Lecture 4.
Astronomy in the Middle Ages in Europe

4.1 Cultural context of the European Middle Ages

What are the Middle Ages?

- We're talking about the period in Europe beginning roughly from the end of the Roman Empire, ca. 450 CE.
- The end of the Middle Ages is usually defined by the beginning of the Renaissance, ca. 1450 CE.
- This began as a period of decline in almost every sense: populations fell, there was continual political and social upheaval, there was de-urbanization, little commerce, little wealth, and life became rather primitive with a constant struggle to survive.

Demography

- With the end of the Roman Empire the population declined.
- Compare populations of cities in East & West ca. 1000 CE:
  - Baghdad: 1,000,000.
  - Cordoba: >500,000.
  - Constantinople: 300,000.
  - Rome: 35,000.
  - Paris: 20,000.
  - London: 15,000.

Political & economic instability

- After the collapse of the Roman empire, the West suffered continual invasion and warfare.
- One invader after another established hegemony.
- With no political stability there was little commerce and trade.
- There was de-urbanization and a return to a patchwork of rural settlements.
- The economy became more of a hard-scrabble agricultural economy.
- There were no strong urban centers, no wealthy private or royal patrons for science and culture.

Literacy & learning

- Under these conditions there was little opportunity for education.
- Literacy declined.
- The connections with classical civilization and learning were lost.
- The barbarian invaders were generally illiterate and had no appreciation for whatever remnants of civilization they had conquered.
- Comparison of libraries East & West ca. 1000 CE:
  - In the East there were many libraries across the Islamic empire with 100,000s of volumes; more than 500,000 volumes in libraries in Baghdad & Cordova.
  - Compare the Royal Library in Paris with ~2,000 volumes.
4.2 The Role of Christianity

The Christian Church

- Perhaps the strongest cultural institution in the Middle Ages was the Church.
- What culture there was in the Middle Ages tended to be dominated by Christianity.
- The Church provided a cultural context that transcended national boundaries.
- With the rise of monasteries, beginning in the 4th C, there was an institution that could provide support for education and scholarship.

Intellectual life

- In the early Middle Ages the principal focus of any intellectual pursuit was chiefly in study of the Bible.
- Understanding and developing Christian doctrine was another area of great interest.
- As the Church matured this was extended to the writing of the Church Fathers (e.g. Augustine) and matters of church law and governance.
- It was the Church that provided the major support for education and scholarship.

Monastic schools

- Christian monasticism developed in the 4th C, and spread rapidly across Europe.
- The daily life of a monk was devoted to worship, study of the Scriptures, contemplation, & manual labor (cf. the Benedictine Rule ca. 550 CE).
- As a result monasteries developed libraries, scriptoria, and eventually schools.
- There is mixed evidence on how much secular learning was included in the monastic schools, but there were at least some places, e.g. Ireland, where secular material was part of the curriculum, e.g. mathematics and the calendar.
- Noteworthy medieval natural philosophers: Isidore of Seville (6th C) and the Venerable Bede (8th C), both of whom wrote treatises entitled On the Nature of Things.

Carolingian educational reform

- Charlemagne, ca. 800 CE, inherited a substantial empire and enlarged it further to include most of Europe—except Spain and Britain.
- He ordered that schools be established at cathedrals and monasteries throughout the empire.
- He imported teachers from abroad to help staff them.
- Taught the seven liberal arts, including astronomy.

Cathedral & public schools

- Beginning about 1000 CE Europe began a phase of political, economic, and social renewal.
- The improvements in political stability fostered a re-urbanization, growth in commerce and trade, creation of more wealth, and a rapid increase in population.
- These changes led to introduction of new schools: private, as well as monastic and cathedral schools.
- Curricula were more varied to meet a larger range of needs than the early monastic schools were.
- Plato's Timaeus was a central text, with its discussion of cosmology. (Translations of Aristotle were still not available.)
- Schools were sometimes mobile, following a particular teacher.
Rise of the universities

- Schools that grew to have a larger number of teachers seem to have evolved into universities.
- Three earliest in the 12th C were in Bologna, Paris, and Oxford.
- Typically had an undergraduate faculty in liberal arts: logic, rhetoric, & grammar, and arithmetic, astronomy, geometry, & music.
- Three graduate faculties in law, medicine, & theology.
- Size of student body typically 200-800.
- The majority of students dropped out after a year or two—or died.
- Major emphasis in all universities was use of Aristotelean methods & logic to critically examine any text or idea.

