Two lectures, march 1&2, 2016

Science in the Golden Age of Islam

Timeline

Birth of Prophet Mohammad in Mecca, Arabia 570 CE

Hegira to Medina, start of the Muslim calendar 622

Death of Prophet Muhammad 632

The Holy Koran put in a written form 650

The City of Baghdad founded by Al-Mansur 762

Islamic conquest of Spain 756 to early 11th

“House of Wisdom” in Baghdad 832

First Muslim Indian empire begins 1175

Mongol attack on Baghdad, end of the Golden Age of sci. 1258

In this lecture, we will look at the contributions of largely Islamic, Arabic-speaking scientists in the Golden Age of Islamic science (from around 800-1200 CE). While Islamic science covered a wide range of subjects – from mathematics to alchemy and medicine -- We will focus on the following three elements:

1. “The House of Wisdom” and the translation movement
2. Advances in astronomy
3. Al-Biruni’s travels to India. (in another lecture, later).

Before we get into these themes, it is important to know something about the origins and spread of Islam.

THE RISE OF ISLAM:

Islam began with the birth of Prophet Mohammad in the year 570 according to the Western calendar. (Islamic calendar begins with the year of Hegira, year 622, when the Prophet left Mecca for Medina along with his followers. Muslims measure their time as A.H, B.H., i.e., after and before the Heigra. ) The Koran is a record of the revelations the Prophet received from Allah and was compiled later by his followers. Its central message is the existence of one all-powerful and all-knowing God (Allah) to whom the faithful must submit. Over time, the Koran became the source of Islamic theology, law, morality, culture and science.

**The SPREAD OF ISLAM**

At the time of Mohammad, the entire Europe, North Africa and West Asia (what is also called the Middle East) was under the control of two empires: the Byzantine (which was the Eastern part of the Roman Empire) and the Persian Empire centered on Iran. (The power of the Persian empire had been smashed by the conquest of Alexander. Yet, Iran was still a major power, both politically and culturally. )

Within three years of Mohammad’s death in 632 CE, Arab armies began to expand. Within a few years they managed to take over territories which make up today’s Syria, Iraq, Iran, Jerusalem, Palestine and Egypt. Within a century, Islamic armies were making raids as far west into Spain and as far East into India. Spain was conquered around 750 CE while Islamic rule began in India in 1175 AD.

Spain under Islam, known as Al-Andalus became a center of learning. Important centers of science and scholarship emerged in cities like Cordoba and Toledo. Spain under Islam was a cosmopolitan place where Jews (who were suffering persecution in Christian lands) were welcomed and lived with Christians and Muslims.

**Causes of Islam’s spread**:

Muslims were energized by their new faith and sought to spread it both by military and cultural means. But looks like there was no planned agenda for conquest: initial success motivated them to keep on expanding.

The Muslim conquest was aided by the weakness of the Byzantine and Persian empires which were suffering from political oppression and widespread revolts. By and large, Islamic rule was benevolent and did not demand conversion to Islam from the “people of the Book”(i.e, Christians and Jews) if they paid suitable tax.

**The emergence of a new cosmopolitan intellectual culture**

Muslim rule unified broke down political barriers over a vast region, previously divided into small political units, including Spain, all of north Africa, Egypt, the Arabian peninsula, Syria, Palestine, and the former Persian empire, as far as Samarkand and Kabul. This allowed a free movement of scholars and scientists speaking different languages and coming from different philosophical/religious backgrounds: they could now acquire books, rub shoulders, trade ideas and debate with each other.

Key areas of the new Islamic empire -- Syria, Iraq, Iran, Palestine, Egypt – had been a part of Alexander’ and Roman empire for nearly a thousand years before they were conquered by Islam. Thus, they were already quite familiar with Greek sciences and philosophy. Greek sciences had already been translated into Syriac, a variant of Aramaic which was the common language of this part of the world.

