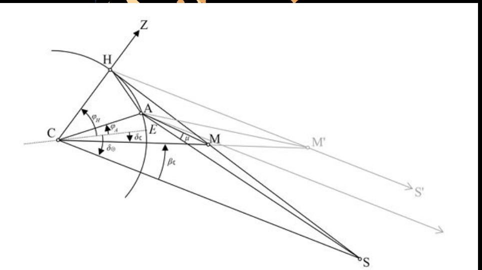
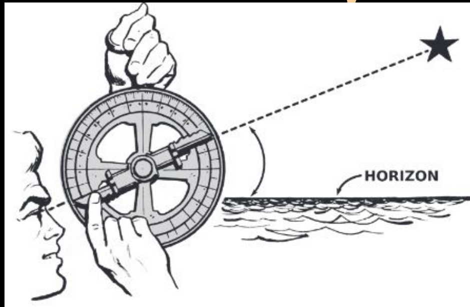
Hipparchus





Brief video on hipparchus

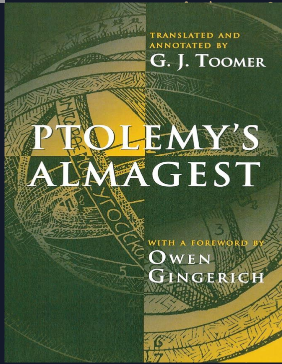
Timeline Section

Where does he place?

1. Places after Plato and Aristotle
2. Before Ptolemy, The Almagest
3. l. c. 190 - c. 120 BCE
4. The greatest astronomer of his time. (Mark, 2024)
5. Known to have drawn on Mesopotamian and Egyptian astronomical works

Figure 1: A picture of Hipparchus (Robertson)

Figure 2: Ptolemy's almagest, which tells us about hipparchus contributions.



Where does he place? (detailed)

1. Hipparchus of Nicea (l. c. 190 - c. 120 BCE) was a Greek astronomer, geographer, and mathematician regarded as the greatest astronomer of antiquity and one of the greatest of all time.

2. Hipparchus drew on the work of earlier Greek thinkers such as the Pre-Socratic Philosophers, Aristarchus of Samos (l. c. 310 - c. 230 BCE), Eratosthenes (l. 276-195 BCE), and Archimedes of Syracuse (l. c. 287-212 BCE) as well as from Babylonian and Egyptian sources. (Mark, 2024)

3. Ptolemy used a lot of Hipparchus' work in his book, The *Almagest,* which became the standard astronomical text for almost 2,000 years.

4. Hipparchus' methodology & conclusions gave rise to his reputation as the greatest astronomer of his time.

Personal Life

Personal Life

- **Hipparchus** (born, Nicaea, Bithynia [now Iznik, Turkey]
- Born around 190 BC
- Greek Astronomer and Mathematician
- Compiled records of local weather patterns.
- Most of Hipparchus's adult life, spent carrying out a program of astronomical observation and research on the island of Rhodes.
- Also wrote critical commentaries on some of his predecessors and contemporaries.
- Very little is known about his life, and only one of his many writings is still in existence.
- Died around 120 BC in Rhodes? No one is certain since no records were kept.

Personal Life (detailed)

1. **Hipparchus** was born around 190 BC in Nicaea, Bithynia, 190 BC, now Iznik in Turkey

2. As a young man in Bithynia, Hipparchus compiled records of local weather patterns throughout the year.

3. Most of Hipparchus's adult life, however, seems to have been spent carrying out a program of astronomical observation and research on the island of Rhodes.

4. Ptolemy cites more than 20 observations made there by Hipparchus on specific dates from 147 to 127, as well as three earlier observations from 162 to 158 that may be attributed to him.

5. Very little of Hipparchus's original work has survived. We know about some of his most important observations and discoveries, because other ancient scholars commented on them or used them in their own work.

6. Nicea seems to have been proud of Hipparchus, placing his image on coins between 138 and 253 AD.

7. Assumed to have died around 120 BC in Rhodes.

Major Contributions

Eclipses

- Calculated the moon's distance between 71-83 earth radii using a **solar eclipse**.
- Calculated that solar eclipses can occur **within 30 days** of each other but visible to **different nations**.
- The calculations must have been made using early **Spherical Trigonometry** or **planar approximations**.

