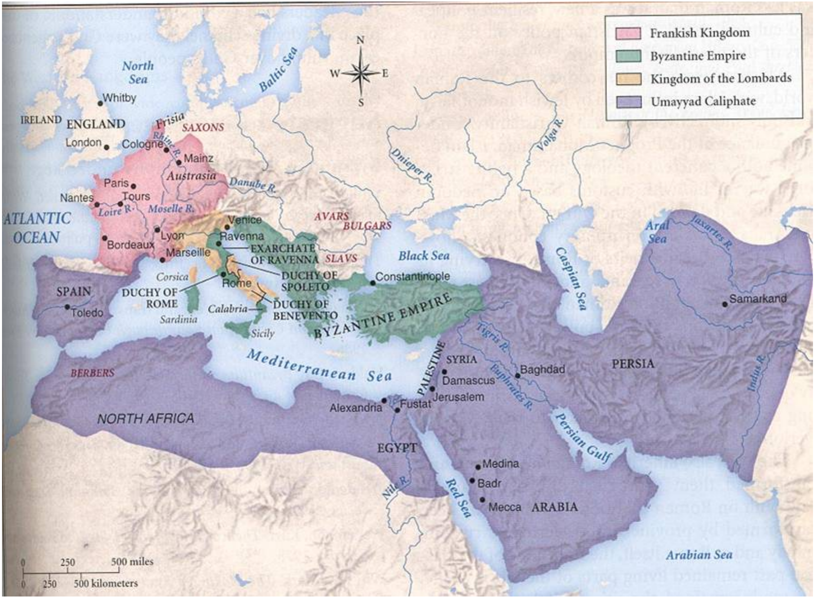
Sciences in the Islamic Middle Ages

The reception and development of the ancient sciences

Waseda University, SILS,
Introduction to History and Philosophy of Science

The Umayyad Caliphate (mid-7th to mid-8th century)



The ʿAbbasid Revolution

The ʿAbbasids moved the seat of the Caliphate from Damascus to the newly founded Baghdad.

The Umayyads had followed Byzantine and Persian imperial practices and the early language of administration (until around 700 CE) was still in Greek and Persian. Many of the Umayyads' ministers were Christian Greeks. At the beginning of the 8th century, under the Umayyads, there was a translation of the institutions of the bureaucracy into Arabic.

The ʿAbbasid rule was multicultural (Muslims of many ethnicities and languages (mostly Arabs and Persians), Aramaic and Syriac speaking Christians, Jews, Sabians, and so on.)

Many of these groups embraced secular knowledge. (Where *secular* is understood not in a post-Enlightenment sense, but as meaning non-Islamic.)

Translation under the ʿAbbasid Caliphs

Some of the key ʿAbbasid Caliphs, under whom the translation movement flourished, were Al-Mansur (754–775 CE), Harun ar-Rashid (789–809 CE), and al-Maʾmun (813–833 CE).

Desire for translations came from astrology, alchemy, medicine, the needs of bureaucracy, and research programs in philosophy and the sciences.

Translation became a lucrative professional activity. New research created the demand for good translations. This lead to increased study of the languages involved (Greek, Arabic, Syriac, Pahlavi (Middle Persian), etc.).

The ʿAbbasid Caliphate (mid-8th to mid-11th century)

Al-Maʾmun (813–33)

Al-Maʾmun, the most famous supporter of the translation movement, succeeded to the Caliphate when his generals executed his brother, al-Amin, in 813 CE.

His mother was Persian and he was educated in Persia. Hence he began his reign as a proponent of Zoroastrian imperialism. Once in Baghdad, however, he rejected this in favor of a centralized Islamic imperialism with himself as the arbiter of dogma—the Caliph.

He named himself "God's Caliph" in 817 CE. He established a centralized empire based on *a single interpretation of Islam*.

He promoted the expansion of the empire and the religion. This policy was both anti-Christian and pro-Hellenic.