**Islamic Quest for Science and Philosophy:**

Despite its beginnings in the tribal culture of a desert, Islamic culture valued philosophical and scientific knowledge: Islamic rulers patronized scholars and scientists who undertook a massive effort to first translate the available Greek sciences of the antiquity into Arabic and then to develop them further through more study, observation and even experimentation.

Three phases:

* 1. Greek science entered the world of Islam as an invited guest, and was translated into Arabic
  2. Greek ideas inspired new and original scientific achievement in many fields like mathematics, astronomy, optics and medicine.
  3. Naturalization: Integration with Islamic theology and law.

What explains this enthusiasm for science?

1. The Koran itself: the Koran encourages the faithful to seek knowledge. Koran includes many saying like the following

“he who pursues the road of knowledge, God will direct to the road of Paradise”

“the scholar’s ink is holier than the martyr’s blood.”

1. The Koran (like the Bible) teaches that the entire material universe is a sign of God’s activity, a creation by God, which God maintains, Thus, in order to understand God, it is necessary to investigate all aspects of His creation including all natural phenomena. So to investigate nature is a considered a religious duty.
2. Usefulness of science: the Greek sciences were useful for religious and secular purposes. For eg., astronomical sciences were needed to figure out the direction of Mecca. Medicine was of course useful and considered theologically neutral.

The “Golden Age” of Islamic Science:

The so-called Golden Age coincided with what is called the Abbasid caliphate/ dynasty roughly from 750-1258.

**The first Abbasid Caliph (khalifa, considered successors to the Prophet Muhmmad) by the name of Al-Mansur (754-75) founded the city of Baghdad on the river Tigris in 762 CE. His grandson, Harun al Rashid (763-809) and Rashid’s son, al-Mamun (who ruled from (786-833) are responsible for making the city of Baghdad the center of science and intellectual activity of the entire Muslim world.** They cultivated a political atmosphere that was relatively open to critical inquiry and was cosmopolitan and tolerant. **They were both enlightened caliphs who** had sympathies with a rationalist, non-literalist stream of Islam called Mu’tazil-ism. **The Mu’tazilites believe that the Koran is not eternal and can be understood by reason.**

The House of Wisdom

The House of Wisdom (Bayt-ul-Hikma in Arabic) was the library/research institute that was founded by Al-Rashid and later thrived under the rule of his son, al-Mamun. The aim of this institution was to sponsor scholars, scientists and other intellectuals interested in a fusion of Greek sciences with Islamic faith. It became a hub of intellectuals of all cultural and religious backgrounds: there were many Christian, Jews and Zorastrian scholars working in the House of Wisdom.

The House of Wisdom was really a “house for books,” a library, modeled after Persian libraries. But it was no ordinary library: it collected books from all around the world and got them translated into Arabic. The great “translation movement” started here.

The Abbasids were closely allied with Persians and the translation movement started with translating Persian and Sanskrit astrology/astronomy texts into Arabic. In the earlier period, al-Fazari, a Persian astrologer, translated Brhamagupta’s Siddhanta into Arabic: it was calld “Sindhind” in Arabic.

While this was going on, the Arabs learned the art of making paper from the Chinese: the story is that the Arab armies defeated the Chinese armies at Samarkand which is in Central Asia along the Silk Road. They took prisoners of war and these Chinese prisoners taught then how to make paper. The Arabs set up the first paper mill in Samarkand and the first paper mill in Baghadad started in late 700s. Availability of paper and newer kinds of inks gave a boost to translation.

Under al-Rashid, medical, astronomical and mathematical texts from Greek, Persian and Sanskrit were translated. It was realized that many of the Persian books were actually translated from original Greek books. So They got especially interested in Greek science and philosophy and sent many scholars/agents to Byzantine (the Greek part of the old Roman Empire) to look for greek texts which were translated into Arabic and studied by Arab/Islamic scientists and philosophers.