Figure 3: 2024 Total Eclipse. (NASA, 2024)

Moon Distance Calculation

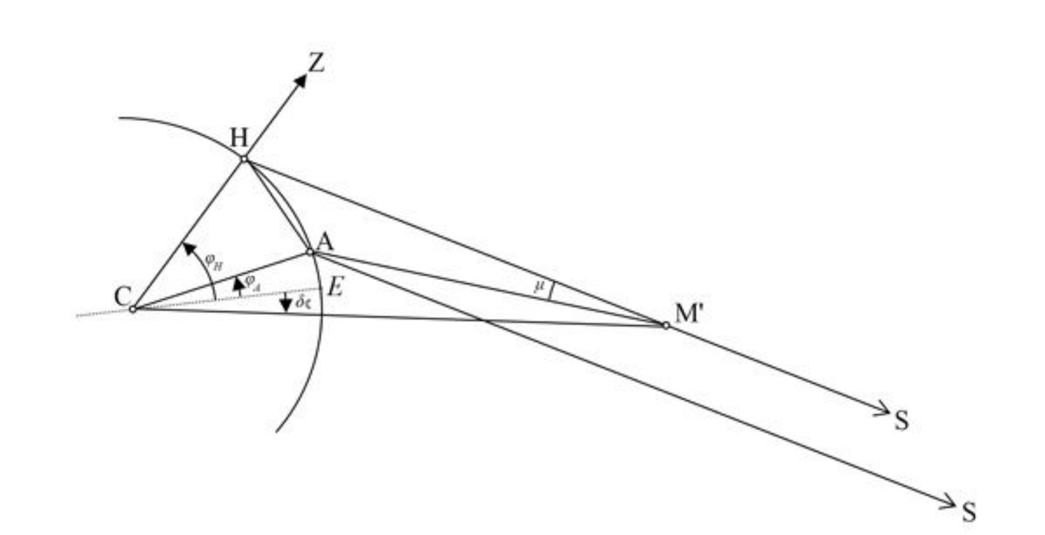
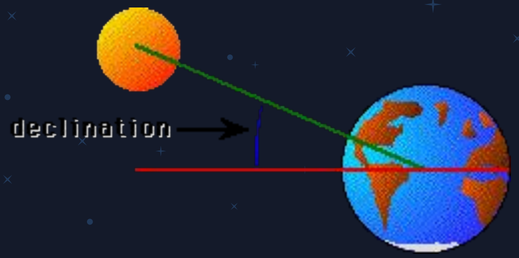


Figure 4: Hipparchus's method for calculating the moon distance using a solar eclipse. (Carman)

Moon Distance Calculation



Figure?: Solar Declination. Retrieved from https://www.susdesign.com/popups/sunangle/declination.php

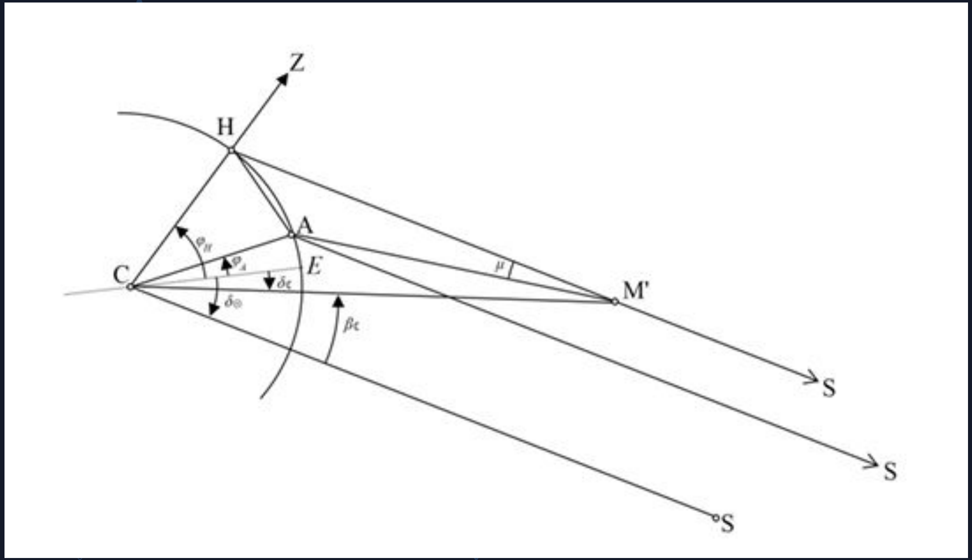


Figure 5: Hipparchus's method for calculating the moon distance using a solar eclipse. Now with solar declination and lunar latitude. (Carman)