Al-Maʾmun's Policy, I

Al-Jahiz (medieval historian)

"Had the common people but known that Christians and the Byzantines have neither wisdom nor clarity nor depth of thought … they would have removed them from the ranks of scholars and dropped them from roster of philosophers and sages because works like the *Organon*, *On Coming to Be and Passing Away*, and *Meteorology* were written by Aristotle, and he is neither Byzantine nor Christian; the *Almagest* was written by Ptolemy, and he is neither Byzantine nor Christian, the *Elements* by Euclid, and he is neither Byzantine nor Christian, …"

Al-Maʾmun's Policy, II

Al-Masʿudi (medieval historian)

"During the time of the ancient Greeks, and for a little while during the Byzantine empire, the philosophical sciences kept on growing and developing, and scholars and philosophers were respected and honored… The sciences continued to be in great demand and intensely cultivated until the religion of Christianity appeared among the Byzantines; they then effaced the signs of philosophy, eliminated its traces, destroyed its paths, and they changed and corrupted what the ancient Greeks had set fourth in clear expositions."

Aristotle, teaching a Muslim student

Aristotle, in Muslim dress and holding an astrolabe, teaching Muslim students

Note that the astrolabe was not developed until centuries after Aristotle had lived.

Two Methods of Translation, I

The first method, and the problems with it:

As-Safadi (medieval scholar)

"The translators use two methods of translation…

According to the first method, the translator studies each Greek word and its meaning, chooses an Arabic word of corresponding meaning and uses it…

This method is bad for two reasons. First it is impossible to find Arabic expressions corresponding to all Greek words, so many words remain untranslated… Second, certain syntactical combinations in one language do not correspond to similar combinations in the other…

This is a kind of literal, word-for-word translation. It does not require mastering the material, but is not reliable.

Two Methods of Translation, II

The second method:

As-Safadi (medieval scholar)

The second method is that of Hunayn ibn Ishaq[1]… Here, the translator considers the whole sentence, ascertains its full meaning and then expresses it in Arabic with a sentence of identical meaning, without concern for the correspondence of individual words. This method is superior and hence there is no need to improve the works of Hunayn ibn Ishaq. The exception is those dealing with mathematics, which he had not mastered… On the other hand, Euclid has been improved by Thabit ibn Qurra al-Harrani, as have been the *Almagest* and the *Middle Books*."

This is a more complete, and competent translation, but it requires that the translator also understand the fundamentals of the material being translated.

[1] "Ibn" means *son of*, or more generally *of the family of*.

Hunayn ibn Ishaq's Practices

Hunayn ibn Ishaq was a practicing physician who became the greatest medical translator of his day.

Hunayn, from Galen's work on the sects (of physicians)

"When I was a young man of twenty… I translated it for a physician from Jundishapur… from a very faulty Greek manuscript. Later, when I was about forty, my pupil Hubaysh asked me to correct the translation. Meanwhile a number Greek manuscripts had accumulated in my possession. I collated these and thereby produced a single correct copy. Next, I collated the Syriac text with it and corrected it. I am in the habit of doing this with everything I translate."

The Banu Musa

The three sons of Musa ibn-Shakir, a warlord who befriended Caliph al-Maʾmun. Their names were Muhammad, al-Hasan, Ahmad. ("Banu" means *sons of*, or more generally *the family of*.)

They were raised at Maʾmun's order and received an excellent education. They became wealthy and powerful ministers, gifted mathematicians, and patrons of the translators.

- They paid 500 dinars a month to Hunayn, Hubaysh, and Thabit for "full time translation."

Thabit ibn Qurra

Muhammad ibn Musa discovered Thabit and brought him back to Baghdad, where the latter was trained in mathematics and medicine and became a brilliant scholar.

He became a key figure in the translation of the exact sciences and produced many original texts that themselves became canonical in later centuries.

Although Thabit was a Sabian pagan who never converted to Islam, he and the Banu Musa collaborated together on a number of projects in the sciences.

The Example of Apollonius' *Conics*, I

Apollonius' *Conics* is a work in eight books of pure geometry, treating the properties of the parabola, hyperbola and ellipse.

Banu Musa, preface to their version of Apollonius' *Conics*

"Now we had got hold of seven of the eight books which Apollonius composed on conics... So we wanted to translate and understand them, but that proved impossible because of the excessive errors which had accrued in the treatise... Then al-Hasan, through his superiority in the science of geometry, succeeded in the theory of the section of the cylinder... So al-Hasan composed a treatise on what he had discovered and died—may God have mercy on him ...