Hunayan ibn Ishaq (808-73) was one of the most prolific translators of this era. He was a medical man, bilingual in Greek and Arabic. Served al-Mamun as a doctor. He was sent to Byzantium to collect manuscripts. He is credited with translating:

95 of Galen’s works

15 Hippocratic works

3 of Plato’s dialogues, including the Timeus

Many works of Aristotle

Euclid’s *Elements*

Ptolemy’s Almagest (al Kitab al-Majisti, or the “Great Book”. The title Almagest is derived from the Arabic title)

By the year 1000, almost the entire corpus of Greek medicine, natural philosophy and mathematic sciences had been rendered into usable Arabic versions.

**Translation into Latin in the Christian West:**

The reports of Greco-Arabic texts in the Arab-controlled countries, especially Spain and Sicily aroused the curiosity of Christians in the Western part of Europe. This led to many expeditions into Muslim controlled parts of the world.

The Western Crusades against Muslims in Spain resulted in the fall of Toledo (Spain) in 1085, and it was from that time that the Arabic version of Greek scientific works were translated into Latin. Between 1125 to 1200, there was a flood of translations. Spain was the most important part of the contact between Christians, Muslims and Jews, many of whom were bi- or even tri-lingual, speaking Latin, Greek and Arabic.

The most important translator from Arabic to Latin was **Gerard of Cremona (1114-87).** He went looking for Ptolemy’s *Almagest*, which the Latins had heard about , but had no copy of. He went to Toledo, there he learned Arabic language and translated the *Almagest* into Latin. He did not stop there: he translated some 70 other texts from Arabic into Latin, including the basic works of Aristotle (Physics, On the Heavens and World, On Generation and Corruption, and Meterology), as well as Aristotle’s works on logic and scientific method. He also translated Euclid’s Geometry and the Algebra of the Arab mathematician, al-Khwarizmi. In addition, he translated a large number of medical texts, including many by Galen, as well as notable works by Arabic doctors and philosophers

In addition to Arabic-Latin, translations were also made between Greek and Latin texts.

**Achievements of Islamic Science:**

There is a tendency among even otherwise respectable historians to treat Islam as merely a conduit for bringing the forgotten classics of greek knowledge back to Western Europe. But that is a serious mistake, as **Islamic scientists and philosophers not only translated the ancient texts, but made significant discoveries and inventions in just about every area of science**. In this lecture we will look only at their contributions to mathematics and astronomy. Their contribution to medicine will be examined when we talk of the revolution in medicine later

**Mathematics**

a mixture of Greek and Indian systems. Earliest surviving works are by a mathematician by the name of al-Khwarizimi (780-850) who worked in the court of al-Mamun. He introduced the Indian decimal system that gradually replaced the Mesopotamian 60-based system that was first adopted by Muslims.

His other work was *Algebra*, in which he used Euclid’s geometry for solving problems which we NOW consider algebraic, e.g., quadratic equations. This book circulated widely in Europe and contributed greatly to the development of symbolic algebra. The word Algebra is derived from al-jabr, from the title of his 830 book on the subject, *Al Kitab al-mukhtasar fi hisab al-jabr* wa-l-*muquabala*. (Al-jabr means subtracting a number from both sides of an equation). It provided an exhaustive account of solving polynomial equations up to the second degree, and discussed the fundamental methods of "reduction" and "balancing", referring to the transposition of subtracted terms to the other side of an equation, that is, the cancellation of like terms on opposite sides of the equation.

This book was translated into Latin as Liber Algebra in the 12th century by none other than the great Gerard of Cremona. Thus, algebra in Europe was introduced through the work of Al-K.

His 825 book, *On the Calculation with Hindu Numbers*, is responsible for spreading the Indian system of enumeration in Europe and the Middle East.

Islamic trigonometry took its starting point from Ptolemy’s Almagest and Indian Siddhanta which introduced the sine function.

**Astronomy**

Astronomy served important religious functions in Islam: for direction toward Mecca and for the time of fasts and prayers.

Early developments: the House of Wisdom phase:

Thanks to the translation movement, scholars in Baghdad had access to a wide variety of astronomical theories and ideas. Which one was correct? Which one to believe?

