

Lecture 3

Astronomy in Antiquity
and the Middle Ages

Outline of Lecture 3

- Spread of Greek Knowledge in the Classical World
- Scientific Contributions of India, Islam, & China
 - Unlike depiction in most textbooks, including Pasachoff & Filippenko, science did not jump directly from Greeks to Renaissance Europe
 - Middle Ages were “Dark” only in Europe
- Why did Renaissance Europe develop modern science, and not other world cultures?

Great Civilizations of Antiquity

- Mesopotamia (Babylonia – Iraq):
 - Sumerian writing – 3300 BC
 - Fall of dynasty of Hammurabi – 1600 BC
- Egypt:
 - Unification under single Pharaoh – 3000 BC
 - Defeat of Antony & Cleopatra by Octavian (Augustus) – 31 BC
- Greece:
 - Beginning of natural philosophy (Thales) – 585 BC
 - Defeat of Athens in Peloponnesian War – 404 BC
 - Death of Alexander the Great at age 32 – 323 BC
- Rome:
 - Defeat of Hannibal of Carthage at Zama – 202 BC
 - Assassination of Julius Caesar – 44 BC
 - Constantine proclaimed emperor – 306 AD
 - Fall of Roman (Western) Empire – 476 AD
- India:
 - Composition of Rig-Veda – 1500-900 BC
 - “Arabic” numbers on Rock Edicts of Ashoka – 256 BC
 - Muslim Conquest – 712-1202 AD
- China:
 - Beginning of Shang Dynasty – 1700 BC
 - Life of Confucius – 551-479 BC
 - End of Dynastic China – 1911 AD