The Example of Apollonius' *Conics*, II

Banu Musa, preface to their version of Apollonius' *Conics*

"Then Ahmad managed to travel to Syria… for he intended to search for manuscripts of that work… That proved impossible, but he got hold of one manuscript of the first four books of Apollonius, although it too had accumulated errors… So he expended toil on understanding them until he was done… When he returned to Iraq, he went back to commenting on the rest of the seven books which had come down to us from the original treatise of Apollonius …

The man entrusted with translating the first four books was Hilal ibn Hilal and the one entrusted with translating the remaining three was Thabit ibn Qurra."

Overview of Islamic Astronomy

The Islamicate societies inherited the astral sciences of the cultures they conquered and fought with—Persia, India and Byzantium—but these sciences came to play a number of important roles within Islamic culture:

- The requirements of Islam created a number of astrological research agendas. (Mostly solved using solar and lunar theories.)
- The ruling classes needed astrology (and the subsidiary tables) for practical, strategic reasons. (This involved the full force of astronomical theory, including planetary theories and various elaborate mathematical techniques for astrology.)
- Mathematically minded scholars came to view astronomy and astrology as inherently interesting.

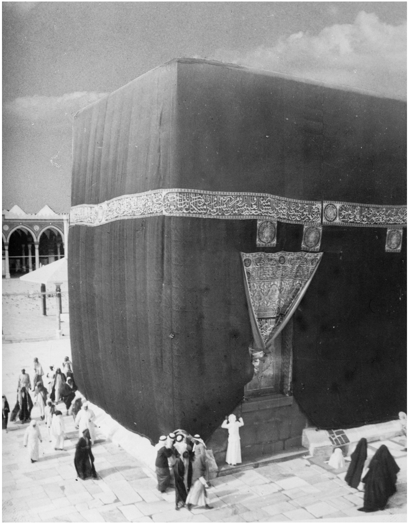
The Kaʿba

The Kaʿba is the physical center of Islam.

It was a pagan shrine which was adopted by Muhammad as the focal point of the new religion. The stone itself has an astronomically significant positioning.

Every Muslim is required, if possible, to make at least one pilgrimage (*hajj*) to pray at the Kaʿba.

The daily prayers should face the Kaʿba.



Sacred Geography

The Islamic world can be thought of as focused on Mecca, as both a physical and a spiritual center.

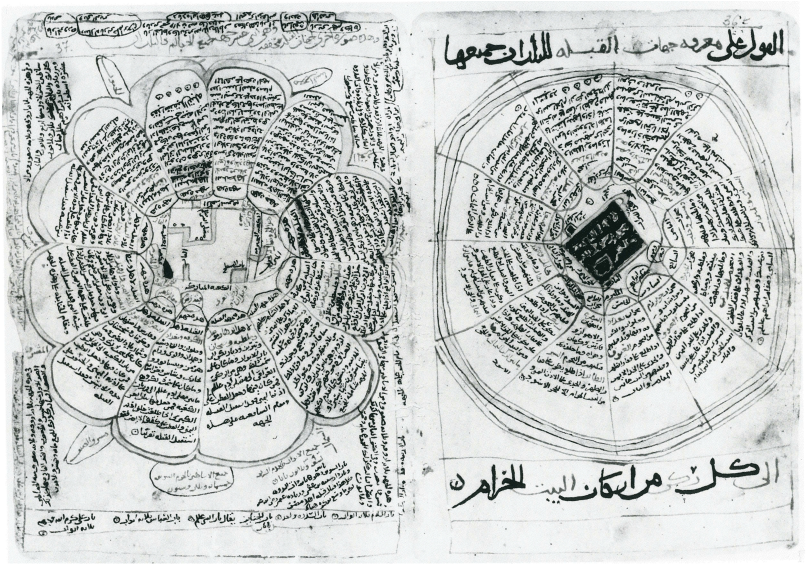
Because mosques are places of prayer, they must face the Kaʿba, and world geography is envisioned as formed by the rays of all these mosques converging on Mecca.

In the medieval period, many schema and world maps were constructed with the regions of the Islamic world arranged around the Kaʿba.

