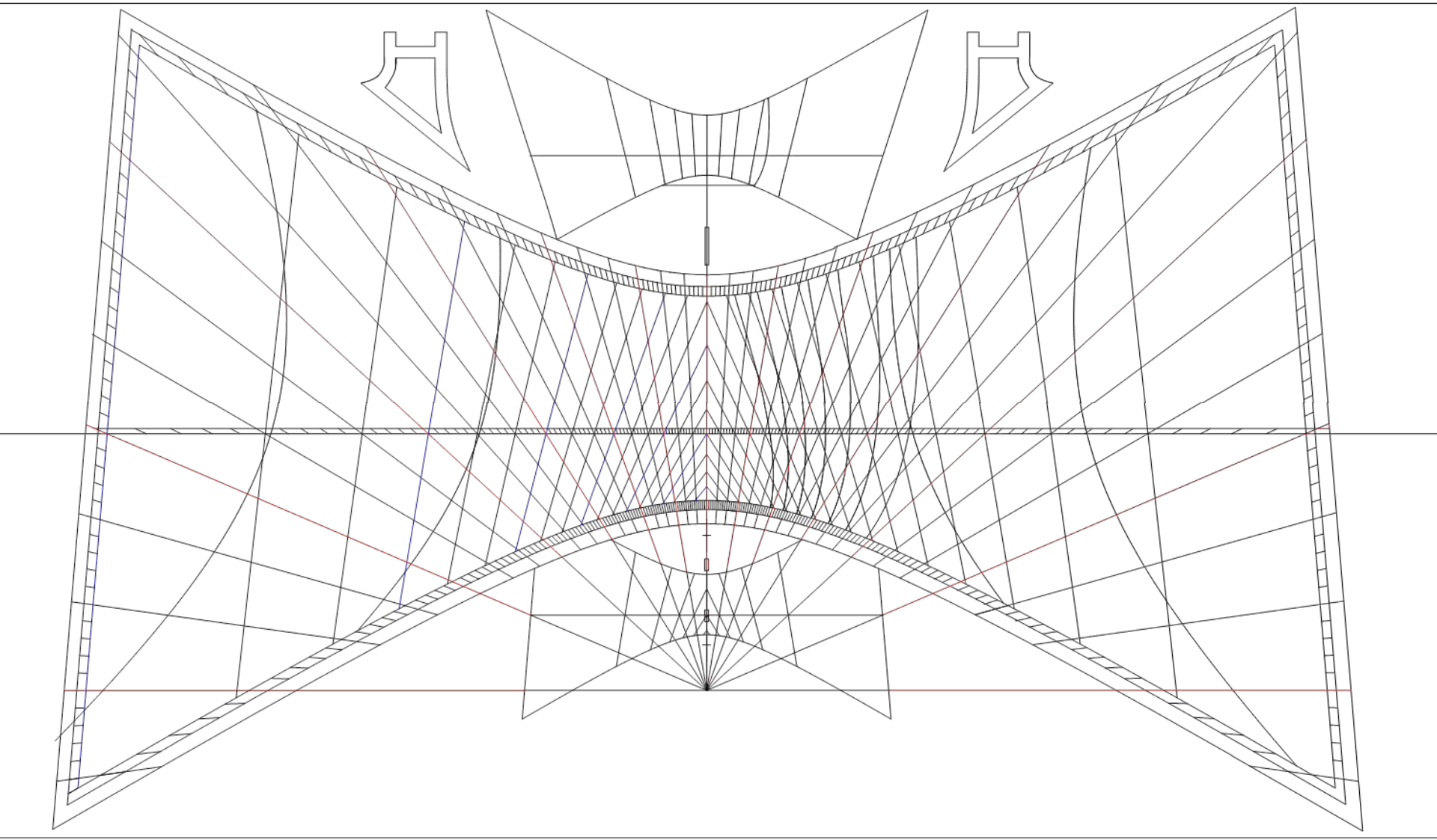
Water Clock of Ridhwan al-Sa'ati

- Clock at Bab Jayrun Gate, east of Great Uymayyad Mosque in Damascus
- Built in 1202 by Muhammad b.'Ali, and son Ridhwan al-Sa'ati
- Adjustable to track seasonal hours
- Birds dropped balls for intervals,
- Doors opened to show hours
- Working model at IBTTM, Frankfurt