Western discovery of the Greek tradition

- With the Christian re-conquest of Spain in the Crusades in the 11th C, scholars in the West gradually became aware of the rich cultural legacy in the Islamic world.
- However, there were no texts in Latin for learning Arabic, so the best course was to go to an Arabic-speaking country.
- Another problem: medieval Latin did not have the required technical terms.
- The 12th C became a major period of translation from Arabic to Latin.
- By 1200 the West had major parts of the Greek and Islamic works available in Latin.
- It was the institutions of the Church that made this possible.

Intellectual problems

- Latin translations of the Greek and Islamic texts spread rapidly throughout European institutions.
- This flood of ancient wisdom produced enormous intellectual excitement to try to assimilate and organize it all.
- But it also raised significant challenges to the traditional Christian world view and doctrine.
- Thus reconciliation of Christianity with Greek philosophy became the major intellectual enterprise among European scholars.
- Interest condensed around several general themes.

Medieval universities

- As we have seen, a central tenet in Aristotle's philosophy is the eternity of the Universe.
- The cosmos did not have a beginning, nor can it ever have an end.
- This would seem to be absolutely inconsistent with the Biblical account of the creation in Genesis.
- N.B. here is a cosmological issue already appearing that will stay with us into the 20th C.

4.3 Reconciling Aristotle and Christian Doctrine

- Creation vs. eternal existence
  - N.B. this is a cosmological issue already appearing that will stay with us into the 20th C.
Determinism vs. free will

- In Aristotle, the elements of which everything is made (earth, water, air, & fire) have characteristic natures which determine how things of which they are made behave.
- The uniform circular motion in the heavens is an example.
- This does not seem to permit free will to make moral choices, existence of miracles, the viability of intercessory prayer, etc.

Immortality of the soul

- Aristotle argues that the soul is the full realization (in the Platonic sense) of the person.
- But since a person is also a material body, the soul cannot exist independently of the body.
- (This would be like separating the redness of a rose from the rose itself or the sharpness of an axe from the axe itself.)
- Therefore, Aristotle argued that the soul disappears when a person dies.
- This is obviously incompatible with the Christian doctrine of the immortality of the soul.

Rationalism vs. revelation

- Some argued that it is inappropriate to apply the methods of Aristotle to Christian theology.
- Theology has been revealed by God, who is the source of all wisdom, through the Scriptures, and its truth comes to us through faith.
- Aristotelean rational argument, on the other hand, cannot provide any insight into the truth that we receive through religious faith.
- Tertullian (2nd C CE) “What has Jerusalem to do with Athens, the Church with the Academy, the Christian with the heretic? ... All curiosity is at an end after Jesus, all research after the Gospel. Let us have faith, and wish for nothing more.”
- (N.B. this faith vs. reason debate has been with us for over 800

4.4 Major Thinkers and their Response to these Issues

Program of resolution

- European scholars were so in awe and enamored of Aristotle that there appears to have been no serious suggestion that such a pagan thinker should simply be ignored or repudiated.
- This may be surprising, but it is evidence of Aristotle’s overwhelming philosophical achievements.
- Instead, the aim was to reconcile Aristotle with Christian theology and doctrine, as well as to use Aristotle's methods (logic) to critically examine and refine that doctrine.

