Sunset Astronomical Society

The Sunset *Gazette*

Serving the Tri-Cities since 1975

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Meeting information

Meetings are generally in the theater in the Delta College Planetarium in Bay City. The meetings will usually be on the 2nd Friday of each month at 7:00 PM. Watch the newsletter for changes in dates and times. Membership is not required to participate in meetings and activities. See last Page for this month's meeting site.

Membership Information

Our club has switched to e-mailing our newsletters. For those wishing to receive a hard copy mailed an additional dues of $10.00 per year is required.

Student / Senior: (17 years & younger, 65+ years)

1 year - $15 (mailed Newsletter add $10)

2 year - $20 (mailed Newsletter add $10)

Regular: (18+ years)

1 year - $20 (mailed Newsletter add $10)

2 year - $30 (mailed Newsletter add $10)

Family:

1 year - $25 (mailed Newsletter add $10)

2 year - $40 (mailed Newsletter inclusive)

Membership includes voting privileges, the newsletter and free admission into Delta College Planetarium shows.

Treasurer's address for renewals and subscriptions:

Tom Smith, 3423 Hidden Road,

Bay City, MI 48706-1243

Subscription Information

Subscription prices for "Sky and Telescope" Magazine or "Astronomy" Magazine are available at club rate with the purchase of individual or family membership. For prices please refer to the treasurer or the club's website:

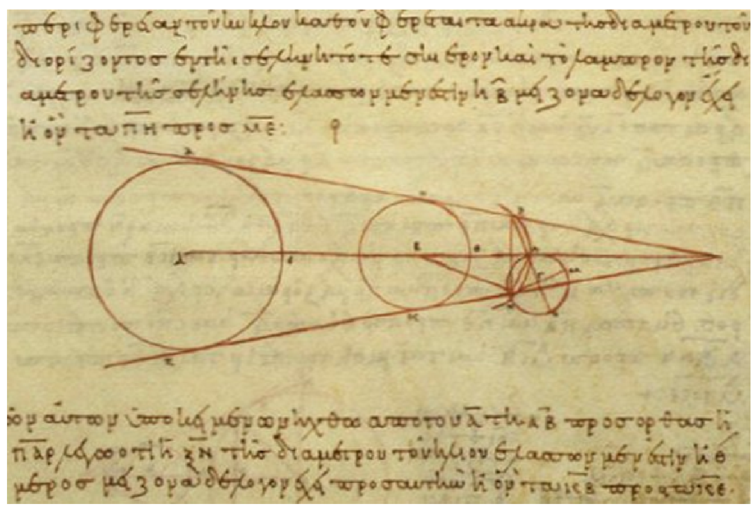
http://www.sunsetastronomicalsociety.com/SASMembership.htm

Measuring Astronomical Distances Over The Centuries

This new series is about how astronomers determined and measured distances to astronomical objects over the course of more than two thousand years. The series will span from the beginnings in Greek antique to the latest development using earth and space based telescopes.

The first astronomer and mathematician who attempted to measure the distance of the Moon and Sun as well as their sizes was the **Aristarchus of Samos**, who lived circa 310 BC – 210 BC. In his work 'On the Sizes and Distances' (of the Sun and Moon) he makes calculations using three basic observations. 1) The apparent size of the Sun and the Moon in the sky seems the same (solar eclipses!). 2) The size of the shadow of the Earth in relation to the Moon during a lunar eclipse. 3) The angle formed between the Sun and the Moon during the half moon phase which is very close to 90 °C.

Aristarchus estimated that during the half moon phase the angle between Sun and Moon was 87° instead of the real value of 89° 50'. Though, despite using the correct geometry, Aristarchus calculated that the Sun was between 18 to 20 times farther away than the Moon instead of ca 400 times. This false solar parallax of slightly less than 3° somehow became firmly fixed in the scientific literature for over more than 1800! years up to and including Tycho Brahe around 1600 AC.



Aristarchus's 3rd century BC calculations on the relative sizes of from left the Sun, Earth and Moon, from a 10th

The picture (right) points out that the Sun and Moon have nearly equal apparent angular sizes which means that their diameters must be in proportion to their distances from Earth. Therefore the diameter of the Sun should be between 18 and 20 times larger than the diameter of the Moon, Apparently this is wrong (the diameter of the Sun is ca 400 times larger than the diameter of the Moon) but the result follows logically from his data. Aristarchus further concluded that the that the Sun's diameter should be almost seven times greater than the Earth's and the volume of the Sun would be almost 300 times greater than the Earth. Interestingly Aristarchus was also the first astronomer who believed in the heliocentric model of the universe and the size difference between the Earth and the Sun may be one reason to have inspired his view. The other reason is that Aristarchus believed the stars to be very far away, so that no movement (=no observable parallax) of the stars relative to each other can be observed during the year when the Earth moves around the Sun.