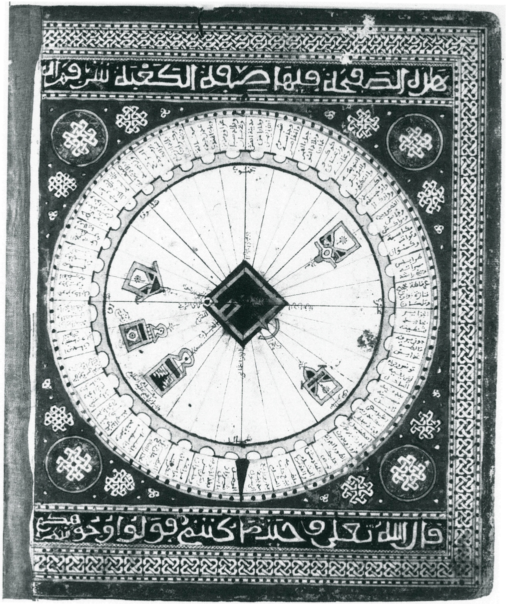
Al-Idrisi’s World Map, 1154 CE

South faces up; Mecca (al-Hijāz, “the barrier”) is in the center of the world

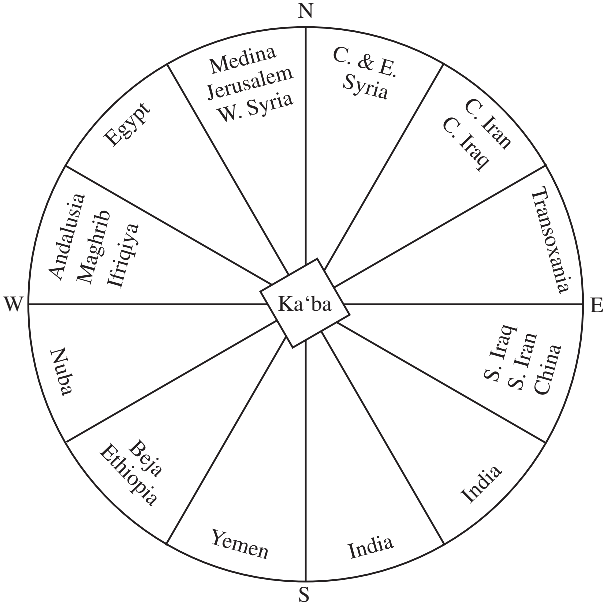
Al-Farisi's Sacred Geography, 13th century CE



Al-Sharafi's Sacred Geography, 16th century CE



Ibn Suraqa's Sacred Geography



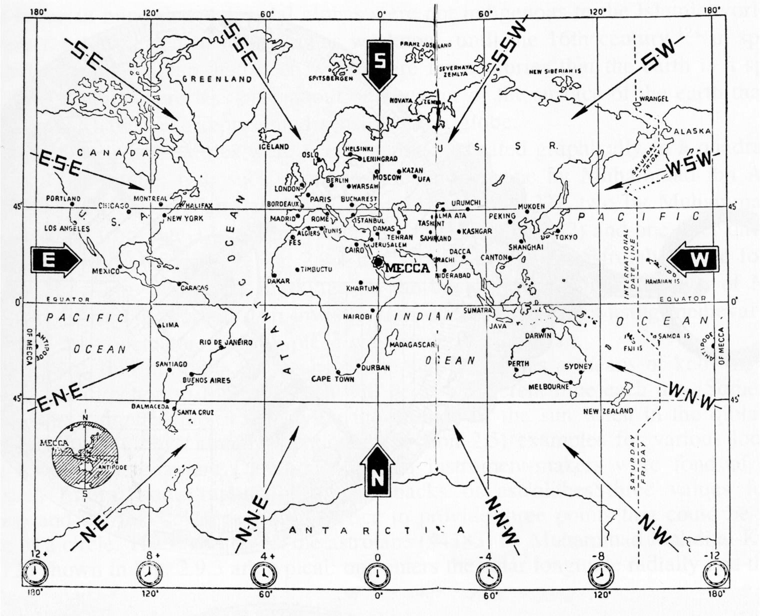
The *Qibla*

From any particular location, the direction toward Mecca, in which Muslims must pray, is called the *qibla*. Hence, mosques should also be oriented along the qibla.