Moon Distance Calculation

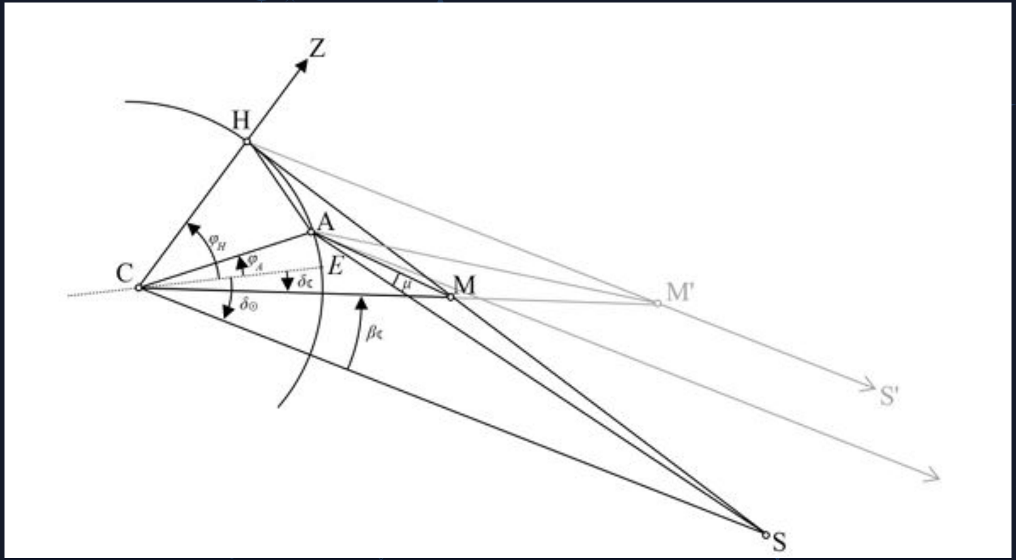


Figure 6: Hipparchus's method for calculating the moon distance using a solar eclipse. Now without assuming the sun is at an infinite distance. (Carman)

Eclipses (Detailed)

- Hipparchus was able to calculate the moon's distance from earth in radii using a solar eclipse where he reached the result that the distance varies between 71 and 83 earth radii (Mozaffari, 2024). Hipparcchus could use the region he lived in (where the eclipse occurred) and another location where the solar eclipse was only partially occurring to draw a triangle formed by the two locations and the moon.

- Discovered that an eclipse of the sun can happen twice in 30 days but the eclipses would be visible to different nations in even different hemispheres (Pliny the Elder, n.d., II.X). It can be assumed that this was a calculated discovery as opposed to observation as the southern hemisphere was not accessible to Hipparchus.

- Calculating solar eclipses to the highest degree of accuracy would require spherical trigonometry. It is a contested fact that Hipparchus would have had knowledge of it at the time. Therefore he would likely have used planar approximation which is a mathematical simplification where curved surfaces are approximated as flat, two-dimensional, to simplify calculations.

Mapping the Motion of the Sun

Hipparchus believed in the **geocentric model**.

His observations and calculations of the motion of the sun were quite accurate but he had **incorrect theory**.

Developed an earlier version of Ptolemy’s model of the solar system. Including **epicycles** on the **deferent** and Earth off center of the Deferent.

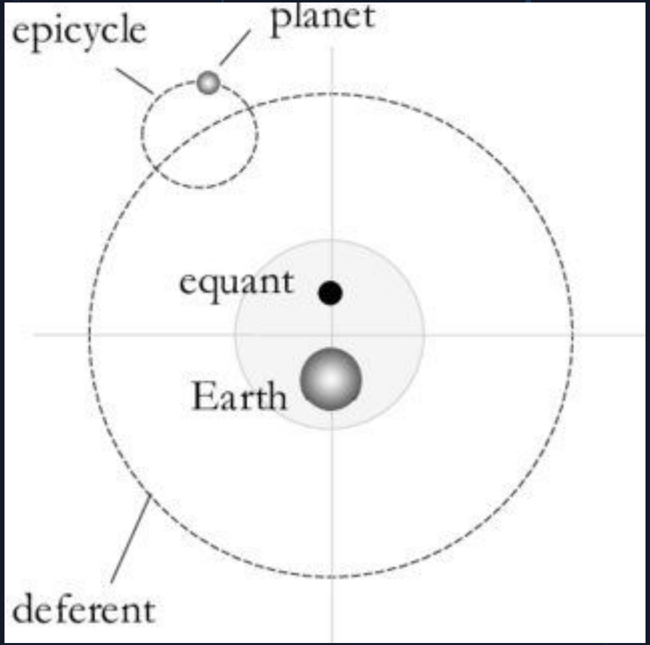


Figure 7: Structure of the epicyclic system. (Suntola, 2018)