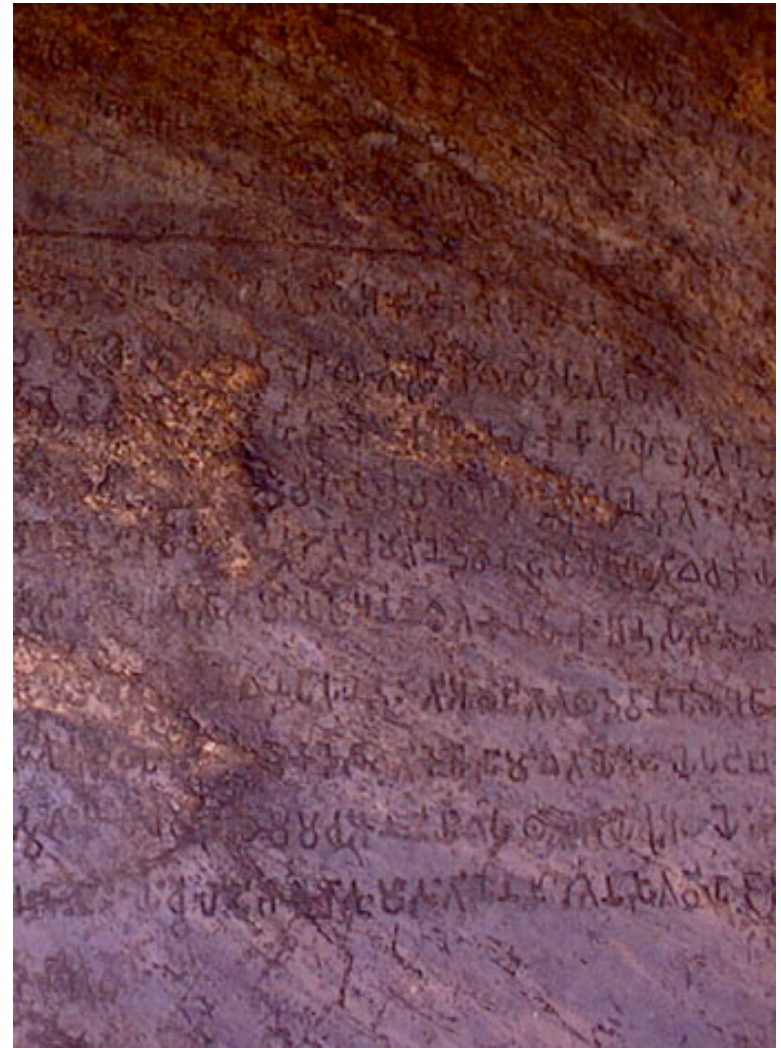
Disintegration of Greece



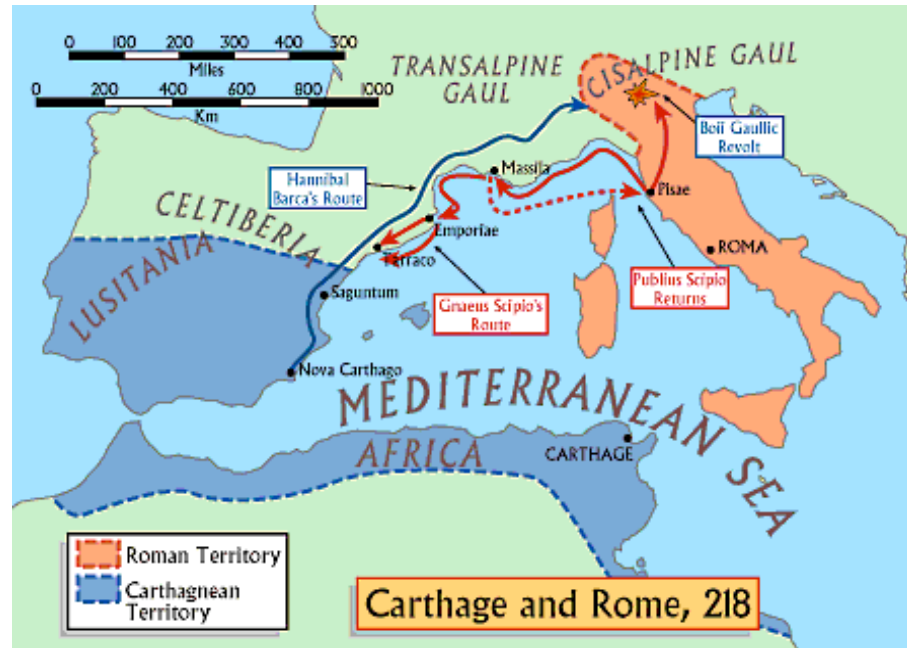
- Conquests of Alexander the Great (356-323 BC), Aristotle's pupil, carried Classical Greek knowledge to Persia, Egypt, Syria, Babylonia, Afghanistan, and India.
- After his death at age 32, the Greek Empire shattered into many pieces. (Asked to whom he left his kingdom, Alexander replied, "To the strongest.")

Indian Mathematics and Astronomy

- Inscription of “Arabic” numbers on Rock of Ashoka (256 BC):
1, 2, 3, 4, 5, 6, 7, 8, 9
(0 as a placeholder due to China’s use of counting box)
- Improved trigonometry and co-developed (with China) beginnings of algebra in form of “word problems”
- Achievements reached summit with Aryabhata (476-550):
 - $\pi \approx 31416 / 10000$ (= 3.1416, decimal point is Renaissance invention)
 - Earth a sphere that rotates on its axis once a day
 - Planetary orbits referred to Sun instead of Earth
 - Planetary orbits as ellipses rather than circles with epicycles



Punic Wars



Greek collapse followed by struggle for dominance in power vacuum by Carthage and Rome.

- Victory for Rome
- Exaltation of military values.
- Ascent of politics, law, engineering.
- Stagnation of art and science.

Rise and Fall of Roman Empire

- Degeneration with ending of Republic during rule of Augustus.
- Birth of Christ and rise of Christianity among Jews.
- Constantine crowned first Christian Emperor in 306 AD.
- Council of Nicea in 325 to debate nature of Holy Trinity and the establishment of the Roman Catholic Church.
- Split of Roman Empire into Western part centered on Rome and Eastern part centered on Constantinople (Byzantium) after death of Constantine in 337.
- Fall of Rome in 476. Europe enters “Dark Age.”
- Fall of Constantinople in 1453 to invading Turks.
- Middle Ages sandwiched by the dates 476 and 1453.



Ascent of Islam

- Classical knowledge won by the Greeks kept alive and extended in Middle East, India, and Far East (China, Japan, Korea)
- Adoption from Jews of idea of one God by Mohammed:
 - Flight from Mecca to Medina in 622
 - Rise of Islam (“to surrender”)
- Mohammedan conquest of India:
 - Beginning of conflict between Muslims and Hindus (712-1202)
 - Flowering of Islamic culture (700-1200) in mathematics, astronomy, medicine, etc.