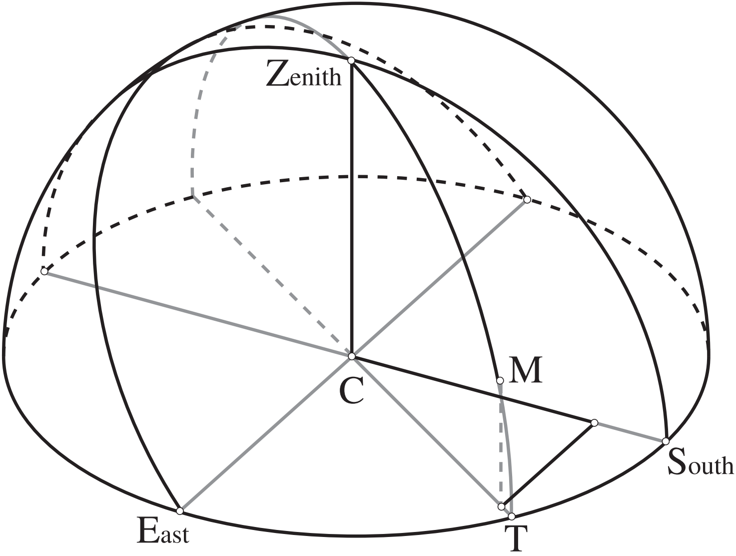
In the early period of Islam, mosques were aligned fairly roughly, according to the schema of sacred geography.

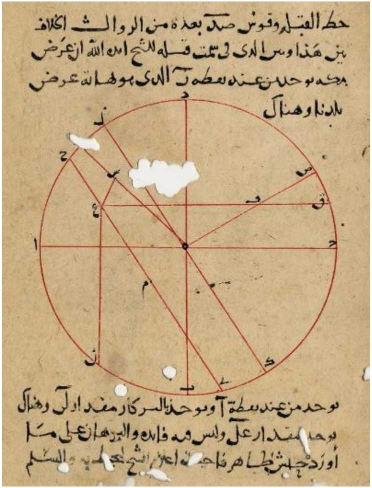
Later, mathematical astronomers realized that the problem of finding the *qibla* could be solved through exact methods – such as *analemma* methods and spherical trigonometry.