Mapping the Motion of the Sun (Detailed)

- Hipparchus believed in the geocentric model and therefore made efforts to figure out the orbit of the sun around Earth.
- The observations and calculations done by Hipparchus were incorrect independent to errors in recorded data. The flaws in his solar hypothesis stemmed from the limitations of his theory, which was, of course, incorrect. Thus, for 1800 years between Hipparchus and Kepler the error of Hipparchus' model was not his math or observations, but his baseline theory (Maeyama, 1998).
- Using his observations Hipparchus determined a hypothetical orbit for the sun around the earth which included a deferent and epicycle just as Ptolemy's did which we went over in class. Ptolemy's model was much more refined than Hipparchus'

Discovery of Axial Precession

Hipparchus realized his measurements were **consistently inconsistent** with previous measurements. What changed?

Figured out that it must be the **observing platform** (Earth) moving.

Axial Precession occurs when the gravitational forces of the Sun and Moon act on Earth's **equatorial bulge**.

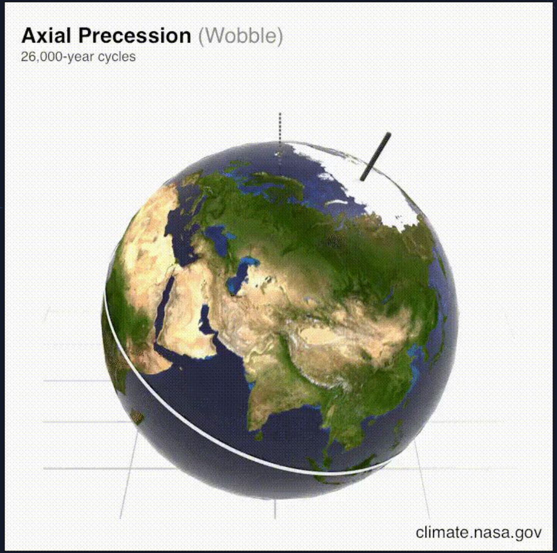


Figure 8: What axial precession looks like over 26000 years (NASA, 2020).

Discovery of Axial Precession (Detailed)

- What is Axial Precession? It is the movement of the rotational axis of an astronomical body, whereby the axis slowly traces out a cone. It was found when Hipparchus noticed that the positions of the stars shifted in a systematic way from earlier measures. There was an indication that it was not the stars moving, but rather the observing platform which in this case was earth (Encyclopædia Britannica)

- Axial Precession occurs because of the gravitational influence that the Sun and Moon have acting on the Earth's equatorial bulge. That is, the diameter of Earth at the equator is 43 km than its polar diameter and therefore “Earth is not a perfect square but an oblate spheroid” (LONGAIR, 2021).

- When Hipparchus compared his measurements with older measurements he found a consistent difference between them. This led him to believe that there must be something moving to cause this inconsistency. The length of axial precession he determined was close to the actual time it takes for a cycle of axial precession.

World's First Star Catalogue

- Hipparchus is credited with the creation of a large catalogue of **hundreds of stars** (Schaefer, 2005).

- His catalogue **did not survive** into the modern day but there is evidence to support that Ptolemy's star catalogue in *Almagest* is at the very least largely based off Hipparchus' findings, if not **copied** (Thurston, 2002).

- Hipparchus loved to be "**approximate**" (Maeyama, 1984).

- Before this discover some scholars argued that his catalogue did not exist. Others like **Tycho Brahe** were convinced that Ptolemy had **stolen** Hipparchus' data and flaunted it as his own.