The next name we have to mention is that of **Hipparchos** who many believe to be greatest ancient astronomical observer and maybe even the greatest astronomer in antique times. He lived from ca 190 BC – to ca 120 BC and was born in Nicaea which is in Turkey. Of his many accomplishments he is named the founder of trigonometry, developed a reliable method to predict solar eclipses, discovered the Earth precession, compiled the first comprehensive star catalog of the western world, and may have had a hand in the invention of the astrolabe and the armillary sphere. Apart from studying the motions of the Moon and the Sun he also tried to find the distances and sizes of the Sun and the Moon. Hereby he measured the apparent diameters of the Sun and Moon with his *diopter* and found (like many others before and after him) that the Moon's size varies due to its eccentric orbit but the apparent diameter of the Sun did not seem to change. Like Aristarchus before him he found that the apparent diameters of the Moon and Sun are nearly the same and that the Moon's diameter fits 650 times into the circle, which accounts to an apparent mean diameter of 360/650 = 0°33'14". Aristarchus also noticed that the Moon has a noticeable parallax. This means that the Moon appears to be displaced from its calculated position when compared to stars or the Sun. That difference also seems to be greater when the Moon is positioned closer to the horizon. The reason for this fact is that in contemporary models the Moon circles the center of the Earth (Earth was already assumed as a sphere back then!) but the observer stands on the surface of the Earth: the Moon, Earth and observer therefore form a triangle with a sharp angle that changes all the time due to the Moons movement. From the size of this parallax Aristarchus could measure the distance of the Moon as measured in Earth radii. Doing the same for Sun does not work due to the fact that the parallax of the Sun is about 8.8" which is several times smaller than the resolution of the unaided eye. So Hipparchus assumed that the parallax of the Sun was 0, as it was at infinite distance.

So how did Hipparchus measure the distance of the Moon? By analyzing a solar eclipse! Today we think it was the eclipse which took place on 14 March 190 BC. The eclipse was total in the region of his birth place Nicaea but in Alexandria, Egypt, the Moon only obscured 4/5 of the Sun. Luckily Alexandria and Nicaea are on the same meridian, with Alexandria at about 31° north, and Nicaea at about 40° north.

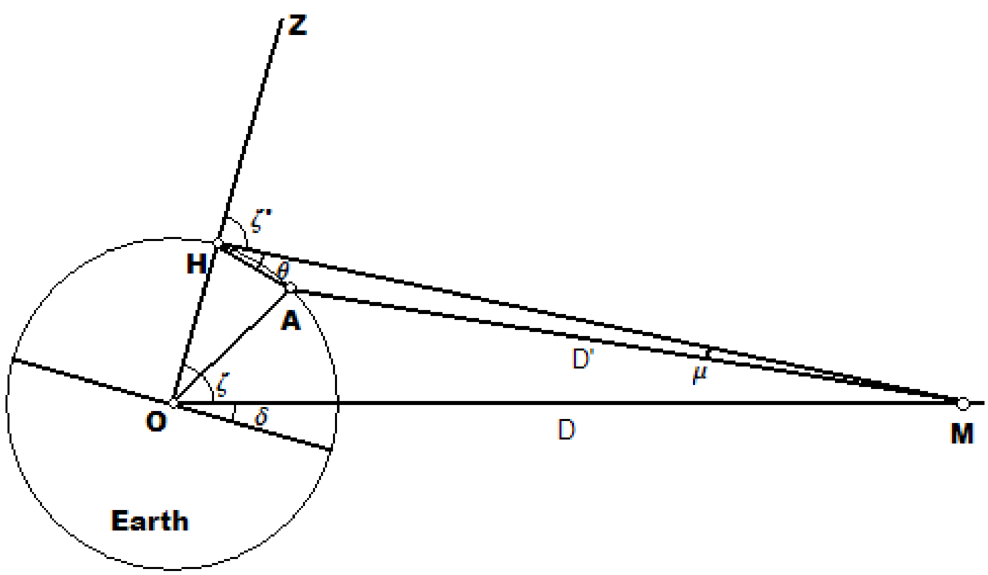


Diagram used in reconstructing one of Hipparchus' methods of determining the distance to the moon. This represents the earth-moon system during a partial solar eclipse at A (Alexandria) and a total solar eclipse at Helespont = Niceae. Graphic from Wikipedia.

If one now draws a triangle between the two places and the Moon simple geometry gives you the distance of the Moon expressed in Earth radii.