Modern Map: *Qibla* from Every Place on Earth

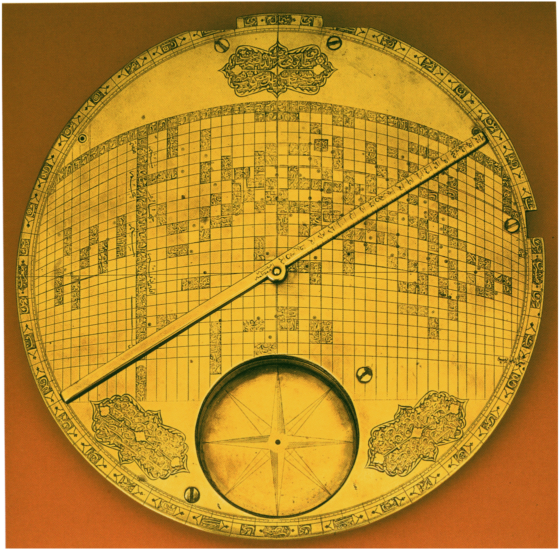


Spherical *Qibla* Figure

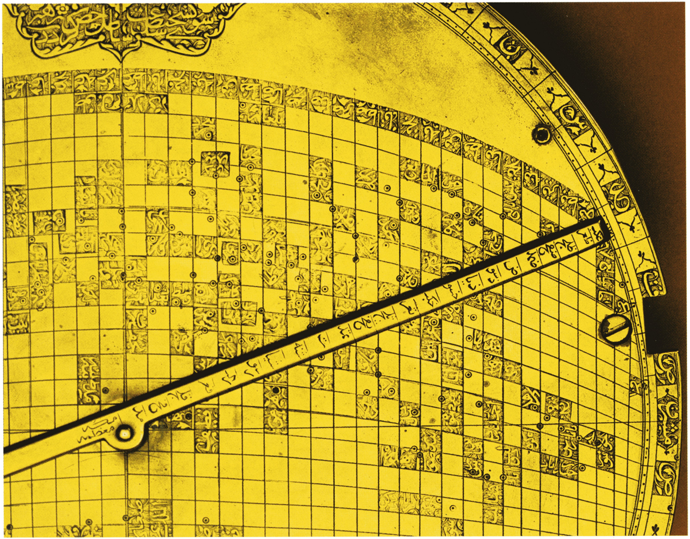




Habash’s *analemma* diagram for determining the *qibla*

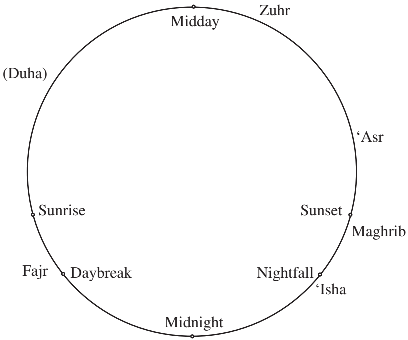


Instrument for determining the *qibla*, Iran, 16th century



Detail of the same instrument

Prayer Times



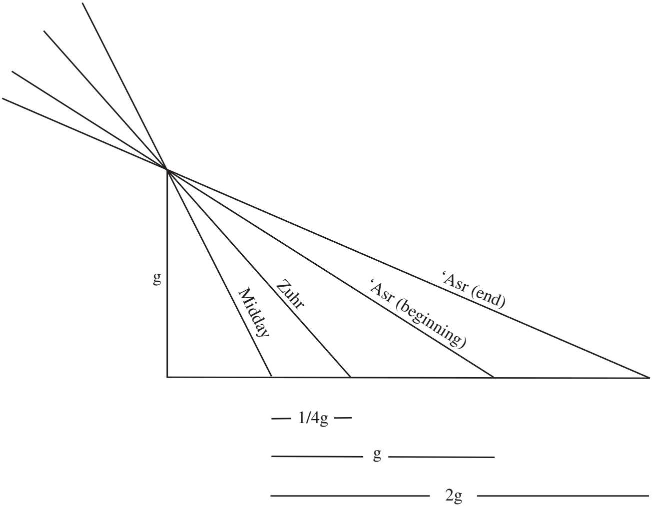
Devout Muslims are expected to pray at five appointed times.

The timing of these prayers is structured according to local, diurnal solar phenomena (dawn, daybreak, noon, etc), hence the times will vary from place to place and throughout the year.

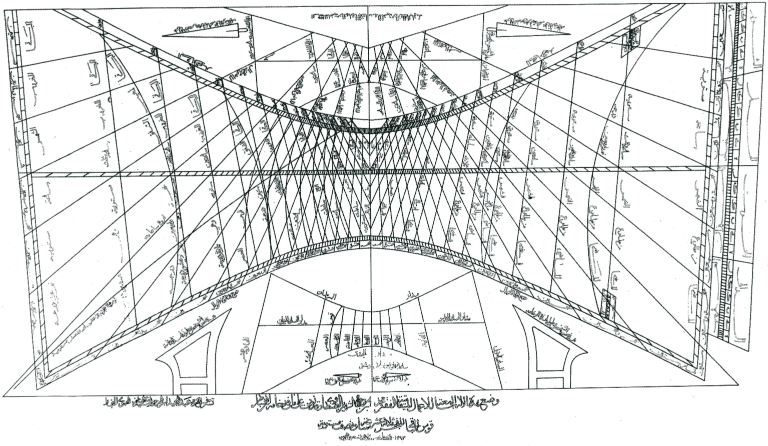
The determination of solar and horizon phenomena is a problem in the branch ancient and medieval mathematical astronomy known as spherical astronomy.

Jean-Léon Gérôme, La Prière au Caire, 1865

The Gnomonics of Prayer Times



The precise time of the prayers was determined with sundials, using the science known as gnomonics.



Ash-Shatir’s sundial on the Umayyad Mosque, Damascus, 1371.

The mosques were often adorned with elaborate sundials that indicated significant daily and yearly times, both astronomical and religious.

Theoretical Astronomy

As early as the 8th century, the Muslims rulers, and scholars working in Islamic cultures, perceived the value of the astronomy practiced by the Greeks, Indians and Persians.

They began a project of importation, criticism, synthesis and extension.

They carried out various observational programs, constructed elaborate numerical tables and formulated mathematical models that were meant to reconcile a predictive, Ptolemaic account of the phenomena with a physical, Aristotelian cosmology.

The *Zijes* (Astronomical Tables)

A *zij* is a set of astronomical and astrological tables, along with instructions for their use, and occasionally an account of their construction.