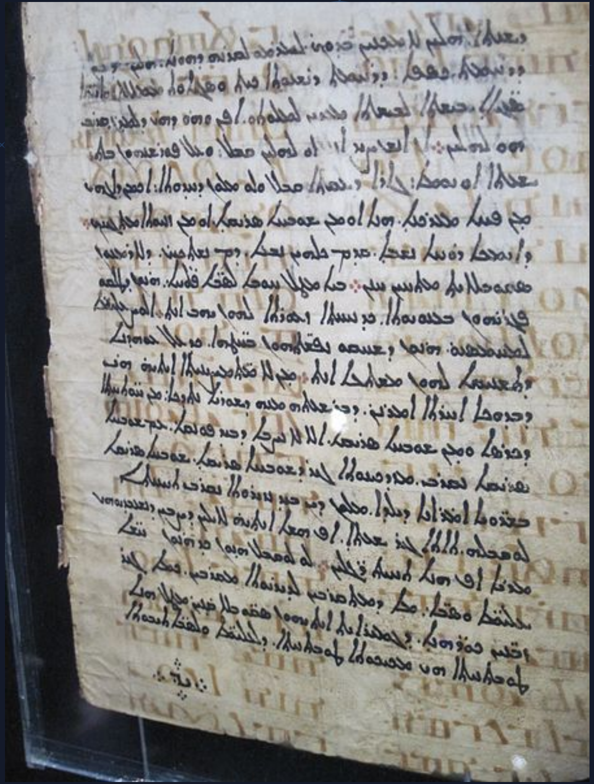


Figure 9: A leaf from the Codex Climaci Rescriptus. The manuscript contains a partial rediscovery of some of Hipparchus' catalogue (Wikimedia Commons Contributors)

World's First Star Catalogue (Detailed)

- Hipparchus is credited with the creation of the first large star catalogue that contained at least hundreds of stars (Schaefer, 2005).

- Ptolemy's *Almagest* from 128 AD, which contained his own large catalogue of stars, shared many similarities with the findings of Hipparchus while simultaneously being very different from other ancient sources. Therefore it is believed that Ptolemy's star catalogue was closely related to the now lost Hipparchus star catalogue (Schaefer, 2005).

- In addition, Ptolemy's catalogue "contains no stars that rise less than 5° above the horizon at Alexandria". This wouldn't make sense if the observations were done from Alexandria where Ptolemy worked. This meant that the observations must have happened farther north. Conveniently, Hipparchus worked from the island of Rhodes, about 5° north of Alexandria (Thurston, 2002).

- Ptolemy's description of how he used the astrolabe is also impossible in actual use leading to the conclusion that he likely did not know how to use it (Thurston, 2002). This is just another piece of evidence that points to the star catalogue in *Almagest* being a copy, or largely a copy of Hipparchus' star catalogue.

- There is no clear answer on how closely related the two catalogues are and it is a debated subject among scholars.

- Hipparchus's observations were decent as best as a coordinate system for the heavens was not firmly established and the system he used was not completely accurate. He supposedly threw around the word "approximate" arbitrarily without ever applying a specific meaning to the word. His observations were compared to his successors, but were done at a time before astronomical observations were firmly established (Maeyama, 1984).

- Parts of Hipparchus' catalogue were rediscovered in 2022 the *Codex Climaci Rescriptus*.

- Before this discover some scholars argued that his catalogue did not exist. Others like Tycho Brahe were convinced that Ptolemy had stolen Hipparchus' data and flaunted it as his own (Marchant, 2022).

-

Tools & Instruments

Astrolabe

1. Tool was credited to Hipparchus in Ptolemy's *The Almagest*

2. Ancient tool used for **measuring angles in the sky** and to **tell time during the night** based on position of celestial bodies