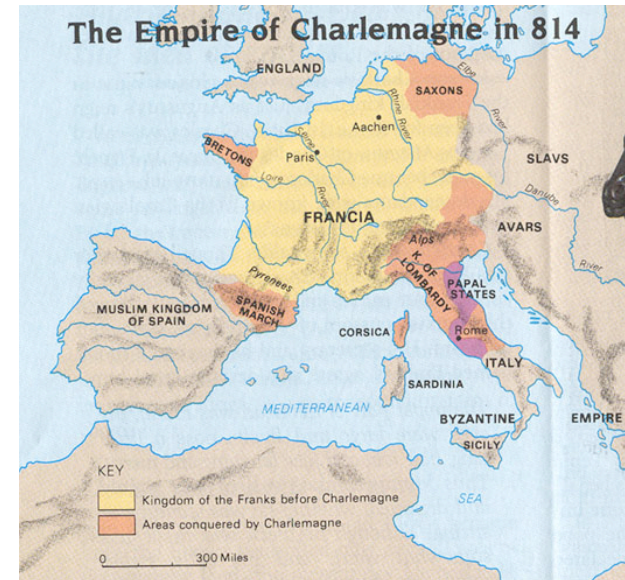
Whipple Collection

Islamic Astronomy & Mathematics

- Accurate timekeeping for religious observances.
- Ability to face Mecca from any location.
- High premium on astronomical knowledge:
 - Ptolemy's "Syntaxis" called "Almagest" in Arabic, meaning "the most majestic"
 - Islamic legacy in bright star names:
 - Vega, Altair, Deneb (summer triangle)
 - Rigel and Betelgeuse (in Orion)
 - Acherner, Adebaran, Fomalhaut, Algol
- Islamic law, poetry, symbolic algebra ("the transposition")

Middle Ages in Europe: The Age of Faith

- Descent into chaos after fall of Rome halted by Charlemagne the Great (747-814), first Emperor of what came to be called the Holy Roman Empire.
- Saint Augustine (354-430), Peter Abelard (1079-1142), William Occam (d. 1349):
 - Nature of free will
 - Relation between reason and faith
 - Still a struggle among world's great religions
- Saint Thomas Aquinas (1225?-1274):
 - Reinterpretation of Aristotle's texts in the context of Christian beliefs
 - "Proofs" of the existence of God (need for "prime mover")

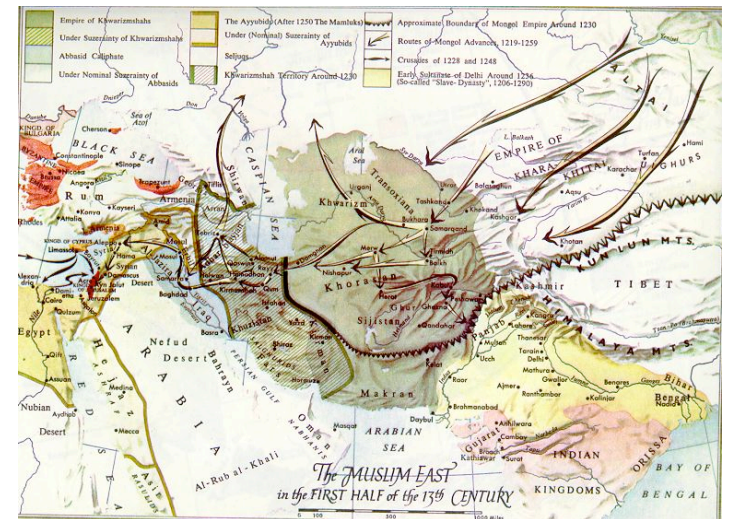


Crusades & Mongol Invasions

- Rivalry, commercial and religious, between Muslims and Christians led to armed conflict – the Crusades (four in the 11th, 12th, & 13th centuries).
- Christians unsuccessful in recovering holy city Jerusalem.
- Brought back much more valuable commodity – classical knowledge preserved and extended in Middle and Far East.
- Islamic knowledge brought back by Crusaders spurred the rebirth of European culture – the Renaissance.
- Downfall of Islam as Mongols, led by Genghis Khan and descendants, swept repeatedly in 1219-1258 through the heart of the Muslim world.
- Mixing of Islamic and Mongol cultures promoted later rise of Ottoman Empire.