Ptolemy’s Almagest was the most important of all astronomical books of that era. So al-Mamun wanted to put Ptolemy to test to see if the star tables he had calculated were correct or not. Two observatories founded by Al-Mamun where new, more accurate star-tables that record the positions of the sun, moon and the planets were created. Called zij in Arabic, these star tables were used for religious purposes.

Another “big science” project of the House of Wisdom was a fresh measurement of the circumference of the earth. Al Mamun wanted to know exactly how big was the earth and since there was some confusion about Eratosthenes’ unit of measurement (“stadia” :how long was it? ) a new test was planned.

The method was different: team of scientists were sent to the flat plains of Sinjar in Iraq, about 70 miles form the present city of Mosul. One team started walking south and the other north: they counted steps as they walked, placing markers on the ground as they walked. They stopped when they had measured a 1-degree angle of the earth’s curve based upon the position of the stars. From here they calculated the earth to be 24,500 miles in circumference.

Ibn al-Haytham (“Alhazen”) (b. 965) on Optics and Astronomy:

The first experimental physicist, enormously important work on optics and astronomy.

Al-Haytham work on optics was considered THE standard work on the subject until Newton.

HOW DO WE SEE?

“Extramission” theory of vision put forth by Euclid: radiation emanates from the eye in the form of a cone; we see when an opaque object intercepts the cone. Purely interested in mathematics of light rays.

Intromission: the object we seen emanates light which enters our eyes. But the exact image of the object enters our eyes: light from the object is emitted in a coherent manner. Rays were not supposed to proceed independently from individual points; rather the object as a whole was supposed to send a coherent image through the medium to the eyes.

Al-haytham theorized that light radiates from the object in an incoherent manner, i.e., individual parts of a luminous body give out rays of light independently of each other. These rays can be understood as cones and anaylyzed mathematically using Euclid.

Al-Haytham work on astronomy

In his *Al-Shukūk ‛alā Batlamyūs*, variously translated as *Doubts Concerning Ptolemy* or *Aporias against Ptolemy*, published at some time between 1025 and 1028, Alhazen criticized [Ptolemy](http://en.wikipedia.org/wiki/Ptolemy)'s *Almagest*, *Planetary Hypotheses*, and *Optics*, pointing out various contradictions he found in these works, particularly in astronomy. Ptolemy's *Almagest* concerned mathematical theories regarding the motion of the planets, whereas the *Hypotheses* concerned what Ptolemy thought was the actual configuration of the planets. Ptolemy himself acknowledged that his theories and configurations did not always agree with each other, arguing that this was not a problem provided it did not result in noticeable error, but Alhazen was particularly scathing in his criticism of the inherent contradictions in Ptolemy's works.[[78]](http://en.wikipedia.org/wiki/Alhazen#cite_note-Sabra_1998-79) He considered that some of the mathematical devices Ptolemy introduced into astronomy, especially the [equant](http://en.wikipedia.org/wiki/Equant), failed to satisfy the physical requirement of uniform circular motion, and noted the absurdity of relating actual physical motions to imaginary mathematical points, lines and circles:[[79]](http://en.wikipedia.org/wiki/Alhazen" \l "cite_note-80)

Ptolemy assumed an arrangement (*hay'a*) that cannot exist, and the fact that this arrangement produces in his imagination the motions that belong to the planets does not free him from the error he committed in his assumed arrangement, for the existing motions of the planets cannot be the result of an arrangement that is impossible to exist... [F]or a man to imagine a circle in the heavens, and to imagine the planet moving in it does not bring about the planet's motion.[[80]](http://en.wikipedia.org/wiki/Alhazen#cite_note-81)[[81]](http://en.wikipedia.org/wiki/Alhazen#cite_note-82)

Having pointed out the problems, Alhazen appears to have intended to resolve the contradictions he pointed out in Ptolemy in a later work. Alhazen's belief was that there was a "true configuration" of the planets which Ptolemy had failed to grasp; his intention was to complete and repair Ptolemy's system, not to replace it completely.[[78]](http://en.wikipedia.org/wiki/Alhazen#cite_note-Sabra_1998-79)

In the *Doubts Concerning Ptolemy* Alhazen set out his views on the difficulty of attaining scientific knowledge and the need to question existing authorities and theories:

Truth is sought for itself [but] the truths, [he warns] are immersed in uncertainties [and the scientific authorities (such as Ptolemy, whom he greatly respected) are] not immune from error...[[13]](http://en.wikipedia.org/wiki/Alhazen#cite_note-Sabra-14)

He held that the criticism of existing theories—which dominated this book—holds a special place in the growth of scientific knowledge.