3. Constructed from a wheel, a movable pointer with sights for aiming on each end of it

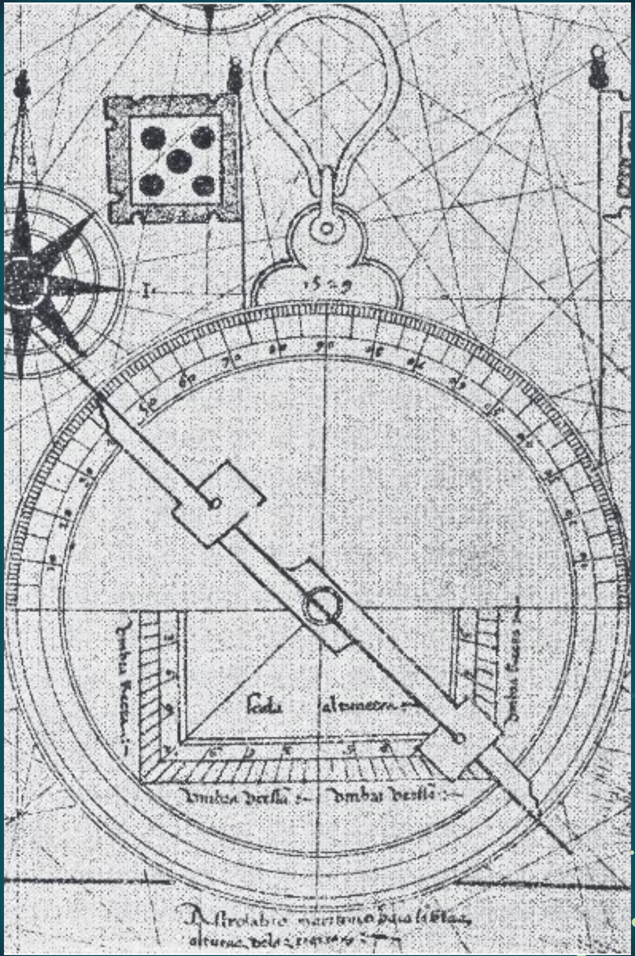


Figure 10: Drawings of an early version of the astrolabe. Hipparchus most likely used one similar to this design (Kardasz. 2023, p.214)

Astrolabe

- Tool was hung or held such that it was **level with the ground**
- Dial adjusted to get the **angle of the stars relative to the horizon**
- Two People required to operate
- Inspired the creation of the **Armillary Sphere** later used by Ptolemy

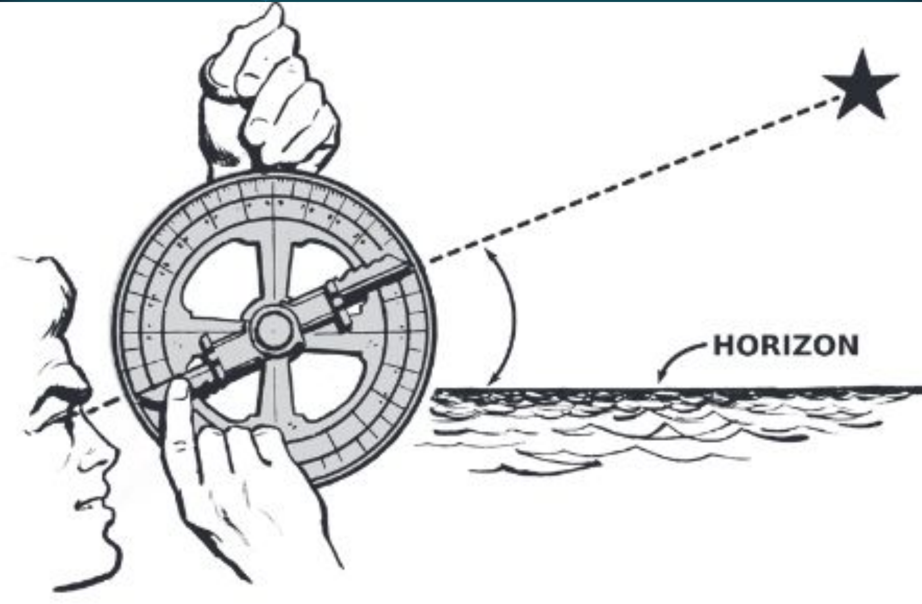


Figure 11: This image shows how the astrolabe was used to look at celestial bodies(Kardasz. 2023, p.213)

Astrolabe(Detailed)

1. The astrolabe was first said to be used by Hipparchus during the age of Ancient Greece.

2. It is a tool used for measuring the position of objects such as stars and planets with respect to the horizon. He used this tool to create the first attempt at a complete star catalogue.

3. The tool is used by hanging or holding the instrument level with the ground and having the first person look through the sight at the object in the sky and align the pointer with where it appears. The second person notes down the angle that the pointer is positioned at.

4. The Hipparchus' Astrolabes were most likely made from a wooden or brass wheel

5. The astrolabe was the stepping stone for developing the Armillary Sphere, a spherical tool used for observing the positions of celestial objects more accurately as it was a 3d model made with multiple rings. Hipparchus' astrolabe has been