We know of over 200 zijes in Arabic, Persian, Syriac, and Turkish. (There must have once been many more, now lost.)

Observation and Instrumentation

Throughout the medieval period there were a number of state-sponsored observation programs. (9th century: al-Maʾmun in Baghdad; 13th century: the Maragheh Observatory; 15th century: Ulugh Beg's Observatory at Samarkand). Most were fairly short lived.

Observations were used to advance astronomy, astrology and geography on both the practical and theoretical levels.

We have many surviving scientific instruments from medieval Islamic cultures.

A universal astrolabe, which can be used for any latitude, 1328 CE

The front of an astrolabe, showing the movable rete for a particular latitude

Reconciling Ptolemy and Aristotle, I

A crucial goal of Islamic cosmology was to reconcile Aristotle's *physical* theories with Ptolemy's *mathematical* theories. [True theories, should cohere with one another. Unity of science, web of belief.]

A number of features of Ptolemy's models seemed to be incompatible with an Aristotelian *physical* interpretation.

- Ptolemy had introduced the *equant point* which would imply that the spheres that carried the planets would move at irregular or changing speeds.
- Ptolemy had supposed that the heavenly bodies have motions towards and away from the earth, since the earth was not in the exact center of all of their orbits.

Ibn al-Haytham (965–c. 1040 CE) published a seminal study of all the theoretical problems with the *Almagest* called *Doubts Regarding Ptolemy*.

Reconciling Ptolemy and Aristotle, II

Al-Haytham's main objections came from trying to rectify Ptolemy's *mathematical* models with a *physical* account grounded in Aristotelian physics.

For example, he pointed out that there are problems with:

- the lunar diameter vs. the lunar distance, and
- the equant as center of equable motion for points versus spheres.

Furthermore, Aristotle had claimed that celestial bodies move in circles at a constant angular speeds. Moreover, celestial bodies, being made out of *aether*, have no tendency to move toward or away from the earth.

Ptolemy's work violates both of these principles.

The Maragheh School

The Maragheh School is a modern name given to a loose grouping of astronomers centered around the observatory in Maragheh and funded by Mongol rulers, and others who were influenced by them.

They used new observations to reform astronomy, and introduced new mathematical models *to get rid of the equant*, and create a different type of geocentric astronomy.

The most important figures were al-ʿUrdi (d. 1266 CE), at-Tusi (1201–1274 CE), both at Maragheh, and Ibn ash-Shatir, in Damascus (d. 1375 CE).

The Maragheh Observatory

The observatory was funded by the Mongol ruler Hülegü Khan (1217–1265 CE) at the urging of his brother Möngke Khan, and with the advice of Nasir ad-Din at-Tusi. It lasted for about 50 years.

It housed specially designed instruments and a large research library.

The Grounds and Instruments

Starting in 1259, the observatory was built on a hill near Maragheh (south of Tabriz). The ruins are still extant.

The buildings were mostly designed by al-ʿUrdi.

- Rooms for the instruments, a mosque, a residence for Hülegü, a library, etc. (Maybe a system of tunnels.)

Al-ʿUrdi published a list of the instruments that he made for the observatory: mural quadrant, armillary sphere, azimuth rings, a parallactic ruler, etc. His son also made astronomical instruments, of which some survive.

Ruins of the Maragheh Observatory

New Mathematical Tools

The Maragheh astronomers developed new mathematical devices that would allow them to get the same basic results as Ptolemy without having to use an equant point.

Al-ʿUrdi used a rotating parallelogram to translate uniform circular motion to a distant point.

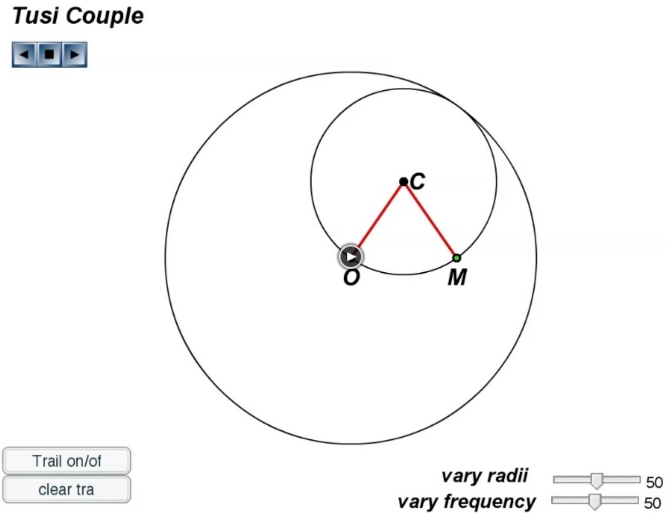
At-Tusi used two rotating circles to create rectilinear motion. [Called the Tusi couple.]