Albertus Magnus

- Albert (ca. 1200-1280) was born in Germany, and became a Dominican.
- He went to Paris to study theology eventually taught there for a few years before returning to Cologne.
- He produced the first major attempt to interpret Aristotle’s philosophy in Europe.
- He wrote commentaries on virtually all of Aristotle’s works and/or paraphrases of them.
Albert’s responses

• On the problem of the eternity of the Universe, he eventually argued that no beginning for the cosmos is philosophical nonsense.
• Regarding the soul, he argued that the soul is not the Platonic form of the body, but only functions as the form, so it does not need to disappear when we die.
• Albert dealt with the rationalism-revelation issue by saying that God normally works through natural causes, and therefore it was entirely appropriate to use Aristotle’s methods in understanding what God’s will and purpose are by investigating those natural causes.
• Albert even applied this to discussing the Biblical flood, which he saw as God using natural forces rather than divine intervention.

Thomas’s responses

• On creation of the Universe: it has always existed but is continually dependent on God's creative power to maintain its existence.
• On the soul: he agreed with Aristotle that the soul is combined with the body to produce an individual person, but Thomas argued that it is a special kind of form that exists eternally.
• Overall, Thomas effectively Christianizes Aristotle, bringing into Christian theology major ideas from Aristotle’s metaphysics and natural philosophy.
• Although Thomas had some significant clashes with Church authorities, his philosophy became official Church doctrine in due course.
• N.B. a significant part of this integration is the Aristotelean understanding of the heavens.

4.5 Medieval Astronomy

The Heavens

• The picture of nested celestial spheres was adopted, but except for the specialists doing calculations, the details with epicycles & deferents, and eccentrics and equants in Ptolemy’s formulation were ignored.
• The order of the 7 planetary spheres going outward from the Earth was: Moon, Mercury, Venus, Sun, Mars, Jupiter, & Saturn.
• Above this was the sphere of fixed stars, and then the Primum Mobile.
• To square with the Genesis account of the creation in which heaven was created on the first day and the firmament on the second day, some writers added the empyreum (where angels live), then below this the crystalline heaven (the “waters above” in Genesis), and then the firmament in which the fixed stars were placed.

Thomas Aquinas

• Thomas (ca. 1224-1274) was born in Italy into a family of minor nobility.
• He became a Dominican and went to Paris to study with Albertus Magnus.
• Thomas became the greatest of the Scholastics, whose idea was that the source of all knowledge lies in the Scriptures and in the writings of the Church Fathers. From this any new knowledge can be derived using Aristotelean logic and methods.
• His great work is the Summa Theologica, which is a synthesis of Aristotle’s philosophy with Christian theology.
The Sub-Lunar regions

• Underneath the Moon there are four concentric spheres, in the order of: fire, air, water, and earth as one gets closer to the Earth.
• Although these spheres are the natural places of these elements, they are continually being modified and mixed. For example:
  ♦ water is transformed into air in evaporation.
  ♦ air is transformed into water in rain.
• The spheres of air and fire were the sites of various meteorological phenomena such as rainbows and lightning.
• This was also the region where comets moved.

The Earth

• Everyone understood that the Earth is a sphere, and the ancient estimates of its diameter of about 15,000 km were generally accepted. (Actual diameter is about 13,000 km.)
• The globe was divided into 5 climatic zones: the arctic and antarctic, the temperate zones, and a torrid zone along the equator, which was generally thought to be so hot it was uninhabitable.
• Maps were not intended to be geometric representations with correct scale, and one of the most common world maps was a “T-O map.”
• With a “T” inside an “O” the T represented major waterways, and Asia was above the T, while Europe and Africa were in the lower left and right.

Climate & geographical maps, 1503

Does the Earth rotate?

• John Buridan (Paris, ca. 1330) noted that in astronomy only relative motion is measured and so a rotating Earth would not affect any astronomical calculations.
• Therefore he said that astronomical measurements cannot answer this question.
• However, since an arrow shot straight up returns to its starting point, rather than falling behind its starting point due to the rotation of the Earth, this proves that the Earth is not rotating.

Relative motion

• Nicole Oresme (Paris, ca. 1350) also noted that one sees only relative motion in astronomy.
• He refuted Buridan’s objection, noting that an arrow shot straight up returns to its starting point also.
• Here is a first awareness of relative motion and velocity components.
• He then went on to argue that it is also easier to rotate the Earth than all the heavens.
• He finally chose faith over reason, citing Psalm 92: “God has established the world, which shall not be moved.”