Museum for the History of Science and Technology in Islam

Complete Design

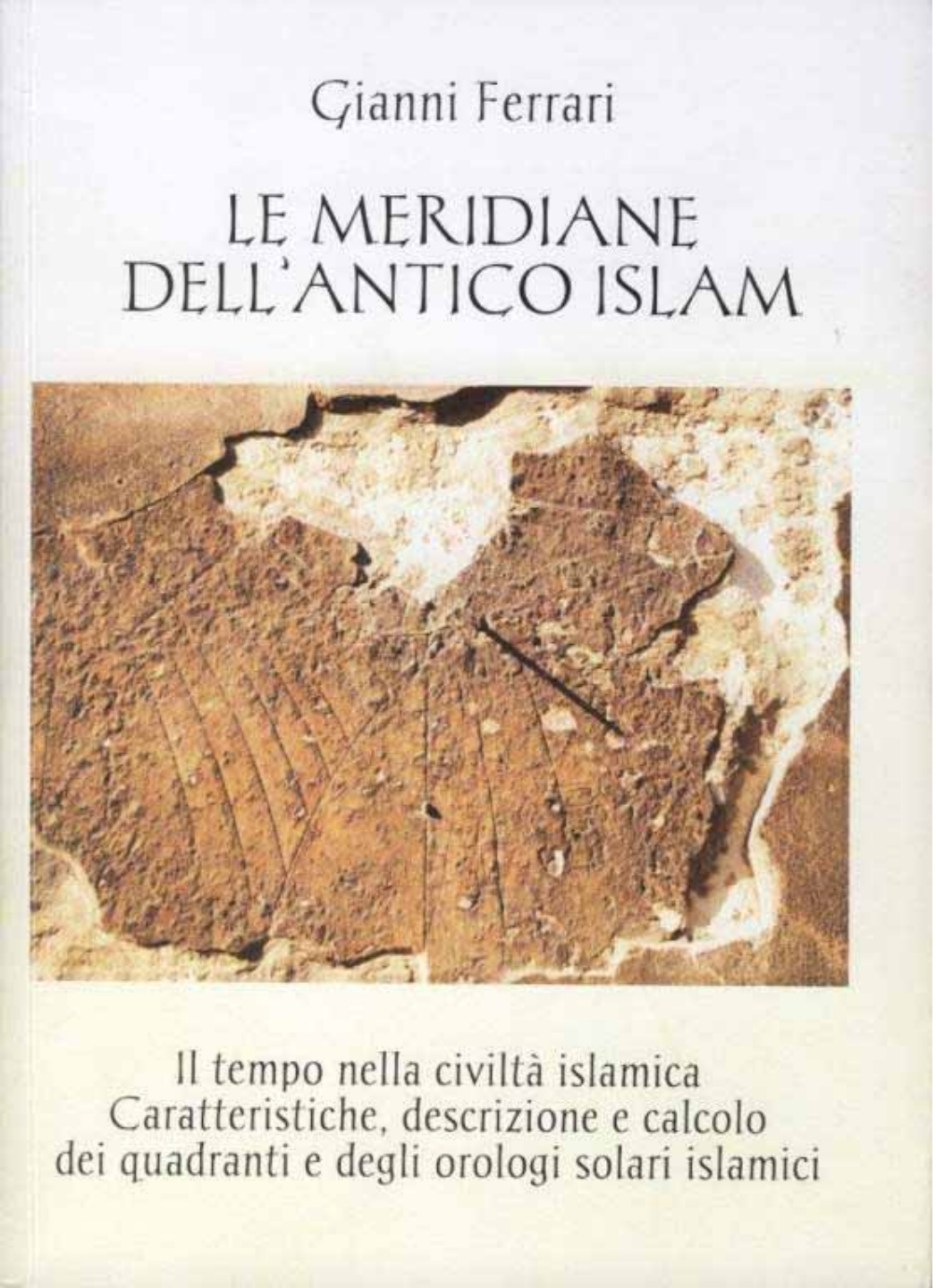
al-Shatir Sundial @ Latitude 39°



Tamerlane Conquest

- "Timur Lane (the Lame)" sacked Damascus in 1399
- Mosque was burned, Astronomy School destroyed
- Ibn Al-Shatir was the last great astronomer from the Damascus School of Astronomy
- The Turkish Ottoman Empire became dominant after the death of Timur Lane
- Al-Shatir type Ottoman sundials in Istanbul
  - Topkapi Palace, major Mosques, etc
- Science, mathematics, astronomy etc bloomed in Europe in the Renaissance
- Not so in the Islamic world

Library Hagia Sophia
The End
One Book: Koran



References

- I was pleased to collaborate with Gianni Ferrari on this research on Islamic sundials
- We both benefited by sharing information and ideas
- The book is a detailed and comprehensive thesis on Islamic sundials. Seed details
- I recommend his book, now published at significant personal expense
- The text is in Italian, no big deal as the content is gnomonics
- € 35 + € 10 postage
  gfmerid@gmail.com

References & Acknowledgements

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