The minimum distance Hipparchus found was at least 71 (452300 km) and the greatest 81 Earth radii (516000 km). In a second attempt to measure the distance to the Moon, Hipparchus first made the assumption that the Sun is at least 450 Earth radii away from Earth. He came to that assumption because he thought that this distance would correspond to a parallax of 7', apparently the greatest parallax that would not be noticed by the human eye (he was a little bit too pessimistic about this value because the typical resolution of the human eye is about 2'; Tycho Brahe, the greatest pre-telescope observer, made naked eye observation with an accuracy down to 1'!). Under this assumption the shadow of the Earth is a cone rather than a cylinder. During lunar eclipses he observed the diameter of the Earth's shadow cone and found it to be 2+½ lunar diameters. As we remember he calculated the apparent diameter to 360/650 degrees. Hipparchus could then determine the mean Earth – Moon distance. Because he assumed a minimum distance of the Sun, the value he found is the maximum mean distance possible for the Moon. He found a least distance of 62 (393000 km), a mean of 67 (426800 km), and a greatest distance of 72 Earth radii (458600 km). Given that the assumed parallax of the Sun was a maximum value and if one now decreases the parallax of the Sun (=by putting it farther away from Earth), the minimum limit for the mean distance becomes 59 Earth radii (376300 km).
As you have probably already realized Hipparchus now faced the problem that in his first attempt the minimum distance was greater than the maximum distance he found in his second attempt. As a real scientist he realized that his first attempt was very sensitive to the accuracy of the observations and parameters. For example modern calculations found that the totality of the 190 BC eclipse in Alexandria was closer to 9/10 than 4/5. Nonetheless his calculated values gave a relatively accurate picture about the real astronomical distances with the Moon being 363000 km away in its perigee and ca 405700 km in its apogee (today's values).

The third name of the antique is **Claudius Ptolemy** believed to be born in the town of Ptolemais Hermiou. He lived between ca AD 90 – c. AD 168. Ptolemy was the author of several scientific works, three of them were especially important to later Islamic and European science. For us his great astronomical work the Almagest' (Greek: The Great Treatise) is of special importance. His work is the only surviving comprehensive ancient collection on astronomy, in which Ptolemy incorporated the arithmetical techniques the astronomers from Babylon had developed for calculating astronomical phenomena; the geometric models from Greek astronomers such as Hipparchus for calculating celestial motions and others. For the convenience of many future generations of astronomers he then presented his astronomical models in tables, which turned out very useful to compute the future or past position of the planets. In addition the *Almagest* also contains a star catalogue, which is actually an appropriated version of a catalogue originally created by Hipparchus. Through the Middle Ages the Almagest became more and more *the* authoritative text on astronomy. Like most of the classical Greek works, The *Almagest* was preserved in Arabic manuscripts and translated twice into Latin in the 12th century.
Ptolemy later measured the lunar parallax directly and thereby used the second method of Hipparchus (lunar eclipse) to calculate the distance of the Sun. The result 60.3 Earth radii (384000 km) for the distance of the Moon was the best so far and still within the limits from Hipparchus' second attempt.

The next parts of this series will demonstrate how the accuracy of astronomical distance measurements was more and more perfected in the same way as the accuracy of scientific instruments and mathematical methods improved.

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SERVING THE TRI- CITIES SINCE 1975

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New (Old) Elected Officers for the SAS:

President, Steve VanTol stevenv106@aol.com

1. Vice President, Dale Sisson dalesisson@hotmail.com

2. Vice President, Tim Ross tjrastronomy@hotmail.com

Treasurer, Thomas Smith tom55net@att.net

Secretary, Newsletter Editor, Martin Grasmann
martin.grasmann@sbcglobal.net

This issue can be accessed in color on the website of the SAS!!!
http://sunsetastronomicalsociety.com

SAS Meeting

Start: 7:00 PM

Friday, March11th, 2011

Delta Planetarium

1. **Welcome, new members**

2. Evening's theme:

Presentation by Mohammed Khan:

Topic TBD

3. Club Stuff

What's up in the Sky

March 12: 1st quarter Moon

March 13: Daylight saving time at 2 am.

March 13 -16: *Dusk:* Mercury passes right of Jupiter. Easiest chance to catch Mercury of the

March 17 – 28: *Dusk:* Mercury still very good visible at >10 deg above western horizon 1/2 hour after sunset.

March 19: Full Moon.

March 20: Spring begins.

March 20 - 21: *Night - Dawn:* Spica near Moon.

March 17 – 28: Good time to view the zodiacal light at dark locations with clear view to the western horizon. Look for a dome of light ca 80 min after sunset.

March 26: Last quarter Moon

March 31: *Dawn:* Venus at lower right to crescent Moon.

April 1: *Dawn:* Crescent Moon ca 13 to 14 deg left of Venus low in the east just before sunrise.

April 3: New Moon

April 3 - 4: *Night - Dawn:* Saturn as its biggest!

April 9: *Evening:* M35 to be seen ca 6 deg above or upper left of the Moon. Binoculars needed!

April 11: 1st quarter Moon

April 13: *Evening:* Regulus can be seen ca 6 deg above or upper left of the Moon.

UPCOMING EVENTS

Messier Marathon:
Planned for the first weekend in April (1st, 2nd April)
Location: Filion Rd Public access between Bay Port and Caseville.
Date: Likely to be Friday (1st) evening with alternate Saturday (2nd).
Let's all hope for clear weather and a warm 😉 night.