Gnomon

1. Basic tool that **tracked the shadow** that occurred when the sun hit a vertical pillar

2. Measured **time of day** as well as **time of year**

3. **Length** and **angle** of the shadow were recorded

4. Allowed Hipparchus to determine and predict **solstices and equinoxes**

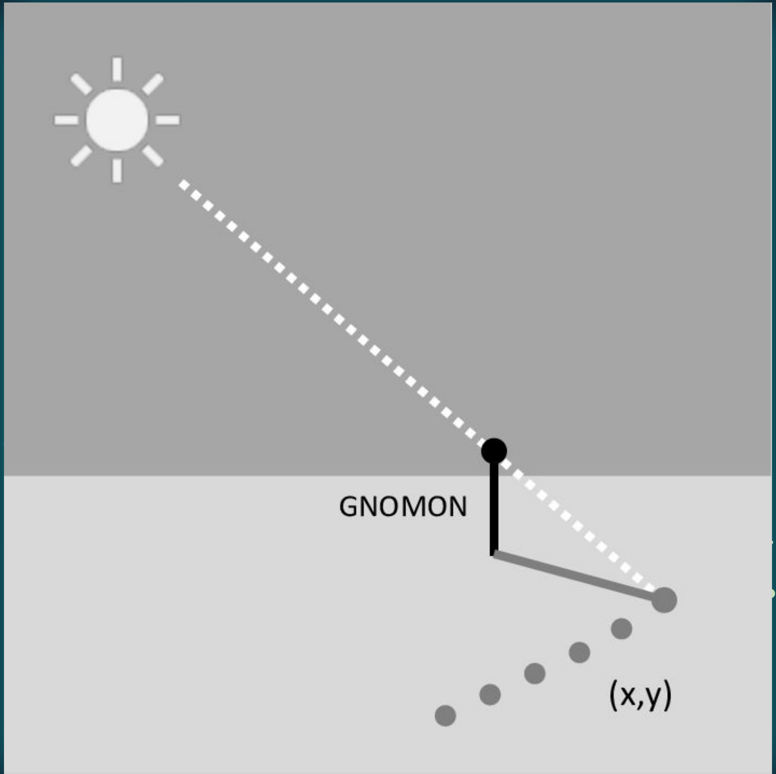


Figure 12: Diagram of gnomon functionality (Carlotto 2021)

Gnomon(Detailed)

1. The Gnomon is a tool very similar to a sundial.

2. It is simply a pillar placed vertically in the ground whose shadow is recorded and measured throughout different times of the day and different times of the year

3. This shadow is used to determine the time of day as well as predicting the dates of solstices and equinoxes.

4. Hipparchus was very thorough with his observations and made consistent notes of the information the shadow produced. Ptolemy later created a meaning and organization to the observations made by his predecessor

5. Hipparchus is called the father of trigonometry due to the mathematics he used with the results of the shadows position.

6. For information on the Gnomon, the sources cited in the references page from Carlotto (2021) and Martínek(2023) were used.

Dioptra

- Optical tool used for measuring **angles and altitudes**
- It was a rod with a sight at both ends, or a sighting tube, that could be attached to a **stand**
- Worked similarly to the **astrolabe**
- Hipparchus used this tool for his **star catalogue**

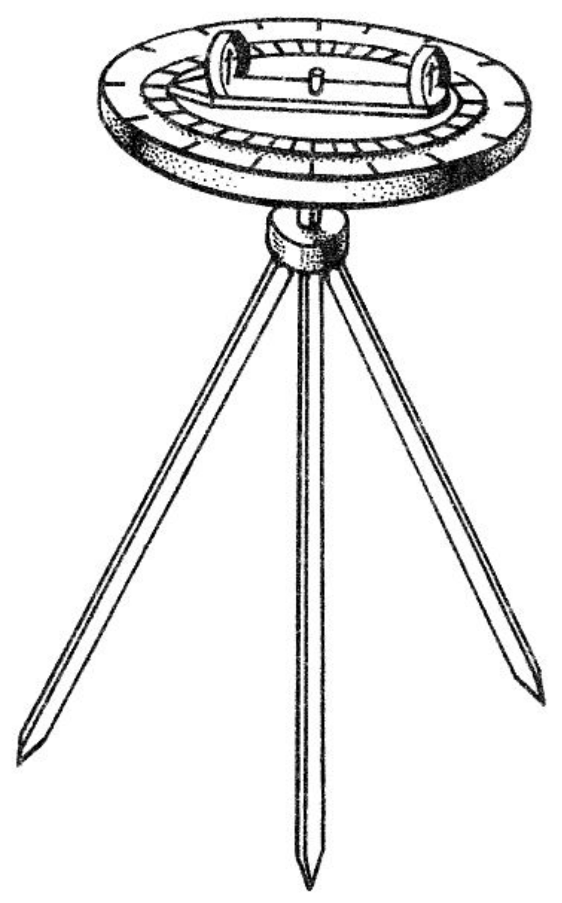


Figure 13: Drawing of a classic Dioptra Ancient Rome. (1989)

Dioptra(Detailed)

1. The Dioptra was another optical tool used for measuring the position of celestial objects in the sky
2. The Dioptra was a fixed instrument with dials and a protractor attached to a stand.
3. Worked similarly to the astrolabe except it had a fixed stand and didnt require a second person for noting the angles
4. For information on the Dioptra, the sources cited in the references page from Bennet(2023) and de Jong(2021) were used.