The Maragha Revolution

the Maragha school of astronomy: later flowering in what is now north-east Iran. The grandson of Genghis Khan build an observatory there with a substantial scientific Library and staff. The prime mover of this institution was an astronomer by the name of Nasir al-Din al-Tusi ( 1201-74). He invented what is now called the **Tusi-couple** – a device that converts two uniform circular motions into back-and-forth straight line motions. This device was used by Copernicus in his own work.

The major quest of this Maragha school was to try to resolve discrepancies between the mathematical model of Almagest and the physical models of the sky. The Margha astronomers tried to find physically plausible substitutes for Ptolemy’s equant points.

The crowning glory of the Maragha circle was the work by Ibn-al-Shatir (1305-1375) from Damascus. He produced lunar and planetary models, using double epicycles, which provided a physically plausible and mathematically accurate **substitute for the Ptolemaic equant**. Mathematically identical counterparts of his model turned up two centuries later in Copernicus’ famous texts.

**Construction of observatories:**

The observatory at Maragha: . **Maragheh observatory** is an [astronomical observatory](http://en.wikipedia.org/wiki/Astronomical_observatory) which was established in [1259](http://en.wikipedia.org/wiki/1259) CE by [Nasir al-Din al-Tusi](http://en.wikipedia.org/wiki/Nasir_al-Din_al-Tusi), an [Iranian](http://en.wikipedia.org/wiki/Iranian_peoples) [scientist](http://en.wikipedia.org/wiki/Islamic_science) and [astronomer](http://en.wikipedia.org/wiki/Islamic_astronomy). Located in the heights west of [Maragheh](http://en.wikipedia.org/wiki/Maragheh), [East Azarbaijan province](http://en.wikipedia.org/wiki/East_Azarbaijan_Province), [Iran](http://en.wikipedia.org/wiki/Iran), it was once considered one of the most prestigious observatories in the world. It included a dome with an observation aperture, a library, astronomical instruments of highest quality, and a team of resident astronomers

The Samarqand observatory built in 1420 is best known for its underground sextant of 40 meters radius used for making meridian observations.

What kind of instruments were used in these observatories? There were no telescopes yet. The use of glass or lenses for observation had not yet been discovered. The observatories were structures for locating the position of stars through naked eye observation forma fixed location. The instruments used for time keeping and measurement of altitude and azimuth of the sun and other stars included sundials and cross bars.

One of the major inventions of Arab astronomers was the astrolabe, a compact device that functions like a slide-rule in solving astronomical and time-keeping problems. (see pictures in the pdf file).

Other instruments included quadrants, celestial globes an sundials. (see pictures)

**Movement of Science:**

Baghdad was the earliest center of science for. Later Cairo under the Fatimid dynasty came to rival Baghadad. Later in 11th and 12th centuries, Cordoba in Spain became the center. By the end of middle ages, the centre of gravity of mathematics and astronomy shifted eastward to Maragha and Samarkand.

**Decline of the Golden Age:**

Islamic science gradually lost steam – the scientific revolution had to wait and was accomplished in Europe, who built upon the advances made by Islamic scientists.

Why the decline?

1. Nothing equivalent of autonomous universities in Islam where natural science could be freely taught. Religious orthodoxy controlled what could be taught
2. Crusades by the Christians to take back Spain and other countries formerly a part of the Christedom
3. Mongol attacks from Central Asia.
4. Decline of free-thought.