Ptolemaic theory & Aristotelean cosmology

• Translations of Ptolemy’s Almagest were available by the end of the 12th C.
• Teachers in universities soon produced their own accounts of Ptolemaic theory, e.g.:
  ♦ Johannes de Sacrobosco in mid-1200s wrote The Sphere, which was an elementary astronomy textbook.
  ♦ Theorica planetarum was another more comprehensive text with full explanation of epicycles, deferents, eccentrics, and the equant, and this was widely used.
• A number of scholars objected to the Ptolemaic constructions and the way they violated Aristotle’s principles of motion, and they tried, unsuccessfully, to find ways to harmonize Ptolemy with Aristotle.
Summary

- Astronomy in the West didn't make much progress in the Middle Ages.
- Effort was largely confined to re-learning and mastering what the Greeks up through Ptolemy's *Almagest* had accomplished.
- There was progress in making new measurements of the heavens, and obtaining better values of phenomena such as precession (the 26,000 year wobble of the Earth's axis) and calculating new astronomical tables with improved accuracy.
- There began to be some questioning of Ptolemy's use of non-Aristotelean motion in his constructions, but it did not go anywhere.

4.6. The Medieval World-View

Introduction

- The Scholastic synthesis of Aristotle with Christian theology produced an integrated conception of Man and his place in the world.
- The cosmology of Aristotle and Ptolemy was an integral part of this picture.
- The central idea was that God, in his perfection, had created a world of order.
- This order was evident in a variety of ways, both in the heavens and on Earth.
- There was a purpose for everything in the Creation.

Order in creation

- Everything in the creation had a reason for existence, and had its own proper place in the large overall scheme of things.
- This demand for order produced a beautiful and elaborate framework for understanding the relationships between all elements of the creation.
- In some cases the evidence for order was in hierarchical relationships.
- In other cases order was seen in correspondences or connections between.
- *N.B.* that sometimes the word “degree” means “order.”

Structure of the Cosmos

- A primary example of the order in the created world is the cosmos itself.
- The regular, predictable, and apparently eternal motions of the stars and planets in the heavens provide objective evidence for order in God’s creation.
- We have already discussed the structure of the heavens shown on the next slide.
- (There are 9 orders of angels to match the 9 celestial spheres, but they aren’t distinguished in this picture.)
God the Unmoved Mover

• We have seen that Aristotle conceived of a Prime Mover who made all the spheres turn in his cosmology.
• It was an obvious step for Aquinas to identify Aristotle’s Prime Mover with the Christian God.
• For Aquinas God is the Unmoved Mover; He does not move Himself because He is the end of the series of causes for any effect.

What made the planets move?

• How then is God responsible for the movement of the planets and stars?
• Aristotle said about the Unmoved Mover, “He moves as beloved.”
• In the Middle Ages this was taken to mean that the Primum Mobile is moved by its love for God.
• Each of the spheres had an Intelligence, or angel, and it is their love of God which also moves each of their spheres.
• Naturally the closer a sphere is to God, the faster it moves and the closer its motion is to perfect circular motion.

Effects in the sub-lunar world

• Each of the planetary Intelligences also influenced events in the sub-lunar world.
• Examples included the usual astronomical phenomena such as the seasons and the tides, weather, etc.
• These could also affect the reason and will of Men.
• Each planet had unique influences are shown on the next table.

Planetary influences

<table>
<thead>
<tr>
<th>Planet</th>
<th>Metal</th>
<th>Temperament</th>
<th>Association</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saturn</td>
<td>lead</td>
<td>melancholy</td>
<td>sickness &amp; old age</td>
</tr>
<tr>
<td>Jupiter</td>
<td>tin</td>
<td>“jovial,” i.e. kingly</td>
<td>prosperity</td>
</tr>
<tr>
<td>Mars</td>
<td>iron</td>
<td>warlike</td>
<td>war</td>
</tr>
<tr>
<td>Sun</td>
<td>gold</td>
<td>liberal</td>
<td>wisdom</td>
</tr>
<tr>
<td>Venus</td>
<td>copper</td>
<td>amorousness</td>
<td>beauty</td>
</tr>
<tr>
<td>Mercury</td>
<td>mercury</td>
<td>active</td>
<td>skill</td>
</tr>
<tr>
<td>Moon</td>
<td>silver</td>
<td>wandering</td>
<td>witless</td>
</tr>
</tbody>
</table>