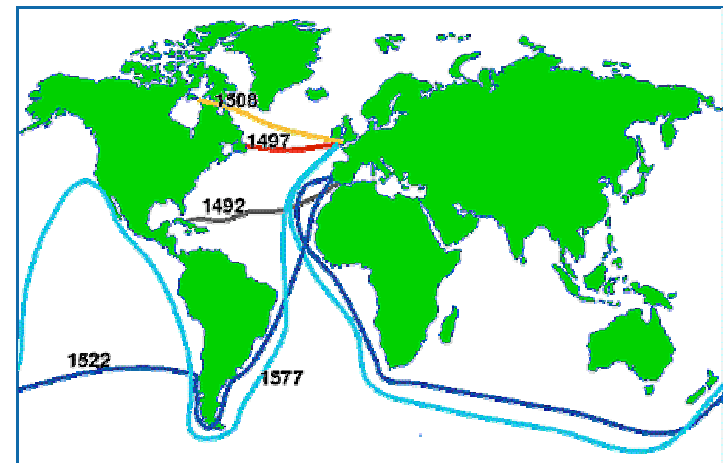


Ridley Scott: Kingdom of Heaven



European Renaissance: An Age of Exploration

- Art:
 - Michelangelo (1475-1564).
 - Raphael (1483-1520).
 - Leonardo Da Vinci (1452-1519).
- Literature:
 - Cervantes (1547-1616).
 - Shakespeare (1564-1616).
- Physical Exploration:
 - Marco Polo (1254-1324).
 - Vasco da Gama (1469-1524).
 - Columbus (1446?-1506).
 - Magellan (1480-1521).