These works were largely "descriptive" – That is, they gave a mathematical account of the tools and what they could do, but not a full-fledged computational theory.

The Tusi Couple

A manuscript of at-Tusi's work in which he sets out the couple

The Tusi Couple



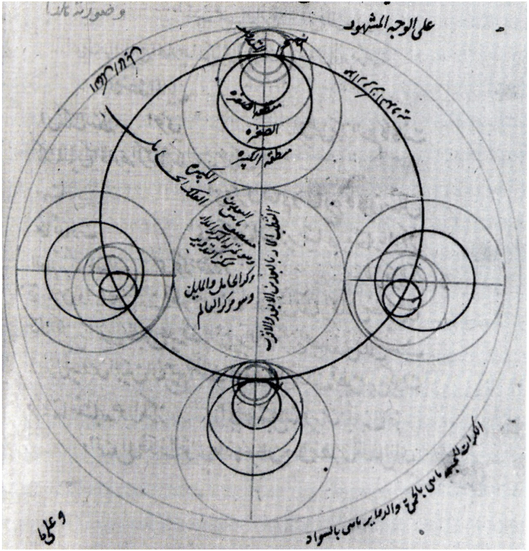
Ash-Shatir's Lunar Model

The most sophisticated "Maragheh" model was devised by a 14th-century Umayyad Mosque time-keeper (*muwaqqit*), ash-Shatir.

He used all of the mathematical tools of the Maragheh school to produce a fully predictive lunar model that was fairly accurate and made no use of the equant.

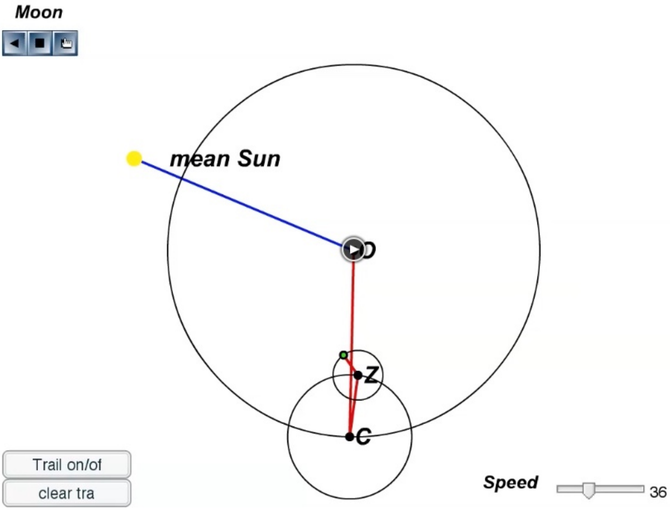
His model is geometrically equivalent to that of Copernicus.

Ash-Shatir's Lunar Model



A diagram of ash-Shatir's full lunar model, 1285 CE

As-Shatir's Model of the Moon



Realism

The Maragheh school astronomers were attempting to make a new version of Ptolemaic astronomy that would be compatible with Aristotlelian physics.

The planets could be modeled in actual spheres – that is, not just purely mathematical models.

All of the hypotheses of astronomy would be compatible with *Aristotelian physical* theory.

We can compare the Maragheh school astronomers with Ptolemy and ask ourselves where they stand with respect to realism and instrumentalism.

Overview

Islamic culture was a nexus where the scientific work of the various ancient cultures around the Middle East converged. Scholars working in the Islamic sphere translated works from Greek, Persian, Sanskrit, and so on, to produce a new synthesis.

Astronomy played a key role in Islam itself and those who worked to solve astronomical problems became interested in the mathematical sciences for their own sake.

Islamic astronomers worked to create a further development of Ptolemaic astronomy which was more fully consistent with Aristotelian physics.