Armillary Sphere

- Ancient Greek tool used for creating a 3D mapping of the sky
- Along with the Dioptra, was used to complete Hipparchus' star catalogue at a precision of one degree off from their modern values
- While an earlier version of the armillary sphere may have been invented by Eratosthenes, Hipparchus reformed it

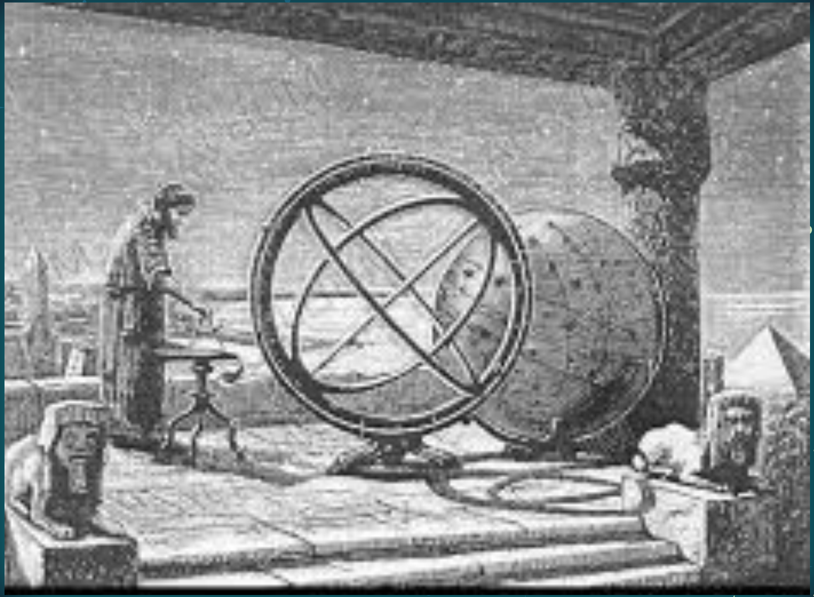


Figure 14: Drawing depicting Hipparchus in his observatory

Armillary Sphere

- Tool was made up of rings, a gnomon and an adjustable frame
- These separate components could all be adjusted and rotated
- Rings could be rotated to align with positions of celestial bodies
- Measured angles and tracked movement of stars and planets

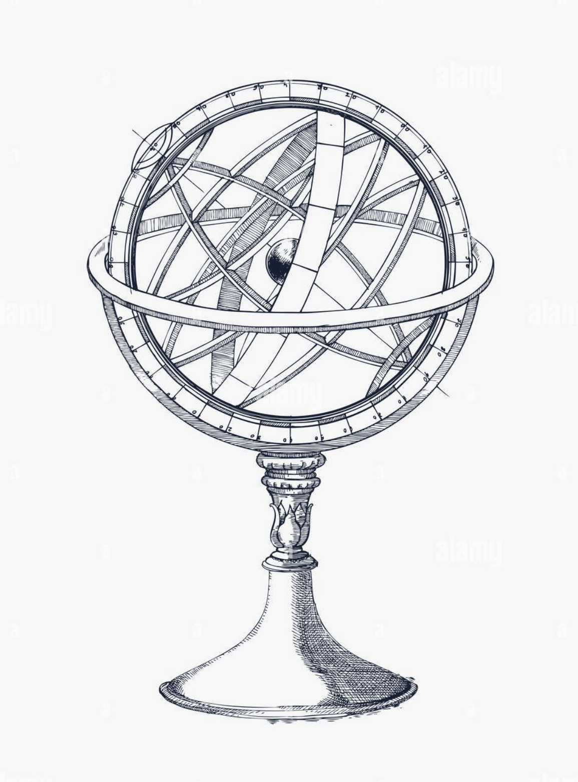


Figure 15: Drawing of a classic armillary sphere

Astrolabe(Detailed)

- Ancient Greek tool used for creating a 3D mapping of the sky
- Along with the Dioptra, was used to complete Hipparchus’ star catalogue at a precision of one degree off from their modern values
- While an earlier version of the armillary sphere may have been invented by Eratosthenes, Hipparchus reformed it
- Tool was made up of rings, a gnomon and an adjustable frame
- These separate components could all be adjusted and rotated
- Rings could be rotated to align with positions of celestial bodies
- Measured angles and tracked movement of stars and planets
- National Geographic source (13) was used for information on the astrolabe and its integration by Hipparchus

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