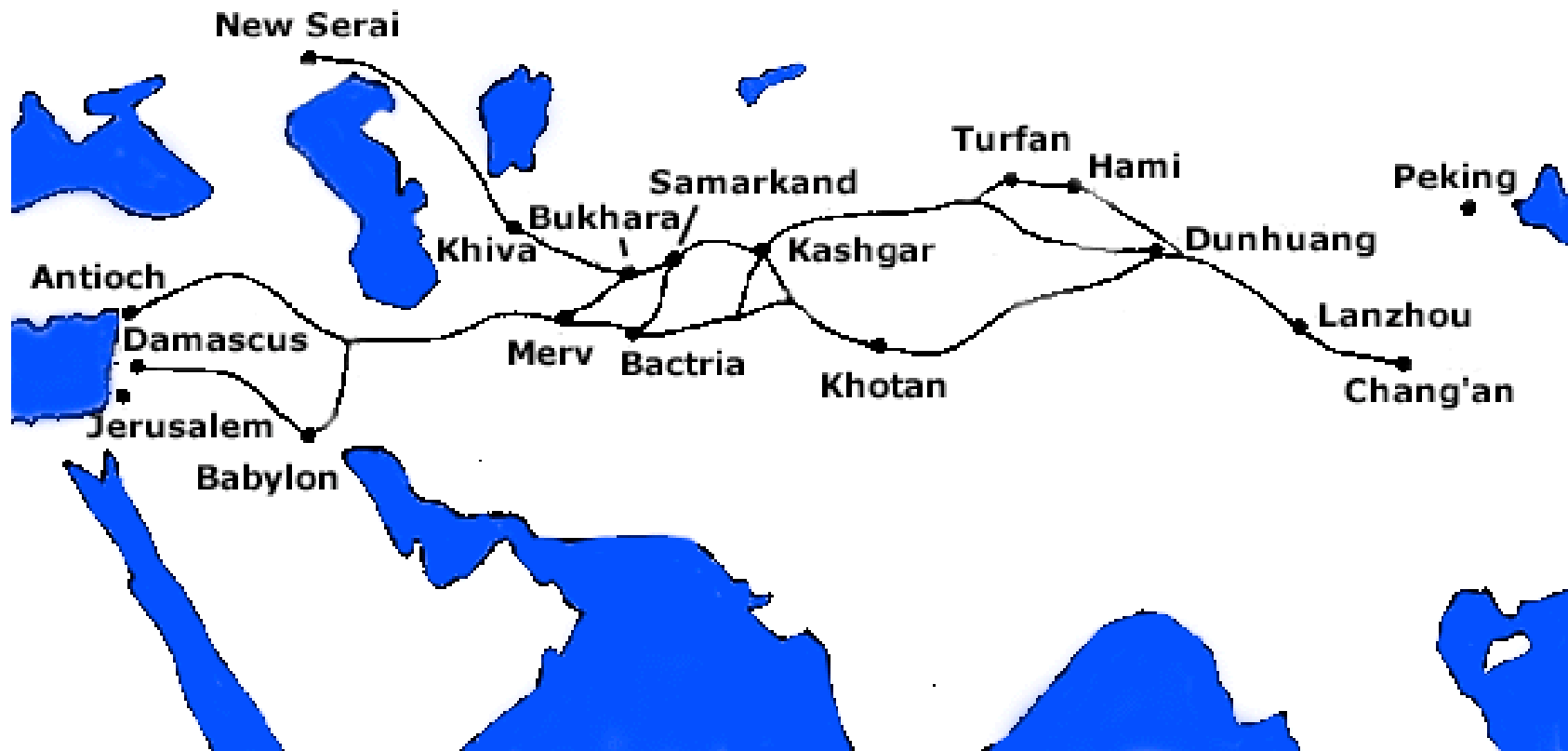
Religion Confronts Science

- Prior intellectual activity in Europe focused almost exclusively, during the Middle Ages, on religious scholarship and contemplation.
- All the great thinkers were theologians, e.g., Saint Augustine, Peter Abelard, etc.
- Reappearance of Aristotle's texts resonated with teachings of Catholic Church, especially with the writings of Saint Thomas Aquinas in the 13th century.
- Stage was set in Renaissance Europe for the Copernican Revolution (Lecture 4).



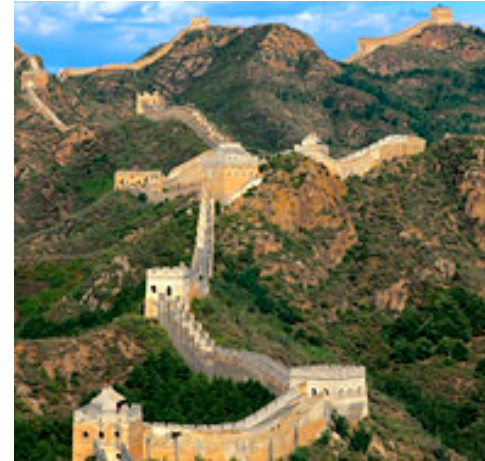
Silk Road Connecting Middle East, India, China