The Great Chain of Being

• A major example of the order in creation was the hierarchy in the Great Chain of Being.
• This idea has Greek precedents in both Plato and in Homer (the golden chain let down from heaven by Zeus).
• Everything in the world was classified in a hierarchy:
  ♦ Holy
  ♦ Animal
  ♦ Vegetable
  ♦ Mineral

More detailed breakdowns

• God
• Angels
• Man
• Birds
• Fish
• Mammals
• Plants
• Rocks
• Kings
• Aristocrats
• Gentry
• Peasants
• Slaves
The Great Chain of Being

God’s creativity

- God’s creativity knew no bounds, and there were three consequences.
  - **Plenitude**: the Universe is brimming with every conceivable kind of life.
  - **Continuity**: each species along the Chain differs only infinitesimally from the adjacent ones above and below, so there is an unbroken continuity along the Chain from top to bottom.
  - **Gradation**: there is an hierarchy of increasing status going up the Chain from the lowest insect to God.

Example: Pope’s Essay on Man

Even as late as the early 18th C in Alexander Pope’s Essay on Man the principles of Plenitude, Continuity, and Gradation were taken for granted:

Vast chain of being! which from God began,
Natures aethereal, human, angel, man,
Beast, bird, fish, insect, what no eye can see,
No glass can reach; from Infinite to thee,
From thee to nothing.--On superior pow’rs
Were we to press, inferior might on ours;
Or in the full creation leave a void,
Where, one step broken, the great scale’s destroy’d;
From Nature’s chain whatever link you strike,
Tenth, or ten thousandth, breaks the chain alike.

Excellence in the Chain

- First, there was a primate or “king) within each species, e.g. the whale among fish, the eagle among birds, the lion among animals, the King among Men.
- Guess where snakes come in the Chain!
- Second, each class in the Chain had one particular feature in which it excelled. Examples:
  - Stones are lower than plants, but the exceed plants in strength and durability.
  - Man is higher than the animals, but the animals exceed man in physical strength.
  - Angels are above Man, but Man exceeds them in ability to learn (angels were thought to already have all the knowledge they were capable of holding).

Dante’s Divine Comedy

- The *Commedia* is considered perhaps the best literary example incorporating the Medieval worldview, although there are many other examples.
- Dante probably did not finish the *Commedia* long before his death in 1321.
- It is the story of a pilgrim’s journey to God, and the moral is that God will likewise bring everyone to Himself who is willing to make the journey.
- The pilgrim is taken by the poet *Virgil* (representing reason) through the *Inferno* and *Purgatorio*, but it takes *Beatrice* (Dante’s muse, representing divine revelation) to show him the way to God in the *Paradiso*.

Dante, Santa Croce, Florence
We find hierarchies in both the *Inferno* and in *Purgatory* related to the degree of sinfulness or willfulness in disobeying God’s commandments.

In the *Paradiso* Beatrice takes Dante through all the planetary spheres.

Souls are found in spheres appropriate to their lives on Earth, e.g., martyrs are in the Martian sphere, wise and just princes are in the Jovian sphere, contemplatives are in the sphere of Saturn.

N.B. that the medieval geocentric cosmology is an integral part of the whole picture.

Beatrice & Dante in the *Paradiso*. All earthly creatures obey divine laws as well as they understand them, while the 9 spheres of Heaven are ruled by the figure of Love.
Conclusion

• The Medieval world-view was a remarkably imaginative and internally consistent construction.

• This world-view quite elegantly incorporates the prevailing Christian understanding of God's relation to Man and the created world, and Man's relation to God.

• At no time before or since did people have so clear an understanding of self-identity, how they fit into the grand scheme of things, and the purpose and meaning of life.

• The geocentric cosmology of Aristotle played as central role as a paradigmatic example of the order in God's creation.