■ Moscow

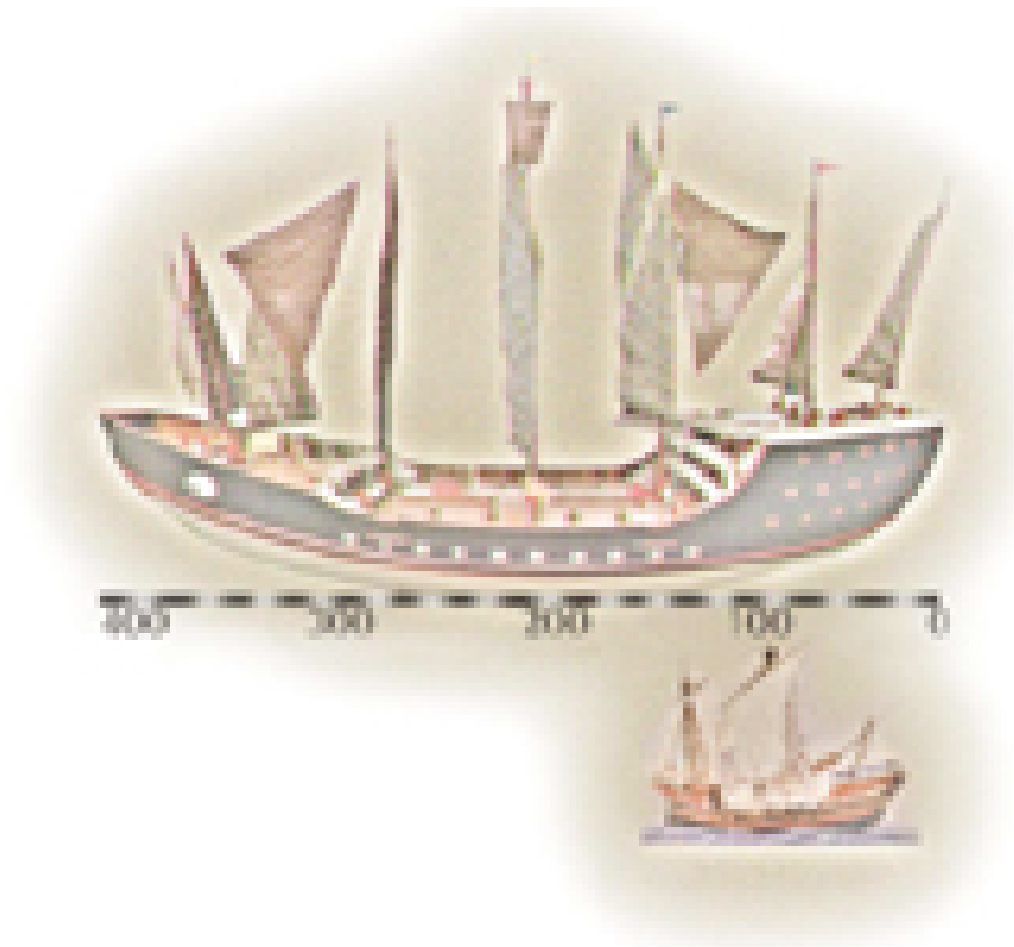


Technological Achievements of Ancient China

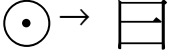
- Great Wall
- Grand Canal (Beijing to Suzhou)
- Forbidden City
- Gunpowder
- Bamboo & metal cannon (Yuan Dynasty during Mongol Rule)
- Printing blocks
- Wheelbarrow
- Magnetic compass



Comparison of Ships of Zheng He (1421) and Columbus (1492)



Missed Opportunities

- Why did China or India or Islam not develop modern science during the Middle Ages when Europe was asleep?
- No lack of good astronomers:
 - Confucius observed sunspots 20 centuries before Galileo. 
 - Guo Shoujing determined length of year (= 365.242 days) with accuracy surpassing the best Greek astronomers.
 - Asian astronomers observed many supernovae, the most famous in 1054, at a time when Europeans believed that the heavens were immutable.
 - Aryabhatta taught that the Earth was a sphere and rotated once a day on its axis at a time when Europeans had forgotten everything that the Greeks had learned.
 - Al Sufi (903-986) described the Magellanic Clouds and the Andromeda Galaxy several centuries before Westerners “discovered” them.
 - Alhazen (965-1039) described the principle behind lenses and parabolic mirrors several centuries before Galileo and Newton are credited with inventing the refracting and reflecting telescopes.
- No lack of good mathematicians:
 - Invention of modern numerals and zero.
 - Invention and development of symbolic algebra
 - Aryabhata knew π to be irrational yet advocated approximating it as $31416/10000 = 3.1416$.
 - Not afraid of approximation in lieu of exact answers, a necessary accommodation to make progress in the practical sciences.
- No lack of brave explorers:
 - Voyages of Zheng He in early fifteenth century.
 - Reached Africa and beyond in boats that could carry 3000 people.

Speculations on Causes

- China, as Rome, placed too much emphasis on the practical:
 - Little regard for theoretical approach.
 - Opposite problem of Classical Greece.
 - Greece breathed theoretical imagination and China and Rome exhaled technological experimentation.
 - Modern science cannot flourish without a proper blend of **both** theory and experimentation.
- Among civilizations earlier than Renaissance Europe, only India and Islam possessed an appropriate mix of theory and experiment, but India was thrown into chaos by the Muslim invasion. In turn, Islam, at the crossroads of East and West, was destroyed by the Mongol onslaught, before it could exploit its fledgling physical science.
- Thus, the full development of physical science had to wait until a well-fermented mixture of Western and Eastern thought reached Europe via the returning Crusaders, where it would find the perfect practitioner of the modern scientific method in the person of Galileo Galilei in Renaissance Italy.